The Electromagnetic Radiation Spectrum

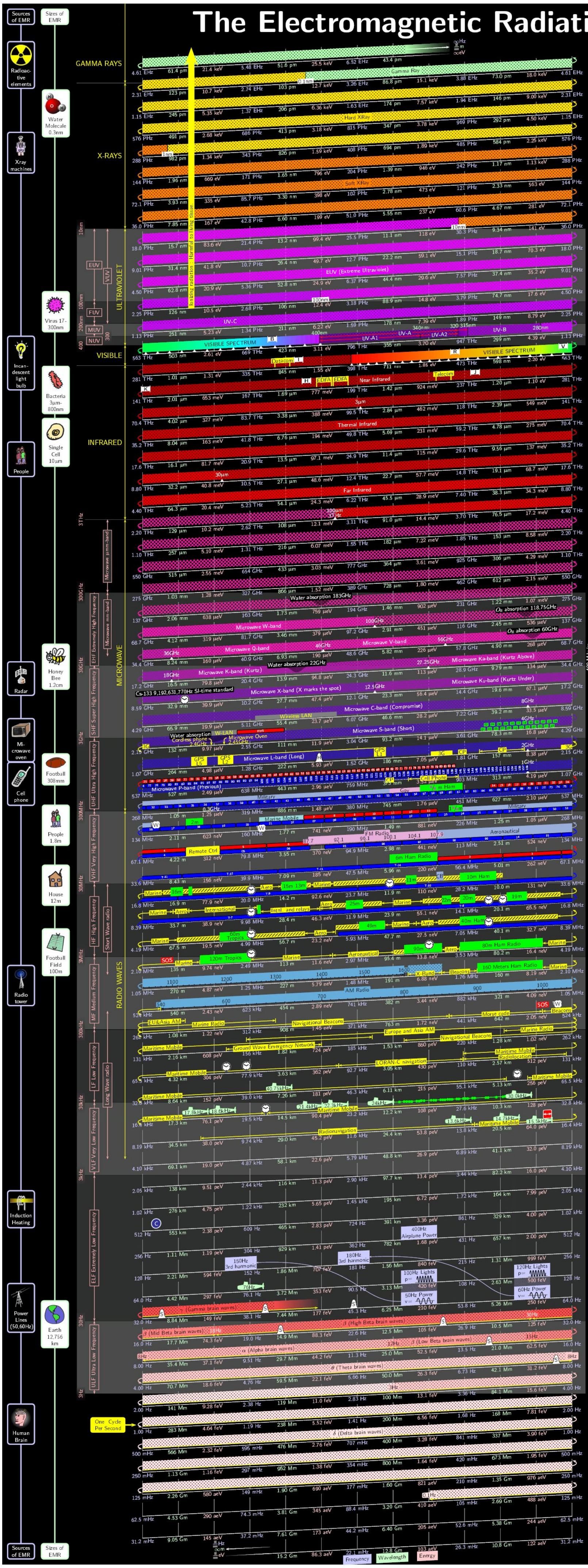

How to read this chart

- This chart is organized in octaves (frequency doubling/halving) starting at 1Hz and going higher (2,4,8, etc) and lower (1/2, 1/4, etc). The octave is a natural way to represent frequency.
- Frequency increases on the vertical scale in the upward direction.
- The horizontal bars wrap around from far right to far left as the frequency increases upwards.
- There is no limit to either end of this chart, however, due to limited space, only the "known" items have been shown here. A frequency of 0Hz is the lowest possible frequency but the method of depicting octaves used here does not allow for ever reaching 0Hz, only approaching it. Also, by the definition of frequency (Cycles per second), there is no such thing as negative frequency.
- Values on the chart have been labelled with the following colours: Frequency measured in Hertz, Wavelength measured in meters, Energy measured in electronVolts.

Ultraviolet Light

- Ultraviolet light is beyond the range of human vision.
- Physicists have divided ultraviolet light ranges into Vacuum Ultraviolet (VUV), Extreme Ultraviolet (EUV), Far Ultraviolet (FUV), Medium Ultraviolet (MUV), and Near Ultraviolet (NUV).
- UV-A, UV-B and UV-C were introduced in the 1930's by the Commission Internationale de l'Éclairage (CIE, International Commission on Illumination) for photobiological spectral bands.
- Short-term UV-A exposure causes sun-tanning which helps to protect against sunburn. Exposure to UV-B is beneficial to humans by helping the skin produce vitamin D. Excessive UV exposure causes skin damage. UV-C is harmful to humans but is used as a germicide.
- The CIE originally divided UVA and UVB at 315nm, later some photo-dermatologists divided it at 320nm.
- UVA is subdivided into UVA1 and UVA2 for DNA altering effects at 340nm.
- The sun produces a wide range of frequencies including all the ultraviolet light, however, UVB is partially filtered by the ozone layer and UVC is totally filtered out by the earth's atmosphere.
- A bumblebee can see light in the UVA range which helps them identify certain flowers.

Emission and Absorption

- As EMR passes through elements, certain wavelength bands get absorbed and some new ones get emitted. This absorption and emission produces characteristic spectral lines for each element which are useful in determining the makeup of distant stars. These lines are used to prove the red-shift amount of distant stars.
- When a photon hits an atom it may be absorbed if the energy is just right. The energy level of the electron is raised – essentially holding the radiation. A new photon of specific wavelength is created when the energy is released. The jump in energy is a discrete step and many possible levels of energy exist in an atom.
- Johann Balmer created this formula defining the photon emission wavelength (λ); where m is the initial electron energy level and n is the final electron energy level:

$$\lambda = 364.56nm\left(\frac{m^2}{m^2-n^2}\right)$$

- Much of the interstellar matter is made of the simplest atom hydrogen. The hydrogen visible-spectrum emission and absorption lines are shown below:

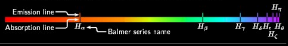

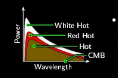

- Max Planck determined the relationship between the temperature of an object and its radiation profile; where R_λ is the radiation power, λ is the wavelength, T is the temperature:

$$R_\lambda = \frac{37418}{\lambda^{5}\epsilon\left(\frac{14388}{\lambda T}-1\right)}$$

Cosmic Microwave Background Radiation

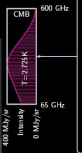

- CMB radiation is the leftover heat from the hot early universe, which last scattered about 400,000 years after the Big Bang.
- CMB permeates the entire universe at a temperature of 2.725 ± 0.001K.
- CMB was predicted in the 1940's by Ralph Alpher, George Gamow and Robert Herman.
- Arno Penzias and Robert Wilson accidentally discovered CMB while working for Bell Telephone Laboratories in 1965.
- The intensity is measured in Mega Jansky (Jy) per steradian. $1Jy = 10^{-26}W/m^2/Hz$

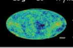

Close examination of slight CMB intensity variations in different parts of the sky help cosmologists study the formation of galaxies.

WMAP photo by NASA

Television

- Television is transmitted in the VHF and UHF ranges (30MHz - 3GHz).
- TV channels transmitted over the air are shown as TV.
- TV channels transmitted through cable (CATV) are shown as TV. CATV channels starting with "T-" are channels fed back to the cable TV station (like news feeds).
- Air and cable TV stations are broadcast with the separate video, colour, and audio frequency carriers grouped together in a channel band as follows:

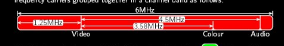

- Satellite channels broadcast in the C-Band are depicted as TV. These stations are broadcast in alternating polarities (Ex. Ch 1 is vertical and 2 is horizontal and vice versa on neighbouring satellites).
- The 15.7 kHz horizontal sweep signal produced by a TV can be heard by some young people. This common contaminant signal to VLF spectra listening is depicted as ↔.

Radio Bands

- The radio spectrum (ELF to EHF) is populated by many more items than can be shown on this chart, only a small sampling of bands used around the world have been shown.
- Communication using EMR is done using either:
  - Amplitude Modulation (AM)

    OR
  - Frequency Modulation (FM)

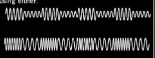

- Each country has its own rules and regulations for allotting bands in this region. For more information, look up the radio communications authority in your area (Ex. FCC in the US, DOC in Canada).
- Not all references agree on the ULF band range, the HAARP range is used here.
- **RA**dio **D**etecting **A**nd **R**anging (RADAR) uses EMR in the microwave range to detect the distance and speed of objects.
- **C**itizens **B**and Radio (CB) contains 40 stations between 26.965-27.405MHz.
- Schumann resonance is produced in the cavity between the Earth and the ionosphere. The resonant peaks are depicted as S
- Hydrogen gas emits radio band EMR at 21cm H
- Some individual frequencies are represented as icons:

xxHz Submarine communications
Time and frequency standards
xxm Ham radio and international meter bands
▨ Miscellaneous short wave radio
W Weather stations
CP Cellular and PCS Phones (including; FDMA, TDMA, CDMA ranges)

Sound

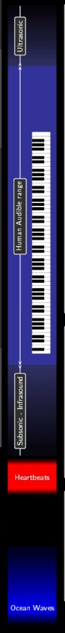

- Although sound, ocean waves, and heartbeats are not electromagnetic, they are included on this chart as a frequency reference. Other properties of electromagnetic waves are different from sound waves.
- Sound waves are caused by an oscillating compression of molecules. Sound cannot travel in a vacuum such as outer space.
- The speed of sound in air is 1240kph (770mph).
- Humans can only hear sound between ≈20Hz to ≈20kHz.
- Infrasound (below 20Hz) can be sensed by internal organs and touch. Frequencies in the 0.2Hz range are often the cause of motion sickness.
- Bats can hear sound up to ≈50kHz.
- The 88 piano keys of the Equal Temperament scale are accurately located on the frequency chart.
- Over the ages people have striven to divide the continuous audio frequency spectrum into individual musical notes that have harmonious relationships. Microtonal musicians study various scales. One recent count lists 4700 different musical scales.
- Middle C is depicted on the chart as C

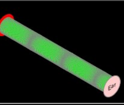

This image depicts air being compressed as sound waves in a tube from a speaker and then travelling through the tube towards the ear.

Gravity Waves

- Gravity is the mysterious force that holds large objects together and binds our planets, stars and galaxies together. Many people have unsuccessfully theorized about the details of gravity and its relationship to other forces. There have been no links between gravity waves and electromagnetic radiation.
- Gravity is theorized to warp space and time. In fact, gravity is responsible for bending light as observed by the gravity-lens example of distant galaxies.
- "Gravity waves" would appear as ripples in space-time formed by large objects moving through space that might possibly be detected in the future by very sensitive instruments.
- The speed that gravity propagates through space has been theorized to be the same as the speed of light.

Brain Waves

- By connecting electrodes from the human head to an electroencephalograph (EEG), it is possible to measure very small cyclic electrical signals.
- There has been much study on this topic, but like all effects on humans, the science is not as exact as the science of materials.
- Generally, lower brain wave frequencies relate to sleep, and the higher frequencies relate to alertness.
- Devices have been made for measuring and stimulating brain waves to achieve a desired state.

Electro**m**agnetic **R**adiation (EMR)

- EMR is emitted in discrete units called photons but has properties of waves as seen by the images below. EMR can be created by the oscillation or acceleration of electrical charge or magnetic field. EMR travels through space at the speed of light ($2.997\,924\,58 \times 10^{8}$ m/s). EMR consists of an oscillating electrical and magnetic field which are at right angles to eachother and spaced at a particular wavelength. There is some controversy about the phase relationship between the electrical and magnetic fields of EMR, one of the theoretical representations is shown here:

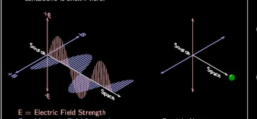

E = Electric Field Strength
B = Magnetic Field Strength
Wave Nature

Particle Nature

- The particle nature of EMR is exhibited when a solar cell emits individual electrons when struck with very dim light.
- The wave nature of EMR is demonstrated by the famous double slit experiment that shows cancelling and addition of waves.
- Much of the EMR properties are based on theories since we can only see the effects of EMR and not the actual photon or wave itself.
- Albert Einstein theorized that the speed of light is the fastest that anything can travel. So far he has not been proven wrong.
- EMR can have its wavelength changed if the source is receding or approaching as in the red-shift example of distant galaxies and stars that are moving away from us at very high speeds. The emitted spectral light from these receding bodies appears more red than it would be if the object was not moving away from us.
- We only have full electronic control over frequencies in the microwave range and lower. Higher frequencies must be created by waiting for the energy to be released from elements as photons. We can either pump energy into the elements (ex. heating a rock with visible EMR and letting it release infrared EMR) or let it naturally escape (ex. uranium decay).
- We can only see the visible spectrum. All other bands of the spectrum are depicted as hatched colours ▒.

Système International d'unité prefixes (SI unit prefixes)			
Symbol	**Name**	**Exp.**	**Multiplier**
Y	yotta	10^{24}	1,000,000,000,000,000,000,000,000
Z	zetta	10^{21}	1,000,000,000,000,000,000,000
E	exa	10^{18}	1,000,000,000,000,000,000
P	peta	10^{15}	1,000,000,000,000,000
T	tera	10^{12}	1,000,000,000,000
G	giga	10^{9}	1,000,000,000
M	mega	10^{6}	1,000,000
k	kilo	10^{3}	1,000
		10^{0}	1
m	milli	10^{-3}	0.001
µ	micro	10^{-6}	0.000 001
n	nano	10^{-9}	0.000 000 001
p	pico	10^{-12}	0.000 000 000 001
f	femto	10^{-15}	0.000 000 000 000 001
a	atto	10^{-18}	0.000 000 000 000 000 001
z	zepto	10^{-21}	0.000 000 000 000 000 000 001
y	yocto	10^{-24}	0.000 000 000 000 000 000 000 001

Measurements on this chart		
Symbol	**Name**	**Value**
c	Speed of Light	$2.997\,924\,58 \times 10^{8}$ m/s
h	Planck's Constant	$6.626\,1 \times 10^{-34}$ J·s
$\hbar$	Planck's Constant (freq)	$1.054\,592 \times 10^{-34}$ J·s
f	Frequency (cycles / second)	Hz
λ	Wavelength (meters)	m
E	Energy (Joules)	J

Conversions
$E = h \cdot f$
$\lambda = \frac{c}{f}$
1Å = 0.1nm
1nm = 10Å
1Joule = 6.24×10^{18} eV

Gamma Rays

- Gamma radiation is the highest energy radiation (up to ≈ 10^{20} eV) that has been measured. At this energy, the radiation could be from gamma-rays, protons, electrons, or something else.
- Alpha, beta, and delta radiation are not electromagnetic but are actually parts of the atom being released from a radioactive atom. In some cases this can cause gamma radiation. These are not to be confused with brain waves of similar names.

Visible Spectrum

- The range of EMR visible to humans is also called "Light". The visible spectrum also closely resembles the range of EMR that filters through our atmosphere from the sun.
- Other creatures see different ranges of visible light, for example bumble-bees can see ultraviolet light and dogs have a different response to colours than do humans.
- The sky is blue because our atmosphere scatters light and the shorter wavelength blue gets scattered the most. It appears that the entire sky is illuminated by a blue light but in fact that light is scattered from the sun. The longer wavelengths like red and orange move straight through the atmosphere which makes the sun look like a bright white ball containing all the colours of the visible spectrum.
- Interestingly, the visible spectrum covers approximately one octave.
- Astronomers use filters to capture specific wavelengths and reject unwanted wavelengths, the major astronomical (visual) filter bands are depicted as X

Infrared Radiation

- Infrared radiation (IR) is sensed by humans as heat and is below the range of human vision. Humans (and anything at room temperature) are emitters of IR.
- IR remote control signals are invisible to the human eye but can be detected by most camcorders.
- Night vision scopes/goggles use a special camera that senses IR and converts the image to visible light. Some IR cameras employ an IR lamp to help illuminate the view.
- IR LASERs are used for burning objects.
- A demonstration of IR is to hold a metal bowl in front of your face. The IR emitted by your body will be reflected back using the parabolic shape of the bowl and you will feel the heat.
- Fiber-optic based infrared communication signals are sometimes amplified with Erbium-Doped Fiber Amplifiers EDFA

LASER

- LASER is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.
- A LASER is a device that produces monochromatic EMR of high intensity.
- With proper equipment, any EMR can be made to operate like a LASER. For example, microwaves are used to create a MASER.

Polarization

- As a photon (light particle) travels through space, its axis of electrical and magnetic fluctuations does not rotate. Therefore, each photon has a fixed linear polarity of somewhere between 0° to 360°. Light can also be circularly and elliptically polarized.
- Some crystals can cause the photon to rotate its polarization.
- Receivers that expect polarized photons will not accept photons that are in other polarities. (ex. satellite dish receivers have horizontal and vertical polarity positions).
- A polarized filter (like Polaroid™ sunglasses) can be used to demonstrate polarized light. One filter will only let photons that have one polarity through. Two overlapping filters at right angles will almost totally block the light that exits, however, a third filter inserted between the first two at a 45° angle will rotate the polarized light and allow some light to come out the end of all three filters.
- Light that reflects off an electrical insulator becomes polarized. Conductive reflectors do not polarize light.
- Perhaps the most reliably polarized light is a rainbow.
- Moonlight is also slightly polarized. You can test this by viewing the moonlight through a Polaroid™ sunglass lens, then rotate that lens, the moonlight will dim and brighten slightly.

Refraction

- Refraction of EMR is dependent on wavelength as can be seen by the prism example below.

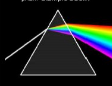

By using a glass prism, white light can be spread by refraction into a spectrum of its composite colours. All wavelengths of EMR can be refracted by using the proper materials.

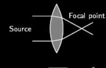

Convex lenses make objects appear closer and are used to correct far-sitedness.

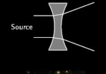

Concave lenses make objects appear farther away and are used to correct near-sitedness.

Photo by STScI

Heavy objects like dense galaxies and large planets cause light to bend due to gravitational lensing.

Reflection

- Reflection of EMR is dependent on wavelength as demonstrated when visible light and radio waves bounce off objects that X-Rays would pass through. Microwaves, which have a large wavelength compared to visible light, will bounce off metal mesh in a microwave oven whereas visible light will pass through.

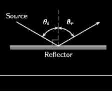

EMR of any wavelength can be reflected, however, the reflectivity of a material depends on many factors including the wavelength of the incident beam.

The angle of incidence (θ_i) and angle of reflection (θ_r) are the same.

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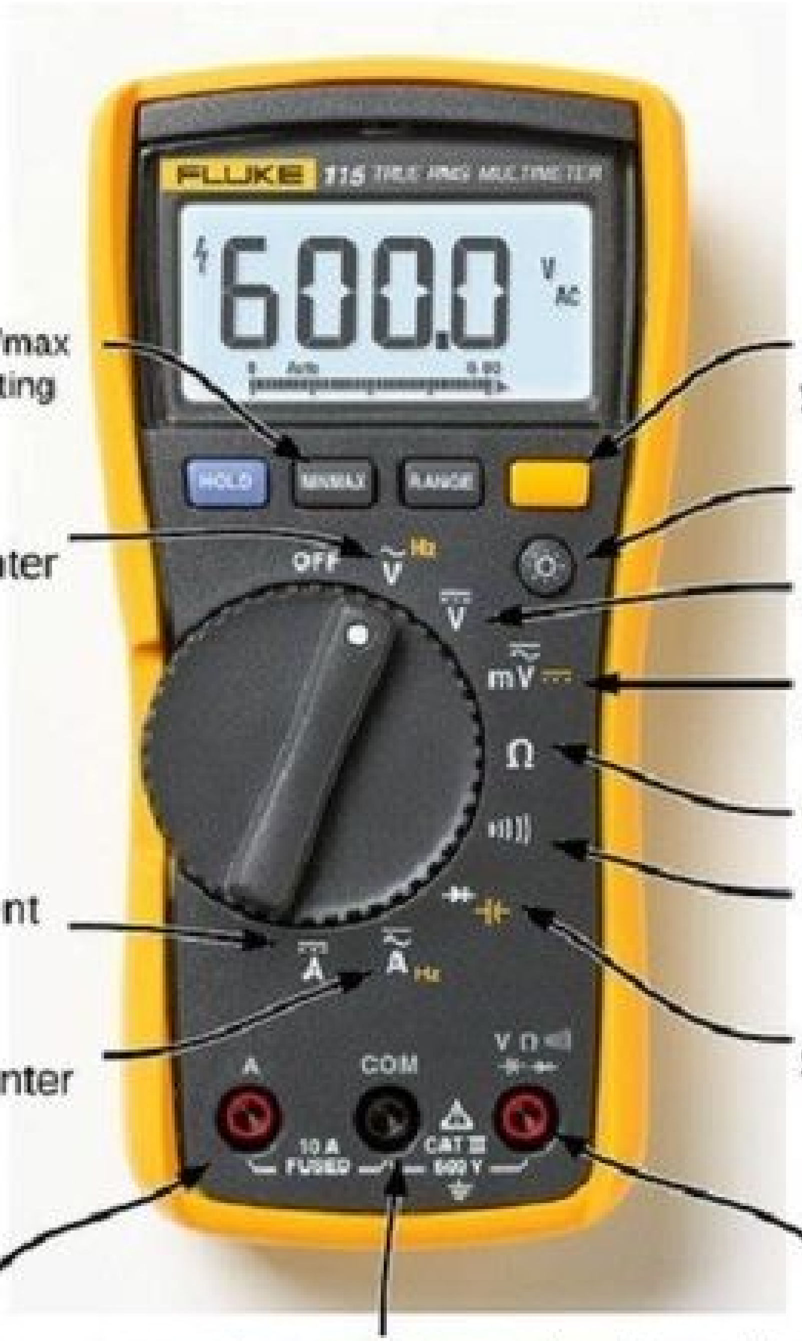
FLUKE
115 TRUE RMS MULTIMETER
600.0
V AC
HOLD
MIN MAX
RANGE
OFF
V Hz
V
mV
Ω
A
A Hz
A
COM
V Ω
10 A FUSED
CAT III 600 V

Min/Max:
Beeps when a new min/max observed while calculating running average

Shift Key:
Use to access the yellow labeled features

AC Voltage
Shift: Frequency Counter

Screen Backlight:
Auto-off in 40 sec.

DC Voltage

Millivolts for AC
Shift: Millivolts for DC

Ohmmeter Setting

Continuity Beeper

DC Current

Diode Test
Shift: Capacitometer

AC Current
Shift: Frequency Counter

Ammeter Terminal

Common Ground
(COM)

Everything but Ammeter
Terminal

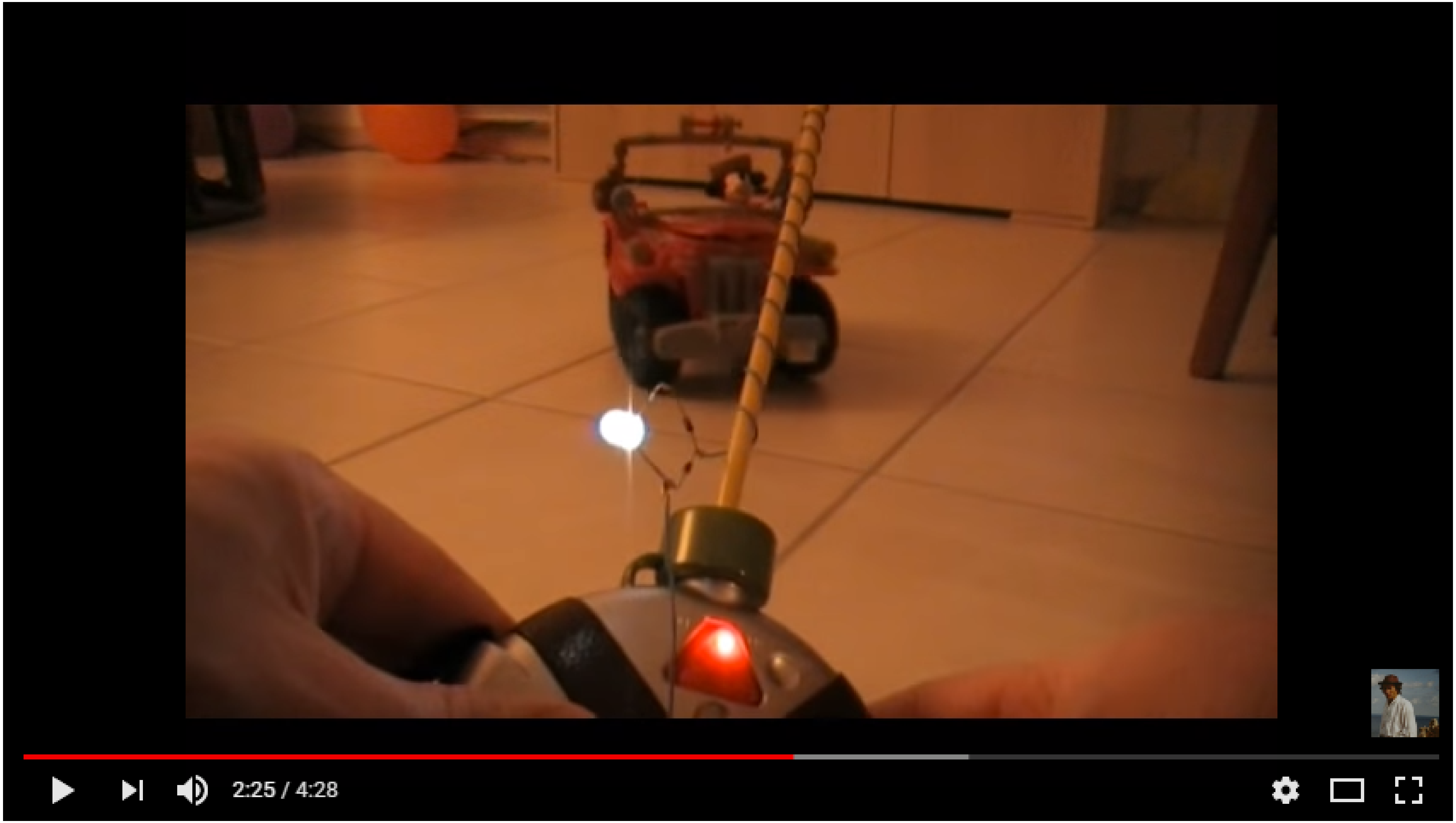

electricity from radiowaves 3

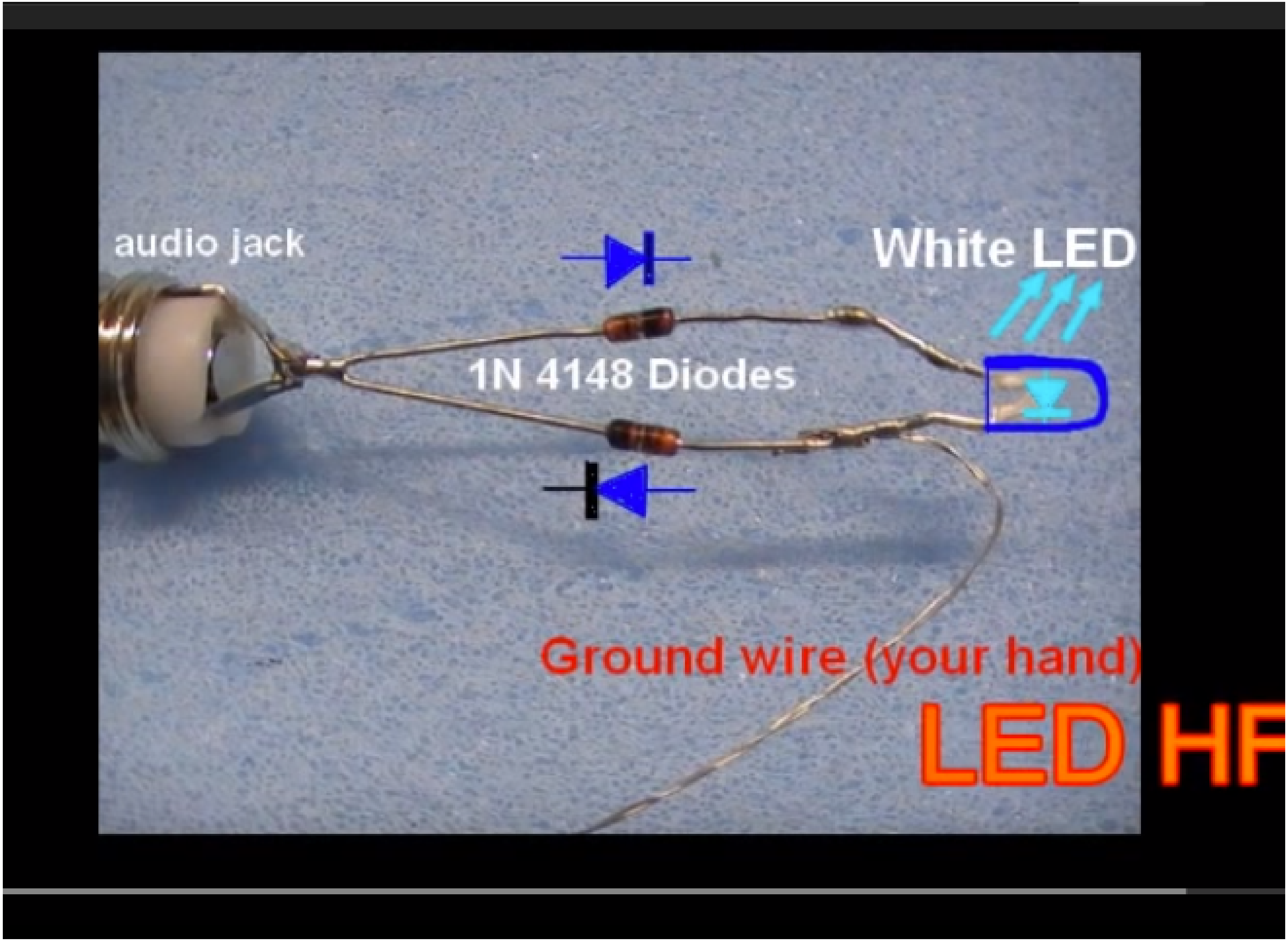
audio jack
White LED
1N 4148 Diodes
Ground wire (your hand)
LED HF

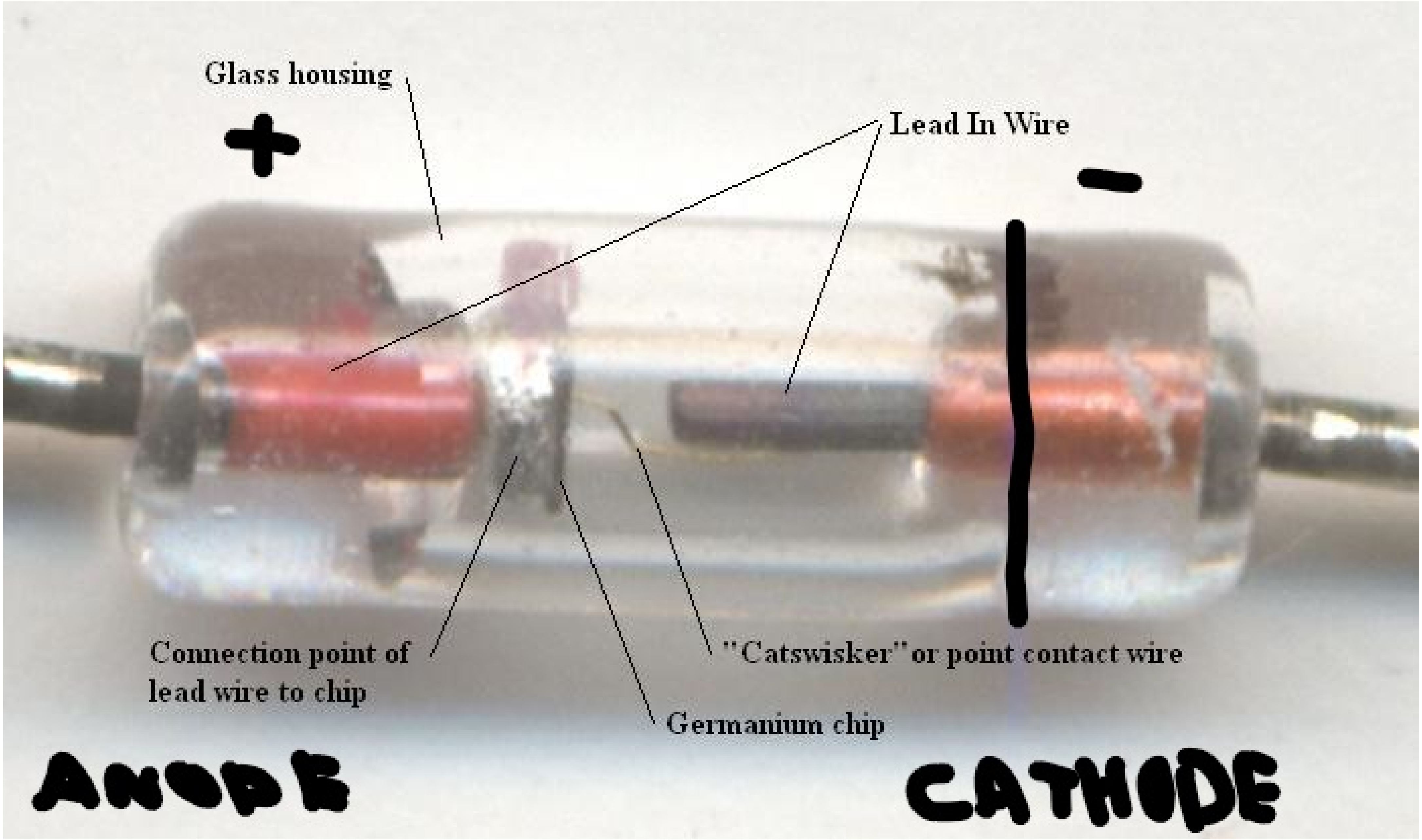
Glass housing
+
Lead In Wire
–
Connection point of lead wire to chip
"Catswisker" or point contact wire
Germanium chip
ANODE
CATHODE

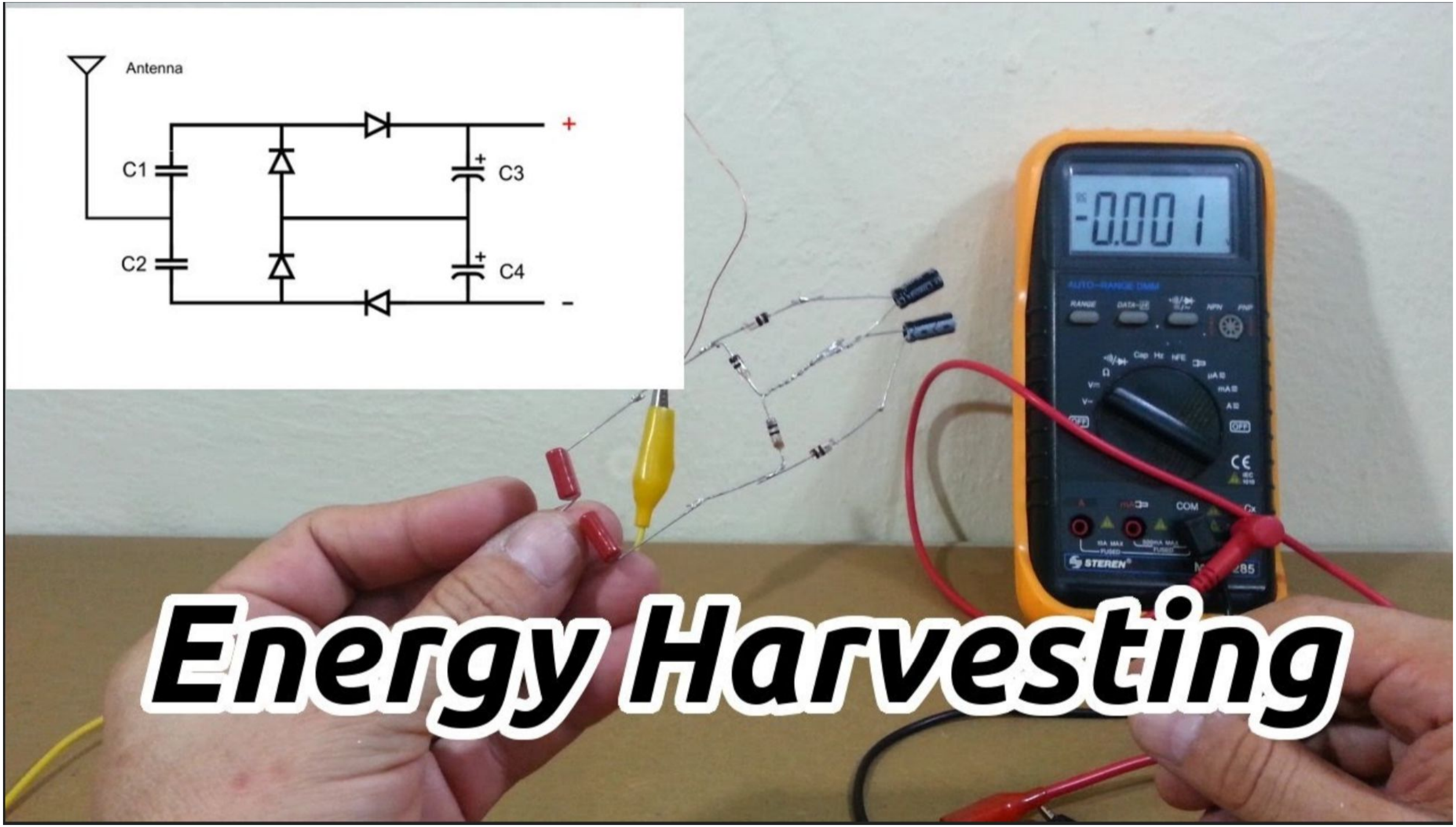
Antenna
C1
C2
C3
C4
+
-
-0.001
AUTO-RANGE DMM
RANGE
DATA-H
NPN
PNP
Cap
Hz
hFE
Ω
V
μA
mA
A
OFF
COM
Cx
STEREN
Energy Harvesting

feluri (fig. III.9), schemele fiind echivalente cu reprezentarea de bază din fig. III.8. Diodele sînt legate în serie, în formă de patrulater, două avînd comun anodul (punctul *2*), iar celelalte două catodul (punctul *4*). Tensiunea alternativă de intrare se aplică pe diagonala *1—3*, iar consumatorul se conectează pe diagonala *2—4*.

Pentru a urmări funcționarea punții, să presupunem că prima alternanță sosită în nodul *1* este pozitivă. Ea blochează dioda D_2 și o deschide pe D_1, debitînd prin R_S un curent I_1 (săgețile pline), care se întoarce la

tice sau cu parametri cît mai apro-

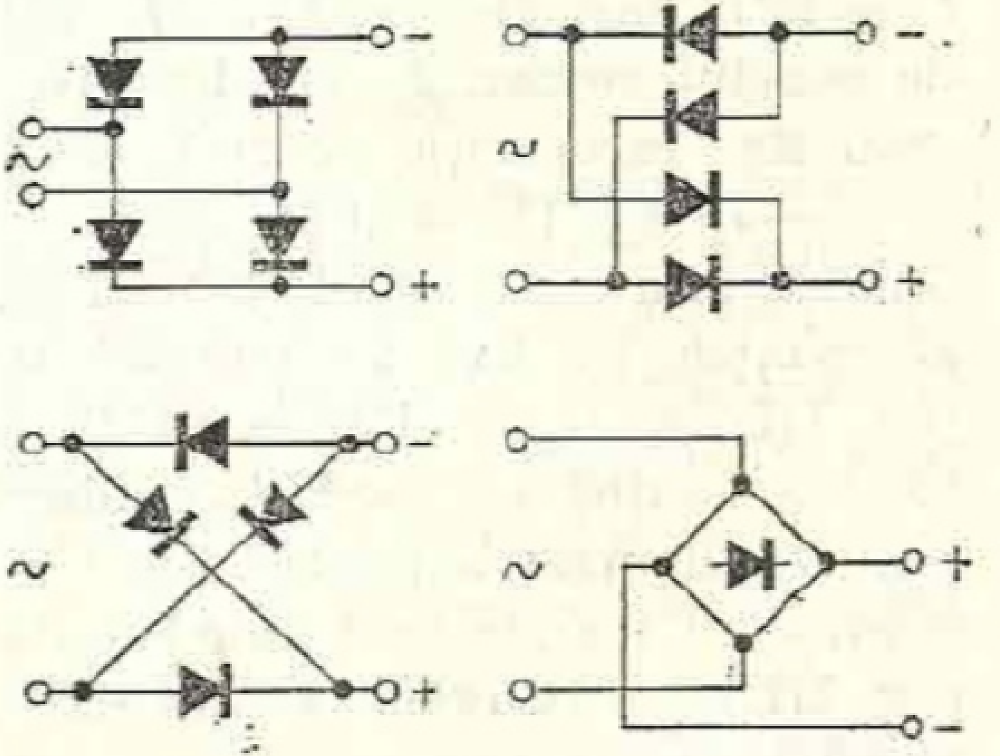

III.9. Puntea redresoare în diferite reprezentări.

circuits used on LC "RadioWaves"

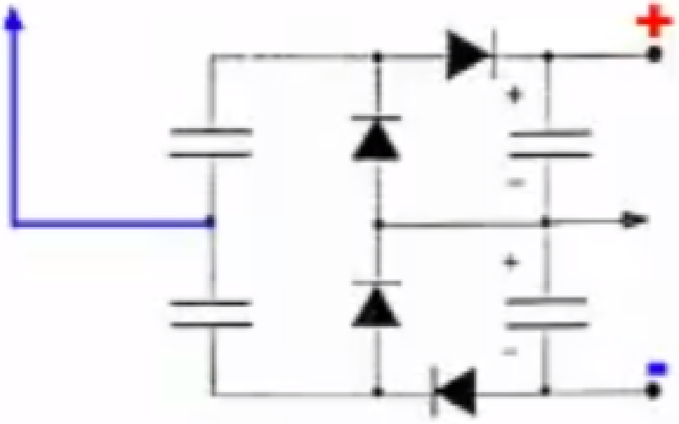

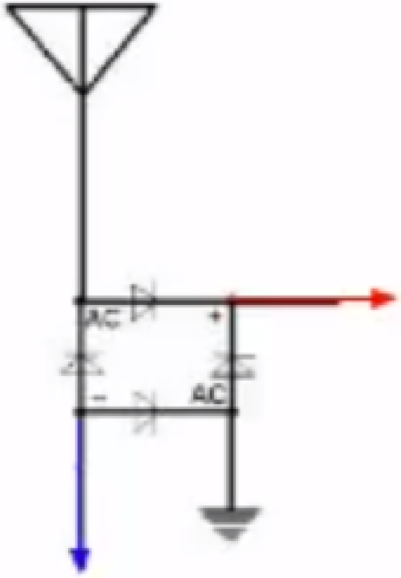

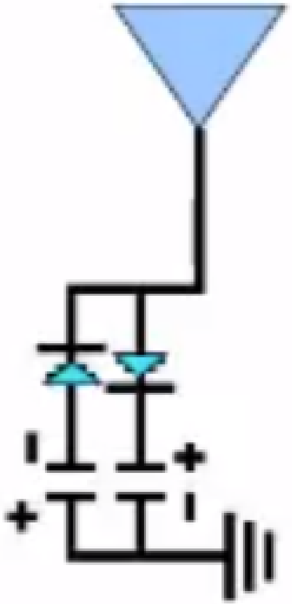

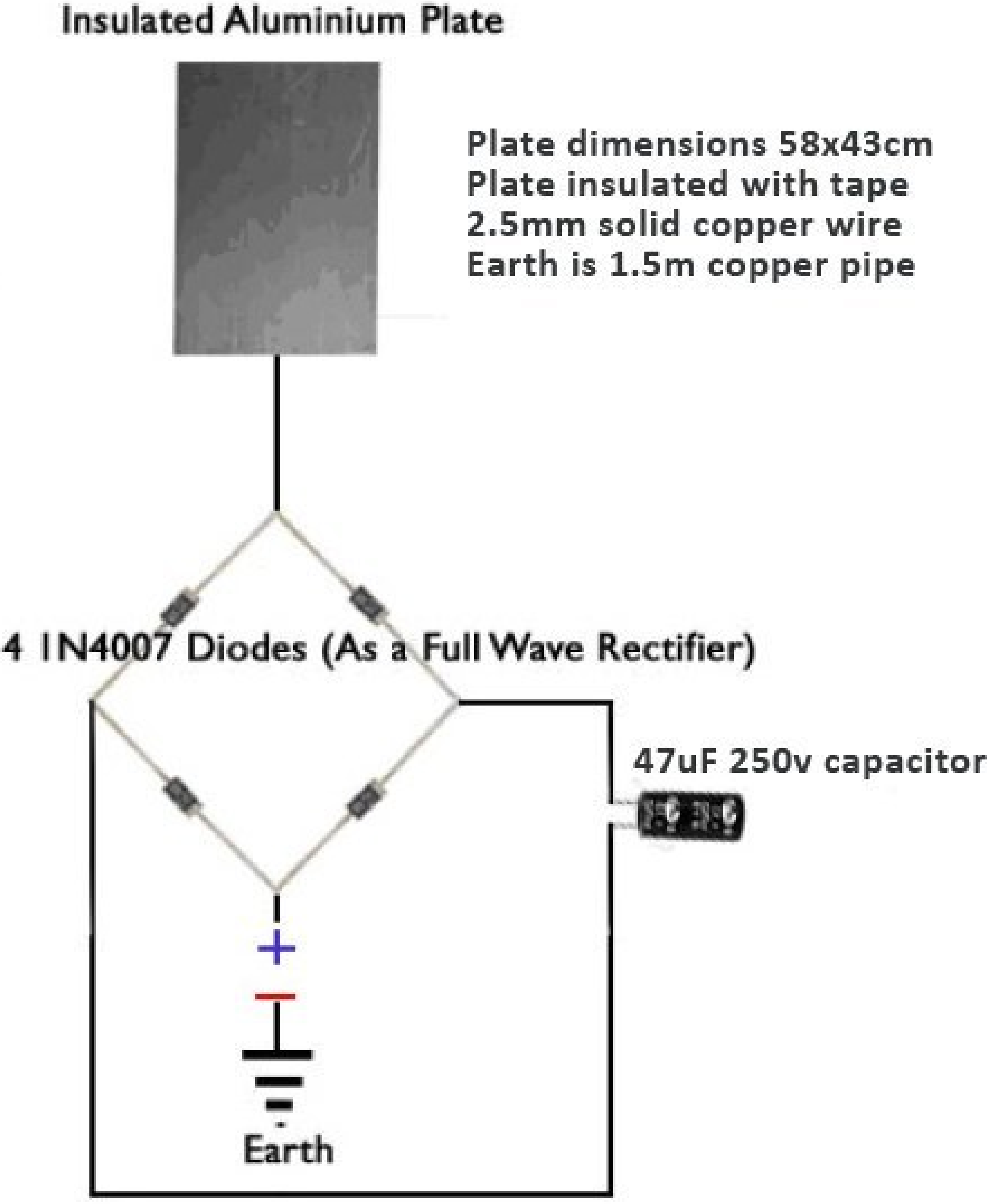
Insulated Aluminium Plate
4 1N4007 Diodes (As a Full Wave Rectifier)
47uF 250v capacitor
+
−
Earth

Plate dimensions 58x43cm
Plate insulated with tape
2.5mm solid copper wire
Earth is 1.5m copper pipe

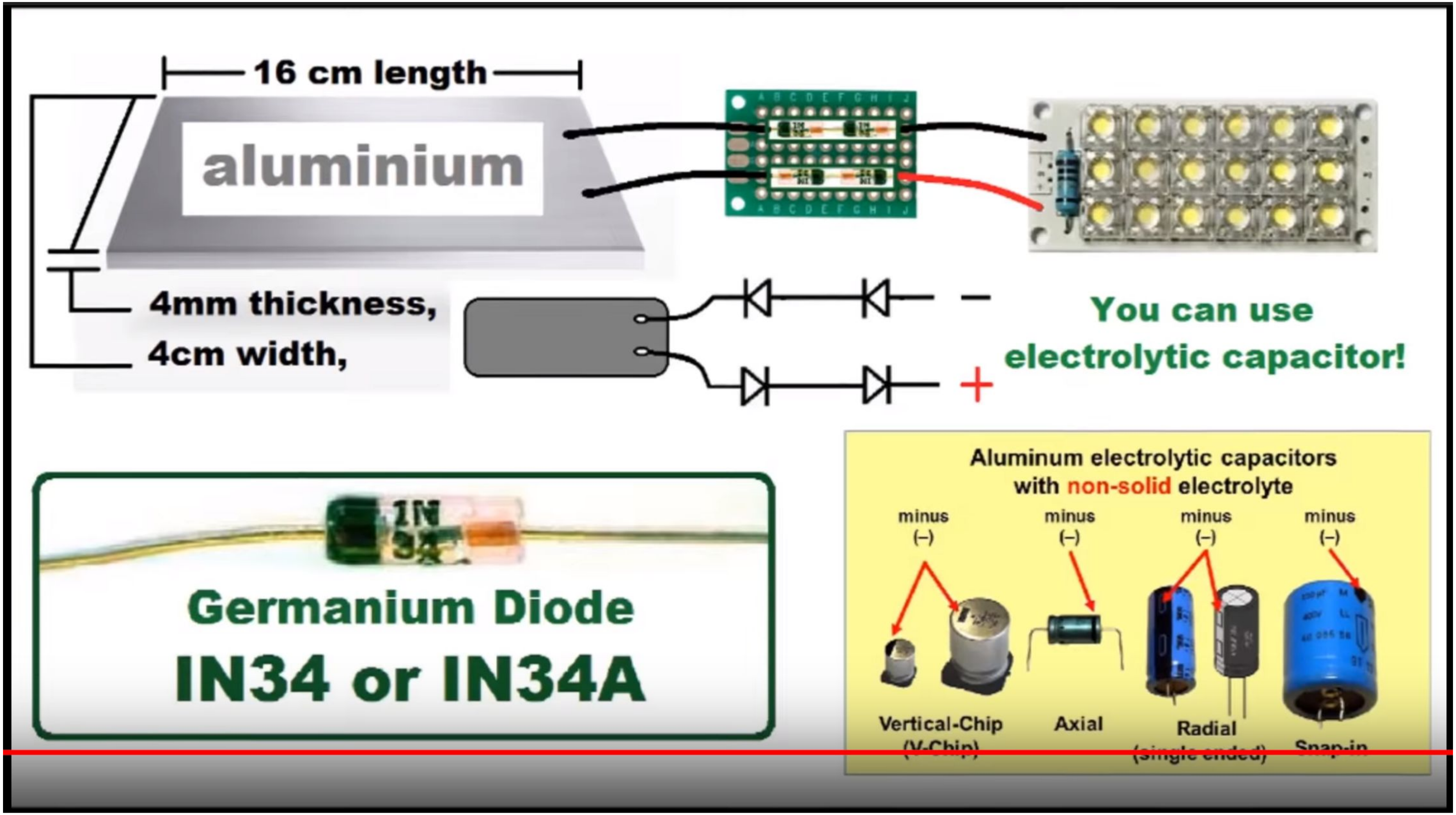

16 cm length

aluminium

4mm thickness,

4cm width,

−

+

You can use electrolytic capacitor!

Germanium Diode

IN34 or IN34A

Aluminum electrolytic capacitors with non-solid electrolyte

1N
34
minus (–)
minus (–)
minus (–)
minus (–)
Vertical-Chip (V-Chip)
Axial
Radial (single ended)
Snap-in

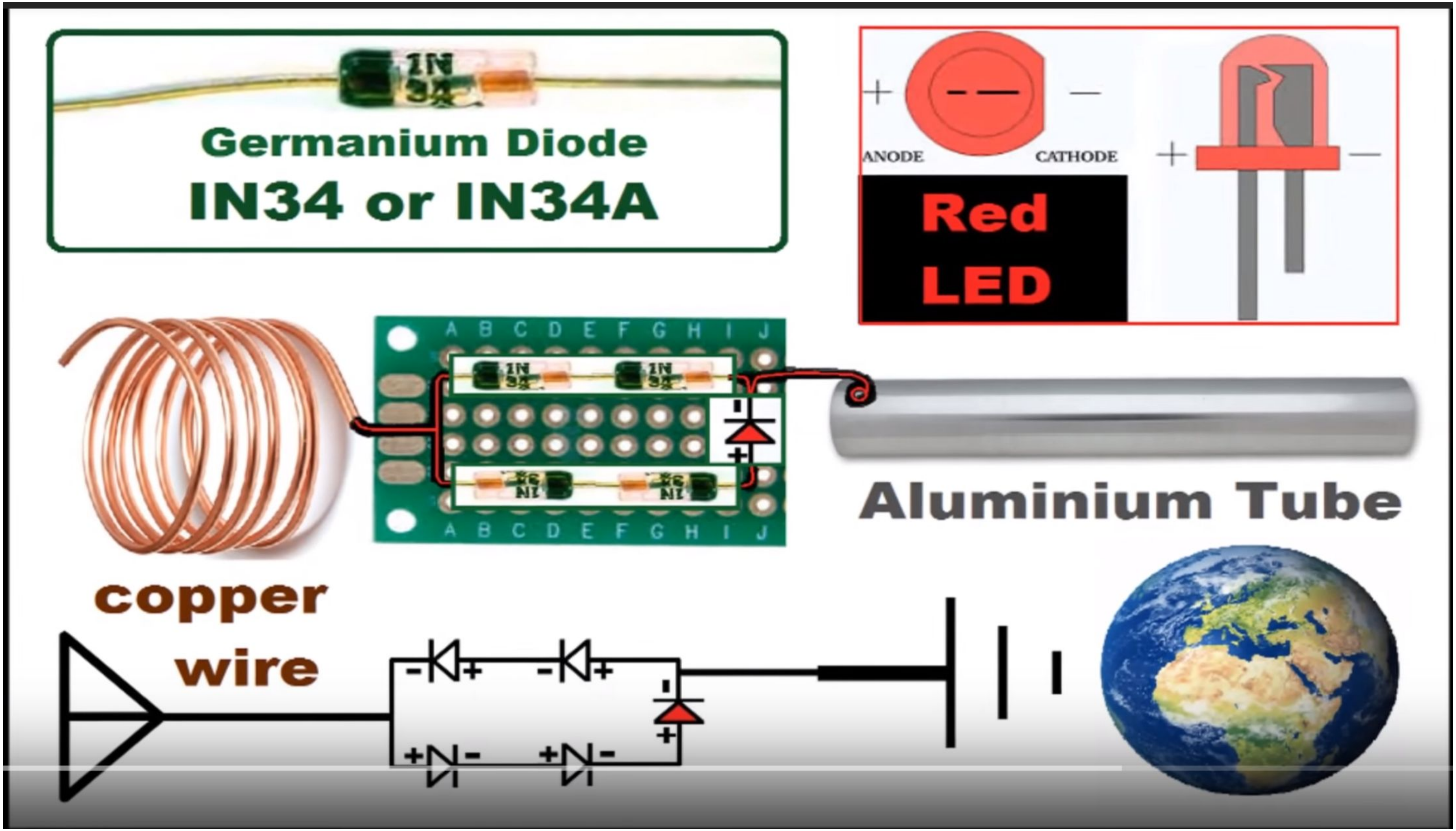
1N 34
Germanium Diode
IN34 or IN34A
+
−
ANODE
CATHODE
Red LED
A B C D E F G H I J
Aluminium Tube
copper wire
- +
- +
+ -
+ -

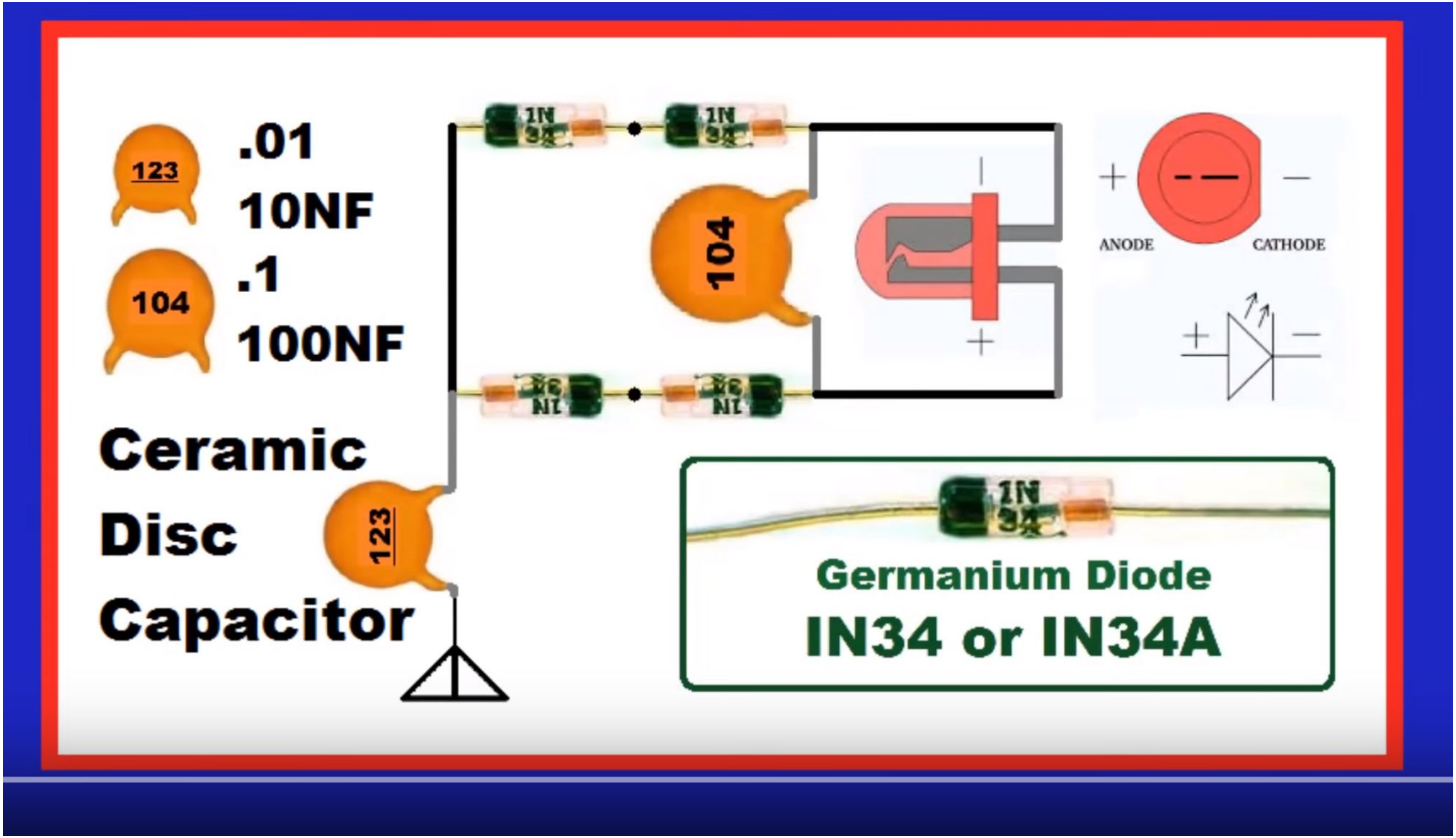

.01

10NF

.1

100NF

Ceramic Disc Capacitor

Germanium Diode

IN34 or IN34A

123
104
1N
34
104
123
+
–
ANODE
CATHODE
+
–

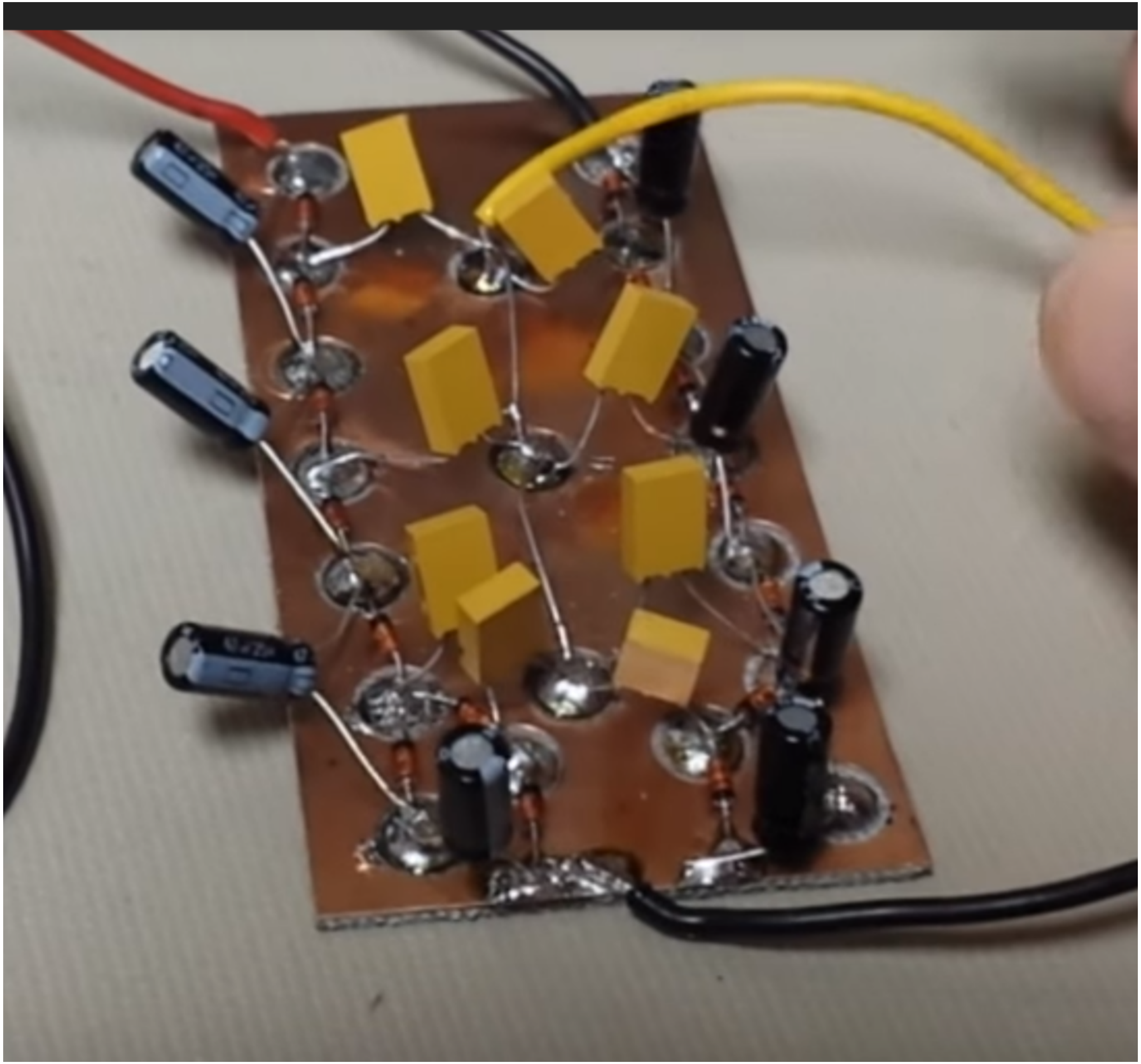

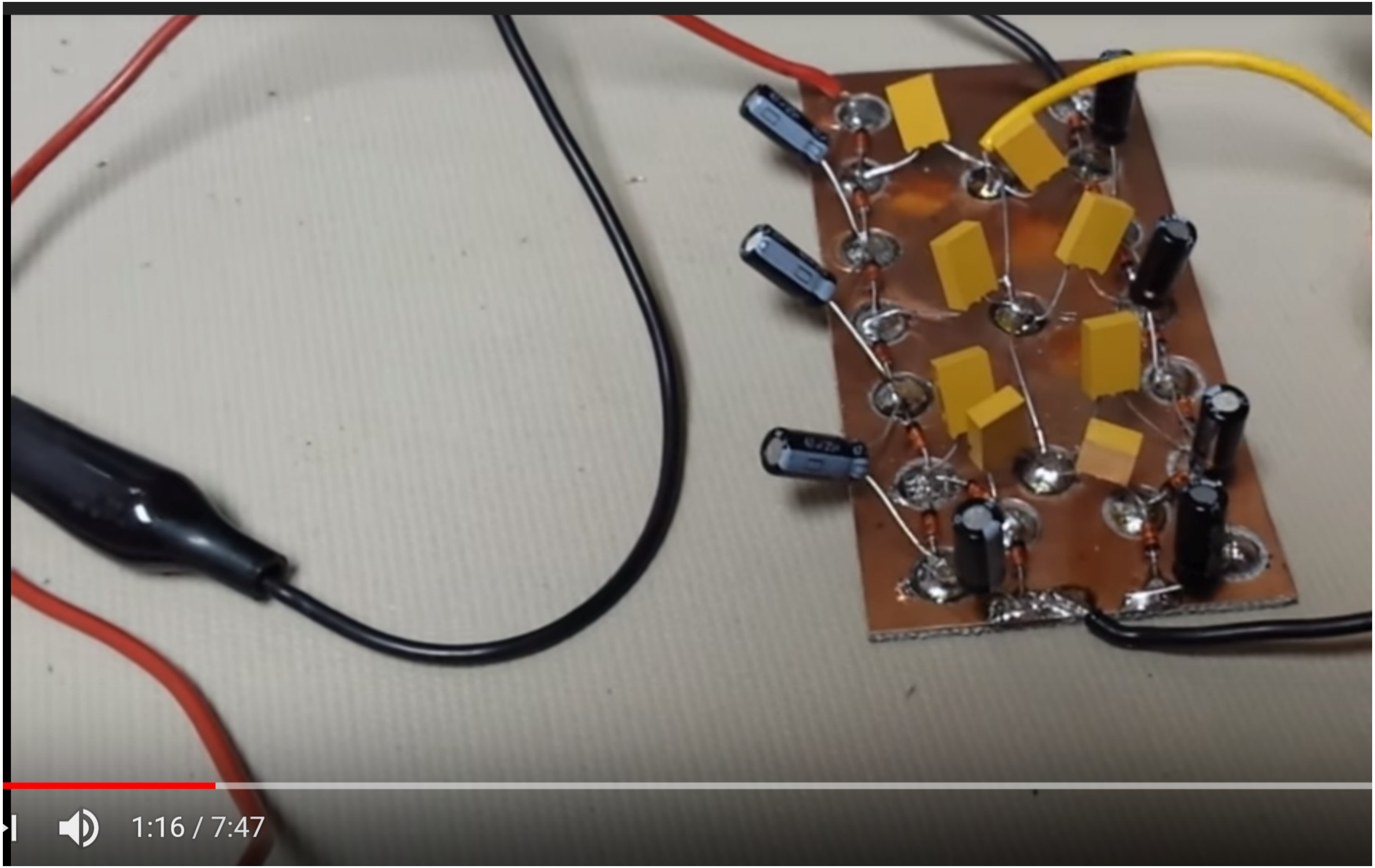
1:16 / 7:47

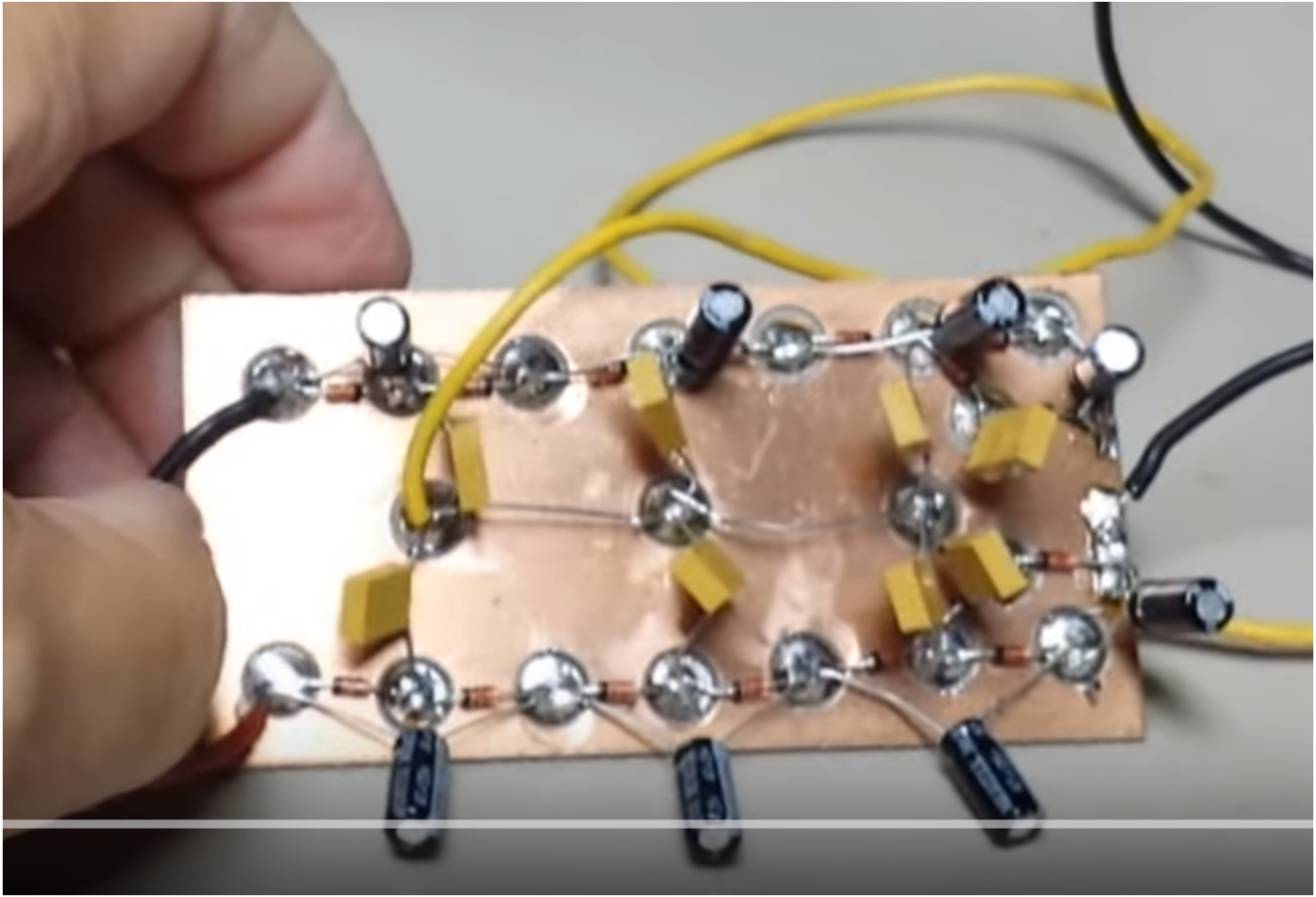

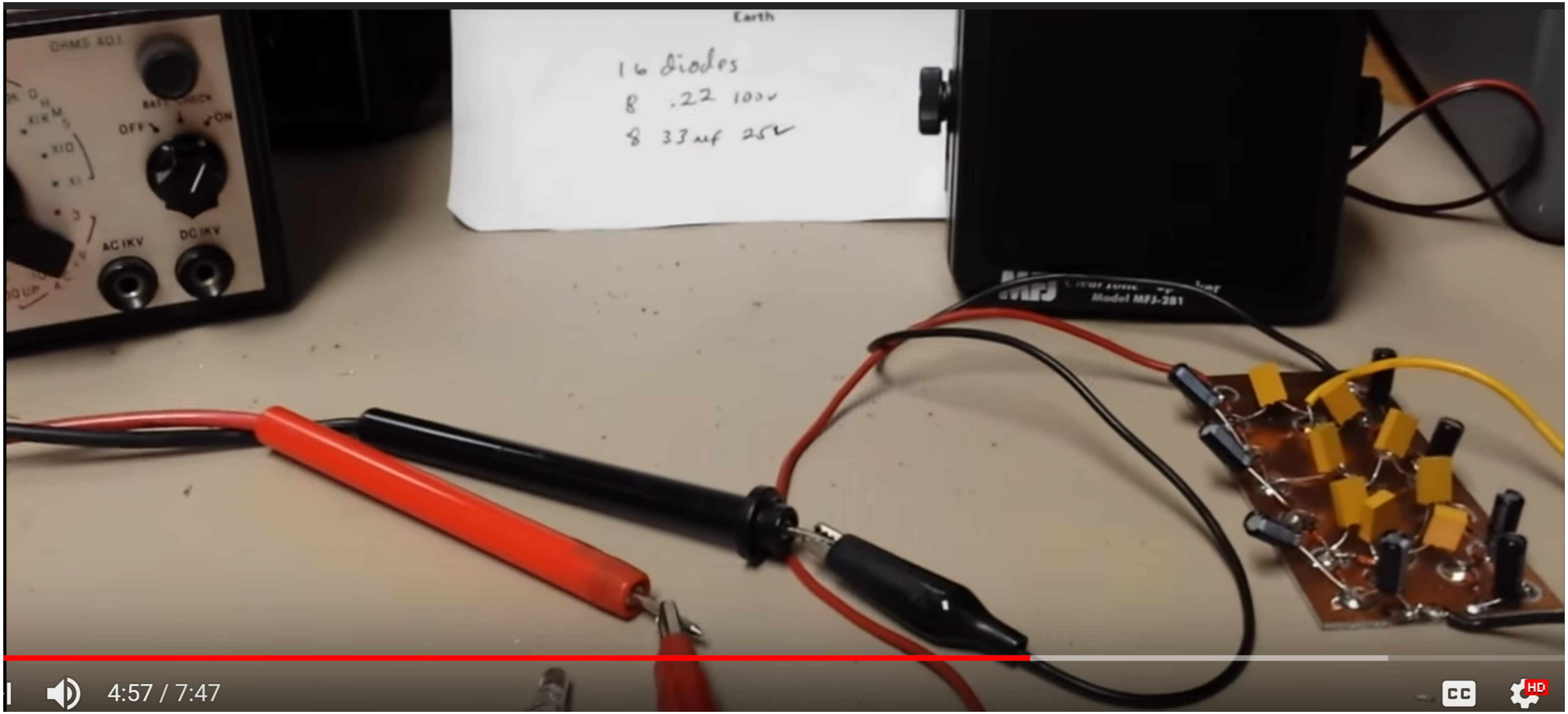
OHMS ADJ
BATT CHECK
OFF
ON
AC IKV
DC IKV
Earth
16 diodes
8 .22 100v
8 33uf 25v
MFJ
Model MFJ-281
4:57 / 7:47
CC
HD

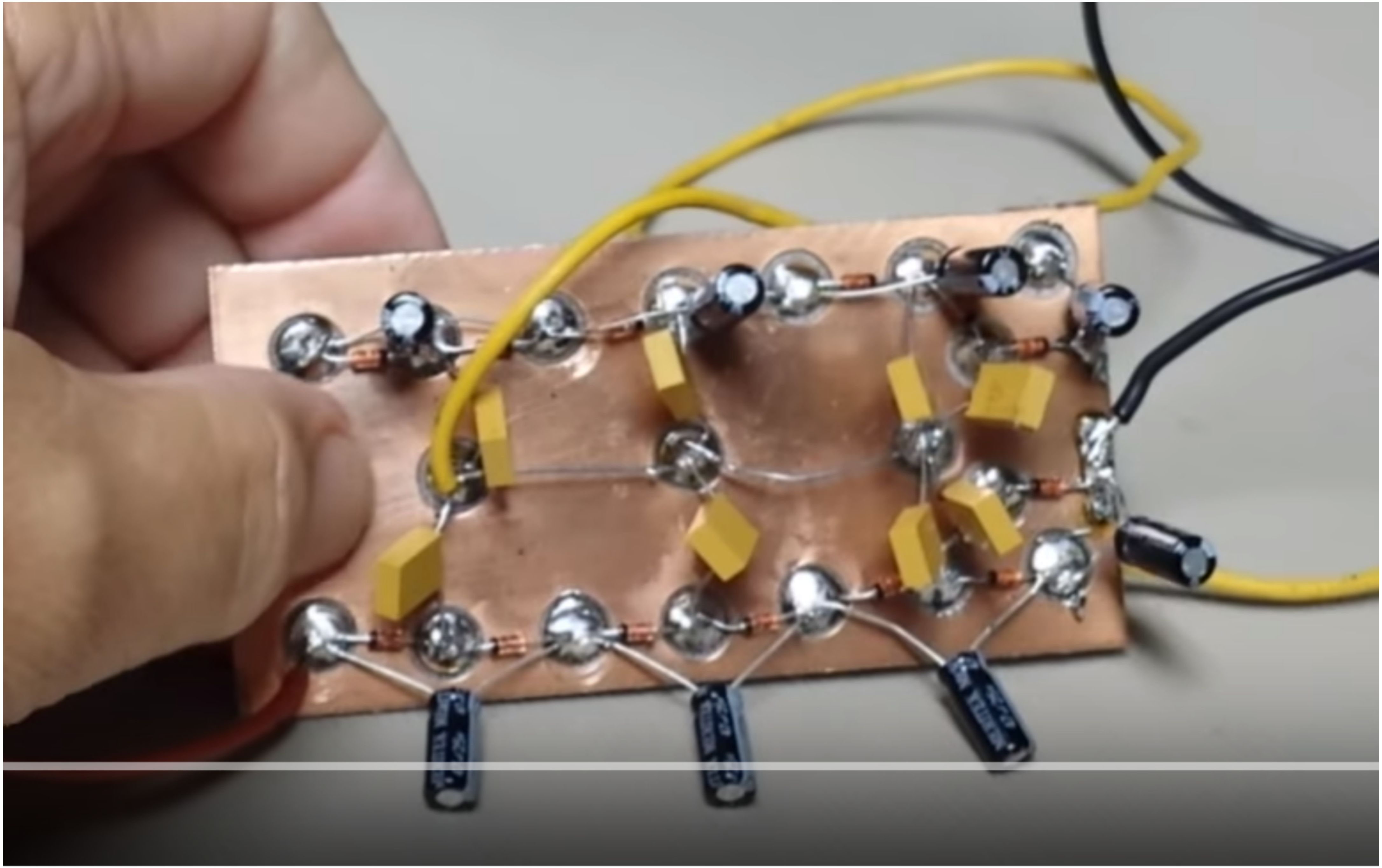

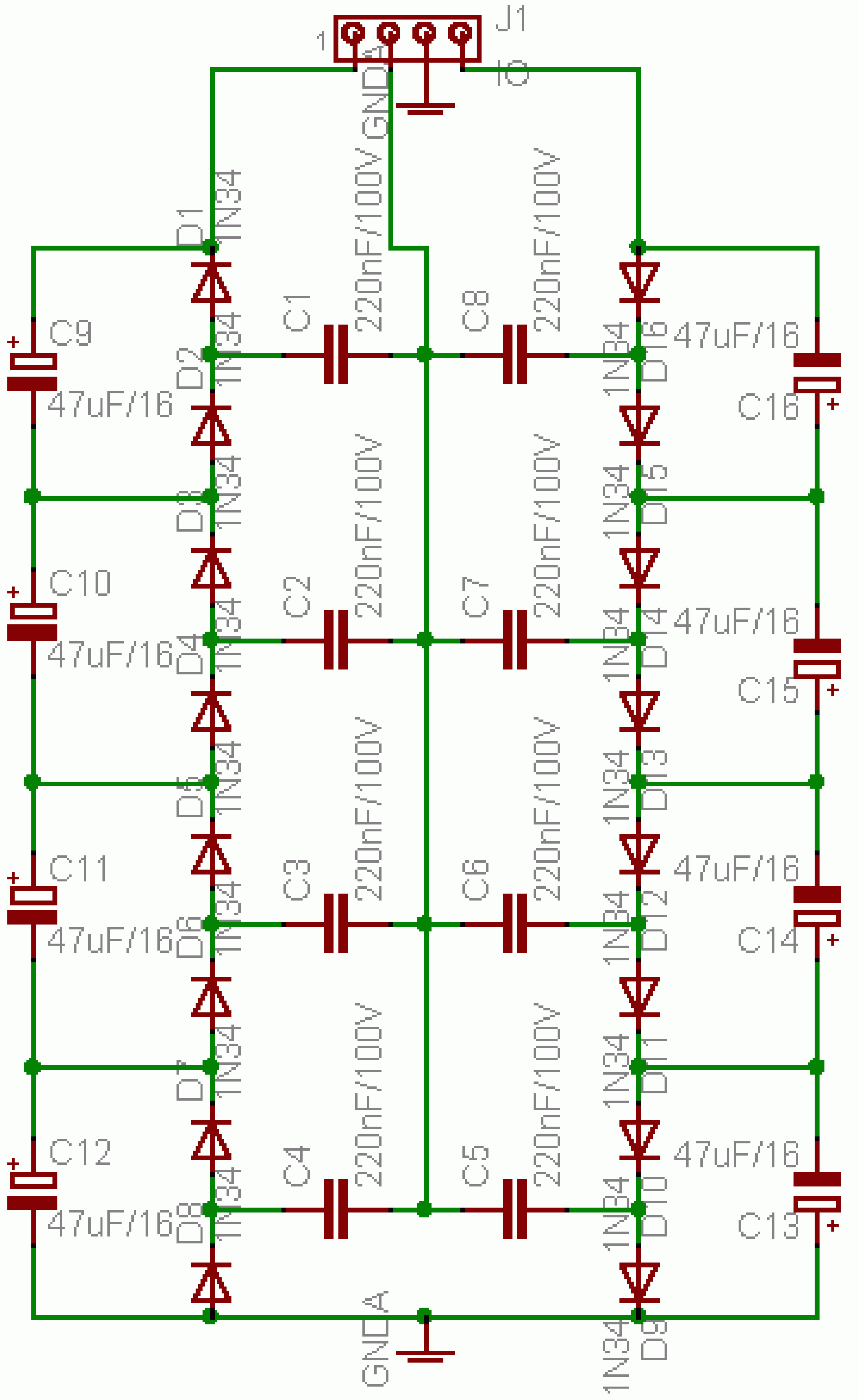
J1
1
GNDA
IO
D1
1N34
C9
+
47uF/16
D2
1N34
C1
220nF/100V
C8
220nF/100V
1N34
D16
47uF/16
C16
+
D3
1N34
220nF/100V
220nF/100V
1N34
D15
C10
+
47uF/16
D4
1N34
C2
220nF/100V
C7
220nF/100V
1N34
D14
47uF/16
C15
+
D5
1N34
220nF/100V
220nF/100V
1N34
D13
C11
+
47uF/16
D6
1N34
C3
220nF/100V
C6
220nF/100V
1N34
D12
47uF/16
C14
+
D7
1N34
220nF/100V
220nF/100V
1N34
D11
C12
+
47uF/16
D8
1N34
C4
220nF/100V
C5
220nF/100V
1N34
D10
47uF/16
C13
+
GNDA
1N34
D9

AMBIENT POWER MODULE

(C) - GROUNDLOOP 2012

Circuit Diagram

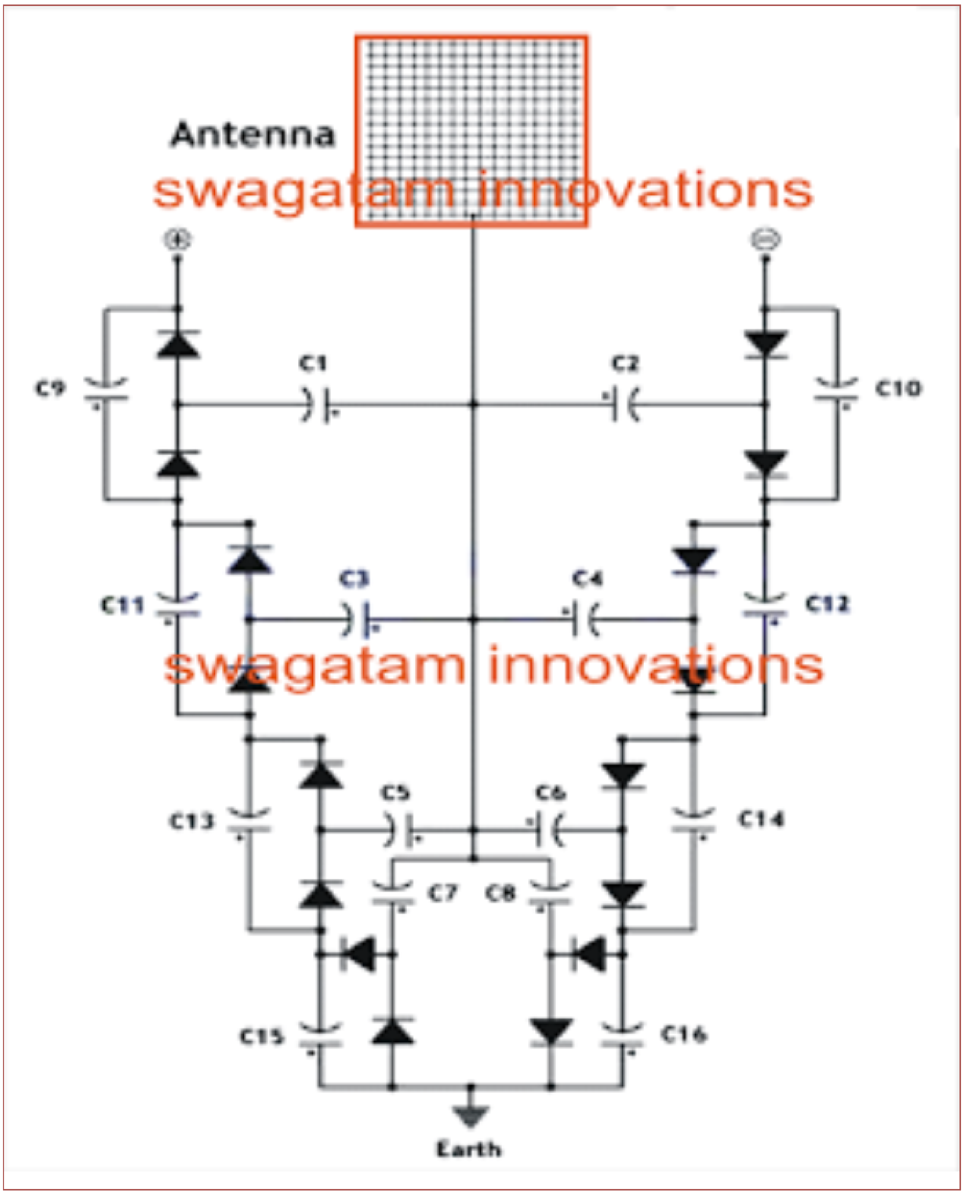
Antenna
swagatam innovations
⊕
⊖
C1
C2
C9
C10
C3
C4
C11
C12
swagatam innovations
C5
C6
C13
C14
C7
C8
C15
C16
Earth

Parts List

All Diodes are 1N4148

C1---C8 = 0.22uF/100V mylar

C9----C16 = 33uF/25V electrolytic

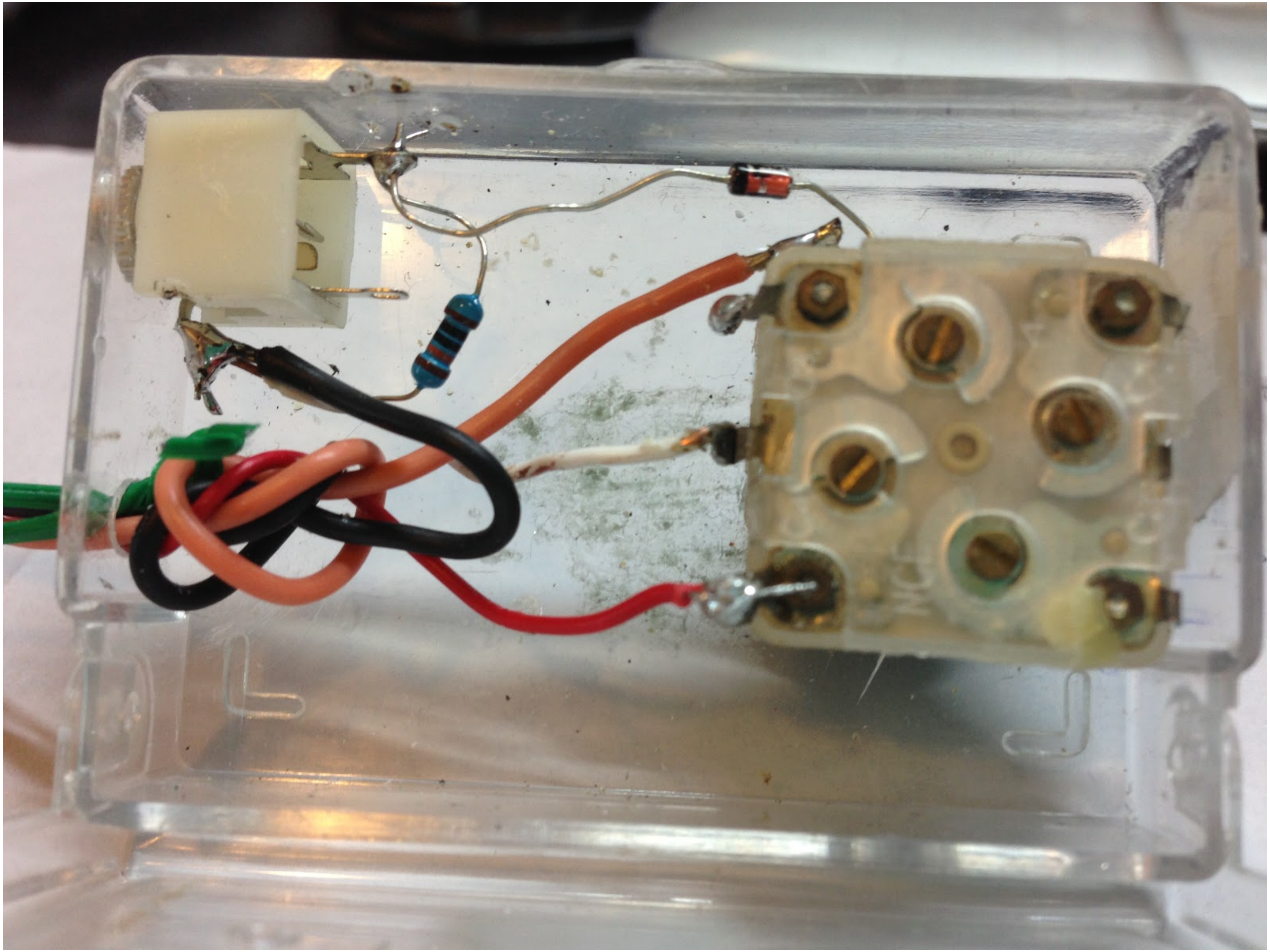

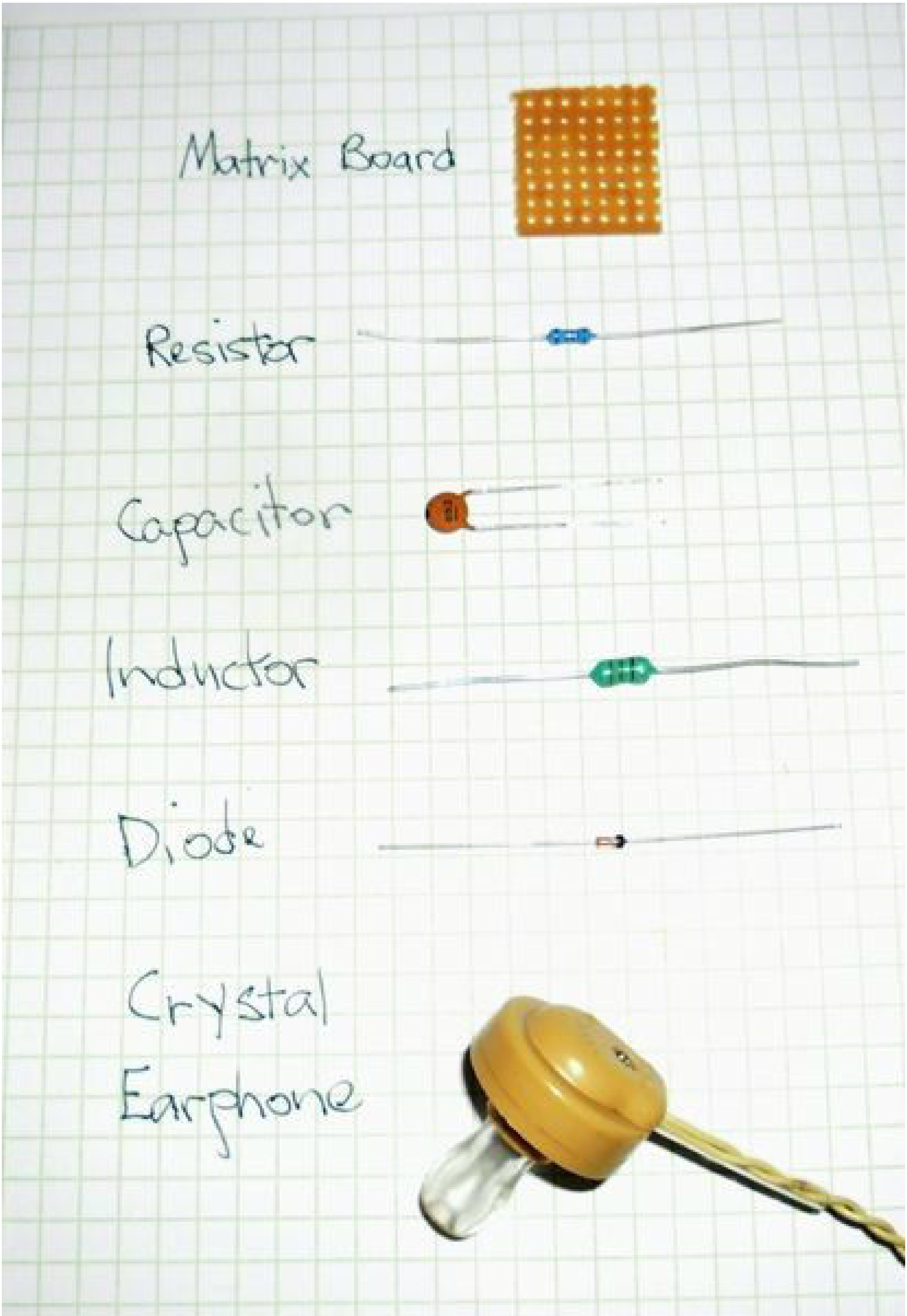
Matrix Board
Resistor
Capacitor
Inductor
Diode
Crystal
Earphone

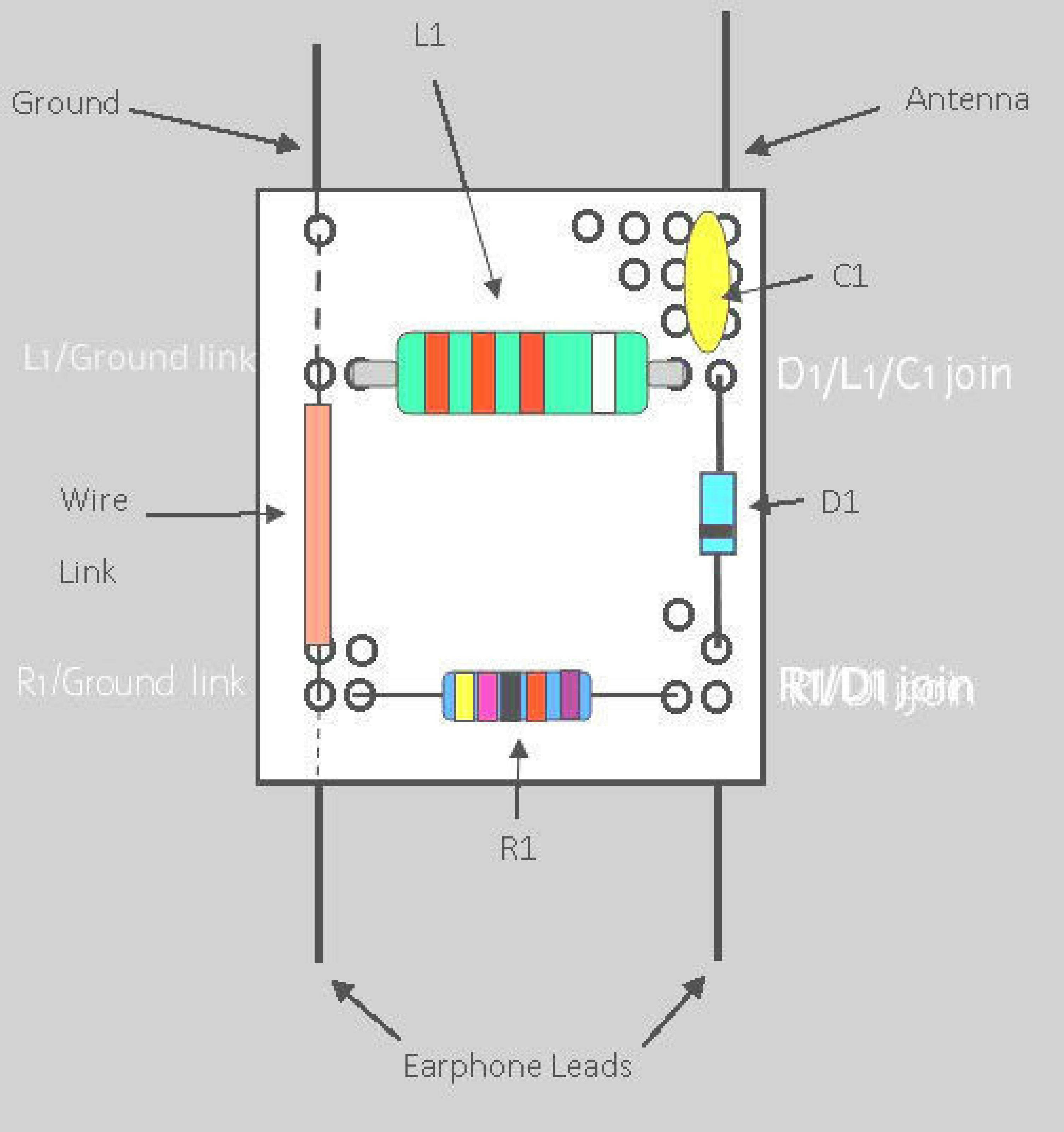
L1
Ground
Antenna
C1
L1/Ground link
D1/L1/C1 join
Wire
Link
D1
R1/Ground link
R1/D1 join
R1
Earphone Leads

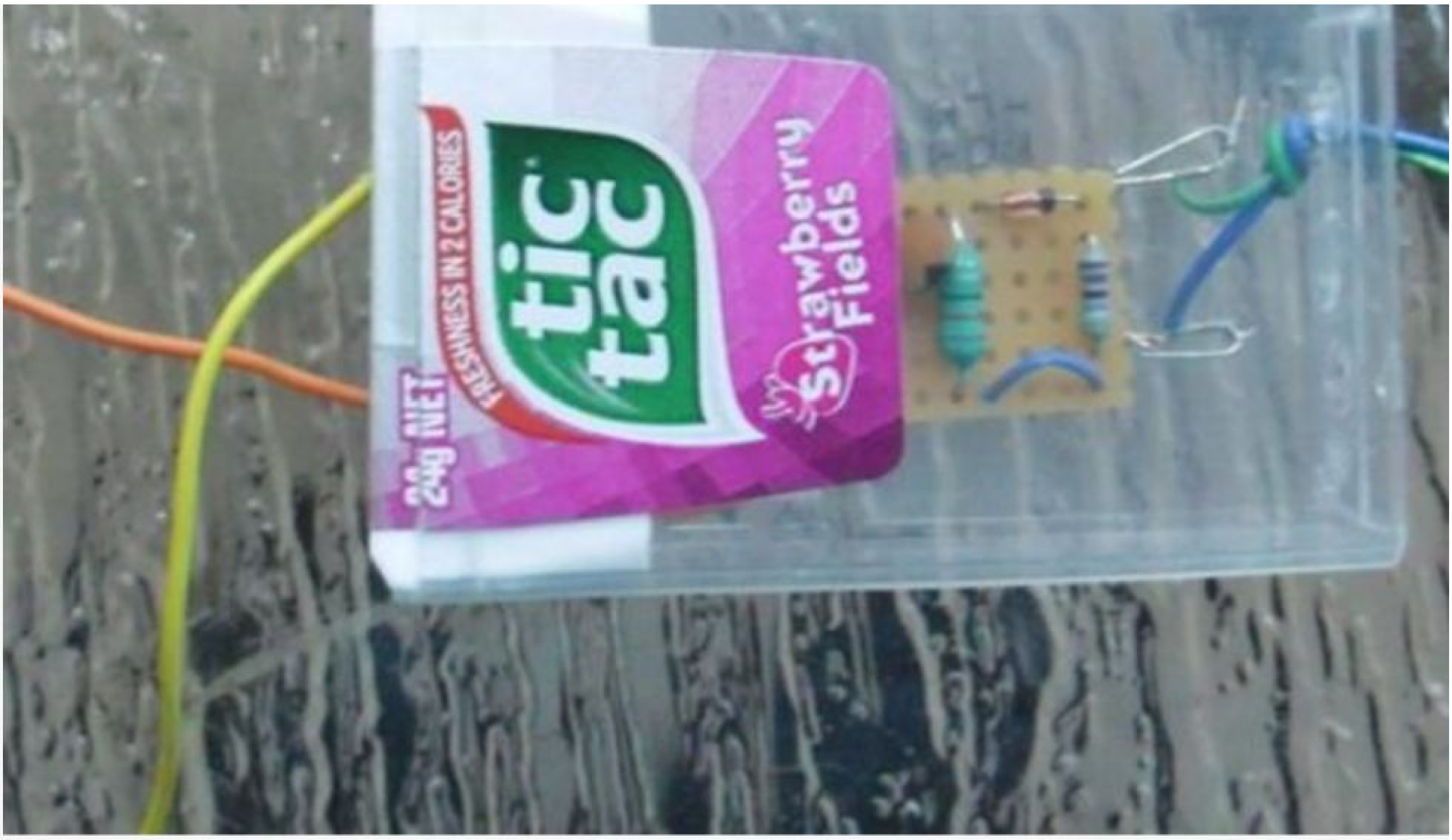
24g NET
FRESHNESS IN 2 CALORIES
tic tac
Strawberry Fields

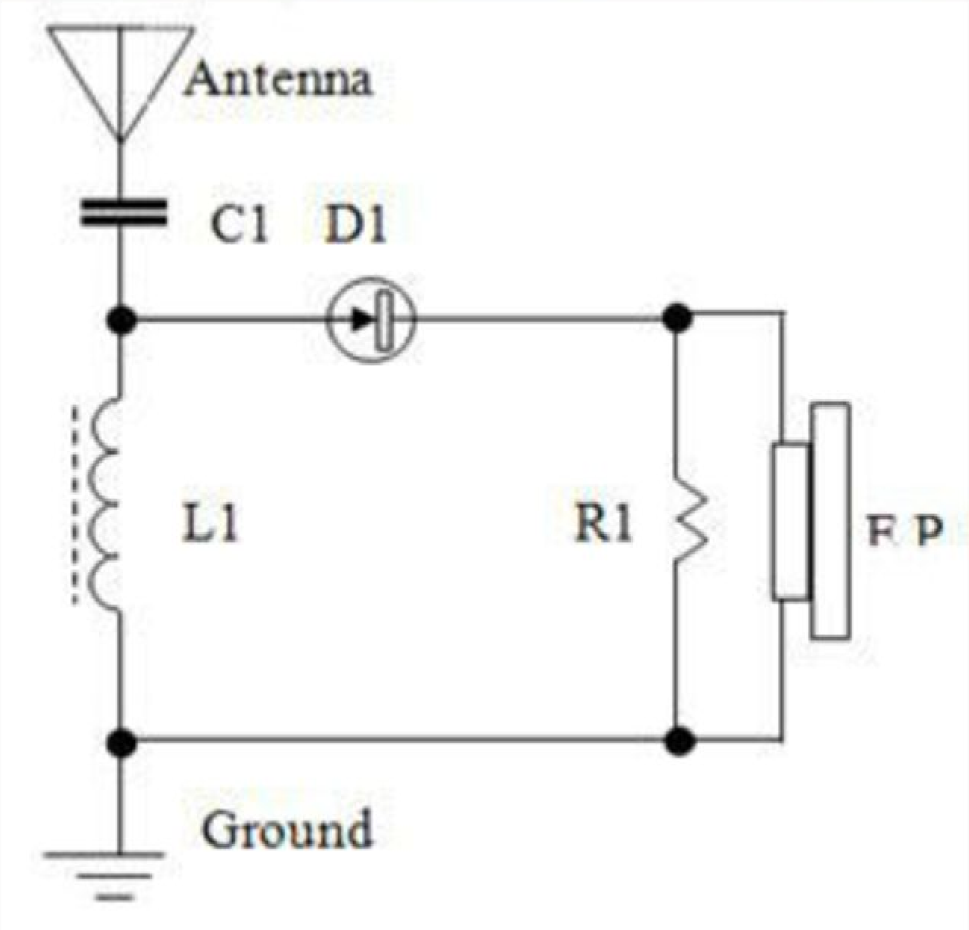
Antenna
C1
D1
L1
R1
EP
Ground

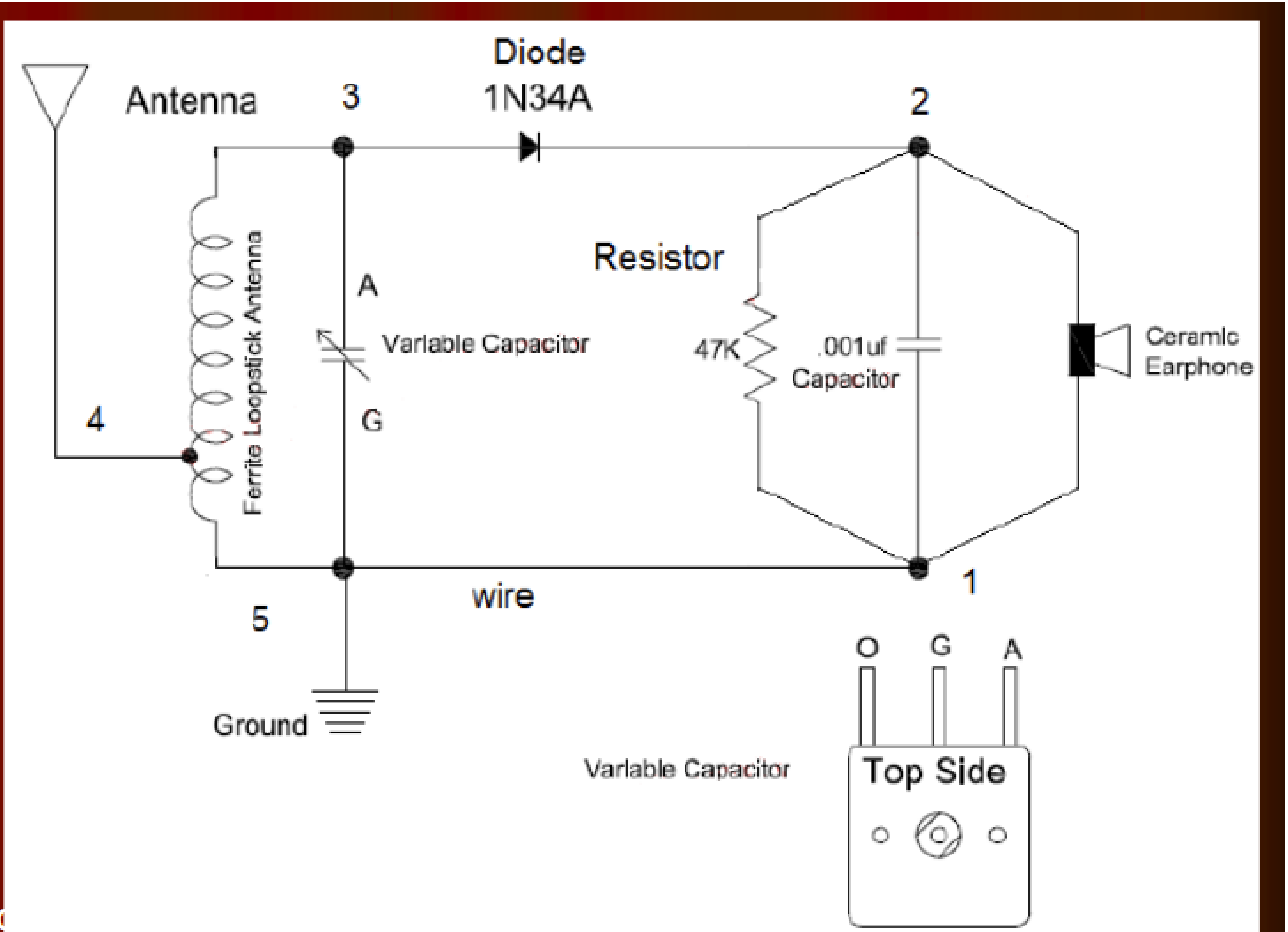
Diode
1N34A
Antenna
3
2
Resistor
Ferrite Loopstick Antenna
A
Variable Capacitor
47K
.001uf
Capacitor
Ceramic
Earphone
G
4
1
wire
5
Ground
O
G
A
Variable Capacitor
Top Side

[So

http://www.angelfire.com/electronic2/index1/DmCrystalSet.html]

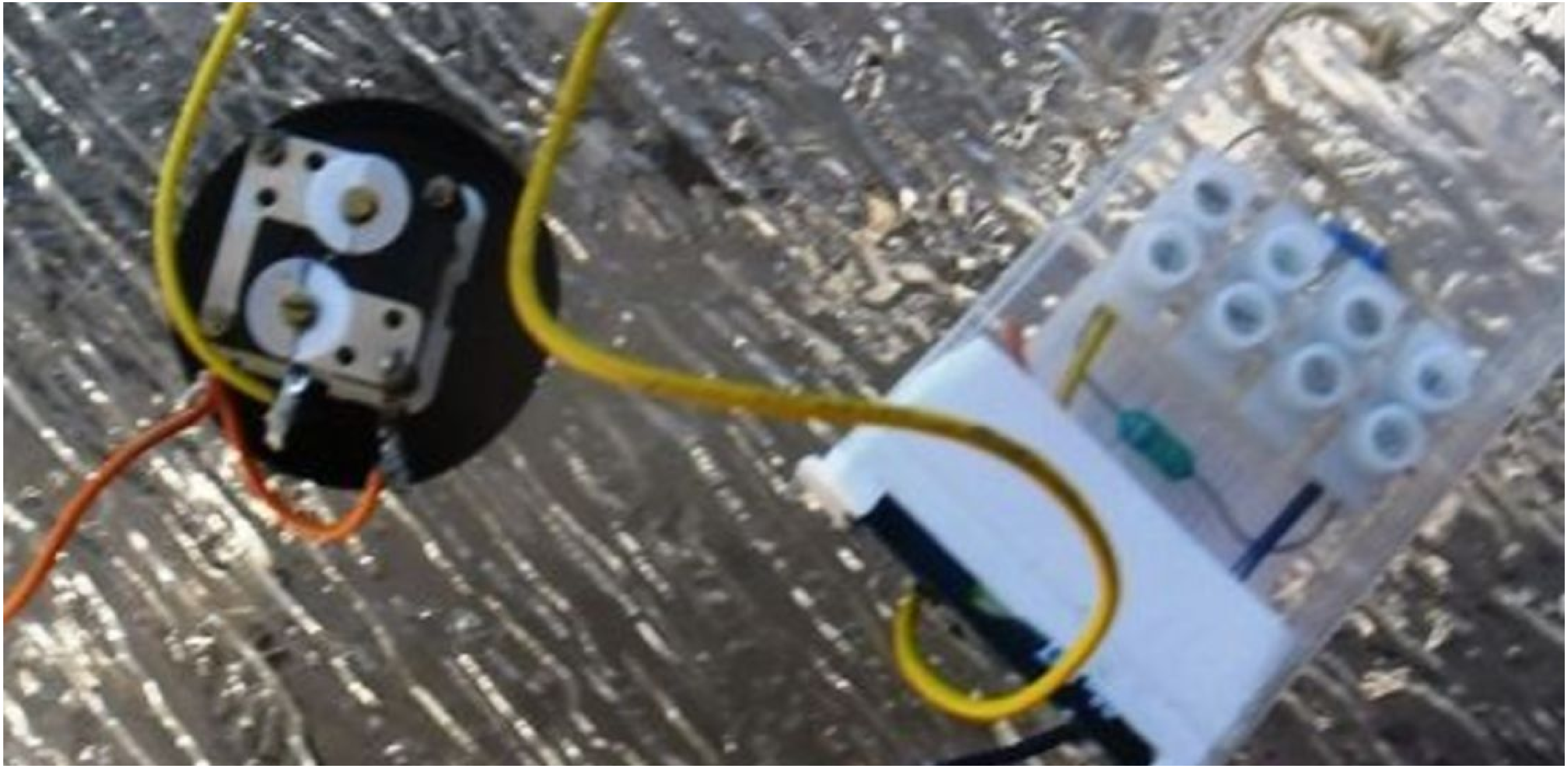

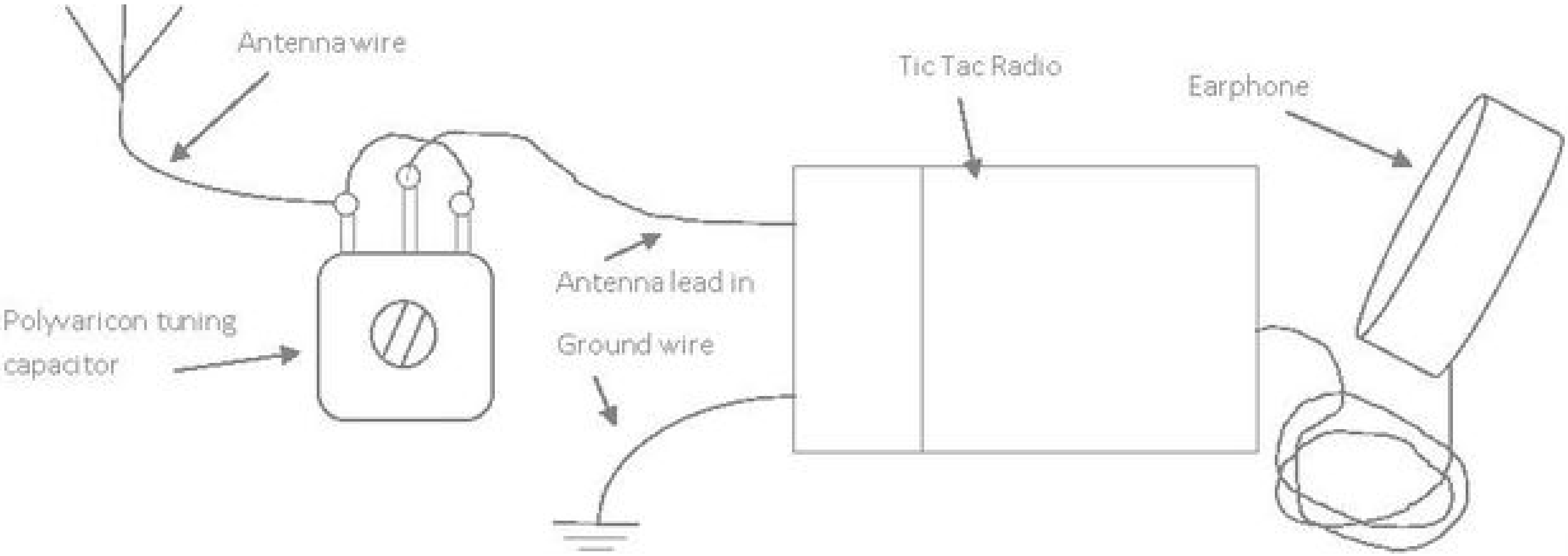
Antenna wire
Tic Tac Radio
Earphone
Antenna lead in
Ground wire
Polyvaricon tuning capacitor

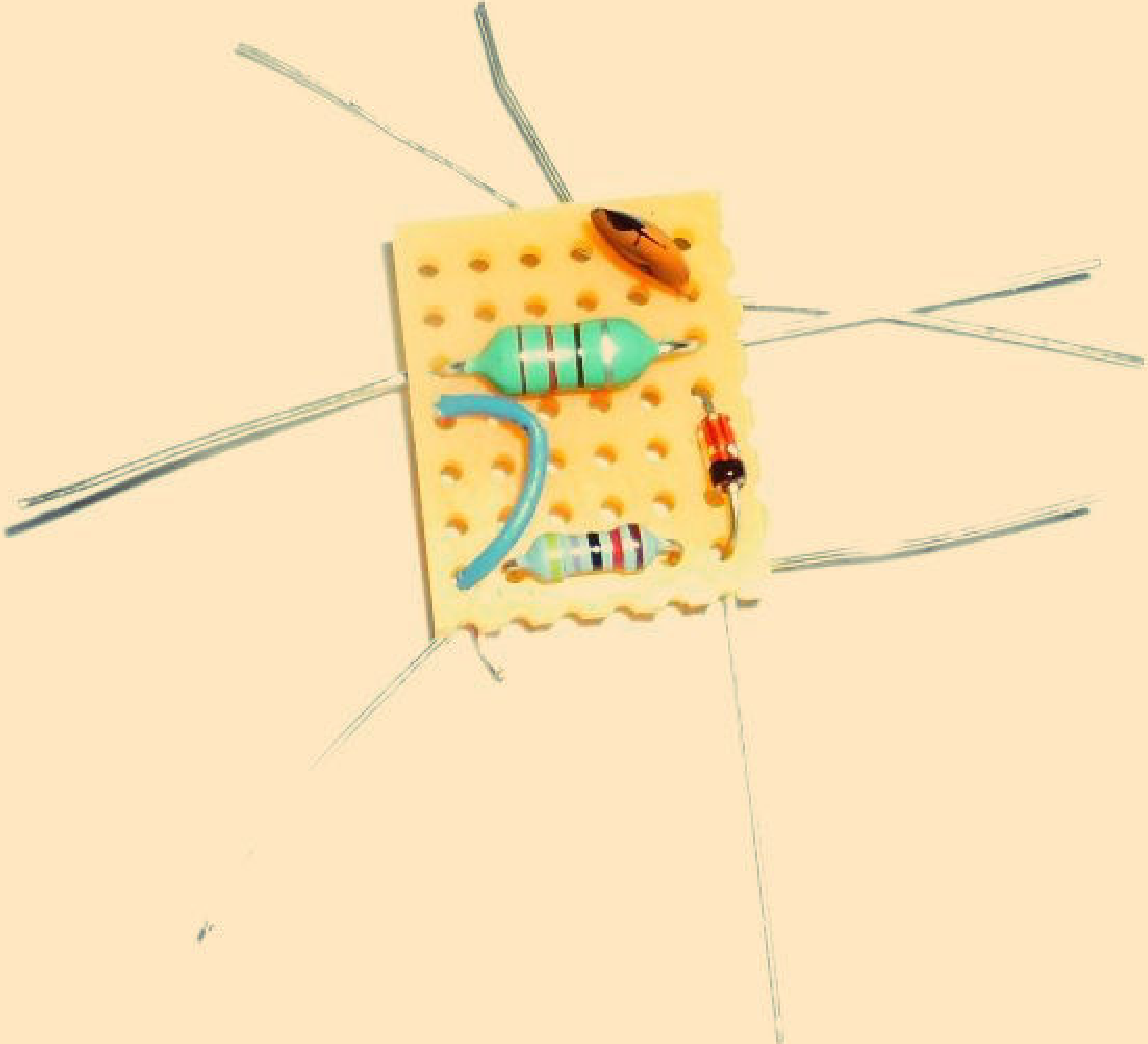

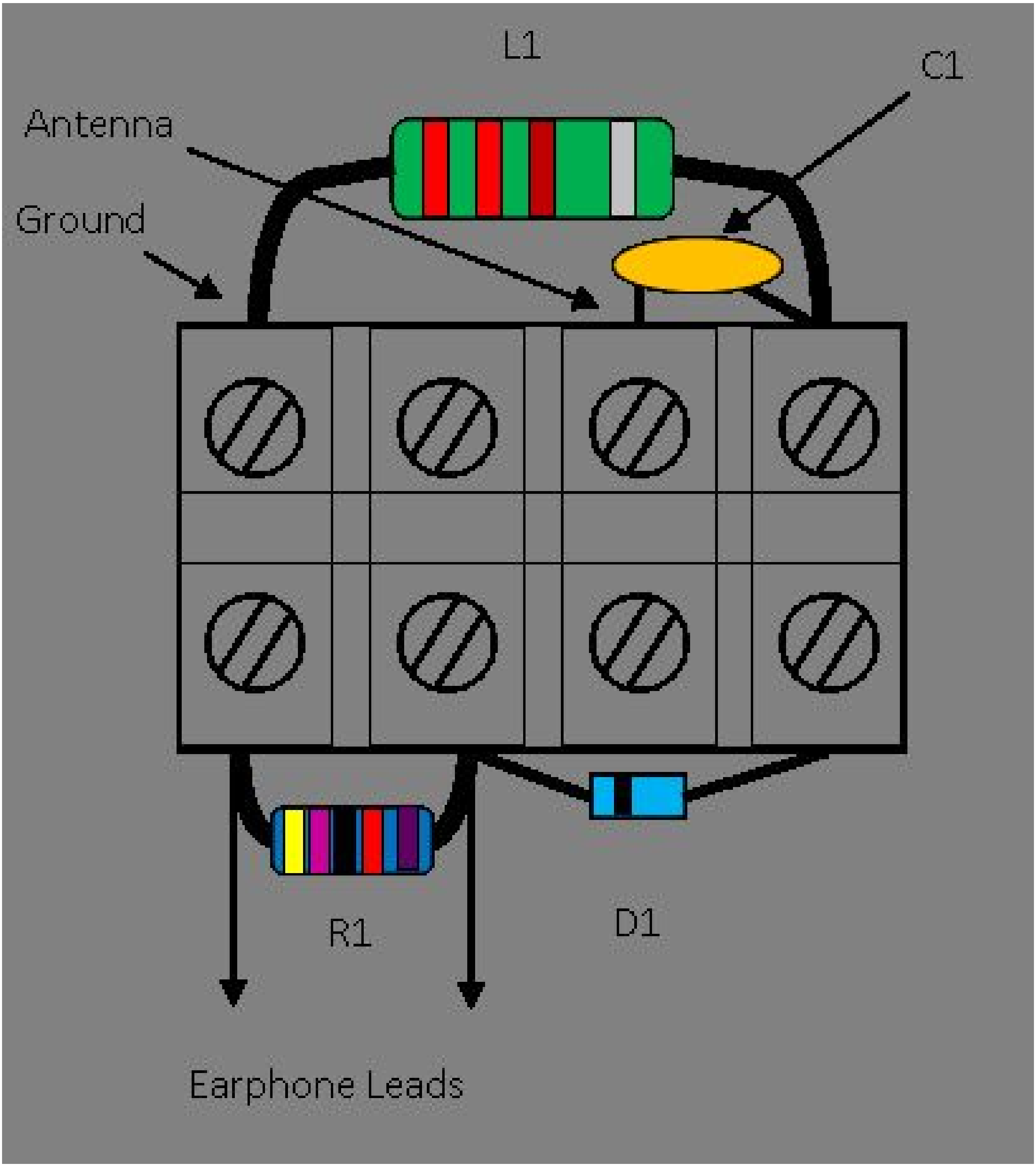
L1
C1
Antenna
Ground
R1
D1
Earphone Leads

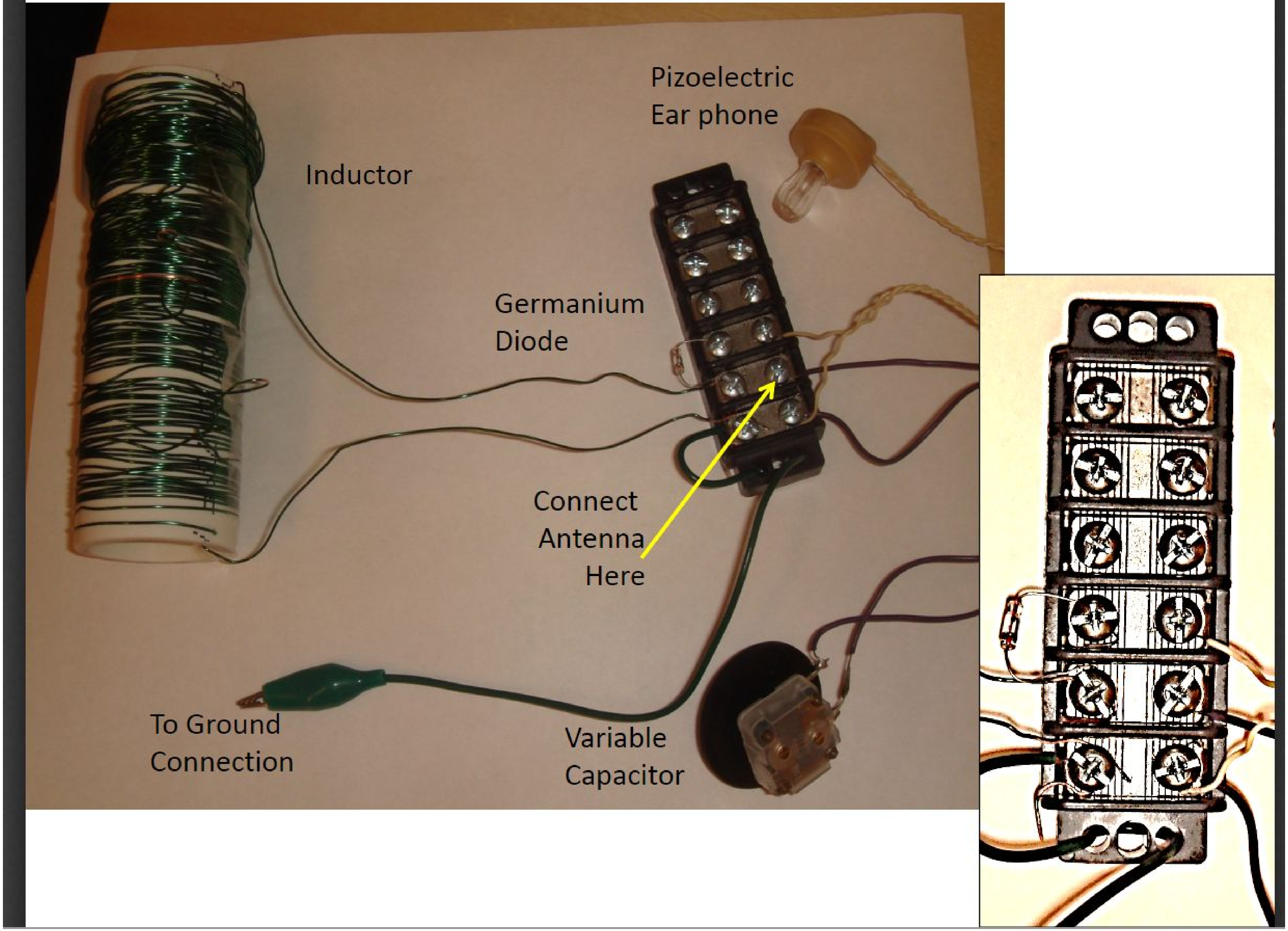
Pizoelectric
Ear phone
Inductor
Germanium
Diode
Connect
Antenna
Here
To Ground
Connection
Variable
Capacitor

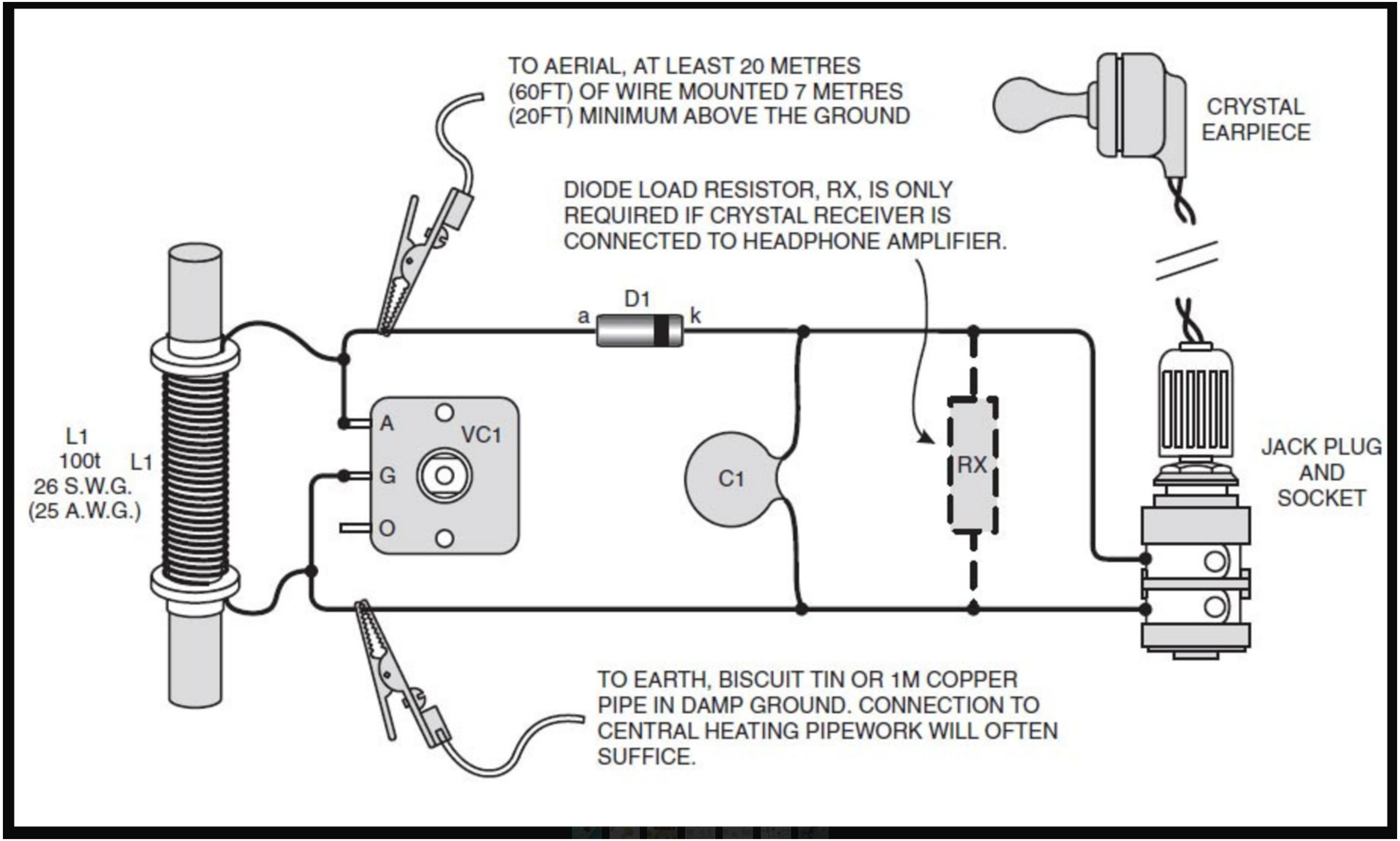
TO AERIAL, AT LEAST 20 METRES
(60FT) OF WIRE MOUNTED 7 METRES
(20FT) MINIMUM ABOVE THE GROUND
CRYSTAL
EARPIECE
DIODE LOAD RESISTOR, RX, IS ONLY
REQUIRED IF CRYSTAL RECEIVER IS
CONNECTED TO HEADPHONE AMPLIFIER.
D1
a
k
L1
100t
L1
26 S.W.G.
(25 A.W.G.)
A
G
O
VC1
C1
RX
JACK PLUG
AND
SOCKET
TO EARTH, BISCUIT TIN OR 1M COPPER
PIPE IN DAMP GROUND. CONNECTION TO
CENTRAL HEATING PIPEWORK WILL OFTEN
SUFFICE.

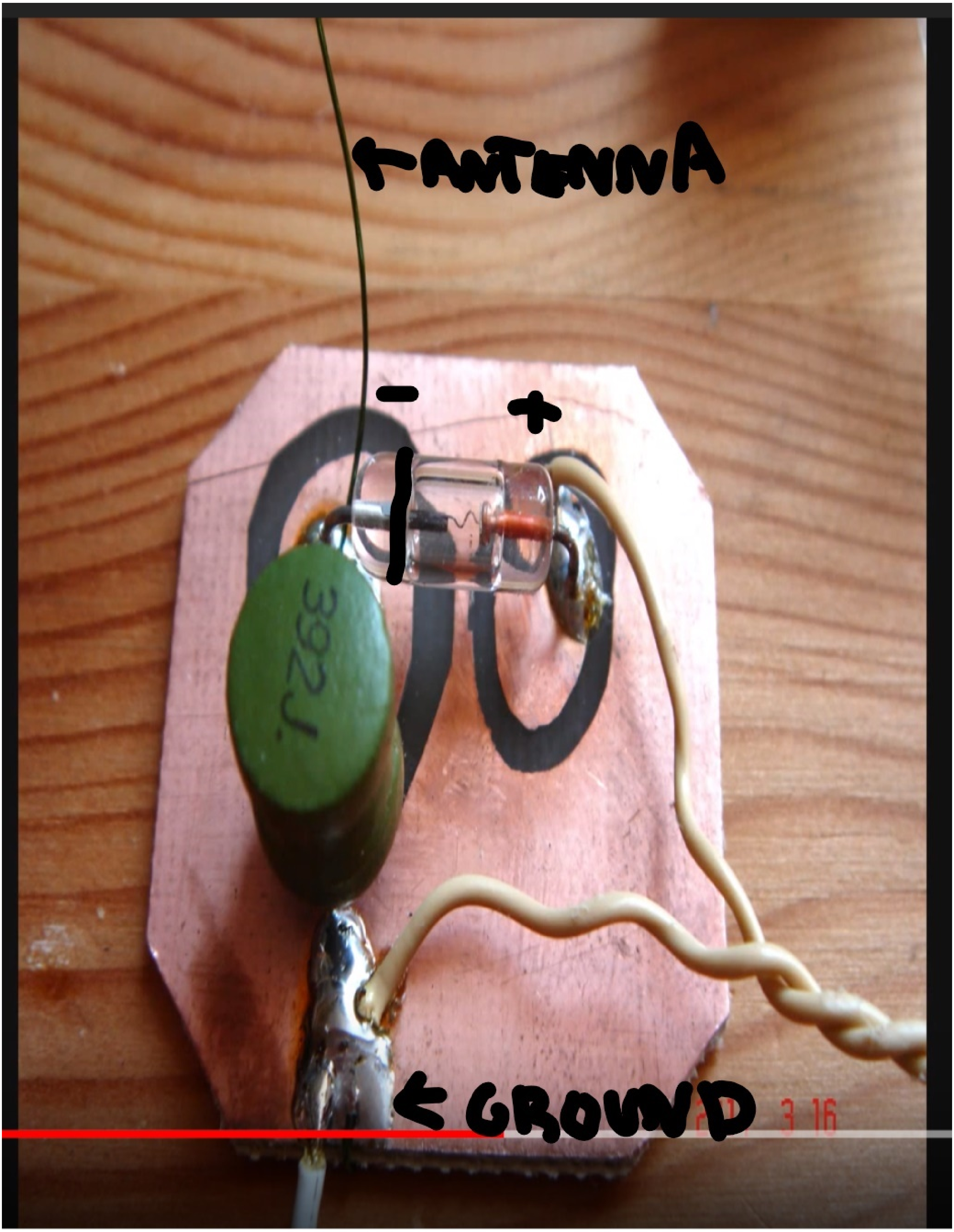
← ANTENNA
−
+
392J
← GROUND
3 16

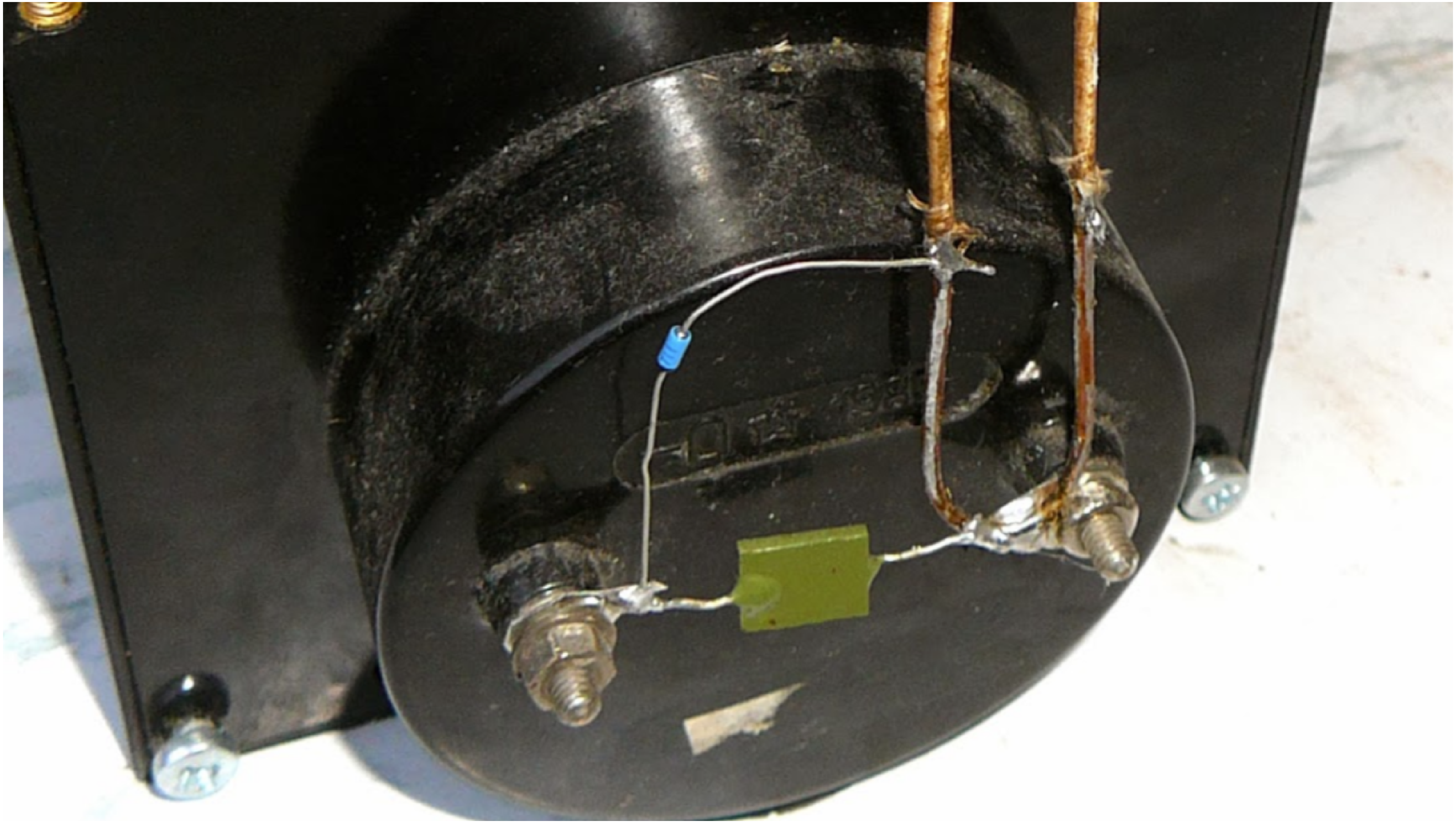

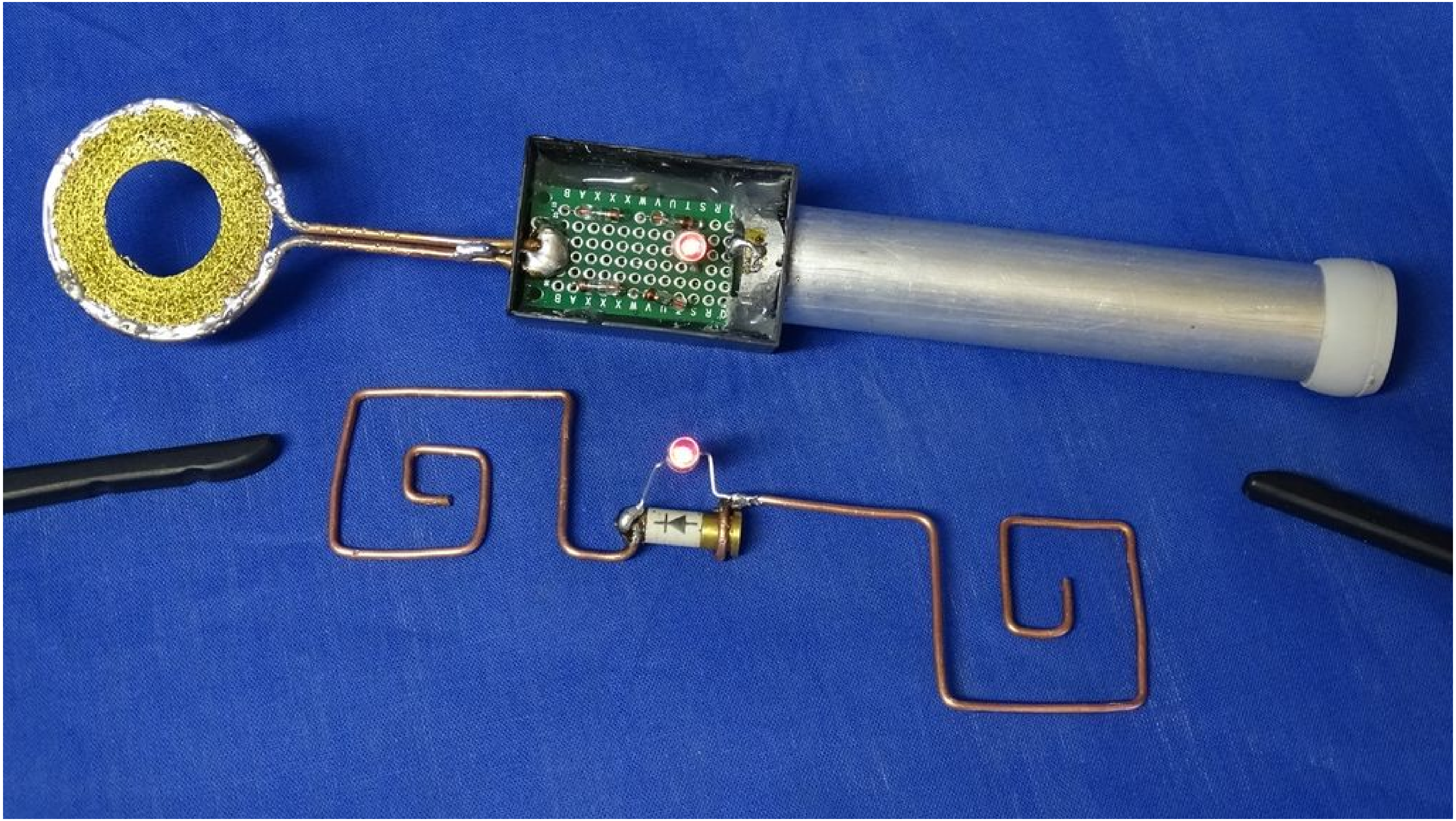

Step 1: LED+RF Diode

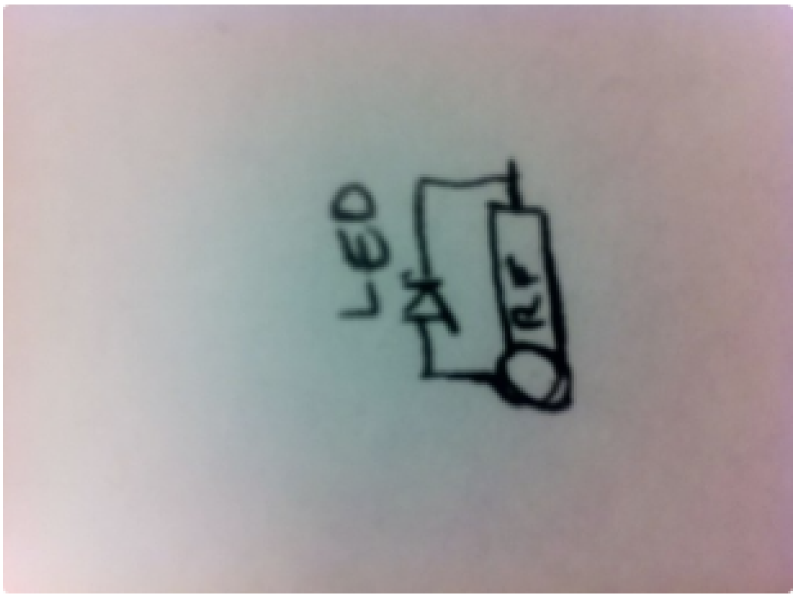

First Solder the led parallel to the Rf diode

Add Tip Ask Question Comment Download

Step 2: RF Diode+ LED+ Wires

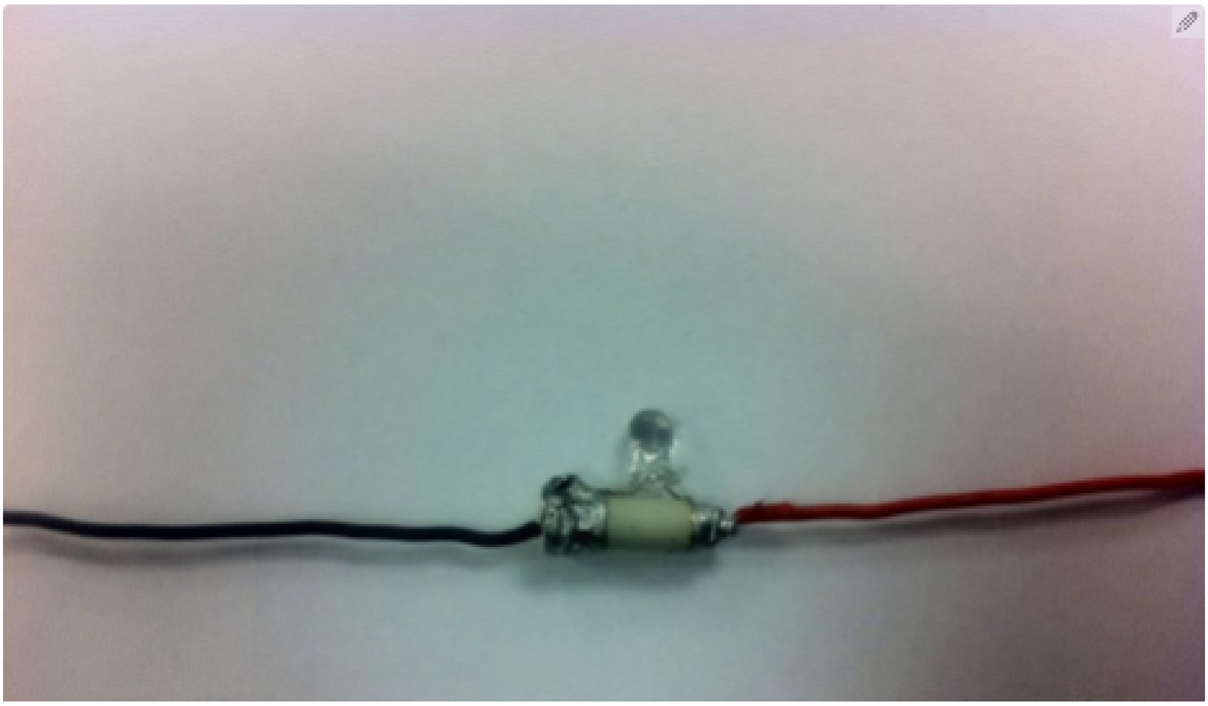

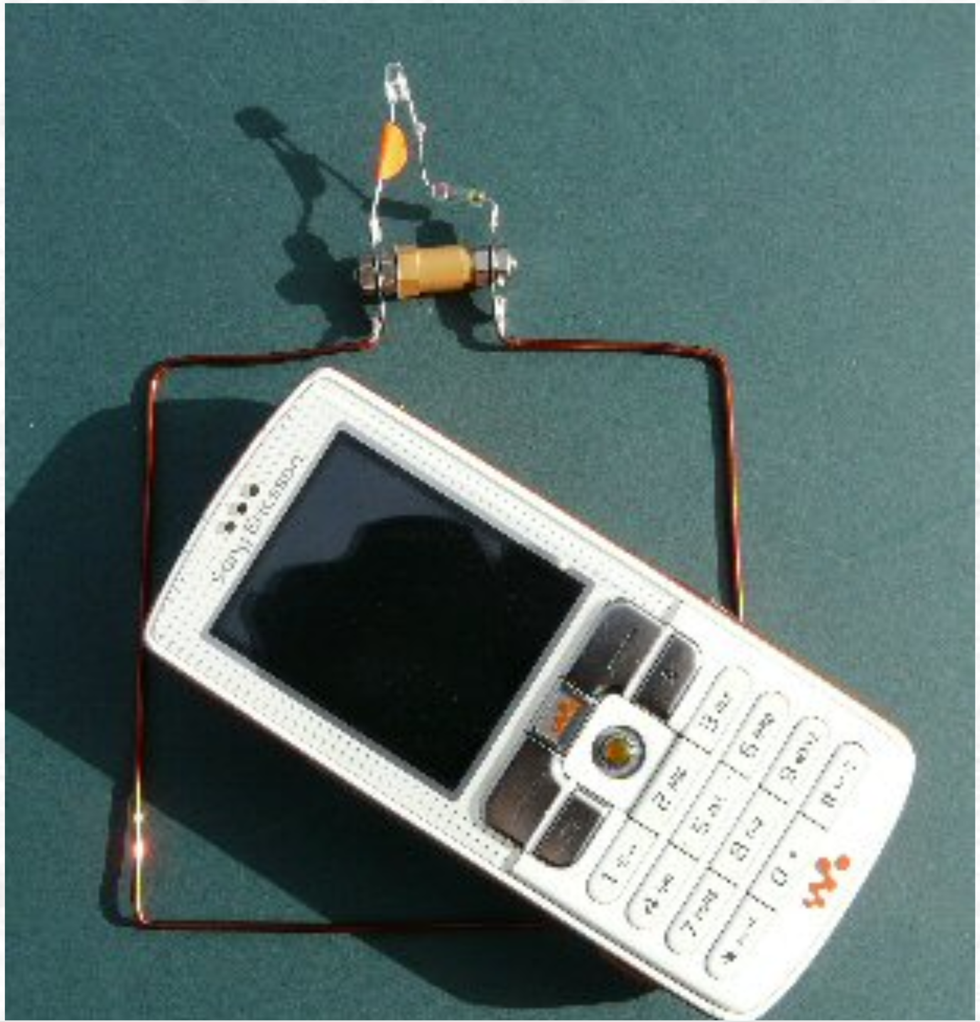

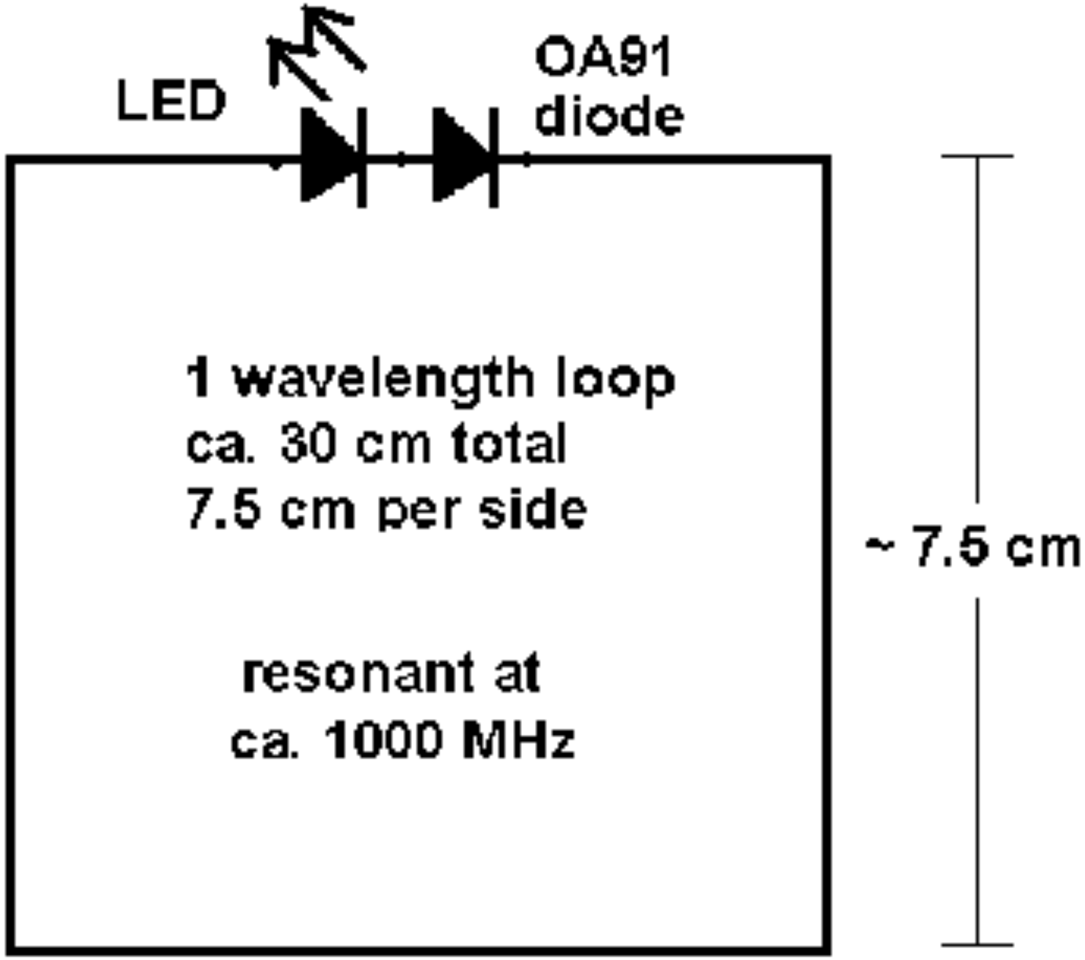

LED

OA91
diode

1 wavelength loop
ca. 30 cm total
7.5 cm per side

resonant at
ca. 1000 MHz

~ 7.5 cm

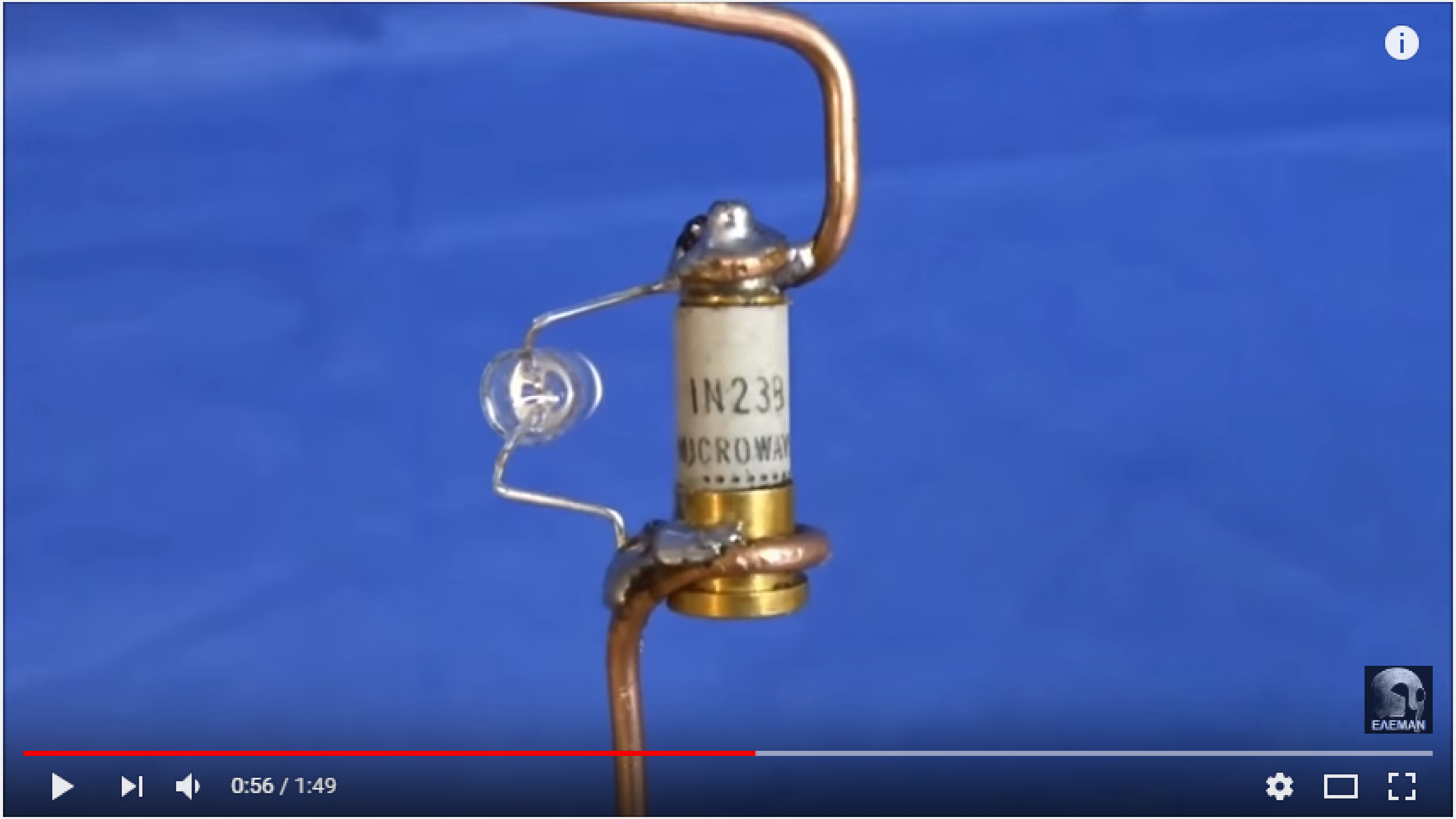
IN23B
CROWAV
ΕΛΕΜΑΝ
0:56 / 1:49

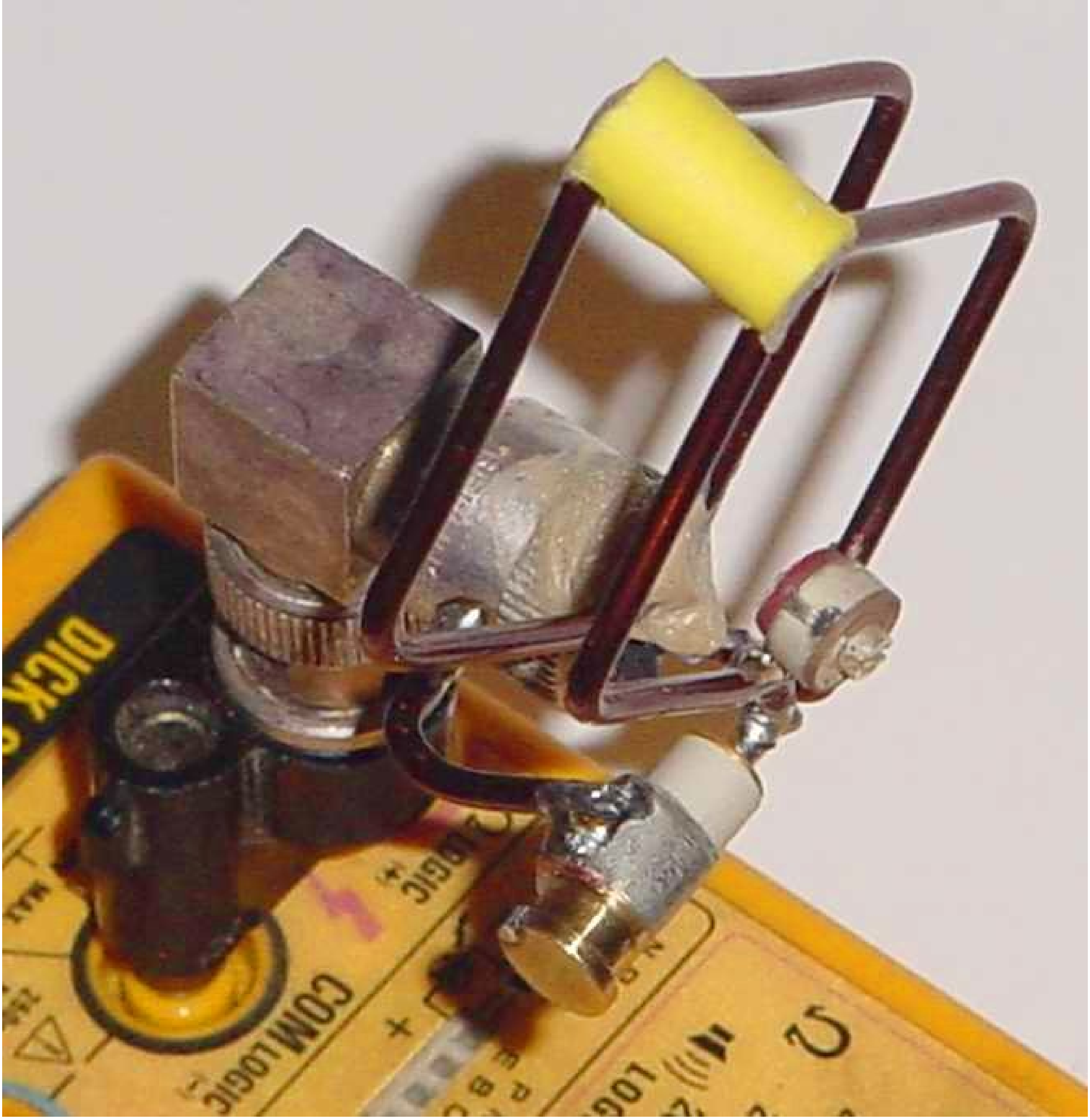

COM LOGIC
LOGIC

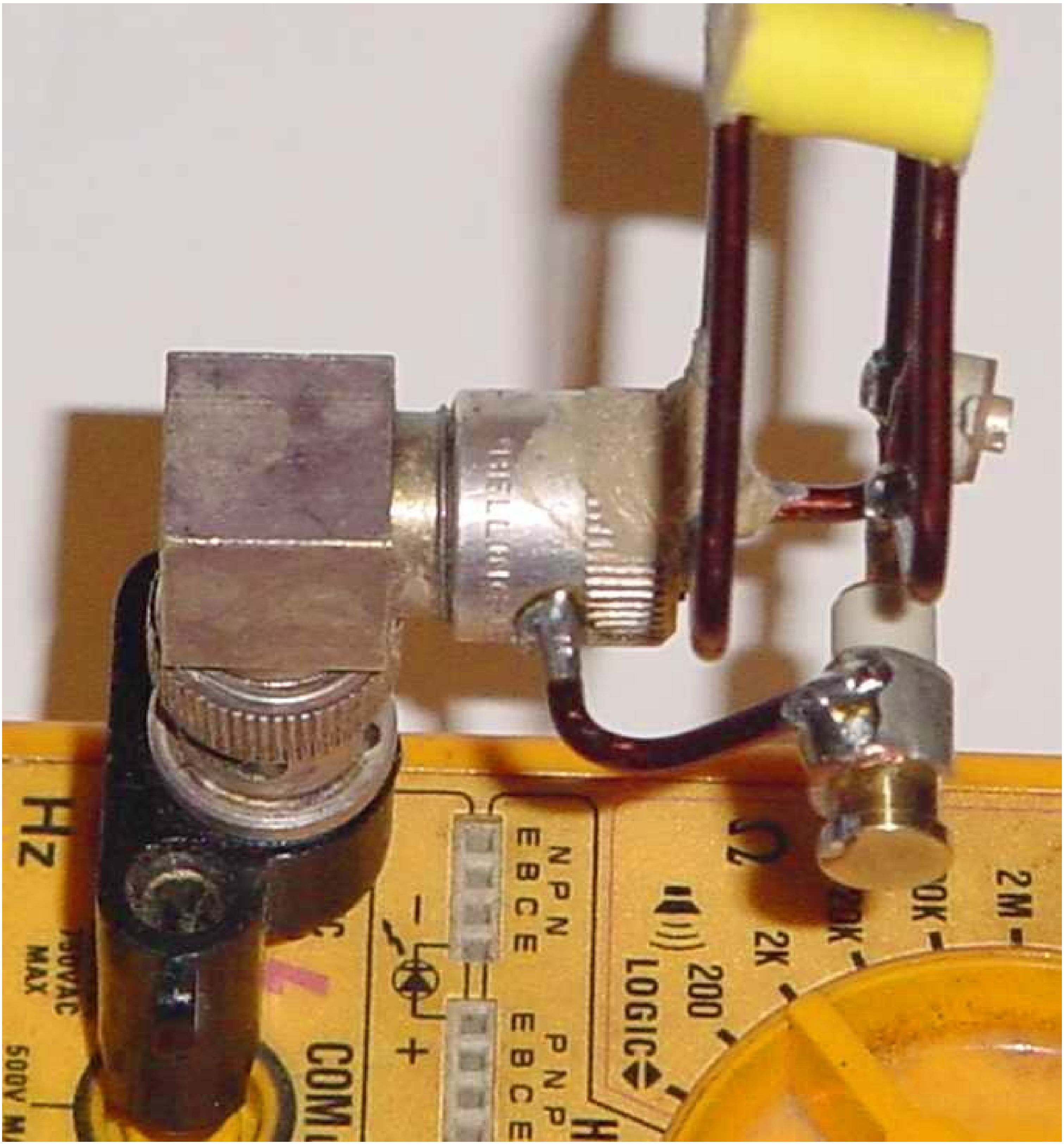
Hz
750VAC MAX
500V MAX
COM
NPN
EBCE
PNP
EBCE
LOGIC
200
2K
20K
200K
2M

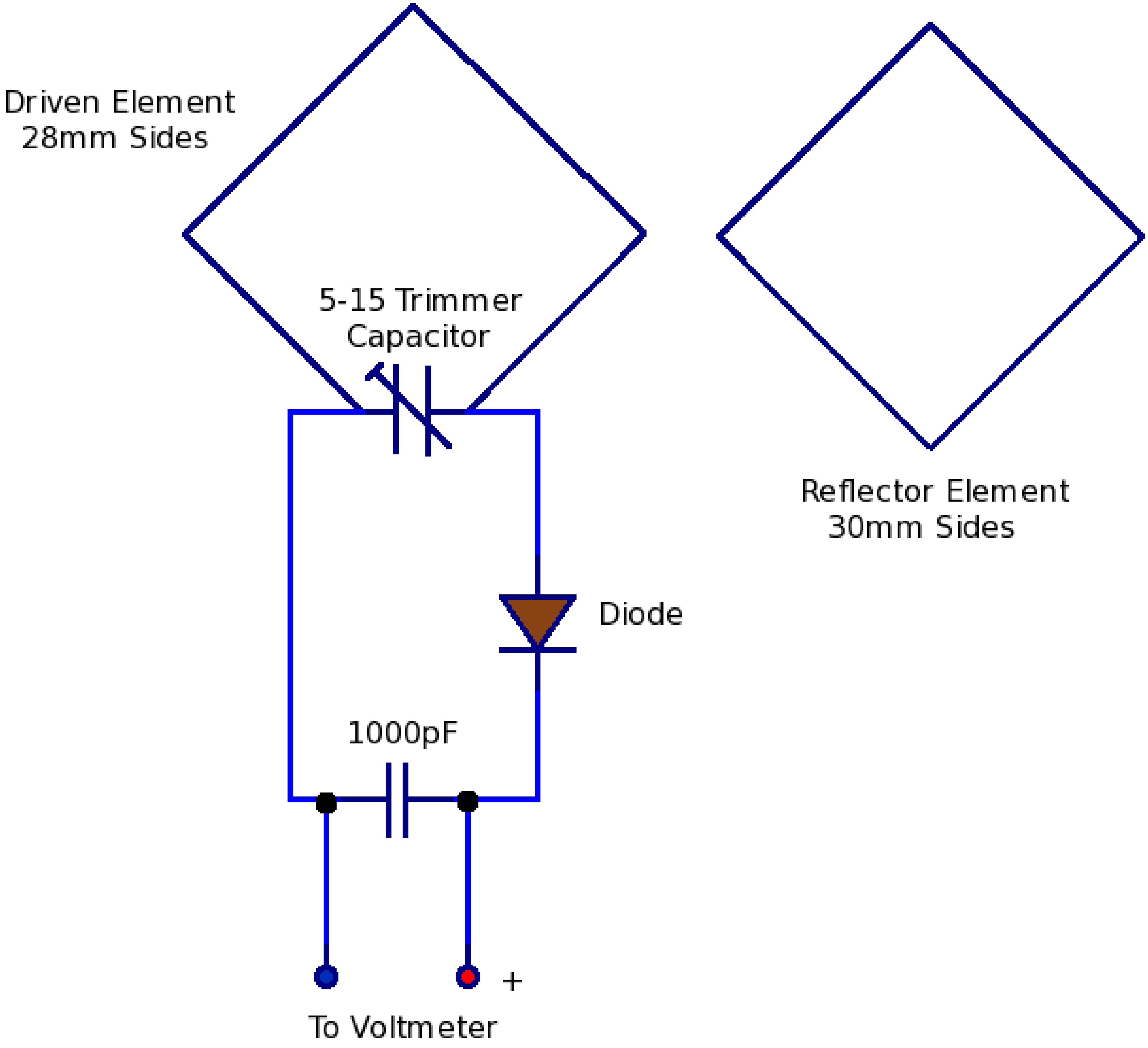
Driven Element
28mm Sides
5-15 Trimmer
Capacitor
Reflector Element
30mm Sides
Diode
1000pF
+
To Voltmeter

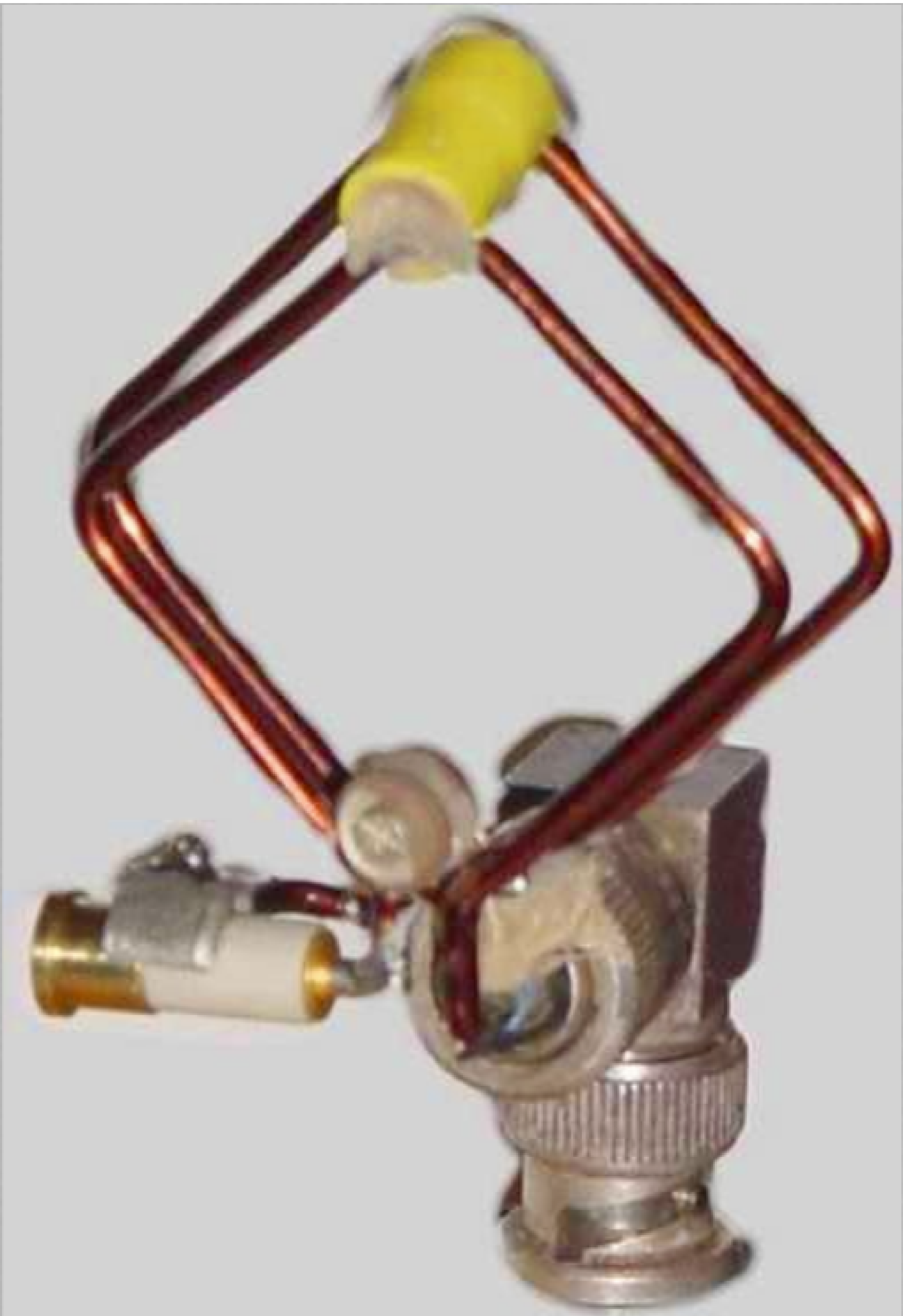

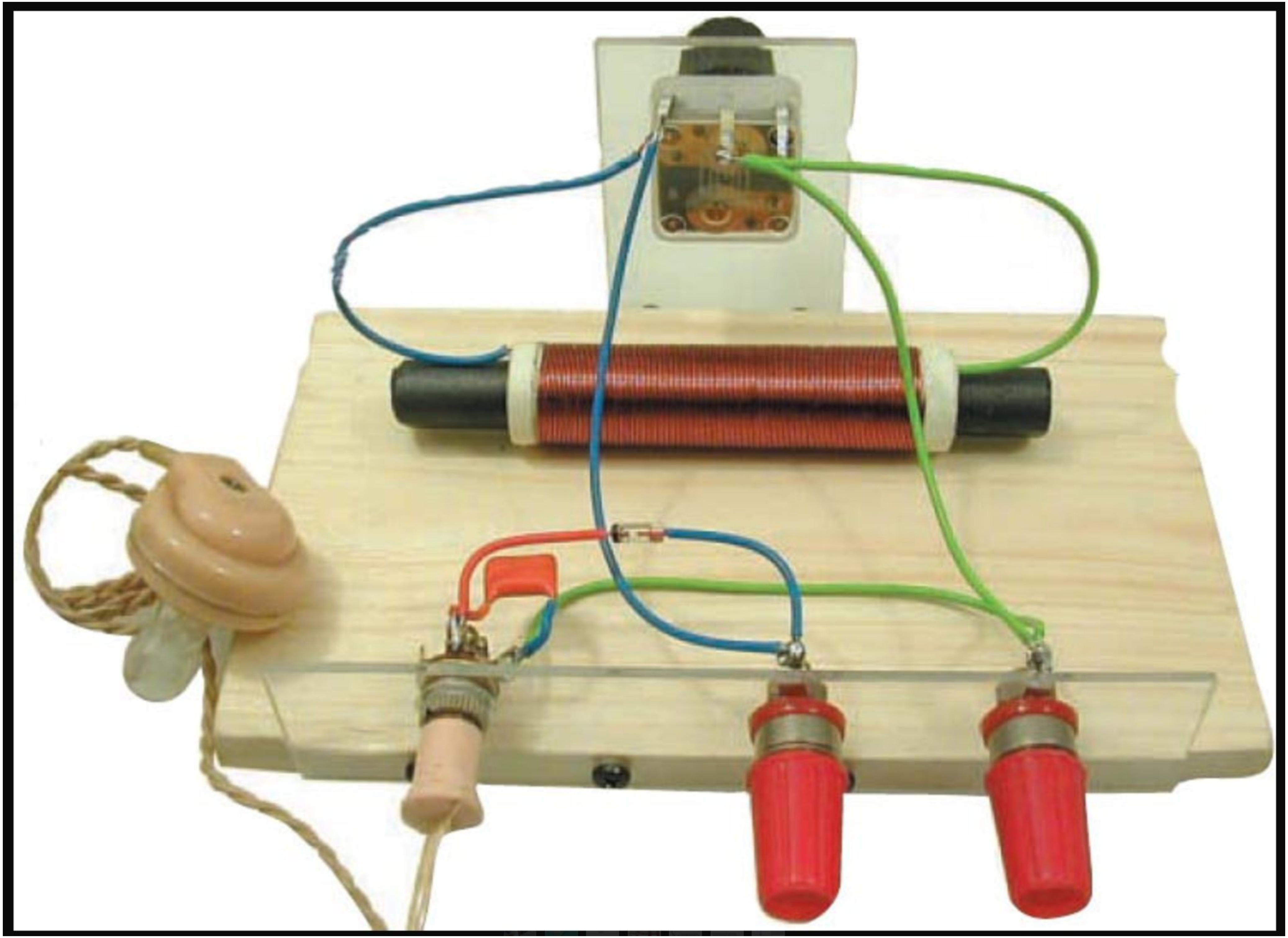

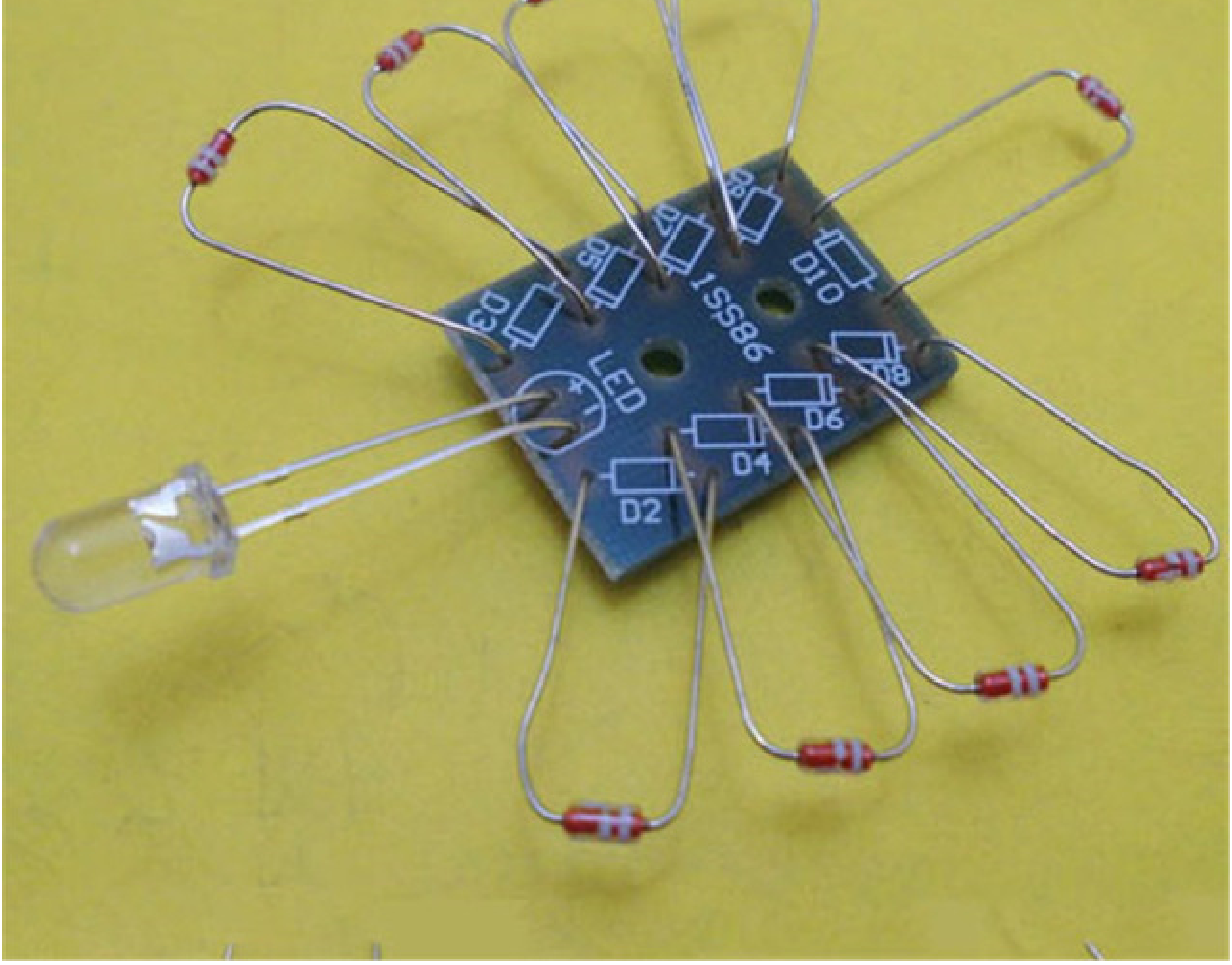
D3
D5
1SS86
D10
LED
+
D8
D6
D4
D2

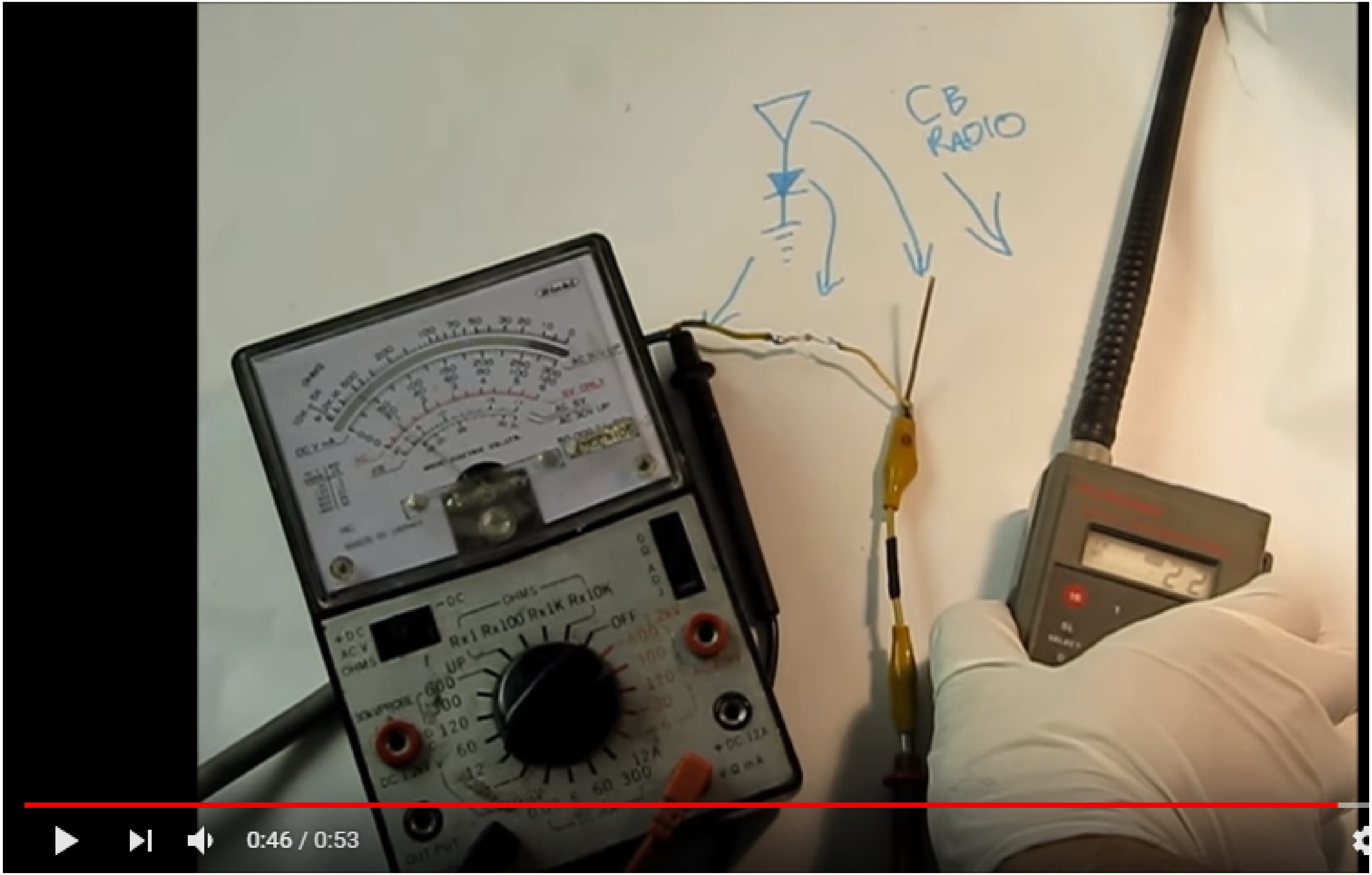
CB
RADIO
0:46 / 0:53

DIY Wireless Power - Part 2: Simple Wireless Power Transmission! (CB)

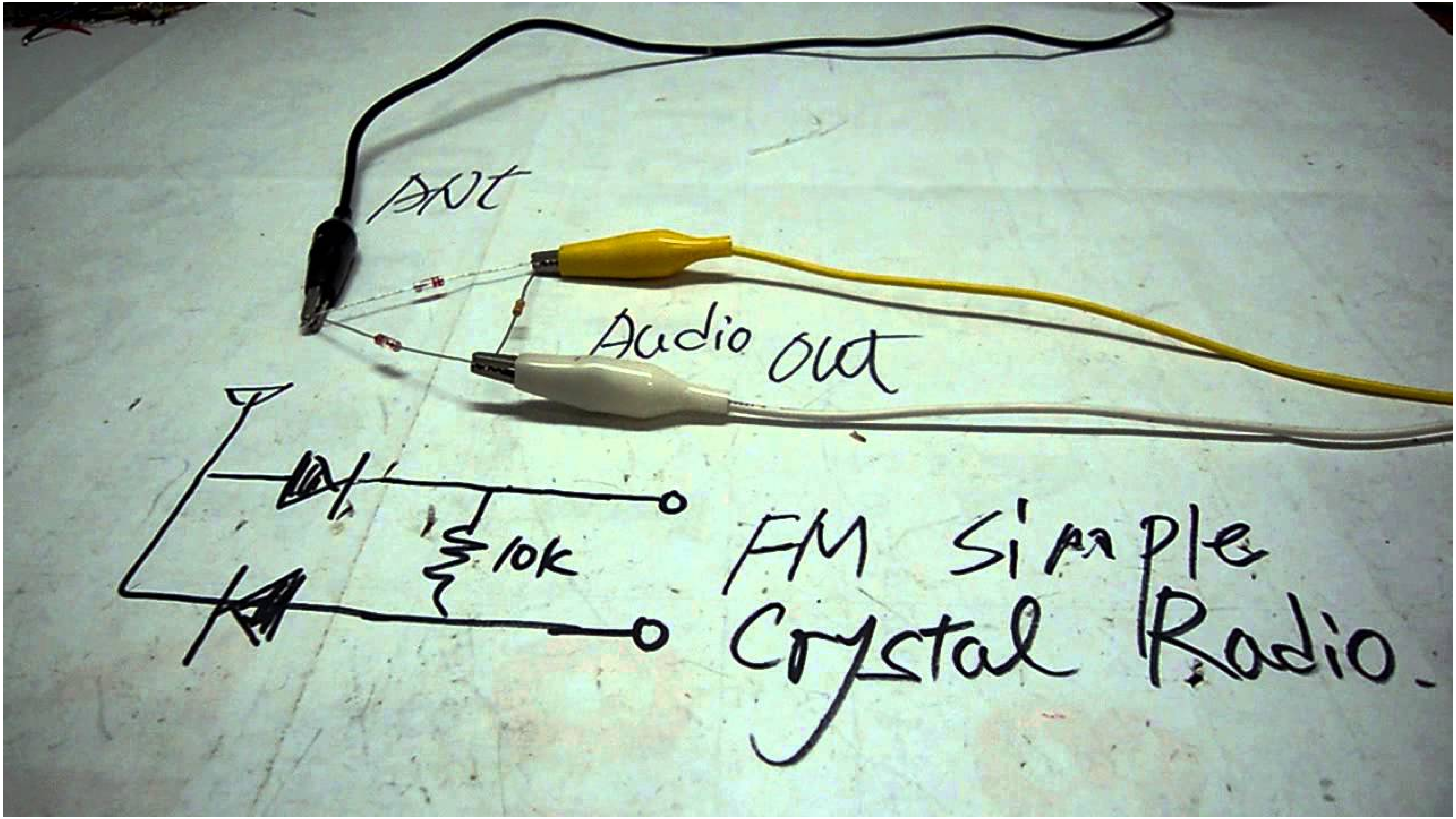
ANt
Audio out
10K
FM simple
Crystal Radio

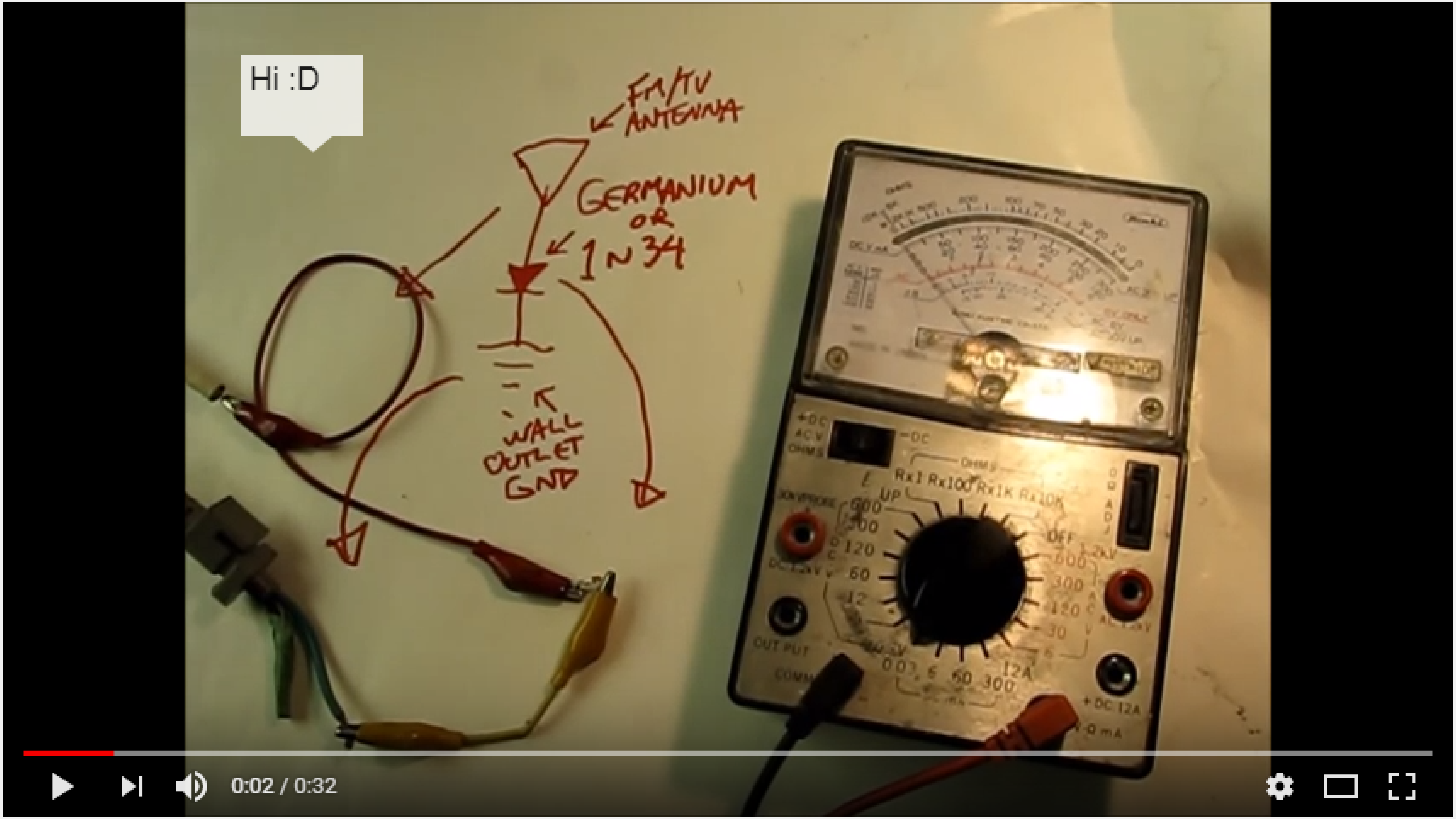

Hi :D
FM/TV ANTENNA
GERMANIUM OR 1N34
WALL OUTLET GND
0:02 / 0:32

DIY Wireless Power - Part 1: TV/FM Antenna,1N34/Germanium Diode

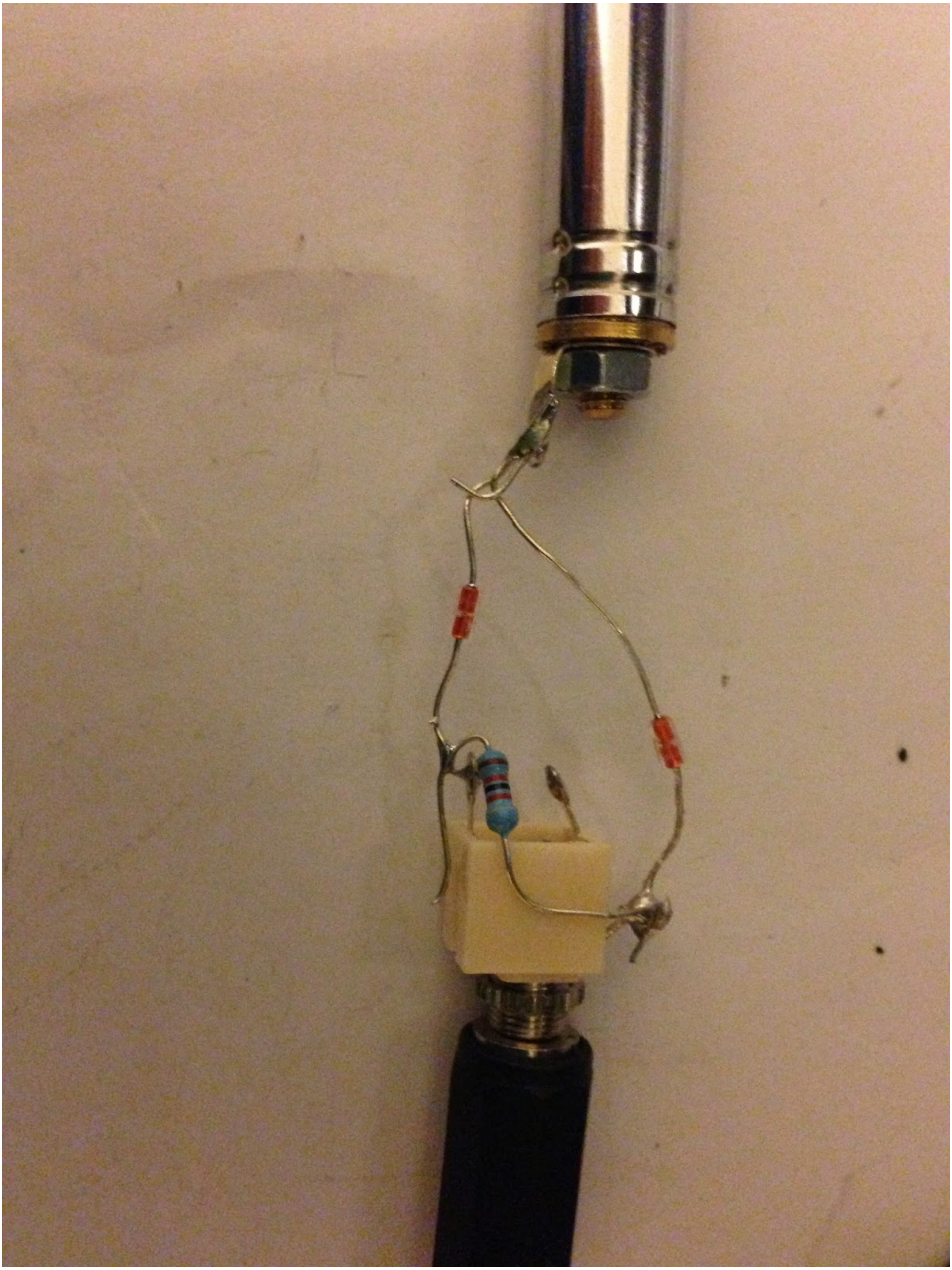

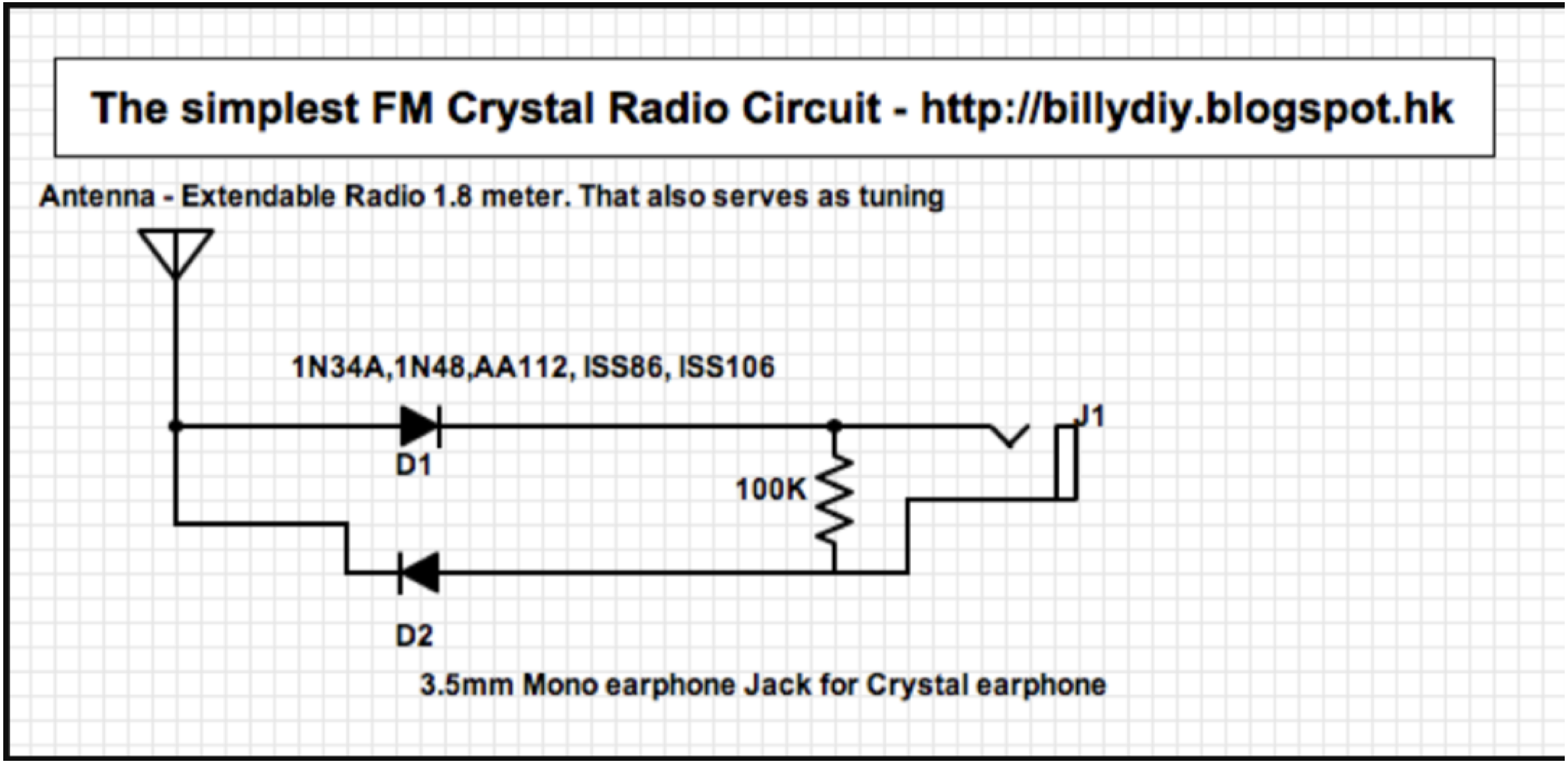

The simplest FM Crystal Radio Circuit - http://billydiy.blogspot.hk

Antenna - Extendable Radio 1.8 meter. That also serves as tuning

3.5mm Mono earphone Jack for Crystal earphone

1N34A,1N48,AA112, ISS86, ISS106
D1
100K
J1
D2

Simple crystal receiver for FM

Carlo Bramanti

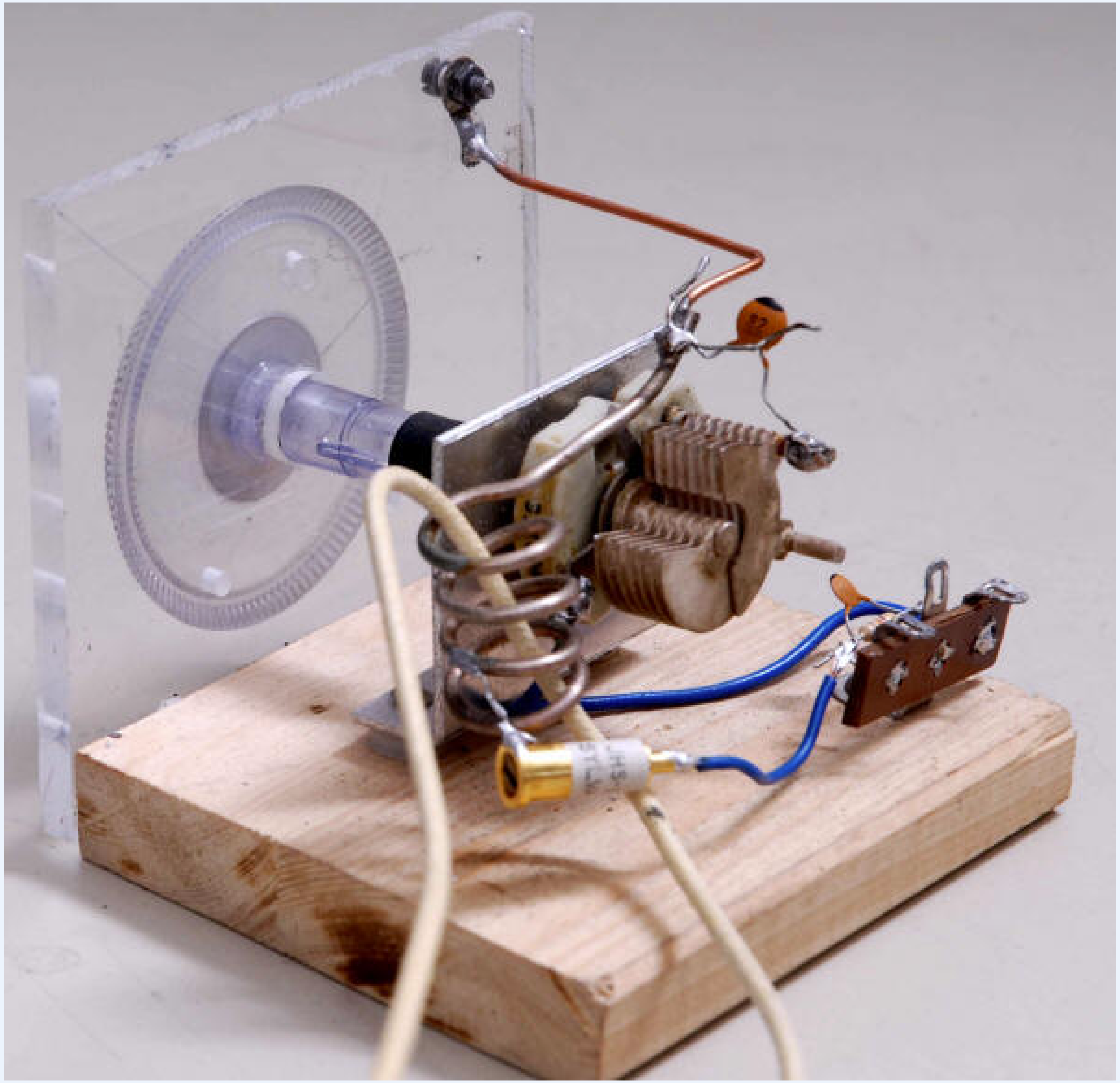

FM Crystal Radio Circuit

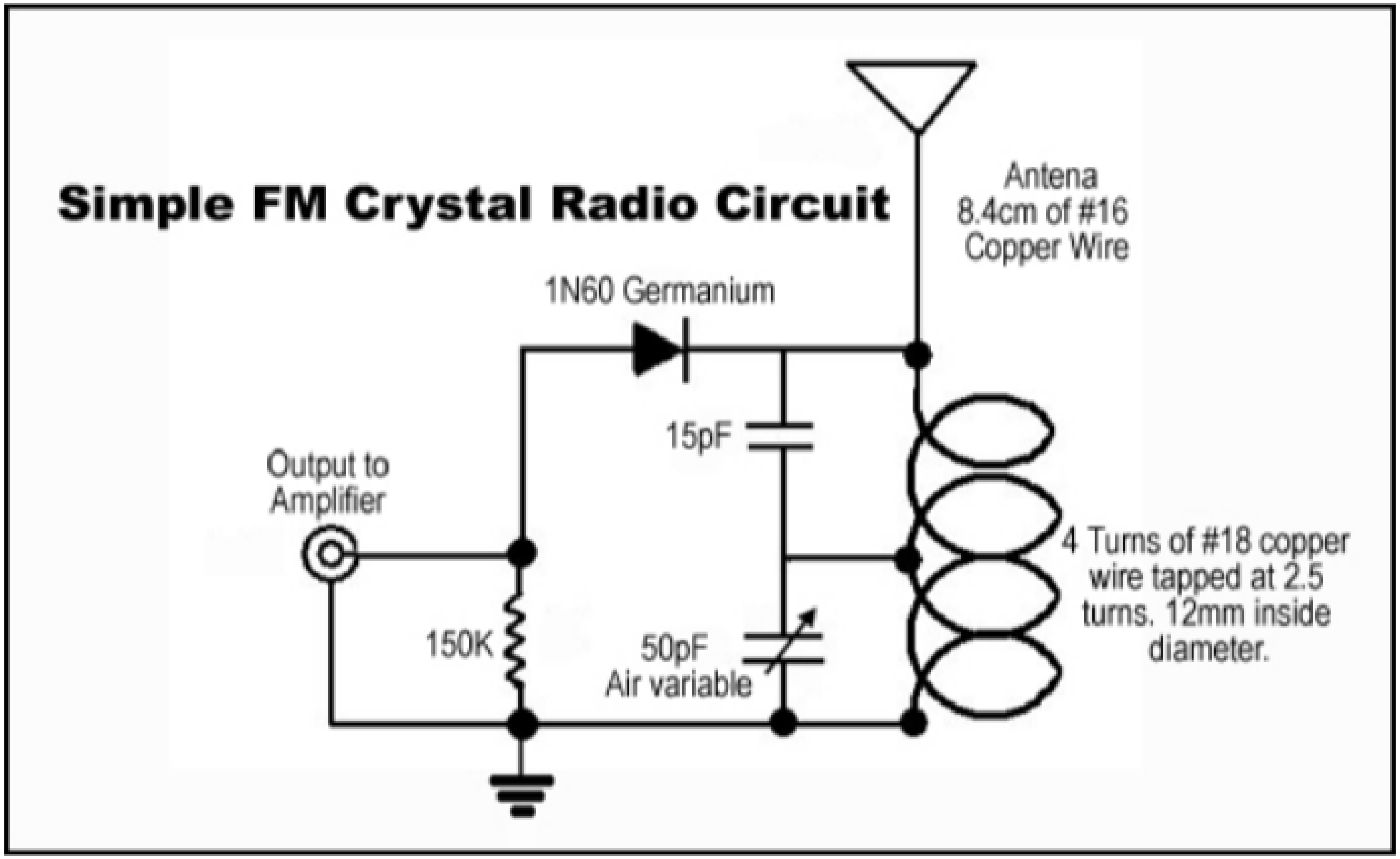
Simple FM Crystal Radio Circuit
Antena
8.4cm of #16
Copper Wire
1N60 Germanium
15pF
Output to
Amplifier
4 Turns of #18 copper
wire tapped at 2.5
turns. 12mm inside
diameter.
150K
50pF
Air variable

Parts List (some of these parts you can buy from our online store):

- 1N60 Germanium Diode
- 15pF Ceramic Capacitor
- 50pF Variable Capacitor
- 150K Ohm Resistor
- #16 & #18 Copper wires

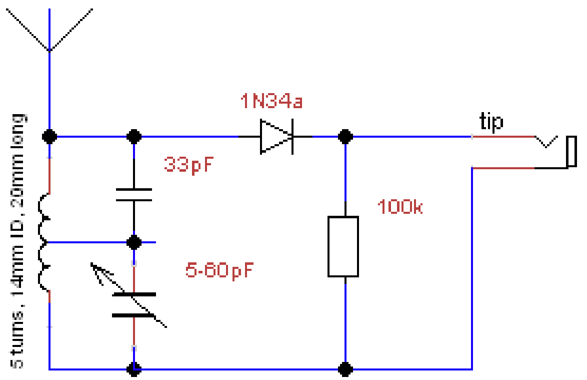
1N34a
tip
33pF
100k
5-60pF
5 turns, 14mm ID, 20mm long

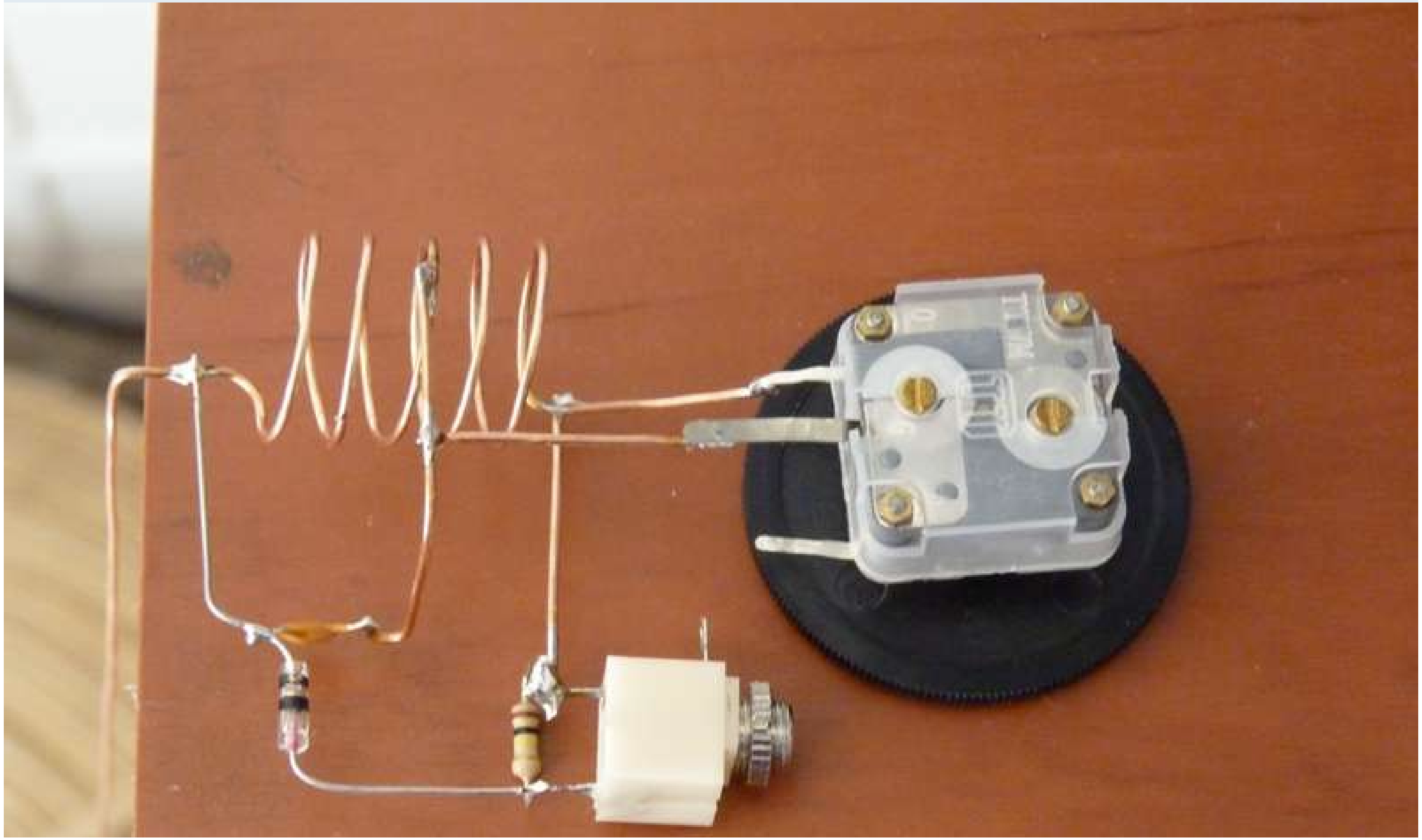

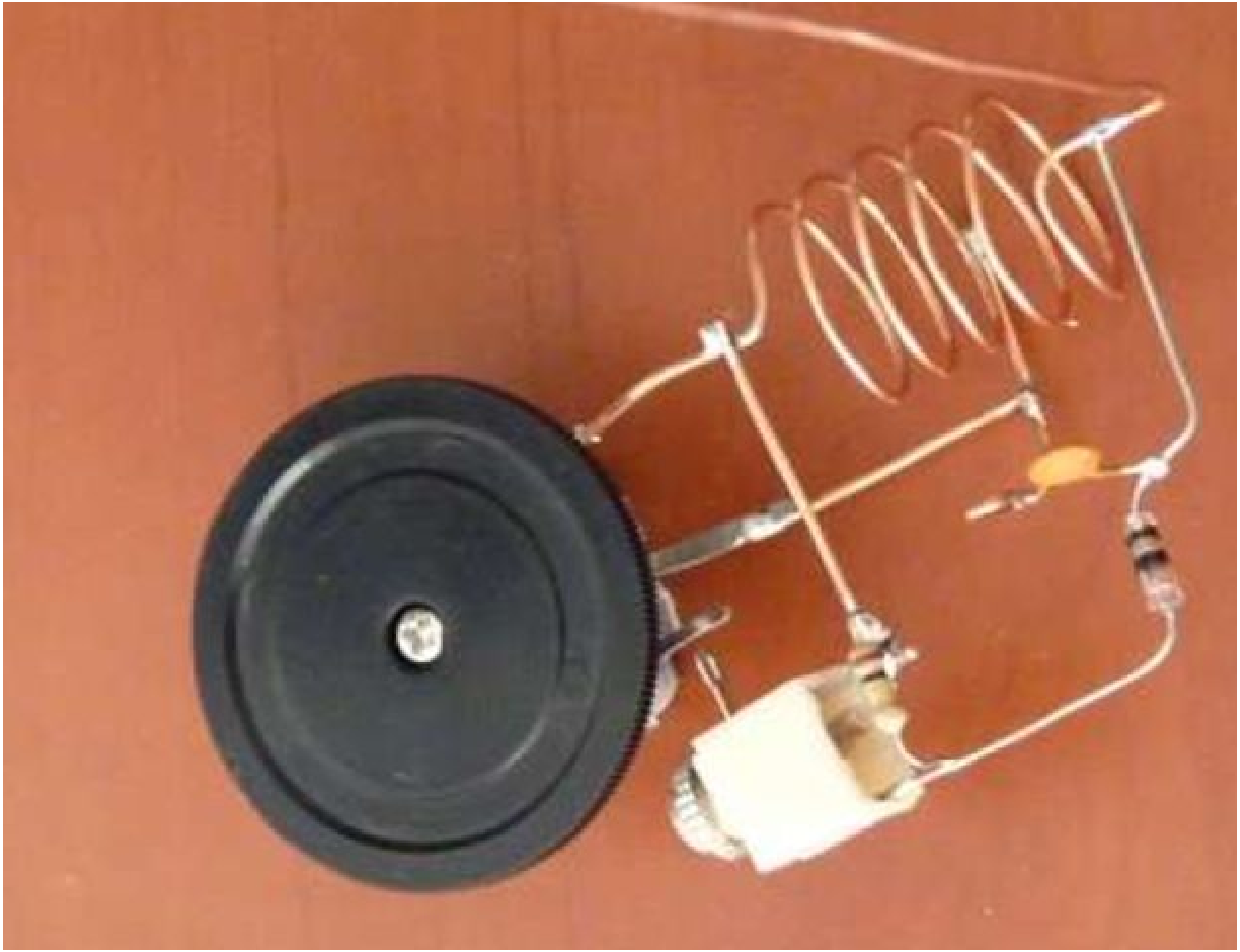

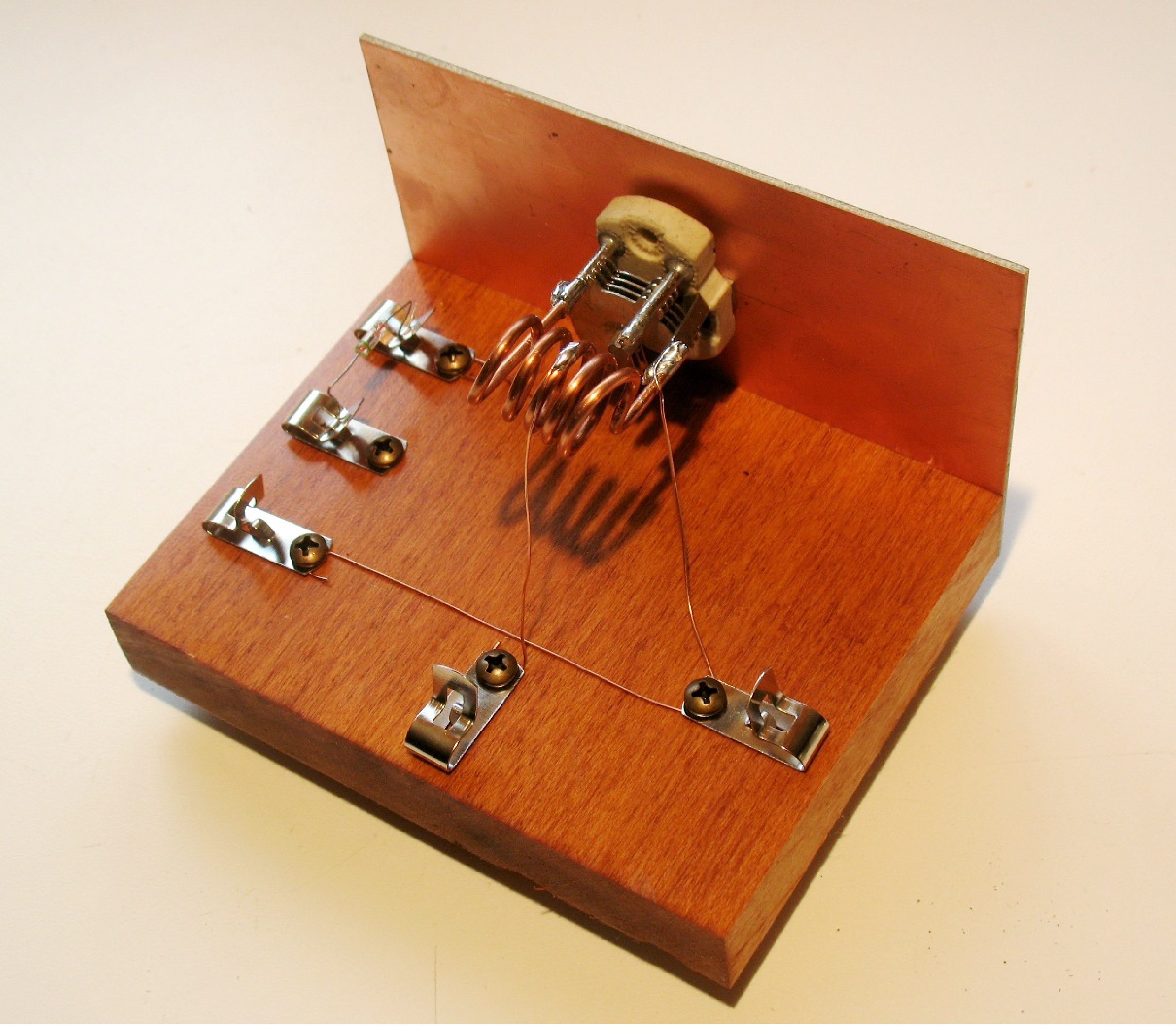

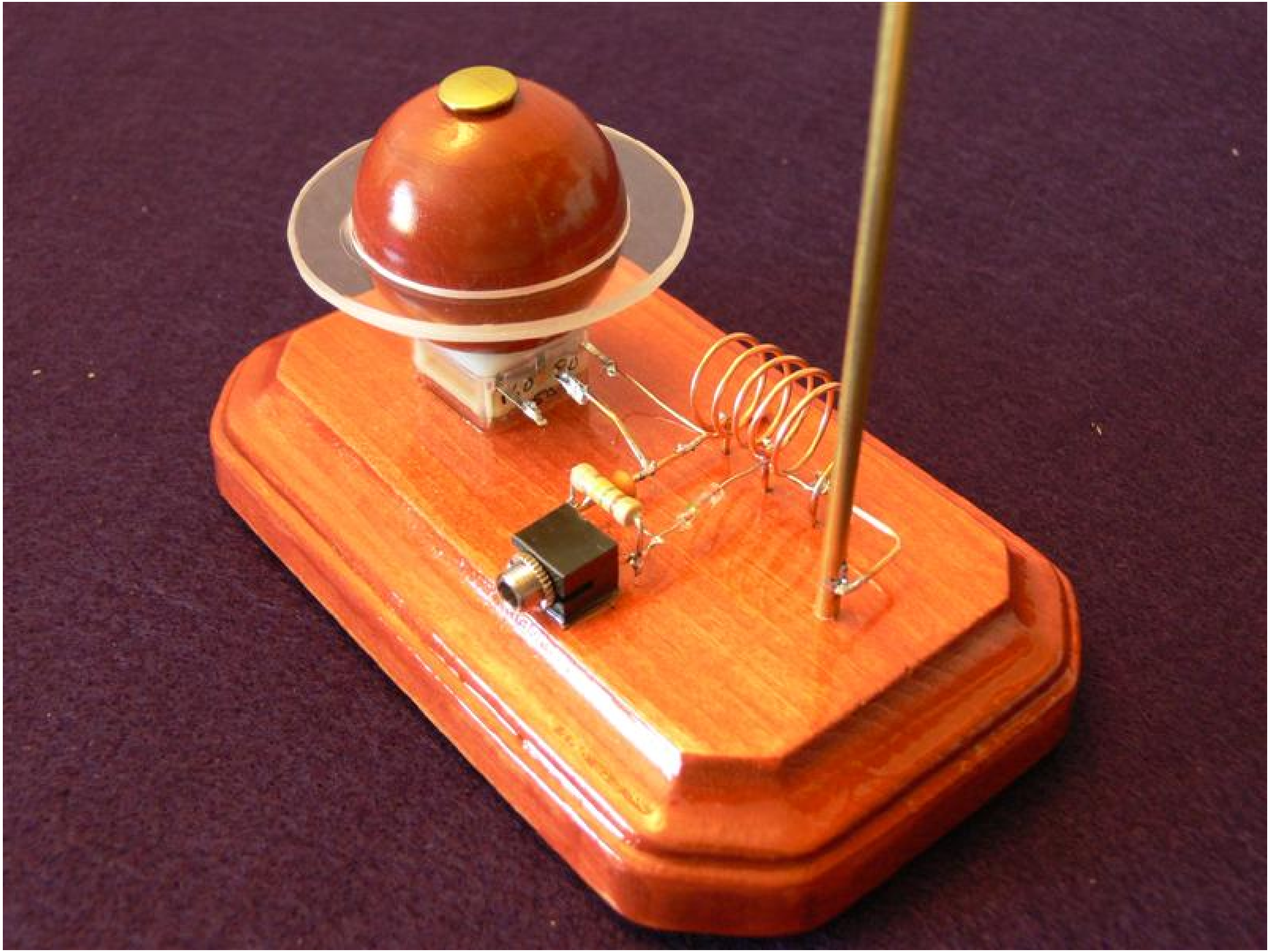

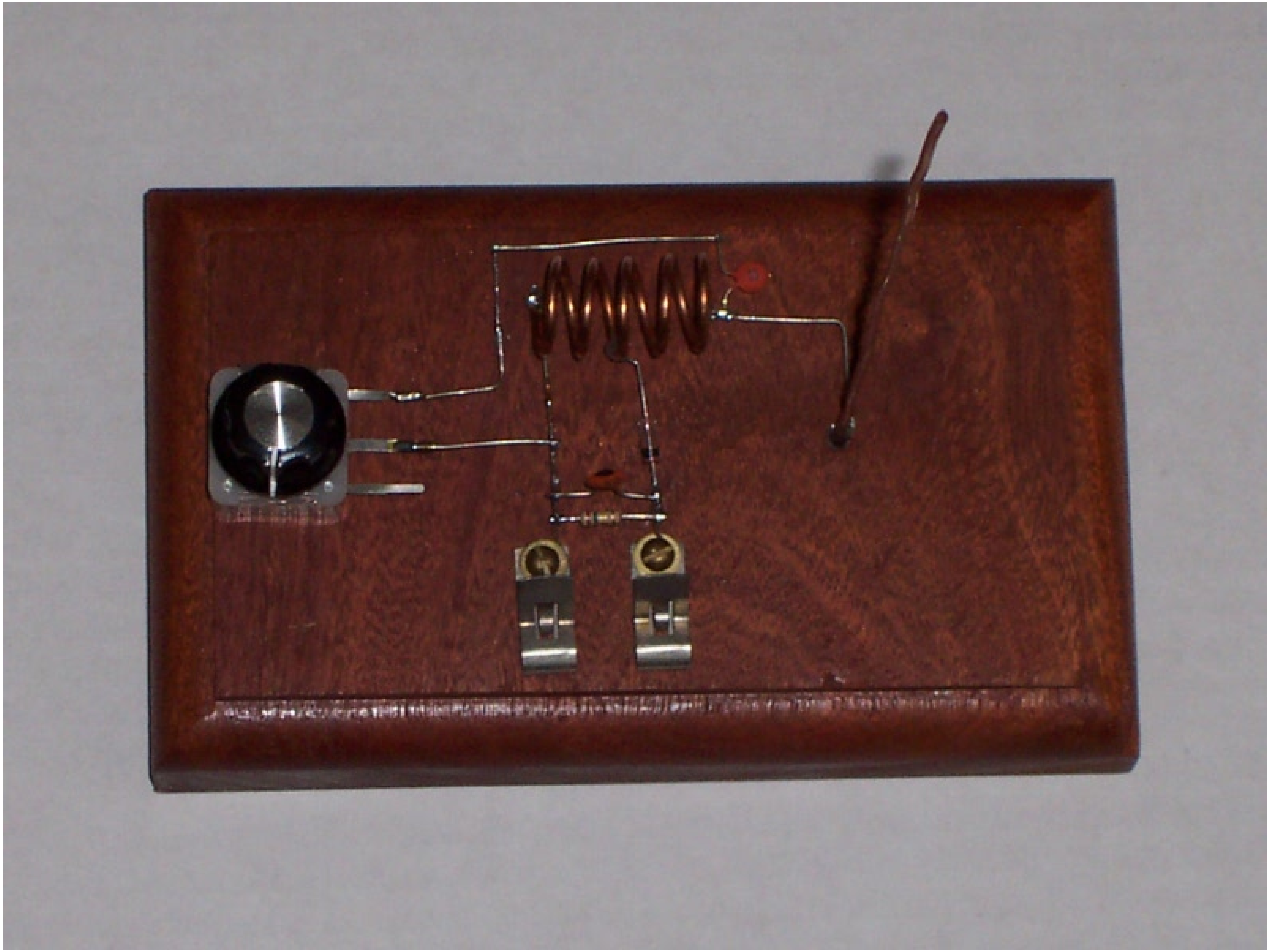

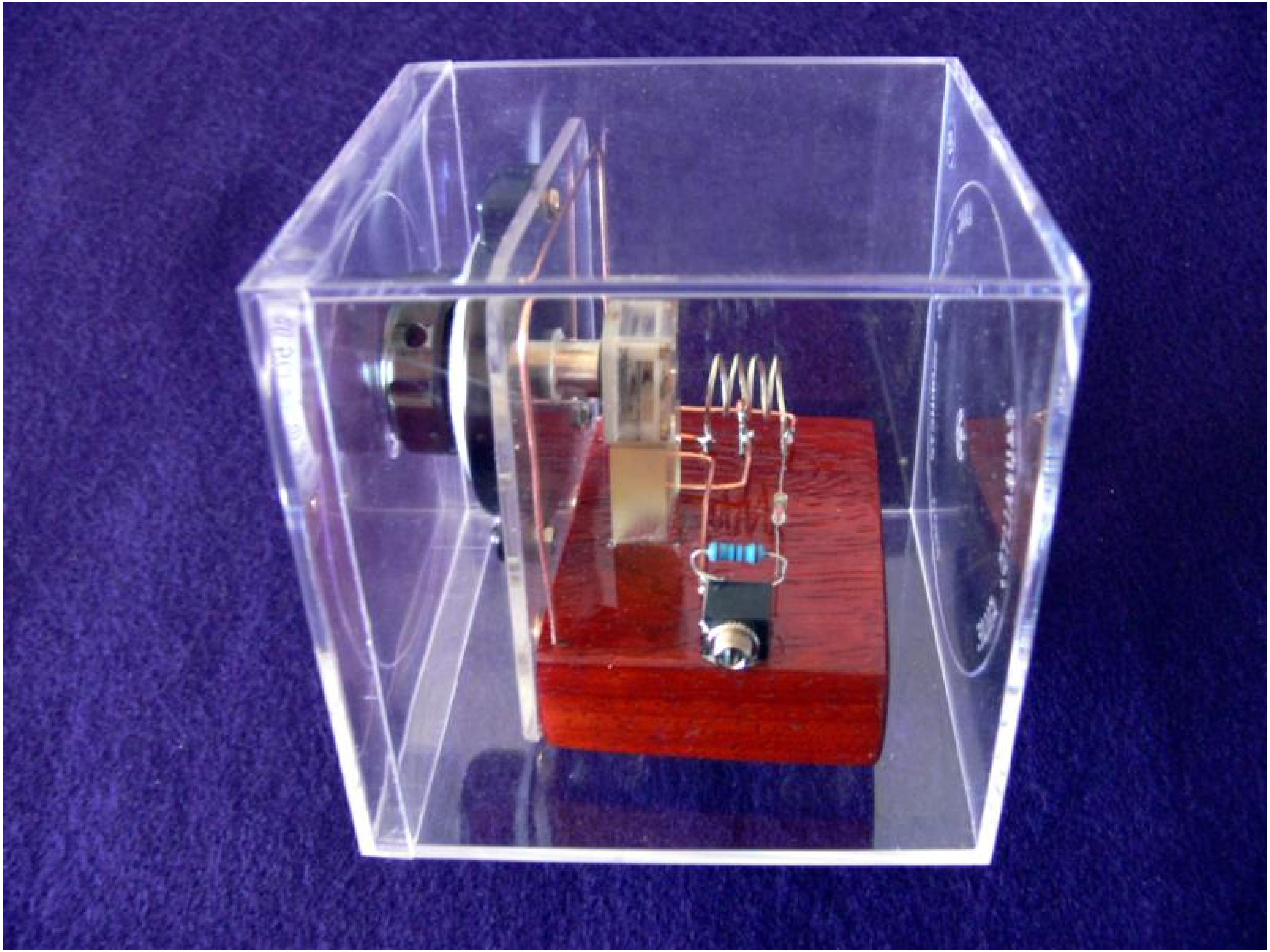

L - 4 turns #18 copper or silver wire, 12mm inside diameter, tapped at 2.5 turns
Ant - 7 inches of #18 bare copper wire
C1 - 18 pf ceramic capacitor
C2 - 50 pf air variable capacitor
D - 1N34 diode or rock crystal
R - 150K resistor

All passive components

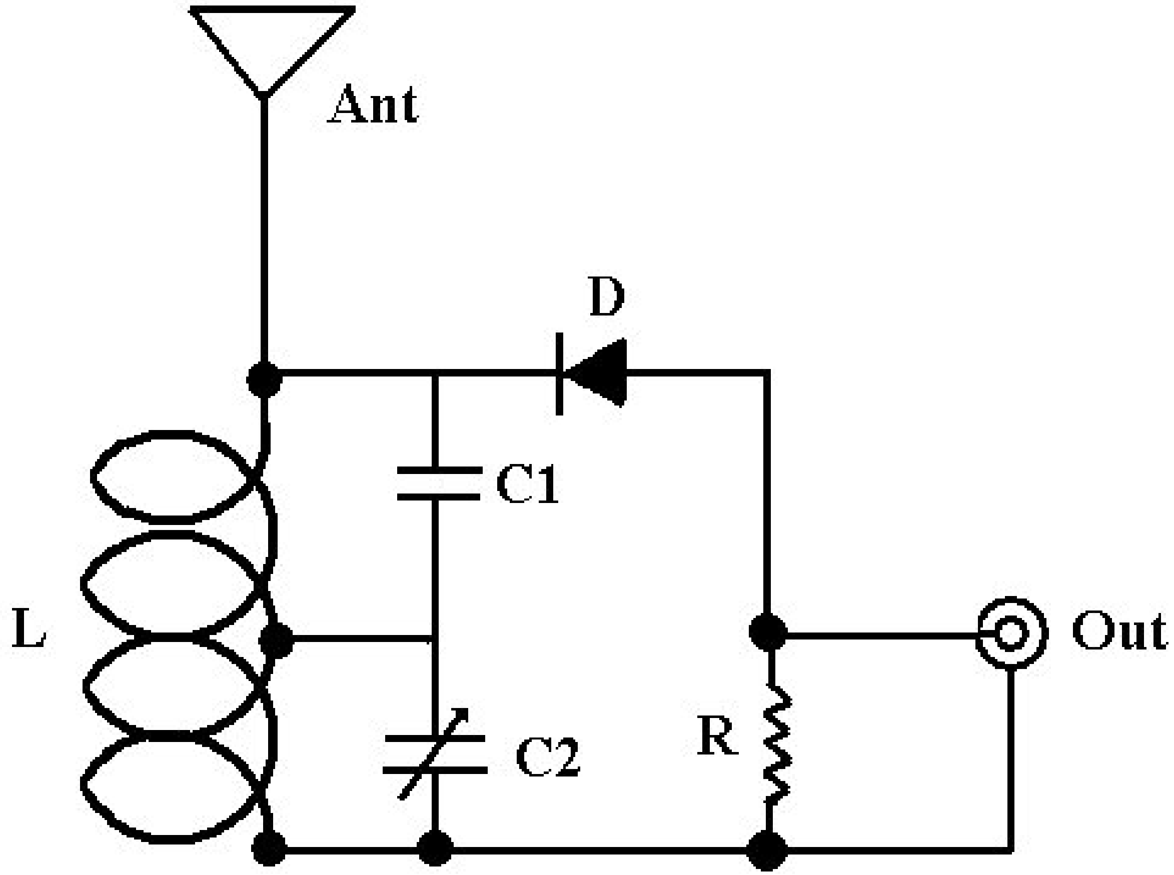

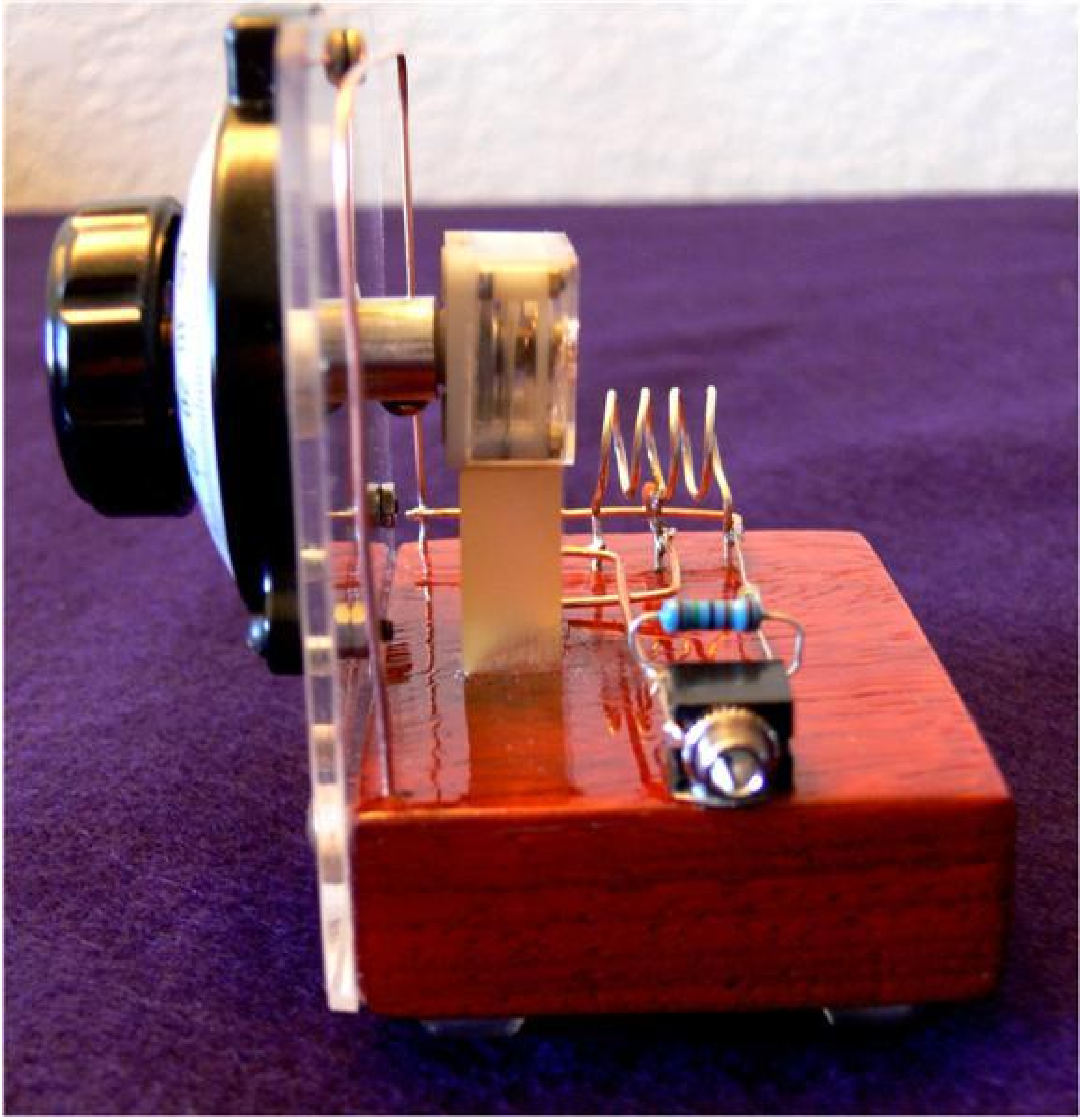

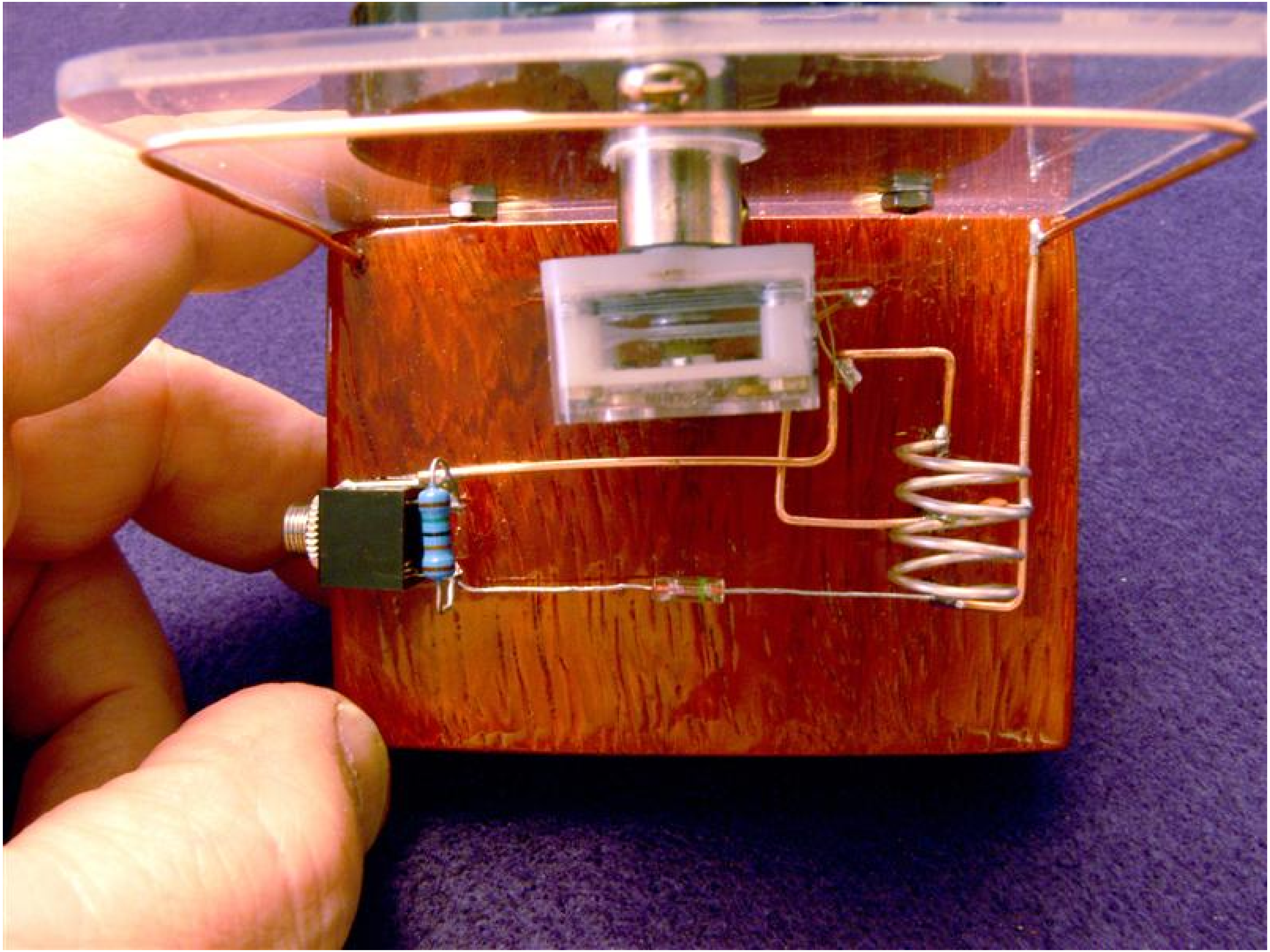

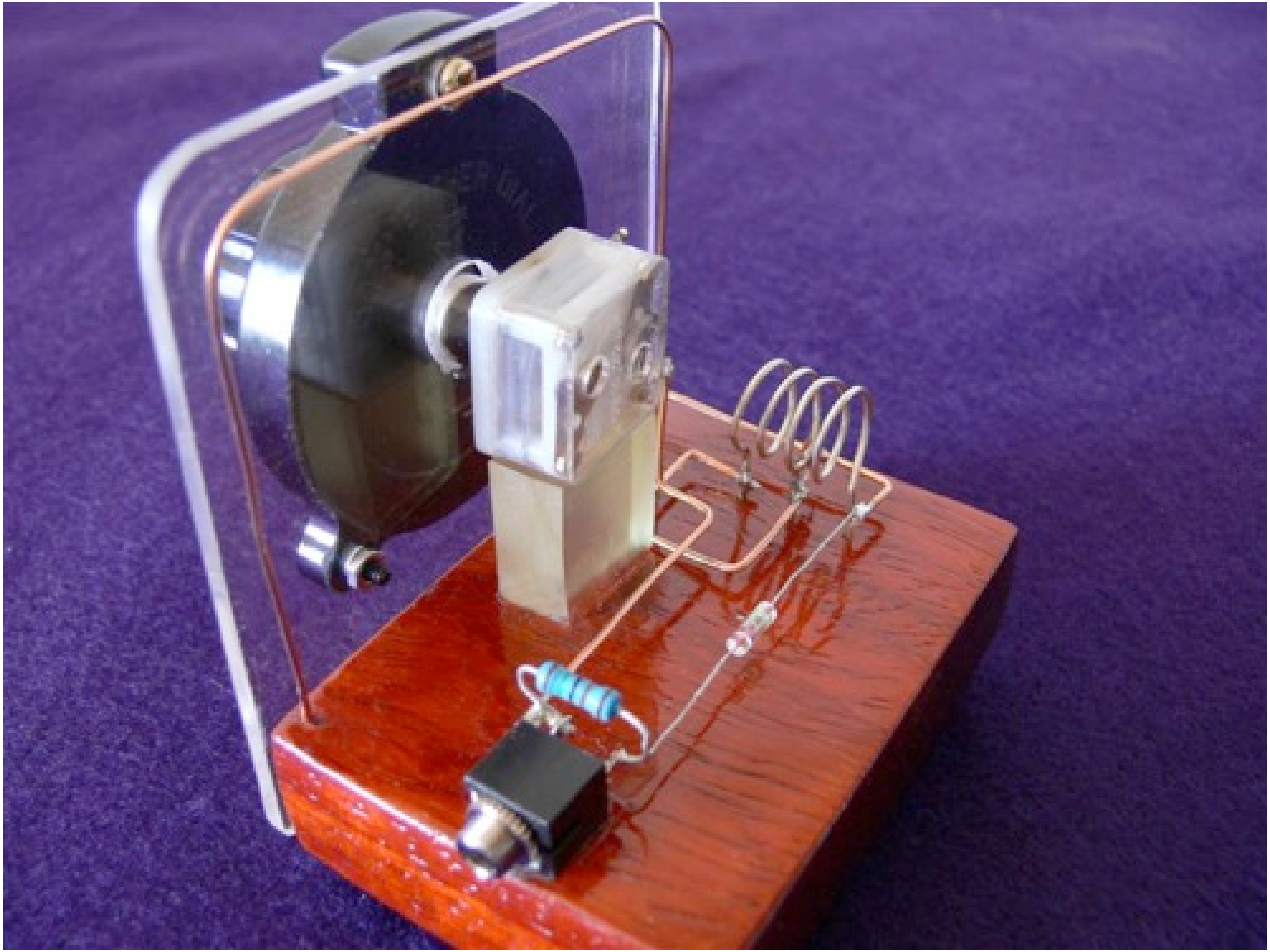

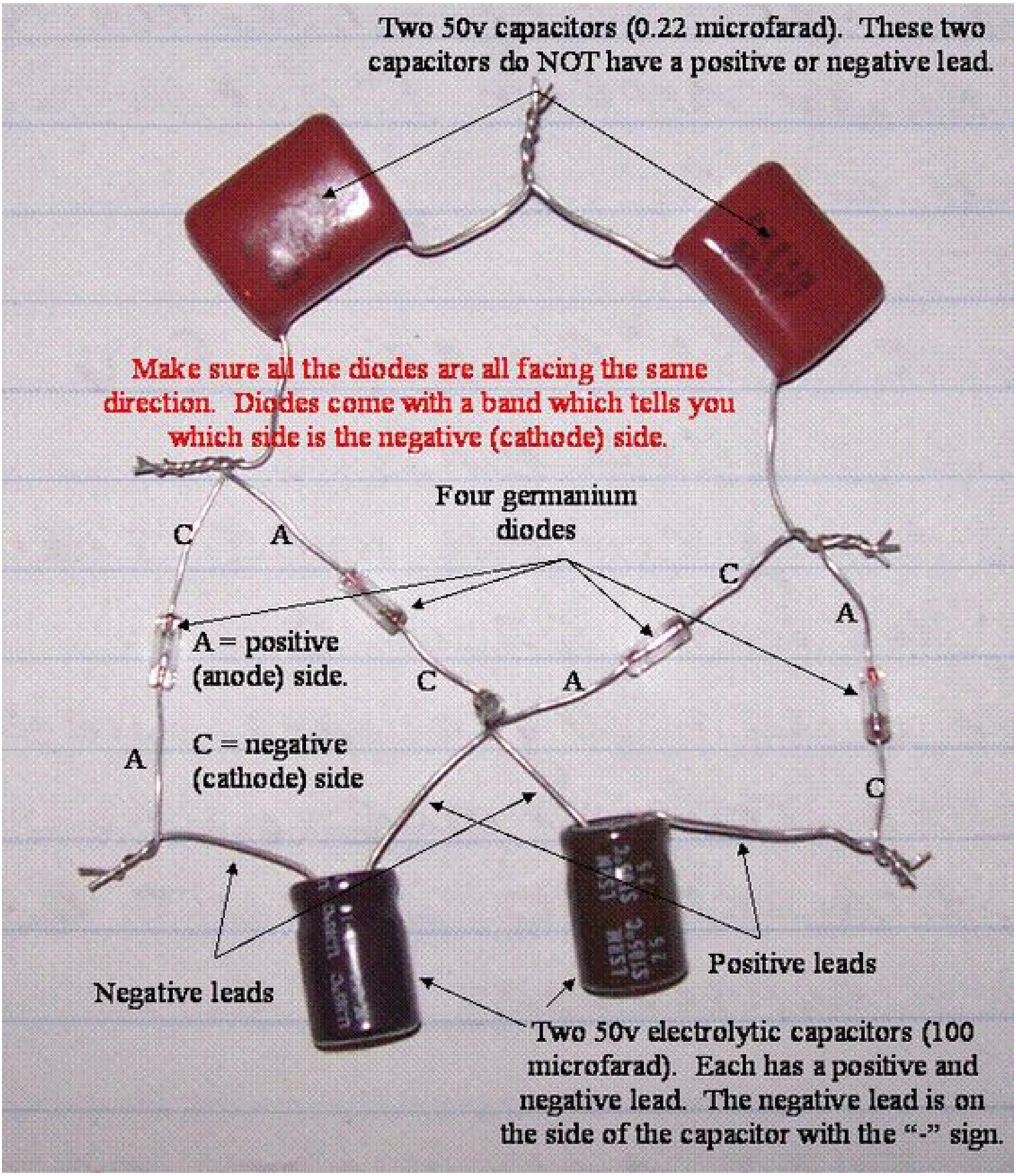

Two 50v capacitors (0.22 microfarad). These two capacitors do NOT have a positive or negative lead.

Make sure all the diodes are all facing the same direction. Diodes come with a band which tells you which side is the negative (cathode) side.

Four germanium diodes

A = positive (anode) side.

C = negative (cathode) side

Negative leads

Positive leads

Two 50v electrolytic capacitors (100 microfarad). Each has a positive and negative lead. The negative lead is on the side of the capacitor with the "-" sign.

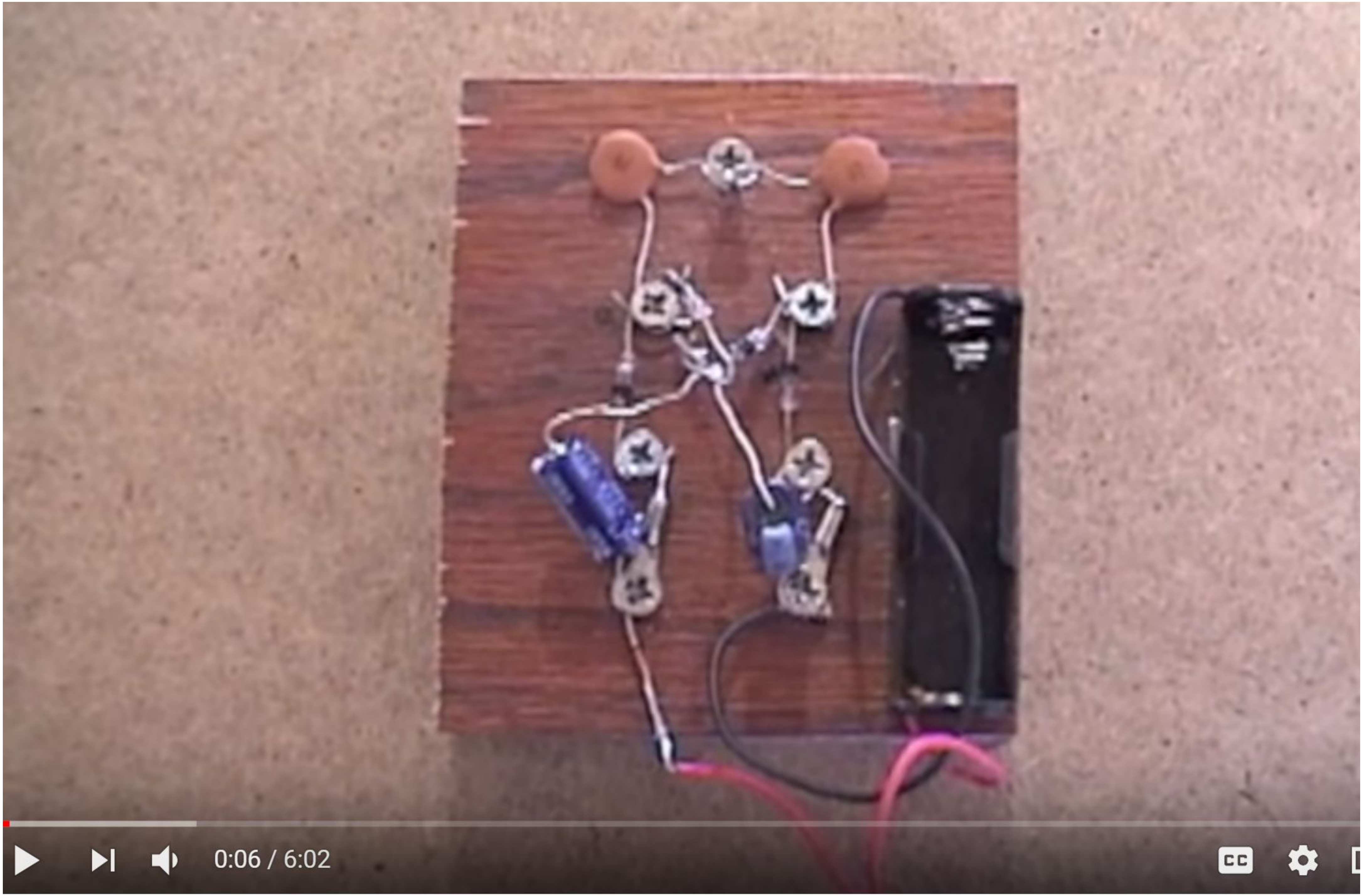
0:06 / 6:02
CC

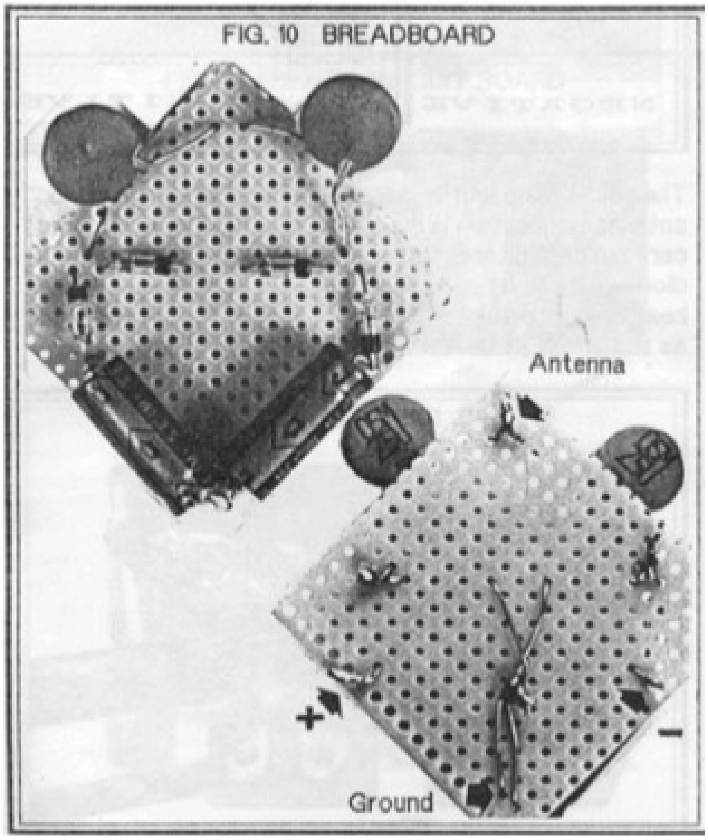

FIG. 10 BREADBOARD

Antenna
+
−
Ground

the board as shown in Figure 11. This unit is powering a small red LED indicated by the arrow.

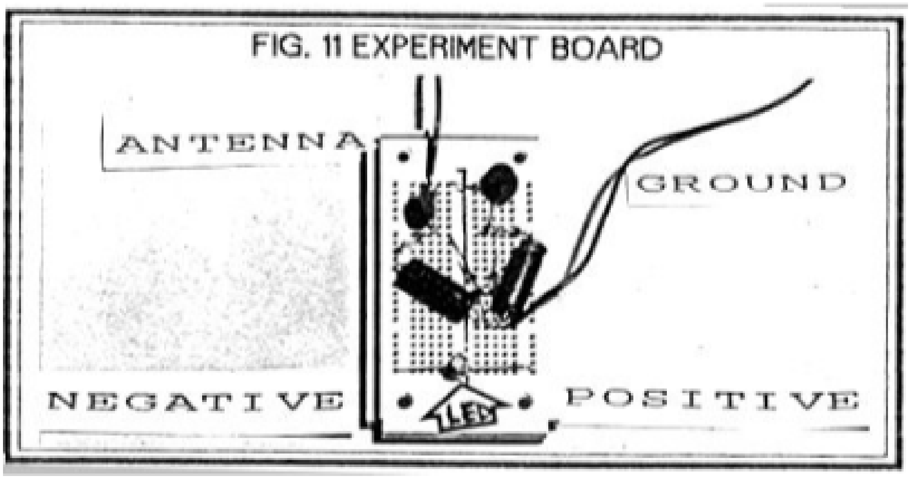

FIG. 11 EXPERIMENT BOARD

ANTENNA
GROUND
NEGATIVE
LED
POSITIVE

ade to the twisted ends of the ceramic capacitors. When soldering the leads of the 1N34 diodes, care must be taken t

FIG. 9 TERMINAL STRIP

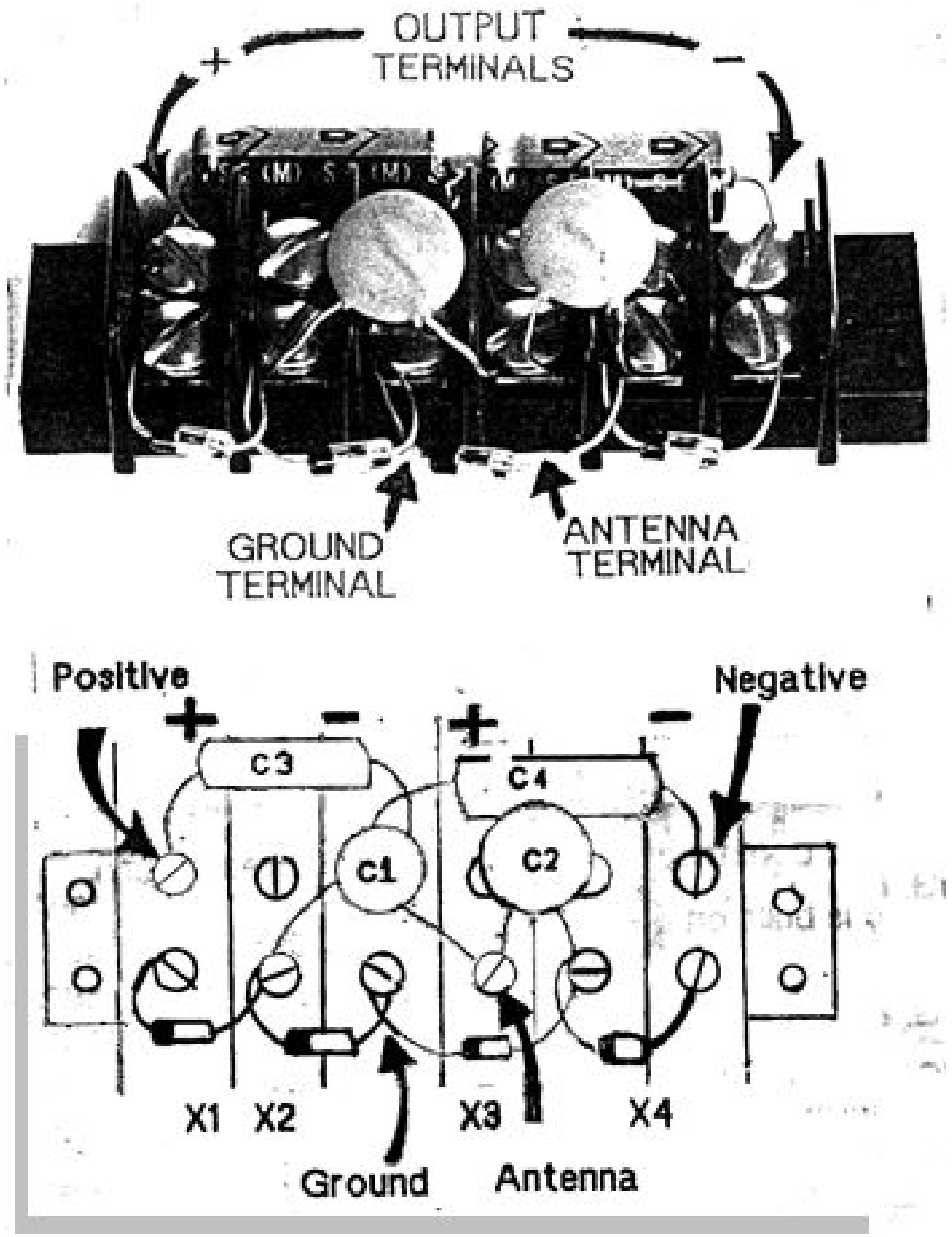
+
OUTPUT TERMINALS
−
GROUND TERMINAL
ANTENNA TERMINAL
Positive
Negative
+
−
+
−
C3
C4
C1
C2
X1
X2
X3
X4
Ground
Antenna

Amplifier circuit. The crystal radio used for example purposes is the crystal radio made from scraps here.

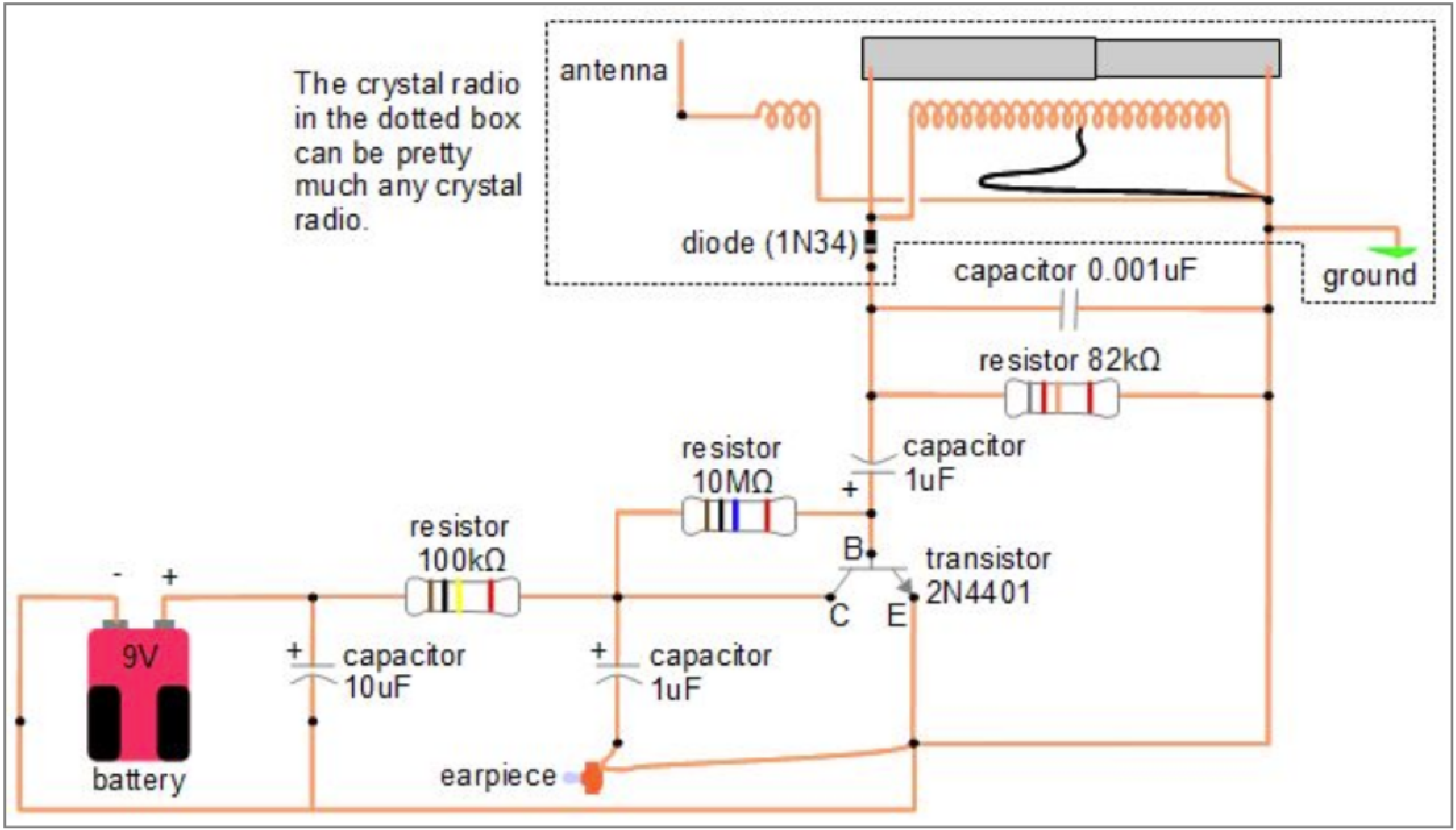
The crystal radio in the dotted box can be pretty much any crystal radio.
antenna
diode (1N34)
ground
capacitor 0.001uF
resistor 82kΩ
capacitor 1uF
+
resistor 10MΩ
B
transistor 2N4401
C
E
resistor 100kΩ
-
+
9V
battery
+
capacitor 10uF
+
capacitor 1uF
earpiece

SATURDAY, NOVEMBER 13, 2010

SIMPLE FIELD STRENGTH METER

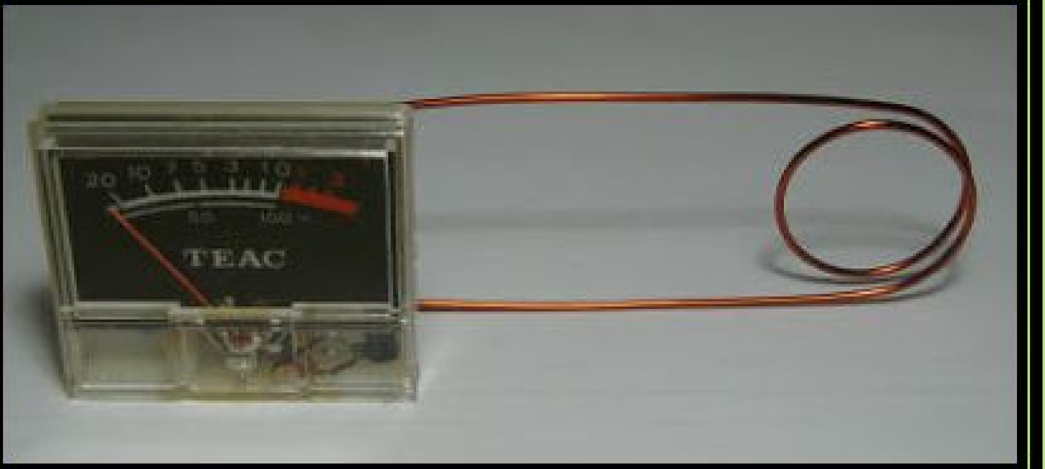
20
10
7
5
3
1
0
3
50
100
%
TEAC

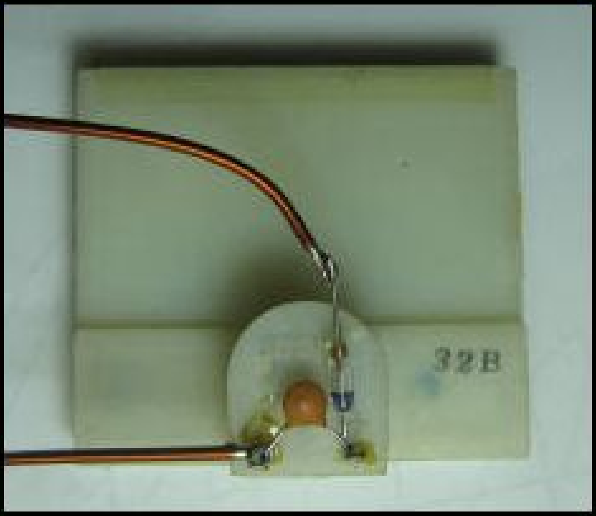

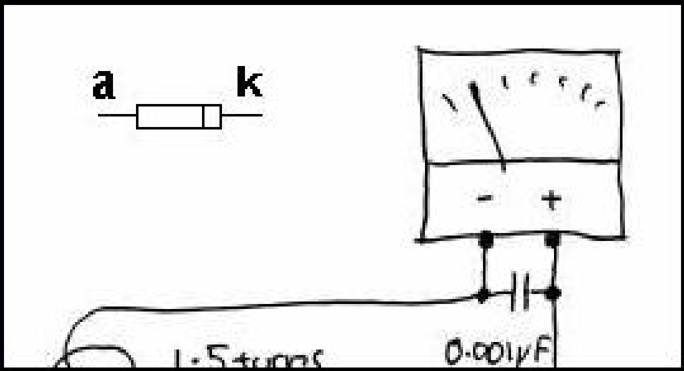
a
k
-
+
0.001uF
1-5 turns

MY

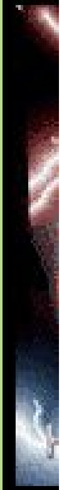

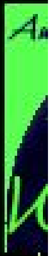

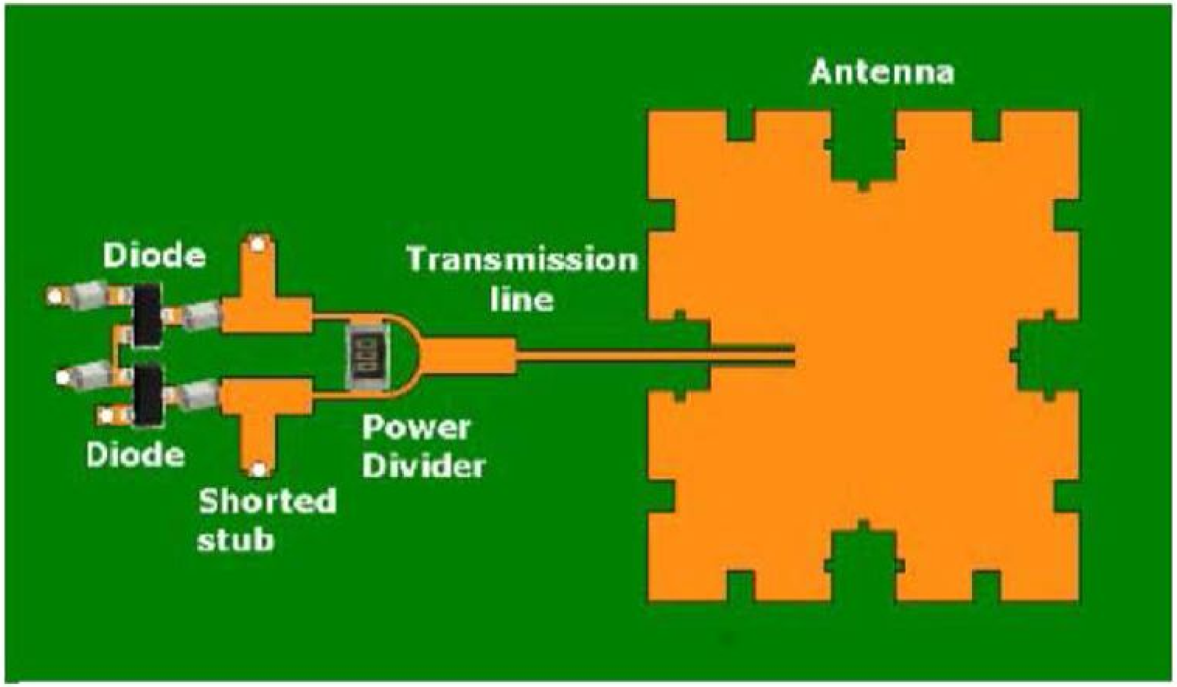
Antenna
Diode
Transmission line
Diode
Shorted stub
Power Divider

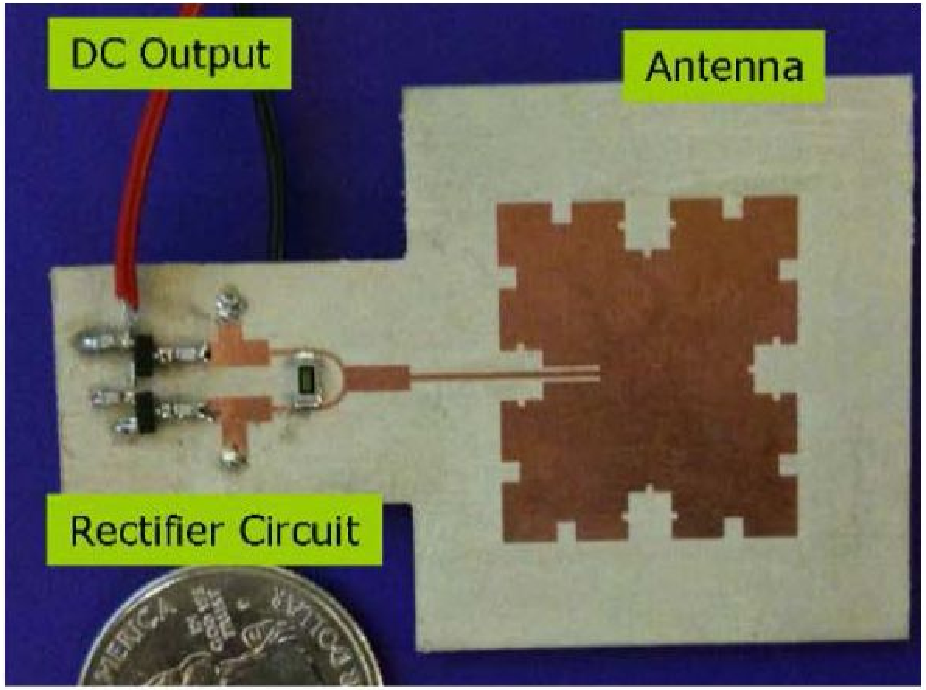
DC Output
Antenna
Rectifier Circuit

4. Results and Analysis

The simulated and measured results at the output voltage of voltage multiplier circuit are shown graphically in **Figure 8**. From the graph analysis, the simulated and the measured results agree considerably with each other. The measured results are shown to be better than the simulation results. The reason behind this may be due to the uncertainty in series resistance value of the diode obtained from SPICE parameters in modeling as explained in Equation (5). This resistance vale of diodes in practical circuit may be lower than in the model, which provides fast discharge path, in turn rise in voltage as passes through the stages and reaches to final output. In this work, the DC output voltages obtained through simulation and measurement at 0 dBm re 2.12 V and 5.0 V respectively. These results are comparatively much better than in ref. [9], where in at 0 dBm, 900 MHz they achieved 0.5 V and 0.8 V through simulation and measurement increasing to 1.4 V, 1.67 V, 1.87 V and 2.12 V for 4, 5, 6 and 7 stages respectively compared to 2 mS as shown in [10]. **Figure 12** shows that the conversion ratio of 22 is achieved at 0 dBm input power and drops to 2.5 at –40 dBm. The highest value at 0 dBm is due to the innate characteristics of the zero bias Schottky diodes which conduct fairly well at higher input voltages.

5. Conclusion

From the experimental results, it is found that the pro-

Table 2. Component used in 7 stage voltage multiplier.

Name of component	Label	Value
Stage capacitors	C_1 - C_{14}	3.3 nF
Stage diodes	D_1 - D_{14}	HSMS 2850
Filter capacitor	C_L	100 nF
Load resister	R_L	100 kΩ

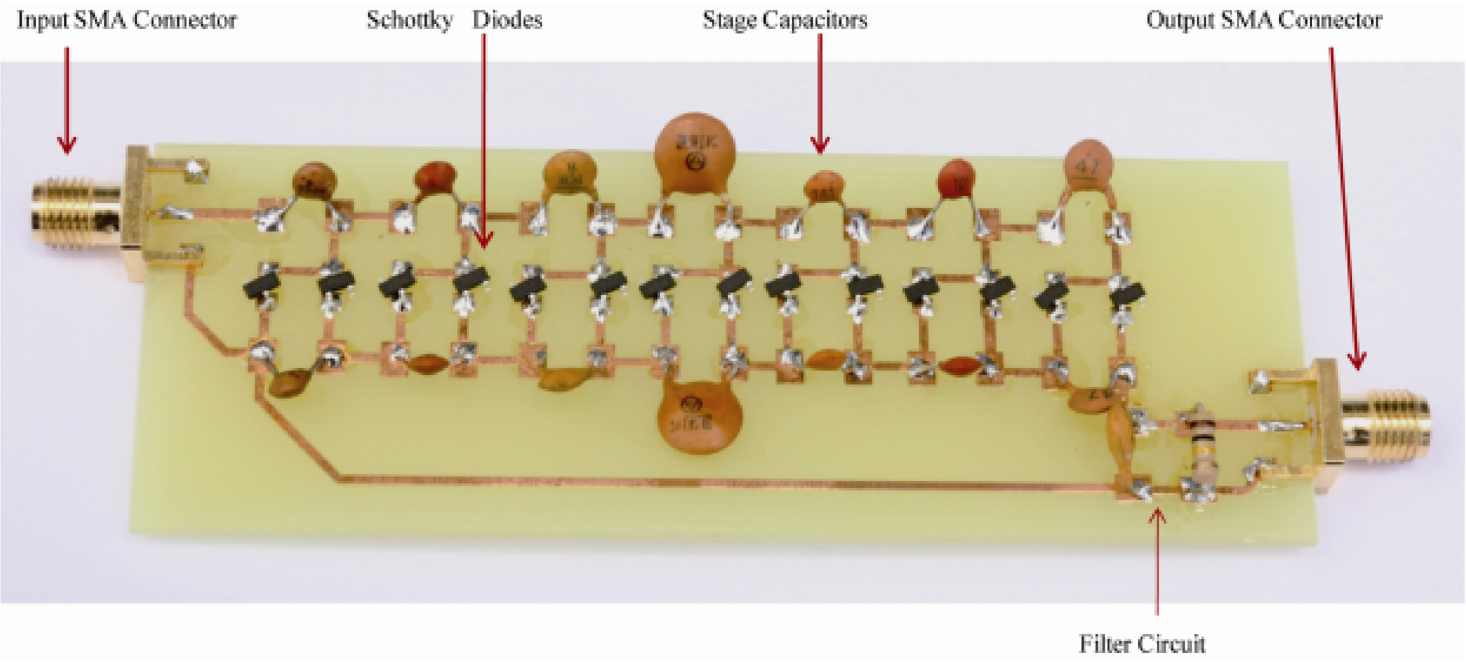

Figure 7. Photograph of assembled circuit board.

sign in this paper uses a capacitor across the load to store and provide DC leveling of the output voltage and its value only affects the speed of the transient response. Without a capacitor across the load, the output is not a good DC signal, but more of an offset AC signal.

In addition to the above, an equivalent load resistor is connected at the final node. The output voltage across the load decreases during the negative half cycle of the AC input signal. The voltage decreases is inversely proportional to the product of resistance and capacitance across the first stage was 3.3 nF, the second stage was 1.65 nF, third stage was 825 pF, fourth stage was 415 pF and so on. But keeping in view of testing, the capacitance values were chosen to have a close match with the standard available values in the market.

Simulation was carried out through 4 to 9 voltage doubler stages. Based on results obtained a 7 stage doubler is best to implemented for this application.

The design of the printed circuit board (PCB) was carried out using DipTrace software. The material used to

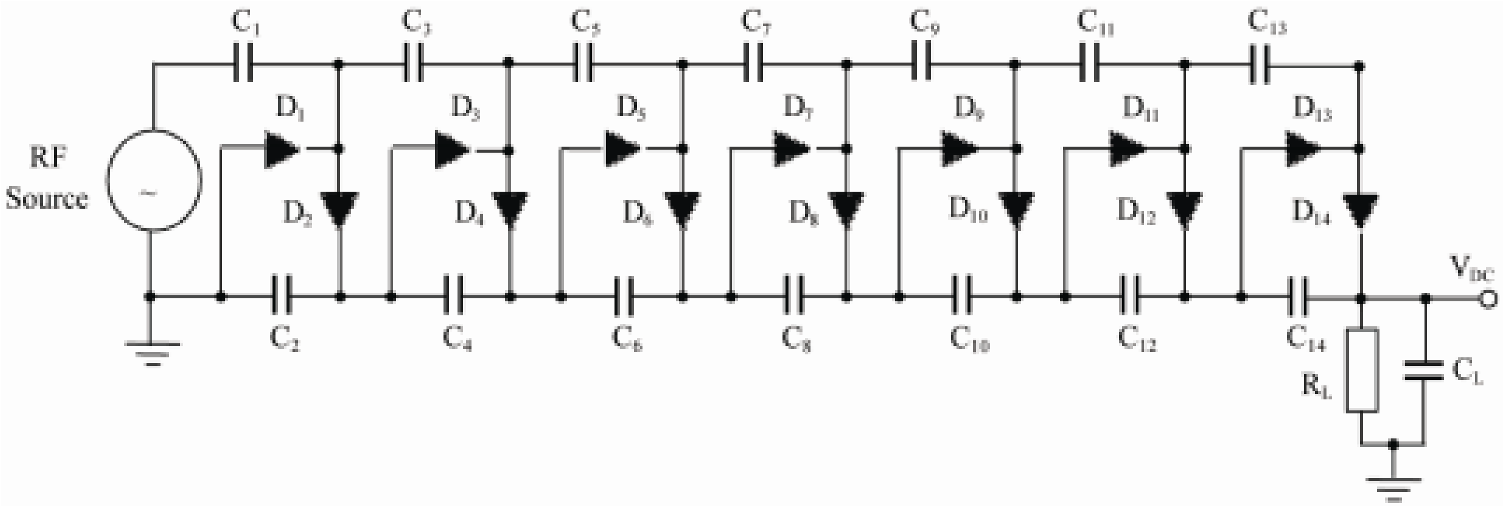

Figure 6. Schematic of 7 stage voltage multiplier.

Copyright © 2012 SciRes.

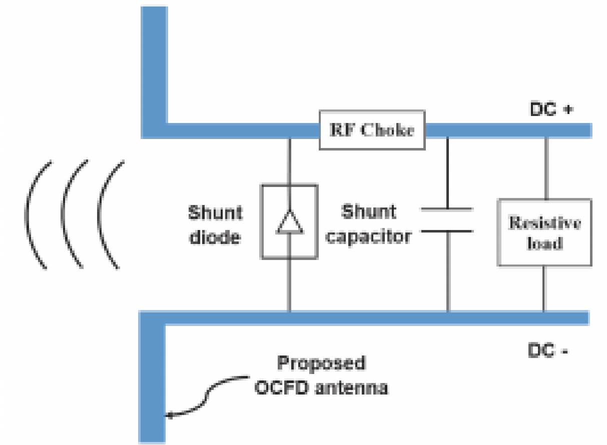

Fig. 9. Configuration of a single shunt diode (Class F) rectifier with a dipole antenna.

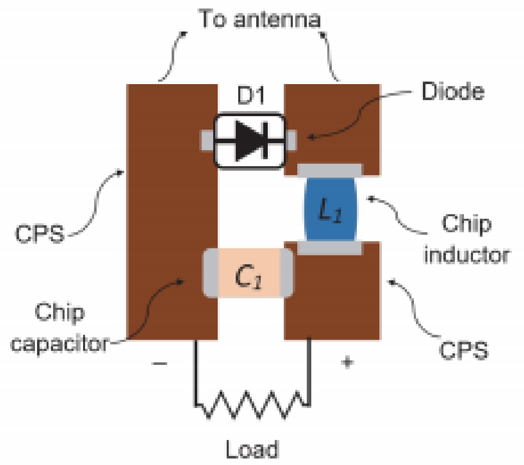

Fig. 10. Configuration of the proposed rectifier on coplanar striplines (CPS).

TABLE III
CIRCUIT COMPONENTS USED IN THE DESIGN

Component name	Nominal Value	Part number and supplier
D1	Schottky diode	SMS7630-079LF, Skyworks
L1	47 nH chip inductor	0603HP47N, Coilcraft
C1	100 nF chip capacitor	GRM188R71H104JA93D, Murata

antenna have a radius of 50 mm and a circumference angle of

respectively. While the imaginary part of the proposed OCFD is around 0 Ω at resonant frequencies 0.6 GHz, 1.2 GHz and 2.4 GHz, which are f_0, $2f_0$, and $4f_0$ respectively. These results have demonstrated that the simulated results agree with the OCFD theory as discussed in Section III–A. Furthermore, the imaginary part of the impedance of the antenna over the resonant frequency band from 1.4 to 2 GHz turns from negative values (for the reference antenna) to positive values (for the proposed antenna). As shown in Fig. 7(b), the value of the imaginary part of the proposed antenna impedance varies between 0 and 300 Ω over the desired frequency band. This feature could help the proposed antenna to produce a better conjugate matching with the rectifier, since the imaginary part of the impedance of the rectifier normally varies between -700 and 0 Ω as we discussed earlier. The simulated 3D radiation patterns of the proposed antenna at the frequencies of interest are depicted in Fig. 8. The 2D polar plots of antenna patterns in *E-plane* and *H-plane* are shown as well. Here we have only showed the directivity (maximum gain) of the antenna (without taking the mismatch loss into account). From Fig. 8, it can be seen that the antenna has symmetrical patterns about YOZ plane with a maximum directivity of 1.8 dBi at 0.9 GHz, 3.5 dBi at 1.8 GHz and 3.3 dBi at 2.4 GHz. The antenna is more directive towards the long arm direction at 1.8 GHz and 2.4 GHz with the half-power beam-widths (HPBW) of around 174° and 185° respectively. The HPBW is about 96° at 0.9 GHz.

Therefore, the proposed broadband OCFD antenna has obtained high impedance over a wide frequency range. The proposed design is just an example to illustrate the proposed new method. The details of the dipole could be modified according to the frequency of interest.

IV. RECTENNA INTEGRATION

A. *Rectifier Configuration*

The proposed high impedance OCFD antenna may directly conjugate match with the input impedance of a rectifier over a wide frequency band. The rectifier should only consist of few circuit components for rectification, DC storage and output. A single shunt diode rectifier is selected due to its very simple structure and high conversion efficiency [33]. The configuration of the single shunt diode rectifier with a dipole

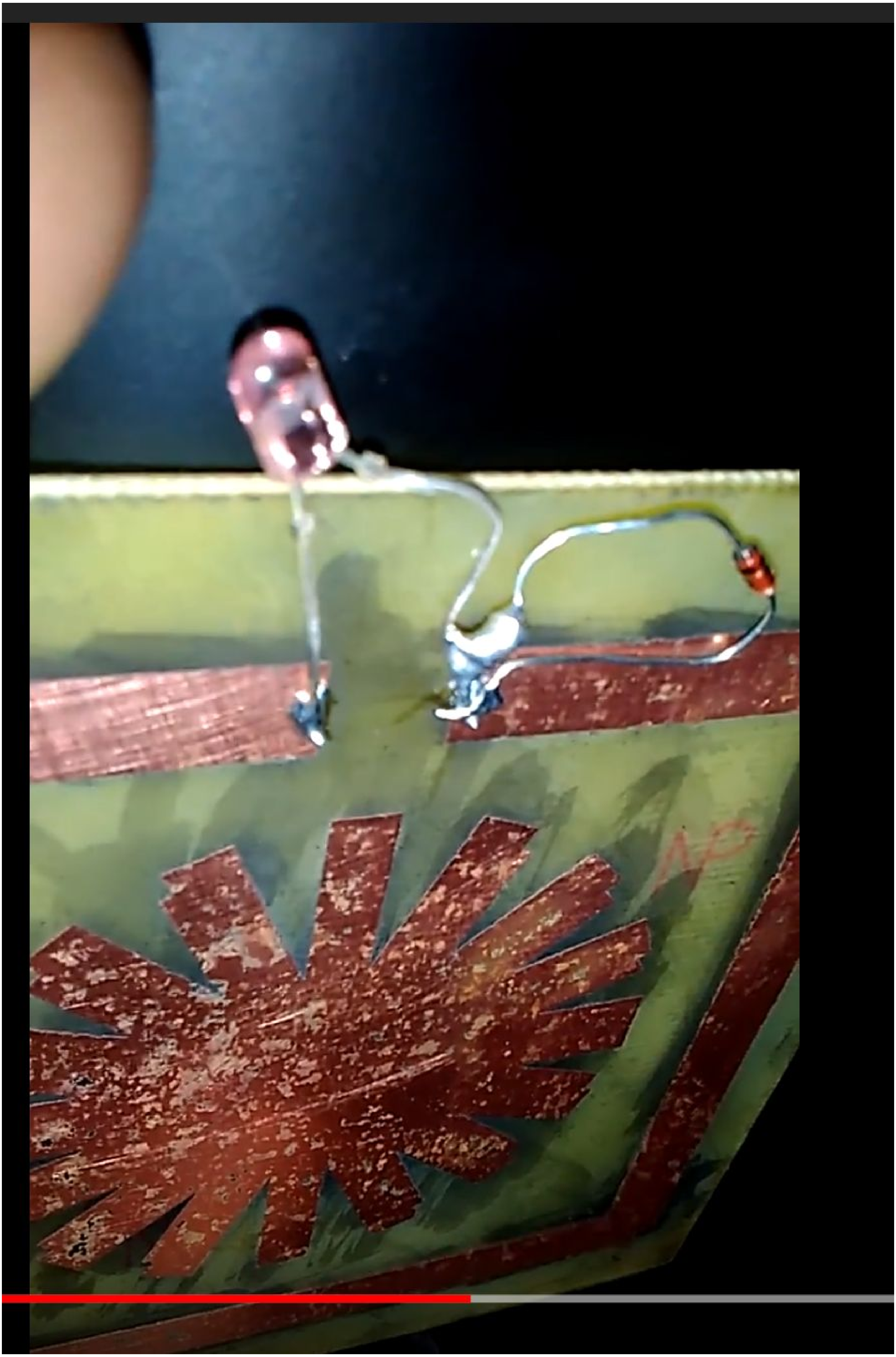
AP

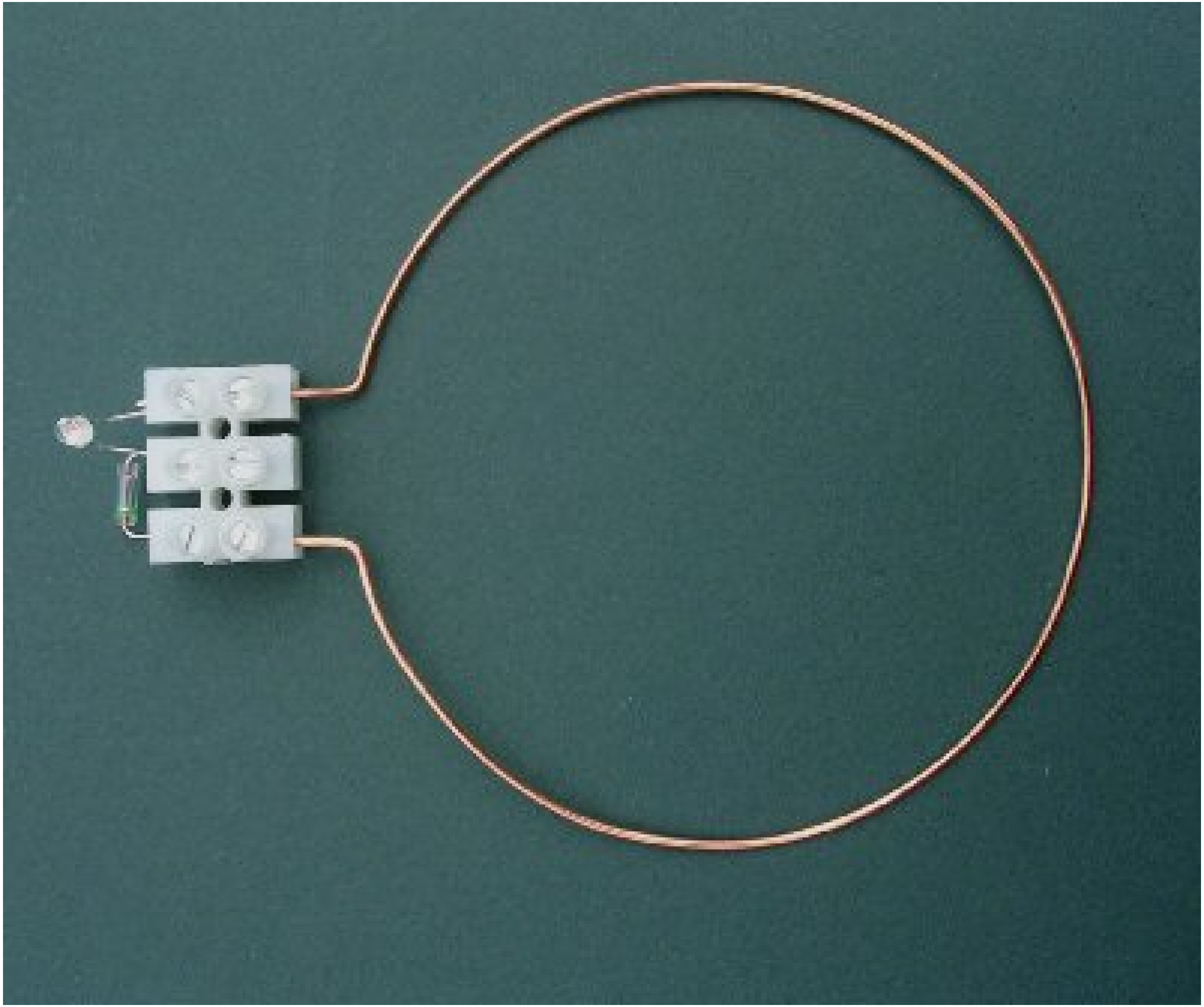

Sony Ericsson

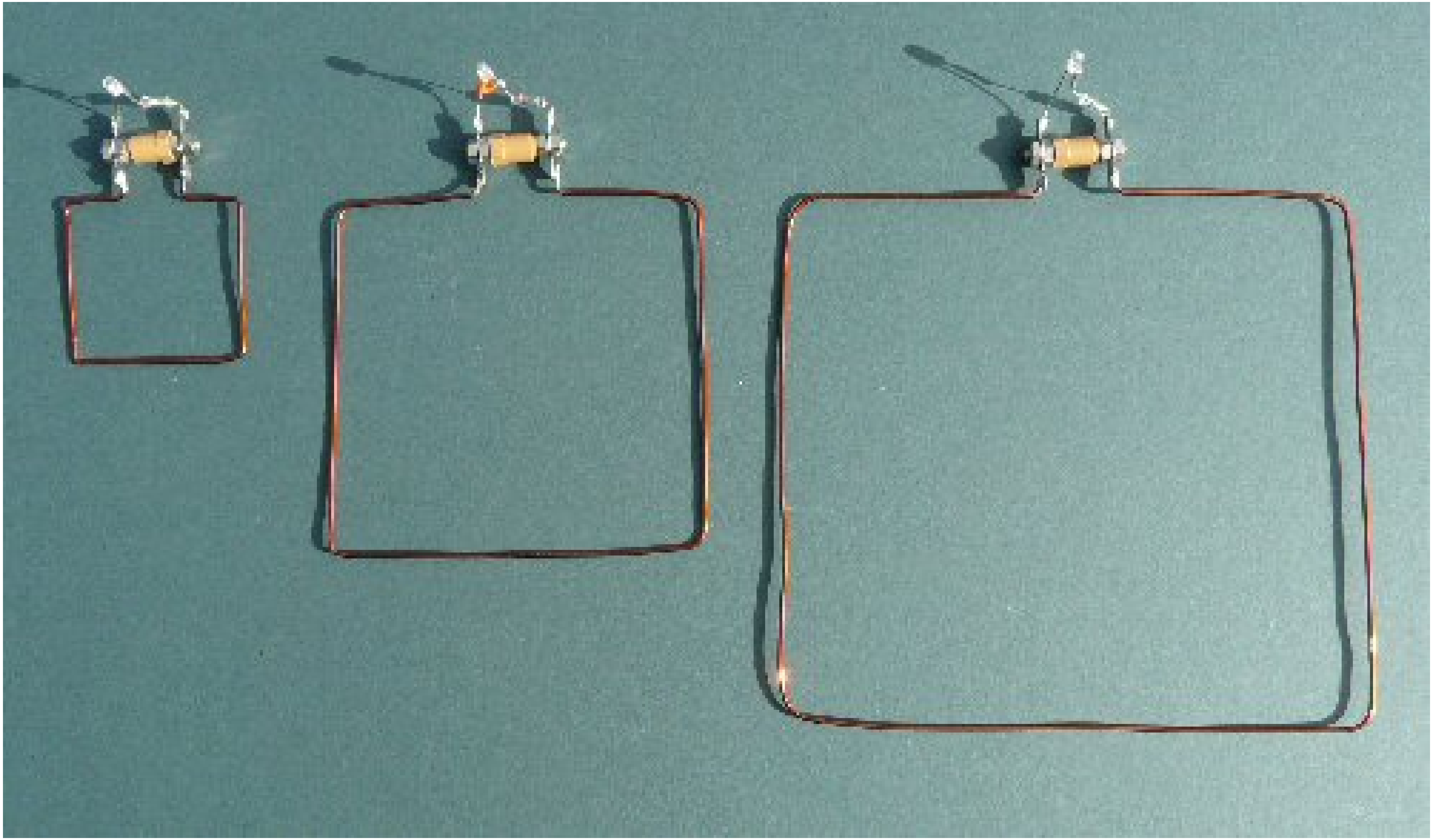

ake and it can be sent in an envelope. I made tens of them and sent them to politicians, newspapers, universities... I gave some to local people, together with a user
later version, that can be rolled up in an envelope that fits the conditions to be sent with only one stamp.

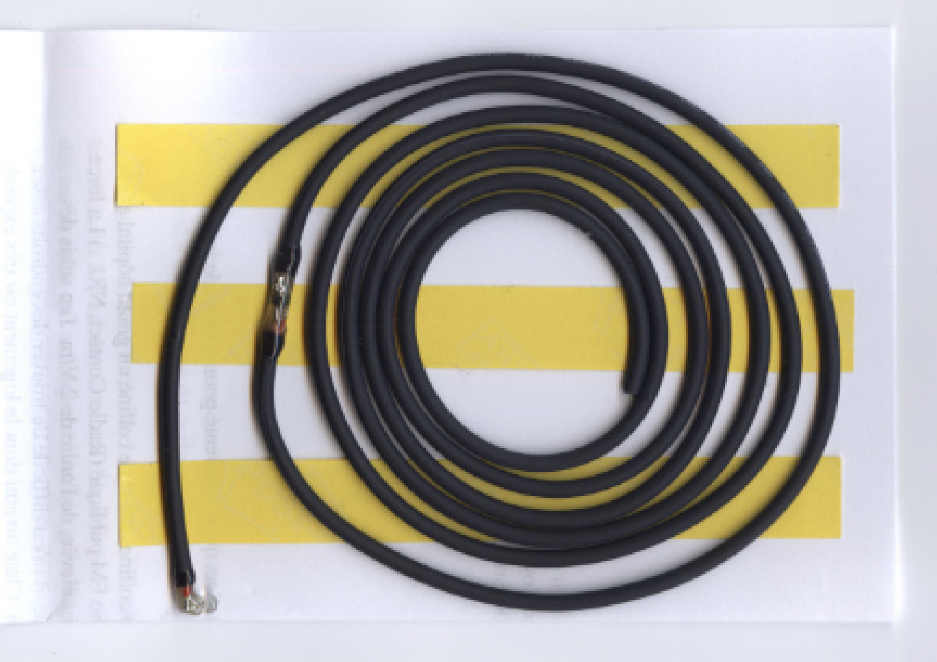

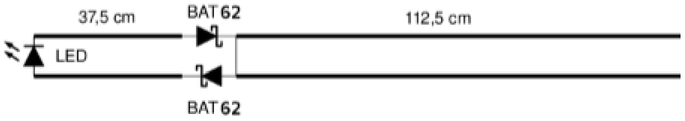

BAT62 detection diodes are no more produced. **BAT15** diodes work fine but they wear out; after a few months they stop functioning. **SMS7630** diodes are great but very little and mechanically fragile. **MMSD701T1G** diodes are sturdy and powerful; an excellent choice for a beginner. Such SMD diodes do also work for cell phone frequencies, which allows to test out a snake with a calling cell phone pushed against it. But any detection diodes that can manage 100 MHz will do.

The LED I'm currently using is the **L-7113SEC-H** . It lights up with a low tension and a very low current (the bluer a LED, the more tension it needs). Its color is red yet close to orange hence it is easily seen by the human eye (the eye is most sensitive to green, yellow and orange). The beam is quite narrow so when the LED is directed towards somebody's eyes it will appear quite bright.

For the lengths of 37.5 and 112.5 centimeters, any electric wire with two copper conductors will do. Audio signal wire is a practical solution. Use the shielding as one of the two conductors. The lengths of the two segments must not be precise. What matters is that the total length of the snake be 1.5 meters. Do not hesitate to try out if a little longer or shorter snake gives better results.

A schematic of my current probes, that I connect to a standard multimeter, measuring Volts DC. The measure displayed by the multimeter must be multiplied by 10. When using a 200.0 mV scale, just read while forgetting the dot:

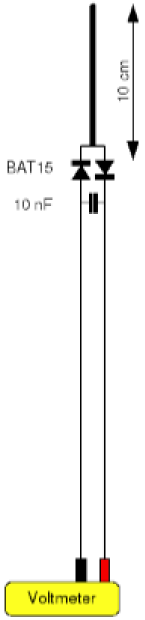

Lead Free Status	Lead Free
RoHS Status	RoHS Compliant

Features, Applications

The MMSD301T1, and MMSD701T1 devices are spin-offs of our popular MMBD301LT1, and MMBD701LT1 SOT-23 devices. They are designed for high-efficiency UHF and VHF detector applications. Readily available to many other fast switching RF and digital applications.

Extremely Low Minority Carrier Lifetime Very Low Capacitance Low Reverse Leakage AEC Qualified and PPAP Capable S Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant*

XXX G = Specific Device Code SMMSD701T1G = Date Code = Pb-Free Package
Rating Reverse Voltage MMSD701T1G, SMMSD701T1G Forward Current (DC) Continous Forward Power Dissipation = 25C Junction Temperature Storage Temperature Range Symbol VR Value to +150 Unit Vdc M G

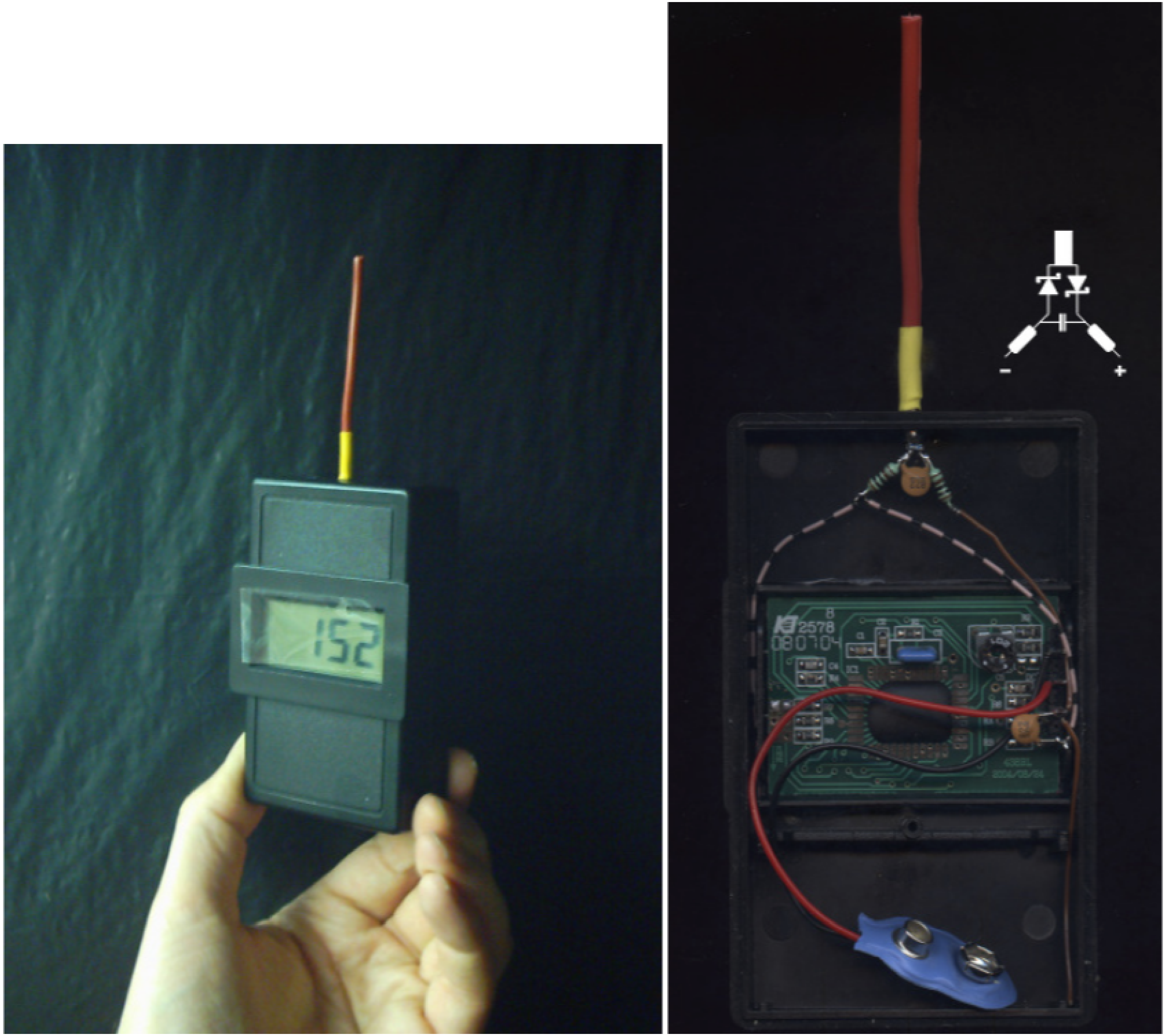
152
2578
080704
-
+

Parts Required:

1. 100nF & 100pF
2. n4148 Diode x(2)
3. A bright good quality LED

Circuit Diagram:

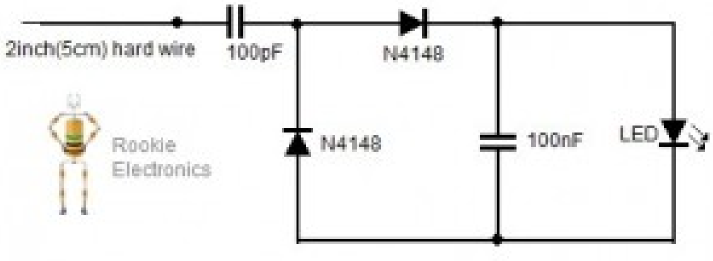
2inch(5cm) hard wire
100pF
N4148
N4148
100nF
LED
Rookie
Electronics

Bread board Arrangement:

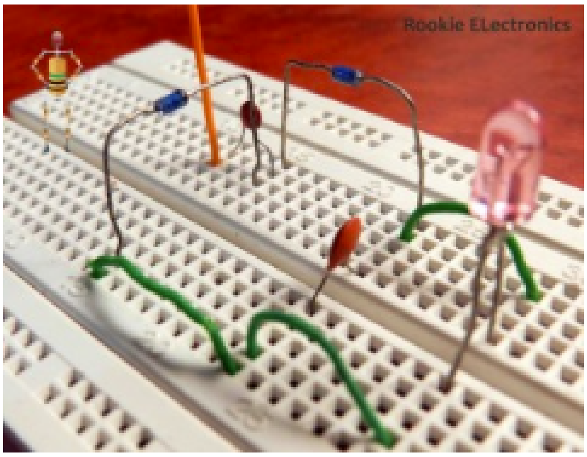
Rookie ELectronics

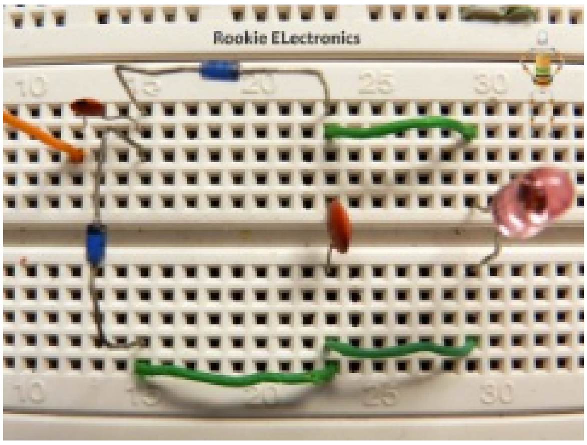
Rookie ELectronics

Strip Board:

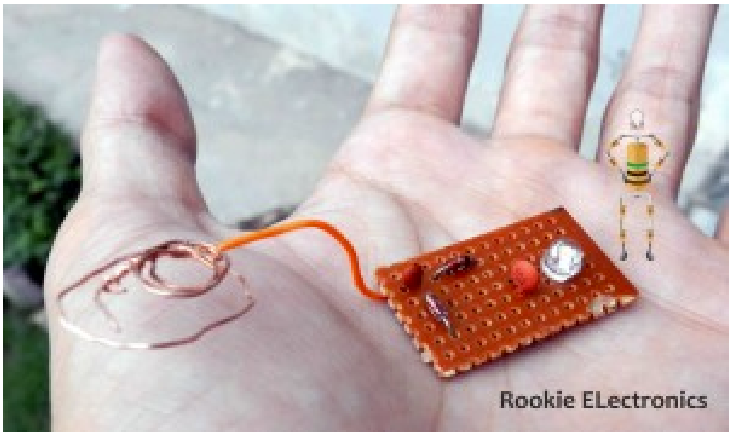
Rookie ELectronics

Rookie ELectronics

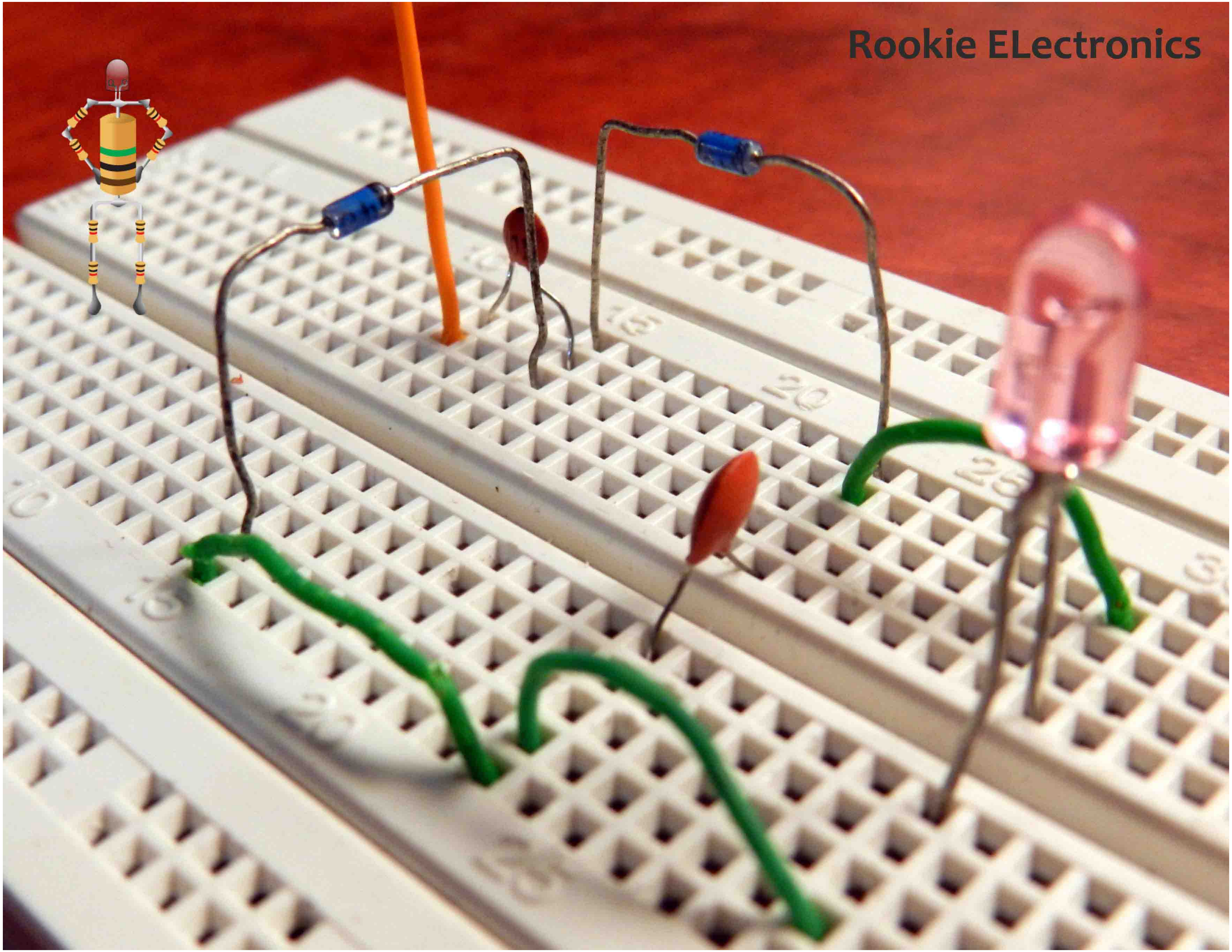

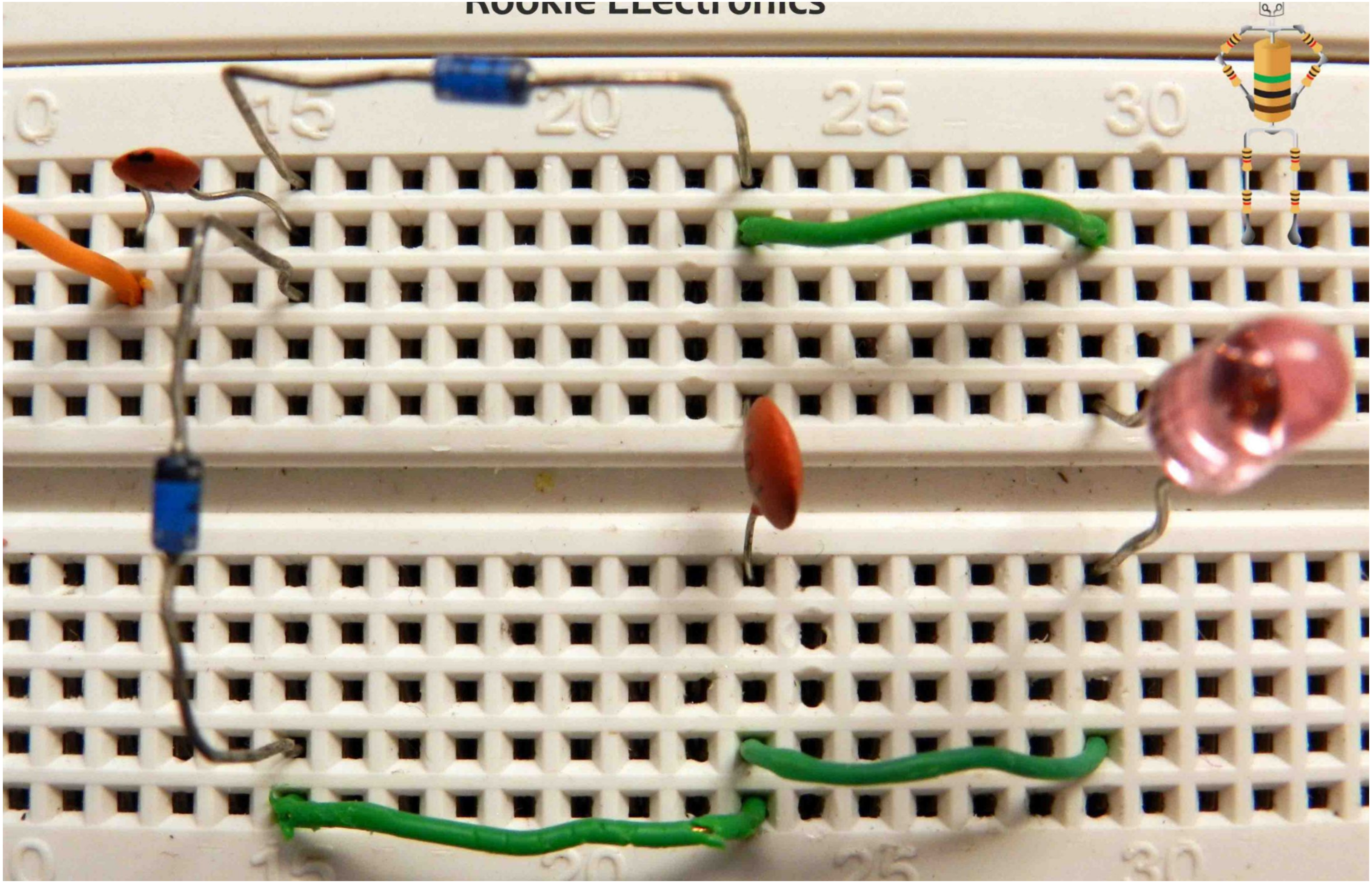
10
15
20
25
30
10
15
20
25
30

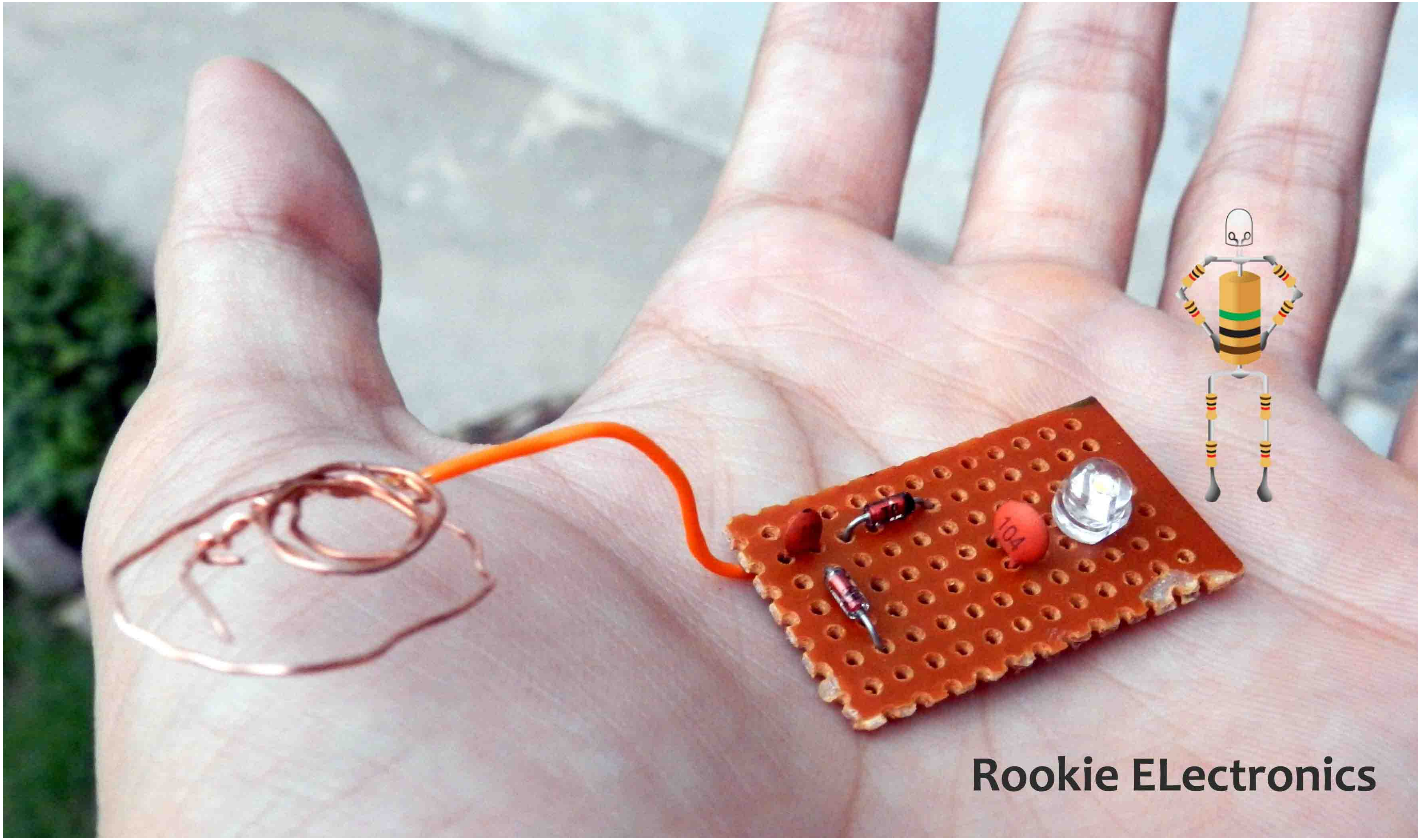

Rookie ELectronics

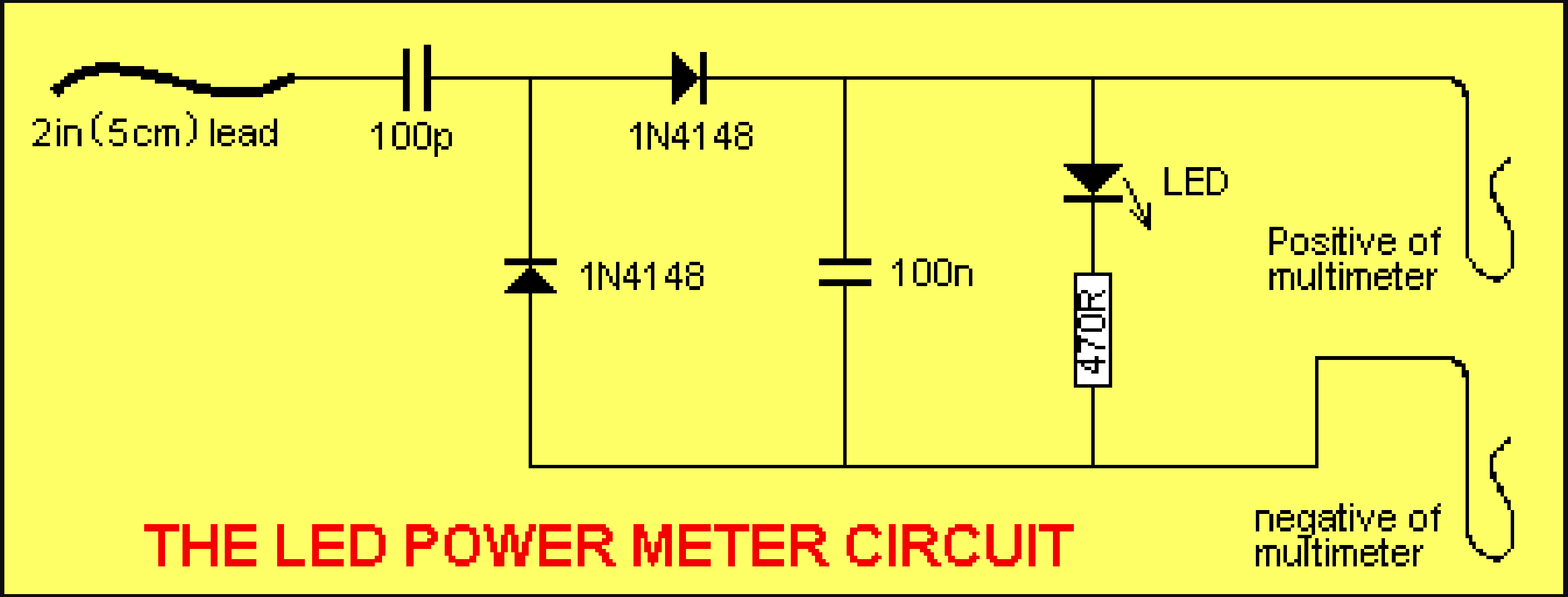
2in(5cm) lead
100p
1N4148
1N4148
100n
LED
470R
Positive of multimeter
negative of multimeter

THE LED POWER METER CIRCUIT

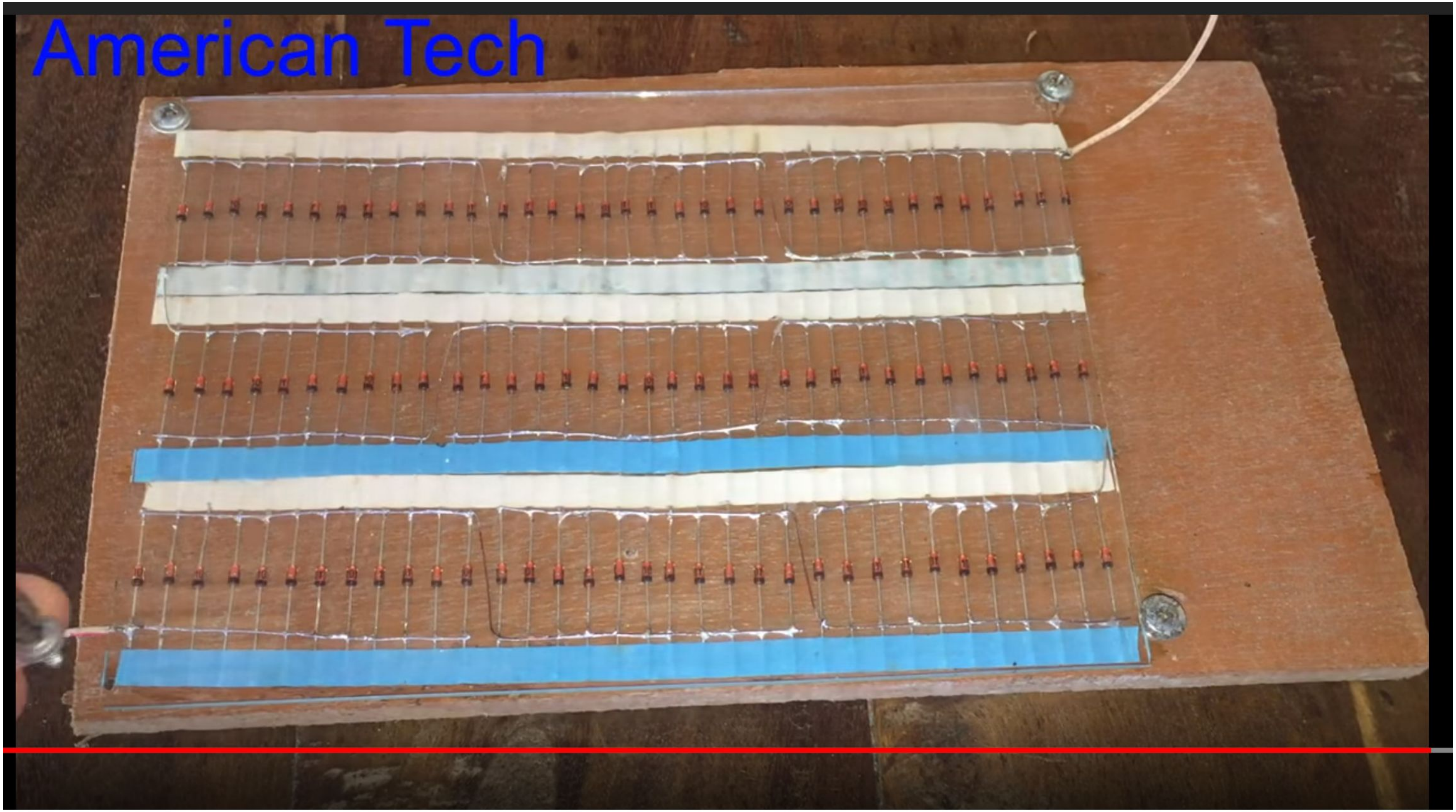
American Tech

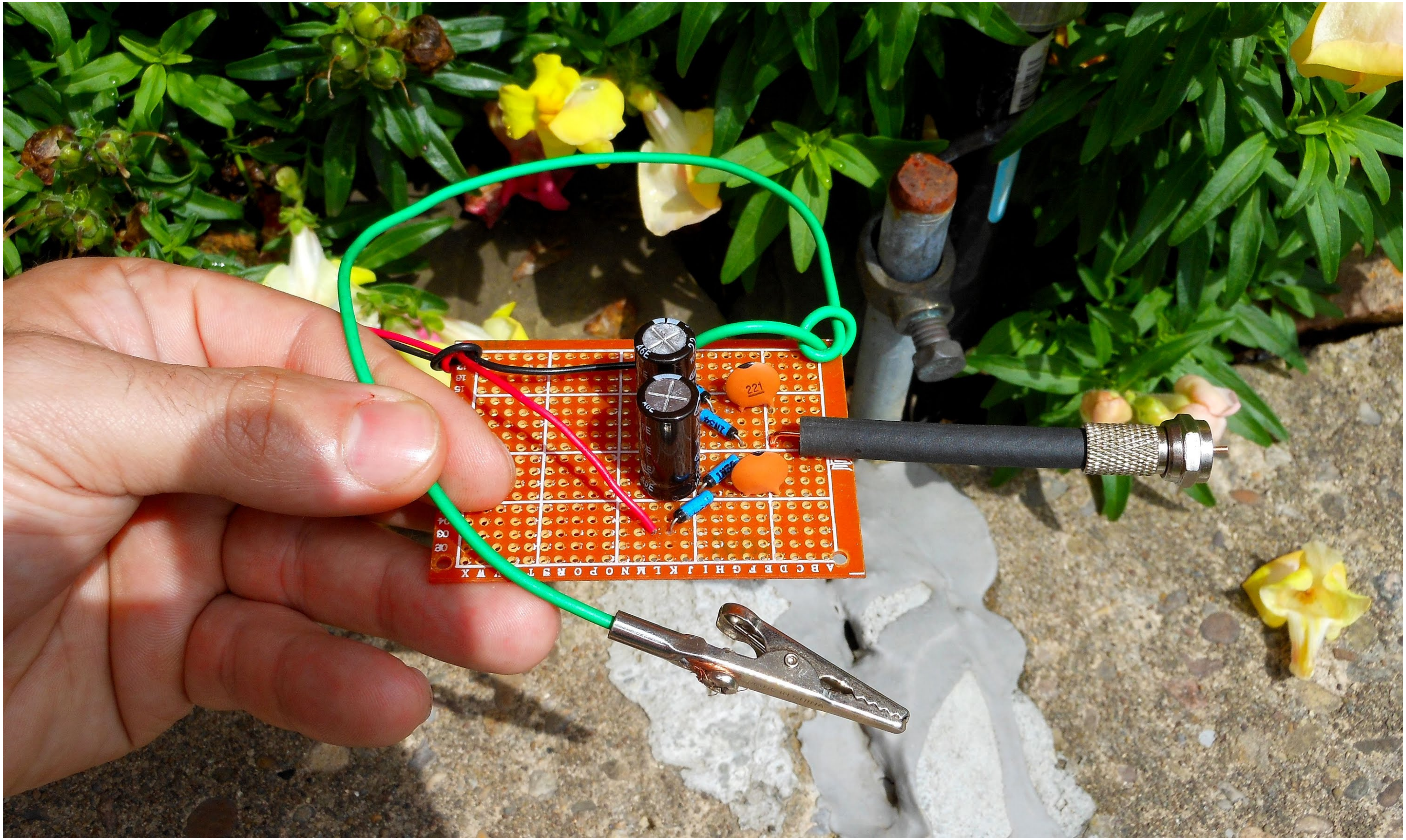
221

24 - 1N34A'S
12 - DISC CAP'S .001µF
12 - ELEC CAP'S 200V 22µF

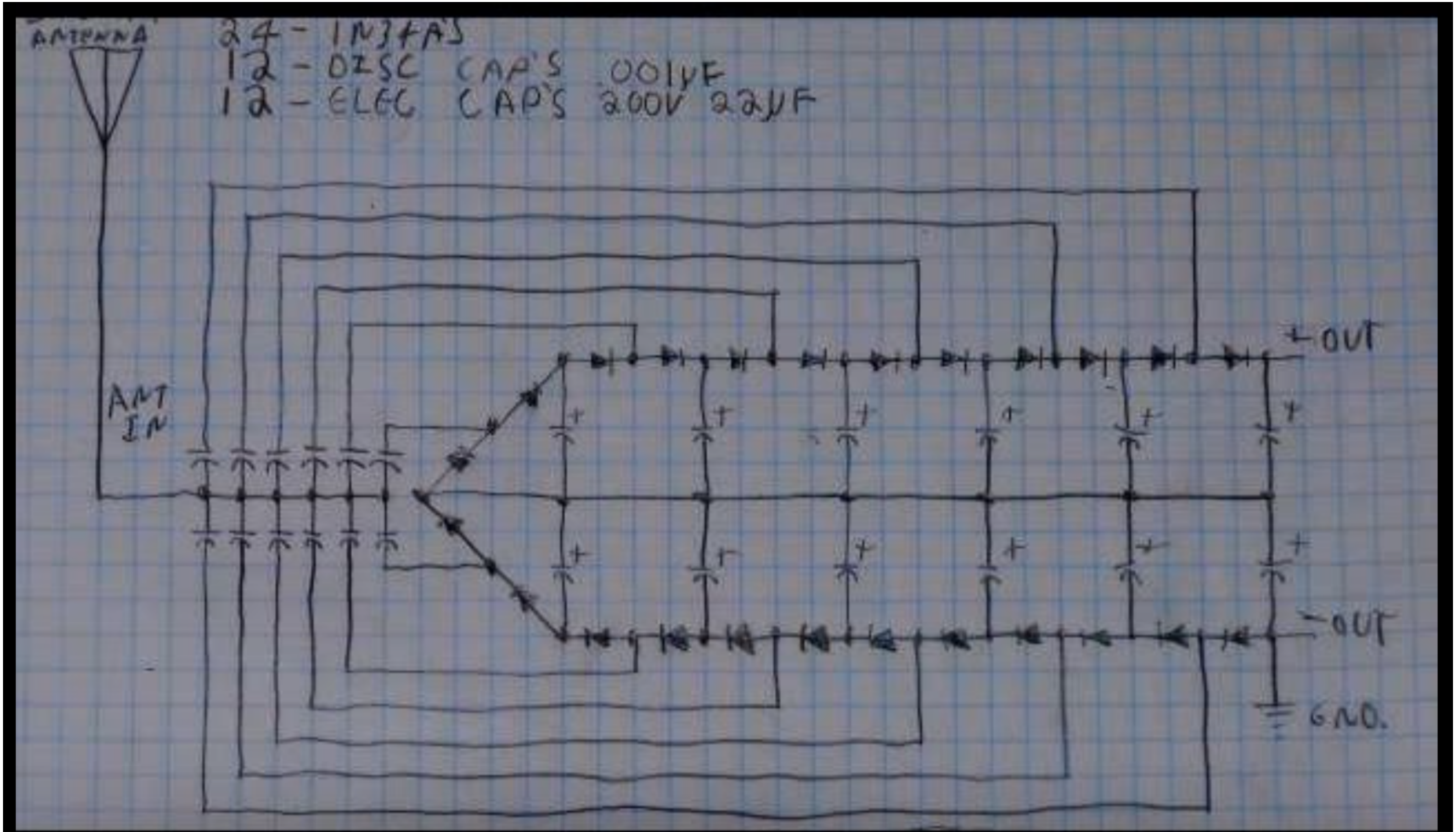
ANTENNA
ANT IN
+OUT
-OUT
GND.

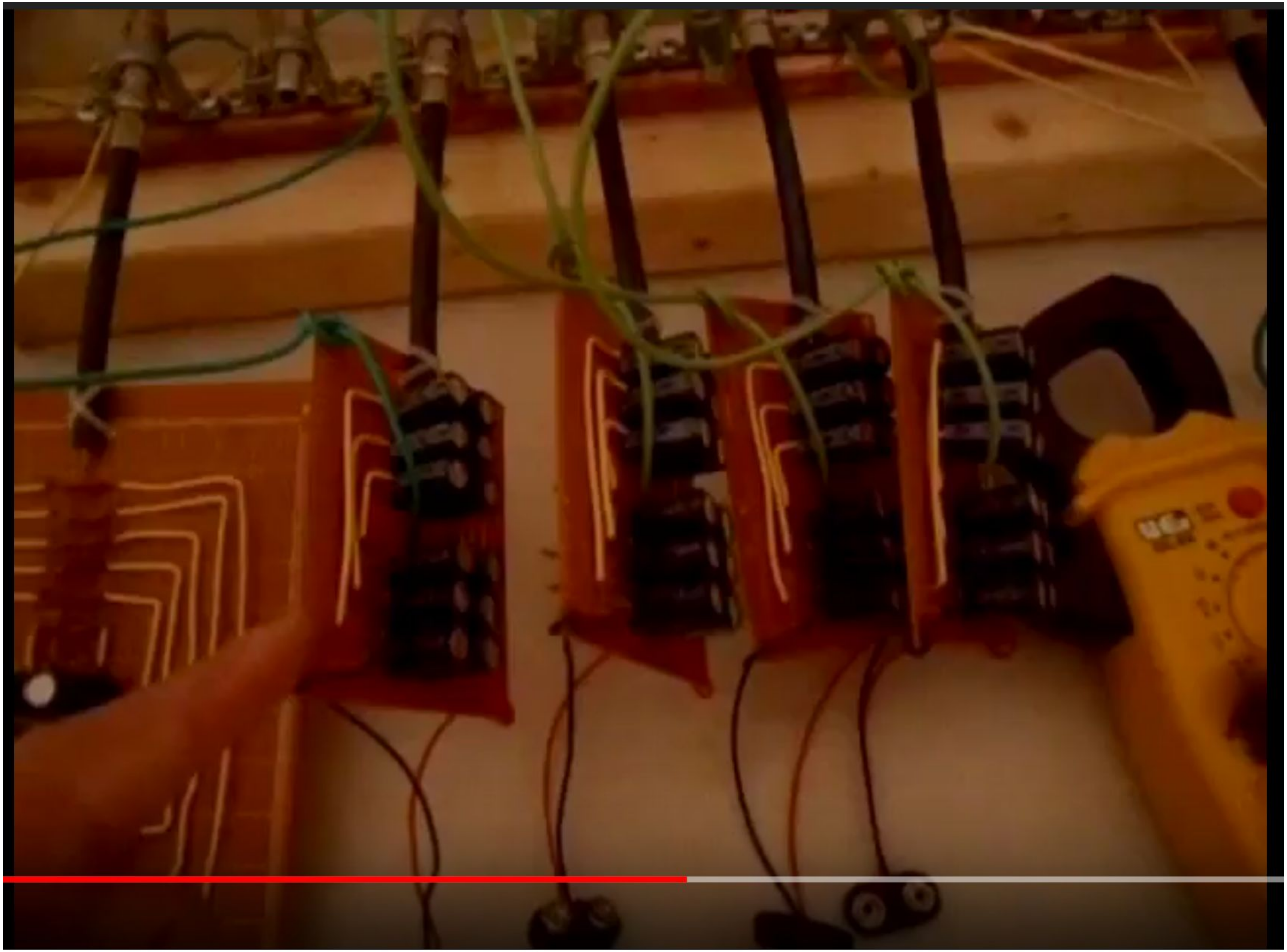

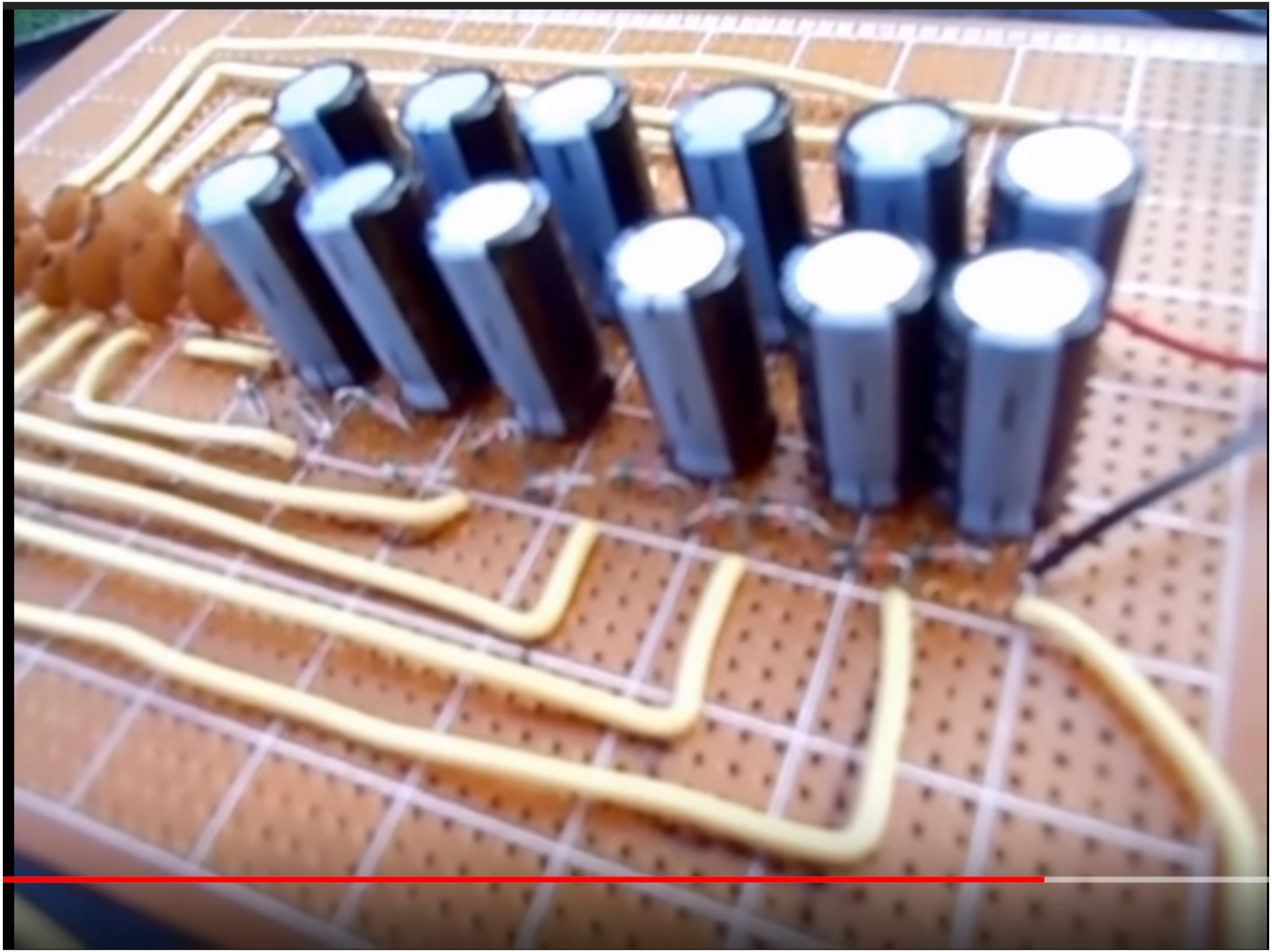

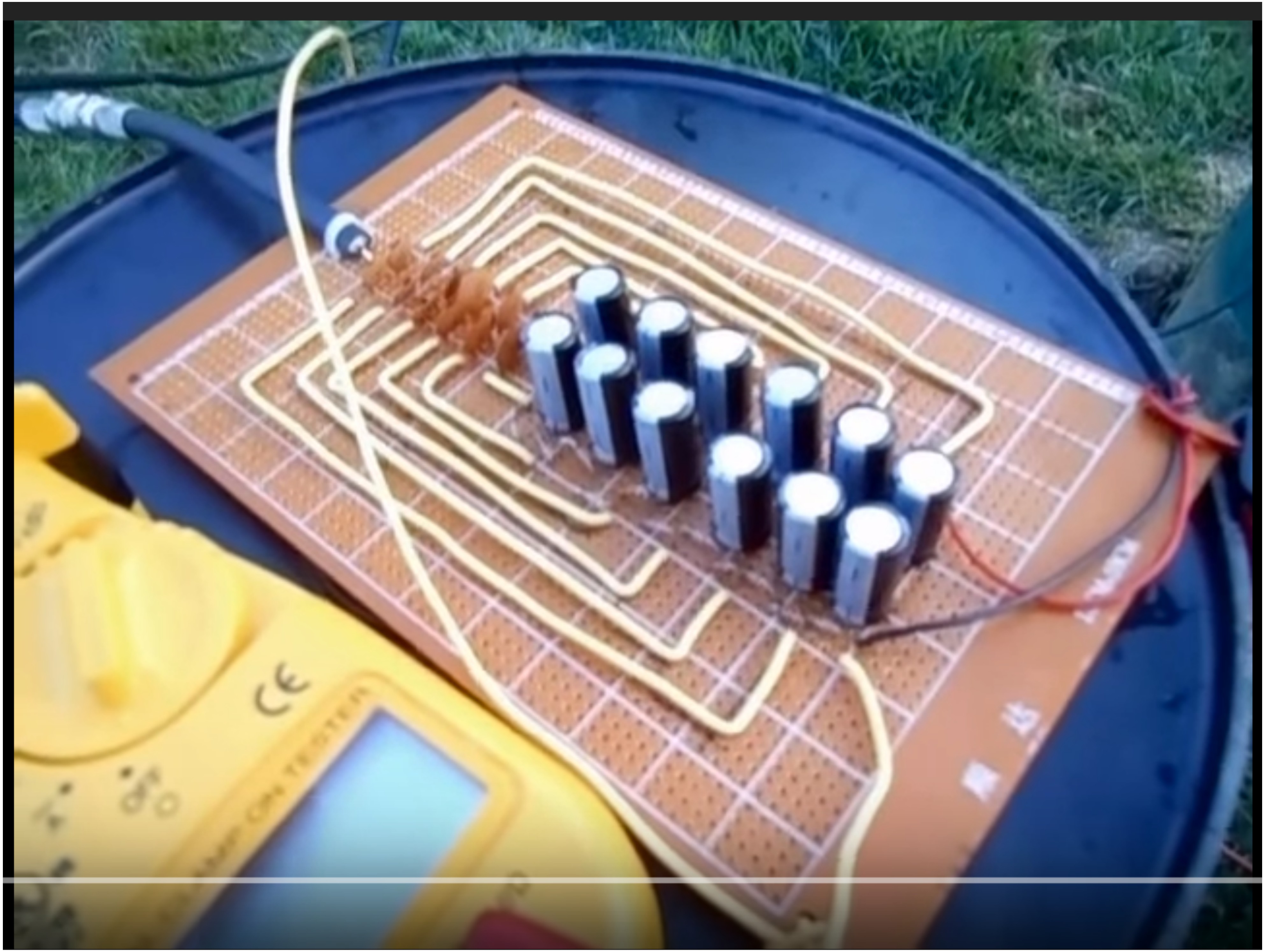
CE

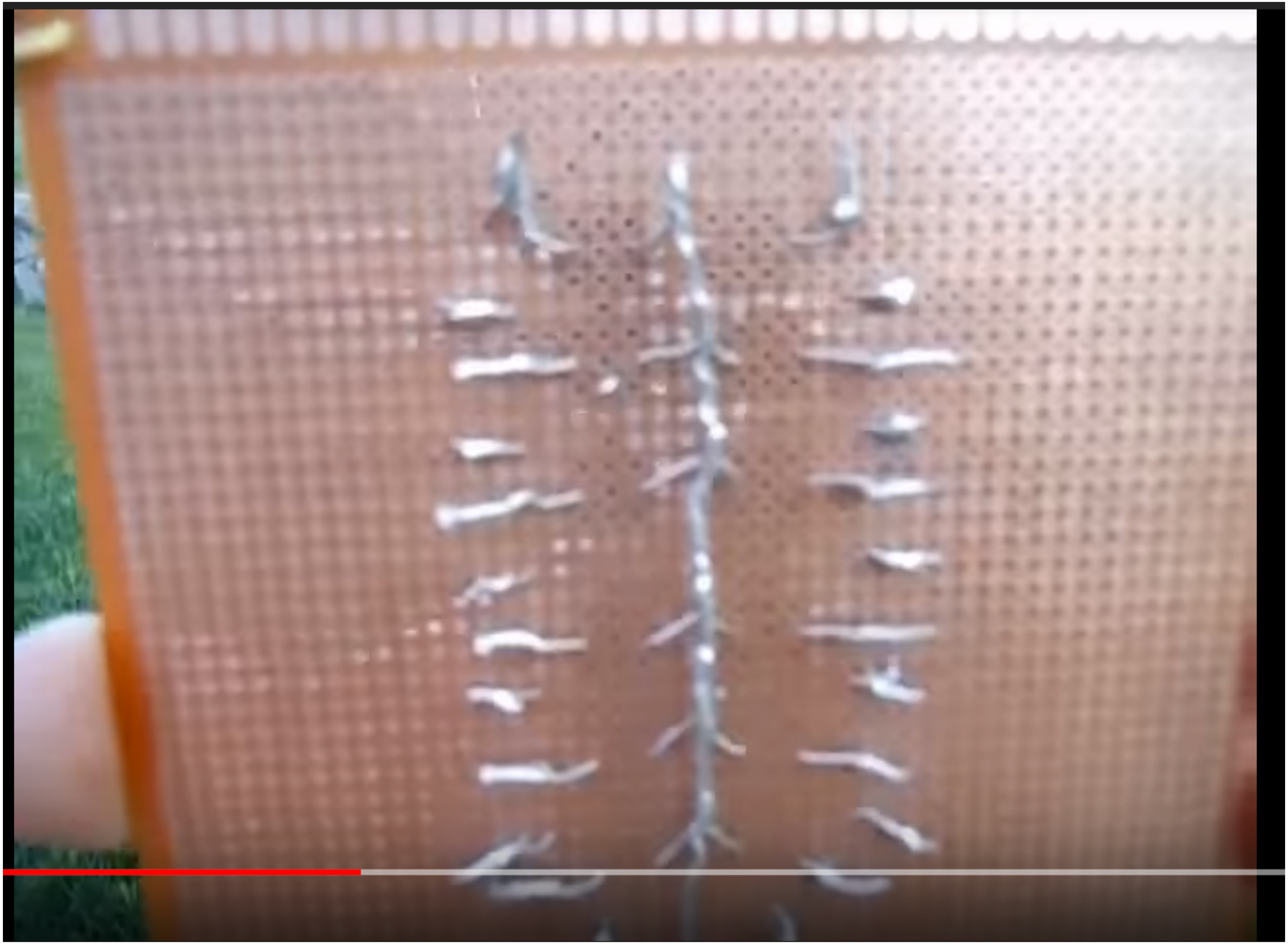

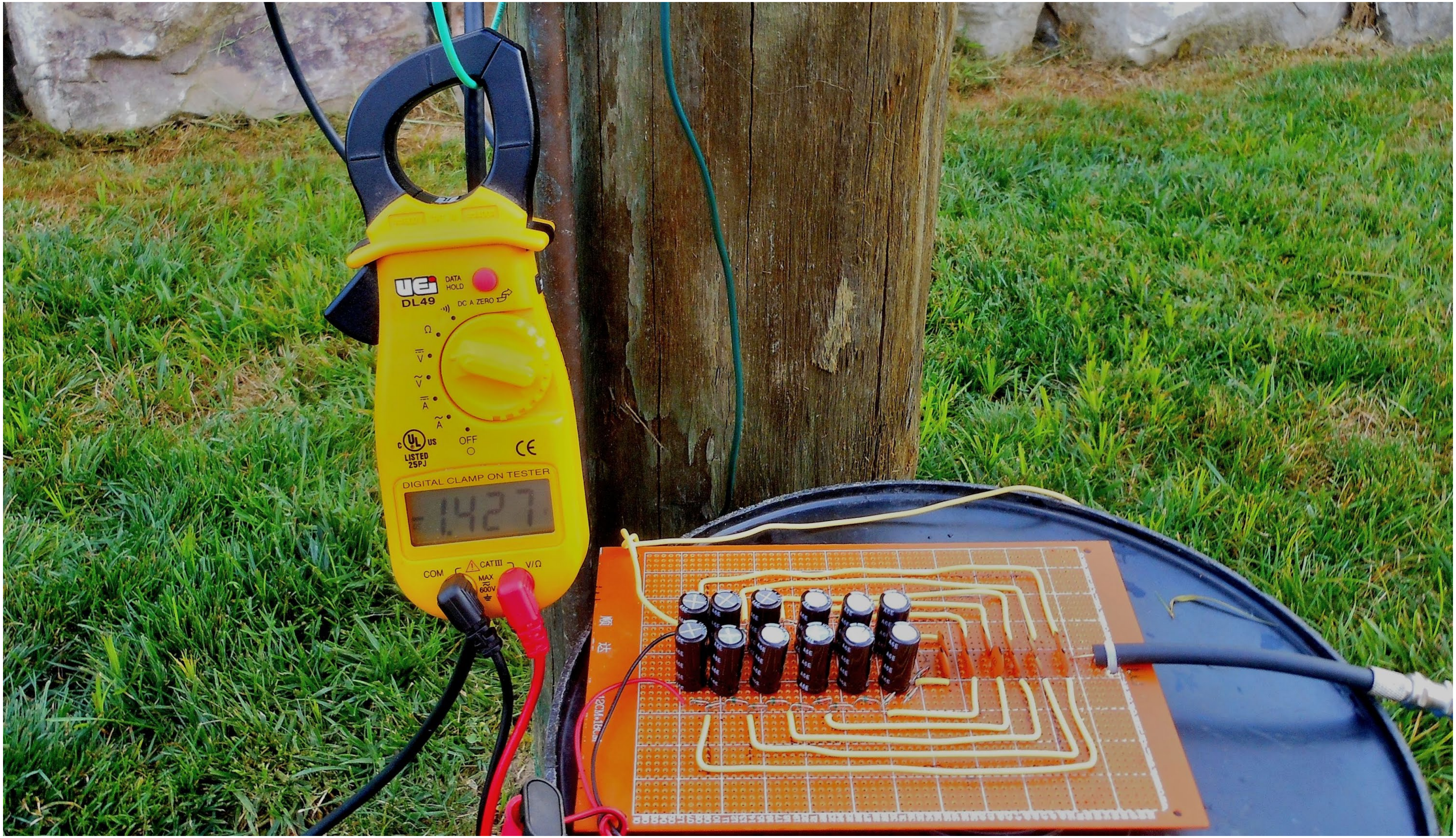
UEi
DL49
DATA HOLD
DC A ZERO
OFF
LISTED 25PJ
CE
DIGITAL CLAMP ON TESTER
-1.427
COM
CAT III
MAX 600V
V/Ω

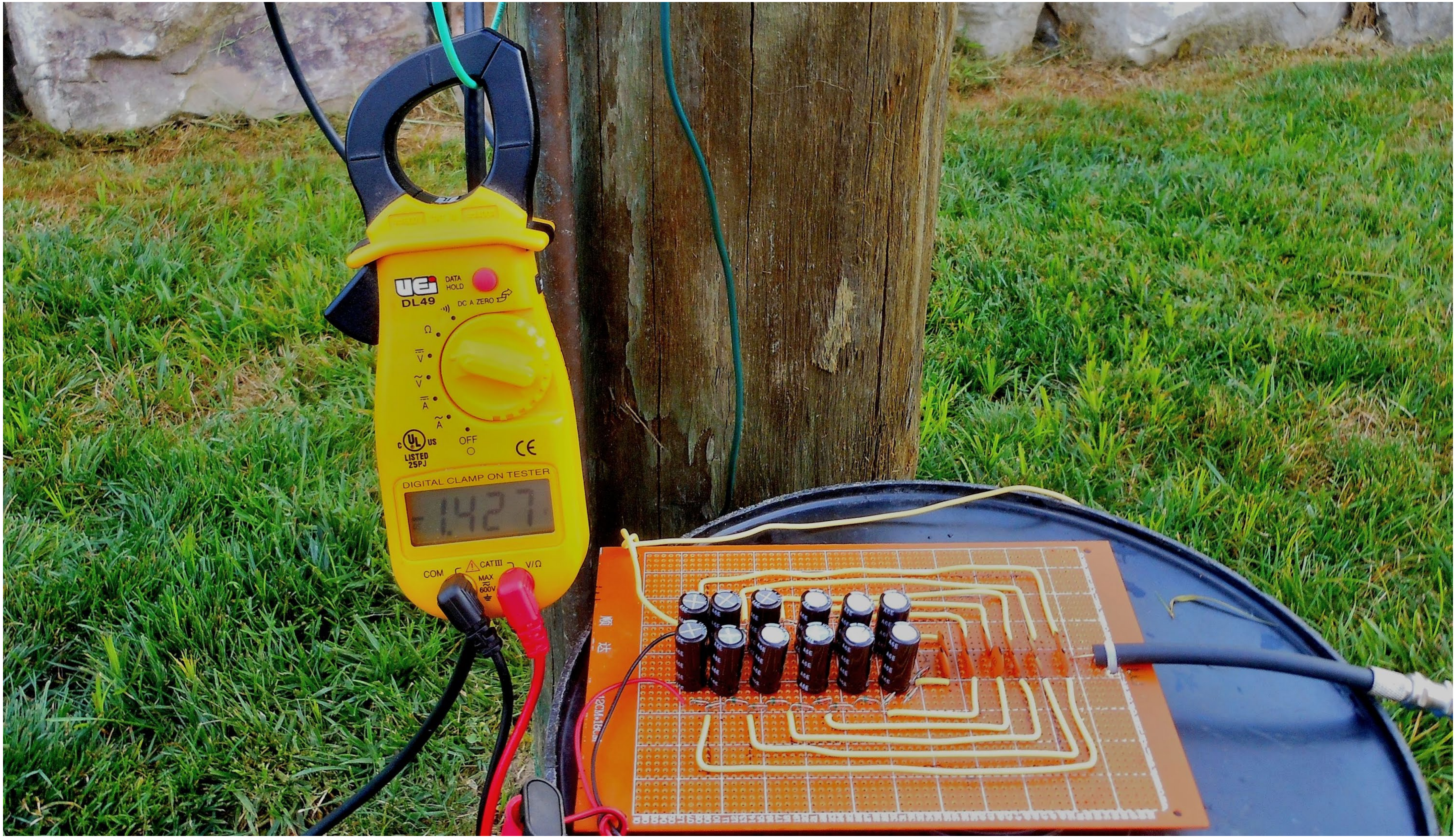
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DC A ZERO
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CAT III
MAX 600V
V/Ω

UEi
DL49
OFF
CE
DIGITAL CLAMP ON TESTER
45.8
COM

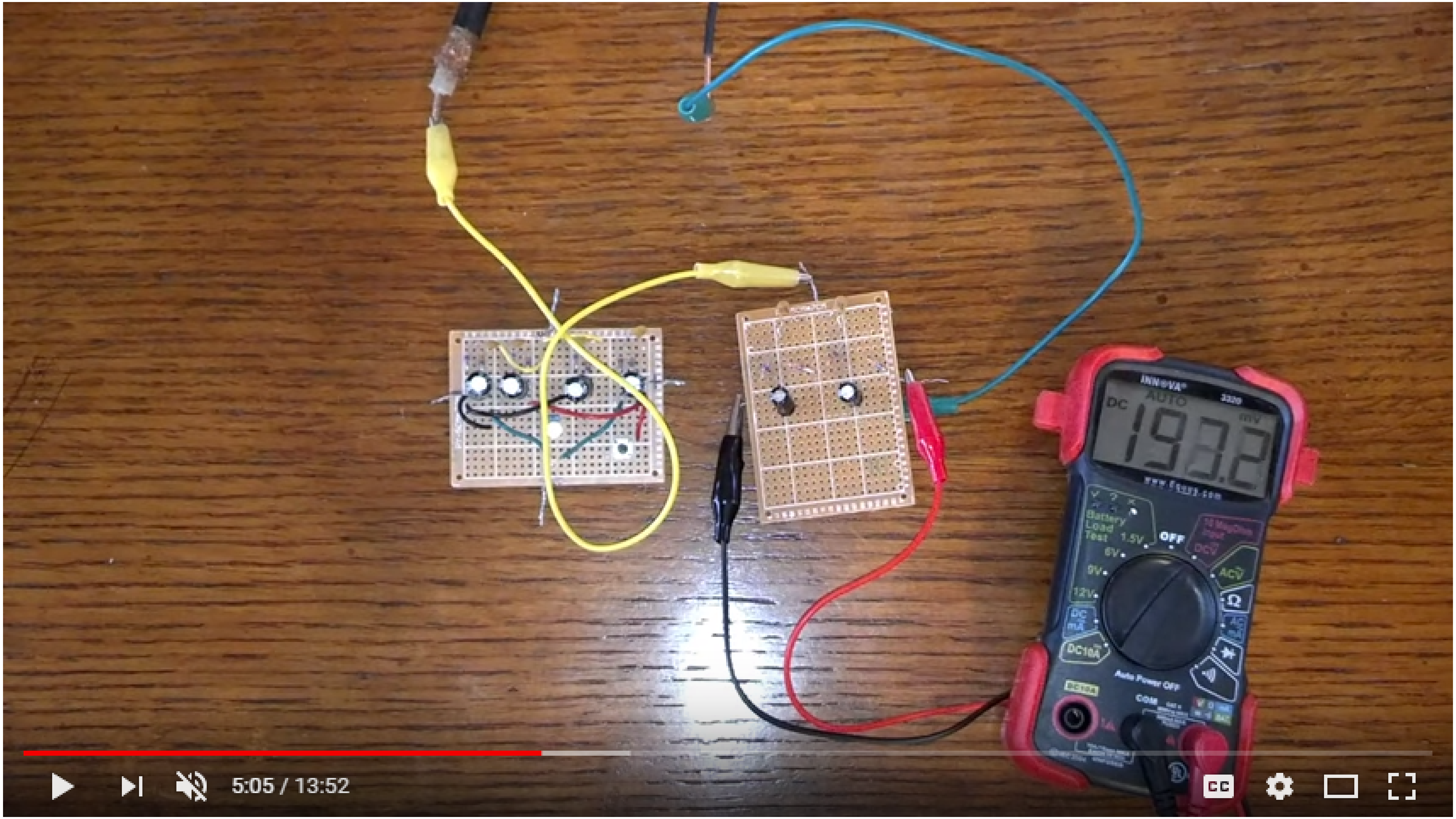
INNOVA
3320
DC
AUTO
mV
OFF
5:05 / 13:52

Tesla Free Energy Air Circuit

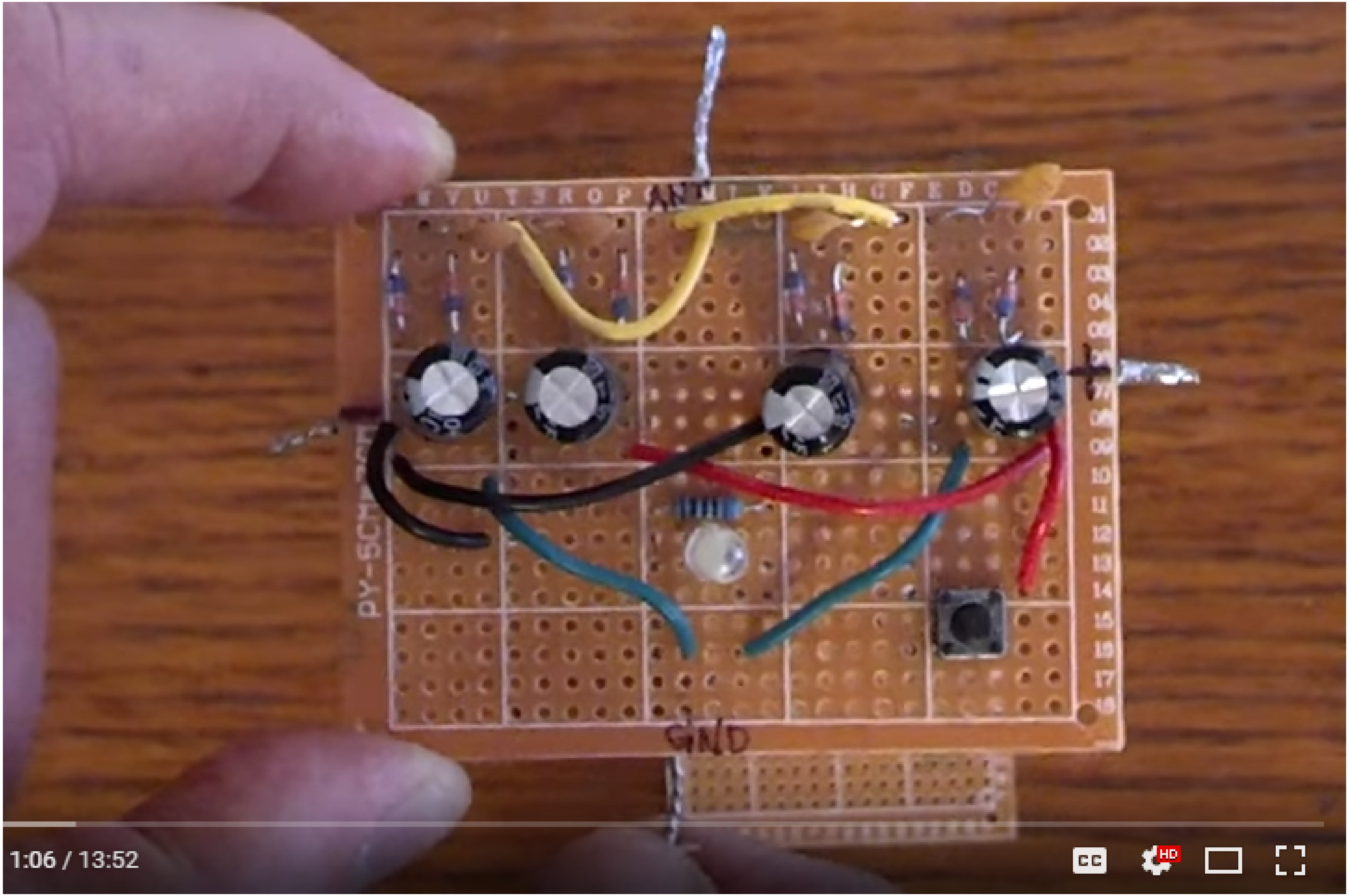
ANT
+
GND
PY-SCH
1:06 / 13:52
HD

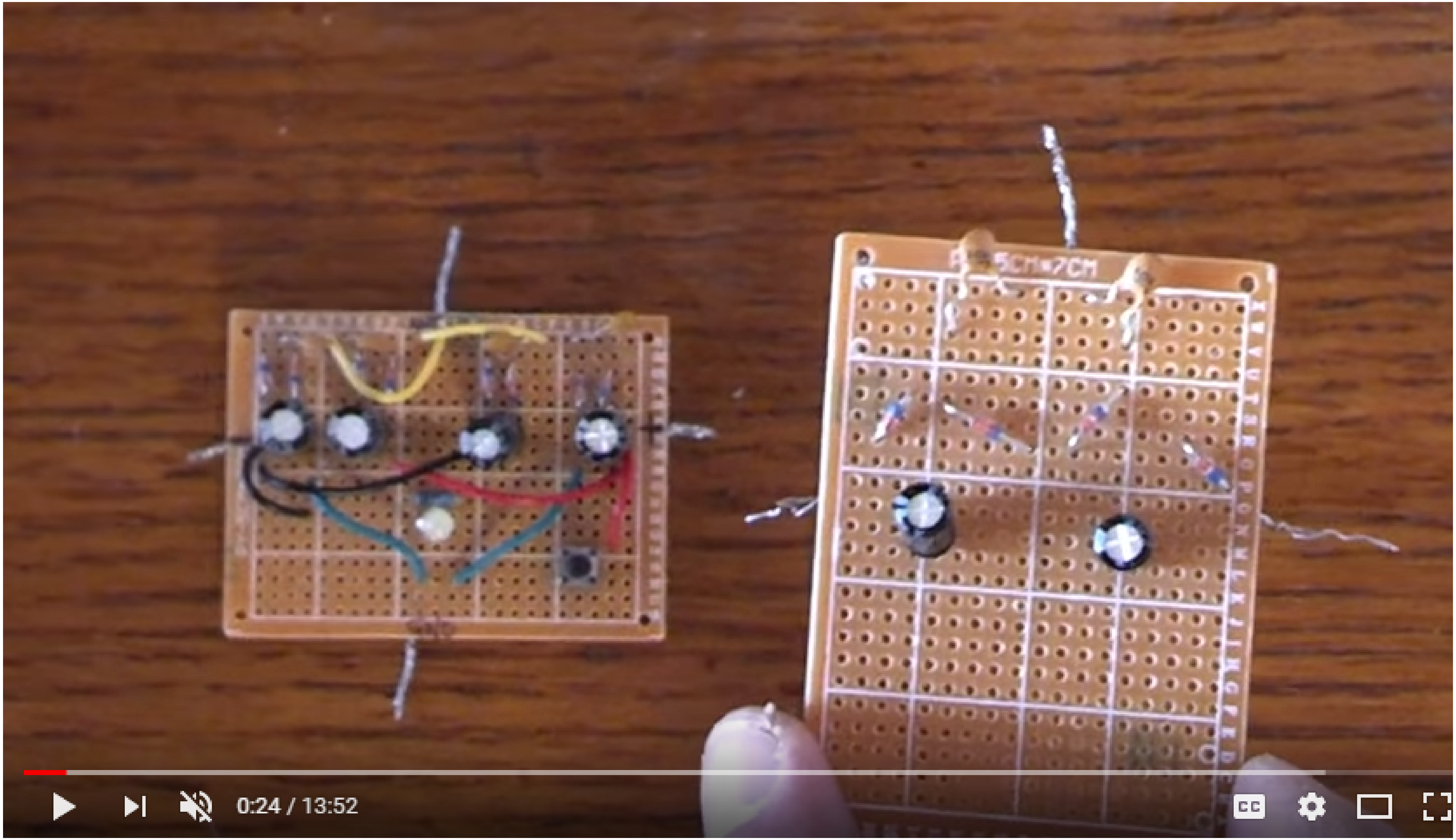
5CM*7CM
0:24 / 13:52

Tesla Free Energy Air Circuit

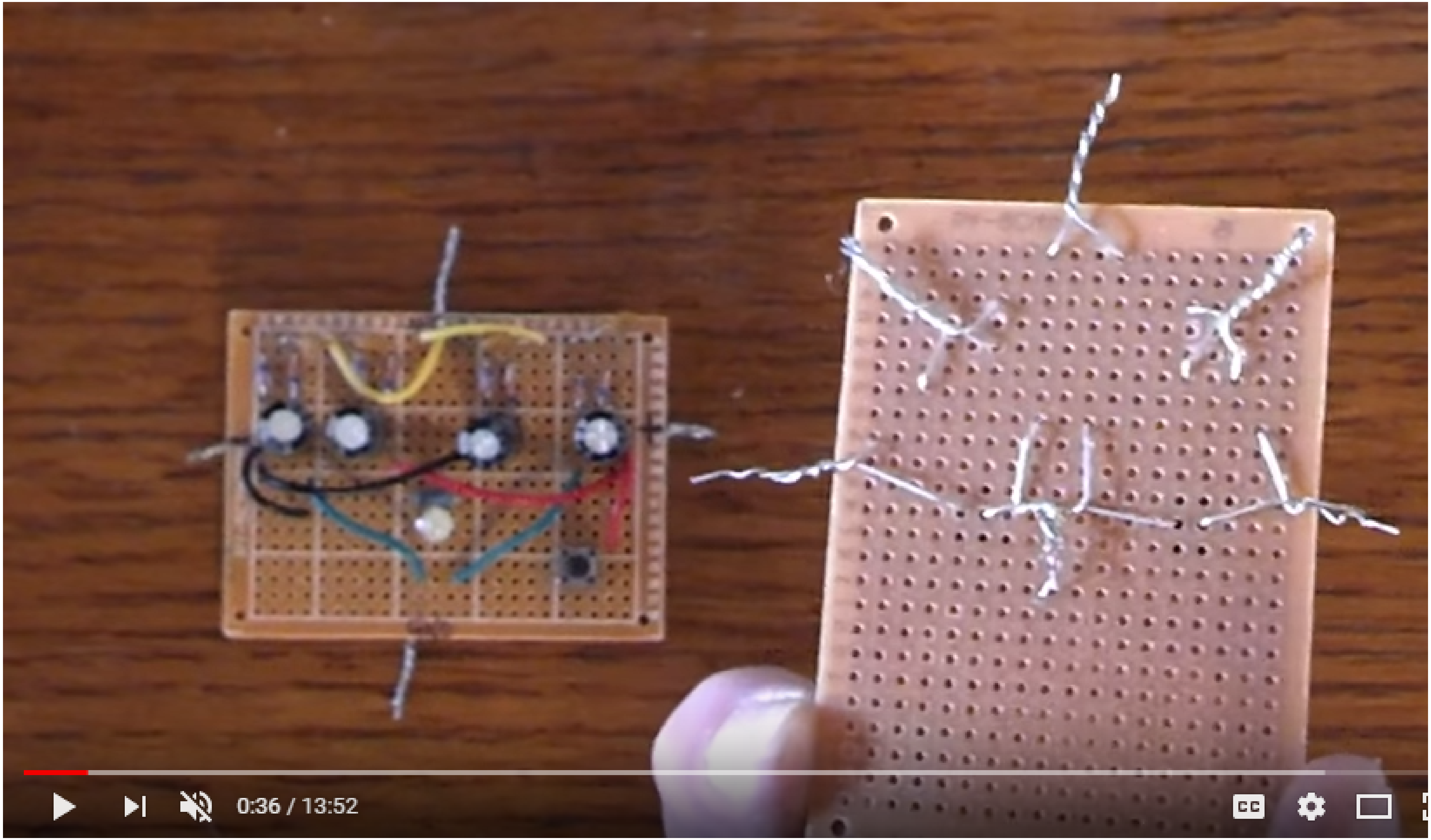

Tesla Free Energy Air Circuit

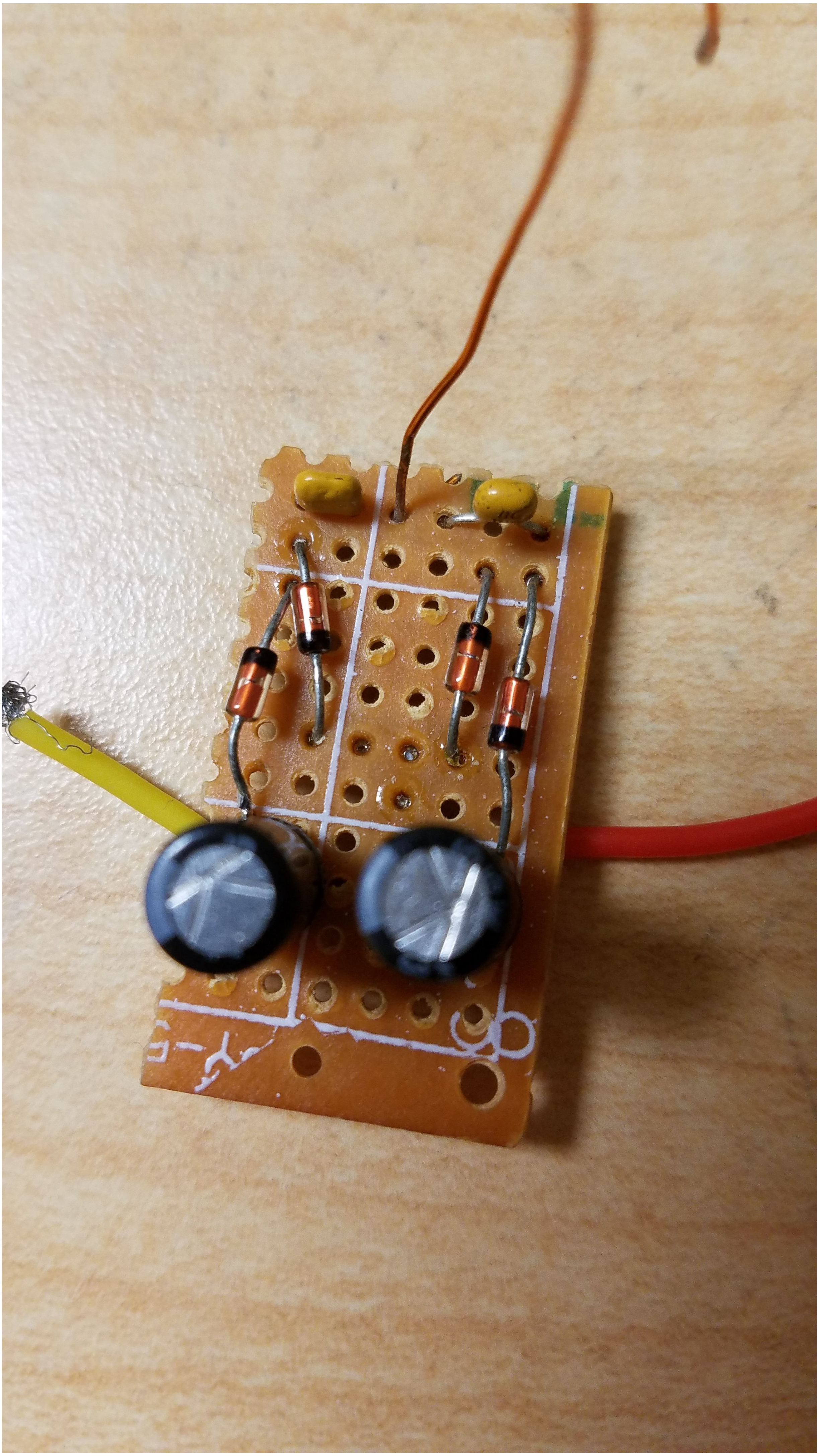

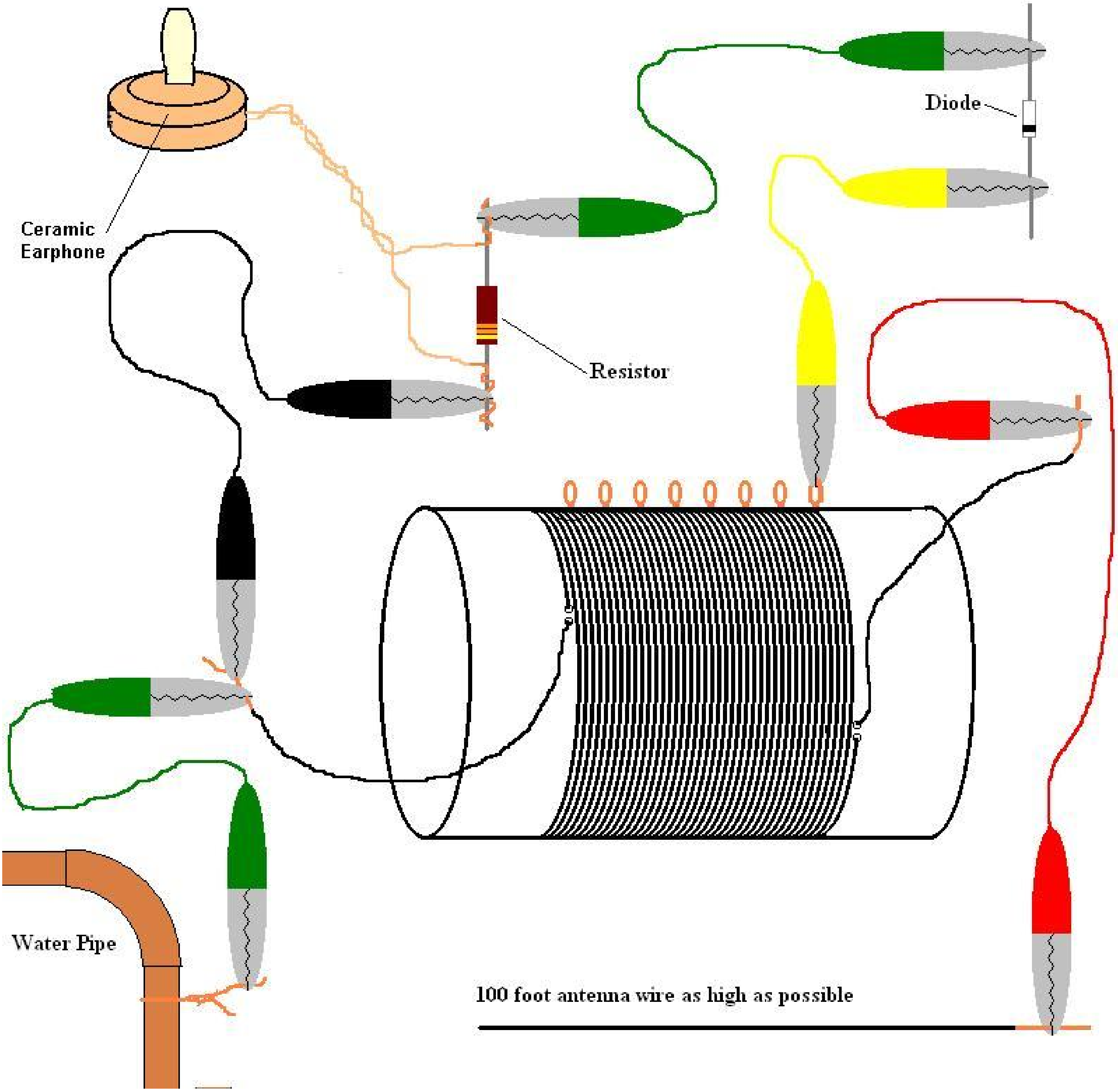
Ceramic Earphone
Diode
Resistor
Water Pipe
100 foot antenna wire as high as possible

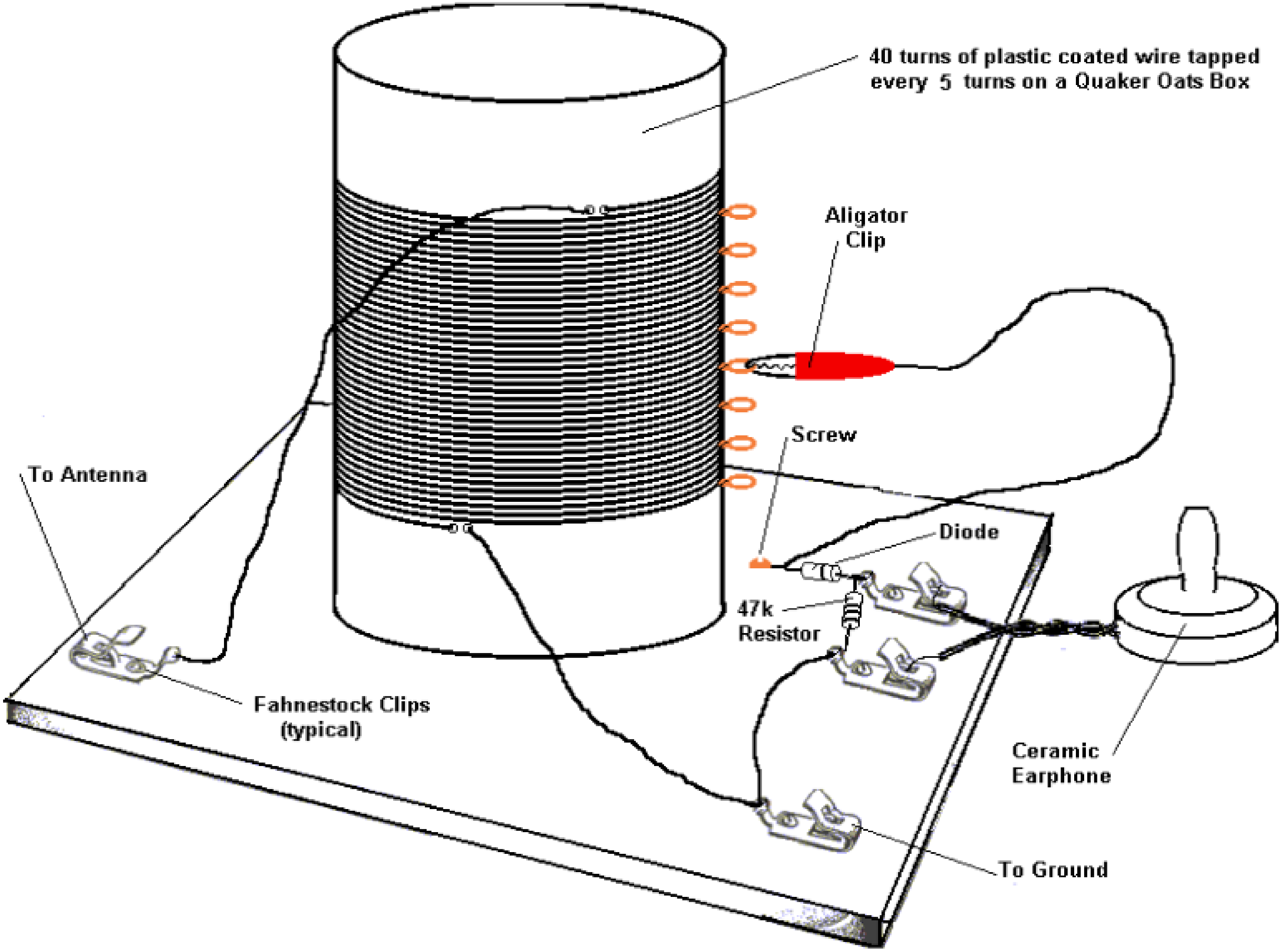
40 turns of plastic coated wire tapped every 5 turns on a Quaker Oats Box
Aligator Clip
Screw
To Antenna
Diode
47k Resistor
Fahnestock Clips (typical)
Ceramic Earphone
To Ground

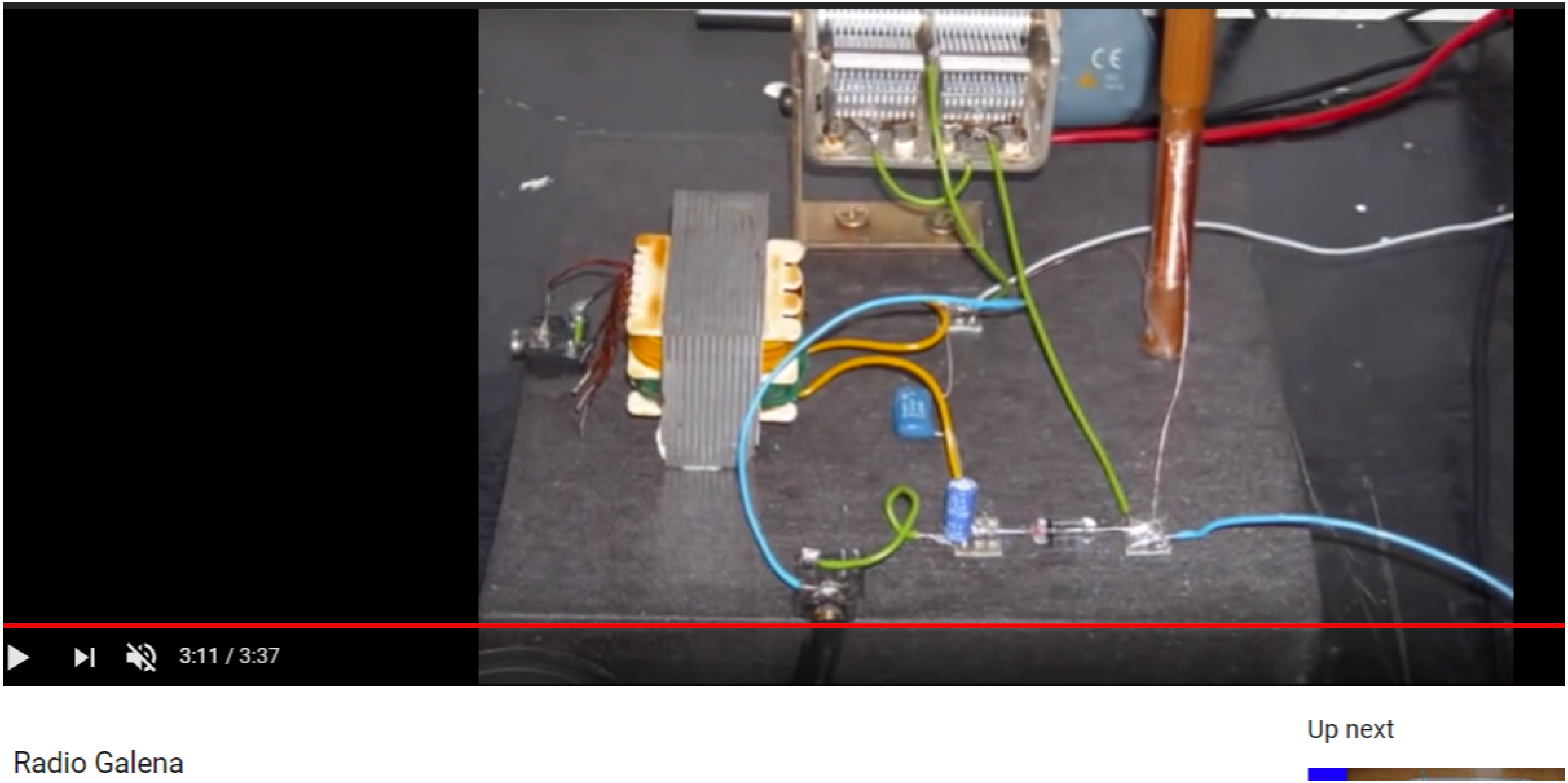
3:11 / 3:37
Up next

Radio Galena

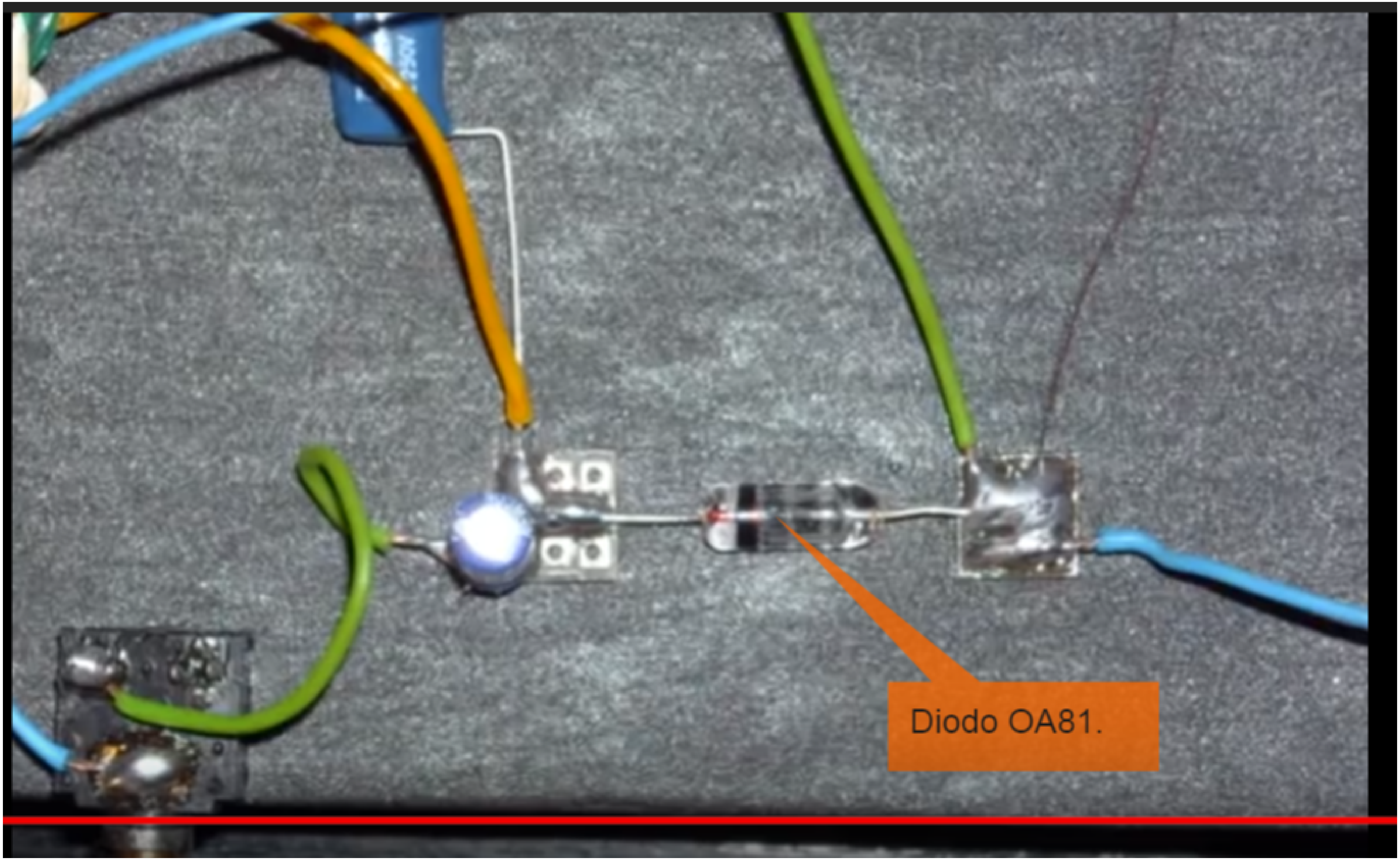
Diodo OA81.

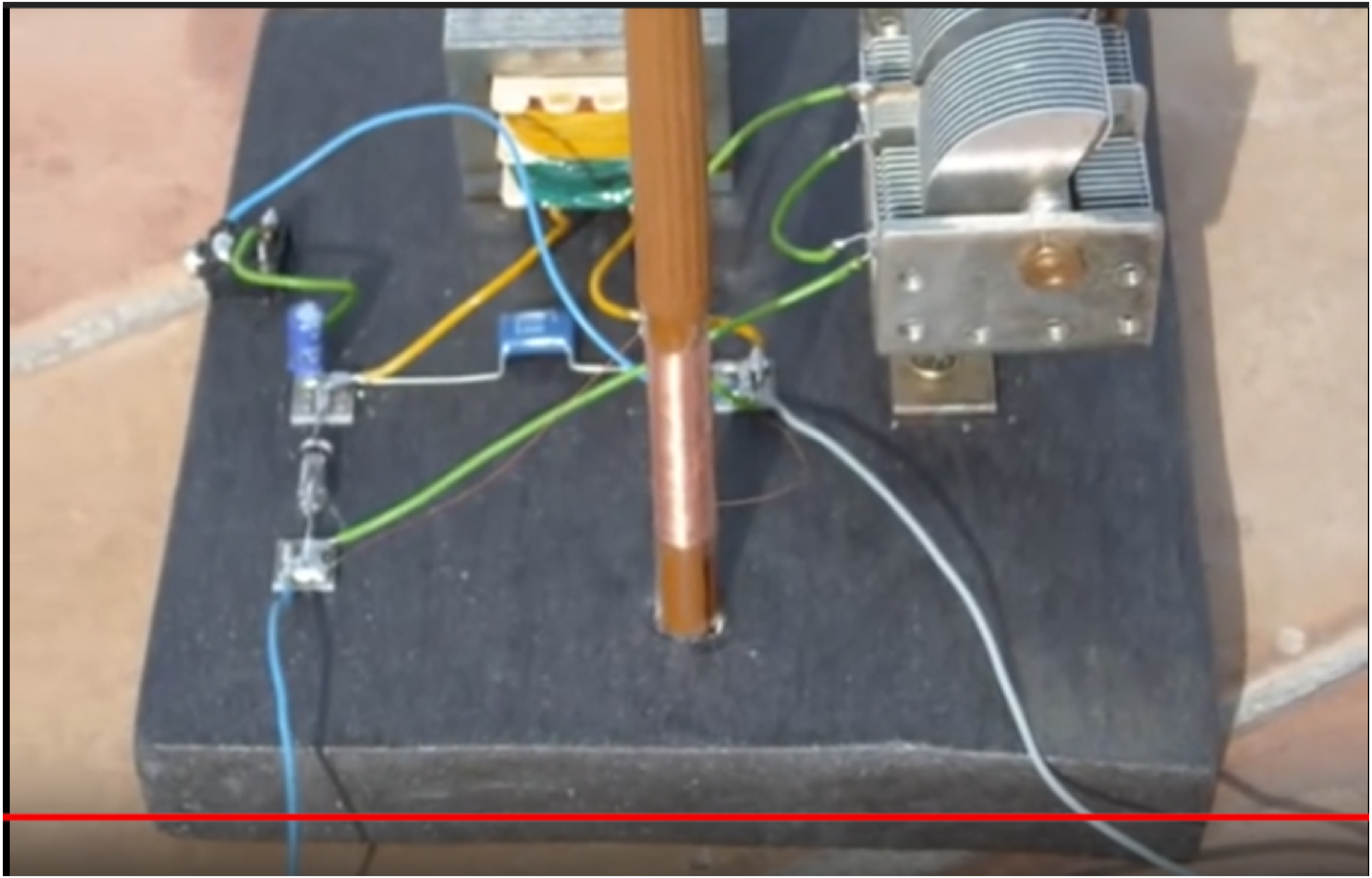

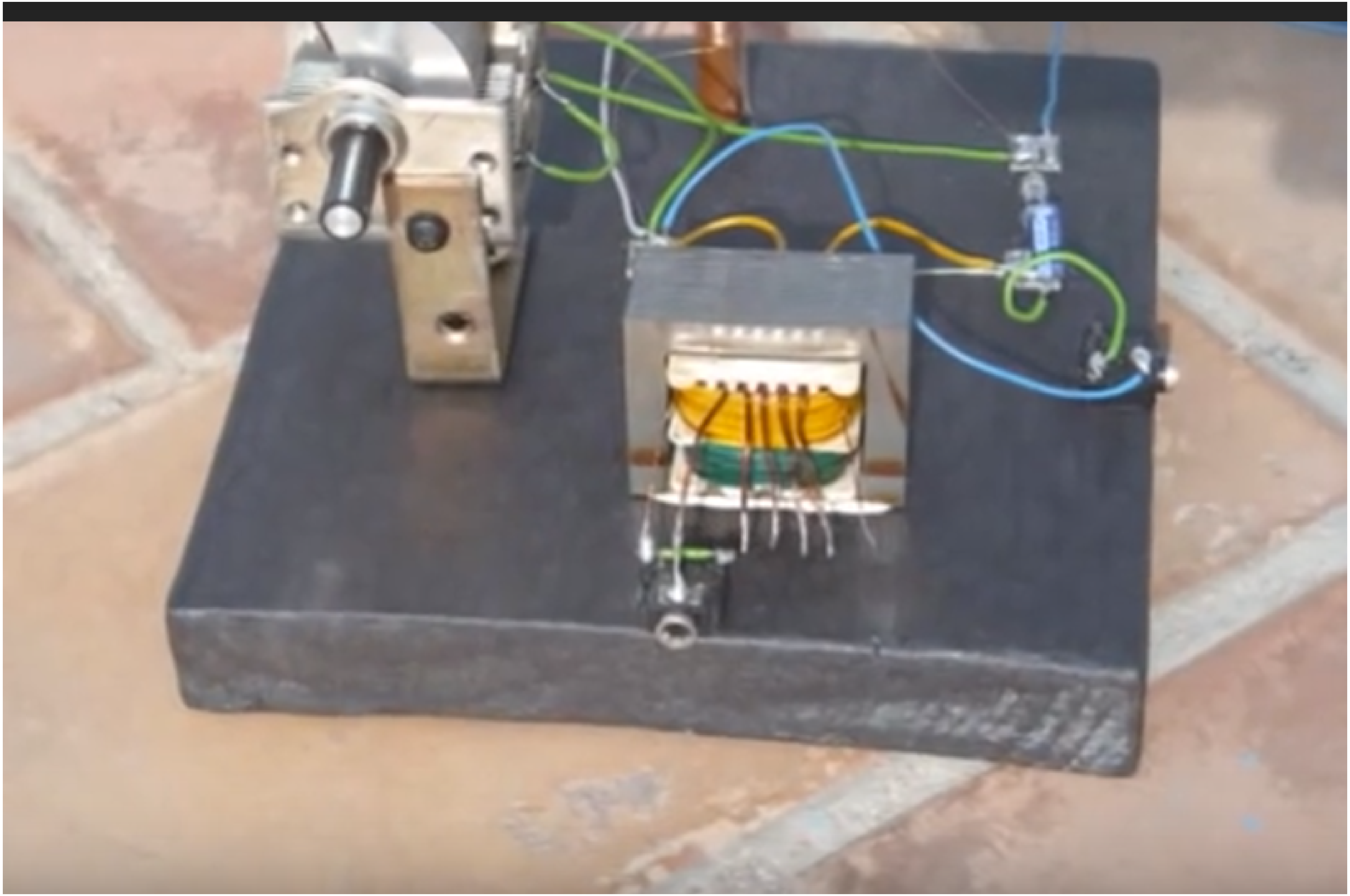

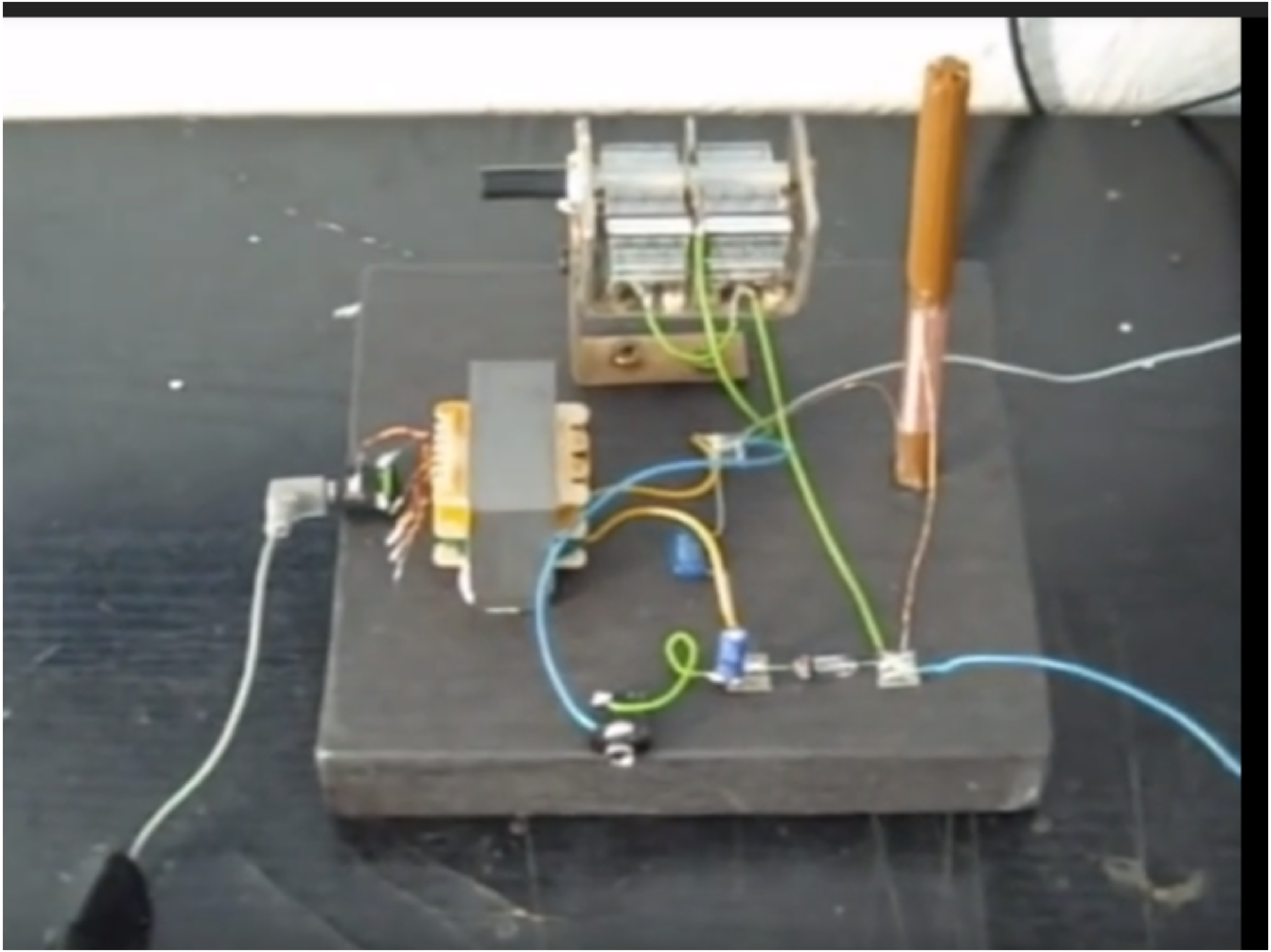

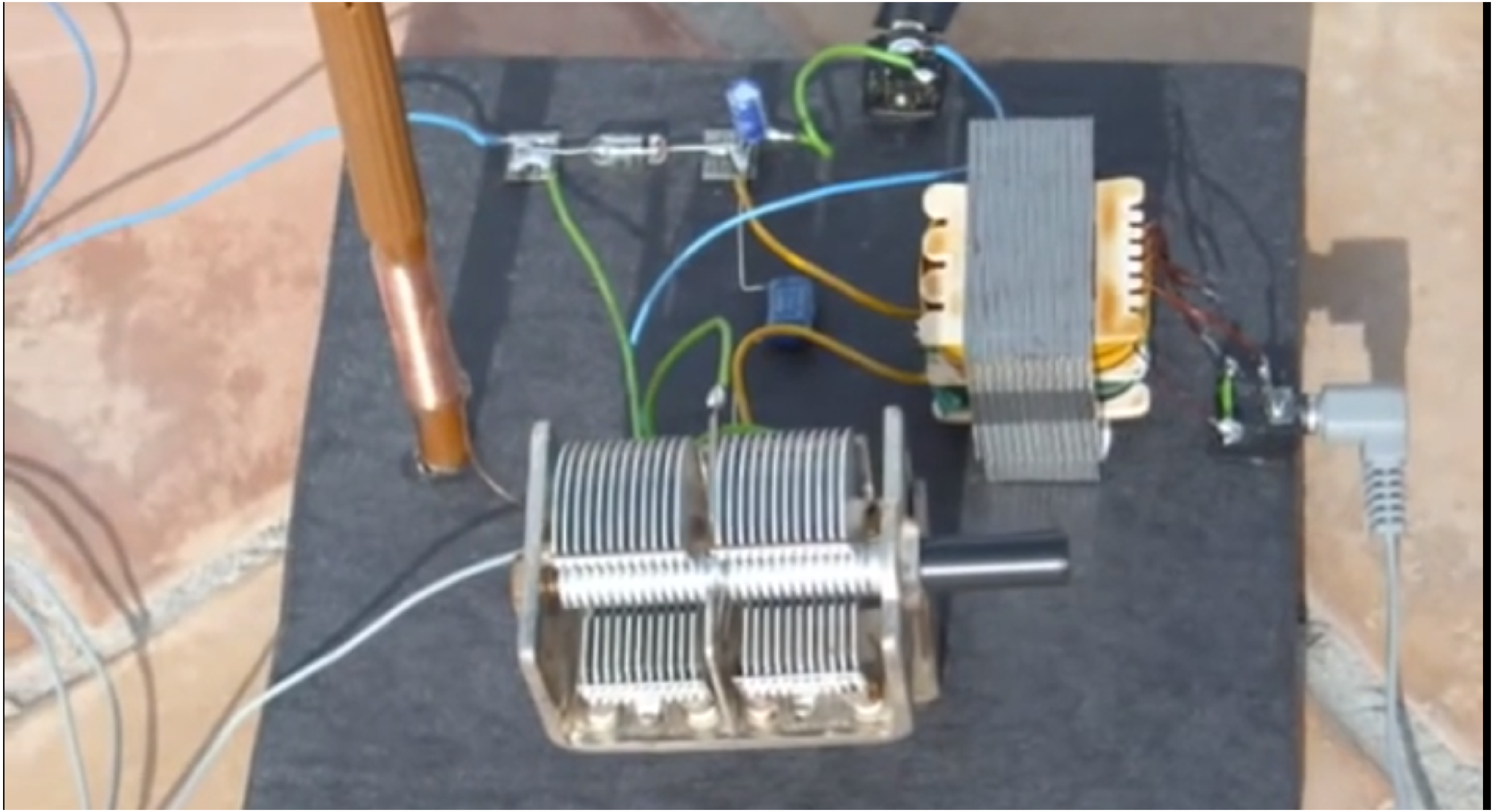

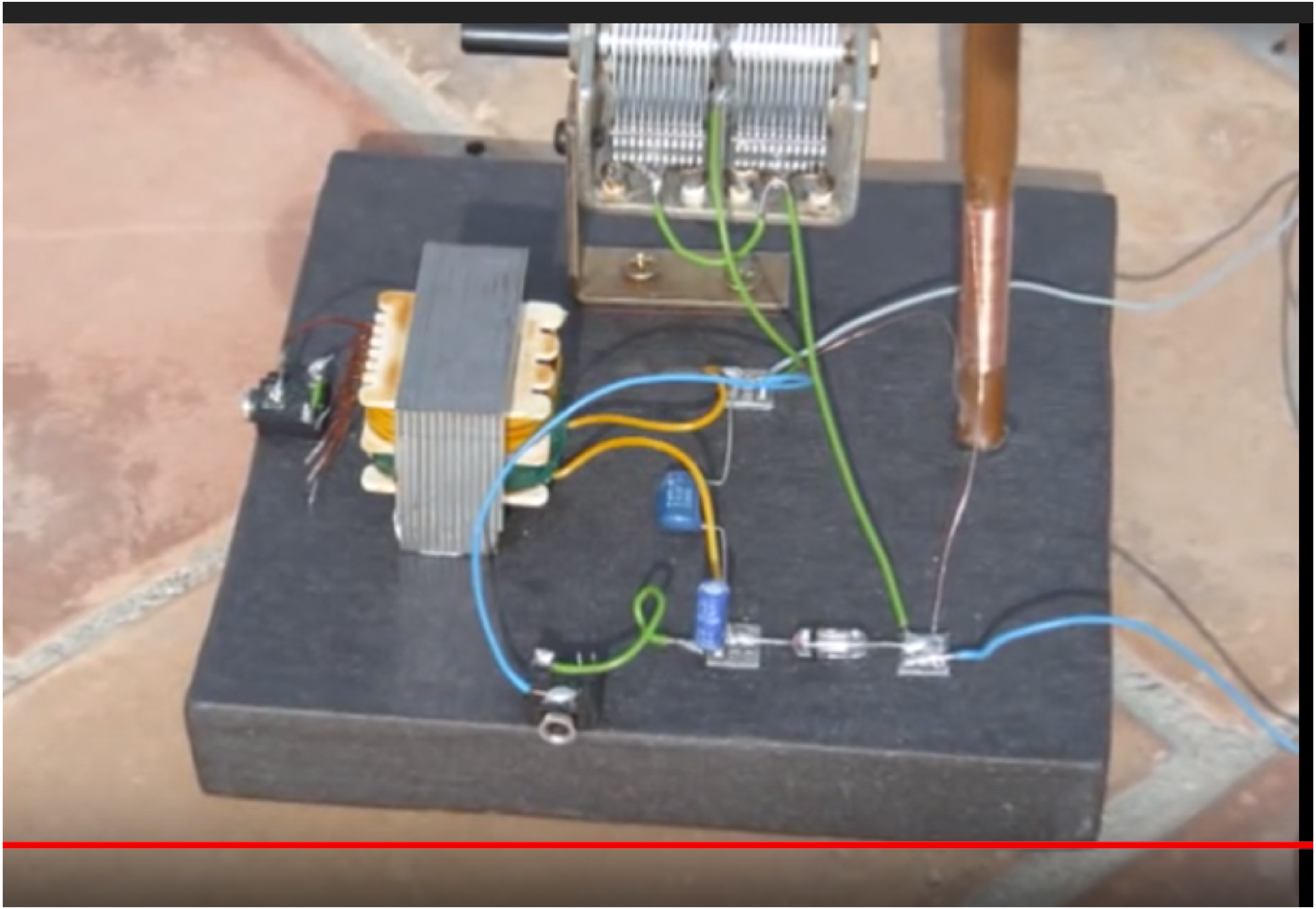

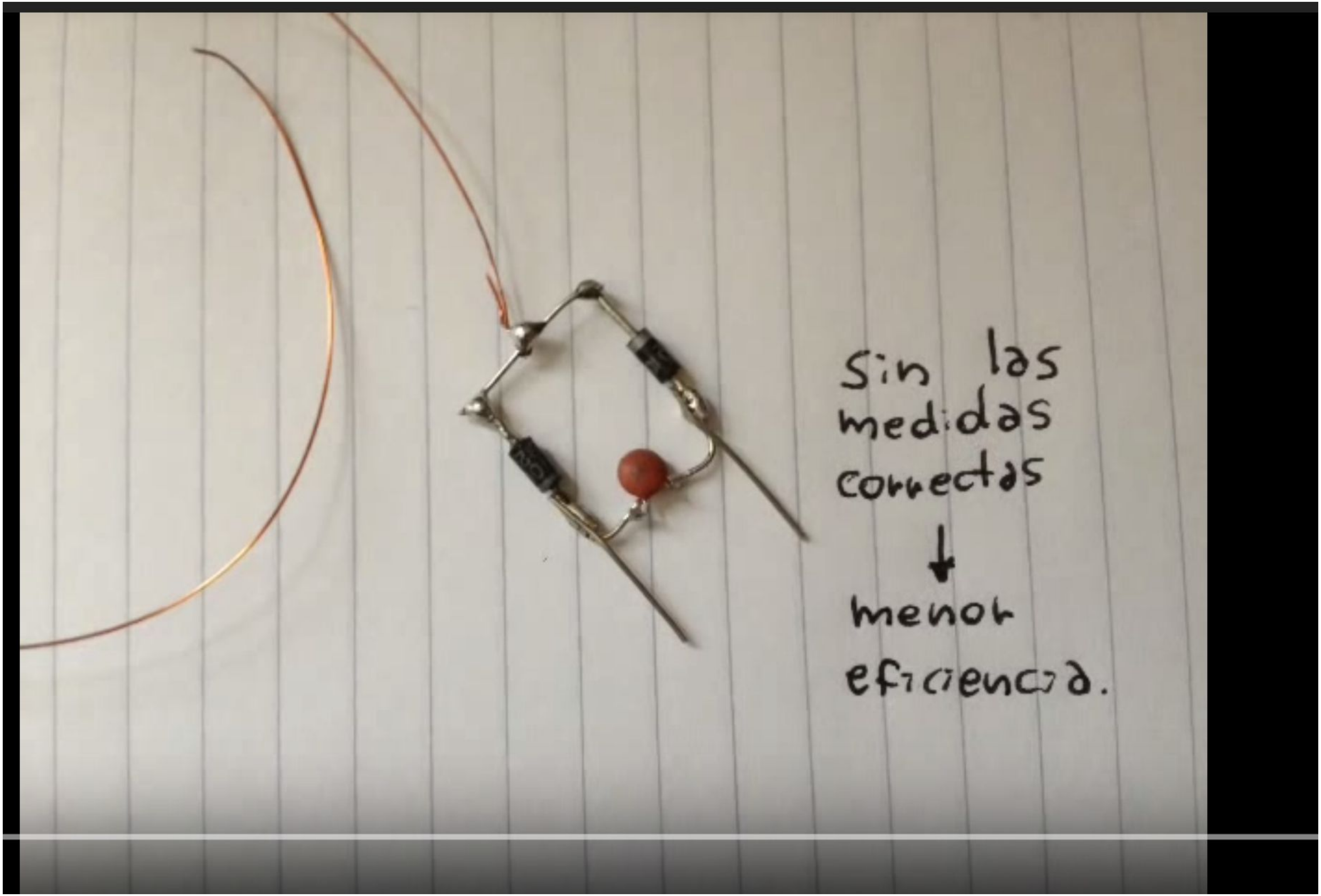

Sin las
medidas
correctas
↓
menor
eficiencia.

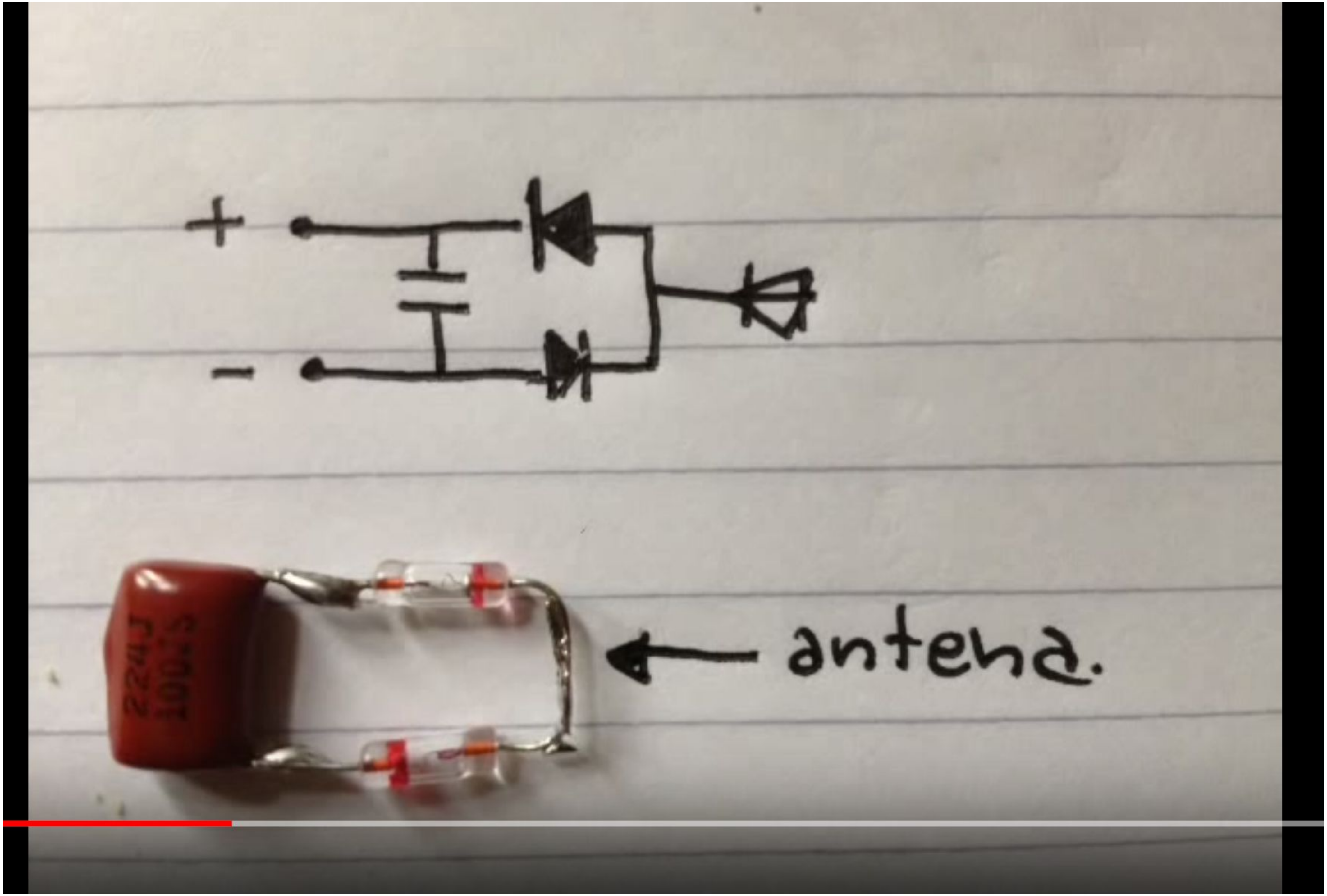
+
-
224J
100.5
antena.

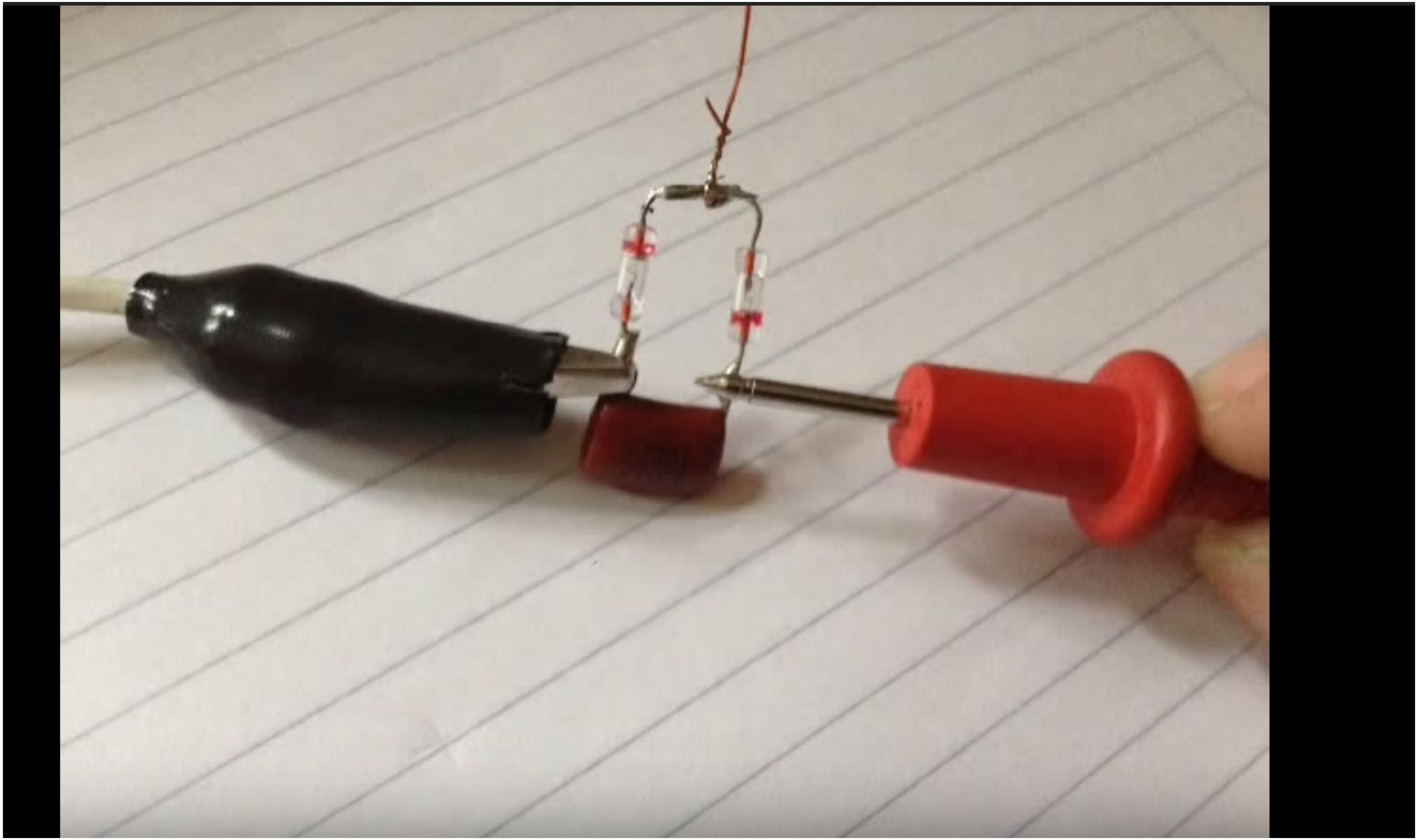

Ricevitore a cristallo per FM

Un progetto di Giacomo Cavuoti

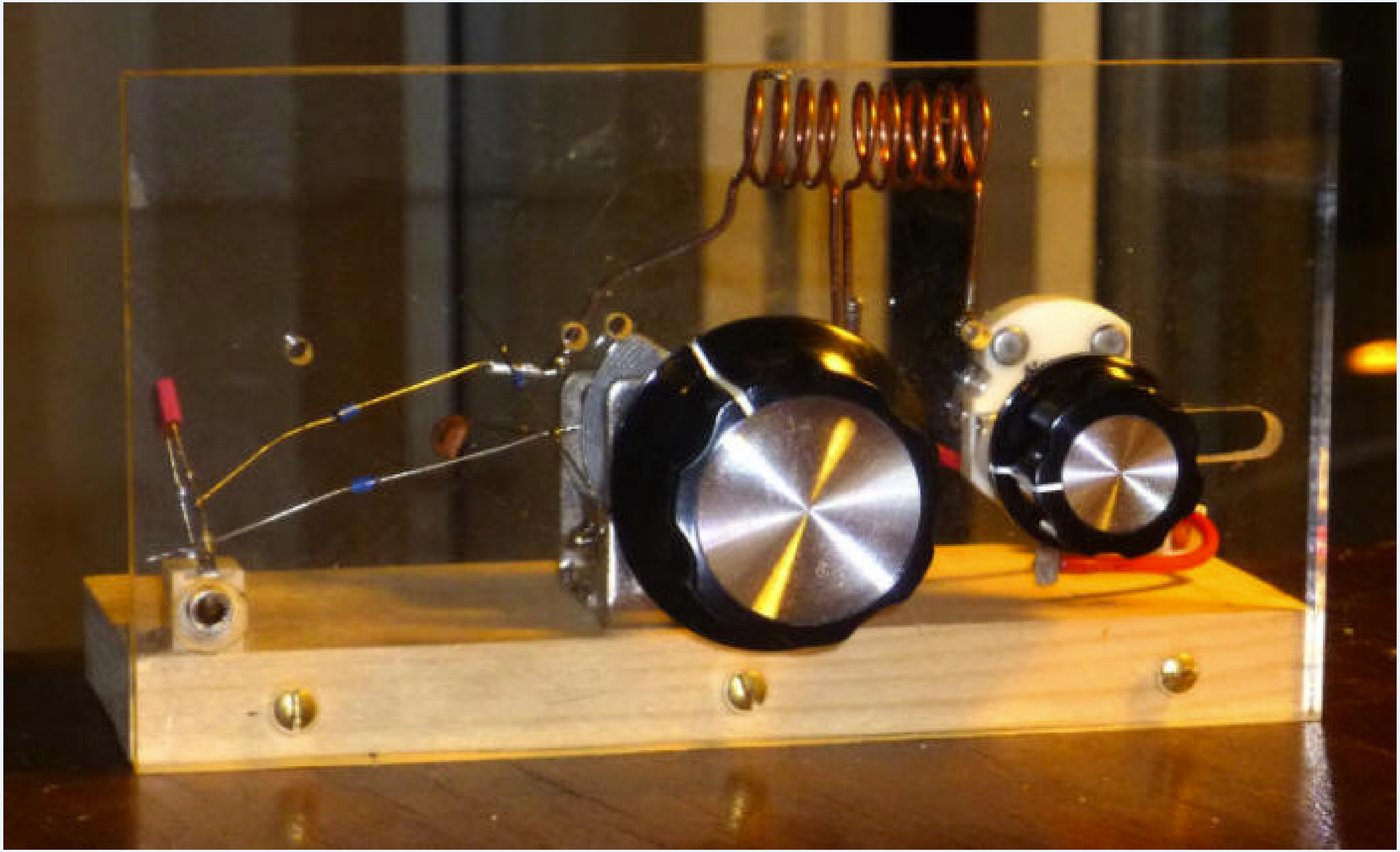

Seguendo l'invito di Leonardo ho realizzato questo semplice ricevitore a cristallo per FM (fare clic sullo schema qua sotto per vederlo ingrandito).

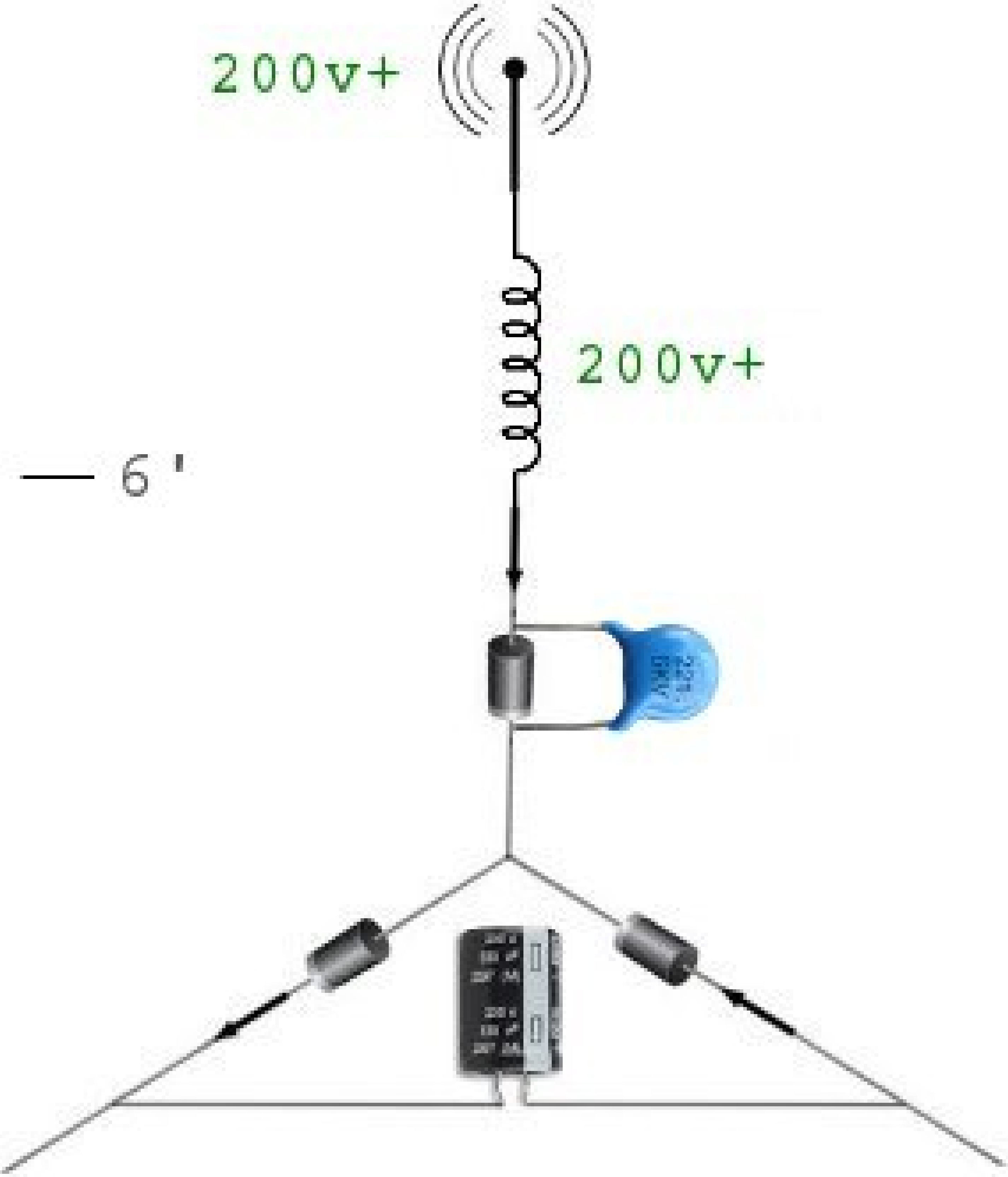
200v+
200v+
— 6 '

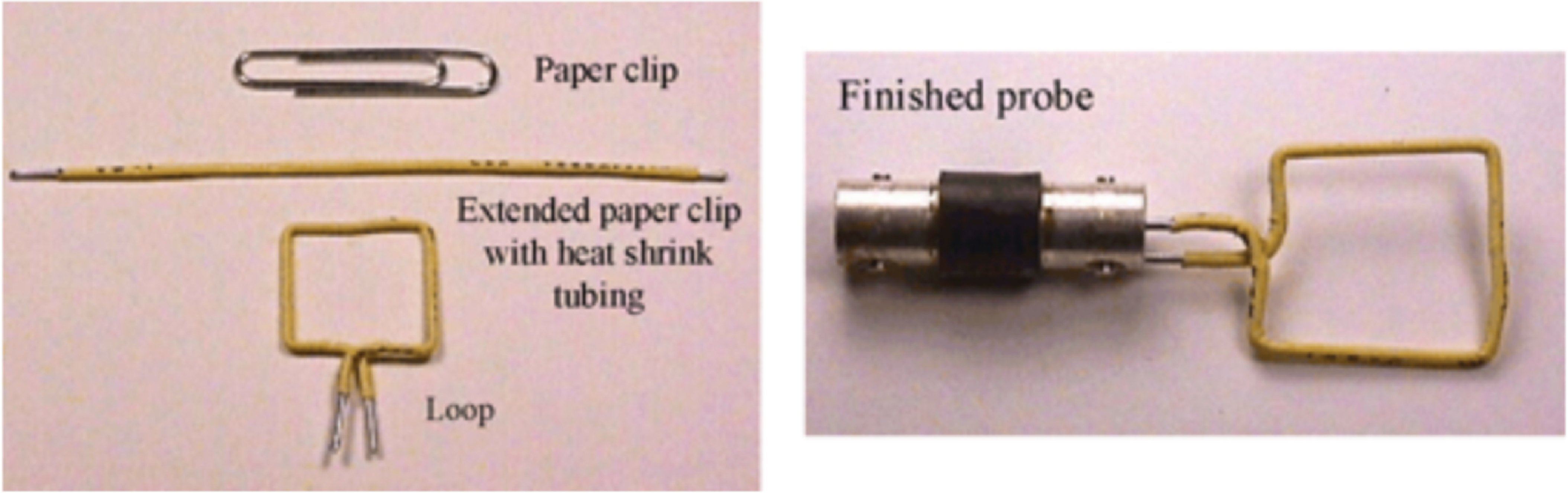
Paper clip
Extended paper clip with heat shrink tubing
Loop
Finished probe

Figure 1: Magnetic field probe build from a paper clip.

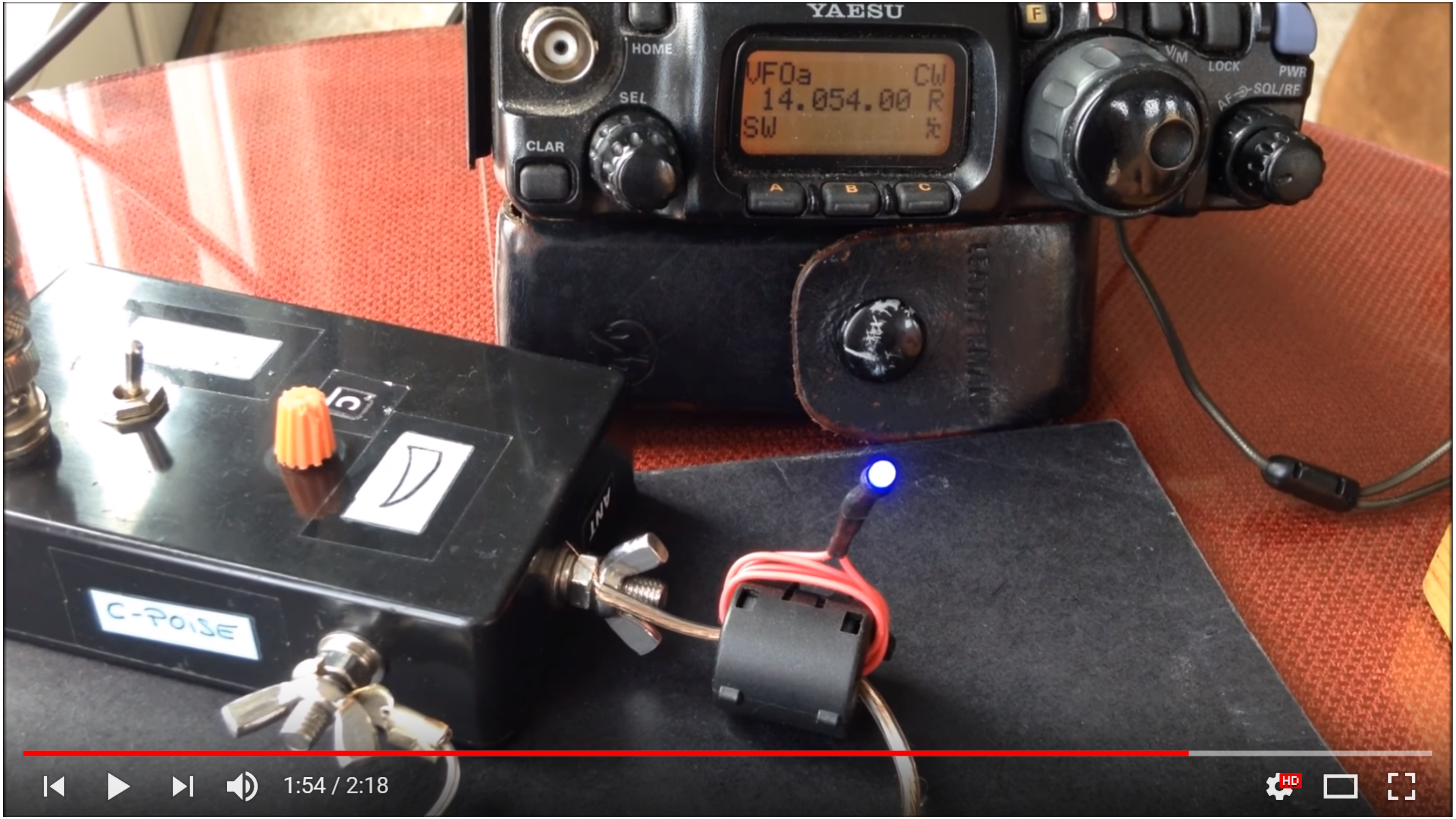
YAESU
HOME
SEL
CLAR
VFOa CW
14.054.00 R
SW
A
B
C
F
V/M
LOCK
PWR
AF SQL/RF
ANT
C-POISE
1:54 / 2:18
HD

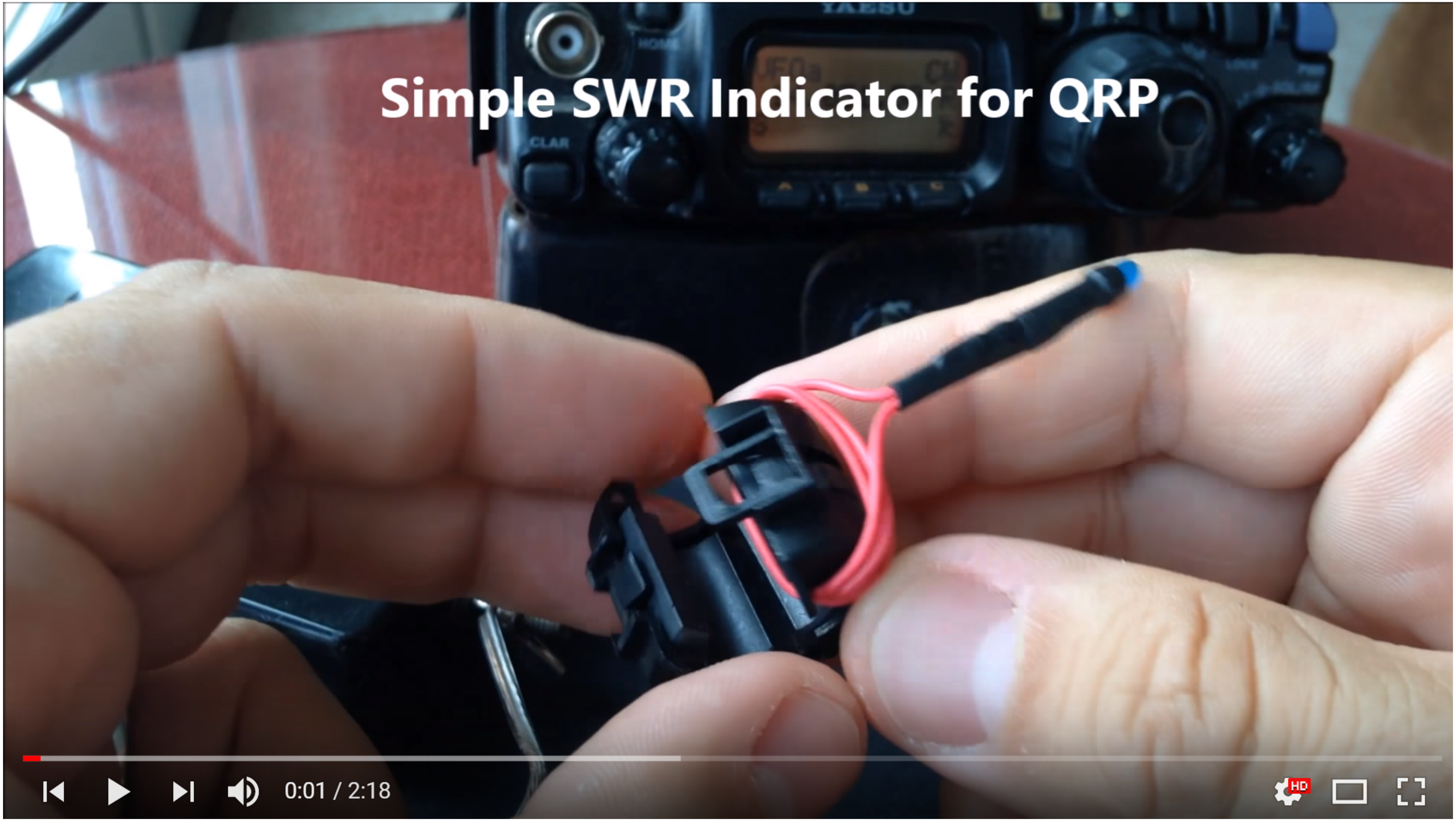

Simple SWR Indicator for QRP

YAESU
HOME
CLAR
0:01 / 2:18
HD

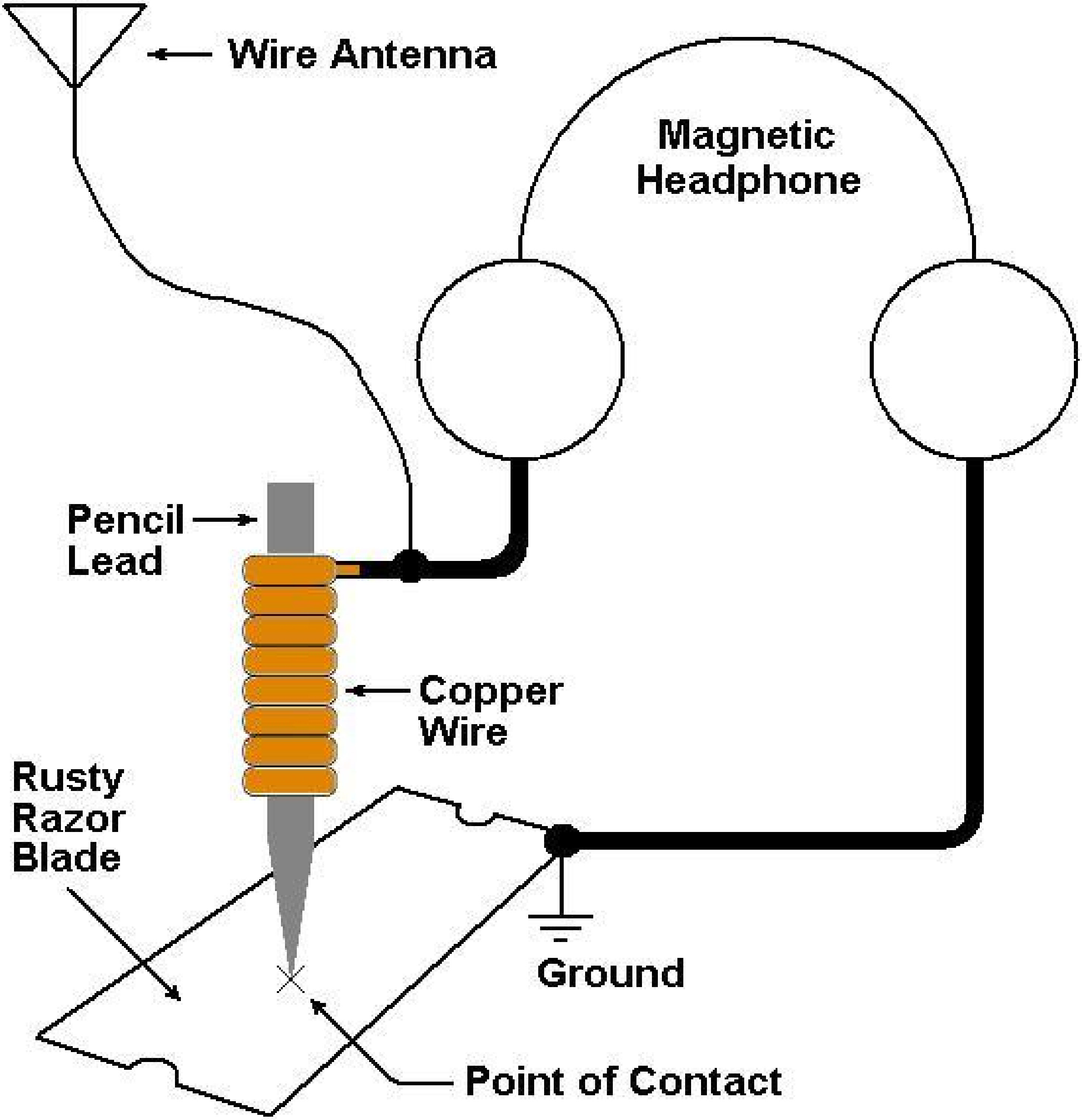
Wire Antenna
Magnetic Headphone
Pencil Lead
Copper Wire
Rusty Razor Blade
Ground
Point of Contact

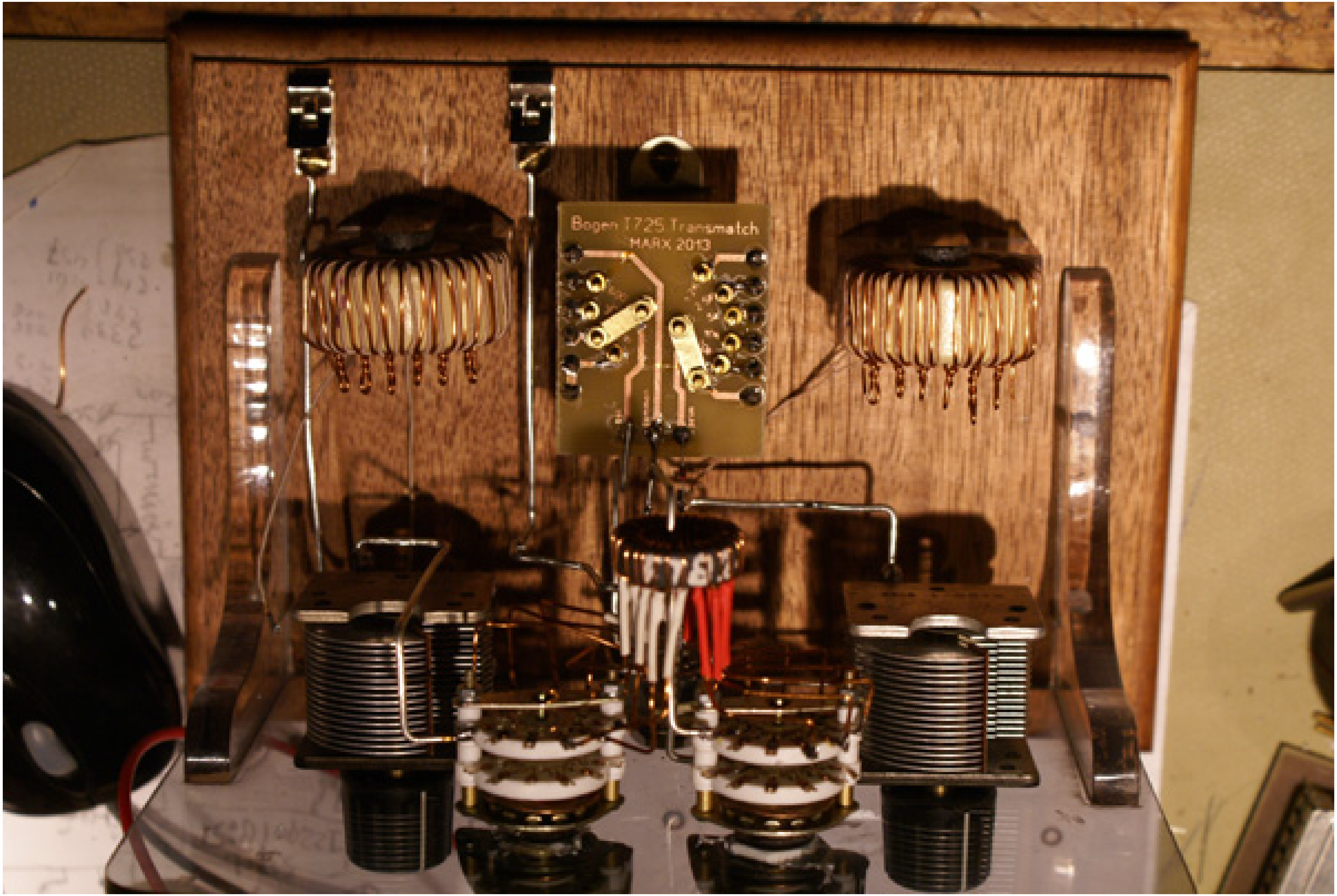
Bogen T725 Transmatch
MARX 2010

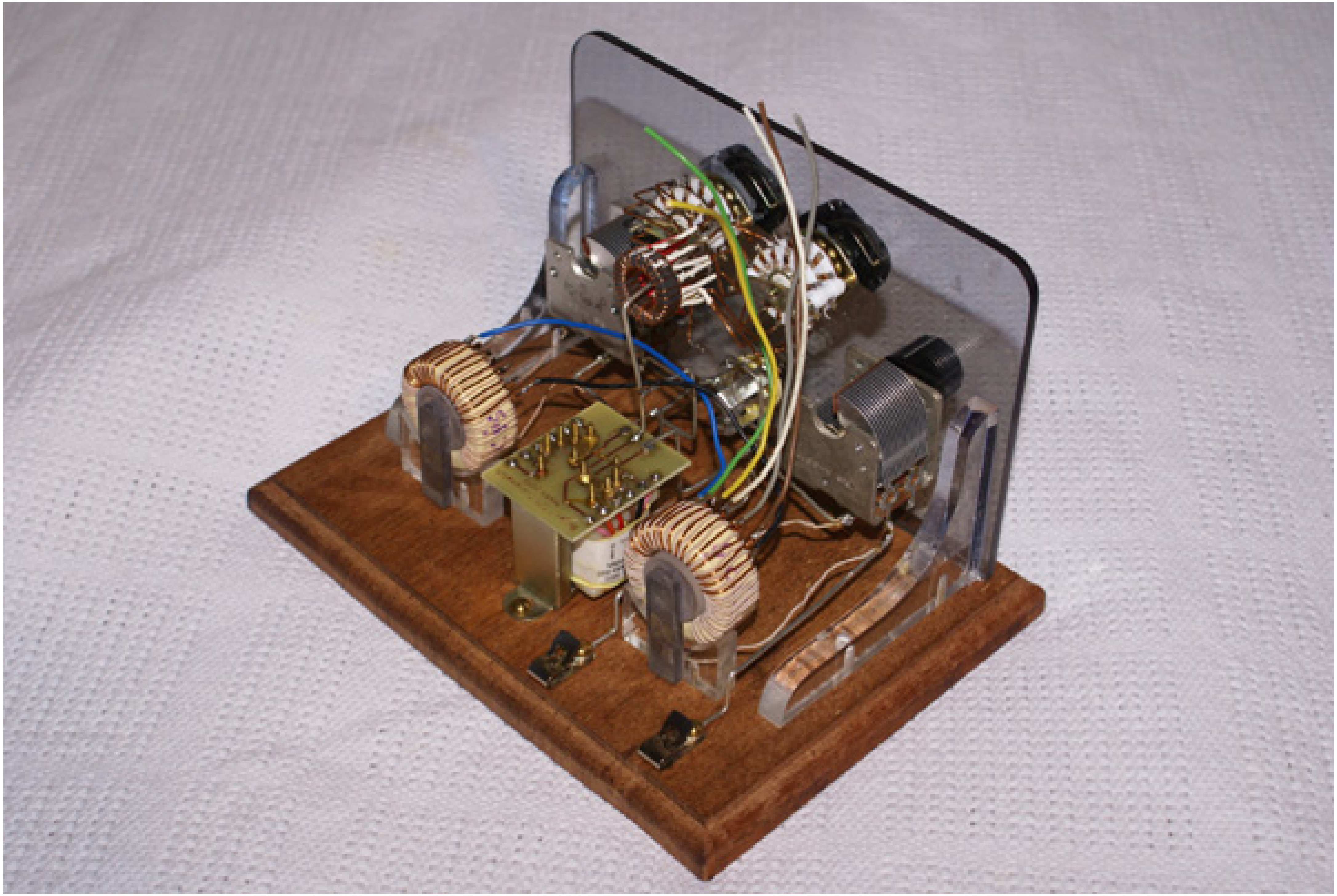

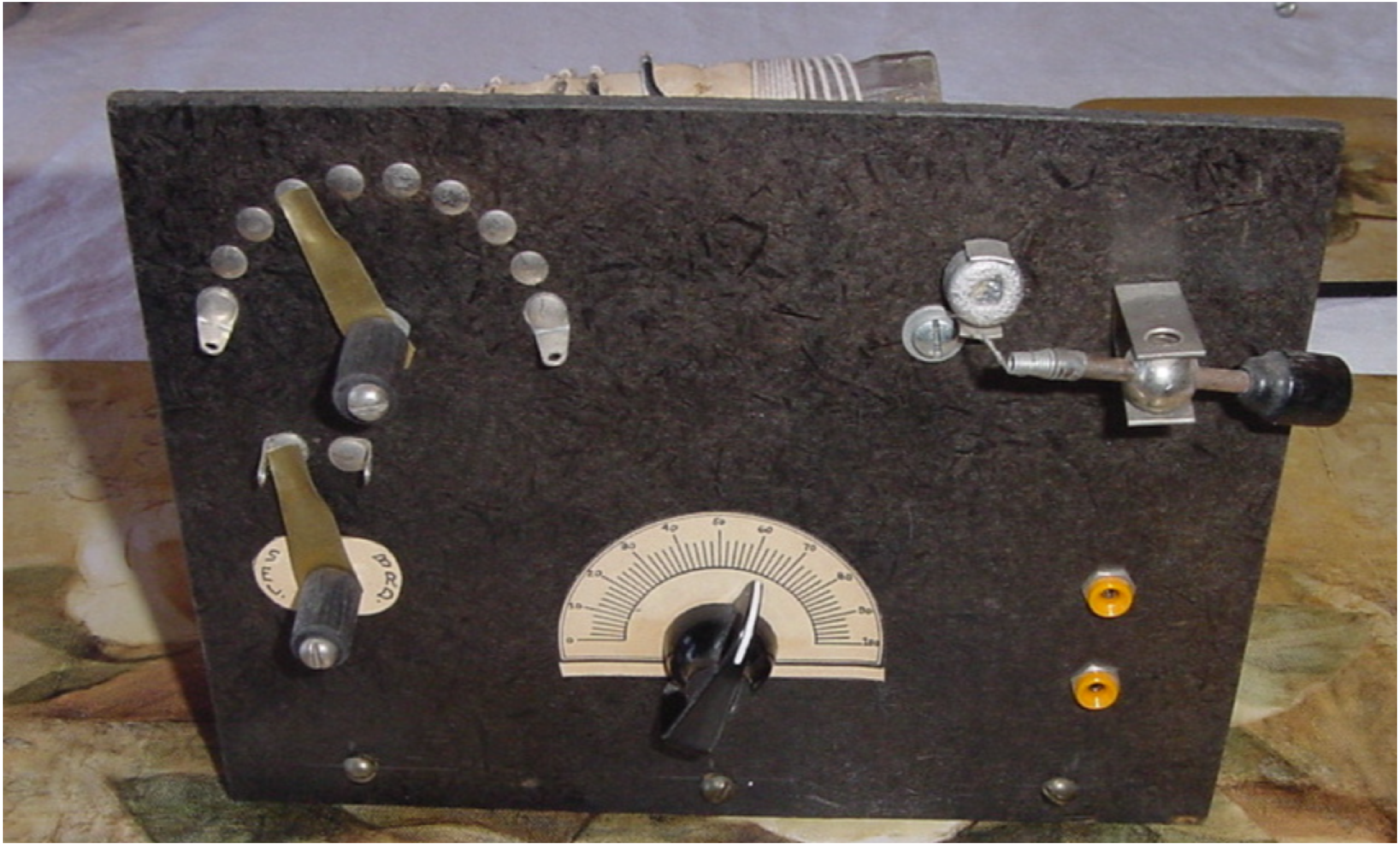
SEL.
BRD.
0
10
20
30
40
50
60
70
80
90
100

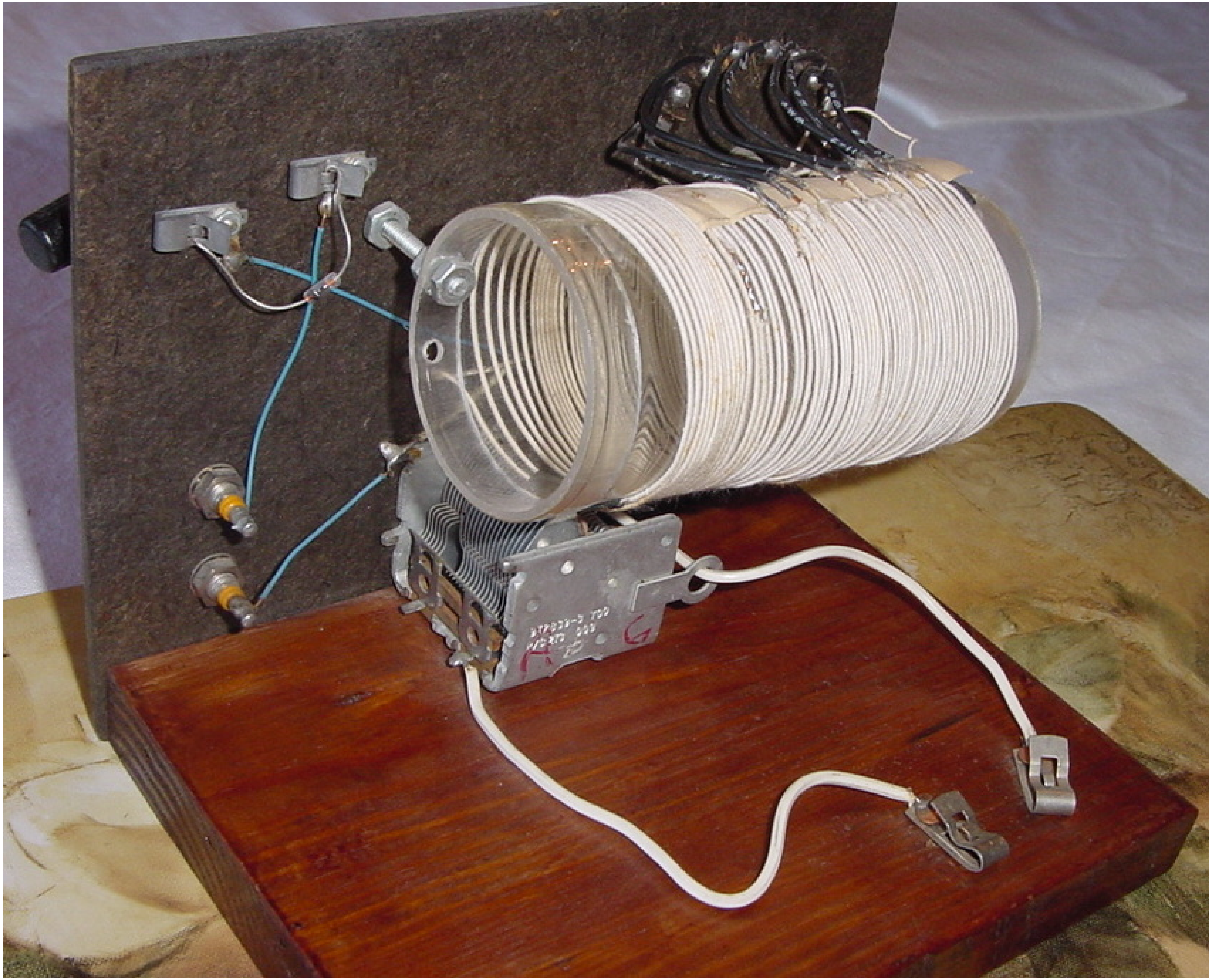
A
G

Another Prototype similar to the Heathkit using toroid coil

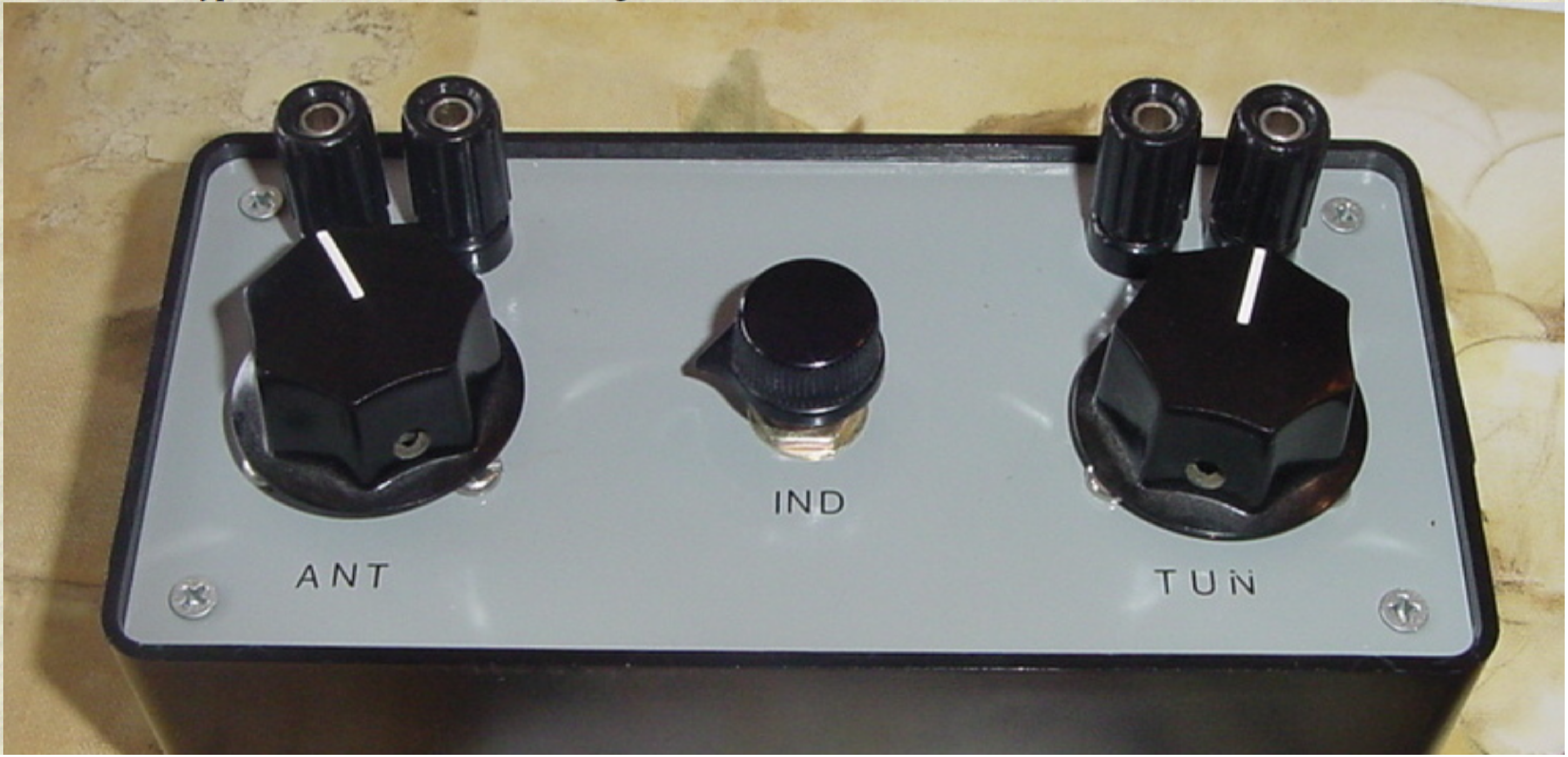

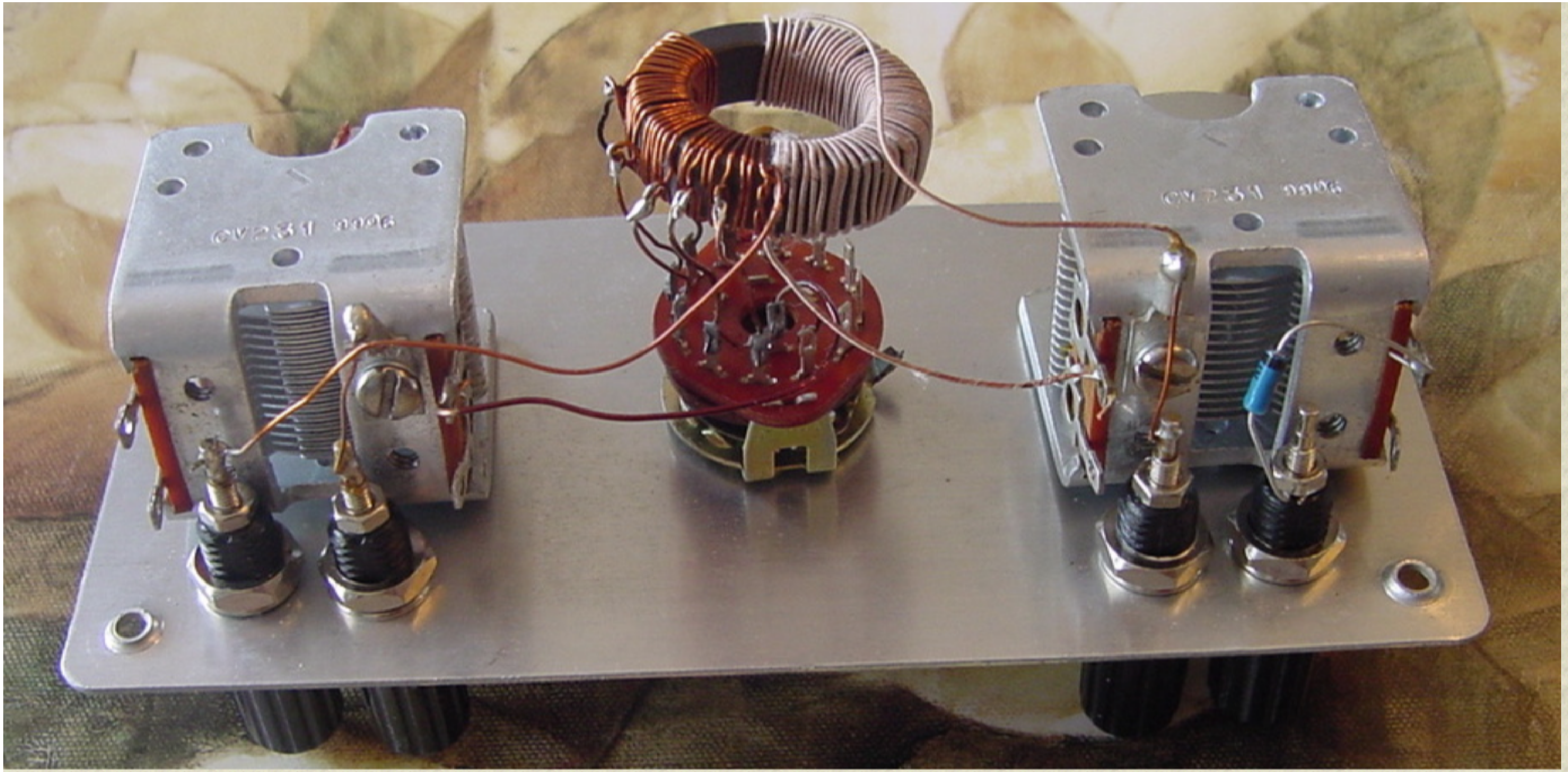
CV231 2006
CV231 2006

This is a dual tuned crystal set made in a box like the CR-1, just a fun prototype I made a few years back. It pulls in AM stations loud and clear.

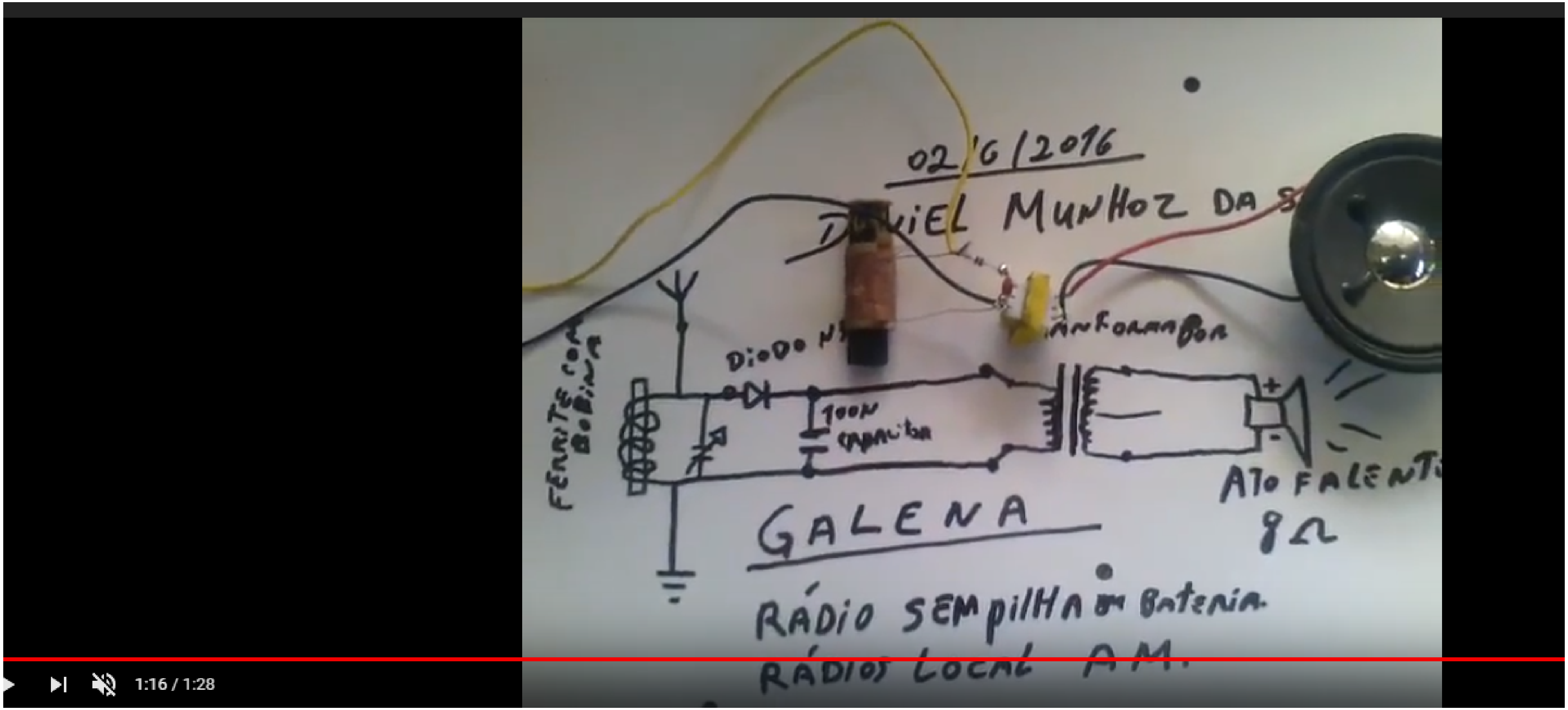
02/6/2016
D[illegible]IEL MUNHOZ DA S
DIODO N
[illegible]ANFORMADOR
FERRITE COM BOBINA
100N capacitor
ATO FALENT
8Ω
GALENA
RÁDIO SEM pilHA ou BATERIA.
RÁDIOS LOCAL AM.
1:16 / 1:28

GALENA , Rádio AM ,sem pilha.

Up next

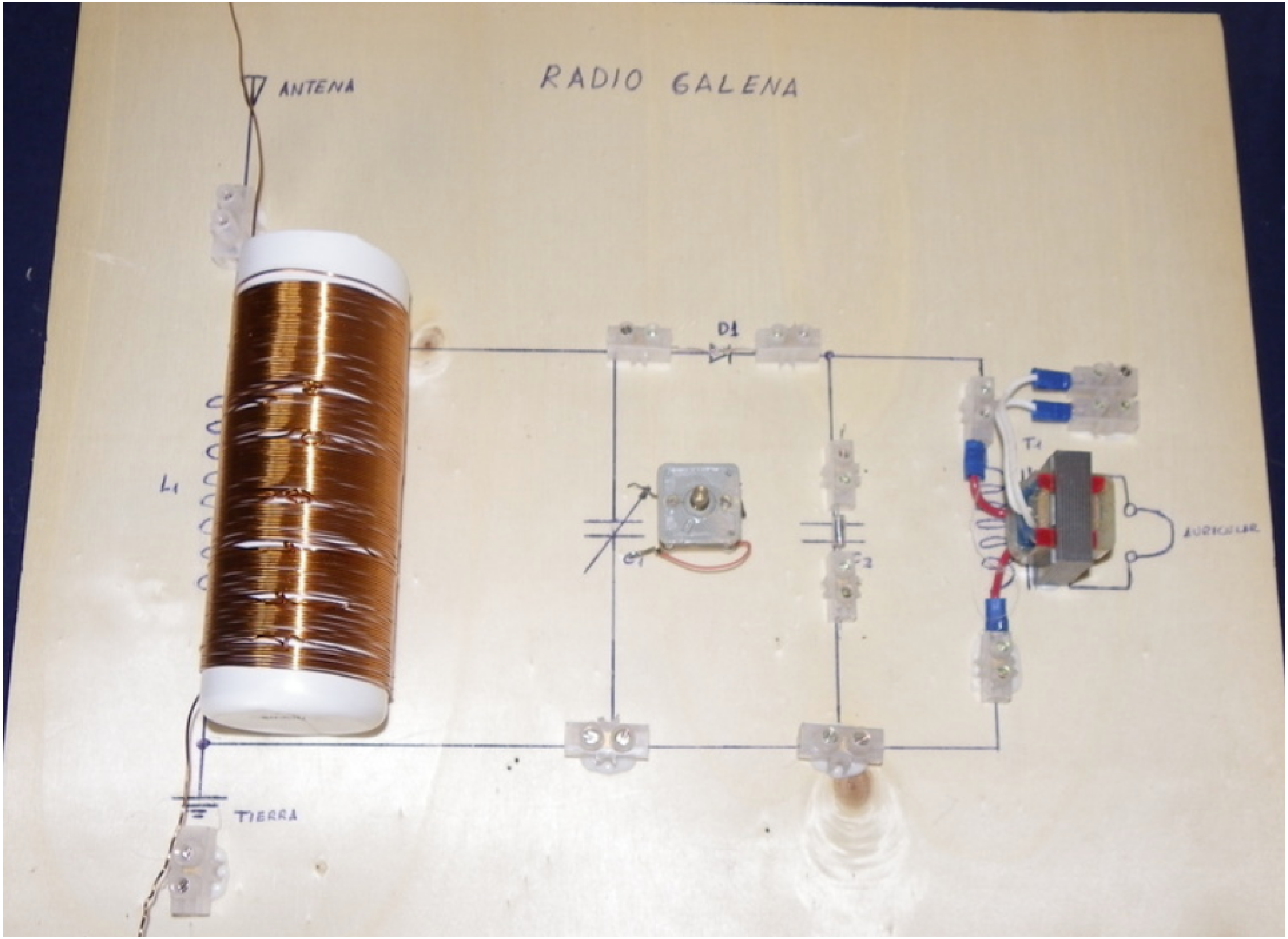
RADIO GALENA
ANTENA
L1
D1
C1
C2
T1
AURICULAR
TIERRA

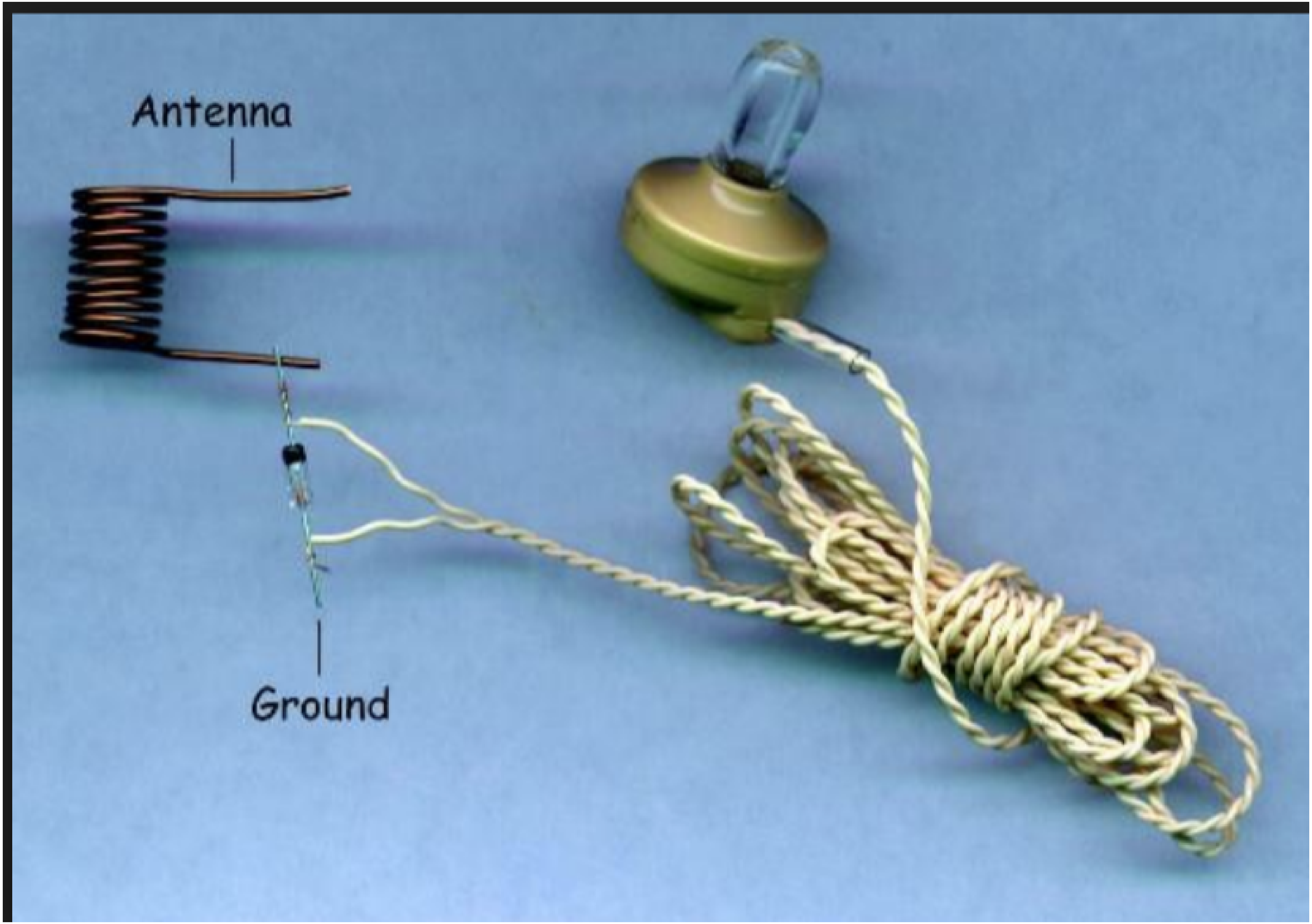
Antenna
Ground

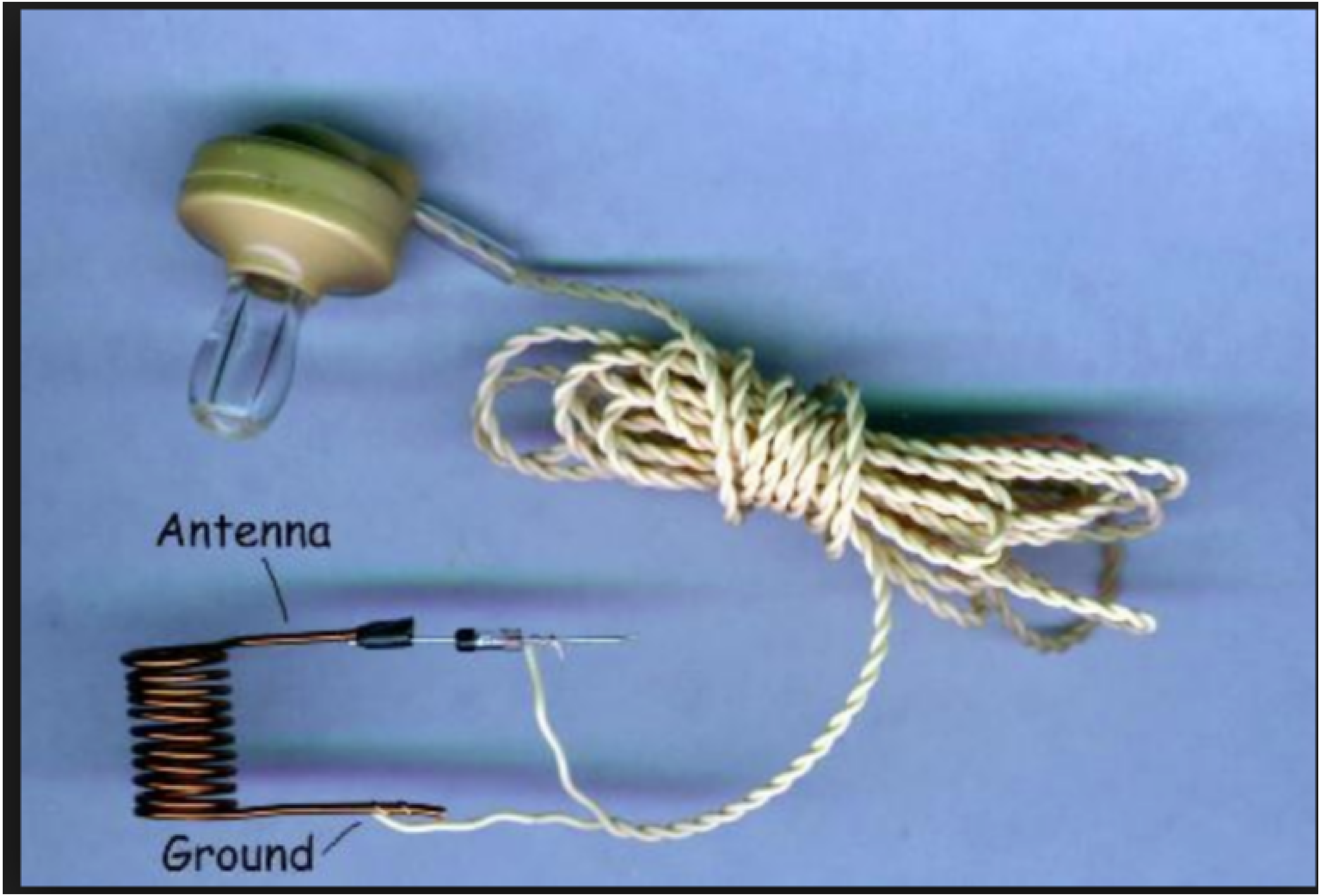
Antenna
Ground

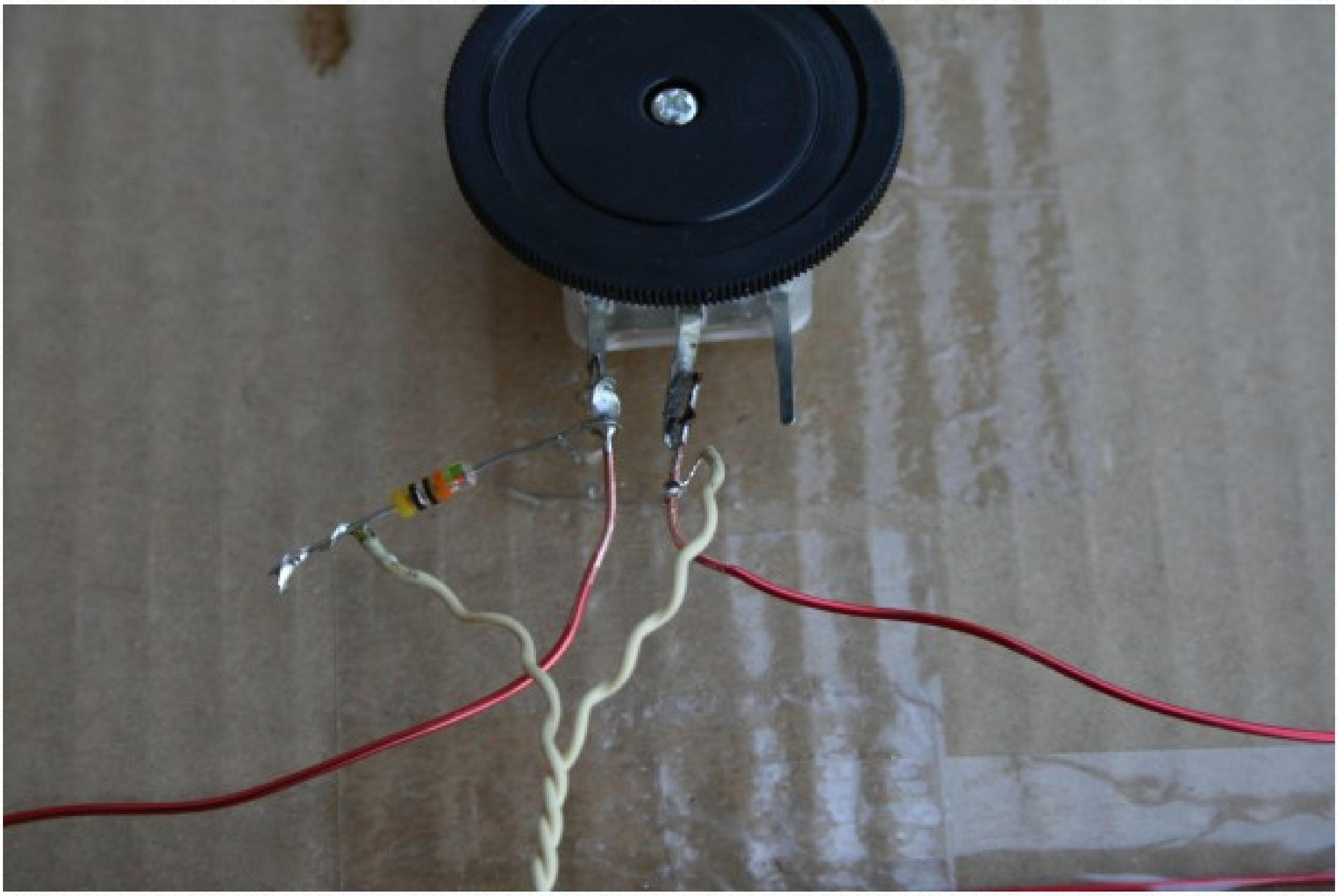

Click on photo for a larger picture

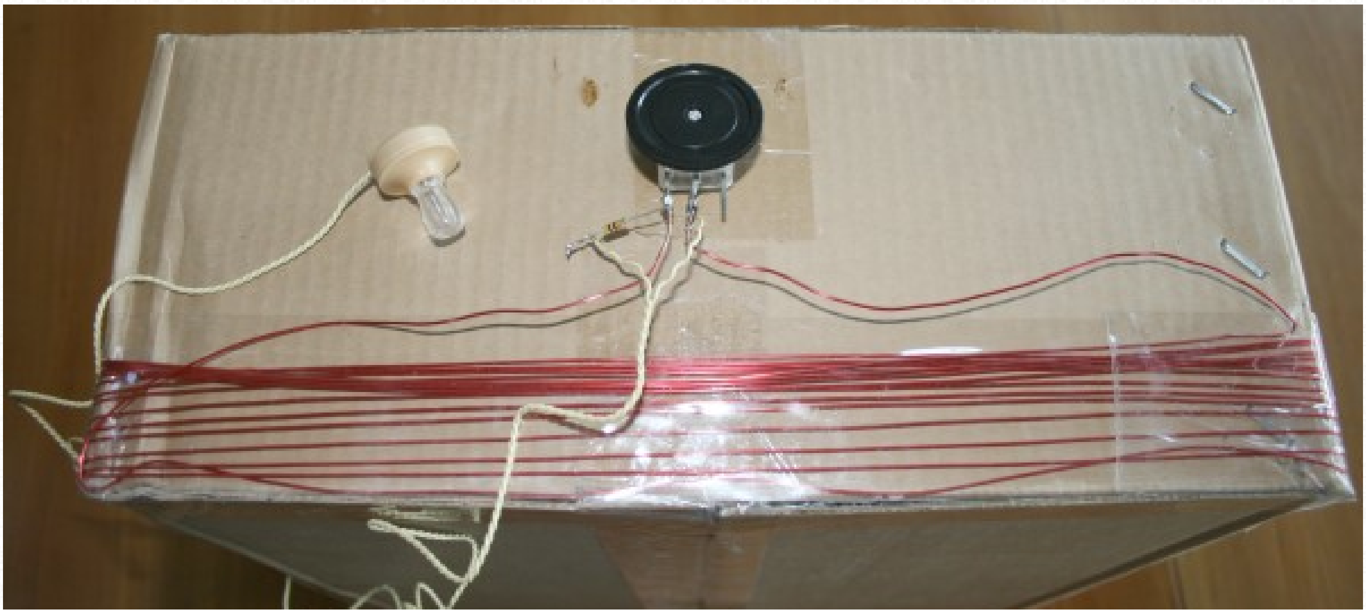

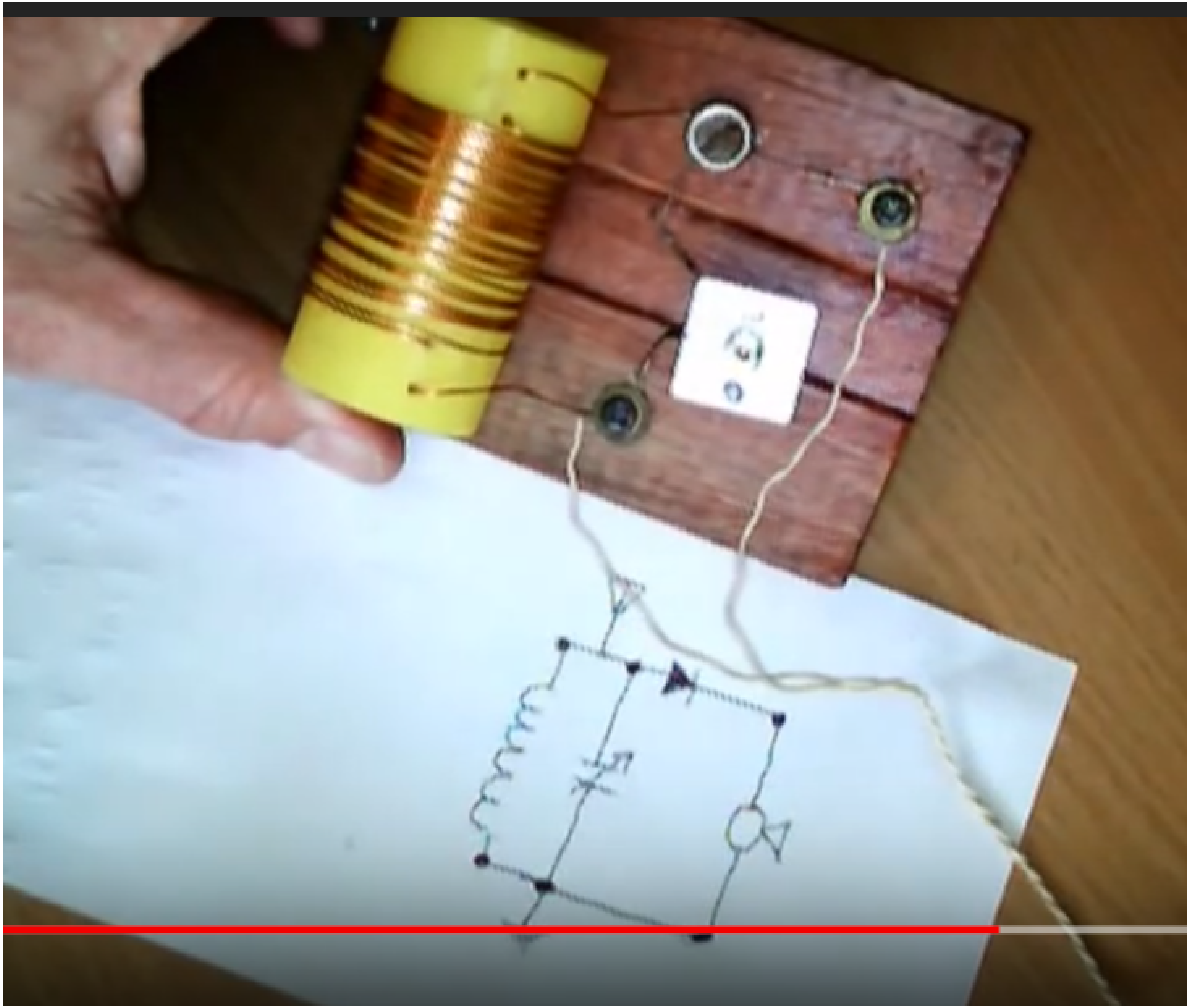

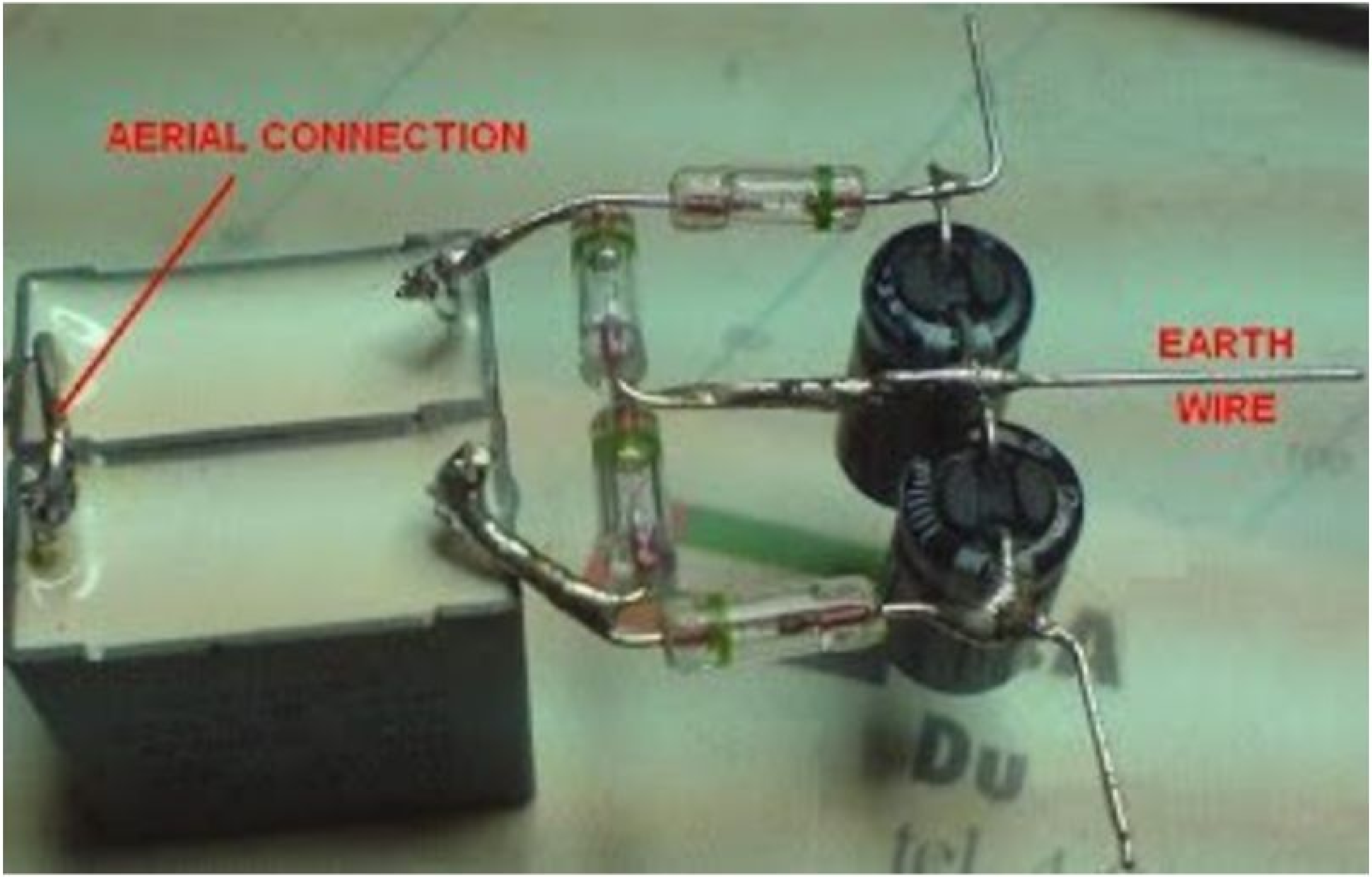
AERIAL CONNECTION
EARTH WIRE

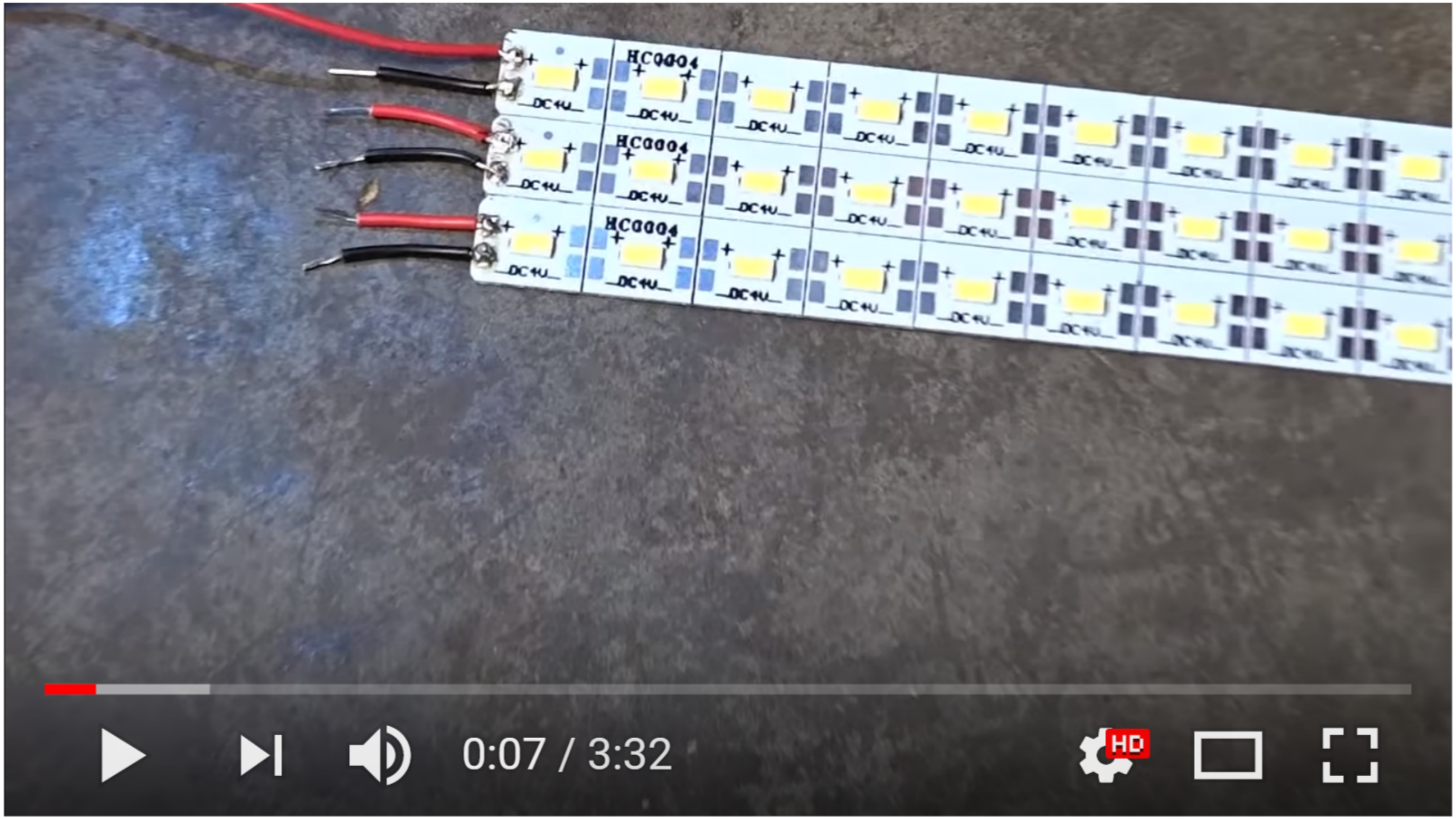
HC0004
DC4V
0:07 / 3:32
HD

New idea - You can make Solar Cell from LED (Free Energy)

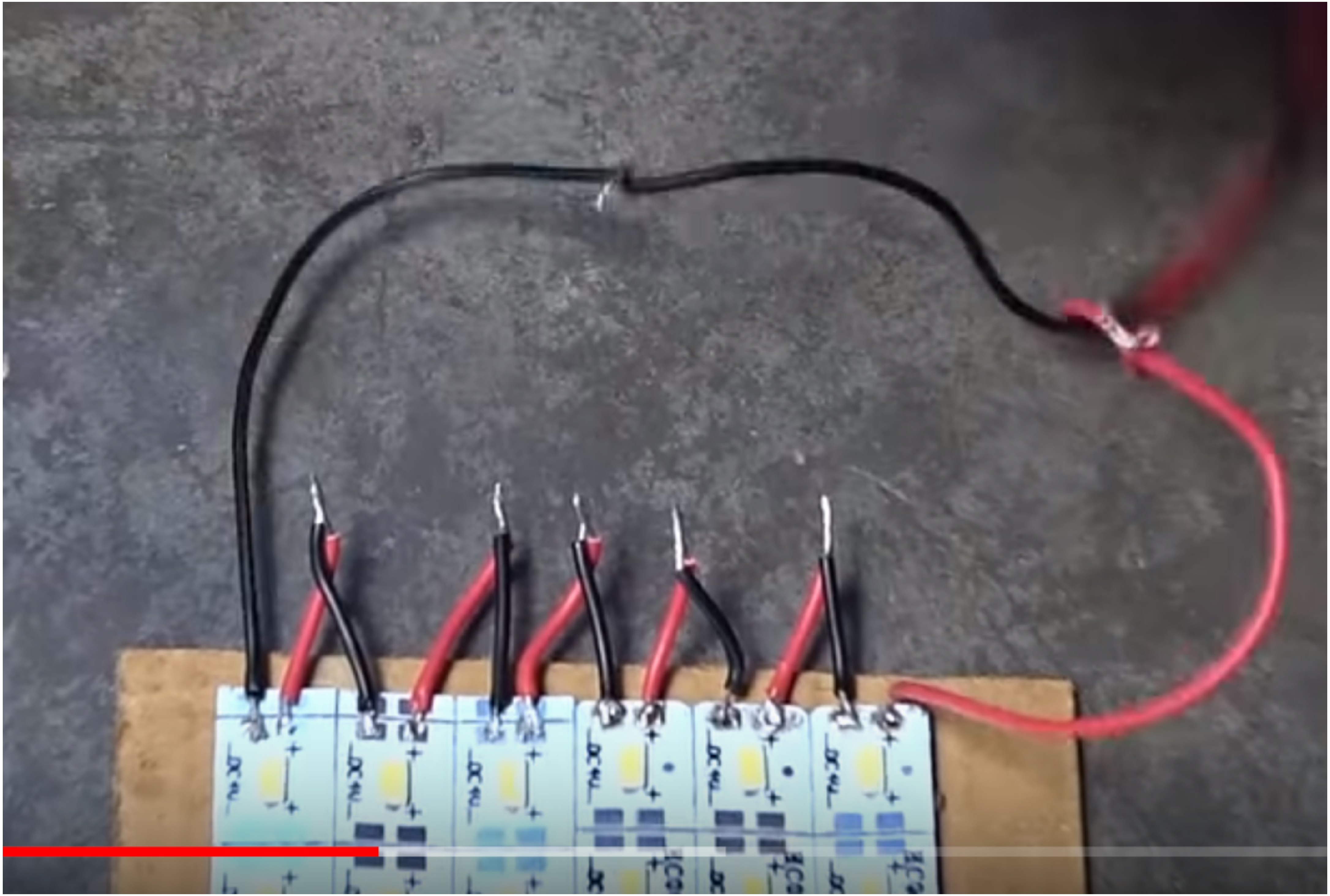

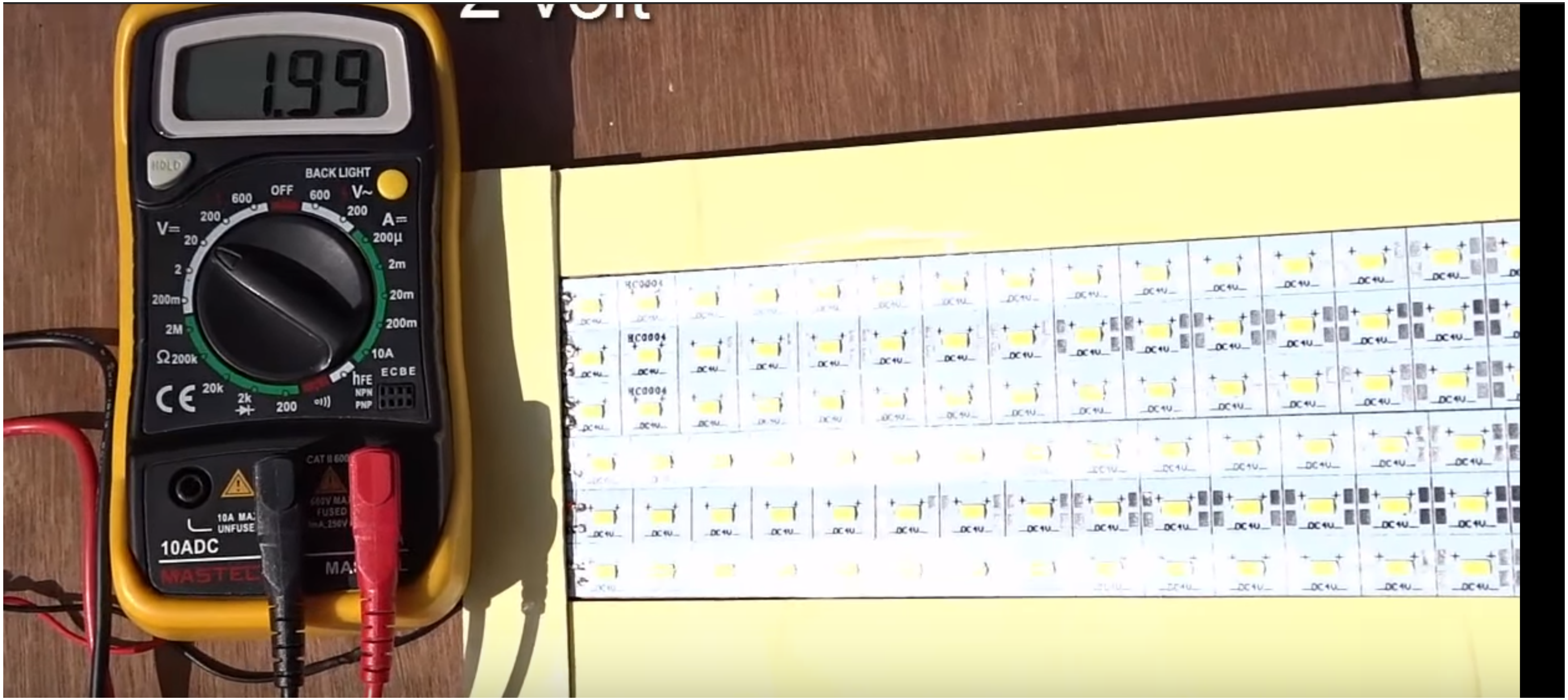
1.99
BACK LIGHT
OFF
10ADC
MASTECH

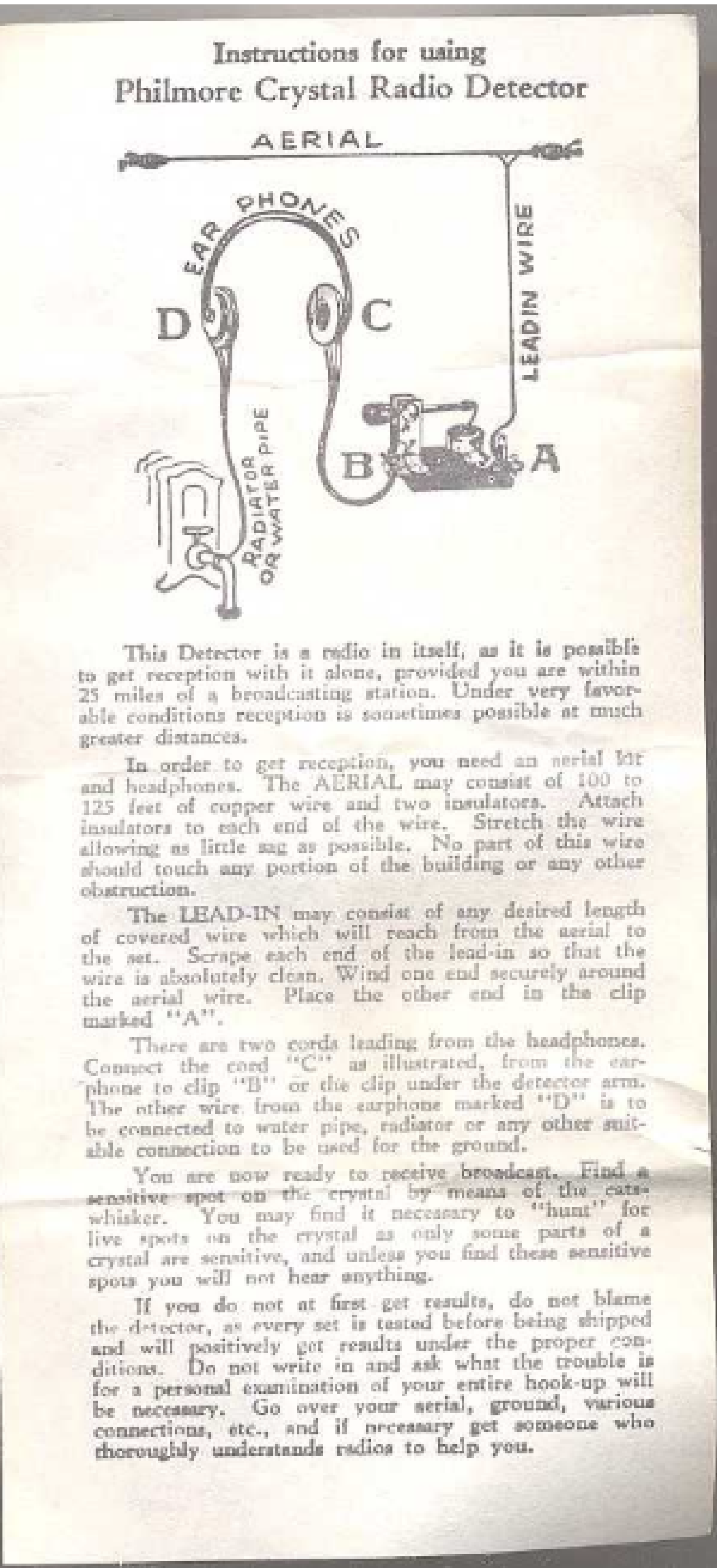

Instructions for using Philmore Crystal Radio Detector

AERIAL
EAR PHONES
LEADIN WIRE
D
C
B
A
RADIATOR OR WATER PIPE

This Detector is a radio in itself, as it is possible to get reception with it alone, provided you are within 25 miles of a broadcasting station. Under very favorable conditions reception is sometimes possible at much greater distances.

In order to get reception, you need an aerial kit and headphones. The AERIAL may consist of 100 to 125 feet of copper wire and two insulators. Attach insulators to each end of the wire. Stretch the wire allowing as little sag as possible. No part of this wire should touch any portion of the building or any other obstruction.

The LEAD-IN may consist of any desired length of covered wire which will reach from the aerial to the set. Scrape each end of the lead-in so that the wire is absolutely clean. Wind one end securely around the aerial wire. Place the other end in the clip marked "A".

There are two cords leading from the headphones. Connect the cord "C" as illustrated, from the earphone to clip "B" or the clip under the detector arm. The other wire from the earphone marked "D" is to be connected to water pipe, radiator or any other suitable connection to be used for the ground.

You are now ready to receive broadcast. Find a sensitive spot on the crystal by means of the cats-whisker. You may find it necessary to "hunt" for live spots on the crystal as only some parts of a crystal are sensitive, and unless you find these sensitive spots you will not hear anything.

If you do not at first get results, do not blame the detector, as every set is tested before being shipped and will positively get results under the proper conditions. Do not write in and ask what the trouble is for a personal examination of your entire hook-up will be necessary. Go over your aerial, ground, various connections, etc., and if necessary get someone who thoroughly understands radios to help you.

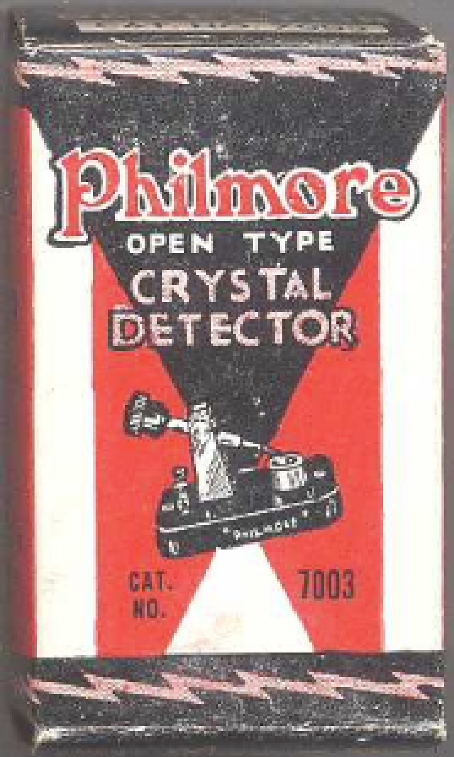

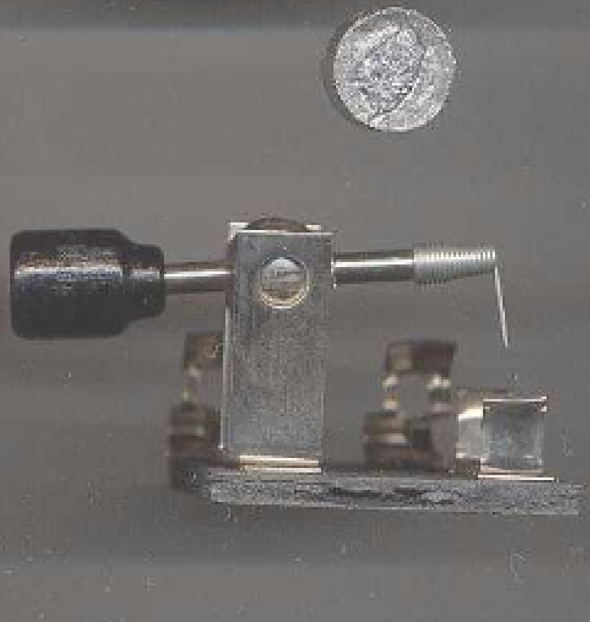

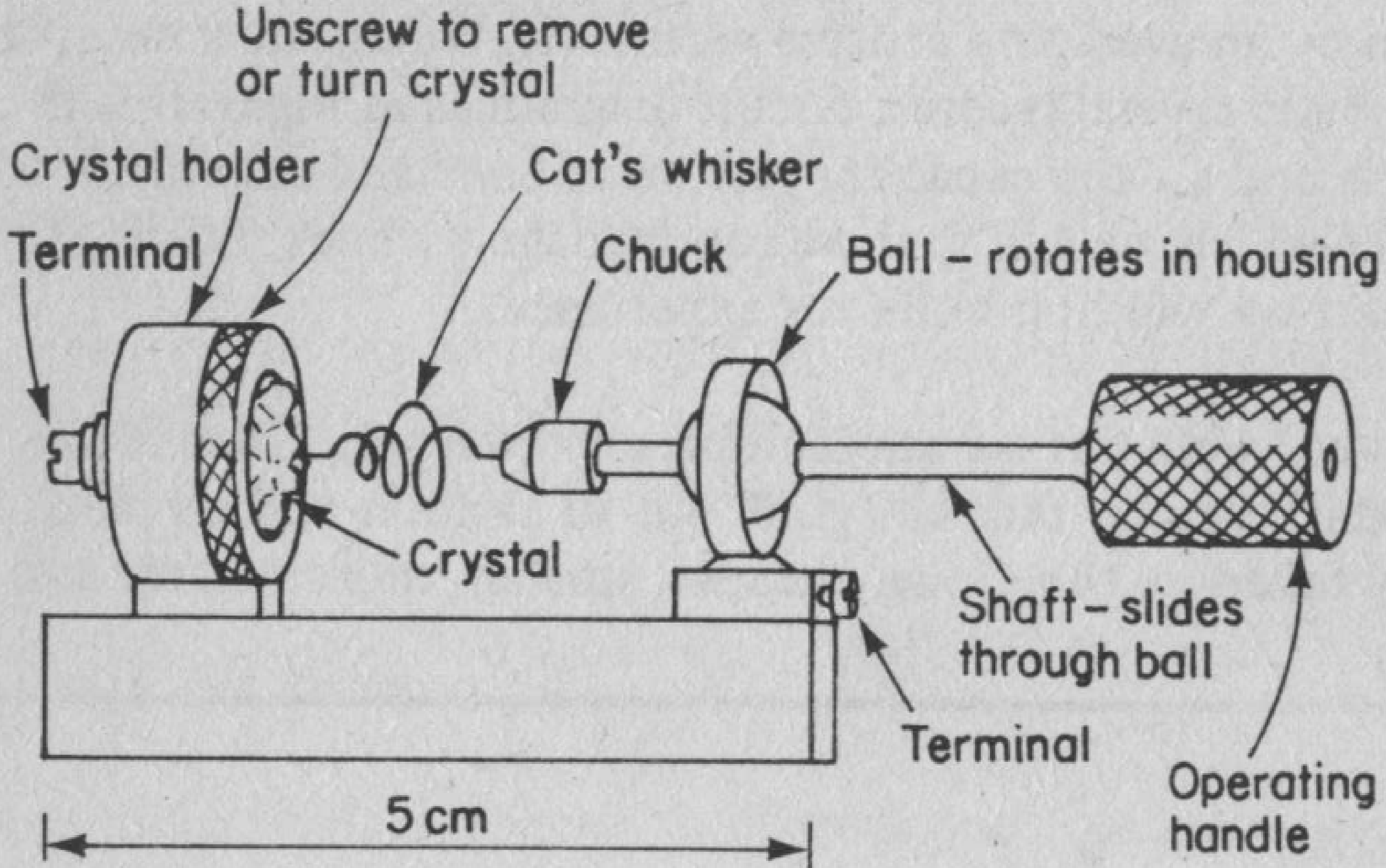
Unscrew to remove or turn crystal
Crystal holder
Cat's whisker
Terminal
Chuck
Ball – rotates in housing
Crystal
Shaft – slides through ball
Terminal
Operating handle
5 cm

Modern diode (7·5 X 2·5 mm)

Majoritatea componentelor active folosite în circuitele electronice moderne sînt dispozitivele bazate pe semiconductoare.

Cel mai simplu dispozitiv este *dioda* punctiformă cu germaniu. Ea are proprietatea de bază de a se comporta ca şi cum este conectată direct la o sursă electrică de curent continuu (plusul sursei la plusul diodei) şi ca un izolator, cînd este conectată invers la aceeaşi sursă (plusul sursei la minusul diodei), ca în figura 2.9.

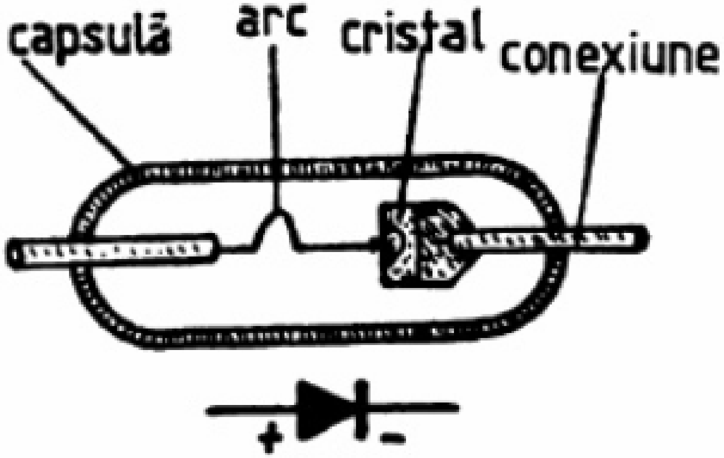
capsulă
arc
cristal
conexiune
+
-

FIG. 2.9.

Dioda punctiformă cu germaniu

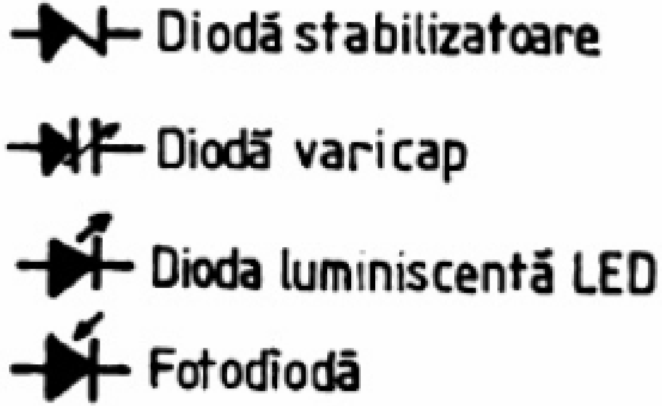
Diodă stabilizatoare
Diodă varicap
Dioda luminiscentă LED
Fotodiodă

FIG. 2.10.

Tipuri de diode semiconductoare

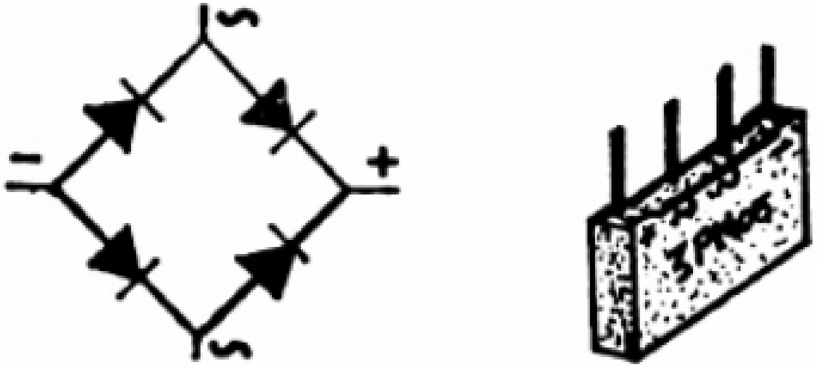

FIG. 2.11.

Puntea redresoare

Fig. 7

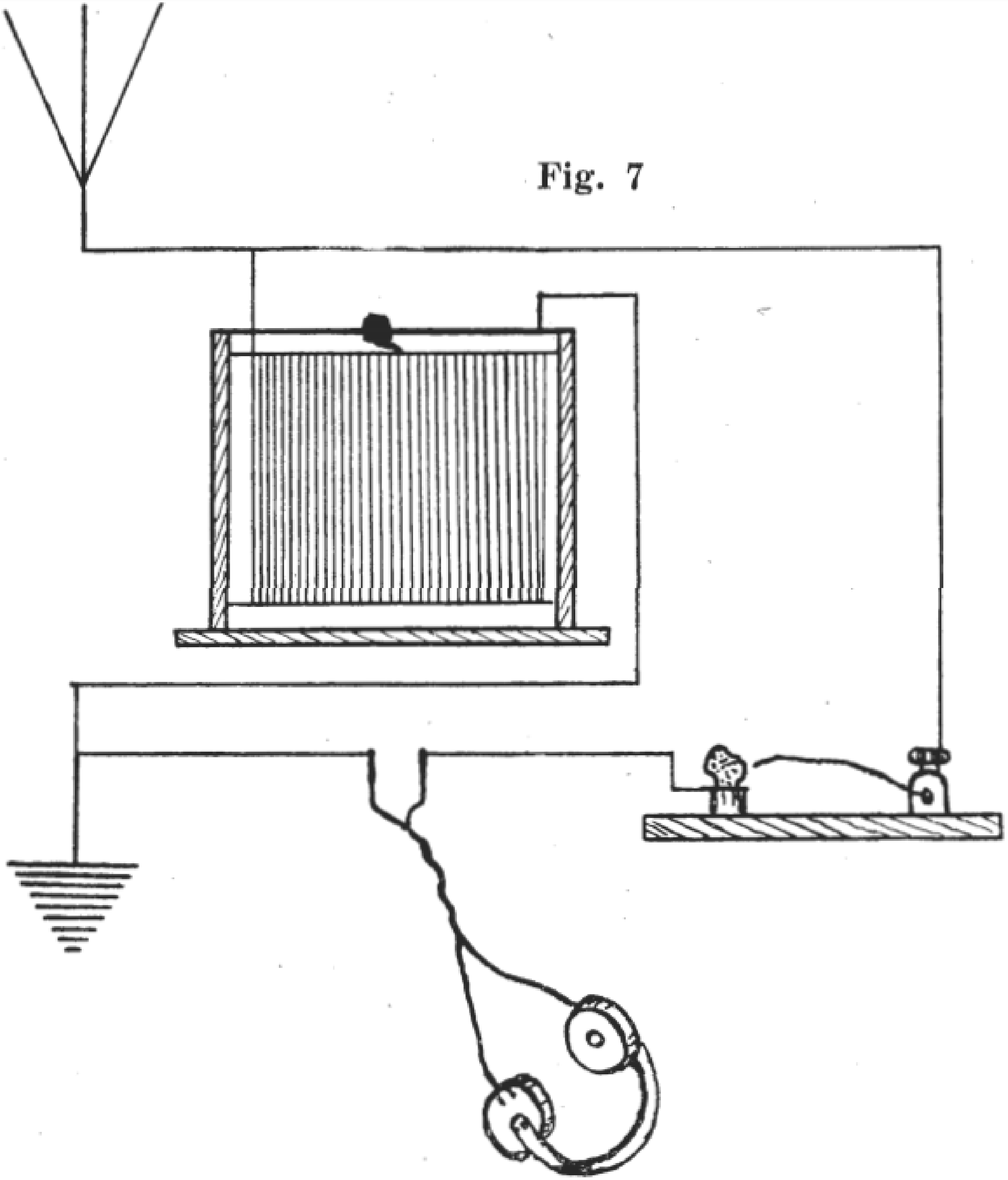

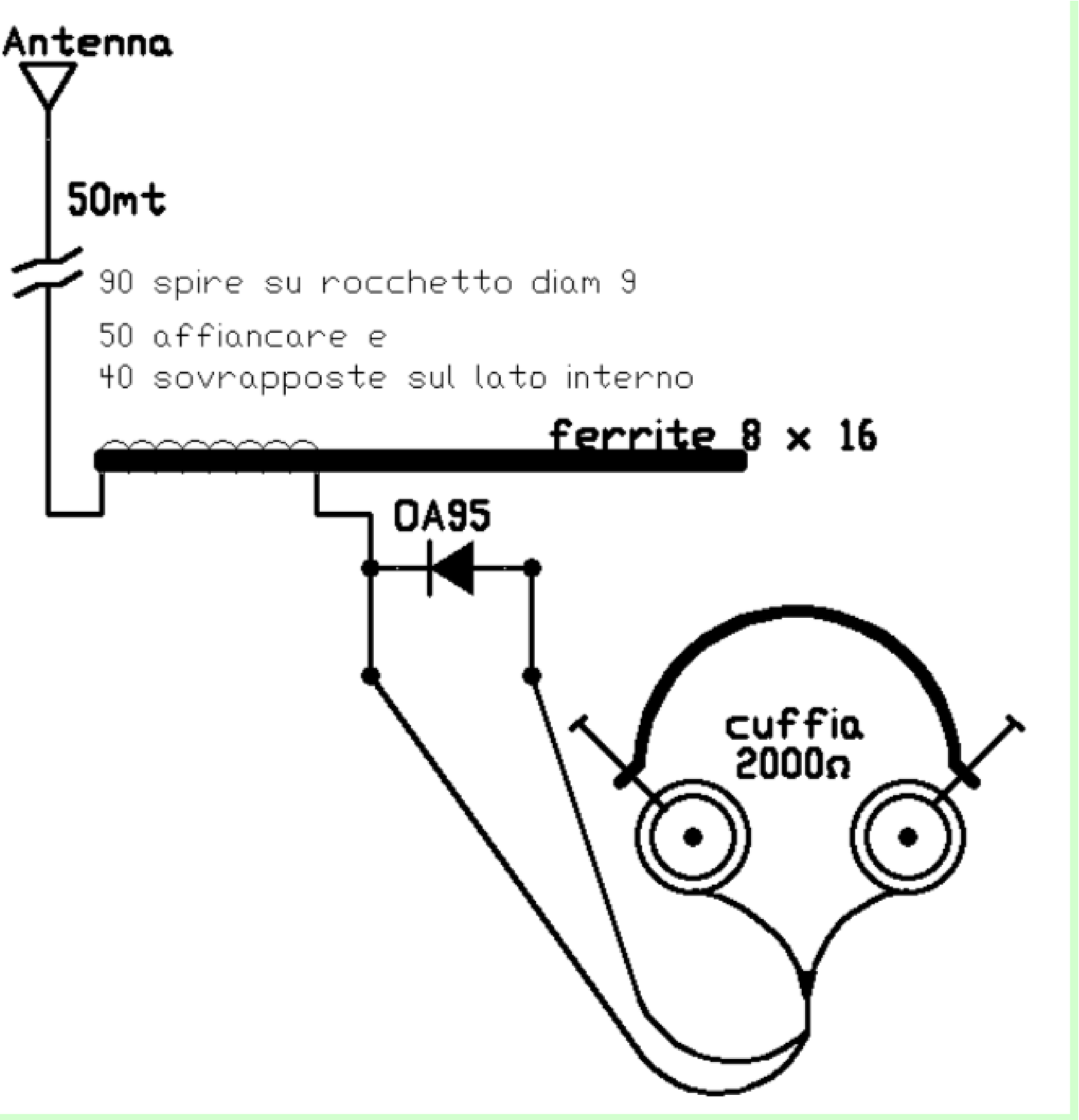
Antenna
50mt
90 spire su rocchetto diam 9
50 affiancare e
40 sovrapposte sul lato interno
ferrite 8 x 16
OA95
cuffia
2000Ω

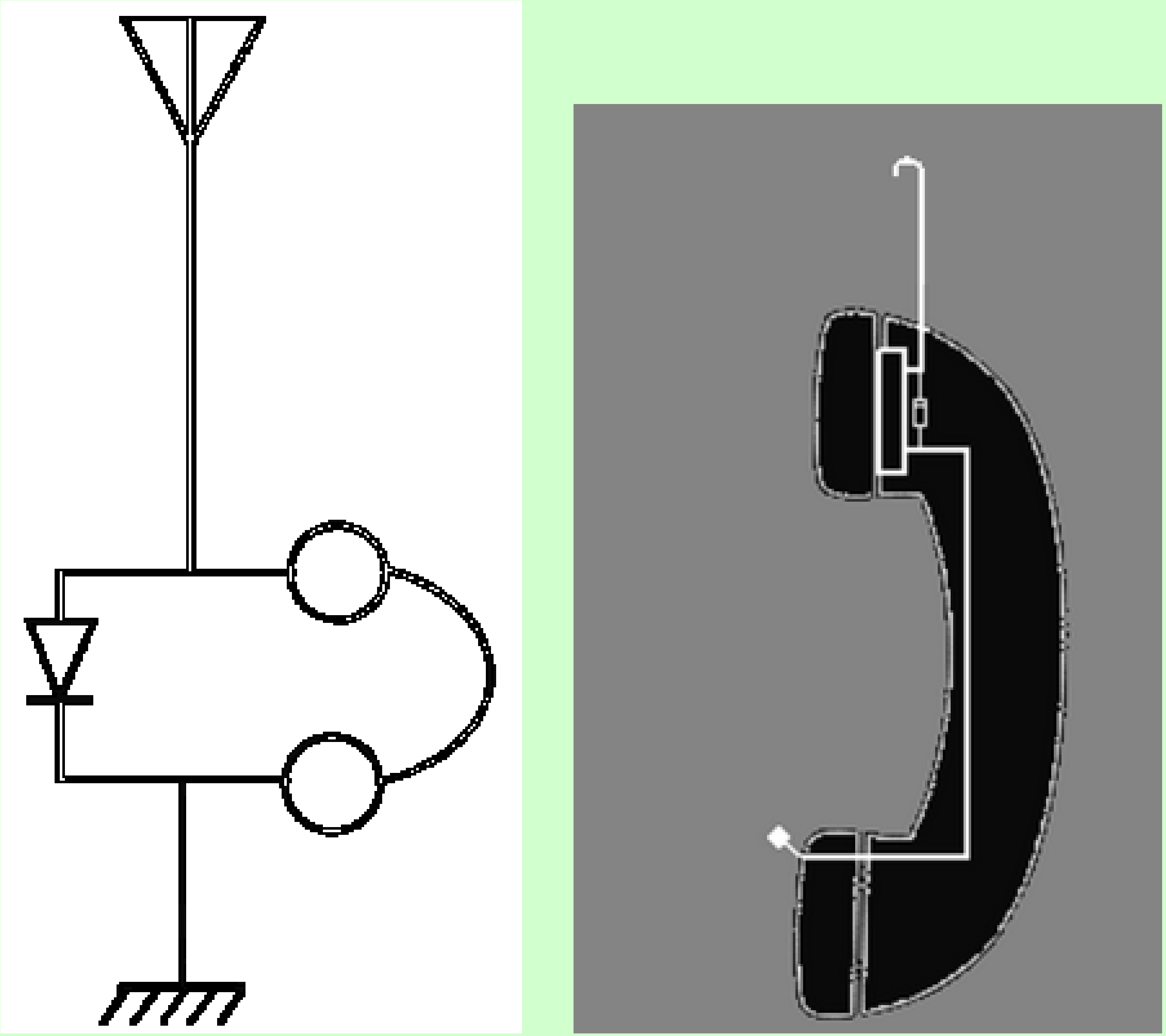

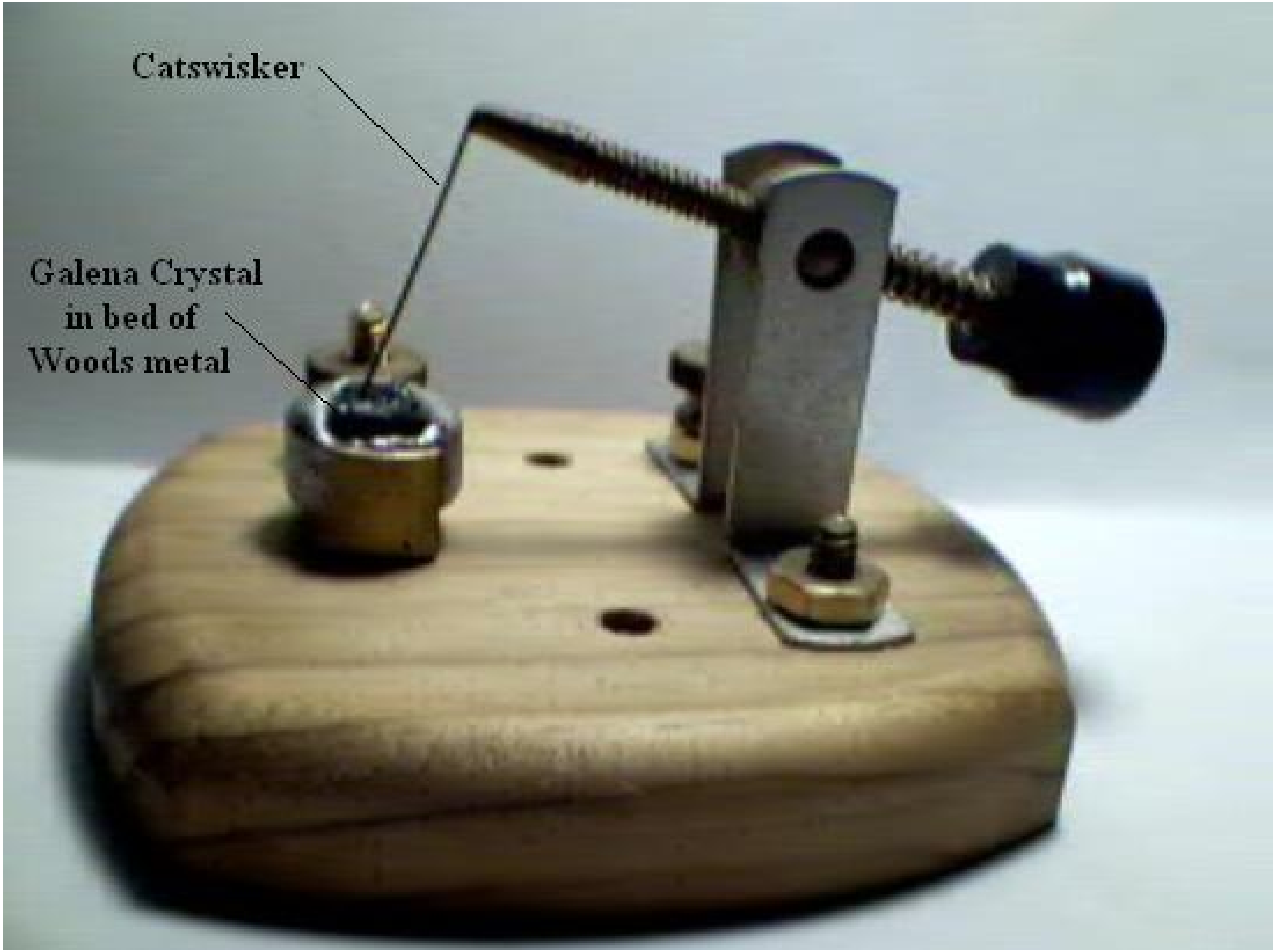
Catswisker
Galena Crystal in bed of Woods metal

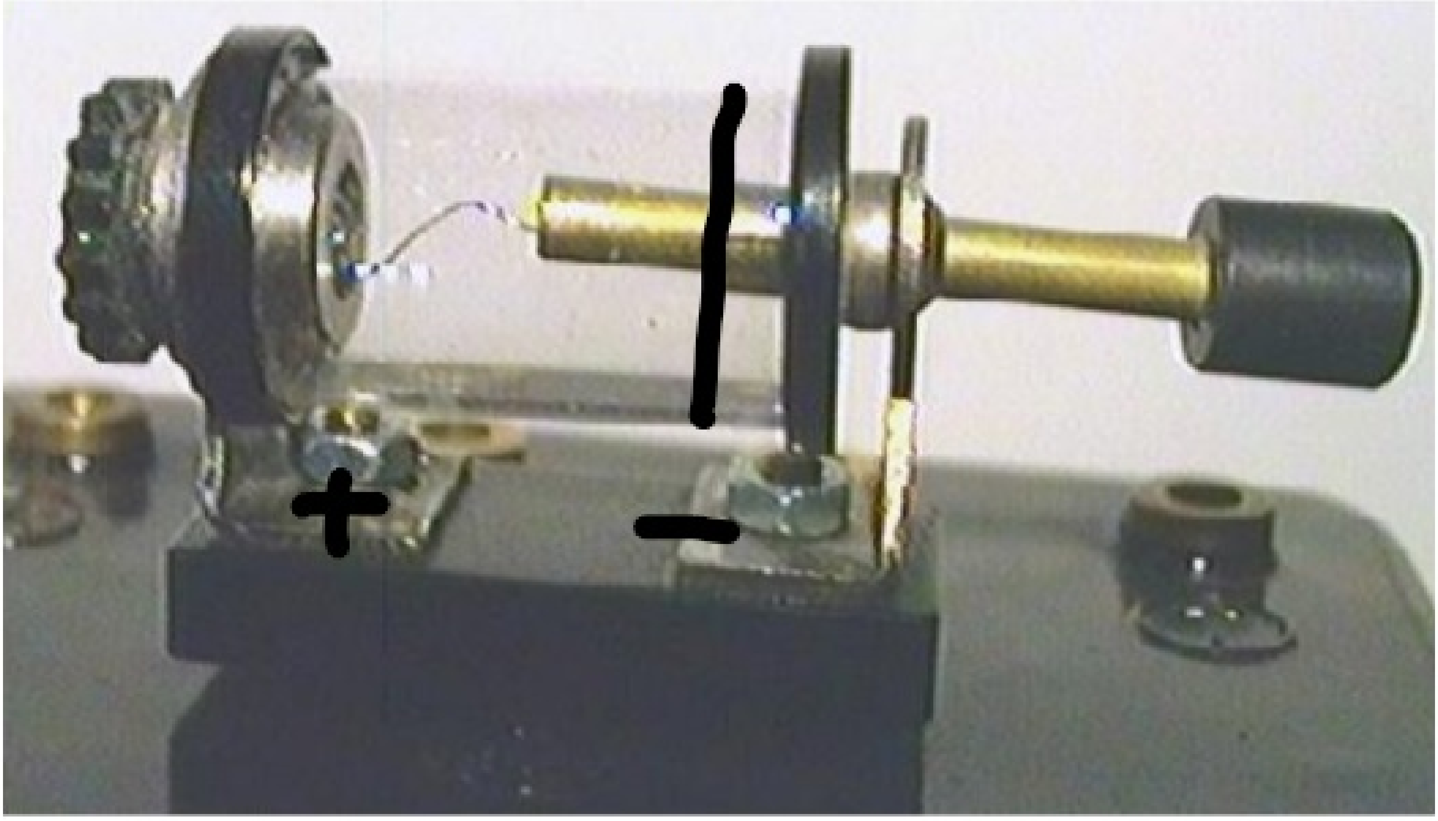
+
–

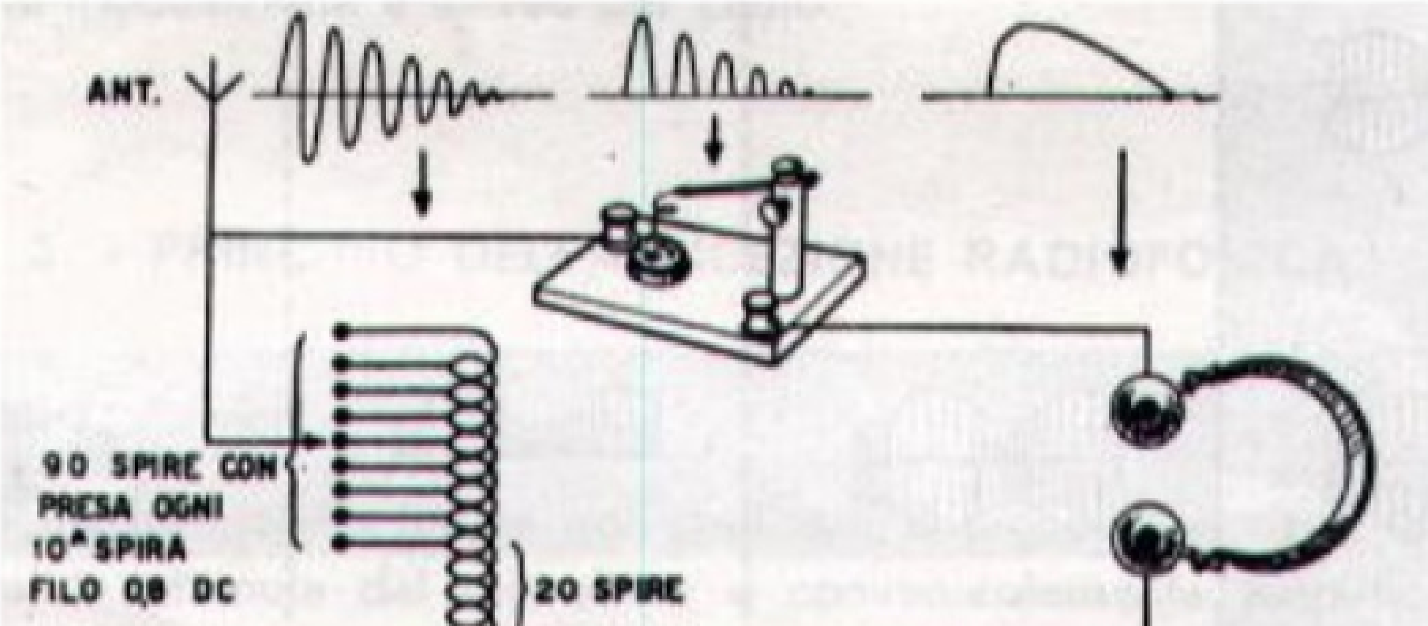
ANT.
90 SPIRE CON PRESA OGNI 10ª SPIRA FILO 0,8 DC
20 SPIRE
6 cm. ∅
TERRA

Lead sulfide crystals, also called "galena"

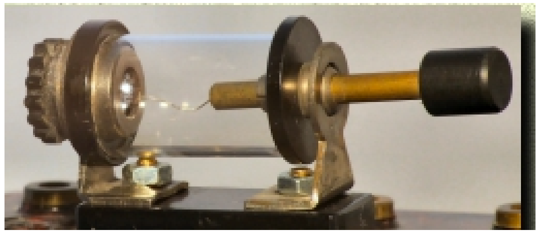

Crystal detector, the lever was used to position the spring contact on a crystal face capable of performing the radio signal detection.

Yeah , but how does a galena radio work? Here is the constructive scheme of a receiver of this kind, obtained from a book of popular radio commu
to the knowledge of the radio, ed.Hepep 1943):

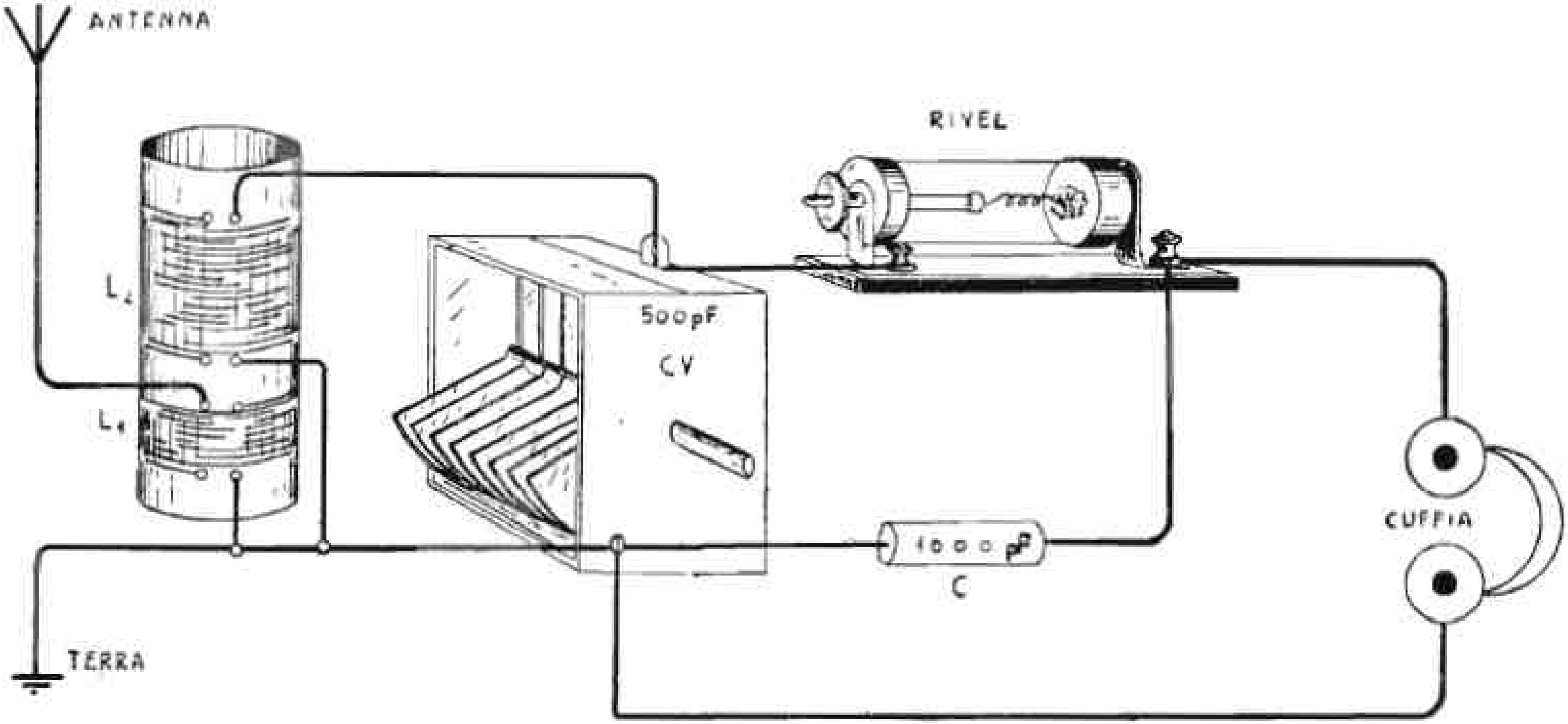

Fig. 13.5. – Realizzazione pratica dello schema di fig. 13.3 con aggiunta della bobina d'antenna.

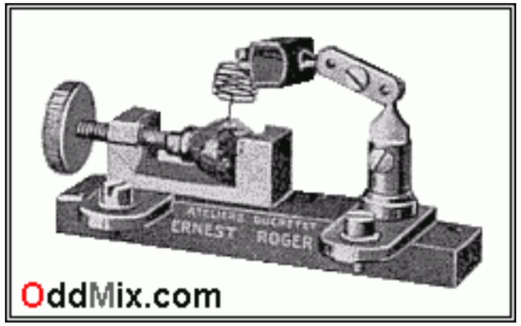

Picture 1. "Ernest Roger" Crystal detector from 1920

Many of the **younger generation** never had the pleasure to have, or to even see a real beautiful crystal detector as shown on **Picture 1**. A detector like that was the product of the early 1920's, and it was an expensive, quality, well made product. They were usually hands assembled with machine made components.

This particular "**Ernest Roger**" detector device is built on an insulated base, either wood or most likely of Bakelite, the most widely used and only available plastic material at the times.

Many of the younger generation never had the pleasure to have, or to even see a real beautiful crystal detector as shown on **Picture 1**. The new generations are much too involved with technology and playing on their computers or going to an **online University**. This excellent detector holder used copper, brass and bronze generously for the crystal holder and for all of the **electrodes**.

The most often used crystal in this and similar detectors - then and now - was **pyrite** or galena as shown in the 1925 listing in a table in the **"American Mineralogist"** publication, that has a listing of thirty three minerals catalogued with rectifying detector properties.

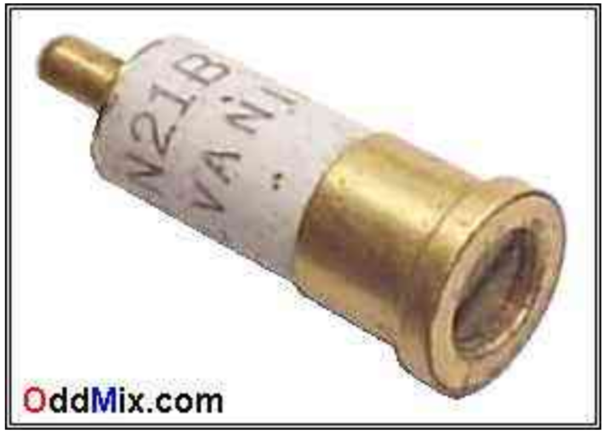

Picture 2. Early point contact diode with adjustable srew

Among the very first commercially produced diodes is the 1N21B shown on **Picture 2**. It is more than curious, that this "diode" is enclosed in a case on which there is a slotted screw-head is just visible on the wide side (lower right). That screw is connected to a fine "cats whisker" steel wire, a few turns of a spring-like device, terminating in a point that is in touch of the germanium semiconductor material connected to the top left diode terminal.

The arrangement is much smaller, and more diode like, then the detector on **Picture 1**., but it made in a very similar arrangement, which has became known as the point contact diode. From these and similar germanium diodes, evolutionary progress leads us to current PN junction Silicon, Gallium Arsenide or other more exotic semiconductor materials which are the achievement of the latest scientific age and many years of steady experimentation, research and development.

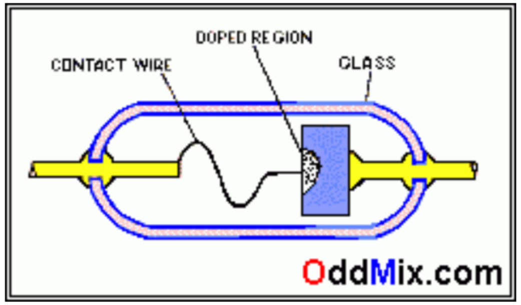

Picture 3. Point contact diode

Picture 3 shows the cross section of a hermetically glass enclosed, point contact diode. If the left side, point contact terminal would be attached to a screw and a short spring, and the glass envelope would have a threaded metal part in it, the **Picture 2** and **Picture 3** devices would be nearly identical.

These point contact "cat's whisker" devices, are still made occasionally because of their very small capacitance. As it was discovered early on, they are highly useful in high frequency electronics. All the way up to microwave frequencies they useable. The simplest radar detectors usually made with a simple horn **antenna**, a diode similar to **Picture 2** and **Picture 3** and a transistor amplifier. If the designer keeps it simple, and don't use a local oscillator, such radar detectors

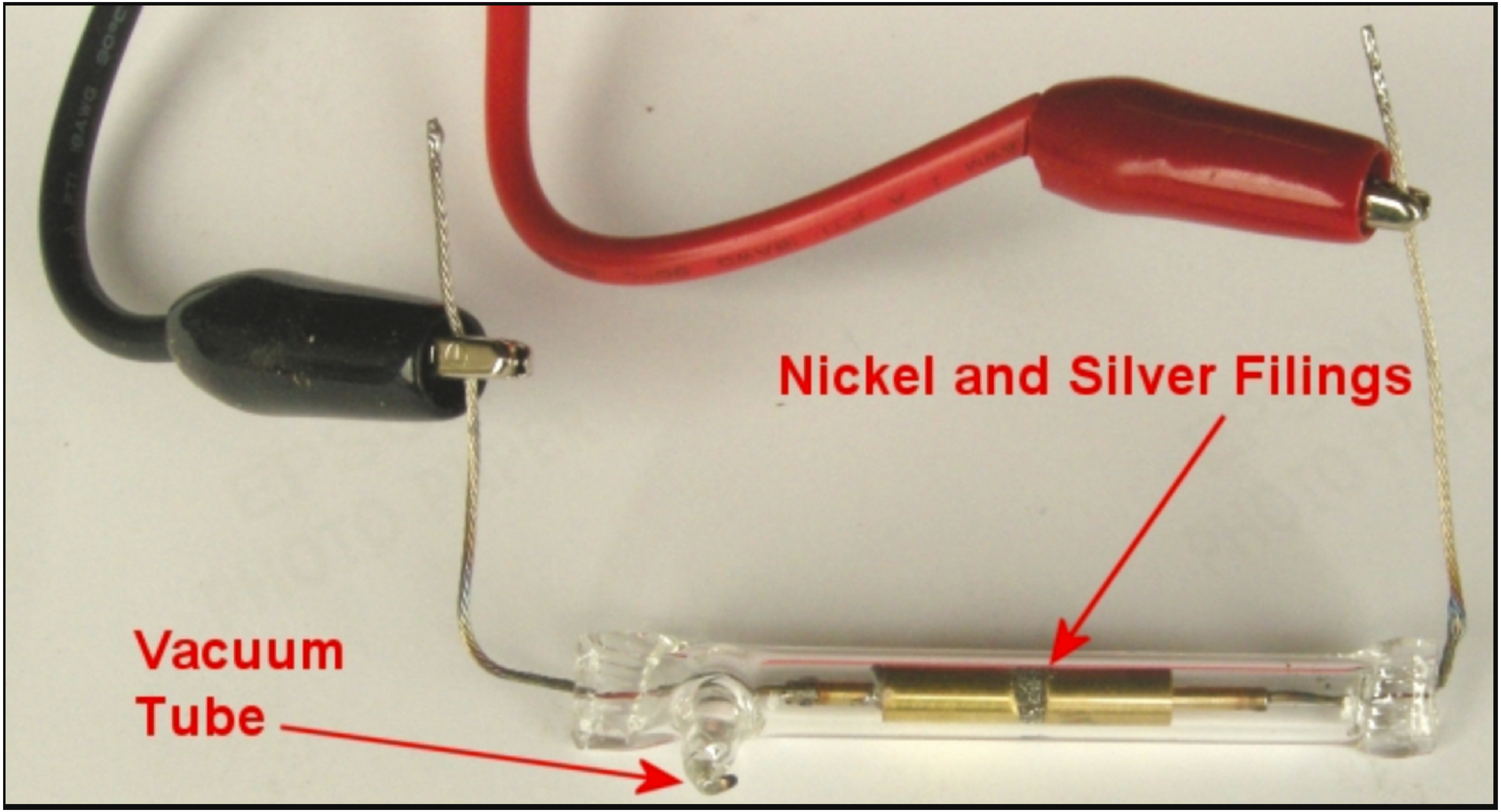
Nickel and Silver Filings
Vacuum Tube

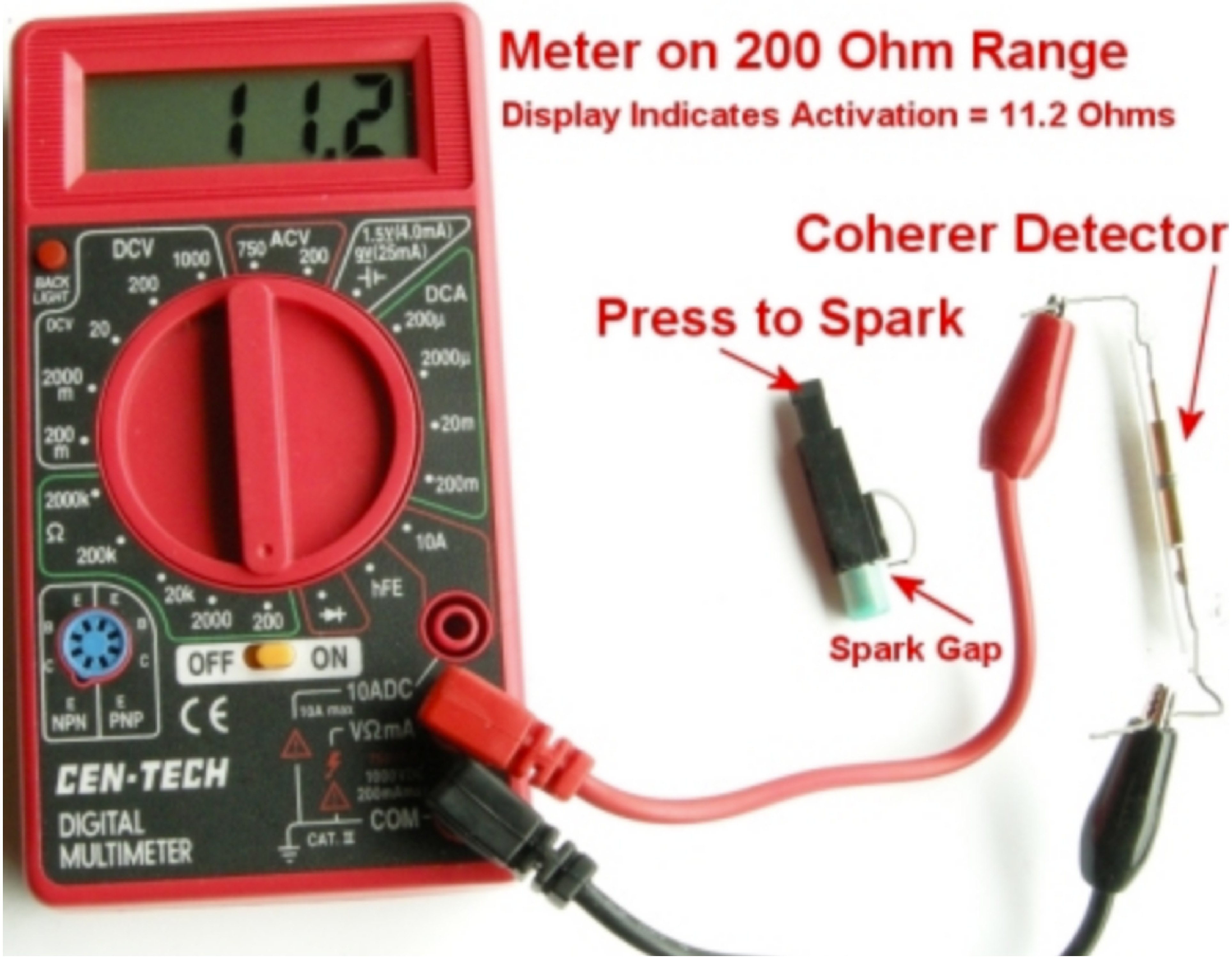

Meter on 200 Ohm Range

Display Indicates Activation = 11.2 Ohms

Coherer Detector

Press to Spark

Spark Gap

11.2
DCV
ACV
DCA
OFF ON
10ADC
VΩmA
COM
CEN-TECH
DIGITAL MULTIMETER

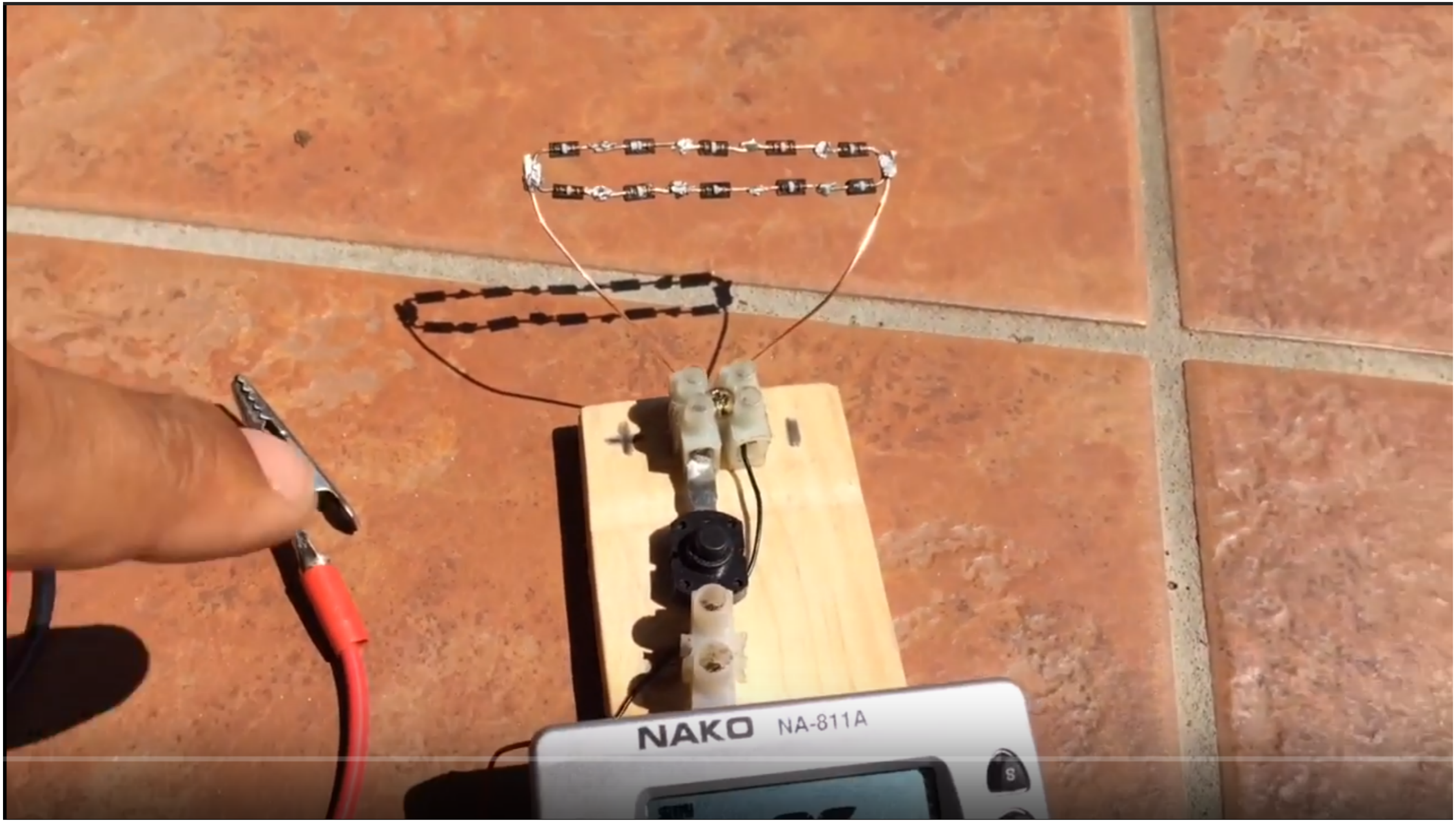
NAKO
NA-811A
S

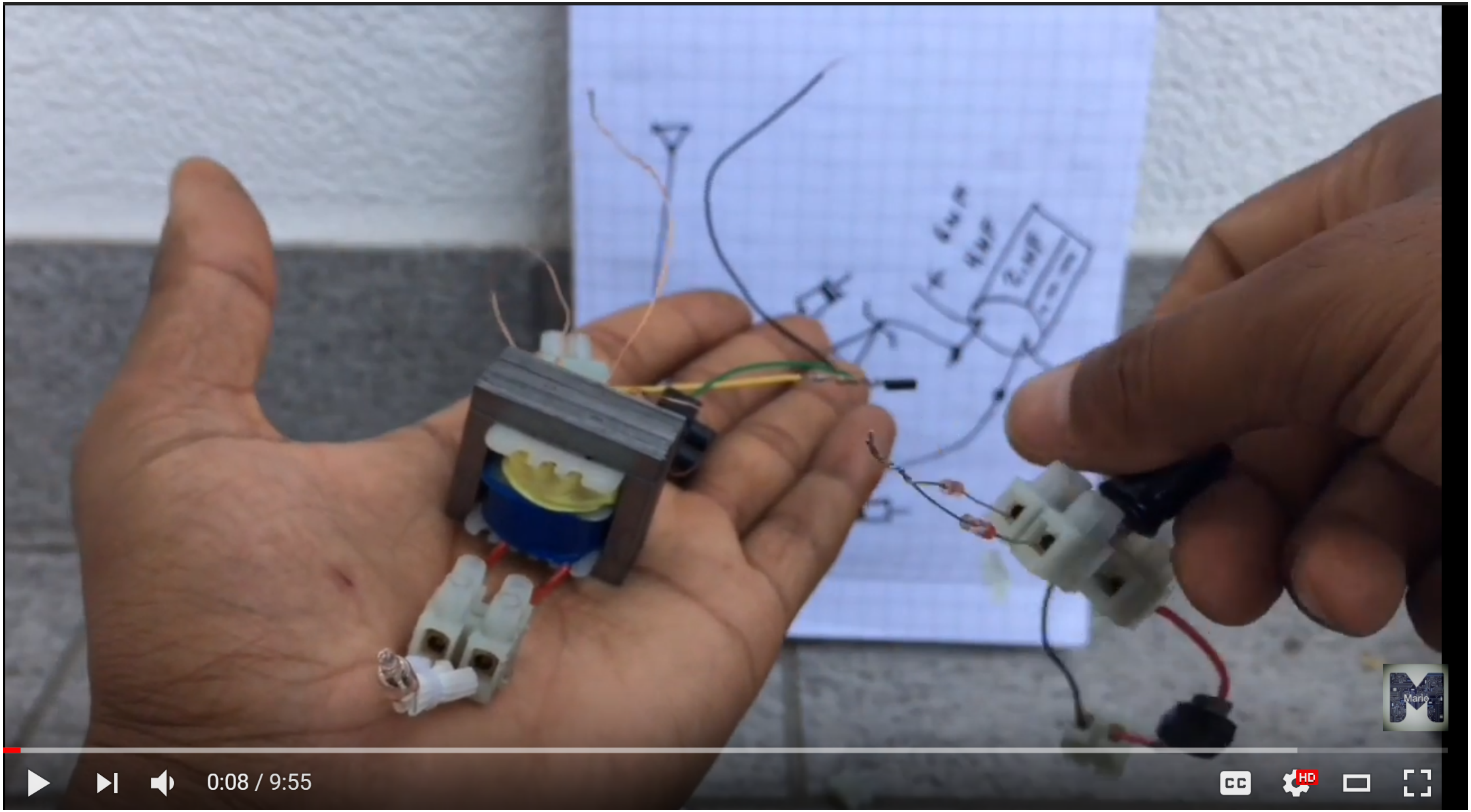
0:08 / 9:55
HD
Mario

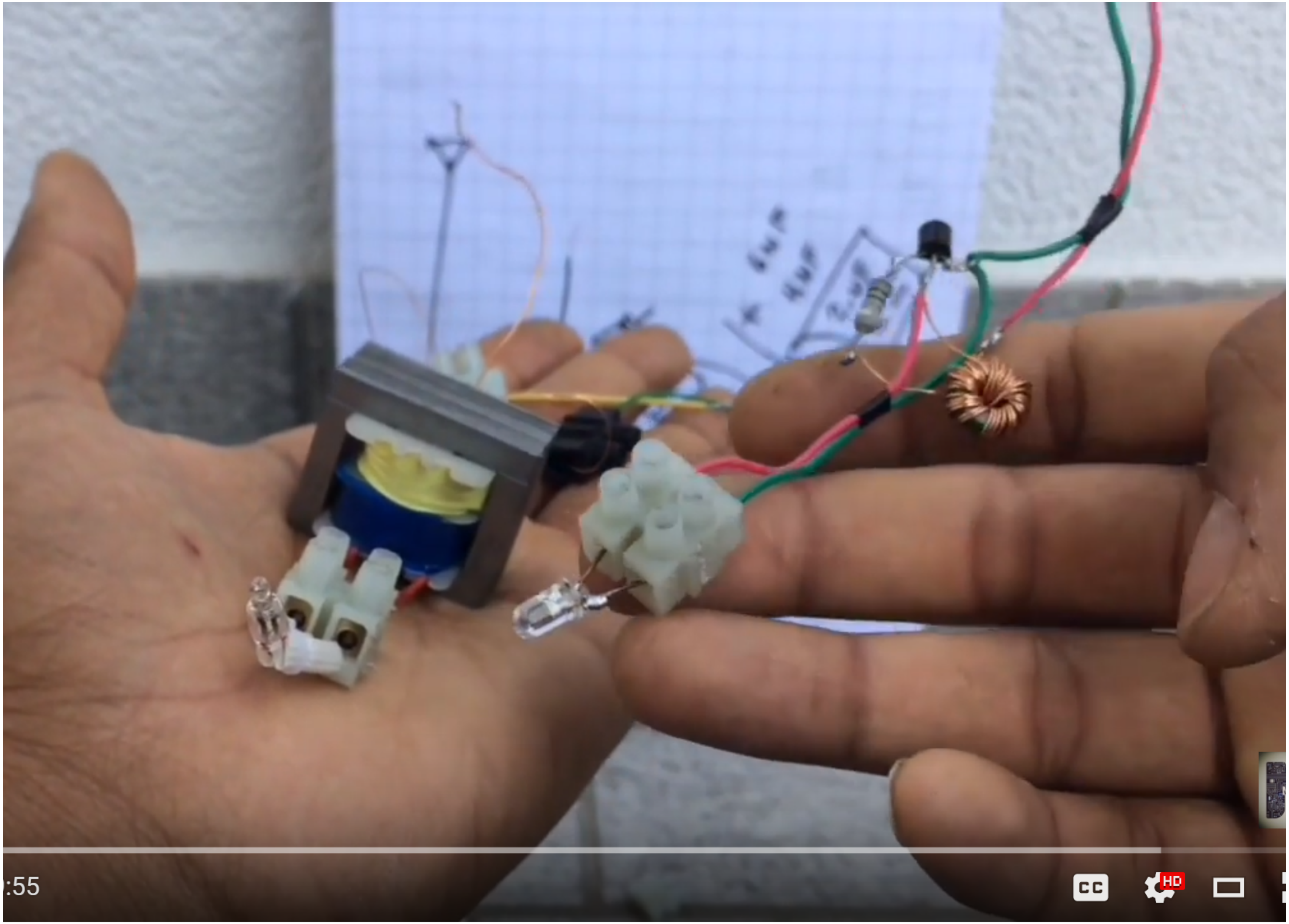
:55
CC
HD

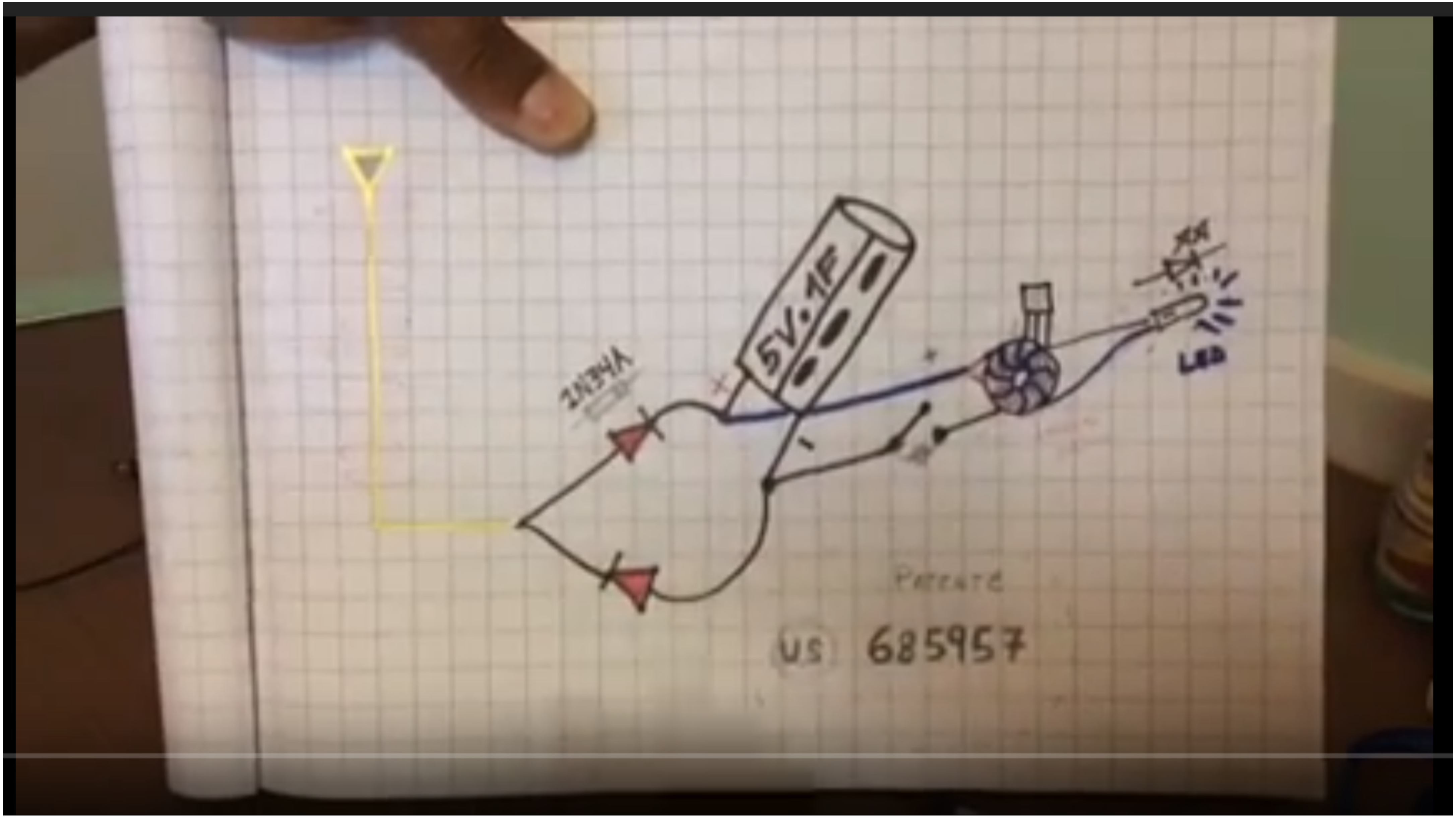
1N34A
+
5V .1F
-
+
LED
Patente
US 685957

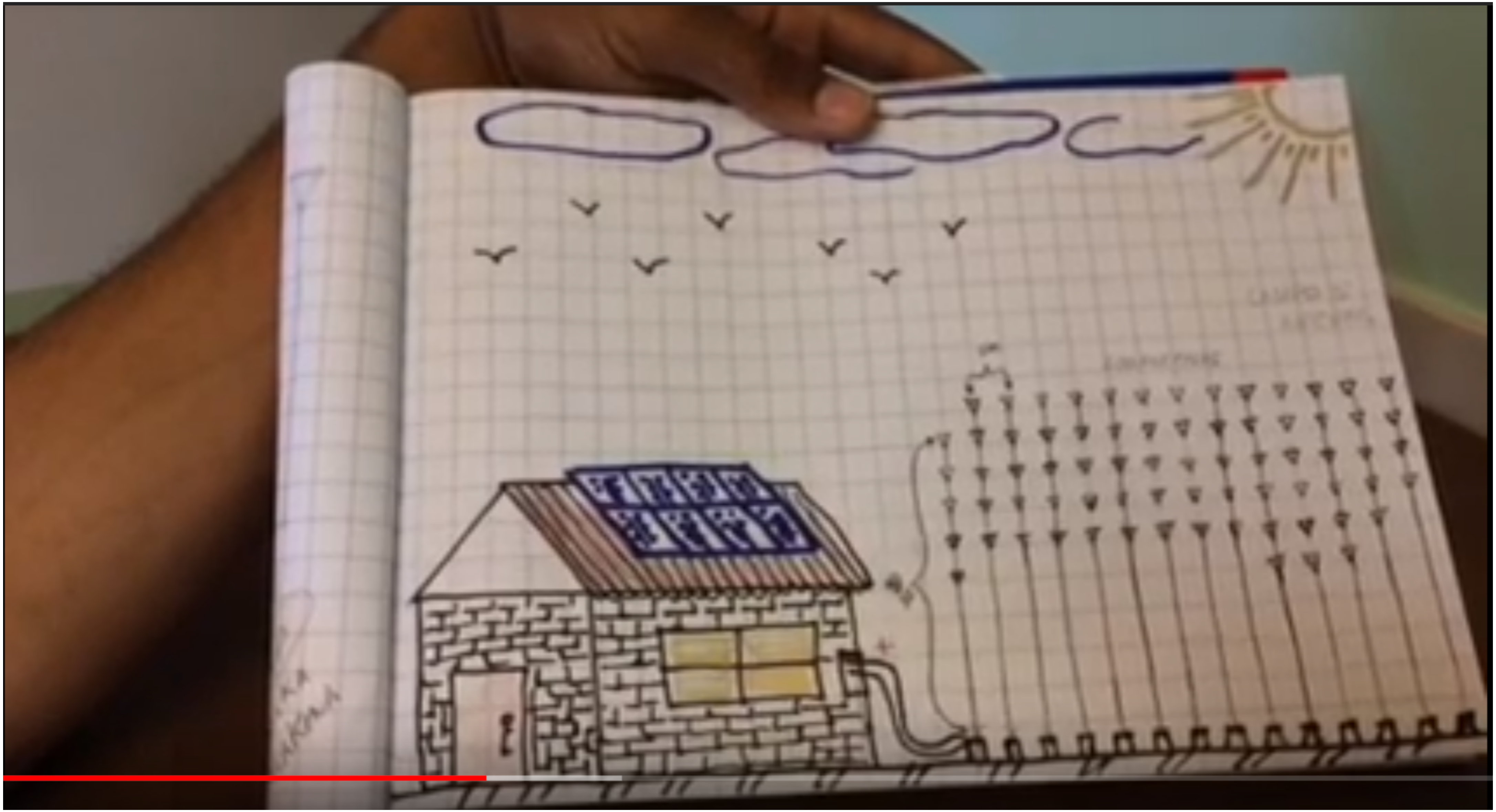

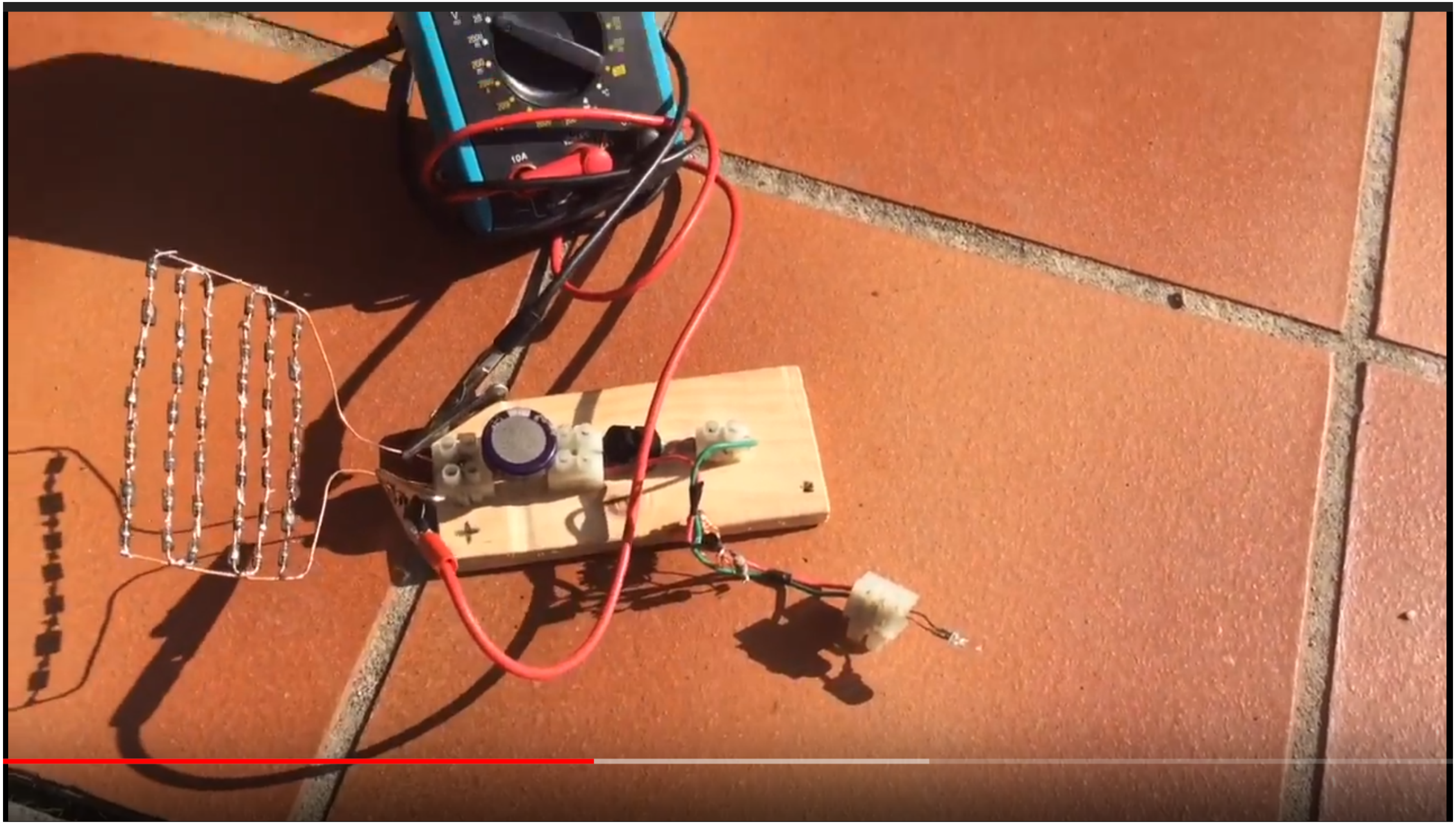

10A

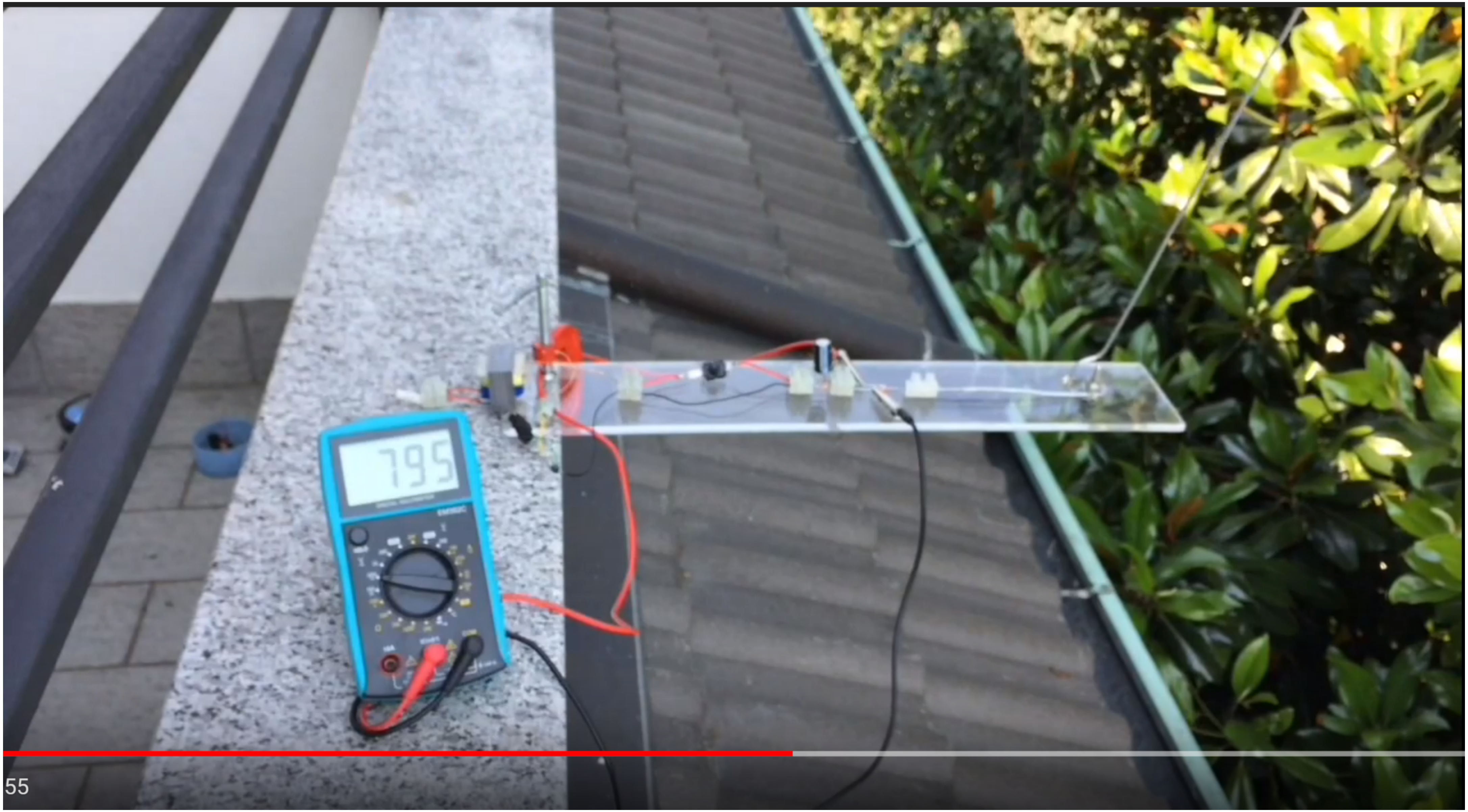
795
55

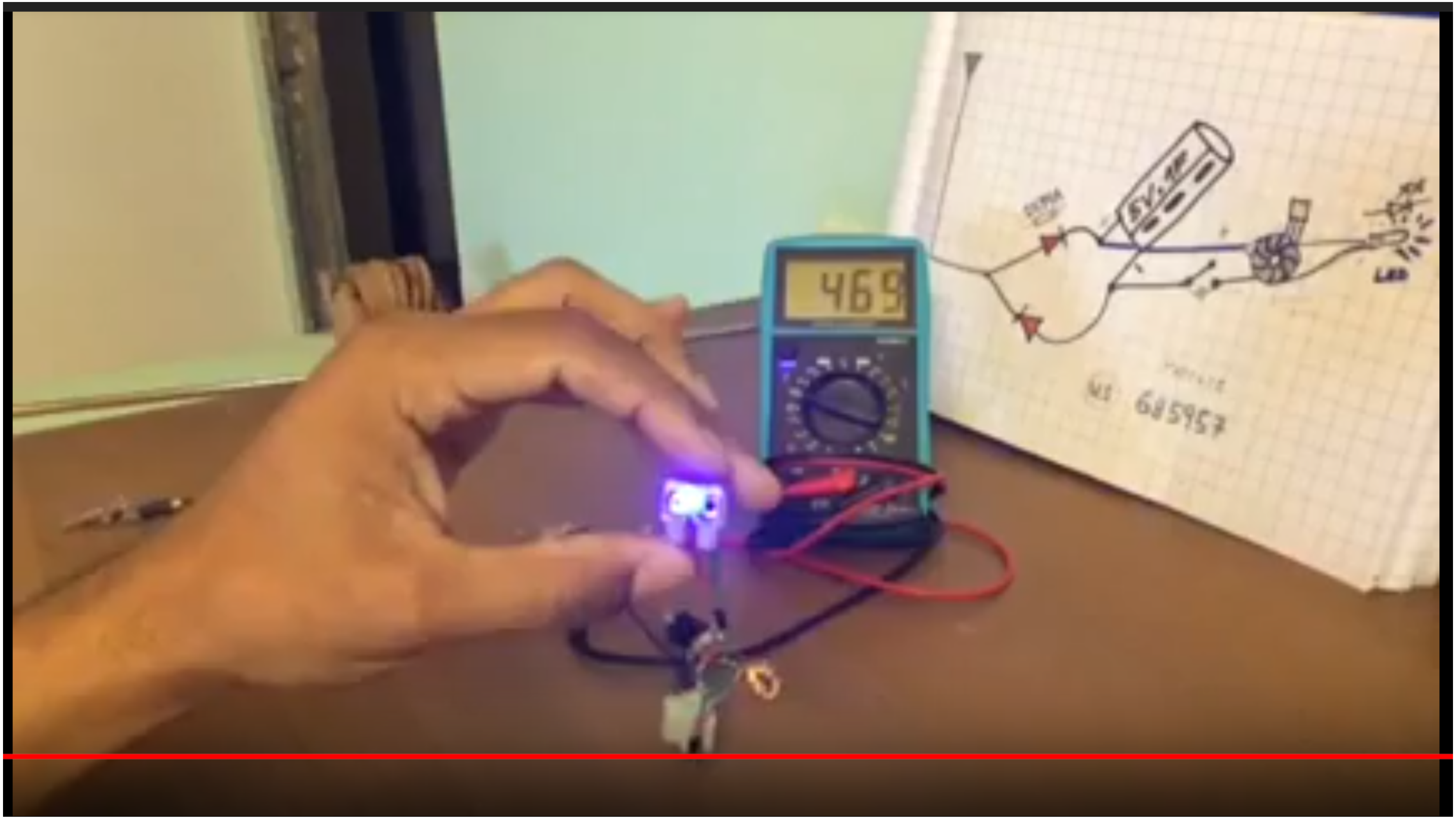
469
5V 1A
LED
685957

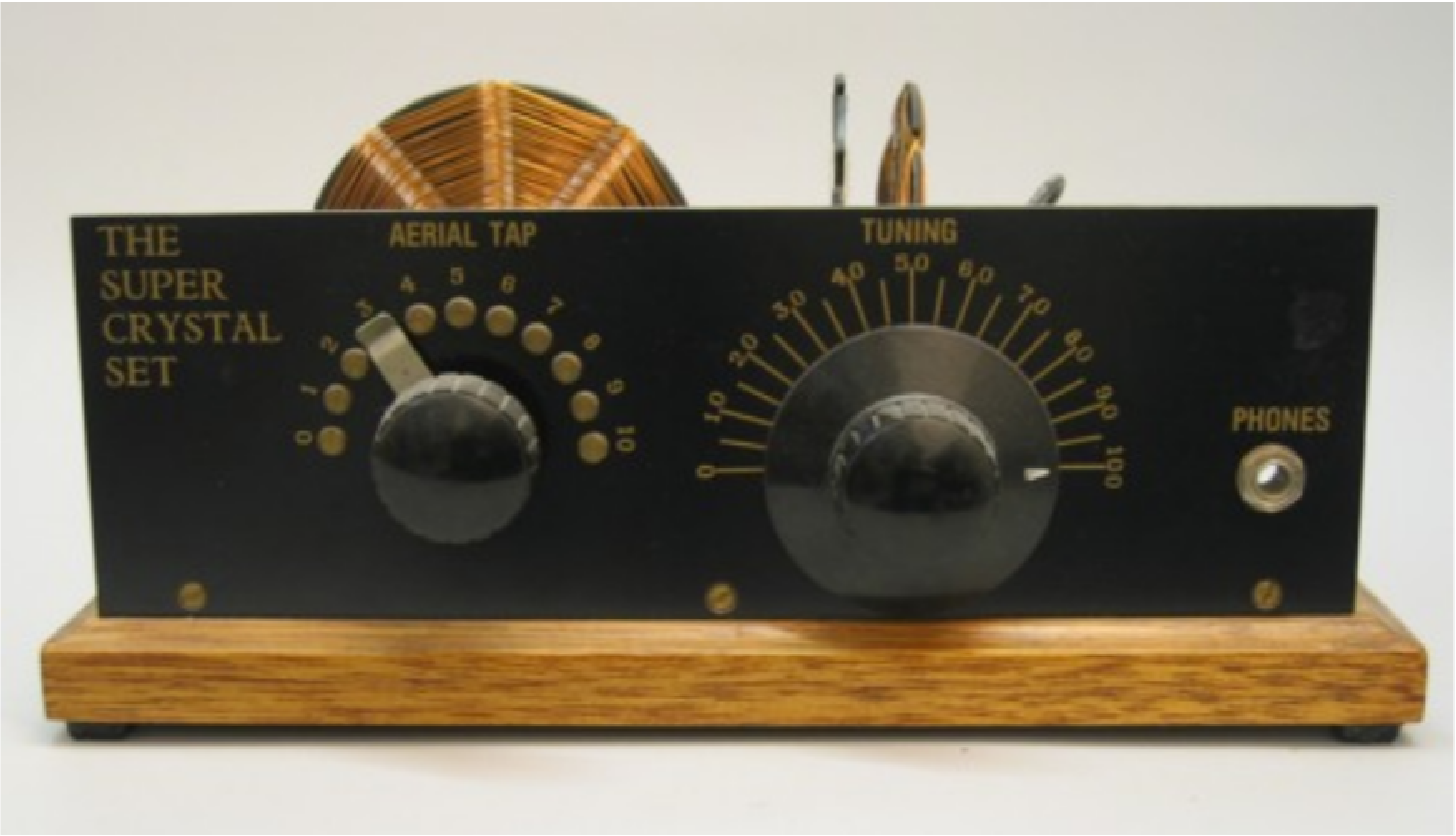
THE SUPER CRYSTAL SET
AERIAL TAP
0 1 2 3 4 5 6 7 8 9 10
TUNING
0 10 20 30 40 50 60 70 80 90 100
PHONES

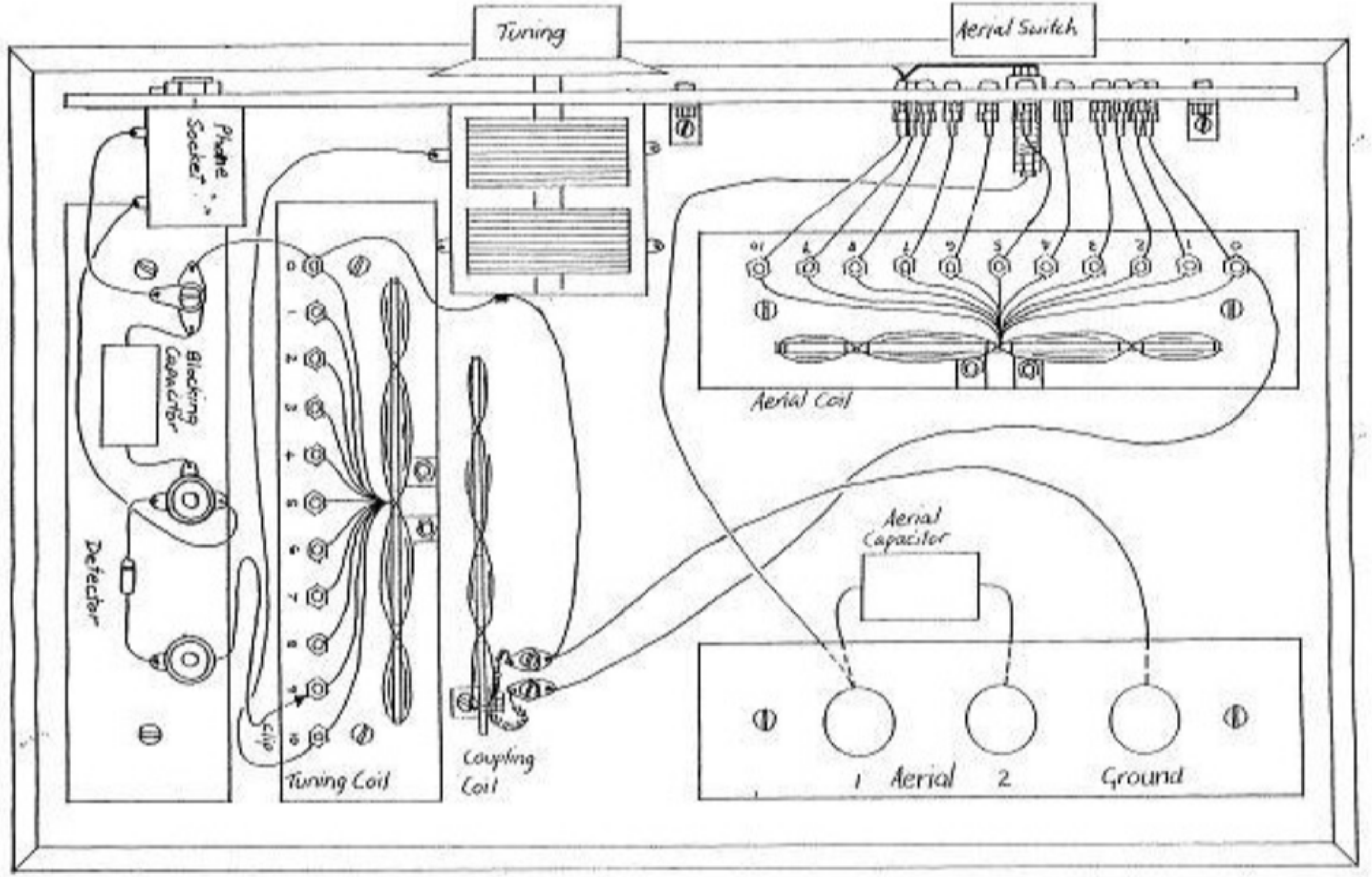
Tuning
Aerial Switch
Phone Socket
Blocking Capacitor
Detector
Clip
Tuning Coil
Coupling Coil
Aerial Coil
Aerial Capacitor
1 Aerial 2
Ground

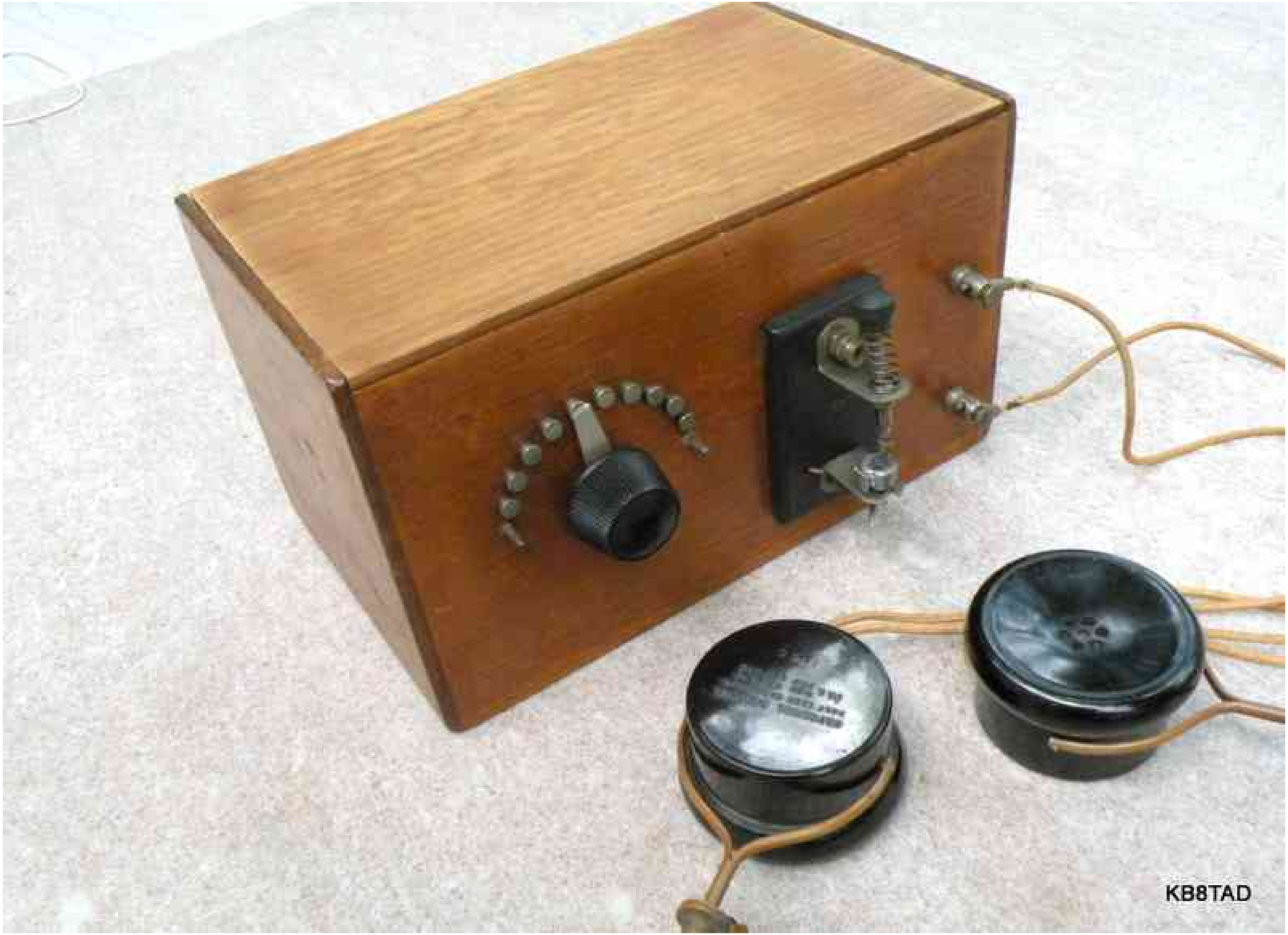

KB8TAD

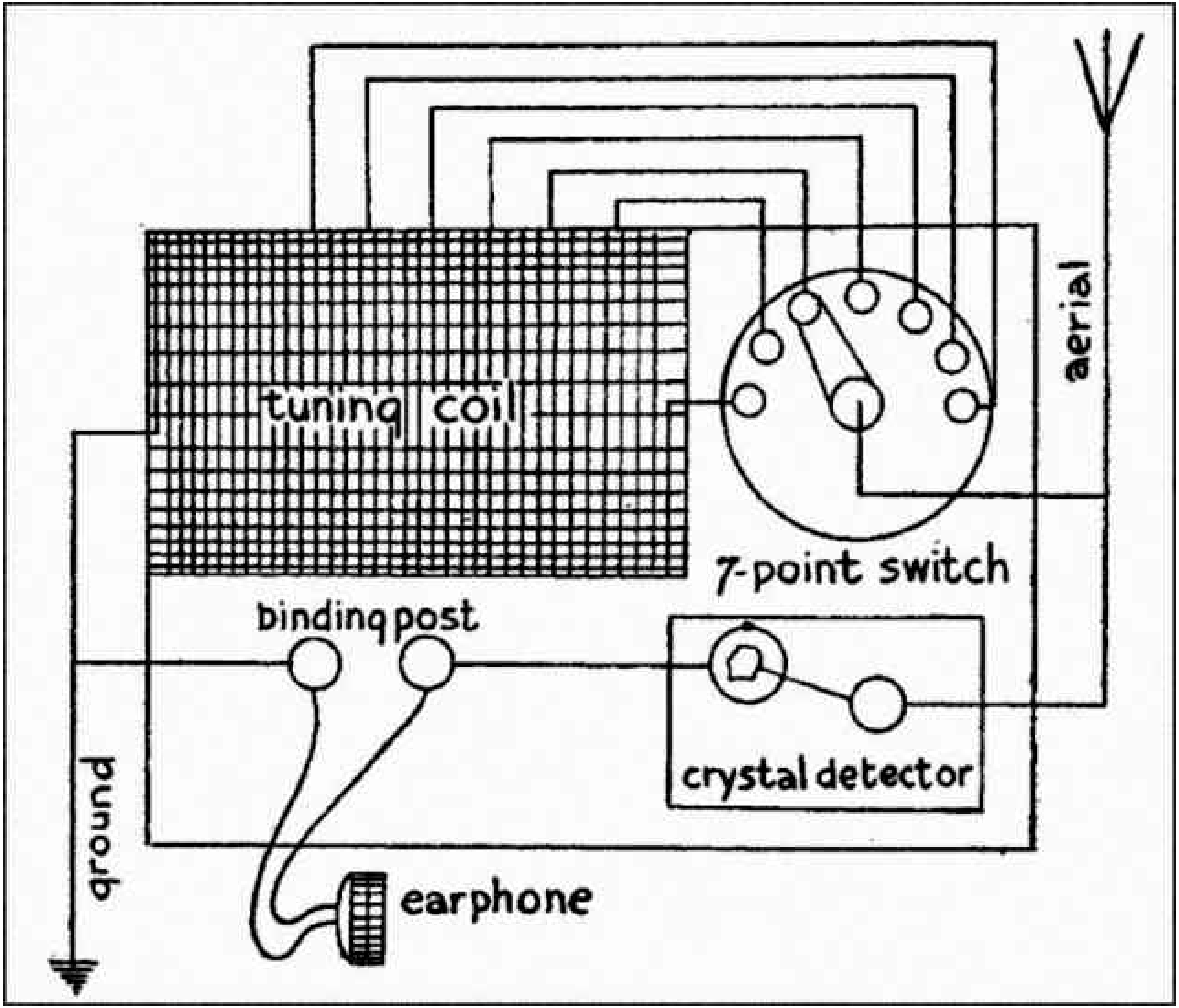
tuning coil
7-point switch
aerial
binding post
crystal detector
ground
earphone

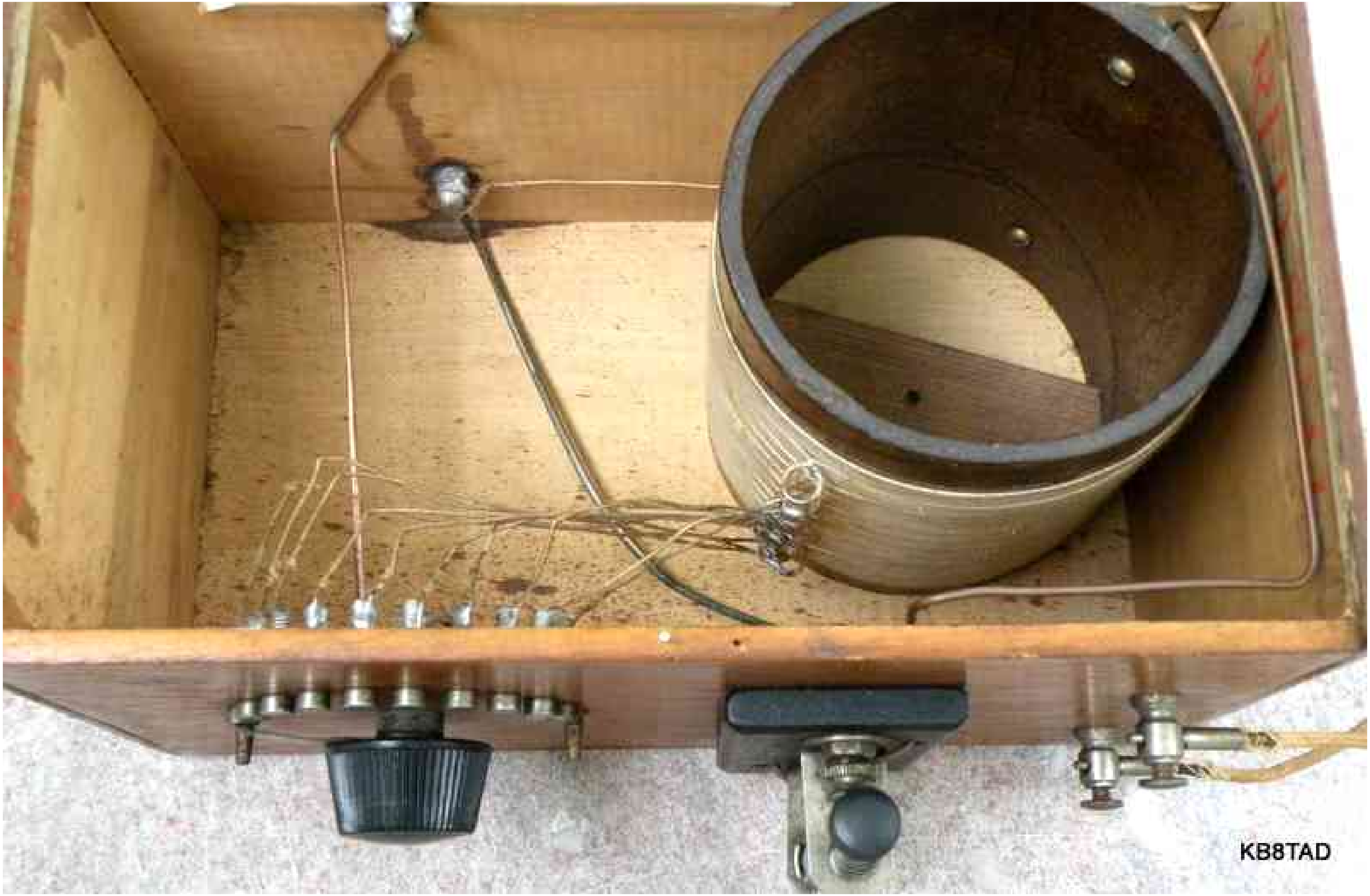

KB8TAD

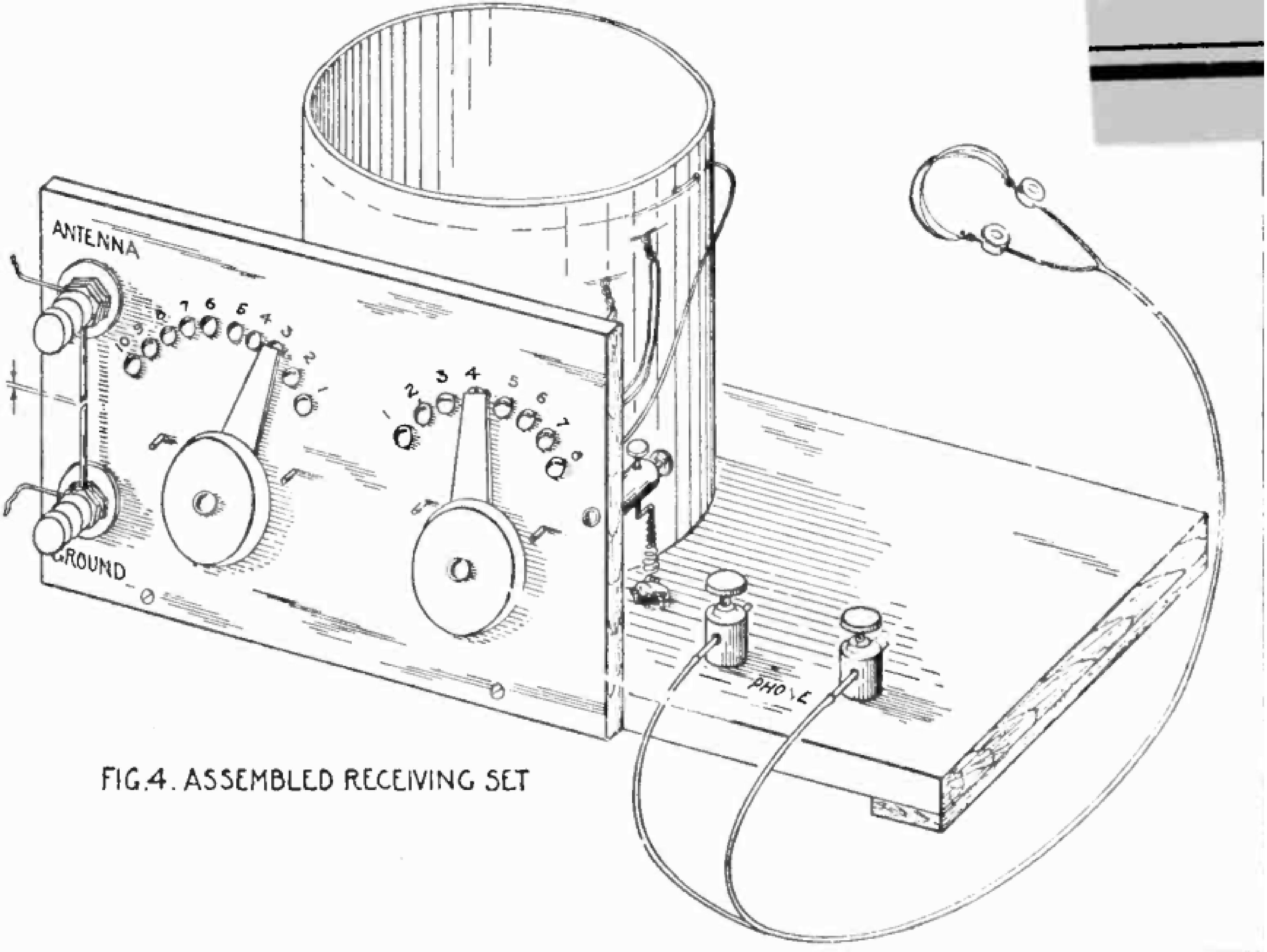
ANTENNA
GROUND
1/16 IN
10
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
PHONE

FIG. 4. ASSEMBLED RECEIVING SET

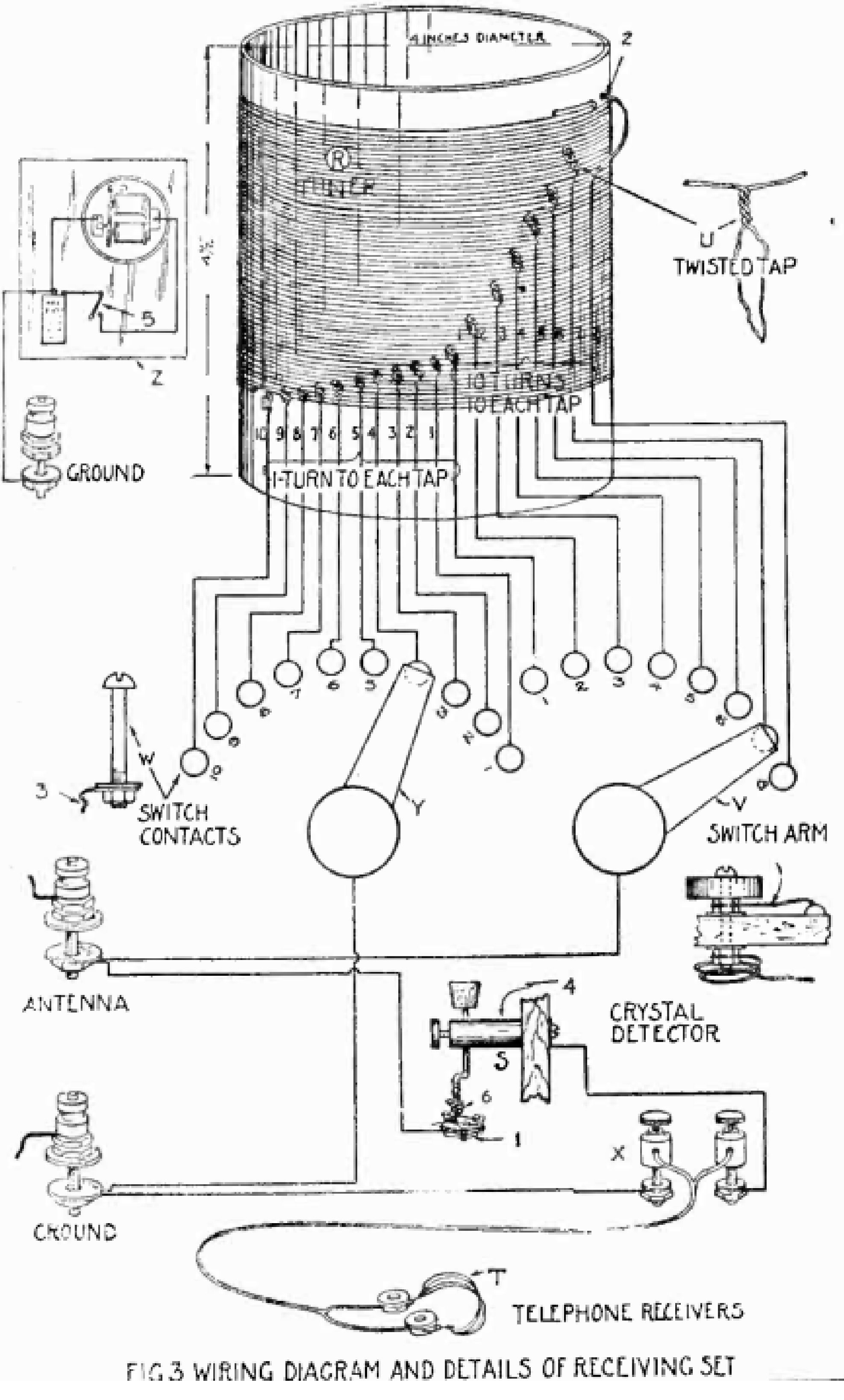
4 INCHES DIAMETER
2
R
TUNER
4½
U
TWISTED TAP
Z
5
GROUND
10 TURNS TO EACH TAP
10 9 8 7 6 5 4 3 2 1
1-TURN TO EACH TAP
W
3
SWITCH CONTACTS
Y
V
SWITCH ARM
ANTENNA
4
CRYSTAL DETECTOR
S
6
1
X
GROUND
T
TELEPHONE RECEIVERS

FIG.3 WIRING DIAGRAM AND DETAILS OF RECEIVING SET

FIG 2. RECEIVING SET, WITH ANTENNA AND GROUND CONNECTIONS

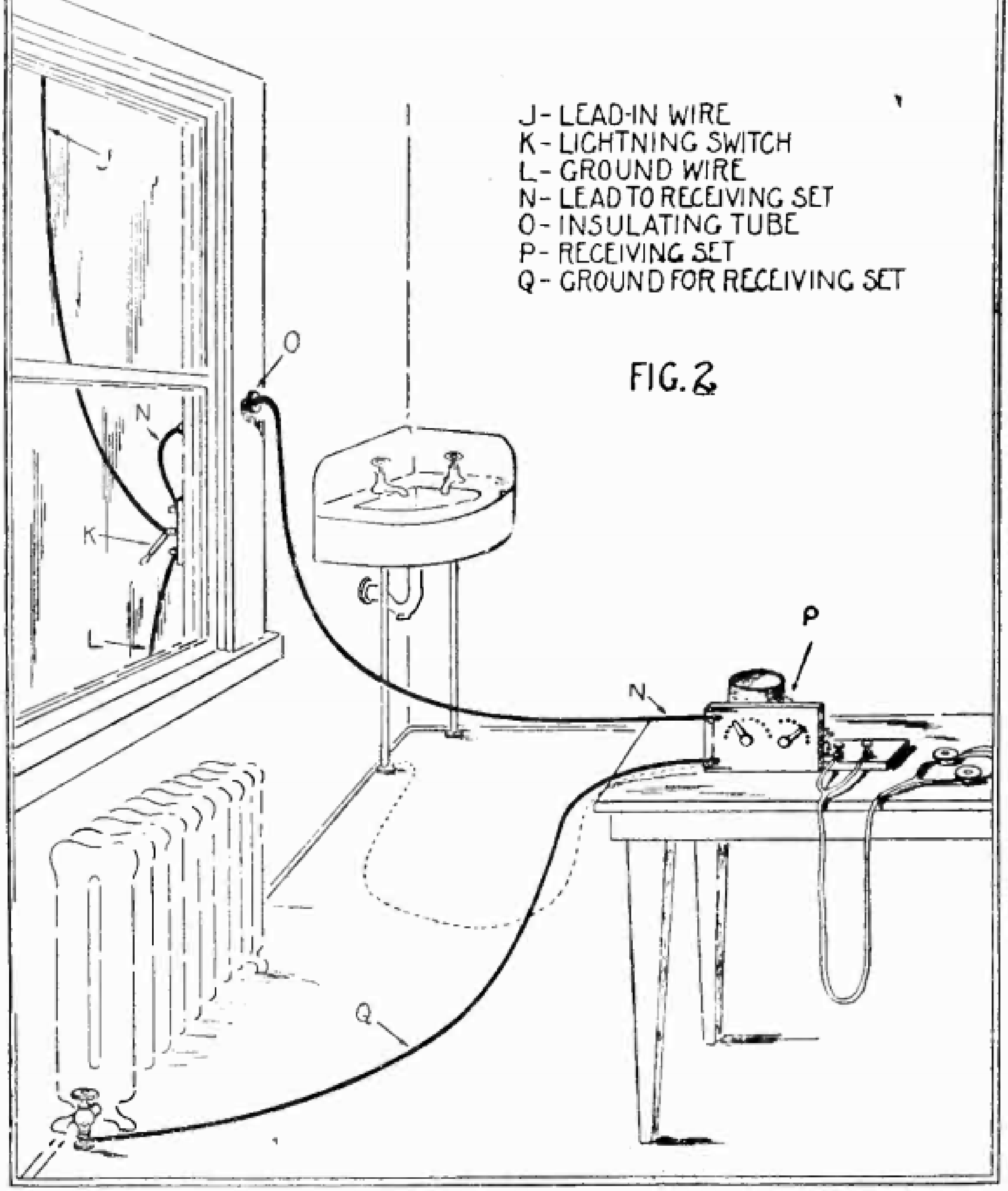
J- LEAD-IN WIRE
K- LIGHTNING SWITCH
L- GROUND WIRE
N- LEAD TO RECEIVING SET
O- INSULATING TUBE
P- RECEIVING SET
Q- GROUND FOR RECEIVING SET
J
O
N
K
L
P
N
Q

FIG. 2

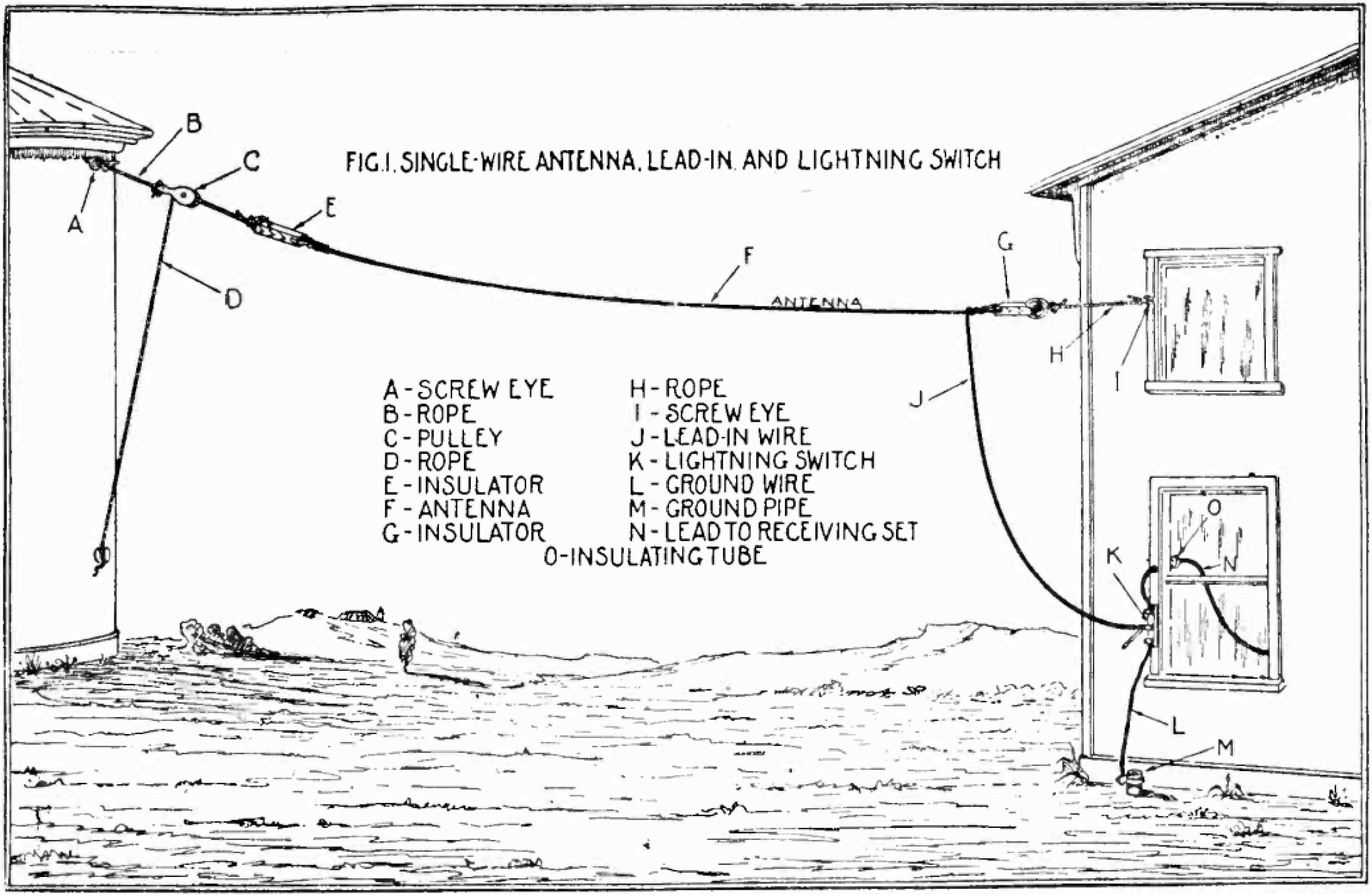
B
C
A
E
D
F
ANTENNA
G
H
I
J
O
K
N
L
M

FIG. I. SINGLE-WIRE ANTENNA, LEAD-IN, AND LIGHTNING SWITCH

A - SCREW EYE
B - ROPE
C - PULLEY
D - ROPE
E - INSULATOR
F - ANTENNA
G - INSULATOR
H - ROPE
I - SCREW EYE
J - LEAD-IN WIRE
K - LIGHTNING SWITCH
L - GROUND WIRE
M - GROUND PIPE
N - LEAD TO RECEIVING SET
O - INSULATING TUBE

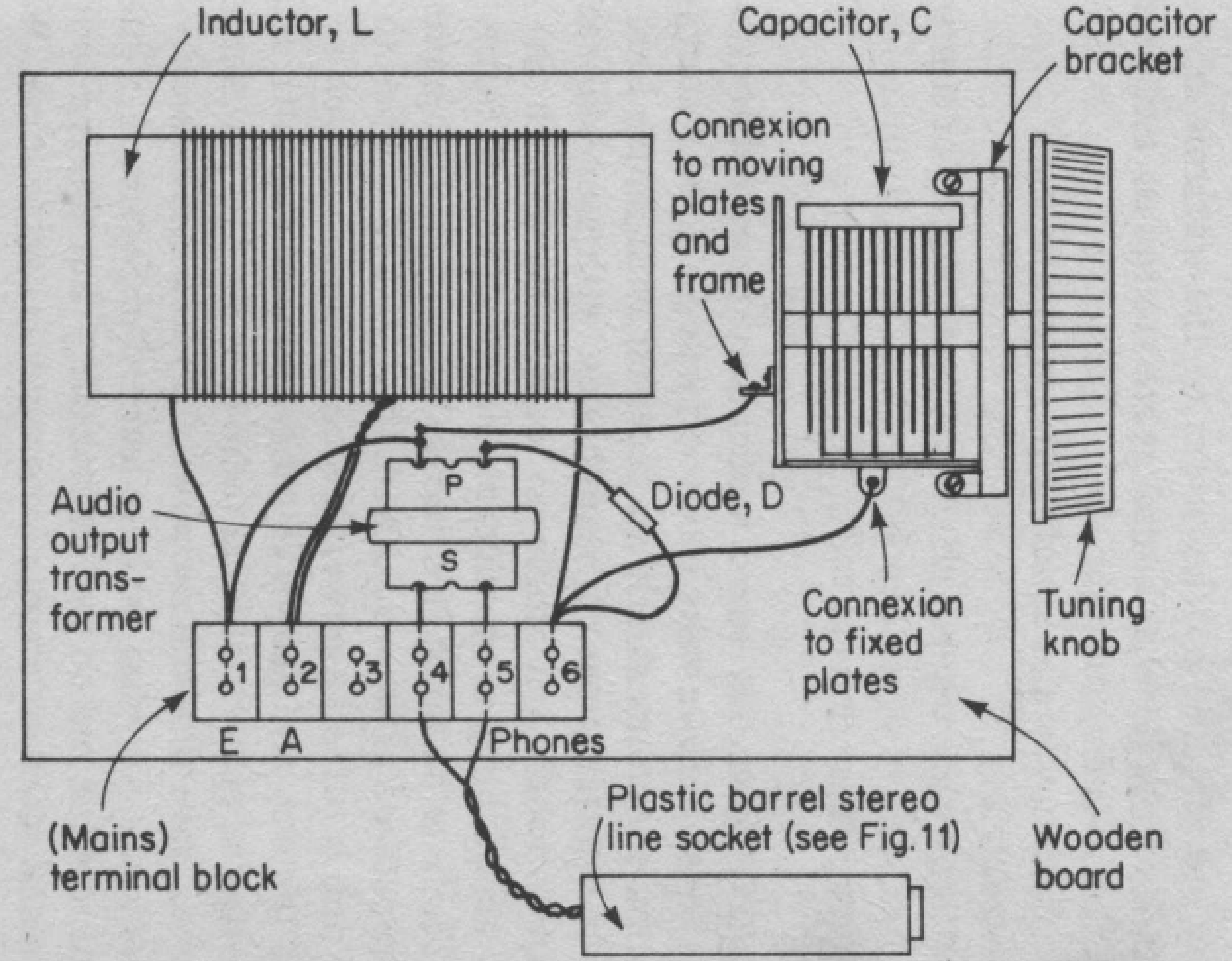
Inductor, L
Capacitor, C
Capacitor bracket
Connexion to moving plates and frame
Audio output transformer
P
S
Diode, D
Connexion to fixed plates
Tuning knob
1
2
3
4
5
6
E
A
Phones
Plastic barrel stereo line socket (see Fig.11)
(Mains) terminal block
Wooden board

Fig. 14 Suggested component arrangement for elementary crystal set

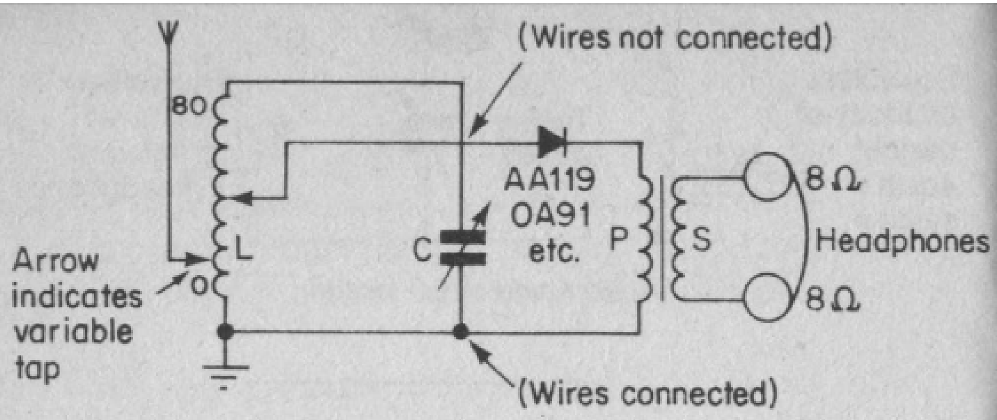
(Wires not connected)
80
L
Arrow indicates variable tap
0
AA119
OA91
etc.
C
P
S
8 Ω
Headphones
8 Ω
(Wires connected)

(i) Circuit

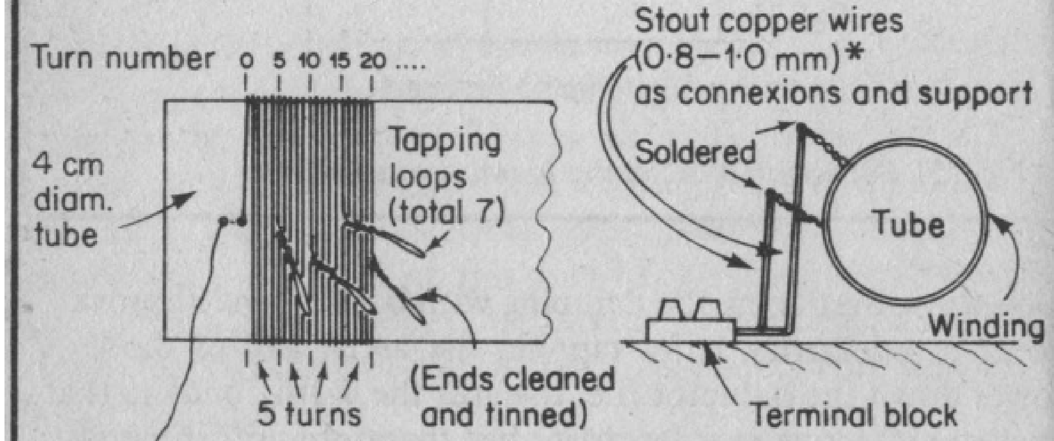
Turn number 0 5 10 15 20 ....
4 cm diam. tube
Tapping loops (total 7)
5 turns
(Ends cleaned and tinned)
Stout copper wires (0·8–1·0 mm)* as connexions and support
Soldered
Tube
Winding
Terminal block

(ii) Coil tappings and mounting

Fig. 16 Circuit with tapped inductor

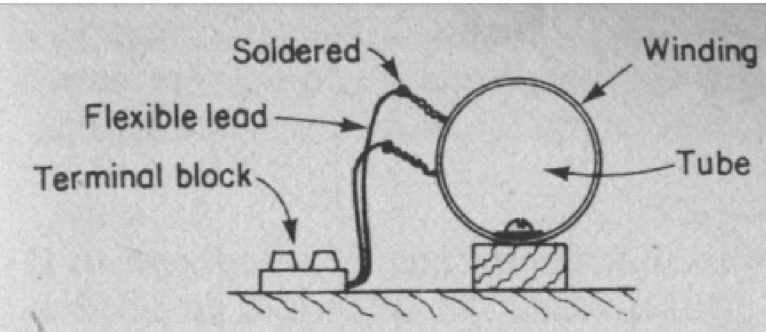
Soldered
Winding
Flexible lead
Tube
Terminal block

(iii) Alternative mounting

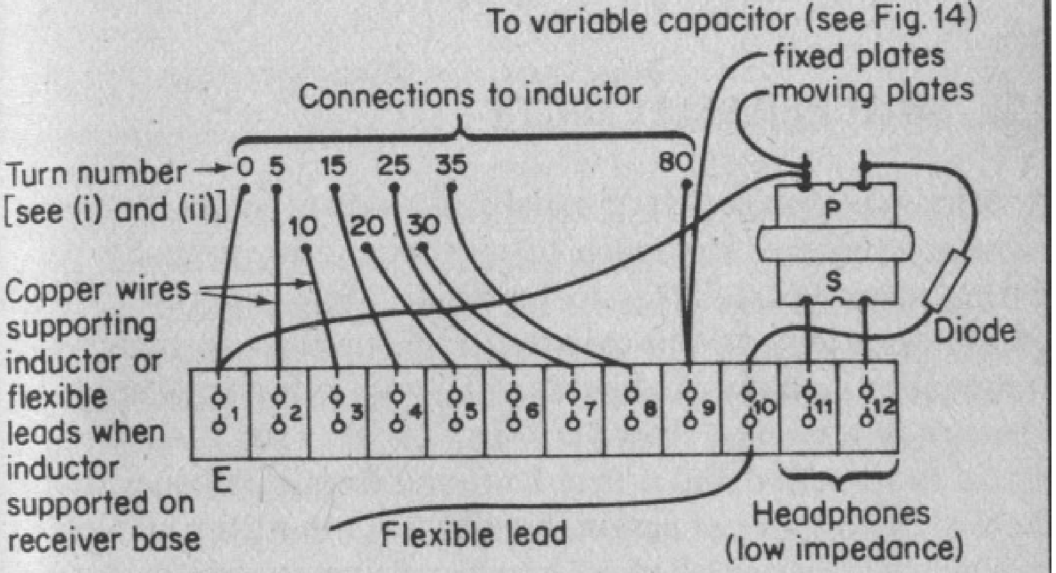
To variable capacitor (see Fig. 14)
fixed plates
moving plates
Connections to inductor
Turn number → 0 5 15 25 35 80
[see (i) and (ii)]
10 20 30
Copper wires supporting inductor or flexible leads when inductor supported on receiver base
P
S
Diode
1 2 3 4 5 6 7 8 9 10 11 12
E
Flexible lead
Headphones (low impedance)

(iv) Suggested component arrangement

---

* 21–19 SWG, 20–18 AWG

required) and a *flying lead* for the diode, these components are shown in Fig.16(iv). This is doing the job properly, there is no reason however (except for unreliability of contact) why both aerial and diode flying leads should not terminate on *crocodile clips* and be clipped onto the chosen taps as required.

Earth is connected to terminal 1 and the headphones to 11 and 12. Both the aerial and the diode lead are tried at terminals 2 – 9, a game of "poke and hope" but one which can be rewarding. Remember that generally but not always, the tappings with the lower numbers reduce loudness but increase selectivity. Aerial to terminal 8, diode to 9 brings us back to Fig.13(i) of course.

5.2 SWITCHED SELECTIVITY

A technique of selection of aerial and diode tappings by means of rotary switches has much to recommend it especially if setting changes are likely to be needed for reception of different stations. In this case two single-pole 8-way switches are required, usually obtainable as 12-way so leaving 4 spare. The drawing symbol shown in Fig.17 speaks for itself with regard to its action and it may be found from catalogues that there are two types of *action*, by which is meant the manner in which the switch changes over from one contact to the adjoining one. *Break before make* switches disconnect one circuit before the next is connected and *make before break* have a change-over period during which both circuits are connected at once for a short time. Either type is suitable for us. A knob to rotate each switch is also required, a small one, say 2 cm diameter or less is ample, if with an indicator line or pointer, so much the better. The modifications to Fig.16 for switching are given in Fig.17.

With such rotary switches a search for the optimum arrange-

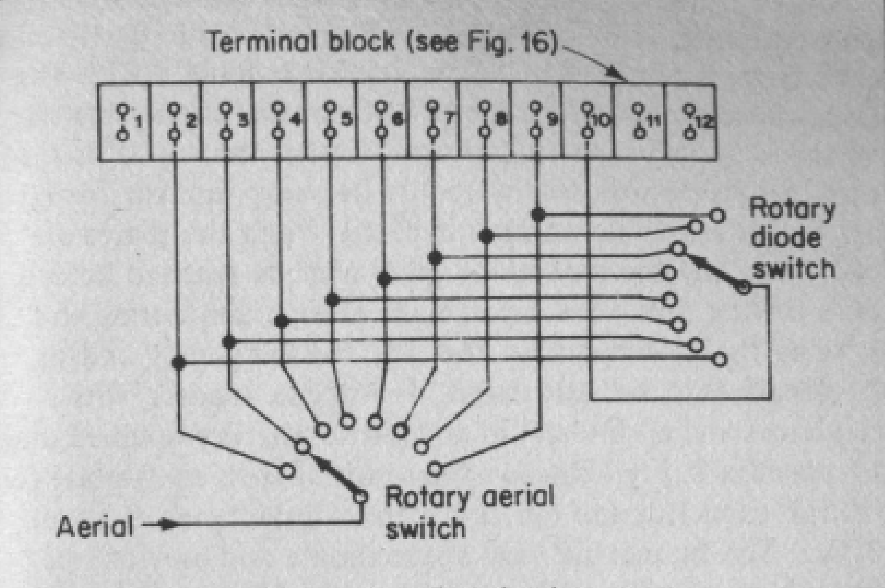

Fig. 17 - Switching aerial and diode leads

variable capacitor, the two switches and the headphone socket, the latter must then be of the chassis type. A pair of terminals for aerial and earth completes the receiver. On the panel the two rotary switches are easily labelled 1 – 8 but we are still uncertain about a tuning dial because we may not have the right variable capacitor for the inductor, this is the subject of the next section.

5.3 GETTING THE RANGE RIGHT

This is where we pause in receiver construction to remove some of the confusion which may still exist with regard to the tuning ingredients, wavelength, frequency, inductance and capacity, each of which has some bearing on the others, to fit together these four pieces of the puzzle, so to speak. For most crystal sets the inductance is fixed according to the variable capacitor available and we tune the receiver over the range by rotating the variable capacitor knob over half a

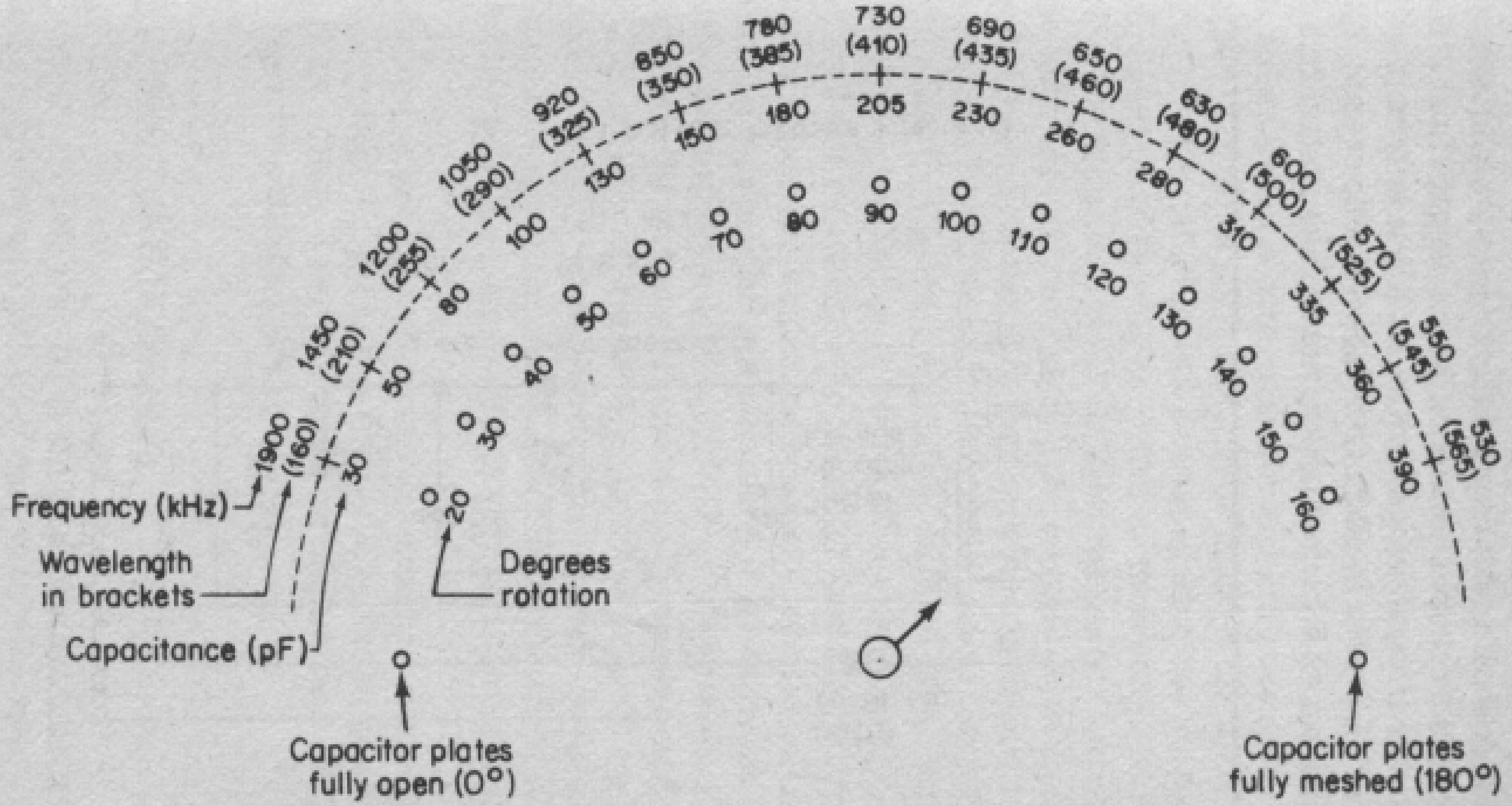

1900
(160)
30
1450
(210)
50
1200
(255)
80
1050
(290)
100
920
(325)
130
850
(350)
150
780
(385)
180
730
(410)
205
690
(435)
230
650
(460)
260
630
(480)
280
600
(500)
310
570
(525)
335
550
(545)
360
530
(565)
390
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
Frequency (kHz)
Wavelength in brackets
Capacitance (pF)
Degrees rotation
Capacitor plates fully open (0°)
Capacitor plates fully meshed (180°)

Fig. 18 Approximate capacitance and frequency values for 365 pF variable capacitor and 230 μH coil

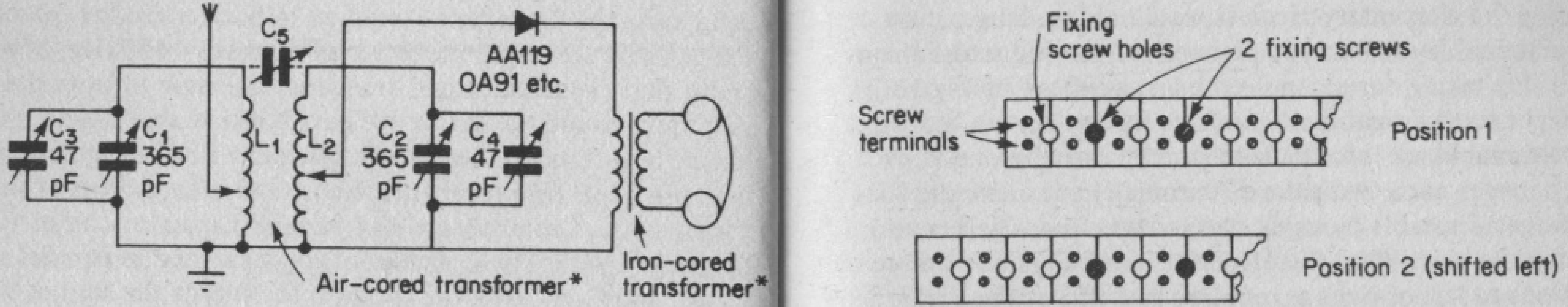
C5
AA119
OA91 etc.
C3
47
pF
C1
365
pF
L1
L2
C2
365
pF
C4
47
pF
Air-cored transformer*
Iron-cored
transformer*
Fixing
screw holes
2 fixing screws
Screw
terminals
Position 1
Position 2 (shifted left)

(i) Circuit

(iii) Moving inductor L_1

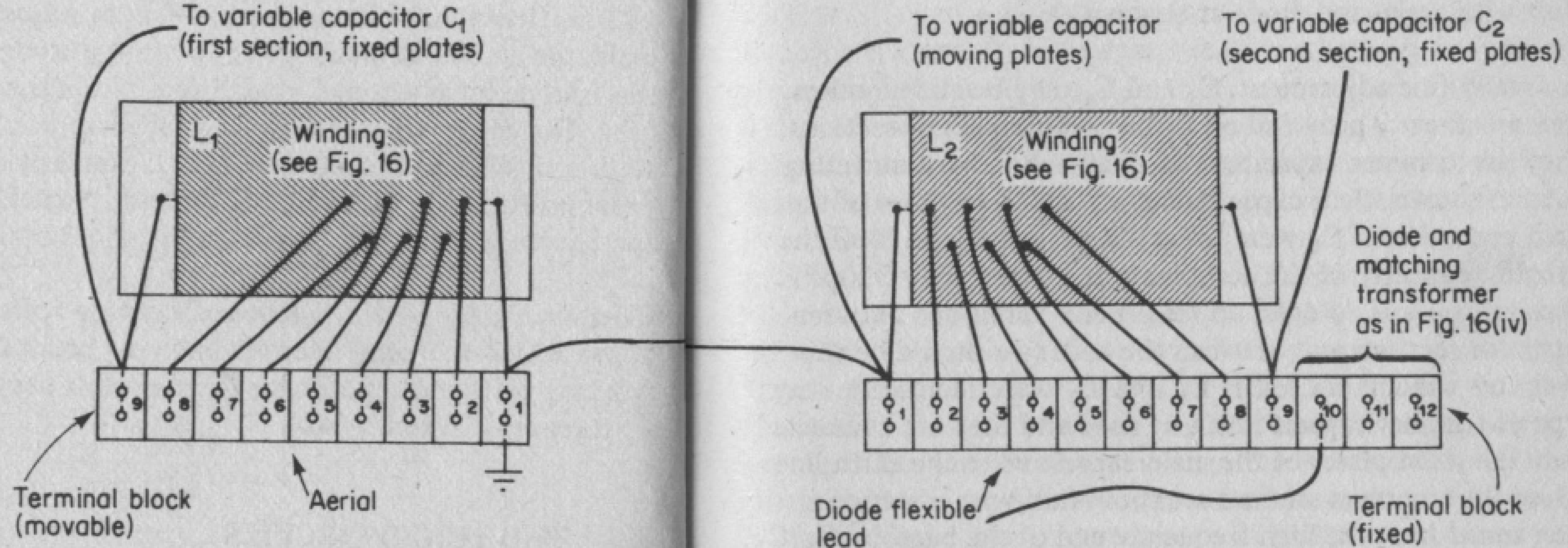
To variable capacitor C1
(first section, fixed plates)
L1
Winding
(see Fig. 16)
9
8
7
6
5
4
3
2
1
Terminal block
(movable)
Aerial
To variable capacitor
(moving plates)
To variable capacitor C2
(second section, fixed plates)
L2
Winding
(see Fig. 16)
Diode and
matching
transformer
as in Fig. 16(iv)
1
2
3
4
5
6
7
8
9
10
11
12
Diode flexible
lead
Terminal block
(fixed)

(ii) Arrangement of inductors

Fig. 21 A double-tuned crystal receiver

* See Section 2.4

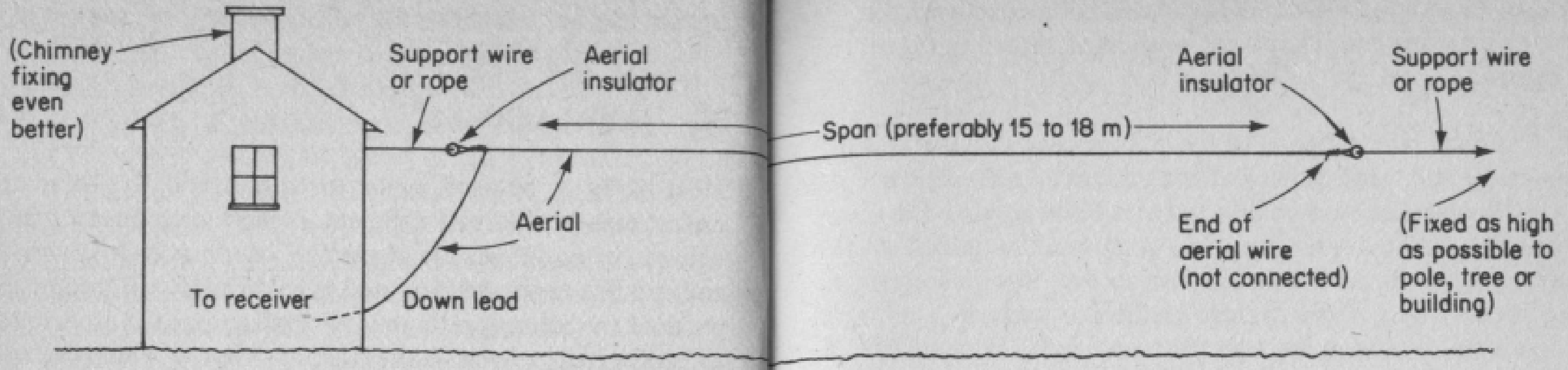
(Chimney fixing even better)
Support wire or rope
Aerial insulator
Aerial
To receiver
Down lead
Span (preferably 15 to 18 m)
Aerial insulator
Support wire or rope
End of aerial wire (not connected)
(Fixed as high as possible to pole, tree or building)

(i) Outdoor Aerial

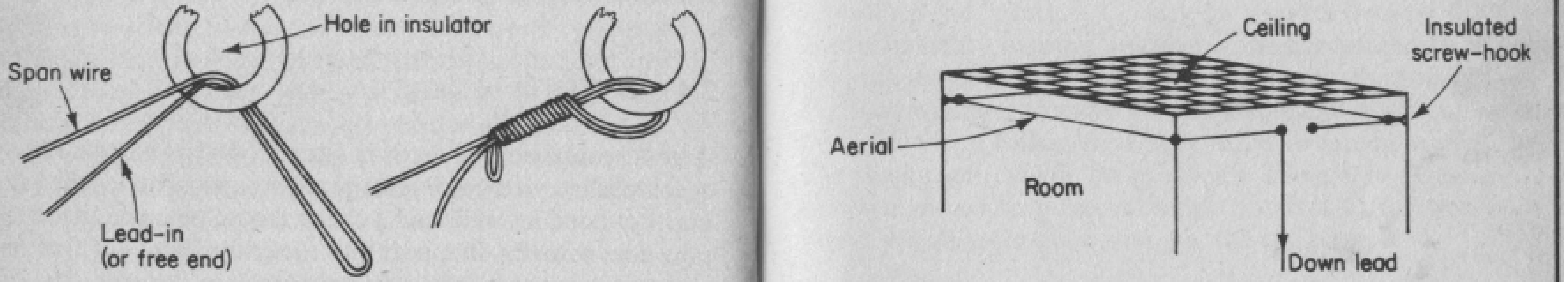
Hole in insulator
Span wire
Lead-in (or free end)
Ceiling
Insulated screw-hook
Aerial
Room
Down lead

(ii) Attaching aerial to insulator

(iii) Room aerial

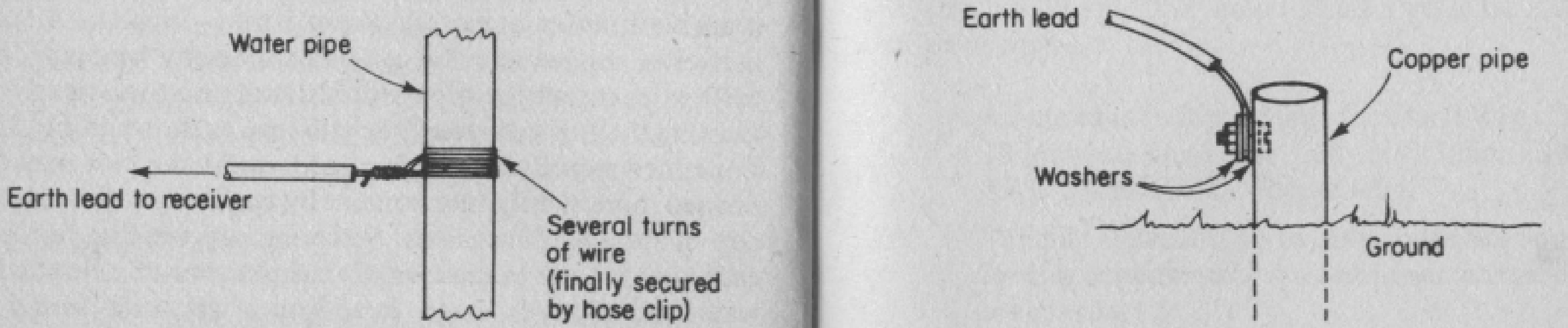
Water pipe
Earth lead to receiver
Several turns of wire (finally secured by hose clip)
Earth lead
Copper pipe
Washers
Ground

(iv) Earth connection to water pipe

(v) Lead bolted to earth spike

Fig. 12 Aerial/earth systems

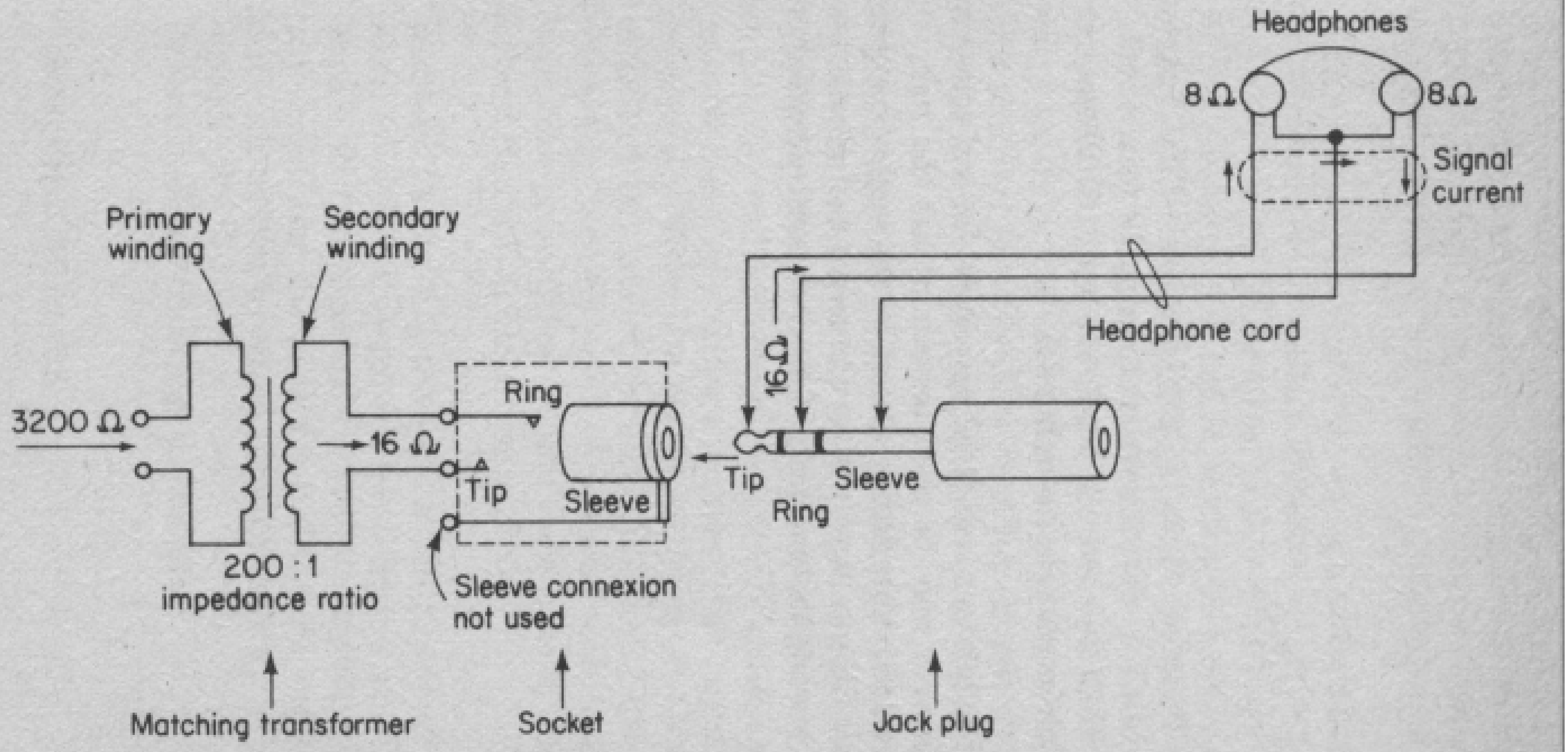
Headphones
8 Ω
8 Ω
Signal current
Headphone cord
Primary winding
Secondary winding
16 Ω
3200 Ω
16 Ω
Ring
Tip
Sleeve
Tip
Ring
Sleeve
200 : 1 impedance ratio
Sleeve connexion not used
Matching transformer
Socket
Jack plug

Fig. 11 Matching a high impedance receiver to low impedance headphones

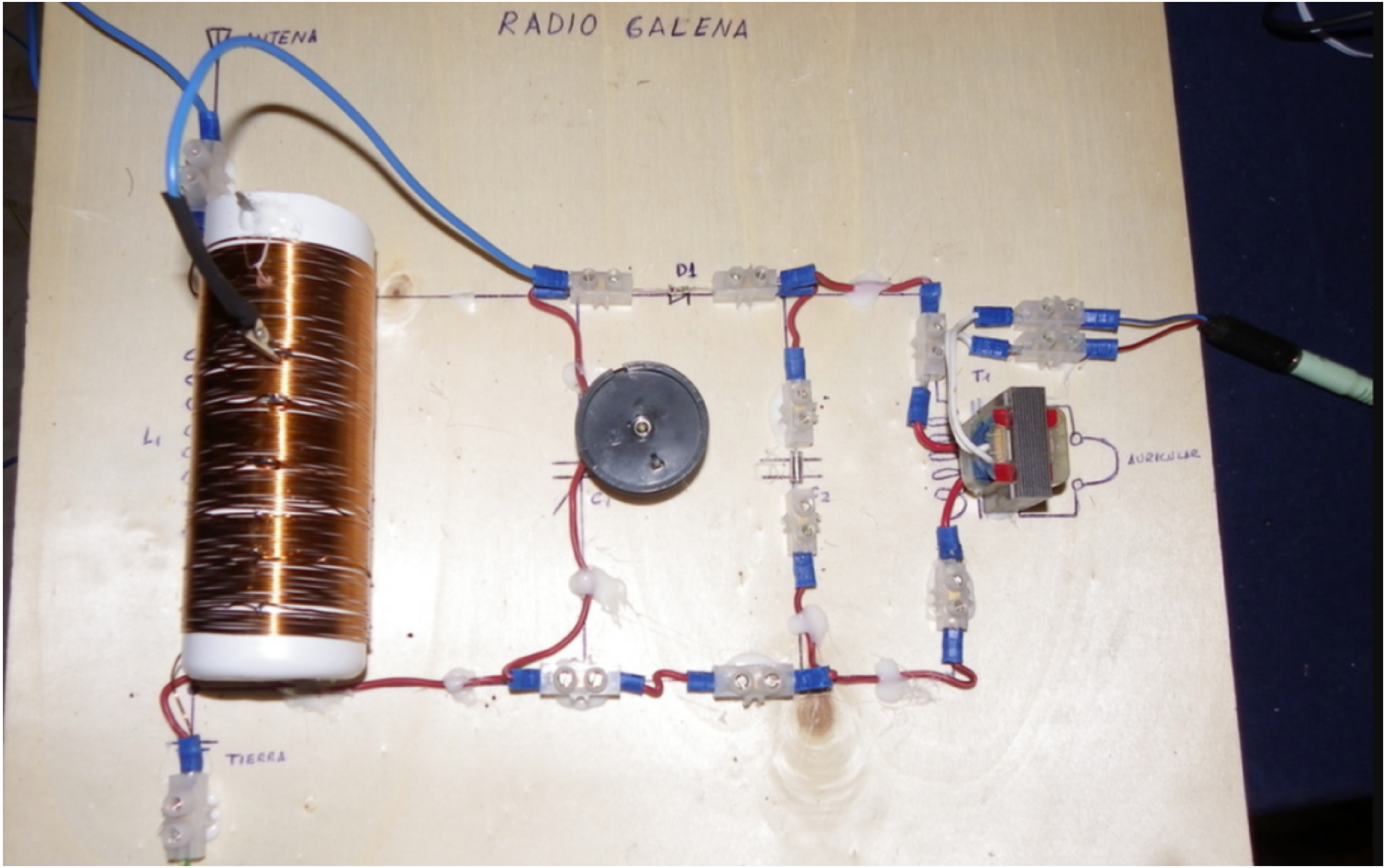
RADIO GALENA
ANTENA
D1
L1
C1
C2
T1
AURICULAR
TIERRA

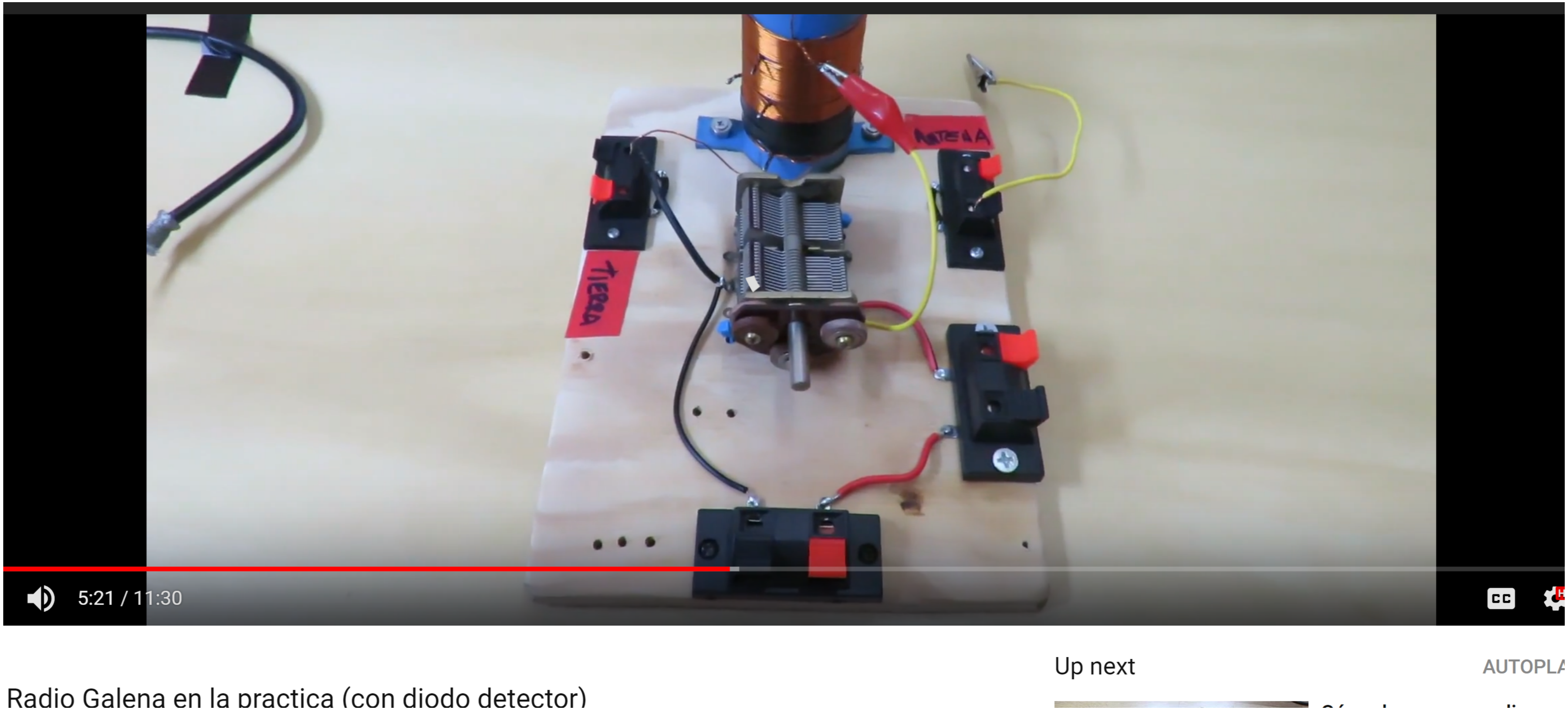
ANTENA
TIERRA
5:21 / 11:30
Up next
AUTOPLA

Radio Galena en la practica (con diodo detector)

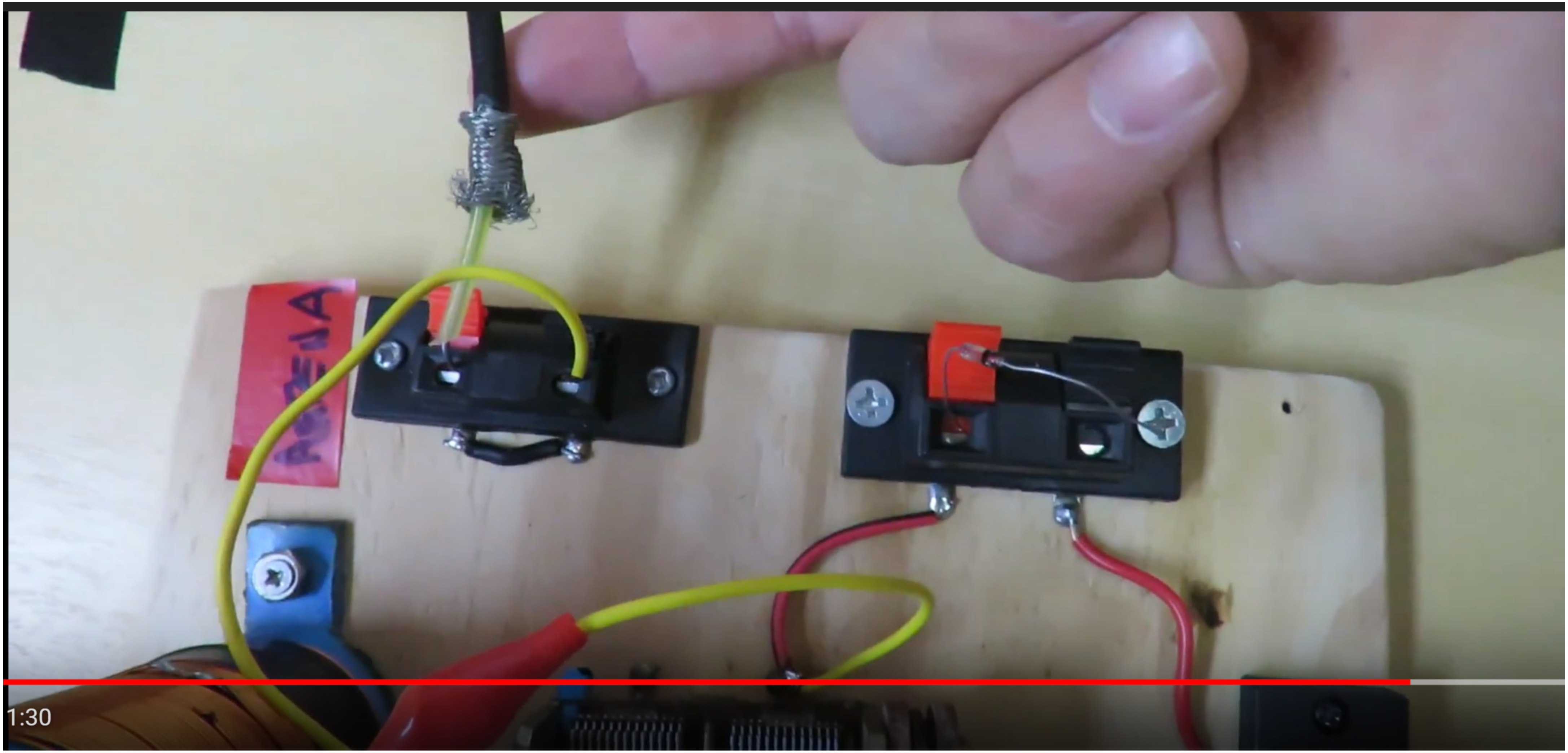
1:30

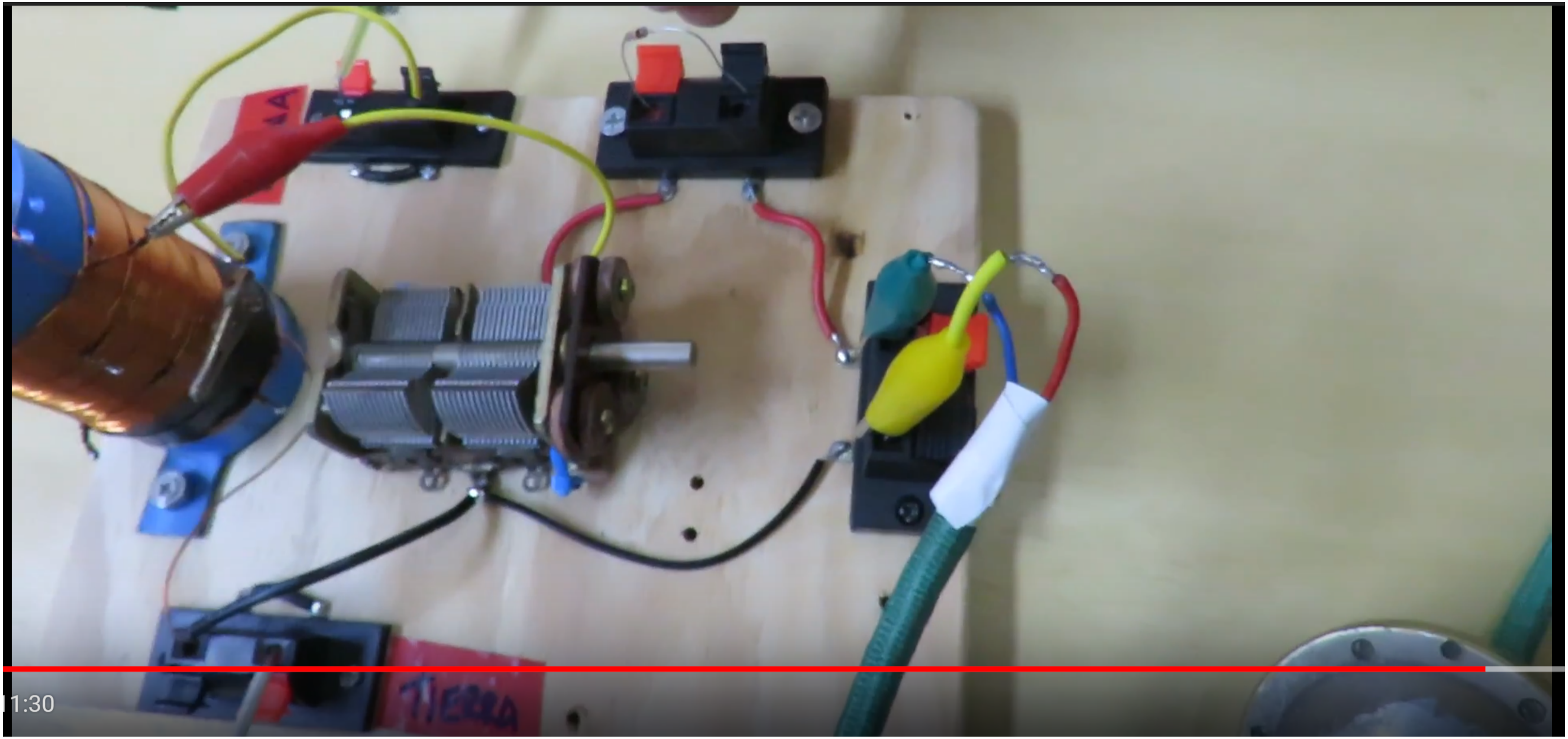
NA
TIERRA
1:30

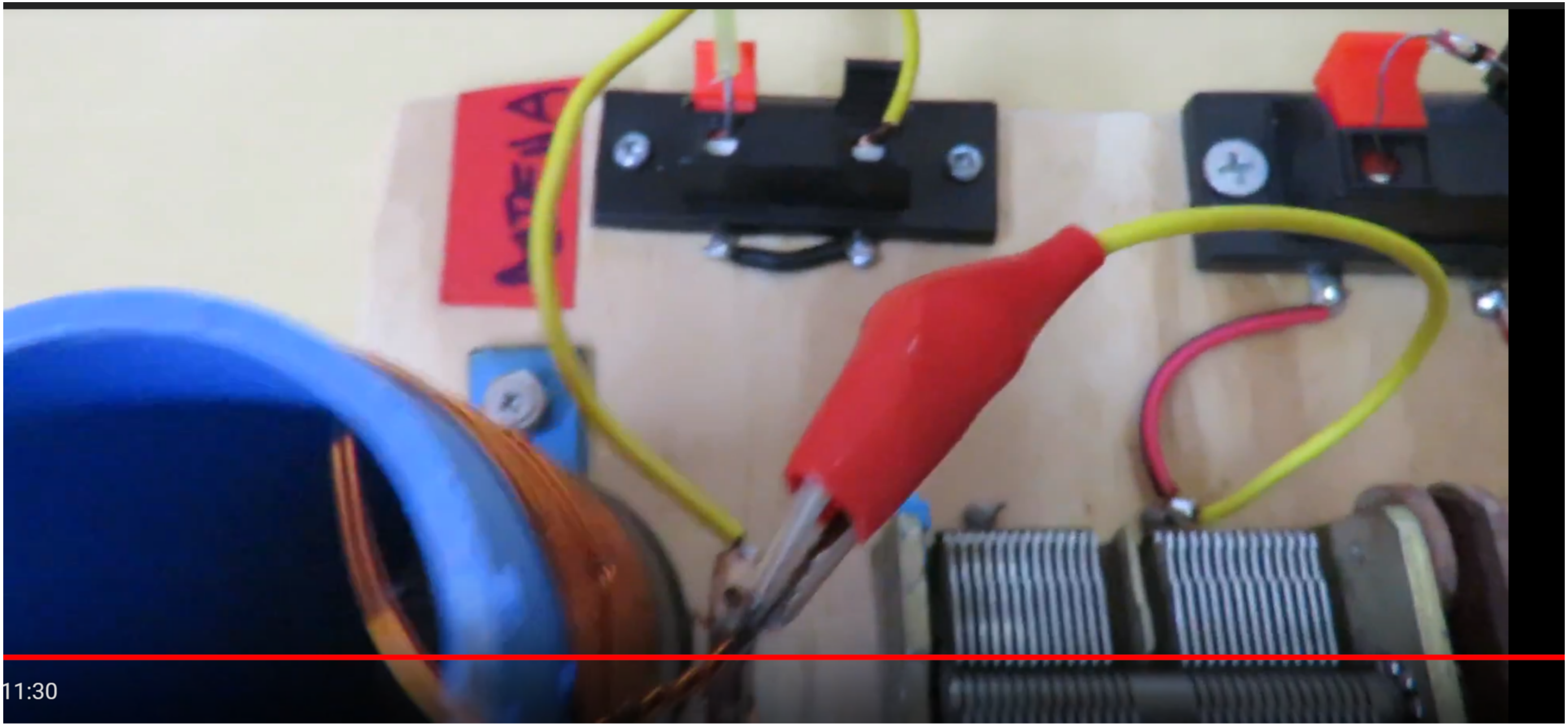

11:30

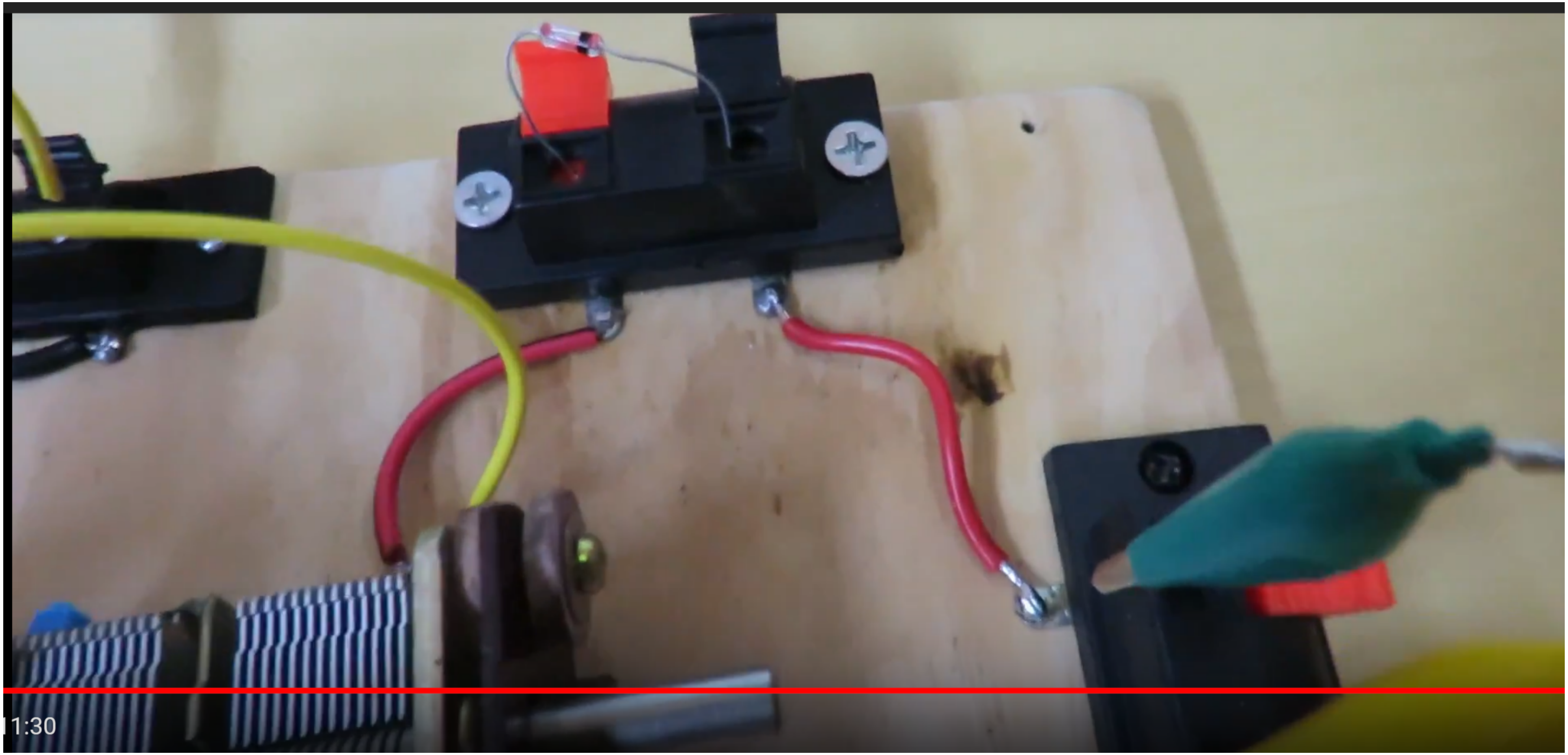
1:30

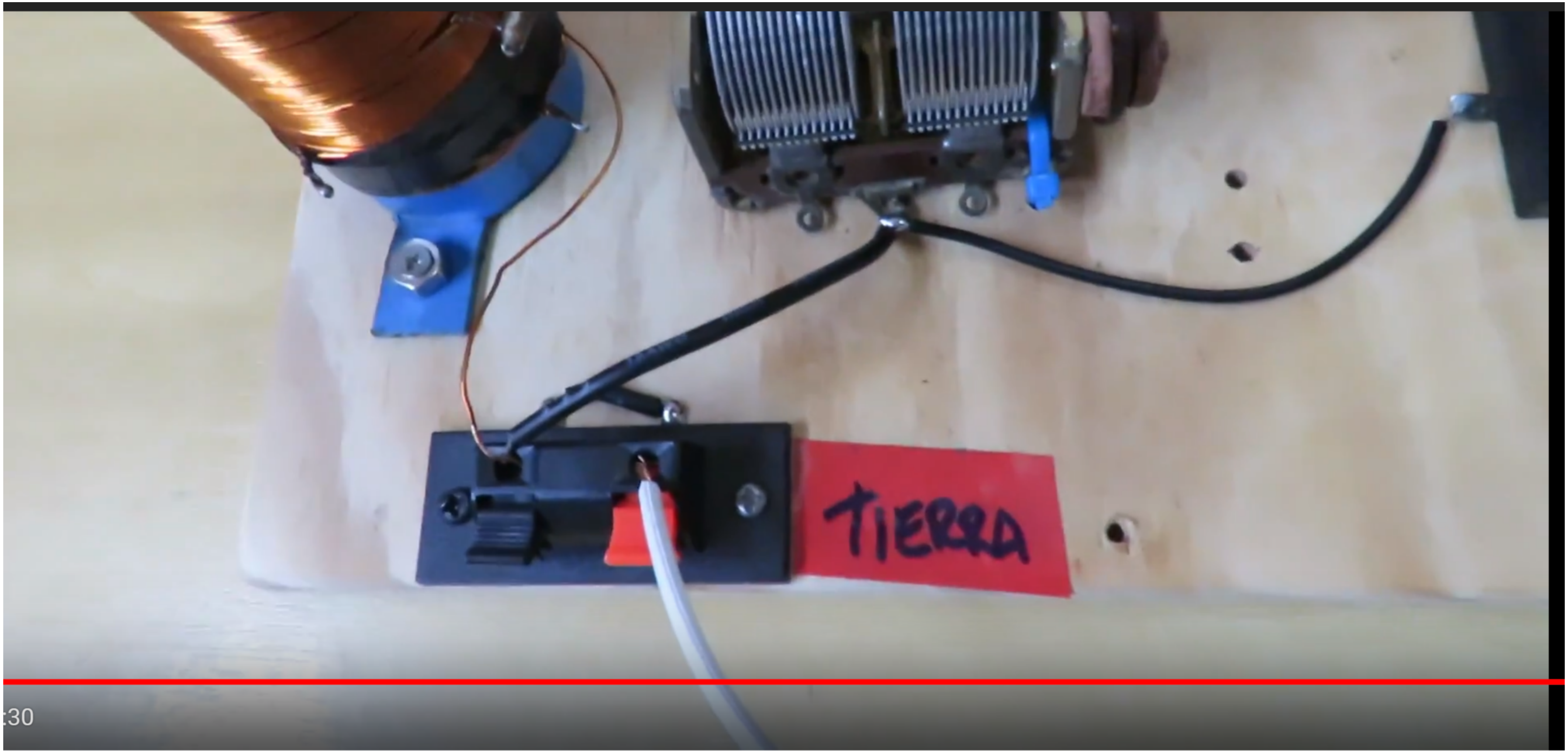
TIERRA
:30

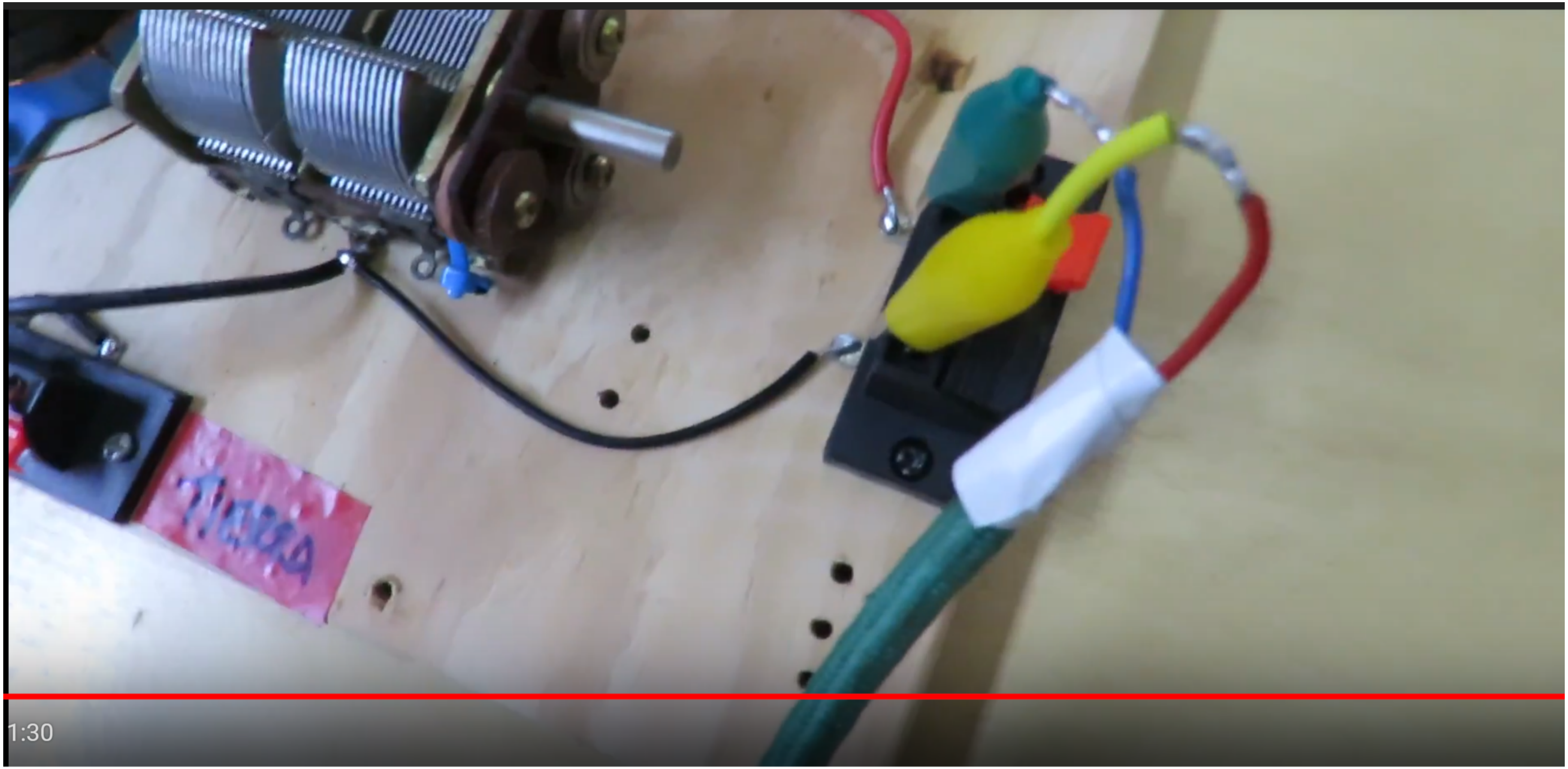
TIERRA
1:30

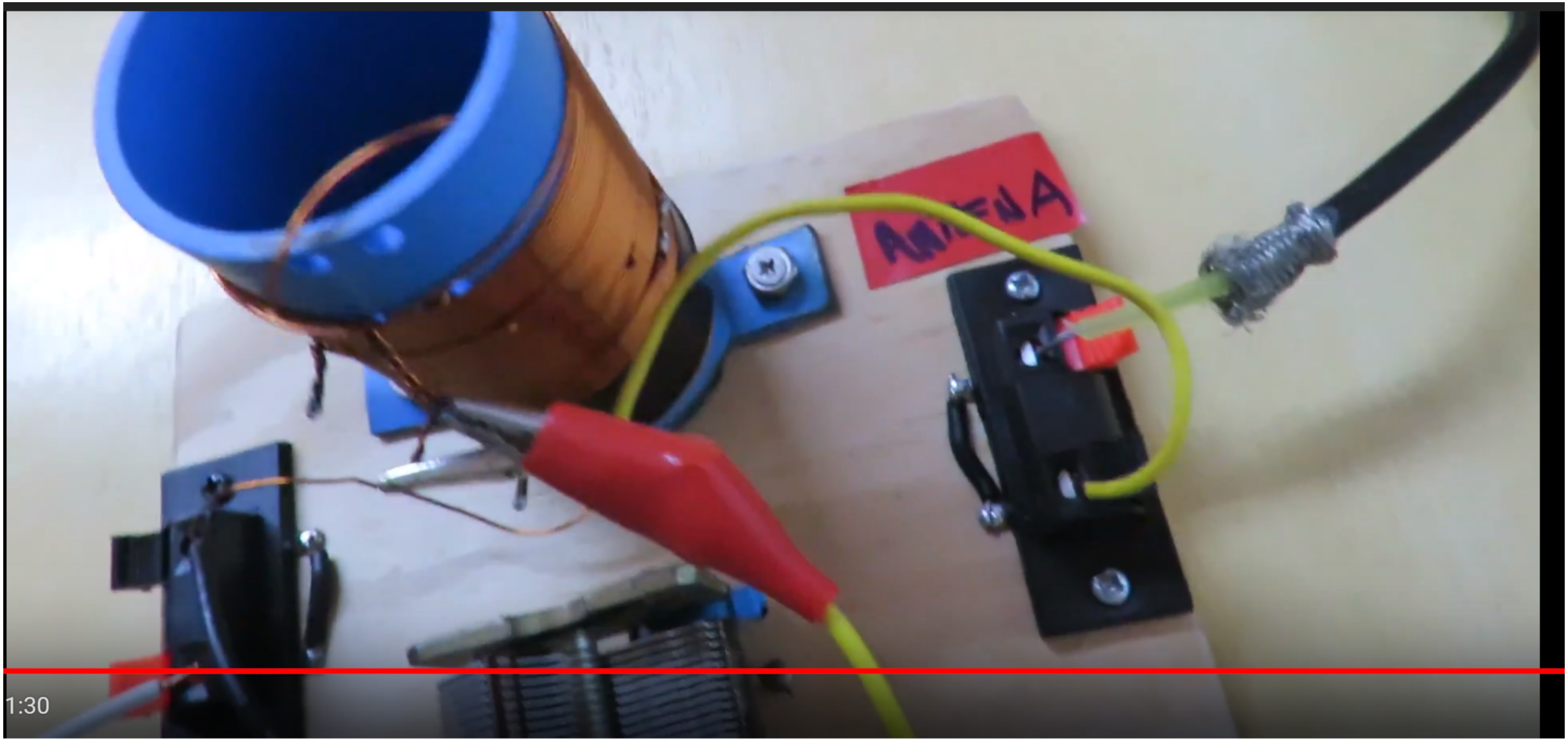
ANTENA
1:30

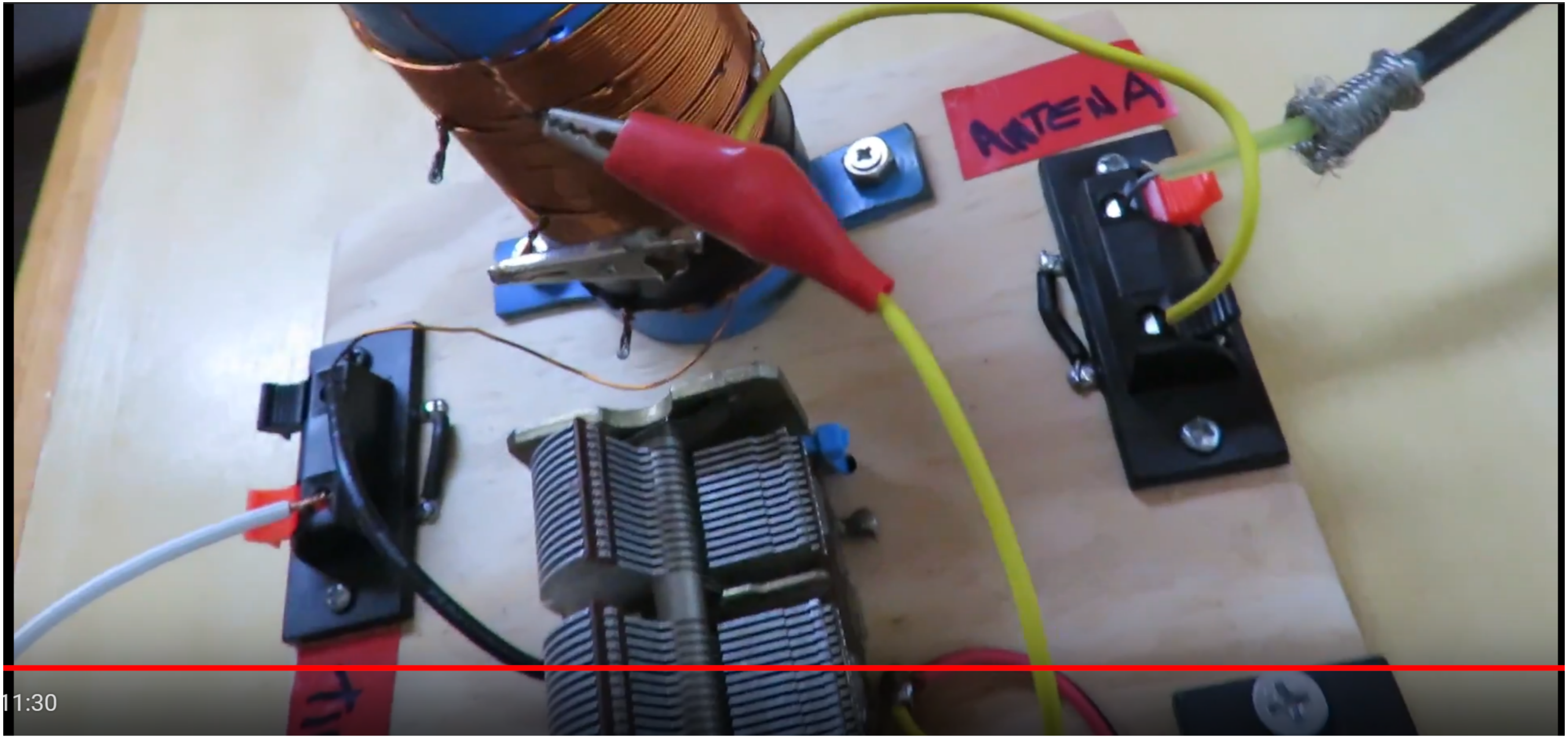
ANTENA
11:30

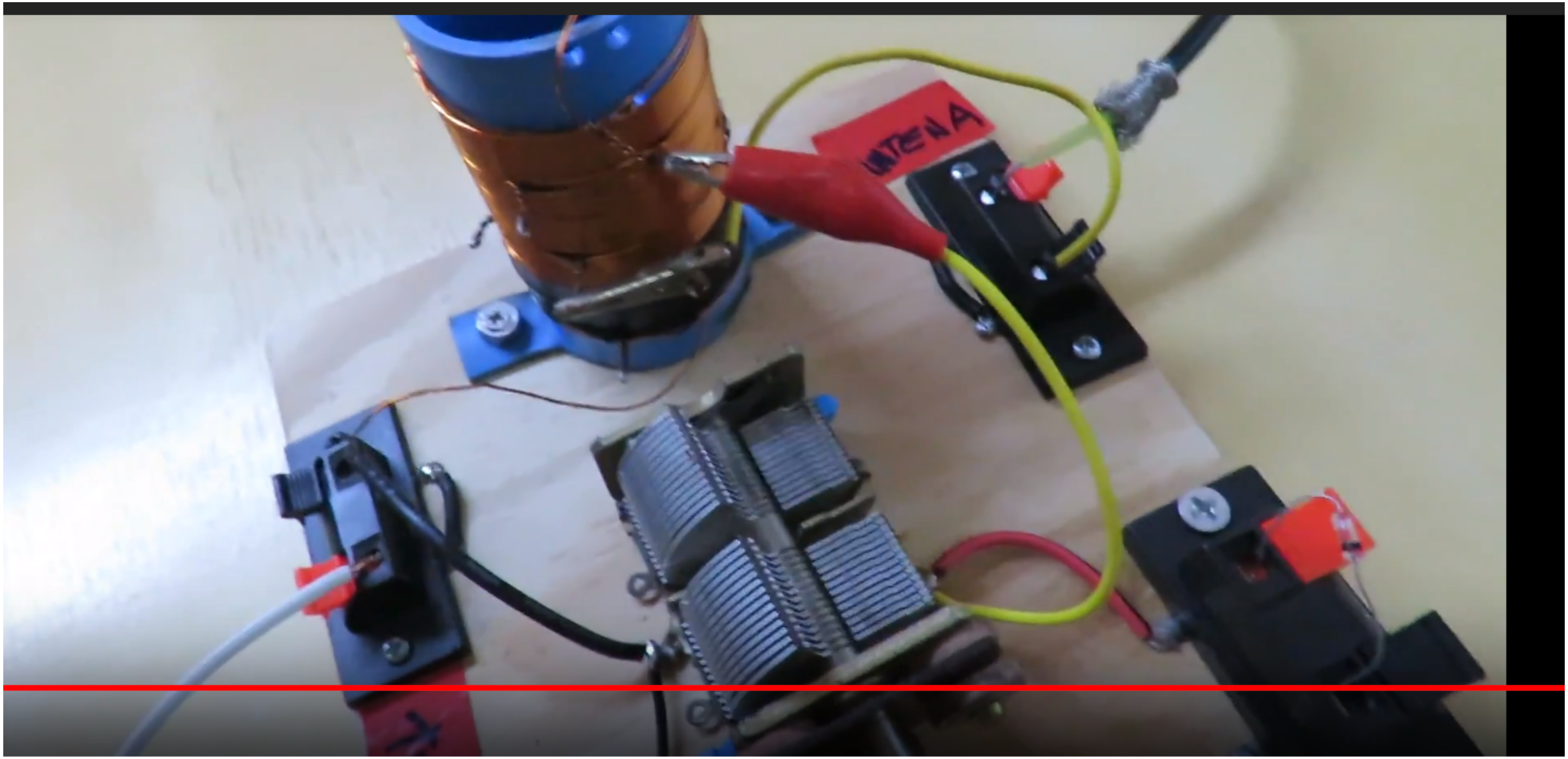
NTENA

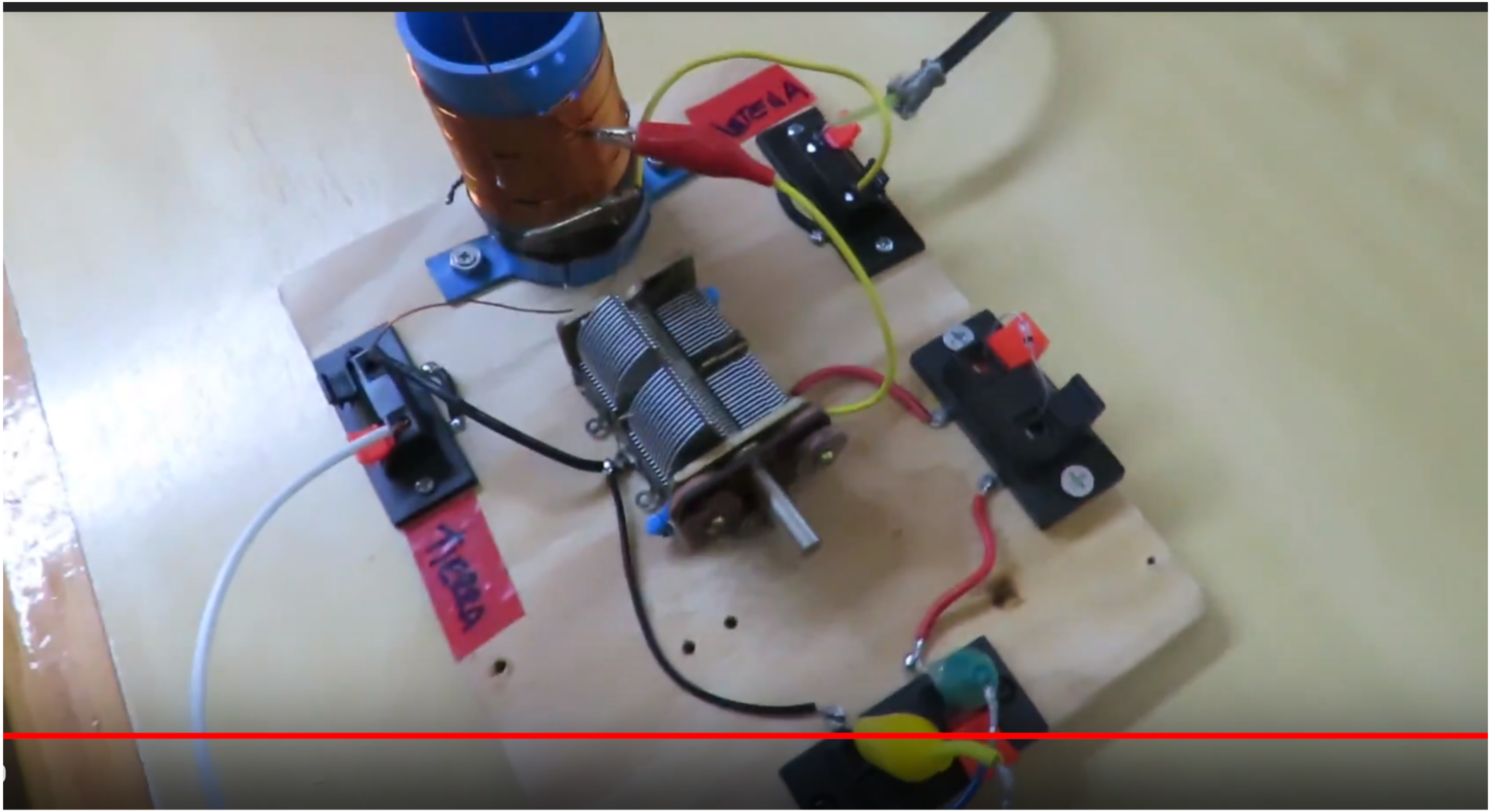
ANTENA
TIERRA

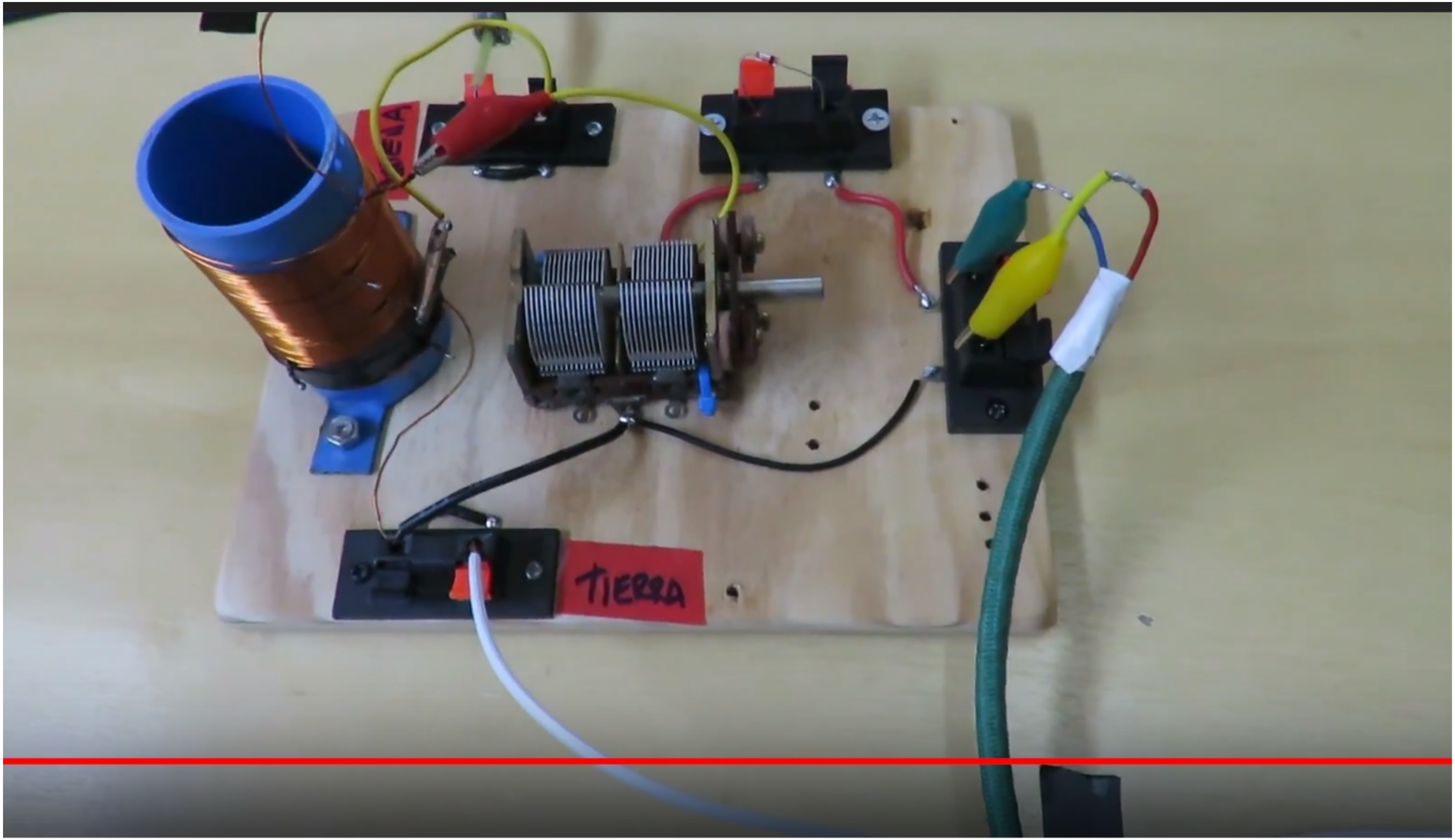
TIERRA

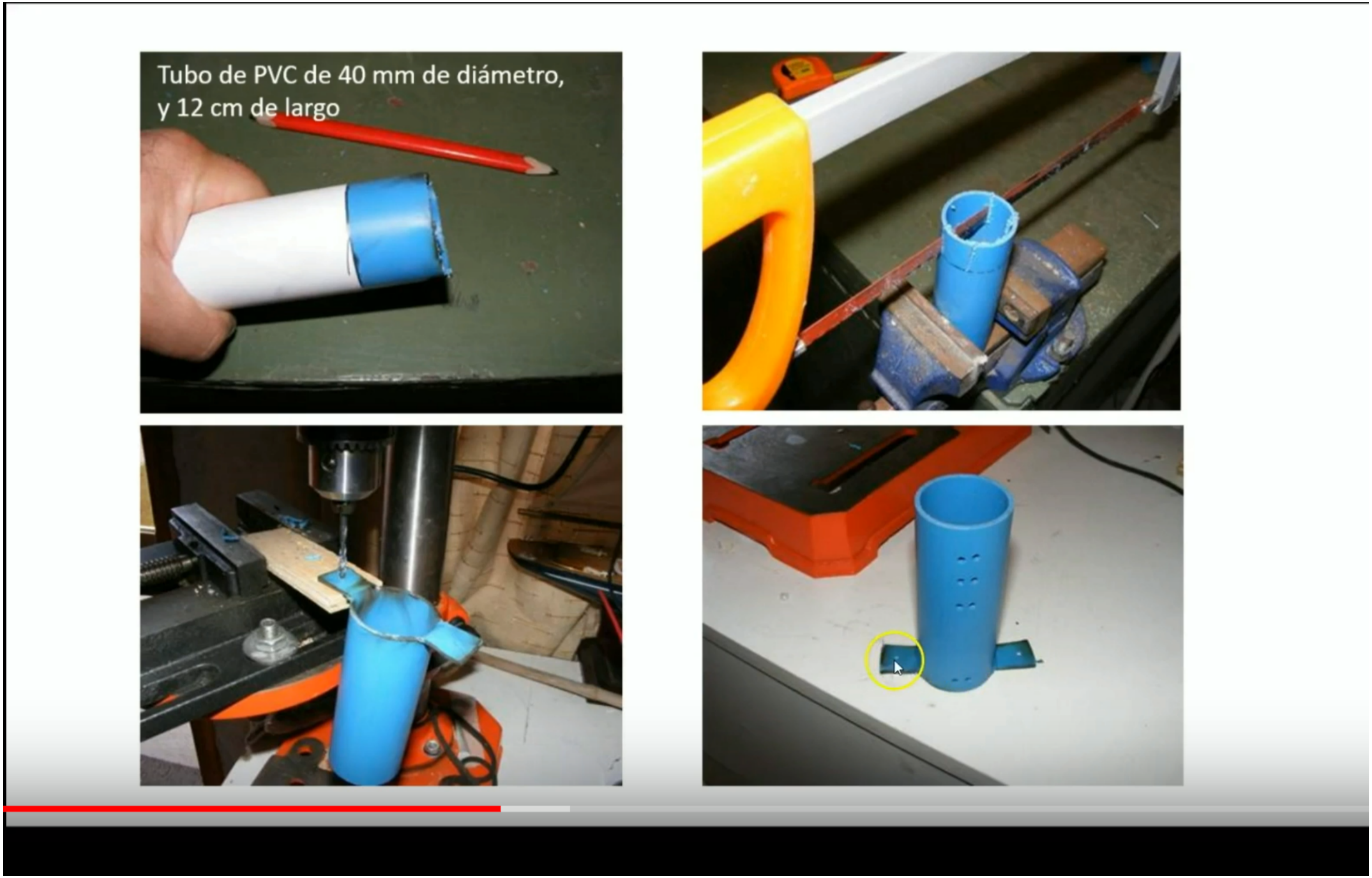

Tubo de PVC de 40 mm de diámetro, y 12 cm de largo

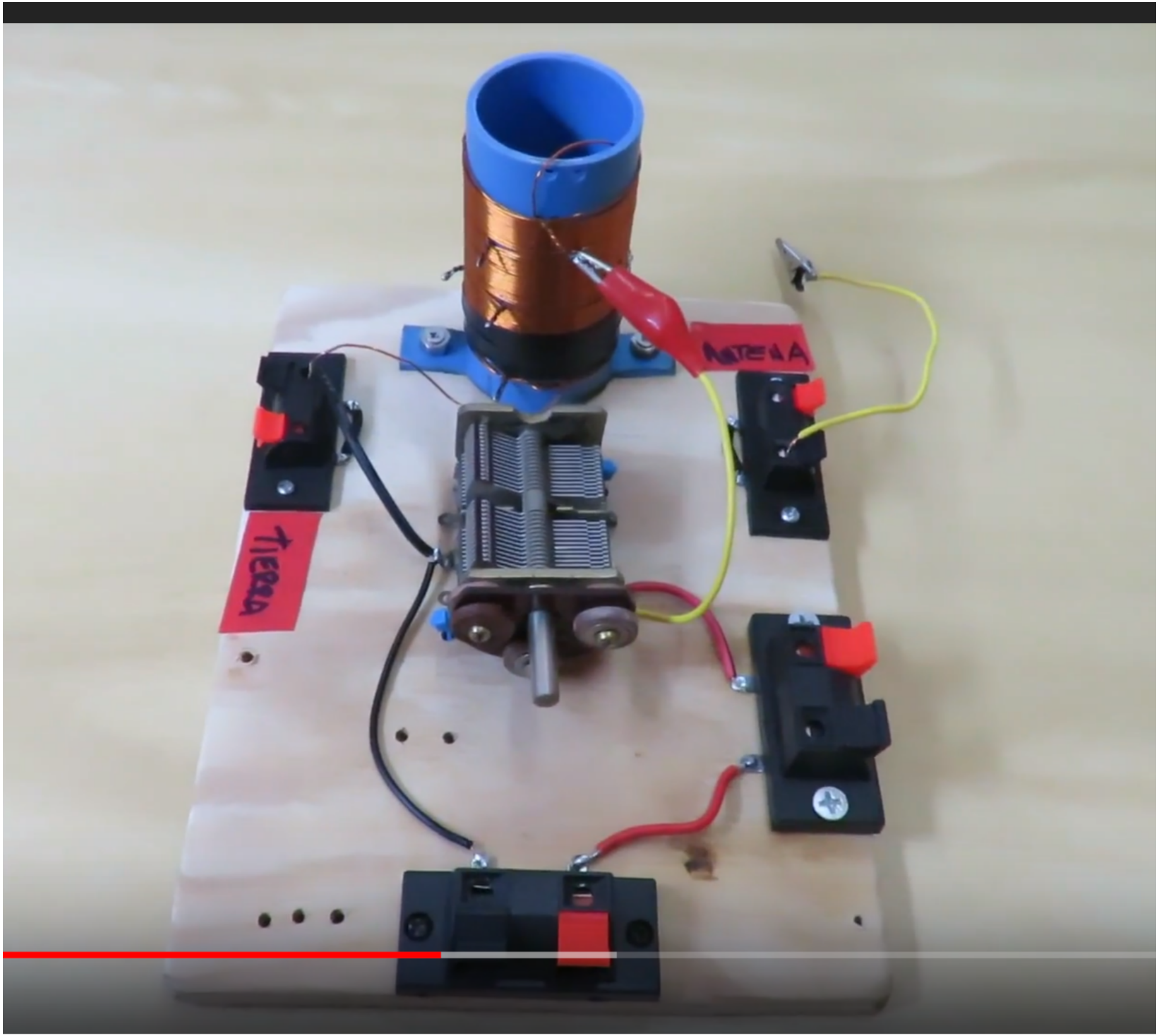
ANTENA
TIERRA

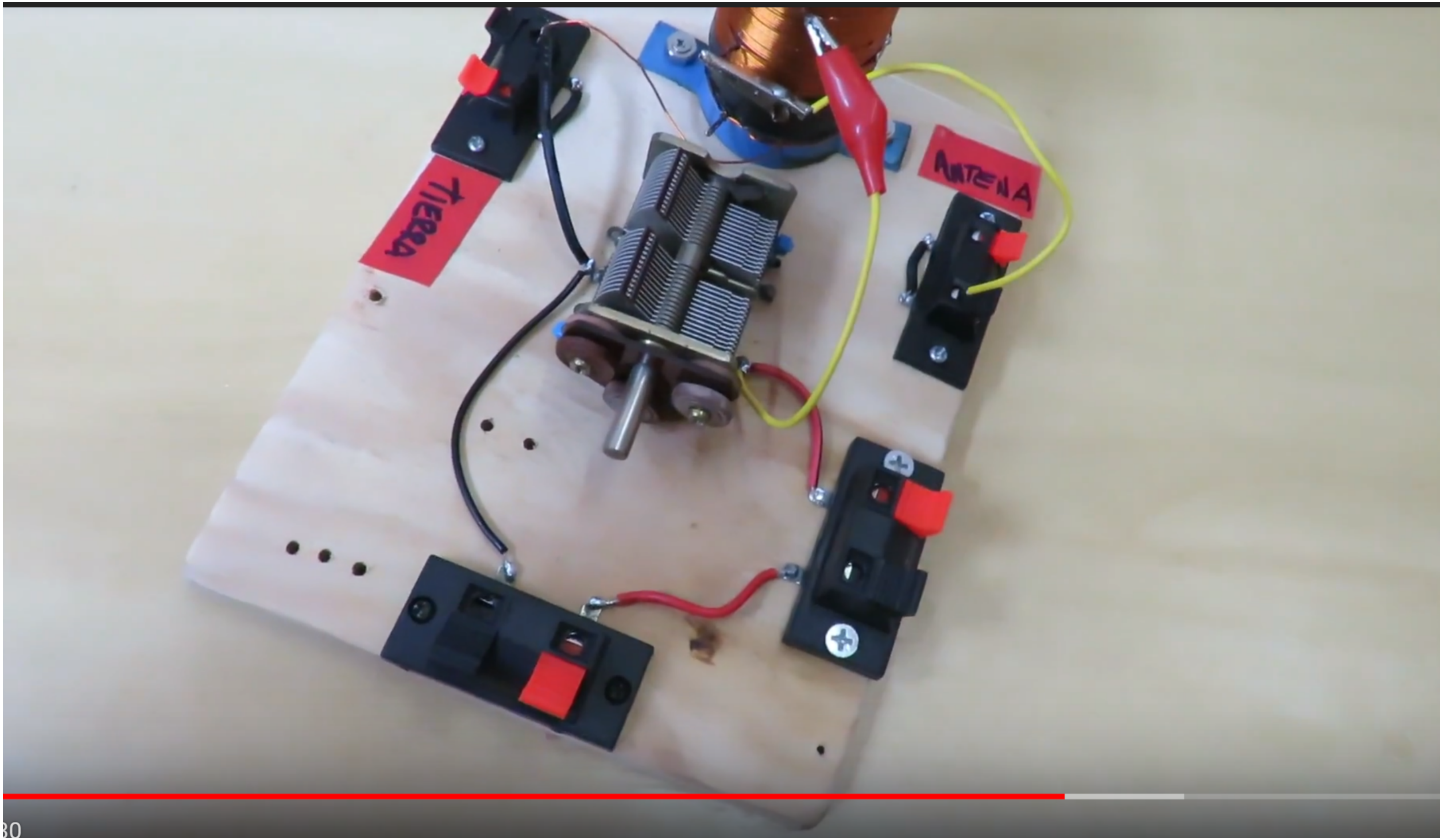
TIERRA
ANTENA

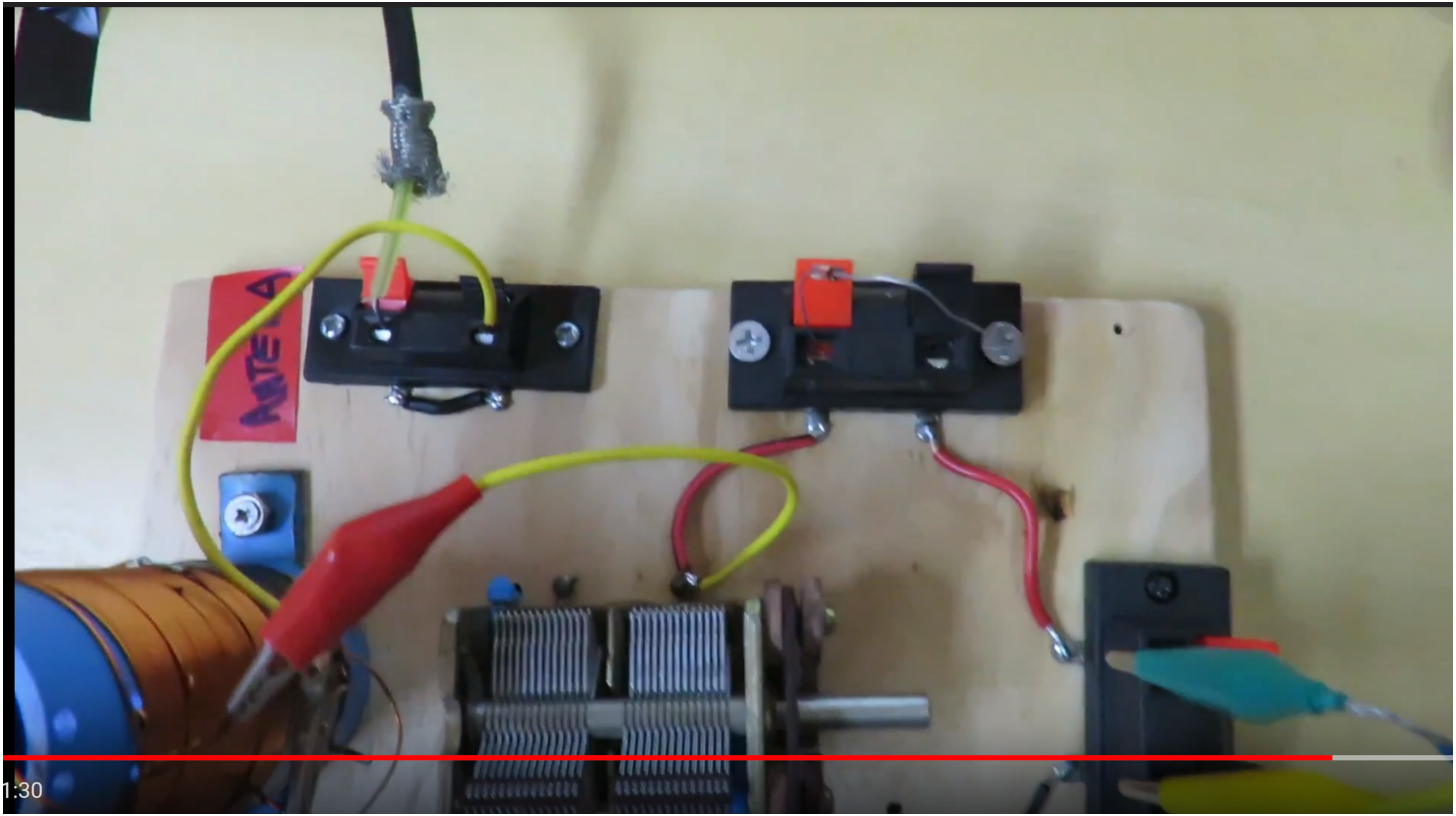
ANTENA
1:30

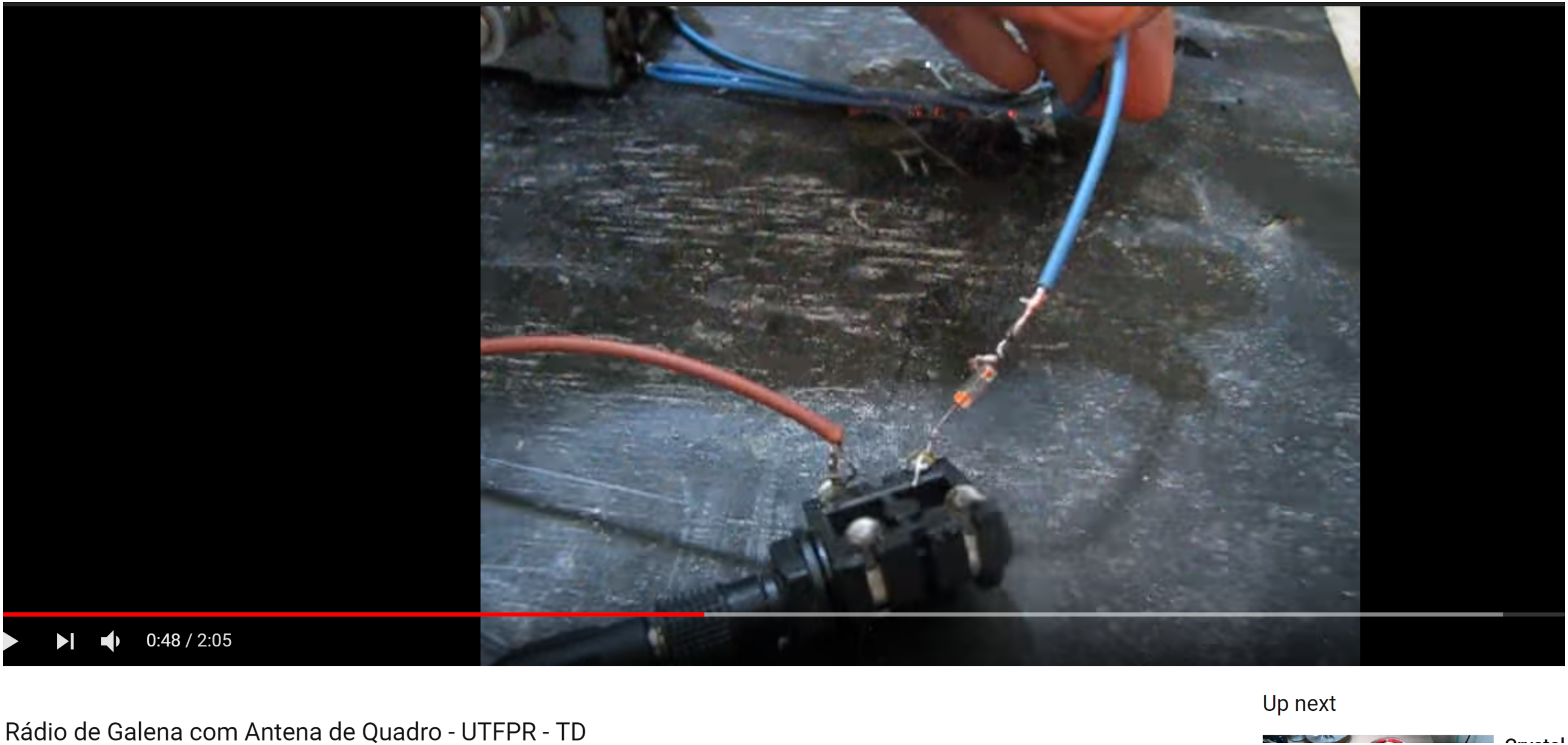
0:48 / 2:05
Up next

Rádio de Galena com Antena de Quadro - UTFPR - TD

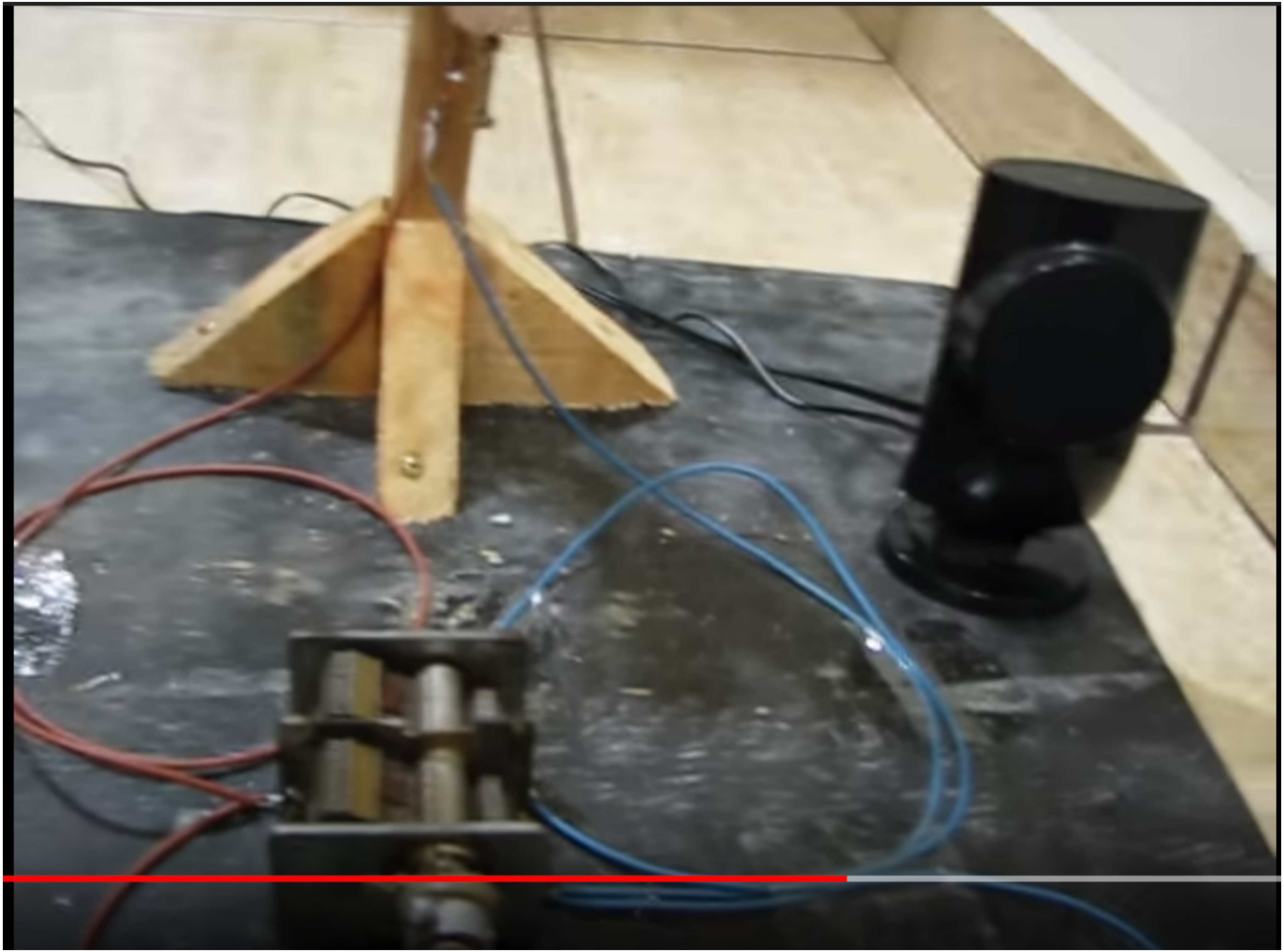

BiNGR R.
BRiel T.

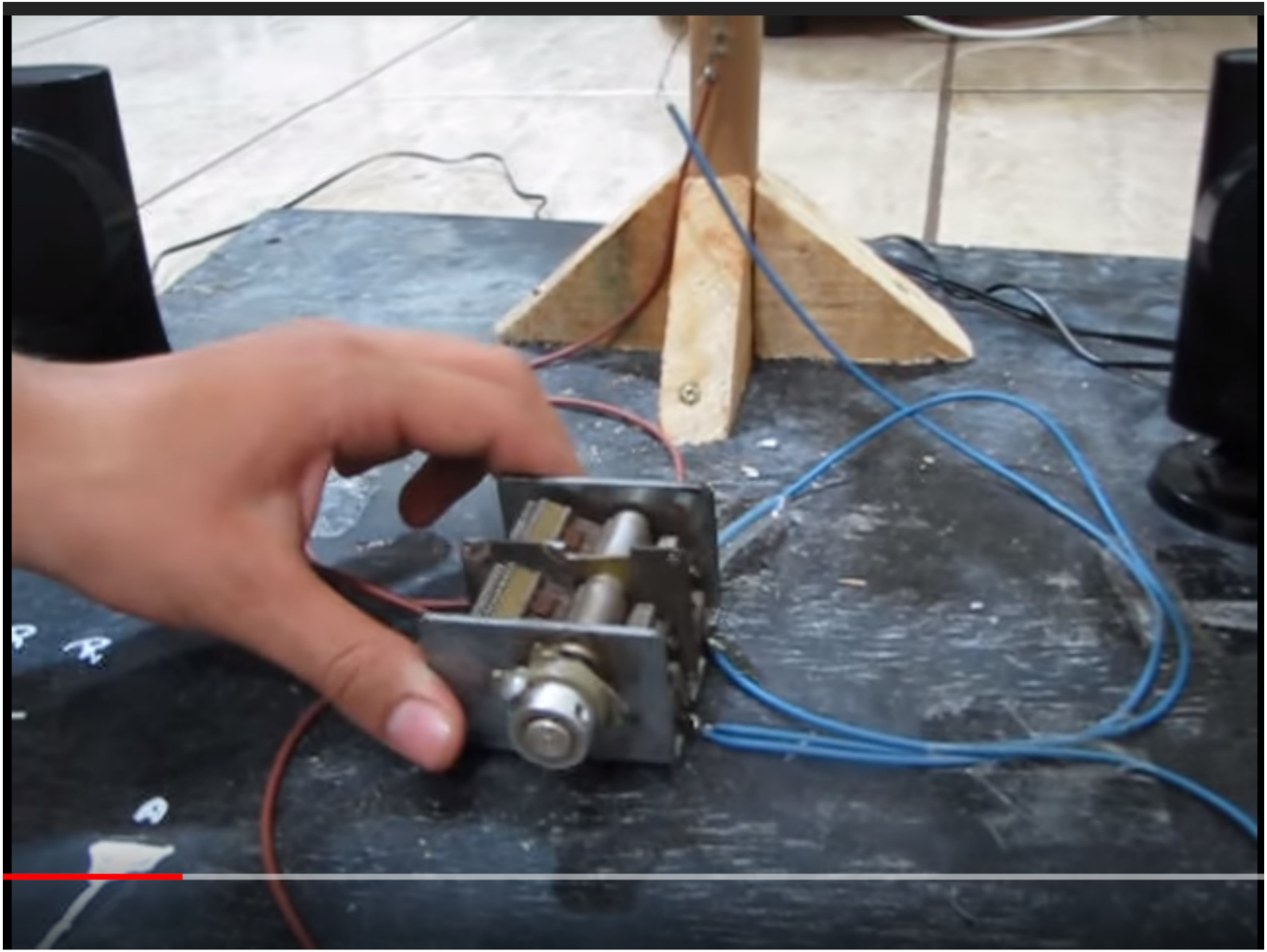
R
R
A

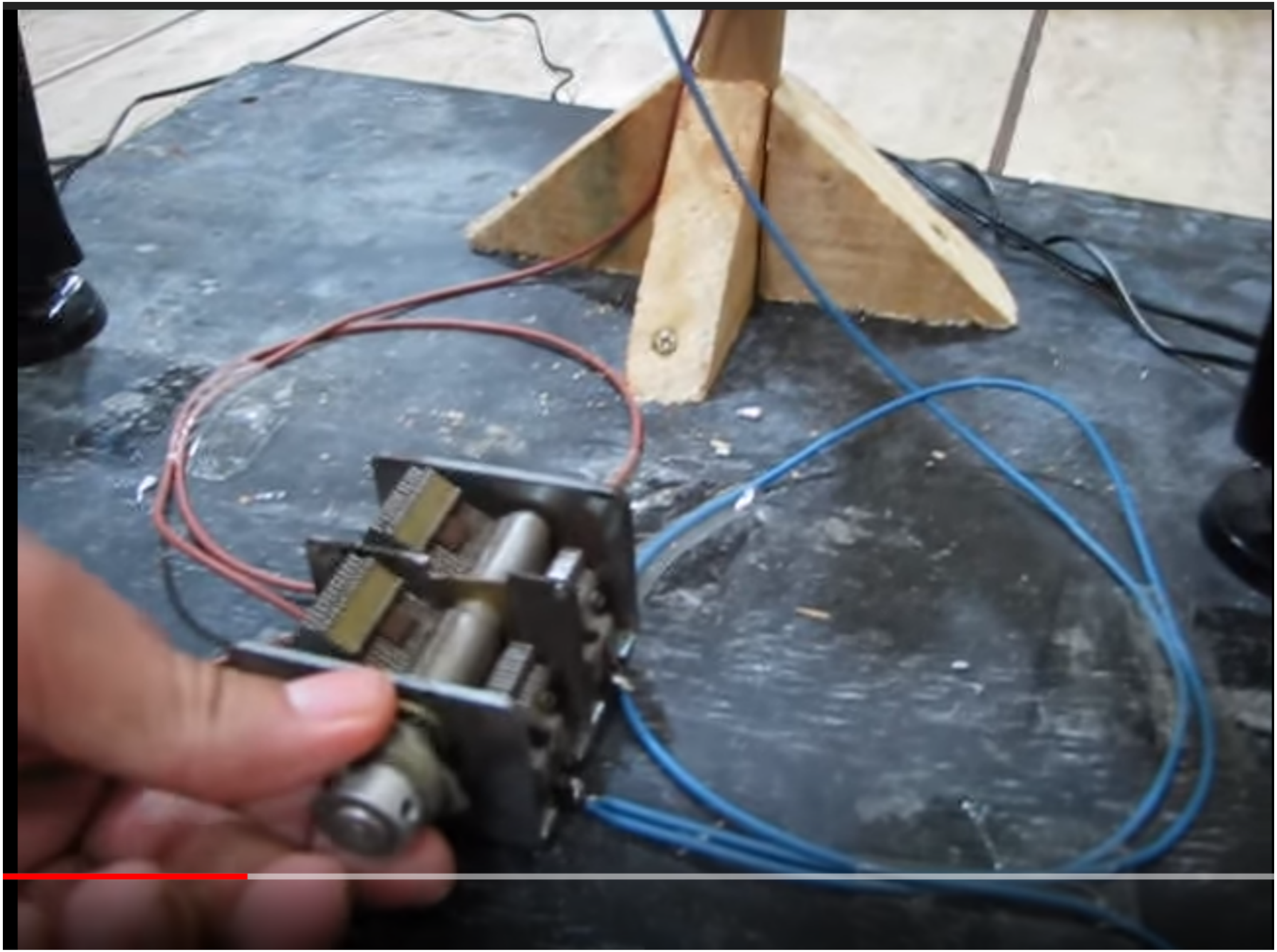

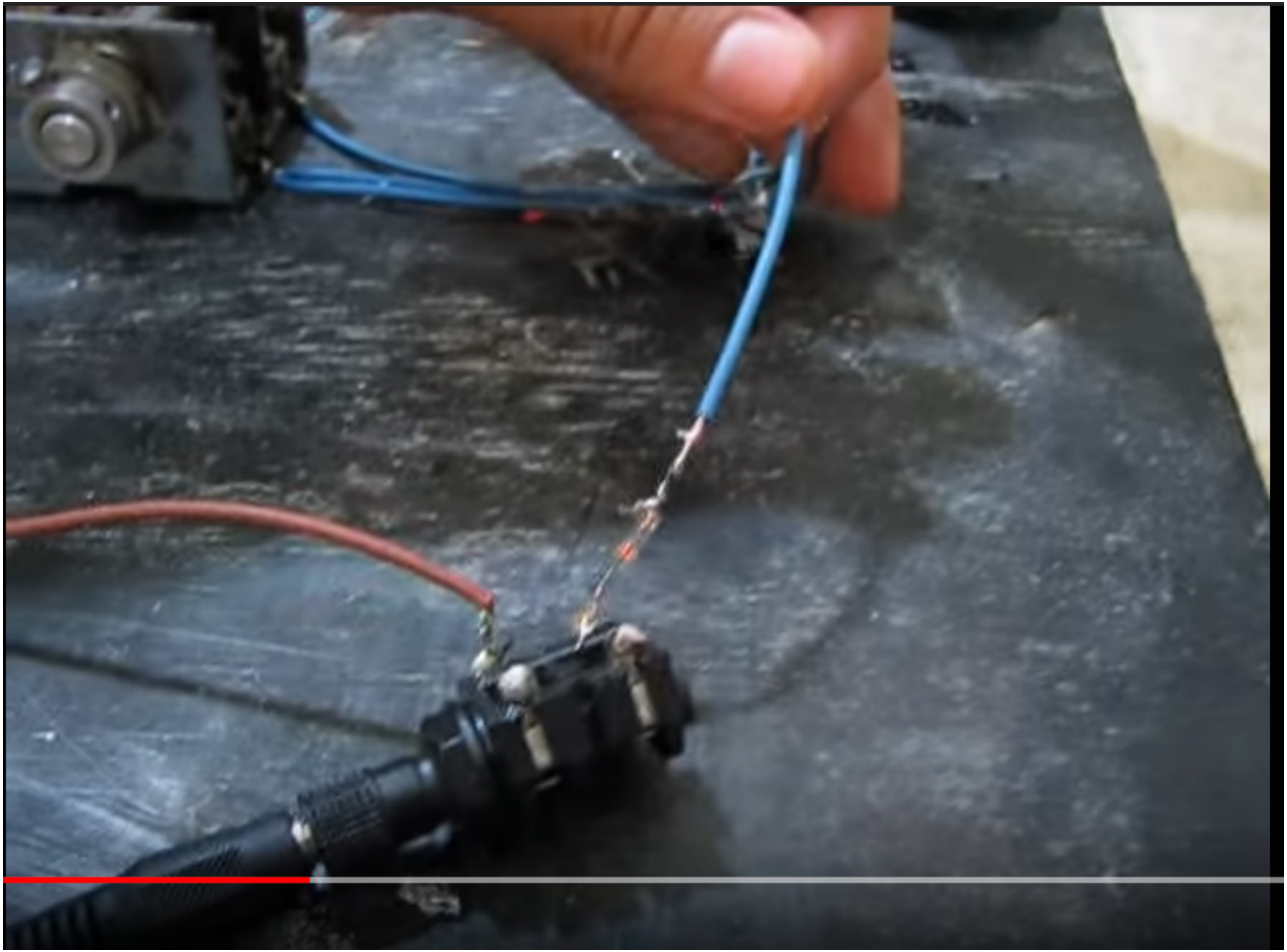

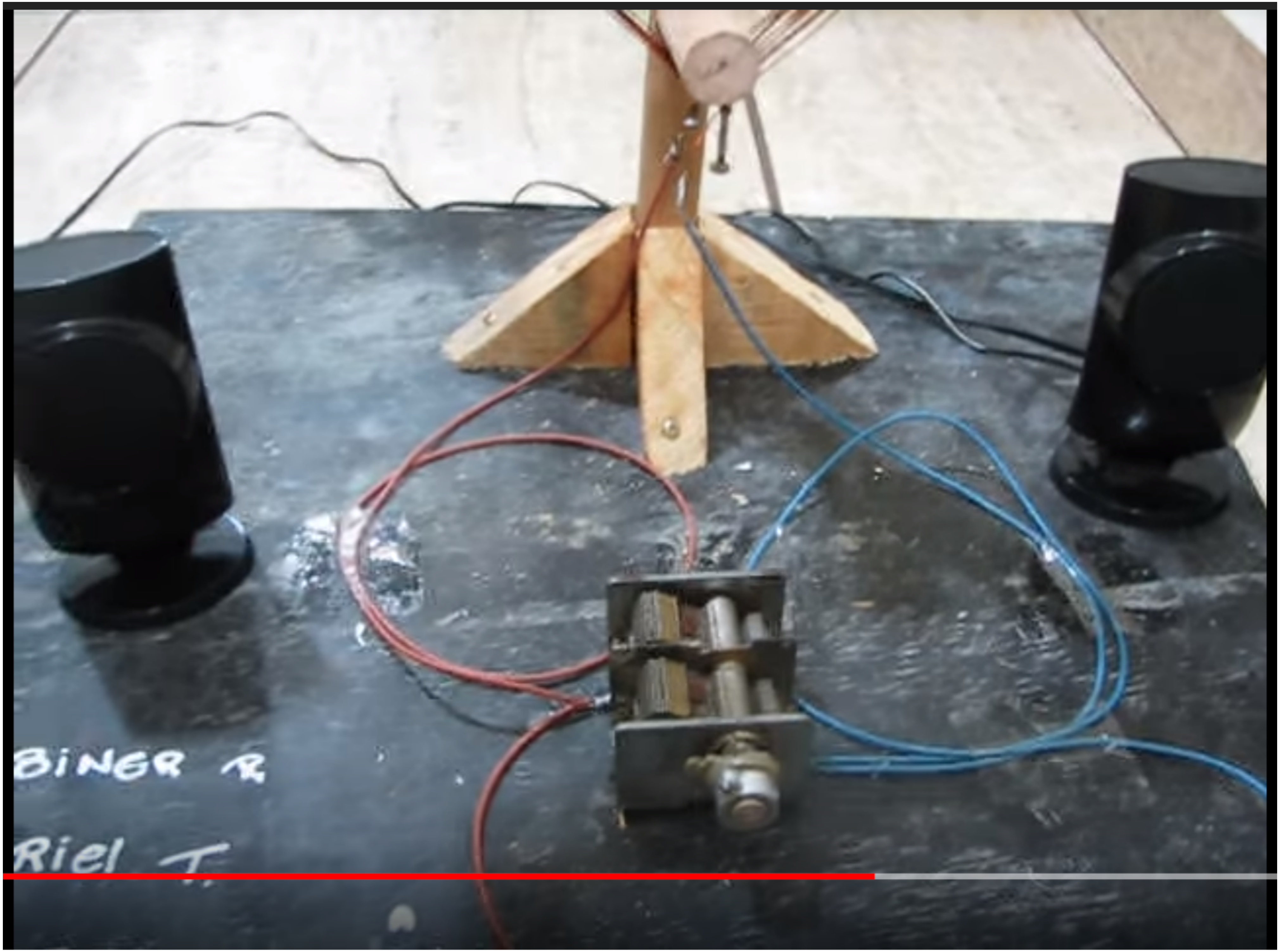
BiNGR R
Riel J.

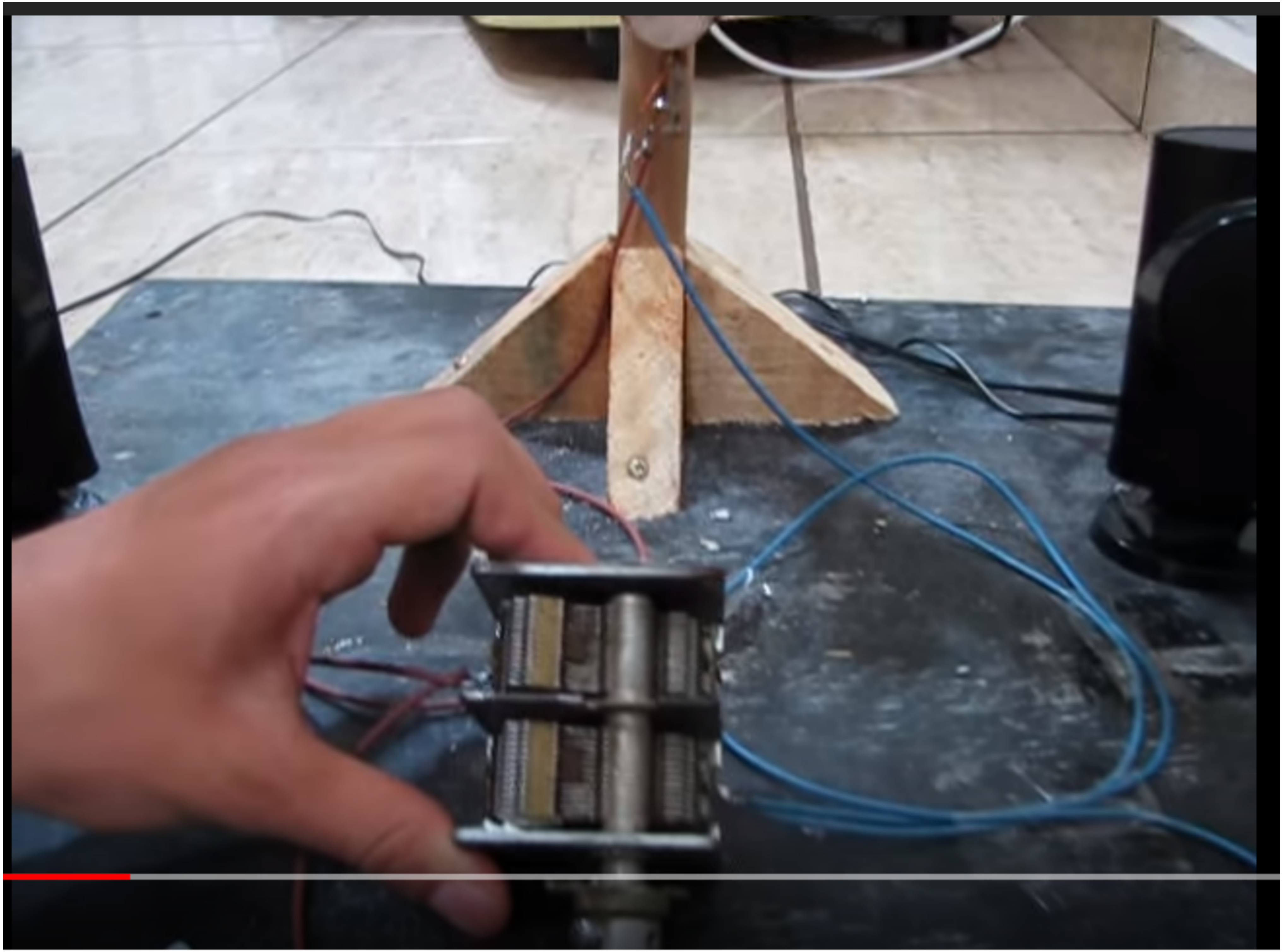

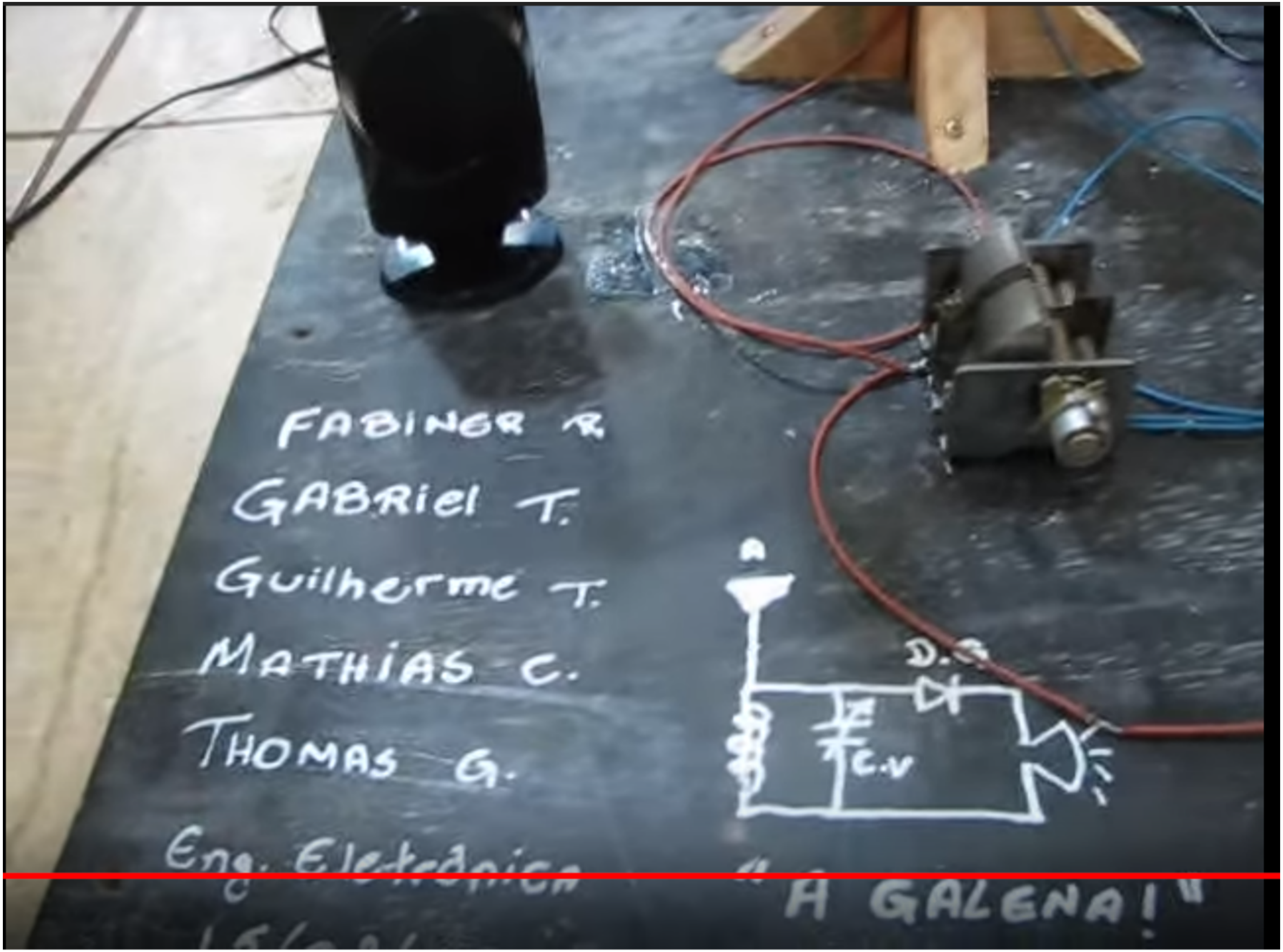
FABINER R.
GABRIEL T.
Guilherme T.
MATHIAS C.
THOMAS G.
A
D.G
C.V
Eng. Eletrônica
"A GALENA!"

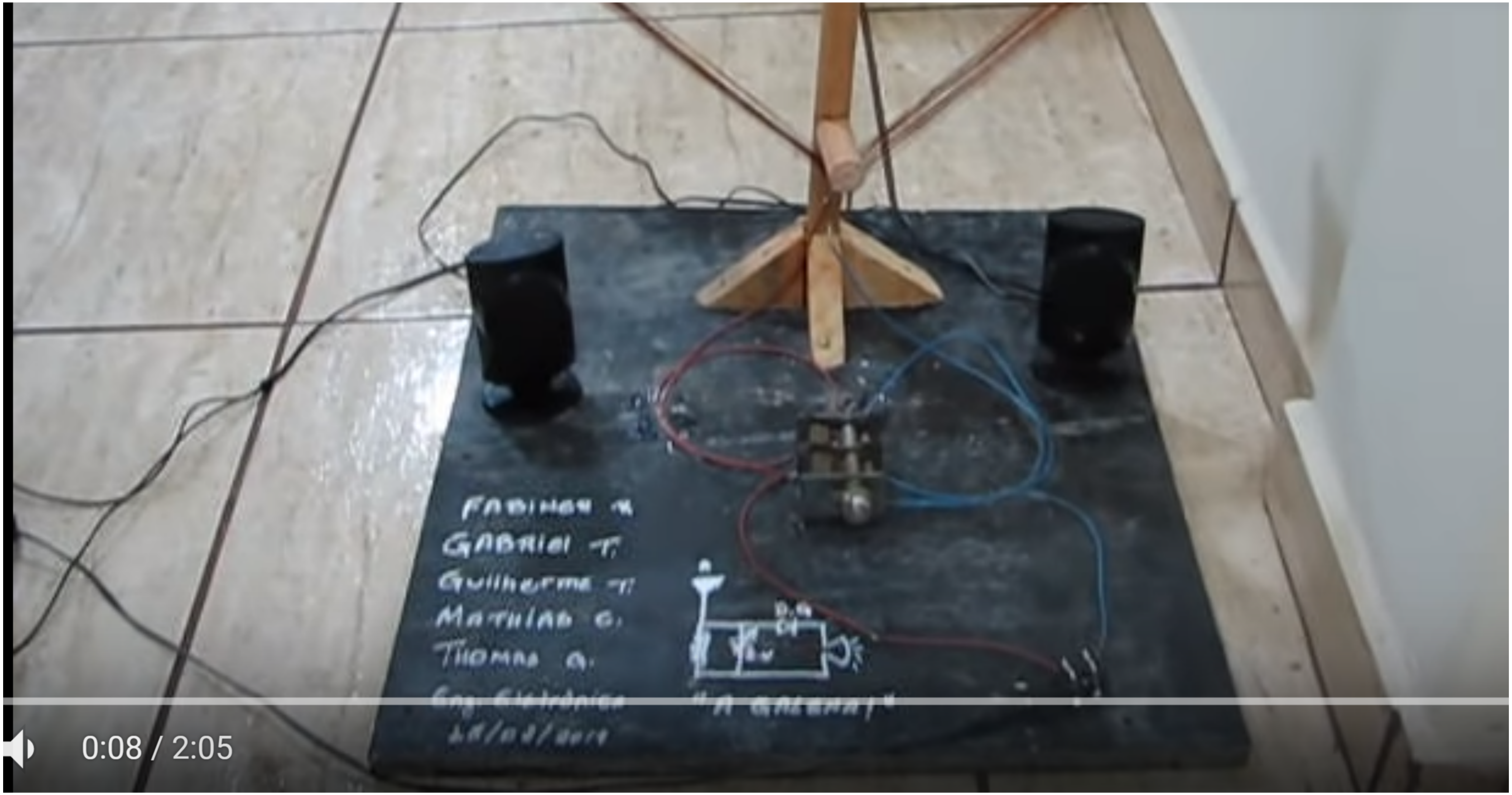
FABINHO R.
GABRIEL T.
Guilherme T.
MATHIAS G.
THOMAS G.
Eng. Eletrônica
"A GALENA!"
0:08 / 2:05

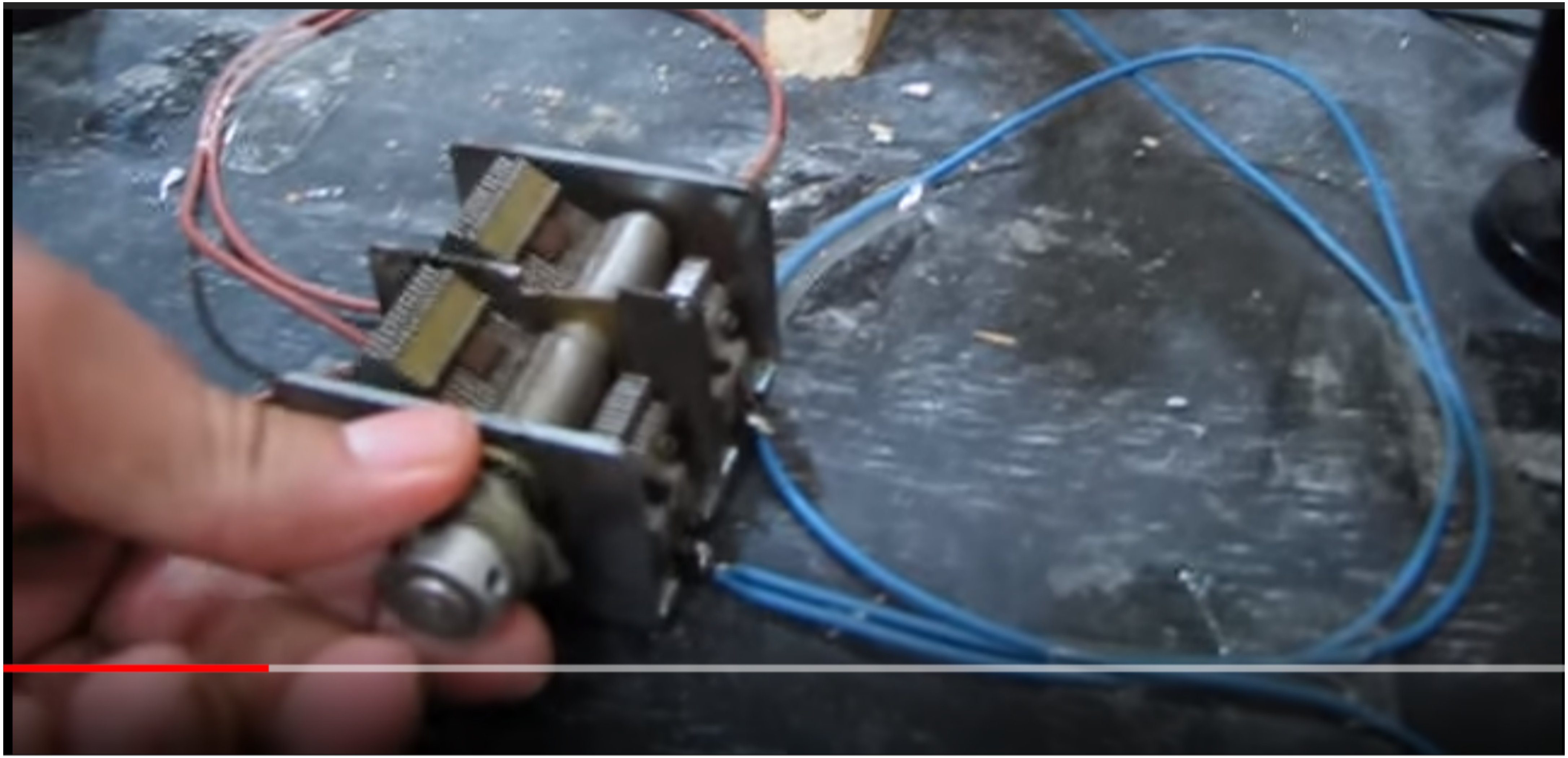

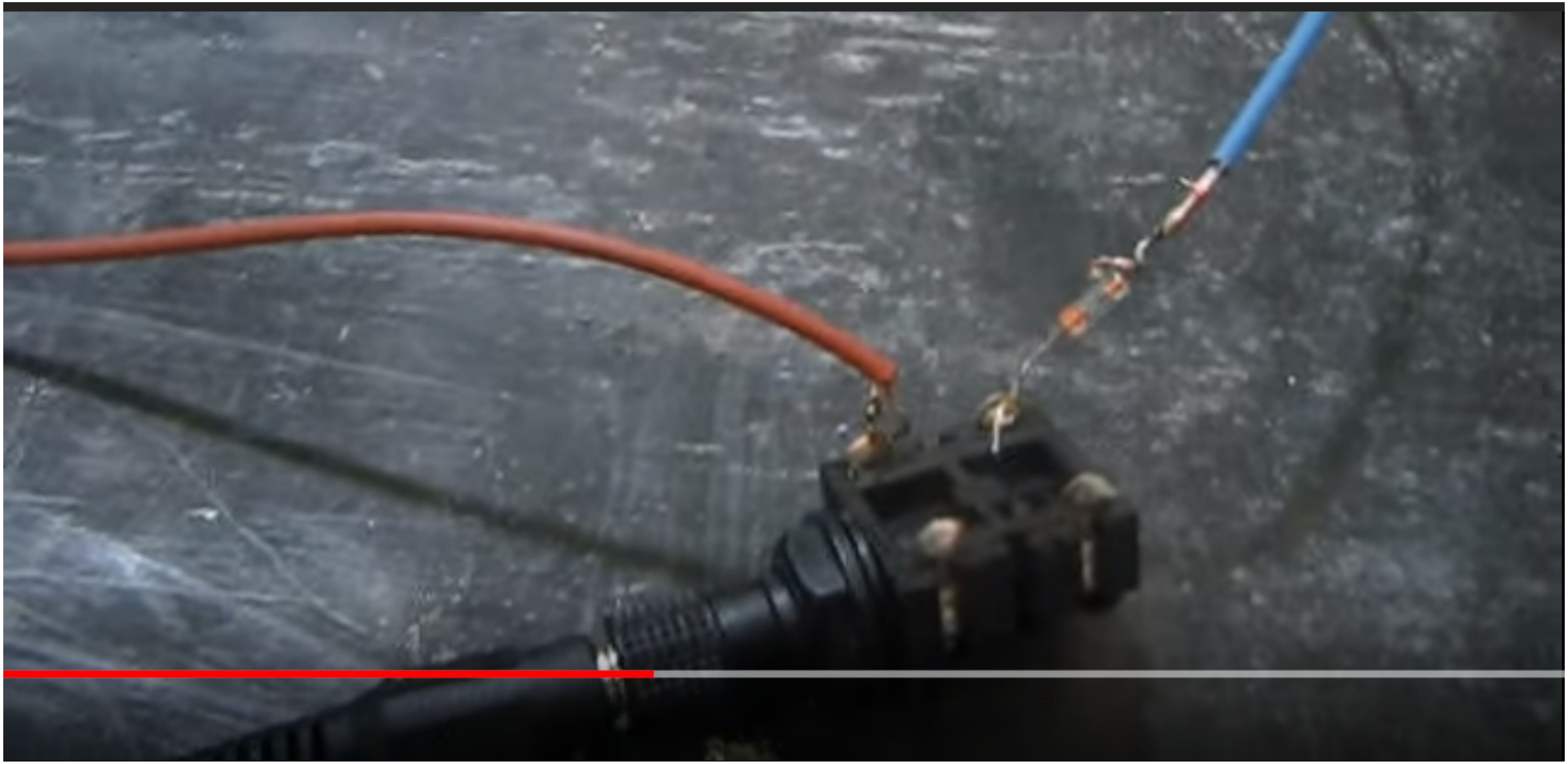

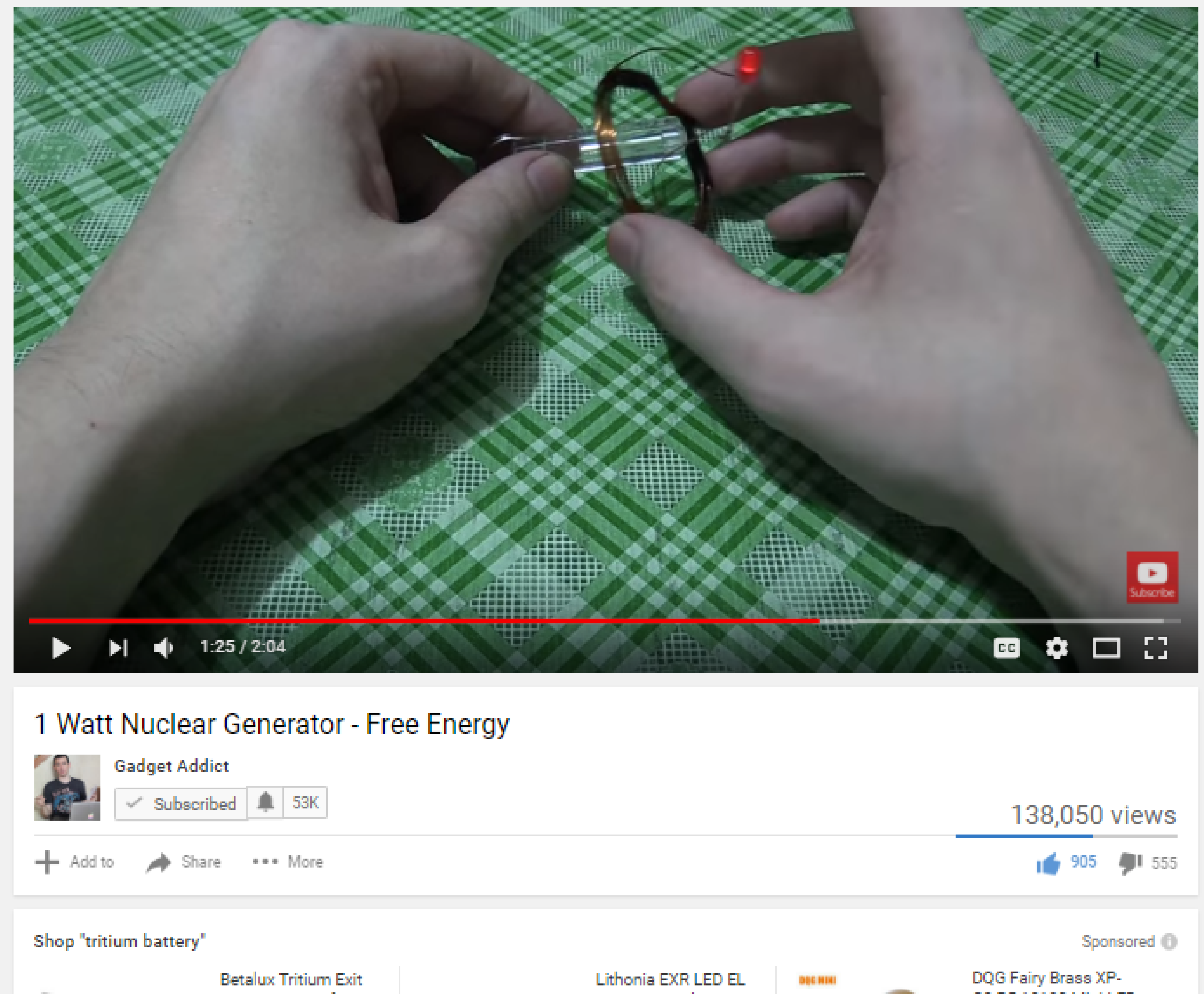
Subscribe
1:25 / 2:04
CC

1 Watt Nuclear Generator - Free Energy

Gadget Addict

✓ Subscribed
53K

138,050 views

Add to
Share
More
905
555

Shop "tritium battery"

Sponsored

Betalux Tritium Exit

Lithonia EXR LED EL

DQG Fairy Brass XP-

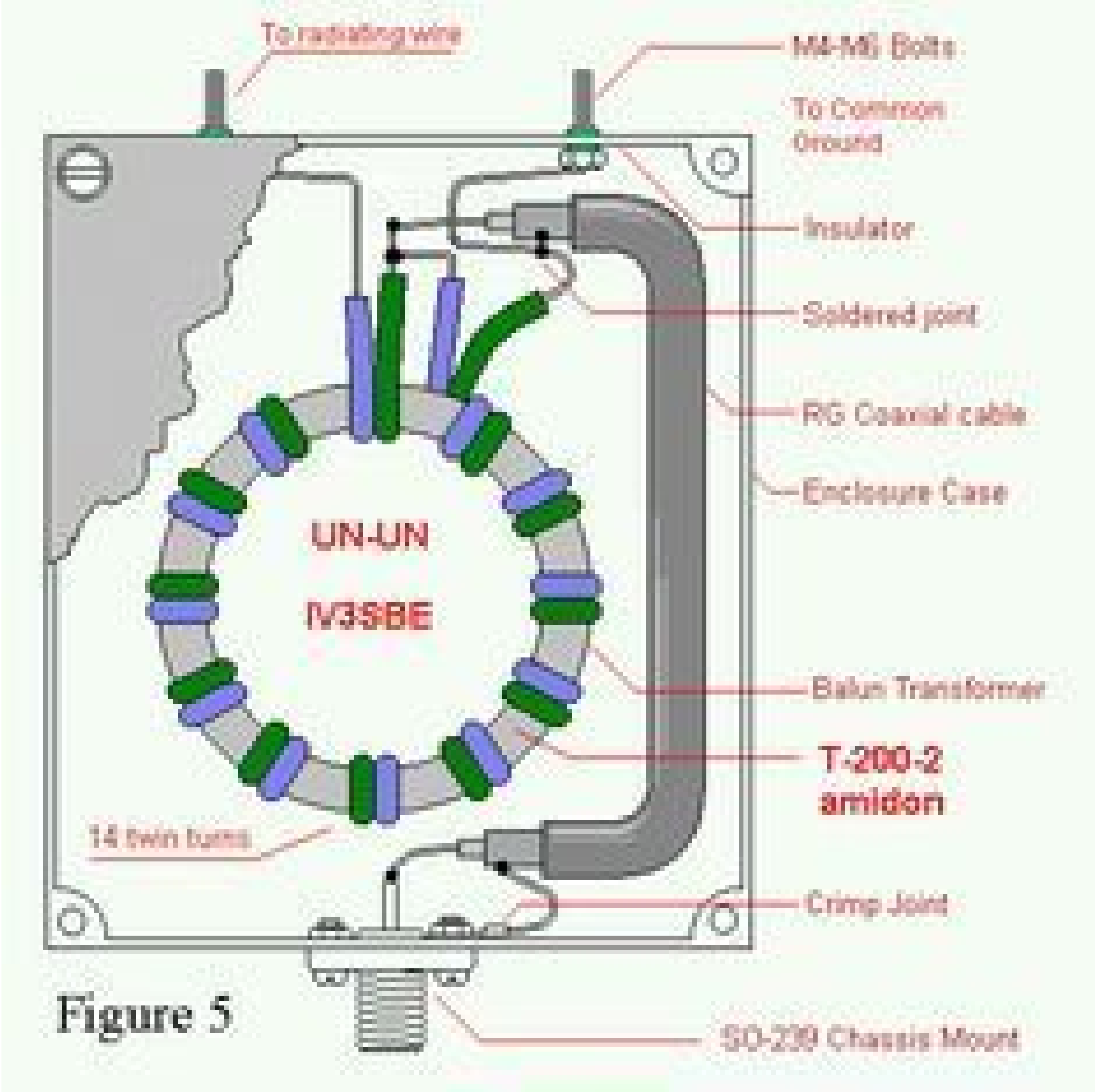
To radiating wire
M4-M6 Bolts
To Common Ground
Insulator
Soldered joint
RG Coaxial cable
Enclosure Case
UN-UN
IV3SBE
Balun Transformer
T-200-2 amidon
14 twin turns
Crimp Joint
SO-239 Chassis Mount

Figure 5

Voltage Balun / "Magnetic Balun"

From GW0VMR's plan

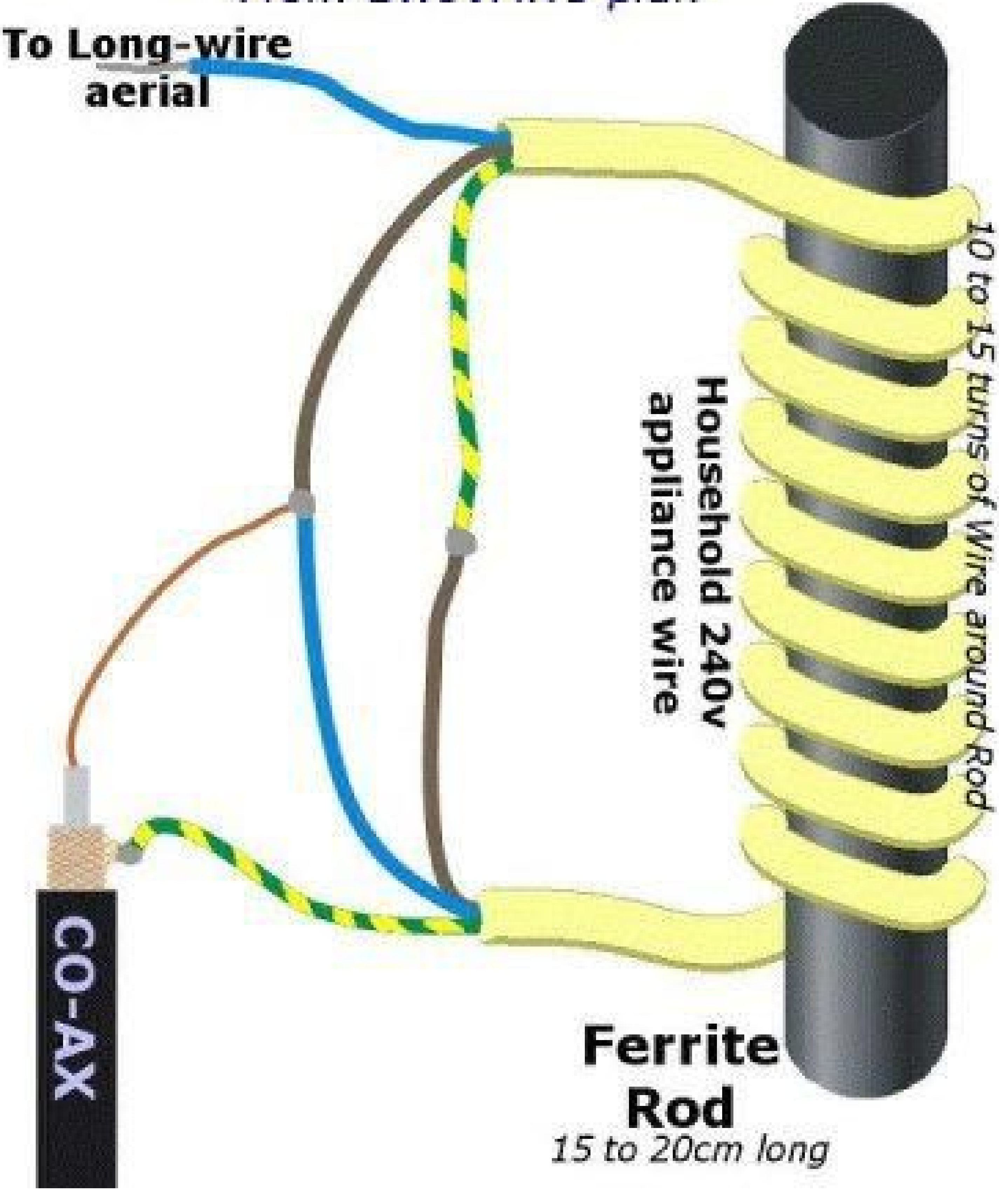
To Long-wire aerial
10 to 15 turns of Wire around Rod
Household 240v appliance wire
CO-AX
Ferrite Rod
15 to 20cm long

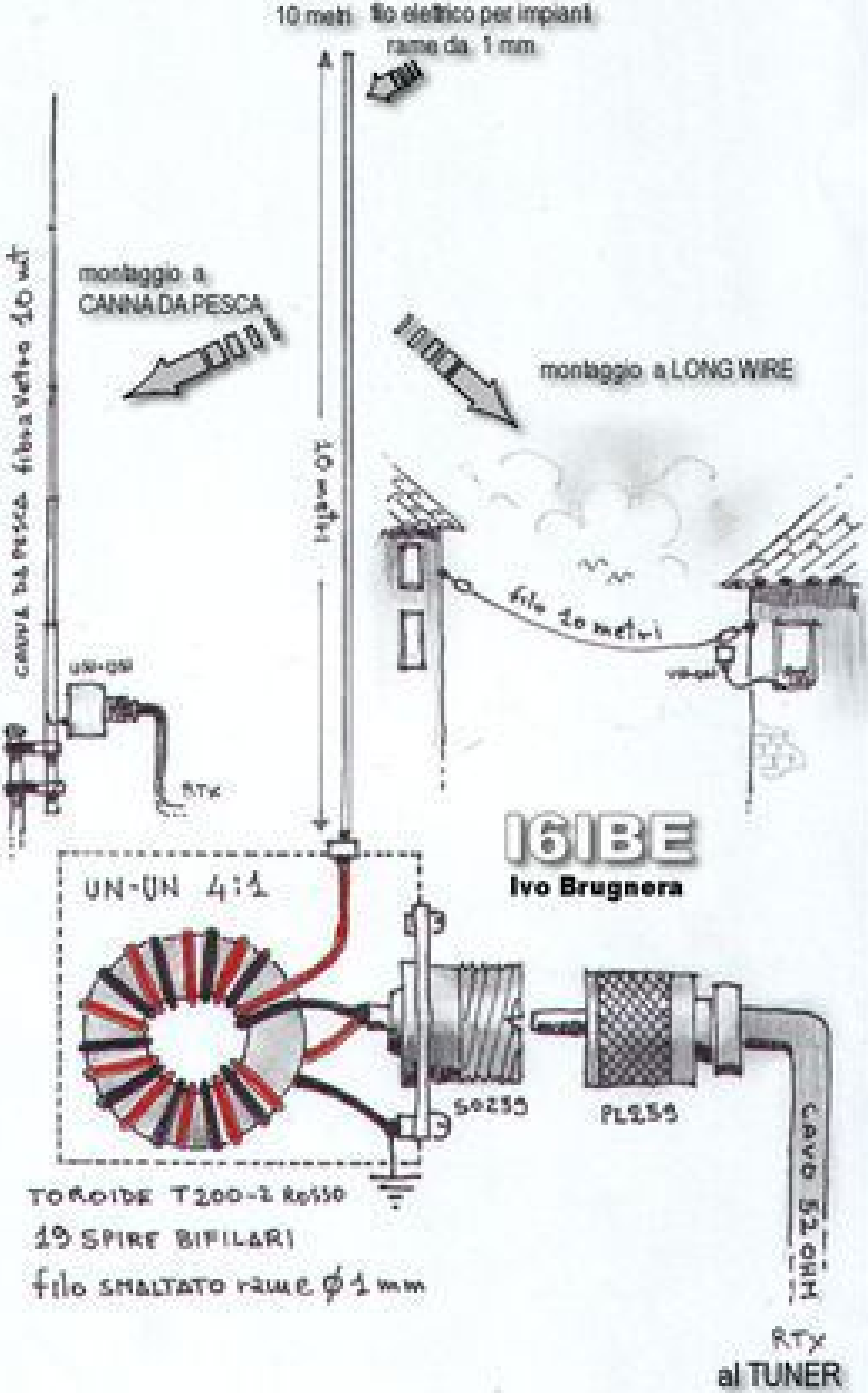
10 metri filo elettrico per impianti
rame da 1 mm
montaggio a
CANNA DA PESCA
CANNA DA PESCA fibra vetro 10 mt
UN-UN
RTX
10 metri
montaggio a LONG WIRE
filo 10 metri
UN-UN
I6IBE
Ivo Brugnera
UN-UN 4:1
SO239
PL259
CAVO 52 OHM
RTX
al TUNER
TOROIDE T200-2 ROSSO
19 SPIRE BIFILARI
filo SMALTATO rame ∅ 1 mm

BALUN 9:1 Antenna Long Wire

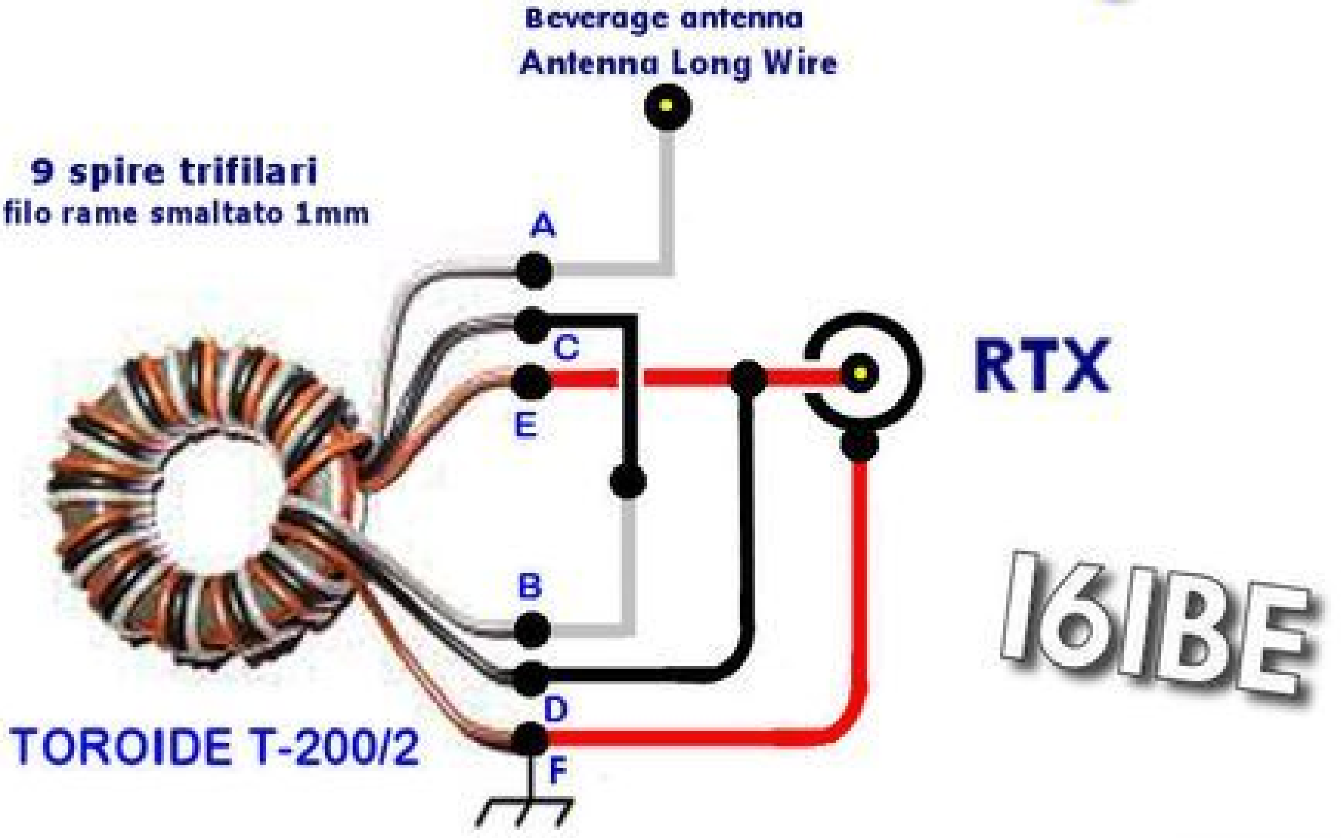
Beverage antenna
Antenna Long Wire
9 spire trifilari
filo rame smaltato 1mm
A
C
E
RTX
B
D
F
TOROIDE T-200/2
I6IBE

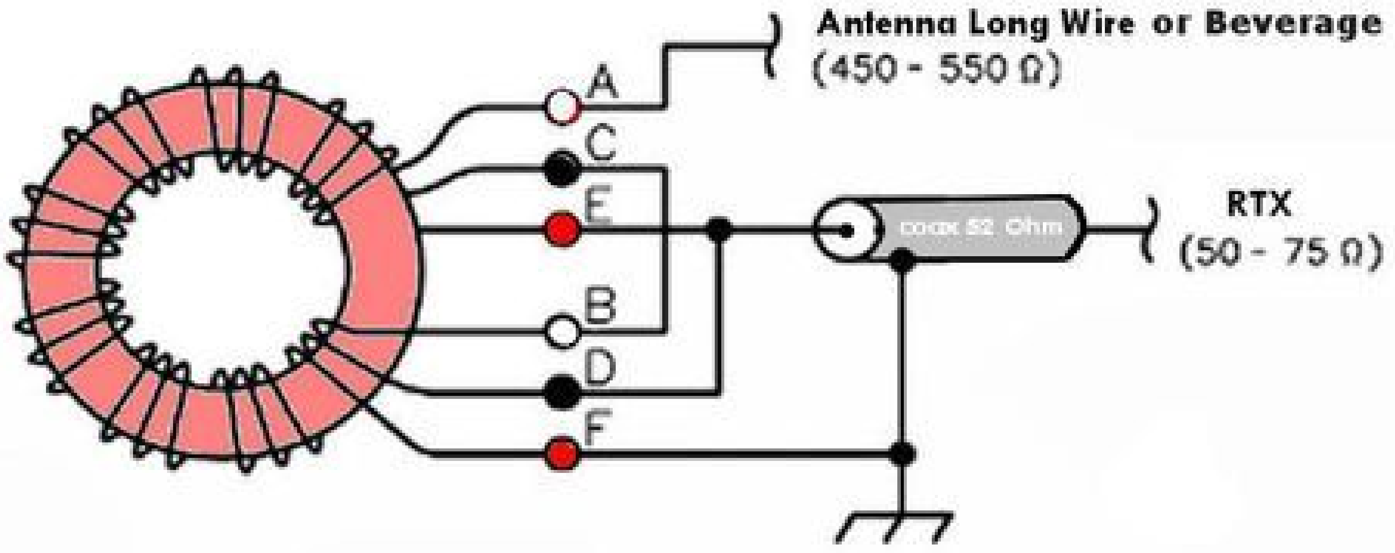
Antenna Long Wire or Beverage
(450 - 550 Ω)
A
C
E
coax 52 Ohm
RTX
(50 - 75 Ω)
B
D
F

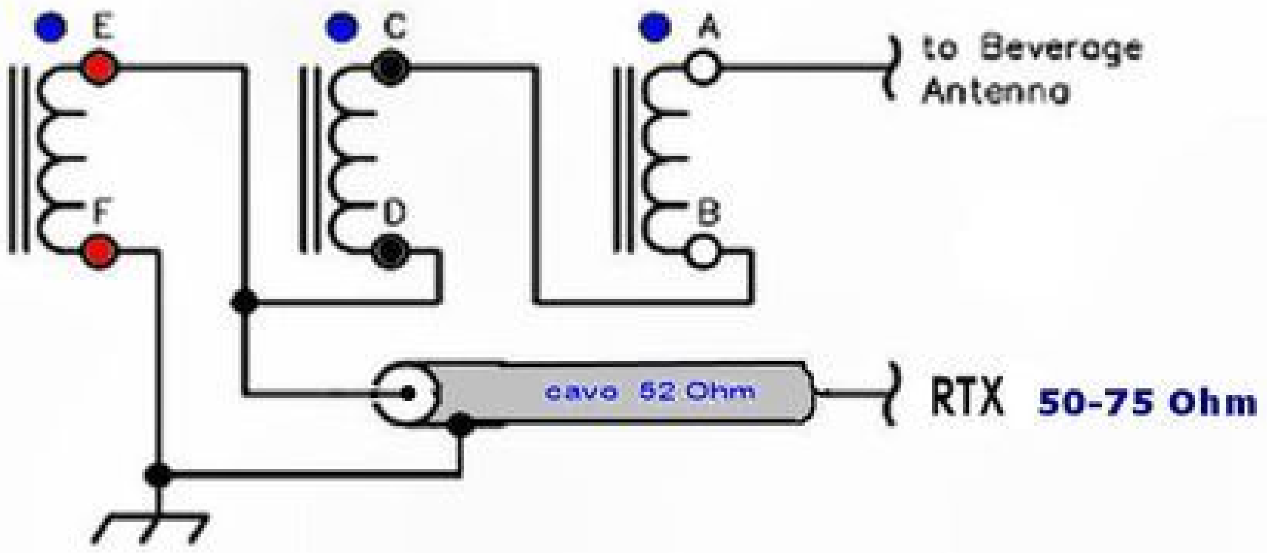
E
C
A
to Beverage
Antenna
F
D
B
cavo 52 Ohm
RTX 50-75 Ohm

Bal-Un 2:1 per antenna DELTA-LOOP

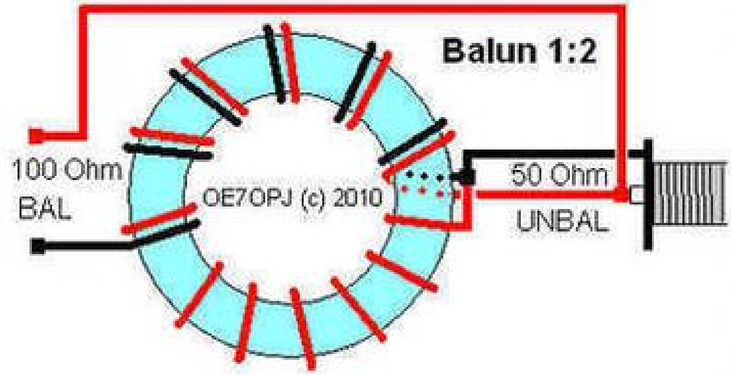
Balun 1:2
100 Ohm
BAL
OE7OPJ (c) 2010
50 Ohm
UNBAL

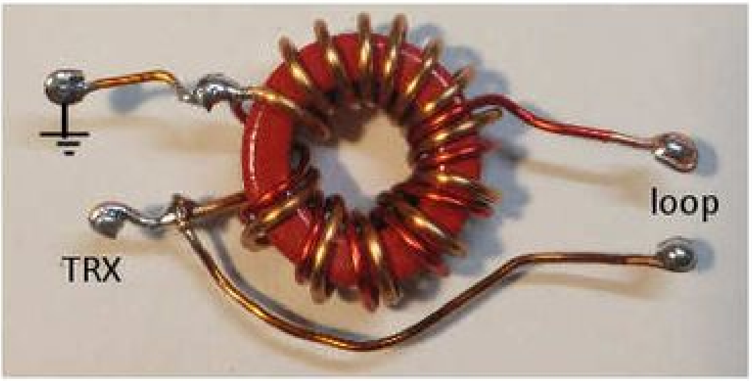

by OE7OPJ

Toroide	Numero di Spire	Potenza Supportata
T80-2	25	60 Watts
T106-2	16	100 Watts
T130-2	18	150 Watts
T157-2	16	250 Watts
T200-2	17	400 Watts
T200A-2	13	400 Watts
T400-2	14	1000 Watts

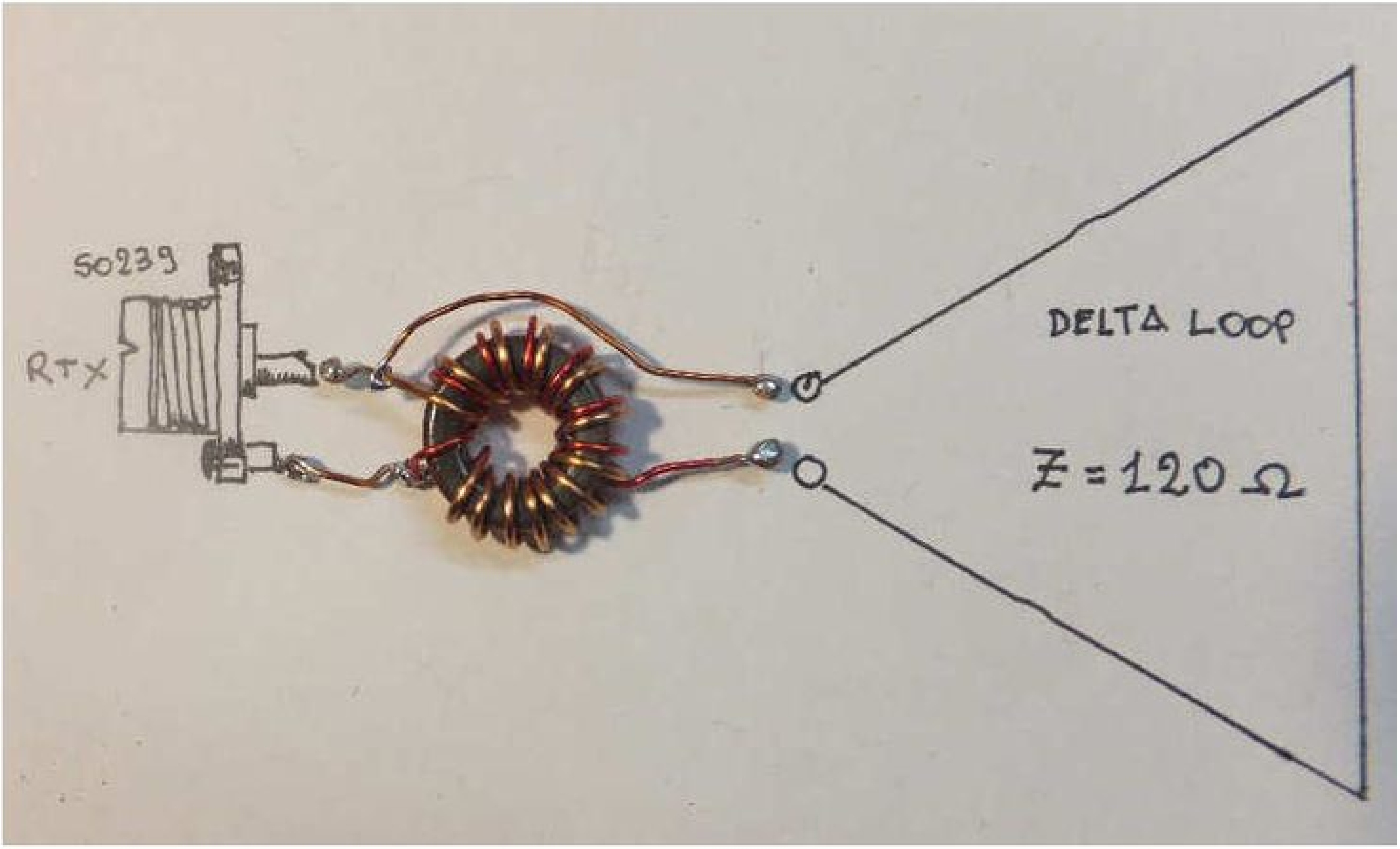
SO239
RTX
DELTA LOOP
Z = 120 Ω

Autoformer, not a parallel transmission line – Ruthroff balun (voltage)

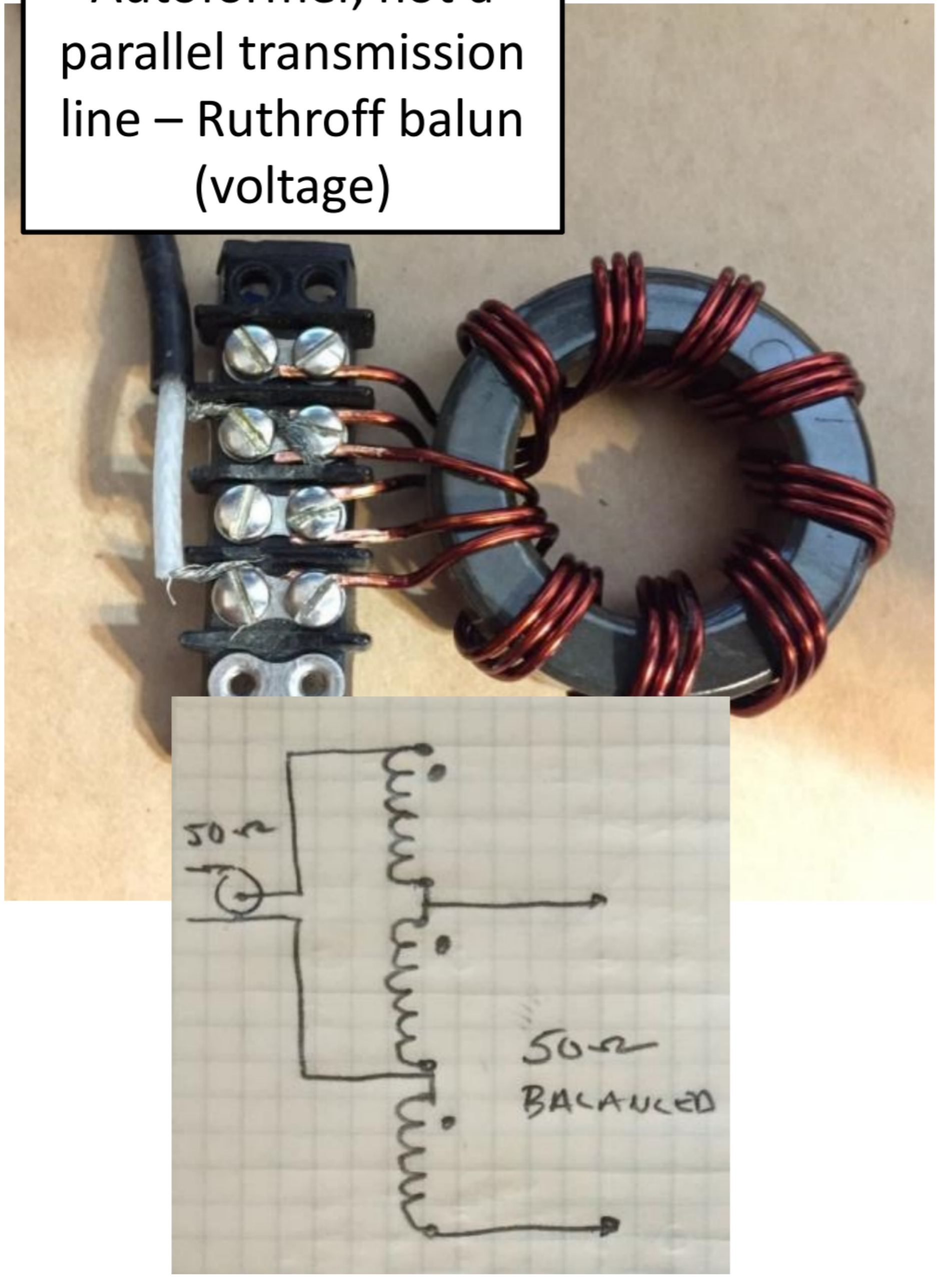

One or more parallel transmission lines, connected various ways – Guanella balun (current) – core is used solely for choking action

F/B: 0.00 dB; Rear: Azim. 120 deg, Elev. 60 deg

Coax is unbalanced …..

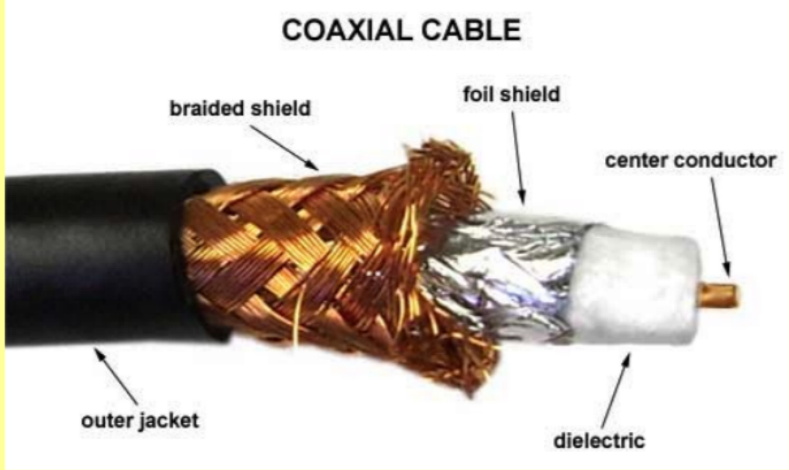
COAXIAL CABLE
braided shield
foil shield
center conductor
outer jacket
dielectric

300 Ohm
450 Ohm

… Ladder line is balanced

Coax is unbalanced, while ladder line and open wire feeder is balanced, as long as it is used properly and is kept away from metal and "earthy" materials

Convert parallel feedline to coax

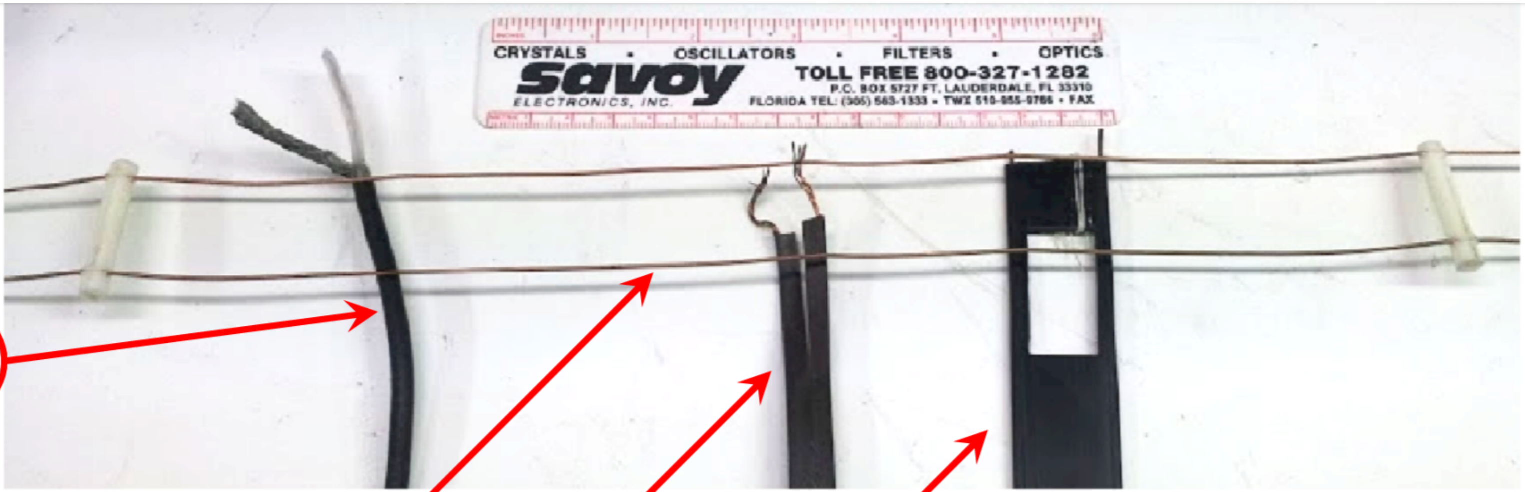
CRYSTALS • OSCILLATORS • FILTERS • OPTICS
Savoy
ELECTRONICS, INC.
TOLL FREE 800-327-1282

Types of Parallel Line

- **Open Feeder** or **Ladder line**
  - Typ 450 and 600 ohm
- **Twin Lead**
  - Common for (old) outdoor TV antennas
- **Window line**
  - Commonly available today

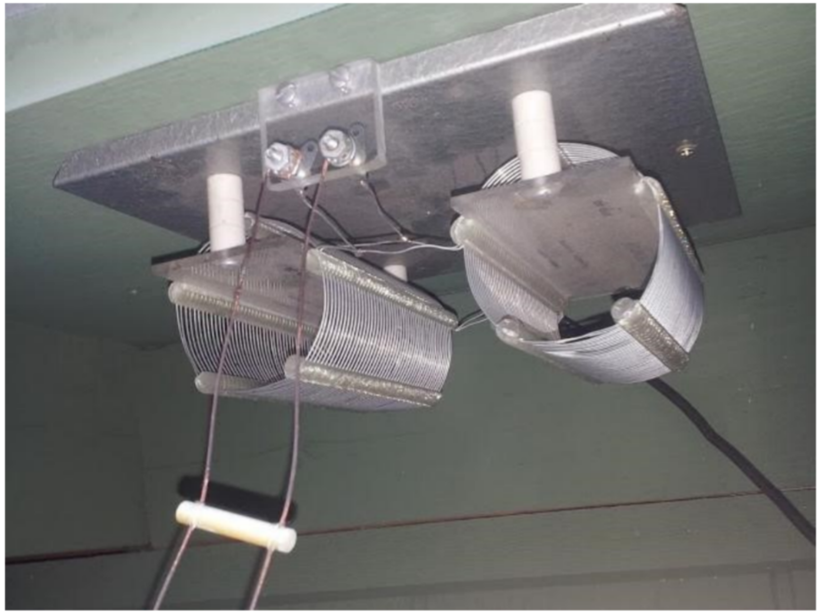

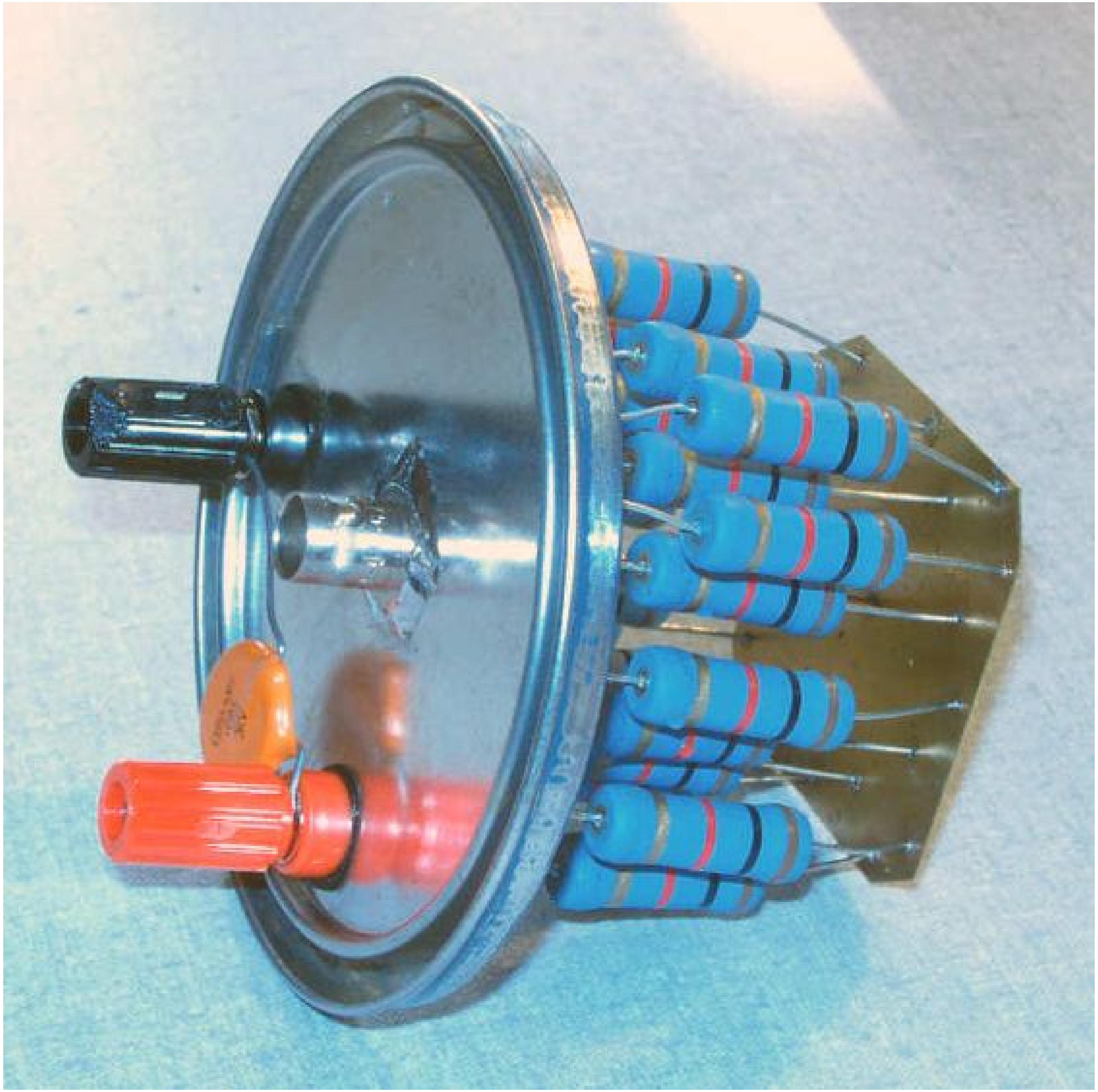

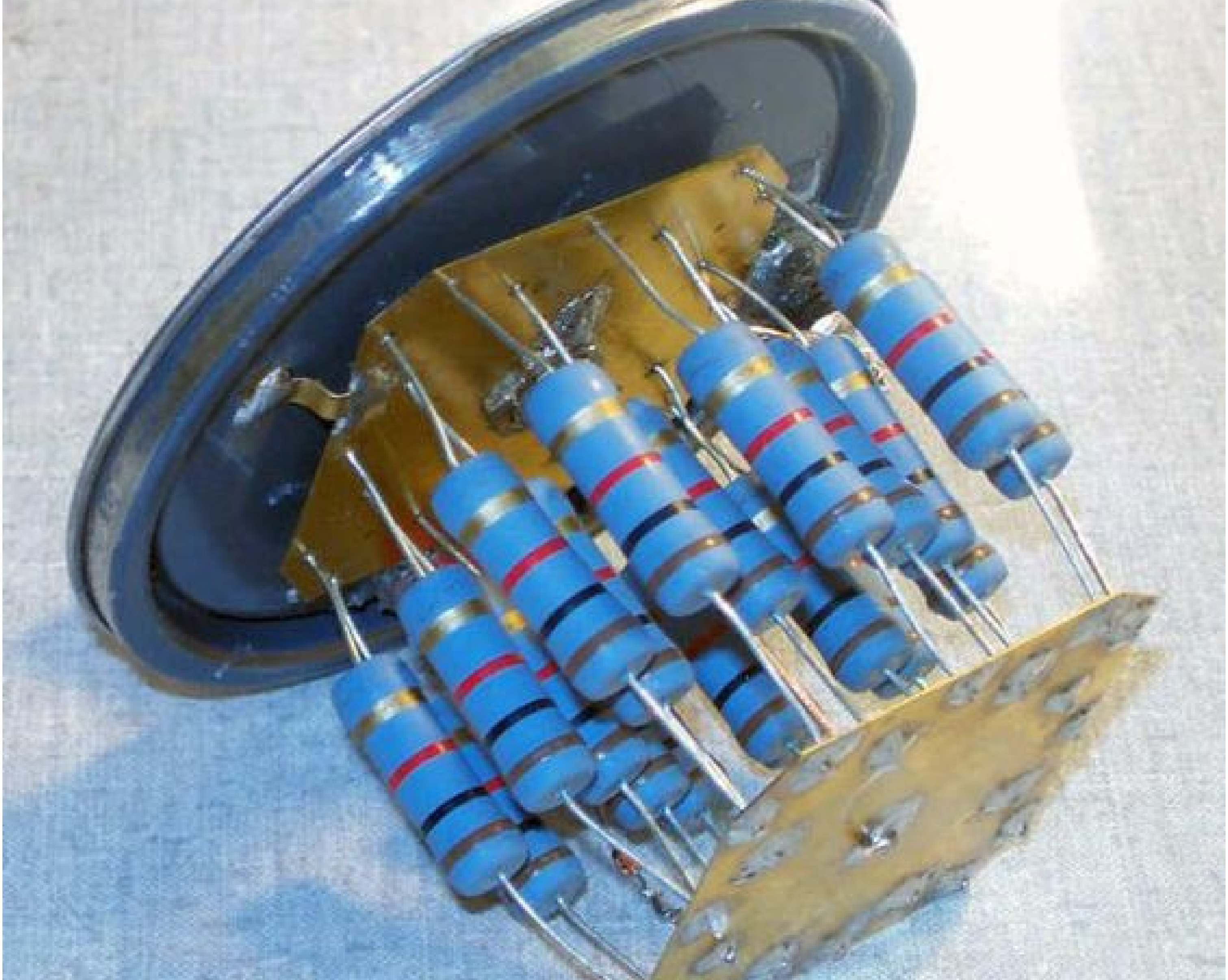

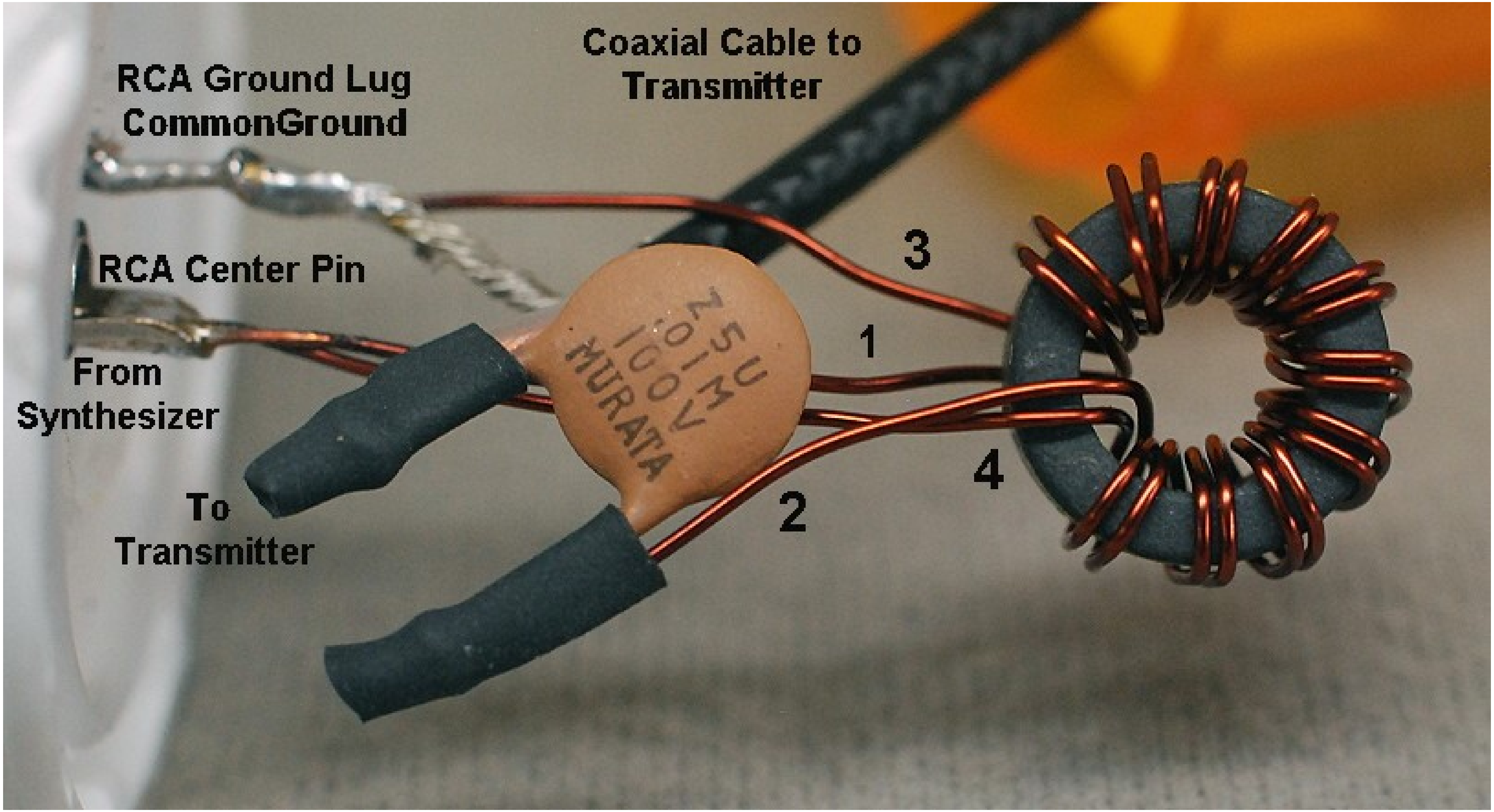
Coaxial Cable to Transmitter
RCA Ground Lug CommonGround
RCA Center Pin
From Synthesizer
To Transmitter
3
1
4
2
Z5U
.01M
100V
MURATA

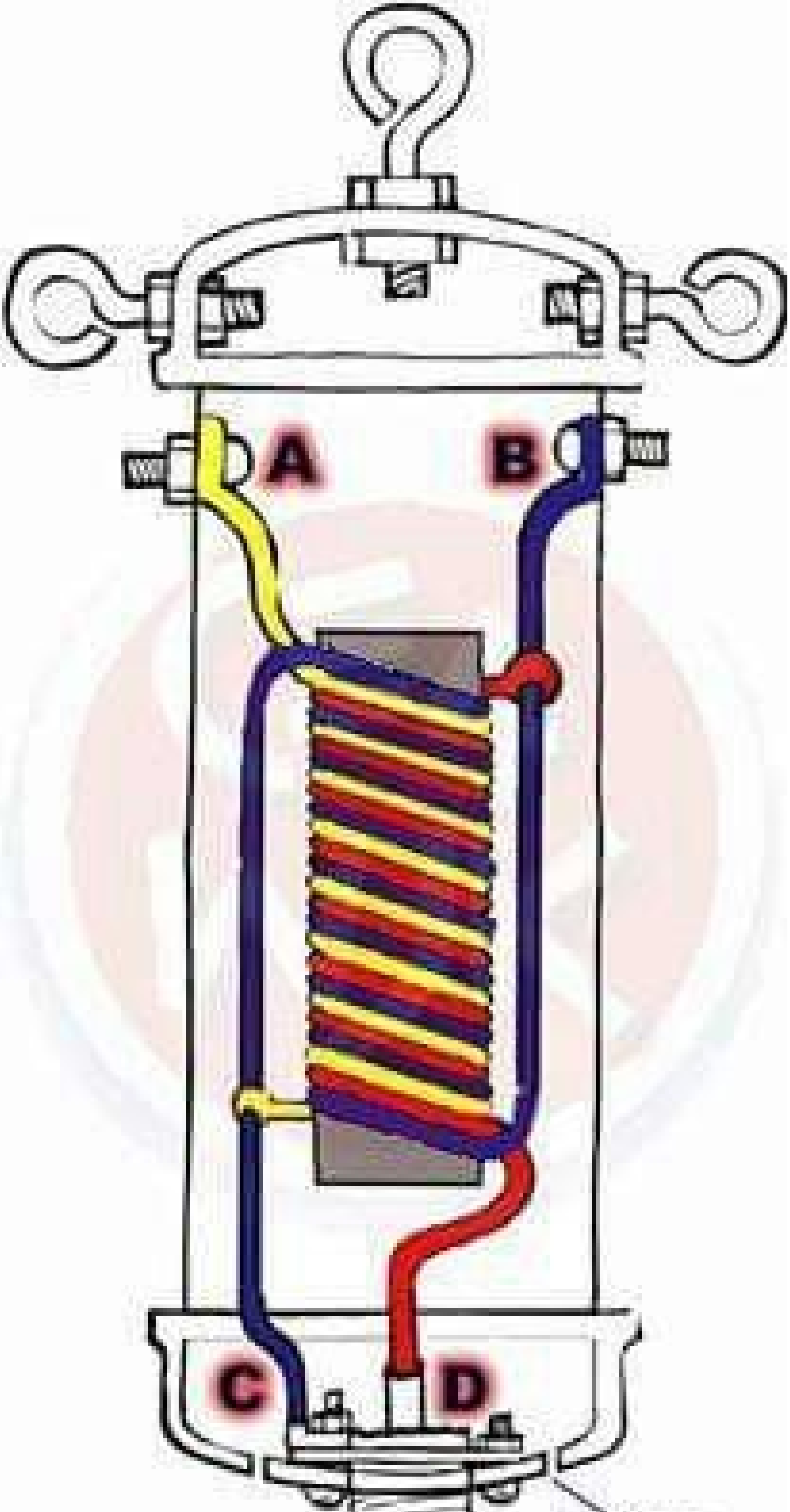
A
B
C
D
agujeros
ventilación

Formula LUNGHEZZA DELTA LOOP	Esempio 14.00 MHz (20 metri)	Lunghezza TOTALE del LOOP
Velocita'Luce : Freq MHz x **0.97= L**	**299.8** VL **: 14.100** MHz x **0,97**	**20.624** metri totale loop
$L=\frac{300.000}{MHz}\times 0.97$	I6IBE	
Formula LUNGHEZZA Stub coax 75 Ohm	Esempio 14.00 MHz (20 metri)	Lunghezza TOTALE cavo 75 Ohm
Lunghezza LOOP x 0.66 : 4	**20.624** x **0.66** : **4**	**3.402** Metri coax RG-59

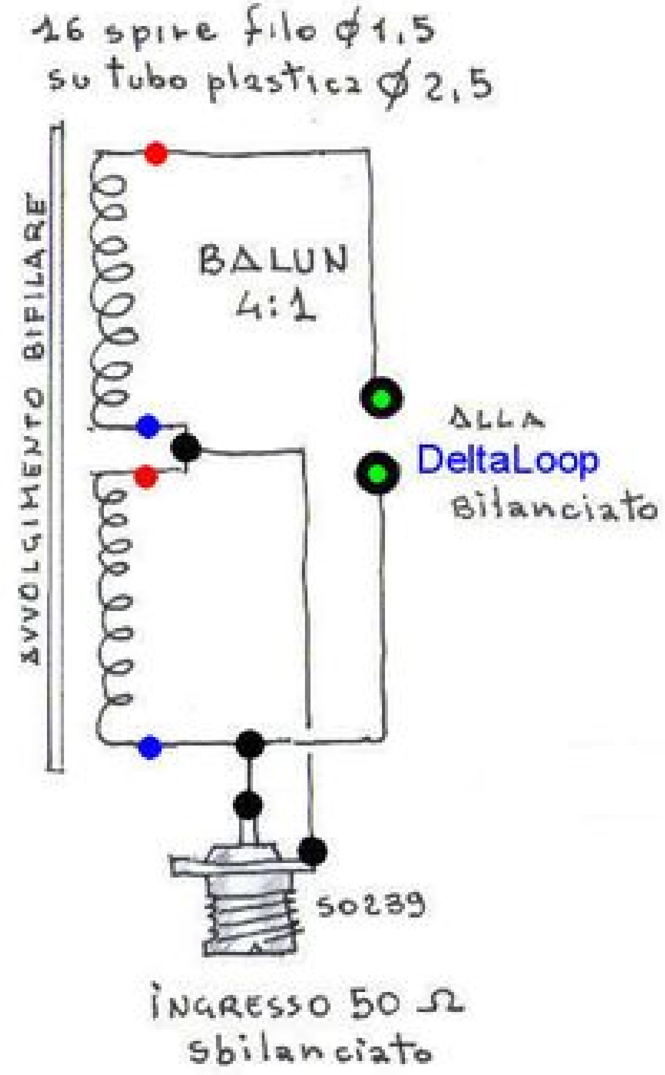
16 spire filo ∅ 1,5
su tubo plastica ∅ 2,5
AVVOLGIMENTO BIFILARE
BALUN
4:1
ALLA
DeltaLoop
Bilanciato
SO239
iNGRESSO 50 Ω
sbilanciato

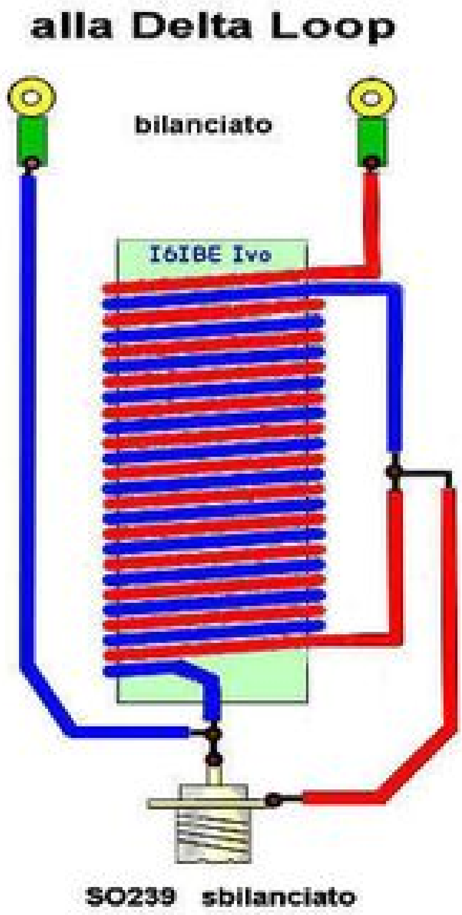
alla Delta Loop
bilanciato
I6IBE Ivo
SO239 sbilanciato

BALUN 4:1

I6IBE

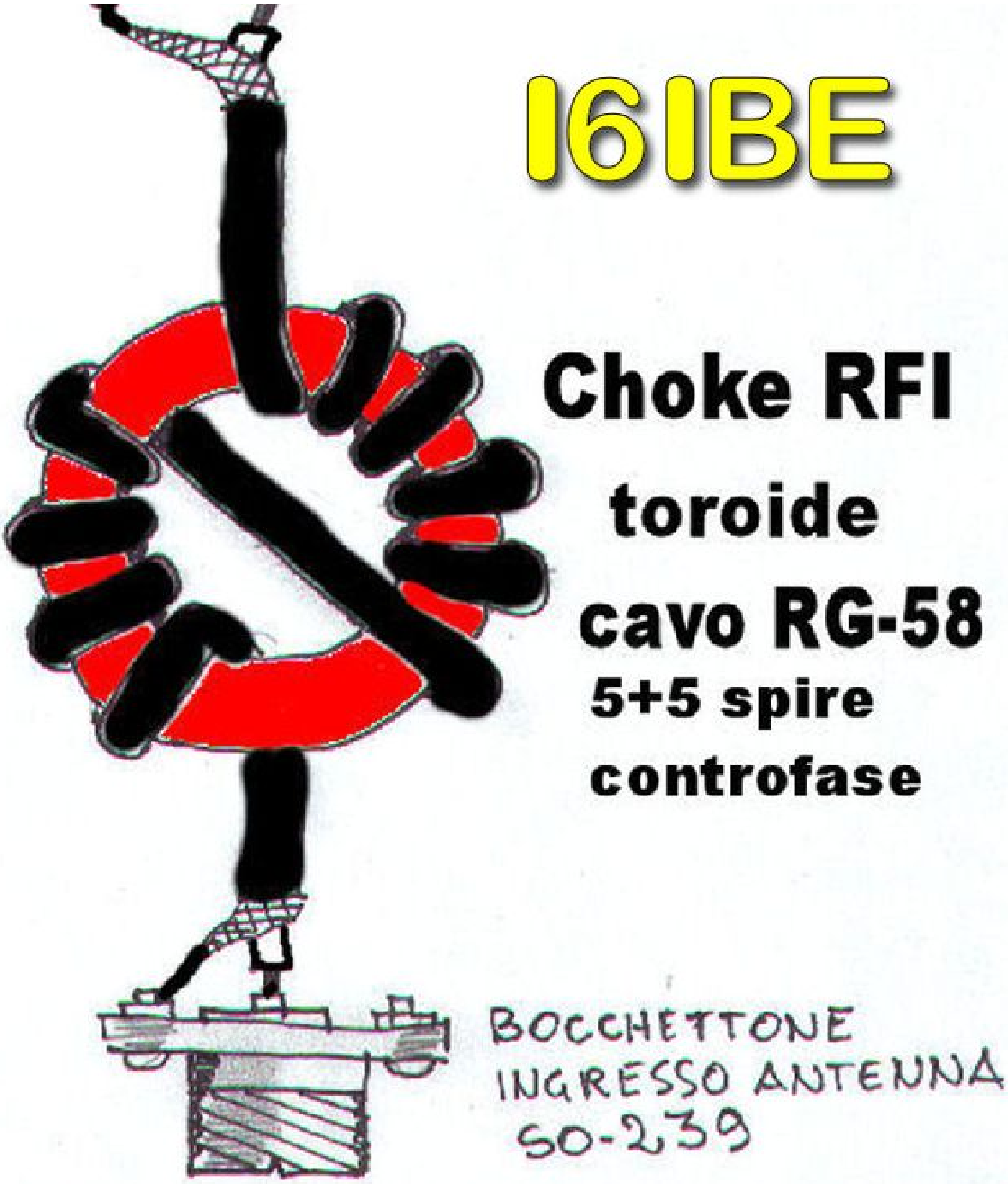
BOCCHETTONE
INGRESSO ANTENNA
SO-239

Choke RFI

toroide

cavo RG-58

5+5 spire

controfase

2. Insert metal electrodes and attach multimeter leads [copper (+), aluminum (-)] For measuring direct current voltage: set multimeter function switch to "DCV: 20" take a reading in volts DC. for measuring direct current: set multimeter function switch to "DCA: 20m" take a reading in milliamps (mA) DC.

Calculating Earth Battery Power (W = I * V)

EXAMPLE: A lawn battery in late summer (little rain) produces a 0.65V, 0.2mA current. A battery power calculation of 0.00013W (0.13mW).

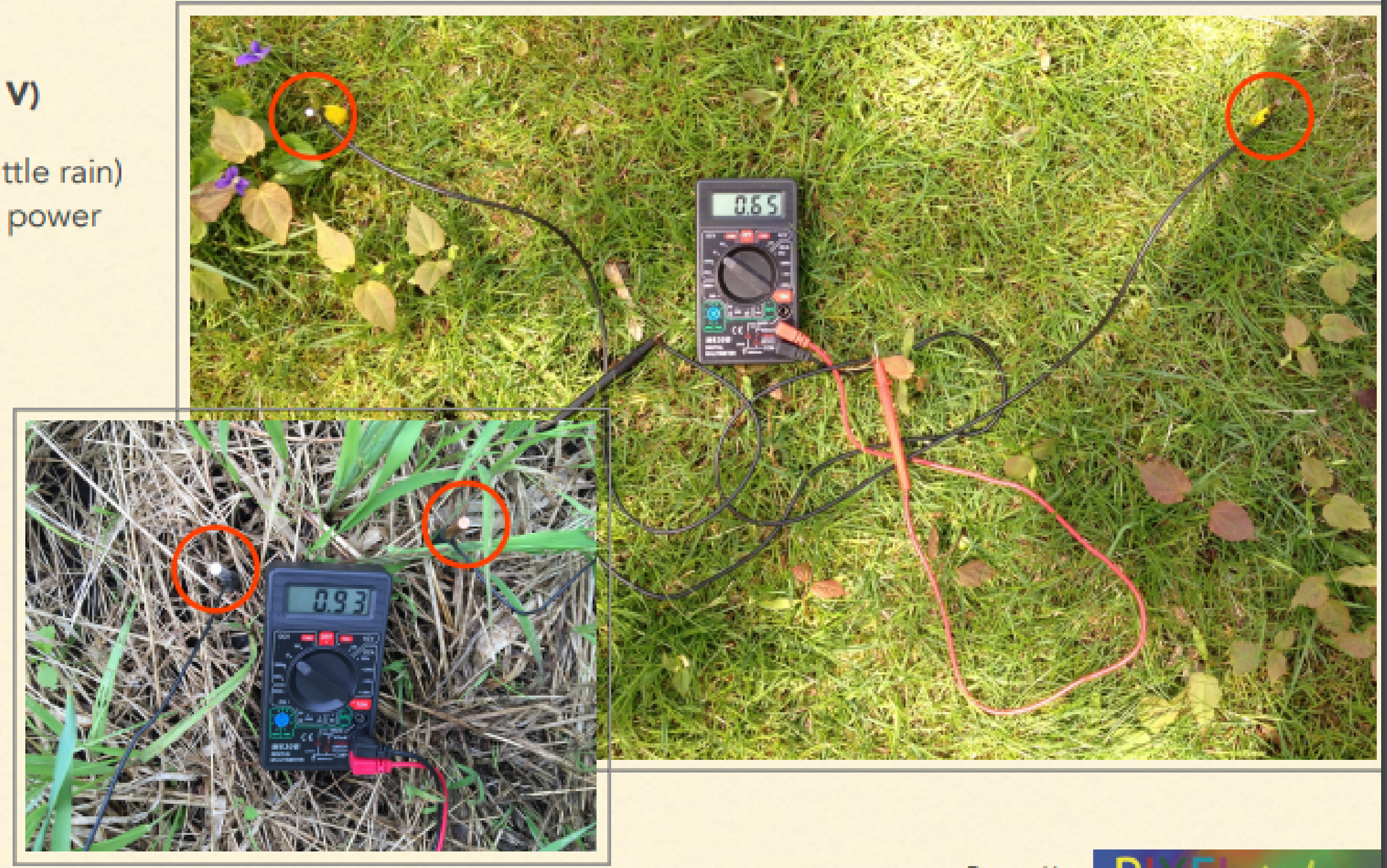

Lawn battery (summer). INSET: Marsh mud battery. (Circles show position of electrodes.)

Powered by: PIXEL ink LLC

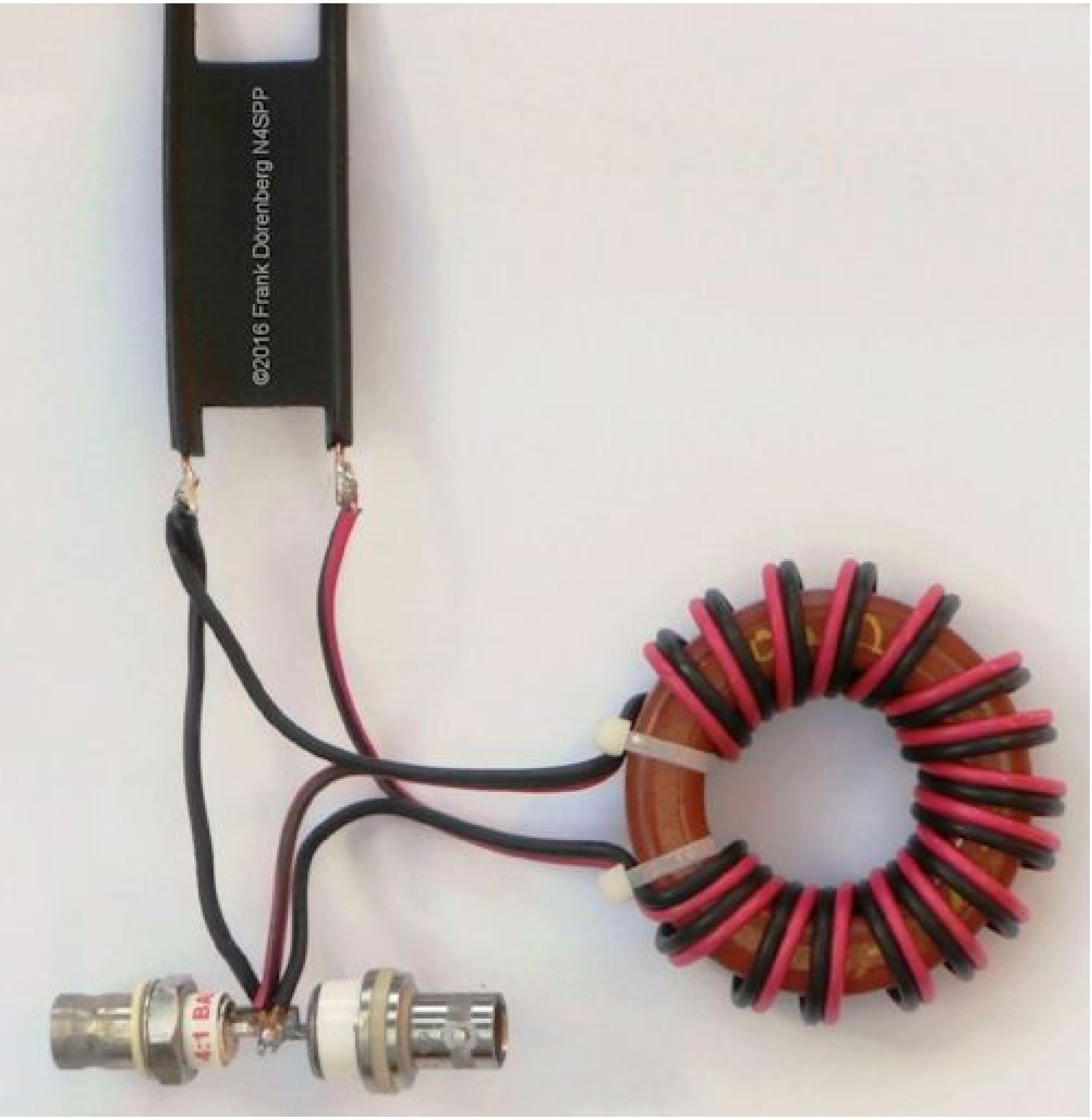
©2016 Frank Dörenberg N4SPP
4:1 BA

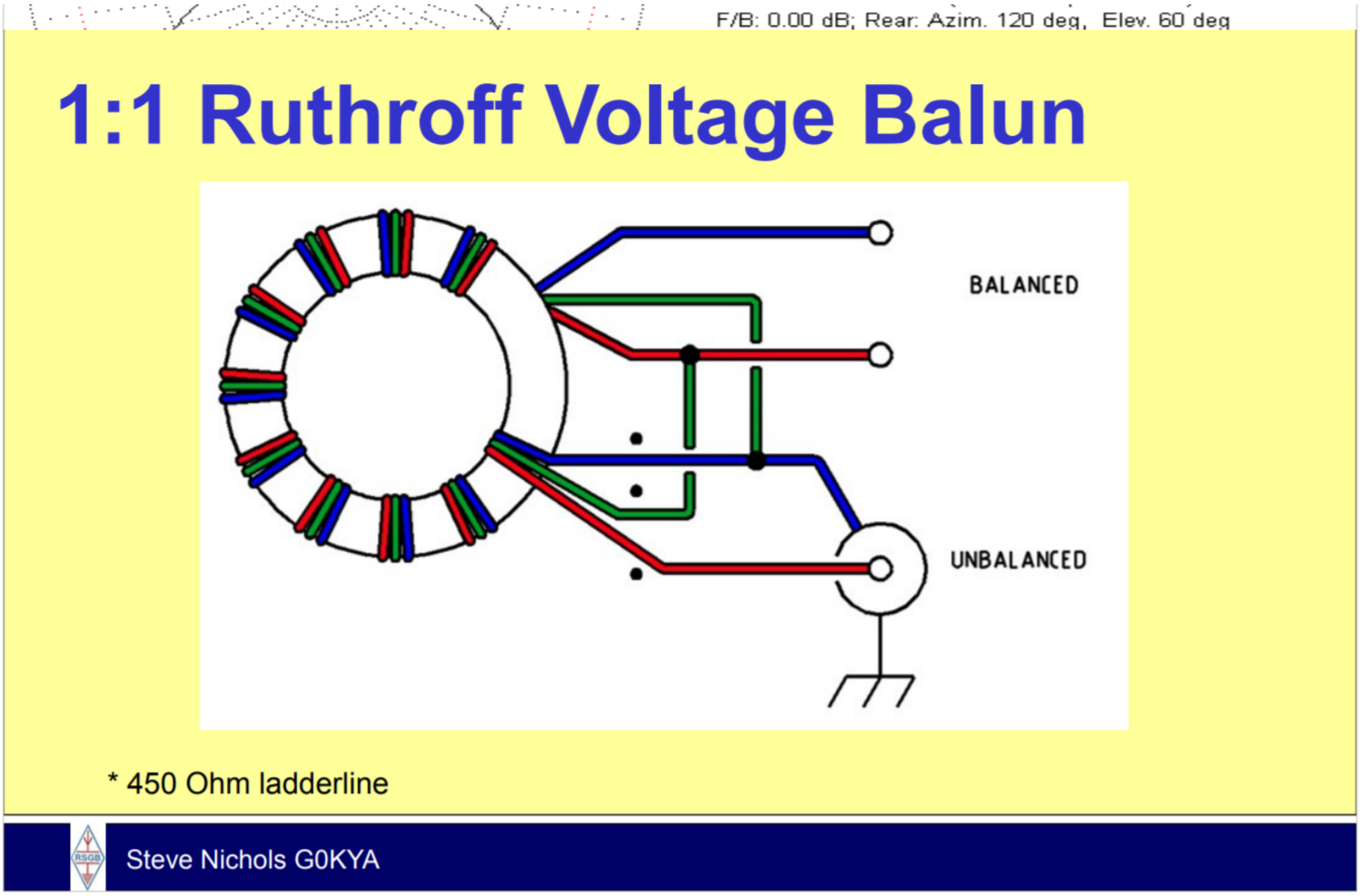

1:1 Ruthroff Voltage Balun

* 450 Ohm ladderline

Steve Nichols G0KYA

The Ruthroff or voltage balun is another type. Voltage baluns balance the voltages. Current balance is considered to be superior to voltage balance. Voltage baluns should not be used in lines with high SWR. They have the narrowest impedance and frequency range of any balun type. Properly designed voltage baluns have low common mode impedance. Properly designed current baluns have high common mode impedance, and provide better balance. If you want to stop common mode currents flowing on your coax a current balun is a better choice. But in the Carolina Windom, which uses the vertical coax as a radiator you WANT common mode currents, so a Ruthroff voltage balun is better.

F/B: 0.00 dB; Rear: Azim. 120 deg, Elev. 60 deg

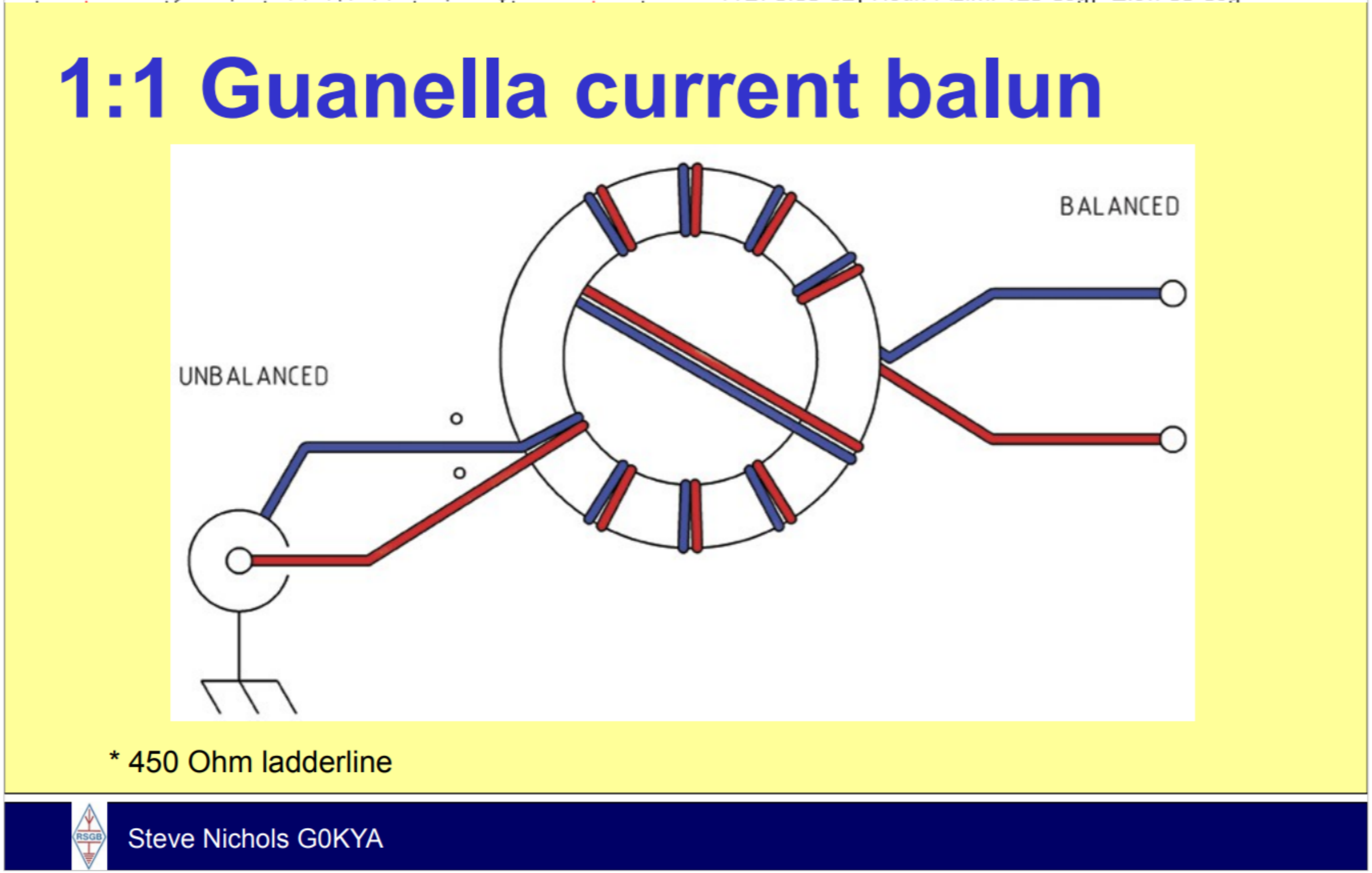

1:1 Guanella current balun

* 450 Ohm ladderline

Steve Nichols G0KYA

A Guanella or current balun is very common. Current baluns stop RF from coming back down the outside of the coax shield, and are so called that because they "force equal currents in each side of a dipole"

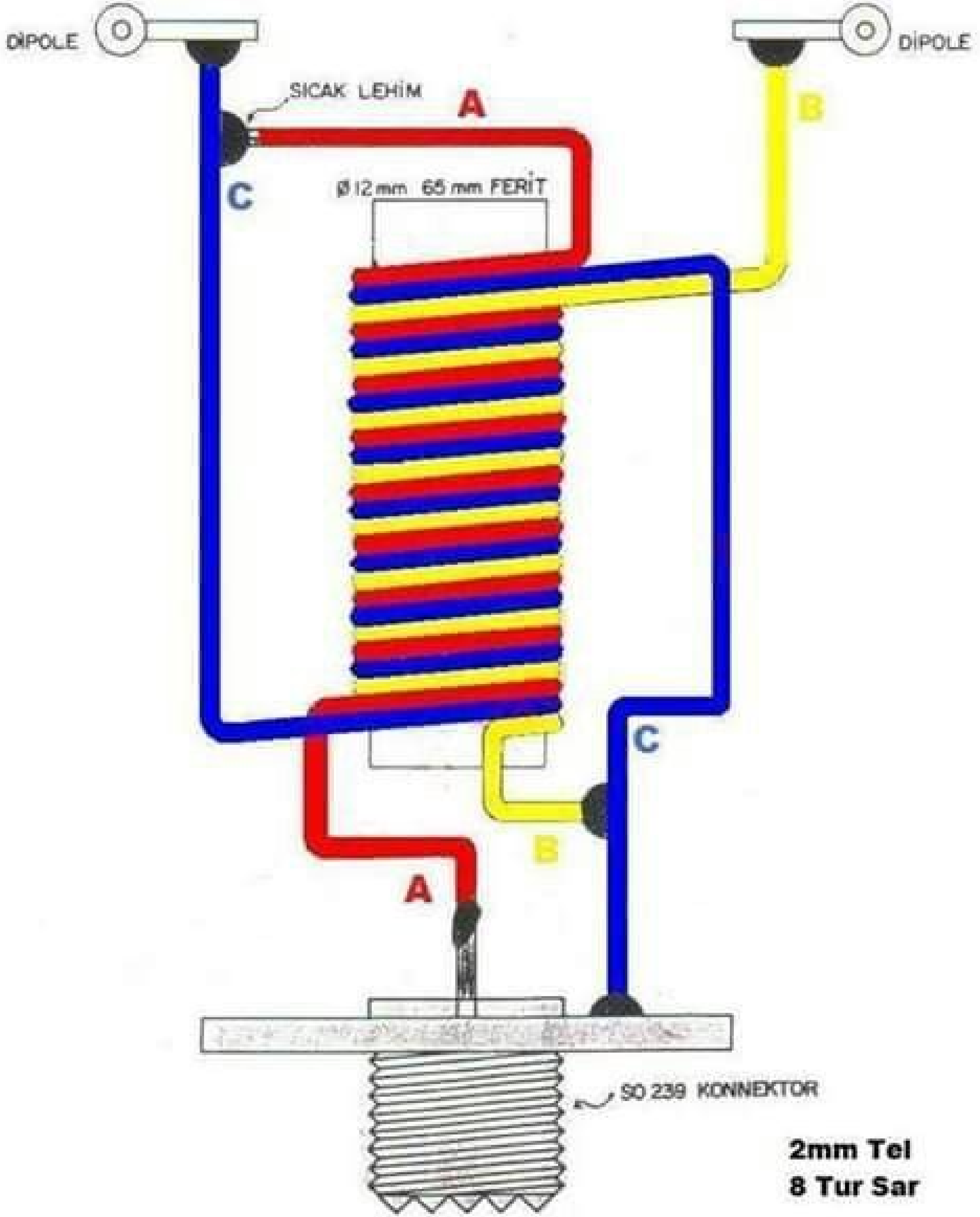
DİPOLE
DİPOLE
SICAK LEHİM
A
B
C
Ø 12 mm 65 mm FERİT
C
B
A
SO 239 KONNEKTOR

2mm Tel
8 Tur Sar

© Azega.com

Ion Harvesting Materials Test Fixture

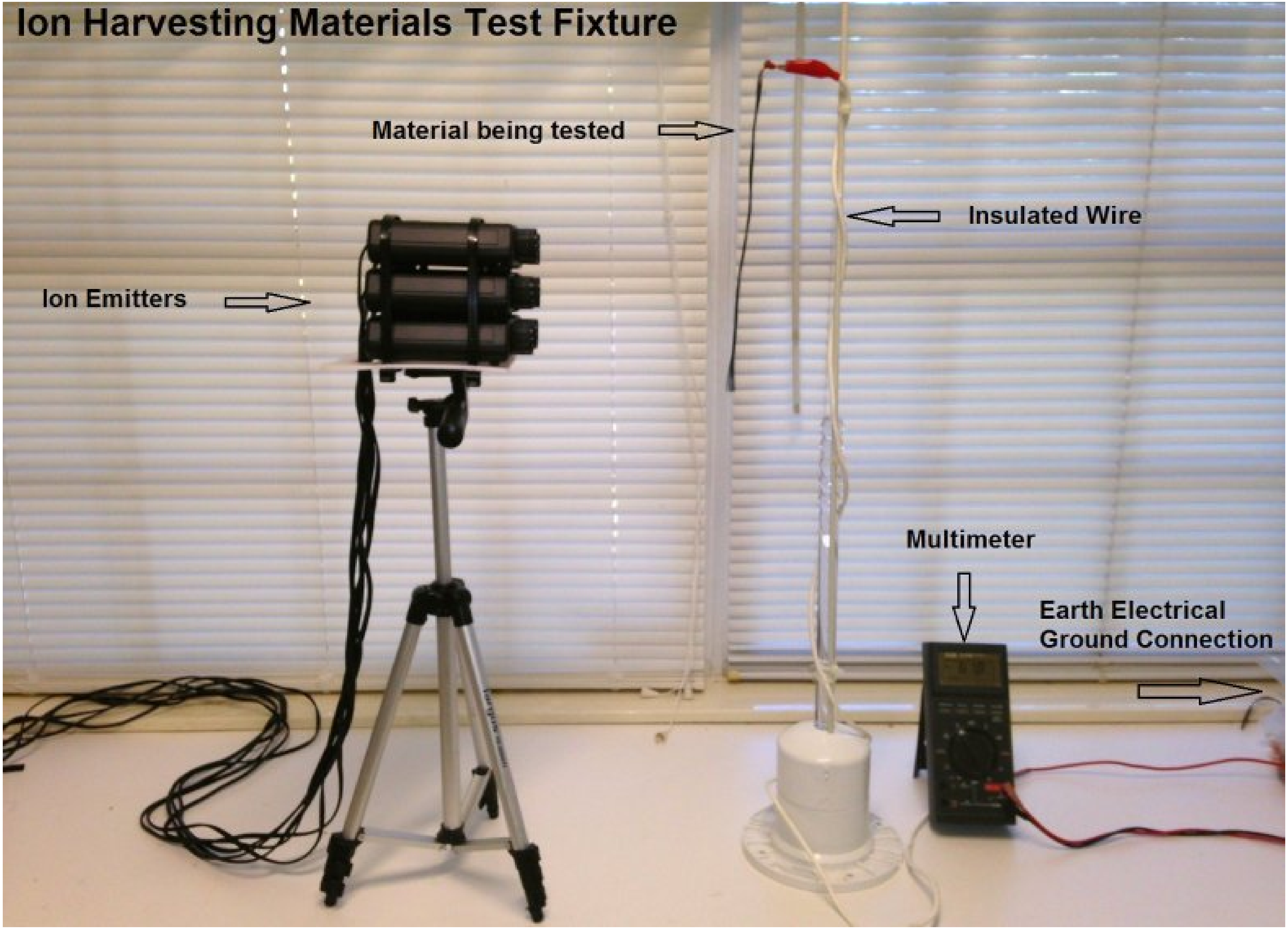
Material being tested
Insulated Wire
Ion Emitters
Multimeter
Earth Electrical
Ground Connection

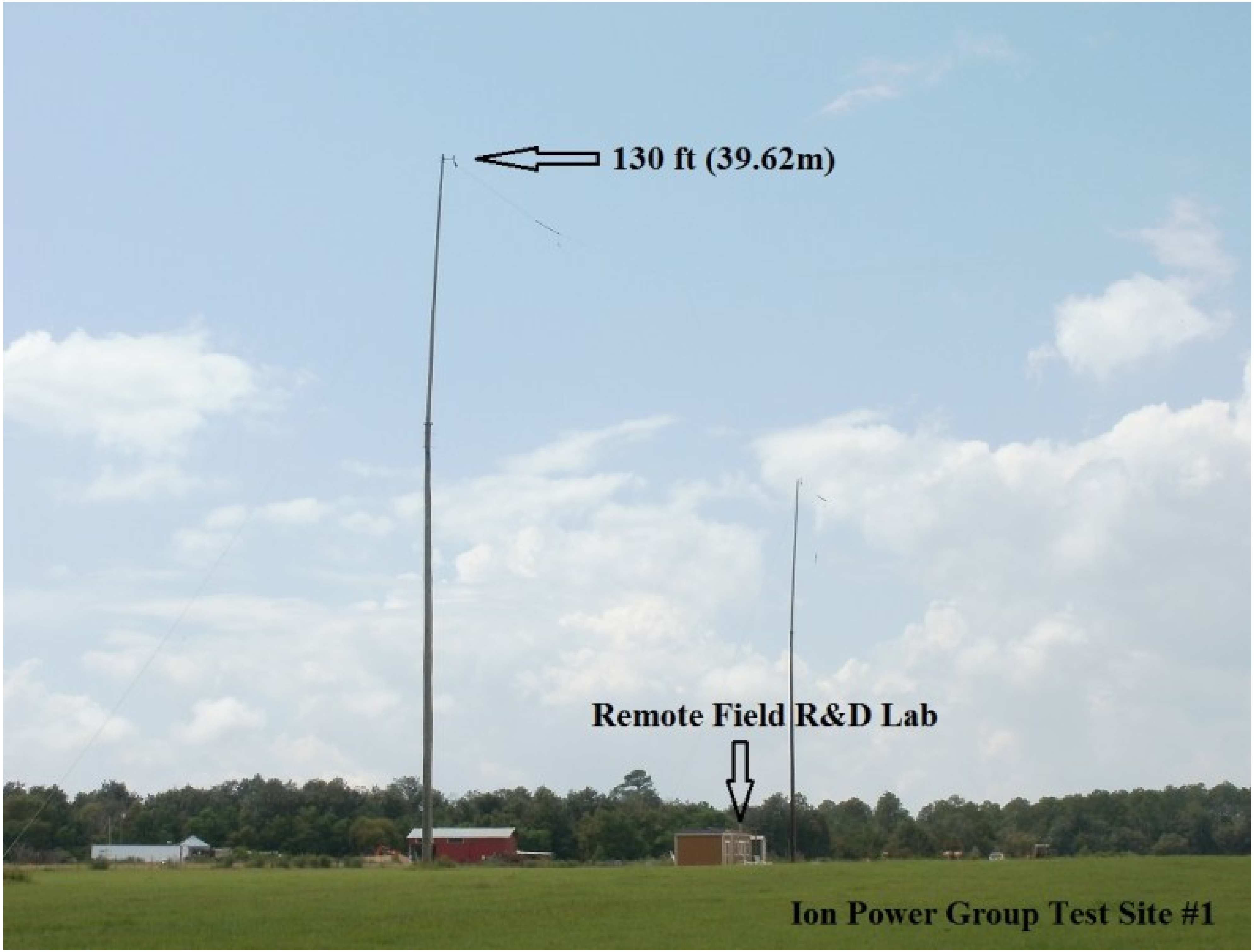
130 ft (39.62m)
Remote Field R&D Lab
Ion Power Group Test Site #1

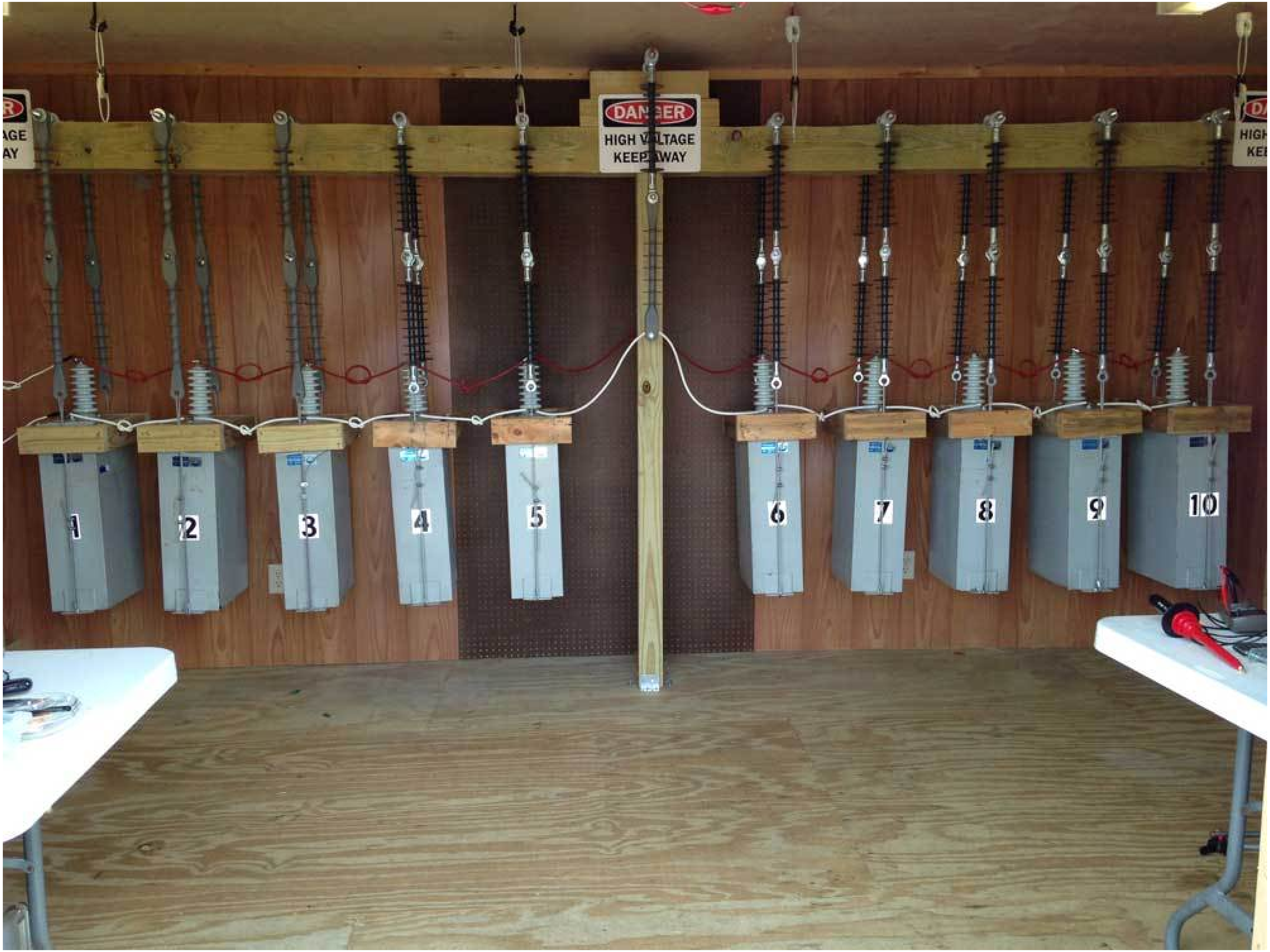
DANGER
HIGH VOLTAGE
KEEP AWAY
1
2
3
4
5
6
7
8
9
10

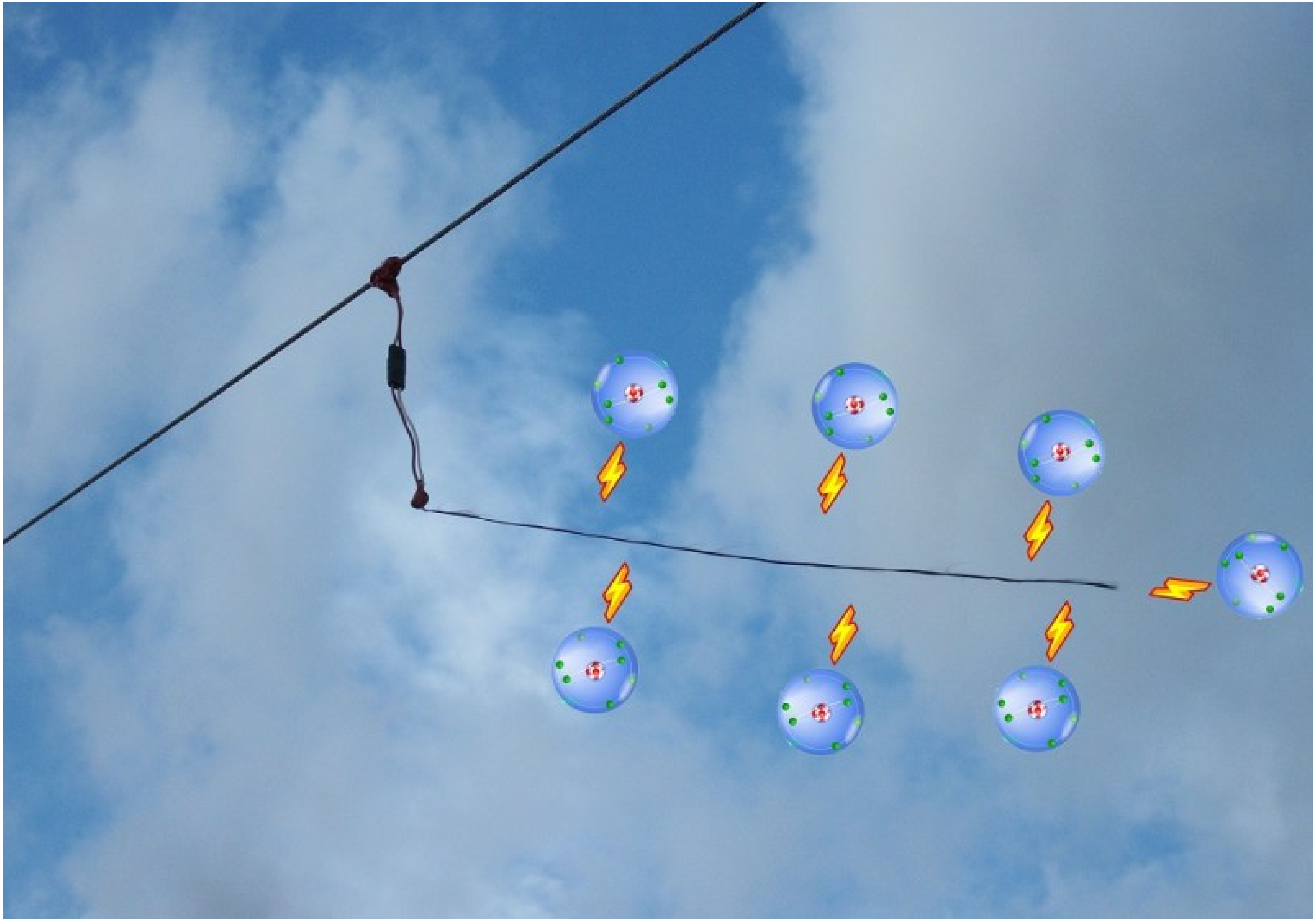

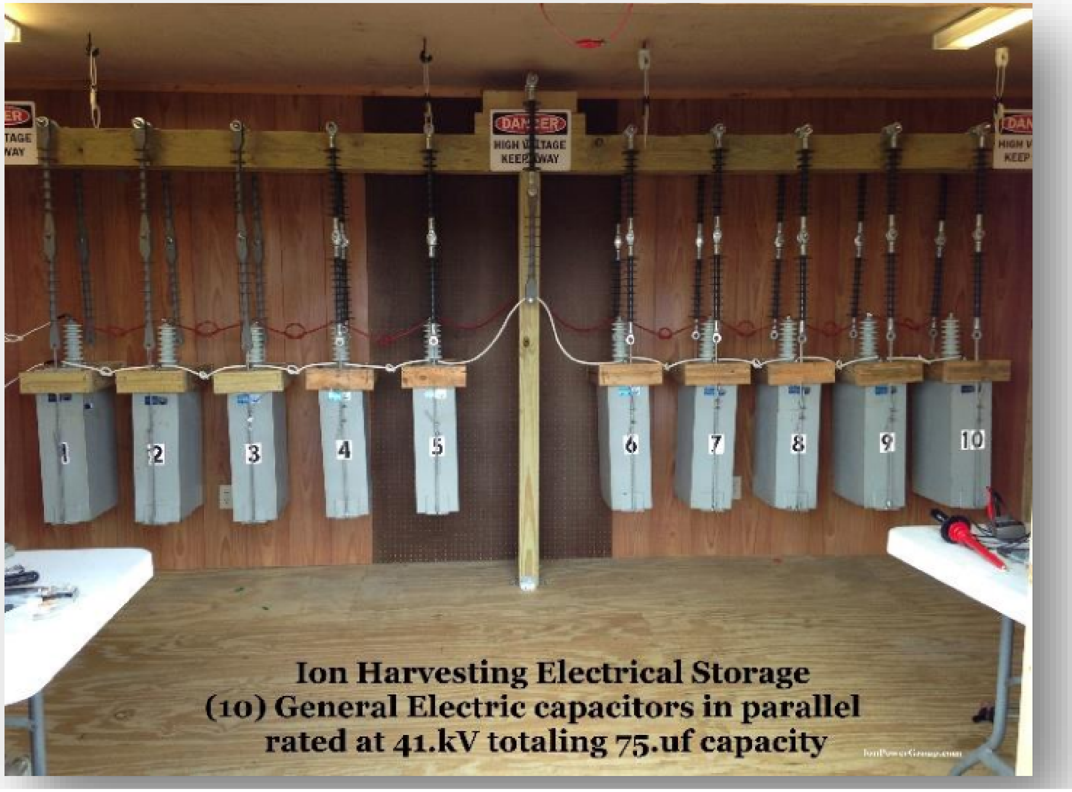

Ion Harvesting Electrical Storage
(10) General Electric capacitors in parallel
rated at 41.kV totaling 75.uf capacity

DANGER
HIGH VOLTAGE
KEEP AWAY
1
2
3
4
5
6
7
8
9
10
IonPowerGroup.com

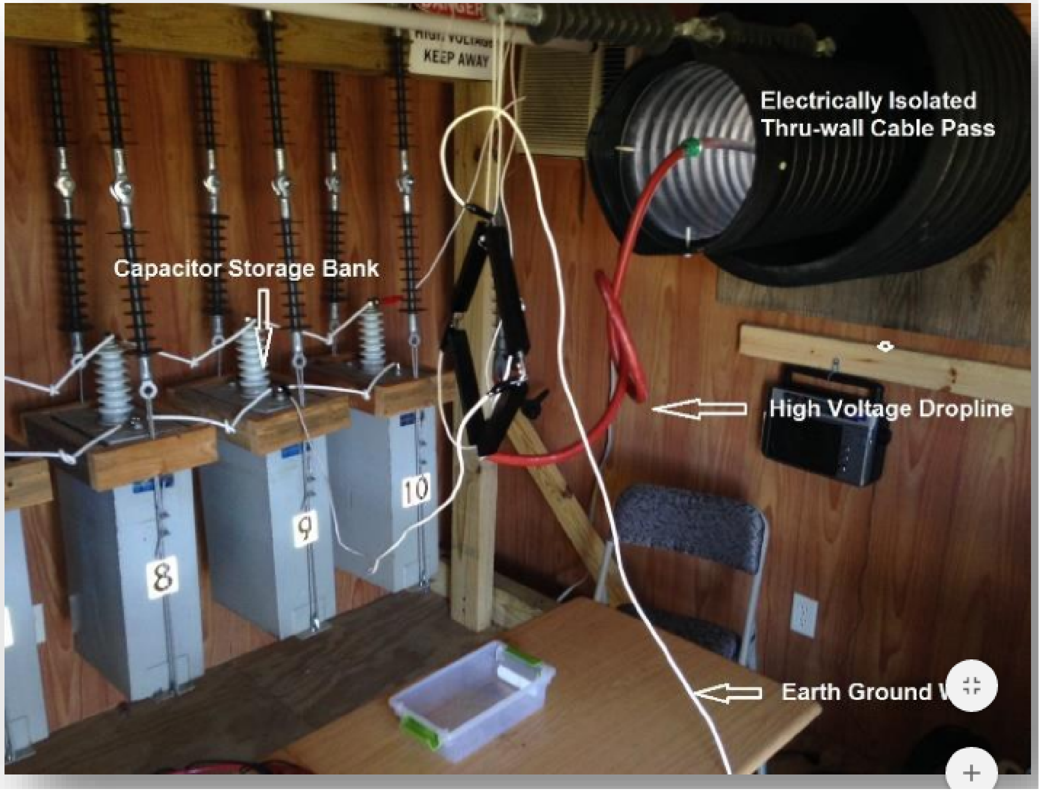

KEEP AWAY
Electrically Isolated
Thru-wall Cable Pass
Capacitor Storage Bank
High Voltage Dropline
Earth Ground W
8
9
10

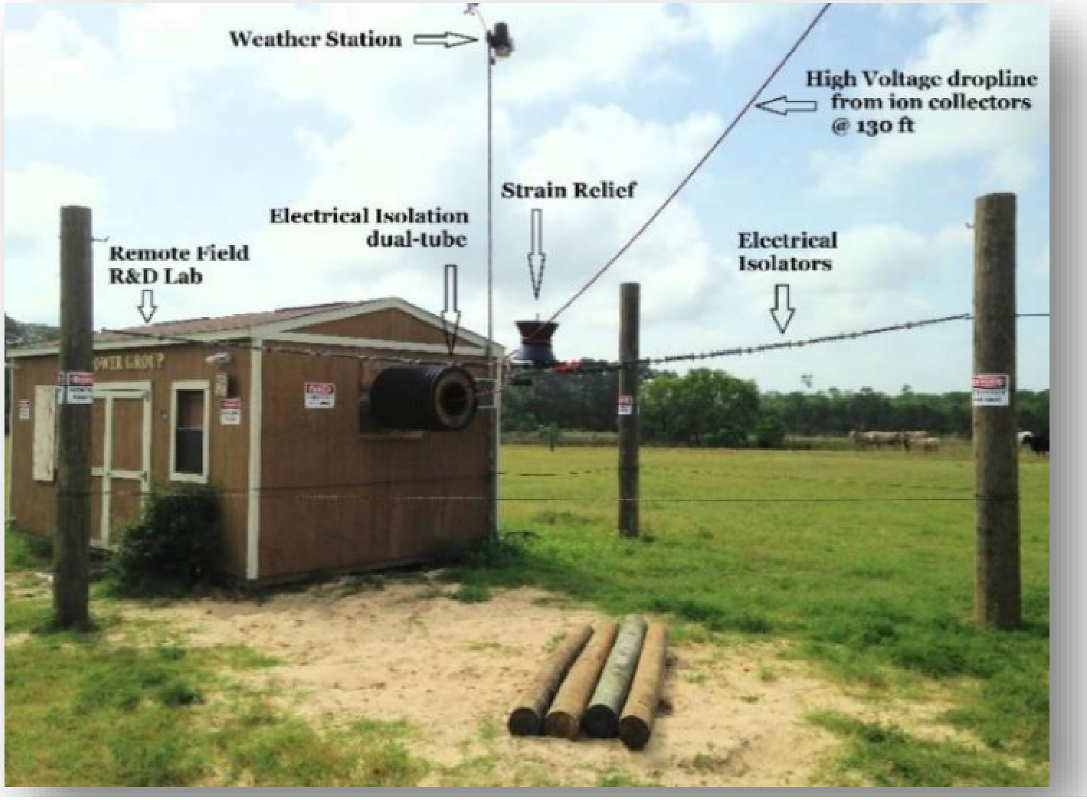
Weather Station
High Voltage dropline from ion collectors @ 130 ft
Strain Relief
Electrical Isolation dual-tube
Remote Field R&D Lab
Electrical Isolators

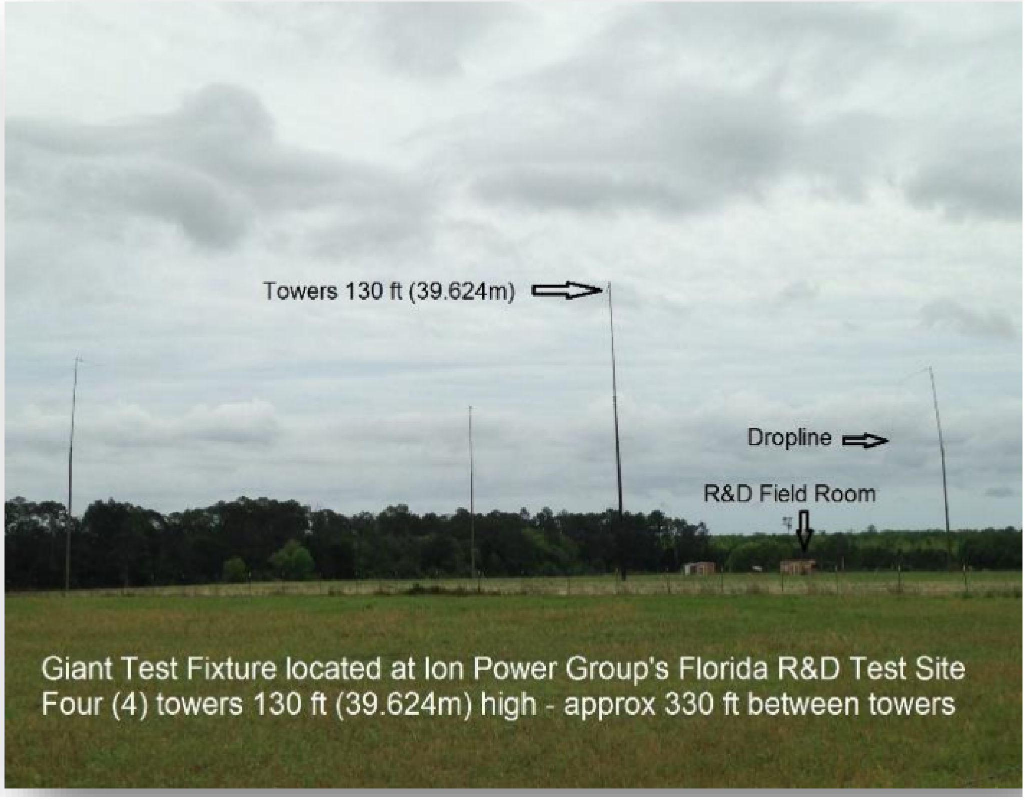
Towers 130 ft (39.624m)
Dropline
R&D Field Room

Giant Test Fixture located at Ion Power Group's Florida R&D Test Site
Four (4) towers 130 ft (39.624m) high - approx 330 ft between towers

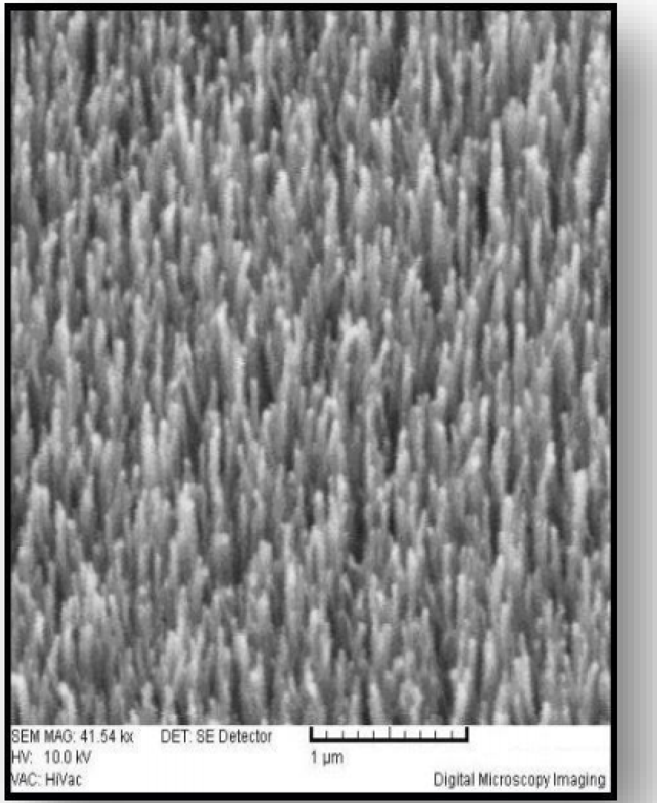
SEM MAG: 41.54 kx
DET: SE Detector
1 μm
HV: 10.0 kV
VAC: HiVac
Digital Microscopy Imaging

Ion Power Group’s new method of coupling to atmospheric electricity is vastly different from all previous techniques by virtue of our patented breakthrough revealing that carbon nanomaterials such as **Graphite (and Graphene) microscopic shown at left, macroscopic shown at right are significantly more effective at coupling to airborne charge carriers (ions) than metal.** The use of carbon based nanomaterials distinguishes Ion Power Group from all other researchers.

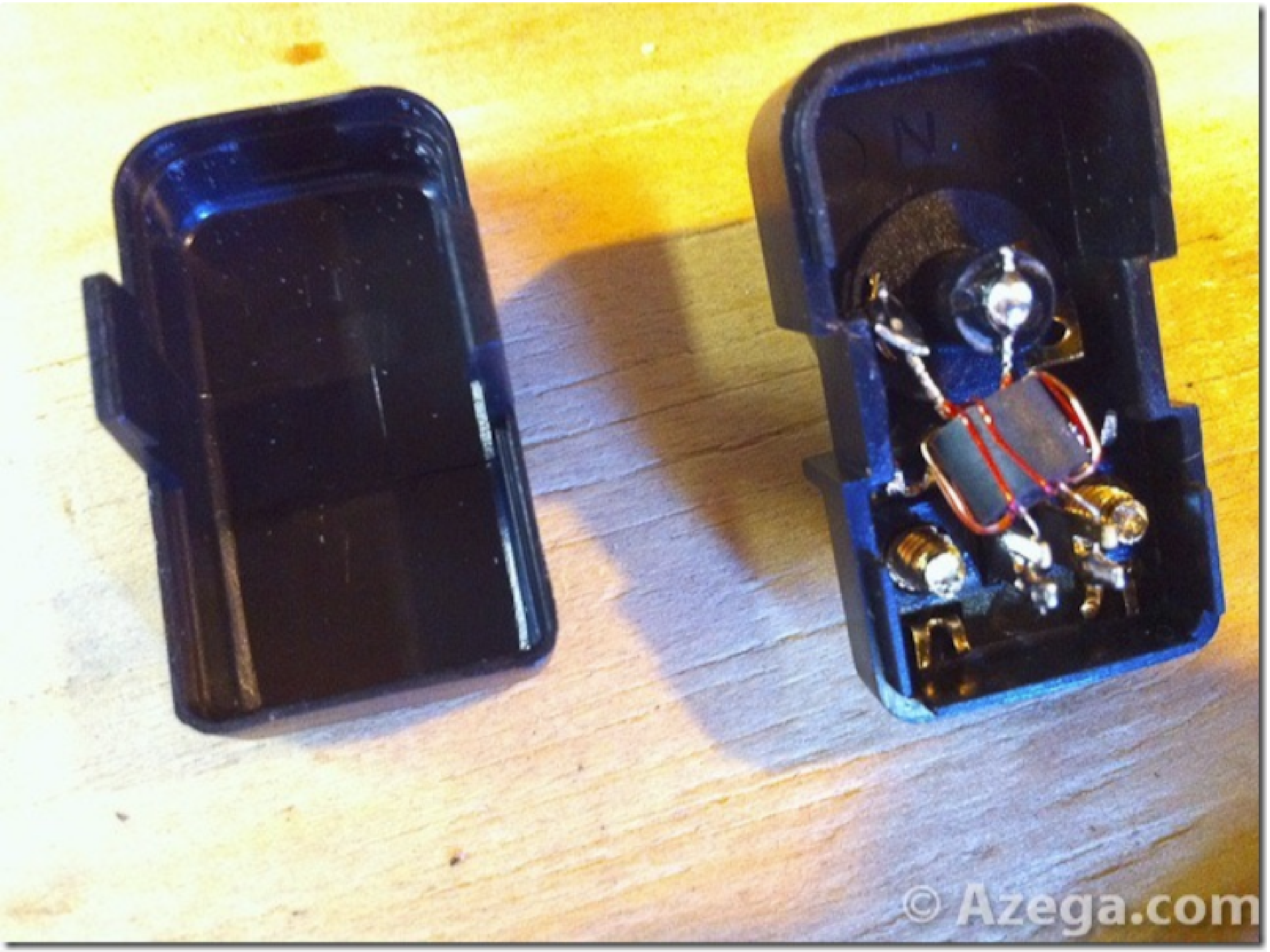

I cut a hole in the side of the balun then cut the end off a piece of coax cable I had and soldered it to the contacts of the coax connection.

EXAMPLE: W1JR (Reisert) Cross-Winding Method

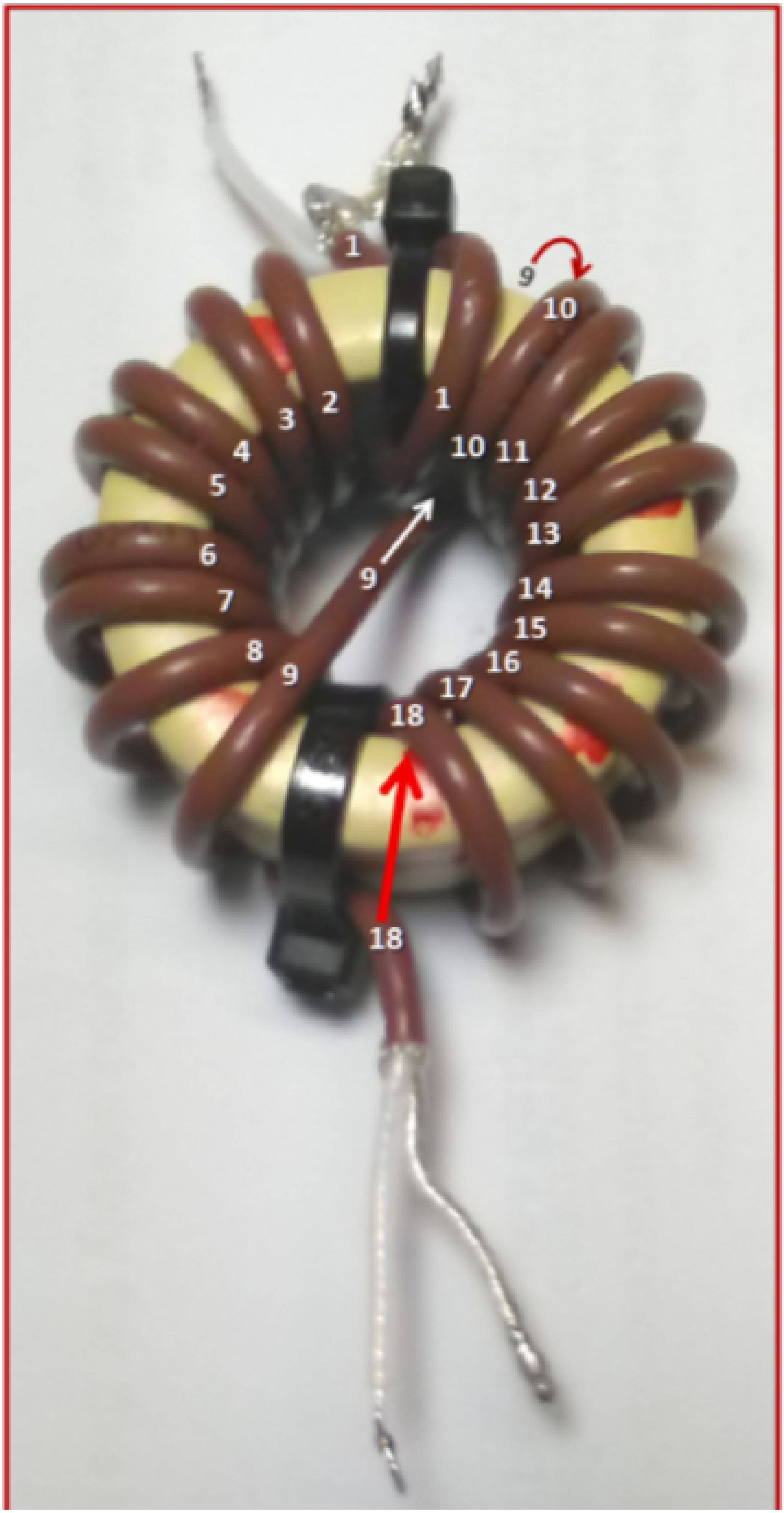
1
9
10
2
3
1
4
10
11
5
12
13
6
9
14
7
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8
16
9
17
18
18

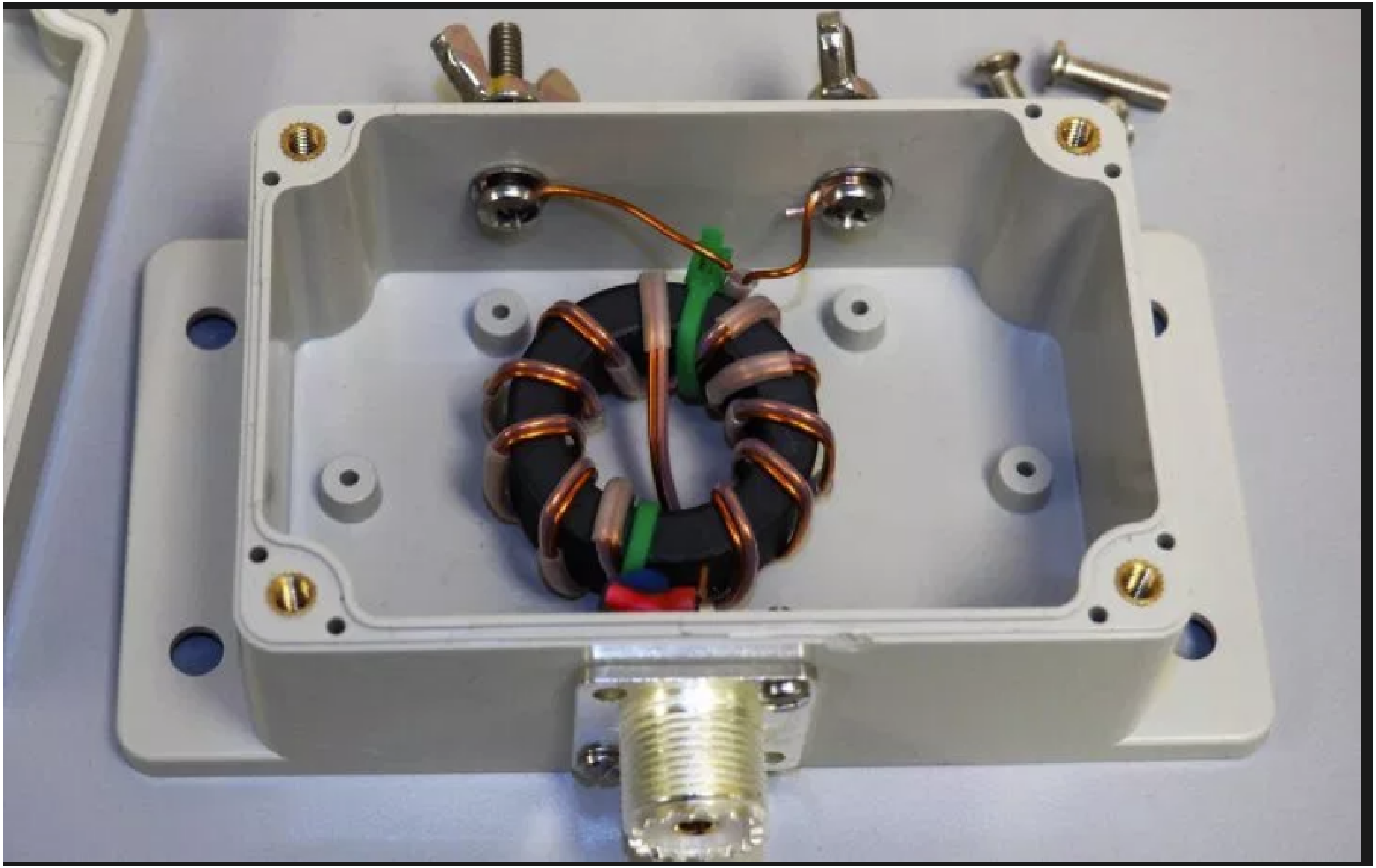

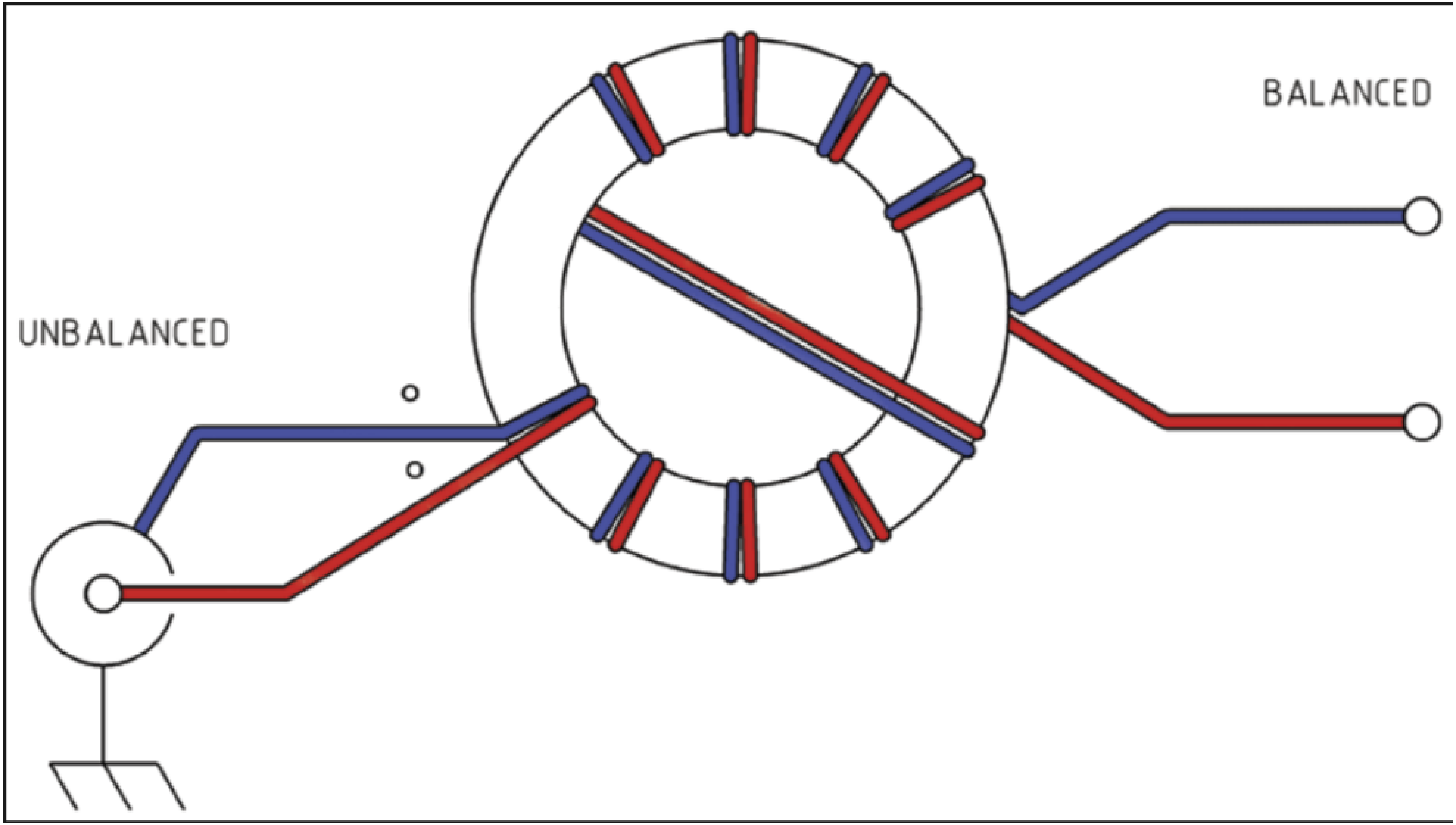
BALANCED
UNBALANCED

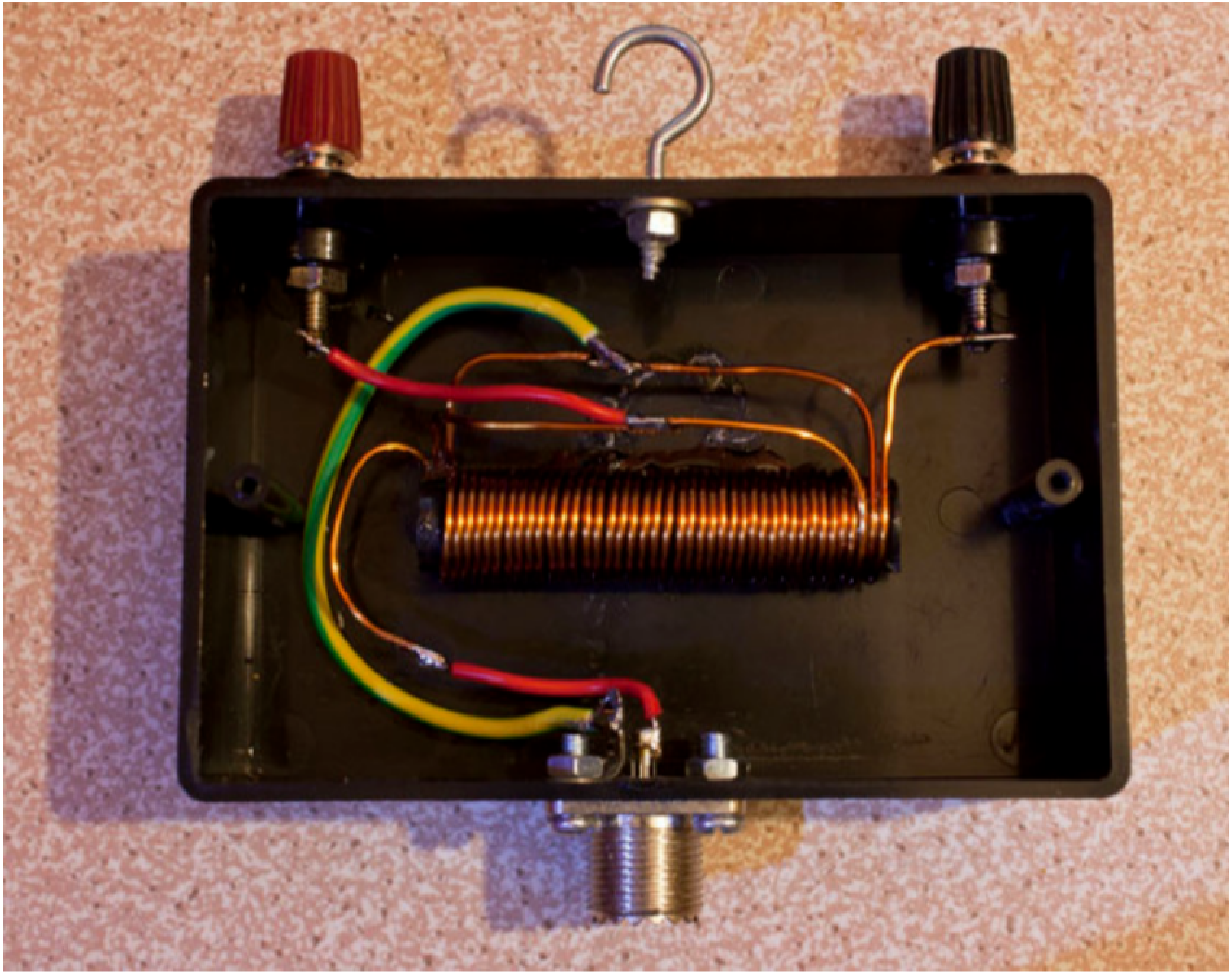

Balun 1: 1 for HF

1:1 Voltage balun ("Ruthroff")

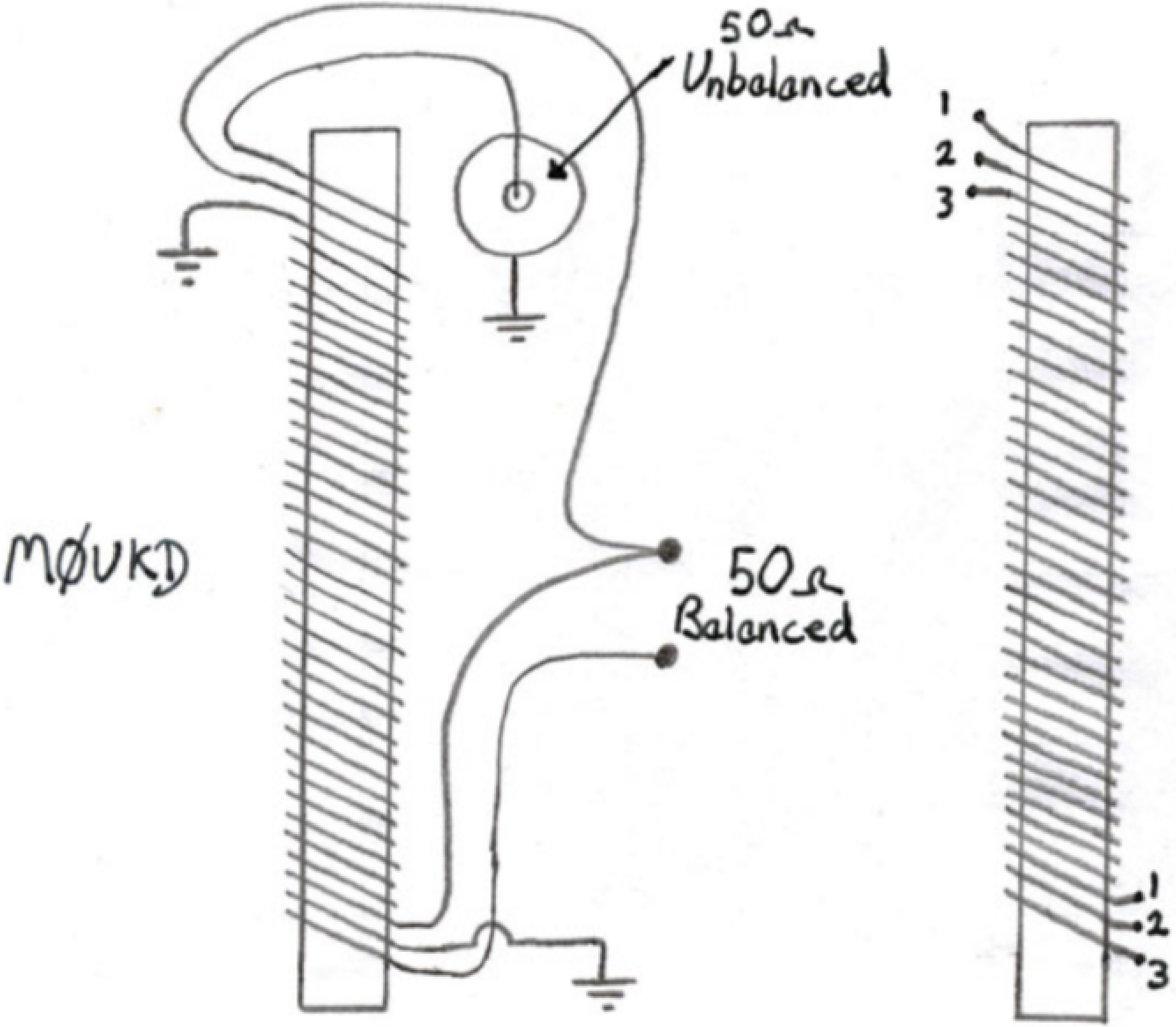
50Ω
Unbalanced
1
2
3
M0UKD
50Ω
Balanced
1
2
3

10 - 15 trifiler turns on ferrite rod.

1:1 ferrite rod voltage balun

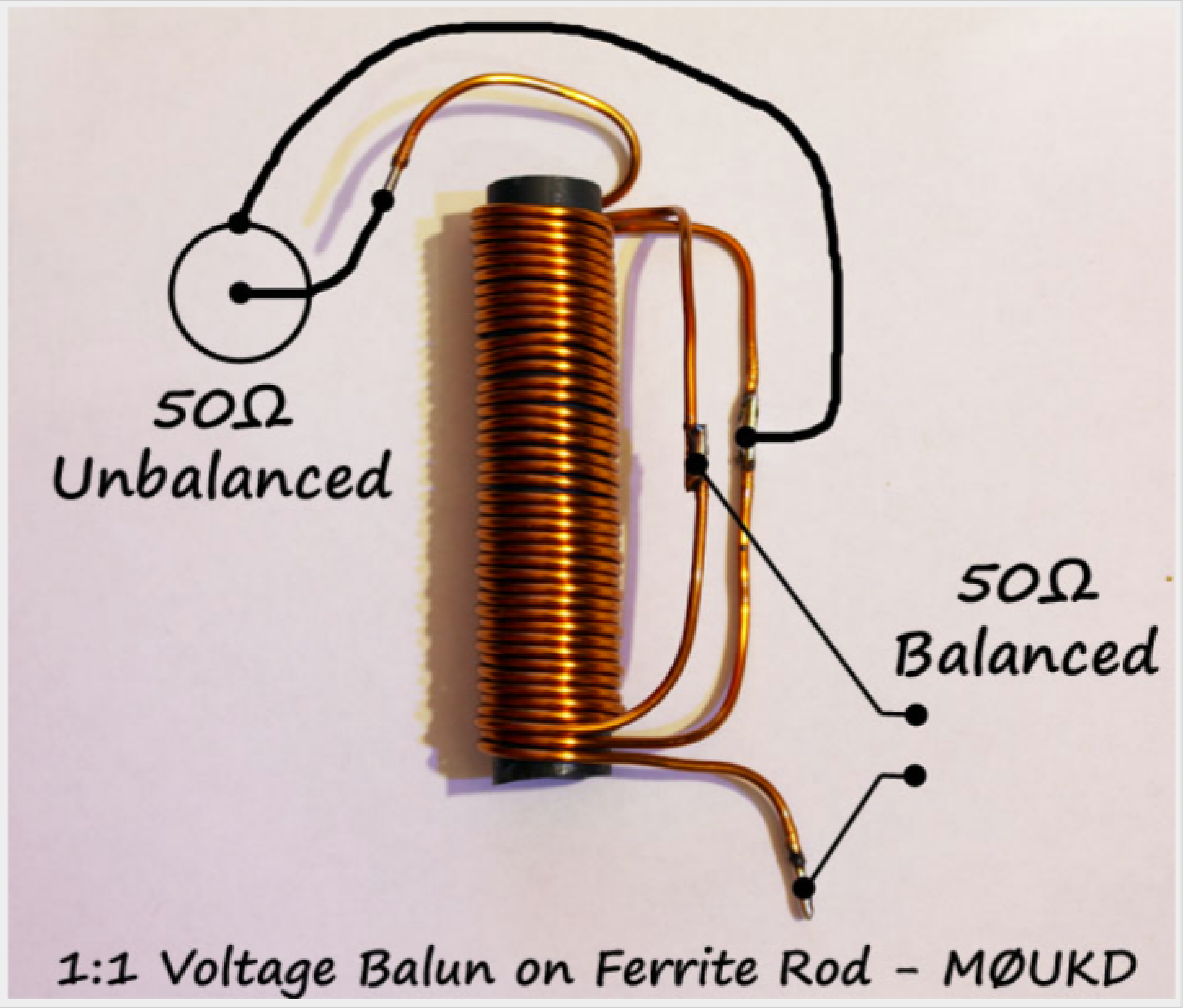
50Ω
Unbalanced
50Ω
Balanced
1:1 Voltage Balun on Ferrite Rod - MØUKD

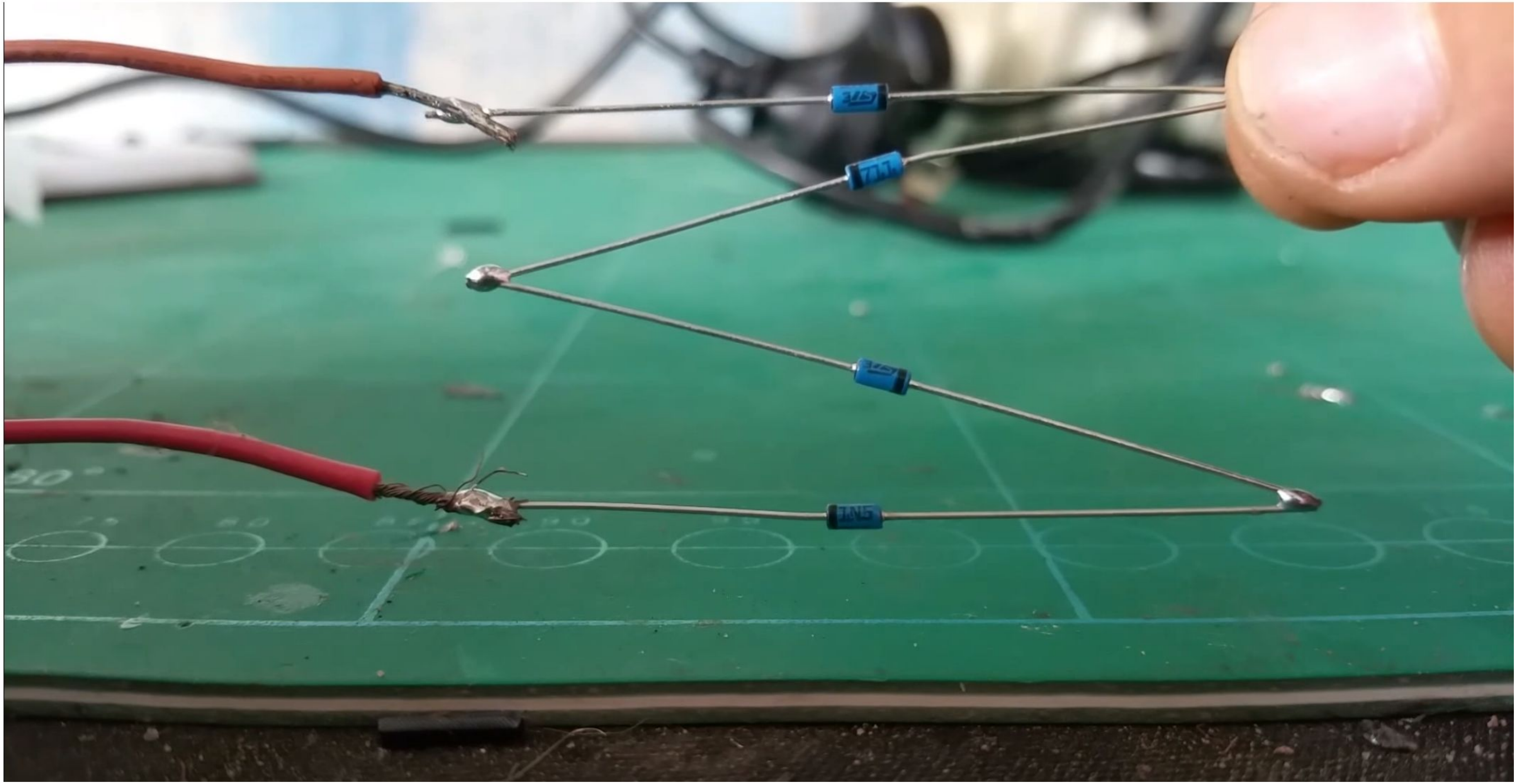
1N5

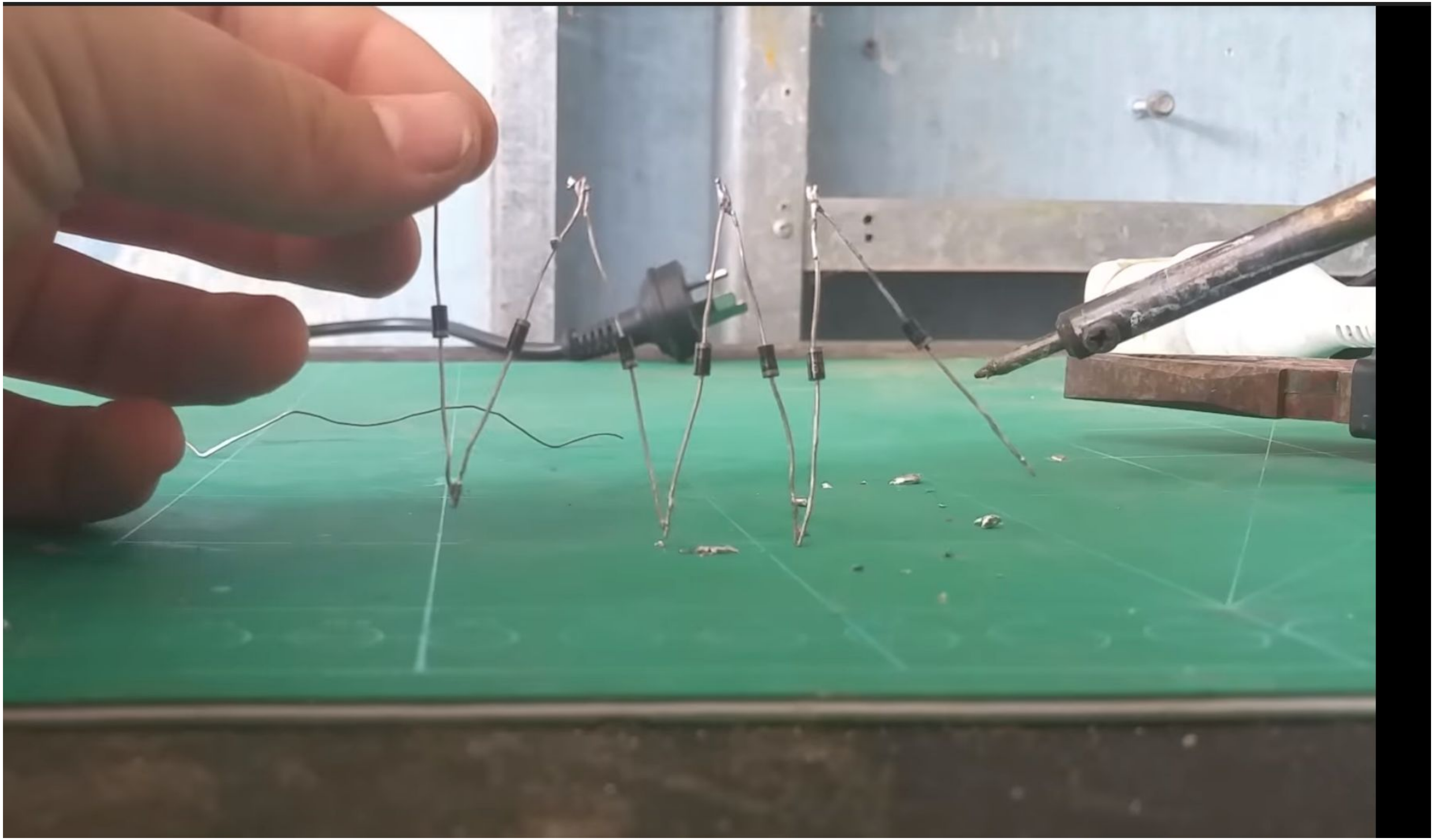

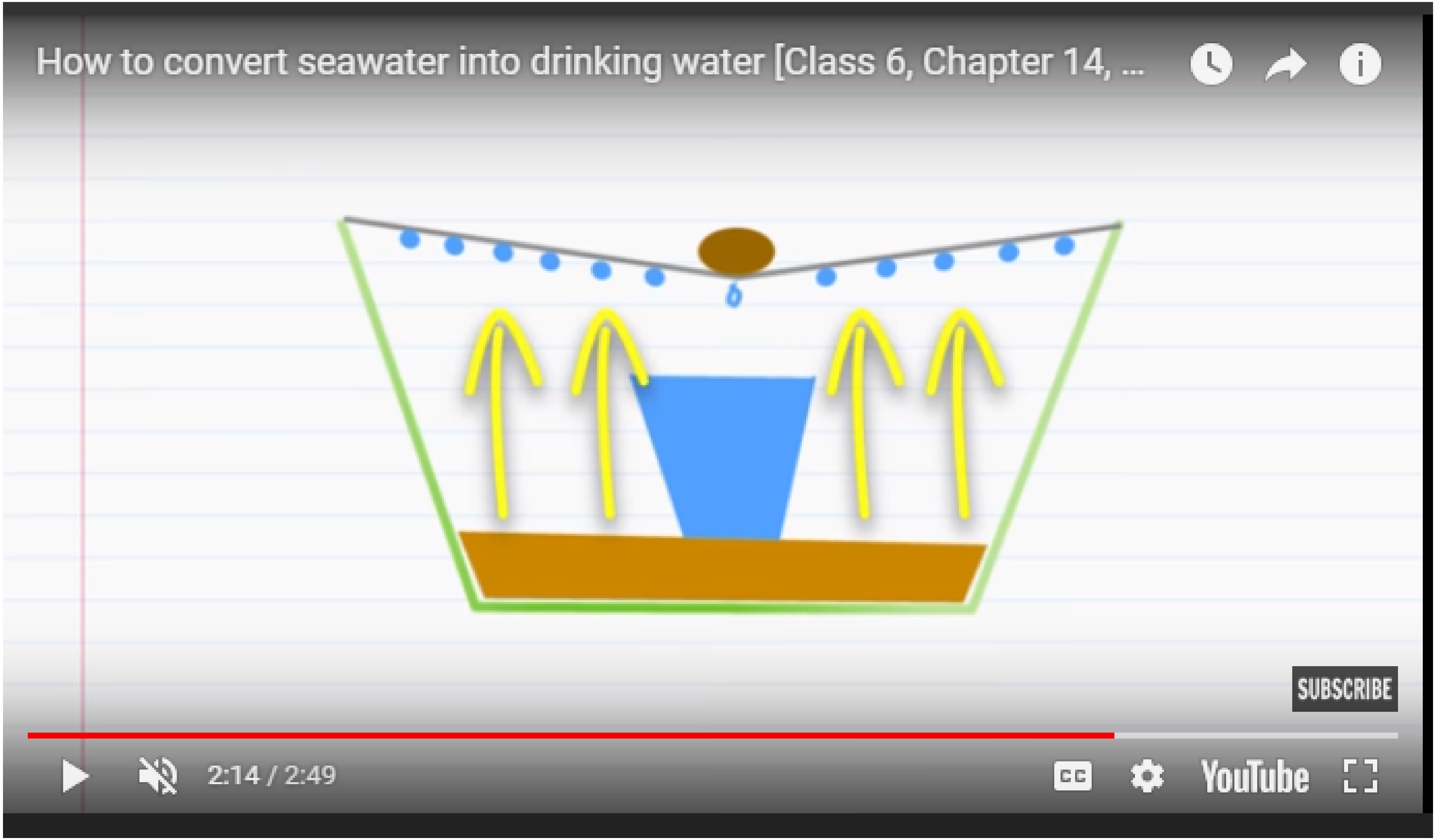

How to convert seawater into drinking water [Class 6, Chapter 14, ...

SUBSCRIBE
2:14 / 2:49
CC
YouTube

How to convert seawater into drinking water [Class 6, Chapter 14, ...

SUBSCRIBE
1:09 / 2:49
YouTube

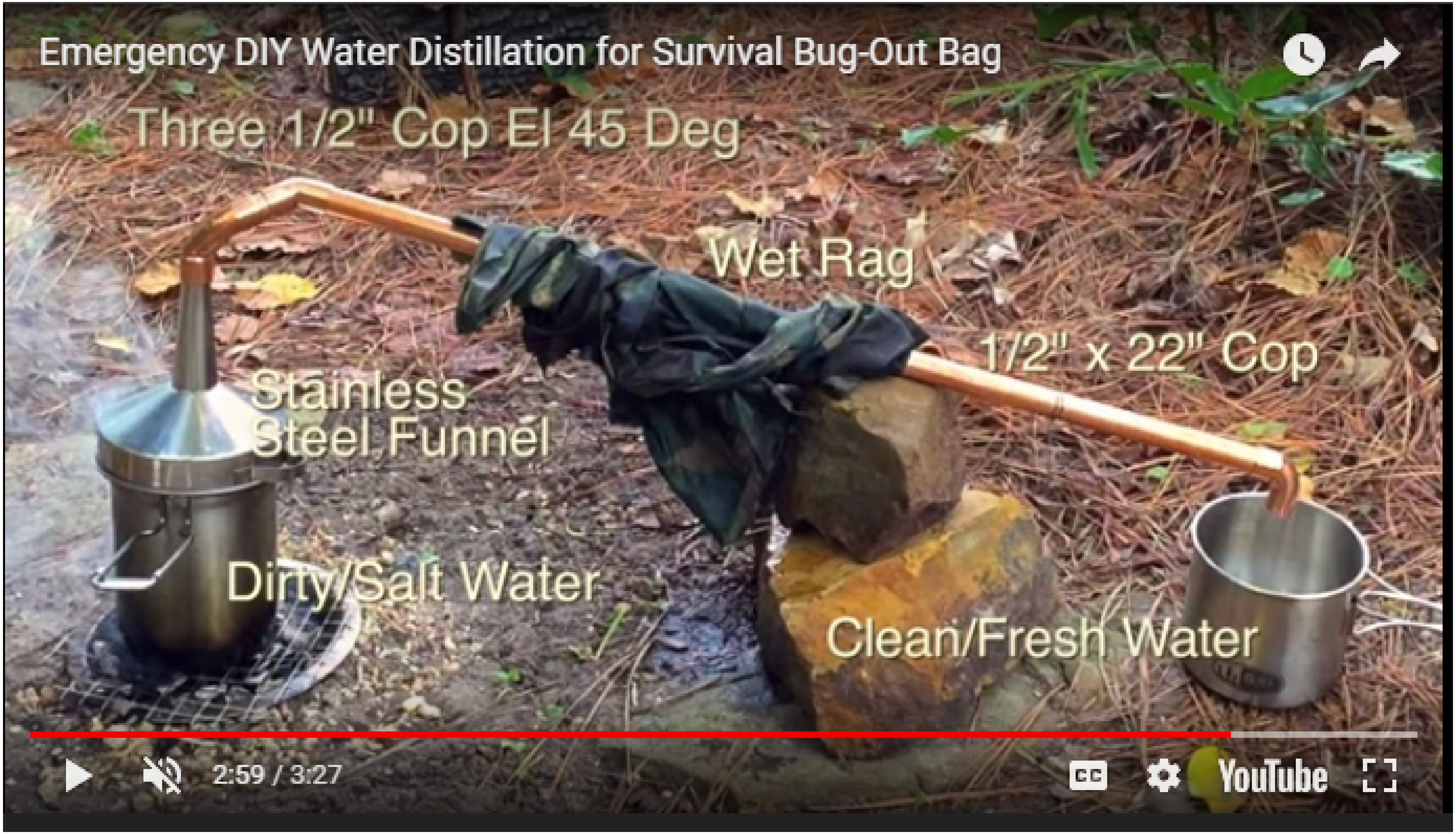
Emergency DIY Water Distillation for Survival Bug-Out Bag
Three 1/2" Cop El 45 Deg
Wet Rag
1/2" x 22" Cop
Stainless
Steel Funnel
Dirty/Salt Water
Clean/Fresh Water
2:59 / 3:27
CC
YouTube

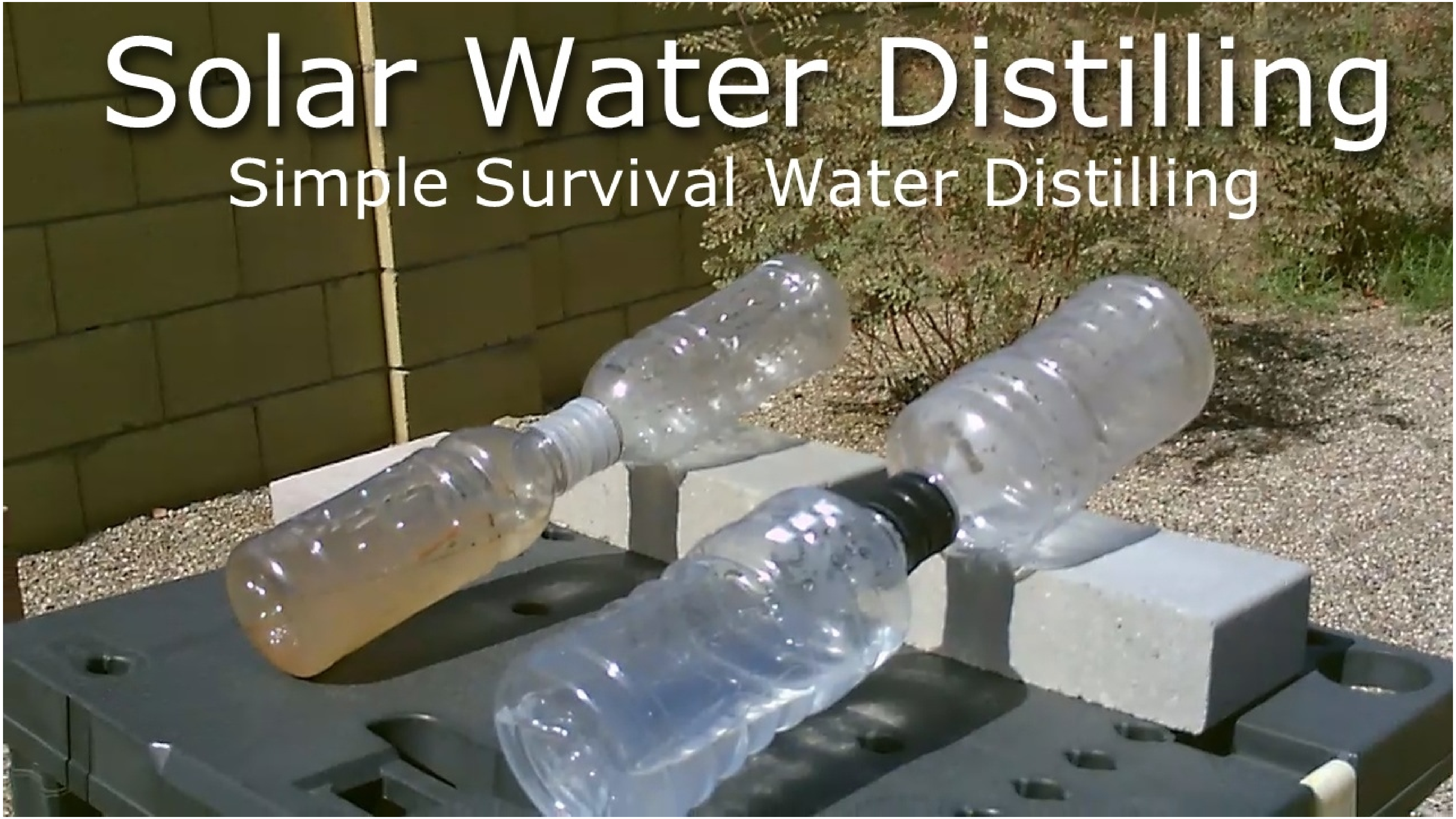

Solar Water Distilling

Simple Survival Water Distilling

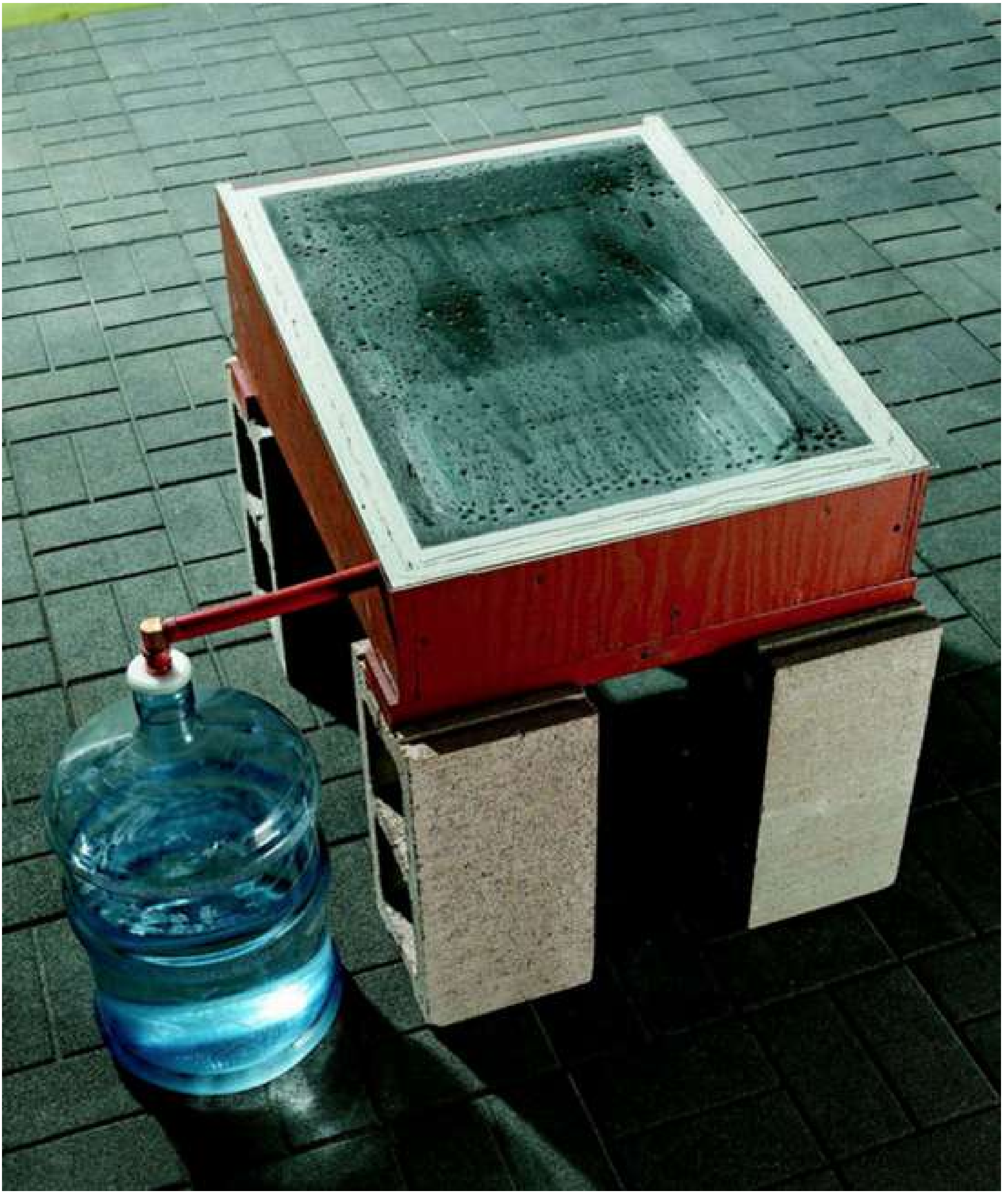

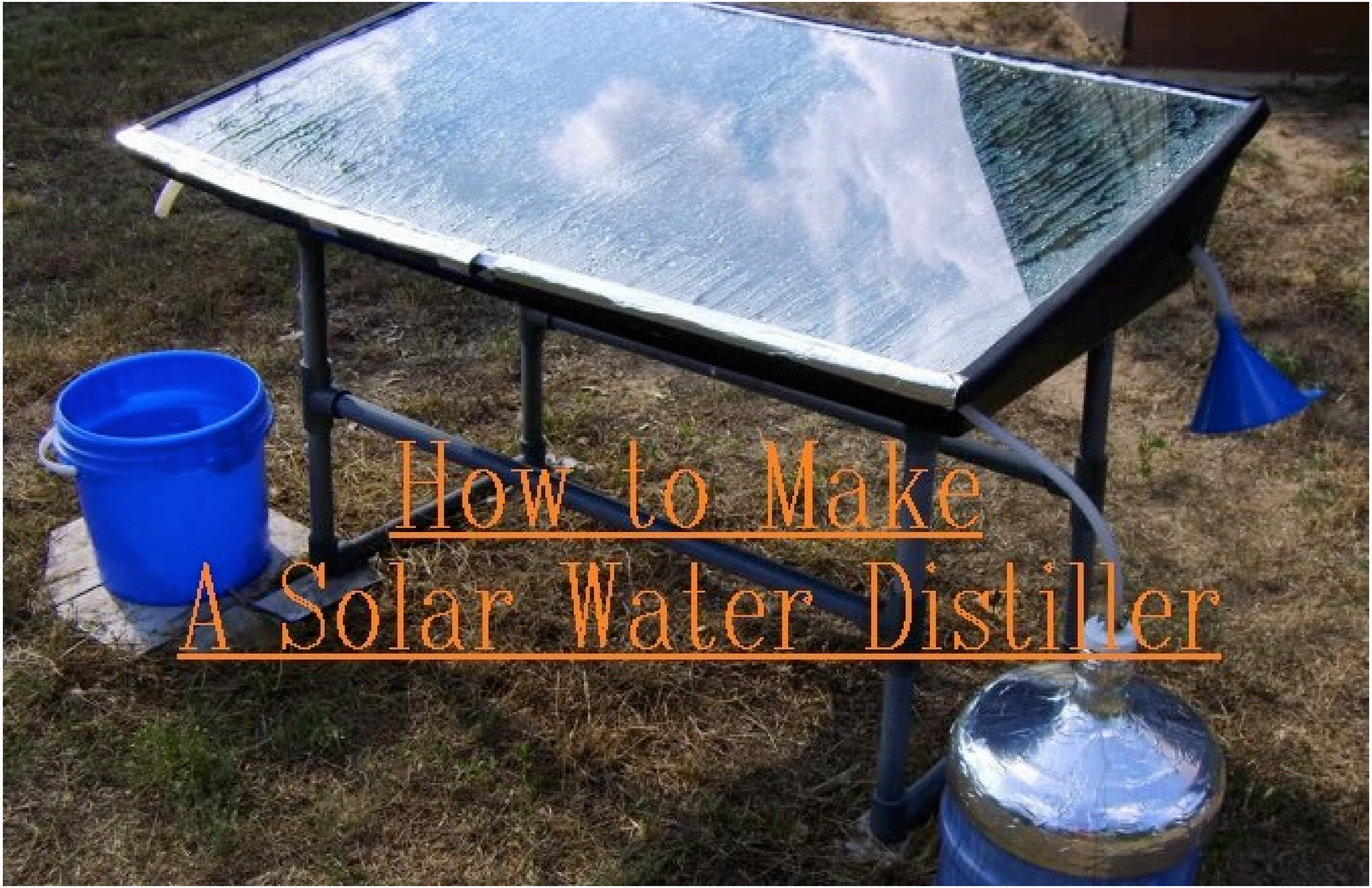

How to Make A Solar Water Distiller

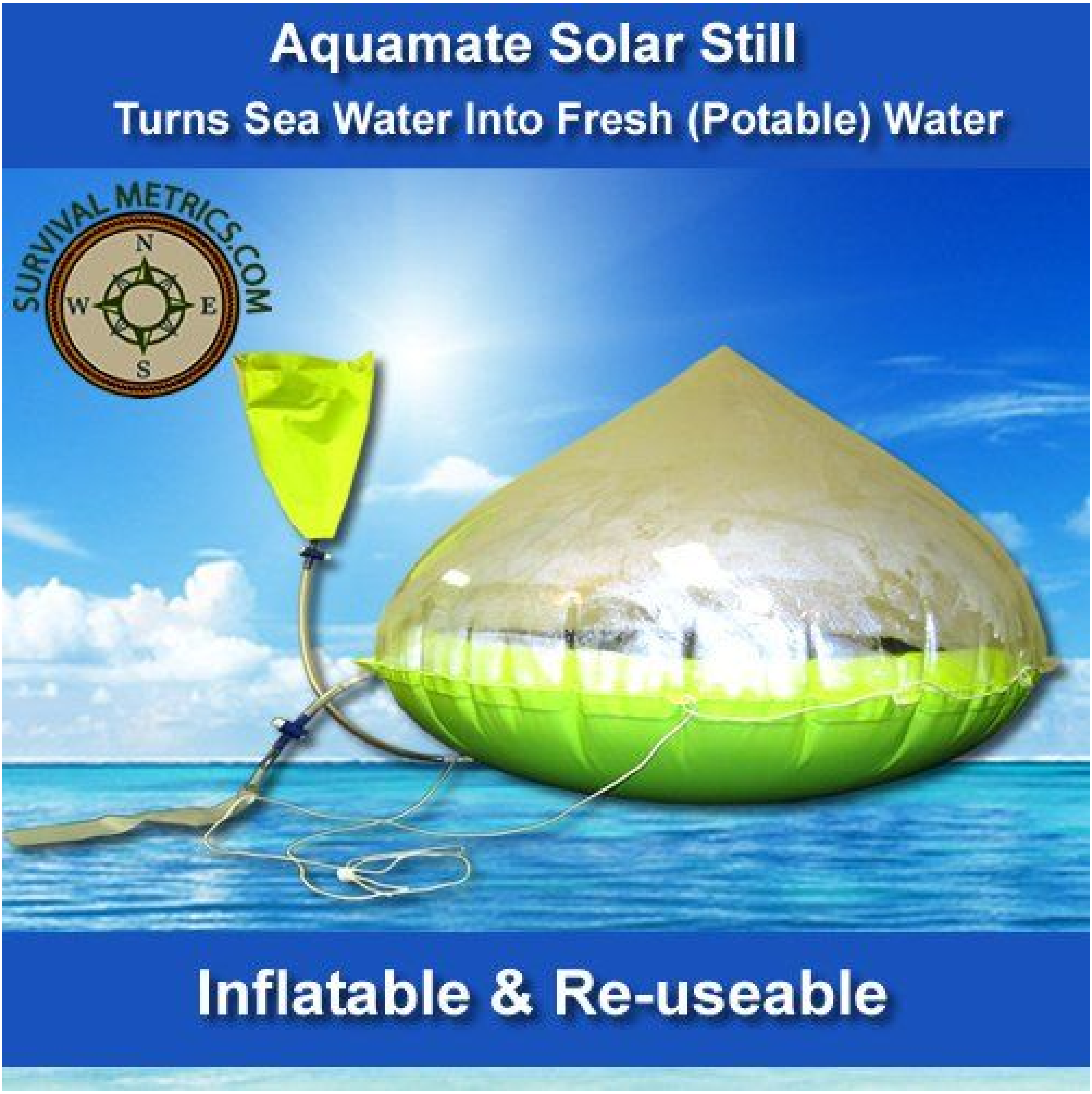

Aquamate Solar Still

Turns Sea Water Into Fresh (Potable) Water

Inflatable & Re-useable

SURVIVALMETRICS.COM
N
W
E
S

Solar Still

Turns sea water or impure water into drinking water

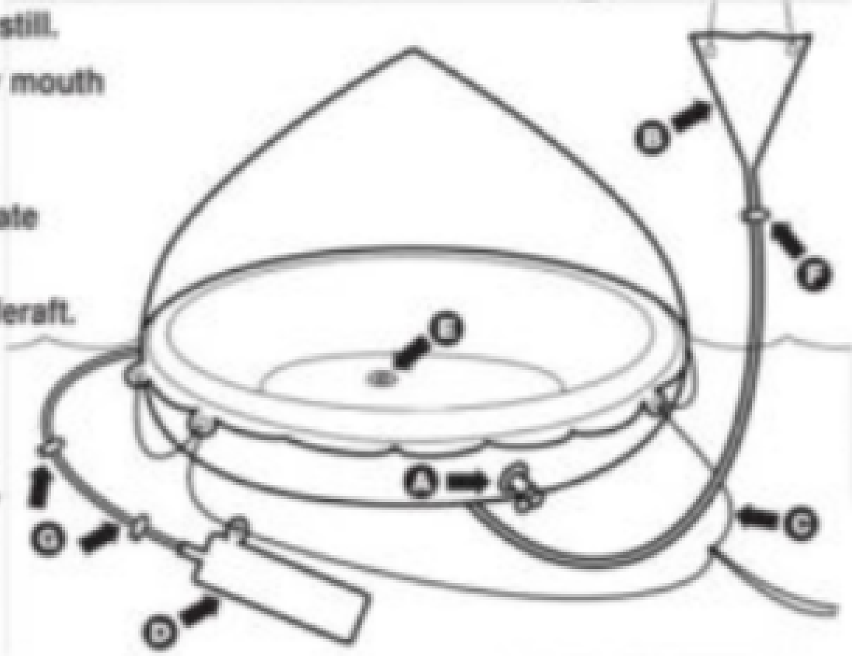

1 Remove from pack and retain pack to top up salt water in still.

2 Lay out Solar Still and inflate valve Ⓐ on floatation ring by mouth or by liferaft or dinghy pump.

3 Inflate clear dome to obtain shape using valve Ⓔ in base. Do not over inflate. It may be necessary to manually regulate dome pressure during high temperatures.

4 Attach tapered bag Ⓑ and attachment cord Ⓒ to boat or liferaft.

5 Pour 5 litres of sea water into tapered bag Ⓑ using pack which holds 5 litres (approx). Close valve Ⓕ after filling.

6 Ensure both valves Ⓖ are open in reservoir feed tube and drinkable water will start to collect in reservoir Ⓓ. Air may need to be squeezed out to assist collection of water.

7 Ensure the Solar Still is kept in direct sunlight whenever possible.

8 Re-fill Solar Still and inflate/deflate dome as required.

9 Daily – Agitate Solar Still to dampen fabric.

10 To drain unwanted water open valve Ⓔ in base.

11 Shelter Solar Still during bad weather.

IMPORTANT

IF INNER BLACK MATERIAL SALTS UP FILL WITH SEA WATER AND AGITATE TO CLEAR SALT CRYSTALS AND DRAIN AWAY. PROCESS DRINKING WATER AS INSTRUCTIONS UNTIL SALT IS NO LONGER PRESENT. IN NO CIRCUMSTANCES DRINK WATER THAT TASTES OF SALT.

5 060259 930188 >

AQUAMATE
PRODUCTS

NATO Stock No. 4610-66-144-2646

P.O. Box 6032 Dunmow CM6 3AS U.K. Tel: +44 (0)1371 830 216 Fax: 831 733 e-mail: aquamatesales@aol.com

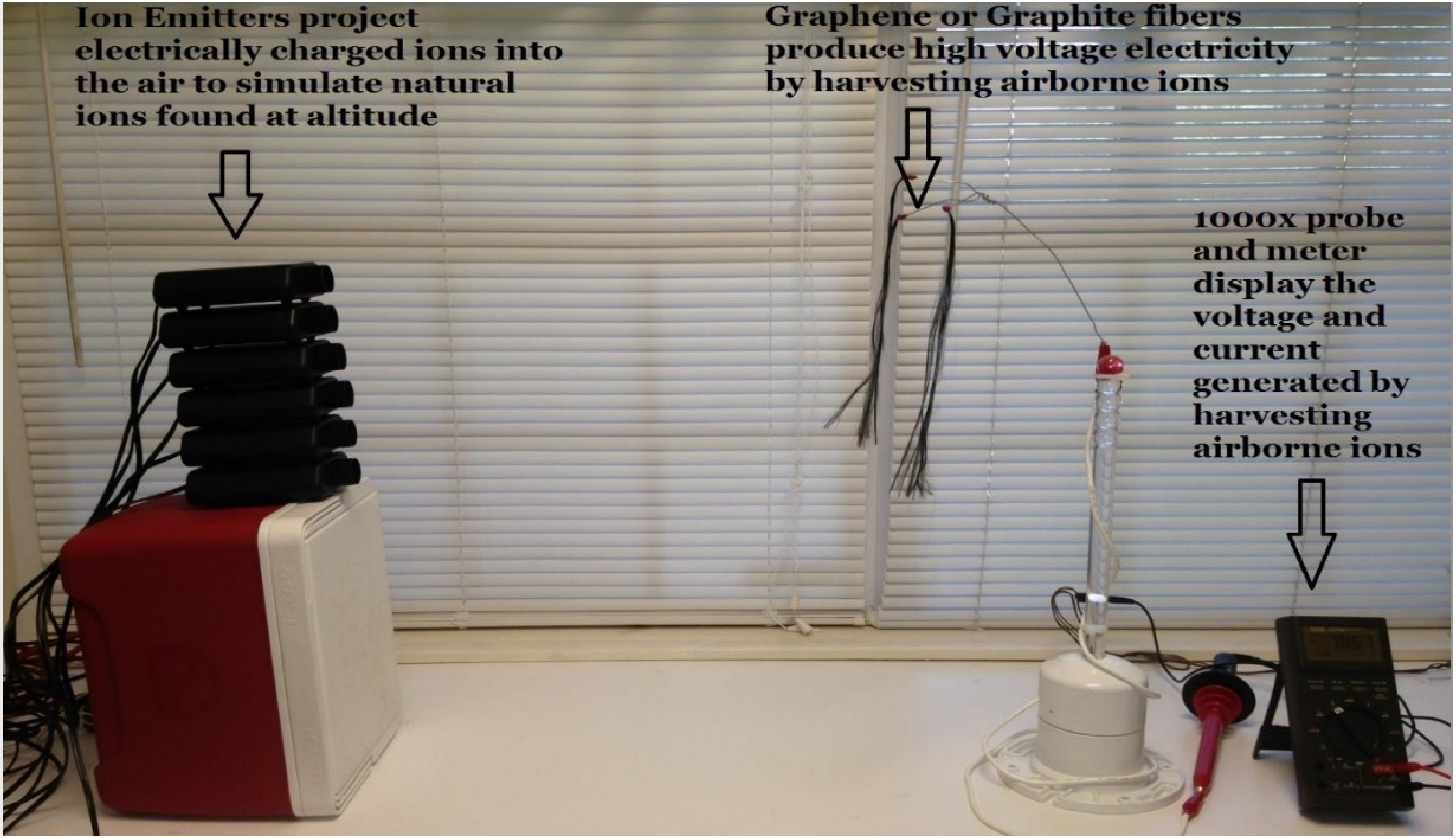

Ion Emitters project electrically charged ions into the air to simulate natural ions found at altitude

Graphene or Graphite fibers produce high voltage electricity by harvesting airborne ions

1000x probe and meter display the voltage and current generated by harvesting airborne ions

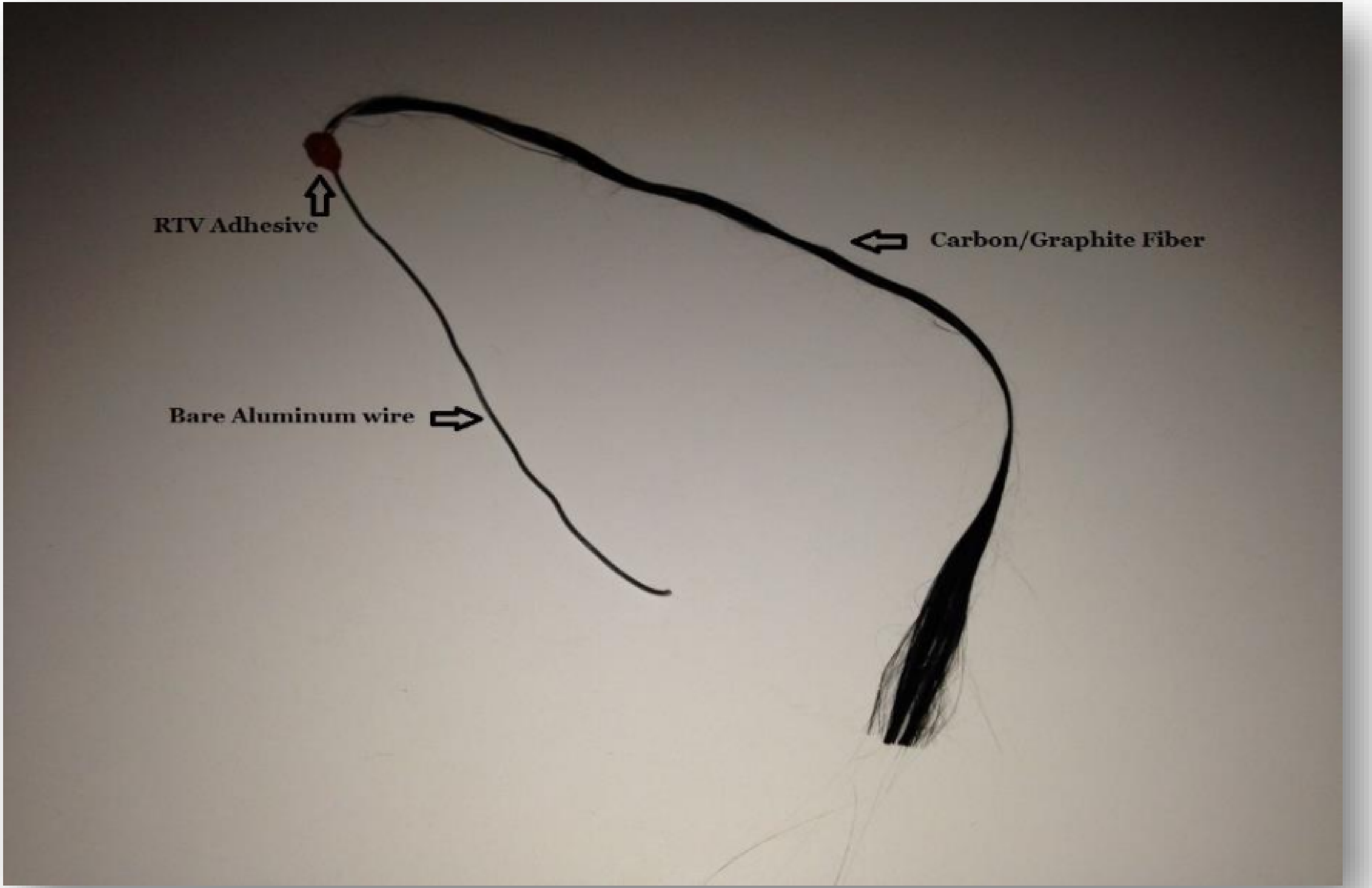
RTV Adhesive
Carbon/Graphite Fiber
Bare Aluminum wire

Image of a patented Ion Collector made of carbon/graphite weighing approximately 1 ounce.

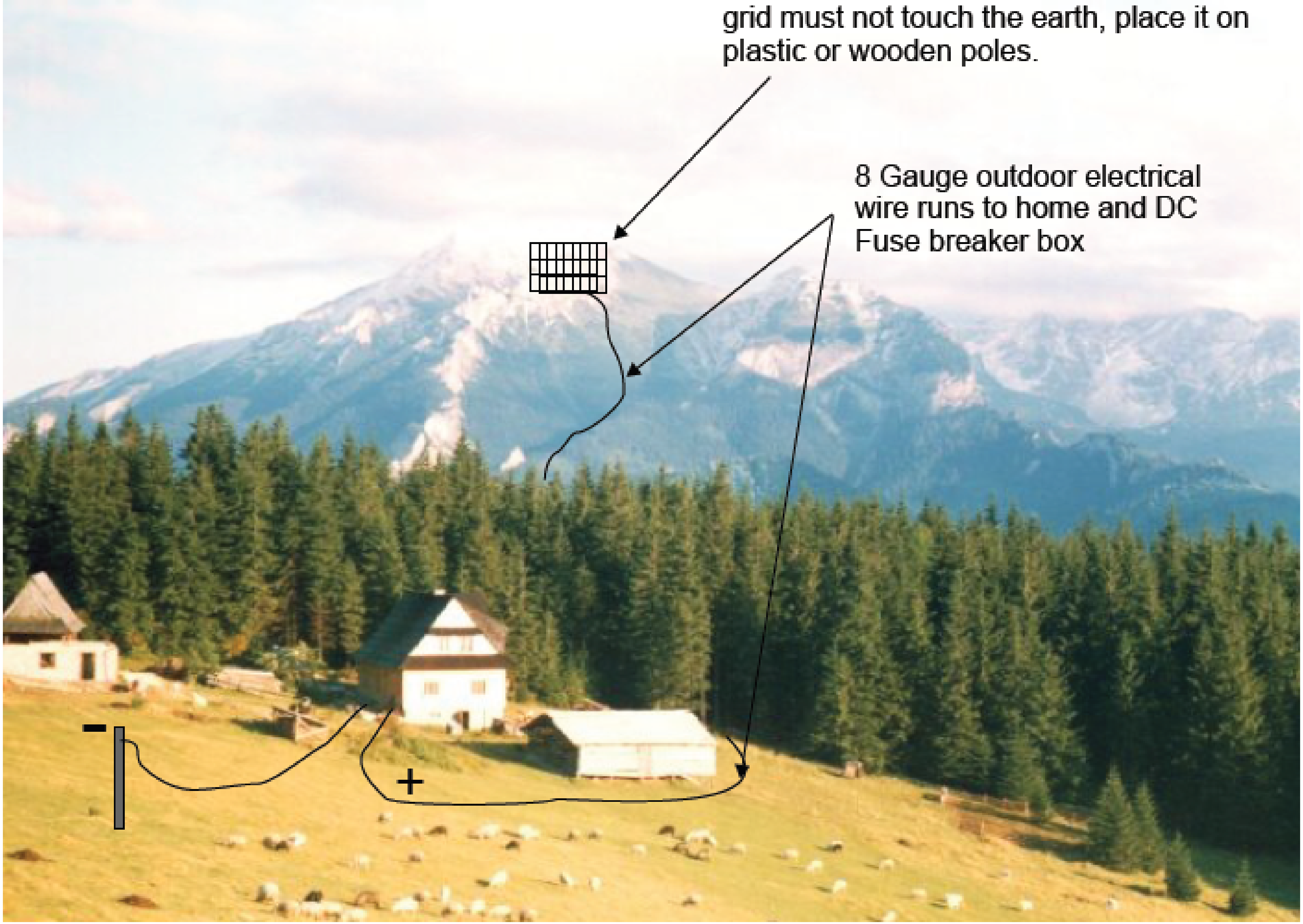

Large aluminum collection grid (Mesh type)
grid must not touch the earth, place it on
plastic or wooden poles.

8 Gauge outdoor electrical
wire runs to home and DC
Fuse breaker box

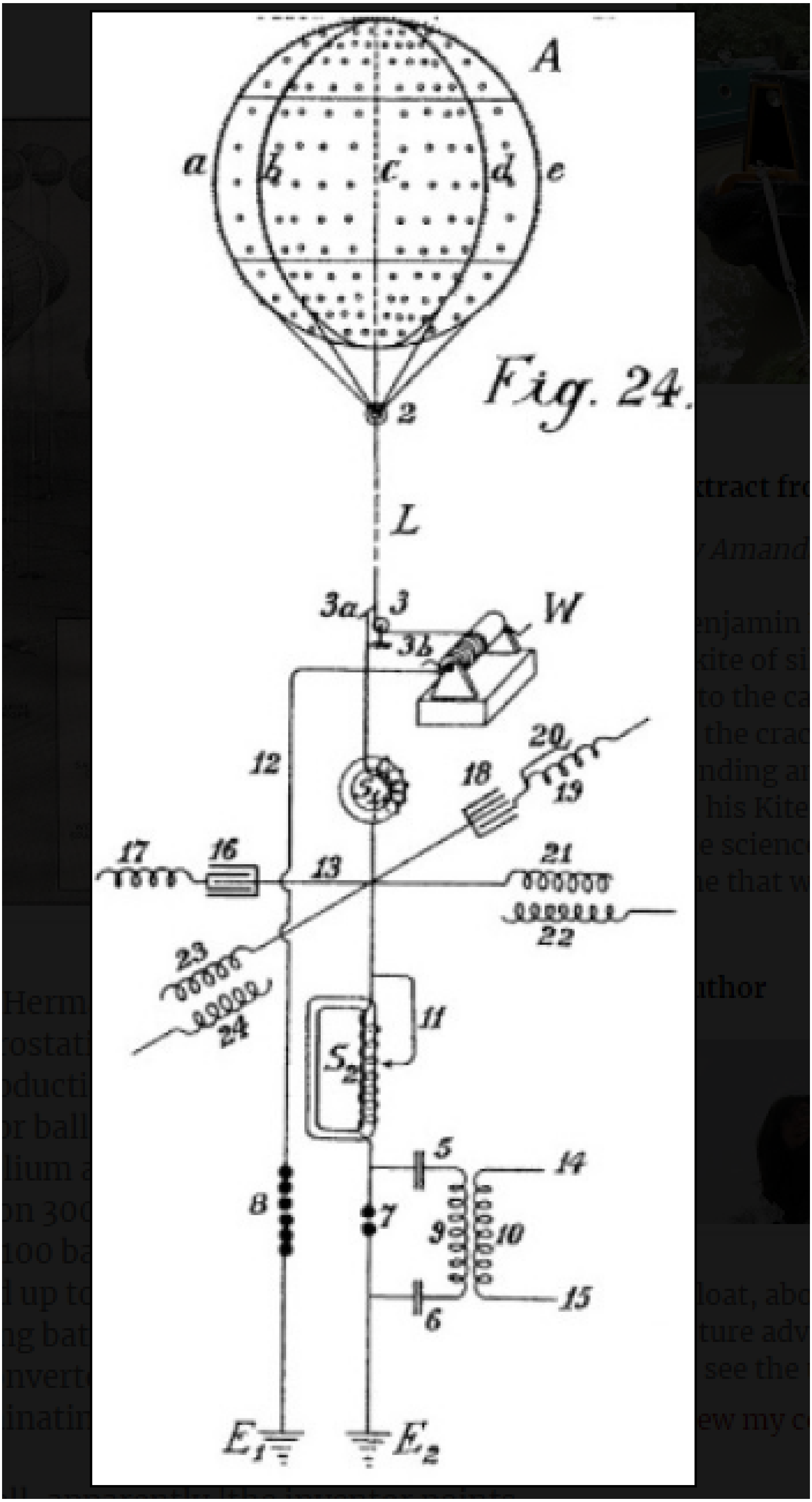
Fig. 24.
A
a
b
c
d
e
L
3a
3b
W
S1
S2
E1
E2

HARNESSING NATURE'S ELECTRICITY

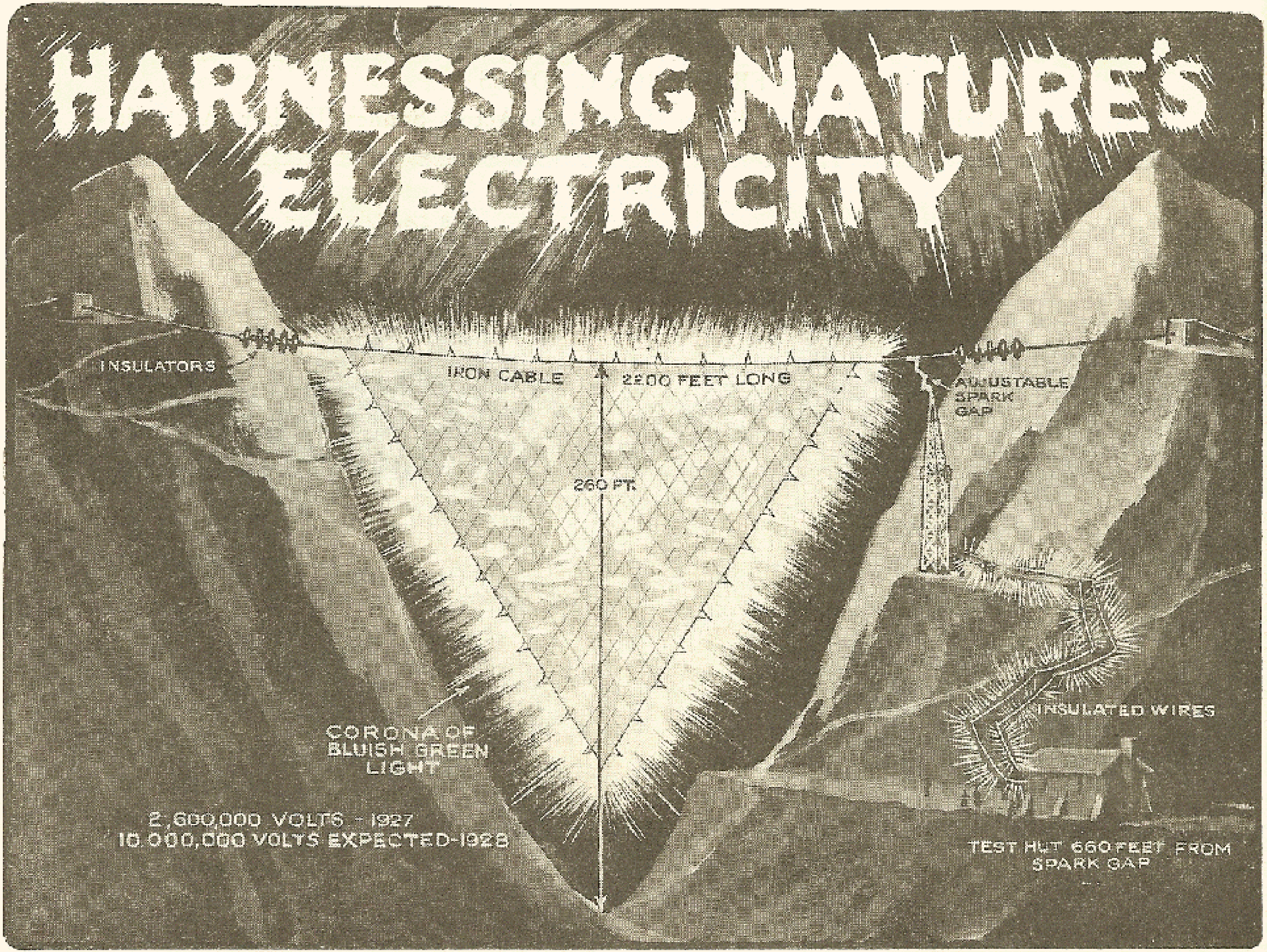
INSULATORS
IRON CABLE
2200 FEET LONG
ADJUSTABLE SPARK GAP
260 FT.
INSULATED WIRES
CORONA OF BLUISH GREEN LIGHT
2,600,000 VOLTS - 1927
10,000,000 VOLTS EXPECTED-1928
TEST HUT 660 FEET FROM SPARK GAP

Remarkable European Experiments with Atmospheric Electrical Discharges with Potentials as High as 3,000,000 Volts

By HENRY TOWNSEND

elevation of 350 ft., and these students of natural electrical phenomena have found a very desirable location in the Alps, where they can suspend between one mountain and an adjacent one, a strong iron cable having a length of about 2,000 ft. This cable is about 250 feet above the intervening valley, and from it these daring engineers have suspended a coarsely woven wire net, which serves as an electrical capacity to gather the electricity from the atmosphere. As shown in the pictures, the wire net is supplied with numerous sharp points to aid in collecting the current from the air.

As the accompanying photographs of the actual apparatus and wire cable used last year clearly show, an adjustable spark gap of considerable length is provided. By adjusting this spark gap to various lengths, it is possible to judge the voltage of the discharge which leaps the gap at any moment. Mr. F. W. Peek, Jr., the well-known American worker in the realm of high voltage measurements, together with other engineers, have provided tabulated data and curves for various lengths of both needle and sphere type spark gaps. As one of the accompanying diagrams shows, it is a simple matter to calculate the voltage when a certain length of gap is used. The engineer first checks the length of the gap on the chart; he then follows a line horizontally from the gap length, to where it intersects with the angular line on the chart; and from the point of intersection he looks in a visual line downward to a place where the voltage is given. For needle spark gap measurements, the characteristic curve on the chart is practically a straight line, while for sphere gaps the characteristic curve on the voltage versus gap length, is a curved line. Those interested in high voltage measurements by means of the spark gap method can find the voltage-gap tables and charts in the *Standardization Rules* of the American Institute of Electrical Engineers. According to Mr. Peek's researches, the voltage per foot of atmospheric electrical discharges is about 100,000, while in laboratory measurements with A.C., transformer high potential discharges, the average voltage per foot of spark was found to be about 150,000 volts. The voltage of a lightning flash may

(*Continued on page* 156)

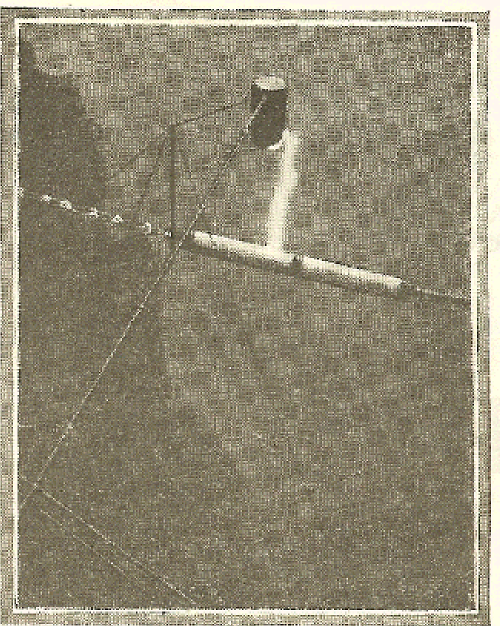

↑ **Actual photo above shows 13 ft., heavy spark obtained from the collecting net in the Alps by the German scientists. The voltage is about 2,000,000. The spark occurred once per second for 30 minutes.**

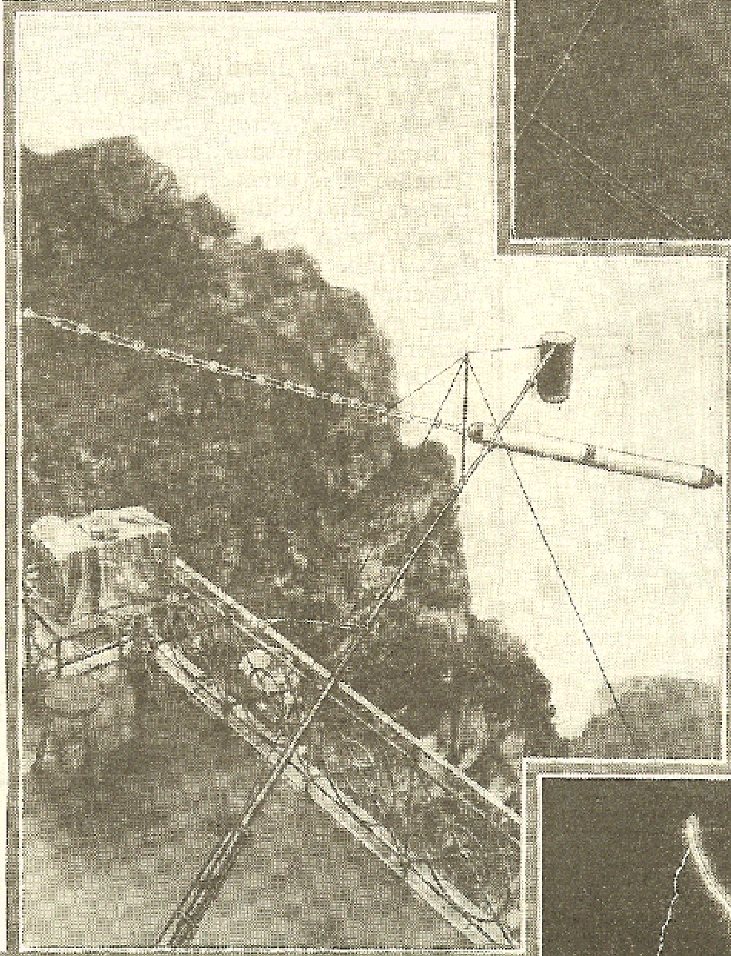

Photo, left, shows the adjustable spark gap used in the Alps. Notice the heavy electrode on the end of the adjustable arm to which the spark jumps.

←

Actual photograph of the experimental "kite" used by the German experimenters in the Alps Mountains, for the purpose of accumulating high potential electrical discharges from the atmosphere. Note the size of the insulators.

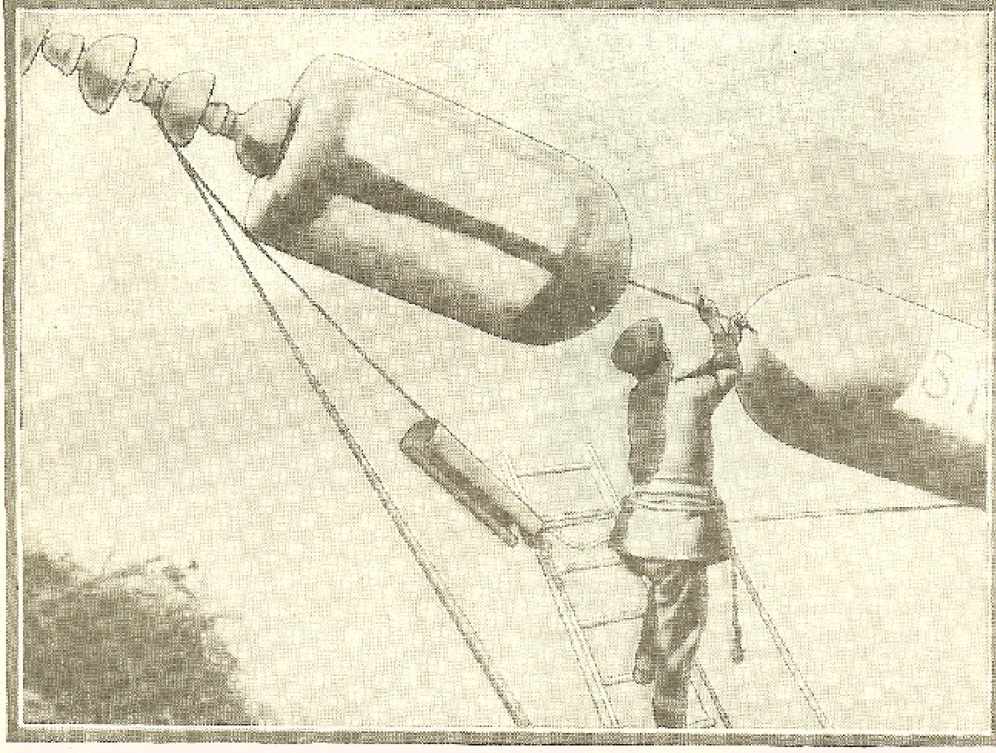

Below we see 3,000,000-volt artificial lightning stroke produced in G. E. Laboratory at Pittsfield, Mass. Note man. ↓

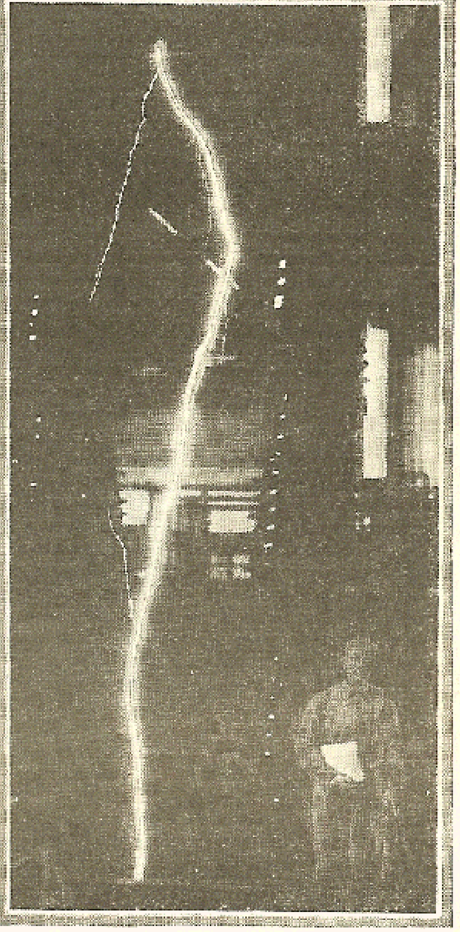

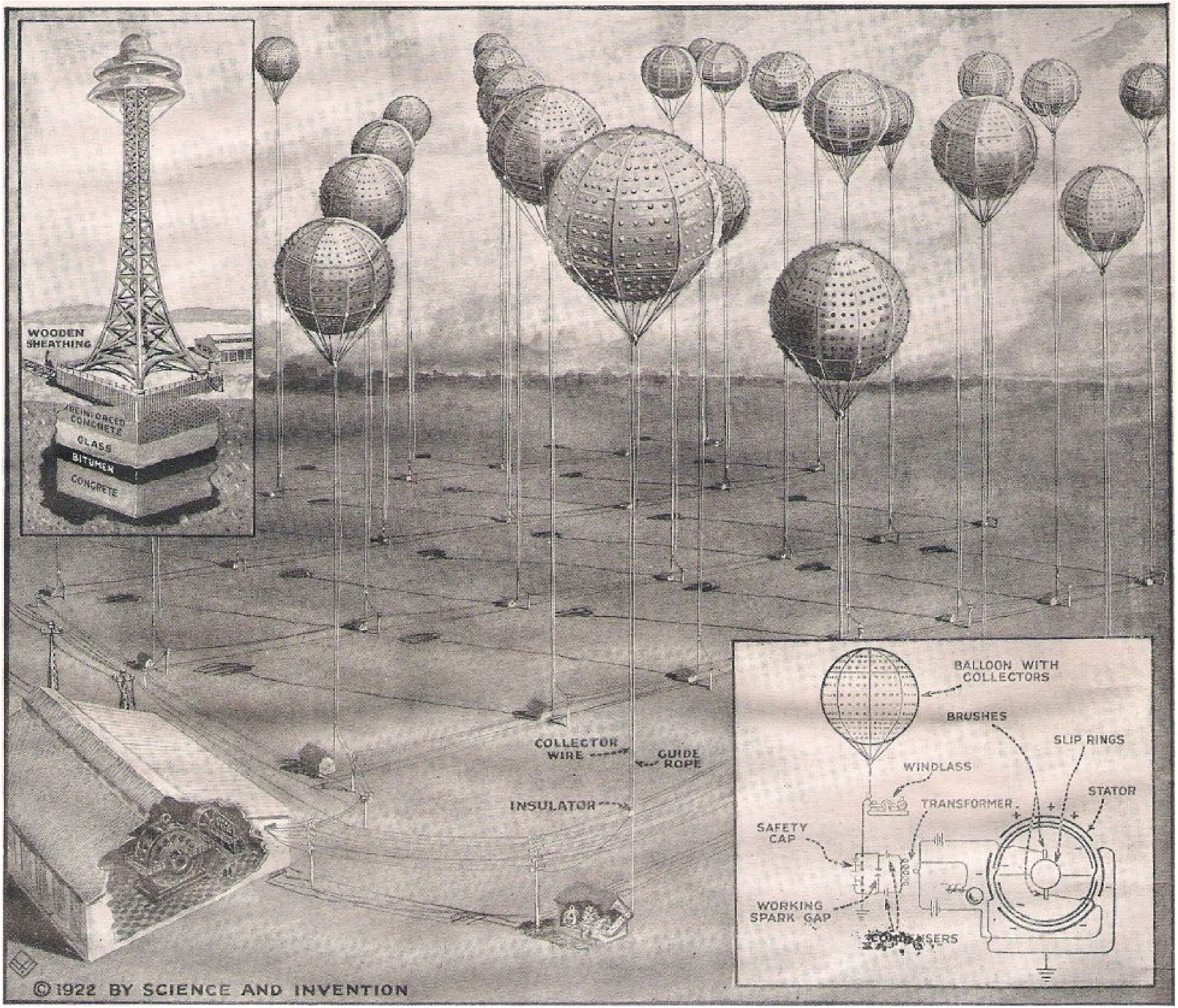
WOODEN SHEATHING
REINFORCED CONCRETE
GLASS
BITUMEN
CONCRETE
COLLECTOR WIRE
GUIDE ROPE
INSULATOR
BALLOON WITH COLLECTORS
BRUSHES
SLIP RINGS
STATOR
WINDLASS
TRANSFORMER
SAFETY CAP
WORKING SPARK GAP
CONDENSERS

© 1922 BY SCIENCE AND INVENTION

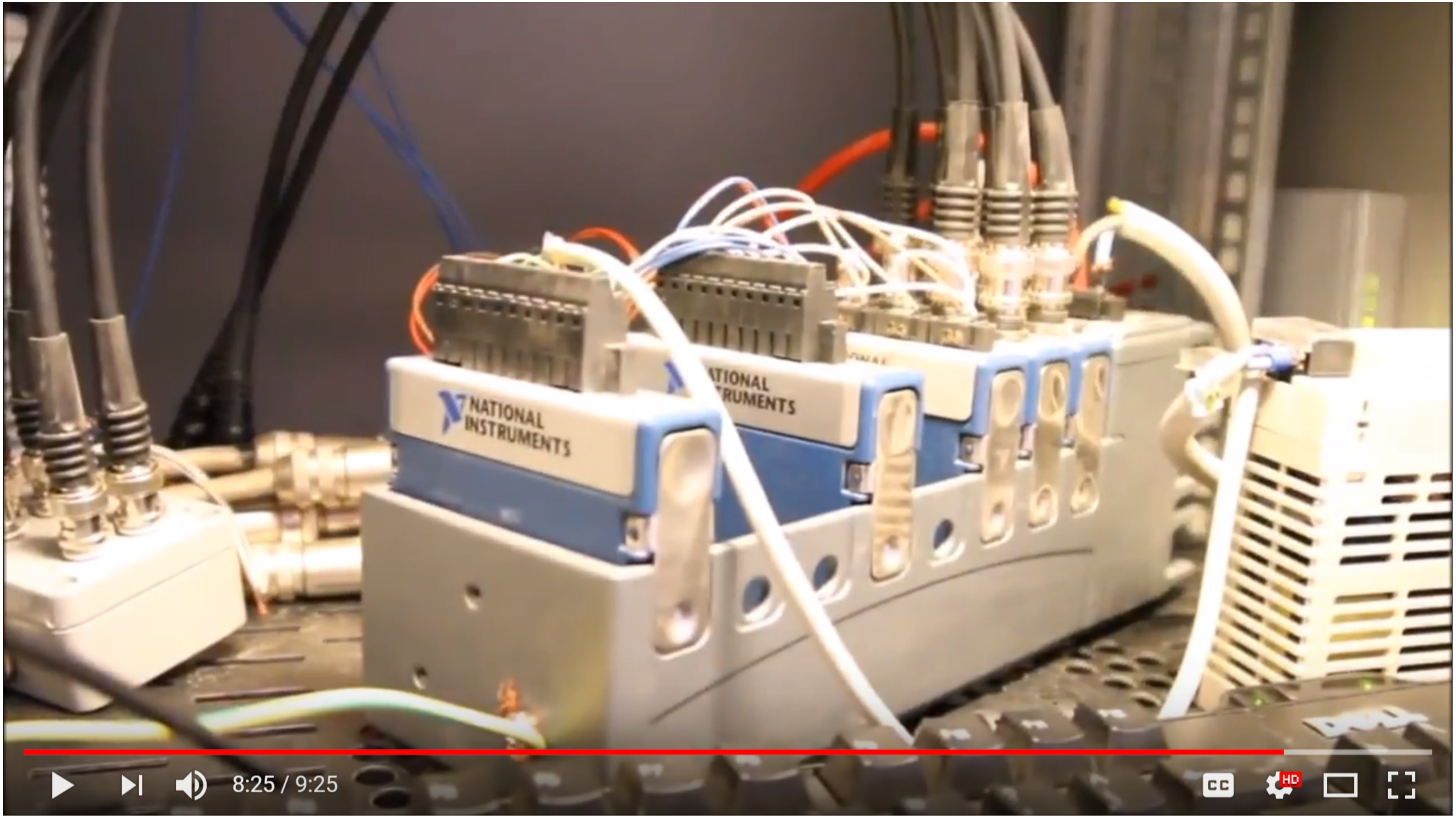
NATIONAL INSTRUMENTS
NATIONAL INSTRUMENTS
DELL
8:25 / 9:25
CC
HD

Flat Earth CON SPIRES! Cathedral Spires Are Secretly Atmospheric Electricity Ma

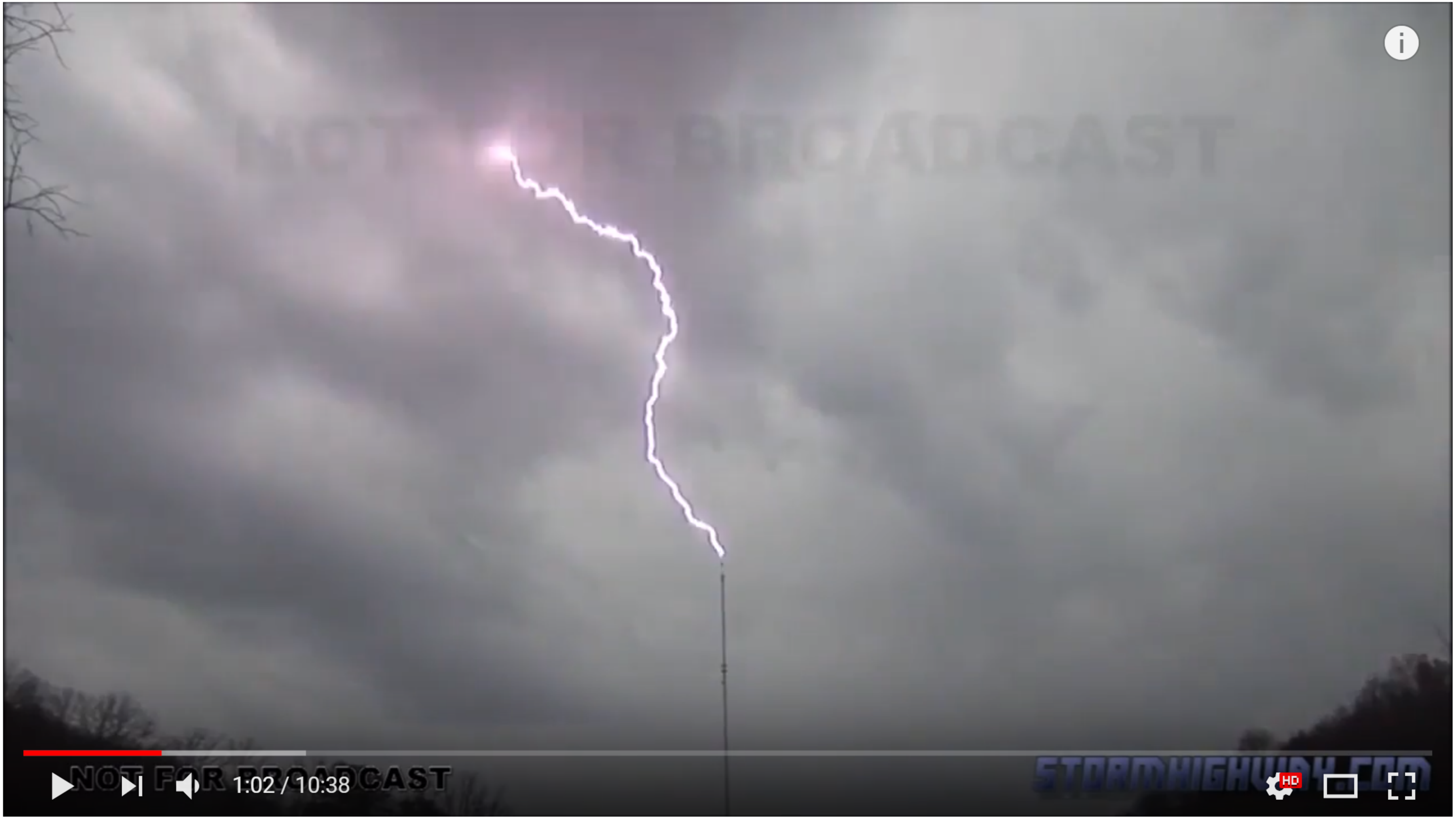
NOT FOR BROADCAST
NOT FOR BROADCAST
STORMHIGHWAY.COM
1:02 / 10:38
HD

1:45 / 9:25
CC
HD

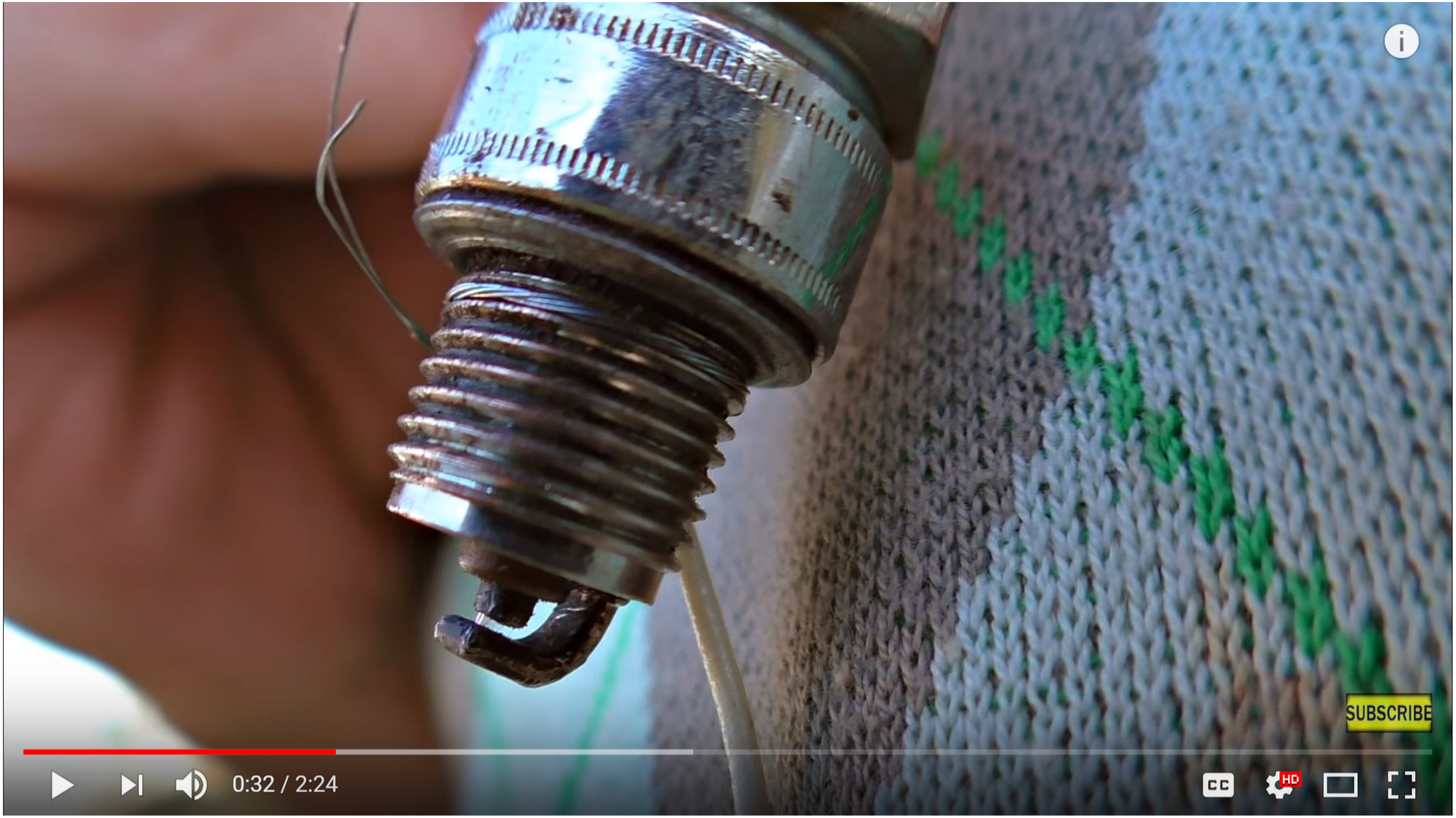
SUBSCRIBE
0:32 / 2:24
HD

Charging from the power lines.

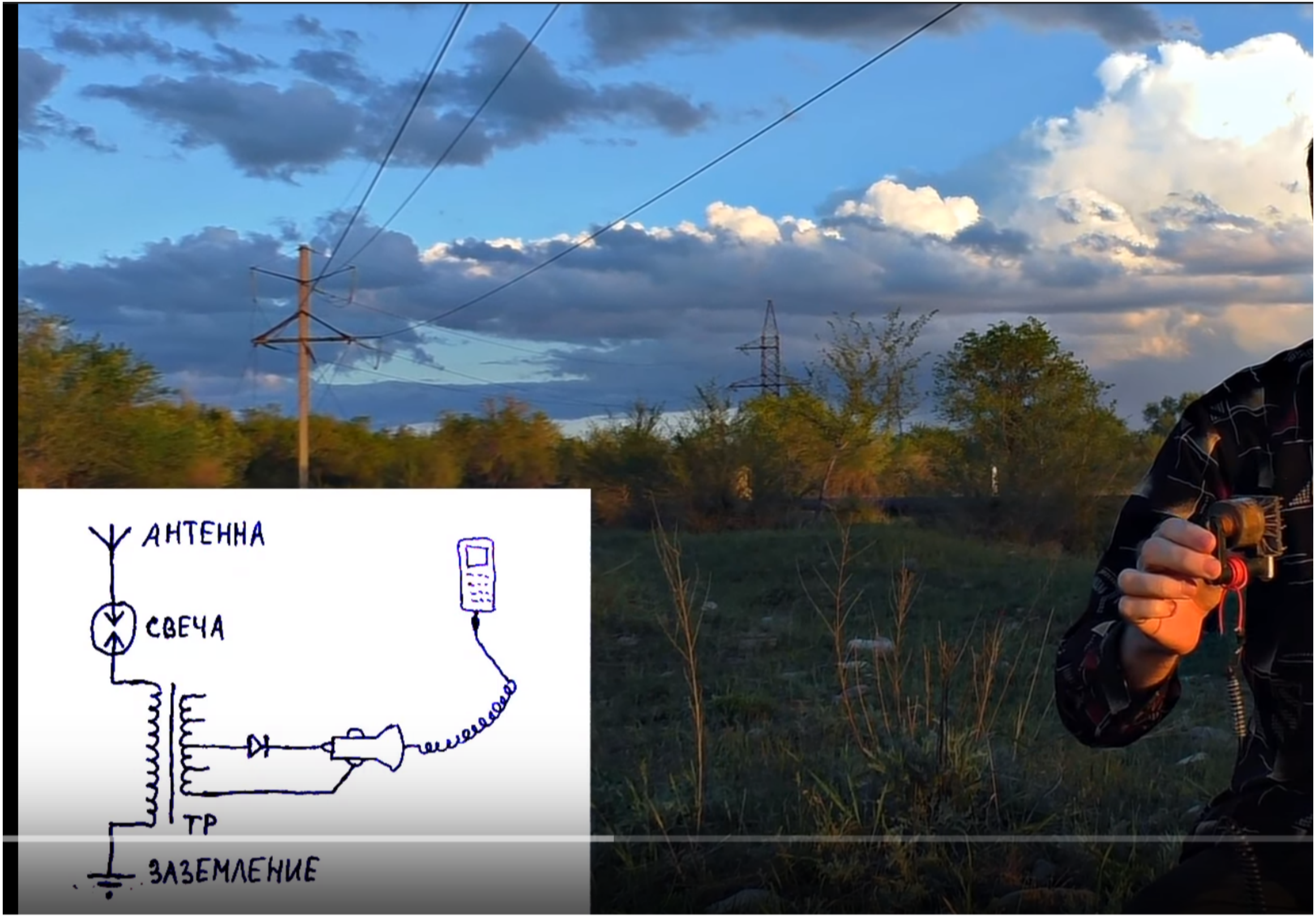
АНТЕННА
СВЕЧА
ТР
ЗАЗЕМЛЕНИЕ

E6

MULTI DISPLAY DMM
10.1
POWER
COM
VΩ

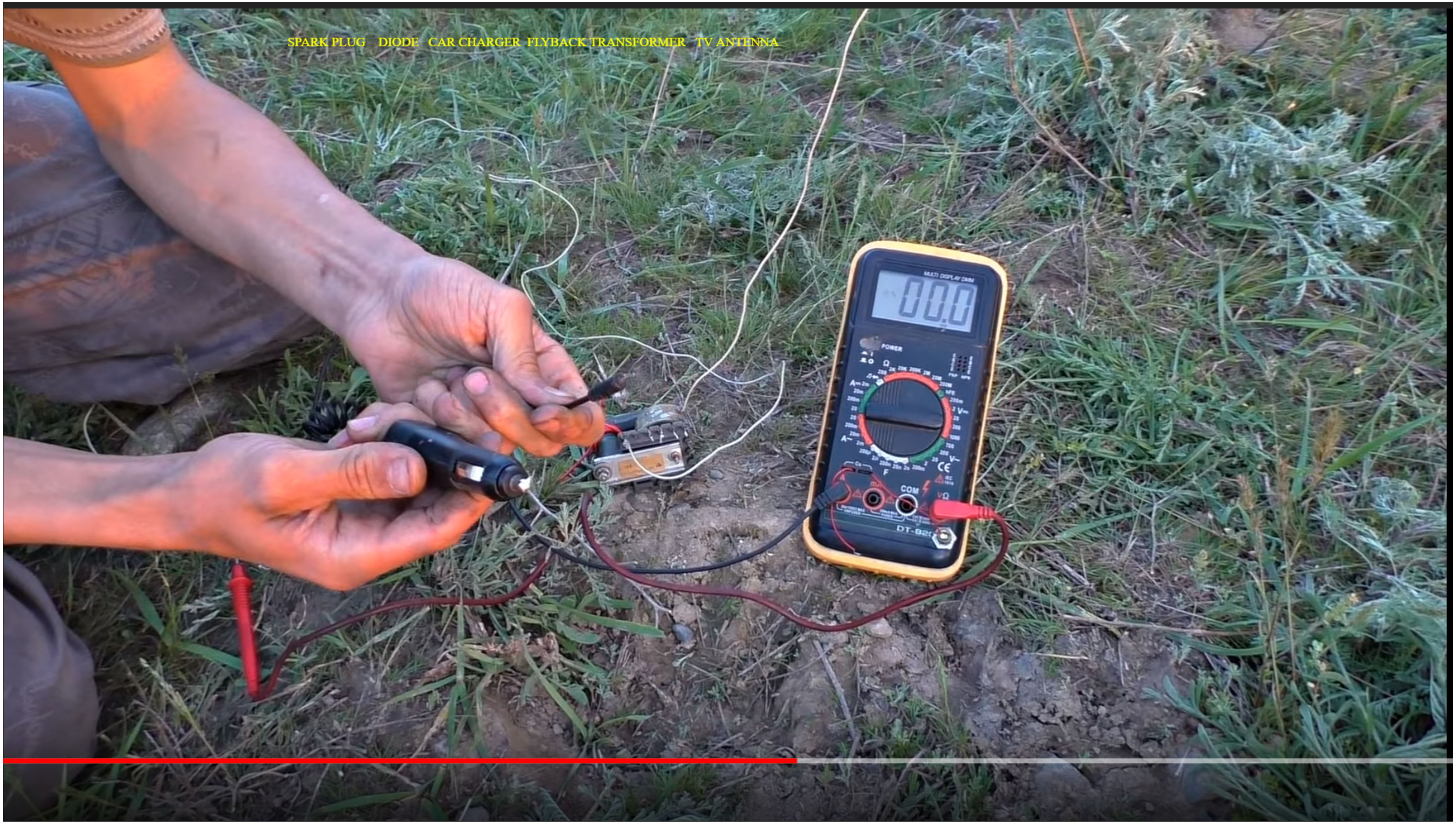
SPARK PLUG
DIODE
CAR CHARGER
FLYBACK TRANSFORMER
TV ANTENNA
MULTI DISPLAY DMM
00.0
POWER
COM
DT-92

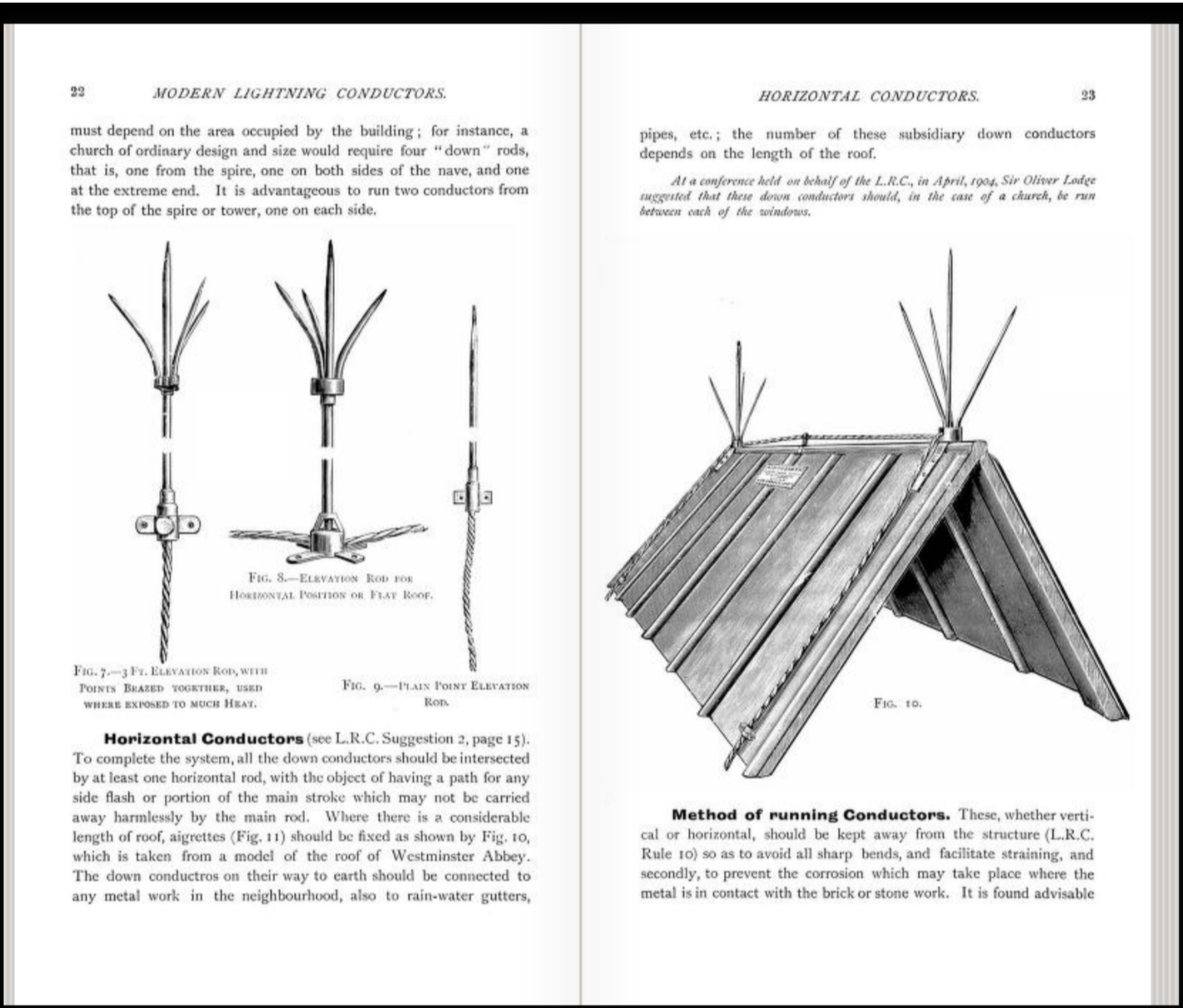

22 *MODERN LIGHTNING CONDUCTORS.*

must depend on the area occupied by the building; for instance, a church of ordinary design and size would require four "down" rods, that is, one from the spire, one on both sides of the nave, and one at the extreme end. It is advantageous to run two conductors from the top of the spire or tower, one on each side.

FIG. 7.—3 FT. ELEVATION ROD, WITH POINTS BRAZED TOGETHER, USED WHERE EXPOSED TO MUCH HEAT.

FIG. 8.—ELEVATION ROD FOR HORIZONTAL POSITION OR FLAT ROOF.

FIG. 9.—PLAIN POINT ELEVATION ROD.

Horizontal Conductors (see L.R.C. Suggestion 2, page 15). To complete the system, all the down conductors should be intersected by at least one horizontal rod, with the object of having a path for any side flash or portion of the main stroke which may not be carried away harmlessly by the main rod. Where there is a considerable length of roof, aigrettes (Fig. 11) should be fixed as shown by Fig. 10, which is taken from a model of the roof of Westminster Abbey. The down conductros on their way to earth should be connected to any metal work in the neighbourhood, also to rain-water gutters, pipes, etc.; the number of these subsidiary down conductors depends on the length of the roof.

HORIZONTAL CONDUCTORS. 23

At a conference held on behalf of the L.R.C., in April, 1904, Sir Oliver Lodge suggested that these down conductors should, in the case of a church, be run between each of the windows.

FIG. 10.

Method of running Conductors. These, whether vertical or horizontal, should be kept away from the structure (L.R.C. Rule 10) so as to avoid all sharp bends, and facilitate straining, and secondly, to prevent the corrosion which may take place where the metal is in contact with the brick or stone work. It is found advisable

Modern lightning conductors: an illustrated surface of the joint need not necessarily exceed that of the cross section of the conductors. The joint should be put together previously by screws or rivets, and the soldered joint, especially if used in underground work, should be carefully protected from local electrical action by tarred rope. Stranded iron conductors can be connected (as previously described) by use of a box joint; the box, Fig. 28, must be of the same metal as the conductors.

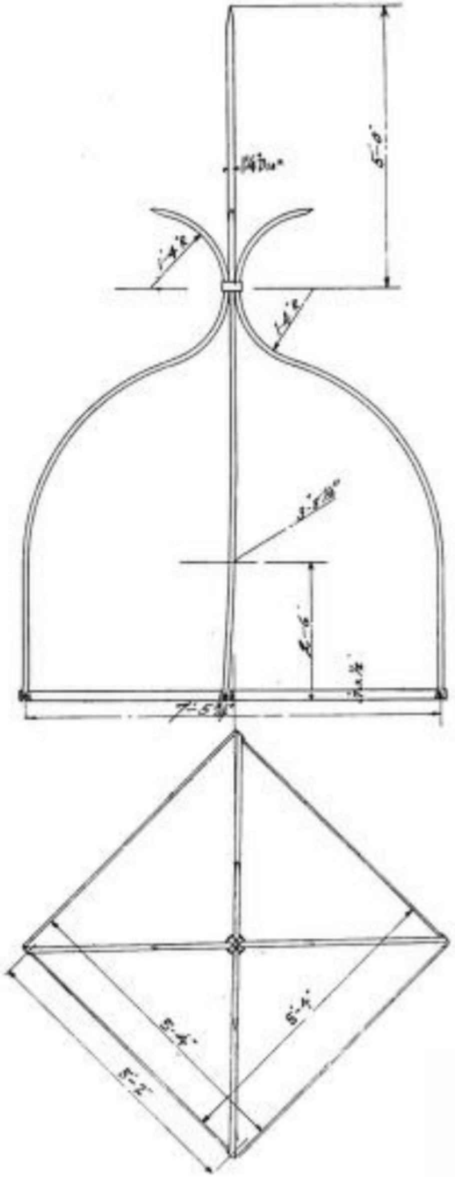

FIG. 27.—TERMINALS IN FORM OF AN ARCH FOR CHIMNEY STACK.

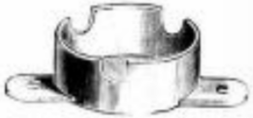

FIG. 28.

Vanes.—Particular attention must be paid to the necessity of making a permanent joint to the spindle. A clamp is prepared of the same material as the spindle, and is furnished with two bolts to tighten; if iron is used it is well to line the clamp with a piece of sheet lead. The conductor is sweated into a socket which is fitted with an eye, through which one of the tightening bolts passes. In the case of the vanes of churches and those fixed in inaccessible positions, two separate clamps should be used.

Internal Masses of Metal.—Roof trusses fitted with longitudinal iron tie rods will, as a rule, be found to be electrically connected, but should this not be the case each truss must be joined to the conductors. All large and long masses of metal, such as beams, girders, roof trusses, tie rods, hot water systems, traveller ways, hoisting crabs, engines, boilers, large machines, and ventilators fixed in the interiors of buildings, should be connected to all conductors that pass near them, and as far as possible with one another. The discontinuous parts of traveller rails should be connected by straps, or in some cases tramway bonds might be used. If electric light wires are run in tubes, such as the "SIMPLEX," this should be earthed. Metallic contact between lead or zinc sheeting and flashings should be carefully studied, and for special work strips of sufficient size should be either burnt on to lead or soldered in such a way that the joint will stand rough usage, and allow for expansion or contraction.

Earth Connection.—"*It is essential that the lower extremity of the conductor be buried in permanently damp soil; hence proximity to rain-water pipes, and to drains, is desirable. It is a very good plan to make the conductor bifurcate close below the surface of the ground, and adopt two of the following methods for securing the escape of the lightning into the earth. A strip of copper tape may be led from the bottom of the rod to the nearest gas or water* main—*not merely to a lead pipe—and be soldered to it; or a tape may be soldered to a sheet of copper* 3 *feet by* 3 *feet and* $\frac{1}{16}$ *inch thick, buried in permanently wet earth, and surrounded by cinders or coke; or many yards of the tape may be laid in a trench filled with coke, taking care that the surfaces of copper are, as in the previous cases, not less than* 18 *square feet. Where iron is used for the rod, a galvanised iron plate of similar dimensions should be employed.*

"The use of cinders or coke appears to be questionable owing to the chemical or electrolytic effect on copper or iron. Charcoal or pulverised carbon (such as ends of arc-light rods) is better. **A tubular earth** consisting of a perforated steel spike driven tightly into moist ground and lengthened up to the surface, the conductor reaching to the bottom and being packed with granulated charcoal, gives as much **effective area** as a plate of larger surface, and can easily be kept moist by connecting it to the nearest rain-water pipe. The resistance of a tubular earth on this plan should be very low and practically constant."—*Lightning Research Committee, 1905.*

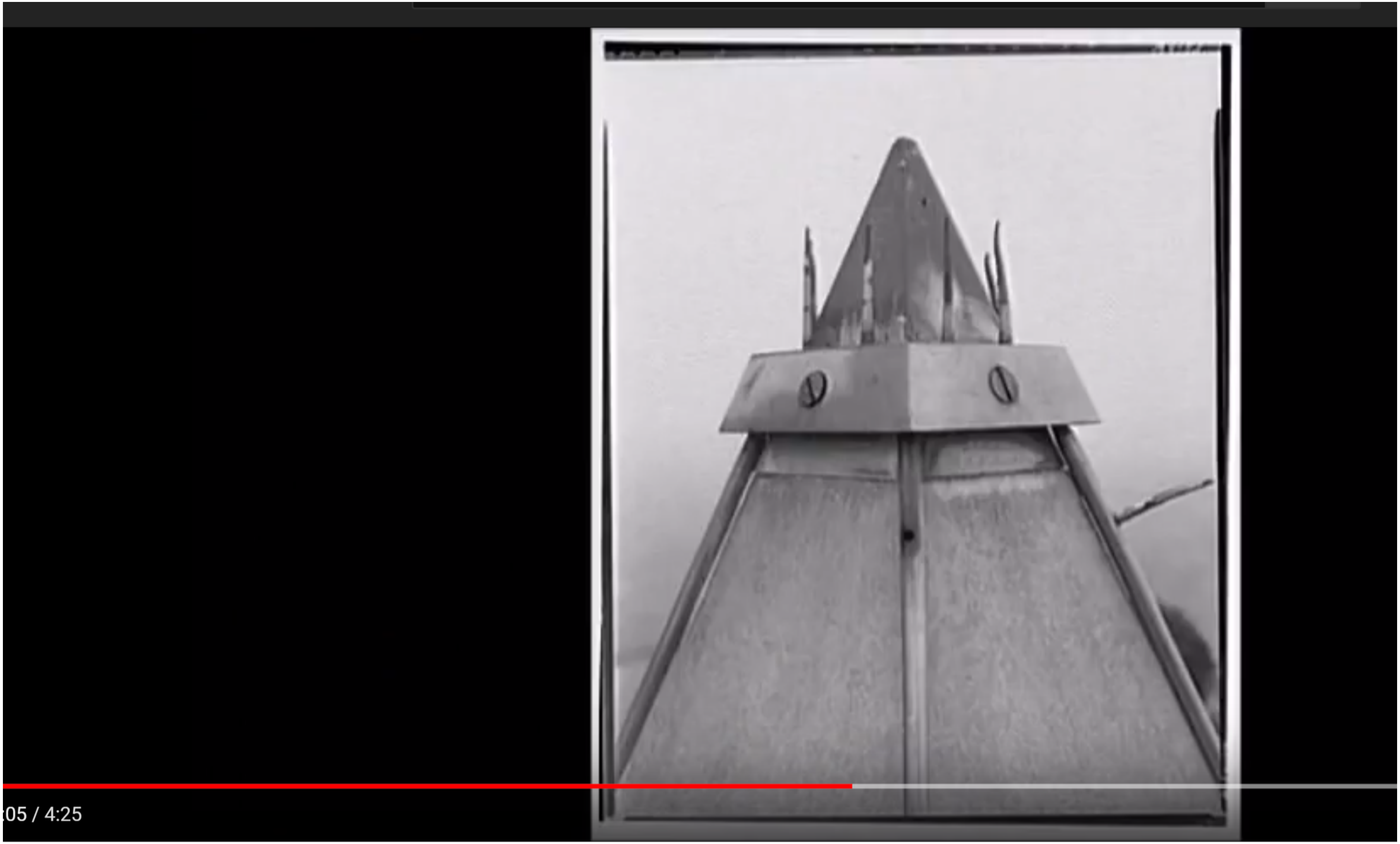

Washington Monument is an Atmospheric Electricity Mast

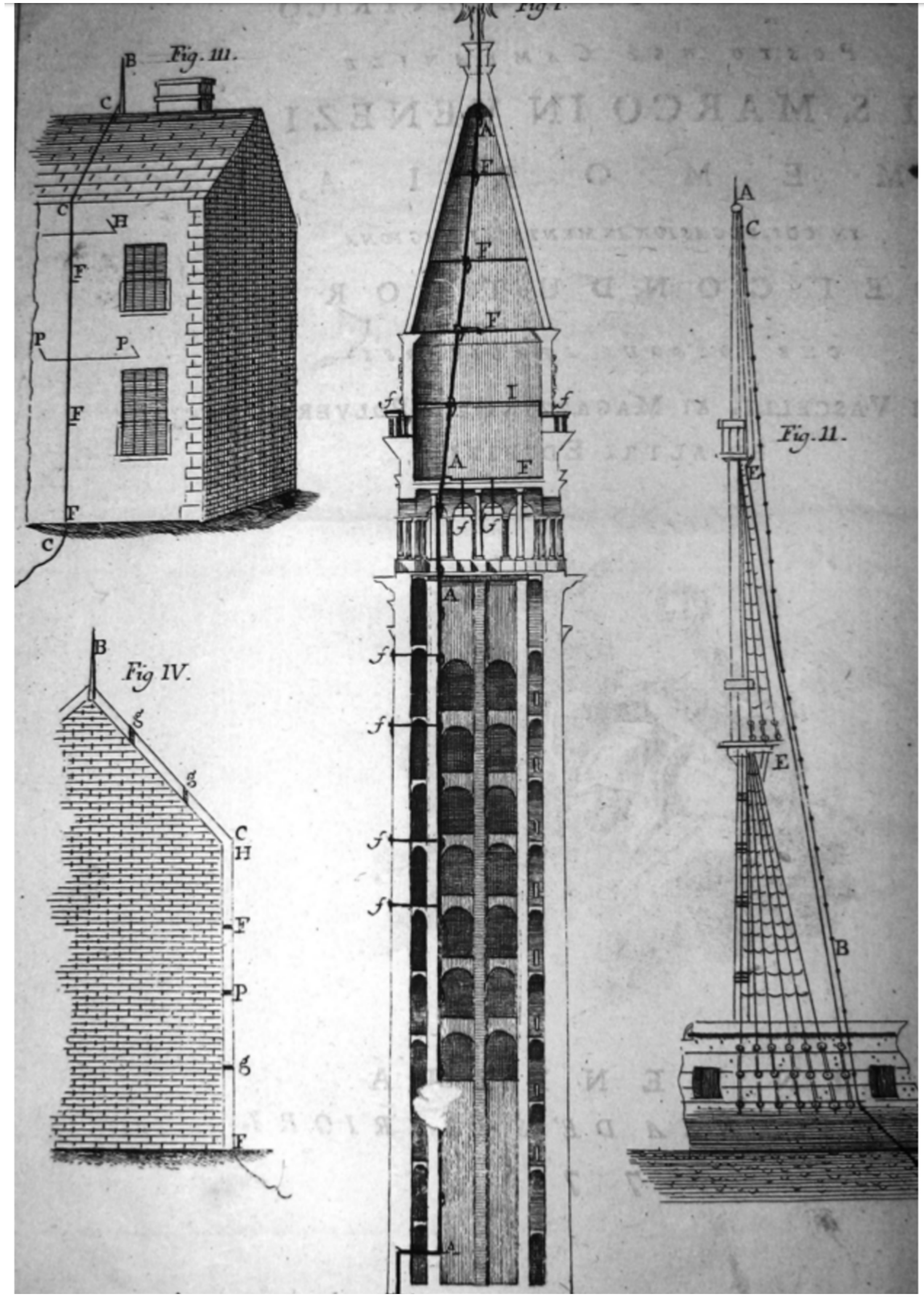
Fig. I.
Fig. II.
Fig. III.
Fig. IV.
A
B
C
E
F
H
I
P
f
g

Figure 2.3. The lightning rod that Toaldo designed for the church of San Marco in Venice. GiuseppeToaldo, “Del conduttore elettrico posto nel campanile” (Padua, 1776). Franklin Collec-

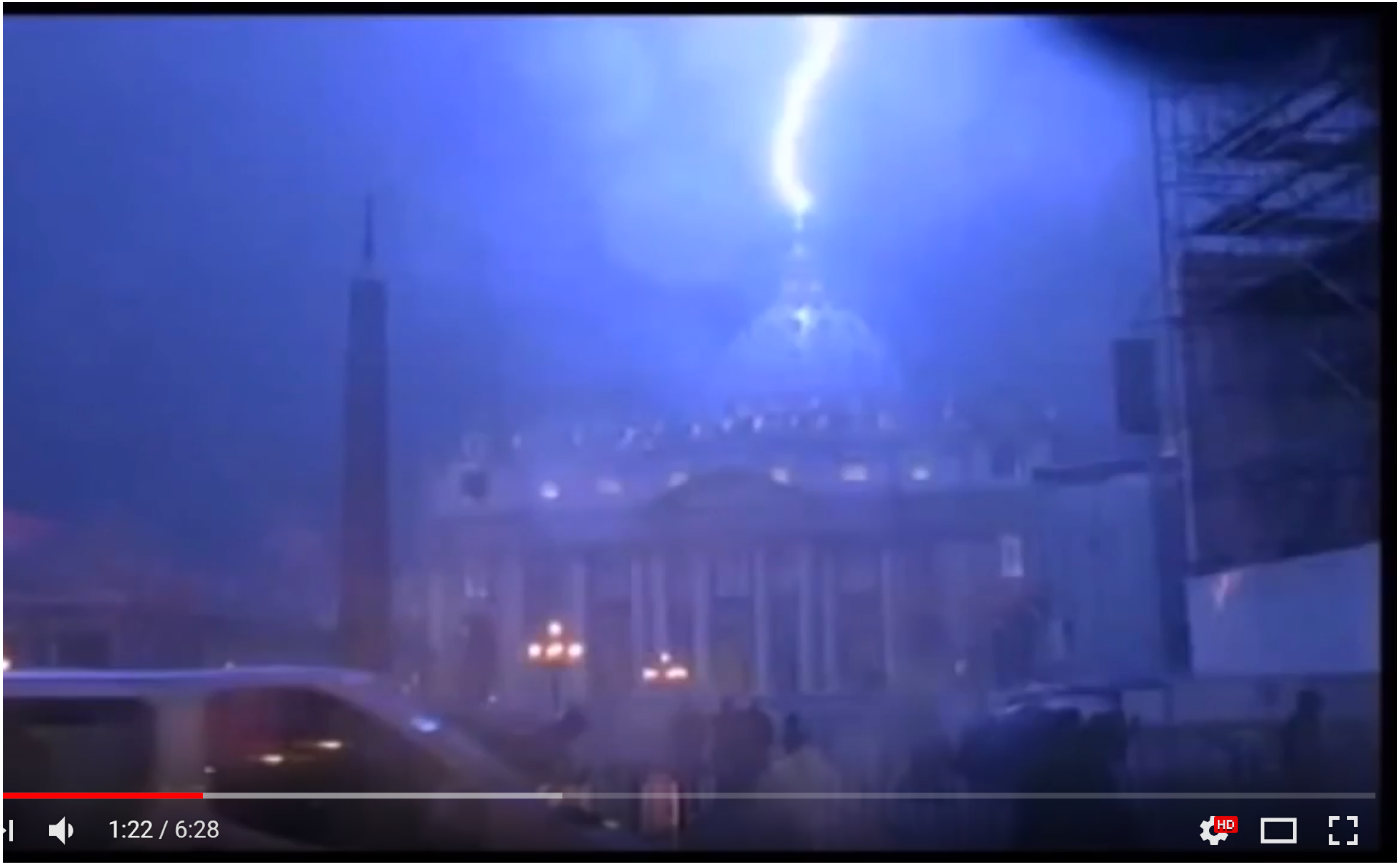

Gilded Temples Are Secretly Atmospheric Electricity Masts

~ EUROPEAN STATIONS ~

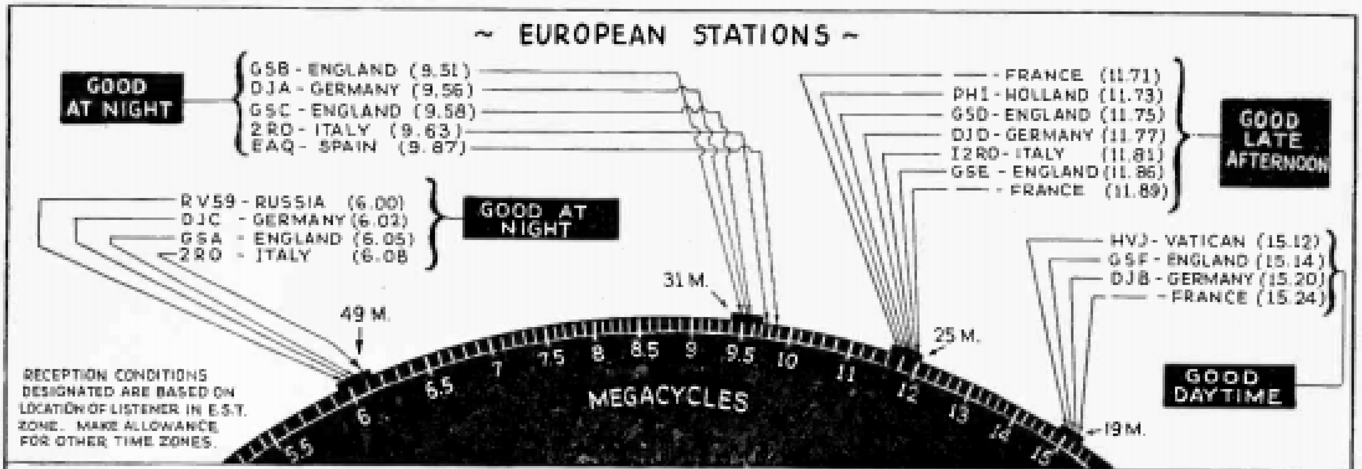
GOOD AT NIGHT
GSB - ENGLAND (9.51)
DJA - GERMANY (9.56)
GSC - ENGLAND (9.58)
2RO - ITALY (9.63)
EAQ - SPAIN (9.87)
— - FRANCE (11.71)
PHI - HOLLAND (11.73)
GSD - ENGLAND (11.75)
DJD - GERMANY (11.77)
I2RO - ITALY (11.81)
GSE - ENGLAND (11.86)
— - FRANCE (11.89)
GOOD LATE AFTERNOON
RV59 - RUSSIA (6.00)
DJC - GERMANY (6.02)
GSA - ENGLAND (6.05)
2RO - ITALY (6.08)
GOOD AT NIGHT
HVJ - VATICAN (15.12)
GSF - ENGLAND (15.14)
DJB - GERMANY (15.20)
— - FRANCE (15.24)
GOOD DAYTIME
31 M.
49 M.
25 M.
19 M.
RECEPTION CONDITIONS DESIGNATED ARE BASED ON LOCATION OF LISTENER IN E.S.T. ZONE. MAKE ALLOWANCE FOR OTHER TIME ZONES.
MEGACYCLES
5.5
6
6.5
7
7.5
8
8.5
9
9.5
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12
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14
15

~ CANADIAN SHORT-WAVE STATIONS ~

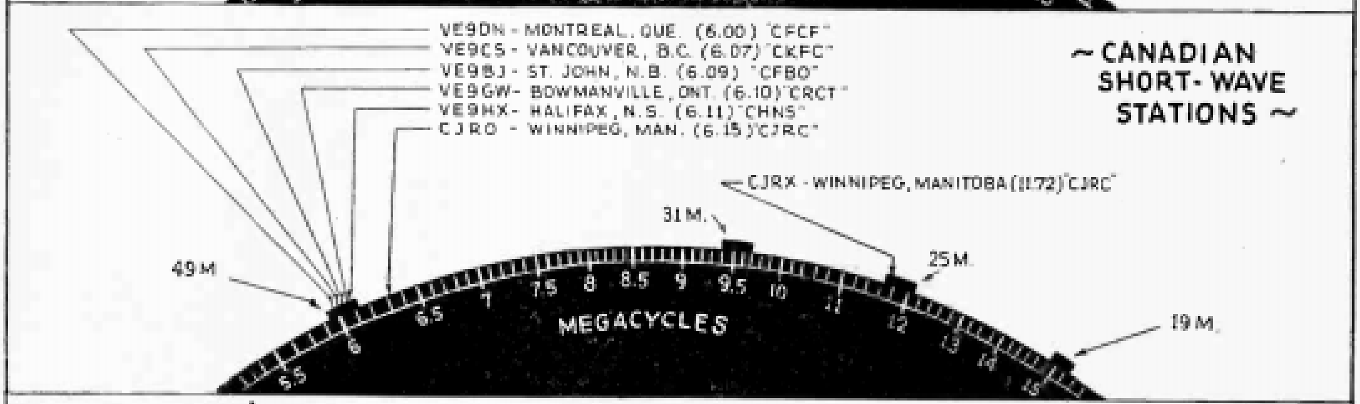
VE9DN - MONTREAL, QUE. (6.00) "CFCF"
VE9CS - VANCOUVER, B.C. (6.07) "CKFC"
VE9BJ - ST. JOHN, N.B. (6.09) "CFBO"
VE9GW - BOWMANVILLE, ONT. (6.10) "CRCT"
VE9HX - HALIFAX, N.S. (6.11) "CHNS"
CJRO - WINNIPEG, MAN. (6.15) "CJRC"
CJRX - WINNIPEG, MANITOBA (11.72) "CJRC"
31 M.
49 M
25 M.
19 M.
MEGACYCLES
5.5
6
6.5
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~ UNITED STATES SHORT-WAVE STATIONS ~

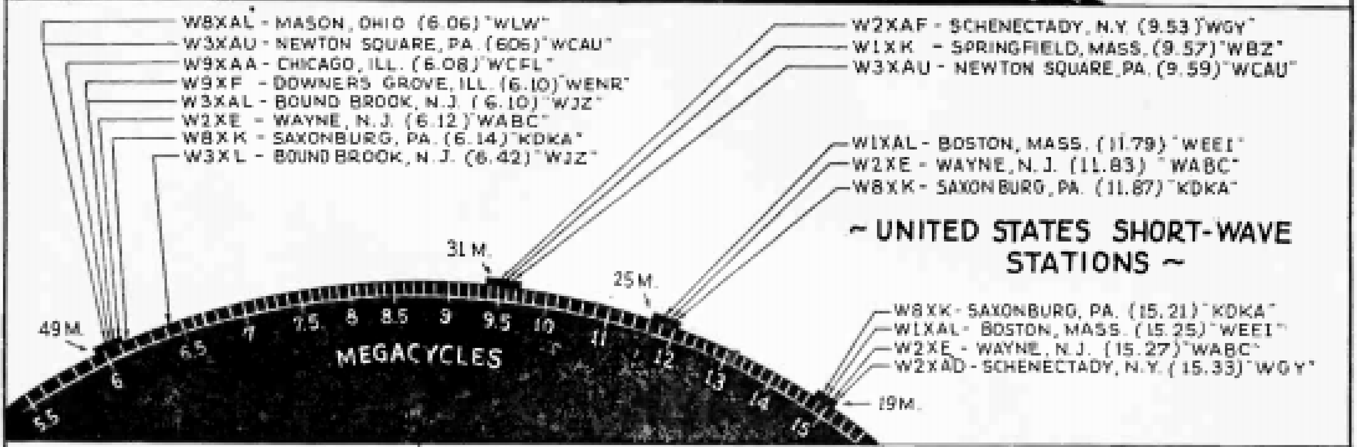
W8XAL - MASON, OHIO (6.06) "WLW"
W3XAU - NEWTON SQUARE, PA. (6.06) "WCAU"
W9XAA - CHICAGO, ILL. (6.08) "WCFL"
W9XF - DOWNERS GROVE, ILL. (6.10) "WENR"
W3XAL - BOUND BROOK, N.J. (6.10) "WJZ"
W2XE - WAYNE, N.J. (6.12) "WABC"
W8XK - SAXONBURG, PA. (6.14) "KDKA"
W3XL - BOUND BROOK, N.J. (6.42) "WJZ"
W2XAF - SCHENECTADY, N.Y. (9.53) "WGY"
W1XK - SPRINGFIELD, MASS. (9.57) "WBZ"
W3XAU - NEWTON SQUARE, PA. (9.59) "WCAU"
W1XAL - BOSTON, MASS. (11.79) "WEEI"
W2XE - WAYNE, N.J. (11.83) "WABC"
W8XK - SAXONBURG, PA. (11.87) "KDKA"
W8XK - SAXONBURG, PA. (15.21) "KDKA"
W1XAL - BOSTON, MASS. (15.25) "WEEI"
W2XE - WAYNE, N.J. (15.27) "WABC"
W2XAD - SCHENECTADY, N.Y. (15.33) "WGY"
31 M.
49 M.
25 M.
19 M.
MEGACYCLES
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
11
12
13
14
15

When To Tune and Where

● Until you have had considerable experience in short wave tuning, it is well to confine your efforts to the four bands indicated on the dial. These may look small, compared to the total length of the dial, but they contain the best "plums" among the foreign stations and many faint ones which, at first, you will probably pass unnoticed until you learn to tune slowly and carefully, intent upon identifying each slight "swish", which may be a station.

U.S. STATIONS BROADCASTING PROGRAMS ON - SHORT-WAVE CHANNELS

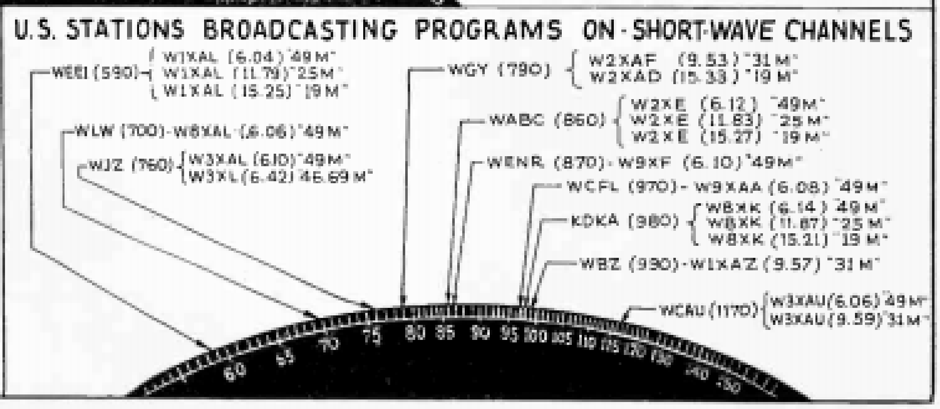
WEEI (590) - W1XAL (6.04) "49 M" / W1XAL (11.79) "25 M" / W1XAL (15.25) "19 M"
WLW (700) - W8XAL (6.06) "49 M"
WJZ (760) - W3XAL (6.10) "49 M" / W3XL (6.42) "46.69 M"
WGY (790) - W2XAF (9.53) "31 M" / W2XAD (15.33) "19 M"
WABC (860) - W2XE (6.12) "49 M" / W2XE (11.83) "25 M" / W2XE (15.27) "19 M"
WENR (870) - W9XF (6.10) "49 M"
WCFL (970) - W9XAA (6.08) "49 M"
KDKA (980) - W8XK (6.14) "49 M" / W8XK (11.87) "25 M" / W8XK (15.21) "19 M"
WBZ (990) - W1XAZ (9.57) "31 M"
WCAU (1170) - W3XAU (6.06) "49 M" / W3XAU (9.59) "31 M"
60
65
70
75
80
85
90
95
100
105
110
115
120
130
140
150

Copyright 1935 by H. Gernsback.

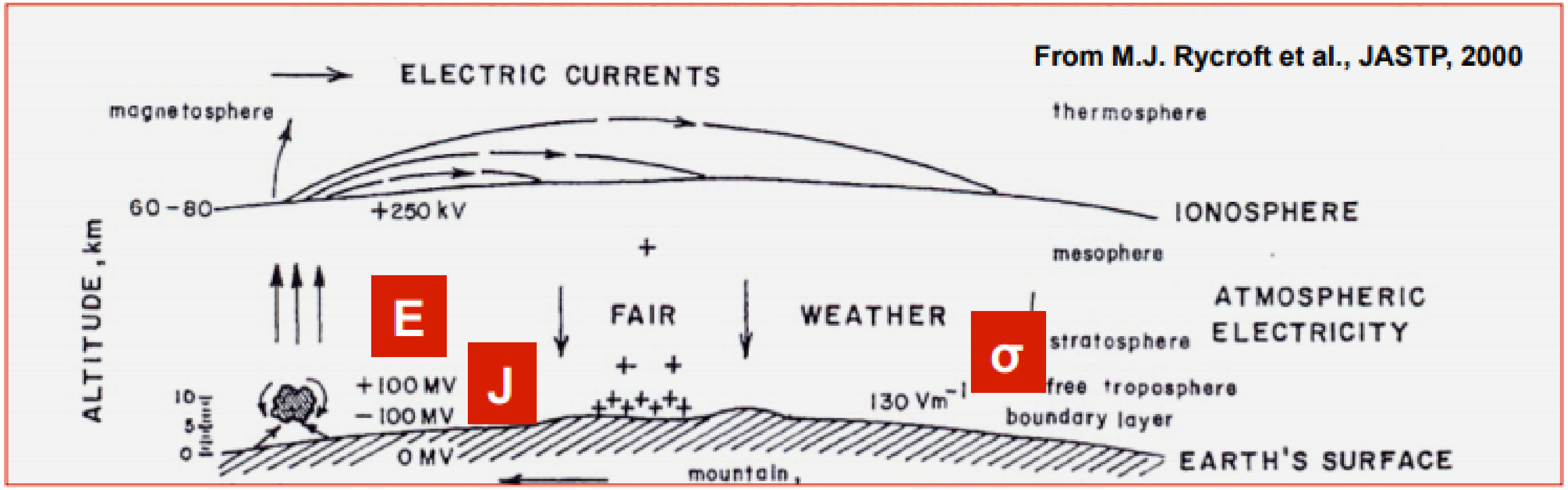
ELECTRIC CURRENTS
magnetosphere
thermosphere
60 − 80
+250 kV
IONOSPHERE
+
mesophere
ALTITUDE , km
E
FAIR
WEATHER
ATMOSPHERIC ELECTRICITY
σ
stratosphere
J
+100 MV
− 100 MV
0 MV
10
5
0
+ +
+ + + + + + +
130 Vm^{-1}
free troposphere
boundary layer
EARTH'S SURFACE
mountain ,

From M.J. Rycroft et al., JASTP, 2000

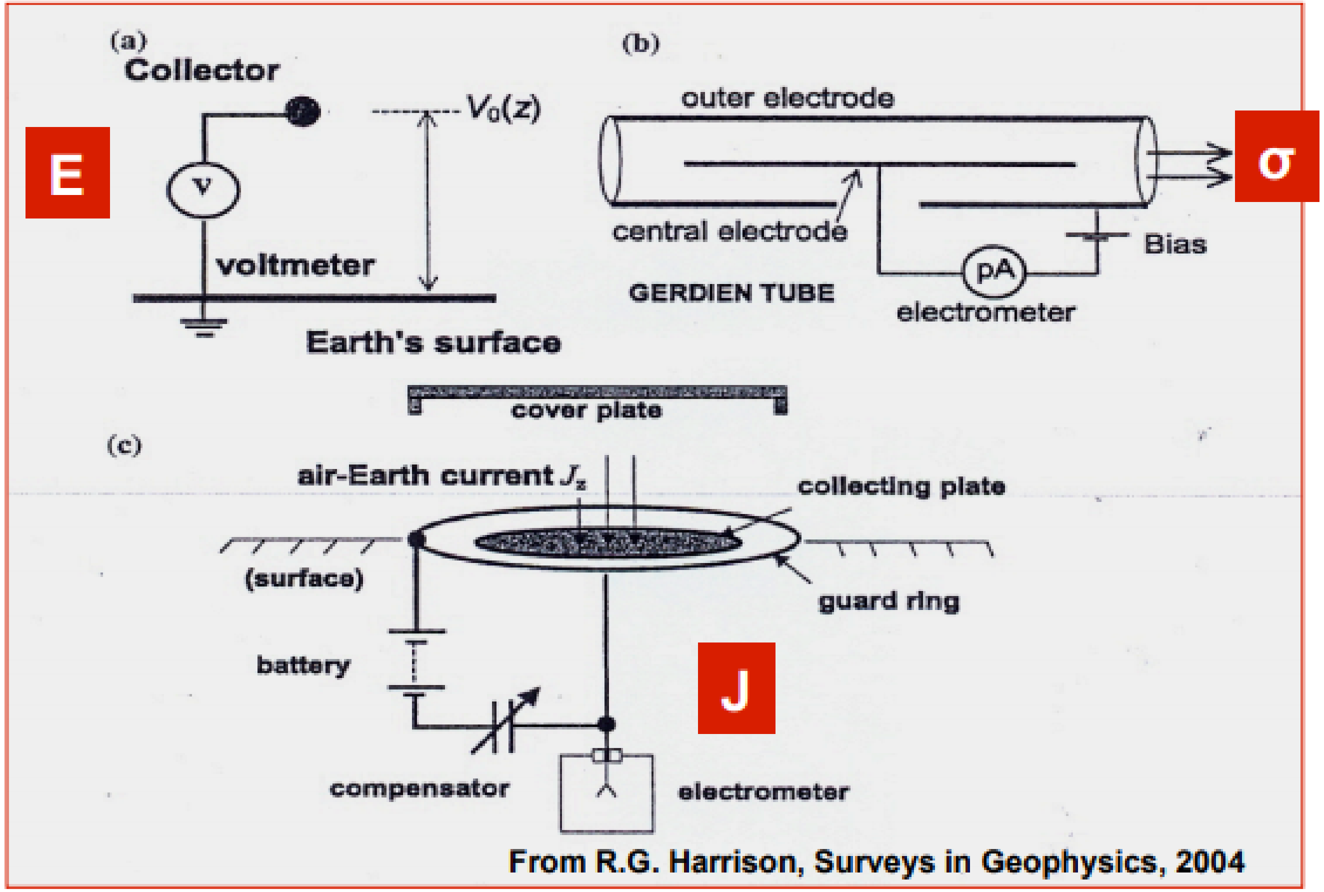
(a)
Collector
$V_0(z)$
E
V
voltmeter
Earth's surface
(b)
outer electrode
central electrode
GERDIEN TUBE
pA
electrometer
Bias
σ
cover plate
(c)
air-Earth current J_z
collecting plate
(surface)
guard ring
battery
J
compensator
electrometer

From R.G. Harrison, Surveys in Geophysics, 2004

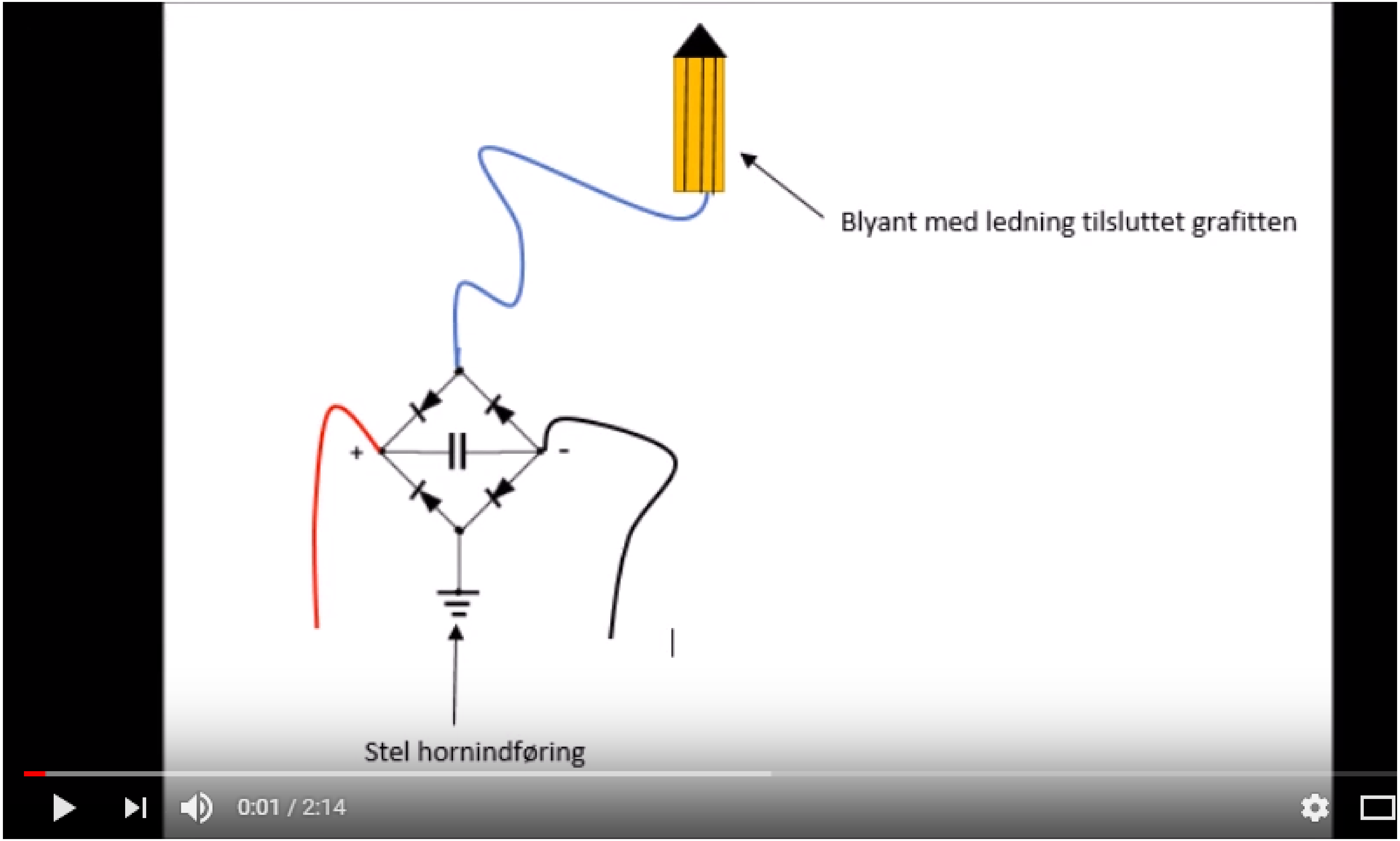
Blyant med ledning tilsluttet grafitten
+
-
Stel hornindføring
0:01 / 2:14

tesla radiant collector/ion collector with pencil

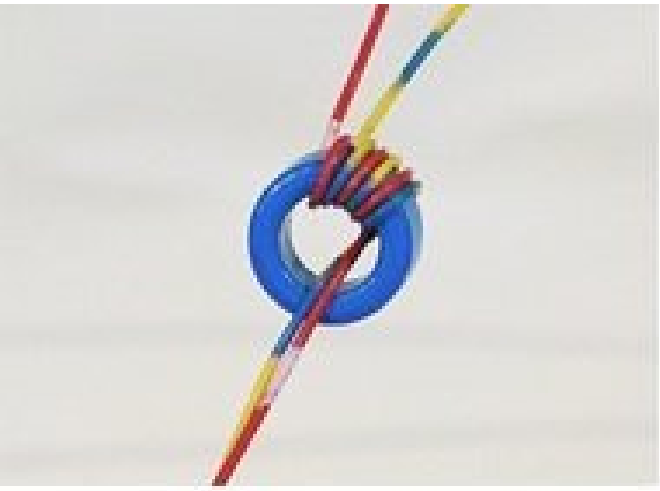

Keeping the two wires together, make a few more turns through the center.

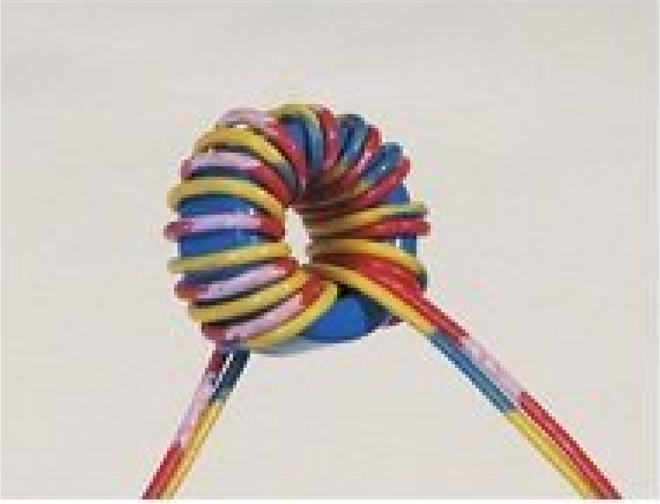

Keep winding until you fit as many turns as will fit in a single layer around the toroid, typically 7-10 turns with thin insulated wire.

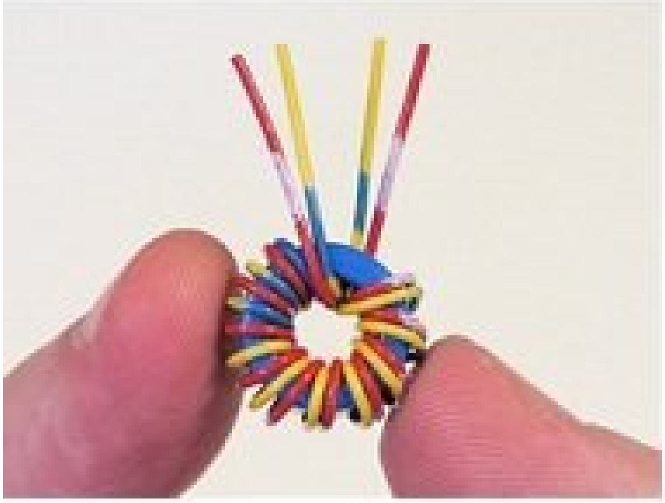

Clip the wire leads down. Note that we have two pairs of wires: one coming out the front, and one coming out the back.

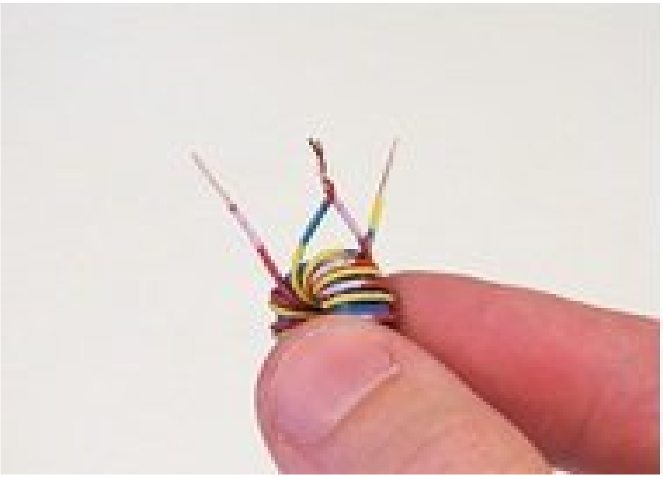

Strip the wire ends. Take one wire from each pair *of different color* and attach them together.

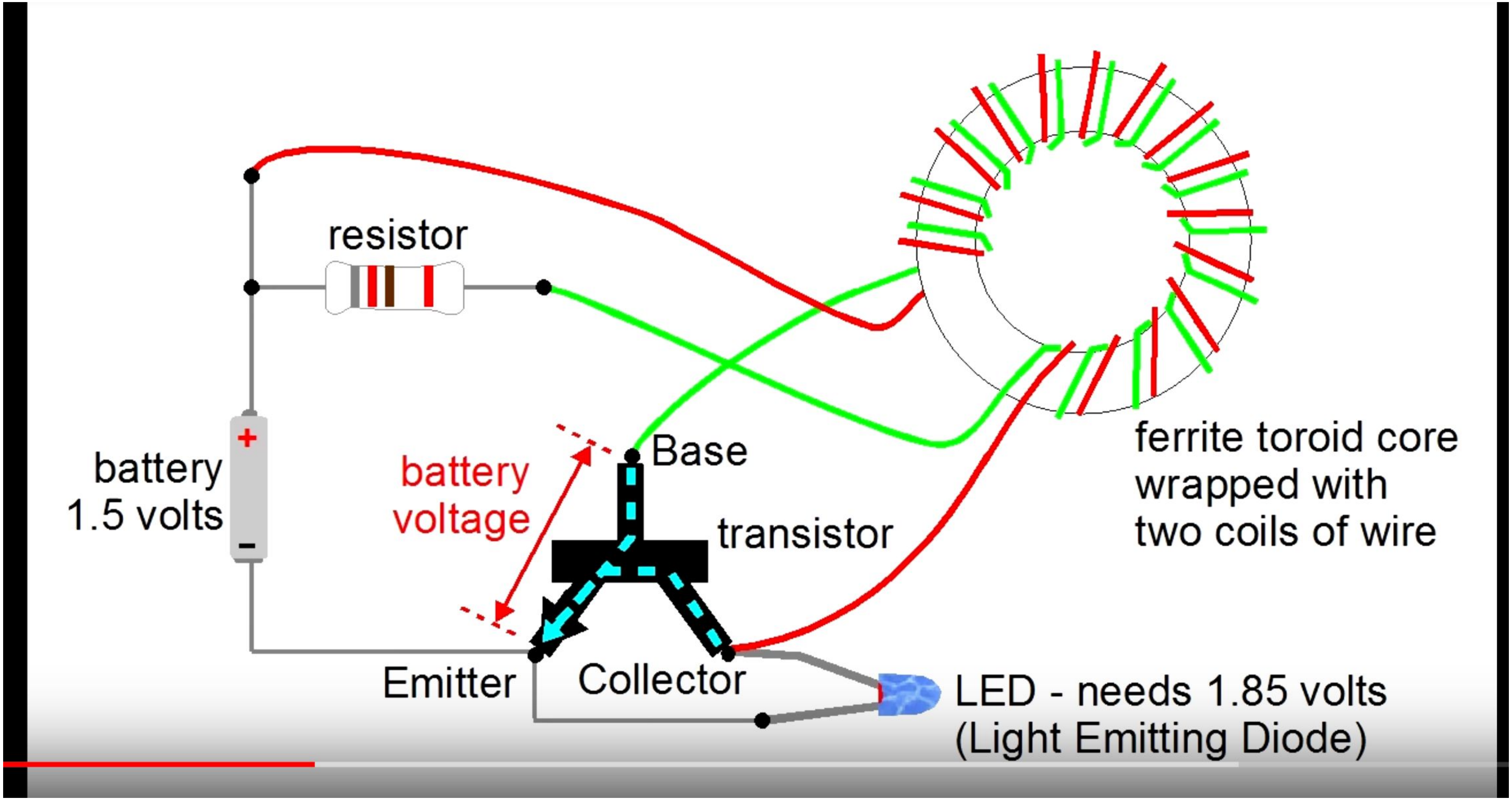
resistor
battery
1.5 volts
+
-
battery
voltage
Base
transistor
Emitter
Collector
ferrite toroid core
wrapped with
two coils of wire
LED - needs 1.85 volts
(Light Emitting Diode)

...A LAMP LED... EASY TO DO witch Circuit JOULE THIEF
Alternative without Ferrite toroid

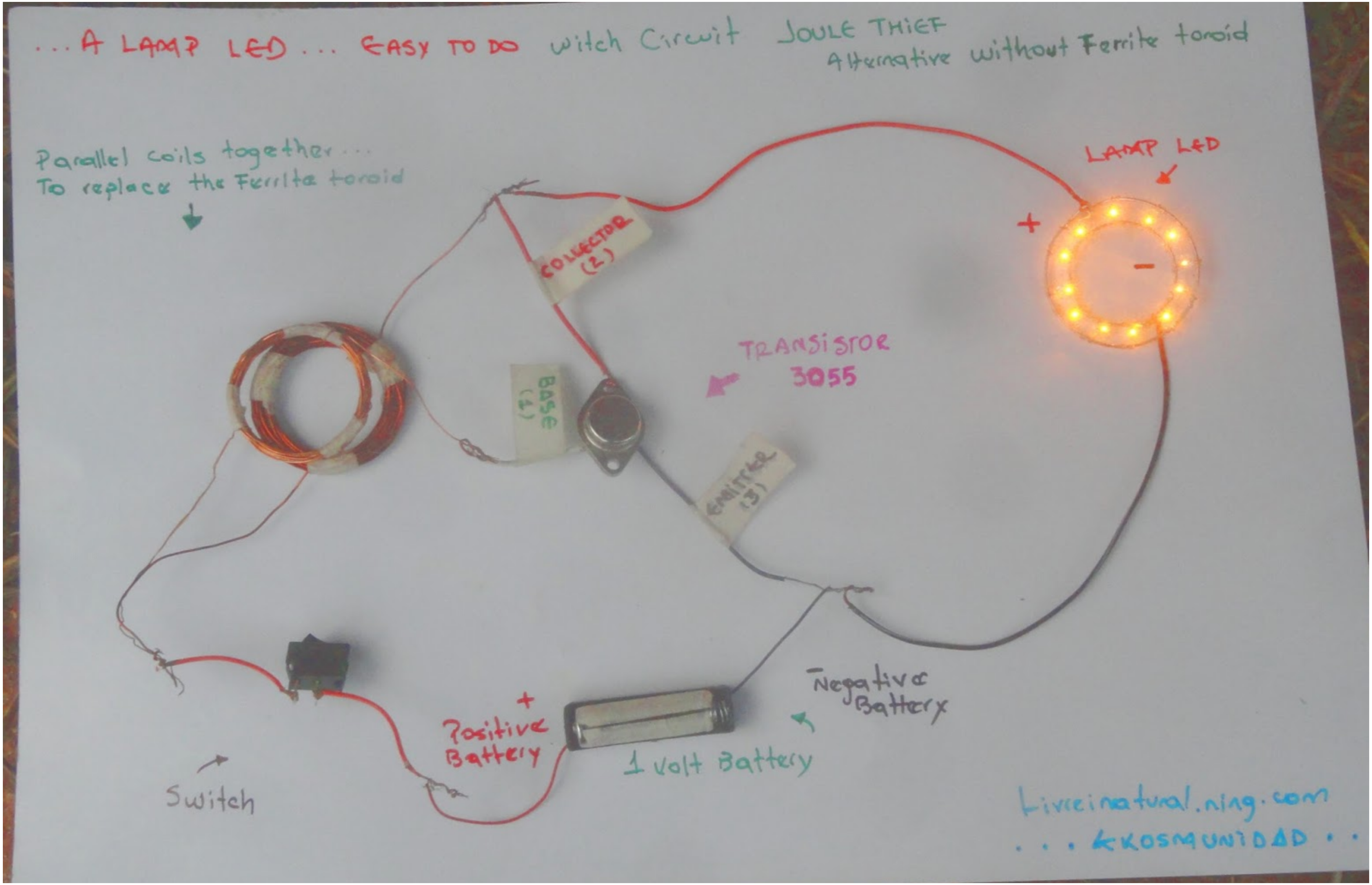
Parallel coils together...
To replace the Ferrite toroid

COLLECTOR (2)
BASE (1)
EMITTER (3)
TRANSISTOR 3055
LAMP LED
+
-
+
Positive Battery
-Negative Battery
1 volt Battery
Switch
Livreinatural.ning.com
...KOSMUNIDAD..

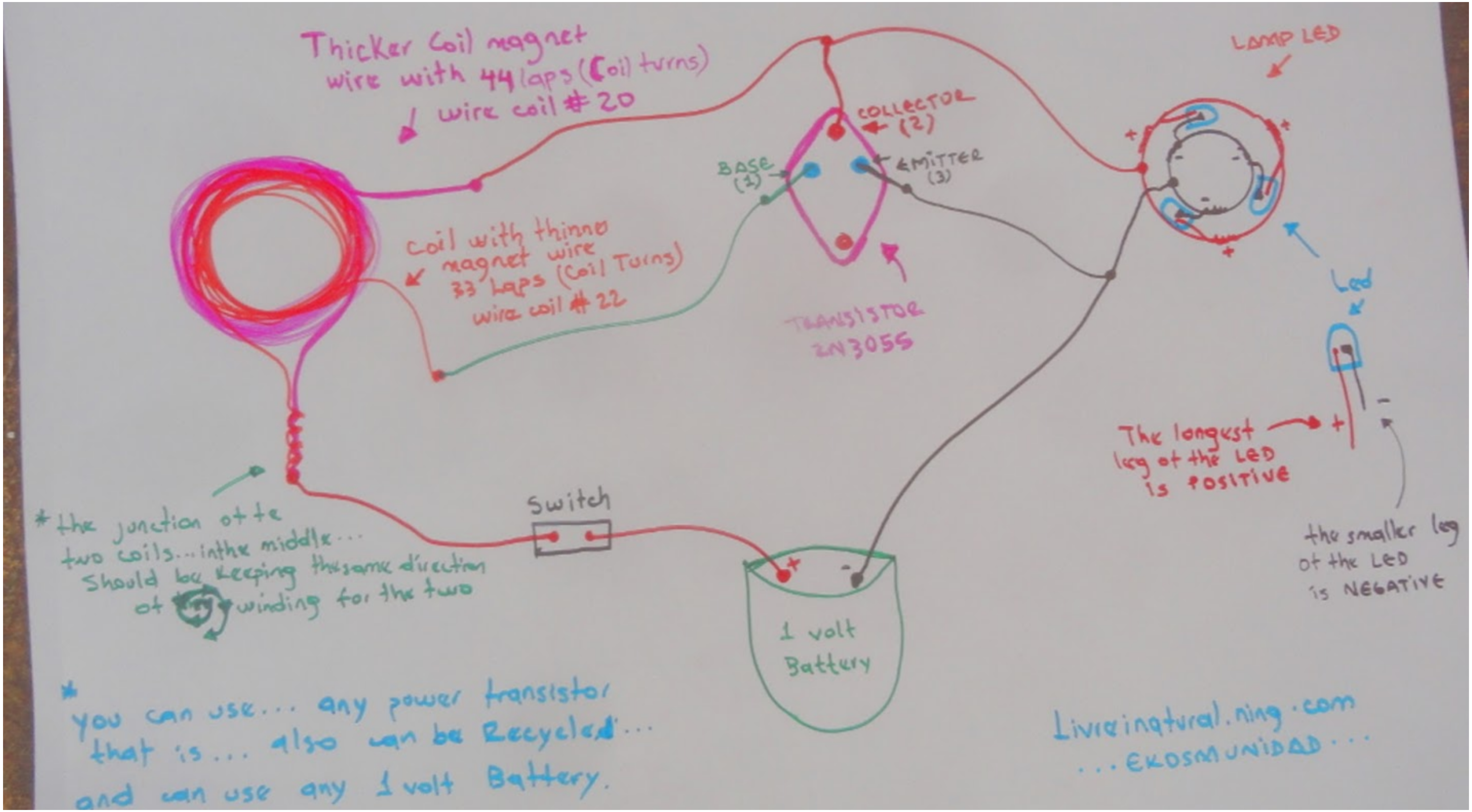
Thicker Coil magnet wire with 44 laps (Coil turns) wire coil #20
Coil with thinner magnet wire 33 Laps (Coil Turns) wire coil #22
BASE (1)
COLLECTOR (2)
EMITTER (3)
TRANSISTOR 2N3055
Lamp LED
+
+
+
+
Led
-
+
The longest leg of the LED is positive
the smaller leg of the LED is NEGATIVE
Switch
+
-
1 volt Battery

* the junction of te two coils... inthe middle... Should be keeping thesame direction of winding for the two

* you can use... any power transistor that is... also can be Recycled... and can use any 1 volt Battery.

Livreinatural.ning.com
...EKOSMUNIDAD...

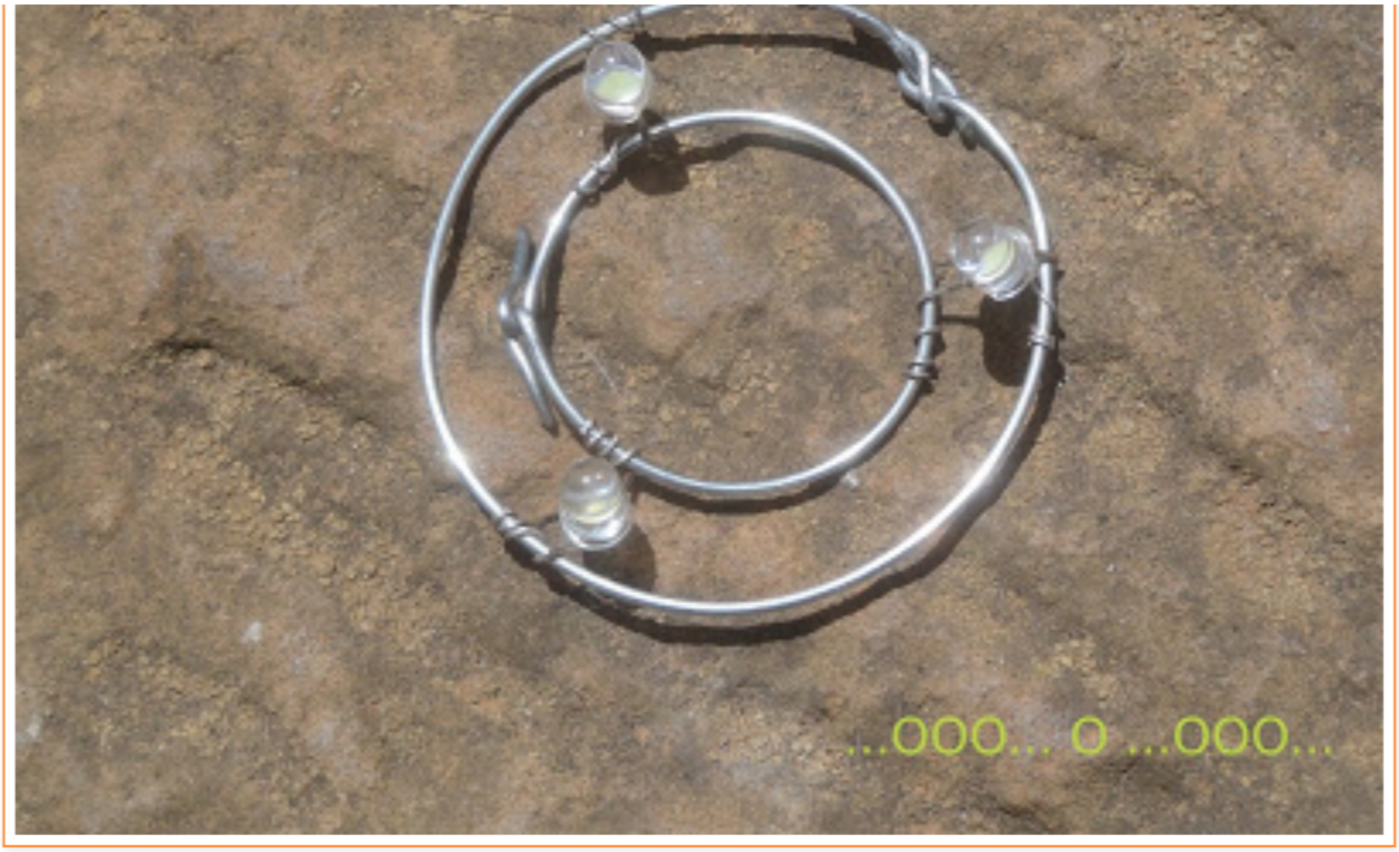
...OOO... O ...OOO...

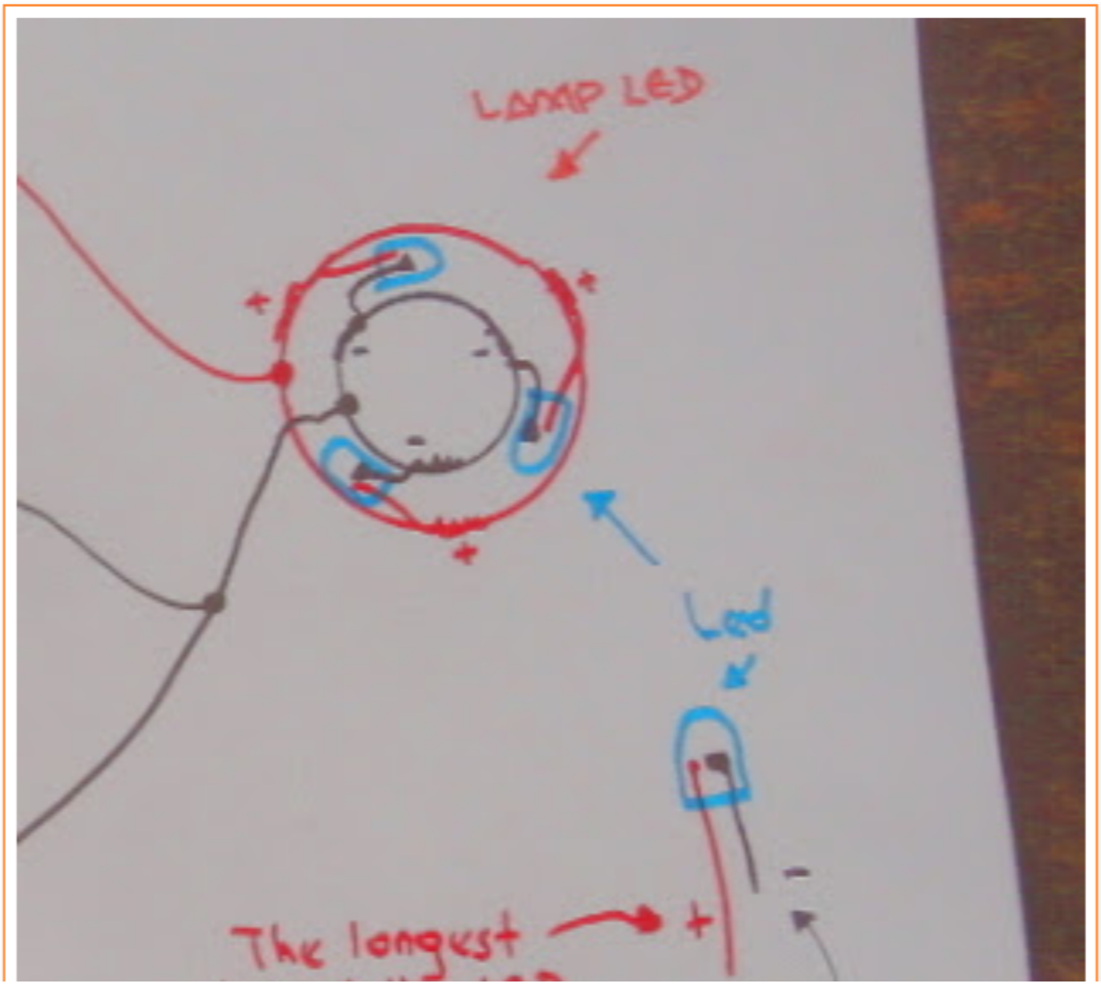
Lamp LED
+
+
+
-
-
-
Led
+
-
The longest

...Livreinatural.ning.com... ... EkosOphia ...O...

...Livreinatural.ning.com...

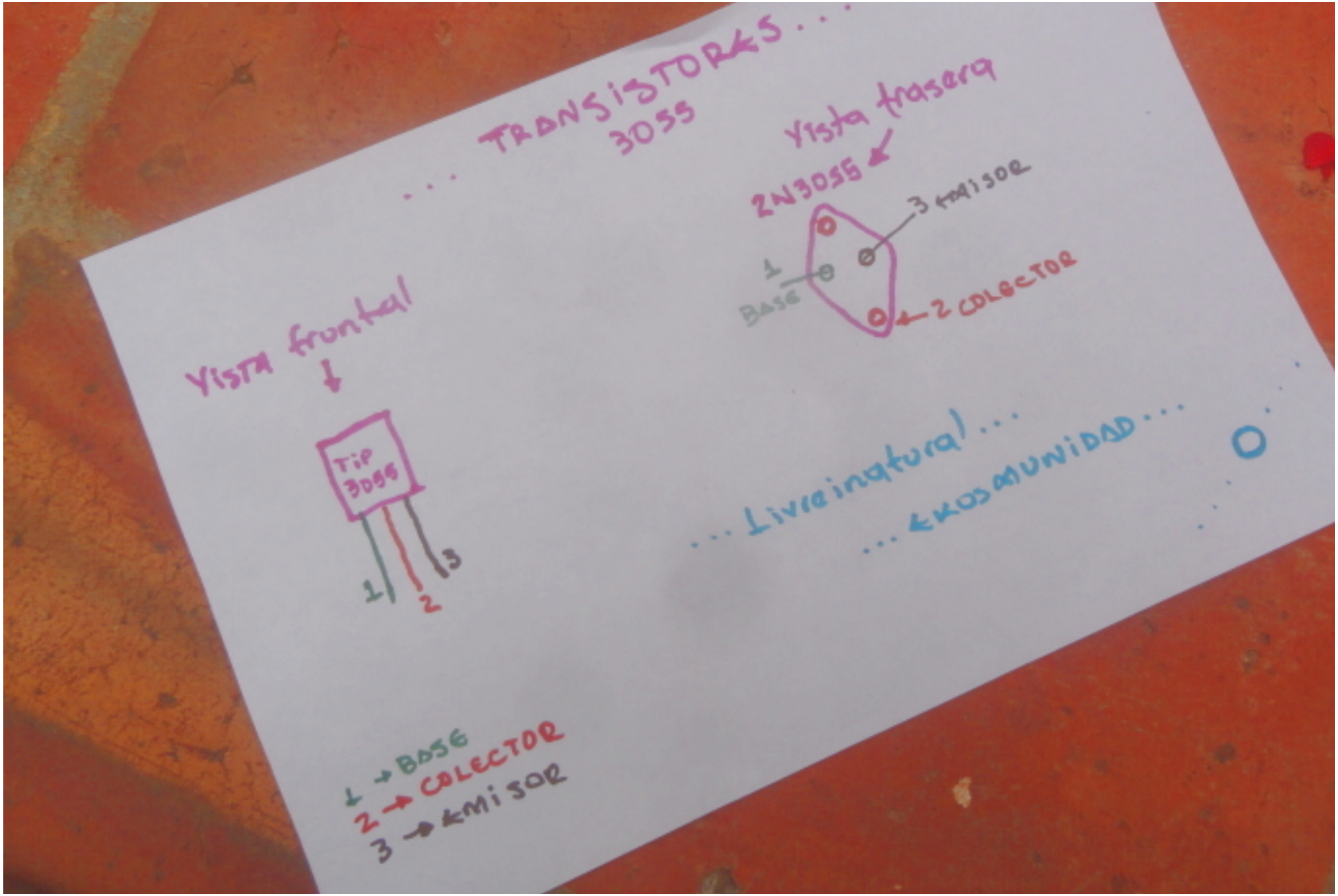

... TRANSISTORES ...
3055

Vista frontal

Tip
3055
1
2
3

Vista trasera

2N3055
3 EMISOR
1
BASE
2 COLECTOR

1 → BASE
2 → COLECTOR
3 → EMISOR

... Livreinatural ...
... EKOSMUNIDAD ...

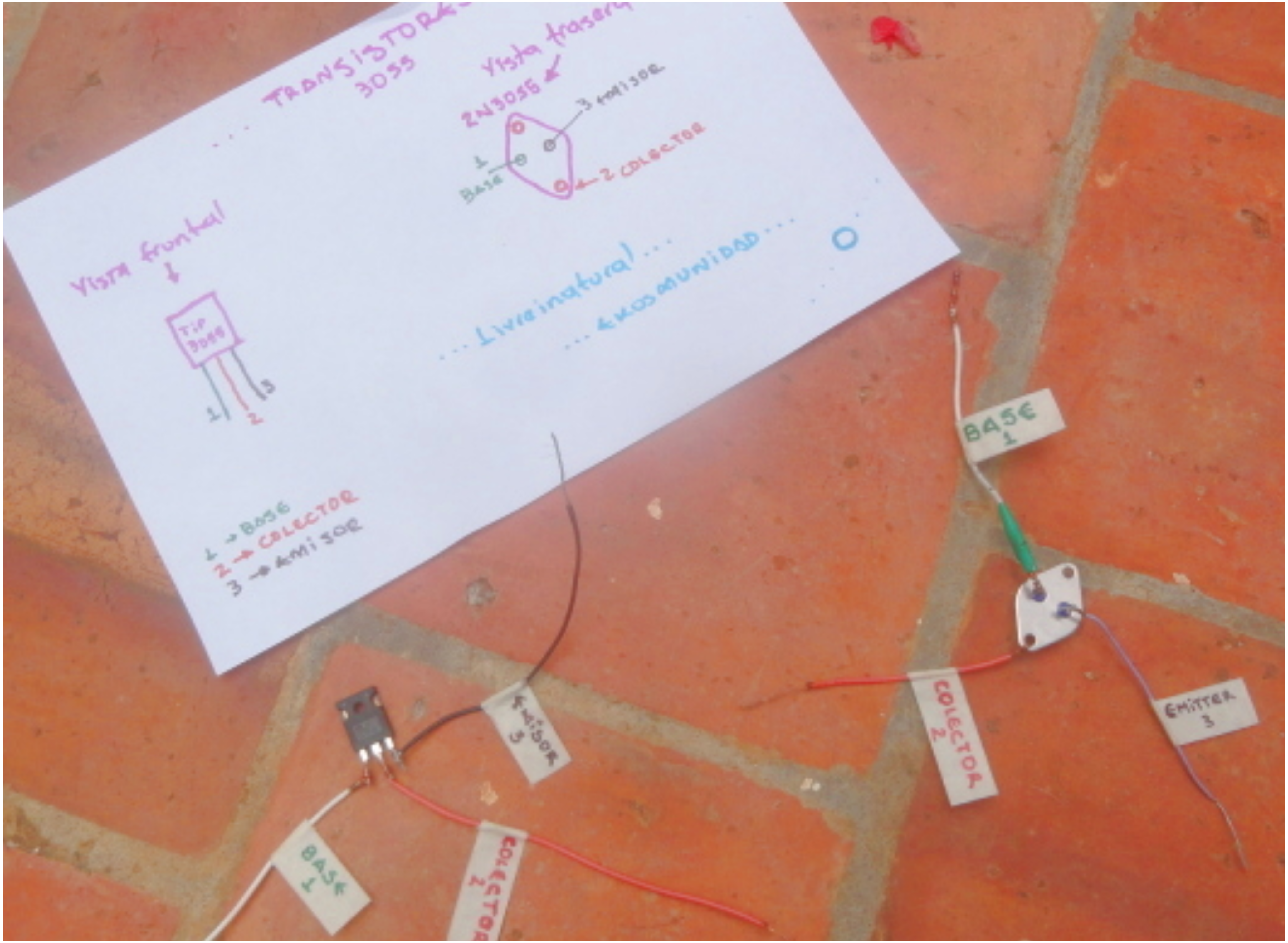
TRANSISTORE
3055
Vista trasera
2N3055
3 EMISOR
2 COLECTOR
1 BASE
Vista frontal
TIP 3055
1
2
3
...Livreinatural...
...ECOSMUNIDAD...
1 → BASE
2 → COLECTOR
3 → EMISOR
BASE 1
COLECTOR 2
EMITTER 3
EMISOR 3
BASE 1
COLECTOR 2

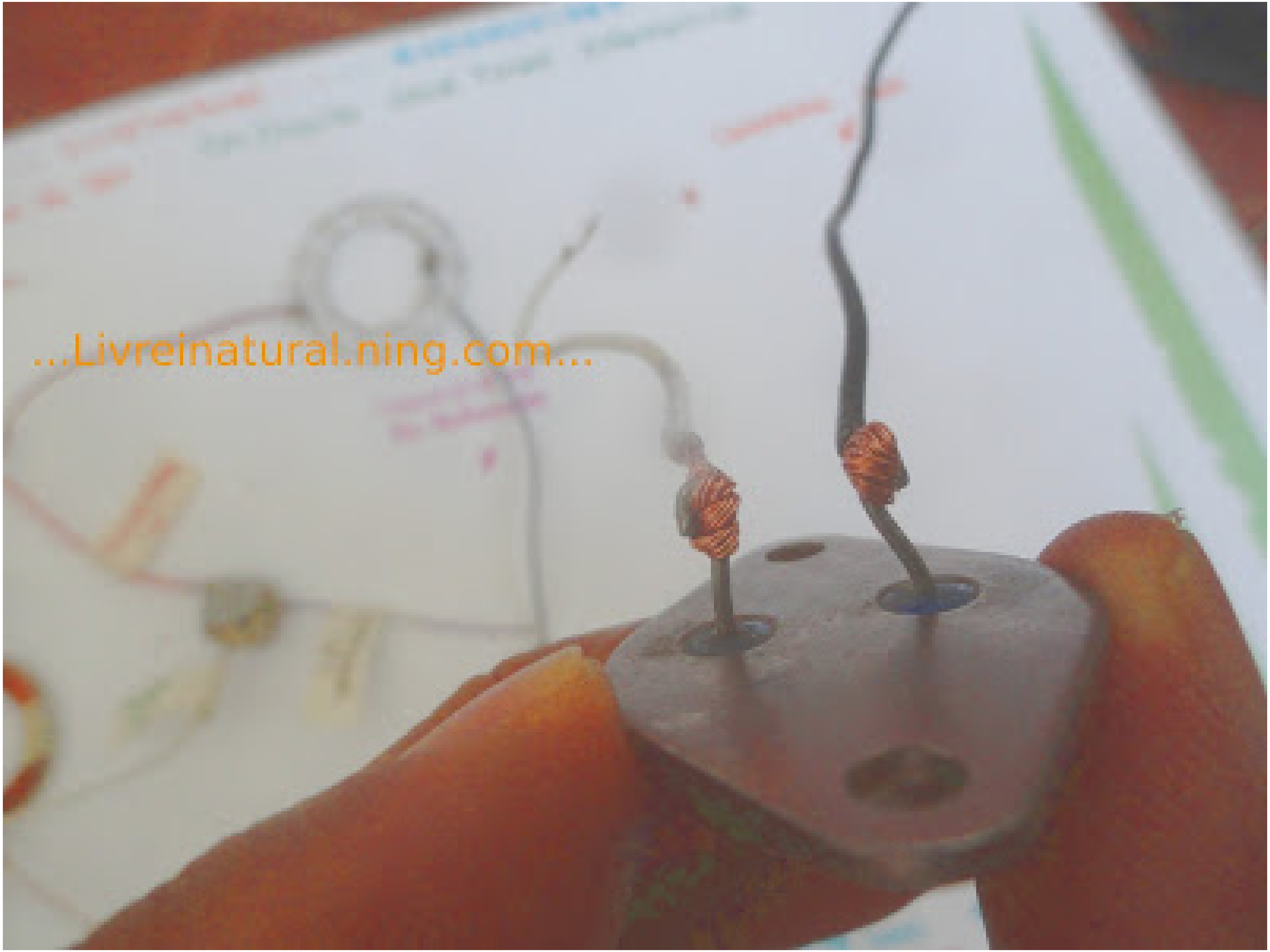

...Livreinatural.ning.com...

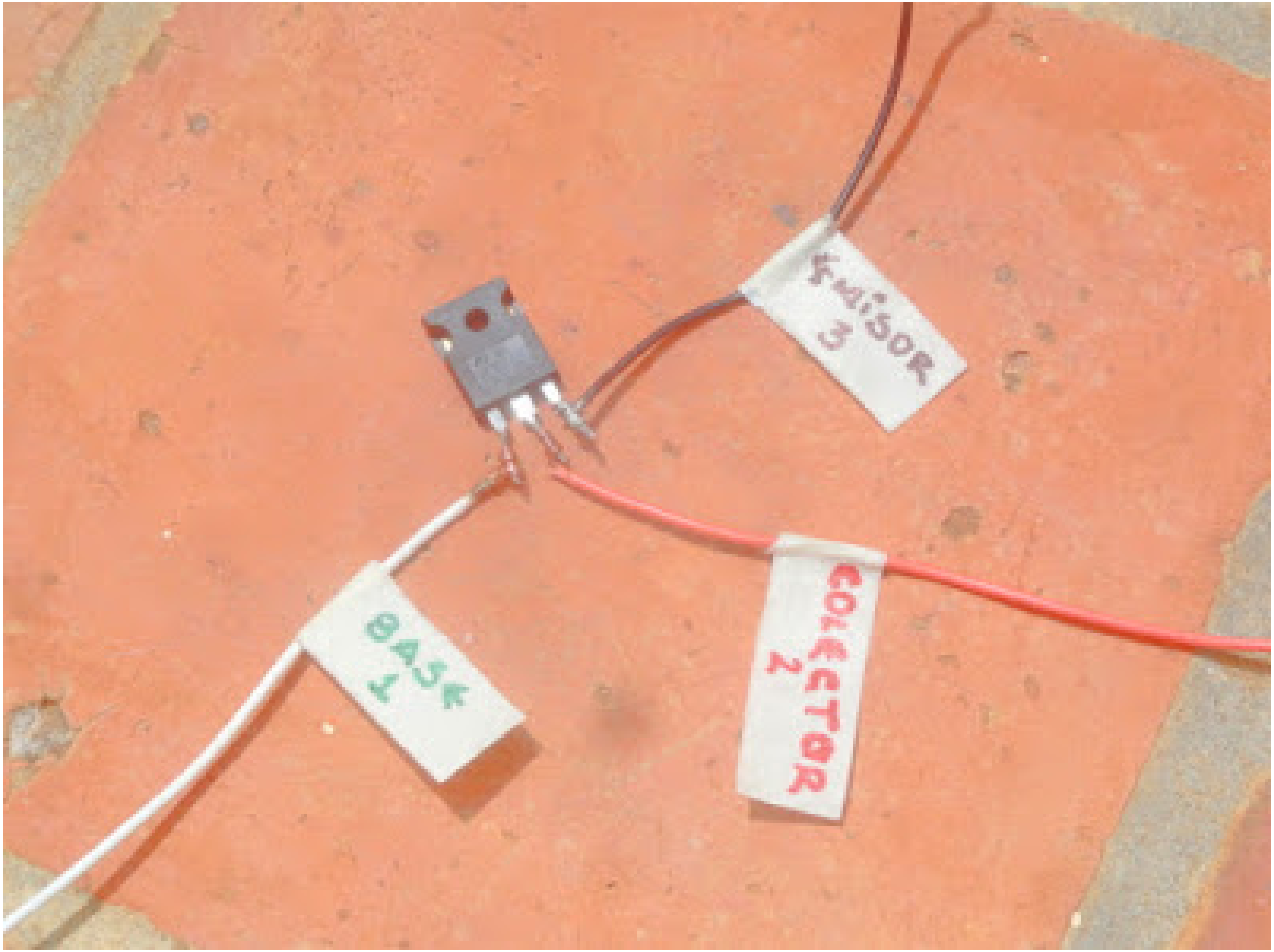
EMISOR
3
BASE
1
COLECTOR
2

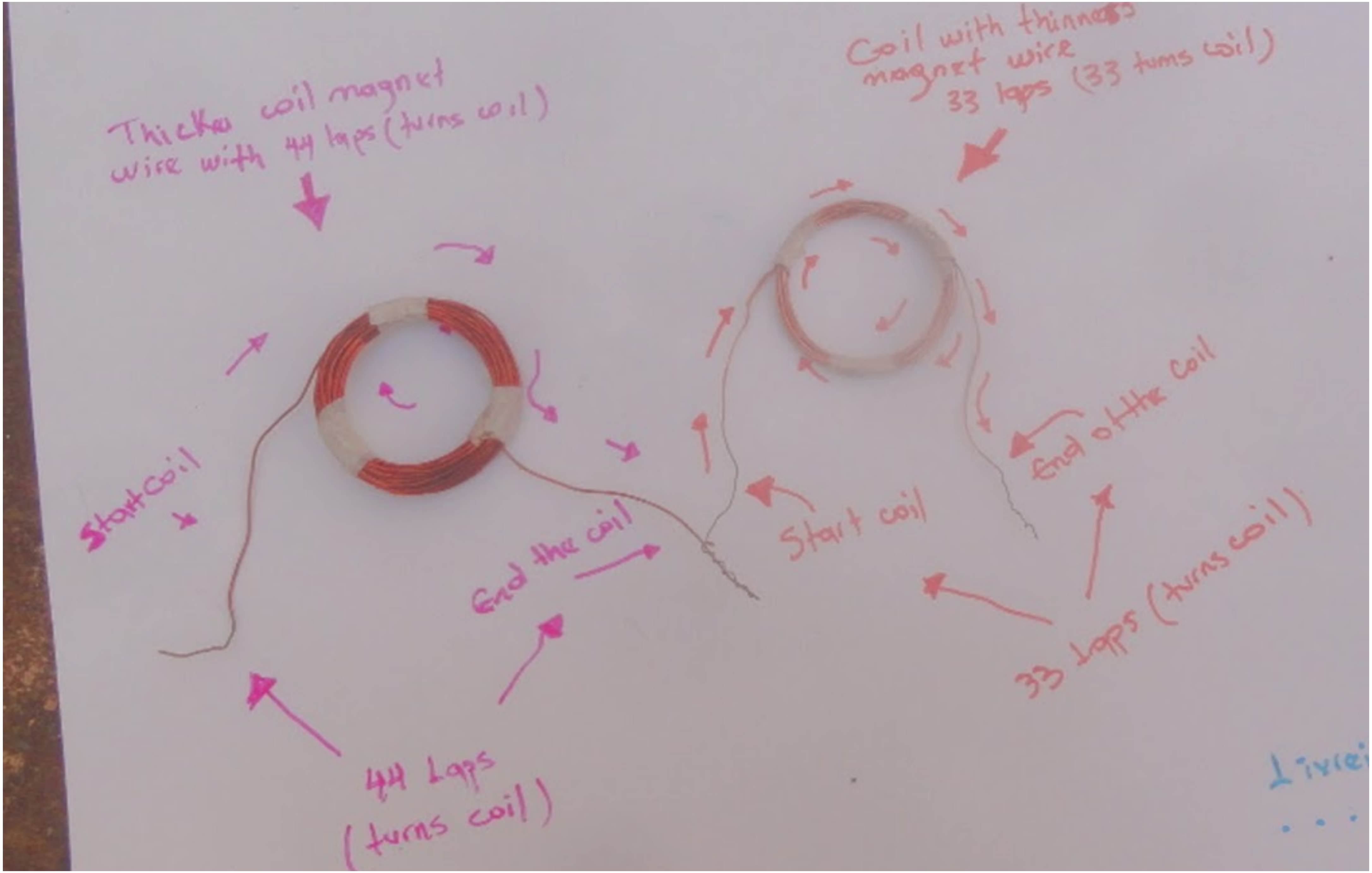
Thicker coil magnet wire with 44 laps (turns coil)
Coil with thinness magnet wire 33 laps (33 turns coil)
Start coil
End the coil
44 Laps (turns coil)
Start coil
End of the coil
33 laps (turns coil)
Livrei

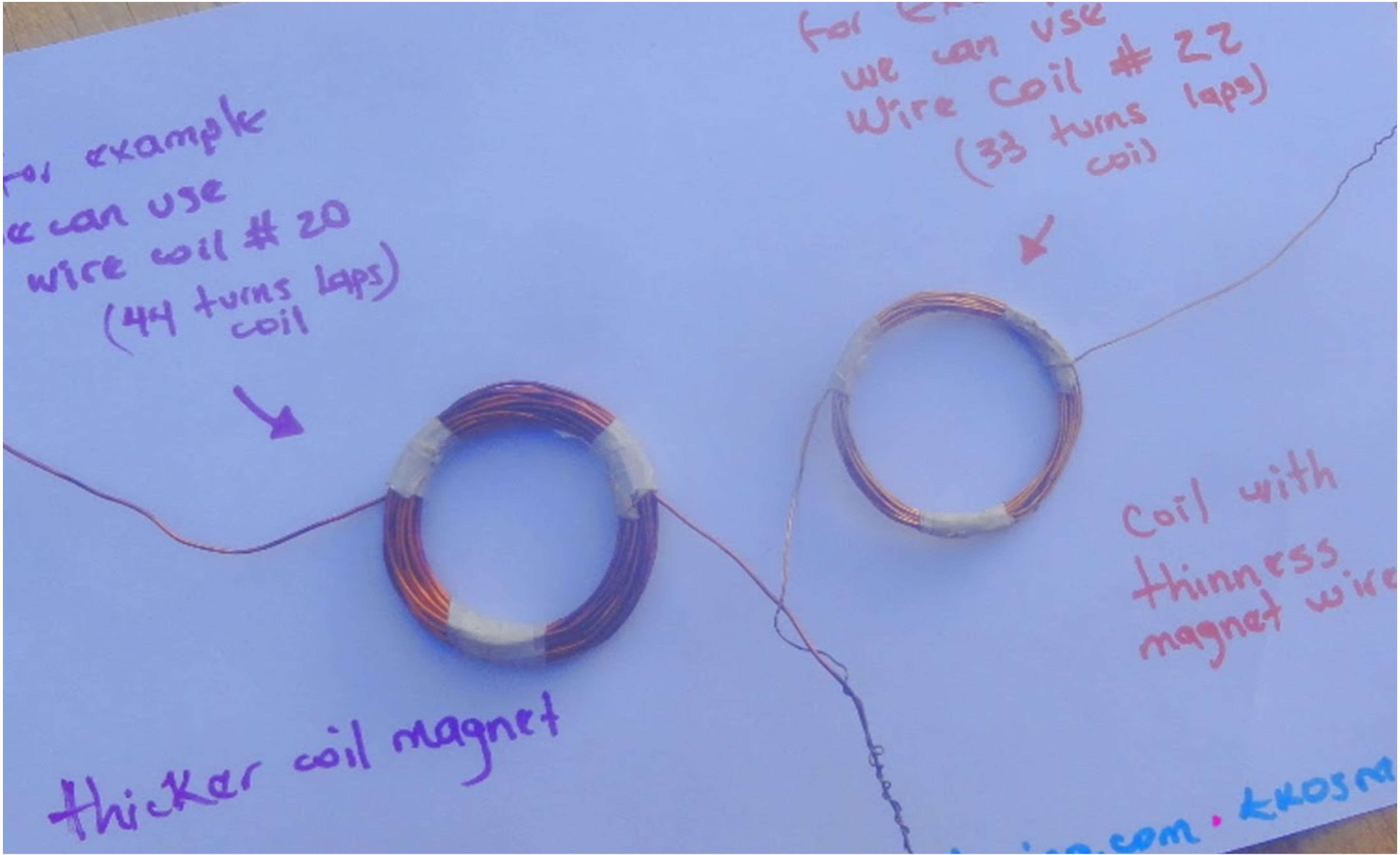
or example
e can use
wire coil # 20
(44 turns laps)
coil
for
we can use
Wire Coil # 22
(33 turns laps)
coil)
Coil with
thinness
magnet wire
thicker coil magnet
.com . kkosm

This provision replaces the use of the ferrite toroid in the Joule Thief

thicker coil magnet wire with 44 laps (coil turns) for example we can use wire coil # 20

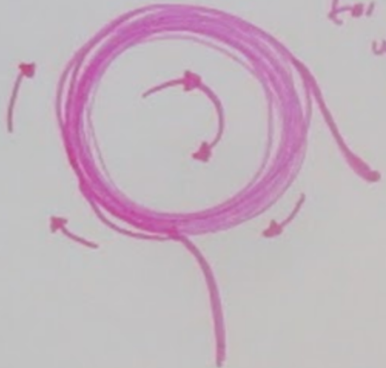

Coil with thinness magnet wire 33 laps (coil turns) for example we can use wire coil # 22

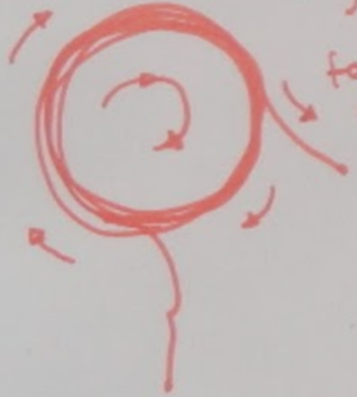

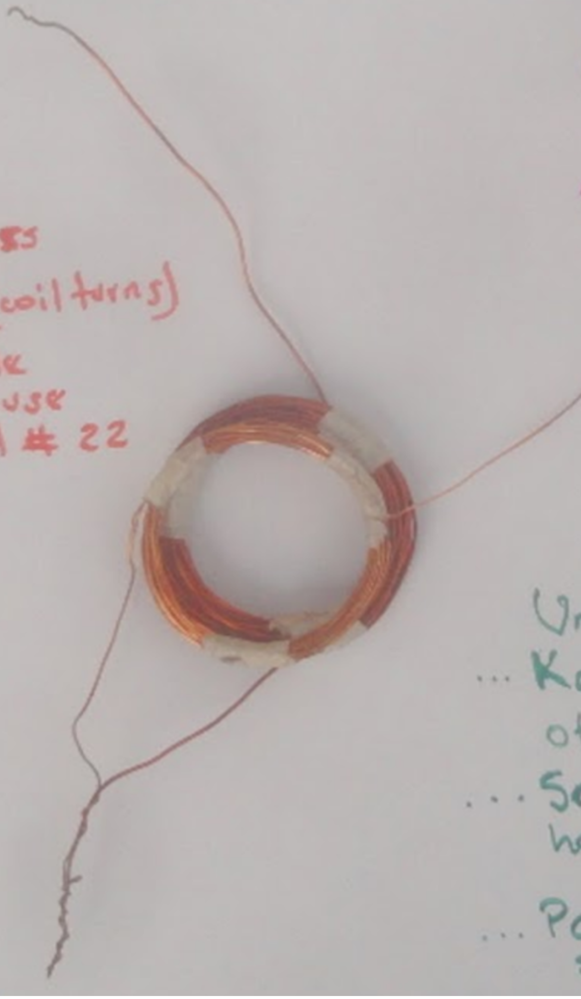

The junction of the two coils... in the middle should be keeping the same direction of winding for the two

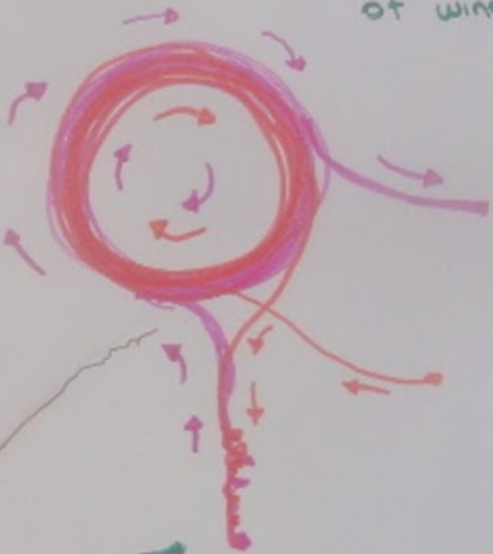

for Example

Unite these two coils...

... Keeping the same rotation direction of each coil...

... So in total the union of the two coils have the same rotational.

... Position a coil above the other so they are parallel

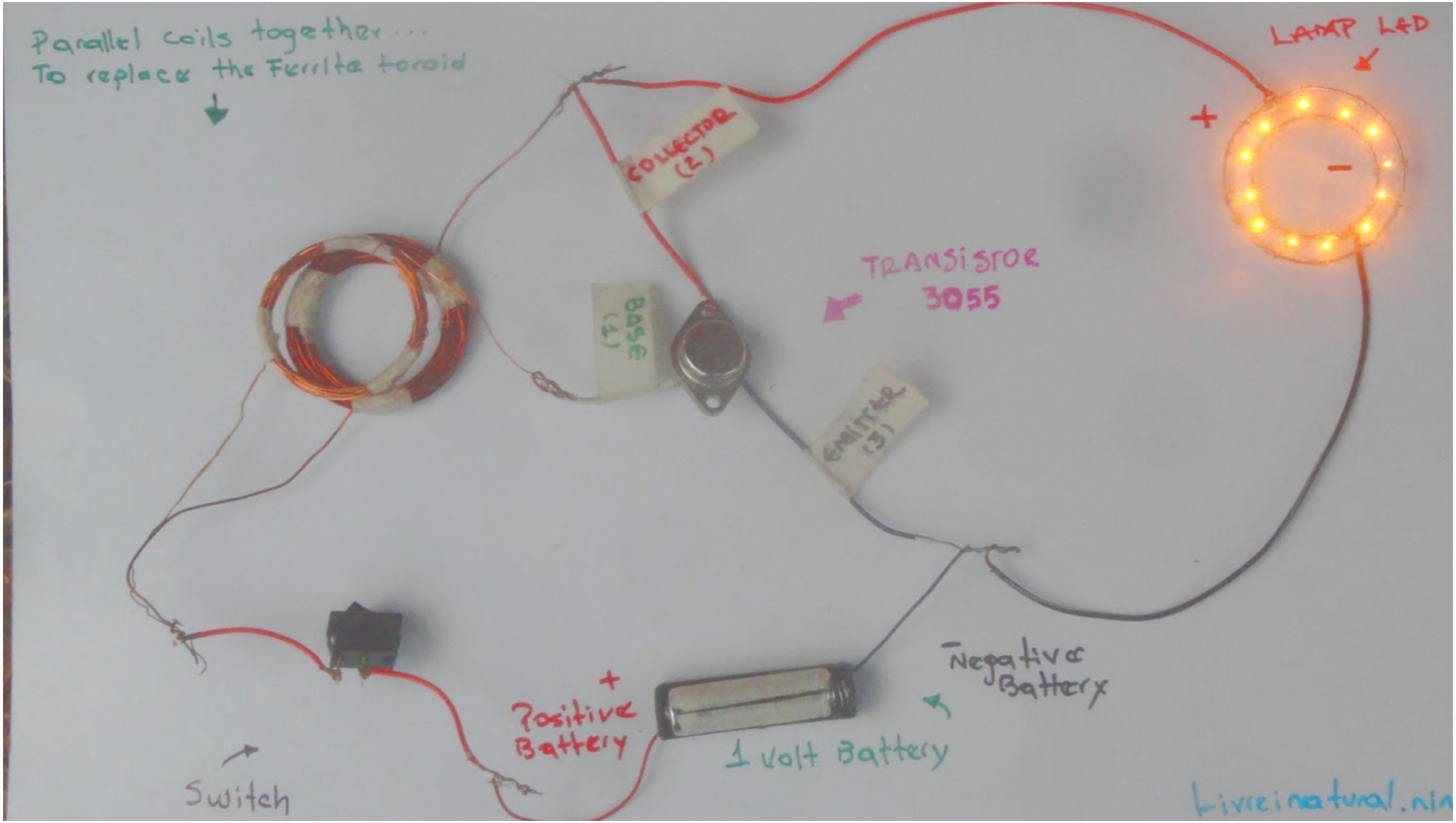
Parallel coils together...
To replace the Ferrite toroid
LAMP LED
+
-
COLLECTOR (2)
BASE (1)
TRANSISTOR 3055
EMITTER (3)
+
Positive Battery
Negative Battery
1 volt Battery
Switch
Livreinatural.nin

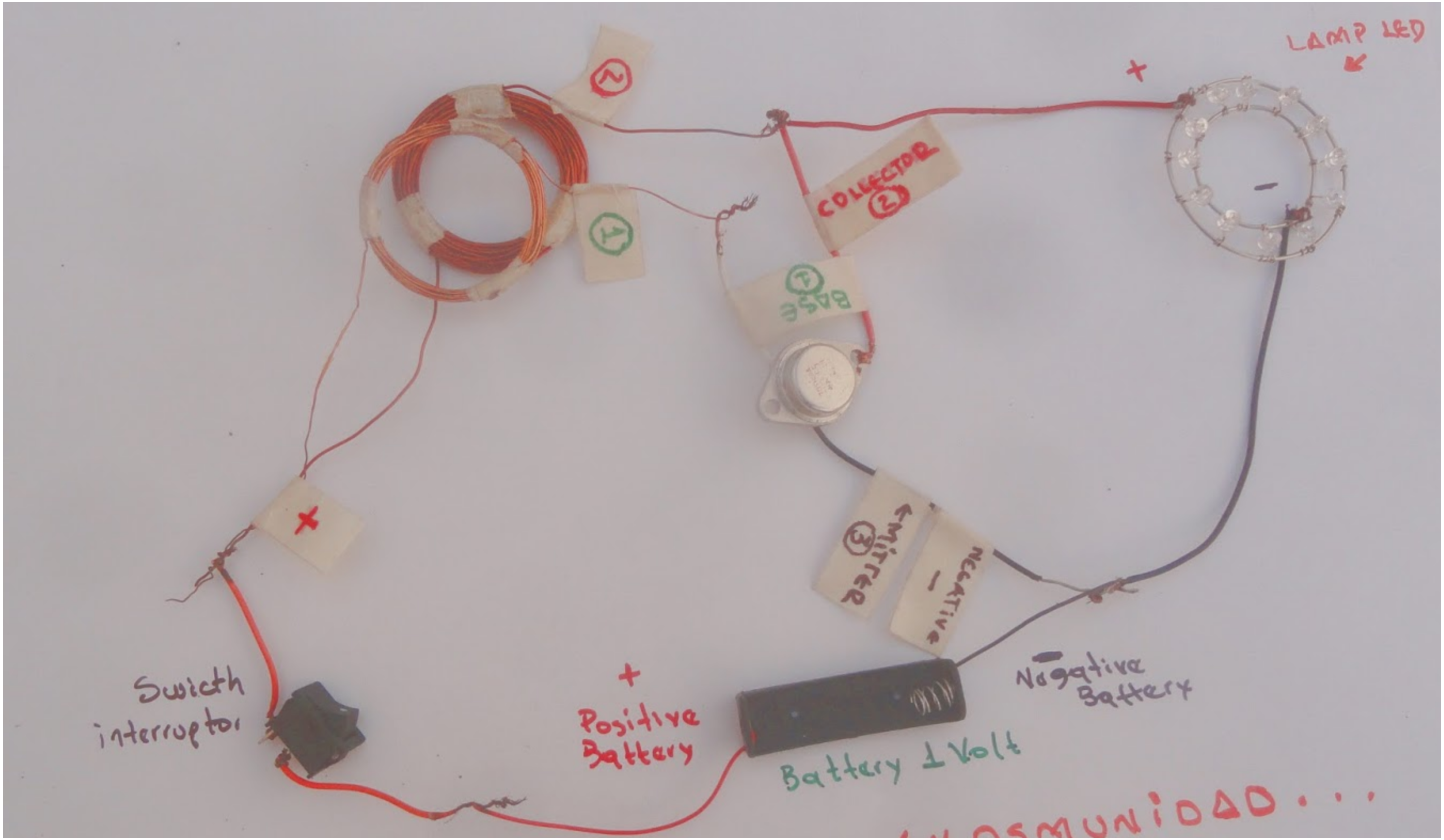
LAMP LED
+
②
①
COLLECTOR ②
BASE ①
—
+
EMITTER ③
NEGATIVE —
Swicth interruptor
+ Positive Battery
— Negative Battery
Battery 1 Volt
OSMUNIDAD...

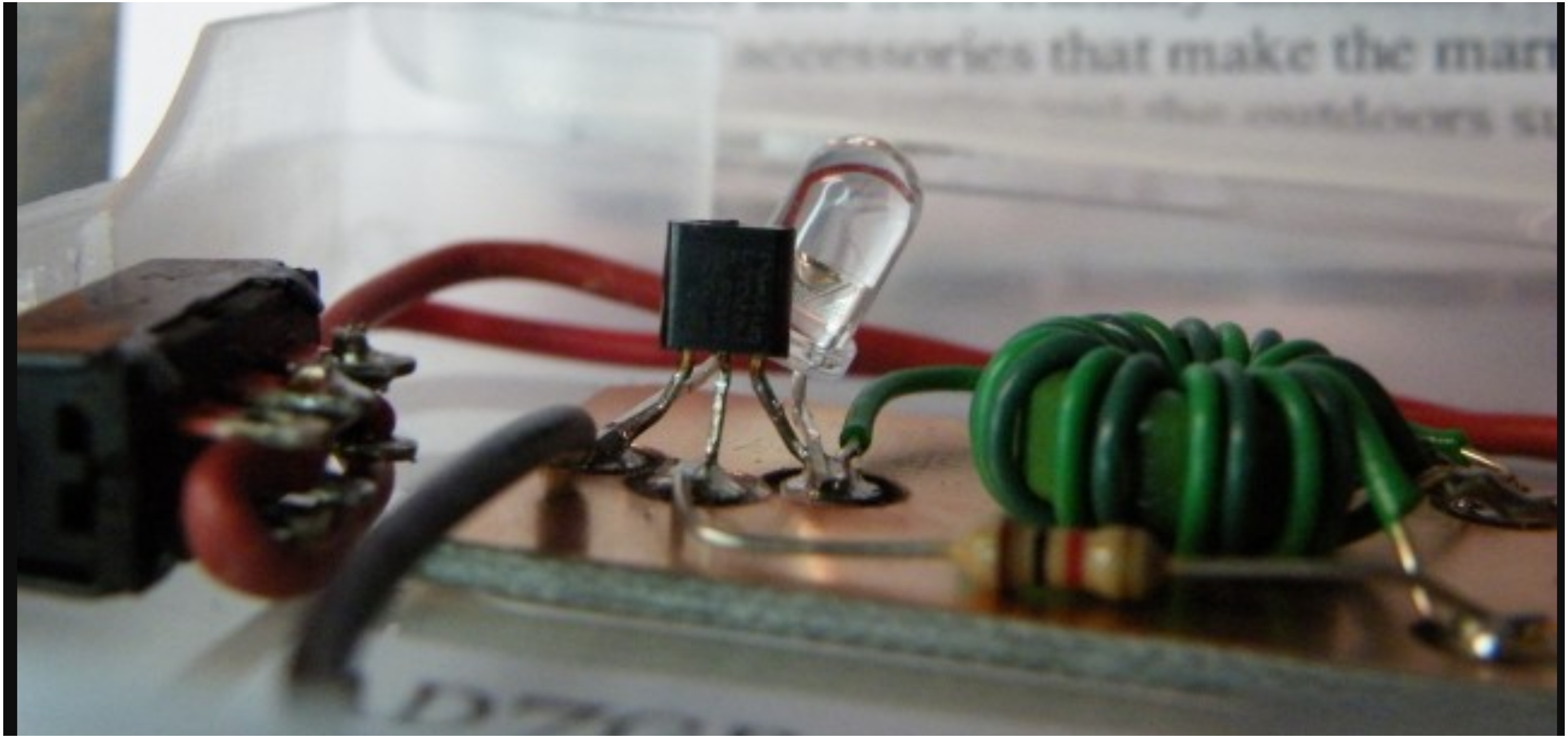

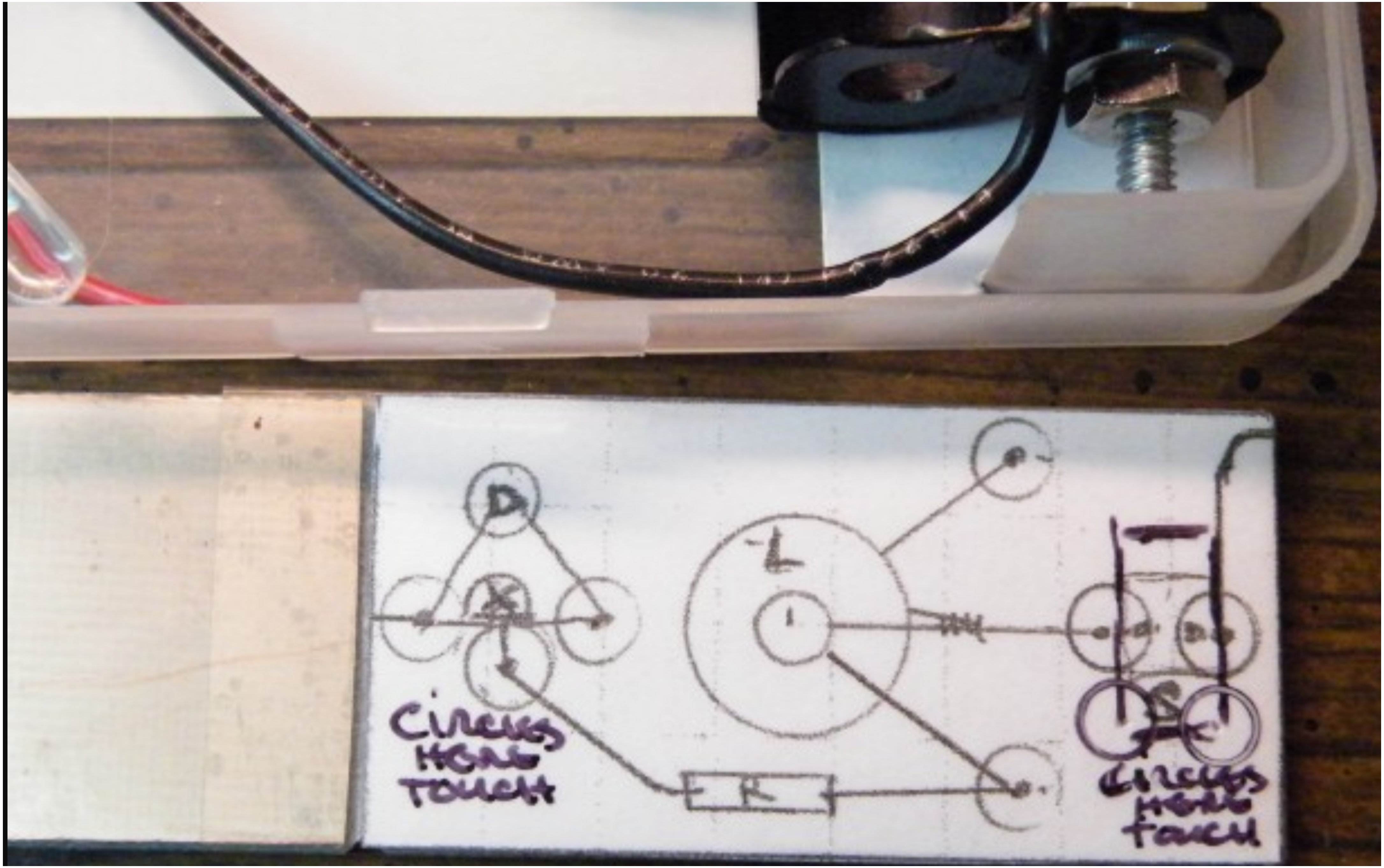
D
X
L
R
S
Circles here touch
Circles here touch

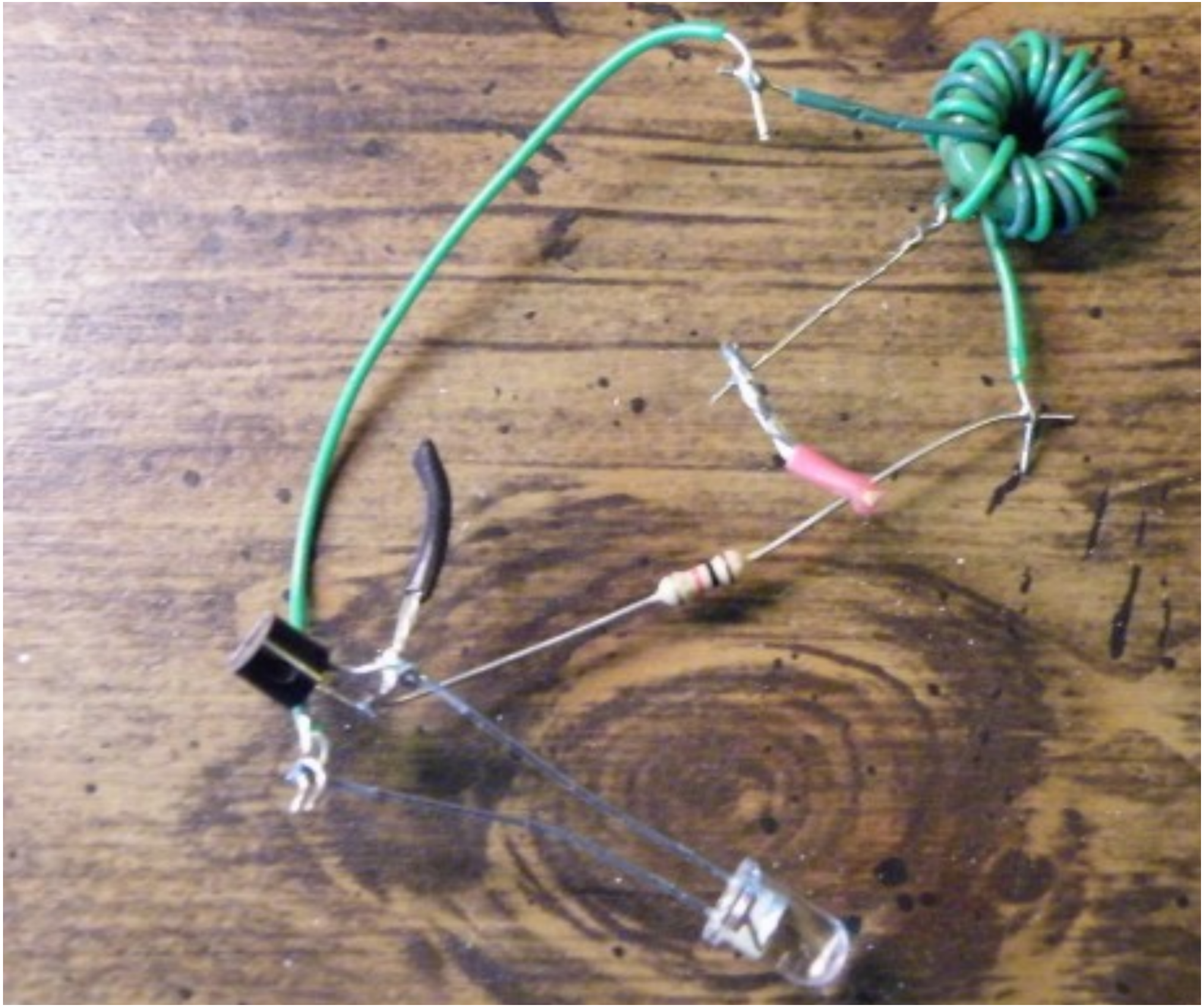

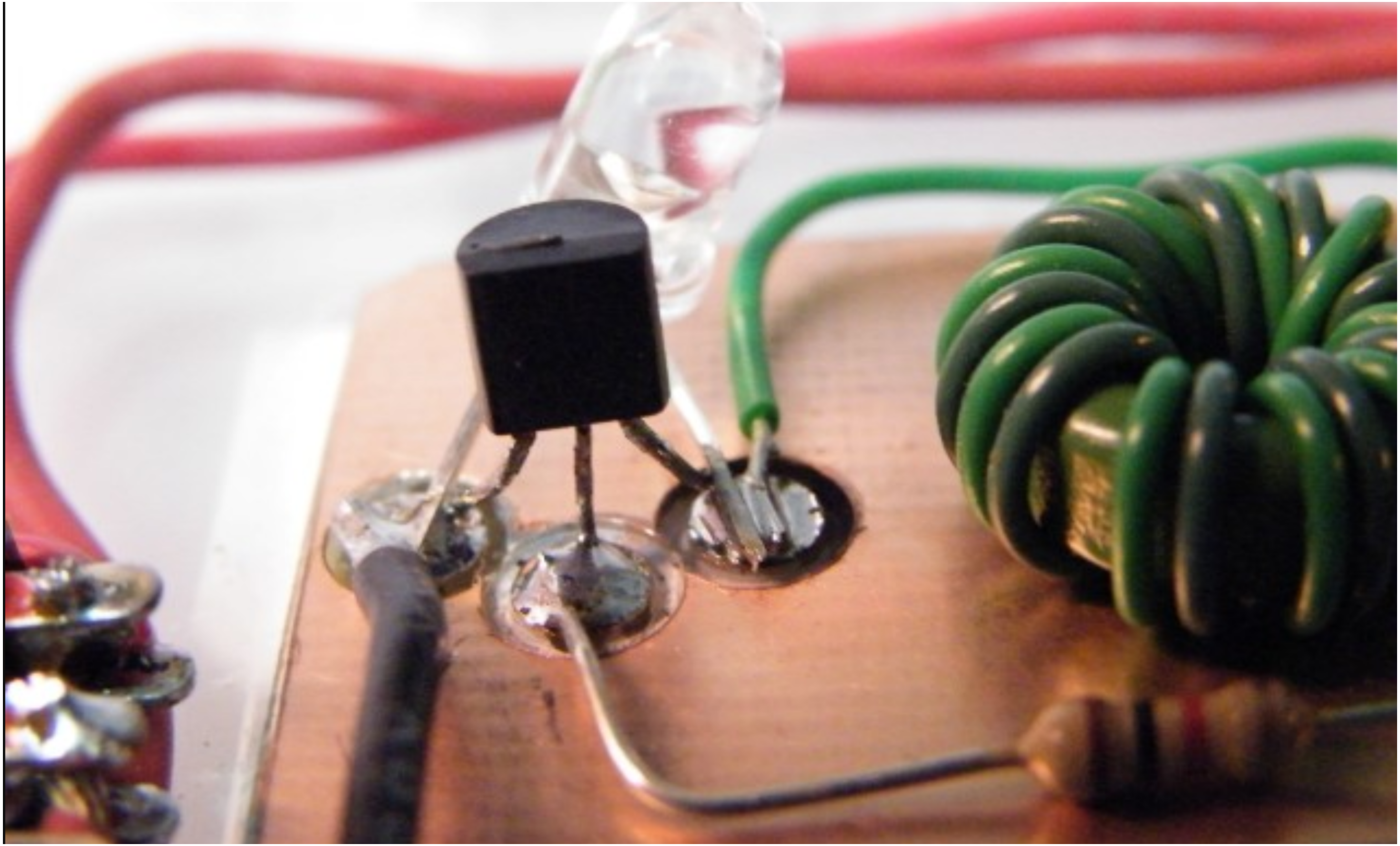

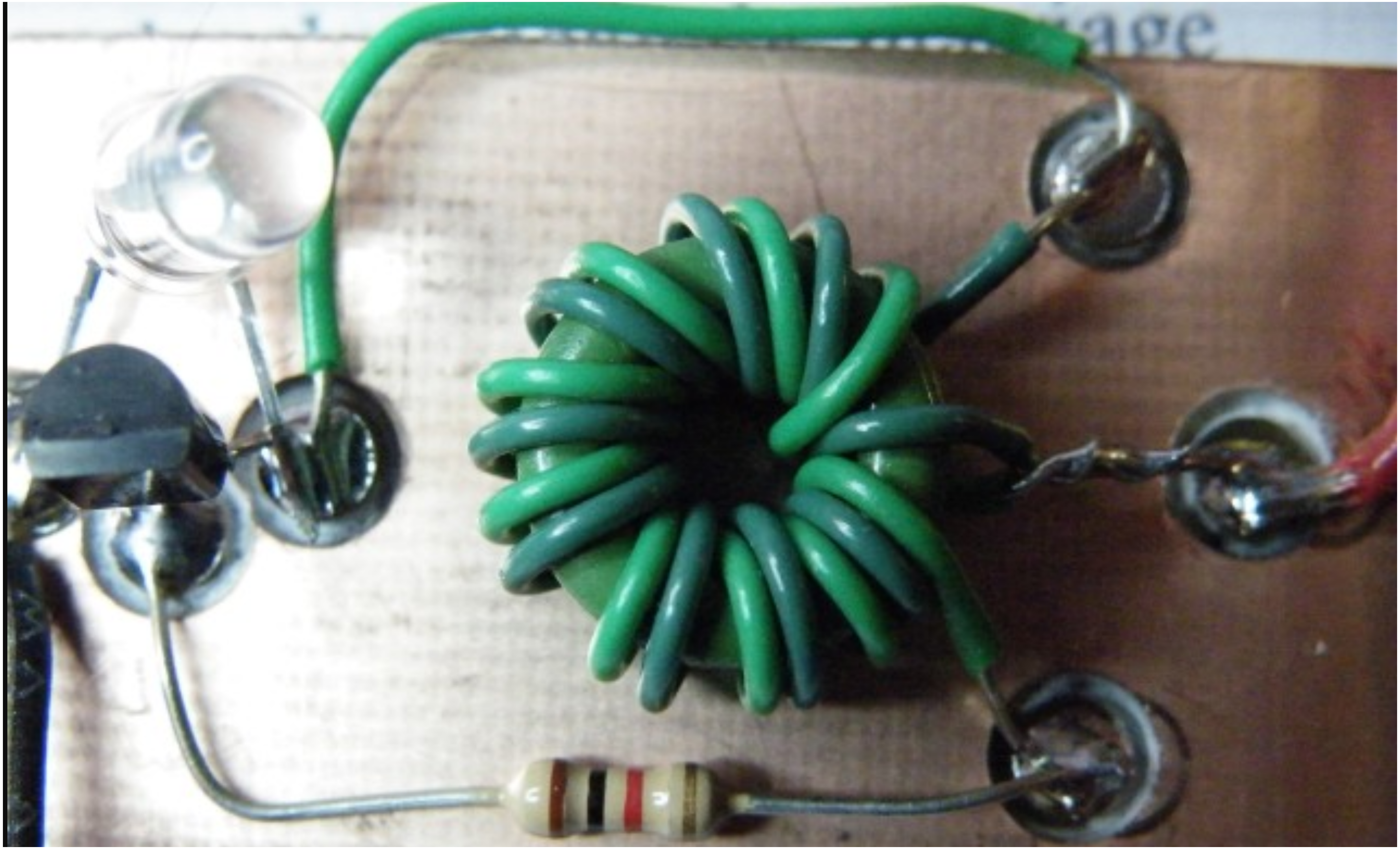
age

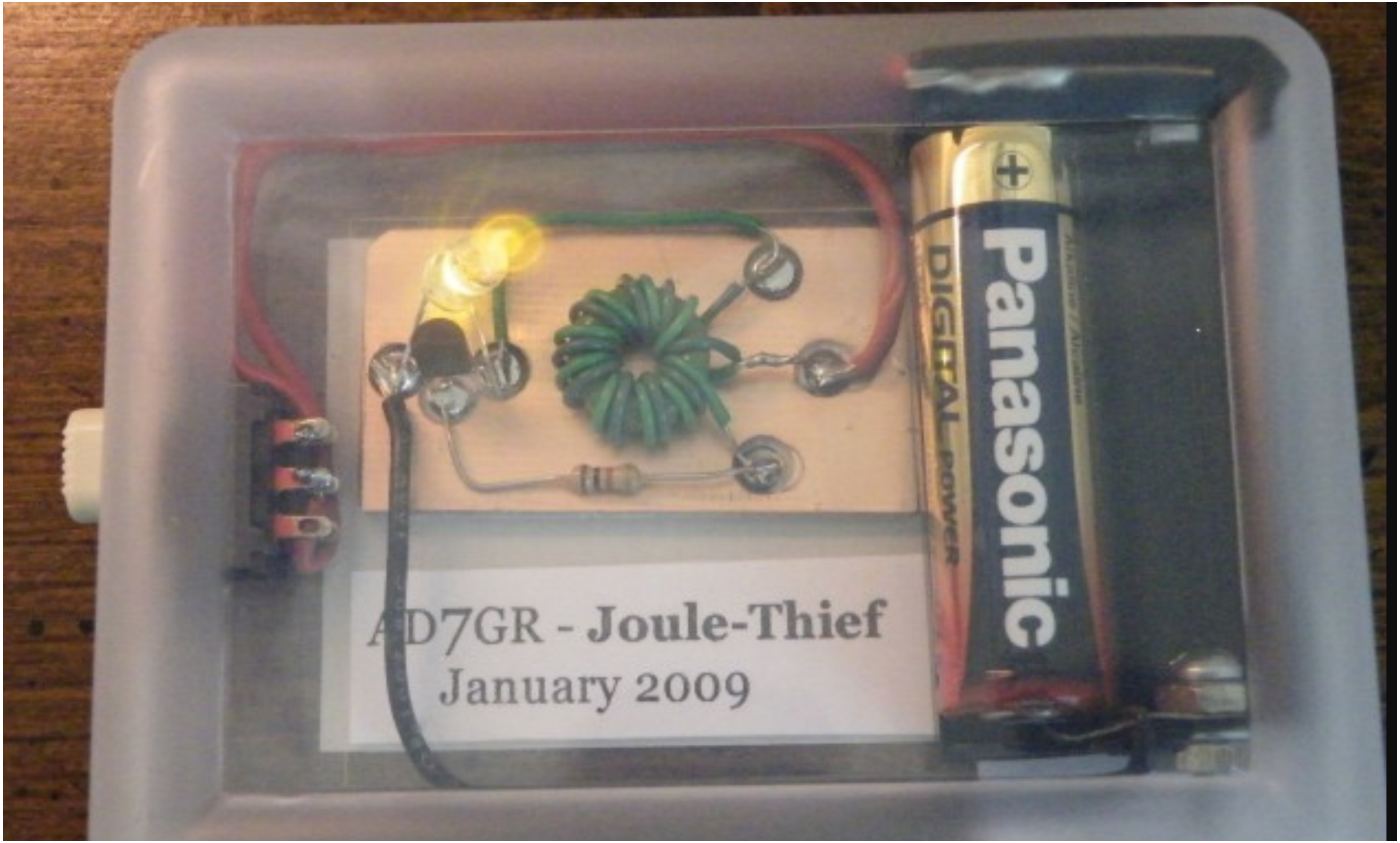
AD7GR - Joule-Thief
January 2009
Panasonic
DIGITAL POWER

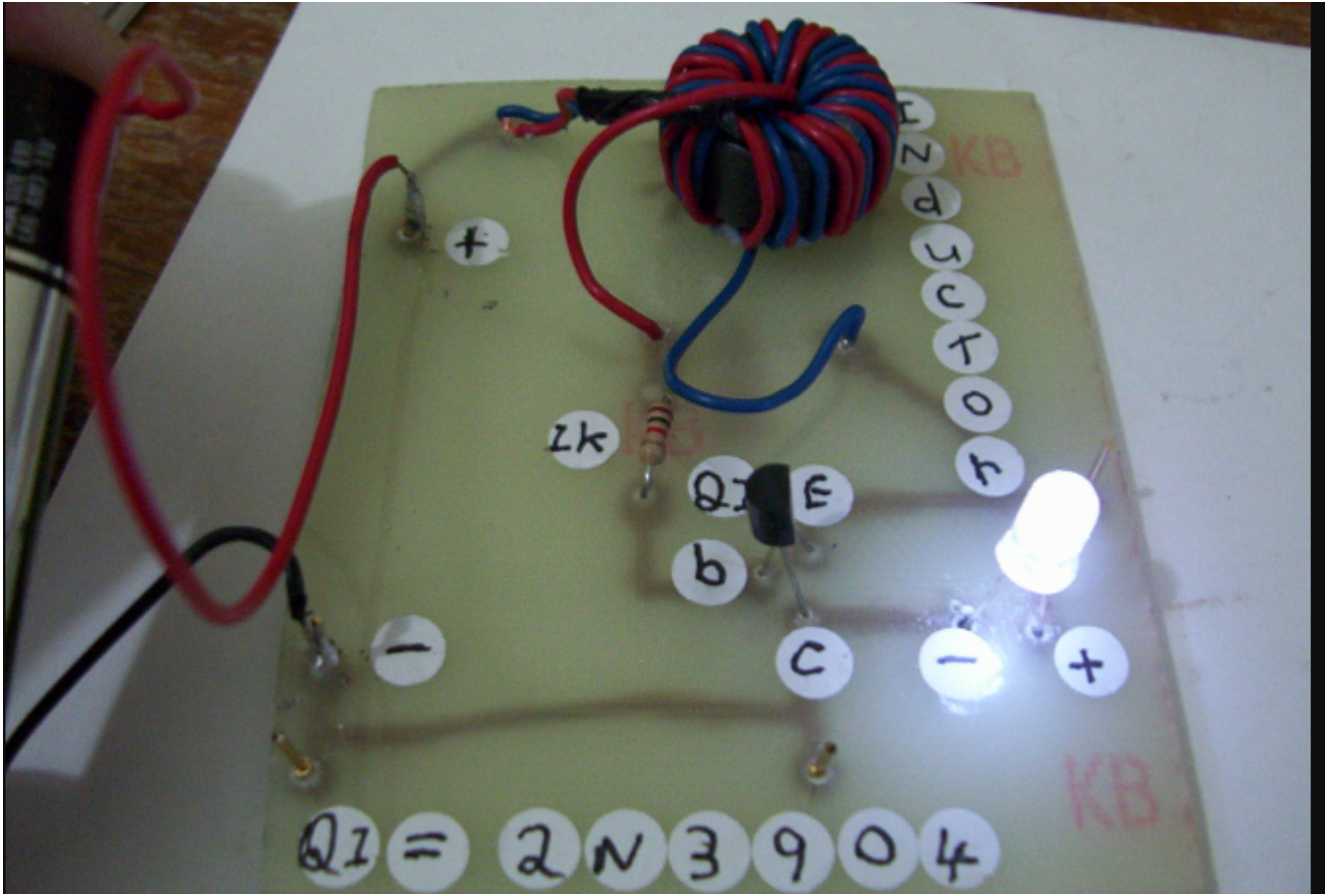
+
Inductor
KB
2k
Q1
E
b
−
C
−
+
KB
Q1 = 2N3904

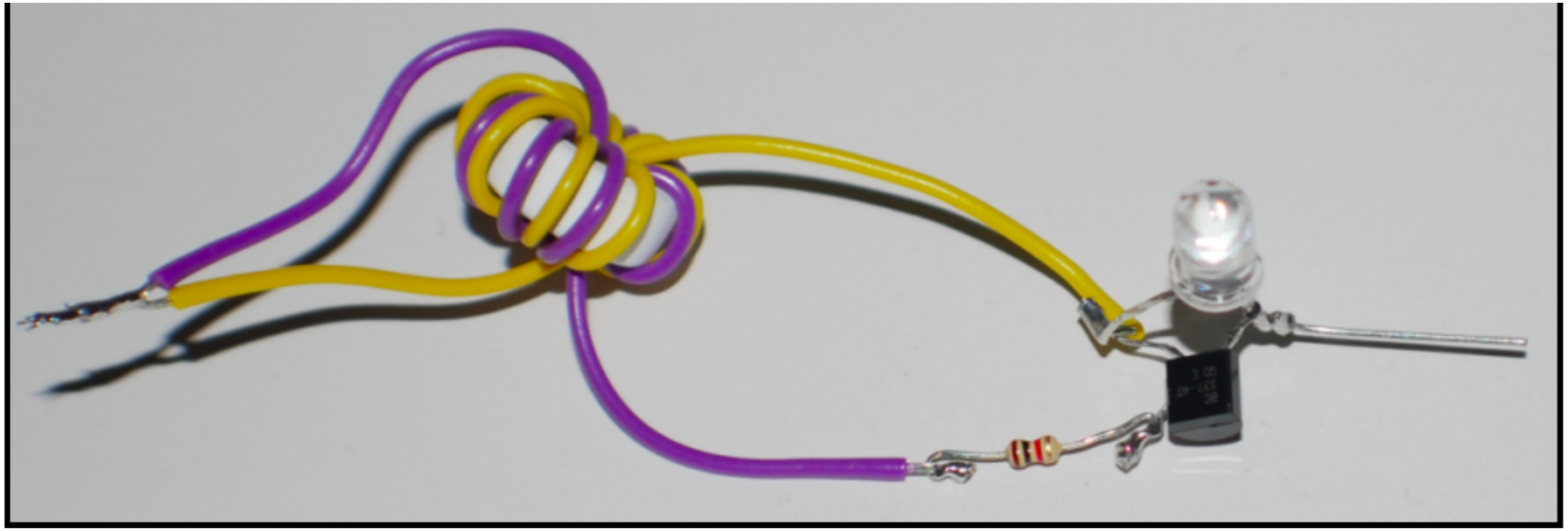

... and these are the components you need:

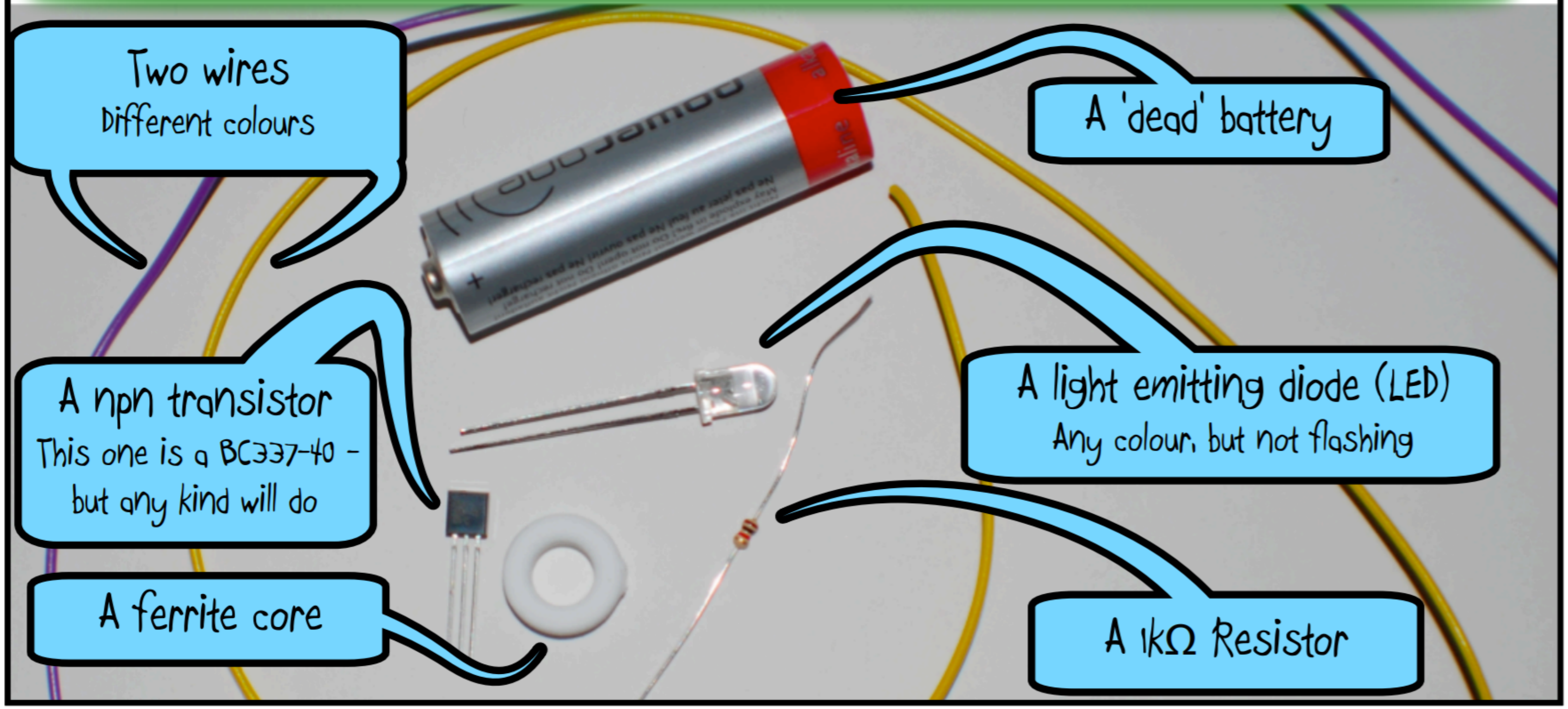
Two wires
Different colours
A 'dead' battery
A npn transistor
This one is a BC337-40 – but any kind will do
A light emitting diode (LED)
Any colour, but not flashing
A ferrite core
A 1kΩ Resistor

Solder the 1kΩ Resistor to either of the unsoldered wires coming from the inductor.

Solder the other end of the resistor to the base lead of the transistor.
On the transistor used here, that is the middle lead.
Cut off the spare ends of leads.

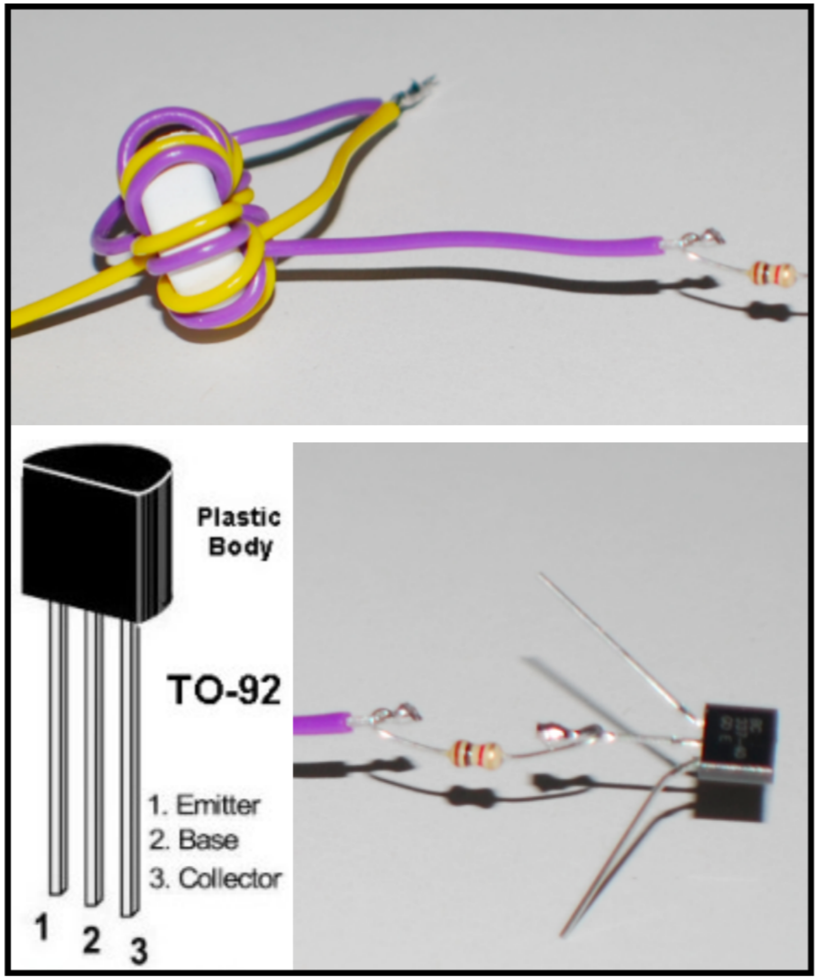
Plastic Body
TO-92
1. Emitter
2. Base
3. Collector
1
2
3

Solder the anode of the LED (the longer leg) to the collector lead of the transistor AND the remaining wire from the inductor.
Cut off the ends of the leads.

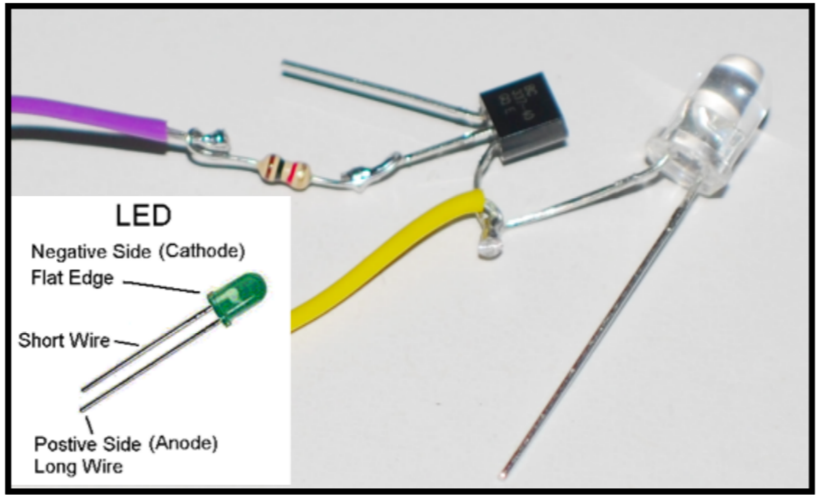
LED
Negative Side (Cathode)
Flat Edge
Short Wire
Postive Side (Anode)
Long Wire

Solder the other leg of the LED (the cathode) to the emitter lead of the transistor.

Do NOT cut off the LED leg.

(Don't wory if you have cut it off - you'll just need to solder another wire to this leg so that you can connect it to the battery.)

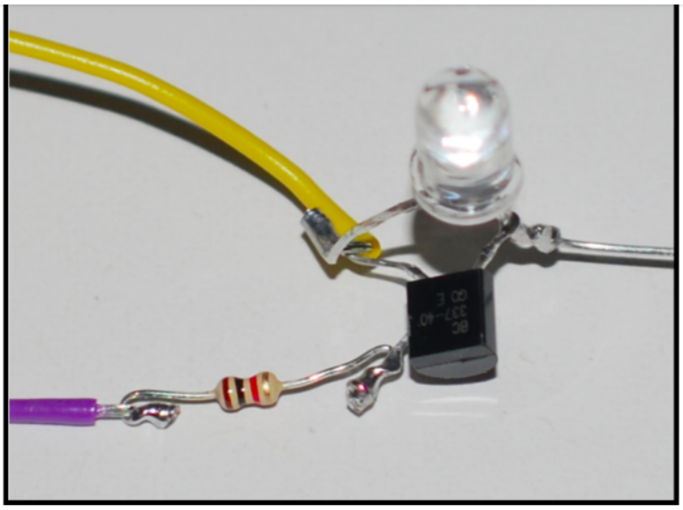

That's the circuit finished. Now use it.

First you need a 'dead' battery - that means one where the voltage is less than 1.3V.

You can see that the battery used here has a Voltage of just over 1V.

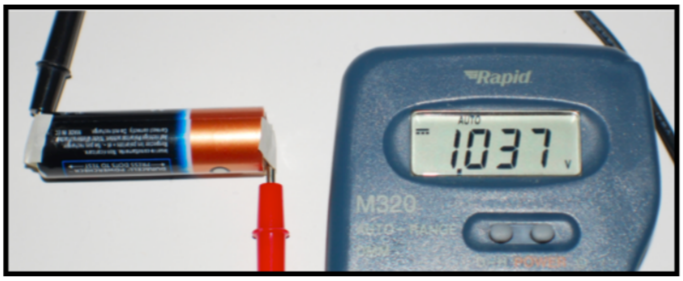
Rapid
1.037
M320
AUTO - RANGE
POWER

Connect the two soldered wires coming from the inductor to the positive (+) side of the battery.

Connect the uncut LED leg (the athode) to the negative (-) side of the battery.

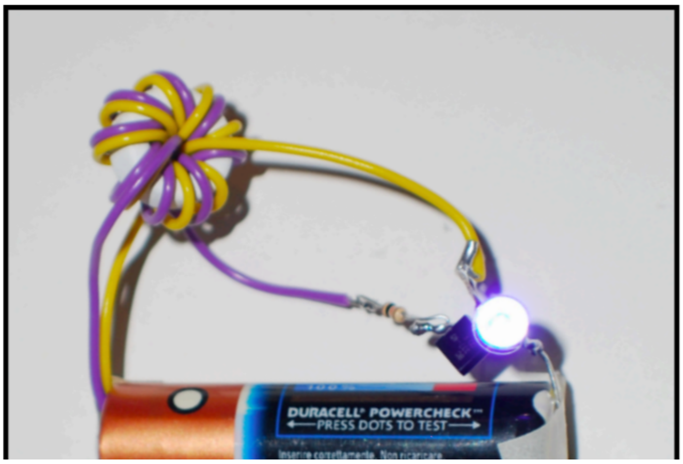
DURACELL POWERCHECK
PRESS DOTS TO TEST

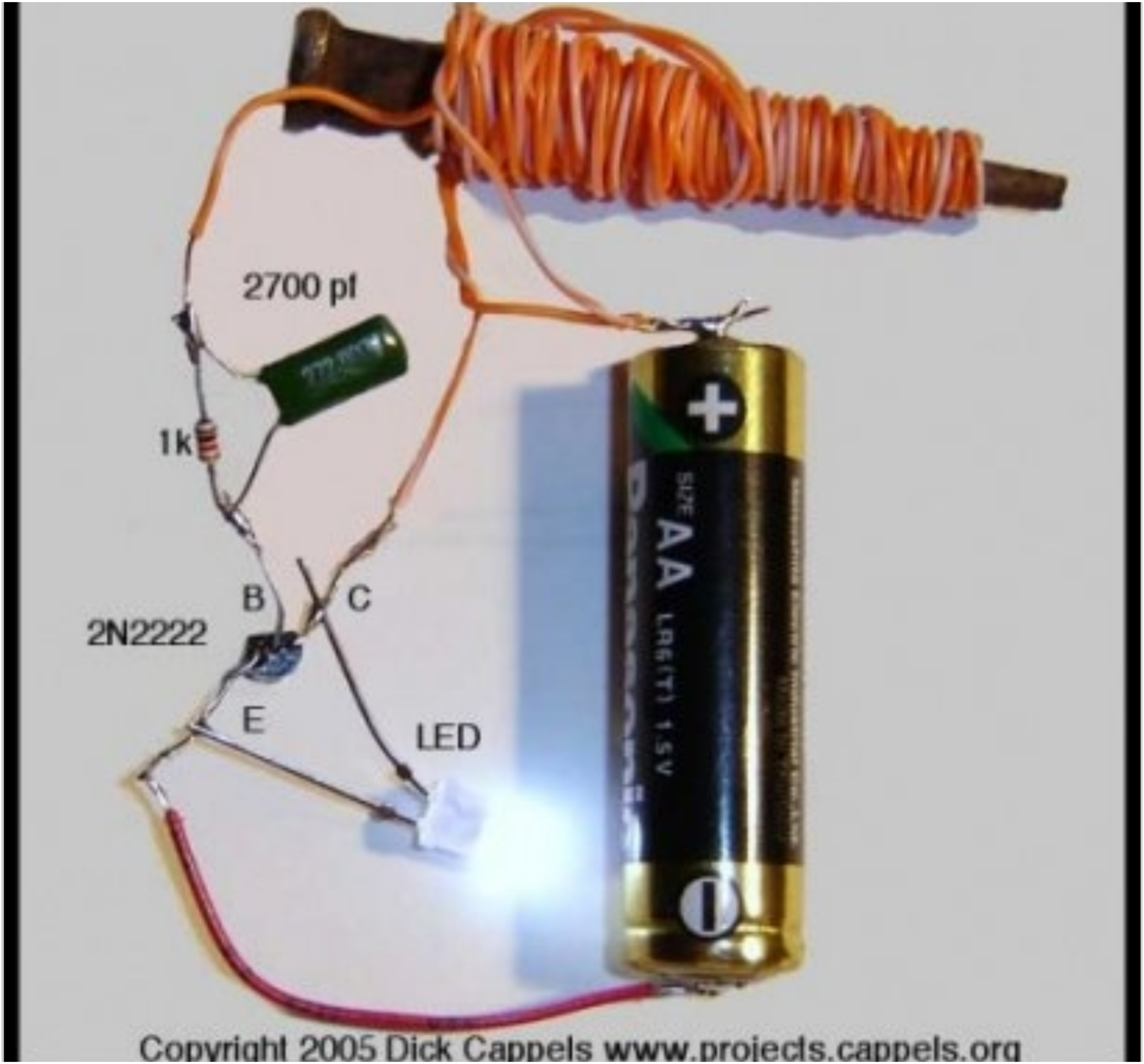
2700 pf
1k
B
C
2N2222
E
LED

Copyright 2005 Dick Cappels www.projects.cappels.org

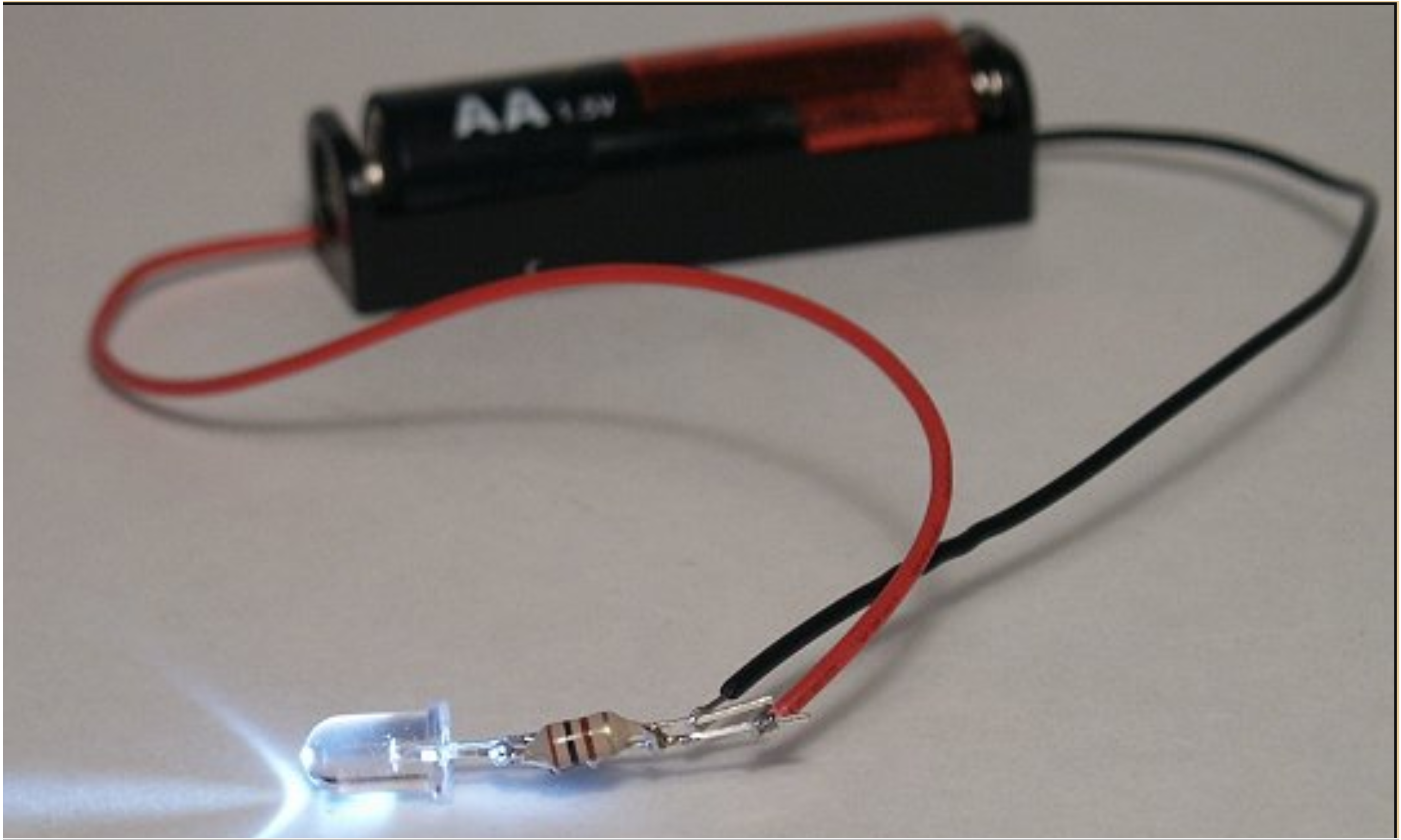
AA 1.5V

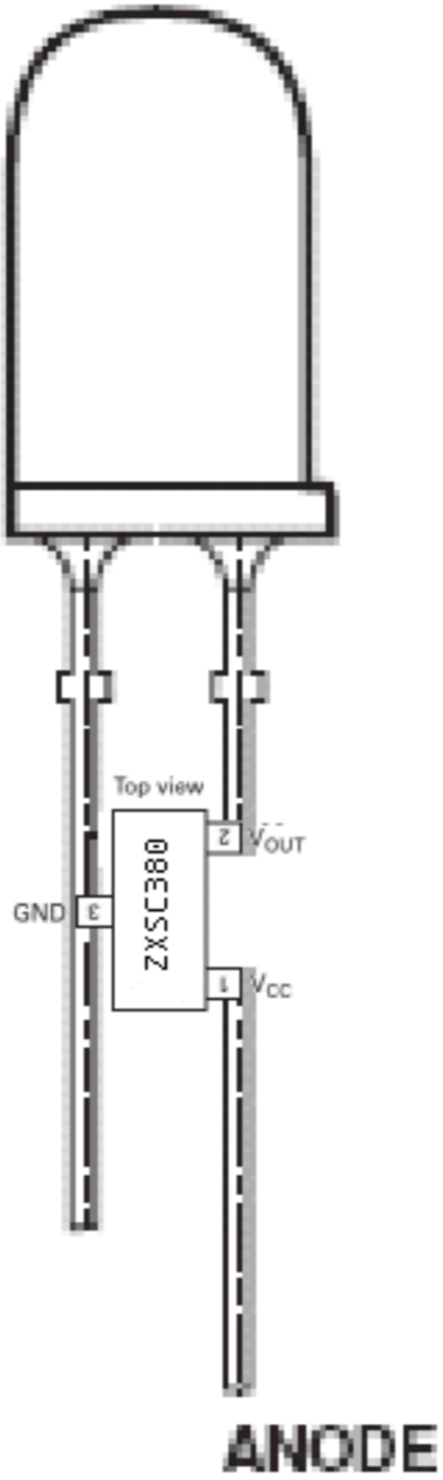

The chip is soldered onto the legs of the LED and then the wire between pins 1 and 2 is cut out so there is no connection. The inductor is then soldered so as to bridge pins 1 and 2. I soldered the inductor on before cutting out the wire but it might be easier to try some other method.

As I said previously, this is a tedious solder job, and the SOT23 IC is easily damaged (ask me how I know!) It takes patience and a steady hand to assemble these few parts.

This circuit would work for the LED indicator in the 1.5v boosters and would most likely be a better choice than the Joule Thief that I posted previously.

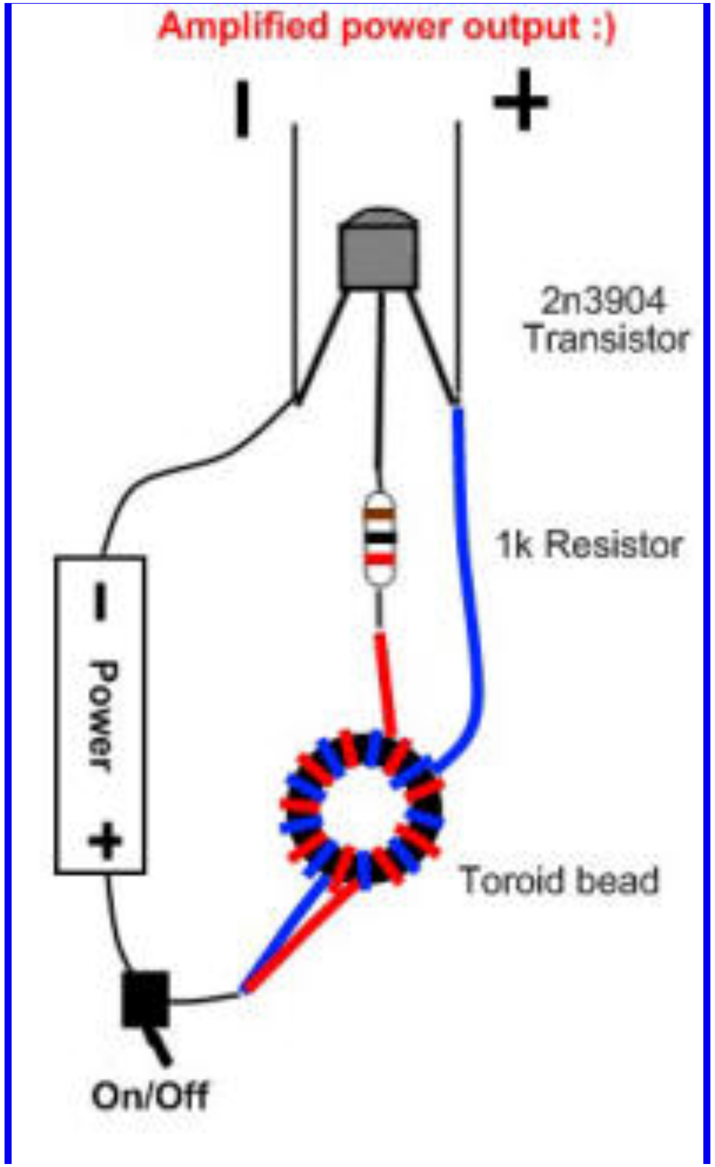
Amplified power output :)
-
+
2n3904
Transistor
1k Resistor
-
Power
+
Toroid bead
On/Off

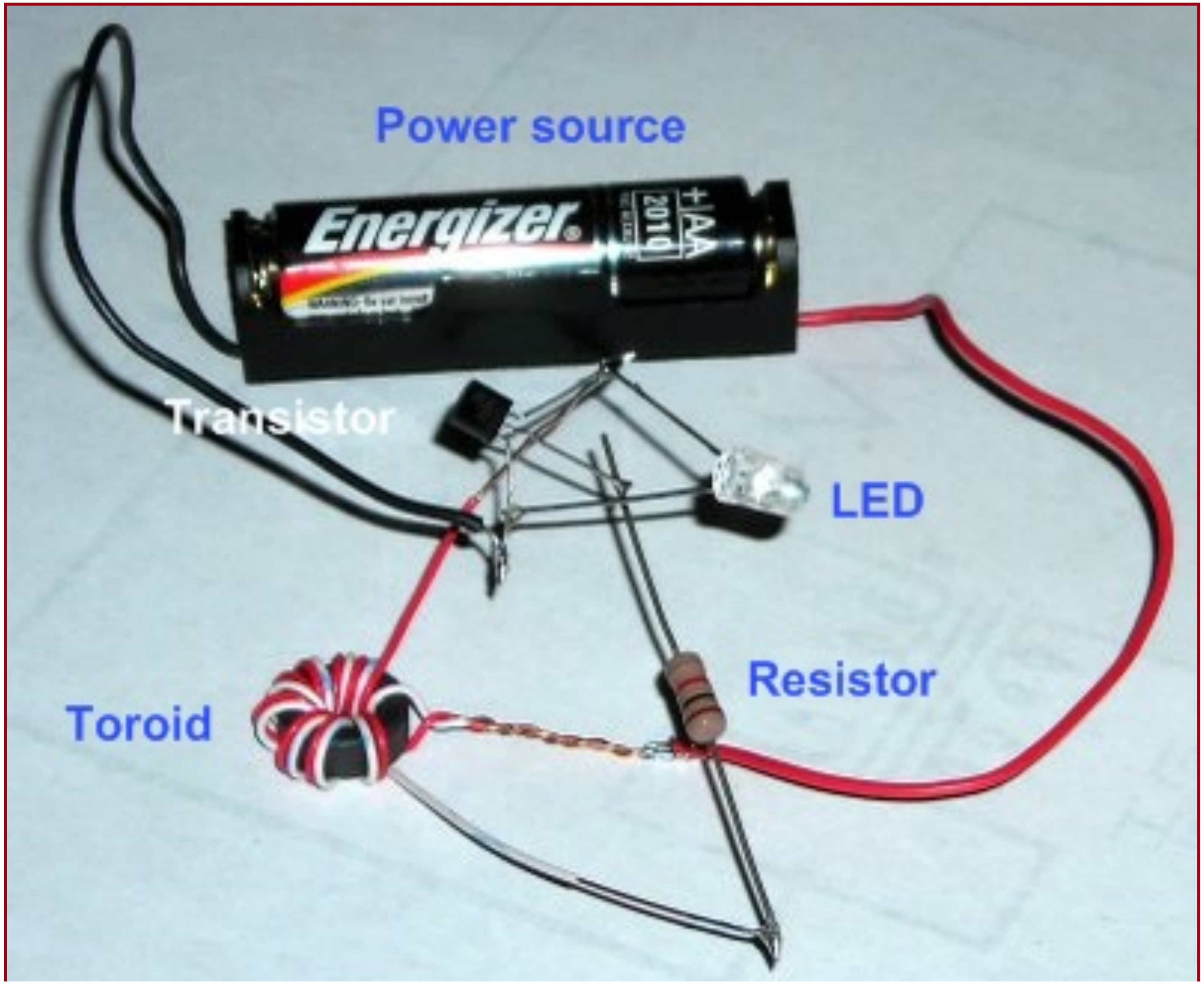
Power source
Energizer
+ AA
2010
Transistor
LED
Resistor
Toroid

The CIRCUIT

The circuit is very simple. All the work is done by the 5252F chip.
It contains an oscillator, a high speed diode and a power transistor. All these components inside the "IC" that looks like a 4-leaded transistor!
This IC is smaller and cheaper than all the parts individually and is less expensive than the competition (that costs 70 cents).
We can produce a complete project for a few dollars and it has two "test features."
You can place a LED across one of the LEDs on the board and find out the colour as many LEDs come in a "clear-as-glass" package and you cannot tell the colour until they are illuminated.
The other feature is INDUCTOR TESTING.
The current taken by the circuit changes according to the value of the inductor.
You just need a few reference values and you can work out the value of an inductor within the range of the inductors you have used as samples, or slightly higher or lower values.

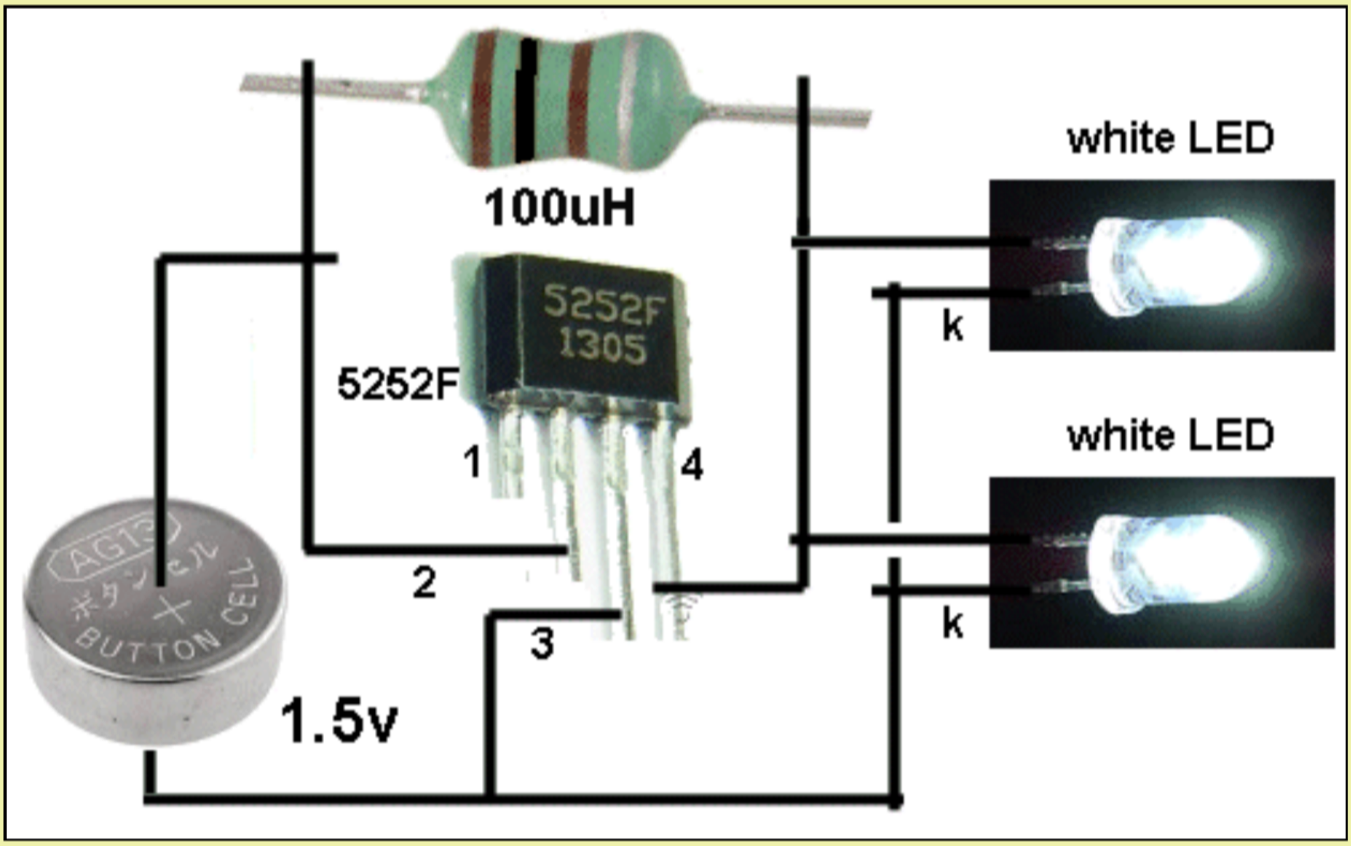

The layout using component pictures.

Using a 220uH, the circuit takes 13mA and illuminates 2 white LEDs very brightly.
Using 100uH the circuit takes 30mA and the LEDs are really the same brightness.
Using 33uH the circuit takes 80mA and the LEDs are just about the same brightness.
Obviously the 220uH creates the most efficient circuit.
The QX5252F is capable of delivering more than 100mA to the LEDs but we only need

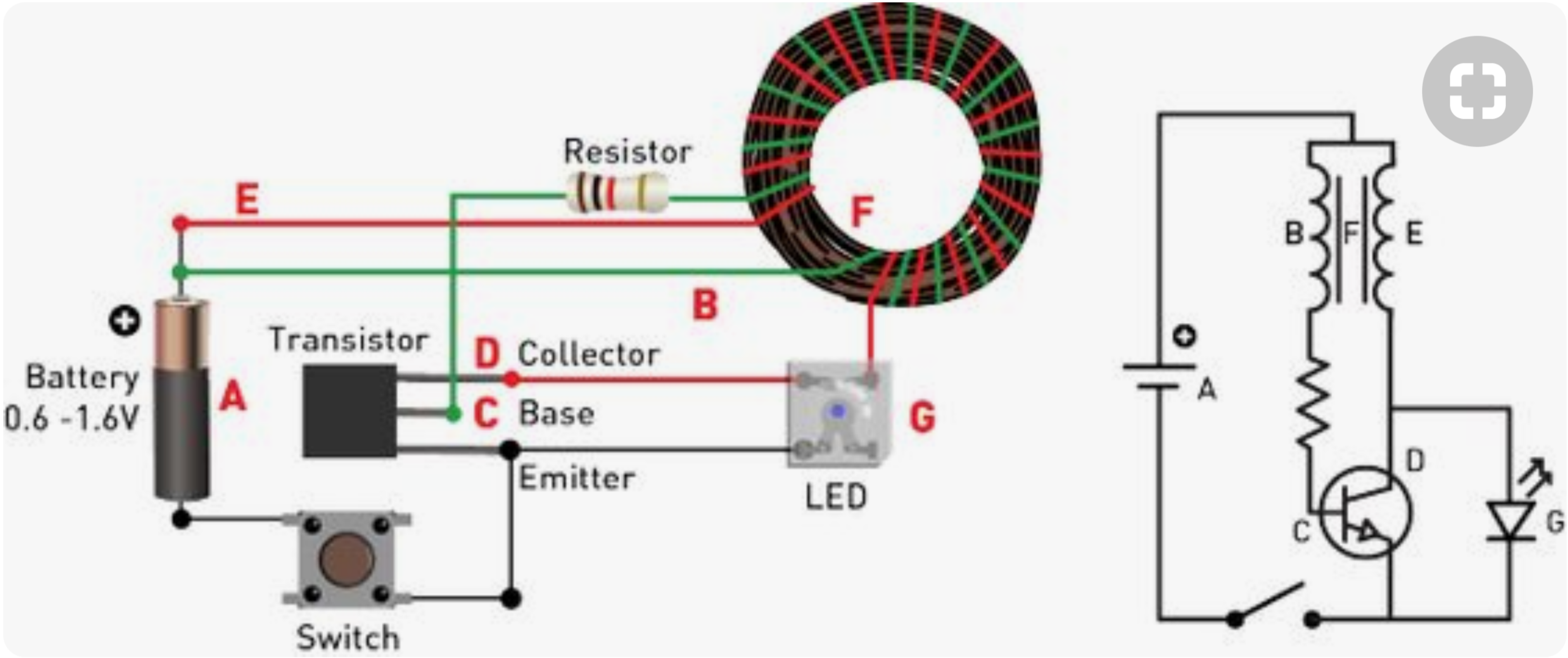
Resistor
E
F
B
⊕
Battery
0.6 -1.6V
A
Transistor
D Collector
C Base
Emitter
G
LED
Switch
⊕
A
B
F
E
D
C
G

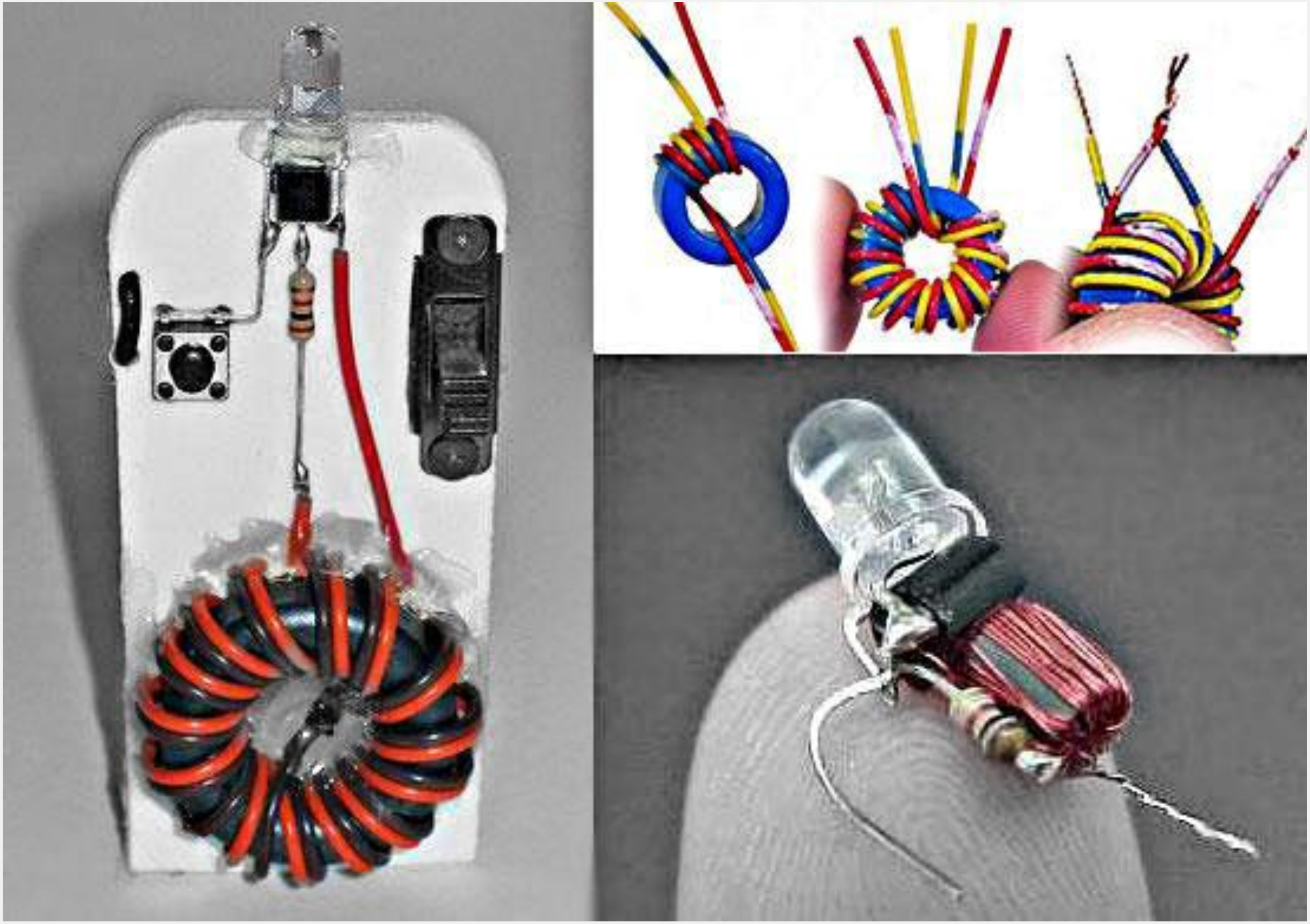

Watson's 2 Transistor "Joule Thief" V. Booster

Uses 2N3904 for output. Coil is 180 microhenry,
2.5 ohm RF choke (green blob)

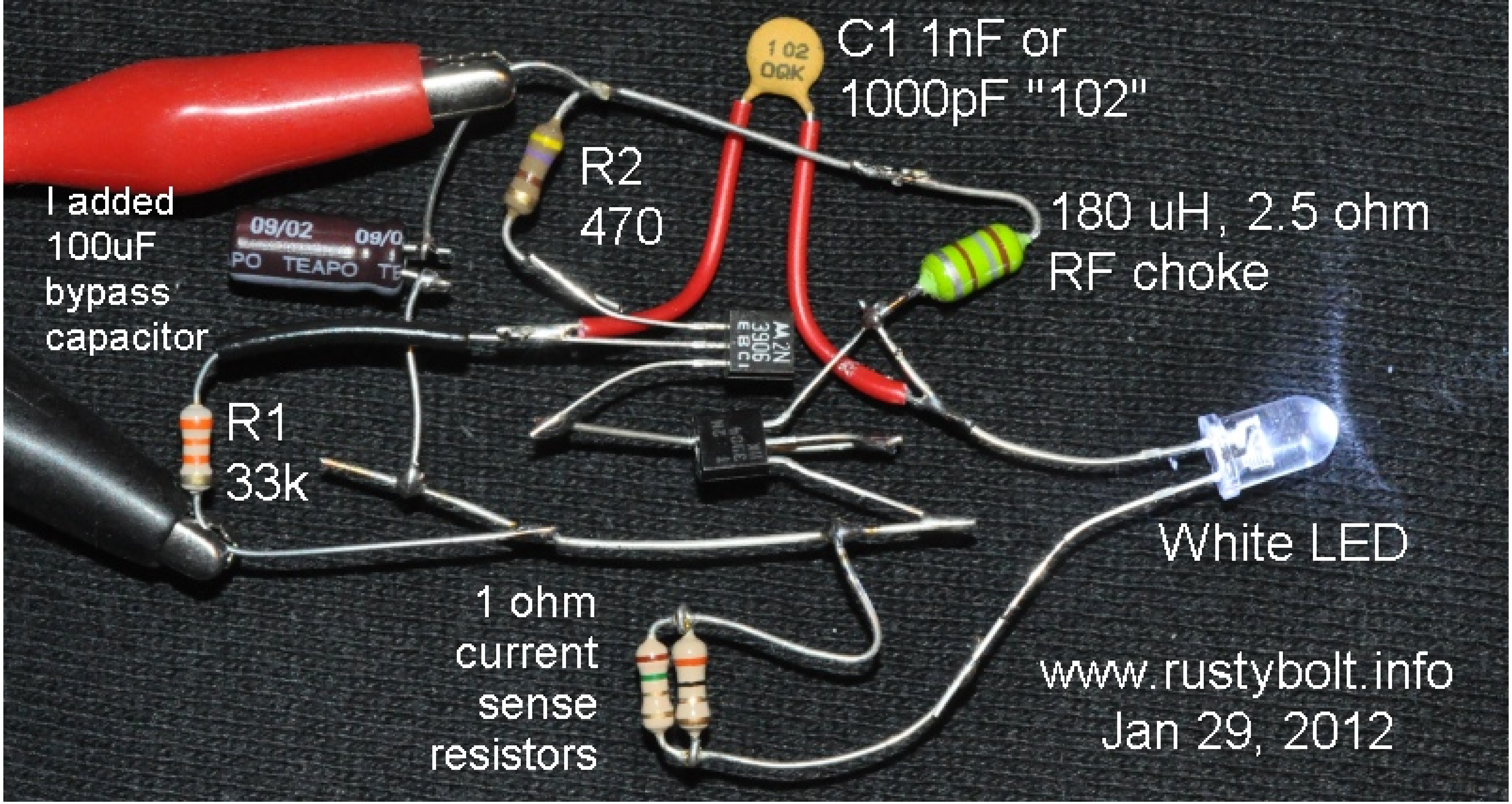
C1 1nF or 1000pF "102"
R2 470
180 uH, 2.5 ohm RF choke
I added 100uF bypass capacitor
R1 33k
1 ohm current sense resistors
White LED
102
09/02 TEAPO
2N 3906 EBC

www.rustybolt.info
Jan 29, 2012

Watson's Version of "1.5v Joule Thief -Blinks Led"

Taken from http://www.youtube.com/watch?v=GVP2QGpk5KE Nov 14, 2012

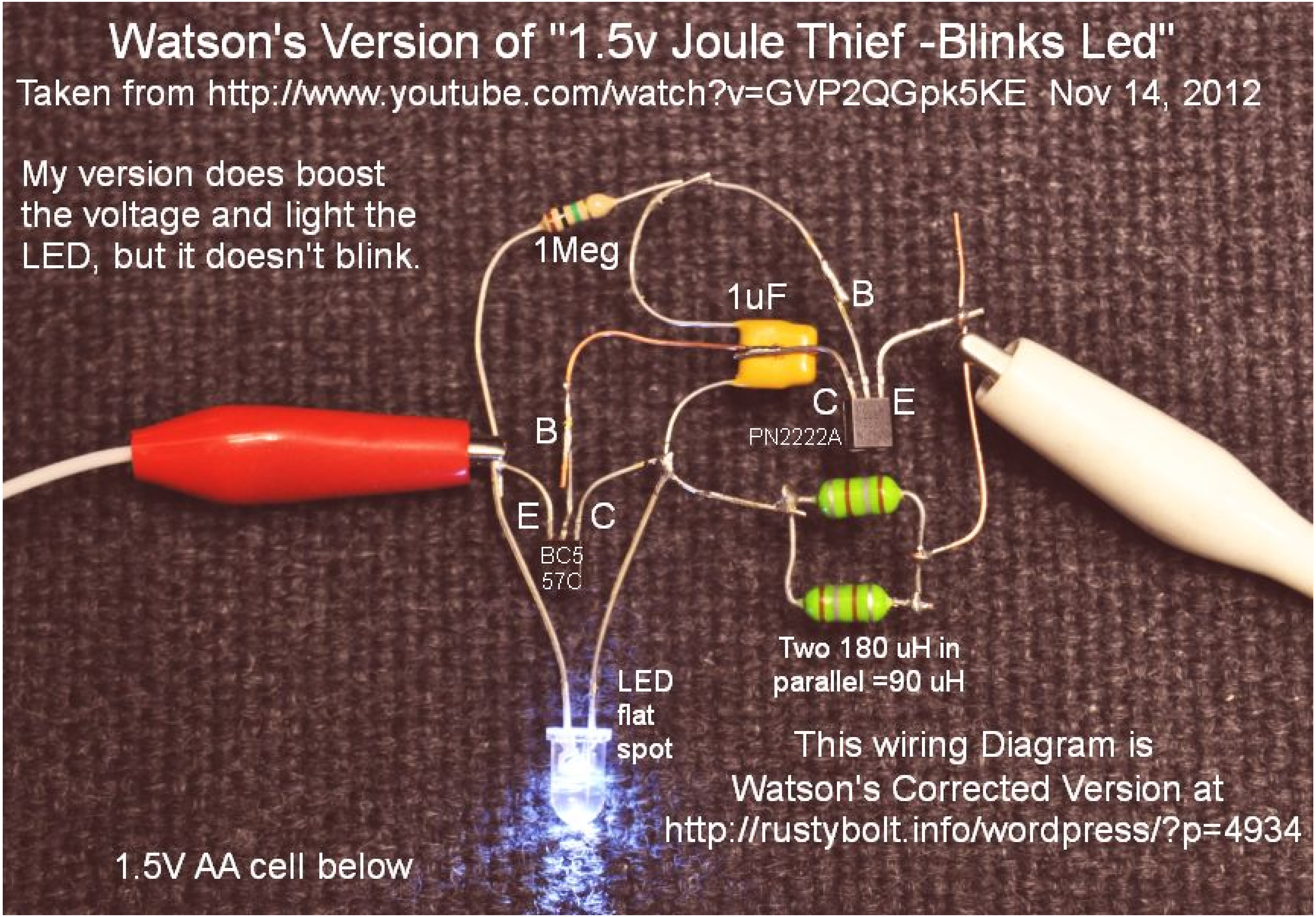

My version does boost the voltage and light the LED, but it doesn't blink.

This wiring Diagram is Watson's Corrected Version at http://rustybolt.info/wordpress/?p=4934

1.5V AA cell below

1Meg
1uF
B
C
E
PN2222A
B
E
C
BC5
57C
LED
flat
spot
Two 180 uH in
parallel =90 uH

Watson's Joule Thief Pictorial Diagram

http://rustybolt.info/wordpress/?p=128 2011 Dec 07

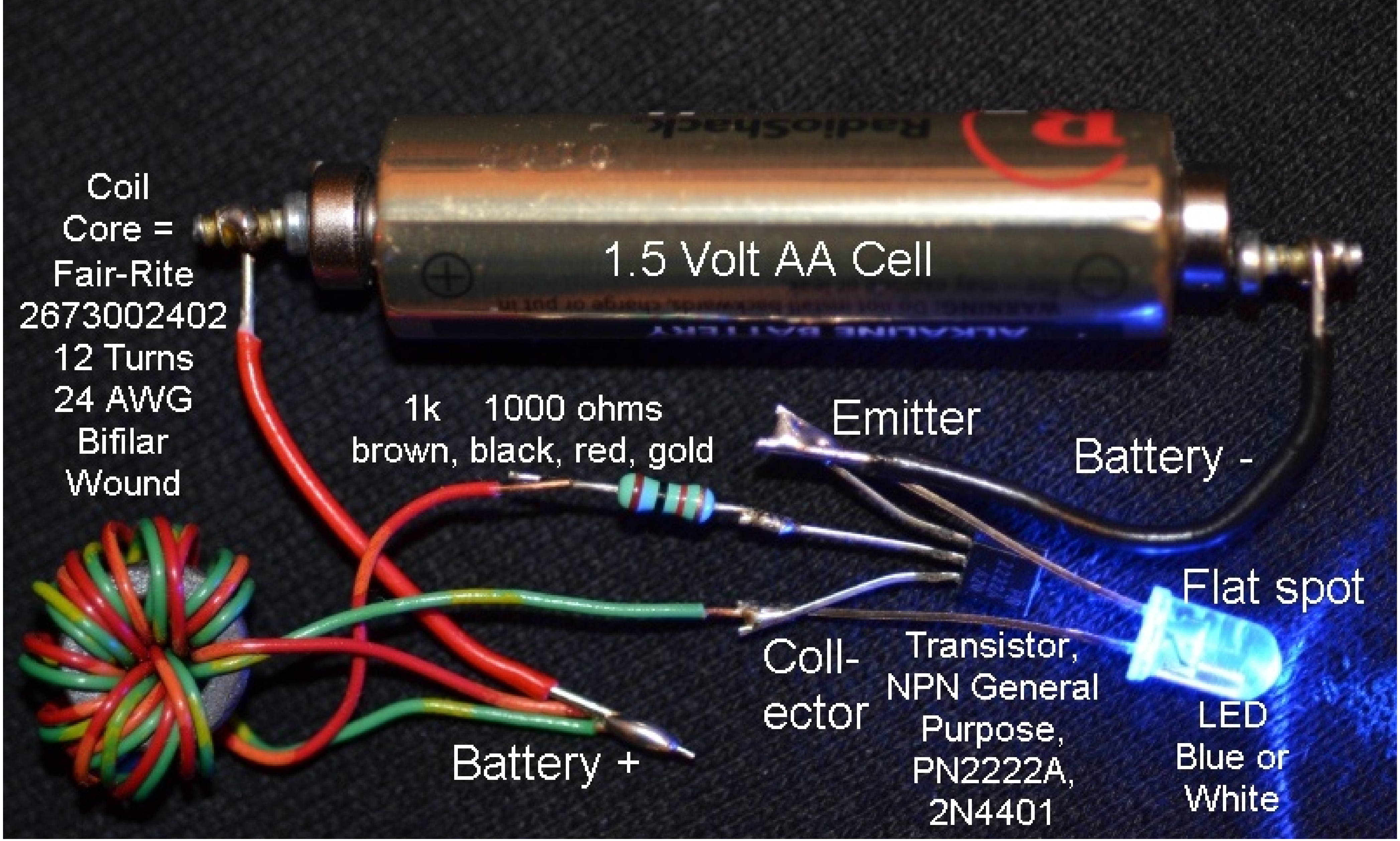
Coil
Core =
Fair-Rite
2673002402
12 Turns
24 AWG
Bifilar
Wound
1.5 Volt AA Cell
1k 1000 ohms
brown, black, red, gold
Emitter
Battery -
Flat spot
Coll-
ector
Transistor,
NPN General
Purpose,
PN2222A,
2N4401
LED
Blue or
White
Battery +

Joule Thief

Pictorial Wiring Diagram Dec 11, 2009

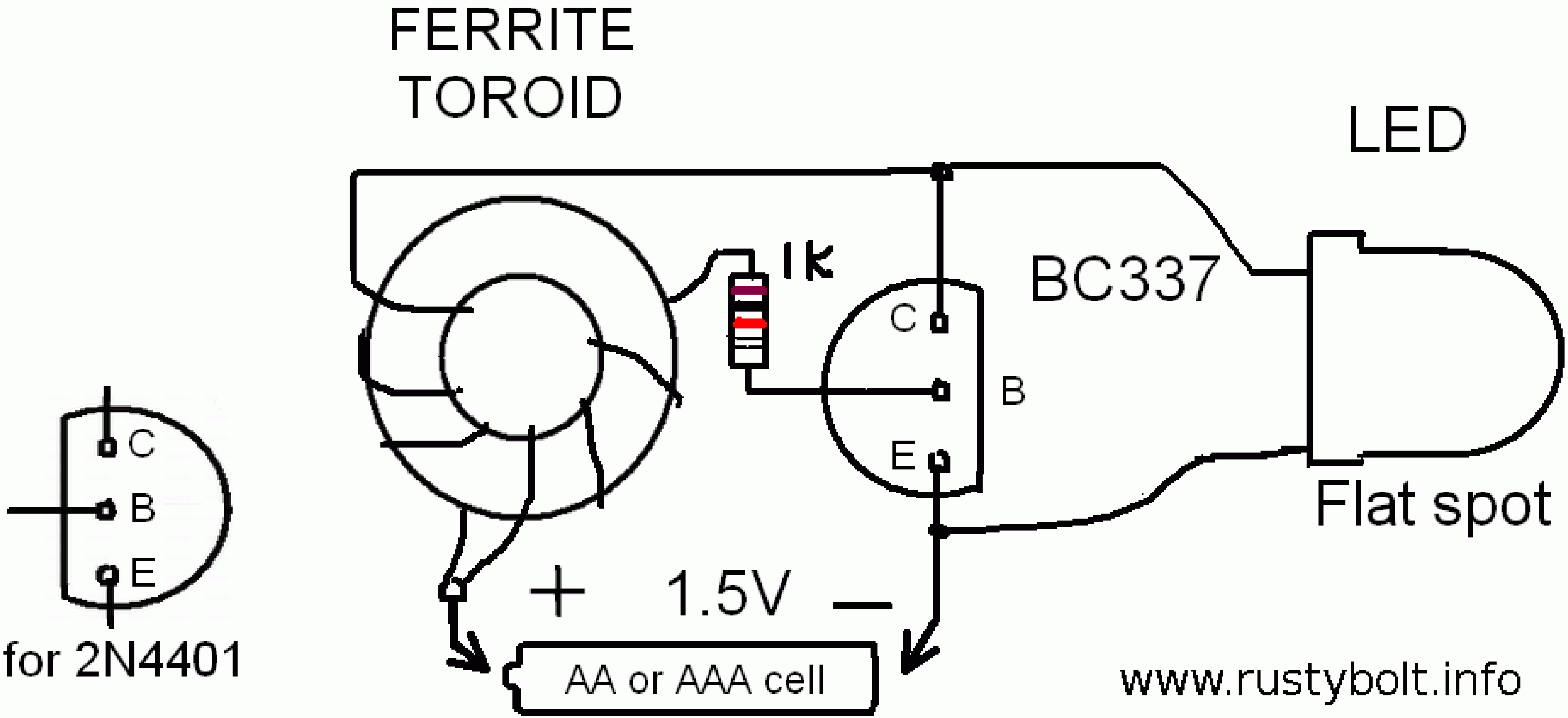
FERRITE
TOROID
1K
C
B
E
BC337
LED
Flat spot
+
1.5V
—
AA or AAA cell
C
B
E
for 2N4401

www.rustybolt.info

Watson's True 2N2222 Joule Thief

Oct 31, 2010 Boo!

Not very good performance from an expensive transistor

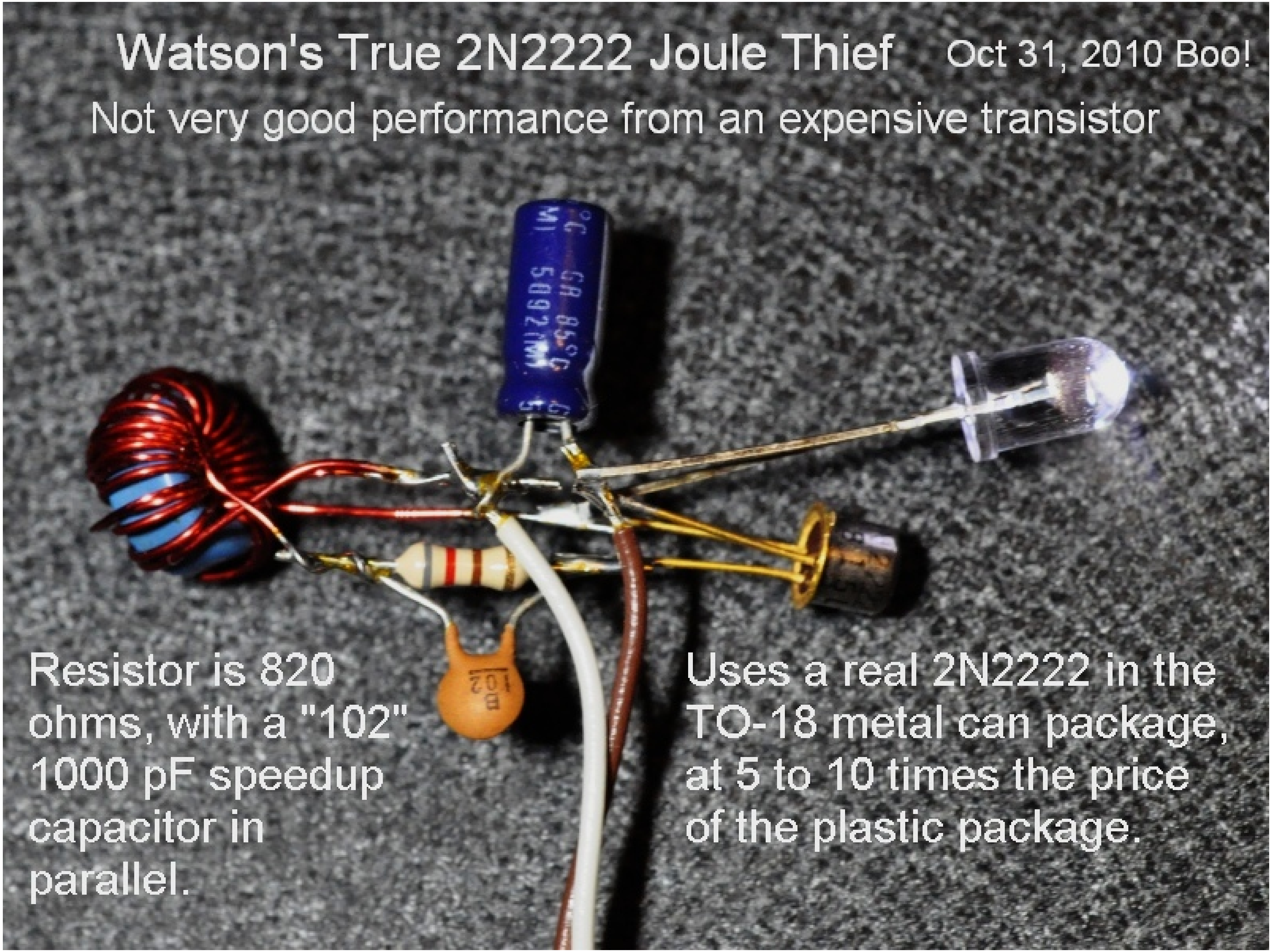

Resistor is 820 ohms, with a "102" 1000 pF speedup capacitor in parallel.

Uses a real 2N2222 in the TO-18 metal can package, at 5 to 10 times the price of the plastic package.

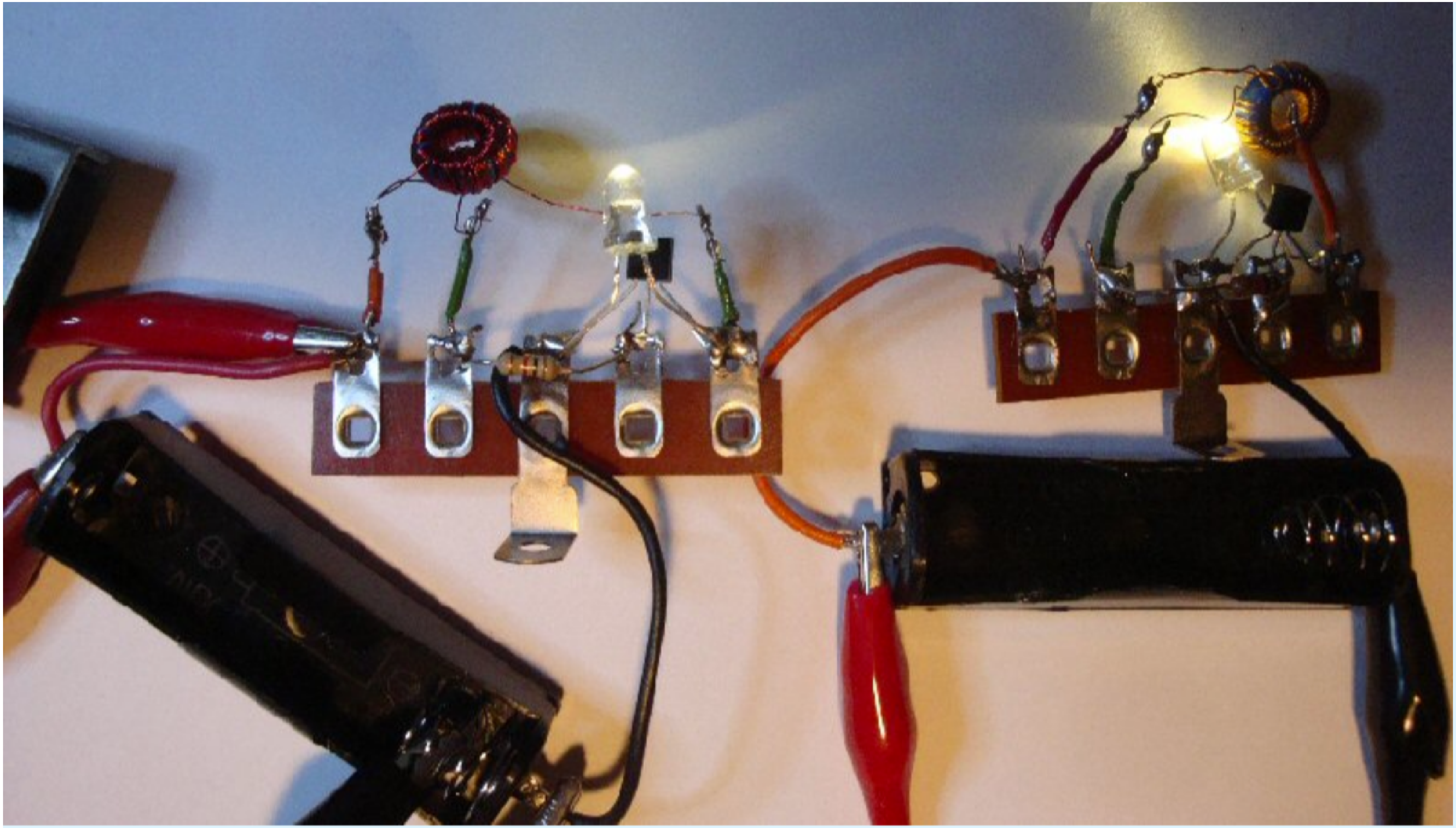

Watson's Tiny Toroid Conventional Joule Thief - Nov 18, 2009 Not much bigger than the transistor!

www.rustybolt.info

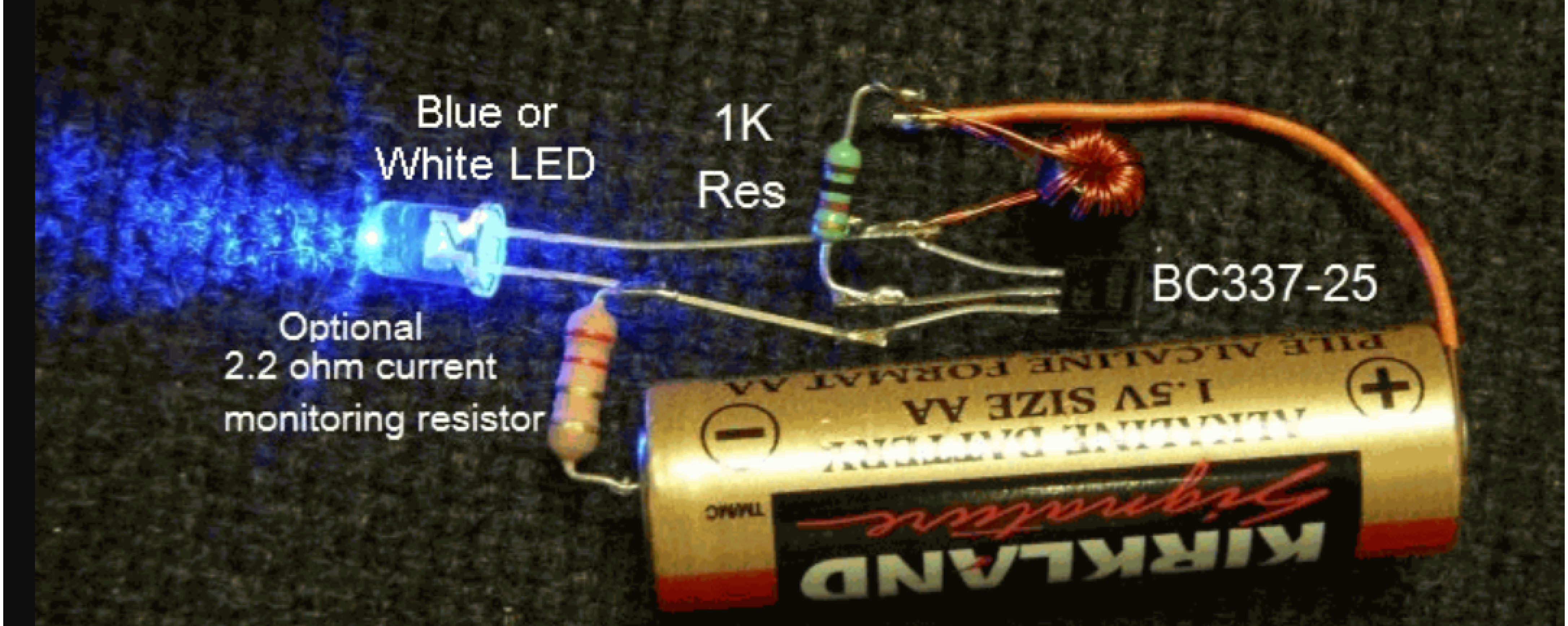
Blue or
White LED
1K
Res
BC337-25
Optional
2.2 ohm current
monitoring resistor
PILE ALCALINE FORMAT AA
1.5V SIZE AA
ALKALINE BATTERY
KIRKLAND Signature

Three windings 30 AWG, each about 6 inches long, trifilar wound on 0.229 inch O.D. toroid, 2 in parallel for main winding.

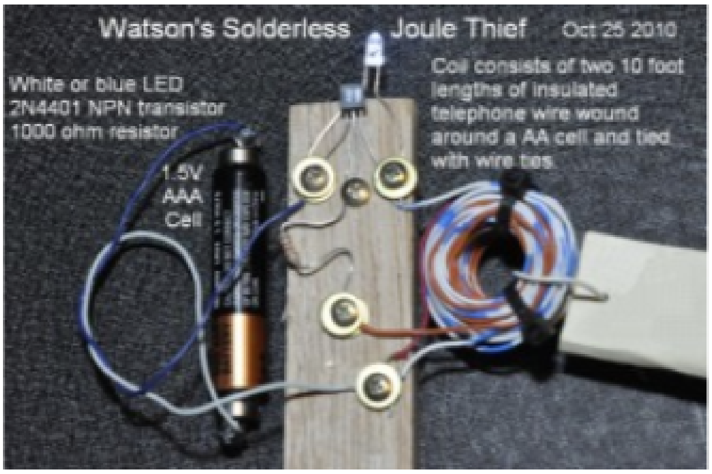
Watson's Solderless Joule Thief
Oct 25 2010
White or blue LED
2N4401 NPN transistor
1000 ohm resistor
1.5V
AAA
Cell
Coil consists of two 10 foot lengths of insulated telephone wire wound around a AA cell and tied with wire ties.

I took this photo just before Halloween back in 2010, after I made this Joule Thief without solder and without a toroid. It shows that you don't have to know how to solder and you don't have to have a toroid to make a working Joule Thief – all you need is a screwdriver. So do your thing and experiment a bit, and see what you can come up with.

Each screw (except for one) has two washers to hold the wires. Putting two or more wires under the screw head without the washers will be difficult and the wires will try to come loose. Two or three washers makes it easier and the wires are held much firmer. The wood block is a piece of solid oak that is about a half inch (12mm) thick. The oak is very hard and the screw holes have to be drilled out before the screws are put in. This also makes it possible to use small screws with a flat end which were used for holding plastic parts together. The screw size is about #3 by 3/8 inch long, with coarse threads like a sheet metal screw.

The LED is not very bright because it's a cheap 3 mm white LED I got from an eBay seller, and it has been used a bit so it has dimmed. Use a decent LED and this circuit will be as bright as a toroid JT.

Watson's Solderless Joule Thief

Another Joule Thief I put together is shown in the second photo. This uses the bare wires to wrap around the joints in place of solder. The joints are not as mechanically strong as solder but for a quick experiment they should work okay. If the JT is going to be used, the wire joints may become intermittent or loose. The solder joints are a much better connection.

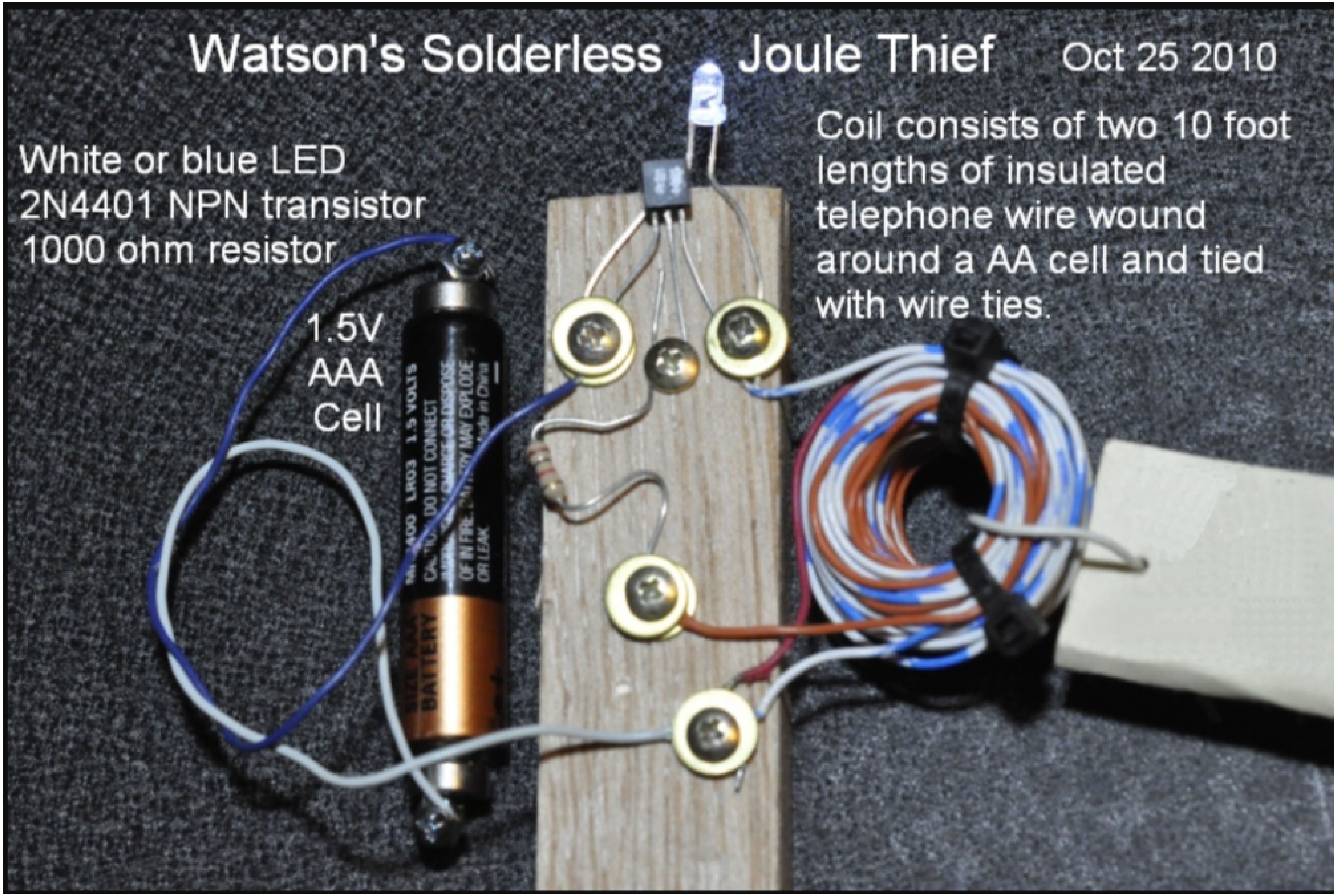

Watson's Solderless Joule Thief Oct 25 2010

White or blue LED
2N4401 NPN transistor
1000 ohm resistor

1.5V
AAA
Cell

Coil consists of two 10 foot lengths of insulated telephone wire wound around a AA cell and tied with wire ties.

Watson's 'Toroid Free' Air Core Joule Thief

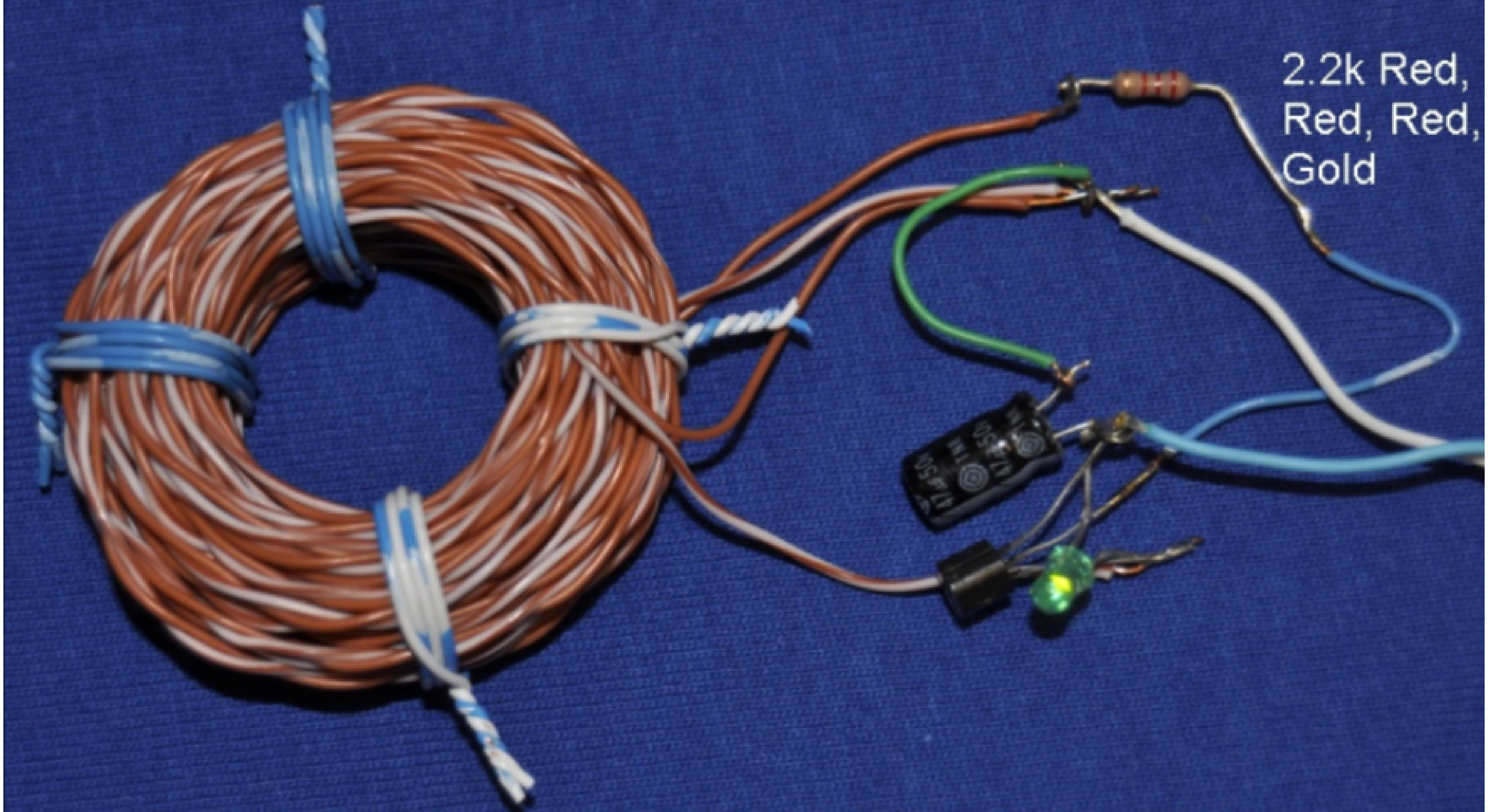
2.2k Red, Red, Red, Gold

rustybolt.info/wordpress/?p=2872 May 21, 2012

Watson's Nearly Disposable Joule Thief Light

rustybolt.info/wordpress/?p=2133 Fri. Apr 13 2012

Completed circuit ready for coating of silicone sealant. Transistor is a BC337. If it was a PN2222A or 2N4401, the flat side would be facing up.

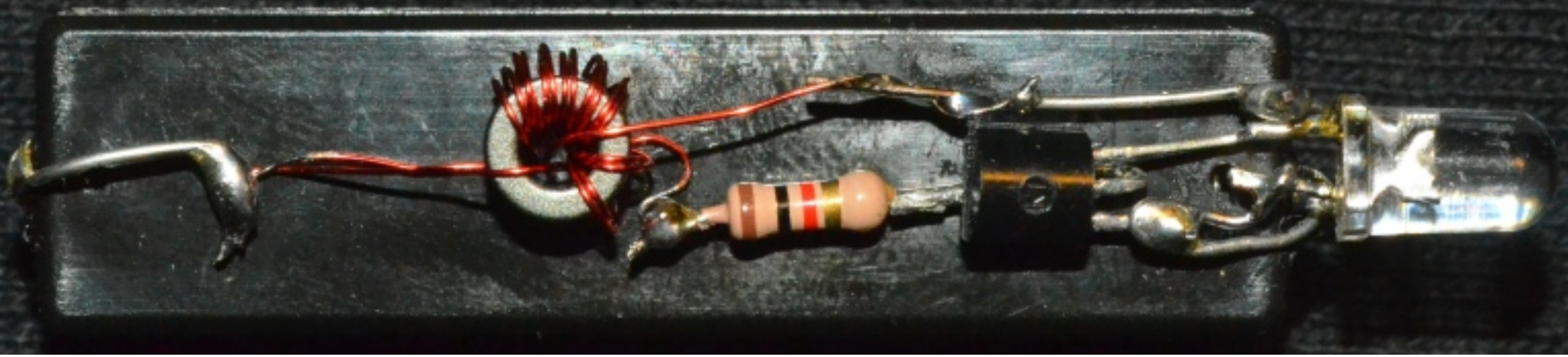

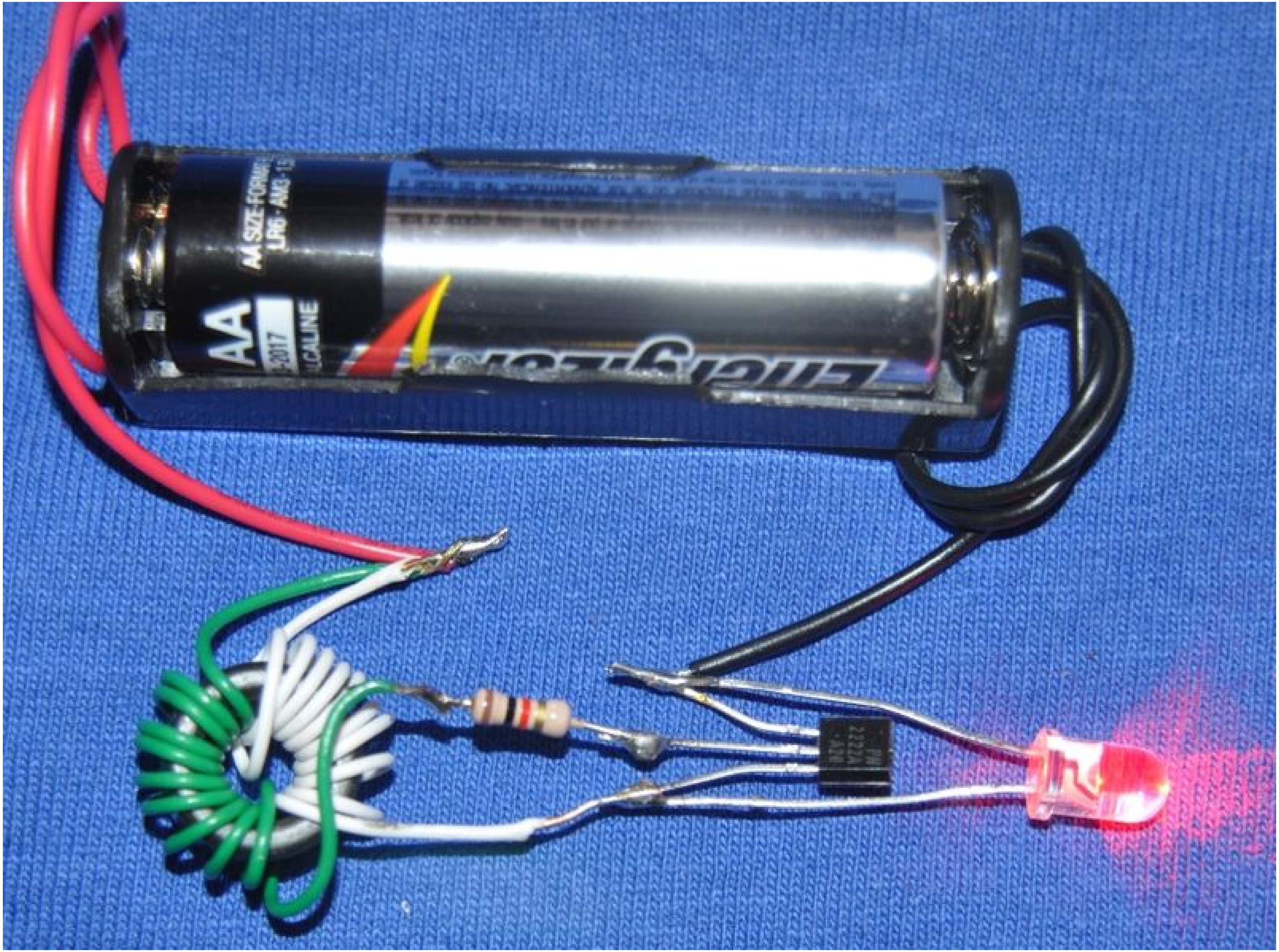
AA
AA SIZE·FORMAT
LR6 · AM3
ALKALINE
Energizer
PN
2222A

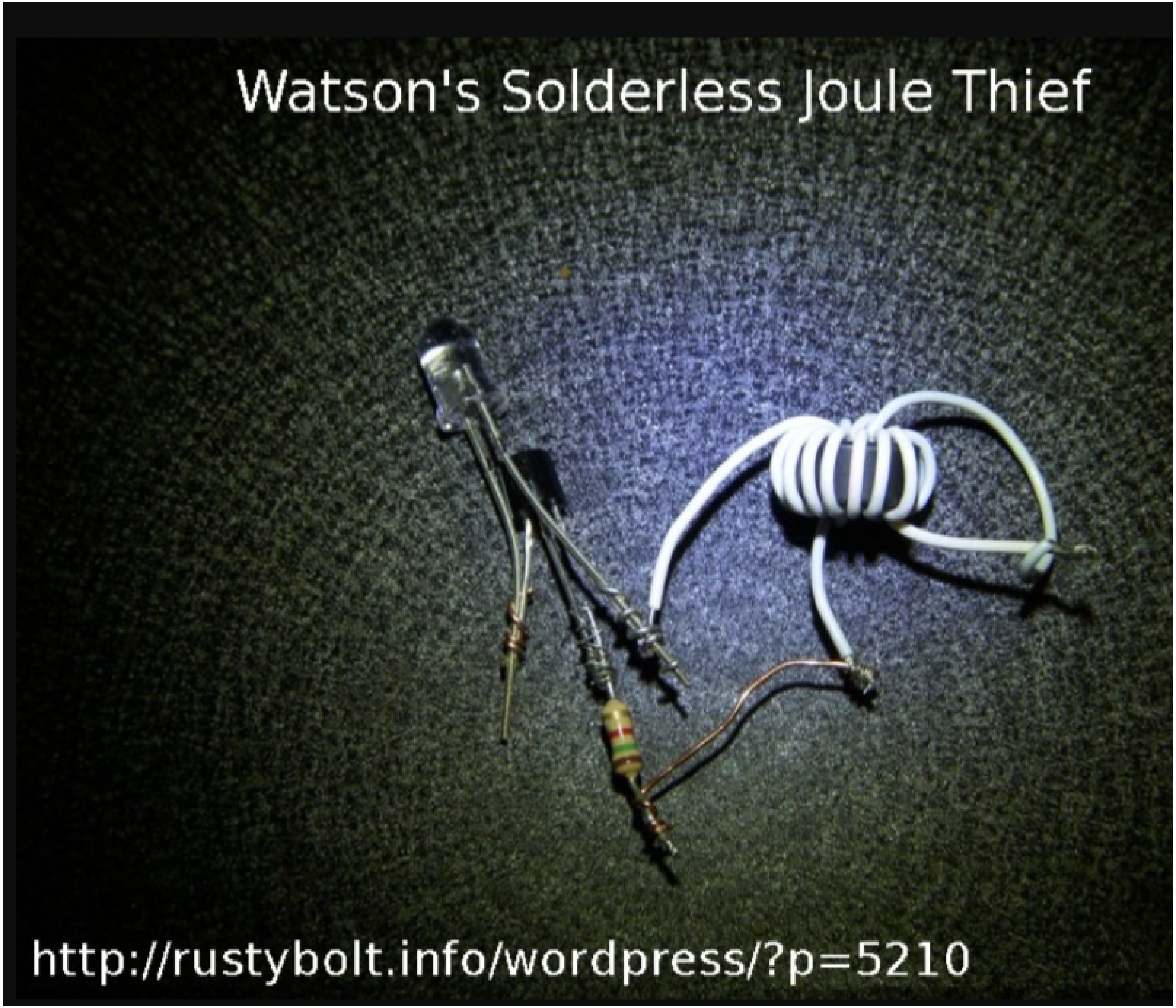

Watson's Solderless Joule Thief

http://rustybolt.info/wordpress/?p=5210

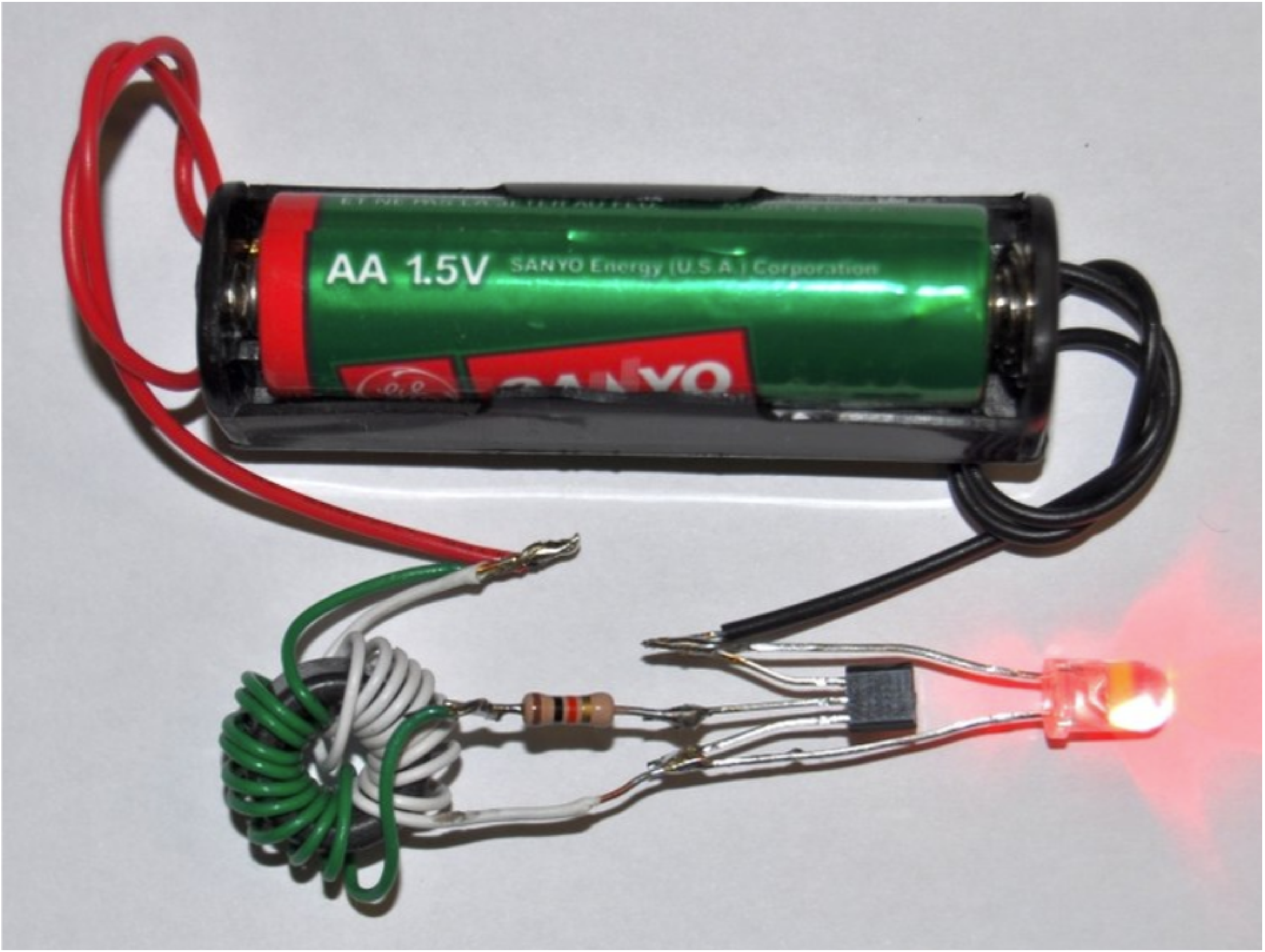
AA 1.5V
SANYO Energy (U.S.A.) Corporation
SANYO

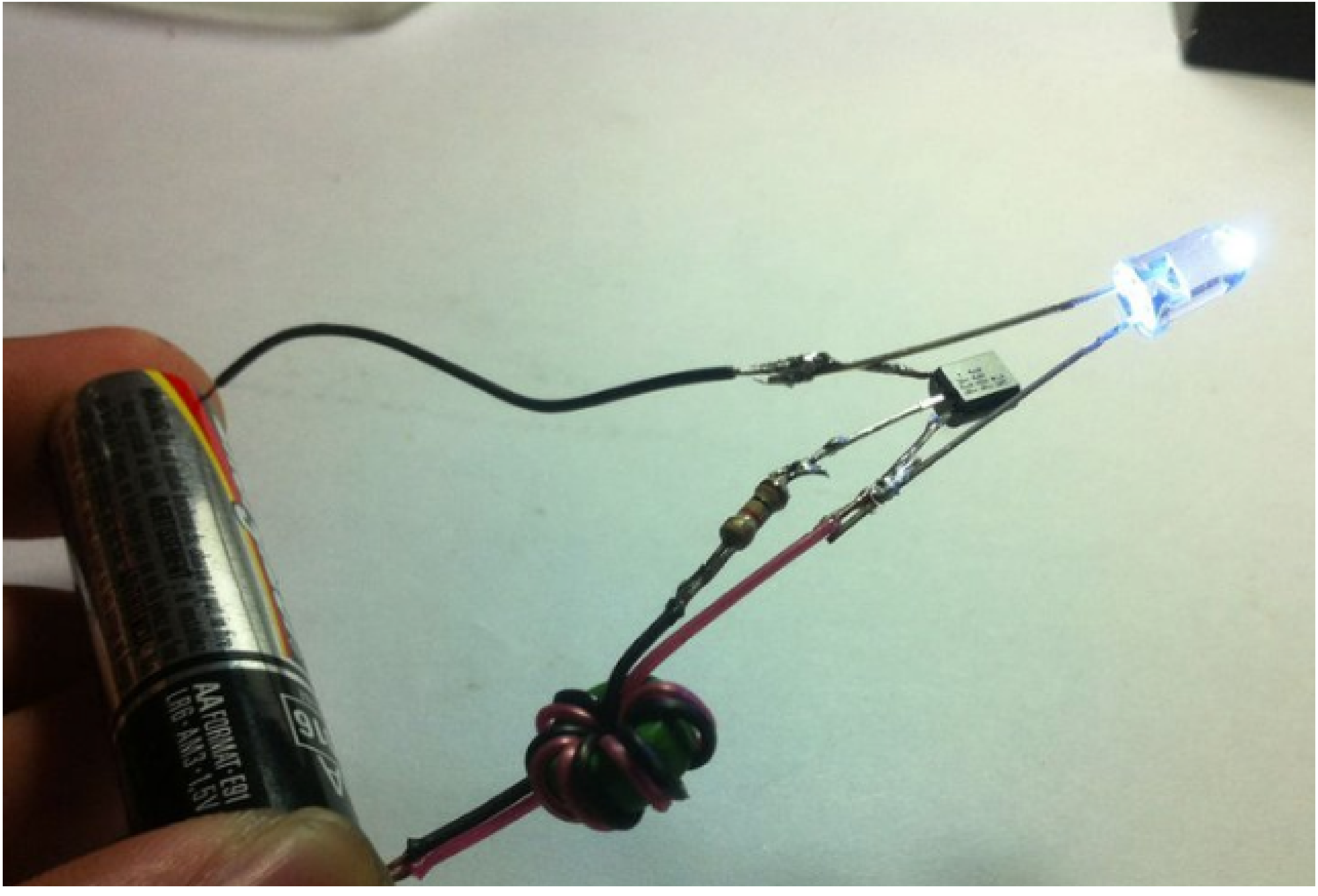
AA FORMAT · E91
LR6 · AM3 · 1.5V

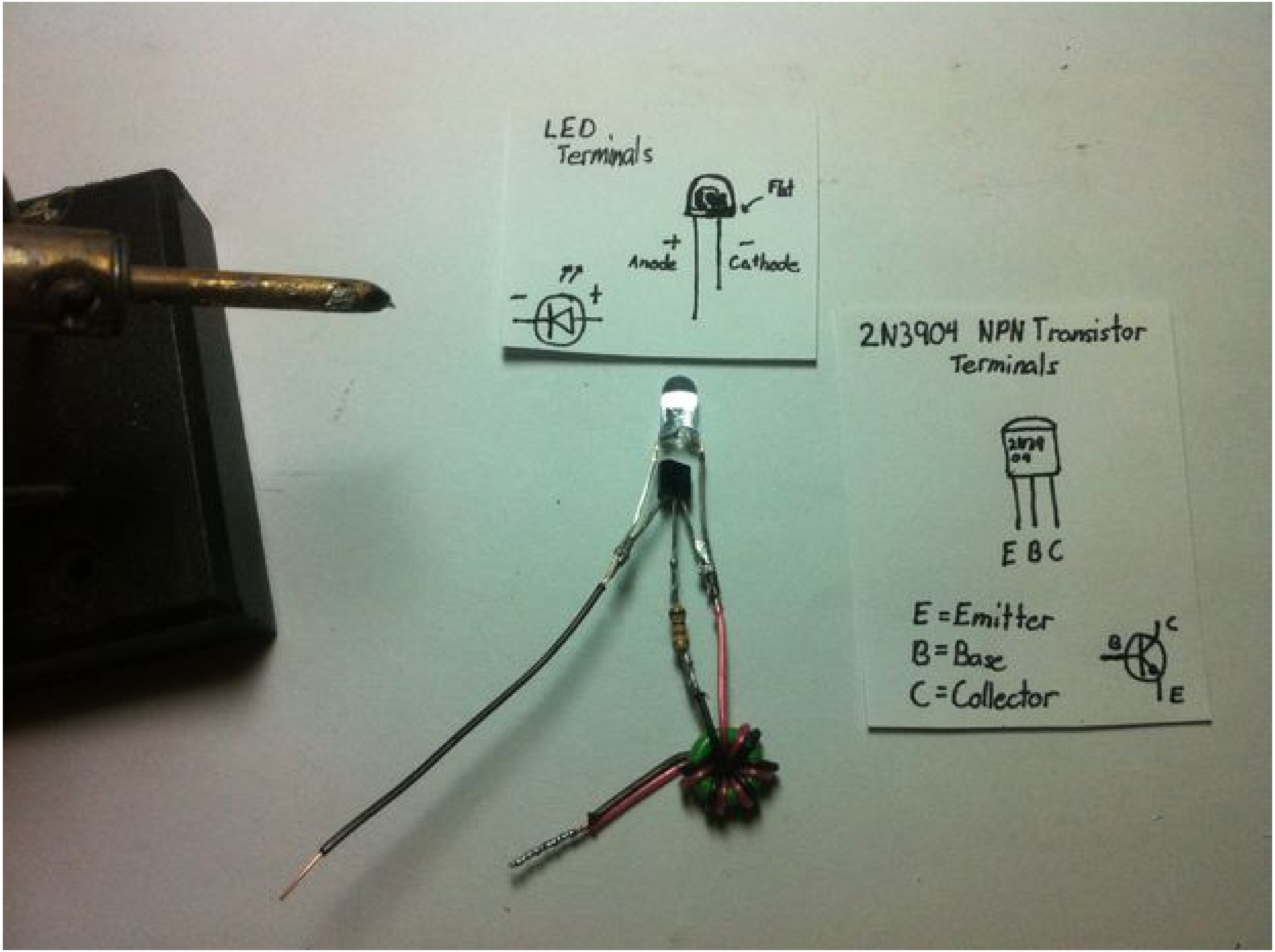
LED Terminals
Flat
+
Anode
−
Cathode
−
+
2N3904 NPN Transistor Terminals
2N39 04
E B C
E = Emitter
B = Base
C = Collector
B
C
E

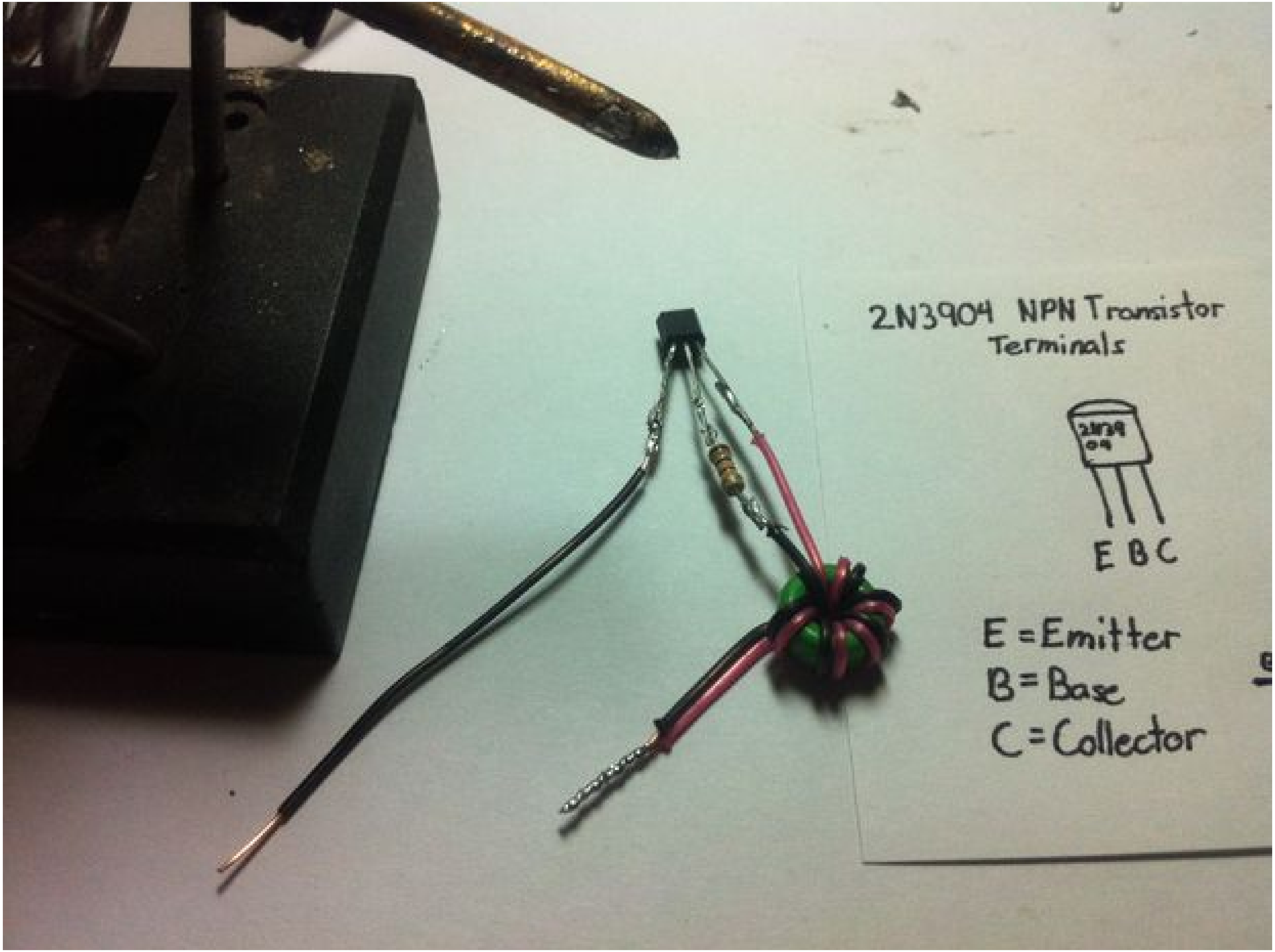
2N3904 NPN Transistor
Terminals
2N39
04
E B C
E = Emitter
B = Base
C = Collector

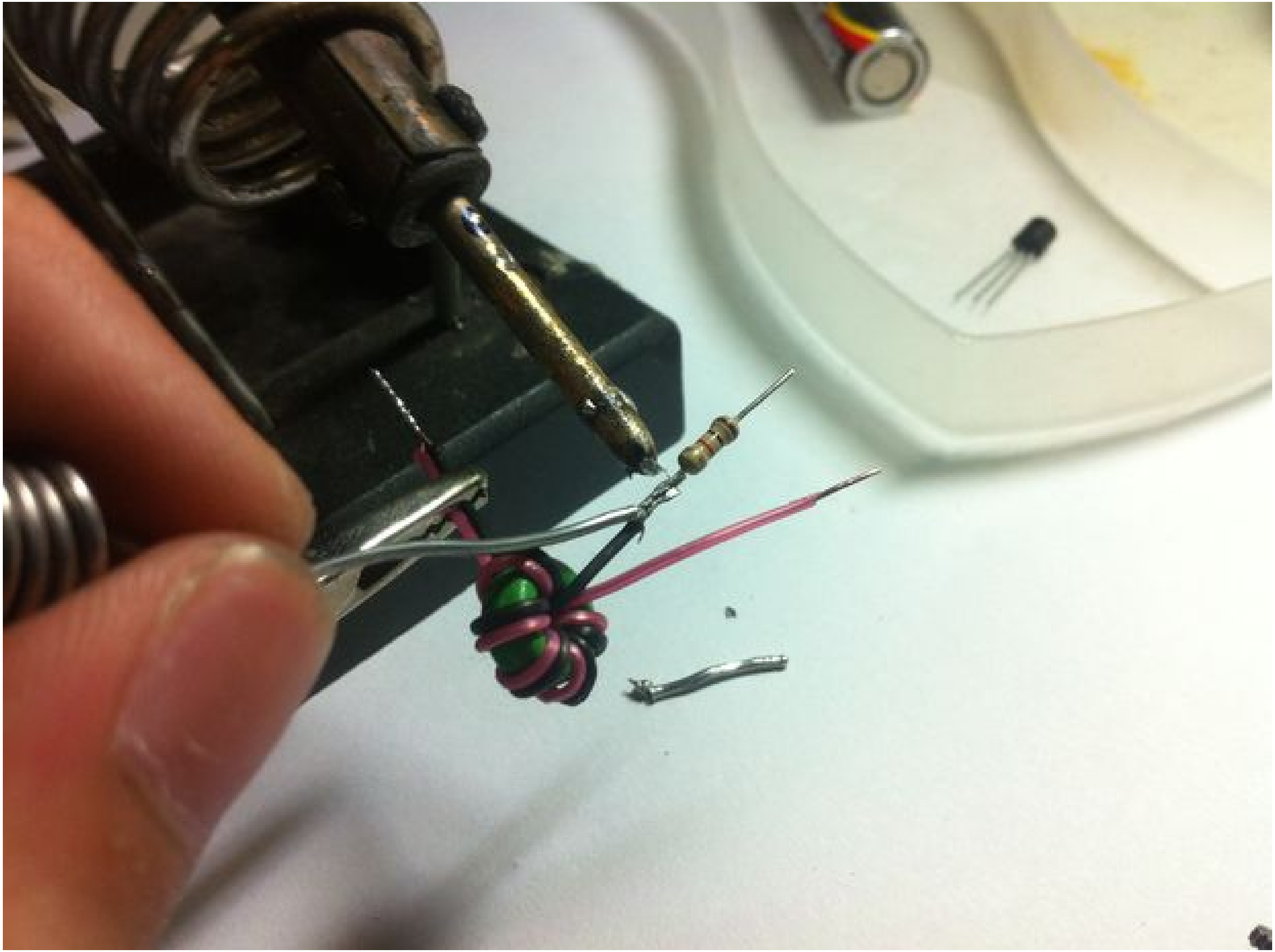

Transistor Terminals

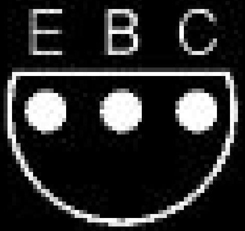

2N3904
(NPN Transistor)

LED Terminals

Negative Side (Cathode)
Flat Edge

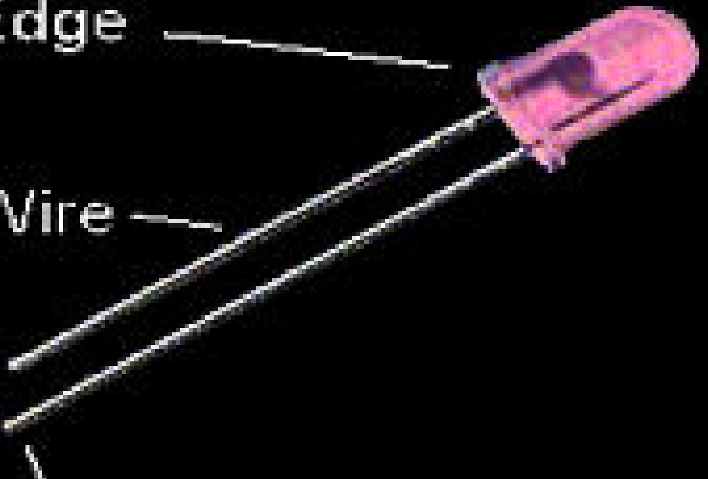

Short Wire

Postive Side (Anode)
Long Wire

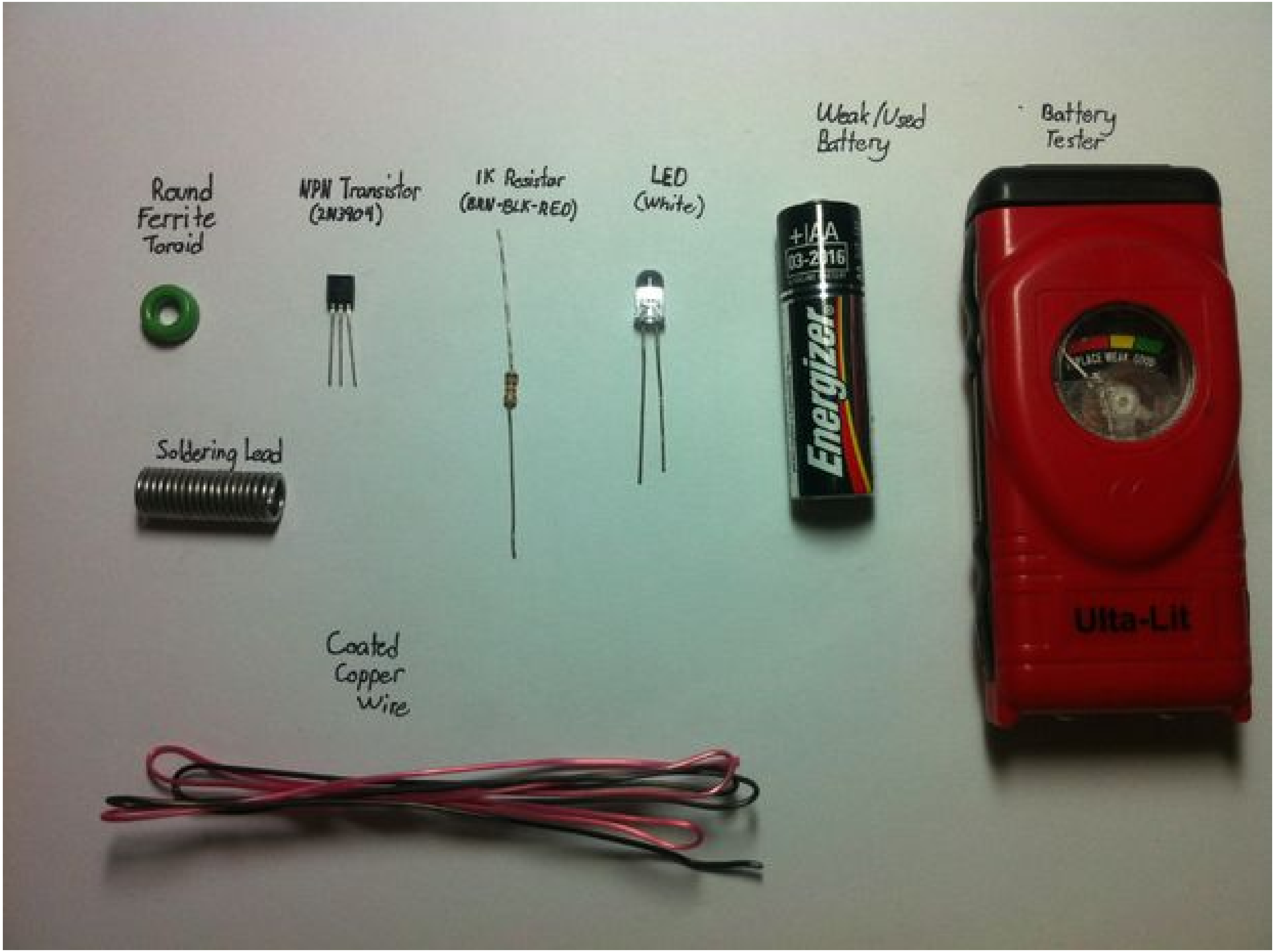
Round Ferrite Toroid
NPN Transistor (2N3904)
1K Resistor (BRN-BLK-RED)
LED (White)
Weak/Used Battery
Battery Tester
+AA
03-2016
Energizer
REPLACE WEAK GOOD
Soldering Lead
Ulta-Lit
Coated Copper Wire

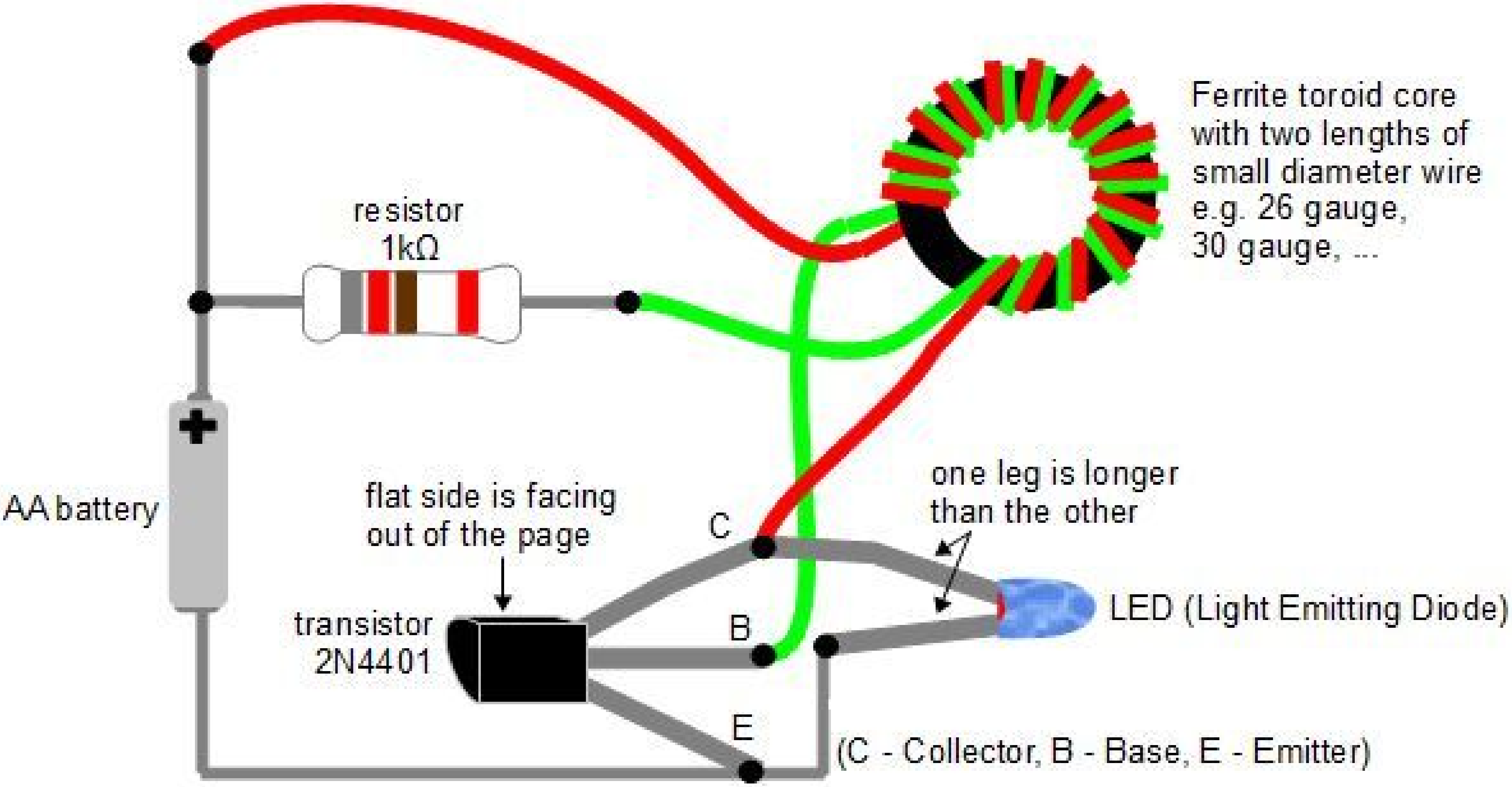resistor
1kΩ
Ferrite toroid core
with two lengths of
small diameter wire
e.g. 26 gauge,
30 gauge, ...
AA battery
flat side is facing
out of the page
one leg is longer
than the other
C
B
E
transistor
2N4401
LED (Light Emitting Diode)
(C - Collector, B - Base, E - Emitter)

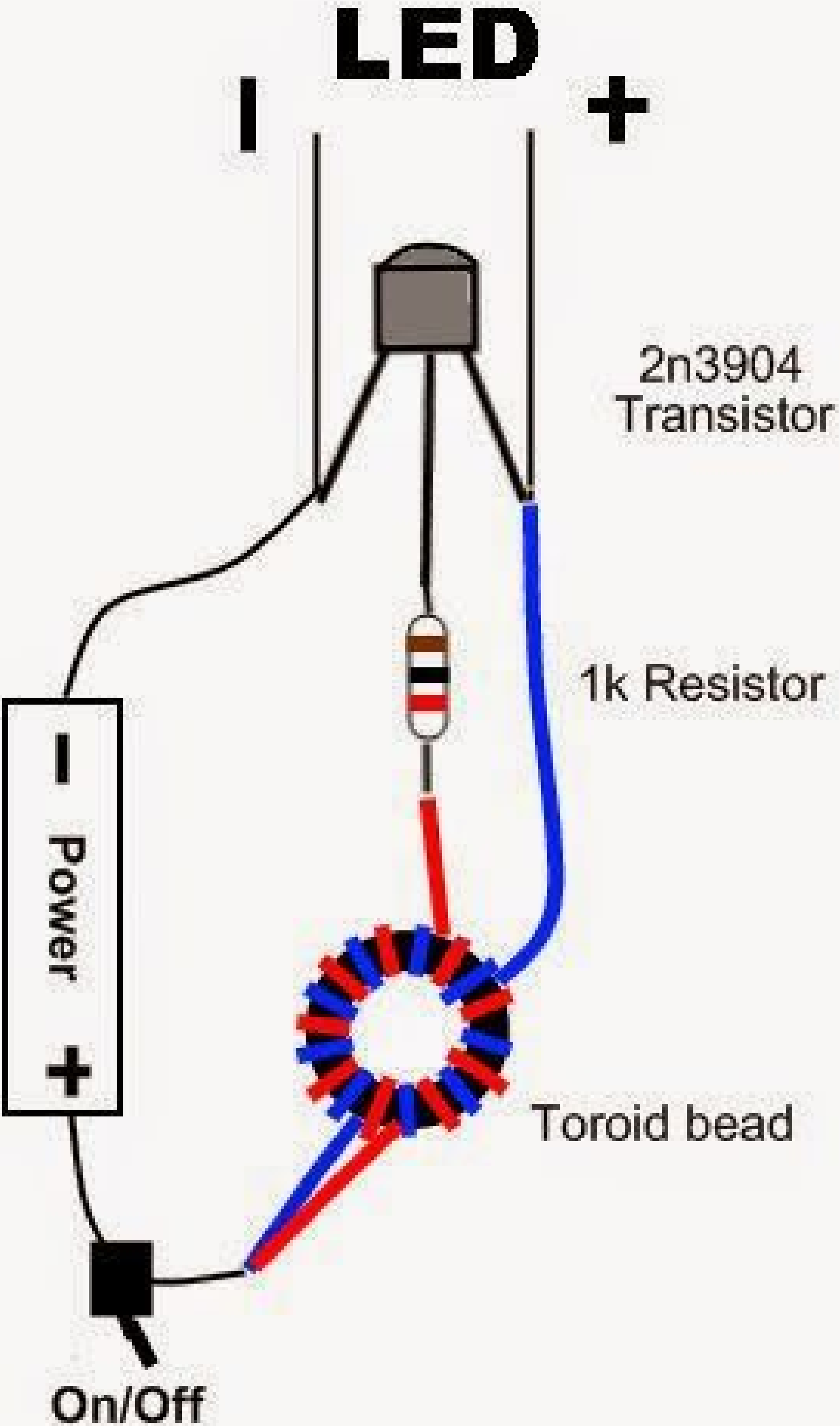
LED
I
+
2n3904
Transistor
1k Resistor
–
Power
+
Toroid bead
On/Off

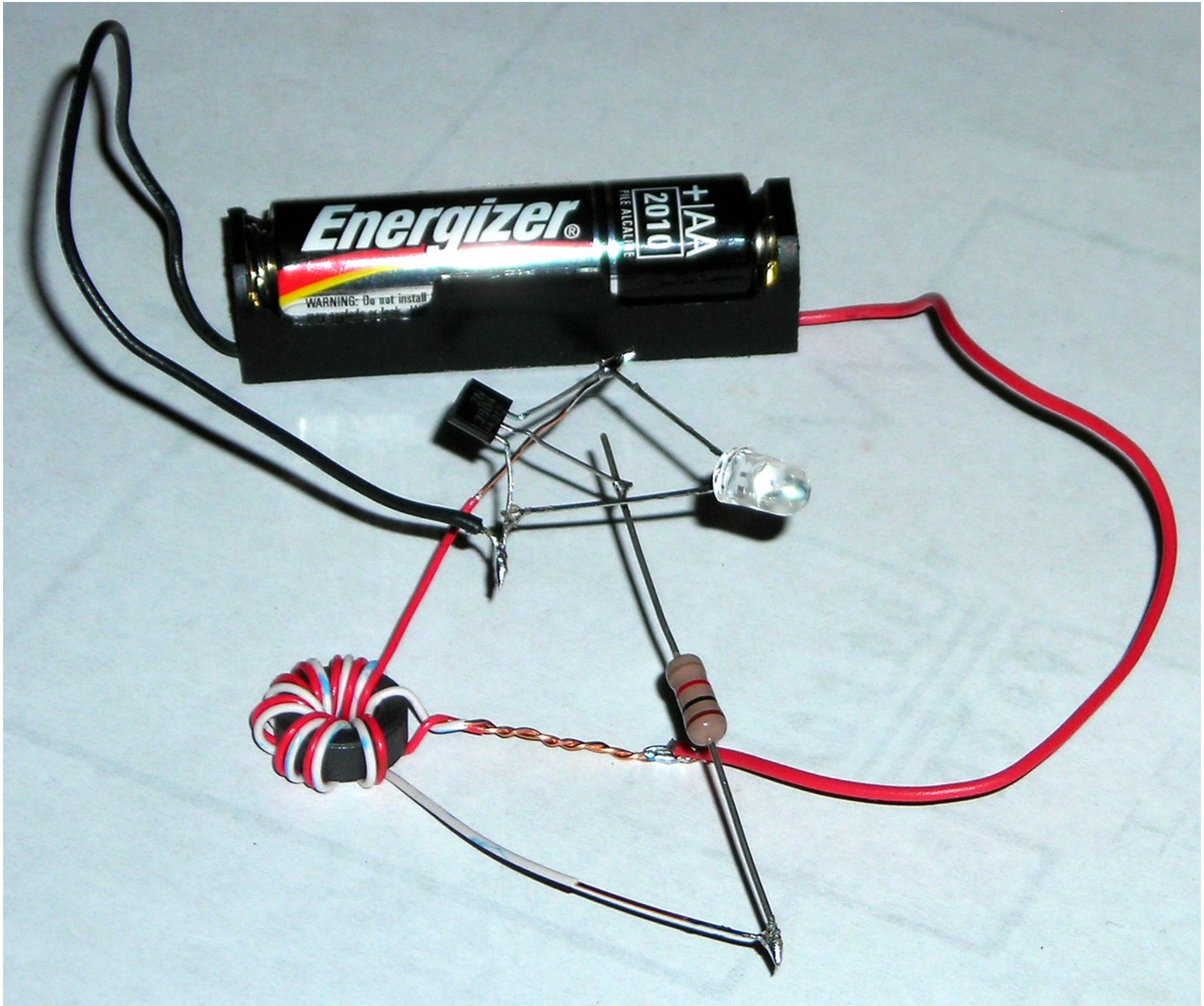
Energizer
+|AA
2010
PILE ALCALINE
WARNING: Do not install

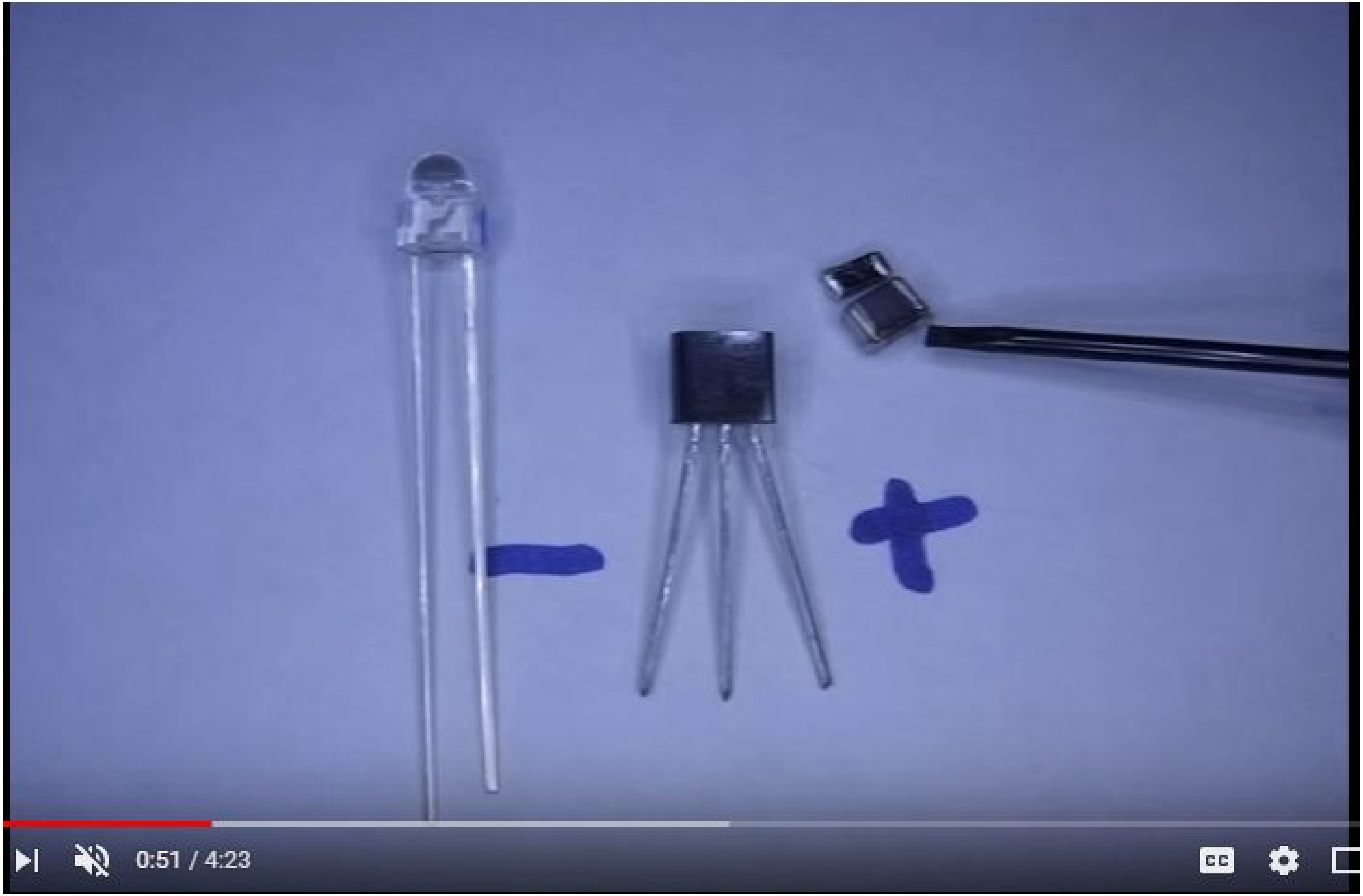
−
+
0:51 / 4:23
CC

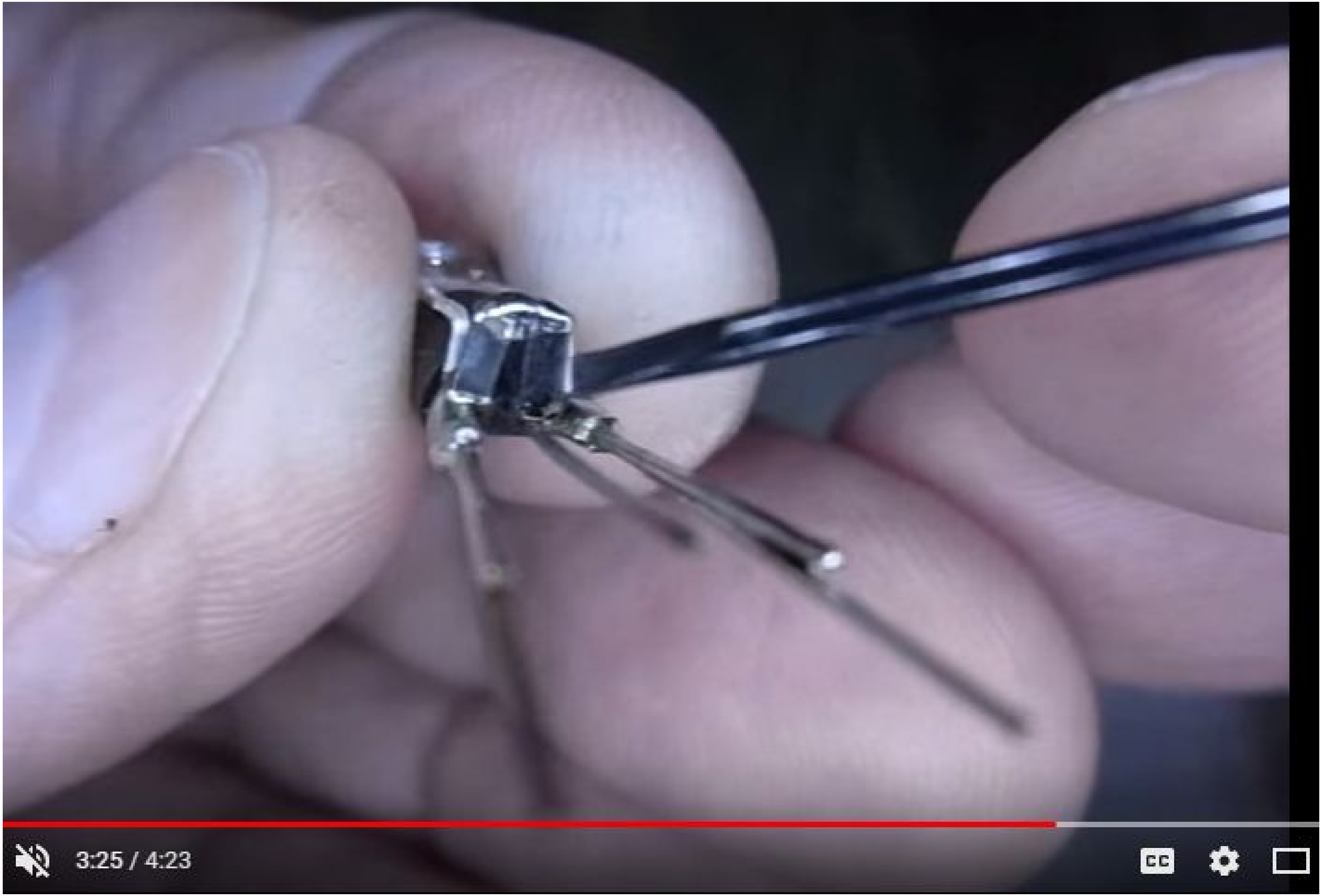
3:25 / 4:23
CC

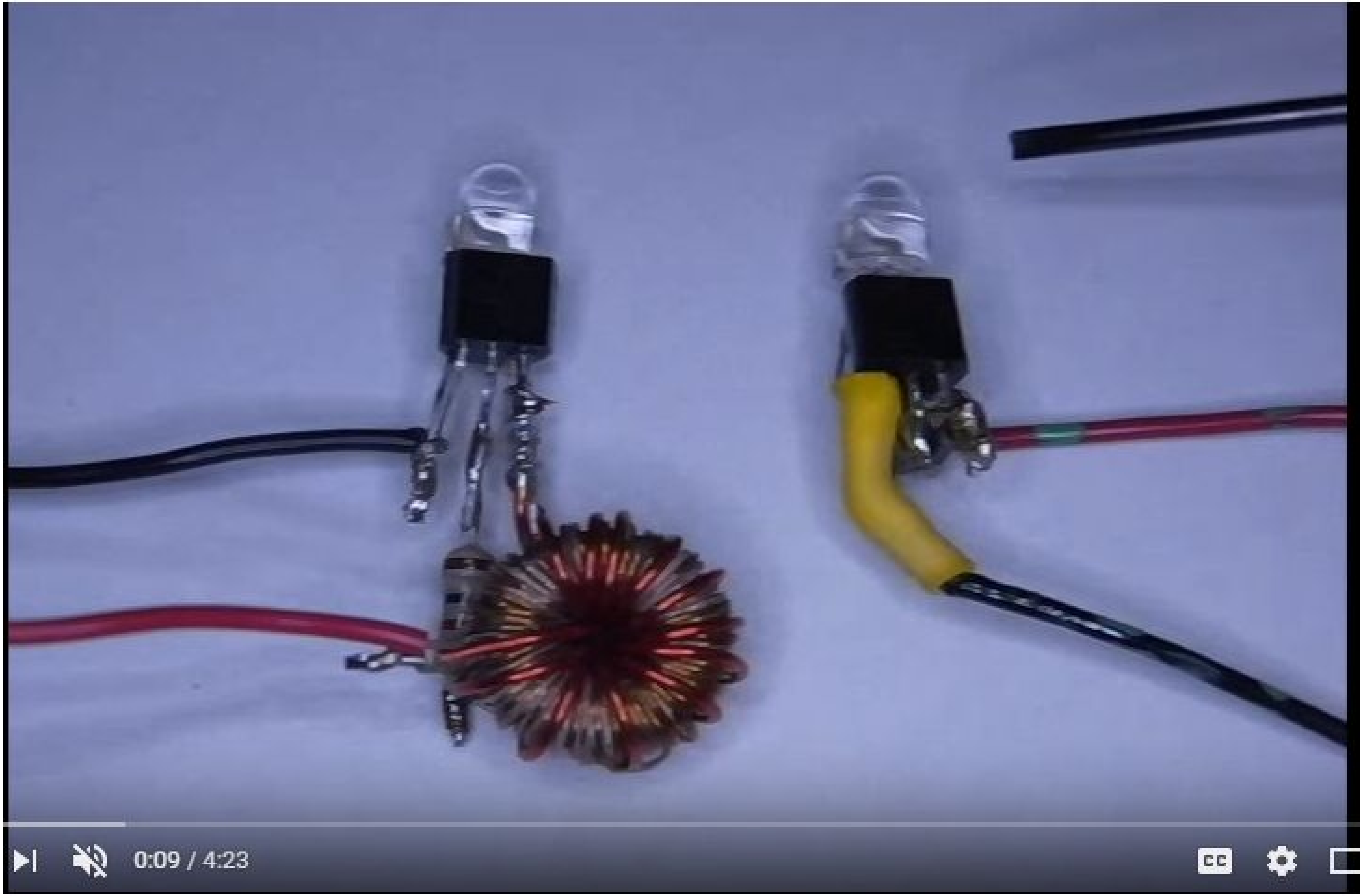
0:09 / 4:23

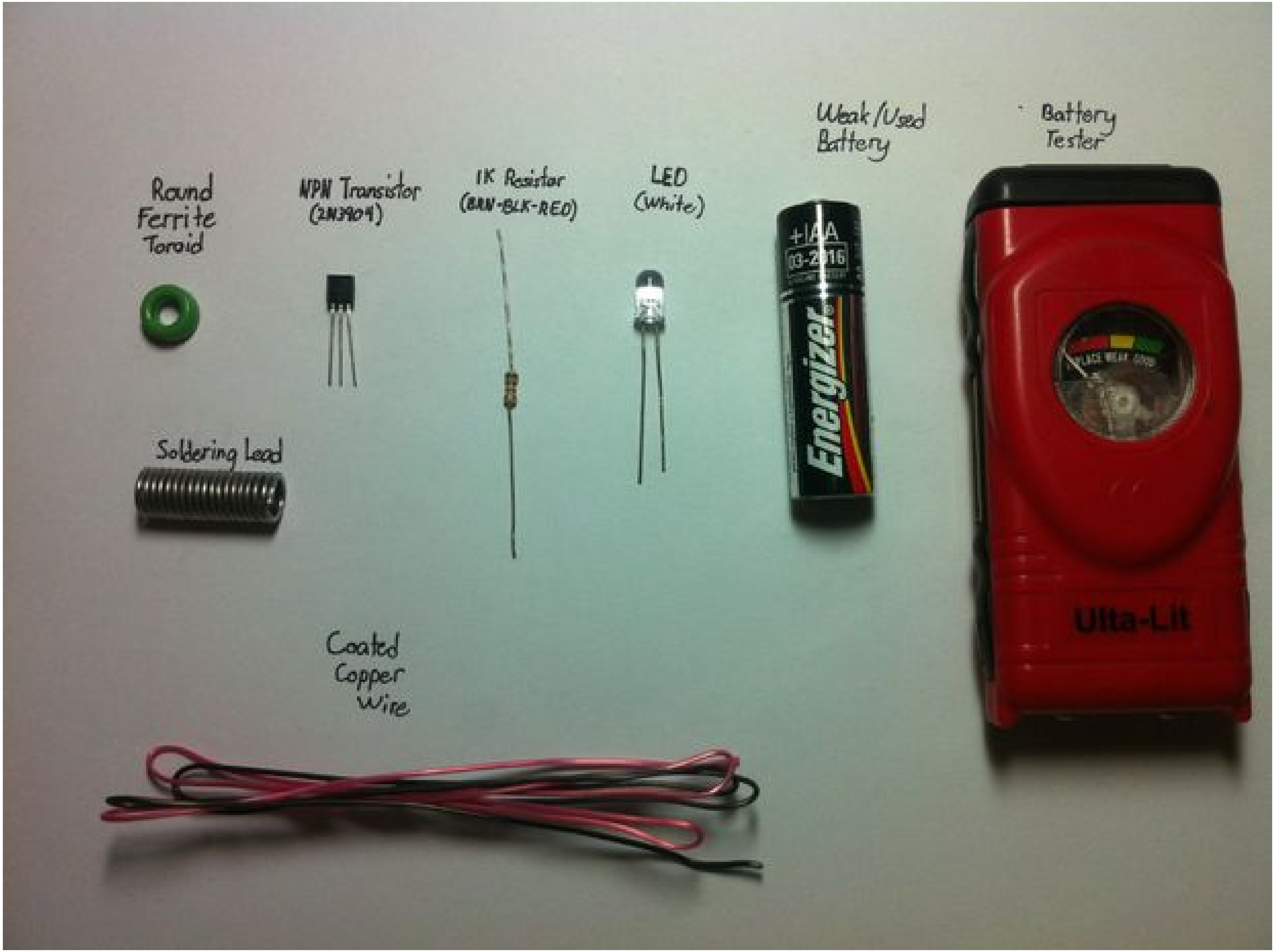
Round Ferrite Toroid
NPN Transistor (2N3904)
1K Resistor (BRN-BLK-RED)
LED (White)
Weak/Used Battery
Battery Tester
+AA
03-2016
Energizer
REPLACE WEAK GOOD
Ulta-Lit
Soldering Lead
Coated Copper Wire

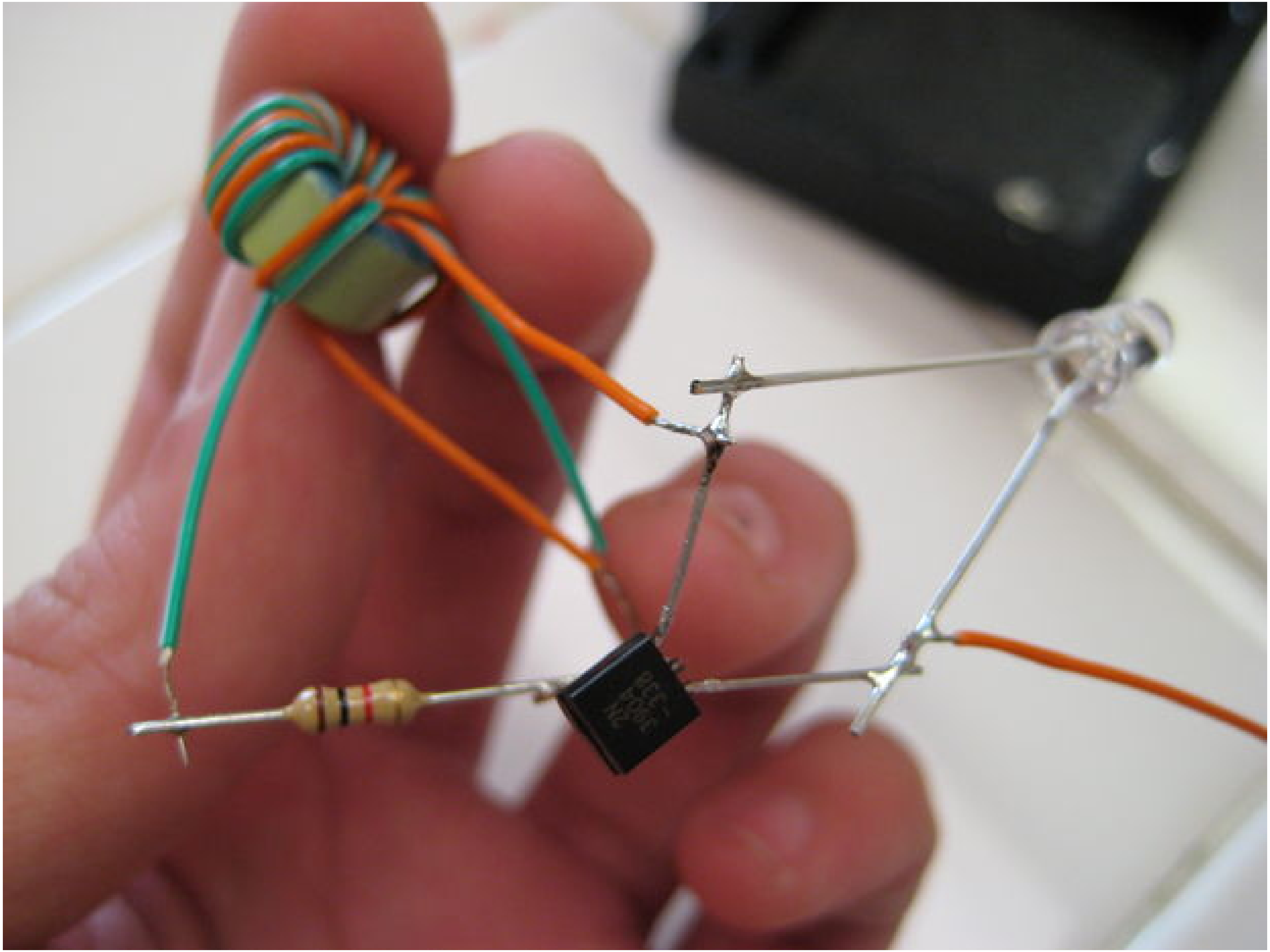

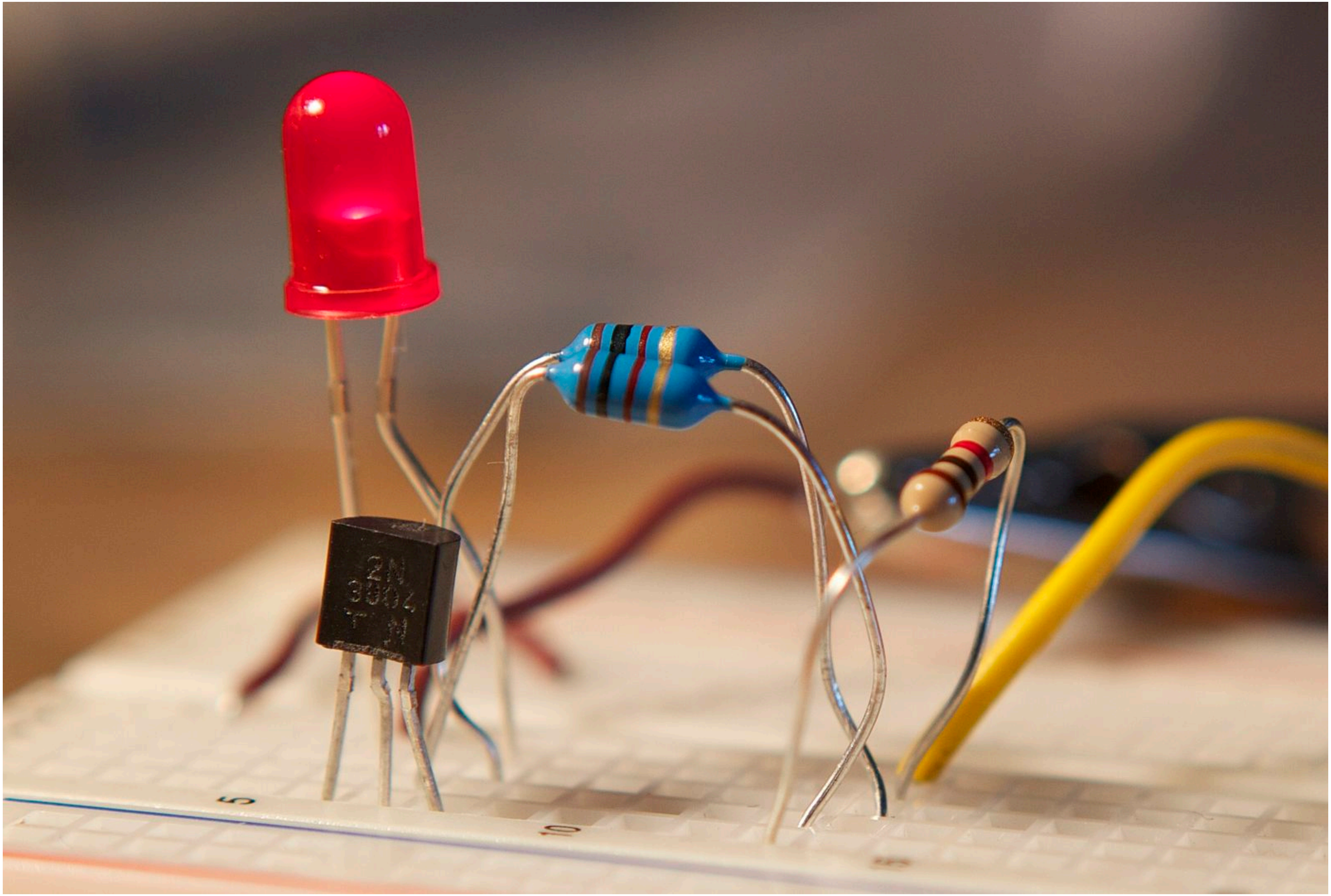
2N
3904
T M
5
10
15

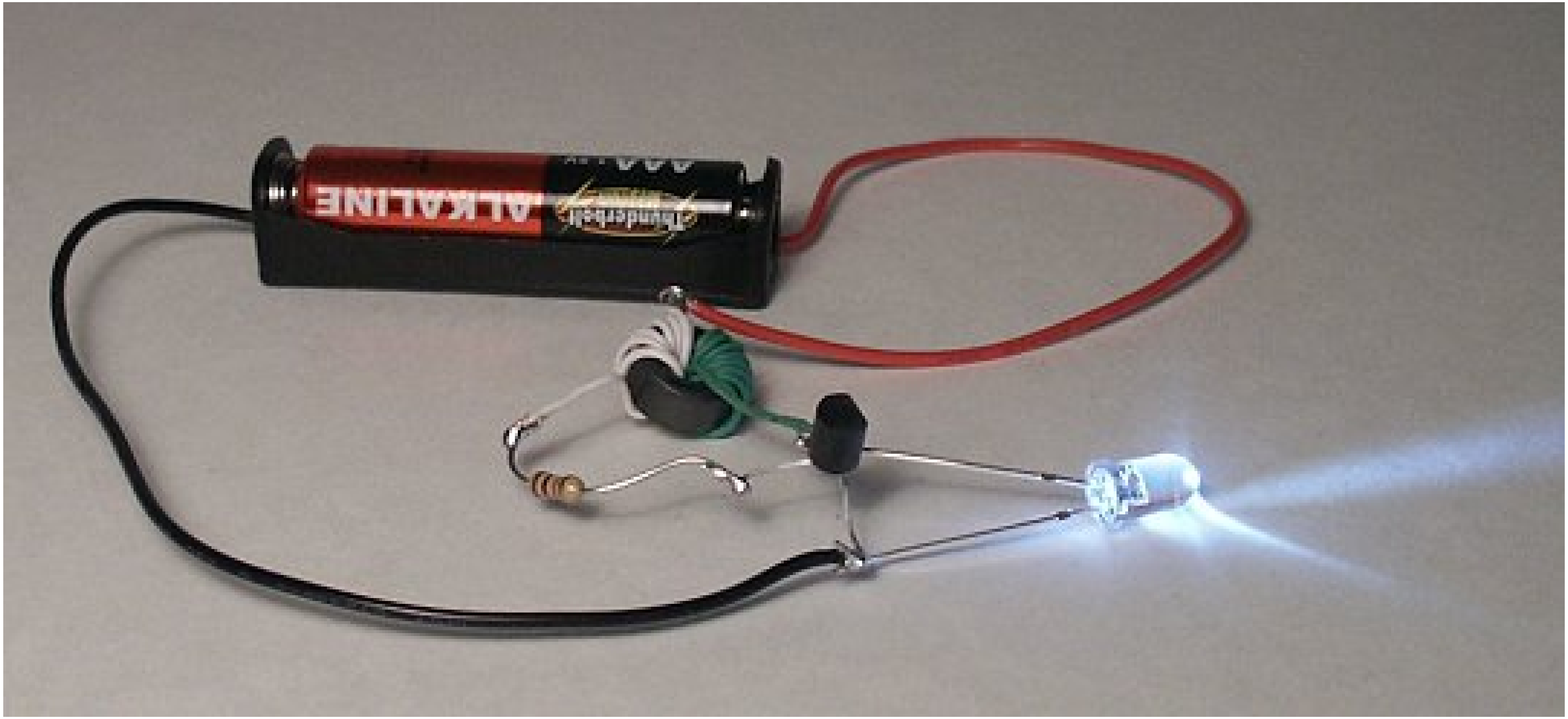
ALKALINE
Thunderbolt
AAA

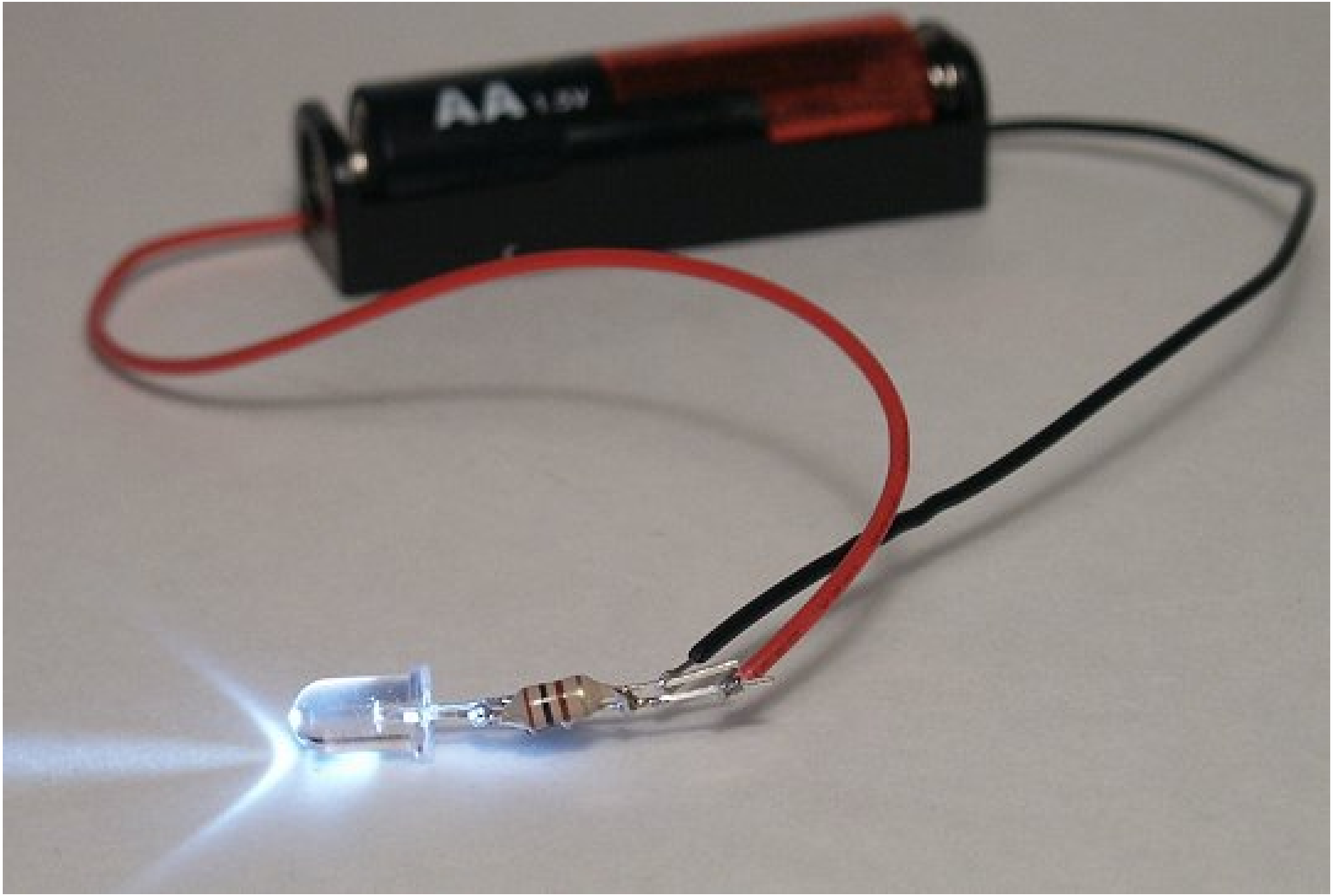
AA 1.5V

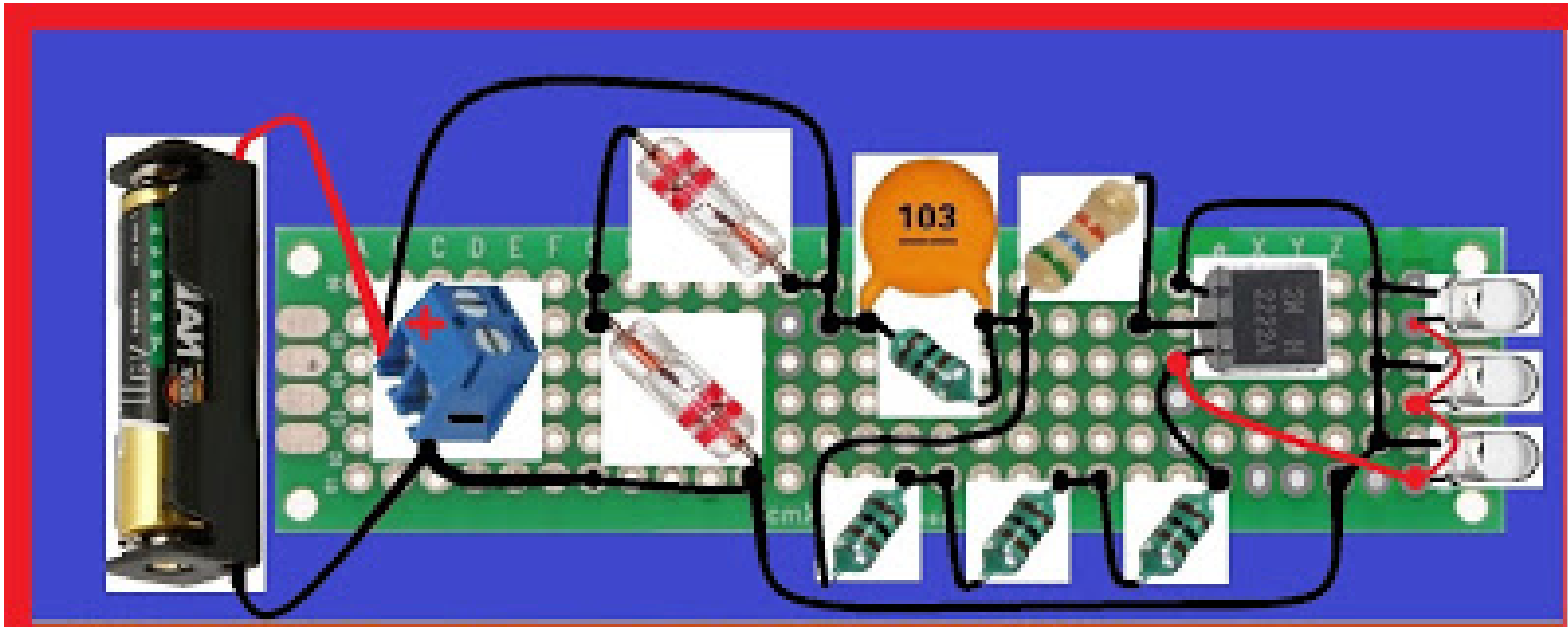

3* Axial lead inductor 82uH 1/4W

1* 10nf ceramic capacitor 103

2* AO90 Germanium signal diode

1* 2N2222 NPN Transistor bipolar 0.6A 40V

1* RESISTOR 5.6K Ohm 1/4W

3* 5mm white Emitting led Diode 20 mA 3.2 V

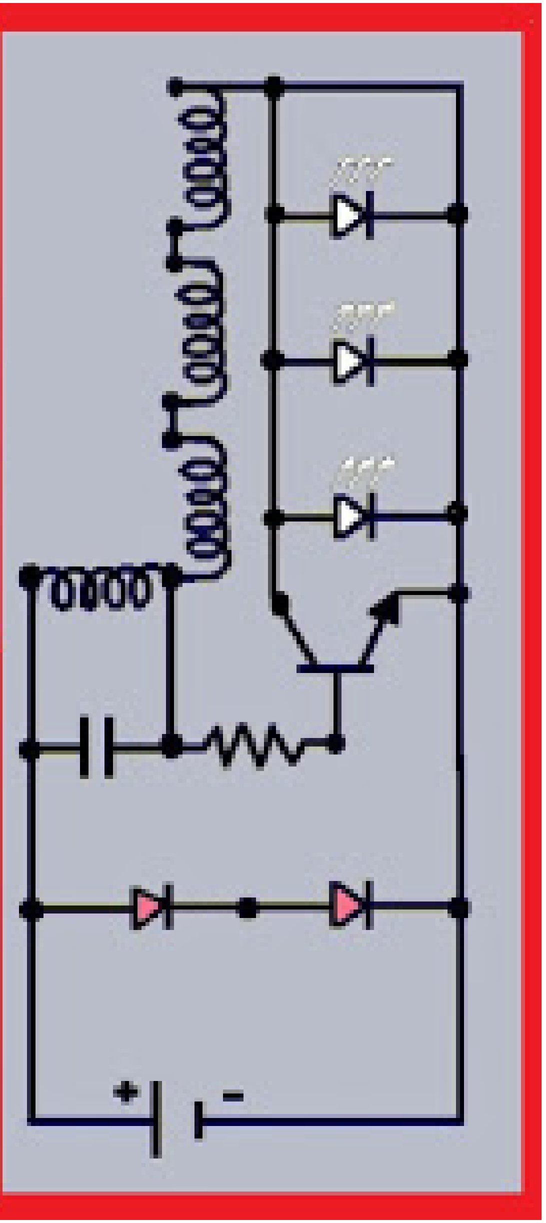

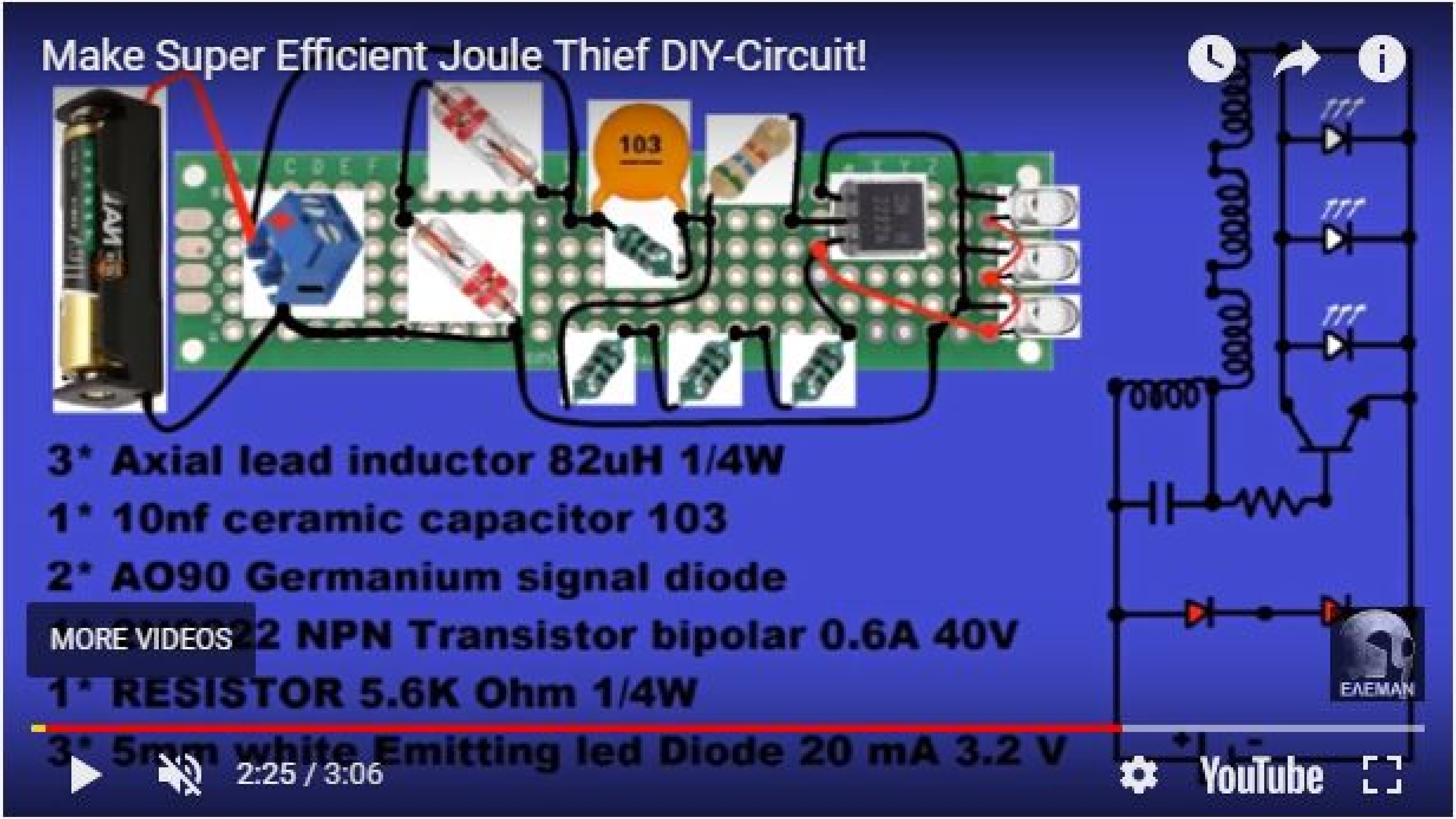

Make Super Efficient Joule Thief DIY-Circuit!

3* Axial lead inductor 82uH 1/4W

1* 10nf ceramic capacitor 103

2* AO90 Germanium signal diode

1* 2N2222 NPN Transistor bipolar 0.6A 40V

1* RESISTOR 5.6K Ohm 1/4W

3* 5mm white Emitting led Diode 20 mA 3.2 V

103
MORE VIDEOS
2:25 / 3:06
YouTube
ΕΛΕΜΑΝ
+
-

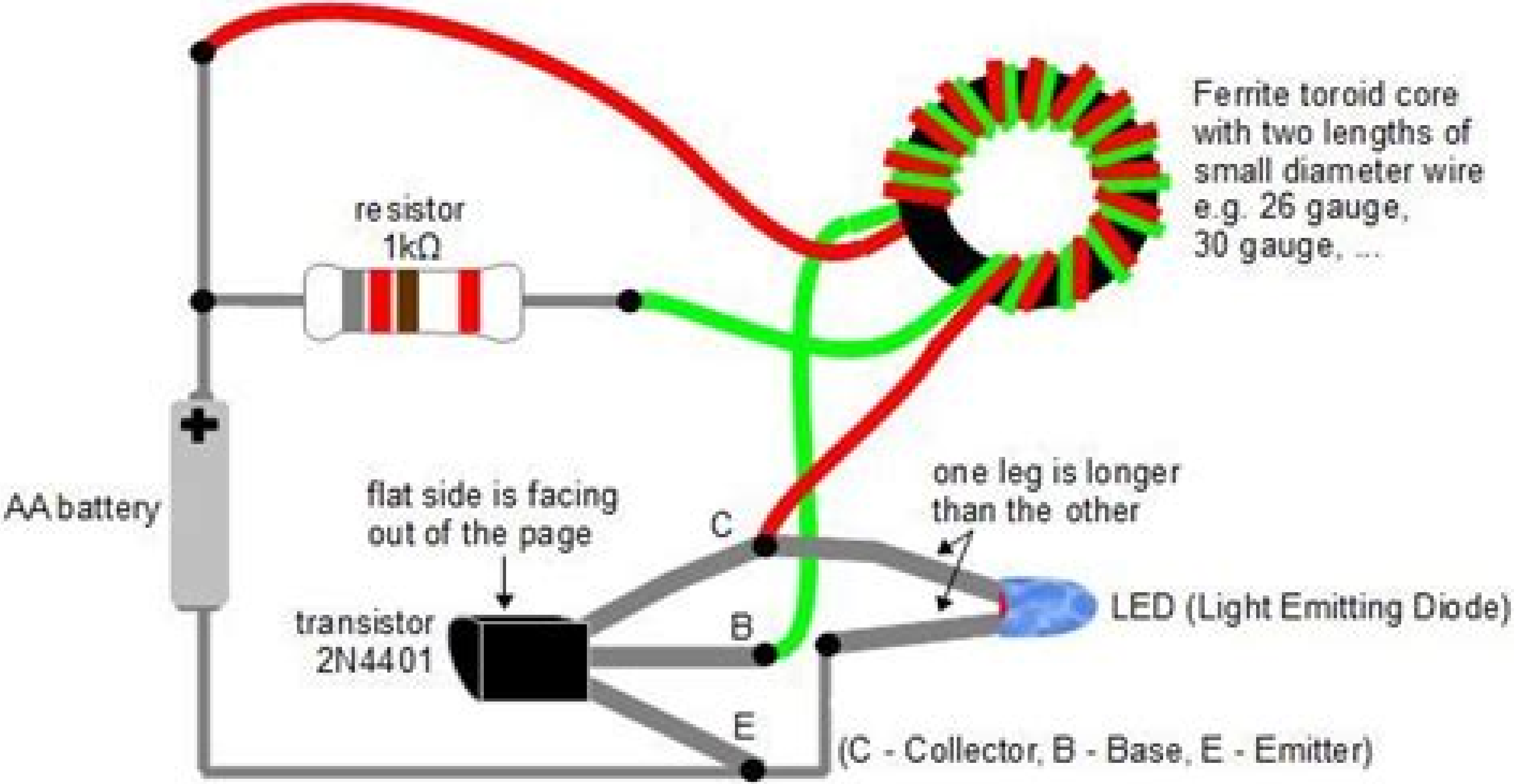
Ferrite toroid core
with two lengths of
small diameter wire
e.g. 26 gauge,
30 gauge, ...
resistor
1kΩ
AA battery
flat side is facing
out of the page
transistor
2N4401
C
B
E
one leg is longer
than the other
LED (Light Emitting Diode)
(C - Collector, B - Base, E - Emitter)

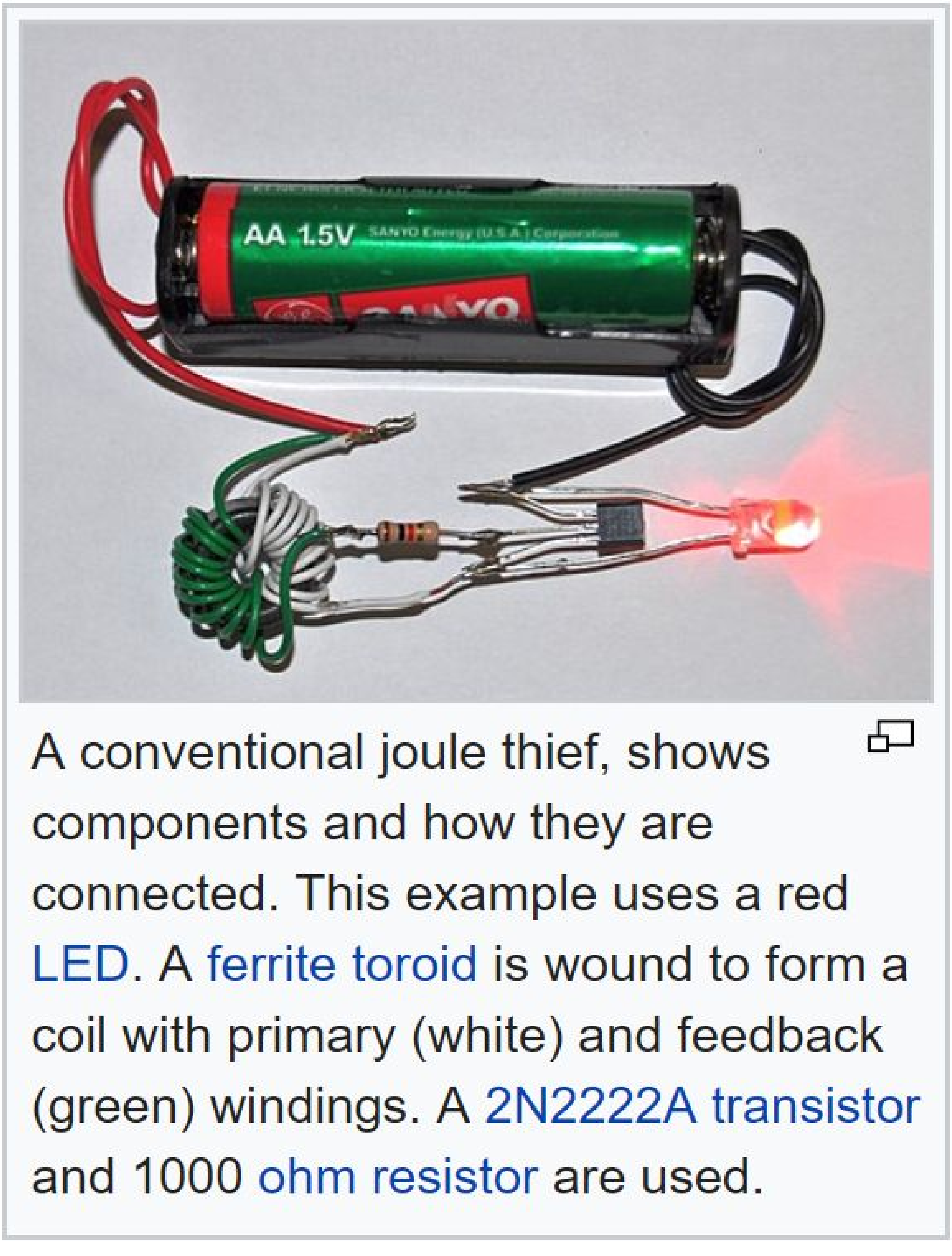
AA 1.5V
SANYO Energy (U.S.A.) Corporation
SANYO

A conventional joule thief, shows components and how they are connected. This example uses a red LED. A ferrite toroid is wound to form a coil with primary (white) and feedback (green) windings. A 2N2222A transistor and 1000 ohm resistor are used.

The Joule Thief

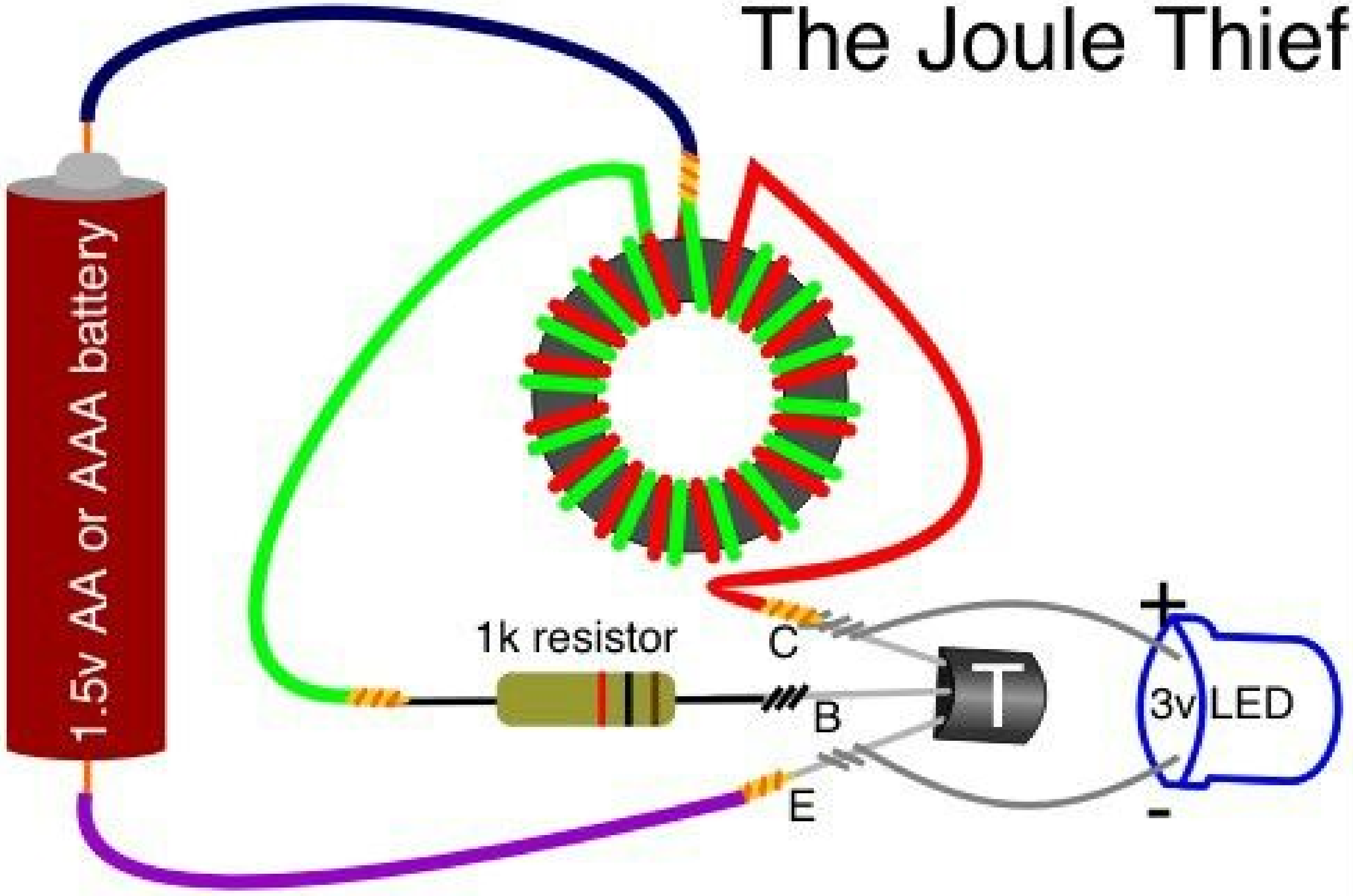
1.5v AA or AAA battery
1k resistor
C
B
E
T
+
3v LED
-

Transistor shown (T) is 2N3904 (can also use 2N2222).

Note LED pins - negative is shorter and has flat on bulb edge.

2 wires round ferrite ring are wound together, then start of one joined to end of other.

Try adding more and more LEDs...

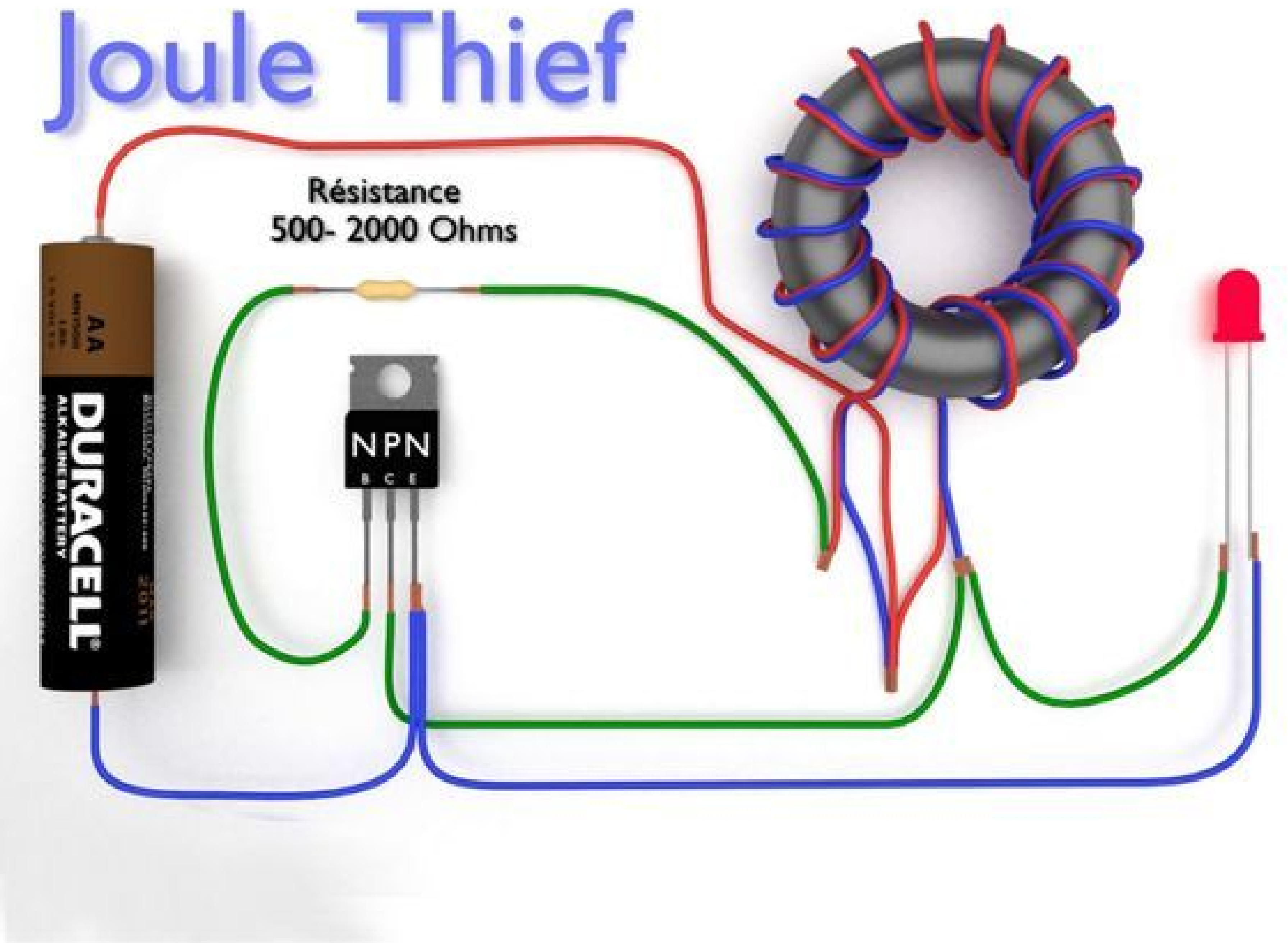
Joule Thief
Résistance
500- 2000 Ohms
AA
DURACELL
ALKALINE BATTERY
NPN
B C E

Its a Rubbish Challenge
Dog Light
Joule Thief
electronics circuit

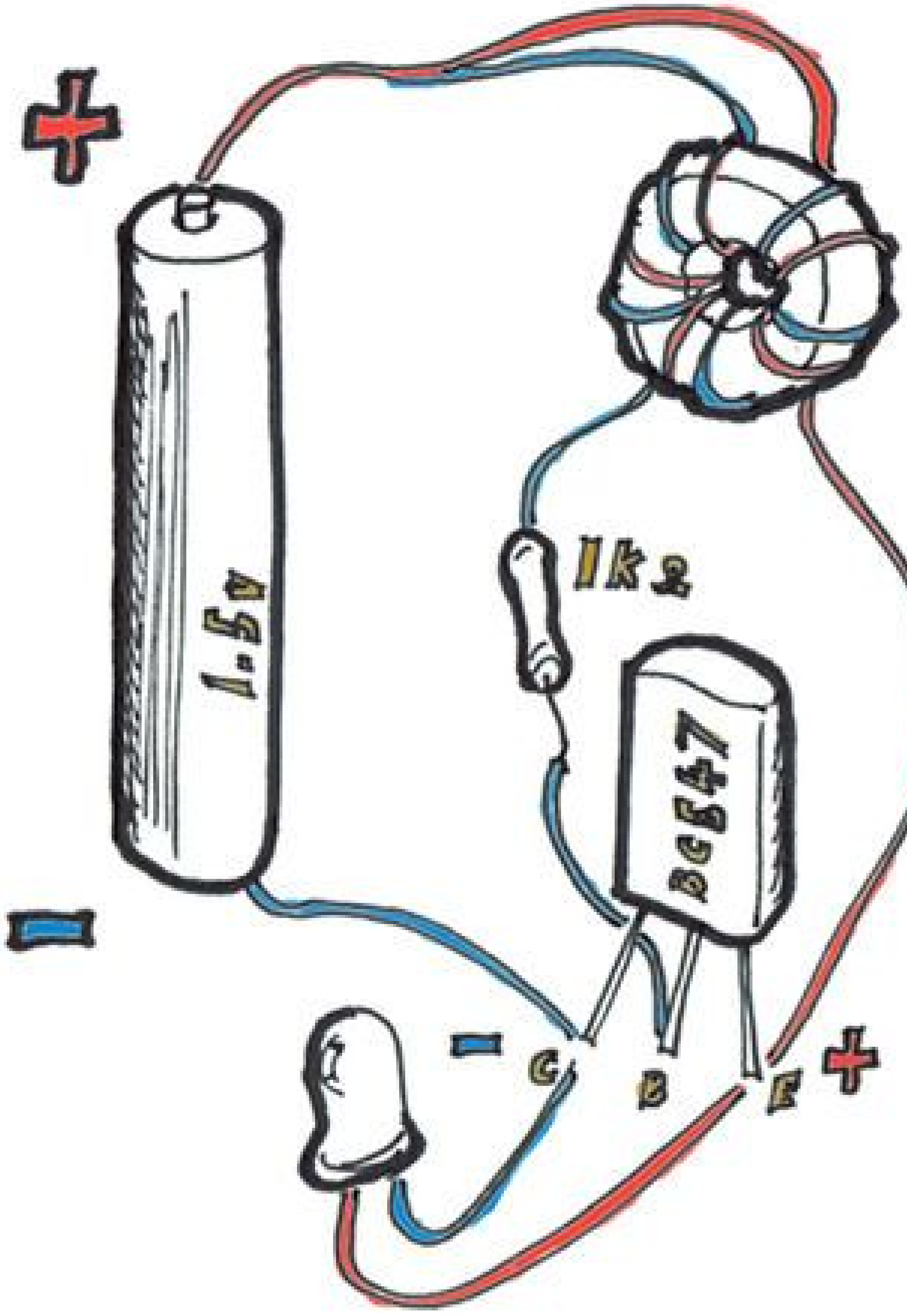
+
1.5v
1kΩ
BC547
-
-
C
B
E
+

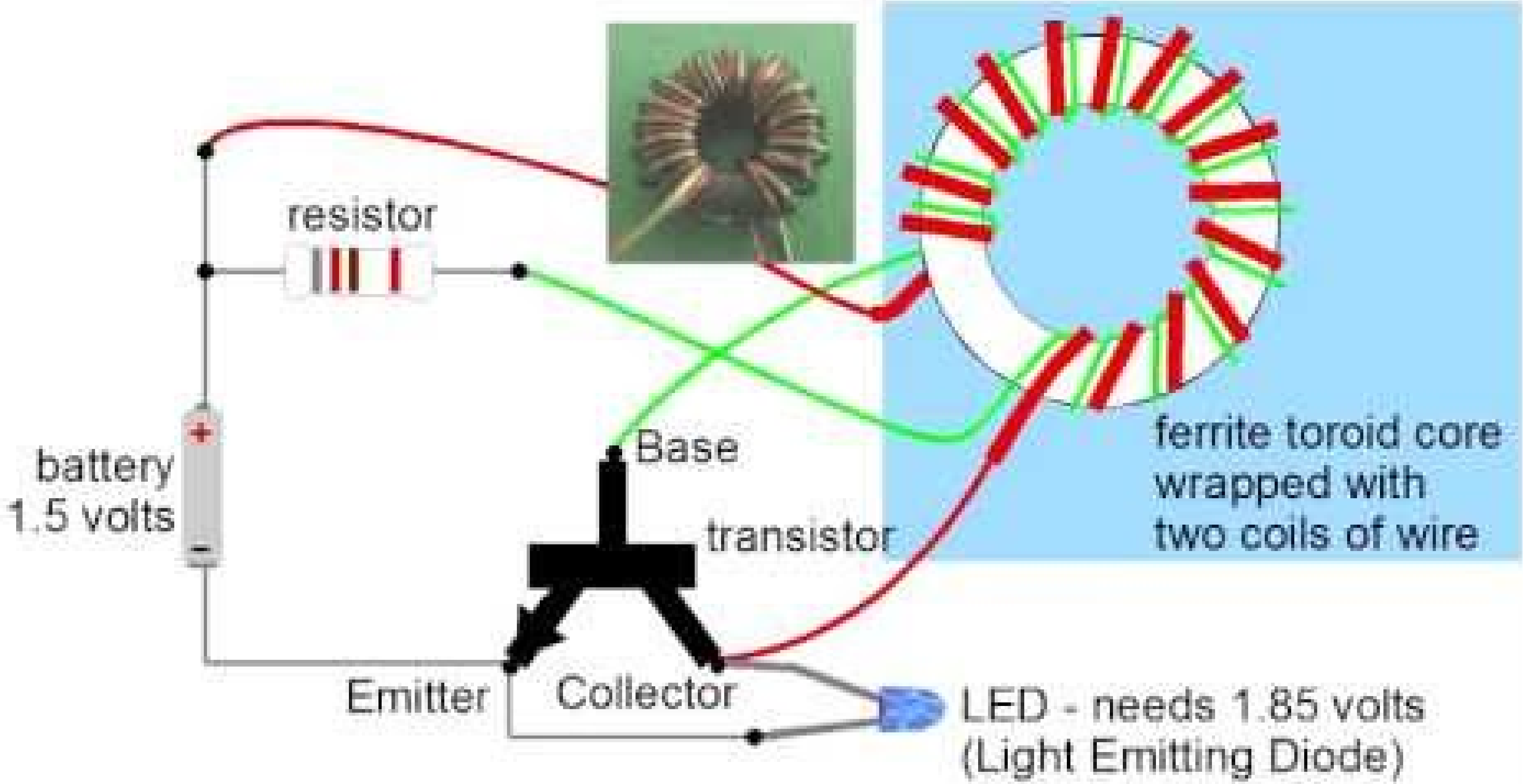
resistor
battery
1.5 volts
+
-
Base
transistor
Emitter
Collector
ferrite toroid core
wrapped with
two coils of wire
LED - needs 1.85 volts
(Light Emitting Diode)

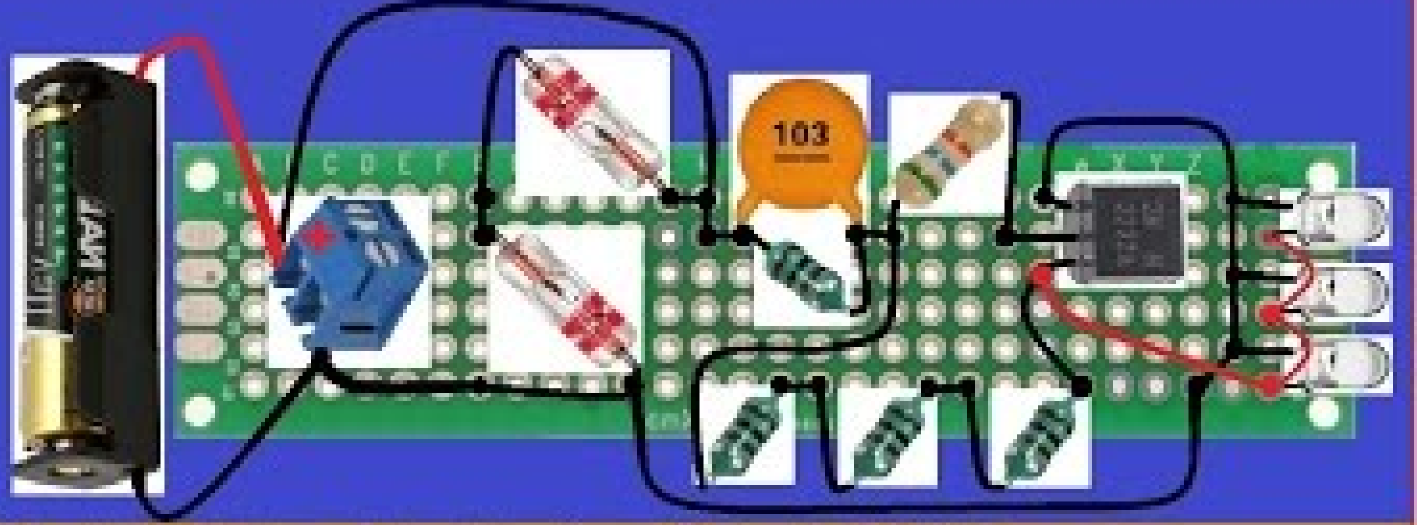

3* Axial lead inductor 82uH 1/4W
1* 10nf ceramic capacitor 103
2* AO90 Germanium signal diode
1* 2N2222 NPN Transistor bipolar 0.6A 40V
1* RESISTOR 5.6K Ohm 1/4W
3* 5mm white Emitting led Diode 20 mA 3.2 V

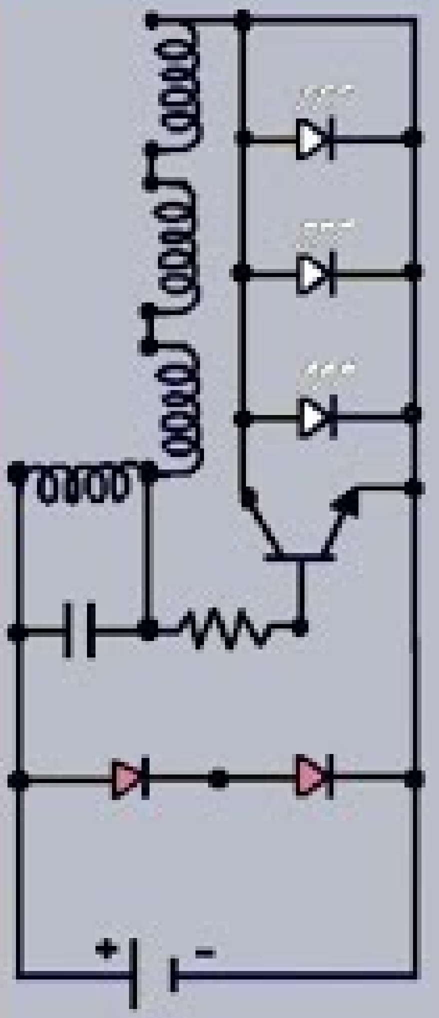

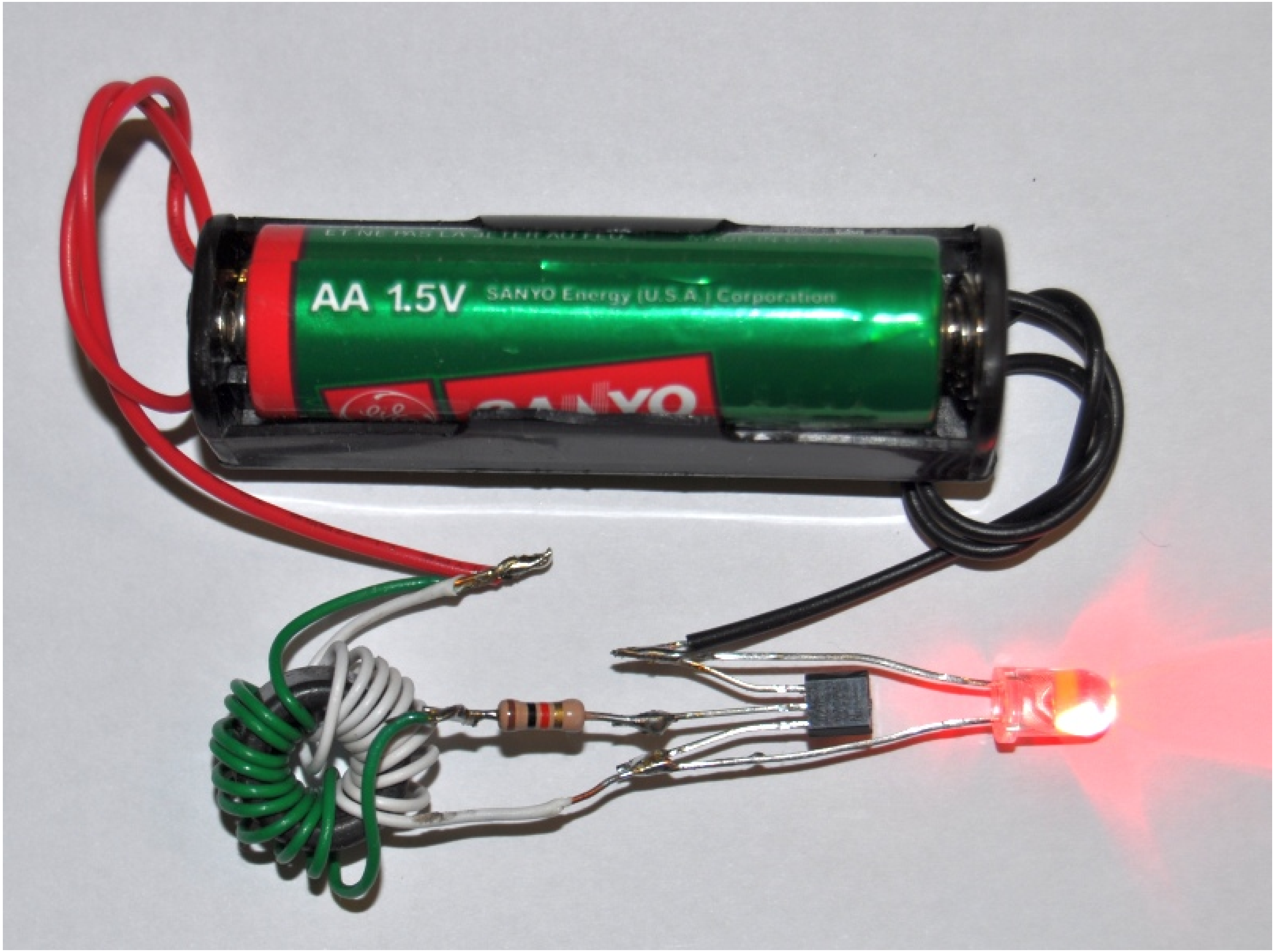
AA 1.5V
SANYO Energy (U.S.A.) Corporation
SANYO

The joule thief circuit.

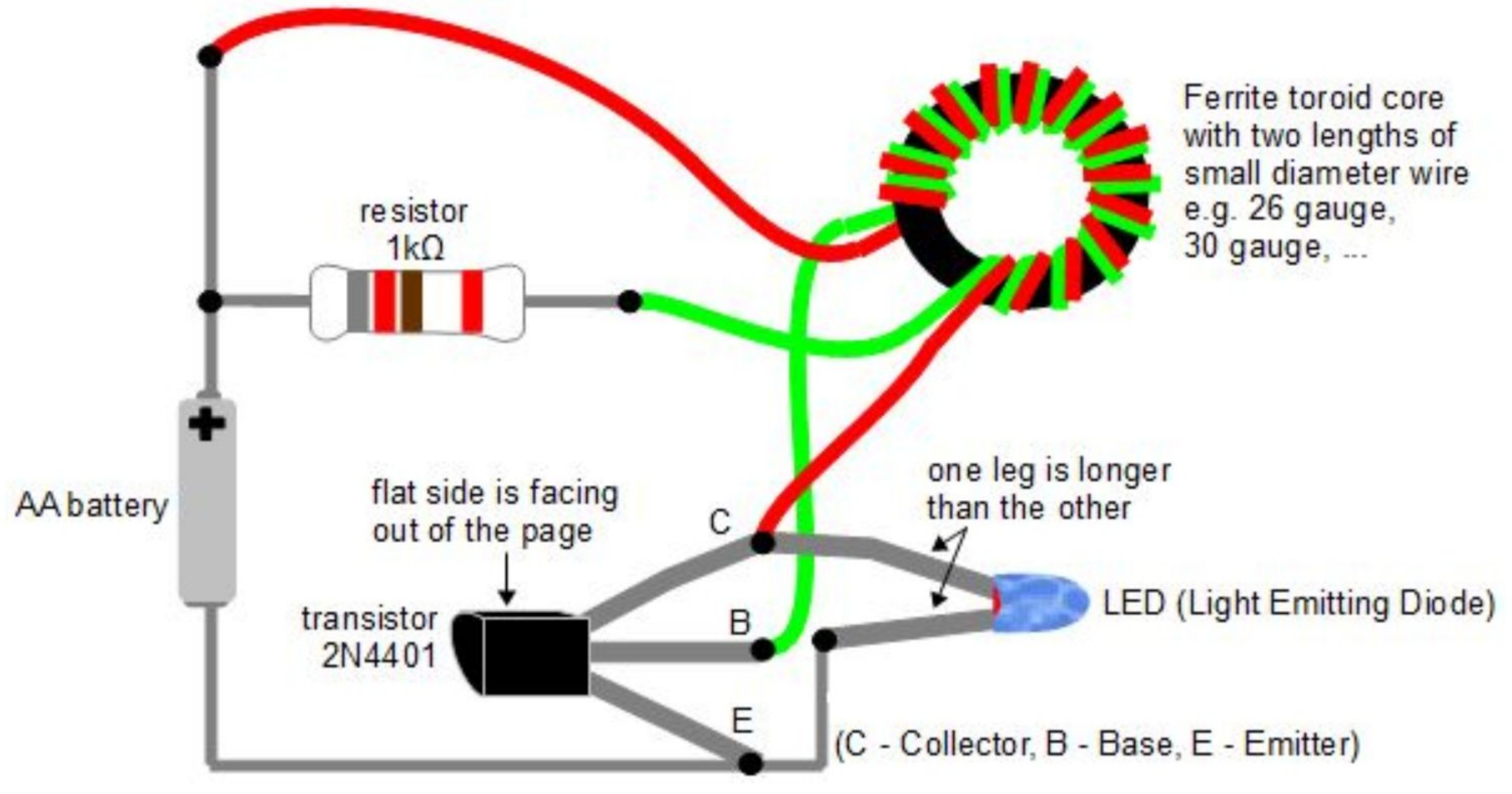
Ferrite toroid core
with two lengths of
small diameter wire
e.g. 26 gauge,
30 gauge, ...
resistor
1kΩ
AA battery
flat side is facing
out of the page
transistor
2N4401
C
B
E
one leg is longer
than the other
LED (Light Emitting Diode)
(C - Collector, B - Base, E - Emitter)

Transistor - The legs of the transistor can be determined by noticing that there's a flat side to the transistor case. See the diagram above. A large number of transistors have been reported to work: 2N4401, NET123AP, BC547B, 2SC2500, BC337, PN2222, to name just a few.

LED - One leg of the LED is longer than the other leg. Use this to determine which one goes where. See the diagram above.

Resistor - The diagram says use a 1 kilo ohm resistor but I've used an 820 ohm one just fine. I've also seen a 2 kilo ohm one in use. Use whatever works for you. You can also use a potentiometer (a variable resistor) so that you can easily adjust it to select the resistance that gives the best light.

Toroid ferrite core - Some people have gotten these by opening up compact fluorescent lightbulbs (CFLs). I took mine out of some device whose original function I don't know. To get it working, my first one had just 13 turns for each wire and I used a 30 gauge wire and a 26 gauge wire. The wire must be insulated. A variety of number of turns will work. This is something you can play with. Look at the diagram carefully to determine where the wires connect to.

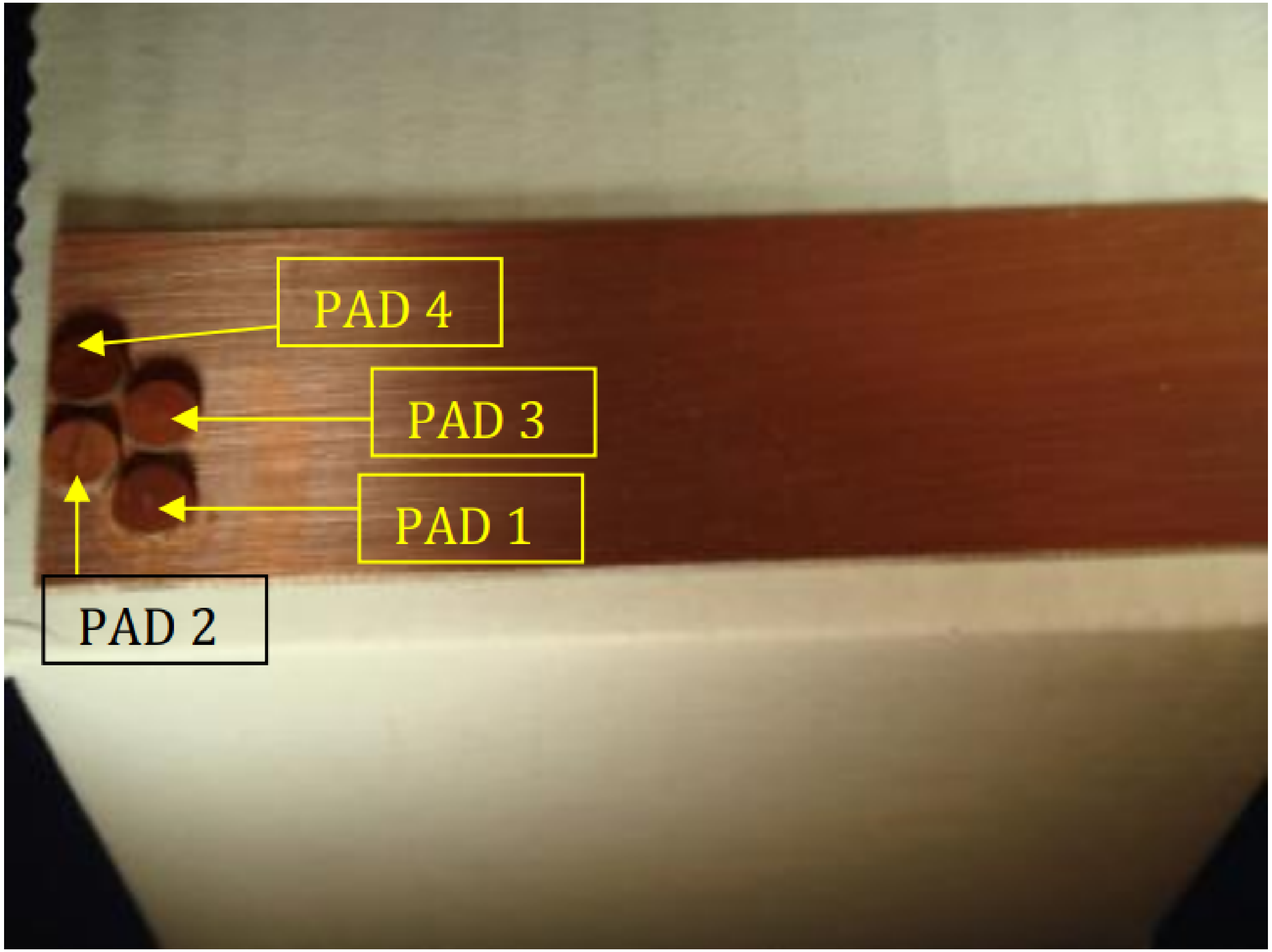

Superglue four pads to the PC board. Make sure they are not touching each other. You should have roughly 1/8 inch between the pads. Apply a small drop of superglue on the board and press the pad onto the board with the small dimple up. Use a small screwdriver to hold pressure on the pad until the glue dries (about 10 seconds).

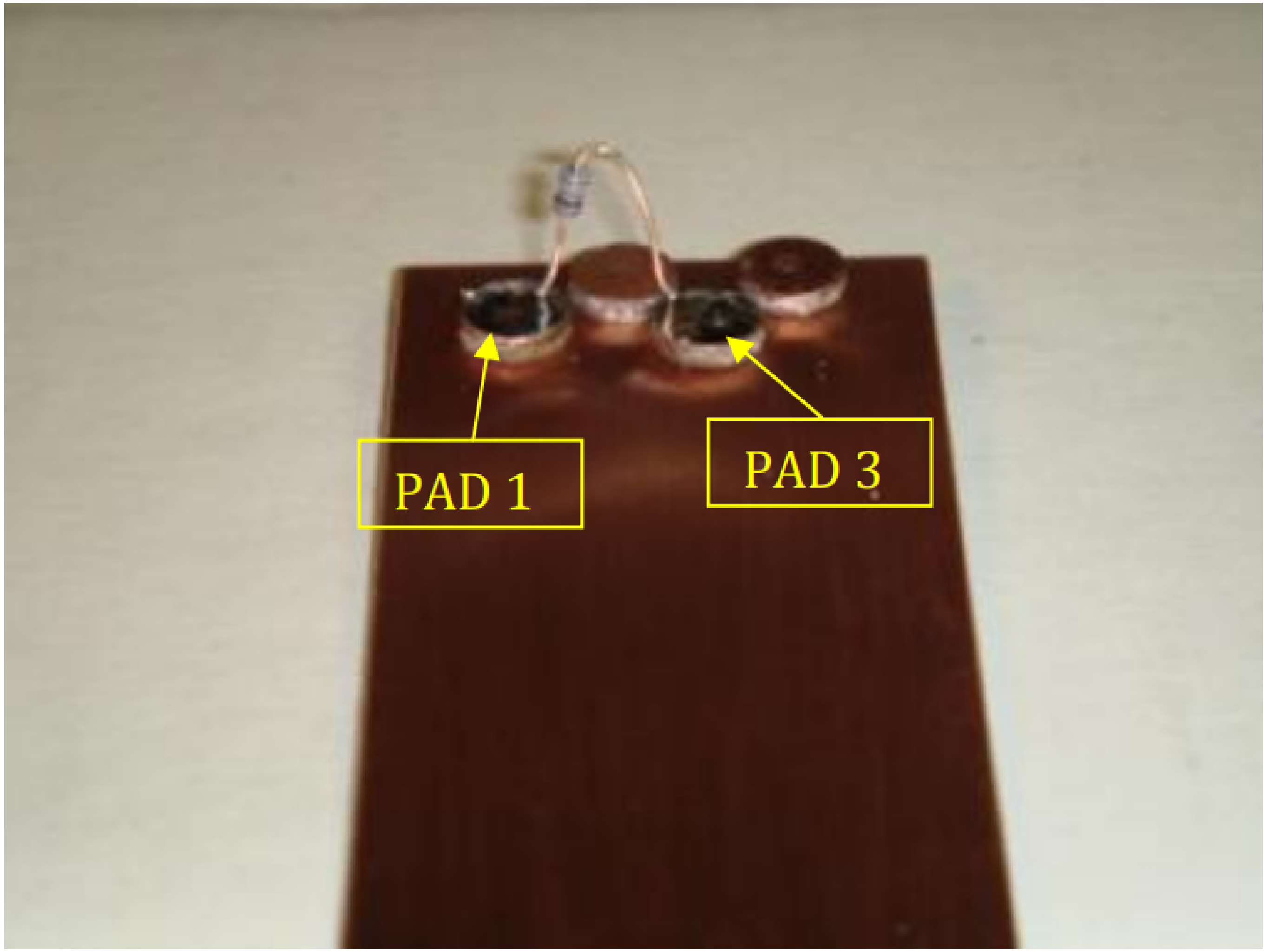

Solder the 1,000 ohm resistor onto pads 1 and 3. When soldering all components, place a 90-degree bend on the ends of the component where they touch the pad to allow better soldering. There is no polarity on a resistor.

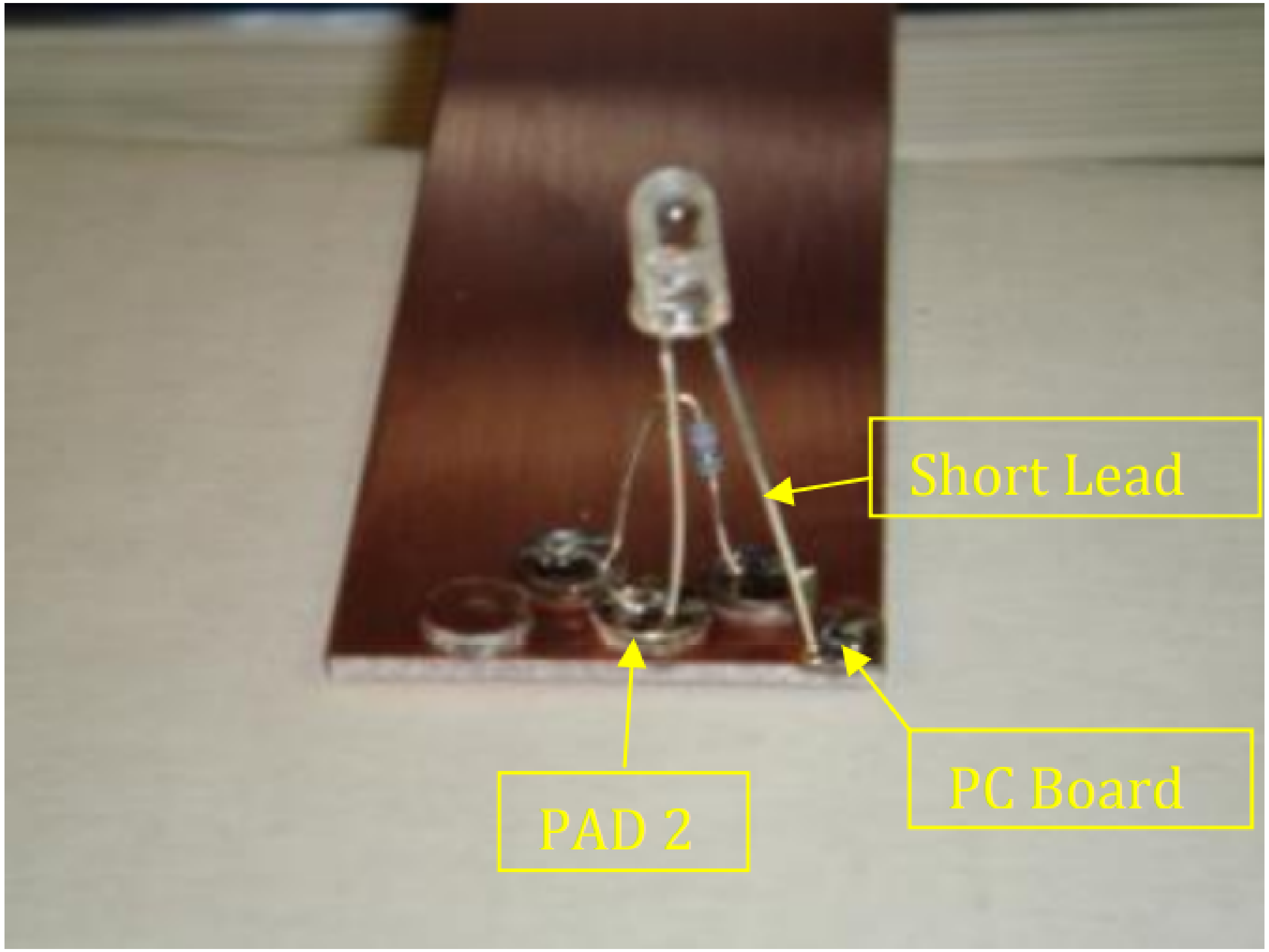

Solder the LED to the board. **VERY IMPORTANT**: Solder the **long lead** to pad 2 and the **short lead** directly to the PC board. The LED will not illuminate of you put it in backwards. If you look into the LED, the anvil shaped part is the lead that gets soldered to the PC board.

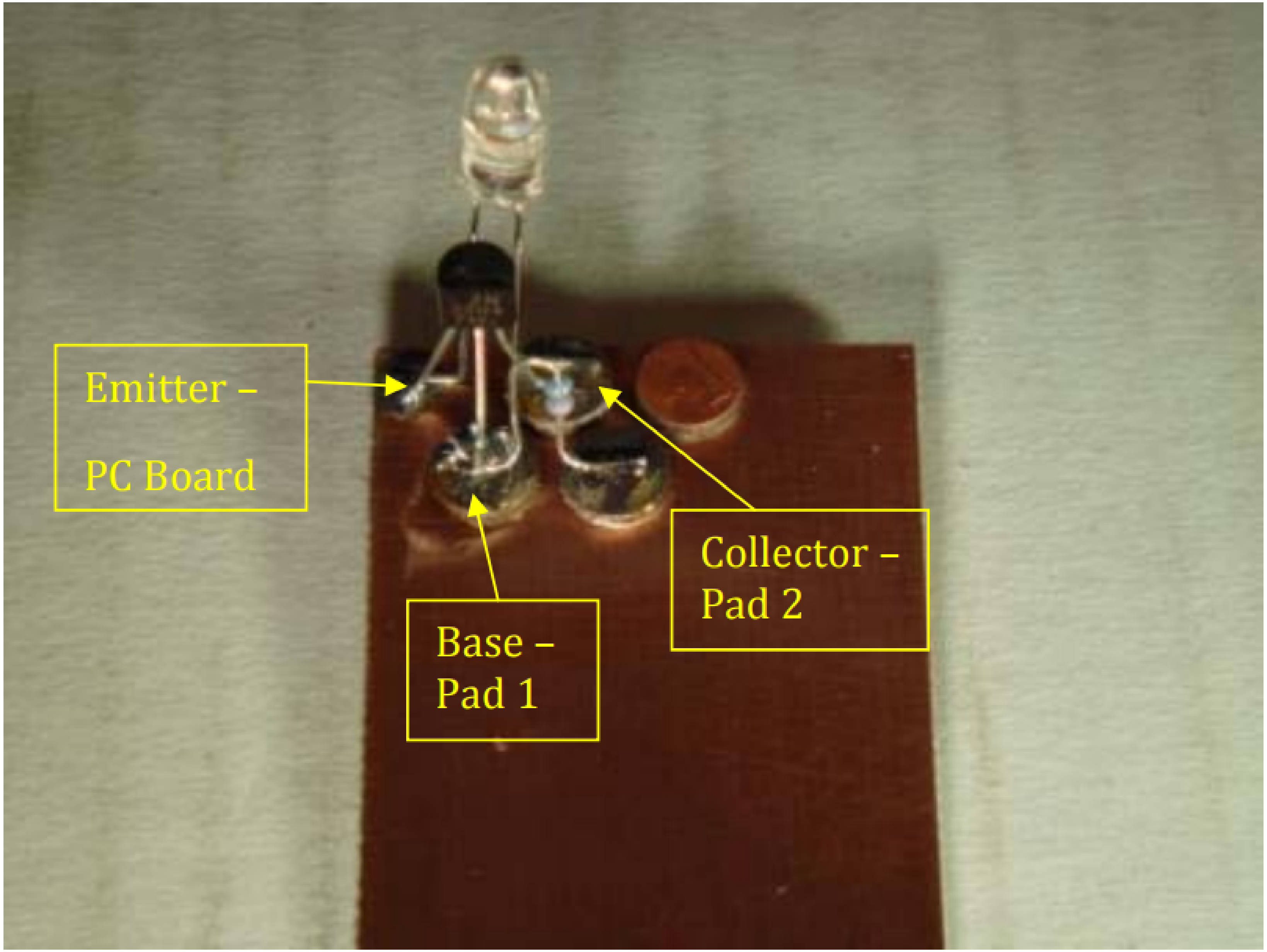
Emitter –
PC Board
Collector –
Pad 2
Base –
Pad 1

Solder the transistor to the board. With the flat part facing you the left lead (emitter) is soldered directly to the PC board. The center lead (base) is soldered to pad 1. The right lead (collector) is soldered to pad 2. Failure to install this part correctly will prevent the Joule Thief from working.

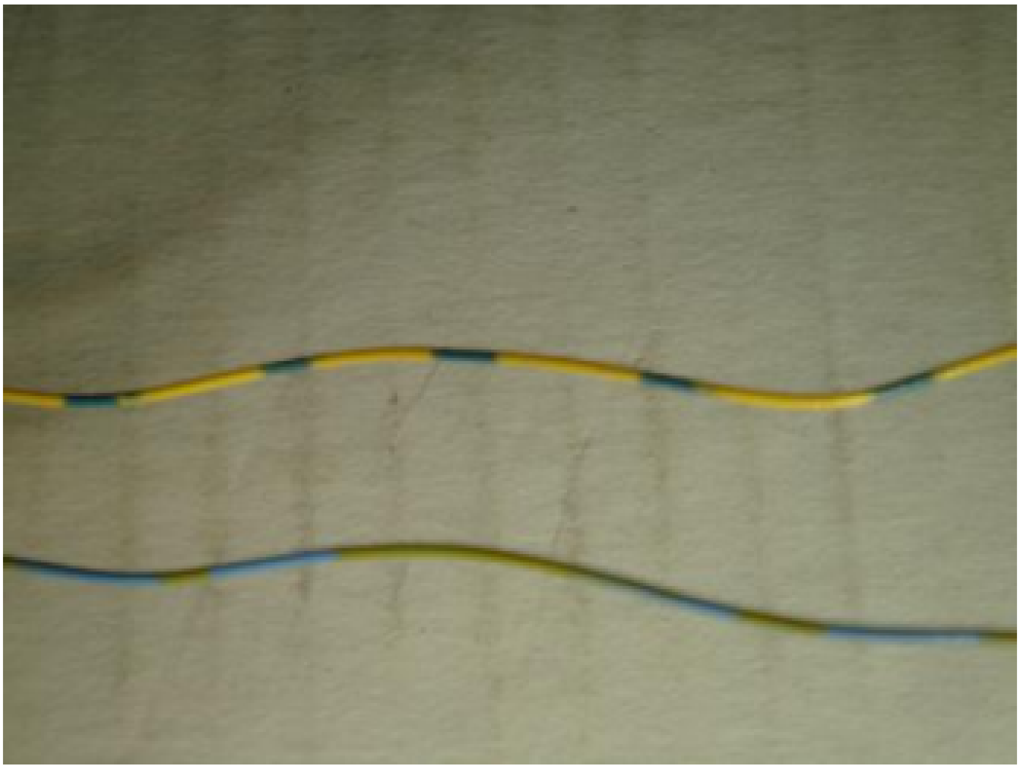

Take the two pieces of wire and **untwist** them if they are twisted. The toroid requires 12 inches of wire. You will wind the toroid with this pair of wires side by side.

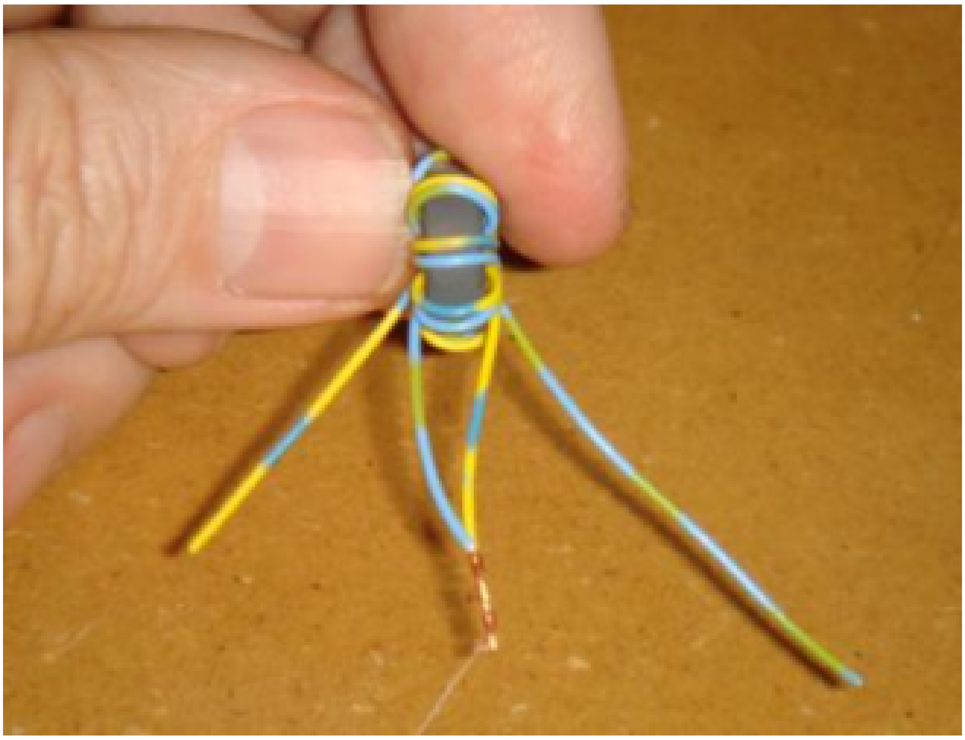

Wind the toroid with **9 turns** of the wire. Each turn through the hole in the center counts as one turn. **VERY IMPORTANT:** You must take one wire **from each side of the winding** and twist them together. This makes the transformer windings out of phase. This is critical to operation. Connect one wire of each color.

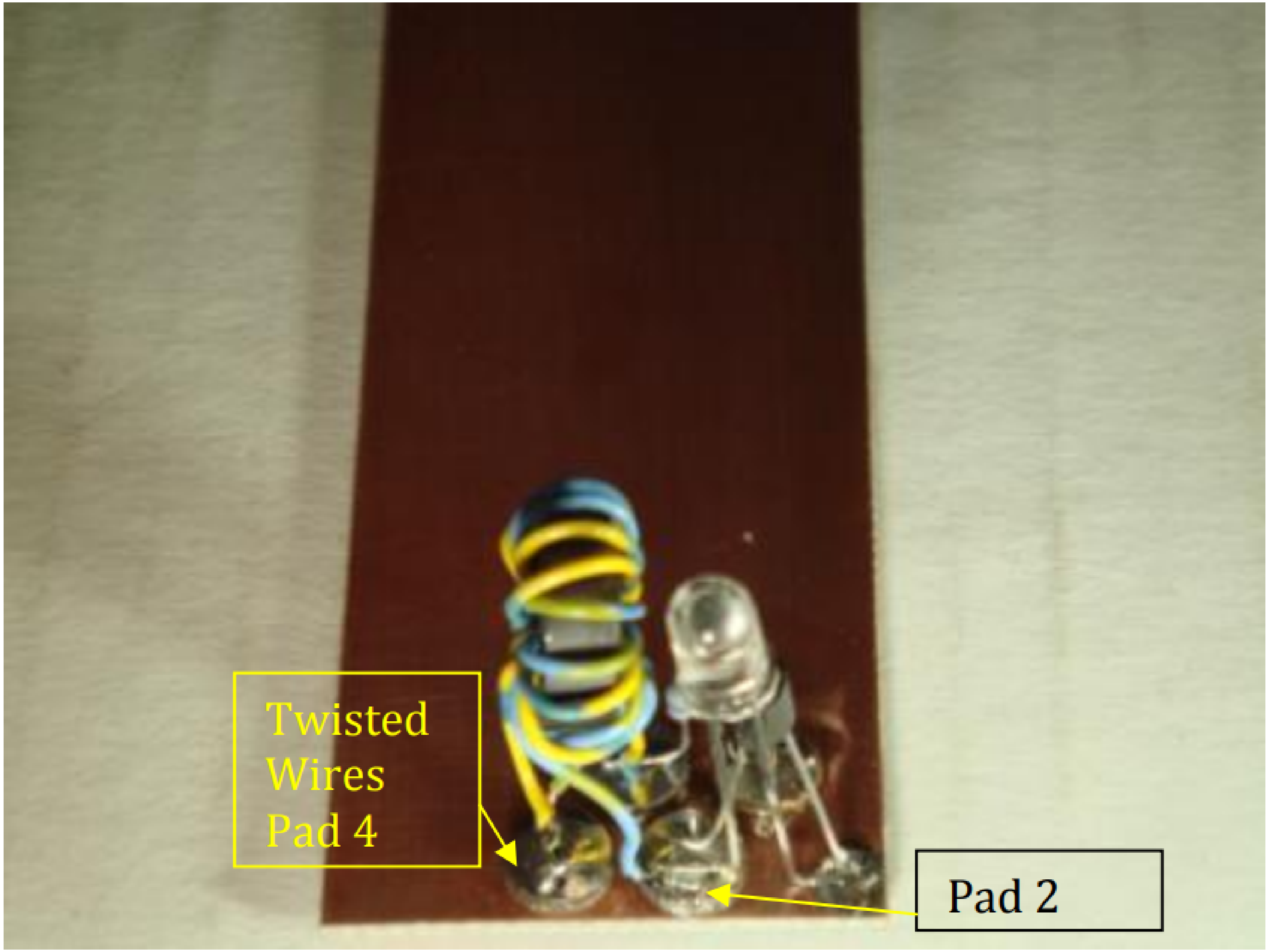
Twisted
Wires
Pad 4
Pad 2

Solder the twisted wires on the toroid to pad 4. Solder one of the other toroid wires (doesn't matter which one) to pad 2.

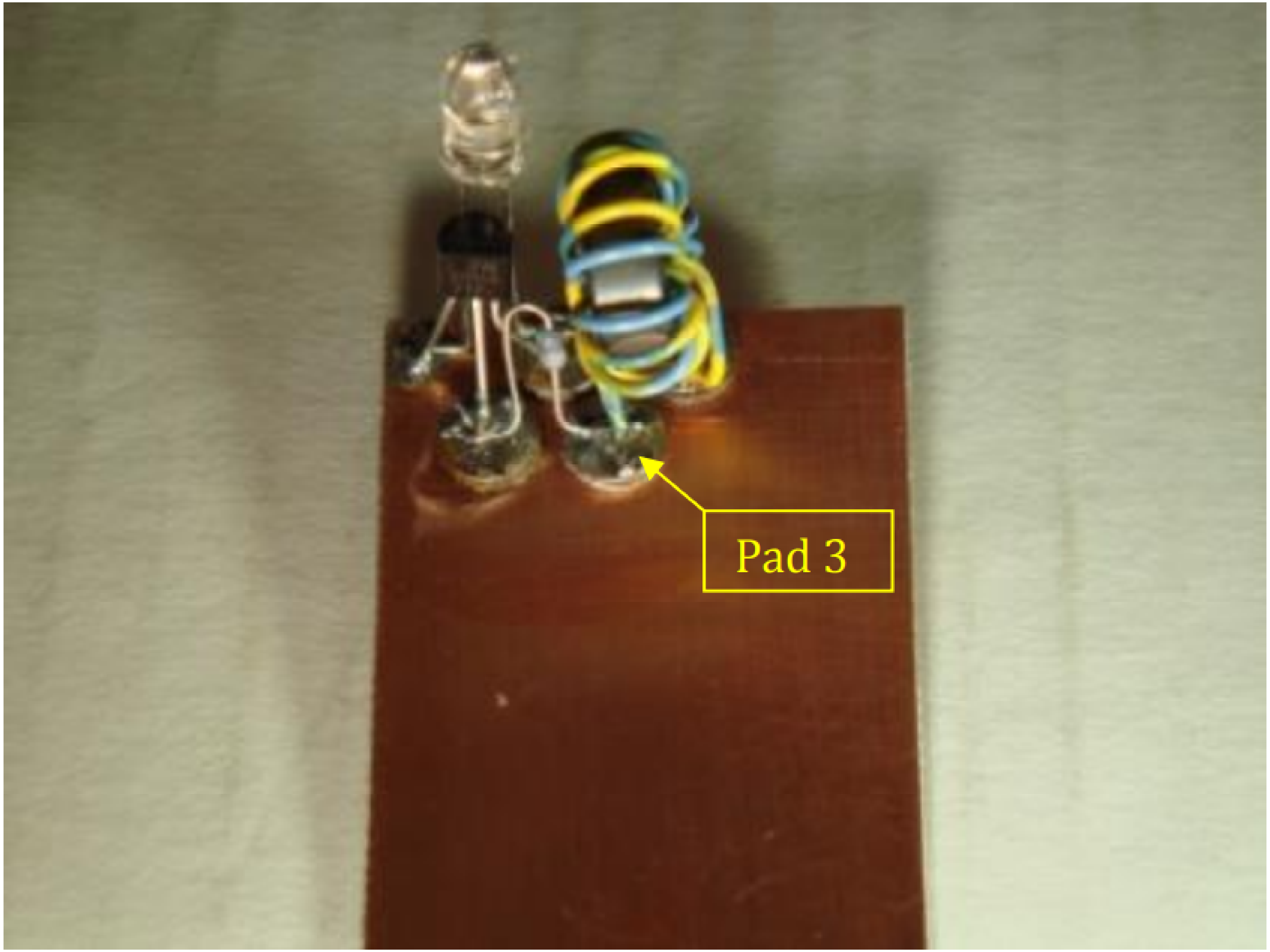

Solder the other wire on the toroid to pad 3.

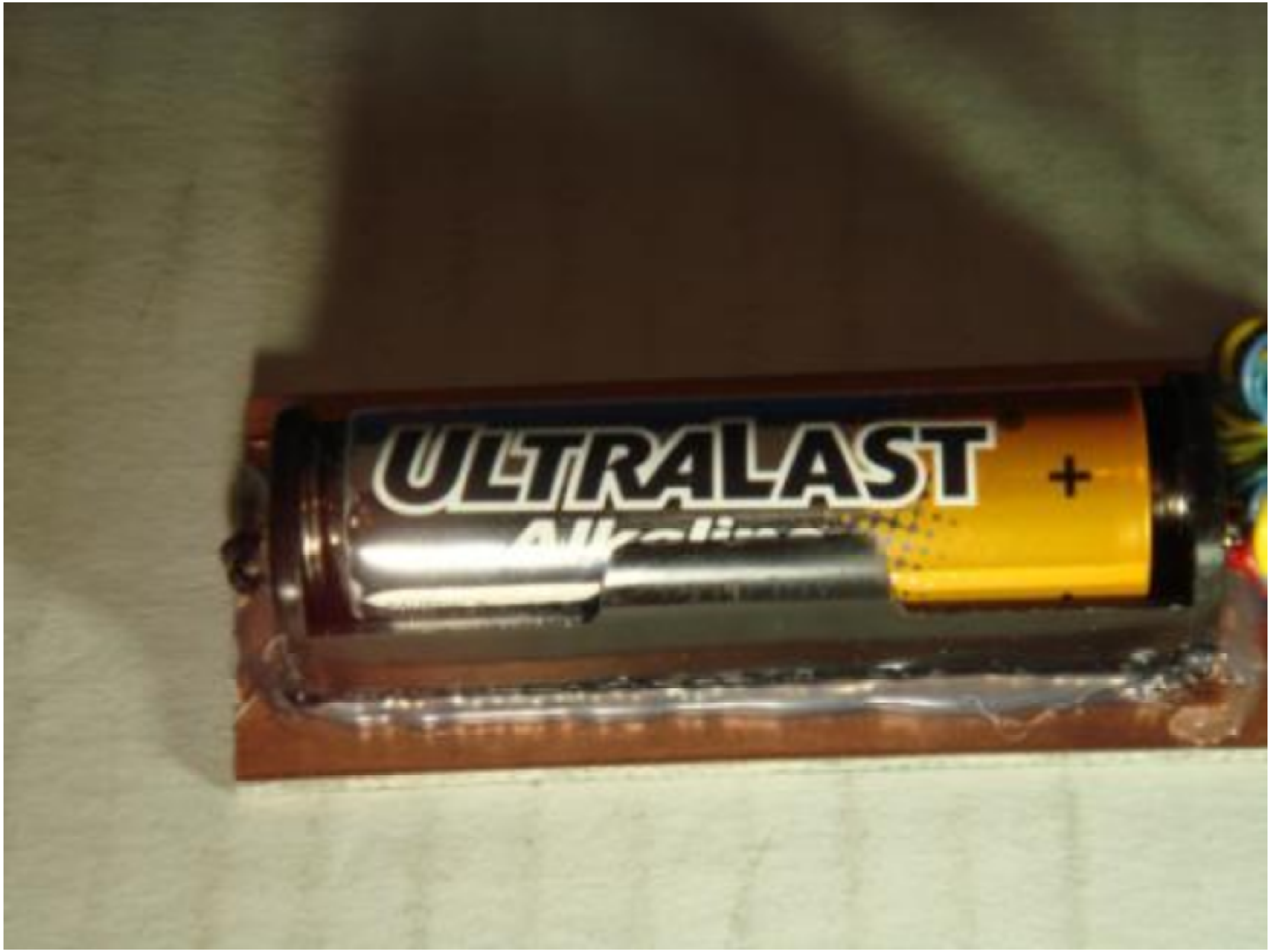

Solder the battery holder. Connect a short piece of wire from the positive terminal (the one without the spring) to pad 4. Solder the negative terminal (the one with the spring) directly to the PC board using a short piece of wire. Use hot glue or some other glue to secure the battery holder to the PC

Step 1 – Wound the Toroid

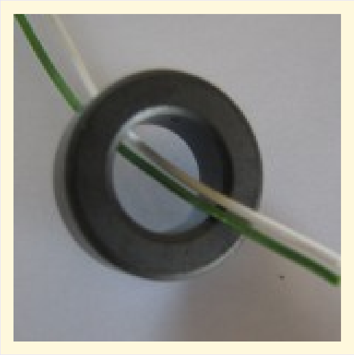
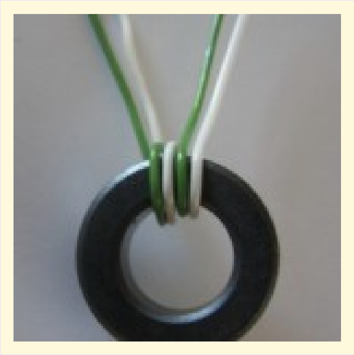
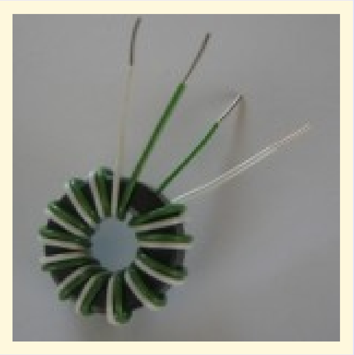

Take the two strands of plastic insulated wire and hold them together. Start off by sticking then through the middle of the toroid until you have 2 cm of wire left to make a connection with later. Keep the two wires together and wrap them around the toroid until you have covered the whole toroid. If you have wire left you can continue until you have about 2 cm of wire free on either side. Remove about a 0.5 cm of the plastic insulation on all four of the wires as in the photo. You have now wound your toroid and we are ready to continue.

Step 2 – Join the two coils of Toroid

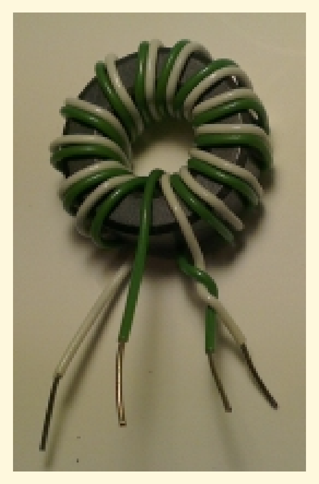

The next step is to join the two coils or windings of the toroid. You may have noticed the two dots next to the toroid windings in the circuit diagram. These two dots indicate the polarity of the transformer and as you can see the two windings are opposite to each other. To make sure that the polarity of our toroid windings are correct we must do the following:

- If we look at the toroid we noticed that we have two wires of different colours sticking out at both ends of the toroid.
- Take one wire of a specific colour (green in the example) on the one side of the toroid and one wire of the other colour (white in the example) on the other side of the toroid and connect (or solder) them together. These two wires forms the top pole of the toroid as in the circuit diagram and is connected to the positive terminal of the battery.

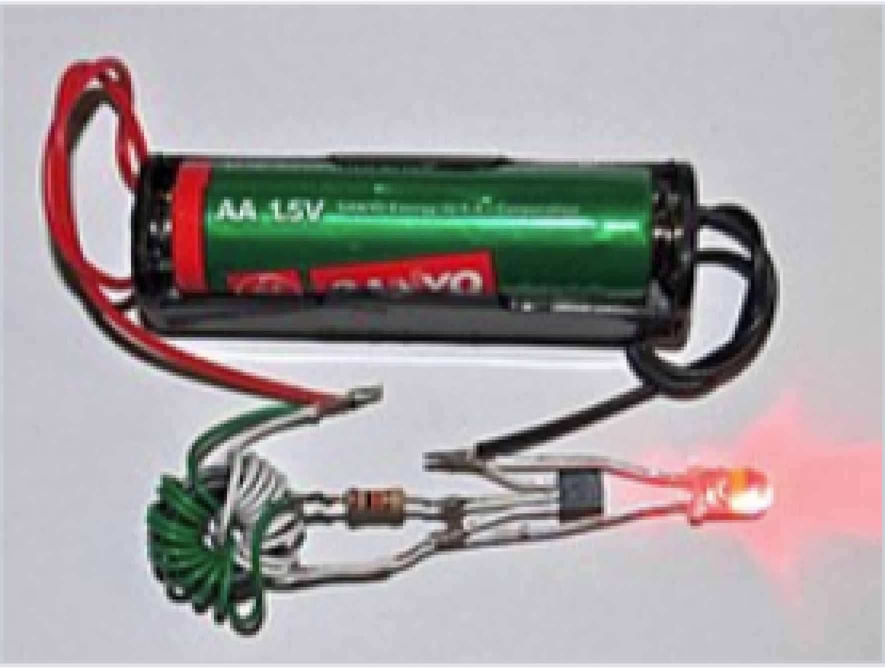

A conventional joule thief, shows components and how they are connected. This example uses a red LED. A ferrite toroid is wound to form a coil with primary (white) and feedback (green) windings. A 2N2222A transistor and 1000 ohm resistor are used.

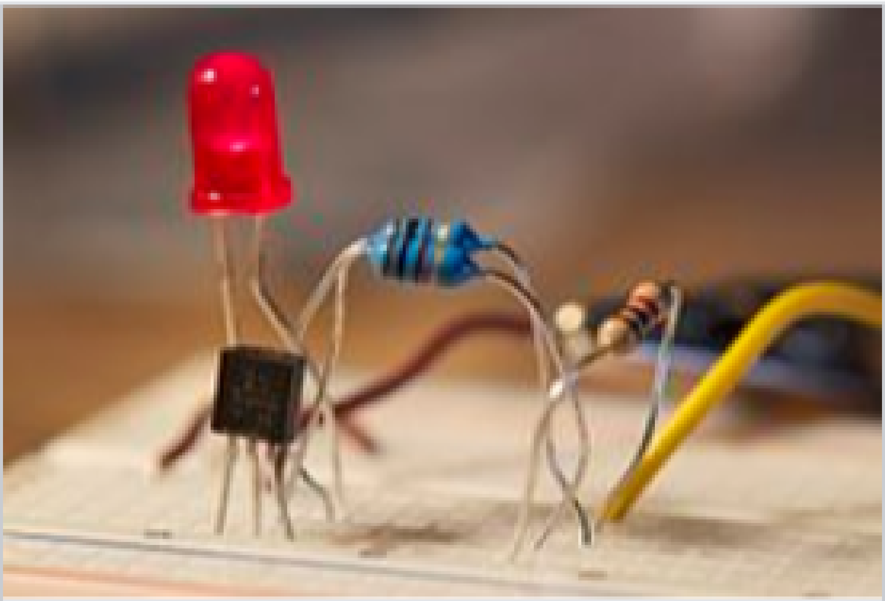

A joule thief with two axial inductors replacing the ferrite toroid, shown on a solderless breadboard

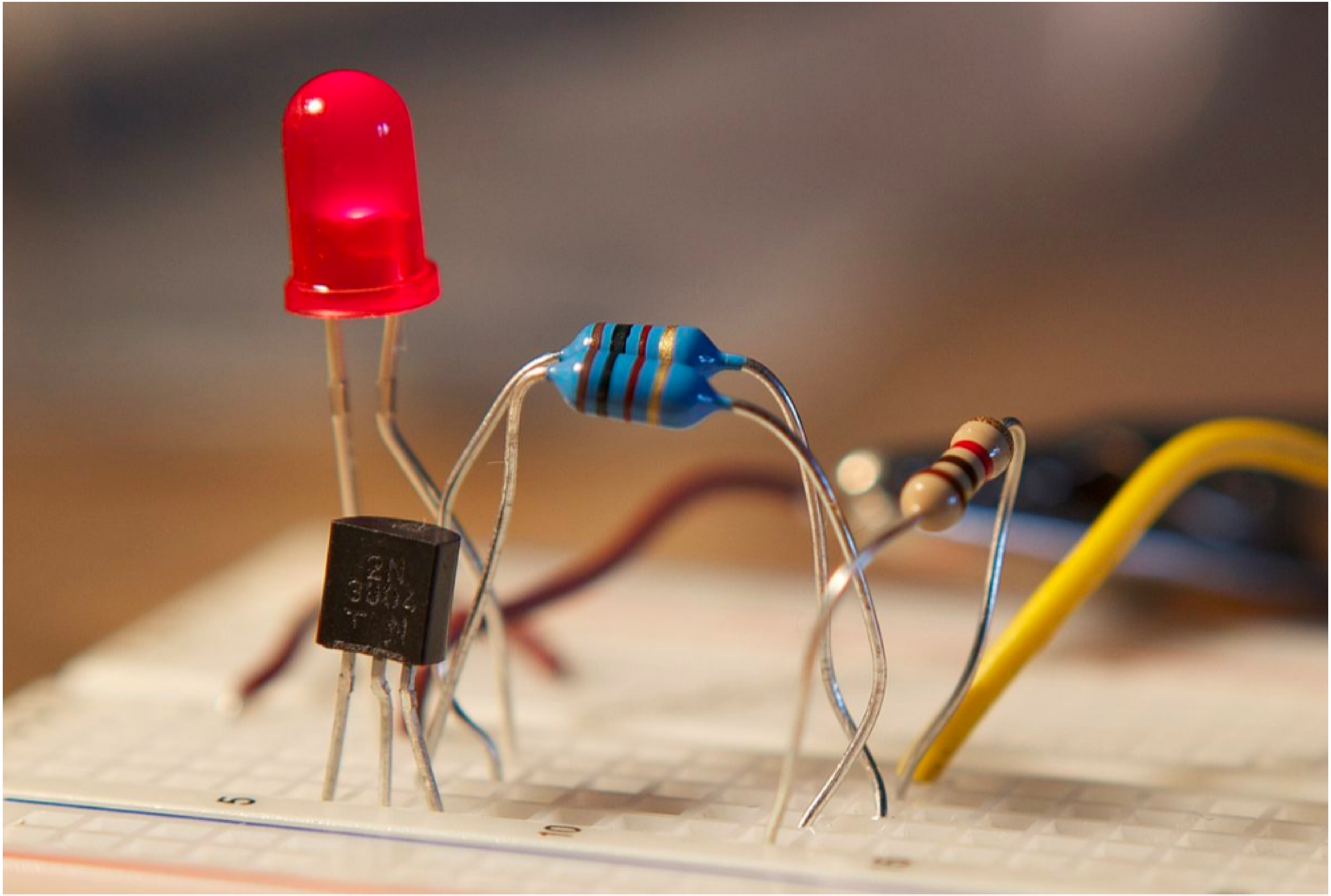
2N
3904
5
10

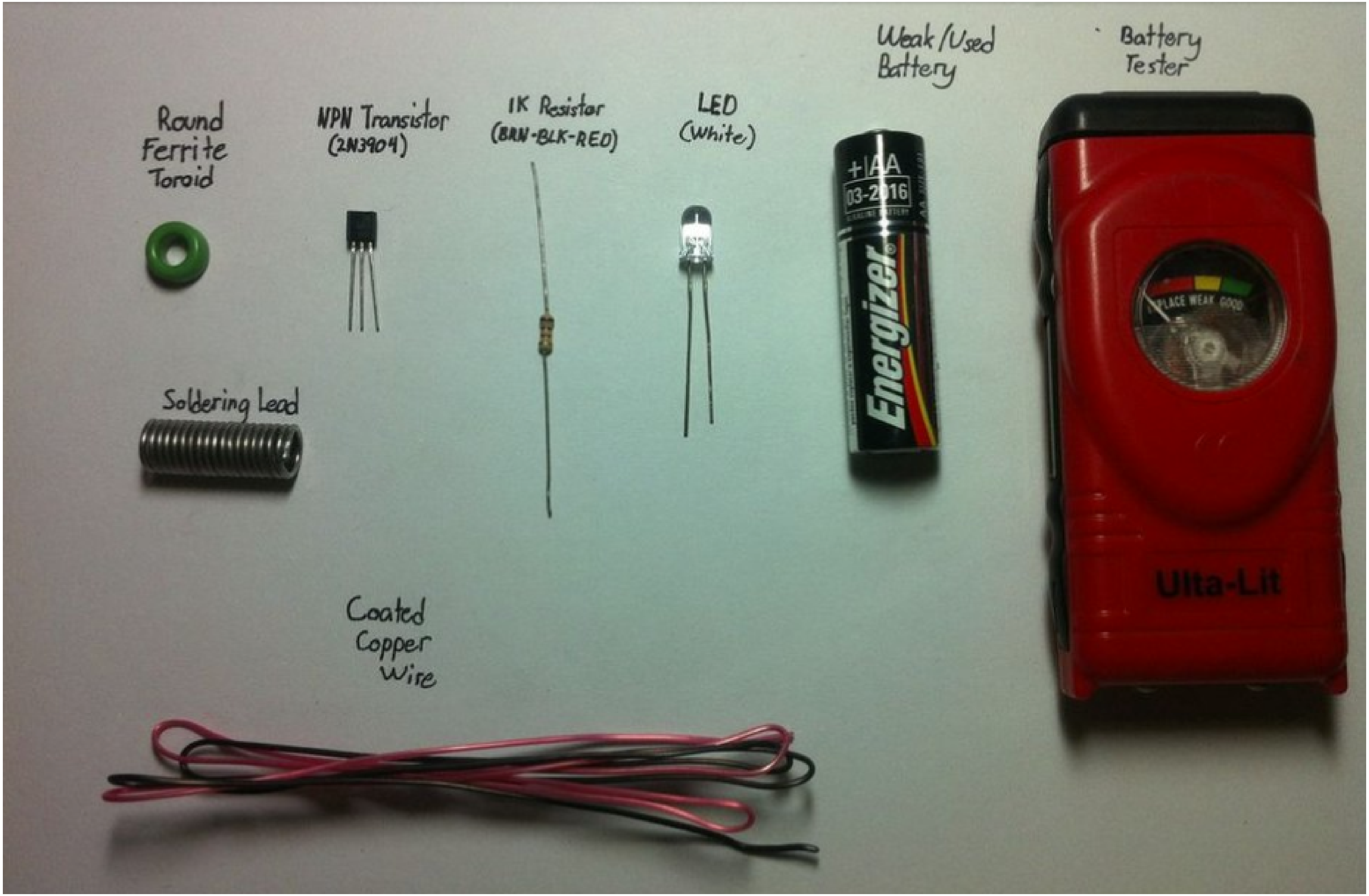
Round Ferrite Toroid
NPN Transistor (2N3904)
1K Resistor (BRN-BLK-RED)
LED (White)
Weak/Used Battery
Battery Tester
+AA
03-2016
Energizer
REPLACE WEAK GOOD
Ulta-Lit
Soldering Lead
Coated Copper Wire

Step 2: Schematic Diagrams

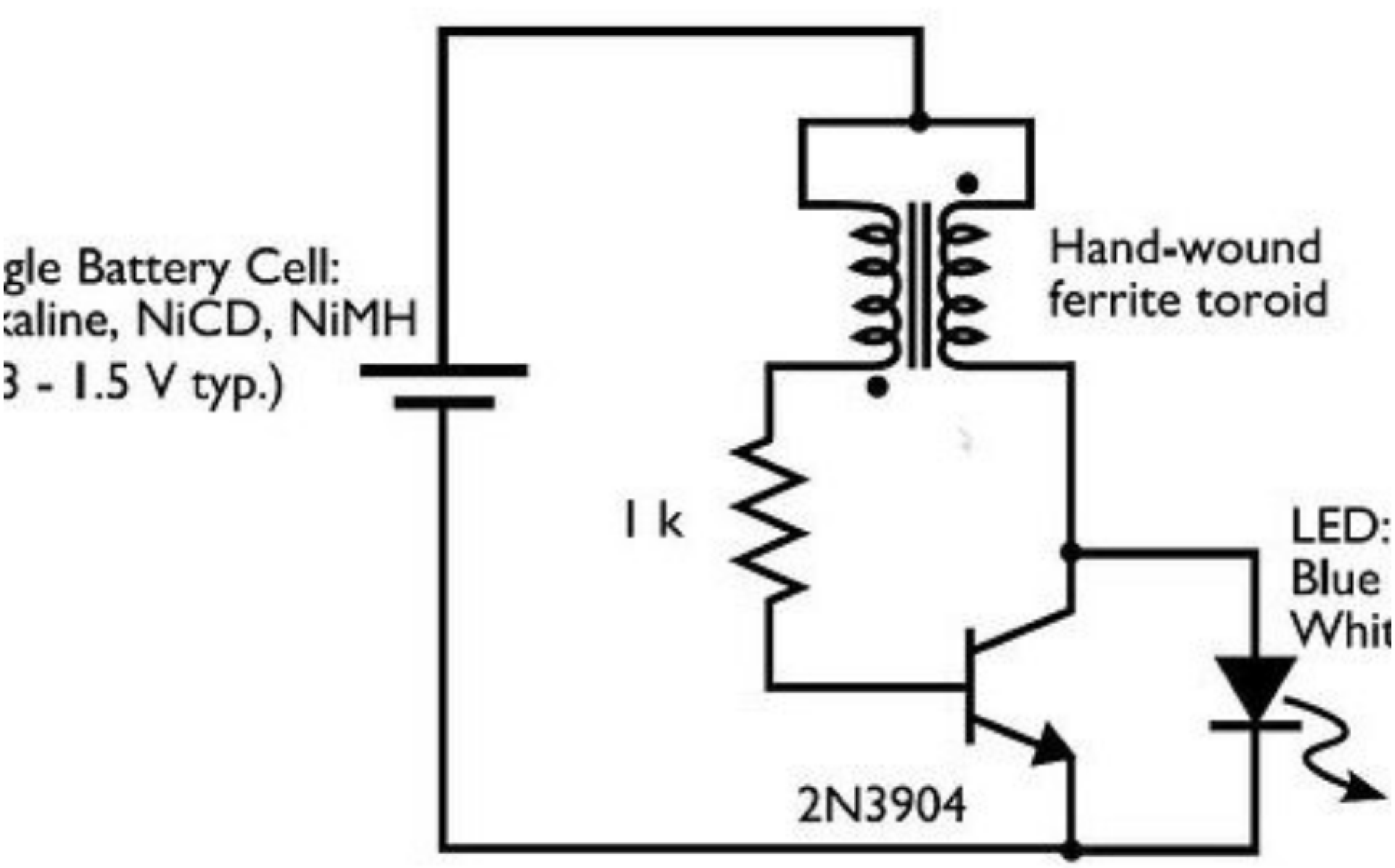
gle Battery Cell:
aline, NiCD, NiMH
3 - 1.5 V typ.)
Hand-wound
ferrite toroid
1 k
2N3904
LED:
Blue
Whit

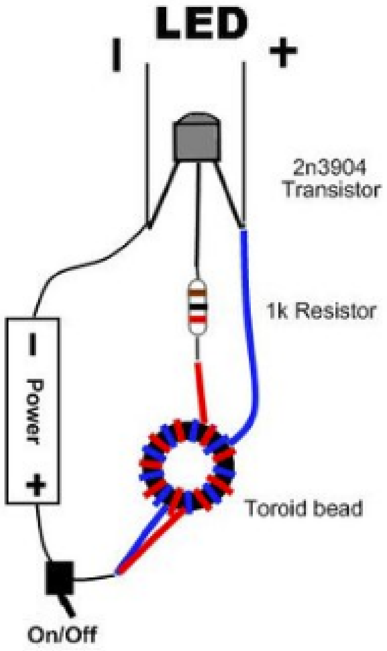
LED
I
+
2n3904
Transistor
1k Resistor
– Power +
Toroid bead
On/Off

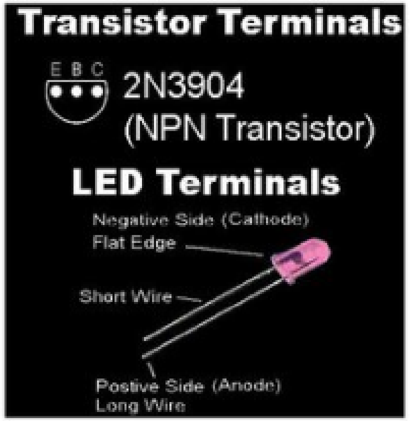
Transistor Terminals
E B C
2N3904
(NPN Transistor)
LED Terminals
Negative Side (Cathode)
Flat Edge
Short Wire
Postive Side (Anode)
Long Wire

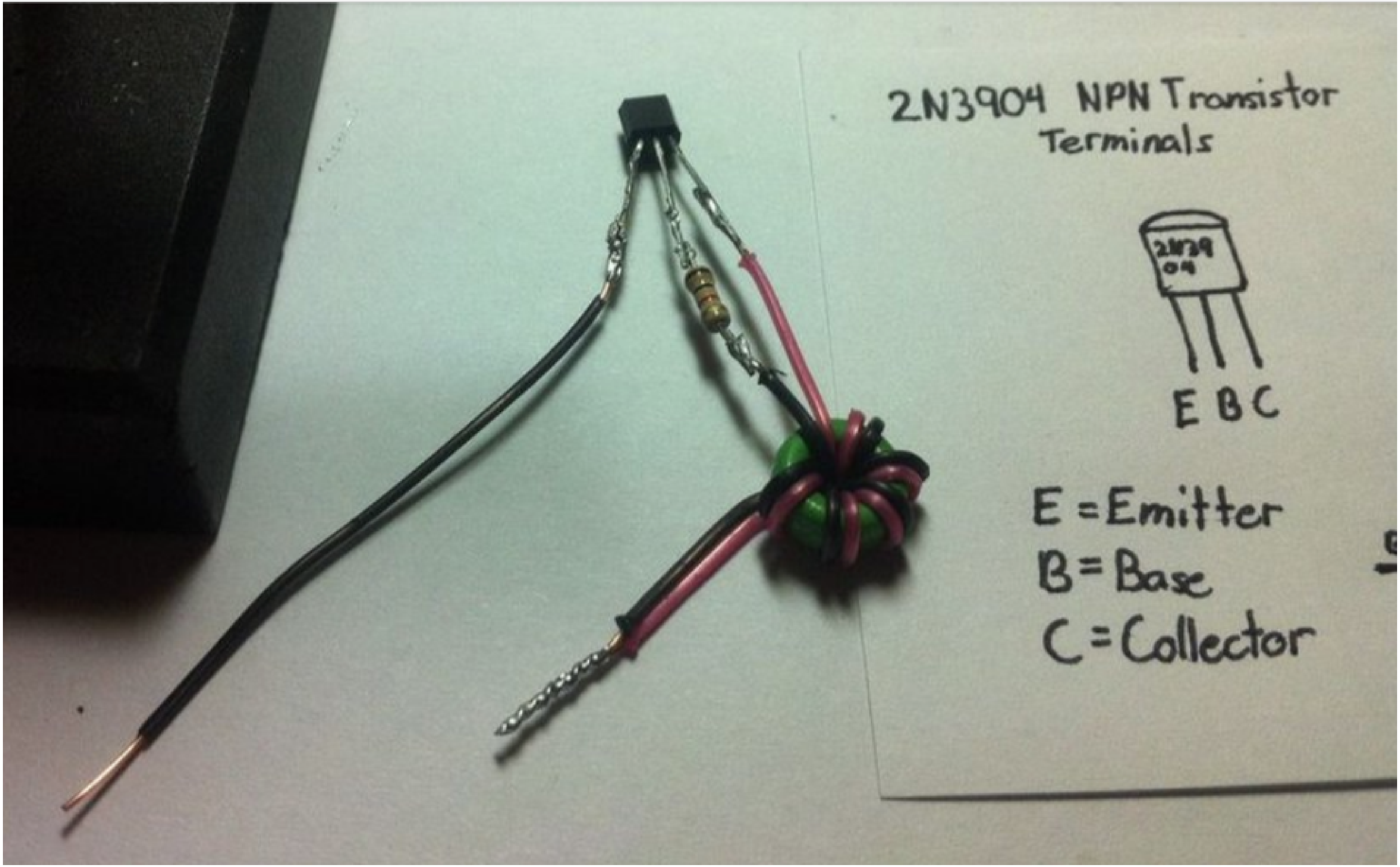
2N3904 NPN Transistor
Terminals
2N39
04
E B C
E = Emitter
B = Base
C = Collector

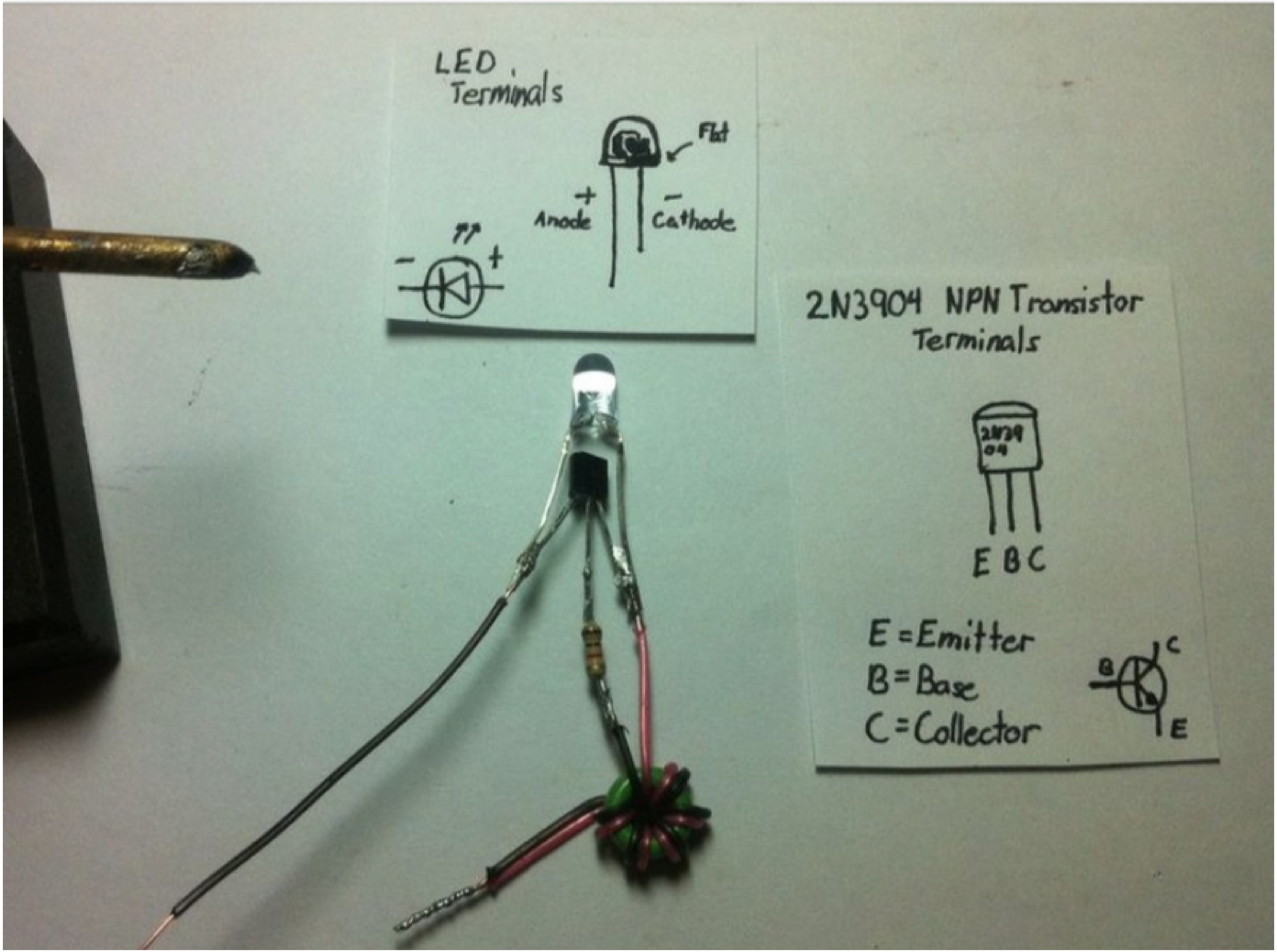
LED Terminals
Flat
+
Anode
−
Cathode
−
+
2N3904 NPN Transistor Terminals
2N39 04
E B C
E = Emitter
B = Base
C = Collector
B
C
E

These tiny T231212T toroids from Surplussales.com are high permeability so it doesn't take much wire to make a good Joule Thief coil. The core is less than a quarter inch diameter (here is a data sheet in .PDF.). Six inches of 30 AWG magnet wire trifilar wound, with two of the windings connected in parallel for the primary winding.

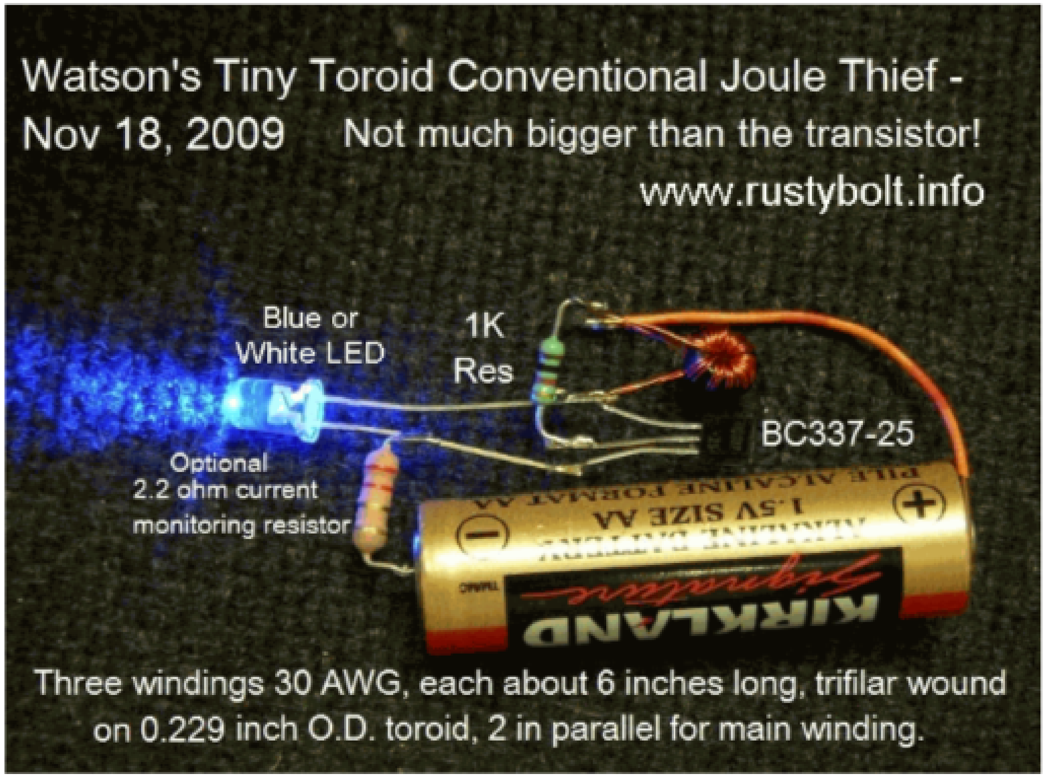
Watson's Tiny Toroid Conventional Joule Thief - Nov 18, 2009
Not much bigger than the transistor!
www.rustybolt.info
Blue or White LED
1K Res
BC337-25
Optional 2.2 ohm current monitoring resistor
Three windings 30 AWG, each about 6 inches long, trifilar wound on 0.229 inch O.D. toroid, 2 in parallel for main winding.

The transistor is a BC337-25. I put a 2.2 ohm resistor in series with the circuit to measure the battery current. It can be put there temporarily and removed when the LED current is what you want. How do you change the LED current? Change the 1k resistor to a different value. Higher values will reduce the LED current. With the BC337-25 and 1k resistor, the LED current should be close to 20 milliamps so it's probably not wise to go much below 1k. If you use another transistor, especially the pipsqueak 2N3904, you may have a hard time getting it to put out 20 milliamps.

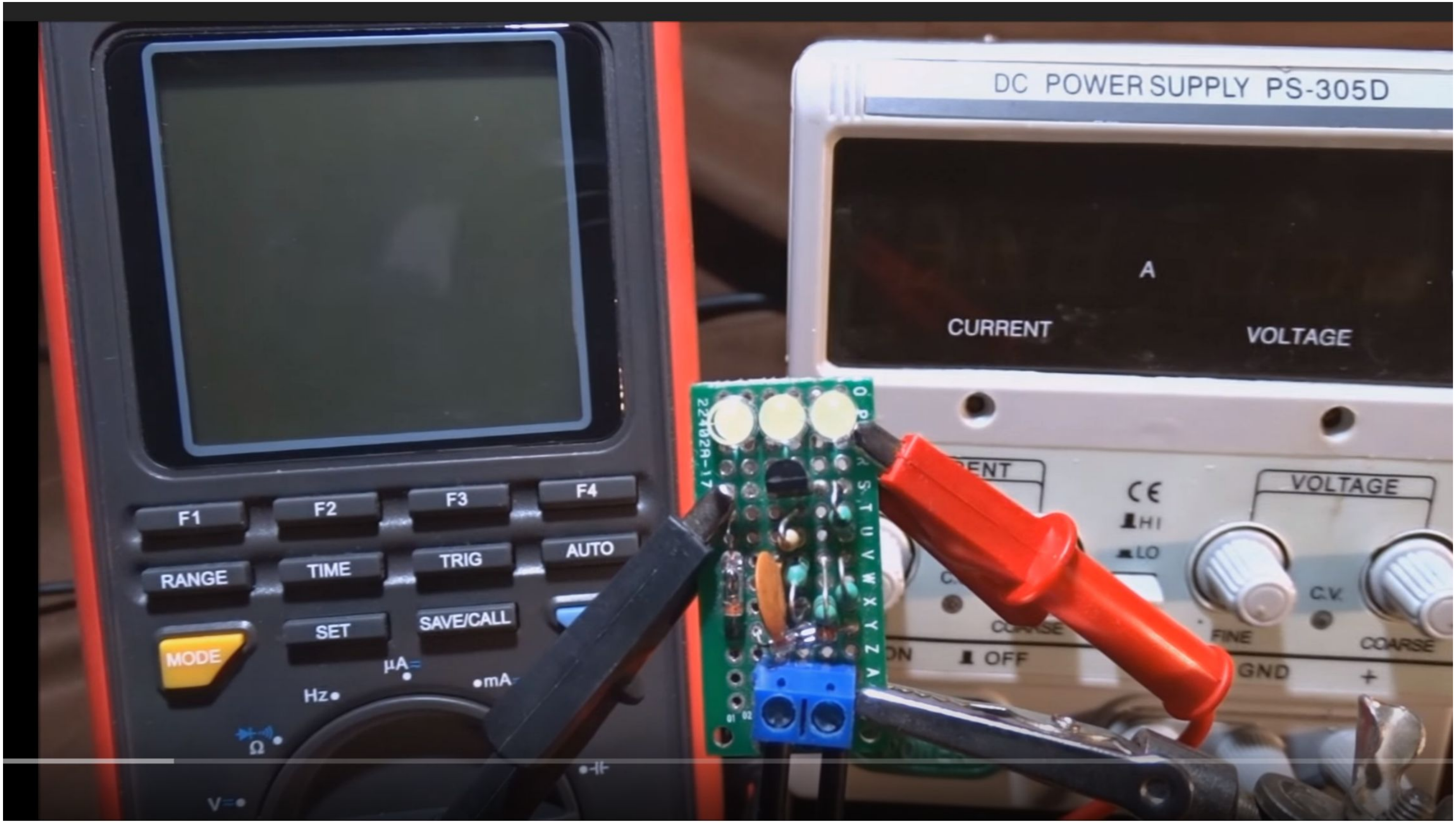
DC POWER SUPPLY PS-305D
A
CURRENT
VOLTAGE
VOLTAGE
C.V.
FINE
COARSE
GND
+
OFF
HI
LO
F1
F2
F3
F4
RANGE
TIME
TRIG
AUTO
MODE
SET
SAVE/CALL
μA
mA
Hz
Ω
V
22402A-17
O P Q R S T U V W X Y Z A

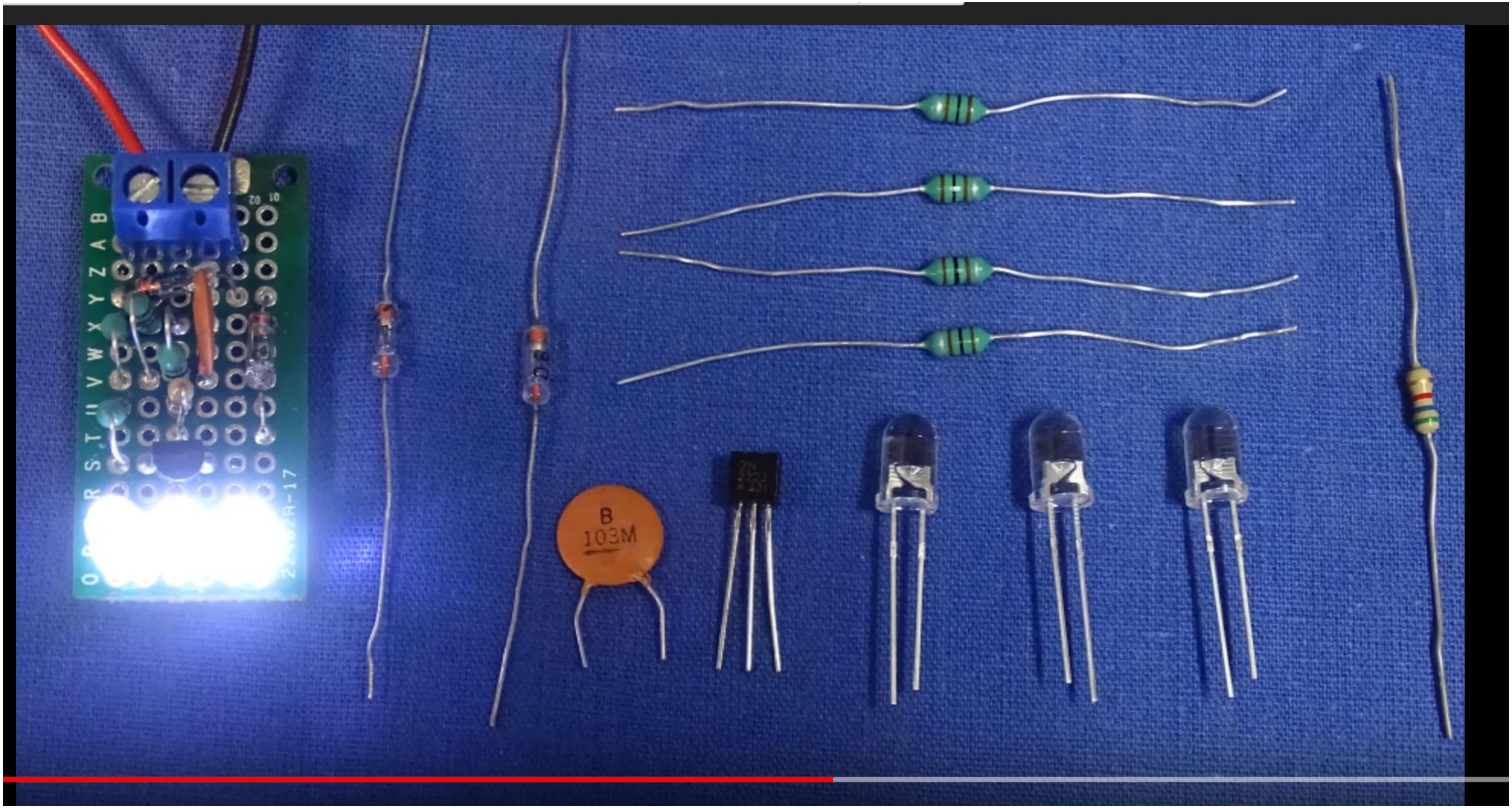
B
103M
2N
2222
A 231

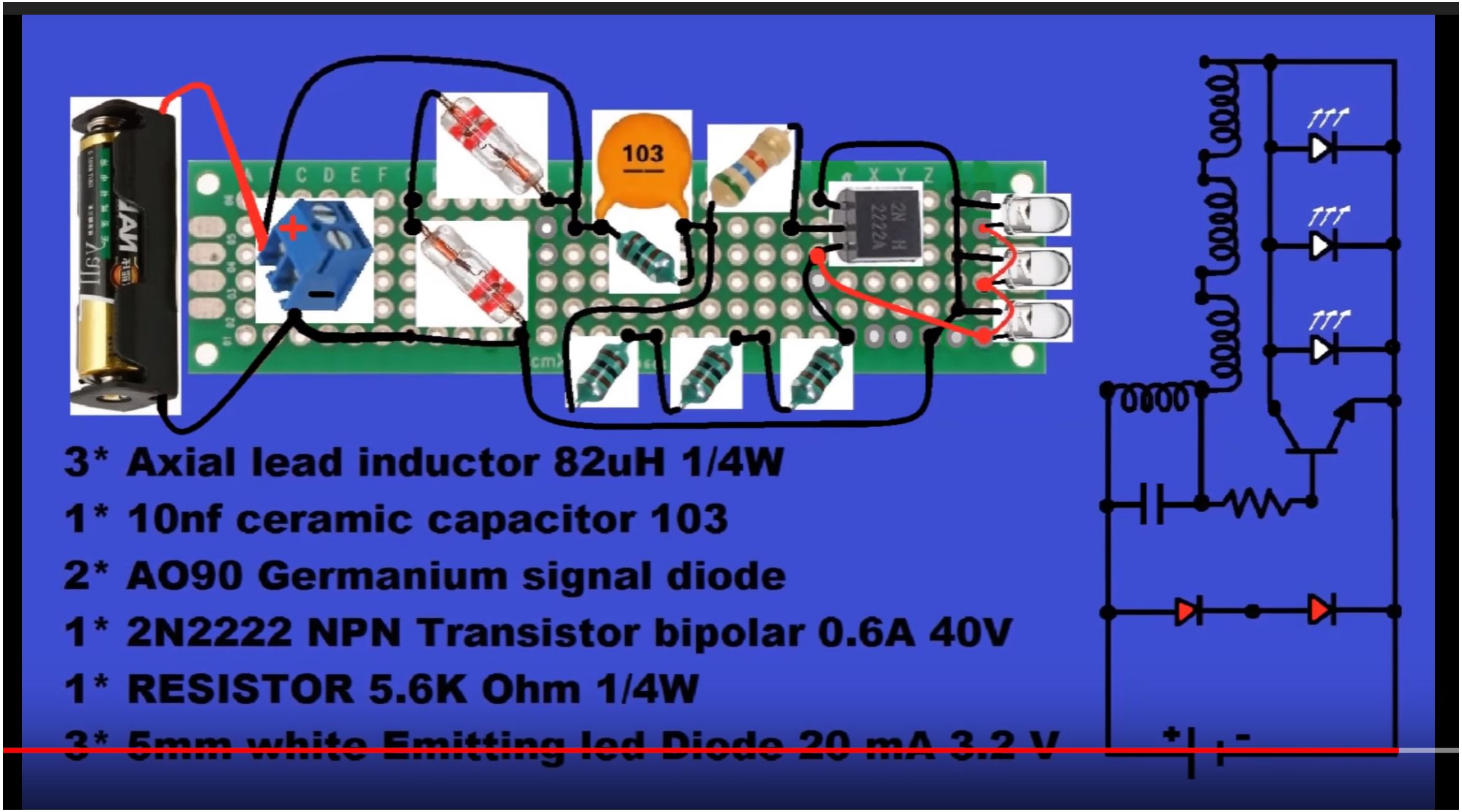

3* Axial lead inductor 82uH 1/4W

1* 10nf ceramic capacitor 103

2* AO90 Germanium signal diode

1* 2N2222 NPN Transistor bipolar 0.6A 40V

1* RESISTOR 5.6K Ohm 1/4W

3* 5mm white Emitting led Diode 20 mA 3.2 V

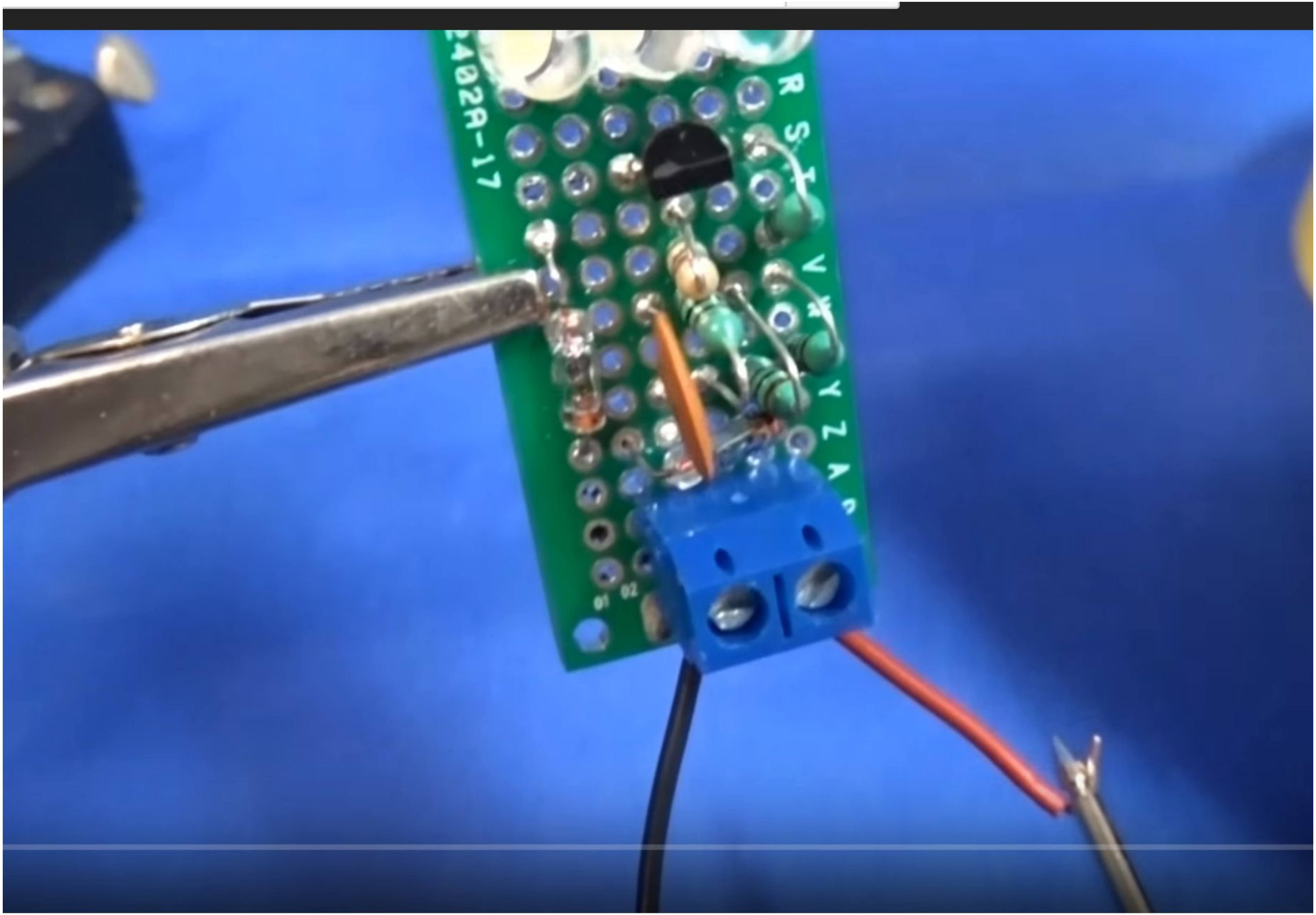
2402A-17
R
S
V
Y
Z
A
01
02

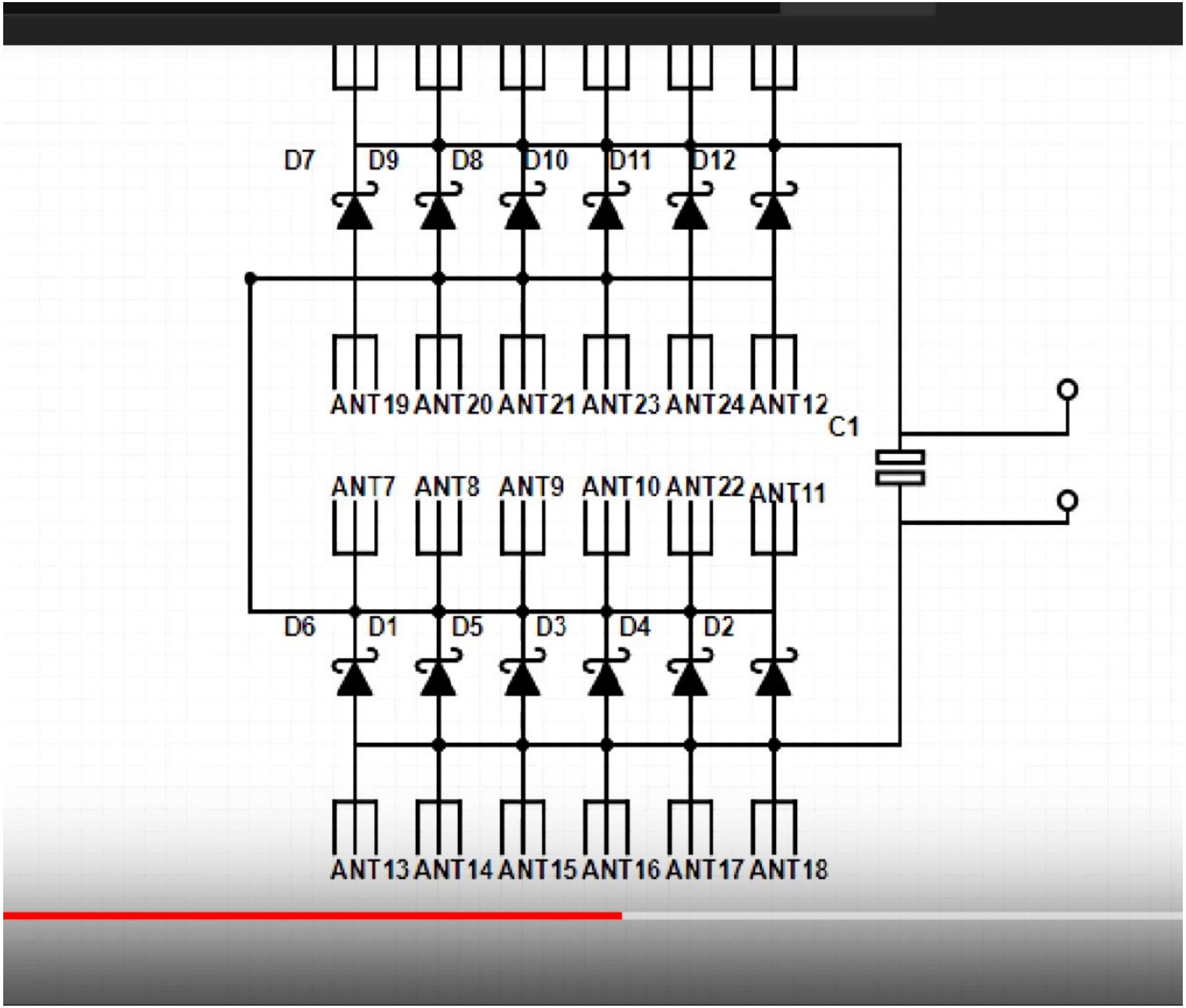
D7
D9
D8
D10
D11
D12
ANT19
ANT20
ANT21
ANT23
ANT24
ANT12
C1
ANT7
ANT8
ANT9
ANT10
ANT22
ANT11
D6
D1
D5
D3
D4
D2
ANT13
ANT14
ANT15
ANT16
ANT17
ANT18

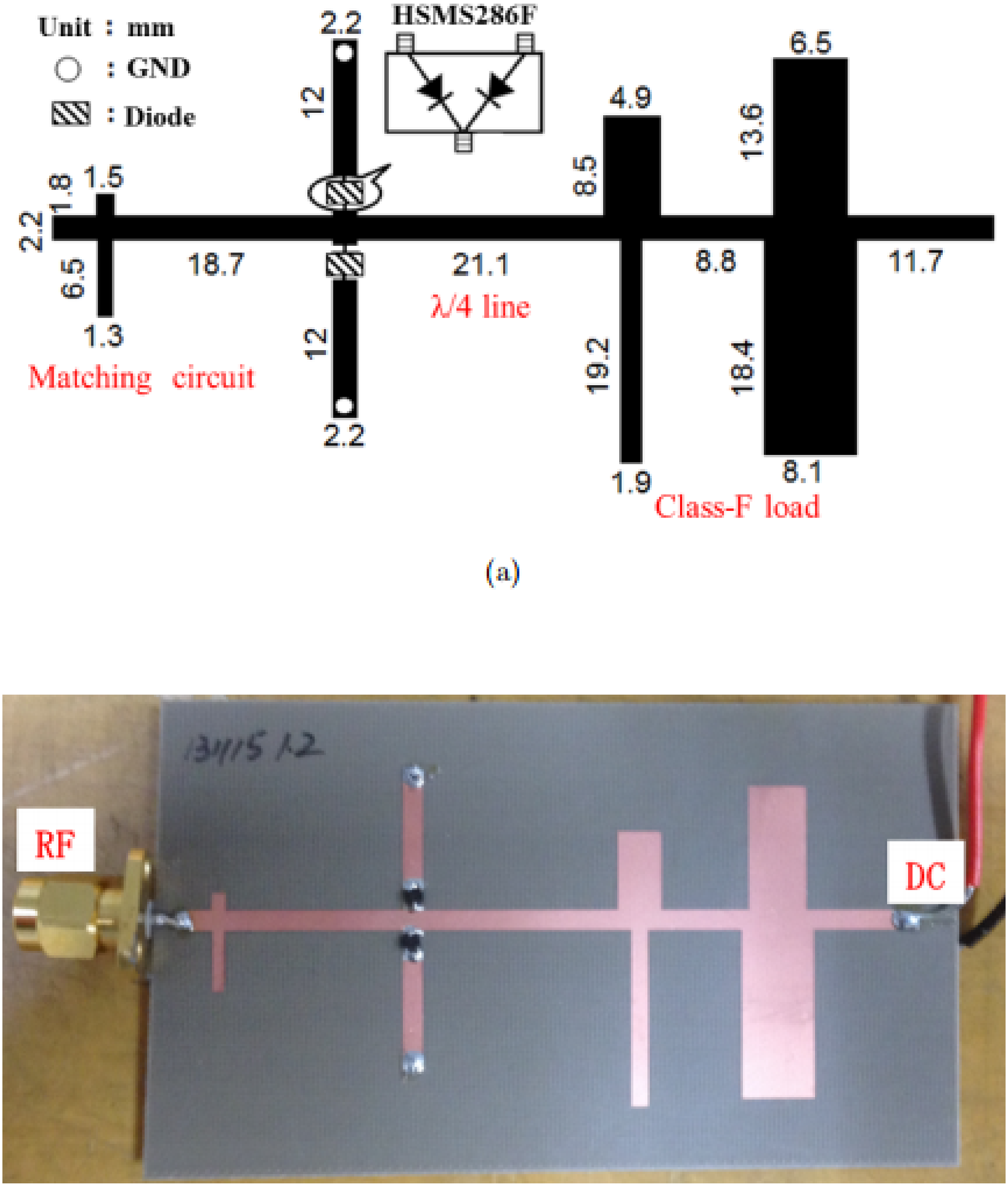
Unit : mm
○ : GND
▨ : Diode
HSMS286F
2.2
12
1.8
1.5
2.2
6.5
1.3
18.7
12
2.2
21.1
λ/4 line
Matching circuit
4.9
8.5
6.5
13.6
8.8
11.7
19.2
18.4
1.9
8.1
Class-F load
131115 12
RF
DC

(a)

(b)

Figure 4.1: Proposed positive output voltage rectifier. (a) Structure and size. (b) Photograph.

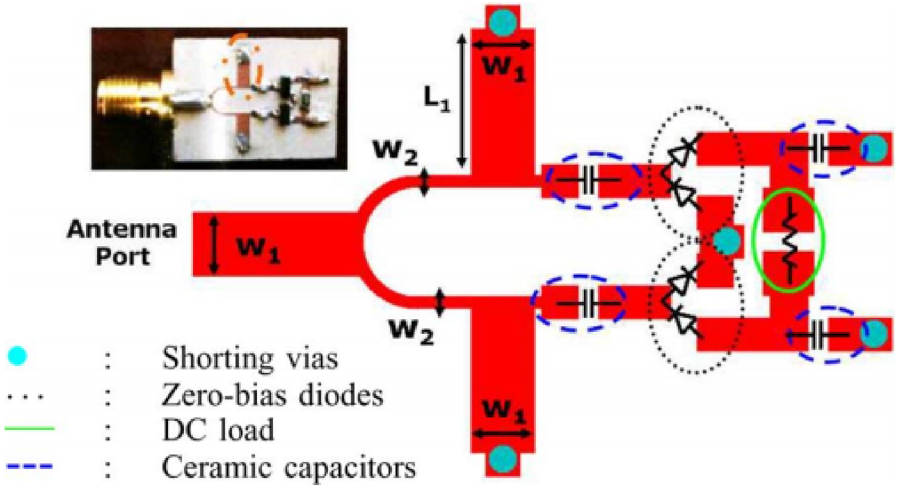
L1
W1
W2
Antenna Port
W1
W2
W1
Shorting vias
Zero-bias diodes
DC load
Ceramic capacitors

Fig. 3. Layout of the rectifier prototype, printed on RO3206. $w_1 = 72$ mil, $w_2 = 15$ mil, and $L_1 = 171$ mil. Fabricated sample is shown in top left, and the impedance matching stub is encircled.

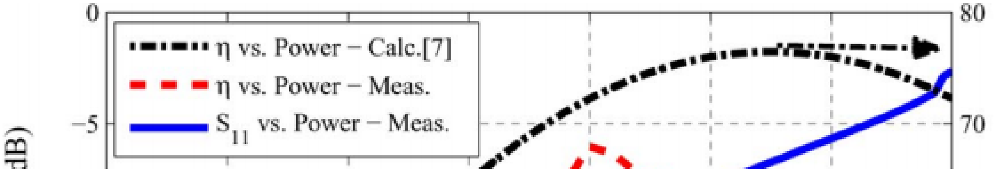

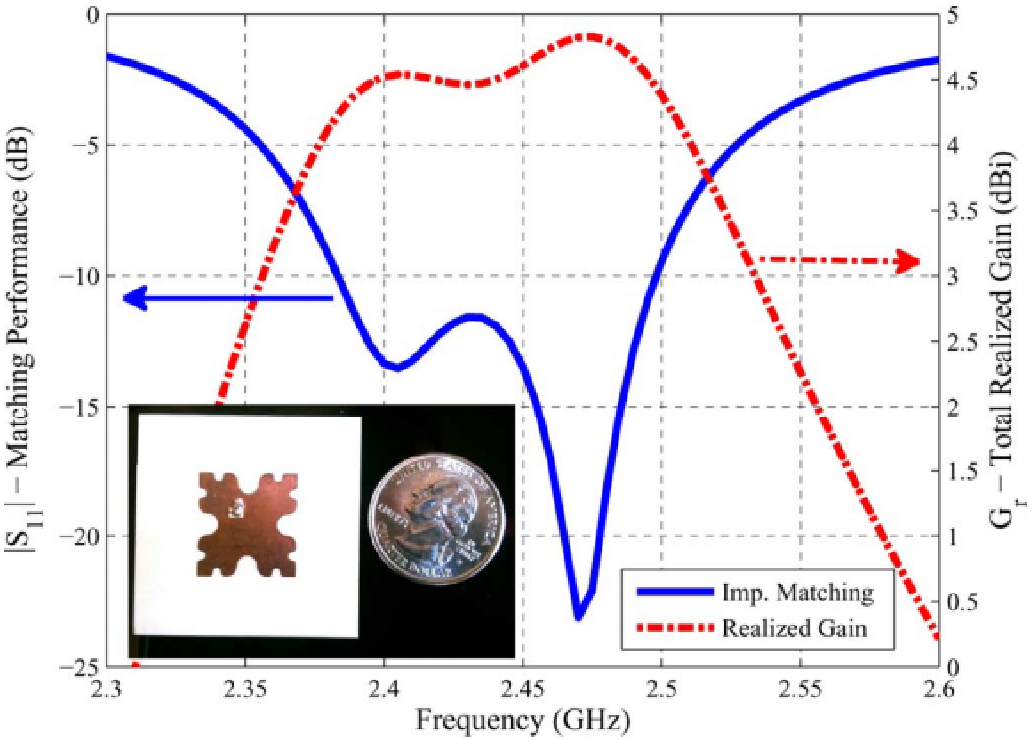

Fig. 5. Measured $|S_{11}|$ performance and total realized gain (at boresight) of the proposed antenna. Fabricated sample is shown in bottom left.

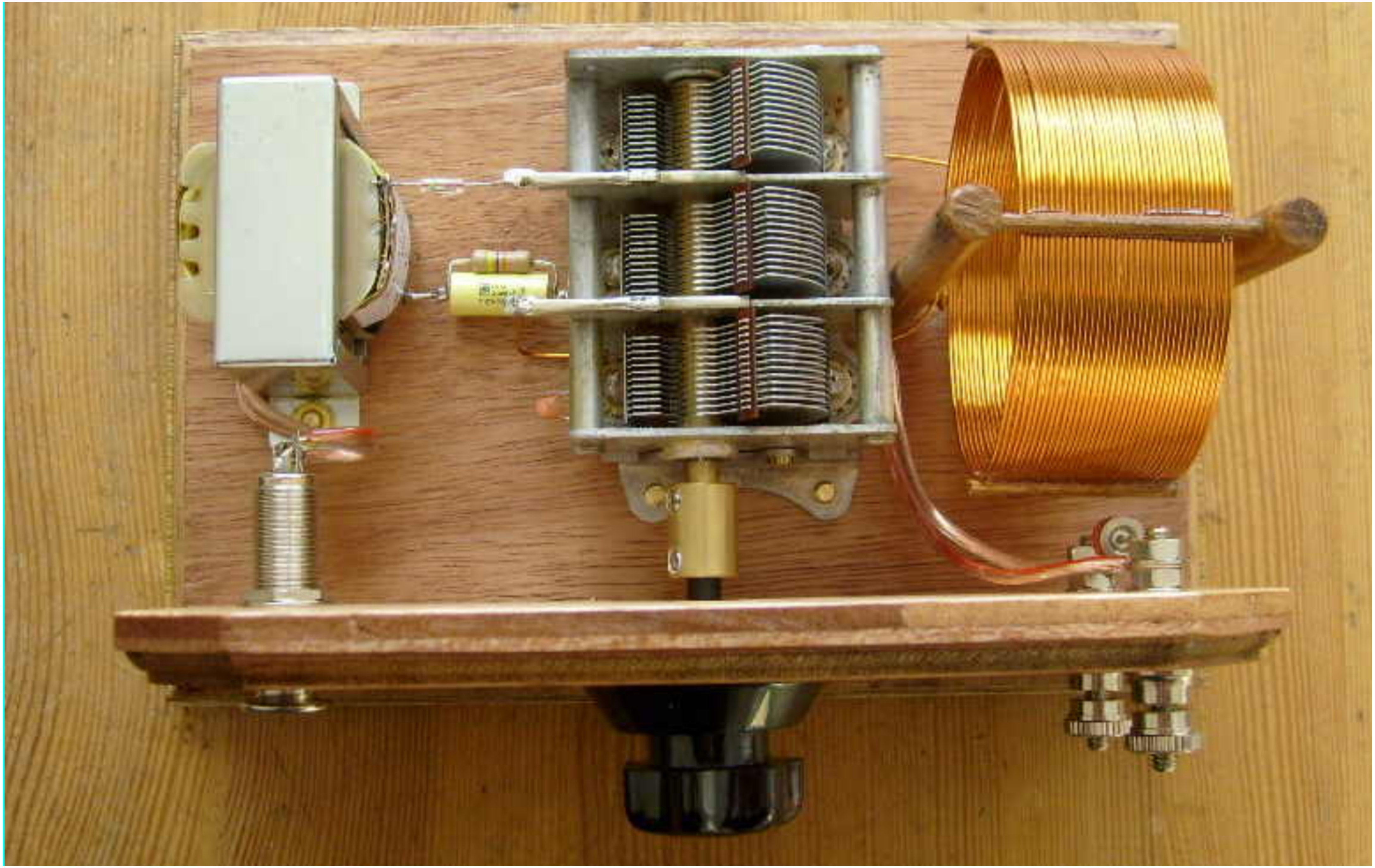

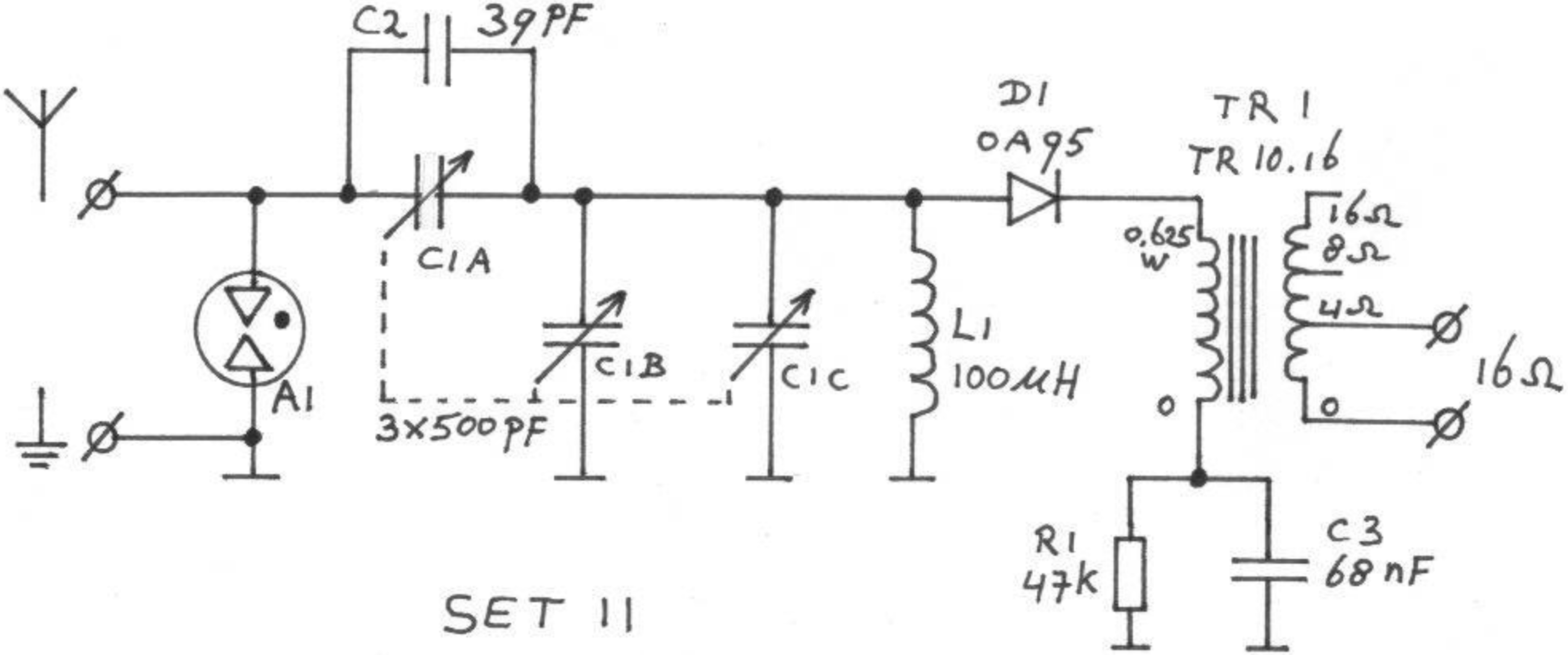
C2
39PF
D1
0A95
TR1
TR 10.16
0.625 W
16Ω
8Ω
4Ω
16Ω
C1A
C1B
C1C
L1
100μH
A1
3×500PF
o
o
R1
47k
C3
68nF

SET 11

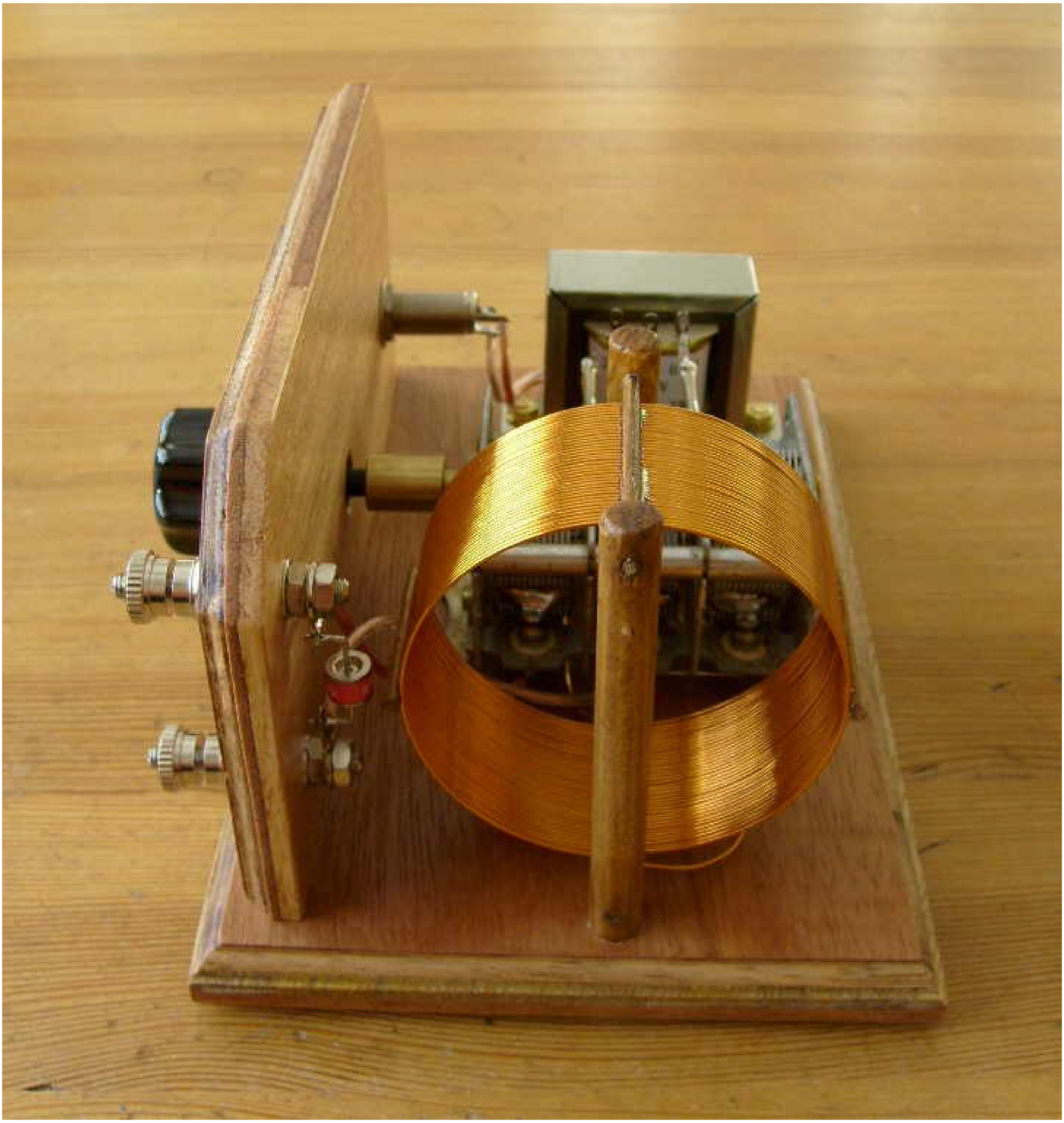

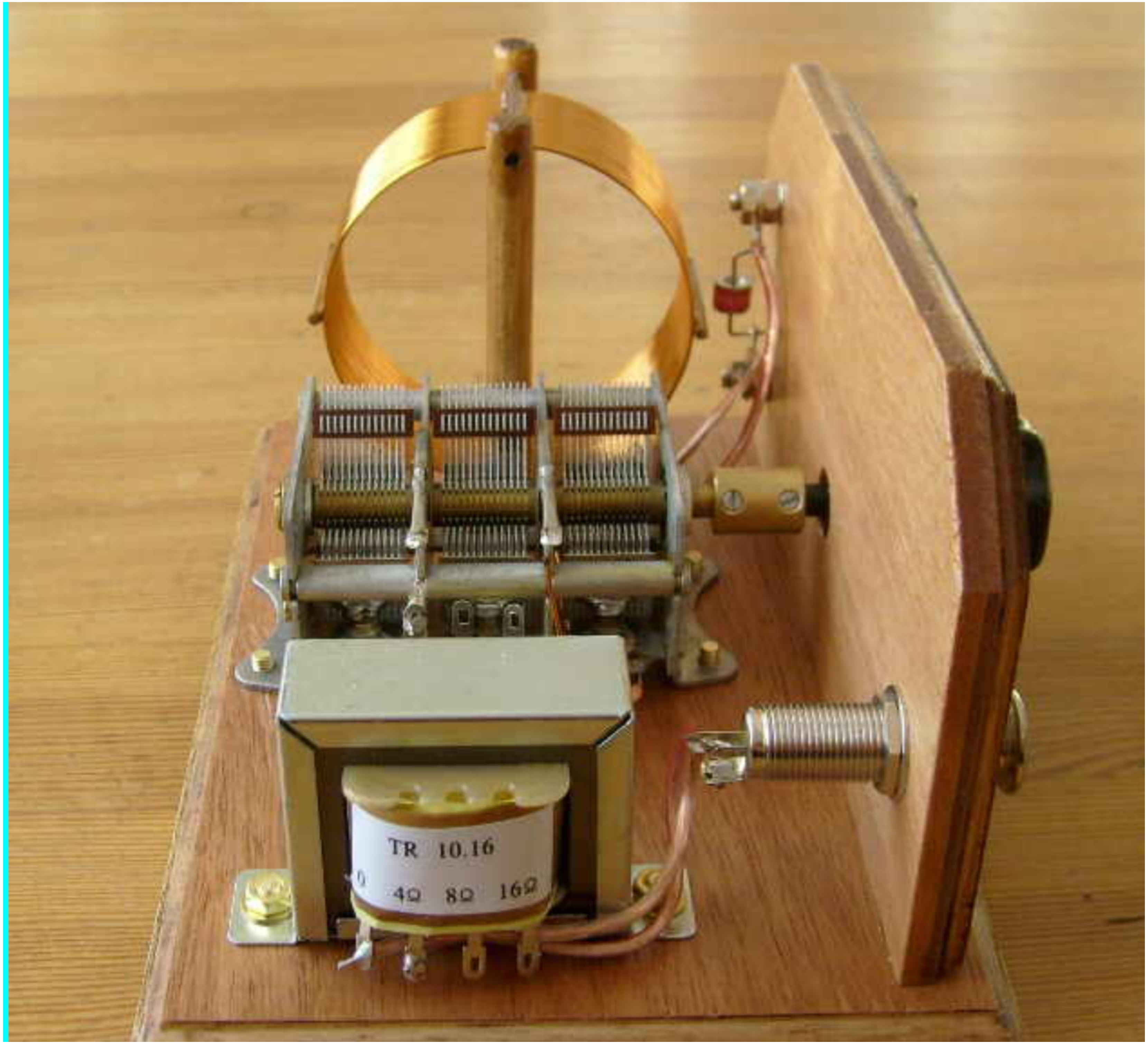
TR 10.16
0 4Ω 8Ω 16Ω

Preparation of the tuning capacitor

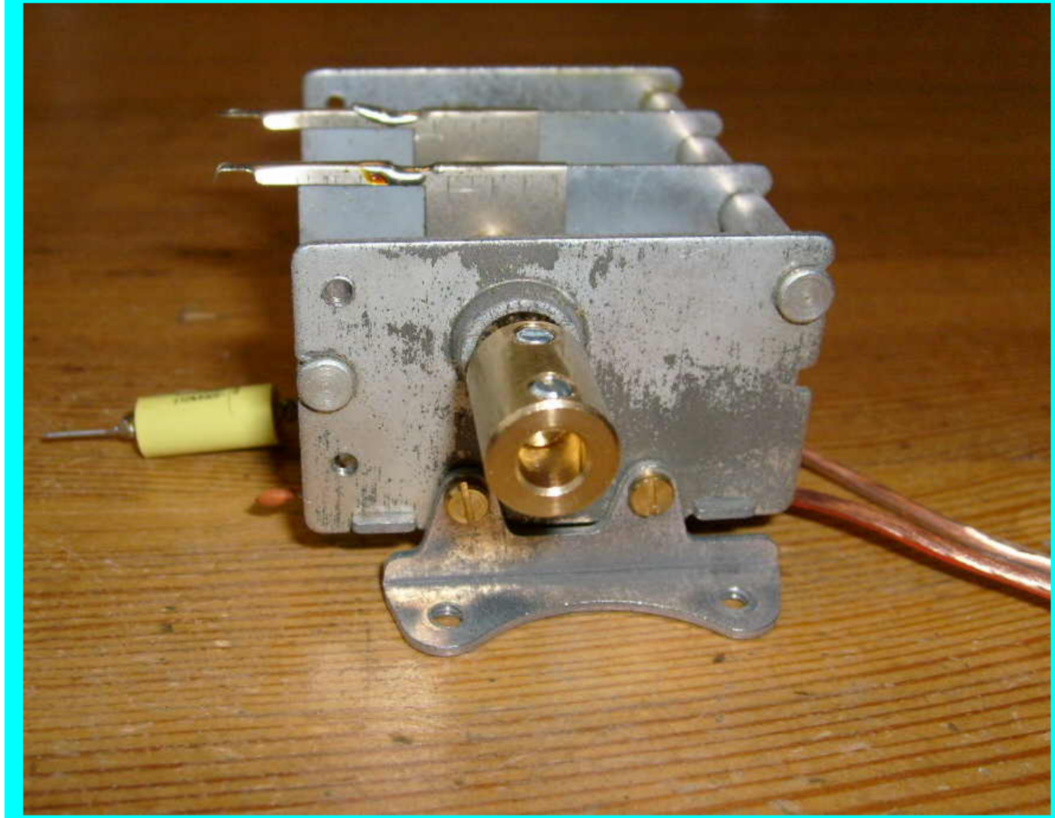

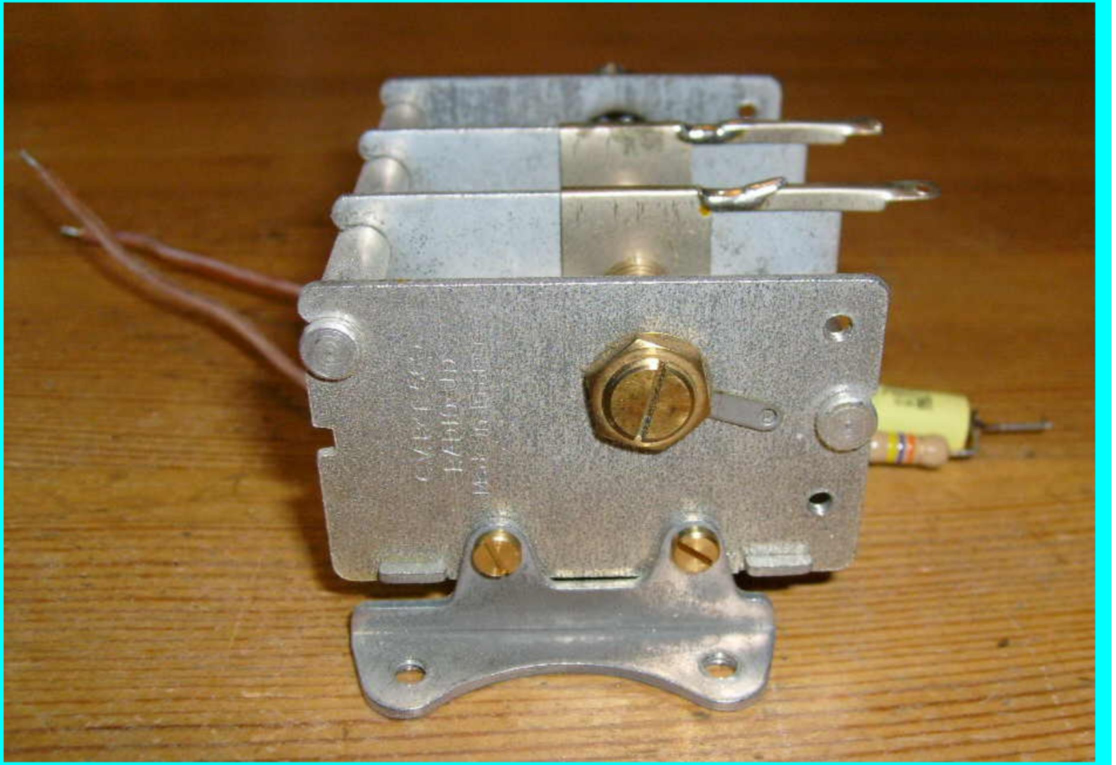

Mount the mounting supports on the tuning capacitor (they are delivered with the tuning capacitor).
Place the shaft coupler on the shaft of the tuning capacitor.

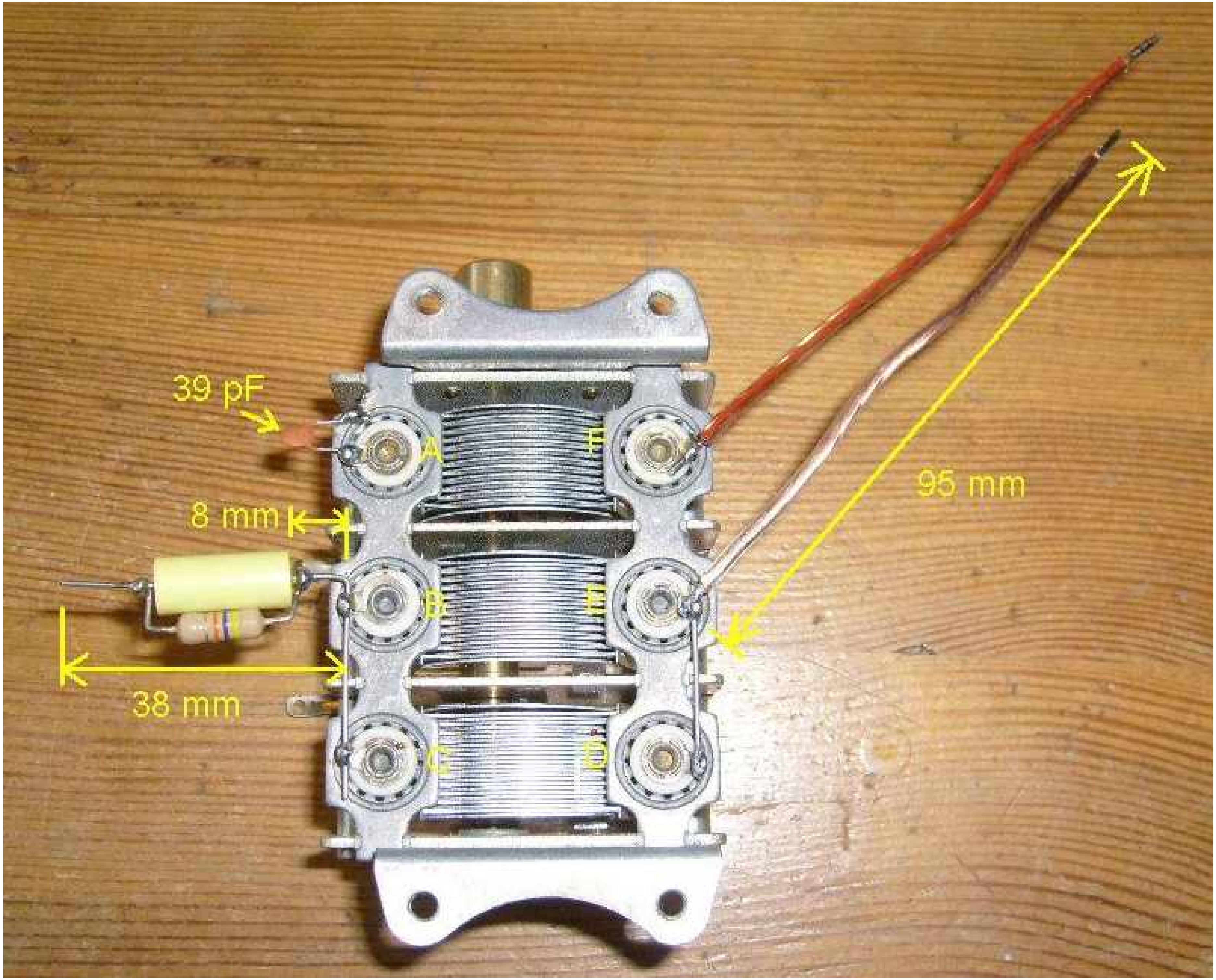
39 pF
A
F
95 mm
8 mm
B
E
38 mm
C
D

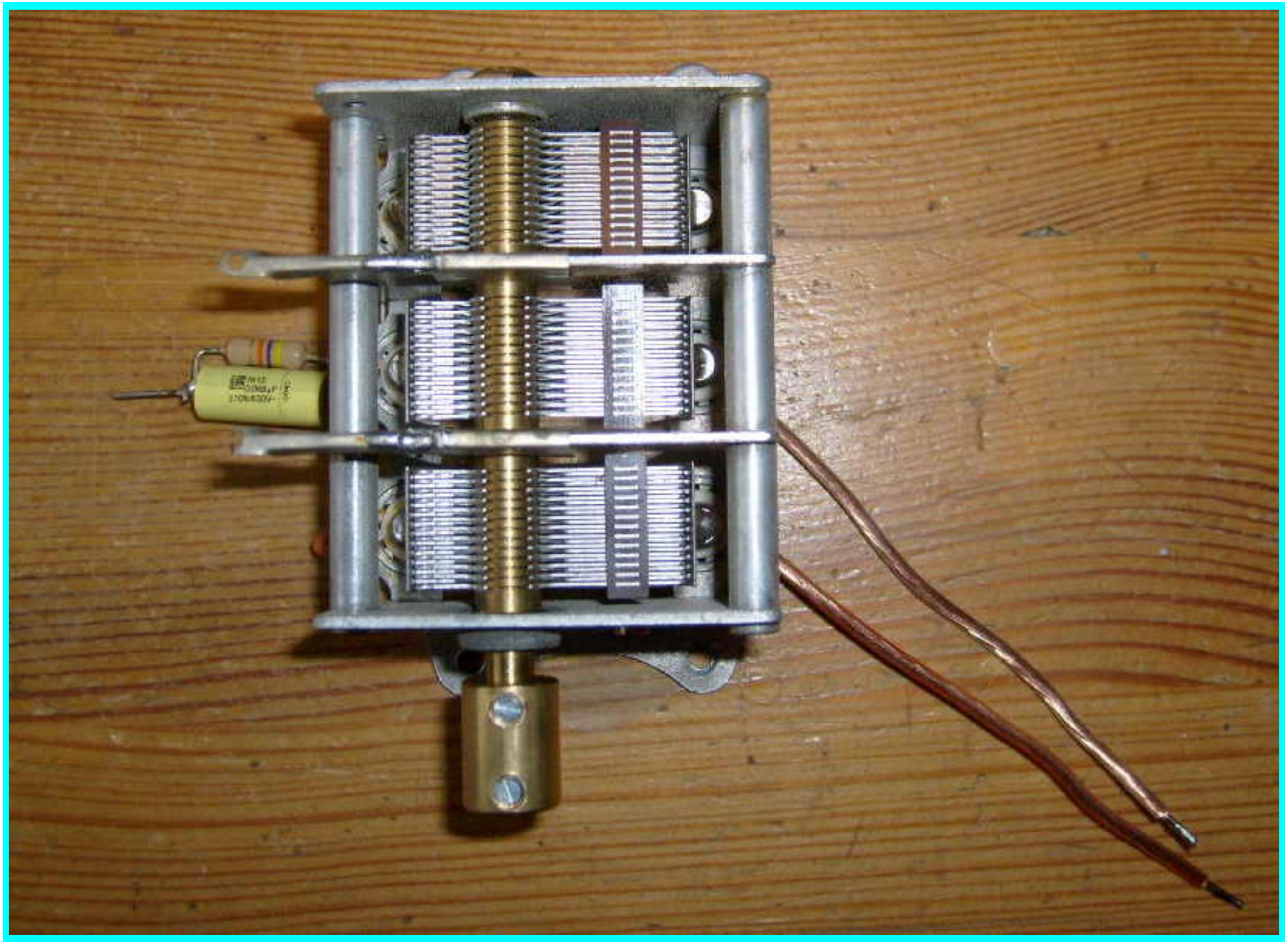
N12
0.068µF
±10%630V~

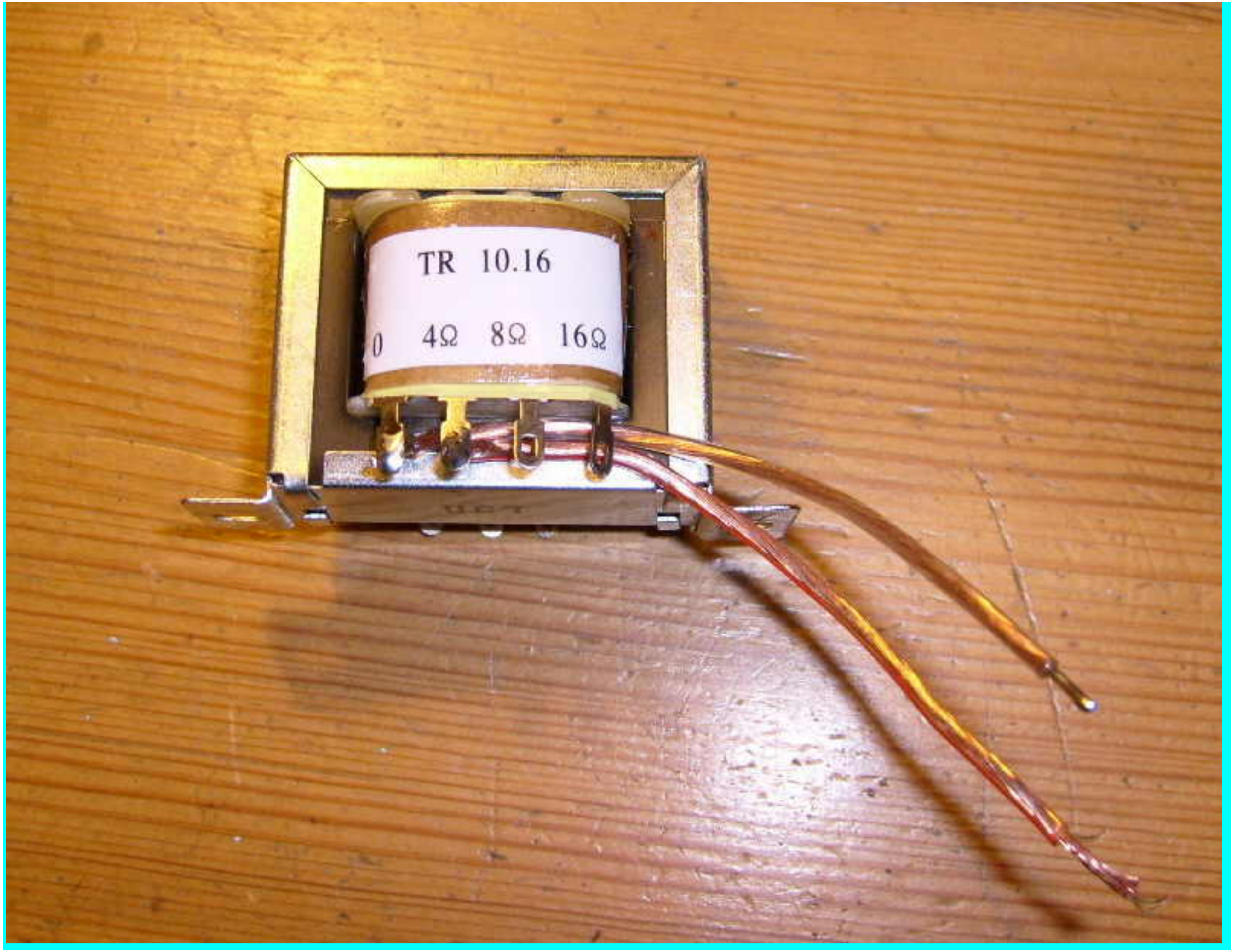
TR 10.16
0 4Ω 8Ω 16Ω

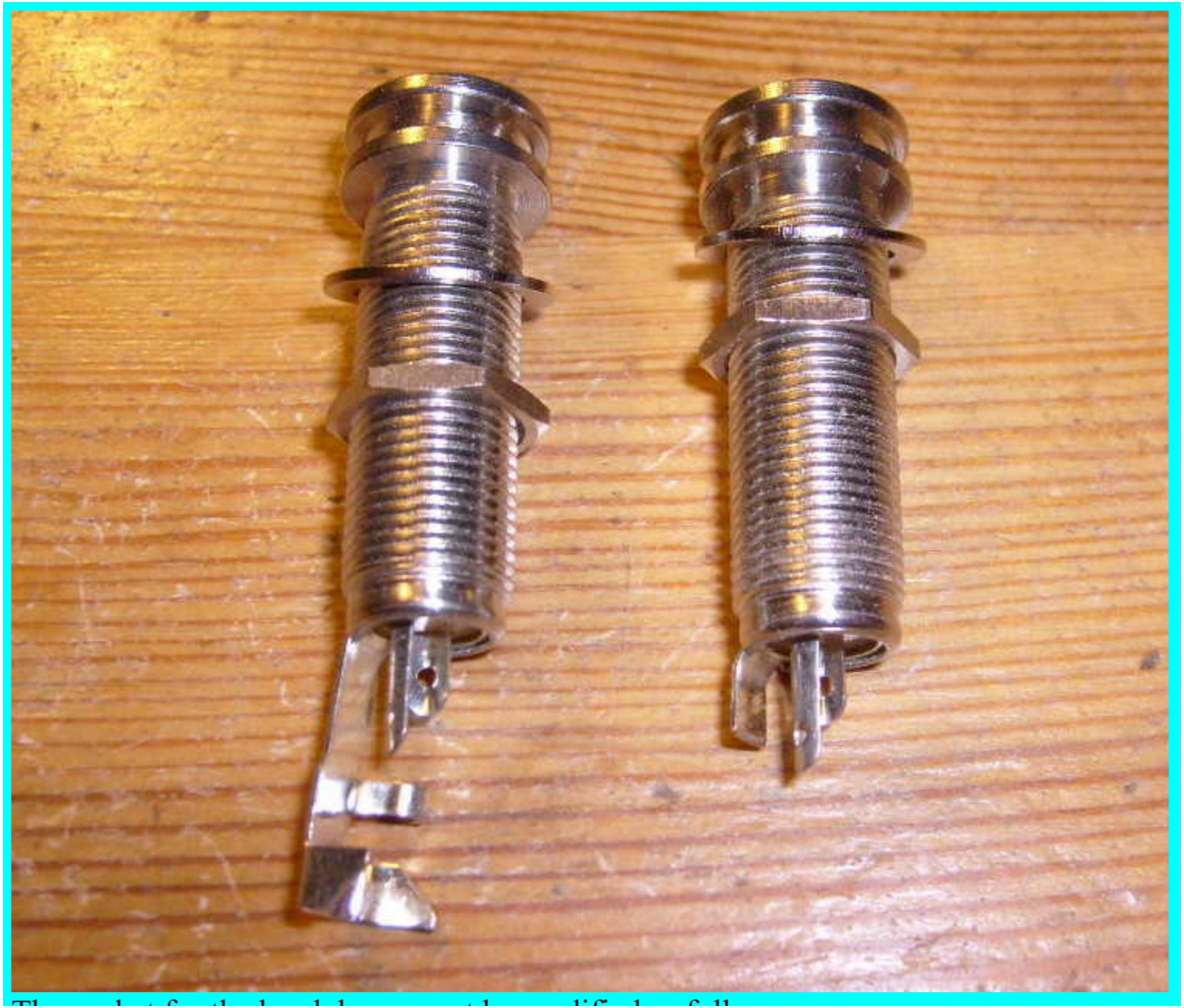

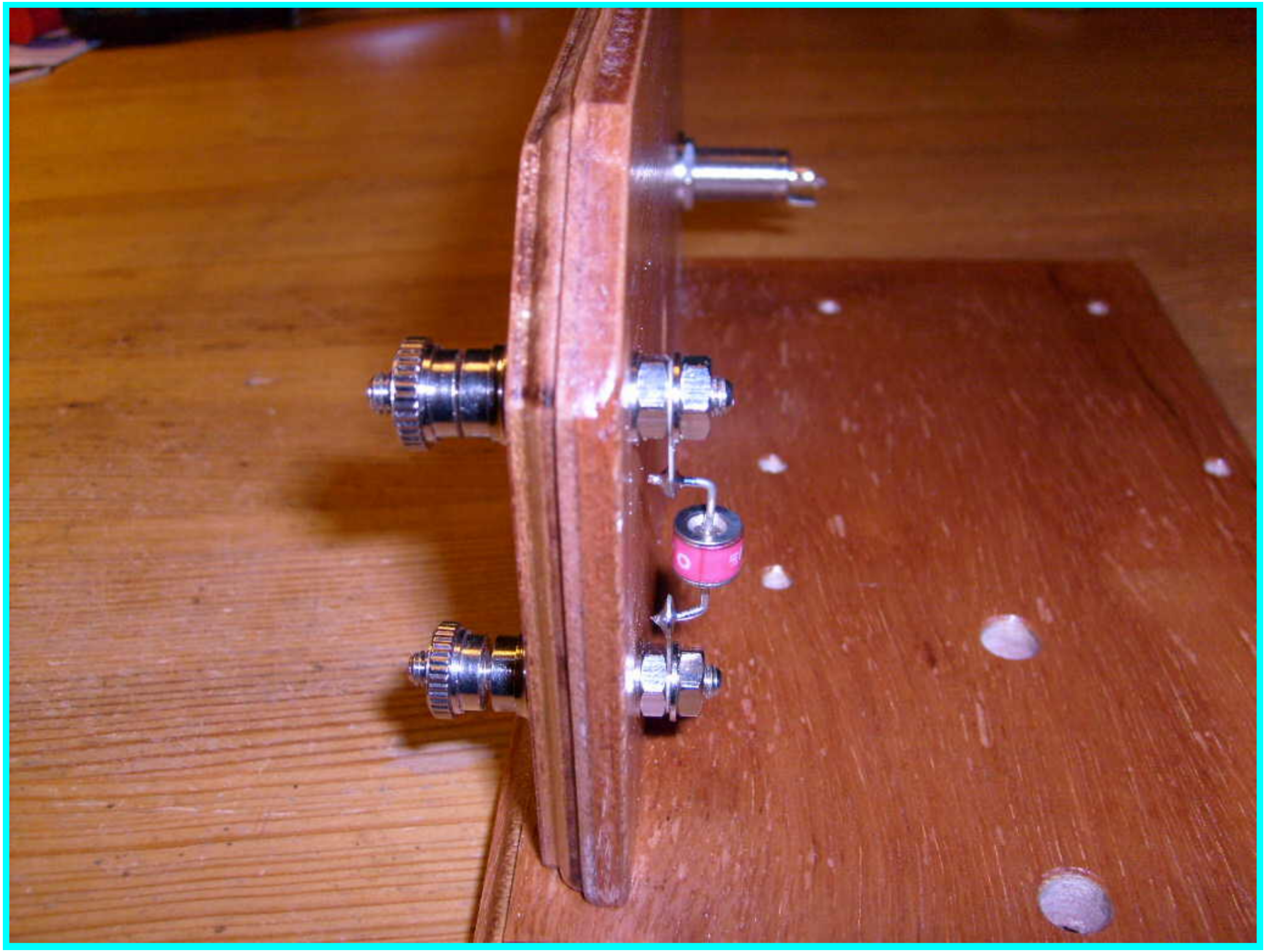

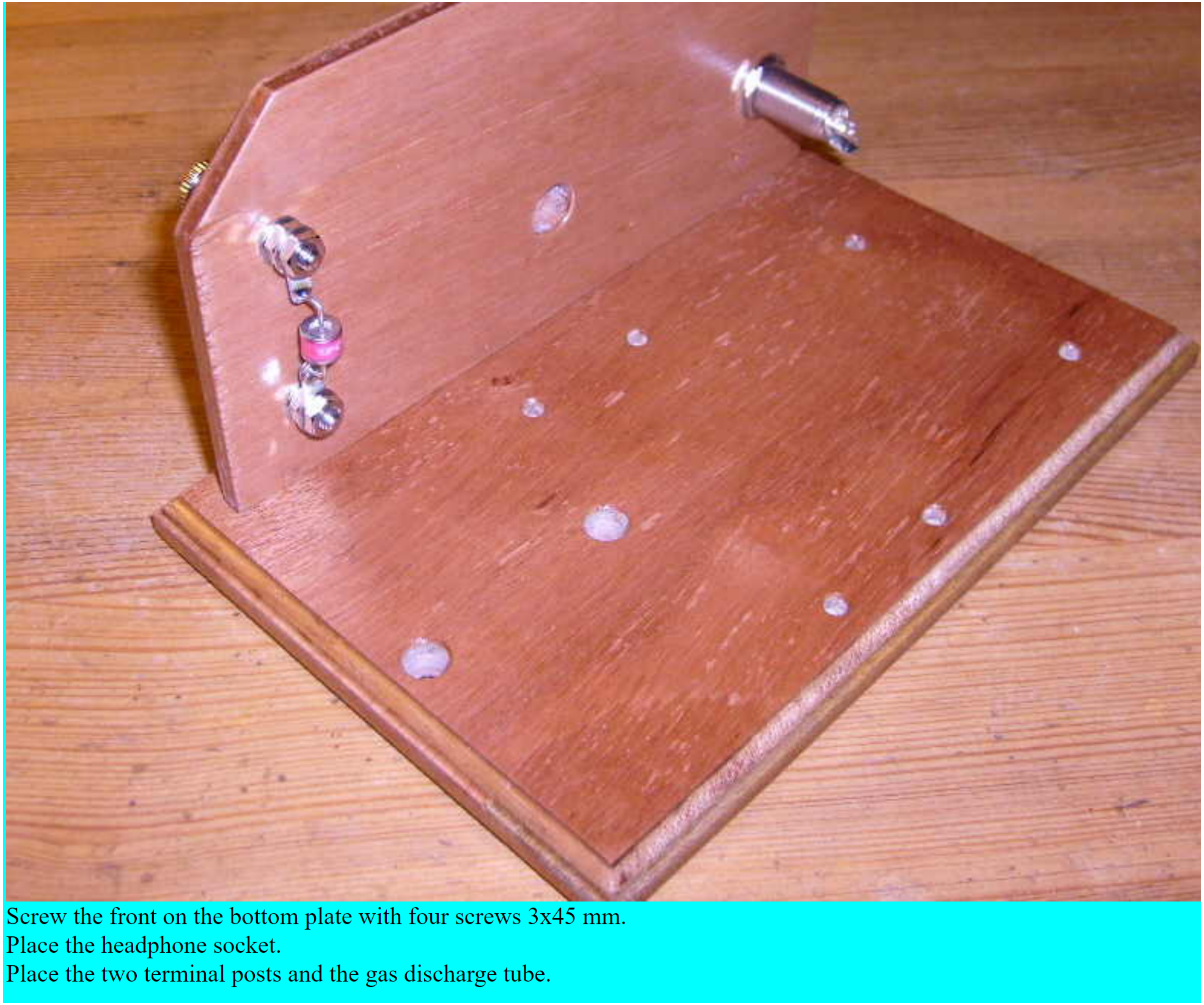

Screw the front on the bottom plate with four screws 3x45 mm.
Place the headphone socket.
Place the two terminal posts and the gas discharge tube.

Make a paper strip with 4 sections of 40x55 mm on it.
Do the strip around the tube, and fix it with a piece of tape.
Don't tape the strip onto the tube on places where later the coil is wound.

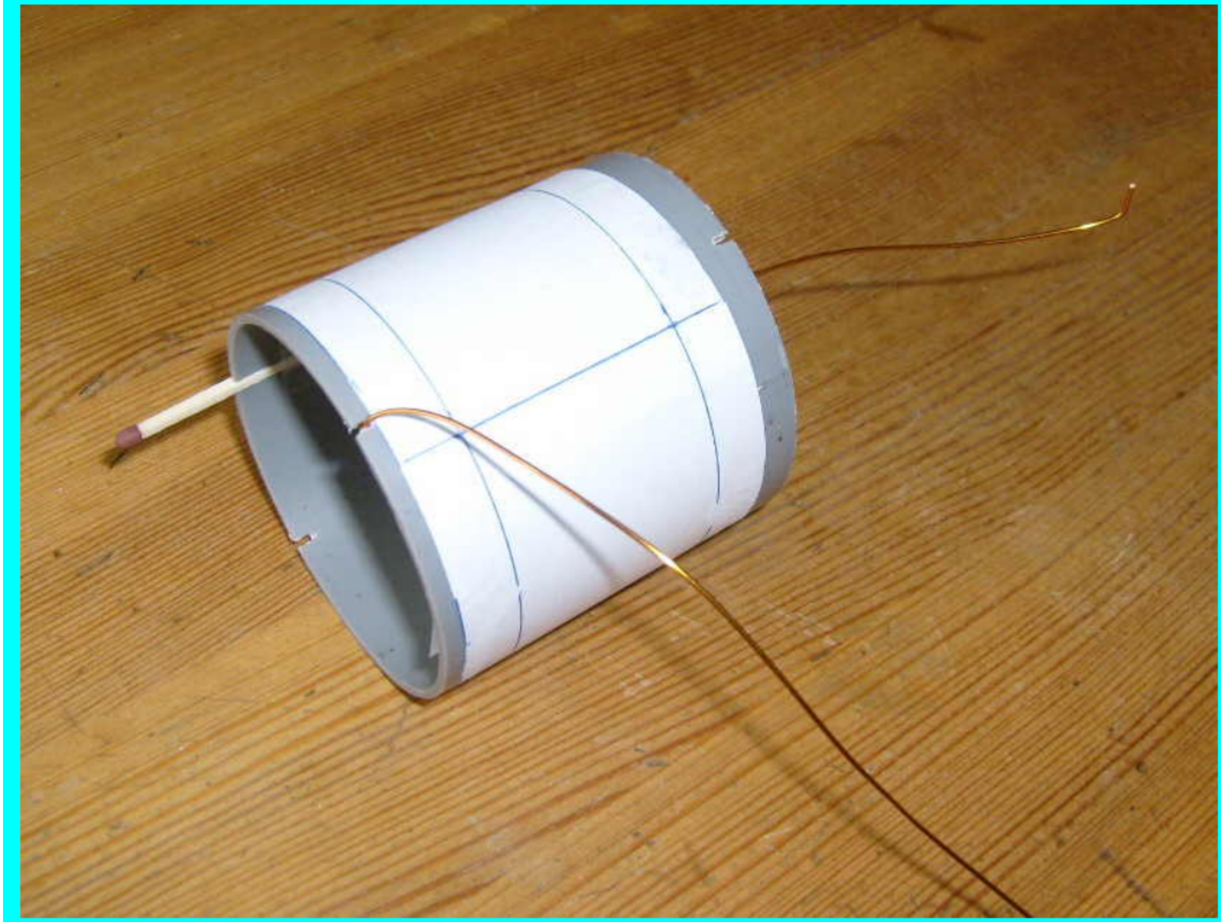

For the coil we need 8.6 meter enamelled copper wire with 0.8 mm thickness.
Hook the begin of the coilwire onto the slot in the tube.
Also fix the begin of the wire on the inside of the tube with some tape.

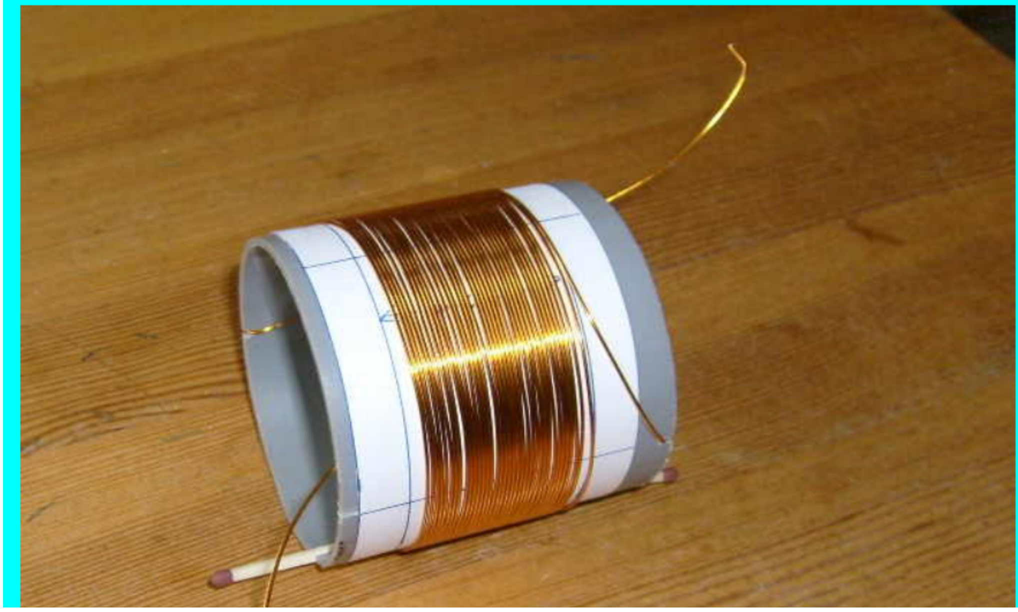

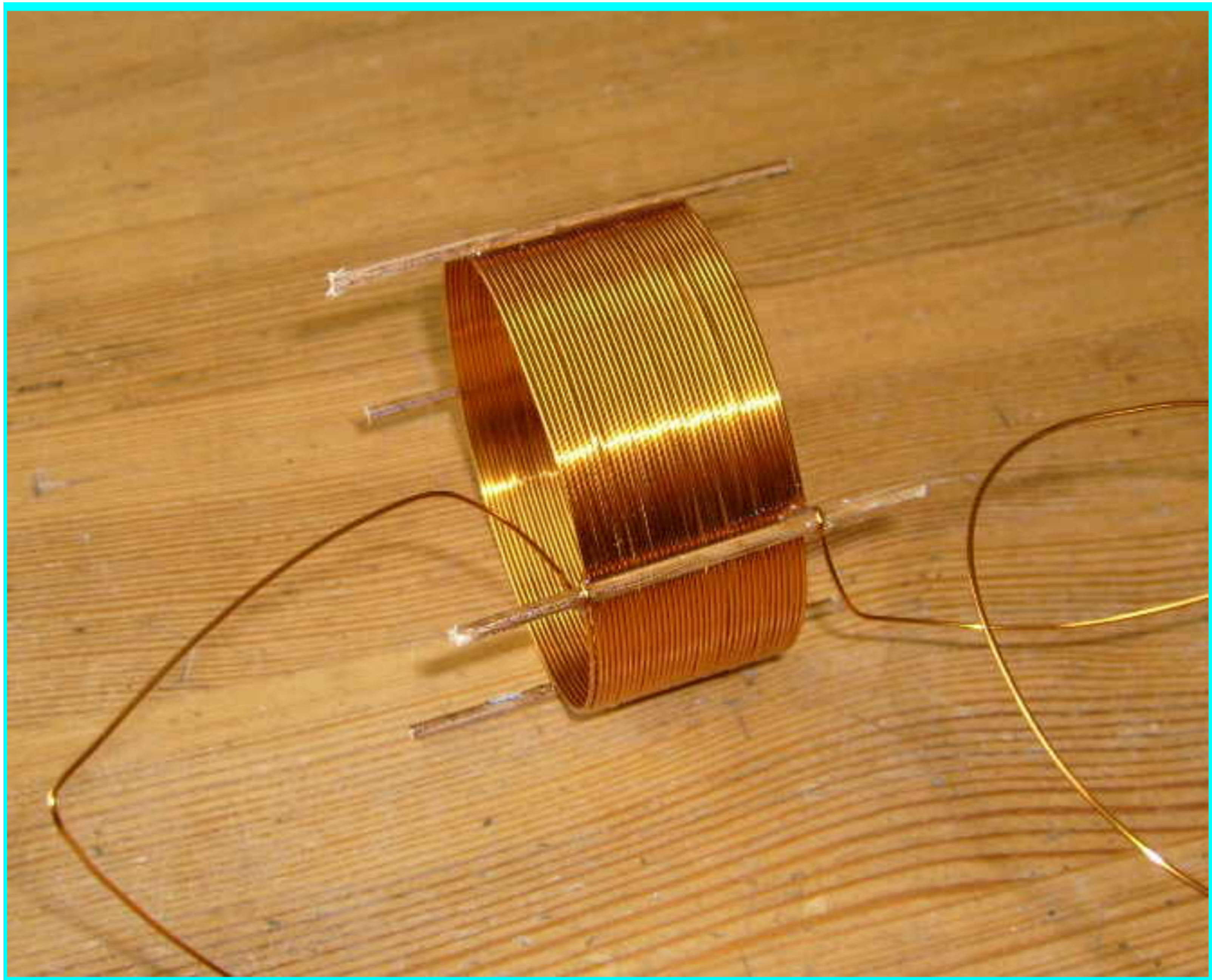

Wait until the glue is hardened.
Remove the rubber bands, the tape and the matches.
Shift the tube out of the coil, and remove the paper out of the coil.
Turn the both ends of the wire one time around the stick at the bottom side of the coil, and apply some extra glue here.

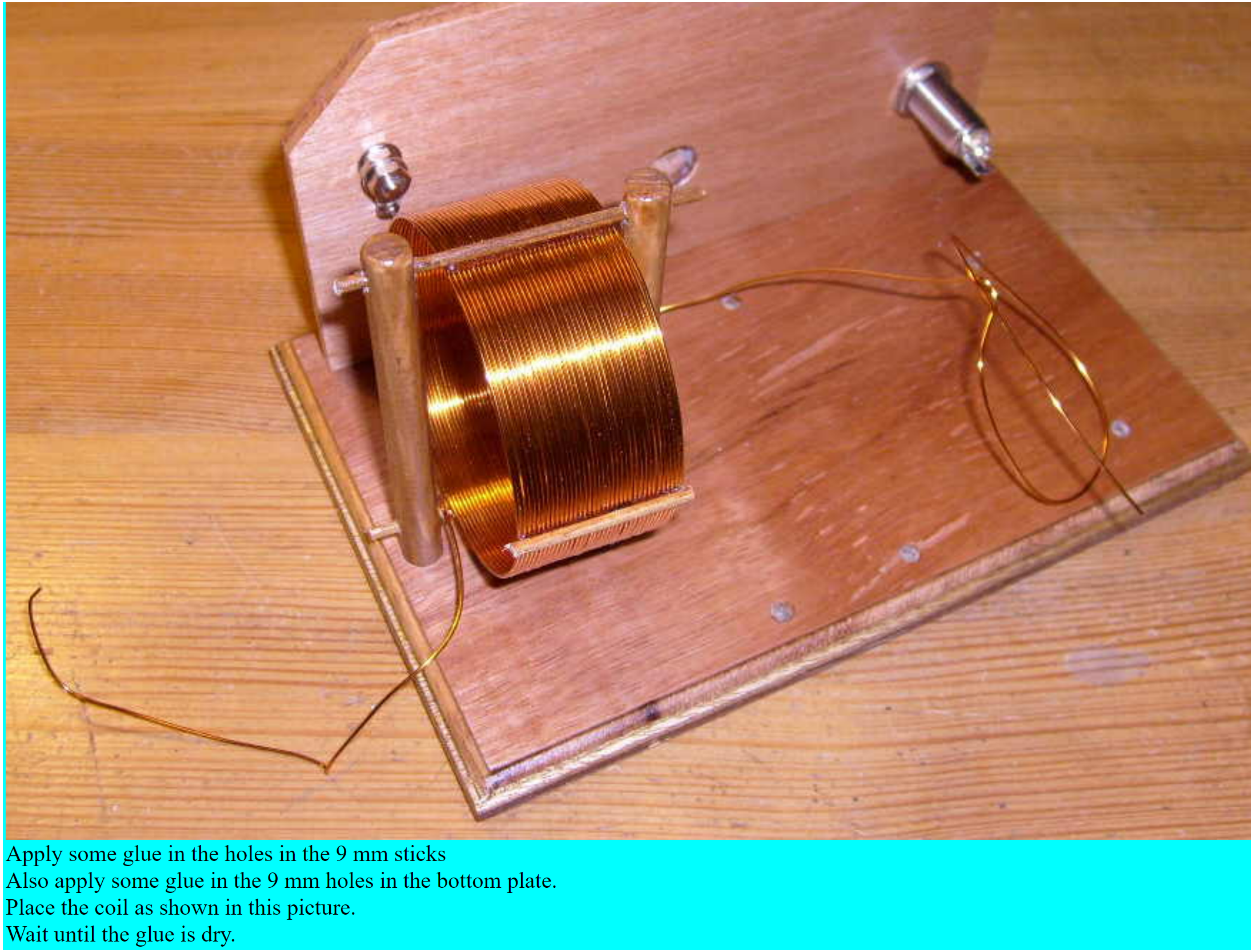

Apply some glue in the holes in the 9 mm sticks
Also apply some glue in the 9 mm holes in the bottom plate.
Place the coil as shown in this picture.
Wait until the glue is dry.

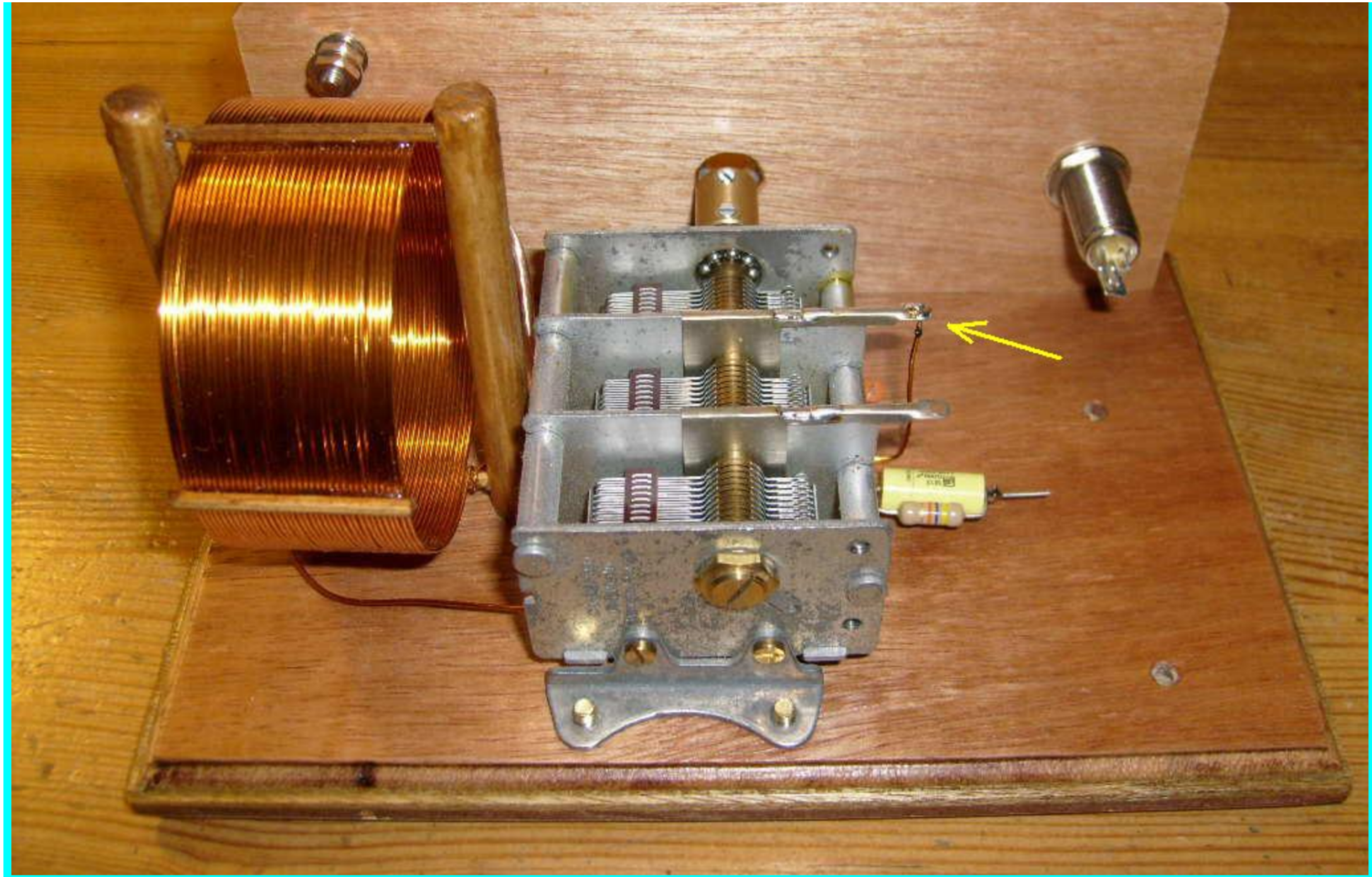

Place the tuning capacitor on the frame.
Fix it with four screws M4x16
One coilwire runs underneath the tuning capacitor, is then bend upwards and cut to length.
Solder this wire to the tuning capacitor (indicated with the arrow in the above picture).
Scrap of the lacquer from the wire, before soldering.

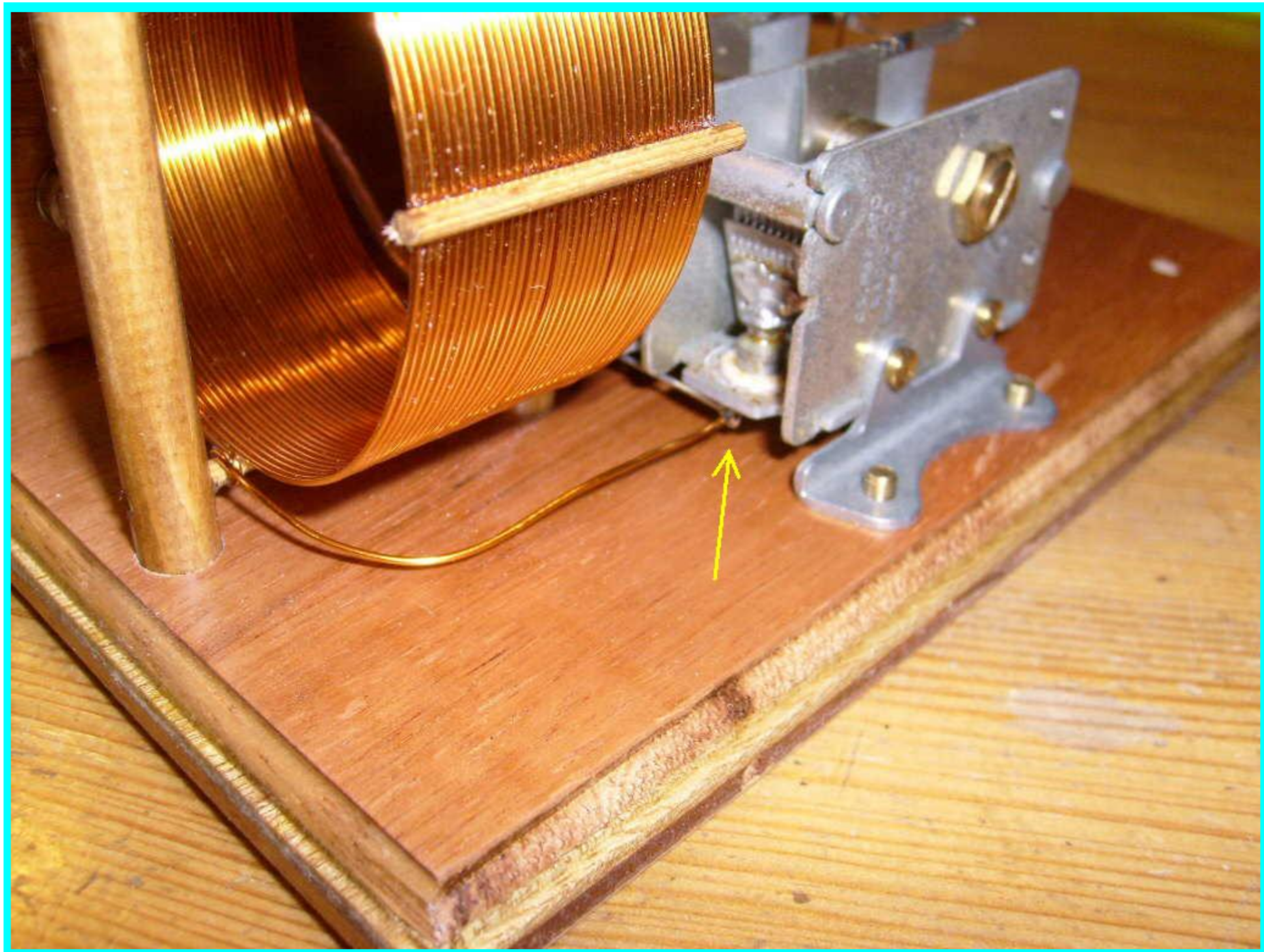

The other wire is cut to length, and soldered to the solder tag of the tuning capacitor (indicated with arrow).

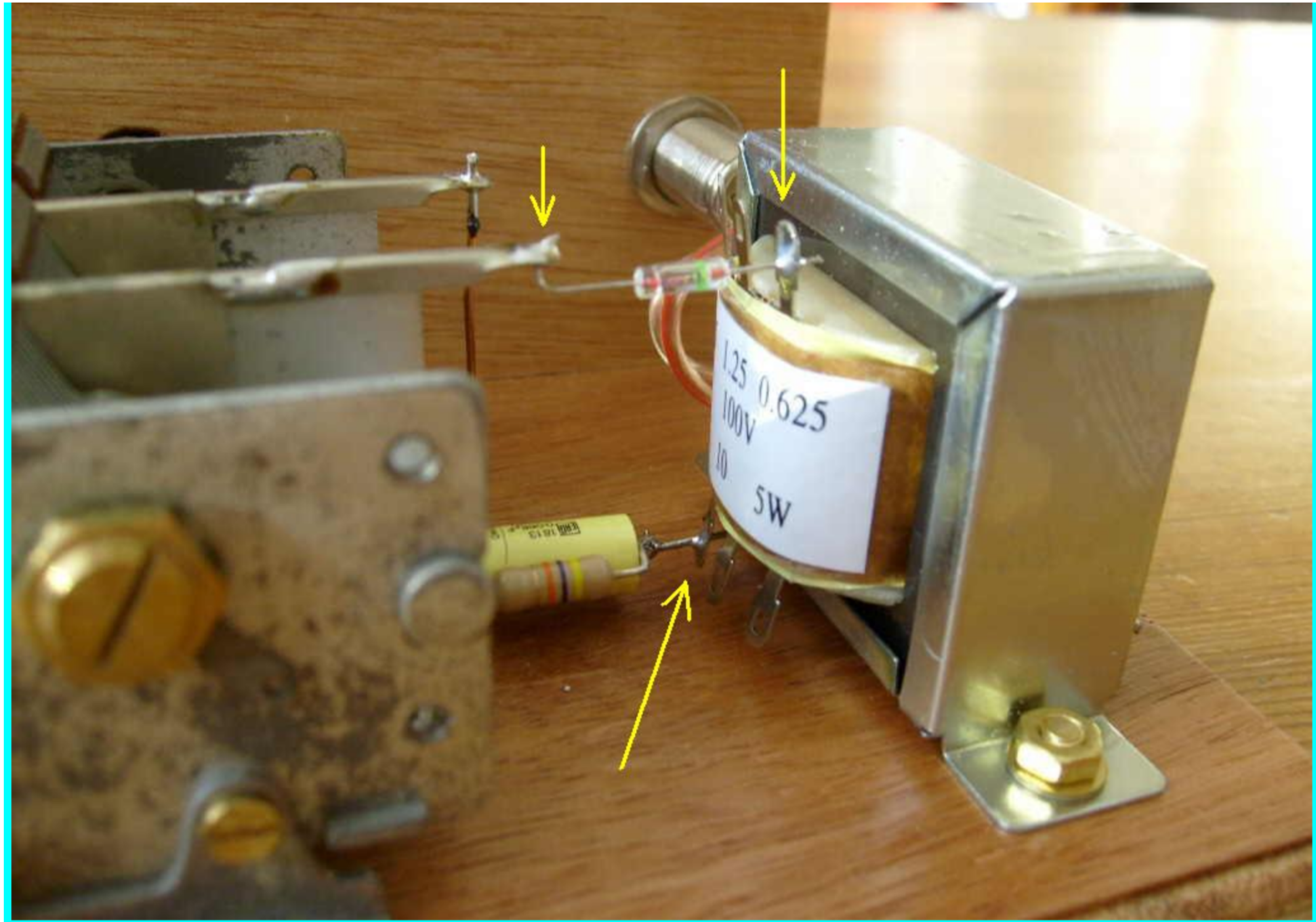

Place the transformer on the frame, fix it with two M4x16 screws, 2 rings and 2 nuts
The wire of the 68 nF capacitor must stick through the "0" connection of the transformer, and is then soldered.
Solder the OA95 diode between tuning capacitor and the "0.625W" connection of the transformer.
The green band on the diode must point towards the transformer.

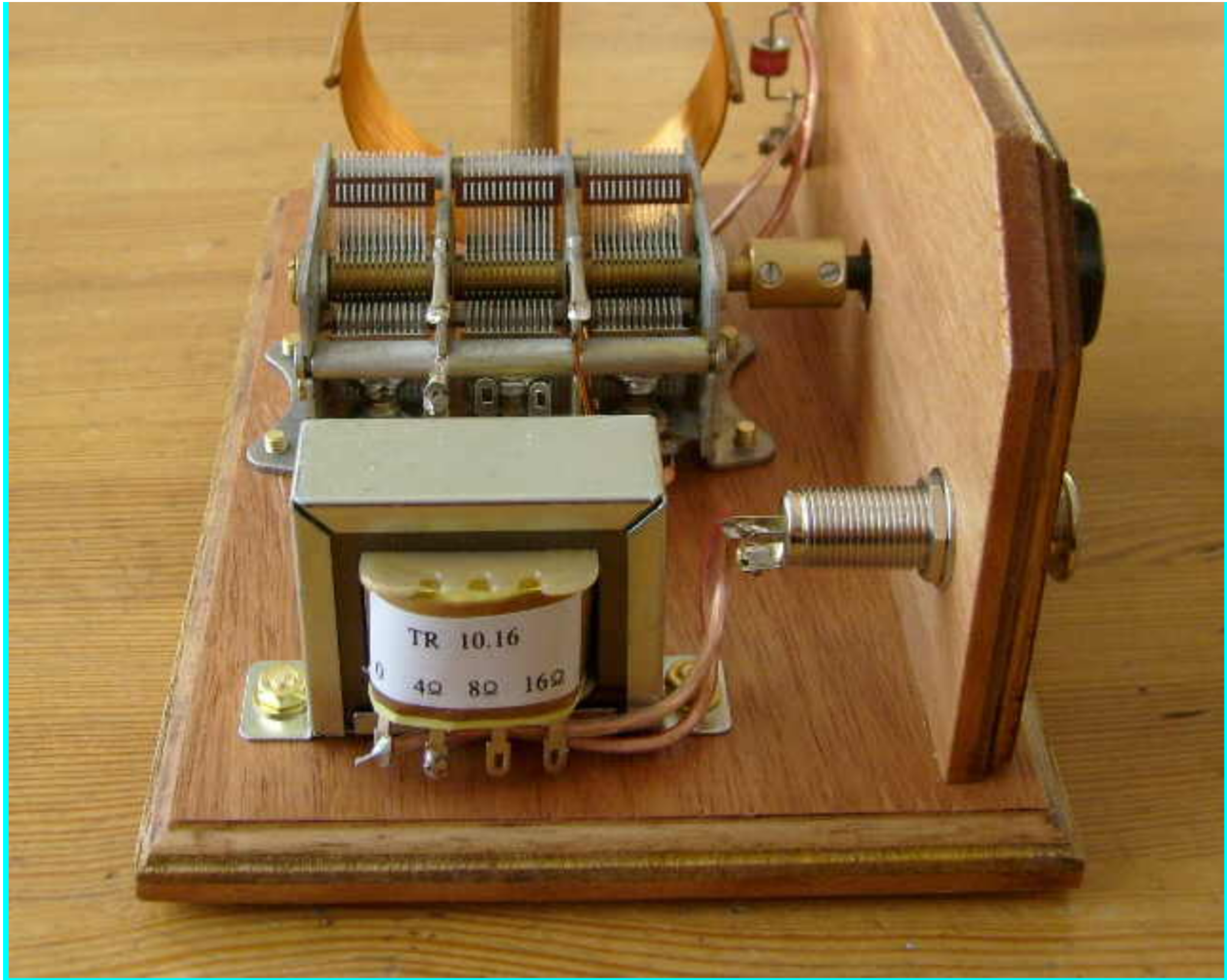
TR 10.16
0 4Ω 8Ω 16Ω

Solder the two wires from the transformer to the headphone socket (see for detail: next picture).

Solder the two wires from the tuning capacitor to the terminal posts.
The wire with the red line on it, comes on the upper (antenna) connection.
The wire without red line, comes on the lower (ground) connection.

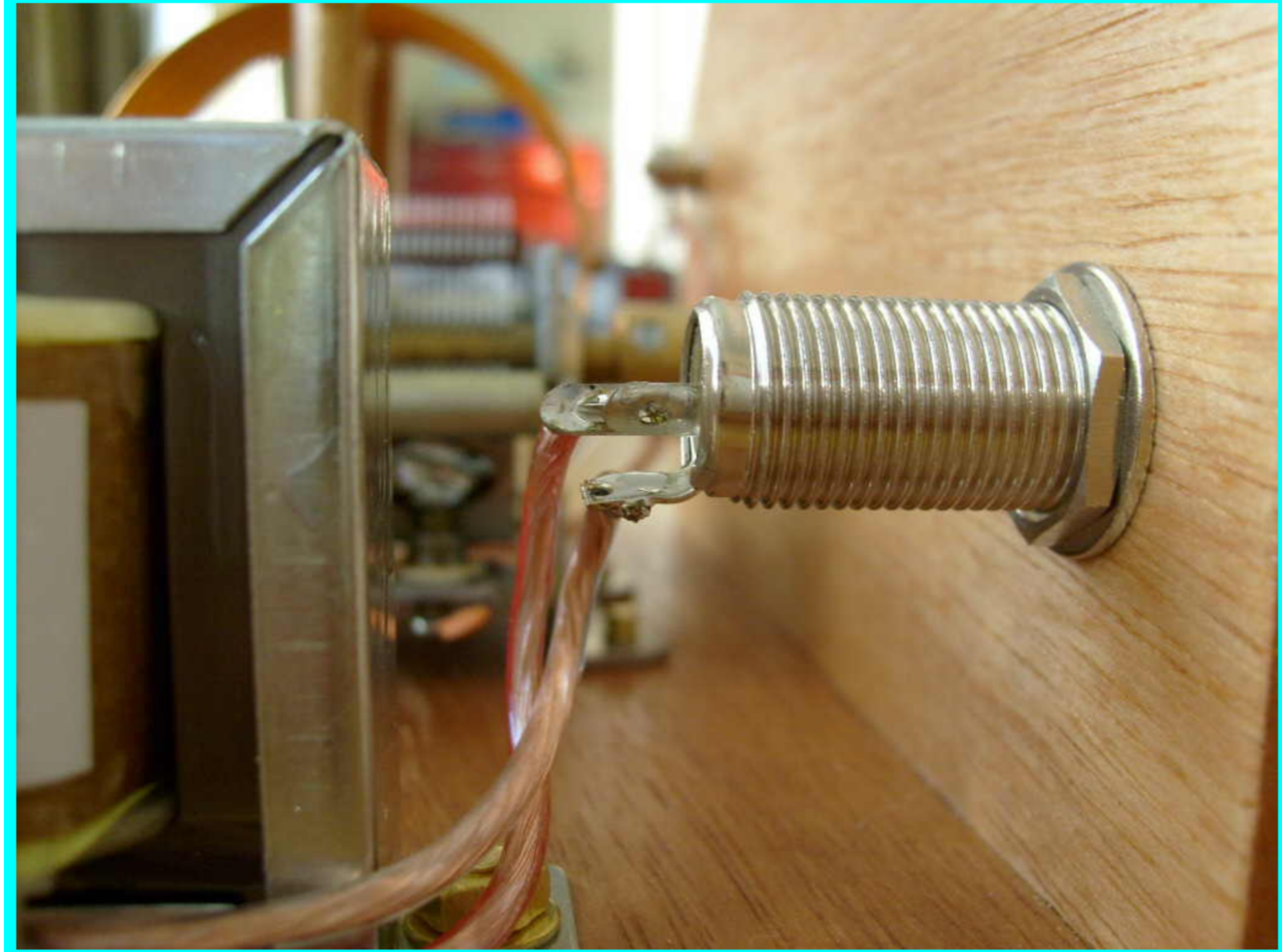

Detail of the wires on the headphone socket.
The wire without red line comes on the ground connection.
The wire with the red line comes on the two signal pins, so these two signal pins are connected together.

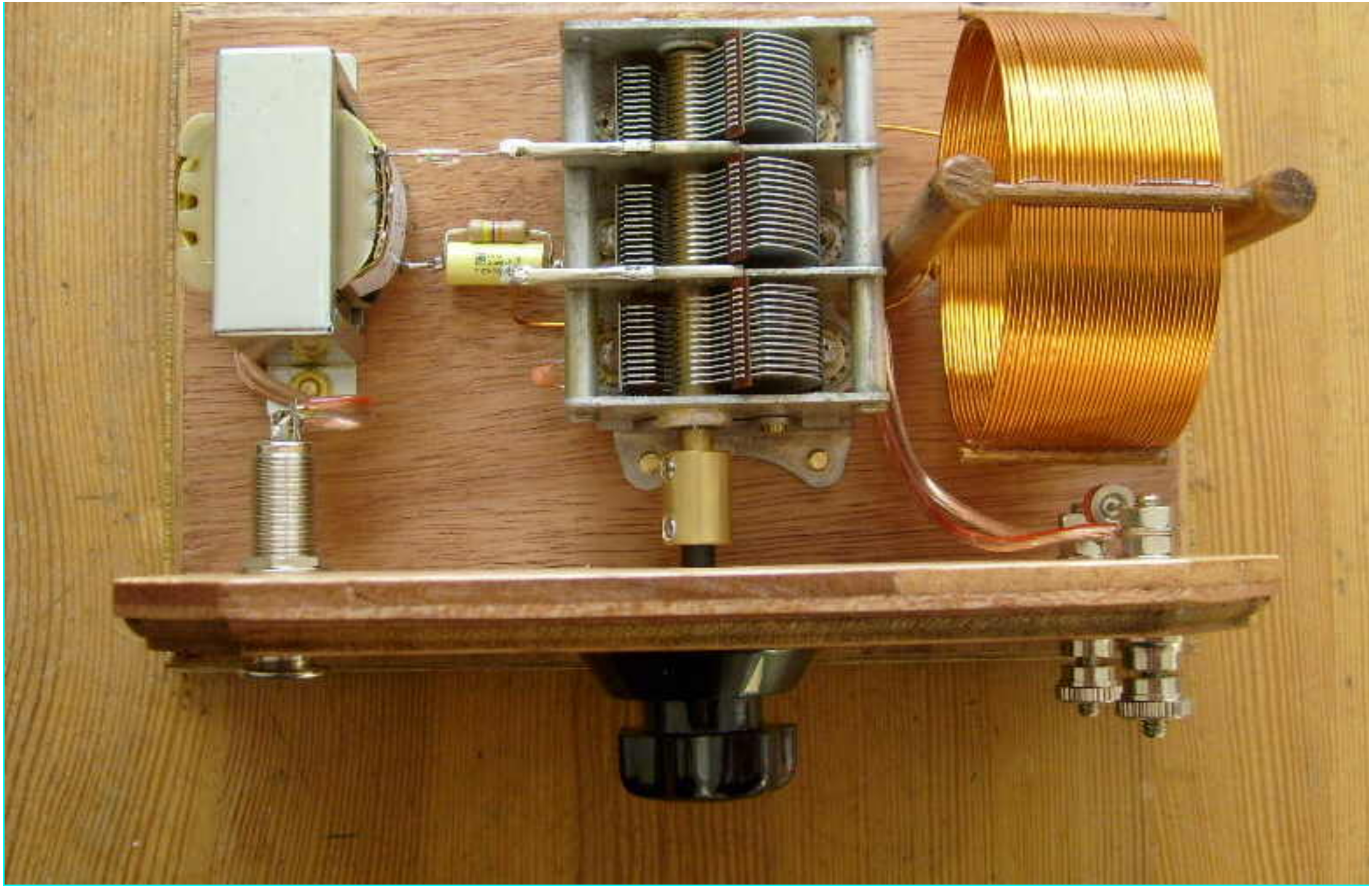

Mount the extension shaft and the knob on the tuning capacitor.
In the middle position, the pointer on the knob must point upwards.

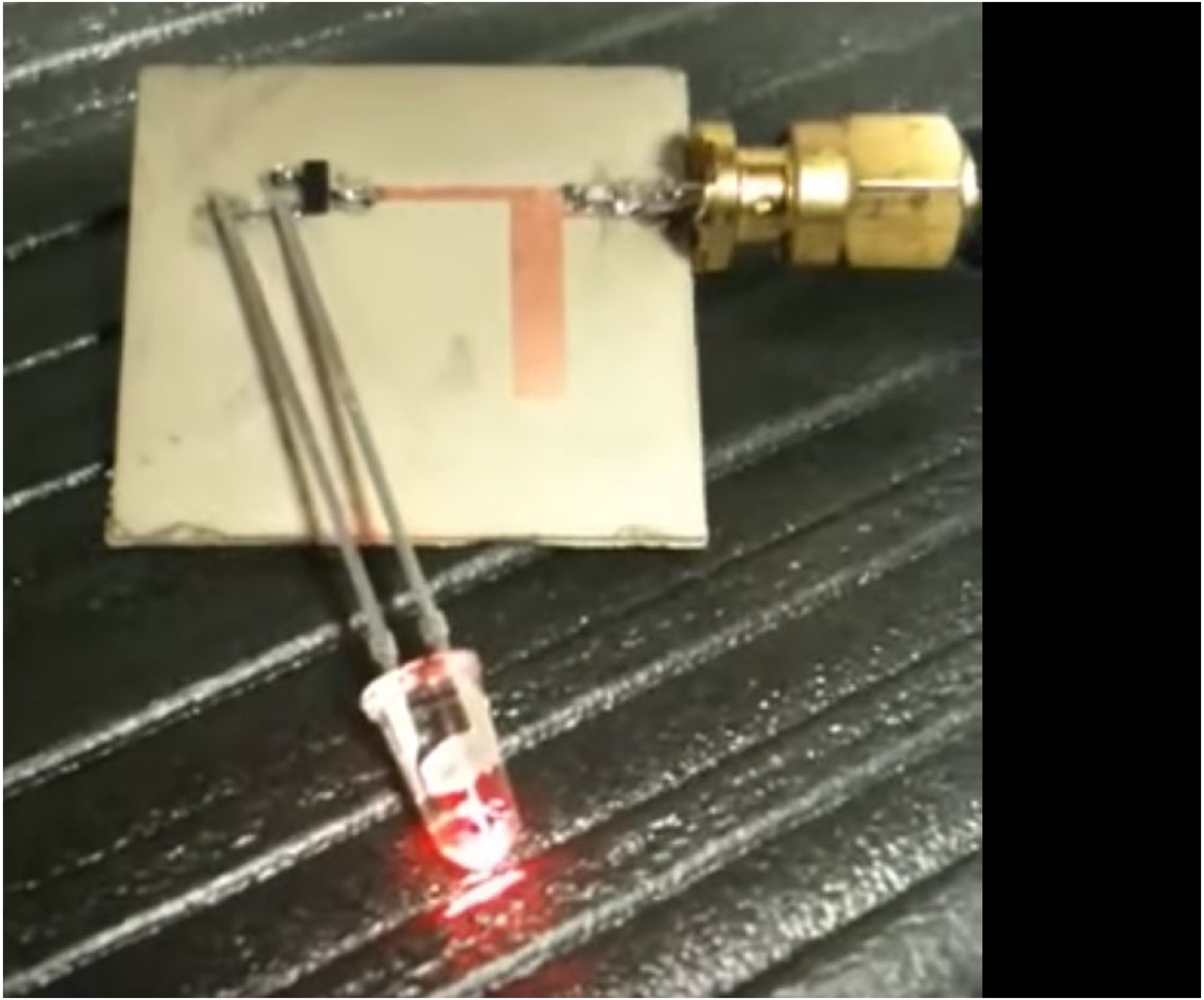

$10,000
in $100 bills

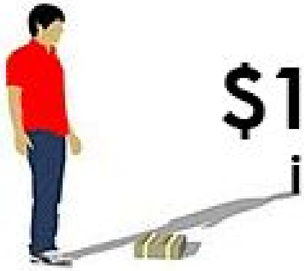

$1,000,000
in $100 bills

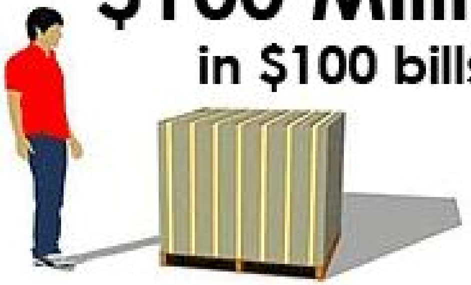

$100 Million
in $100 bills

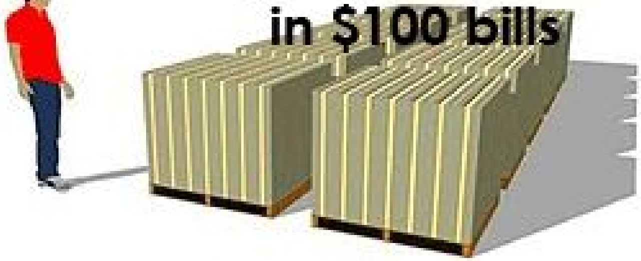

$1 Billion
in $100 bills

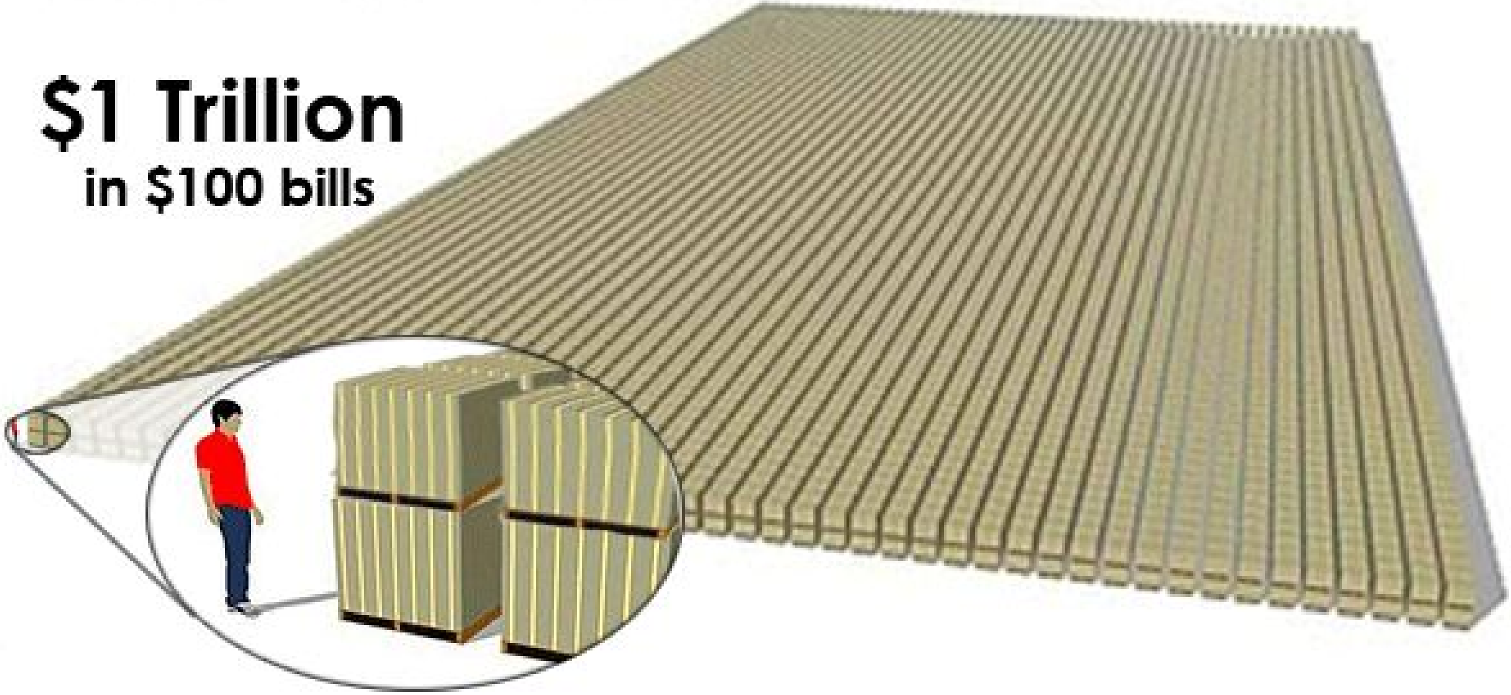

$1 Trillion
in $100 bills

USB Type A Female Field Termination Connector

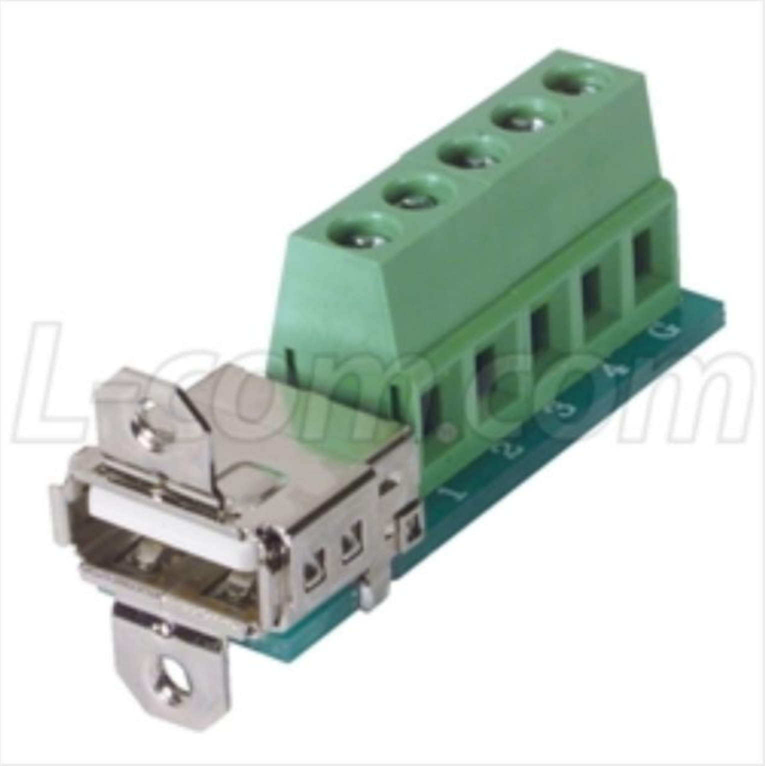

Roll over image to zoom in

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Your Price 1-9	**$7.24**
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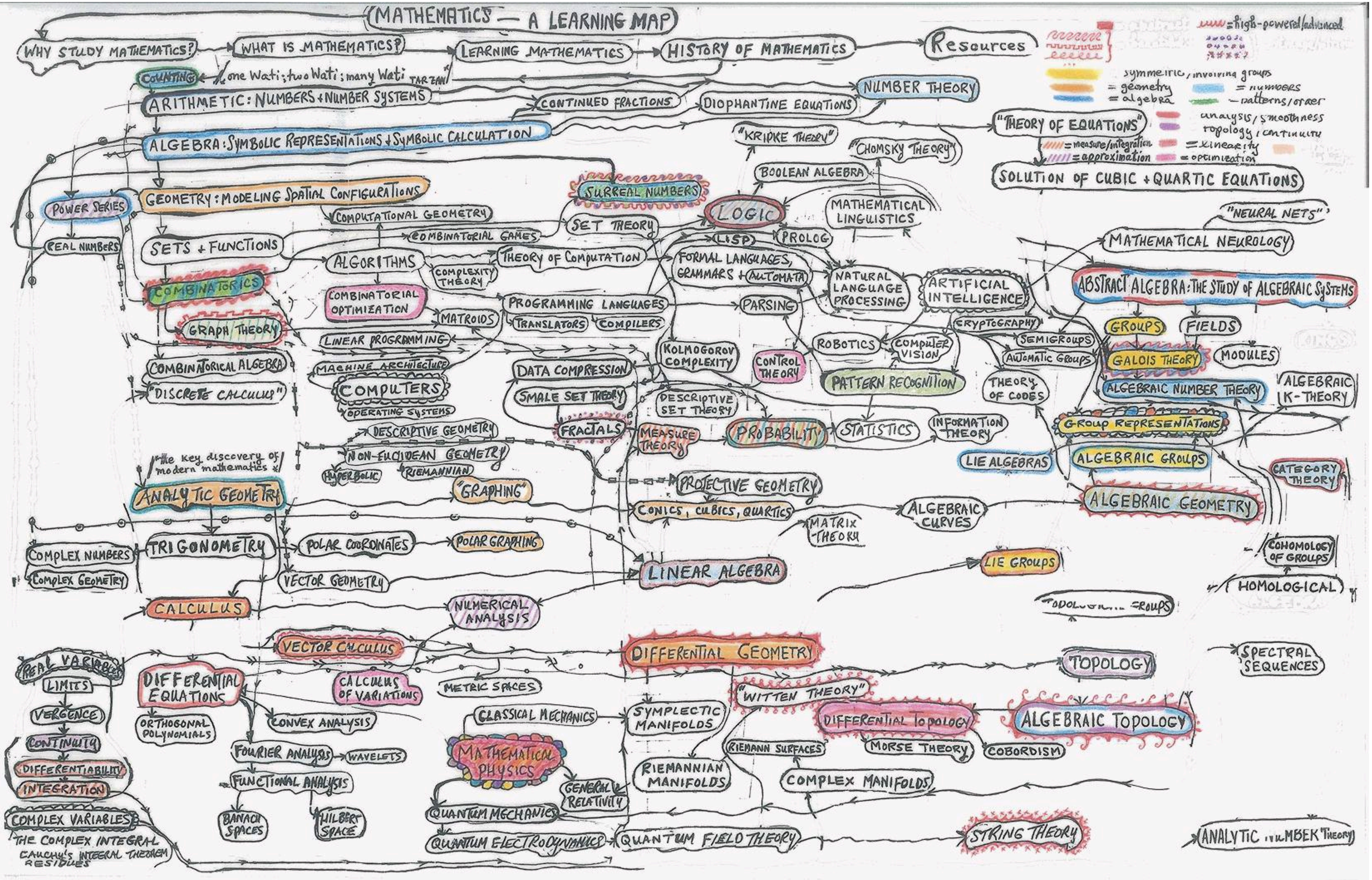
MATHEMATICS — A LEARNING MAP
WHY STUDY MATHEMATICS?
WHAT IS MATHEMATICS?
LEARNING MATHEMATICS
HISTORY OF MATHEMATICS
Resources
= high-powered/advanced
symmetric, involving groups
= geometry
= algebra
= numbers
= patterns/order
analysis/smoothness
topology/continuity
= measure/integration
= approximation
= linearity
= optimization
COUNTING
one Wati; two Wati; many Wati TARZAN
ARITHMETIC: NUMBERS + NUMBER SYSTEMS
CONTINUED FRACTIONS
DIOPHANTINE EQUATIONS
NUMBER THEORY
"THEORY OF EQUATIONS"
SOLUTION OF CUBIC + QUARTIC EQUATIONS
ALGEBRA: SYMBOLIC REPRESENTATIONS + SYMBOLIC CALCULATION
"KRIPKE THEORY"
"CHOMSKY THEORY"
BOOLEAN ALGEBRA
POWER SERIES
GEOMETRY: MODELING SPATIAL CONFIGURATIONS
SURREAL NUMBERS
LOGIC
MATHEMATICAL LINGUISTICS
"NEURAL NETS"
COMPUTATIONAL GEOMETRY
SET THEORY
REAL NUMBERS
SETS + FUNCTIONS
COMBINATORIAL GAMES
LISP
PROLOG
MATHEMATICAL NEUROLOGY
ALGORITHMS
COMPLEXITY THEORY
THEORY OF COMPUTATION
FORMAL LANGUAGES, GRAMMARS + AUTOMATA
NATURAL LANGUAGE PROCESSING
ARTIFICIAL INTELLIGENCE
ABSTRACT ALGEBRA: THE STUDY OF ALGEBRAIC SYSTEMS
COMBINATORICS
COMBINATORIAL OPTIMIZATION
PROGRAMMING LANGUAGES
PARSING
GRAPH THEORY
MATROIDS
TRANSLATORS
COMPILERS
CRYPTOGRAPHY
GROUPS
FIELDS
LINEAR PROGRAMMING
KOLMOGOROV COMPLEXITY
ROBOTICS
COMPUTER VISION
SEMIGROUPS
COMBINATORICAL ALGEBRA
MACHINE ARCHITECTURE
CONTROL THEORY
AUTOMATIC GROUPS
GALOIS THEORY
MODULES
DATA COMPRESSION
PATTERN RECOGNITION
THEORY OF CODES
ALGEBRAIC NUMBER THEORY
ALGEBRAIC K-THEORY
"DISCRETE CALCULUS"
COMPUTERS
OPERATING SYSTEMS
SMALE SET THEORY
DESCRIPTIVE SET THEORY
DESCRIPTIVE GEOMETRY
FRACTALS
MEASURE THEORY
PROBABILITY
STATISTICS
INFORMATION THEORY
GROUP REPRESENTATIONS
"the key discovery of modern mathematics"
NON-EUCLIDEAN GEOMETRY
HYPERBOLIC
RIEMANNIAN
LIE ALGEBRAS
ALGEBRAIC GROUPS
CATEGORY THEORY
"GRAPHING"
PROJECTIVE GEOMETRY
ANALYTIC GEOMETRY
CONICS, CUBICS, QUARTICS
ALGEBRAIC CURVES
ALGEBRAIC GEOMETRY
MATRIX THEORY
COMPLEX NUMBERS
TRIGONOMETRY
POLAR COORDINATES
POLAR GRAPHING
COHOMOLOGY OF GROUPS
COMPLEX GEOMETRY
VECTOR GEOMETRY
LINEAR ALGEBRA
LIE GROUPS
HOMOLOGICAL
CALCULUS
NUMERICAL ANALYSIS
TOPOLOGICAL GROUPS
VECTOR CALCULUS
DIFFERENTIAL GEOMETRY
TOPOLOGY
SPECTRAL SEQUENCES
REAL VARIABLES
LIMITS
DIFFERENTIAL EQUATIONS
CALCULUS OF VARIATIONS
METRIC SPACES
"WITTEN THEORY"
VERGENCE
ORTHOGONAL POLYNOMIALS
CONVEX ANALYSIS
CLASSICAL MECHANICS
SYMPLECTIC MANIFOLDS
DIFFERENTIAL TOPOLOGY
ALGEBRAIC TOPOLOGY
CONTINUITY
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WAVELETS
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MORSE THEORY
COBORDISM
DIFFERENTIABILITY
FUNCTIONAL ANALYSIS
GENERAL RELATIVITY
RIEMANNIAN MANIFOLDS
COMPLEX MANIFOLDS
INTEGRATION
BANACH SPACES
HILBERT SPACE
QUANTUM MECHANICS
COMPLEX VARIABLES
THE COMPLEX INTEGRAL
CAUCHY'S INTEGRAL THEOREM
RESIDUES
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QUANTUM FIELD THEORY
STRING THEORY
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MODEL NO.
VC-1000

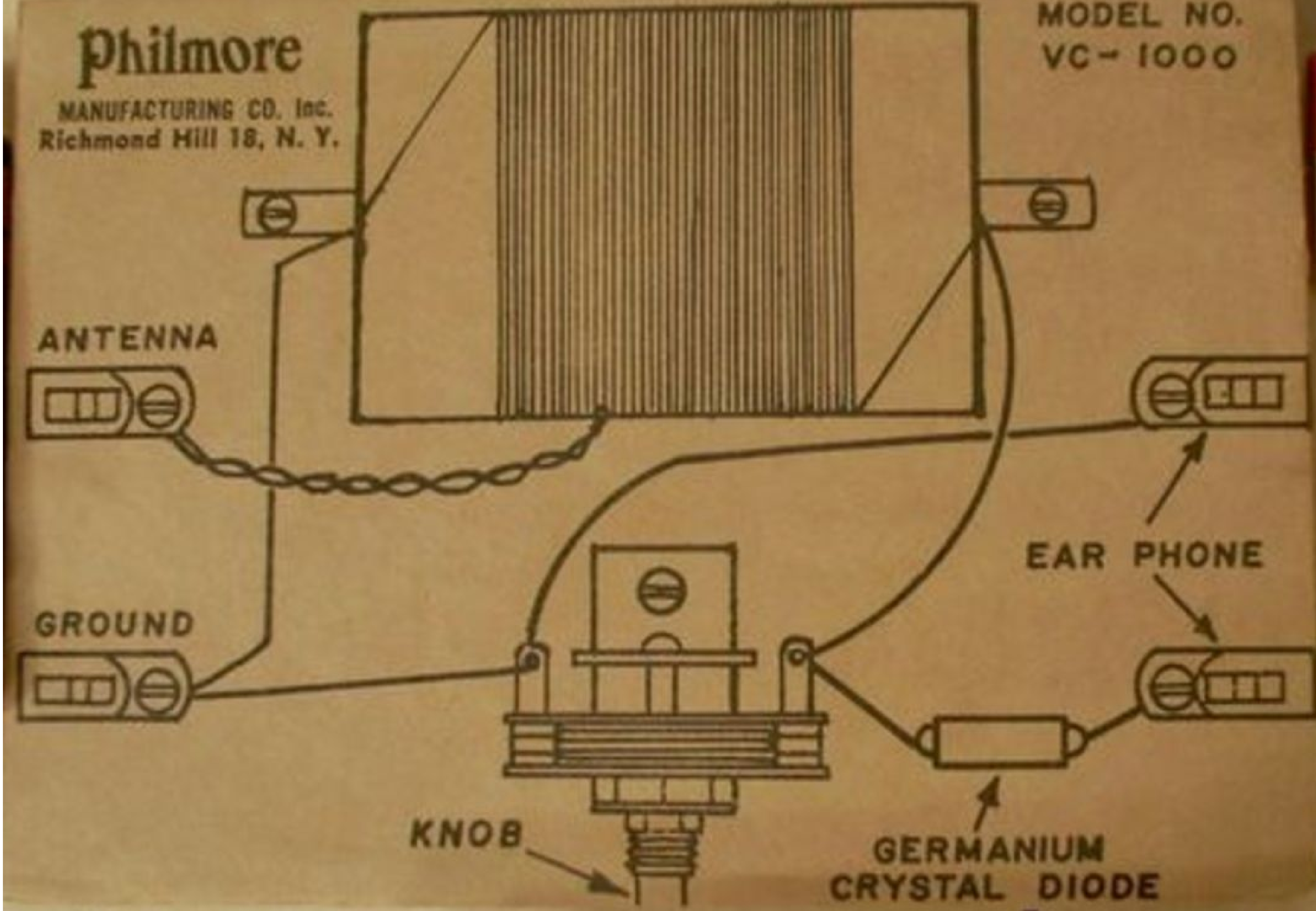
ANTENNA
GROUND
EAR PHONE
KNOB
GERMANIUM
CRYSTAL DIODE

1 LED azul
(con tensión entre 3V y 3,6V)

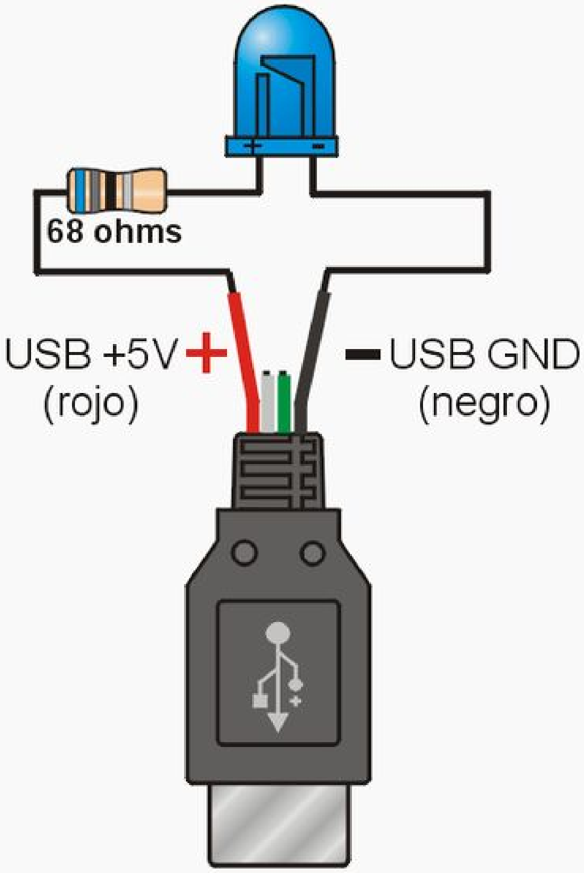
68 ohms
USB +5V +
(rojo)
− USB GND
(negro)

WWW.INVENTABLE.EU

1 LED rojo
(con tensión entre 1,8V y 2,1V)

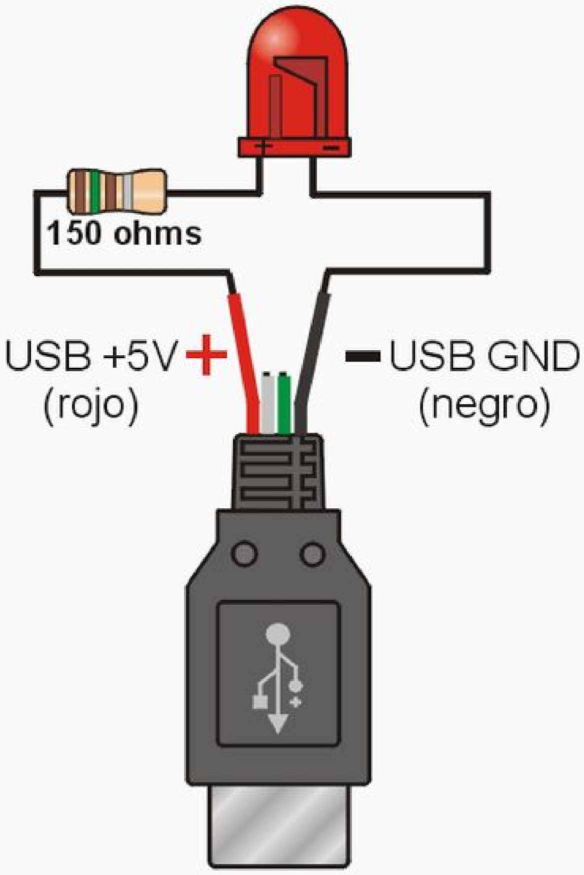
150 ohms
USB +5V +
(rojo)
− USB GND
(negro)

The Tesla Experiment

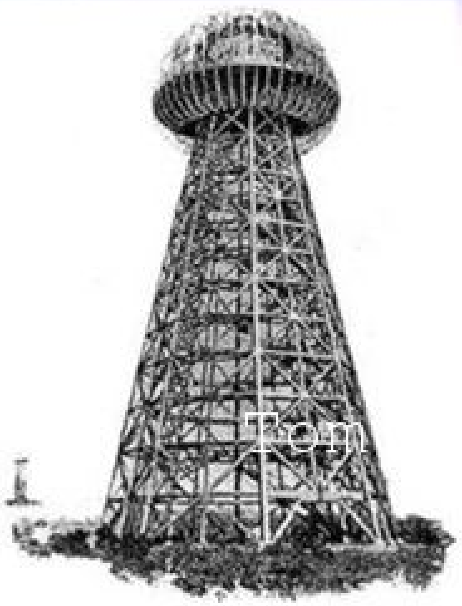

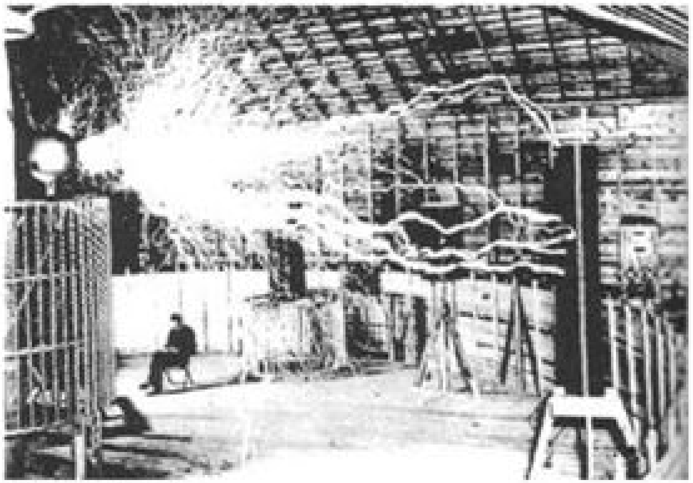

TRANSVERSE WAVE INTERFERENCE

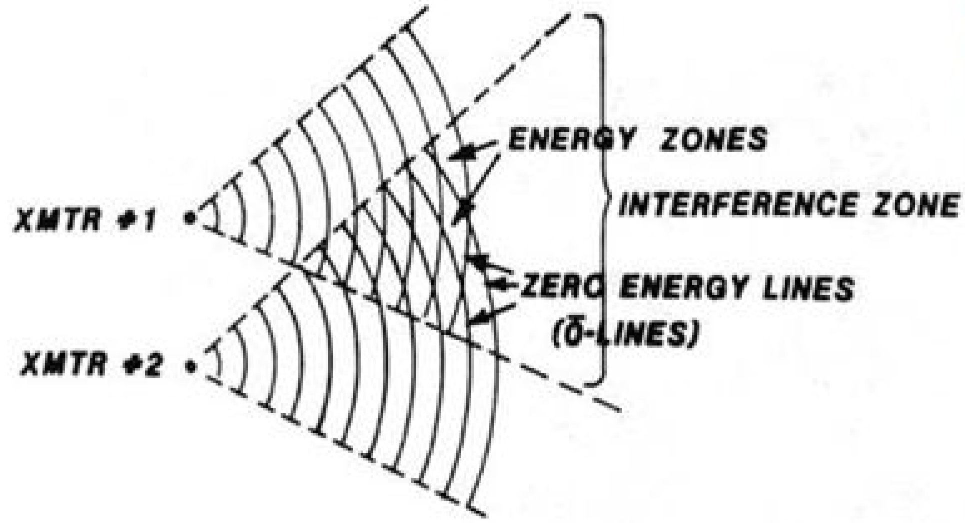
ENERGY ZONES
INTERFERENCE ZONE
XMTR #1
ZERO ENERGY LINES
(Ō-LINES)
XMTR #2

LONGITUDINAL WAVE INTERFERENCE
(SCALAR WAVES)

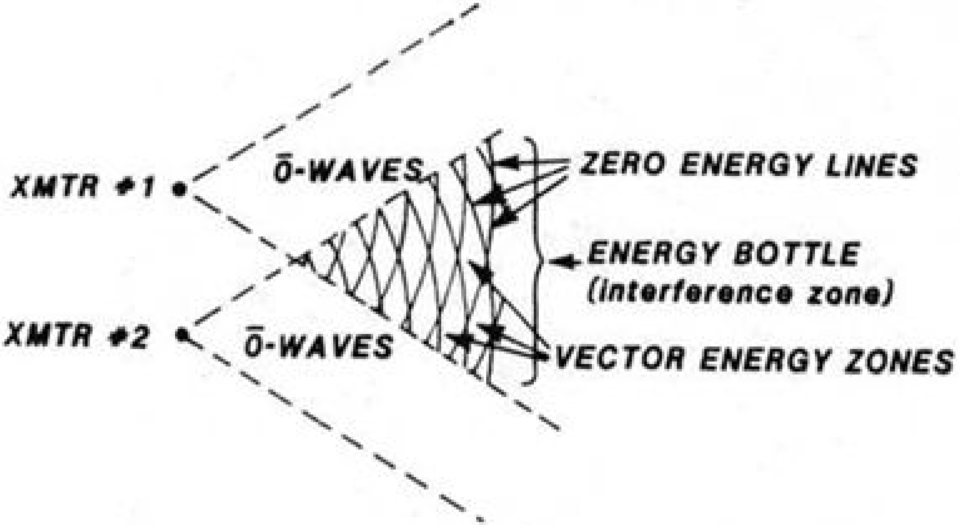
XMTR #1
Ō-WAVES
ZERO ENERGY LINES
ENERGY BOTTLE
(interference zone)
XMTR #2
Ō-WAVES
VECTOR ENERGY ZONES

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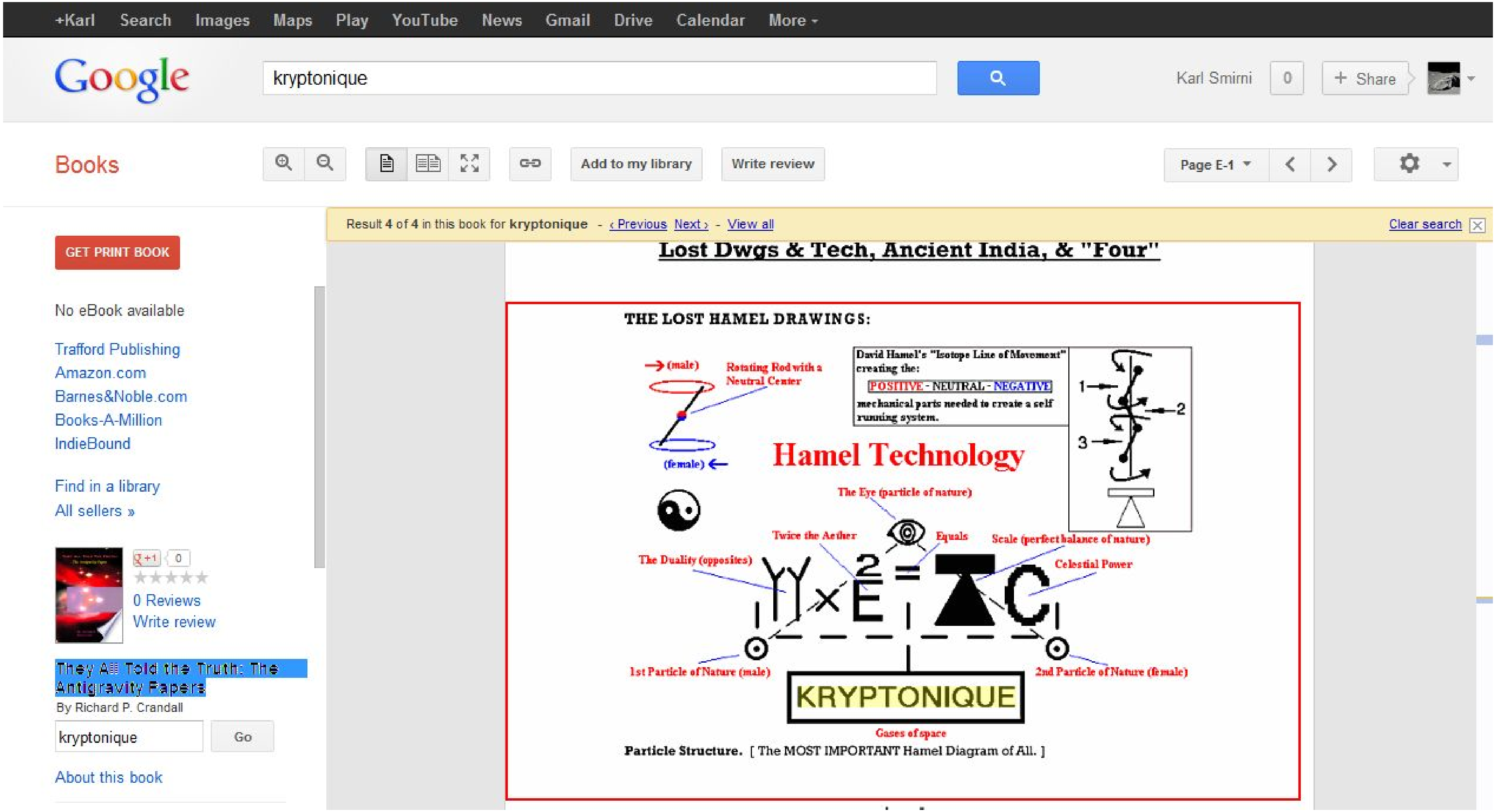
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Drive
Calendar
More
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kryptonique
Karl Smirni
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They All Told the Truth: The Antigravity Papers

By Richard P. Crandall

Lost Dwgs & Tech, Ancient India, & "Four"

THE LOST HAMEL DRAWINGS:

David Hamel's "Isotope Line of Movement" creating the:

POSITIVE - NEUTRAL - NEGATIVE

mechanical parts needed to create a self running system.

Hamel Technology

(male)
Rotating Rod with a Neutral Center
(female)
1
2
3
The Eye (particle of nature)
Twice the Aether
Equals
Scale (perfect balance of nature)
The Duality (opposites)
Celestial Power
× E 2 =
C
1st Particle of Nature (male)
2nd Particle of Nature (female)
KRYPTONIQUE
Gases of space

Particle Structure. [The MOST IMPORTANT Hamel Diagram of All.]

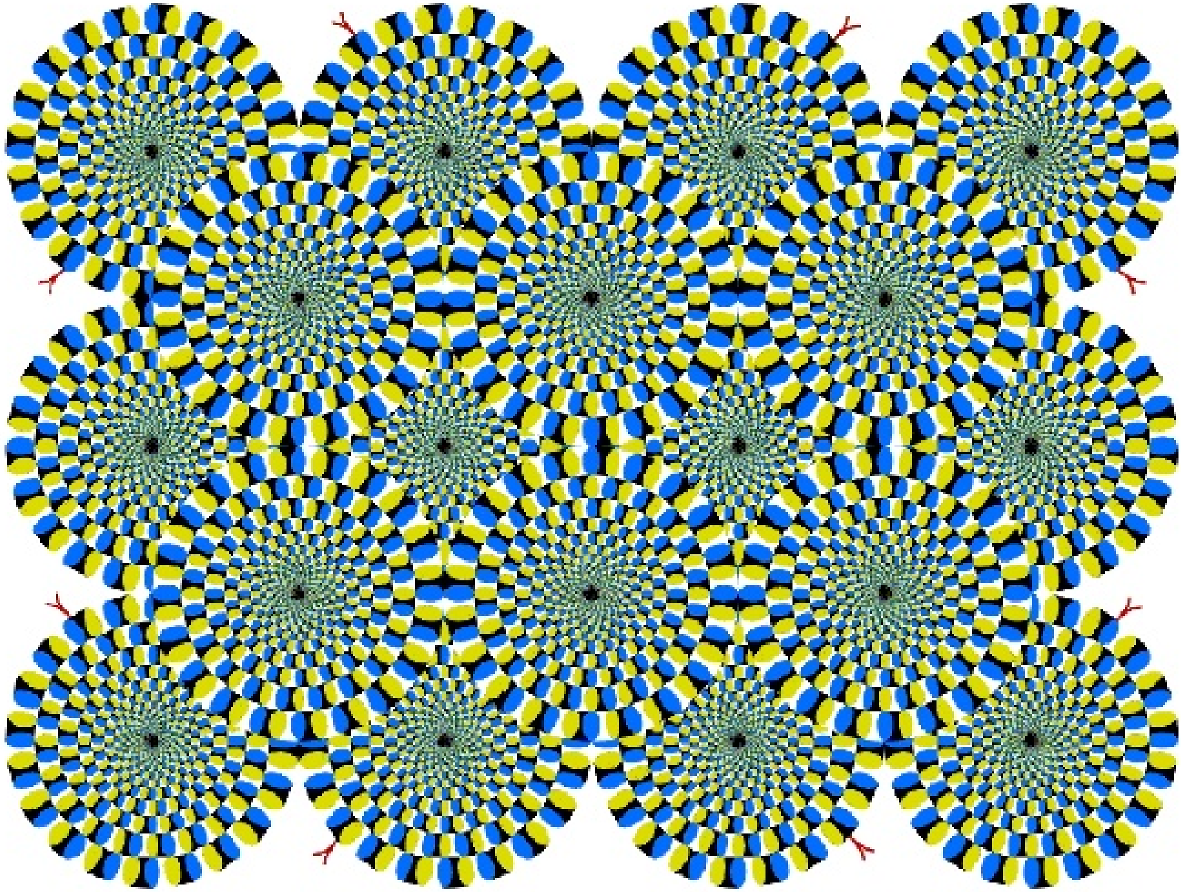

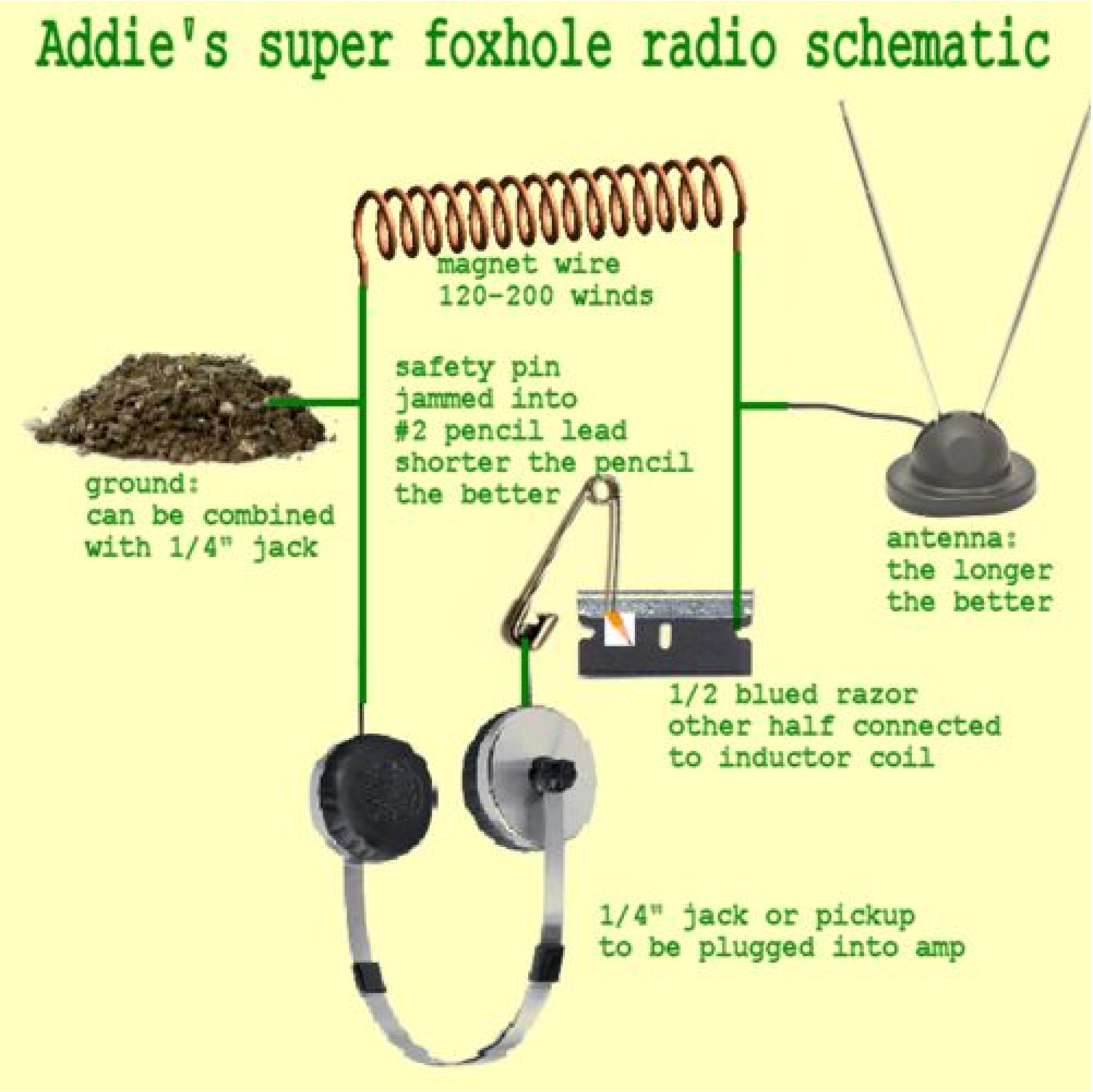
Addie's super foxhole radio schematic
magnet wire
120-200 winds
safety pin
jammed into
#2 pencil lead
shorter the pencil
the better
ground:
can be combined
with 1/4" jack
antenna:
the longer
the better
1/2 blued razor
other half connected
to inductor coil
1/4" jack or pickup
to be plugged into amp

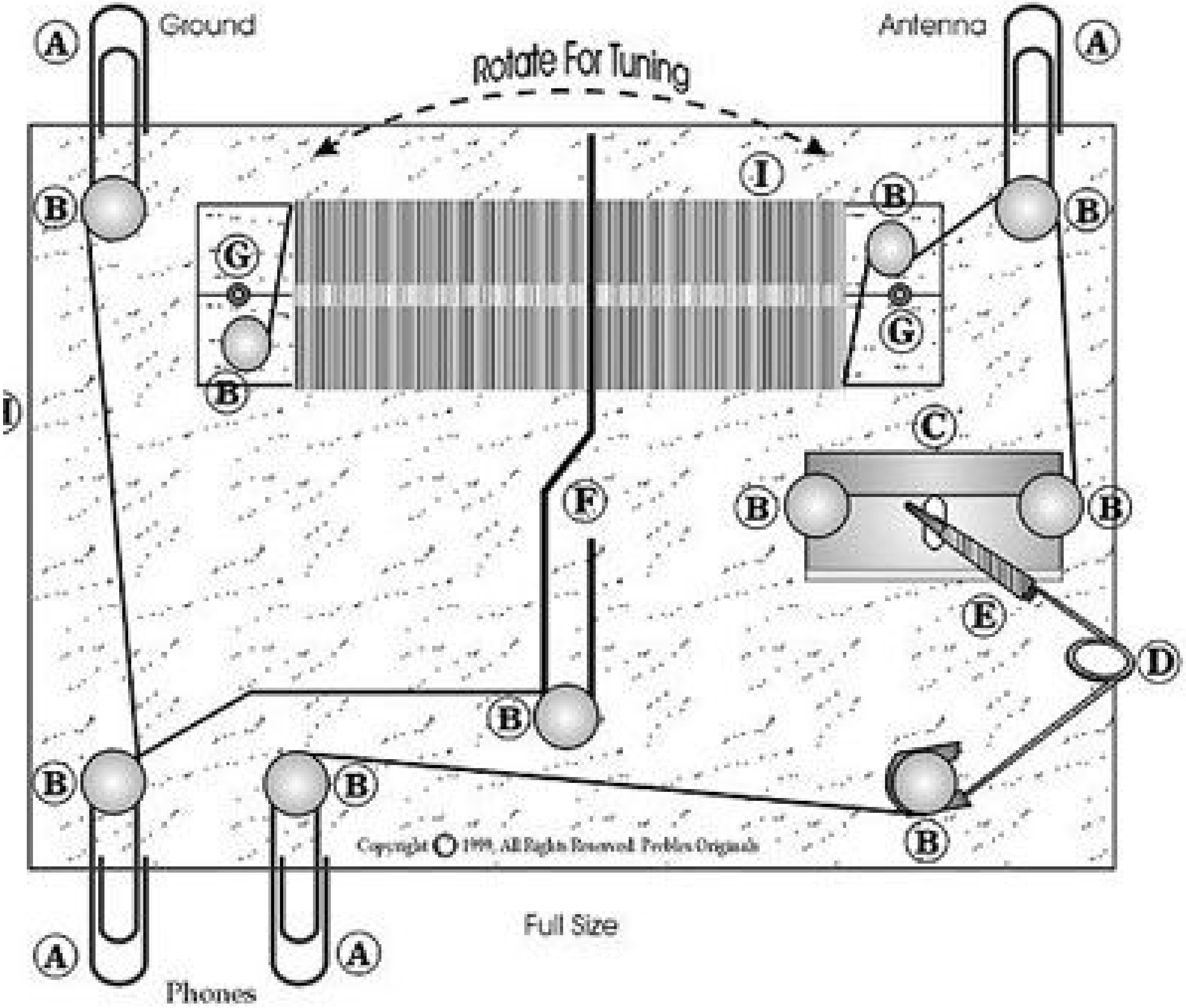
Ground
Antenna
A
A
Rotate For Tuning
I
B
B
B
G
G
B
B
C
F
B
B
E
D
B
B
B
B
Copyright © 1999, All Rights Reserved. Prebles Originals
A
A
Phones

Full Size

The PO-102, Crystal Radio Kit, w/Slider-Tuning!

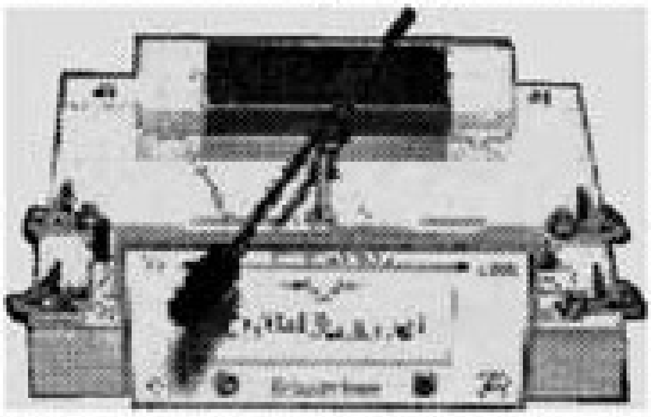

Perfect for parents, grandparents, and teachers to build with kids! Also a super starter kit for the beginning adult builder! Includes small coil form, wire, slider assembly, capacitors, and diode. Easy parts layout guide provided for kids. Excellent performance for such a simple but elegant classic slider. Earplug included.

PO-102, w/Crystal Earphone

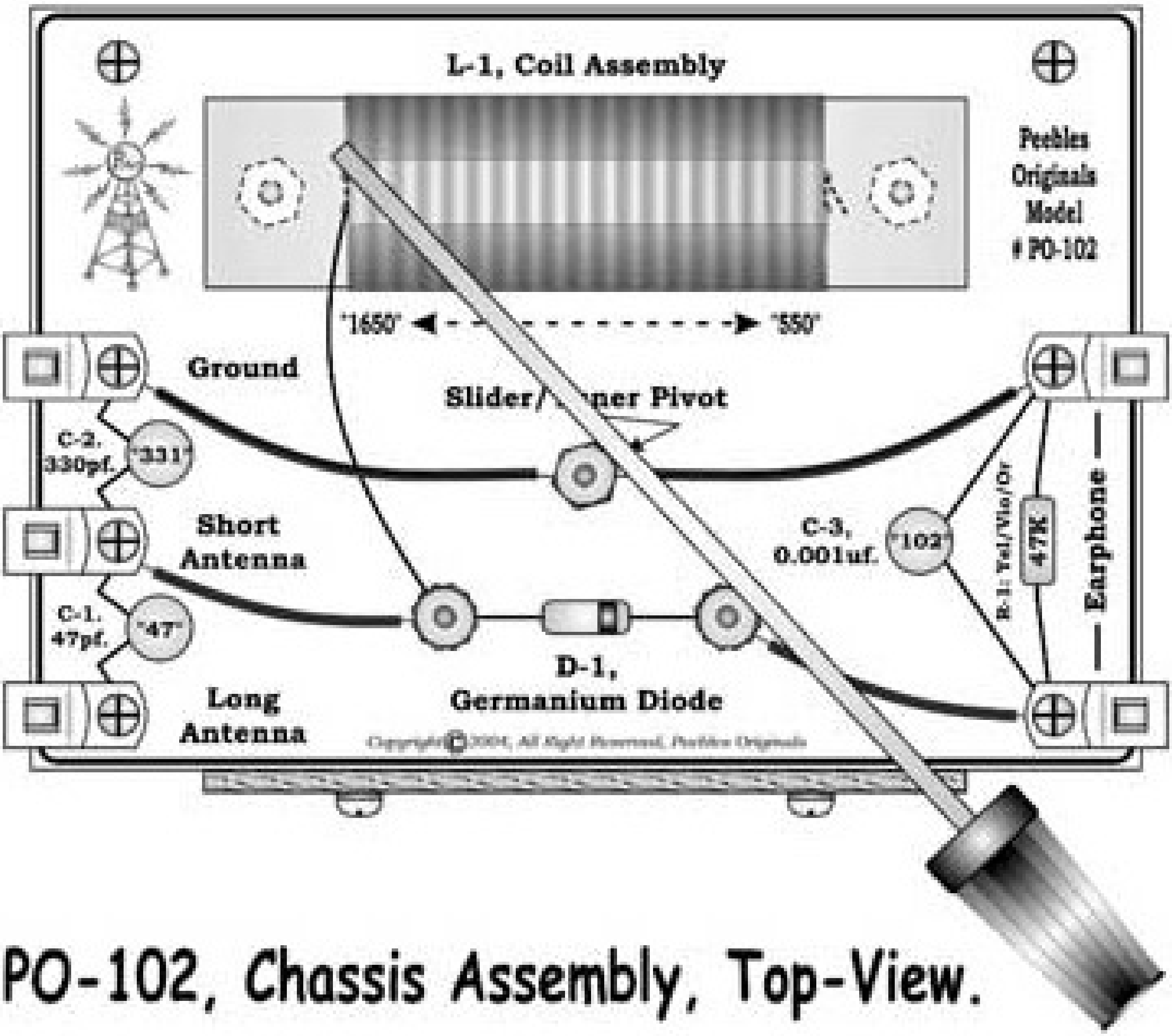
L-1, Coil Assembly
Peebles
Originals
Model
# PO-102
"1650"
"550"
Ground
Slider/ ner Pivot
C-2,
330pf.
"331"
Short
Antenna
C-1,
47pf.
"47"
Long
Antenna
D-1,
Germanium Diode
C-3,
0.001uf.
"102"
R-1: Yel/Vio/Or
47K
Earphone
Copyright © 2004, All Right Reserved, Peebles Originals

PO-102, Chassis Assembly, Top-View.

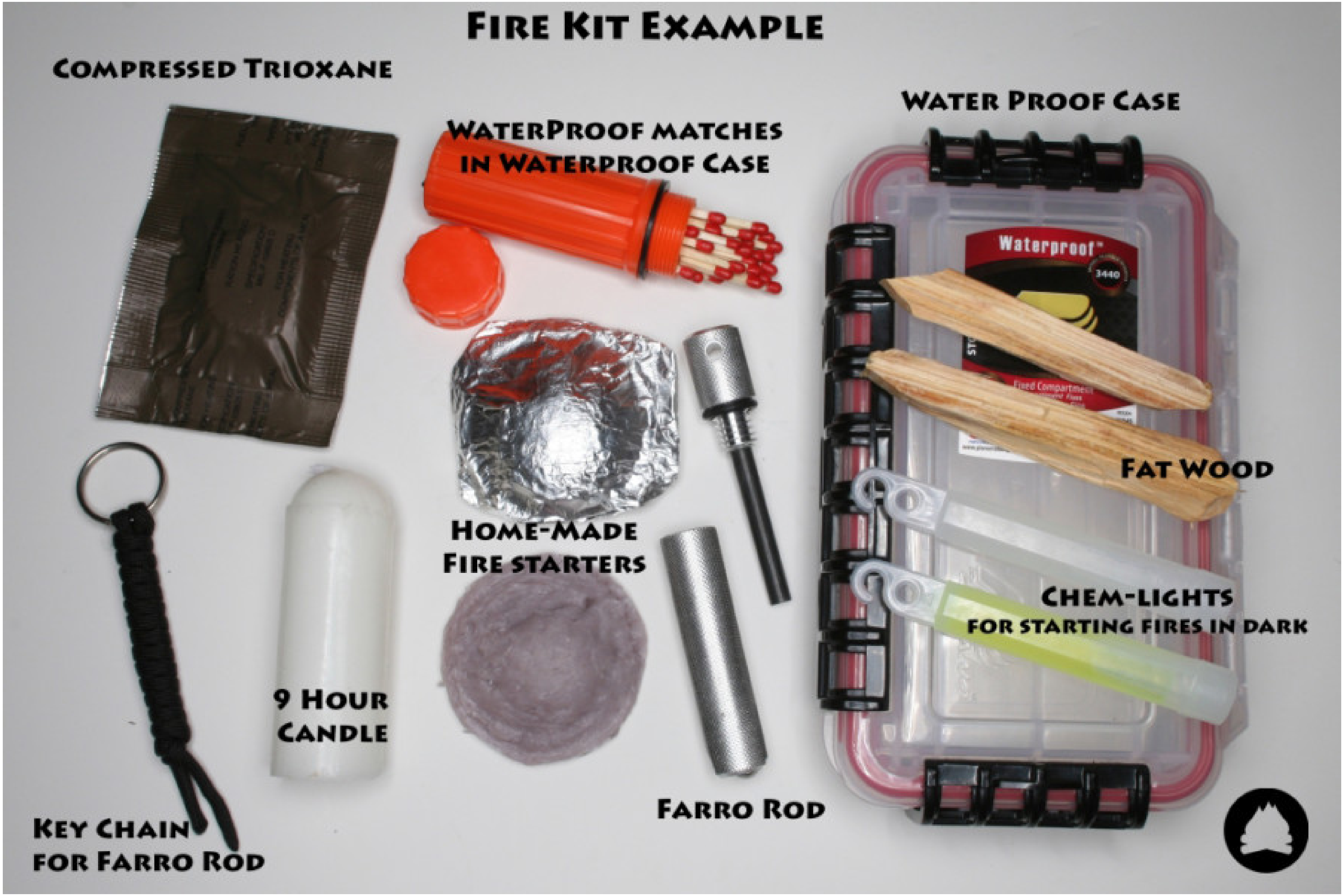
Fire Kit Example
Compressed Trioxane
WaterProof matches in Waterproof Case
Water Proof Case
Waterproof
Fat Wood
Home-Made Fire starters
Chem-lights for starting fires in dark
9 Hour Candle
Farro Rod
Key Chain for Farro Rod

PREPPERS SHOP
PREPARE
DEFEND
SURVIVE
FIRST
KOMBAT
CONSERVE WATER
NAVIGATION
HIGHLANDER
SURVIVAL BAG
SAWYER

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2. Anglo Arms Machete
3. Austrian Ex-Military Water Flask
4. BCB Trekker Lifesaver Pack
5. BCB Compact Fishing Kit
6. Canadian Gas Mask w/ Filters
7. Feit Electric 500 LED Torch
8. French Military Mess Tins
9. Hexamine Solid Fuel Cooker
10. Heavy Duty Camo Tarp
11. Highlander Survival Bag
12. Highlander Solid Fuel Cooker
13. Highlander Trekker Hammock
14. Highlander Folding Saw
15. Kombat UK W/proof Matches
16. Kombat UK 40l Molle Bag
17. Kombat UK Fire Starting Kit
18. Kombat UK Compass
19. Kombat UK Throwing Axe
20. Oasis Water Purification Tablets
21. Pro Force Survival Saw
22. Sawyer Mini Water Filter
23. Sharpening Stone
24. Survival Mirror
25. Turboflame Lighter
26. UST Survival Poncho
27. Wateproof Rucksack Liner
28. Wind Up Solar Torch
29. Wooden Deluxe Knife w/ Case
30. 100ft Paracord
31. 24hr Ration Pack

£280

ERbar
DRINKING WATER
DATREX
SLEEPING BAG
DUCT
FRONTIER STRAW

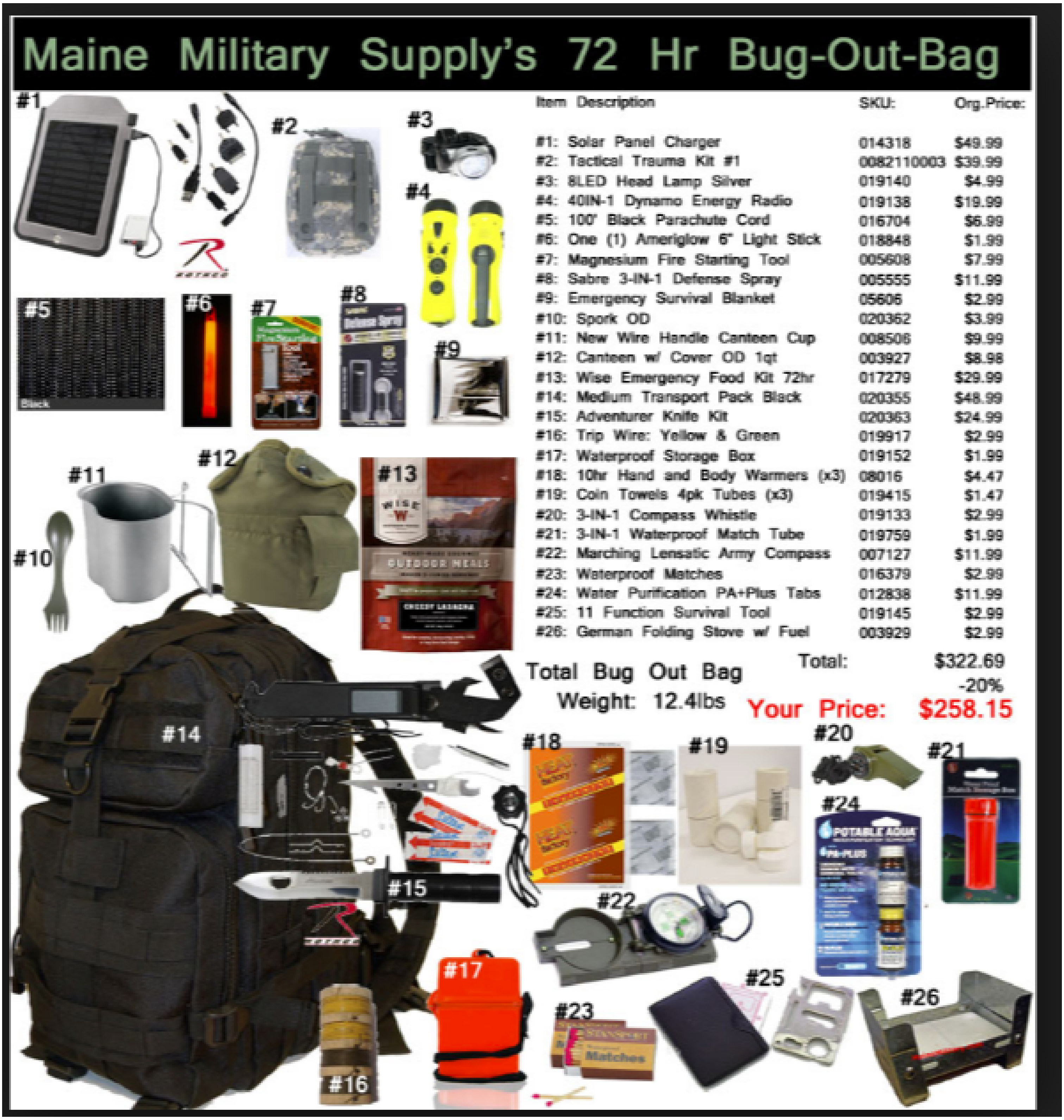

Maine Military Supply's 72 Hr Bug-Out-Bag

Item Description	SKU:	Org.Price:
#1: Solar Panel Charger	014318	$49.99
#2: Tactical Trauma Kit #1	0082110003	$39.99
#3: 8LED Head Lamp Silver	019140	$4.99
#4: 40IN-1 Dynamo Energy Radio	019138	$19.99
#5: 100' Black Parachute Cord	016704	$6.99
#6: One (1) Ameriglow 6" Light Stick	018848	$1.99
#7: Magnesium Fire Starting Tool	005608	$7.99
#8: Sabre 3-IN-1 Defense Spray	005555	$11.99
#9: Emergency Survival Blanket	05606	$2.99
#10: Spork OD	020362	$3.99
#11: New Wire Handle Canteen Cup	008506	$9.99
#12: Canteen w/ Cover OD 1qt	003927	$8.98
#13: Wise Emergency Food Kit 72hr	017279	$29.99
#14: Medium Transport Pack Black	020355	$48.99
#15: Adventurer Knife Kit	020363	$24.99
#16: Trip Wire: Yellow & Green	019917	$2.99
#17: Waterproof Storage Box	019152	$1.99
#18: 10hr Hand and Body Warmers (x3)	08016	$4.47
#19: Coin Towels 4pk Tubes (x3)	019415	$1.47
#20: 3-IN-1 Compass Whistle	019133	$2.99
#21: 3-IN-1 Waterproof Match Tube	019759	$1.99
#22: Marching Lensatic Army Compass	007127	$11.99
#23: Waterproof Matches	016379	$2.99
#24: Water Purification PA+Plus Tabs	012838	$11.99
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#26: German Folding Stove w/ Fuel	003929	$2.99

Total: $322.69

-20%

Your Price: $258.15

Total Bug Out Bag
Weight: 12.4lbs

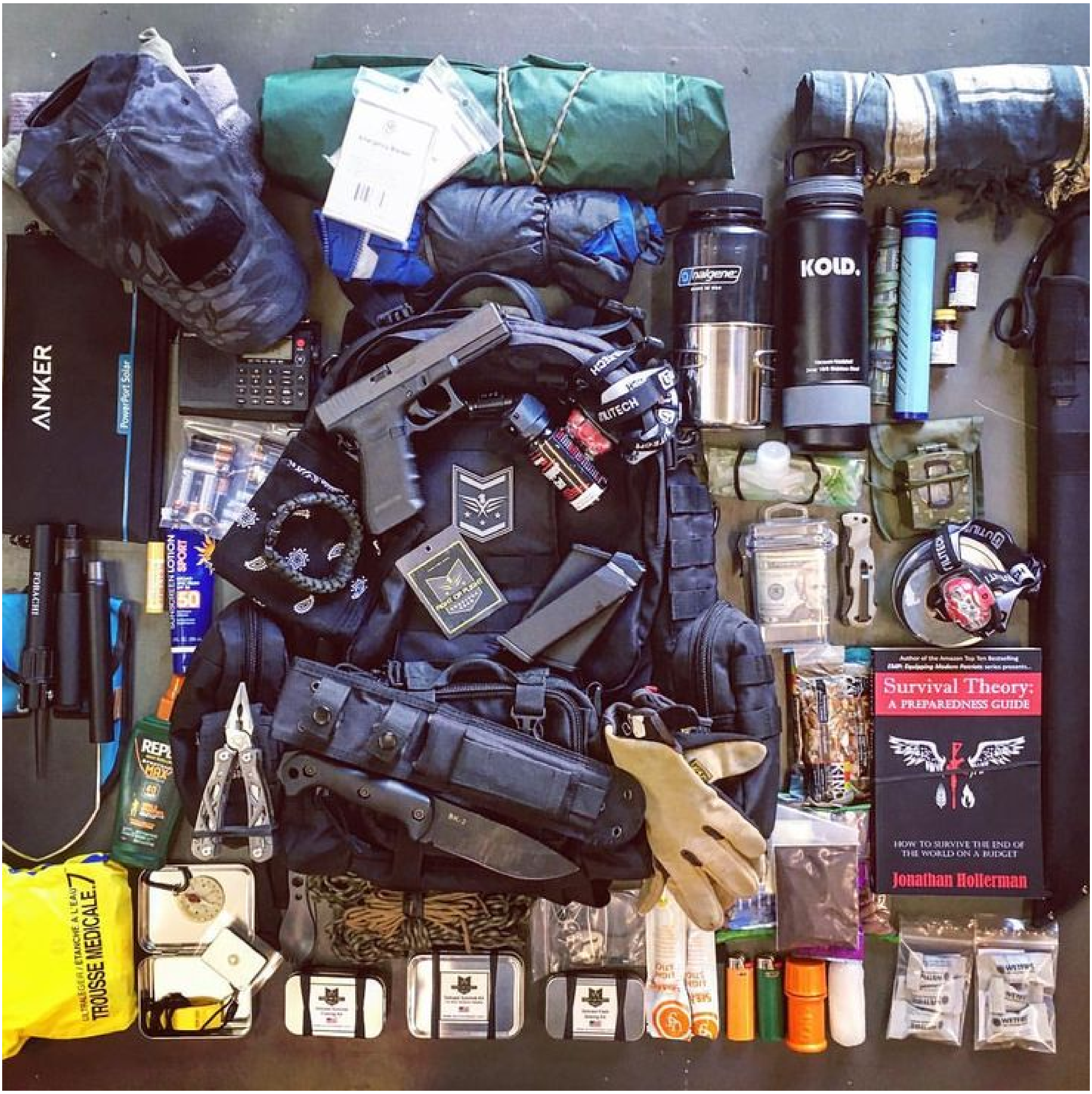
ANKER
PowerPort Solar
nalgene
KOLD.
SUNSCREEN LOTION SPORT 50
REPEL
BK-2
Survival Theory:
A PREPAREDNESS GUIDE
HOW TO SURVIVE THE END OF THE WORLD ON A BUDGET
Jonathan Hollerman
ULTRALÉGER / ÉTANCHE À L'EAU
TROUSSE MÉDICALE .7

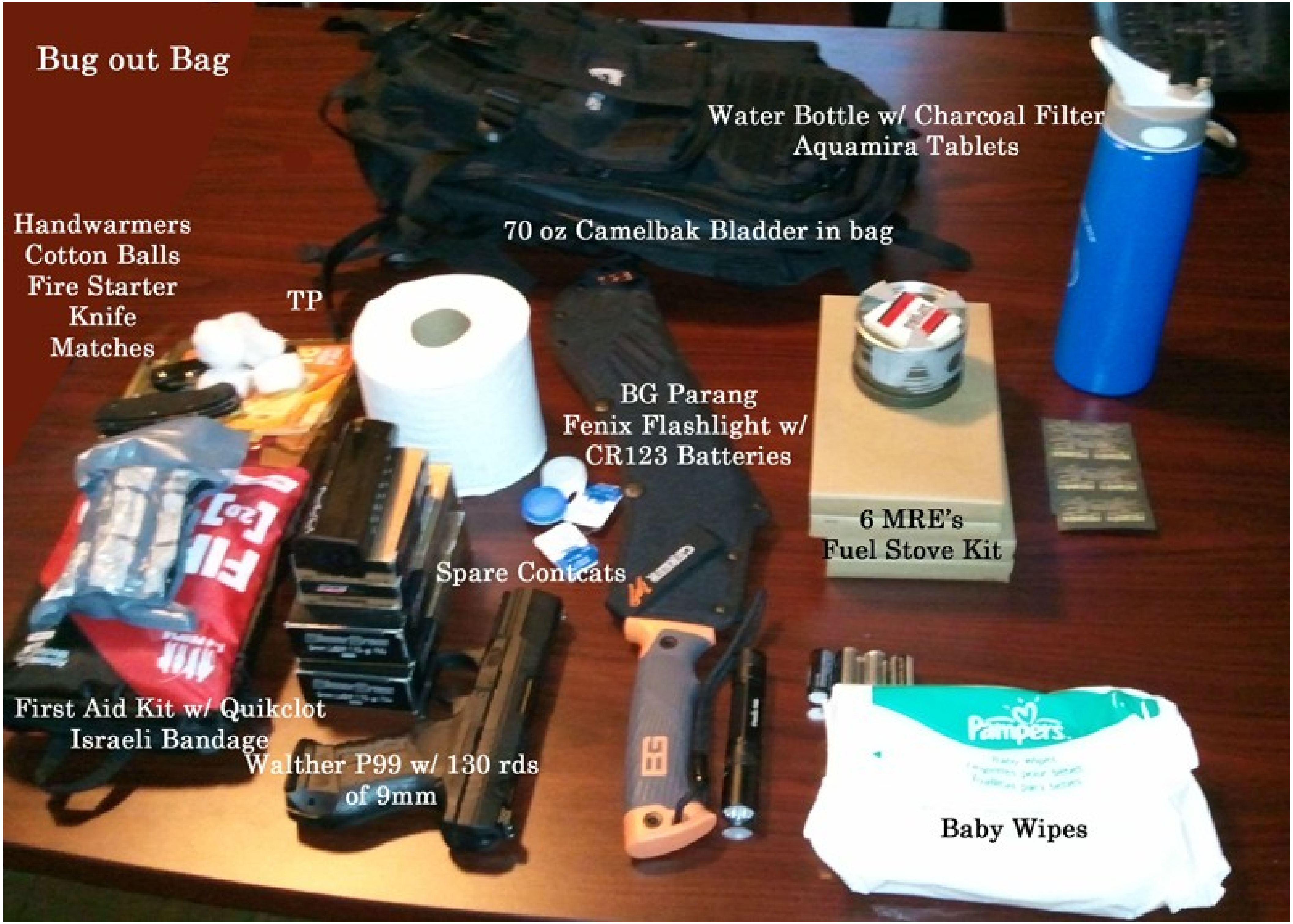
Bug out Bag
Water Bottle w/ Charcoal Filter
Aquamira Tablets
70 oz Camelbak Bladder in bag
Handwarmers
Cotton Balls
Fire Starter
Knife
Matches
TP
BG Parang
Fenix Flashlight w/
CR123 Batteries
6 MRE's
Fuel Stove Kit
Spare Contcats
First Aid Kit w/ Quikclot
Israeli Bandage
Walther P99 w/ 130 rds
of 9mm
Baby Wipes

6 EMERGENCY USES FOR PARACORD

1. Snare Trap

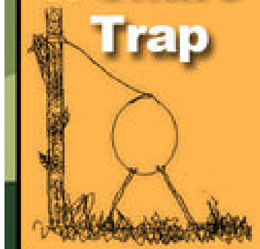

2. Fishing Line

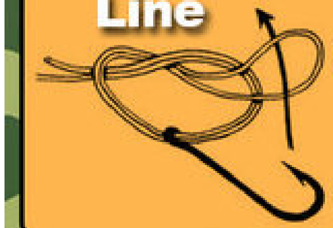

3. Shelter

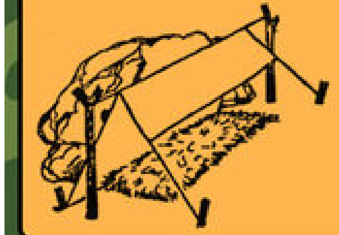

4. Fishing Net

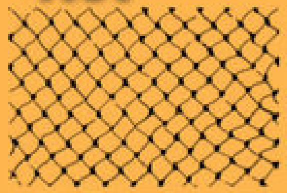

5. Fire

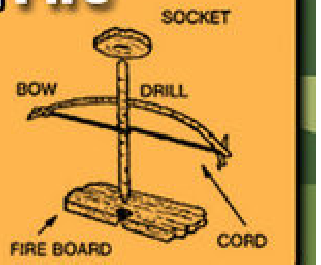
SOCKET
BOW
DRILL
FIRE BOARD
CORD

6. Bear Bag

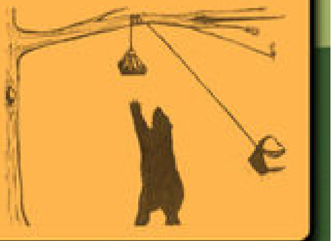

Did you know?

A single length of paracord has been tested to handle 550 lbs of weight.

Did you know?

There are seven internal strands, each of which comes apart into two, so there's 14 thin lines.

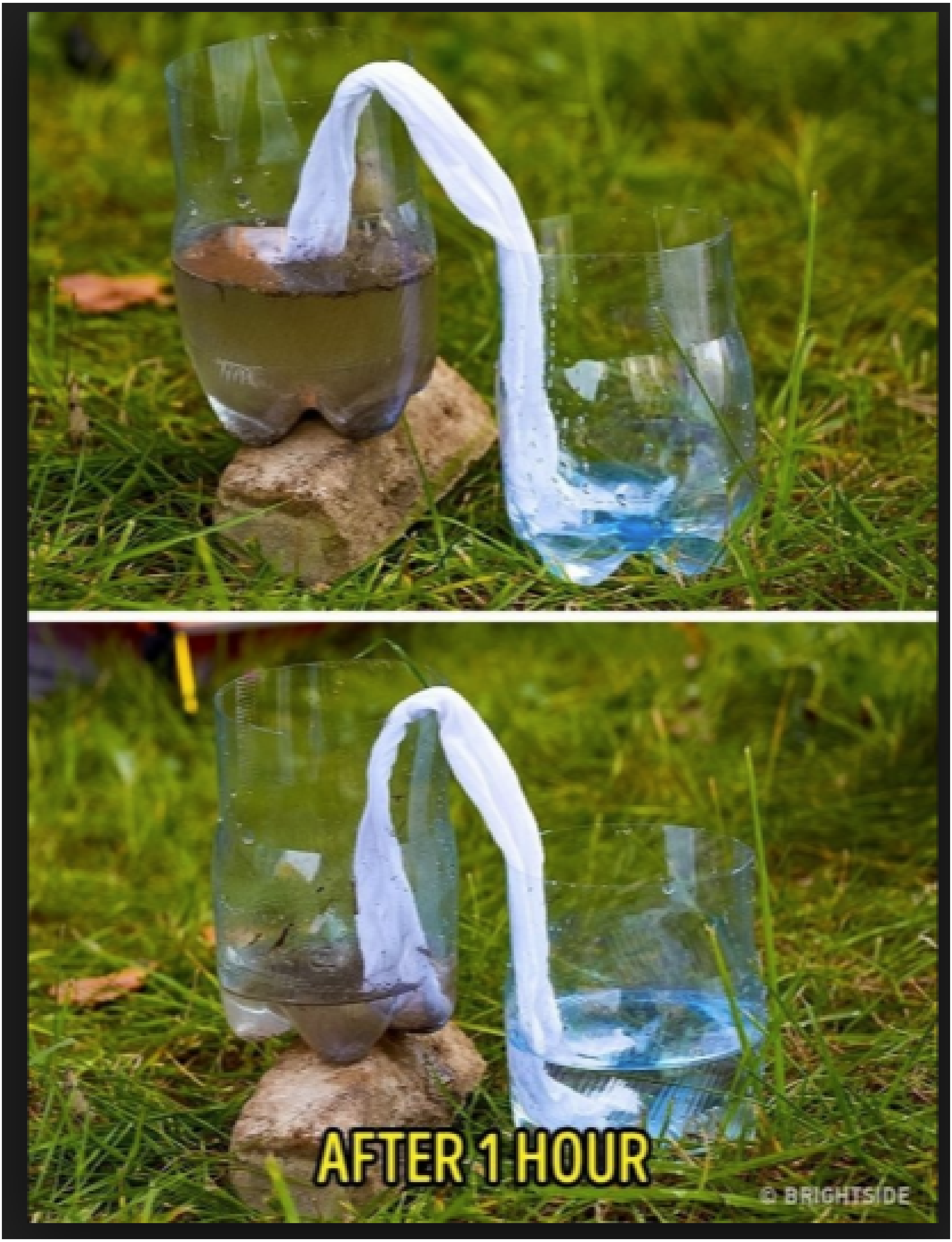
AFTER 1 HOUR
© BRIGHTSIDE

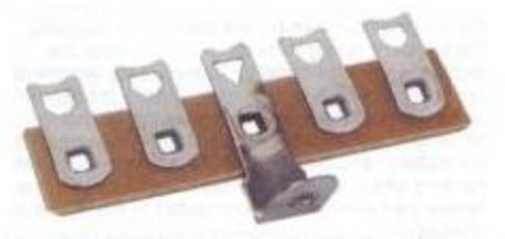

5 WAY TAG STRIP

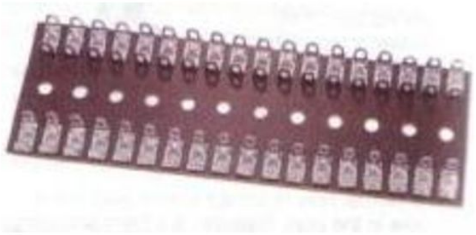

36 WAY TAG STRIP - TWO ROWS

e wired together ,with a little ingenuity, with the component wires being held together in the grip of solderless crocodile clips, whereby the conne
older.

ex circuits a plastic Terminal Block (sometimes referred to as a choc' or chocolate block) can be utilised very effectively indeed. These are used
15 Amp and 30 Amp. The 5 and 15 Amp Terminal Blocks I have found to be the most suitable. The various component wires can be trappec
makes it easy to change the components around when experiment with different circuits. See The EXPERMENTAL CRYSTAL SET for more de

'CHOCOLATE' TERMINAL BLOCK

Where to connect to the earbud jack.

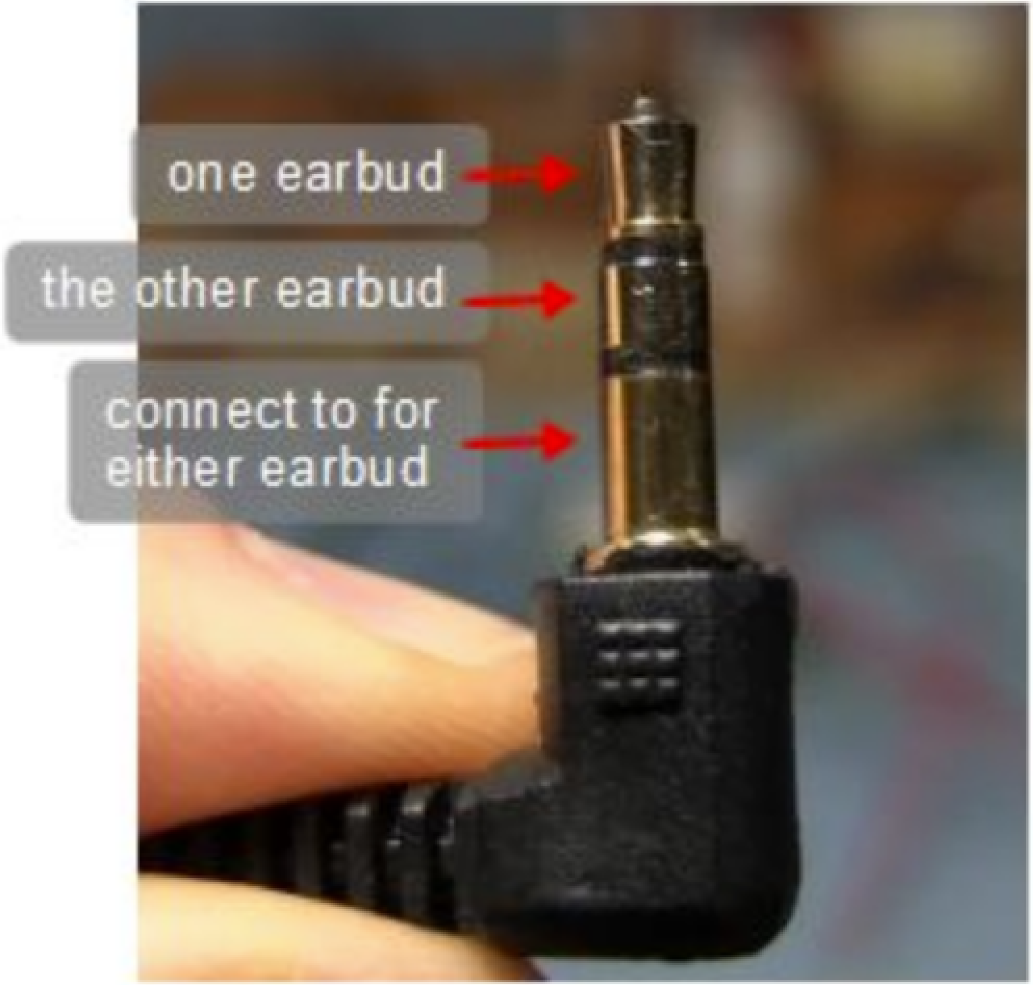
one earbud
the other earbud
connect to for either earbud

For connecting to one earbud only.

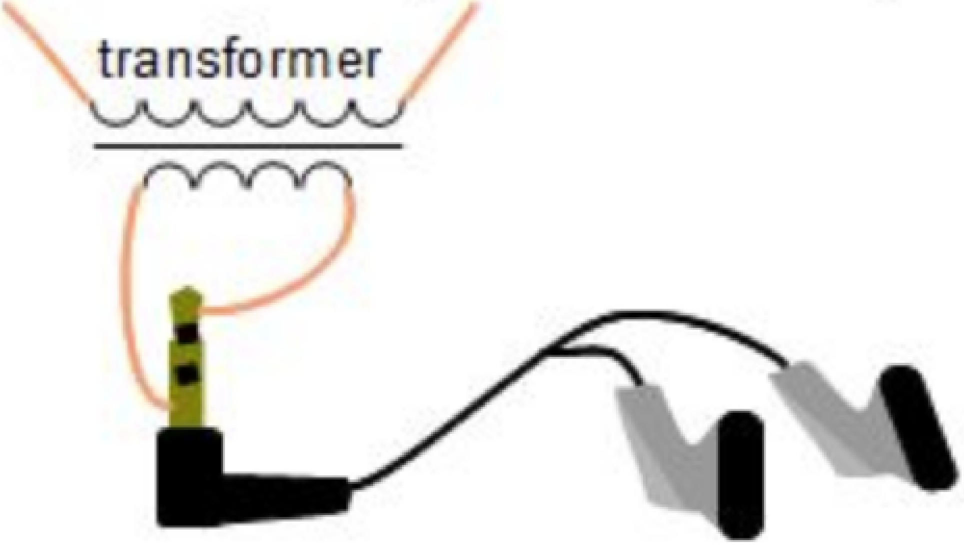
transformer

For connecting to both earbuds.

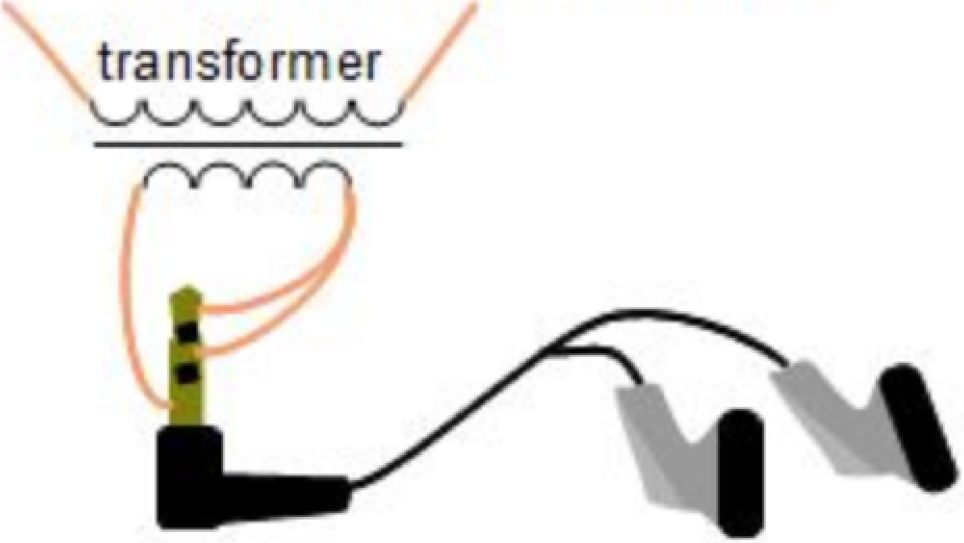
transformer

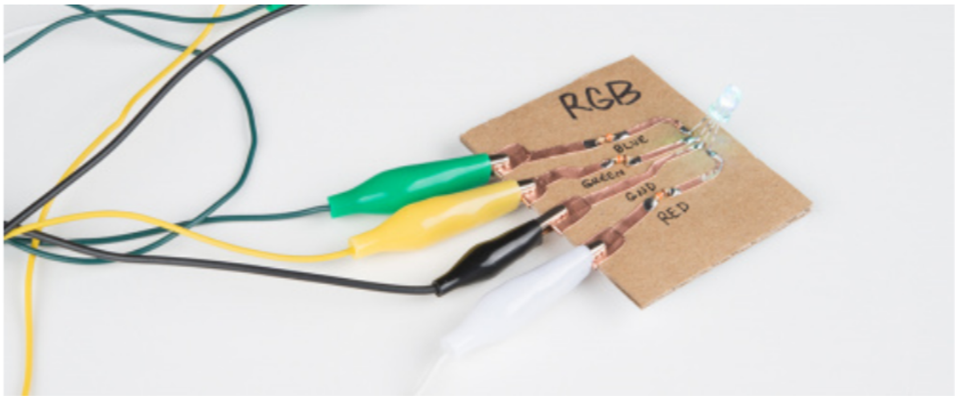
RGB
BLUE
GREEN
GND
RED

The current-limiting resistors are part of the cardboard circuit. The black spots are where I used the Bare Conductive paint

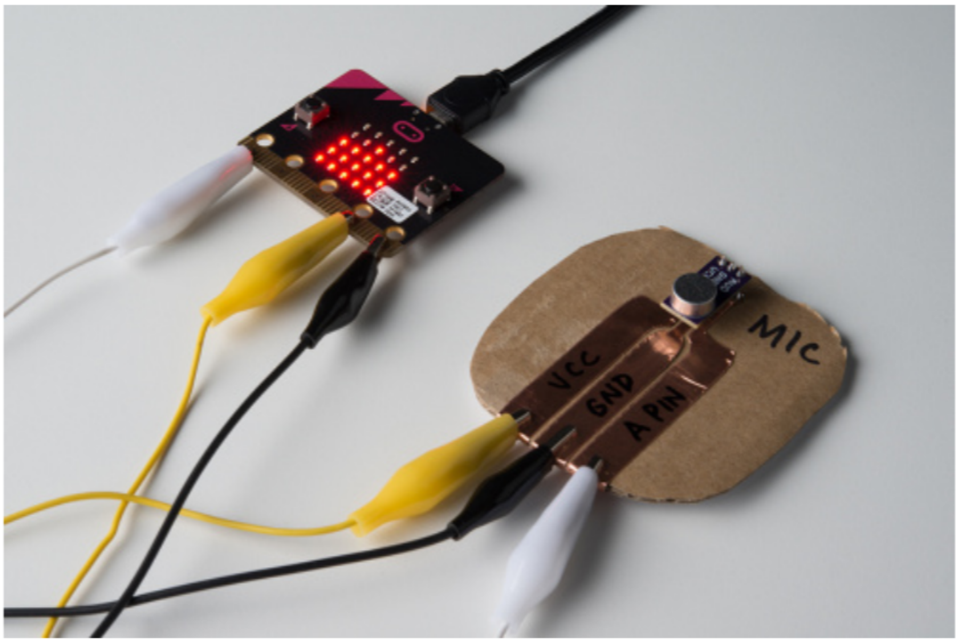
MIC
VCC
GND
A PIN

The micro:bit is plotting the analog values on the 5x5 LED matrix, which represent the noise level in the room.

D PIN
2 BUTTON BOARD
"ACTIVE LOW"
D PIN
GND
BARE
ELECTRIC PAINT

All you need to get started is a roll of copper tape, a few components and conductive paint. One roll of tape and tube of paint can make about 200 circuits.

COSMIC VIBRATIONS

Octave	Manifestation	Vibrations per second	Gaps
1	TOUCH	2	
2		4	
3		8	
4	SOUND	16	
5		32	
6		64	
7		128	
8		256	
9		512	
10		1,024	
11		2,048	
12		4,096	
13		8,192	
14	ELECTROMAGNETIC (Longer Radio Waves)	16,384	
15		32,768	
16		65,536	
17		131,072	
18		262,144	
19		524,288	
20		1,048,576	
21		2,097,152	
22		4,194,304	
23		8,388,608	
24		16,777,216	
25		33,554,432	
26		67,108,864	
27		134,217,728	
28	ELECTROMAGNETIC (Microwaves)	268,435,456	
29		536,870,912	
30		1,073,741,824	
31		2,147,483,648	
32		4,294,967,296	
33		8,589,934,592	
34		17,179,869,184	
35		34,359,738,368	
36		68,719,476,736	
37		137,438,953,472	
38	HEAT OR INFRARED	274,877,906,944	
39		549,755,813,888	
40		1,099,511,627,776	
41		2,199,023,255,552	
42		4,398,046,511,104	
43		8,796,093,022,208	
44		17,592,186,044,416	
45		35,184,372,088,832	
46		70,368,744,177,664	
47		140,737,488,355,328	
48	VISIBLE LIGHT	281,474,976,710,656	
49		562,949,953,421,312	
50		1,125,899,906,842,624	
51	ULTRAVIOLET	2,251,799,813,685,248	SPIRIT ELECTRONS
52		4,503,599,627,370,496	
53		9,007,199,254,740,992	
54		18,014,398,509,481,984	
55		36,028,797,018,963,968	
56	X-RAY	72,057,594,037,927,936	
57		144,115,188,075,855,872	
58		288,230,376,151,711,744	
59		576,460,752,303,423,488	
60			PSYCHIC PROJECTIONS
61			
62	GAMMA AND COSMIC RAYS	4,611,686,018,427,387,904	
63			
64		*The Vibrations in these octaves increase to an incomprehensible number per second.*	
65			
66			
67			
68			
69			
70		*The phenomena of psychic projections and soul essence occur in octaves considerably beyond those of any known material manifestations. Consequently, they must not be considered as immediately following any manifestations which we have shown on this chart.*	
71			
72			SOUL ESSENCE
73			
74			
75			
76			
77			
78			
79			
80			

(THESE INTERVALS AND FIGURES ARE APPROXIMATE AND NOT EXACT)

NOTICE

This chart was carefully compiled by the Editorial and Research Departments of AMORC College after consulting the most eminent scientific authorities on the subjects of physics and chemistry and comparing their observations and notations with the reports from the Rosicrucian laboratories in foreign countries.

There is a slight disagreement in regard to the rates of vibrations for the various keys of the musical keyboard, due to different standards of pitch in various countries, and there is some disagreement among scientific authorities in regard to the colors associated with various musical notes. This chart represents not only the consensus of most of these authorities but also adheres strictly to what the Rosicrucians have been able to demonstrate as truth in our own laboratories and in the experiments of thousands of members in various parts of the world. Regardless, therefore, of any disagreement with authorities outside the organization, this chart is the authentic presentation of the Rosicrucian knowledge.

This chart is to be used by the members of the Rosicrucian Order in connection with their studies and experiments and is not to be used for any other purpose or in any other way. Like the lessons themselves, this chart and the facts contained on it are reserved and restricted in use under the rules and regulations of the organization.

INTERNATIONAL
SEAL OF THE
SUPREME LODGE
of the
Rosicrucian
Order

AD ROSAM PER CRUCEM • AD CRUCEM PER ROSAM

THE SOLAR SPECTRUM

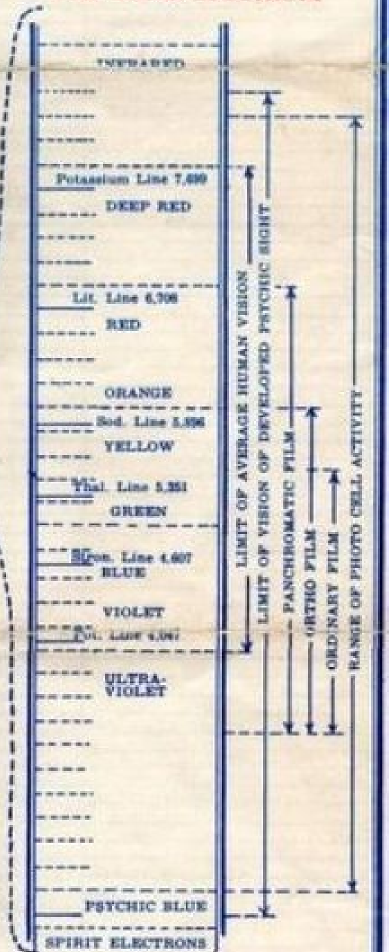

AMORC
THE
Rosicrucian Order
San Jose, California

LITHO. IN U. S. A.

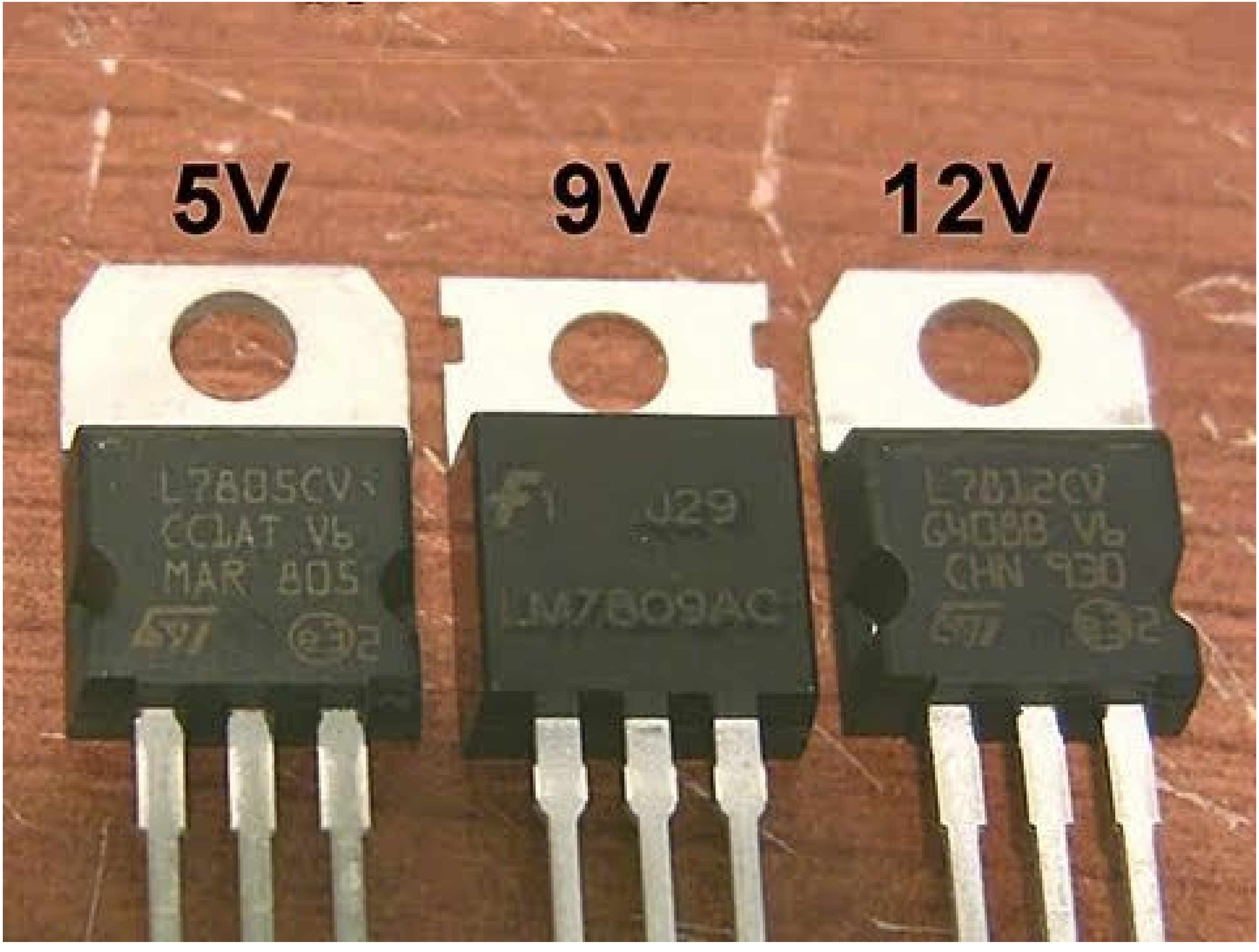
5V
9V
12V
L7805CV
CC1AT V6
MAR 805
J29
LM7809AC
L7812CV
G408B V6
CHN 930

7 LOGIC GATES & 4 USEFUL COMBINATIONS

Standard Logic Gates

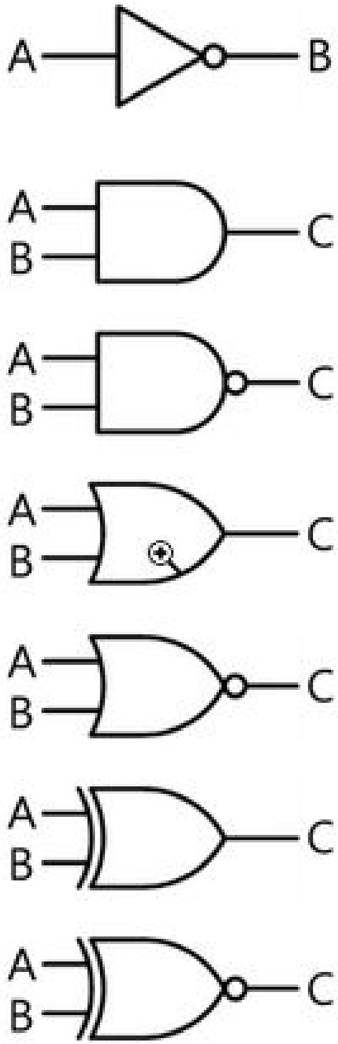
A
B
A
B
C
A
B
C
A
B
C
A
B
C
A
B
C
A
B
C

NOT

A	B
1	0
0	1

AND

A	B	C
1	1	1
1	0	0
0	1	0
0	0	0

NAND

A	B	C
1	1	0
1	0	1
0	1	1
0	0	1

OR

A	B	C
1	1	1
1	0	1
0	1	1
0	0	0

NOR

A	B	C
1	1	0
1	0	0
0	1	0
0	0	1

XOR

A	B	C
1	1	0
1	0	1
0	1	1
0	0	0

XNOR

A	B	C
1	1	1
1	0	0
0	1	0
0	0	1

Preceding NOT Gate on One Input for AND, NAND, OR, NOR Gates

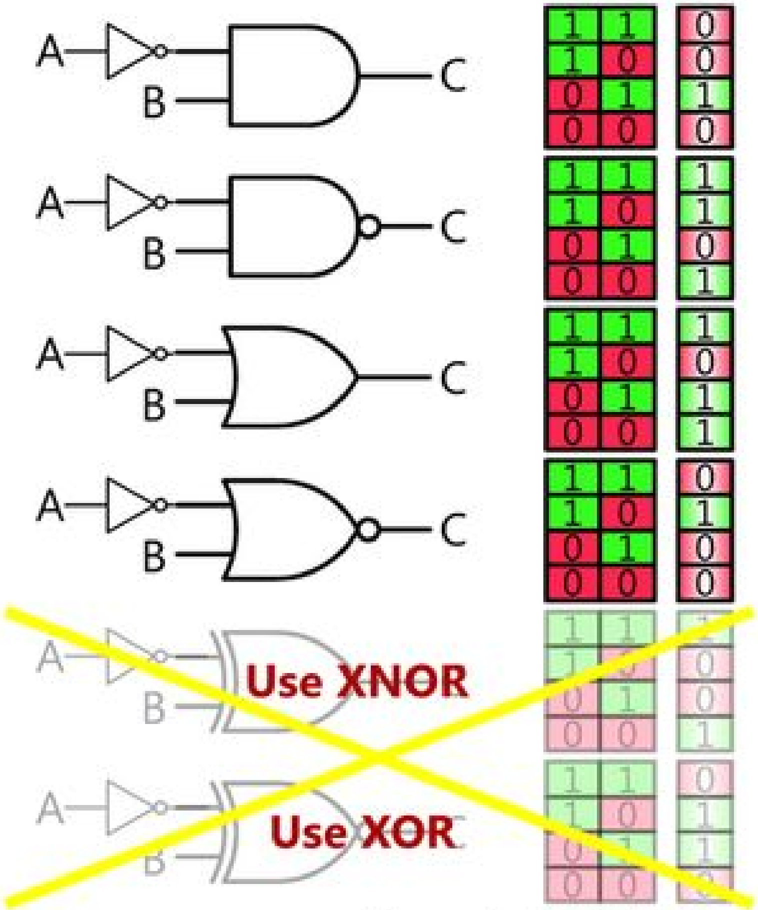
A
B
C
A
B
C
A
B
C
A
B
C
A
B
Use XNOR
A
B
Use XOR

A	B	C
1	1	0
1	0	0
0	1	1
0	0	0

A	B	C
1	1	1
1	0	1
0	1	0
0	0	1

A	B	C
1	1	1
1	0	0
0	1	1
0	0	1

A	B	C
1	1	0
1	0	1
0	1	0
0	0	0

A	B	C
~~1~~	~~1~~	~~1~~
~~1~~	~~0~~	~~0~~
~~0~~	~~1~~	~~0~~
~~0~~	~~0~~	~~1~~

A	B	C
~~1~~	~~1~~	~~0~~
~~1~~	~~0~~	~~1~~
~~0~~	~~1~~	~~1~~
~~0~~	~~0~~	~~0~~

Copyright 2012 PicoKit

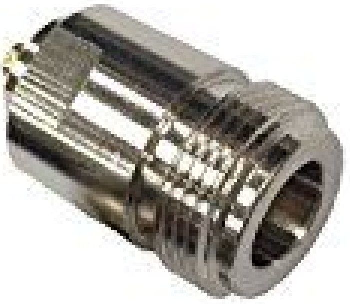

TYPE N F

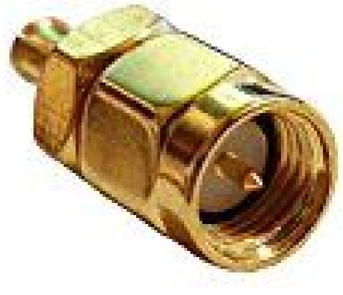

SMA M

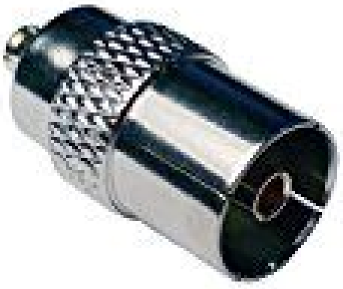

PAL/BELLING LEE F

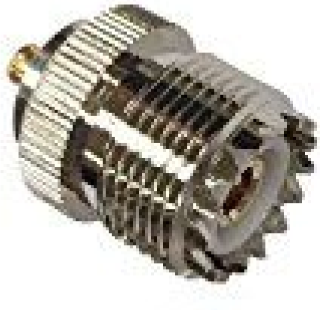

UHF F

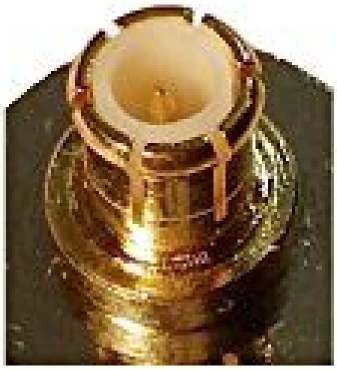

MCX MALE
(OTHER END)

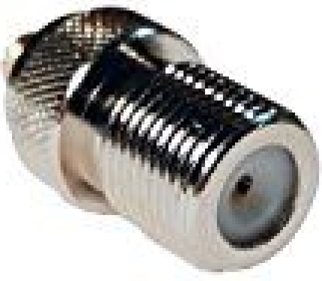

TYPE F F

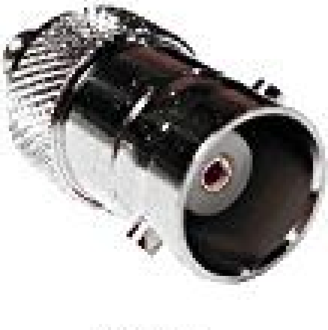

BNC F

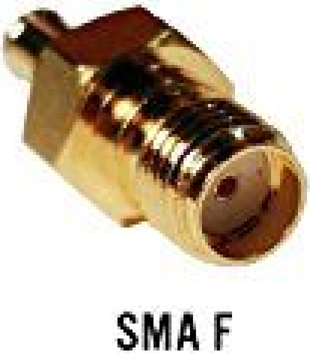

SMA F

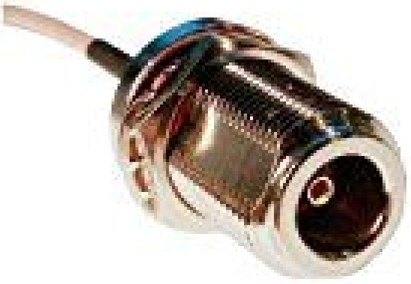

TYPE N F

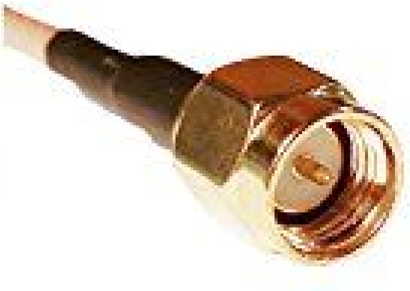

SMA M

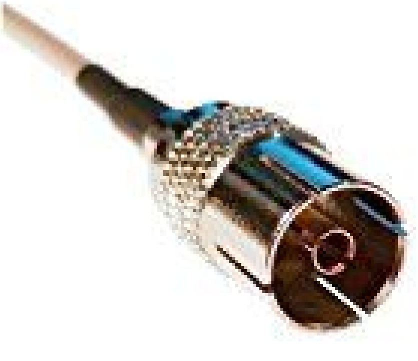

PAL/BELLING LEE F

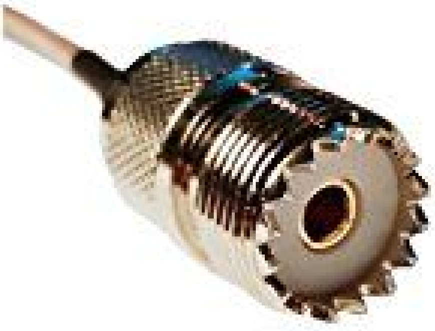

UHF F

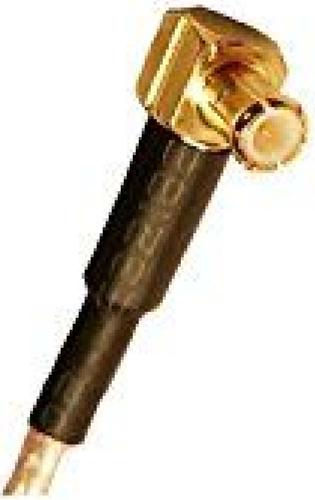

MCX MALE
(OTHER END)

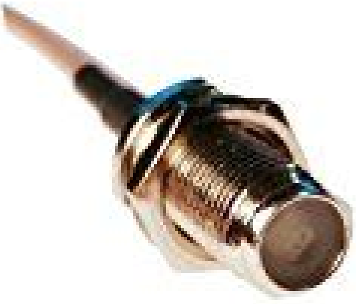

TYPE F F

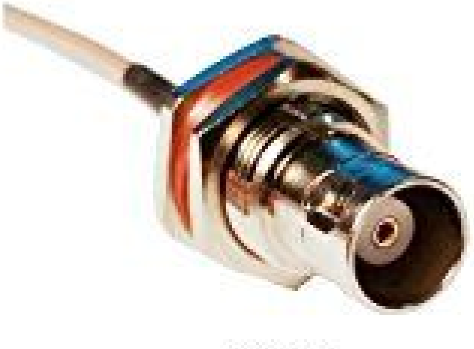

BNC F

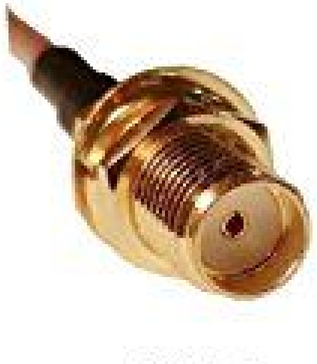

SMA F

DIODE

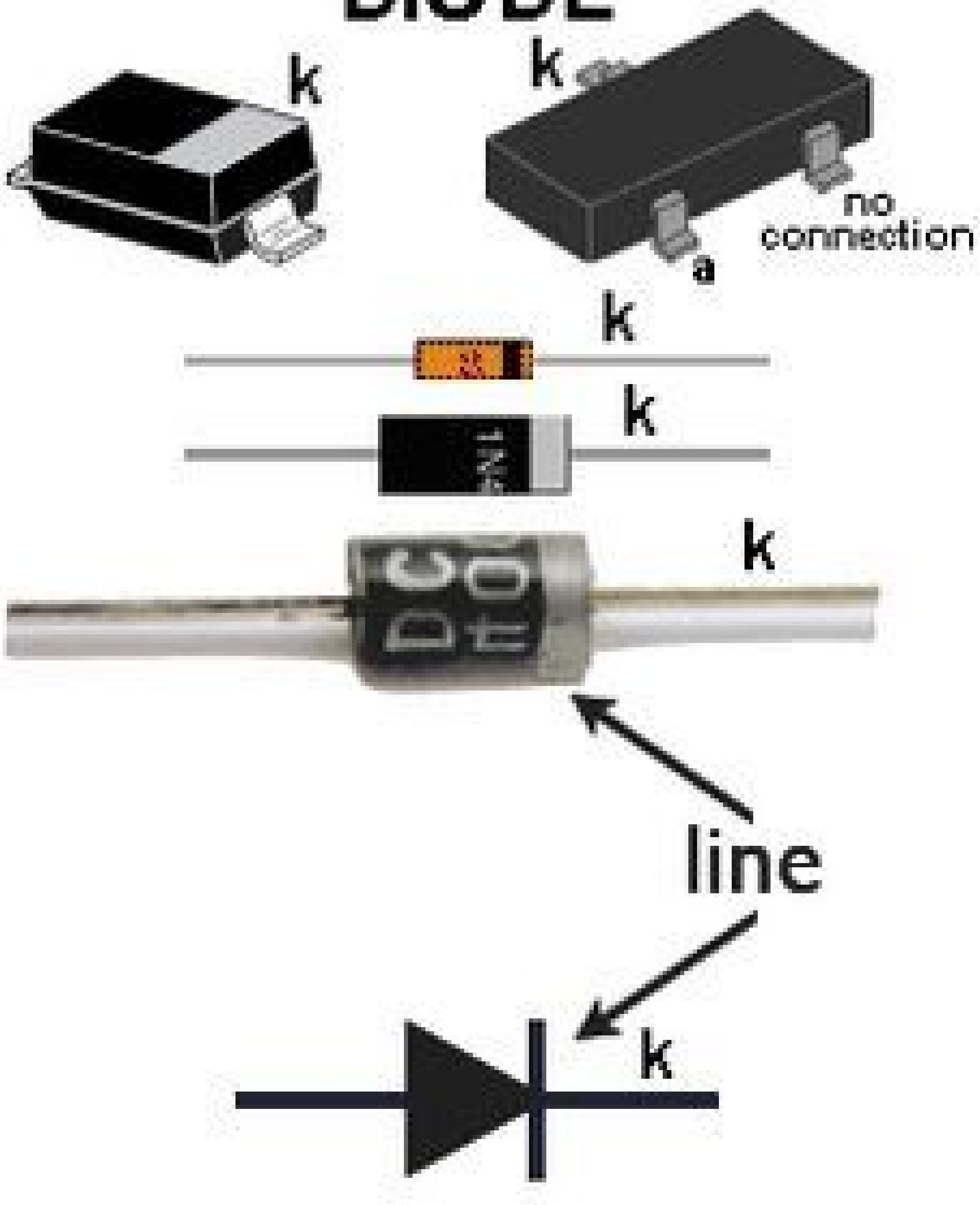
k
k
no connection
a
k
k
k
line
k

schematic symbol

direction of current flow

→

7. 555 Timer Projects

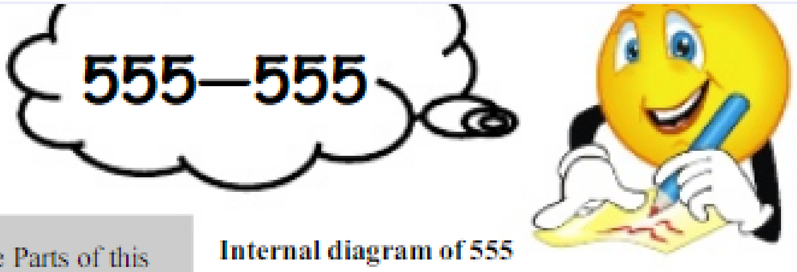

In this section we will make :

- 7.1 4 Key Piano
- 7.2 Light sensitive music circuit
- 7.3 Light controlled Police Siren
- 7.4 Touch Switch
- 7.5 Timer
- 7.6 Continuity Tester
- 7.7 Knight Rider
- 7.8 Cricket Game
- 7.9 Multipurpose circuit
- 7.10 Johnson counter

Some Parts of this project are available in Video CD ROM

What is it about ?

555 timer integrated circuit (IC) is a very popular chip used in variety of applications like timer, pulse generation and oscillators. This is a low cost, stable and widely available chip which makes it favorite for hobbyists. The internal components of 555 as shown in figure consists of 2 comparators and a flip flop. All of these components contain 25 transistors and 15 resistors packed in the IC.

The three highlighted 5k resistors shown in figure are the reason why this IC is named as 555.

Internal diagram of 555

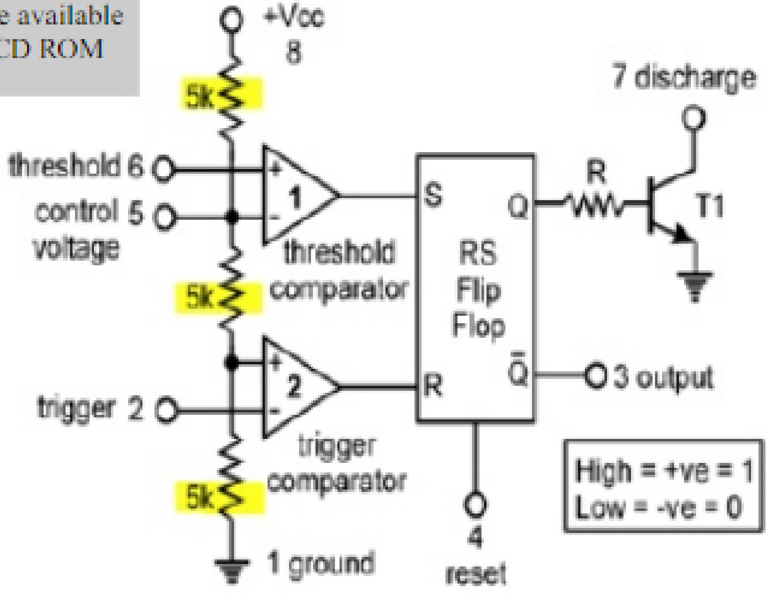
+Vcc
8
5k
threshold 6
control 5
voltage
7 discharge
R
T1
1
threshold
comparator
S
Q
RS
Flip
Flop
Q̄
3 output
R
2
trigger 2
5k
trigger
comparator
5k
1 ground
4
reset
High = +ve = 1
Low = -ve = 0

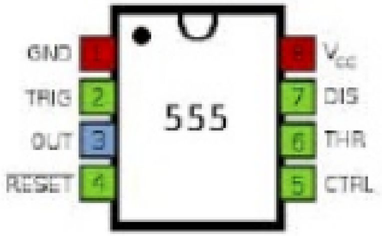
GND 1
TRIG 2
OUT 3
RESET 4
555
8 Vcc
7 DIS
6 THR
5 CTRL

Please note the notch near first pin. This is made to indentify the first pin of IC.

Pin	Name	Purpose
1	GND	Ground reference voltage, low level (0 V)
2	TRIG	The OUT pin goes high and a timing interval starts when this input falls below 1/2 of CTRL voltage (which is typically 1/3 of V_{CC}, when CTRL is open).
3	OUT	This output is driven to approximately 1.7V below +V_{CC} or GND.
4	RESET	A timing interval may be reset by driving this input to GND, but the timing does not begin again until RESET rises above approximately 0.7 volts. Overrides TRIG which overrides THR.
5	CTRL	Provides "control" access to the internal voltage divider (by default, 2/3 V_{CC}).
6	THR	The timing (OUT high) interval ends when the voltage at THR is greater than that at CTRL.
7	DIS	Open collector output which may discharge a capacitor between intervals. In phase with output.
8	V_{CC}	Positive supply voltage, which is usually between 3 and 15 V depending on the variation.

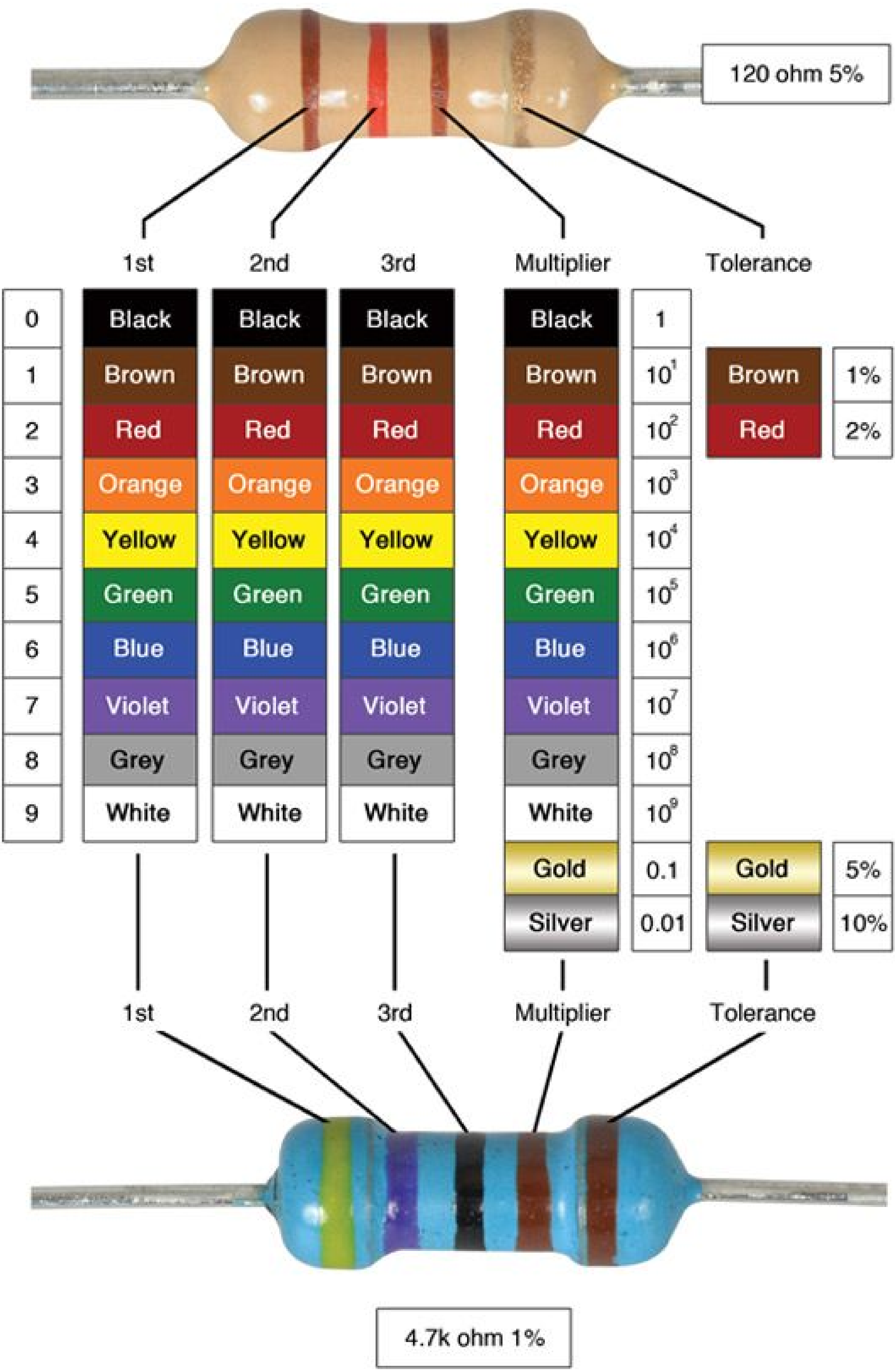

	1st	2nd	3rd	Multiplier		Tolerance	
0	Black	Black	Black	Black	1		
1	Brown	Brown	Brown	Brown	10^1	Brown	1%
2	Red	Red	Red	Red	10^2	Red	2%
3	Orange	Orange	Orange	Orange	10^3		
4	Yellow	Yellow	Yellow	Yellow	10^4		
5	Green	Green	Green	Green	10^5		
6	Blue	Blue	Blue	Blue	10^6		
7	Violet	Violet	Violet	Violet	10^7		
8	Grey	Grey	Grey	Grey	10^8		
9	White	White	White	White	10^9		
				Gold	0.1	Gold	5%
				Silver	0.01	Silver	10%

ELECTROMAGNETIC RADIATION SPECTRUM

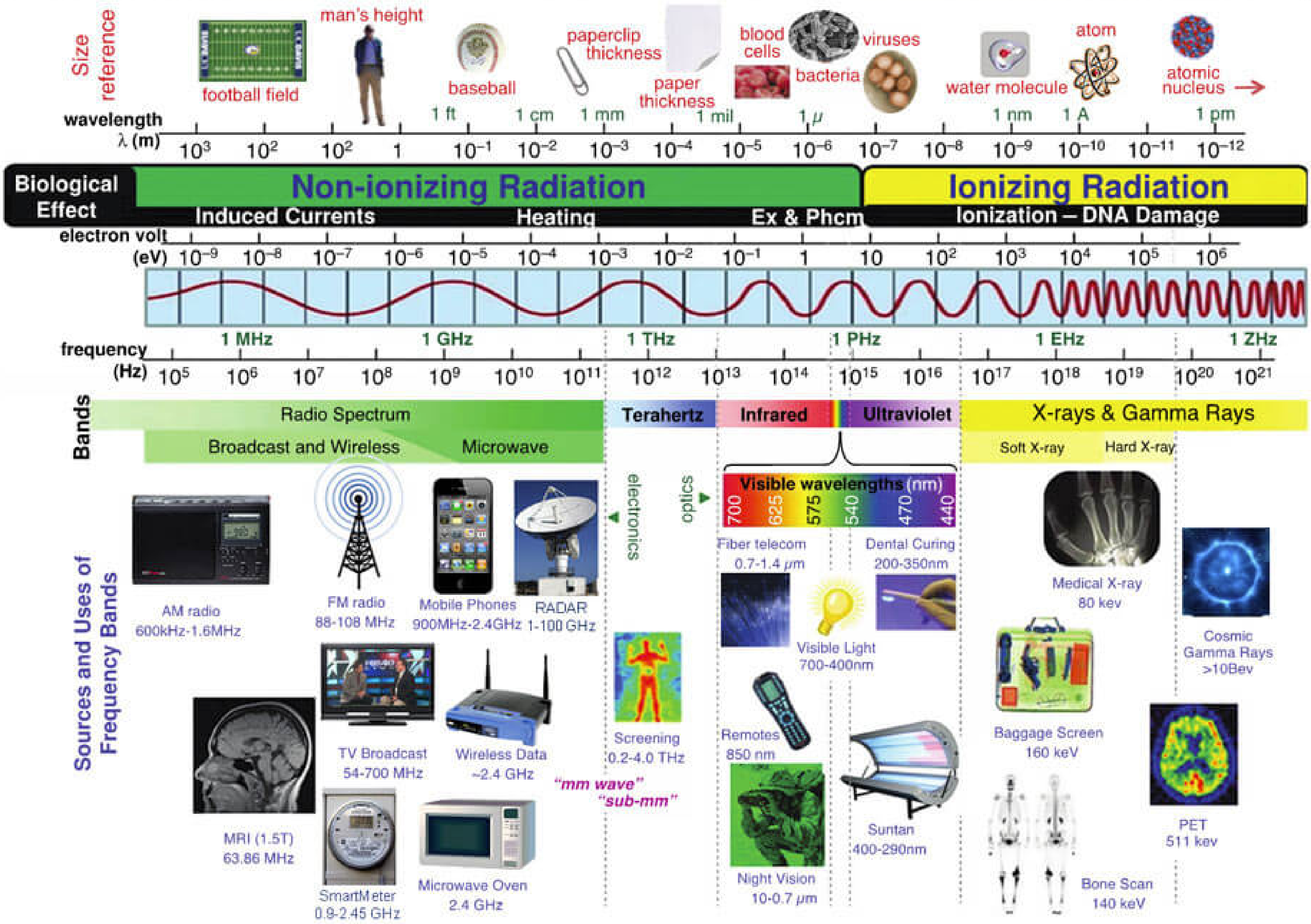
Size reference
football field
man's height
baseball
paperclip thickness
paper thickness
blood cells
bacteria
viruses
water molecule
atom
atomic nucleus →
wavelength
λ (m)
1 ft
1 cm
1 mm
1 mil
1 μ
1 nm
1 A
1 pm
10³ 10² 10² 1 10⁻¹ 10⁻² 10⁻³ 10⁻⁴ 10⁻⁵ 10⁻⁶ 10⁻⁷ 10⁻⁸ 10⁻⁹ 10⁻¹⁰ 10⁻¹¹ 10⁻¹²
Biological Effect
Non-ionizing Radiation
Induced Currents
Heating
Ex & Phcm
Ionizing Radiation
Ionization – DNA Damage
electron volt
(eV)
10⁻⁹ 10⁻⁸ 10⁻⁷ 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 1 10 10² 10³ 10⁴ 10⁵ 10⁶
frequency
(Hz)
1 MHz
1 GHz
1 THz
1 PHz
1 EHz
1 ZHz
10⁵ 10⁶ 10⁷ 10⁸ 10⁹ 10¹⁰ 10¹¹ 10¹² 10¹³ 10¹⁴ 10¹⁵ 10¹⁶ 10¹⁷ 10¹⁸ 10¹⁹ 10²⁰ 10²¹
Bands
Radio Spectrum
Broadcast and Wireless
Microwave
Terahertz
Infrared
Ultraviolet
X-rays & Gamma Rays
Soft X-ray
Hard X-ray
◄ electronics
optics ►
Visible wavelengths (nm)
700 625 575 540 470 440
Sources and Uses of Frequency Bands
AM radio
600kHz-1.6MHz
FM radio
88-108 MHz
Mobile Phones
900MHz-2.4GHz
RADAR
1-100 GHz
MRI (1.5T)
63.86 MHz
TV Broadcast
54-700 MHz
Wireless Data
~2.4 GHz
SmartMeter
0.9-2.45 GHz
Microwave Oven
2.4 GHz
"mm wave"
"sub-mm"
Screening
0.2-4.0 THz
Fiber telecom
0.7-1.4 μm
Visible Light
700-400nm
Dental Curing
200-350nm
Remotes
850 nm
Night Vision
10-0.7 μm
Suntan
400-290nm
Medical X-ray
80 kev
Cosmic Gamma Rays
>10Bev
Baggage Screen
160 keV
PET
511 kev
Bone Scan
140 keV

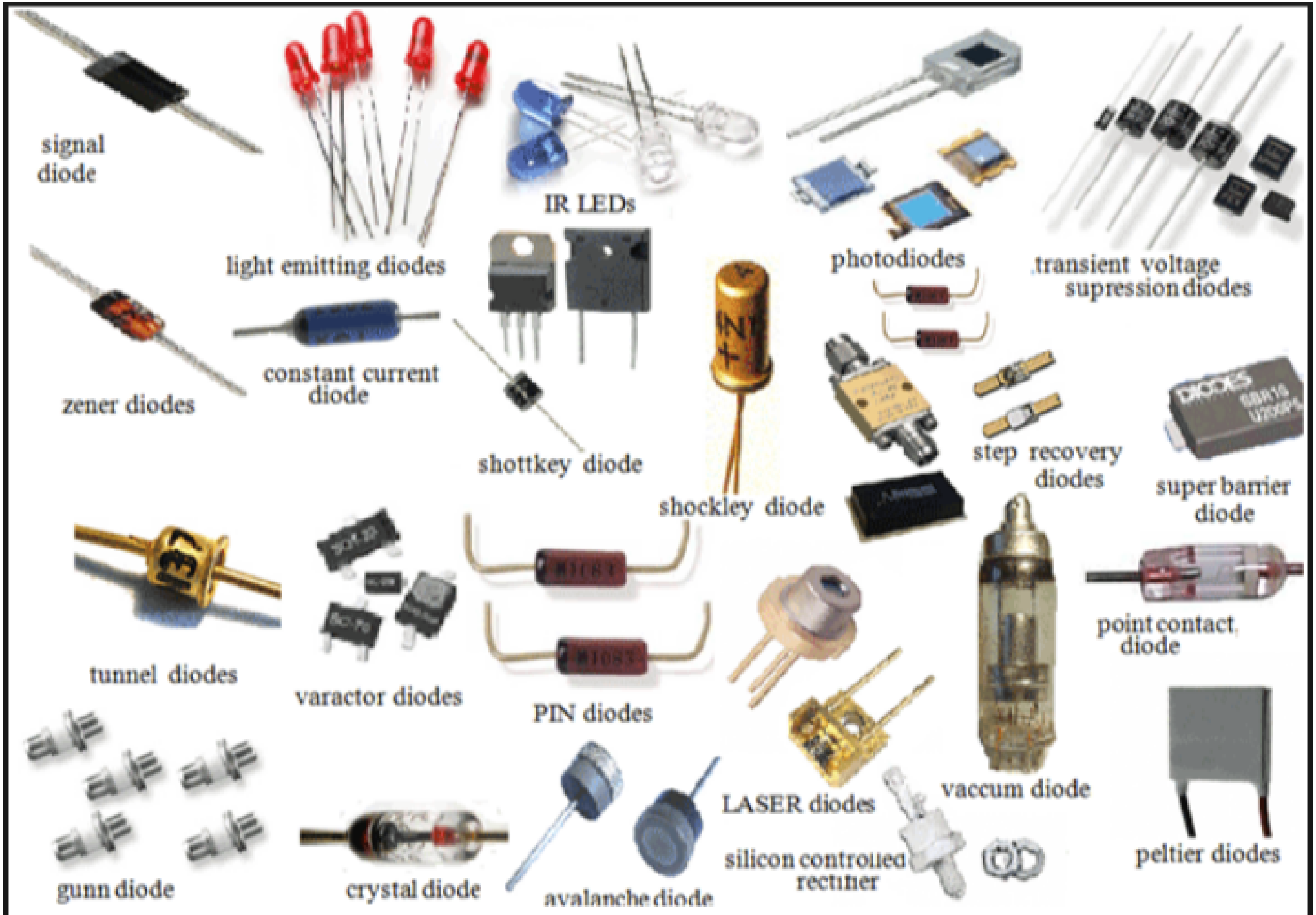
signal diode
light emitting diodes
IR LEDs
photodiodes
transient voltage supression diodes
zener diodes
constant current diode
shottkey diode
shockley diode
step recovery diodes
super barrier diode
tunnel diodes
varactor diodes
PIN diodes
point contact diode
vaccum diode
LASER diodes
peltier diodes
gunn diode
crystal diode
avalanche diode
silicon controlled rectifier

Types of Diode

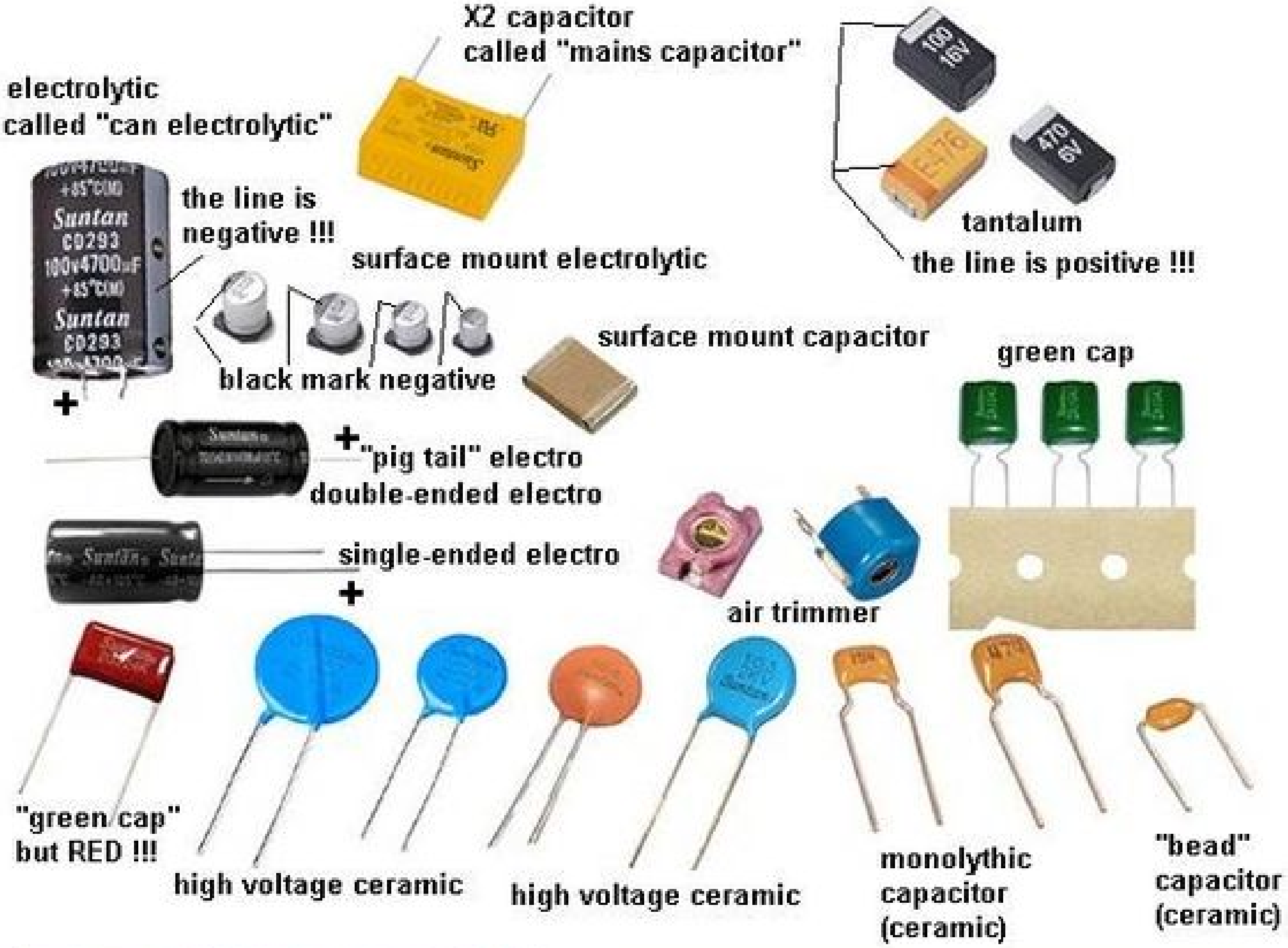
X2 capacitor
called "mains capacitor"
electrolytic
called "can electrolytic"
Suntan
CD293
100v4700uF
+85°C
the line is
negative !!!
surface mount electrolytic
100
16V
E476
470
6V
tantalum
the line is positive !!!
black mark negative
surface mount capacitor
green cap
+
+
"pig tail" electro
double-ended electro
single-ended electro
+
air trimmer
"green cap"
but RED !!!
high voltage ceramic
high voltage ceramic
monolythic
capacitor
(ceramic)
"bead"
capacitor
(ceramic)

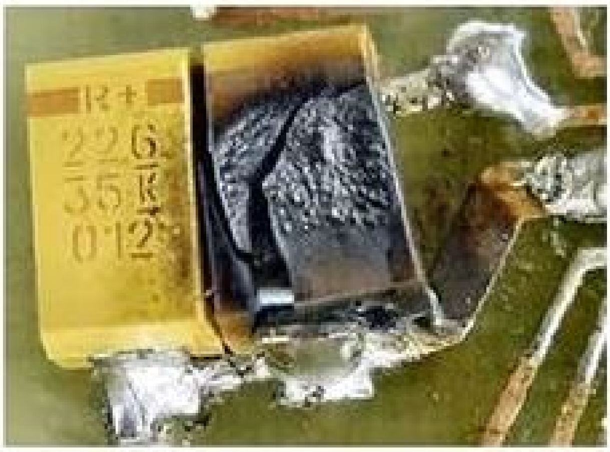

tantalum capacitors can
"go up in smoke"

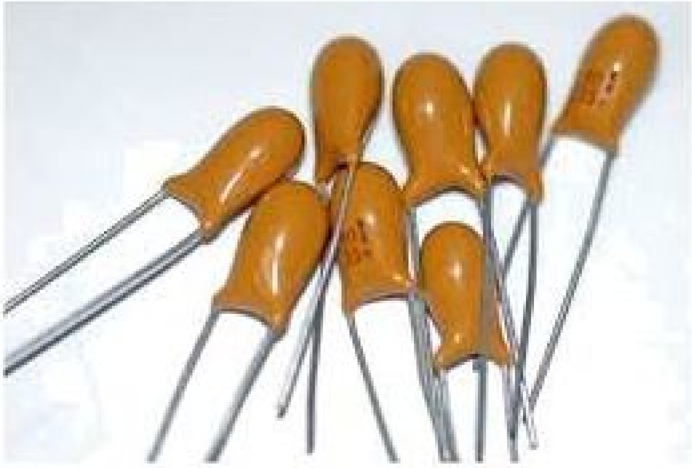

"bead" tantalum

Electronics
Reference Sheet v1.1b

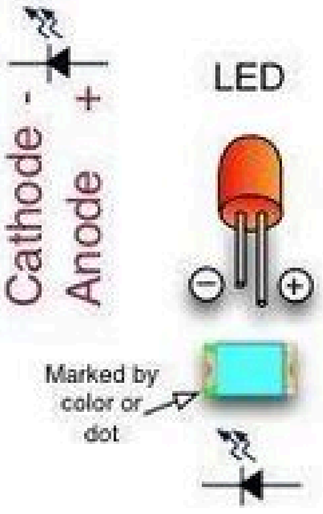
Cathode -
Anode +
LED
Marked by color or dot

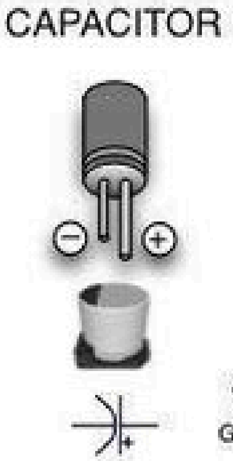

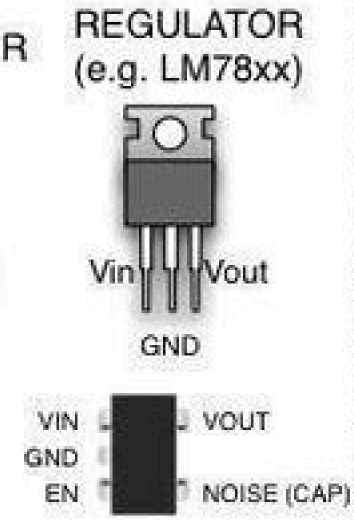
REGULATOR
(e.g. LM78xx)
Vin
Vout
GND
VIN
GND
EN
VOUT
NOISE (CAP)

Resistor

	Digit	Multiplier	Tolerance
Silver	-	0.01	±10%
Gold	-	0.1	±5%
Black	0	1	-
Brown	1	10	±1%
Red	2	100	±2%
Orange	3	1k	-
Yellow	4	10k	-
Green	5	100k	±0.5%
Blue	6	1M	±0.25%
Violet	7	10M	±0.1%
Gray	8	-	-
White	9	-	-

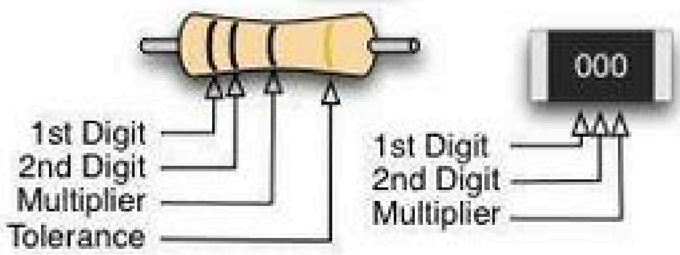
1st Digit
2nd Digit
Multiplier
Tolerance
000
1st Digit
2nd Digit
Multiplier

DIODE

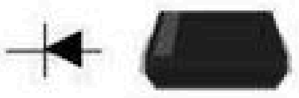

NPN transistor (Current sink)
(e.g. PN2222)

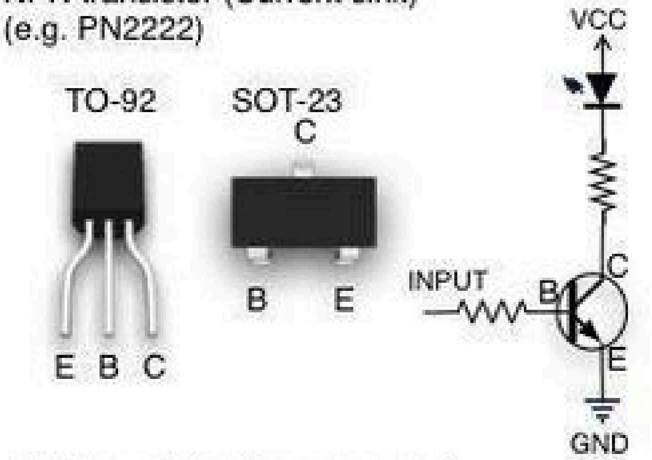
TO-92
E B C
SOT-23
C
B E
VCC
INPUT
B
C
E
GND

N-channel MOSFET

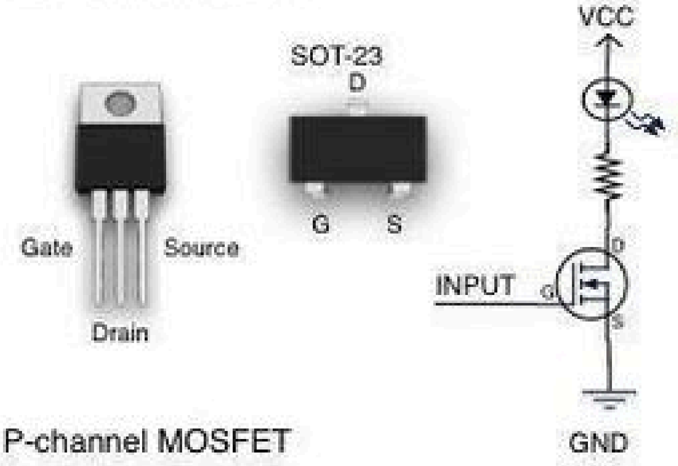
Gate
Source
Drain
SOT-23
D
G S
VCC
INPUT
G
D
S
GND

PNP transistor (Current source)
(e.g. PN2907)

P-channel MOSFET

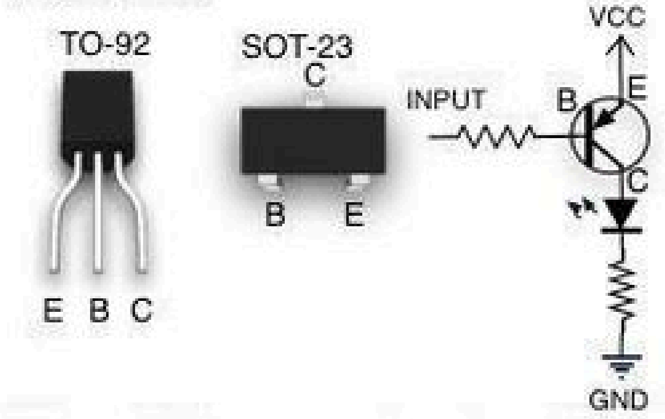
TO-92
E B C
SOT-23
C
B E
VCC
INPUT
B
E
C
GND

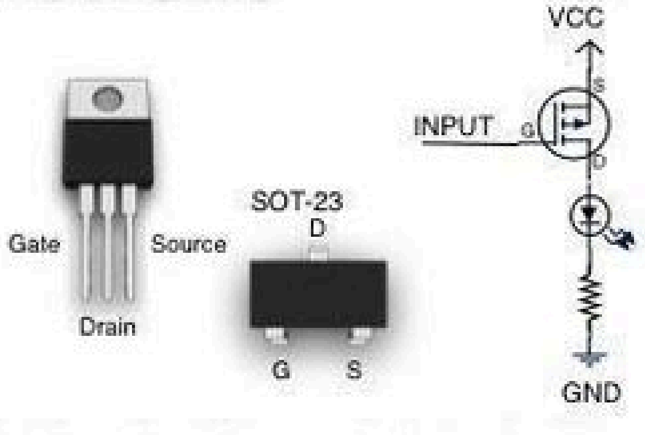
Gate
Source
Drain
SOT-23
D
G S
VCC
INPUT
G
S
D
GND

* Please note that some components may have a different pinout than the one showed above, you should always check the data sheet before using a new component.

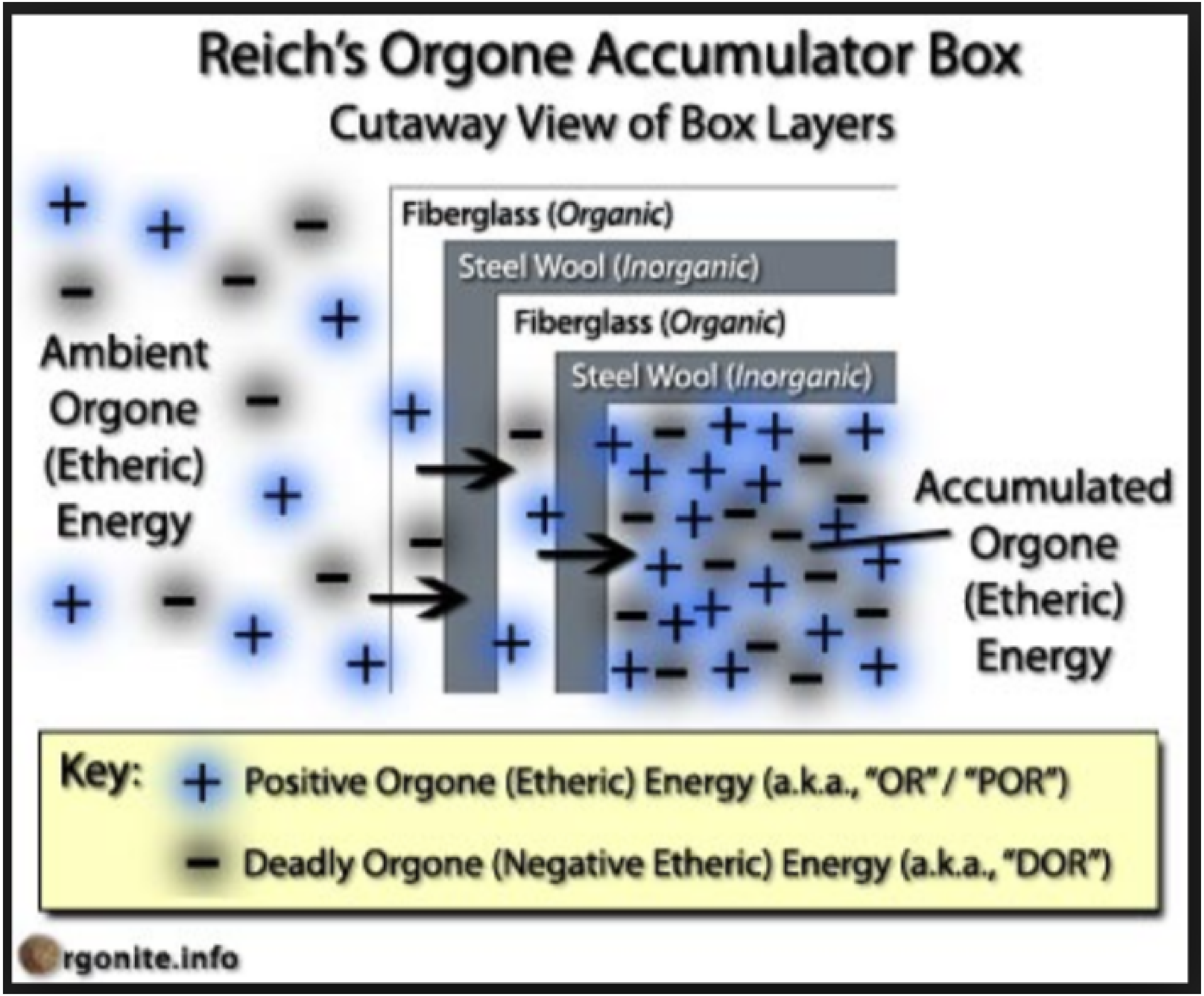
Reich's Orgone Accumulator Box
Cutaway View of Box Layers
Fiberglass (*Organic*)
Steel Wool (*Inorganic*)
Fiberglass (*Organic*)
Steel Wool (*Inorganic*)
Ambient Orgone (Etheric) Energy
Accumulated Orgone (Etheric) Energy
Key:
+ Positive Orgone (Etheric) Energy (a.k.a., "OR" / "POR")
− Deadly Orgone (Negative Etheric) Energy (a.k.a., "DOR")
rgonite.info

How to build a Don Croft ORGONITE CLOUD BUSTER

Materials List:

Wear safety gear as necessary
- respirator, gloves when pouring resin.
- gloves & goggles when cutting wood - with a respirator if cutting MDF etc.

4 x 10' lengths of copper (or other) pipe (cut 3 lengths in half, and one length into six 1' pieces)

6 pipe endcaps and 6 pipe connectors

2 gallon bucket (polypropylene if possible)

10 double terminated quartz (6 of these must fit into garden hose for insertion into base of pipes)

6 pieces of garden hose (3/4" - 1" long)

Resin and metal suitable for orgonite

A roll of tape (duct tape etc)

Glue (silicone glue will work)

Stick for mixing metal into resin when pouring layers

Top, middle (temporary) and bottom spacers cut and drilled out of wood. If not buying readymade, use templates or measure with copmass, ruler, pencil.
Drill the holes with 1 1/8" and 1 1/4" wood drill bits, and cut into shape with a Jigsaw.

Refer to (Part 1 - 2) How to Make an Orgonite CloudBuster:
http://www.youtube.com/watch?v=cCn1DO2Rj6k

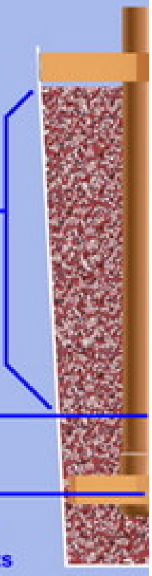

Third - The temporary spacer is removed and the pipe-tops are taped up to stop resin or metal getting into them.
Further layers are poured, allowing resin to cure and cool between pouring.
More crystals or other components may be added with the basic orgonite mixture.
When done, the tape is removed from the pipe ends.

Second poured layer (the temporary spacer is fixed in place while this layer is curing, and then removed)

First poured layer (1" - 1 1/2" high) Include four double-terminated crystals at compass points

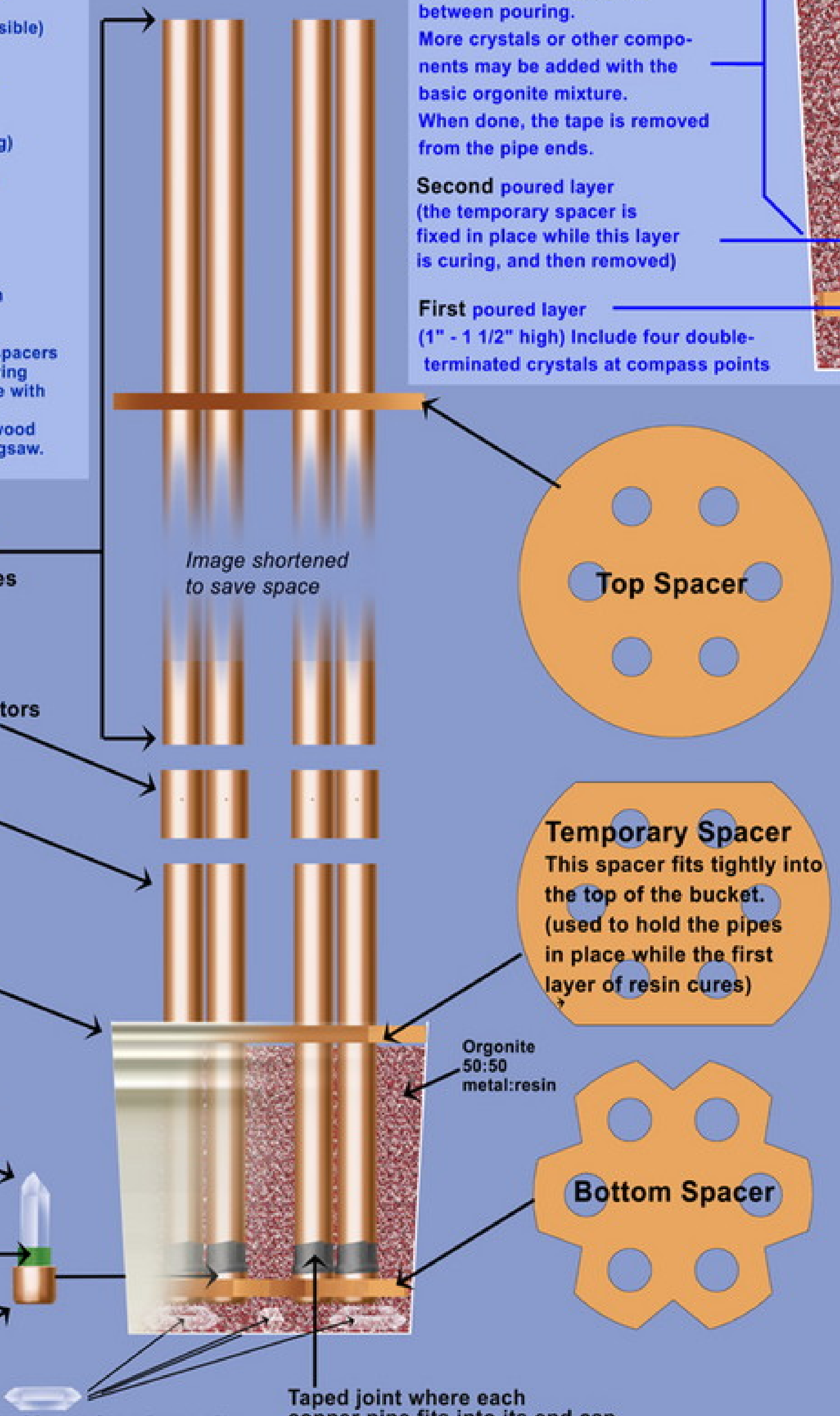

Six 5' lengths of copper pipe
When the orgonite base of the cloud buster is complete, fix the top pipes to the bottom ones using pipe connectors, then fix the top spacer in place to provide stability.

Image shortened to save space

Top Spacer

Pipe connectors

Six 1' lengths of copper pipe
(1" diameter pipe)

Temporary Spacer
This spacer fits tightly into the top of the bucket. (used to hold the pipes in place while the first layer of resin cures)

2 Gallon ......plastic bucket (8" bottom-interior diameter, 9" top interior diameter)

Orgonite 50:50 metal:resin

Double Treminated Crystal (secured into hose with glue)

Bottom Spacer

Section of garden hose 3/4" - 1" piece (glued into end cap with silicone glue)

Copper end cap

Four double terminated crystals in the base are aligned with the cardinal directions

Taped joint where each copper pipe fits into its end cap (duct tape or any kind to stop resin seeping into endcap)

BOAT
BOAT
GOOP
HOUSEHOLD

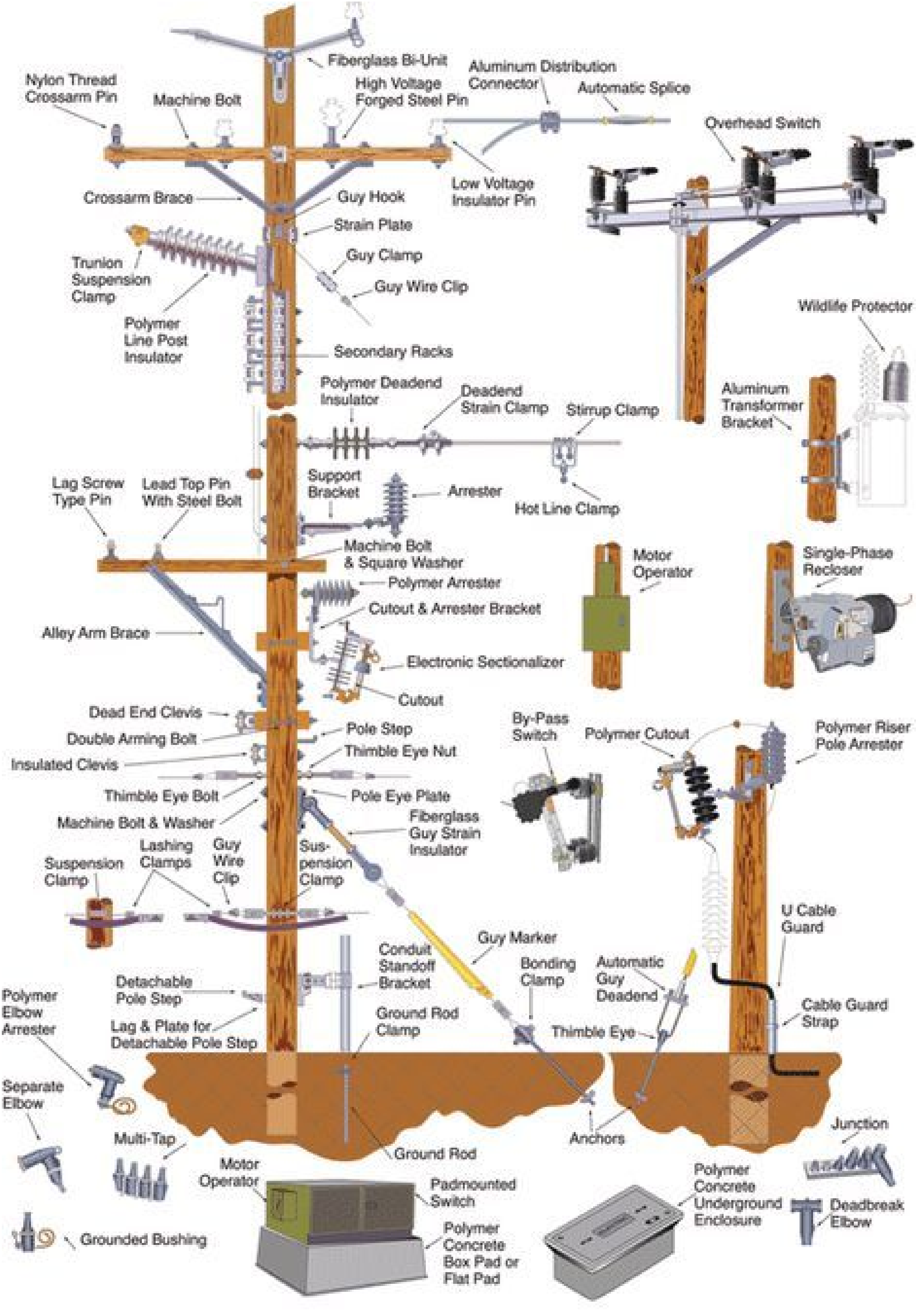
Fiberglass Bi-Unit
Nylon Thread Crossarm Pin
Machine Bolt
High Voltage Forged Steel Pin
Aluminum Distribution Connector
Automatic Splice
Overhead Switch
Low Voltage Insulator Pin
Crossarm Brace
Guy Hook
Strain Plate
Trunion Suspension Clamp
Guy Clamp
Guy Wire Clip
Polymer Line Post Insulator
Secondary Racks
Wildlife Protector
Polymer Deadend Insulator
Deadend Strain Clamp
Stirrup Clamp
Aluminum Transformer Bracket
Support Bracket
Arrester
Hot Line Clamp
Lag Screw Type Pin
Lead Top Pin With Steel Bolt
Machine Bolt & Square Washer
Motor Operator
Single-Phase Recloser
Polymer Arrester
Cutout & Arrester Bracket
Alley Arm Brace
Electronic Sectionalizer
Cutout
Dead End Clevis
Double Arming Bolt
Pole Step
By-Pass Switch
Polymer Cutout
Polymer Riser Pole Arrester
Insulated Clevis
Thimble Eye Nut
Thimble Eye Bolt
Pole Eye Plate
Machine Bolt & Washer
Fiberglass Guy Strain Insulator
Suspension Clamp
Lashing Clamps
Guy Wire Clip
Sus-pension Clamp
U Cable Guard
Guy Marker
Conduit Standoff Bracket
Bonding Clamp
Automatic Guy Deadend
Detachable Pole Step
Polymer Elbow Arrester
Lag & Plate for Detachable Pole Step
Ground Rod Clamp
Thimble Eye
Cable Guard Strap
Separate Elbow
Multi-Tap
Anchors
Ground Rod
Junction
Motor Operator
Padmounted Switch
Polymer Concrete Underground Enclosure
Deadbreak Elbow
Grounded Bushing
Polymer Concrete Box Pad or Flat Pad

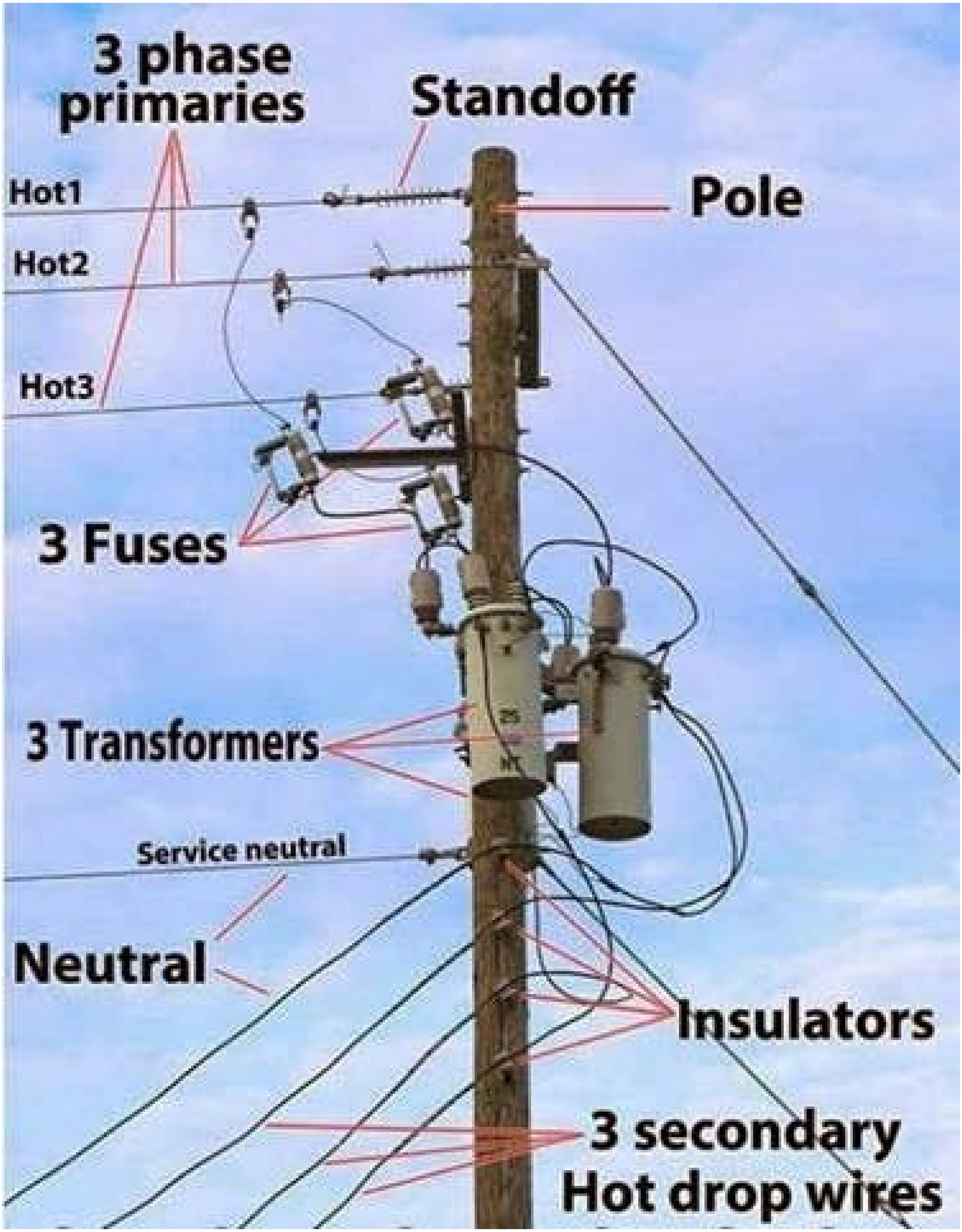
3 phase primaries
Standoff
Hot1
Pole
Hot2
Hot3
3 Fuses
3 Transformers
Service neutral
Neutral
Insulators
3 secondary Hot drop wires

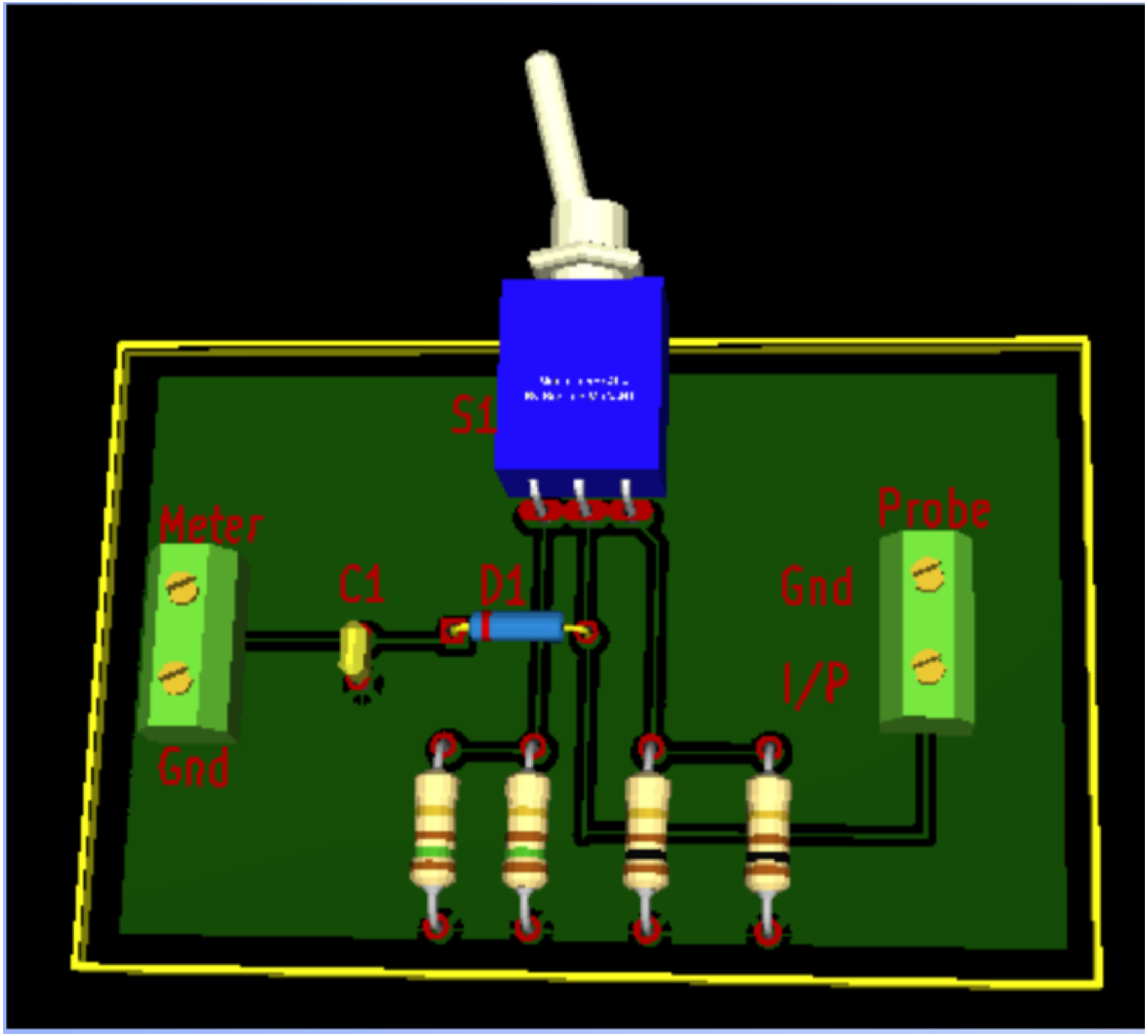
S1
Meter
Gnd
C1
D1
Probe
Gnd
I/P

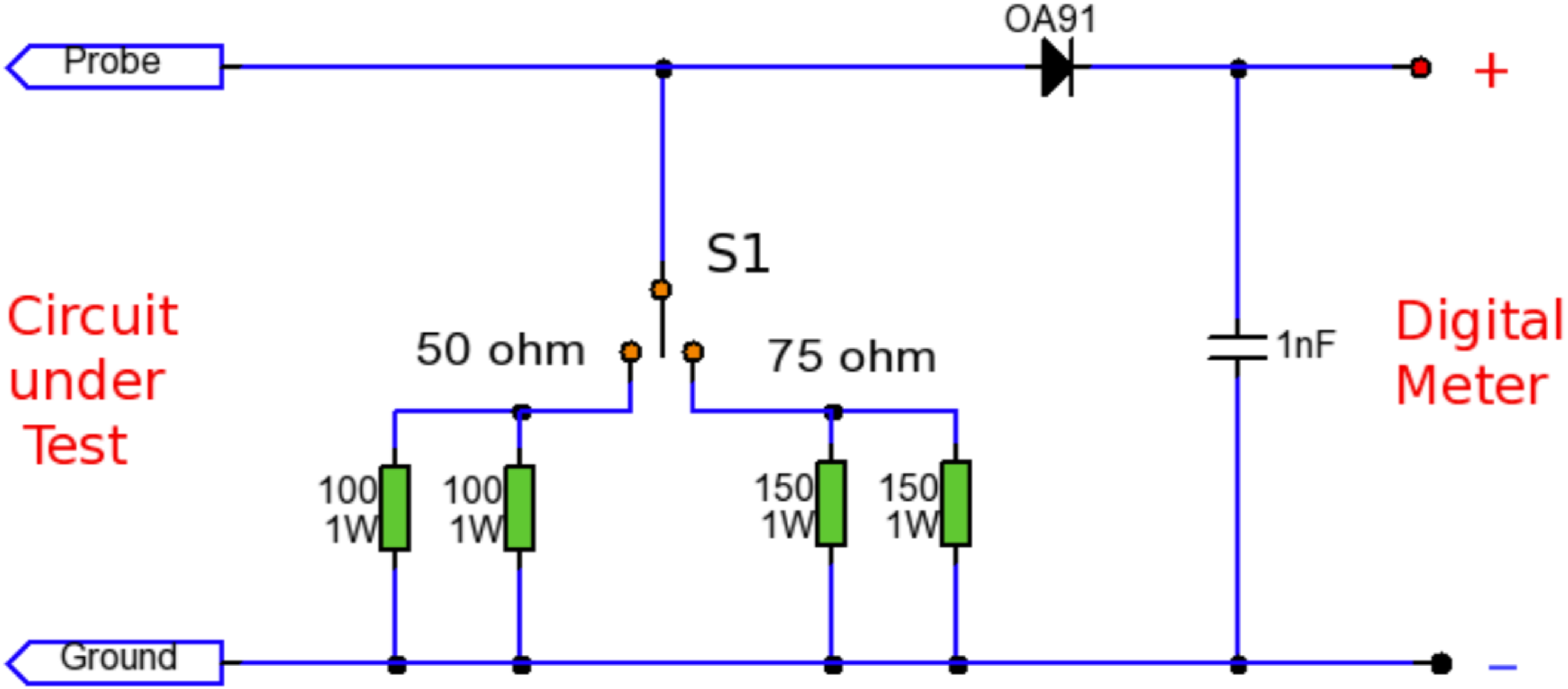
Probe
OA91
+
S1
Circuit under Test
50 ohm
75 ohm
1nF
Digital Meter
100 1W
100 1W
150 1W
150 1W
Ground
–

N. TESLA.
APPARATUS FOR TRANSMITTING ELECTRICAL ENERGY.
APPLICATION FILED JAN. 18, 1902. RENEWED MAY 4, 1907.

1,119,732. Patented Dec. 1, 1914.

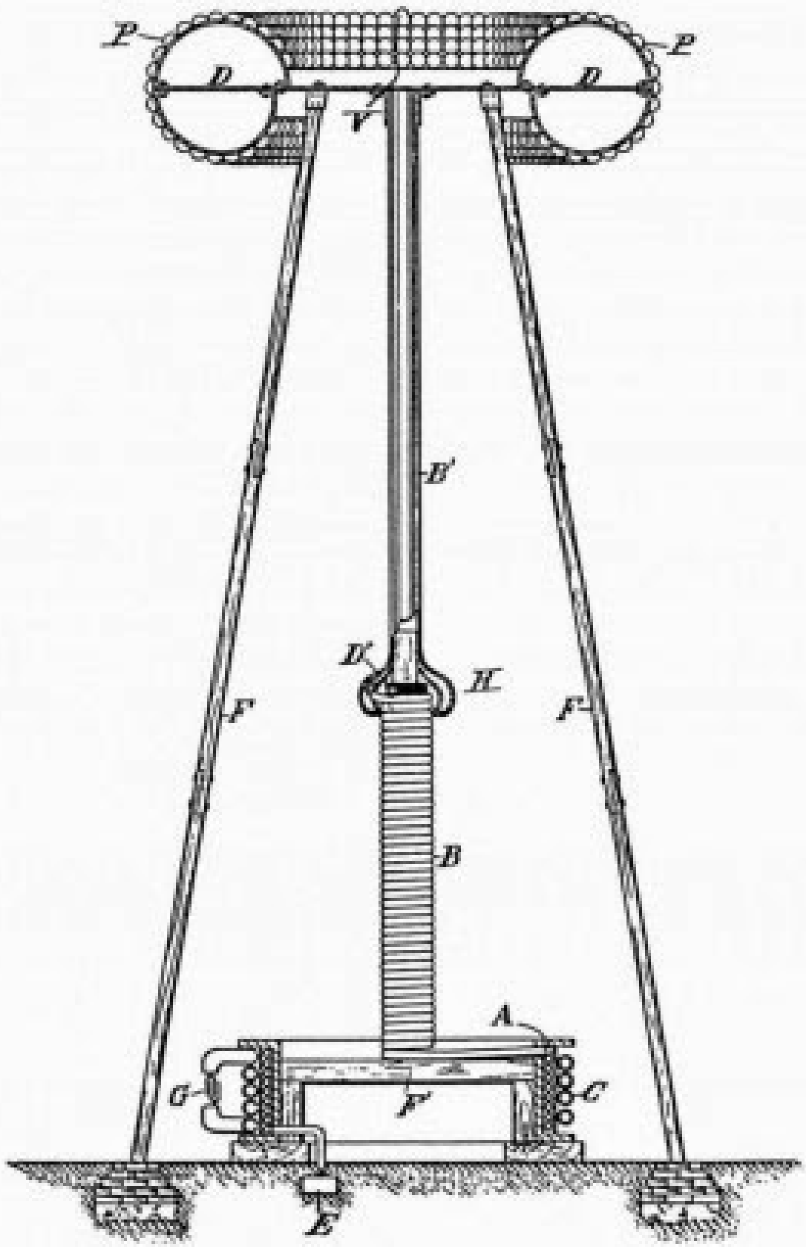
P
P
D
D
V
E'
D'
H
F
F
B
A
C
G
F'
E

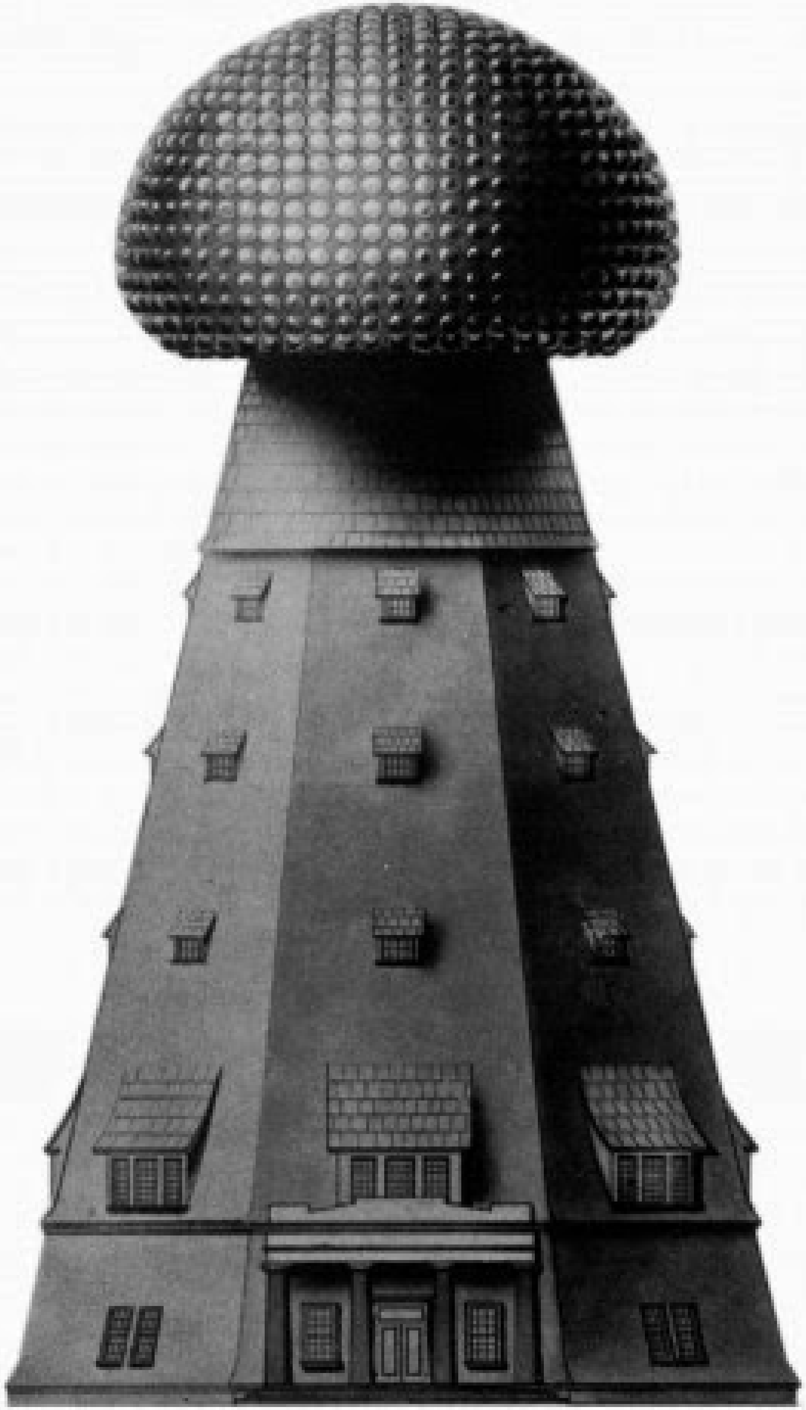

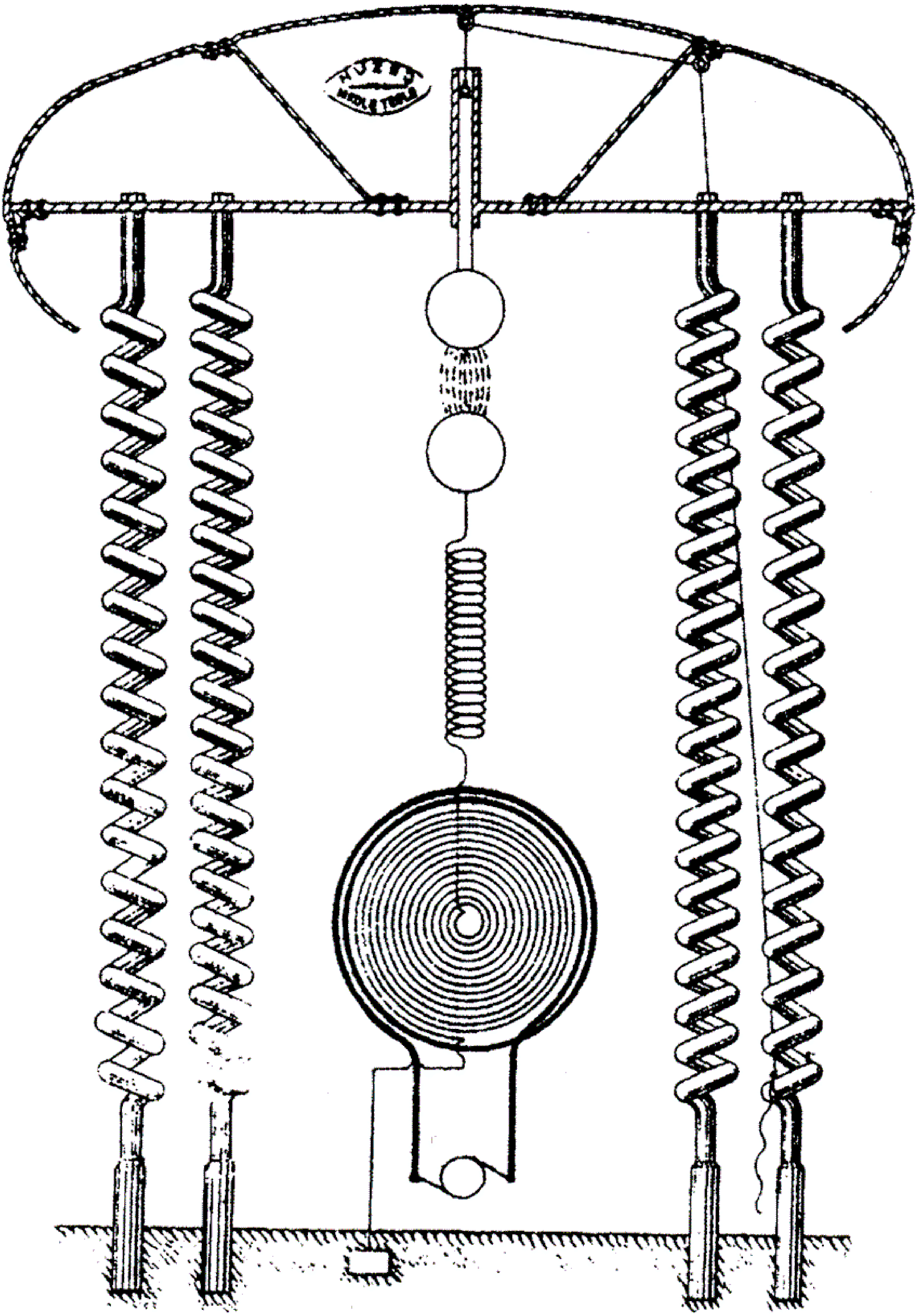

New York, Aug. 30th, 1901
46 & 48 East Houston Str.

Mr. Stanford White
160 Fifth Ave.
New York City

My Dear Stanford:
Many thanks for your suggestions. I am writing to Mr. Powell today. Perhaps he will be able to clear the land altogether.

I want you to understand that I went to the American Bridge Company simply because of my anxiety to have the work pushed through as fast as practicable. I am only too glad to follow your advice and beg you to consider yourself absolutely free in your choice and arrangements regarding this work.

Yours very sincerely,
N. Tesla

New York, Sep. 12th, 1901
46 & 48 East Houston Str.

Babcock & Wilcox Co.
85 Liberty Street
New York City

Gentlemen:
Under enclosure I forward sketch showing your two boilers as they will be placed in my building and their position relative to and exact distance from the chimney. The scale is ½ inch to a foot.

You will greatly oblige me by furnishing the drawings of the flues leading to the chimney and the position of the breech, as the builder cannot proceed without this information.

Yours very truly,
Encl.

Anyone familiar with the Wardenclyffe Tower knows it to have been a colossal structure. Yet, few realize that it was supposed to have been even larger. Although the exact figures are not revealed, Tesla must have drastically underestimated the cost of building his structure as is evidenced by the following response to White.

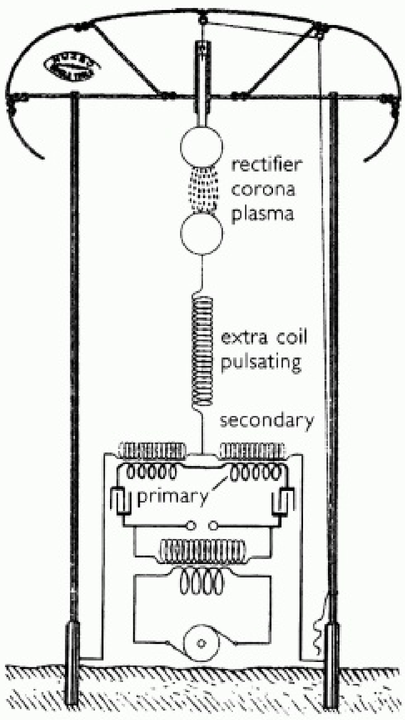

Fig. 5 Oscillating statically charged terminal.

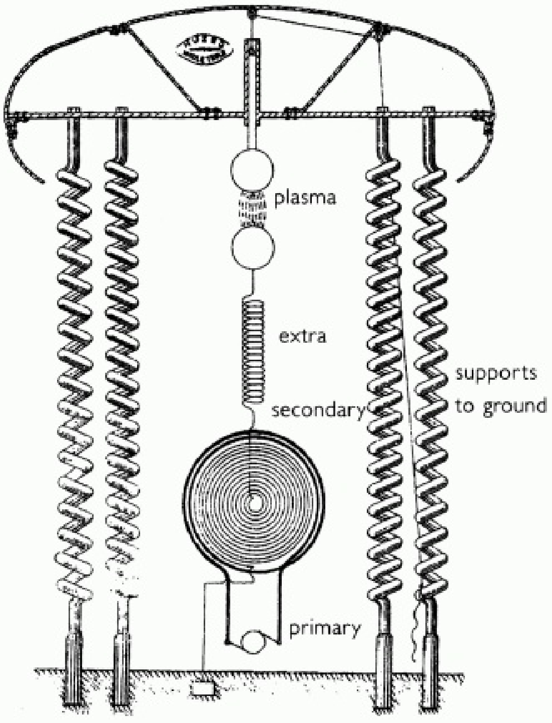

Fig. 6 Oscillating electrostatically charged dome.

N. TESLA

APPARATUS FOR TRANSMITTING ELECTRICAL ENERGY.

APPLICATION FILED JAN. 18, 1902. RENEWED MAY 4, 1907.

1,119,732. Patented Dec. 1, 1914.

This patent was the result of Tesla's many high voltage transmission experiments at Colorado Springs during the early 1900's. It served as the basis for the construction of the famous:-''Waldencliff Tower,'' which was intended to become a transmission station for wireless electrical power.

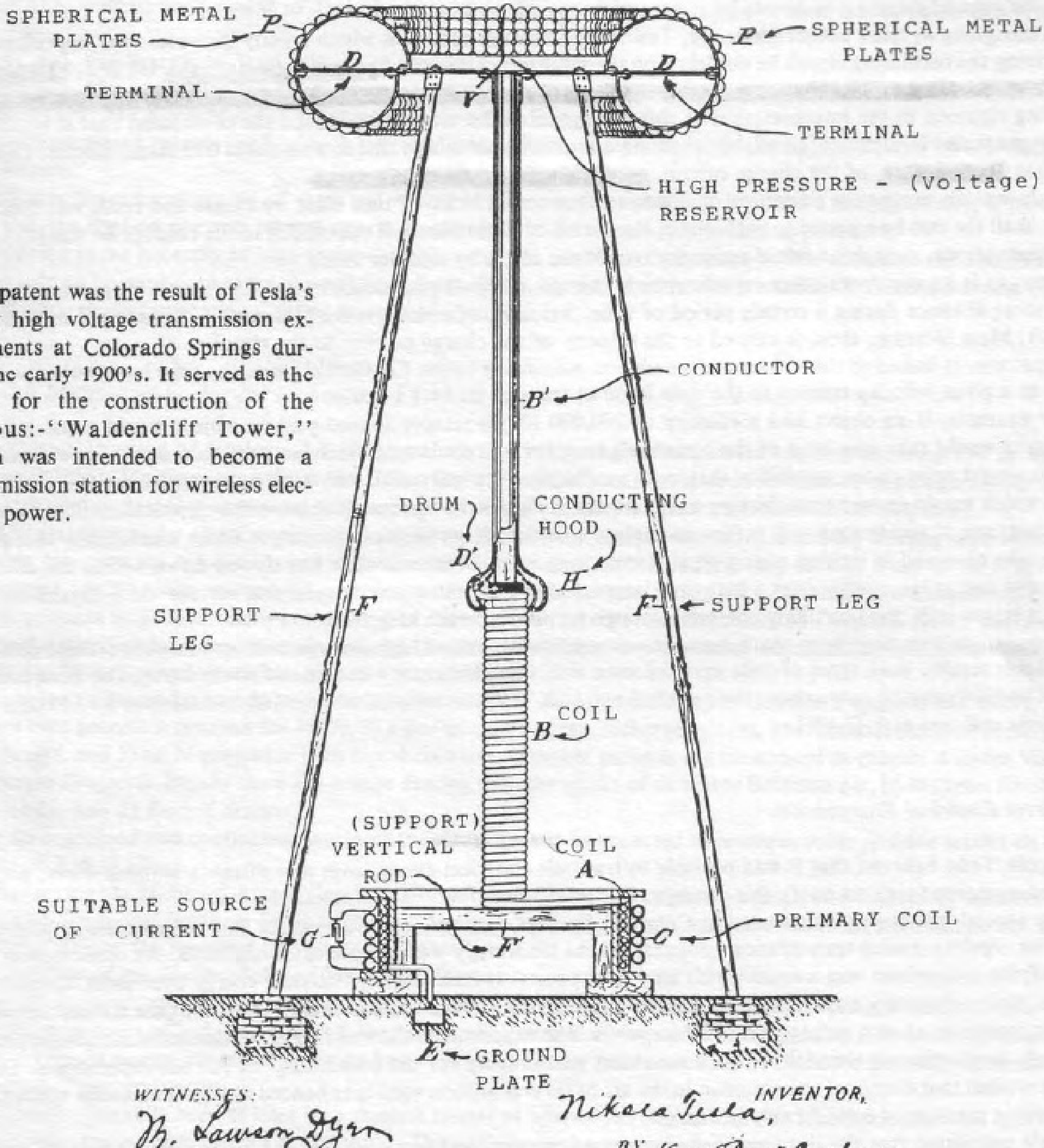
SPHERICAL METAL PLATES
P
SPHERICAL METAL PLATES
P
D
D
TERMINAL
TERMINAL
V
HIGH PRESSURE - (Voltage) RESERVOIR
CONDUCTOR
B'
DRUM
CONDUCTING HOOD
D'
H
SUPPORT LEG
F
F
SUPPORT LEG
COIL
B
(SUPPORT) VERTICAL ROD
COIL
A
SUITABLE SOURCE OF CURRENT
G
F'
PRIMARY COIL
C
E
GROUND PLATE

WITNESSES:

M. Lawson Dyer

Benjamin Miller.

Nikola Tesla, INVENTOR,

BY Kerr, Page & Cooper,
his ATTORNEYS.

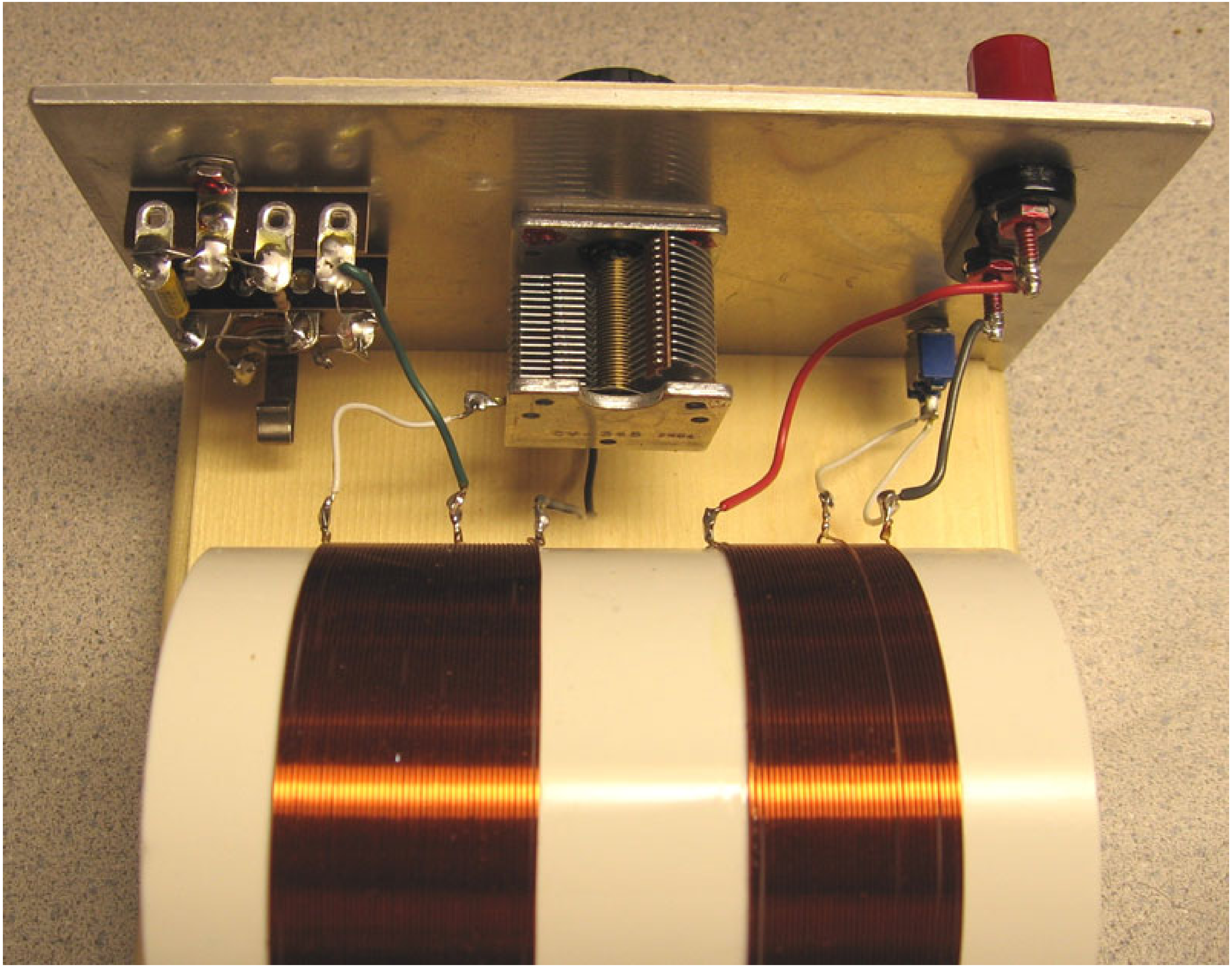

"HIGH SELECTIVITY CRYSTAL RADIO"
[WITH SHORT WAVE]

RGK 2007

570KHZ → 2.5MHZ

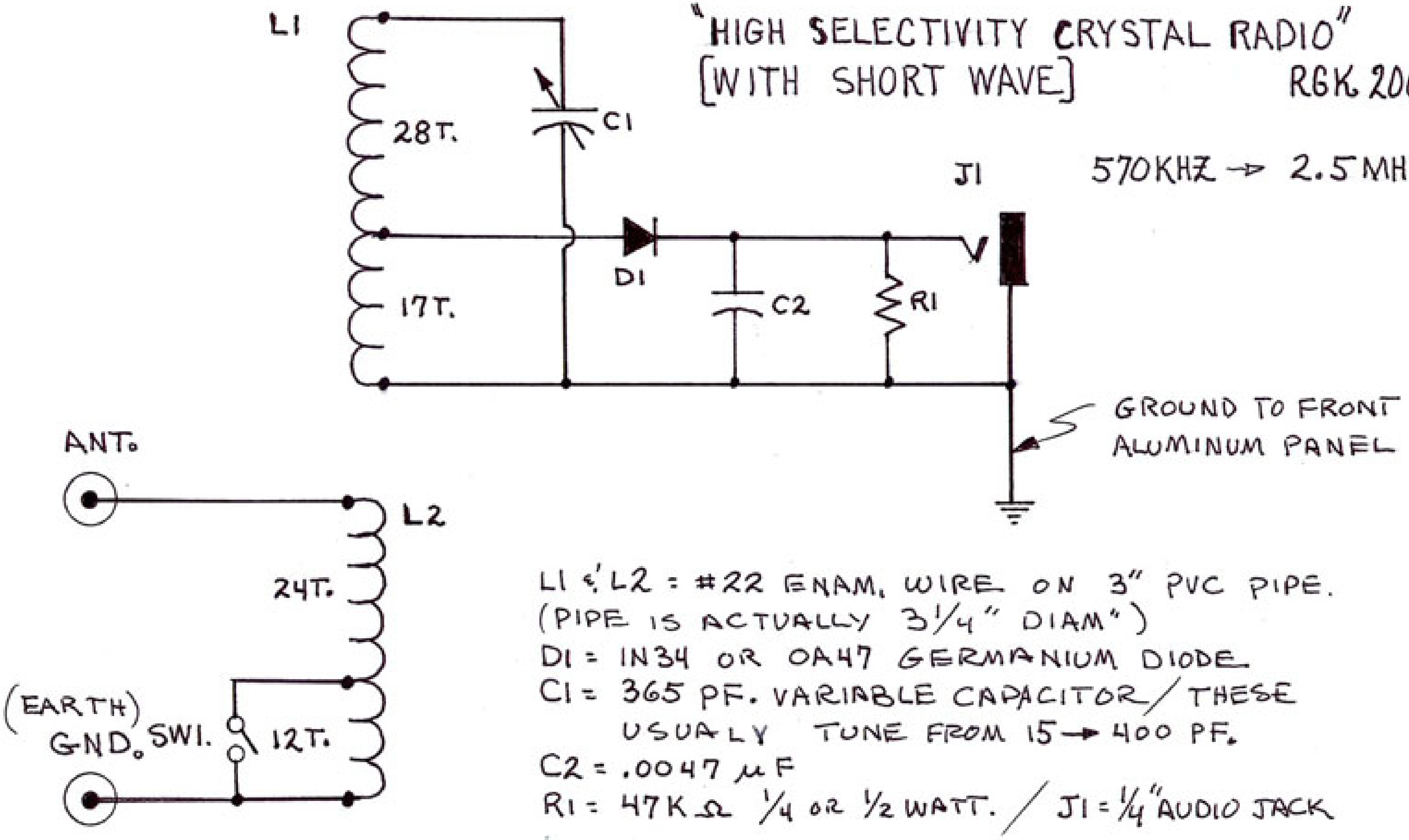
L1
28T.
C1
17T.
D1
C2
R1
J1
GROUND TO FRONT ALUMINUM PANEL
ANT.
L2
24T.
(EARTH)
GND.
SW1.
12T.

L1 & L2 = #22 ENAM. WIRE ON 3" PVC PIPE.
(PIPE IS ACTUALLY 3¼" DIAM")
D1 = 1N34 OR OA47 GERMANIUM DIODE
C1 = 365 PF. VARIABLE CAPACITOR / THESE USUALY TUNE FROM 15 → 400 PF.
C2 = .0047 µF
R1 = 47K Ω ¼ or ½ WATT. / J1 = ¼" AUDIO JACK

[L1/L2 NOTES: L1 = 45 TURNS TOTAL & L2 = 36 TURNS TOTAL. THE SPACE BETWEEN L1 & L2 IS 1 1/16".]

SW1 = SP.S.T. SWITCH / FOR ANTENNA MATCHING

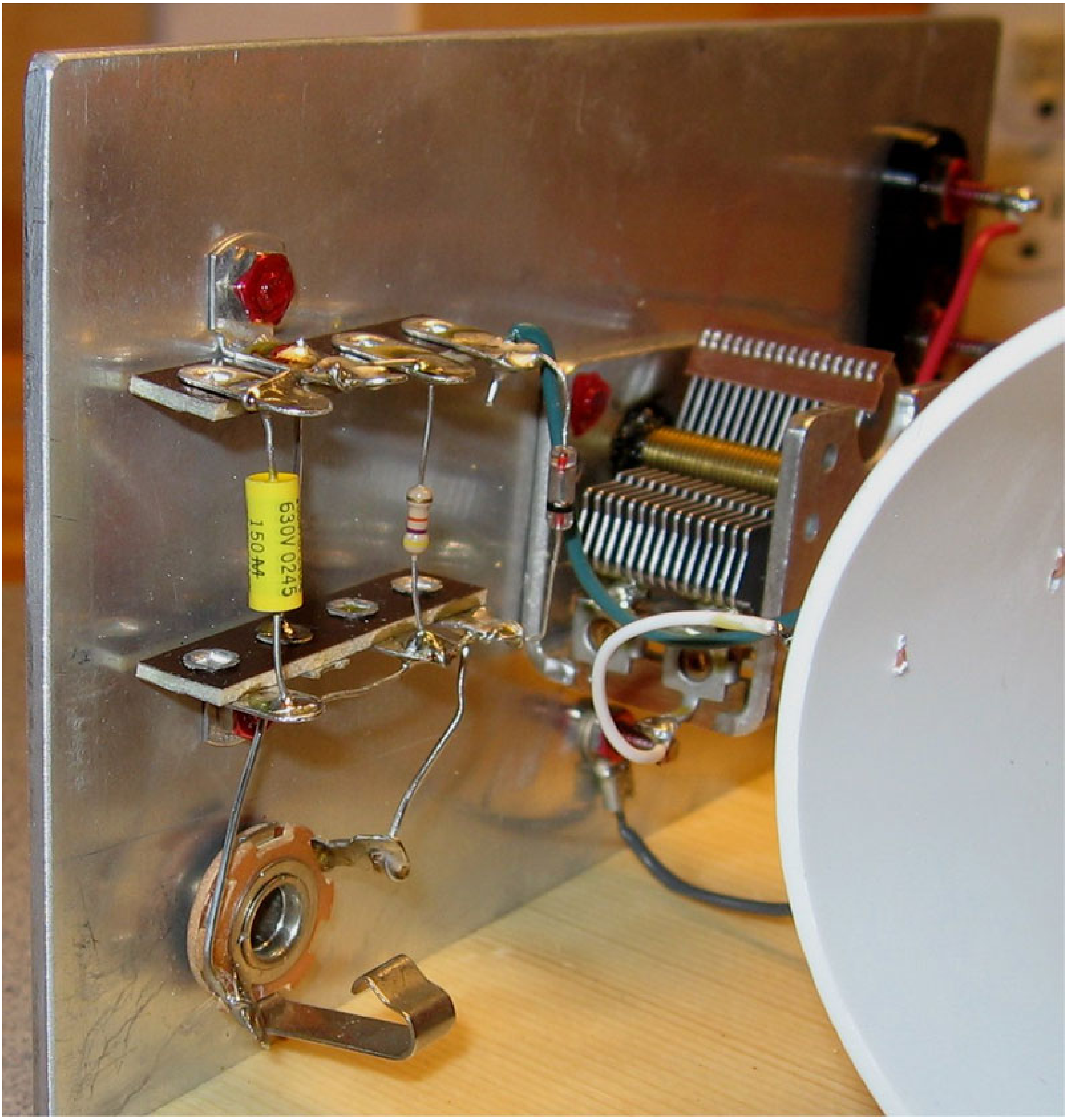
630V 0245
150M

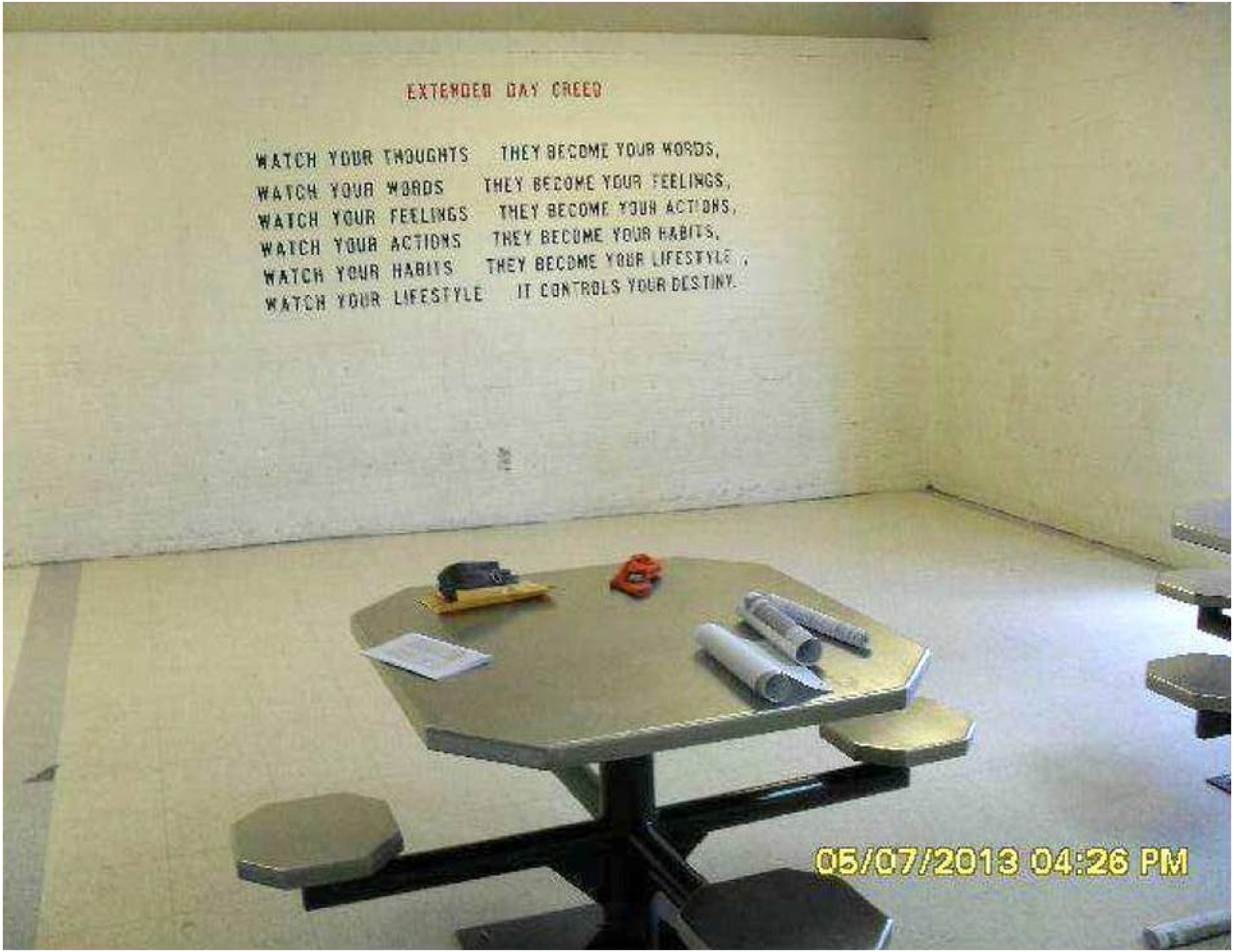
EXTENDED DAY CREED
WATCH YOUR THOUGHTS THEY BECOME YOUR WORDS,
WATCH YOUR WORDS THEY BECOME YOUR FEELINGS,
WATCH YOUR FEELINGS THEY BECOME YOUR ACTIONS,
WATCH YOUR ACTIONS THEY BECOME YOUR HABITS,
WATCH YOUR HABITS THEY BECOME YOUR LIFESTYLE,
WATCH YOUR LIFESTYLE IT CONTROLS YOUR DESTINY.

05/07/2013 04:26 PM

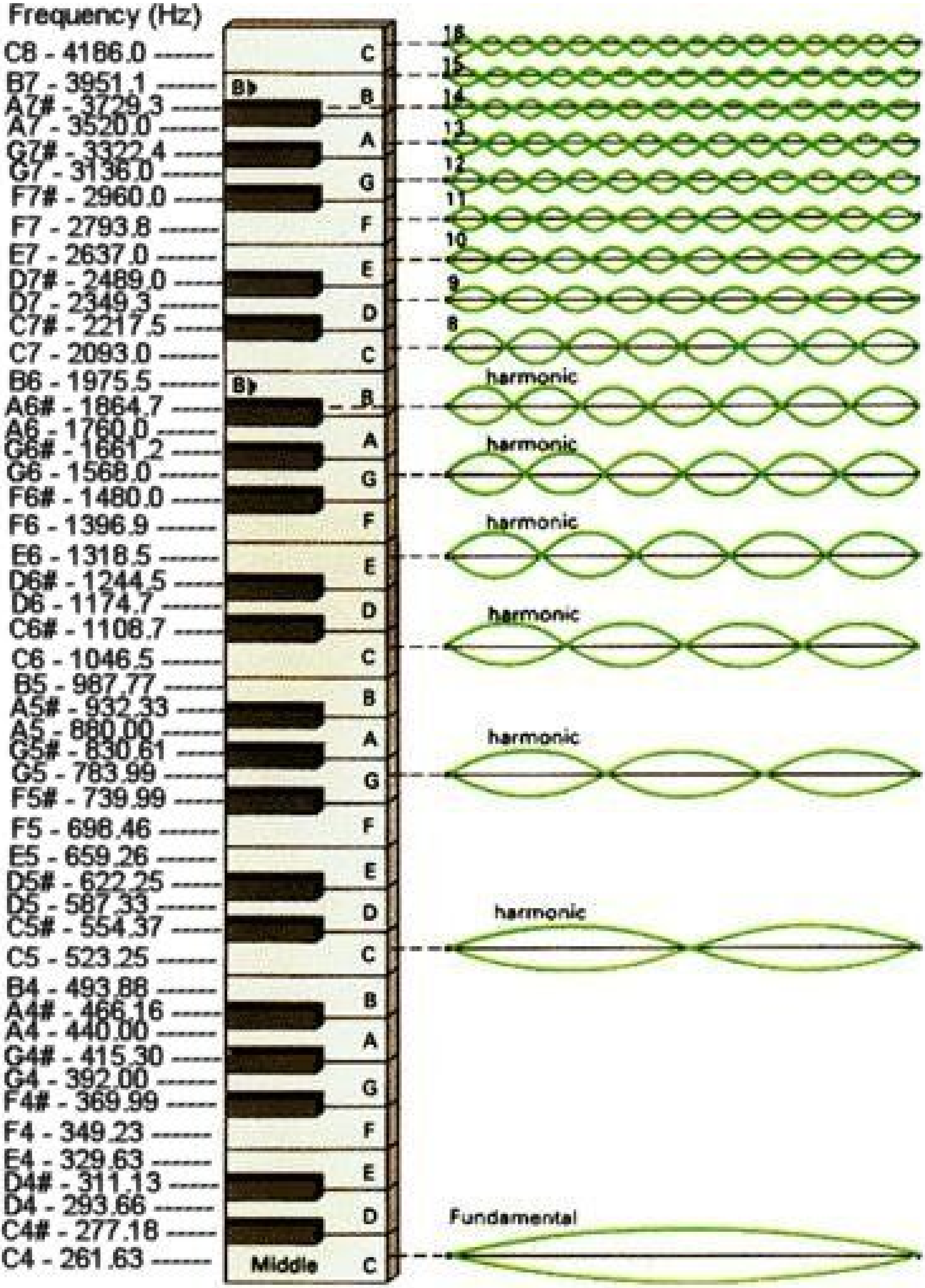
Frequency (Hz)
C8 - 4186.0
B7 - 3951.1
A7# - 3729.3
A7 - 3520.0
G7# - 3322.4
G7 - 3136.0
F7# - 2960.0
F7 - 2793.8
E7 - 2637.0
D7# - 2489.0
D7 - 2349.3
C7# - 2217.5
C7 - 2093.0
B6 - 1975.5
A6# - 1864.7
A6 - 1760.0
G6# - 1661.2
G6 - 1568.0
F6# - 1480.0
F6 - 1396.9
E6 - 1318.5
D6# - 1244.5
D6 - 1174.7
C6# - 1108.7
C6 - 1046.5
B5 - 987.77
A5# - 932.33
A5 - 880.00
G5# - 830.61
G5 - 783.99
F5# - 739.99
F5 - 698.46
E5 - 659.26
D5# - 622.25
D5 - 587.33
C5# - 554.37
C5 - 523.25
B4 - 493.88
A4# - 466.16
A4 - 440.00
G4# - 415.30
G4 - 392.00
F4# - 369.99
F4 - 349.23
E4 - 329.63
D4# - 311.13
D4 - 293.66
C4# - 277.18
C4 - 261.63
C
B♭
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Fundamental

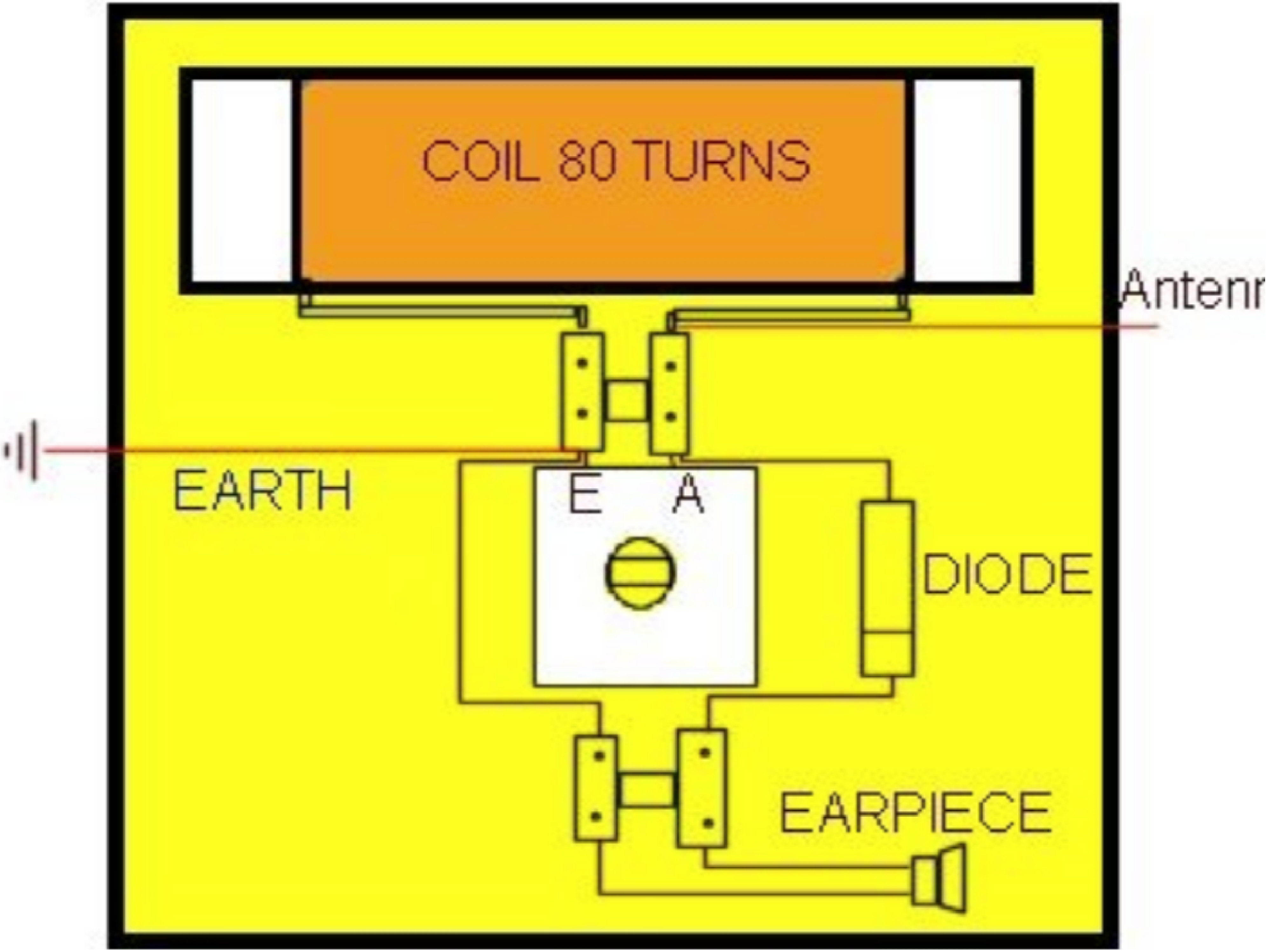
COIL 80 TURNS
Antenn
EARTH
E
A
DIODE
EARPIECE

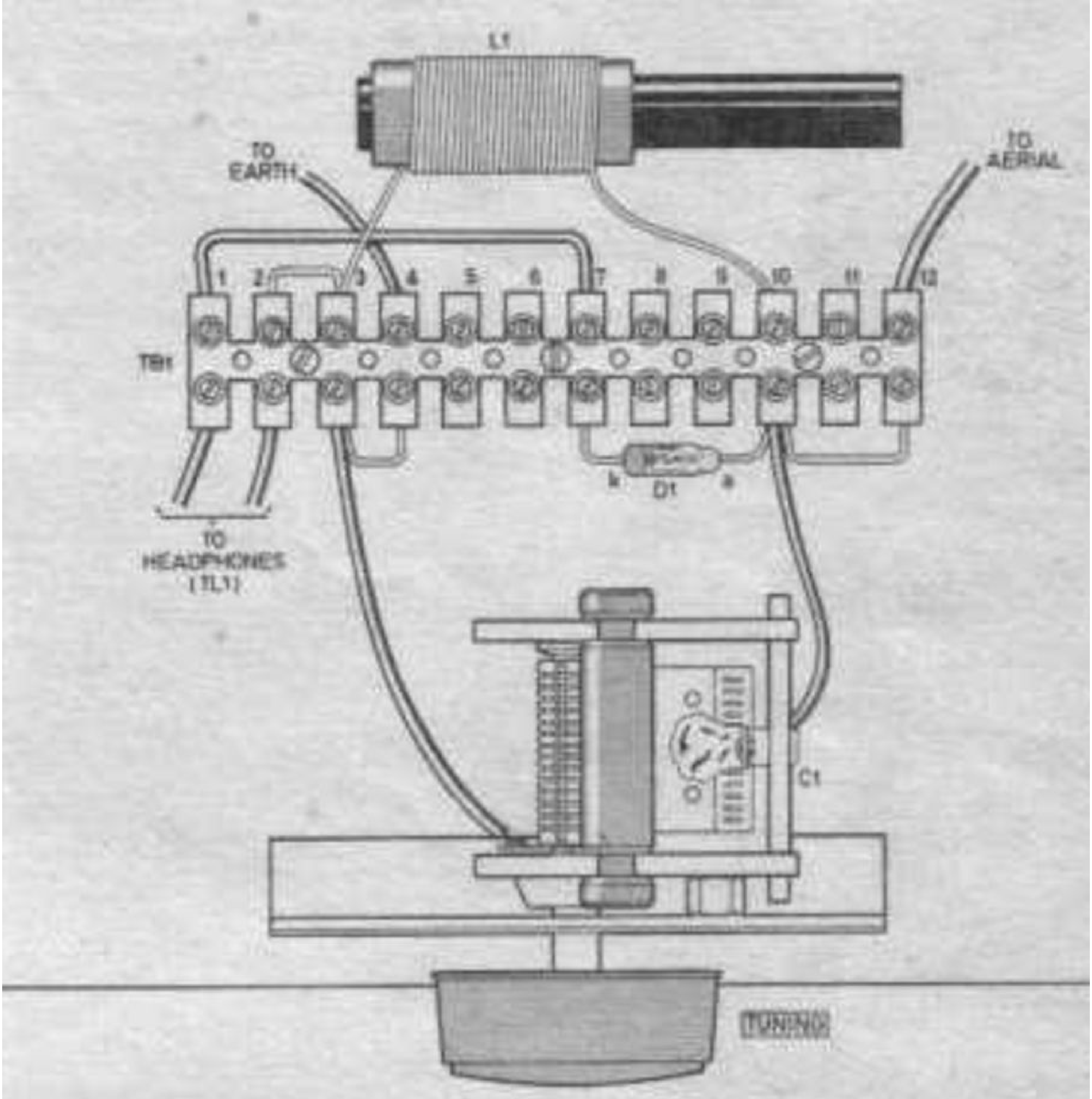
L1
TO EARTH
TO AERIAL
1
2
3
4
5
6
7
8
9
10
11
12
TB1
k
D1
a
TO HEADPHONES (TL1)
C1
TUNING

RF Energy Harvesting for INTERNET OF THINGS

The world
is the index
Take the world
on line
Take control
of the world
Let the things
talk to each
other
Let thing
become
intelligen

K.J. Vinoy

ECE Dept
Indian Institute of Science
Bangalore 560012

ECE Dept, Indian Institute of Science

- **Vision Statement:** Excellence in Theoretical and Experimental Research in Communications, Signal Processing, Microelectronics and RF/Photonics.
- **Faculty: 24;** Fellows of IEEE: 4; Fellows of INAE: 8
- Active in Publications: Books, Book Chapters, Journal & Conference Papers; Patents; Standardization etc
- Collaborative research

People
Masters Students
[ME, MSc→ Mtech, Mtech(Res)]
PhD Students
Project Staff

INTERNATIONAL COLLABORATION
ILLINOIS
LOS ANGELES
MASSACHUSETTS
MICHIGAN
SAN DIEGO
FRANCE
FINLAND
GERMANY
NETHERLANDS
NORWAY
SWEDEN
SWITZERLAND
HONGKONG
JAPAN
KOREA
TURKEY
AUSTRALIA
MELBOURNE

NATIONAL COLLABORATION
Major collaborative initiatives

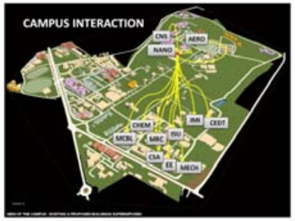
CAMPUS INTERACTION
CNS
AERO
NANO
CHEM
MCBL
MBC
ISU
IMI
CEDT
CSA
EE
MECH

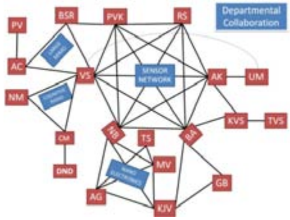
Departmental Collaboration
PV
BSR
PVK
RS
AC
VS
SENSOR NETWORK
AK
UM
NM
CM
DND
NB
TS
BA
KVS
TVS
MV
GB
AG
KJV

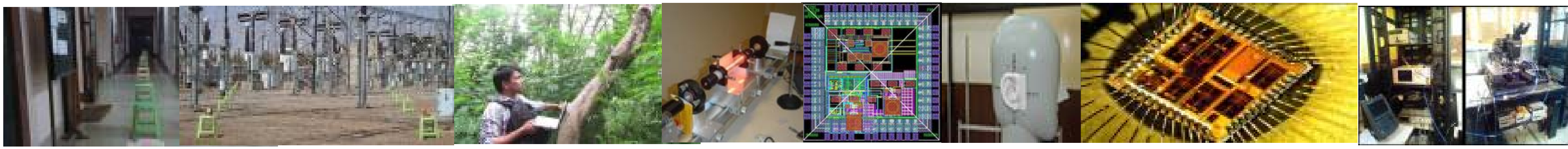

ECE: Microwave Engineering

K.J. Vinoy

- Low-Actuation Voltage Capacitive RF MEMS Switch (<10V)
  - Low-complexity fabrication process to enhance process yield
  - High reliability: no failure even up to 10 million cycles of operation tested
- Meso-scale Electrostatic Phase Shifter on microwave Laminate (MEPL)
  - Utilizes modern printed circuit board fabrication technology.
  - X-band monolithic antenna array system on the microwave laminate board demonstrated.

- Wideband group delay engineering in RF circuits for radar, medical imaging, and spectrum sensing.
  - Demonstration uses two stage All – Pass Networks; can be extended over multiple stages to obtain a higher bandwidth and/or higher group delay slope.
- RF energy harvesting circuits
  - Integrated with RF transmitters and sensors for practical IoT nodes
  - High efficiency RF-DC converter which can operate at input power of -20dBm (10µW) at 2.4GHz using UMC 130nm process MOSFETs.
- FEM based algorithms for Electromagnetic circuits & components (periodic structures such as metamaterials)
  - Fast computation of electromagnetic propagation characteristics
  - Especially suited for evaluation of processes uncertainties

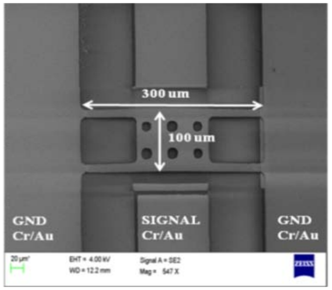

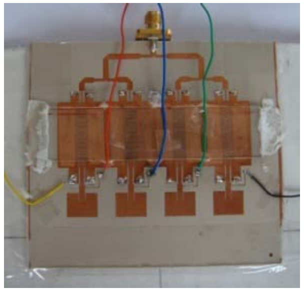

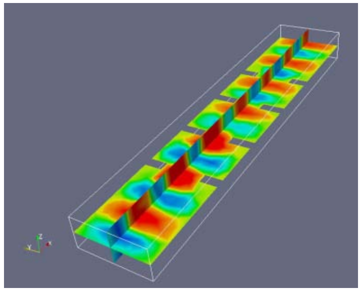

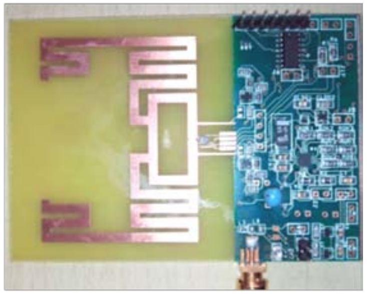

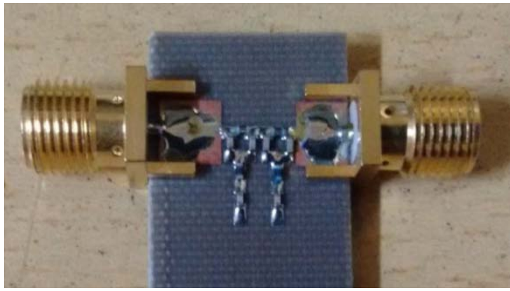

Setting the stage….

- **Introduction**
  - **Wireless Power Transfer**
    - **Energy Harvesting**
  - **Internet of Things**
- Highlights of Recent Development (Hardware)
  - Powering wireless terminals
  - RFID with integrated sensors

Ongoing Research Challenges

Wireless Power Transfer (WPT)

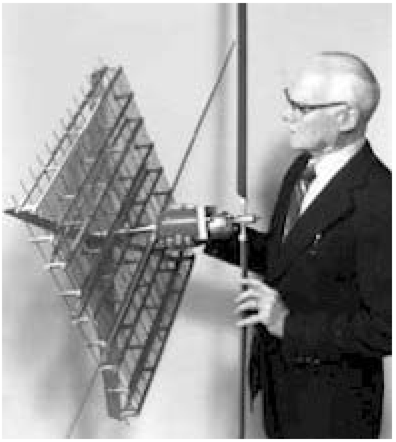

- Indicates transfer of electric energy remotely

- WPT has a long history!!
  - Tesla demonstrated it in 1899 by wirelessly powering fluorescent lamps 40 kms away from the power source.
  - Had multiple patents in early 1900s.

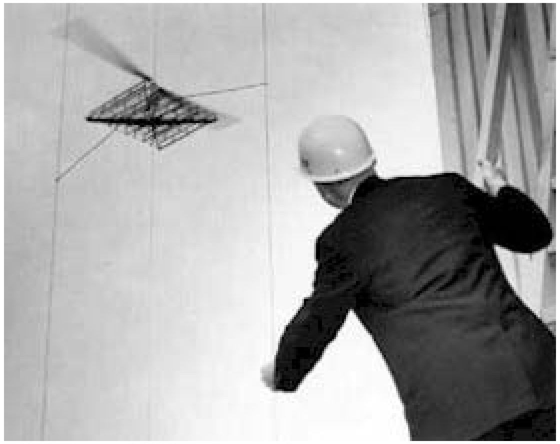

- In 1960s W.C. Brown coined the term Rectenna, which he used to directly converts incoming microwaves to DC.
  - He demonstrated its ability to power a helicopter solely through microwaves for 10 hours continuously.

- These demonstrations involved dedicated sources with **large power to transmit over long distances**.

http://mainland.cctt.org/istf2008/brown.asp

SSPS

- Space Solar Power Satellites

- WPT is widely investigated for putting **solar power generating satellites** into space and transmitting power to Earth stations. (Mainly in Japan)

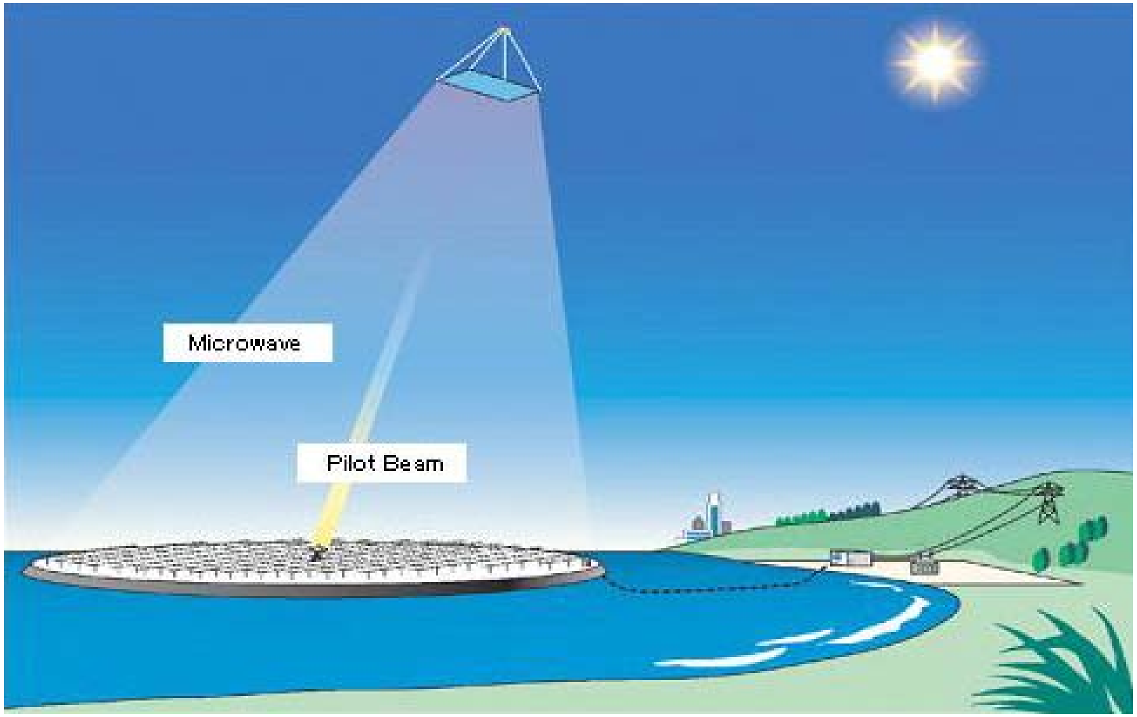

http://www.jspacesystems.or.jp/en_project_ssps/

Near field Wireless Power Transfer

- Recent demonstration by MIT to transfer high RF power (Watts) transferred across meters.
- Resonant coils are used
- Typically at 100 kHz to 10's of MHz
- Many new applications emerged

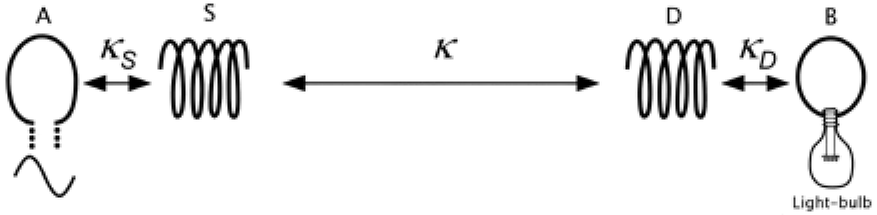

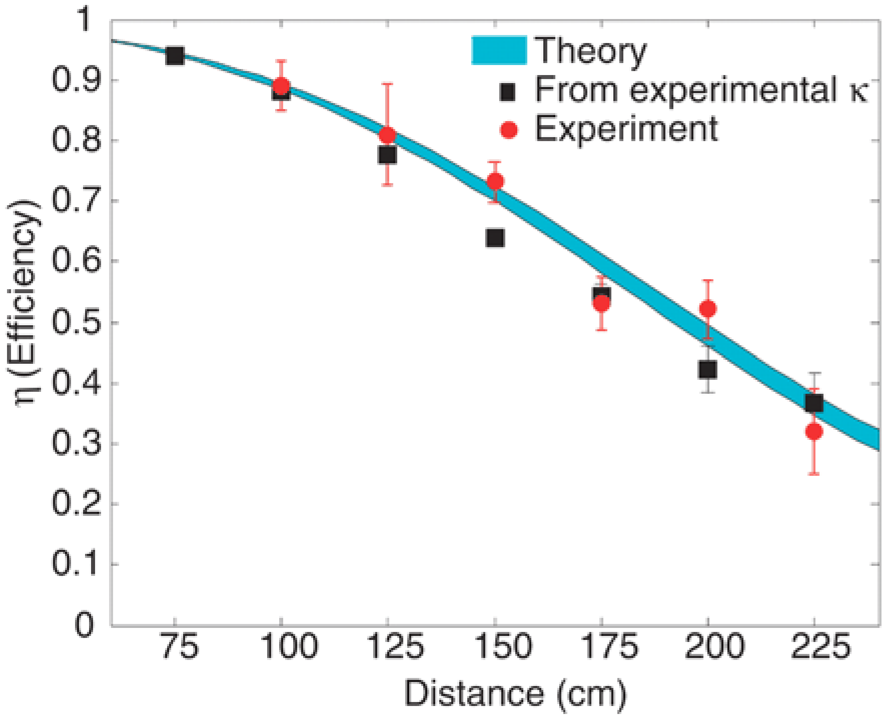

André Kurs et al, Wireless Power Transfer via Strongly Coupled Magnetic Resonances , Science, Vol. 317 no. 5834 pp. 83-86. 6 July 2007.

System Schematic Qi

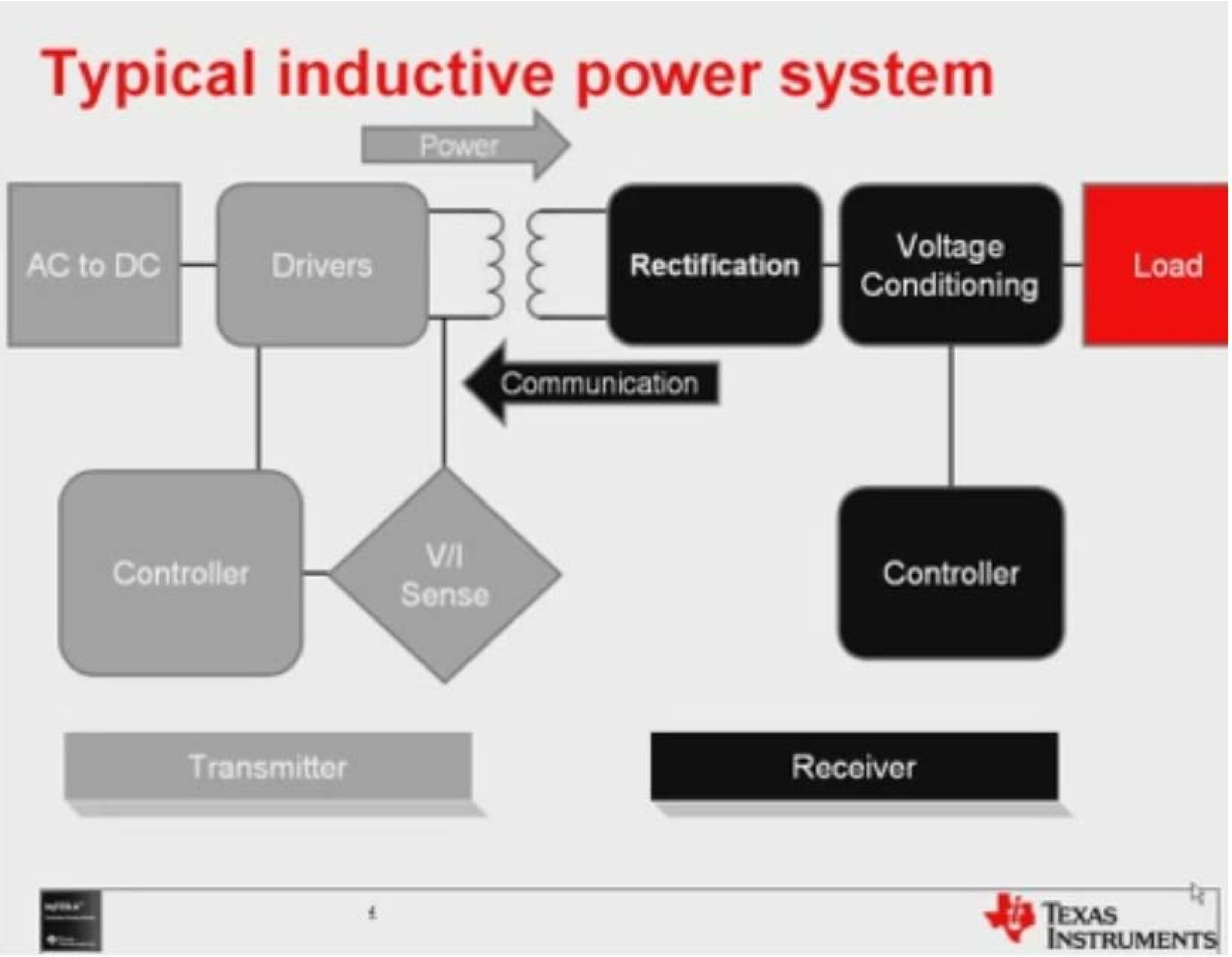

Typical inductive power system

Power

AC to DC

Drivers

Rectification

Voltage Conditioning

Load

Communication

Controller

V/I Sense

Controller

Transmitter

Receiver

Source: Texas Instruments Qi Development kit

Far → Near in WPT

- Free space loss factor is a major bottleneck for power transfer at large distances

- Short distance/ Near field options
  - MIT demonstration (2007)
  - Qi Standard
  - Phone charging solutions
  - Vehicles running on wireless power
- Two extremes in WPT
  - mW ← → MW
  - mm ← → 1000s km
  - 100kHz ← → 2.4/5.8GHz
  - 10cm x 10cm ← → km x km
  - Commercial vs bluesky

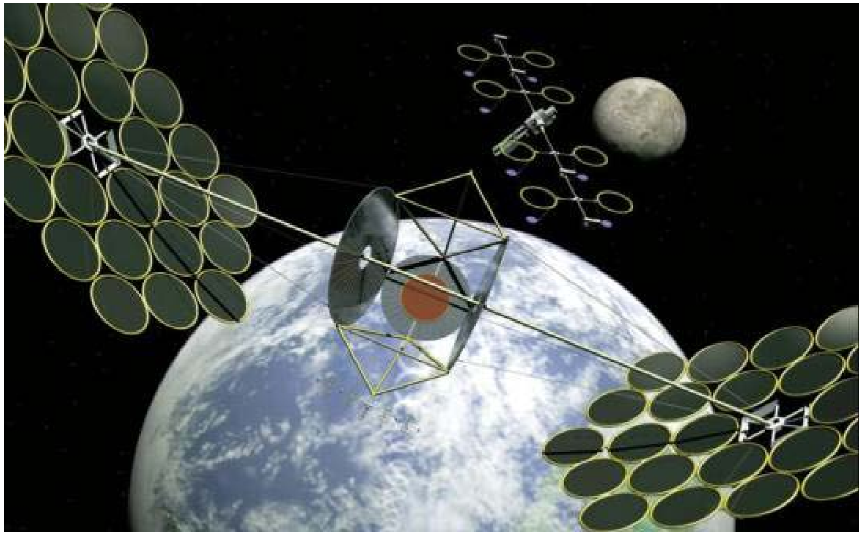

Far Field Transfer of RF Energy

- Focus of this talk
- Applications: RFID tags, Wireless Sensor Network nodes, biomedical equipment, home automation and structural monitoring can benefit from RF energy harvesting.
- Block diagram and a design example:

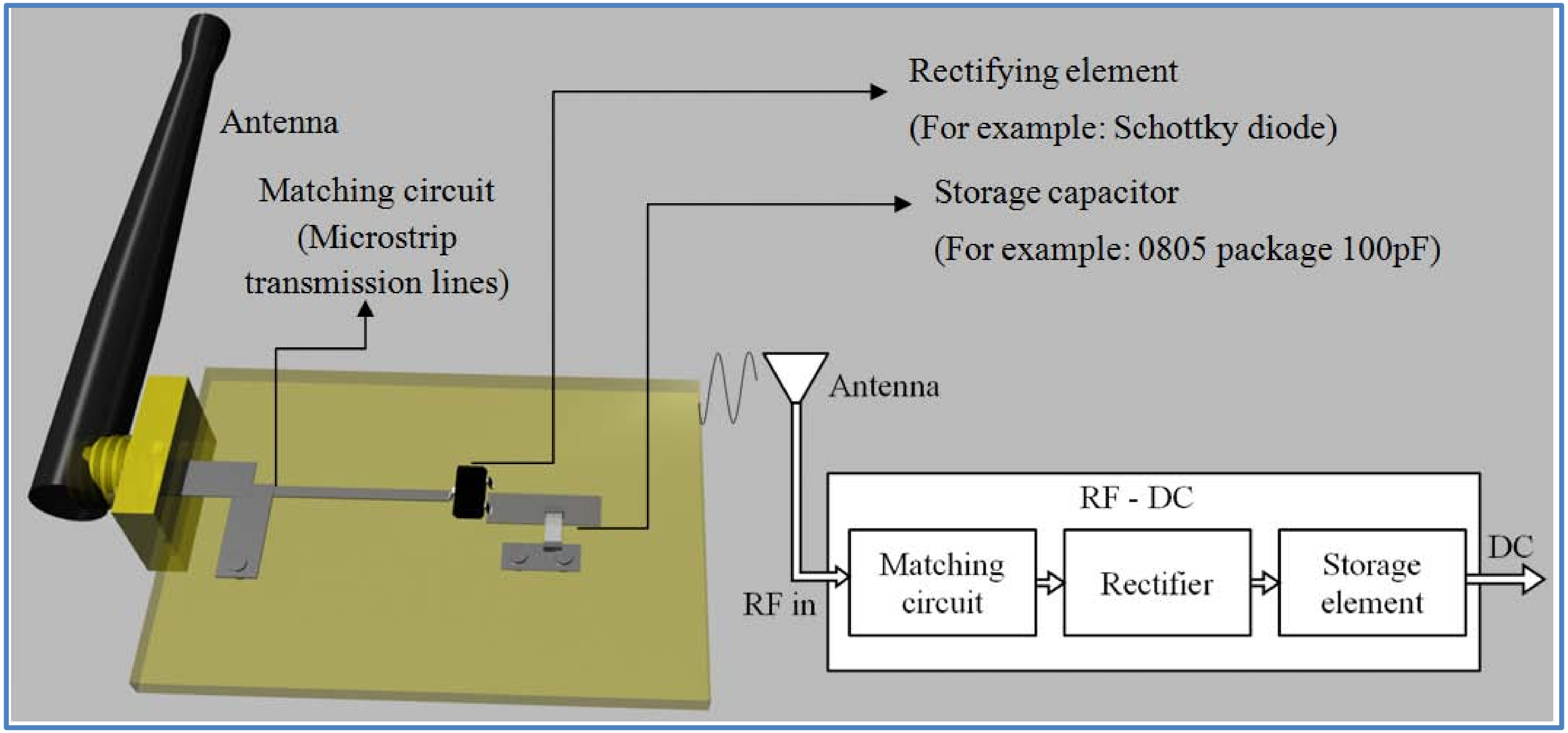
Antenna
Matching circuit
(Microstrip
transmission lines)
Rectifying element
(For example: Schottky diode)
Storage capacitor
(For example: 0805 package 100pF)
Antenna
RF in
RF - DC
Matching
circuit
Rectifier
Storage
element
DC

A New Paradigm: Internet of Things (IoT)

- IoT refers to uniquely identifiable objects and their virtual representations in an Internet-like structure.

Connects Anytime, Anyplace for Anyone (ICT)

AAA + for Anything (IoT)

- IoT is a scheme for connecting things: sensors, actuators, and other smart technologies, thus enabling person-to-object and object-to-object communications.

- **Continuous availability of power is crucial for their deployment**

IoT Applications

- Transportation and logistics
  - Logistics
  - Assisted driving
  - Mobile ticketing
  - Environment monitoring
  - Augmented maps
- Heathcare
  - Tracking
  - Identification, authentication
  - Data collection
  - Sensing
- Smart environments
  - Comfortable homes/offices
  - Industrial plants
  - Smart museum and gym
- Personal and social
  - Social networking
  - Historical queries
  - Losses
  - Thefts
- Futuristic
  - Robot taxi
  - City information model
  - Enhanced game room

L. Atzori , A. Iera, G. Morabito, The Internet of Things: A survey Computer Networks 54 (2010) 2787–2805

Comparison of different wireless protocols

Today, a lot can be done at low power!!

Characteristics of key 2.4GHz ISM Band Radios studied :

	BLE	ANT	Zigbee	WLAN
Topologies	P2P , Star	P2P , Star, tree, mesh	P2P , Star, mesh	P2P , Star
Modulation	GFSK	GFSK	OQPSK	DSSS (802.11b)
Max data rate	1Mbps	12.8-60 Kbps	250Kbs (@2.4Ghz)	1- 11Mbps (802.11b)
Throughput	305 kbps	20Kbps	100Kbps	6Mbps (802.11b)
Range (in m)	10-100(0-10dBm)	30 (@ 0dBm)	10-100 (0-20dBm)	100+(20dBm)
Max nodes in piconet	7	65533	Star-65536	32-64
Battery life	1-2 years (coin cell)	1-2years (coin cell)	100-1000 days	0.5-5days

Key Aspects :

BLE is robust and has lowest power consumption but cannot natively form mesh networks,

Zigbee can support large mesh networks, power consumption is higher than BLE and throughput is lower: It is suitable for low data rate, low power, large size networks.

WLAN is primarily suitable for transferring bulk data at high speeds, Not suitable for low power applications.

Power Requirements in Common WSN

	Crossbow MICAz	Intel IMote2	Jennic JN5139
Radio standard	IEEE802.15.4/ZigBee	IEEE802.15.4	IEEE802.15.4/ZigBee
Typical range	100m (outdoor), 30m (indoor)	30m	1 km
Data rate (kbps)	250 kbps	250 kbps	250 kbps
Sleep mode (deep sleep)	15 μA	390 μA	2.8 μA (1.6μA)
Processor only	8mA active mode	31–53mA$*$	2.7+0.325mA/MHz
RX	19.7mA	44mA	34mA
TX	17.4mA (+0dbm)	44mA	34mA (+3 dBm)
Supply voltage (minimum)	2.7V	3.2V	2.7V
Average	2.8mW	12mW	3mW

JM. Gilbert$*$ F. Balouchi, Comparison of Energy Harvesting Systems for Wireless Sensor Networks, International Journal of Automation and Computing 05(4), October 2008, 334-347

	Jennic JN5148	**TI- CC430**	**BLE**	**Zarlink ZL70250**
Active mode current at 16MHz [mA]	6	4	6.7	3.2
Deep sleep current [nA]	100	1000	400	20
Transmission current [mA]@Tx-power [dBm]	15@2.5	18@0	36@2	2@-10
Transmit frequency	2.4 GHz	2.4 GHz	2.4 GHz	868 MHz
Wakeup time [ms]	1	3	0.12	0.16
Energy consumption for a transmission cycle of 2ms [µJ]	183	300	196	32
Power supply voltage [V]	2.2 – 3.6	1.8 -3.6	2-3.6	1.2 – 1.8

In perspective

- Energy requirements in different devices/systems
- 6 orders of magnitude variation!!!

- Energy requirements in WSN
  - Depends on the complexity/ standard/ range
  - eg 90 µW to power a pulse oxymeter sensor, to process data and to transmit them at intervals of 15 s

Device type	Power consumption
Smartphone	1W
MP3 decoder chip	58 mW
Hearing aid	1 mW
Wireless sensor node	100 µW*
RF receiver chip	24 mW
GPS receiver chip	15 mW
6D motion sensor	14.4 mW
Cell phone (standby)	8.1 mW
PPG sensor	1.473 mW
Humidity	1 mW
Pressure	0.5 mW
3D accelerometer	0.324 mW
Temperature	27 µW
Cardiac pacemaker	50 µW
Wristwatch	7 µW
Memory R/W	2.17 µW
A-D conversion	1 µW

J Yun, S. Patel, M.Reynolds, G. Abowd “A Quantitative Investigation of Inertial Power Harvesting for Human-powered Devices,” UbiComp’08, September 21-24, 2008, Seoul, Korea.

R.J.M. Vullers, et.al, Micropower energy harvesting, Solid-State Electronics 53 (2009) 684–693

Power Density from Various Harvesters

Ambient RF	< 1 μW/cm^2
Ambient light	100 mW/cm^2 (directed toward bright sun)
	100 μW/cm^2 (illuminated office)
Thermoelectric	60 μW/cm^2
Vibrational	4 μW/cm^3 (human motion ~Hz)
microgenerators	800 μW/cm^3 (machines ~kHz)
Ambient airflow	1 mW/cm^2
Push buttons	50 μJ/N
Hand generators	30 W/kg
Heel strike	Up tp 7 W for 1 cm deflection

Power requirements in conventional sensor network nodes may not be met by harvesting alone!

J Yun, S. Patel, M.Reynolds, G. Abowd "A Quantitative Investigation of Inertial Power Harvesting for Human-powered Devices," UbiComp'08, September 21-24, 2008, Seoul, Korea.

Electromagnetic: Solar → RF

- PV is a good source of energy. Recall,

Ambient light	100 mW/cm^2 (directed toward bright sun)
	100 μW/cm^2 (illuminated office)

- However, it light is not always available.
  - At night
  - Specific scenarios: in a closed chamber, or mine.

- RF is an alternative
  - Unlike others, RF sources may be ambient or intentional.
  - Ambient sources such as base stations or broadcast stations
  - Special sources: RF ID reader, Phone charger, special beacons

Demand and Supply

- The peak currents needed during transmit and receive operation is not achievable using the harvester alone.
- Buffering is also needed to ensure continuous operation during times without power generation.
- The combination of an energy harvester with a small-sized storage is the best approach to enable energy autonomy of the network over the entire lifetime.
    - Rechargeable battery
    - Thin film batteries
        - can be integrated directly in Integrated Circuit (IC) packages in any shape or size,
        - Flexible when fabricated on thin plastics
        - Thin film batteries have high impedance;
        - Low discharge efficiency compared to Li-ion batteries
    - super capacitor
        - Leakage in super capcitors depends on the voltage. Low at low voltage

Internet of Things (IoT)

Embedding short-range mobile transceivers into a wide array of gadgets and everyday items, enabling new forms of communication between people and things, and between things themselves.

RFID + Sensor + Smart Tech + Nano Tech = IoT

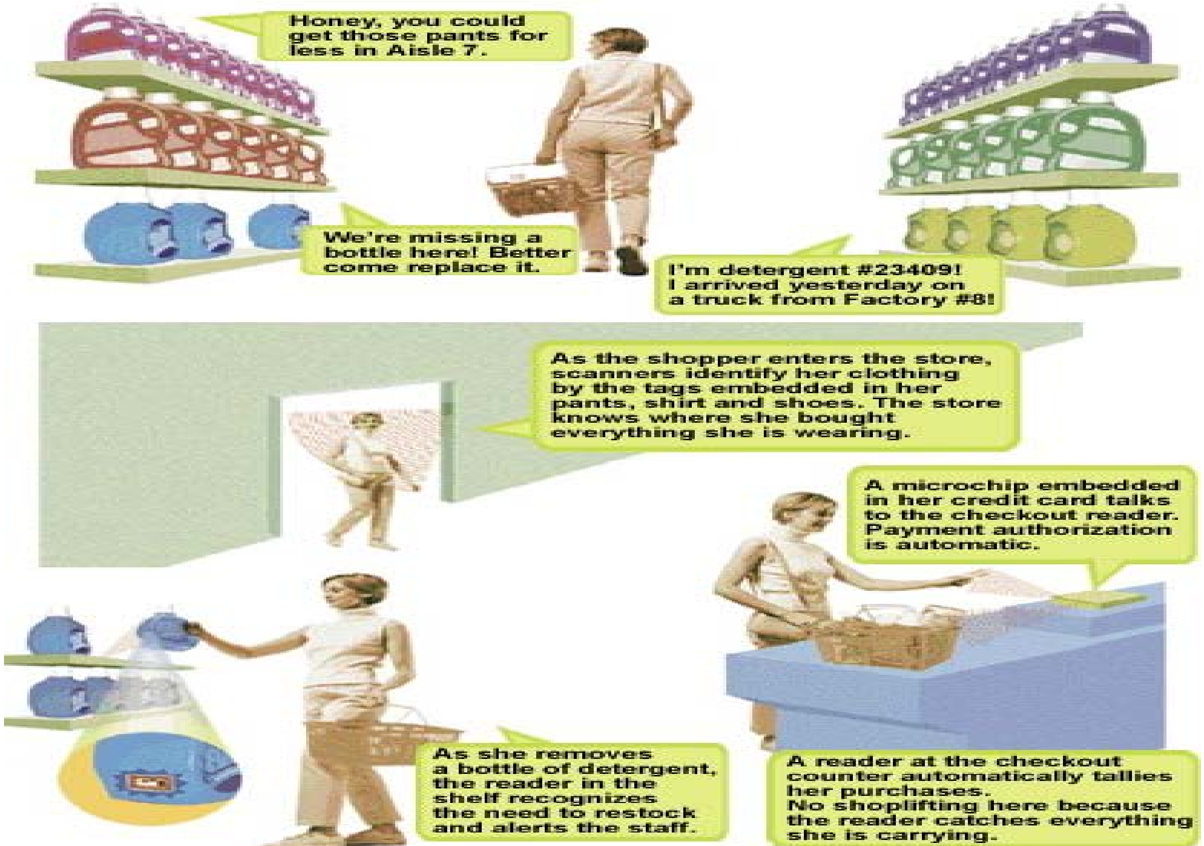
Honey, you could get those pants for less in Aisle 7.
We're missing a bottle here! Better come replace it.
I'm detergent #23409! I arrived yesterday on a truck from Factory #8!
As the shopper enters the store, scanners identify her clothing by the tags embedded in her pants, shirt and shoes. The store knows where she bought everything she is wearing.
A microchip embedded in her credit card talks to the checkout reader. Payment authorization is automatic.
As she removes a bottle of detergent, the reader in the shelf recognizes the need to restock and alerts the staff.
A reader at the checkout counter automatically tallies her purchases. No shoplifting here because the reader catches everything she is carrying.

When shopping in the market, the goods will introduce themselves.

When entering the doors, scanners will identify the tags on clothing.

When paying for the goods, the microchip of the credit card will communicate with checkout reader.

When moving the goods, the reader will tell the staff to put a new one.

Introduction to RFID

- The reader converts incident field and returns useful data
- In passive RFID systems reader transmits EM energy that "wakes up“ the tag and provides power for the tag to respond to the reader.

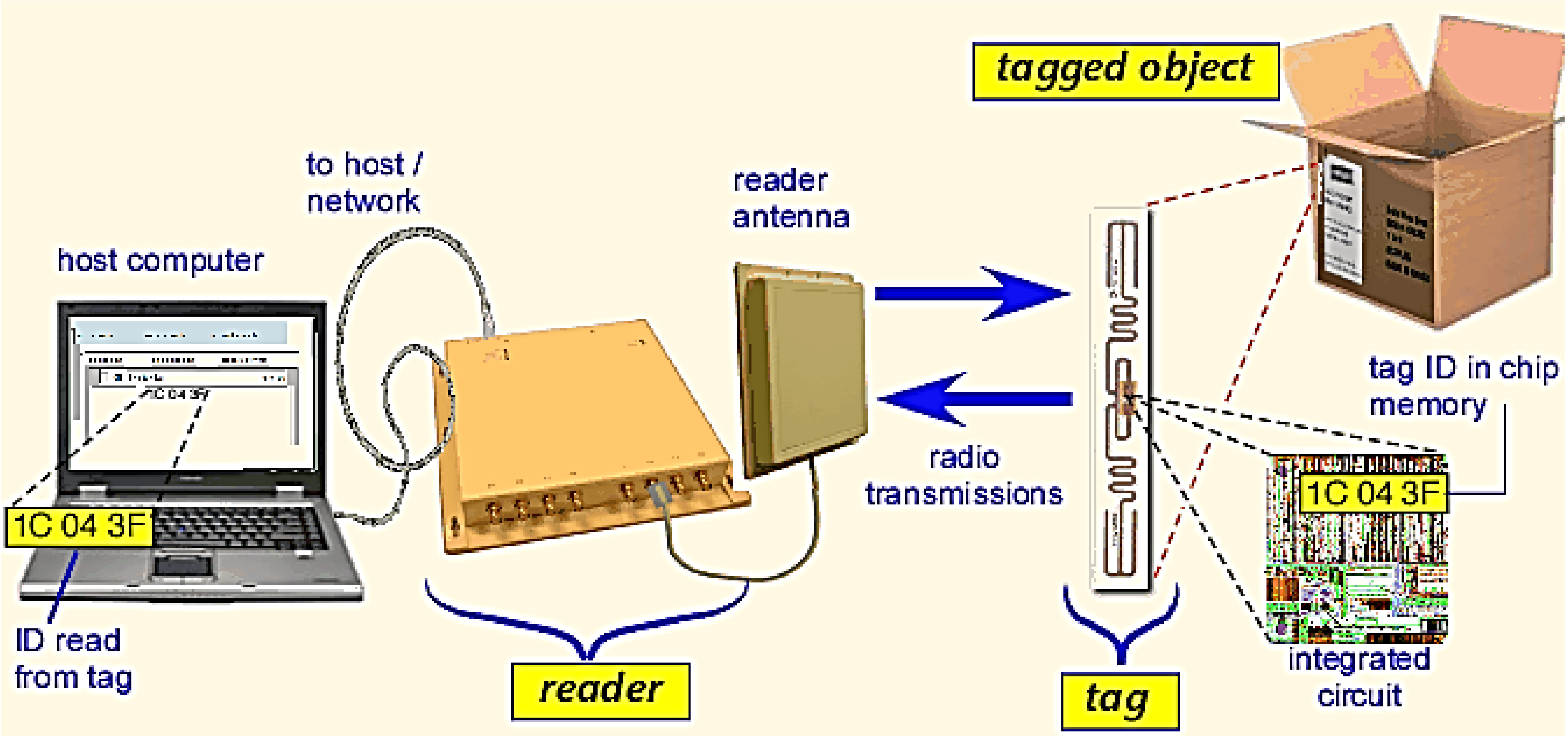
tagged object
to host /
network
reader
antenna
host computer
tag ID in chip
memory
radio
transmissions
1C 04 3F
1C 04 3F
ID read
from tag
reader
tag
integrated
circuit

Backscatter Communication

- **Backscatter** is the reflection of signals back towards their source.
  - In this scheme, two devices communicate using incident (or ambient) RF as the source of power.
  - Backscattering is achieved by changing the impedance of a receiver in the presence of an incident signal.
  - When waves encounter a new media that have different impedances, a part of the wave is reflected.
  - The reflection depends on the difference in the impedances.
- By modulating the impedance at the receiver port, one can control the scattered RF energy, hence enabling information transmission.

abc.cs.washington.edu/files/comm153-liu.pdf

RFID → IoT

- RFID
  - Uses radio waves for identifying or tracking the object.
  - Proven to be a simple and cost effective system
  - Tags are very cheap and is possible to be attached to everyday objects.

- RFID is considered a prerequisite of **Internet of Things.**

- **Example: RFID tags can be integrated with sensors**
  - When a reader reads a tag, the sensor information will be sent to the reader along with the identity of the object.

Some Examples

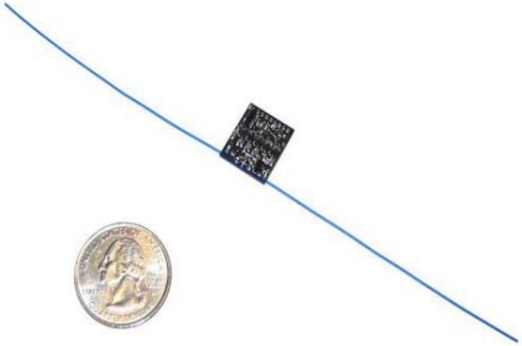

Discrete Element Based

WISP (Wireless Identification Sensing Platform)

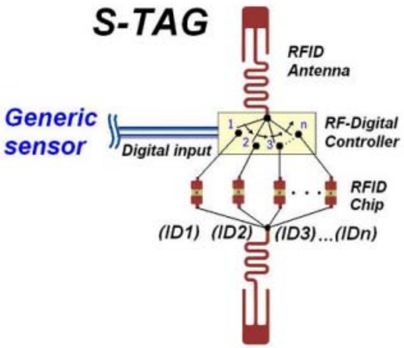
S-TAG
RFID Antenna
Generic sensor
Digital input
RF-Digital Controller
1
2
3
n
RFID Chip
(ID1) (ID2) (ID3)...(IDn)

Multi-Chip Based S-tag

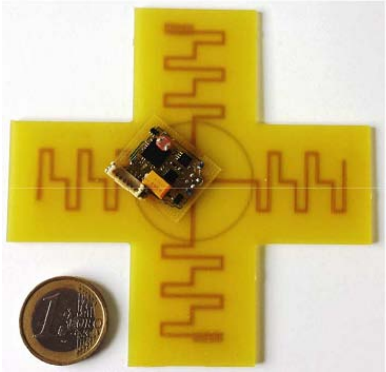

Chips with I2C / SPI

SPARTACUS / RAMSES (Self-Powered Augmented RFID Tag for Autonomous Computing and Ubiquitous Sensing / RFID Augmented Module for Smart Environmental Sensing)

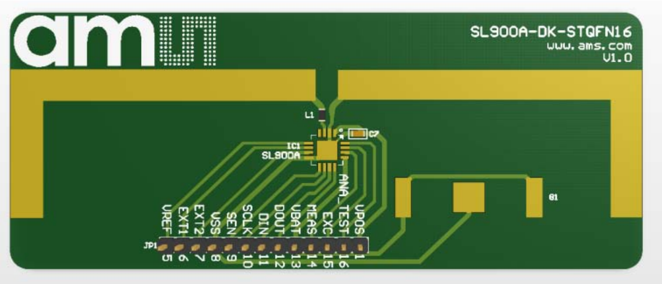
ams
SL900A-DK-STQFN16
www.ams.com
V1.0
L1
IC1
SL900A
C7
JP1
VREF
EXT1
EXT2
VSS
SEN
SCLK
DIN
DOUT
VBAT
MEAS
EXC
ANA_TEST
VPOS
5
6
7
8
9
10
11
12
13
14
15
16
1

Single IC Based Sensing Tags

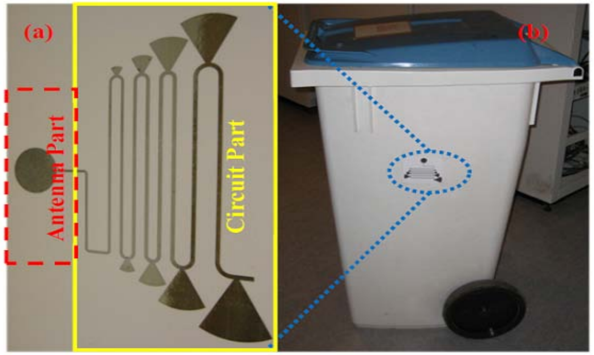
(a)
Antenna Part
Circuit Part
(b)

Printed Chipless RFID Tag

WISP

- Wireless Identification Sensor Platform (2009)
  - WISPs are a wireless, battery-free sensing and computation platform, powered by harvested energy from off-the-shelf UHF RFID readers.
  - To a RFID reader, a WISP is a EPC gen1 or gen2 tag; but inside the WISP, the harvested energy is operating a 16-bit general purpose microcontroller.
  - The microcontroller can perform computing tasks, including sampling sensors, and communicate to the RFID reader.
  - WISPs have been built with various sensors, WISPs can write to flash and perform cryptographic computations.

A collaboration between Intel Research Seattle and the University of Washington.

WISP 4.1DL
Intel Research Seattle

http://wisp.wikispaces.com/Wisp+4.1+DL

RFID Sensors (Products)

- ID operation is passive; yet most sensors require power sources

- Powercast has a wireless sensor that is battery-less. Uses RF energy harvesting.
- Harvesting schemes works at power as low as -12dBm. (RF-DC conversion efficiency above 40% only above -8dBm)
- Harvested power >0.4mW for RF in of >-1dBm.
- Multiple custom ICs and discretes

- Other suppliers include
  - Phase IV
  - RFID sensor systems
  - etc

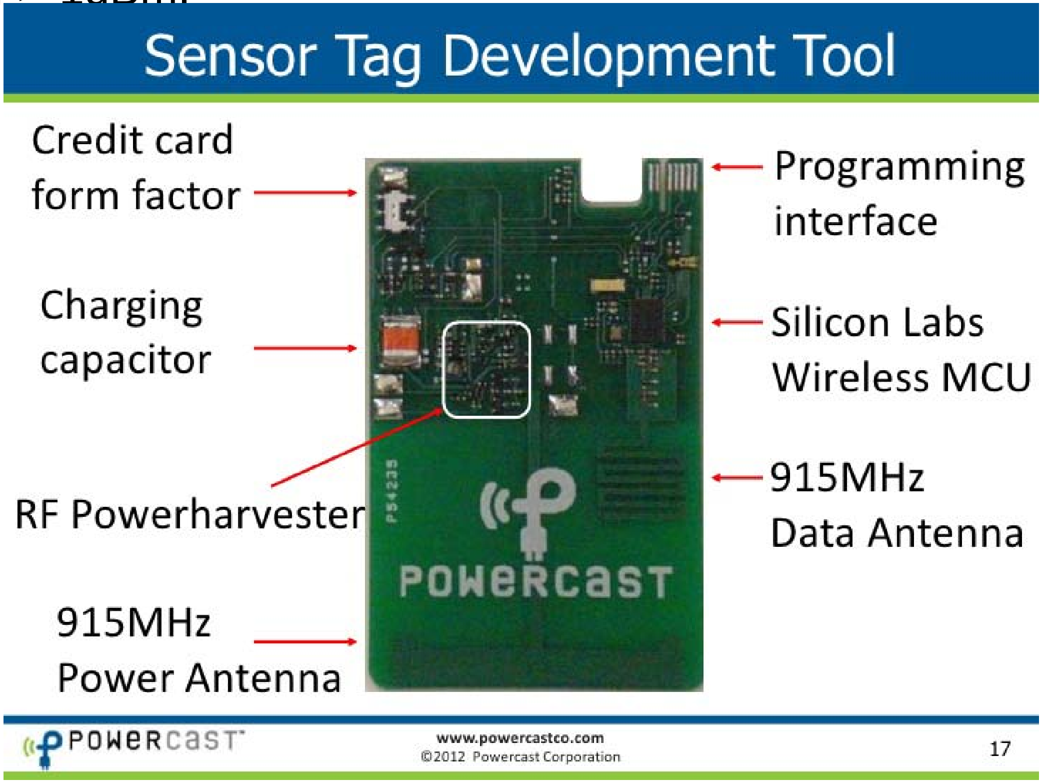

Sensor Tag Development Tool

Credit card form factor

Charging capacitor

RF Powerharvester

915MHz Power Antenna

Programming interface

Silicon Labs Wireless MCU

915MHz Data Antenna

POWERCAST

www.powercastco.com
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http://www.powercastco.com/uhf-rfid-sensing-passive-rfid-wireless-sensor-tags/

Battery-less Wireless Terminals

- Most of our work in this direction was towards battery-less terminals
- Long life terminals without wiring
- These are useful when
  - Terminals are embedded within structures (or body)
  - Devices to be deployed in hostile environments
  - Use of battery is not allowed (potential cause for explosion)
- Other factors
  - Cost, weight, etc.
- Primary focus: use of radio frequencies (ambient/intentional)

Ambient RF Sources

- Several sources:
  - WiFi Access points (mW) [2.4/.6GHz]
  - Cellular Tower (W) [900/1800 MHz]
  - TV Broadcast (MW) [150-450MHz]
  - FM broadcast (kW) [90-108MHz]
  - AM Radio broadcast (kW) [<1MHz]

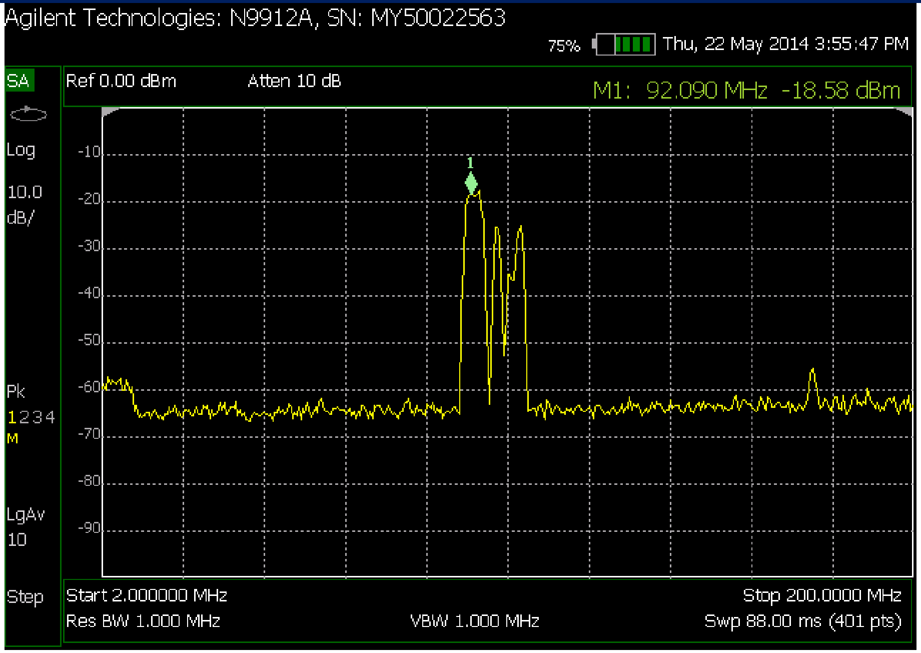

Agilent Technologies: N9912A, SN: MY50022563

75% Thu, 22 May 2014 3:55:47 PM

Ref 0.00 dBm Atten 10 dB

M1: 92.090 MHz -18.58 dBm

Start 2.000000 MHz Stop 200.0000 MHz

Res BW 1.000 MHz VBW 1.000 MHz Swp 88.00 ms (401 pts)

- In general
  - Lower frequencies help non-line-of sight propagation
  - Power availability from ambient sources is limited and varies from place to place.

- Note
  - Unlike other sources, most practical RF harvesters (eg in RF ID) depend on **intentionally generated energy**.
  - This is called **wireless power transfer (WPT)** in the conventional RF/Microwave parlance.

Wireless Communication System

- Power transfer scheme is no different!!

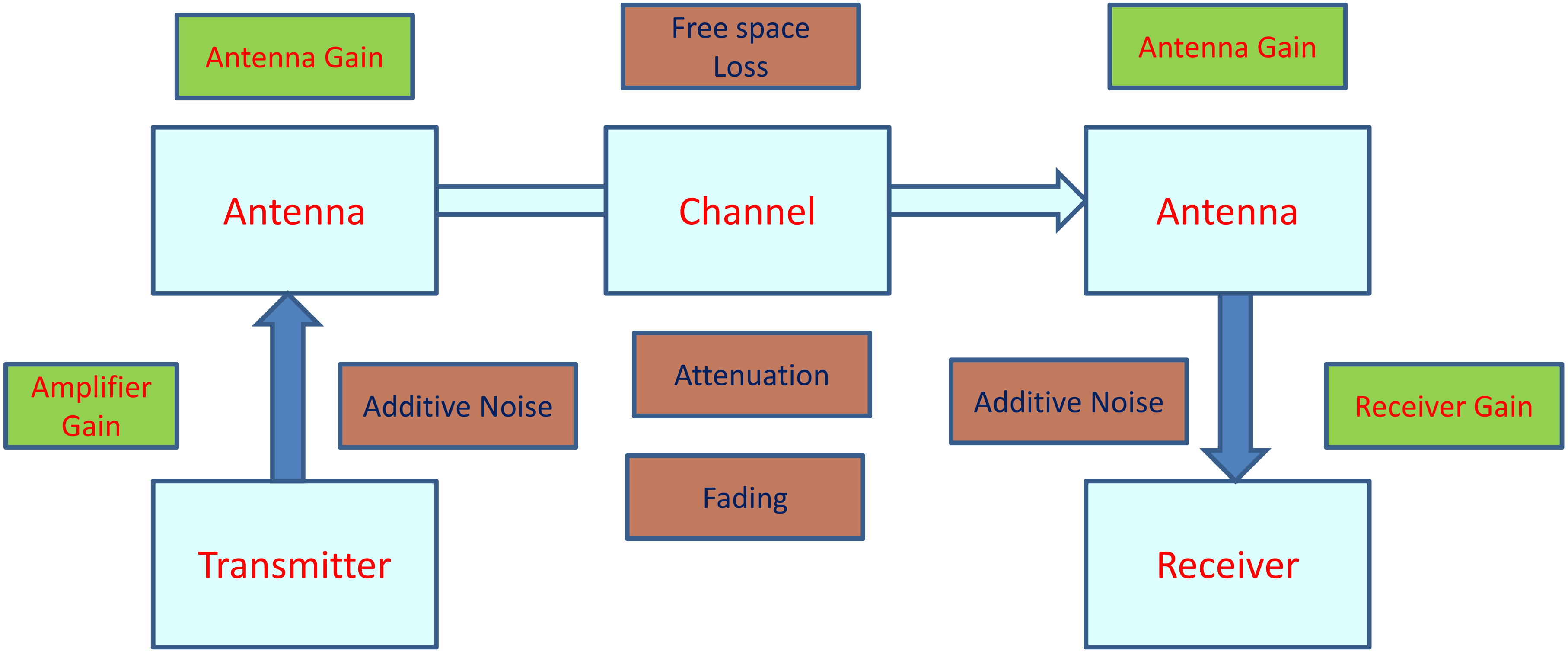

Antenna Gain

Free space Loss

Antenna Gain

Antenna

Channel

Antenna

Amplifier Gain

Additive Noise

Attenuation

Additive Noise

Receiver Gain

Fading

Transmitter

Receiver

Antenna Fundamentals: Directivity

This is the ratio of the radiation intensity ***in a given direction*** *to the radiation intensity averaged over all direction*

Average radiation intensity, $U_0 = \dfrac{P_{rad}}{4\pi}$

Directivity,

$$D(\theta,\phi) = \frac{U(\theta,\phi)}{U_0} = \frac{4\pi U(\theta,\phi)}{P_{rad}}$$

- If direction is not specified, it implies the direction of maximum radiation intensity

$$D_{\max} = \frac{4\pi U_{\max}}{P_{rad}} \qquad D_{dB} = 10\log D$$

Maximum directivity and Maximum effective area

The radiated power density by a transmitter at a distance R

$$W_t = \frac{P_t D_t}{4\pi R^2}$$

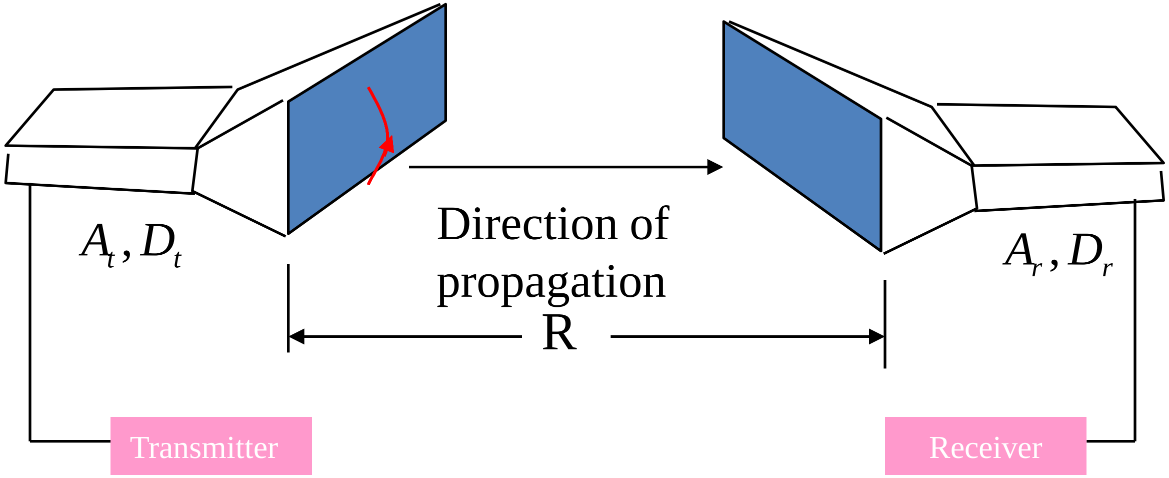

A_t, D_t
Direction of propagation
R
A_r, D_r
Transmitter
Receiver

Power received

$$P_r = W_t . A_r = \frac{P_t D_t A_r}{4\pi R^2}$$

$$or,\ D_t . A_r = \frac{P_r}{P_t} . 4\pi R^2$$

By reversing the transmission direction

$$D_r A_t = \frac{P_r}{P_t} \cdot 4\pi R^2$$

$$\therefore \frac{D_t}{A_t} = \frac{D_r}{A_r}$$

this can be generalized by

$$\frac{D_1}{A_1} = \frac{D_2}{A_2} = k = \frac{4\pi}{\lambda^2}$$

$if,\ D_0 = \text{max. directivity}$

$A_{em} = \text{max. effective area}$

$$D = \frac{4\pi A_{em}}{\lambda^2}$$

Frii's Transmission Equation

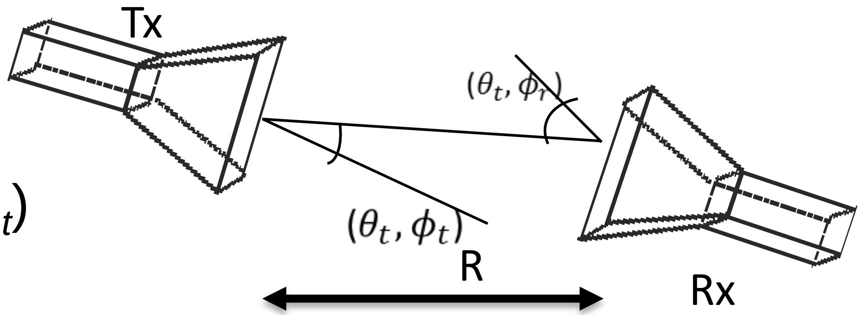

- The radiation intensity for an isotropic radiator is $W_0 = \frac{P_t}{4\pi R^2}$
- For an antenna of gain G_t (or directivity D_t)

$$W_t = \frac{P_t G_t(\theta_t, \phi_t)}{4\pi R^2} = e_t \frac{P_t D_t(\theta_t, \phi_t)}{4\pi R^2}$$

- The effective aperture of a receiving antenna is given by $A_r = e_r D_r(\theta_r, \phi_r) \frac{\lambda^2}{4\pi}$
- Therefore,

$$P_r = e_r D_r(\theta_r, \phi_r) \frac{\lambda^2}{4\pi} W_t = e_t\, e_r D_t(\theta_t, \phi_t) D_r(\theta_r, \phi_r) \frac{\lambda^2}{(4\pi R)^2} |\hat{\boldsymbol{\rho}}_t . \hat{\boldsymbol{\rho}}_r|^2$$

$$\frac{P_r}{P_t} = e_t e_r D_t(\theta_t, \phi_t) D_r(\theta_r, \phi_r) \frac{\lambda^2}{(4\pi R)^2} |\hat{\boldsymbol{\rho}}_t . \hat{\boldsymbol{\rho}}_r|^2$$

$$\frac{P_r}{P_t} = e_{cdt} e_{cdr} (1 - |\Gamma_t|^2)(1 - |\Gamma_r|^2) D_t(\theta_t, \phi_t) D_r(\theta_r, \phi_r) \frac{\lambda^2}{(4\pi R)^2} |\hat{\boldsymbol{\rho}}_t . \hat{\boldsymbol{\rho}}_r|^2$$

- When the antennas are pointing towards each others' peak radiation direction,

$$\frac{P_r}{P_t} = G_{0t} G_{0r} \left(\frac{\lambda}{4\pi R}\right)^2$$

Note that includes a loss factor (usually called **Free space Loss factor)**
Does not include dissipation/attenuation in medium; caused by spreading

Some numbers on Radiative form of WPT…

- Practical systems will have
  - Operational frequencies in ISM bands.
  - Most terminals are compact.
  - Antenna efficiency is compromised.
  - Nearly isotropic radiations expected.

- Main bottleneck is the physical limits in transmission.

$$P_r = P_t{*}G_t{*}G_r{*}(\lambda/4\pi r)^2$$

  - At 1 GHz (λ=30cm) *r*=1m; Antenna gain @0dBm, free space loss factor is about **0.06%**
  - Even with a moderate gain transmitter antenna (6dBi) power received @1m for 1W transmission, is just 2mW.
    - Drops to 23μW at 10m !!
    - **The voltage of the signal is low!!**

- In radiative power transfer, Distance from transmitter is a major concern.

Some questions addressed in our work

- **Harvesting of ambient radiations or Radiative transfer of energy addressed**
  - Is it possible to harvest the RF energy from base stations
  - Are there other viable sources of RF energy
- Can low power communication systems be designed to operate entirely from harvested energy
  - Integrate sensors, control, etc
- Can we use RF EH/ WPT to increase the range of backscatter communication (RFID scenario)

Design of Rectifiers

Required for converting incoming RF into DC power.

The challenge lies in maximizing the power conversion efficiency for low input power and minimizing the dimensions.

- RF to DC conversion by rectification of the incident RF signal by a ***Schottky diode***
  - Most diodes have a finite cut-in voltage
  - Diode is a non-linear device (performance depends on current or load)
  - Impedance matching required between antenna and diode
  - In most cases, the input voltage needs to be boosted

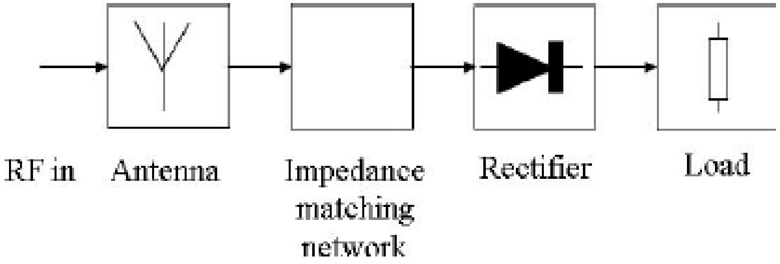
RF in
Antenna
Impedance matching network
Rectifier
Load

Conceptual diode based Rectenna

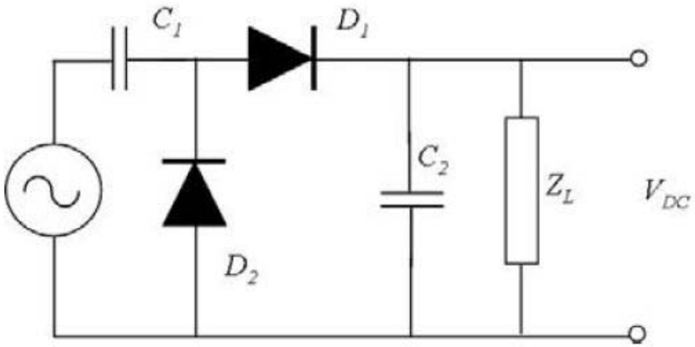
C_1
D_1
C_2
Z_L
V_{DC}
D_2

Voltage doubler

Voltage magnification in Matching circuit

- Matching circuit is required to provide impedance match between antennas (50Ω typical) to diode terminated with high impedance load (capacitor and/or high R in parallel).
  - LC matching networks provide voltage magnification.
  - This helps the diode conduct a good fraction of half cycle.
- The higher the voltage across the diodes, the more efficient the rectifier gets.
  - In practice Q is limited
  - Applications requiring higher voltages, a voltage multiplier configuration is used.

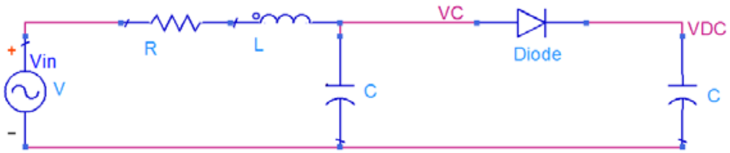

$$V_C = V_{in} \times \frac{\frac{1}{j\omega C}}{R + j\omega L + \frac{1}{j\omega C}}$$

At resonance,

$$V_C = V_{in} \times \frac{1}{j\omega_0 CR} = -jQV_{in}$$

Tuned Rectifier at RF

- A tuned rectifier implemented using discrete components

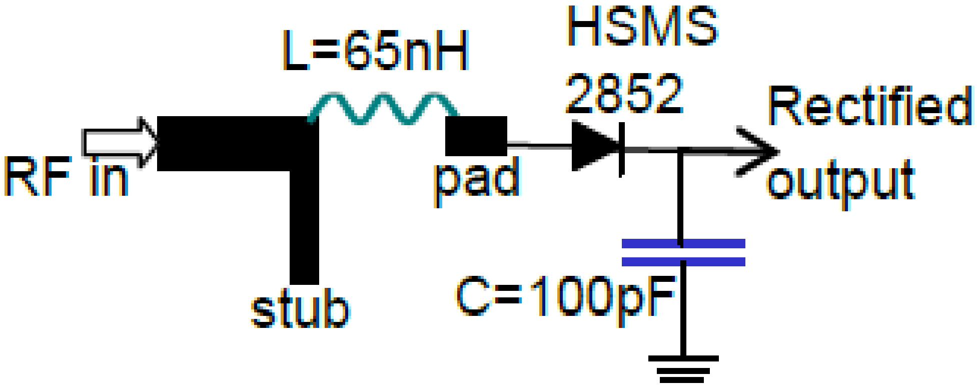

P_in→	**-10dBm**	**-13dBm**	**-16dBm**	**-20dBm**	**-25dBm**
Freq. ↓					
930MHz	917mV	664mV	469mV	281mV	131mV
945MHz	1016mV	736mV	515mV	300mV	132mV
955MHz	1038mV	747mV	513mV	289mV	122mV
960MHz	1032mV	736mV	499mV	276mV	114mV
Peak efficiency	51%	47%	39%	33%	20%

K. J. Vinoy, T. V. Prabhakar, A Universal Energy Harvesting Scheme for Operating Low-Power Wireless Sensor Nodes Using Multiple Energy Resources, pp. 453-466, Micro and Smart Devices and Systems, Springer 2014.

Typical Performance of Rectifier

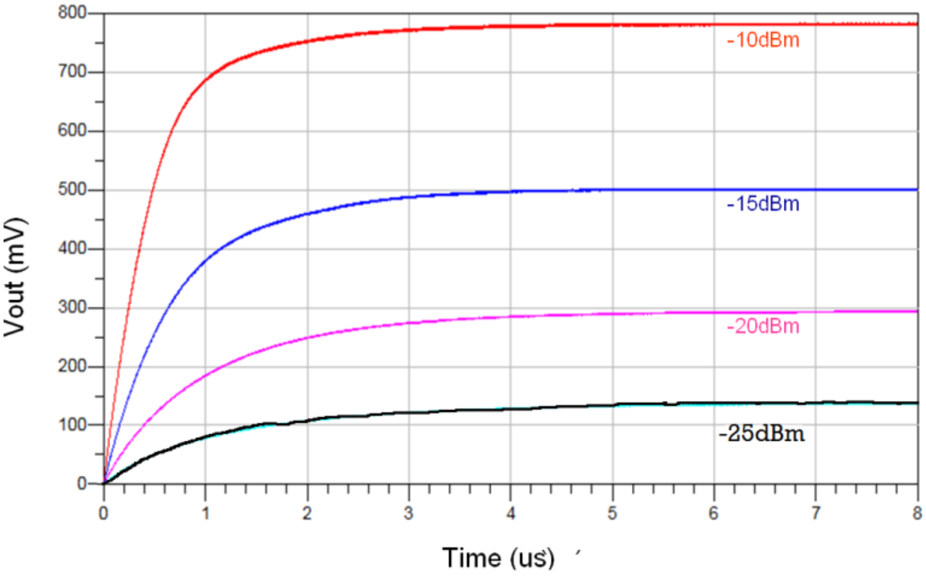

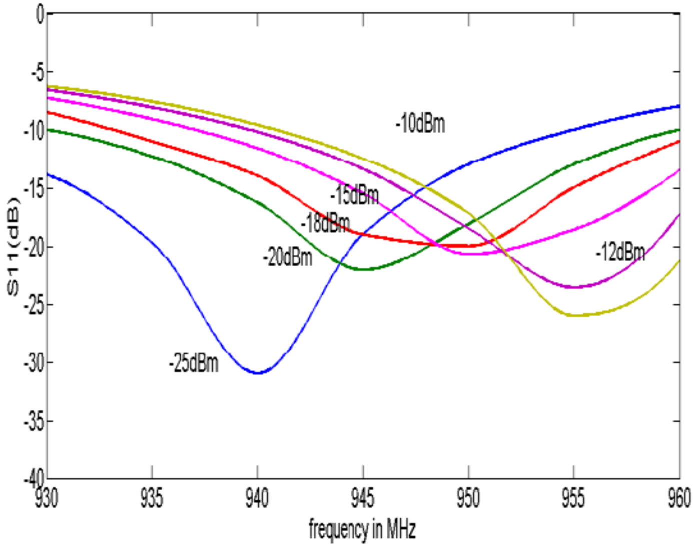

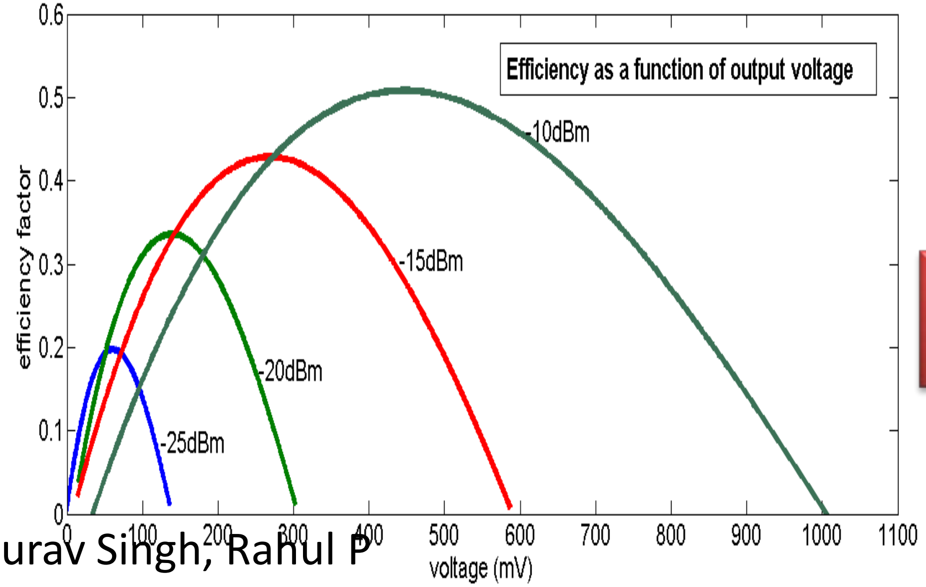

RF-DC Conversion efficiency depends on various conditions

Rectifier Circuit using 4 diodes

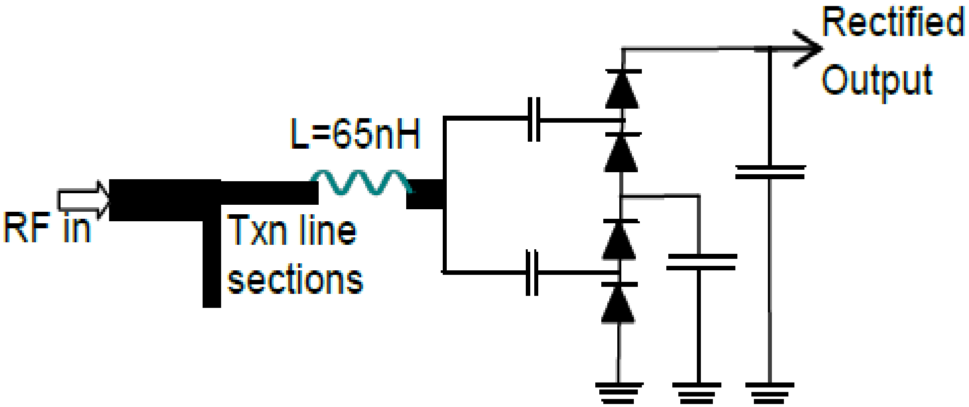
Rectified
Output
L=65nH
RF in
Txn line
sections

Power level (dBm)	Charging time (ms)	Efficiency (%)
0	40	64.11
-2	55	63.77
-3	67.5	63.5
-5	90	63
-7	230	59.89
-10	370	56.78
-12	500	53.89
-15	900	45
-18	2000	20.56

K. J. Vinoy, T. V. Prabhakar, A Universal Energy Harvesting Scheme for Operating Low-Power Wireless Sensor Nodes Using Multiple Energy Resources, pp. 453-466, Micro and Smart Devices and Systems, Springer 2014.

Aditya Mitra, Chaithanya (2011-12)

1: Scavenging Mobile Tower Radiations

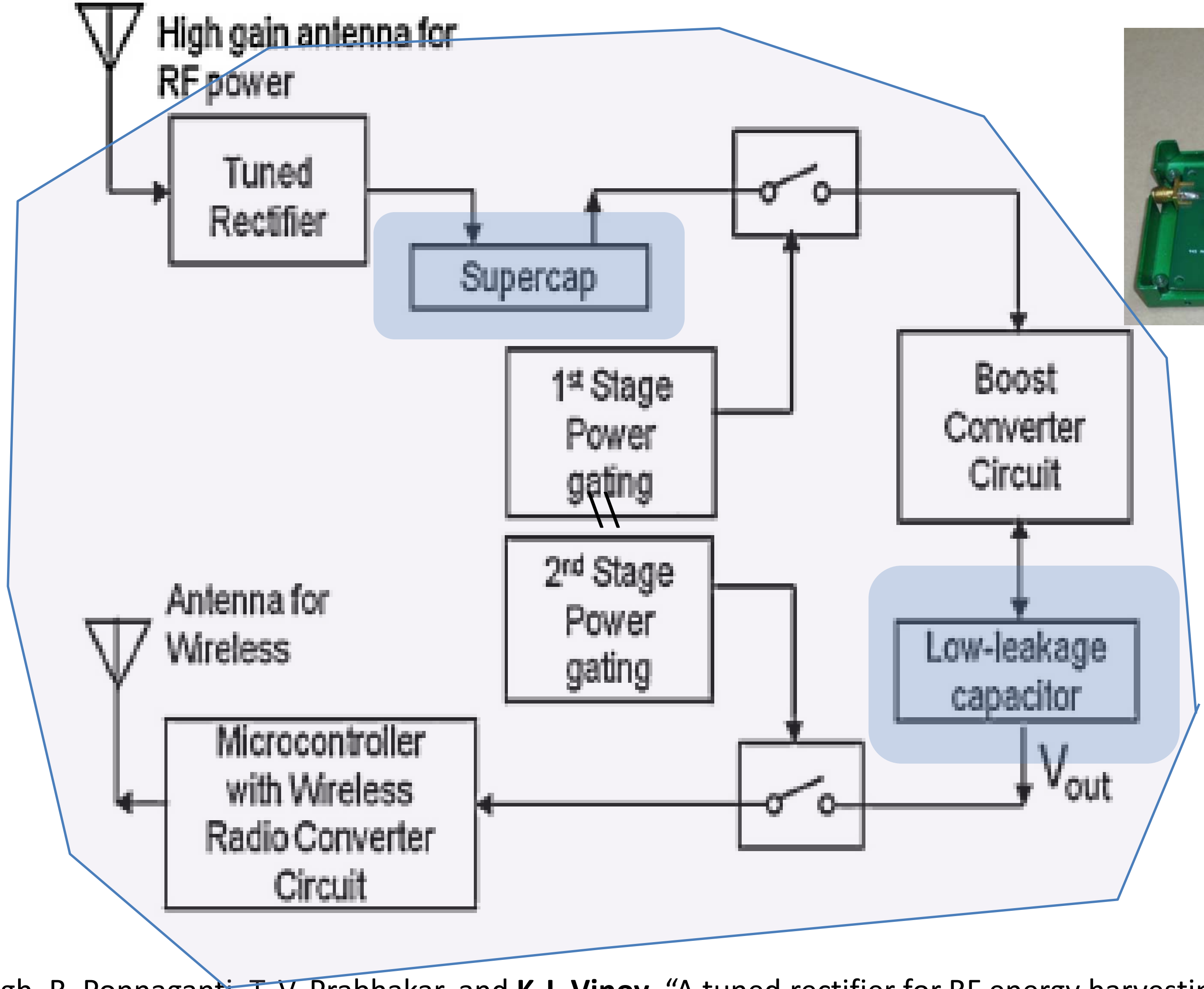
High gain antenna for RF power
Tuned Rectifier
Supercap
1st Stage Power gating
2nd Stage Power gating
Boost Converter Circuit
Low-leakage capacitor
V_{out}
Antenna for Wireless
Microcontroller with Wireless Radio Converter Circuit

G. Singh, R. Ponnaganti, T. V. Prabhakar, and **K.J. Vinoy**, "A tuned rectifier for RF energy harvesting from ambient radiations," Int. J. Electronics & Communications, vol. 67, no. 7, pp. 564-569, July 2013

Gaurav Singh, Rahul P (2010-11)

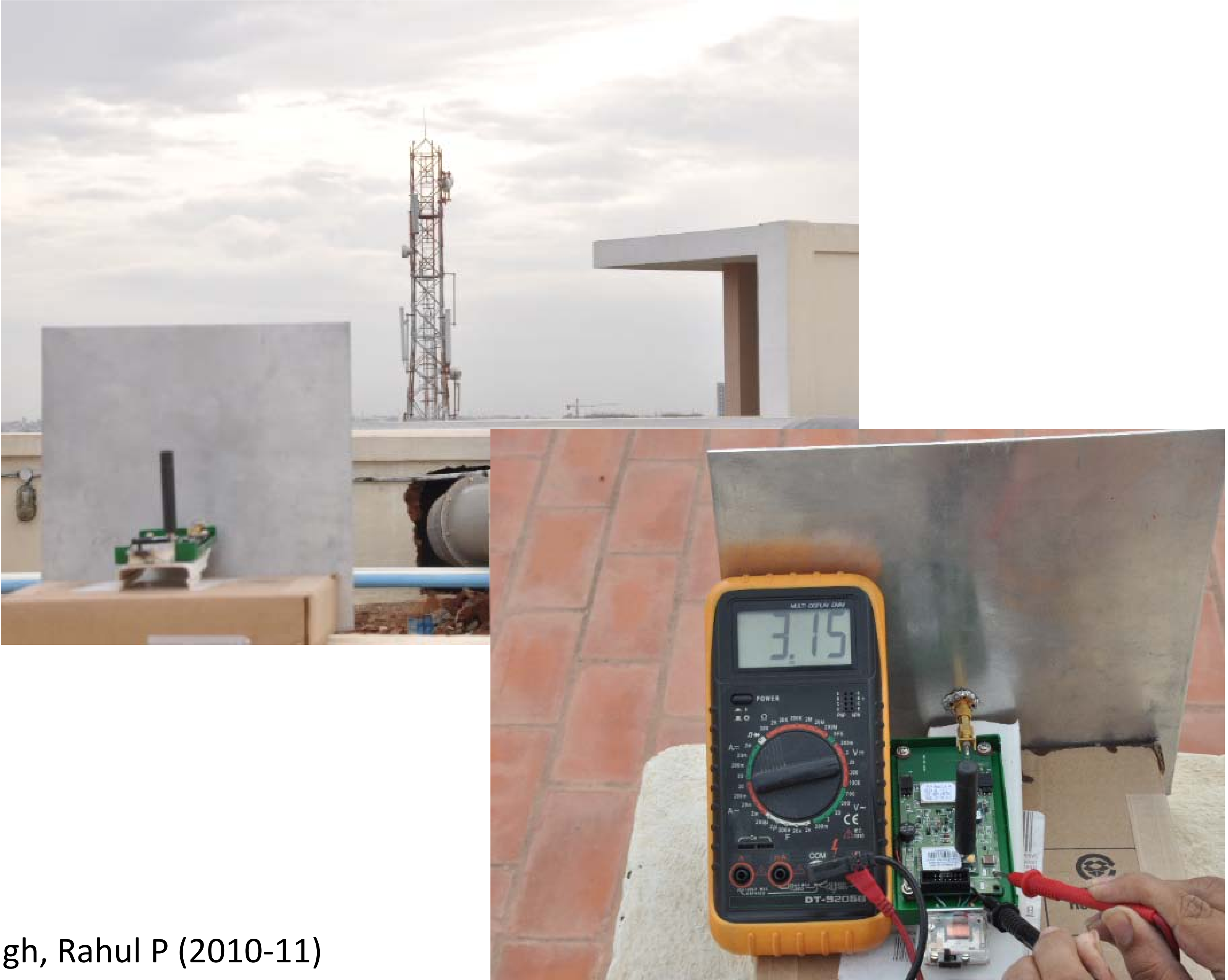
3.15
POWER
DT-9205B

Gaurav Singh, Rahul P (2010-11)

Characterization in Lab

- Using various antennas

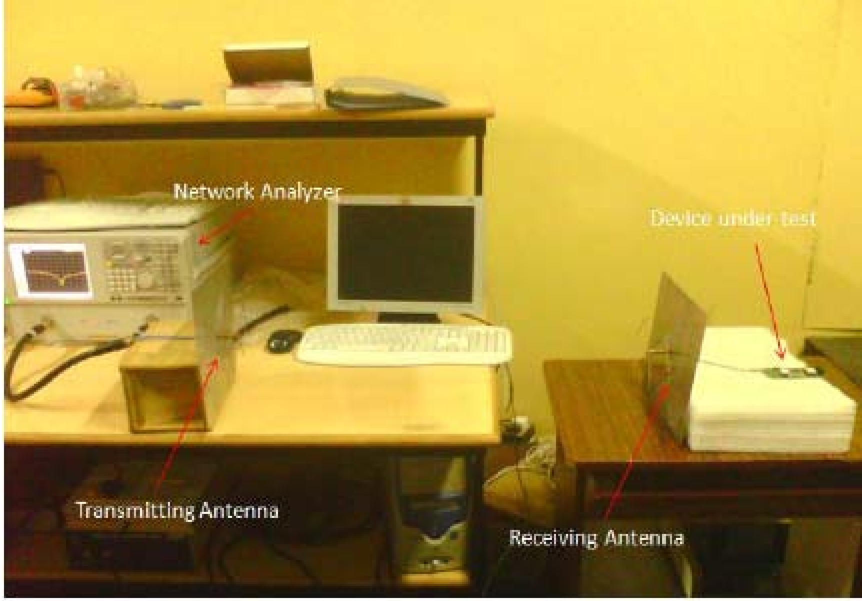
Network Analyzer
Device under test
Transmitting Antenna
Receiving Antenna

Distance from Transmitter [m]	1.5	2	2.5	3
Power received by dipole antenna [dBm]	-20.5	-22.1	-23.9	-25.2
Calculated power density [uW/cm^2]	0.078	0.055	0.035	0.03
Power received by patch antenna [dBm]	-15.1	-16.1	-17.6	-19.2
Transmit interval [mm:ss]	07:26	12:13	25:00	never
Power received by biquad antenna [dBm]	-11.8	-13.2	-14.9	-15.9
Transmit interval [mm:ss]	02:20	03:25	7:10	10:33

G. Singh, R. Ponnaganti, T. V. Prabhakar, and **K.J. Vinoy**, “A tuned rectifier for RF energy harvesting from ambient radiations,” Int. J. Electronics & Communications, vol. 67, no. 7, pp. 564-569, July 2013

Gaurav Singh, Rahul P (2010-11)

Incident power above -18dBm required for operation

2. Universal Energy Harvesting Platform

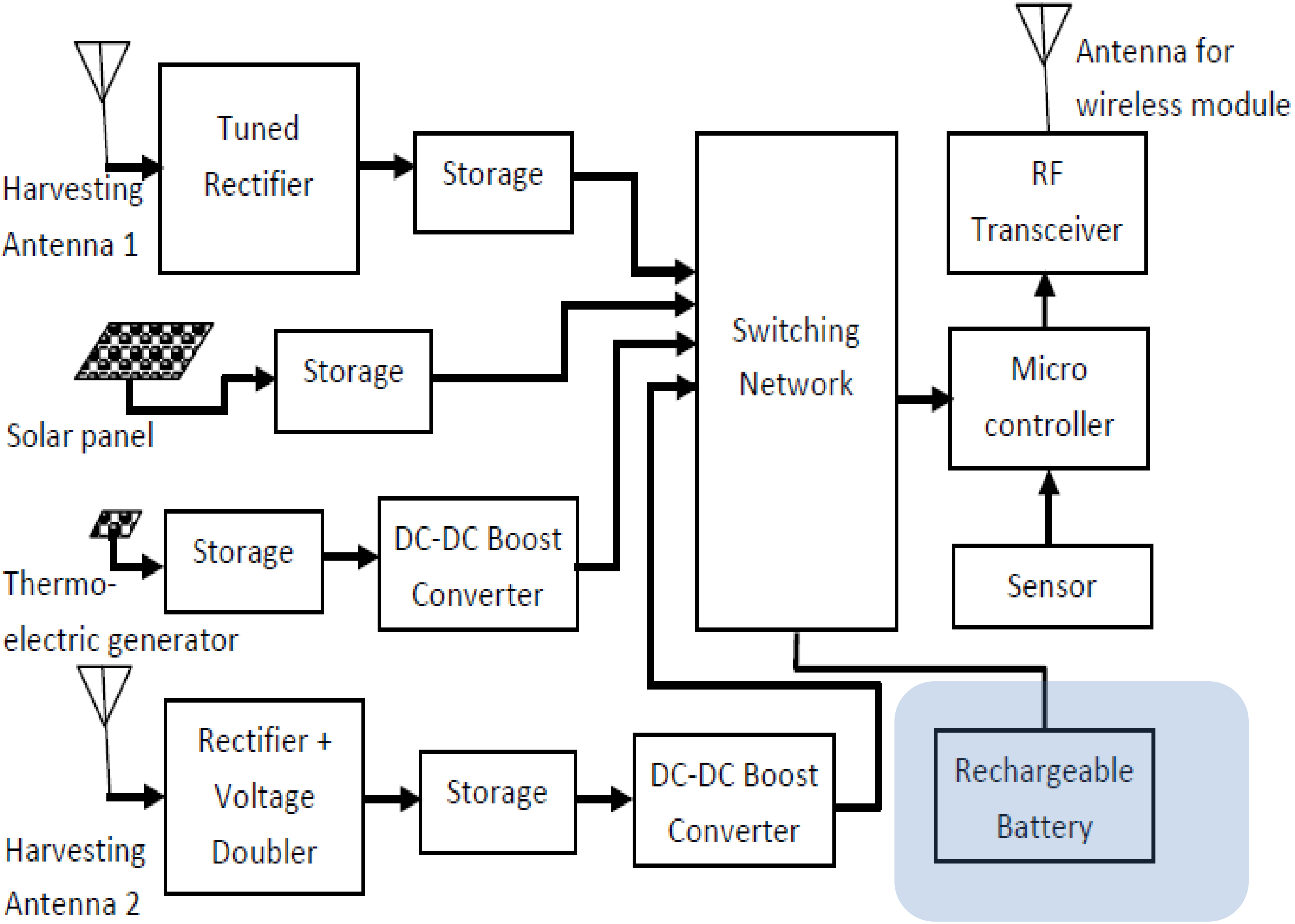

Antenna for wireless module
Harvesting Antenna 1
Tuned Rectifier
Storage
Switching Network
RF Transceiver
Solar panel
Storage
Micro controller
Thermo-electric generator
Storage
DC-DC Boost Converter
Sensor
Harvesting Antenna 2
Rectifier + Voltage Doubler
Storage
DC-DC Boost Converter
Rechargeable Battery

Only a small thin film battery is used

UEHP: Performance with different sources

Solar		**RF**		**TEG**	
Light Intensity (Lux)	Duty Cycle of operation (s)	Power Level (dBm)	Duty Cycle of Operation (s)	Temperature Differential (^oC)	Duty Cycle of Operation (s)
1000	7	0	3	55	9
300	11	-5	6	45	13
200	**20**	**-7**	20	35	240
100	42	-10	50	-	-
-	-	-12	240	-	-

An incident RF power of -7dBm (~0.2mW) performs similarly as at low light PV.

An appropriately oriented 20mW source with a high gain antenna (~10dB) can reach this RF power at a low gain rectenna (eg using PIFA) at 1 m distance.

Power levels within emission guidelines…

K. J. Vinoy, T. V. Prabhakar, A Universal Energy Harvesting Scheme for Operating Low-Power Wireless Sensor Nodes Using Multiple Energy Resources, pp. 453-466, Micro and Smart Devices and Systems, Springer 2014.

Aditya Mitra, Chaithanya (2011-12)

Other Possibilities using Wireless Power Transfer

- Power transfer by radiation is not efficient
- Waveguiding systems can ensure better transmission of power
  - Loss in waveguide is a small fraction of a dB/m (~0.2dB/m)
  - Metal ducts may carry higher order modes with higher losses
  - Extended to conducting ducts, Tunnels, mine shafts etc with some compromise
- Other possibilities
  - Surface wave
  - Focusing of fields

- Empty enclosures with metallic walls
  - Containers, tanks, airplane cabin, trains, etc
  - Other objects in the path may reduce the efficiency!

3: Antenna for RFID sensors

- Work involved design of antenna for RF harvesting sensors
  - These fuel level sensors to be deployed in a fuel tank of aircrft.
  - Optimization of design should focus on efficiency
  - High gain or directivity is not required.

- EH platform to be used with RFID sensors deployed inside fuel tank

- Requirements/Assumptions:
  - Incident energy is of random polarity and direction.
  - Operating frequency is 902MHz-928MHz.
  - Antenna must operate in air (relative permittivity = 1) and fluid (relative permittivity = 2.1)
  - Dimensions of planar antenna board:
    - Target dimensions: 3 in. x 2 in.
    - Maximum dimensions: 6 in. x 4 in.

Antenna Design dimensions

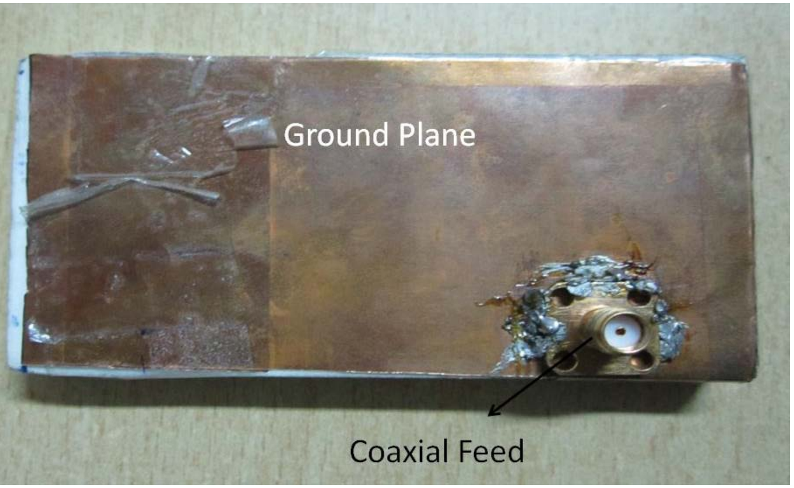
Ground Plane
Coaxial Feed

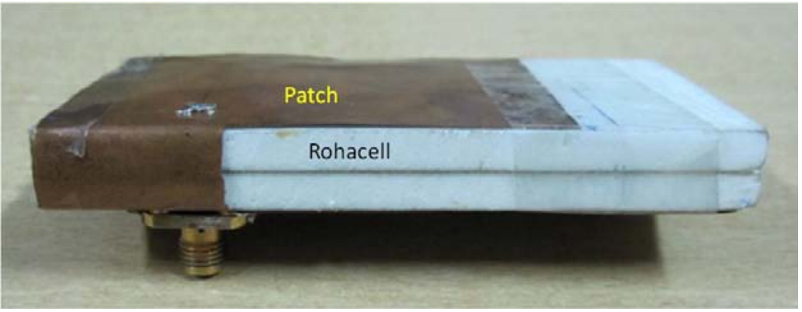
Patch
Rohacell

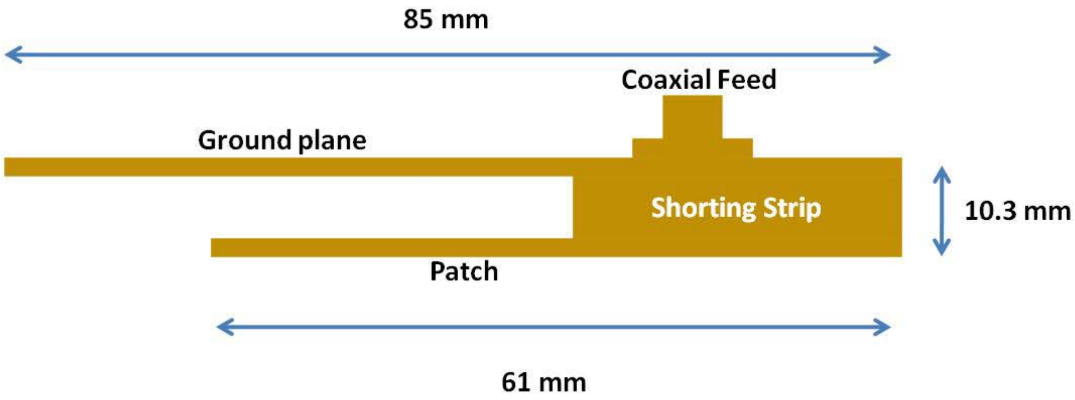
85 mm
Coaxial Feed
Ground plane
Shorting Strip
10.3 mm
Patch
61 mm

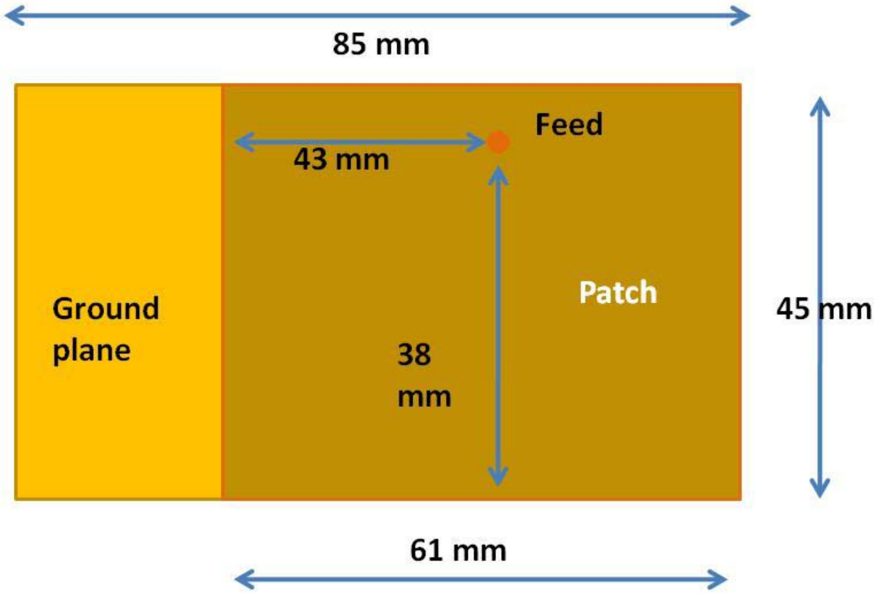
85 mm
Feed
43 mm
Ground plane
Patch
38 mm
45 mm
61 mm

Vivekanand M, Harikiran M

Measurements at Boeing (Nov 2013)

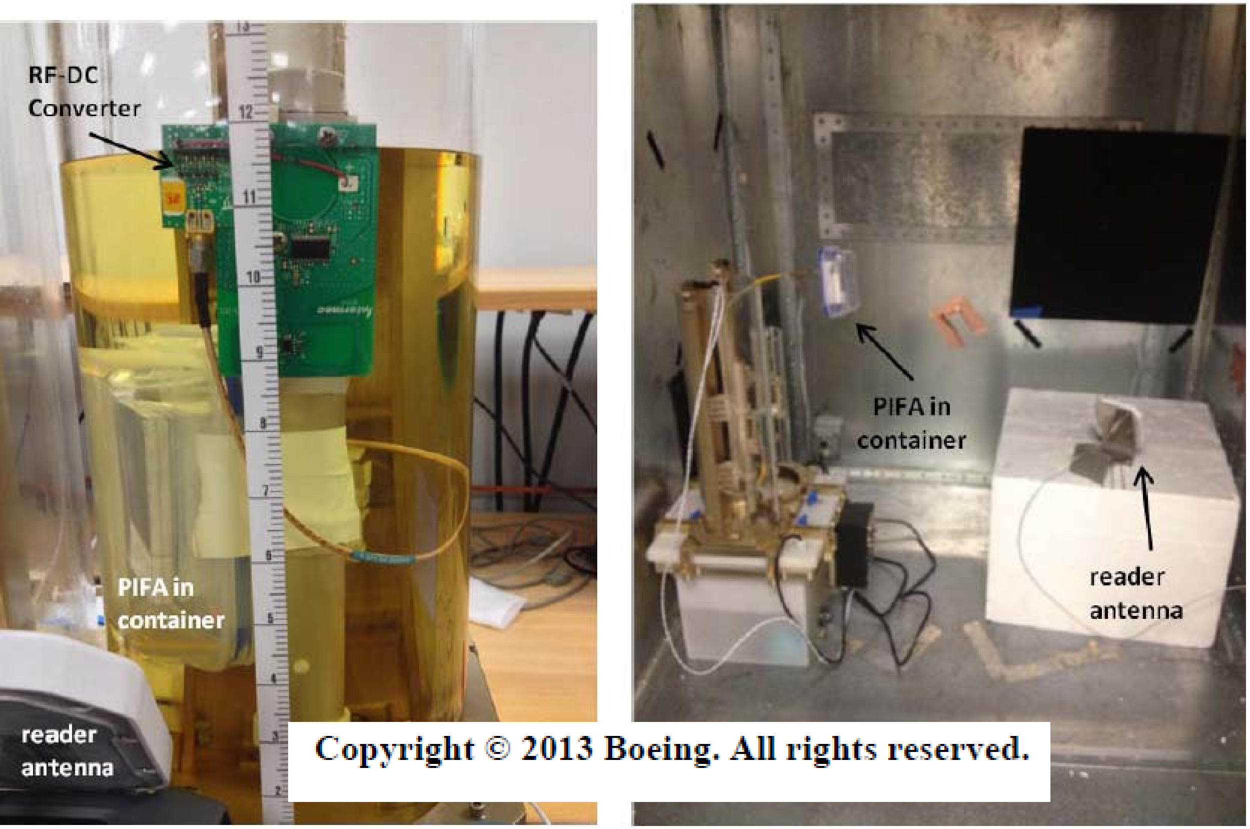
RF-DC
Converter
PIFA in
container
reader
antenna
PIFA in
container
reader
antenna

Copyright © 2013 Boeing. All rights reserved.

After Integrating with Sensor and RFID board;

Measured in a room and reverberation chamber

Resolution of fluid height measurement to within 0.25”.
1W maximum transmit power.
Uses a modified reader protocol.

A. Robb, J. Bommer, R. Martinez, J. Harrigan, S. Ramamurthy , H. Muniganti, V. Mannangi, and KJ Vinoy, “Wireless Aircraft Fuel Quantity Indication System,” 2014 IEEE Sensors Applications Symposium - , Feb 18-20, 2014, Queenstown, Newzealand.

4. RFID Integrated with Sensor

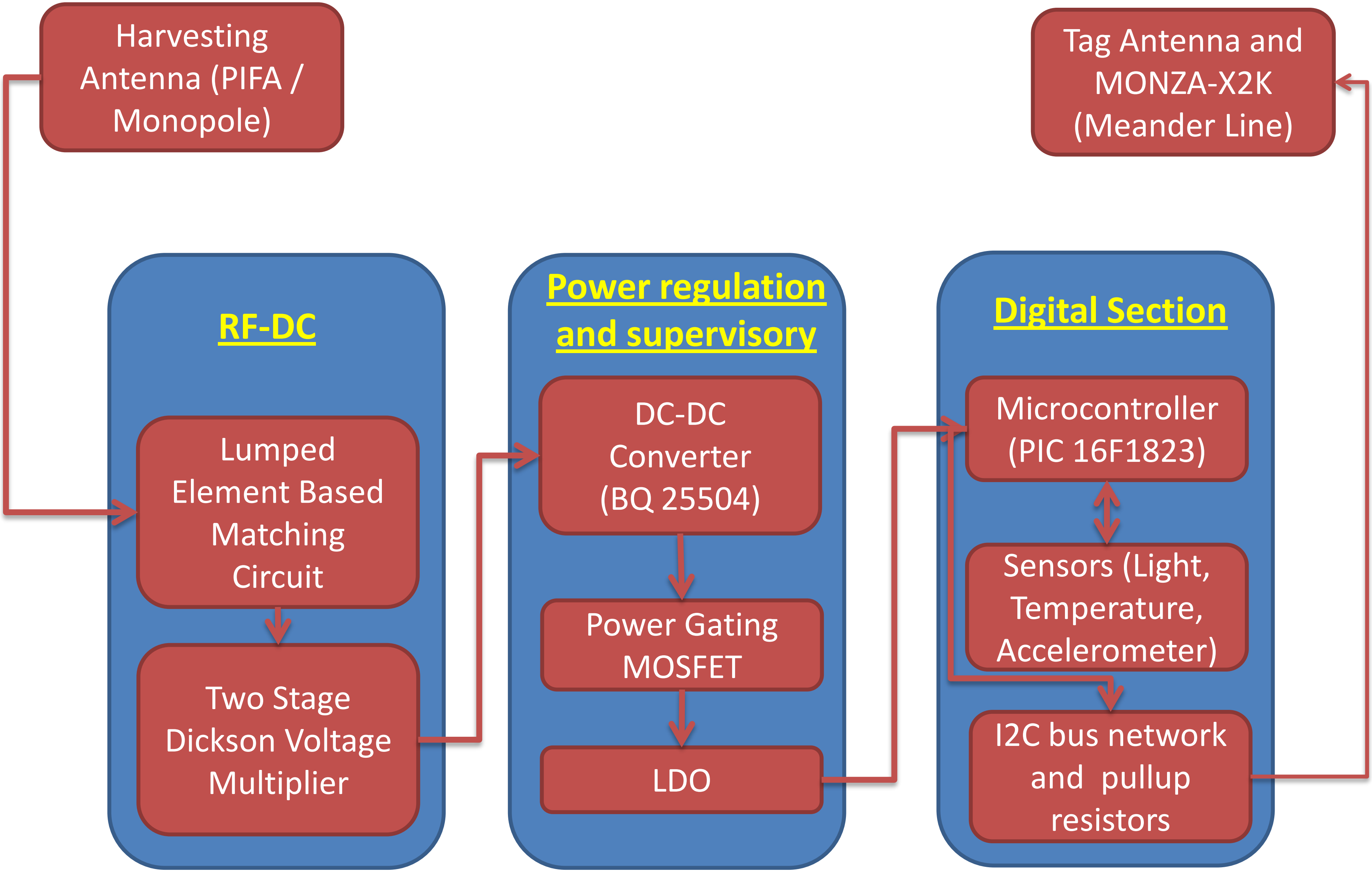

Harvesting Antenna (PIFA / Monopole)

Tag Antenna and MONZA-X2K (Meander Line)

RF-DC

Lumped Element Based Matching Circuit

Two Stage Dickson Voltage Multiplier

Power regulation and supervisory

DC-DC Converter (BQ 25504)

Power Gating MOSFET

LDO

Digital Section

Microcontroller (PIC 16F1823)

Sensors (Light, Temperature, Accelerometer)

I2C bus network and pullup resistors

Parts of Fabricated System

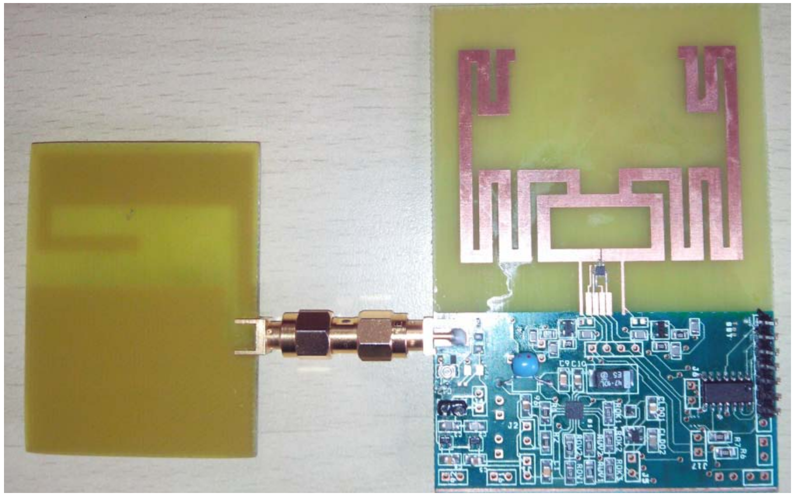

PIFA CONNECTED SENSING TAG

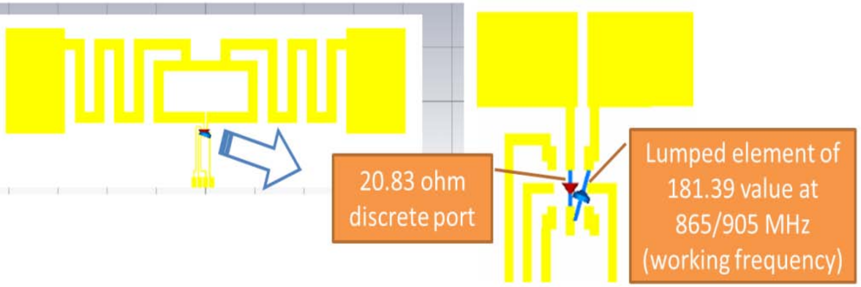
20.83 ohm discrete port
Lumped element of 181.39 value at 865/905 MHz (working frequency)

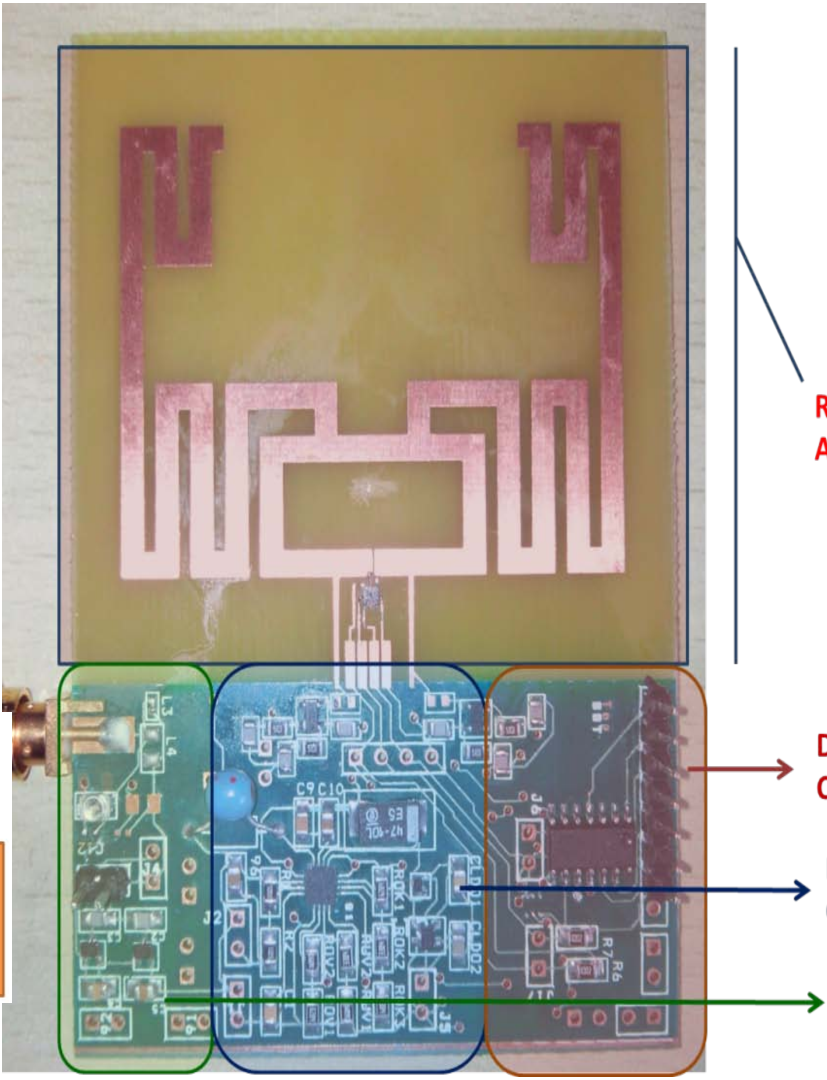
RFID Tag Antenna
Data processing Circuitry
DC-DC Boost Converter
RF-DC Conversion

Sandeep Rana 2014-15

Sandeep Rana, TV Prabhakar, KJ Vinoy, An Efficient Architecture for Battery-less Terminals for Internet of Things, Applied Computational Electromagnetic Conference, Guwahati, Dec 28-21, 2015

Characterization of Performance

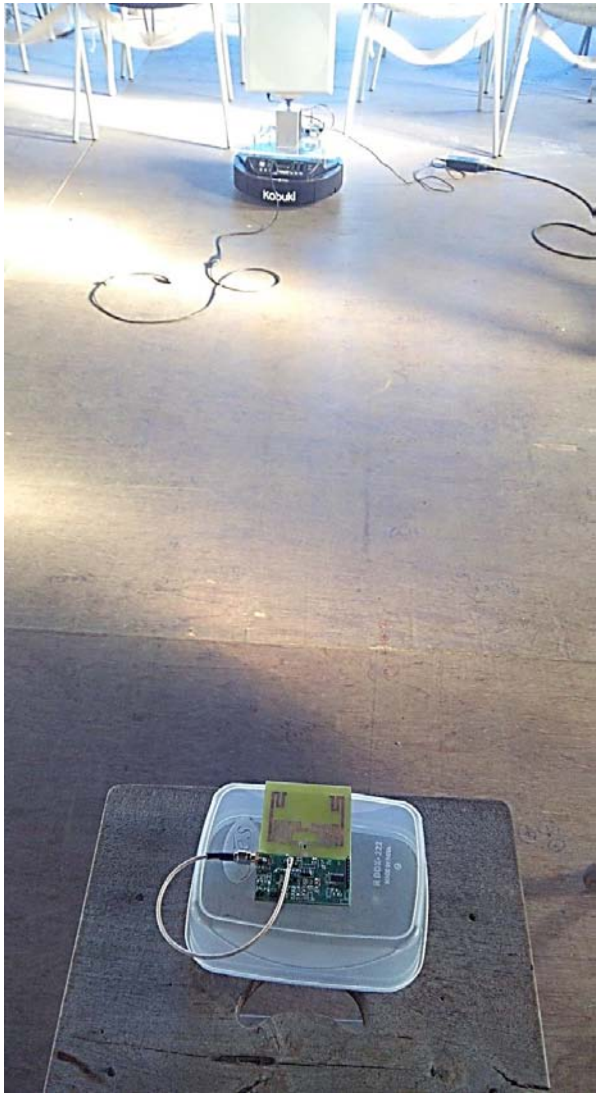

Source	Power
RFID Reader	30 dbm
Circularly polarized antenna	8 dbi
Polarization loss	3 dbi
Monopole Antenna	5 dbi
PIFA antenna	1 dbi
Meander Antenna	0.4 dbi

Tag Antenna	EIRP (dbm) + Gr	Rg Expected (-10 dbm) and 50 % overall efficiency	Range Achieved
Monopole	40	7.5 mtr	7 mtr
PIFA	36	5 mtr	5.5 mtr
Meander Line	35.4	4.5 mtr	4.5 mtr

$\lambda = 34.5\ cm$ $\quad$ $Prx = EIRP * Gr * (\frac{\lambda}{4*\pi*r})^2$

Efficiency worked out for -10 dbm
RF-DC efficiency – 20 % and DC-DC efficiency – 80%
Overall efficiency – 16%

Sandeep Rana 2014-15

5. Harvesting at 2.4GHz

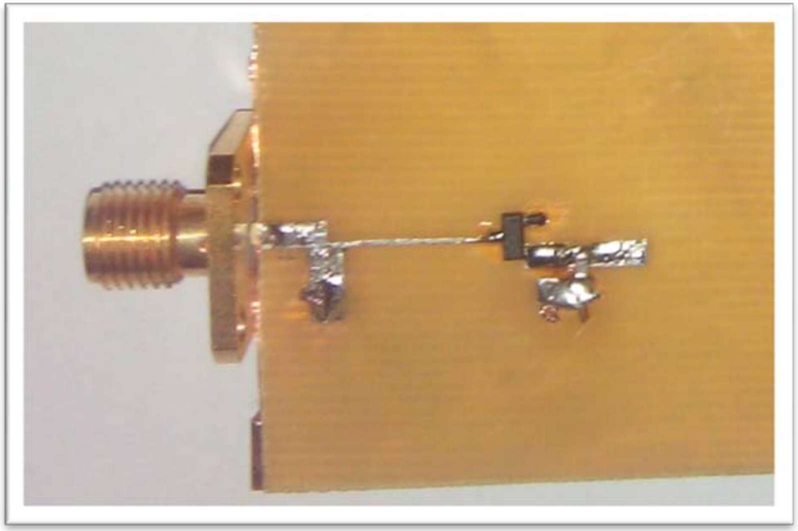

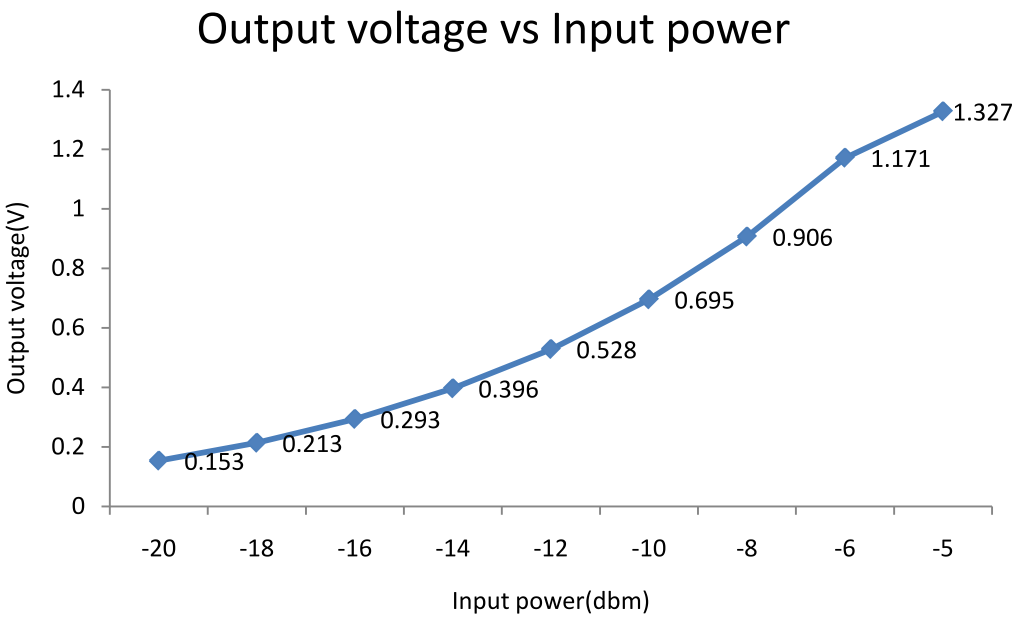

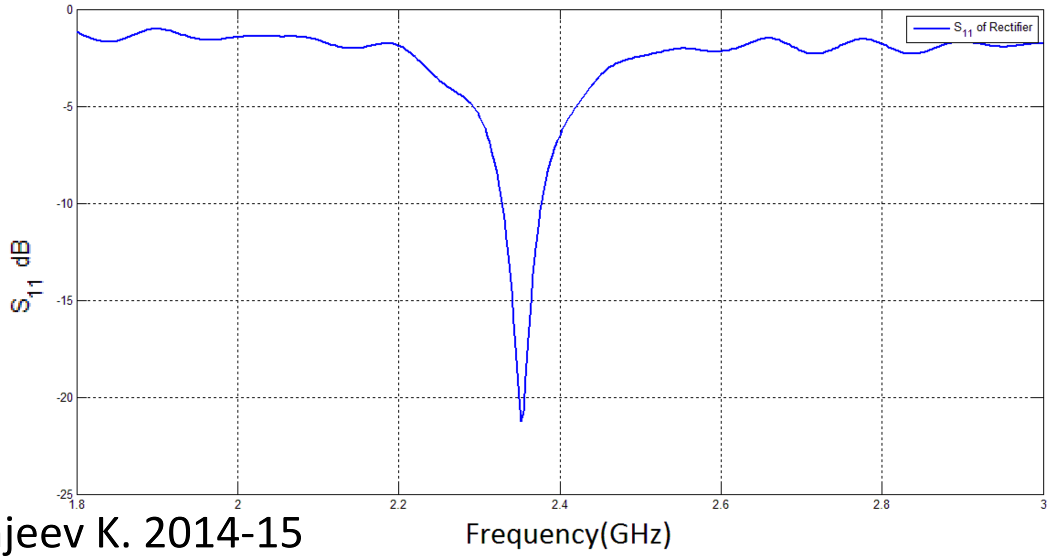

Sanjeev K. 2014-15

RICOH imagine. change.

Comparison of Efficiencies

Schottky diode

	900MHz	2400MHz
-15dbm	Efficiency=47% Output voltage=0.29V Load resistor=6K	Efficiency =17% Output voltage=0.2V Load resistor=6K
-20dbm	Efficiency=31% Output voltage=0.15V Load resistor=6K	Efficiency=5% Output voltage=0.1V (0.153V unloaded) Load resistor=6K
	Used HSMS 2852	Used HSMS 2862

Diode connected MOS with high Q matching

	900MHz	2400MHz
-14dbm	Efficiency=6.2% Output voltage=1.1V Load resistor=500K	Efficiency=2% Output voltage=0.632V Load resistor=500K
-20dbm	Efficiency=1.8% Output voltage=0.3V Load resistor=500K	Efficiency=0.2% Output voltage=0.118V Load resistor=500K

Zero V_{TH} CMOS

	900MHz	2400MHz
-15dbm	Efficiency=4.6% Output voltage=0.86V Load resistor=500K	Efficiency=3.79% Output voltage=0.774V Load resistor=500K
-25dbm	Efficiency=2.4% Output voltage=0.198V Load resistor=500K	Efficiency=1.7% Output voltage=0.165V Load resistor=500K

← Power

← Technologies

Frequencies →

Cross-coupled Rectifiers for Low Power

- CMoS integration requires diodes using MoSFETs.
- Simple diode connected configurations are not effective at low power/voltage levels
- In Cross Coupled Rectifiers
  - Biasing of MOSFETs by charge stored in capacitors. This is a way of threshold compensation.
  - Low ON resistance due to high overdrive voltage.
  - In both cycles of input, output capacitor is charged. Although DCP uses both cycles, only alternate cycles charges the output capacitor and the other cycle charges the input capacitor.

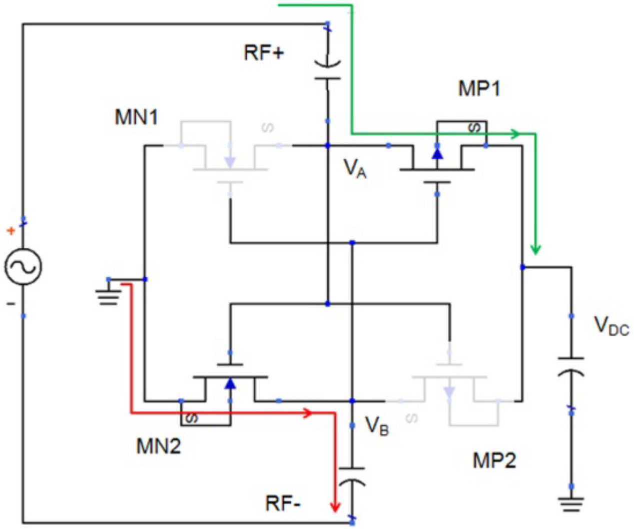

DC-DC converter

- Low loss switched capacitor DC-DC converter:

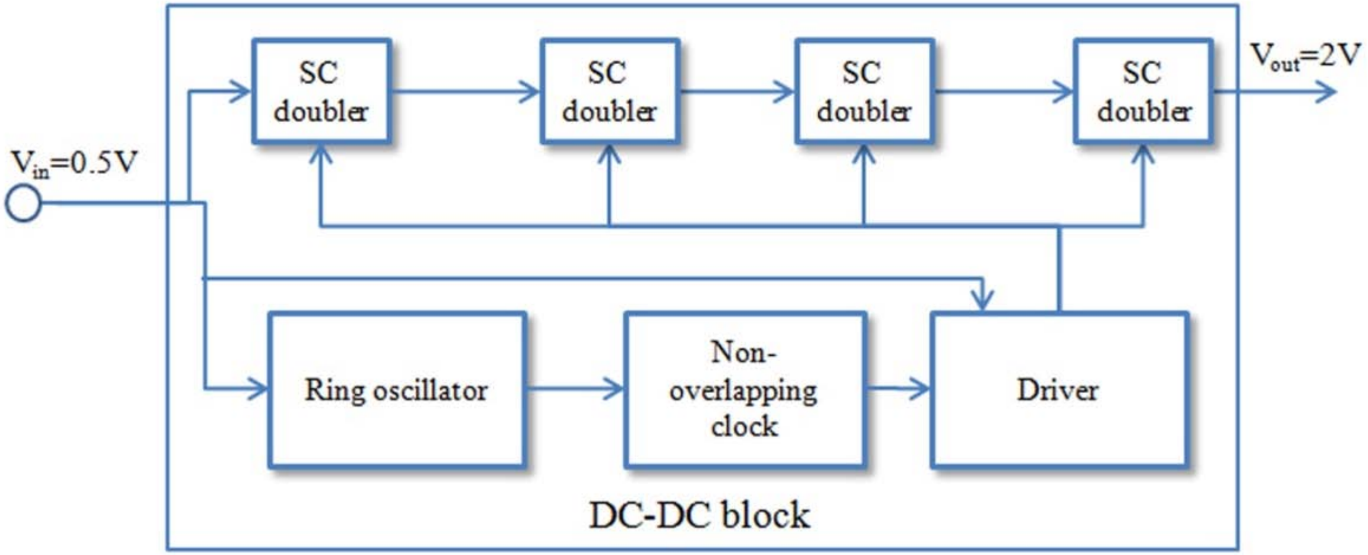
V_in=0.5V
SC doubler
SC doubler
SC doubler
SC doubler
V_out=2V
Ring oscillator
Non-overlapping clock
Driver
DC-DC block

Full system block diagram

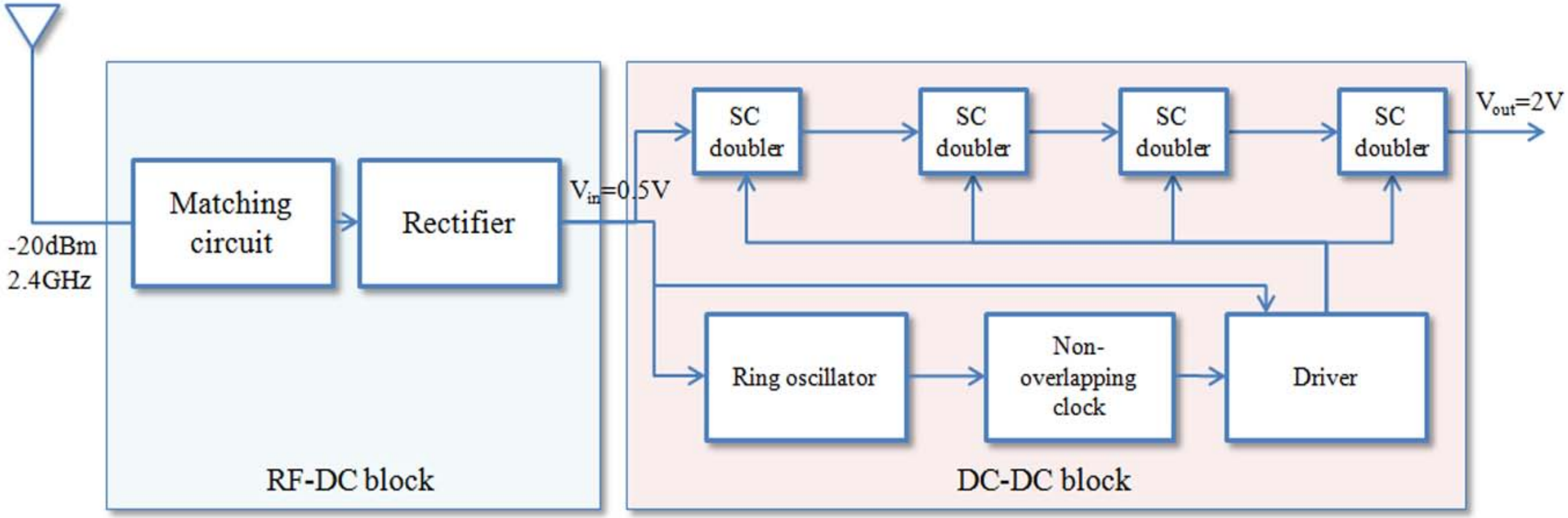
-20dBm
2.4GHz
Matching circuit
Rectifier
V_{in}=0.5V
RF-DC block
SC doubler
SC doubler
SC doubler
SC doubler
V_{out}=2V
Ring oscillator
Non-overlapping clock
Driver
DC-DC block

1. Output capacitor of RF-DC supplies DC-DC
2. Enable generator logic constructed using back to back inverters
3. 5 MOSFETs added to limit supply voltage to ring oscillator

RICOH
imagine. change.

Sanjeev K, Manjunath M, TV Prabhakar, KJ Vinoy, Some Practical Considerations of RF to DC Converter using Low Vth CMOS Rectifier, Applied Computational Electromagnetic Conference, Guwahati, Dec 28-21, 2015

Full system simulations

- Output capacitor of RF-DC loaded heavily when clocks transition, so ripples exist in RF-DC output.
- Below 0.5V at clock transitions, above 0.5V between clock transitions
- Time step is 8ps for RF-DC simulation and DC-DC has to run for hundreds of µs or few ms, so simulations times are large.

Output voltage=2V across a load of 1.6MΩ, which gives

$$Efficiency = \frac{2^2/1.6\times10^6}{10^{-5}} = 25\%$$

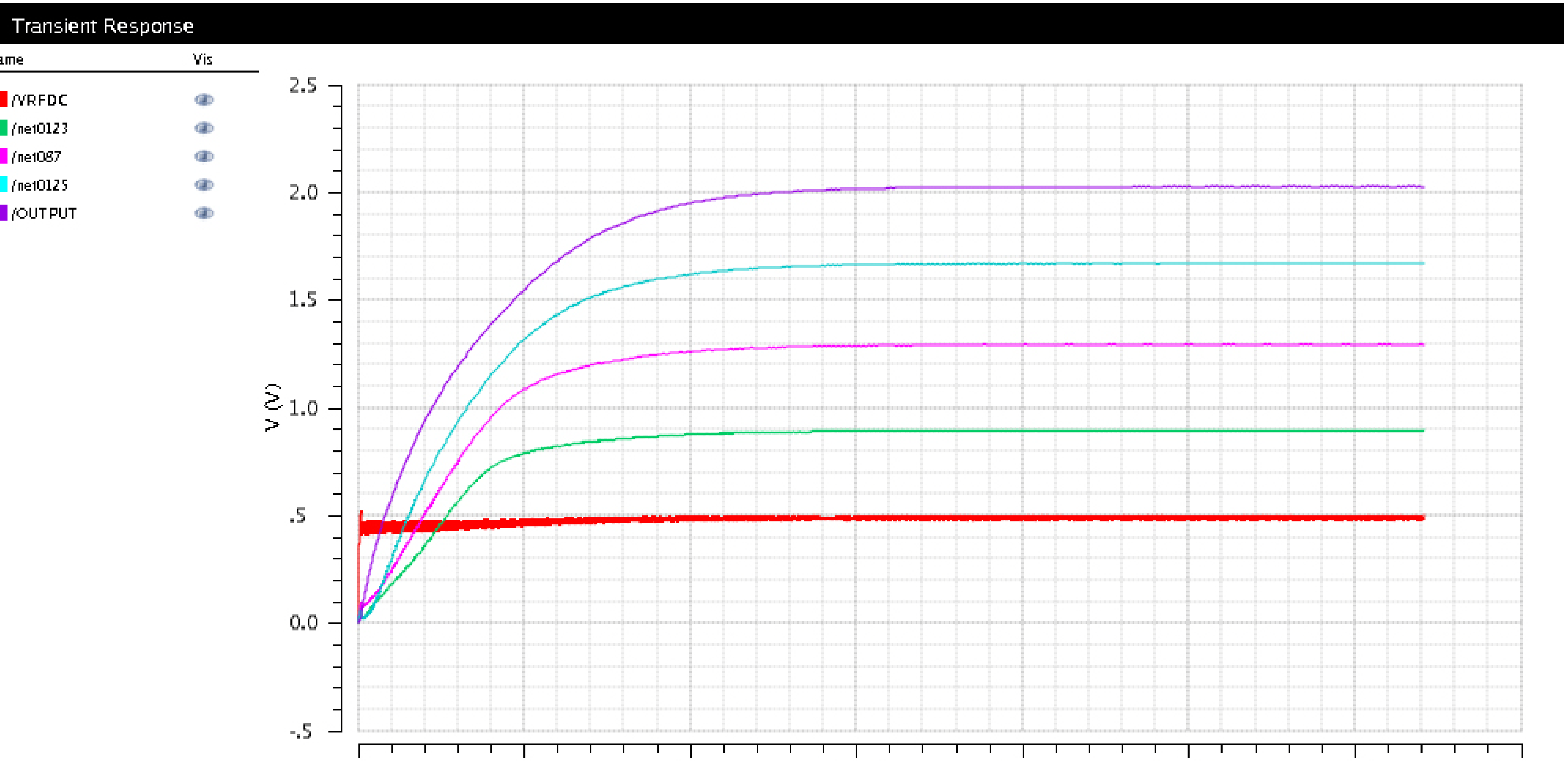

Summary with IC Design

- Low Vth NMOS based DCP gives 42.3% efficiency.
- FGCCR gives 55% efficiency.
- The overall system efficiency is 25%.
- Higher than efficiency reported in literature for RF-DC converter operating at -20dBm, 2.4GHz in 130nm technology.

Reference	This work	[5]	[7]	[6]
Power level	-20dBm	-25.7dBm	-22.6dB	-20dBm
Frequency	2.4GHz	2.45GHz	906MHz	2.4GHz
Efficiency	55%(simulated)	37%(measured)	10%(measured)	36%(simulated)
Rectifier	FGCCR in UMC 130nm CMOS	DCP in 0.5µm Silicon on Sapphire	DCP with floating gate transistors in 0.25µm CMOS	FGCCR in 130nm CMOS

6. ASIC Design for IOT

- Working on a 3-chip architecture
  - Our chip to enable sensing, and control functions
  - Communication using an external Monza chip
- Fabricated chip using commercial services!!

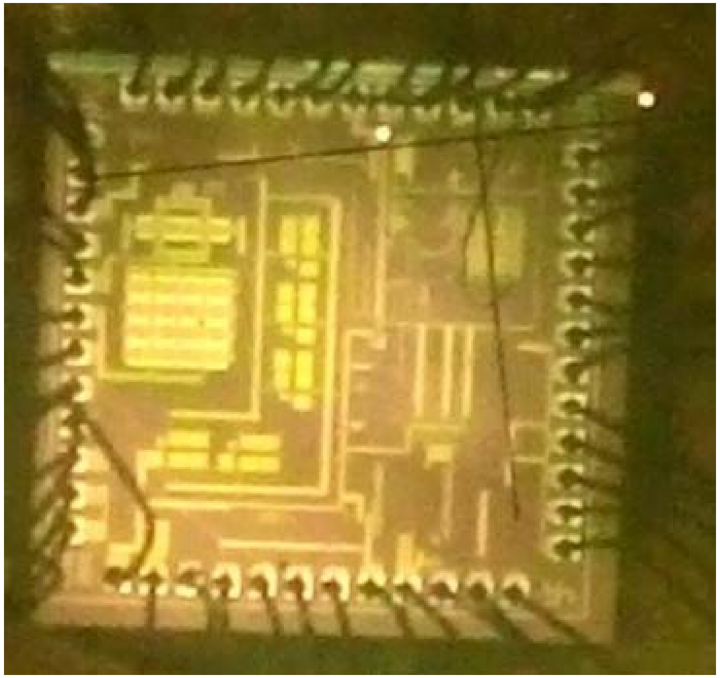

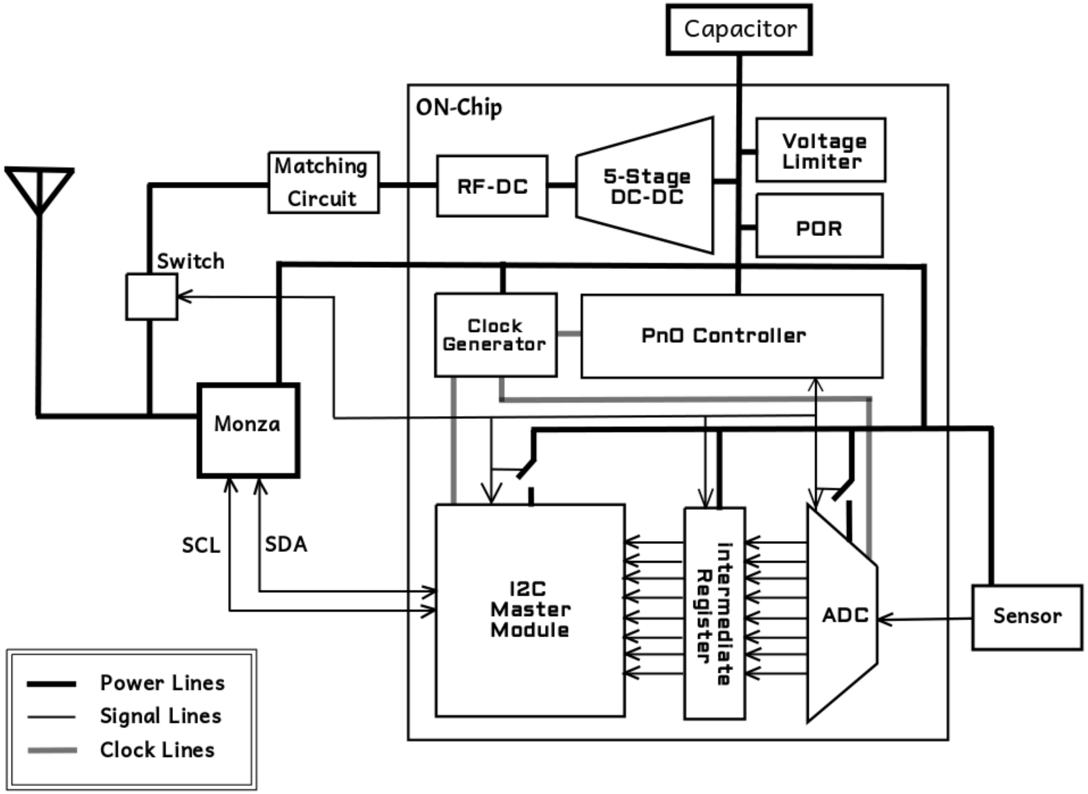
Capacitor
ON-Chip
Matching Circuit
RF-DC
5-Stage DC-DC
Voltage Limiter
POR
Switch
Clock Generator
PnO Controller
Monza
SCL
SDA
I2C Master Module
Intermediate Register
ADC
Sensor
Power Lines
Signal Lines
Clock Lines

Bharat Hegde & Syed Younis 2015-16

Battery-less Sensor node for BLE

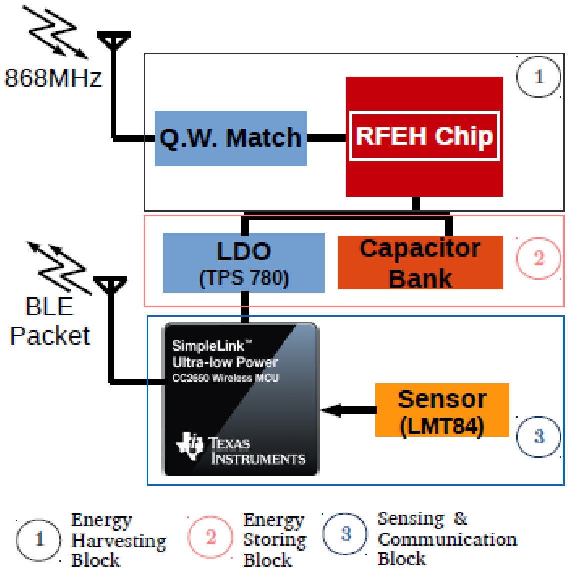
868MHz
Q.W. Match
RFEH Chip
1
LDO
(TPS 780)
Capacitor Bank
2
BLE Packet
SimpleLink™ Ultra-low Power CC2650 Wireless MCU
Texas Instruments
Sensor
(LMT84)
3
1 Energy Harvesting Block
2 Energy Storing Block
3 Sensing & Communication Block

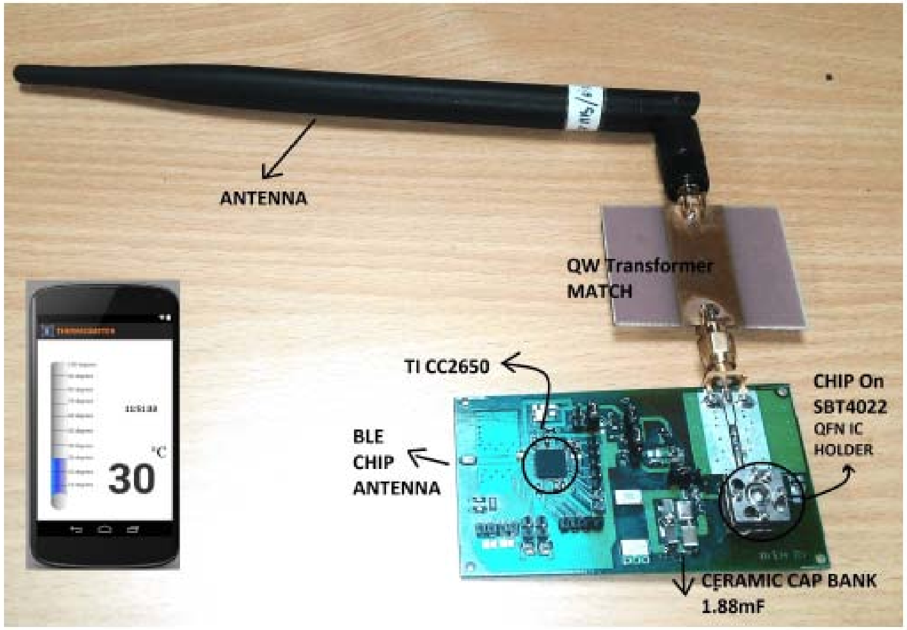
ANTENNA
QW Transformer MATCH
TI CC2650
BLE CHIP ANTENNA
CHIP On SBT4022 QFN IC HOLDER
CERAMIC CAP BANK 1.88mF
30
°C

Distance from Reader (m)	Input Power (dBm)	Cold Start Time (min)	Packet Time (min)	Efficiency (%)
3	-2	15	1.75	2.2
4	-5	35	7	1.7
5	-8	120	32	1

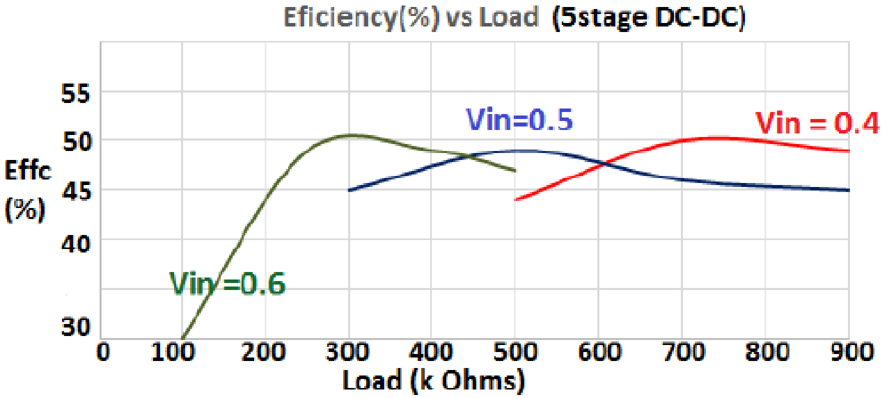

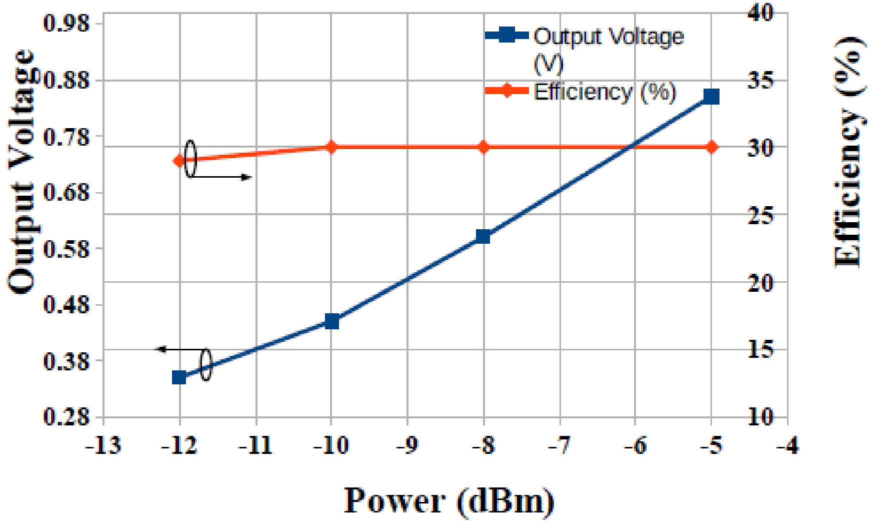

Bharat Hegde & Syed Younis 2015-16

Summary

- Most low power wireless terminals operate intermittently
- These require anywhere 50uW to about 10mW for their operation.
  - Batteries limited: cost, size, stored energy
  - Solar: not dependable through

- WPT and RF EH can enable wide use of IoT
  - Main challenges in the design is the low incident energy/power/voltage
  - High Quality factor components may help

- Several fabricated examples discussed here: All can transmit data to an aggregator wirelessly
  - Different standards implemented.

Acknowledgements

- Dr. TV Prabhakar, DESE, IISc
  - Gaurav Singh
  - Rahul P
  - Chaithanya C
  - Aditya Mitra
  - Prashuk Jain
  - Prashanth Raja
  - Nirmal John
  - Nithin Jose
  - Syed Younis
  - Bharat Hegde
  - Niharika Thakuria

- Prof Bharadwaj Amrutur
  - Uday S
  - NS Sreeram

- Others
  - Vivekanand M
  - Harikiran M
  - Manjunath M
  - Sanjeev K
  - Sandeep Rana

- Partial Funding From
  - ANRC (Boeing, Wipro, HCL)
  - Ricoh Research, India

ANRC

RICOH
imagine. change.

Thank YOU

Take the world on line
Take control of the world
Let the things talk to each other
Let things become intelligent

Free Energy From Air Circuit

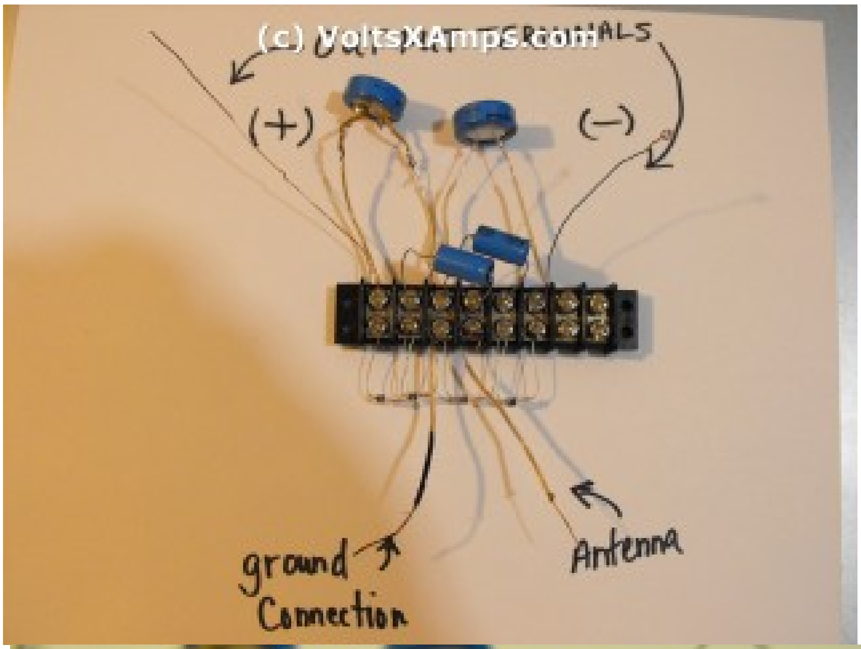
(c) VoltsXAmps.com
(+)
(−)
ground Connection
Antenna

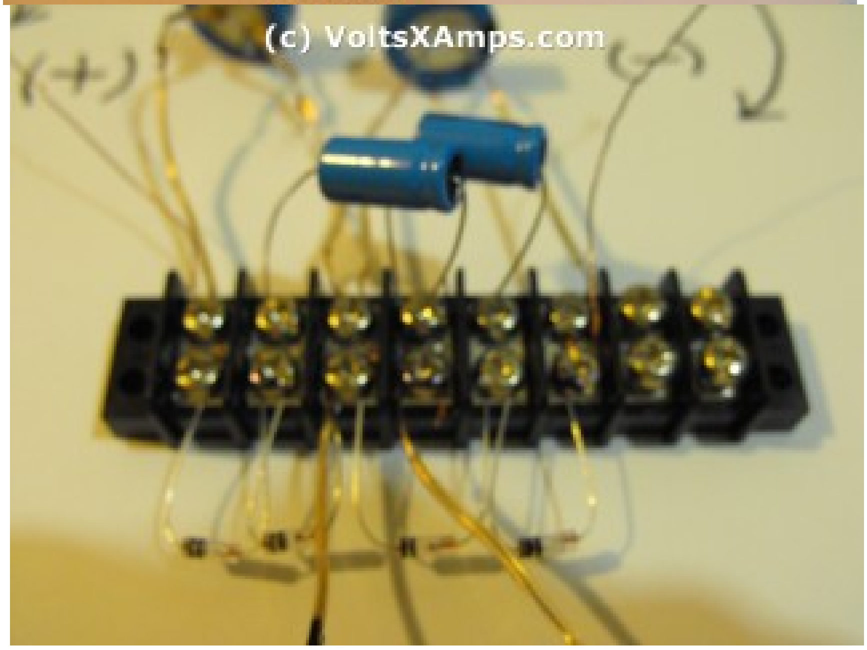
(c) VoltsXAmps.com
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Last year I found a United States Patent that showed how to collect ambient energy right from the air. I finally decided to build this curcuit just to see what it could do.

[protected]

The above images are from the circuit I built. Most of the text and info comes direct from the US4628299filed by Joseph Tate. US4628299

The Amazing Ambient Power Module

Parts List for the APM-2

Four 1N34 germanium diodes (Radio shack #276-1123) ~ Figure 1, X1, X2, X3, & X4
Two 0.2 mfd 50 V ceramic capacitors ~ Figure 1, C1 & C2
Two 100 mfd 50V electrolytic capacitors (Radio Shack #272-1016) ~ Figure 1, C3 & C4
Copper wire for antenna & ground connections

Introduction

The Ambient Power Module (APM) is a simple electronic circuit which, when connected to antenna and earth ground, will deliver low voltage up to several milliwatts. The amount of voltage and power will be determined by local radio noise levels and antenna dimensions

Generally a long wire antenna about 100' long and elevated in a horizontal position about 30' above ground works best. A longer antenna may be required in some locations. Any type copper wire, insulated or not, may be used for the antenna. More details about the antenna and ground will be discussed further on.

The actual circuit consists of two oppositely polarized voltage doublers (Figure 1). The DC output of each doubler is connected in series with the other to maximize voltage without using transformers. Single voltage doublers were often found in older TV sets for converting 120 VAC to 240 VDC. In the TV circuit the operating frequency is 60 Hz.

FIG. 1

APM-2 SCHEMATIC DIAGRAM

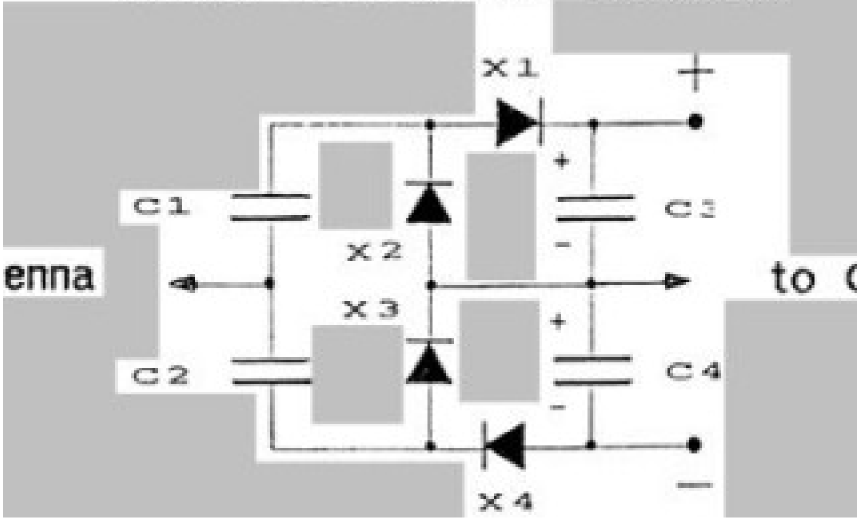

The APM operates at radio frequencies, receiving most of its power from below 1 MHz. The basic circuit may be combined with a variety of voltage regulation schemes, some of which are shown in Figure 2. Using the APM-2 to charge small NiCad batteries provides effective voltage regulation as well as convenient electrical storage. This is accomplished by connecting the APM-2 as shown in Figure 2B.

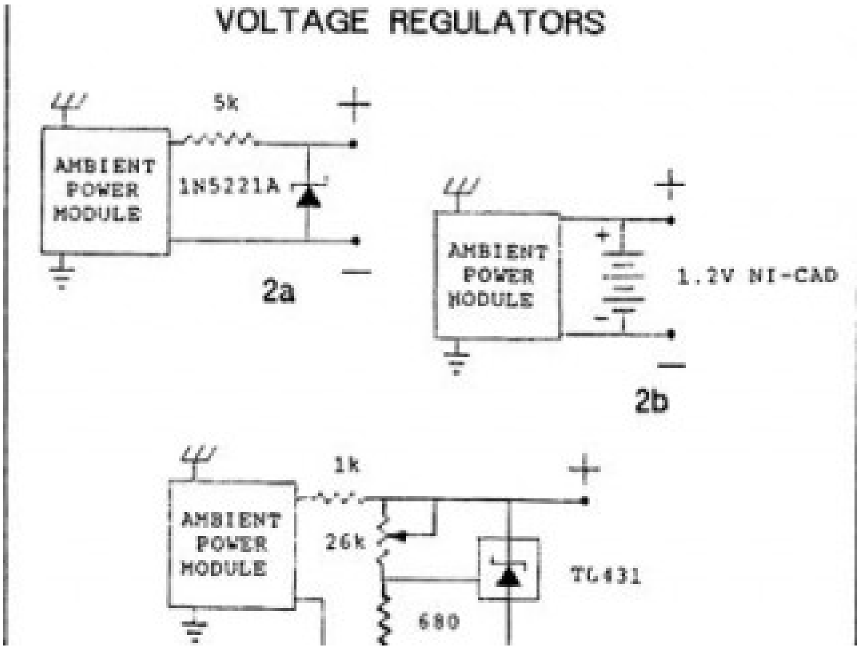

Charging lead acid batteries is not practical because their internal leakage is too high for the APM to keep up with. Similarly, this system will not provide enough power for incandescent lights except in areas of very high radio noise.

It can be used to power small electronic devices with CMOS circuitry, like clocks and calculators. Smoke alarms and low voltage LEDs also can be powered by the APM.

Figure 3 is a characteristic APM power curve measured using various loads from 0-19 kOhm. This unit was operating from a 100' horizontal wire about 25' high in Sausalito CA. As can be seen from the plot, power drops rapidly as the load resistance decrease from 2 kOhm. This means that low voltage, high impedance devices, like digital clocks, calculators and smoke alarms are the most likely applications for this power source. Some applications are shown in Figures 4 through 7.

FIG. 3 AMP Power Envelope

Volts vs. Resistance

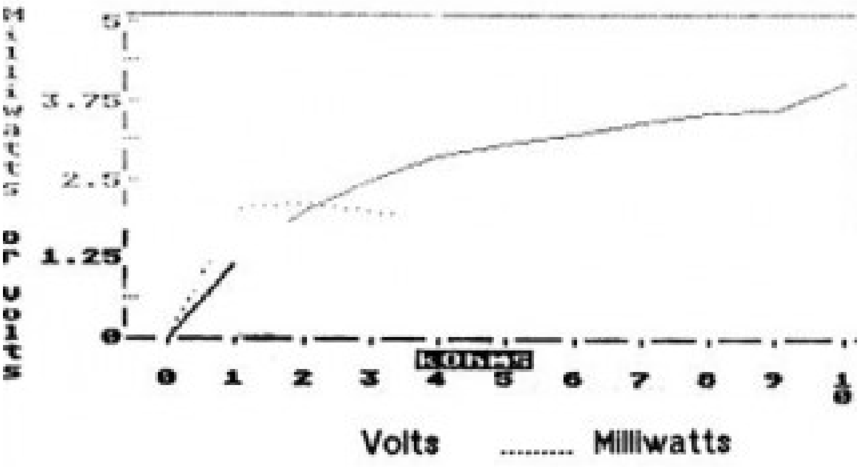

Figure 4 ~ A digital clock is shown powered by the APM-2. The 1.5 volt clock draws 28 microamps. Its position on the power envelope curve would be off the scale to the right and almost on the bottom line, dissipating only 42 microwatts.

FIG. 4 Clock powered by APM

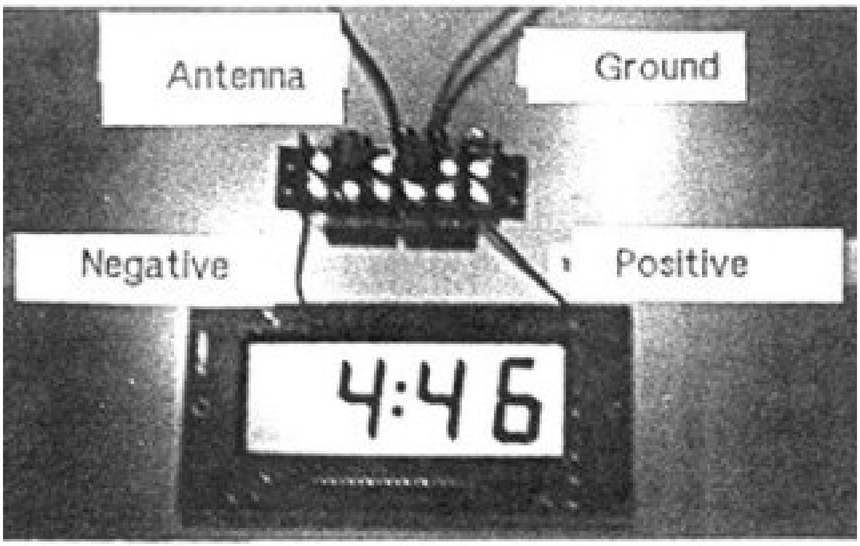

FIG. 5 APM charging a battery

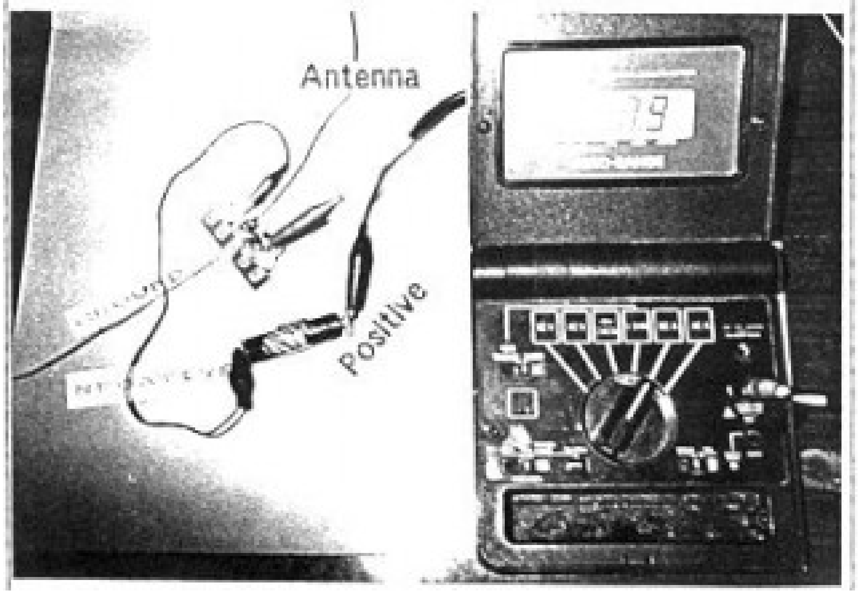

Figure 6 shows a clock which has the APM-2 built into it so it is only necessary to connect the antenna and ground wires directly to the clock. The antenna for this clock, which is a low frequency marine type, is shown in Figure 7.These antenna are expensive, not generally available, and usually don't work any better than the long wire mentioned above. But it may be necessary to use them in urban areas where space is limited and radio noise is high.

FIG. 6

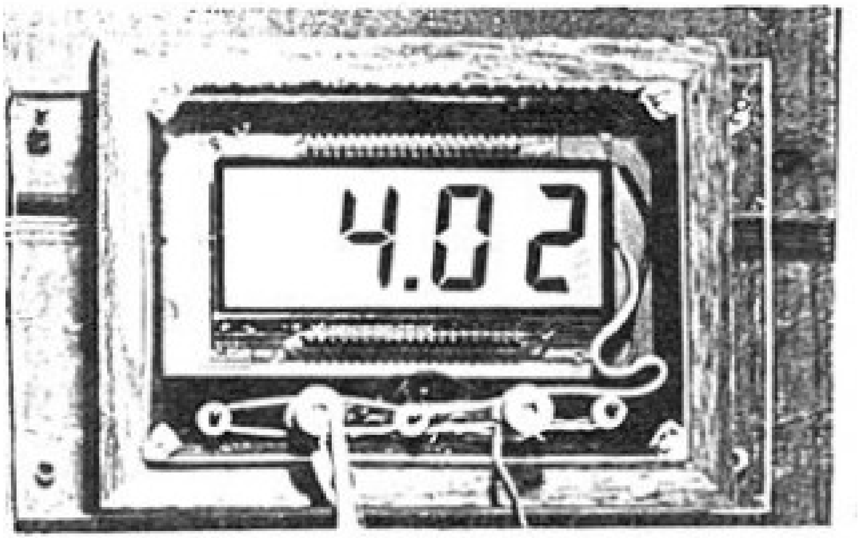

Building the Module

The builder has a choice of wiring techniques which may be used to construct the module. It may be hand wired onto a terminal strip, laid out on a bread board, experiment board, or printed circuit. Figure 8 shows some of the different ways of constructing the APM-2.

Figure 8A is constructed on a screw strip terminal; Figure 8B is constructed on a perforated breadboard; Figure 8C is built on a standard experiment board; Figures 8D, 8E, and 8F are all printed circuits; Figure 8F is made up on a solder strip terminal.

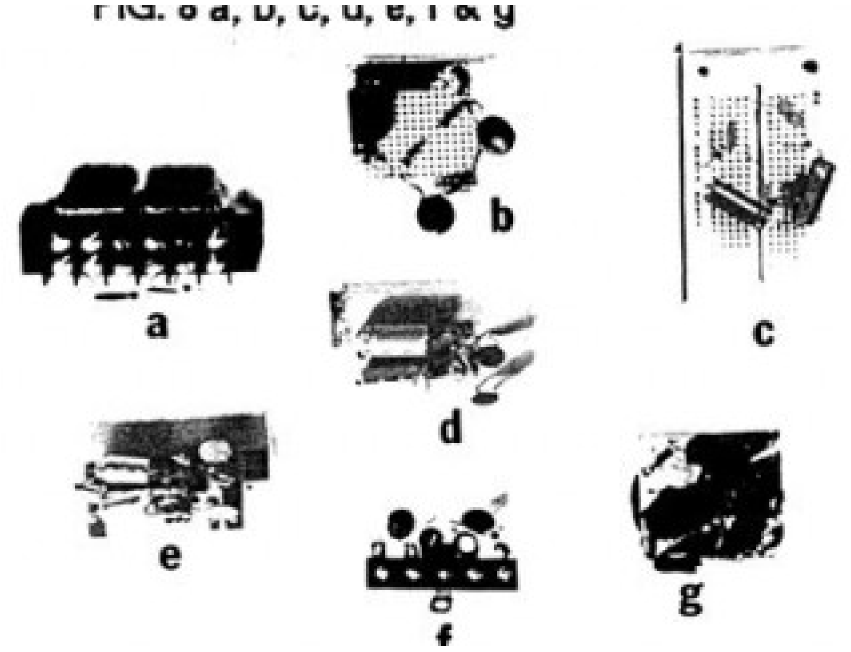

If you wish to make only one or two units, hand wiring will be most practical, either on a terminal strip or breadboard. Assembly on the terminal strip (Figure 8A) can be done easily and without soldering. It is important to get the polarity correct on the electrolytic capacitor. The arrow printed on the side of the capacitor points to negative.

Figure 9 is a closer view of the terminal strip with an illustration of the components and how they are connected.

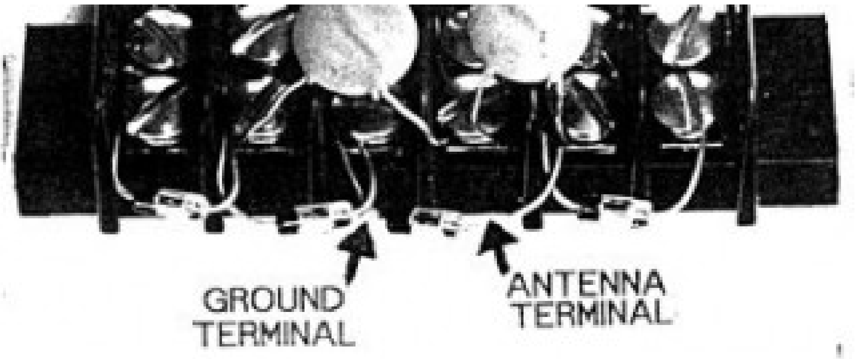

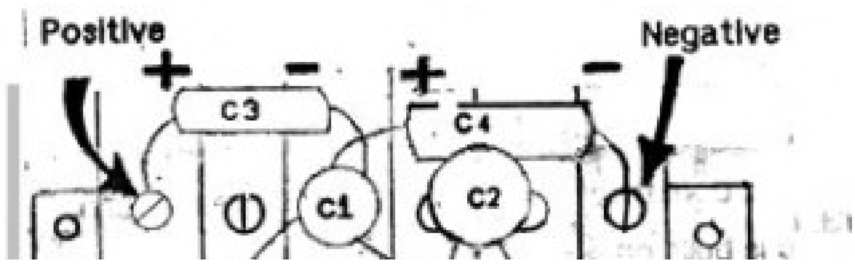

The breadboard unit is shown in Figure 10 with all components on one side and all connections on the other. All you need is a 2" x 2" piece of perforated breadboard (Radio Shack #276-1395) and the components on the parts list. Push component wires through the holes and twist them together on the other side. Just follow the pattern in the photo, making sure to observe the correct polarity on the electrolytic capacitors and the diodes. The ceramic capacitors may be inserted in either direction.

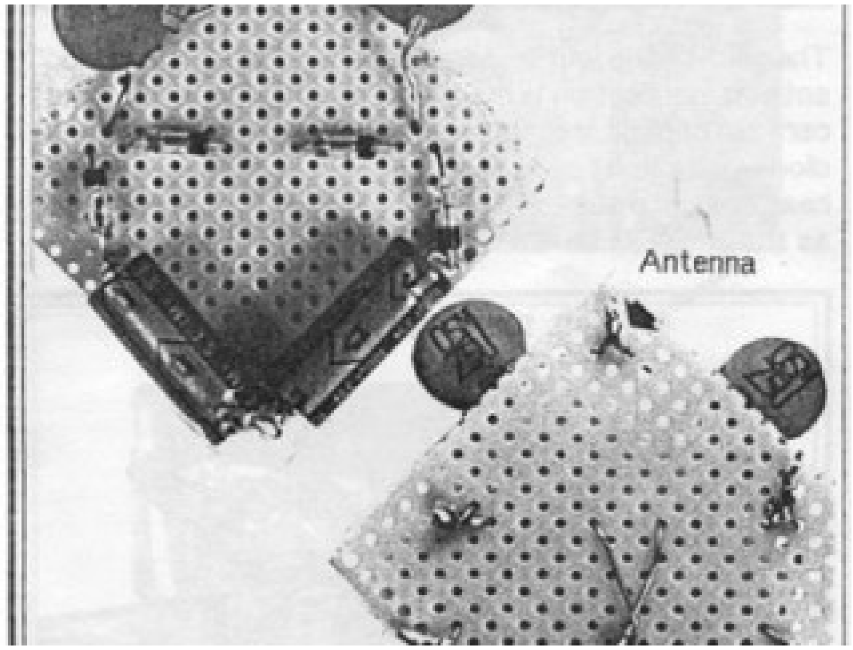

The experiment board unit is assembled by simply pushing the component leads into the board as shown in Figure 11. This unit is powering a small red LED indicated by the arrow.

FIG. 11 EXPERIMENT BOARD

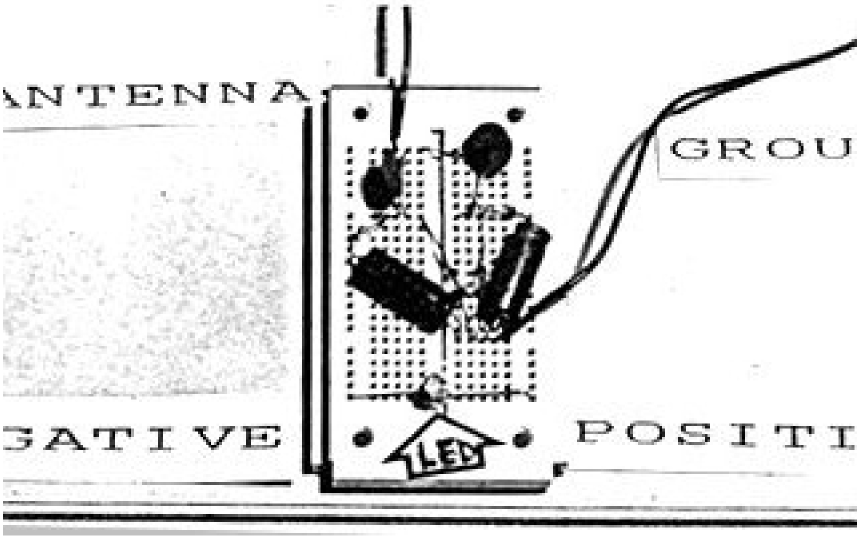

The solder strip unit is made up on a five terminal strip. The antenna connection is made to the twisted ends of the ceramic capacitors. When soldering the leads of the 1N34 diodes, care must be taken to avoid overheating. Clip a heat sink onto the lead between the diode and the terminal as shown in Figure 12.

FIG. 12 SOLDER STRIP UNIT

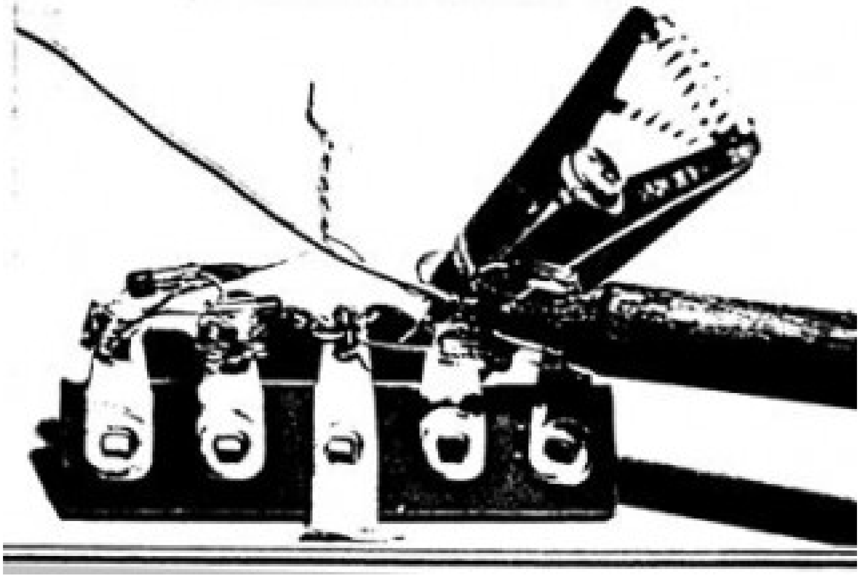

FIG. 13

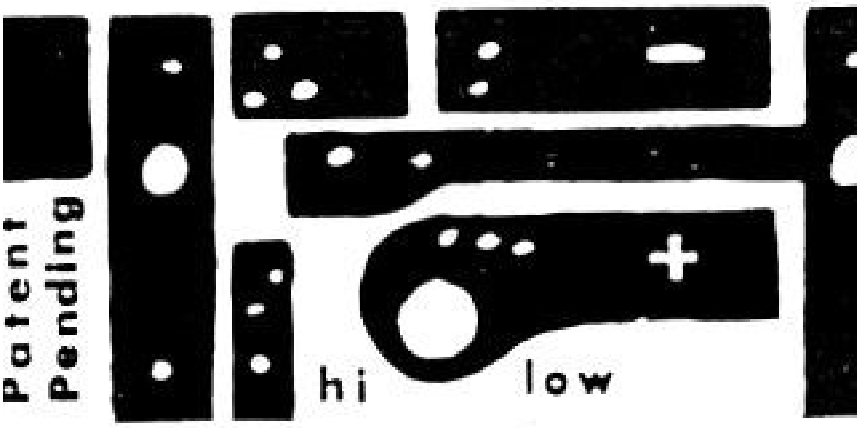
Patent Pending
−
+
hi
low

Figure 14 shows the front and back view of the completed printed circuit.

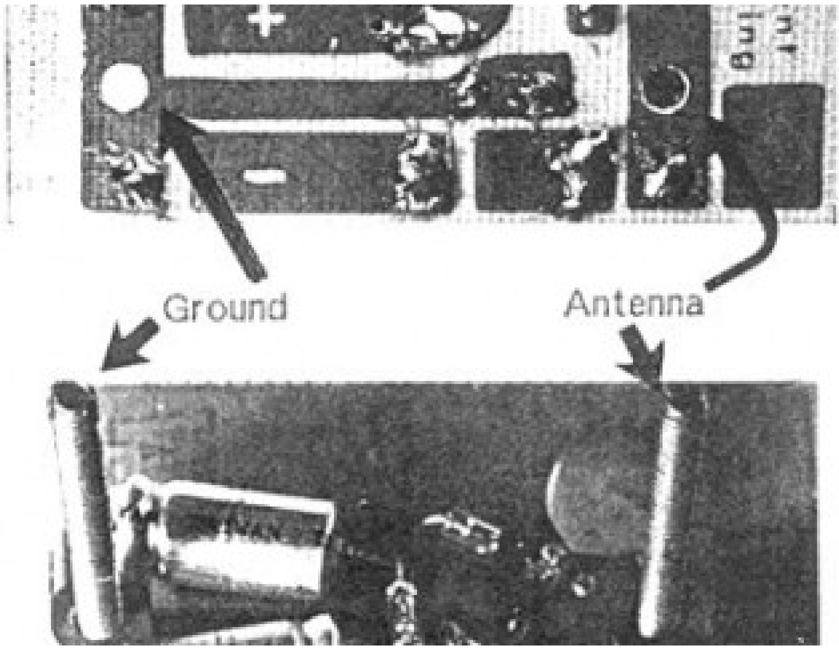
+
−
Ground
Antenna

A small switch may be installed on the board to activate the zener regulator (Figure 15). This board was designed for use in clocks.

FIG. 15

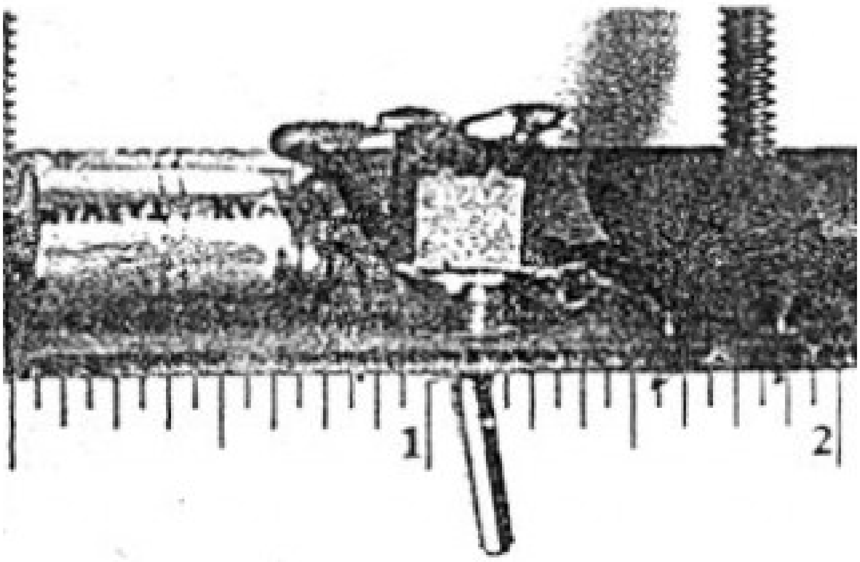

Antenna Requirements

The antenna needs to be of sufficient size to supply the APM with enough RF current to cause conduction in the germanium diodes and charge the ground coupling capacitors. It has been found that a long horizontal wire works best. It will work better when raised higher. Usually 20-30 feet is required. Lower elevations will work, but a longer wire may be necessary.

In most location, possible supporting structures already exist. The wire may be stretched between the top of a building and some nearby tree or telephone pole. If live wires are present on the building or pole, care should be taken to keep your antenna and body well clear of these hazards.

To mount the wire, standard commercial insulators may be sued as well as homemade devices. Plastic pipe makes an excellent antenna insulator. Synthetic rope also works very well, and has the advantage of being secured simply by tying a knot. It is convenient to mount a pulley at some elevated point so the antenna wire may be pulled up to it using the rope which doubles as an insulator (Figure 16).

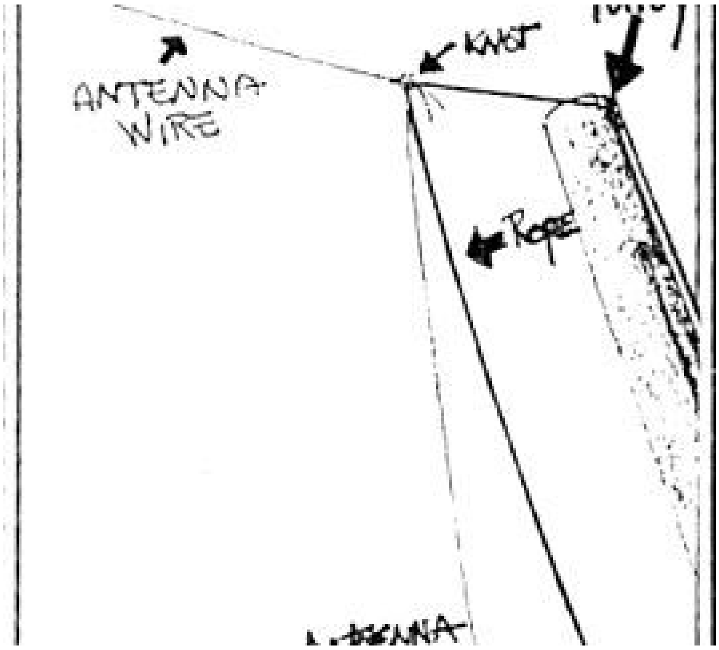

Figure 17 is an illustration of a horizontal wire antenna using a building and tree for supports.

FIG. 17

Horizontal Wire Installation

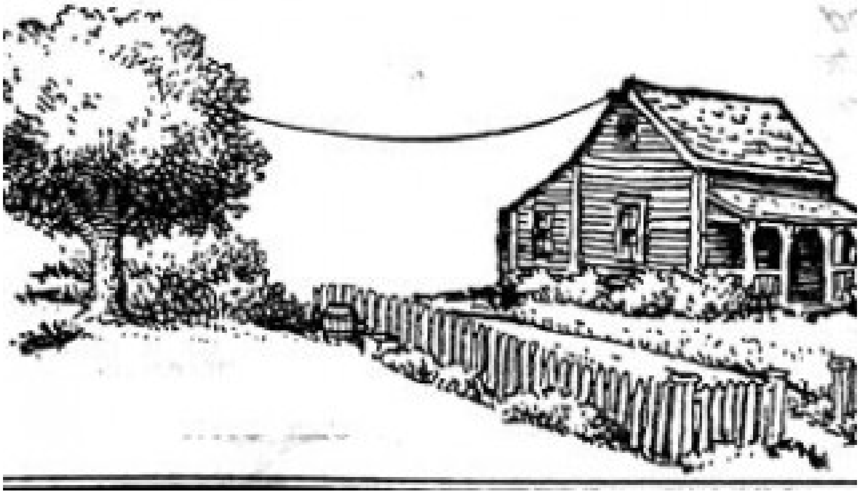

Grounding

Usually a good ground can be established by connecting a wire to the water or gas pipes of a building. Solder or screw the wire to the APM-2 ground terminal. In buildings with plastic pipes or joints, some other hookup must be used. A metal rod or pipe may be driven into the ground in a shady location where the earth usually is damper. Special copper coated steel rods are made for grounds which have the advantage of good bonding to copper wire. A ground of this type usually is found within the electrical system of most buildings.

Conduit is a convenient ground provided that the conduit is properly grounded. This may be checked with an ohmmeter by testing continuity between the conduit and system ground (ground rod). Just as with the antenna, keep the ground wire away form the hot wires. The APM's ground wire may pass through conduit with other wires but should only be installed by qualified personnel.

Grounding in extremely dry ground can be enhanced by burying some salts around the rod. The slats will increase the conductivity of the ground and also help retain water. More information on this subject may be found in an antenna handbook.

Good luck getting your Ambient Power Module working. It is our hope that experimenters will find new applications and improve the power capabilities of the APM.

CopyRight Joseph Tate

Inventors: Tate, Joseph B. (Sausalito, CA)
Brown, David E. (Mill Valley, CA)

Application Number: 06/695632

Publication Date: 12/09/1986

Filing Date: 01/28/1985 NOTE: The images maybe hard to see as they were originally scanned and uploaded in black and white. If it helps you to replicate this device you may want to check the images of the one I built at the very top (in color) Here are some more photos of my completed unit for your review.

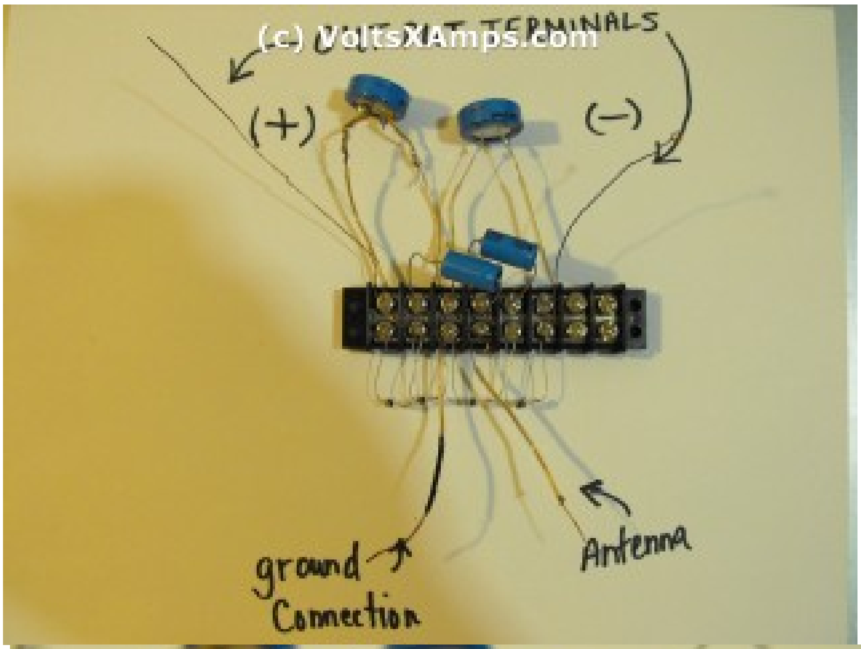
(c) VoltsXAmps.com
TERMINALS
(+)
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ground Connection
Antenna

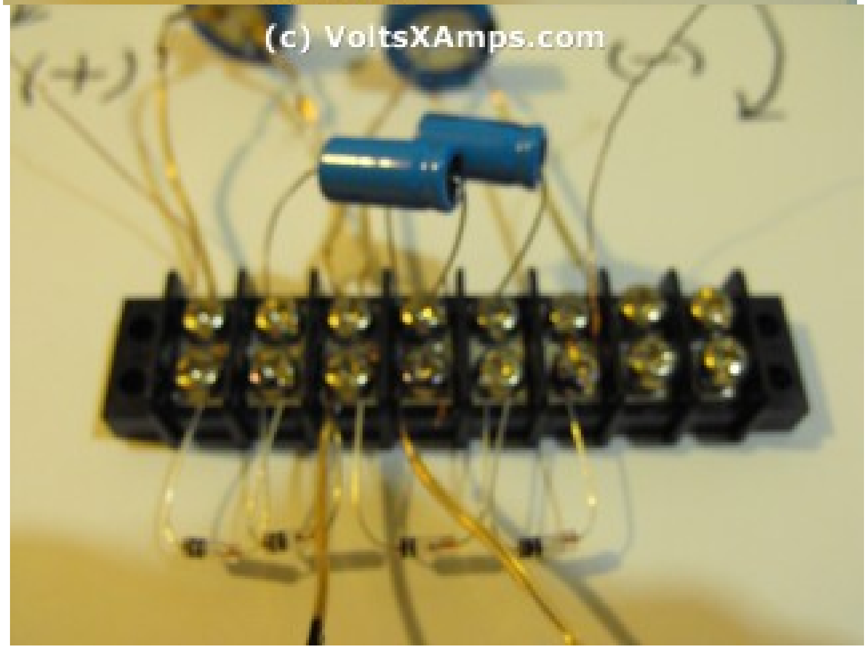
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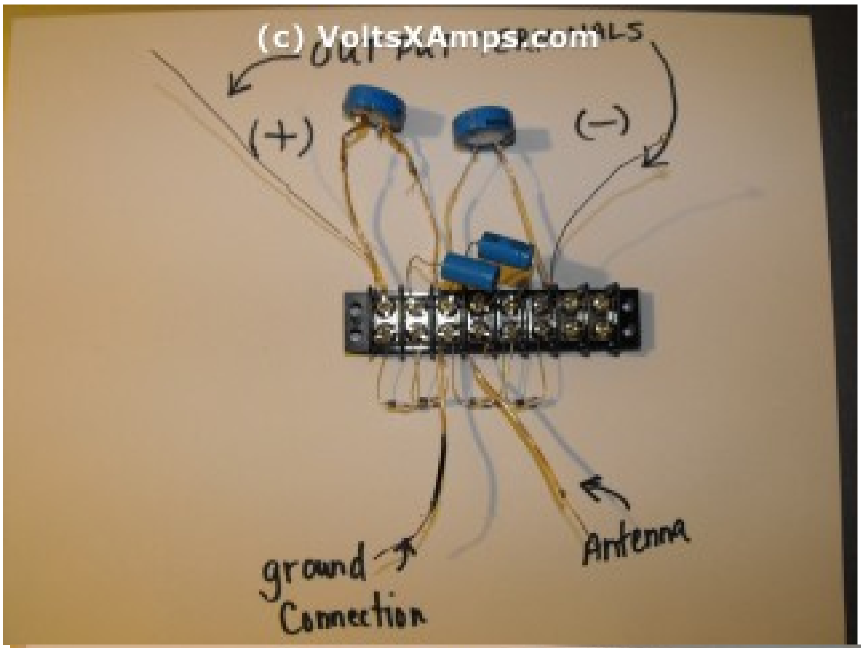
(c) VoltsXAmps.com
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Antenna
ground Connection

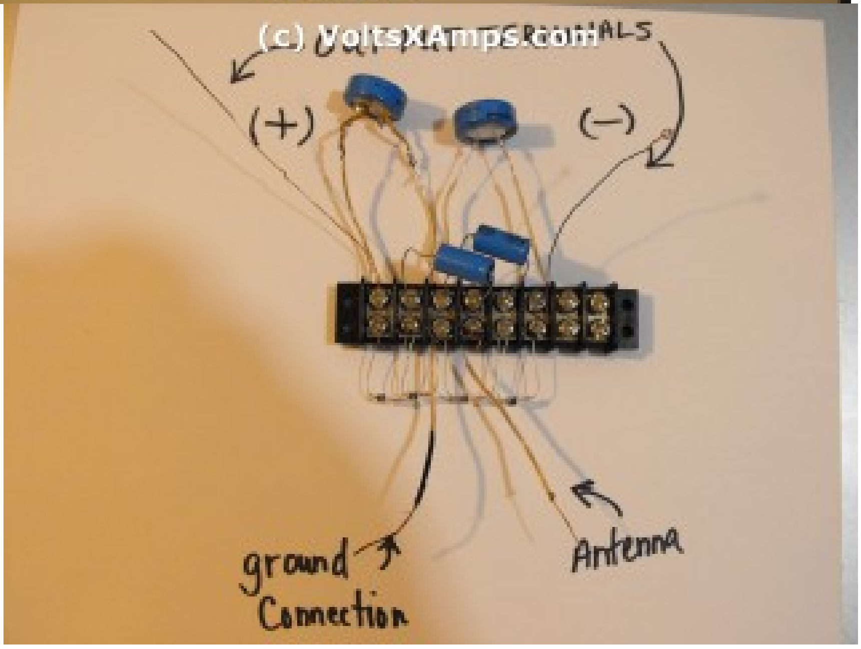
(c) VoltsXAmps.com
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Antenna
ground Connection

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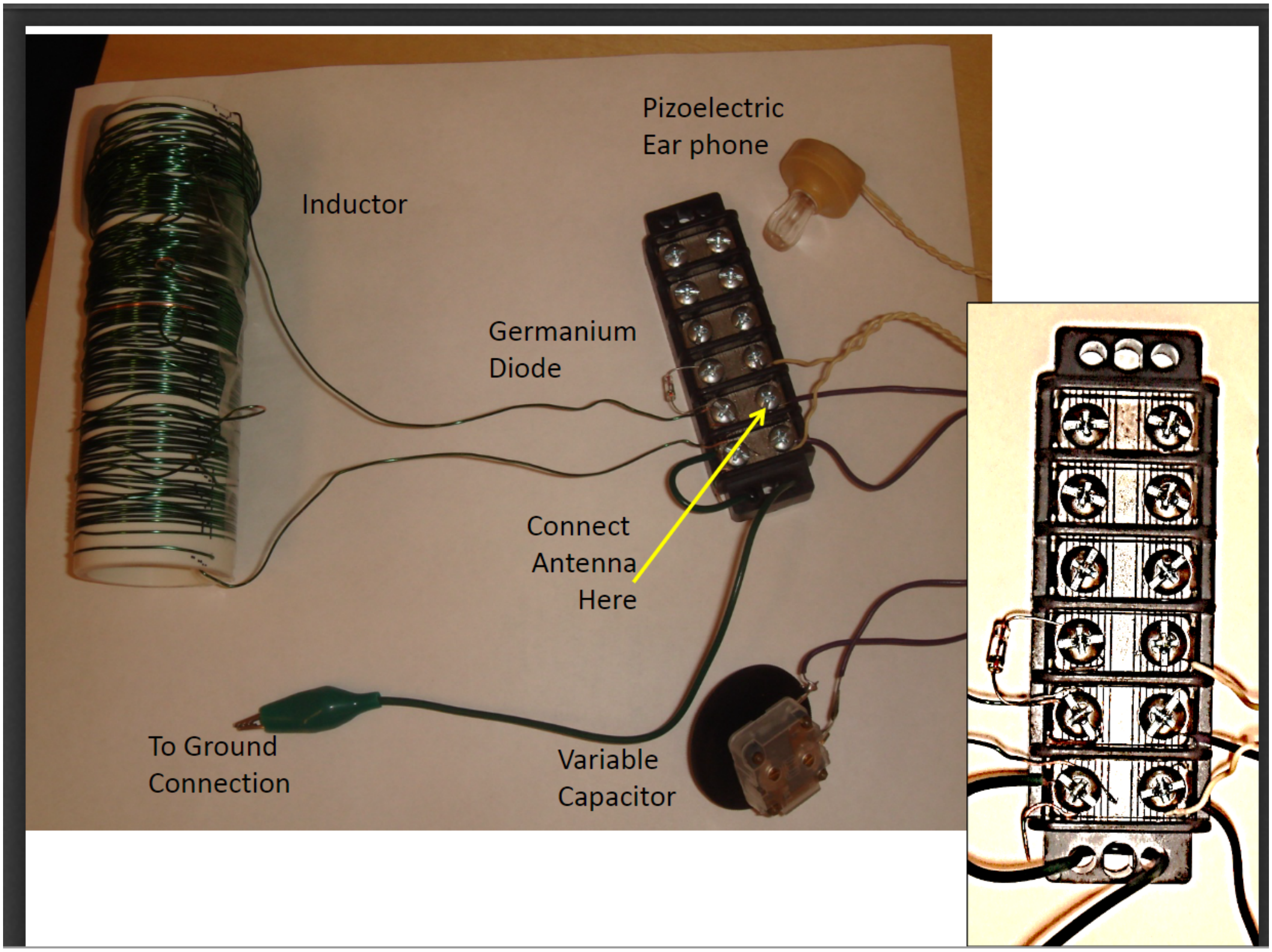
Pizoelectric Ear phone
Inductor
Germanium Diode
Connect Antenna Here
To Ground Connection
Variable Capacitor

FM Crystal Radios?

copyright © 2006 by Larry J Solomon

I have heard, even from a physicist, that it is impossible to build FM crystal radios. On the other hand some experimenters claim that they have built them. This argument intrigued me to try and build an FM crystal radio, which I have done successfully. To my surprise, the result is an astounding performer, pulling in four local stations in Tucson. When connected as a receiver to a good sound system the sound fidelity is as good or better than more expensive AM radios. In fact, it sounds "high-fidelity".

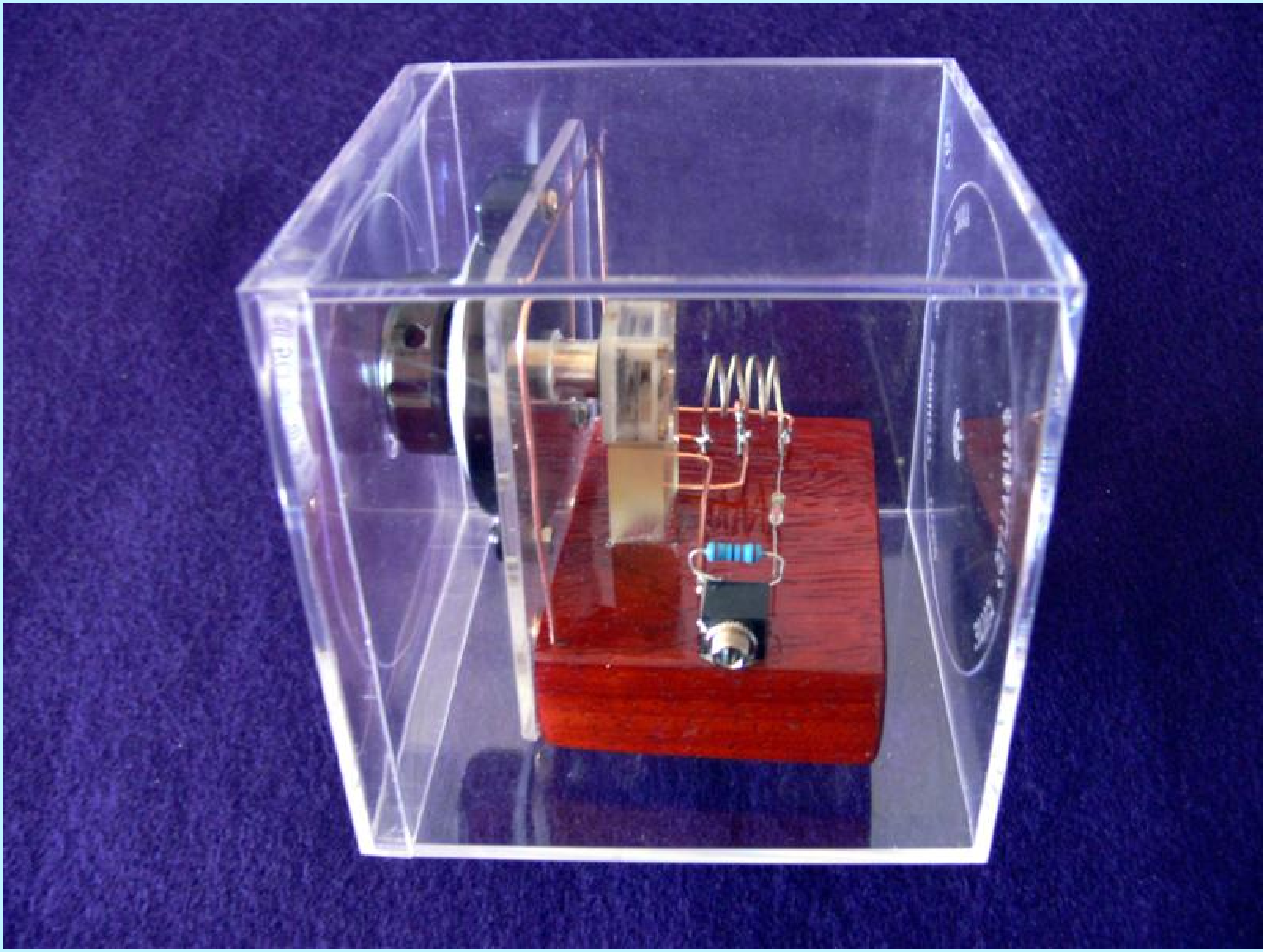

This picture shows the Solomon FM Crystal Set in an acrylic display case. I made the set specifically to fit inside this case (the case came first).

My definition of a crystal radio is one that is not powered, except by the radio transmission itself and employs a crystal detector. So, it should work without any batteries or AC power. An FM crystal receiver must be able to detect and receive FM signals well enough to be heard in earphones without any such extra power.

This FM receiver is an amazing performer. It has crystal clear reception (pun intended), good sensitivity, but only fair selectivity. This set was a discovery for me. I started out by designing and building the normal AM sets. Then one day while testing the "Mystery" set (see my other web links), to my surprise, in addition to the expected panoply of AM stations, I heard a very faint signal that I could not tune out. At first, it seemed too weak to identify. When I tuned out all the AM stations, I was astonished to hear the announcement "KiiM FM, 99.5"! This is a

country music FM station here in Tucson. It was all over the dial, untunable, but the much louder AM signals masked it when they were tuned in.

I set myself the task of trying to improve the FM reception. I tried some simple circuit modifications that did not seem to improve anything. Then I connected a dipole antenna instead of the AM antenna I normally use. Suddenly, the FM signal was much clearer, although still weak. By using the audio output and sound system amplifier, I was even more amazed that four different FM stations came in loud (or rather medium) and clear. I found that changing the telescoping antenna length and position I could tune the stations in and out. They were KRQ, KLPX, KiiM, and KHYT all local FM stations with transmitters nearby. Their reception was also affected by the length and position of the audio output cable.

After doing some research, I discovered that there was a physical theory that claimed that FM reception was possible and even probable using the same circuit as an AM receiver. The theory is called "slope detection". So, I set out to find circuit improvements. A web search yielded little, mostly theory. But there was enough information that I thought I could make some modifications to the AM circuits to make them more tunable to FM signals and less tunable to AM. Since FM operates at higher frequencies, all I had to do, I thought, was make the coil and caps smaller. After much "tinkering" I arrived at the current circuit.

The circuit looks identical to a classic AM crystal circuit but is even simpler to build. The components were reduced in dimension to resonate at higher frequencies. This was done by experimenting with smaller and smaller coils and capacitors. The antenna is also much reduced in size (from that of AM) to resonate at higher frequencies (the antenna is crucial). The air variable capacitor I used has two trimmers in it which should be adjusted for best reception.I have found that a commonly available vernier dial and knob will fit the capacitor nicely. See end of article for a picture of the variable. C3 is a ceramic capacitor of 18 pf, but may be anywhere from 10 to 50pf. A detected FM signal is converted to AM due to an effect called slope detection that modulates amplitude.

This FM Crystal Set works best near the transmitter (I have not tested it beyond about 10 miles). Secondly, the sound level is quiet, especially without an amplifier. A quiet room is needed for listening with earphones. One must be willing to move the set around to find a location for the best reception of signals. However, in addition to listening with high impedance earphones (crystal or otherwise), the set can be connected directly to an audio amplifier's low level magnetic input which can then play amplified through a sound system at any volume -- sounds GREAT. In fact, I recommend starting tests with the FM crystal set by connecting it to the low-level phono inputs of a receiver or preamplifier. (Nowadays, many receivers don't even have a phono input!) That way you can crank up the volume, which makes it more likely to find the FM stations. If no signals are detected, I also recommend connecting an external "rabbit ear" antenna or hanging a short wire (12 inches or so) in various positions next to the internal antenna. The variable length of rabbitt ears can help to tune in stations.

No additional wiring or antenna is necessary (the antenna is optimized in length for FM.)

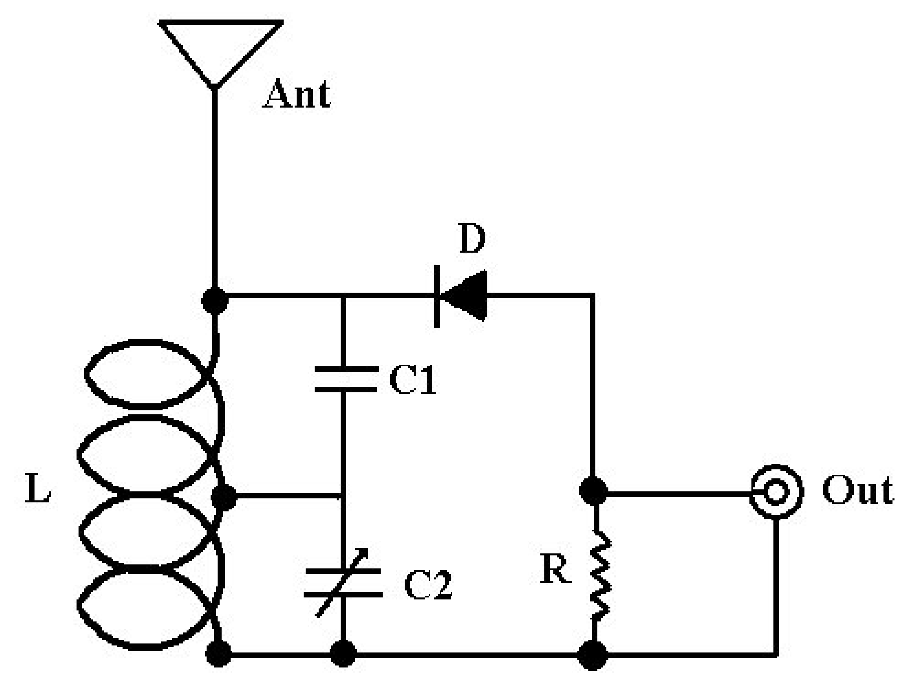

L - 4 turns #18 copper or silver wire, 12mm inside diameter, tapped at 2.5 turns
Ant - 7 inches of #18 bare copper wire
C1 - 18 pf ceramic capacitor
C2 - 50 pf air variable capacitor
D - 1N34 diode or rock crystal
R - 150K resistor

The diode is tapped directly to the antenna. The vernier dial fits directly on the tuning capacitor. The antenna parallels the perimeter of the acrylic face plate. "Military style" #18 AWG wiring is used without any insulation. It is important to keep the components physically close together. The component specifications are the same as in circuit #2. The coil is silver rather than copper, but copper does just as well. I think that the contrast of the silver and copper is beautiful. The coil was wrapped around a Sharpie Permanent Marker, then slipped off and expanded slightly. The wooden base is made from lacquered, polyurethane padouk.

I consider this set a work of art as well as science and think it is the most elegant crystal receiver I have created. I love the contrast of the silver coil, the copper antenna, the clear acrylic faceplate, the black vernier dial, the white and transparent variable capacitor, and the subtle colorings on the resistor, the diode, and the lucite base. Yet the circuit is so ridiculously simple that some will not believe it is possible without building it themselves. No shielding is necessary, and there is no problem with hand capacitance. However, the output cable position may affect reception sensitivity.

Photos of wired circuit

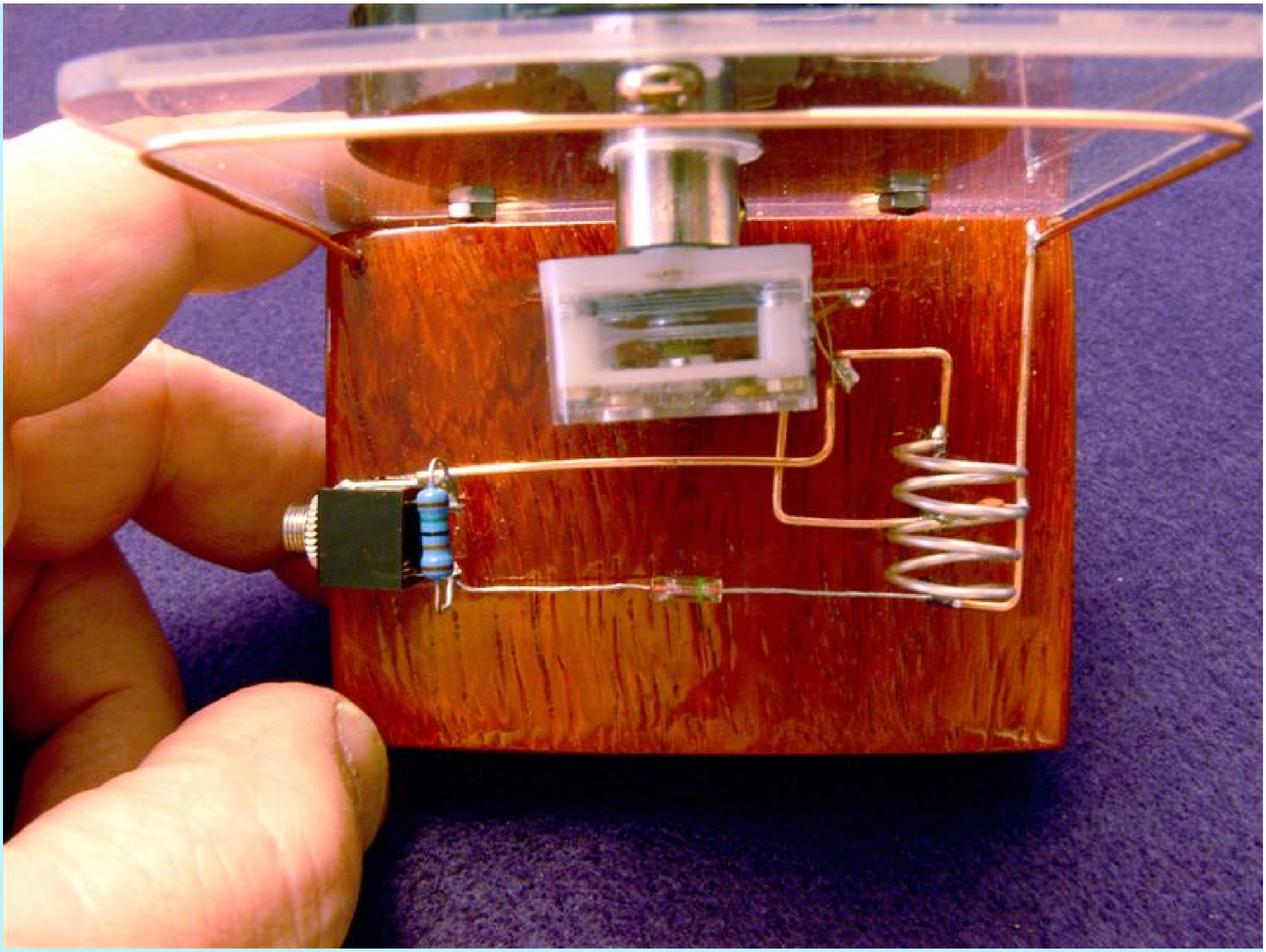

A hand is included in this photograph to show scale. Note the military style wiring, diode, and antenna. I wanted the wiring to create a modern design similar to a Mondrian painting. Not only is this set beautiful, it works! No power and no long antenna! It looks like a work of fiction.

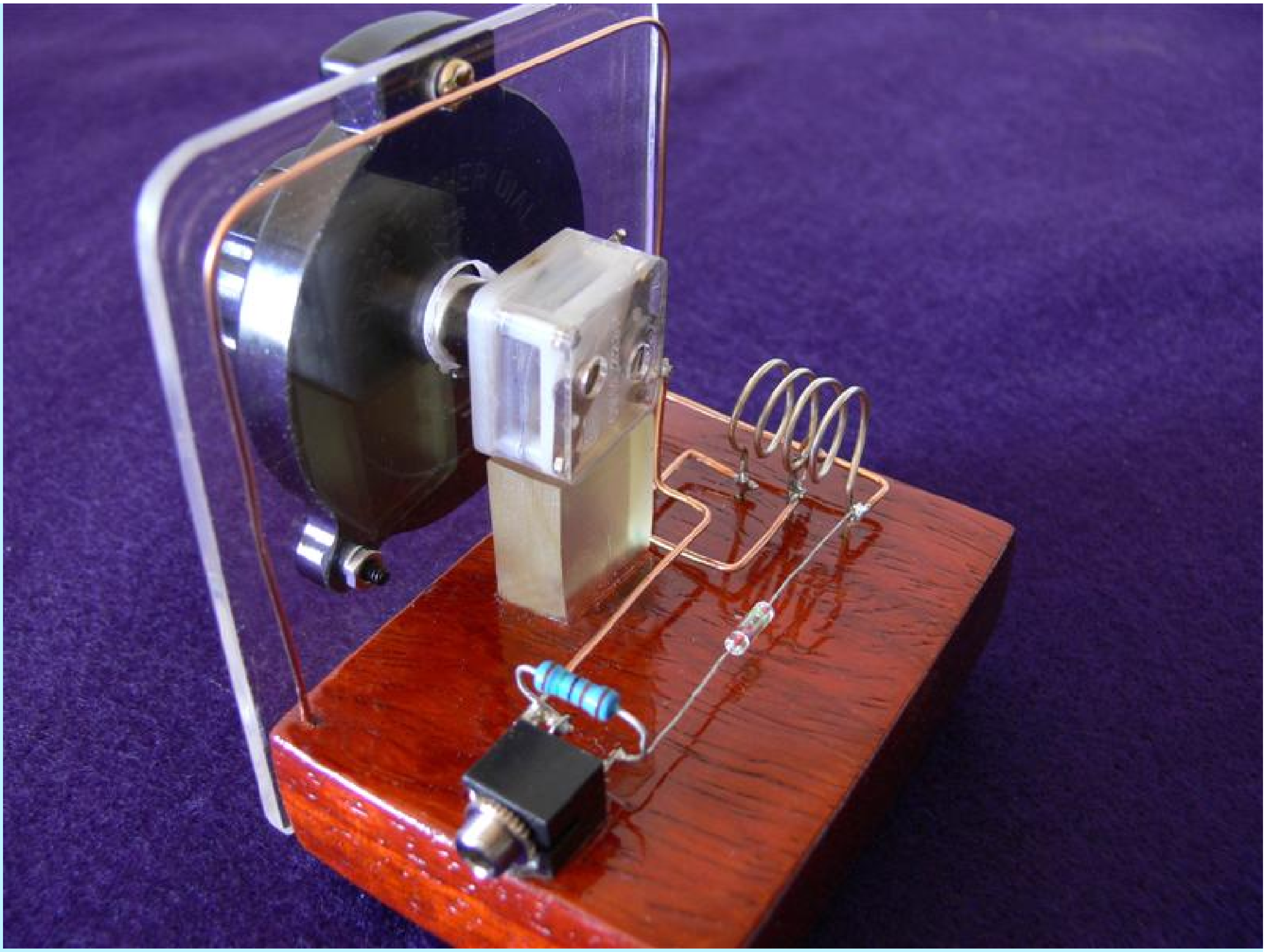

Is this thing imaginary -- science fiction? Well, imagination did play a part, but it is definitely not science fiction. This shot shows the elegance of the FM set best, I think. There is only one resistor and one fixed capacitor.

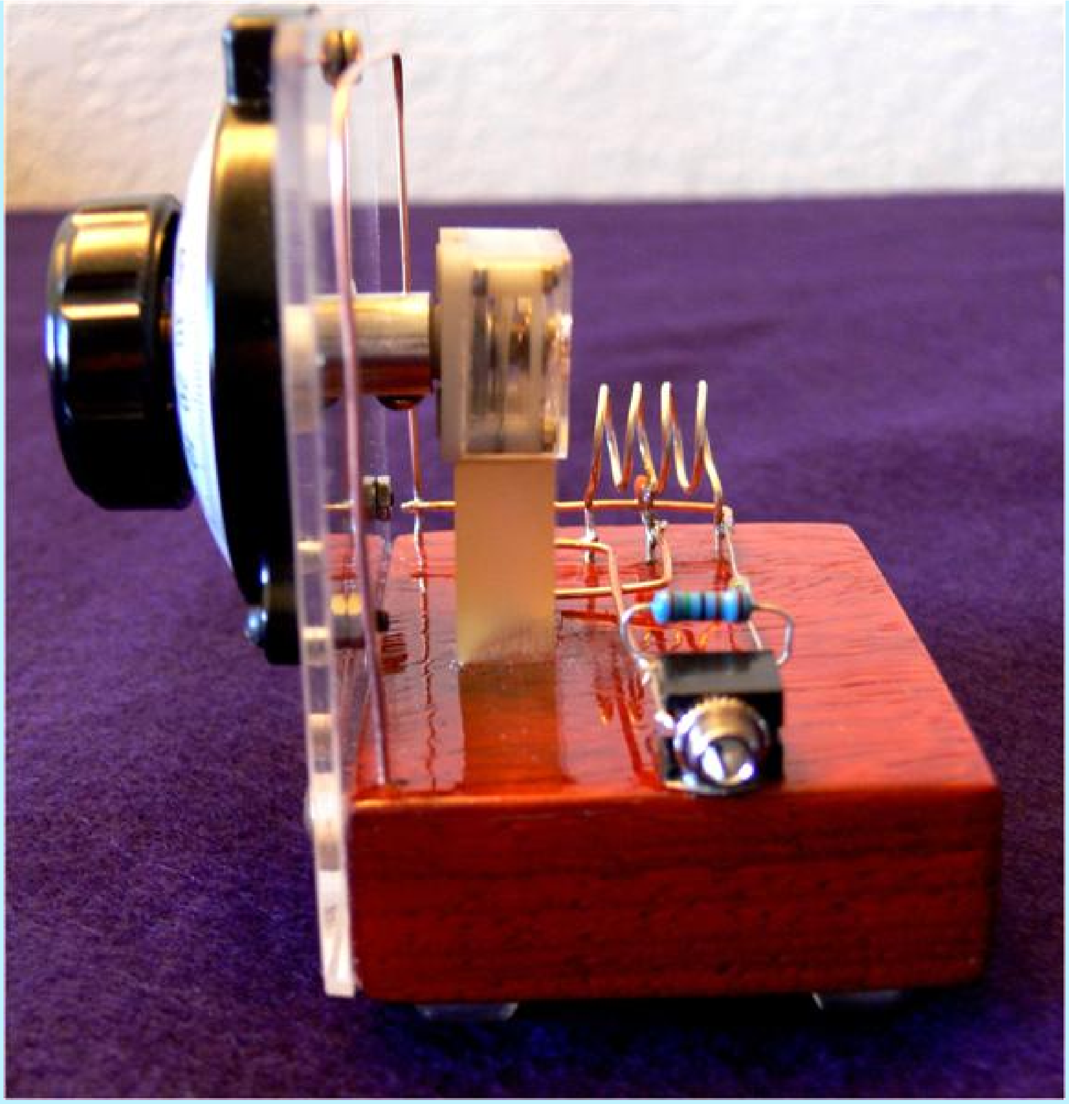

The inside of the tuning capacitor and the phono jack/output can be seen here. Can you spot the fixed ceramic capacitor? Note the polished edge of the face plate and the reflection in the wooden base.

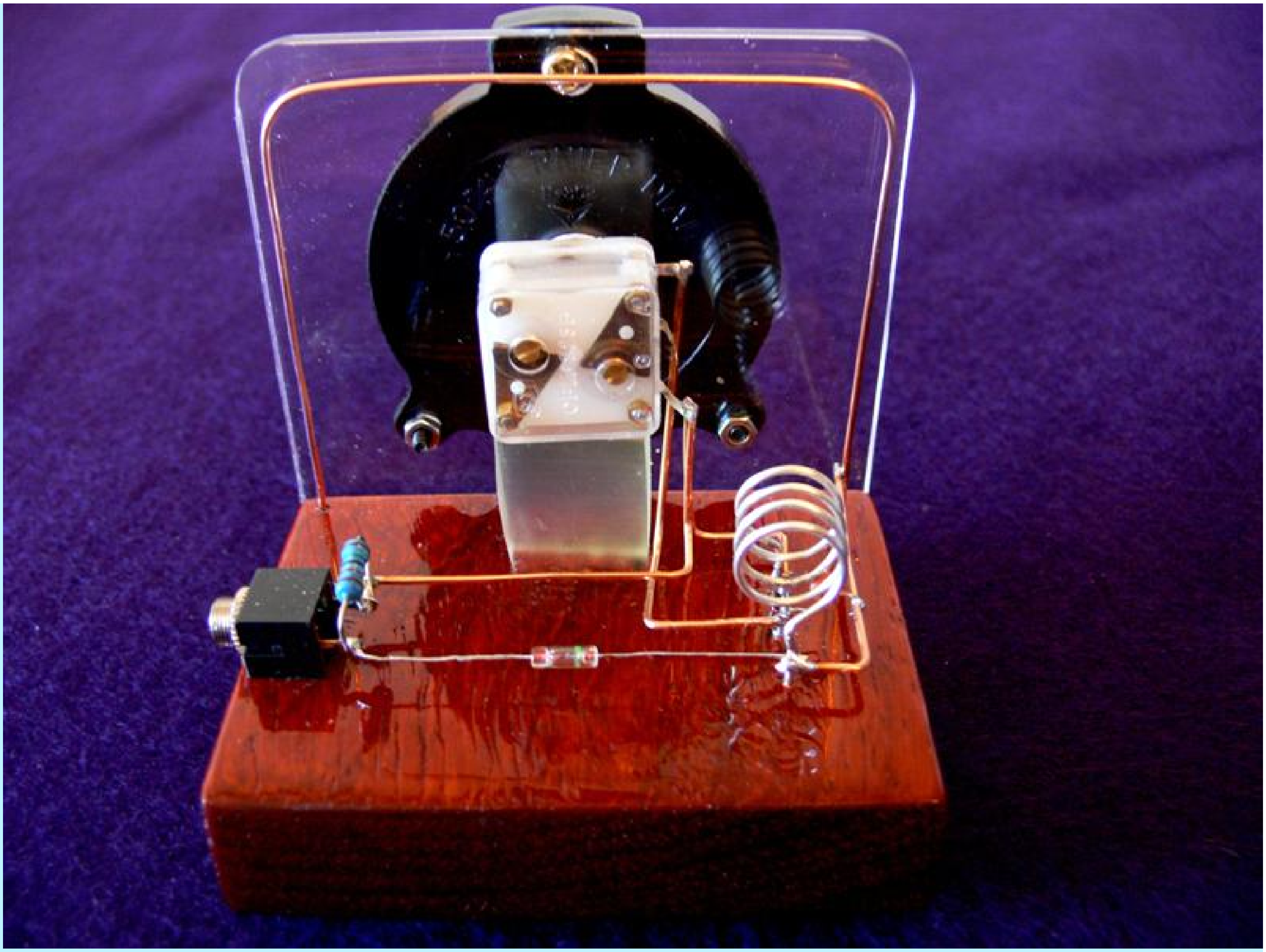

A quarter-inch piece of lucite was fitted under the tuning capacitor to anchor it. Note the two tiny trimmers on the back of the tuning capacitor. Brass screws were used to enhance appearance.

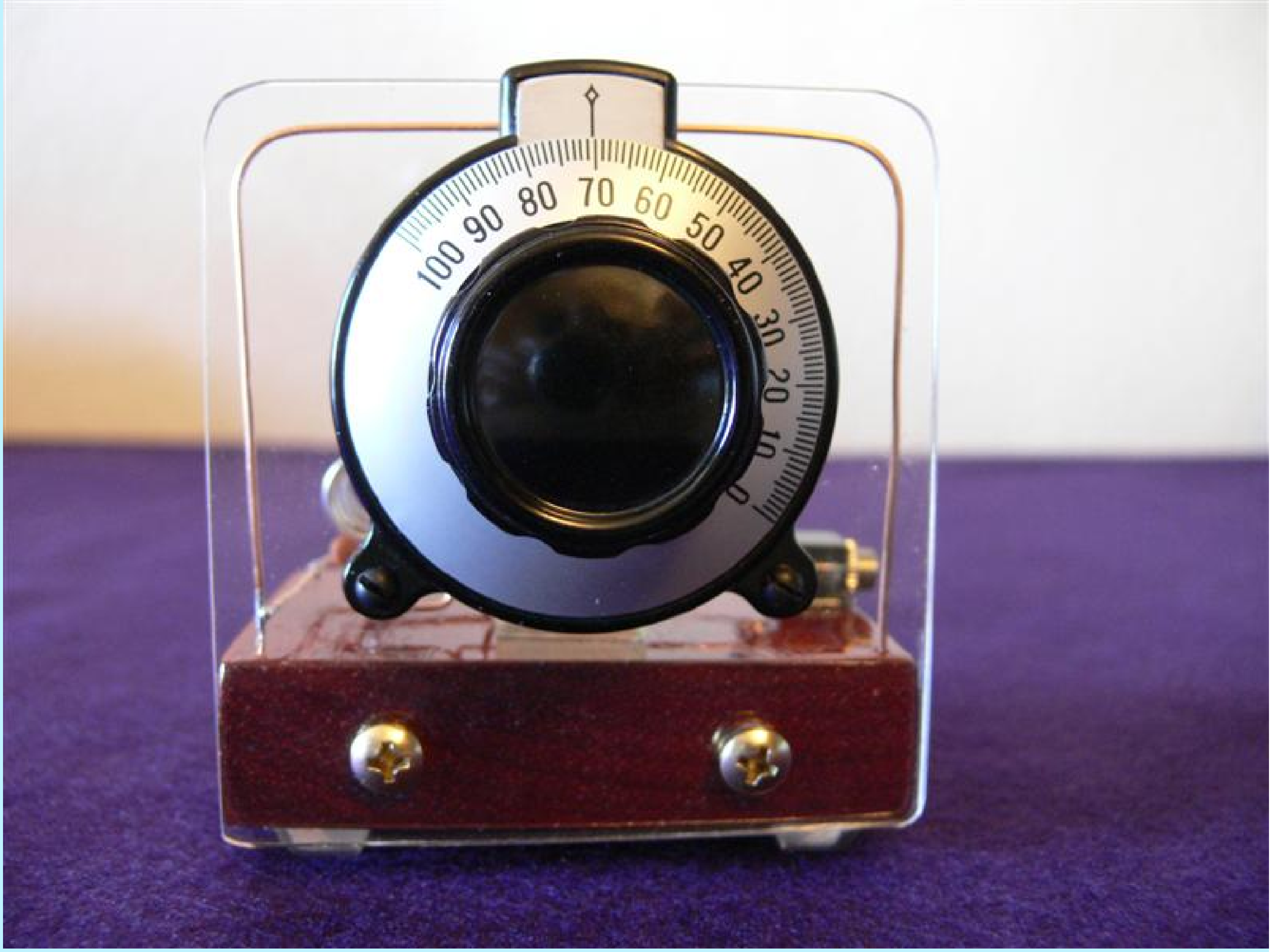

The vernier dial is large to accomodate ease of tuning, and the vernier makes it easy to separate stations. Two golden (brass) wood screws fix the face plate to the base. Holes for the face plate were made with special plastic drills, but ordinary drills may be used if drilled very SLOWLY. The knob is removable.

FM Crystal Circuit #2

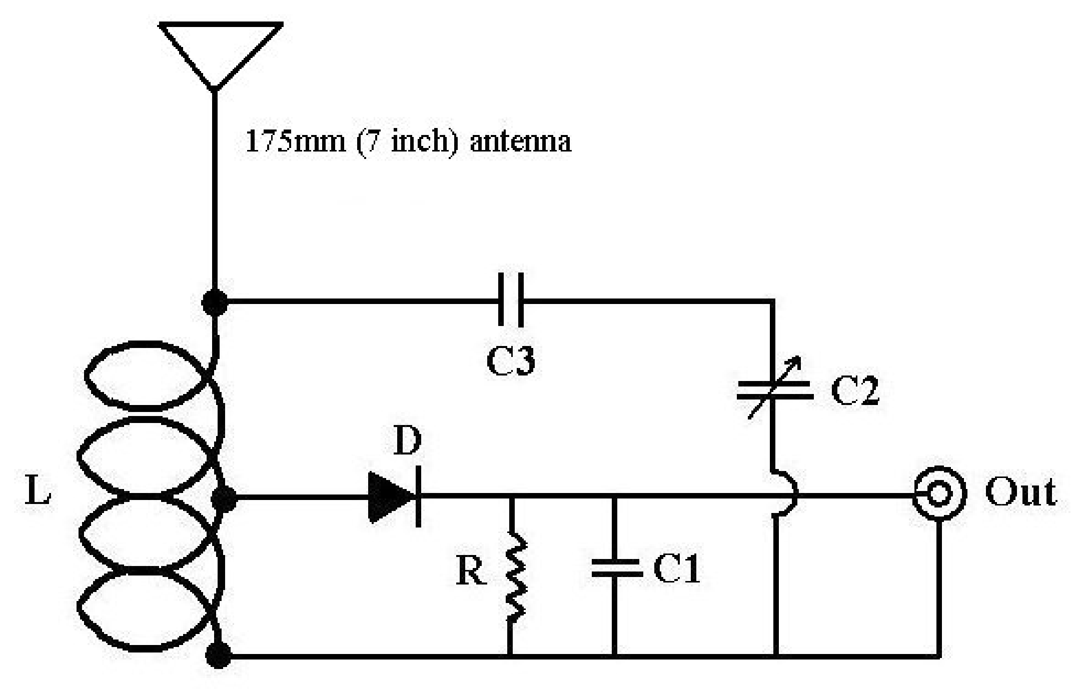

L - 5 turns AWG#18 bare copper or silver wire, 12mm inside diameter, tapped at 2.5 turns
D - 1N34 or rock crystal diode
C1 - 82 pf capacitor
C2 - 80 pf air variable capacitor
C3 - 18 pf capacitor
R - 150K resistor

The following photographs show the circuit wired with the handmade Saturn Dial. and knob. It is perhaps not as visually striking as set No. 1, but it works just as well. In fact, this set was the original version. Notice that all the wiring and coil are copper.

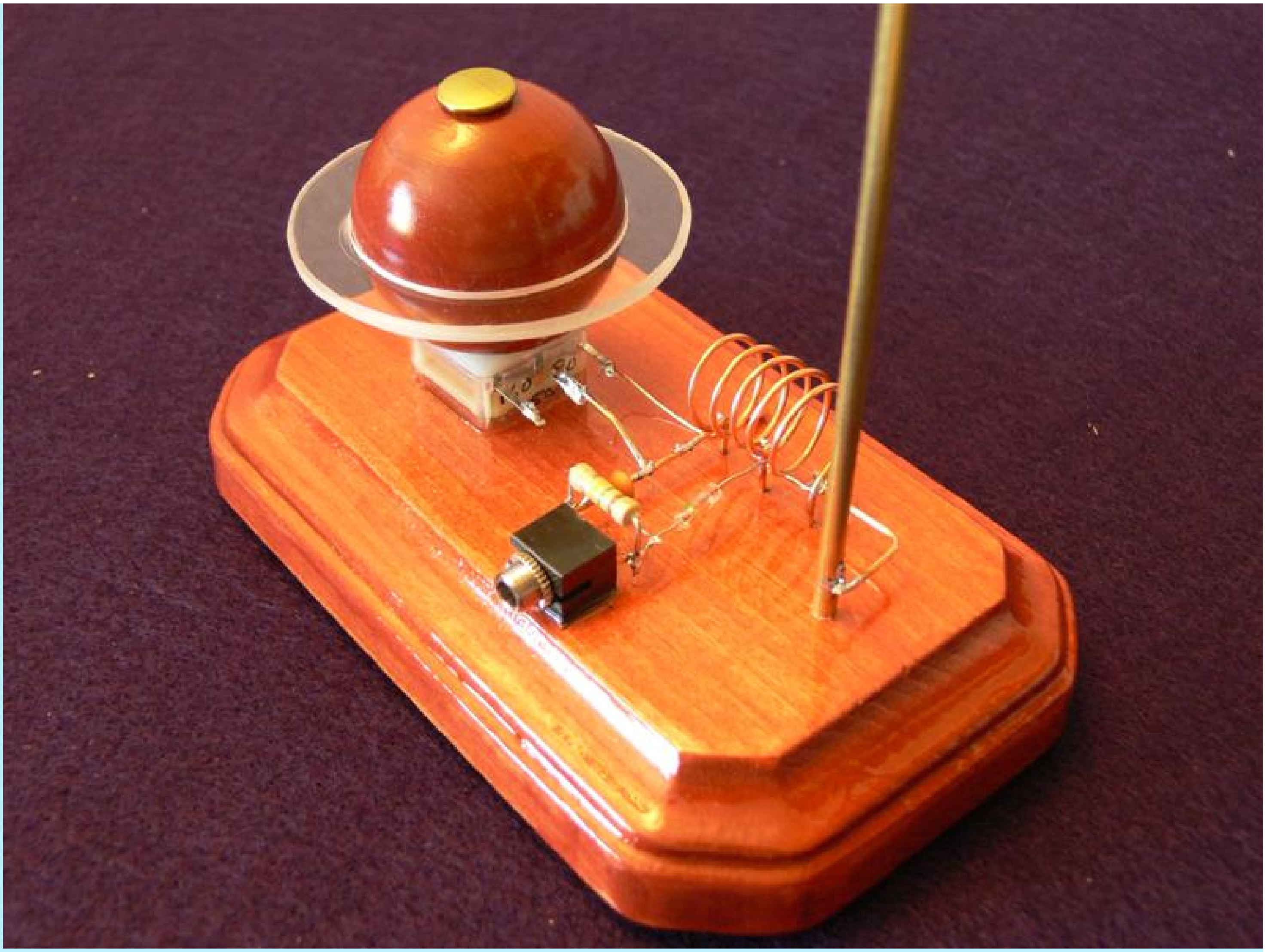

The Saturn dial and knob were fashioned from a "doll's head" from Michael's Arts and Crafts, a piece of lucite cut with two circle cutters, and a brass paper fastener. The knob is fixed to the tuning capacitor with a small machine screw that fits in the hole below the brass fastener. The most difficult part of this was fashioning "Saturn's rings". This must be done very carefully and slowly. The inside edge should be cut slightly undersized and then sanded with a drum sander to fit snugly. The outside edges can be sanded with fine sandpaper and polished with a plastic polisher.

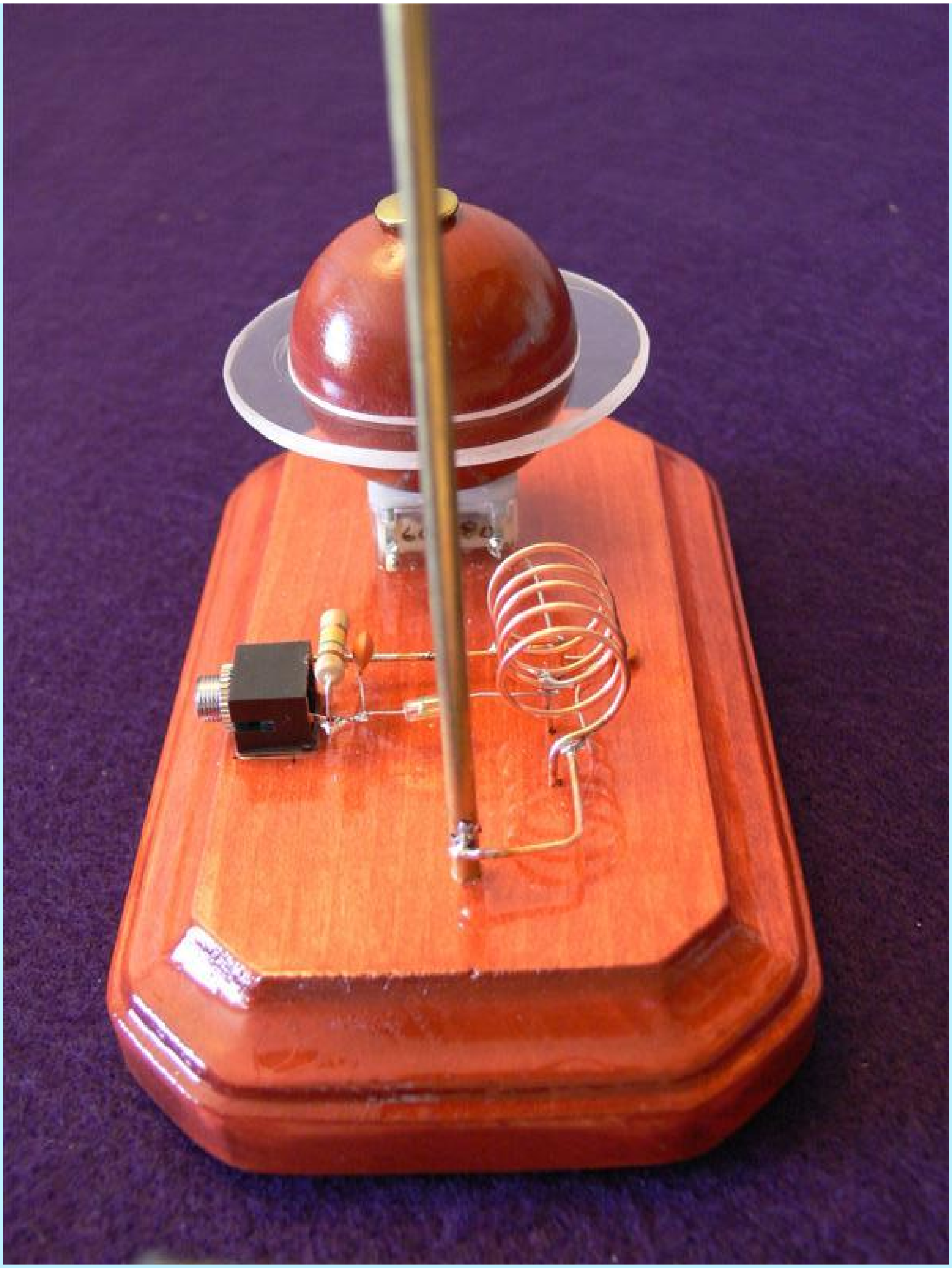

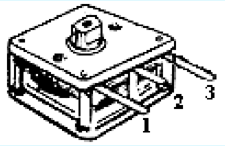

The air variable capacitor may be obtained from Electronix Express at http://www.elexp.com/. Part number 14VCRF10-280P. The 80 pf side is recommended for the second circuit, contacts 2-3. Contacts 1 and 3 were used for the first circuit (50pf).

- OSC: 5-59 pf
- ANT: 5-142 pf
- OSC and ANT Trimmer 10pf range

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"Dendera Light"
circa 1500 BC
Image: creative commons, Wikipedia

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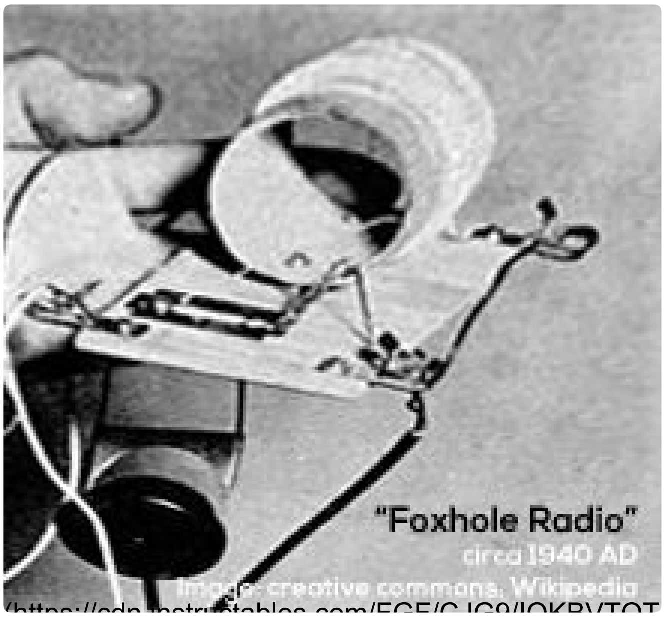
"Foxhole Radio"
circa 1940 AD
Image: creative commons, Wikipedia

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"Free energy from the air?, Yea, right!" Sardonic skepticism was my first reaction to this unusual concept, as well.

Though, its not so far out there, in fact. Light can be converted to DC current with solar panels, electricity can be converted to magnetism as I did in my last article (https://www.instructables.com/id/DIY-Electro-Magnetic-Levitation/), in a microphone sound waves are converted to an electrical signal (by vibrating a magnet near a coil (http://hyperphysics.phy-astr.gsu.edu/hbase/audio/mic.html)), solar rays can even be focused and converted to heat in awesome devices like this! (http://www.gosunstove.com/) When we think about it, energy is all around us and can be harvested in an enumerable many of ways.

Today, we are going to take a rather novel approach. We are going to build a device specifically designed to sense and capture a particular band of energy which is all around us.

The earth is magnetic and anyone who has ever used a compass knows this. Magnetic bodies in motion produce electricity, we can see this in any alternator, like the one in your car. So, therefore the earth is electric as well as magnetic, by definition.

Can we detect this energy? Yes, we sure can! Ever turn on a radio in the middle of nowhere and heard static? That is your radio picking up naturally occurring energy in the RF spectrum!

Can we use this energy to do work? Absolutely! This has been known for a long time. Crystal radios (https://en.wikipedia.org/wiki/Crystal_radio) have been around since before the 1930's and can run with no input energy other than the radio signal. Even when completely isolated, but from the atmosphere, a crystal radio will produce a voltage in the earpiece resulting in a sound (albeit and undesirable one).

Well, this is where it gets interesting...

Can we replicate this effect? Yea, and with modern components like the high quality crystals found in germanium diodes, we can even increase efficiency. By applying this concept as a Crystal Energy Receiver we can take advantage of a wide range of energetic frequencies rather than tuning in to just one.

Can we scale it up? Definitely. Things like micro germanium diodes, high efficiency antennas and compact contemporary capacitors make the components that are required to build a crystal receiver fit in the palm of your hand. While there may or may not be a more efficient way, this renewable energy solution is simple to employ and can be scaled up, or down, indefinitely.

Download

It sounds like we can build a Crystal Energy Receiver. Let's give it a shot...

Add Tip Ask Question

Step 1: What You'll Need

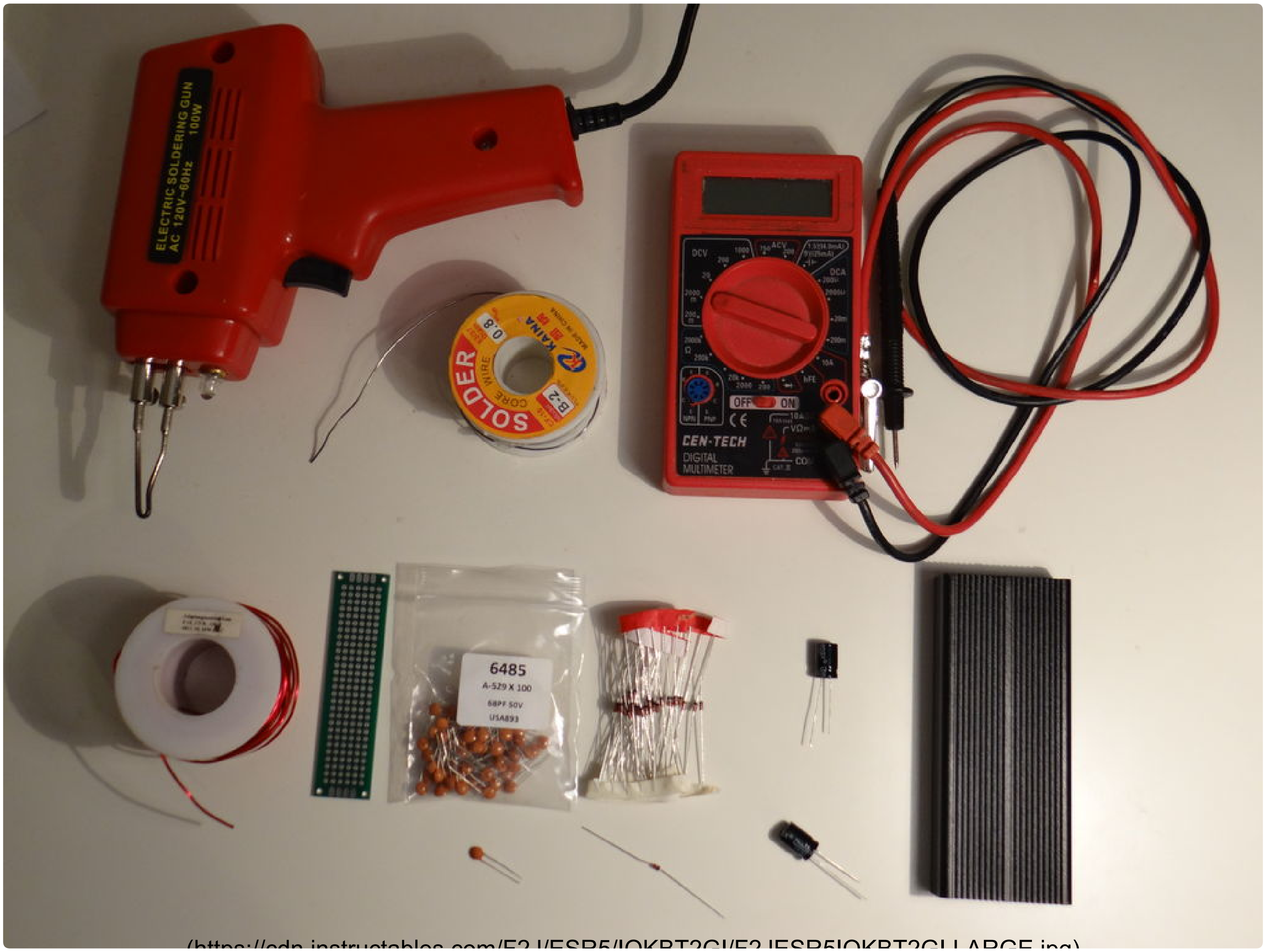
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AC 120V~60Hz 100W
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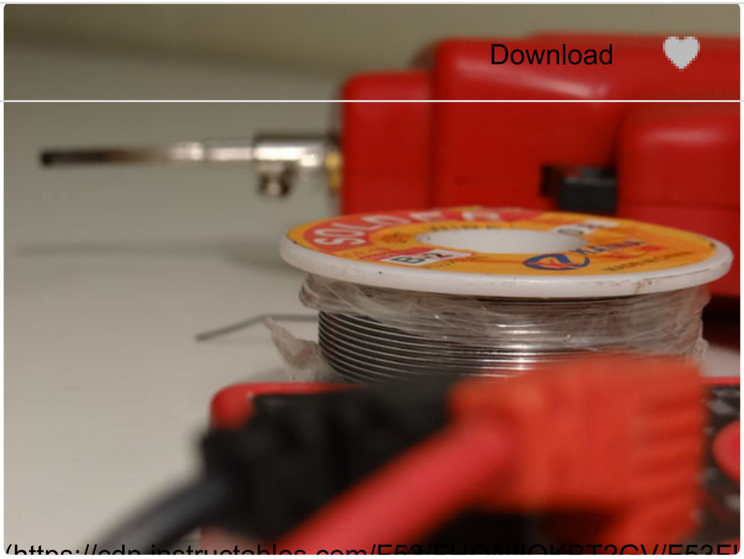

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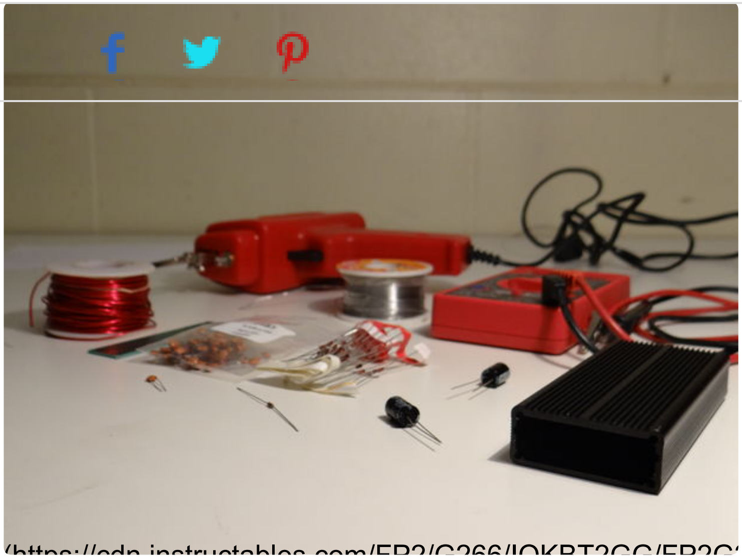

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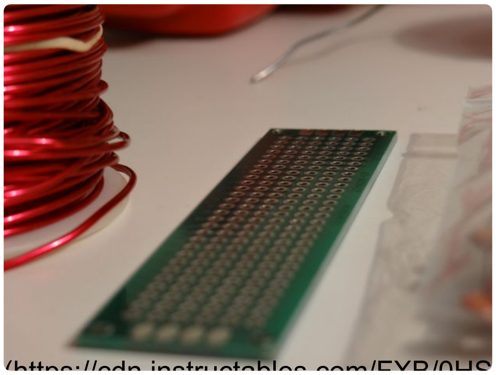

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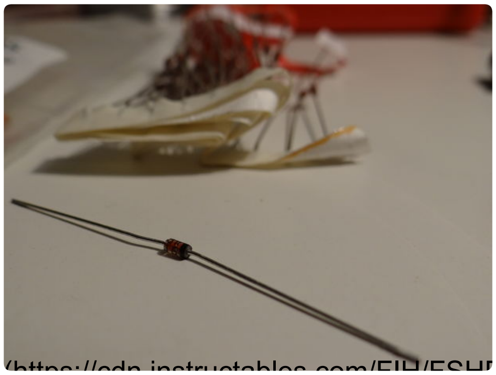

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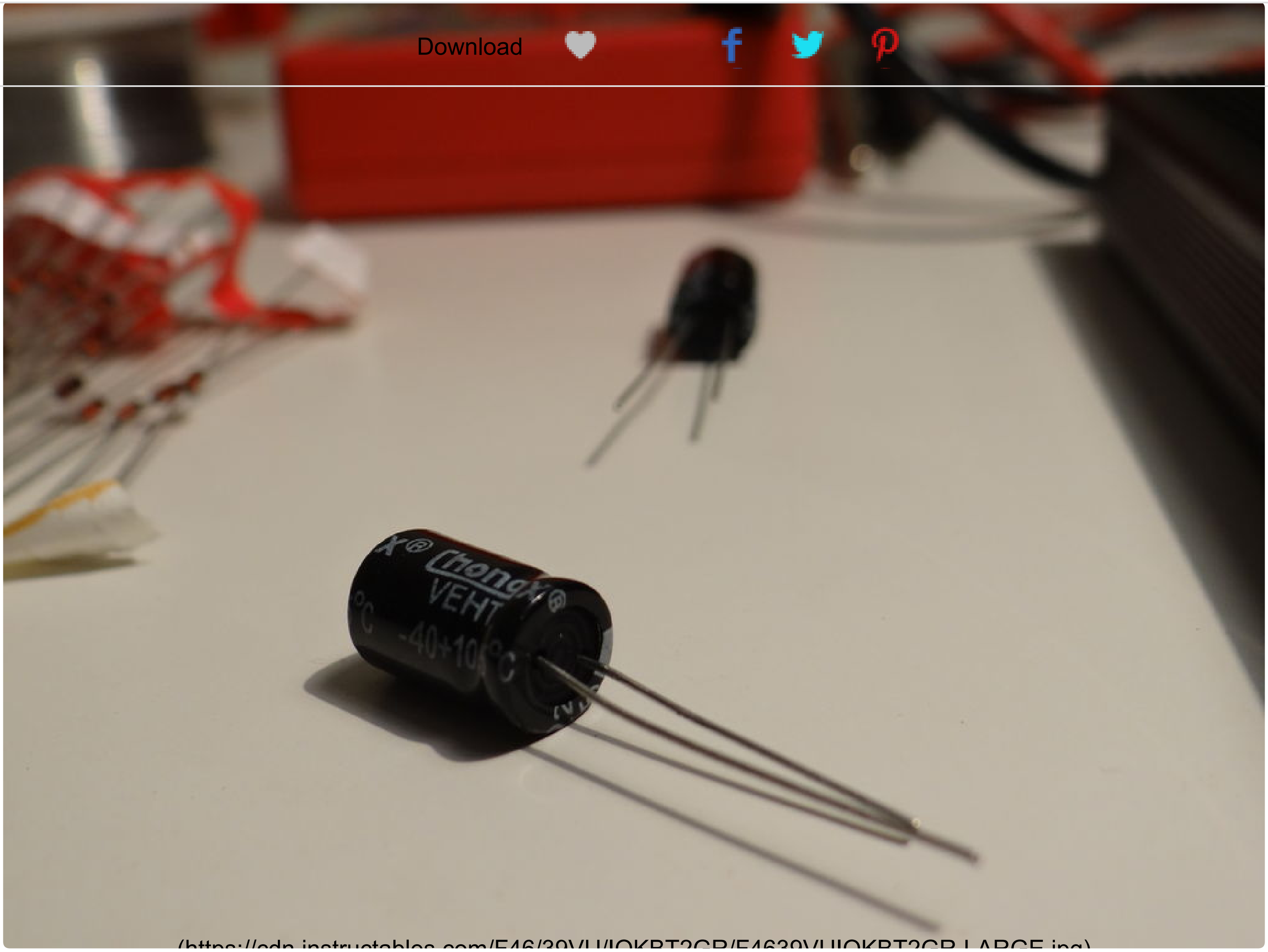
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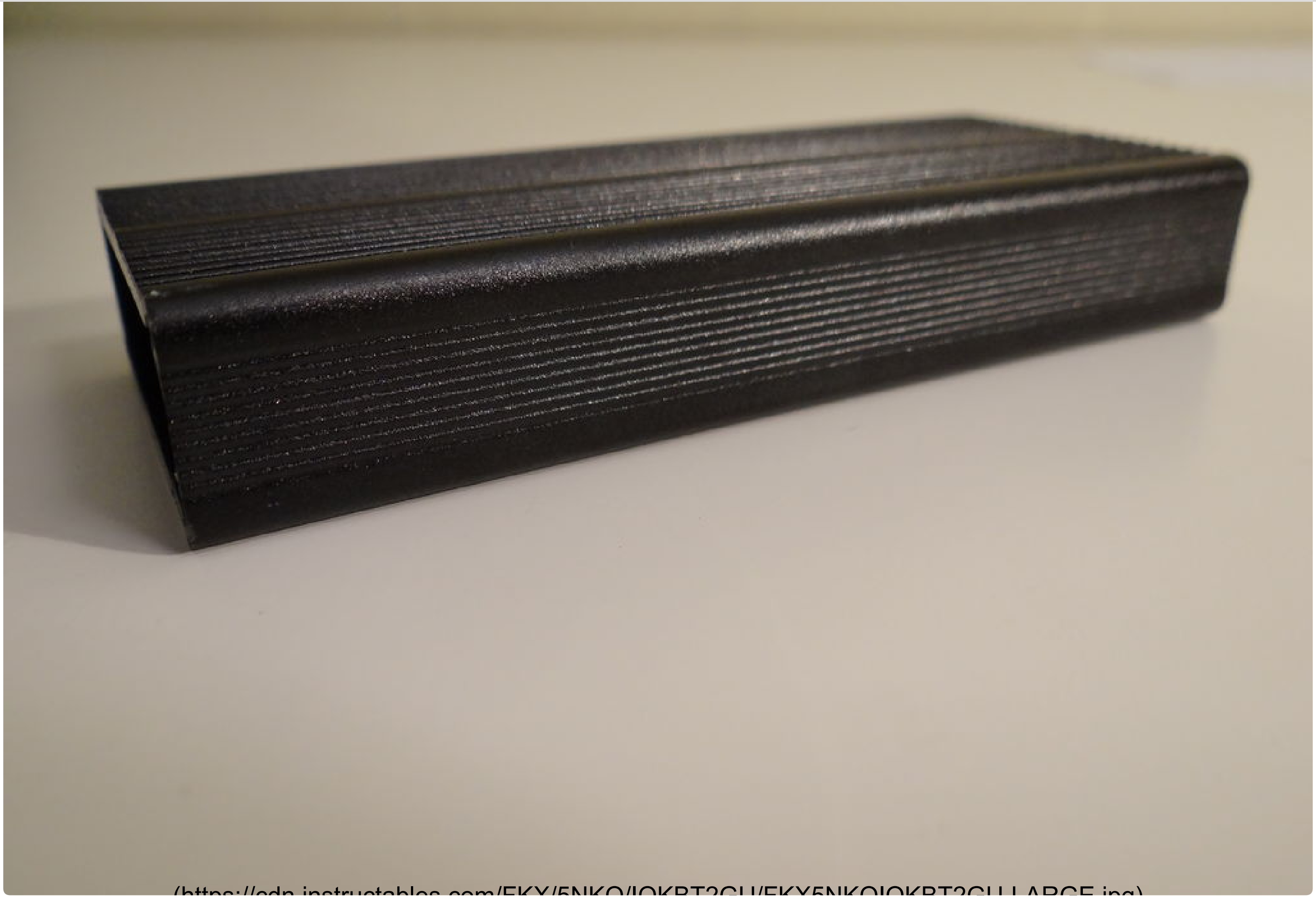

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One of the reasons this particular renewable energy harvesting method is so viable is the relatively few and easy to obtain materials required.

The simplest crystal receiver design needs no power and can be built with only three parts: a coil, a crystal and a resistor. We're going to optimize that design in order to produce a cleaner and more reliable output signal by first polarizing the input amplitude, then rectifying and filtering the signal. Then we'll add an antenna, case and connections.

Get the circuit diagram here (http://www.drewpauldesigns.com/crystal-energy-receiver-kit.html)
Get the kit here (http://www.drewpauldesigns.com/crystal-energy-receiver-kit.html)

The parts for the circuit include:
(1) Circuit Board (http://www.drewpauldesigns.com/crystal-energy-receiver-kit.html)
(1) 10-18 gauge Copper Wire
(2-12+) Ceramic Capacitors (matched)
(2-6+) Electrolytic Capacitors (matched)
*note various types of capacitors can be used
(4) Germanium Crystal Diodes (1A+)

Total Unit Cost: +/- $0.40 (USD, scaled for volume of 1,000+ units)

In addition, you'll probably want to get:
(1) Project box (optional)
(1) Antenna (a loop antenna or elevated antenna is recommended and can be made with copper wire)

The tools you'll need are:
Soldering Iron/ Solder (optional)
Multimeter
Oscilloscope (http://www.seeedstudio.com/depot/DSO-Nano-v3-p-1358.html?cPath=63_65) (optional)

That's it. Yup, that's all. Once we've got it all, let's begin.

Add Tip   Ask Question

Step 2: Build the Circuit

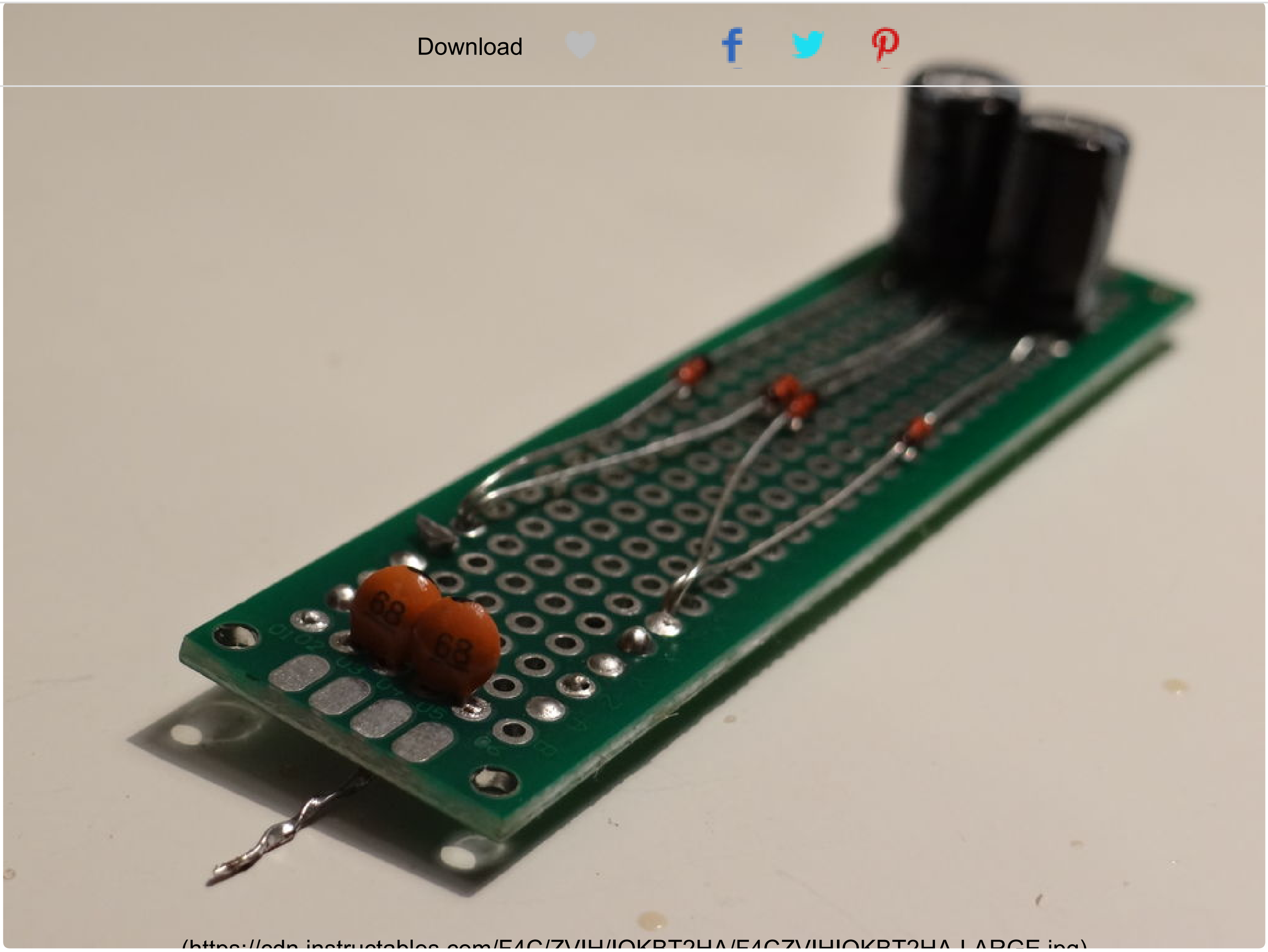

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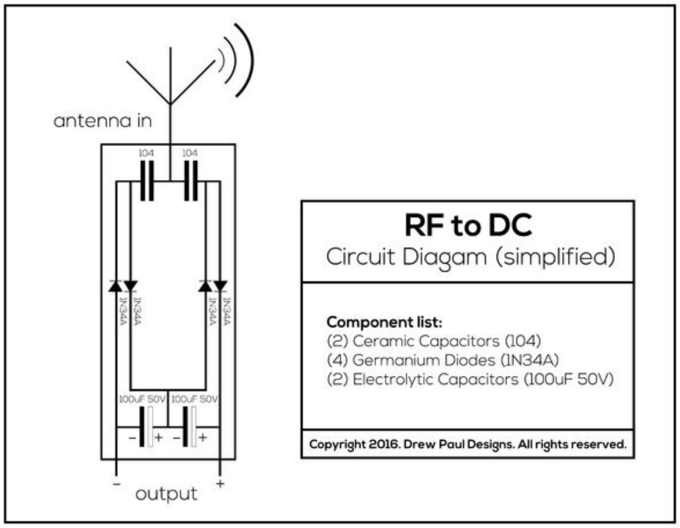
antenna in
104
104
1N34A
1N34A
1N34A
1N34A
100uF 50V
100uF 50V
-
+
-
+
-
output
+

RF to DC
Circuit Diagam (simplified)

Component list:
(2) Ceramic Capacitors (104)
(4) Germanium Diodes (1N34A)
(2) Electrolytic Capacitors (100uF 50V)

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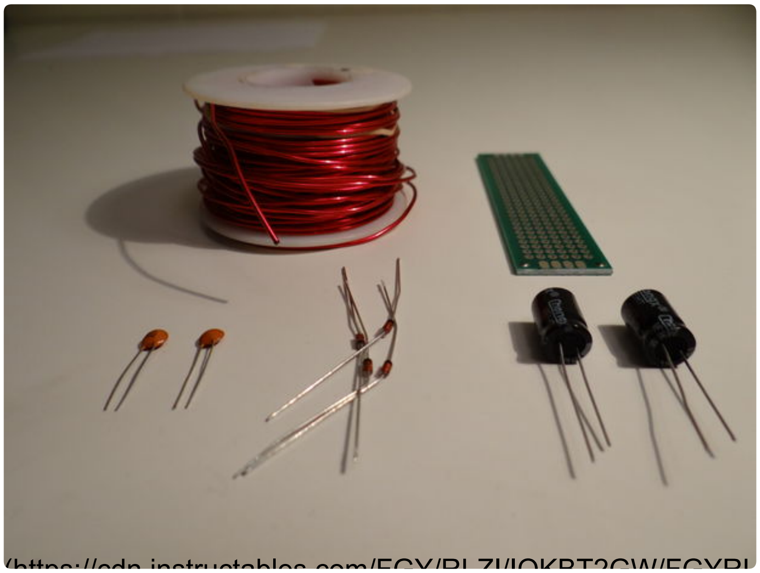

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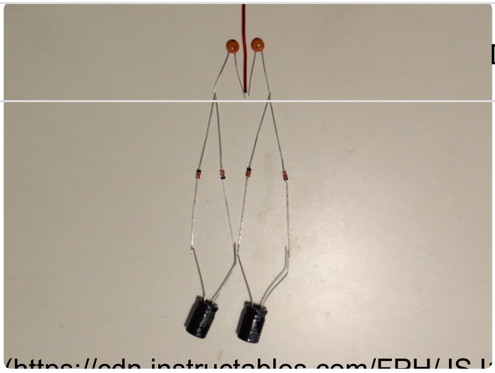

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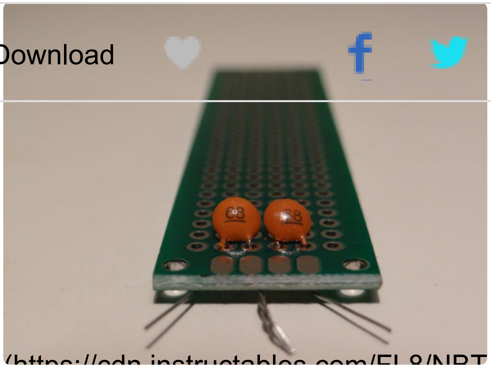

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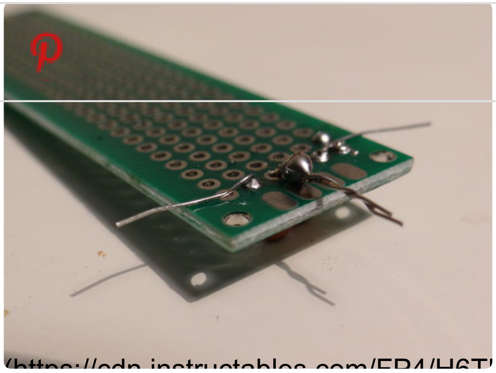

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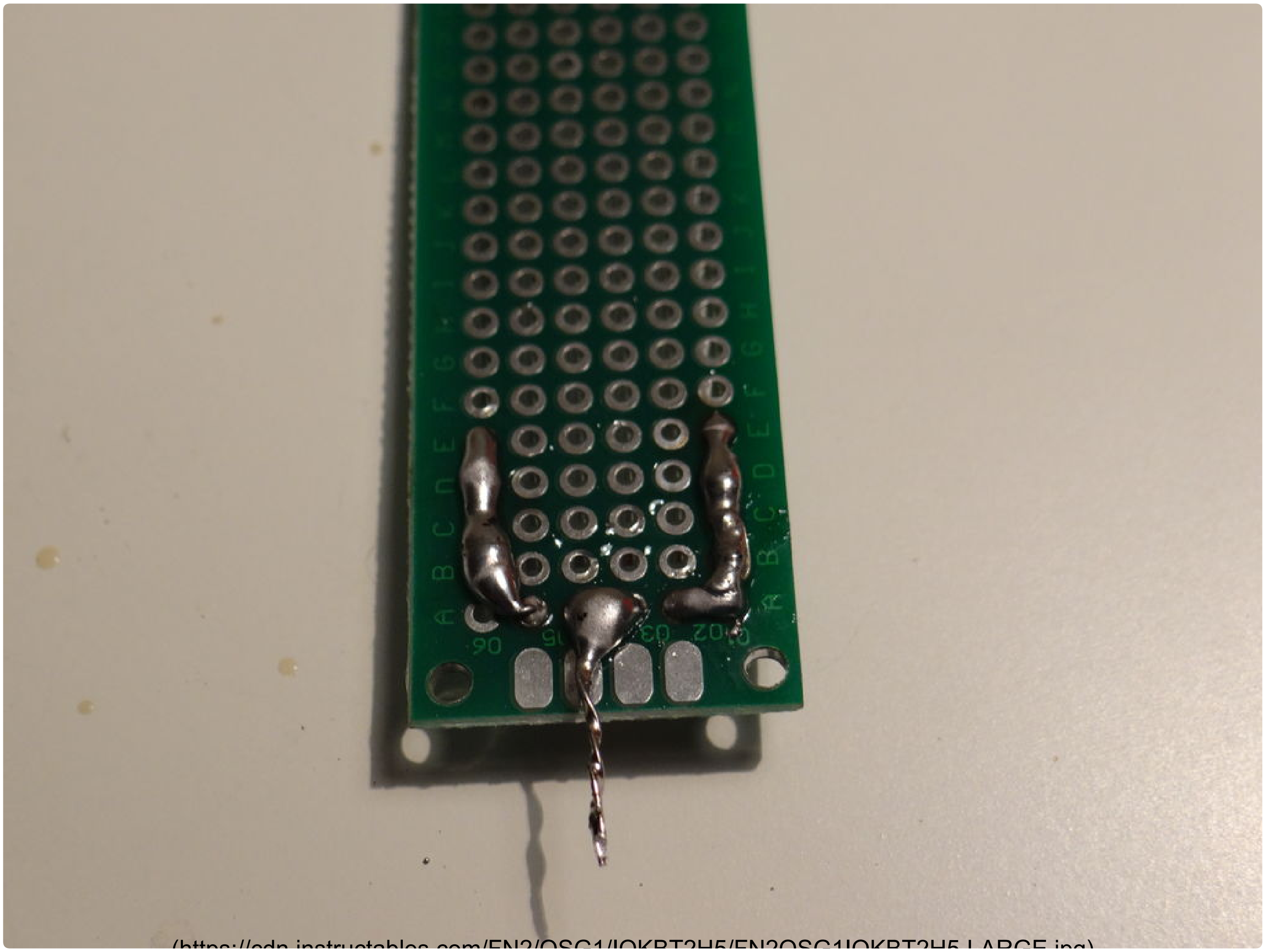

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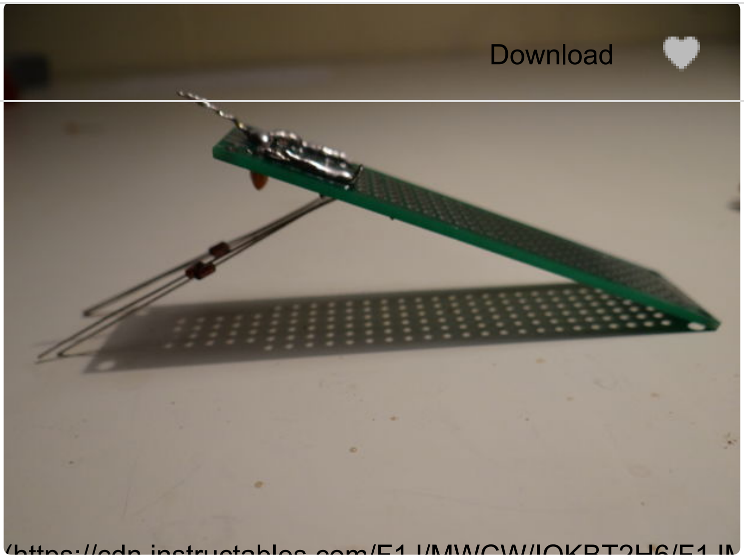

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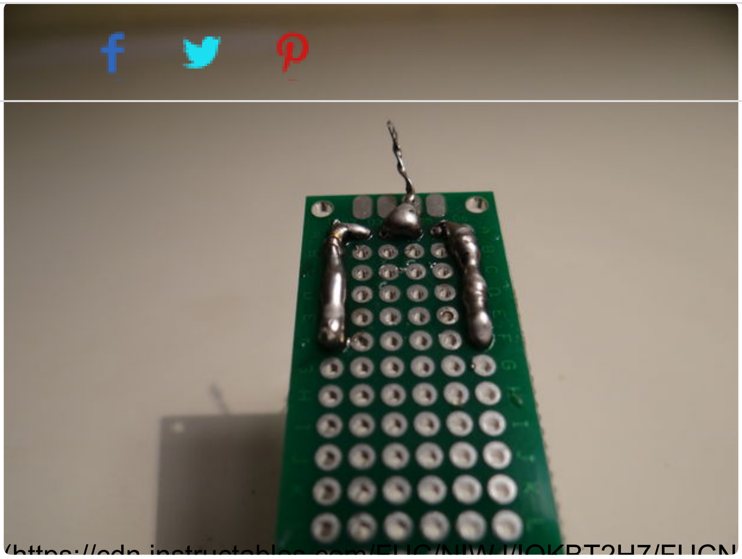

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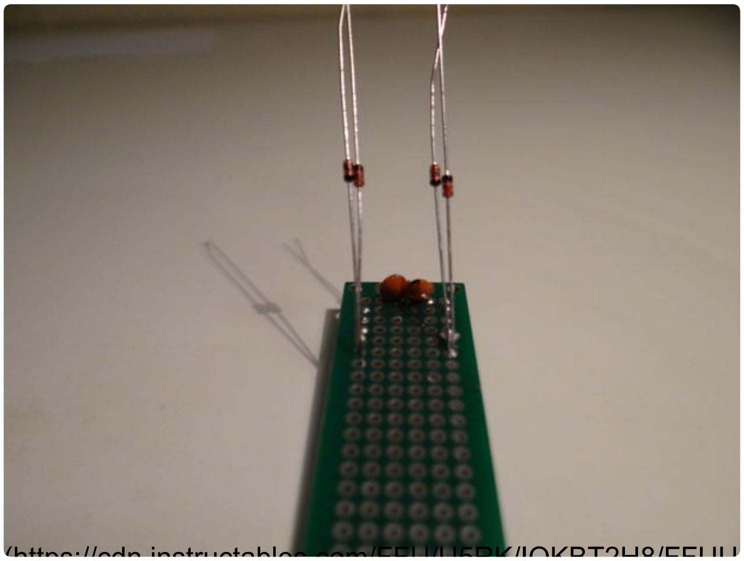

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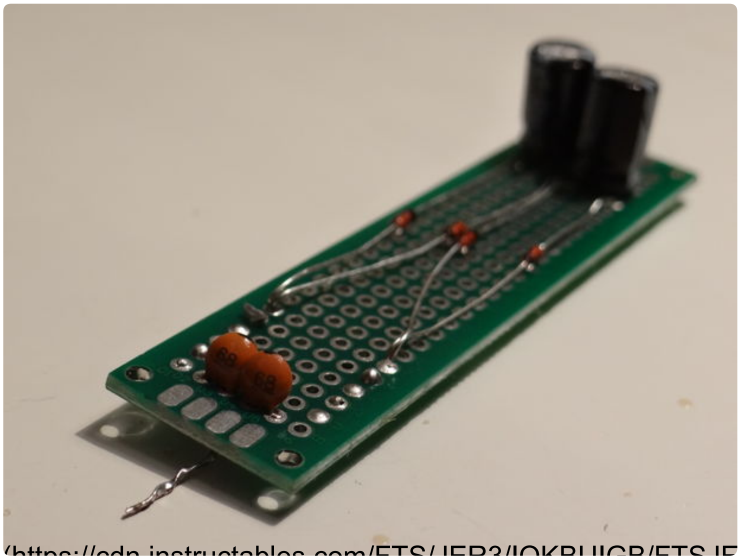

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We're going to build the simplest version of this circuit variation in order to understand how each component interacts and as a proof of concept.

There are three simple systems at work in the circuit that are composed of capacitors, which store energy, and diodes that direct it.

Energy in the band of radio waves, among others, will vibrate a wire antenna on an atomic level, sending a discernible signal to its lead. This signal will then meet the junction between two ceramic capacitors wired in series. This junction will force positive charge from the wave to travel in one direction and negative charge in the other direction which, when collected again, makes the signal uniform and polar. Connecting the two capacitors in series creates leads on each end; the now positively charged side of one and the now negatively charged side of the other creates a two cell battery. Download

This next stage of the circuit takes a signal with a net value of zero, adds the absolute values of the positive and negative amplitudes with respect to the origin and produces a positive integer. This concept can be thought of as taking:

(+1) + (-1) + (+1) + (-1) = 0

and converting it to:

| [(+1) + (+1)] | = 2
+
| [(-1) + (-1)] | = 2
= 4

Isn't math fun?

To each of these leads from our two capacitors in series, we will connect two crystal diodes, one facing each direction, to form what is called a bridge rectifier. A bridge rectifier is a configuration which will convert an alternating current to a direct one by cleverly rerouting the signal.

By connecting the bridge rectifier as shown in the circuit diagram, this direct current from the diodes then charges the electrolytic capacitors. This stage normalizes the amplitude, making the current constant and usable.

Components can easily be twisted together for testing and then soldered to a circuit board to secure.

Add Tip Ask Question

Step 3: Test and Optimize Your Circuit

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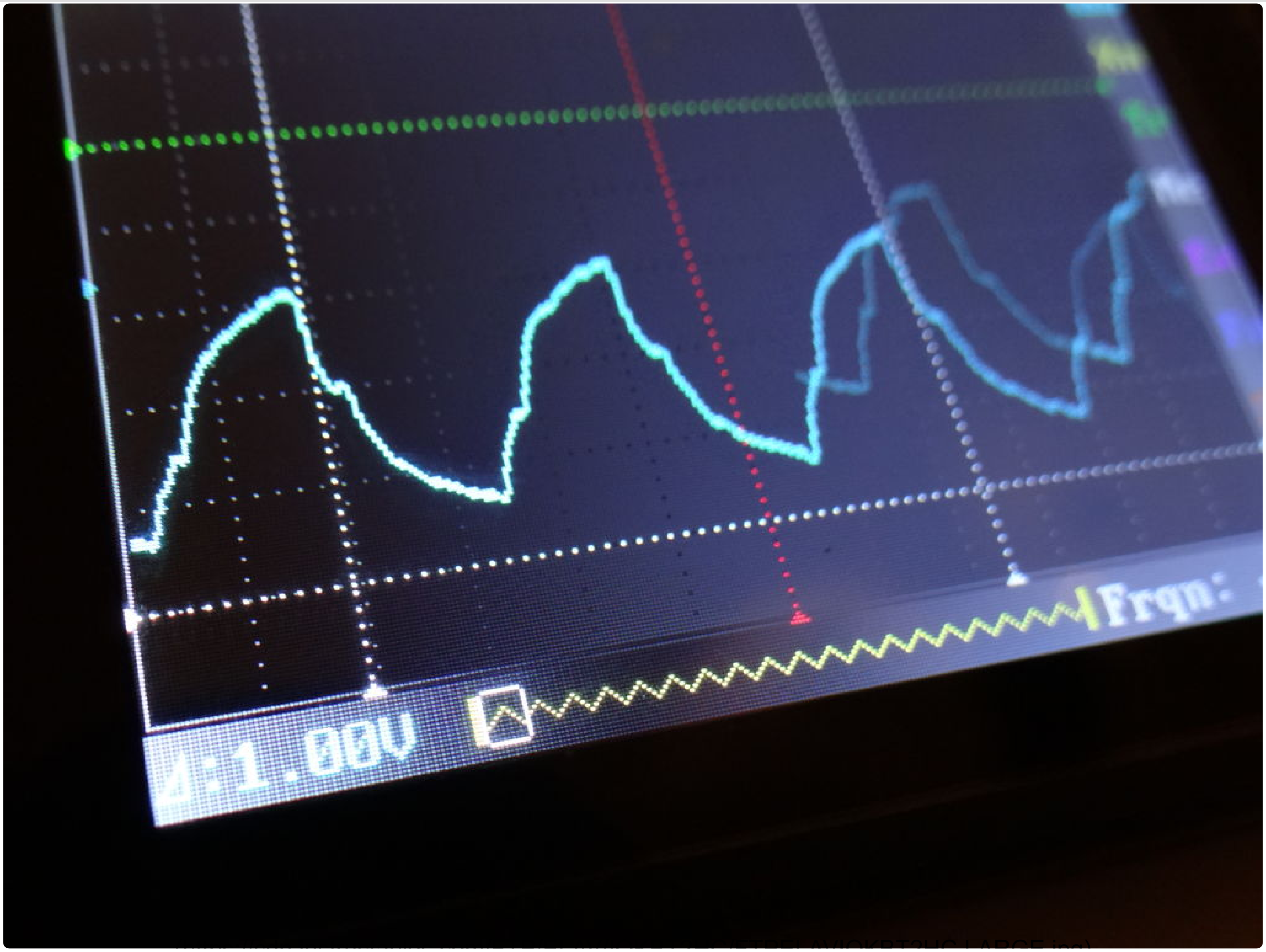

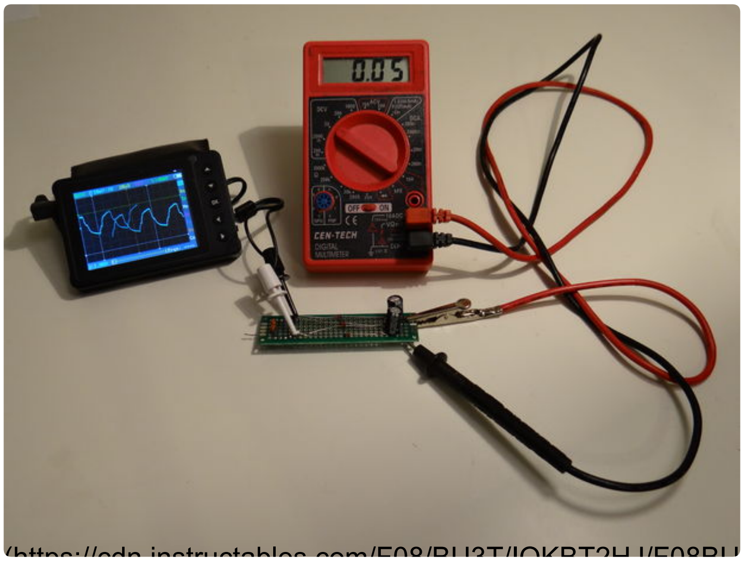
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DIGITAL MULTIMETER

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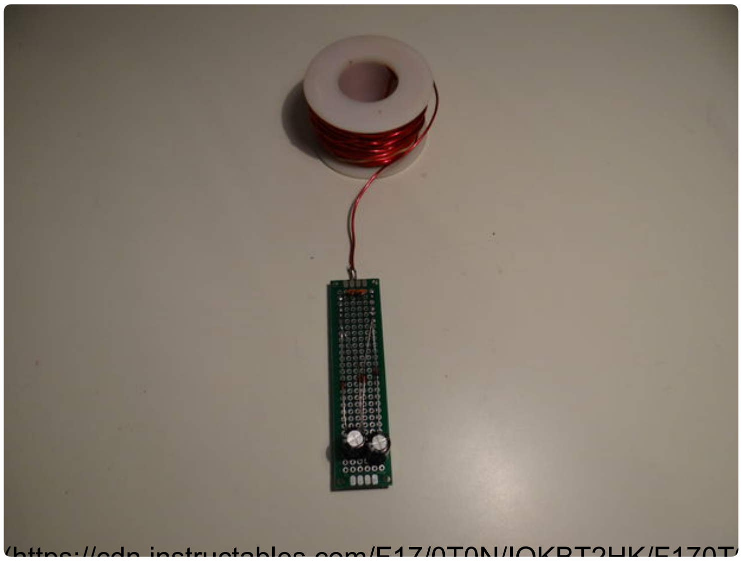

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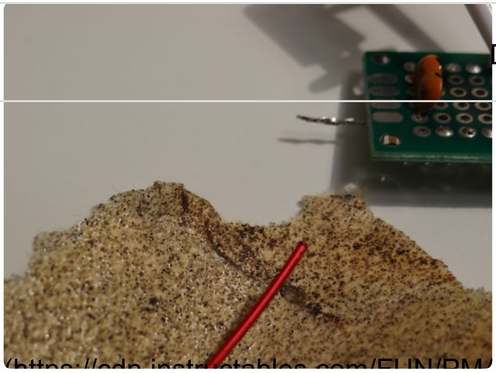

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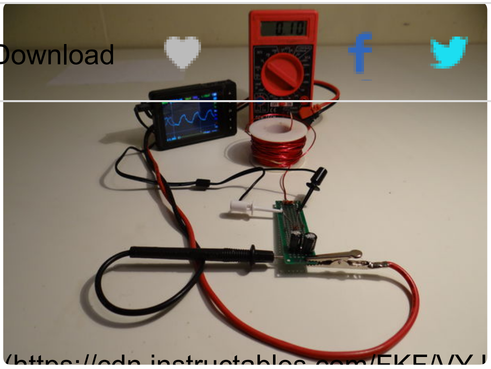

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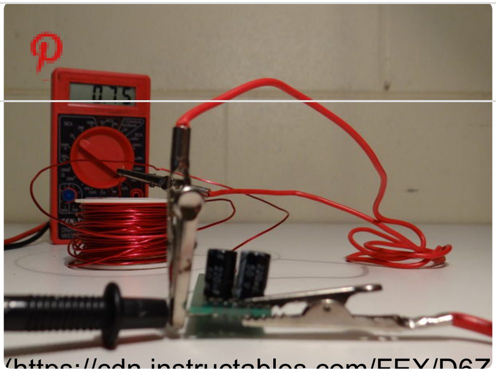

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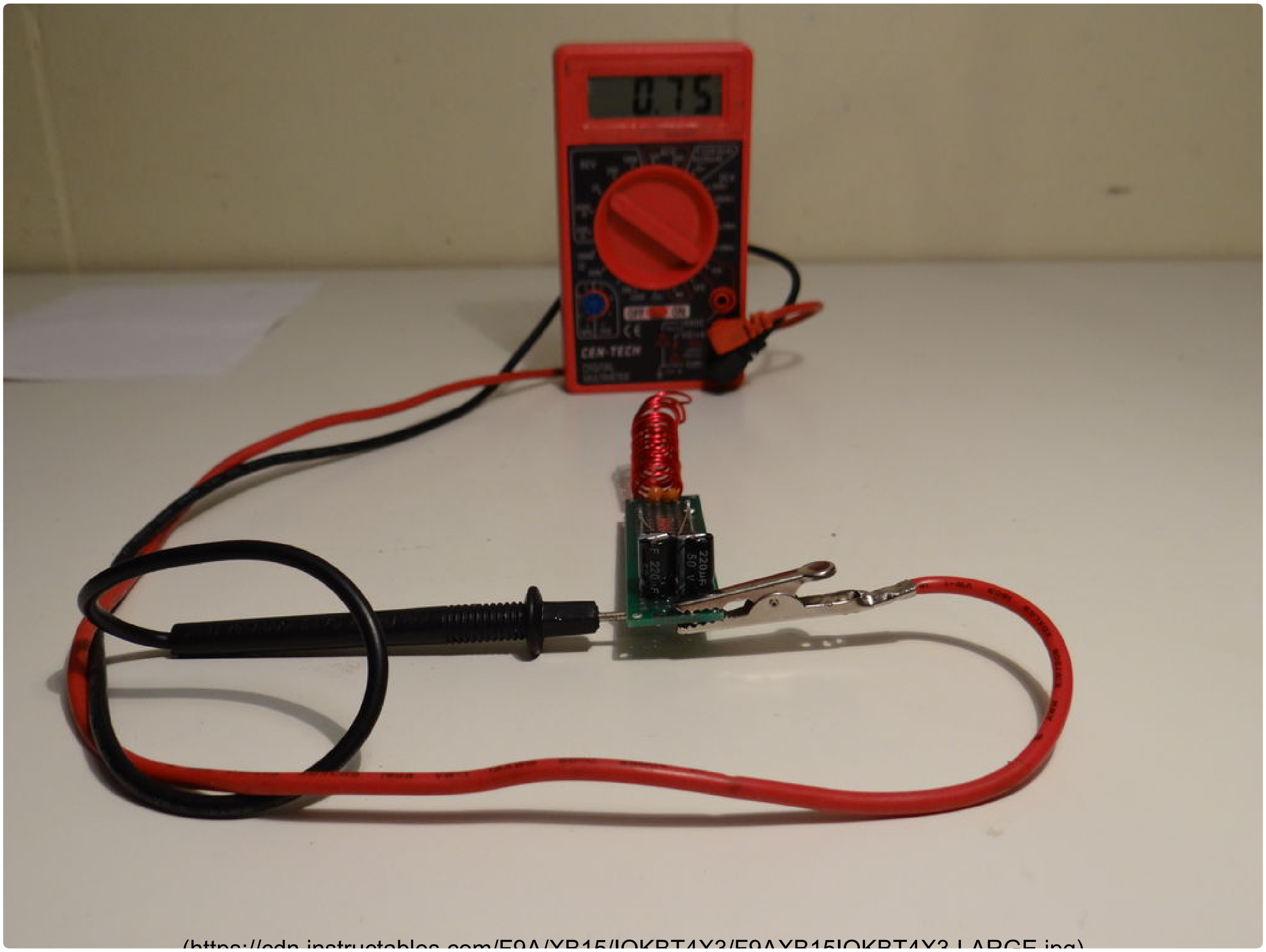

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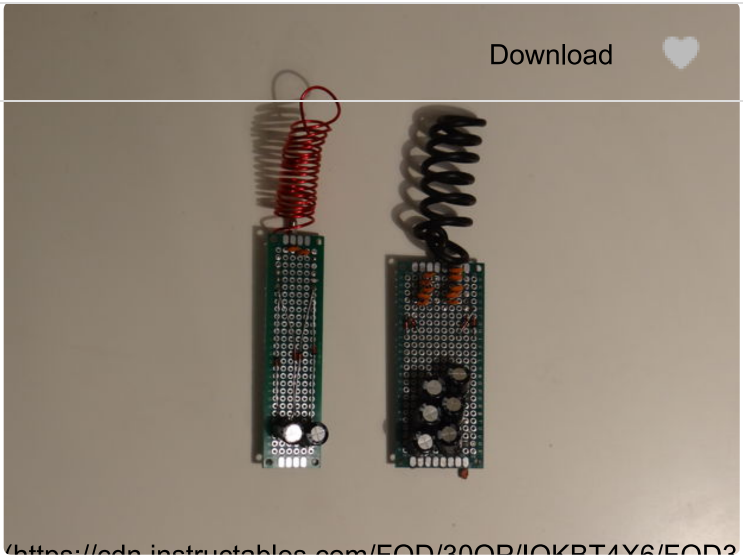

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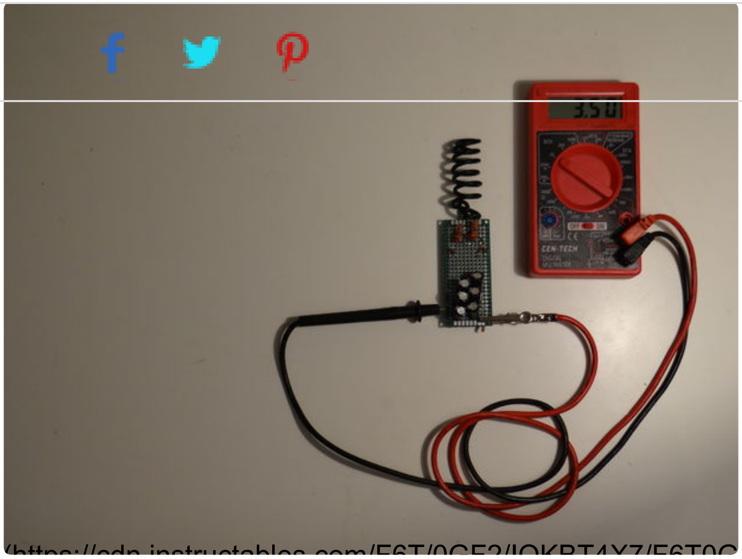

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To test and analyze our circuit, we'll be using a digital voltmeter and oscilloscope.

By connecting a voltmeter to the output, we'll immediately begin to see a small voltage climbing in the 10-100mV range. If not, we'll want to check our connections and make sure the circuit is not isolated from the environment by taking it outside to a clear area.

Then, by connecting an oscilloscope to the outside leads of our two ceramic capacitor bank, we will see the the polarized signal being captured from the air around us. We can then connect after the diodes to see our varying direct current and then to after the electrolytic capacitors to see a normalized, usable direct current at our output.

We can then optimize the input resistance in two ways. Firstly, we can add additional ceramic capacitors in parallel to our original two and make sure our soldered connections are consistent and thick in this area.

We can optimize the circuit's capacity by adding electrolytic capacitors in parallel to our original two which will allow this circuit to charge slightly when not in use. For this purpose, a charging circuit can also be added here in order to incorporate an optional battery bank.

We can optimize the antenna by attaching loops and coils of copper wire in various positions, store-bought antennas or by stringing some wire up to the highest point you can reach.

We don't have to stop there, either. We can now connect multiple circuits in series to increase voltage or in parallel to increase current. This can be done indefinitely.

Add Tip Ask Question

Step 4: Add a Case and Antenna

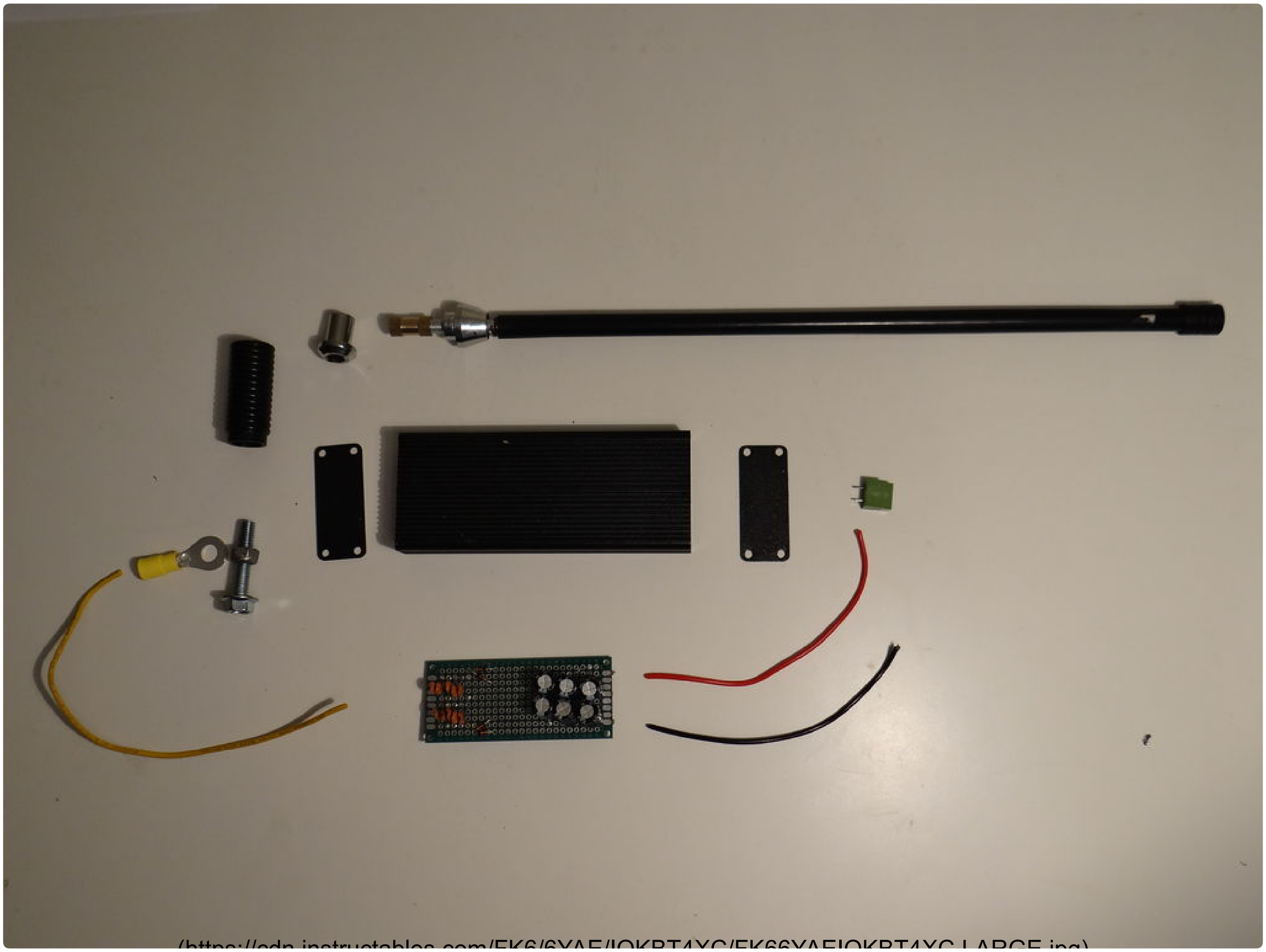

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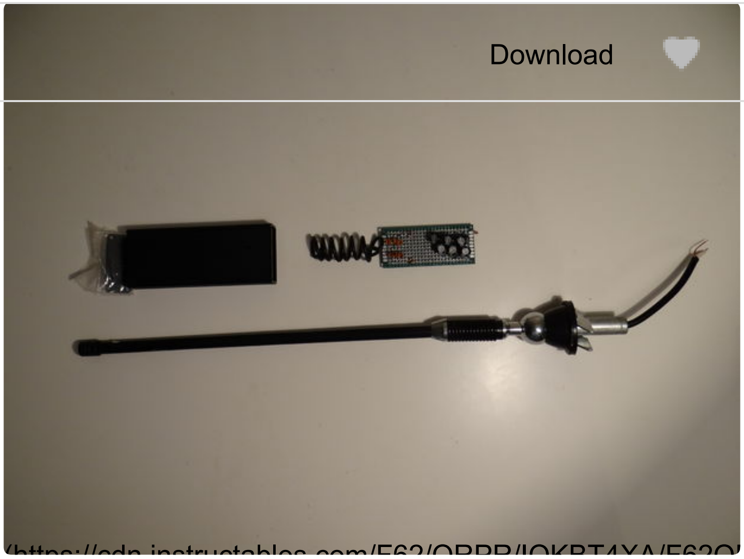

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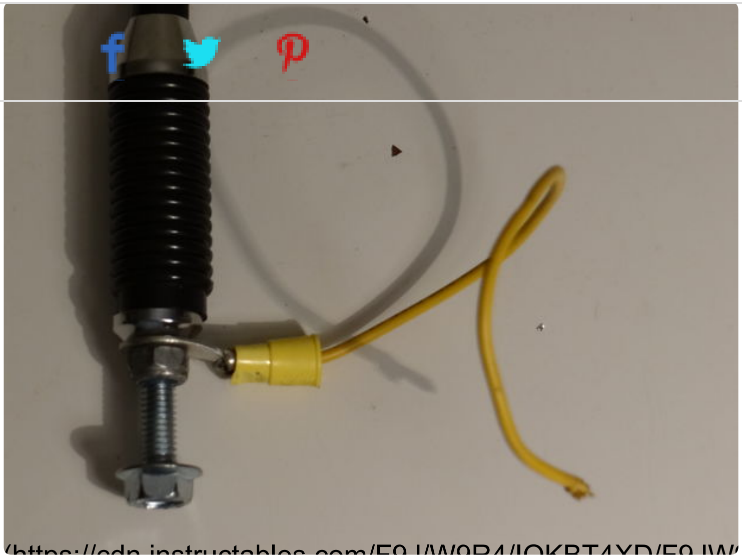

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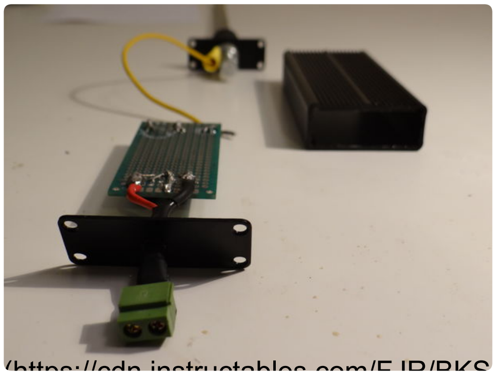

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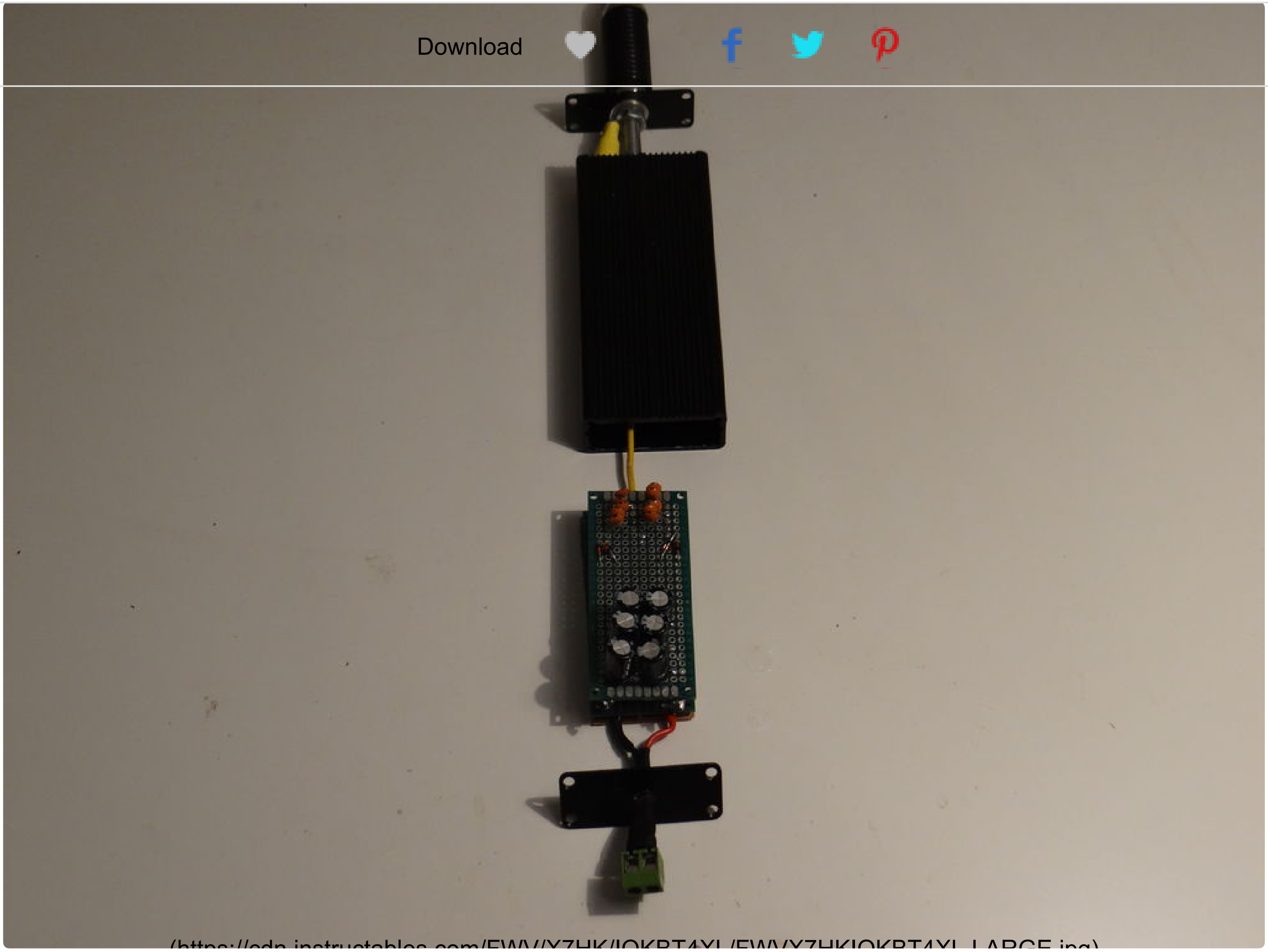

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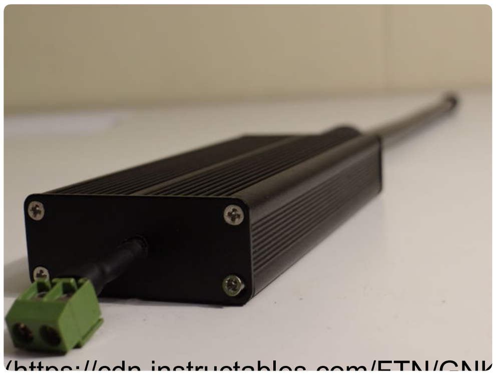

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After choosing an antenna in the last step we'll now want to permanently wire it. Whether you choose a compact antenna for portability or a tall fixed antenna for power and range, we will wire it in the same manner according to the diagram in the previous step. Note that the input on the configuration here is grounded to the metallic case, and thus the users hand, and incorporation of longer antennas will require proportionally more substantial grounding.

We will then attach a terminal to the output to allow us to connect this circuit to an electrical device or charging circuit and battery bank.

Next, we will add a case, making sure to isolate exposed leads with non-conductive material especially if mounting in a conductive case. A piece of cardboard secured with glue is sufficient for the circuit's bottom and shrink wrap or electrical tape can be used in the case of any additional exposed leads. Drill two holes in your enclosure, one for the antenna or antenna lead and another for your output terminals. You can then insert your components, fasten the enclosure and your device is ready to use!

Add Tip Ask Question

Step 5: Your Crystal Energy Receiver Is Complete!

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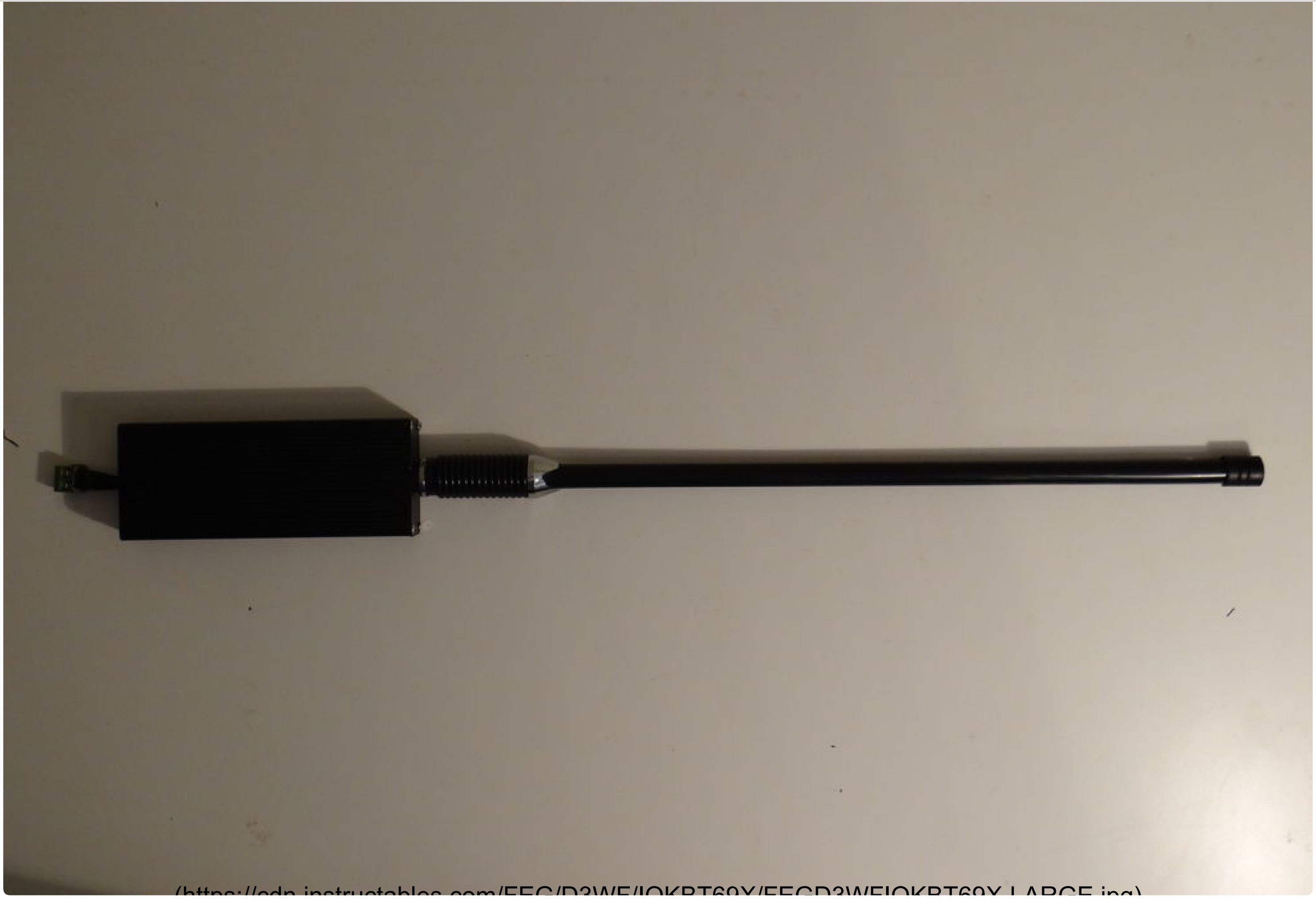

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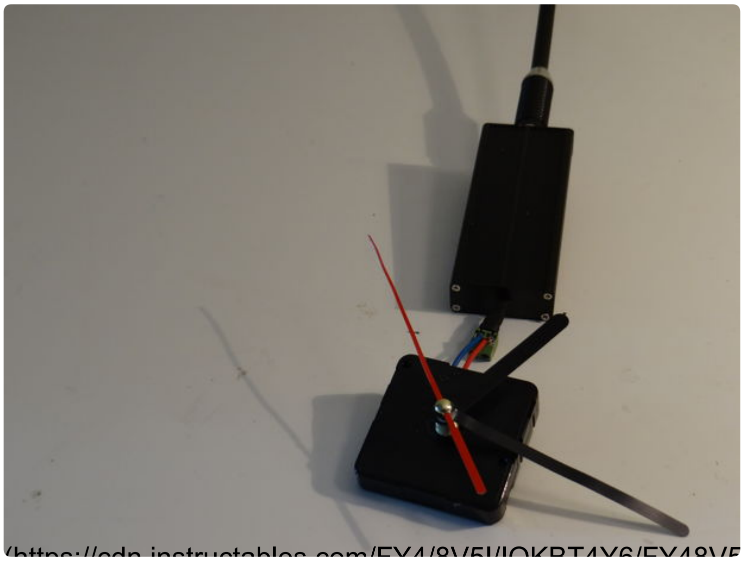

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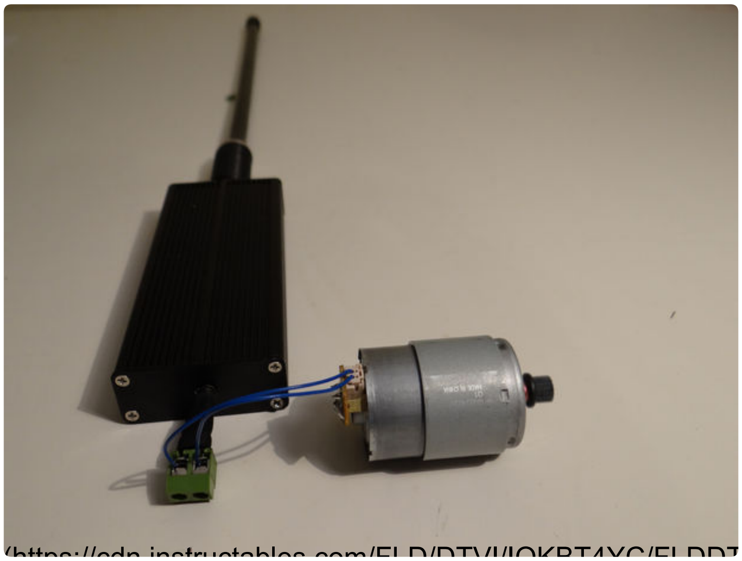

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Your Crystal Energy Receiver is now complete and ready to use!

I built a portable version, for proof of concept and demonstration purposes. However, you can go as big as you want- to passively charge batteries or run equipment remotely; or go as small as you want- to power sensors, RFID devices, small electronics and more.

I used this harvested energy to easily power a low-consumption quartz clock, a digital chronograph with integrated circuits and LCD and was even able to momentarily rotate a small dc motor.

Because of its simplicity this device is a durable, efficient and reasonably effective method of harvesting radiant energy in a simple, replicable and sustainable way. I humbly hope that the contributions made here, and by those reading, can be one day used by people worldwide to conveniently capture free energy.

Thanks for checking out my project and I look forward to seeing everyone's variations, suggestions and improvements!

Add Tip Ask Question

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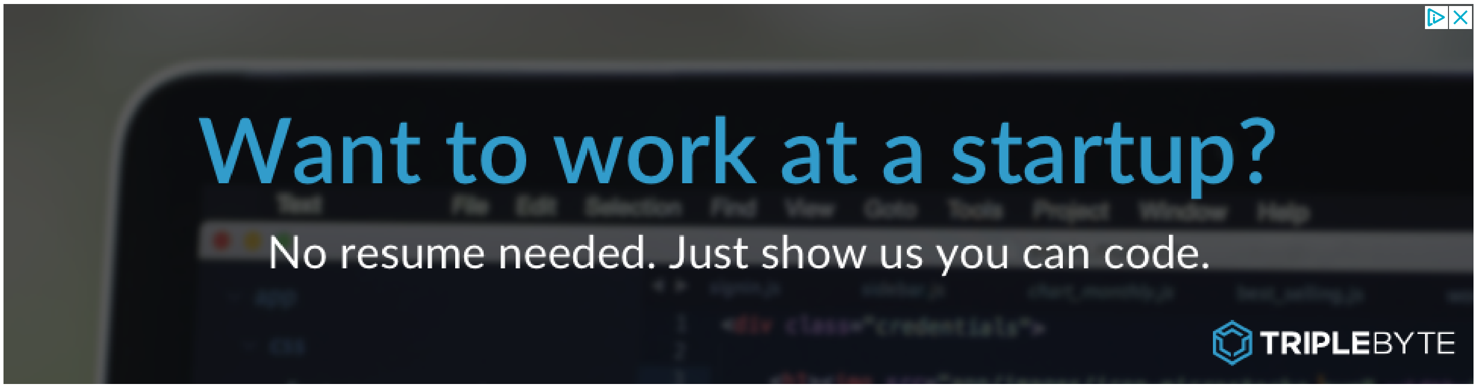
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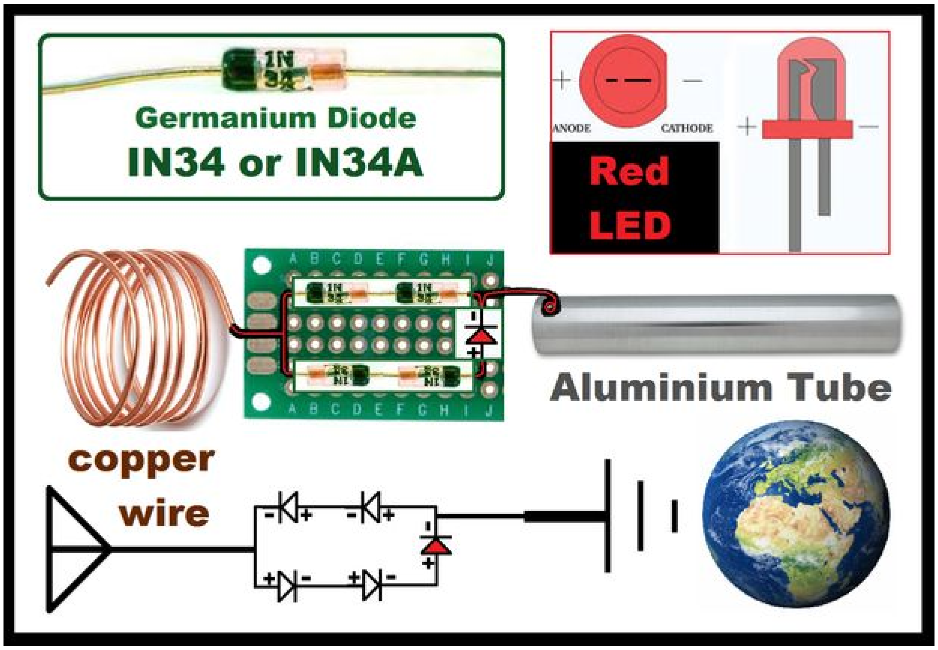
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Germanium Diode
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Red LED
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Aluminium Tube
copper wire

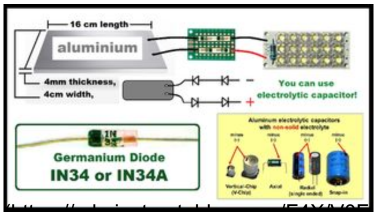
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aluminium
4mm thickness, 4cm width,
You can use electrolytic capacitor!
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IN34 or IN34A
Aluminum electrolytic capacitors with non-solid electrolyte

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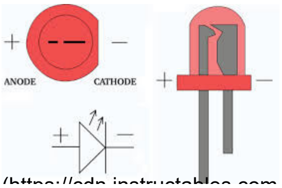
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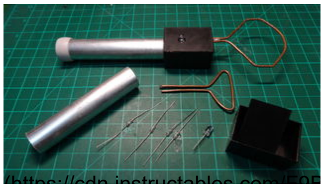

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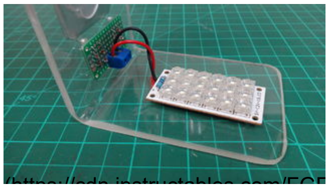

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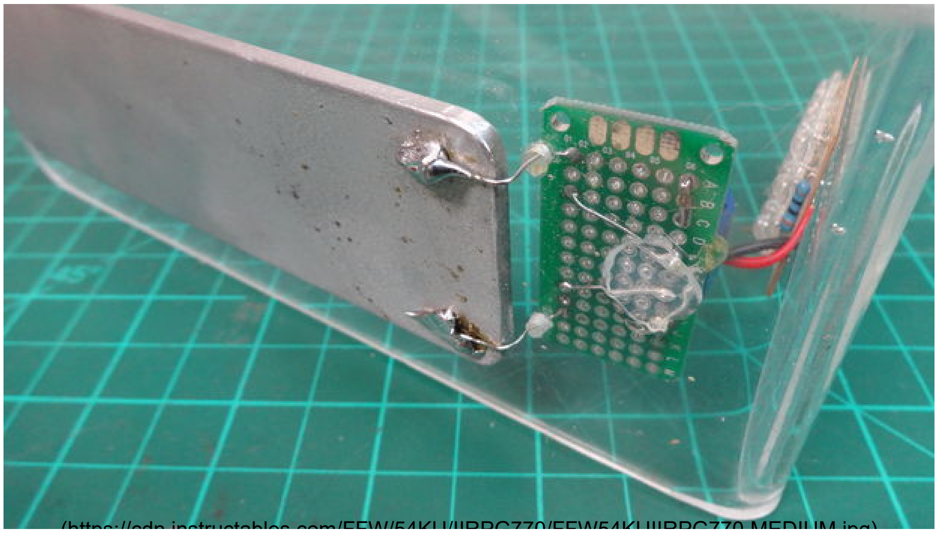

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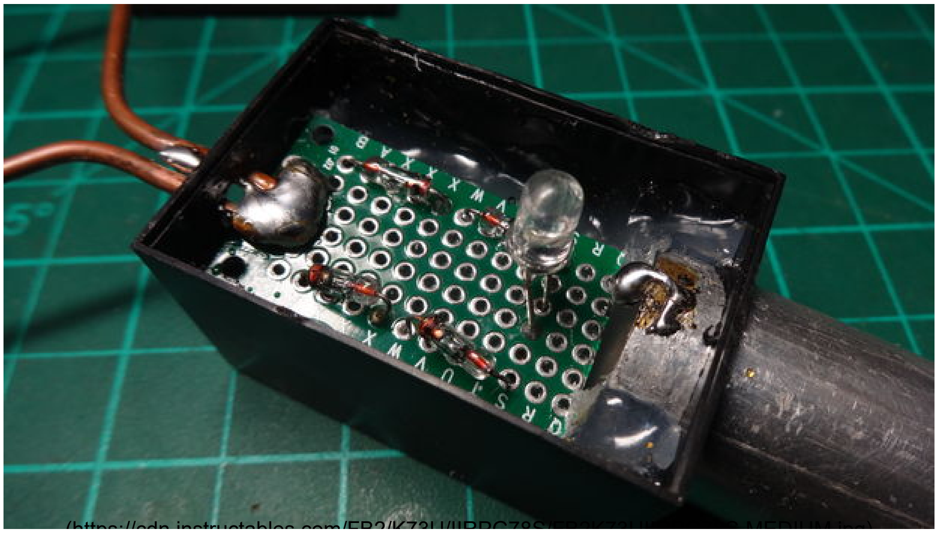

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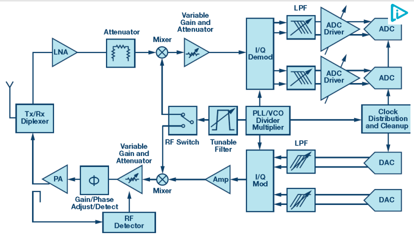

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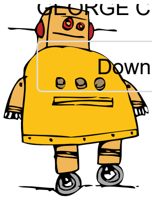

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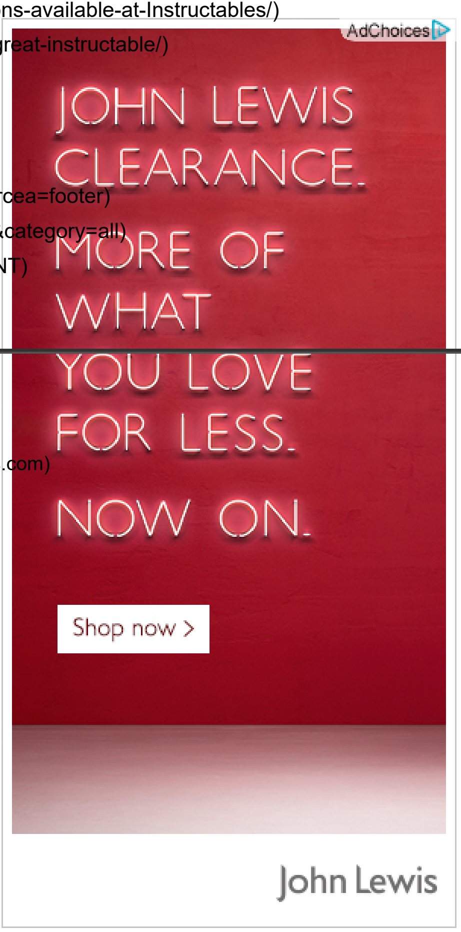

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Build a Homebrew Radio Telescope

Explore the basics of radio astronomy with this easy to construct telescope.

Mark Spencer, WA8SME

There are many ham radio related activities that provide a rich opportunity to explore and learn more about the science of radio. One of those opportunities is radio astronomy.

All matter emits radio frequency (RF) energy dependent on the temperature and makeup of the matter, including the matter in space. The foundation of radio astronomy is to study the heavens by collecting and analyzing the RF energy that is emitted by bodies in space, very much as optical astronomers use light energy collected by telescopes. It sounds complicated. While professionals use very sophisticated and expensive equipment, you can, with some simple equipment and a little investment, build a radio telescope that will allow you to learn and explore the fundamentals of radio astronomy.

A Homemade Radio Telescope

In this article, I will build on an existing design of a radio telescope made from one of those ubiquitous TV dish antennas that you see around your neighborhood. The radio telescope (RT) project described here can easily be reproduced. Although this is not a fully capable RT, it can provide a wonderful learning opportunity for you, or perhaps students in your local school.

Figure 1 shows the radio telescope set up. The major components include a modified TV dish antenna mounted on a wooden support structure to allow pointing the antenna, a commercial satellite signal strength detector that displays the signal strength of signals collected by the dish on a meter and an interface that converts the signal strength into a amplitude modulated tone. The tone is fed into a computer sound card and finally a computer and software graphically displays the signal strength as a function of time.

The TV dish modifications are structural, and any available TV dish system can be used. The signal strength detector costs between $40 and $65 and is widely available from Web retailers. The interface circuit, which will be described shortly, is easily duplicated and costs approximately $20. Finally, the display software is free.

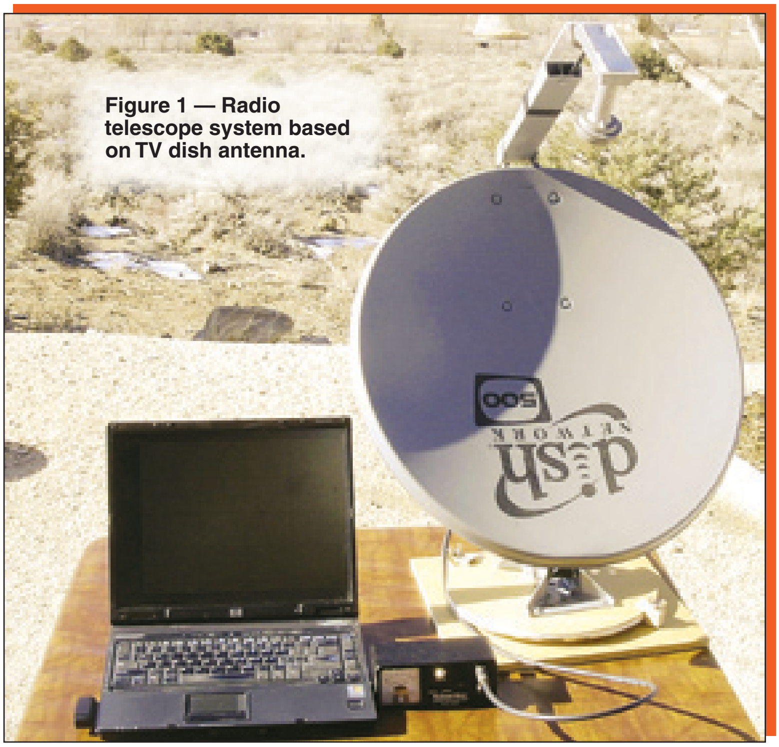

Figure 1 — Radio telescope system based on TV dish antenna.

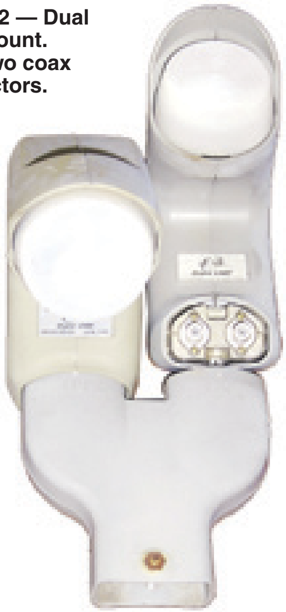

Figure 2 — Dual LNB mount. Note two coax connectors.

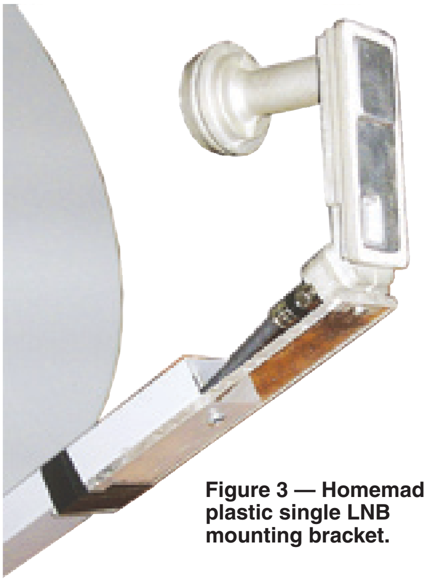

Figure 3 — Homemade plastic single LNB mounting bracket.

What it Can Do

The following is just a sample of what you can do with this simple RT:

- Use the sun to study and determine the beamwidth of the dish and verify the mathematic formula that is used to predict dish antenna performance.
- Measure the radiation intensity of the Sun and perhaps detect changes in solar activity.
- Measure the relative changes in the surface temperature of the moon.
- Learn about and explore a common radio astronomy collection technique called the *drift scan*.

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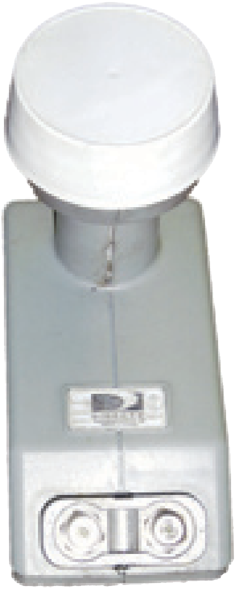

Figure 4 — Dual coax connector configured LNB. Terminate one connector with a dummy load.

- Explore the fundamental principle of energy emission as a function of temperature by detecting the relative differences between the temperatures of emitting bodies.
- Detect satellites parked along the Clarke Belt in geosynchronous orbit and illustrate how crowded space has become.

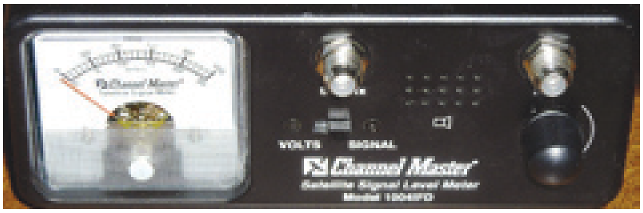

Figure 5 — CM satellite signal strength meter.

- Detect the Earth's rotation around the Sun and the Earth's spin on its axis by comparing daily drift scans of the horizon.

Antenna Subsystem

The basic RT system is based on the "Itty-Bitty" design that is described in two Web pages.[1,2] The TV dish is an offset 18 inch dish that has down converter(s) mounted at the focal point of the dish. The down converter is called a low noise block (LNB). The LNB is a preamplifier/down converter that converts the satellite signals from around 12 GHz down to around 2.4 GHz. Most modern dishes have two or more LNBs to access more than one TV satellite at a time without changing the pointing of the dish (Figure 2). The LNBs are mounted to share the focal point of the dish. Since only one LNB is required for the RT, I made a minor adjustment to the published Itty-Bitty design to position the single LNB at the dish focal point. Mounting the single LNB at the focal point really helps in pointing the antenna.

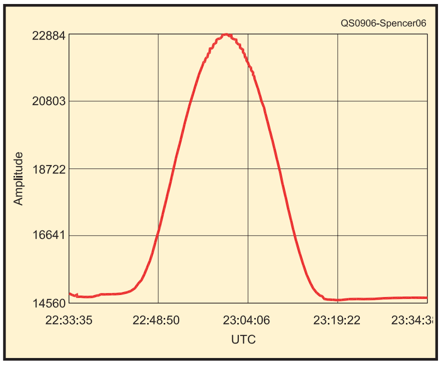

Figure 6 — *SkyPipe* screen showing antenna response.

I used the existing LNB housing and mounting bracket as a template to determine the distance between the edge of the mounting arm to the mounting hole of the LNB. I then used a piece of plastic to fabricate a new mounting bracket for the LNB as shown

[1] Notes appear on page 45.

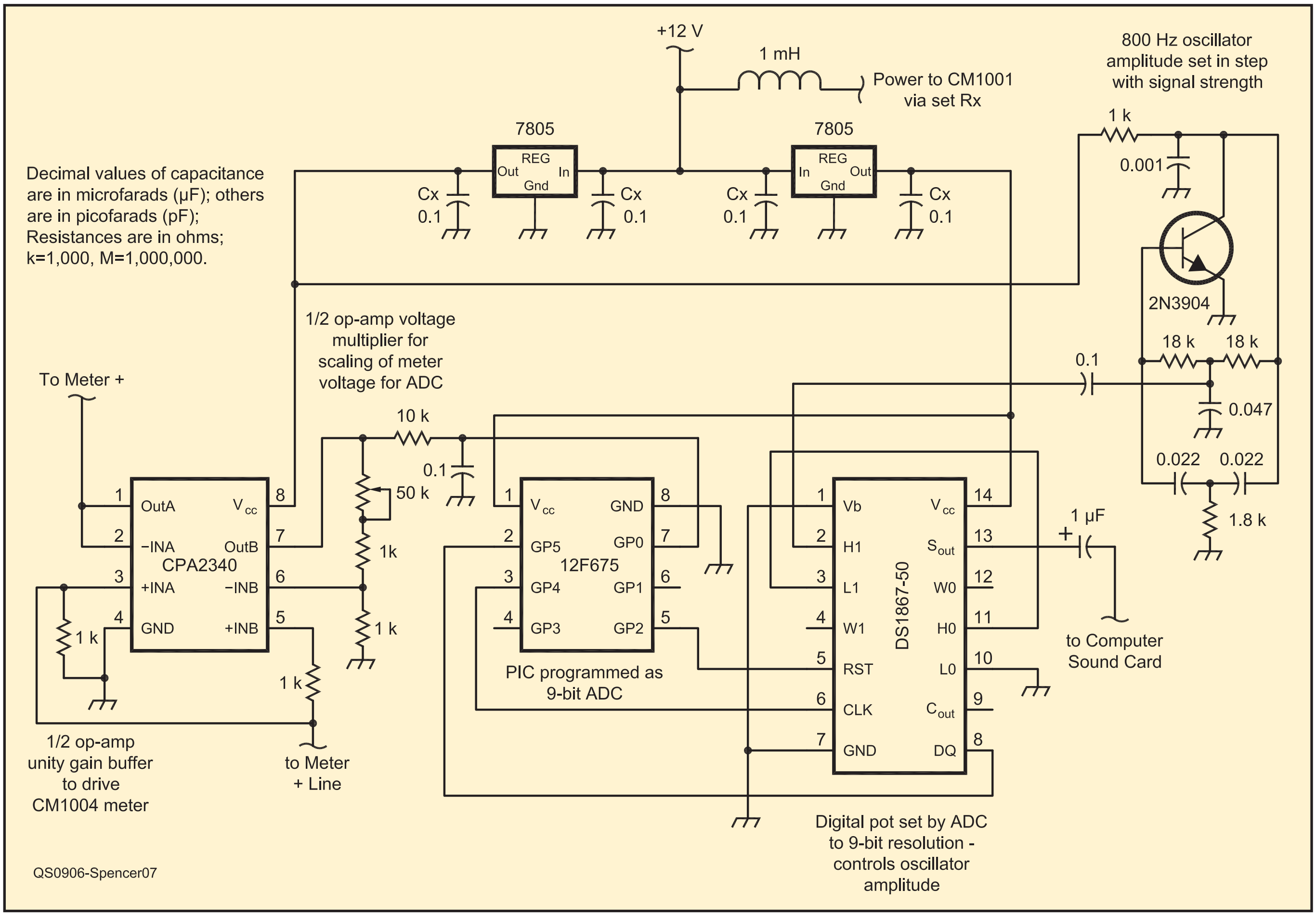
+12 V
1 mH
Power to CM1001 via set Rx
800 Hz oscillator amplitude set in step with signal strength
7805
REG
Out
In
Gnd
7805
REG
In
Out
Gnd
Cx 0.1
Cx 0.1
Cx 0.1
Cx 0.1
1 k
0.001
2N3904
Decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); Resistances are in ohms; k=1,000, M=1,000,000.
1/2 op-amp voltage multiplier for scaling of meter voltage for ADC
To Meter +
10 k
0.1
50 k
1k
1 k
0.1
18 k
18 k
0.047
0.022
0.022
1.8 k
1 μF
OutA
Vcc
−INA
OutB
CPA2340
+INA
−INB
GND
+INB
1 k
1 k
Vcc
GND
GP5
GP0
12F675
GP4
GP1
GP3
GP2
PIC programmed as 9-bit ADC
Vb
Vcc
H1
Sout
L1
W0
W1
H0
RST
L0
CLK
Cout
GND
DQ
DS1867-50
to Computer Sound Card
1/2 op-amp unity gain buffer to drive CM1004 meter
to Meter + Line
Digital pot set by ADC to 9-bit resolution - controls oscillator amplitude
QS0906-Spencer07

Figure 7 — RT Interface circuit diagram.

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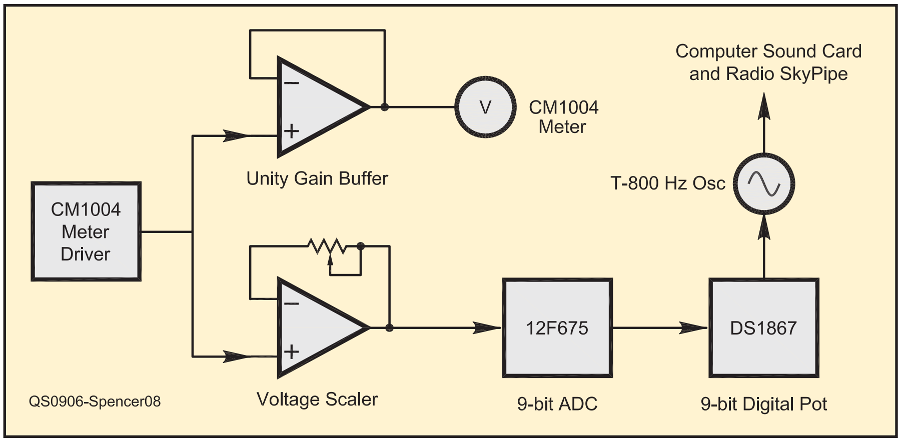

Figure 8 — RT Interface block diagram.

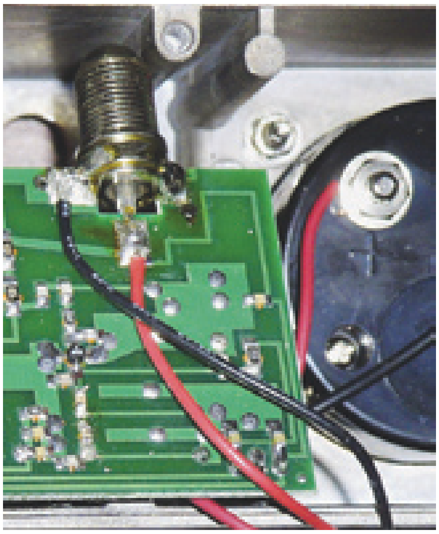

Figure 9 — Power and ground connection to CM board.

in Figure 3. The dimensions are not super critical, but careful placement certainly will improve the RT performance.

Some LNBs have two coax connectors. Only one will be used in the RT (Figure 4). It is a good idea to terminate the extra coax connector with a 75 Ω dummy load plug to balance the load on the LNB. The dummy loads for F type TV coax connectors are readily available from electronic parts retailers.

Note that the dish is mounted upside down. Though this orientation is not ideal for receiving satellite signals, this arrangement helps with pointing the dish in its radio telescope role.

Satellite Detector

The detector used in this project is the Channel Master (CM) satellite signal level meter model 1004IFD (Figure 5).[3] The CM is connected to the LNB. Power is supplied to the LNB through the coax connection from the CM. The CM detects the signal coming from the LNB and gives a meter indication of the signal strength and also varies the frequency of an audio tone to help technicians point the dish at the desired satellite. As you move the dish through the beam coming from the satellite, the meter indication will increase and then decrease coincident with the pitch of the audio tone.

The Itty-Bitty plans detail how to connect power to the CM and in turn connect power to the LNB (this power connection is handled by the interface in this project). Though somewhat effective, the CM meter and variable frequency tone indications provide limited utility in detecting changes in signal strengths required for radio astronomy.

Display

To really study the signals received by the RT, you will need to see them displayed graphically on a strip chart. There is an excellent software package called *Radio-SkyPipe* that is posted on radio astronomy Web sites.[4] The free version of this software is a good place to start. *SkyPipe* uses the computer sound card to measure the incoming signal strength and graphically displays the signal strength as a function of time. Figure 6 is illustrative of a signals detected by the RT. *SkyPipe* is very easy to use but some study of the HELP files will make it easier for you to fully tap into the capabilities of this software.

SkyPipe requires audio signals to be fed into the sound card MICROPHONE jack. The output of the CM detector is either an analog meter reading or a frequency modulated (constant amplitude) tone that is not really compatible with *SkyPipe*. An interface is required.

Interface

What is required to make the CM output work with *SkyPipe* and a sound card is to convert the signal level into an amplitude varying audio tone. The interface designed to do this is shown in Figure 7 and as a block diagram in Figure 8. Refer to the block diagram during the description of the interface function.

The unity-gain op-amp is used as a buffer between the CM meter driver circuit and the analog meter. The other op-amp is used as a voltage multiplier to scale the CM meter driver output voltage to match the 5 V reference voltage of the following analog to digital converter (ADC). The variable resistor in this voltage multiplier circuit is used to calibrate the CM to *SkyPipe*. The voltage from the multiplier is fed to a programmable interface controller (PIC) that is programmed as a 9-bit ADC to covert the analog voltage that is a function of received signal strength to a 9-bit digital word that is used to control a digitally controlled variable resistor. The interface includes a simple Twin-T audio oscillator circuit that provides a tone of approximately 800 Hz that is fed to the computer sound card. The amplitude of this audio oscillator is varied by the digital pot that is being controlled by the PIC. The result is the audio amplitude being varied in step with the signal strength detected by the CM.

The circuit provides power to the CM and the LNB. A 12 V source in the CM is tapped through an RF choke and this is connected to the LNB coax connector inside the CM (Figure 9). The 12 V is also regulated to 5 V to provide power to the interface. Though probably not required, there are two 5 V sources, one for the digital components of the interface, and the other for the analog components with one common ground point. This arrangement is used to isolate potential digital and analog noise sources within the circuit.

The interface is built on a circuit board and mounted right inside the CM box

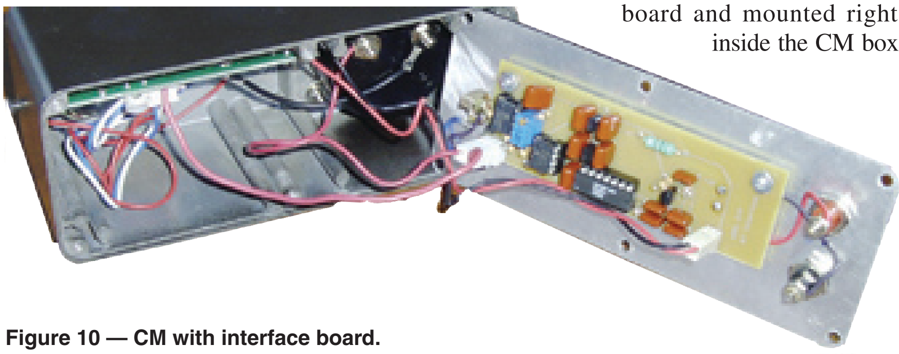

Figure 10 — CM with interface board.

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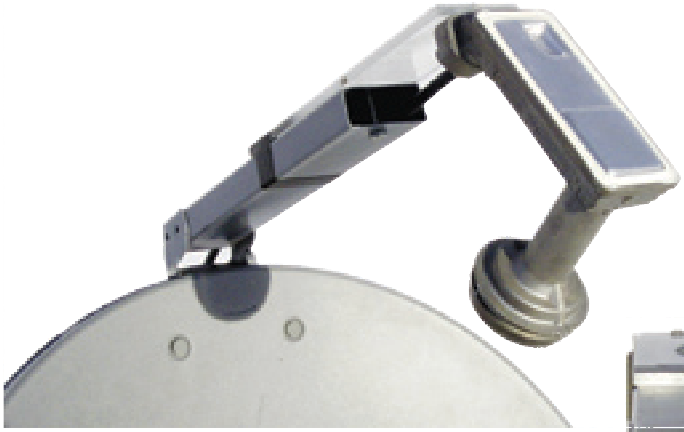

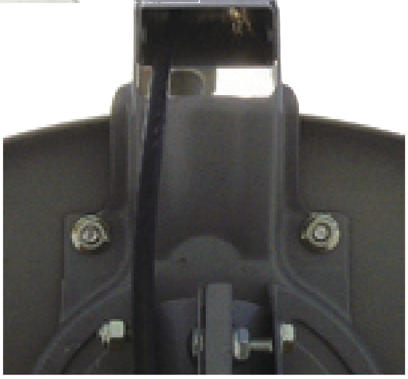

Figure 11 — Aiming the RT at the Sun, note LNB shadow location.

(Figure 10). Though I made an etched circuit board for the circuit, the hand wired prototype worked equally well for those who would rather roll their own. The PIC firmware is available on the *QST* Web site.[6]

RT in Action

The first thing you need to do is learn how to point the RT antenna. The best place to start is to connect the CM to the antenna and point the antenna at the Sun. *Caution*: Do not look into the Sun as you do this, or at any time. Adjust the pointing angle and elevation until you get peak signal strength as indicated on the CM meter or hear the highest pitch audio tone. With the antenna pointed directly at the Sun, take note of the position of the shadow of the LNB on the surface of the dish (left in Figure 11). If you look from behind the dish, along the LNB

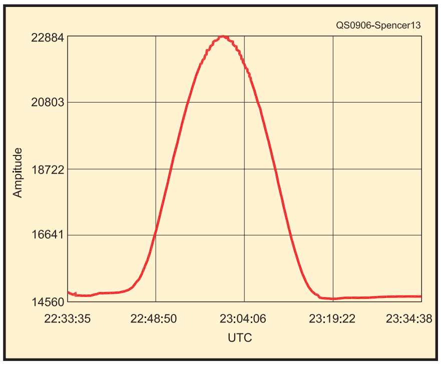

Figure 13 — Drift scan of the Sun indicating antenna's azimuth pattern.

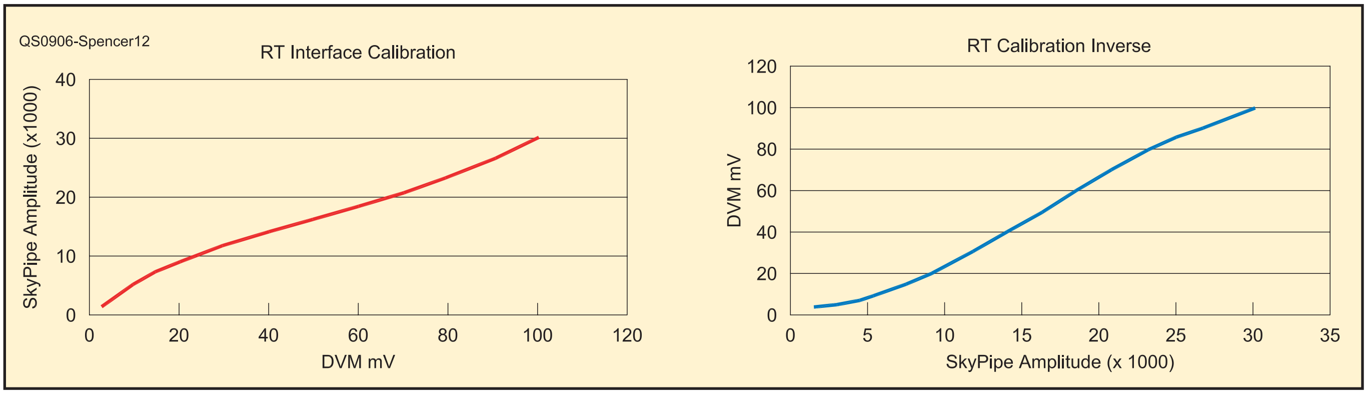

Figure 12 — Example calibration curves.

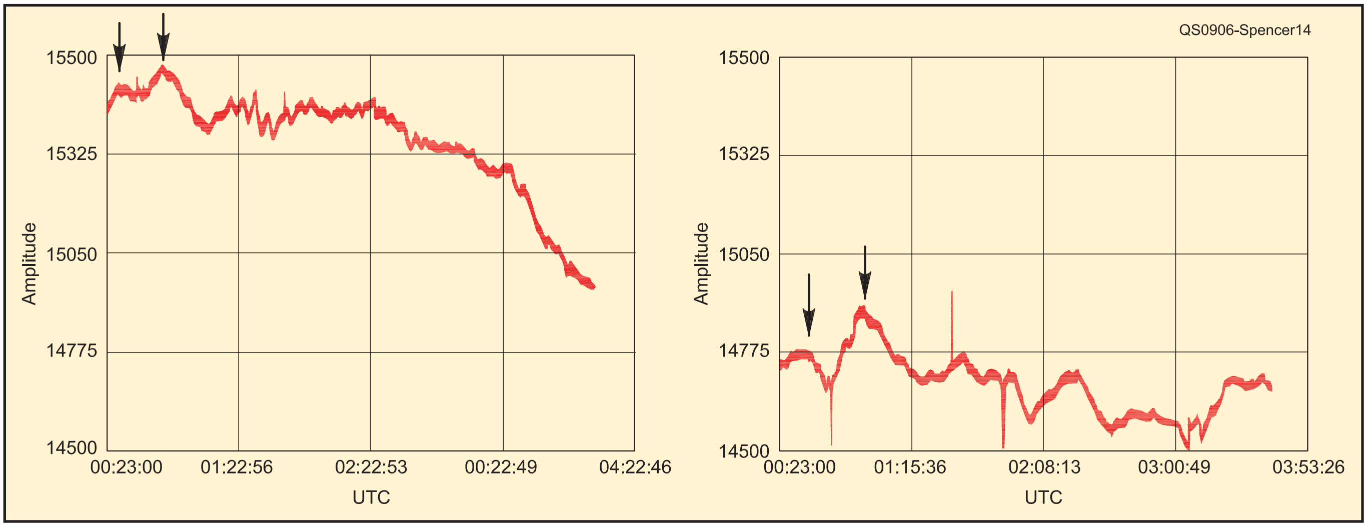

Figure 14 — Sequential drift scans. Note the time offsets between the peaks.

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supporting arm (between the arm and the rim of the dish), you will see the Sun being blocked by the LNB.

Once you have the RT set up, it needs to be calibrated to match the output of the CM to *SkyPipe*. I have developed an *Excel* spreadsheet template to help with the calibration and a few of the other activities that you can accomplish with the RT (also available from the *QST* Web site). Turn the RT to a signal source, the Sun, or the side of a building would work. Turn the gain control of the CM to set the meter to maximum. Run *SkyPipe* and adjust the variable resistor on the interface board until you get a reading on the *SkyPipe* graph vertical (y) axis of approximately 32,000. With the maximum value set, adjust the CM gain control through the voltage range (0 to 100 mV) in 10 mV steps and record the corresponding y axis value on *SkyPipe*. This data is entered into the *Excel* spreadsheet to compute the calibration curve between voltage and y axis value. Both voltage and y axis values are used in analyzing recorded signal strength data (Figure 12).

A good first activity is to do a drift scan of the Sun. A drift scan means that you set the antenna azimuth (AZ) and elevation (EL) to some fixed pointing angle and allow the Earth to serve as the rotator to drag the antenna across the sky. To do a drift scan of the Sun, first set the elevation and azimuth to point directly at the Sun (maximum signal) and then move the azimuth toward the west (leave the elevation set) until you are off the peak signal. Now start *SkyPipe*. In about 15 minutes, the Sun will pass through the antenna pattern beam width and the result will be as illustrated in Figure 13. You can also use this collection technique to explore the antenna performance parameters.

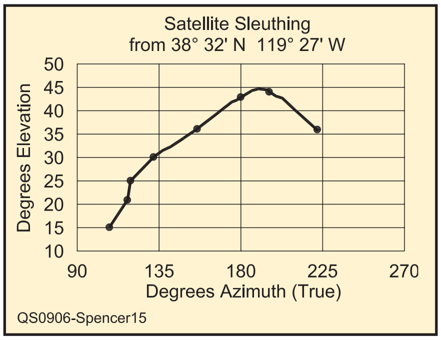

Figure 15 — Clarke Belt plot — tracking down satellites.

A good second activity is to do two drift scans of the night sky on two consecutive nights (beginning the scans at the same time each night) using the same fixed antenna azimuth (AZ) and elevation (EL). Figure 14 shows two such drift scans. Although at first glance they may not seem similar, there are some interesting features that are pointed to by arrows. If you compare the time that these two peaks occurred, the time difference is about 4.5 minutes. This shift is the result of the distance the Earth had traveled during the 24 hours between collections. This illustrates that the Earth's rotation as well as its travel in orbit needs to be considered when comparing drift scans. Enough to make your head spin (pun intended)?

A final good starting activity is to point the antenna toward the Clarke Belt and find all the satellites in geosynchronous orbit transmitting on 12 GHz. If you record signal strength peaks and AZ and EL for each peak, you will develop a graph of the Clarke belt as illustrated in Figure 15.

I have only scratched the surface, and the sky is the limit of this little project. The RT project can certainly broaden your horizons and expand your understanding of our universe. If you would like more detail than can be presented here, please contact the author.

Notes

[1] **www.setileague.org/articles/lbt.pdf**.

[2] **www.aoc.nrao.edu/epo/teachers/ittybitty/procedure.html**.

[3] **www.pctinternational.com/channelmaster/0612/satellite.html**.

[4] **radiosky.com/skypipeishere.html**.

[5] **en.wikipedia.org/wiki/Geostationary**.

[6] **www.arrl.org/files/qst-binaries/**.

Mark Spencer, WA8SME, is ARRL Education and Technology Program Coordinator. He is an ARRL member and holds an Amateur Extra class license. You can reach Mark at 774 Eastside Rd, Coleville, CA 96107 or at **wa8sme@arrl.org**.

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Simple demonstration to explore the radio waves generated by a mobile phone.

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Note: this article has been published: Simple demonstration to explore the radio waves generated by a mobile phone J P Hare, 2010, Journal of Physics Education, Institute of Physics, 45, p. 481 45 481

Also see the brief full article at: mobile phone detector

IMPORTANT NOTE: this device works very well on the old style mobile phones (as shown in the photo above). However, it does not always work well with modern smart phones. This may be because modern phones use higher frequencies, less power and use the power in a slightly different way (e.g. spread spectrum). Some smart phones do work and success may be due to the signal strength of the local mobile phone mast nearby. If you are in a low signal area the phone will create more power to ensure reliable communications. If you are in a very strong signal area (very near the local network) your phone will drop its output power and consiquently there will be less power to pick-up and to convert to a voltage to light the LED.

Described is a simple low cost home-made device that converts the radio wave energy from a mobile phone signal into electricity to light an LED. No battery or complex circuitry is required. The device can form the basis of a range of interesting experiments on the physics and technology of our mobile phones.

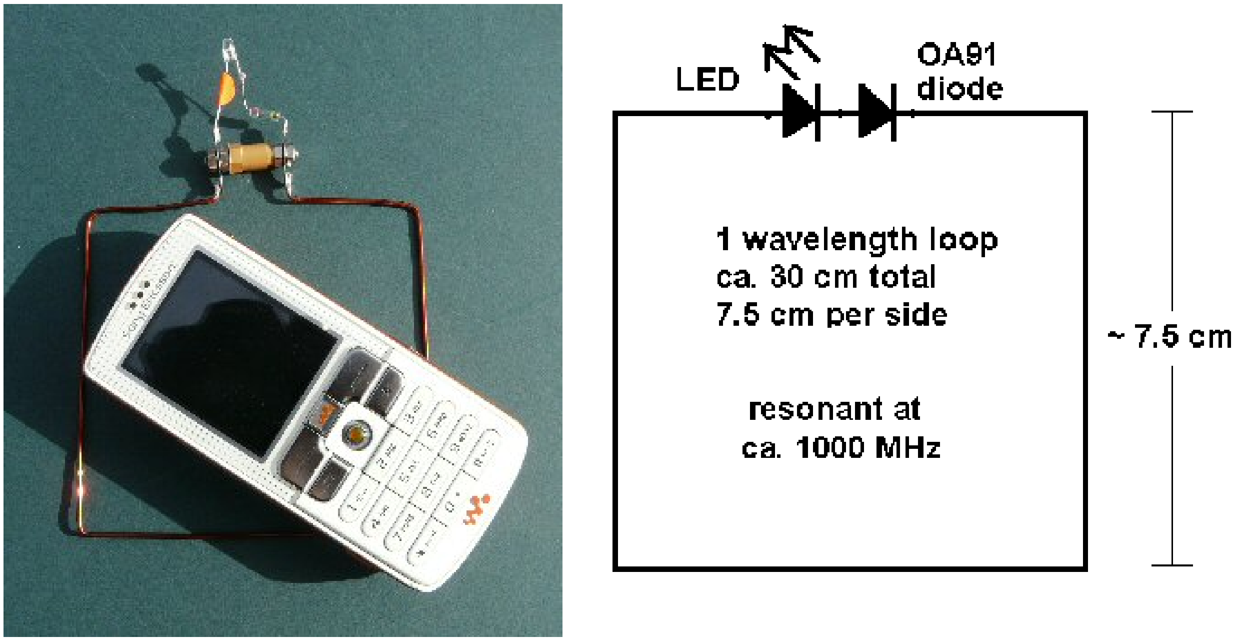

Fig. 1: left: mobile phone radio wave detector and right: the simple schematic

Introduction

Electromagnetic radiation (EMR) is at the heart of modern mobile phone data communications networks. The way a mobile phone and local base stations (the antenna covered masts you see dotted all around the place) communicate between each other is by using EMR in the radio wave part of the spectrum [1,2,3]. On switch-on your mobile sends digital information pulses by rapidly switching on and off the radio waves rather like a fast Morse code signal. Your text or voice is also converted into a series of digital pulses and sent across the network to be decoded (reassembled) by another mobile phone you dialled.

EM radiation and radio waves

Mobiles make use of various bands of radio frequencies to communicate between the mobile to base and the base to mobile: in Europe these include 900 and 1800 MHz (850 and 1900 MHz in the USA and Canada) [2, 3].

The relationship between wavelength, speed of light and the frequency follows the well known formula:
Wavelength λ (m) = speed / frequency = c (ms^{-1}) / ν (Hz)
λ (m) = 300,000,000 / ν (Hz) or approximately:
λ (m) = 300 / ν (MHz) ..... Equation 1.

So for a mid-range of about 1000 MHz (1 GHz) we get a typical mobile phone wavelength of about:
λ = 300/ 1000 = 0.3 m = 30 cm.

Simple radio wave detector

The loop consists of about a wavelength of wire, ca. 30 cm so each side is about 30/4 = 7.5 cm. The dimensions are not critical. The two ends are connected directly to a simple series circuit consisting of a high brightness LED and a germanium diode. They need to be connected correctly. All these components are cheap and readily available from electronic stores [4]. The loop can be made from a piece of copper wire roughly bent into a square (although a circular loop or rectangle will also work). If the wire is insulated remember to scrap off the insulation and solder-tin the ends. Simply solder the germanium diode and LED into circuit as shown in the diagram.
On a new LED the long lead is the positive (anode) while the short lead is the negative (cathode). The germanium diode has a line (band) around the end which is the cathode. When correctly wired the LED and the germanium diodes are connected so they both allow current to pass in the same direction, i.e. in the circuit diagram the arrows point in the same direction. In practice this means the LED and germanium diode are joined at the cathode of one and the anode of the other.
In my prototypes I used an insulator between the loop ends (light coloured cylinder in the photo) to make the whole thing more sturdy but this was purely for mechanical reasons and is not needed for the circuit to function properly. Note: a much more sensitive version using a x10 and x100 DC amplifier is described on my web site [6].

How it works and how to use it

When a radio wave passes across a metal object the EM fields cause the charged electrons in the metal to oscillate and this causes small AC currents at the same frequency to be induced into the metal. If a mobile is brought near to the loop and a call or text is made [5] the radio waves emitted from the phone pass across the loop. This induces a voltage into the antenna (the loop) and if it is close enough will be large enough to light the LED. As the loop is about one wavelength in size it is resonant and so there is a good transfer of power (low reactance) between the radio wave and LED.

The mobile phone automatically tests the network and adjusts its transmission power to maximise the battery life and minimise network interference. As a result the brightness of the LED will depend on the data being sent (the average signal), the local signal strength and how close the loop is to the phone. Why the second diode? - It's curious why the germanium diode is needed at all. The LED is a Light Emitting Diode after all and one would not think that another diode would help. However my initial experiments failed because I had not included it. The LED will have a relatively high capacitance which at these frequencies will tend to de-tune the loop and short out the LED. The germanium diode however is made up of a tiny wire which only makes a point-of-contact onto a piece of semiconducting germanium so it's 'self' capacitance is very low keeping the loop resonant.

The germanium diode will rectify the AC signal from the loop forming a series of DC pulses that will be nicely smoothed by the LED's capacitance. Without the diode however the raw AC signal from the loop will tend to be averaged to zero by the LED's capacitance.

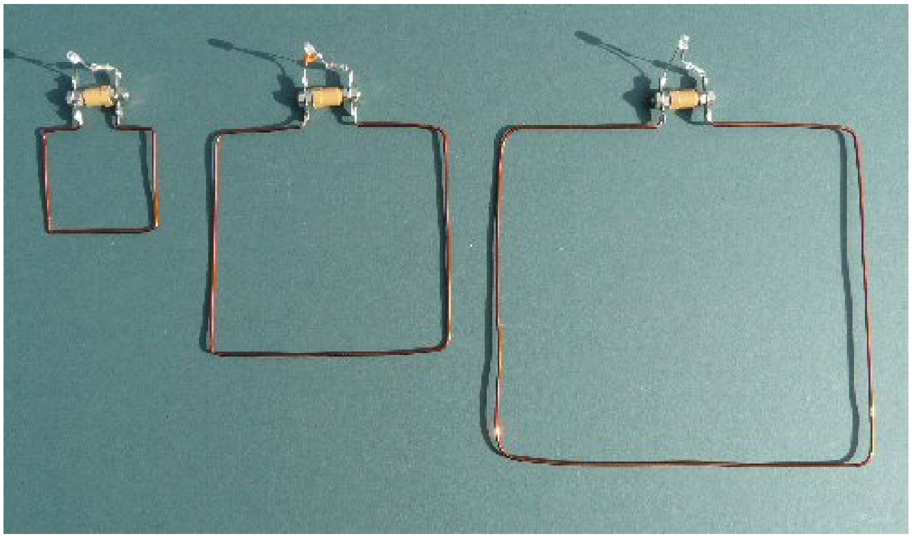

Fig. 2: Three loops in a row of varying size. The one described here and shown in Fig. 1 is shown in the middle. Smaller ones may well work better for higher frequencies such as the 3G networks (see below).

Other size loops

Fig. 2 shows a set of three loop devices with edge lengths of roughly 3.7, 7.5 and 15 cm. You can find out for yourself that the best match to the mobile signal is with the full wave loop of ca. 7.5cm per side. The other loops do work to varying degrees however (smaller ones may work better for the 3G network). The larger loop works well for the '70 cm' amateur radio bands.

Polarisation

The electric and magnetic fields making up the EM wave are orthogonal (they are at right angles to each other as they pass through space) to each other but depending how they are generated by the transmitting antenna can arrange themselves in any orientation with respect to the ground. If the electric field is parallel with the ground we say the wave is 'horizontally polarised' while if its normal to the ground we say its 'vertically polarised'. The loop antenna will respond best to one type of polarisation (depending on its orientation) so it's worth experimenting with the orientation of the mobile (or the loop) to get the strongest signal - brightest LED.

Mobile antenna

Inside your mobile phone is a transmitter / receiver and antenna. Many mobiles have this antenna at the top of the phone but some of the PDA type phones have it at the bottom. As a result you can locate the position of the antenna by moving it around the center of the loop till you get maximum LED brightness.

Networks

There are various different networks that a mobile may use both in the UK and abroad. It may be that you need to adjust the network phone settings on your mobile i.e. change from "automatic select" to set for "GSM" so as it get the strongest signal to light the LED. Note: the 3G network might not be powerful enough to light the LED. As the GMS network is currently the main network over the UK the device should work anywhere where you can get a signal as long as you check the correct selection on your mobile menus [5, 7]. The 3G network operates on a higher frequency (smaller wavelength) so you might find a smaller loop will work better than the main one described here. See 'other experiments' section below.

Test signals

In order to pick up the radio wave energy from the phone it obviously needs to be transmitting a signal. There are a few ways to do this:

1) On switch 'on' (or change of network) you can see that the mobile initially transmits for a few seconds to the network to tell it it's there (especially if you have moved since turning it off). You don't actually need to dial a number to detect these signals.
2) Even if don't text or call, throughout the day the mobile will send out data to 'keep up' with the network, especially if you are moving around (going through train tunnels etc. see below).

3) When you make a phone call you will transmit. Initially there is quite a lot of data being sent but in a few seconds data / power only gets transmitted when you speak. So to light the LED continuously you need to talk or provide some background sound continuously. Your service provider voicemail might be a good free phone number to try for these experiments [5].

4) Texting is the easiest way to show the radio wave power being transmitted. Long texts will light the LED for longer than short texts.

5) Finally set up the mobile on the loop and use another phone to text or phone the mobile. Even though you are not directly using the phone you will see that even on 'receive' the mobile phone transmits data to and fro. Ring off before you get charged.

Note: If you can use a free phone number it will save you money [5].

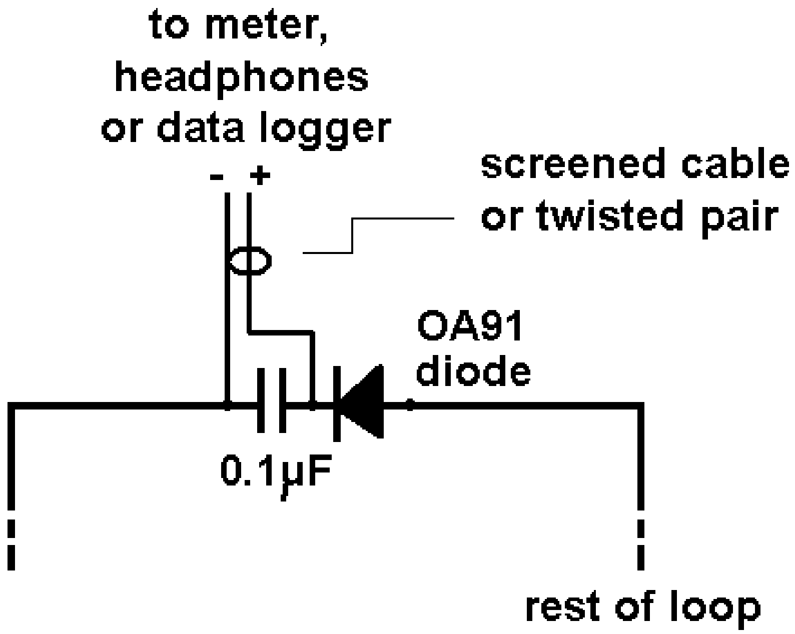

Fig. 3: Adding a capacitor and coax (or twin) lead so that headphones, a meter or a data logger can be connected (Note: diode is reverse wired compared to Fig. 1).

Other experiments:
Hearing data - if headphones are wired across the LED they will convert the voltages into sound and you can 'hear' the clicks of the digital data being transmitted. These are the same clicks that so easily get picked up by sensitive electronics such as a stereo amp or recording equipment when making a video for example. Hence - 'no phones on' when filming.

Logging data - if a meter, or better still a stand-alone data logger, is attached across the LED then one can monitor the EMR from the phone. For example even if you are not making a call your mobile will send signals too (and receive signals from) the network while travelling around. Fig. 3 shows a simple modification using a de-coupling capacitor so that a coax cable (or twisted pair) can be used to go to headphones, meter or data logger. Note the diode has been reversed so that the logger has the correct + and – connections for a unipolar input logger. The capacitor should help average the signal and stop radio frequencies going down to the logger. If one is available a few turns of the wire can be wound within a ferrite ring near to the logger so that maximum immunity to the mobile phone signal can be obtained for the logger electronics.

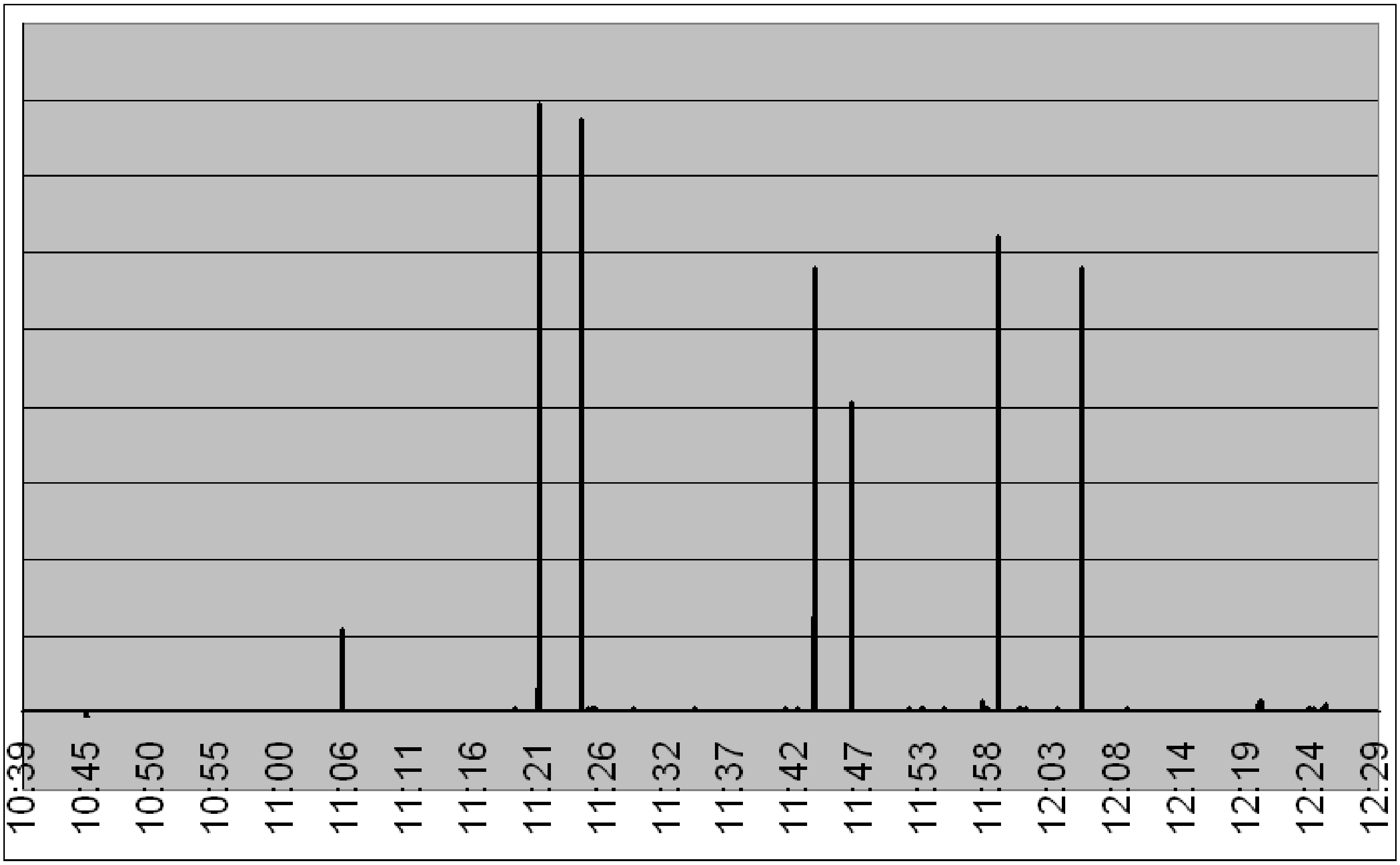

Fig. 4: Typical mobile phone data signals sent out onto the network while travelling around. These were recorded by a data logger from a mobile using the loop (no calls or text were made) while travelling on the train from Brighton to London Victoria (and then around London and return). Many of these peaks were the phone sending out 'I am here' data after coming out of one of the many long tunnels under the South Downs during the journey.

Out and about - Once you can log data you can discover all sorts of interesting things your mobile phone is doing without you realising it. Fig. 4 shows the plot over a few hours of travelling between Brighton and London (and within London) on the train. The detector was simply placed near to a phone that was not making or receiving a phone call or text, but was turned on.

The graph shows that the mobile sends out signals to tell the network where it is as it travels along and in particular goes in and out of long train tunnels. The peak heights vary because of the different powers the mobile transmits at depending on the signal strength of the local network and also because of the way the data logger 'snatches' a reading from the circuit every few seconds. As your phone sends out data onto the network to ensure the very best communications as you move around, so your mobile and the network obviously knows where you are and where you have been. Thieves and criminals beware the police can track you!

The inverse square law - If the transmitting mobile phone is moved away from the loop one would expect the signal to drop off. Unfortunately because both diodes need a certain threshold before they conduct the detector is not sensitive to small signals and not very linear. Therefore it's not very easy to use the device to measure the inverse square law (drop in signal v distance away) but of course you can see the signal go down. You could perhaps use the device to plot isobars - i.e. plot the equal intensity signals around the phone / nearby objects.

Changing the resonant frequency of the loop - you might be able to make some simple sliding mechanism (e.g. a small trombone-like mechanism) out of metal tube for example to tune the loop device for different frequencies. Then you can use it to find the average wavelength and so determine the center frequency by adjusting the size for maximum brightness of the LED. The wavelength can be determined by measuring the total distance around the loop. If we assume the antenna is one wavelength in total length then the frequency can be established by rearranging Equation 1, i.e. ν (MHz) = 30,000 / L (cm), where L is the length around the loop (cm).

Note: You will need to allow the transmitted digital signal to 'settle down' i.e. make measurements only after a few seconds after dialling / pick up so that only the sound data is being transmitted rather than the initial connection data. A constant sound will also need to be made so that the mobile phone continuously transmits data. It's worth playing music near to the phone or constantly whistling to keep sound coming into the phones microphone.

Mobile phone detector - teachers who want to know if the students / pupils really have turned-off their mobile phones (rather than just put on 'silent') can wire the loop device into the class room white-board speakers. Any mobile that is on in the class will send out signals which (if you are close enough) you will hear the data going to and fro - you will have your very own 'who's got their mobiles on' device which might be useful for exams etc.

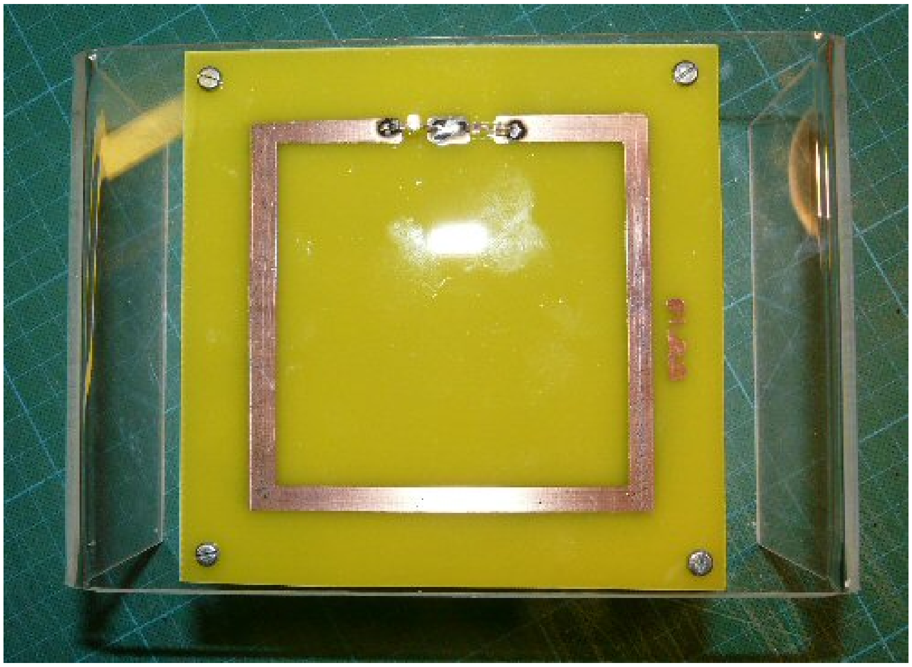

Fig. 5: The SEPNet 'deluxe' printed circuit board version (pcb) on a perspex stand where the loop is composed of a pcb copper track and the diode and LED soldered onto the board (top) [8,9].

Summary
All in all then, for such a simple easy to make device I hope you agree that there is a lot of scope for interesting science / technology investigations with your mobile phone. The device would make a good science week project (for radio amateur clubs etc.) A 'deluxe' pcb version (Fig. 5) on a perspex display case (Fig. 5) is currently going around the southern UK as part of the SEPnet outreach work, see the 'Radiation Exhibition' [8] and also as part of my on-going lecture series [9].

Post publication additions
(What follows was not included in the published article as this calculation was worked out later). A full wave loop is resonant and so looks purely resistive to the radio waves. Such a loop will have a resistance of about 100 ohms (Note: this is the AC resistance and not the DC resistance which will be very low). Now power P = V x I (V = voltage and I = current) and resistance = R = V/ I therefore $P = V^2 / R$ or rearranging $V = \sqrt{(P \times R)}$ which means that the voltage created by a power level of say 50mW (say for argument that roughly half the mobile phone power) arriving at the antenna will be about $V = \sqrt{(100 \times .05)}$ which is aprox. V = 2V, enough to light an LED.

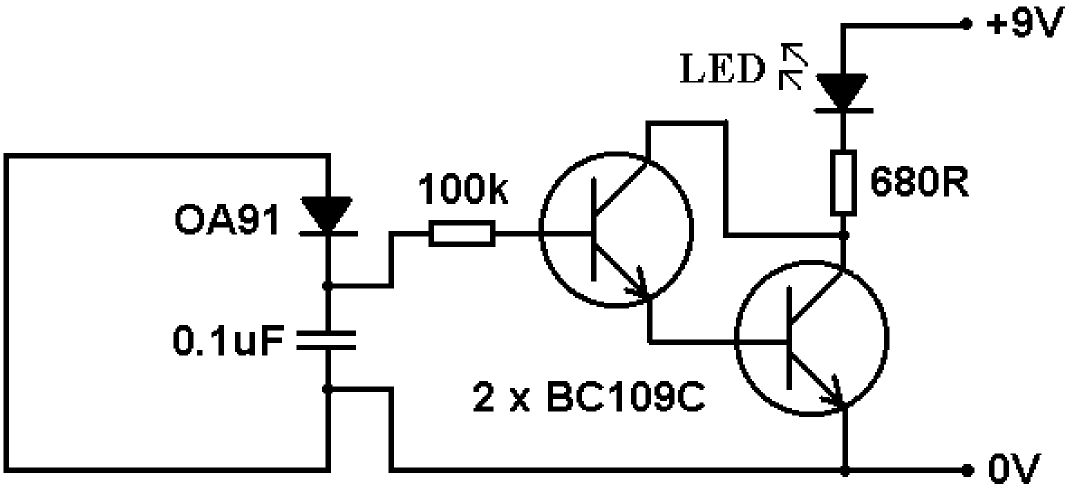

This circuit uses a two transistor darlington driver to amplify the signal from the loop and diode making the detector much more sensitive. The LED will be much brighter using this circuit. Note: the circuit needs a battery to power it (e.g. a PP3 9V)

References
[1] These ultra high frequencies (UHF, > 1000 MHz) are also often called microwaves.
[2] wiki pages
[3] Elektor Electronics magazine, June 2005
[4] order codes for the germanium diode and LED are:
e.g. Germanium diode: Maplin Electronics: QH71N, Rapid Electronics: 47-3114
e.g. LED: Maplin Electronics: UF72P , Rapid Electronics: 55-0085
[5] to save money use your voice mail service (often you simply dial 121).
[6] for details of an amplified detector see: wavemeter
[7] select 'network setting' from the mobile phone 'settings' menu and then go to 'network mode' and select 'GSM 900/1800' rather than 'automatic'.
[8] SEPnet mobile phone device on display throughout southern UK. [9] for details of my talks see: talks and workshops

THE CREATIVE SCIENCE CENTRE

Dr Jonathan Hare, Brighton, East Sussex. BN1 9QJ.

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Simple demonstration to show mobile phones emit radio waves

Dr Jonathan Hare, Sussex University, Department of Physics, Falmer, Brighton. BN1 9QH

Note: this article is in press: Elektor Magazine, July-August 2010, p. 56-57

For other experiments with this device please see my full article at: mobile phone detector

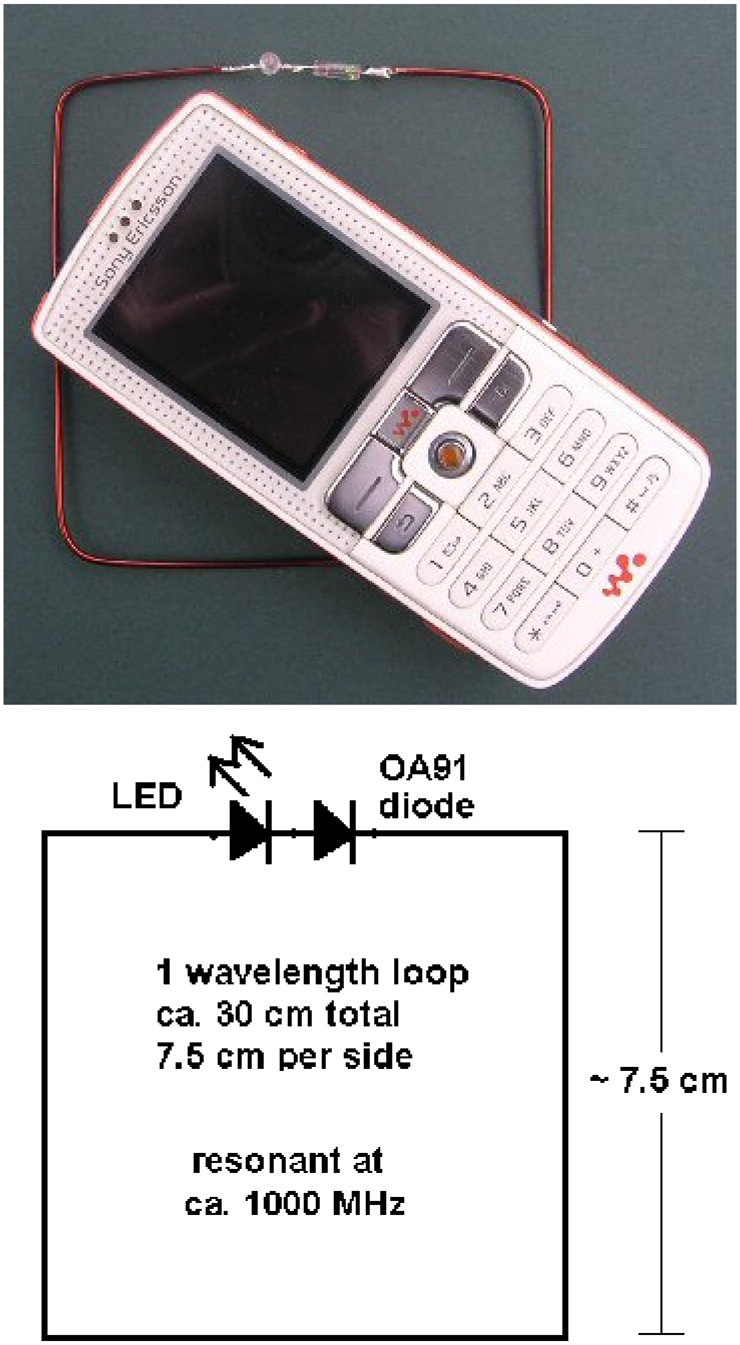
LED
OA91
diode
1 wavelength loop
ca. 30 cm total
7.5 cm per side
resonant at
ca. 1000 MHz
~ 7.5 cm

left: mobile phone radio wave detector and right: the simple schematic. Below: detail of the LED and germanium diode.

IMPORTANT NOTE: this device works very well on the old style mobile phones (as shown in the photo above). However, it does not always work well with modern smart phones. This may be because modern phones use higher frequencies, less power and use the power in a slightly different way (e.g. spread

spectrum). Some smart phones do work and success may be due to the signal strength of the local mobile phone mast nearby. If you are in a low signal area the phone will create more power to ensure reliable communications. If you are in a very strong signal area (very near the local network) your phone will drop its output power and consiquently there will be less power to pick-up and to convert to a voltage to light the LED.

This is a very simple and cheap device that demonstrates mobile phones ('cell phones' or 'handies') generate radio waves. We have a 30 cm (7.5 cm per side) full-wavelength loop antenna (a 'Quad' to radio amateurs) connected to a germanium diode and a hyper-bright LED. The loop can be made of copper wire, thin sheet metal or a track on a pcb. The diodes need to be wired correctly. I think the germanium diode is needed as the LED probably has too great a self-capacitance to perform at the very high AC frequencies generated by the phone (ca. 900 or 1800 Hz) but will work well with the DC pulses from the germanium diode (which has a very small capacitance).

To show the mobile generates radio waves put the mobile near to the loop and dial a number (use a free phone number, e.g. your voice mail) or text. The radio waves will induce a voltage into the loop, large enough to light the LED. The LED will flash indicating the digital data being sent by the mobile phone transmitter. You may need to set your phone to 'GSM 900/1800' rather than the '3G' network in the settings menu.

parts:
germanium diode: Maplin Electronics: QH71N or Rapid Electronics: 47-3114
LED: Maplin Electronics: UF72P or Rapid Electronics: 55-0085

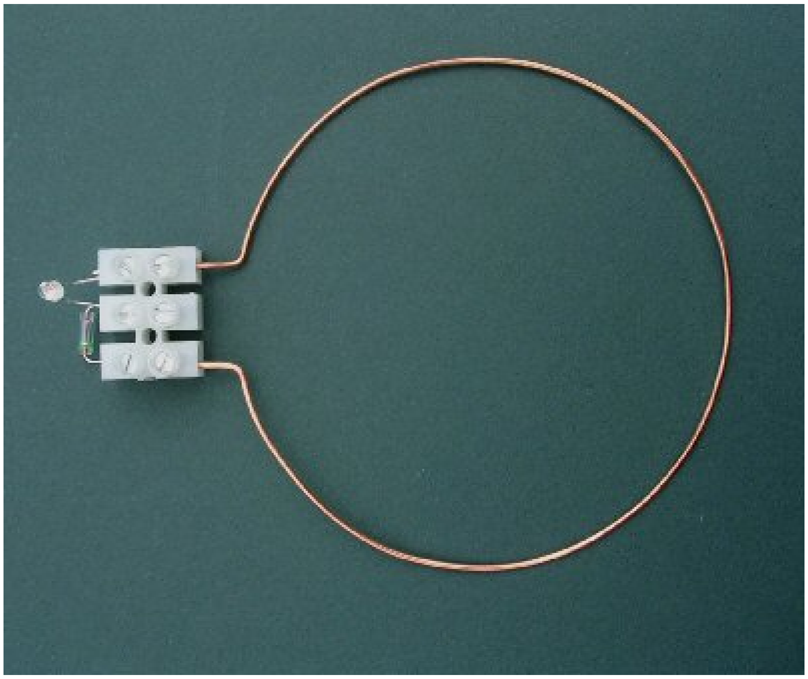

A very simple connector block version and a circular 1 wavelength loop

THE CREATIVE SCIENCE CENTRE

Dr Jonathan Hare, Brighton, East Sussex. BN1 9QJ.

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BACK TO G1EXG RADIO PAGE

EPAD MOSFET - 'near zero' and 'zero' threshold devices
(e.g. the ALD110900)

I will add more details to this page later on but for the moment it gives links to important and inspiring sites.

ARTICLES
1) High Sensitivity Crystal sets, Technical Topics, Pat Hawker, Rad Com, p. 77-78, May 2007.
2) A novel kind of 'crystal set' radio, Giles Read, Rad Com, p. 60-61, June 2007.
3) also see Pat Hawker, Technical Topics, Rad. Com. January 200, page 53-57.
4) High Sensitivity Crystal Set by By Bob Culter (N7FKI)
5) Next-generation Zero-Threshold Voltage EPAD™ design enables circuits with greater operating range in low voltage supply environments

LINKS ABOUT THE CHIPS / DEVICES
1) Advanced Linear Devices web site
2) EPAD MOSFET (ALD web site)
3) ALD110800 and ALD110900 page (ALD web site)
4) ALD110802 and ALD110802 page (ALD web site)

ORDERING THE CHIPS / DEVICES
1) mouser.com (USA)

'CRYSTAL SET' RADIO'S - DIFFERENT DETECTORS

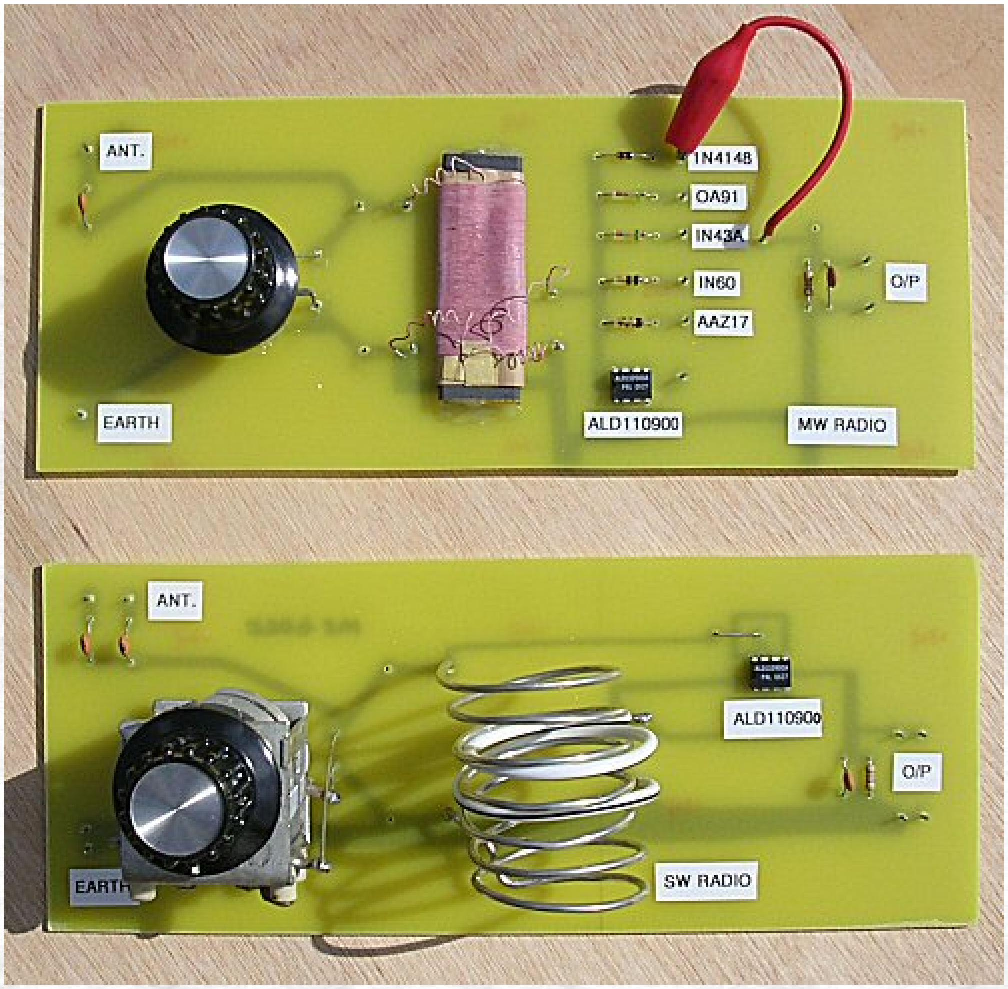

Top: the medium wave (MW) test radio with a selection of 'detectors' (selected by the croc clip lead) Bottom: the short wave (SW) version with a ALD110900 detector (on each circuit board the connections are: antenna - top left, Earth - bottom left, audio output (heaphones / amp) - far right.)

RADIO AND RADIO WAVES

The simplest 'radio' can be a piece of wire attached to the input of an amplifier. Why does this pick up radio signals? Well in principle it should not be able to pick up anything but in reality poor solder joints in the amplifier circuitry, as well as point contact effects between the ends of the anenna wire going into the input socket of the amp as well as other effects mean that you do often hear radio signals.

Radio waves are electromagnetic waves as they pass through a metal they induce small voltages into it. Any piece of metal e.g. metal fram specs, tape measures, metal window frames, a piece of wire etc. will act as an antenna and have tiny voltages induced into them. These voltages will be due to natural radio waves (from Space as well as the Sun and Earth), radio stations, satellites, mobile phones, garage door remote controls, microwave ovens .... the list goes on and on.

In the case of long, medium and short wave radio stations the amplitude of the radio wave signal is modified by the music, voice or program - we call it Amplitude modulation AM. Here the strength of the radio waves varies as the tones, loudness and pitch of the program vary. As a result the voltages induced in the metal object antennas distant from the radio wave stations also vary in accord this program information or modulation.

To actually hear the programs on the radio waves you cant actually take this tiny signal and listen to it directly (say with headphones or an amplifier). This is because the signal is a very high frequency signal out of the range of human hearing. To get the audible information - the program - 'off' the radio signal you need a device known as a 'detector'. This is usually a diode but lots of other things can act as inefficent detectors for example a mineral called galena, coke (burnt coal) ... as well as rusty screws and bad solder joints which is how the ampilfier mentioned above apparently picks up radio signals.

In the early days of radio crystals of galina were used as diodes and so these radios became known as 'crystal set radios'. They did not have any amplifiers and did not require any battery to work. They got all their power from that induced into the (of very long) antenna by the radio signal(s). The radio detector is an extremely important part of the radio and its proper function determines how well the radio works.

The radio signal is an AC signal. A speaker or headphones can not resonate at such high frequencies as radio waves and if you try to wire in the RF to the headphones the diaphram just averages the power. As half the time the RF is positive and half the time negative, in an AC signal, the average is zero and so you dont hear anything. The diode or detector is a device called a diode which only conducts electricity in one direction. So it only allows the positive, or negative half (one half but but not both) of the AC signal to go through (depending on which way it is wired). After the diode the average is now no longer zero its actually a changing signal dependant on the modulation of the radio wave - which is the information we want to hear. As this is at audio frequencies, and as the diaphram can move at audio frequencies, you hear the information on the detected RF signal - the music, voice or what ever.

Why should some detectors (diodes) be 'better' than others? The answer is not that some are better at 'magnifying' the signals but rather that each diode requires a certain threshold voltage in order to start conducting (one way). Signals below this level will not get passed through and a signal only slightly larger will therefore only pass through weekly (the diode unfortunatly absorbing the majority of the signal). As a result for large signals you wont expect to see much difference between different detectors but for weak signals there can be a great deal of difference. In an ideal world the diode would start to (forward) conduct at just above zero volts and this ideal detector (which does not conduct at all in reverse) would produce the greatest signal possible for the particular strength signal applied to it.

Recently I was playing around with OA91 germanium diodes for a mobile phone detector. I made a simple 10cm per side square loop and wired it directly to an LED. I was hoping that if I brought the mobile near to the loop and texted, or made a phone call, the RF should be picked up by the loop (which is almost resonant) and the LED should light - it didnt work! But putting an OA91 in series I did get it to work. So why did I need the OA91 diode when the LED is itself a diode?

It can't be due to the threshold voltage in this case as I am still using the LED and I did get it to work with the same signal! So I guess it because the capacitance of the LED is very high compared to the point-contact germanium diode. If we extend this thinking to the crystal set radio I guess the germanium diodes have very little capacitance and so dont allow any of the 'wrong' half of the AC signal through and so act as a more perfect detector. An LED would have a high capacitance and so let some of the wrong half of the AC signal through which on averaging by headphones would be nearer zero (see above) - hence less sound.

A low threshold (turn-on) voltage and a low self capacitance are crucial things in a good detector. Point contact germanium diodes having a very small area (a point of contact) have low capacitance and the germanium semiconductor-metal junction of the contact has a low turn on voltage. EPAD Mosfets also have low capacitance, high input resistance (low loading of the signal) and low turn on voltage.

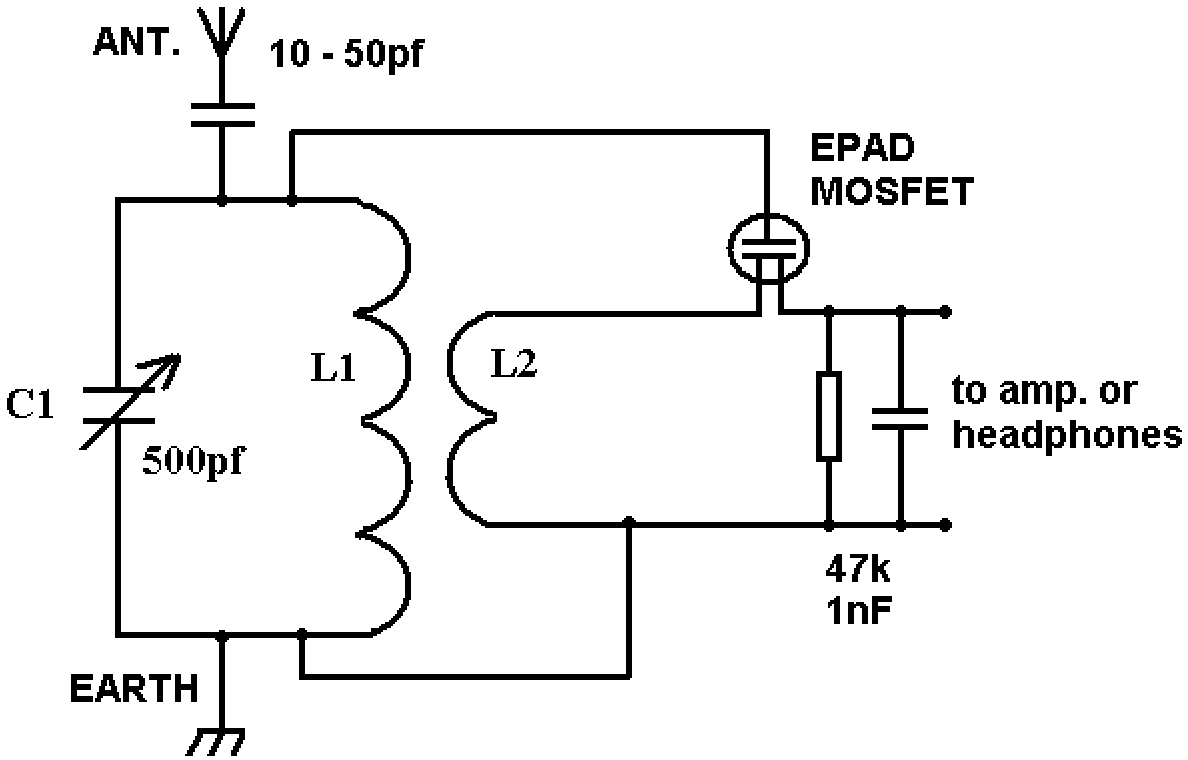

MEDIUM WAVE TEST CIRCUIT (top in photo)
As a simple test circuit to compare detectors I made up a simple 'crystal set' radio from a ferrite rod coil from an old radio, tuning capacitor an array of diodes (crystals) and a simple RF filter composed of a 47k resistor and 1nF capacitor. The coil and capacitor formed the resonant circuit which was fed via a 10 - 50pf capacitor by the antenna (long wire). This capacitor helps to reduce the effect of the antennas own capacitance and inductance from modifying the resonant frequency of the tuned circuit. Ideally this should be as small a capacitance as you can get away with but too small a value will reduce the radios sensitivity ....

An earth was connected to the ground connection of the circuit. Instead of taking the antenna end of the resonant circuit to a diode detector (as many simple crystal sets do) I used a ca. 10 turn coupling coil around the coil. This was done to limit the loading on the resonant circuit by the detector. It should help keep the tuning sharp and also help to keep the overall (band) spread of tuning as large as possible.

Because of the reduction in turns (ca. 100 turns : 10 turns, i.e. 10:1) the coupling coil reduces the signal that is available to drive the detector. For example if I use a standard silicon diode (e.g. a 1N4148) which requires about 0.6V to conduct then we might need ca. 10 x 0.6 = 6V of RF to be developed in the resonant circuit! A high Q resonant circuit might do this with a long antenna coupled to it but without such a generious antenna such a set-up wont be very sensitive.

RESULTS
I tried an array of 'crystal set' type diodes to campare them. Typical rough results are shown in the table below. This was with an Earth and about 3-4m of antenna wire randomly strung near to ground level (so its a pretty bad set up really - a good test).

The EPAD MOSFET data sheets described how the gate and drain of one of the MOSFETS can be joined together to form the anode of a diode the source then forms the cathode. I tried this arangement with the ALD110900 in order to make up a 'crystal set' diode from this MOSFET but it didnt perform well.

Then I tried the alternative arrangement as described in the references above. In these articles they dont use the MOSFETS as diodes but connect the gate directly to the resonant circuit. As the input resistance is extremely high (c.a. 1E12 ohms) and the input capacitance is very low (c.a 3pf) it does not load the tuned circuit by any appreciable amount. The source and drain are then wired between the coupling coil and filter just as the usual diode detector is in a crystal set radio. In this configuration the MOSFET is working more as a gate voltage controlled resistor rather than a diode i.e 'off' for half an RF cycle and 'on' for the rest - this lets the envelope through and you hear the music or sound. One article describes the arrangement as a synronious detector. As there are two MOSFETS in one package the two are wired in parallel i.e. gate to gate, drain to drain (there is a common source) etc.

DETECTOR TYPE	AF voltage produced after filtering
1N4148 silicon	no signal
OA91 germanium	1mV
1N43A germanium	1mV
1N60 germanium	1mV
AAZ17 germanium	1.5mV
ALD110900 EPAD MOSFET wired as diode	<1mV
ALD110900 EPAD MOSFET wired as sync. detc.	10mV

Typical results of the AF voltages produced by the detector (for use by headphones or amplifier) for an Earth connection, small (ca. 3-4m antenna wire near ground level) and the prototype 'crystal set' radio.

For the simple set-up described above there was not enough signal to get the silicon diode to work at all (although a much longer wire did provide a very small signal). A simple listening test and measurement of the AF prodiced by each diode showed that their was very little difference between the various germanium diodes. The MOSFET simply wired as a diode (gate wired directly the drain) was a poor detector - better than a silicon but not nearly so good as any of the germanium diodes. Finally the EPAD MOSFET wired as a syncronious detector worked really very well apparently producing ca. 10 times the signal (in other words it has much less loss than a germanium diode) for this particular set up and station than the germanium diodes.

As the syncronious arrangement was so succesful it got me thinking about this circuit. As the gate goes straight in on the main resonant circuit where the voltages, in a good Q circuit, might well be relatively high I thought I would try a standard FET (2N3819) and MOSFET (VN10KM) instead - and they worked! (they are a lot cheaper than an EPAD MOSFET chip and easier to get). Some FETS have a larger input capacitance so it helped to put a 10pf capacitor in series to the gate (a 10M ohm from gate to earth might reduce 50Hz pick up).

They were not as good as the EPAD MOSFET (although I only tried a single device) but the arrangment was still better than a simple 'crystal set' diode. For weak signals the EPAD MOSFET should perform better as it is able to keep going while the FET and the standard MOSFET will start to trail off as the resonant circuit voltage drops below the relatively higher gate voltage required for these devices. However it was interesting to see that it seems to be possible to get a more efficent set-up for a 'crystal' radio using a standard FET or MOSFET than with the standard germanium diode detector.

By the way I recently re-tried the 1N4148 diode but wired a 1.5V AA battery with a 100k resistor across it to forward bias it - and it worked ! It seemed to work better than a OA91!

SHORT WAVE 'CRYSTAL SET RADIO (bottom in photo)
The bottom circuit shown in the photo above is my own short wave version of the 'crystal set' radio but based on the references above. It's the same circuit as the MW radio but has a reduction drive tuning capacitor and different coil. I used about 7 turns (ca. 4cm diameter) for the resonant circuit and a couple of turns of insulated wire (white) for the coupling coil. I guess the radio tunes from about 3-8 MHz - I havent tried a sig gen on it yet.

I made this in the summer months (not the best time for listening on this part of the spectrum). Using an Earth and few meters of wire for antenna I heard 2 or 3 stations from around the world during the day while at night there were at least 7 including the voice of Russia world service, Radio Thailand as well as German and French speaking stations.

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10

Design Issues in Radio Frequency Energy Harvesting System

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Japan

1. Introduction

Emerging self powered systems challenge and dictate the direction of research in energy harvesting (EH). State of the art in energy harvesting is being applied in various fields using different single energy sources or a combination of two or more sources. In certain applications like smart packaging, radio frequency (RF) is the preferred method to power the electronics while for smart building applications, the main type of energy source used is solar, with vibration & thermal being used increasingly. The main differences in these power sources is the power density; for example RF (0.01 ~ 0.1 μW/cm^2), Vibration (4 ~ 100 μW/cm^2), Photovoltaic (10 μW/cm^2 ~ 10mW/cm^2) and Thermal (20 μW/cm^2 ~ 10mW/cm^2). Obviously RF energy though principally abundant, is the most limited source on account of the incident power density metric, except when near the base stations. Therefore, in general, RF harvesting circuits must be designed to operate at the most optimal efficiencies.

This Chapter focuses on RF energy harvesting (EH) and discusses the techniques to optimize the conversion efficiency of the RF energy harvesting circuit under stringent conditions like arbitrary polarization, ultra low power (micro or nanopower) incidences and varying incident power densities. Harvested power management and application scenarios are also presented in this Chapter. Most of the design examples described are taken from the authors' recent publications.

The Chapter is organised as follows. Section 2.1 is the introduction on RF energy sources. Section 2.2 presents the antenna design for RF EH in the cellular band as well as DTV band. The key issue in RF energy harvesting is the RF-to-DC conversion efficiency and is discussed in Section 2.3, whereas Section 2.4 and 2.5 present the design of DTV and cellular energy harvesting rectifiers, respectively. The management of micropower levels of harvested energy is explained in Section 2.6. Performance analysis of the complete RF EH system is presented in Section 3.0. Finally, conclusions are drawn in Section 4.0.

1.1 RF energy sources

These include FM radio, Analogue TV (ATV), Digital TV (DTV), Cellular and Wi-Fi. We will present a survey of the measured E-field intensity (V/m) for some of these RF sources as shown in Table 1, [1]-[2]. Additionally, measured RF spectrums for DTV and Cellular signals are presented as shown in Fig. 1 to show on the potential for energy-harvesting in these frequency bands. In general, many published papers on RF-to-DC conversion, have presented circuits capable of converting input or incident power as low as -20dBm. This means that, if an RF survey or scan finds signals in space, with power spectrum levels around -20dBm, then, it is potentially viable to harvest such signal power. In Fig. 1 (left side), the spectrum level is well above -20dBm and hence, a higher potential for energy harvesting. In Fig. 1 (right side), while the spectrum level is below -20dBm, what we observe is that the level increases with decrease in the distance toward the base station (BTS). Using free space propagation equation with this data, it was calculated that at a distance 1.4 m from the BTS, the spectrum level could measure 0dBm. An example calculation and plot for the estimated received power level, assuming 0dBi transmitter (BTS) and receiver antenna gains and free space propagation loss (FSPL) for FM and DTV is presented in Section 2.1.1. For the example estimation in Section 2.1.1, we select FM and DTV because they measured with a higher level than cellular and Wi-Fi for example.

Source	**V/m**	**dBm**	**Reference**	
FM radio	0.15~3		Asami et al.	
Analogue TV	0.3~2			
Digital TV	0.2~2.4	-40~0.0	Asami et al.	Arai et al.
Cellular		-65~0.0	Mikeka and Arai	
Wi-Fi		≅ -30		

Table 1. RF energy sources, measured data.

In Table 1, FM radio has the highest E-field intensity implying the highest potential for energy harvesting. However, due to the requirements for a large antenna size and the challenges for simulations and measurements at the FM frequency i.e. 100 MHz or less (See Section 2.2.3, example FM antenna at 80 MHz), this Chapter will focus on DTV (470~770 MHz band) and Cellular (2100 MHz band) energy harvesting.

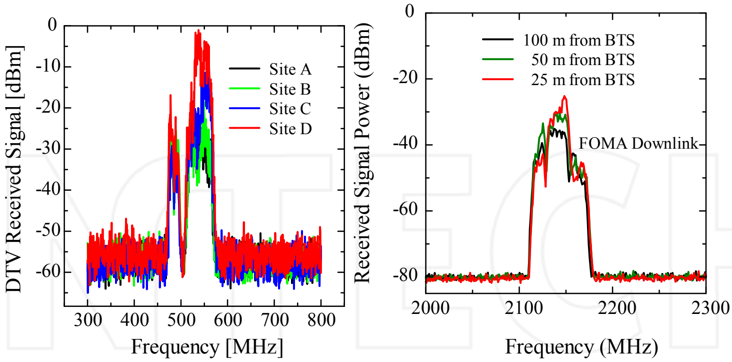

Fig. 1. DTV signal spectrum measured in Tokyo City (left side graph) and Cellular signal spectrum measured in Yokohama City (right side graph).

The received DTV signal power is high and also wide band, presenting high potential for increased energy harvesting unlike in cellular signals. We demonstrated in [2] that the total RF-to-DC converted power is roughly the integral over the DTV band (1), and is significantly larger than in the case of narrow band cellular energy harvesting.

$$P_{DC(DTV)} = \alpha \int_{470}^{770} \delta P_{DC}(f)\,df \;, \tag{1}$$

where α is the attenuation factor on the rectifying antenna's RF-to-DC conversion efficiency due to multiple incident signal excitation. δP_{DC} is the small converted DC power from each of the single DTV signals in the 470 MHz to 770 MHz band.

In detail, we derive (1) from fundamentals as follows.

The incident power density on the rectifying antenna (rectenna), $S(\theta,\phi,f,t)$, is a function of incident angles, and can vary over the DTV spectrum and in time. The effective area of the antenna, $A_{eff}(\theta,\phi,f)$, will be different at different frequencies, for different incident polarizations and incidence angles. The average RF power over a range of frequencies at any instant in time is given by:

$$P_{RF}(t) = \frac{1}{f_{high} - f_{low}} \int_{f_{low}}^{f_{high}} \int_{0}^{4\pi} S(\theta,\phi,f,t) A_{eff(\theta,\phi,f)} d\Omega df \tag{2}$$

The DC power for a single frequency (f_i) input RF power, is given by

$$P_{DC}(f_i) = P_{RF}(f_{i,}t).\eta\left(P_{RF}(f_i,t),\rho,Z_{DC}\right), \tag{3}$$

where η is the conversion efficiency, and depends on the impedance match $\rho(P_{RF},f)$ between the antenna and the rectifier circuit, as well as the DC load impedance. The reflection coefficient in turn is a nonlinear function of power and frequency.

The estimated conversion efficiency is calculated by P_{RF}/P_{DC} . This process should be done at each frequency in the range of interest. However, DC powers obtained in that way cannot be simply added in order to find multi-frequency efficiency, since the process is nonlinear. Thus, if simultaneous multi-frequency or broadband operation like in DTV band is required, the above characterization needs to be performed with the actual incident power levels and spectral power density. In this Chapter, we shall demonstrate DTV spectrum power harvest, given a rectenna than has been characterised in house at each single frequency in the DTV band.

1.1.1 An example calculation and plot for the estimated received power level

In this example we consider Tokyo's DTV and FM base stations (BS) as the RF sources. Both DTV and FM BS transmitter power (P_t) equals 10 kW (70dBm). The antenna gains are assumed 0dBi in both cases but also at the points of reception for easiness of calculation but with implications as follows. Assuming 0dBi antenna at each reception point, demands that we specify the frequency of the transmitted signal. For this reason we specify DTV signal frequency to be equal to 550 MHz while the FM signal frequency equals 80 MHz (Tokyo FM).

The received power, P_r is calculated using the simplest form of Friis transmission equation given by

$$P_r = P_t + G_t + G_r + FSPL\,, \tag{4}$$

where P_t = 70dBm, $G_t = G_r$ = 0dBi. G_r is the receiving antenna gain while FSPL is the free-space path loss given by

$$FSPL(dB) = 20\log(d) + 20\log(f) + 32.45\,, \tag{5}$$

where ***d*** is in (km) and ***f*** is in (MHz). The plot for the received power as a function of distance from the DTV and FM base stations is shown in Fig. 2.

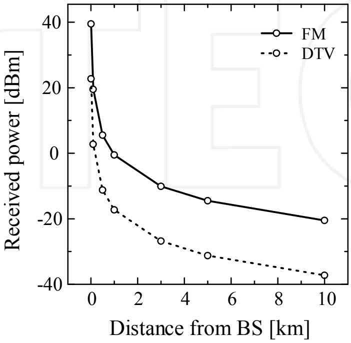

Fig. 2. DTV and FM received signal power level against distance.

With respect to Fig. 2, FM registers higher received power level than DTV at every reception point due to its lower transmit frequency and hence lower free-space path loss. For example at 1 km distance, FM received power level is -0.51dBm while for DTV, the received power is -17.26dBm. The important thing however, is that the received power level is frequency independent. It means that P_t is the transmitter power and the received power level at the position of distance ***d*** is $\frac{P_t}{4\pi d^2}$. However, if we assume 0dBi antenna at each reception point as in the above example, the power level is different because the antenna size of 0dBi is frequency dependent. As a result, high transmit power level is favorable for RF energy harvesting. Also near the base station is favorable.

1.2 Antenna design for the proposed RF energy harvesting (EH) system

It is well known that RF EH system requires the use of antenna as an efficient RF signal power receiving circuit, connected to an efficient rectifier for RF-to-DC power conversion. Depending on whether we want to harvest from cellular or DTV signals, the antenna design requirements are different. We will discuss the specific designs in the following sub sections.

1.2.1 Cellular energy harvesting antenna design

We propose a circular microstrip patch antenna (CMPA) for easy integration with the proposed rectifier (Section 2.5.1). However, the use of circular microstrip patch antennas (CMPA) is often challenged by the need for impedance matching, circular polarization (CP) and higher order harmonic suppression.

To address the above concerns, we create notches on the circular microstrip patch antenna. In our approach, we use only two, thin, fully parameterized triangular notches to achieve higher order harmonic suppression, impedance matching and circular polarization, all at once. This is the novelty in our proposed antenna. Our proposed CMPA is shown in Fig. 3. We study the behaviour of CMPA surface current vectors when notches (triangles ABC) are created on the structure at $\alpha = 45^0$ and $\alpha = 225^0$.

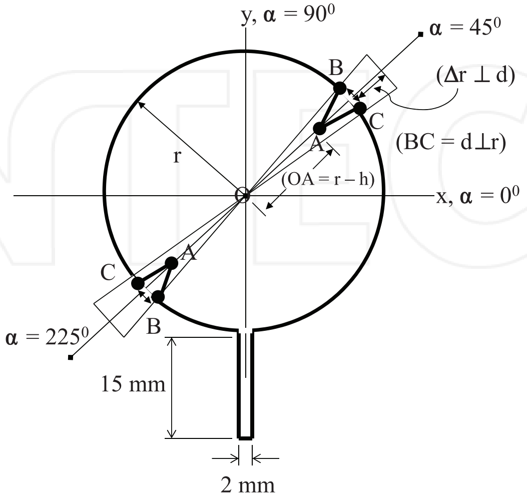

Fig. 3. Cellular energy harvesting antenna structure.

Notch parameters ***d*** and ***h*** in Fig. 3 were investigated by calculation using CST microwave Studio.

Without notches, the CMPA's input is not matched at f_c= 2.15 GHz as shown in Fig. 4 (left side). However, with notches, matching is achieved. The parameter combination ***d*** = 7 and ***h*** = 6 offers a matched and widest band input response and hence we adopt it for cellular energy harvesting applications.

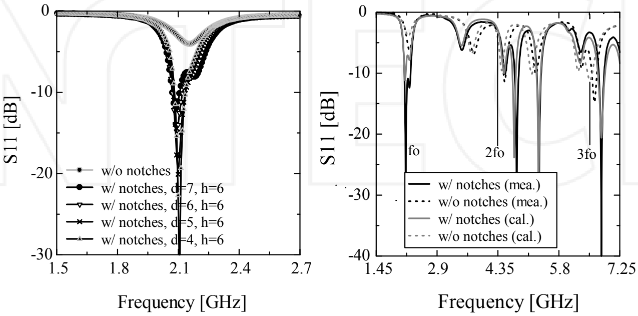

Fig. 4. *Left side:* ***d*** and ***h*** parameter investigation. *Right side:* Comparison between (cal.) and (mea.) S_{11} at f_0 = 2.175 GHz, $2f_0$ = 4.35 GHz and $3f_0$ = 6.53 GHz. The adopted notch parameters are ***d***=7 mm while ***h***= 6 mm.

The comparison between calculated and measured S_{11} is shown in Fig. 4 (right side). The 2nd and 3rd harmonics are suppressed as required by design. The comparison between calculated and measured radiation patterns is shown in Fig. 5, where $E_\vartheta \cong E_\varphi$ due to the 45^0 tilted surface current vector. Ordinarily, without notches, the surface current vector is parallel to the microstrip feeder axis. In conclusion, our proposed CMPA is sufficiently able to suppress higher order harmonics while simultaneously radiating a circularly polarized (CP) wave. The CP is required to efficiently receive the arbitrary polarization of the incident cellular signals at the rectenna.

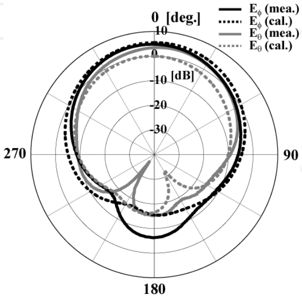

Fig. 5. Cellular energy harvesting antenna pattern at f_c= 2.15 GHz.

1.2.2 DTV energy harvesting antenna design

Unlike in the cellular energy harvesting antenna, the DTV energy harvesting antenna must be wideband (covering 470 MHz to 770 MHz), horizontally polarized and omni-directional.

The proposed antenna is typically a square patch (57 mm x 76 mm) with a partial ground plane (9 mm x 100 mm). The patch is indirectly fed by a strip line (9 mm x 3 mm). The proposed antenna geometry is shown in Fig. 6. The partial ground plane is used to achieve omni-directivity and a certain level of wide bandwidth. To tune the impedance of this antenna as well as to adjust the bandwidth within the target band, a "throttle" with stepped or graded structures is used between the microstrip feed line and the square patch, as shown in Fig. 6 (left side).

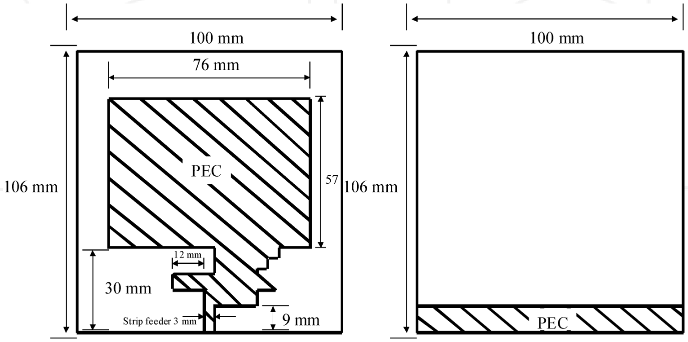

Fig. 6. Proposed DTV antenna geometry. *Left side:* Front view. *Right side:* Back view. The antenna is printed on FR4 substrate; t = 1.6 mm, ε_r = 4.4.

The input response for the proposed antenna is shown in Fig. 7 (left side). The omni directivity is confirmed by measurement at 500 MHz, 503 MHz, and 570 MHz as shown in Fig. 7 (right side). The radiation patterns shown in Fig. 7 are for the xz plane, which happens to be the vertical polarization for the antenna. DTV signals are horizontally polarized and therefore, when using this antenna, the orientation must be in such a way as to efficiently receive the DTV signal. Simply a 90 degree rotation of the antenna along the z axis achieves this requirement.

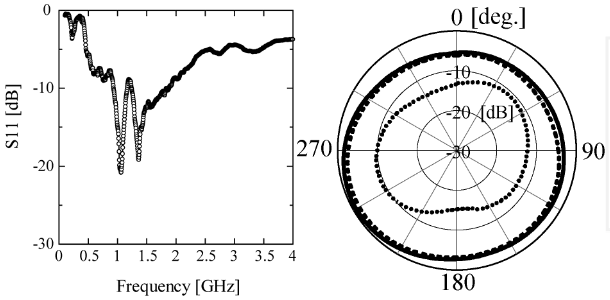

Fig. 7. Proposed DTV antenna performance. *Left side:* The antenna's measured input performance. *Right side:* The omni directivity in the vertical plane is confirmed at 500 MHz, 503 MHz, and 570 MHz. The outermost, black solid and dotted line patterns represent 503 MHz and 500 MHz directivity, respectively. The innermost dotted line pattern is the directivity at 570 MHz.

1.2.3 Example design for an 80 MHz FM half-wave dipole antenna

A half-wave dipole is the simplest practical antenna designed for picking up electromagnetic radiation signals, see Fig. 8 (courtesy of Highfields Amateur Radio Club). Calculating the optimal antenna length to pick up a certain frequency signal is fairly straightforward because antenna physics demand that the total length of wire used in the antenna be equal to one wavelength of the type of electromagnetic radiation it will be picking up. This means that the total length of the antenna should be equal to half the desired wavelength. By converting the 80 MHz frequency into a wavelength, you can thus obtain your antenna length as 1.875m by using the magic equation, $\lambda = \frac{c}{f}$. However, the actual length is typically about 95% of a half wavelength in free space, hence a half-wave dipole for this frequency should be 1.788m long, which would make each leg of the dipole 0.894m in length.

1.3 RF-to-DC conversion efficiency improvement techniques

A Schottky diode circuit connected to an antenna is used for RF-to-DC power conversion. To convert more of the antenna surface incident RF power to DC power, high RF-to-DC conversion efficiency is required of the rectifying circuit. Many authors have shown that the efficiency depends on several factors like Schottky diode type, harmonics suppression capability, load resistance selection, and the capability to handle arbitrary polarized incident waves. What is missing in most of these published works is the efficiency optimization for

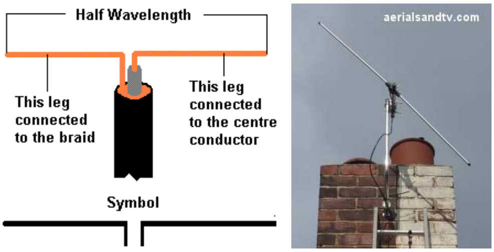
Half Wavelength
This leg connected to the braid
This leg connected to the centre conductor
Symbol
aerialsandtv.com

Fig. 8. Half-wave dipole. *Left side:* Antenna structure. *Right side:* Typical deployment.

ultra low power incident waves and the explanation of the physical phenomena behind most of the recommended efficiency optimization approaches.

This Chapter will show for example that a Schottky diode that delivers the highest efficiency at 0dBm incidence may not necessarily deliver the highest efficiency at lower power incidence e.g. –20dBm. We will therefore classify which diodes perform better at given power incidences; of course, this will also be compared to the diode manufacturers' application notes. Simulations in Agilent's ADS using SPICE and equivalent circuit models will compare the performance of few selected Schottky diodes namely; HSMS-2820, HSMS-2850, HSMS-2860, HSC-276A, and SMS7630. Moreover, the effect of the Schottky diode's junction capacitance (C_j) and junction bias resistance (R_j) on the conversion efficiency will be shown from which, special techniques for Schottky diode harmonic suppression and rectifying circuit loading for maximum efficiency point tracking will be presented.

1.3.1 The schottky diode

The classical *pn* junction diode commonly used at low frequencies has a relatively large junction capacitance that makes it unsuitable for high frequency application [3]. The Schottky barrier diode, however, relies on a semiconductor-metal junction that results in a much lower junction capacitance. This makes Schottky diodes suitable for higher frequency conversion applications like rectification (RF-to-DC conversion) [3]. We will demonstrate the effects of junction capacitance and resistance in the following sub section.

1.3.2 The effect of Schottky diode's C_j and R_j on the conversion efficiency

We have studied Schottky diode's C_j and R_j and published our results in [4]. In this work, we designed a rectifying antenna tuned for use at 2 GHz. The circuit proposed in [4] is a voltage doubler by configuration, but we replaced the amplitude detection diode (series diode) with its equivalent circuit adapted from [5]. The results of this investigation show that variation of C_j shifts the tuned frequency position and also introduces a mismatch in the resonant frequency, see Fig. 9 (left side graph). Therefore for this circuit at 2 GHz, we recommend using a Schottky diode having $C_j = 0.2$pF. In general, a smaller value of C_j is desirable at higher frequencies. Similarly, for R_j investigation, a smaller value is desirable for better matching at 2 GHz for example. If the R_j is increased towards 10kΩ, there is a mismatch in the resonant frequency but no shift in the frequency, see Fig. 9 (right side graph). Another approach to the study of Schottky diodes for higher frequency and efficiency rectenna design is presented in [6].

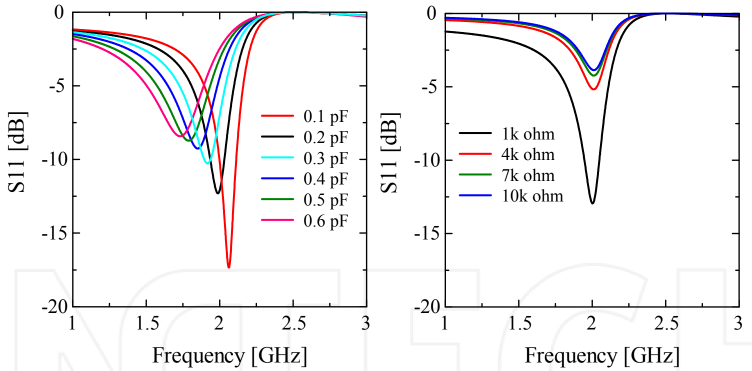

Fig. 9. Schottky diode's C_j effect (Left) and R_j effect (Right) on 2 GHz rectenna's input response.

1.4 Rectifying circuit for DTV energy harvesting

In the design of a DTV energy harvesting circuit, several basic design considerations must be paid attention to. First is the antenna; it must be wideband (covering 470 MHz to 770 MHz), horizontally polarized and omni-directional. Secondly is the rectifier; it must also be wideband, and optimized for RF-to-DC conversion for incident signal power at least -40dBm. Until recently, very few authors have published on DTV energy harvesting circuit. For the few publications, the antenna could not meet all those three requirements and a discussion on the performance of the harvesting circuit for ultra low power incidences has been neglected. In this Chapter we will present such a rectenna with conversion efficiencies above 0.4% at -40dBm, above 18.2% at -20dBm and over 50% at -5dBm signal power incidence. We will closely compare simulated and measured performance of the rectenna and discuss any observed disparities.

Agilent's ADS will be used to simulate the nonlinear behaviour of the rectifying circuit based on harmonic balance tuning methods. To simulate the multiple incident waves, a multi-tone excitation in the DTV band will be invoked. The wideband input characteristic will be achieved by the input matching inductors and capacitors.

The generic version of our proposed DTV energy harvesting circuit is shown below in Fig. 10. The implementation, however, is in two phases or scenarios as follows. First, we investigate the class called "ultra low power" DTV band rectenna. Secondly, we introduce the "medium power" DTV band rectenna.

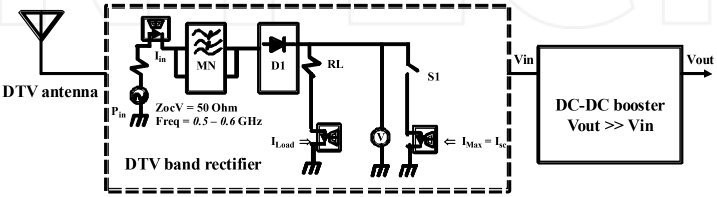

Fig. 10. Generic version of our proposed DTV energy harvesting circuit.

1.4.1 Ultra low power DTV rectenna

We define an ultra low power rectenna as one impinged by RF power incidence in the range between – 40dBm and -15dBm. Below in Fig. 11 is the circuit we designed; optimized for -20dBm input. The matching network is complex so as to achieve a wide band input characteristic. The fabricated circuit was well matched for the frequency range between 470 MHz and 600 MHz. More details about the circuit design can be found in [7].

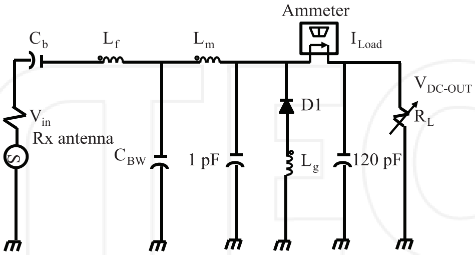

Fig. 11. Ultra low power DTV band rectenna circuit. SMS7630 Schottky diode by SKYWORKS offered the best performance.

The RF-to-DC conversion efficiency for this circuit is shown in Fig. 12 where at input power equal to -40dBm, efficiency is at least 0.4% and rectified voltage equals 1mV; at -20dBm, we have at least 18.2% by measurement and a rectified voltage of 61.7mV. The level of rectified voltage is too low and disqualifies this circuit for purposes of charging capacitors or batteries to accumulate such micropower over time. Instead, boosting the low voltage to usable levels is the option available and we shall discuss this at a later stage, (in Section 2.6).

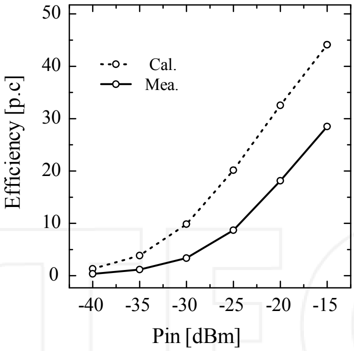

Fig. 12. Ultra low power DTV band rectenna efficiency.

1.4.2 Medium power DTV rectenna

We define a medium power rectenna as one impinged by RF power incidence in the range between – 5dBm and 0dBm. Below in Fig. 13 is the circuit we designed, optimized for -5dBm input. The matching network is simpler than as shown in section 2.4.1 since we require a narrow band around 550 MHz, with received peak power spectrum levels at least -5dBm. The circuit in Fig. 13 is a modification of Greinacher's doubler rectifier. In the circuit, C_b equals 1 pF and is used to block DC current against flowing towards the source. The shunt capacitance, C_{BW} equals 3300 pF and is used to set the input bandwidth. The grounding inductance, L_g equals 56nH (optimal) and is used to improve the RF-to-DC conversion efficiency by cancelling the Schottky diodes (D_b and D_D) capacitive influence; thereby minimizing the harmonic levels (harmonic suppression). We used HSMS2850 diodes in these circuits for their better performance at this level of incident power.

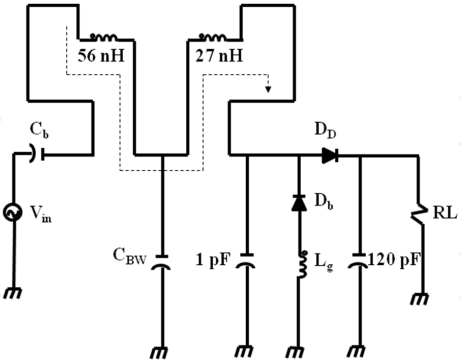

Fig. 13. Medium power DTV rectenna circuit. HSMS 2850 or 2820 from Hewlett-Packard offered the best performance.

The RF-to-DC conversion efficiency for this circuit is shown in Fig. 14 where at input power equal to -5dBm, we achieve at least 50% conversion efficiency by measurement, equivalent to 1.2 V DC rectified at 8.2kΩ optimal load. If we change the load to 47kΩ, over 2 V DC is rectified. This rectenna circuit is ideal for powering small sensors that run on 1.5 V or 2.2 V and draw around 6μA nominal current. If we need to power sensors demanding more power, say at least 2.2 V and 0.3mA to 1.47mA current consumption, we have to accumulate the power in a capacitor over time.

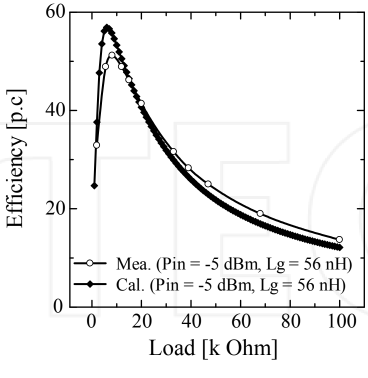

Fig. 14. Medium power DTV band rectenna efficiency.

1.4.3 DTV energy harvesting scenario and application demo

Using the medium power DTV band rectenna, connected to a gold capacitor as an accumulator, energy harvesting was initiated as shown in Fig. 15. Details about the gold capacitor, which include its charge function, backup time and leakage losses are presented in [8]. For the scenario shown in Fig. 15, the accumulated voltage by measurement i.e. capacitor charge function follows the path;

$$V_{acc} = 0.5388\ln(t) + 1.4681 \tag{6}$$

where V_{acc} is the accumulated voltage in volts and t the time in hours. It takes 4.5 hours to accumulate 2.25 V, given a rectified charging voltage and current of 2.4 V and 51μA, respectively, supplied by the DTV band rectenna instantaneously.

With this rectenna, it was possible to power up many different kinds of sensors. Sensors with ultra low power consumption were powered directly, without need to accumulate the power in a capacitor, as shown in Fig. 16.

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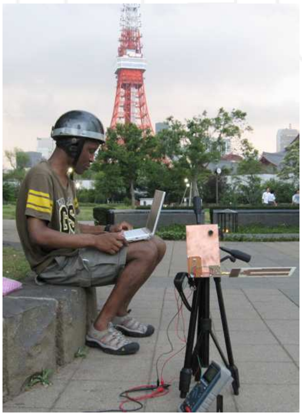

Fig. 15. DTV energy harvesting in a park at some line of sight from the base station.

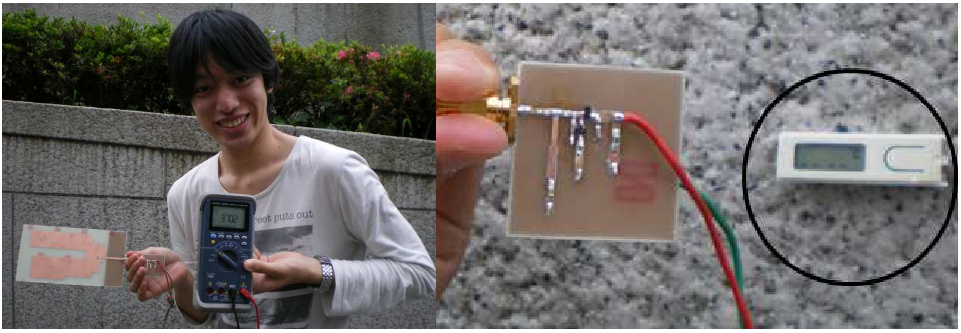

Fig. 16. Directly powering a thermometer mounted on a car park wall (right picture). The maximum instant voltage rectification on record equals 3.7 V (left picture).

1.5 Rectifying circuit for cellular energy harvesting

Unlike in the DTV energy harvesting circuit, for cellular energy harvesting, the antenna must be narrowband (50 MHz bandwidth is acceptable), and circularly polarized even though cellular signals are vertically polarized. The circular polarization is desired to maximize the RF-to-DC conversion efficiency of the arbitrary polarization incident signals in the multipath environment. Similarly, the rectifier must be narrowband, and optimized for RF-to-DC conversion over a wide range of incident signal power.

Thinking about the potential applications for cellular energy harvesting is useful. Other authors have reported on powering a scientific calculator or a temperature sensor from GSM energy harvesting. In this Chapter we will present a special application for energy harvesting in the vicinity of the W-CDMA cellular base station and analyze the system performance by calculation from experimental data. A cellular energy harvesting circuit optimized for over 50% RF-to-DC conversion efficiency given approximately 0dBm incidence will be presented.

1.5.1 Cellular band rectenna

Below in Fig. 17 is the circuit we designed, optimized for 0dBm input. Simple input matching network is ideal since we require a narrow band response around 2.1 GHz. The optimum value for L_g equals 5.6nH, where L_g is used to improve the RF-to-DC conversion efficiency as earlier discussed. HSMS2850 diode was used.

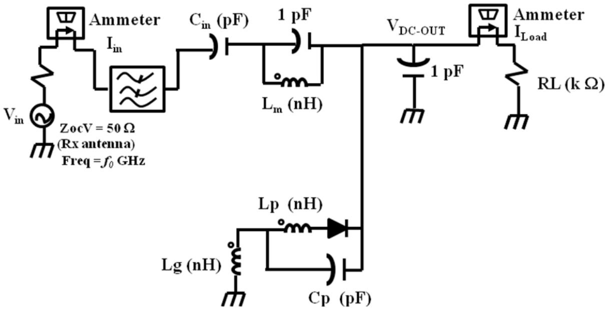

Fig. 17. Shunt rectifier configuration for the cellular band. The matching elements L_m = 3.2nH, while C_{in} =2.5pF. The load resistance is fixed at R_L = 2.1kΩ.

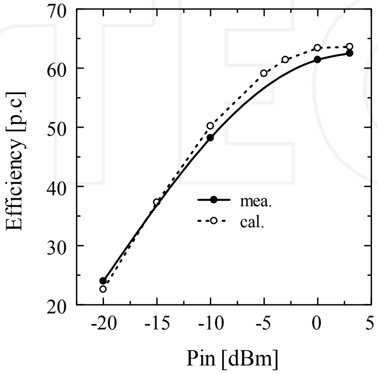

Fig. 18. Conversion efficiency as a function of input power (P_{in}) in the cellular band.

The RF-to-DC conversion efficiency for this circuit is shown in Fig. 18 where at input power equal to 0dBm, we achieve at least 60% conversion efficiency by measurement, given a 2.1kΩ optimal load. This rectenna circuit is ideal for powering small sensors that run on 1.5 V or 2.2 V and 6μA nominal current consumption. If we need to power sensors demanding more power, say at least 2.2 V and 0.3mA to 1.47mA, we have to accumulate the power in a capacitor over time as discussed in section 2.4.3 above.

1.5.2 Cellular energy harvesting application example

Environmental power generation in the neighbourhood of a cellular base station to power a temperature sensor is proposed as shown in Fig. 19 below. Electric field strength measurements in the base station neighbourhood have demonstrated the potential for environmental power generation, and the proposed temperature sensor system is designed based on these values. The rectenna described in Section 2.5.1 is used as the RF-to-DC rectifying circuit with the notched circular microstrip patch antenna (CMPA) proposed in Section 2.2.1. RF-to-DC conversion efficiency equal to 53.8% is obtained by measurement. The temperature sensor made for trial purposes clarifies the capability for temperature data wireless transmission for 20 seconds per every four hours in the base station neighbourhood.

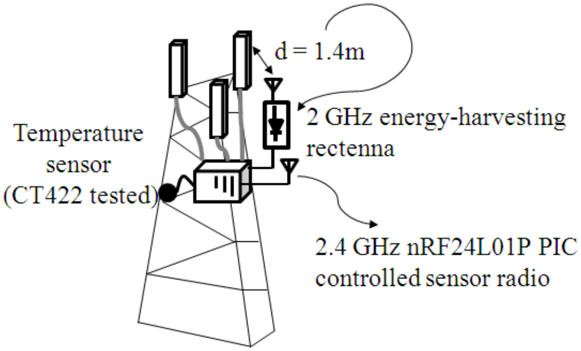
d = 1.4m
2 GHz energy-harvesting rectenna
Temperature sensor (CT422 tested)
2.4 GHz nRF24L01P PIC controlled sensor radio

Fig. 19. Application example in the vicinity of the cellular base station.

1.6 Micropower energy harvesting management

A rectifying antenna circuit for -40dBm incident power harvesting generates 1mV at 2kΩ load, given 0.4% efficiency as presented in Section 2.4.1. At -20dBm incidence and at least 18.2% efficiency, 61.7mV is generated given a 2kΩ load [7]. The generated DC power in both of these two cases is in the μW range, hence the micropower definition. To manage such micropower, power accumulation or energy storage is required. Storage devices may either be a gold capacitor, super capacitor, thin film battery or the next generation flexible paper batteries. These storage devices have specific or standard maximum voltage and trickle charging current minimum requirements. Typically, gold capacitors have voltage ratings like 2.7 V, 5.5 V for 100 μA, 10mA or 100mA maximum discharge current. On the other hand, standard ratings for batteries are 1.8 V, 2 V, 3.3 V and 4.1 V. Therefore, to directly charge any of these storage devices from 1mV, or 61.7mV DC is impractical.

Published works have demonstrated the need for a DC-to-DC boost converter placed between the rectifying antenna circuit (rectenna) and the storage device. Recent efforts have demonstrated that a 40mV rectenna output DC voltage could be boosted to 4.1 V to trickle charge some battery. A Coilcraft transformer with turns ratio ($N_s : N_p$) equal to 100 was used in the boost converter circuit. An IC chip leading manufacturer (Linear Technology Corp., LT Journal, 2010) has released a linear DC-to-DC boost regulator IC chip capable of boosting an input DC voltage as low as 20 mV and supplying a number of possible outputs, specifically suited for energy harvesting applications. While this IC is a great milestone, readers and researchers need to understand the techniques to achieve such ICs and also the limitations that apply. In the following sub section, we will describe the methods toward designing a DC-DC boost converter, suitable for micropower RF energy harvesting.

In the design, we will attempt to clarify the parameters that affect the DC-DC conversion efficiency. For this design, Envelope simulation in Agilents's ADS is used. This simulation technique is the most efficient for the integrated rectenna and DC-DC boost converter circuits.

1.6.1 DC-DC boost converter design theory and operation

The DC-DC boost converter design theory and actual implementation are presented in this section. The inequality $V_{in} \ll V_{out}$ defines the boost operation. In this Chapter, our boost converter concept is illustrated in Fig. 20. A small voltage, V_{in} is presented at the input of the boost converter inductive pump which as a result, generates some output voltage, V_{out}. The output voltage is feedback to provide power for the oscillator. The oscillator generates a square wave, F_{OSC} that is used for gate signalling at the N-MOSFET switch.

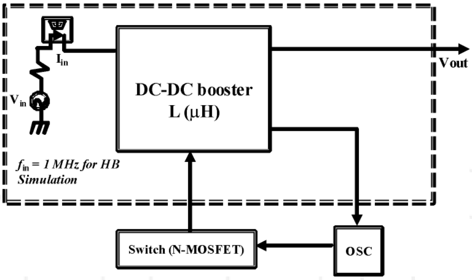

Fig. 20. Boost converter concept.

The drain signal of the N-MOSFET is used as the switch node voltage, V_{sn} at the anode of the diode inside the boost converter circuit block. From the concept presented in Fig. 20, the actual implemented circuit is shown in Fig. 21. The circuit was designed in Agilent's ADS and fabricated for investigation by measurement.

The circuit in Fig. 21 is proposed for investigation. Since a DC-DC boost converter is supposed to connect to the rectenna's output, it therefore, becomes the load to the rectenna circuit. This condition demands that the input impedance of the boost converter circuit emulates the known optimum load of the rectenna circuit. This has the benefit of ensuring maximum power transfer and hence higher overall conversion efficiency from the rectenna input (RF power) to the boost converter output (DC power). In this investigation, as shown in [7], the optimum load for the rectenna is around 2kΩ. In general, emulation resistance R_{em} is given by

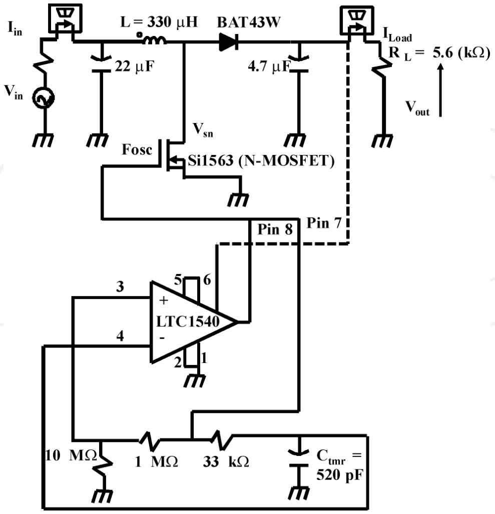

Fig. 21. The proposed boost converter circuit diagram. Designed in Agilent's ADS and fabricated for investigation by measurement.

$$R_{em} = \frac{2LT}{t_1^2 k}\left(\frac{M-1}{M}\right) \tag{7}$$

where L is the inductance equal to 330μH as shown in Fig. 20, $M = \frac{V_{out}}{V_{in}}$, T is the period of F_{OSC}, t_1 is the switch"ON" time for the N-MOSFET, and k is a constant that according to [3] is a low frequency pulse duty cycle if the boost converter is run in a pulsed mode and typically, k may assume values like 0.06 or 0.0483. With reference to (7), we select L as the key parameter for higher conversion efficiency while V_{in} = 0.4 V DC is selected as the lowest start up voltage to achieve oscillations and boost operation. Computing the DC-DC boost conversion efficiency against different values of L, we have results as shown in Fig. 22.

From the results above, L = 100μH is the optimum boost inductance that ensures at least 16.5% DC-DC conversion efficiency, given R_L = 5.6kΩ.

Now having selected the optimum boost inductance given some load resistance, the emulation resistance shown in Fig. 23 is evaluated from the ratio of voltage versus current at the boost converter circuit's input.

The results show a constant resistance value against varying inductance. In general, we can say that this boost converter circuit has a constant low input impedance around 82.5Ω. This impedance is too small to match with the optimum rectenna load at 2kΩ. This directly affects the overall RF-to-DC conversion efficiency.

The results show a constant resistance value against varying inductance. In general, we can say that this boost converter circuit has a constant low input impedance around 82.5Ω. This impedance is too small to match with the optimum rectenna load at 2kΩ. This directly affects the overall RF-to-DC conversion efficiency.

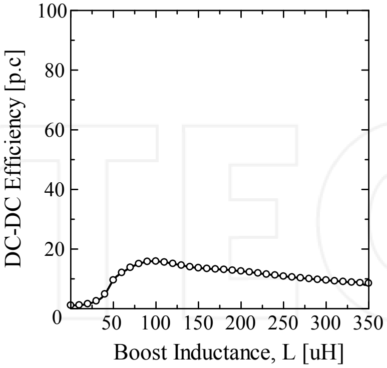

Fig. 22. Boost inductance variation with DC-DC conversion efficiency for a 5.6 kΩ load.

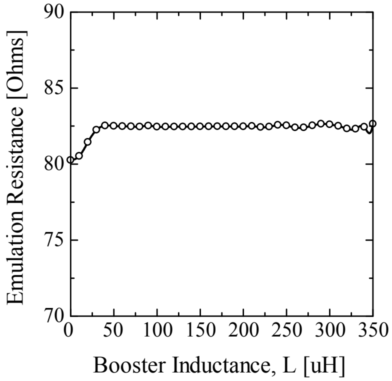

Fig. 23. Boost converter's input impedance: the emulation resistance.

Another factor, which affects the overall conversion efficiency is the power lost in the oscillator circuit. Unlike the circuit proposed in [9], which uses two oscillators; a low frequency (LF) and high frequency (HF) oscillator; in Fig. 21, we have attempted to use a single oscillator based on the LTC1540 comparator, externally biased as an astable multivibrator.

The power loss in this oscillator is the difference in the DC power measured at Pin 7 (supply) to the power measured at pin 8 (output). We term this loss, L_{osc}; converted to heat or sinks through the 10MΩ load. A comparison of the oscillator power loss to the power available at the boost converter output is shown in Fig. 24.

Looking at Fig. 24; we notice that the power loss depends on whether the oscillator output is high or low. The low loss corresponds to the quiescent period where the power lost is almost negligible. However, during the active state, the lost power (power consumed by the oscillator) nearly approaches the DC power available at the boost converter output. This results in low operational efficiency.

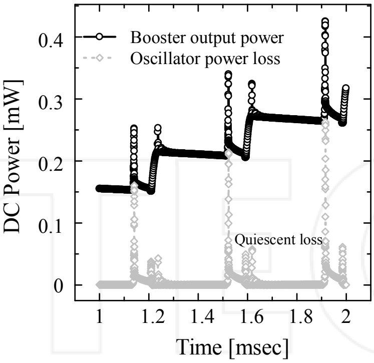

Fig. 24. The power loss in the oscillator.

To confirm whether or not the circuit of Fig. 21 works well, we did some measurements and compared them with the calculated results. Unlike in calculation (simulation), during measurement, L = 330µH was used due to availability. All the other component values remain the same both in calculation and measurement. In Fig. 25 (left side graph) and (right side graph), we see in general that the input voltage is boosted and also that the patterns of F_{osc} and V_{sn} are comparable both by simulation and measurement. To control the duty cycle of the oscillator output (F_{osc}), and the level of ripples in the boost converter output voltage (V_{out}), we change the value of the timing capacitance, C_{tmr} in the circuit of Fig. 21. Simulations in Fig. 25 (left side graph) show that C_{tmr} = 520pF realizes a better performance i.e. nearly constant V_{out} level (very low ripple).

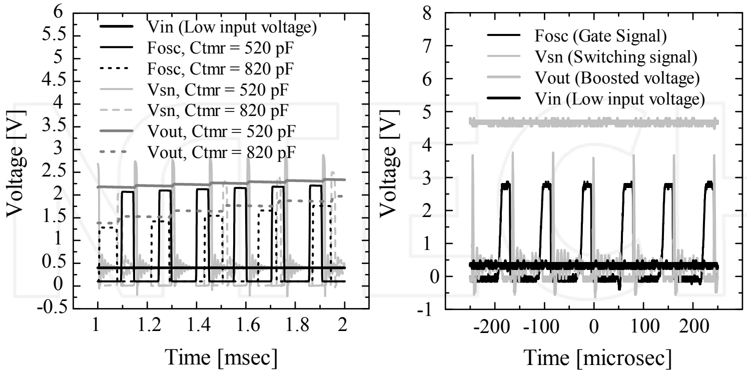

Fig. 25. Voltage characteristics of the developed boost converter circuit. The left side graph represents simulation while the right side graph is for measurements.

Generally, we observe that with this kind of boost converter circuit topology, it is difficult to start up for voltages as low as 61.7mV DC generated by the rectenna at -20dBm power incidence and at least 18.2% rectenna RF-to-DC conversion efficiency. Self starting is the issue for this topology at very low voltages.

At least 11.3% DC-DC conversion efficiency was recorded by measurement and is comparable to the calculation in Fig. 22. During measurement it was clearly revealed that the boost converter efficiency does depend on the value of **L** and the duty cycle derived from $\mathbf{t_1}$. To efficiently simulate the complete circuit, from the RF input to the DC output, envelope transient simulation (ENV) in Agilent's ADS was used. The (ENV) tool is much more computationally efficient than transient simulation (Tran). This simulation is appropriate for the boost converter circuit's resistor emulation task. Moreover, the boost converter's DC-DC conversion efficiency, and the overall RF-to-DC conversion efficiency can be calculated at once with a single envelope transient simulation.

In summary, though not capable to operate for voltages as low as 61.7mV DC, the proposed boost converter has by simulation and measurement demonstrated the capability to boost voltages as low as 400mV DC, sufficient for battery or capacitor recharging, assuming that the battery or the capacitor has some initial charge or energy enough to provide start-up to the boost converter circuit.

The limitations of our proposed boost converter circuit include; low efficiency, lack of self starting at ultra low input voltages, and unregulated output. To address these limitations, circuit optimization is required. Moreover, alternative approaches which employ a flyback transformer to replace the boost converter inductance must be investigated. A regulator circuit with Low Drop Out (LDO) is necessary to fix the boost converter output voltage commensurate with standard values like 2.2 V DC for example. For further reading, see [7]

2. Performance analysis of the complete RF energy harvesting sensor system

To demonstrate how one may analyze the performance of an RF energy harvesting system including its application, we extend the discussion of Section 2.5.2 to this Section. We propose a transmitter assembled as in Fig. 26 for temperature sensor wireless data transmission.

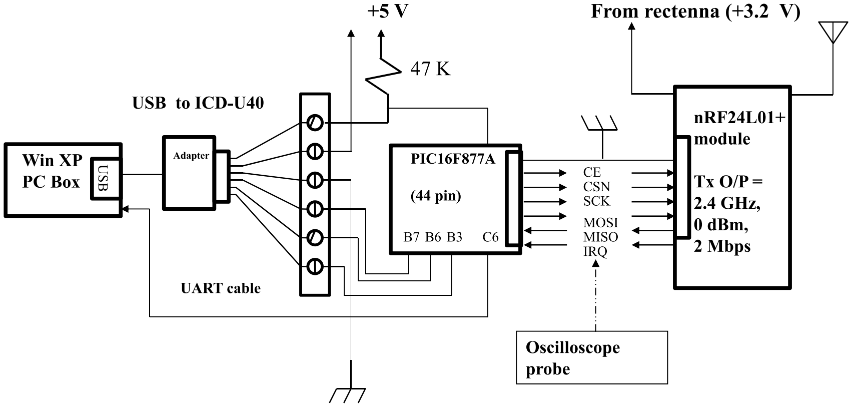

Fig. 26. The assembly and test platform for the proposed battery-free sensor transmitter.

The transmitter consists of one-chip microcomputer (MCU) PIC16F877A and wireless module nRF24L01P for the control, and MCU can be connected with an outside personal computer using ICD-U40 or RS232 cable. The wireless module operates in transmission and reception mode, and controls power supply on-off, transmitting power level, the receiving mode status, and transmission data rate via Serial Peripheral Interface (SPI). Figure 27 shows the operation flow when transmitting.

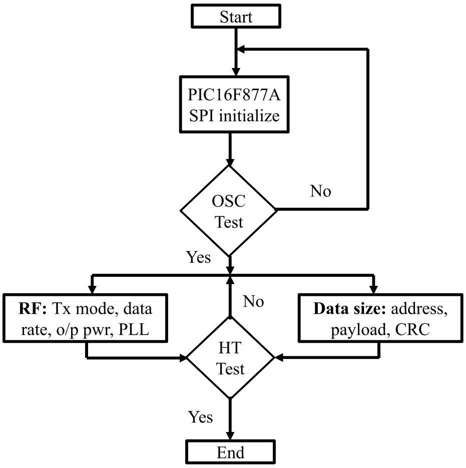
Start
PIC16F877A SPI initialize
OSC Test
No
Yes
RF: Tx mode, data rate, o/p pwr, PLL
No
Data size: address, payload, CRC
HT Test
Yes
End

Fig. 27. Operation flow during transmission.

The experimental system composition is shown in Fig. 28 to transmit acquired data by the temperature sensor with WLAN at 2.4 GHz (ISM band). An ISM band sleeve antenna is used for the transmission. Using the cellular band rectenna shown and discussed in Section 2.5.1, at least 3.14 V is stored in the electric double layer capacitor over a period of four hours. To harvest a maximum usable power for the overall system, we charge the capacitor up to 5V. The operation voltage for the wireless module presented in Fig. 26 above is between 1.9V and 3.6V.

The signal was transmitted from the wireless module while a sleeve antenna, same like the one for transmission was used with the spectrum analyzer and the reception experiment was performed. Received signal level equal to -43.4dBm was obtained at a distance 3.5m between transmitter and reception point. The capacitor's stored voltage was used to supply the wireless module in the above-mentioned experiment. Successful transmission was possible for 5.5 minutes after which, the capacitor terminal voltage decreased from 3.16V to 1.47V, and the transmission ended. The sending and receiving distance of data can be estimated to be about 10m when the sensitivity of the receiver is assumed to be -60dBm, given 0dBm maximum transmit power.

Hereafter, the overall system examination is done by environmental power generation using the transmitted electric waves from the cellular phone base station, proposed based on the above-mentioned results. First of all, the power consumption shown in Fig. 29 is based on the fact that 120mW (5V, 24mA) is saved in the electric double layer capacitor by environmental power generation, achieved by calculation as discussed earlier.

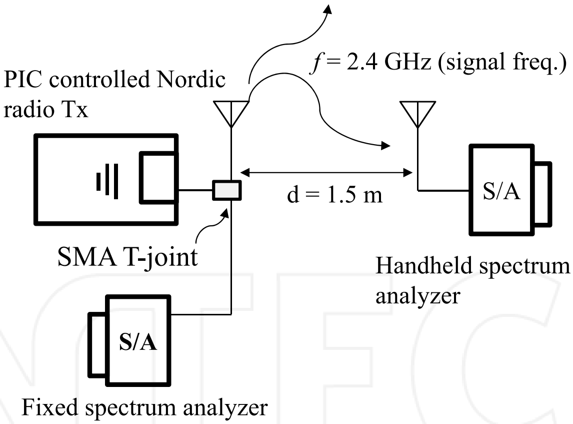
PIC controlled Nordic radio Tx
f = 2.4 GHz (signal freq.)
d = 1.5 m
S/A
SMA T-joint
Handheld spectrum analyzer
S/A
Fixed spectrum analyzer

Fig. 28. Indoor measurement setup for received traffic from the sensor radio transmitter.

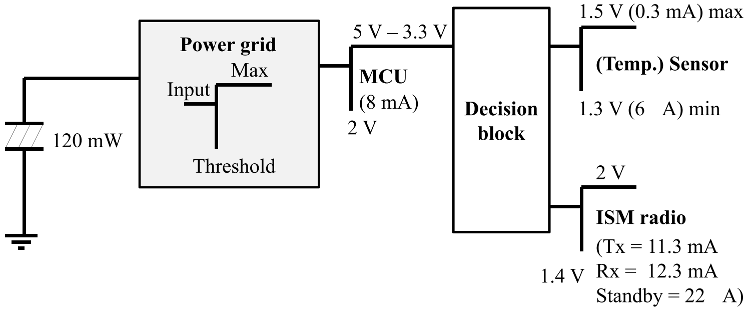
120 mW
Power grid
Max
Input
Threshold
5 V – 3.3 V
MCU
(8 mA)
2 V
Decision block
1.5 V (0.3 mA) max
(Temp.) Sensor
1.3 V (6 A) min
2 V
ISM radio
(Tx = 11.3 mA
Rx = 12.3 mA
Standby = 22 A)
1.4 V

Fig. 29. Power management scheme for the cellular energy-harvesting sensor node.

The sensor data packet is transmitted wirelessly in ShockBurst mode for energy efficient communication. The data packet format includes a pre-amble (1 byte), address (3 bytes), and the payload i.e. temperature data (1 byte). The flag bit is disregarded for easiness, and cyclic redundancy check (CRC) is not used.

The operation of the proposed system is provisionally calculated. When the rectenna is set up in the place where power incidence of 0dBm is obtained in the base station neighbourhood (as depicted in Section 2.5.2), an initially discharged capacitor accumulates up to 3.3V by a rectenna with 53.8% conversion efficiency (presented in Section 2.5.1). At this point, it takes 1.5 minutes to start and to initialize a wireless module, and the voltage of the capacitor decreases to 2V. This trial calculation method depends on the capacitor's back up time discussed in [8]. After this, when the wireless module is assumed to be in sleep mode, the capacitor is charged by a 0.28mA charging current for four hours whereby the capacitor's stored voltage increases up to 5V. The power consumption in the sleep mode or standby is 33μW (1.5V, 22μA).

When the wireless module starts, after data transmission and the confirmation signal is sent, the voltage of the capacitor decreases by 0.6V, and consumes the electric power of 7.4mW.

The voltage of the capacitor decreases to 2V when 3.2mW is consumed to the acquisition of the sensor data, and the operation time of MCU is assumed to be one minute to the data storage in the wireless module etc. As for the capacitor voltage, when the wireless module continuously transmits data for 20 seconds, it decreases from 2V to 1.4V and even the following operation saves the electric power. Therefore, a temperature sensing system capable of transmitting wireless data in every four hours becomes feasible by environmental power generation from the cellular phone base station if we consider intermittent operation by sleep mode.

3. Conclusion

This Chapter has given an overview of the present energy harvesting sources, but the focus has stayed on RF energy sources and future directions for research. Design issues in RF energy harvesting have been discussed, which include low conversion efficiency and sometimes low rectified power. Solutions have been suggested by calculation and validated by measurement where possible, while highlighting the limitations of the proposed solutions. Potential applications for both DTV and cellular RF energy harvesting have been proposed and demonstrated with simple examples. A discussion is also presented on the typical performance analysis for the proposed RF energy harvesting system with sensor application.

4. Acknowledgment

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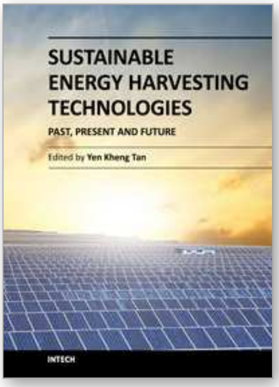

Sustainable Energy Harvesting Technologies - Past, Present and Future

Edited by Dr. Yen Kheng Tan

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In the early 21st century, research and development of sustainable energy harvesting (EH) technologies have started. Since then, many EH technologies have evolved, advanced and even been successfully developed into hardware prototypes for sustaining the operational lifetime of low?power electronic devices like mobile gadgets, smart wireless sensor networks, etc. Energy harvesting is a technology that harvests freely available renewable energy from the ambient environment to recharge or put used energy back into the energy storage devices without the hassle of disrupting or even discontinuing the normal operation of the specific application. With the prior knowledge and experience developed over a decade ago, progress of sustainable EH technologies research is still intact and ongoing. EH technologies are starting to mature and strong synergies are formulating with dedicate application areas. To move forward, now would be a good time to setup a review and brainstorm session to evaluate the past, investigate and think through the present and understand and plan for the future sustainable energy harvesting technologies.

How to reference

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Multi-Service Highly Sensitive Rectifier for Enhanced RF Energy Scavenging

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Due to the growing implications of energy costs and carbon footprints, the need to adopt inexpensive, green energy harvesting strategies are of paramount importance for the long-term conservation of the environment and the global economy. To address this, the feasibility of harvesting low power density ambient RF energy simultaneously from multiple sources is examined. A high efficiency multi-resonant rectifier is proposed, which operates at two frequency bands (478–496 and 852–869 MHz) and exhibits favorable impedance matching over a broad input power range (−40 to −10 dBm). Simulation and experimental results of input reflection coefficient and rectified output power are in excellent agreement, demonstrating the usefulness of this innovative low-power rectification technique. Measurement results indicate an effective efficiency of 54.3%, and an output DC voltage of 772.8 mV is achieved for a multi-tone input power of −10 dBm. Furthermore, the measured output DC power from harvesting RF energy from multiple services concurrently exhibits a 3.14 and 7.24 fold increase over single frequency rectification at 490 and 860 MHz respectively. Therefore, the proposed multi-service highly sensitive rectifier is a promising technique for providing a sustainable energy source for low power applications in urban environments.

AMBIENT energy harvesting is attracting widespread interest as it has the potential to provide a sustainable energy source for future growth and protection of the environment. Considerable research effort has been directed toward low-profile, low-power, energy efficient and self-sustainable devices aiming to harvest energy from inexhaustible sources such as solar energy, thermal, biomass, mechanical sources (e.g. wind, kinetic, vibration, and ocean waves) wastewater, and microwave energy. A thorough set of reviews is given in the literature[1–4]. Among these green energy sources, there has been a growing interest for radio frequency (RF) energy scavenging, as the availability of ambient RF energy has increased due to advancements in broadcasting and wireless communication systems. Furthermore, the development of wireless power transmission (WPT) technologies[5] that allow micro sensors[6], mobile electronic devices[7], wireless implantable neural interfaces[8] and far-field passive RFID (Radio-Frequency Identification) systems[9–11] to operate without batteries has triggered impetus for RF energy harvesting.

Efficient RF energy harvesting is a very challenging issue, as it deals with the very low RF power levels available in the environment. Furthermore, the scavengeable power level can vary unpredictably, depending on several factors such as the distance from the power source, the transmission media, the telecommunication traffic density and the antenna orientation. The majority of available literature on RF rectification has been dedicated to narrowband rectennas, which essentially operate at a single frequency and hence provide low DC output power[12,13]. Various topologies, such as voltage doublers or multipliers have been employed in order to increase the RF to DC conversion efficiency and the output DC voltage for specific applications[14–16]. However, from an ambient RF scavenging perspective, harvesting energy from various available frequencies could maximize power collection and hence increase the output DC power. Ultra-wideband and broadband rectenna arrays have been proposed as a potential solution[17,18]. However in some cases, simulation and experimental results were not provided to demonstrate the findings[17]. A broadband rectenna consisting of a dual-circularly polarized spiral rectenna array operating over a frequency range of 2–18 GHz was demonstrated[18]. The rectified DC power was characterized as a function of DC load, RF frequency and polarization for power densities between 10^{-5} and 10^{-1} mW/cm^2. However, the proposed rectenna was matched at a single input RF power level for a specified load resistance for the characterization. Also, due to the low Q value of the rectifier circuit, the conversion efficiency was a fraction of 1% at −15.5 dBm. From a design point of view, while it is relatively easy to achieve a broadband antenna, it is very challenging to realize a broadband rectenna due to the non-linearity of the rectifier impedance with input power across the frequency band[19].

To address this, a promising approach is to use a dual-band or multi-band configuration. This can maximize the power conversion efficiency (PCE) at the specific frequencies where the maximum ambient signal level is available. Various dual-band RF energy harvesting systems has been demonstrated[20–24], however a large signal analysis of the rectifier was commonly not provided over a broad input power range. A dual-band RF energy harvesting using frequency limited dual-band impedance matching has been proposed[20] and the PCE was shown over a high power range of 0 to 160 mW, however it was only matched at a single input power level (10 dBm). A CMOS dual-narrowband energy harvester circuit was modeled at environmental power levels[21]. Again, the rectifier efficiency was demonstrated with only single input power levels of −19 and −19.3 dBm at 2 GHz and 900 MHz respectively, and a large signal analysis was not presented. A compact dual-band rectenna operating at 915 MHz and 2.45 GHz has been demonstrated[22] and the PCE was shown for input power levels of −15, −9 and −3 dBm. However, the reflection coefficient was evaluated at a single incident power level. Furthermore, the efficiency results with dual-tone excitation simultaneously and single-tone excitation (at 915 MHz) are very similar, hence the impact of applying a dual-band technique does not demonstrate a clear advantage over a single band. A dual-frequency rectenna for WPT has been proposed[23] which achieved a conversion efficiency of 84.4% and 82.7% at 2.45 and 5.8 GHz with a high input power level of 89.84 and 49.09 mW respectively. These power levels far exceed ambient levels in the environment[19]. A conformal hybrid solar and electromagnetic (EM) energy harvesting rectenna has been presented[24] and the PCE was provided with −30 to 5 dBm input power, achieving an efficiency up to 40% at 1.85 GHz for higher input power levels (above −5 dBm). However the reflection coefficient was not provided at low input power range.

A multi-resonant rectenna that uses a multi-layer antenna and rectifier has been evaluated for a −16 dBm to +8 dBm RF received power level, but the rectifier circuit layout and large signal analysis were not provided to clarify the findings[25]. Furthermore, a rectenna for triple-band biotelemetry communications has been proposed using a triple-band antenna and single frequency rectifier[26]. However, this rectenna is not suitable for RF energy scavenging due to the low efficiency at lower input power levels. Another triple band rectenna presented an RF-DC efficiency over the input power range of −14 to +20 dBm[27], however the reflection coefficient results were only evaluated at a single input power level. This rectenna was shown to harvest 7.06 μW of DC power from three sources simultaneously at a high input power level of +10 dBm. A multi-band harvesting system has also been proposed where four individual harvesters are designed to cover four frequency bands[28]. However, a large signal analysis was not provided over a broad input power range. Furthermore, the proposed harvesting system has a minimum sensitivity of −25 dBm, whilst in a real environment more sensitive systems are required as the available RF power levels are very low[19].

Tunable impedance matching networks have been demonstrated in order to collect RF signals from various sources and convert them to DC power[29]. However from an application point of view, this is still single frequency rectification and it is not widely applicable to environmental RF energy scavenging where the available power is very low.

In order to increase the amount of RF energy scavenged by a rectenna, it is crucial to identify and harvest multiple ambient frequency sources over their realistic available energy range. Our previous research has demonstrated the feasibility of RF energy harvesting through RF field investigations and maximum available power analysis in metropolitan areas of Melbourne, Australia[19]. The maximum available power for different frequency bands based on antenna aperture and number of antennas in a given collection area was analyzed. Measured results and analysis indicated that cellular systems and broadcast sources are well suited to harvesting, with scavengeable RF power ranging from −40 to −10 dBm. This identifies two important considerations in the design of efficient rectenna for RF energy harvesting: the scavengeable ambient RF power sources available, and the significant variance of this power.

The RF to DC rectifier solutions proposed in recent literature have focused on maximizing the system efficiency at a given, and often quite high, input power level. This neglects the issues related to input power variation which can lead to unexpected variations in the matching network due to diode non-linearity. Also, the scavangeable levels of ambient RF power have been shown to be orders of magnitude lower. Therefore, based on our previous research outcomes and recommendations[19], an efficient power harvesting solution could encompass a multi-band matching circuit at the specific frequencies where maximum signal power is available, enabling greater power harvesting due to the combination of RF signals. This also results in a higher power being fed to a single rectifier, utilizing the diode function more efficiently.

This paper presents an RF energy harvesting method that can scavenge a wide range of ambient power levels which are orders of magnitude lower than previous reported techniques in the literature. An efficient dual resonant rectifier circuit is proposed, matched to a 50 Ω input port at 490 and 860 MHz over a broad low input RF power range from −40 to −10 dBm. The proposed dual resonant matching network operates efficiently at two identified harvesting frequency bands over a wide input power range, maximizing DC power by scavenging two sources simultaneously.

The remainder of this paper is organized as follows. First, the key results for the reflection coefficient and output DC power are presented. Subsequently, the Discussion section summarizes the results and demonstrates their potential implications, the limitations of this study, open questions and future research. Finally, the Method section describes the proposed rectifier design.

Results

A dual resonant rectifier was fabricated on a 1.58 mm FR-4 substrate with a dielectric constant $\varepsilon_r \approx 4.5$ and a loss tangent $\delta \approx 0.025$. These substrate parameters were measured using the Nicolson-Ross method[30] so accurate values could be used in the rectifier design. A photograph of the fabricated dual resonant rectifier is shown in Fig. 1 which depicts input RF port, dual-band matching network lumped components, Schottky diodes and the output terminal. The performance of the rectifier was verified by measuring the input reflection properties, and the output power was calculated from the measured output DC voltage for the input powers from −40 to −10 dBm.

Reflection Coefficient. The $|S_{11}|$ of the rectifier was evaluated using a vector network analyzer (VNA). The VNA was re-calibrated for each input power level. Figure 2 compares the simulated and measured $|S_{11}|$ versus frequency for the dual resonant rectifier circuit at four different input power levels from −40 to −10 dBm. The measured results show very good agreement to the simulations. Slightly higher reflection was observed for the resonant frequencies at the lower part of the input power range (due to the diode characteristics). However, the proposed rectifier circuit is well-matched ($|S_{11}| < -10$ dB) at the desired frequency bands of

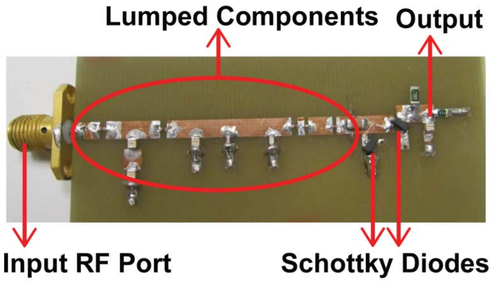

Figure 1 | Fabricated rectifier prototype.

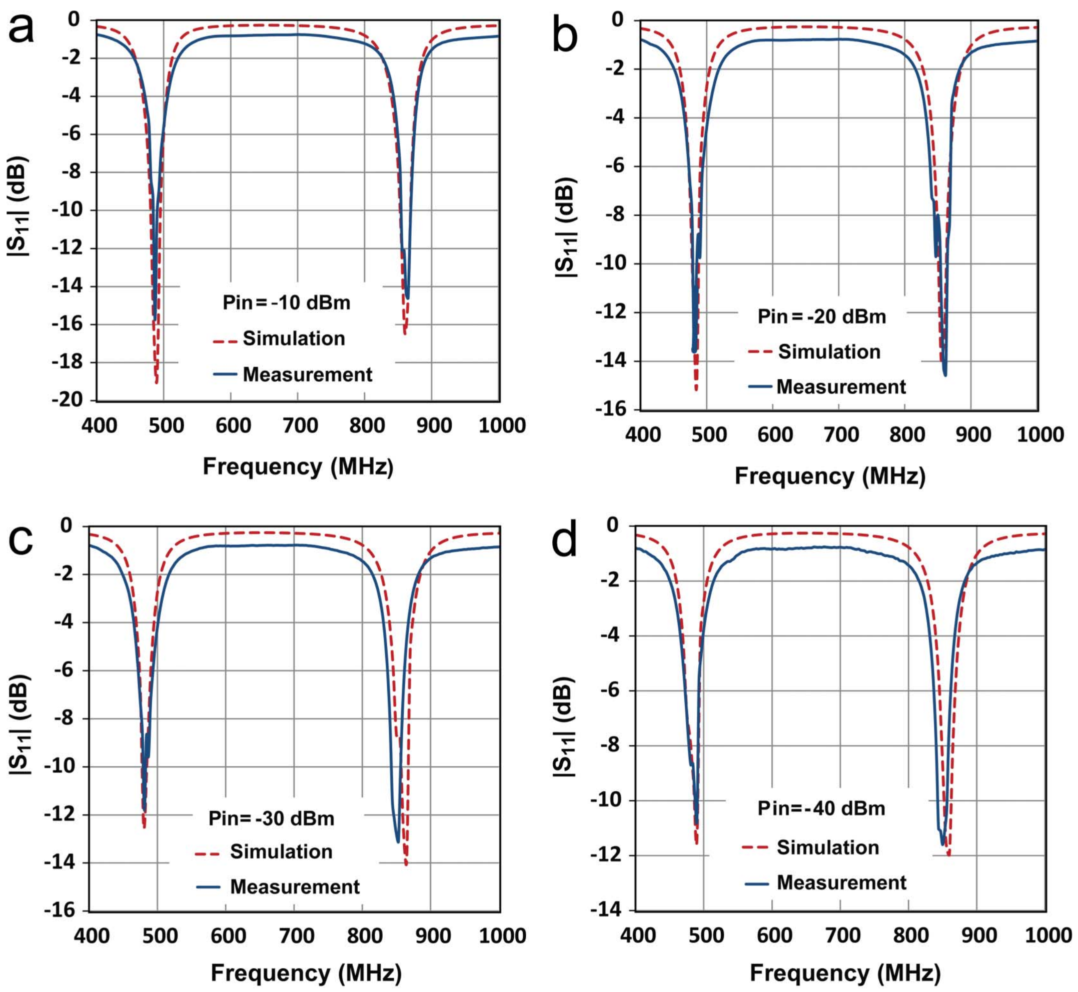

Figure 2 | Simulated and measured $|S_{11}|$ as a function of frequency and input RF power for the proposed dual resonant rectifier circuit. (a) −10 dBm. (b) −20 dBm. (c) −30 dBm. (d) −40 dBm.

478–496 MHz and 852–869 MHz over the broad range of input powers from −40 to −10 dBm. The small difference between simulation and measurement is due to the parasitic extraction accuracy.

Output DC Power. In the frequency domain, the Harmonic Balance method of analysis provides a comprehensive treatment of a multispectral problem[18]. The method intrinsically takes into account the DC component and a specified number of harmonics, while allowing the ability to specify the source impedance and harmonic terminations. A Harmonic Balance simulation was used to numerically evaluate the output DC voltage of the dual resonant rectifier for both a single and two tone input. The output DC voltage across the load resistor was also measured and used to calculate output DC power. Measurements were performed using a Wiltron 68247B synthesized signal generator as a RF power source for the rectifier circuit. Recording of the output DC voltage across the load resistance was achieved with a Fluke 79III digital voltage meter. The RF source power was initially set at −10 dBm, and decreased in 2 dB steps. In the dual-band measurement case, two RF signal generators were fed to the rectifier circuit simultaneously via a power combiner.

The simulation and measurement results for single and dual input tones are summarized in Fig. 3(a) and (b). A measured DC voltage of 772.8 mV is achieved with two simultaneous input tones at an input power of −10 dBm. For single tone measurements, DC voltages of 436 mV and 286 mV at 490 MHz and 860 MHz respectively are produced. The comparison between the 490 and 860 MHz single rectifiers highlights the impact of the input frequency on the PCE. A higher amount of DC voltage can be generated at the lower frequency. This difference comes from decreasing diode performance at the higher frequency due to the higher junction capacitance of the diode[31].

Importantly, a slightly higher DC voltage can be generated with the dual resonant rectifier as compared to the sum of output voltage from the two single bands, particularly at the lower input power levels as can be seen in Fig. 3(b) which shows the lower power section of Fig. 3(a) in more detail. By maximizing power collection from various sources of different frequencies and delivering the combined power to the rectification circuit, the diode conversion efficiency is enhanced which results in a higher level of rectified voltage. Figure 4 compares the simulated and measured output DC power for the dual resonant rectifier circuit with both single and dual input tones. A measured DC power of 17.3 μW and 7.5 μW can be generated at 490 MHz and 860 MHz respectively with a single tone input of −10 dBm (100 μW). This represents true efficiencies of 17.3% and 7.5% for the individual single band rectification (see Fig. 5). However, the measured DC output power with two concurrent input tones of −10 dBm is 54.3 μW which corresponds to an effective efficiency of 54.3% for the dual-band rectifier (see Fig. 6). This represents a 3.14 and 7.24 times increase in output DC power over the single tone excitation at 490 MHz or 860 MHz respectively. This trend is evident down to low input power levels (around 40 μW). Furthermore, there is a significant increase in the PCE of the dual resonant rectifier for lower input power levels (<40 μW).

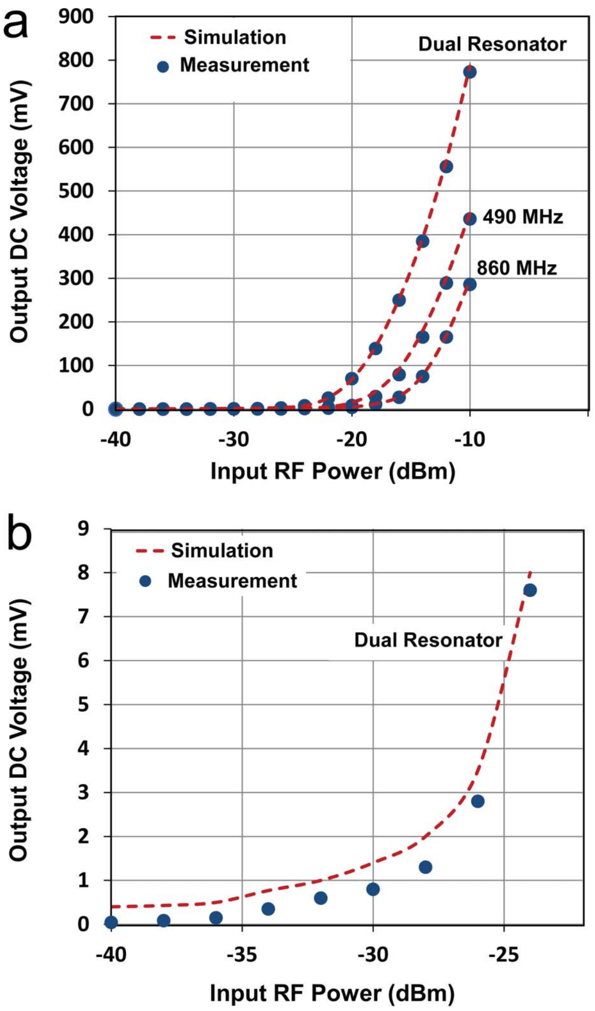

Figure 3 | Output DC voltage as a function of input RF power for single input tone at both 490 MHz and 860 MHz and for dual input tones (a) with −40 to −10 dBm input RF power (b) with −40 to −25 dBm input RF power. (This power range is associated with the signal source).

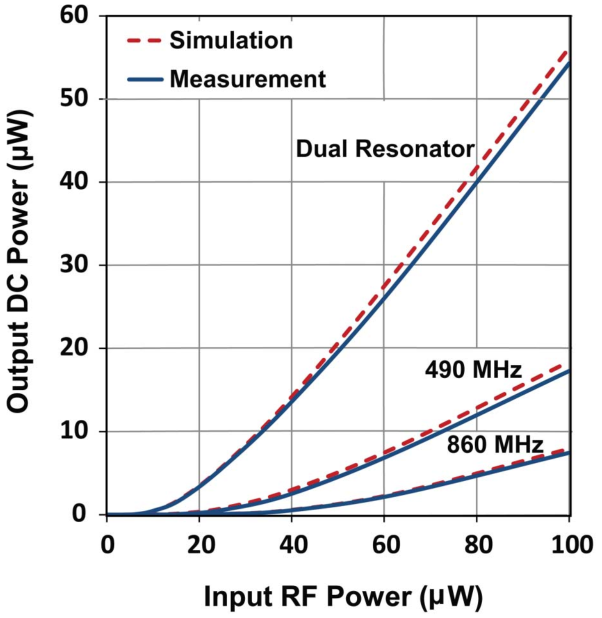

Figure 4 | Output DC power as a function of input RF power for single and dual input tones.

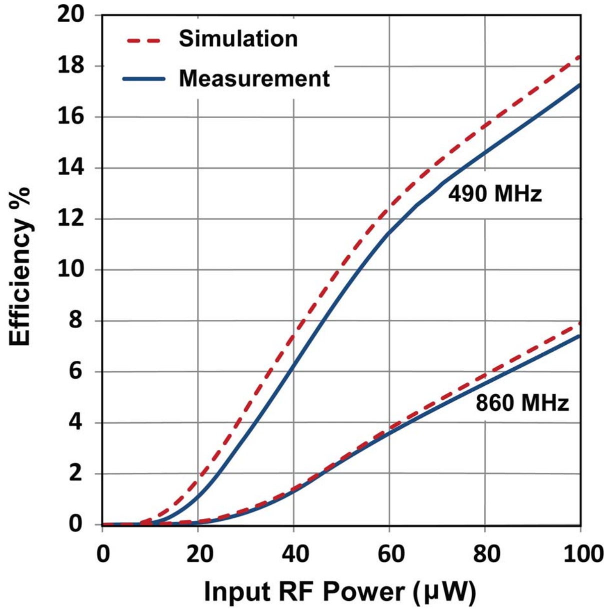

Figure 5 | RF to DC conversion efficiency as a function of input RF power for single band rectification.

Here, the effective efficiency is defined as the ratio of output DC power to the available input RF power rather than the power delivered to the diodes (equation (1)). The available power level is associated with the signal source. For the single resonator, the available input power is −10 dBm and the delivered power is also −10 dBm (assuming no loss). However, by creating a dual resonant matching network the power delivered to the diodes is −7 dBm (combined total input power from two signal generators) but the available power is still −10 dBm.

$$\eta = \frac{p_o}{p_i} = \frac{\left(\frac{V_o^{2}}{R_L}\right)}{p_i} \qquad (1)$$

Therefore, combining input RF signals into a single rectification stage results in high sensitivity rectifier, which is widely applicable to

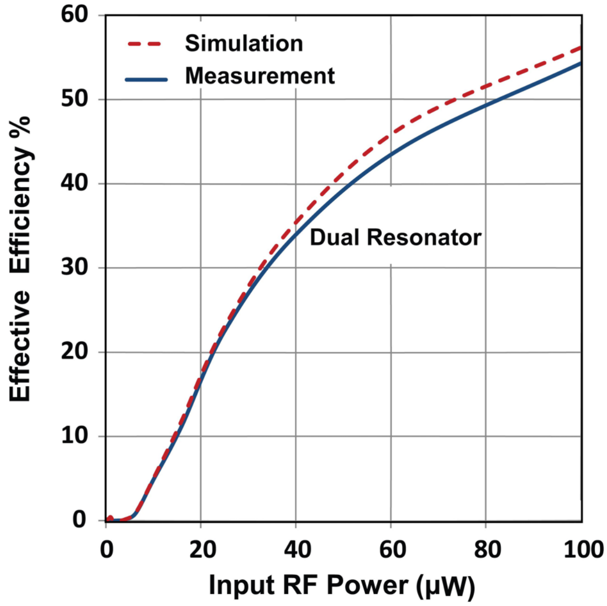

Figure 6 | Effective RF to DC conversion efficiency as a function of input RF power for dual resonant rectification.

Table 1 | Rectifier performance comparison

Ref.	Technology	Measured Efficiency (%)	RF power variation (in PCE evaluation)	Rectification Technique
13	Schottky diode	82@50 mW	N/A	Single resonator
16	Schottky diode	44@−10 dBm	N/A	Single resonator
18	Schottky diode	20@0.07 mW/cm^2 0.1@5×10^{-5} mW/cm^2	10^{-5} to10^{-1} mW/cm^2	Broad band
20	Schottky diode	77.13@22 dBm (158.49 mW)	0 to 160 mW	Dual resonator
21	CMOS	9.1@−19.3 dBm (900 MHz) 8.9@−19 dBm (2 GHz)	N/A	Dual resonator
22	Schottky diode	37 (915 MHz)@−9 dBm 30 (2.45 MHz)@−9 dBm	−40 to 0 dBm	Dual resonator
23	Schottky diode	84.4@89.84 mW (2.45 GHz) 82.7@49.09 mW (5.8 GHz)	0 to 100 mW	Dual resonator
27	Schottky diode	80@10 dBm (940 MHz) 47@8 dBm (1.95 GHz) 43@16 dBm (2.44 GHz)	−14 to 20 dBm	Triple resonator
29	Schottky diode	50@−5 dBm	−25 to 0 dBm	Dual resonator with tunable input response
This work	Schottky diode	54.3@−10 dBm 11.25@−18 dBm (490 and 860 MHz)	−40 to −10 dBm	Dual resonator

Table 2 | Environmental measurement results

Suburb	Available frequencies (MHz)	Respective available RF power (dBm) [μW]	Measured DC power (μW)
Bayswater	486, 488, 489, 490, 491, 867, 868, 869, 870, 871, 872, 873, 874	−19[12.5], −20[10], −17[19.95], −15[31.62], −22[6.3], −37[0.199], −37[0.199], −30[1], −24[3.98], −20[10], −30[1], −37[0.199], −40[0.1]	39.38
Bentleigh	491, 492, 494, 495, 865, 866, 867, 868, 869, 870, 871	−12[63.09], −46[0.02], −42[0.063], −57[0.001], −27[1.99], −27[1.99], −30[1], −37[0.199], −40[0.1], −40[0.1], −41[0.07]	30.9
RMIT University (Melbourne CBD)	487, 488, 489, 490, 491, 851, 861, 862, 866, 867, 868, 869	−30[1], −22[6.3], −29[1.25], −22[6.3], −20[10], −23[5.01], −21[7.94], −21[7.94], −30[1], −35[0.31], −40[0.1], −40[0.1]	14.5

real environmental RF energy scavenging. This multi-band technique can provide higher DC power than combining two separate single frequency rectifier circuits operating at the same frequencies. This is due to the fact that harvesting RF energy from various available sources simultaneously increases the delivered power to the rectifier, which improves the diode conversion efficiency and consequently enhances the output DC power. Table 1 summarizes this work as compared to previous published work.

In order to provide a realistic scenario for the proposed dual-band rectifier, measurement results were taken in three suburbs of Melbourne, Australia, congruent with our previous research outcomes[19]. Table 2 summarizes these environmental measurement results. It should be noted that the lower band (478–496 MHz) has a 3.67% fractional bandwidth and the higher band (852–869 MHz) has around 2% fractional bandwidth. Hence, various RF frequencies from different sources can be harvested within these two bands. The environmental measurement results demonstrate the feasibility of harvesting ambient EM energy from multiple sources simultaneously.

Discussion

The feasibility of harvesting ambient EM energy from multiple sources simultaneously is investigated in this paper. The proposed dual resonant rectifier operates at two frequency bands (478–496 and 852–869 MHz), which are used for broadcasting and cellular systems respectively. The dual resonant rectifier exhibits favorable impedance matching over a broad input power range (−40 to −10 dBm) at these two bands. The achieved sensitivity and dynamic range demonstrate the usefulness of this innovative low input power rectification technique. Simulation and experimental results of input reflection coefficient and rectified output power are in excellent agreement. The measurement results demonstrate that a two tone input to the proposed dual-band RF energy harvesting system can generate 3.14 and 7.24 times more power than a single tone at 490 or 860 MHz respectively, resulting in a measured effective efficiency of 54.3% for a dual-tone input power of −10 dBm. It is evident that this dual resonant rectification technique increases the RF to DC effective conversion efficiency, and hence the recoverable DC power for low power applications. Furthermore from a design and economic perspective, utilizing a large number of components (e.g. antennas, diodes) to realize individual rectifier circuits for each frequency band creates additional expense. In order to provide more realistic measurement results, the proposed dual-band rectifier was tested in three suburbs of Melbourne, Australia. Therefore, this dual-band technique offers a simple and cost-effective solution which is of paramount importance for environmental power harvesting systems. This innovative technique has the potential to generate a viable perpetual energy source for low power applications in urban environments.

Limitation of the study, open questions and future work

Utilizing diodes which are more suitable to low power applications ($P_i < -20$ dBm) could increase the voltage sensitivity, resulting in a higher RF-DC conversion efficiency[32]. Applying a power optimized waveform excitation to the rectifier circuit in these frequency bands, a higher amount of DC power can be generated when compared with a single and dual tone excitations with the same input power[33,34]. However this technique is not applicable to energy harvesting where the input waveform is arbitrary.

Utilizing our proposed dual resonant rectification technique to combine resonant circuits for any other arbitrary frequency bands could lead to PCE improvement, provided that suitable diodes for the desired frequency bands are selected. Note that by increasing the operating frequency the rectification performance degrades due to

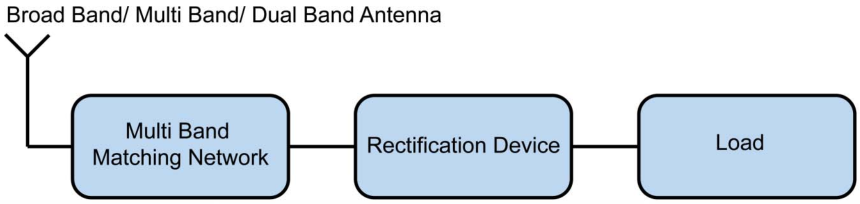
Broad Band/ Multi Band/ Dual Band Antenna
Multi Band Matching Network
Rectification Device
Load

Figure 7 | **General block diagram of the RF energy harvesting system.**

the higher junction capacitance of the diode. Hence, lower output voltage is expected at higher frequency bands.

It is the object of our future work to design a multi-band rectenna array for enhanced RF energy harvesting. Furthermore, increasing the bandwidth, sensitivity and efficiency will also be investigated.

Methods

The major goal in designing an efficient RF harvesting system is to produce high DC output power. Toward this goal, a high sensitivity rectifier is crucial for optimum RF scavenging. A significant factor governing the sensitivity of a rectifier is the threshold voltage of the diode used for rectification. The diode must be able to "switch on" for very low ambient energy levels.

To address this sensitivity issue, a system that scavenges power from multiple frequency bands and combines them to activate a rectification circuit is proposed. The general block diagram of the proposed system is depicted in Fig. 7. Various environmental RF energy sources of different frequencies are collected by an appropriately designed antenna, and delivered to the rectification circuit via a multi-band matching network. The rectification circuit converts the combination of RF signals into DC power for low-power applications. The embodiment in this paper realizes a dual resonant matching circuit as a transition between a 50 Ω nominal antenna output and the non-linear rectification device at 490 and 860 MHz. Based on the Australian Radiofrequency Spectrum Plan[35], these bands are allocated to broadcasting services and cellular systems.

Device Selection. Due to the very low ambient power available in a real environment[19], a very low threshold voltage rectification device is required in order to increase sensitivity. For this reason, Schottky diodes (GaAs or Si) are commonly employed for RF energy harvesting. In this work, a microwave Schottky detector HSMS2820 ($C_{j0} = 0.7$ pF, $R_s = 6\ \Omega$, $I_s = 2.2e^{-8}$ A) is chosen due to its excellent high frequency performance, low series resistance (R_s) and junction capacitance (C_j), and low threshold voltage with high-saturation current[31]. This low threshold voltage (0.15–0.3 V) supports rectification at low input power levels.

Proposed Rectifier Design. In order to design an efficient RF harvesting system, the non-linearity of the rectifier impedance with frequency and input power should be matched to the 50 Ω output of the antenna at the desired frequency bands. Therefore, the diode input impedance as a function of frequency and different power levels were calculated and analyzed[36]. In order to match the input impedance of the rectifier to the 50 Ω output of the antenna, the total load impedance for different input power and frequencies should be determined. A circuit consisting of a pair of Schottky Barrier Diodes (SBD) terminated with a load resistor ($R_{Load} = 11$ kΩ) and an output bypass capacitor ($C2 = 6.8$ pF) was simulated using Agilent ADS software. Figure 8 shows the proposed geometry of the voltage-doubler topology[31,37]. The voltage doubler rectifier structure is employed for the design of the RF-DC power conversion system as this topology is well suited to low power rectification. The resistor and capacitor at the output will filter high frequencies. The high load resistor (11 kΩ) was chosen to observe a reasonable output voltage at very low currents. Using Large Signal S-Parameters analysis in Agilent ADS software, the load impedance and bypass capacitor were determined and optimized.

The voltage doubler rectifier in Fig. 8 consists of a peak rectifier formed by *D2* and bypass capacitor *C2* (6.8 pF) and a voltage clamp formed by *D1* and *C1* (total capacitance of the transmission lines and diode's parasitic capacitance (C_p)). In the negative phase of the input, current flows through *D1* while *D2* is cutoff. The voltage across *D1* stays constant around its threshold voltage and the voltage at node 1 is charged to $-V_{th1}$ (where $-V_{th1}$ is the threshold voltage of the *D1*). At the negative peak, the voltage across *C1* is $V_{amp} - V_{th1}$ (where V_{amp} is the amplitude of the input signal). In the positive phase of the input, current flows through *D2* while *D1* is cutoff. The voltage across *C1* remains the same as the previous phase because it has no way to discharge. At the positive peak, the voltage across *D1* is $2V_{amp} - V_{th1}$. Since *D2* is conducting current to charge *C2*, the voltage at the output is $V_{out} = 2V_{amp} - V_{th1} - V_{th2}$.

The DC equivalent circuit of the SBD is a voltage source in series with the junction resistor R_j which is obtained by differentiating the diode voltage–current characteristic and is given by equation (2)[31,38]:

$$R_j = \frac{nKT}{q(I_s + I_b)} \tag{2}$$

Where n is the diode ideality factor, *K* is the Boltzmann's constant, *T* is the temperature in degrees Kelvin, *q* is the electronic charge, I_s is the diode saturation current and I_b is the external bias current. At low power levels, the saturation current is very small ($I_s = 2.2\ e^{-8}$ A) and for a zero-biased diode, $I_b = 0$. Therefore, the resulting value of junction resistance at room temperature is approximately 1.7 MΩ. Since, the saturation current is highly temperature dependent, R_j will be even higher at lower temperatures which tends to decrease the output voltage. As the input power increases, some circulating rectified current will cause a drop in the value of R_j and this phenomenon will increase the value of the DC output voltage. Furthermore, it is worth to highlight that the rectified current produced by the first diode (*D1*) in Fig. 8 constitutes the external bias current of the second diode (*D2*) which will help to reduce the R_j and hence the detection sensitivity is improved. Therefore, depending on the amount of available bias current, R_j is varying (equation (2)), hence the matching network is changing which impacts the amount of delivered power to the diode and results in different values of PCE.

A Schottky barrier diode can be modeled by the linear equivalent circuit shown in Fig. 9, where L_p and C_p are the diode's parasitic inductance and capacitance respectively due to packaging ($L_p = 2$ nH and $C_p = 0.08$ pF) which are generally unwanted[39]. This linear model is used for determining the diode impedance at a given input power.

The diode impedance analyzed using a Harmonic Balance simulator and a non-linear model of the diodes over the frequency range of 400 to 900 MHz at various input power levels (Fig. 10). Due to the large junction resistor at low input RF power levels, the rectification device is turned off in absence of an appropriate matching network. Large Signal S-parameter analysis was conducted and higher input power (associated with the signal source) is applied directly to the Schottky diodes configuration of Fig. 8 which does not include a matching network in order to turn on the diodes (reduce the value of R_j) and extract approximate input impedance value as our starting point in design of a matching network. As it can be seen in Fig. 10, with increasing the source power, the diode impedance is varying and it is beginning to switch on. Hence, the input impedance needs to be determined when the diode is

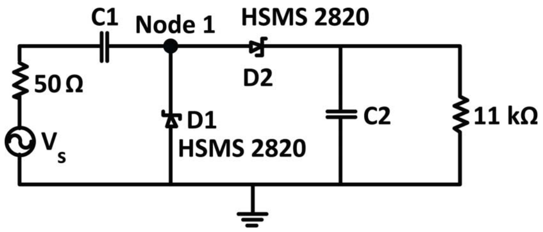

Figure 8 | **Schematic of a voltage-double rectifier without matching network.**

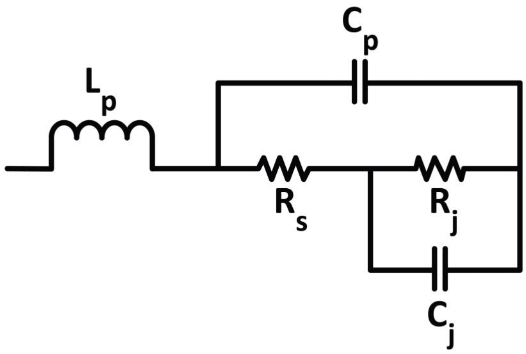

Figure 9 | **HSMS 2820 Schottky diode equivalent circuit.**

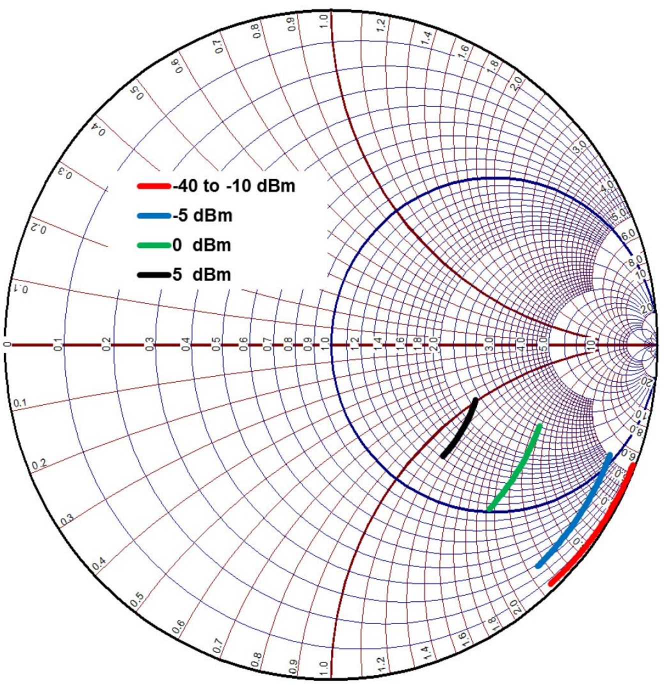

Figure 10 | Diode input impedance calculated with Large Signal S-parameter analysis over the frequency range of 400 to 900 MHz with various unmatched input power levels.

turned on to realize the matching network for a rectifier circuit. Obviously, in the presence of an appropriate matching network the rectification device can be turned on at lower power levels, whilst in the absence of a matching network a higher input power should be applied to switch on the diode. (Note that, with an unmatched rectifier the total applied input power from the signal source cannot be delivered to the diode due to the high reflection in the circuit).

The aim is to match the input impedance of the device to 50 Ω at 478–496 MHz and 852–869 MHz bands over a broad range of input RF powers. The procedure commences by matching the diode input impedance at high unmatched source power and shifting the diode input impedance at various power levels to within the voltage standing wave ratio (VSWR) <2 circle on the Smith chart. This procedure assumes that diode input impedance does not drastically change in this low power range. The simulation results of Fig. 10 prove that this is the case.

In order to provide maximum power transfer from the antenna to the rectifier circuit, a dual resonant rectifier network is designed as a transition between a 50 Ω nominal antenna output and the non-linear rectification device over the power range of −40 to −10 dBm (see Fig. 11). Hence, a coupled-resonator structure with both series and shunt resonators is designed to achieve a dual-band network[40]. The linear equivalent circuit model of the SBD chip[39] has been taken into consideration to design the dual band match at the desired frequency bands. In Fig. 11, $C_{equivalent}$ represents the total capacitance of the diodes and bypass capacitor and $L_{equivalent}$ is the overall parasitic inductance of the diodes. The series *L-C* resonator ($L4 + L_{equivalent}$ and $C_{equivalent}$) and the parallel L-C resonator (*C3* and *L3*) define the dual resonant circuit. The series resonator corresponds closely to the higher band specification of 852–869 MHz, whilst the parallel resonator approximates the lower 478–496 MHz band. A minimum number of components were used in order to reduce the ohmic and parasitic losses.

The resonant frequency of each sub-circuit was determined in isolation using the following equation:

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{3}$$

The 852–869 MHz band resonator circuit components were calculated. Here, $C = C_{equivalent} \cong 1.3$ pF consists of the combination of the bypass capacitor (6.8 pF) and

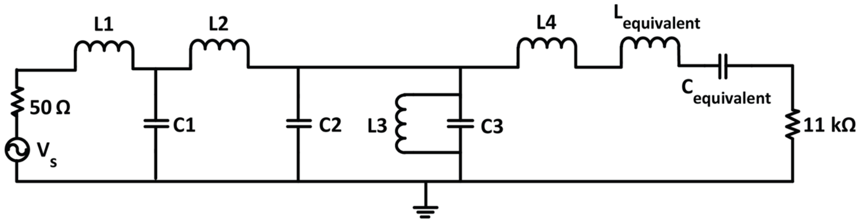

Figure 11 | Schematic of a dual resonant rectifier (optimized parameters of the chip components are: *L1* = 3.9 nH, *C1* = 0.2 pF, *L2* = 12 nH, *C2* = 1.8 pF, *L3′* = 3.9 nH, *C3′* = 7.5 pF, *L4′* = 11.6 nH, $L_{equivalent} \cong 1$ nH, $C_{equivalent} \cong 1.3$ pF).

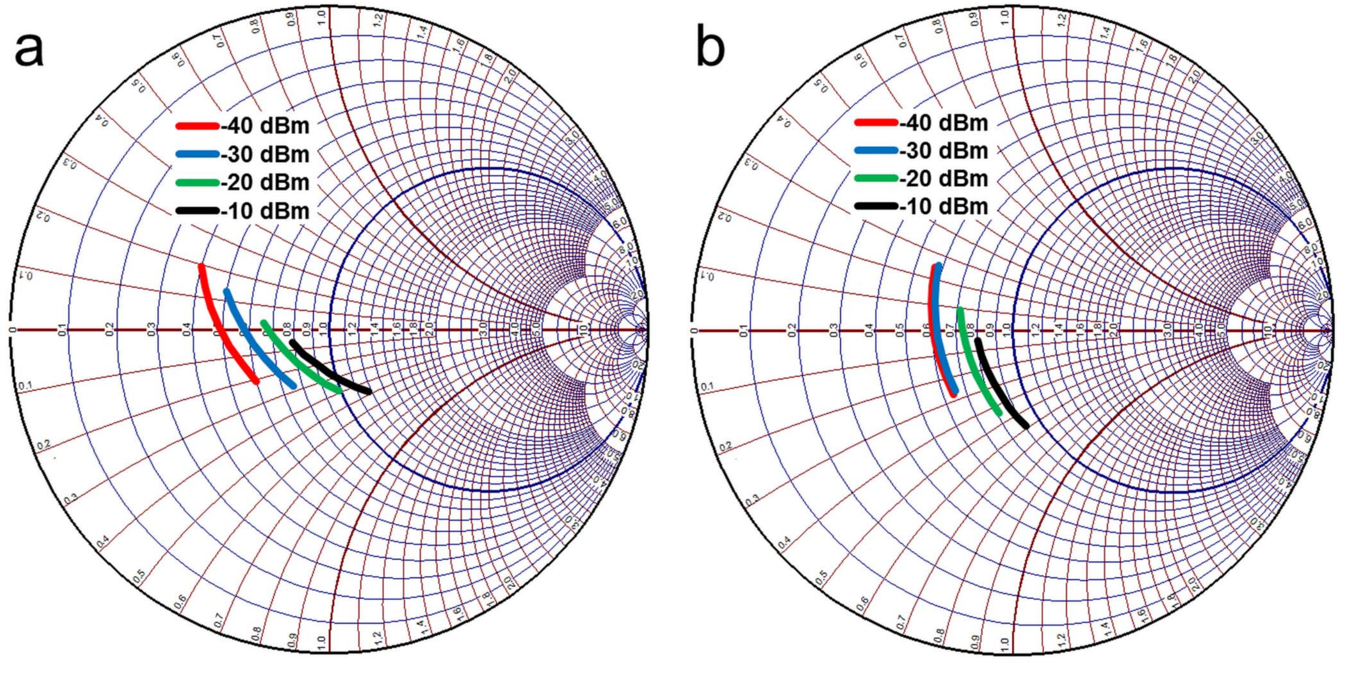

Figure 12 | Dual resonant impedance matching with −40 to −10 dBm input RF power. (a) 478–496 MHz. (b) 852–869 MHz.

the overall junction ($C_{j0} = 0.7$ pF) and parasitic capacitance ($C_p = 0.08$ pF) of *D1* and *D2*. Thus, *L* is calculated to be 26.5 nH in order to achieve an appropriate resonant frequency. Note that, *L* consists of L_4 and the overall parasitic inductance ($L_{equivalent} \cong$ 1 nH) of *D1* and *D2*. The 478–496 MHz band resonator circuit components were calculated as $C3 \cong 15$ pF and $L3 \cong 7.2$ nH. Hence, the initial component values are determined for the two resonant circuits.

Initially these resonators were combined to achieve a dual-band structure. Then standard *LC* matching technique[40] is utilized to determine *C1*, *C2*, *L1*, and *L2* to achieve minimum reflection at the resonant frequencies. The substitution of realistic chip component values with their associated parasitics, and addition of 50 Ω microstrip lines and T-junctions introduce delay and shift the imaginary part of the input impedance. The via-holes also contribute to extra inductance in the circuit. Hence minor circuit adjustments are made in order to fine tune the resonant frequencies to the desired values. The final optimized values of the standard chip components are: $L3' = 3.9$ nH, $C3' = 7.5$ pF and $L4' = 11.6$ nH. Large Signal S-parameter analysis is also performed to demonstrate the matching network performance as the input power is varied. Simulation results for the input impedance of the circuit depicted in Fig. 11 are illustrated in Fig. 12. The proposed dual-resonant matching circuit achieves a VSWR <2 at 478–496 MHz and 852–869 MHz for input power ranging from −40 to −10 dBm. It should be noted that the matching circuit was designed based on the input impedance of two diodes and the output resistor and capacitor (Fig. 10). Therefore, selecting a different value for the load resistor requires a new matching circuit to be designed.

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Author contributions

N.S. designed and simulated the rectifier, carried out the measurements, interpreted results and wrote the paper. K.G. directed the research, contributed to perform the simulation and measurement and validation of design and results. W.S.T.R. supervized the research, analyzed the data and contributed to the general concept, validation of design and results. J.R.S. analyzed the data and contributed to the general concept, validation of design and results. All authors reviewed the manuscript.

Additional information

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Article

Optimization of Passive Low Power Wireless Electromagnetic Energy Harvesters

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Abstract: This work presents the optimization of antenna captured low power radio frequency (RF) to direct current (DC) power converters using Schottky diodes for powering remote wireless sensors. Linearized models using scattering parameters show that an antenna and a matched diode rectifier can be described as a form of coupled resonator with different individual resonator properties. The analytical models show that the maximum voltage gain of the coupled resonators is mainly related to the antenna, diode and load (*remote sensor*) resistances at matched conditions or resonance. The analytical models were verified with experimental results. Different passive wireless RF power harvesters offering high selectivity, broadband response and high voltage sensitivity are presented. Measured results show that with an optimal resistance of antenna and diode, it is possible to achieve high RF to DC voltage sensitivity of 0.5 V and efficiency of 20% at −30 dBm antenna input power. Additionally, a wireless harvester (*rectenna*) is built and tested for receiving range performance.

Keywords: RF energy harvesting; wireless power transmission; coupled resonators; Schottky diode; RF to DC power converter; impedance matching; PI-matching; L-matching; rectenna

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1. Introduction

For autonomous powering of sensor nodes in remote or inaccessible areas, wireless power transfer provides the only viable option to power them from an energy source. Due to the low power density of ambient RF at far-field from transmitters, there is a need to optimize each aspect of a wireless RF energy harvester for possible realistic applications. Today remote autonomous sensors are mostly powered by batteries, which have limited lifespan. Renewable powering has the potential to power autonomous sensors perpetually. Due to the expansion of telecommunications technology ambient electromagnetic (EM) power is among the most common sources of ambient energy. There are power transmitters/receivers scattered in practically any society, ranging from television transmission stations to cell phone transmitters and even wireless routers in our homes/offices or mobile phones. These transmitters in our environment and others which are on special dedicated frequencies produce ambient RF power (on the order of microwatts) which can be used as a source for powering remote microwatt budget sensors through wireless energy harvesting. This work presents different matching techniques based on different application requirements using Schottky diode-based RF to DC power converting circuits for wireless remote EM energy harvesting around 434 MHz and 13.6 MHz. Generalized analytical models and limitations of the matched RF to DC power converters are discussed. A wireless RF energy harvester consisting of an antenna and a matched diode rectifier is then realized and its performance tested. Passive wireless energy harvesting also finds applications in near field communications (NFC) [1], RFID tags [2–5], implantable electronics [6,7], and environmental monitoring [8], among others.

1.1. State of the Art

Hertz was the first to demonstrate the propagation of EM waves in free space and to demonstrate other properties of EM waves such as reflection using parabolic reflectors [9]. Wireless power transmission was then investigated and demonstrated for possible wireless remote powering by Tesla. Electromagnetic power beaming for far field wireless power transfer using collimated EM waves was proposed in the 1950s [9]. Recent advances in ultralow power sensors means ambient omni-directional EM power can be used as a source for powering remote sensors without the need to collimate the EM power through the wireless space. Mickle [10] and McSpadden [11] have presented earlier work on wireless energy harvesting systems using Schottky diodes and rectennas where the usability of ambient RF power into DC power was shown. Sample [12] presented a wireless harvester which can harvest EM power from TV and radio base stations transmitting 960 kW of effective radiated power; 60 µW was harvested at a range of about 4 km. Umeda [13] and Le [14] have presented more integrated wireless energy harvesters based on CMOS RF to DC rectifying circuits. CMOS-based rectifying power converters provide full compatibility with standard CMOS technologies and have advantages in batch processes for mass production. The drawback of CMOS-based diode connected transistors is the need to bias the gate of the transistors for the rectifying circuits to effectively function. This gate bias is provided externally, which makes the system not passive. Without the injection of external charges or a biasing of the transistor gate, the circuit has low efficiency, especially when the amplitude of the input voltage is low [15]. Shameli [2] presented a passive CMOS RF to DC power converter with a voltage sensitivity of 1 V at −14.1 dBm input, but the circuit efficiency was only 5 %. Zbitou [16] presented an RF to DC converter based on Schottky diodes and achieved 68 % efficiency at 20 dBm RF input power. Ungan [17,18] presented antennas and high quality factor RF to DC power converters at 24 MHz and 300 MHz for RF wireless energy harvesting at -30 dBm input power. The power converter used high quality factor resonators for impedance matching the EM source and the diodes and achieved high open circuit voltage sensitivity of 1 V/μW. Boquete [19] presented a risk assessment system for calculating insurance premiums by monitoring mobile phone usage while driving. This was done by harvesting EM power from detected mobile phone usage during driving for risk assessment. Heikkinen [20] presented rectennas on different substrates at 2.4 GHz using transmisson lines to match the antennas output resistance (*at resonance*) to the rectifying diodes. Akkermans [21] presented a rectenna design by complex conjugating impedance provided by a microstrip structure to a diode so that resonance may be achieved for a working frequency. This design approach may need sophisticated tools to realize and the dominant resonance frequency of the rectenna can be unpredictable in practice. Hagerty [22] presented rectenna arrays for broadband ambient EM harvesting and characterized the harvesters from 2 GHz to 18 GHz; rectennas combine impedance matching the RF rectifying circuit and the antenna into one compact device, but an array of rectennas may increase the overall size of an EM harvester. Herb [23] and Vullers [24] have provided a comprehensive state of the art for micro energy harvesting and have explored the various techniques used for harvesting ambient renewable energy.

2. RF to DC Power Converter

2.1. Diode Rectifier

A junction diode equivalent circuit and simple Schottky diode rectifier are shown in Figure 1. R_{DS} is the diode resultant series resistance, C_{DS} is the diode resultant series capacitance, R_{DP} is the diode resultant parallel resistance, C_{DP} is the diode resultant parallel capacitance, Vs is the sinusoidal source voltage and Vc is the voltage across the capacitor.

Figure 1. (**a**) Diode series equivalent model, (**b**) Diode parallel equivalent model, (**c**) Simple diode detector.

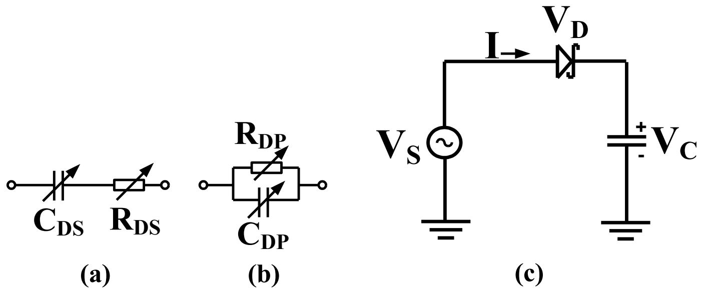

The diode capacitive impedance is mainly due to the junction capacitances provided by the metal, its passivation and the semiconductor forming the diode. AC power incident on a forward biased diode input is converted to DC power at the output. The current-voltage behavior of a single metal/semiconductor diode is described by the Richardson equation [25] as in Equation (1):

$$I = I_S\left(e^{\left(qV_D/_{nKT}\right)} - 1\right) \tag{1}$$

where I is the current through the diode, I_S is the saturation current, q is the charge of an electron, V_D is the voltage across the diode, T is the temperature in degrees Kelvin and K is Boltzmann constant. The voltage equation around the loop can be derived from Figure 1(c) and is given in Equation (2):

$$V_D = V_S - V_C \tag{2}$$

Since the same current flows through the diode and the capacitor, one can find the average current through the circuit by integrating Equation (1) over a time period. By substituting Equation (2) into Equation (1), V_C can be expressed in terms of V_S by averaging the diode current to zero. This is given in Equation (3) [26]:

$$V_C = \frac{KT}{q}\ln\left[\vartheta_0\left(\frac{qV_S}{KT}\right)\right], \tag{3}$$

where ϑ_0 is the series expansion of the sinusoidal source voltage. Equation (3) can further be simplified for very small amplitude V_S as Equation (4):

$$V_C \approx \frac{qV_S^2}{4KT} \tag{4}$$

Equation (4) shows that for a small voltage source, the circuit output voltage is proportional to the square of the input sinusoidal voltage; hence it's so-called square law operation. Extensions of this model for voltage multipliers and other input signals are presented in [27] and [28]. Equation (4) further confirms that for low input voltage (power ≤ 10 dBm), an impedance matching network between the source and the diode is necessary to improve the detected output voltage and efficiency.

2.2. Impedance Matching

The maximum power transfer theorem states that the highest power is transferred to the load when the source resistance is the same as the load resistance. For systems with both resistive and reactive impedances from source and load, the source and the load impedance should be adjusted in a way that they are the complex conjugate of each other through impedance matching. For the purposes of this work, a 50 Ω resistive source is chosen as reference for load impedance matching. The antenna which captures the ambient RF signals is tuned to provide this source resistance at resonance for the rectifying circuit in a complete EM wireless remote harvester. The load is the resistance of the Schottky diodes and the actual connected resistance (*remote sensor*). The specific type of matching network which can be used for complex conjugation depends on the nature of load or source impedance, the desired RF to DC converter functionality and other factors like circuit size, cost, *etc.* The response of a matched RF to DC power converter depends on the matching network used as well as the source or load component quality factors and impedances.

2.3. Diode Impedance

Schottky diodes HSMS-285C and HSMS-286C from Avago [29,30] are used to build the RF to DC power converters. The HSMS-285× or 286× series diodes can be operated as zero biased with relatively low forward junction potential. This allows for the realization of completely passive RF to DC power converters for wireless energy harvesting. The HSMS-285C or 286C is a pair of series connected Schottky diodes in a SOT-323 package. The impedance of the HSMS-285C and HSMS-286C diodes was first measured so it can be matched to the resistance (50 Ω) of the antenna source. This is done by connecting the input of the diodes to a network analyzer and measuring the scattering parameters. These scattering parameters are then converted to the corresponding impedances. The input impedance of a diode depends mainly on the resistive and capacitive impedance provided by the junction of the diode and its connected load. For a couple of diodes arranged in a package such as the HSMS-285C or 286C, the input impedance is the vector sum of the impedances provided by each diode in the package arrangement, the extra impedance associated with the packaging and the connected load. The diode measuring board is as shown in Figure 2. The diodes were measured at room temperature for an input power of -30 dBm at a diode connected load of 1 MΩ with a 100 pF filter capacitor. For the sake of this work, the input impedance of the diodes will always be referred to at these connected load conditions.

Figure 2. (**left**) Reference circuit layout for measuring diodes input impedance, (**right**) measuring printed circuit board (PCB) for diodes input impedance on 1 mm FR4 substrate.

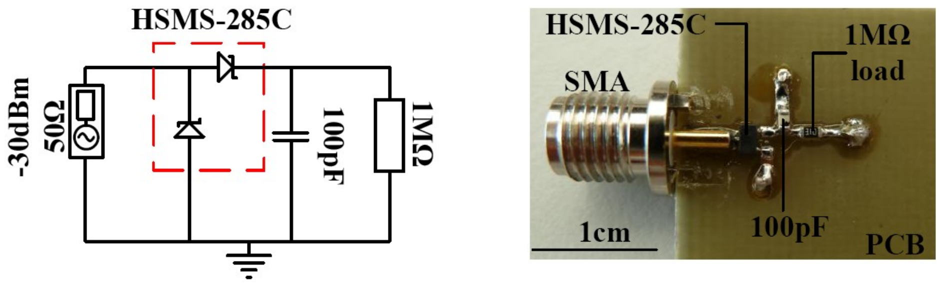

Figure 3. Measured input impedance (Δ resistive, □ capacitive) of HSMS-285C (**left**) and HSMS-286C (**right**) diodes at −30 dBm input with 1 MΩ load and 100 pF filter.

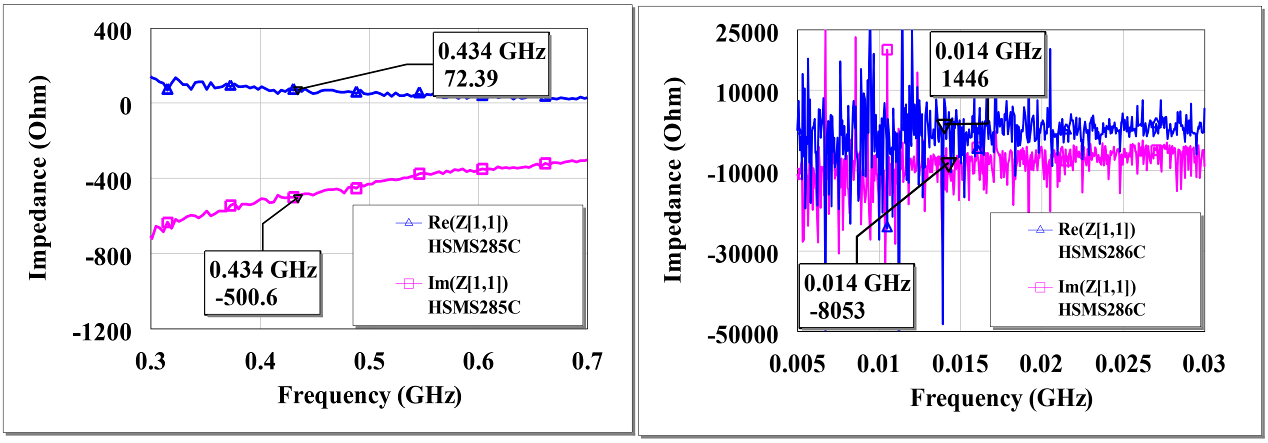

The board is fabricated such that components are soldered directly one into another to prevent additional impedances introduced by copper route. The PCB backside had the ground layer. An example of measured input impedance for HSMS-285C and HSMS-286C is shown in Figure 3.

The diodes quality factor is given by $X_{DS}R_{DS}^{-1}$, where X_{DS} is the resultant series capacitive impedance of the diodes. At an input power of −30 dBm, the measured input impedance of the HSMS-285C diodes is 72–j501 Ω at 434 MHz and 587–j1239 Ω at 13.6 MHz. For HSMS-286C diodes, it is 10–j503 Ω at 434 MHz and ~1.5–j8.1 kΩ at 13.6 MHz for −30 dBm input. The measured impedance of the HSMS-286C diodes at low frequencies (< 60 MHz) shows pronounced fluctuations. The low-frequency excess flicker noise and the shot noise observed in the HSMS-286C have been studied by several authors [31–33]. The pronounced presence of trap states in the depletion region of the semiconductor, mobility fluctuations in carriers, edge effects among other reasons is reported to cause deviations from the ideal Schottky diode behavior and hence generation-recombination noise for some diodes such as the HSMS-286C [34]. When a diode rectifier is matched at a reference operating condition, the matching network may function less effectively at other input power levels, connected load and other operating frequencies. This is due to possible changes in the diode input impedance. Throughout this work the imperfections of the matching circuit at other operating conditions away from the matched reference conditions are accepted without changes to the matching network.

2.4. Voltage Doubler

The Delon voltage doubler and Greinacher doubler are both used to realize the RF to DC power converters presented in this work. The Delon voltage doubler and Greinacher doubler are shown in Figure 4. The diodes output voltage (V_{out}) is doubled what is detected by a simple detector circuit shown in Figure 1. Both doublers produce the same output performance, the only difference is that the Delon doubler has an instantaneous input ground which is not shared with the output.

Figure 4. Circuit diagram of voltage doubler, (**a**) Delon doubler and (**b**) Greinacher doubler.

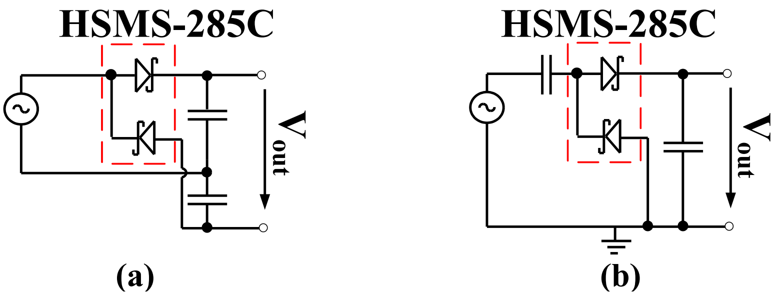

2.5. Matching Techniques for Antenna Source and RF to DC Power Converter

2.5.1. L-match RF to DC Power Converter

An L-match network converts a source series impedance to its equivalent load parallel impedance or *vice-versa* and tunes out by subtracting or adding any surplus reactance from the load or source with the counter impedance. Series impedance is converted to its parallel equivalent impedance using Equations (5–7):

$$Q_S = \frac{X_S}{R_S} \tag{5}$$

$$Q_P = \frac{R_P}{X_P} \tag{6}$$

where X_S is the total series reactive impedance, R_S is the total series resistance, R_P is the total parallel resistance, X_P is the total parallel reactive impedance, Q_S and Q_P are the series and parallel quality factors respectively:

$$R_S + jX_S = \frac{R_P \times jX_P}{R_P + jX_P} \tag{7}$$

Equation (7) is the equation of a series sum of impedances and a parallel sum of impedances. It is interesting to note that Q_S and Q_P from an L-matched network may be different from the individual component quality factors as a result of the inherent resistive and reactive impedances in that component. By virtue of Equation (7), Q_S and Q_P must be equal in an L-matched network. Using Equations (5,6) and (7), the ratio of the parallel resistance (*or reactance*) to the series resistance (*or reactance*) can be derived in terms of the quality factors Q_P or Q_S [35]. Since at match conditions, only the resistive impedances dissipate power, the loaded quality factor Q, of the L-matched network can be expressed as in Equation (8):

$$R_P = (Q^2 + 1)R_S \tag{8}$$

Using Equations (5,6) and (8), series impedance can be converted to its parallel equivalent for a fixed frequency and power level. As an example; a series impedance 72–j501 Ω (HSMS-285C at 434 MHz for −30 dBm input power) is easily converted to $-j510(3519)/(-j510 + 3519)$ Ω as its parallel equivalent with a component quality factor of 6.96. The source resistance is taken as part of the parallel matching network in an L-match circuit if the source series equivalent resistance is greater than the load series equivalent resistance. On the other hand, the load resistance is taken as part of the parallel matching network if the load series equivalent resistance is greater than the source series equivalent resistance. For the purpose of this work, inductors were only used for series impedance matching and capacitors as shunts. This prevents power seeping through any shunt inductor used for impedance matching due the short circuit provided by a shunt inductor to ground and resulting in less output efficiency. Resistors were not used for impedance matching.

2.5.2. L-match RF to DC Converter Generalized Analytical Model

The classical matching technique using Equations (5,6) and (8) is first used to L-match the 50 Ω resistance of the antenna to the resistance of the HSMS-286C diodes (and load) at 434 MHz for −30 dBm input and then the generalized model is discussed. The antenna source resistance was L-matched to the resistance of the diodes (and load). The 50 Ω resistance of the antenna is taken as the parallel matching component and the diodes 10 Ω resistance is the series matching component. The loaded Q is found as 2 between the 50 Ω antenna source resistance and the 10 Ω diode series resistance using Equation (8). From this loaded Q, a shunt capacitive impedance of 25 Ω (14.6 pF at 434 MHz) using Equation (6) and a series inductive impedance of 20 Ω (7.3 nH at 434 MHz) using Equation (5) will match the 50 Ω source to the 10 Ω HSMS-286C diodes (and load) series resistance at −30 dBm input. Since the HSMS-286C diodes inherently provides 503 Ω series capacitive impedance at −30 dBm, a resultant series inductive impedance of 523 Ω (192 nH at 434 MHz) is needed to tune the 50 Ω resistive source to the complete HSMS-286C diodes impedance at 434 MHz for −30 dBm input. The L-matched HSMS-286C diodes rectifier is as shown in Figure 5(a).

Figure 5. (**a**) L-match RF to DC harvester using the HSMS-286C diodes at 434 MHz for −30 dBm input. (**b**) Small signal impedance model of a generalized L-matched RF to DC power converter as capacitive coupled series RLC resonator with different resonator elements.

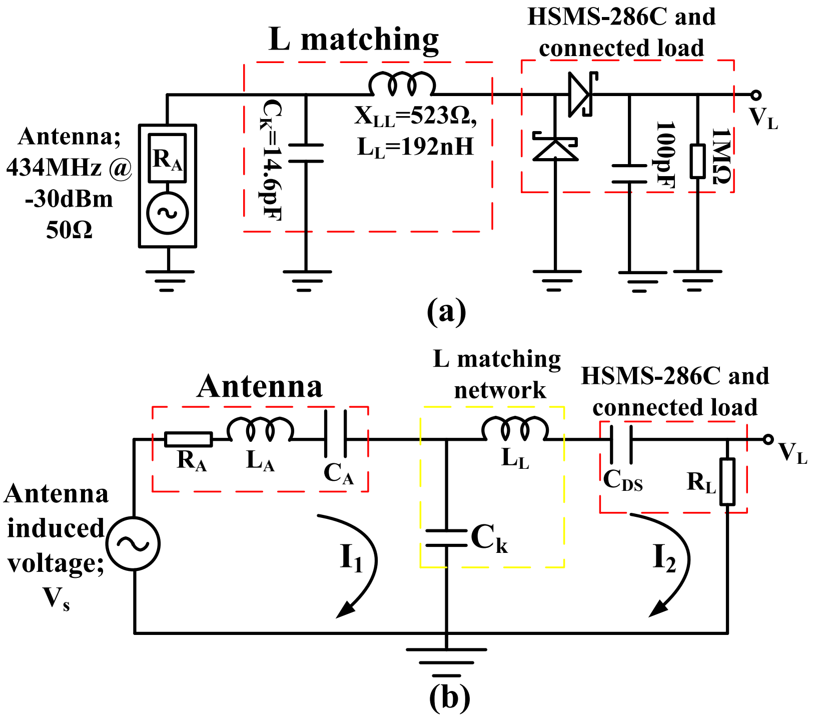
L matching
HSMS-286C and connected load
Antenna; 434MHz @ -30dBm 50Ω
R_A
C_K=14.6pF
X_{LL}=523Ω, L_L=192nH
V_L
100pF
1MΩ
(a)
Antenna
L matching network
HSMS-286C and connected load
R_A
L_A
C_A
L_L
C_{DS}
R_L
V_L
Antenna induced voltage; V_s
I_1
C_k
I_2
(b)

C_K is the tuning capacitance, L_L is the tuning inductance, X_{LL} is the tuning inductive impedance, C_{DS} is the diodes series capacitance, X_{DS} is the diodes series capacitive impedance, V_S is the antenna captured ambient EM voltage, R_A is the resistance of antenna, L_A is the inductance of antenna, C_A is the capacitance of antenna, R_L is the resultant series resistance from the diodes and the connected load resistance, V_L is the resistive load voltage. From Figure 5(a) the power dissipated in the resistance of the diodes (and connected load); P_L is given by Equation (9), where R_L is the series resistance of the diodes and load:

$$P_L = \frac{V_L^2}{R_L} \tag{9}$$

The source power; P_S is given by Equation (10), where V_S* is the root mean squared (RMS) antenna captured source voltage. Half of the source power is transferred to the resistance of the diodes (and connected load) at match conditions as described by the maximum power transfer theorem:

$$P_S = \frac{V_S^2}{R_A} \quad \text{or} \quad P_S = \frac{V_{S*}^2}{2R_A} \tag{10}$$

Equating P_L and half RMS P_S gives a condition of maximum voltage gain for the matched RF to DC power converter shown in Figure 5(a):

$$\frac{V_L}{V_{S*}} = \frac{1}{2}\sqrt{\frac{R_L}{R_A}} \tag{11}$$

From Equation (8), substituting the series and parallel resistance ratio into Equation (11) the voltage gain can be expressed in terms of the loaded quality factor as in Equations (12) and (13), where Q is the loaded quality factor of the RF to DC power converter:

$$\frac{V_L}{V_{S*}} = \frac{1}{2}\sqrt{\frac{1}{1 + Q^2}} \tag{12}$$

Equation (12) is the voltage gain in-terms of the loaded Q if the resistance of the diodes (and connected load) is part of the series matching network and the resistance of the antenna source is part of the parallel matching network as in Figure 5(a). If the resistance of the diodes is part of the parallel matching network, then Equation (13) may be written as the voltage gain in-terms of the loaded Q in an L-matched circuit:

$$\frac{V_L}{V_{S*}} = \frac{1}{2}\sqrt{1 + Q^2} \tag{13}$$

Equations (12) and (13) shows that the maximum voltage gain is directly related to the relative differences between the diodes (and connected load) resistance and source resistance at matched conditions or the circuit loaded quality factor. It is interesting to note that the circuit shown in Figure 5(a) has a loaded Q of 2, but an HSMS-286C unloaded quality factor of 50 (at 434 MHz for −30 dBm).

Figure 5(a) is generally modeled as capacitive coupling of two series RLC resonators with a voltage source. This linearized model can be made at any defined frequency and power level. The model however neglects the metal/semiconductor physics of the diode's junction potentials which results in a Schottky barrier. The first series RLC resonator is modeled as impedance from the antenna with or without some passive matching components. The voltage source V_S, is the antenna captured electromagnetic voltage. The second series RLC resonator is the impedance from the diodes (at a defined condition), connected resistance and some passive matching components. Ck is modeled as the coupling element between the two series RLC resonators. Figure 5(b) gives a more general look at the special scenario shown in Figure 5(a). The voltage equations in the two loops are given by Equations (14,15) according to Kirchhoff's voltage loop laws, where ω is the angular frequency and I_1, I_2 are the currents in the first loop and second loop, respectively:

$$V_S = I_1\left[R_A + j\omega L_A - \frac{j}{\omega C_A} - \frac{j}{\omega C_K}\right] + \frac{jI_2}{\omega C_K} \tag{14}$$

$$0 = \frac{jI_1}{\omega C_K} + I_2\left[R_L + j\omega L_L - \frac{j}{\omega C_{DS}} - \frac{j}{\omega C_K}\right] \tag{15}$$

Using Cramers rule, I_2 can be expressed as:

$$I_2 = \frac{\dfrac{-jV_S}{\omega C_K}}{\left[R_A + j\omega L_A - \dfrac{j}{\omega C_A} - \dfrac{j}{\omega C_K}\right]\left[R_L + j\omega L_L - \dfrac{j}{\omega C_{DS}} - \dfrac{j}{\omega C_K}\right] + \dfrac{1}{\omega^2 C_K^2}}. \tag{16}$$

The voltage across R_L is V_L; given by $I_2 R_L$:

$$V_L = \frac{\dfrac{-jV_S}{\omega C_K} R_L}{\left[R_A + j\omega L_A - \dfrac{j}{\omega C_A} - \dfrac{j}{\omega C_K}\right]\left[R_L + j\omega L_L - \dfrac{j}{\omega C_{DS}} - \dfrac{j}{\omega C_K}\right] + \dfrac{1}{\omega^2 C_K^2}} \tag{17}$$

The voltage gain of the coupled resonator can be expressed as in Equation (18):

$$\frac{V_L}{V_S} = \frac{\dfrac{-jR_L}{\omega C_K}}{\left[R_A + j\omega L_A - \dfrac{j}{\omega C_A} - \dfrac{j}{\omega C_K}\right]\left[R_L + j\omega L_L - \dfrac{j}{\omega C_{DS}} - \dfrac{j}{\omega C_K}\right] + \dfrac{1}{\omega^2 C_K^2}} \tag{18}$$

At resonance, there is no resultant reactance in the RLC resonators or the capacitive and inductive impedances become equal; hence Equation (19) can be written:

$$\omega L_A - \frac{1}{\omega}\left\{\frac{1}{C_A} + \frac{1}{C_K}\right\} = 0 \text{ and } \omega L_L - \frac{1}{\omega}\left\{\frac{1}{C_{DS}} + \frac{1}{C_K}\right\} = 0 \tag{19}$$

Equations in Equation (19) can be used to find the resonant frequencies of the series coupled resonator. The voltage gain of the coupled resonator at resonance can then be expressed as in Equation (20):

$$\frac{V_L}{V_S} = V_{gain} = \frac{\dfrac{-jR_L}{\omega C_K}}{R_A R_L + \dfrac{1}{\omega^2 C_K^2}} \tag{20}$$

where V_{gain} is the voltage gain. V_{gain} at resonance is a function of the resistance of the source and load and the coupling element. The maximum of Equation (20) is obtained when:

$$\frac{dV_{gain}}{dC_K} = 0. \tag{21}$$

This gives the results as in Equation (22):

$$\frac{dV_{gain}}{dC_K} = \frac{j2R_L}{\omega^3 C_K^4} - j\left\{R_A R_L + \frac{1}{\omega^2 C_K^2}\right\}\frac{R_L}{\omega C_K^2} = 0 \text{ or } R_A R_L^2 = \frac{R_L}{\omega^2 C_K^2} \tag{22}$$

Equation (22) can be simplified to find $C_{K(max)}$:

$$C_{K(\max)} = \pm\frac{1}{\omega}\sqrt{\frac{1}{R_A R_L}} \tag{23}$$

where C_{Kmax} is the value of the coupling element where maximum power transfer from the first resonator to the second resonator occurs. Using Equations (19) and (23) the unknown optimal matching impedances can be found from the known impedances just like the classical L-matched procedure using Equations (5,6) and (8). By substituting $C_{K(max)}$ into Equation (20) and taking the magnitude of V_{gain}, gives the maximum voltage gain of the coupled series resonator at resonance:

$$\left|\frac{V_L}{V_S}\right| = \frac{1}{2}\sqrt{\frac{R_L}{R_A}} \text{ or simply } \frac{V_L}{V_{S*}} = \frac{1}{2}\sqrt{\frac{R_L}{R_A}} \qquad (24)$$

For wireless harvesters consisting of an antenna and a diode rectifying circuit, the diode resistive impedance at any condition is dependent on the diode realized parameters, signal frequency, connected load and the input power level. The source impedance is determined by the impedance of the antenna. For maximum efficiency, the ratio of the source resistance to the load resistance must tend to zero at matched conditions. The efficiency η of the circuit is given by Equation (25):

$$\eta = \frac{P_L}{P_S}\,;\ \eta \rightarrow 1 \ \ when \ \frac{R_A}{R_L} \rightarrow 0 \qquad (25)$$

2.5.3. L-Match RF to DC Converter Experimental Results and Discussion

The presented circuit was L-matched between the 50 Ω resistance of the antenna source and the resistance of the HSMS-285C diodes (and load) at 434 MHz for −30 dBm input as shown in Figure 6. Since the series equivalent resistance of the HSMS-285C diodes and load (72 Ω) is greater than the 50 Ω series resistive antenna source, the diode is taken as parallel matching network with a parallel equivalent impedance of $-j510(3519)/(-j510 + 3519)$ Ω. The analysis follows the same procedure as in Section 2.5.2 after this step. Figure 6(b) shows the resultant L-matched RF to DC power converter. C_{DP}* is the resultant shunt matching capacitance.

Figure 6. (**a**) L-matched impedance circuit for matching the HSMS-285C diodes at 434 MHz for −30 dBm input. (**b**) Resultant network, (**c**) PCB layout of the L-matched Delon doubler with adjusted values on FR4 substrate (**d**) Fabricated PCB of the L-network matched Delon voltage doubler.

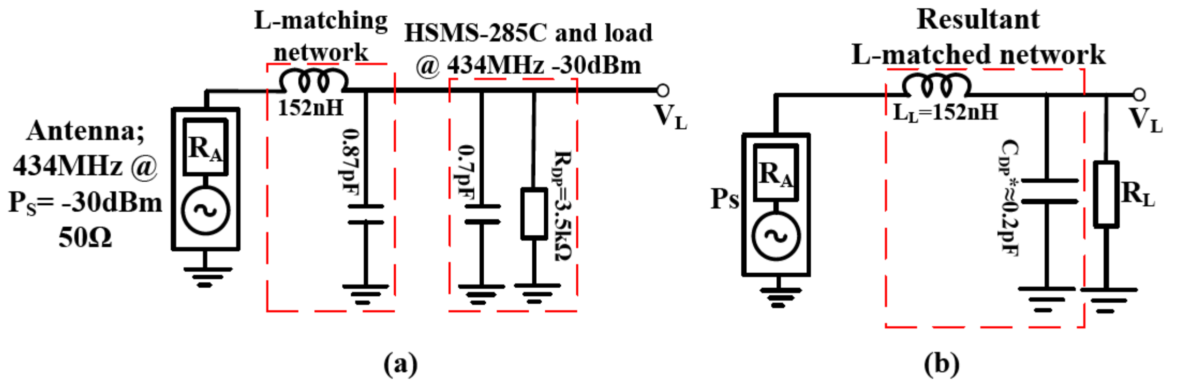

Figure 6. *Cont.*

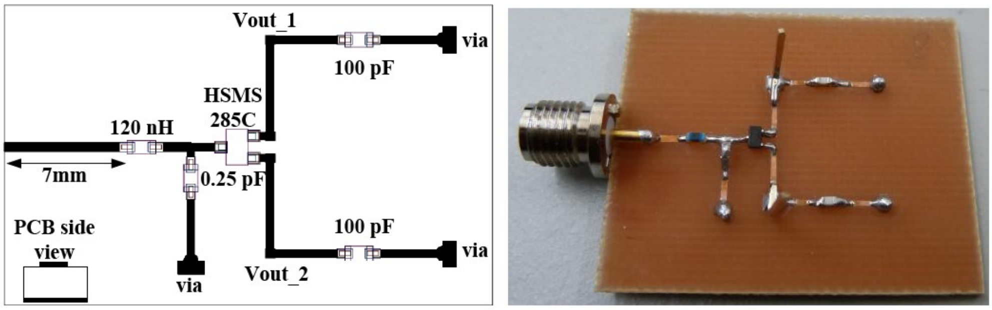

(c) **(d)**

Figure 6(a,b) assume perfect characteristic impedance between the various components in the matched circuit. When a copper route is introduced between components and on a material substrate, it must be accounted for in the total impedance as seen by the source or load. This PCB impedance compensation is carried out in Advance Design Systems (ADS) from Agilent [36]. ADS has extensive models for microstrip substrates to account for its impedances. The optimized layout using ADS microstrip models and its compensated values in the passive tuning components for a Delon doubler is shown in Figure 6(c).

The circuit reflection coefficient (S_{11}) and input impedance at open circuit are shown in Figure 7. There is high return loss and resonance around 434 MHz. The circuit input impedance at open circuit conditions is ~38 Ω at resonance for −40 dBm and ~17 Ω at −10 dBm input.

The measured L-matched circuit efficiency and voltage sensitivity is shown in Figure 8. The maximum measured L-matched efficiency at −30 dBm is 22% at ~20 kΩ load and an open circuit voltage of 124 mV. At −10 dBm, the maximum efficiency and open circuit voltage is 47% and 2 V respectively. At the optimal load of ~20 kΩ, the detected voltage is 58 mV and 1 V at −30 dBm and −10 dBm respectively.

Figure 7. Measured open circuit S_{11} of the L-matched Delon circuit at different input power levels from a 50 Ω source (**left**), measured open circuit input impedance at −10 dBm and −40 dBm of the L-matched circuit (**right**).

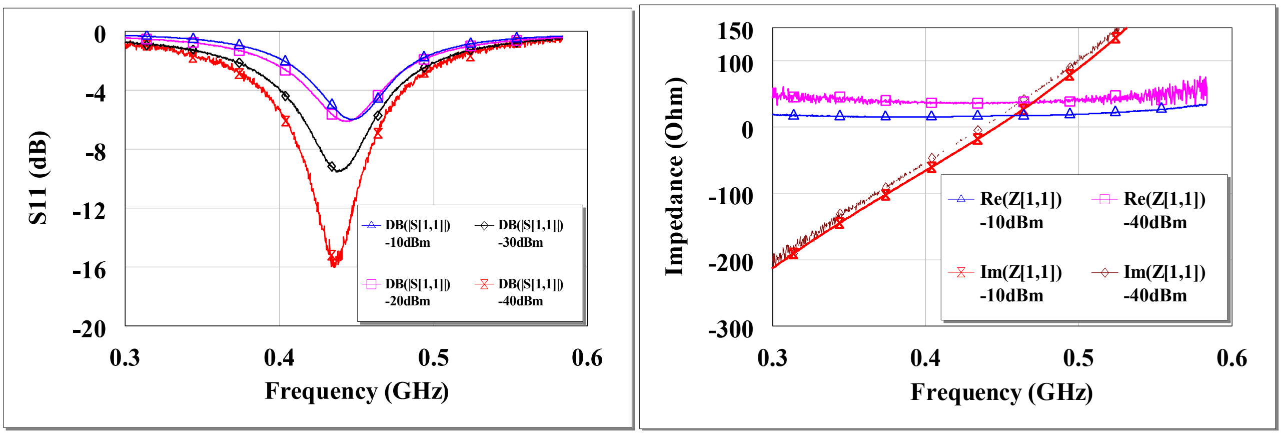

The open circuit voltage gain is 25 at −30 dBm and 40 at −10 dBm. The maximum measured efficiency at −35 dBm is 27%. This is higher than that of −30 dBm due to the better matched circuit impedance at −35 dBm (35 Ω) than at −30 dBm (27 Ω) input. The L-matched RF to DC power converter has a loaded *Q*, sensitivity and efficiency determined mainly by the diodes resistance, diodes junction potential, connected resistance and antenna source resistance at matched conditions.

Figure 8. Measured L-matched circuit efficiency *versus* resistive load at various input power levels at 434 MHz (**left**), measured open circuit voltage and at 17 kΩ load *versus* input power at 434 MHz (**right**).

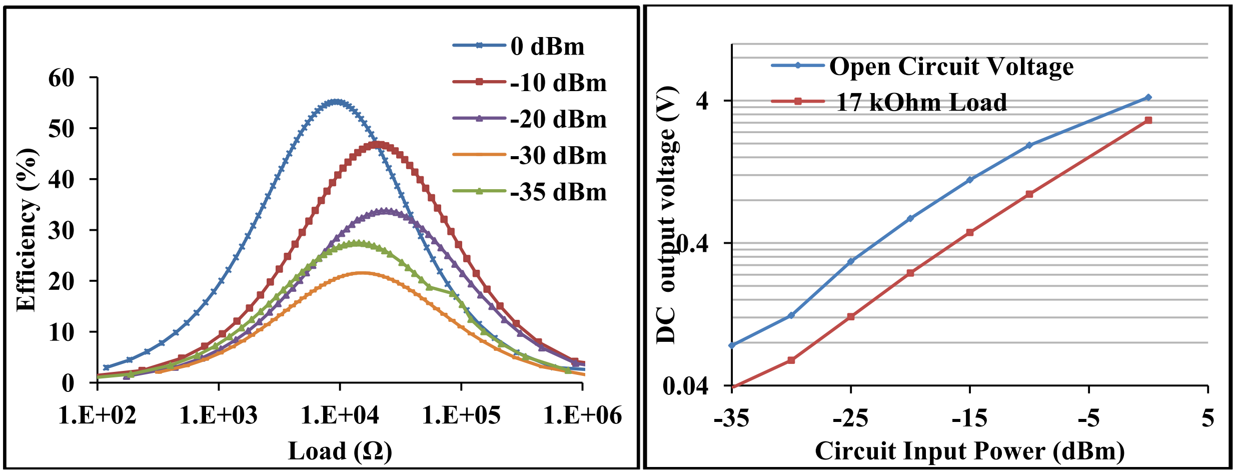

2.5.4. PI-match RF to DC Power Converter

A highly selective or small frequency bandwidth RF power converter is realized with a PI-network in-between the source impedance from the antenna and the diode rectifier. A PI-network is a 'back to back' L-network that are both configured to match the load and source impedance to an invisible resistance located at the junction between the two L-networks [37]. The quality factor of the L-network with the parallel resistance is given by Equation (26):

$$Q_P^{*} = \sqrt{\frac{R_P}{R^{*}} - 1}, \tag{26}$$

where R_P is the parallel resistance, R^* is a virtual resistance and Q_P^* is the quality factor of the L-network with the parallel resistance. The quality factor of the L-network with the series resistance is given by Equation (27):

$$Q_S^{*} = \sqrt{\frac{R_S}{R^{*}} - 1}, \tag{27}$$

where Q_S^* is the quality factor of the L-network with the series resistance. The unloaded quality factor; Q_S^* or Q_P^* is set higher than what is normally achieved with a single L-network [37] to realize the small frequency bandwidth circuit. The resistance of the load is assigned the parallel network in a PI-matched circuit if its series equivalent resistance is higher than the source series equivalent resistance; the opposite is true if the source is higher than the load. Equation (26) and Equation (27) are synonymous to Equation (8), except the lowest resistive impedance in Equation (8) is substituted with the virtual resistance which is dependent on the newly desired circuit selectivity. From Equations (26) and (27) the loaded quality factor of the PI-matched circuit can be written as Equation (34) in terms of Q_S^* and Q_P^*:

$$Q^2 = \left[\left(\frac{Q_P^{*2}+1}{Q_S^{*2}+1}\right)-1\right], \tag{28}$$

where Q is the loaded quality factor of the PI-network. Q_S* or Q_P* are the unloaded quality factors of the PI-matched network. The larger value among the unloaded quality factors result in small frequency bandwidth response which is desired when matching a source and load impedance with a PI-network. Some authors approximate the highest value of Q_S* or Q_P* or their algebraic sum as the loaded quality factor of the PI-network as in [35] and [37], but Equation (28) gives the exact loaded Q of the PI-matched circuit in terms Q_S* and Q_P*. This allows for the correct estimation of the maximum voltage gain from the loaded quality factor.

2.5.5. Selectivity RF to DC Converter Generalized Analytical Model

An example of a PI-matched RF to DC converter using the HSMS-285C diodes operating at 434 MHz for −30 dBm input is presented first and then the generalized model is discussed. The circuit is matched for Q_P* of 60 between the antenna and the resistance of the diodes as shown in Figure 9.

Figure 9. Impedance diagram of PI-matched RF power converter; (**a**) Impedance diagram of 50 Ω source and the HSMS-285C diodes at 434 MHz, (**b**) Resultant PI matched network between the antenna source and load resistance.

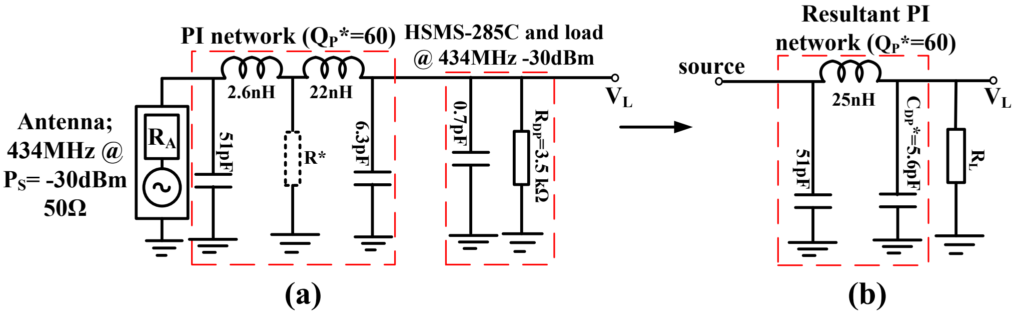
PI network (QP*=60)
HSMS-285C and load @ 434MHz -30dBm
Antenna; 434MHz @ PS= -30dBm 50Ω
RA
2.6nH
22nH
51pF
R*
6.3pF
0.7pF
RDP=3.5 kΩ
VL
(a)
Resultant PI network (QP*=60)
source
25nH
51pF
CDP*=5.6pF
RL
VL
(b)

Figure 9(b) can also be modeled as an inductive coupling of two parallel RC circuits. A more general look at such a circuit is shown in Figure 10, as an inductive coupling of two parallel RLC resonators with a current source.

Figure 10. Inductive coupled parallel RLC small signal model of a generalized PI-matched antenna and diode rectifier.

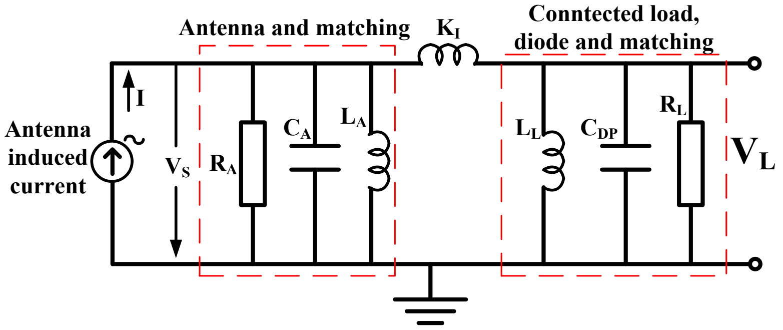
Antenna and matching
KI
Conntected load, diode and matching
I
Antenna induced current
VS
RA
CA
LA
LL
CDP
RL
VL

The first parallel RLC resonator is modeled as impedance from the antenna and some passive matching components. The second parallel RLC resonator is modeled as impedance from the linearized diodes, its connected load and some passive matching components. I is the antenna induced current, V_S this time is the voltage across the parallel R_A and K_1 is the coupling element between the two parallel resonators. Using Kirchoff's current laws, the node equations can be expressed as Equations (29) and (30):

$$I = V_S\left[\frac{1}{R_A} + j\omega C_A - \frac{j}{\omega L_A} - \frac{j}{\omega K_1}\right] + \frac{jV_L}{\omega K_1} \tag{29}$$

$$0 = \frac{jV_S}{\omega K_1} + V_L\left[\frac{1}{R_L} + j\omega C_{DP} - \frac{j}{\omega L_L} - \frac{j}{\omega K_1}\right] \tag{30}$$

Load voltage (V_L) and the source voltage (V_S) at resonance are given by the equations in Equation (31). The resonance frequencies are given by Equation (32):

$$V_L = \frac{\frac{-jI}{\omega K_1}}{\left[\frac{1}{R_A R_L} + \frac{1}{\omega^2 K_1^2}\right]} \quad \text{and} \quad V_S = \frac{\frac{I}{R_L}}{\left[\frac{1}{R_A R_L} + \frac{1}{\omega^2 K_1^2}\right]} \tag{31}$$

$$\omega C_A - \frac{1}{\omega}\left\{\frac{1}{L_A} + \frac{1}{K_1}\right\} = 0 \text{ and } \omega C_{DP} - \frac{1}{\omega}\left\{\frac{1}{L_L} + \frac{1}{K_1}\right\} = 0 \tag{32}$$

From V_L and Vs in Equation (31), the voltage gain at resonance can be expressed as:

$$\frac{V_L}{V_S} = \frac{R_L}{j\omega K_1} \tag{33}$$

The maximum of Equation (33) is obtained when:

$$j\omega K_1 \rightarrow 0 \;\; or \;\; R_L \rightarrow \infty \tag{34}$$

Since $j\omega K_1$ is restricted by the conditions in Equation (32) to attain resonance, one cannot manipulate $j\omega K_1$ alone without changing the resonance conditions. What can drive the voltage gain is if R_L is very large at resonance conditions. If the input impedance (V_S/I) of the coupled resonator is maximum at resonance, conditions in Equation (35) hold:

$$\left(\frac{Vs}{I}\right) \rightarrow maximum \;\; when \;\; \frac{R_L}{\omega^2 K_1^2} \rightarrow 0 \tag{35}$$

Equation (36) may be assumed when $\frac{R_L}{\omega^2 K_1^2} \rightarrow 0$:

$$\frac{V_S}{I} = R_A \tag{36}$$

Under these conditions and an optimal coupling coefficient K_{1max}, the maximum voltage gain of the parallel coupled resonator can be written as in Equation (37), where K_{1max} is given by Equation (38):

$$\left|\frac{V_L}{V_S}\right| = \left|V_{gain}\right| = \left|\frac{1}{2}\sqrt{\frac{R_L}{R_A}}\right| \tag{37}$$

$$K_{1(\max)} = \mp\frac{1}{\omega}\sqrt{R_A R_L} \tag{38}$$

The analysis of Section 2.5.2 and parallel coupled RLC resonators show that any antenna and matched rectifying diode can be described as an equivalent circuit of a coupled resonator at a defined operating point. This general model can be applied to optimize other harvesters with complex output impedance such as piezo-harvesters or vibration harvesters for maximum transfer of power or voltage to its connected load. The model can also be applied to near field magnetically coupled antennas/coils for optimization.

2.5.6. Broadband RF to DC power converter

A broadband network is preferred when an RF to DC power converter is to be operated for a wide range of frequencies. A broadband converter is realized by connecting successive L-networks together in a multi-network between the antenna source and the rectifying diodes. The result is broadband or multiband RF power converter around certain frequencies. This can be deduced from the general model of a coupled resonators that by choosing certain passive components between a source and the load, it is possible to have more frequencies (ω) fulfilling Equation (32) and hence a result of multiple resonant frequencies or broader bandwidth at match conditions. For a two stage L-connected match, the quality factor of the L-network with the parallel resistance is given by Equation (39):

$$Q_P^{\,*} = \sqrt{\frac{R_P}{R^*} - 1} \tag{39}$$

The quality factor of the L-network with the series resistance is given by Equation (40):

$$Q_S^{\,*} = \sqrt{\frac{R_*}{R_S} - 1} \tag{40}$$

From Equations (39) and (40) the loaded quality factor of the two stage L-connected broadband network may be written as Equation (41) in terms of the unloaded quality factors; Q_S* and Q_P*:

$$Q^2 = \{(Q_P^{*2} + 1)(Q_S^{*2} + 1)\} - 1 \tag{41}$$

R^* in this case may be chosen if it is larger than R_S and lower than the R_P. The highest possible bandwidth between a resistive source and resistive load is found for a virtual resistance (R^*) given in Equation (42) [37]:

$$R^* = \sqrt{R_S R_P} \tag{42}$$

For complex loads such as rectifying diodes or transistors, the largest achievable bandwidth prescribed by Equation (42) is limited by the load or source component quality factor, since Equation (42) does not take into account reactive impedance associated with the source or load.

2.5.7. Broadband-Match RF to DC Converter Results and Discussion

The antenna source resistance was broadband matched to the HSMS-285C diodes (and load) resistance at −30 dBm input around 434 MHz. For a desired Q_P* and Q_S* of 2.7 there is ~0.4 pF inherent diode capacitance which is un-tuned using a two stage L-matching network [Figure 11(b)]. This is because the HSMS-285C diodes provides an inherent component quality factor of 6.96 at 434 MHz for −30 dBm input, hence a broadband circuit with Q_P* lower than this inherent component quality factor of the diodes (and load) is difficult to achieve without trade-offs. However, connected L-networks with Q_P* as high as the diode component quality factor may perform worse than a single L-matched network with similar loaded quality factor. This is due to redundant components of the connected L-networks which have inherent losses.

Figure 11. Impedance diagram of broadband RF power converter; (**a**) Broadband match around 434 MHz with loaded Q of 2.7, (**b**) Resultant impedance matching network with un-turned capacitance of 0.4 pF.

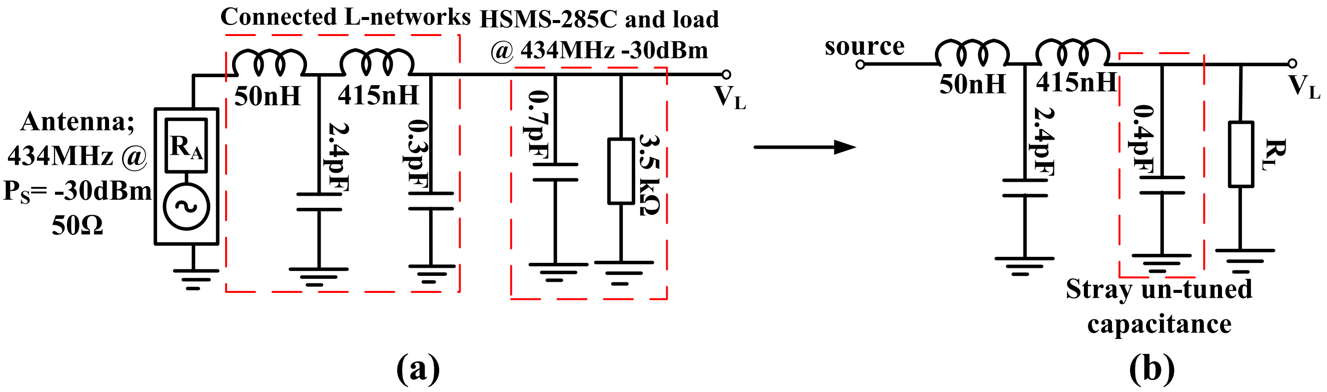
Connected L-networks
HSMS-285C and load
@ 434MHz -30dBm
Antenna;
434MHz @
P$_S$= -30dBm
50Ω
R$_A$
50nH
415nH
2.4pF
0.3pF
0.7pF
3.5 kΩ
V$_L$
(a)
source
50nH
415nH
2.4pF
0.4pF
R$_L$
V$_L$
Stray un-tuned
capacitance
(b)

Figure 12. Measured open circuit S_{11} of the broadband circuit around 434 MHz at different input power levels from a 50 Ω source (**left**), measured open circuit input impedance at −10 dBm and −40 dBm of the broadband circuit (**right**).

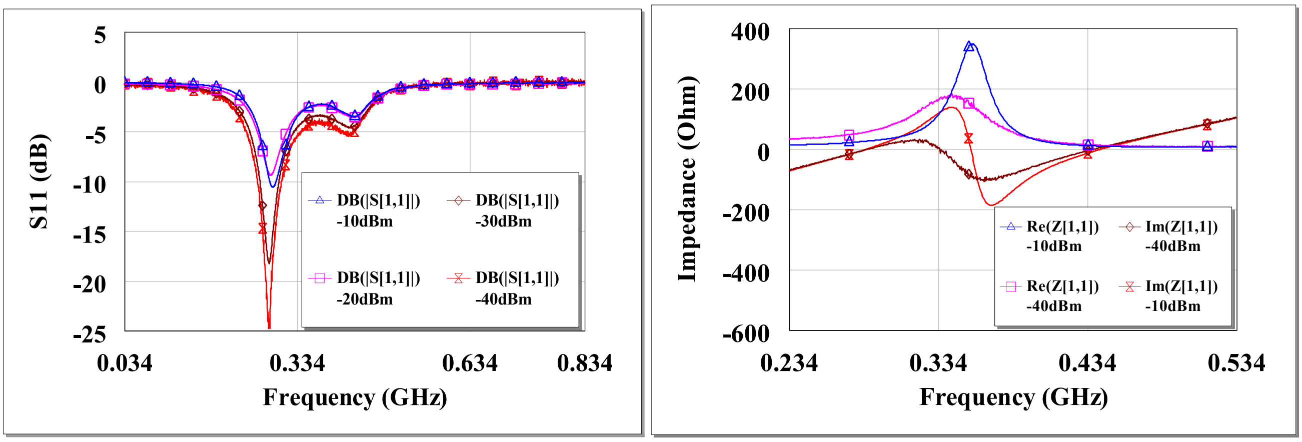

Therefore the broadband circuit is matched for Q_P* of 2.7, notwithstanding the un-tuned shunt capacitance as can be seen in Figure 11(b). Figure 12 shows the circuit S_{11} at various input power levels and input impedance at open circuit conditions. From Figure 12 (left) there is ~−5 dB return loss from 200 MHz to 500 MHz providing an operating band of ~300 MHz. The impedance of the circuit shows resonances at ~290 MHz and ~450 MHz as shown in Figure 12(right). A third resonance occurs around 356 MHz at −10 dBm as the frequency of highest harvester input resistance (~350 Ω) and where the reactive impedances approach their extremes. Figure 12 show that a wireless EM harvester can exhibit different resonance scenarios depending on the dominant instantaneous conditions. The efficiency and voltage sensitivity of the broadband matched wireless EM harvester are shown in Figure 13. The average open circuit voltage is 47 mV and 1.1 V at −30 dBm and −10 dBm, respectively, when operating from 200 MHz to 500 MHz.

Figure 13. Measured open circuit voltage *versus* frequency sweep from 200 MHz to 500 MHz for −10 dBm and −30 dBm (**left**), measured efficiency at 17 kΩ load *versus* frequency sweep for −10 dBm and −30 dBm (**right**).

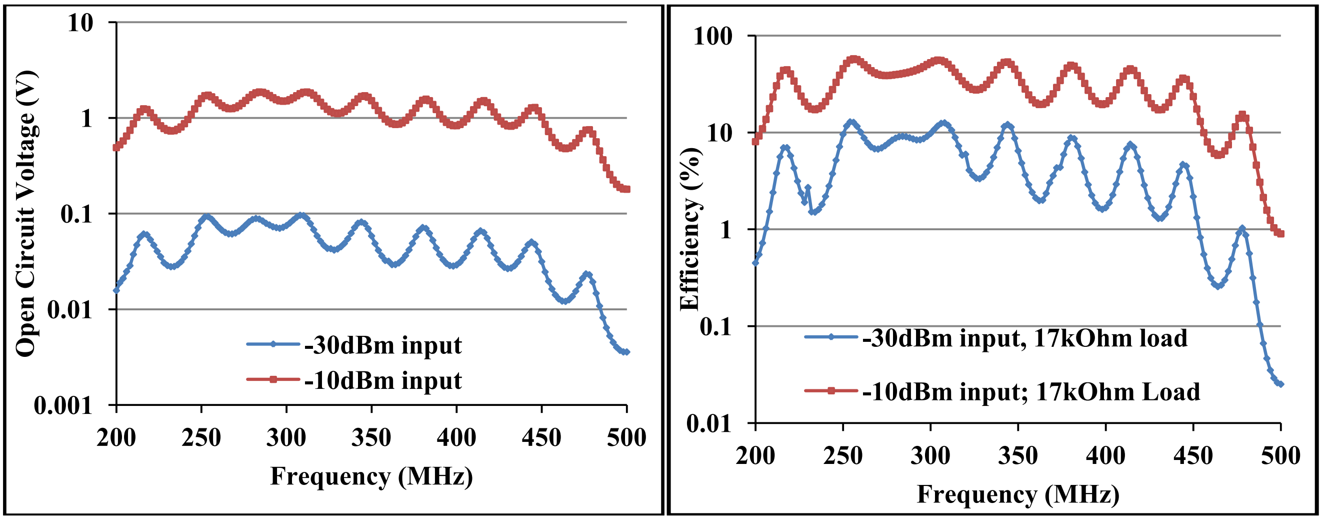

The broadband circuit achieves average efficiency of 5% at 17 kΩ load for −30 dBm and 30% at 17 kΩ load for −10 dBm input power from 200 MHz to 500 MHz. Figure 13 further confirm a direct link between frequency response and the unloaded quality factors. For Q_S* and Q_P* of ~2.7, the circuit response is broadband around 434 MHz.

2.6. High Voltage Sensitive RF to DC Converter

The current state of the art low power remote sensors would require a DC voltage supply of about 1 V and DC current of about 30 µA for operation. Therefore, the issue is not only how efficient a wireless EM harvester is in converting RF to DC power, but also what the output DC voltage and current of the EM harvester are at the RF input power level [38]. Equations (11,24) and (33) show that the maximum voltage sensitivity of a coupled resonator system or an RF to DC power converter is mostly related to the load and the source resistances at resonance. Therefore high voltage sensitive wireless EM harvester can be achieved with a diode voltage doubler with a very high input resistance relative to the antenna source without the need to cascade the diodes as in voltage multipliers. If the diodes been used for the RF to DC power conversion cannot provide high resistive impedance at the working frequency relative to the antenna source, then a DC-DC converter can be applied after the EM harvester as presented in [39] or the diodes may be cascaded by way of multipliers as presented in our earlier work [40] and by several other authors [3,5,14]. In case of multipliers, the input voltage ought to be high enough to overcome the junction potential of the several diodes in the multiplier network. If frequency is not a constraint, then a frequency sweep *versus* impedance for the diodes can be made and the frequency where the diodes exhibits high resistive impedance can be used to realize high voltage sensitive wireless RF harvester. For Schottky diodes, high resistive impedance occurs mostly at lower frequencies (see Figure 3). The measured voltage gain of a high resistive diode pair (voltage doubler) is presented in the next results.

2.6.1. High Voltage Sensitive RF to DC Converter Results and Discussion

The presented result was L-matched using 50 Ω resistance of the antenna source and the resistance of the HSMS-286C diodes (and load). The HSMS-286C diodes do provide high resistive impedance at low frequencies; notwithstanding the flicker noise which causes its resistive (and reactive) impedance to fluctuate. The HSMS-286C has low forward junction potential (~350 mV at 1 mA) per diode and series impedance of ~1.5–j8.1 kΩ or parallel impedance of ~−*j*8.3(46.3)/(−*j*8.3 + 46.3) kΩ at 13.6 MHz for −30 dBm input. Even though the HSMS-286C diodes unloaded component quality factor at 13.6 MHz is similar to that of the HSMS-285C diodes at 434 MHz, the elevated resistive impedance at 13.6 MHz fulfills the condition for high voltage sensitivity relative to a 50 Ω antenna source at resonance conditions.

Figure 14. (**a**) L-matched impedance diagram for matching the HSMS-286C diodes at 13.6 MHz at -30 dBm input. (**b**) Resultant network, (**c**) PCB layout of the L-matched Greinacher doubler with adjusted values due to impedances provided by copper route on FR4 substrate with thickness of 1 mm. (**d**) Fabricated PCB of the L-matched RF to DC power converter.

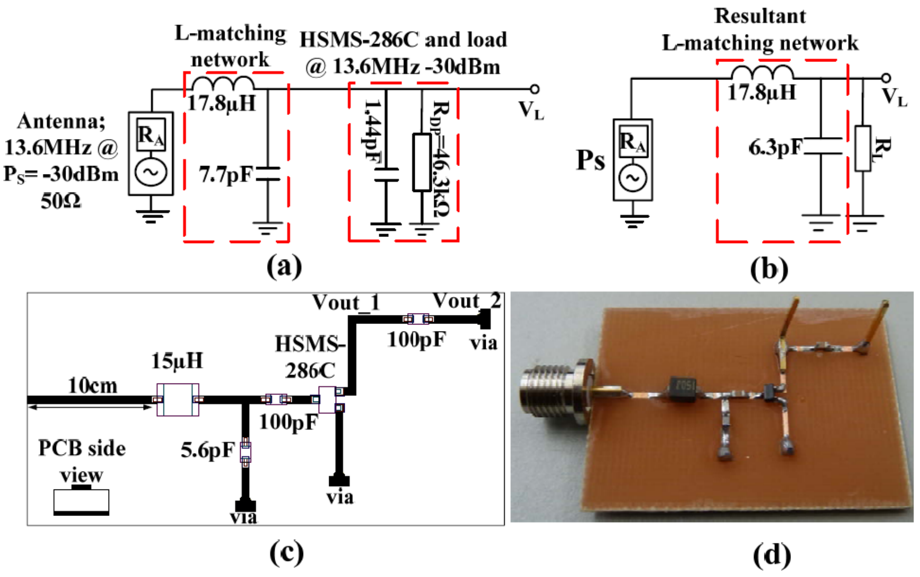
L-matching network
HSMS-286C and load @ 13.6MHz -30dBm
Antenna; 13.6MHz @ P_S= -30dBm 50Ω
R_A
17.8μH
7.7pF
1.44pF
R_DP=46.3kΩ
V_L
Resultant L-matching network
Ps
R_A
17.8μH
6.3pF
R_L
V_L
Vout_1
Vout_2
100pF
via
HSMS-286C
15μH
10cm
100pF
PCB side view
5.6pF
via
via

(a) (b)

(c) (d)

The high voltage sensitive EM harvester operating at 13.6 MHz is as shown in Figure 14. On the realized PCB is a Greinacher doubler. An inductance of 15 μH and a shunt capacitance of 5.6 pF were the adjusted values after the microstrip contributions.

The measured S_{11} and input impedance at open circuit are shown in Figure 15. There is high return loss and resonance around 13.6 MHz. The circuit input impedance at open circuit conditions is 58 Ω at resonance for both −40 dBm and −10 dBm.

Figure 15. Measured open circuit S_{11} of the L-matched HSMS-286C diodes at 13.6 MHz for different input power levels from a 50 Ω source (**left**), measured open circuit input impedance at −10 dBm and −40 dBm of the L-matched HSMS-286C diode at 13.6 MHz (**right**).

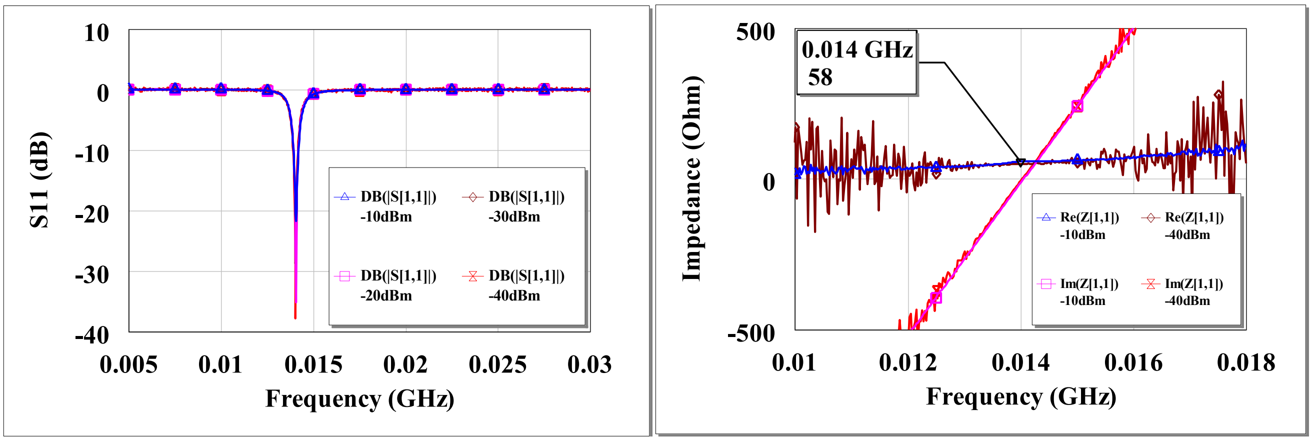

The efficiency and voltage sensitivity of the high voltage sensitive wireless EM harvester are shown in Figure 16.

Figure 16. Measured circuit efficiency *versus* load at various input power levels at 13.6 MHz (**left**), measured open circuit voltage and at 200 kΩ load *versus* input power at 13.6 MHz (**right**).

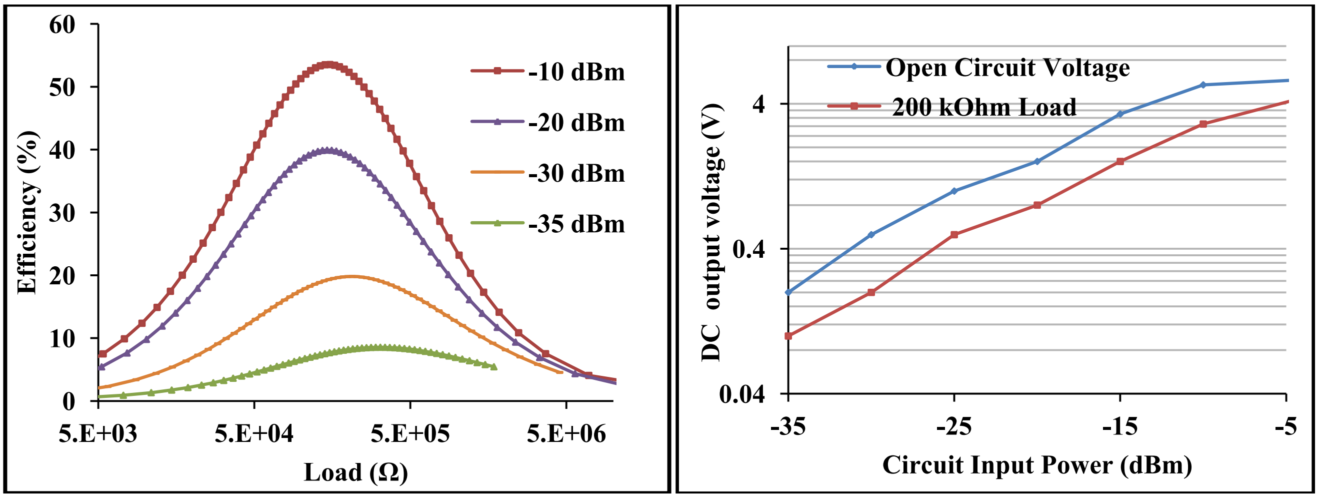

The maximum measured efficiency at −30 dBm is 20% for ~200 kΩ load and an open circuit voltage of 0.5 V. At −10 dBm, the maximum efficiency and open circuit voltage are 54% and 5.4 V respectively. At the optimal load of ~200 kΩ, the detected voltage is 0.2 V and 2.9 V at −30 dBm and −10 dBm respectively. The open circuit voltage gain is 100 at −30 dBm and 108 at −10 dBm.

Even though the RF to DC converter presented in Section 2.5.3 is the same as the L-match circuit realized with the HMSM-286C diodes at 13.6 MHz, the voltage gain is increased by a factor of 4 due to the large difference between the diodes (and load) resistance and source resistance so that at matched conditions high voltage gain occurs. The loaded Q of the L-matched circuit is 30 which results in small frequency bandwidth just like a PI-matched diode rectifier presented in our earlier work [40]. From this result and the results from our earlier presented PI-matched EM harvester, it can be inferred that all high loaded Q RF to DC circuits have high selectivity but not all highly selective RF to DC circuits have high loaded Q. The voltage sensitivity of the matched HSMS-286C diode at 13.6 MHz can be improved if its resistive impedance is not lowered by the flicker noise.

3. Wireless EM Power Harvester

A wireless EM harvester, consisting of a rectifying antenna (*rectenna*) was designed to find a compromise between size and performance of its antenna. The rectenna is shown in Figure 17.

Figure 17. Rectenna realized on a Duroid 5880, 1.57 mm substrate. (**a**) Backside of the rectenna, (**b**) cross-section of antenna output coplanar stripline dimensions (**c**) frontside of the rectenna.

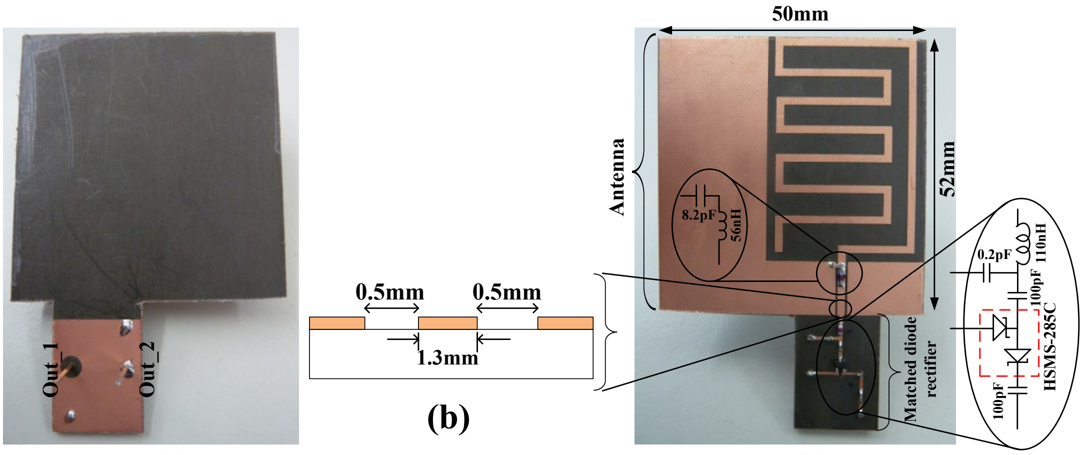

(a) (b) (c)

The antenna (planar) part of the rectenna is based on our earlier work [41]. In contrast to the earlier presented antenna, this rectenna is realized on a Duroid [42] substrate of thickness 1.57 mm. Duroid 5880 has lower loss tangent of 0.0004 at 1 MHz compared to 0.025 at 1 MHz for FR4. This means there is less loss in the transmission of signals on a Duroid PCB at this frequency range. The antenna part is fabricated to resonate around 434 MHz; hence its dimensions of 5 × 5.2 cm make it electrically small. The antenna is tuned with a chip inductor and a capacitor to achieve the resonance frequency around 434 MHz [Figure 17(c)]. This is done at a cost of reduced antenna radiation efficiency. An antenna is one of the few components the size of which is related to the operating frequency. Thus, if the size of an antenna is fixed, resonance frequency reduction of the antenna can only be achieved with penalty factors [10]. The antenna's output impedance is tuned with the dimensions of the coplanar stripline as shown in Figure 17(b).

HFSS [43] was used to simulate the presented antenna and to find the correct capacitive and inductive components for frequency tuning before the optimized design was fabricated. The simulated antenna resonances occur at 438 MHz and 445 MHz. At these frequencies, the radiation efficiency is 20% and a peak gain of −6 dBi. The rectifying part of the rectenna consists of L-matched HSMS-285C diodes (Figure 17(c)). The L-matched HSMS-285C part of the rectenna can be engineered to be as small as possible if required. The separate parts of the rectenna were characterized by terminating their ends and measuring the individual reflection coefficients just like the power converters presented in Section 2. Figure 18 shows the measured antenna and matched rectifier individual S_{11} and impedance. Figure 18 (left) also show the HFSS simulated S_{11} results. From Figure 18 (right), the measured antenna resonance where the input impedance is at maximum is ~434 MHz. At ~434 MHz, the antenna input resistance is 376 Ω and the reactive impedances approach their extreme (*so called anti-resonance*). The other resonance occurs when the input resistance is 'finite' and the reactive impedance is zero; at ~441 MHz. The input resistance is 57 Ω at ~441 MHz. The rectifier circuit is matched for the antenna's resistance at ~441 MHz.

Figure 18. Antenna HFSS simulated, antenna measured, and measured L-matched diode rectifier S_{11} on a Duroid 5880 PCB for −30 dBm input (**left**), Measured open circuit input impedance of antenna and rectifier at −30 dBm input (**right**).

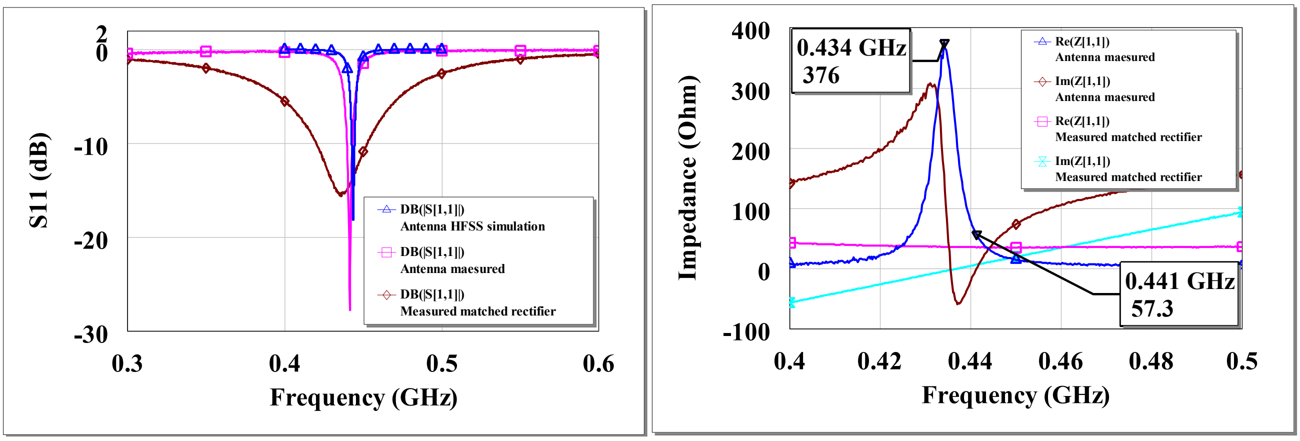

3.1. EM Range Results and Discussion

At far field between wireless EM transmitting and receiving antenna, the coupling mechanism between the transmitting and receiving antenna is neither capacitive nor inductive as is the case for the RF to DC converters. The coupling is radiative which can be described by the Friis equation of transmission on the assumption that the transmitting and receiving antenna are in free space [44]. A modified Friis equation for a transmitting and receiving antenna at far-field (R >> λ and R >> transmitting antenna largest dimension) to each other at a specified direction is given by Equation (43) [45]. Equation (43) assumes real world open space conditions:

$$\frac{P_r}{P_t} = F_{envt} G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2, \tag{43}$$

where *Pr* is the power at the receiving antenna port, *Pt* is the power supplied at the transmitting antenna port, F_{envt} is a factor accounting for environmental effects as such ground reflections among others, *Gt and Gr* are the transmitting and receiving antenna gain (*at specified direction*) respectively. *R* is the distance between the transmitting and receiving antenna and λ is the wavelength of the transmitting EM wave. The rectenna receiving range measurements were carried out in an open space (*hall*) with the antennas 2 m above ground level. The transmitting and receiving antennas were arranged in the direction of their peak gain. The rectenna range performance is shown in Figure 19. According to Equation (43), the efficiency of RF power transferred between a sending and receiving antenna depends on controllable factors like the gain of the antennas in the arranged direction and the radiation efficiency of the antennas. Since the receiving/transmitting antenna's incorporated in remote harvesters for sensor powering are normally small in relation to their operating frequencies, they tend to be less efficient.

Figure 19. Rectenna receiving range performance by sending 17 dBm (50 mW) at a gain of −6 dBi at 437 MHz. Output DC voltage *versus* receiving distance for different loads (**left**), loads output power *versus* receiving distance (**right**).

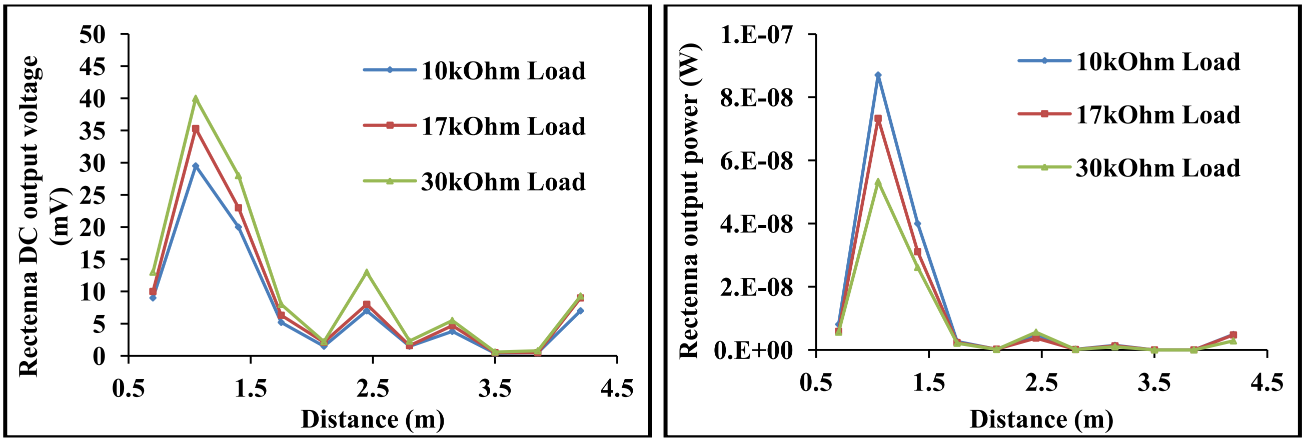

The efficiency of the rectenna's antenna is ~20% at resonance. A 'perfectly' matched RF to DC power converter operating in its square law region has efficiencies in the region of 20% as depicted in Section 2. The transmitting antenna was the same as the antenna incorporated in the rectenna. By transmitting the EM power with a small antenna (5 cm × 5.2 cm) at 437 MHz with efficiency of ~20% and at a gain of −6 dBi, the power delivered by the rectenna is generally low at far-field from the transmitter as can be seen in Figure 19. A mediocre transmitting antenna was used to transmit the EM waves due to limitations in the European Union about transmitting EM power at certain frequencies; so the goal in the rectenna range experiment is to show the lowest limit functionality of such a harvester. At 4.2 m from the electrically small transmitting antenna transmitting at 17 dBm, the rectenna harvested DC voltage and power are 9 mV and 5 nW respectively for 10 kΩ load. It can be seen from Figure 19 that the harvested voltage/power generally degrades as an inverse square of distance from transmitter as described by Friis equation. The measured received power however alternate along this R^{-2} fit as shown in Figure 19. This anomaly is accounted for by F_{envt} [Equation (43)] as influence of ground reflections and polarization in real world open field measurements [45]. For any particular distance *R*, the signals reflected from ground can be constructive with the direct signal to the rectenna, in which case the measured power may be higher than that predicted by the original Friss equation as in [44]. The ground effect can also be destructive, in which case the measured power will be lower than what is predicted by the original Friis equation.

4. Conclusions

Optimization of Schottky diode-based RF to DC power converters using different matching techniques for wireless EM energy harvesting applications is presented. Using scattering parameters for small signal modeling, it is shown that wireless EM harvesters can be generally described as coupled resonators with efficiencies and maximum voltage sensitivity depending mostly on the source and load resistances under matched conditions. The analytical models allow systematic control in the design of passive wireless EM harvesters. Based on these analyses, a rectenna is built and tested for lower limit functionality from harvesting ambient EM waves. The analysis presented in this work may also be applied to optimize derivatives of wireless EM harvesters like RFID tags, NFC, wireless chargers *etc.*, for efficient powering of their sensors or integrated circuits. Generally, most energy harvesters and their matched loads can be described as coupled resonators and thus may be optimized with the methods presented in this work.

Acknowledgments

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Appendix A: Measuring Setup for RF Rectifier Efficiency and Voltage Sensitivity

The measuring setup is as shown in Figure A1.

Figure A1. RF to DC Power converter characterization setup.

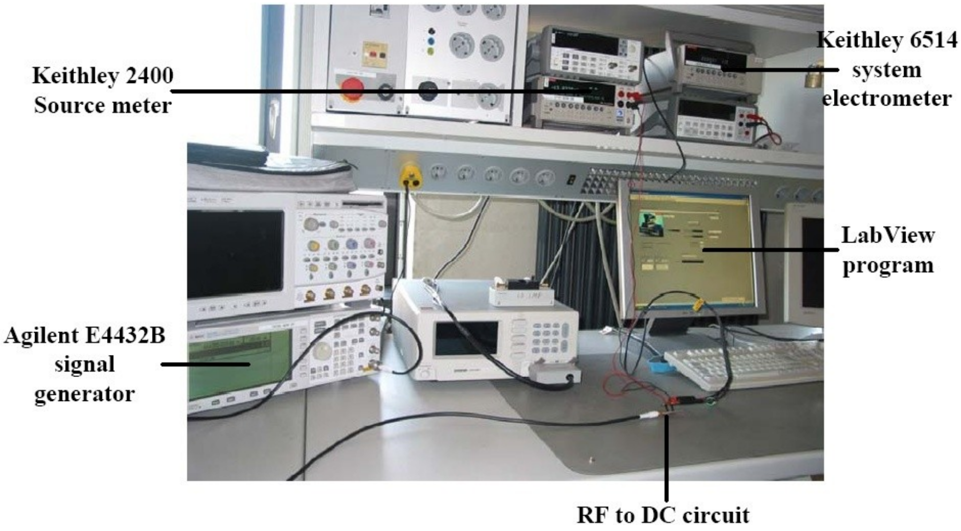

The RF to DC circuit efficiency and voltage sensitivity measurements were made with a Keithley 2400 source meter and Keithley 6514 system electrometer with an Agilent E4432B signal generator providing 50 Ω RF signal into the circuit board.

The closed circuit current drawn by the RF to DC power converter (*without load*) from the generator is first determined by the Keithley 2400 source meter; then starting from this current, the value of the current is decreased at set intervals to creates virtual load resistances to the circuit for up to a lowest current of 0.1 µA. The 6514 system electrometer is used to measure the output voltage. The number of data point is set through LabView [46] as well as the measurements. Additionally open circuit voltage or at specific loads and frequency sweep can be made through the LabView program. At −40 dBm input power and below, the detected voltages and currents were difficult to measure accurately with the measuring setup; hence measurements were made up to a minimum of -35 dBm input power. The circuit layout for the efficiency and voltage sensitivity measurements is schematically shown in Figure A2.

Figure A2. RF to DC power converter characterization circuit.

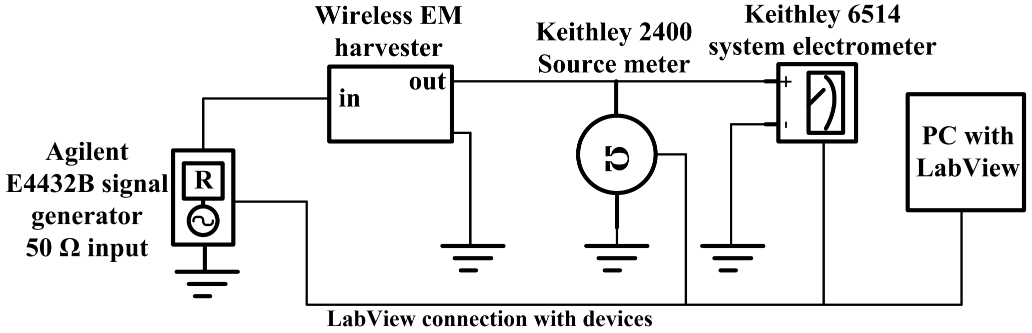
Wireless EM harvester
in
out
Keithley 2400 Source meter
Keithley 6514 system electrometer
+
-
Agilent E4432B signal generator 50 Ω input
R
PC with LabView
LabView connection with devices

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Antenna Research

STANDARD ANTENNA TERMS AND RELATED FORMULAS

The "IEEE Standard Definitions of Terms for Antennas" (IEEE STD-145) represents a consistent and comprehensive vocabulary suited for the effective communication and understanding of antenna theory. General use of these definitions of terms would eliminate much of the wide-spread inconsistency concerning antenna characteristics, particularly with regard to the basic parameters of gain, beamwidth, polarization and efficiency. For convenience, IEEE antenna terms of general interest are listed here. Wherever these terms appear in this catalog, the definitions given below apply. Other commonly used terms, not covered by the IEEE standard, are shown with an "*."

ANTENNA APERTURE. A surface, near or on an antenna, on which it is convenient to make assumptions regarding the field values for the purpose of computing fields at external points. **Note:** The aperture is often taken as that portion of a plane surface near the antenna, perpendicular to the direction of maximum radiation, through which the major part of the radiation passes.

ANTENNA EFFICIENCY OF APERTURE - TYPE ANTENNA. For an antenna with a specified planar aperture, the ratio of the maximum effective area of the antenna to the aperture area.

*** ANTENNA FACTOR.** That quantity by which the voltage developed across the output of an antenna is related to the incident field strength in which the antenna is immersed. **Note:** Applicable to low frequency antennas and usually refers to a 50 ohm output.

$$\mathrm{AFE}\ (\mathrm{dB\ m}^{-1}) = \mathrm{E}\ (\mathrm{dB\ V/m})\ -\ \mathrm{V}\ (\mathrm{dB\ V})$$

AFE = Electric Field Antenna Factor
E = Electric Field Strength at antenna
V = Voltage at terminals of antenna

$$\mathrm{AFH}\ (\mathrm{dB\ AV}^{-1}\,\mathrm{m}^{-1}) = \mathrm{H}\ (\mathrm{dB\ A/m}) - \mathrm{V}(\mathrm{db\ V})$$

AFH = Magnetic Field Antenna Factor
H = Magnetic Field Strength at antenna
V = Voltage at terminals of antenna

$$\mathrm{AFE}\ (\mathrm{dB\ m}^{-1})\ =\ \mathrm{AFH}\ (\mathrm{dB\ AV}^{-1}\,\mathrm{m}^{-1}) + 51.53$$

for a plane wave in free space.

$$\mathrm{AFB}\ (\mathrm{dB}\frac{\mathrm{pT}}{\mu\mathrm{V}})\ =\ \mathrm{B}\ (\mathrm{dBpT})\ -\ \mathrm{V}_{\mathrm{o}}\,(\mathrm{dB}\mu\mathrm{V})$$

AFB = Magnetic flux Antenna Factor
B = Magnetic flux at the antenna
pT: picoTesla units
V = Voltage at the terminals of the antenna

$$\mathrm{AFB}\ (\mathrm{dB}\frac{\mathrm{pT}}{\mu\mathrm{V}}) = \mathrm{AFH}\ (\mathrm{dB}\frac{\mathrm{A}}{\mathrm{Vm}})\ +2$$

APERTURE ILLUMINATION. The field over the aperture as described by amplitude, phase, and polarization distributions.

APERTURE ILLUMINATION EFFICIENCY. For a planar antenna aperture, the ratio of its directivity to the directivity obtained when the aperture illumination is uniform.

BEAM. The major lobe of the radiation pattern.

CIRCULAR POLARIZATION. It may be either right hand circular polarization (RHCP) or left hand circular polarization (LHCP). The sense of polarization is determined by observation of the direction of rotation of the electric field vector from a point behind the source, RHCP and LHCP correspond to clockwise and counter-clockwise respectively. **Note:** RHCP transmit requires a like polarization to receive.

CO-POLARIZED. The polarization which the antenna is intended to radiate or receive. Also "like polarization".

*** CROSS POLARIZATION DISCRIMINATION (XPD).** Cross polarization discrimination is the measure of the antenna’s ability to differentiate between the vertical and the horizontal polarization of an antenna. This difference, shown in relative signal level, is indicated on directional pattern envelopes (DPE’s).

STANDARD ANTENNA TERMS AND RELATED FORMULAS

* **DIRECTIONAL PATTERN ENVELOPES (DPE'S).** In accordance with standard practice, radiation characteristics in any given plane of polarization are measured and plotted using 360-degree polar coordinate systems. The resultant Directional Pattern Envelope is the smoothed composite of all these measurements. The purpose of these DPE's is to emphasize the worst composite condition.

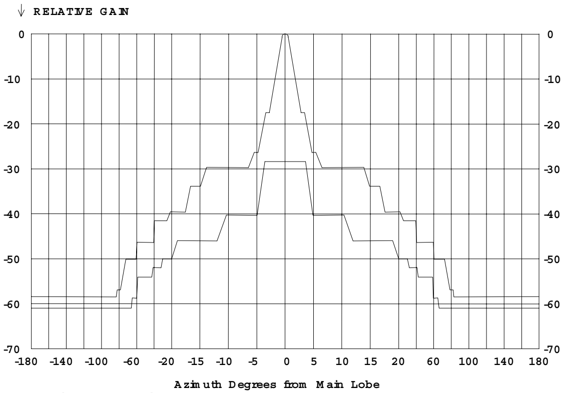

DIRECTIVE GAIN. In a given direction, 4 times the ratio of the radiation intensity in that direction to the total power radiated by the antenna.

DIRECTIVITY. The value of the directive gain in the direction of its maximum value.

EFFECTIVE AREA OF AN ANTENNA. In a given direction, the ratio of power available at the terminals of a receiving antenna to the power per unit area of a plane wave incident on the antenna from that direction, polarized coincident with the polarization that the antenna would radiate.

FAR FIELD REGION. That region of the field of an antenna where the angular field distribution is essentially independent of the distance from a specified point in the antenna region.

* **FRONT-TO-BACK RATIO**. The ratio of the maximum directivity of an antenna to its directivity in a specified rearward direction.

* **Gain, dBi**. The gain expressed in decibels relative to an isotropic radiator that is linearly polarized.

$$G(\mathrm{dBi}) = 10\log(G) \qquad G = 10^{\frac{G(\mathrm{dBi})}{10}}$$

* **GAIN, dBic**. The gain expressed in decibels relative to an isotropic radiator that is circularly polarized.

HALF-POWER BEAMWIDTH. In plane containing the direction of the maximum of a beam, the angle between the directions in which the radiation intensity is one half the maximum value of the beam.

HALF-WAVE DIPOLE. A half wavelength antenna, center fed so as to have equal current distribution in both halves. Mounted vertically, it has a doughnut shaped pattern, circular in the horizontal plane. It is an antenna that can be constructed. It has some inherent losses. When used as a gain reference, the half-wave dipole has a power gain of about 1.7 dBi.

* **ISOLATION.** Refers to the ability of one port of a dual polarized feed to discriminate against a signal fed into the other port.

ISOTROPIC RADIATOR. A hypothetical antenna having equal radiation intensity in all directions. Note: An isotropic radiator represents a convenient reference for expressing the directive properties of actual antennas.

NEAR-FIELD REGION. The spherical region of space between the antenna and the far field region.

NULL. The region of a radiation pattern, either computed or measured, where the amplitude goes through a minimum value. Note: (1) It represents the angular position where the phase or the far field pattern crosses the zero axis if the pattern is plotted as a phasor instead of a scalar value. Note: (2) The region outside the main beam of a directive antenna pattern consists of a series of minor lobes separated by nulls.

PARALLEL POLARIZATION. The condition where the electric vector is parallel to the local conducting surface. Note: Over the earth, this is usually referred to as being horizontal polarization.

PHASE CENTER. The location of a point associated with an antenna such that, if it is taken as the center of a sphere whose radius extends into the far-field, the phase of a given component over the surface of that radiation sphere is essentially constant, at least over the portion of the sphere where the radiation is significant.

STANDARD ANTENNA TERMS AND RELATED FORMULAS

POLARIZATION. The polarization of an antenna is defined as the polarization of the electromagnetic wave as described by the shape and orientation of an ellipse, which is the locus of the extremity of the field vector, and the sense in which the ellipse is traversed with time. The elliptical locus is called the polarization ellipse and the wave is said to elliptically polarized. Circular polarization and linear polarization are degenerate cases of elliptical polarization.

POWER DENSITY AT A POINT

$$S_{av} = \frac{GP_t}{4\pi r^2}$$

S_{av} = Time average power density in W/m^2
P_t = Power transmitted in watts
G = Antenna gain relative to an isotrope
r = Distance from antenna to point in meters

POWER DENSITY TO VOLTS/METER IN FREE SPACE

$$E^2 \ (V/m) = 377\ S_{av}\ (W/m^2)$$

$$S_{av}\ (W/m^2) = E^2\ (V/m)\ /\ 377$$

$$1\ V/m = 2.65\ mW/m^2$$

POWER GAIN. In a given direction, 4 times the ratio of the radiation intensity in that direction to the net power accepted by the antenna from the connected transmitter. **Note:** (1) When the direction is not stated, the power gain is usually taken to be the power gain in the direction of its maximum value. (2) Power gain does not include reflection losses arising from mismatch of impedance.

POWER GAIN IN PHYSICAL MEDIA. In a given direction and at a given point in the far field the ratio of the power flux per unit area from an antenna to the power flux per unit area from an isotropic radiator at a specified location with the same power input as the subject antenna.

Note: The isotropic radiator must be within the smallest sphere containing the antenna. Suggested locations are antenna terminals and points of symmetry, if such exist.

POWER GAIN REFERRED TO A SPECIFIED POLARIZATION. The power gain of an antenna, reduced by the ratio of that portion of the radiation intensity corresponding to the specified polarization to the radiation intensity.

POWER TRANSMISSION FORMULAS

$$P_r = P_t \frac{G_t G_r \lambda^2}{(4\pi r)^2}$$

$$P_r\ (\text{dB W}) = P_t\ (\text{dB W}) + G_t\ (\text{dBi}) + G_r\ (\text{dBi}) - 20 \log r - 20 \log f + 27.56$$

$$P_r\ (\text{dB W}) = P_t\ (\text{dB W}) - AFE_t\ (\text{dB m}^{-1}) - AFE\ (\text{dB m}^{-1}) - 20 \log r + 20 \log f - 32$$

P_r = Power received
P_t = Power transmitted
G_r = Gain of receiving antenna
G_t = Gain of transmitting antenna
f = Frequency in MHz, λ = Wavelength
r = distance between antennas in meters
AFE_r = AFE of receiving antenna
AFE_t = AFE of transmitting antenna

RADIATOR. Any antenna or radiation element that is a discrete physical and functional entity.

RADIATION, ELECTROMAGNETIC. The emission of energy in the form of electromagnetic waves.

RADIATION INTENSITY. In a given direction, the power radiated from an antenna per unit solid angle.

RADIATION LOBE. A portion of the radiation pattern bounded by regions of relatively weak radiation intensity

RADIATION PATTERN (ANTENNA PATTERN). A graphical representation of radiation properties of the antenna as a function of space coordinates. **Note:** (1) In the usual case the radiation pattern is determined in the far-field region and is represented as a function of directional coordinates. (2) Radiation properties include power flux density, field strength, phase, and polarization.

*** RADIATION RESISTANCE OF AN ELECTRICALLY SMALL LOOP ANTENNA.** The resistive component of an antenna's input impedance that results from the coupling of the antenna to its environment. This resistance dissipates the power that is actually radiated from the antenna.

$$R_r = 20\,(2\pi/\lambda)^4\, n^2 A^2 \text{ ohms}$$

n = number of turns
A = area of the loop

REALIZED GAIN. The power gain of an antenna in its environment, reduced by the losses due to the mismatch of the antenna input impedance to a specified impedance.

*** REALIZED RADIATOR EFFICIENCY.** The efficiency of an antenna in its environment reduced by all losses suffered by it, including: ohmic losses, mismatch losses, feedline transmission losses, and radome losses.

RELATIVE POWER GAIN. The ratio of the power gain in a given direction to the power gain of a reference antenna in its reference direction. **Note:** Common reference antennas are half-wave dipoles, electric dipoles, magnetic dipoles, monopoles, and calibrated horn antennas.

RETURN LOSS. The reflection coefficient of a mismatch expressed in decibels. **Note:** Modern swept VSWR techniques actually sense the reflected component which is normalized to the forward component to yield return loss. A 2:1 VSWR is equivalent to 9.5 dB return loss.

VSWR. The voltage standing wave ratio of a component such as an antenna. It is referred to the characteristic impedance of the transmission line being used. **Note:** The most common characteristic impedance is 50 ohms, but 75 and 300 ohms are frequently used in coaxial or twin lines for VHF, UHF applications.

NOTES:

THE HANDYMAN'S GUIDE TO OSCILLOSCOPES (Part 2 of 2)

by Paul Harden, NA5N

Making some advanced measurements with your Oscilloscope

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8½ x 11 or A4

In Part 1, oscilloscope operation was covered for making basic voltage, time and frequency measurements. In this part, we'll continue with some more advanced uses of a scope, and in particular, how to use a scope for testing and troubleshooting ham radio QRP transceivers in the homebrewer's workshop.

Receiver Filter Bandwidth.

This procedure uses a scope (a DVM can be used with less accuracy) for determining the overall filter bandwidth (or selectivity) of a receiver. It is basically measured by plotting output voltage vs. audio frequency to construct a picture of the filter response.

Connect scope to the receiver audio output (speaker or phone jack); measurement will be based on peak-to-peak voltages (Vpp) on a scope, or rms voltage (Vrms) on a DVM.

Using a signal generator, set the frequency for the band of interest on your radio. For example, on a general coverage shortwave receiver, you might set it for 10 MHz (top end of the 31M band), or perhaps to 7.040 MHz on a 40M ham radio receiver/transceiver. Tune the receiver to the signal generator signal. If you don't have a signal generator, you can also tune to a steady carrier or station to produce a hetrodyne audio "pitch." Tune in the signal to the pitch that causes the maximum peak-to-peak display. Adjust the scope and volume control to produce a 2Vpp display (4 divisions). This is the peak response of the overall filtering stages as shown in **Fig. 13**.

Now determine the audio frequency at this peak response by measuring the time period between cycles and covert to frequency. In the example to the right, the period of one cycle is 1.7mS, which is an audio tone of 750Hz (1/.0017sec). A frequency counter on the output can also be used.

Next, tune the receiver such that the sidetone pitch goes UP in frequency and the peak-to-peak signal will decrease in magnitude. Tune to the point where the signal is exactly 1Vpp on the scope. See **Fig. 12**.

This is the –6dB point of the high end of the filter (20log 1v/2v =–6dB). Determine the frequency of the audio pitch as before. In the example, this is 1100 Hz. Record the data.

From these two data points, the –6dB bandwidth can be estimated. The bandwidth from the filter peak (750 Hz) to the –6dB point (1100 Hz) is 350 Hz. The bandwidth (BW) between the two –6dB points is usually twice this value, or 700 Hz. A filter with a –6dB BW of 700Hz is a mediocre filter for CW reception, and way too narrow for SSB or AM.

Of course you can determine the exact –6dB BW by tuning the receiver back to the 2Vpp peak response, and continue tuning DOWNward in frequency until the audio is again exactly 1Vpp. Determine this frequency and record. In this example, it should occur around 400 Hz if the filter shape is symmetrical.

Plot these three data points on a sheet of graph paper as shown in **Fig. 15** to construct the filter shape. Return to the upper –6dB point (1100Hz in the example) and continue tuning upwards in audio pitch, recording the frequency at 0.5v (–12 dB), 0.25v (–18 dB), 125mV (–24 dB), etc. Everytime you "halve the voltage," it is a 6 dB change. The more points you collect, the more accurate your filter response plot will be.

Fig. 13 – Displaying Filter Peak Response

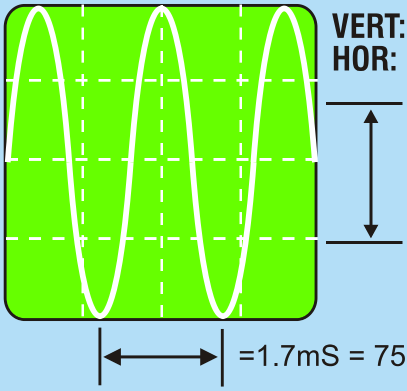

VERT: 0.5v/div ACV
HOR: 1.0mS/div

Set peak filter response for 2Vpp vertical display, then determine the audio freq.

=1.7mS = 750 Hz Audio Tone

Fig. 14 – Displaying –6dB Frequency

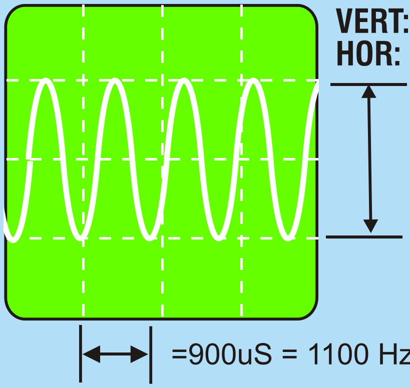

VERT: 0.5v/div ACV
HOR: 1.0mS/div

Tune receiver until vertical display is 1/2 of 2Vpp peak, or 1Vpp, for the –6dB point.

=900uS = 1100 Hz Audio Tone

Of interest to proper rig alignment is to repeat the above using the output of the product detector. To maximize the effectiveness of the filtering, the receive offset frequency set by the BFO should be adjusted to the same frequency as the peak frequency response of the audio. In this example, with the peak audio response occuring at 750Hz, if your BFO is set for a sidetone frequency of 700 Hz, you are loosing 2–3 dB, since this is in your filter skirt. This is shown on the response plot in **Fig. 15** by the dashed lines. By adjusting your BFO for a sidetone frequency of 750 Hz, you will pick up 3-4dB of overall gain in your receiver, plus increase the selectivity a bit as well. Why? Because nearby stations, such as one at 800–900Hz tone, could actually be louder than the 700Hz tone signal you are trying to copy, since the gain of the receiver is greater at those tones than at 700Hz, as shown in the plot.

Fig. 15 – Plotting Audio Response

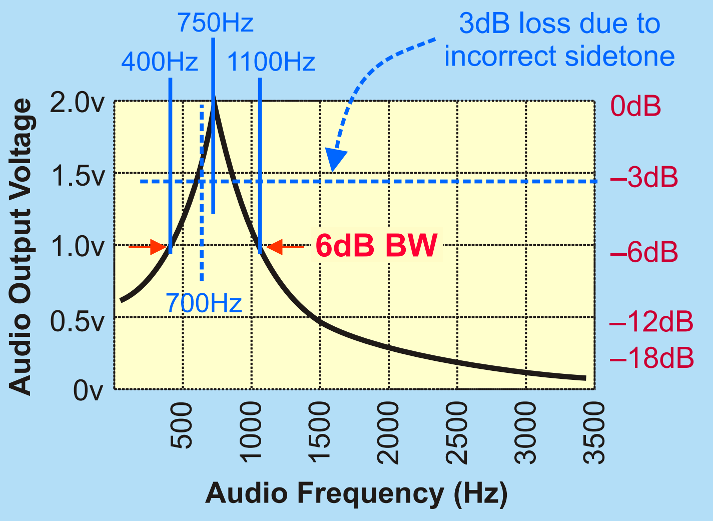

Opposite Sideband Rejection

A superhet receiver is supposed to pass just one sideband and reject the other. Poor opposite sideband rejection could indicate the crystals in your IF filter are not well matched or other problems. It is measured almost identical to plotting the filter response just described. First, you tune the receiver to the test signal to find the peak response frequency, or 750Hz in this example. Set the scope display for 2Vpp. Now tune downward in audio pitch, passing zero-beat, and continue tuning and you should hear the test signal, much weaker, now rising again in tone. This is the *opposite sideband*. Measure the peak-to-peak voltage, if you can. For example, say it is 80mVpp, as shown in **Fig. 16**. Calculate the opposite sideband rejection by:

$$\text{rejection} = 20\log\frac{80\text{mV}}{2.0\text{v}} = \frac{80\text{mV}}{2000\text{mV}} = -28\text{dB}$$

If you can't hear the opposite sideband, then obviously you have excellent filter rejection. If you can just barely hear it, you may have to increase the sensitivity of your scope (set vertical gain to 20 or 50 mV/div). In this example, –28dB rejection of the opposite sideband is quite good. A –30dB rejection means the opposite sideband is only 1/1000th of the desired sideband, a very suitable attenuation of the opposite sideband.

Fig. 16
Calculating Opposite Sideband Rejection

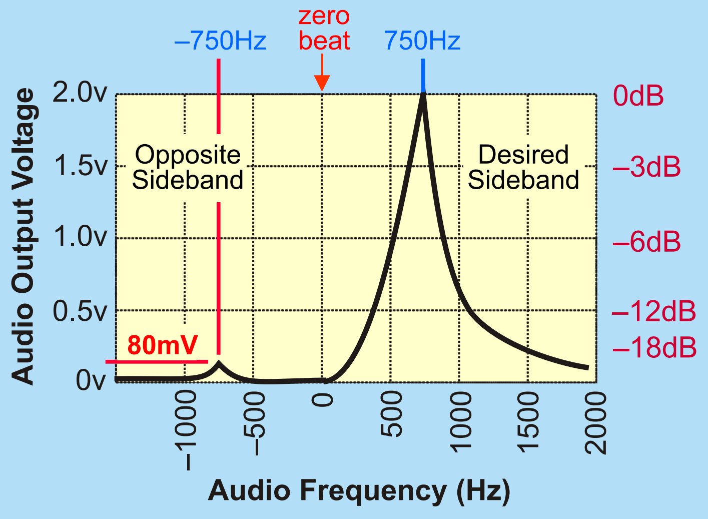

These tests are important to perform on your rig for documenting it's current performance, and repeated periodically to detect unfavorable changes or for troubleshooting when a problem is evident. For homebrewing, these tests can allow you to evaluate different circuits or when experimenting with different components or part values.

Oscillator Phase Noise

When homebrewing a basic oscillator circuit, such as a VFO, looking at the oscillator output on a scope can reveal several problems. One is to check for excessive phase noise. Phase noise is small variations of the oscillator frequency that causes power in the close-in sidebands, usually measured on laboratory equipment within 100KHz, or even within 10 KHz.

To check for oscillator phase noise, connect the oscilloscope to the oscillator output, loading the output of the oscillator as little possible. Most scopes have sufficiently high input impedances where this shouldn't be a problem, but some cheaper scopes can load an oscillator circuit. If you suspect your scope is loading the oscillator, couple the scope to the circuit with a small value capacitor, less than 20pF.

Display 2–3 cycles of the oscillator output as shown on the scope display shown in **Fig. 17**. Properly focus the scope and carefully observe if the waveform appears in focus at the peaks, but slightly out-of-focus at the zero-crossing points, that is, on the rising and falling edges of the sine wave.

If it appears out-of-focus, this is excessive phase noise jittering the signal and "smearing" the waveform along the time (horizontal) axis. Extreme phase noise may show 2-3 sine waves very close to each other, as shown in the exagerated waveform to the right — assuming you have your scope properly triggered.

Fig. 17 – Checking Oscillator Phase Noise

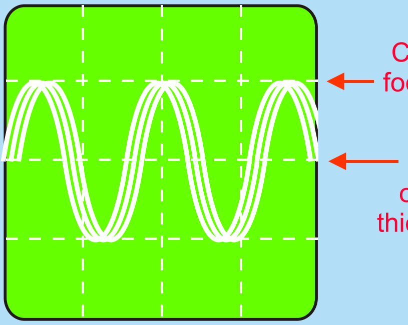

Check for a clean, focused signal here

Check for an out-of-focus or thicker signal here

Phase noise is random, instantaneous changes in the oscillator frequency that smears the display. If you can see this on a scope, the phase noise is excessive! If you can't see it, it doesn't mean the oscillator has no phase noise (all oscillators have some phase noise), it just means it is not excessive enough to see on a scope. A scope is not a good instrument for checking phase noise, but for homebrew circuits, it is a check to ensure you do not have a serious oscillator problem.

Excessive oscillator phase noise in receivers can cause IMD products and noise in the audio range at the output of the mixer(s), including the product detector. In a transmitter, excessive oscillator phase noise will put power in the close-in sidebands of your carrier, not only wasted power for lower transmitter efficiency, but may produce strange sounds (buzzing or chirping) to the receiving station. A few causes of phase noise are excessive current in the oscillator transistor, low-Q coil(s), high dissipation in the tuning caps or poor power supply filtering at the oscillator frequency.

AM (Amplitude) Noise

Another oscillator problem may be AM noise, or amplitude modulated noise. It is an opposite effect on a scope when displaying the oscillator output — the sine wave appears out-of-focus or thicker at the peaks, and in-focus elsewhere as shown in **Fig. 18**.

Fig. 18 – Checking for AM Oscillator Noise

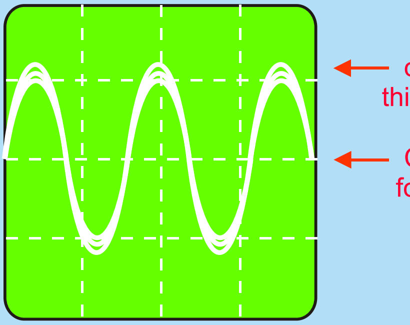

Check for an out-of-focus or thicker signal here

Check for a clean, focused signal here

If you detect AM noise, slow down the scope's sweep rate to the audio frequencies or slower to see if you can notice a lower frequency component. A common cause of AM oscillator noise is 60 Hz from the power mains leaking into the circuits. This is particularly true if using a power supply off of 120v 60 Hz, or sometimes it can be due to the AC lighting above your head! If the AM noise seems to be at the same frequency as the audio output tone, it means audio is getting into the Vcc bus, likely due to poor bypass filtering at the audio amplifier stages (particular if using an LM386 or similar).

If you can't find a low frequency component, the AM noise may be random, which may indicate poor voltage regulation, a noisy voltage regulator, or perhaps a circuit in VHF oscillation. If the AM noise seems to occur on key-down only on a transmitter, the transmit current may be loading the power supply, the voltage regulator is under-rated, or just simply loading the oscillator. In the case of loading the power supply or regulator(s), perhaps a separate voltage regulator or zener circuit should be used, dedicated for the oscillator(s). In the case of transmit loading, adding a buffer amplifier or emitter follower to isolate the load from the oscillator may help.

Much of this can be diagnosed also with the scope, by looking at the AC ripple on the DC power lines. You should have less than 50mV of any AC component on the 8-12v DC wiring, whether 60Hz, audio or RF. If >50mV, then additional low or high frequency filtering on the DC power is needed.

Monitoring Transmitter RF Output

RF Power (in watts) is E^2/R, where E is in rms and R=50 . The voltage displayed on the scope (peak-to-peak) must be converted to rms by Erms=.707(Epp/2). To measure properly, the transmitter should be on a 50 dummy load using the normal hi-Z scope input. If your scope has a selectable "50 "input, it can be the transmitter dummy load directly, providing it can tolerate the 50Vpp input. (Always know what the maximum p-p input voltage your oscope will tolerate. It is often stated on your scope at the vertical channel inputs. 50Vpp to 100Vpp are typical).

Measuring Transmitter RF Output Power

Figure 19 shows how you can use an oscilloscope to fairly accurately measure output power from a low power transmitter (generally 10W or less with a 1X probe and 20-30W with a 10X probe). Connect transmitter output to a 50 dummy load. Connect the scope lead to the transmitter output (after the low pass filters) or directly to the dummy load. Do not connect the scope leads to the collector or drain of the final PA transistor. The displayed voltage in this case will be erroneous.

In the example, the output transmit voltage across the dummy load measures 24Vpp. Convert this voltage to Vrms, then use the equation (Vrms squared divided by the load resistance) to calculate the power in watts. In the example, 24Vpp, the output power is 1.4 watts. A 5W QRP transmitter should produce about 45Vpp.

The accuracy of your power measurements depend upon the condition of your oscilloscope:

1) Ensure your scope's vertical sensitivity (volts/division) is properly calibrated (see Part I)
2) Ensure your vertical sensitivity is properly calibrated with the 1X or 10X probe you are using.
3) Ensure that the transmitter frequency is well within the bandwidth of your scope. A 100 MHz scope should give reliable readings on all HF bands. A 50 MHz scope should be reliable on all HF bands except slight errors at 28MHz.

Fig. 19 –Oscilloscope as a Power Meter

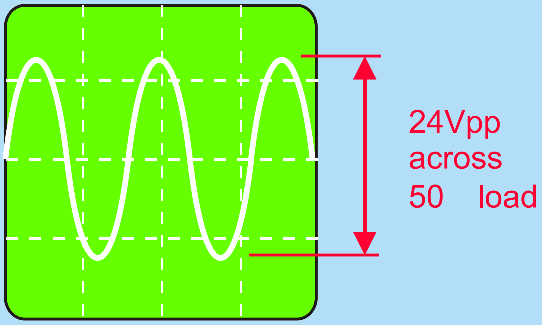

1. Measure output voltage. 24Vpp
2. Convert Vpp to Vrms
Vrms=.707(Vpp/2) 8.5Vrms
3. Calculate power in watts

$$\frac{Vrms^2}{R} = \frac{8.5v^2}{50} = 1.4W$$

Checking Transmitter Purity

Phase Noise of the transmitter is measured identically to the phase noise checks on page 2–3. With the scope properly triggered and focused, you are looking for an out-of-focus "fuzziness" around zero crossing. If it appears phase noise exists, the fault is generally at the beginning of the transmit chain. That is, seldom does the PA transistor add phase noise; it's merely amplifying what it is given. Phase noise on the transmitter output is more likely due to the transmit oscillator, or the transmit mixer if used.

Harmonic Power can also be detected on a scope while looking at the transmitter RF output power. In **Fig. 20**, notice the "dips" or the two "peaks" on the top and bottom of each sine wave. This is caused by excessive 2nd harmonic output power. The rule-of-thumb is – if you can see any 2nd harmonic power (a dip or flattening at the peaks), then you are right at or exceeding the –30dBc FCC harmonic specification. A clean sine wave implies FCC compliance, providing the 2nd harmonic is within your scope's bandwidth. Obviously, a spectrum analyzer should be used for accurate harmonic evaluation, but a scope can be used to indicate if you have a problem. If you build your own transmitter, it is your responsibility to ensure it is compliant. An approximate method of estimating 2nd harmonic attenuation is shown.

–30dBc means the 2nd harmonic power is 1/1000th of the fundamental power. For a 5W transmitter, this means the 2nd harmonic power should be 5mW or less, or about 1Vpp. In displaying a 5W signal on a scope (45Vpp), it would be difficult to resolve much less than a 1Vpp dip or ripple.

Fig. 20 –Checking 2nd Harmonic Power

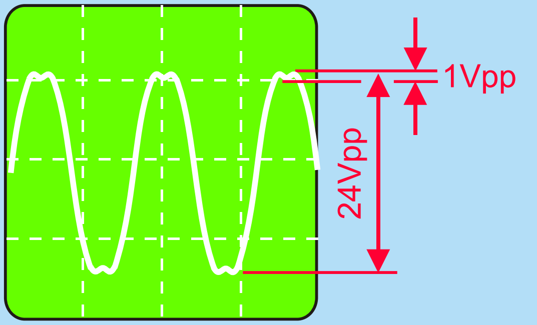

1. Measure output voltage. 24Vpp
2. Measure ripple voltage. 1Vpp
3. Calculate dBc of 2nd harmonic ripple

$$20\log\frac{V2}{V1} = 20\log\frac{1v}{24v} = -27.6\text{ dBc}$$

or, not quite FCC compliant!

Conclusion. This concludes the NA5N "Handiman's Guide to Oscilloscopes." Hopefully, it has helped you to understand your oscilloscope to make simple measurements, and with some practice, perform the more advanced measurements discussed. An oscilloscope is a very powerful tool that is invaluable on the homebrewer's workbench. If there is a particular measurement you feel I omitted, please let me know and I will add it when time permits.

73, Paul Harden, NA5N (na5n@zianet.com or pharden@nrao.edu)

THE HANDYMAN'S GUIDE TO OSCILLOSCOPES (Part 1 of 2)

by Paul Harden, NA5N

Print as .pdf file
5 pages
8½ x 11 or A4

Getting Acquainted with your Scope and making some measurements

Updated May 2004 with actual oscope waveforms

When in the course of human events, it becomes necessary to look at neat signals floating around your radio, you go to a hamfest and buy that $50 o-scope. Now what? This two part article will attempt to explain basically how an oscilloscope works, operator functions, basic measurements, and some advanced applications. An o-scope is a powerful tool in any shack – even a real "cheapie" with limited bandwidth.

HOW AN OSCILLOSCOPE WORKS

A block diagram of a typical o-scope is shown in **Fig. 1**. The test probe usually plugs into the scope via a BNC connector, then passes through a switch to determine whether the input signal will be dc or ac coupled (to remove any dc component). Often this switch will have a "ground" position for setting the zero-volts reference. Next is the input attenuators. The vertical input amplifier is quite sensitive, designed for 20-50mV of input. For larger input voltages, the signal is applied to attenuators comprised of simple voltage dividers. This is the first area of concern for cheap o-scopes, as the input attenuators may not be very linear or accurate. For example, if you appy a 10Vpp signal on the 10v/division setting, the signal should be 1 division high. Switching to 1v/div., the signal should be 10 divisions (usually full-scale) high. If it is not exactly 10 divisions, the attenuator for that setting needs adjusting. Some scopes have internal adjustments for fine-tuning each attenuator setting.

Following the attenuators, the signal is applied to the first vertical amplifier, which converts the input to a differential signal. This differential signal is amplified up to high voltages for the oscilloscope deflecting plates – moving the beam up and down (in the vertical axis).

The sweep generator is usually a constant current source charging a capacitor to make a sawtooth waveform that eventually deflects the beam in the horizontal axis. The frequency of the sawtooth determines how fast the beam travels from the left to the right side of the tube, and is controlled by the sweep control, usually calibrated in seconds, milli-seconds or micro-seconds per division. This is the second area of concern for an oscilloscope – how linear the sawtooth waveform is generated. For example, a sawtooth with a nonlinear ramp will cause the signal displayed in the central portion of the tube to be expanded or compressed compared to the signal at the ends.

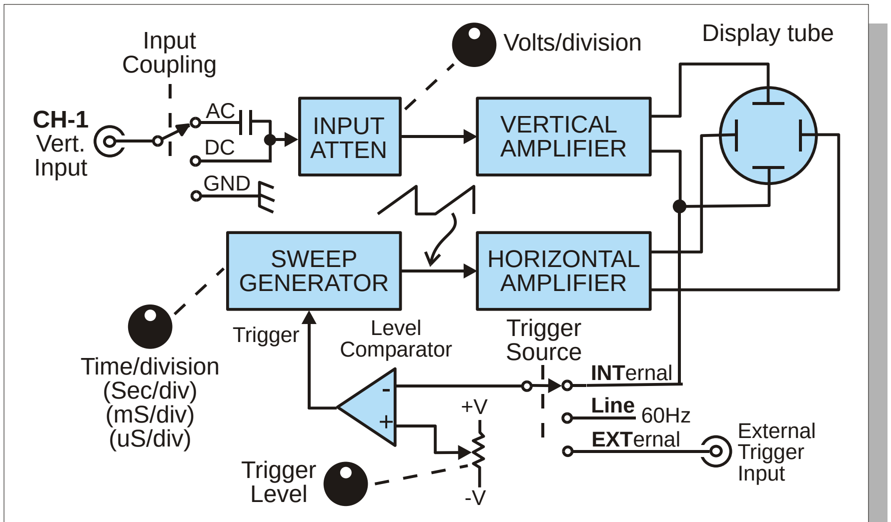

FIG. 1 - Basic block diagram of an Oscilloscpe

The sawtooth ramp is amplified to high voltages, applied to the oscope tube, to deflect the beam from left to right. An important task of an oscope is when the horizontal deflection begins. Normally a switch labeled "Trigger Source" determines what initiates the sawtooth ramp. In the "Internal" position, a sample of the input signal (in the vertical amplifiers) is sampled, with a variable resistor setting the level. When the input signal exceeds the "Trigger Level," a pulse is generated to start the sawtooth ramp and hence the horizontal sweep. The purpose of triggering is to keep the input waveform synchronized to the sweep so it appears stationary on each sweep. The trigger source usually has a "Line" position, which simply triggers the sweep off of 60Hz from the power supply. This synchronizes the sweep to the AC power frequency and is useful for checking television signals, which are synchronized to the power mains. Also, an "External" position may be present, which connects an external input signal (via a BNC connector) to trigger the sweep generator.

Other features your oscope may have are two vertical channels for dual trace operation, various modes to display both waveforms (alternate, chopped, A+B added, etc.), delayed sweep features, dual sweep time bases, built in calibrators, etc.

CALIBRATING YOUR OSCILLOSCOPE

The first thing you should do upon acquiring an o-scope is to check its calibration.

The vertical amplfiers can be checked with a known voltage source or 9v transistor radio battery. Measure the output voltage of the battery with an accurate voltmeter. Let's say it just happens to be +9v exactly. Set the input coupling to ground (0v) and move the trace to the bottom division. Switch the input coupling to DC and set the attenuators to 1v/div. The deflection should be 9 divisions. Switching to 10v/div., deflection should be 0.9 divisions. Internal to the oscope (or perhaps accessible from the outside) are adjustments for the vertical amplifier gain. Adjust this for 9 divisions of deflection in the 1v/div. range. Procedure can be repeated with a 1.5v flashlight battery (assuming you know the exact voltage from a DVM).

The horizontal amplifiers should be checked/calibrated using a signal generator. For example, a 1MHz signal has a period of 1uS. Setting the sweep rate to 1.0uS/div., a 1MHz signal should take exactly 1 division per cycle. Set the horizontal width control properly to ensure the beam starts at the first division and ends at the last division. If the sweep rate appears incorrect, an internal adjustment (Sweep gain or similar) can be set for proper display of the test signal.

The main operator controls are:

- **Intensity** - controls the brightness of the beam. **NOTE: Too bright a beam can damage to the CRT tube!**
- **Focus** - adjusts the beam for the thinnest and sharpest display.
- **VERT & HOR Position** - controls the vertical and horizontal position of the display respectively
- **VERT V/div** - controls the vertical sensitivity of the display, i.e., how many volts (or mV) per division.
- **HOR Sweep Speed** - sets the horizontal sensitivity, i.e., how many mS or uS per division.
- **VERT & HOR vernier** - allows the vertical and horizontal sensitivity settings to be varied in small steps.

Other adjustments you may find on your scope are:

Astigmatism - With the scope intensity and focus properly set, this adjustment compensates for the curvature of the CRT tube by making it in-focus across the sweep. If your trace is out-of-focus in certain areas, but in-focus elsewhere, the astigmatism needs to be adjusted. See ***Fig. 2***.

Trace Rotation - is a small coil around the CRT that skews the trace to ensure it is perfectly horizontal. On scopes without this adjustment, the trace is leveled by physically rotating the CRT to align the trace to the graticle grid. See ***Fig. 2***.

Fig. 2 – Effects of Astigmatism & Trace Rotation

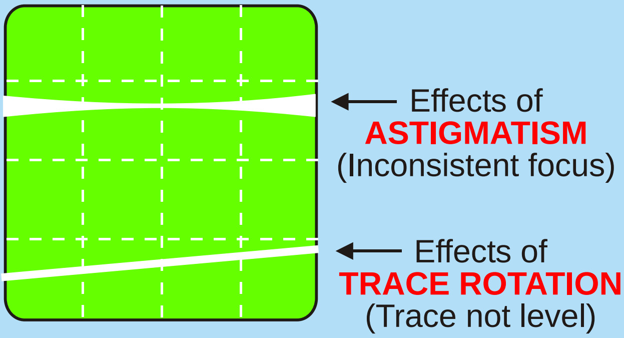

DC BAL (DC Balance) - is a dc offset in the vertical amplifiers that causes a shift in the trace baseline when changing vertical scales. It is most obvious when measuring ac voltages. For example, you are displaying a 10Vpp sine wave, centered on the center graticle, at 2v/div. Changing to 5v/div, the sine wave shifts off the center graticle ... that is, it assumes a dc bias error. The DC BAL is adjusted until the shift no longer occurs when changing vertical scales.

HV ADJ. - is the high voltage that controls the intensity of the trace. Turn up the **Intensity** control to its brightest position, then adjust the HV ADJ for a trace slightly brighter than normal intensity. The **Intensity** control now has the proper range. The HV ADJ might have to be re-adjusted to acquire proper focus.

NOTE: Very bright trace displays can cause permanent damage to the CRT, particularly on a well-used scope.

LET'S MAKE SOME MEASUREMENTS

It is assumed you have your scope relatively calibrated and familiar with the front panel controls. The sample o-scope displays are based on eight vertical and ten horizontal divisions on the CRT screen, typical to most oscilloscopes. Most waveforms are actual displays of the signal cited, photographed from my trusty Tektronix 475 oscilloscope.

First ... a word on TRIGGERING.

Most oscilloscopes have a knob or two for "Triggering." This tells the oscilloscope when to start the sweep. When the **Triggering Slope** is placed in the **(+)** position, the scope will begin its trace when the *input* signal goes positive. Likewise, when **(–)** triggering is selected, the trace will begin when the input signal goes negative, as shown in **Fig. 3**. Often there will be the option to chose the **Triggering Source**, such as "CH.1" or "LINE." Line means the scope is triggered off the 60Hz line voltage, and is useful when synchronizing on television signals or looking at 60Hz power supply noise. CH.1 or CH.2 means the scope will trigger off the signal on channel 1 or 2 respectively. **Trigger Level** is at what voltage of the input signal triggering begins. For example, if set high, triggering may not begin until the input signal reaches several volts. When set around zero, it will trigger the moment the signal goes positive (if set for (+) triggering). This setting can be troublesome if noise exists on the signal. Adjust for stable triggering.

Fig. 3 – Triggering

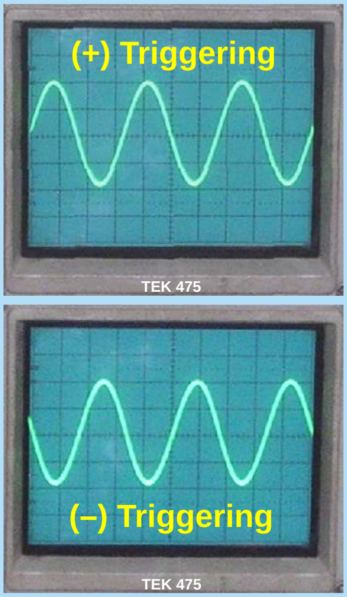

DC Voltages.

Say you want to check the transmit-receiver (T-R) switch in your QRP rig, or other digital signal. See ***Fig. 4.*** The key line is the input to the HCT240 inverter to form the 0v TX– on key- down and the 0v RX– on key- up. This switches the rig between transmit and receive (T-R Switch). It is a logic function, that is, a voltage to represent ON or OFF.

Place the scope lead on pin 13 at 10v/div. and you should see the waveform like the top trace in ***Fig. 4*** ... about +6v on key-up and 0v on key down. Move the scope lead to pin 7 and you should see 0v on key-up and about +8v on key-down (bottom trace). If the output does not go "HI" (+8v) on key-down, or does not go to a solid "LO" (<1v) on key-up, the inverter is not working properly. (It's busticated). Many shortwave receivers use similar schemes for switching filters or attenuators.

While this test could be done with a DVM, the integration time is slow, requiring long key-downs to get the voltages. A scope will also show you how clean the switching is, or if there is an ac voltage (or RF noise) riding on the T-R voltage.

Scopes are thus good dc voltmeters, with about a 5% reading accuracy.

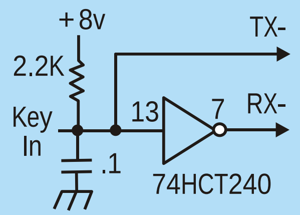

Fig. 4 - 38-Special T-R Switch

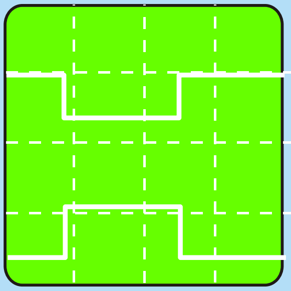

VERT: 10v/div DC
HOR: 500mS/div

AC Voltages.

Here is where an oscilloscope pays for itself by making AC voltage (and frequency) measurements. You must remember, AC voltages are displayed on a scope as ***peak-to-peak voltages***, while a voltmeter measures in ***rms***. RMS voltages are about 1/3 the p-p voltage read on a scope, or specifically:

$$V_{rms} = \tfrac{1}{2}(.707 \times V_{pp}) = 0.354 \times V_{pp}$$

For example, let's measure the output voltage and frequency from the sidetone oscillator in your QRP rig. Place the scope lead on the audio amplifier output. On key-down, you get the waveform shown in ***Fig. 5***. The transmit sidetone audio is 1.9Vpp.

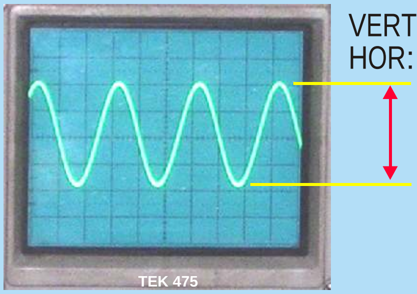

VERT: 0.5v/div ACV
HOR: 0.5mS/div

3.8 divisions peak-to-peak times 0.5v/div
= 1.9 Vpp
= 0.67 Vrms

Fig. 5

AC Frequency Measurement.

With this waveform, we might as well see what frequency our sidetone or transmit-offset frequency is. Most operators prefer the sidetone to be about 700–750Hz. Trigger the scope for a stable waveform and set the time-base (sweep) to display 2 or 3 cycles, as shown in ***Fig. 6***. Center the waveform between two horizontal divisions so zero volts on the waveform is on a graticle line, then move the horizontal position so the first "zero– crossing" is also on a division line.

Fig. 6

VERT: 0.5v/div ACV
HOR: 0.5mS/div

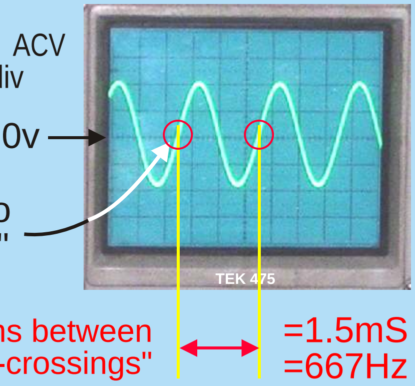

3 divisions between "zero-crossings" =1.5mS =667Hz

Measure the time it takes to make one complete sine wave from one zero-crossing to the next. In this example, it is 1.5 divisions, at 1mS per division, or 1.5mS. Frequency is simply the reciprocal of time, such that the sidetone frequency is:

$$f = \frac{1}{t} = \frac{1}{1.5\text{mS}} = 667\text{ Hz}$$

For some, this may be about right. For others, this may be a little low to your liking. To raise it to 700Hz, calculate the time period of 700Hz (1/700 = 1.4mS). At 1.0mS/div, you can adjust your sidetone or transmit offset until zero-crossings for a single sinewave is 1.4 divisions. This will be about 700 Hz. (Sidetone may not be adjustable on some rigs).

All frequency measurements are made in this fashion, by measuring the distance between zero-crossings (or from one peak to the next) and converting the time period to frequency. This should emphasize the importance of ensuring your sweep speed is calibrated; as any error in the time base will cause a corresponding error in the accuracy of your time or frequency measurements.

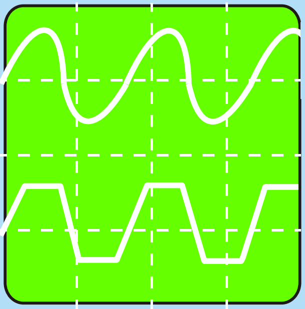

Fig. 7

Example of Waveform Quality

VERT: 2v/div ACV
HOR: 1.0mS/div

Quality of the waveform is another feature of a scope that is unsurpassed since you are "seeing" the waveform in real time. Two examples of waveform quality are shown in ***Fig. 7***.

The top trace shows the sidetone frequency with distortion, perhaps due to improper time-constant on the coupling capacitors or improperly biased audio amplifiers. The bottom trace would be a raspy sounding side tone, due to the amplifier being over-driven and in compression (clipping). The o-scope is an invaluable tool for detecting and diagnosing such impurities in the signal quality.

FIG. 8 – Full Scale Signal Display

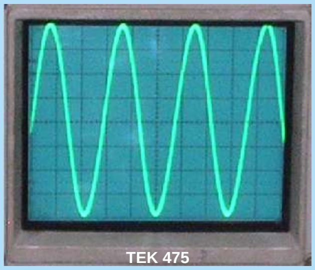

Actual display
Tektronix 475

MORE NIFTY MEASUREMENTS

Amplifier Gain.

The gain of an amplifier can be measured in terms of voltage or decibels (dB). For voltage gain, it is simply Vout/Vin of the amplifier. For example, if the input is 1Vpp and the output is 4Vpp, then the amplifier has a voltage gain of 4.

Gain in dB is often more useful and is how the gains of amplifiers are usually expressed. With dB's, every-time you double the AC voltage, you add 6dB of gain. It is the **ratio** of output to the input, and this **ratio** is easy to measure on a scope.

It is often easier to start with the output. Set the vertical amplifier gain to display the amplifier **output** as a full-scale signal as shown in ***Fig. 8***. Now move the scope probe to the amplifier **input** without disturbing the scope gain. You will of course have a much smaller signal, and the ratio of the input to the output will be the gain in dB. In our example of using eight divisions for full-scale, then four divisions would be 6db, 2 divisions 12dB, etc. as shown in **Fig. 9.** You may want to add your own dB scale along your scope display to remind you of this relationship. Note: this is ***voltage gain*** (Av=20log x Vout/Vin). In this example, with 4Vpp output and 1Vpp input (Av=4), then the gain is dB=20log(4) = 20(0.602) = 12dB, or as shown directly on the CRT tube. Since this is a relative measurement, the absolute Vin or Vout voltage does not need to be determined.

Fig. 9 – Volt. vs. dB relationship

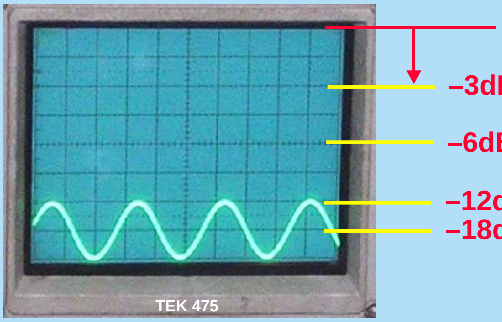

Fig. 10
Measuring
Phase
Shifts

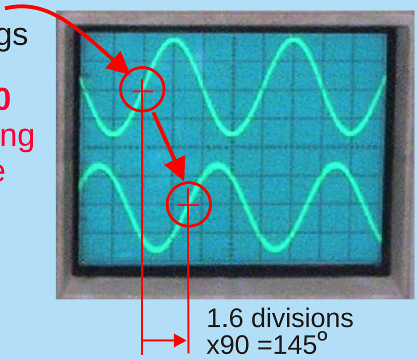

Insertion Loss.

In some circuits, such as filters or attenuators, the ***loss*** in the circuit needs to be measured, and like circuit gain – expressed in dB. The loss through a circuit is called the ***insertion loss***. It is determined in the same way as amplifier gain just presented, except start with the input (the highest AC voltage) as the full-scale or reference display, then measure the output AC voltage (the lowest level). **The ratio is the insertion loss in dB.**

For example, with a signal generator connected to your receiver, you want to measure the insertion loss through the IF crystal filter. At the filter input, you can just barely squeek out 2 divisions of input signal on your scope at its most sensitive setting. The output from the crystal filter is 1.5 divisions. The insertion loss would be 20log(1.5/2.0 div.) = –2.5 dB. If the output were only 1.0 division (50% reduction), the insertion loss would be 6dB.

Fig. 11 –Phase Shift by imposition

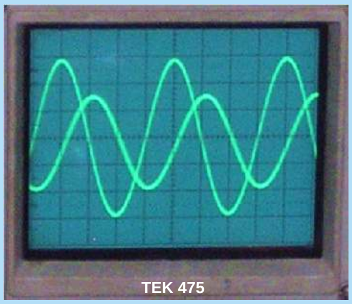

Measuring Phase Shifts.

Phase relationships between two signals at the same frequency can be measured with 2-5^{o} accuracy with a scope, although more suited for a dual-trace scope. The reference signal is applied to CH. 1 and the signal to be measured to CH. 2. For proper phase measurements, ensure your dual trace display is in the **chopped** mode, not **alternate** mode for proper phased referenced triggering.

There are many methods to do this. One is to stretch out the signal so it takes 4 horizontal divisions, such that each division is 90^{o} of phase, as shown in **Fig. 10**. By measuring from a common point on one signal (zero-crossing or from peak-to-peak) to the next, the phase can be measured. For example, say you are making a phased-array antenna in which one feedline must cause a 90^{o} delay. You calculate the electrical length for a ¼λ [L=(246/f) x Velocity Factor] and cut the coax to that length. You are now working on blind faith that you have exactly 90^{o}. With a scope, you can measure it fairly accurately by injecting a signal into one end with a signal generator (at the frequency of interest) and a 50Ω load on the other. Connect the scope CH.1 to the coax (signal) input and CH.2 to the load end and measure the phase. In the **Fig. 10** example, the CH.2 signal is delayed by 1.6 divisions, at 90^{o} /div is 145. ***Your delay line is too long!*** Cut off an inch or two at a time until the CH.2 signal is 90^{o} from CH.1 for precise tuning of the delay line. (While departing from o-scopes for a moment, the sharp null of a phased array is astounding when exactly 90^o delay is achieved. More than $10\text{-}15^o$ in error causes a very “mushy” null with little difference over a single vertical antenna. Most errors in achieving exactly 90° by the "measure-and-cut" method are due to uncertainties in the stated velocity factor of the coax).

Another method is to superimpose the two signals on top of eachother. Make one signal larger than the other so you know which one is what, as shown in **Fig. 11**. In this example, the smaller signal lags the larger signal by about 100^o, estimated by where they cross. For more accurate determination, use the time base to measure the time period of one cycle (T1), then the time period one signal lags (or leads) the other (T2). The phase shift is then $\theta=(T2/T1)x360^o$.

Phase measurements can be made on a single trace scope as well. First, connect the reference signal, uisng a BNC "T," to both the *external trigger* and the normal *vertical input*. Adjust the trigger level so the zero-crossing occurs at the beginning of the trace (left-hand graticle). Remove the reference from the vertical input, but not the e*xternal trigger,* and apply the signal to be tested to the vertical input – without altering the time base or trigger level. The distance of zero-crossing of the test signal is from the left-hand graticle can now be measured to determine the phase, though with slightly less accuracy than using a dual-trace scope.

An interesting experiment is to measure the phase shift of the audio signal at different frequencies as it travels through the stages in a CW, SSB or AM active filter. What is the phase shift of the wanted vs unwanted frequencies?

Measuring Rise and Fall Times.

In digital circuits, it is sometimes important to know the rise and fall times of a signal through a gate. In amateur radio transceivers, this same interest could be applied to how fast the T-R switch switches. On key-down, if the transmitter turns on slightly before the receiver is turned off, it can produce an annoying "thump" in the receiver. Rise and fall times are measured by triggering on the edge of the signal of interest, then increase to a faster sweep speed to measure the time it takes the signal to reach 90% of its final level. The signal to be measured is shown in **Fig. 12** on the top trace, and the expanded version on the bottom. For proper rise times, the signal being measured should be well within the bandwidth of your scope and using a low capacity probe.

For example, in **Fig. 12** (bottom trace), the rise time is about 1/4th of a division. If the sweep speed is 100nS/division, the rise time would then be about 25nS.

Fig. 12 –
Rise and Fall Times

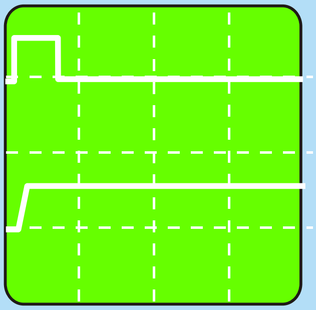

USING LIMITED BANDWIDTH SCOPES

Today's scopes have 200–500MHz bandwidths. Likely your scope is much less than that. A limited bandwidth scope is still very useful to the amateur or homebrewer. Say the bandwidth of your scope is 5MHz. This does not mean you can't see 7MHz signals. It just means the peak-to-peak value has lost meaning, and will likely be very weak, since it is beyond the bandwidth of the scope. (Like other bandwidth measurements in electronics, the “bandwidth” of a scope is usually based on the “3dB bandwidth.” That is, at the maximum bandwidth, you are already at the –3dB point, or a 25% reduction in the peak-to-peak voltage display). You can still resolve individual cycles higher than the cited bandwidth to a certain degree and make gain and phase measurements, since they are based on ***ratios.***

Most of the examples in this article explore many regions of a communications receiver or ham transceiver without the benefit of any great bandwidth. Experiment with your scope to learn its limitations. ***Use a good scope probe and make measurements with a good ground to get the most out of the bandwidth you have.***

For the homebrewer building circuits in the HF bands, a 50 MHz scope **with good calibration** will yield fairly accurate measurements up to 30 MHz with little concern for accuracy. The old 465 or 475 series of Tektronix scopes, with 100/200 MHz bandwidths, make an excellent oscilloscope for the amateur or experimenter. They can often be found at hamfests today for $100–150, and tend to maintain a fairly good calibration almost regardless of how much use they have seen.

In Part 2 - we'll probe (bad pun) into some advanced measurement techniques, even with a simple scope ... such as measuring sideband rejection, filter responses, VCO phase noise, etc. (and what it all means).

72, Paul NA5N

na5n@zianet.com
pharden@nrao.edu

Colophon:
Article prepared by NA5N using CorelDraw 11

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NIC NAC TIC TAC CRYSTAL RADIO SET - AN IDEAL PRIMARY SCHOOL PROJECT...

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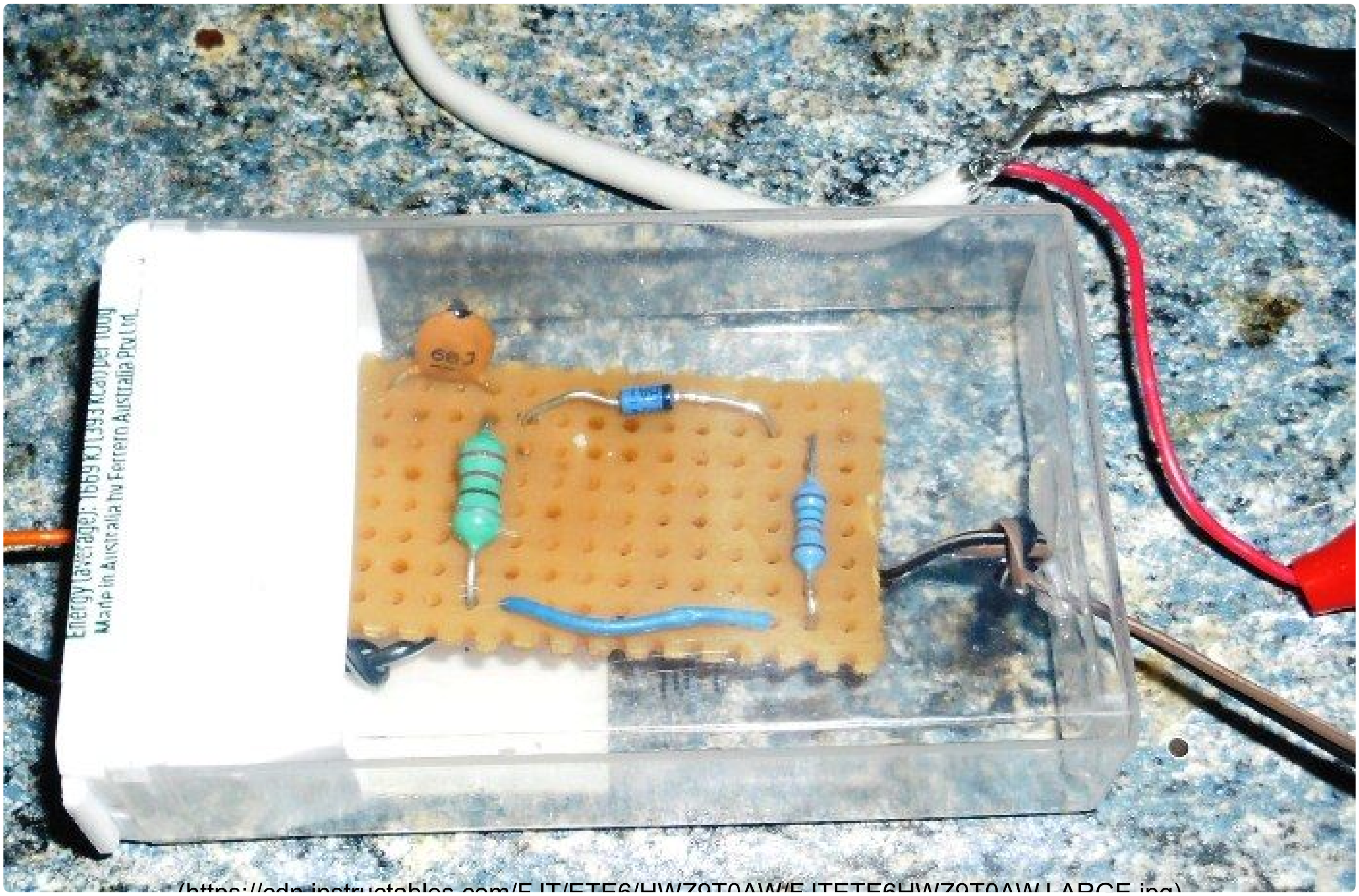
Energy (average): 1669 kJ/393 kcal per 100g
Made in Australia by Ferrero Australia Pty Ltd
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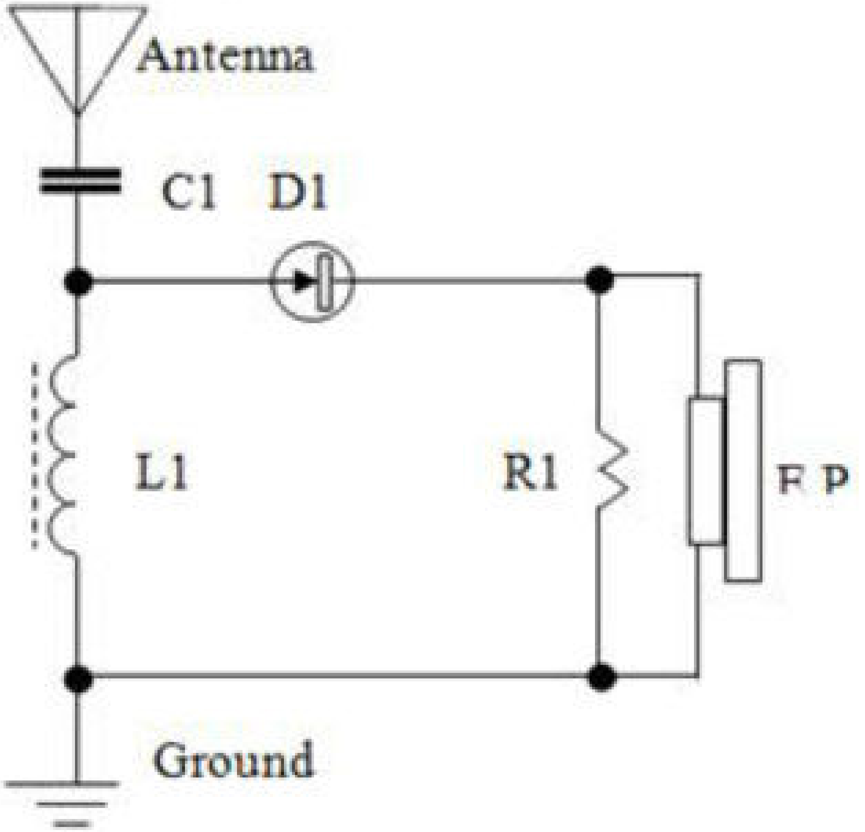

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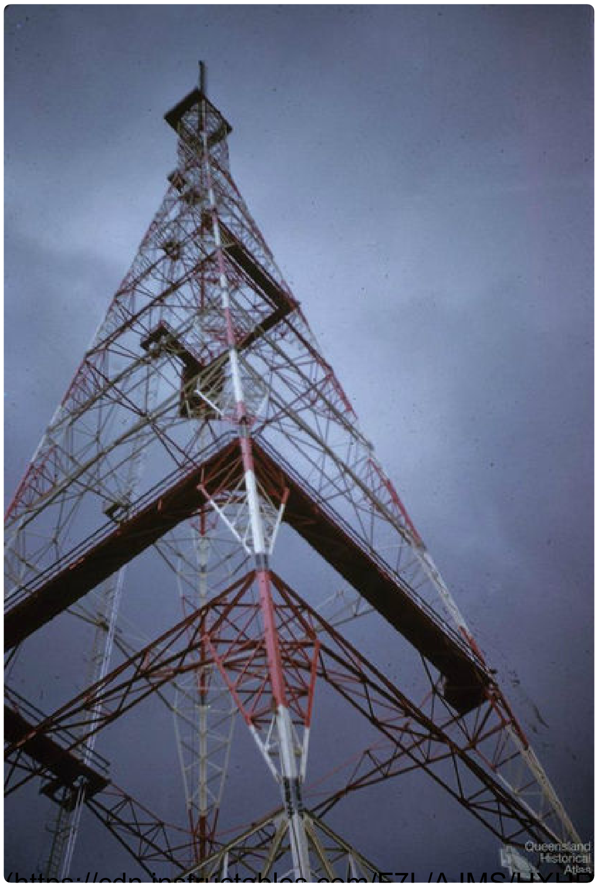

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Hi there! This Instructable is all about building a basic crystal radio set that is so simple to build and understand, that a child could do it - with help from mum or dad - or even at school, as a class project. Parts can be bought "off the shelf" at Jaycar Electronics and other suppliers, or purchased online via Ebay and Paypal.

I built my first ever crystal set when I was 9 years old, but that was a different world. We're going to build a 21st century style radio with all modern components which are relatively easy to obtain at your local electronics store or on the Internet.

The radio is contained inside a Tic Tac box, and is called "The Nic Nac Tic Tac Radio". It is built on a square of matrix board, with the component leads poked through the holes in the board, and joined underneath. It is a very simple crystal set, designed to initially receive only one station, but you can expand the tuning range with the addition of only one extra component.

The Tic Tac radio can be constructed by simply twisting the component leads together, underneath the matrix board and attaching antenna/ground wires as well as the earphone wires to the board, using that same technique. You don't have to solder any wires, but there is another way to join them all together - more on that later.

The Tic Tac Radio is a very easy set to put together - you don't need to wind bulky coils or use heavy tools and screw strange looking parts onto a large breadboard. See step 1 for the parts list you will need.

Add Tip Ask Question

Step 1: Parts and Tools You Will Need

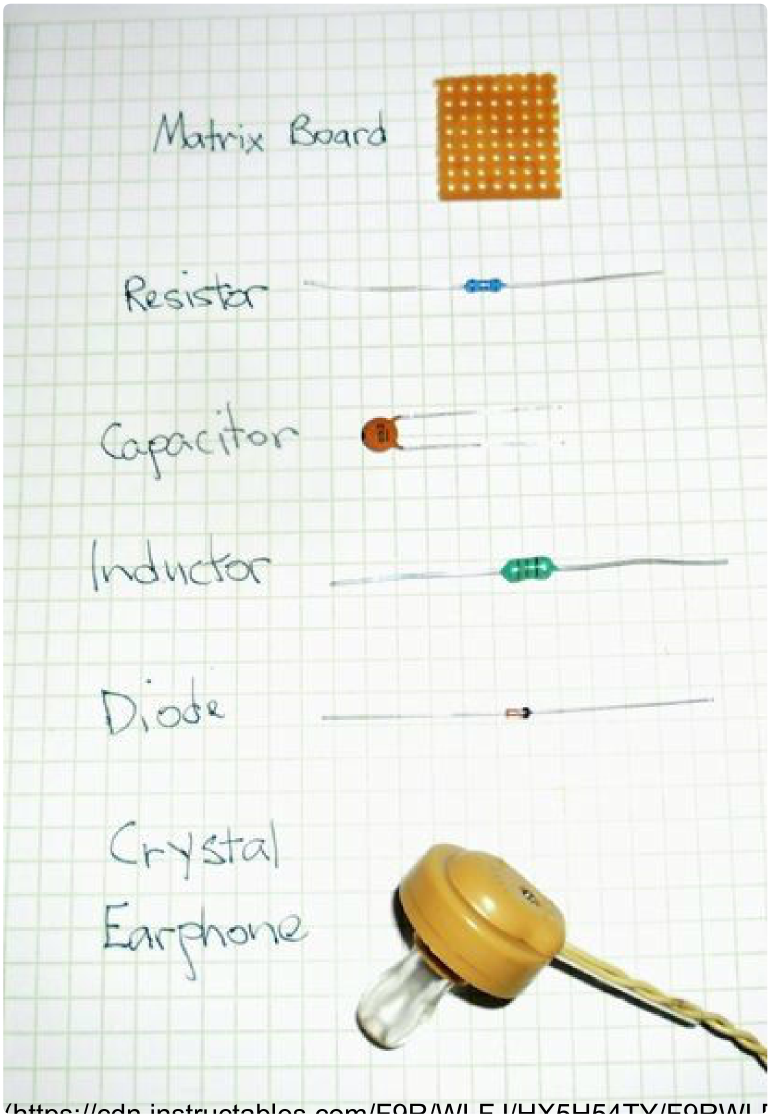
Matrix Board
Resistor
Capacitor
Inductor
Diode
Crystal Earphone

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You will need to acquire the following components from a local electronics shop or an online electronics business.

I am adding the catalogue numbers for Jaycar Electronics, so if you live in Australia or North America, you may be able to visit a Jaycar store and buy the parts over the counter, if not then you may be able to do an online mail order via Paypal:

Parts List

Resistor - 47k - yellow-purple-black-red and brown - RR 0612 (pkt of 8)

Capacitor - 68pF - ceramic x 2 - RC 5322 (pkt of 2) and a 100 or 120 pF value as well for experiments.

Inductor - 220 uH - red-red-brown silver - LF 1538 (resistive type)

Polyvaricon tuning capacitor - 220 pF - RV 5728 - with knob and mounting screws

Diode - BAT46 - ZR 1141 (You can also use a 1N34A Germanium Diode too if you have one at home)

Ceramic Earphone - AS 3305 *

A 25 meter roll of yellow hook up wire for the Antenna wire and a 3 meter length of wire for the Ground wire.

Please note that some Jaycar parts come in multiples of 2 or more per packet. And please note the following:

PLEASE NOTE: THIS PROJECT/KIT CONTAINS SMALL PARTS THAT MAY FORM A CHOKING HAZARD FOR SMALL CHILDREN OR PETS. NOT SUITABLE FOR CHILDREN UNDER FIVE (5) YEARS OLD.

*A normal crystal radio earphone is OK, but if you can't get one of these, or if the one you bought goes dead (as they sometimes do,) you can use a substitute, such as the Murata PKM44EW passive transducer (see picture above) which is available from an old Telstra TF200 touchphone, (the one on the left in the diagram above,) or an equivalent, such as the ARIO transducer, from an old Telstra T1000 pushbutton phone.

The ARIO unit is soldered to the phone's pc board so you'll need to be able to unsolder the three mounting pins underneath the board, or find someone in the neighbourhood who is able.

Take the back off the TF200 (if you've obtained one of these phones,) and you'll see a black disc shaped object 2" round by 1/2' thick - with a red and black wire. Unplug the wires from the circuit board, and unscrew any retaining screws and remove the transducer. Cut the mini plug off, carefully strip the insulation from the ends of the wires and extend them by about 18" with 2 thin lengths of hookup wire. These pietzo devices make good earphones for crystal sets and can be housed in an old pair of ear muffs.

Miscellaneous Materials:

A Tic Tac box (smaller size)

A piece of matrix board at least 7 holes long by 8 holes across. Cut the board to fit neatly inside the Tic Tac box.

A short length of 2 differently coloured wires 60 mm in length and 2 crocodile clips with red and black plastic covers

A length of antenna wire at least 25 metres long and a 3 metre length of a different colour for the Ground wire.

A metal rod or cold water pipe for the ground stake. Be careful which pipes you connect your Ground wire to.

You will need a small sharp object for punching holes in the Tic Tac box.

A small pair of wire cutters for cutting and stripping wires.

Add Tip Ask Question

Step 2: How a Crystal Radio Works

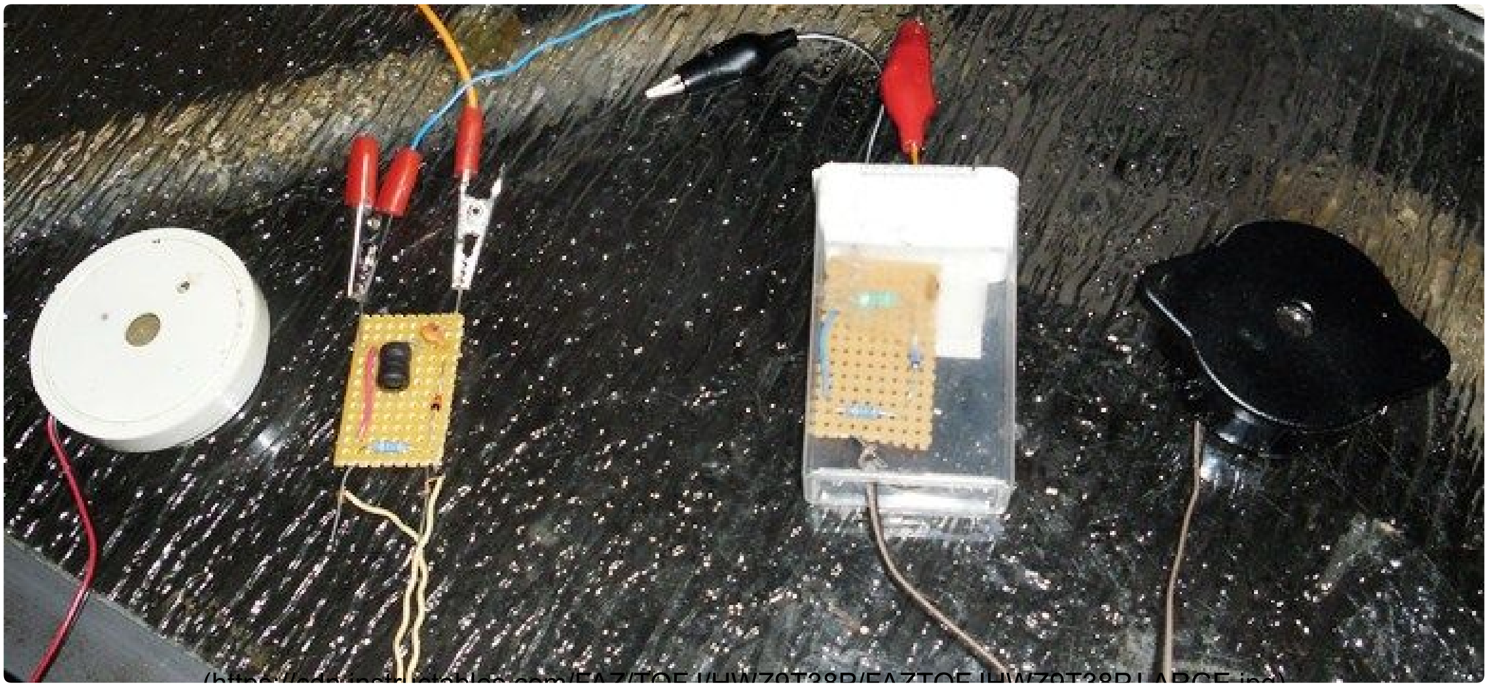

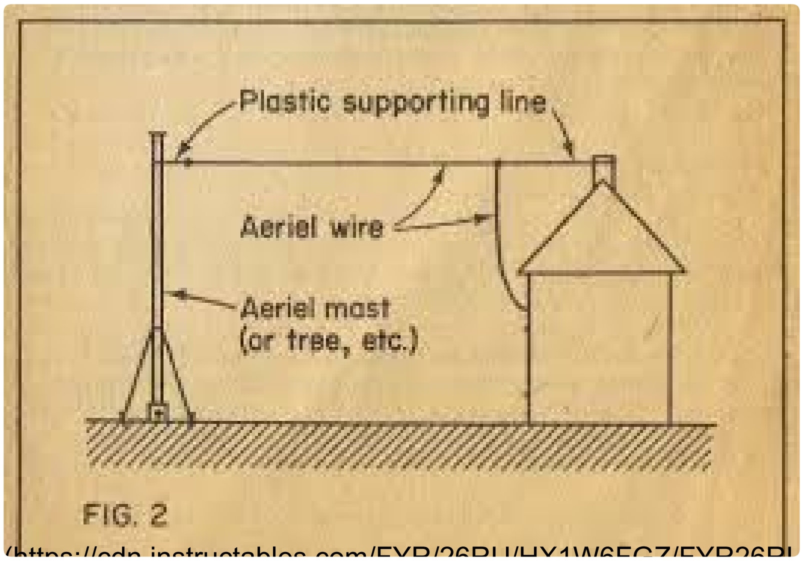

FIG. 2

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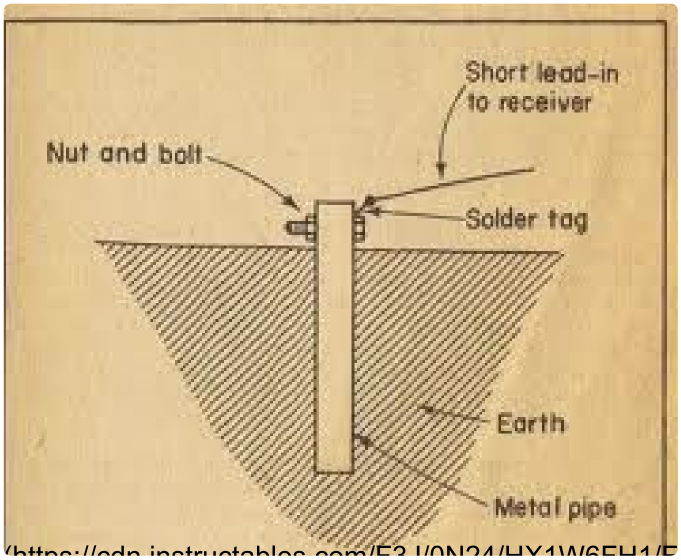

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Radio signals consists of two parts - the 'carrier wave' which is the AM radio station's frequency of operation, and the 'program signal' which is mixed with the carrier wave for transmission.

Radio waves travel out from the AM transmitter tower through the atmosphere. We want to capture one specific frequency so we can listen to it, so we need the antenna/ground wire system to capture that signal. We also need a 'tuned circuit' that will filter out the desired AM signal, and discard the rest, so that all the other unwanted radio signals pass out through the ground wire to earth.

Two components in our circuit will perform that task for us. The capacitor C1, together with L1 inductor, form a basic 'series tuned' circuit. Their respective values will determine just which local AM radio station we will capture.

We also need a diode to 'detect' the voice and music, so we can hear them in our earphone, which transduces electrical signals into sound waves that we can hear.

In the photo above you can see a completed Tic Tac crystal radio. It is already inside the box. The other set is connected to the antenna/ground wire circuit, undergoing a 'soak test'. It is necessary to do this to ensure that the radio will work once inside the box!

The first diagram shows a typical antenna wire installation. Coming out of a window, the wire is anchored to the building and then over some distance (10 metres +) to a nearby tree or other building.

You must take great care not to erect antenna wires near to power or telephone cables, near your home!

The ground wire comes out the same window and is anchored to a metal pipe/water pipe or metal ground stake, embedded in soft, moist soil.

You must not connect ground wires to electrical mains wiring installations, including wall power outlets!

Another electrical hazard to consider is lightning strikes! Although it is very rare for anyone to be seriously injured or die from a lightning strike it is not impossible. So, if you hear a thunderstorm coming your way (you may hear the lightning 'crashes' in your earphone first,) then disconnect your antenna wire immediately, connect it to the ground wire and put it well up out of the way. Stay well clear of this temporary antenna/ground connection until the storm has completely passed away from your general area - miles away!

Add Tip Ask Question

Step 3: How to Build the Tic Tac Crystal Radio Set

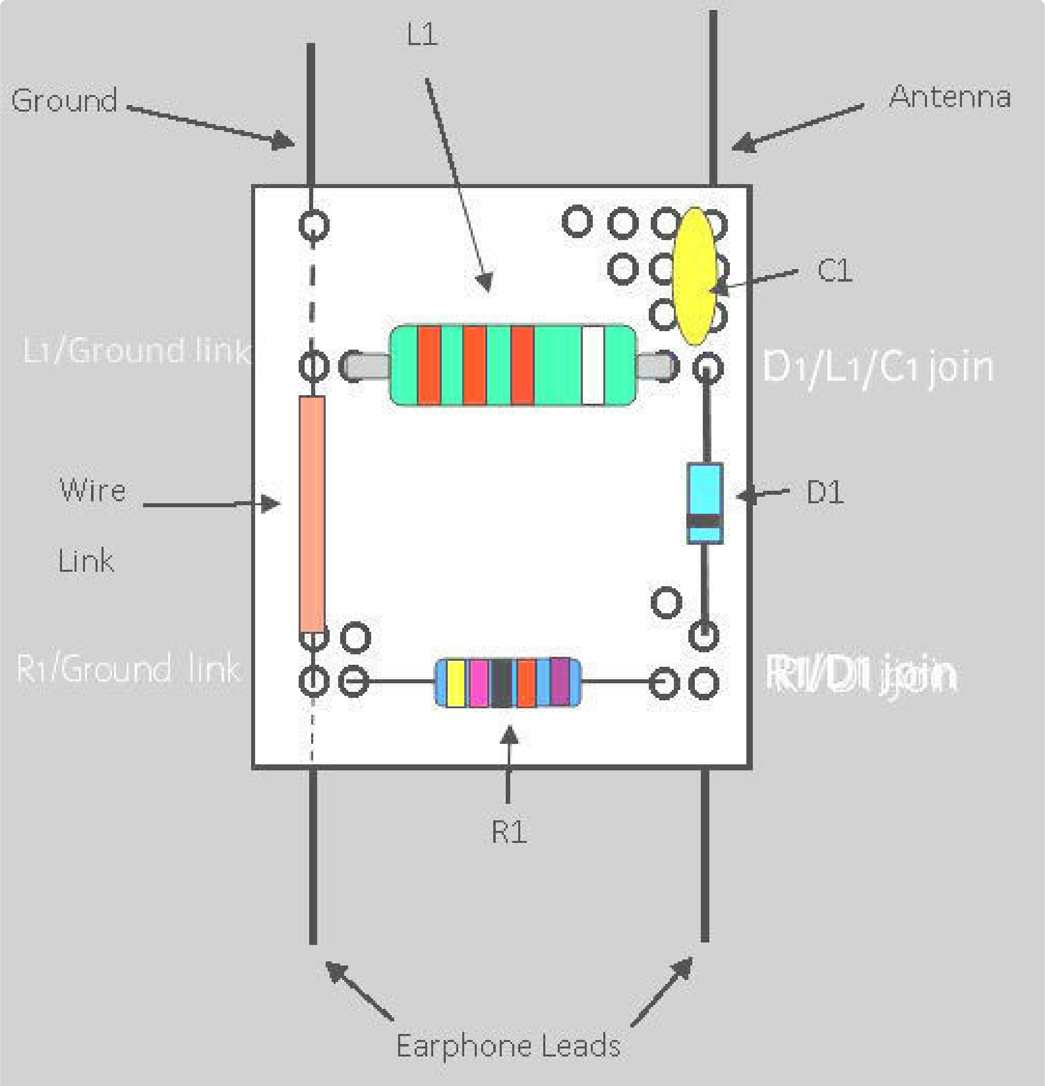
L1
Ground
Antenna
C1
L1/Ground link
D1/L1/C1 join
Wire
Link
D1
R1/Ground link
R1/D1 join
R1
Earphone Leads

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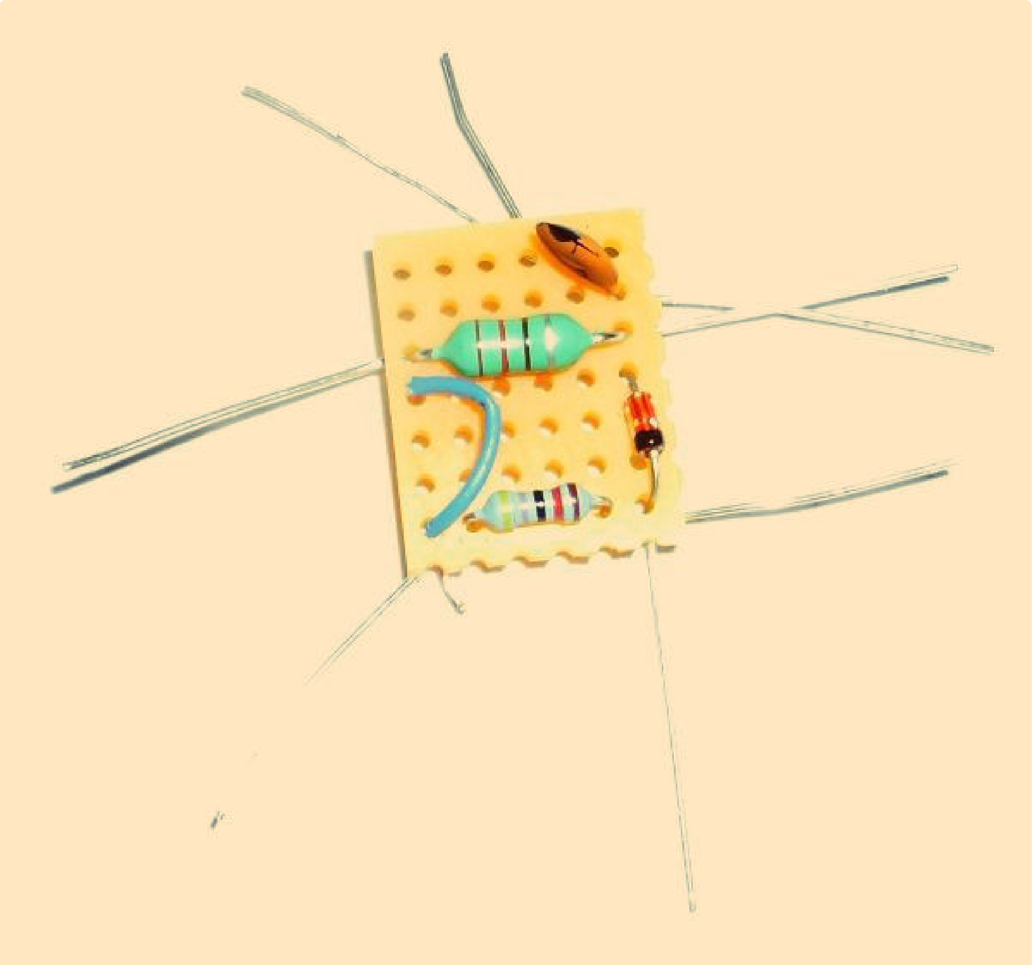

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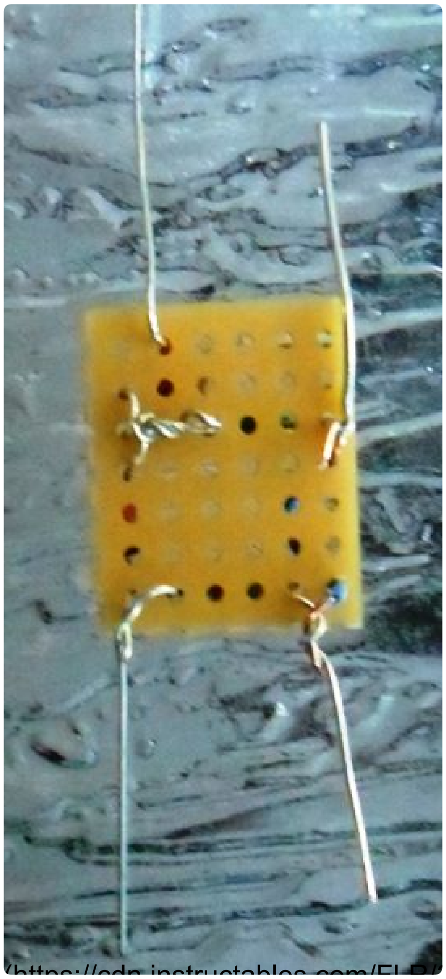

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1. Take the components and lay them out on a clean surface.

2. Take the square of matrix board (this is also called 'perf board' because of all the holes or perforations in the material) and beginning with the 220uH (uH = micro-Henry) and place it as shown in the diagram.

3. Then take the diode, capacitor and resistor and place them in the places shown for them, making sure that the coloured band at one end of the diode joins with the resistor wire, as shown

4. Then take each junction where wires come together through their respective holes and gently twist them together, until they form a neat, tight bundle. Take your side cutters and cut off any excess length, taking care not to cut any one wire too short, so that it comes undone from the join.

.5. Take the link wire, strip 2 centimetres of insulation from each end of the wire and install that wire between the free ends of the inductor and resistor, and the matrix board construction is complete.

6. Then take the ceramic earphone, cut the plug off the end, and strip the 2 wire ends about 1.5 centimetres in length. Wrap each earphone wire around each end of the resistor component, underneath the matrix board.

7. Finally, strip the insulation off both ends of the 60mm long differently coloured wires, and attach them to the matrix board - one goes to the inductor/link wire junction and this will be the Ground connection wire. Attach the other one to the free end of capacitor C1 and this will be the antenna wire connection. Both connections are made underneath the matrix board. The Nic Nac Tic Tac Crystal Radio is now ready for testing.

Add Tip Ask Question

Step 4: Final Checks and Installation of Wires

24g NET
FRESHNESS IN 2 CALORIES
tic tac
Strawberry Fields

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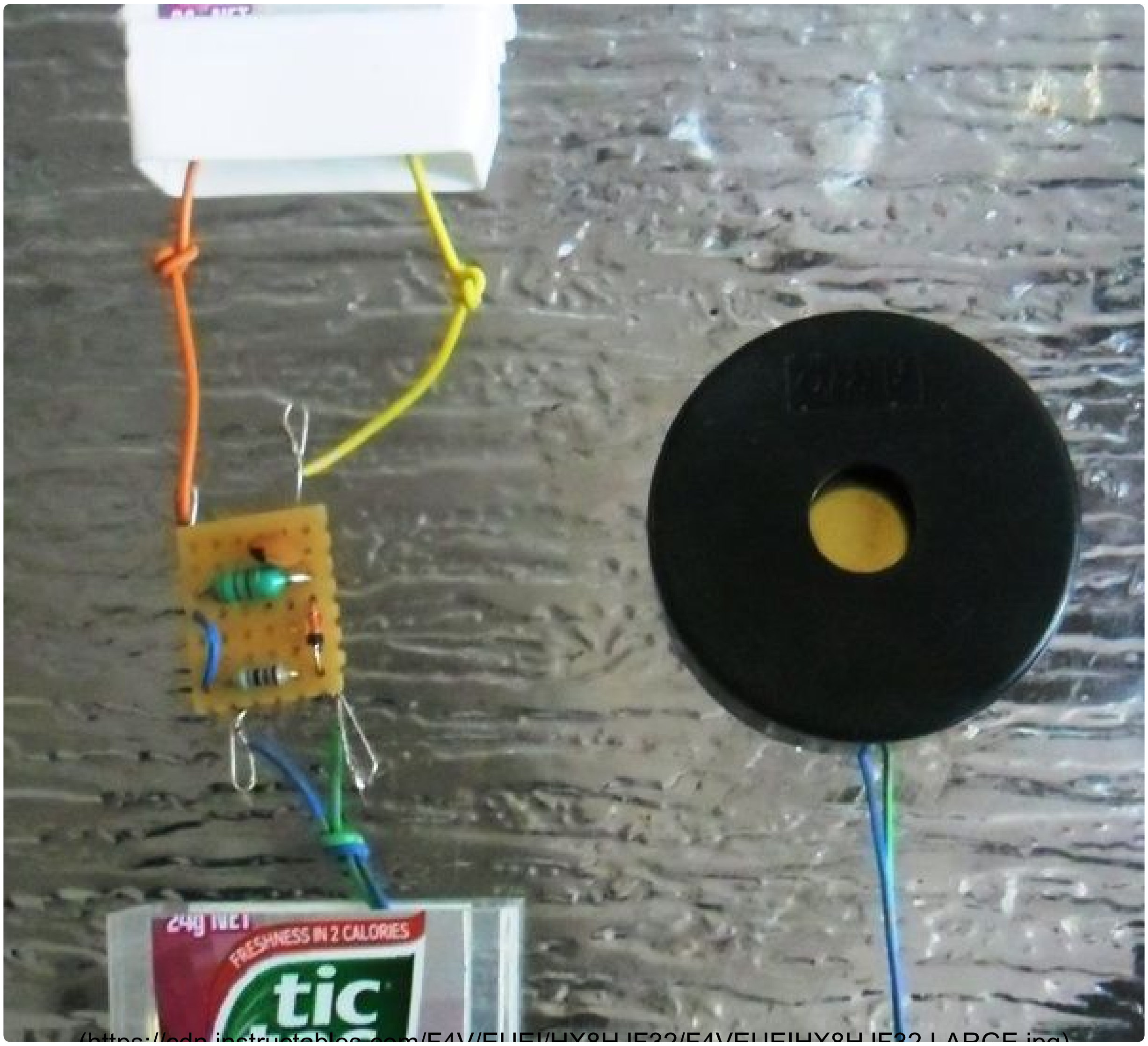

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When you've finished constructing the matrix board circuit and have clipped all the excess component leads off, puncture three (3) holes in the Tic Tac box - 2 small holes on the top lid of the box, about an inch (24mm) apart, so that your antenna and ground wire leads can come through the box lid, and be connected to the matrix board at those 2 points.

Feed the wires through the holes and then tie small knots in each one, near the underside of the box lid, so that they won't pull back out if strained, and disconnect themselves from the matrix board.

Then make one larger hole in the centre of the bottom of the box (clear part) so that your earphone wires can be fed through to the connecting points on that part of the matrix board. Tie a larger knot in the earphone lead so as to prevent it from pulling out of the box if it is strained. Strip the insulation off the earphone leads, and wrap them around the matrix board leads at those 2 points. You are now ready to test out the Nic Nac Tic Tac Crystal Radio.

Add Tip Ask Question

Step 5: Testing Out the Tic Tac Radio

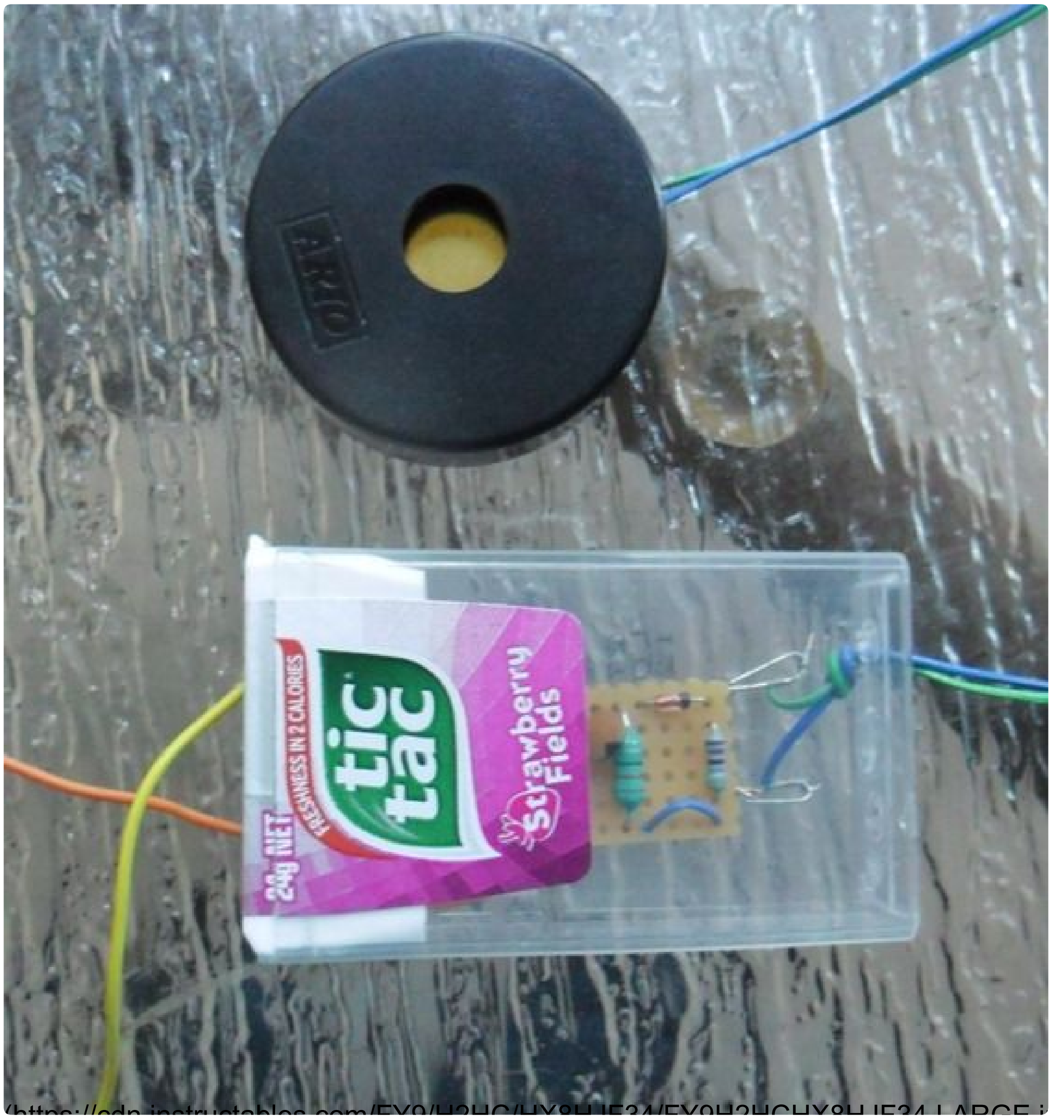
tic tac
Strawberry Fields
FRESHNESS IN 2 CALORIES
24g NET

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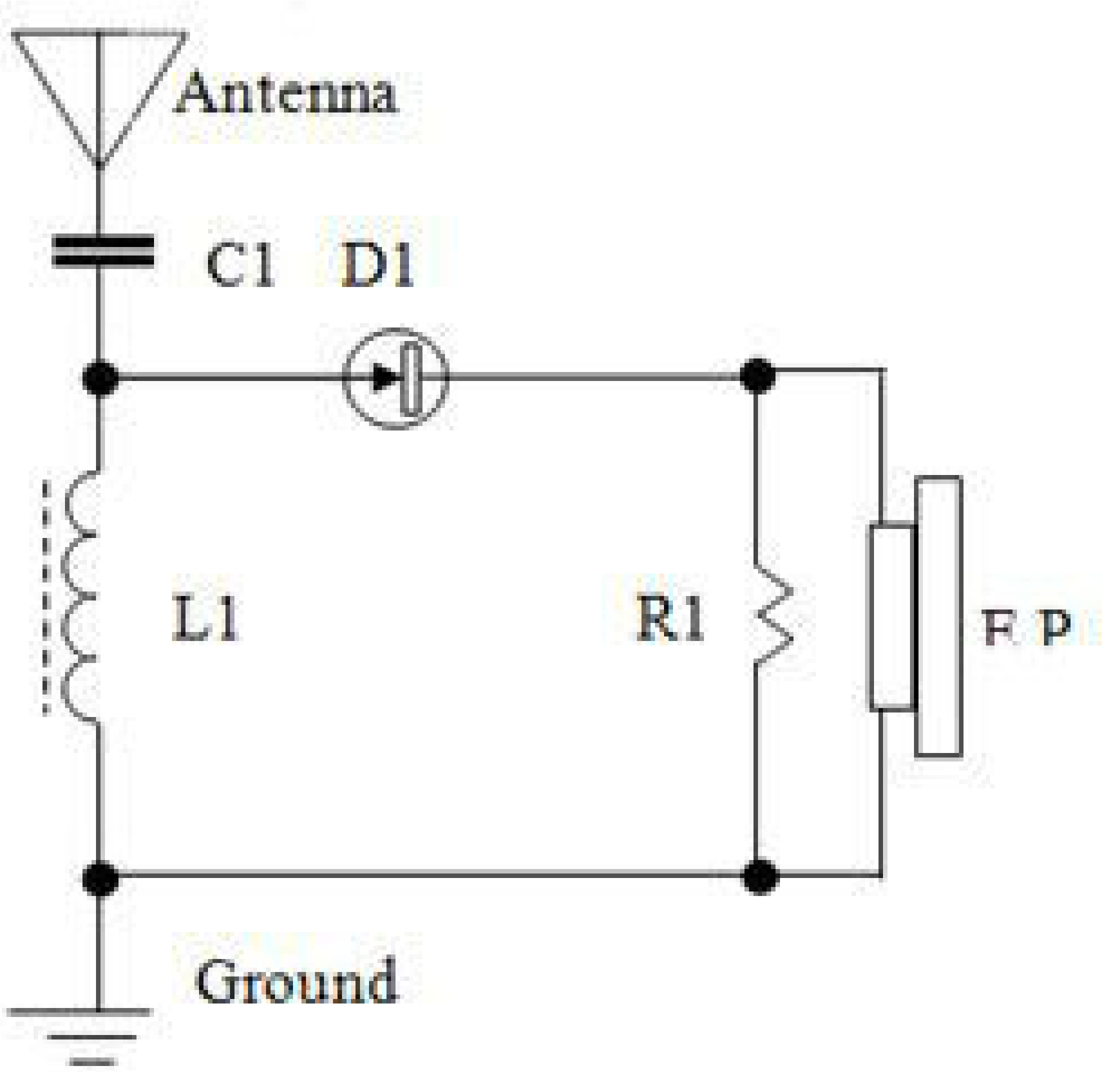

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Take your finished Tic Tac Radio (with the lid part gently pushed back inside the top of the box) and connect your Antenna and Ground wires to the lead outs from the box lid. Place the earphone in/over your ear,and listen carefully for a local AM radio station. This crystal radio is a simple one, and you may have to make one or two adjustments to the components, before you succeed in receiving one or more local AM radio stations, in your area.

If you can't hear anything in the earphone, don't panic. It might just be a simple wiring mistake, which is easily fixed. Go back over all of the steps, making sure that you have the right value components from the electronics store. Make sure that each component is in the right place on the matrix board, (don't confuse the L1 inductor with the R1 resistor - they look a lot like each other!) and that no component wires have come undone from the twisted joins you have just made. I'll be writing up a troubleshooting step soon, so if you run into any problems, post your questions in the 'comments' section down at the bottom of the page, and I'll try and answer them as soon as possible.

Make sure that your antenna and ground wires aren't snagged on anything metal or anything dangerous!

If you have ANY doubts about the electrical safety of your antenna or ground wires, then consult a licensed electrical trades person, who will be able to advise you on electrical safety principles and procedures!

Always remember that electrical safety is your responsibility! If you don't think it is safe to proceed, then don't!

You will need at least 10 to 15 metres of antenna wire, strung between 2 insulating points (not connected to anything metallic, or that gets wet,) at least 2 to 3 metres in height - anything less than this minimum arrangement may mean that you cannot receive any signals at all.

Some places are regarded as 'radio dead spots', so you may need to try an open space, such as a park or a remote corner of a beach. If you do erect antenna and ground wires in public places, hang some streamers or balloons off of them, to alert people to their presence, otherwise people going past may become entangled with them - and get cranky with you!!!

As a final word for now, you'll be happy to know that the completed "Nic Nac Tic Tac Radio" shown in the picture above, picked up local AM radio station 1116 khz 4BC here in Brisbane, with a very clear signal and quite good volume. It works! So be safe kids, have some fun and look forward to more... mk484

Add Tip Ask Question

Step 6: Nic Nac Extras

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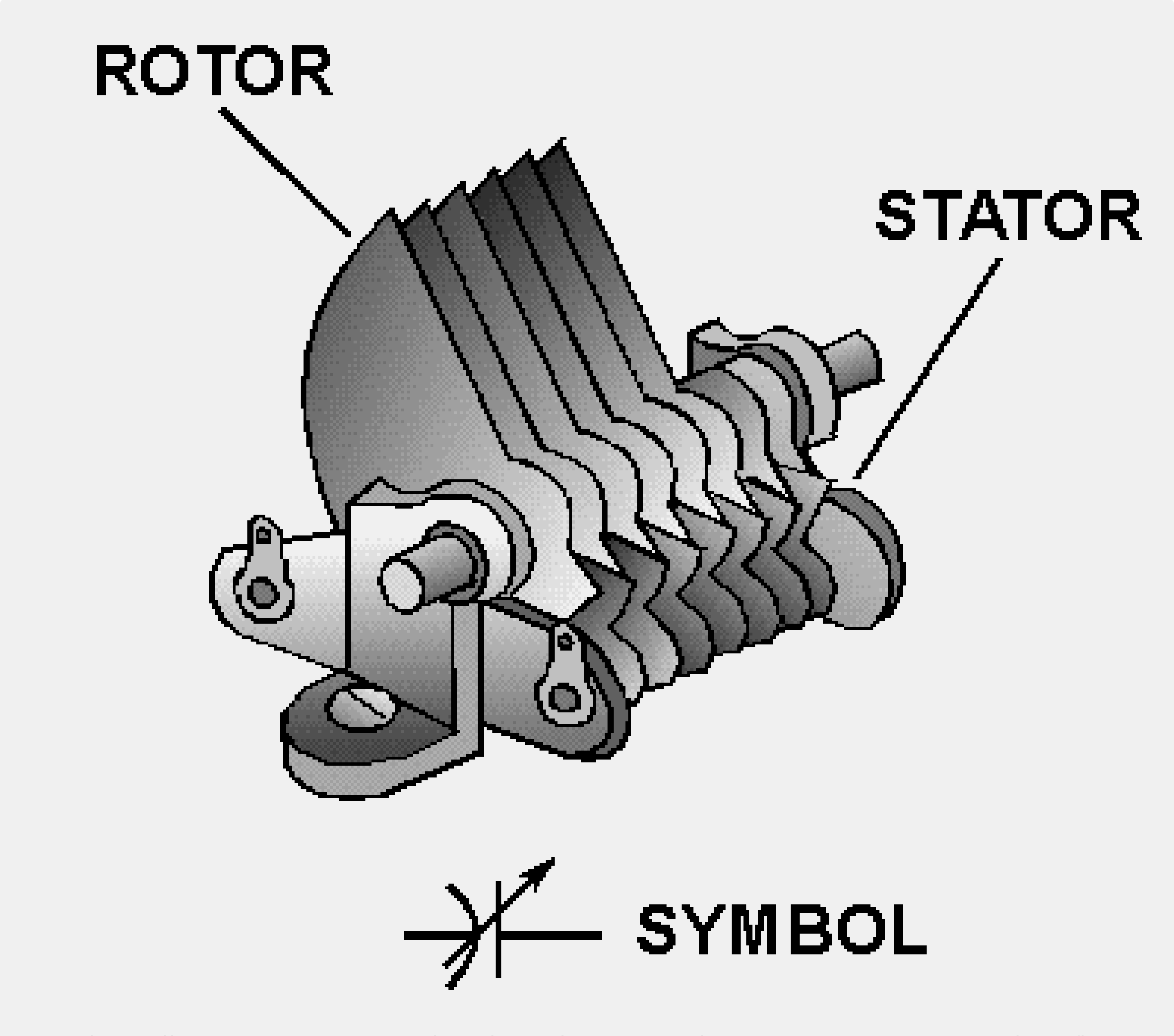
ROTOR
STATOR
SYMBOL

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If you've built your Tic Tac crystal set and found that you can't receive a local AM radio station yet - don't panic - help is in on the way. You have just built the simplest version of the Tic Tac crystal radio and you may need to add one more component part for it to work properly. This is called a 'polyvaricon' - a miniature tuning capacitor, which can vary the frequency that your radio will receive at. You can see a picture of one up above - the small white box with the black knob next to it. It has 3 connecting tags - the one in the middle ('G') goes to the moving plates and the shaft, while the 2 outer tags ('O' and 'A') go to 2 sets of fixed plates. the smaller set of plates has a value of 60pF - pF is short for 'picoFarad' - a unit of measurement for capacitance. The larger set of plates is valued at 160 pF so that the combined value of the polyvaricon is 220 pF - or 220 picoFarads.

The other picture shows you what happens inside a basic tuning capacitor. there are 2 sets of metal plates - one set is fixed and the other set moves on a rotating shaft, connected to the tuning knob of your radio set. Both sets of plates are mounted on an insulating frame so that they won't 'short out' by touch each other.

The fixed capacitor C1, was chosen to tune somewhere close to the middle of the AM radio band. This band of frequencies starts at 531 kilohertz (Khz) and goes as far as 1701 Khz here in Australia. So we need a combination of coil and capacitor which will tune across all of those frequencies. Our simple Tic Tac radio is known as a 'series tuned' set. If you look at the circuit diagram, you can see electronic symbols for all components in the radio set.If you start at the top with the antenna symbol, you can see the capacitor C1 underneath that, the inductor L1 underneath C1 and then finally, the ground symbol - all wired in series with each other.

The diode D1 detector, the resistor and the earphone plus the link wire, can be considered as one block - the "detector unit". The Antenna wire, ground wire, inductor/coil and capacitor/polyvaricon, can be also be considered as another block - the "tuned circuit". So joining both blocks together, we have the tuned circuit that tunes in only one frequency, passing all other unwanted signals out through the ground wire to earth. This one 'tuned frequency' passes through the diode detector, which strips away the 'carrier wave' and leaves only the 'program signal' (voice, music etc,) behind, which is then fed via the resistor into the earphone. The earphone changes electrical impulses from the diode detector, into sound waves that we can hear. You need the R1 resistor to provide a pathway for the signals going through the diode, out to the ground wire connection. Without this resistor, the signals would sound very distorted and you couldn't hear the program signal very clearly.

Add Tip Ask Question

Step 7: Adding the Polyvaricon Tuning Capacitor

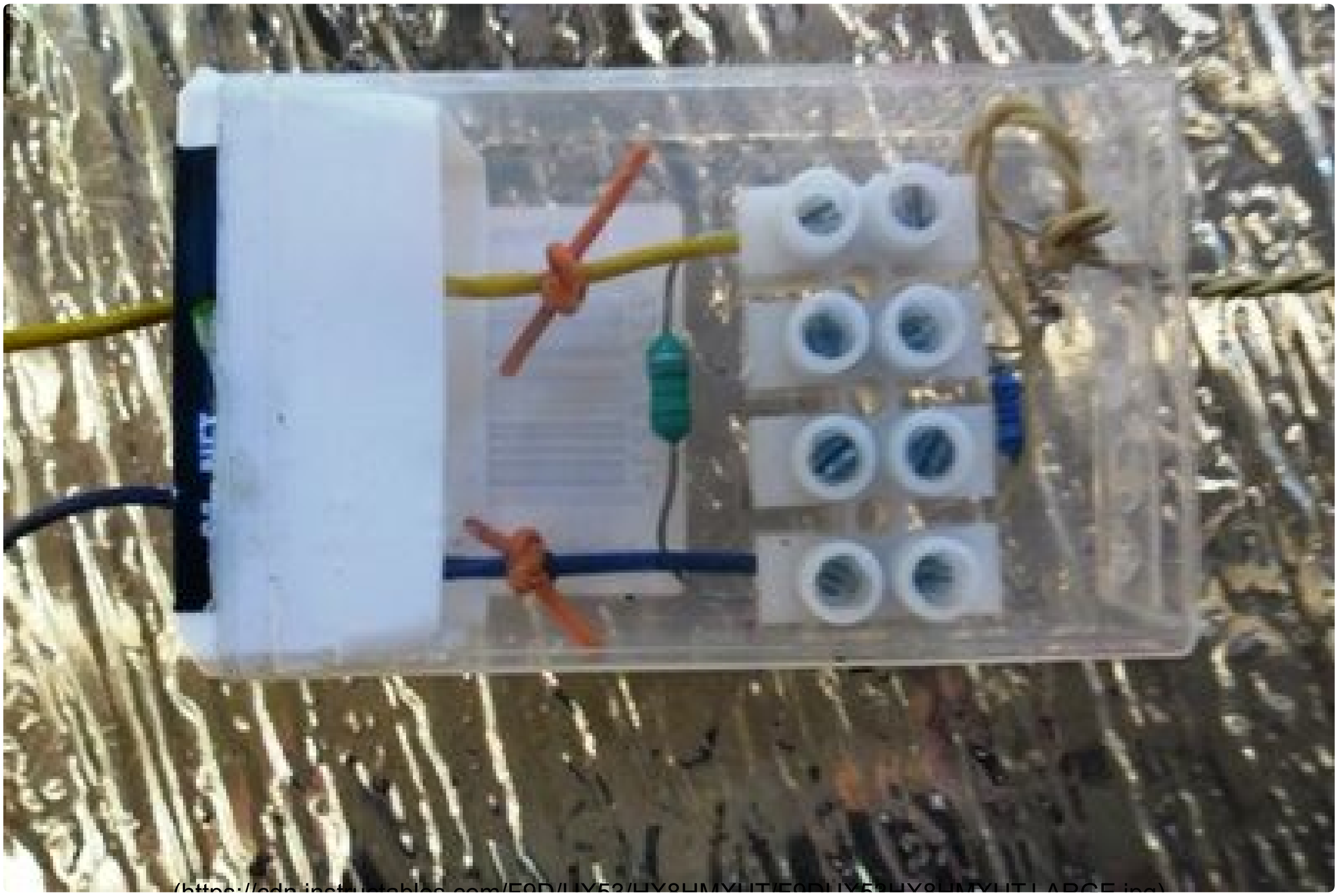

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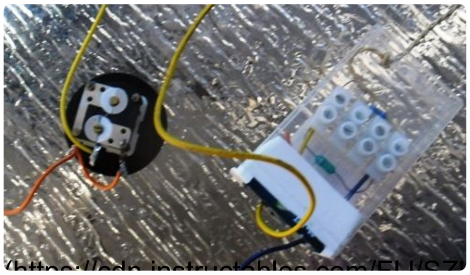

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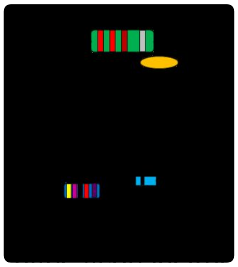

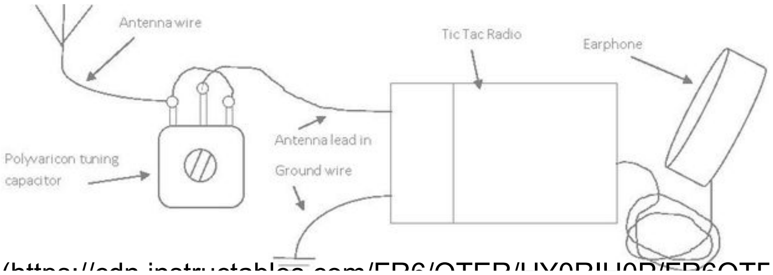

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If you want to expand the tuning range of your Tic Tac Radio, than all you have to do is a simple modification (change) to the circuit of your radio set. You can see from the 2 pictures above, that there's an alternative way of building the crystal radio - you can use the matrix board method or you can use a 4 way screw terminal strip.

To use the screw terminal version, cut yourself a 4 way strip of terminals as shown in the diagram and pictures. Undo the screws right out as far as they will go without falling out of the strip. Connect the component leads and wires from the antenna/ground system as well as the earphone wires. Cut off any excess from component leads that you don't need. Wrap thin wires from the antenna/ground system and the earphones, around the thicker component leads before screwing the screws in tight.

Regardless of which method you have used, all we will now wire up the tuning capacitor between the actual Antenna wire and the junction (join) where the diode D1, the fixed capacitor C1 and one end of the inductor meet. Remove the capacitor from the matrix board, and connect the Antenna lead out wire straight to the join of the diode and inductor. Then take the polyvaricon and another piece of wire. Strip both ends of that wire and join the two outer tags (tagged 'O' and 'A' - the centre on is tagged 'G') and then connect you actual Antenna wire to one of the outer tags. Connect the antenna lead out wire, coming out of the box, to the 'G' (middle) tag of the tuning capacitor,so that the antenna wiring now looks like the picture up above.

If you're having problems following the pictures, then refer to the diagrams, which clearly shows all of the connections Make sure your ground wire is connected to the set, and then, listening with your earphone in/over your ear, slowly turn the tuning cap's flat knob, until you hear one or more stations. Congratulations - you now have a "tuneable" Tic Tac crystal set! Happy listening! And don't forget to post in your results, questions, problems etc... mk484 :)

Add Tip　Ask Question

Step 8: Tic Tac One Transistor Amplifier - Use Your Earbuds and Hear Great Sound...

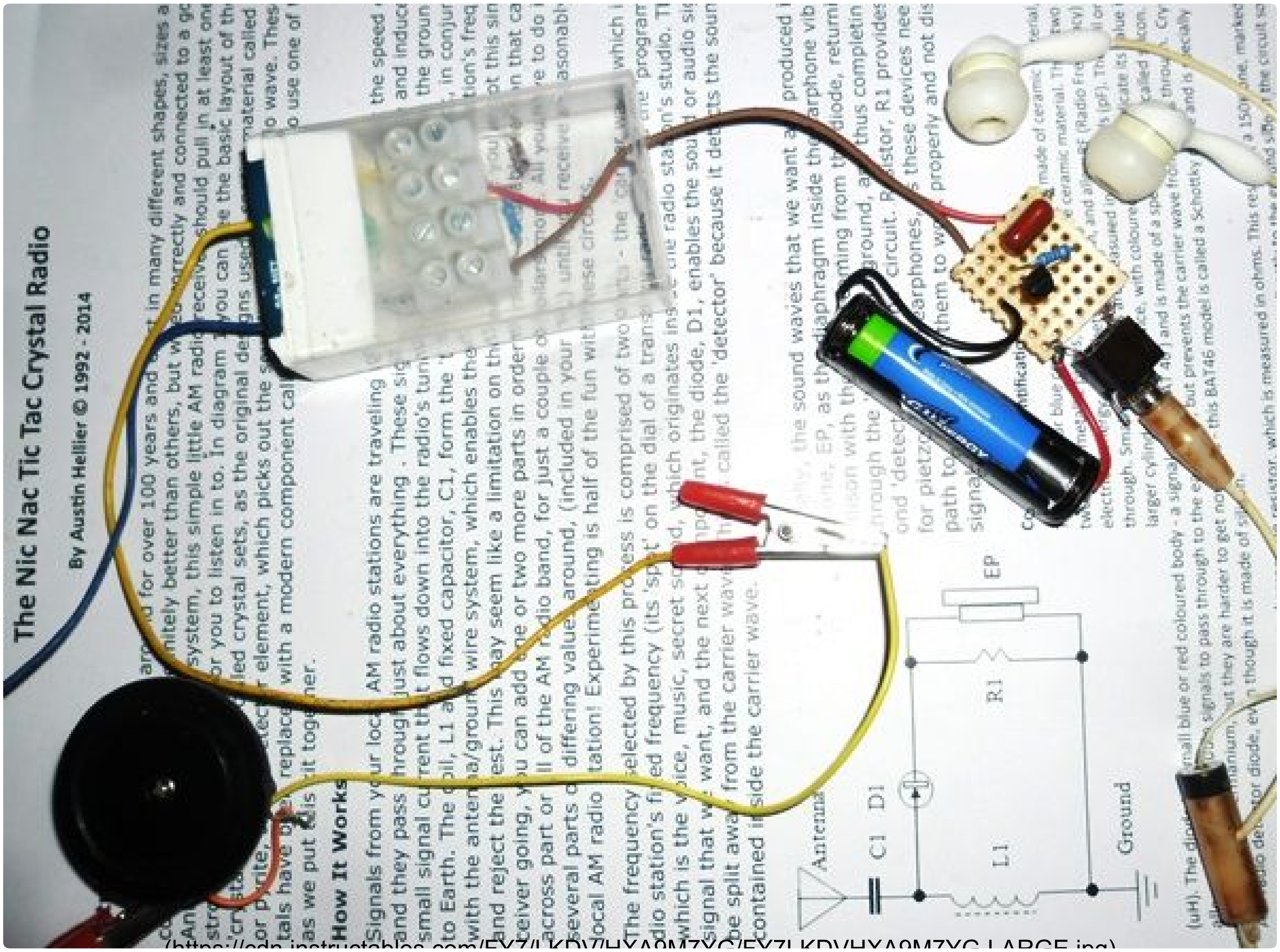

The Nic Nac Tic Tac Crystal Radio
By Austin Hellier © 1992 - 2014
How It Works
Antenna
C1
D1
L1
R1
EP
Ground

(https://cdn.instructables.com/FYZ/LKDV/HYA9MZYG/FYZLKDV/HYA9MZYG.LARGE.jpg)

Hi there folks - this isn't really an extra 'Step' as such - it's a sneak preview at a picture of my upcoming Instructable for a one transistor amplifier, which will connect to the Tic Tac Radio - and give you some really good volume - in your Iphone earbuds!

Yes, it's entirely possible nowadays, with modern circuit design, to fit a one transistor amp in such a small space (yes kiddies - it WILL fit inside the smaller Tic Tac box...) and at the same time, get that great sound that comes from those "inside your ear" type earbuds.

This circuit took me about a half hour to complete, uses only 3 electronic components, costing about $1.00, a stereo earphone jack and a 1.5 volt AAA battery and plastic holder costing about another $3 to $4, so you can build the amplifier for about $5 all up - don't forget to shop around and - mums and dads - cheap batteries will be OK for this project, and the battery can simply be replaced without soldering or undoing half a dozen screws....

I can hear my Tic Tac Radio with great volume and clarity - and so will you, so "stay tuned" (ha ha ha) to this series of Instructables, and you will hear great sound too...

mk484

Add Tip

Ask Question

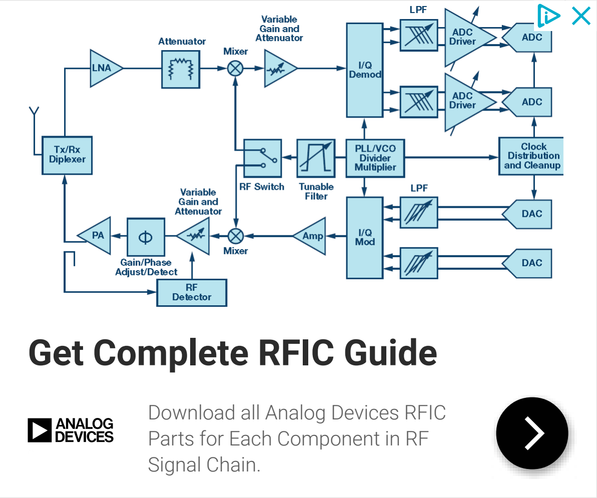
LPF
Variable
Gain and
Attenuator
Attenuator
Mixer
LNA
I/Q
Demod
ADC
Driver
ADC
ADC
Driver
ADC
Tx/Rx
Diplexer
RF Switch
Tunable
Filter
PLL/VCO
Divider
Multiplier
Clock
Distribution
and Cleanup
LPF
DAC
PA
Variable
Gain and
Attenuator
Mixer
Amp
I/Q
Mod
DAC
Gain/Phase
Adjust/Detect
RF
Detector
ANALOG
DEVICES
Get Complete RFIC Guide

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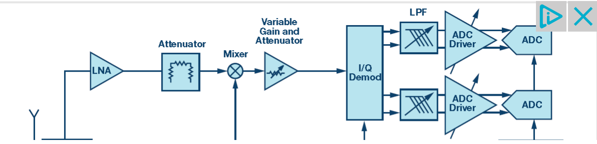

go to: Talking Electronics Website

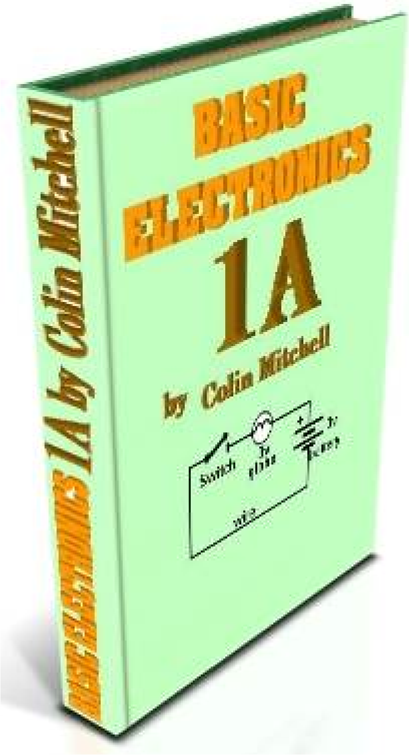
BASIC ELECTRONICS 1A
by Colin Mitchell
BASIC ELECTRONICS 1A by Colin Mitchell
Switch
wire

For any enquiries email Colin Mitchell

THE MULTIMETER

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The capacitor - how it works
The Diode - how the diode works
Circuit Symbols - EVERY Circuit Symbol
Soldering - videos
Page 2: The Transistor
- PNP or NPN Transistor TEST
Page 2a: The 555 IC
The 555 - 1
The 555 - 2
The 555 - 3
The 555 TEST
Page 3: The Power Supply download as .pdf (900kB)
3a: - Constant Current
3b: - Voltage Regulator
3c: - Capacitor-fed Power Supply
Page 4: Digital Electronics
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Diode - measuring
Pressure Cell
Resistance - measuring
TEST
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Voltage - measuring

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TWO MULTIMETERS

There are basically two different types of MULTIMETER. ANALOGUE and DIGITAL
Analogue Multimeters have a NEEDLE or POINTER that moves across a scale.
Digital Multimeters have a numeric display of 3 or more digits. A Digital Multimeter with 3½ digits means the first digit shows only "1."

You really need both types to cover the number of tests needed for designing and repair-work. We will discuss how they work, how to use them and some of the differences between them.

The black (negative lead) ALWAYS stays in the

black hole and the red lead changes to the other red hole to measure 10 amps

to Index

BUYING A MULTIMETER

There are many different types on the market.
The cost is determined by the number of ranges and also the extra features such as diode tester, buzzer (continuity), transistor tester, high DC current and others.
Since most multimeters are reliable and accurate, buy one with the greatest number of ranges at the lowest cost. The cheapest multimeters are on **eBay**.
This article explains the difference between an analogue meter and a digital meter.

Multimeters are sometimes called a "meter", a "VOM" (Volts-Ohms-Milliamps or Volt Ohm Meter) or "multi-tester" or even "a tester" - they are all the same.

One term used to describe a **DIGITAL MULTIMETER** is **3½ digits**.
This is the number of digits on the display. The first digit is usually made from two pixels and can only produce "1." This is called a half-digit. The other digits are full digits. The cheapest digital multimeters have 3½ digits. This will produce a reading of 1999 and the decimal point can produce values from 1.999 to 19.99 to 199.9 to 1999.
Another term is **DISPLAY COUNTS**. This is connected with the accuracy of the display, but since digital meters are accurate to 1% or less and we are using resistors with an accuracy of 5%, even a $10.00 digital meter will be perfect.

to Index

USING A MULTIMETER

Analogue and **digital** multimeters have either a rotary selector switch or push buttons to select the appropriate function and range. Some Digital Multimeters (DMMs) are auto ranging; they automatically select the correct range of voltage, resistance, or current when doing a test. However you need to select the function.

Before making any measurement you need to know what you are checking. If you are measuring voltage, select the AC range (10v, 50v, 250v, or 1000v) or DC range (0.5v, 2.5v, 10v, 50v, 250v, or 1000v). If you are measuring resistance, select the Ohms range (x1, x10, x100, x1k, x10k). If you are measuring current, select the appropriate current range DCmA 0.5mA, 50mA, 500mA, 10A. Every multimeter is different however the photo below shows a low cost Analogue multimeter with the basic ranges.

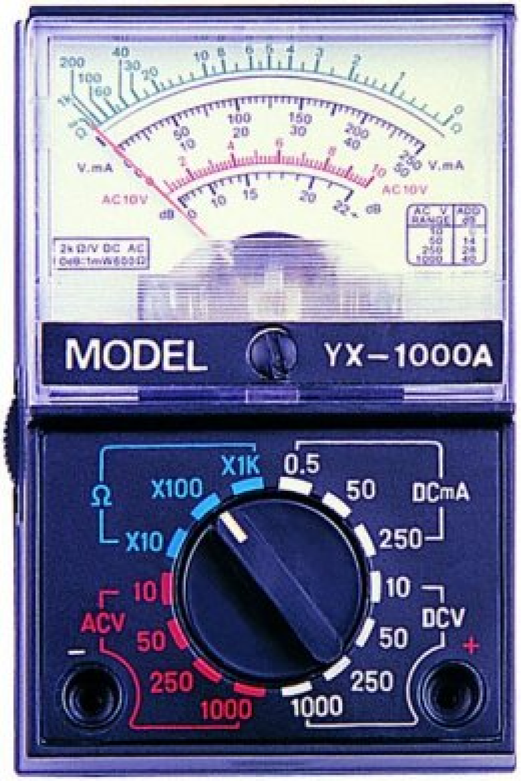
MODEL YX–1000A
Ω
X10
X100
X1K
0.5
50
DCmA
250
10
DCV
50
250
1000
ACV
10
50
250
1000

An ANALOGUE MULTIMETER

The most important point to remember is this:
You must select a voltage or current range that is bigger or HIGHER than the maximum expected value, so the needle does not swing across the scale and hit the "end stop."
If you are using a DMM (Digital Multi Meter), the meter will indicate if the voltage or current is higher than the selected scale, by showing "OL" - this means "Overload."
If you are measuring resistance such as 1M on the x10 range the "OL" means "Open Loop" and you will need to change the range. Some meters show "1' on the display when the measurement is higher than the display will indicate and some flash a set of digits to show over-voltage or over-current. A "-1" indicates the leads should be reversed for a "positive reading."
If it is an AUTO RANGING meter, it will automatically produce a reading, otherwise the selector switch must be changed to another range.

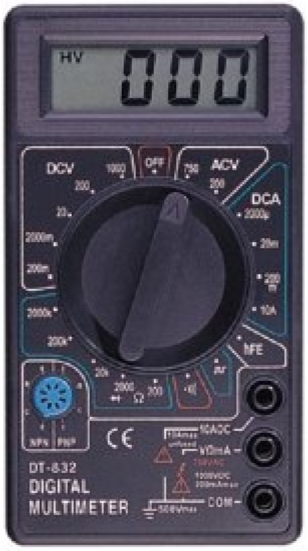
HV
000
DCV
OFF
ACV
DCA
hFE
DT-832
DIGITAL
MULTIMETER
COM

A typical DIGITAL Multimeter

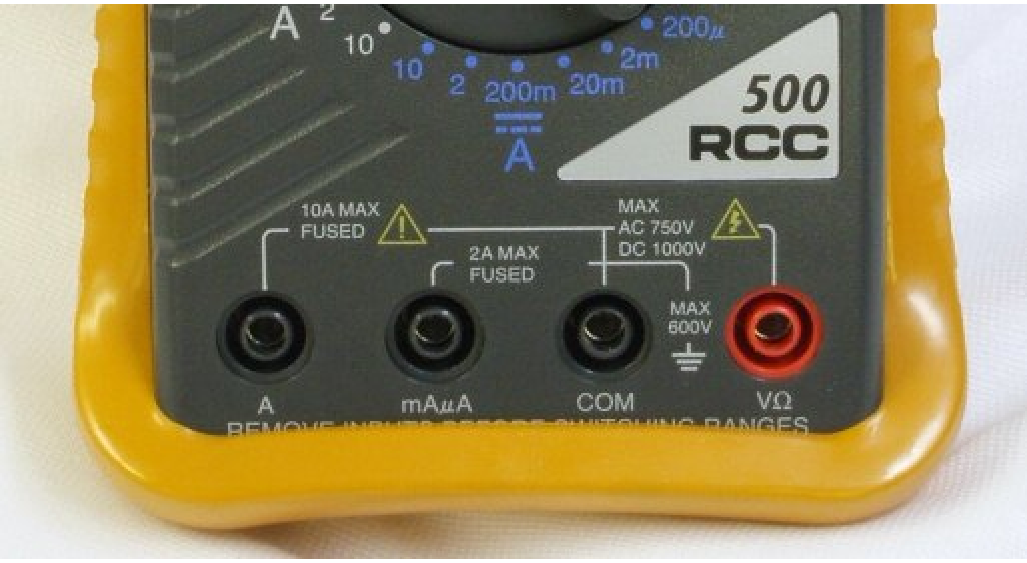
A 2
10
10 2 200m 20m 2m 200μ
A
500
RCC
10A MAX FUSED
2A MAX FUSED
MAX AC 750V DC 1000V
MAX 600V
A
mAμA
COM
VΩ

The Common (negative) lead ALWAYS fits into the "COM" socket. The red lead fits into the red socket for Voltage and Resistance. Place the red lead (red banana plug) into "A" (for HIGH CURRENT "Amps") or mA,uA for LOW CURRENT.

The black "test lead" plugs into the socket marked "-" "Common", or "Com," and the red "test lead" plugs into the meter socket marked "+" or "V-W-mA." The third banana socket measures HIGH CURRENT and the positive (red lead) plugs into this. You DO NOT move the negative "-" lead at any time.
The following two photos show the test leads fitted to a digital meter. The probes and plugs have "guards" surrounding the probe tips and also the plugs so you can measure high voltages without getting near the voltage-source.

FLUKE 115 TRUE RMS MULTIMETER
600.0
V AC
HOLD
MIN MAX
RANGE
OFF
mV
Ω
A
COM
10 A FUSED
CAT III 600V

000
10ADC
CE

Analogue meters have an "Ohms Adjustment" to allow for the change in voltage of the battery inside the meter (as it gets old).

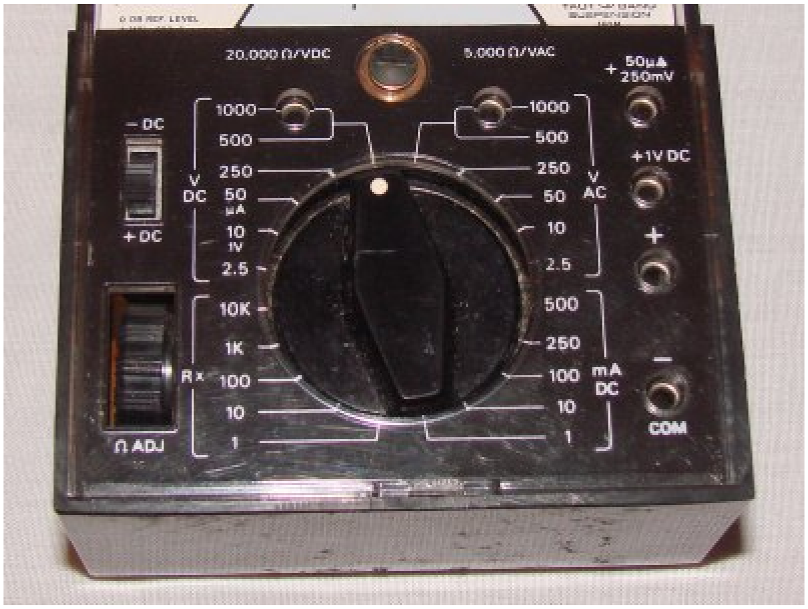

"Ohms Adjust" is also called "ZERO SET"
The sensitivity of this meter is 20,000ohms/volt on the DC ranges and 5k/v on the AC ranges

Before taking a resistance reading (each time, for any of the Ohms scales) you need to "ZERO SET" the scale, by touching the two probes together and adjust the pot until the needle reads "0" (swings FULL SCALE). If the pointer does not reach full scale, the batteries need replacing. Digital multimeters do not need "zero adjustment."

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ANALOGUE Vs DIGITAL

You cannot say one meter is better than the other because BOTH have advantages and disadvantages.
An analogue multimeter is the "old style" and it puts a load on a circuit and this may change the reading to give an incorrect readout, but it has the advantage of the needle moving across the scale fairly quickly so you can sometimes see if the voltage is fluctuating.
It also gives a more-accurate result in some high frequency circuits as it does not pick up stray fields and produce a false reading.
Digital meters put almost no load on a circuit and produce accurate readings from both low-impedance and high-impedance circuits.
Digital meters can display very low resistances.
You must remember to turn a Digital meter OFF to prevent the battery going flat.

If you are testing a circuit containing a high-frequency oscillator, use BOTH an ANALOGUE and DIGITAL meter to check the reading. Sometimes the leads of a Digital multimeter will pick up signals and create a false reading.
Sometimes you will get a voltage reading with a Digital multimeter due to a high resistance leak and a zero reading with an Analogue meter. This is why you need **BOTH** meters.

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MEASURING VOLTAGE

Most of the readings taken with a multimeter will be VOLTAGE readings.
Before taking a reading, you should select the highest range and if the needle does not move up scale (to the right), you can select another range.
Always switch to the highest range before probing a circuit and keep your fingers away from the component being tested.
If the meter is Digital, select the highest range or use the auto-ranging feature, by selecting "V." The meter will automatically produce a result, even if the voltage is

AC or DC.
If the meter is not auto-ranging, you will have to select V⎓ if the voltage is from a DC source or V~ if the voltage is from an AC source. DC means Direct Current (but this does not mean you select the CURRENT range - you are taking a voltage reading that is not rising and falling. That's why we say it is **DC** and do not say the words "direct current"). The voltage is coming from a battery or supply where it is steady and not "rising and falling."
You can measure the voltage at different points in a circuit by connecting the black probe to chassis. This is the 0v reference and is commonly called "Chassis" or "Earth" or "Ground" or "0v."
The red lead is called the "measuring lead" or "measuring probe" and it can measure voltages at any point in a circuit. Sometimes there are "test points" on a circuit and these are wires or loops designed to hold the tip of the red probe (or a red probe fitted with a mini clip).
You can also measure voltages ACROSS A COMPONENT. In other words, the reading is taken in PARALLEL with the component. It may be the voltage across a transistor, resistor, capacitor, diode or coil. In most cases this voltage will be less than the supply voltage.
If you are measuring the voltage in a circuit that has a HIGH IMPEDANCE, the reading will be inaccurate, up to 90% !!!, if you use a cheap analogue meter.

Here's a simple case.

The circuit below consists of two 1M resistors in series. The voltage at the mid point will be 5v when nothing is connected to the mid point. But if we use a cheap analogue multimeter set to 10v, the resistance of the meter will be about 100k, if the meter has a sensitivity of 10k/v and the reading will be incorrect.
Here how it works:
Every meter has a sensitivity. The sensitivity of the meter is the sensitivity of the movement and is the amount of current required to deflect the needle FULL SCALE. This current is very small, normally 1/10th of a milliamp and corresponds to a sensitivity of 10k/volt (or 1/30th mA, for a sensitivity of 30k/v).
If an analogue meter is set to 10v, the internal resistance of the meter will be 100k for a 10k/v movement.
If this multimeter is used to test the following circuit, the reading will be inaccurate.
The reading should be 5v as show in diagram **A**.
But the analogue multimeter has an internal resistance of 100k and it creates a circuit shown in **C**.
The top 1M and 100k from the meter create a combined PARALLEL resistance of 90k. This forms a series circuit with the lower 1M and the meter will read less than 1v
If we measure the voltage across the lower 1M, the 100k meter will form a value of resistance with the lower 1M and it will read less than 1v
If the multimeter is 30k/v, the readings will be 2v. See how easy it is to get a totally inaccurate reading.

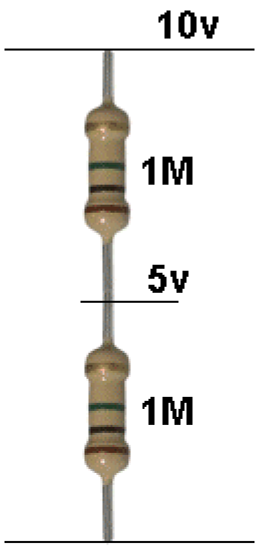

A

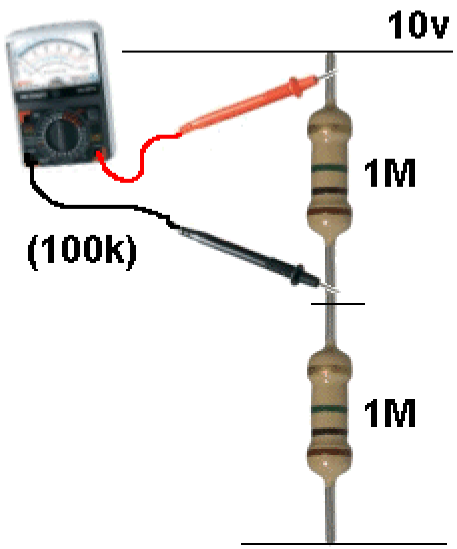

B

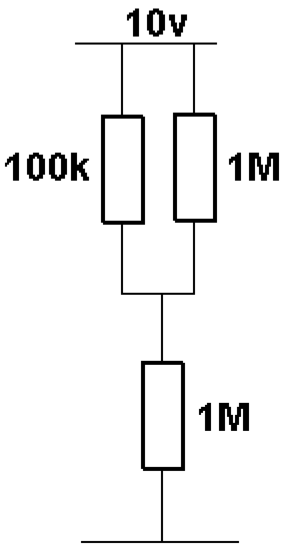

C

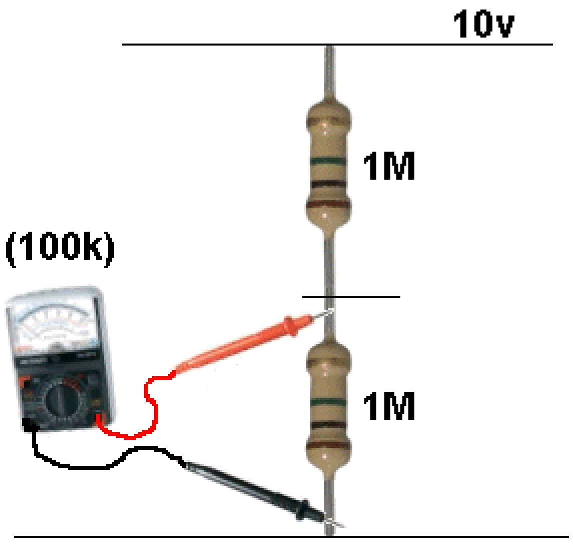

D

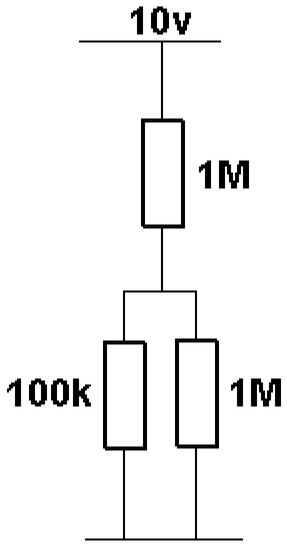

E

If the reading is taken with a Digital Meter, it will be more accurate as a DMM does not take any current from the circuit (to activate the meter). In other words it has a very HIGH input impedance. Most Digital Multimeters have a fixed input resistance (impedance) of 10M - no matter what scale is selected. That's the reason for choosing a DMM for high impedance circuits. It also gives a reading that is accurate to about 1%.

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MEASURING VOLTAGES in a CIRCUIT

You can take many voltage-measurements in a circuit. You can measure "across" a component, or between any point in a circuit and either the positive rail or earth rail (0v rail). In the following circuit, the 5 most important voltage-measurements are shown. Voltage "A" is across the electret microphone. It should be between 20mV and 500mV. Voltage "B" should be about 0.6v. Voltage "C" should be about half-rail voltage. This allows the transistor to amplify both the positive and negative parts of the waveform. Voltage "D" should be about 1-3v. Voltage "E" should be the battery voltage of 12v.

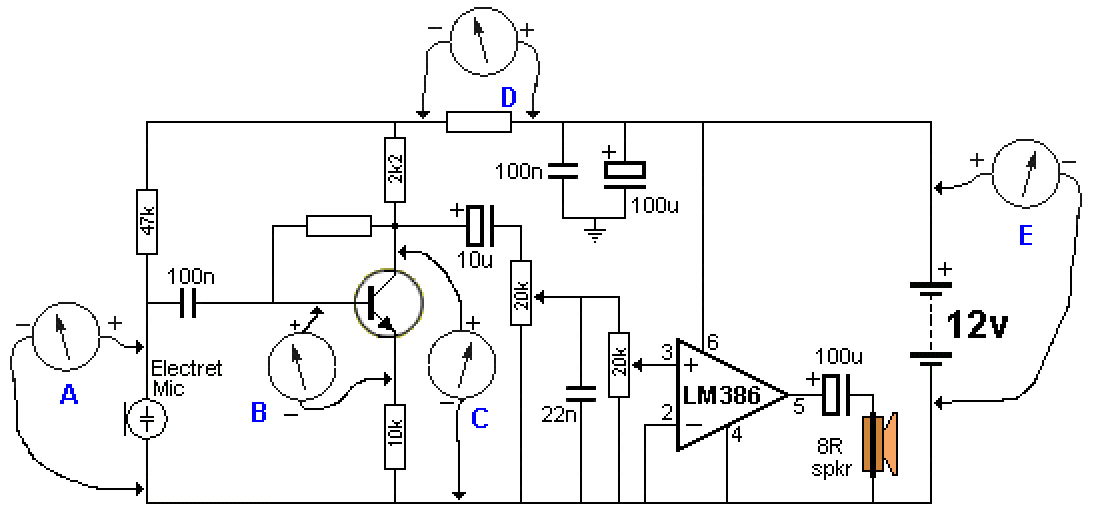

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MEASURING CURRENT

You will rarely need to take current measurements, however most multimeters have DC current ranges such as 0.5mA, 50mA, 500mA and 10Amp (via the extra banana socket) and some meters have AC current ranges. Measuring the current of a circuit will tell you a lot of things. If you know the normal current, a high or low current can let you know if the circuit is overloaded or not fully operational.

Current is always measured when the circuit is working (i.e: with power applied).
It is measured IN SERIES with the circuit or component under test.
The easiest way to measure current is to remove the fuse and take a reading across the fuse-holder. Or remove one lead of the battery or turn the project off, and measure across the switch.
If this is not possible, you will need to remove one end of a component and measure with the two probes in the "opening."
Resistors are the easiest things to desolder, but you may have to cut a track in some circuits. You have to get an "opening" so that a current reading can be taken.
The following diagrams show how to connect the probes to take a CURRENT reading.
Do not measure the current ACROSS a component as this will create a "short-circuit."
The component is designed to drop a certain voltage and when you place the probes across this component, you are effectively adding a "link" or "jumper" and the voltage at the left-side of the component will appear on the right-side. This voltage may be too high for the circuit being supplied and the result will be damage.

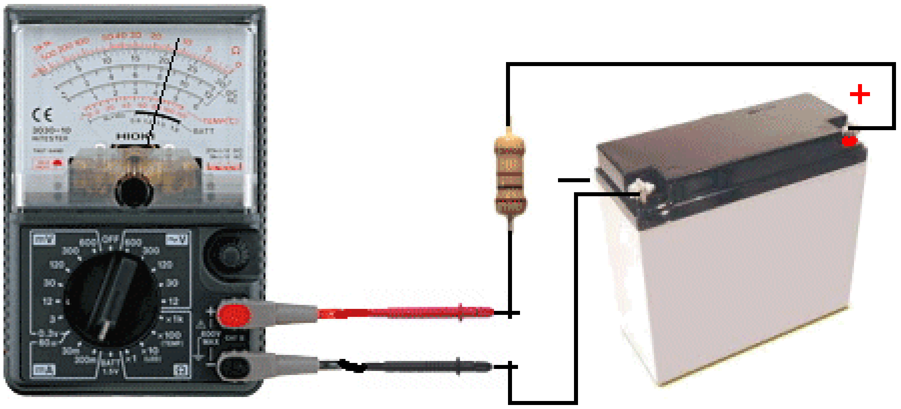

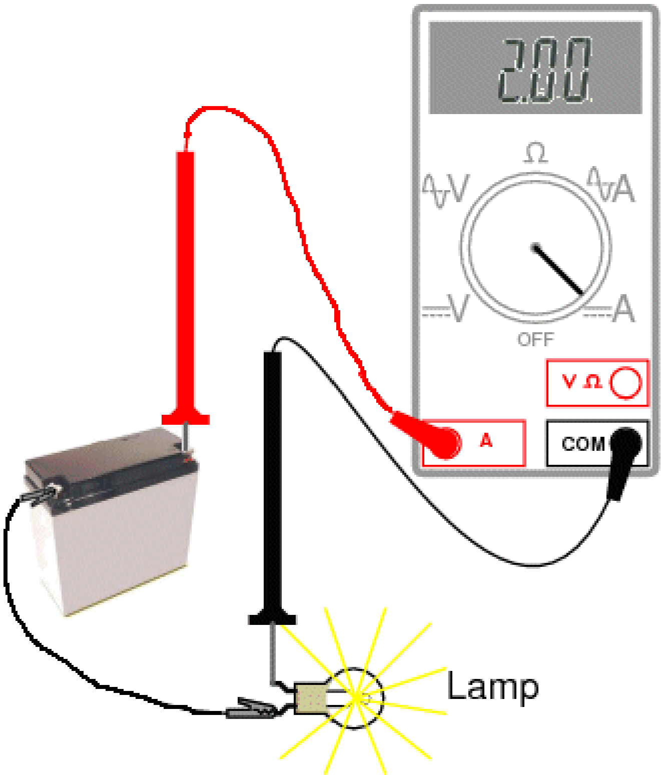

Measuring the current of a globe

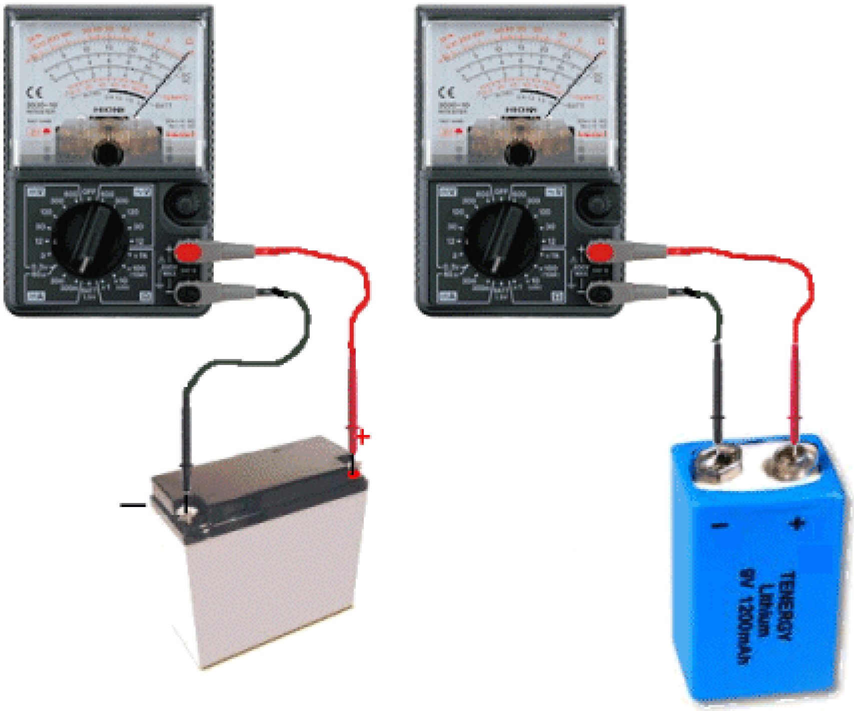

**Do NOT measure the CURRENT of a battery
(by placing the meter directly across the terminals)
A battery will deliver a very HIGH current
and damage the meter**

Do not measure the "current a battery will deliver" by placing the probes across the terminals. It will deliver a very high current and damage the meter instantly. There are special battery testing instruments for this purpose.

When measuring across an "opening" or "cut," place the red probe on the wire that supplies the voltage (and current) and the black probe on the other wire. This will produce a "POSITIVE" reading.
A positive reading is an UPSCALE READING and the pointer will move across the scale - to the right. A "NEGATIVE READING" will make the pointer hit the "STOP" at the left of the scale and you will not get a reading. If you are using a Digital Meter, a negative sign "-" will appear on the screen to indicate the probes are around the wrong way. No damage will be caused. It just indicates the probes are connected incorrectly.
If you want an accurate CURRENT MEASUREMENT, use a digital meter.

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MEASURING RESISTANCE

Turn a circuit off before measuring resistance.
If any voltage is present, the value of resistance will be incorrect.
In most cases you cannot measure a component while it is in-circuit. This is because the meter is actually measuring a voltage across a component and calling it a "resistance." The voltage comes from the battery inside the meter. If any other voltage is present, the meter will produce a false reading.
If you are measuring the resistance of a component while still "in circuit," (with the power off) the reading will be lower than the true reading.

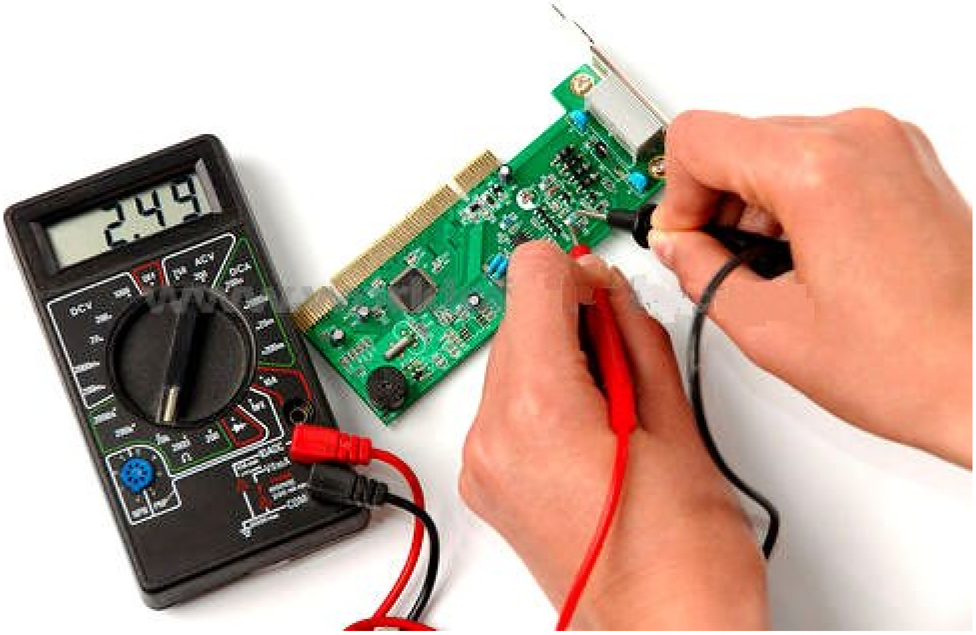

Measuring resistance

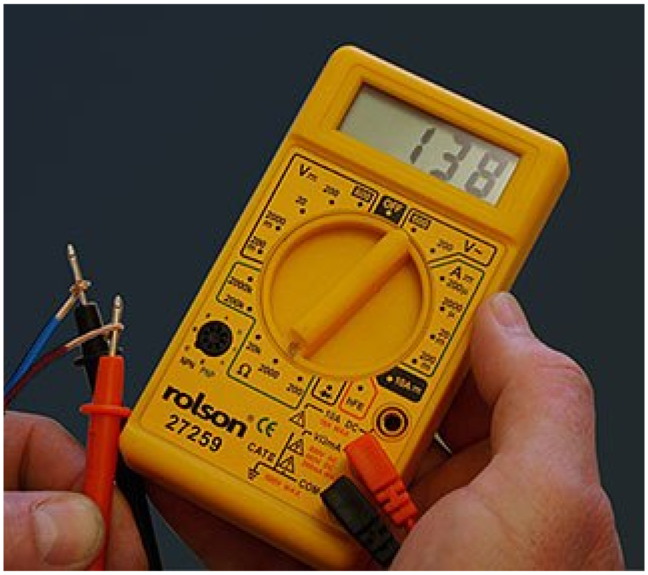
138
rolson
27259

**Measuring resistance of a heater
(via the leads)**

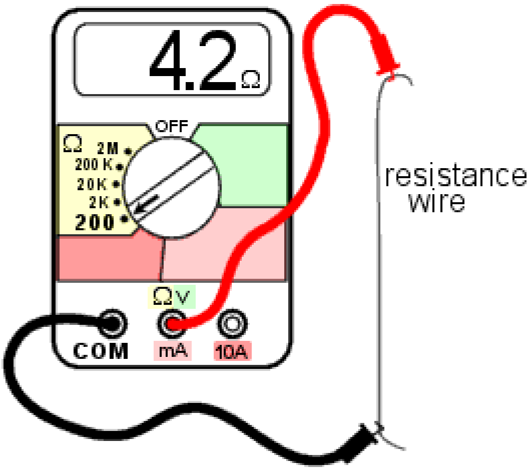
4.2 Ω
OFF
Ω 2M
200 K
20K
2K
200
ΩV
COM
mA
10A
resistance wire

Measuring the resistance of a piece of resistance-wire

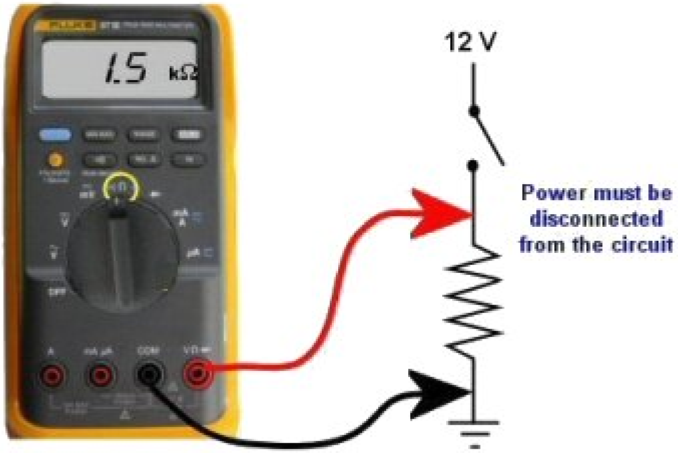

Power must be disconnected from the circuit

Measuring the resistance of a resistor

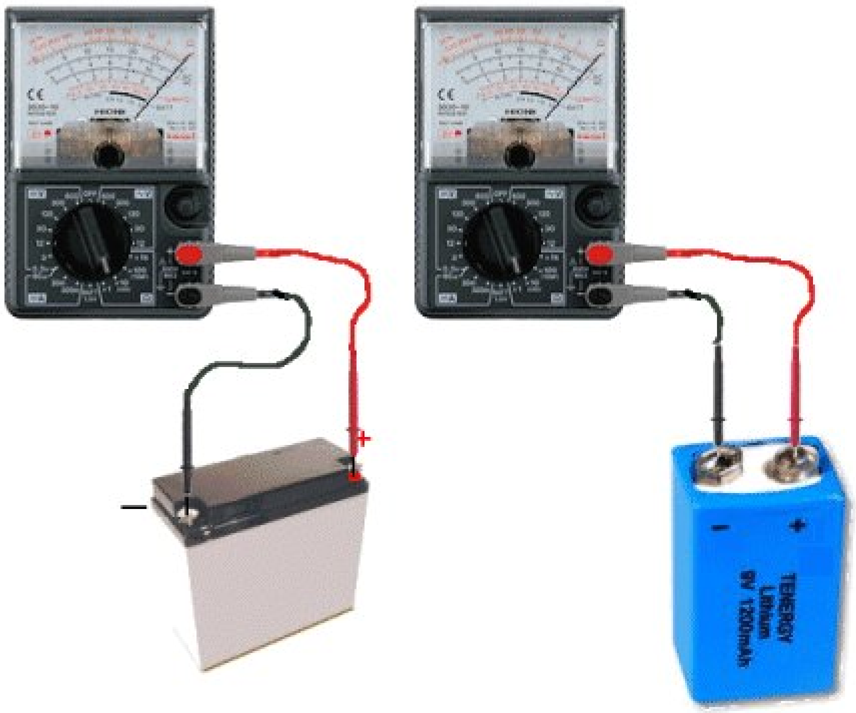

Do not measure the "Resistance of a Battery"

1. Do not measure the "resistance of a battery." The resistance of a battery (called the Internal impedance) is not measured as shown in the diagrams above. It is measured by creating a current-flow and measuring the voltage across the battery. Placing a multimeter set to **resistance** (across a battery) will destroy the meter.
2. Do not try to measure the resistance of any voltage or any "supply."

Resistance is measured in OHMs.
The resistance of a 1cm x 1cm bar, one metre long is 1 ohm.
If the bar is thinner, the resistance is higher. If the bar is longer, the resistance is higher.
If the material of the bar is changed, the resistance is higher.
When carbon is mixed with other elements, its resistance increases and this knowledge is used to make RESISTORS.
Resistors have RESISTANCE and the main purpose of a resistor is to reduce the CURRENT FLOW.
It's a bit like standing on a hose. The flow reduces.
When current flow is reduced, the output voltage is also reduced and that why the water does not spray up so high. Resistors are simple devices but they produce many different effects in a circuit.
A resistor of nearly pure carbon may be 1 ohm, but when non-conducting "impurities" are added, the same-size resistor may be 100 ohms, 1,000 ohms or 1 million ohms.
Circuits use values of less than 1 ohm to more than 22 million ohms.

Resistors are identified on a circuit with numbers and letters to show the exact value of resistance - such as 1k 2k2 4M7
The letter Ω (omega - a Greek symbol) is used to identify (or express) (or represent) the word "Ohm."
But this symbol is not available on some word-processors, so the letter "R" is used. The letter "E" is also sometimes used and both mean "Ohms."
A one-ohm resistor is written "1R" or "1E." It can also be written "1R0" or "1E0."
A resistor of one-tenth of an ohm is written "0R1" or "0E1." The letter takes the place of the decimal point.
10 ohms = 10R
100 ohms = 100R

1,000 ohms = 1k (k= kilo = one thousand)
10,000 ohms = 10k
100,000 ohms = 100k
1,000,000 ohms = 1M (M = MEG = one million)

The size of a resistor has nothing to do with its resistance. The size determines the wattage of the resistor - how much heat it can dissipate without getting too hot.
Every resistor is identified by colour bands on the body, but when the resistor is a surface-mount device, numbers are used and sometimes letters.
You MUST learn the colour code for resistors and the following table shows all the colours for the most common resistors from 1/10th of an ohm to 22 Meg ohms for resistors with 5% and 10% tolerance.

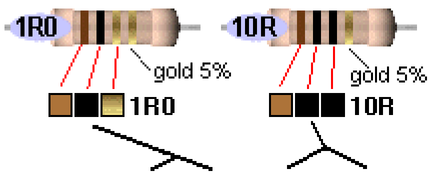

If 3rd band is gold, Divide by 10
If 3rd band is silver, Divide by 100
(to get 0.22ohms etc)

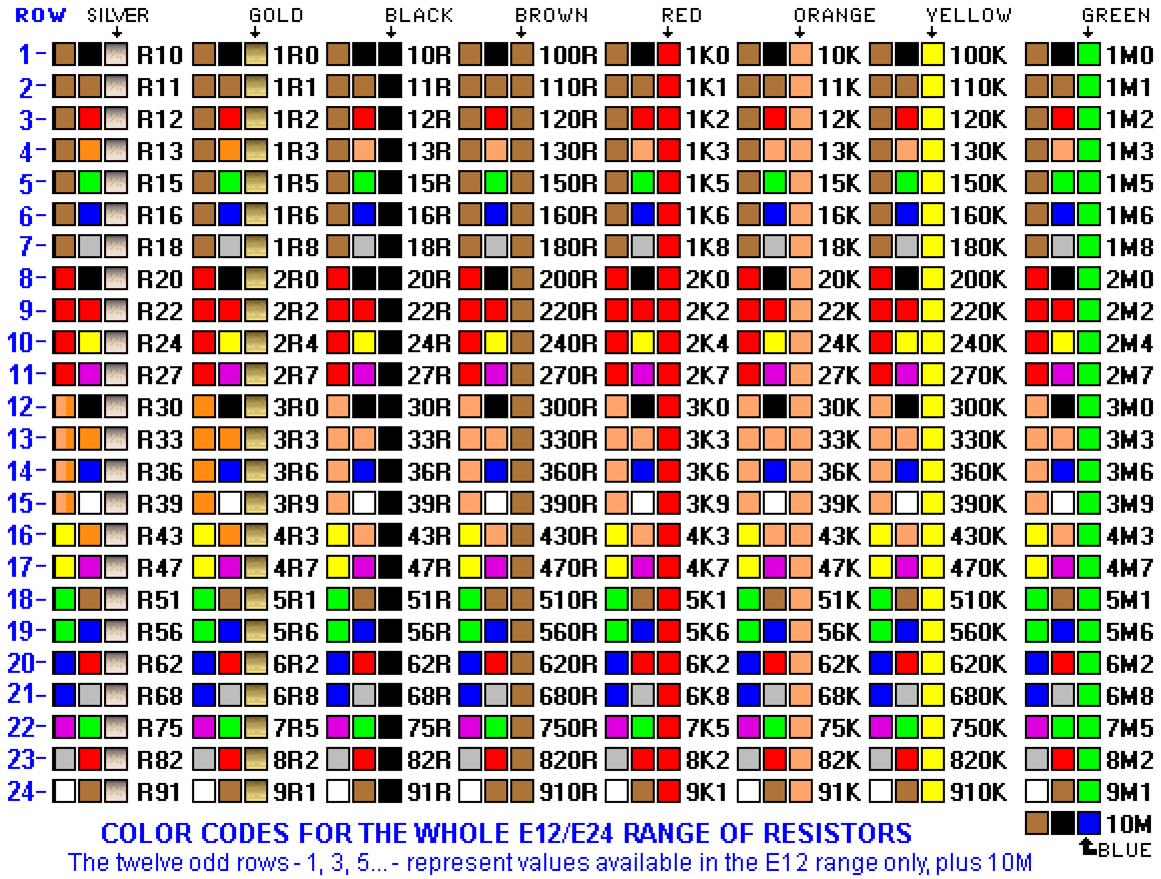

ROW	SILVER	GOLD	BLACK	BROWN	RED	ORANGE	YELLOW	GREEN
1-	R10	1R0	10R	100R	1K0	10K	100K	1M0
2-	R11	1R1	11R	110R	1K1	11K	110K	1M1
3-	R12	1R2	12R	120R	1K2	12K	120K	1M2
4-	R13	1R3	13R	130R	1K3	13K	130K	1M3
5-	R15	1R5	15R	150R	1K5	15K	150K	1M5
6-	R16	1R6	16R	160R	1K6	16K	160K	1M6
7-	R18	1R8	18R	180R	1K8	18K	180K	1M8
8-	R20	2R0	20R	200R	2K0	20K	200K	2M0
9-	R22	2R2	22R	220R	2K2	22K	220K	2M2
10-	R24	2R4	24R	240R	2K4	24K	240K	2M4
11-	R27	2R7	27R	270R	2K7	27K	270K	2M7
12-	R30	3R0	30R	300R	3K0	30K	300K	3M0
13-	R33	3R3	33R	330R	3K3	33K	330K	3M3
14-	R36	3R6	36R	360R	3K6	36K	360K	3M6
15-	R39	3R9	39R	390R	3K9	39K	390K	3M9
16-	R43	4R3	43R	430R	4K3	43K	430K	4M3
17-	R47	4R7	47R	470R	4K7	47K	470K	4M7
18-	R51	5R1	51R	510R	5K1	51K	510K	5M1
19-	R56	5R6	56R	560R	5K6	56K	560K	5M6
20-	R62	6R2	62R	620R	6K2	62K	620K	6M2
21-	R68	6R8	68R	680R	6K8	68K	680K	6M8
22-	R75	7R5	75R	750R	7K5	75K	750K	7M5
23-	R82	8R2	82R	820R	8K2	82K	820K	8M2
24-	R91	9R1	91R	910R	9K1	91K	910K	9M1
								10M BLUE

COLOR CODES FOR THE WHOLE E12/E24 RANGE OF RESISTORS
The twelve odd rows - 1, 3, 5... - represent values available in the E12 range only, plus 10M

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MAKE YOUR OWN RESISTOR

Make your own variable resistor that changes resistance according to the pressure.
Use a piece of conductive foam used to package Integrated Circuits. You can ask at an electronics shop.
Use two coins or pieces of printed circuit board or aluminium foil for the top and bottom conductors.
You can solder wires to the PC board or fold the aluminium foil over a few times to hold the wires.
The resistance of the foam will reduce as you press on the "cell."
The actual resistance-values will depend on the size of the foam, the thickness and

pressure.
This cell is a very simple cell called a **LOAD CELL**.

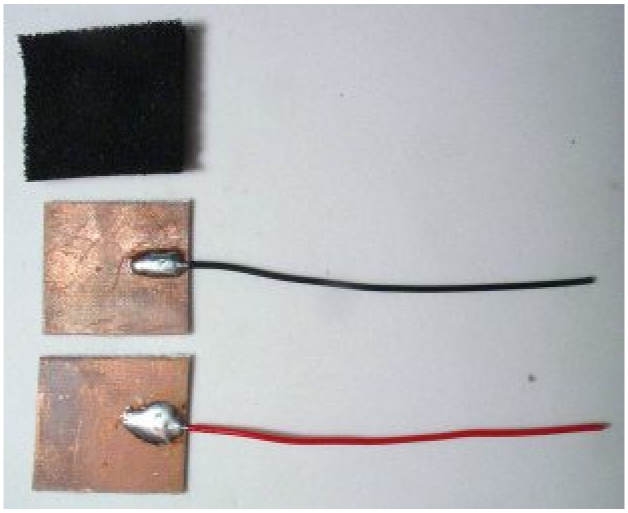

The top and bottom "plates"

The foam is placed between the plates.

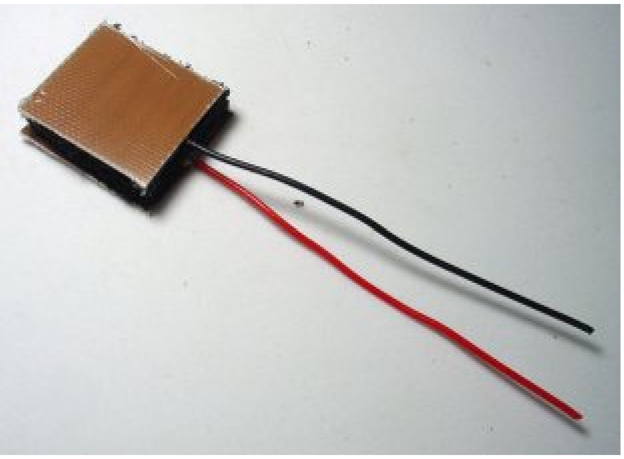

The complete LOAD CELL

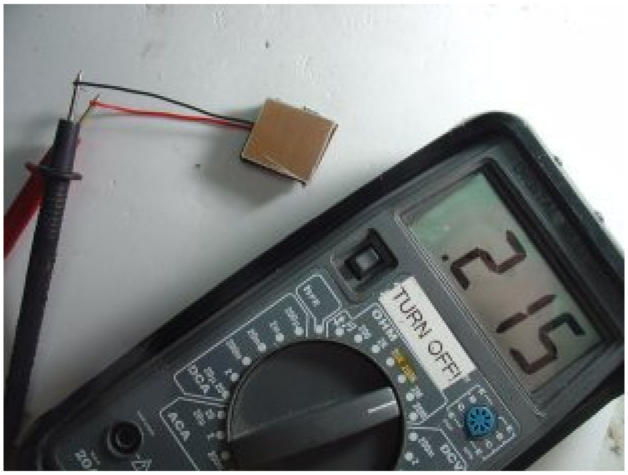

The resistance of the unloaded LOAD CELL

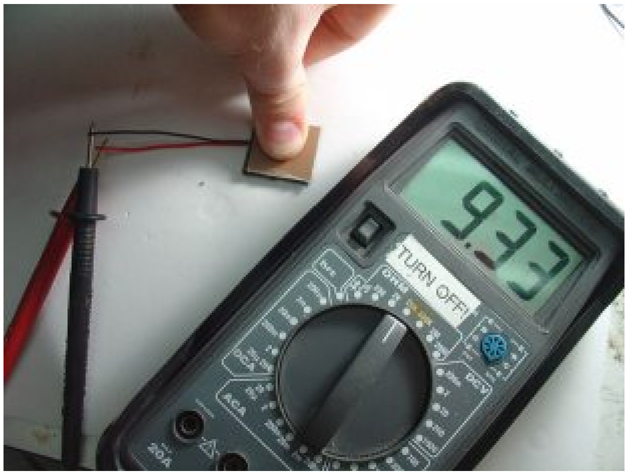

The fully loaded resistance can be as low as 9,330 ohms

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MEASURING CONTINUITY

CONTINUITY is the same as **ZERO OHMS** or the resistance of a short length of wire. It can also mean the resistance through a switch or globe or a low-value resistor.
It basically means a "PATH" and sometimes refers to a whole circuit when the switch is closed. In other words CONTINUITY means we have a "circuit." We have "current flowing" and generally refers to a low-resistance circuit.
Both ANALOGUE and DIGITAL multimeters can measure CONTINUITY and you have to work out the approximate value of resistance for the circuit you are testing, - BEFORE TAKING A READING.
If the reading is above 300 ohms or contains a diode, you cannot use a DIGITAL MULTIMETER as the buzzer on the continuity setting will not respond.

The project being tested must not have the power applied as the resistance ranges on a multimeter are actually measuring a voltage across the leads and any voltage on the circuit or contained in any electrolytics, will upset the reading.

To take a reading with an **ANALOGUE** multimeter, select the x1 setting and the pointer will move across the scale to the actual value of resistance.
It it move full scale, you have ZERO OHMS resistance and this can mean a short-circuit or continuity via a wire.
If a diode is in the circuit you must also reverse the leads to get a reading.
The resistance of a globe will be very low when it is not illuminated, so don't think a fault is present.
Measuring CONTINUITY is the same as measuring LOW RESISTANCE.

To take a reading with a **DIGITAL** multimeter, select the buzzer setting. It will respond if the resistance is less than 300 ohms. It will not respond if a diode is in the circuit.

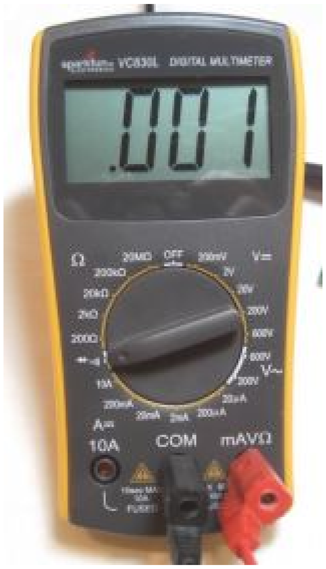

Meter set to BUZZER - CONTINUITY

You can also use the x1 resistance setting to get an accurate value of resistance. Touch the probes together to get the initial reading and subtract this value from the final reading.
When probing a circuit containing electrolytics, you may get a beep from the buzzer. This indicates the resistance is low because the multimeter is charging the electrolytic and it will beep until the electrolytic is charged to about 0.7v.
The same applies when probing across the power rails of a circuit. The circuit may contain electrolytics that will charge when probing and the buzzer will beep.
The Digital multimeter is actually detecting a voltage less than 0.7v across the probes and is created by a voltage-divider network inside the meter.
The voltage divider put 2v across the probes and when this drops to less than 0.5v, the buzzer is activated. That why it odes not buzz when testing a diode as the diode drops the voltage to 0.6v.

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MEASURING A DIODE

A diode can be measured to see if it is "open" or "damaged" or "working" by placing the probes across the component.
If the diode is "open" (it will not work), the needle will NOT swing across the scale when touching the component with the probes in one direction or when the probes are reversed.
If the diode is "damaged" (does not work), the needle will swing fully across the scale when touching the component with the probes in one direction or when the probes are reversed.
If the diode is FUNCTIONAL, (works) the needle will swing about mid-way when touching the leads of the diode in one direction and it will not move when the probes are reversed.

WHY?

The positive of the battery inside an analogue multimeter comes out the black probe and that is why you will get a reading when the probers are "around the wrong way." The needle will swing a different amount for each resistance setting on the dial as the needle represents 0.6v drop and NOT an actual resistance.

There are two things you must remember.
1. When the diode is measured in one direction, the needle will will **not move at**

all. The technical term for this is the diode is **reverse biased**. It will not allow any current to flow. Thus the needle will not move.

When the diode is connected around the other way, the needle will swing to the right (move up scale) to about 80% of the scale. This position represents the voltage drop across the junction of the diode and is NOT a resistance value. If you change the resistance range, the needle will move to a slightly different position due to the resistances inside the meter. The technical term for this is the diode is **forward biased**. This indicates the diode is not faulty.

The needle will swing to a slightly different position for a "normal diode" compared to a Schottky diode. This is due to the different junction voltage drops.

However we are only testing the diode at very low voltage and it may break-down when fitted to a circuit due to a higher voltage being present or due to a high current flowing.

2. The leads of an **Analogue Multimeter** have the positive of the battery connected to the black probe and the readings of a "good diode" are shown in the following two diagrams:

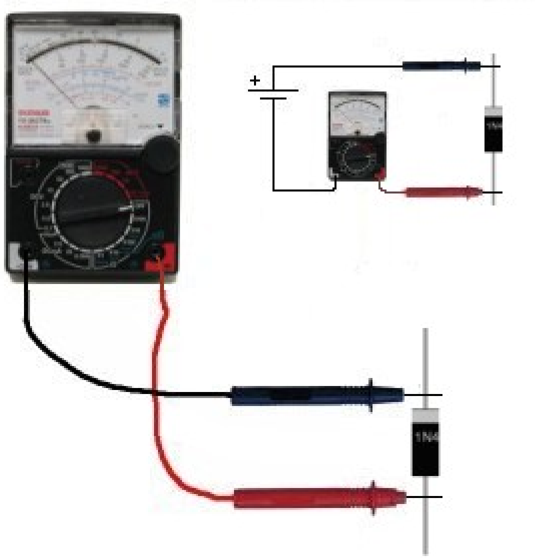

The diode is REVERSE BIASED in the diagram above and diodes not conduct.

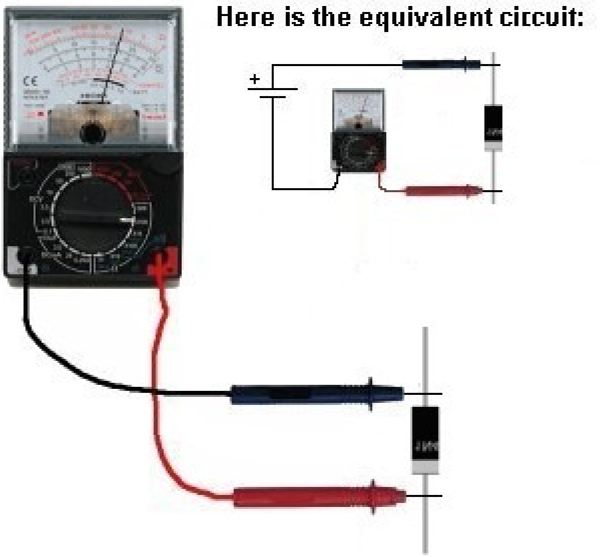

The diode is FORWARD BIASED in the diagram above and it conducts

TESTING A DIODE ON A DIGITAL METER

A Digital multimeter will measure the voltage-drop across the diode when the probes are connected in one direction (approx 0.640 on the scale) and a high reading (1) in the other direction. You need to select the "DIODE" setting on the dial as the other settings will produce a meaningless reading.

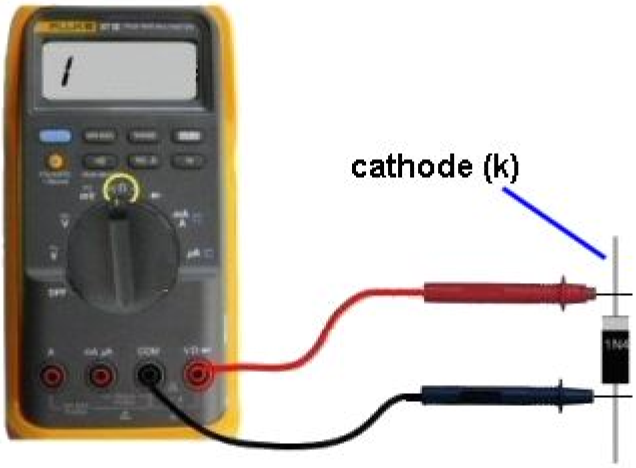

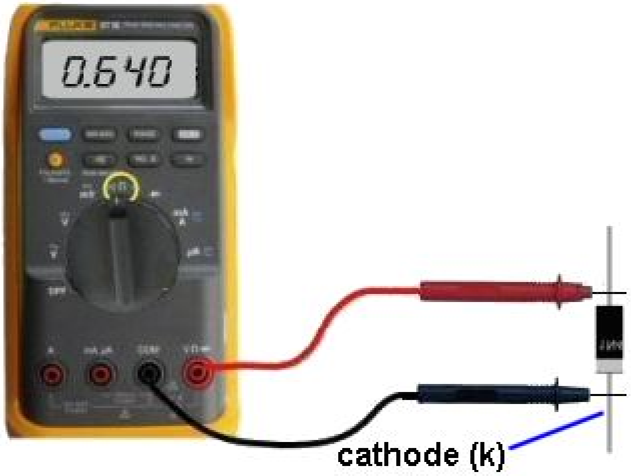

Some DIGITAL MULTIMETERS will show mV drop across the diode when the setting on the meter is "diode" or the "x1" or "x10" resistance range.

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TESTING A LED

Some multimeters will test LEDs.
It depends on the voltage of the battery inside the case of the multimeter.
Many analogue multimeters have a single 1.5v cell and these cannot test LEDs.
Analogue Multimeters with 3v (for the resistance ranges) can test some LEDs.
White LEDs need about 3.6v and they may not illuminate on 3v.

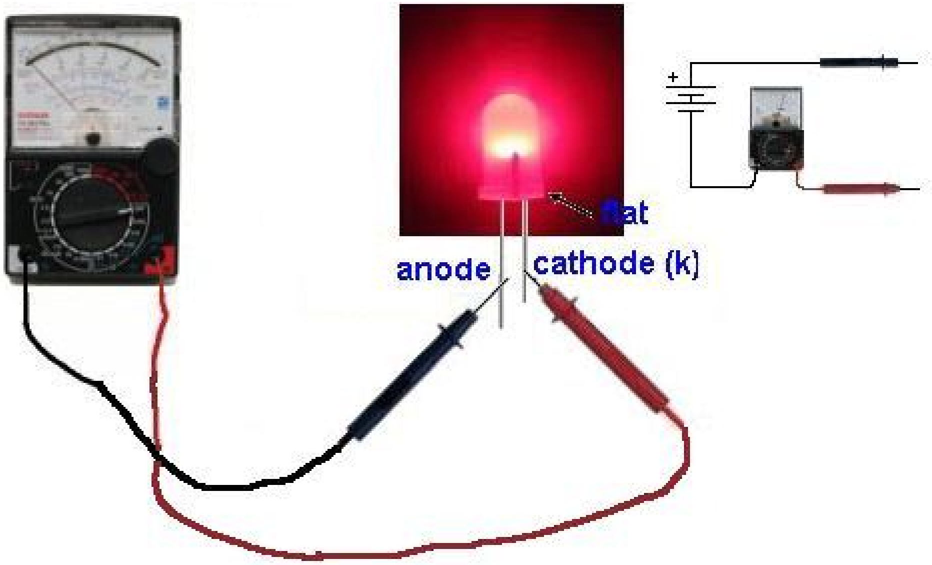

The negative lead of an ANALOGUE meter is POSITIVE!
The multimeter must have 3v (2 cells)

Digital multimeters have a 9v battery and they will illuminate all colour LEDs when the leads are placed as shown in the diagram:

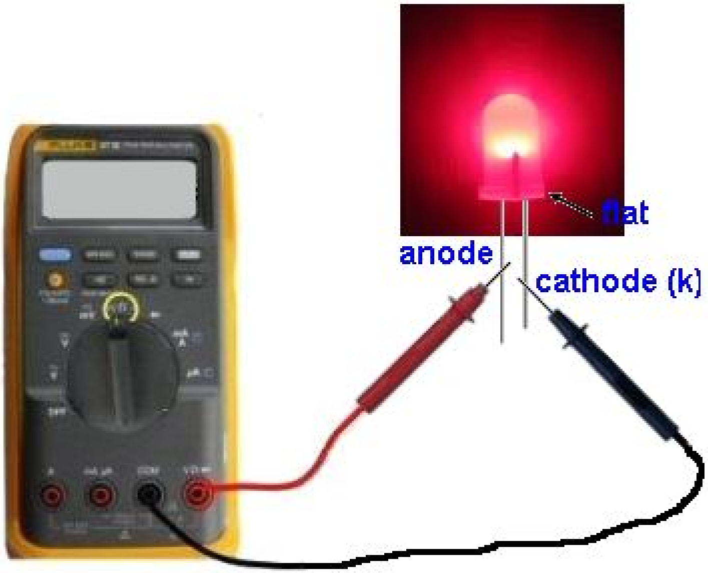

A Digital meter will illuminate all LEDs and the black probe touches the cathode.

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TESTING A TRANSISTOR WITH A DIGITAL METER

Testing a transistor with a **Digital Meter** must be done on the "DIODE" setting as a digital meter does not deliver a current through the probes on some of the resistance settings and will not produce an accurate reading.
The "DIODE" setting must be used for diodes and transistors. It should also be called a "TRANSISTOR" setting.

TESTING A TRANSISTOR WITH AN ANALOGUE METER

The first thing you may want to do is test an unknown transistor for COLLECTOR, BASE AND EMITTER. You also want to perform a test to find out if it is NPN or PNP. That's what this test will provide.
You need a cheap multimeter called an ANALOGUE METER - a multimeter with a

scale and pointer (needle).
It will measure resistance values (normally used to test resistors) - (you can also test other components) and Voltage and Current. We use the resistance settings. It may have ranges such as "x10" "x100" "x1k" "x10"
Look at the resistance scale on the meter. It will be the top scale.
The scale starts at zero on the right and the high values are on the left. This is opposite to all the other scales.
When the two probes are touched together, the needle swings FULL SCALE and reads "ZERO." Adjust the pot on the side of the meter to make the pointer read exactly zero.

How to read: "x10" "x100" "x1k" "x10"
Up-scale from the zero mark is "1"
When the needle swings to this position on the "x10" setting, the value is 10 ohms.
When the needle swings to "1" on the "x100" setting, the value is 100 ohms.
When the needle swings to "1" on the "x1k" setting, the value is 1,000 ohms = 1k.
When the needle swings to "1" on the "x10k" setting, the value is 10,000 ohms = 10k.
Use this to work out all the other values on the scale.
Resistance values get very close-together (and very inaccurate) at the high end of the scale. [This is just a point to note and does not affect testing a transistor.]

Step 1 - FINDING THE BASE and determining NPN or PNP
Get an unknown transistor and test it with a multimeter set to "x10"
Try the 6 combinations and when you have the black probe on a pin and the red probe touches the other pins and the meter swings nearly full scale, you have an NPN transistor. The black probe is BASE
If the red probe touches a pin and the black probe produces a swing on the other two pins, you have a PNP transistor. The red probe is BASE
If the needle swings FULL SCALE or if it swings for more than 2 readings, the transistor is **FAULTY**.

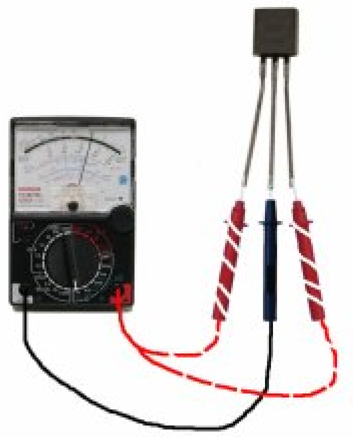

This is an NPN transistor
The black probe is the BASE

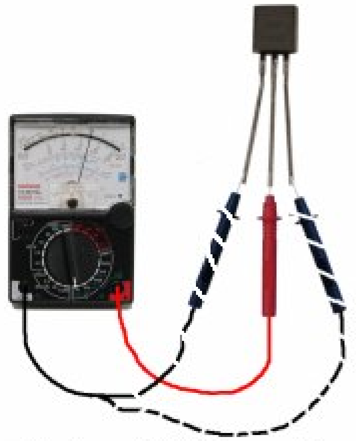

This is a PNP transistor
The red probe is the BASE

Step 2 - FINDING THE COLLECTOR and EMITTER
Set the meter to "x10k."
For an NPN transistor, place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.

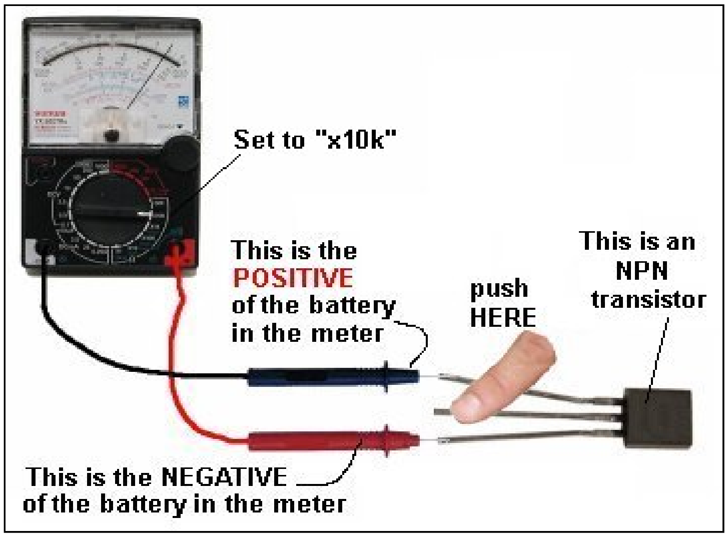
Set to "x10k"
This is the
POSITIVE
of the battery
in the meter
push
HERE
This is an
NPN
transistor
This is the NEGATIVE
of the battery in the meter

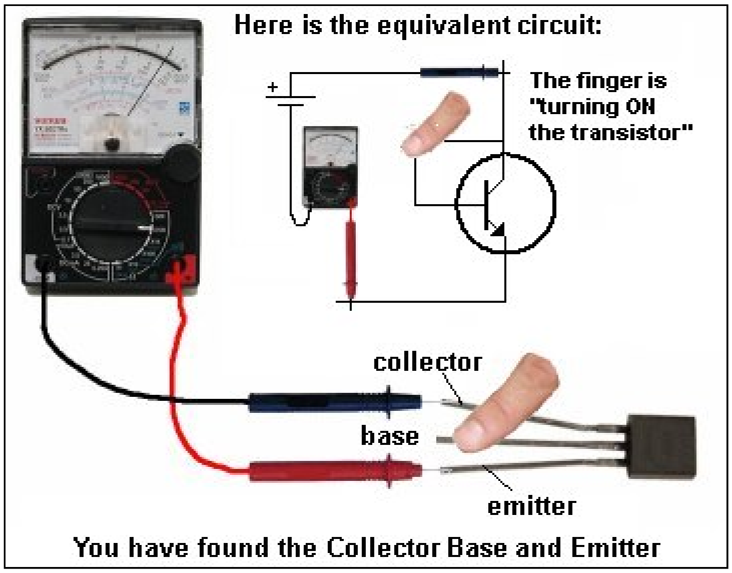
Here is the equivalent circuit:
+
The finger is
"turning ON
the transistor"
collector
base
emitter
You have found the Collector Base and Emitter

For a PNP transistor, set the meter to "x10k" place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.

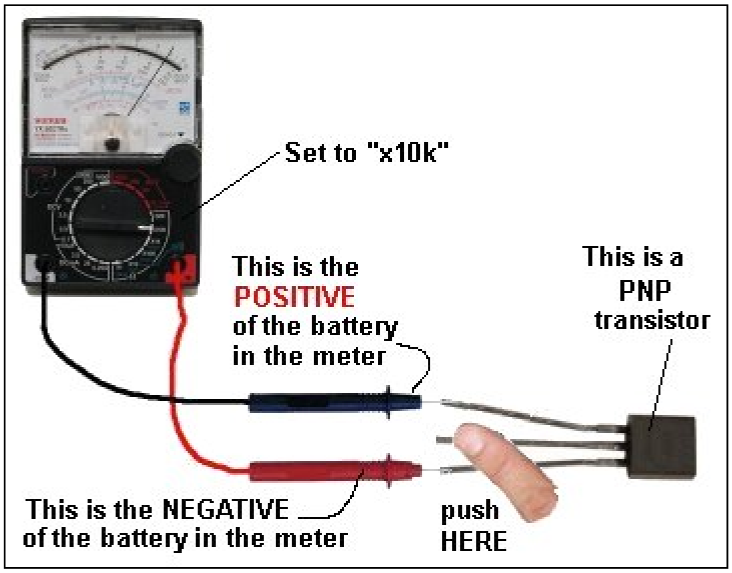
Set to "x10k"
This is the
POSITIVE
of the battery
in the meter
This is a
PNP
transistor
This is the NEGATIVE
of the battery in the meter
push
HERE

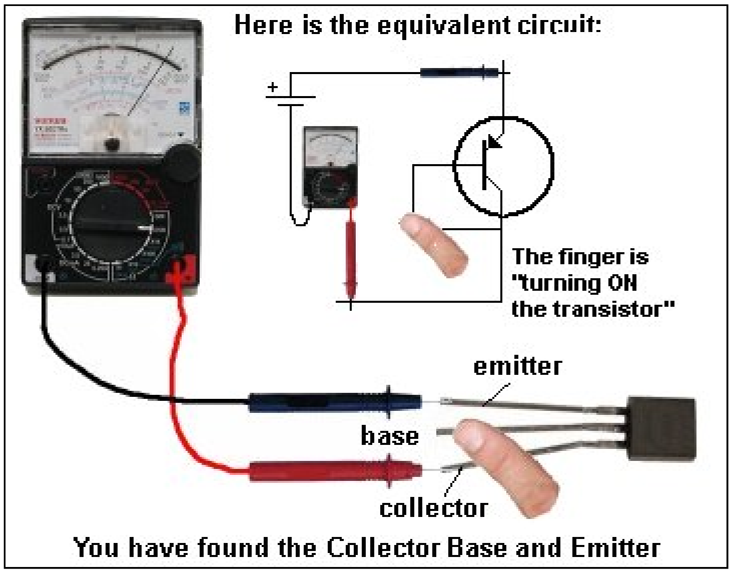
Here is the equivalent circuit:
+
The finger is "turning ON the transistor"
emitter
base
collector
You have found the Collector Base and Emitter

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For more details on testing components with a multimeter, see:
Testing Electronic Components.

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MULTIMETER TEST

1. What is the reading on the multimeter:

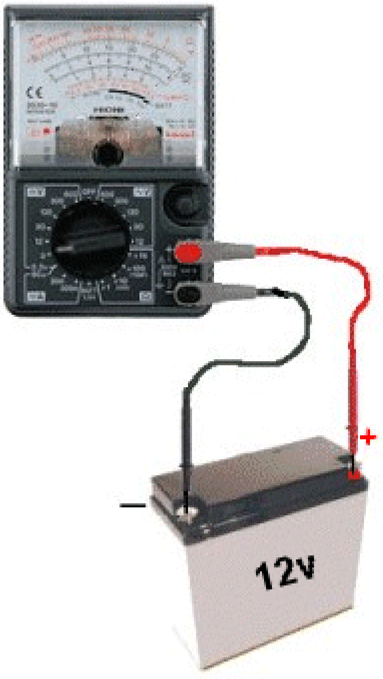

Answer

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2. What is the reading on the multimeter:

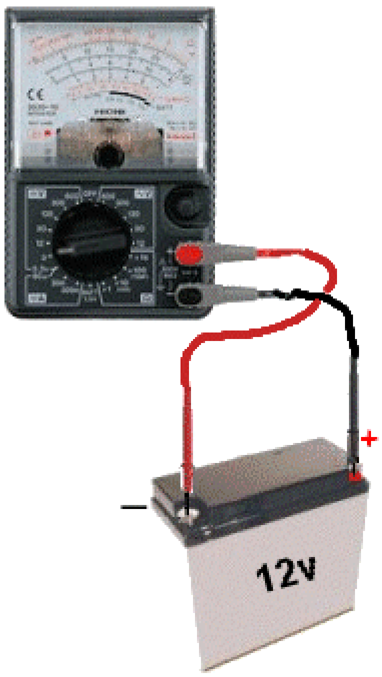

Answer

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3. What is the reading on the multimeter:

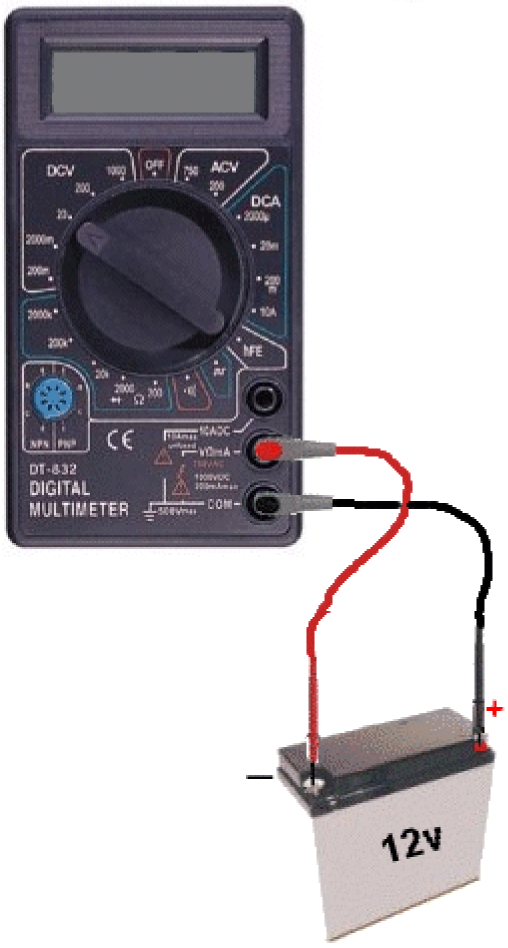
DCV
OFF
ACV
DCA
hFE
NPN
PNP
CE
10ADC
VΩmA
COM
DT-832
DIGITAL
MULTIMETER
+
–
12v

Answer

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4. What is the voltage between the following points:

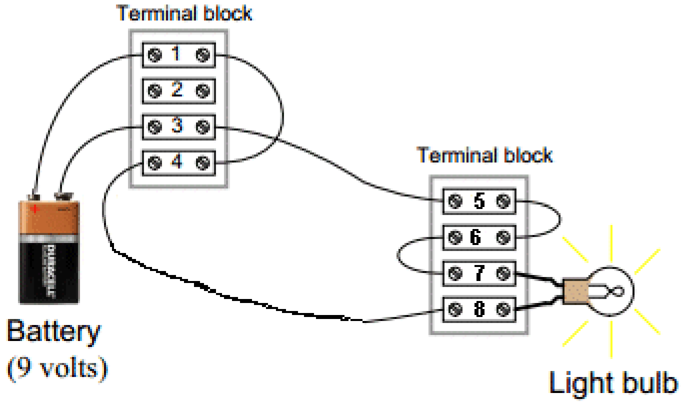
Terminal block
1
2
3
4
Terminal block
5
6
7
8
Battery
(9 volts)
Light bulb

Between 1 & 3	Between 5 & 7	Between 3 & 8	Between 1 & 7
Answer	**Answer**	**Answer**	**Answer**

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5. What is the voltage on each multimeter:

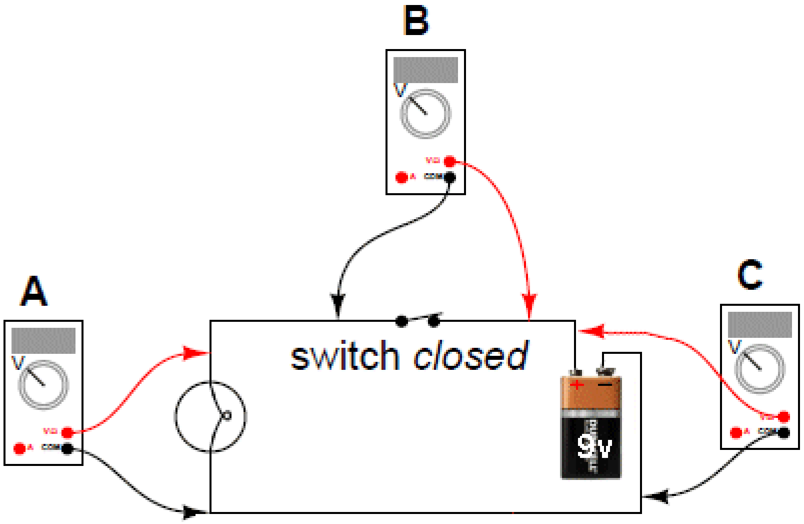
B
A
C
V
switch closed
9v

Meter A	Meter B	Meter C
Answer	**Answer**	**Answer**

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6. What is the voltage on each multimeter:

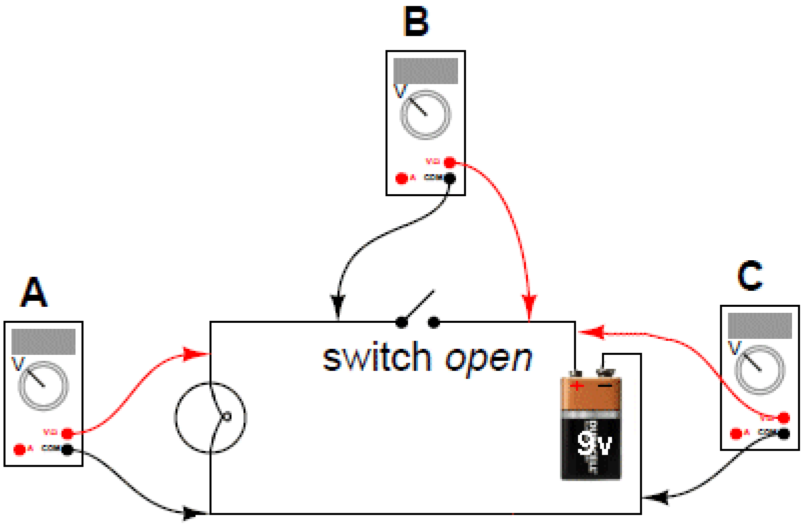
B
A
C
V
VΩ
A
COM
switch *open*
9v

Meter A	**Meter B**	**Meter C**
Answer	**Answer**	**Answer**

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7. What is the reading on the multimeter:

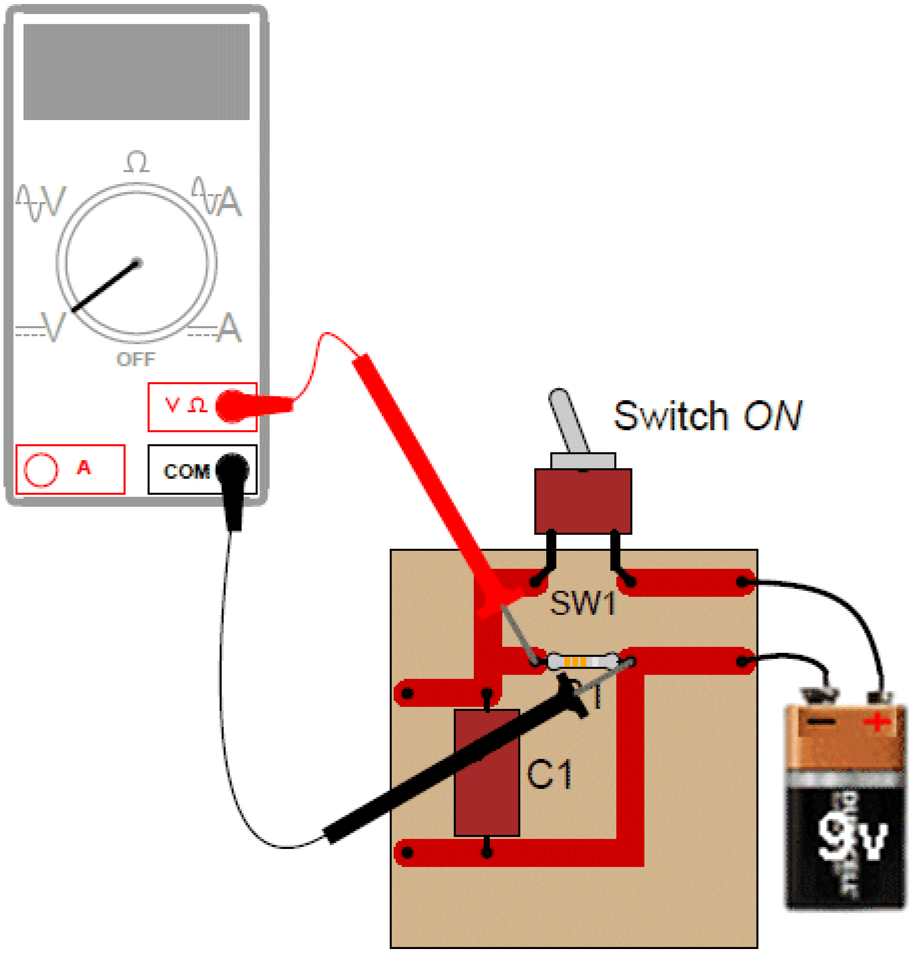
Ω
V
A
V
A
OFF
V Ω
A
COM
Switch *ON*
SW1
C1
9v

Answer

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8. The multimeter has three resistance ranges: **x1 ohms x100 ohms x10k ohms**. How far across the scale will the needle move on each range for a 4k7 resistor:

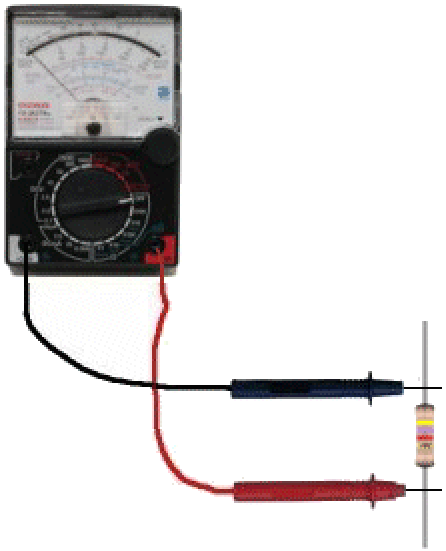

x1	**x100**	**x10k**
Answer	**Answer**	**Answer**

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9. The resistance ranges on an ANALOGUE multimeter use the battery inside the case to move the pointer. If the multimeter is left on "**ohms range**" with the probes apart, will the battery go flat?

Answer

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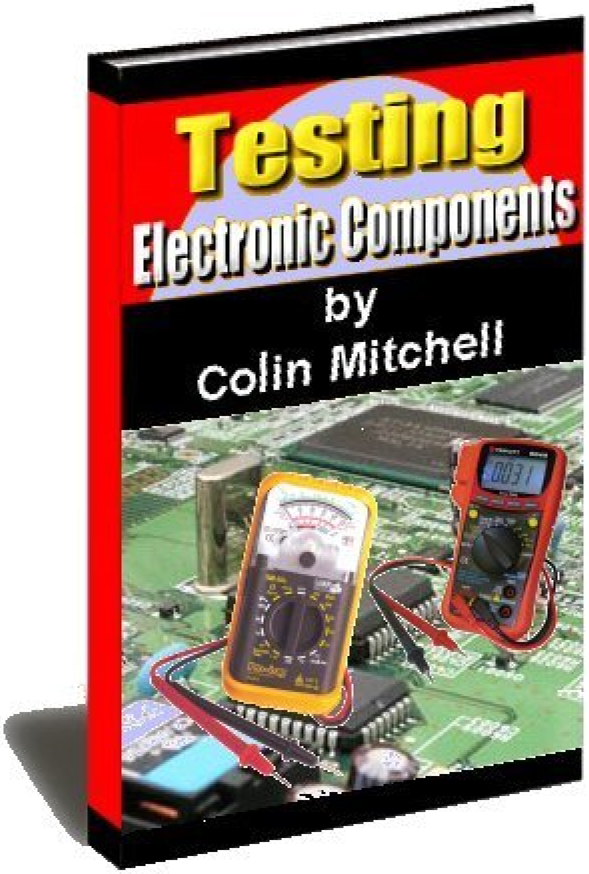

This eBook shows you how to TEST COMPONENTS.
To do this you need "TEST GEAR." The best item of Test Gear is a MULTIMETER. It can test almost 90% of all components. And that's what we will do in this eBook:

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Audio Stages
Batteries - testing
Burnt Resistor
Buying A Multimeter
Capacitors
Capacitors - decoupling caps
Capacitors in Parallel
Capacitor Substitution Box
Cells - batteries
Circuit Symbols
Co-Ax Cables
Colour Code (Resistor)
Coils
Continuity
Creating any value of R
Multimeters
Non-polar Capacitor (electrolytic)
Open Circuit
"Open" Resistor - damaged
Opto-couplers
Parallel - resistors
Parallel and Series Capacitors
Piezo Diaphragms
Piezo Buzzers
Potentiometers
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Power Diodes
Power Supply -see Basic Electronics 1A
Reed Switch
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Current - measuring
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Current Transformer
Damper Diodes
Darlington Transistors
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Digital Multimeter
Digital Transistors
Diodes replacing a diode
Discharge a Capacitor
Earth Leakage Detectors
Electrolytics
FETs
Fingers - to feel temperature
Focus pots
Fuses and 100mA fuses
Germanium Diodes
Heatsinks
Impedance - of a stage
IC's - also called Digital Chips
IC's - Analogue Chips
"In-Circuit" testing
Inductors
Inductors - measuring
Integrated Circuits
Isolation Transformer
Latching Reed Switch
LEDs
Logic Probe MkIIB
Logic Probe - Simple
Logic Probe - using CD4001
Logic Probe - using CD4011
Making your own components
Measuring Resistance
Measuring Voltage
Mica Washers and Insulators
Motor - testing
MOSFETs
Resistor Colour Code
Resistor Networks
Resistors - series
Resistor Substitution Box
Ripple Factor
Schottky Diodes
SCRs
Short Circuit
Signal Injector
Silicon diodes
Soldering
Spark Gaps
Speaker
Substitution Box
Super Probe MkII
Surface Mount - Packs
Surface-Mount Resistors
Surface-Mount Resistor Markings
Switches
Symbols
Test Equipment
Testing A Circuit
Testing A Resistor
Testing Components "In-Circuit"
Transformers - current transformer
Transformer Ratings 28v-0-28v
Transistor Outlines
Transistors
Transistors Digital
Triacs
Unknown resistors - testing
Using A Multimeter
Voltage Divider
Voltage Regulators
Voltages on a circuit
Wire Wound Resistor
Yokes
Zener Diodes
4-Band Resistors
5-Band Resistors
10-Turn Pots

Use your "brain, knowledge and your fingers."

Before we start, fixing anything is a combination of skill, luck and good diagnosis.
Sometimes you can fix something by letting it run until it finally fails.
Some things start to work as soon as you touch them.
Some things can never be fixed.
But some things can be fixed by feeling the temperature rise and deciding if it is getting too hot.
Sometimes you can smell something getting too hot.
Sometimes you can see SMOKE.
All these things make you a very clever technician and about 50% of faults will be fixed by looking for dry joints, burnt parts, overheating and carefully inspecting an item before you disturb it.

By simply touching different items you can quite often feel a hot item and home-in on the fault - at a saving of hours of work.
Servicing is not "A bull at a gate" approach.
You may be able to service something by turning it on and leaving it for hours - and start thinking.
It may take you a day to come up with the answer.
Believe me. That's how it worked for me - while fixing over 35,000 TV's.

TEST EQUIPMENT

Everyone thinks TEST EQUIPMENT will "solve the problem."
This is a big big MISTAKE.
Test equipment can help solve a problem and it can "lead to frustration," "give an incorrect answer," "mess you up," and make things worse.
You have to be very careful with test equipment and especially EXPENSIVE equipment because it is very sensitive and can detect pulses and glitches and voltages that are not affecting the operation of the circuit.
You will learn a lot of tricks when reading through this article, but let me say two things.
There are lots of faults and components that you cannot test with "test equipment" because they are either intermittent or the equipment does not load the device to the same extent as the circuit.
And secondly you need both an ANALOGUE multimeter and a DIGITAL meter to cover all the situations.
And if you are working on a car, you only need a $5.00 analogue meter because it will be dropped or fall into a crack, and you will only lose $5.00
You will learn that a digital meter will pick up spikes and signals on a line and show an incorrect reading.
That's why you need to back-up your readings with an analogue meter.
When you charge a battery it gets a "floating voltage" and this will be higher than the actual voltage, when the battery is fitted to a project. An analogue meter will draw a slight current and remove the "floating voltage."
Component testers can also give you a false reading, either because the component is out of range of the tester or intermittent and you need to be aware of this.
Oscilloscopes can also display waveforms that are parts of glitches or noise from other chips and these do not affect the operation of the part of the circuit you are investigating.
Sometimes you cannot pickup a pulse because it is not regular and the trigger on the oscilloscope does not show it on the screen. You may think it is missing.
It all depends on the "speed of the oscilloscope" - it's maximum frequency of operation.
Lastly- Power Supplies. You cannot test globes and motors on a power supply because the starting current can be 5 times more than the operating current. The power supply may not be able to deliver this high current and thus you will think the motor or globe is faulty.

MULTIMETERS

There are two types:

DIGITAL and ANALOGUE

A **Digital Multimeter** has a set of digits on the display and an Analogue Multimeter has a scale with a pointer (or needle).
You really need both types to cover the number of tests needed for designing and repair-work. We will discuss how they work, how to use them and some of the differences between them.

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DIGITAL AND ANALOGUE MULTIMETERS

BUYING A MULTIMETER

There are many different types on the market.
The cost is determined by the number of ranges and also the extra features such as diode tester, buzzer (continuity), transistor tester, high DC current and others.
Since most multimeters are reliable and accurate, buy one with the greatest number of ranges at the lowest cost.
This article explains the difference between a cheap analogue meter, an expensive analogue meter and a digital meter. You will then be able to work out which two meters you should buy.

Multimeters are sometimes called a "meter", a "VOM" (Volts-Ohms-Milliamps or Volt Ohm Meter) or "multi-tester" or even "a tester" - they are all the same.

USING A MULTIMETER

Analogue and digital multimeters have either a rotary selector switch or push buttons to select the appropriate function and range. Some Digital Multimeters (DMMs) are auto ranging; they automatically select the correct range of voltage, resistance, or current when doing a test. However you need to select the function.

Before making any measurement you need to know what you are checking. If you are measuring voltage, select the AC range (10v, 50v, 250v, or 1000v) or DC range (0.5v, 2.5v, 10v, 50v, 250v, or 1000v). If you are measuring resistance, select the Ohms range (x1, x10, x100, x1k, x10k). If you are measuring current, select the appropriate current range DCmA 0.5mA, 50mA, 500mA. Every multimeter is different however the photo below shows a low cost meter with the basic ranges.

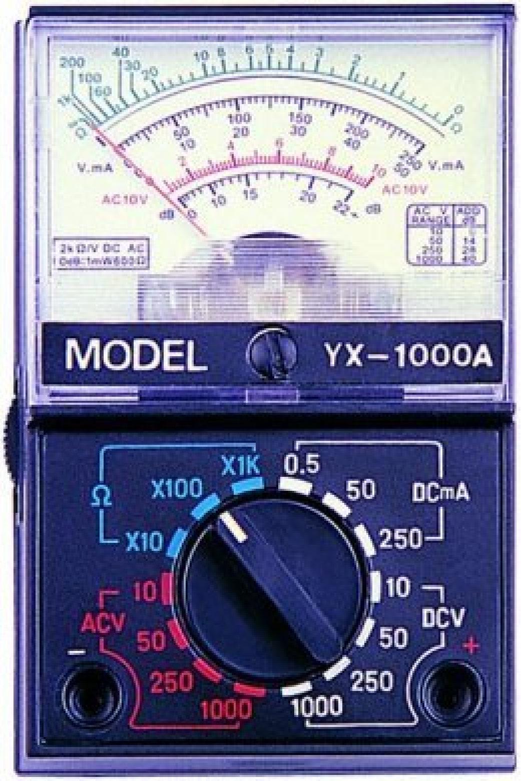
MODEL YX-1000A
Ω
X1K
X100
X10
0.5
50
250
DCmA
10
ACV
50
250
1000
DCV
+
-

The most important point to remember is this:
You must select a voltage or current range that is bigger or HIGHER than the maximum expected value, so the needle does not swing across the scale and hit the "end stop."
If you are using a DMM (Digital Multi Meter), the meter will indicate if the voltage or current is higher than the selected scale, by showing "OL" - this means "Overload." If you are measuring resistance such as 1M on the x10 range the "OL" means "Open Loop" and you will need to change the range. Some meters show "1' on the display when the measurement is higher than the display will indicate and some flash a set of digits to show over-voltage or over-current. A "-1" indicates the leads should be reversed for a "positive reading."
If it is an AUTO RANGING meter, it will automatically produce a reading, otherwise the selector switch must be changed to another range.

HV
000
DCV
OFF
ACV
DCA
hFE
NPN PNP
DT-832
DIGITAL
MULTIMETER
10ADC
VΩmA
COM

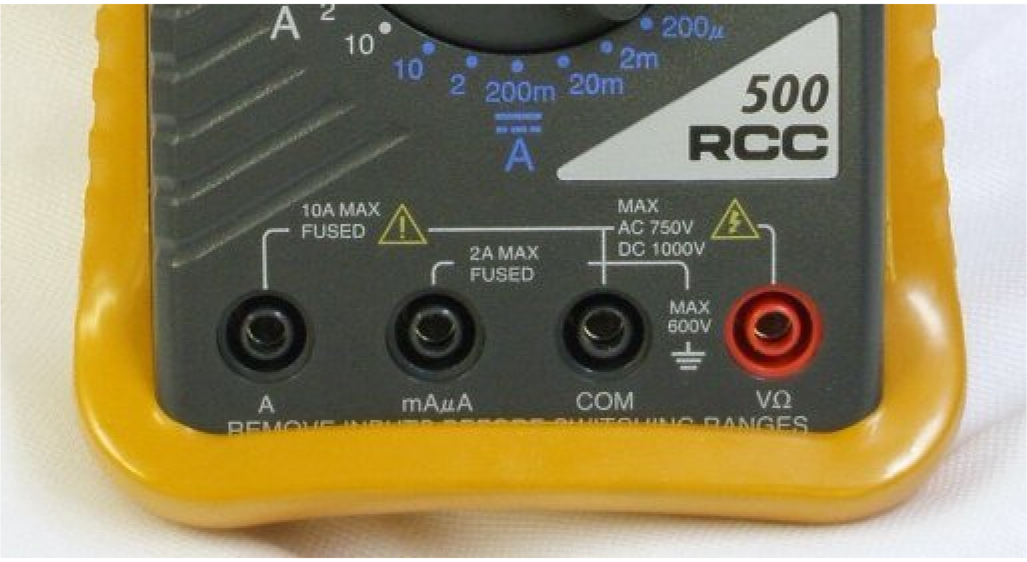
A
10
10
2
200m
20m
2m
200µ
A
500
RCC
10A MAX
FUSED
2A MAX
FUSED
MAX
AC 750V
DC 1000V
MAX
600V
A
mAµA
COM
VΩ
REMOVE INPUTS BEFORE SWITCHING RANGES

The Common (negative) lead ALWAYS fits into the "COM" socket. The red lead fits into the red socket for Voltage and Resistance. Place the red lead (red banana plug) into "A" (for HIGH CURRENT "Amps") or mA,uA for LOW CURRENT.

The black "test lead" plugs into the socket marked "-" "Common", or "Com," and the red "test lead" plugs into meter socket marked "+" or "V-W-mA." The third banana socket measures HIGH CURRENT and the positive (red lead) plugs into this. You DO NOT move the negative "-" lead at any time.

The following two photos show the test leads fitted to a digital meter. The probes and plugs have "guards" surrounding the probe tips and also the plugs so you can measure high voltages without getting near the voltage-source.

FLUKE
115 TRUE RMS MULTIMETER
600.0
HOLD
MIN MAX
RANGE
OFF
V
mV
Ω
A
COM
10ADC
000

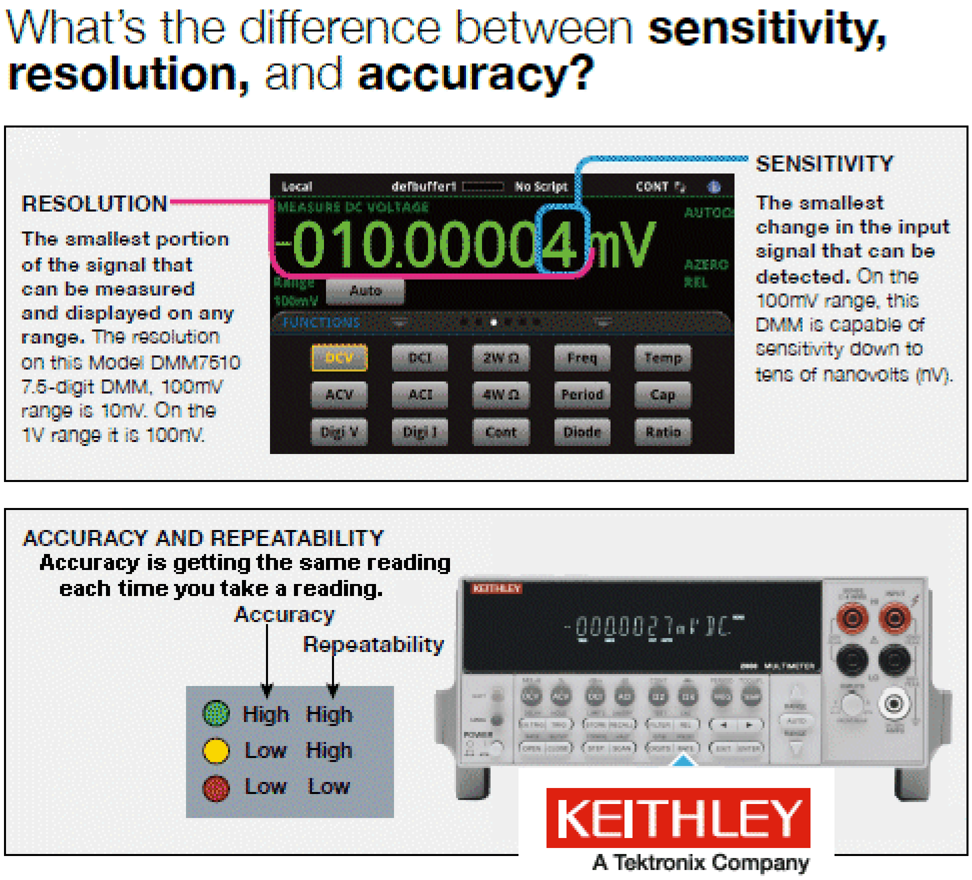

Local
defbuffer1
No Script
CONT
MEASURE DC VOLTAGE
-010.000004 mV
AUTOZ
AZERO
REL
Range 100mV
Auto
FUNCTIONS
DCV
DCI
2W Ω
Freq
Temp
ACV
ACI
4W Ω
Period
Cap
Digi V
Digi I
Cont
Diode
Ratio
KEITHLEY
-0.00002 mV DC
2000 MULTIMETER
KEITHLEY
A Tektronix Company

What's the difference between **sensitivity, resolution,** and **accuracy?**

RESOLUTION

The smallest portion of the signal that can be measured and displayed on any range. The resolution on this Model DMM7510 7.5-digit DMM, 100mV range is 10nV. On the 1V range it is 100nV.

SENSITIVITY

The smallest change in the input signal that can be detected. On the 100mV range, this DMM is capable of sensitivity down to tens of nanovolts (nV).

ACCURACY AND REPEATABILITY

Accuracy is getting the same reading each time you take a reading.

	Accuracy	Repeatability
🟢	High	High
🟡	Low	High
🔴	Low	Low

The question above applies to both (every) type of multimeter and the type of meter you use depends on the accuracy you need. Sometimes you are looking for 1mV change on a 20v rail. Only a DMM will (or a CRO) will produce a result.

Analogue meters have an "Ohms Adjustment" to allow for the change in voltage of the battery inside the meter (as it gets old).

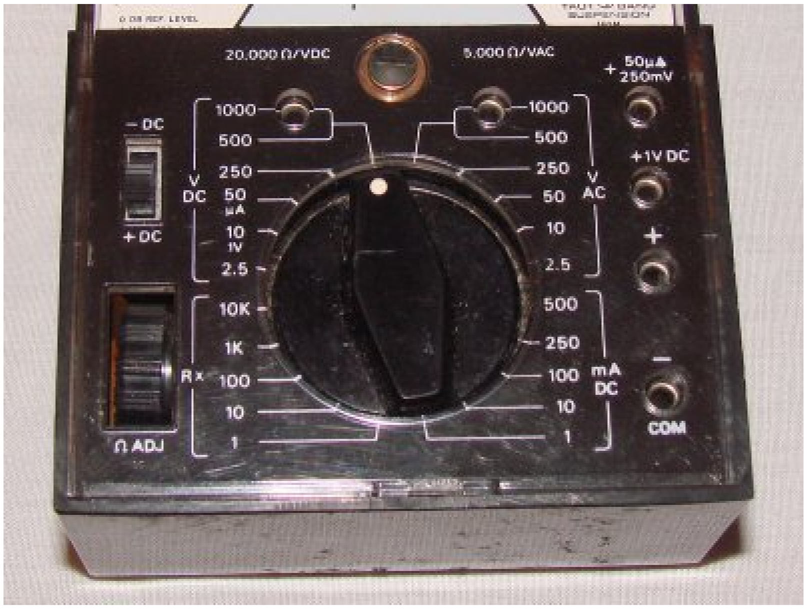

20,000 Ω/VDC
5,000 Ω/VAC
+ 50μA 250mV
- DC
+ DC
V DC
1000
500
250
50 μA
10 1V
2.5
10K
1K
Rx 100
10
1
Ω ADJ
1000
500
250
50
10
2.5
V AC
500
250
100
10
1
mA DC
+1V DC
+
-
COM

"Ohms Adjust" is also called "ZERO SET"

The sensitivity of this meter is 20,000ohms/volt on the DC ranges and 5k/v on the AC ranges

Before taking a resistance reading (each time on any of the Ohms scales) you need to "ZERO SET" the scale, by touching the two probes together and adjust the pot until the needle reads "0" (swings FULL SCALE). If the pointer does not reach full scale, the batteries need replacing. Digital multimeters do not need "zero adjustment."

FIXING A MULTIMETER

A multimeter can get "broken" "damaged" and go "faulty."
I don't know why, but eventually they stop working.
It can be something simple like a flat battery, corroded battery contacts, broken switch or something complex, like the circuitry failing.
Multimeters are so cheap, you can buy a new one for less than $10.00
These meters can have a 10 amp range, transistor tester and measure up to 2 meg ohms.
That's why I suggest buying a $10.00 meter. They are just as good as a $60.00 meter and the cheapest meters last the longest.
Dropping an analogue meter can cause the hair spring to loop over one of the supports and the needle will not zero correctly. You will need to open the cover on the movement and lift the spring off the support with a needle.
A faulty meter can be used in a battery-charger circuit to measure the current or voltage if that scale is still reading-correctly.
Otherwise keep the leads and throw the meter out. It is too dangerous keeping a meter that shows an incorrect reading.

MEASURING FREQUENCY

VICHY
VC99
APO
DC
-000.0
AUTO
mV
MAX/MIN
Hz/DUTY
REL
HOLD
RANGE
DC/AC
Hz
°C °F
hFE
V~
Vm
OFF
AUTO OFF POWER
TEMP
A
mA
COM
VΩHz
CAT II 1000V

Before we cover the normal uses for a multimeter, it is interesting to note that some **Digital Multimeters (DMM)** have features such as Capacitance, Frequency and measuring the gain of a transistor as well as a number of other features using probes such as a temperature probe. The VICHY VC99 meter above is an example and costs about $40.00.

Basic function	Range
DCV	600mV/6V/60V/600V/1000V
ACV	6V/60/600/1000V
DCA	600uA/6000uA/60mA/600mA/6A/20A
ACA	600uA/6000uA/60mA/600mA/6A/20A
Capacitance	40nF/400nF/4uF/40uF/400uF/2000uF
Resistance	600Ω/6kΩ/60kΩ/600kΩ/6MΩ/60MΩ
Frequency	100Hz/1kHz/10kHz/100kHz/1MHz/60MHz

Temperature	-40°C~1000°C
	0°F~1832°F

MEASURING VOLTAGE

Most of the readings you will take with a multimeter will be VOLTAGE readings.

Before taking a reading, you should select the highest range and if the needle does not move up scale (to the right), you can select another range.

Always switch to the highest range before probing a circuit and keep your fingers away from the component being tested.

If the meter is Digital, select the highest range or use the auto-ranging feature, by selecting "V." The meter will automatically produce a result, even if the voltage is AC or DC.

If the meter is not auto-ranging, you will have to select V⎓ if the voltage is from a DC source or V~ if the voltage is from an AC source. DC means Direct Current and the voltage is coming from a battery or supply where the voltage is steady and not changing and AC means Alternating Current where the voltage is coming from a voltage that is rising and falling.

You can measure the voltage at different points in a circuit by connecting the black probe to chassis. This is the 0v reference and is commonly called "Chassis" or "Earth" or "Ground" or "0v."

The red lead is called the "measuring lead" or "measuring probe" and it can measure voltages at any point in a circuit. Sometimes there are "test points" on a circuit and these are wires or loops designed to hold the tip of the red probe (or a red probe fitted with a mini clip or mini alligator clip).

You can also measure voltages ACROSS A COMPONENT. In other words, the reading is taken in PARALLEL with the component. It may be the voltage across a transistor, resistor, capacitor, diode or coil. In most cases this voltage will be less than the supply voltage.

If you are measuring the voltage in a circuit that has a HIGH IMPEDANCE, the reading will be inaccurate, up to 90% !!!, if you use a cheap analogue meter.

Here's a simple case.

The circuit below consists of two 1M resistors in series. The voltage at the mid point will be 5v when nothing is connected to the mid point. But if we use a cheap analogue multimeter set to 10v, the resistance of the meter will be about 100k, if the meter has a sensitivity of 10k/v and the reading will be incorrect.

Here how it works:

Every meter has a sensitivity. The sensitivity of the meter is the sensitivity of the movement and is the amount of current required to deflect the needle FULL SCALE. This current is very small, normally 1/10th of a milliamp and corresponds to a sensitivity of 10k/volt (or 1/30th mA, for a sensitivity of 30k/v).

If an analogue meter is set to 10v, the internal resistance of the meter will be 100k for a 10k/v movement.

If this multimeter is used to test the following circuit, the reading will be inaccurate. The reading should be 5v as show in diagram **A**.

But the analogue multimeter has an internal resistance of 100k and it creates a circuit shown in **C**.

The top 1M and 100k from the meter create a combined PARALLEL resistance of 90k. This forms a series circuit with the lower 1M and the meter will read less than 1v

If we measure the voltage across the lower 1M, the 100k meter will form a value of resistance with the lower 1M and it will read less than 1v

If the multimeter is 30k/v, the readings will be 2v. See how easy it is to get a totally inaccurate reading.

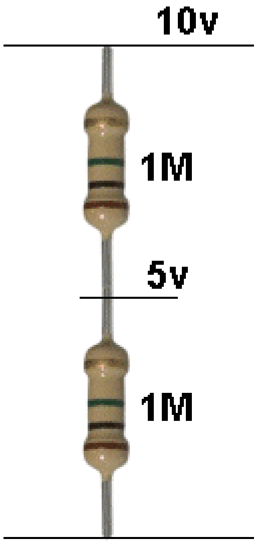

A

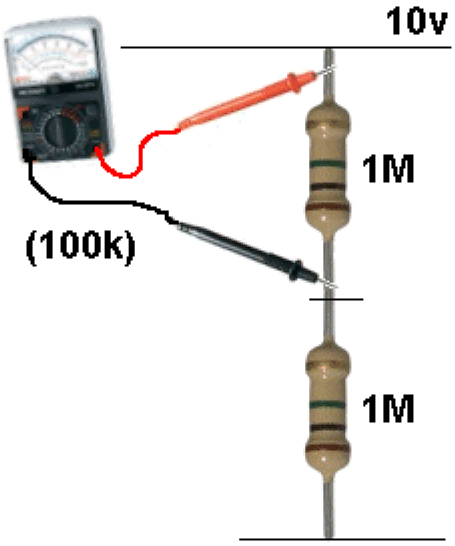

B

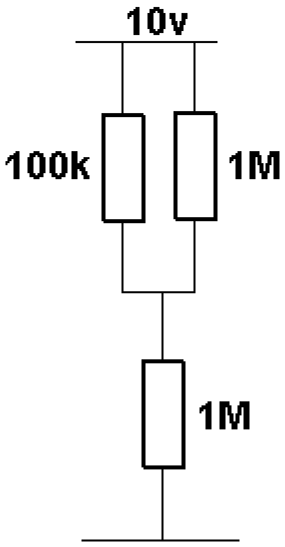

C

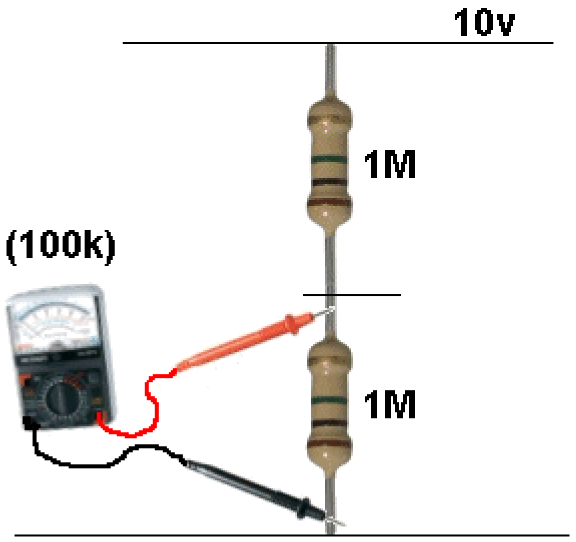

D

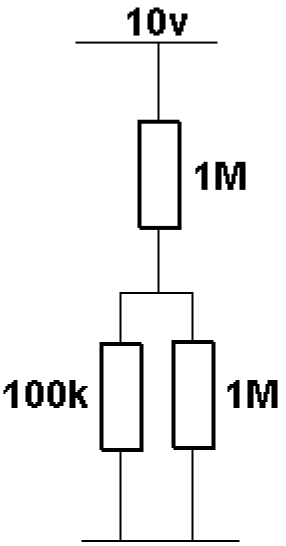

E

This introduces two new terms:
HIGH IMPEDANCE CIRCUIT and "RESISTORS in SERIES and PARALLEL."

If the reading is taken with a Digital Meter, it will be more accurate as a DMM does not take any current from the circuit (to activate the meter). In other words it has a very HIGH input impedance. Most Digital Multimeters have a fixed input resistance (impedance) of 10M - no matter what scale is selected. That's the reason for choosing a DMM for high impedance circuits. It also gives a reading that is accurate to about 1%.

MEASURING VOLTAGES IN A CIRCUIT

You can take many voltage-measurements in a circuit. You can measure "across" a component, or between any point in a circuit and either the positive rail or earth rail (0v rail). In the following circuit, the 5 most important voltage-measurements are shown. Voltage "A" is across the electret microphone. It should be between 20mV and 500mV. Voltage "B" should be about 0.6v. Voltage "C" should be about half-rail voltage. This allows the transistor to amplify both the positive and negative parts of the waveform. Voltage "D" should be about 1-3v. Voltage "E" should be the battery voltage of 12v.

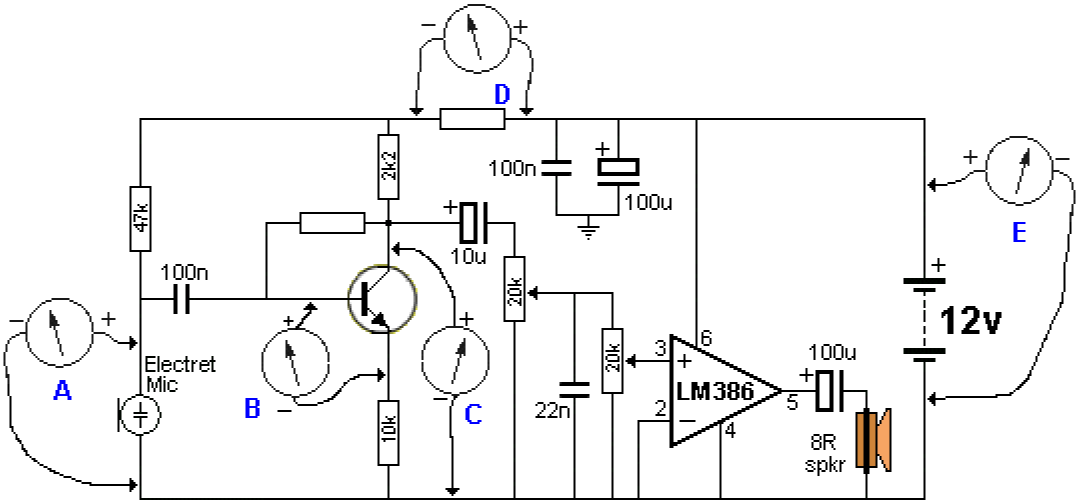

MEASURING VOLTAGES IN A CIRCUIT

MEASURING CURRENT

You will rarely need to take current measurements, however most multimeters have DC current ranges such as 0.5mA, 50mA, 500mA and 10Amp (via the extra banana socket) and some meters have AC current ranges. Measuring the current of a circuit will tell you a lot of things. If you know the normal current, a high or low current can let you know if the circuit is overloaded or not fully operational.

Current is always measured when the circuit is working (i.e: with power applied).
It is measured IN SERIES with the circuit or component under test.
The easiest way to measure current is to remove the fuse and take a reading across the fuse-holder. Or remove one lead of the battery or turn the project off, and measure across the switch.
If this is not possible, you will need to remove one end of a component and measure with the two probes in the "opening."
Resistors are the easiest things to desolder, but you may have to cut a track in some circuits. You have to get an "opening" so that a current reading can be taken.
The following diagrams show how to connect the probes to take a CURRENT reading.
Do not measure the current ACROSS a component as this will create a "short-circuit."
The component is designed to drop a certain voltage and when you place the probes across this component, you are effectively adding a "link" or "jumper" and the voltage at the left-side of the component will appear on the right-side. This voltage may be too high for the circuit being supplied and the result will be damage.

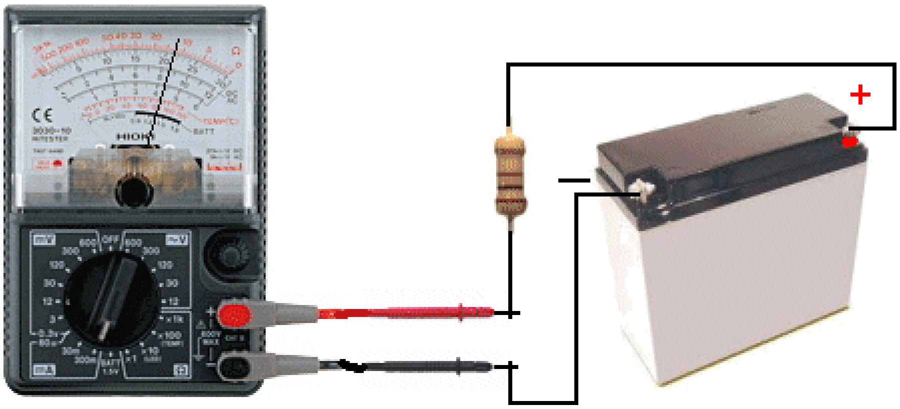

Measuring current through a resistor

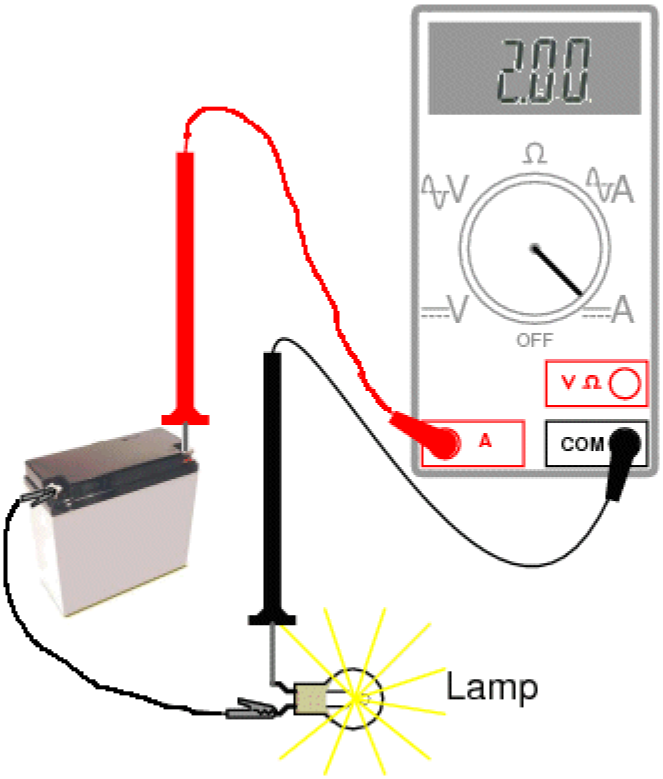

Measuring the current of a globe

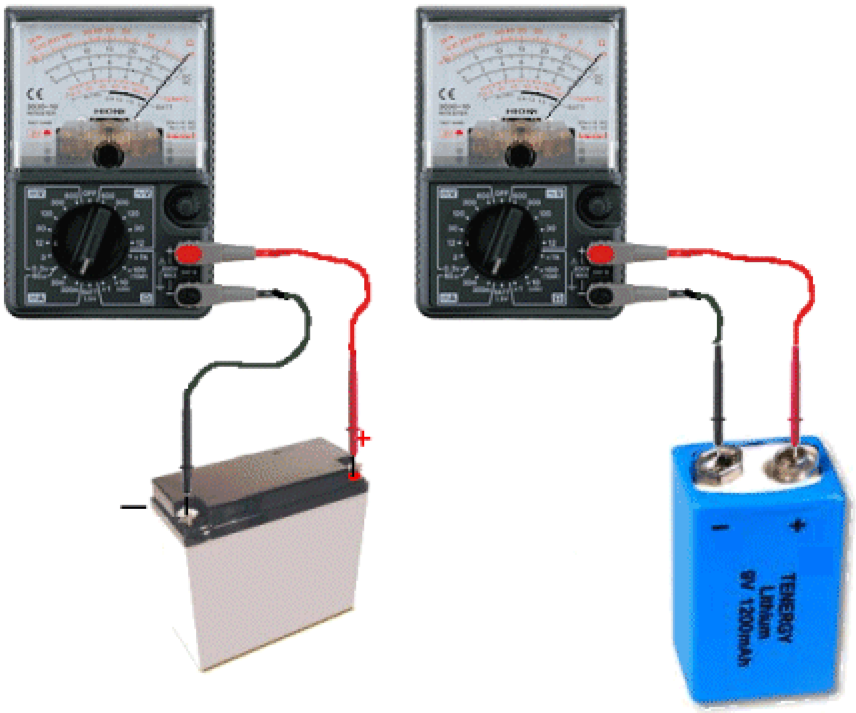

Do NOT measure the CURRENT of a battery
(by placing the meter directly across the terminals)
A battery will deliver a very HIGH current
and damage the meter

Do not measure the "current a battery will deliver" by placing the probes across the terminals. It will deliver a very high current and damage the meter instantly. There are special battery testing instruments for this purpose.
When measuring across an "opening" or "cut," place the red probe on the wire that supplies the voltage (and current) and the black probe on the other wire. This will produce a "POSITIVE" reading.

A positive reading is an UPSCALE READING and the pointer will move across the scale - to the right. A "NEGATIVE READING" will make the pointer hit the "STOP" at the left of the scale and you will not get a reading. If you are using a Digital Meter, a negative sign "-" will appear on the screen to indicate the probes are around the wrong way. No damage will be caused. It just indicates the probes are connected incorrectly.
If you want an accurate CURRENT MEASUREMENT, use a digital meter.

MEASURING RESISTANCE

Turn a circuit off before measuring resistance.
If any voltage is present, the value of resistance will be incorrect.
In most cases you cannot measure a component while it is in-circuit. This is because the meter is actually measuring a voltage across a component and calling it a "resistance." The voltage comes from the battery inside the meter. If any other voltage is present, the meter will produce a false reading.
If you are measuring the resistance of a component while still "in circuit," (with the power off) the reading will be lower than the true reading.

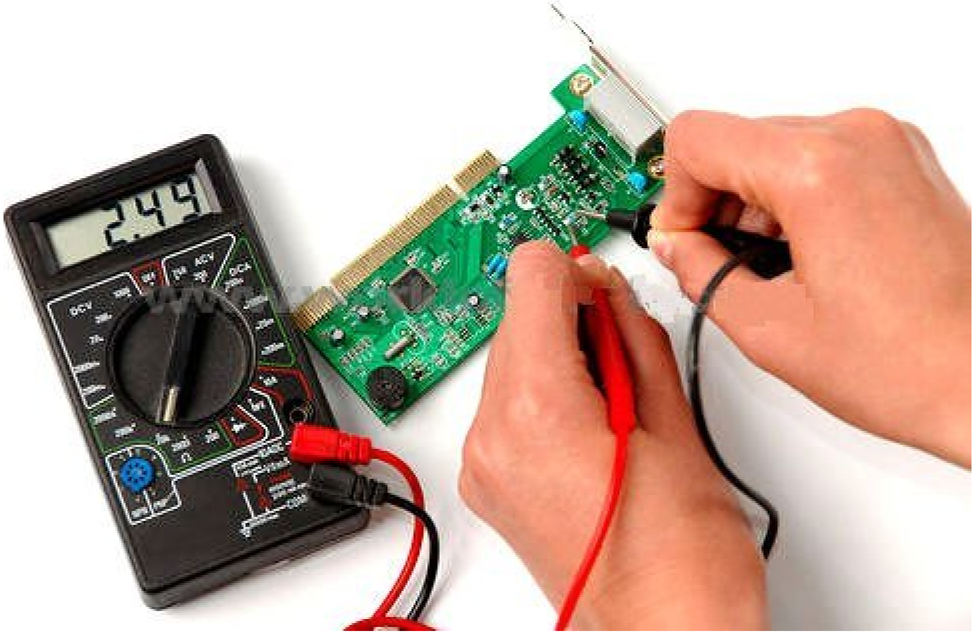

Measuring resistance

138
rolson
27259

**Measuring resistance of a heater
(via the leads)**

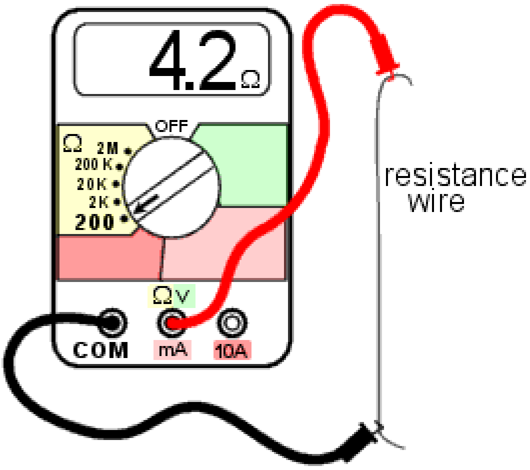
4.2 Ω
OFF
Ω
2M
200 K
20 K
2 K
200
Ω V
COM
mA
10A
resistance wire

Measuring the resistance of a piece of resistance-wire

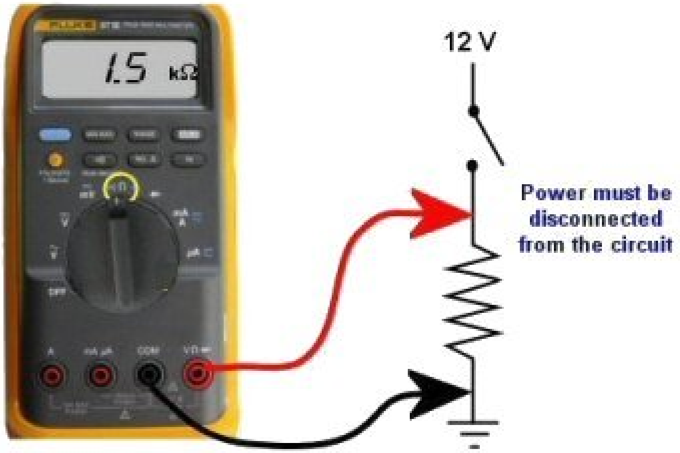

Power must be disconnected from the circuit

Measuring the resistance of a resistor

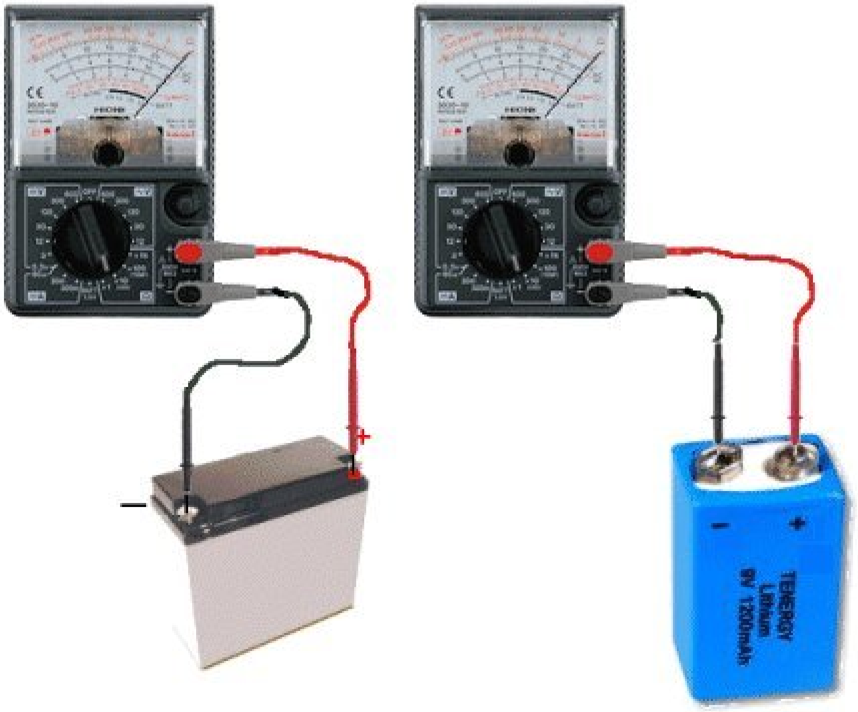
+
–
-
+
TENERGY
Lithium
9V 1200mAh

Do not measure the "Resistance of a Battery"

1. Do not measure the "resistance of a battery." The resistance of a battery (called the Internal impedance) is not measured as shown in the diagrams above. It is measured by creating a current-flow and measuring the voltage across the battery.

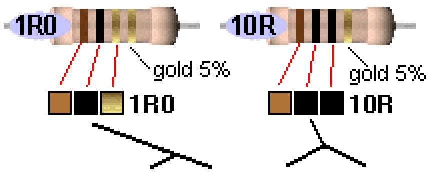

Placing a multimeter set to **resistance** (across a battery) will destroy the meter.
2. Do not try to measure the resistance of any voltage or any "supply."

Resistance is measured in OHMs.
The resistance of a 1cm x 1cm bar, one metre long is 1 ohm.
If the bar is thinner, the resistance is higher. If the bar is longer, the resistance is higher.
If the material of the bar is changed, the resistance is higher.
When carbon is mixed with other elements, its resistance increases and this knowledge is used to make RESISTORS.
Resistors have RESISTANCE and the main purpose of a resistor is to reduce the CURRENT FLOW.
It's a bit like standing on a hose. The flow reduces.
When current flow is reduced, the output voltage is also reduced and that why the water does not spray up so high. Resistors are simple devices but they produce many different effects in a circuit.
A resistor of nearly pure carbon may be 1 ohm, but when non-conducting "impurities" are added, the same-size resistor may be 100 ohms, 1,000 ohms or 1 million ohms.
Circuits use values of less than 1 ohm to more than 22 million ohms.

Resistors are identified on a circuit with numbers and letters to show the exact value of resistance - such as 1k 2k2 4M7
The letter Ω (omega - a Greek symbol) is used to identify the word "Ohm." but this symbol is not available on some word-processors, so the letter "R" is used. The letter "E" is also sometimes used and both mean "Ohms."
A one-ohm resistor is written "1R" or "1E." It can also be written "1R0" or "1E0."
A resistor of one-tenth of an ohm is written "0R1" or "0E1." The letter takes the place of the decimal point.
10 ohms = 10R
100 ohms = 100R
1,000 ohms = 1k (k= kilo = one thousand)
10,000 ohms = 10k
100,000 ohms = 100k
1,000,000 ohms = 1M (M = MEG = one million)

The size of a resistor has nothing to do with its resistance. The size determines the wattage of the resistor - how much heat it can dissipate without getting too hot.
Every resistor is identified by colour bands on the body, but when the resistor is a surface-mount device, numbers are used and sometimes letters.
You MUST learn the colour code for resistors and the following table shows all the colours for the most common resistors from 1/10th of an ohm to 22 Meg ohms for resistors with 5% and 10% tolerance.

If 3rd band is gold, Divide by 10
If 3rd band is silver, Divide by 100
(to get 0.22ohms etc)

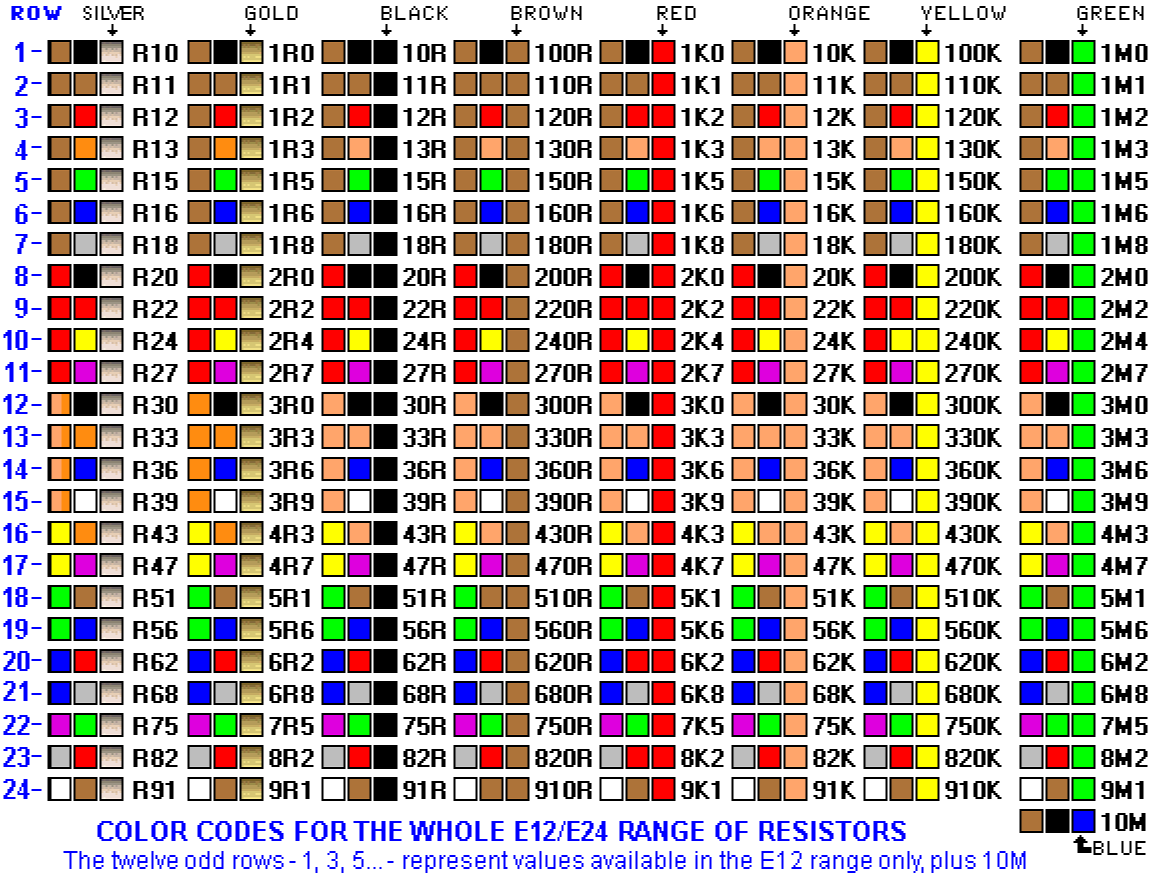

ROW	SILVER	GOLD	BLACK	BROWN	RED	ORANGE	YELLOW	GREEN
1-	R10	1R0	10R	100R	1K0	10K	100K	1M0
2-	R11	1R1	11R	110R	1K1	11K	110K	1M1
3-	R12	1R2	12R	120R	1K2	12K	120K	1M2
4-	R13	1R3	13R	130R	1K3	13K	130K	1M3
5-	R15	1R5	15R	150R	1K5	15K	150K	1M5
6-	R16	1R6	16R	160R	1K6	16K	160K	1M6
7-	R18	1R8	18R	180R	1K8	18K	180K	1M8
8-	R20	2R0	20R	200R	2K0	20K	200K	2M0
9-	R22	2R2	22R	220R	2K2	22K	220K	2M2
10-	R24	2R4	24R	240R	2K4	24K	240K	2M4
11-	R27	2R7	27R	270R	2K7	27K	270K	2M7
12-	R30	3R0	30R	300R	3K0	30K	300K	3M0
13-	R33	3R3	33R	330R	3K3	33K	330K	3M3
14-	R36	3R6	36R	360R	3K6	36K	360K	3M6
15-	R39	3R9	39R	390R	3K9	39K	390K	3M9
16-	R43	4R3	43R	430R	4K3	43K	430K	4M3
17-	R47	4R7	47R	470R	4K7	47K	470K	4M7
18-	R51	5R1	51R	510R	5K1	51K	510K	5M1
19-	R56	5R6	56R	560R	5K6	56K	560K	5M6
20-	R62	6R2	62R	620R	6K2	62K	620K	6M2
21-	R68	6R8	68R	680R	6K8	68K	680K	6M8
22-	R75	7R5	75R	750R	7K5	75K	750K	7M5
23-	R82	8R2	82R	820R	8K2	82K	820K	8M2
24-	R91	9R1	91R	910R	9K1	91K	910K	9M1
								10M BLUE

COLOR CODES FOR THE WHOLE E12/E24 RANGE OF RESISTORS

The twelve odd rows - 1, 3, 5... - represent values available in the E12 range only, plus 10M

Reading 4-band resistors

The most "common" type of resistor has 4 bands and is called the 10% resistor. It now has a tolerance of 5% but is still called the "10% type" as the colours increase by 20% so that a resistor can be 10% higher or 10% lower than a particular value and all the resistors produced in a batch can be used.

The first 3 bands produce the resistance and the fourth band is the "tolerance" band.

Gold = 5%

(Silver =10% but no modern resistors are 10%!! - they are 5% 2% or 1%)

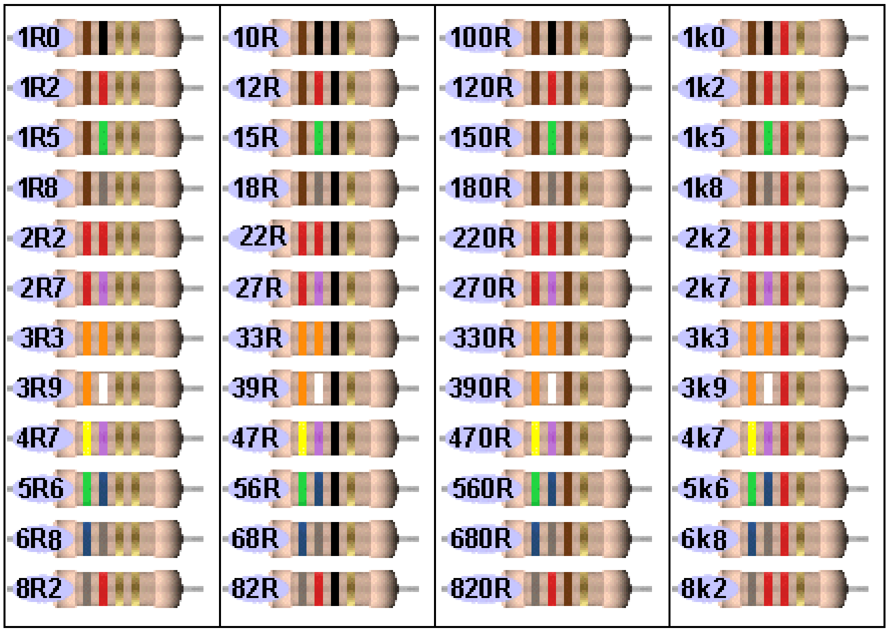
1R0
10R
100R
1k0
1R2
12R
120R
1k2
1R5
15R
150R
1k5
1R8
18R
180R
1k8
2R2
22R
220R
2k2
2R7
27R
270R
2k7
3R3
33R
330R
3k3
3R9
39R
390R
3k9
4R7
47R
470R
4k7
5R6
56R
560R
5k6
6R8
68R
680R
6k8
8R2
82R
820R
8k2

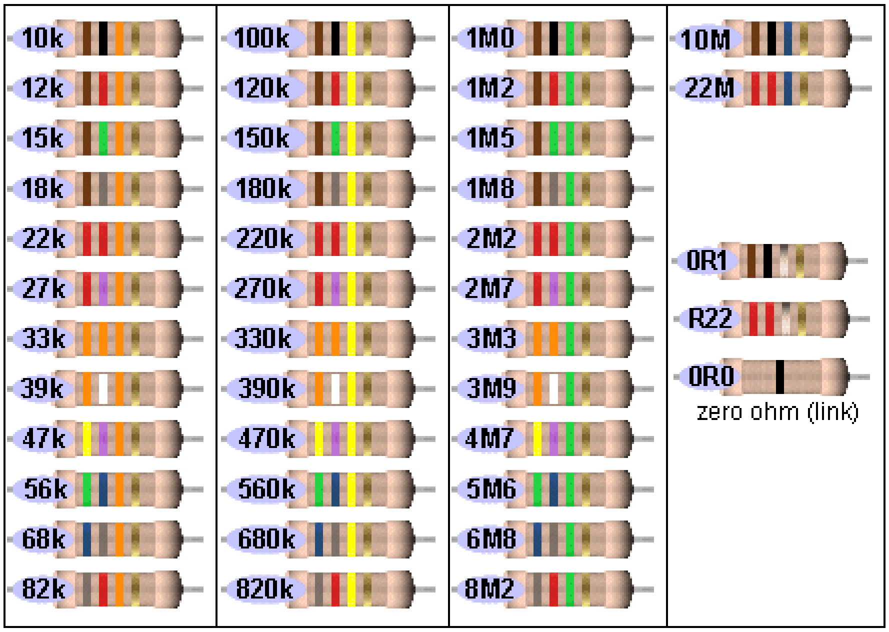
10k
12k
15k
18k
22k
27k
33k
39k
47k
56k
68k
82k
100k
120k
150k
180k
220k
270k
330k
390k
470k
560k
680k
820k
1M0
1M2
1M5
1M8
2M2
2M7
3M3
3M9
4M7
5M6
6M8
8M2
10M
22M
0R1
R22
0R0
zero ohm (link)

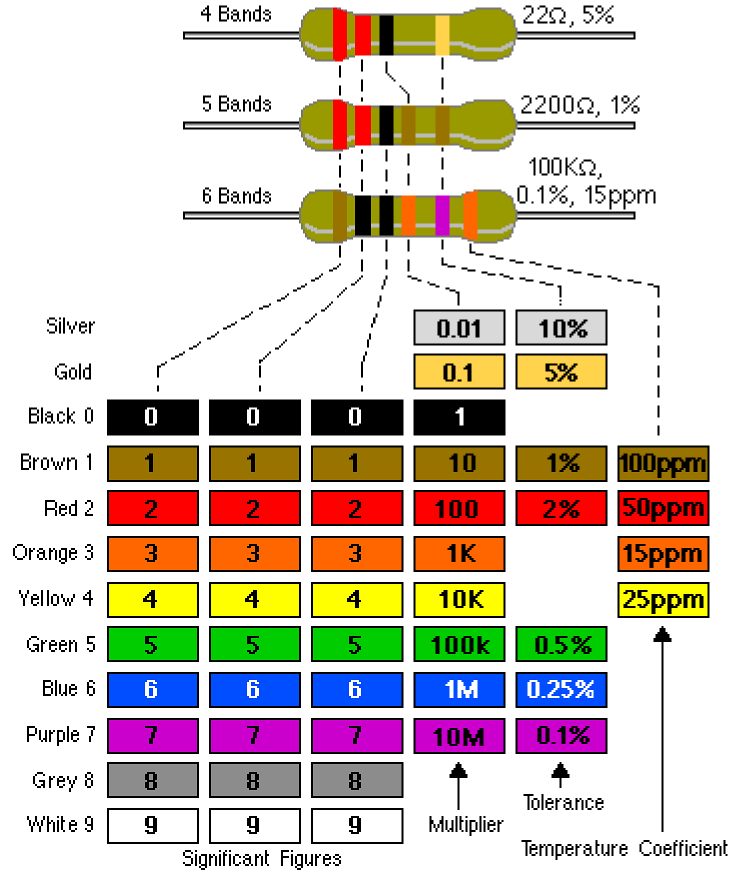
4 Bands
22Ω, 5%
5 Bands
2200Ω, 1%
6 Bands
100KΩ,
0.1%, 15ppm

Silver				0.01	10%	
Gold				0.1	5%	
Black 0	0	0	0	1		
Brown 1	1	1	1	10	1%	100ppm
Red 2	2	2	2	100	2%	50ppm
Orange 3	3	3	3	1K		15ppm
Yellow 4	4	4	4	10K		25ppm
Green 5	5	5	5	100k	0.5%	
Blue 6	6	6	6	1M	0.25%	
Purple 7	7	7	7	10M	0.1%	
Grey 8	8	8	8			
White 9	9	9	9			
	Significant Figures			Multiplier	Tolerance	Temperature Coefficient

Resistor Color Code System

Here is another well-designed resistor colour code chart:

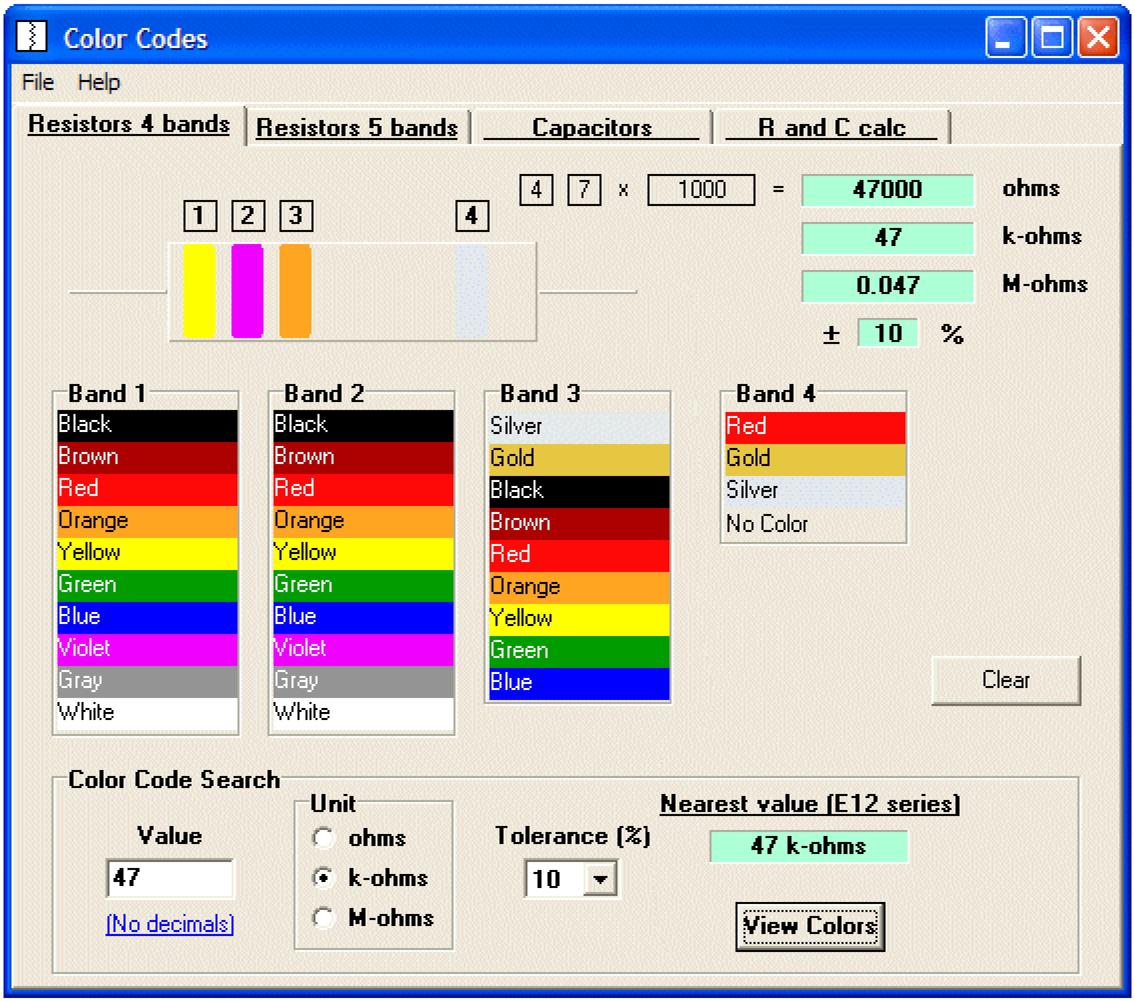
Color Codes
File
Help
Resistors 4 bands
Resistors 5 bands
Capacitors
R and C calc
1
2
3
4
Band 1
Black
Brown
Red
Orange
Yellow
Green
Blue
Violet
Gray
White
Band 2
Black
Brown
Red
Orange
Yellow
Green
Blue
Violet
Gray
White
Band 3
Silver
Gold
Black
Brown
Red
Orange
Yellow
Green
Blue
Band 4
Red
Gold
Silver
No Color
Clear
Color Code Search
(No decimals)
View Colors

4 7 × 1000 = 47000 ohms
47 k-ohms
0.047 M-ohms
± 10 %

Value: 47
Unit: ○ ohms ● k-ohms ○ M-ohms
Tolerance (%): 10
Nearest value (E12 series): 47 k-ohms

Download the program and save it on your desk-top for future reference:
ColourCode.exe (520KB)
ColourCode.zip (230KB)
ColourCode.rar (180KB)

RESISTORS LESS THAN 10 OHMS

When the **third** band is gold, it indicates the value of the "colors" must be divided by 10.
Gold = "divide by 10" to get values 1R0 to 8R2
When the **third** band is silver, it indicates the value of the "colors" must be divided by 100. (Remember: more letters in the word "silver" thus the divisor is "a larger division.")
Silver = "divide by 100" to get values R1 to R82
e.g: 0R1 = 0.1 ohm 0R22 = point 22 ohms
See 4th Column above for examples.

The letters "R, k and M" take the place of a decimal point.
e.g: 1**R**0 = 1 ohm 2**R**2 = 2 point 2 ohms 22**R** = 22 ohms
2**k**2 = 2,200 ohms 100**k** = 100,000 ohms
2**M**2 = 2,200,000 ohms

HOW TO REMEMBER THE COLOUR CODE:

Each colour has a "number" (or divisor) corresponding to it.
Most of the colours are in the same order as in the spectrum. You can see the spectrum in a rainbow. It is: ROY G BIV and the colours for resistors are in the same sequence.

black
brown - colour of increasing temperature

red
orange
yellow
green
blue
(indigo - that part of the spectrum between blue and violet)
violet
gray
white

colour	**value**	No of zero's
silver	-2	divide by 100
gold	-1	divide by 10
black	0	No zeros
brown	1	0
red	2	00
orange	3	,000 or k
yellow	4	0,000
green	5	00,000
blue	6	M
violet	7	
gray	8	
white	9	

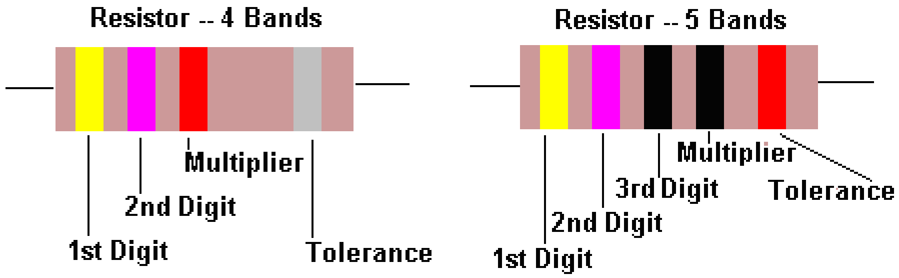
Resistor -- 4 Bands
Multiplier
2nd Digit
1st Digit
Tolerance
Resistor -- 5 Bands
Multiplier
3rd Digit
Tolerance
2nd Digit
1st Digit

Band Color	Digit	Multiplier	Tolerance
Black	⬛ 0	1	---
Brown	🟫 1	10	±1%
Red	🟥 2	100	±2%
Orange	🟧 3	1,000	±3%
Yellow	🟨 4	10,000	±4%
Green	🟩 5	100,000	---
Blue	🟦 6	1,000,000	---
Violet	🟪 7	10,000,000	---
Gray	◼ 8	100,000,000	---
White	⬜ 9	---	---
Gold	▨ ---	0.1	±5%
Silver	▨ ---	0.01	±10%
None	---	---	±20%

Here are some common ways to remember the colour code:

Bad Beer Rots Our Young Guts, But Vodka Goes Well
Bright Boys Rave Over Young Girls But Violet Gets Wed
Bad Boys Rave Over Young Girls But Violet Gets Wed with Gold and Silver.

Reading 5-band resistors:

5-band resistors are easy to read if you remember two simple points. The first three bands provide the digits in the answer and the 4th band supplies the number of zero's.

Reading "STANDARD VALUES" (**on 5-band resistors**)

5-band resistors are also made in "Standard Values" but will have different colours to 4-band "common" resistors - and will be confusing if you are just starting out. For instance, a 47k 5% resistor with 4-bands will be: yellow-purple-orange-gold. For a 47k 1% resistor the colours will be yellow-purple-black-red-brown. The brown colour-band represents 1%.
The first two colour-bands for a STANDARD VALUE or "common value" in 1% or 5% will be the SAME. These two bands provide the digits in the answer.
It's the 3rd band for a 5% resistor that is expanded into two bands in a 1% resistor. But it's easy to follow.
For a standard value, the 3rd band in a 1% resistor is BLACK. This represents a ZERO in the answer. (For 5-band resistors BLACK represents a ZERO when in the third band. This is different to 4-band resistors where black represents the word OHMS! If the third band is BROWN, the answer will be 1).
So the 4th band has to represent one-less ZERO and is one colour UP THE COLOUR CHART! In other words the 3rd and 4th bands (combined) on a 1% resistor produces the same number of zero's as the 3rd band on a 5% resistor!

Resistors come in a range of values and the two most common are the E12 and E24 series. The E12 series comes in twelve values for each decade. The E24 series comes in twenty-four values per decade.

E12 series - 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82

E24 series - 10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91

Here is the complete list of 1% 1/4watt resistors from:
CIRCUIT SPECIALISTS. The following list covers 10 ohms (10R) to 1M.
To buy 1% resistors from Circuit Specialists, click: HERE.

10R
12R1
15R
18R2
22R1
27R4
30R1
33R2
36R5
39R2
47R5
49R9
51R1
56R2
68R1
75R
82R5
90R9
100R
121R
150R
182R
200R
221R
240R
249R
274R
301R
332R
348R
392R
402R
475R
499R
565R
604R
681R
750R
806R
825R
909R
1k0
1k21
1k5
1k82
2k
2k21
2k2
2k43
2k49
2k67
2k74
3k01
3k32
3k48
3k57
3k74
3k83
3k92
4k02
4k22
4k64
4k75
4k7
4k87
4k99
5k11
5k23
5k36
5k49
5k62
5k76
5k9
6k04
6k19
6k81
7k15
7k5
7k87
71k5
8k06
8k25
8k45
8k66
8k87
9k09
9k31
9k53
9k76
10k
11k
12k
12k1
12k4
13k
14k7
15k
15k8
16k9
17k4
17k8
18k2
20k
22k1
22k6
23k7
24k9
27k4
29k4
30k1
33k2
34k8
36k5
38k3
39k2
40k2
44k2
46k4
47k
47k5
49k9
51k1
53k6
56k2
61k9
68k1
69k8
75k0
82k5
90k
90k9
95k3
100k
121k
147k
150k
182k
200k
212k
221k
226k
249k
274k
301k
332k
357k
392k
475k
487k
499k
562k
604k
1M

Here is the list of 1% resistors from suppliers (such as Farnell):

1R0
1R2
1R5
2R2
2R7
3R3
3R9
4R7
5R6
6R2
6R8
7R5
8R2
9R1
10R
11R
12R
13R
15R
16R
18R
20R
22R
24R
27R
30R
33R
36R
39R
43R
47R
51R
56R
62R
68R
75R
82R
91R
100R
110R
120R
130R
150R
160R
180R
200R
220R
240R
270R
300R
330R
360R
390R
430R
470R
510R
560R
620R
680R
750R
820R
910R
1k
1k1
1k2
1k3
1k5
1k6
1k8
2k0
2k2
2k4
2k7
3k
3k3
3k6
3k9
4k3
4k7
5k1
5k6
6k2
6k8
7k5
8k2
9k1
10k
11k
12k
13k
15k
16k
18k
20k
22k
24k
27k
30k
33k
36k
39k
43k
47k
51k
56k
62k
68k
75k
82k
91k
100k
110k
120k
130k
150k
160k
180k
200k
220k
240k
270k
300k
330k
360k
390k
430k
470k
510k
560k
620k
680k
750k
820k
910k
1M

Surface Mount Resistors

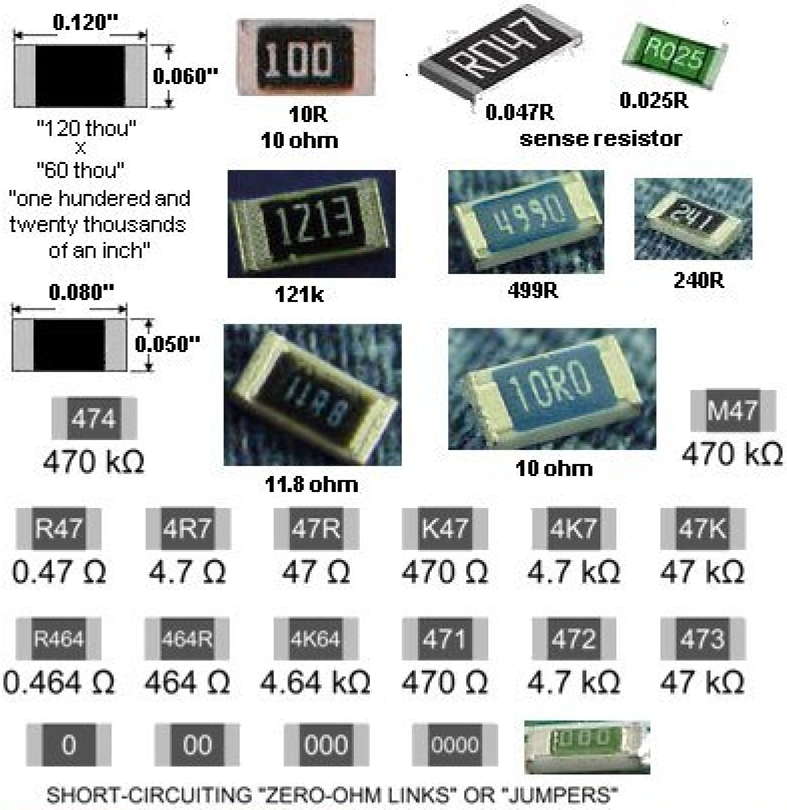
0.120"
0.060"
"120 thou"
x
"60 thou"
"one hundred and twenty thousands of an inch"
100
10R
10 ohm
R047
0.047R
R025
0.025R
sense resistor
1213
121k
4990
499R
241
240R
0.080"
0.050"
474
470 kΩ
11R8
11.8 ohm
10R0
10 ohm
M47
470 kΩ
R47
0.47 Ω
4R7
4.7 Ω
47R
47 Ω
K47
470 Ω
4K7
4.7 kΩ
47K
47 kΩ
R464
0.464 Ω
464R
464 Ω
4K64
4.64 kΩ
471
470 Ω
472
4.7 kΩ
473
47 kΩ
0
00
000
0000
SHORT-CIRCUITING "ZERO-OHM LINKS" OR "JUMPERS"

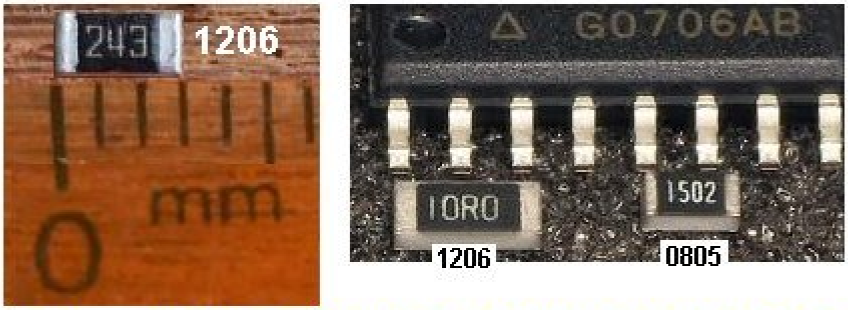
243
1206
0
mm
G0706AB
10R0
1206
1502
0805

1206 and 0805 SURFACE MOUNT RESISTORS

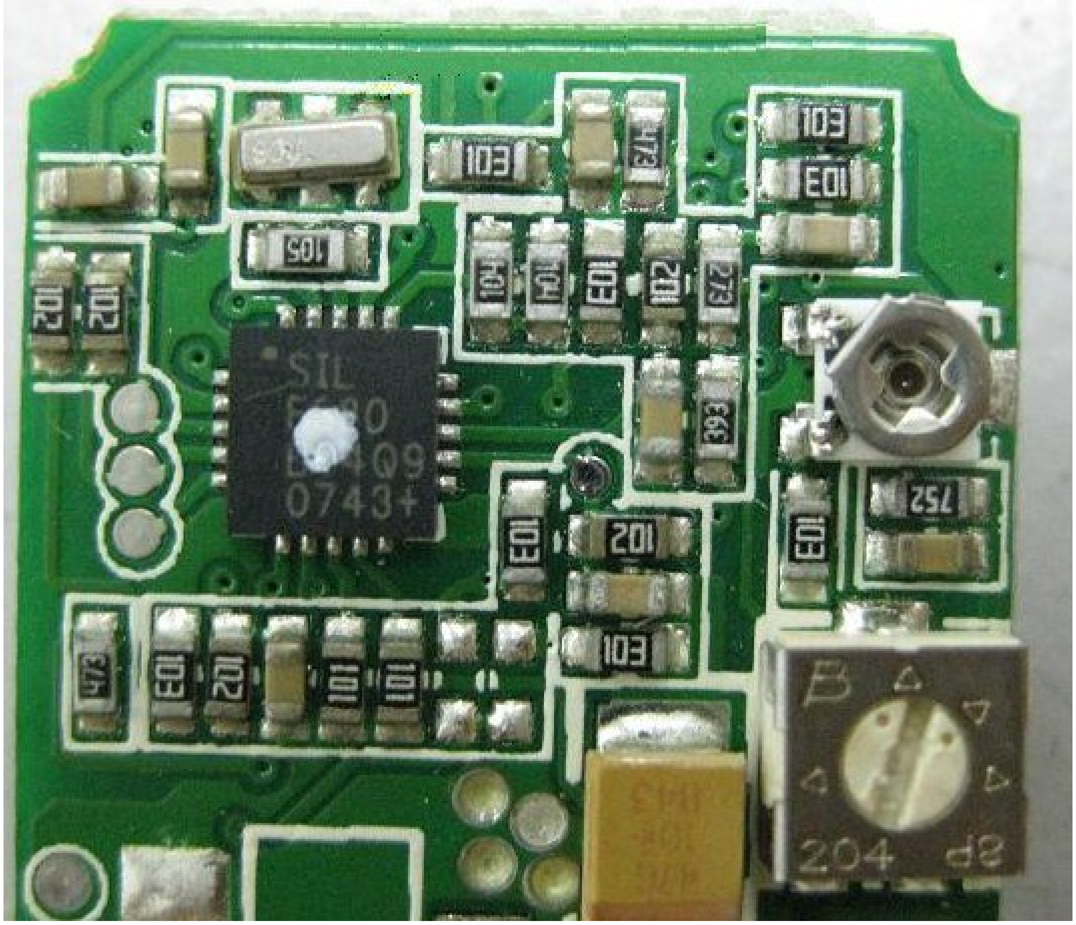

3-digit Surface Mount resistors on a PC board

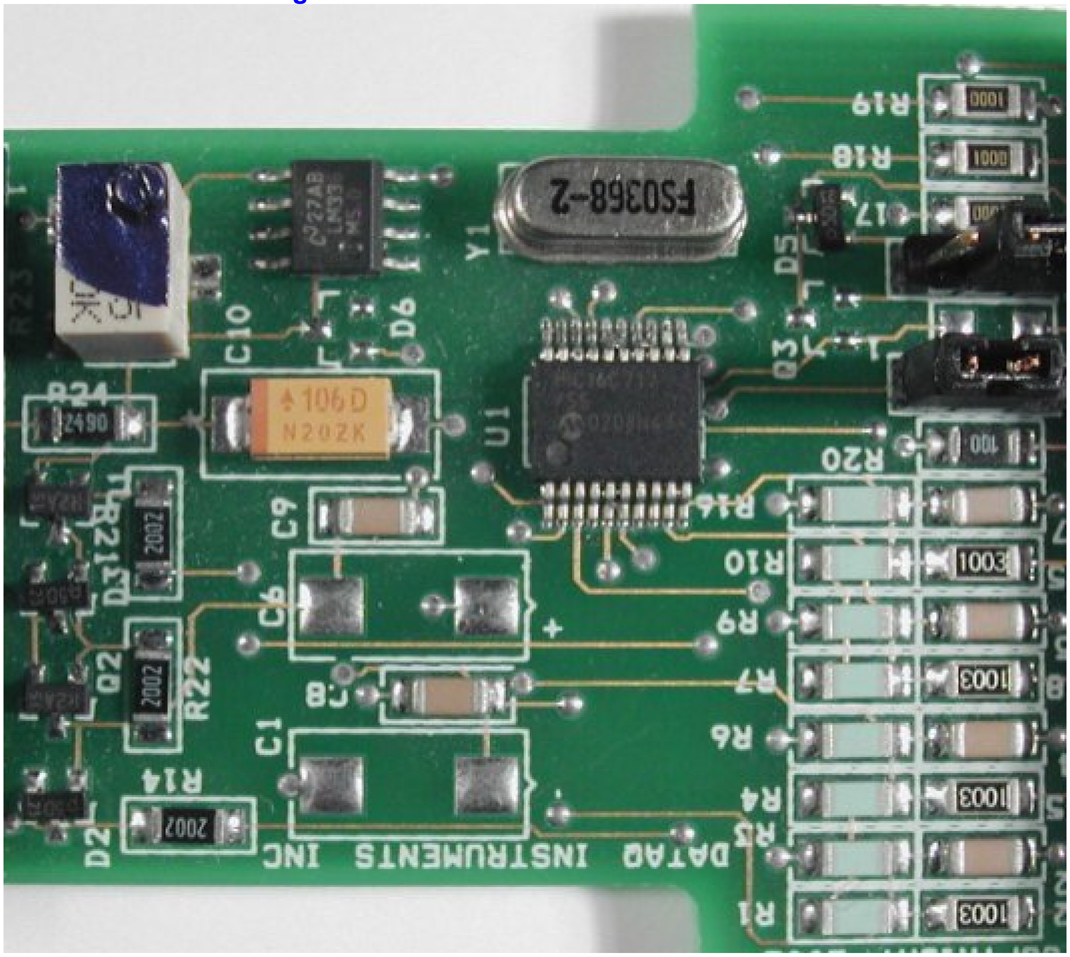

4-digit Surface Mount resistors on a PC board

The photo above shows surface mount resistors on a circuit board. The components

that are not marked are capacitors (capacitors are NEVER marked).
All the SM resistors in the above photos conform to a 3-digit or 4-digit code. But there are a number of codes, and the 4-digit code caters for high tolerance resistors, so it's getting very complicated.
Here is a basic 3-digit SM resistor:

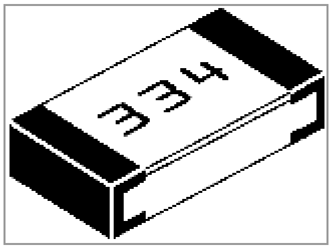

A 330k SM resistor

The first two digits represent the two digits in the answer. The third digit represents the number of zero's you must place after the two digits. The answer will be OHMS. For example: 334 is written 33 0 000. This is written 330,000 ohms. The comma can be replaced by the letter "k". The final answer is: 330k.
222 = 22 00 = 2,200 = 2k2
473 = 47 000 = 47,000 = 47k
474 = 47 0000 = 470,000 = 470k
105 = 10 00000 = 1,000,000 = 1M = one million ohms
There is one trick you have to remember. Resistances less than 100 ohms are written: 100, 220, 470. These are 10 and NO zero's = 10 ohms = 10R
or 22 and no zero's = 22R or 47 and no zero's = 47R. Sometimes the resistor is marked: 10, 22 and 47 to prevent a mistake.

Remember:
R = ohms
k = kilo ohms = 1,000 ohms
M = Meg = 1,000,000 ohms
The 3 letters (R, k and M) are put in place of the decimal point. This way you cannot make a mistake when reading a value of resistance.

Surface Mount **CURRENT SENSING** Resistors

Many new types of CURRENT SENSING surface-mount resistors are appearing on the market and these are creating lots of new problems.
Fortunately all resistors are marked with the value of resistance and these resistors are identified in MILLIOHMS. A miili ohm is one thousandth or an ohm and is written 0.001 when writing a normal mathematical number.
When written on a surface mount resistor, the letter R indicates the decimal point and it also signifies the word "OHM" or "OHMS" and one milli-ohm is written R001
Five miiliohms is R005 and one hundred milliohms is R100
Some surface mount resistors have the letter "M" after the value to indicate the resistor has a rating of 1 watt. e.g: R100M These surface-mount resistors are specially-made to withstand a high temperature and a surface-mount resistor of the same size is normally 250mW or less.
These current-sensing resistors can get extremely hot and the PC board can become burnt or damaged.
When designing a PC board, make the lands very large to dissipate the heat.
Normally a current sensing resistor is below one ohm (1R0) and it is easy to identify them as R100 etc.
You cannot measure the value of a current sensing resistor as the leads of a multimeter have a higher resistance than the resistor and few multimeters can read values below one ohm.
If the value is not visible, you will have to refer to the circuit.
Before replacing it, work out why it failed.
Generally it gets too hot. Use a larger size and add tiny heatsinks on each end.
Here are some surface=mount current-sense resistors:

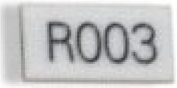

3 milli-ohm

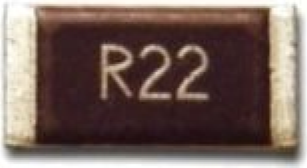

220 milli-ohm

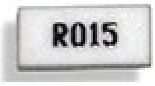

15 milli-ohm

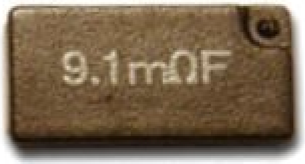

9 point 1 milli-ohm

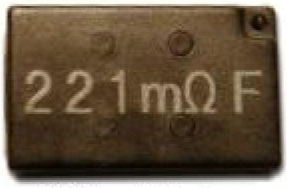

220 milli-ohm

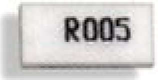

5 milli-ohm

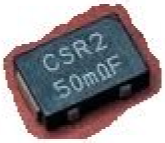

50 milli-ohm 1%

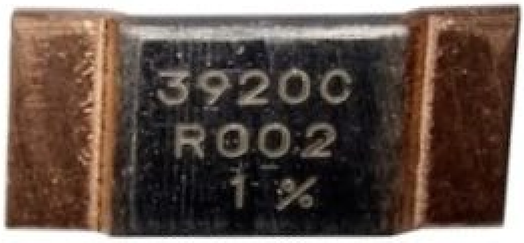
39200
R002
1 %

2 milli-ohm

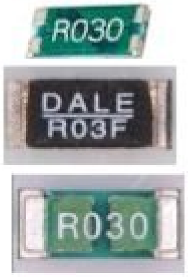
R030
DALE
R03F
R030

30 milli-ohm

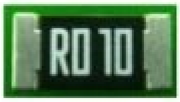

10 milli-ohm

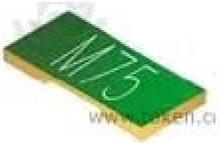

1-watt   ????

THE COMPLETE RANGE OF SM RESISTOR MARKINGS

Click to see the complete range of SM resistor markings for 3-digit code:

Click to see the complete range of SM resistor markings for 4-digit code:

0000 is a value on a surface-mount resistor. It is a zero-ohm **LINK**!
Resistances less than 10 ohms have 'R' to indicate the position of the decimal point.
Here are some examples:

Three Digit Examples	Four Digit Examples
330 is 33 ohms ***- not 330 ohms***	**1000 is 100 ohms** ***- not 1000 ohms***
221 is 220 ohms	**4992 is 49 900 ohms, or 49k9**
683 is 68 000 ohms, or 68k	**1623 is 162 000 ohms, or 162k**
105 is 1 000 000 ohms, or 1M	**0R56 or R56 is 0.56 ohms**
8R2 is 8.2 ohms	

A new coding system has appeared on **1% types**. This is known as the EIA-96 marking method. It consists of a three-character code. The first two digits signify the 3 significant digits of the resistor value, using the lookup table below. The third character - a letter - signifies the multiplier.

code	value	code	value	code	value	code	value	code	value	code	value
01	100	**17**	147	**33**	215	**49**	316	**65**	464	**81**	681
02	102	**18**	150	**34**	221	**50**	324	**66**	475	**82**	698
03	105	**19**	154	**35**	226	**51**	332	**67**	487	**83**	715
04	107	**20**	158	**36**	232	**52**	340	**68**	499	**84**	732
05	110	**21**	162	**37**	237	**53**	348	**69**	511	**85**	750
06	113	**22**	165	**38**	243	**54**	357	**70**	523	**86**	768
07	115	**23**	169	**39**	249	**55**	365	**71**	536	**87**	787
08	118	**24**	174	**40**	255	**56**	374	**72**	549	**88**	806
09	121	**25**	178	**41**	261	**57**	383	**73**	562	**89**	825
10	124	**26**	182	**42**	267	**58**	392	**74**	576	**90**	845
11	127	**27**	187	**43**	274	**59**	402	**75**	590	**91**	866
12	130	**28**	191	**44**	280	**60**	412	**76**	604	**92**	887
13	133	**29**	196	**45**	287	**61**	422	**77**	619	**93**	909
14	137	**30**	200	**46**	294	**62**	432	**78**	634	**94**	931
15	140	**31**	205	**47**	301	**63**	442	**79**	649	**95**	953
16	143	**32**	210	**48**	309	**64**	453	**80**	665	**96**	976

The **multiplier** letters are as follows:

letter	mult	letter	mult
F	**100000**	**B**	**10**
E	**10000**	**A**	**1**
D	**1000**	**X or S**	**0.1**
C	**100**	**Y or R**	**0.01**

22A is a 165 ohm resistor, **68C** is a 49900 ohm (49k9) and **43E** a 2740000 (2M74). This marking scheme applies to 1% resistors only.

A similar arrangement can be used for **2% and 5%** tolerance types. The multiplier letters are identical to 1% ones, but occur **before** the number code and the following **code** is used:

2%				**5%**			
code	**value**	**code**	**value**	**code**	**value**	**code**	**value**
01	100	**13**	330	**25**	100	**37**	330
02	110	**14**	360	**26**	110	**38**	360
03	120	**15**	390	**27**	120	**39**	390
04	130	**16**	430	**28**	130	**40**	430
05	150	**17**	470	**29**	150	**41**	470
06	160	**18**	510	**30**	160	**42**	510
07	180	**19**	560	**31**	180	**43**	560

08	200	**20**	620	**32**	200	**44**	620
09	220	**21**	680	**33**	220	**45**	680
10	240	**22**	750	**34**	240	**46**	750
11	270	**23**	820	**35**	270	**47**	820
12	300	**24**	910	**36**	300	**48**	910

With this arrangement, **C31** is 5%, 18000 ohm (18k), and **D18** is 510000 ohms (510k) 2% tolerance.
Always check with an ohm-meter (a multimeter) to make sure.

Chip resistors come in the following styles and ratings:
Style: 0402, 0603, 0805, 1206, 1210, 2010, 2512, 3616, 4022
Power Rating: 0402(1/16W), 0603(1/10W), 0805(1/8W), 1206(1/4W), 1210(1/3W), 2010(3/4W), 2512(1W), 3616(2W), 4022(3W)
Tolerance: 0.1%, 0.5%, 1%, 5%
Temperature Coefficient: 25ppm 50ppm 100ppm

EIA marking code for surface mount (SMD) resistors

01S = 1R	01R = 10R	01A = 100R	01B = 1k	01C = 10k	01D = 100k	01E = 1M	01F = 10M
02S = 1R02	02R = 10R2	02A = 102R	02B = 1k02	02C = 10k2	02D = 102k	02E = 1M02	
03S = 1R05	03R = 10R5	03A = 105R	03B = 1k05	03C = 10k5	03D = 105k	03E = 1M05	18F = 15M
04S = 1R07	04R = 10R7	04A = 107R	04B = 1k07	04C = 10k7	04D = 107k	04E = 1M07	
05S = 1R1	05R = 11R	05A = 110R	05B = 1k1	05C = 11k	05D = 110k	05E = 1M1	30F = 20M
06S = 1R13	06R = 11R3	06A = 113R	06B = 1k13	06C = 11k3	06D = 113k	06E = 1M13	
07S = 1R15	07R = 11R5	07A = 115R	07B = 1k15	07C = 11k5	07D = 115k	07E = 1M15	
08S = 1R18	08R = 11R8	08A = 118R	08B = 1k18	08C = 11k8	08D = 118k	08E = 1M18	
09S = 1R21	09R = 12R1	09A = 121R	09B = 1k21	09C = 12k1	09D = 121k	09E = 1M21	
10S = 1R24	10R = 12R4	10A = 124R	10B = 1k24	10C = 12k4	10D = 124k	10E = 1M24	
11S = 1R27	11R = 12R7	11A = 127R	11B = 1k27	11C = 12k7	11D = 127k	11E = 1M27	
12S = 1R3	12R = 13R	12A = 130R	12B = 1k3	12C = 13k	12D = 130k	12E = 1M3	
13S = 1R33	13R = 13R3	13A = 133R	13B = 1k33	13C = 13k3	13D = 133k	13E = 1M33	
14S = 1R37	14R = 13R7	14A = 137R	14B = 1k37	14C = 13k7	14D = 137k	14E = 1M37	
15S = 1R4	15R = 14R	15A = 140R	15B = 1k4	15C = 14k	15D = 140k	15E = 1M4	
16S = 1R43	16R = 14R3	16A = 143R	16B = 1k43	16C = 14k3	16D = 143k	16E = 1M43	
17S = 1R47	17R = 14R7	17A = 147R	17B = 1k47	17C = 14k7	17D = 147k	17E = 1M47	
18S = 1R5	18R = 15R	18A = 150R	18B = 1k5	18C = 15k	18D = 15k	18E = 1M5	
19S = 1R54	19R = 15R4	19A = 154R	19B = 1k54	19C = 15k4	19D = 154k	19E = 1M54	
20S = 1R58	20R = 15R8	20A = 158R	20B = 1k58	20C = 15k8	20D = 158k	20E = 1M58	
21S = 1R62	21R = 16R2	21A = 162R	21B = 1k62	21C = 16k2	21D = 162k	21E = 1M62	
22S = 1R65	22R = 16R5	22A = 165R	22B = 1k65	22C = 16k5	22D = 165k	22E = 1M65	
23S = 1R69	23R = 16R9	23A = 169R	23B = 1k69	23C = 16k9	23D = 169k	23E = 1M69	
24S = 1R74	24R = 17R4	24A = 174R	24B = 1k74	24C = 17k4	24D = 174k	24E = 1M74	
25S = 1R78	25R = 17R8	25A = 178R	25B = 1k78	25C = 17k8	25D = 178k	25E = 1M78	
26S = 1R82	26R = 18R2	26A = 182R	26B = 1k82	26C = 18k2	26D = 182k	26E = 1M82	
27S = 1R87	27R = 18R7	27A = 187R	27B = 1k87	27C = 18k7	27D = 187k	27E = 1M87	
28S = 1R91	28R = 19R1	28A = 191R	28B = 1k91	28C = 19k1	28D = 191k	28E = 1M91	
29S = 1R96	29R = 19R6	29A = 196R	29B = 1k96	29C = 19k6	29D = 196k	29E = 1M96	
30S = 2R0	30R = 20R0	30A = 200R	30B = 2k0	30C = 20k0	30D = 200k	30E = 2M0	
31S = 2R05	31R = 20R5	31A = 205R	31B = 2k05	31C = 20k5	31D = 205k	31E = 2M05	
32S = 2R10	32R = 21R0	32A = 210R	32B = 2k10	32C = 21k0	32D = 210k	32E = 2M10	
33S = 2R15	33R = 21R5	33A = 215R	33B = 2k15	33C = 21k5	33D = 215k	33E = 2M15	
34S = 2R21	34R = 22R1	34A = 221R	34B = 2k21	34C = 22k1	34D = 221k	34E = 2M21	
35S = 2R26	35R = 22R6	35A = 226R	35B = 2k26	35C = 22k6	35D = 226k	35E = 2M26	
36S = 2R32	36R = 23R2	36A = 232R	36B = 2k32	36C = 23k2	36D = 232k	36E = 2M32	
37S = 2R37	37R = 23R7	37A = 237R	37B = 2k37	37C = 23k7	37D = 237k	37E = 2M37	
38S = 2R43	38R = 24R3	38A = 243R	38B = 2k43	38C = 24k3	38D = 243k	38E = 2M43	
39S = 2R49	39R = 24R9	39A = 249R	39B = 2k49	39C = 24k9	39D = 249k	39E = 2M49	
40S = 2R55	40R = 25R5	40A = 255R	40B = 2k55	40C = 25k5	40D = 255k	40E = 2M55	
41S = 2R61	41R = 26R1	41A = 261R	41B = 2k61	41C = 26k1	41D = 261k	41E = 2M61	
42S = 2R67	42R = 26R7	42A = 267R	42B = 2k67	42C = 26k7	42D = 267k	42E = 2M67	
43S = 2R74	43R = 27R4	43A = 274R	43B = 2k74	43C = 27k4	43D = 274k	43E = 2M74	
44S = 2R80	44R = 28R0	44A = 280R	44B = 2k80	44C = 28k0	44D = 280k	44E = 2M80	
45S = 2R87	45R = 28R7	45A = 287R	45B = 2k87	45C = 28k7	45D = 287k	45E = 2M87	
46S = 2R94	46R = 29R4	46A = 294R	46B = 2k94	46C = 29k4	46D = 294k	46E = 2M94	
47S = 3R01	47R = 30R1	47A = 301R	47B = 3k01	47C = 30k1	47D = 301k	47E = 3M01	
48S = 3R09	48R = 30R9	48A = 309R	48B = 3k09	48C = 30k9	48D = 309k	48E = 3M09	
49S = 3R16	49R = 31R6	49A = 316R	49B = 3k16	49C = 31k6	49D = 316k	49E = 3M16	
50S = 3R24	50R = 32R4	50A = 324R	50B = 3k24	50C = 32k4	50D = 324k	50E = 3M24	
51S = 3R32	51R = 33R2	51A = 332R	51B = 3k32	51C = 33k2	51D = 332k	51E = 3M32	
52S = 3R4	52R = 34R0	52A = 340R	52B = 3k4	52C = 34k0	52D = 340k	52E = 3M4	
53S = 3R48	53R = 34R8	53A = 348R	53B = 3k48	53C = 34k8	53D = 348k	53E = 3M48	

54S = 3R57	54R = 35R7	54A = 357R	54B = 3k57	54C = 35k7	54D = 357k	54E = 3M57
55S = 3R65	55R = 36R5	55A = 365R	55B = 3k65	55C = 36k5	55D = 365k	55E = 3M65
56S = 3R74	56R = 37R4	56A = 374R	56B = 3k74	56C = 37k4	56D = 374k	56E = 3M74
57S = 3R83	57R = 38R3	57A = 383R	57B = 3k83	57C = 38k3	57D = 383k	57E = 3M83
58S = 3R92	58R = 39R2	58A = 392R	58B = 3k92	58C = 39k2	58D = 392k	58E = 3M92
59S = 4R02	59R = 40R2	59A = 402R	59B = 4k02	59C = 40k2	59D = 402k	59E = 4M02
60S = 4R12	60R = 41R2	60A = 412R	60B = 4k12	60C = 41k2	60D = 412k	60E = 4M12
61S = 4R22	61R = 42R2	61A = 422R	61B = 4k22	61C = 42k2	61D = 422k	61E = 4M22
62S = 4R32	62R = 43R2	62A = 432R	62B = 4k32	62C = 43k2	62D = 432k	62E = 4M32
63S = 4R42	63R = 44R2	63A = 442R	63B = 4k42	63C = 44k2	63D = 442k	63E = 4M42
64S = 4R53	64R = 45R3	64A = 453R	64B = 4k53	64C = 45k3	64D = 453k	64E = 4M53
65S = 4R64	65R = 46R4	65A = 464R	65B = 4k64	65C = 46k4	65D = 464k	65E = 4M64
66S = 4R75	66R = 47R5	66A = 475R	66B = 4k75	66C = 47k5	66D = 475k	66E = 4M75
67S = 4R87	67R = 48R7	67A = 487R	67B = 4k87	67C = 48k7	67D = 487k	67E = 4M87
68S = 4R99	68R = 49R9	68A = 499R	68B = 4k99	68C = 49k9	68D = 499k	68E = 4M99
69S = 5R11	69R = 51R1	69A = 511R	69B = 5k11	69C = 51k1	69D = 511k	69E = 5M11
70S = 5R23	70R = 52R3	70A = 523R	70B = 5k23	70C = 52k3	70D = 523k	70E = 5M23
71S = 5R36	71R = 53R6	71A = 536R	71B = 5k36	71C = 53k6	71D = 536k	71E = 5M36
72S = 5R49	72R = 54R9	72A = 549R	72B = 5k49	72C = 54k9	72D = 549k	72E = 5M49
73S = 5R62	73R = 56R2	73A = 562R	73B = 5k62	73C = 56k2	73D = 562k	73E = 5M62
74S = 5R76	74R = 57R6	74A = 576R	74B = 5k76	74C = 57k6	74D = 576k	74E = 5M76
75S = 5R9	75R = 59R0	75A = 590R	75B = 5k9	75C = 59k0	75D = 590k	75E = 5M9
76S = 6R04	76R = 60R4	76A = 604R	76B = 6k04	76C = 60k4	76D = 604k	76E = 6M04
77S = 6R19	77R = 61R9	77A = 619R	77B = 6k19	77C = 61k9	77D = 619k	77E = 6M19
78S = 6R34	78R = 63R4	78A = 634R	78B = 6k34	78C = 63k4	78D = 634k	78E = 6M34
79S = 6R49	79R = 64R9	79A = 649R	79B = 6k49	79C = 64k9	79D = 649k	79E = 6M49
80S = 6R65	80R = 66R5	80A = 665R	80B = 6k65	80C = 66k5	80D = 665k	80E = 6M65
81S = 6R81	81R = 68R1	81A = 681R	81B = 6k81	81C = 68k1	81D = 681k	81E = 6M81
82S = 6R98	82R = 69R8	82A = 698R	82B = 6k98	82C = 69k8	82D = 698k	82E = 6M98
83S = 7R15	83R = 71R5	83A = 715R	83B = 7k15	83C = 71k5	83D = 715k	83E = 7M15
84S = 7R32	84R = 73R2	84A = 732R	84B = 7k32	84C = 73k2	84D = 732k	84E = 7M32
85S = 7R5	85R = 75R0	85A = 750R	85B = 7k5	85C = 75k0	85D = 750k	85E = 7M5
86S = 7R68	86R = 76R8	86A = 768R	86B = 7k68	86C = 76k8	86D = 768k	86E = 7M68
87S = 7R87	87R = 78R7	87A = 787R	87B = 7k87	87C = 78k7	87D = 787k	87E = 7M87
88S = 8R06	88R = 80R6	88A = 806R	88B = 8k06	88C = 80k6	88D = 806k	88E = 8M06
89S = 8R25	89R = 82R5	89A = 825R	89B = 8k25	89C = 82k5	89D = 825k	89E = 8M25
90S = 8R45	90R = 84R5	90A = 845R	90B = 8k45	90C = 84k5	90D = 845k	90E = 8M45
91S = 8R66	91R = 86R6	91A = 866R	91B = 8k66	91C = 86k6	91D = 866k	91E = 8M66
92S = 8R87	92R = 88R7	92A = 887R	92B = 8k87	92C = 88k7	92D = 887k	92E = 8M87
93S = 9R09	93R = 90R9	93A = 909R	93B = 9k09	93C = 90k9	93D = 909k	93E = 9M09
94S = 9R31	94R = 93R1	94A = 931R	94B = 9k31	94C = 93k1	94D = 931k	94E = 9M31
95S = 9R53	95R = 95R3	95A = 953R	95B = 9k53	95C = 95k3	95D = 953k	95E = 9M53
96S = 9R76	96R = 97R6	96A = 976R	96B = 9k76	96C = 97k6	96D = 976k	96E = 9M76

If you want an accurate RESISTANCE measurement, remove the resistor from the circuit and use a Digital meter.

SURFACE MOUNT COMPONENTS - PACKS

Talking Electronics has packs of components for the repairman. The following packs are available:

SURFACE MOUNT RESISTOR PACK consists of 1 off each standard value
10 ohms to 1M & 2M2 (60 resistors)
$14.20 including pack and post

SURFACE MOUNT CAPACITOR PACK consists of:
2 - 10p 5 - 47p 5 - 100p 5 - 470p 5 - 1n 5 - 10n 5 - 22n 5 - 100n
5 - 1u 16v electrolytic 5 - 10u 16v electrolytic
(40 components)
$23.80 including pack and post

SURFACE MOUNT DIODE PACK consists of:
5 - 1N 4148 (marked as "A6")
$10.00 including pack and post

SURFACE MOUNT TRANSISTOR PACK consists of:
5 - BC 848 (marked as "1K") NPN
5 - BC858 PNP
$10.00 including pack and post

email **Colin Mitchell** for details on how to pay by credit card or PayPal.

CREATING ANY VALUE OF RESISTANCE

Any value of resistance can be created by connecting two resistors in PARALLEL or SERIES.
You can also create a higher wattage resistor by connecting them in SERIES OR PARALLEL.
We are only going to cover two EQUAL VALUE resistors in SERIES or in PARALLEL.
If you want to create a "Special Value," simply connect two resistors and read the value with a Digital Meter. Keep changing the values until you get the required value.
We are not going into series or Parallel formulae. You can easily find a value with a multimeter.

TWO EQUAL-VALUE RESISTORS IN SERIES

Two equal-value resistors IN SERIES creates a value of DOUBLE. You simply ADD the values.
This can be done with any to two values as shown. Three equal-value resistors in series is three times the value.

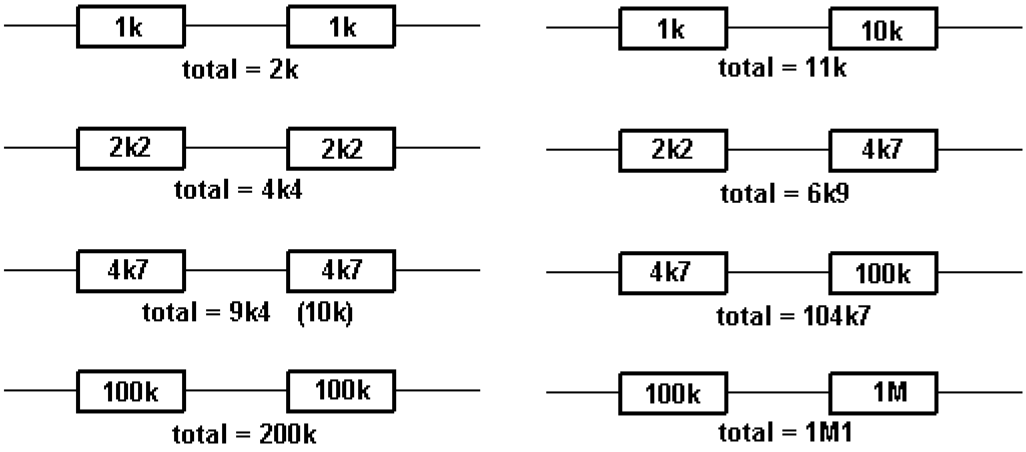
1k
1k
total = 2k
1k
10k
total = 11k
2k2
2k2
total = 4k4
2k2
4k7
total = 6k9
4k7
4k7
total = 9k4 (10k)
4k7
100k
total = 104k7
100k
100k
total = 200k
100k
1M
total = 1M1

TWO EQUAL-VALUE RESISTORS IN PARALLEL

Two equal-value resistors IN PARALLEL creates a value of HALF. Three equal-value resistors in parallel is equal to one-third the value.

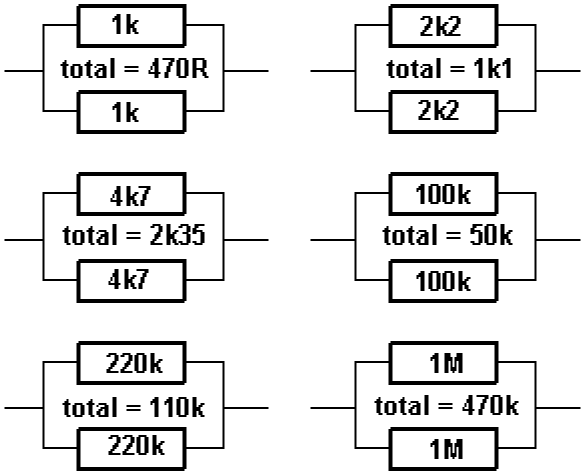
1k
total = 470R
1k
2k2
total = 1k1
2k2
4k7
total = 2k35
4k7
100k
total = 50k
100k
220k
total = 110k
220k
1M
total = 470k
1M

If you want a particular value and it is not available, here is a chart.
Use 2 resistors in series or parallel as shown:

Required Value	R1	Series/ Parallel	R2	Actual value:

10	4R7	S	4R7	9R4
12	10	S	2R2	12R2
15	22	P	47	14R9
18	22	P	100	18R
22	10	S	12	22
27	22	S	4R7	26R7
33	22	S	10	32R
39	220	P	47	38R7
47	22	S	27	49
56	47	S	10	57
68	33	S	33	66
82	27	S	56	83

There are other ways to combine 2 resistors in parallel or series to get a particular value. The examples above are just one way. 4R7 = 4.7 ohms

TESTING A RESISTOR

To check the value of a resistor, it should be removed from the circuit. The surrounding components can affect the reading and make it lower.

Resistors **VERY RARELY** change value, but if it is overheated or damaged, the resistance can increase. You can take the reading of a resistor "in-circuit" in one direction then the other, as the surrounding components may have diodes and this will alter the reading.

You can also test a resistor by feeling its temperature-rise. It is getting too hot if you cannot hold your finger on it (some "metal film" resistors are designed to tolerate quite high temperatures).

TESTING AN "AC" RESISTOR

There is no such thing as an "AC" resistor. Resistors are just "resistors" and they can be in AC circuits or DC circuits. Resistors can be given names such as "Safety Resistor" "Ballast Resistor" "LOAD Resistor" "Feed Resistor"   "Dropper Resistor" or "Supply Resistor." These are just normal resistors with a normal resistance - except a "Safety Resistor."

A safety resistor is made of a flame-proof material such as metal-oxide-film and not carbon-composition. It is designed to "burn out" when too much current flows BUT NOT CATCH FIRE.

It is a low-value resistor and has a voltage-drop across it but this is not intentional. The voltage-drop is to create a "heating-effect" to burn out the resistor. In all the other types of resistor, the voltage-drop is intentional.

A Ballast resistor is a normal resistor and can be called a Power resistor, Dropper resistor, Supply resistor or Feed resistor. It is designed to reduce the voltage from one source and deliver a lower voltage. It is a form of: "in-line" resistor.

A Load Resistor is generally connected across the output of a circuit and turns the energy it receives, into heat.

RESISTOR NETWORKS

To reduce the number of resistors in a circuit, some engineers use a set of identical resistors in a package called a Single-In-Line (SIL) resistor network. It is made with many resistors of the same value, all in one package. One end of each resistor is connected all the other resistors and this is the common pin, identified as pin 1 and has a dot on the package.

These packages are very reliable but to make sure all the resistors are as stated, you need to locate pin 1. All values will be identical when referenced to this pin.

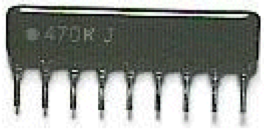

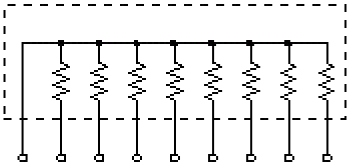

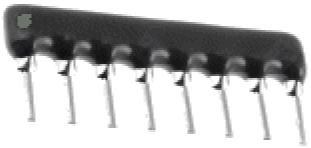

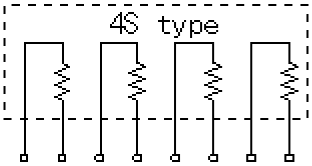

RESISTOR NETWORKS

Some resistor networks have a "4S" printed on the component. The 4S indicates the package contains 4 independent resistors that are not wired together inside. The housing has eight leads as shown in the second image.
Independent resistors have an even number of pins and measuring between each pair will produce identical values. Resistance between any pair will indicate leakage and may be a fault.

WIRE WOUND RESISTOR

A wire wound resistor is also called a POWER RESISTOR. This type of resistor can have a resistance as low as 0.1 ohms (one-tenth of an ohm) or as high as about 10k.
The image shows a 0.68 ohm resistor as the letter "R" represents the DECIMAL POINT and R68 is the same a .68 and this is 0.68 ohms. The wattage is 9 watts.
This resistor will allow xxx amps to flow. To work out the current, use the formula:
Power = Current x Current x resistance
9 = Current x Current x .68
Divide both sides by 0.68
13.2 = Current x Current
Find the square root of 13.2
Current = 3.6 amps

When 3.6 amps flow through the resistor, the voltage appearing across it will be:
V = current x resistance
= 3.6 x 0.68
= 2.5v and the wattage (heat) loss will be 9 watts.

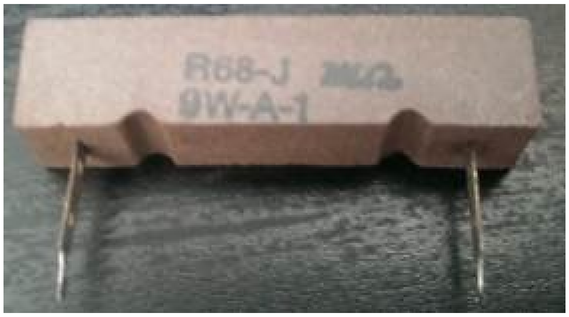

The purpose of a resistor like this is to stop or reduce "ripple." Ripple is the noise or hum in an amplifier when the sound is turned up.
There are many reasons why you need to reduce the level of hum and this resistor will remove ripple as large as 2.5v when 3.6 amps is flowing, provided you have filter electrolytics on both side of the resistor to assist in removing the ripple.

If the letter "R" is in a different position, the value of resistance would be:

68R = 68Ω
6R8 = 6.8Ω
R68 = 0.68Ω

If you replace the R68 resistor a 6R8 resistor by mistake, the voltage across it will rise to 25v and if 3.6 amps flows, the wattage will be: 90 watts!!!
The resistor will glow red and burn out.

TESTING A POSISTOR

A Posistor is a resistor that connects in series with the degaussing coil around the picture tube or **Monitor.** When cold, it has a very low resistance and a large current flows when the monitor or TV is switched on. This current heats up the Posistor and the resistance increases. This causes the current to decrease and any magnetism in the shadow mask is removed. The posistor can one or two elements and it is kept warm so the resistance remains high. Many Posistors have a second element inside the case that connects directly to the supply to keep the Positive Temperature Coefficient resistor high so that the current through the degaussing coil falls to almost zero. This constant heat eventually destroys the package.
The heavy current that flows when a set is turned ON also causes the posistor to crack and break and this results in poor purity on the screen - as the shadow mask gradually becomes magnetic..
Posistors have different resistance values from different manufacturers and must be replaced with an identical type.
They can be checked for very low resistance when cold but any loose pieces inside the case will indicate a damaged component.

A "BURNT" RESISTOR - **normally and technically called a "burnt-out" resistor.**

The resistance of a "burnt" resistor can sometimes be determined by scraping away the outer coating - if the resistor has a spiral of resistance-material. You may be able to find a spot where the spiral has been damaged.

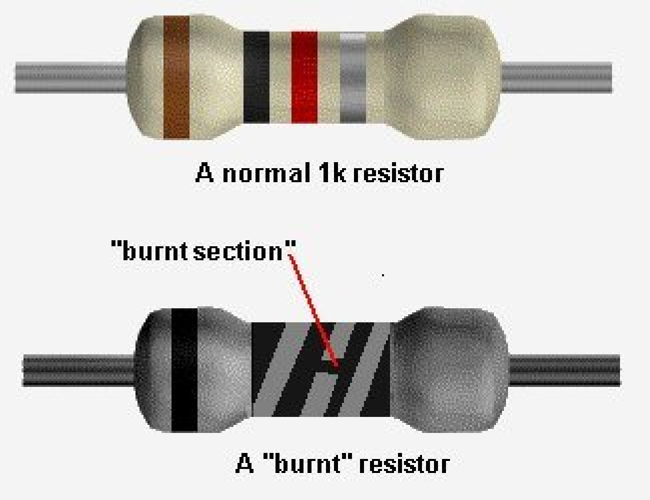

Note the spirals of conductive carbon.
The number of spirals has nothing to with the resistance.
It is the amount of carbon particles in the "track" that determines the resistance. It is also the thickness and width of the track that determines the resistance.
And then it is the overall size of the resistor that determines the wattage.
And then the size of the leads, the closeness to the PCB and the size of the lands that eventually determines how hot the resistor will get.

Clean the "spot" (burnt section of the spiral) very carefully and make sure you can get a good contact with the spiral and the tip of your probe. Measure from one lead of the resistor to the end of the damaged spiral. Then measure from the other lead to the other end of the spiral.
Add the two values and you have an approximate value for the resistor. You can add a small amount for the damaged section.
This process works very well for damaged wire-wound resistors. They can be pulled apart and each section of the resistance-wire (nichrome wire) measured and added to get the full resistance.

There is another way to determine the value of a damaged resistor.
Get a set of resistors of the same wattage as the damaged component and start with a high value. It's handy to know if the resistor is in the range: 10ohm to 100ohms or 1k to 10k etc, but this is not essential.
Start with a very high value and turn the circuit ON. You can perform voltage tests and if you know the expected output voltage, decrease the resistance until this voltage is obtained.
If you do not know the expected voltage, keep reducing the value of resistance until the circuit works as designed.
This is the best advice in a situation where you do not know the value of a resistor.

There is a third way to determine the value and this requires measuring the voltage drop across the resistor and the current-flow. By multiplying the two you will get a wattage and this must be less than the wattage of the resistor being replaced.

TESTING POTENTIOMETERS (variable resistors)

To check the value of a variable resistor, it should be removed from circuit or at least 2 legs should be removed. A Rheostat is a variable resistor using only one end and the middle connected to a circuit.
The resistance between the two outside pins is the value marked on the component and the centre leg will change from nearly zero to the full resistance as the shaft is rotated.
"Pots" generally suffer from "crackle" when turned and this can be fixed by spraying up the shaft and into the pot via the shaft with a tube fixed to a can of "spray-lubricant" (contact cleaner).
"Pre-set pots" and "trim pots" are miniature versions of a potentiometer and they are all tested the same. The photo shows a pot, two mini pots and 3 mini trim pots.

103
102
P102
N911

10-Turn POTs

A 10-turn pot is one of the worst items to be designed. I remove them immediately from any design.
You don't know the position of the wiper. You don't know which way you are turning the wiper and you can't remember which way you turned the post "the last time."
The screwdriver always falls out of the slot.
If you need fine adjustment, place fixed resistors on each side of the pot and use a normal mini trim pot with much less resistance.

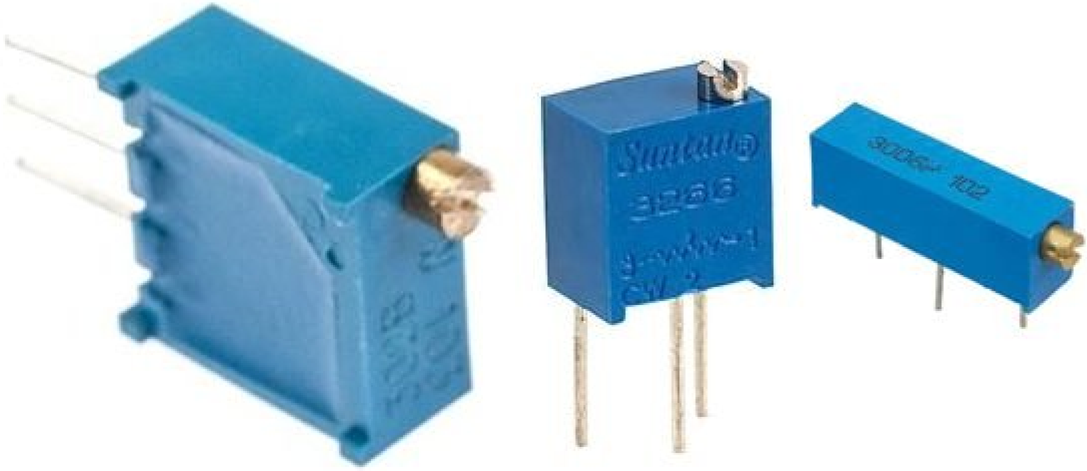

FOCUS POTS

Focus pots quite often get a spot of dirt where the wiper touches the track. Cleaning with spray fixes the bad focus but if the pot is leaking to chassis from inside the pot (due to the high voltage on the terminals) simply remove it from the chassis and leave it floating (this will restore the high voltage to the picture tube) or you can use one from an old chassis.

MAKING YOUR OWN RESISTOR, CAPACITOR, INDUCTOR or DIODE

Quite often you will not have the exact value of resistance or capacitance for a repair.
We have already covered placing resistors and capacitors in parallel and series:

Resistors in Parallel and/or Series
Capacitors in Parallel and/or Series

Here are some extras:

RESISTORS
Two 1k 0.5watt resistors in parallel produces a 470R 1watt resistor.
Two 1k 0.5watt resistors in series produces a 2k 1watt resistor.

CAPACITORS
Two 100n 100v capacitors in series produces a 50n capacitor @200v

INDUCTORS: Two inductors in series - **ADD THE VALUES**

DIODES: Two 1Amp 400v diodes in series produces a 1Amp 800v diode
Two 1Amp 400v diodes in parallel produces a 2Amp 400v diode

ZENER DIODES: Zener diodes can be connected in series to get a higher voltage.
Two 12v zener diodes in series produces a 24v zener.

CONTINUITY

Some multimeters have a "buzzer" that detects when the probes are touching each other or the resistance between the probes is very LOW. This is called a CONTINUITY TESTER.
You can use the resistance scale "x1" or "x10" to detect low values of resistance.
Set the pointer to "0" (right end of the scale) by touching the probes together and adjusting the "zero ohms" control.
When taking a reading, you will have to decide if a low value of resistance is a short-circuit or an "operating value."
For instance, the cold resistance of a 12v car globe is very low (about 2 ohms) and it increases (about 6 times) to 12 ohms when hot.
The "resistance of a circuit" may be very low as the electrolytics in the circuit are uncharged. This may not indicate a true "short-circuit."
The measurement across a diode is not a resistance-value but a "voltage-drop" and that is why the needle swings nearly full-scale.
Leads and wires and cords have a small resistance and depending on the length of the lead, this small resistance may be affecting a circuit.
Remember this:
When a circuit takes 1 amp, and the resistance of the leads is 1 ohm, the voltage drop across the leads will be 1v.
That's why a 12v battery supplying a circuit with these leads will have 11v at the circuit.
Note:
Turn off the equipment before making any continuity tests. The presence of even a small voltage (from an electrolytic) can give a false reading.
You can determine the resistance of a lead very accurately by taking the example above and applying it to your circuit.
If the battery is 12.6v and the voltage across the circuit is 10v, when the current is 2.6 amps, the resistance of the "leads" is 12.6 - 10 = 2.6 R=V/I = 2.6/2.6 = 1ohm. By making the lead shorter or using thicker wire, the resistance will be less and the voltage on the project will increase.
When taking readings in a circuit that has a number of diodes built-into IC's (Integrated Circuits) and transistors, some Continuity Testers will beep and give a false reading.
The following circuit has the advantage of providing a beep when a short-circuit is detected but does not detect the small voltage drop across a diode. This is ideal when testing logic circuits as it is quick and you can listen for the beep while

concentrating on the probe. Using a multimeter is much slower.

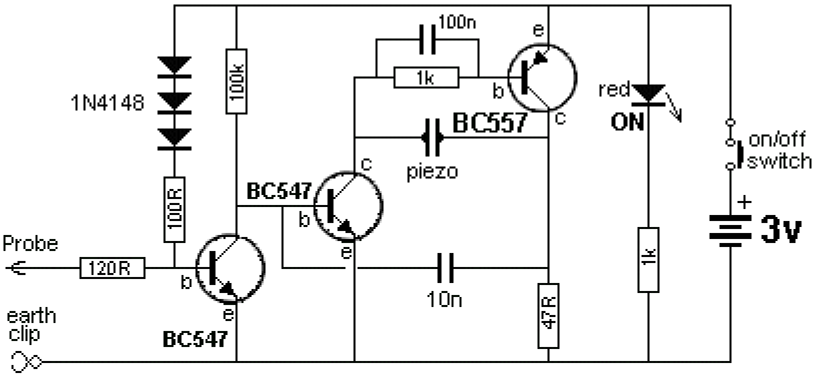

CONTINUITY TESTER

You can build the circuit on Matrix Board and add it to your Test Equipment.
You will need lots of "Test Equipment" and they can be built from circuits in this eBook.

TESTING FUSES, LEADS AND WIRES

All these components come under the heading TESTING for CONTINUITY. Turn off all power to the equipment before testing for shorts and continuity. Use the low resistance "Ohms Scale" or CONTINUITY range on your multimeter. All fuses, leads and wires should have a low, very low or zero resistance. This proves they are working.

A BLOWN FUSE

The appearance of a fuse after it has "blown" can tell you a lot about the fault in the circuit.
If the inside of the glass tube (of the fuse) is totally blackened, the fuse has been damaged very quickly. This indicates a very high current has passed through the fuse.
Depending on the rating of the fuse, (current rating) you will be able to look for components that can pass a high current when damaged - such as high power transistors, FETs, coils, electrolytics. Before re-connecting the supply, you should test the "SUPPLY RAILS" for resistance. This is done by measuring them on a low OHMs range in one direction then reverse the leads to see if the resistance is low in the other direction.
A reading can be very low at the start because electrolytics need time to charge-up and if the reading gradually increases, the power rail does not have a short. An overload can occur when the supply voltage rises to nearly full voltage, so you sometimes have to fit a fuse and see how long it takes to "blow."
If the fuse is just slightly damaged, you will need to read the next part of this eBook, to see how and why this happens:

FAST AND SLOW BLOW FUSES

There are many different sizes, shapes and ratings of a fuse. They are all current ratings as a fuse does not have a voltage rating. Some fuses are designed for cars as they fit into the special fuse holders. A fuse can be designed for 50mA, 100mA, 250mA, 315mA, 500mA, 1Amp, 1.5amp, 2amp, 3amp, 3.15amp 5amp, 10amp, 15amp, 20amp, 25amp, 30amp, 35amp, 50amp and higher.
Some fuses are fast-blow and some are slow-blow.
A "normal" fuse consists of a length of thin wire. Or it may be a loop of wire that is thin near the middle of the fuse. This is the section that will "burn-out."
A "normal" fuse is a fast-blow fuse. For instance, a 1amp fuse will remain intact when up to 1.25 amp flows. When a circuit is turned on, it may take 2-3 amps for a very short period of time and a normal 1 amp fuse will get very hot and the wire will stretch but not "burn-out." You can see the wire move when the supply turns on.
If the current increases to 2amps, the fuse will still remain intact. It needs about 3 amp to heat up the wire to red-hot and burn out.

If the current increases to 5 amp, the wire VOLATILISES (burns-out) and deposits carbon-black on the inside of the glass tube.
A slow-blow fuse uses a slightly thicker piece of wire and the fuse is made of two pieces of wire joined in the middle with a dob of low-temperature solder. Sometimes one of the pieces of wire is a spring and when the current rises to 2.5 amp, the heat generated in the wire melts the solder and the two pieces of wire "spring apart."
A slow-blow fuse will allow a higher current-surge to pass through the fuse and the wire will not heat up and sag.
Thus the fuse is not gradually being damaged and it will remain in a perfect state for a long period of time.
A fuse does not protect electronic equipment from failing. It acts AFTER the equipment has failed.
It will then protect a power supply from delivering a high current to a circuit that has failed.
If a slow-blow fuse has melted the solder, it could be due to a slight overload, slight weakening of the fuse over a period of time or the current-rating may be too low.
You can try another fuse to see what happens.
You can replace a fast-acting fuse (normal fuse) with a slow blow if the fast-acting fuse has been replaced a few times due to deterioration when the equipment is turned on.
But you cannot replace a slow-blow fuse with a fast acting fuse as it will be damaged slightly each time the equipment is turned on and eventually fail.

100mA FUSES

Fuses below about 100mA are very hard to make and very unreliable.
Many circuits take a high current when turned to charge the electrolytics and a 100mA (or 50mA or 63mA fuse) will bow and stretch and change shape, every time the equipment is turned ON.
Eventually it will break, due to it heating-up and stretching.
To produce a reliable fuse below 100mA, some manufacturers have placed a resistor inside the fuse and connected it to a spring. One end of the resistor is soldered to a wire with low-temperature metal and when the resistor gets hot, the metal softens and the spring pulls the resistor away from the wire.
Quite often you can heat up the metal and connect the wire and the fuse is perfect.
This type of fuse is called a DELAY fuse and the current rating is shown on the end-cap.
The value of the resistor determines the current rating.
There is a small voltage across this type of fuse and it means the circuit sees a slightly lower voltage than the supply voltage.
The third photo shows the pot of solder or low-temp metal and a wire connected to a spring. The heat generated in the wire is passed to the solder and it softens. The spring pulls the two components apart. You can smash the glass and set up the fuse in the two fuse-holders and repair the fuse while you wait for a new fuse to arrive.

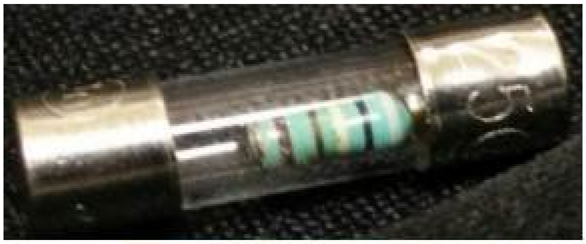

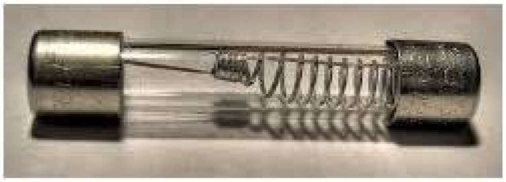

TESTING COILS, INDUCTORS and YOKES

Coils, inductors, chokes and yokes are just coils (turns) of wire. The wire may be wrapped around a core made of iron or ferrite.
It is labeled "L" on a circuit board.
You can test this component for continuity between the ends of the winding and also make sure there is no continuity between the winding and the core.
The winding can be less than one ohm, or greater than 100 ohms. A coil of wire is also called an INDUCTOR and it might look like a very simple component, but it can operate in a very complex way.
The way it works is a discussion for another eBook. It is important to understand the turns are insulated but a slight fracture in the insulation can cause two turns to touch each other and this is called a "SHORTED TURN" or you can say the inductor has "SHORTED TURNS."
When this happens, the inductor allows the circuit to draw MORE CURRENT. This causes the fuse to "blow."
The quickest way to check an inductor is to replace it, but if you want to measure the inductance, you can use an INDUCTANCE METER. You can then compare the inductance with a known good component.
An inductor with a shorted turn will have a very low or zero inductance, however you may not be able to detect the fault when it is not working in a circuit as the fault may be created by a high voltage generated between two of the turns.
Faulty yokes (both horizontal and vertical windings) can cause the picture to reduce in size and/or bend or produce a single horizontal line.
A TV or monitor screen is the best piece of Test Equipment as it has identified the fault. It is pointless trying to test the windings further as you will not be able to test them under full operating conditions. The fault may not show up when a low voltage (test voltage) is applied.

MEASURING AND TESTING INDUCTORS

Inductors are measured with an INDUCTANCE METER but the value of some inductors is very small and some Inductance Meters do not give an accurate reading. The solution is to measure a larger inductor and note the reading. Now put the two inductors in SERIES and the values ADD UP - just like resistors in SERIES. This way you can measure very small inductors. VERY CLEVER!

Question from a reader: *Can I add an inductor to stop a fuse blowing?*

Basically, an inductor NEVER prevents a fuse blowing because an inductor prevents spikes on one lead (we will call the INPUT lead), appearing on its other lead.
This is the detection and prevention of current that exists for a very short period of time.
A fuse detects an excess of current that occurs over a very long period of time and they are entirely two different "detectors."
One cannot assist the other in any way.

An inductor is basically a coil of wire. It may be thick or thin wire. The value of the inductor is a combination of the number of turns and the material on which the wire is wound.
The value of an inductor does not change over say a period of 20 years but it can go faulty by the enamel cracking and two turns touching. This can also be due to the difference in voltage between the two turns creating a spark between the turns and creating a "short."
When you test it, the high voltage is not present and it will test ok.
You may not think a few turns of wire will have any effect on improving a circuit, but spikes are very high frequency and the inductor will have a very big effect on reducing them.
An inductor (say 100uH) can be produced in many different sizes and the thickness of the wire will be important as it determines the current that can flow through the inductor.
The term "inductor" also includes those with two or more windings and these components are called TRANSFORMERS. These devices can get "shorts" and "leaks" between the windings and sparks can be seen between the windings. These sparks do not occur when you are testing them on test-equipment so the only way to

guarantee success is to replace it with an identical replacement.

TESTING SWITCHES and RELAYS

Switches and relays have contacts that open and close mechanically and you can test them for CONTINUITY. However these components can become intermittent due to dirt or pitting of the surface of the contacts due to arcing as the switch is opened.
It is best to test these items when the operating voltage and current is present as they quite often fail due to the arcing. A switch can work 49 times then fail on each 50th operation. The same with a relay. It can fail one time in 50 due to CONTACT WEAR.
If the contacts do not touch each other with a large amount of force and with a large amount of the metal touching, the current flowing through the contacts will create HEAT and this will damage the metal and sometimes reduce the pressure holding the contact together.
This causes more arcing and eventually the switch heats up and starts to burn.
Switches are the biggest causes of fire in electrical equipment and households.

A relay also has a set of contacts that can cause problems.
There are many different types of relays and basically they can be put into two groups.
1. An electromagnetic relay is a switch operated by magnetic force. This force is generated by current through a coil. The relay opens and closes a set of contacts. The contacts allow a current to flow and this current can damage the contacts.
Connect 5v or 12v to the coil (or 24v) and listen for the "click" of the points closing.
Measure the resistance across the points to see if they are closing.
You really need to put a load on the points to see if they are clean and can carry a current.
The coil will work in either direction.
If not, the relay is possibly a CMOS relay or Solid State relay.

2. An electronic relay (Solid State Relay) does not have a winding. It works on the principle of an opto-coupler and uses a LED and Light Activated SCR or Opto-TRIAC to produce a low resistance on the output. The two pins that energise the relay (the two input pins) must be connected to 5v (or 12v) around the correct way as the voltage is driving a LED (with series resistor). The LED illuminates and activates a light-sensitive device.

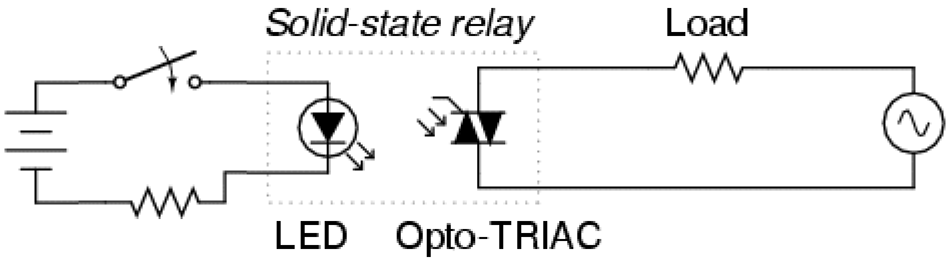

TESTING REED SWITCHES

A reed switch is generally contained in a long glass tube:

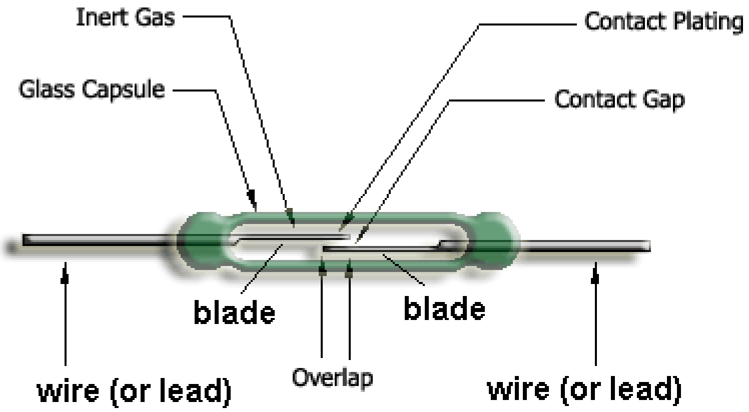

A wire or lead comes out each end for soldering to the reed switch to the project. The two "blades" inside the switch are made from a material that can be magnetised but does not retain its magnetism. This effect is called "temporally magnetised" (not permanently magnetised) and really only "passes" magnetism from one end to the other when in the presence of a magnet. One of the blades is made of a soft material and it will bend very easily. The other one is much stiffer.

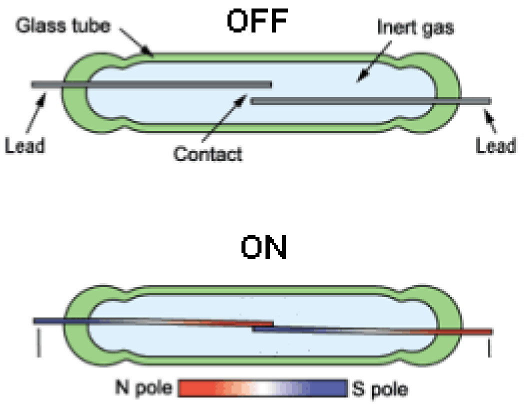

When a magnet is placed under the two blades (or on top), the magnetism from the magnet is passed to the two blades (INDUCTION or MUTUAL INDUCTION - commonly called INDUCED) and it produces a very weak magnet (in the blade) that is identical to the powerful magnet as far as the position of the north and south poles are concerned). Initially it produces a N-S and N-S set of poles and this makes the two blades click together because the top blade will be South at the contact and the bottom blade will be North.

When the two blades click together the magnetism runs through the two blades and keeps them together. The two blades attract and the switch is closed. When the magnet is removed, the magnetism in the two blades ceases and the two blades move apart.

Since there is a very small amount of movement in the top blade, this switch has a limited number of operations. Eventually it will fail. It is a mechanical device and is not suited for detecting a spinning shaft as 100,000 revolutions will very quickly weaken the switch.

If the switch does not make contact or remains closed, the moveable blade can be cracked or broken. This can be very hard to see. So replace the switch.

LATCHING REED SWITCH

A "normal" reed switch can be converted into a **LATCHING REED SWITCH** by carefully placing a magnet below the switch and moving it away so the two blades open. Now move it slightly closer but do not allow the blades to close.

This is called putting a "SET" on the switch and the two blades will have a small magnetic effect "induced" in them but not enough to close the contacts:

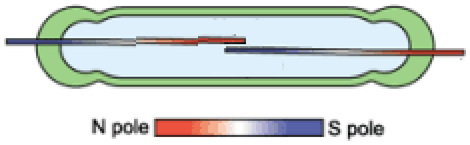

Now bring a strong magnet up to the reed switch on the other side of the glass tube with the north pole above the north of the lower magnet. This effect will increase the INDUCED MAGNETISM in the blades and close the contacts:

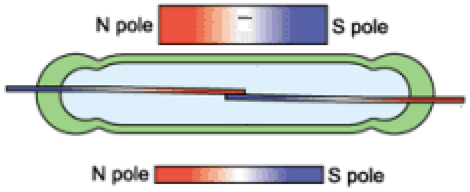

Remove the top magnet and the lower magnet will induce enough magnetism into the blades to keep them closed:

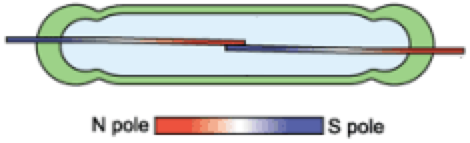

Now bring the upper magnet near the reed switch with the south pole above the north pole of the lower magnet. (In other words: AROUND THE OTHER WAY) This will have the effect of reducing the induced magnetism in the blades and a point will be reached when the two contacts will separate:

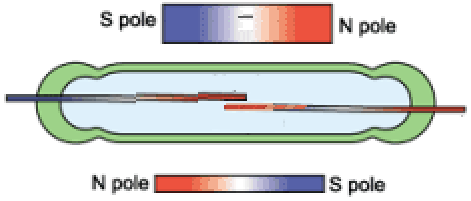

Remove the top magnet and the switch will remain separated because the lower magnet will not have sufficient influence on the blades to close the contact:

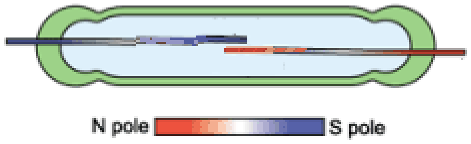

CAPACITORS

Capacitors are one of the most difficult things to test. That's because they don't give a reading on a multimeter and their value can range from 1p to 100,000u.
A faulty capacitor may be "open" when measured with a multimeter, and a good capacitor will also be "open."

You need a piece of test equipment called a CAPACITANCE METER to measure the value of a capacitor.

HOW A CAPACITOR WORKS

There are two ways to describe how a capacitor works. Both are correct and you have to combine them to get a full picture.
A capacitor has INFINITE resistance between one lead and the other.
This means no current flows **through** a capacitor. But it works in another way.
Suppose you have a strong magnet on one side of a door and a piece of metal on the other. By sliding the magnet up and down the door, the metal rises and falls.
The metal can be connected to a pump and you can pump water by sliding the magnet up and down.
A capacitor works in exactly the same way.
If you raise a voltage on one lead of a capacitor, the other lead will rise to the same voltage. This needs more explaining - we are keeping the discussion simple.
It works just like the magnetic field of the magnet through a door.
The next concept is this:
Capacitors are equivalent to a tiny rechargeable battery.
They store energy when the supply-voltage is present and release it when the supply drops.
These two concepts can be used in many ways and that's why capacitors perform tasks such as filtering, time-delays, passing a signal from one stage to another and create many different effects in a circuit.

CAPACITOR VALUES

The basic unit of capacitance is the FARAD. (C) This is the value used in all equations, but it is a very large value. A one FARAD capacitor would be the size of a car if made with plates and paper. Most electronic circuits use capacitors with smaller values such as 1p to 1,000u. 1p is about equal to two parallel wires 2cm long. 1p is one picofarad.

The easiest way to understand capacitor values is to start with a value of 1u. This is one microfarad and is one-millionth of a Farad. A 1 microfarad capacitor is about 1cm long and the diagram shows a 1u electrolytic.

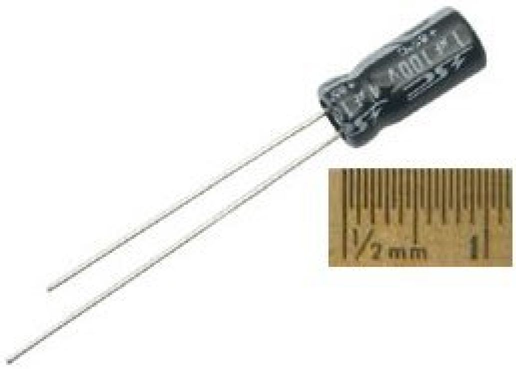

Smaller capacitors are ceramic and they look like the following. This is a 100n (0.1u)ceramic:

To read the value on a capacitor you need to know a few facts.

The basic value of capacitance is the FARAD.
1 microfarad is one millionth of 1 farad.
1 microfarad is divided into smaller parts called nanofarad.
1,000 nanofarad = 1 microfarad
Nanofarad is divided into small parts called picofarad
1,000 picofarad = 1 nanofarad.

Recapping:
1p = 1 picofarad.   1,000p = 1n (1 nanofarad)
1,000n = 1u (1 microfarad)
1,000u = 1millifarad
1,000,000u = 1 FARAD.

Examples:
All ceramic capacitors are marked in "p" (puff")
A ceramic with 22 is 22p = 22 picofarad
A ceramic with 47 is 47p = 47 picofarad
A ceramic with 470 is 470p = 470 picofarad
A ceramic with 471 is 470p = 470 picofarad
A ceramic with 102 is 1,000p = 1n
A ceramic with 223 is 22,000p = 22n
A ceramic with 104 is 100,000p = 100n = 0.1u

TYPES OF CAPACITOR
For testing purposes, there are two types of capacitor.
Capacitors from 1p to 100n are non-polar and can be inserted into a circuit around either way.
Capacitors from 1u to 100,000u are electrolytics and are polarised. They must be fitted so the positive lead goes to the supply voltage and the negative lead goes to ground (or earth).
There are many different sizes, shapes and types of capacitor. They are all the same. They consist of two plates with an insulating material between. The two plates can be stacked in layers or rolled together.
The important factor is the insulating material. It must be very thin to keep things small. This gives the capacitor its VOLTAGE RATING.
If a capacitor sees a voltage higher than its rating, the voltage will "jump through" the insulating material or around it.
If this happens, a carbon deposit is left behind and the capacitor becomes "leaky" or very low resistance, as carbon is conductive.

CERAMIC CAPACITORS

Nearly all small capacitors are **ceramic capacitors** as this material is cheap and the capacitor can be made in very thin layers to produced a high capacitance for the size of the component. This is especially true for surface-mount capacitors.
All capacitors are marked with a value and the basic unit is: "p" for "puff" However NO surface mount capacitors are marked and they are very difficult to test.

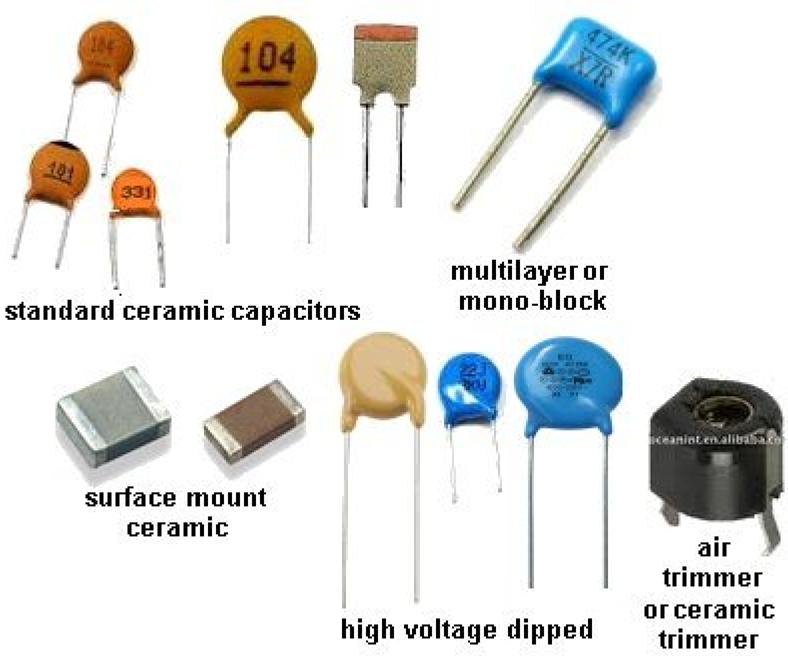
104
101
331
104
474K X7R
standard ceramic capacitors
multilayer or mono-block
surface mount ceramic
high voltage dipped
air trimmer or ceramic trimmer

VALUE:	VALUE WRITTEN ON THE COMPONENT:
0.1p	0p1
0.22p	0p22
0.47p	0p47
1.0p	1p0
2.2p	2p2
4.7p	4p7
5.6p	5p6
8.2p	8p2
10p	10 or 10p
22p	22 or 22p
47p	47 or 47p
56p	56 or 56p
100p	100 on 101
220p	220 or 221
470p	470 or 471
560p	560 or 561
820p	820 or 821
1,000p (1n)	102
2200p (2n2)	222
4700p (4n7)	472
8200p (8n2)	822
10n	103
22n	223
47n	473
100n	104
220n	224
470n	474
1u	105

POLYESTER, POLYCARBONATE, POLYSTYRENE, MYLAR, METALLISED POLYESTER, ("POLY"), MICA and other types of CAPACITOR

There are many types of capacitor and they are chosen for their reliability, stability, temperate-range and cost.

For testing and repair work, they are all the same. Simply replace with exactly the same type and value.

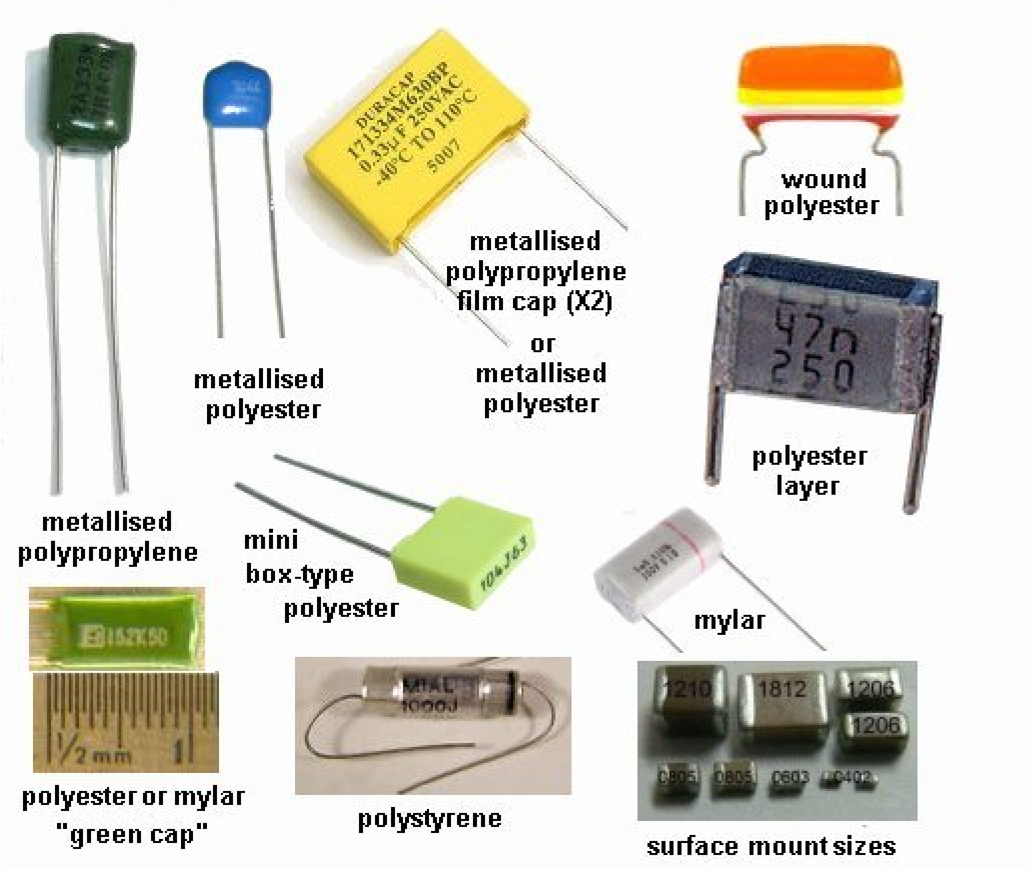

wound polyester
metallised polypropylene film cap (X2)
or
metallised polyester
metallised polyester
polyester layer
metallised polypropylene
mini box-type polyester
mylar
polyester or mylar "green cap"
polystyrene
surface mount sizes
1210
1812
1206
1206
0805
0805
0603
0402

Capacitor Colour Code Table

Colour	Digit A	Digit B	Multiplier D	Tolerance (T) > 10pf	Tolerance (T) < 10pf	Temperature Coefficient (TC)
Black	0	0	x1	± 20%	± 2.0pF	
Brown	1	1	x10	± 1%	± 0.1pF	$-33x10^{-6}$
Red	2	2	x100	± 2%	± 0.25pF	$-75x10^{-6}$
Orange	3	3	x1,000	± 3%		$-150x10^{-6}$
Yellow	4	4	x10,000	± 4%		$-220x10^{-6}$
Green	5	5	x100,000	± 5%	± 0.5pF	$-330x10^{-6}$
Blue	6	6	x1,000,000			$-470x10^{-6}$
Violet	7	7				$-750x10^{-6}$
Grey	8	8	x0.01	+80%,-20%		
White	9	9	x0.1	± 10%	± 1.0pF	
Gold			x0.1	± 5%		

Silver			x0.01	± 10%		

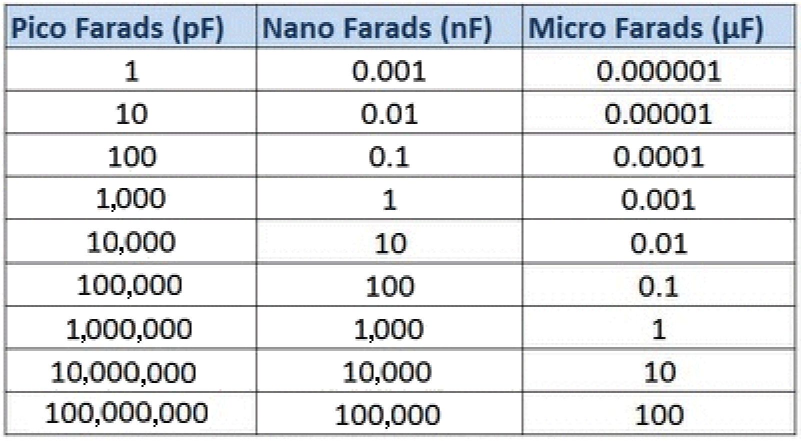

Pico Farads (pF)	Nano Farads (nF)	Micro Farads (µF)
1	0.001	0.000001
10	0.01	0.00001
100	0.1	0.0001
1,000	1	0.001
10,000	10	0.01
100,000	100	0.1
1,000,000	1,000	1
10,000,000	10,000	10
100,000,000	100,000	100

Type ⊕ = polarized	**Pic**	**Cap Range**
Ceramic		**pF - µF**
Mica **(silver mica)**		**pF - nF**
Plastic Film **(polyethylene polystyrene)**		**few µFs**
Tantalum ⊕		**µFs**
OSCON ⊕		**µFs**
Aluminum Electrolytic ⊕		**high µFs**

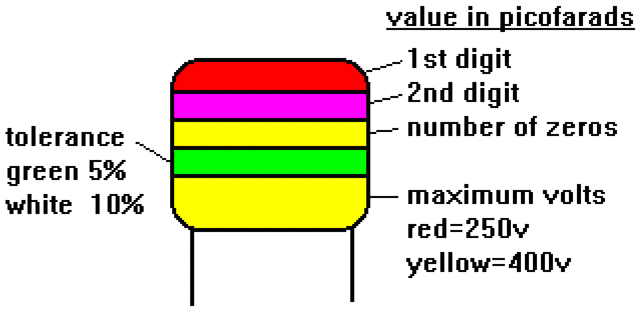
value in picofarads
1st digit
2nd digit
number of zeros
tolerance
green 5%
white 10%
maximum volts
red=250v
yellow=400v

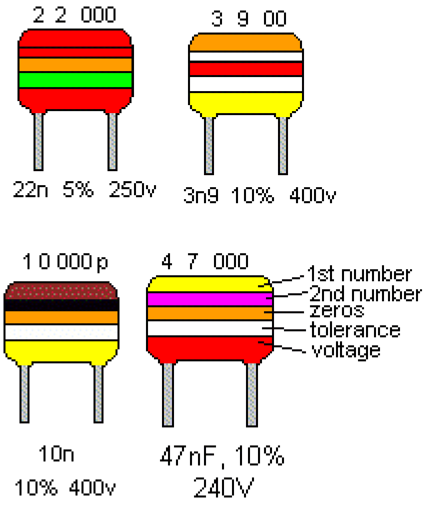
2 2 000
22n 5% 250v
3 9 00
3n9 10% 400v
1 0 000 p
10n
10% 400v
4 7 000
1st number
2nd number
zeros
tolerance
voltage
47nF, 10%
240V

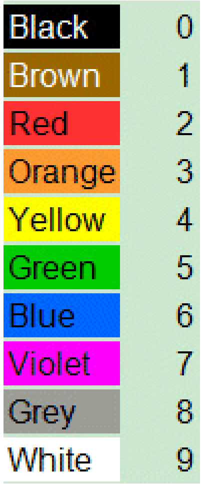

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

ELECTROLYTIC and TANTALUM CAPACITORS

Electrolytics and Tantalums are the same for testing purposes but their performance is slightly different in some circuits. A tantalum is smaller for the same rating as an electrolytic and has a better ability at delivering a current. They are available up to about 1,000u, at about 50v but their cost is much higher than an electrolytic.

Electrolytics are available in 1u, 2u2 3u3 4u7 10u, 22u, 47u, 100u, 220u, 330u, 470u, 1,000u, 2,200u, 3,300u, 4,700u, 10,000u and higher.
The "voltage" or "working voltage" can be: 3.3v, 10v, 16v, 25v, 63v, 100v, 200v and higher.
There is also another important factor that is rarely covered in text books. It is RIPPLE FACTOR.
This is the amount of current that can enter and leave an electrolytic. This current heats up the electrolytic and that is why some electrolytics are much larger than others, even though the capacitance and voltage-ratings are the same.
If you replace an electrolytic with a "miniature" version, it will heat up and have a very short life. This is especially important in power supplies where current (energy) is constantly entering and exiting the electrolytic as its main purpose is to provide a smooth output from a set of diodes that delivers "pulsing DC." (see "Power Diodes")

Remember:
104 = 100n
105 = 1u
106 = 10u
107 - 100u

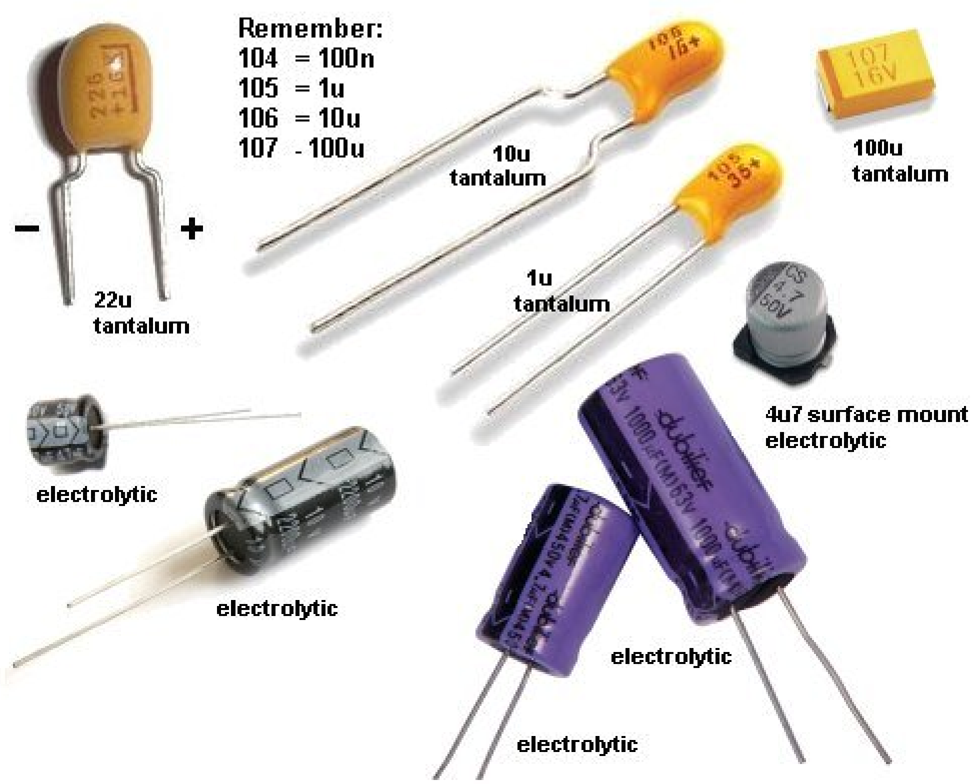
226 +16
−
+
22u tantalum
106 16+
10u tantalum
105 35+
1u tantalum
107 16V
100u tantalum
CS 4.7 50V
4u7 surface mount electrolytic
electrolytic
electrolytic
dubilier 1000uF (M) 63V
electrolytic
electrolytic

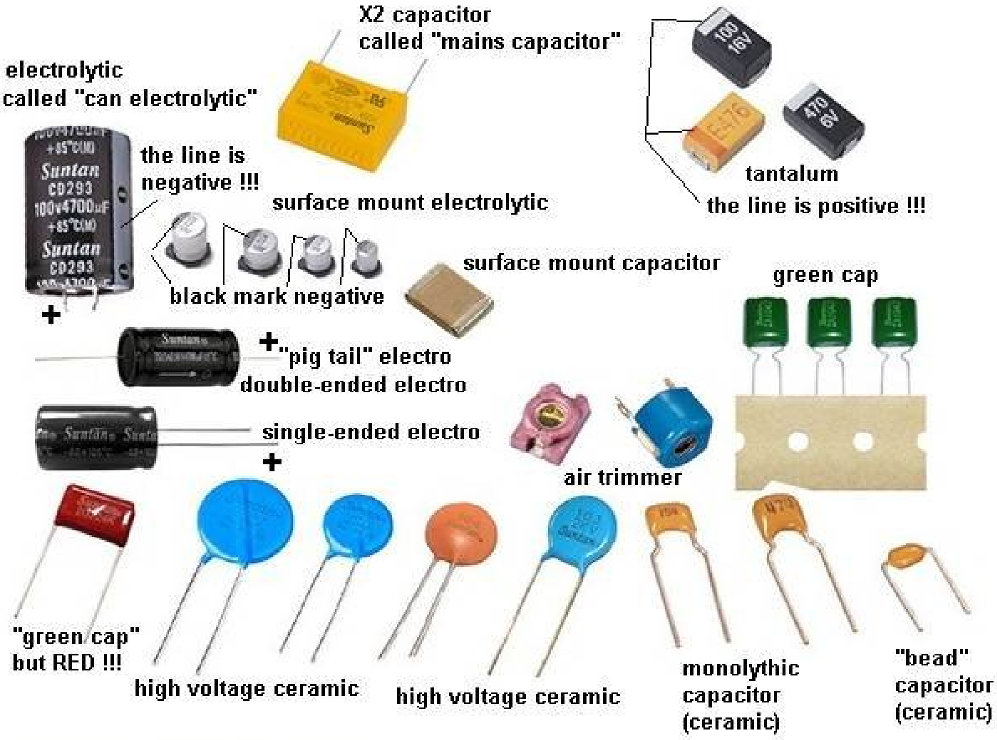
electrolytic
called "can electrolytic"
Suntan CD293 100v4700uF +85°C(M)
the line is negative !!!
+
X2 capacitor
called "mains capacitor"
surface mount electrolytic
black mark negative
surface mount capacitor
100 16V
E476
470 6V
tantalum
the line is positive !!!
green cap
+
"pig tail" electro
double-ended electro
single-ended electro
+
air trimmer
"green cap"
but RED !!!
high voltage ceramic
high voltage ceramic
monolythic
capacitor
(ceramic)
"bead"
capacitor
(ceramic)

tantalum capacitors can
"go up in smoke"

"bead" tantalum

PARALLEL and SERIES CAPACITORS

Capacitors can be connected in PARALLEL and/or SERIES for a number of reasons.

1. If you do not have the exact value, two or more connected in parallel or series can produce the value you need.
2. Capacitors connected in series will produce one with a higher voltage rating.
3. Capacitors connected in parallel will produce a larger-value capacitance.

Here are examples of two equal capacitors connected in series or parallel and the results they produce:

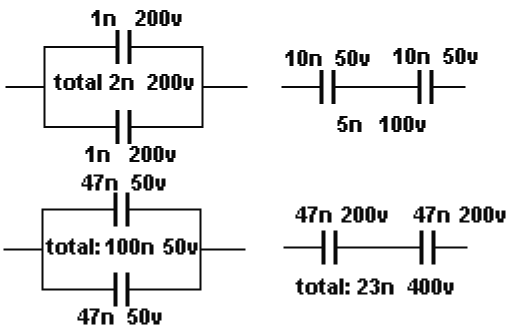
1n 200v
total 2n 200v
1n 200v
10n 50v
10n 50v
5n 100v
47n 50v
total: 100n 50v
47n 50v
47n 200v
47n 200v
total: 23n 400v

NON-POLAR CAPACITORS (ELECTROLYTICS)

Electrolytics are also available in non-polar values. It sometimes has the letters "NP" on the component. Sometimes the leads are not identified.

This is an electrolytic that does not have a positive and negative lead but two leads and either lead can be connected to the positive or negative of the circuit.

These electrolytics are usually connected to the output of an amplifier (such as in a filter near the speaker) where the signal is rising and falling.

A non-polar electrolytic can be created from two ordinary electrolytics by connecting the negative leads together and the two positive leads become the new leads.

For example: two 100u 63v electrolytics will produce a 47u 63v non-polar electrolytic.

In the circuit below, the non-polar capacitor is replaced with two electrolytics.

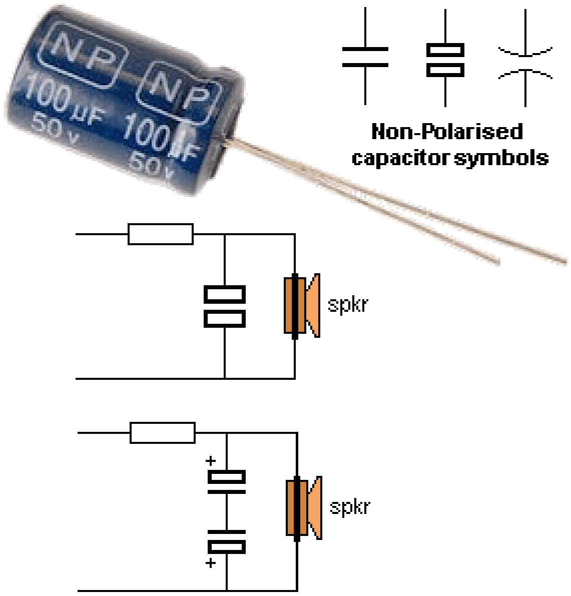
NP
100µF
50v
NP
100µF
50v
Non-Polarised capacitor symbols
spkr
+
+
spkr

MAKING A NON-POLAR ELECTROLYTIC

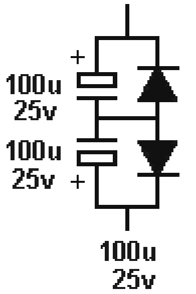

non-polar

A normal electrolytic must be connected the correct way in a circuit because it has a thin insulating layer covering the plates that has a high resistance.
If you connect the electrolytic around the wrong way, this layer "breaks-down" and the resistance of the electrolytic becomes very small and a high current flows. This heats up the electrolytic and the current increases. Very soon the capacitor produces gasses and explodes.
One big mistake in many text books shows how to make a non-polar electrolytic by connecting two "back-to-back."
They claim 2 x 100u connected back-to-back is equal to 47u.
This appears to be case when testing on a meter but the meter simply charges them for a short period of time to get a reading.
If you allow them to charge fully you will find the reverse electrolytic has a very small voltage across it.
Secondly, when you are charging them, you are putting a high current through the reverse electrolytic and damaging the layer.
To prevent this, you need to add two diodes as shown in the diagram.
In addition, 2 x 100u "back-to-back" is very near 100u.

Here is a question from a reader:
I have an amplifier with 2 x2,200u electrolytics on the output of a bridge. Can I replace them with a single 10,000u?

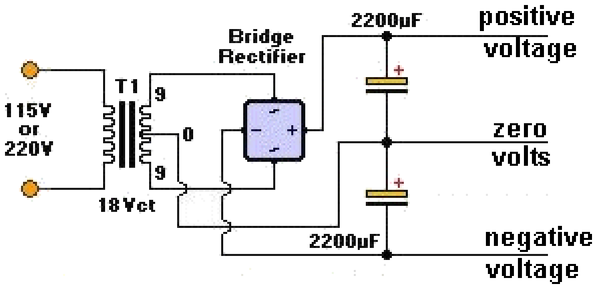

You need to look at the circuit of your amplifier. The two 2,200u electrolytics are possibly connected as shown in the circuit above and you will notice they are joined to produce a positive rail and a negative rail with zero (called earth) in the centre.
This forms two different circuits with the top electrolytic filtering the positive rail and the bottom electro filtering the negative rail. They must be connected to the zero volts rail.
A single 10,000u cannot be connected to the 0v rail and cannot be substituted for the two electro's.
You can easily determine of the two electro's are connected as shown above.
Test the positive terminal of each electro by placing the negative of the meter on the chassis.
If the positive of one electro have zero volts, it will be the lower electro in the diagram above. The negative terminal of the electro will have a minus voltage on it.

VOLTAGE RATING OF CAPACITOR
Capacitors have a voltage rating, stated as WV for working voltage, or WVDC. This specifies the maximum voltage that can be applied across the capacitor without puncturing the dielectric. Voltage ratings for "poly," mica and ceramic capacitors are typically 50v to 500 VDC. Ceramic capacitors with ratings of 1kv to 5kv are also available. Electrolytic capacitors are commonly available in 6v, 10v 16v, 25v, 50v, 100v, 150v, and 450v ratings.

THE SIZE OF A CAPACITOR - RIPPLE FACTOR

The size of a capacitor depends on a number of factors, namely the value of the capacitor (in microfarads etc) and the voltage rating. But there is also another factor that is most important. It is the RIPPLE FACTOR. **Ripple Factor** is the amount of voltage-fluctuation the capacitor (electrolytic) can withstand without getting too hot. When current flows in and out of an electrolytic, it gets hot and this will eventually dry-out the capacitor as some of the liquid inside the capacitor escapes through the seal. It's a very slow process but over a period of years, the capacitor looses its capacitance.

If you have two identical 1,000u 35v electrolytics and one is smaller, it will get hotter when operating in a circuit and that's why it is necessary to choose the largest electrolytic.

CAUTION

If a capacitor has a voltage rating of 63v, do not put it in a 100v circuit as the insulation (called the dielectric) will be punctured and the capacitor will "short-circuit." It's ok to replace a 0.22uF 50WV capacitor with 0.22uF 250WVDC.

SAFETY

A capacitor can store a charge for a period of time after the equipment is turned off. High voltage electrolytic caps can pose a safety hazard. These capacitors are in power supplies and some have a resistor across them, called a bleed resistor, to discharge the cap after power is switched off.

If a bleed resistor is not present the cap can retain a charge after the equipment is unplugged.

How to discharge a capacitor

Do not use a screwdriver to short between the terminals as this will damage the capacitor internally and the screwdriver.

Use a 1k 1 watt or 3watt or 5watt resistor on jumper leads (or held with pliers) and keep them connected for up to 15 seconds to fully discharge the electro.

Test it with a voltmeter to make sure all the energy has been removed.

Before testing any capacitors, especially electrolytics, you should look to see if any are damaged, overheated or leaking. Swelling at the top of an electrolytic indicates heating (and pressure inside the case) and will result in drying out of the electrolyte. Any hot or warm electrolytic indicates leakage and ceramic capacitors with portions missing indicates something has gone wrong (such as it being "blown apart").

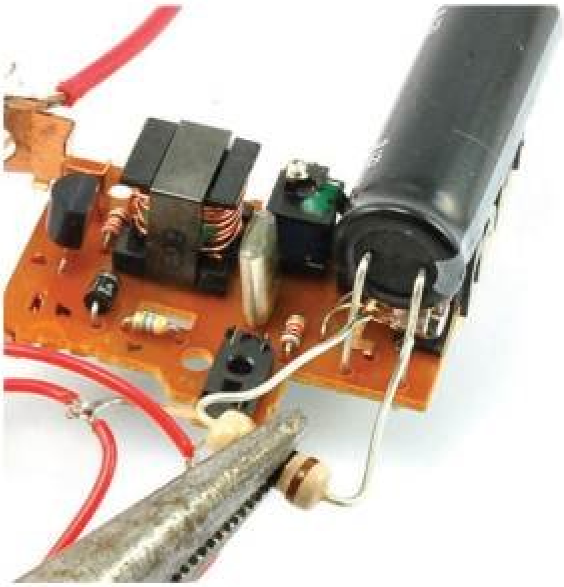

Here is a 120u 330v electrolytic from a flash circuit in an old-fashioned film camera. If the flash does not "fire," the electrolytic will be charged to about 350 volts !!

Use a 1k resistor (held with pliers) to slowly discharge it. It may take 15 seconds to fully discharge.

TESTING A CAPACITOR

There are two things you can test with a multimeter:

1. A short-circuit within the capacitor
2. Capacitor values above 1u.

You can test capacitors in-circuit for short-circuits. Use the x1 ohms range.
To test a capacitor for leakage, you need to remove it or at least one lead must be removed. Use the x10k range on an analogue or digital multimeter.
For values above 1u you can determine if the capacitor is charging by using an analogue meter. The needle will initially move across the scale to indicate the cap is charging, then go to "no deflection." Any permanent deflection of the needle will indicate leakage.
You can reverse the probes to see if the needle moves in the opposite direction. This indicates it has been charged. Values below 1u will not respond to charging and the needle will not deflect.
This does not work with a digital meter as the resistance range does not output any current and the electrolytic does not charge.

Rather than spending money on a capacitance meter, it is cheaper to replace any suspect capacitor or electrolytic.
Capacitors can produce very unusual faults and no piece of test equipment is going to detect the problem.
In most cases, it is a simple matter to solder another capacitor across the suspect component and view or listen to the result.
This saves all the worry of removing the component and testing it with equipment that cannot possibly give you an accurate reading when the full voltage and current is not present.
It is complete madness to even think of testing critical components such as capacitors, with TEST EQUIPMENT. You are fooling yourself. If the Test Equipment says the component is ok, you will look somewhere else and waste a lot of time.

FINDING THE VALUE OF A CAPACITOR

If you want to find the value of a surface-mount capacitor or one where the markings have been removed, you will need a CAPACITANCE METER. Here is a simple circuit that can be added to your meter to read capacitor values from 10p to 10u.
The full article can be found HERE.

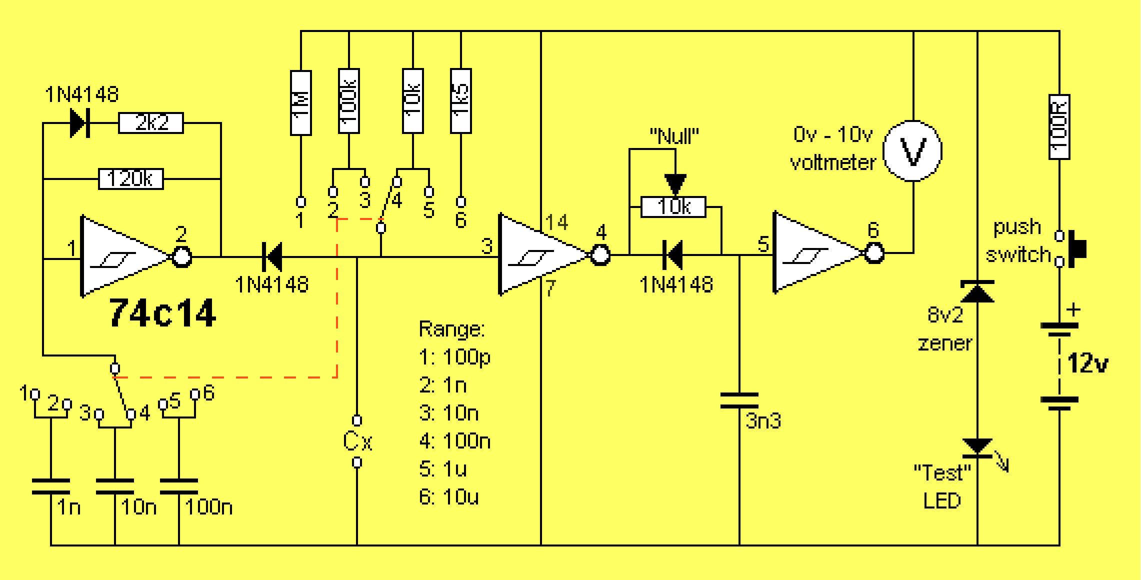

ADD-ON CAPACITANCE METER

CAPACITOR SUBSTITUTION BOX

CAPACITANCE SUBSTITUTION BOX
pF
µF
470
560
680
820
1000
1500
2200
3300
100
150
220
330
.01
.015
.022
.033
.047
.056
.068
.1
.0047
.0056
.0068
.0082
ELENCO® MODEL CS-440

You can get a kit or a ready-made piece of test gear called **CAPACITOR SUBSTITUTION BOX** and also **RESISTOR SUBSTITUTION BOX**.
I bought one of each 30 years ago and I have only used them ONCE.
They appear to be very handy but when you are testing a circuit, you want the component next to the other parts.
It is just as easy to pick the component you need from your junk box and connect it to the circuit via jumper leads.

REPLACING A CAPACITOR

Always replace a capacitor with the exact same type.
A capacitor may be slightly important in a circuit or it might be extremely critical.
A manufacturer may have taken years to select the right type of capacitor due to previous failures.
A capacitor just doesn't have a "value of capacitance."
It may also has an effect called "tightening of the rails."
In other words, a capacitor has the ability to react quickly and either absorb or deliver energy to prevent spikes or fluctuations on the rail.
This is due to the way it is constructed. Some capacitors are simply plates of metal film while others are wound in a coil. Some capacitors are large while others are small.
They all react differently when the voltage fluctuates.
Not only this, but some capacitors are very stable and all these features go into the decision for the type of capacitor to use.
You can completely destroy the operation of a circuit by selecting the wrong type of capacitor.
No capacitor is perfect and when it gets charged or discharged, it appears to have a small value of resistance in series with the value of capacitance. This is known as "ESR" and stands for EQUIVALENT SERIES RESISTANCE. This effectively makes the capacitor slightly slower to charge and discharge.
We cannot go into the theory on selecting a capacitor as it would be larger than this eBook so the only solution is to replace a capacitor with an identical type.
However if you get more than one repair with identical faults, you should ask other technicians if the original capacitor comes from a faulty batch.
The author has fixed TV's and fax machines where the capacitors have been inferior and alternate types have solved the problem.
Some capacitor are suitable for high frequencies, others for low frequencies.

DECOUPLING CAPACITORS

A Decoupling Capacitor can severe one, two or three functions. You need to think of a decoupling capacitor as a miniature battery with the ability to deliver a brief pulse of energy when ever the line-voltage drops and also absorb a brief pulse of energy when ever the line voltage rises (or spikes).
Decoupling capacitor can range from 100n to 1,000u.
100n capacitors are designed to absorb spikes and also have the effect of tightening-

up the rails for high frequencies. They have no effect on low frequencies such as audio frequencies.

These capacitors are generally ceramic and have very low internal impedance and thus they can operate at high frequencies.

Capacitors above about 10u are used for decoupling and these are nearly always electrolytics.

Decoupling means "tightening-up the power rails." The electrolytic acts just like a miniature rechargeable battery, supplying a small number of components in a circuit with a smooth and stable voltage.

The electrolytic is usually fed from a dropper resistor and this resistor charges the electrolytic and adds to the ability of the electrolytic to create a "separate power supply."

These two components help remove spikes as an electrolytic cannot remove spikes if connected directly to the supply rails - it's internal impedance is high and the spikes are not absorbed.

Decoupling capacitors are very difficult to test.

They rarely fail but if a project is suffering from unknown glitches and spikes, it is best to simply add more 100n decoupling caps on the underside of the board and replace all electrolytics.

Some small electrolytics will dry out due to faulty manufacture and simply replacing every one on a board will solve the problem.

Some of the functions of a decoupling capacitor are:

Removing ripple - hum or buzz in the background of an amplifier

Removing glitches or spikes.

Separating one stage from another to reduce or remove MOTORBOATING - a low frequency sound due to the output putting a pulse on the power rails that is picked up by the pre-amplifier section and amplified.

TESTING DIODES

Diodes can have 4 different faults.

1. Open circuit in both directions.
2. Low resistance in both directions.
3. Leaky.
4. Breakdown under load.

TESTING A DIODE ON AN ANALOGUE METER

Testing a diode with an **Analogue Multimeter** can be done on any of the resistance ranges. [The high resistance range is best - it sometimes has a high voltage battery for this range but this does not affect our testing]

There are two things you must remember.

1. When the diode is measured in one direction, the needle will **not move at all**. The technical term for this is the diode is **reverse biased**. It will not allow any current to flow. Thus the needle will not move.

When the diode is connected around the other way, the needle will swing to the right (move up scale) to about 80% of the scale. This position represents the voltage drop across the junction of the diode and is NOT a resistance value. If you change the resistance range, the needle will move to a slightly different position due to the resistances inside the meter. The technical term for this is the diode is **forward biased**. This indicates the diode is not faulty.

The needle will swing to a slightly different position for a "normal diode" compared to a Schottky diode. This is due to the different junction voltage drops.

However we are only testing the diode at very low voltage and it may break-down when fitted to a circuit due to a higher voltage being present or due to a high current flowing.

2. The leads of an **Analogue Multimeter** have the positive of the battery connected to the black probe and the readings of a "good diode" are shown in the following two diagrams:

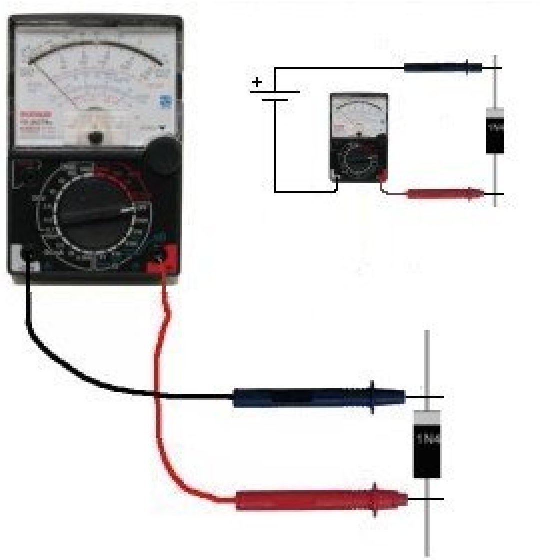

The diode is REVERSE BIASED in the diagram above and diodes not conduct.

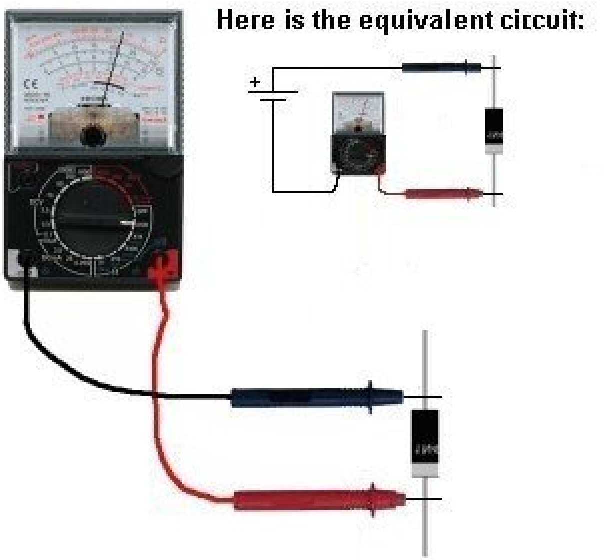

The diode is FORWARD BIASED in the diagram above and it conducts

TESTING A DIODE ON A DIGITAL METER

Testing a diode with a Digital Meter must be done on the "DIODE" setting as a digital meter does not deliver a current through the probes on some of the resistance settings and will not produce an accurate reading.

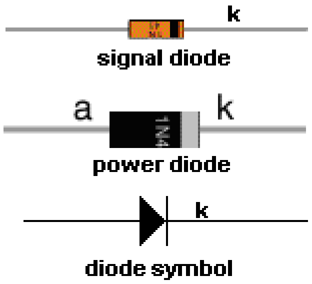

The best thing to do with a "suspect" diode is to replace it. This is because a diode has a number of characteristics that cannot be tested with simple equipment. Some diodes have a fast recovery for use in high frequency circuits. They conduct very quickly and turn off very quickly so the waveform is processed accurately and

efficiently.
If the diode is replaced with an ordinary diode, it will heat up as does not have the high-speed characteristic.
Other diodes have a low drop across them and if an ordinary is used, it will heat up.
Most diodes fail by going: SHORT-CIRCUIT. This can be detected by a low resistance (x1 or x10 Ohms range) in both directions.
A diode can also go OPEN CIRCUIT. To locate this fault, place an identical diode across the diode being tested.
A leaky diode can be detected by a low reading in one direction and a slight reading the other direction.
However this type of fault can only be detected when the circuit is working. The output of the circuit will be low and sometimes the diode heats up (more than normal).
A diode can go open under full load conditions and perform intermittently.
Diodes come in pairs in surface-mount packages and 4 diodes can be found in a bridge.
They are also available in pairs that look like a 3-leaded transistor.
The line on the end of the body of a diode indicates the cathode and you cannot say "this is the positive lead." The correct way to describe the leads is to say the "cathode lead." The other lead is the anode. The cathode is defined as the electrode (or lead) through which an electric current flows out of a device.
The following diagrams show different types of diodes:

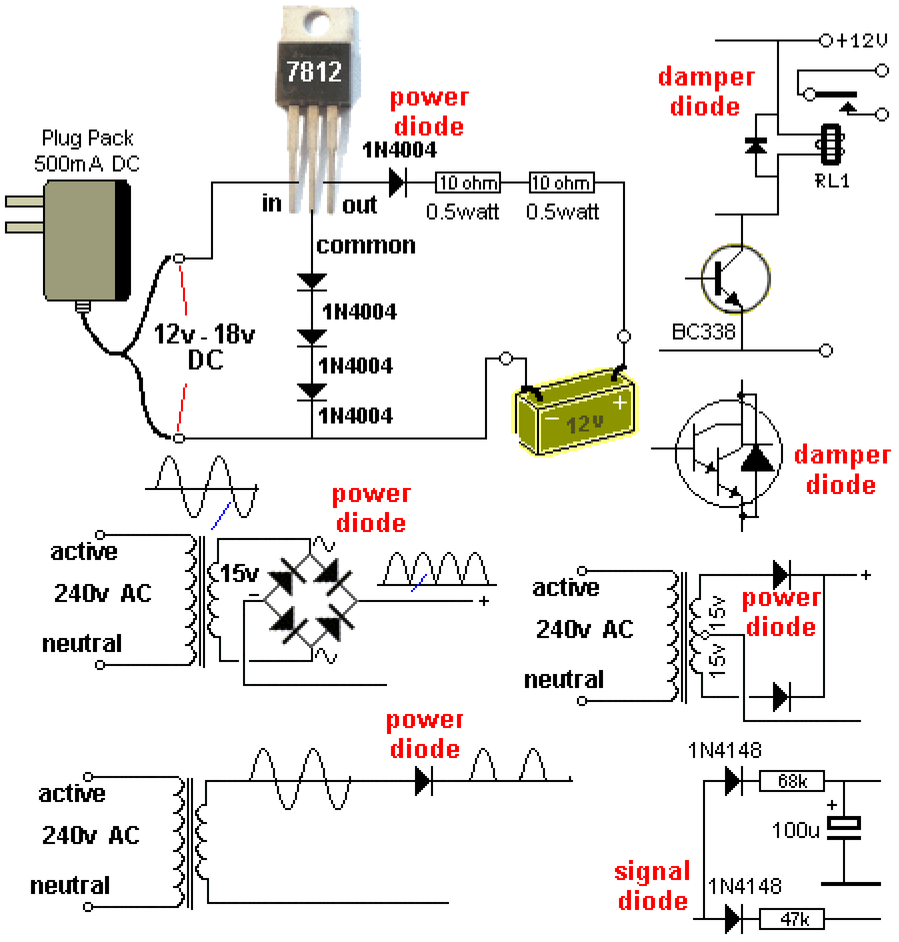
7812
power diode
1N4004
Plug Pack
500mA DC
in
out
common
10 ohm
10 ohm
0.5watt
0.5watt
12v - 18v DC
1N4004
1N4004
1N4004
12v
damper diode
+12V
RL1
BC338
damper diode
power diode
active
240v AC
neutral
15v
+
active
240v AC
neutral
15v
15v
power diode
+
power diode
active
240v AC
neutral
1N4148
68k
100u
+
signal diode
1N4148
47k

POWER DIODES

To understand how a power diode works, we need to describe a few things. This has NEVER been described before, so read carefully.
The 240v AC (called the "mains") consists of two wires, one is called the ACTIVE and the other is NEUTRAL. Suppose you touch both wires. You will get a shock. The neutral is connected to an earth wire (or rod driven into the ground or connected to a water pipe) at the point where the electricity enters the premises and you do not get a shock from the NEUTRAL.

But the voltage on the active is rising to +345v then goes to -345v at the rate of 50 times per second (for a complete cycle).
345v is the peak voltage of 240v. You never get a 240v shock. (It is a 345v shock.)
In other words, if you touch the two wires at a particular instant, you would get a POSITIVE 345v shock and at another instant you would get a negative 345v shock.
This is shown in the diagram below.
We now transfer this concept to the output of a transformer. The diagram shows an AC waveform on the output of the secondary.
This voltage is rising 15v higher than the bottom lead then it is 15v LOWER than the bottom lead. The bottom lead is called "zero volts." You have to say one lead or wire is not "rising and falling" as you need a "reference" or starting-point" or "zero point" for voltage measurements.
The diode only conducts when the voltage is "above zero" (actually when it is 0.7v above zero) and does not conduct (at all) when the voltage goes below zero.
This is shown on the output of the Power Diode. Only the positive peaks or the positive parts of the waveform appear on the output and this is called "pulsing DC."
This is called "half-wave" and is not used in a power supply. We have used it to describe how the diode works. The electrolytics charge during the peaks and deliver energy when the diode is not delivering current. This is how the output becomes a steady DC voltage.
Power supplies use FULL WAVE rectification and the other half of the AC waveform is delivered to the output (and fills in the "gaps") and appears as shown in "A."

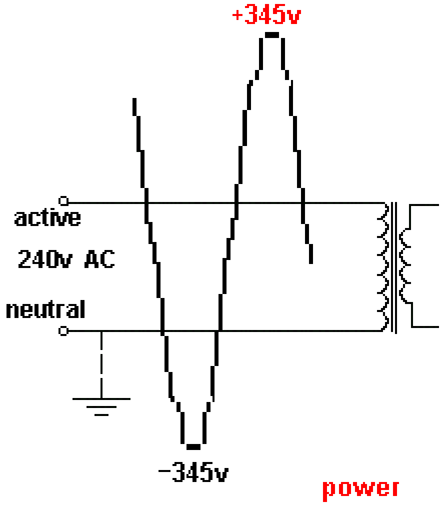

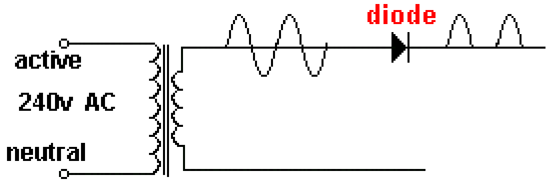

Half-wave rectifier

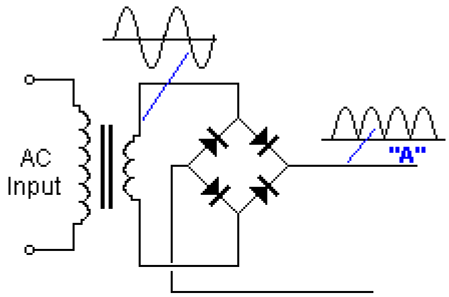

Full-wave rectifier

ONE FAULTY DIODE

One diode in a bridge can go open (any of the 4 diodes will produce the same effect) and produce an output voltage that can be slightly lower than the original voltage.

The actual "voltage-drop" will depend on the current taken by the circuit and the ability of the transformer to produce the required voltage and current during half-wave operation. The voltage during each half cycle (when none of the diodes is delivering any energy to the circuit) is maintained by the electrolytic and its size (relative to the current taken by the circuit) will determine the size of the ripple that will result when the diode fails. The ripple will be 100 to 1,000 times greater after the failure of a diode, depending on the value of the filter capacitor.
To locate the faulty diode, simply get a diode and place it across each of the diodes in the bridge (in turn) when the circuit is working.
For a bridge rectifier, the ripple-frequency will be twice the mains frequency and its ripple will be very small if the electrolytic is the correct value. When a diode fails, the ripple-frequency will be equal to mains-frequency and the amplitude will increase considerably. You may even hear background hum from audio equipment.
If you cannot find a faulty diode, the filter capacitor will be at fault. Turn off the equipment and connect an electrolytic across the filter capacitor via jumper leads. Turn the power ON and see if the hum has reduced.

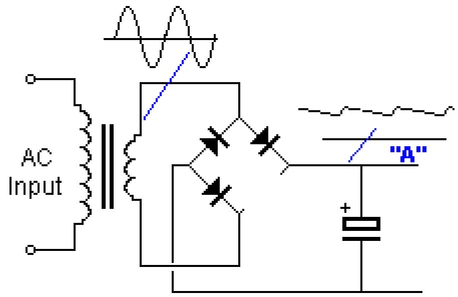

One diode "burnt-out"

DAMPER DIODES

A damper diode is a diode that detects a high voltage and SQUELCHES IT (reduces it - removes it). The signal that it squelches is a voltage that is in the opposite direction to the "supply voltage" and is produced by the collapsing of a magnetic field. Whenever a magnetic filed collapses, it produces a voltage in the winding that is opposite to the supply voltage and can be much higher. This is the principle of a flyback circuit or EHT circuit. The high voltage comes from the transformer.
The diode is placed so that the signal passes through it and less than 0.5v appears across it.
A damper diode can be placed across the coil of a relay, incorporated into a transistor or FET or placed across a winding of a flyback transformer to protect the driving transistor or FET.
It can also be called a "Reverse-Voltage Protection Diode," "Spike Suppression Diode," or "Voltage Clamp Diode."
The main characteristic of a Damper Diode is HIGH SPEED so it can detect the spike and absorb the energy.
It does not have to be a high-voltage diode as the high voltage in the circuit is being absorbed by the diode.

SILICON, GERMANIUM AND SCHOTTKY DIODES

When testing a diode with an analogue meter, you will get a low reading in one direction and a high (or NO READING) in the other direction. When reading in the LOW direction, the needle will swing nearly full scale and the reading is not a resistance-value but a reflection of the characteristic voltage drop across the junction of the diode. As we mentioned before, a resistance reading is really a voltage reading and the meter is measuring the voltage of the battery minus the voltage-drop across the diode.
Since Silicon, Germanium and Schottky Diodes have slightly different characteristic voltage drops across the junction, you will get a slightly different reading on the scale. This does not represent one diode being better than the other or capable of handling a higher current or any other feature.
The quickest, easiest and cheapest way to find, fix and solve a problem caused by a

faulty diode is to replace it.
There is no piece of test equipment capable of testing a diode fully, and the circuit you are working on is actually the best piece of test equipment as it is identifying the fault UNDER LOAD.

Only very simple tests can be done with a multimeter and it is best to check a diode with an ANALOGUE MULTIMETER as it outputs a higher current though the diode and produces a more-reliable result.
A Digital meter can produce false readings as it does not apply enough current to activate the junction.
Fortunately almost every digital multimeter has a **diode test mode.** Using this, a silicon diode should read a voltage drop between 0.5v to 0.8v in the forward direction and open in the reverse direction. For a germanium diode, the reading will be lower, around 0.2v - 0.4v in the forward direction. A bad diode will read zero volts in both directions.

REPLACING A DIODE

It is alway best to replace a diode with the same type but quite often this is not possible. Many diodes have unusual markings or colours or "in-house" letters.
This is only a general guide because many diodes have special features, especially when used in high-frequency circuits.
However if you are desperate to get a piece of equipment working, here are the steps:
Determine if the diode is a signal diode, power diode, or zener diode.
For a signal diode, try 1N4148.
For a power diode (1 amp) try 1N4004. (for up to 400v)
For a power diode (3 amp) try 1N5404. (for up to 400v)
For a high-speed diode, try UF4004 (for up to 400v)

If you put an ordinary diode in a high-speed application, it will get very hot very quickly.
To replace an unknown zener diode, start with a low voltage such as 6v2 and see if the circuit works.
The size of a diode and the thickness of the leads will give an idea of the current-capability of the diode.
Keep the leads short as the PC board acts as a heat-sink.
You can also add fins to the leads to keep the diode cool.

LIGHT EMITTING DIODES (LEDs)

Light Emitting Diodes (LEDs) are diodes that produce light when current flows from anode to cathode. The LED does not emit light when it is revered-biased. It is used as a low current indicator in many types of consumer and industrial equipment, such as monitors, TV’s, printers, hi-fi systems, machinery and control panels.
The light produced by a LED can be visible, such as red, green, yellow or white. It can also be invisible and these LEDs are called Infrared LEDs. They are used in remote controls and to see if they are working, you need to point a digital camera at the LED and view the picture on the camera screen.
An LED needs about 2v - 3.6v across its leads to make it emit light, but this voltage must be exact for the type and colour of the LED. The simplest way to deliver the exact voltage is to have a supply that is higher than needed and include a voltage-dropping resistor. The value of the resistor must be selected so the current is between 2mA and 25mA.
The cathode of the LED is identified by a flat on the side of the LED. The life expectancy of a LED is about 100,000 hours. LEDs rarely fail but they are very sensitive to heat and they must be soldered and de-soldered quickly. They are one of the most heat-sensitive components.
Light emitting diodes cannot be tested with most multimeters because the characteristic voltage across them is higher than the voltage of the battery in the meter.
However a simple tester can be made by joining 3 cells together with a 220R resistor

and 2 alligator clips:

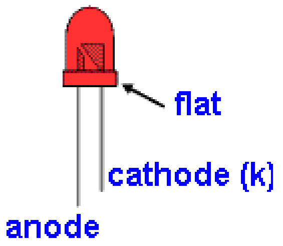

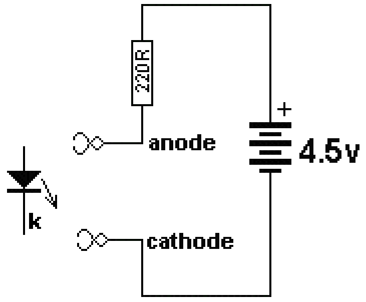

LED TESTER

Connect the clips to a LED and it will illuminate in only one direction.
The colour of the LED will determine the voltage across it. You can measure this voltage if you want to match two or more LEDs for identical operation.
Red LEDs are generally 1.7v to 1.9v. - depending on the quality such as "high-bright"
Green LEDs are 1.9v to 2.3v.
Orange LEDs are about 2.3v and
White LEDs and IR LEDs are about 3.3v to 3.6v.
The illumination produced by a LED is determined by the quality of the crystal. It is the crystal that produces the colour and you need to replace a LED with the same quality to achieve the same illumination.
Never connect a LED across a battery (such as 6v or 9v), as it will be instantly damaged. You must have a resistor in series with the LED to limit the current.

ZENER DIODES

All diodes are Zener diodes. For instance a 1N4148 is a 120v zener diode as this is its reverse breakdown voltage.
And a zener diode can be used as an ordinary diode in a circuit with a voltage that is below the zener value.
For instance, 20v zener diodes can be used in a 12v power supply as the voltage never reaches 20v, and the zener characteristic is never reached.
Most diodes have a reverse breakdown voltage above 100v, while most zeners are below 70v. A 24v zener can be created by using two 12v zeners in series and a normal diode has a characteristic voltage of 0.7v. This can be used to increase the voltage of a zener diode by 0.7v. See the diagram above. It uses 3 ordinary diodes to increase the output voltage of a 3-terminal regulator by 2.1v.
To tests a zener diode you need a power supply about 10v higher than the zener of the diode. Connect the zener across the supply with a 1k to 4k7 resistor and measure the voltage across the diode. If it measures less than 1v, reverse the zener. If the reading is high or low in both directions, the zener is damaged.

Here is a zener diode tester. The circuit will test up to 56v zeners.

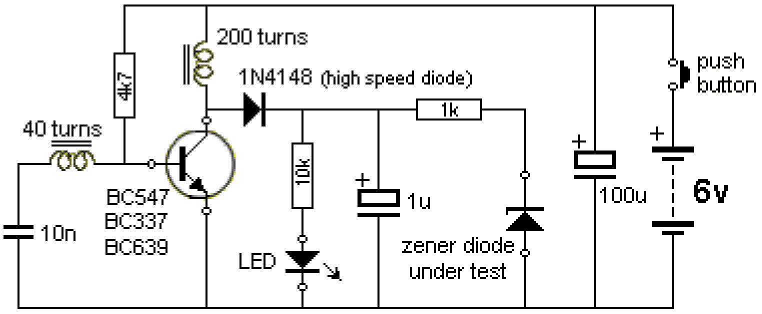

ZENER DIODE TESTER

TRANSFORMERLESS POWER SUPPLY

Here's a circuit that uses zener diodes in a power supply to show how they work. This clever design uses 4 diodes in a bridge to produce a fixed voltage power supply capable of supplying 35mA.

If we put 2 zener diodes in a bridge with two ordinary power diodes, the bridge will break-down at the voltage of the zener. This is what we have done. If we use 18v zeners, the output will be 17v4.

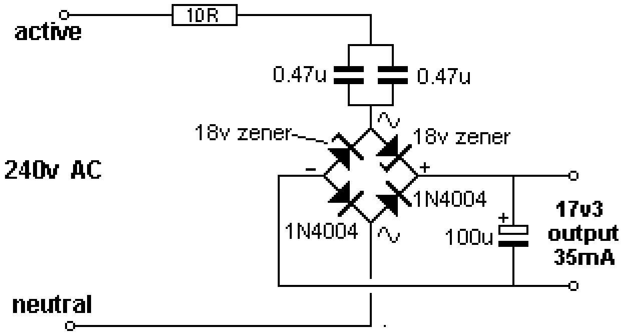

SUPPLY USING ZENER DIODES

When the incoming voltage is positive at the top, the left zener provides 18v limit (and the other zener produces a drop of 0.6v). This allows the right zener to pass current just like a normal diode. The output is 17v4. The same with the other half-cycle.

You cannot use this type of bridge in a normal power supply as the zener diode will "short" when the input voltage reaches the zener value. The concept only works in the circuit above.

VOLTAGE REGULATORS

A Voltage Regulator takes a high input voltage and delivers a fixed output voltage. Providing the input voltage is 4v above the output voltage, the regulator will deliver a fixed output voltage with almost no ripple.

Voltage regulators are also called "3-TERMINAL REGULATORS" or "REGULATOR IC's" - although this name is not generally used.

In most cases, a voltage regulator gets quite hot and for this reason it has a high failure-rate.

If a regulator is not getting hot (or warm) it has either failed or the circuit is not operating.

A regulator can only decrease the voltage. It cannot increase the current. This means the current being supplied to a circuit must also be available from the circuit supplying the regulator.

All regulators have different pin-outs, so you need to find the input pin and output pin and make sure the voltage-difference is at least 4v. Some regulators will work with a difference as low as 1v, so you need to read the specifications for the type you are servicing.

Some regulators are called "negative voltage regulators" and the input voltage will be negative and the output will be negative.

You need to test a voltage regulator with the power "ON".

Make sure you do not allow the probes to short any of the pins together as this will destroy the regulator or the circuit being supplied.

With the power turned off or the regulator removed from the circuit, you can test it with a multimeter set to resistance to see if it is ok. If any resistance readings are very low or zero ohms, the regulator is damaged.

TRANSFORMERS

All transformers and coils are tested the same way. This includes chokes, coils,

inductors, yokes, power transformers, EHT transformers (flyback transformers), switch mode transformers, isolation transformers, IF transformers, baluns, and any device that has turns of wire around a former. All these devices can go faulty.
The coating on the wire is called insulation or "enamel" and this can crack or become overheated or damaged due to vibration or movement. When two turns touch each other, a very interesting thing happens. **The winding becomes two separate windings.**

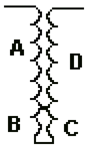

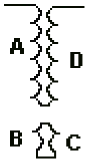

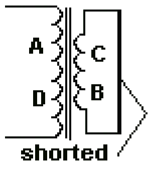

We will take the case of a single winding such as a coil. This is shown in the first diagram above and the winding is wound across a former (a former is a bobbin or plastic molding or something to hold the winding) and back again, making two layers. The bottom and top layers touch at the point shown in the diagram and the current that originally passed though A, B, C, D now passes though A & D.

Winding B C becomes a separate winding as shown in the second diagram.
In other words the coil becomes a TRANSFORMER with a SHORT CIRCUIT on the secondary winding as shown in the third diagram.
When the output wires of a transformer are shorted together, it delivers a very high current because you have created a SHORT-CIRCUIT. This short-circuit causes the transformer to get very hot.
That's exactly what happens when any coil or transformer gets a "shorted turn."
The shorted turns can be a single turn or many turns.
It is not possible to measure a fault like this with a multimeter as you don't know the exact resistance of a working coil or winding and the resistance of a faulty winding may be only 0.001 ohms less.
However when a transformer or coil is measured with an inductance meter, an oscillating voltage (or spike) is delivered into the core as magnetic flux, then the magnetic flux collapses and passes the energy into the winding to produce a waveform. The inductance meter reads this and produces a value of inductance in Henry (or milliHenry or microHenry.)
This is done with the transformer removed from the circuit and this can be a very difficult thing to do, as most transformers have a number of connections.
If the coil or transformer has a shorted turn, the energy from the magnetic flux will pass into the turns that are shorted and produce a current. Almost no voltage will be detected from winding.
The reading from the inductance meter will be low or very low and you have to work out if it is correct.
However there is one major problem with measuring a faulty transformer or coil.
It may only become faulty when power is applied.
The voltage between the turns may be sparking or jumping a gap and creating a problem. A tester is not going to find this fault.
Secondly, an inductance meter may produce a reading but you do not know if the reading is correct. An improved tester is a RING TESTER.
The circuit for a ring tester can be found here:

http://www.flippers.com/pdfs/k7205.pdf

It sends a pulse to the coil and counts the number of returning pulses or "rings." A faulty coil (or winding) may return one pulse but nearly all the energy will be passed to the shorted turns and you will be able to see this on the scale. You will only get one or two return pulses, whereas a good winding will return more pulses.

One way to detect a faulty power transformer is to connect it to the supply and feel the temperature-rise (when nothing is connected to the secondary).
It should NOT get hot.
Detecting shorted turns is not easy to diagnose as you really need another identical

component to compare the results.

Most transformers get very hot when a shorted turn has developed. It may deliver a voltage but the heat generated and a smell from the transformer will indicate a fault.

ISOLATION TRANSFORMER

An isolation transformer is a piece of **Test Equipment** that provides "Mains Voltage" but the voltage is "floating." You will still get a shock if you touch the two output leads, but it has a special use when testing unknown equipment.

Many electrical appliances are fully insulated and only have two leads connected to the mains.

When you take these appliances apart, you do not know which end of say a heating element is connected to the "live" (active) side of the mains and which end connects to the neutral.

I am not suggesting you carry out the following tests, but they are described to show how an isolation transformer works.

If you touch a soldering iron on the "live" (active) end of the heating element it will create a short-circuit.

However when the appliance is connected to the mains via an **isolation transformer**, you can touch an earthed soldering iron on either end of the heater as both leads from the isolation transformer are "floating."

Note: As soon as you earth one lead of the output an isolation transformer, the other lead becomes "active."

You can make your own **Isolation Transformer** by connecting two identical transformers "back-to-back."

The following diagram shows how this is done:

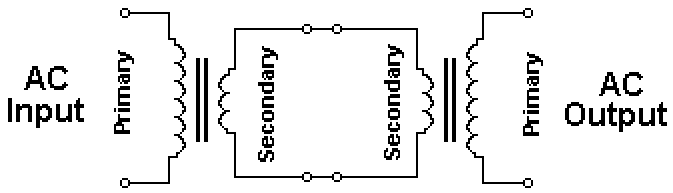

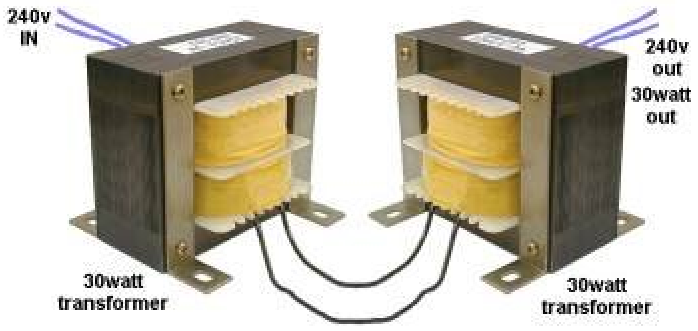

You can use any transformers providing the primary and secondary voltages are the same. The current capability of the secondary winding does not matter. However if you want a supply that has almost the same voltage as your "Mains," you need two transformers with the same voltages.

This handy isolation transformer will provide you with "Mains Voltage" but with a limited current.

In other words it will have a limited capability to supply "wattage." If you are using two 15VA transformers, you will only be able to test an appliance rated at 15 watts.

This has some advantages and some disadvantages.

If you are working on a project, and a short-circuit occurs, the damage will be limited to 15 watts.

If you are using two transformers with different VA ratings, the lower rating will be the capability of the combination.

If the secondaries are not equal, you will get a higher or lower "Mains Voltage."

If you get two transformers from TVs or Monitors, with a rating on the compliance plate of 45 watts, or 90 watts, you can assume the transformers are capable of delivering this wattage and making an isolation transformer will enable you to test

similar items with the safety of being isolated from the mains.
Colin Mitchell designs a lot of "LED lighting lamps" that are connected directly to the mains. He always works with an isolating transformer, just to be safe. Working on exposed "mains" devices is extremely nerve-wracking and you have to be very careful.
The isolation transformer will prevent a BIG EXPLOSION.

DETERMINING THE SPECS OF A TRANSFORMER
Suppose you have a "mains transformer" with unknown output voltages and unknown current capability.
You must be sure it is a mains transformer designed for operation on 50Hz or 60Hz. Switch-Mode transformers operate at frequencies 40kHz and higher and are not covered in this discussion.
To be on the safe-side, connect the unknown transformer to the output of your isolating transformer.
Since the transformer will take almost no current when not loaded, the output voltages it produces will be fairly accurate. Measure the input AC voltage and output AC voltage.
If the transformer has loaded your isolating transformer it will be faulty.
Mains transformers are approx 15VA for 500gm, 30VA for 1kgm 50VA for 2kgm and and 100VA for 2.5kgm.
VA stands for Volts-Amps and is similar to saying watts. Watts is used for DC circuits, while VA refers to AC circuits.
Once you have the weight of the transformer and the output voltage, you can work out the current capability of the secondary.
For transformers up to 30vA, the output voltage on no-load is 30% higher than the final "loaded voltage."
This is due to the poor regulation of these small devices.
If the transformer is 15VA and the output voltage is 15v AC, the current will be 1 amp AC.
You can check the "quality" of the transformer, (the regulation) by fully loading the output and measuring the final voltage. If the transformer has a number of secondaries, the VA rating must be divided between all the windings.

240v to 110v ISOLATION TRANSFORMER

Here's how to create a 110v isolating transformer:
Find a 240v:12v transformer.
Now find a transformer that has two secondary windings, such as 240v:12v+12v.

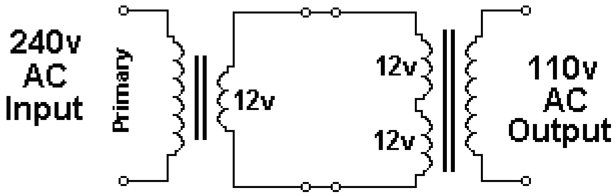

Connect the two transformers as shown in the circuit above. If the output is zero, connect ONE of the 12v windings of the second transformer around the other way.

110v to 240v ISOLATION TRANSFORMER

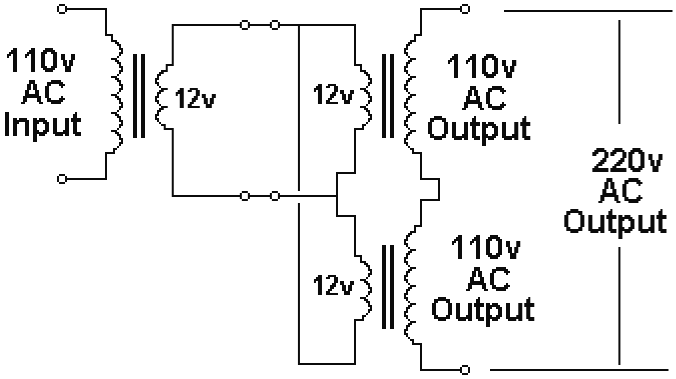

A 110v to 240v isolation transformer can be created by connecting 3 identical transformers as shown in the diagram above. If the output is zero, connect one of the outputs around the other way.

TRANSFORMER RATINGS

Question from a reader:
I have a 28v - 0 - 28v transformer @3amps. Does this mean each side is 1.5 amps?
The transformer is called CENTRE TAPPED and is shown in figures B and C.
It is designed to be connected to two diodes so each winding takes it in turn to deliver the current as shown in diagram C and the output will be 28v AC at 3 amps.
The 28v and 3 amp are both AC values.
If you connect across both outside wires, the output will be 56v at 1.5 amp.
This is because the transformer has a VA rating of 28 x 3 = 84VA. This is very similar to the term "watts."
When the 28v AC is rectified and smoothed, it becomes 28 x 1.4 = 39v (minus 0.6v across the diode) and since the transformer has a rating of 84 VA, the current must be reduced to 84/39 = 2.1 amps to maintain the VA rating.
Some transformers are specified as say: 12v - 0 - 12v, but the wiring diagram is shown as "A." This transformer should be specified as 12v + 12v as the secondaries are separate.
12v - 0 - 12v means the two secondary windings are NOT separate.
It does not make any difference to the output voltage and current, if the windings are separate or joined. The only difference is 12v +12v can be turned into two separate 12v outputs.
If you do not know the output current for a particular transformer, go to the website of electronic parts suppliers and compare the weight of your transformer with others. This will give you a VA rating and you can work out the current, once you know the output voltage.
Note: the output current finishes up ONLY 60% of the rating on the transformer tag because the rating is an **AC RATING**.
With 2 separate secondaries, you can parallel the outputs to get double the current, but don't forget 12v + 12v @ 3amp means 12v in parallel with 12v will provide 2amp DC and the DC voltage will be about 17v.

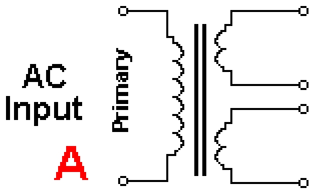

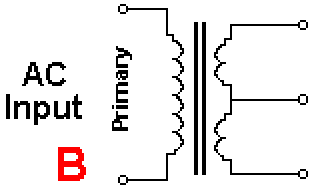

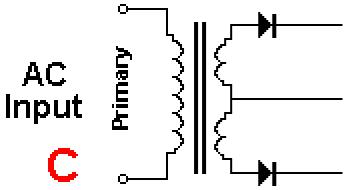

CURRENT TRANSFORMER

A Current Transformer is really an ordinary transformer.
All transformers produce a CURRENT output and a VOLTAGE output.
If you put an ammeter across the secondary, the current will increase through the meter when the primary voltage is increased.
This is because the output voltage will increase and this voltage will allow a higher current to flow.

WHY DETECT CURRENT? Why not voltage?

Because the voltage of say the "240v AC" is always 240v but the current can increase from say 1 amp to nearly 15 amps, depending what appliance is connected. So it is pointless measuring voltage.
A Current Transformer is a step-up transformer. When we say step-up and step-down, we are referring to the voltage - comparing the primary voltage to the secondary voltage. (Most transformers on the "mains" are step-down transformers and are used as power supplies to laptops, phone chargers etc.) Even a welding transformer is a step-down device and produces about 20v to 70v, while the current can be as high as 100 amps. This current is higher than the mains will deliver and is needed to melt the metal at the point of contact of the probe and the item being welded.
A Current Transformer is a step-up transformer. The primary consists of a single turn (or maybe 2 - 5 turns) and the secondary has 100 turns (or more).
This means the voltage seen by the primary will be increased 100 times and appear as anything from a few hundred millivolts to a few volts, depending on the quality of the coupling. (the magnetic coupling between the wire through the centre of the core, the quality of the core to transfer this magnetic flux to the secondary turns.)
This voltage is then passed to a low value resistor, where the voltage is reduced to a level that suits the detection circuit and the resulting millivolts is interpreted as current in the wire being tested.

Recapping:

The reading on the secondary has no relation to the current in the primary. We need to add a LOAD RESISTOR and create a table before we can use the transformer.
There is no such thing as a CURRENT TRANSFORMER. It is really an INSTRUMENT TRANSFORMER and the scale has been marked in units of CURRENT after measurements have been made.   (INSTRUMENT TRANSFORMER means it is a device that helps us to produce a connection between current flowing through a wire and a reading on a meter or display).
If we connect a load to the secondary, (say an ammeter), it will produce a reading that increases when the current through the single primary turn is increased. That's because the ammeter is a LOAD. But the reading is meaningless until be calibrate the scale.

Now, lets look at the primary.
A wire (or cable) through the centre of the core is counted as one turn. If the turn is wrapped around the core, the coupling will be improved, but if we always use a straight wire, it does not matter where it is positioned inside the centre of the core.
It does not matter if the magnetic interaction of the flux from the wire is good or bad, we just have to keep to the same way of using the transformer.
The calibration can be done with any poor coupling and the result will be accurate for all future readings.
If a low-value resistor is placed across the secondary, the voltage across this resistor will increase and also the current through it will increase. But we are not going to measure the current through the resistor. We are going to measure the voltage across the resistor and by taking lots of reading we will finish up with a scale or table and this is called CALIBRATION. The results will be equated to the current flowing through the primary wire (primary turn).
A clamp meter uses a current transformer and the jaws must be closed completely and cleanly for the flux to flow around the core and produce a reading in the secondary.
Dirt in the jaws will reduce the reading considerably.
You cannot measure the current in a "power cord" because it contains both the active and neutral wires.
Even though the current is a maximum in both conductors at the same time, the current is flowing in two different directions and the magnetic flux produced by one conductor is clockwise and the other is anticlockwise and they are cancelled by each other.

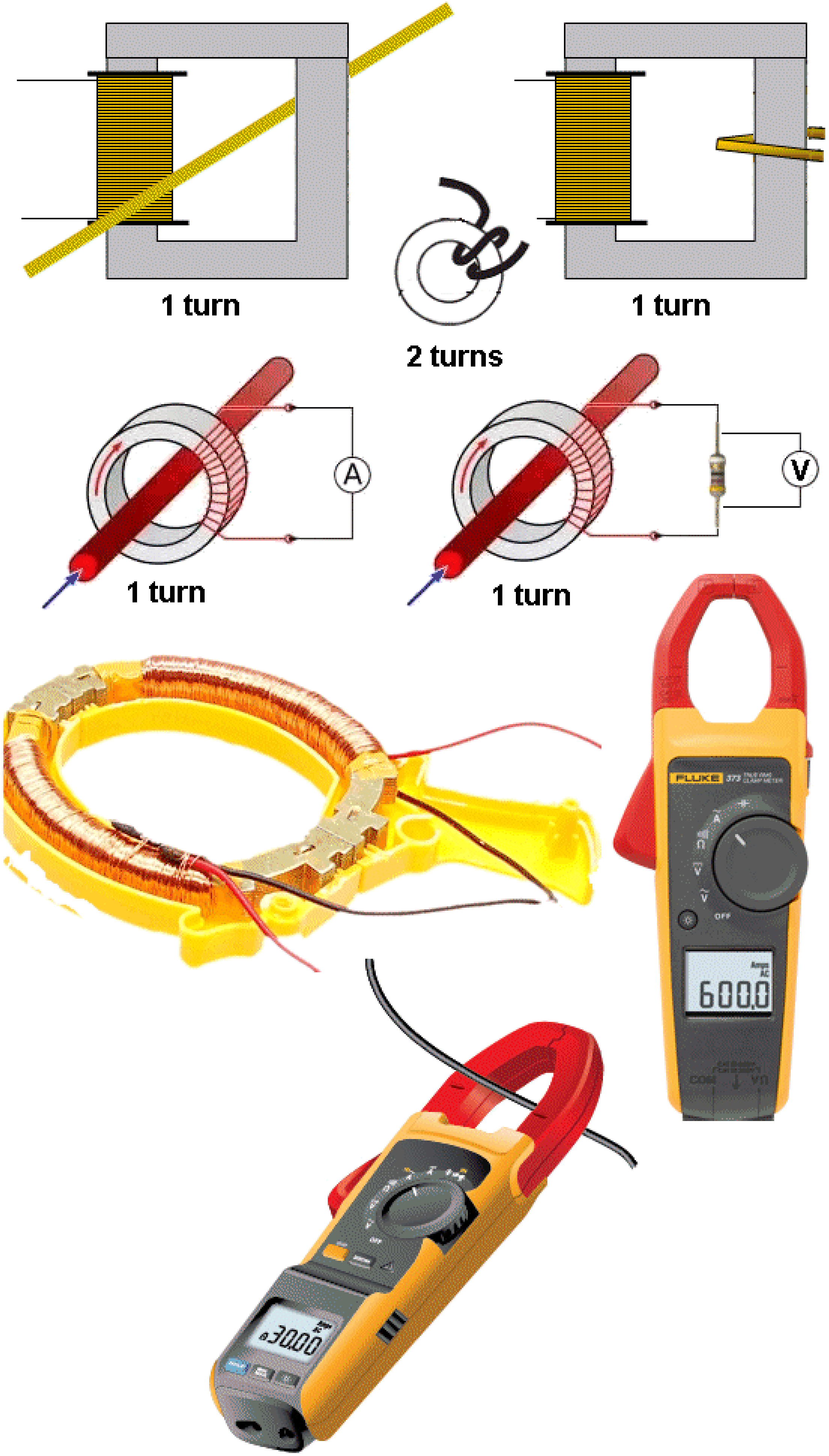
1 turn
2 turns
1 turn
A
V
1 turn
1 turn
FLUKE 373
600.0
30.00

Identifying ONE TURN.
The quality (the coupling) of a single STRAIGHT wire

through the centre of a core is very poor
but if all readings are taken with this amount
of coupling, the readings will be accurate, as the
calibrations have been done with this arrangement.

OPTO ISOLATORS and OPTO COUPLERS

Opto Isolators and Opto Couplers are the same thing. A common opto-coupler is 4N35. It is used to allow two circuits to exchange signals yet remain electrically isolated. The signal is applied to the LED, which shines on a silicon NPN photo-transistor in the IC.
The light is proportional to the signal, so the signal is transferred to the photo transistor to turn it on a proportional amount. Opto-couplers can have Light Activated SCR's, photodiodes, TRIAC's and other semiconductor devices as an output. The 4N35 opto-coupler schematic is shown below:

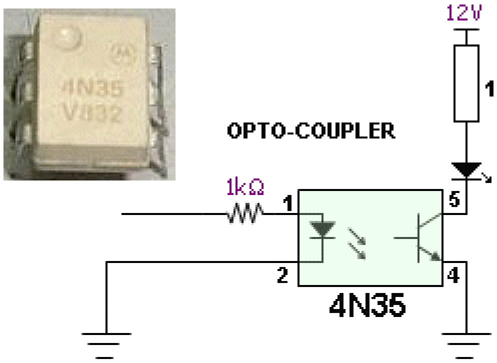

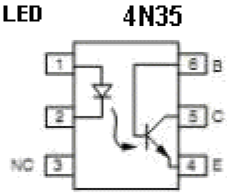

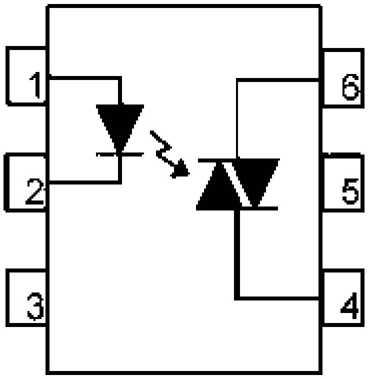

An opto-Coupler using a TRIAC
Note: the pinout is different to 4N35

TESTING AN OPTO COUPLER

Most multimeters cannot test the LED on the input of an opto-coupler because the ohms range does not have a voltage high enough to activate the LED with at least 2mA.
You need to set-up the test-circuit shown above with a 1k resistor on the input and 1k5 on the output. When the 1k is connected to 12v, the output LED will illuminate.
The opto-coupler should be removed from circuit to perform this test.

TRANSISTORS

Transistors are solid-state devices and although they operate completely differently to a diode, they appear as two back-to-back diodes when tested.
There are basically 2 types of transistor NPN and PNP.
A transistor is sometimes referred to as BJT (Bi-polar Junction Transistor) to distinguish it from other types of transistor such as Field Effect transistor, Programmable Unijunction Transistor and others.

In the following diagram, two diodes are connected together and although the construction of a transistor is more complex, we see the transistor as two diodes when testing it.

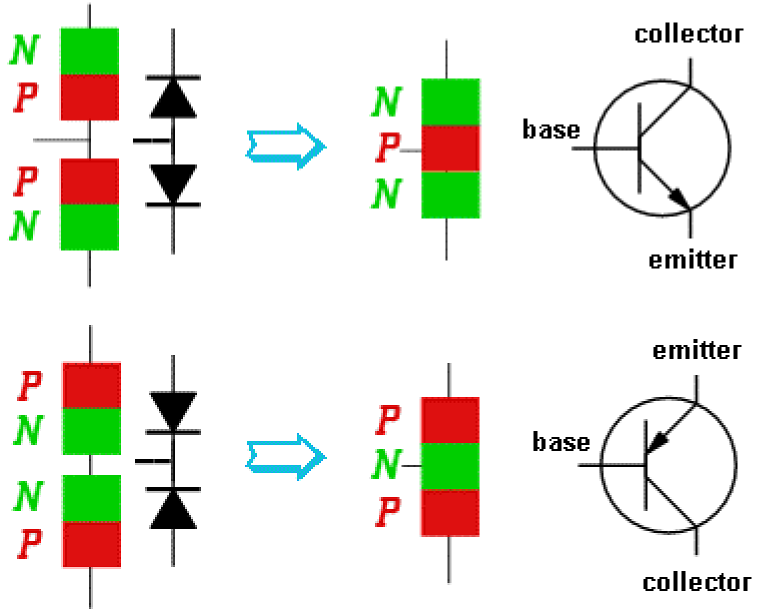

A TRANSISTOR APPEARS AS TWO DIODES WHEN TESTING IT

All transistors have three leads. Base (b), Collector (c), and Emitter (e).
For an NPN transistor, the arrow on the emitter points away from the base.
It is fortunate that the arrow on both symbols points in the direction of the flow of current (Conventional Current) and this makes it easy to describe testing methods using our simplified set of instructions. The symbols have been drawn exactly as they appear on a circuit diagram.

All transistors **are the same** but we talk about digital and analogue transistors.
There is no difference between the two.
The difference is the circuit. And the only other slight difference between transistors is the fact that some have inbuilt diodes and resistors to simplify the rest of the circuit.
All transistors work the same way. The only difference is the amount of amplification they provide, the current and voltage they can withstand and the speed at which they work. For simple testing purposes, they are all the same.

NPN transistors are the most common and for an NPN transistor, the following applies.
(the opposite applies for PNP)
To test a transistor, there is **one thing** you have to know:
When the base voltage is higher than the emitter, current flows though the collector-emitter leads.
As the voltage is increased on the base, nothing happens until the voltage reaches 0.55v. At this point a very small current flows through the collector-emitter leads. As the voltage is increased, the current-flow increases. At about 0.75v, the current-flow is a MAXIMUM. (can be as high as 0.9v). That's how it works. A transistor also needs **current** to flow into the base to perform this amplifying function and this is the one feature that separates an ordinary transistor from a FET.

If the voltage on the base is 0v, then instantly goes to 0.75v, the transistor initially passes NO current, then FULL current. The transistor is said to be working in its two states: OFF then ON (sometimes called: "cut-off" and "saturation"). These are called digital states and the transistor is said to be a **DIGITAL TRANSISTOR** or a **SWITCHING TRANSISTOR** , working in **DIGITAL MODE.**

If the base is delivered 0.5v, then slowly rises to 0.75v and slowly to 0.65v, then

0.7v, then 0.56v etc, the transistor is said to be working in ANALOGUE MODE and the transistor is an **ANALOGUE TRANSISTOR**.
Since a transistor is capable of amplifying a signal, it is said to be an active device. Components such as resistors, capacitors, inductors and diodes are not able to amplify and are therefore known as passive components.

In the following tests, use your finger to provide the **TURN ON** voltage for the base (this is 0.55v to 0.7v) and as you press harder, more current flows into the base and thus more current flows through the collector-emitter terminals. As more current flows, the needle of the multimeter moves UP-SCALE.

TESTING A TRANSISTOR ON A DIGITAL METER

Testing a transistor with a **Digital Meter** must be done on the "DIODE" setting as a digital meter does not deliver a current through the probes on some of the resistance settings and will not produce an accurate reading.
The "DIODE" setting must be used for diodes and transistors. It should also be called a "TRANSISTOR" setting.

TESTING AN unknown TRANSISTOR

The first thing you may want to do is test an unknown transistor for COLLECTOR, BASE AND EMITTER. You also want to perform a test to find out if it is NPN or PNP. That's what this test will provide.
You need a cheap multimeter called an ANALOGUE METER - a multimeter with a scale and pointer (needle).
It will measure resistance values (normally used to test resistors) - (you can also test other components) and Voltage and Current. We use the resistance settings. It may have ranges such as "x10" "x100" "x1k" "x10"
Look at the resistance scale on the meter. It will be the top scale.
The scale starts at zero on the right and the high values are on the left. This is opposite to all the other scales.
When the two probes are touched together, the needle swings FULL SCALE and reads "ZERO." Adjust the pot on the side of the meter to make the pointer read exactly zero.

How to read: "x10" "x100" "x1k" "x10"
Up-scale from the zero mark is "1"
When the needle swings to this position on the "x10" setting, the value is 10 ohms.
When the needle swings to "1" on the "x100" setting, the value is 100 ohms.
When the needle swings to "1" on the "x1k" setting, the value is 1,000 ohms = 1k.
When the needle swings to "1" on the "x10k" setting, the value is 10,000 ohms = 10k.
Use this to work out all the other values on the scale.
Resistance values get very close-together (and very inaccurate) at the high end of the scale. [This is just a point to note and does not affect testing a transistor.]

Step 1 - FINDING THE BASE and determining NPN or PNP
Get an unknown transistor and test it with a multimeter set to "x10"
Try the 6 combinations and when you have the black probe on a pin and the red probe touches the other pins and the meter swings nearly full scale, you have an NPN transistor. The black probe is BASE
If the red probe touches a pin and the black probe produces a swing on the other two pins, you have a PNP transistor. The red probe is BASE
If the needle swings FULL SCALE or if it swings for more than 2 readings, the transistor is **FAULTY**.

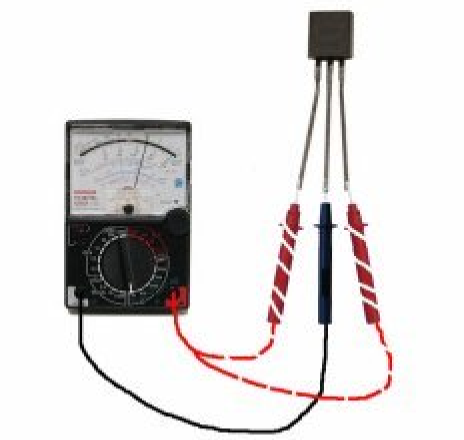

This is an NPN transistor
The black probe is the BASE

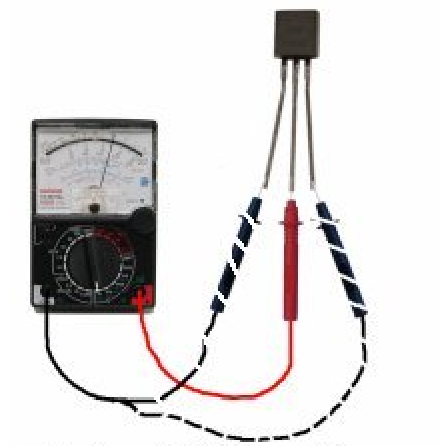

This is a PNP transistor
The red probe is the BASE

Step 2 - FINDING THE COLLECTOR and EMITTER
Set the meter to "x10k."
For an NPN transistor, place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.

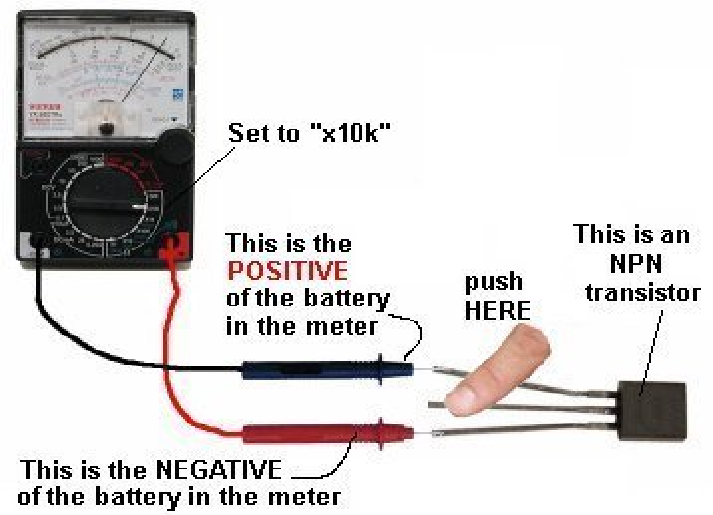
Set to "x10k"
This is the POSITIVE of the battery in the meter
push HERE
This is an NPN transistor
This is the NEGATIVE of the battery in the meter

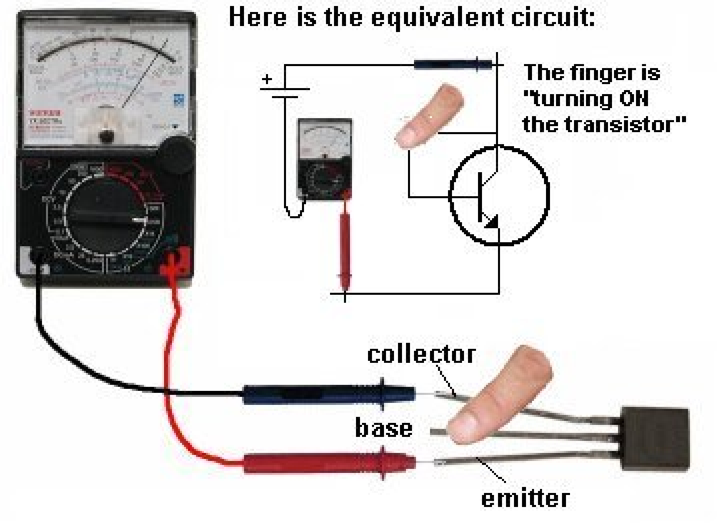
Here is the equivalent circuit:
+
The finger is "turning ON the transistor"
collector
base
emitter

You have found the Collector Base and Emitter

For a PNP transistor, set the meter to "x10k" place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.

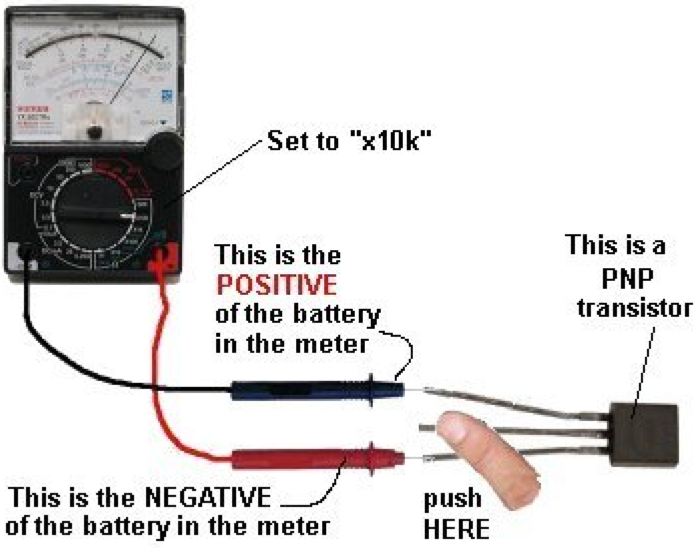
Set to "x10k"
This is the POSITIVE of the battery in the meter
This is a PNP transistor
This is the NEGATIVE of the battery in the meter
push HERE

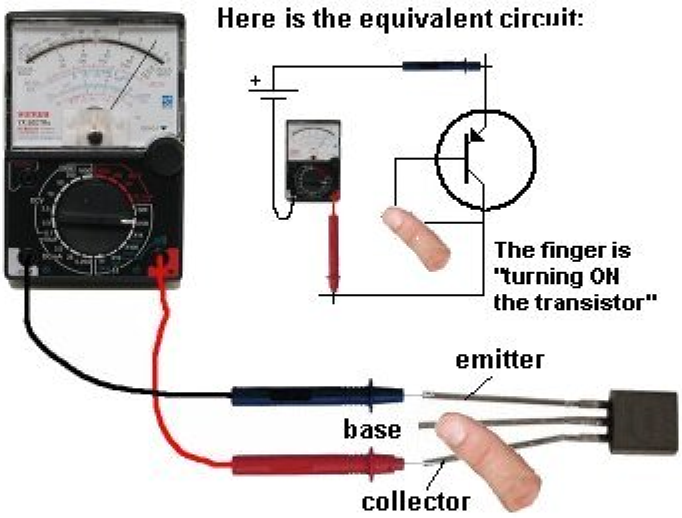
Here is the equivalent circuit:
+
The finger is "turning ON the transistor"
emitter
base
collector

You have found the Collector Base and Emitter

SIMPLEST TRANSISTOR TESTER

The simplest transistor tester uses a 9v battery, 1k resistor and a LED (any colour). Keep trying a transistor in all different combinations until you get one of the circuits below. When you push on the two leads, the LED will get brighter.
The transistor will be NPN or PNP and the leads will be identified:

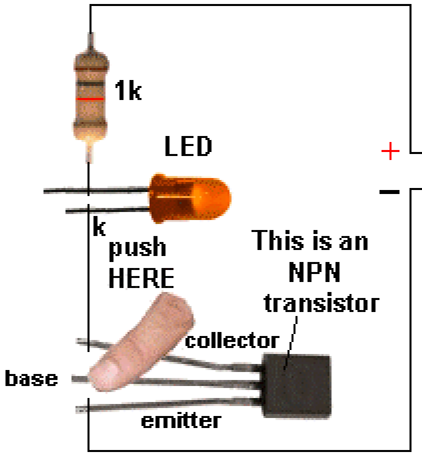
1k
LED
+
−
k
push
HERE
This is an
NPN
transistor
collector
base
emitter

Here is the equivalent circuit:

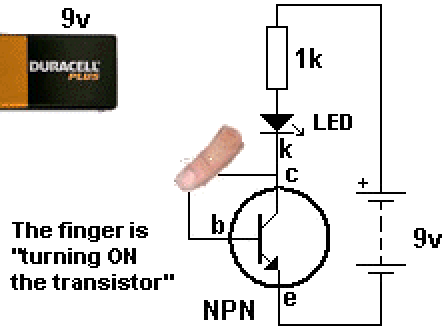
9v
1k
LED
k
c
b
The finger is
"turning ON
the transistor"
NPN
e
+
9v

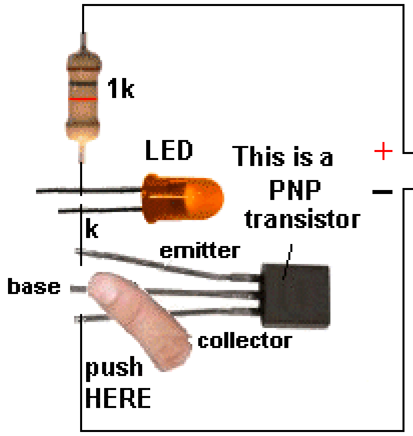
1k
LED
This is a
PNP
transistor
+
−
k
emitter
base
collector
push
HERE

Here is the equivalent circuit:

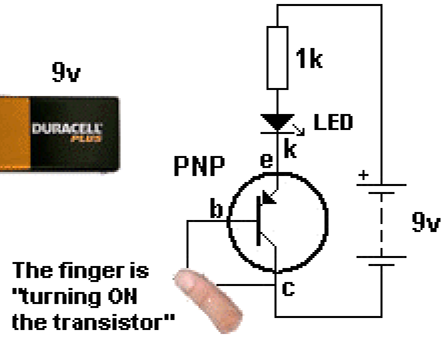
9v
1k
LED
k
PNP
e
b
+
9v
The finger is
"turning ON
the transistor"
c

The leads of some transistors will need to be bent so the pins are in the same positions as shown in the diagrams. This helps you see how the transistor is being turned on. This works with NPN, PNP transistors and Darlington transistors.

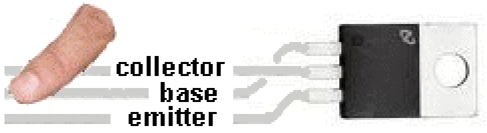
collector
base
emitter

NPN transistor

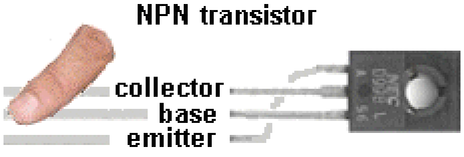
collector
base
emitter

NPN transistor

HEATSINKING

Heat generated by current flowing between the collector and emitter leads of a transistor causes its temperature to rise. This heat must be conducted away from the transistor otherwise the rise may be high enough to damage the P-N junctions inside the device. Power transistors produce a lot of heat, and are therefore usually mounted on a piece of aluminium with fins, called a **HEATSINK**.
This draws heat away, allowing it to handle more current. Low-power signal transistors do not normally require heat sinking. Some transistors have a metal body or fin to connect to a larger heatsink. If the transistor is connected to a heatsink with a mica sheet (mica washer), it can be damaged or cracked and create a short-circuit. (See Testing Mica Washers). Or a small piece of metal may be puncturing the mica. Sometimes white compound called **Heatsink Compound** is used to conduct heat through the mica. This is very important as mica is a very poor conductor of heat and the compound is needed to provide maximum thermal conduction.

TRANSISTOR FAILURE

Transistor can fail in a number of ways. They have forward and reverse voltage ratings and once these are exceeded, the transistor will ZENER or conduct and may fail. In some cases a high voltage will "puncture" the transistor and it will fail instantly. In fact it will fail much faster via a voltage-spike than a current overload.

It may fail with a "short" between any leads, with a collector-emitter short being the most common. However failures will also create shorts between all three leads.
A shorted transistor will allow a large current to flow, and cause other components to heat up.
Transistors can also develop an open circuit between base and collector, base and emitter or collector and emitter.
The first step in identifying a faulty transistor is to check for signs of overheating. It may appear to be burnt, melted or exploded. When the equipment is switched off, you can touch the transistor to see if it feels unusually hot. The amount of heat you feel should be proportional to the size of the transistor's heat sink. If the transistor has no heat sink, yet is very hot, you can suspect a problem.
DO NOT TOUCH A TRANSISTOR IF IT IS PART OF A CIRCUIT THAT CARRIES 240VAC. Always switch off the equipment before touching any components.

TRANSISTOR REPLACEMENT

If you can't get an exact replacement, refer to a transistor substitution guide to identify a near equivalent.

The important parameters are:
- Voltage
- Current
- Wattage
- Maximum frequency of operation

The replacement part should have parameters equal to or higher than the original.

Points to remember:
- Polarity of the transistor i.e. PNP or NPN.
- At least the same voltage, current and wattage rating.
- Low frequency or high frequency type.
- Check the pinout of the replacement part
- Use a desoldering pump to remove the transistor to prevent damage to the printed circuit board.
- Fit the heat sink.
- Check the mica washer and use heat-sink compound
- Tighten the nut/bolt - not too tight or too loose.
- Horizontal output transistors with an integrated diode should be replaced with the same type.

DIGITAL TRANSISTORS

There is no such thing as a DIGITAL TRANSISTOR or an AUDIO TRANSISTOR.
All transistors are just "TRANSISTORS" and the surrounding components as well as the type of signal, make the transistor operate in DIGITAL MODE or ANALOGUE MODE.
But we have some transistors that have inbuilt resistors to make them suitable for connecting to a digital circuit without the need for a base resistor.
Here is the datasheet for an NPN transistor BCR135w and PNP datasheet for BCR185w.
These transistors are called "Digital Transistors" because the "base lead" can be connected directly to the output of a digital stage. This "lead" or "pin" is not really the base of the transistor but a 4k7 (or 10k) resistor connected to the base allows the transistor to be connected to the rest of a digital circuit.
You cannot actually get to the base. The resistor(s) are built into the chip and the transistor is converted into a "Digital Transistor" because it will accept 5v on the "b"

lead.
The 47k is not really needed but it makes sure the transistor is fully turned OFF if the signal on the "b" lead is removed (in other words - if the input signal is converted to a high-impedance signal - see tri-state output from microcontrollers for a full explanation).
This transistor is designed to be placed in a circuit where the input changes from low to high and high to low and does not stop mid-way. This is called a DIGITAL SIGNAL and that is one reason why the transistor is called a digital transistor. (However you could stop half-way but the transistor may heat up and get too hot).
Any transistor placed in a digital circuit can be called a "digital transistor" but it is better to say it is operating in DIGITAL MODE.

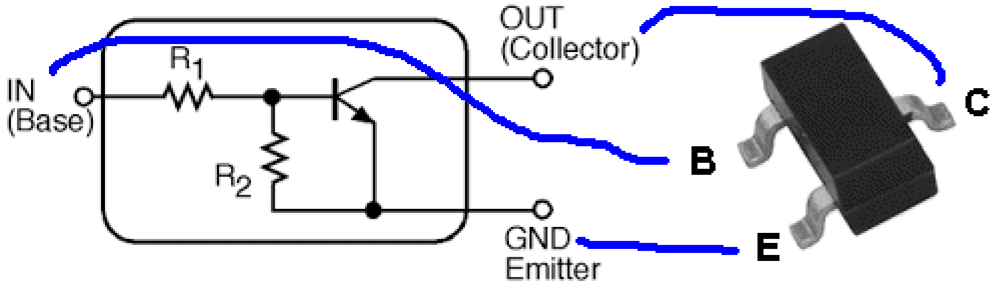
OUT
(Collector)
IN
(Base)
R_1
R_2
GND
Emitter
B
C
E

The digital transistor has two resistors included inside the case
R1 is about 10k and R2 is approx 47k

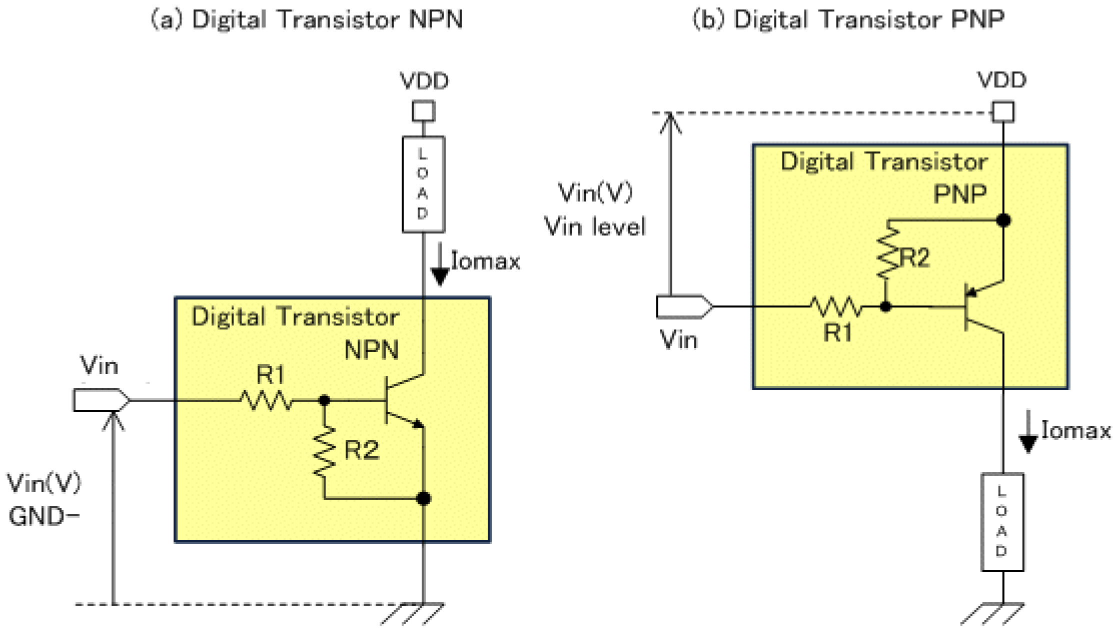
(a) Digital Transistor NPN

(b) Digital Transistor PNP
VDD
LOAD
Iomax
Digital Transistor
NPN
Vin
R1
R2
Vin(V)
GND−
VDD
Vin(V)
Vin level
Digital Transistor
PNP
R2
Vin
R1
Iomax
LOAD

Equivalent circuit of the digital transistor

These transistors can be made to work in analogue circuits because they are ordinary transistors with a 10k base resistor, but you will have to know what you are doing.

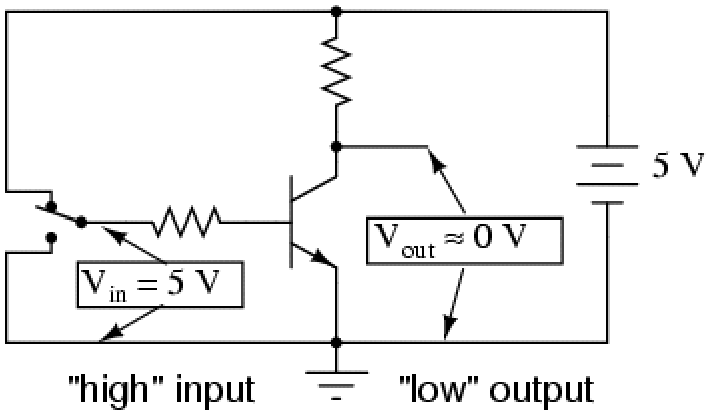

Transistor in saturation

The circuit above shows the digital transistor is designed to allow a voltage of 5v to be supplied to the "base" pin and the transistor will Fully Conduct.
This type of transistor saves putting a base resistor on the PC board.
It can be tested just like a normal transistor but the resistance between base and emitter will be about 5k to 50k in both directions. If the collector-emitter is low in both directions the transistor is damaged.
Here's how to look at how the transistor works:
The 10k resistor on the base will allow 0.5mA to flow into the base. But the 47k will reduce this to 0.4mA. If the transistor has a gain of 100, the collector-emitter current can be 40mA.
To determine the current capability of the transistor, connect 100R load and turn the transistor ON. This will allow about 100mA for the collector-emitter current. Measure the collector-emitter voltage. If it is more than 0.5v, the transistor is OVER-LOADED.

DARLINGTON TRANSISTORS

A DARLINGTON TRANSISTOR is two transistors in a single package with three leads. They are internally connected in cascade so the gain of the pair is very high. This allows a very small input signal to produce a large signal at the output. They have three leads (Base, Collector and Emitter and can be PNP or NPN) and are equivalent to the leads of a standard individual transistor, but with a very high gain. The second advantage of a Darlington Transistor is its high input impedance. It puts very little load on the previous circuit.
Some Darlington transistors have a built-in diode and/or built-in resistor and this will produce a low reading in both directions between the base and emitter leads.

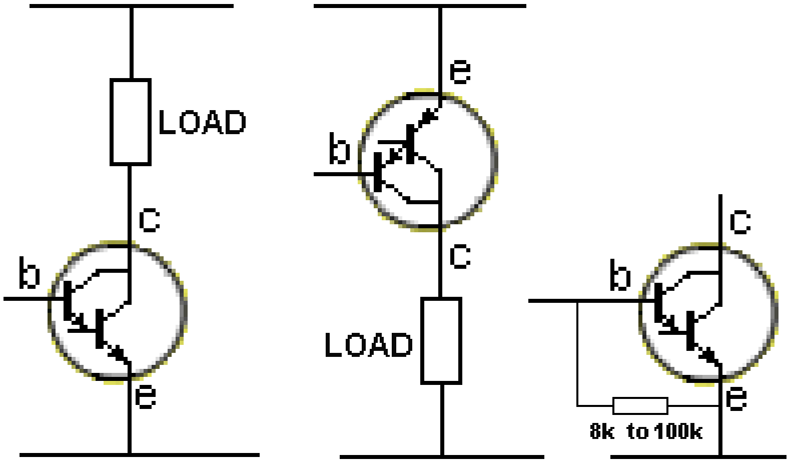

NPN Darlington PNP Darlington

Darlington transistors are tested the same as an ordinary transistor and a multimeter will produce about the same deflection, even though you will be measuring across two junctions, (and a base-emitter resistor is present).

HORIZONTAL OUTPUT TRANSISTORS, SWITCH-MODE TRANSISTORS, FLYBACK TRANSISTORS, POWER TRANSISTORS, VERTICAL TRANSISTORS . . . .

These are all names given to a transistor when it is used in a particular circuit. ALL these transistors are the same for testing purposes.

We are not testing for gain, maximum voltage, speed of operation or any special feature. We are just testing to see if the transistor is completely faulty and SHORTED.

A transistor can have lots of other faults and the circuit **using the transistor** is the best piece of TEST EQUIPMENT as it is detecting the fault.

TESTING MOSFETs and FETs

MOSFETs and **JFETs** are all part of the **FET** family.

MOSFET stands for **Metal Oxide Semiconductor Field Effect Transistor.**

FETs operate exactly the same as a "normal" transistor except they have different names for the input and output leads and the voltage between the gate and the source has to between 2v to 5v for the device to turn on fully. A FET requires almost NO CURRENT into the Gate for it to turn on and when it does, the voltage between drain and source is very low (only a few mV). This allows them to pass very high currents without getting hot. There is a point where they start to turn on and the input voltage must rise higher than this so the FET turns on FULLY and does not get hot.

Field Effect Transistors are difficult to test with a multimeter, but "fortunately" when a power **MOSFET** blows, it is completely damaged. All the leads will show a short circuit. 99% of bad **MOSFETs** will have GS, GD and DS shorted.

The following symbols show some of the different types of MOSFETs:

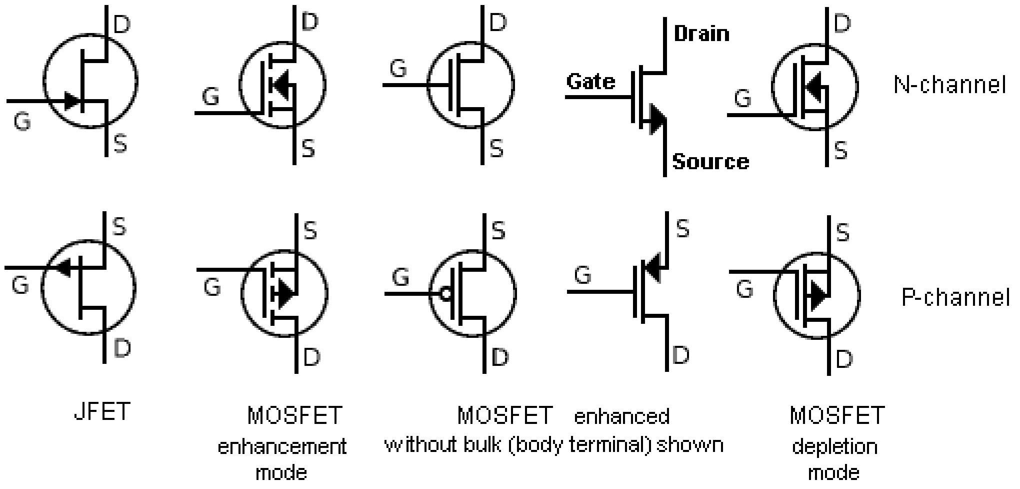

Most **MOSFET** transistors cannot be tested with a multimeter. This due to the fact that the Gate needs 2v - 5v to turn on the device and this voltage is not present on the probes of either meter set to any of the ohms ranges.

You need to build the following Test Circuit:

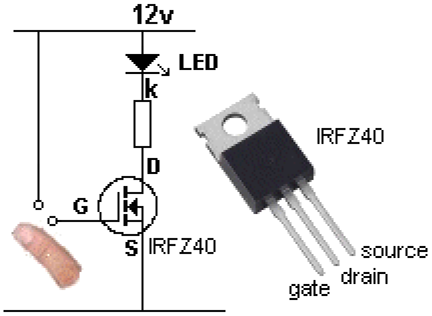

N-channel

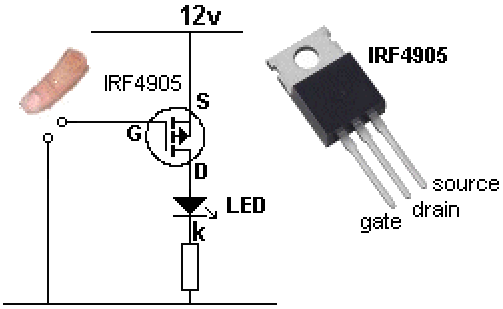

P-channel

Touching the Gate will increase the voltage on the Gate and the MOSFET will turn ON and illuminate the LED. Removing your finger will turn the LED off.
Large devices such as the TO-220 types shown above do not like static electricity on the gate and you have to be careful not to "spike" the gate with any static. Generally this type of device is not "super sensitive" and you can use your finger or a large value resistor.
When replacing one of these devices, there are 2 things to match-up.
Voltage and Current.
In most cases, the "turn-ON" resistance (the resistance between Source and Drain) will be the same (something like 22 milli ohms) and the speed of operation will be ok.
Check the voltage needed to turn the gate ON and make sure you can supply the required voltage.

SILICON CONTROLLED RECTIFIERs (SCR)

The **Silicon Controlled Rectifier** (SCR) is a semiconductor device that is a member of a family of control devices known as **Thyristors**. It is a 3-leaded device and when a small current enters the Gate, the **thyristor** turns on. AND STAYS ON. It only conducts current between Anode and Cathode in one direction and it is mainly only used in DC circuits. When it is used with AC, it will only conduct for a maximum of half the cycle.

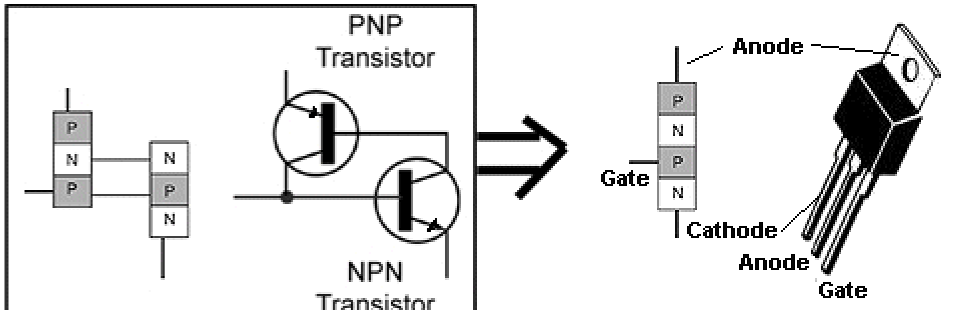
PNP
Transistor
P
N
P
N
P
N
NPN
Transistor
Anode
P
N
P
N
Gate
Cathode
Anode
Gate

THYRISTOR or SCR

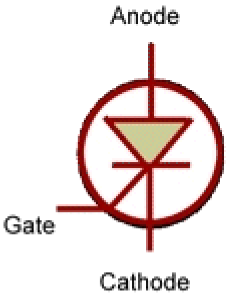
Anode
Gate
Cathode

SCR

Silicon Controlled Rectifier

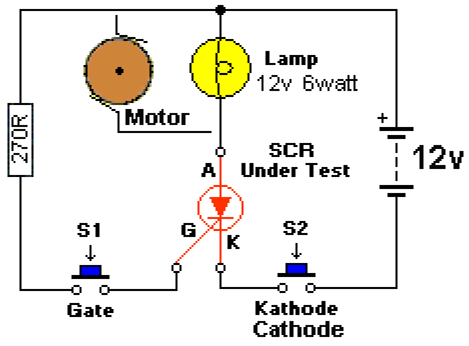
Lamp
12v 6watt
Motor
270R
+
12v
SCR
Under Test
A
G
K
S1
S2
Gate
Kathode
Cathode

SCR TESTER

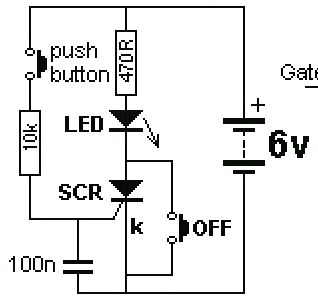
push
button
470R
10k
LED
SCR
k
OFF
100n
+
6v

A

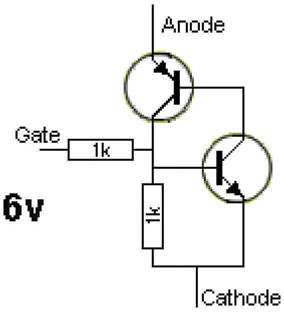
Anode
Gate
1k
1k
Cathode

SCR WITH TRANSISTORS

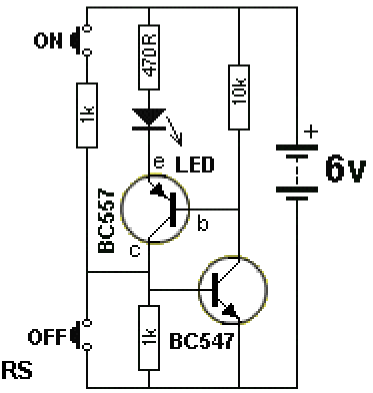
ON
470R
1k
10k
e
LED
BC557
b
c
+
6v
OFF
1k
BC547

B

To understand how an SCR "latches" when the gate is provided with a small current, we can replace it with two transistors as shown in diagram B above. When the ON button is pressed, the BC547 transistor turns on. This turns ON the BC557 and it takes over from the action of the switch.

To turn the circuit off, the OFF button removes the voltage from the base of the BC547.

Testing an SCR

An **SCR** can be tested with some multimeters but a minimum current Anode-to-Cathode is needed to keep the device turned on. Some multimeters do not provide this amount of current and the **SCR Tester** circuit above is the best way to test these devices.

Shorted SCRs can usually be detected with an ohmmeter check (SCRs usually fail shorted rather than open).

Measure the anode-to-cathode resistance in both the forward and reverse direction; a good SCR should measure near infinity in both directions.

Small and medium-size SCRs can also be gated ON with an ohmmeter (on a digital meter use the Diode Check Function). Forward bias the SCR with the ohmmeter by connecting the black (-) lead to the anode and the red (+) lead to the cathode

(because the + of the battery is connected to the negative lead, in most analogue multimeters). Momentarily touch the gate lead to the anode while the probes are still touching both leads; this will provide a small positive turn-on voltage to the gate and the cathode-to-anode resistance reading will drop to a low value. Even after removing the gate voltage, the SCR will stay conducting. Disconnecting the meter leads from the anode or cathode will cause the SCR to revert to its non-conducting state.
When making the above test, the meter impedance acts as the SCR load. On larger SCRs, it may not latch ON because the test current is not above the SCR holding current.

Using the SCR Tester
Connect an SCR and press Switch2. The lamp should not illuminate. If it illuminates, the SCR is around the wrong way or it is faulty.
Keep Switch 2 PRESSED. Press Sw1 very briefly. The lamp or motor will turn ON and remain ON. Release Sw 2 and press it again. The Lamp or motor will be OFF.

TRIACs

A triac is a bidirectional, three-terminal dual, back-to-back thyristor (SCR) switch. This device will conduct current in both directions when a small current is constantly applied to the Gate.
If the gate is given a small, brief, current during any instant of a cycle, it will remain triggered during the completion of the cycle until the current though the Main Terminals drops to zero.
This means it will conduct both the positive and negative half-cycles of an AC waveform. If it is tuned on (with a brief pulse) half-way up the positive waveform, it will remain on until the wave rises and finally reaches zero. If it is then turned on (with a brief pulse) part-way on the negative wave, the result will be pulses of energy and the end result will be about 50% of the full-energy delivered at a rate of 100 times per second for a 50HZ supply.
TRIACs are particularly suited for AC power control applications such as motor speed control, light dimmers, temperature control and many others.

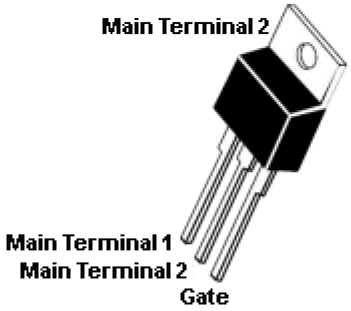

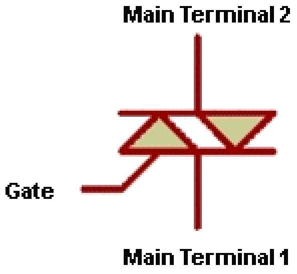

TRIAC (2 SCR's)
TRIode for Alternating Current

Using the TRIAC Tester

Connect a TRIAC and press Switch2. The lamp should not illuminate. If it illuminates, the TRIAC is faulty.
Keep Switch 2 PRESSED. Press Sw1 very briefly. The lamp or motor will turn ON and remain ON. If the lamp does not turn on, reverse the TRIAC as the current into the gate must produce a slight voltage between **Gate** and **Main Terminal 1**.
Release Sw 2 and press it again. The Lamp or motor will be OFF.

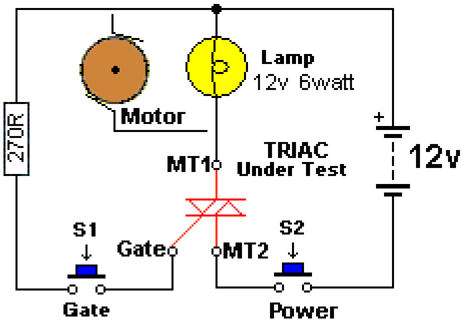

TRIAC TESTER

MICA WASHERS AND INSULATORS

Plastic insulating sheets (washers) between a transistor and heatsink are most often made from mica but some are plastic and these get damaged over a period of time, turn dark and become cracked.
The plastic eventually becomes carbonized and conducts current and can affect the operation of the appliance. You can see the difference between a mica sheet (washer) and plastic by looking where it extends from under the transistor. Replace all plastic insulators as they eventually fail.

SPARK GAPS

Some TV's and monitors with a CRT (picture tube), have spark gaps either on the socket at the end of the tube or on the chassis.
These can consist of two wires inside a plastic holder or a glass tube or special resistive device.
The purpose of a spark gap is to take any flash-over (from inside the tube), to earth. This prevents damage to the rest of the circuit.
However if the tube constantly flashes over, a carbon track builds up between the wires and effectively reduces the screen voltage. This can cause brightness and/or focus problems. Removing the spark-gap will restore the voltage.
These are not available as a spare component and it's best to get one from a discarded chassis.

CO-AX CABLES

Co-Ax cables can produce very high losses and it seems impossible that a few metres of cable will reduce the signal. The author has had a 3 metre cable reduce the signal to "snow" so be aware that this can occur. Faults can also come from a splitter and/or balun as well as dirty plugs and sockets. This can result in very loud bangs in the sound on digital reception.

TESTING EARTH LEAKAGE DETECTORS or Residual Current Devices or Ground Fault Circuit Interrupters or GFCI

An Earth Leakage Detector or Sensor is a circuit designed to continuously monitor the imbalance in the current in a pair of load carrying conductors.
These two conductors are normally the Active and Neutral. Should the imbalance current reach 30mA the sensor will "trip" and remove the voltage (and current) from

the line being monitored.
Some detectors will trip at 15mA.
You cannot alter the sensitivity of the device however there are a number of faults in these devices that can be fixed.
In some devices the contact pressure for the 10Amp or 15 Amp contacts is very weak and they arc and produce an open circuit. The result is this: When you press the rest button, power is not restored to the output.
Clean the contacts with a small file and bend the metal strips to the contacts so they make a very strong contact.
The other fault is the trip mechanism.
The magnetism from the coil does not allow the pin to move and "trip" the contacts.
It may be due to a small metal filing or the pin not moving freely enough.
All good Earth Leakage Detectors have a TEST BUTTON. This connects a resistor between the active line and earth so that 15mA or 30mA flows.
The detector should trip immediately. Make sure the trigger mechanism trips when the test button is pressed.
None of the electronics in the detector can be replaced however you can test the mechanical operation and the pressure on the contacts when the unit is removed from the power. Do not work on the device when it is connected to the mains.

TESTING CELLS AND BATTERIES

There is an enormous number of batteries and cells on the market and a number of "battery testers." Instead of buying a battery tester that may give you a false reading, here is a method of testing cells that is guaranteed to work.
There are two types of cell: a **rechargeable** cell and a non rechargeable cell.

The easiest way to test a **rechargeable** cell is to put a group of them in an appliance and use them until the appliance "runs down" or fails to work. If you consider the cells did not last very long, remove them and check the voltage of each cell. The cell or cells with the lowest voltage will be faulty. You can replace them with new cells or good cells you have in reserve.
There is no other simple way to test a rechargeable cell.
You cannot test the "current of a cell" by using an ammeter. A rechargeable cell can deliver 10 amps or more, even when nearly discharged and you cannot determine a good cell for a faulty cell.

Dry cells are classified as "non-rechargeable" cells.
DRY CELLS and MANGANESE CELLS are the same thing. These produce 1.5v per cell (manganese means the Manganese Dioxide depolariser inside the cell. All "dry cells" use manganese dioxide).
ALKALINE CELLS produce between 2 - 10 times more energy than a "dry cell" and produce 1.5v per cell.
Alkaline cells can fail for no reason at any stage in their life and are not recommended for emergency situations.
The output voltage of some Alkaline cells can fall to 0.7v or 0.9v for not apparent reason.
There are lots of other cells including "button cells," hearing-aid cells, air cells, and they produce from 1.2v to 3v per cell.

Note:
Lithium cells are also called "button cells" and they produce 3v per cell.
Lithium cells are non-rechargeable (they are generally called "button cells") but some Lithium cells can be recharged. These are Lithium-ion cells and generally have a voltage of 3.6v. Some Lithium-ion cells look exactly like 3v Lithium cells, so you have to read the data on the cell before charging.

You cannot test the voltage of a cell and come to any conclusion as to the age of the cell or how much energy remains. The voltage of a cell is characteristic to the chemicals used and the actual voltage does not tell you its condition.
Some "dry cells" deliver 1.5v up to the end of their life whereas others drop to about 1.1v very quickly.

Once you know the name of the cell that drops to 1.1v, avoid them as the operation of the equipment "drops off" very quickly.

However if you have a number of different cells and need to know which ones to keep, here's the solution:

1. Check the voltage and use those with a voltage above 1.1v
2. Next, select 500mA or 10A range on a meter and place the probes on a cell. For a AAA or AA cell, the current should be over 500mA and the needle will swing full scale very quickly.

Keep the testing short as you are short-circuiting the cell but it is the only way to determine the internal impedance of the cell and this has a lot to do with its stage-of-charge.
This will give you a cell with a good terminal voltage and a good current capability.

This also applies to button cells, but the maximum current they will deliver will be less.
If you want to get the last of the energy out of a group of cells they can be used in the following circuits:

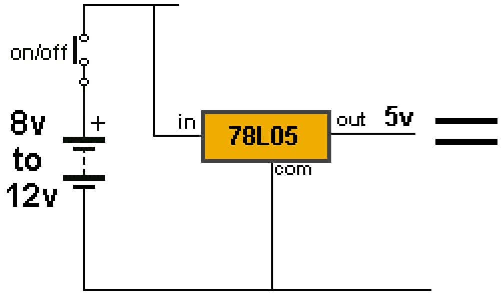

1mV drop @100mA @10v supply

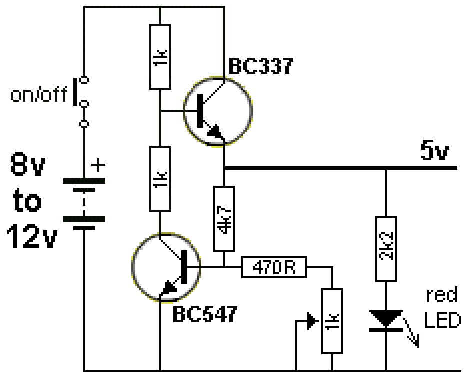

10mV drop @100mA @10v supply

TESTING PIEZO DIAPHRAGMS and PIEZO BUZZERS

There are two types of piezo devices that produce a sound.
They are called **PIEZO DIAPHRAGMS** and **PIEZO BUZZERS**.
A **piezo diaphragm** consists of two metal plates with a ceramic material between. The ceramic expands and contracts when an alternating voltage is placed on the two plates and this causes the main plate to "dish" and "bow."
This creates a high-pitched sound. There are no other components inside the case and it requires an AC voltage of the appropriate frequency to produce a sound.
A **piezo buzzer** has a transistor and coil enclosed and when supplied with a DC voltage, the buzzer produces a sound.
Both devices can look exactly the same and the only way to tell them apart is by connecting a 9v battery. One device may have "+' and "-" on the case to indicate it is a piezo buzzer, but supplying 9v will make the buzzer produce a sound while the piezo diaphragm will only produce a "click."

PIEZO DIAPHRAGM PIEZO BUZZER

A piezo diaphragm will produce a click
when connected to 9v DC.
A piezo buzzer will produce a tone when
connected to a DC voltage.

How a PIEZO BUZZER WORKS

A Piezo Buzzer contains a transistor, coil, and piezo diaphragm and produces sound when a voltage is applied. The buzzer in the circuit above is a PIEZO BUZZER.

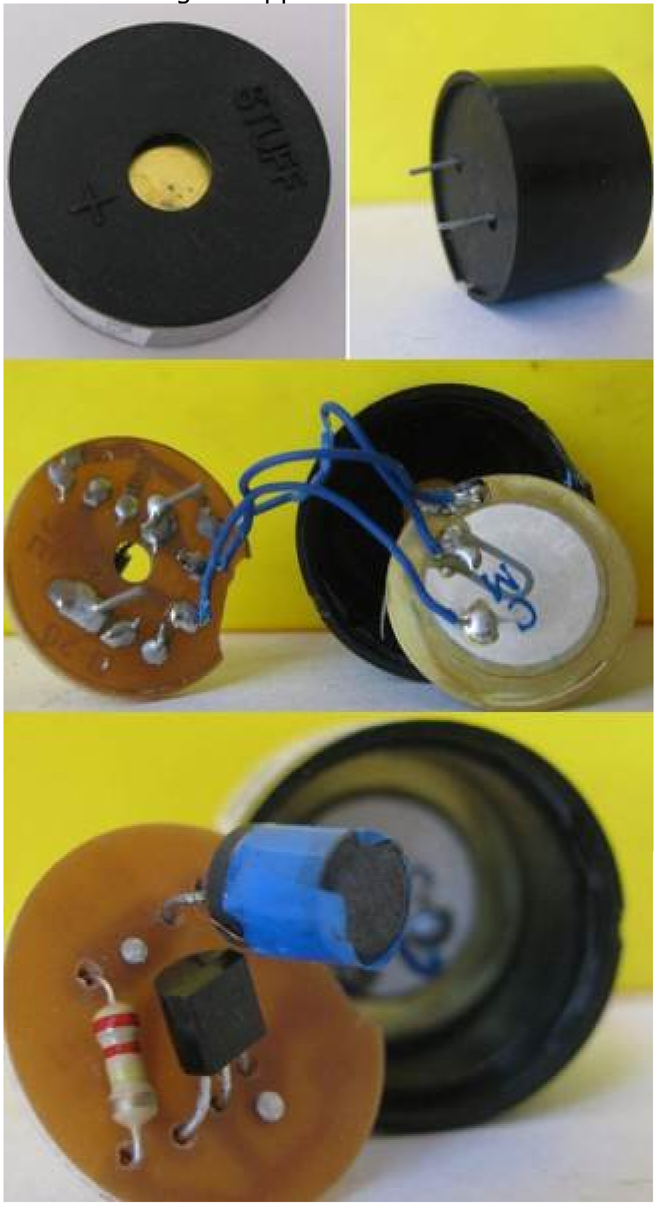

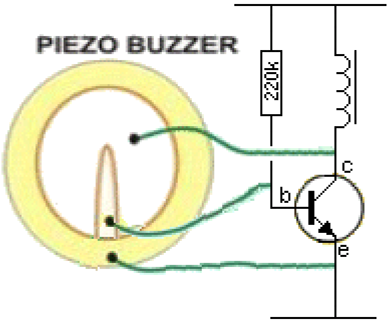

The circuit starts by the base receiving a small current from the 220k resistor. This produces a small magnetic flux in the inductor and after a very short period of time the current does not increase. This causes the magnetic flux to collapse and produce a voltage in the opposite direction that is higher than the applied voltage.

3 wires are soldered to pieces of metal on the top and bottom sides of a ceramic substrate that expands sideways when it sees a voltage. The voltage on the top surface is passed to the small electrode and this positive voltage is passed to the base to turn the transistor ON again. This time it is turned ON more and eventually the transistor is fully turned ON and the current through the inductor is not an INCREASING CURRENT by a STATIONARY CURRENT and once again the magnetic flux collapses and produces a very high voltage in the opposite direction. This voltage is passed to the piezo diaphragm and causes the electrode to "Dish" and produce the characteristic sound. At the same time a small amount is "picked-off" and sent to the transistor to create the next cycle.

TESTING A SPEAKER

A speaker (also called a **loud speaker**) has coil of wire wrapped around a magnet but it does not

touch the magnet as it is wound on a thin cardboard former so that the coil will be pulled closer to the magnet when a current flows in the coil.
When the current flows in the other direction, the coil moves away from the magnet.
The coil is called voice coil and it is connected to a sheet of thin card called a CONE and as the cone vibrates, the speaker reproduces music or noise.
Use a multimeter on a low ohms scale to read the value of resistance of the coil.
It can be as low as 2 ohms or as high as 100 ohms.
Most speakers have an 8R voice coil and the actual resistance may be slightly lower than this.
Some speakers have a resistance of 16R, 32R or 50R and even 75 ohms.
You would think putting a 16R speaker in place of 8R would reduce the sound output, but this is not always the case.
You can even use 50R or 75R and get the same performance.
This may sound amazing, but here is the reason.
The cone is deflected a certain amount due to the current flowing and the number of turns.
These two values are multiplied together to produce a value called AMP-TURNS.
If we have an 8R speaker with 80 turns and 100mA, the result is 0.1 x 80 = 8.
If we use a 16R speaker, the average current flow will be 50mA and the number of turns will be about 160. The multiplication of 0.05 x 160 = 8.
The author then tried a 50R speaker and the sound output was equal to 8R and the same with 75R speaker.
This might not apply in all situations, but the 75R speaker was slightly larger and the ticking sound form the **Metal Detector** kit was louder than using an 8R mini speaker.

To see if the cone of a speaker is undamaged, push it slightly and it will move towards the magnet. If it does not move, it is bent or damaged. If the cone is scratchy when pushed, it is rubbing against the magnet.
A cone should be able to be pushed and pulled from its rest-state. If not, it will produce a distorted sound.

TESTING A CIRCUIT

Whenever you test a circuit, the TEST EQUIPMENT puts "a load" or "a change" on it. It does not matter if the test equipment is a multimeter, Logic Probe, CRO, Tone Injector or simply a LED and resistor.
There are two things you need to know.
1. The IMPEDANCE of the circuit at the location you are testing, and
2. The amount of load you are adding to the circuit via the test equipment.

There is also one other hidden factor. The test equipment may be injecting "hum" due to its leads or the effect of your body at absorbing hum from the surroundings or the test equipment may be connected to the mains.
These will affect the reading on the test equipment and also any output of the circuit. Sometimes the test equipment will prevent the circuit from working and sometimes it will just change the operating conditions slightly. You have to be aware of this.
The last section of this eBook covers High and Low Impedance and understanding impedance is something you need to know.
The point to note here is the fact that the equipment (and the reading) can be upset by hum and resistance/capacitance effects of test equipment. This is particularly critical in high impedance and high frequency circuits.

TESTING INTEGRATED CIRCUITS (IC's)

Integrated Circuits can be tested with a LOGIC PROBE. A Logic Probe will tell you if a line is HIGH, LOW or PULSING.
Most logic circuits operate on 5v and a Logic Probe is connected to the 5v supply so the readings are accurate for the voltages being tested.
A Logic Probe can also be connected to a 12v CMOS circuit.
You can make your own Logic Probe and learn how to use it from the following link:

http://www.talkingelectronics.com/projects/LogicProbeMkIIB/LogicProbeMk-IIB.html

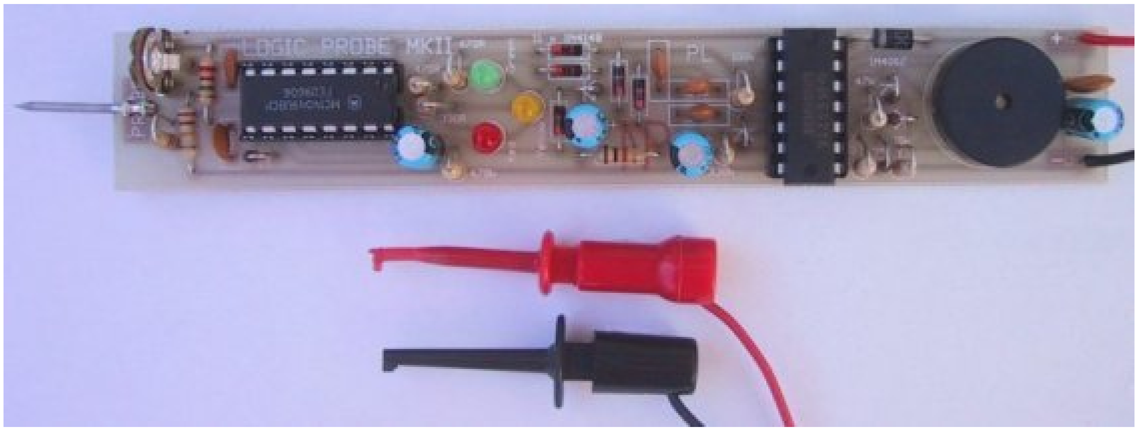
LOGIC PROBE MKII

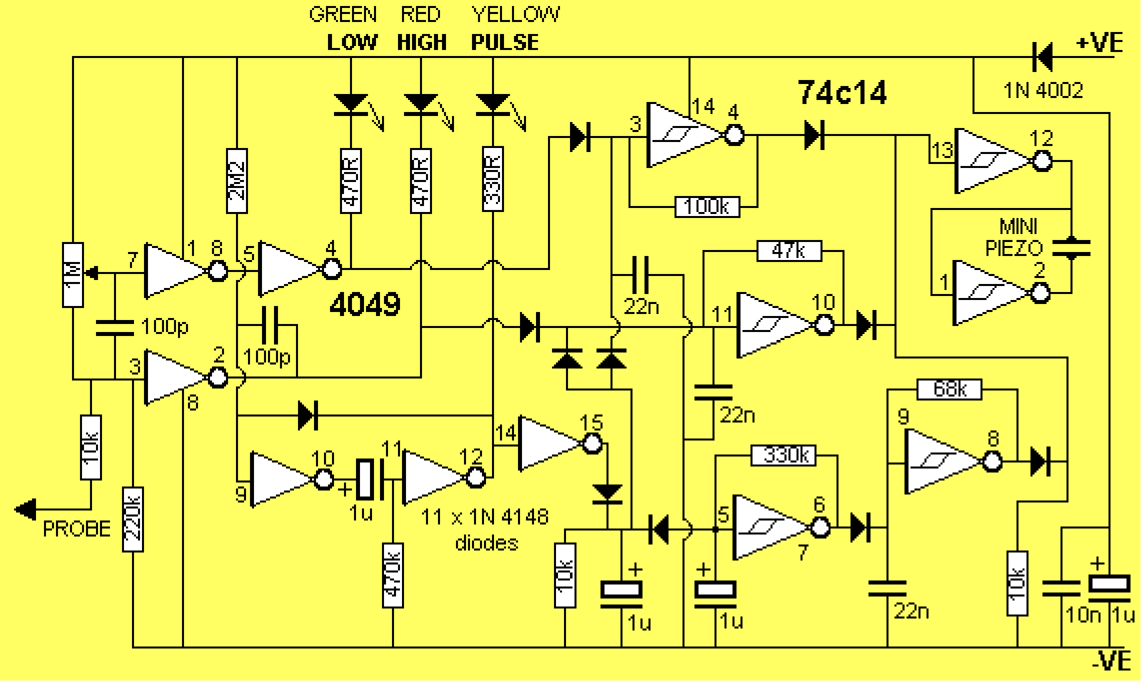
GREEN
RED
YELLOW
LOW
HIGH
PULSE
+VE
1N 4002
74c14
14
4
3
13
12
100k
MINI
PIEZO
47k
2M2
470R
470R
330R
1M
7
1
8
5
4
4049
100p
100p
22n
11
10
1
2
3
2
8
68k
9
8
22n
14
15
10
11
12
9
1u
330k
5
6
7
11 x 1N 4148
diodes
PROBE
10k
220k
470k
10k
1u
1u
22n
10k
10n
1u
-VE

LOGIC PROBE with PULSE

This is a very simple transistor circuit to provide HIGH-LOW-PULSE indication for digital circuits. It can be built for less than $5.00 on a piece of matrix board or on a small strip of copper clad board if you are using surface mount components. The probe will detect a HIGH at 3v and thus the project can be used for 3v, 5v and CMOS circuits.

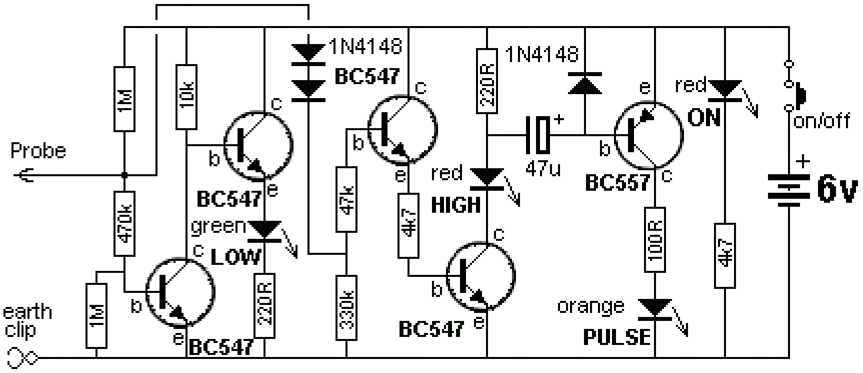
1N4148
BC547
1N4148
Probe
1M
10k
c
b
e
BC547
green
LOW
47k
c
b
e
220R
red
HIGH
47u
e
red
ON
b
BC557
c
on/off
6v
470k
1M
earth
clip
b
c
e
BC547
220R
330k
4k7
c
b
e
BC547
100R
4k7
orange
PULSE

LOGIC PROBE using CD4001 and CD4011

Here is a simple Logic Probe using a single chip. The circuits have been designed for the **CD4001** CMOS quad NOR gate and **CD4011** CMOS NAND gate. The output has an active buzzer that produces a beep when the pulse LED illuminates (the buzzer is not a piezo-diaphragm but an active buzzer containing components).

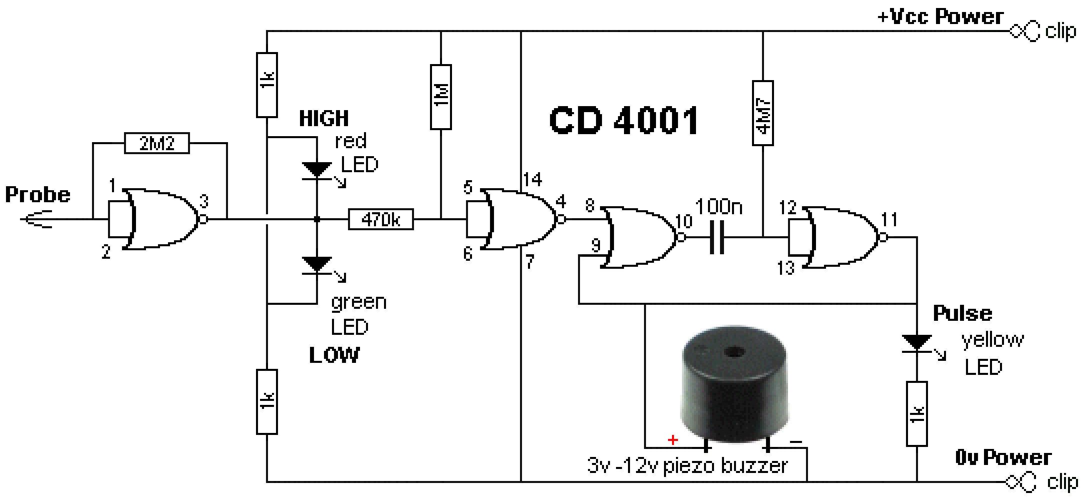
+Vcc Power
clip
CD 4001
1k
1M
4M7
2M2
HIGH
red
LED
Probe
1
2
3
470k
5
6
14
4
7
8
9
10
100n
12
13
11
green
LED
LOW
Pulse
yellow
LED
1k
1k
+
−
3v -12v piezo buzzer
0v Power
clip

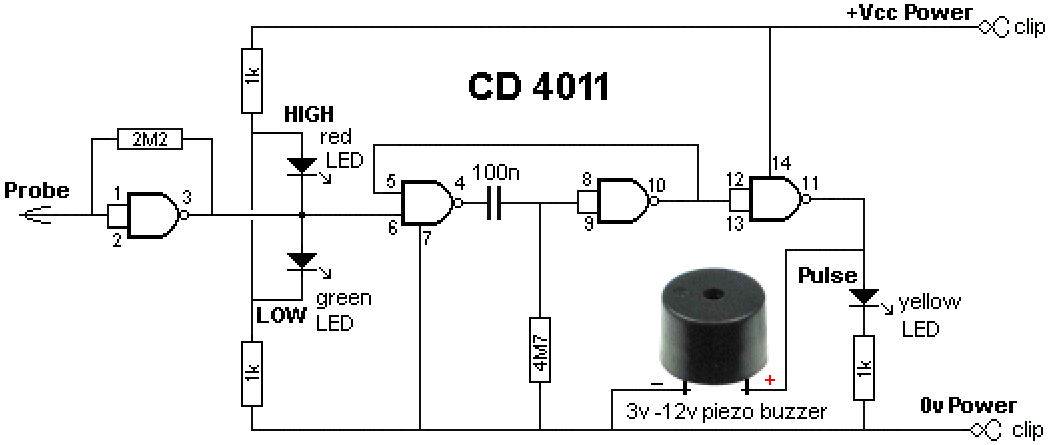
+Vcc Power
clip
CD 4011
1k
HIGH
red
LED
2M2
Probe
1
2
3
5
6
4
7
100n
8
9
10
12
13
14
11
green
LED
LOW
1k
4M7
Pulse
yellow
LED
−
+
1k
3v -12v piezo buzzer
0v Power
clip

SUPER PROBE MkII has 20 different features including a Logic Probe, capacitance tester, Inductance tester, and more.

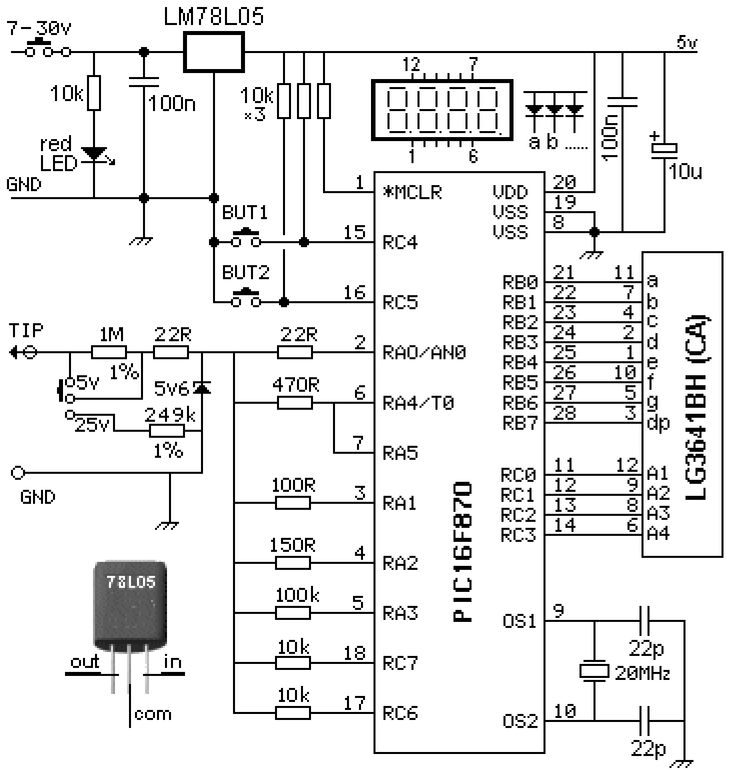
7-30v
LM78L05
5v
10k
100n
red
LED
GND
10k
x3
12
7
1
6
a b .....
100n
10u
1
*MCLR
VDD
VSS
VSS
20
19
8
BUT1
15
RC4
BUT2
16
RC5
RB0
RB1
RB2
RB3
RB4
RB5
RB6
RB7
21
22
23
24
25
26
27
28
11
7
4
2
1
10
5
3
a
b
c
d
e
f
g
dp
LG3641BH (CA)
TIP
1M
1%
22R
22R
2
RA0/AN0
5v
25v
5v6
470R
6
RA4/T0
249k
1%
7
RA5
GND
100R
3
RA1
RC0
RC1
RC2
RC3
11
12
13
14
12
9
8
6
A1
A2
A3
A4
PIC16F870
150R
4
RA2
100k
5
RA3
78L05
out
in
com
10k
18
RC7
10k
17
RC6
OS1
9
22p
20MHz
OS2
10
22p

SUPER PROBE MkII Circuit

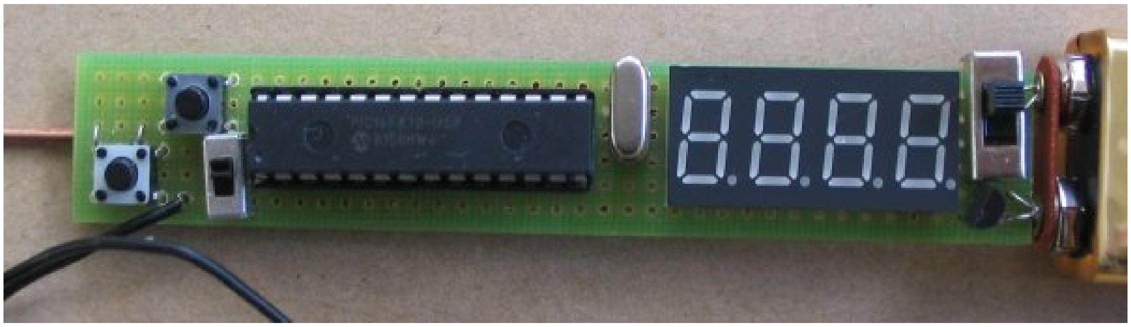
SUPER PROBE MkII

To test an IC, you need a circuit diagram with waveforms. These diagrams will show the signals and are very handy if a CRO (cathode ray Oscilloscope) is used to diagnose the problem. The CRO will reproduce the waveform and prove the circuit is functioning correctly.
A Logic Probe will just show activity and if an output is not producing a "pulse" or "activity," you should check the power to the IC and test the input line.
It is beyond the scope of this eBook to explain how to diagnose waveforms, however it is important to know if signals are entering and exiting an IC and a Logic Probe is designed for this.

SIGNAL INJECTOR

This circuit is rich in harmonics and is ideal for testing amplifier circuits. To find a fault in an amplifier, connect the earth clip to the 0v rail and move through each stage, starting at the speaker. An increase in volume should be heard at each preceding stage. This Injector will also go through the IF stages of radios and FM sound sections in TV's.

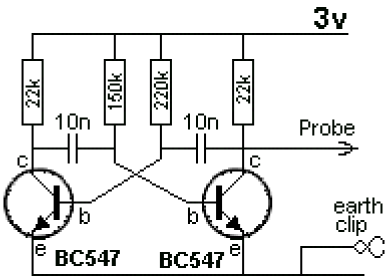

TESTING AUDIO AMPLIFIERS and AUDIO IC's

The **Super Probe MII** described above has a "noise" function and a tone function that allows you to inject a signal into an audio stage, amplifier (made from discrete components) or an audio chip, and detect the output on a speaker.
Audio stages are very difficult to work-with if you don't have a TONE GENERATOR or SIGNAL INJECTOR.
The signals are very small and not detected by a multimeter.
You can start anywhere in an amplifier and when a tone is heard, you can keep probing until the signal is not present or louder. From this you can work out which way the signal is travelling.
A Signal Injector is very handy for finding shorts and broken wires in switches, plugs, sockets and especially leads to headphones.
You can determine the gain of a stage (amplification) by probing before and after a chip or transistor and listen for the relative increase in volume from the speaker.
You can also use your finger to produce "hum" or "buzz" if a **Signal Injector** is not available.
Nearly all audio problems are plugs, sockets and cracks in the PC board, but finding them takes a lot of time and skill.

TESTING IC's - also called "CHIPS"

An Integrated Circuit is also called a "chip." It might have 8 pins or as many as 40. Some chips are ANALOGUE. This means the input signal is rising and falling slowly and the output produces a larger version of the input.

Other chips are classified as DIGITAL and the input starts at 0v and rises to rail voltage very quickly. The output does exactly the same - it rises and falls very quickly.

You might think the chip performs no function, because the input and output voltage has the same value, but you will find the chip may have more than one output and the others only go high after a number of clock-pulses on the input, or the chip may be outputting when a combination of inputs is recognised or the output may go HIGH after a number of clock pulses.

ANALOGUE CHIPS **(also see above)**

Analogue chips are AUDIO chips or AMPLIFIER chips.

To test these chips you will need three pieces of test equipment:

1. A multimeter - this can be digital or analogue.
2. A Signal Injector
3. A Mini Bench Amplifier.

The Mini Bench Amplifier is available as a kit.

TOSHIBA
SUPER HEAVY DUTY
PROBE
MINI BENCH AMPLIFIER

MINI BENCH AMPLIFIER

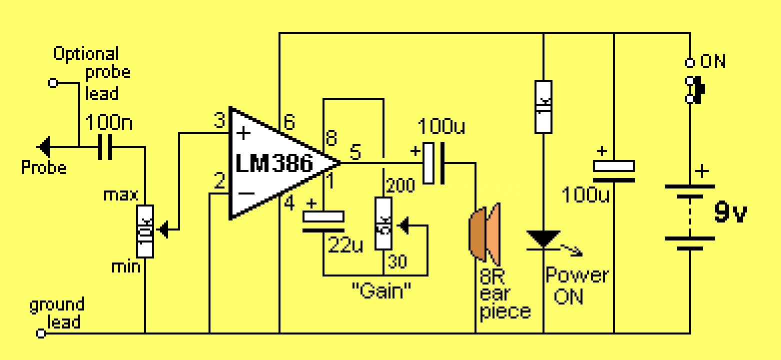

Optional probe lead
100n
Probe
max
10k
min
ground lead
3
2
+
−
LM386
6
8
5
1
4
+
22u
5k
200
30
"Gain"
100u
+
8R ear piece
1k
Power ON
100u
+
ON
+
9v

MINI BENCH AMPLIFIER CIRCUIT

Start by locating the power pin with a multimeter.

If the chip is receiving a voltage, you can use the Mini Bench Amplifier to detect an output.

Connect the Ground Lead of the Mini Bench Amplifier to 0v and touch the Probe tip on each of the pins.

You will hear faint audio on the Input pin and very loud audio on the Output pin.

If no input is detected, you can use a Signal Injector to produce a tone.

Connect the clip of the Signal Injector to 0v and the probe to the input pin of the amplifier chip. At the same time, connect the Mini Bench Amplifier to the output pin and you will hear a very loud tone.
These pieces of test equipment can also be used to diagnose an amplifier circuit constructed with individual components.
Amplifier circuits using discrete components are very hard to trouble-shoot and these pieces of test equipment make it very easy.

DIGITAL CHIPS

It is always best to have data on the chip you are testing, but if this is not available, you will need three pieces of equipment:
1. A multimeter - this can be digital or analogue.
2. A Logic Probe,
3. A logic Pulser.

Firstly test the chip to see if power is being delivered. This might be anything from 3v3 to 15v.
Place the negative lead of the multimeter on the earth rail of the project - this might be the chassis, or the track around the edge of the board or some point that is obviously 0v.
Try all the pins of the chip and if you get a reading, the chip will have "supply."
Identify pin 1 of the chip by looking for the "cut-out" at the end of the chip and you may find a small dimple below the cut-out (or notch). This is pin 1 and the "power pin" can be directly above or any of the other pins.
Next you need to now if a signal is entering the chip.
For this you will need a LOGIC PROBE.
A Logic Probe is connected to the same voltage as the chip, so it will detect a HIGH and illuminate a red LED.
Connect the Logic Probe and touch the tip of the probe on each pin.
You will not know if a signal is an input or output, however if you get two or more active pins, you can assume one is input and the other is output. If none of the pins are active, you can assume the signal is not reaching this IC.
If only one pin is active, you can assume the chip is called a CLOCK (or Clock Generator). This type of chip produces pulses. If more than two pins are active, you can assume the chip is performing its function and unless you can monitor all the pins at the same time, you don't know what is happening.
This is about all you can do without any data on the chip.

If you have data on the chip, you can identify the input(s) and output(s).
A Logic Probe on each of these pins will identify activity.
A Logic Probe has 3 LEDs. Red LED indicates a HIGH, Green indicates a LOW and Orange indicates a PULSE (activity).
Some Logic Probes include a piezo and you can hear what is happening, so you don't take your eyes off the probe-tip.
It is important not to let the probe tip slip between the pins and create a short-circuit.

LOGIC PULSER

If you have a board or a single chip and want to create activity (clock pulses), you can use a Logic Pulser. This piece of test equipment will produce a stream of pulses that can be injected into the clock-line (clock input) of a chip.
You can then use a Logic Probe at the same time on the outputs to observe the operation of the chip.

You can also use the Mini Bench Amplifier to detect "noise" or activity on the inputs and outputs of digital chips.
This only applies if the frequency is in the audio range such as scanning a keyboard or switches or a display.

This is how to approach servicing/testing in a general way. There are thousands of digital chips and if you want to test a specific chip for its exact performance, you will need to set-up a "test-bed."

REMOTE CONTROLS

There are two types of remote control - Infrared and RF. Infrared is used for short-range, line-of-sight for TV's DVD's etc.
A few faults can be fixed, but anything complex needs a new remote control.
Check the batteries and battery-contacts. See if the IR LED is illuminating by focusing it into a digital camera and looking on the screen for illumination.
The only other things are a sticky button, a worn-out button or a crack in the PC board. Water damage is generally too much work to repair.
RF remote controls for cars, garage doors etc need a second working unit to check the power output.
Here is a simple circuit that can be connected to an analog multimeter to detect the signal strength at a very close range:

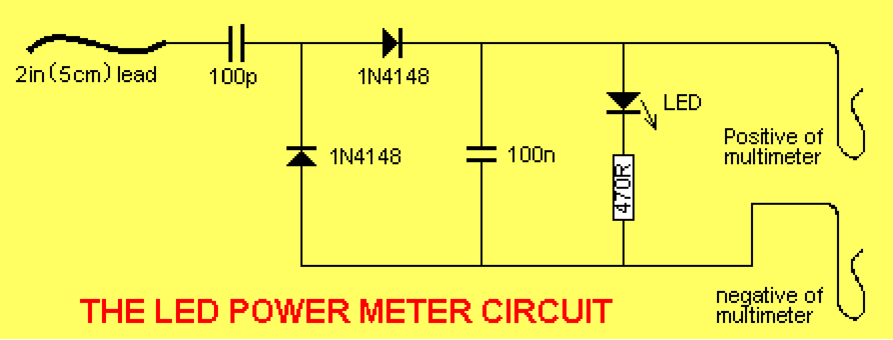
2in (5cm) lead
100p
1N4148
1N4148
100n
LED
470R
Positive of multimeter
negative of multimeter

THE LED POWER METER CIRCUIT

To hear the tone from a transmitter, the **Mini Bug Detector** circuit can be used:

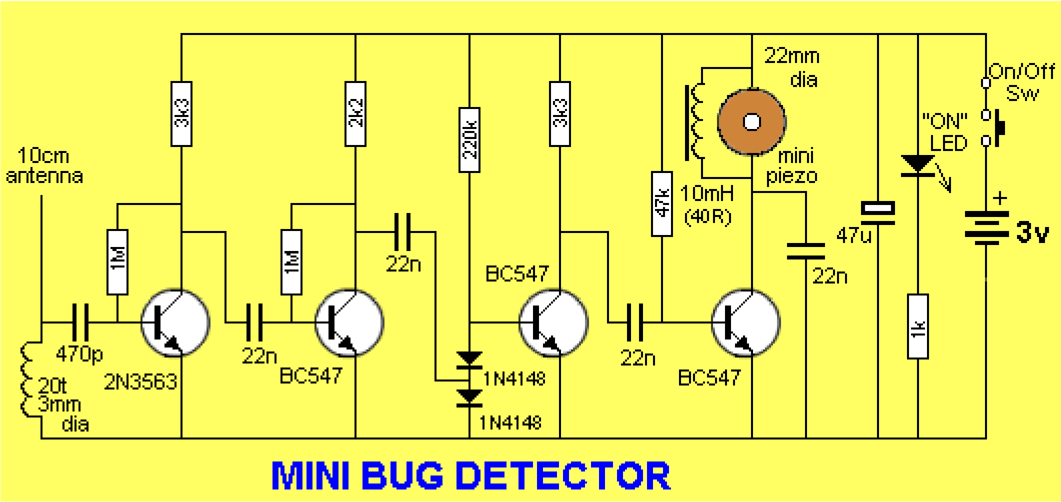
10cm antenna
3k3
2k2
220k
3k3
22mm dia
mini piezo
On/Off Sw
"ON" LED
+
3v
47k
10mH (40R)
47u
22n
1M
1M
22n
BC547
470p
20t 3mm dia
2N3563
22n
BC547
1N4148
1N4148
22n
BC547
1k

MINI BUG DETECTOR

Any further investigation requires a circuit diagram so you can work out what is actually being sent from the transmitter.
Most of the time it is a faulty switch, battery or contacts. Make sure the setting is correct on the "dip switches" and use a working unit to compare all your testing.

TESTING VOLTAGES ON (in) A CIRCUIT

There are basically two different types of circuit.
1. **ANALOGUE CIRCUIT**
An analogue circuit can also be called an AUDIO CIRCUIT and the voltages at different points in a circuit can be measured with a multimeter but the changes (the waveforms) will be quite small or changing at a rapid rate and cannot be detected by a multimeter.
You need a CRO to "see" the signals or a **Signal Injector** to inject a waveform into the circuit and hear the result on the circuit's speaker.

2. **DIGITAL CIRCUIT**
A digital circuit can also be called a "Computer Circuit" or "Logic Circuit" and some of

the voltages can be measured with a multimeter (such as supply voltages) but the "signal lines" will be be changing from HIGH to LOW to HIGH very quickly and these signals are detected with a **Logic Probe**.

Here are some circuits with details of how to test the voltages.
Most circuits do not show voltages at various different points and we will explain what to expect on each "stage."

A "STAGE"

A stage is a set of components with an input and output. A "stage" can also be called a "Building Block."
Sometimes it has a capacitor on the input and one on the output.
This means the stage is completely isolated as far as DC is concerned.
The stage has a supply (a DC supply) and it is producing its own voltages on various points on the "stage." It can only process (amplify) "AC." (signals).
Sometimes the stage can be given a name, such as small-signal amplifier, push-pull amplifier or output.
If the stage has a link or resistor connected to a previous stage, the previous stage will have a "DC effect" on the stage. In other words it will be biasing or controlling the voltages on the stage. The stage may be called a "timer" or "delay" or "DC amplifier."

It is important to break every circuit into sections. This makes testing easy. If you have a capacitor at the input and output, you know all the problems lie within the two capacitors.
In a digital circuit (no capacitors) you need to work on each IC (integrated Circuit) and test the input for activity and all the outputs.

Once you have determined if the circuit is Analogue or Digital, or a combination of both, you have to look at the rail voltage and work out the size or amplitude of the voltage or waveform.
This is done before making a test, so your predictions are confirmed.
You will need a **multimeter** (either Digital or Analogue) a **Logic Probe** and a **Signal Injector** (**Tone Generator**). An analogue meter has the advantage that it will detect slight fluctuations of voltage at a test-point and its readings are faster than a digital meter. A digital meter will produce an accurate voltage-reading - so you should have both available.

HIGH IMPEDANCE AND LOW IMPEDANCE

Every point in a circuit has a characteristic called "IMPEDANCE." This has never been discussed before in any text book. That's why it will be new to you.
In other words, every point will be "sensitive to outside noise."
An audio amplifier is a good example. If you put your finger on the active input, it will produce hum or buzz in the speaker. This is because it is a HIGH IMPEDANCE line or high impedance section of the circuit.
The same applies to every part in a circuit and when you place Test Equipment on a line for testing purposes, the equipment will "upset" the line. It may be very slight but it can also alter the voltage on the point CONSIDERABLY.
We have already mentioned (above) how a cheap multimeter can produce a false reading when measuring across a 1M resistor. That's why you need high impedance test Equipment so you do not "load" the point you are testing and create an inaccurate reading.
The word **Impedance** really means resistance, but when you have surrounding components such as diodes, capacitors, transistors, coils, Integrated Circuits, supply-voltages and resistors, the combined effect is very difficult to work out as a "resistance" and that's why we call it "Impedance."
The term "**High and Low Impedance**" is a relative term and does not have any absolute values but we can mention a few points to help you decide.
In general, the base of a transistor, FET input of an IC are classified as HIGH IMPEDANCE.
The output of these devices are LOW IMPEDANCE.

Power rails are LOW IMPEDANCE.
An oscillator circuit and timing circuit are HIGH IMPEDANCE.
A LOAD is low impedance.
And it gets tricky: An input can be designed to accept a low-impedance device (called a transducer or pick-up) and when the device is connected, the circuit becomes LOW impedance, but the input circuitry is actually high impedance.
The impedance of a diode or LED is HIGH before the device sees a voltage higher than the junction voltage and then it becomes LOW Impedance.
Impedance is one of the most complex topics however it all comes down to testing a circuit without loading it.
That's why test equipment should have an input impedance higher than 1M.

The first circuit we will investigate is the **Mini Bug Detector**, shown above and below. Points on the circuit have been labelled A, B, C etc:

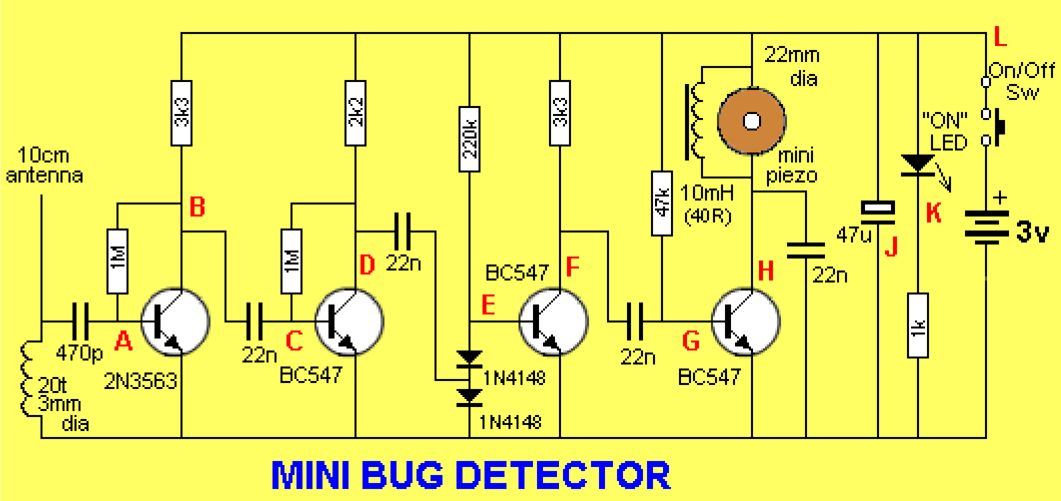

Point A - The first transistor is "self-biased" and will have 0.6v on the base. The antenna is connected to a 20 turn coil and you might think the coil will "short" the signals to earth.
But the coil and 470p capacitor form a circuit that oscillates at a high frequency when the antenna wire picks up stray signals. The coil and capacitor actually amplify the signals (see Talking Electronics website: Spy Circuits to see how a TANK CIRCUIT works) and these signals enter the base of the first transistor.
This is classified as a HIGH Impedance section because the signals are small and delicate and any loading via test equipment will kill them. The first transistor amplifies the signals about 70 times and they appear at **Point B**.

The signal passes though a 22n to **Point C** and the transistor amplifies the signal about 70 times to **point D**. **Point C** is classified as high impedance as any voltage measurement at this point will upset the biasing of the stage as a few millivolts change in base-voltage will alter the voltage on the collector considerably. **Point D** is classified as low impedance as any voltage-testing will not alter the voltage appreciably.
The output of the second stage passes through a capacitor to the join of two diodes. These two diodes are not turned on because the voltage at **Point E** can never rise above 0.7v as this is the voltage produced by the base-emitter of the third transistor.
The purpose of the two diodes is to remove background noise. Background noise is low amplitude waveforms and even though the transistor is turned on via the 220k, low amplitude signals will not be received. The third transistor works like this: It cannot be turned ON any more because any waveform from the 22n will be "clipped" by the bottom diode and it will never rise above 0.6v.
So, the only signal to affect the transistor is a negative signal - to turn it OFF.
Firstly we have to understand the voltage on the 22n. When the second transistor is sitting at mid-rail voltage, the 22n gets charged via the 2k2 and lower diode. When

the transistor gets tuned ON, the collector voltage falls and the left side of the 22n drops. The right side of the 22n also drops and when it drops 0.6v, the top diode starts to conduct and when the voltage on the 22n drops more than 0.6v the third transistor starts to turn OFF. This effect is amplified by the transistor at least 100 times and appears at **Point F.** All the voltages around the two diodes are classified as HIGH Impedance as any piece of test equipment will upset the voltage and change the output.
There are some losses in amplitude of the signal as it passes through the 22n coupling capacitors but the end result is a very high strength signal at **point G.** The 4th transistor drives a 10mH choke and the mini piezo is effectively a 20n capacitor that detects the "ringing" of the inductor to produce a very loud output.
The 22n capacitor on the collector eliminates some of the background noise. The choke and piezo form an oscillatory circuit that can produce voltages above 15v, even though the supply is 3v.
The 47n capacitor at **Point J** is to keep the supply rails "tight" (to create a LOW Impedance) to allow weak cells to operate the circuit.
The "Power-ON" LED tells you to turn the device off when not being used and **Point L** is the power supply - a low impedance line due to the 47u electrolytic.

Testing the Mini Bug Detector
To test the Mini Bug Detector, you will need a Signal Injector.
Place the Injector on **Point G** and you will hear a tone. Then go to **E**, **C** and **A**. The tone will increase in volume. If it does not increase, you have pin-pointed the faulty stage.

The next circuit is a combination of digital and analogue signals. It is a **Logic Probe**:

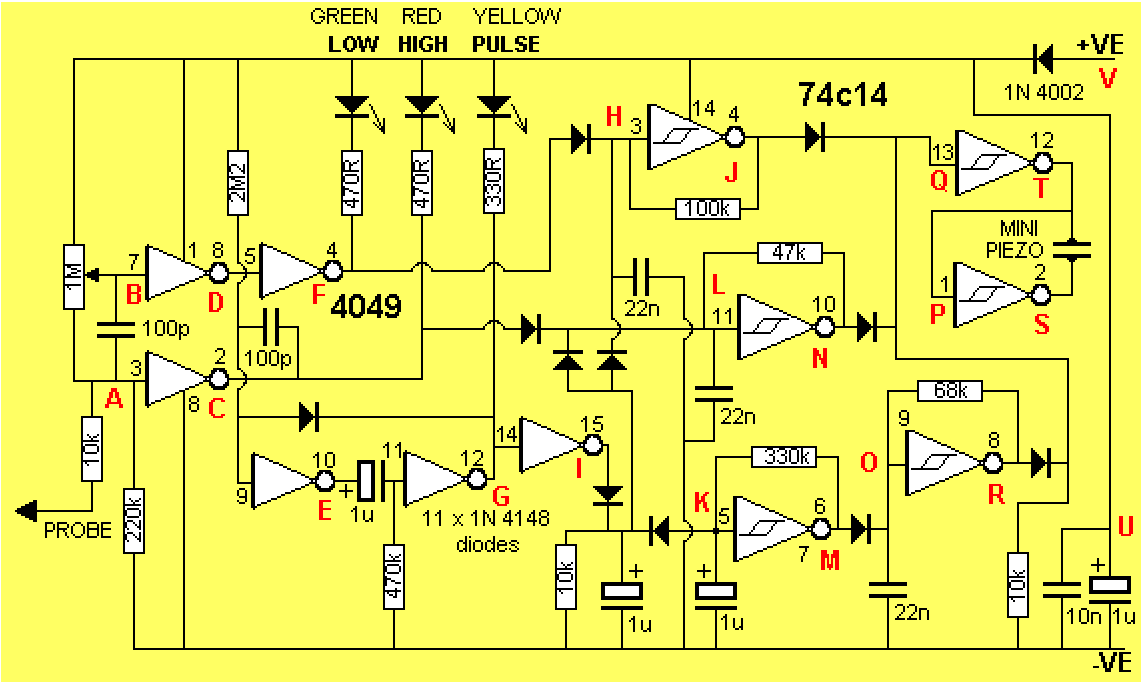

The voltage on a circuit (to be tested) is detected by the probe at **Point A** of the circuit above and the "tip" is classified as "reasonably high impedance" as it has a 220k resistor between the tip and 0v rail. The 1M reduces the impedance by about 20% but the inputs of the two inverters have no effect on the "tip" impedance as they are extremely high input-impedance devices.
The 1M trim pot is designed to put put a voltage on **point B** that is slightly higher than mid-rail so the green LED is turned off.
Point A will see a voltage below mid-rail and **point C** will be HIGH. **Point C** and **F** are low-impedance outputs.
When the tip of the probe is connected to a LOW voltage, Point B sees a LOW and Point F goes LOW to illuminate the green LED. At the same time it removes the "jamming voltage" produced by the diode between pin 4 of the 4049 and pin 3 of the

74C14 and the oscillator between **points H and J** produces a low-tone via the 100k resistor and 22n to indicate a LOW.
When the probe tip sees a HIGH, a lot more things happen.
Point C goes LOW and turns on the red LED. At the same time the 100p is in an uncharged state and the right lead goes LOW. This takes the left lead LOW as the left lead connects to a HIGH Impedance line and pin 9 goes LOW. This makes **point E** HIGH
and since the 1u is in an uncharged state, pin 11 goes HIGH. This makes **point G** LOW and the diode between pins 9 and 12 keeps pin 9 LOW and takes over from the pulse from the 100p. The yellow LED is illuminated. The 1u starts to charge via the 470k and when it is approx half-charged, pin 11 sees a HIGH and **point G** goes low. This creates the length of pulse for the yellow LED.
At the same time, **Point L** goes LOW because the "jamming diode" from pin 2 of the 4049 goes low and allows the inverter between point L and N to produce a tone for the piezo.
In addition, **Point I** goes HIGH and quickly charges a 1u electrolytic. This removes the effect of the jamming diode on pin 5 of the 74C14 and a low frequency oscillator made up of 68k and 1u between pins 5&6 turns on and off an oscillator between **points O** and **R** to get a beep. The mini piezo is driven n bridge mode via the two gates between **points QT** and **PS**.
Point U is a 1u electrolytic to reduce the impedance of the power rail and **Point V** is a protection diode to prevent damage if the probe is connected to the supply around the wrong way.

Testing the Logic Probe
You can test the Logic Probe with the simple Logic Probe with Pulse project described above. It will let you know if each point in the circuit is HIGH or LOW. You will also find out the difficulty in testing the points that are HIGH Impedance, as the Probe will upset the voltage levels and the reading may be inaccurate.

More circuits will be added here in the future.

THE VOLTAGE DIVIDER - this topic could fill a book.

You need to read lots of other sections in this eBook, including the section on measuring across a resistor with a multimeter, and high impedance circuits, to fully understand the complexities of a VOLTAGE DIVIDER CIRCUIT.
It is one of the most important BUILDING BLOCKS to understand. Even though it may consists of two components, you have to understand what is happening between these two components. You have to realise there is a voltage at their join that will be rising and falling due to one of the components changing RESISTANCE. Sometimes you can work out the voltage at the join by using Ohm's LAW but quite often it will be impossible as it is changing (rising and falling) during the operation of the circuit.
At the beginning of this discussion we will only dealing with DC circuits and the voltage across a particular component will be due to its RESISTANCE. We are not going into any formulas, as it is very easy to measure the voltages with a multimeter set to VOLTS and you will have an accurate result.
The simplest two components in series are resistors. They always have the same resistance during the operation of a circuit and the voltage across each will not change.
In a further discussion we will cover "resistors" that change value according to the temperature. These are called THERMISTORS. And we have "resistors" that change value according to the light they receive. These are called LIGHT DEPENDENT RESISTORS (LDR's) or PHOTO RESISTORS.
A transistor that is partly or fully turned ON can be considered to be similar to a resistor.
In these 3 cases we need to measure the voltage at the join with a voltmeter as it will be a lot of work to measure the resistance and work out a value.
You can also keep a voltmeter on the joint and watch the voltage change.
Finally we have some components that produce a fixed voltage across them (or nearly fixed) and the remaining voltage is dropped across a resistor. These

components MUST have a resistor connected in series to limit the current and allow the component to pass the specified in the datasheet.
These devices include LEDs, diodes and zener diodes. A LED will have a fairly fixed voltage across it from 1.7v to 3.6v depending on the colour. A diode will have a voltage of 0.7v across it when it is connected to a voltage via a resistor. And a zener diode will have a fixed voltage across it when it is connected with the cathode to the positive rail via a resistor. The voltage across it will be as marked on the zener.
The concept of a VOLTAGE DIVIDER is very simple, but it takes a lot of understanding because both VOLTAGE and CURRENT are involved in the UNDERSTANDING-PROCESS.
Each component has a resistance and this can be measured with a multimeter. When two components are connected in series, a current will flow and a voltage will develop across each item.
More voltage will develop across the item with the higher resistance and the addition of each voltage will always equal the supply voltage.
That's the simple answer.
There is a little more involved . . . It is the word CURRENT. Here is an explanation:
Suppose we have a 1k and 2k resistor on a 12v supply. The voltage at the join will be 4v.
In other words, there will be 4v across the 1k and 8v across the 2k.
If we have a 10k and 20k resistors in series, the voltage will also be 4v at the join.
If we have a 100k and 200k resistors, the voltage will also be 4v at the join.
The voltage will be the same in all cases, but the current will be different. The current in the second case will be one-tenth and only one hundredth in the third case.
If you want to go further, place a one ohm and two ohm in series and get 4v. But the resistors will get very hot and burn out very quickly.

SOLDERING

Here are three 30-minute videos on soldering.
1. **TOOLS**
2. **Soldering components**
3. Soldering **SURFACE MOUNT** components

TESTING A MOTOR

Strictly speaking, a motor is not an electronic component, but since a website gave a useless description on testing motors, I have decided to supply the correct information.
The only REAL way to test a motor is to have two identical motors and check the torque by connecting them to a low voltage and trying to stop the shaft with your fingers. This will give you two results. Firstly it will let you know the torque of the motor.
This is the twisting effect of the shaft. There is no way to determine the torque by knowing the voltage or current.
The unknown factor is the strength of the field magnets (permanent magnets) and this determines the torque.
Secondly, feeling the shaft will let you know if the torque is even for a complete revolution.
By having two identical motors, you can see if one has a lower torque.
Almost nothing can go wrong with a motor except for the brushes. If the brushes wear out, additional resistance will be produced at the interface between the brush and commutator and this can be detected by allowing the shaft to rotate slowly and feeling the resistance as it revolves. A 3-pole motor will have three places where the strength is greatest and each should have the same feeling. A 5-pole motor will have five places of strength.
If the strength is weak or not uniform, the motor is faulty.
You cannot test a motor with a multimeter as the resistance of the armature winding is very low and if the motor is allowed to spin, the back voltage produced by the spinning, increases the reading on the meter and is false.

Micro motors have a coreless armature. This means the 3 windings for the armature are wound on a machine then bent slightly into shape and glued. A circular magnet with 3 poles is in the centre and the armature rotates around this.

This type of motor is reasonably efficient because the armature is the greatest distance from the point of rotation, and the motor reaches full RPM very quickly because the armature has very little inertia.

I have not heard of the armature-winding flying apart but if you hear any scraping noise, it may be the winding.

3-pole, 5-pole and micro motors can be found in printers, eject mechanisms of CD players, toys, RC helicopters, cars etc and rarely fail.

Motors do not work on "voltage." They actually work on CURRENT and as you increase the voltage, more current will flow and produce a stronger magnetic field (by the winding on each pole). This magnetic field will be attracted by the permanent magnet surrounding the armature and repelled by the surrounding permanent magnet, depending on where the face of the pole is, during each revolution.

If the permanent magnet is not very strong, the repulsion part of the interaction will be very weak and thus the torque will be small.

Because motors work on "current" you must have a high current available when you increase the voltage as the motor will require short bursts of high current during each revolution.

It is the combination of voltage and current (called watts) that gives the motor "strength" (torque) as well as the "strength" of the permanent magnets (called the field magnets) and the number of turns of wire on each pole (and the gauge of wire).

Basically, if a motor is hard to spin, and has 3 "hard spots" on each revolution, it will be powerful.

A 2-pole motor does not self-start and will spin in either direction. But a 3-pole motor will self-start and you can determine the direction of rotation.

A 5-pole motor has a lower RPM. It is slightly smoother in output but is not more powerful than a 3-pole version.

A motor with "permanent magnets" is called a DC motor as it will not work on AC. If the magnets are replaced with a coil, it will work on AC and it will be called a "shunt wound" motor of the field coil is connected across the same terminals as the brushes or a "series wound" motor if the field coil is in series with the armature.

TESTING COMPONENTS "IN-CIRCUIT"

You can test components while they are IN CIRCUIT, but the surrounding components will have an effect on the results.

You can get all sorts of "In-Circuit" testers. They are expensive and offer little more accuracy than a multimeter.

In-Circuit testing with a multimeter can give you the same results as a tester.

All you have to do is turn the project ON and use a multimeter (set to voltage) to determine the voltage at various points. It is best to have a circuit of the equipment so you can what to expect at each point.

Only major departures from the expected can be located in this way.

Obviously the first thing to look for is burnt-out components. Then feel components such as transistors for overheating.

The look for electrolytics that may be dry. Sometimes these have changed colour or are slightly swollen.

If they are near hot components, they will be dry.

For the cost of a few dollars I change ALL THE ELECTROLYTICS in some pieces of equipment, as a dry electrolytic is very difficult to detect.

Testing a transistor "in-circuit" is firstly done with the supply ON. That's because it is quicker.

Measure the voltage between ground and collector.

In most cases you should get a voltage of about half-rail. If it is zero, or close to rail voltage, you may have a problem.

Turn off the supply and use the multimeter on low-ohms to measure all six resistances between the leads.

A low resistance in both directions on two leads will indicate a fault.

Resistors almost NEVER go "HIGH." For instance, a 22k will never go to 50k.

However a low-value resistor will "burn-out" and you will read the value of the surrounding components.

Don't forget, some low-value resistors are designed to burn-out (called fusible resistors) and anytime you find a damaged low-value resistor, you will need to look for the associated semiconductor.

You can replace the resistor quickly and turn the circuit ON to see it burn out again. Alternatively you can trace though the circuit and find the shorted semiconductor. It's always nice to "see the fault" then "fix the fault."

Sometimes a transistor will only break-down when a voltage is present, or it may be influenced by other components.

When the piece of equipment is turned OFF, you can test for resistance values. The main thing you are looking for is "dry joints" and continuity. Dry joints occur around the termination of transformers and any components that get hot. Rather than wasting time checking for dry joints, it is better to simply go over the connections with a hot iron and fresh solder.

You may need to check the continuity of a track (trace) and it may go from one side of the PC board to the other.

Use a multimeter set to low-ohms and make sure the needle reads "zero-ohms."

It is very dangerous to do any testing on a project using a multimeter set to "amps" or "milliamps."

You cannot test "current flowing through a component" by placing the probes across a component. You will simply over-load the rest of the circuit and create a problem.

To find out if current is flowing though a circuit or a low-value resistor, turn the project ON and measure the voltage either across the component or the voltage on one end then the other.

A voltage-drop indicates current is flowing.

That's about it for testing "in-circuit." Use the rest of this eBook to help you with diagnosis.

Don't think an IN-CIRCUIT COMPONENT TESTER is going to find a fault any faster than a multimeter. They all use a multimeter principle.

SHORT CIRCUIT

Nearly every component can fail and produce an effect called a SHORT CIRCUIT.

This basically means the component takes more current than normal and it may fail completely or simply take more current and the operation of the circuit may be reduced only a small amount.

The resistance of the component may reduce a very small amount but this may have a very large effect on the operation of the circuit.

For instance, two turns in the horizontal or vertical winding of a yoke on the picture tube or monitor may arc and weld together and reduce the size of the picture on the screen, but measuring the winding will not detect the difference in resistance.

The same with the windings on a motor and a short between two winding in a transformer.

If the "short" is between two near-by turns, the change in resistance will be very small. If the "short" is between to different layers, the resistance will be reduced and it may be detected.

When a "short" occurs, the winding turns into a transformer. To be exact, an AUTO-TRANSFORMER.

In the following diagram you can see a normal winding in fig A:

A

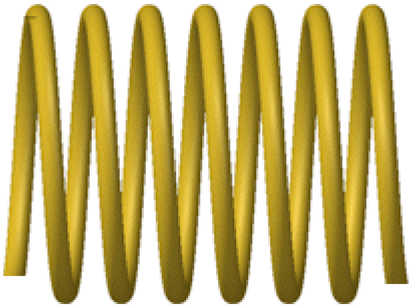

B

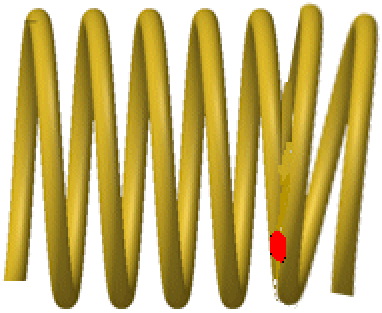

C

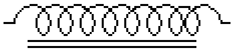

D

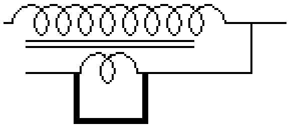

Fig B shows two turns touching each other and if the wire is enamelled, the coating has been damaged so the copper wire from the two turns is touching. This is called a SHORTED TURN.
In fig C you can see two turns touching.
In fig D the shorted-turn has been moved to the other side of the symbol to show the effect it has on the operation of the winding.
The shorted-turn is exactly like the secondary of a transformer with a "jumper" across the output.
This will produce a very high current in the secondary.
A very high current flows through the shorted turn and this changes the operation of the rest of the winding.

1. In most cases a SHORT CIRCUIT can be detected by feeling the additional heat generated by the component.
2. Next, turn off the supply and measure the resistance of the component. If it is lower than expected, the component will be faulty.
3. Next, measure the voltage across the component. If it is lower than normal, the component will be faulty.
4. Next, measure the current taken by the component. If it is higher than normal, the component will be faulty.
5. If the component is an inductor, such as a motor, coil or transformer, you can use an inductance meter. Compare a good winding with a faulty winding. Sometimes the fault will disappear because an arc develops across the fault when the component is operating.

INTERNAL AND EXTERNAL SHORTS

An **internal short** refers to two windings shorting together and the winding has a very high resistance between the winding and the frame on which it is wound. An external short refers to a winding shorting to the frame of the component - such as one of the armature windings shorting to the metal core, around which the wire is

wound.
This may not be important unless another winding shorts to the metal frame and creates "**inter winding**" problems (**inner winding** problems is within the same winding).

The opposite to a short circuit is an OPEN CIRCUIT.

This is generally a broken lead or contact or a wire that has "burnt-out" or been "eaten-away" by acid attack or galvanic action by water and voltage (current).
1. No current will flow when an OPEN CIRCUIT exists.
2. The voltage on each end of the OPEN CIRCUIT will not be the same.
3. Measure the current across the OPEN CIRCUIT and determine if excess current is flowing.
4. Join the two ends of the OPEN CIRCUIT and see if the circuit operates normally.

> HEATSINKS

This is not an electronic component but it can certainly affect the operation of a circuit.
If you cannot hold your fingers on a heatsink, it is getting too hot. This is because the actual location where the heat is being generated is much hotter than the part you are touching.
Transistors and IC's can withstand a high temperature but if they go above this temp, they BLOW UP.
They also have a shorter life when operating at a high temperature.
The secret to a good heatsink is called an INFINITE HEATSINK.
This is the metal frame of a case.
There are lots of charts and data on choosing a heatsink but they don't take into account two factors:
Sometimes a circuit takes a very high current for a short time and this creates a high temperature gradient. This will cause the transistor to get very hot and fail.
The solution is to have two or more transistors in parallel to separate the "heat spots."
The second problem with designing a heatsink is the unknown location of the heatsink and the air-flow. Products placed on a shelf or in a cupboard will get very little air-flow.
Remember: some transistors are mounted on thermal insulators. This means the transistor will have a voltage on it but the heatsink will be zero voltage.
The temperature of the transistor will be MUCH HIGHER than the heatsink under the transistor and the transfer of the heat from the transistor to the heatsink will be very slow. This can be the cause of the transistor failing. Sometimes the transistor will fail because insulation is high temp plastic and it gets brittle. The plastic can carbonise and leak and sometimes a voltage can flash through the insulator. Some amazing things have happened under these transistors and you may need to pull it apart and replace all the insulation.
Finally, feel the heatsink after 15 minutes and feel right up to the transistor. If you cannot touch the transistor, increase the thickness of the heatsink or use two transistors to dissipate the heat.
To design a heatsink, you have to have some idea of the size of a heatsink for the application.
Charts and data can send you in the wrong direction.
Start with a heatsink twice the recommended size and feel the temp after 15 minutes. Put the project in a cupboard and see how the temperature rises.
If possible, connect the heatsink to the metal case to get added dissipation and if you include fan-cooling, remember the fan will eventually gather dust and reduce its efficiency.
It is very difficult to explain how heat passes through a mica washer or plastic washer, but if the transistor has a copper base, the heat transfer has a value of 400. For aluminium it is 200. If it is steel, the transfer has a value of 50. For a mica sheet it is 1 and for plastic it is 0.1
Even though the sheet is very thin, the transfer is a lot less than metal-to-metal transfer.

Most references state the temperature difference is about one degree C for each watt of heat generated by the transistor.
Don't believe anything you read.
Feel the temperature yourself and if you cannot hold your finger on the transistor, fix the problem.

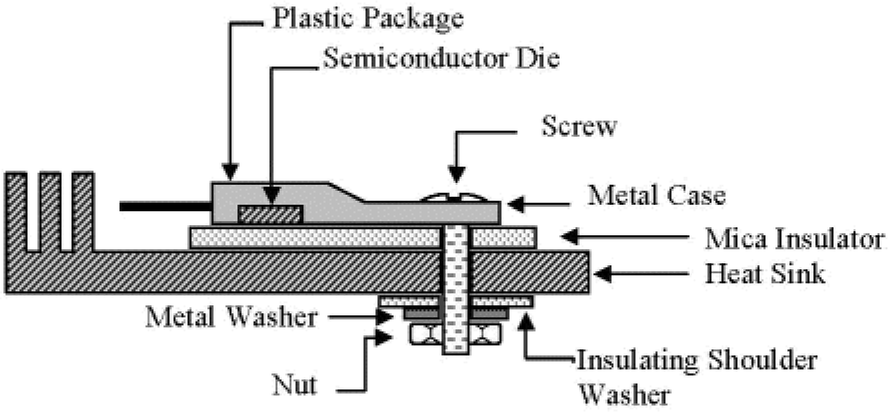

In the end, use a heatsink 50% larger than recommended.

THE END

This is not the full story to learning about servicing. It is just the beginning.
We have only covered the simplest tests and shown how 90% of faults can be found by checking voltages, waveforms and looking for obvious things such as burnt out components, cracks in PC boards.
The author has fixed over 35,000 TV's, radios, stereos, VCRs and all those things that were on the market 30 years ago.
Things have not changed. It's just that some repairs cost nearly as much as buying a new product and half the customers opt for dumping a faulty item and buying the latest "flat screen" version. That's why you have to get things through the workshop as fast and as cheaply as possible, to make a living.

If you want any more devices added to this list, email **Colin Mitchell**.

To help with understanding how a transistor circuit works, we have produced an eBook: **The Transistor Amplifier.** It covers a whole range of circuits using a transistor.

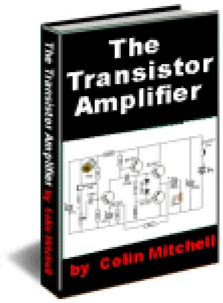

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See the enormous amount of information on Talking Electronics website

CIRCUIT SYMBOLS by TALKING ELECTRONICS

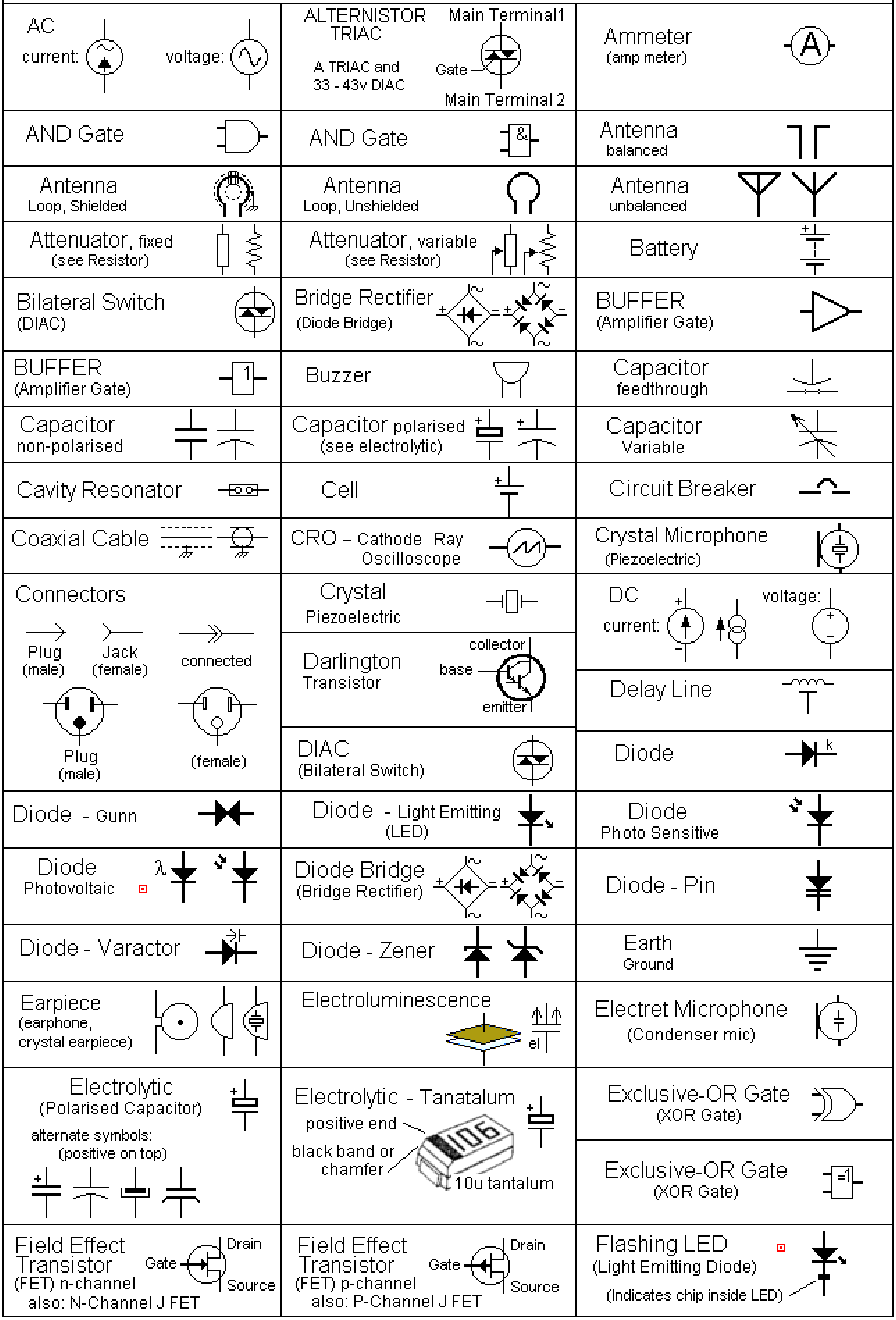
AC
current:
voltage:
ALTERNISTOR
TRIAC
A TRIAC and
33 - 43v DIAC
Main Terminal1
Gate
Main Terminal 2
Ammeter
(amp meter)
A
AND Gate
AND Gate
&
Antenna
balanced
Antenna
Loop, Shielded
Antenna
Loop, Unshielded
Antenna
unbalanced
Attenuator, fixed
(see Resistor)
Attenuator, variable
(see Resistor)
Battery
+
Bilateral Switch
(DIAC)
Bridge Rectifier
(Diode Bridge)
+
=
BUFFER
(Amplifier Gate)
BUFFER
(Amplifier Gate)
1
Buzzer
Capacitor
feedthrough
Capacitor
non-polarised
Capacitor polarised
(see electrolytic)
+
Capacitor
Variable
Cavity Resonator
Cell
+
Circuit Breaker
Coaxial Cable
CRO – Cathode Ray
Oscilloscope
Crystal Microphone
(Piezoelectric)
Connectors
Plug
(male)
Jack
(female)
connected
Plug
(male)
(female)
Crystal
Piezoelectric
DC
current:
+
voltage:
+
Darlington
Transistor
collector
base
emitter
Delay Line
DIAC
(Bilateral Switch)
Diode
k
Diode - Gunn
Diode - Light Emitting
(LED)
Diode
Photo Sensitive
Diode
Photovoltaic
λ
Diode Bridge
(Bridge Rectifier)
+
=
Diode - Pin
Diode - Varactor
Diode - Zener
Earth
Ground
Earpiece
(earphone,
crystal earpiece)
Electroluminescence
el
Electret Microphone
(Condenser mic)
Electrolytic
(Polarised Capacitor)
+
alternate symbols:
(positive on top)
+
Electrolytic - Tanatalum
+
positive end
black band or
chamfer
106
10u tantalum
Exclusive-OR Gate
(XOR Gate)
Exclusive-OR Gate
(XOR Gate)
=1
Field Effect
Transistor
(FET) n-channel
also: N-Channel J FET
Gate
Drain
Source
Field Effect
Transistor
(FET) p-channel
also: P-Channel J FET
Gate
Drain
Source
Flashing LED
(Light Emitting Diode)
(Indicates chip inside LED)

Ferrite Bead 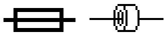	Fuse 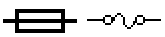	Galvanometer 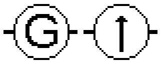
Globe 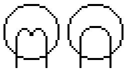	Ground Chassis 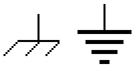	Ground Earth 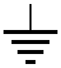
Heater (immersion heater) (cooker etc) 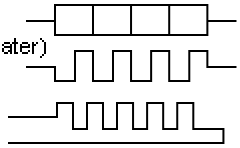	IC Integrated Circuit 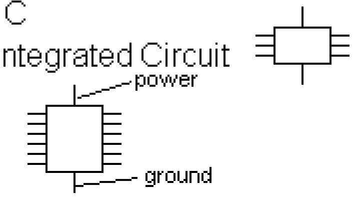	Inductor Air Core 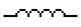
Headphone 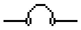		Inductor Iron Core or ferrite core 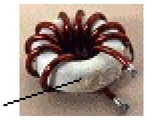 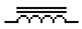
Inductor Tapped 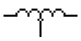	Inductor Variable 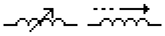	Integrated Circuit 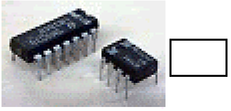
Inverter (NOT Gate) 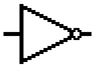	INVERTER (NOT Gate) 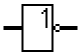	
Jack Co-axial 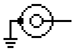	Jack Phone (Phone Jack) 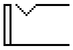	Jack Phone (Switched) 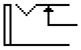
Jack Phone (3 conductor) 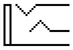	Key Telegraph (Morse Key) 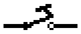	Lamp Incandescent 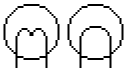
Lamp - Neon 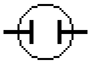	LASCR (Light Activated Silicon Controlled Rectifier) 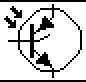	LDR (Light Dependent Resistor) 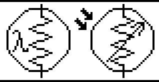
LASER diode 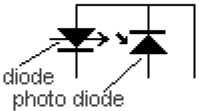	Light Emitting Diode (LED) 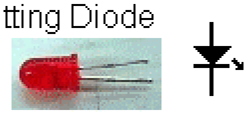	Light Emitting Diode (LED - flashing) 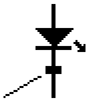 (Indicates chip inside LED)
Mercury Switch 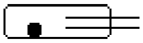	Micro-amp meter (micro-ammeter) 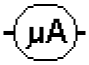	Microphone (see Electret Mic) 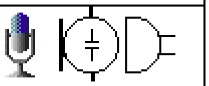
Microphone (Crystal - piezoelectric) 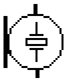	Milliamp meter (milli-ammeter) 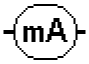	Motor 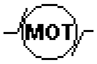
NAND Gate 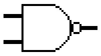	NAND Gate 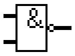	Nitinol wire "Muscle wire" 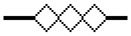
Negative Voltage Connection 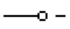	NOR Gate 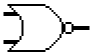	NOR Gate 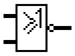
NOT Gate Inverter 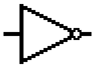	NOT Gate Inverter 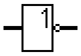	Ohm meter 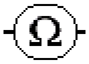
Operational Amplifier (Op Amp) 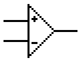	Optocoupler (Transistor output) 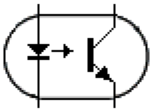	Opto Coupler (Opto-isolator) 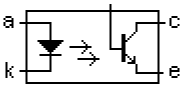 Photo-transistor output
Optocoupler (Darlington output) 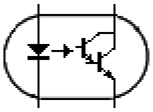	Opto Coupler (Opto-isolator) 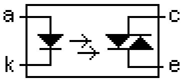 TRIAC output	OR Gate 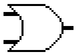
OR Gate 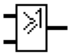	Oscilloscope see CRO 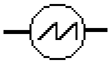	Outlet (Power Outlet) 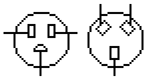
Piezo Diaphragm 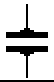	Photo Cell (photo sensitive resistor) 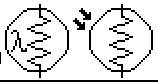	Photo Diode 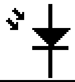
Photo Darlington Transistor 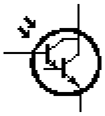	Photo FET (Field Effect Transistor) 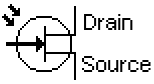	Photo Transistor 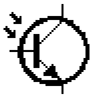

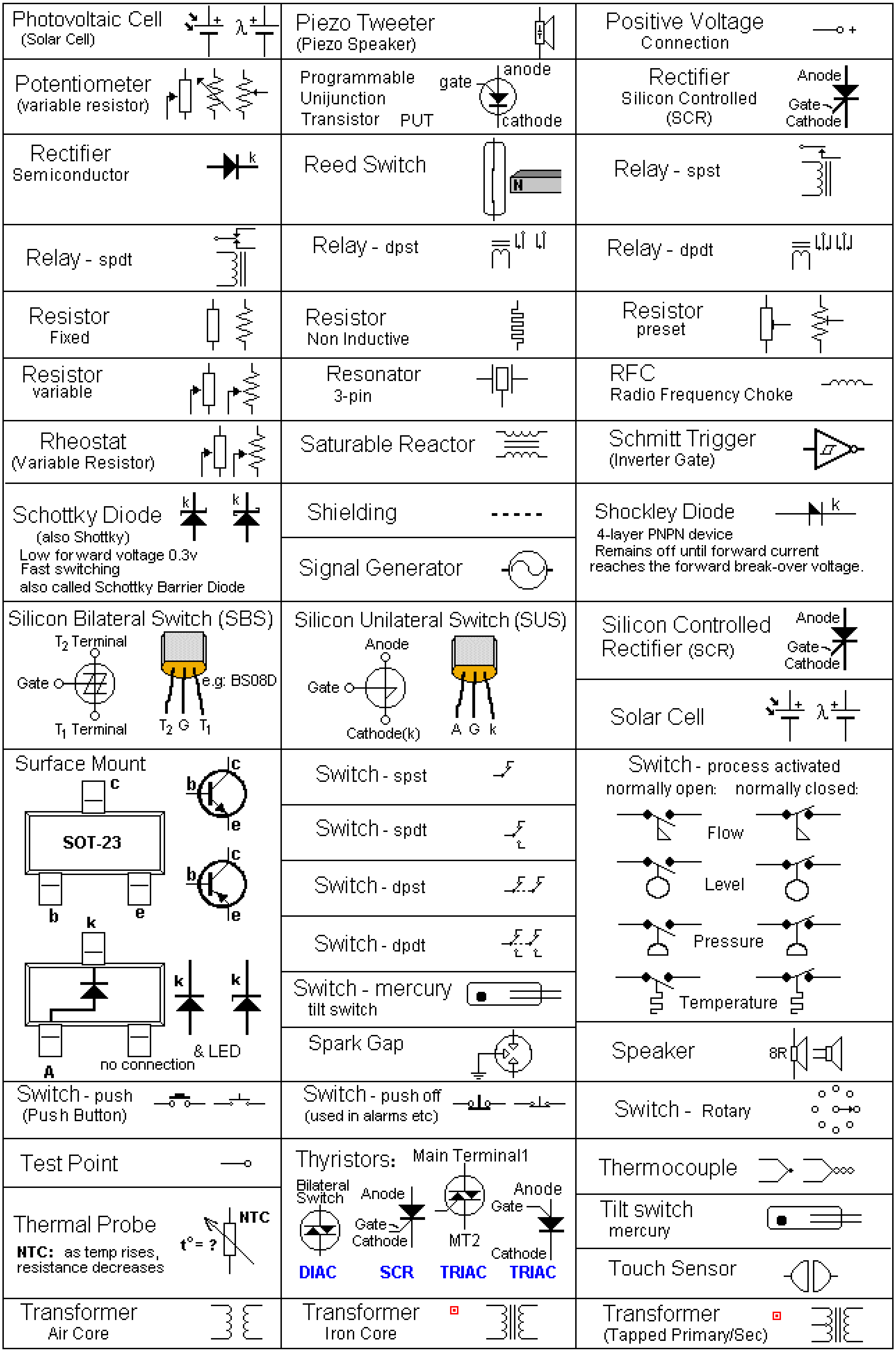

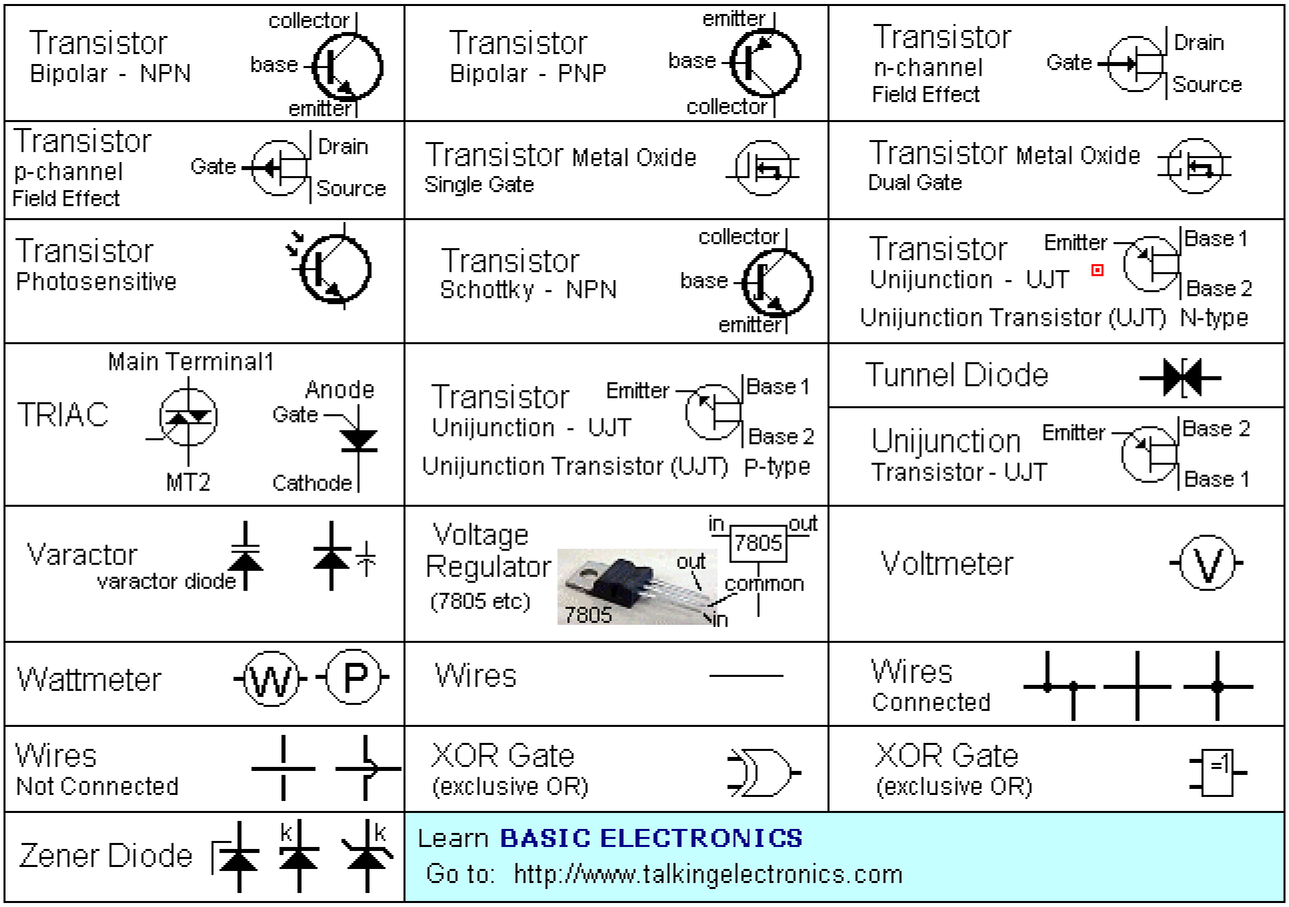

Transistor Bipolar - NPN collector base emitter	Transistor Bipolar - PNP emitter base collector	Transistor n-channel Field Effect Gate Drain Source
Transistor p-channel Field Effect Gate Drain Source	Transistor Metal Oxide Single Gate	Transistor Metal Oxide Dual Gate
Transistor Photosensitive	Transistor Schottky - NPN collector base emitter	Transistor Unijunction - UJT Emitter Base 1 Base 2 Unijunction Transistor (UJT) N-type
TRIAC Main Terminal1 MT2 Anode Gate Cathode	Transistor Unijunction - UJT Emitter Base 1 Base 2 Unijunction Transistor (UJT) P-type	Tunnel Diode Unijunction Transistor - UJT Emitter Base 2 Base 1
Varactor varactor diode	Voltage Regulator (7805 etc) 7805 in out common out in 7805	Voltmeter V
Wattmeter W P	Wires	Wires Connected
Wires Not Connected	XOR Gate (exclusive OR)	XOR Gate (exclusive OR) =1
Zener Diode k k	Learn **BASIC ELECTRONICS** Go to: http://www.talkingelectronics.com	

More chapters of this eBook on: Talking Electronics.com

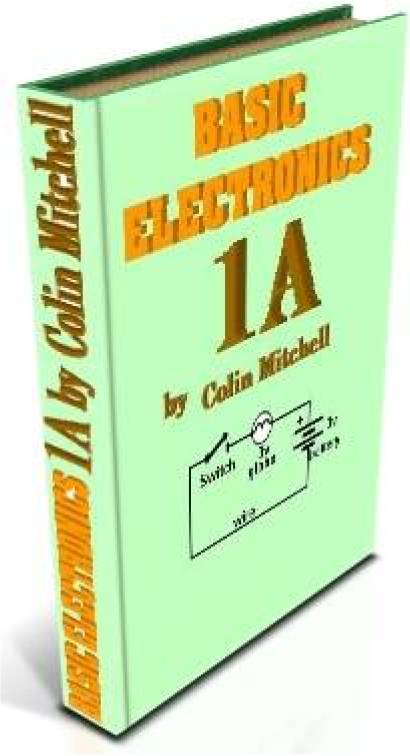
BASIC ELECTRONICS 1A
by Colin Mitchell
Switch
globe
battery
wire
BASIC ELECTRONICS 1A by Colin Mitchell

For any enquiries email Colin Mitchell

BASIC ELECTRONICS

(this is the Basic Electronics section i.e. Page 1)
(Chapters 1 and 3 are available as .pdf)

Quick Quiz - to see how much you know
Encyclopedia of Components - this is excellent !!!

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Page 2: The Transistor
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Page 2a: The 555 IC
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The 555 - 2
The 555 - 3
The 555 TEST
Page 3: The Power Supply download as .pdf (900kB)
3a: - Constant Current
3b: - Voltage Regulator
3c: - Capacitor-fed Power Supply
Page 4: Digital Electronics

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4b: - The DELAY CIRCUIT
Page 5: Oscillators
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Remember: the animations do not work in .pdf
the site is being constantly updated

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KIT OF PARTS

Talking Electronics supplies a kit of parts that can be used to build the majority of the circuits in this eBook.
The kit costs $15.00 plus postage.

Kit for Transistor Circuits - $15.00

BUY NOW

A kit of components to make many of the circuits described in this eBook is available for $15.00 plus $7.00 post.
Or email Colin Mitchell: talking@tpg.com.au

The kit contains the following components:
(plus **extra** 30 resistors and 10 capacitors for experimenting), plus:

3 - 47R
5 - 220R
5 - 470R
5 - 1k
5 - 4k7
5 - 10k
2 - 33k
4- 100k
4 - 1M
1 - 10k mini pot
1 - 100k mini pot
2 - 10n
2 - 100n
5 - 10u electrolytics
5- 100u electrolytics

5 - 1N4148 signal diodes
6 - BC547 transistors - NPN - 100mA
2 - BC557 transistors - PNP - 100mA
1 - BC338 transistor - NPN - 800mA
3 - BD679 Darlington transistors - NPN - 4amp
5 - red LEDs
5 - green LEDs
5 - orange LEDs
2 - super-bright WHITE LEDs - 20,000mcd
1 - 3mm flashing LED
1 - mini 8R speaker
1 - mini piezo
1 - LDR (Light Dependent Resistor)
1 - electret microphone
1m - 0.25mm wire
1m - 0.5mm wire
1 - 10mH inductor
1 - push button
5 - tactile push buttons
1 - Experimenter Board (will take 8, 14 and 16 pin chips)
5 - mini Matrix Boards: 7 x 11 hole,
11 x 15 hole, 6 x 40 hole, surface-mount 6 x 40 hole board and others.

Photo of kit of components.
Each batch is slightly different:

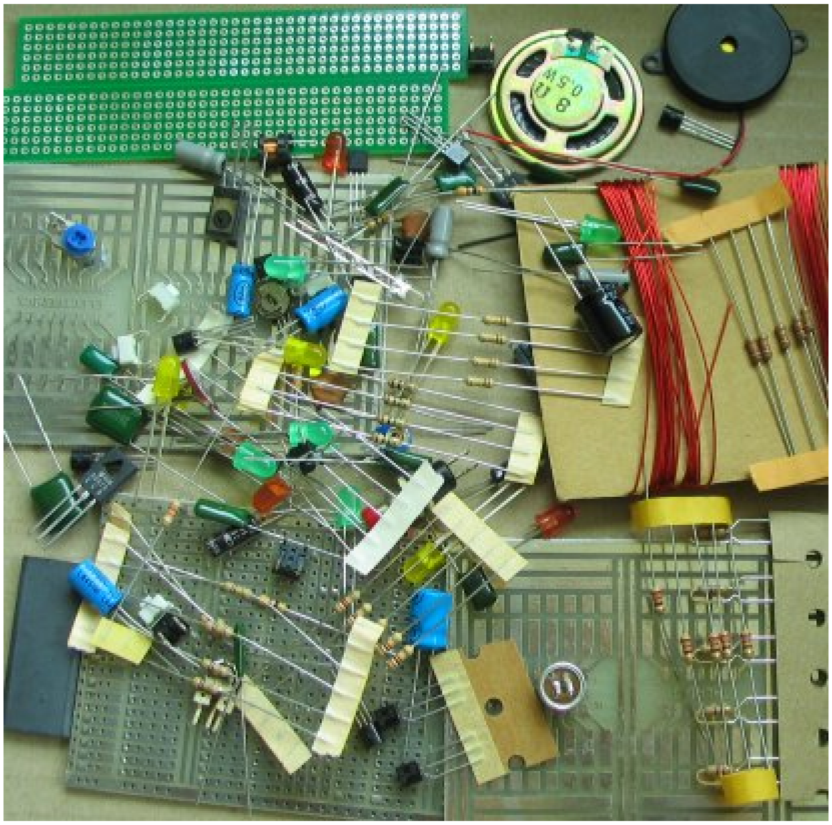

There are more components than you think. . . plus an extra bag of approx 30 components. The 8 little components are switches and the LDR and flashing LED is hiding.
In many cases, a resistor or capacitor not in the kit, can be created by putting two resistors or capacitors in series or parallel or the next higher or lower value can be used.

BEFORE WE START

Too many text books start with the physics of the atom and have equations and mathematics to show how smart the author is.
Don't worry, we wont have any physics or equations.
The reason . . .
This is not a physics course. It is a practical electronics course to teach the basics as quickly as possible. There are no equations because most transistor circuits cannot be worked out mathematically as the gain of a transistor changes according to the current-flow and these gain-values are never provided. So the mathematics is worthless.
To get an answer, all you have to do its build the circuit and measure the values with a multimeter.
Also lots of discussions in text books will never be used in your next 40 years of electronics, so this course doesn't have any unnecessary material and is much-more concentrated than anything you have read before.
Every frame contains important points - especially the animations - as they show you how a circuit works in slow-motion - something that has NEVER been done before.

ELECTRONICS BLOCKS

Here is an idea from Instructables to produce blocks with screws, containing a single component and they can be connected with jumper leads (alligator clips).

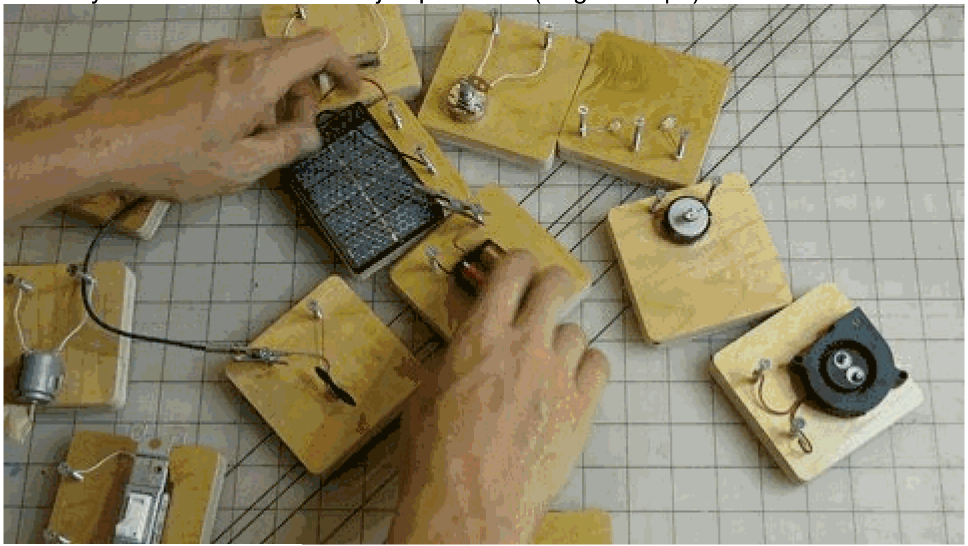

SLOTTED HEAD

PHILIPS HEAD

Use a slotted head for the negative screw and a philips head for the positive screw.

Learn electronics from the beginning . . .

START HERE:

All electrical and electronic components need wire to connect them to the circuit.
In a diagram called a CIRCUIT DIAGRAM, the wires are drawn as lines.
When the wires (or lines) cross, they may be joined or just passing.
It is **VERY IMPORTANT** to show the difference between lines that are **JOINED** and lines that are **NOT JOINED**.
When the lines are joined, it is best to place a dot

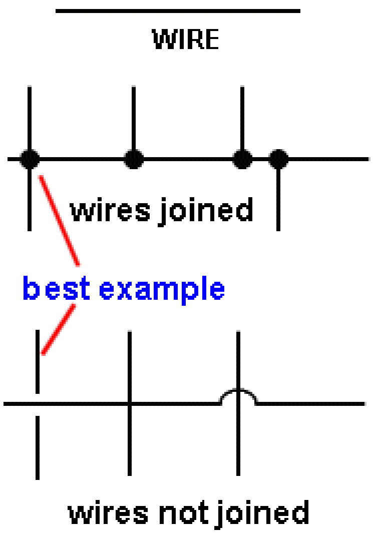

Fig 1 The wire in a circuit diagram

on the connection to PROVE the lines are joined.
When the lines are just crossing, a gap should be made so it is obvious that one wire goes under the other and does not touch.
Lines should be "across the page" or "up and down." Very few lines should be at 45°.
You can make a line thicker to indicate a power rail or a wire that will be thick in reality.

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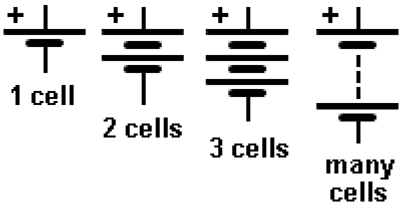

Fig 2 A single Cell and many Cells

Next we need a **battery**. A battery consists of two or more cells. The positive terminal of a battery is the long line in the diagram and you must add the voltage (of the cell or battery) to the symbol as a single cells can be 1.2v, 1.5v, 2.2v or up to 3.6v.
The symbol does not let you know the voltage.
The positive is always at the top and is the longest line on the battery symbol.

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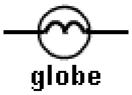

Fig 3: A Globe

Next we need a globe. A globe has two connections (a fine wire inside a glass bulb glows when the globe is connected to a battery).

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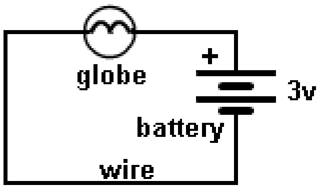

Fig 4: A Circuit

With a globe, battery and wire we have produced a **CIRCUIT**.
A **CIRCUIT** is a complete path and we say the "electricity" the **CURRENT** emerges from the positive of the battery, moves through the globe and returns to the battery via the wire.
If the globe is a "3v GLOBE" it will glow when connected to a 3v battery.
The globe can be connected either way around.
The circuit we have shown is called a **SCHEMATIC** and consists of symbols: a globe symbol and a battery symbol.
The line connecting the two components is called WIRE.

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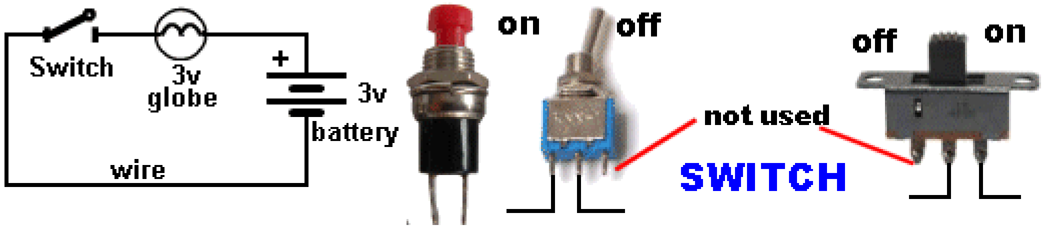

Fig 5:Adding a SWITCH
To turn the globe ON and OFF we need a SWITCH.
The switch may be a push button, a toggle switch (a "click" action) or a slide switch. You could

twist the wires together and untwist them. The result is the same. We say the circuit is "broken" or "open" via the switch and the lamp does not glow. Closing the switch turns ON the globe.

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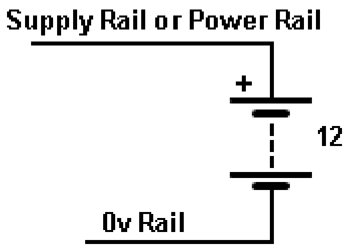

Fig 6: Naming the RAILS

The top rail of the **CIRCUIT DIAGRAM** is called the **SUPPLY RAIL** or **POWER RAIL**.
The lower rail is called the **0v Rail** or **EARTH RAIL**.
Do not connect the Supply rail (+12v) to the 0v rail as this will cause a high current to flow and is called a **SHORT CIRCUIT**:

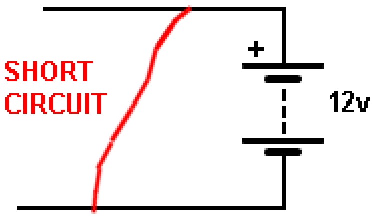

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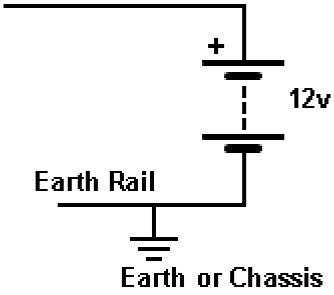

Fig 7: The **EARTH RAIL**

The lower rail is also called the **Chassis**.
This comes from the "old days" when electronics constructors build radios on a metal chassis (metal box) and it was connected via wire to a pipe in the ground to help the radio pick up distant radio stations.
The term also comes from car and truck wiring where one side of each globe is connected to the frame or chassis so that only one wire is needed to each globe and the return "path" is via the chassis.

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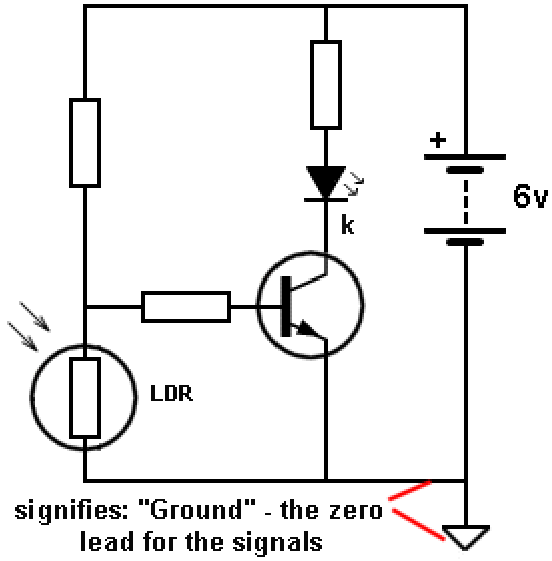

Fig 7a: Ground

Some circuits identify the "**Ground Lead**" or "**Ground Wire**" of a project to show where all the **signals** have been "referenced to." In other words, all the signals rise and fall above and below this "Ground wire" or "Ground Lead." This lead may not be at **earth potential** as the project may be in a plastic box but it identifies where the earth lead of a Cathode Ray Oscilloscope or the negative lead of a multimeter is connected.
On some printed circuit boards, the negative terminal of the battery (the 0v wire or terminal) is connected to a very large area of copper and this is called the EARTH PLANE or GROUND PLANE. It is designed to prevent signals travelling along the tracks (called traces) being radiated and also prevents outside interference upsetting the project. It also "tightens-up" the earth rail.

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The circuit shows a 12v globe connected to a 12v battery and the circuit appears to be "broken" (not continuous).
But the **current returns** via the earth connection.

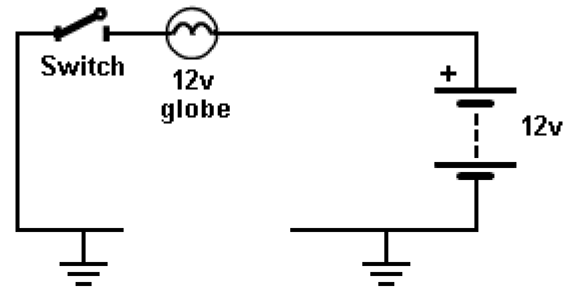

Fig 8: EARTH Return

We talk about the **CURRENT RETURNING**. We don't say: the voltage returning.
The voltage of the globe must be the same as the battery voltage, otherwise it will not glow fully or it will **burn out** if it is say a 6v globe.

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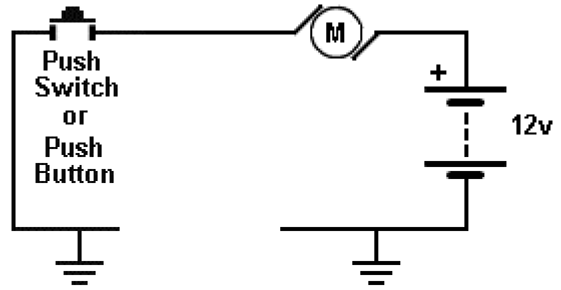

Fig 9: Connecting a Motor

The circuit shows a 12v **Motor**.
It is turned ON when the push-switch is pressed.

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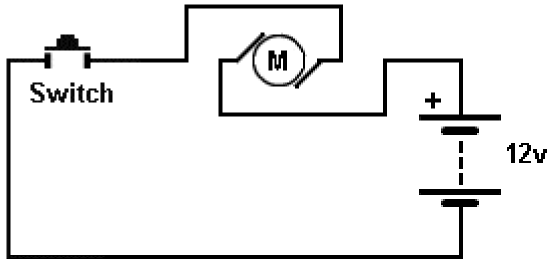

Fig 10: Reversing a Motor

If the wires are connected to the motor "around the other way," the motor will reverse direction.

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VOLTAGE AND CURRENT

What is voltage and what is current?
Here is a very simple description.
A battery produces a voltage called DC. (This is a very confusing name because the letter actually refer to Direct Current, so we just say **DC Voltage**).
A battery also produces current called DC - Direct Current. We say **DC current**.

VOLTAGE

Voltage is a value produced by an electrical component called a battery or cell.
A single cell produces one and a half volts. (1.5v) and although this is not a high voltage, when cells are connected together we get higher voltages.
If 6 cells are connected in series we get 9v.
Here is a 9v battery:

CURRENT

You cannot feel current with your tongue so we have to carry out another experiment:

negative terminal
positive terminal
9 VOLTS
2010
Energizer

Touch the two terminals with your tongue. You get a tingle. This is a 9v tingle. Now you have "felt" electricity. This is a 9v tingle.

9 VOLTS
2010
Energizer

Place a 22 ohm or 47 ohm resistor across the terminals of the battery and hold your fingers on the resistor. It will get hot. This is the result of current flowing through the resistor and heating it up. The current will be about half an amp and the voltage is 9v, so the wattage will be about 2 to 4 watts. Feel the heat produced.

Milli - milli means 1/1,000th (one thousandth) - such as one milliamp or one millivolt.
In other words one thousand milliamps is equal to 1 amp.
One volts is not a very large value as a battery produces 9v and a cell produces 1.5v to 3.6v (depending on the type of cell.
But 1 amp is a large quality when talking about electronic circuits involving LEDs, motors and transistors.
The globe used in the experiments above requires about 300mA. (1,000mA = 1 amp)
The 3v motor used in the experiments requires about 250mA
The LEDs used in the experiments require about 20mA.
Transistors can pass about 100mA to 800mA via the collector-emitter.
In most cases current-flow in the circuits we will be discussing will be less than 1 amp and will be shown as 25mA, 100mA, 350mA etc.

WATTAGE and CAPACITY

A 9v battery has 6 very small cells and they will not last very long.
A "AAA" cell is larger and a "D" cell is much larger.

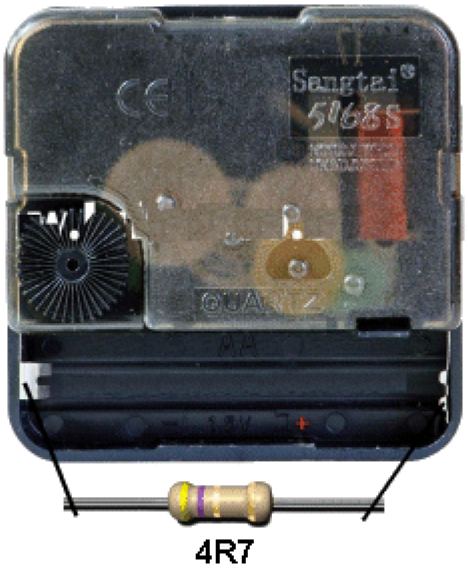

A large cell is said to have a **LARGE CAPACITY.** This means it will deliver a larger current for a longer period of time.
The **WATTAGE** of a cell is the multiplication of the voltage x current. The answer is milliwatts or watts.
The **CAPACITY** of a cell is the wattage x hours. The answer is milliwatt-hours or watt-hours. This is also called watt-hours.
You can determine the capacity of a cell (such as a rechargeable cell) by connecting it to a clock-mechanism that has a 4R7 connected across the terminals. The resistor will take a considerable current and deplete the cell in a few hours. The clock will let you know exactly how long the cell delivered the current. You can then compare other cells.

The simplest electrical circuit consists of a battery and resistor. The current flowing through the circuit will depend on the voltage of the battery and the resistance of the resistor R.

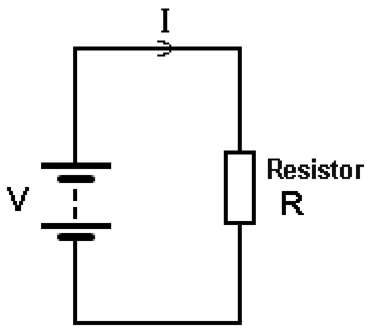

The formula connecting these three quantities is:

$$I = \frac{V}{R}$$

Ohm's Law

$$I = \frac{12}{3}$$

$$I = 4 \text{ amps}$$

This is called **Ohm's Law**. Suppose you have a 12v battery and the resistor is 3 ohms. The current flowing through the resistor will be 4 amps.
Increasing the resistance will decrease the current if the voltage remains fixed.

All the above circuits are called ELECTRICAL CIRCUITS because they contain electrical components (such as a motor, globe, relay, switch).
When the circuit contains an ELECTRONIC component such as a diode, transistor, LED, it is called an ELECTRONIC CIRCUIT or ELECTRONIC SCHEMATIC.

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POWER and ENERGY

Here's an easy way to remember the difference between POWER and ENERGY:
A 9v alkaline battery has enough ENERGY to start a car. But it does not have enough POWER (strength).
Energy is effectively the strength of the battery (and this is the voltage and the current it can deliver) multiplied by the time it can deliver this energy. When the answer is obtained, it consists of three factors ((3 quantities) VOLTS, AMPS and TIME.
This results in an answer called xxxx WATT-HOURS.
For a 9v battery the quantities are: 9 volts, 500mA and the battery will deliver this 9x0.5 = 4.5watts for about 1 hour. This is equal to 4.5 x 60 x 60 = 16,200 watt-seconds.
To start a car requires 250 amps from a 12v battery for 5 seconds.
This is: 12 x 250 x 5 = 15,000 watt-seconds.
This means the energy stored in a 9v battery could start a car if all the energy could be delivered in 5 seconds.
This is not possible however the FACT is this: A 9v battery has enough stored energy to START A CAR.

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POWER STATION
300

BATTERY BOOSTER

One of the simplest things we can do is start a car with a flat battery with the assistance of a BATTERY BOOSTER.
This consists of a 12v rechargeable battery in a handy case with leads to connect to the flat battery in your car.
This simple operation puts two 12v batteries in parallel, but no-one has actually described what happens and why.
That's because the explanation is very complex. We have included it here to show that a simple explanation involves a lot of technical terms and you will understand more after reading the course.

The flat battery in the car is not fully charged but it has some percentage of charge and when it sits for a period of time in a non-fully charged condition, the voltage drops from 12.6v to less than 12v as the battery gradually self-discharges due to the potential at the top of the cell being different to that at the bottom of the cell and the specific gravity of the electrolyte being different at the top and bottom. This causes an internal current to flow within the cell and slowly discharge the cell. But if you try to start the car, the voltage drops to less than 7v because the electrolyte cannot carry the high current and a slight potential is developed across the liquid.

The result is the starter-motor does not crank the car.
The reason is this: When the battery is fully charged, the current taken by the starter motor is about 300 amps. This is about 11v x 300 amps = 3300 watts = 4.4Horsepower.
But when the voltage drops to 7v, the current will drop to 190 amps to deliver 1336 watts = 1.8HP. This is only 40% of normal and that's why the car does not start. The engine needs 4HP to overcome the pressure in the cylinders due to the compression of the air during the "firing stroke."
Let's put it this way. If we have a brand new 7v battery, the car will not start. The starter-motor will only accept 190 amps when the supply is 7v.
So, we have to increase the voltage.
We do this by placing a 12v battery across the flat battery. The voltage of the flat battery will immediately rise to 12.6v. It might take 2 minutes but the flat battery will take a small current (1 to 10amps) from the battery in the "booster" and the output of the combination will be 12.6v. The current-carrying capacity of the electrolyte will improve very quickly and you have effectively given the "flat battery" a very quick charge.
The starter-motor will now accept 300 amps from the combination and **SURPRISINGLY** the cells of the "flat battery" will deliver about 200 amps and the booster battery will deliver about 100 amps. The actual sharing of current will depend on the two batteries but the secret behind the success is the increase in voltage we call **TERMINAL VOLTAGE**. The voltage on the terminals (the alligator clips).
The capacity of the booster battery is not important. It can be from 7AHr to 40AHr. We are just using a very small amount of its capacity to start the car and nearly all batteries will provide 200 Amps for a short period of time.
The voltage of the car battery is very important. The Horsepower taken by the starter-motor is defined by the formula: Pwatts = V^2/R Since the resistance remains constant, a voltage of 7 volts will produce 7x7=49 units and a voltage of 11v will produce 121units. This gives the ratio of 40% to 100% as explained above.

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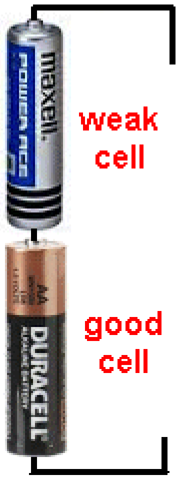

BATTERY BOOST

Continuing from the previous frame where we showed the effect of placing a weak battery in parallel with a good battery, we can show what happens when a weak cell is placed IN SERIES with a good cell.
This also applies when you have 5 good cells and one weak cell.
Basically, the weak cell will reduce the current. In other words, if the 5 cells are driving a motor and supplying 250mA, the 5 cells and 1 weak cell will deliver 200mA or less, depending if it is weak or very weak. The current flowing through the weak cell will have the effect of giving it a small charge - in other words, you will be charging the weak cell from the good cells when the motor is operating.

BUT . . . .

There is a way to use weak cells. If you have say 6 weak cells driving a motor and the RPM is reducing, you can add 2 more weak cells to increase the RPM.
The effect is this: The voltage from the 8 cells will be higher than from 6 cells and this will allow a higher current to flow. Sometimes the cells will provide this higher current and thus more of the energy will be delivered and you will get the last of the energy from the cells.

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INTERNAL RESISTANCE

All batteries and also all individual cells have a "secret, hidden" value of resistance inside each cell due to the resistance of the chemicals. This resistance is very small when the cell is new but it increases as the cell gets older.
It is very easy to measure this value. Simply put an ammeter directly across the cell and measure the current. Use Ohm's law to work out the resistance. But this not always a wise thing to do as some cells will deliver 10 amps and some will deliver 100 amps and damage the meter.
The diagram opposite shows a large internal resistance for the weak cell and a small internal resistance for the good cell.
If a cell did not have any INTERNAL RESISTANCE it would deliver thousands of amps. It's the Internal Resistance that limits the current.

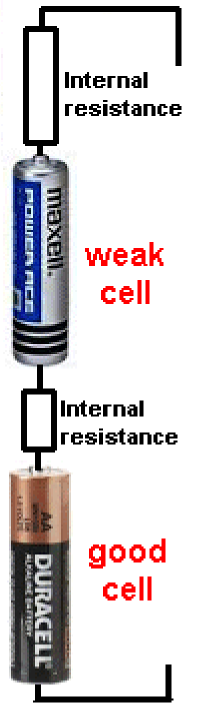

In most cases we neglect (do not consider) the value of internal resistance when making tests and when using a battery in a project.
But when a battery gets old, it cannot deliver a high current and the internal resistance gets so high that the output voltage drops from say 9v to 7v, even when the battery is not connected to a circuit.
This is the result of the INTERNAL RESISTANCE of the chemicals increasing to a point where they become noticeable and what we call "poisoning" of the chemicals due to the cell "aging" and new chemicals being produced in the cell that have a high resistance. Some of the terms we use are: "drying out and sulphating. Some cells produce spikes or needles that completely short-circuit the cell and make it totally useless.

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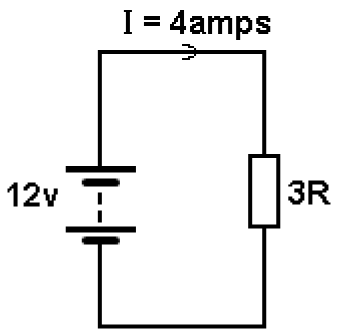

This resistor is dissipating 48 watts.
As a comparison, a soldering iron is dissipating about 10 to 20 watts.

RESISTOR WATTAGE

Resistor Wattage means two things.
1. The physical size of a resistor tells you number of watts it is capable of dissipating. This is called RESISTOR WATTAGE. It is really RESISTOR-SIZE or RESISTOR-CAPABILITY.
2. The multiplication of the voltage across a resistor and the current flowing though it will produce a value called WATTAGE. This is also called RESISTOR-WATTAGE or RESISTOR-LOSS or RESISTOR-DISSIPATION or HEAT-LOSS.
In the circuit shown, the wattage being lost in the resistor is:
12 x 4 = 48 watts.
Most of the resistors we will be using in our projects are 0.25watts. This means they will dissipate 250milliwatts, however the actual wattage being dissipated may be only 70 milliwatts and the resistor will not get hot.
0.25watts is the maximum wattage it can dissipate without overheating.
If it is dissipating 400milliwatts, it will be VERY HOT.
The wattage it is dissipating (the heat it is getting rid of) will depend on the supply voltage and the value of the surrounding components.

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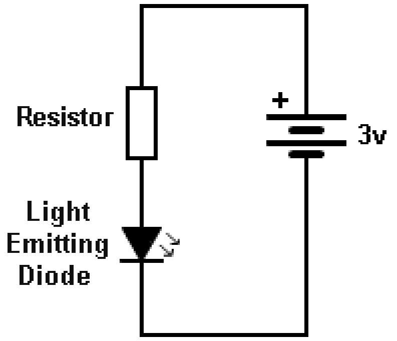

Fig 11. **The LED**

This simple **ELECTRONIC CIRCUIT** contains a **LIGHT EMITTING DIODE (LED), RESISTOR** and battery.

The circuit is classified as electronic because the LED is not an electrical item (such as a globe) but more-complex, as it produces light when current flows through a crystal and the crystal produces the colour.

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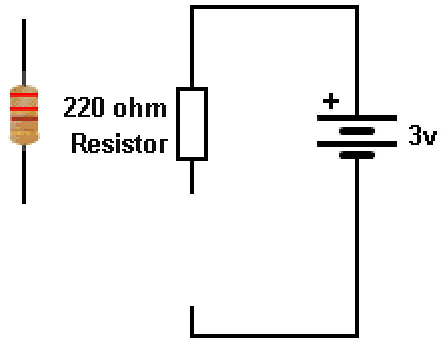

Fig 12. **The Resistor**

A **RESISTOR** must be included in the circuit to prevent the LED being damaged.
The resistor in this circuit must be 220 ohms.
This is shown by the colours on the resistor. The colours for 220 ohms: **red - red - brown**. The 4th band is gold - indicating a tolerance of 5%.
A resistor has **RESISTANCE**.
It reduces the current from the battery to a required amount to prevent the LED glowing too bright.
A resistor is just like putting your foot on a hose. The water trickles out the end. The resistor "resists" the high current-flow that the battery is able to deliver.

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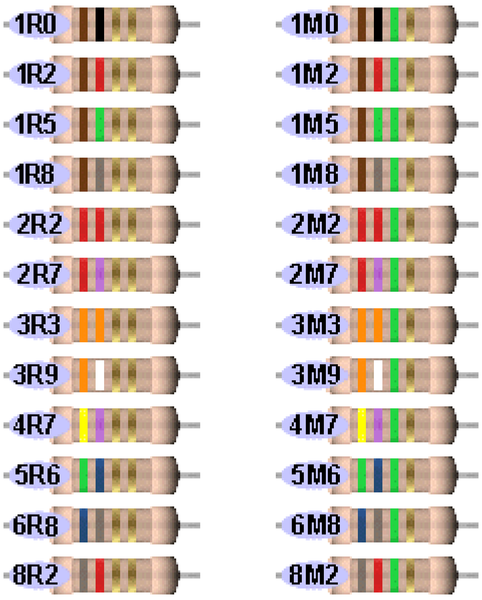

Fig 12a. The **Resistor Colours**

There are hundreds of different resistors because the resistance-values need to cover the range one ohm to 10 million ohms.
There are also small, medium and large resistors.
The resistors on the left are just a few in the range. (See the full range below). They show colour bands for 1 ohm to 8.2 ohms and 1 million ohms to 8.2 million ohms. All the other values are shown below.
An electronics engineer does not have the room to store 10 million different resistors so they make each resistor 5% or 10% higher than the previous. This reduces the number to about 100 to 200.

TOLERANCE

The first 3 bands indicate the value of the resistor and the 4th band indicates either 5% or 10% tolerance.
All modern resistors are 5% or 2% or 1%. The "old" 10% resistors are no longer made.
Gold = 5%
Silver = 10%

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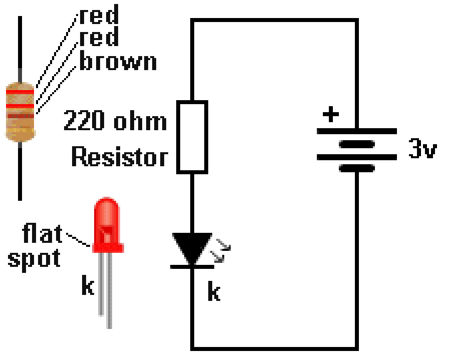

Fig 13. The **Resistor and LED**

The **LIGHT EMITTING DIODE** is called an electronic component (mainly because it is more complex than a globe and it produces light by a more-complex means than heating a wire).
A **LED** must be connected around the correct way. It will not illuminate if connected around the wrong way.
All **LEDs** have one lead longer than the other. The SHORT lead is called the **CATHODE** (k).
All LEDs have a flat on one side and this is the **CATHODE** lead.
The arrows on the diagram indicate light is "given off" (emitted - produced).

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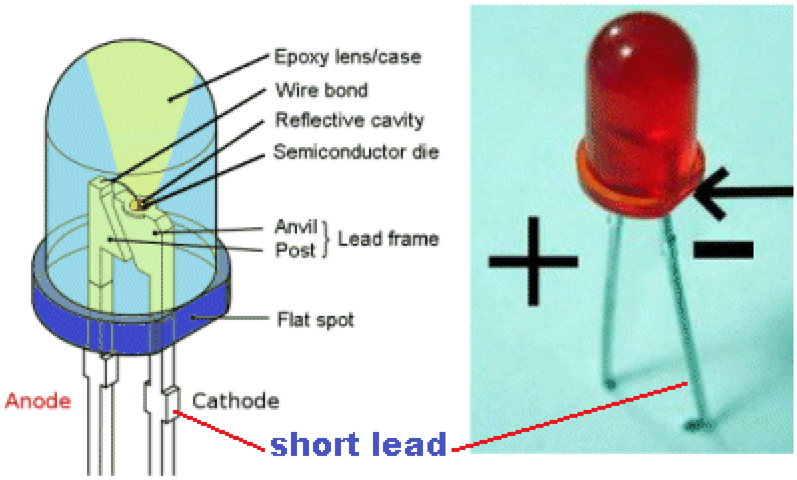
Epoxy lens/case
Wire bond
Reflective cavity
Semiconductor die
Anvil
Post
Lead frame
Flat spot
Anode
Cathode
short lead
+
-

Fig 14. The **LED - showing the flat spot**
A close-up of a red LED. The cathode lead is the short lead and next to a flat side on the LED.
DO NOT show "+" or "-" on a diagram. Only show the letter "k" to indicate cathode.
The symbols "+" and "-" are used when a component produces a voltage or is connected directly to "+" and "-" A LED is connected via a resistor.

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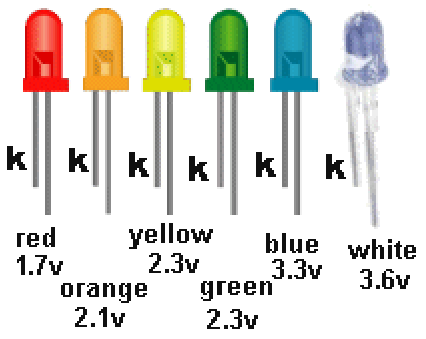
k
k
k
k
k
k
red
1.7v
yellow
2.3v
blue
3.3v
white
3.6v
orange
2.1v
green
2.3v

Fig 15. **LED VOLTAGES**

When a LED is connected to a circuit, (and the correct-value resistor is included), a voltage will be develop across the LED called the **CHARACTERISTIC VOLTAGE DROP**.
This voltage is due to the colour of the LED and the crystal inside the LED that produces the colour.
The diagram on the left shows the approximate voltage developed for each LED.
The voltage **does not change** for small, medium, surface-mount, or large LEDs.

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When a LED is connected to 3v battery, the following **CHARACTERISTIC VOLTAGE DROPs** will develop across each LED.
You will notice we **have not changed** the value of the resistor. It is 220R.
The LED creates the voltage and if the value of resistance is decreased, the LED will illuminate BRIGHTER.
If the LED illuminates too bright it will be DAMAGED.

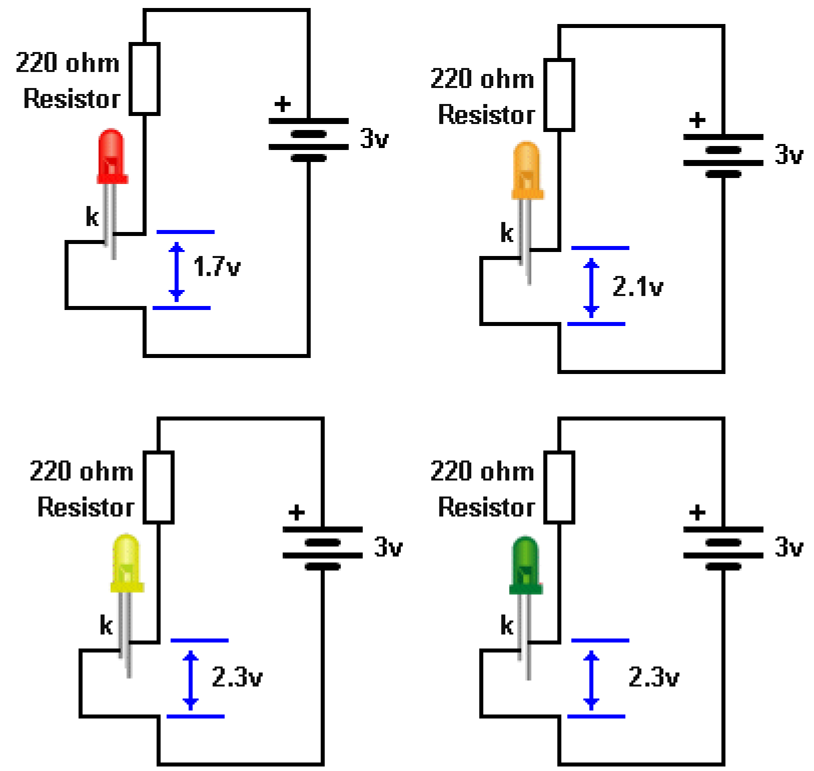
220 ohm Resistor
+
3v
k
1.7v
220 ohm Resistor
+
3v
k
2.1v
220 ohm Resistor
+
3v
k
2.3v
220 ohm Resistor
+
3v
k
2.3v

Fig 16. LED VOLTAGES

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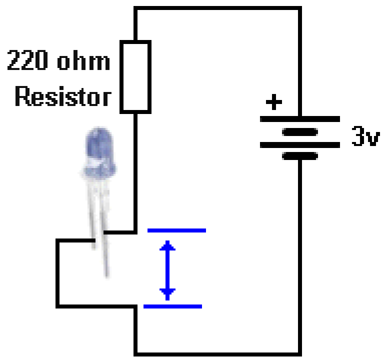
220 ohm Resistor
+
3v

Fig 17. WHITE LED VOLTAGE

If we connect a WHITE LED to 3v supply, it will not illuminate because it needs a supply higher than 3.6v.

The resistor in series with the LED is called a **CURRENT LIMITING RESISTOR**.

In this circuit **no current flows** because the supply is not high enough.

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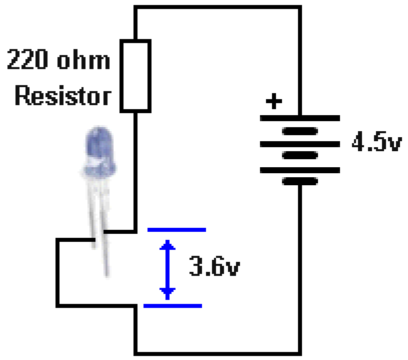
220 ohm Resistor
+
4.5v
3.6v

Fig 18. WHITE LED VOLTAGE

When the supply is increased to 4.5v, the 220R resistor will allow a current to flow through the white LED and it will develop a CHARACTERISTIC VOLTAGE DROP of 3.6v across it.

The supply (the voltage of the battery) must be higher than the CHARACTERISTIC VOLTAGE DROP of the LED so the resistor will allow the correct amount of current to flow.
The ideal current for a LED is 20mA, however some LEDs will work when 1mA flows, so you have to know what you are doing.

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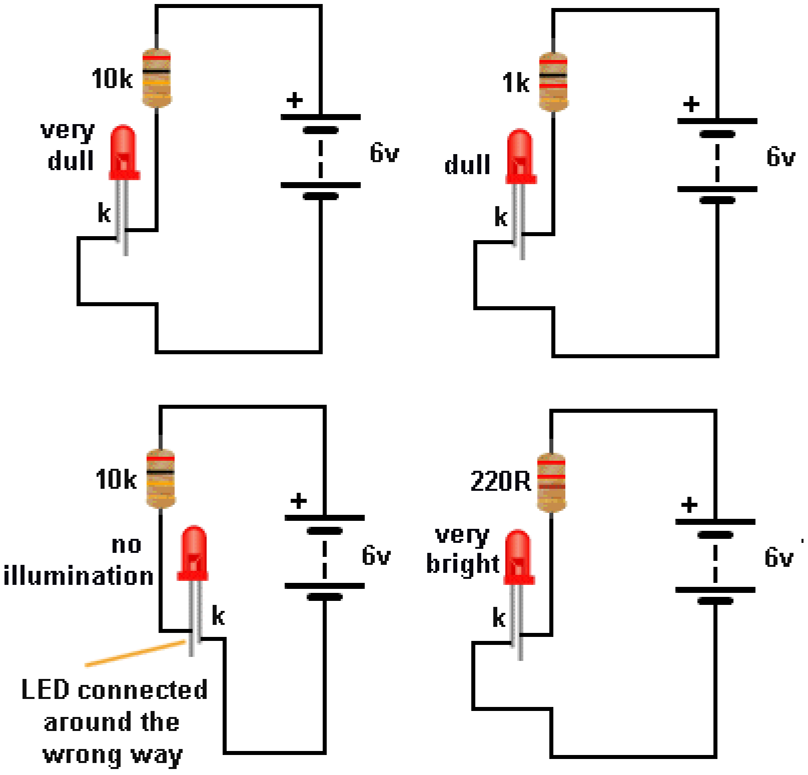
10k
very dull
k
+
6v
1k
dull
k
+
6v
10k
no illumination
k
+
6v
LED connected around the wrong way
220R
very bright
k
+
6v

Fig 19. Testing A LED

Now connect either the 1k, 470R or 220R and determine the brightness you need.
As the brightness increases, the current will be higher.
You can use 3v supply for all LEDs except blue and white.

HOW TO TEST A LED

Some clear LEDs produce red or orange and some LEDs do not have the cathode lead clearly identified.
Here's how to find the colour, cathode lead and the current.
You need a 6v battery, 10k resistor, 1k resistor, 470R resistor and 220R resistor.
Connect the 6v battery and 10k resistor to the LED and it will only illuminate when the cathode is connected to the negative of the battery. This is the short lead.

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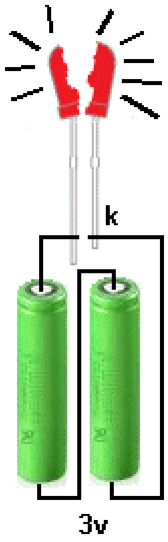

Fig 20. Damage a LED

Do not connect a 3v battery directly across a LED.
It will be DAMAGED. You MUST include a resistor.

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A LED IS CURRENT DRIVEN

You may have seen this statement and tried to work out what it means.
Basically it means an increase in current will make the LED brighter.
But a LED needs 2 things:
It needs a voltage that is EXACTLY the voltage required to produce illumination. And this voltage depends on the colour of the LED.
As soon as you supply the exact voltage, the crystal will begin to glow and as you increase the current, the illumination will increase.
But doing this is VERY VERY difficult.
It is very easy to supply an exact voltage such as 1.7v or 3.4v, but delivering a current such as 10mA or 20mA at the same time is very difficult. You cannot get a 1.7v battery and deliver 10mA to a LED.
As we have shown above, you need a simple components such as a resistor between the battery and LED to achieve the desired result.
A LED is CURRENT DRIVEN but firstly you need to provide a VOLTAGE that is exactly the connect value for the colour of the LED and then the current can be increased.

to Index

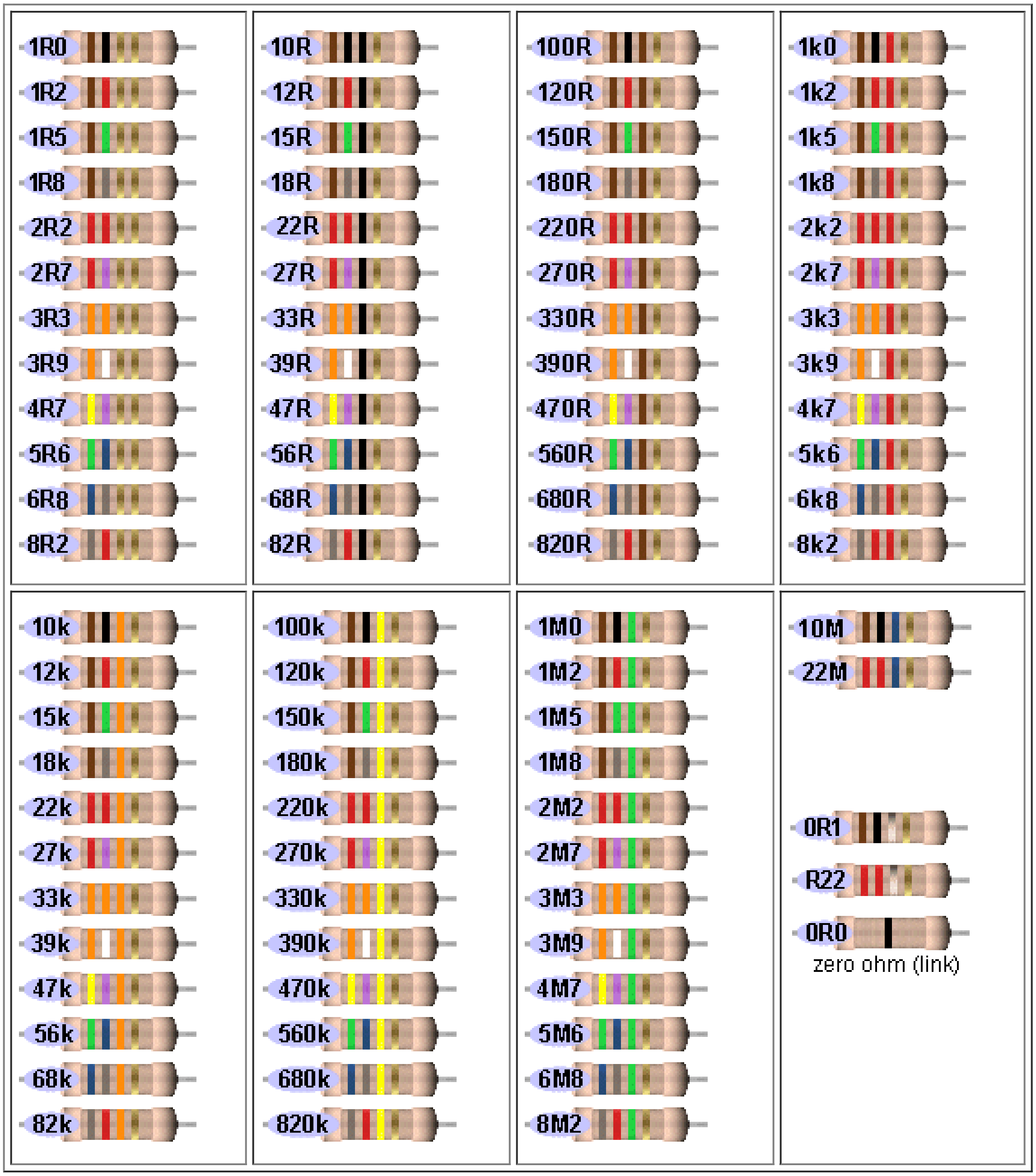
1R0
1R2
1R5
1R8
2R2
2R7
3R3
3R9
4R7
5R6
6R8
8R2
10R
12R
15R
18R
22R
27R
33R
39R
47R
56R
68R
82R
100R
120R
150R
180R
220R
270R
330R
390R
470R
560R
680R
820R
1k0
1k2
1k5
1k8
2k2
2k7
3k3
3k9
4k7
5k6
6k8
8k2
10k
12k
15k
18k
22k
27k
33k
39k
47k
56k
68k
82k
100k
120k
150k
180k
220k
270k
330k
390k
470k
560k
680k
820k
1M0
1M2
1M5
1M8
2M2
2M7
3M3
3M9
4M7
5M6
6M8
8M2
10M
22M
0R1
R22
0R0
zero ohm (link)

Fig 21. All the resistor values

Here are all the colours and values for the resistors you will using in this course. Just match-up the colours on your resistor with the resistors above and you will find the value.

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Resistor values are always OHM values. One ohm is a small value. It might be the resistance of a length of wire 3 metres long.
When a switch is open the resistance is infinite - millions and millions of ohms.
The resistance of your body from one hand to the other will be about 70,000 ohms.
The resistance between two wires dipped in water will be about 1,000 to 100,000 ohms (depending on the dissolved-salts in the water - pure water has a very high resistance)
The resistance of the filament of a 3v globe will be about 30 ohms.
The resistance of the winding of a 3v motor will be about 3 ohms.
Resistors are made with values from less than one ohm to more than 10 million ohms by adding carbon to the mixture inside the resistor (and cutting a track around the outside of the resistor) then connecting a lead to each end. Adding more carbon reduces the value of resistance. Carbon has a low resistance.
Resistance-values are measured with the RESISTANCE settings on a MULTIMETER.
This is called the "Ohms Range." Sometimes with the symbol: **Ω**
A Multimeter will have 2, 3 4 or more scales to cover the range one ohm to 10 million ohms.
Low value resistors (from 1 ohm to 999 ohms) are written as 1R, 220R, 470R, 999R. with the letter "R" indicating Resistance (ohms). You can also use the symbol "omega" **(Ω)**
For values above 1,000 ohms to 99,999 ohms, they are written as: 1k, 2k2, 4k7, 10k, 100k, 220k, 470k, with the letter "k" indicating "kilo" (thousand).
1M = 1,000,000 - one million ohms 1M2, 2M2, 4M7, 10M.
The letters "R, k and M" are placed so they take the place of the decimal point. This prevents any mistake, as a decimal point can be missing in a poor photocopy.

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6.43
OMEGAETTE

MULTIMETERS

There are two types of **MULTIMETER**. The top two are called **DIGITAL MULTIMETERS** (DMM) and show numbers on a display.
The lower two meters are called **ANALOGUE MULTIMETERS** and have a pointer and scale.
All meters come with a set of red and black leads.

The **red lead** is always connected to the positive of the battery or the positive on a project and the **black lead** is connected to the negative or earth or chassis.
When making a resistance measurement, the leads can be around either way.
Resistance measurements are always made with the power removed from a circuit. Any voltage on a circuit will upset the resistance reading.

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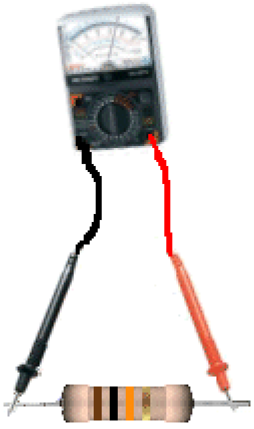

Fig 22. Resistance Measurement with Analogue Multimeter

The resistance of a resistor is measured by placing the leads of the multimeter on the ends of a resistor and turning the dial on the analogue multimeter to the resistance scale to make the pointer move to about the centre of the scale.
The resistance scale is marked with a high value on the left and 0 ohm on the right. This is opposite to all the other scales.
You must get the pointer to move to the middle of the scale as it is not accurate at left-end.
Analogue multimeters are only suitable for reading values from 1 ohm to 100,000 ohms. The scale is too hard to read above 100k.
To find the value of a resistor, you can compare the colours with the table above.

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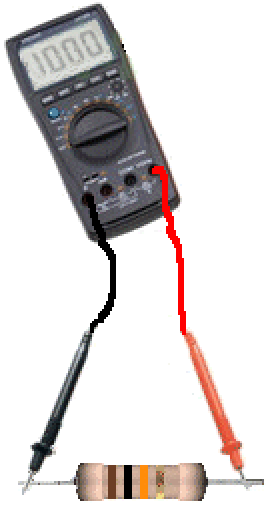

Fig 23. Resistance Measurement with
a DMM

A digital multimeter produces a more-accurate reading of resistance.
It is accurate from 1 ohm to 10M ohms.
Select the scale that provides a reading.

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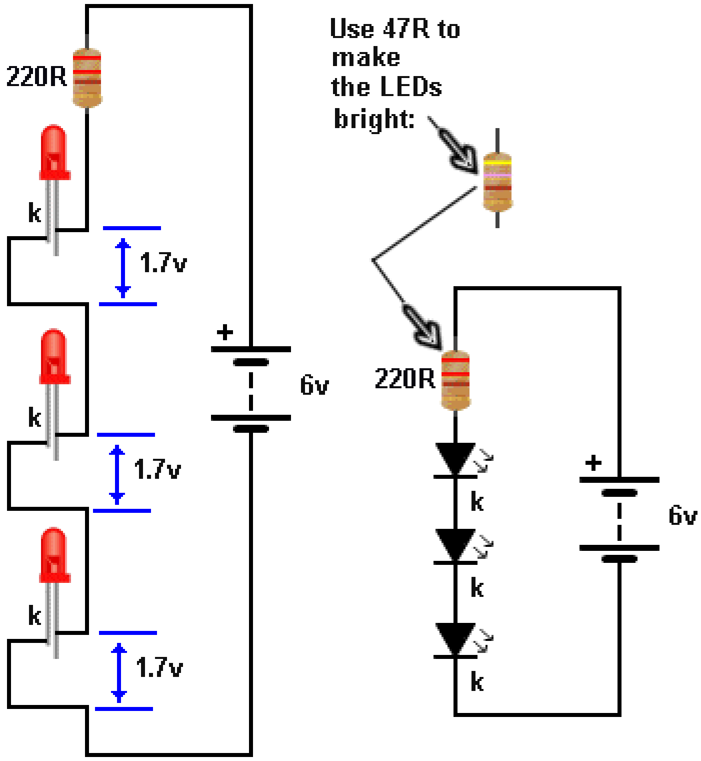
220R
k
1.7v
k
1.7v
k
1.7v
+
6v
Use 47R to make the LEDs bright:
220R
k
k
k
+
6v

Fig 24. Connecting **LEDs in series**
LEDs can be placed in series provided the total **CHARACTERISTIC VOLTAGE DROP** across the LEDs is LESS than the supply voltage.
In this case the voltage across the LEDs is 1.7v + 1.7v + 1.7v = 5.1v
The supply is 6v and this allows 0.9v for the CURRENT LIMITING RESISTOR.
The LEDs will not be very bright with 220R.
Change the resistor to 47R
If you connect 4 LEDs in series, the total **CHARACTERISTIC VOLTAGE DROP** will be 6.8v and no LEDs will illuminate because the total is higher than the 6v supply.

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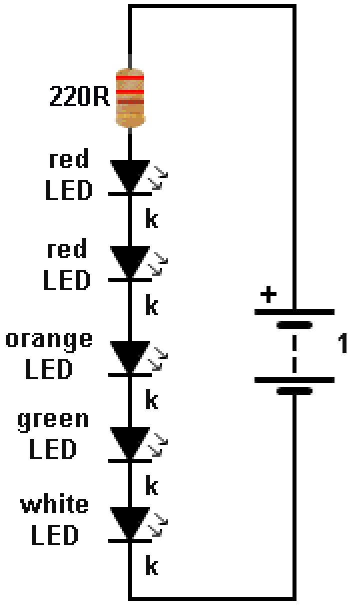
220R
red LED
k
red LED
k
orange LED
k
green LED
k
white LED
k
+
12v

Fig 25. Connecting LEDs in series

Different-colour LEDs can be connected in series. Add up the total Characteristic Voltage for the 5 LEDs and see if it is less than 12v.

The 220R resistor will have to be reduced to 47R to make the LEDs bright.

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LEDs can be connected in parallel if they are the

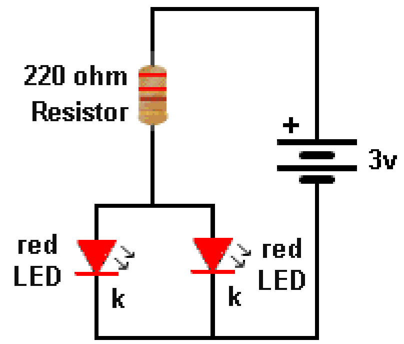

Fig 26. Connecting LEDs in parallel

same colour.
In the diagram a red LED drops a CHARACTERISTIC VOLTAGE of 1.7v and if they are from the same manufacturer or the same batch, they will work ok.
Although we say the characteristic voltage for a red LED is 1.7v, this can change slightly from different manufacturers and one LED may glow brightly while the other is dull.
You have to build the circuit and see the result.

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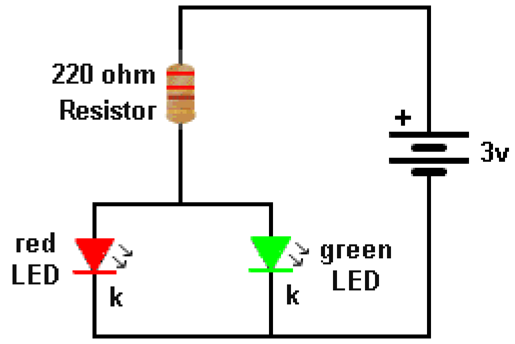

Fig 27. Connecting LEDs in parallel

Different colour LEDs cannot be connected in parallel. The voltage across a red LED is 1.7v. This becomes the "Supply Voltage" for the green LED and it is too low. The green LED needs a supply of 2.1v to 2.3v.
Only the red LED will illuminate.

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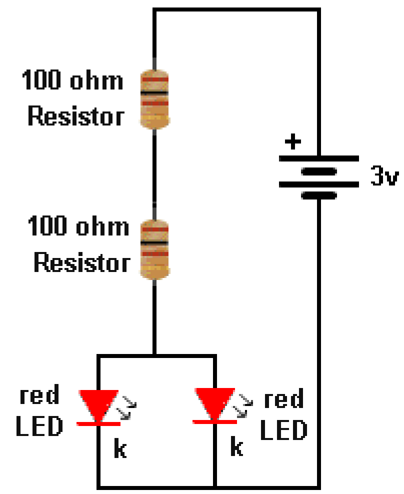

Fig 28. Connecting Resistors in Series

Suppose you don't have a 220 ohm resistor.
You can make a 220 ohm resistor with two resistors in series. The total resistance will be 200 ohms, but resistors are not accurate and the result will be very close to 220R.
Electronic circuits are not very critical. You will not be able to see the difference in brightness between 200 ohms and 220 ohms.

When resistors are connected in series, the total resistance is found by adding the resistance of each resistor.

$$R_{total} = R_1 + R_2 + R_3 + \cdots$$

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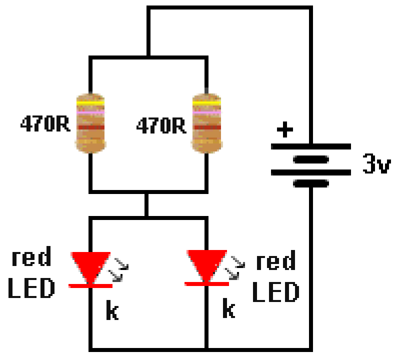

You can create a 220 ohm resistor by connecting two resistors in Parallel.
When two equal-value resistors are connected in Parallel, the total resistance across the combination is HALF.
470R in parallel with 470R produces 235R.
This is very close to 220R.
We are not going into the formula as it is very complex.
Three equal-value resistors in parallel produce a total of **one-third.**
Simply get two resistors and connect them in

Fig 29. Connecting Resistors in Parallel

parallel and measure them with a multimeter.

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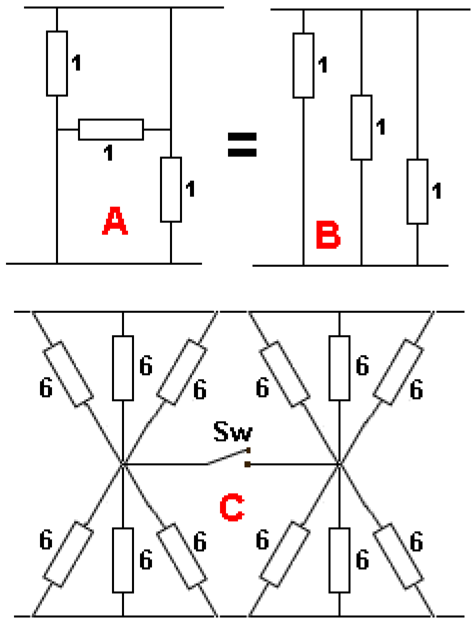

Fig 29a. Two tricky resistor questions

Figure A shows three resistors. It looks hard to solve so the middle resistor is turned so it connects directly to the top and bottom rail. Now you can see the circuit is three resistors in parallel. The result is one-third of an ohm.

Figure C shows twelve 6 ohm resistors. Replace each group with a 2 ohm resistor, because three 6 ohm resistors in parallel is equal to 2 ohms.

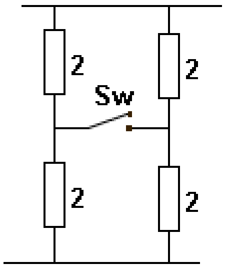

The two left resistors create 4 ohms and the two right resistors create 4 ohms. The result of two 4 ohm resistors in parallel is 2 ohms.
The resistance of the circuit does not change if the switch is open or closed.

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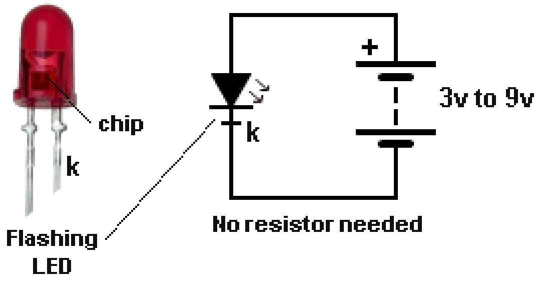

Fig 30. Flashing LED

There are some special LEDs that can be connected to 3v to 9v and they flash or produce a range of colours.
These LEDs have a chip and resistor inside the body of the LED to produce the effect and allow the LED to operate on a voltage without the need for a current limiting resistor.

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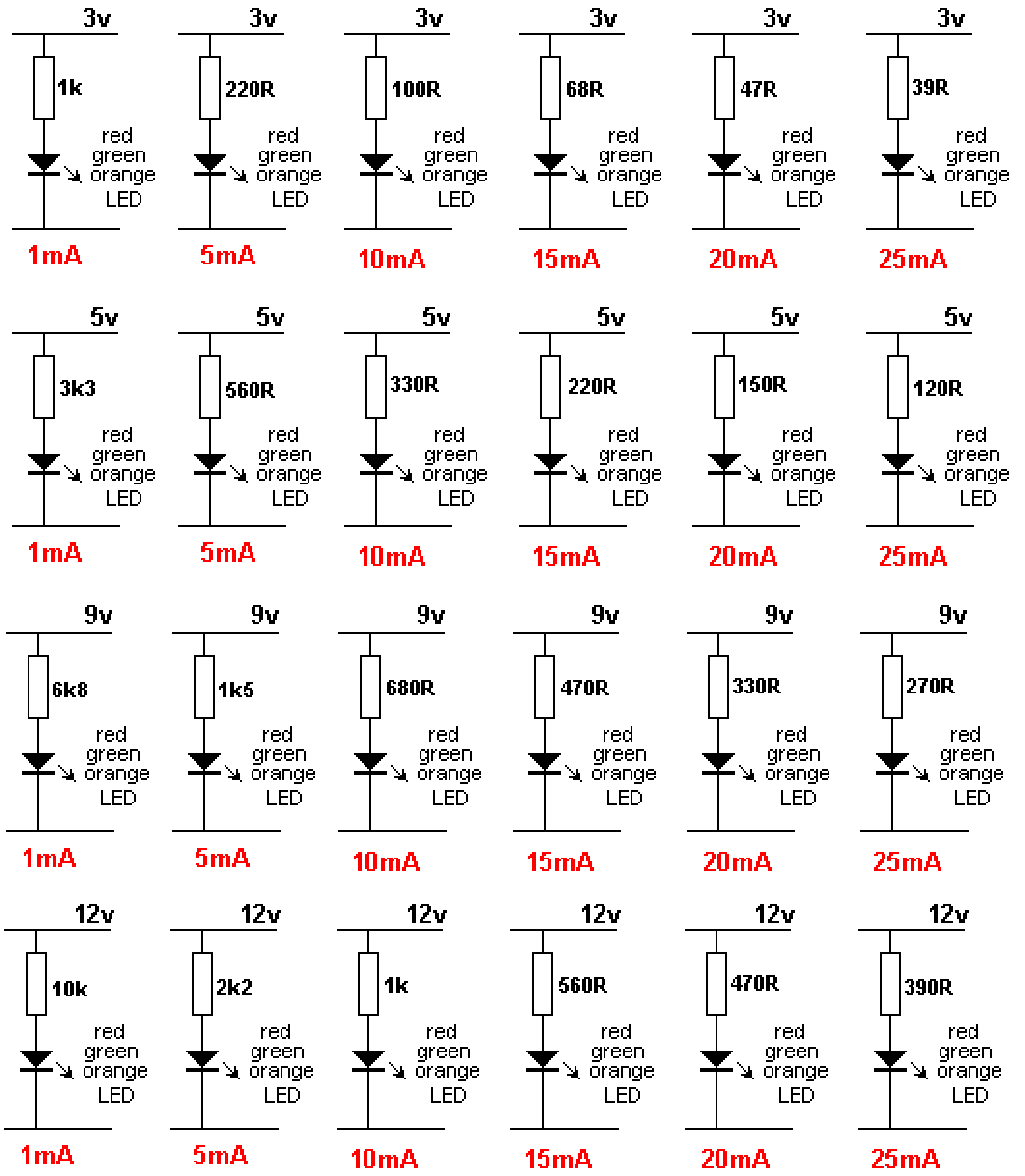
3v
1k
220R
100R
68R
47R
39R
red
green
orange
LED
1mA
5mA
10mA
15mA
20mA
25mA
5v
3k3
560R
330R
220R
150R
120R
9v
6k8
1k5
680R
470R
330R
270R
12v
10k
2k2
1k
560R
470R
390R

Fig 31. These diagrams show the resistor needed to produce 1mA to 25mA current through a single LED on 3v, 5v, 9v and 12v supply.

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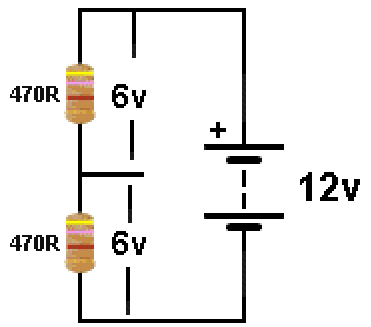
470R
6v
470R
6v
+
12v

Fig 31a. Voltage Divider Circuit.

THE VOLTAGE DIVIDER

In the circuits above, the resistor and LED are forming a VOLTAGE DIVIDER.
A red LED is dropping 1.7v across it and the resistor is dropping the remaining voltage.
Whenever two (or more) components are placed across a battery, they form a **VOLTAGE DIVIDER**.
Sometimes we want a 6v supply and only have 12v.
We can produce the 6v supply by putting two equal-value resistors across the 12v as shown in the circuit opposite.
We are not going into the mathematics because the selection of the correct value is very complex and the circuit is very wasteful.

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THE CURRENT DIVIDER

The **CURRENT DIVIDER CIRCUIT** is actually a

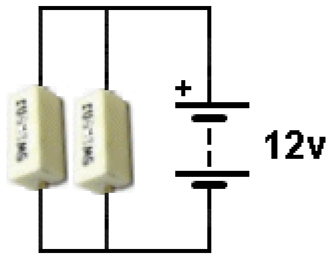

Fig 31b. Current Divider Circuit.

LOAD SHARING CIRCUIT.
Suppose you are testing a Power Supply and need a 10 watt LOAD. But you only have 5 watt resistors.
Placing two 5watt resistors in parallel across the output of the power supply will allow half the current to flow though each resistor. This is called **CURRENT SHARING** or **LOAD SHARING** and the current is divided (or passed) through each resistor according to the value of resistance.

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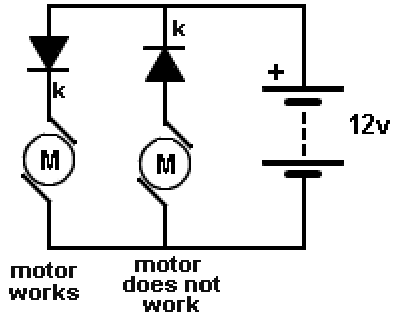

Fig 32. The DIODE

THE DIODE
The next simple electronic component is the **DIODE.**
It only works when connected correctly.
A DIODE allows current to flow through it when it is connected as shown in the diagram.
A Diode is similar to a one-way water valve.
When the diode is "facing down," the motor spins.
When it is "facing up" the motor does not spin.

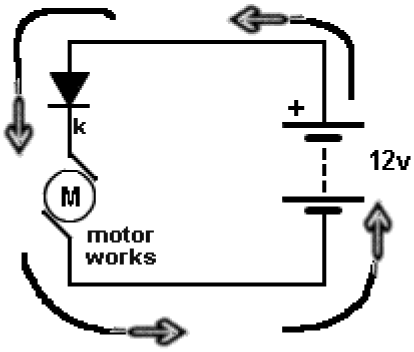

The diagram shows the "current path" around the circuit. The current is measured in AMPS and we discuss current as CONVENTIONAL CURRENT. This is the way current was thought to flow when electricity was born and they said it flows out the POSITIVE TERMINAL of the battery, around the circuit and into the NEGATIVE TERMINAL.
The arrow on the diode shows the current will flow through the diode and allow the motor to spin.
The diode is said to be **FORWARD BIASED**.

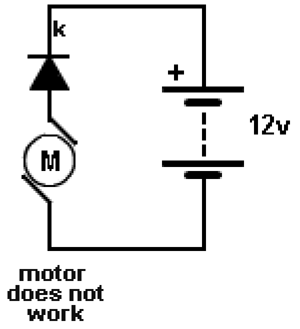

There is no flow of current because the diode prevents any current-flow when connected as shown.
The motor DOES NOT WORK.
The diode is said to be **REVERSE BIASED**.

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There are hundreds of different types of diodes.
Power diodes, signal diodes, low voltage diodes, high voltage diodes, high-speed diodes and many other types.
They all do one thing.
They pass current in one direction and if turned around, they **do not pass** any current.

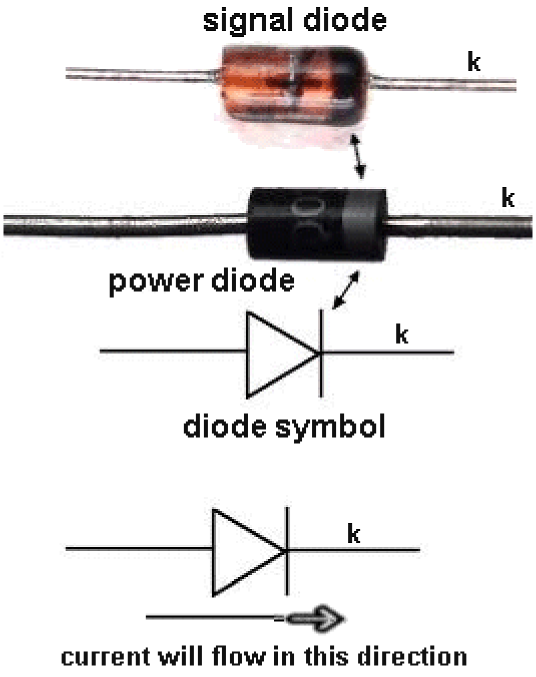
signal diode
k
k
power diode
k
diode symbol
k
current will flow in this direction

Fig 33. A Signal diode and a Power diode

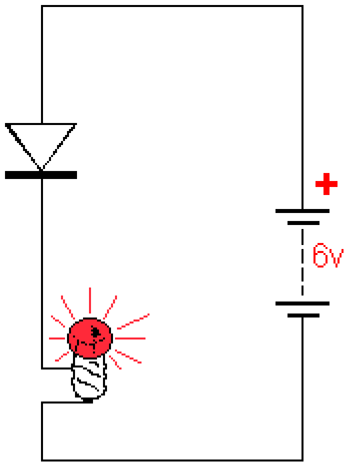

How a diode works

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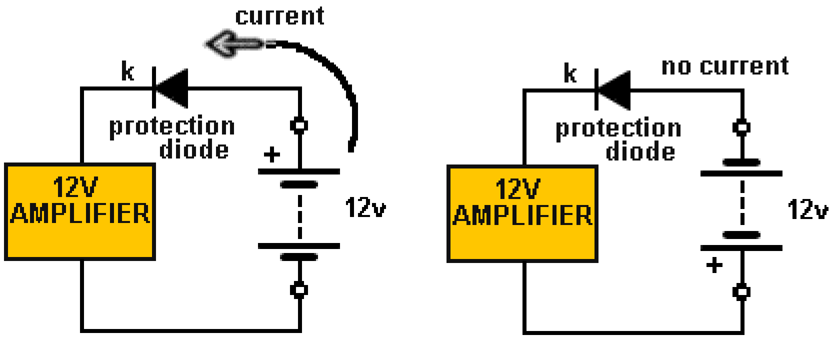
current
k
protection diode
12V AMPLIFIER
12v
k
no current
protection diode
12V AMPLIFIER
12v

Fig 34. A Protection diode

Diodes perform many function in electrical and electronic circuits. Here is an application as a **PROTECTION DIODE.**
It protects the amplifier. If the 12v battery is connected around the wrong way, no current will flow.

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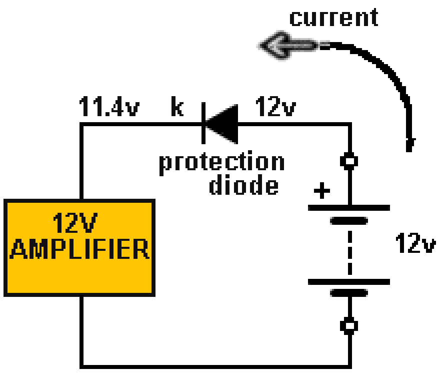
current
11.4v
k
12v
protection diode
12V AMPLIFIER
12v

Fig 35. Diode "Voltage Drop"

When a diode is placed in a circuit (and current is flowing), a small voltage develops across the diode. This voltage is called the **FORWARD VOLTAGE DROP.**
This voltage is approximately 0.6v.
This is due to a junction inside the diode where two different materials are joined.
Normally, this voltage is not important because it is only small, but sometimes you need to take it into account.
For the circuit above, the amplifier only gets 11.4v

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Voltage is measured with a

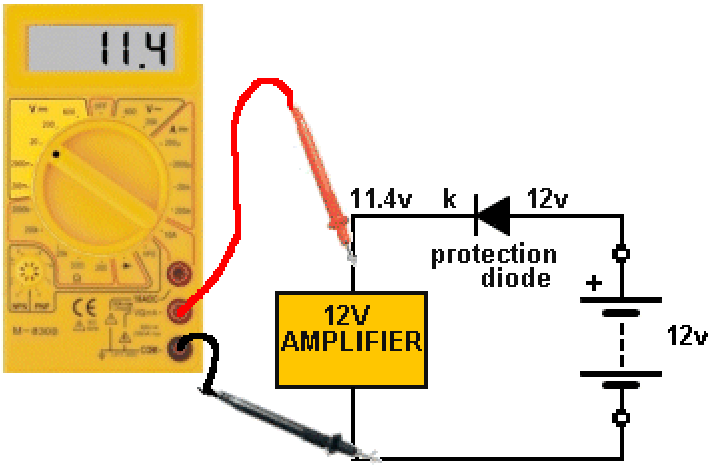
11.4
11.4v
k
12v
protection
diode
+
12V
AMPLIFIER
12v

Fig 36. Measuring Voltage with a Digital Multimeter

VOLTMETER.
Multimeters have 2 or 3 voltage ranges so you can measure low voltage (0v to 20v), medium voltages (0v to 200v and high voltages (0v to 500v).
A voltmeter is placed across the component being tested, as shown in the diagram.
The Digital Multimeter is detecting 11.4v across the amplifier.

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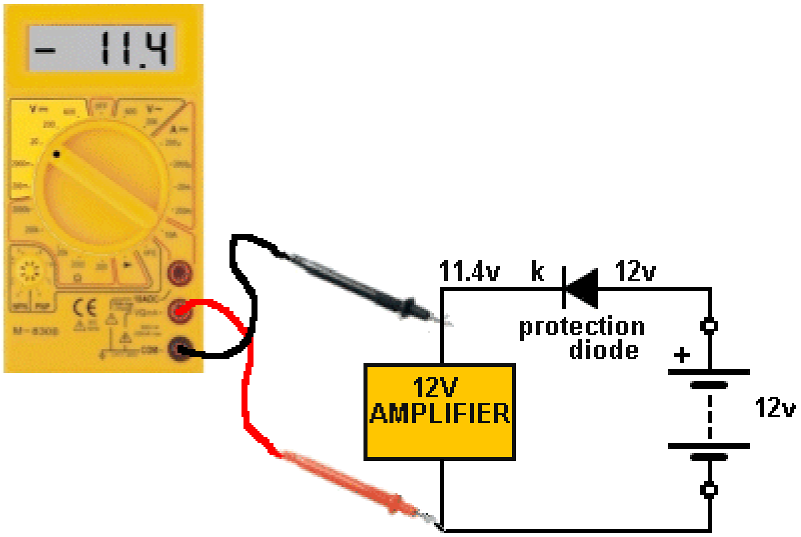
- 11.4
11.4v
k
12v
protection
diode
+
12V
AMPLIFIER
12v

Fig 37. Measuring Voltage with a Digital Multimeter

If you place the probes of a digital multimeter around the wrong way on a component, the display will show a "-" The meter will not be damaged.

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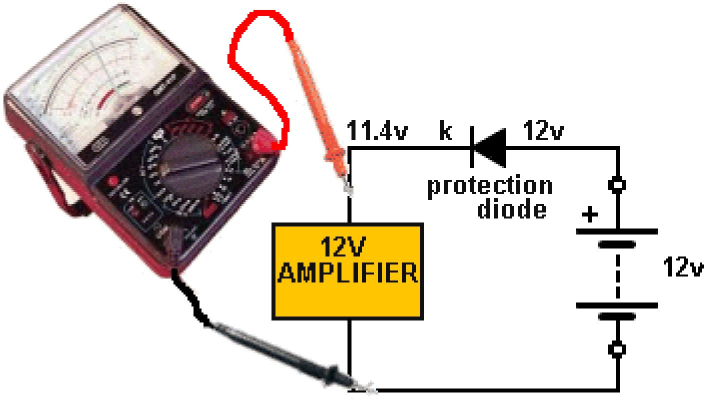
11.4v
k
12v
protection
diode
+
12V
AMPLIFIER
12v

Fig 38. Measuring Voltage with an Analogue Multimeter

An analogue Multimeter must be connected around the correct way to make the pointer move "up scale."
Select the range that will allow the pointer to show somewhere in the middle of the scale.

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Current is measured by

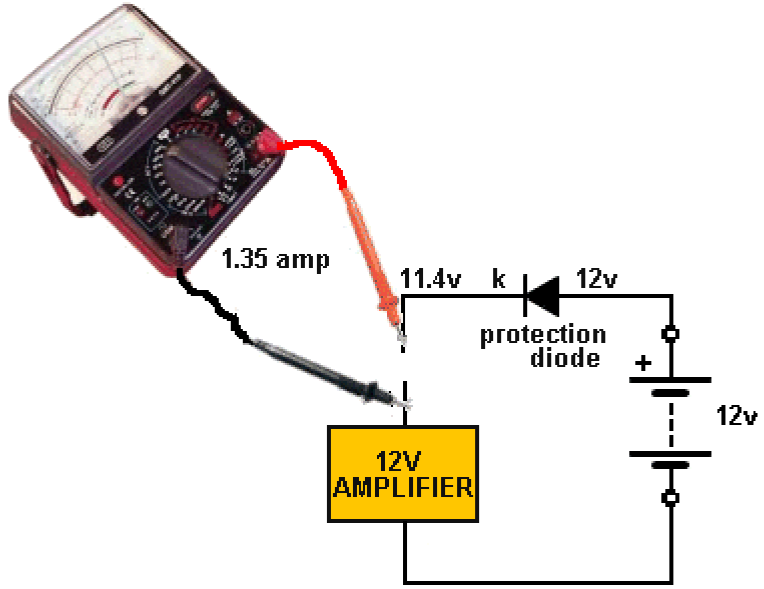
1.35 amp
11.4v
k
12v
protection diode
+
12v
12V AMPLIFIER

Fig 39. Measuring Current with an Analogue Multimeter

"breaking into the circuit" and inserting the leads so the positive probe is closest to the positive of the battery.
If you connect the leads around the other way, the needle will not move but it will hit the "end stop" and you may have to "bump" the meter to get the pointer to move from its jammed position.

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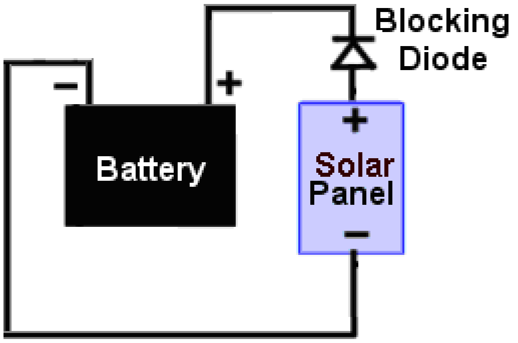
Blocking Diode
−
+
Battery
+
Solar Panel
−

Fig 39a. The Solar Panel and the Blocking Diode

A DIODE is also used with a solar panel to prevent the battery discharging into the solar panel when the sun is not shining.
When the solar panel is not receiving any light it becomes a resistor with a large value and a small current can flow through it from the battery. The diode prevents this current-flow. The diode is called a **BLOCKING DIODE**.

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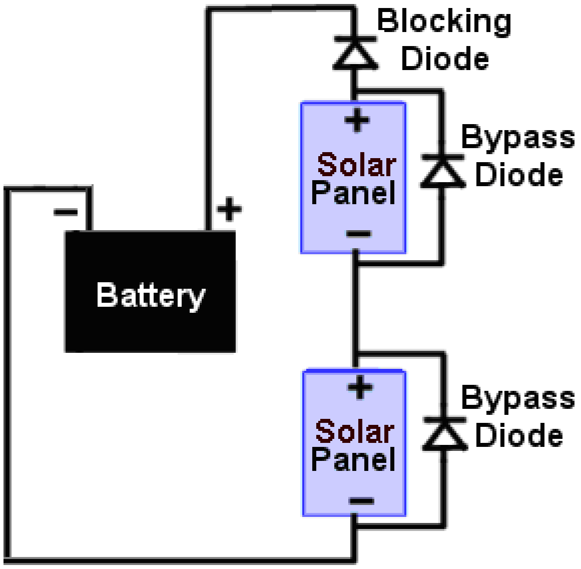
Blocking Diode
+
Solar Panel
−
Bypass Diode
−
+
Battery
+
Solar Panel
−
Bypass Diode

Fig 39b. The Solar Panel with diodes

Diodes are given different names, according to their function. They all perform the same job by passing current in one direction and prevent current-flow in the opposite direction.
When the top solar panel is shaded by a cloud, it generates less current and this will reduce the current into the battery.
By placing a diode across the panel, the diode will pass the current produced by the lower panel to the battery.
These diodes are called **BYPASS DIODES.**

called BLOCKING DIODES and BYPASS DIODES.

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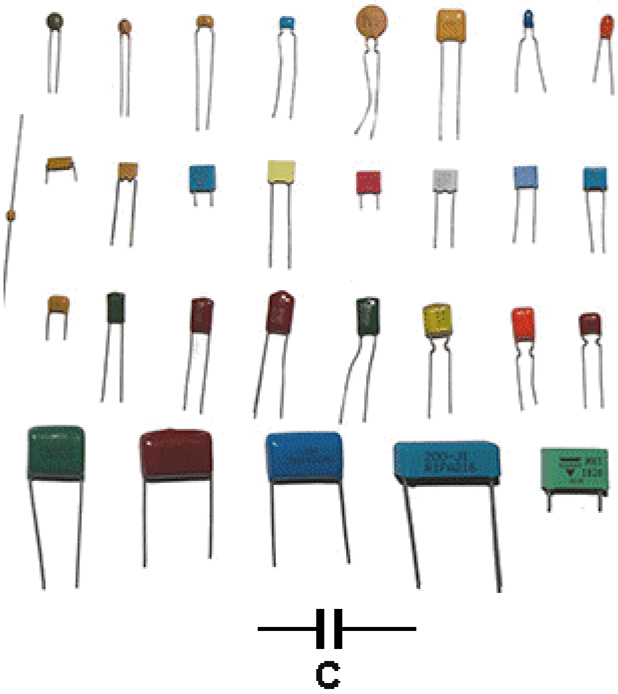

Fig 40. Capacitors and symbol

The next component we cover is the **CAPACITOR**.
There are thousands of different types of capacitor.
Each value of capacitor can have a low voltage rating, medium voltage or high voltage.
Capacitors can be very small in size and shape or very stable with temperature-rise or simply very cheap to make.
A capacitor consists of two thin sheets of metal such as aluminium with a thin sheet of plastic between.
The sheets may be rolled up in a cylinder or laid on top of each other.
The fact is this: the top sheet of metal does not touch the bottom sheet. This is shown in the symbol.
The resistance between the two terminals is INFINITE.
The 6th capacitor in the top row is called a **MONOBLOCK**.

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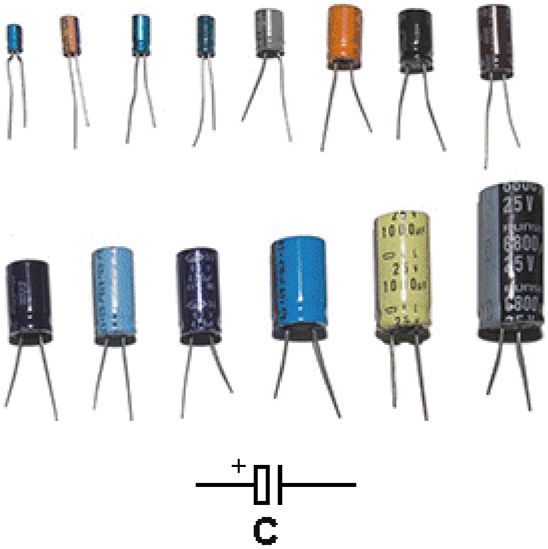

Fig 41. Electrolytic Capacitor

A capacitor gets bigger as its value increases.
It also gets bigger when the voltage-rating increases.
The basic unit of capacitance is the FARAD. A one-farad capacitor would be the size of a house. To make the capacitor smaller the sheets are etched to increase the surface-area and different insulating materials are used between the sheets.
The result is a capacitor called an **ELECTROLYTIC**. It is a bit like a rechargeable battery. It stores a lot of energy in a small space.
The negative lead is shorter and has a black stripe on the side of the electrolytic.

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One FARAD is too big to handle. We use smaller values.
The middle of the range is one microfarad. This is written as 1u. (sometimes you see uF)
This is one-millionth of a FARAD.
The smallest value of capacitance is one picofarad. This is one millionth of a microfarad.
It is written as 1p.
Capacitors are broadly separated into two groups. 1p to 1u and 1u to 100,000u
Capacitors 1p to 1u are ceramic, polyester, air, styroseal, monoblock and other names.
Capacitors 1u to 100,000u are electrolytic or tantalum. A tantalum is the same as an electrolytic - for testing purposes - it is a more-compact electrolytic.

1 microfarad is one millionth of 1 farad.
1 microfarad is divided into smaller parts called nanofarad.
1,000 nanofarad = 1 microfarad
Nanofarad is divided into small parts called picofarad
1,000 picofarad = 1 nanofarad.

Recapping:
1p = 1 picofarad. 1,000p = 1n (1 nanofarad) 1,000,000p = 1u
1,000n = 1u (1 microfarad)
1,000u = 1millifarad
1,000,000u = 1 FARAD.

Examples:
All ceramic capacitors are marked in "p" (puff")
A ceramic with 22 is 22p = 22 picofarad
A ceramic with 47 is 47p = 47 picofarad
A ceramic with 470 is 470p = 470 picofarad
A ceramic with 471 is 470p = 470 picofarad
A ceramic with 101 is 100p (it can also be 100)
A ceramic with 102 is 1,000p = 1n
A ceramic with 223 is 22,000p = 22n
A ceramic with 104 is 100,000p = 100n = 0.1u A common 100n is called a **MONOBLOCK**.
A ceramic with 105 is 1u

TYPES OF CAPACITOR
For testing purposes, there are two types of capacitor.
Capacitors from 1p to 100n are non-polar and can be inserted into a circuit around either way.
Capacitors from 1u to 100,000u are electrolytics (or tantalum) and are polarised. They must be fitted so the positive lead goes to the supply voltage and the negative lead goes to ground (or earth).

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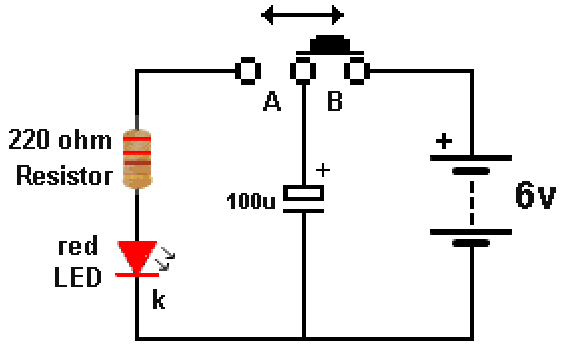

Fig 42. Charging a Capacitor

Here is an experiment to show how much (little) energy is stored in a 100u electrolytic.
When the slide-switch is in position "B", the 100u is charged by the 6v battery.
When the slide switch is moved to position "A" the electrolytic supplies energy to illuminate the red LED via the 220R resistor. It will illuminate for a short period of time.
By moving the switch back and forth, you can keep the LED illuminated.

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Capacitors can be connected in **Series or Parallel** to obtain a value of capacitance you may not have available.
They are also connected in series to increase the effective **VOLTAGE RATING**.
However when two equal-value capacitors are connected in series, the final value is HALF, and thus you need two with double the final-value to get a value with an increased voltage-rating.
When two equal-value capacitors are connected in series, the result is HALF.
(This is the opposite to connecting resistors)

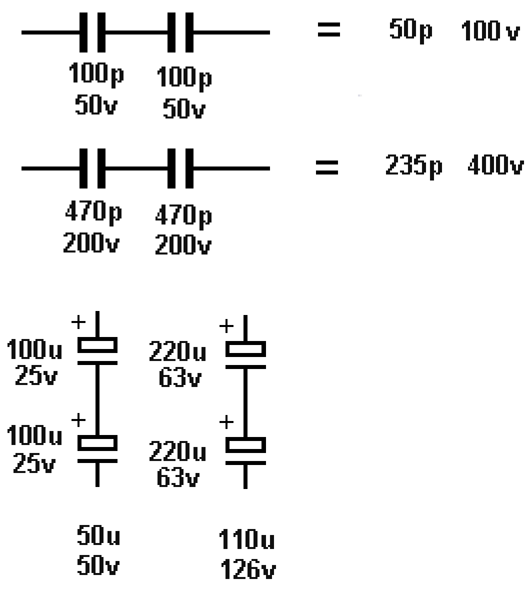

Fig 43. Capacitors in Series

to Index

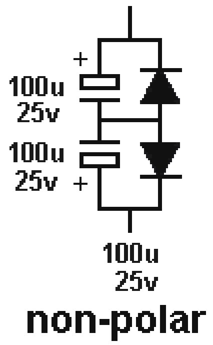

Fig 43a. Non-polar Capacitor

Non-polar Capacitor (electrolytic)

A normal electrolytic must be connected the correct way in a circuit because it has a thin insulating layer covering the plates that has a high resistance.

If you connect the electrolytic around the wrong way, this layer "breaks-down" and the resistance of the electrolytic becomes very small and a high current flows. This heats up the electrolytic and the current increases. Very soon the capacitor produces gasses and explodes.
One big mistake in many text books shows how to make a non-polar electrolytic by connecting two "back-to-back."
They claim 2 x 100u connected back-to-back is equal to 47u.
This appears to be case when testing on a meter but the meter simply charges them for a short period of time to get a reading.
If you allow them to charge fully you will find the reverse electrolytic has a very small voltage across it.
Secondly, when you are charging them, you are putting a high current through the reverse electrolytic and damaging the layer.
To prevent this, you need to add two diodes as shown in the diagram.
In addition, 2 x 100u "back-to-back" is very near 100u.

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Capacitors can be connected in **Parallel** to obtain a value of capacitance you may not have available.
(This does not change the **VOLTAGE RATING**.)
When two equal-value capacitors are connected in parallel, the result is DOUBLE.
(This is the opposite to connecting resistors).
If one electrolytic is 25v

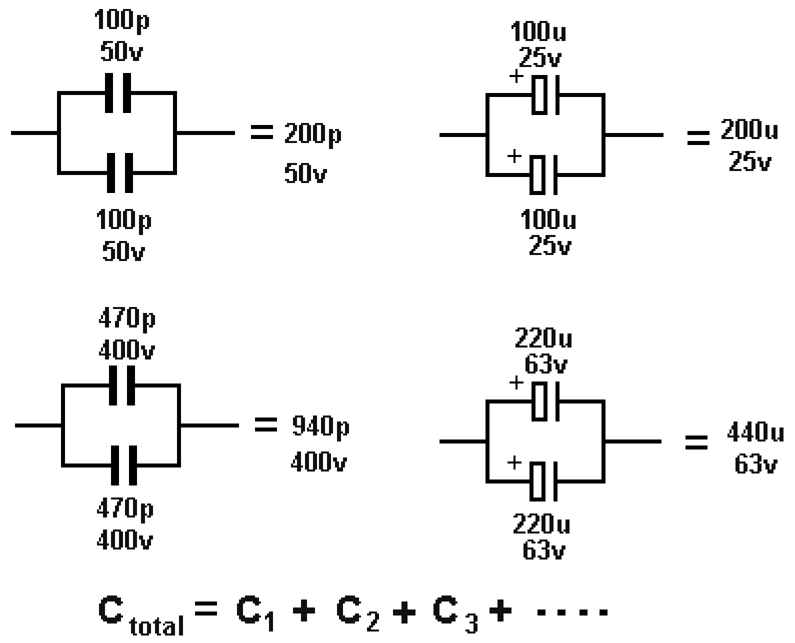
100p
50v
100p
50v
= 200p
50v
100u
25v
100u
25v
= 200u
25v
470p
400v
470p
400v
= 940p
400v
220u
63v
220u
63v
= 440u
63v
$C_{total} = C_1 + C_2 + C_3 + \cdots$

Fig 44. Capacitors in Parallel

and the other 63v, the answer is the LOWER VOLTAGE = 25v.

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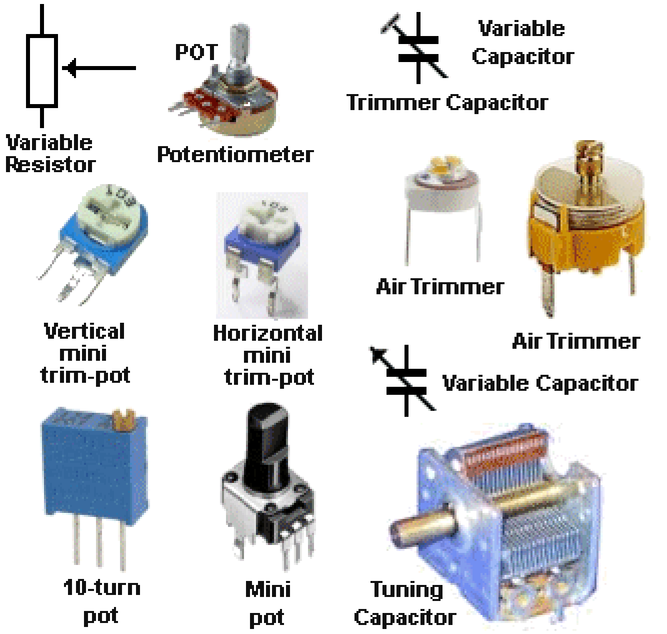
Variable Resistor
POT
Potentiometer
Variable Capacitor
Trimmer Capacitor
Vertical mini trim-pot
Horizontal mini trim-pot
Air Trimmer
Air Trimmer
Variable Capacitor
10-turn pot
Mini pot
Tuning Capacitor

Fig 45. Variable Capacitors and Resistors

The value of a capacitor or resistor may need to be increased or decreased in a circuit to tune in radio stations or increase and decrease the volume of a speaker. The symbol for these components have an arrow to show they can be adjusted.
The resistance of a potentiometer can be from 1 ohm to 5M
They come in many different shapes and sizes to suit the PC board or front-panel layout.
The "T" represents a trimmer capacitor and this can be from 1p to about 120p.
A variable capacitor will be from about 10p to 415p.

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Simple CIRCUITS
We have covered enough symbols and components to create a number of simple circuits.
These circuits will show how to connect a motor, a LED, (how to make it bright or dull) and how to connect 4 cells to make a battery.

Note: The flashing LED

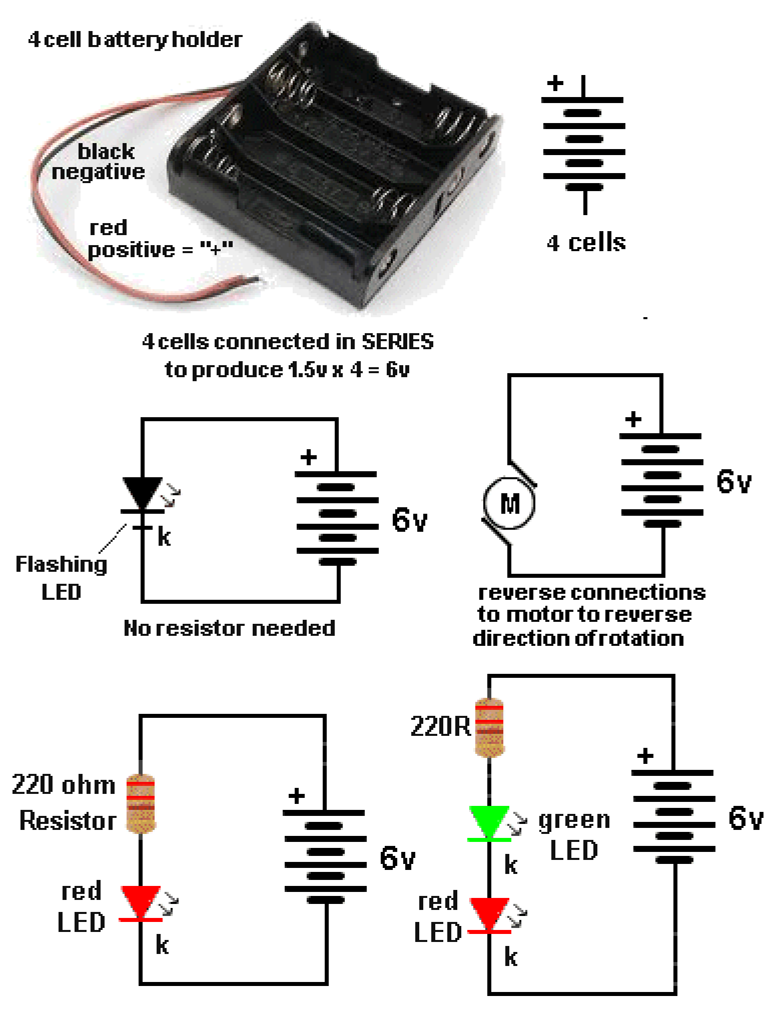
4 cell battery holder
black
negative
red
positive = "+"
+
4 cells
4 cells connected in SERIES
to produce 1.5v x 4 = 6v
+
6v
k
Flashing
LED
No resistor needed
+
6v
M
reverse connections
to motor to reverse
direction of rotation
220 ohm
Resistor
+
6v
red
LED
k
220R
+
green
LED
6v
k
red
LED
k

Fig 46. Simple Circuits

does not need a resistor because a resistor and chip are inside the LED, to make it flash and control the current.

Connect all the components around the correct way and then connect them around the wrong way to see what happens.
Connect the flashing LED in series with a red LED and see what happens.

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QUESTIONS

1. Explain why the Flashing LED circuit has no external resistor.
2. How many 1.5v cells are needed to produce a 6v battery
3. Explain what happens when you reverse the leads to a motor.
4. Identify the positive terminal:

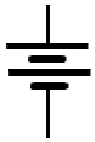

5. Can 3 green LEDs be connected in series to a 6v supply?
6. A variable resistor is also called: ____________________
7. The combined resistance of two 1k resistors in series is: ______________
8. The combined resistance of two 1k resistors in parallel is: ______________
9. Name the short lead on a LED
10. Name the type of multimeter with a pointer and scale: ____________________
11. The total capacitance of two 100u electrolytics in series is: _____________
12. The total capacitance of two 100u electrolytics in series is: _____________
13. Write these values in words:

22R __________
4k7 __________
1n ____________
100u ____________

14. How many 1.5v cells in a 9v battery?

15. The red probe is: ________________ (positive/negative)
16. Conventional current flows from: __________ (positive to negative / negative to positive)
17. Make a 470u electrolytic with two electrolytics:
18. What is the voltage drop across a diode?
19. Name the component that only allows current to flow in one direction: _____________
20. Name this symbol:

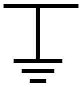

21. When resistors are connected in series, the resistance of the combination: __________ (increases / decreases)
22. When two capacitors are connected in parallel, the voltage-rating of the combination: ________________ (increases / equal to the capacitor with the lowest voltage-rating)
23. Draw two 2k2 resistors in parallel.
24. Which is larger: 470R or 22k
25. What is the value of this combination:

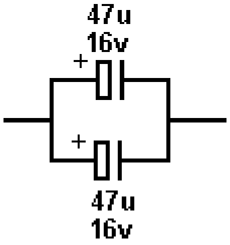

26. What is the name of the resistor in series with a LED: ______________________
27. What is the voltage across the amplifier: __________

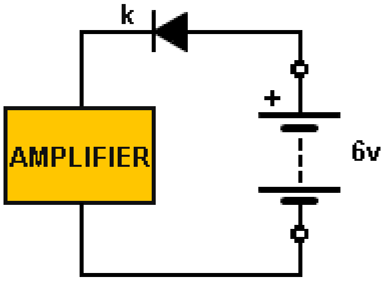

28. Identify the fault with these circuits:

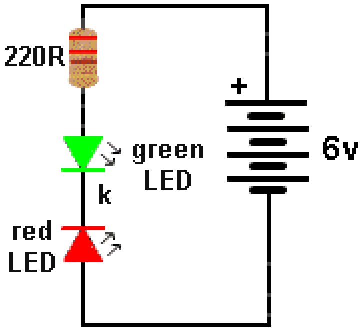

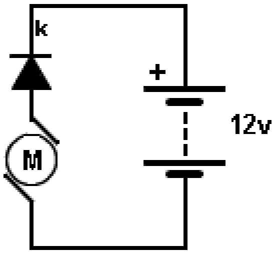

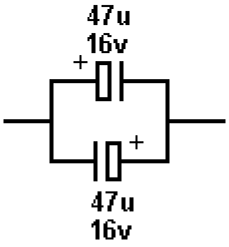

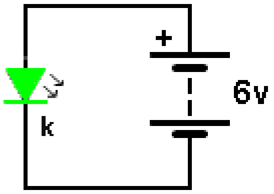

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Passive Components
All the components shown

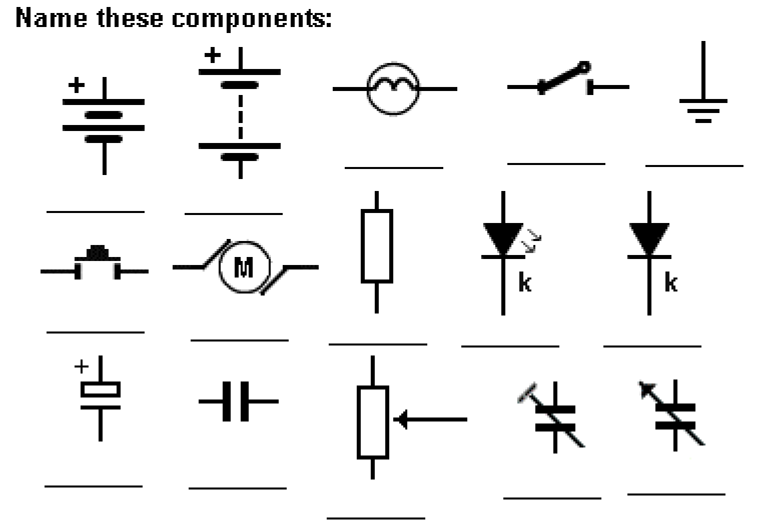

Fig 47. Passive Components

on the left are called PASSIVE COMPONENTS. This means they do not amplify.
Write the name beside each symbol.

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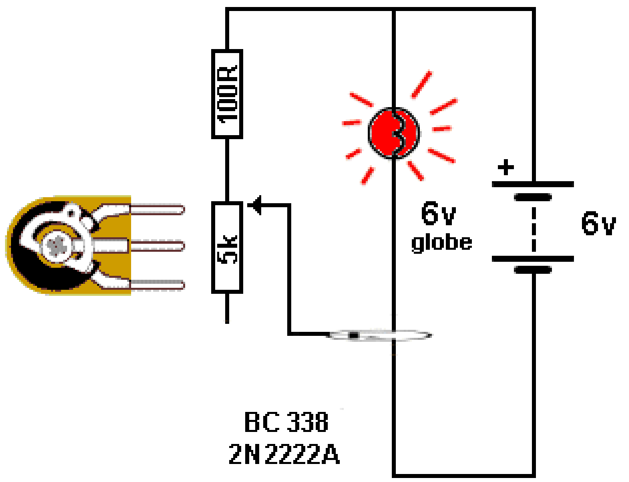

Fig 47a. The Potentiometer in action

The Potentiometer is a variable resistor.
It consists of a curved carbon track with a wiper that touches the track and can be turned via a screwdriver or knob.
The wiper is the middle wire on the circuit symbol and it moves up and down as shown in the animation.
When the three leads are connected the symbol is called a potentiometer.
When two leads are connected it is a variable resistor.
When the resistance increases, less current flows through the pot.

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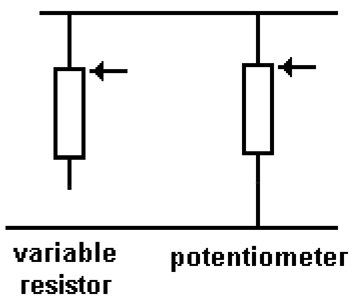

Fig 47b. The Variable Resistor and Potentiometer

There is a difference in operation between a **Variable Resistor** and a **Potentiometer**.
Both will increase or decrease the sound level as a volume control or the speed of a motor or the brightness of a globe, but a Potentiometer will guarantee zero volume or zero brightness when the pot is turned fully anticlockwise (as shown in the animation).
This is because the output will be zero volts, but the variable resistor may still deliver some "energy" (voltage and current) to the circuit when turned fully anticlockwise.

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Potentiometers come in values from 100 ohms to 5 Meg ohms (500R, 1k, 2k, 5k, 10k, 50k, 100k, 200k, 250k, 500k, 1M are most popular).
They come as linear, or logarithmic where the resistance of the track (per mm) is higher at one end. Because our hearing is not linear, these pots can be used as volume controls to produce a gradual (very nearly linear) increase in volume.
Selecting the correct value of resistance for a circuit is VERY complex. If the value is not correct, the volume will not be loud or it will drop to zero before the pot is turned fully anticlockwise. Or

the motor will drop to zero at mid-turn of the pot or it will not reduce in RPM to the desired amount.
The simple answer is to copy a circuit.
Or you can try the whole range of pots and you will find one value is the best.
A Potentiometer can be used in hundreds of different circuits to produce hundreds of different effects, but the actual "thing" that flows between the input and output is a percentage of the voltage. At the same time the current will also be passed to the output at a reduced value. A pot actually delivers BOTH reduced values at the same time and the receiving circuit will be designed to "look for" the change in voltage or current. If the supply voltage is not rising or falling, the "values" are called DC values.
The voltage can also be in the form of a signal (volume). This is called an AC signal.

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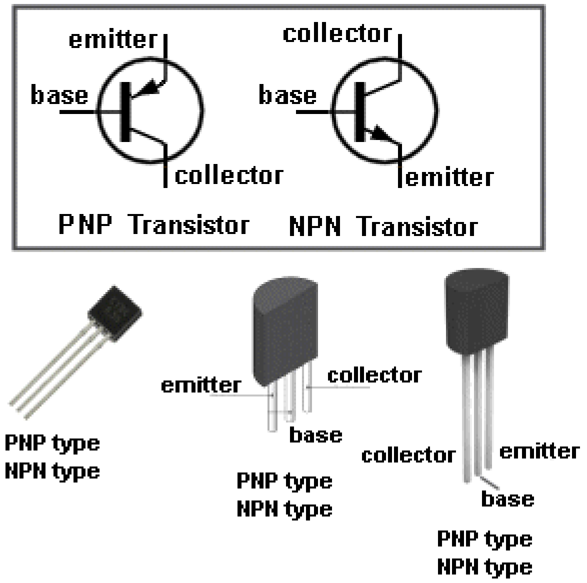
emitter
base
collector
PNP Transistor
collector
base
emitter
NPN Transistor
PNP type
NPN type
emitter
collector
base
PNP type
NPN type
collector
emitter
base
PNP type
NPN type

Fig 48. The TRANSISTOR

The TRANSISTOR

A TRANSISTOR is an ACTIVE device. It AMPLIFIES.
There are many types of transistor (over 20,000 different types) from hundreds of manufacturers and they have many different names.
We are going to study the simplest.
It has the technical name **BIPOLAR JUNCTION TRANSISTOR (BJT)** but we are going to call it a **TRANSISTOR**.
There are two types in this group: **PNP** and **NPN**.

The type we will study is also called a **SMALL-SIGNAL TRANSISTOR.**

You cannot tell an **NPN** transistor from **PNP** by looking at it. You must test it in a circuit.
In **Fig 65** you will make a **Transistor Tester** project, but first some basic facts:

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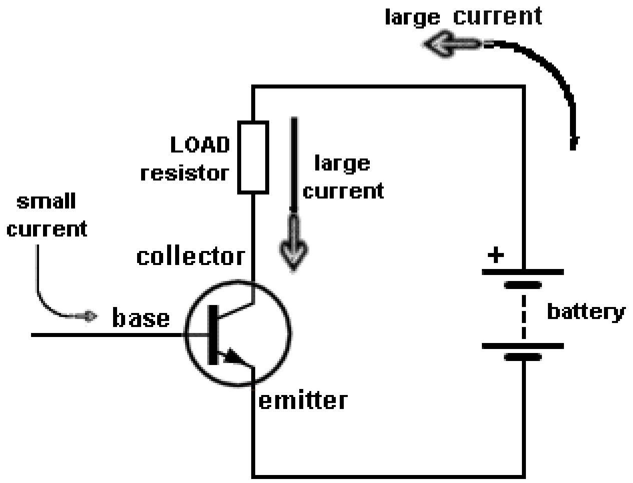
large current
LOAD resistor
large current
small current
collector
base
emitter
+
battery

Fig 49. The NPN TRANSISTOR in a Circuit

The first type of transistor we are going to study is the **NPN**.
A transistor has three leads:
BASE, COLLECTOR and **EMITTER**
Basically, a small current enters the base and a large current flows through the collector-emitter leads as shown in the diagram.
The resistor in the collector lead is called the LOAD Resistor.
Sometimes the load is a speaker.

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The transistor is similar to the diagram opposite. A small drop of water entering the base is amplified to produce a loud DRIP from the speaker.

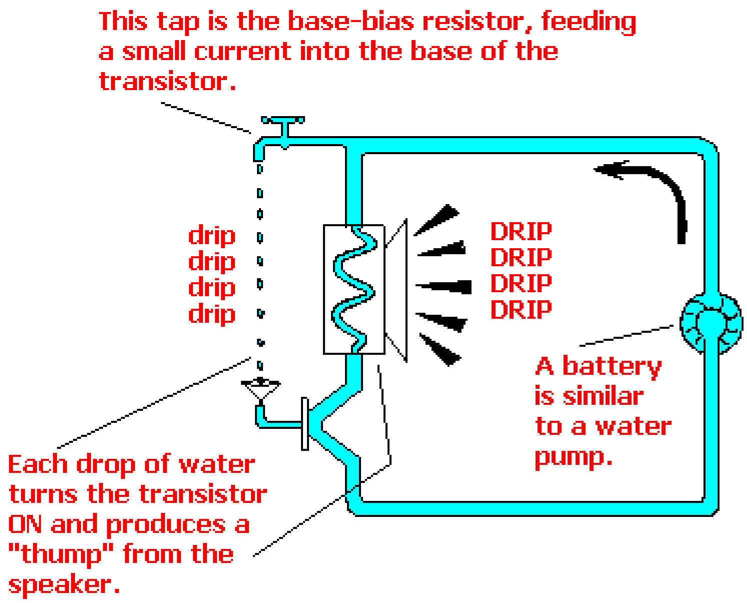
This tap is the base-bias resistor, feeding a small current into the base of the transistor.
drip
drip
drip
drip
DRIP
DRIP
DRIP
DRIP
A battery is similar to a water pump.
Each drop of water turns the transistor ON and produces a "thump" from the speaker.

Fig 50. The Water TRANSISTOR

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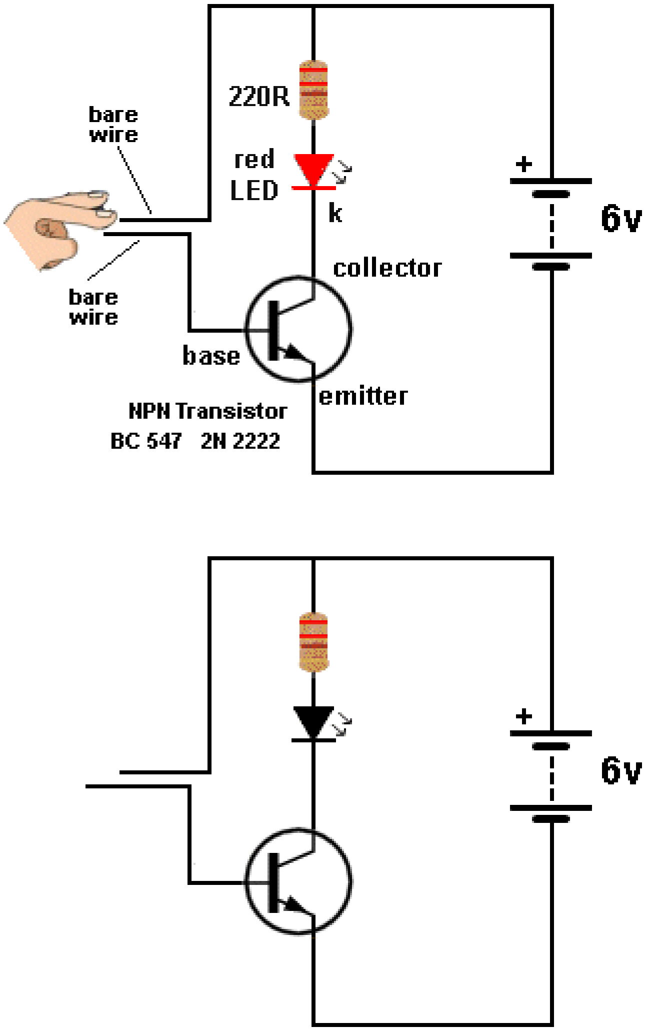
bare wire
220R
red LED
k
+
6v
bare wire
collector
base
emitter
NPN Transistor
BC 547 2N 2222
+
6v

Fig 51. One Transistor Circuit

In this experiment we will construct a ONE TRANSISTOR circuit similar to the WATER TRANSISTOR above and observe the results.
Make sure the two leads DO NOT TOUCH. If they touch, the transistor will be DESTROYED.

The transistor is amplifying the current through your finger via the two leads and it will be very dim.

ANIMATION

The lower diagram shows the transistor turning ON when a finger is pressed against the two wires. The finger produces a resistance that turns the transistor ON and this turns the transistor into a smaller and smaller resistor. That's how more and more current flows through the LED and it gets brighter and brighter.

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By adding another transistor we amplify the

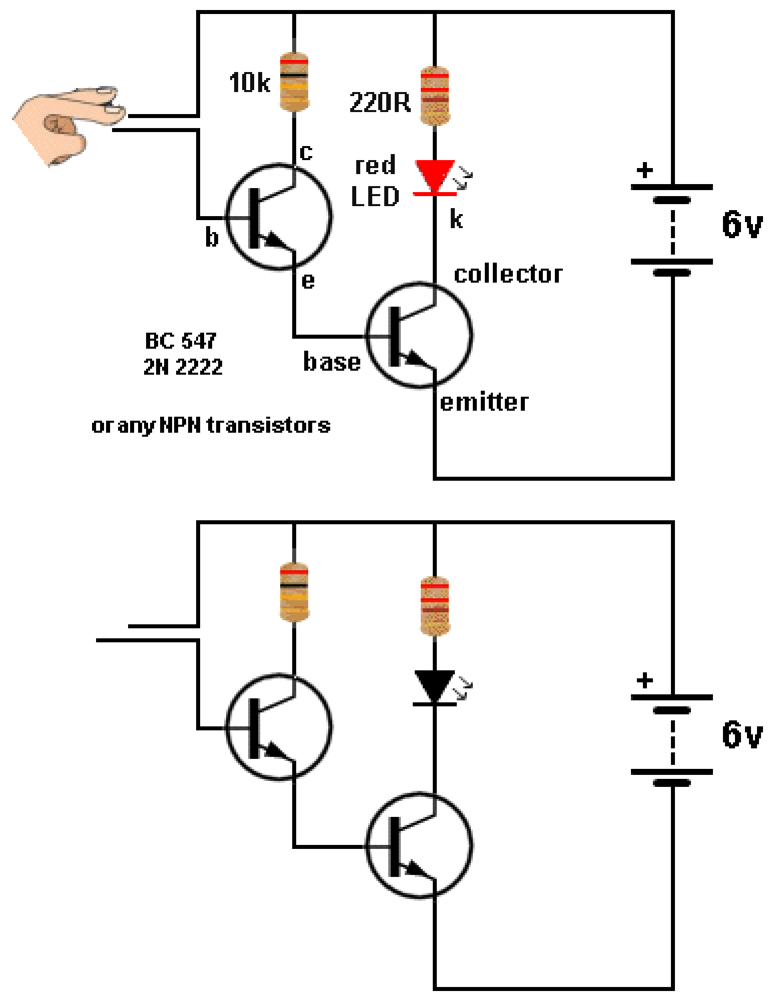
10k
220R
c
red
LED
k
b
e
collector
BC 547
2N 2222
base
emitter
or any NPN transistors
+
6v
+
6v

Fig 52. Two Transistor Circuit

current through the finger about 200 times and now the LED will glow bright.

Make sure the bare wires do not touch each other as this will destroy BOTH transistors.

ANIMATION

The lower diagram shows both transistors turning **ON** when a finger is pressed against the two wires.
They both becomes smaller and smaller resistors.
The first transistor allows more current to flow into the base of the second transistor and this is how the second transistor turns on more and more. This allows more current to flow through the LED and it gets brighter and brighter.

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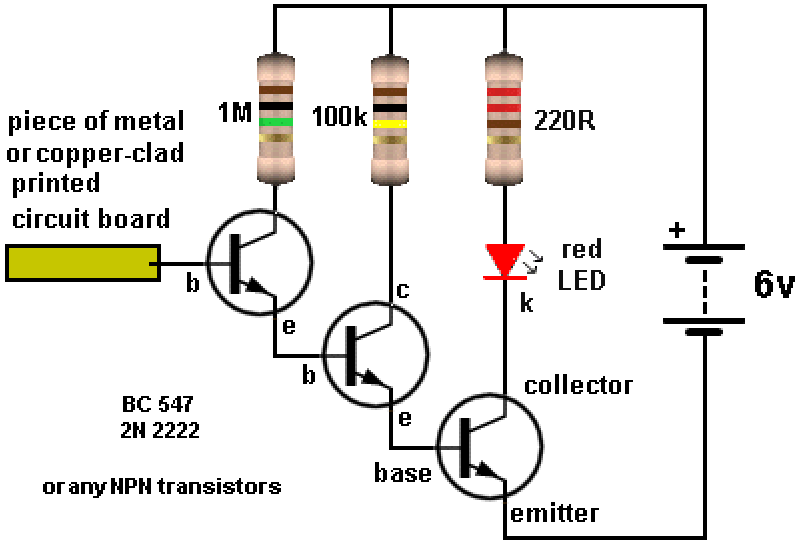
piece of metal
or copper-clad
printed
circuit board
1M
100k
220R
b
e
c
b
e
red
LED
k
collector
BC 547
2N 2222
or any NPN transistors
base
emitter
+
6v

This circuit has enormous gain.
Each transistor has a gain or more than 200 and the final gain will be more than:
200 x 200 x 200 = 8,000,000
8 MILLION!

The circuit is very sensitive to static voltages in the air or electrical waves such as the waveform produced by the electrical wiring in a house.
Move the project around a room and detect all the electrical signals.

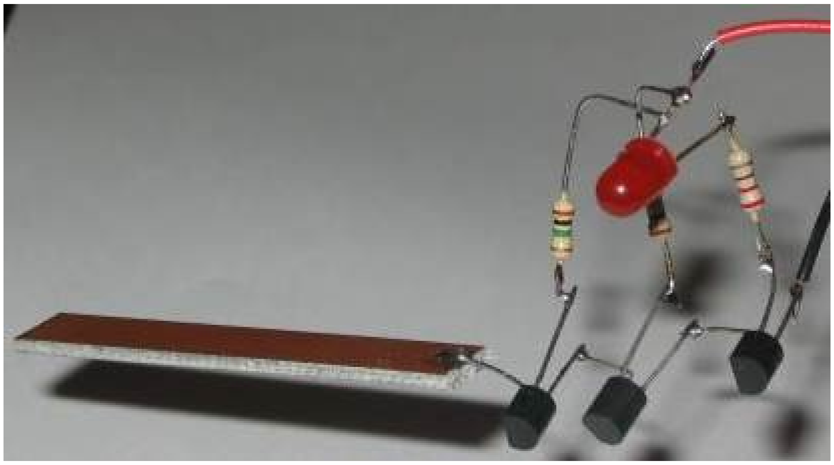

Fig 53. Three Transistors

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You can see the effect of one transistor. It does not do much.
The two transistor circuit allows the resistance of your finger to deliver current into the base of the first transistor and this transistor delivers more current into the base of the second transistor.
The result is more collector-emitter current and the LED illuminates.
The three transistor circuit produce an ENORMOUS effect.
It will pick up STATIC ELECTRICITY and all forms of electro-magnetic energy (radiation) and illuminate the LED.

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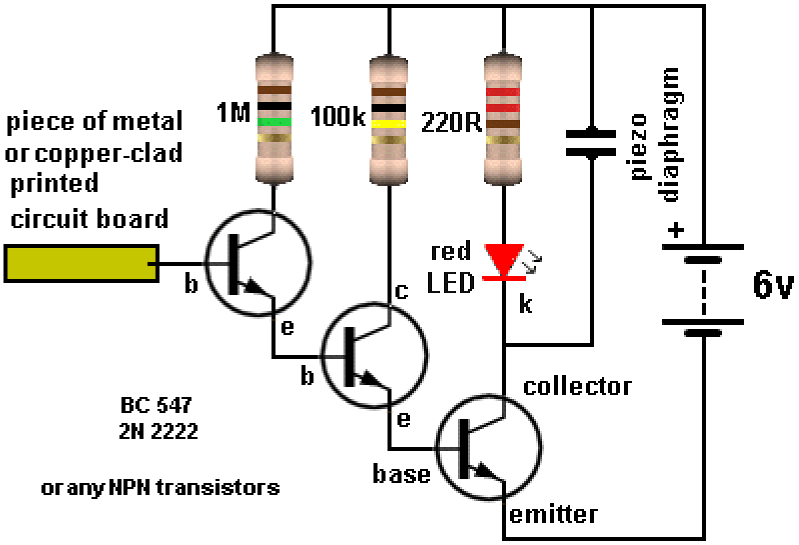
piece of metal
or copper-clad
printed
circuit board
1M
100k
220R
piezo
diaphragm
+
6v
b
e
c
b
e
red
LED
k
collector
base
emitter
BC 547
2N 2222
or any NPN transistors

Fig 54. Adding a PIEZO

By adding a piezo diaphragm to the output you will be able to hear the hum of the mains.
This is the frequency of the supply into your house. It will be either 50 cycles per second or 60 cycles per second.
The term: "cycles per second" is given the name HERTZ after **Heinrich Rudolf Hertz**, who was the first to prove the existence of electromagnetic waves.

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The Piezo diaphragm is held around the outer edge inside a plastic case and when a voltage is applied to the two leads, the thin plate curves very slightly.
When the voltage is removed, the plate returns to its flat shape.
If the voltage is reversed, the plate curves in the opposite direction.

The curving is due to a thin layer of ceramic material under the plate and

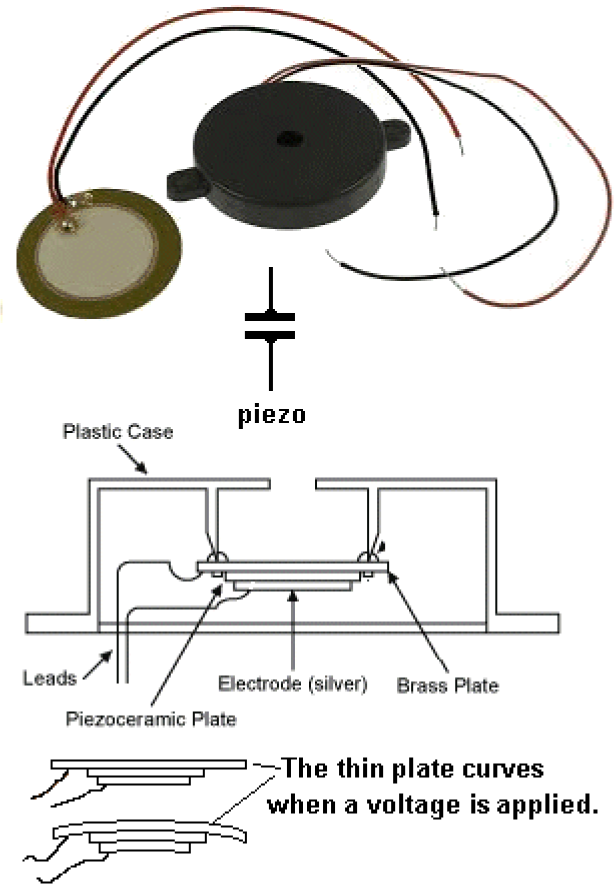
piezo
Plastic Case
Leads
Electrode (silver)
Brass Plate
Piezoceramic Plate
The thin plate curves when a voltage is applied.

Fig 55. The Piezo

then a film of metal is deposited onto the ceramic so a lead can be soldered.

There is infinite resistance between the two leads as the ceramic material is an INSULATOR.
The capacitance between the two leads is approx 22n.
The Piezo is a passive device. It needs a pulse or frequency for it to produce an output.

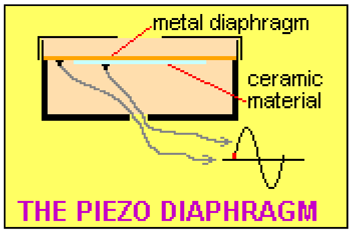
metal diaphragm
ceramic material
THE PIEZO DIAPHRAGM

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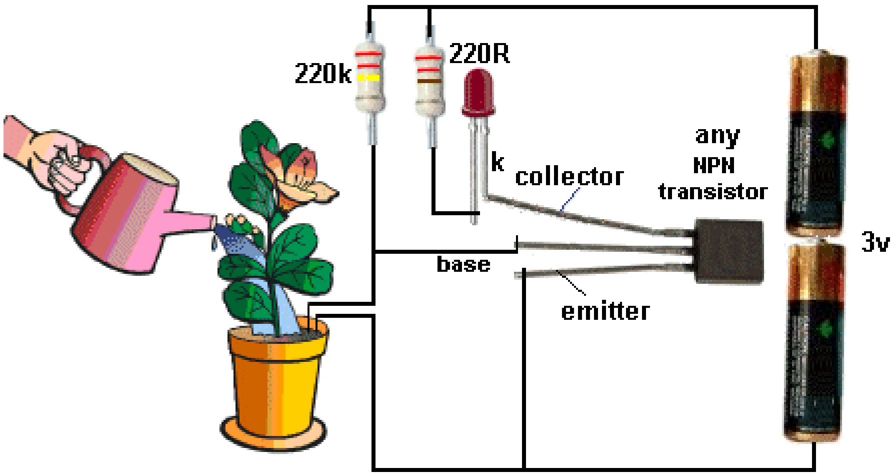
220k
220R
k
collector
any NPN transistor
3v
base
emitter

Fig 56. Plant Needs Water

The **ONE TRANSISTOR CIRCUIT** above can be turned into a detector to show when a plant needs water.
Place the two probes into the soil and water the plant. The LED will turn off. As the water evaporates the LED will turn **ON** to let you know the plant needs watering.

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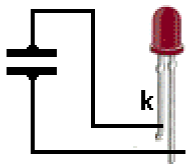

Fig 57. Tap the Piezo

This experiment produces a pulse from the piezo when it is tapped and the LED illuminates briefly.

The LED can be connected either way around.

This proves the diaphragm flexes when a voltage is applied and also in the reverse situation. A voltage is produces when the diaphragm is tapped.

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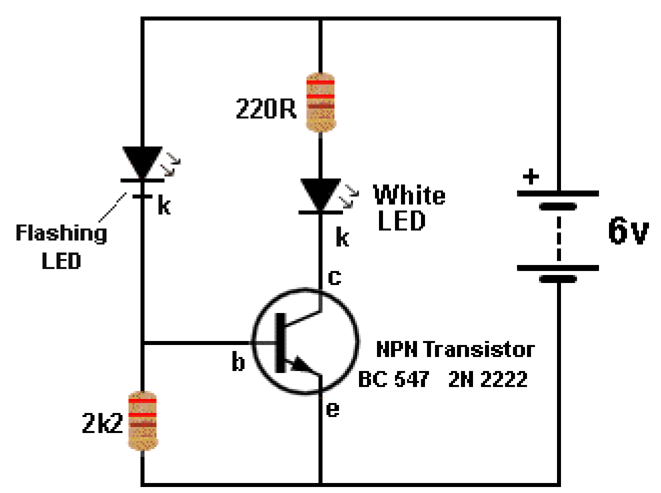

Fig 58. Flashing LED and White LED

A flashing LED is not very bright.
It can be connected to a transistor and the transistor will drive a very bright white LED.
The transistor is an amplifier.
It is amplifying the current flowing through the flashing LED and supplying a higher current for the white LED.

We cannot discuss any further details of the circuit at the moment because the actual operation of the circuit is quite complex.

At the moment we just need to experiment with simple transistor circuits.

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Fig 59. Soldering Iron

We now come to the point of HELPING YOU WITH CONSTRUCTION.
We have already shown you 6 different circuits and there are many ways to build them.
You can:
1. Solder them.
2. Build them on an Experimenter Board
3. Connect the components with clips or twist the leads together.
It does not matter how you build the circuits.
The fact is this: YOU MUST START BUILDING.
The best soldering iron for a beginner is a CONSTANT TEMPERATURE soldering iron.
It has a dial that can be turned to set the desired temperature.
An ordinary soldering iron GETS TOO HOT. It is not suitable for soldering electronic circuits.
This is something that no-one has mentioned before. An ordinary soldering iron will melt the solder TOO QUICKLY and burn the resin inside the solder and make soldering very difficult for a beginner.
Soldering must be done slowly so the resin in the middle of the solder gets hot and cleans the leads of the components so the solder will "stick."
That's why you must apply the solder to the leads you are soldering and allow the resin to "attack" the leads and clean them.
The cheapest TEMPERATURE CONTROLLED soldering Iron is available on eBay for les than $10.00 (post FREE).
You will also need a small roll of solder (0.9mm) and a soldering Iron stand.
Email Colin Mitchell for links to eBay. (talking@tpg.com.au)
A whole book could be written on the ART OF SOLDERING.
Look on the web for articles and videos on SOLDERING.

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SOLDERING

1. Soldering is very easy and very simple. You just need a **Temperature Controlled Soldering Iron**, **Fine solder** and clean components.

2. Remember this: It is **NOT** the solder you need for a joint, but the **FLUX**. And the flux lasts for only 2 seconds. When the flux is **HOT** it attacks and cleans the joint so that the solder will stick.

3. Turn ON the Temperature Controlled Soldering Iron to a low temperature. Put solder on the tip. It will not melt. Turn up the temperature slightly. Try more solder. As soon as the solder starts to melt, this is your starting point. Turn up the temperature slightly MORE and this is the correct temperature for **small, delicate, fine soldering**.

4. Place a component through a hole and bend the lead slightly so the component does not move. Turn the board over and touch the iron on the component and bring the solder **FROM THE OTHER SIDE** so the solder melts and flows towards the iron.
From start-to-finish, count one-two-three and remove the solder. Count four-five and remove the iron. You will have a perfect joint.
If you are soldering thick leads or large pads on a circuit board, you will need to turn the temperature UP slightly.
You must add enough solder to make the joint "bulge" slightly.
Fine solder (1mm or 0.9mm or 0.8mm) makes the best joint because it is easier to use.
Use a wet sponge to clean the tip or a ball of "Steel Wool." Steel wool is the best.
Here is the steel wool, bending the leads and some examples of poor joints due to insufficient solder:

Steel wool cleans the tip beautifully

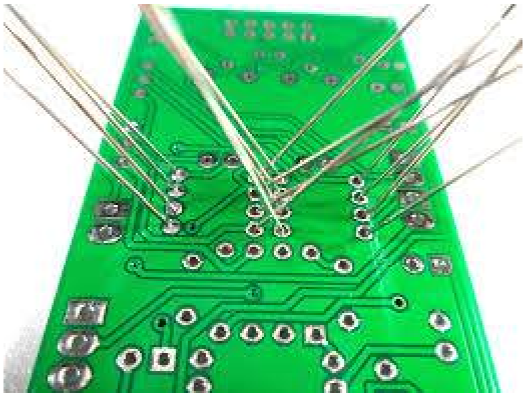

Bend the leads before soldering

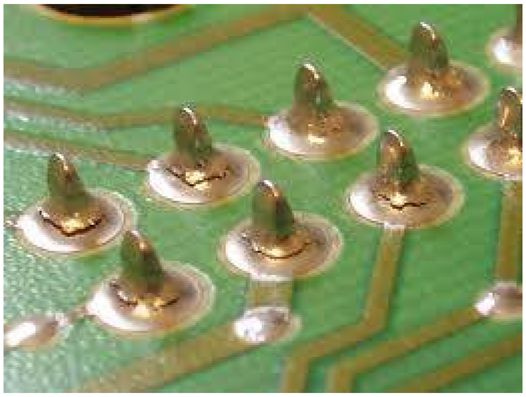

The joints do not have enough solder and that's why they fractured. Called a DRY JOINT.

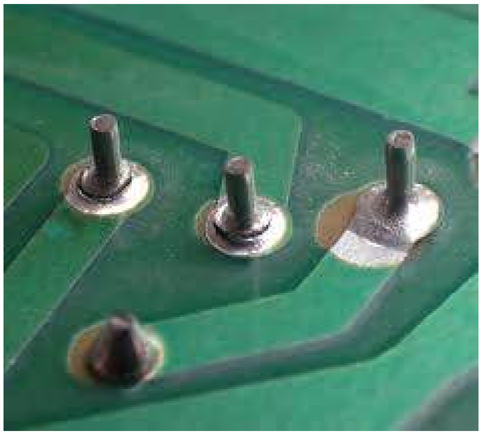

More "Dry Joints."

This is the cheapest and simplest soldering iron stand.

This stand is very messy as the spring grabs the iron and makes it difficult to remove from the stand. Test the stand before buying. You will se why not to buy this type of soldering stand. Get one with a "wide mouth" and a heavy stand is best as it does not move.

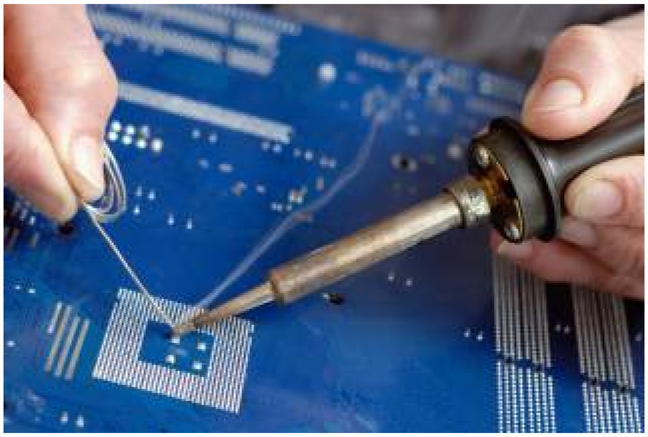

This photo clearly shows how to hold a soldering iron and solder.

This is NOT a temperature-controlled soldering iron and you can see it is too hot as it is burning off the flux too quickly.
Temperature Controlled Soldering Irons are now cheaper than the JUNK soldering iron shown in the photo. See eBay for prices.

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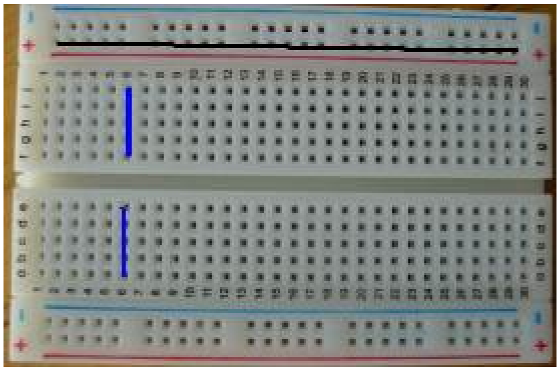

Photo shows a number of components fitted to the breadboard.

BREADBOARD

The term BREADBOARD refers to any piece of wood or plastic containing pins or pegs or clips or holes where you can build a circuit.
The components can be soldered, twisted clipped or fitted into holes.
Breadboard also means the circuit can be easily pulled apart.
Some breadboards do not have two rows for the positive and negative rails. Connections under the board for the positive rail is shown with a black line in the photo. Connections on the main section of the board are shown with blue lines. Your breadboard MUST look exactly like the photo opposite.
Other breadboards are quite useless.
The breadboard in the photo can be purchased on eBay for less than $5.00 (post FREE).

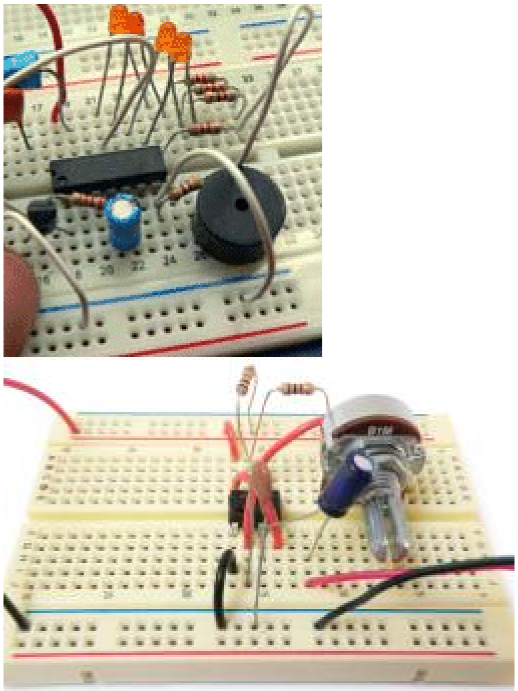

Fig 60. BREADBOARD and Components

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Fig 61. Jumpers

The components on the BREADBOARD are fitted down the holes and metal strips under the board join each column of 5 holes. If you want to join one hole with another, you can use 0.5mm tinned copper wire or JUMPERS. See photo opposite. Jumpers can be purchased on eBay for less than $3.00 posted.

Email Colin Mitchell for links to eBay. (talking@tpg.com.au)

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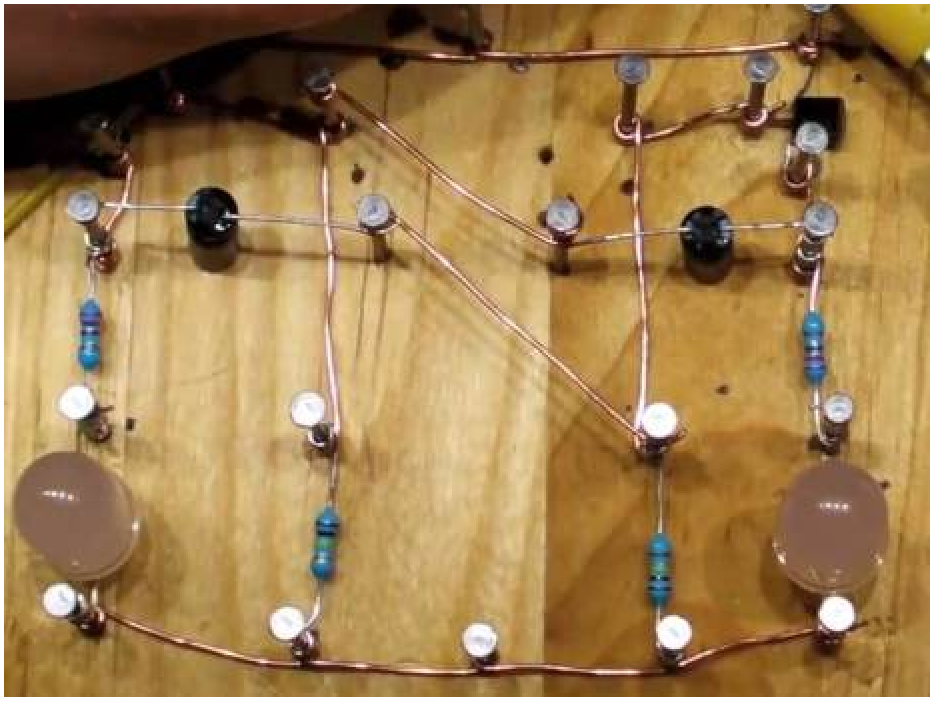

Fig 62. Breadboard with Nails

If you don't have a soldering iron or experimental breadboard, you can make your own board with nails. See the photo above. It is a multivibrator circuit and we will be presenting this circuit in a moment. The components can be twisted around the nails and bare wire used to join some of the nails to complete the circuit.
Another method of connecting the components is called BIRD-NESTING. This involves soldering the components "in the air" as shown in the 27MHz transmitter circuit below:

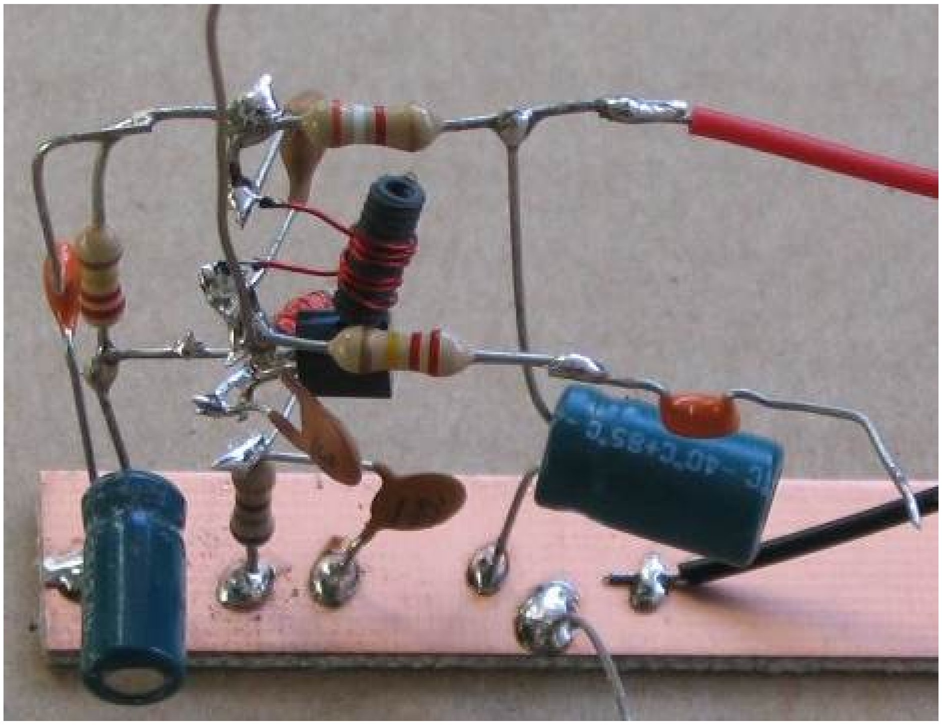

Another way to connect the component(if you don't have a soldering iron), is to wind 6 turns of bare wire around each connection and leaving all the components "in the air." The bare wire can be obtained from hook-up flex. This is plastic coated "wire" containing up to 15 fine strands of wire. Use a single strand for the connections. None of the components will touch each other BY MISTAKE and the circuit will work perfectly. Bird-nesting is a good way to build a quick circuit and test its performance. It might look messy but you can easily change any component.

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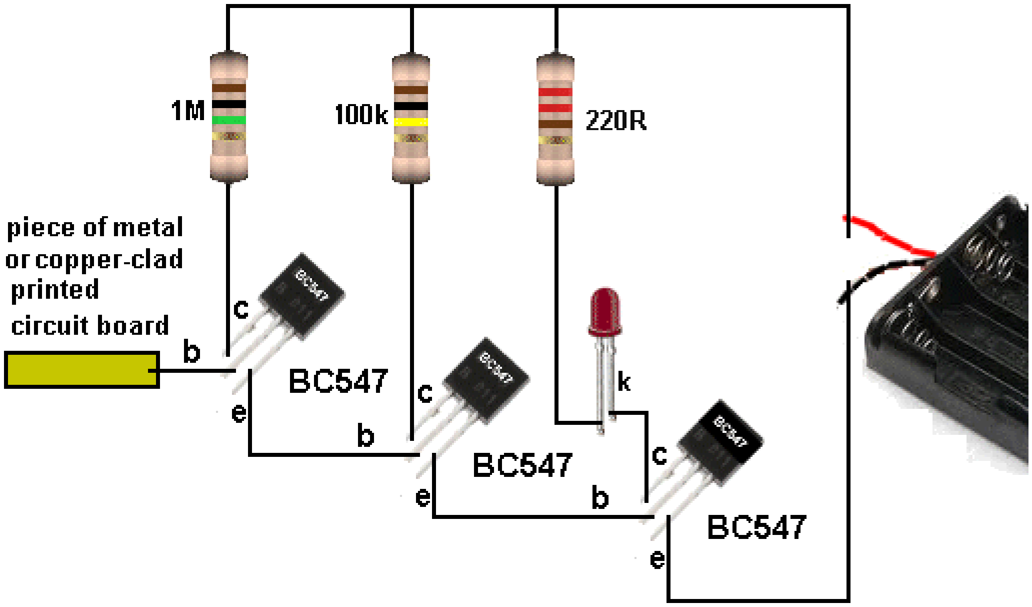
1M
100k
220R
piece of metal
or copper-clad
printed
circuit board
c
b
e
BC547
c
b
e
BC547
k
c
b
e
BC547

Fig 63. Wiring the 3-Transistor Circuit using BC547 Transistors
The diagram shows how to connect 3 x BC 547 transistors.
The leads of a transistor can be collector-base-emitter OR
emitter-base-collector and that's why we have provided 2 different wiring diagrams.

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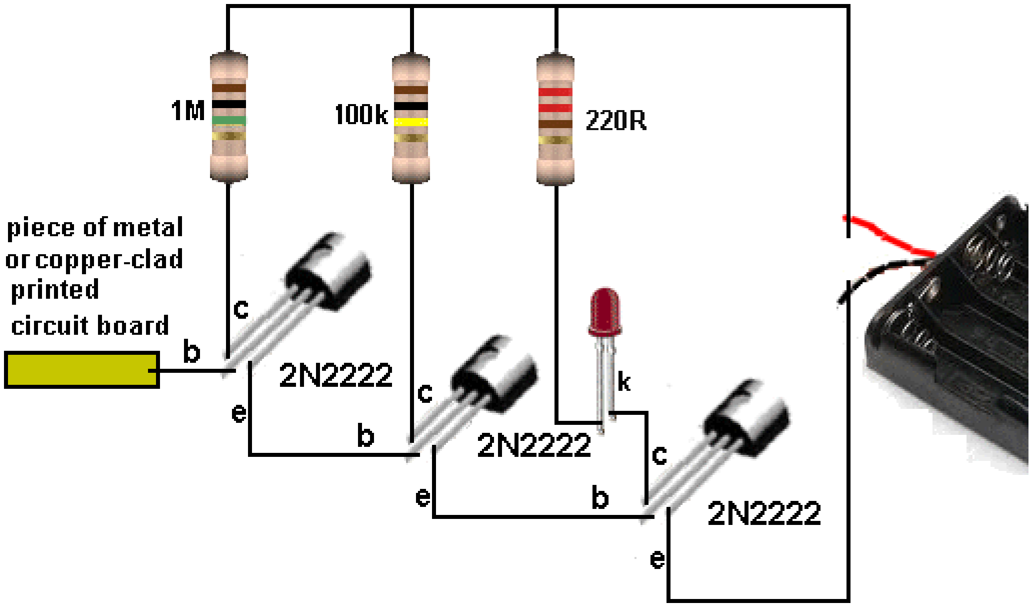
1M
100k
220R
piece of metal
or copper-clad
printed
circuit board
c
b
e
2N2222
c
b
e
2N2222
k
c
b
e
2N2222

Fig 64. Wiring the 3-Transistor Circuit using 2N2222 Transistors
The diagram shows how to connect 3 x 2N2222 transistors.

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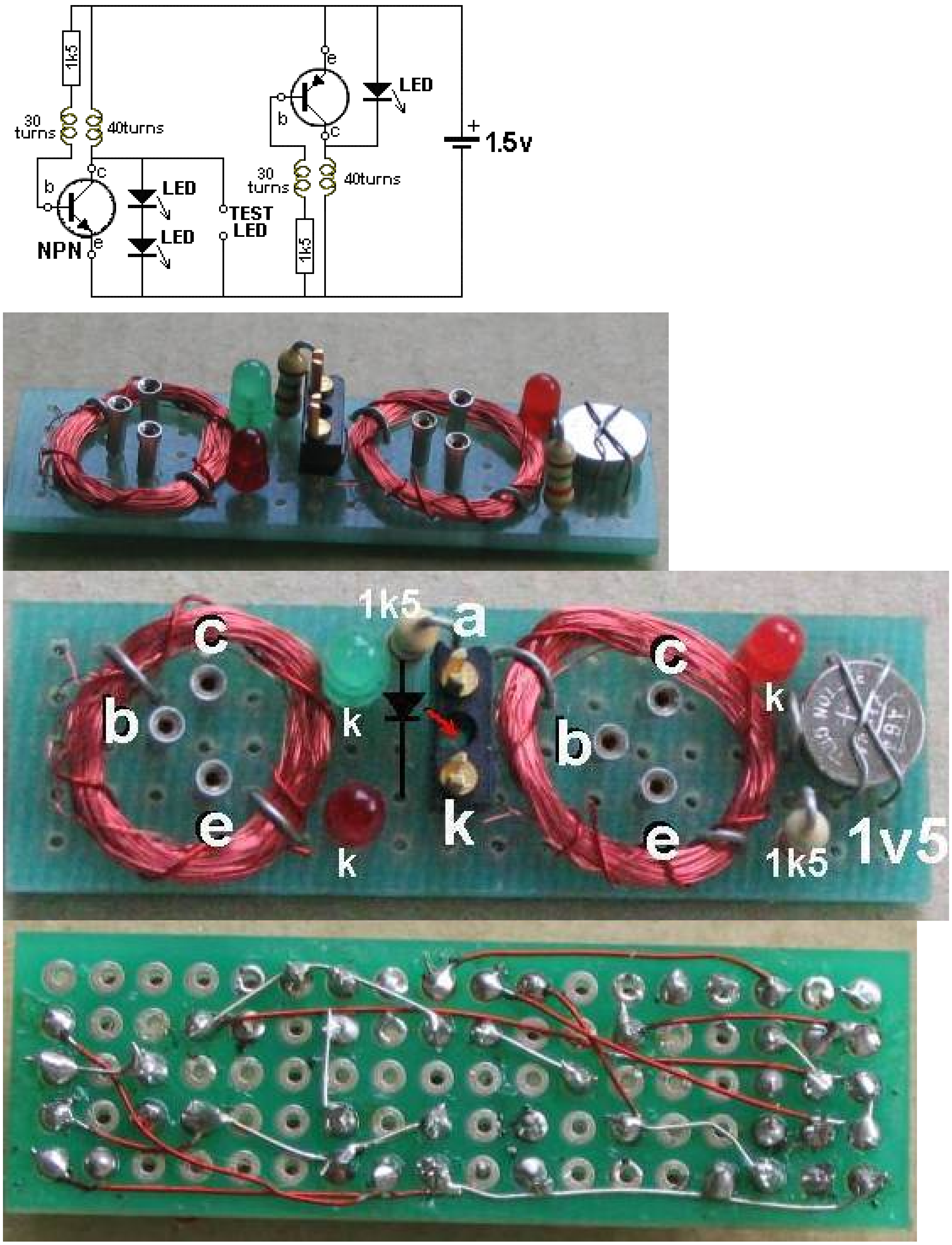
1k5
30 turns
40turns
b
c
e
NPN
LED
LED
TEST LED
e
b
c
LED
30 turns
40turns
1k5
+
1.5v
1k5
a
c
b
e
k
k
k
c
k
b
e
1k5
1v5

Fig 65. Transistor Tester

This handy transistor and LED tester can be built to test LEDs and both PNP and NPN transistors.
The project consists of two identical circuits, one for NPN and one for PNP.
You can build just the NPN section and then build the PNP section later.

LED VOLTAGE

We have shown a LED needs at least 1.7v supply for it to operate.
This circuit works on 1.5v and thus the action of the transistor and coil (called a Transformer) MUST be increasing the voltage for the LED to illuminate.
This circuit works on two "actions."
1. Transistor ACTION - this is the action of a transistor providing gain to make the circuit oscillate.
2. Transformer ACTION - this is the action of a coil of wire producing a voltage higher than the

supply voltage when it is turned off.

This circuit is very technical and very complex.
We will be explaining it in a very simple way because this is a **Basic Electronics Course**.

THE TRANSFORMER - the two coils of wire on the left and the two coils of wire on the right.
When the voltage (actually the current) is switched off, the 40 turn coil in either of the circuits in this project; the voltage across the coil rises to more than the 1.5v supply and is in the opposite direction to the voltage of the supply.
The circuit looks to be very simple but it uses an air-cored transformer to produce the voltage needed to illuminate the LED indicators and the circuit only works when the transistor is connected correctly. There are two separate circuits, one for NPN transistors and one for PNP transistors. We will cover the NPN section:
The circuit turns ON when the NPN transistor is fitted and the current through the 30 turn coil and 1k5 resistor turns ON the transistor and produces expanding flux in the 40 turn coil. This flux cuts the turns of the 30 turn coil and produces a voltage in the coil that adds to the supply voltage and increases the current into the base. This turns the NPN transistor ON more. This action continues until the transistor is fully turned ON. At this point the current in the 40 turn coil is a maximum but it is not expanding flux and the 30 turn coil ceases to see the extra voltage. Thus the current into the base reduces and this turns the transistor OFF slightly. The flux produced by the 40 turn coil now becomes collapsing (or reducing) flux and it produces a voltage in the opposite direction to greatly reduce the current into the base. In a very short period of time the transistor becomes TURNED OFF and it is effectively removed from the circuit. The flux in the 40 turn coil collapses quickly and it produces a voltage in the 40 turn coil that is higher than the supply voltage and is in the opposite direction. This means the voltage produced by the 40 turns ADDS to the supply voltage and is delivered to the LEDs to illuminate them.
The NPN circuit has two LEDs in series so that a LED of any colour (including white) can be connected to the TEST LED terminals and it will illuminate. You can use any colour LED for any of the LEDs, however it is best to use either green or yellow or white for the single LED.
The two "coils" are wound on a 10mm dia pen with 0.1mm wire (very fine wire). The loops of tinned copper wire holding the coils on the board are connected to separate lands under the board and MUST NOT produce a complete loop as this will create a “Shorted Turn” and the circuit WILL NOT WORK.
If the LEDs do not illuminate, simply reverse the wires to the 30 turn coil.
The circuit does not need an ON/OFF switch because the LEDs require a voltage of over 2v to illuminate (the orange LED) and the supply is only 1.5v. A red LED needs about 1.5v to 1.7v to operate but when it is in series with a green LED, this voltage is over 3.5v.
All the components fit on a small matrix board 5 holes x 18 holes. A kit of parts for the project is available for $4.00 plus $3.00 postage and ordering details can be obtained by emailing Colin Mitchell. (talking@tpg.com.au)
Build the circuit and test your transistors and LEDs.
We will be covering more on the action of a transistor and the action of a transformer in the discussion below, but it is important to build the circuit and see it working.
It is your first piece of **TEST EQUIPMENT**.

Questions

1. Identify the letters "c" "b" and "e"
2. What type of transistor is tested in the first set of hollow pins?
3. Put a PNP transistor into the first set of hollow pins and try all positions. Does the red and green LEDs illuminate?
4. When both the red and green LEDs illuminate, what is the approximate voltage across the pair?
5. When you fit a red LED to the test-socket, what is the approximate voltage across it?
6. When you fit a red LED to the test-socket, why does the red LED and green LED on the PC board turn off?
7. Why doesn't the project need an on/off switch?
8. The two coils for the circuit on the left is called a TRANSFORMER. Do the connections of the windings have to be connected to the circuit around a particular way?

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ROBOT MAN

This multivibrator circuit will flash the Robot Man's eyes as shown

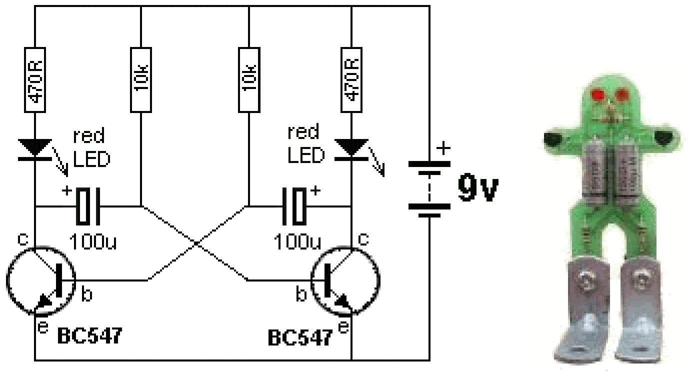

Fig 66. ROBOT MAN
The ASTABLE MULTIVIBRATOR or "free-running" multivibrator.

in the photo. The kit of components is available from Talking Electronics for $8.50 plus postage. Send an email to find out the cost of postage: talking@tpg.com.au
The photo shows the LEDs flashing.
The circuit is called an **ASTABLE MULTIVIBRATOR** and this means it is not stable but keeps switching from one transistor to the other.
It is also called a **FLIP FLOP** circuit.

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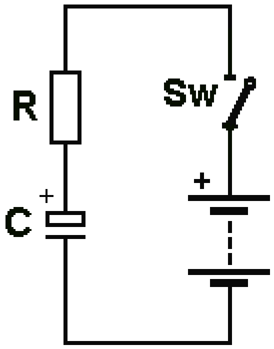

Fig 67. The TIME DELAY

The **TIME DELAY** circuit consists of a Resistor **R** and Capacitor **C** in **SERIES**.
When the switch is closed, the electrolytic (called the CAPACITOR) charges slowly because the resistor only allows a small amount of current to flow.
It's just like charging your mobile phone. The battery takes time to charge because there is a resistor in the circuit to limit the current. If we remove the resistor in the mobile phone, the battery will get too hot when it is being charged but in the **TIME DELAY** circuit, we want the capacitor to charge slowly, because we want a **TIME DELAY.** .

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Fig 68. The charging of a capacitor is the same as building a brick wall.

CHARGING A CAPACITOR

The capacitor in **Fig 67** charges via the resistor **R**.
But the voltage on the capacitor does not rise at a constant rate.
It starts off charging very quickly and as the voltage across it get higher, the voltage increases at a slower and slower rate.
In the photo I am building a brick wall.
I am working at a constant rate.
When I started building the brick wall, I laid 5 rows of bricks (5 courses) in the first hour.
As the wall increased in height, I had to climb the ladder and I could only lay 3 courses an hour and finally the wall was so high I could only lay 1 course per hour.
This is exactly the same as a capacitor charging.
When the capacitor is uncharged, the supply voltage allows a high current to pass through the resistor **R** and the energy quickly fills the capacitor. This results in a rapidly increasing voltage on the capacitor. But as the voltage on the capacitor increases, the difference in voltage between that on the capacitor and the supply is very small and only a small current will pass through the resistor. This means the voltage on the capacitor increases at a slower rate.

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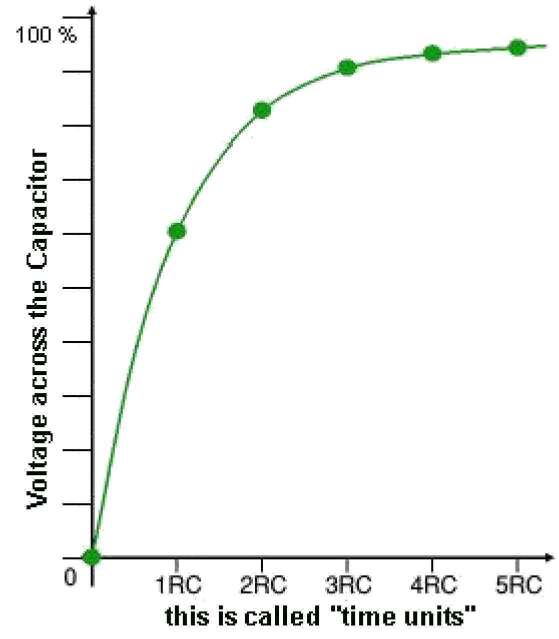

Fig 69. Time Units

It really does not matter how fast or slow or uneven a capacitor charges because most circuits detect a voltage on a capacitor and the time taken to reach this voltage is called the **TIME DELAY**.
But to prevent you thinking the capacitor charges "smoothly" we have to explain what actually happens.
The graph on the left shows the capacitor charging. You can see it charges quickly at the beginning and then charges slowly and then very slowly.
You can see the first part of the graph is fairly "straight" (constant charging) - NOT "straight up and down" but a straight line - and this applies to a voltage of about 63%. The time taken to reach this voltage is called **ONE TIME UNIT** - also called **ONE TIME CONSTANT**. The graph continues for another 4 "time units" (time-constants) and the final voltage is very nearly 100%. (It never reaches 100%.)

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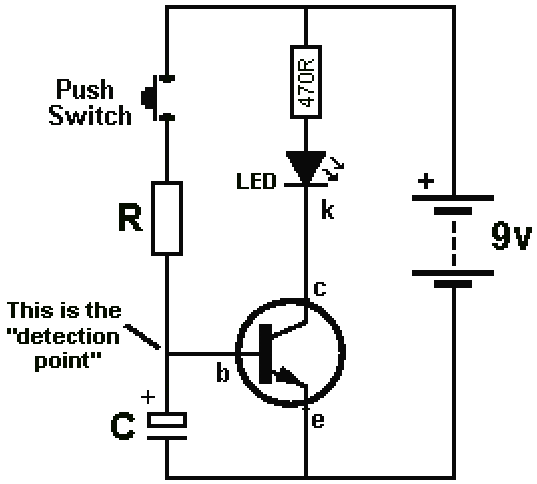

Fig 70. Time Delay Circuit

A **TIME DELAY** circuit needs three things:
1. A Resistor (R)
2. A Capacitor (C)
3. A "Detection Point."

When the switch is pressed, capacitor (**C**) takes time to charge via resistor (**R**) and after a short period of time the voltage at the **DETECTION POINT** is 0.6v and the transistor is TURNED ON. The LED illuminates.

Build the circuit with 100u and 100k and see how long it takes before the LED illuminates.

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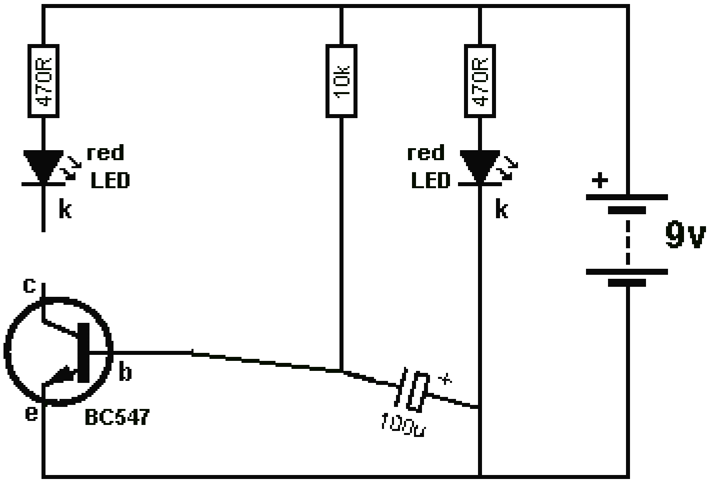

In the **ROBOT MAN** project you can see the "**TIME DELAY**" circuit made up of the 100u, 10k resistor and the base of the transistor.

This is one of the most important **BUILDING BLOCKS** in electronics.
It is the basis of all oscillators and will be discussed below, after we explain a few more details.

Fig 71. The "TIME DELAY" in the ROBOT MAN Project

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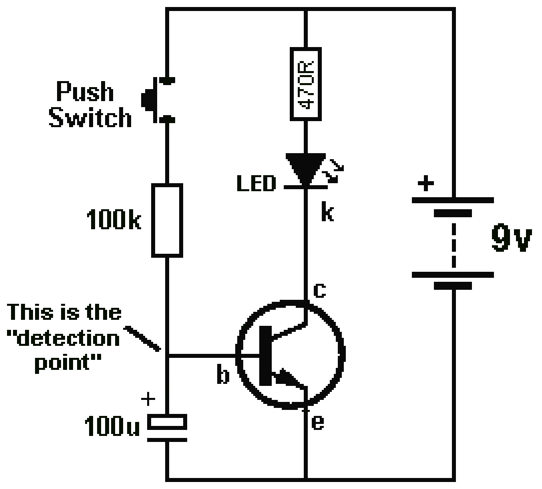
Push
Switch
470R
LED
k
+
9v
100k
c
This is the "detection point"
b
+
100u
e

Fig 72. Turning A Transistor ON

We will use the **TIME DELAY** circuit to turn the transistor **ON**.
Make sure the 100u is uncharged by touching both leads (both ends of the capacitor) at the same time with a JUMPER - this is a piece of wire shown in Fig 61.
Push the switch and noting happens. After a short period of time the LED starts to glow and then comes on fully.
This shows two things:
1. The transistor is not turned ON when the base voltage is zero.
2. The base voltage must be 0.6v for the transistor to start to turn ON and when the voltage is 0.65v the transistor is turned **ON FULLY.**

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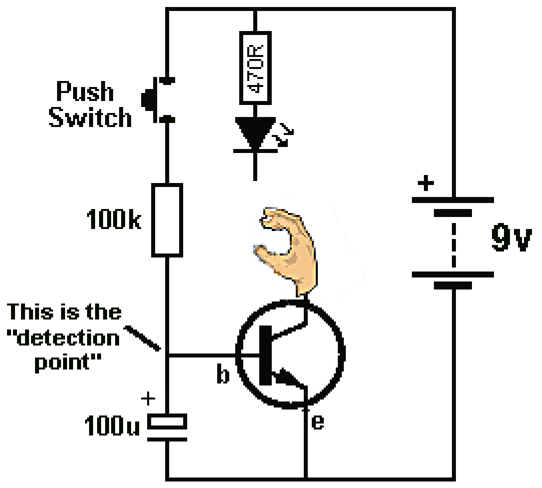
Push
Switch
470R
+
9v
100k
This is the "detection point"
b
+
100u
e

Fig 73. How the LED turns ON

Here is an explanation of how the LED turns ON.
When the circuit is first assembled and the switch is not pressed, the transistor is not turned on and it is just like the diagram opposite. The LED is not connected to the transistor.

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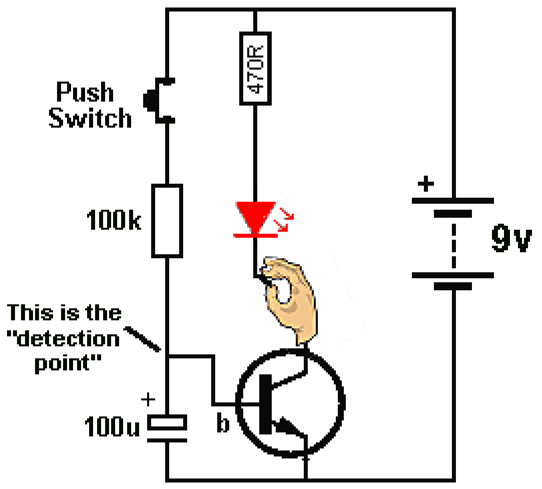
Push
Switch
470R
+
9v
100k
This is the "detection point"
+
100u
b

Fig 74. The LED turned ON

When the switch is pushed, the transistor turns **ON** (after a few seconds) and it pulls the lower lead of the LED down towards the 0v rail and this action turns the LED **ON**.

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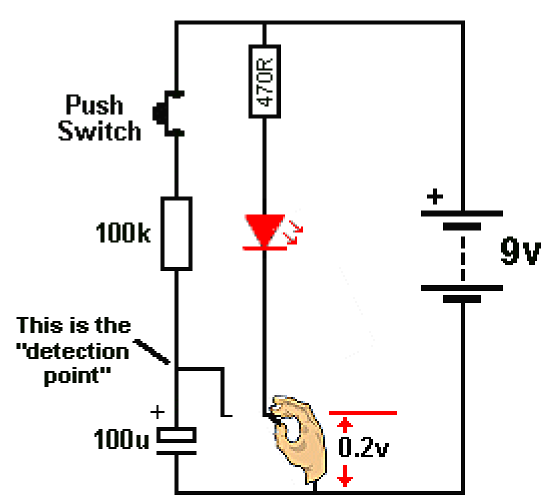

Fig 75. The LED fully turned ON

When the LED is **fully turned ON**, the lower lead of the LED is almost directly connected to the 0v rail.
In other words:
When the transistor is **FULLY TURNED ON**, the lower lead of the LED is almost directly connected to the 0v rail.
The voltage between the lead of the LED and 0v rail is 0.2v. This is the characteristic voltage across the collector-emitter terminals of a transistor when it is TURNED ON.

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In the three diagrams above you can see the LED is changed from an **OFF** condition to an **ON** condition by the action of the transistor.
The transistor is acting **LIKE A SWITCH.**
This action is one of the most important actions in electronics.
It is called: **"The Transistor as a SWITCH"**
It is the basis to ALL Digital Circuits.
It is the basis because of these two facts:
1. When the transistor is **OFF**, the circuit is taking **no current** and no power is being lost or wasted.
2. When the transistor is **ON**, the LED is almost at 0v and no resistor is in the lower lead to waste any power.
Thus we can turn things **ON** and **OFF** without wasting and power.
This is the basis to **DIGITAL ELECTRONICS**.

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DIGITAL ELECTRONICS revolves around circuits that are either **FULLY ON** or **FULLY OFF**. This means they take almost no power and we can combines lots of circuits and still take almost no power.
This means they do not get hot and it also means they will last a long time.
You may not think turning a transistor **ON** and **OFF** will achieve any worthwhile outcome but a circuit can be designed to use two transistors (similar to the **ROBOT MAN** above). The circuit does not Flip-Flop but requires a switch and when the switch is pressed, the circuit changes state. The two transistors are connected together and it takes two presses of the switch to make the output of the second transistor change state ONCE.
The circuit is a divider. It is called a: **divide-by-two** and is the basis of all counting in a computer.
By adding more "**divide-by-two"** circuits we can get "**divide by 4**, **divide by 8**" etc. Two transistors don't do much but when you combine millions of transistors we have a **COMPUTER.**

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Two transistors can do one more thing. They can "**REMEMBER**."
Here is a manual circuit.
Pressing Switch **A** turns the LED **ON** and pressing switch **B** turns the LED **OFF**.
The circuit "remembers" or remains in each state called a stable state.

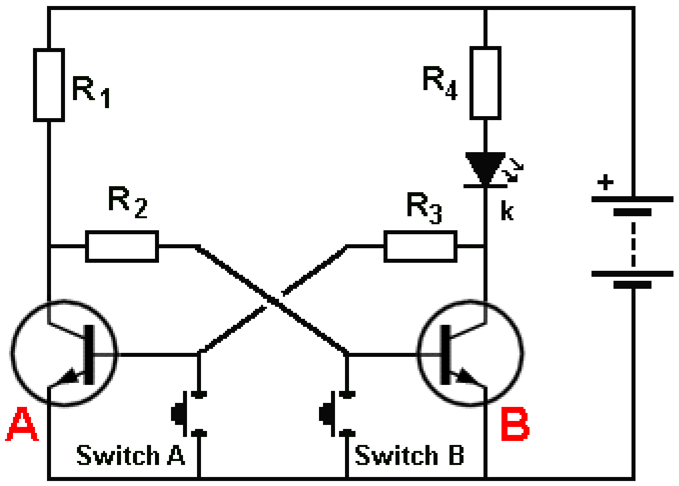

Fig 76. The "MEMORY CELL"

When Switch **A** is pressed, the voltage on the base is removed and transistor **A** turns OFF.
Transistor **B** turns ON via resistors R$_1$ and R$_2$ and the LED is turned **ON**.
When the switch is released, the voltage on the collector of transistor **B** is less than 0.6v and the two transistors remain in this state.
Pressing switch **B** turns the LED **OFF.** (transistor **A** turns ON via R$_3$, R$_4$ and the LED - very little current flows through the LED and you can hardly see it glowing). The voltage on the collector of transistor **A** is less than 0.6v and the two transistors remain in this state.

The technical name for this circuit is:
BISTABLE MULTIVIBRATOR or **BISTABLE SWITCH** or **BISTABLE LATCH**.

This is the basis to all the memory in a computer.

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In electronics, we talk about the **DIGITAL TRANSISTOR** and **ANALOGUE TRANSISTOR**.
This is just an ordinary transistor (called a Bipolar Junction Transistor) in a **DIGITAL CIRCUIT** or **ANALOGUE CIRCUIT**.
We are now discussing the **DIGITAL CIRCUIT** - The Multivibrator - Astable Multivibrator and Bistable Multivibrator (Memory Circuit).
The **DIGITAL CIRCUIT** has **2 STATES**.
The **ON STATE** and the **OFF STATE**.
It is conducting in the ON STATE and the LED is illuminated.
In the OFF STATE, the LED is not illuminated.
In the ON STATE the transistor is said to be **CONDUCTING** or **BOTTOMED**.
In the OFF STATE the transistor is said to be "**CUT OFF** or "**OFF**."
These two states are reliable and guaranteed. They are not "half on" or "quarter on" or "75% off."
These states are easy to transmit "down a wire." The ON STATE is transmitted as "1" (voltage present) and the OFF STATE is transmitted as "0" (voltage not present).
These are the two **DIGITAL STATES**.

The **ROBOT MAN** is a **DIGITAL CIRCUIT**.
Each LED is ON or OFF.
The waveform on the output of each transistor is called a **DIGITAL SIGNAL**.

The waveform is said to be **DIGITAL** or **SQUARE WAVE**.
The top line of the graph represents the LED OFF.
The bottom line of the graph represents the LED ON. The LED is ON when the collector voltage is LOW because we are pulling the lead of the LED to the 0v rail as shown above.
The circuit changes from one state to the other very quickly and this is called the **RISE TIME**.

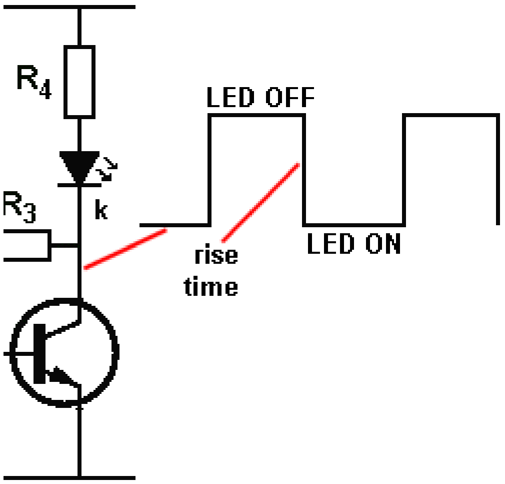
R4
LED OFF
R3
k
rise
time
LED ON

to Index

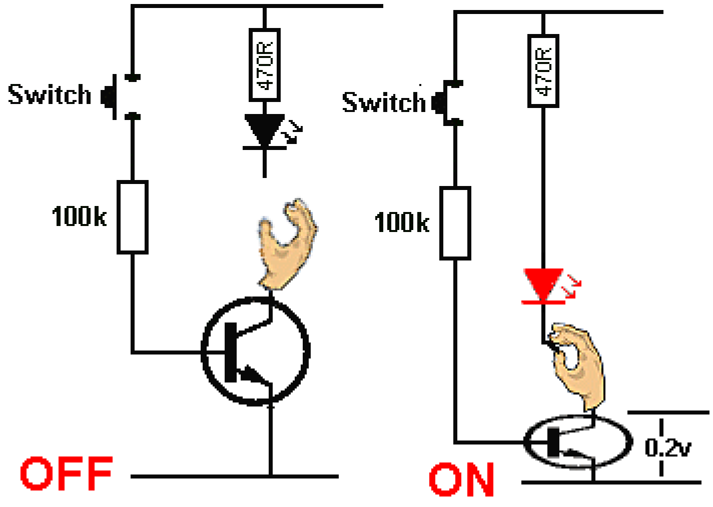
Switch
470R
Switch
470R
100k
100k
0.2v
OFF
ON

Fig 77. The two Digital States

Going over the two **DIGITAL STATES** for a transistor.

In the first diagram the switch is not pressed and the base does not see a voltage to turn the transistor on. The transistor is "**OFF**" (not conducting) and it is not "grabbing" the LED. The LED is not illuminated.
In the second diagram the base of the transistor sees a voltage via the switch and it is TURNED on. The LED is illuminated.

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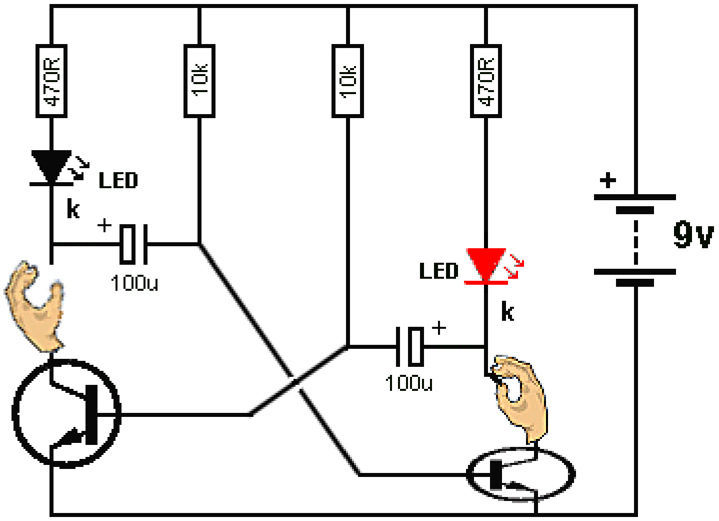
470R
10k
10k
470R
LED
k
+
100u
+
9v
LED
k
+
100u

Fig 78. ROBOT MAN Animation
This animation shows how a transistor grabs a LED and pulls it towards the 0v rail to turn it ON.

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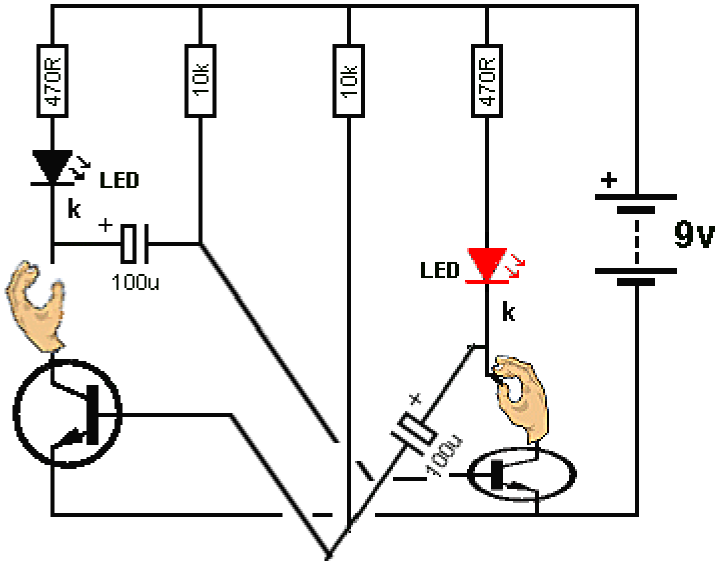

Fig 79. TIME DELAY Animation

The animation in **Fig 78** shows the two transistors turning the LEDs **ON** and **OFF** in a **FLIP FLOP** circuit.
We know the 10k and 100u components form a **TIME DELAY** to create the time for each LED to be illuminated. The timing for one LED plus the other LED creates a **CYCLE** and this is the **FREQUENCY OF OPERATION** for the circuit. It is measured in cycles per second - Hertz - Hz.
We will now go into more detail of how the **TIMING COMPONENTS** create the **TIME DELAY** for each LED.
The circuit is more-complex than you think.
The 100u is already charged from a previous cycle and we show how it gets discharged via the 10k and charged in the opposite direction by the 10k to create a **TIME DELAY**.

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THE CAPACITOR

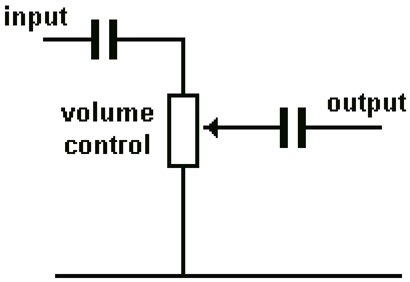

The capacitor can perform many different functions and produce many different effects, depending on its value and the surrounding components.
In this circuit the capacitors on the input and output prevent DC on the volume control creating "scratchy sounds" when the volume is altered.
This is called "DC blocking."
The AC (the signal) passes through the capacitors but the DC voltage on the input is blocked.

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CHARGING A CAPACITOR Part II

It is easy to see how a capacitor charges via a resistor in the **TIMING CIRCUIT** (Delay Circuit) above but many capacitors are not connected to the 0v rail.
They are connected as show in the animation below and their "job" is to pass a waveform.
When they pass the waveform they **CHARGE** and **DISCHARGE**.
The waveform is called an **AC SIGNAL** and the output is smaller than the input.
The circuit is taken from the circuit above, but the same effect applies to all capacitors that "pass a signal."
Here's why:

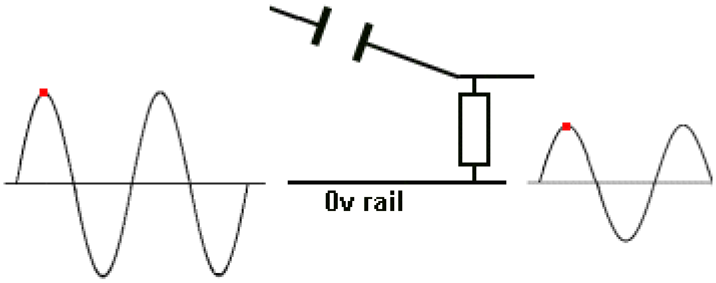

The capacitor charges slightly during the rise of the signal and the right-plate of the capacitor does not rise as high as the left-plate. That's why the output signal is not as large as the input signal.
If the capacitor did not charge, the output would be as large as the input. If you use a capacitor with a large value, it will not charge and thus the output will be as large as the input.
That's why you use a large capacitor !!!!

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CHARGING A CAPACITOR Part III

Here is another CAPACITOR in action.

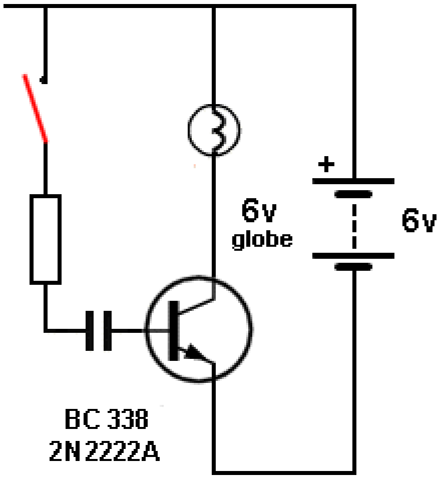

The animation shows a capacitor charging (via a resistor). The initial current is LARGE and this turns the transistor FULLY ON and the globe illuminates. As the capacitor charges, the base current reduces and the transistor starts to turn OFF. Eventually the capacitor is fully charged and the voltage on the base falls to 0v, turning the transistor OFF.

This animation shows three features:
1. The initial charging current is HIGH.
2. It gradually falls to zero.
3.The voltage on the base drops below 0.6v and the transistor turns OFF.

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NEGATIVE VOLTAGE

You will be surprised to learn that many circuits produce a negative voltage or negative spike at some point (when doing circuit-analysis, each location or point or join of components is called a NODE) on the circuit. In other words the voltage will be LESS than the 0v rail of the circuit.
This is due to the presence of a capacitor and the animation shows how a capacitor can produce a negative voltage:

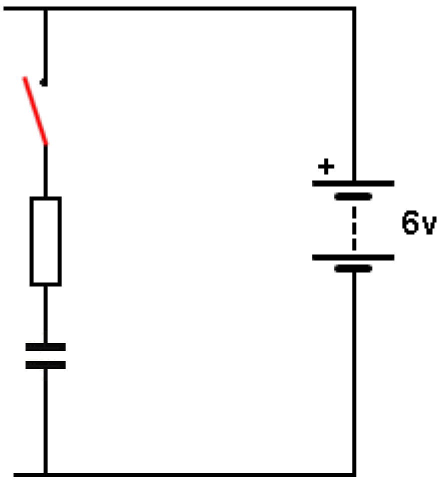

When a charged capacitor is "lowered from one position in a circuit" the positive lead may be lowered by say 3v. This means the other lead will be lowered by 3v. We are assuming the capacitor can be lowered and is not directly connected to the 0v rail.

You can see the electrolytic produces a NEGATIVE VOLTAGE on the base in the following animation, when the two transistors change states:

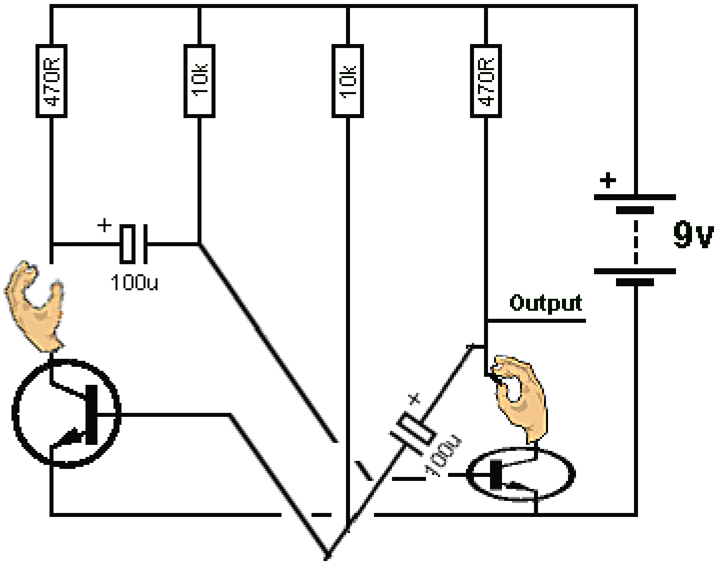

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The Electret Microphone

The most common type of microphone is the ELECTRET MICROPHONE.
It is incorrectly termed the "Capacitor Microphone" or Condenser Microphone." "Capacitor Microphone" descriptions make no mention of a FET as the amplifying device and a polarized diaphragm to detect the audio, so they are something different.
The electret microphone consists of a FET (transistor)

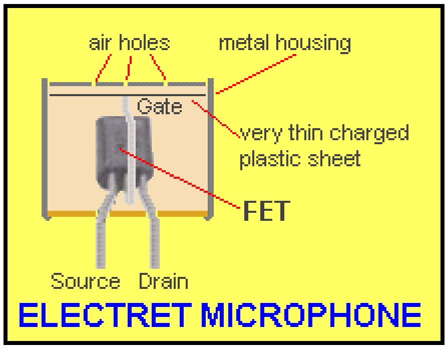
air holes
metal housing
Gate
very thin charged plastic sheet
FET
Source
Drain
ELECTRET MICROPHONE

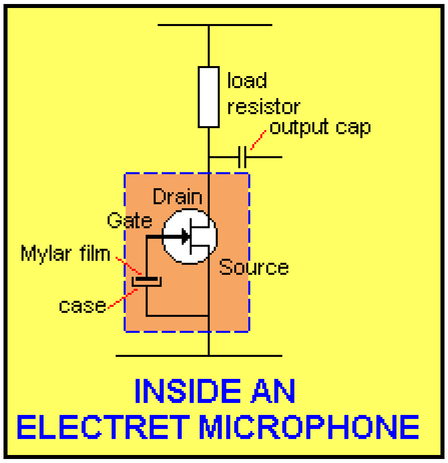
load resistor
output cap
Drain
Gate
Mylar film
Source
case
INSIDE AN ELECTRET MICROPHONE

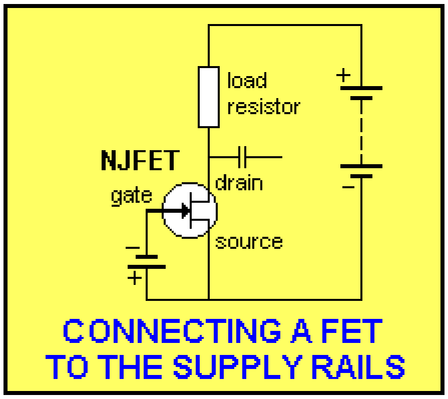
load resistor
+
NJFET
drain
gate
source
–
+
CONNECTING A FET TO THE SUPPLY RAILS

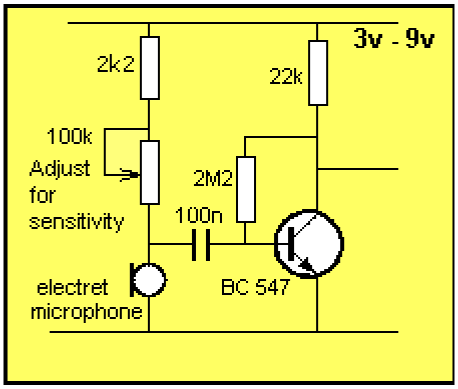
3v - 9v
2k2
22k
100k
Adjust for sensitivity
2M2
100n
electret microphone
BC 547

inside an aluminium case with a very thin Mylar film at the front. This is charged and when it moves (due to the audio it receives via a small hole in the front of the case), it vibrates and sends a very small voltage to the GATE lead of the Field Effect Transistor. This transistor amplifies the signal and produces a waveform of about 2mV to 20mV at the output.
The electret microphone requires about 0.5mA and will operate from 1.5v supply with 4k7 LOAD RESISTOR.
For 3v supply, the Load Resistor can be 22k to 47k.
For higher supply voltages the resistor will be 68k or higher.
Electret microphones are extremely sensitive and will detect a pin-drop at 3 metres.

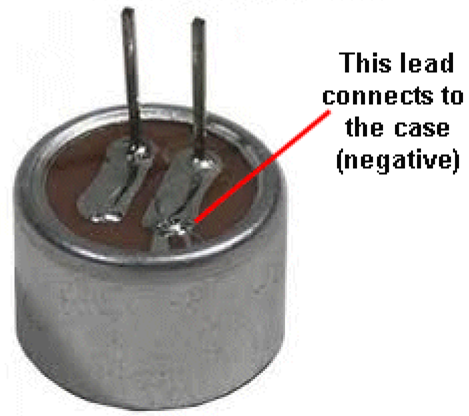
This lead connects to the case (negative)

Most electret microphones have two leads. One lead is connected to the case and this lead goes to the 0v rail. The other lead goes to a LOAD RESISTOR (4k7 to 68k - depending on the voltage of the project).
Reducing the value of the load resistor will increase the sensitivity until the background noise is very noticeable.
They are used in Hearing Aids and are more-sensitive than the human ear.
They are very small, low-cost and very sensitive.

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The Speaker

The most common speaker is about 30mm to 60mm diameter and 8 ohm impedance. This means the voice coil is about 8 ohms resistance.
The two leads can be connected either way to a circuit.
The speaker shown is 32mm diameter and has a realistic wattage of 100mW (NOT 1watt).

These speakers have a Mylar cone and the magnet is a "super magnet" and very small. That's why it is so flat.

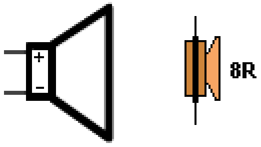

Speaker Symbol

A speaker can be used as a microphone (called a Dynamic Microphone) and a circuit to connect the speaker (mic) to an amplifier can be found on Talking Electronics website. It is not as sensitive as an electret microphone and does not produce the same output amplitude, but it is an emergency microphone.

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Light Dependent Resistor

(LDR)

Also called **PHOTOCELL** or **PHOTO RESISTOR**
A **Light Dependent Resistor** is a 2-leaded component containing a layer of semiconductor material.
The top contains two interleaving combs of conducting wires with a path of semiconductor material between. When light falls on the component, the resistance of the semiconductor material decreases.
In darkness the LDR will be about 300k. In very bright light the resistance will be about 200 ohms.
But if the light changes only a very small amount, the resistance CHANGE is VERY SMALL. For a large change, see **Photo Transistor**.
The **Light Alarm** circuit will produce a squeal when light falls on the LDR.

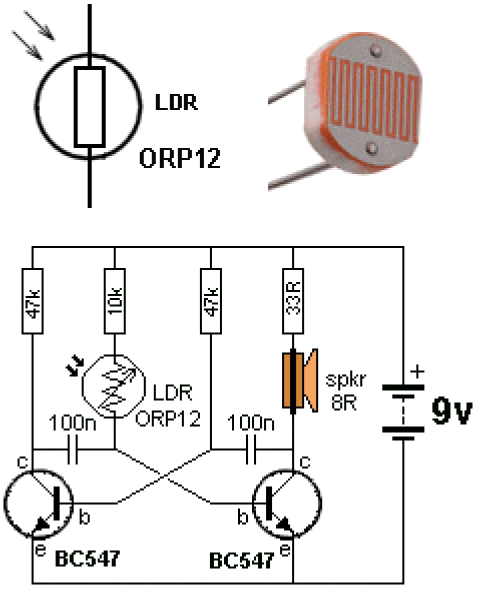

LDR and Light Alarm Circuit

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Photo Transistor

The **Photo Transistor** is very sensitive to changes in illumination. It is about 100 times more sensitive than the **LDR**.
The **Photo Transistor** is also available as a **DARLINGTON.**
The Darlington Photo-transistor is 100 x 100 times (10,000) more sensitive than the LDR.

The **Photo Transistor** and **Photo Darlington Transistor** are connected just like a normal transistor but the base lead is not connected. If the value of the LOAD RESISTOR is large, the

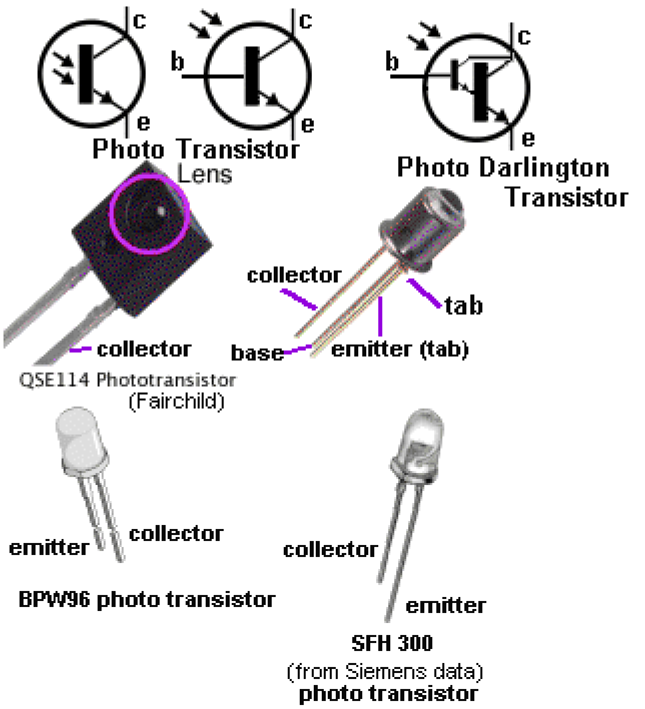
c
b
e
Photo Transistor
c
b
e
Photo Darlington
Transistor
Lens
collector
tab
collector
base
emitter (tab)
QSE114 Phototransistor
(Fairchild)
emitter
collector
BPW96 photo transistor
collector
emitter
SFH 300
(from Siemens data)
photo transistor

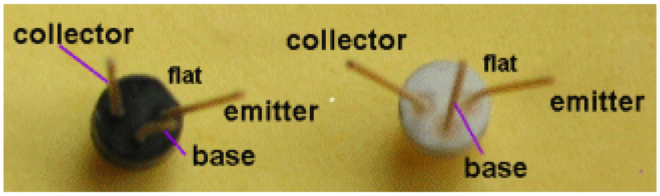
collector
flat
emitter
base
collector
flat
emitter
base

FPT100 Photo Darlington Transistor

The FPT-100 Darlington Photo Transistor is available from Talking Electronics for $1.00 each plus postage.

transistor will not be very sensitive.

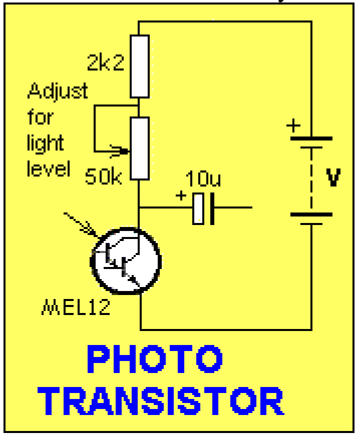
2k2
Adjust
for
light
level
50k
10u
+
+
V
MEL12
PHOTO
TRANSISTOR

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The Inductor

Also called **"coil,"** or **"Choke."**
An **Inductor** consists of one to many turns of wire wrapped around a former (tube of cardboard). The wire can be jumble-wound or wound in layers. The result is the same. This is called an **air-cored coil** or **air-cored inductor**.
The centre can be filled with a metal such as iron or laminations (thin sheets of metal) or a ferrite material. Different cores operate at higher frequencies.
The core can be circular (doughnut) or rectangular and it is called a **MAGNETIC CIRCUIT** (when it is a closed loop).
Additional turns or increasing the diameter of the turns will increase the inductance.
A coil with a magnetic core can be used to pick up nails and metal items. It is called an **electromagnet**. It can be

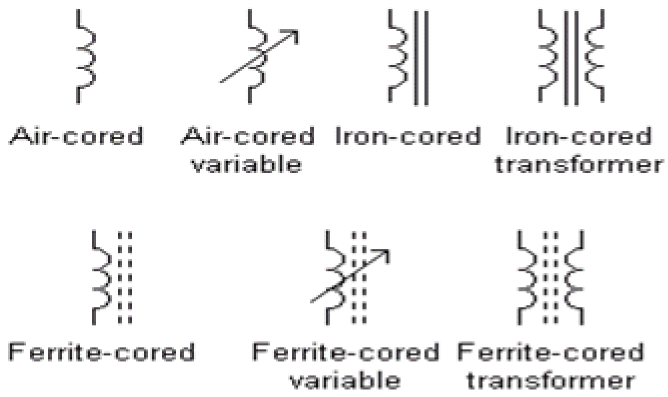

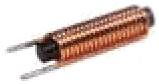

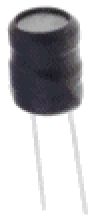

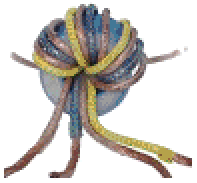

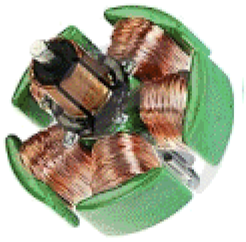

surface-mount inductor 27uH
yes 27uH
270uH = 271

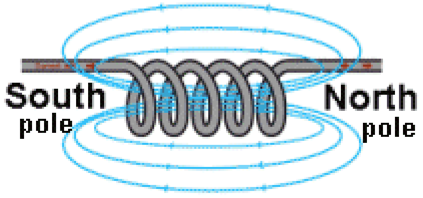

The emerging **magnetic lines of force** from an inductor produce the NORTH POLE - this is just "convention," a simple way to explain things - to get the explanation started.
When two or more coils are wound near each other, the inductor is called a **TRANSFORMER** (but not the armature above).

operated on AC or DC.
When the metal core is loose and gets pulled into the coil it is called a **SOLENOID** or **ACTUATOR** or **LINEAR ACTUATOR**. It can be operated on AC or DC.
The way an inductor works is very complex but we can say it resists any rise or fall in voltage by turning the rise or fall into magnetic flux.
If the applied voltage is suddenly turned off, the inductor produces **a very high voltage** of **opposite polarity** (these are the **two** most important things for you to remember).

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The Antenna

The first time you will need an antenna is when making an FM transmitter.
The antenna is usually a length of wire equal to half the wavelength of the transmitter. The frequency is about 100MHz and the wavelength is 3 metres.
A half-wave antenna is 1.5metres.
The length is important but the height is more important.
The wire should be as high as possible and "up-and-down" if the antenna on the radio is vertical, to get the maximum range.
This is called an **end-fed half-wave antenna** or **half-wave**

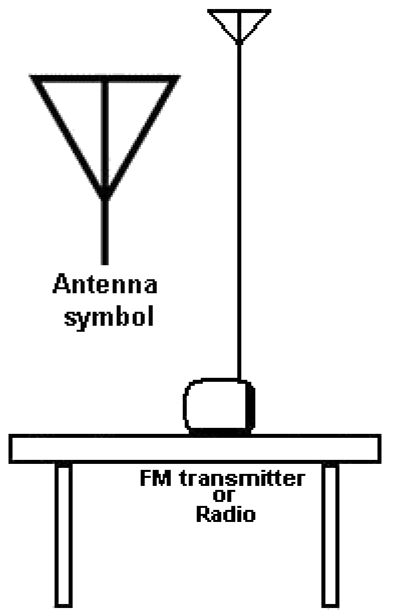

Monopole.
The transmitting circuit should have a good ground-plane such as connection to large batteries so the signal can be pushed and pulled into and out of the antenna.
This signal is then radiated as electromagnetic radiation to the surroundings.

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The RELAY

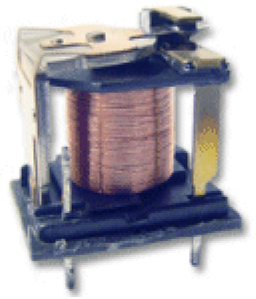

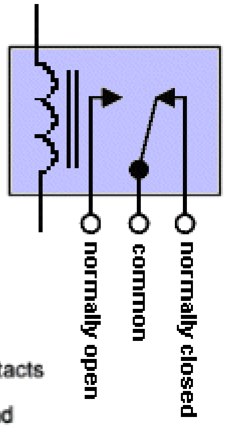

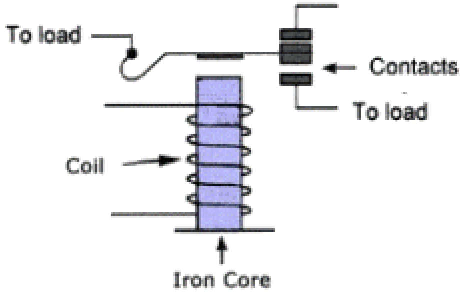

A single contact consists of 2 pins -called SPST (single-pole single-throw).
Or a single pair of contacts can consist of 3 pins - called change-over or SPDT (single-pole double-throw).
A double set of contacts consists of 6 pins, called DPDT (double-pole, double-throw). This is also called a **CHANGE-OVER RELAY** or **REVERSING RELAY** (when connected to a motor).

The word **Relay** comes from the days of Morse Code where a coil of wire (an electromagnet) closed a switch to allow the Morse code to travel further down the telegraph line.
It would "relay" or "pass-on" the information.
A relay allows a "weak circuit" (one with low current) to operate a LOAD that needs a large current. It also separates the two circuits electrically and prevents a voltage such as 240v connecting to a 12v circuit. The coil is separated from the contacts and this gives the two circuits isolation.
A double-pole double-throw relay can be used to reverse a motor as shown here:

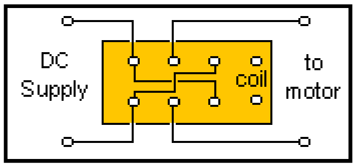

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Driving A Relay

(Powering A Relay)
The first thing you must decide is the voltage of the relay. This will depend on the voltage(s) available. The relay will be driven (activated) by a transistor and the base of the transistor only needs a signal (less than about 1v). This means the project can be operated on a voltage from 3v to 12v and the relay can be connected to a 5v to 12v supply.

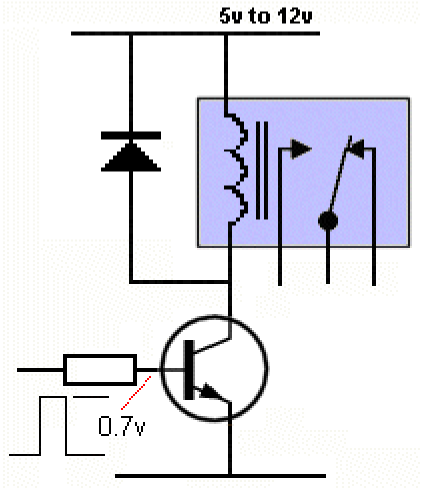

Driving A Relay

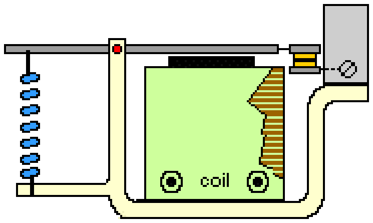

The armature is drawn towards the coil when a current flows through the coil.

Next you need to know the current-rating of the contacts. This will depend on the current taken by the LOAD. The rating of most relays is: 1 amp, 5 amp or 10 amp.
Finally you need to know how many contacts are required.
For a single circuit you will need 2 pins and for two circuits you will need 4 pins (but relays only come with 6 pins).
You can get relays that need a very small current for activation. These are called CMOS relays. But most relays need about 100mA.
To protect the driving-transistor from spikes when the relay is turned off, you will need a diode across the coil.
The top animation shows a "single set of change-over contacts."
The lower animation shows the ARMATURE being drawn to the electromagnet. The electromagnet is the coil with a core of magnetic material that becomes a magnet (an electromagnet) when a current flows through the coil.

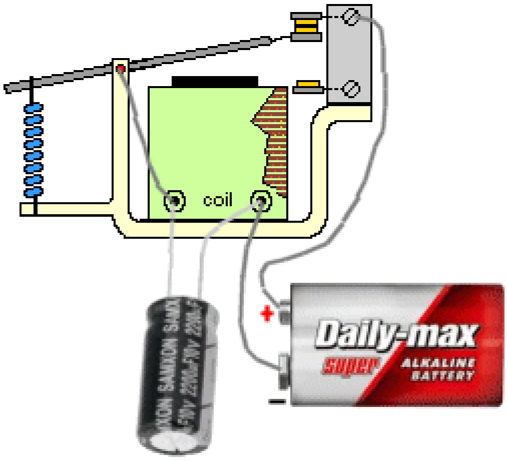

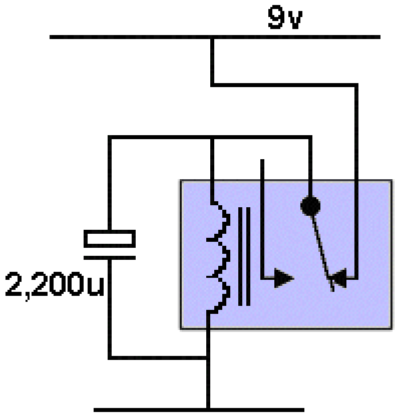

When the circuit is turned ON, the voltage across the 2,200u electrolytic is zero and it gradually charges. When the voltage is about 8v, the coil has enough voltage across it to pull the armature and open the contacts. The electrolytic supplies voltage to the coil for about 1 second and then the electromagnet does not have sufficient magnetism to hold the armature and it returns to close the contacts.

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GATES

Animations of **GATES** and more details of their operation is covered in **DIGITAL ELECTRONICS** chapter.

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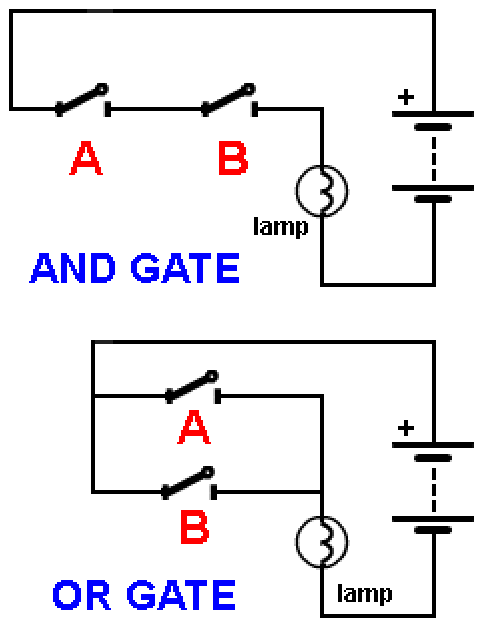

Fig 80. The "AND" GATE and "OR" GATE with switches

The next **BUILDING BLOCK** we will cover is called the **GATE**.
In its simplest form it is an electrical circuit consisting of switches.
Its just two or more switches connected in series or parallel.
We give each circuit a name so we can talk about it and explain its action with a single word.
Later we will cover the electronic version and show how diodes and a transistor are needed to perform a **GATING FUNCTION.**
The type of GATE we are talking about is a **LOGIC GATE**.
The circuit performs an operation called a **LOGICAL OPERATION** on an input or a number of inputs and creates a single output - called a **LOGICAL OUTPUT**.
LOGICAL means "understandable" or "correct" and in this case it means DIGITAL - the signal will rise to full rail voltage or fall to zero voltage. The output will not be half rail or quarter-rail voltage.
The diagram show an **"AND" GATE** and **"OR" GATE** with switches.
For the **AND GATE** close switch A **AND** switch B for the lamp to illuminate.
For the **OR GATE** close switch A **OR** switch B for the lamp to illuminate.

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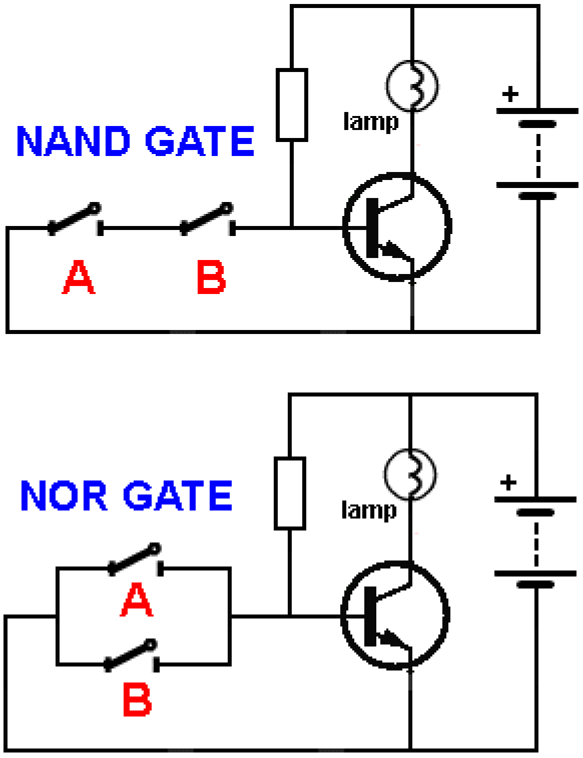

Fig 81. The "NAND" GATE and "NOR" GATE with switches and a transistor

INVERSION

Inversion produces the opposite effect to the results above.
Suppose we want to turn OFF a lamp when one or two switches are pressed.
We need a transistor.
The technical word for Inversion is **NOT**.
It is simplified to the letter "**N**."

For the **NAND GATE** close switch A **PLUS** switch B for the lamp to turn OFF.
For the **NOR GATE** close switch A **OR** switch B for the lamp to turn OFF.

These gates are only **demonstration-gates** to show how one or two switches will turn a lamp OFF.

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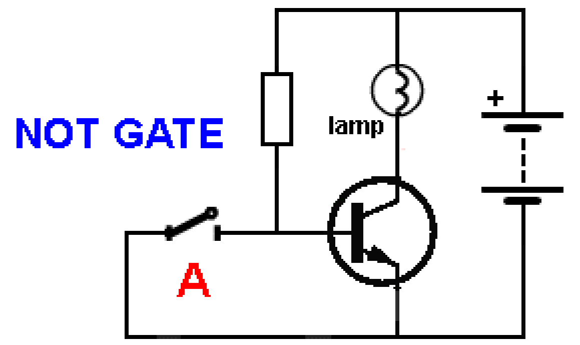

Fig 82. The "NOT" GATE

NOT GATE

A single switch and transistor produces a **NOT GATE.**
This is simply an **INVERSION**.

The resistor turns the transistor **ON** and the lamp illuminates. The switch removes the voltage on the base and the transistor turns **OFF**.
This is only a demonstration circuit to show how a switch can turn a lamp OFF.

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The 5 gates above form the basis to turning a circuit **ON** and **OFF**. We will discuss these gates later in the digital section.

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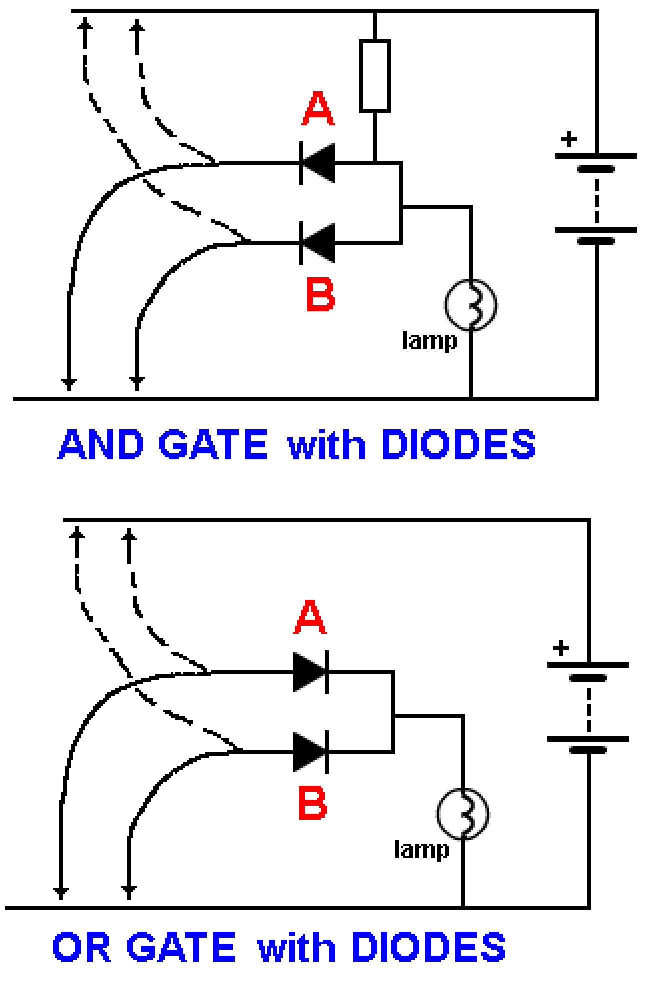

Fig 83. "AND and "OR" gate with diodes

The next building block is the **GATING DIODE**.
We have shown a diode allows current to flow when the diode is correctly placed in a circuit and blocks current when it is reversed.
The 5 gates above are electrical circuits but an electronic circuit works in a slightly different way.
The electronic circuit will be covered later in the DIGITAL section.
For the moment we will explain how a diode can be used to create a **GATE**.
In other words it creates a ONE-WAY PATH to allows signals to pass from one stage to another and prevents signals passing in the opposite direction.
In the AND GATE circuit, both inputs are LOW and current flows through the resistor (it will get HOT). When one input is taken HIGH, current still flows through the other diode and the lamp does not illuminate.
When BOTH inputs are HIGH, current flows through the resistor to illuminate the lamp. No current flows through the diodes.
In the OR GATE, when one input is taken HIGH, current flows through the diode to illuminate the lamp.
This can be done with EITHER input.

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A **NAND** and **NOR** gate can be made with diodes and a transistor.
This time we the output is either HIGH or LOW.
We are gradually producing circuits that

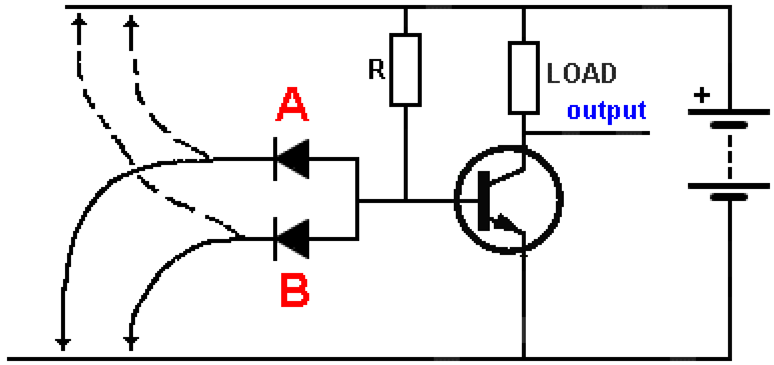

NAND GATE with DIODES and Transistor

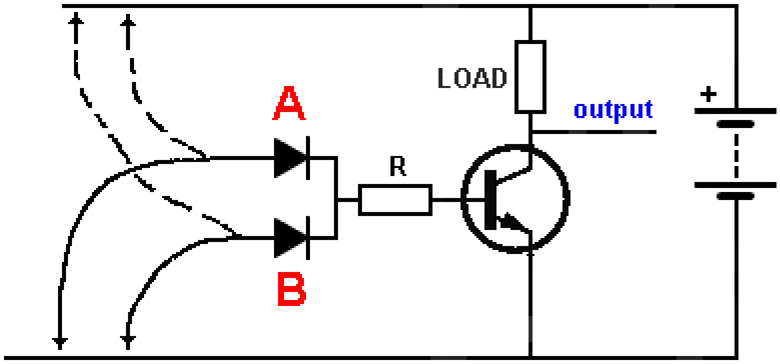

NOR GATE with DIODES and Transistor

Fig 84. "NAND" and "NOR" gate with diodes and a transistor.

are electronic, rather than electrical circuits.
In the **NAND GATE** circuit, taking one of the inputs HIGH will still allow the other input to prevent the transistor turning ON.
When BOTH inputs are HIGH, the transistor turns on via resistor R and the output is LOW.

In the **NOR GATE** circuit, taking one of the inputs HIGH will turn the transistor ON and the output will be LOW.

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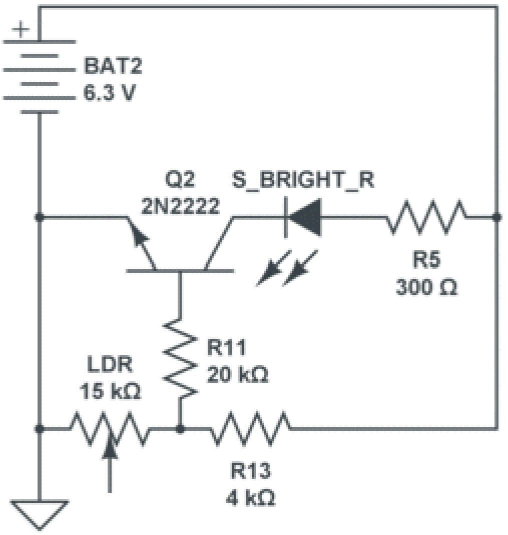

Drawing A Circuit

A circuit must be drawn according to simple rules so it can be instantly recognised.
An electronics engineer can "**see a circuit working**" when it is drawn correctly and can see if it is drawn correctly; if the parts-values are correct and can use the circuit to assist in diagnosing a problem with a faulty circuit.

The top circuit on is very difficult to visualise because it is not drawn in the normal way.
All the components have to be "**turned around in your mind**," to see what the circuit is doing.

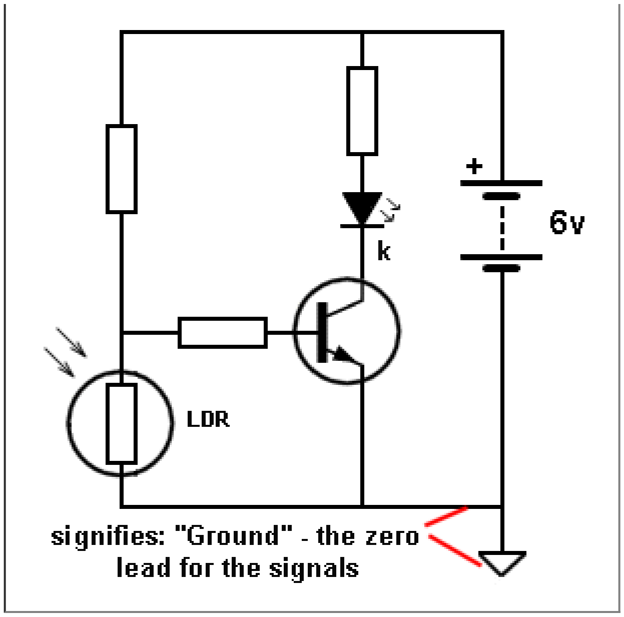

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QUICK QUIZ - to see how much you know

following 50 questions . . . JavaScript is required!
This test will see how much you have learnt.

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☐ An open circuit help

4. What is the approximate characteristic voltage that develops across a red LED?

☐ 1.7v
☐ 3.4v
☐ 0.6v
☐ 5v help

5. If two resistors are placed in series, is the final resistance:

☐ Higher
☐ Lower
☐ The same
☐ Cannot be determined help

6. Which is not a "common" value of resistance:

☐ 2k7
☐ 1M8
☐ 330R
☐ 4k4 help

7. Which value of resistance, placed across a 9v battery will get hot:

☐ 22k
☐ 22R
☐ 220k help

8. If the voltage on the base of a transistor increases, does it:

☐ Turn on
☐ Turn off
☐ Not enough information
☐ Remain the same help

9. The resistor identified in brown is called the:

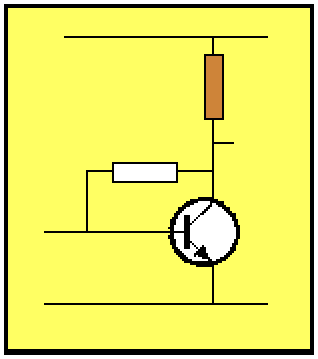

☐ Base Bias Resistor
☐ Load Resistor
☐ Emitter Feedback Resistor
☐ Bypass Resistor

help

10. The first three colour bands on a resistor are: yellow - purple - orange

☐ 47k
☐ 4k7
☐ 470k
☐ 4R7 help

11. A resistor with colour bands: red-red-red-gold, has the value:

☐ 22k 5%
☐ 2k2 5%
☐ 220R 5%
☐ 22R 5% help

12. The lead marked with the arrow is:

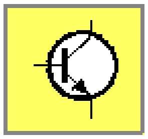

☐ The Collector
☐ The Base
☐ The Emitter
☐ The case **help**

13. A 10k resistor in parallel with 10k produces:

☐ 10k
☐ 5k
☐ 20k
☐ Cannot be determined **help**

14. The symbol is:

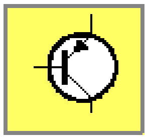

☐ NPN Transistor
☐ PNP Transistor
☐ Photo Transistor
☐ Field Effect Transistor **help**

15. Two 3v batteries are connected as shown.
The output voltage is:

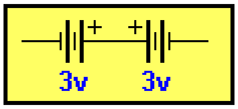

☐ 3v
☐ 0v
☐ 6v **help**

16. 4 resistors in ascending order are:

☐ 22R 270k 2k2 1M
☐ 4k7 10k 47R 330k
☐ 3R3 4R7 22R 5k6
☐ 100R 10k 1M 3k3 **help**

17. The closest value for this combination is:

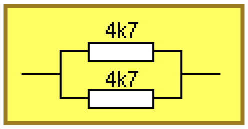

☐ 4k7
☐ 2k3
☐ 9k4 **help**

18. Which LED will illuminate:

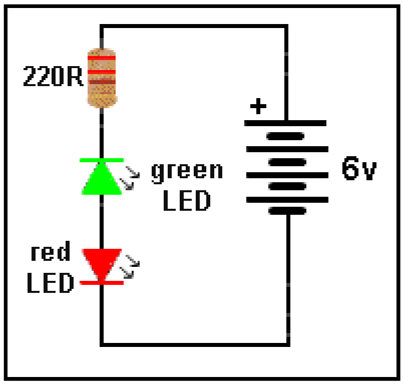

☐ Green
☐ Both
☐ RED
☐ None

19. The four symbols are:

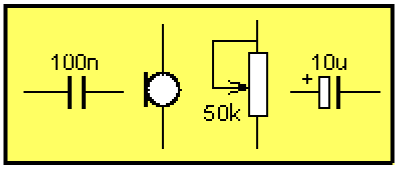

☐ Capacitor, Microphone, Potentiometer, Electrolytic
☐ Electrolytic, Microphone, Resistor, Capacitor
☐ Capacitor, Piezo, Resistor, Electrolytic
☐ Electrolytic, Coil, Resistor, Capacitor help

20. The closest value of the combination is:

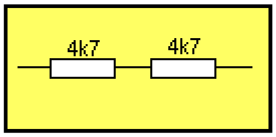

☐ 10k
☐ 2k3
☐ 2k5

21. Which motor will work:

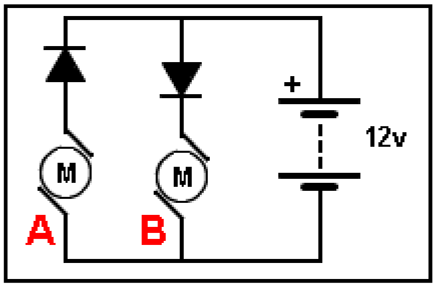

☐ A
☐ B
☐ A and B

22. A resistor and capacitor in series is called a:

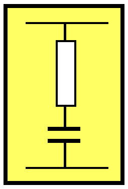

☐ Pulse Circuit
☐ Timing Circuit/Time Delay Circuit
☐ Oscillator Circuit/Frequency Circuit
☐ Schmitt Circuit help

23. A red-red-red-gold resistor in series with an orange-orange-orange-gold resistor produces:

☐ 5k5
☐ 35,200 ohms
☐ 55k
☐ None of the above help

24. Name the 4 components:

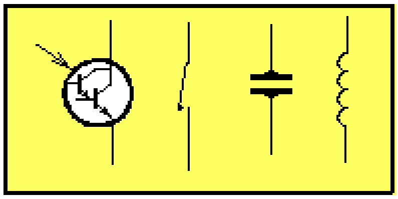

☐ Photo transistor, switch, capacitor, coil
☐ Transistor, mercury switch, piezo, inductor
☐ Photo transistor, reed switch, piezo, coil
☐ Photo Darlington transistor, switch, piezo, inductor help

25. To obtain a higher value of resistance, resistors are connected in:

☐ Reverse
☐ Forward

☐ Parallel
☐ Series help

26. Which LED will illuminate:

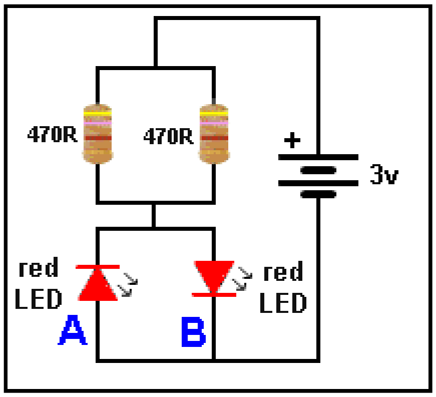

☐ A
☐ B
☐ Both
☐ None

27. Name the component that detects light:

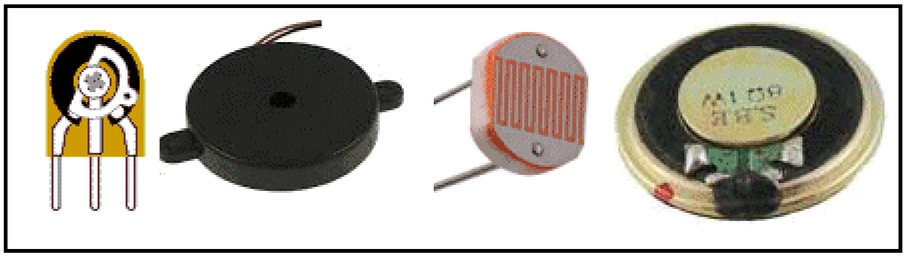

☐ mini trim pot
☐ Light Dependent Resistor
☐ piezo
☐ speaker help

28. What is 1,000p?

☐ 0.01n
☐ 0.0001u
☐ 0.1n
☐ 1n help

29. The current in a circuit is 45mA. This is:

☐ 0.045Amp
☐ 0.00045A
☐ 0.0045A
☐ 0.45A help

30. A 100n capacitor can be expressed as:

☐ 0.1u u = microfarad
☐ 0.01u
☐ 0.001u
☐ none of the above help

31. 1mA is equal to:

☐ 0.001A
☐ 0.00001A
☐ 0.01A
☐ 0.1A help

32. 1,200mV is equal to:

☐ 12v
☐ 1.2v
☐ 0.12v
☐ 0.0012v help

33. The approximate current for a toy 3v motor is:

☐ 10mA
☐ 100mA to 300mA
☐ 1 amp

34. What is the resistance of this resistor:

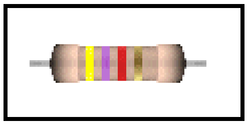

☐ 47k
☐ 4k7
☐ 4R7

35. Identify the correctly connected LED:

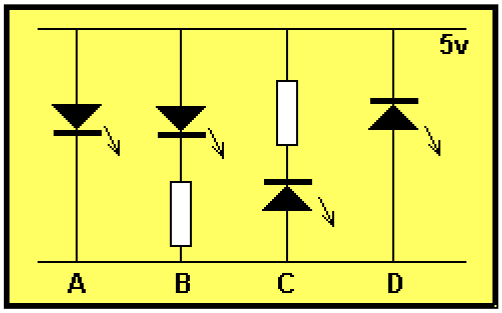

☐ A
☐ B
☐ C
☐ D help

36. Identify the correct statement:

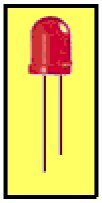

☐ The cathode lead is longer. It goes to the negative rail
☐ The cathode lead is shorter. It goes to the negative rail
☐ The cathode lead is shorter. It goes to the positive rail
☐ The cathode lead is longer. It goes to the positive rail help

37. The current requirement of a LED is:

☐ 1.7mA
☐ 25mA
☐ Between 3 and 35mA
☐ 65mA help

38. The multimeter is measuring . . .

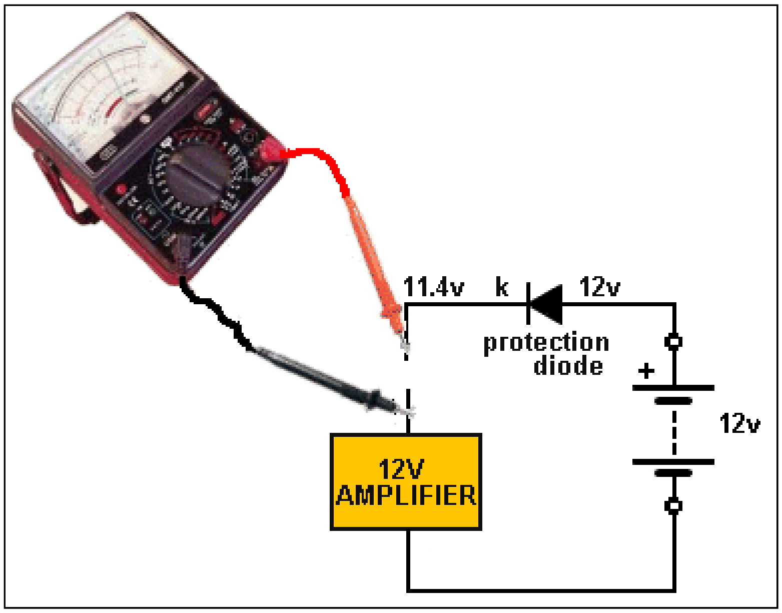

☐ Voltage
☐ Current
☐ Resistance

39. The purpose of the two capacitors:

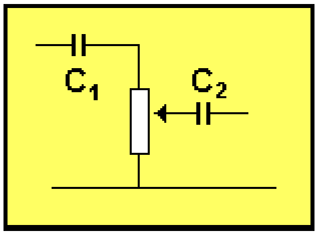

☐ To pass AC from the input to the output
☐ To allow the signal to oscillate
☐ To pass DC from the input to the output
☐ To amplify the signal help

40. The direction of conduction for a diode is:

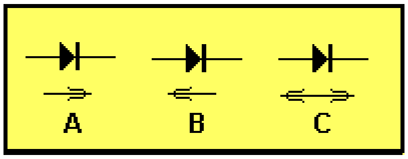

☐ A
☐ B
☐ C help

41. A DC voltage . . .

☐ rises and falls
☐ is a sinewave
☐ remains constant
☐ is an audio waveform help

42. Arrange these in ascending order: k, R, M (as applied to resistor values)

☐ R, k, M
☐ M, R, k
☐ k, M, R
☐ M, k, R help

43. A battery produces AC current:

☐ true
☐ false

44. The tolerance bands: gold, silver, represent:

☐ 5%, 10%
☐ 10%, 5% help

45. 223 on a capacitor represents:

☐ 0.022u u = microfarad
☐ 22n n = nanofarad
☐ 22,000p p = picofarad
☐ All of the above help

46. Arrange these in ascending order: n, p, u (as applied to capacitor values)

☐ p, u, n,
☐ n, u, p
☐ p, n, u help

47. What is the resistance of this resistor:

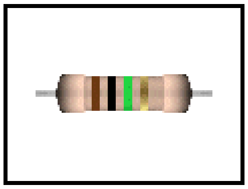

☐ 100k
☐ 1k
☐ 1M
☐ 100R

48. The number "104" on a capacitor indicates:

☐ 0.1u
☐ 100n
☐ 1n
☐ 10n help

49. What is the multimeter detecting:

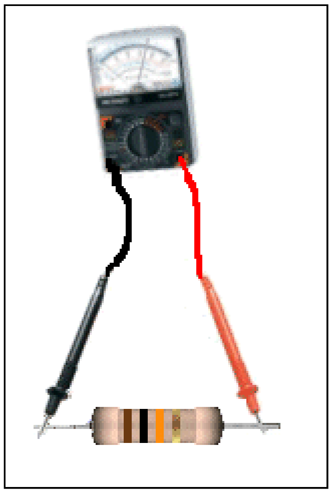

☐ Voltage
☐ Current
☐ Resistance

50. For the LEDs, what is the characteristic voltage for the red and white LEDs:

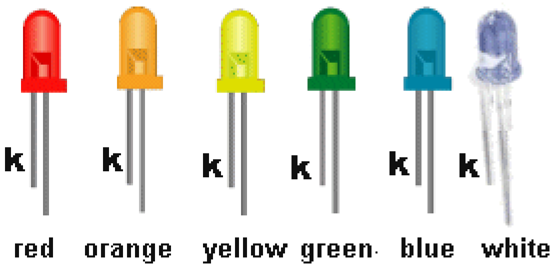

☐ 3.6v, 1.7v
☐ 2.4v, 3.3v
☐ 1.7v, 3.6v

☐ Cannot be determined

Final Assessment

THE CRYSTAL-SET RADIO

100 more Crystal Set plans

Everyone wants to make a RADIO.

The simplest radio is a **CRYSTAL SET**. (Sometimes called a **Crystal-Set Radio** or **Xtal Radio Set** or **Crystal Diode Radio**.)

However a **Crystal Set** needs a number of components that are very hard to get: (tuning capacitor with knob) and (crystal earpiece for $1.25).
The "air" TUNING CAPACITOR (20p to 415p) is not easily available and the postage is expensive. The germanium diode is a special component and the aerial coil wound on a ferrite slab is difficult to obtain.

But you don't need these components. They can be substituted.

There are hundreds of websites on the internet describing the **CRYSTAL SET** and if you want to build a "normal" set, you can Google these sites or **100 more Crystal Set plans**. Many of them sell kits too.

But this article is different.

We are going to have all the fun of making a **CRYSTAL SET** but with modern components and easy-to-make components and with an amplifier stage. The output is loud so you don't need a long antenna. And we are going to make our own TUNING CAPACITOR and a very simple aerial coil (called a FRAME AERIAL) as well as replacements for the germanium diode (use a TRF radio IC or a transistor) and in place of hi-impedance headphones (use a piezo diaphragm) and a crystal earpiece equivalent (a piezo diaphragm).
It's even better to have one of each type of component so you can compare the performance, so no matter how many parts your get, nothing will be wasted.

We are also going to explain the fundaments of how the circuit works as even the simplest circuit has a number of very important features that are used in many other circuits.

But first we are going to learn about the components and how they combine to make the circuit work.
When two or more components are connected together they sometimes produce a completely different result to the capabilities of either item.
This is the case with a capacitor and inductor in parallel. An inductor is simply a coil - turns of wire on a cardboard tube - called a former and the centre of the coil is AIR. It is called an air-cored coil or air-cored inductor.
Each component (the coil and capacitor) is called a PASSIVE DEVICE - in other words it does not amplify, but when the are connected together they create a result very near to amplification. And they also produce a result of picking up a huge number of signals and only allowing one signal to appear across the pair. A truly amazing result.

We start by placing a capacitor across the coil.
There is so much activity in the air, from radio, TV, taxi and mobile phone usage that the air is filled with electromagnetic radiation.
This radiation will cut the turns of the inductor (the coil) and produce a microscopic voltage in the turns. This is enough to start the two components passing energy back and forth at a rate

determined by their values. This is the basis of our first discussion.
These two components are called a TUNED CIRCUIT and make up our first building block called THE FRONT END.
.

THE FRONT END

This consists of a coil and capacitor. These two components are in PARALLEL and the signal (called the RADIO SIGNAL or RADIO WAVE) passes through the centre of the coil and produces a voltage in the turns of the coil. The electromagnetic wave has to pass through the centre of the coil.
This voltage is the result of a mass of signals that are interfering with each other and producing a signal called BACKGROUND NOISE.
The voltage can be increased by an external aerial (called an ANTENNA) and it consists of ALL THE LOCAL radio stations (and everything else).
The voltage is a mass of signals and is absolutely useless as it represents all the stations AT THE SAME TIME.
However, across the coil is a capacitor and these signals charge the capacitor with the very small voltage produced by the energy of the signals. When the capacitor is charged, it delivers its voltage to the coil. The coil accepts the energy and converts it to magnetic flux.
After a very short period of time the capacitor becomes discharged and the magnetic flux collapses and produces a voltage in the coil of the opposite polarity to charge the capacitor again in the opposite direction.
These two components keep oscillating back and forth, using the tiny amount of energy from the stations.
There is a natural frequency for the capacitor and coil to pass energy back and forth and one of the stations will provide energy to assist this natural frequency.
When this happens, the amplitude of the signal increases and the signals from all the other stations cancel themselves out and only one signal (waveform) remains.
This signal is called the NATURAL FREQUENCY OF RESONANCE and it corresponds exactly to one of the radio stations.

The end result is a waveform that is the exact same frequency as one of the radio stations and when voice or music is played, the amplitude of the waveform increases and decreases. This will be the signal you hear in the earpiece or speaker.
It is called an AMPLITUDE MODULATED signal and that is where we get **AM RADIO** from.

Understanding the concept of a CAPACITOR and INDUCTOR in parallel is very important. They form a TUNED CIRCUIT that has a natural RESONANT FREQUENCY.
Here is a very similar analogy. You have a heavy metal ball on a long string attached to the gutter on your house - just like a pendulum. You can push the ball very lightly with a finger and after a number of pushes you will be able to get the heavy ball swinging in a very large arc.
The only way to keep it swinging is to push it very lightly at exactly the right time. If you push it at the wrong time it will eventually stop swinging.
The parallel tuned circuit is exactly like the ball. It wants to oscillate at a particular frequency.
All the radio stations are pushing and pulling the circuit at the wrong times and nothing is happening. But one radio station pushes at exactly the right time and the circuit starts to oscillate.
All the other stations are fighting each other just like one person pushing the ball sideways and another pushing the ball from the opposite side. The results cancel each other and you are the only one assisting the swing.
The TUNED CIRCUIT can also be called a FILTER with a very narrow BAND-PASS frequency but our simple explanation describes the operation much more clearly.

There are a few other terms used to describe the components in the font end:

LOOP STICK ANTENNA -This is an alternate name given to the coil of wire wound on a ferrite rod or slab. It also has the name ROD ANTENNA or FERRITE ROD ANTENNA.
The winding can be enamelled wire or flexible wire called LITZ WIRE. This is very fine strands of enamelled wire twisted together and covered in cotton. The purpose of changing a thick wire to lots of very thin wires is to prevent the radio signals creating loops of signals within the wire and these signals will cancel each other and not produce a signal out the end of the wire.
In our experiments, we have not noticed any difference in a coil made with ordinary enamelled wire and Litz wire.

Here is a set of components to make your own Crystal set from **Scott's Electronic Parts**:
You can see the rod antenna, germanium diode, crystal earpiece, capacitor and resistor. The kit costs about $9.00 plus postage and includes knob, clips and screws but no board to mount the parts.

Here is the circuit for a Crystal Set:

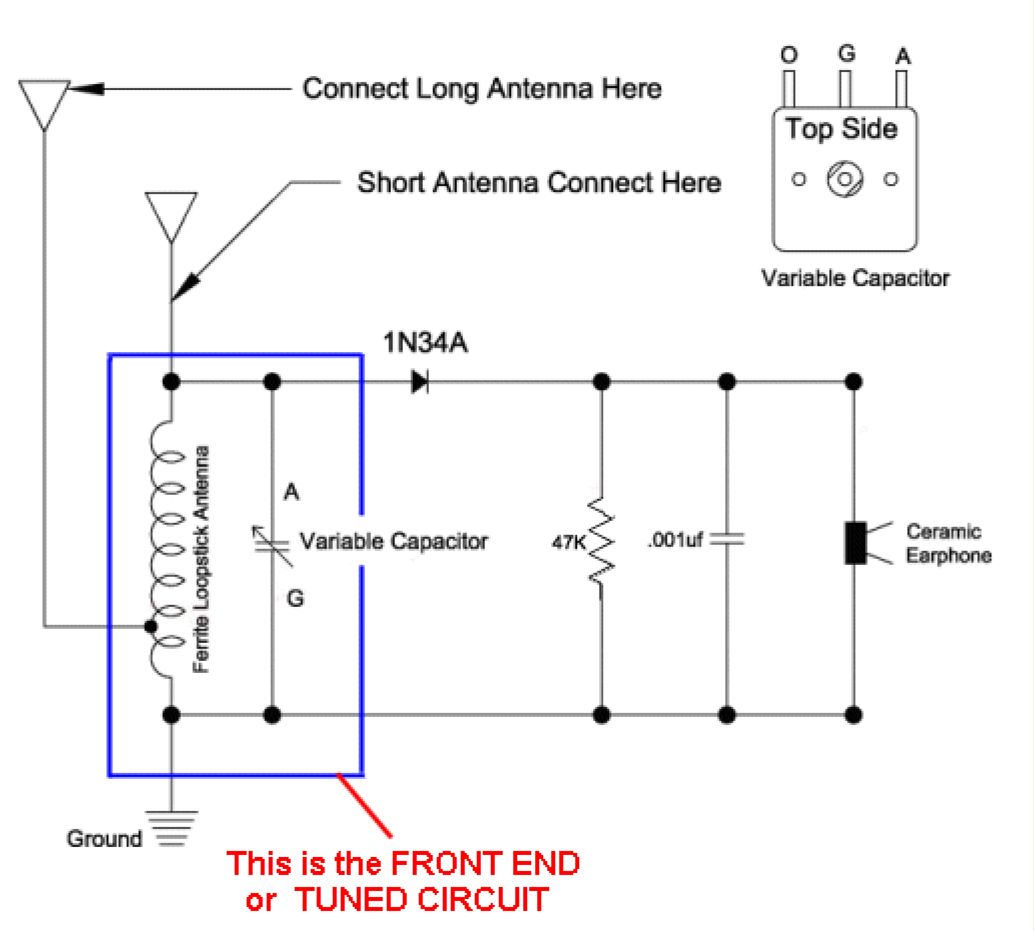
Connect Long Antenna Here
Short Antenna Connect Here
O
G
A
Top Side
Variable Capacitor
1N34A
Ferrite Loopstick Antenna
A
Variable Capacitor
G
47K
.001uf
Ceramic
Earphone
Ground
This is the FRONT END
or TUNED CIRCUIT

Here are the components mounted on a board called BREADBOARD:

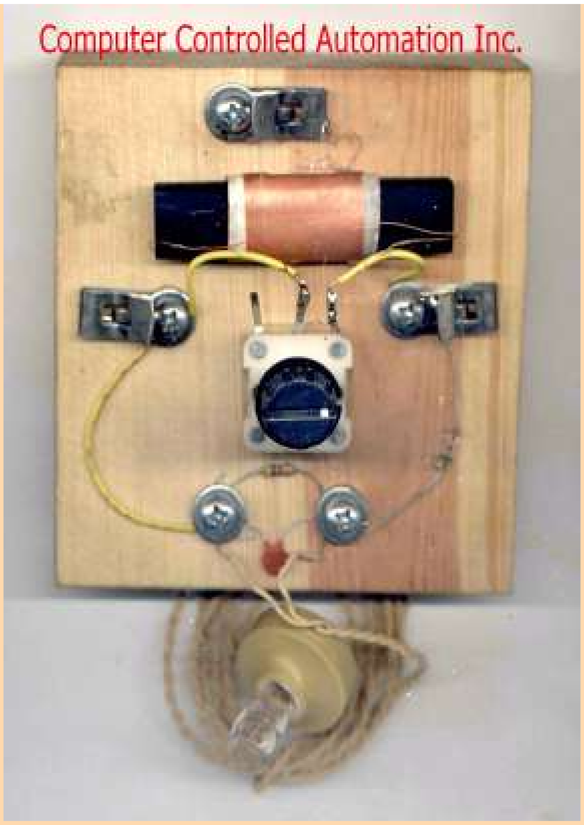

The top clip connects to a long antenna. The left clip connects to ground and the right clip connects to a short antenna.

Let me clear up a point. You do not need a ferrite rod antenna for the coil. You can use an ordinary coil wound on a cardboard tube and it will work just as well if you are using an outside antenna.
Here is the circuit using a home-made coil.

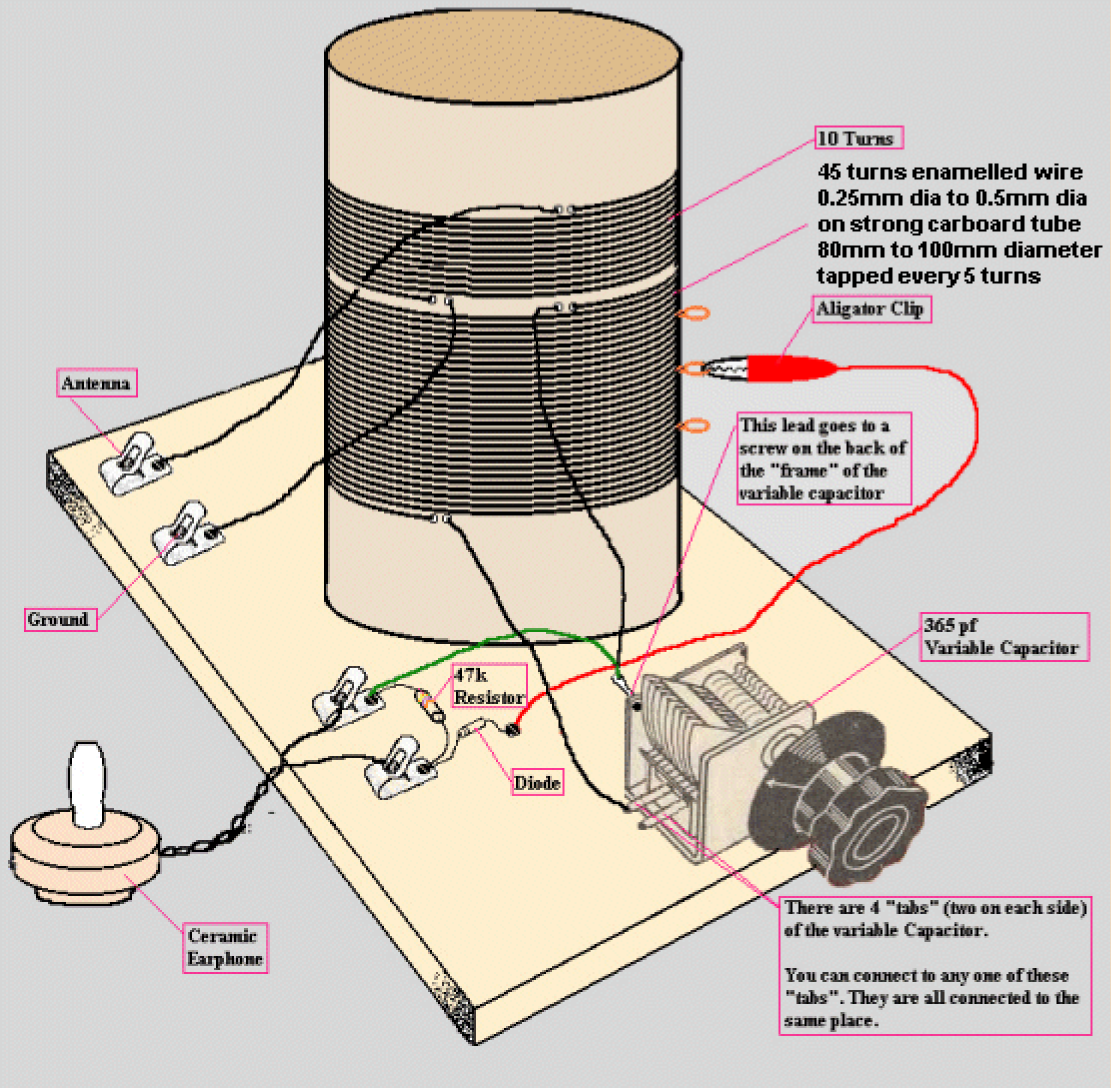
10 Turns
45 turns enamelled wire
0.25mm dia to 0.5mm dia
on strong carboard tube
80mm to 100mm diameter
tapped every 5 turns
Aligator Clip
Antenna
This lead goes to a screw on the back of the "frame" of the variable capacitor
Ground
365 pf Variable Capacitor
47k Resistor
Diode
Ceramic Earphone
There are 4 "tabs" (two on each side) of the variable Capacitor.
You can connect to any one of these "tabs". They are all connected to the same place.

**The tappings on the coil allow a wide band of radio stations to be tuned.
Each tapping allows a different portion of the band to be covered.**

The next part to understand is this:
The coil and capacitor must not be LOADED. In other words, you cannot connect anything to this combination because the signal it is producing will be "taken away" or "removed" or "considerably reduced" by the item you are connecting to the circuit.
These two components are called a TUNED CIRCUIT and when they are not loaded they pick up all the radio stations, one station at a time, when the natural resonant frequency of the coil and capacitor exactly match the frequency of the radio station. The circuit actually "rejects" all the radio stations except one. Because all the other stations are trying to make the Tuned Circuit oscillate at a different frequency and it does not do this.
The result of the TUNED CIRCUIT oscillating under NO LOAD conditions produces a waveform that is very high and this gives the circuit GOOD SELECTIVITY. The circuit can select one station and reject nearby stations.
It also has good SENSITIVITY as it can pick up weak stations.
If you load the circuit, only the strongest signal will be detected and it will be spread across the full range of the tuning capacitor.
Obviously the theory is more-complex but we are explaining the end-result.
Theory talks about the "Q" value of the coil and this is its ability to produce a very good output when the magnetic flux collapses and the "Q" value increases when the circuit is not loaded. .
Although these voltages are very small (in the order of microvolts or millivolts) the result is very important as the rest of the circuit will be amplifying this waveform a few thousand times.
As we explained above, pushing the weight on a string only needs a push of 1 cm and eventually the weight will swing 1 metre. This is a gain of 100:1 The same thing happens with the tuned circuit. The incoming radio signal is in the order of microvolts, but the coil and capacitor will produce a signal as high as 500 millivolts. This is an improvement or "gain" of more than 1,000 and is referred to as the "Q" of the circuit.
You will also notice the TUNED CIRCUIT is not connected to any supply voltage. It does not have

be connected. It generates its own waveform from the signals in the air.
It should not have any DC current flowing through it via the supply as this would put a load on the circuit and reduce its operation.

However we must "pick-off" the signal so it can be amplified.
This must be done with a very high impedance circuit.

THE CONVERTER (detector) - THE DIODE

The next part of the circuit is the CONVERTER. Commonly called the DETECTOR.
It converts the RADIO FREQUENCY signal to an AUDIO FREQUENCY signal.
This is the job of the DIODE.
The radio frequency signal is a very high frequency signal (say one million cycles per second) and it is sending a tone of one thousand cycles per second through the air-waves.
What is happening is this: The one megahertz signal has a certain amplitude and over a range of the first one-thousand cycles, the amplitude gradually decreases and then increases again. If you look at the tops of this 1,000 cycles you will see a waveform that corresponds to the one kilo-Hertz signal.
The 1MHz signal is picked up by the coil and capacitor in the front end and makes it oscillate.
The radio frequency signal is gradually getting larger over 500 cycles then smaller over the next 500 cycles and this increase and decrease represents the 1,000 cycles per second tone.
This is the waveform (the signal) that passes through the diode. This will be explained further in a moment.
The diode does not pass any signals less than 200mV as the first 200mV is lost in the junction of the diode. This means the signals start to appear on the other end of the diode when they are above 200mV.

This is how the diode works:
Across the crystal earpiece is a capacitor. The capacitor gets charged via the diode.
The diode is present to stop the capacitor getting discharged when the waveform is in the wrong direction. (by this we mean - when the waveform is lower or smaller in amplitude than the voltage on the capacitor).
And the waveform is in the wrong direction about 50% of the time. To charge the capacitor for one-half-cycle requires 500 "little increments" in voltage with each increment adding a microscopic increase in voltage. We don't want this voltage to reduce when the waveform is reversing direction and the diode stops the voltage flowing back to the Tuned Circuit.
During the next half of the cycle when the pulses are getting smaller and smaller, the voltage on the capacitor is "bled off" by the load resistor.
The crystal earpiece detects this voltage. What we mean, is the diode allows the voltage to rise (increase) on the capacitor via lots of little "pulses" and the voltage increases in the form of a sinewave to a maximum amount. This voltage is passed to the crystal earpiece.
Once the voltage rises to a maximum, the little pulses of energy are not quite as strong, and the voltage on the capacitor reduces to form the second portion of the sinewave. This voltage is always being passed to the crystal earpiece and you can hear it as an audio signal.

GERMANIUM OR SILICON DIODE

The preferred type of diode for a Crystal Set is germanium. This is because it drops only about 0.3v.
But a silicon diode can be used, even though it drops about 0.7v, if the radio stations are very loud (close by).
You have to remember, you need a very good aerial (and a water-pipe earth) to get any results with a Crystal Set because you are asking the signal to provide the energy to drive the earpiece.
By simply adding a transistor, you are improving the performance 100 times and the long antenna can be reduced to a FRAME ANTENNA and the earth can be the metal frame of your soldering iron.

THE EARPIECE or EARPHONE
also The Magnetic Earpiece or CRYSTAL EARPIECE

The earphone or earpiece used in a Crystal Set must be a high impedance device because the crystal set does not produce a high current and cannot drive a low-impedance earpiece. That's why a CRYSTAL EARPIECE is ideal.
It has a crystal glued to the back of the earpiece and connected to its top surface is an aluminium diaphragm. When the crystal expands and contracts as a result of a voltage applied via two electrodes, the diaphragm moves and you can hear the signal. It exhibits a very high impedance

because it consists of a crystal and no coil of wire is contained inside the case.
If you do not have a Crystal Earpiece, you can make your own from the shell of an 8 ohm earpiece and a piezo diaphragm. Only the front part of the earpiece is used.

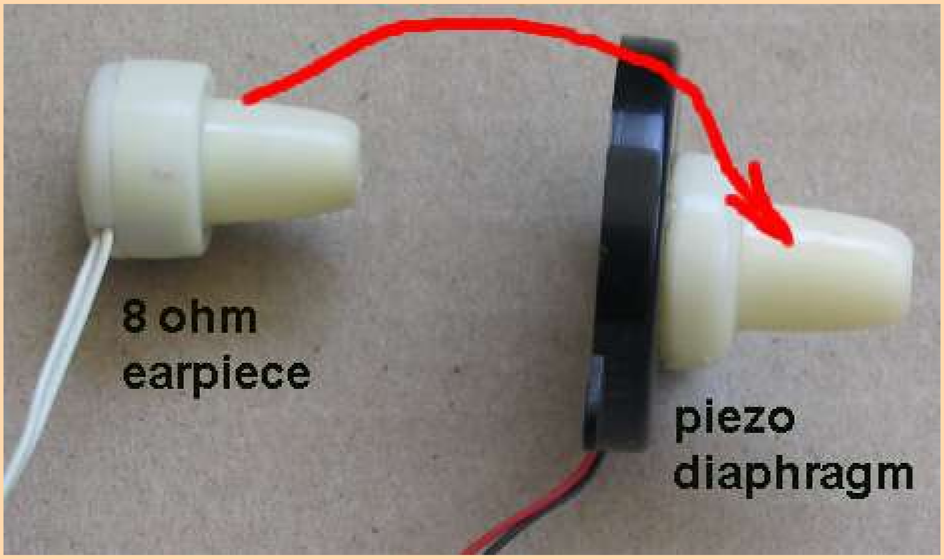

Make your own Crystal Earpiece

Hit the 8 ohm earpiece on the side and the front comes off. Glue the front onto a piezo diaphragm with hot-melt glue. See photo above.
The piezo diaphragm is a ceramic substrate that deflects in the presence of a voltage. It is quite sensitive and you can hear the audio quite clearly.
The waveform emerging from the diode in a Crystal Set is called AUDIO and although it has an amplitude of a few hundred millivolts, it does not have any current associated with it. The crystal earpiece and the piezo diaphragm react to this voltage.

THE 8ohm EARPIECE

The 8 ohm earpiece can be used with our 8ohm Buffer stage shown below.

16ohm 32 ohm and 64 ohm EARPIECE(s)

Earpieces and headsets from mobile phones are 16 ohm or 32 ohm per earpiece and are terminated via a stereo 2.5mm or 3.5mm plug. The earpieces are connected in SERIES to get the best coupling to our radio circuits and you need to find the two pins on a stereo socket to produce series connection. Get a multimeter and switch to "ohms." Try all the pins and you will get a click in the left ear then the right ear. Keep searching until you get a click in both earpieces at the same time. Use these two pins.

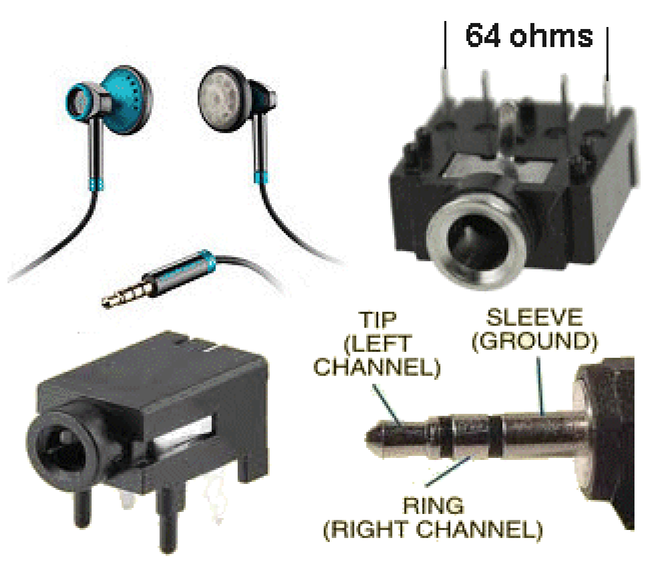

Stereo mobile phone headset - unusually 32R or 64R

PROBLEMS

The biggest problem with a Crystal Set is the need for a long antenna.
The first 200mV to 300mV of a signal is lost in the diode and you need a long antenna to pick up a signal so the output of the TUNED CIRCUIT has enough voltage to drive the high-impedance earpiece.
This requires an outside aerial 5 metres long and 3 metres high.
This is not practical for most hobbyists so we will be adding an amplifying stage to the crystal set so a shorter (smaller) aerial can be used.

THE FRAME AERIAL or FRAME ANTENNA or FRAME COIL

The aerial coil shown in the photo above is a ferrite slab with about 80 turns of Litz wire. You can find one of these in an old broken AM radio or from a parts-shop. In the instructions below we show how to make your own Ferrite Rod Antenna
An equally-good substitute is a frame antenna made by winding insulated wire in a rectangle around wooden sticks.

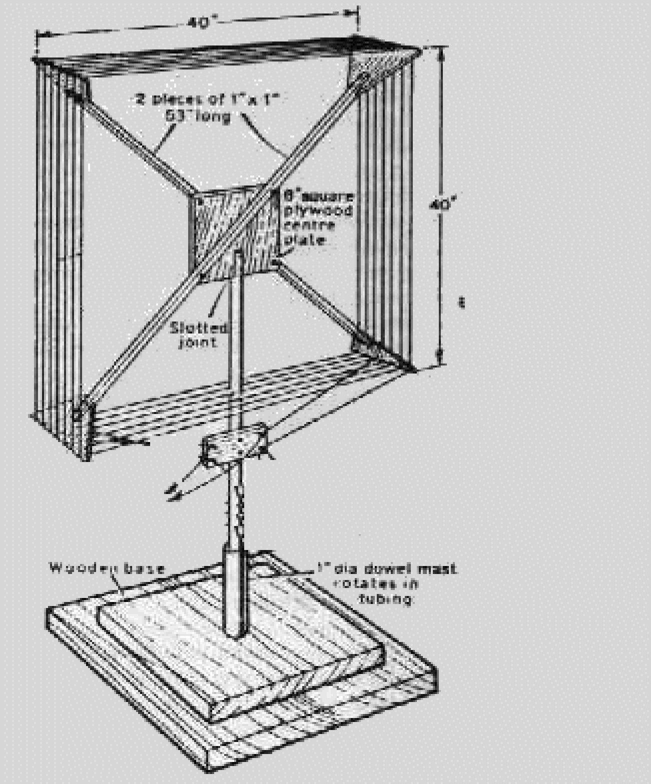
40"
2 pieces of 1" x 1" 53" long
8" square plywood centre plate
40"
Slotted joint
Wooden base
1" dia dowel mast rotates in tubing

FRAME ANTENNA

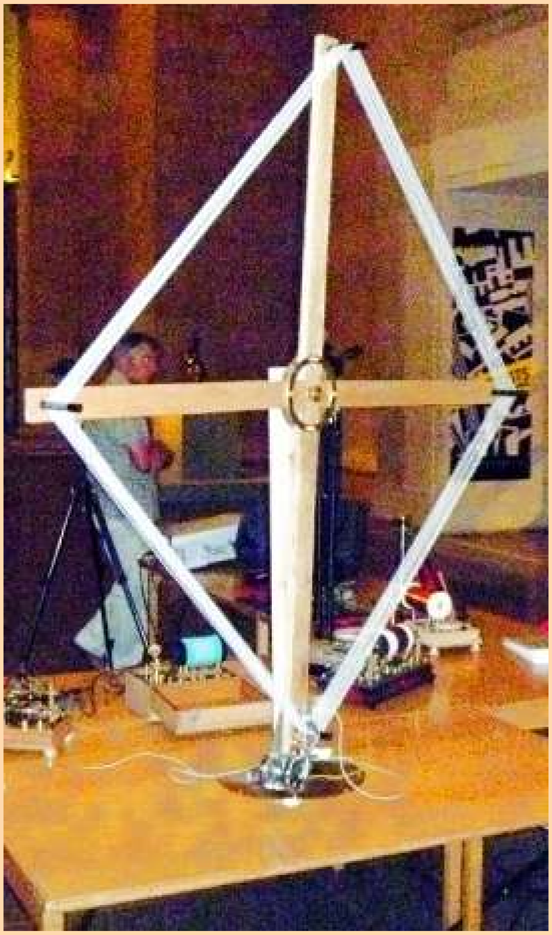

15 turns on a diamond frame

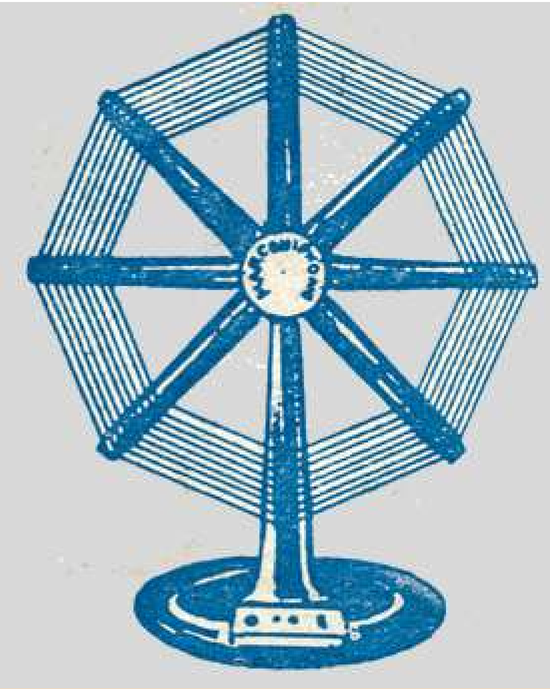

One of the earliest Frame Antennas

The Frame Aerial can be as large as 100cm x 100cm or as small as 10cm x 10cm around a plastic chocolate box.

Here are two FRAME ANTENNAS:

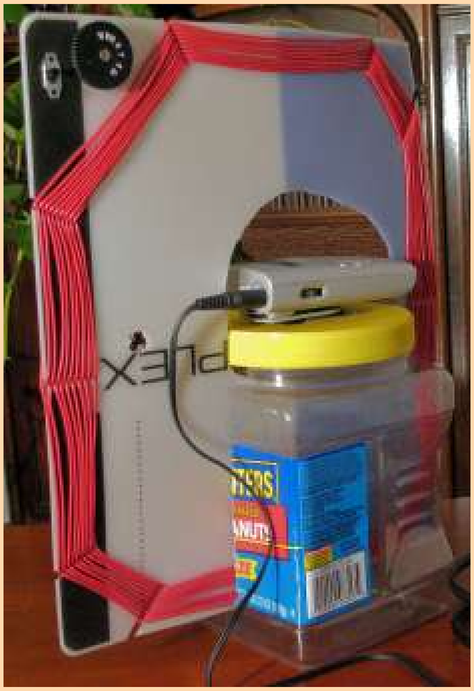

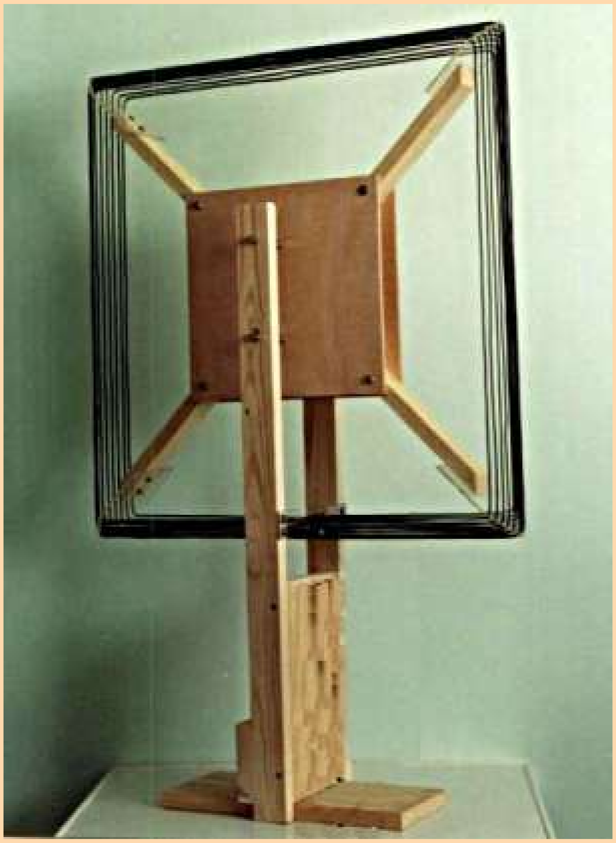

This will work just as good as a ferrite slab antenna. The slab antenna is just 100 times smaller. The slab antenna was invented so a transistor radio could be built in a small case. But if it is not available, you can wind 20 turns around a plastic chocolate box and it will work just as good.

Alternately you can wind 20 turns around a biscuit tin. Put a pencil on the tin and wind the turns over the pencil too. Remove the pencil and it will be easy to remove the turns. Use tape to keep the turns together.

The FRAME AERIAL does two things. It picks up the radio waves and it becomes the coil (called the INDUCTOR) in the TUNED CIRCUIT. It must be placed away from metal objects, such as a refrigerator.

BASKET WEAVE COIL

There is no point making a complex BASKET WEAVE COIL as it will not work any better than simply jumble winding all the turns at the maximum circumference of the coil, because the energy capturing capability of the coil relies entirely on the amount of flux lines passing through the centre of the coil.
By increasing the centre of the coil, the amount of flux is increased for the same coil size.
In fact, the simplest and cheapest is to wind turns around a box, as explained later in this article, or make a frame antenna as shown above. Technically speaking, a round coil has the best performance but only by a few percent.

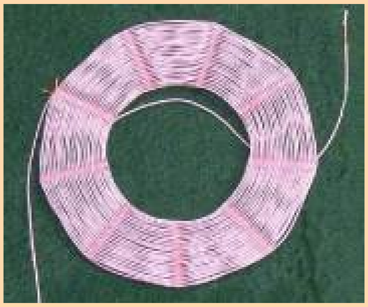

A BASKET WEAVE COIL

THE VARIABLE INDUCTANCE TUNING COIL

Whenever the size or shape of the coil is changed, (or the number of turns), the natural frequency of the Tuned Circuit will change and a different radio station will be picked up.
This means tuning across the band can be done by altering the characteristics of the coil while keeping the value of the capacitor fixed.
Changing the inductance can be done in many different ways.
The coil can have taps every 5 turns and an alligator clips selects the correct tap. But very few radio stations will correspond exactly to each tap.
Another way is to have a slider move up and down the turns as shown in the following image:

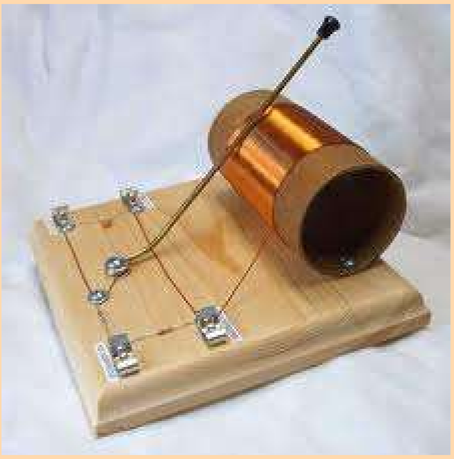

The slider makes contact where the insulation has been removed. But it may touch two turns at the same time and create a "shorted turn" and reduce the "Q" of the coil.

Another way is to move a ferrite bar (rod) in and out of the coil:

THE SLUG TUNED COIL

To tune across the radio band, the natural frequency of oscillation of the TUNED CIRCUIT must be adjusted (changed). This can be done by changing the value of the capacitor or the value of the inductor.

The value of the inductor can be changed by adding or removing turns or changing the amount of magnetic material in the centre of the coil.
A ferrite bar can be screwed in and out of the coil or slid in and out and this component is called a **SLUG TUNED COIL**.
The following diagram shows a **SLUG TUNED CRYSTAL SET**:

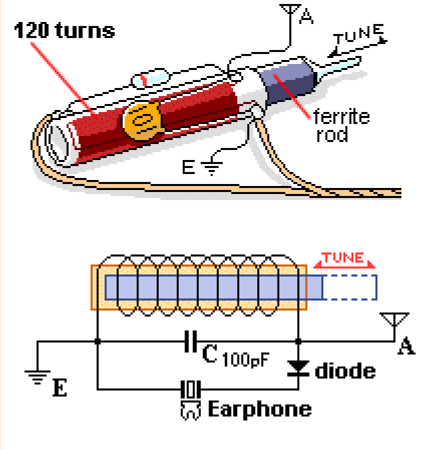
120 turns
A
TUNE
ferrite rod
E
TUNE
A
C 100pF
diode
E
Earphone

By changing the value of the 100p capacitor, different parts of the band can be picked up.

The photo shows a slug tuned coil using 60 turns of insulated wire on a 10mm tube (or any tube that will fit over a 8-10mm ferrite rod) and a circuit containing an AM radio chip plus a buffer driver transistor:

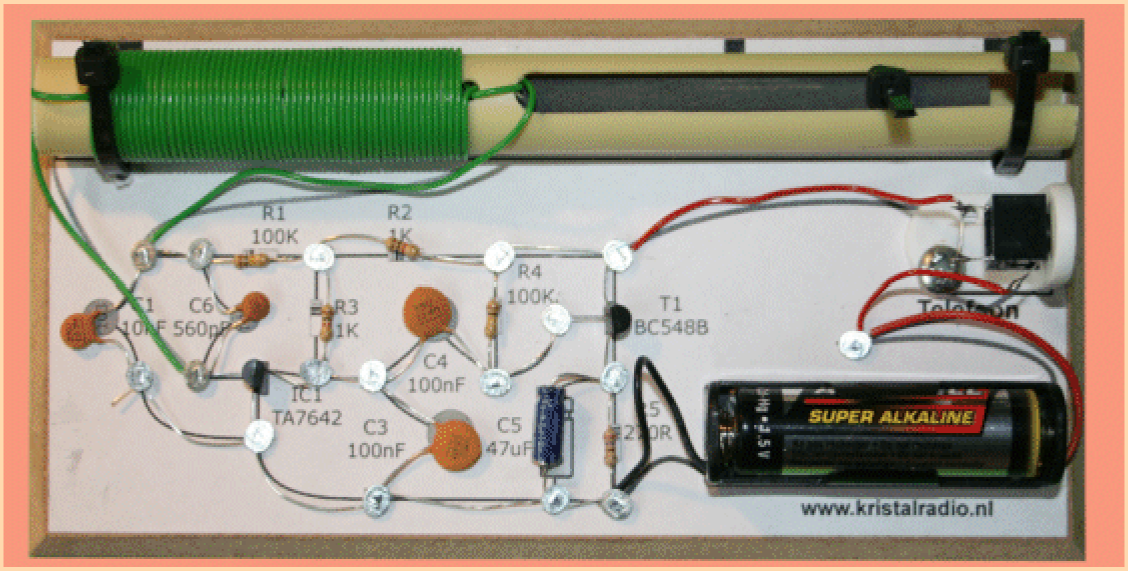
R1
100K
R2
1K
R4
100K
C6
560pF
R3
1K
C4
100nF
IC1
TA7642
C3
100nF
C5
47uF
T1
BC548B
Telefoon
SUPER ALKALINE
www.kristalradio.nl

A SLUG-TUNED RADIO

The circuit above is has a broad-band amplifier consisting of 10 transistors (IC1) and they are directly coupled (connected) to each other because it is not possible to "manufacture" a capacitor inside the IC. The IC has 3 terminals (pins, legs) and it looks like an ordinary transistor.
Experimenting with this type of IC has shown that it is no better than 2 ordinary transistors connected in a direct-coupling arrangement.

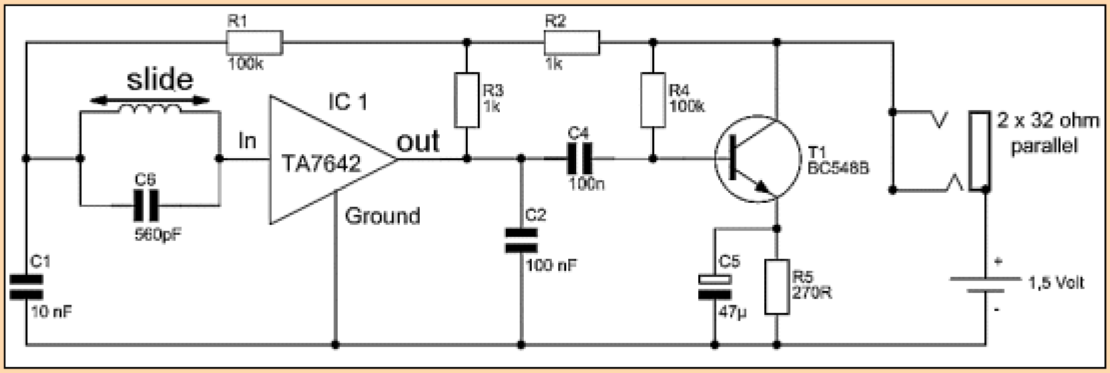
R1
100k
slide
IC 1
In
TA7642
out
Ground
C6
560pF
C1
10 nF
R3
1k
R2
1k
C4
100n
C2
100 nF
R4
100k
T1
BC548B
C5
47µ
R5
270R
2 x 32 ohm
parallel
+
1,5 Volt
-

Here is the address of the site for the slug-tuned radio.
http://www.kristalradio.nl/
Unfortunately the site is in Dutch and the kit is not available. However the photos give a clear picture of the how the parts are connected.

The inductance of the coil can also be altered by winding another coil and placing it near the first coil so that the magnetic field interacts with each other and changes the inductance of the circuit. This is called a VARIABLE INDUCTANCE TUNING COIL.
You can have one coil inside the other, two coils near each other or two flat coils side-by-side. Any two coils will interact with each other.

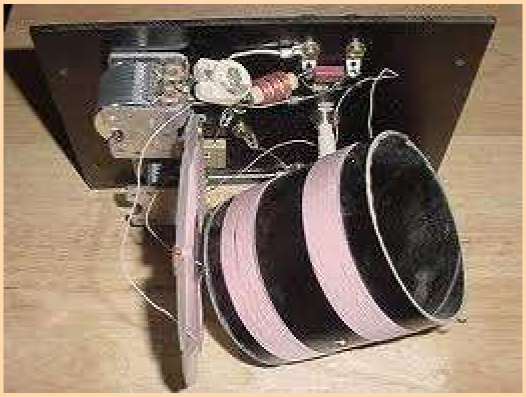

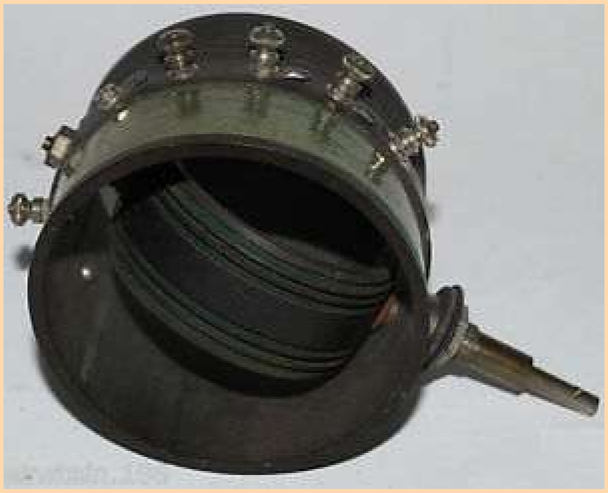

An Inductive TUNING COIL called a VARIOMETER

MAKING YOUR OWN FERRITE ROD ANTENNA

You can make your own FERRITE ROD ANTENNA by winding 60 to 80 turns of 0.25mm enamelled wire onto a 9mm ferrite rod or slab. If you wind it on a paper sleeve, you can move the coil along the rod to get the best performance. When the rod is slid out of the coil, the inductance changes considerably. However the inductance does change very slightly when the coil is moved along the rod.

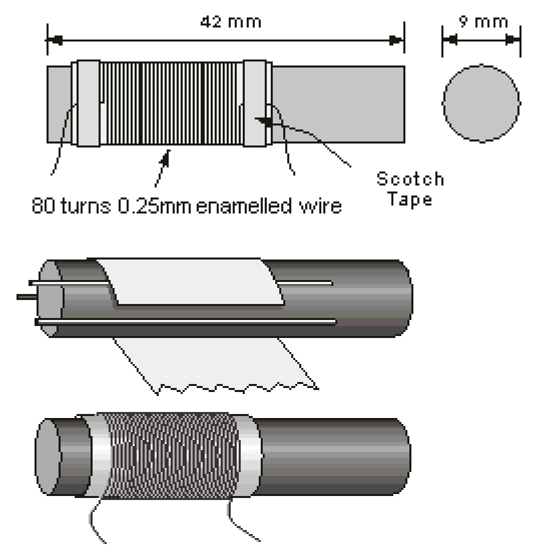

Make your own ferrite antenna

Now we come to the tuning capacitor::

THE TUNING CAPACITOR

The "C" in the "LC" TUNED CIRCUIT can be fixed or variable. When it is variable, it is called a TUNING CAPACITOR. The sheets of aluminium in the air tuning capacitor below are called PLATES and the moving plates are called VANES. The fixed plates make up the STATOR.
The space between the plates is AIR. The photo shows a single capacitor. If two capacitors are connected to the same shaft it is called a GANGED CAPACITOR.
The plates do not come fully out of mesh and that's why the capacitor has a minimum value. The maximum capacitance is when the plates are fully meshed. The odd shape of the plates is designed to produce a fairly constant increase in capacitance as the plates are engaged.

An air tuning capacitor:

**Air Tuning Capacitor
(Variable Capacitor)**

The capacitor can be made much smaller by using thinner vanes and placing plastic between the vanes. Plastic increases the capacitance about 3 times to 10 times.

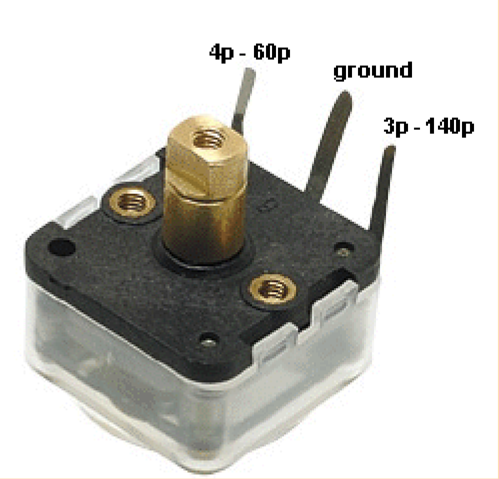

Tuning Capacitor as found in a pocket radio

The tuning capacitor can be replaced with a home-made equivalent that will work just the same.
You need:
4 sheets of aluminium foil (cooking foil) 10cm x 10cm.
4 sheets of thin cardboard 15cm x 20cm (cut A4 sheets in half).

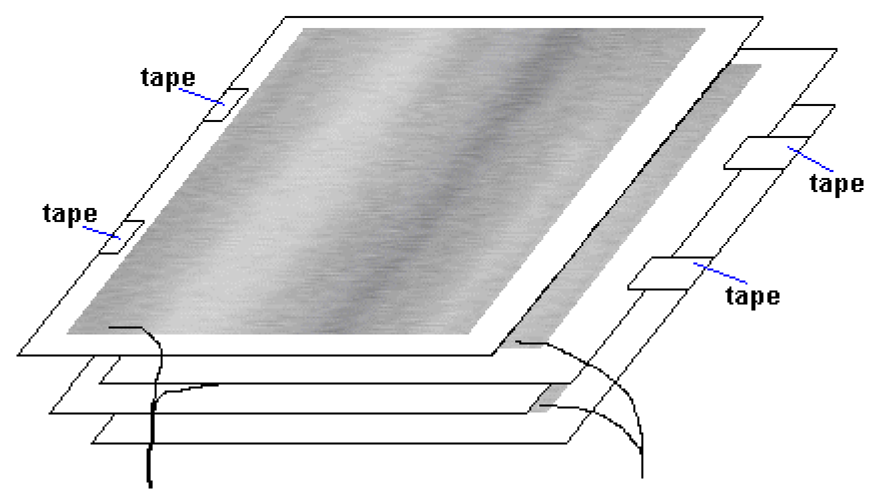

HOME-MADE CAPACITOR

Tape a sheet of aluminium foil to each sheet of cardboard with sticky-tape around all 4 sides. Take one strand of wire from a length of hook-up flex and sticky-tape the end to each sheet of aluminium to make good contact. Place 2 sheets on top of each other and move the top sheet slightly to the left and sticky-tape the edge so they don't move. Do this with the other two sheets but move the top sheet to the right. Now interleave the sets. Connect the wire from the first sheet to the third sheet. Connect the wire from the second sheet to the fourth sheet.
The cardboard (or paper) between the aluminium sheets increases the capacitance three times. The capacitance decreases when the sheets are moved apart and the capacitance increases when the sheets are moved in. The capacitance also INCREASES when the sheets are squashed together such as when a book is placed on them.
You can also make a smaller capacitor by making each sheet smaller and using 6 sheets. You can then add a 100p or 220p in parallel with the home-made capacitor, to select the lower part of the band.

EACH CIRCUIT

Each circuit we describe in the following set of circuits is an improvement or advancement on the previous. We also offer a number of different types of aerial coils, amplifying stages and earphones. Some of the circuits use easy-to-obtain components and home-made equivalents for hard-to-get items. There will be something in this section for everyone to build.

In all radio circuits you will encounter **TWO MAIN PROBLEMS**:

If the FRONT END (the Coil and Capacitor) is loaded too much by the "pick-off" of the amplifying stages, you will only get one station.
If you get squealing or "motor-boating," try a different circuit and layout as the components you are using, plus the voltage of the battery, will need changing.
You cannot always increase the voltage of the supply and get a louder output. Sometimes the increased voltage will stop the circuit working or it may introduce too much gain that the circuit starts to squeal.
The Radio IC (ZN414) DOES NOT WORK on a voltage above 1.5v and some of the transistor circuits completely stop working with a higher voltage. This has to do with the biasing arrangements and if the circuit is designed for a low voltage, you need to keep to the suggested voltage and experiment with a slight increase in voltage and see what happens.
Building a radio is not easy as the enormous amount of amplification of the combined stages creates a feedback loop via the power rail that sets the circuit into oscillation. This effect gets worse with a higher supply voltage and we will explain this further with each of the circuits.

MAKING A CRYSTAL SET

You can buy a **CRYSTAL SET** kit (see the photo of the kit, above) or the individual components (a kit is the cheapest) or use the replacement for the **FERRITE ANTENNA COIL** (16 turns to 20 turns on a 150mm biscuit tin) and/or the **TUNING CAPACITOR** made from aluminium foil and cardboard sheets.
You will need an outside antenna and an earth (such as a water tap or the frame of your soldering iron) to pick up the radio stations.
If you cannot put up an outside antenna, you will need to add one or more amplifying stages and this will allow you to reduce the length of the antenna and increase the volume of the audio.

ADDING AMPLIFYING STAGES TO A CRYSTAL SET

You can add two different types of amplifying stages to a crystal set.
You can connect amplifying stage(s) to the FRONT END and these will be designed to put less load on the front end so the sensitivity and selectivity increases. These stages work at the frequency of the radio signal and they are called RF STAGES (Radio Frequency Stages).
You can build these stages out of individual components or use a chip called a RADIO CHIP or RADIO IC (integrated circuit) for less than $2.00.
The chip contains 5 stages of amplification and these are RF stages (or RF AMPLIFYING STAGES) and the concept is called TRF. (Tuned Radio Frequency).
It is not easy to get this type of amplifier working because the stages produce a very high overall gain and you get a lot of "motor-boating" and squealing if the gain is not controlled. The gain must be reduced when a strong signal is being passed through the circuit because a strong signal will produce a large output and this will be so large that some of the waveform will find its way to the front of the amplifier via the power rail and start to be amplified again. To prevent the output getting too large, the circuit has a negative feedback line - called the AGC line - Automatic Gain Control.
It would be very difficult to reproduce these 5 stages of amplification with discreet components and that's why it is best to use an IC.

The next stage is a DIODE to convert the RF (Radio Frequency) to AF (Audio Frequency). This can be done with the diode-characteristics of a base-emitter junction in a transistor and we will show the alternatives.

Any stages after the diode are AUDIO STAGES or AUDIO AMPLIFIER STAGES.
The main job of the AUDIO AMPLIFIER is to increase the DRIVE CAPABILITY.
In other words, increase the current capability of the circuit for an 8 ohm speaker or 8ohm earpiece (or 16 or 32 ohm).
This is a very difficult thing to do and requires at least 2 stages.
The LOAD you can put on a Crystal Set must be 10,000 ohms or higher. (if you put a lower resistance (impedance) on the output, you will load the FRONT END and reduce its ability to separate the stations.
That's why a crystal earpiece is normally used with a crystal set. It puts almost NO LOAD on the circuit.
If you put a load on the circuit the result will be only one or two stations across the whole dial and only the most powerful station will be received.

If you don't have a crystal earpiece, you will have to use an 8 ohm earpiece. This will require an IMPEDANCE CONVERTING CIRCUIT of 1,250:1
This is a simple way of saying we want the 8 ohm earpiece to appear as 10,000 ohms to the

crystal set.
To produce an overall gain of 1250, we need two stages of amplification.
If a transistor has a gain of 70, it will it will produce an impedance conversion of 70 times. This is a realistic value. Transistors with a gain of 200 will have a gain of about 70 when fitted to a circuit.
This means the other transistor needs to have a gain of about 20 and that is easy to achieve.

ADDING AMPLIFYING STAGES TO THE FRONT OF A CRYSTAL SET

Adding stages to the front of a crystal set are called RF STAGES (Radio Frequency Stages) because they amplify the RADIO STATION SIGNAL.
It does not matter if you amplify RF signals or AF signals. The result is the same.
The only difference is this: The frequency of RF signals is much higher (1,000 times higher) and the coupling capacitors can be much smaller.
This allows an RF amplifier to be built into an IC - called a Radio Chip.
One of the most popular Radio IC's is ZN414 or YS414. This chip has been copied by other manufacturers as: MK484, TA7642 and LMF501T.
All the chips are the same but the pinout is different.
These chips work on a 1.5v supply and if the voltage is increased above 1.5v, the gain of the stages increases to a point of total distortion.
To prevent strong signals producing distortion on 1.5v supply, the output is passed back to the input via a 150k resistor. This feedback line is called the AGC (Automatic Gain Control).
The chip contains 5 stages of amplification plus a stage that converts the RF signal to AF (Detector Stage). This means the signal diode in a Crystal Set is not needed.

Here is the circuit of the TA7642 Radio Chip. It performs the same as the ZN414 Radio Chip.

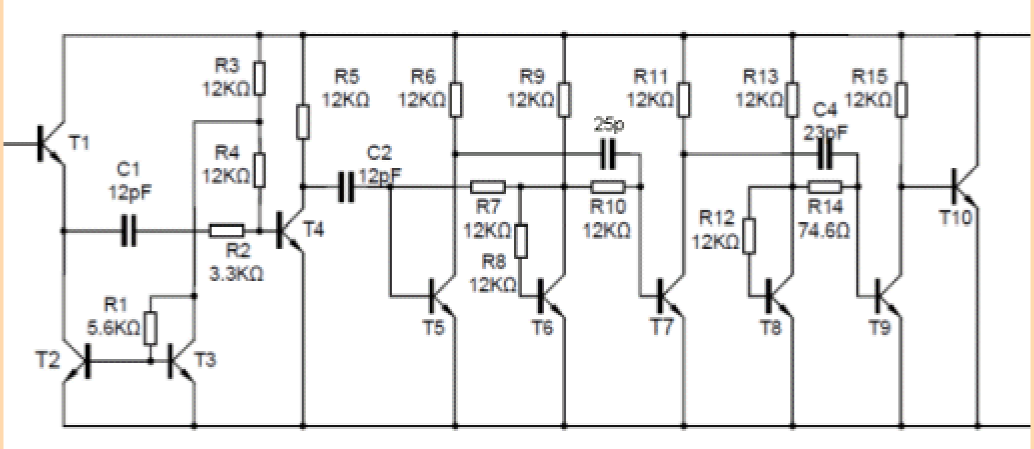
T1
C1
12pF
R3
12KΩ
R4
12KΩ
R2
3.3KΩ
R1
5.6KΩ
T2
T3
T4
R5
12KΩ
C2
12pF
R6
12KΩ
R7
12KΩ
R8
12KΩ
R9
12KΩ
25p
R10
12KΩ
R11
12KΩ
R12
12KΩ
R13
12KΩ
C4
23pF
R14
74.6Ω
R15
12KΩ
T5
T6
T7
T8
T9
T10

Here is the BLOCK DIAGRAM of the ZN414 Radio Chip:

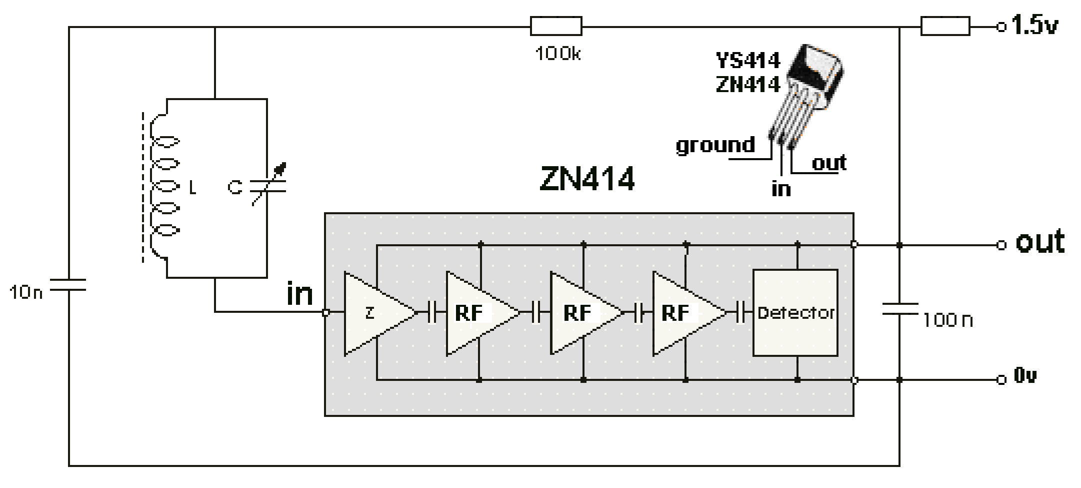
100k
1.5v
YS414
ZN414
ground
out
in
ZN414
L
C
10n
in
Z
RF
RF
RF
Detector
out
100n
0v

The ZN414 chip can be purchased from Talking Electronics for $1.00 plus postage

USING THE ZN414 RADIO IC

By using the ZN414 radio IC (or any if the equivalents) you can create a POCKET RADIO to drive a headphone or speaker.
But it is not easy to use the chip. The main problem is receiving the strong signals without producing distortion and then being able to pick up the weak stations.
A fixed 100k feedback resistor does not provide adequate control and a TRF radio has limited capabilities.
That's why radio manufacturers make SUPERHETRODYNE receivers. Even though they are more complex, the result is far superior.
However a simple TRF set can be made with the Radio IC and a few stages of audio amplification.

The following circuit uses just the Radio IC and a crystal earpiece or the home-made earpiece described above:
You can use a home-made FRAME ANTENNA or a home-made FERRITE ROD ANTENNA and a home-made VARIABLE CAPACITOR.

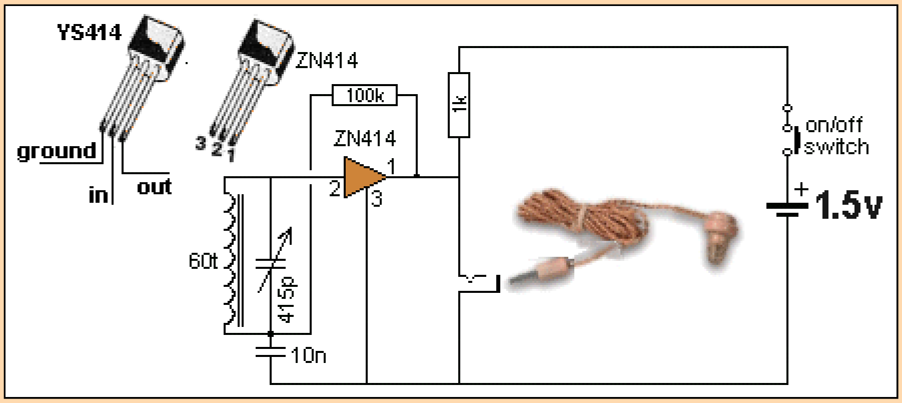

The Simplest ZN414 Radio

Connecting the ground (0v rail) to the frame of your soldering iron or a water tap will increase the output volume. The circuit above shows a Crystal Earpiece. Using a Crystal Earpiece may require adding a 10n across the earpiece to improve the output volume. The substitute Piezo Earpiece is effectively a 20n capacitor and an additional capacitor is not needed.

2 TRANSISTOR RADIO

Here is a simple 2-Transistor radio.
The secret to its performance is the 7 turn "pick-off" from the FRONT END (the TUNED CIRCUIT).
The ratio of 7 turns to 60 turns means a small percentage of the voltage generated in the tuned circuit is passed to the transistor. Thus it puts a small load on the TUNED CIRCUIT.
I don't want to go into any mathematics. The turns ratio is 60:7 = 8 but the effect of the 7 turns "pick-off" has an effect called the IMPEDANCE EFFECT and this is the SQUARE OF THE TURNS RATIO. Thus the IMPEDANCE EFFECT is 8 x 8 = 64. This means the "pick-off" (the LOADING EFFECT) is just a few percent. The front end can produce voltages as high as 500mV because a crystal set can produce a voltage high enough to pass through a diode (350mV) and have sufficient to drive a crystal earpiece.
Even though the front end has a "step-down" ratio, the voltage out the 7 turns will be sufficient to drive the first transistor.
The "transformer" does 2 things: It reduces the loading on the tuned circuit ENORMOUSLY and it produces an output with a higher current than is circuiting in the front end. Even though the transistor is turned ON and biased by the 33k, it is classified as a low-impedance load as far as the front end is concerned and the input signal has to be accompanied by a certain amount of current, otherwise the transistor will not respond to the voltage. The 7-turn "pick-off" is able to provide this current.
Both transistors are biased ON via the 33k base-bias resistors and thus the first transistor responds to the slightest millivolt signal.
This circuit was tested and had the same performance as the **Simplest ZN414 Radio Circuit** above. It can be operated on 1.5v to 6v and the strongest stations tend to overload on 6v. A short antenna is needed.

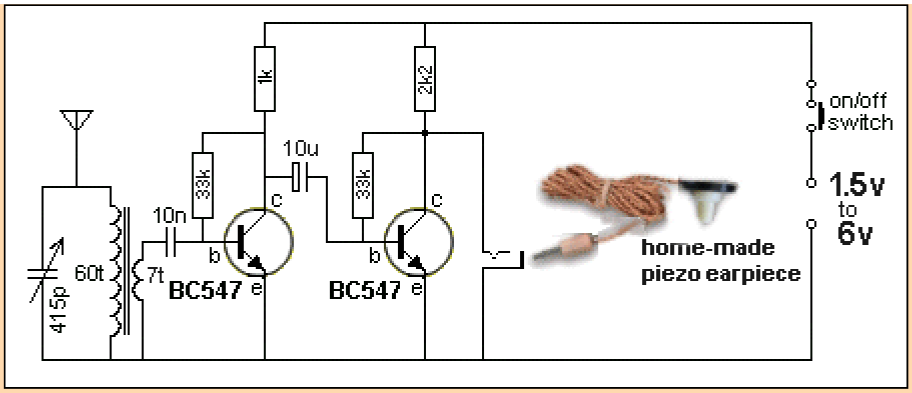
1k
2k2
on/off switch
1.5v to 6v
10u
33k
33k
10n
c
b
60t
7t
415p
BC547 e
BC547 e
home-made piezo earpiece

SIMPLEST 2-TRANSISTOR RADIO
using a very-high-impedance earpiece

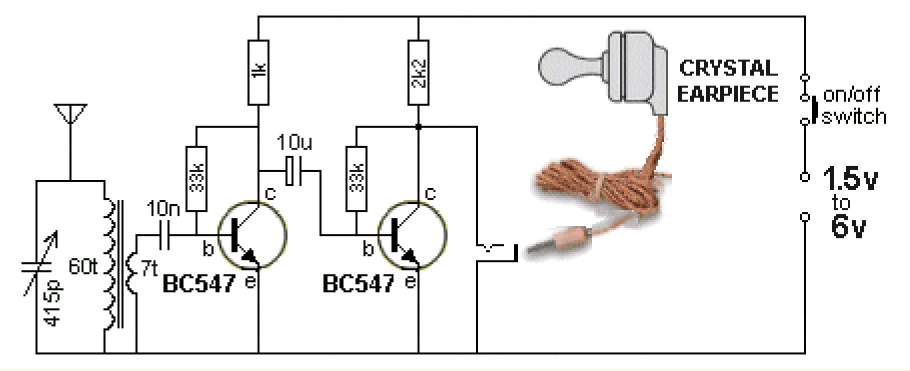
1k
2k2
CRYSTAL EARPIECE
on/off switch
1.5v to 6v
10u
33k
33k
10n
c
b
60t
7t
415p
BC547 e
BC547 e

SIMPLEST 2-TRANSISTOR RADIO
using a crystal earpiece

ADDING AN IMPEDANCE MATCHING STAGE

You can add an IMPEDANCE MATCHING STAGE to the output of the circuit above so a low-impedance earpiece can be used.
We call it an IMPEDANCE MATCHING STAGE because this is the correct technical term. It is an AMPLIFYING stage but it amplifies the CURRENT because the second transistor cannot drive an 8 ohm LOAD. 8 ohms is a very low resistance and if it is connected directly to the second transistor, the output will be almost zero.
The reason for this is covered in our discussion: The Transistor Amplifier.
This stage will not increase the volume but simply match the 8 ohm load to the circuit above.
It is very difficult to connect a LOAD to this type of circuit because it will take more current from the battery and cause the supply voltage to fluctuate. These fluctuations will be passed to the first stage and cause variations in the signal. This will be amplified by the first and second transistors in the form of a low-frequency buzzing called **MOTOR-BOATING**.
The only way to reduce or remove this noise is to add an electrolytic across the power rails and reduce the supply voltage. The third transistor simply takes the waveform on the output of the second transistor and delivers it to the earphone with a higher current. It is called an IMPEDANCE MATCHING STAGE as it effectively increases the 8 ohm load by a factor of about 100.

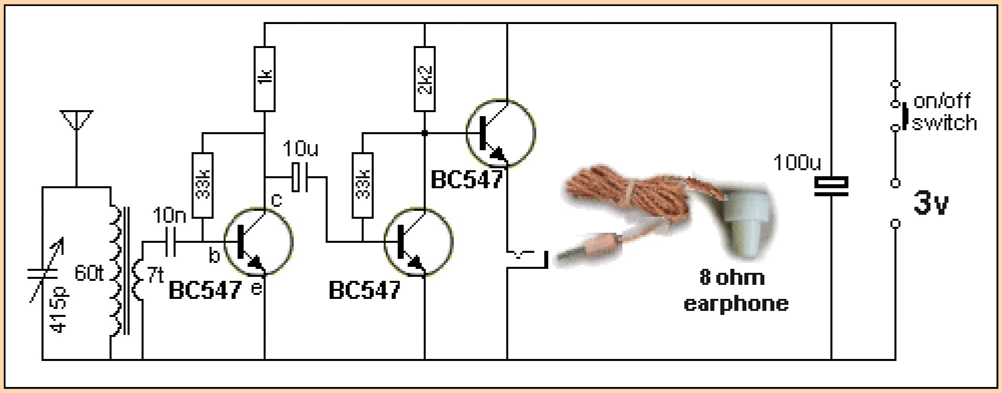
1k
2k2
on/off switch
3v
100u
10u
33k
33k
BC547
10n
c
b
60t
7t
415p
BC547 e
BC547
8 ohm earphone

3-TRANSISTOR RADIO with buffer stage for 8 ohm earpiece

The 3rd transistor converts the 8R to about 800R

You can use 16 ohm, 32 ohm or 64 ohm in place of the 8R earpiece and these will give better performance as they will take less current and improve the stability of the circuit.
Low-impedance earphones create "motor-boating" due to the peaks of current and this can be very hard to fix.

A 2-TRANSISTOR RADIO with REGENERATION

The next stage in our discussion to get better performance is a feature called **REGENERATION**.
Regeneration sends a small output signal back to a previous stage in the form of POSITIVE FEEDBACK to INCREASE the original signal. The signal on the emitter of the first transistor is the same amplitude as the signal entering the base but the FRAME ANTENNA has a turns ratio of 5:15 and this increases the signal on the receiving section of the antenna by up to 3 times. But we want the returning signal to be just above the amplitude of the receiving signal and so a resistive adjustment (attenuator) is provided on the emitter to deliver just the right amplitude.
This has the effect of increasing the amplitude on the TUNED CIRCUIT and is just like reducing the load on the circuit.
As we have mentioned above, when the tuned circuit is lightly loaded, it will pick up a station at the exact frequency of transmission and if the dial is changed slightly, the station will disappear. This quality is called SELECTIVITY.
At the same time, the Tuned Circuit will pick up weak stations and this is called SENSITIVITY.
The quality of a receiver depends on the loading of the TUNED CIRCUIT.

Here is the original circuit from Elektor Magazine with the prototype made on matrix board and fixed to a base-board with a frame antenna made from two sticks of wood. The photo shows a speaker but the output is so low that you really need headphones.

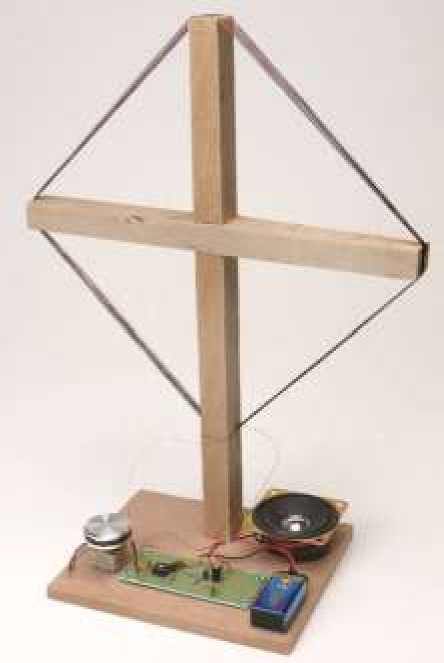

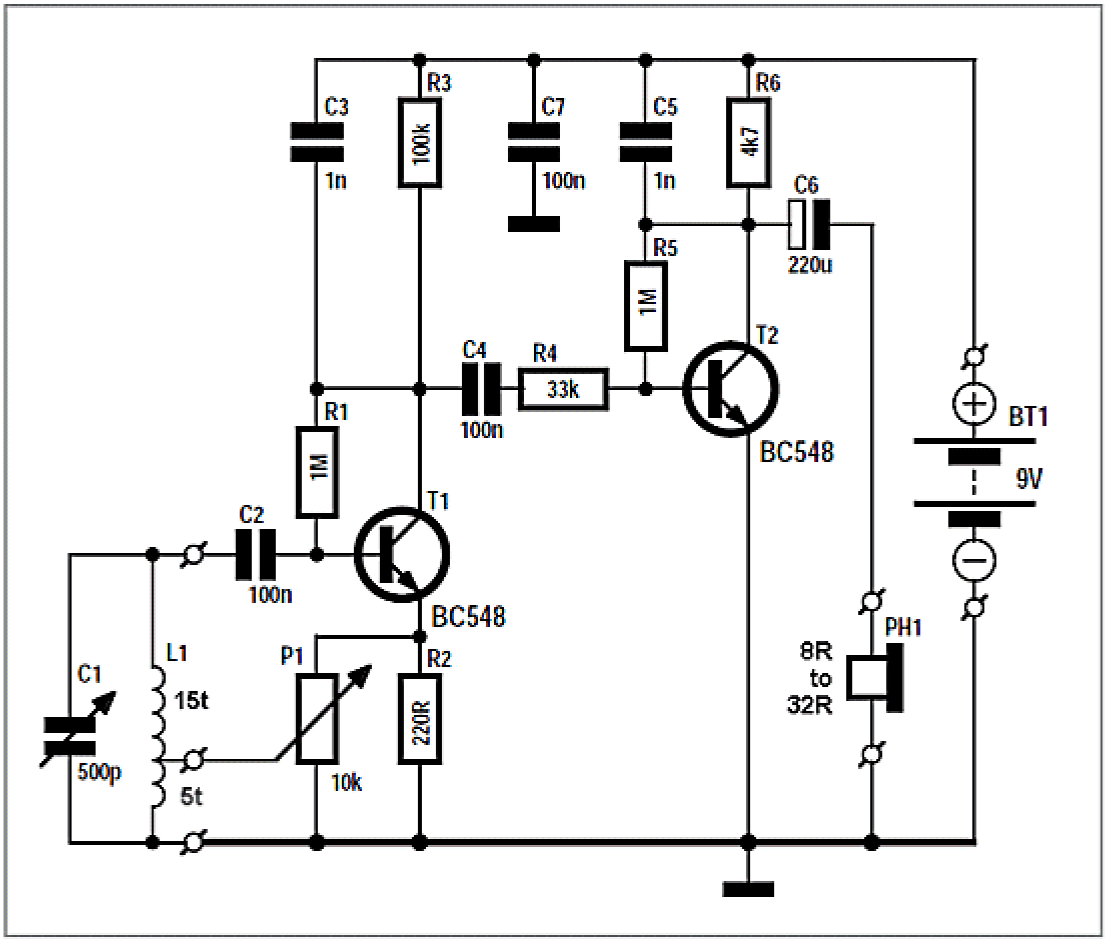
C3
1n
R3
100k
C7
100n
C5
1n
R6
4k7
C6
220u
R5
1M
C4
100n
R4
33k
T2
BC548
BT1
9V
R1
1M
C2
100n
T1
BC548
PH1
8R
to
32R
C1
500p
L1
15t
5t
P1
10k
R2
220R

2 TRANSISTOR REGENERATIVE RADIO from Elektor Magazine

The circuit is very complex and the output will be very low as the circuit cannot drive a low-impedance earphone via a 4k7 load resistor. The 4k7 resistor is actually driving the speaker (the transistor is simply discharging the 220u). The 4k7 only allows 32/4700 x 9 = 61mV to appear across the earphone - a very poor result.
The skill of designing a transistor stage is covered in our comprehensive eBook: The Transistor Amplifier and you wont make a mistake like this !!!
The circuit above can be simplified and we can add the REGENERATIVE feature to our **Simplest 2-Transistor Radio** circuit:

Our circuit uses a 15 turn circular FRAME ANTENNA 15cm diameter and a 5 turn REGENERATION coil.

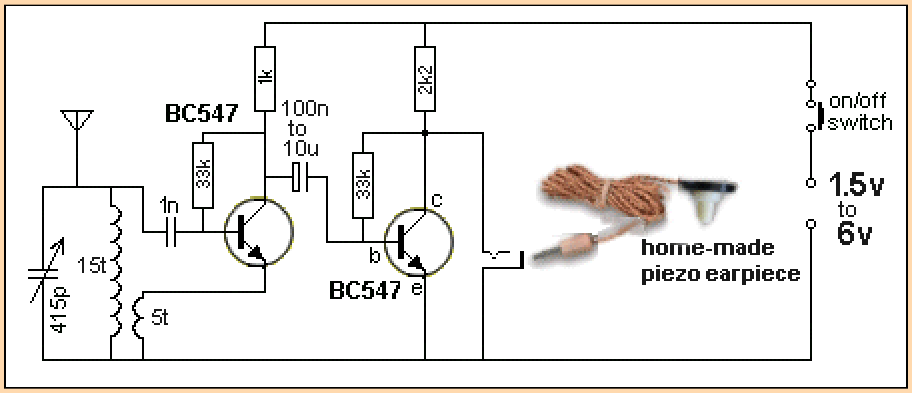
BC547
1k
100n
to
10u
2k2
on/off
switch
33k
1n
33k
c
b
e
BC547
1.5v
to
6v
home-made
piezo earpiece
415p
15t
5t

2 TRANSISTOR RADIO with REGENERATION

The regeneration coil is brought near the main coil and as it gets closer you can hear the audio get louder. If this does not happen, turn the coil around.
Early radios used this technique and the operator had to adjust the coil by hand. No-one minded because radio was a fascination and the simplest radio cost more than a weeks wages. To listen

to a broadcast through headphones was an amazement and listeners would sit all night with headphones listening to music.
This is very fiddly and by adding an extra buffer stage, we can use a Frame Antenna with a very clever "pick-off" that does not load the front end. This gives the circuit very good sensitivity and selectivity without regeneration.

3 TRANSISTOR RADIO

Here is our final design for the simplest self-contained 3-Transistor Radio using our home-made Tuning Capacitor and 250mm x 350mm Frame Antenna. It picks up the local stations and drives a low-impedance earphone or set of earphones (from a mobile phone).

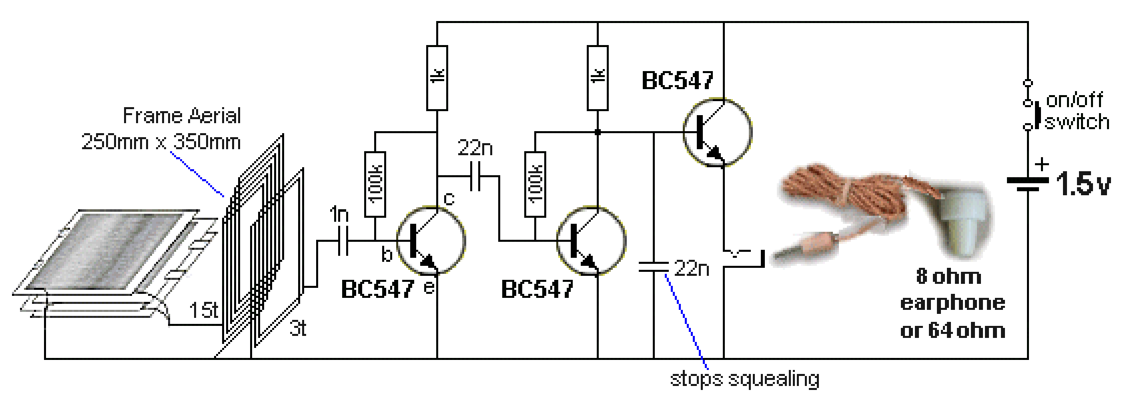

3-TRANSISTOR RADIO

The circuit performs very well and uses readily-available components. The 22n across the output is essential to stop squealing.
The secret to sensitivity and selectivity is the turns-ratio on the Frame Antenna. The 3-turn "pick-off" puts very little load on the front end and this allows the stations to be tuned with our home-made Tuning Capacitor.
The circuit contains all the features we have discussed above and only needs a 1.5v supply.
Build this circuit before you buy any expensive tuning capacitors, IC's or ferrite slab antennas as you will not get any better results.
This is called a TRF circuit and because the stages operate at Radio Frequency or Audio Frequency. Due to the high amount of amplification, the circuit can start to squeal (feedback, motorboat) due to the layout.
You may need to shorten or lengthen the leads or move the parts slightly - it's that critical.
However the result is a portable radio that needs no earth and will pick up the strong stations.
You can try connecting the 0v rail to the metal part of a soldering iron to increase the number of stations.

LOADING

The whole success of picking up a radio station is the RECEIVING CIRCUIT. The receiving circuit is the coil and the signal in the air (from the radio station) must go down the centre of the coil.
It cannot pass over the top or the bottom of the coil. Only the signal that goes down the centre of the coil is received.
As you can see, the centre of the coil is not very big and it is amazing that the signal can pass down the centre. But it does, and that is the only signal that will be amplified.
This signal is passed to the capacitor and we have explained how the signal is gradually increased and increased in amplitude until it is as large as 500mV. The signal from the radio station may be as small as a few millivolts, but as it keeps pushing the "swing" back and forth, the amplitude get larger and larger.
If you put your finger on the "swing" you will prevent it get larger and larger and it only requires the slightest touch of your finger to prevent the swing gaining full amplitude.
In electronic terms, your finger is called LOADING THE CIRCUIT and since we have to pass the signal to further stages of amplification, we need to "tap" or "load" or "pick-off" a signal.
The aim is to load the circuit as least as possible because the actual energy entering the circuit is very small.
In fact, this is all the energy we can remove as that is all the energy entering it.
Because a very small amount of energy is entering the "front-end" we classify it having a very

high impedance. It is very difficult to provide a value of impedance for this circuit because impedance has the term "Z" and the circuit is operating a very high frequency so resistance values are not the same as impedance values.

The actual resistance of the circuit is ONE OHM but the impedance is more like 10,000 ohms to 100,000 ohms.

We can explain its high impedance if we put a 100,000 ohm resistor across the circuit. The waveform will be reduced very slightly. If we put a 10,000 ohm resistor across the circuit, the signal will be reduced a reasonably large amount. If we put 1,000 ohms across the circuit it will stop working.

This means a load of 100,000 ohms will have the least effect.

In a crystal set, the diode creates NO LOAD until a voltage of 350mV is reached. It then passes excess voltage to a crystal earpiece that has a very high impedance. That's why a crystal set will produce a good output. The LOADING is very small.

When a transistor is connected to the TUNED CIRCUIT, it starts to put a load on the circuit after 600mV and this load is VERY HIGH. The "resistance" of the base-emitter junction is about 1k and the signal will find it very difficult to rise above 600mV because the incoming energy is not sufficient to increase the voltage.

Adding a capacitor between the base and the front end allows the transistor to be self-biased and get a turn-on voltage of about 600mV from a base-bias resistor.

The FRONT END is now separated from the transistor and ANY voltage it is producing will be passed to the transistor via the capacitor.

Whereas, with the crystal set, the first 350mV could be produced without any loading, the circuit is now loaded AT ALL TIMES.

This means we have to load the circuit as lightly as possible to be able to pick up individual stations.

The only way we can do this is to use a capacitor of the smallest practical value and this has to be worked out by trying different values. If the value is too small, the transistor will not detect a small signal. If the value is too large, the circuit will stop working.

Values such as 1n, 10n and 100n are suitable.

Values such as 1u, or 10u will be too large.

The CRYSTAL SET loading and a transistor load are completely different.

The transistor loads the front end ALL THE TIME and that's why you need to use a transformer or other ways to reduce the loading. Sometimes a Field Effect Transistor is used as it puts almost no load on the front end.

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TV Bandit
Companies already tried to ban this antenna but failed. Get yours before it's too late!

Recreating an Alfred P. Morgan crystal set

Analog Dial | Page 1 | Page 2 | Page 3 | Page 4

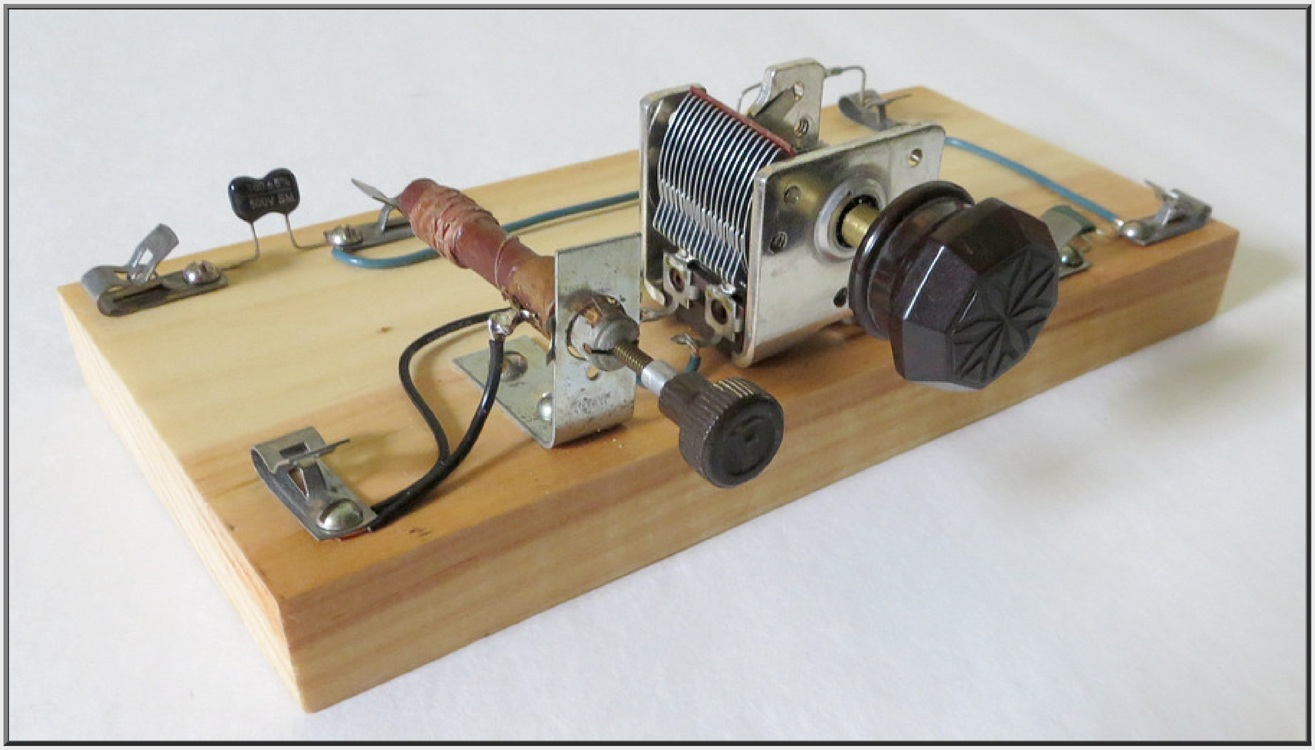

A recreation of my first (working) crystal set, originally built in 1966.

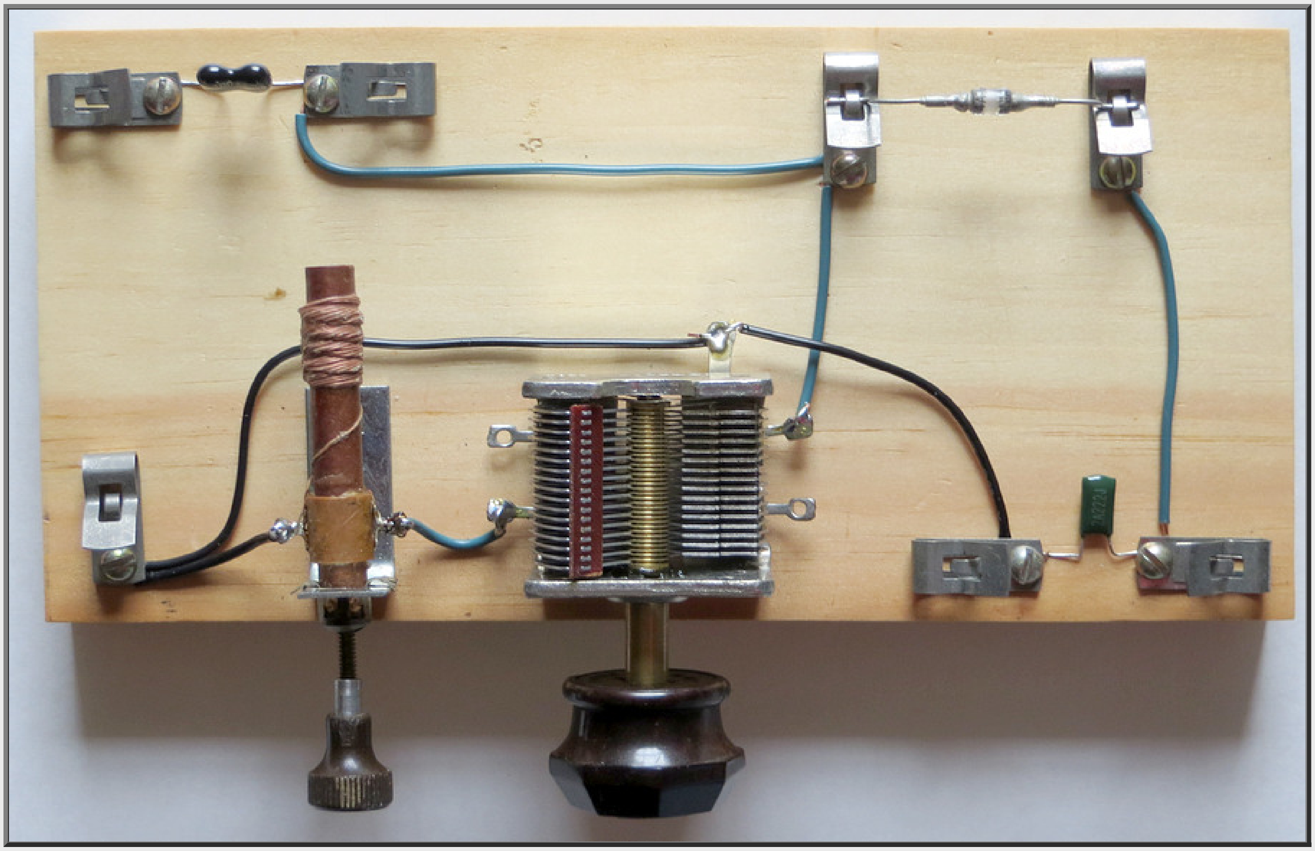

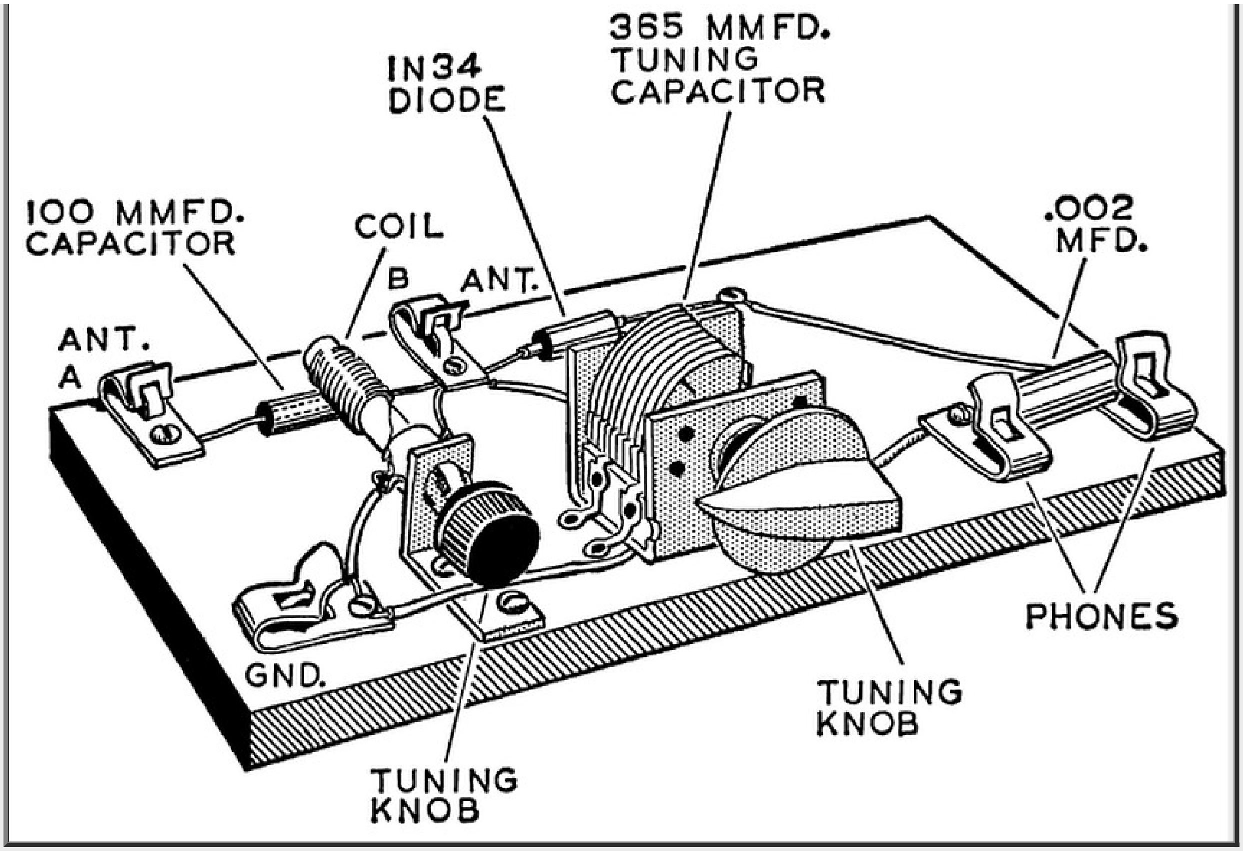
365 MMFD.
TUNING
CAPACITOR
IN34
DIODE
100 MMFD.
CAPACITOR
COIL
B
ANT.
.002
MFD.
ANT.
A
GND.
TUNING
KNOB
TUNING
KNOB
PHONES

Page from "The Boys' Third Book of Radio and Electronics" by Alfred P. Morgan.

Back Story:

In the Summer of 1966 I was 10 1/2 years old and one of my favorite TV shows was "Get Smart". It was a show about a bumbling secret agent named Maxwell Smart who had all sorts of gadgets at his disposal. My friend Billy Meyers and I decided we wanted to be secret agents, like Max. One of the "secret agent" things we'd do was to pick out a guy with a briefcase walking home from work and declare him a Soviet spy. Then we would "tail" him for a few blocks, making up stories about him.

Billy and I had no way to communicate with each other after we had to come in for the night. He lived half a block away. Kids didn't use the phone back then. There was only one phone in the house and I don't remember using it before I was about 14 years old. Maxwell Smart had a phone in the sole of his shoe. We needed something like that!

Maxwell Smart (Don Adams) Agent 86.

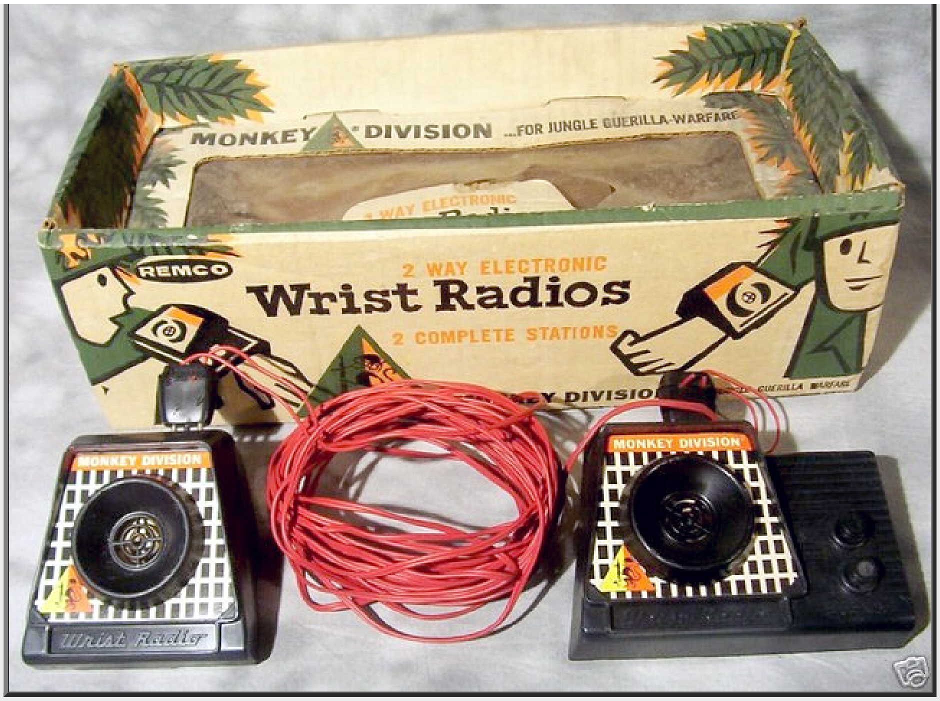
MONKEY DIVISION ...FOR JUNGLE GUERILLA-WARFARE
REMCO
2 WAY ELECTRONIC
Wrist Radios
2 COMPLETE STATIONS
MONKEY DIVISION
MONKEY DIVISION
Wrist Radio

Remco "Monkey Division" Wrist Radios.

One thing I DID have was a set of Monkey Division Wrist Radios. These were powered by a single C battery in the "Master" unit, which also had a button on it that would buzz the other receiver to get the users attention (apparently, the other user was unworthy of a button). A metallic speaker doubled as a microphone. The sound was very tinny, but you could make it out. Unfortunately, they were wired to each other. There was nothing "radio" about them.

I remember taking them outside with my brother Rob, and I could see and hear him talking at the same time his voice was coming over the wrist radio. They were pretty much useless, unless you like running around with a wire connecting you to your brother.

BUT... with some extra wire strung across the driveway, down the backs of the houses and into Billy's bedroom, Billy and I would be able to talk to each other! I immediately presented this great idea to my mom with a request the she fund the cost of the wire, and she immediately refused and told me the electric company would just come out and take the wire down.

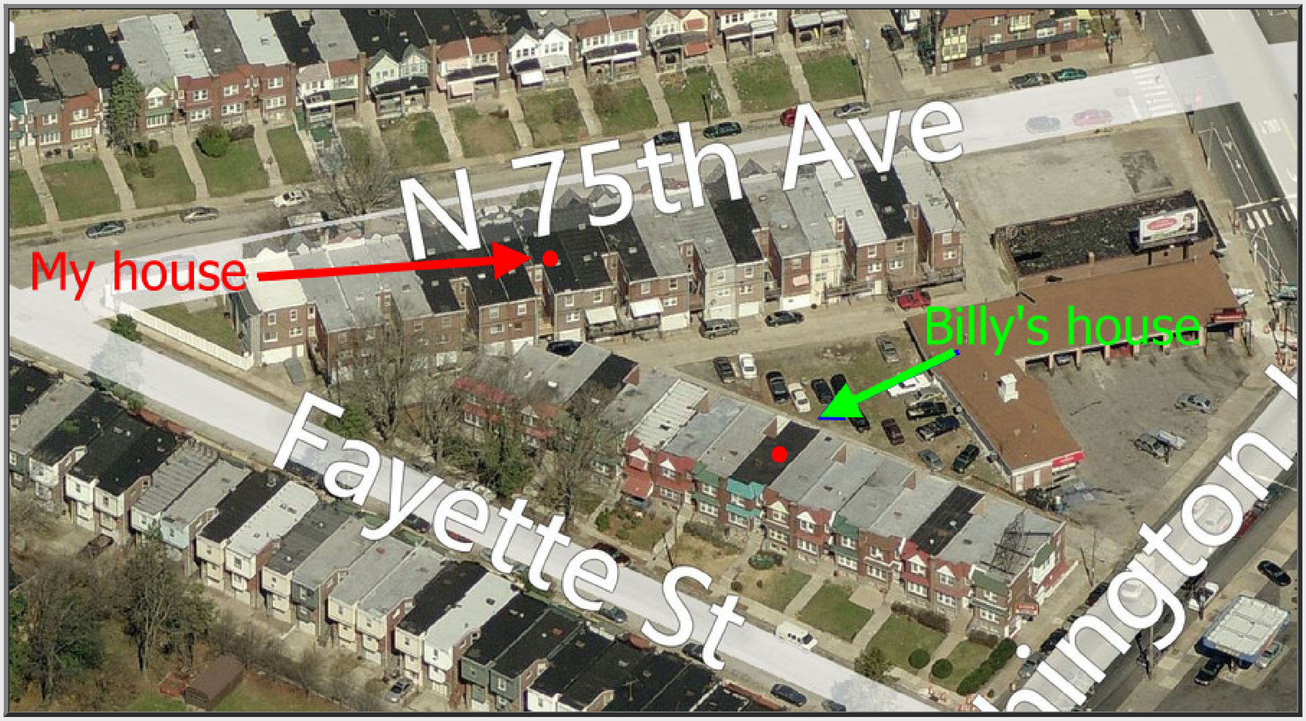
N 75th Ave
My house
Billy's house
Fayette St

Location of my house and Billy's house (actually his grandparent's house) The wire would have to be strung across the driveway. This is part of the West Oak Lane section of Philadelphia.

There was only one thing left to do. Build a radio. I went down the basement and connected a battery to a speaker and used a coat hanger as an antenna. This was similar to the wrist radio, but the coat hanger antenna replaced the wire. It didn't work! All it did was make clicking sounds in the speaker. I had to wait for my dad to come home from work and ask him why.

When my dad came home I showed him the setup and he said, "You don't have a detector." I asked him what a detector was and he told me to go the library and get a book on radio. The next day I had a copy of "**The Boys' Second Book of Radio and Electronics**" by Alfred P. Morgan. Chapter 2, page 15 was titled "Building Your First Radio Receiver". I wouldn't be able to talk to Billy with it, but that was OK. My mom wouldn't buy me a secret agent coat, we didn't have any gadgets, and our secret agent days were coming to an end.

Now there was another problem. None of the parts needed to build anything in the book could be found around my dad's workbench. There was a store on Ogontz Avenue named REE Electronics, so I headed up there with a list of parts. The store sold stereo equipment and fortunately for me, also repaired stereo equipment. I asked the man in the store if he sold diodes or "capacitaters" and he sent me into the back of the place. There were two guys back there and bins of parts along the wall.

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REE Electronics was located at 7709 - 7711 Ogontz Avenue in Philadelphia. The entire block has been razed and rebuilt, and is no longer recognizable. The picture above is the 7900 block of Ogontz Avenue. The store on the left is the only one that retains its original appearance, with the glass store window and the apartment overhead. This is how REE Electronics looked in 1966.

The two guys were pretty cool. I announced that I would like a "three hundred and sixty five micro micro farad variable capacitater". They asked me a couple of questions and told me to come back with the book. They had all the parts I needed except the coil. No problem, I would just build the set with no coil. I came home with Fahnestock clips, a 1N34 Germanium diode, a variable capacitor and a crystal earplug.

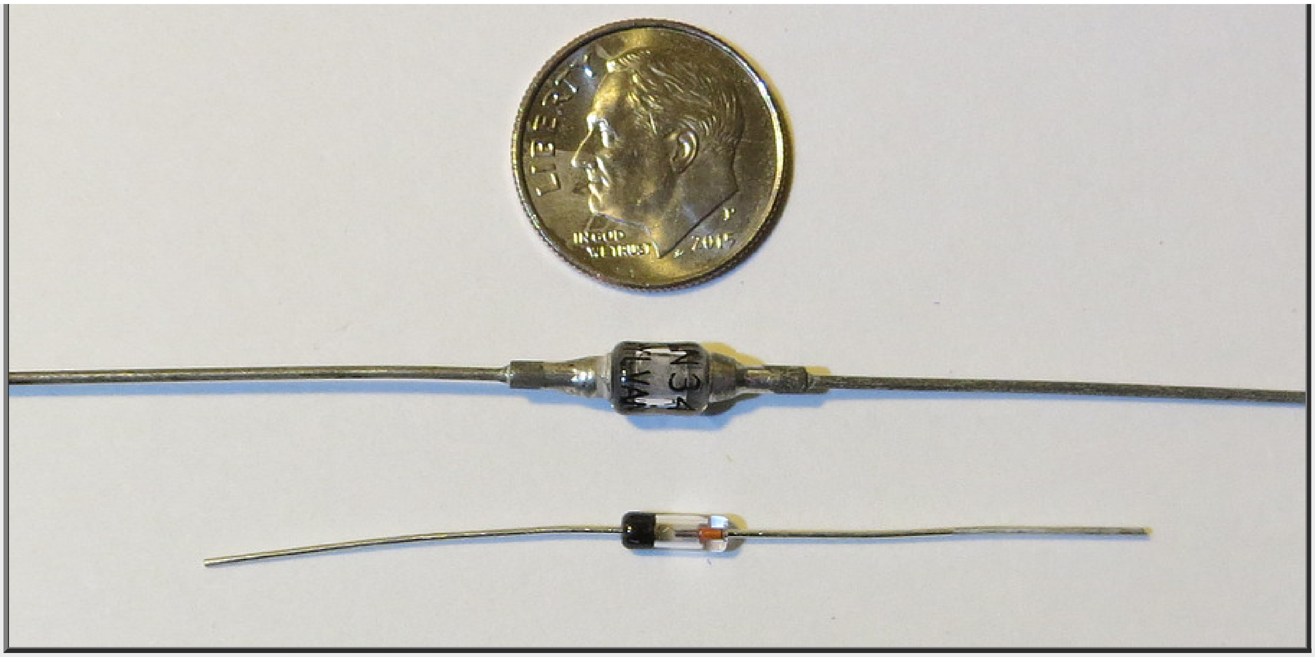

A Sylvania 1N34A Germanium diode (top) from 1949 and its modern counterpart. The new diodes are literally a dime a dozen, less than one cent each. The 1949 Sylvania diode cost me $9.00 in 2015. It is a duplicate of the one I bought at REE Electronics in 1966.

The diode was 65 cents in 1966. I can't use the $9.00 diode because I don't want to bend the leads, so I sort of just look at it.

Of course the radio didn't work without a coil. It did pick up the slightest whisper of KYW AM 1060 mingled with WIBG AM 990. There seemed to be some buzzing associated with it, as what I could hear sounded distorted. I HEARD something, that was the really, really neat part. It made such an impression on me that I remember the date. July 26, 1966.

The "problem" with the Alfred P. Morgan books was that they were not written for anybody as dumb as I was. Morgan didn't write, "If you can't find the coil you can make one." He just said to go buy a coil. Not only that, but there were no photographs in the book, though there were excellent drawings on almost every page. Since I had never seen some of the parts in real life, I didn't know exactly what the coil looked like, and I didn't understand what it did. That's because I didn't read the book! I was stuck on page 15.

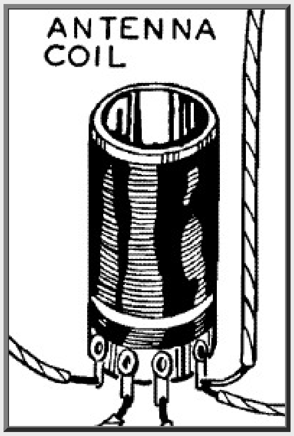

This is the picture of the coil from the book. I didn't know what I was looking at.

I returned the book to the library and came home with "**The Boys' Third Book of Radio and Electronics**." I found a simple radio on page 104 and soon headed back to REE Electronics. This time, they DID have the coil! I can't remember how much time passed after the first non-functioning radio was built. Probably a month or so.

I asked my dad to cut me a wooden base for the radio. I started building the radio and, if I remember correctly, it took me a long time. I didn't have a drill, so any holes in the base were made with the point of a compass. There were three connections that needed soldering. I got some solder from the basement, and the tweezers and alcohol lamp from my chemistry set. The tweezers were heated in the flame of the lamp till the tips began to glow, then I would quickly solder the joint.

One day a friend from school named Leo Pound stopped by on his bicycle. This was a bit unusual because Leo lived miles away. I don't even know how he knew where I lived. He recently told me (via Facebook) that he remembers helping me build the radio. Odd that it was the one and only time he came by. Apparently, we got the radio working that very day.

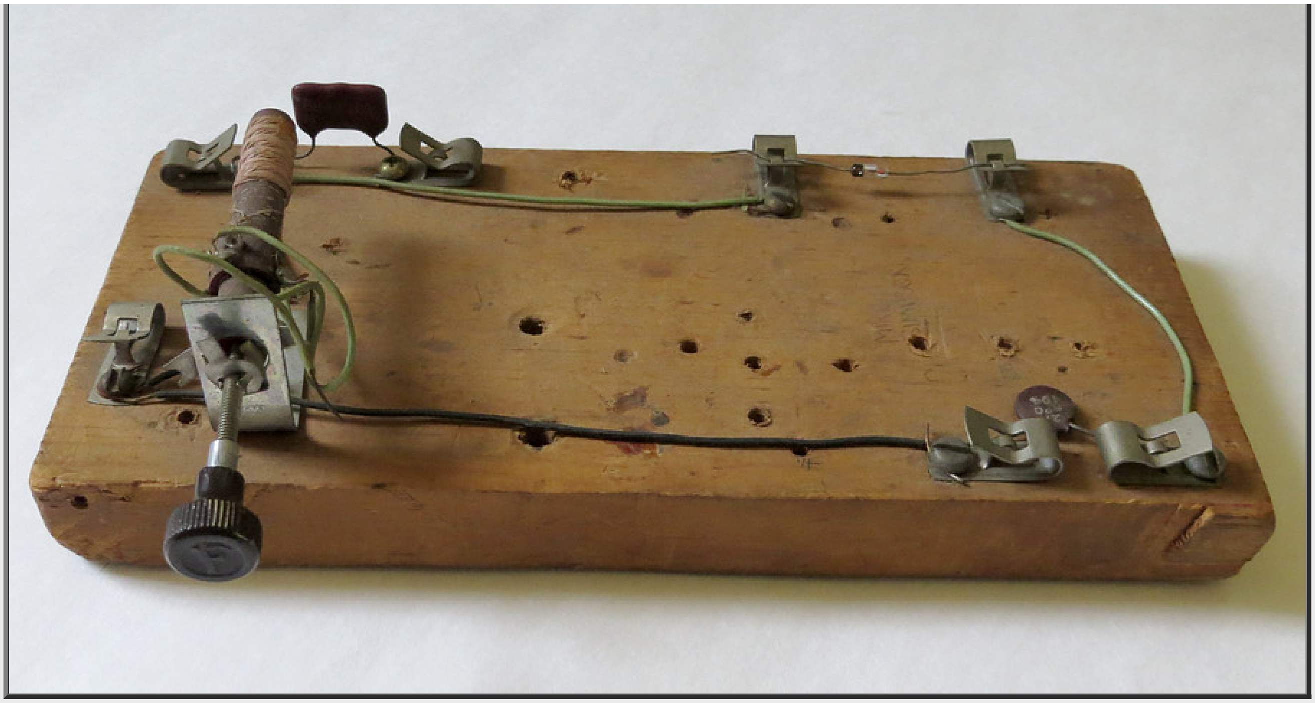

Here is the base of the radio made in 1966.

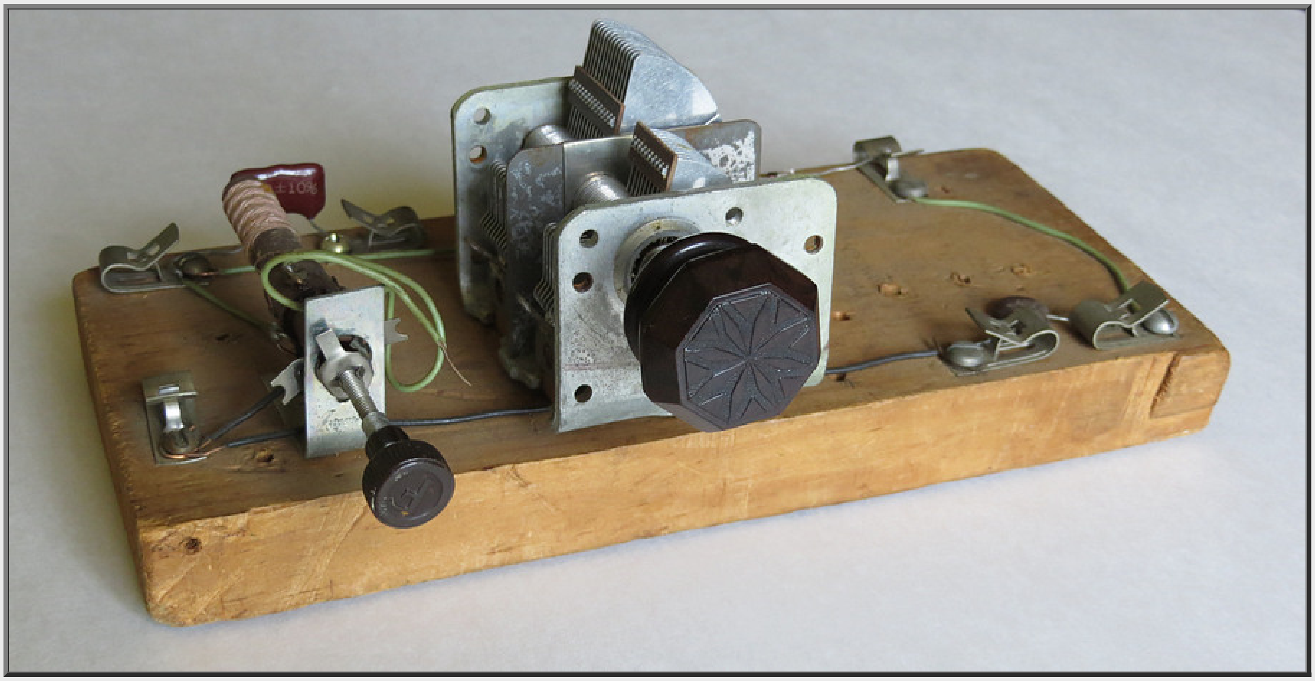

I found all the original parts except for the tuning capacitor. However, it looked like this one. It's just sitting on the base in this photo, but the radio pretty much looked exactly like this. My dad gave me the big tuning knob. The smaller knob came from a lamp in my bedroom. I didn't tell my mom you could no longer turn on the lamp, but eventually I found a lamp in somebody's trash and took the knob off to replace the one on my lamp.

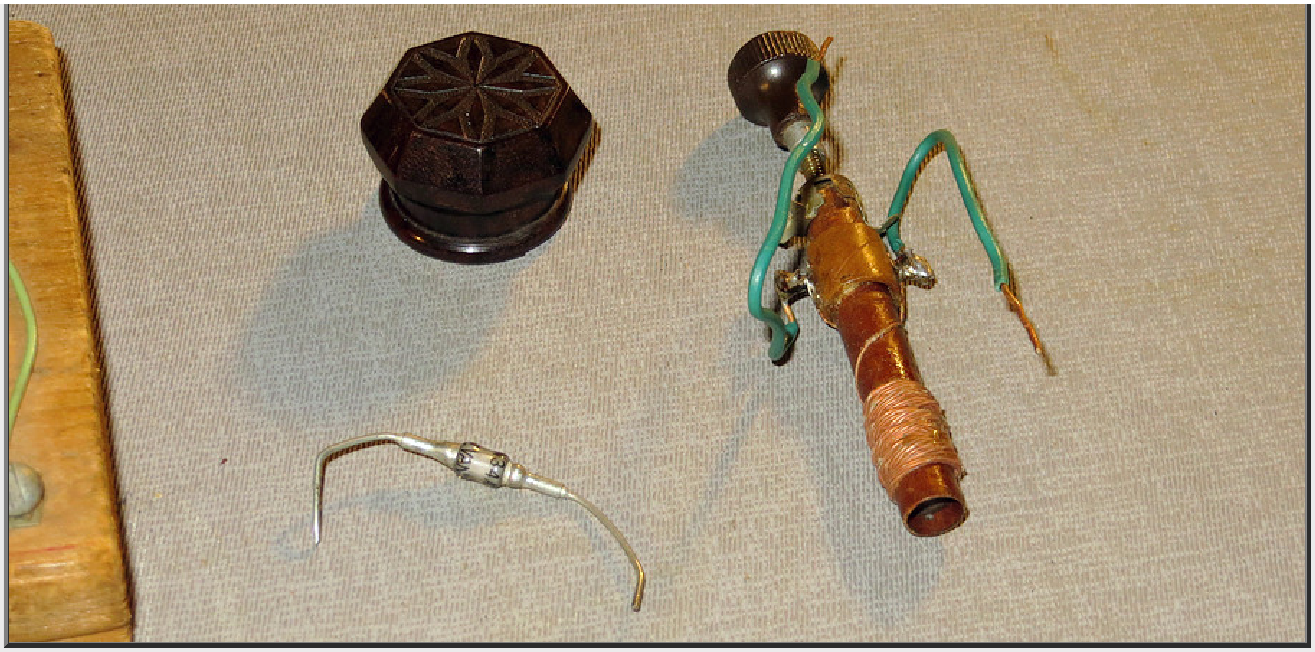

Original coil, diode and main tuning knob from the 1966 radio. The wires on the coil were soldered with a pair of red hot tweezers.

My dad gave me the large knob for the tuning capacitor. He had a second job on the weekends at "John Cusimina's Moving and Storage." I've always wondered if he pulled that knob off of somebody's radio while they were moving. I hope not. He probably did.

Next

CRYSTAL SETS 5
Experimental Crystal Sets

Home | Contact | Site Map | Radio Stations & Memorabilia | Amateur Radio

Crystal Sets Introduction | Resistor & Capacitor Conversion Tables

Crystal Sets (Part1) | Build Your Own Crystal Set (Part 2)

Spider's Web Crystal Set (Part 3) | Crystal Set By Kenneth Rankin (Part 4) | Crystal Radio Links

CRYSTAL SETS 5: EXPERIMENTAL CRYSTAL SETS

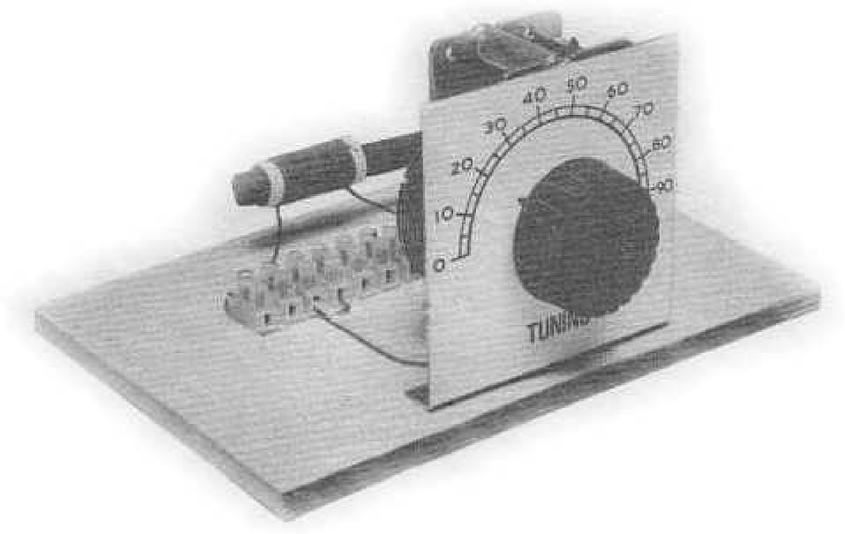

Picture 1 - The Complete Experimental Crystal Set

THE POPULARITY of the crystal radio arises from its simplicity, and the fact that it needs no power supply. The circuit here allows for easy experiments with tuning, aerial and diode coupling, and frequency coverage. Wrong connections can cause no damage to any components.

A Crystal Set is more often than not used for the reception of medium and long wave radio, but short wave reception is also quite feasible. It will normally be possible to receive some of the stronger international radio stations.

This is adapted from an article that appeared in the 1970's in Everyday Electronics, and gave me almost endless hours of fun!

BASIC CIRCUIT

The basic circuit is shown in Picture 2 below. The coil L1 can be air cored, or have a ferrite rod placed in its winding. The variable capacitor C1, in conjunction with aerial-earth capacitance, tunes the circuit to resonate with the wanted radio station frequency. The diode D1 "detects" or demodulates the radio signal so that the programme is heard in the earpiece.

This basic circuit can be modified in various ways to obtain better performance.

EARPHONE

As most constructors will be using a Crystal Earpice to listen to the crystal set it is essential that a 47k Ohm resistor is connected across the earphone terminals (TB1/1 and TB1/2 in the diagram), i.e. in parallel with the earphone, otherwise results will be very quiet.

A High Impedance headset of 20k Ohms (20,000 Ohms) may give even better results, but these are very difficult to obtain , so unless you happen to already own such a headset the Crystal Earphone with 47k resistor will be the only option. An ordinary magnetic earpiece or Walkman headphones will not work with a crystal set.

ASSEMBLY

Construction is of a 'breadboard' type using a wooden board of about 165 x 130 mm. A 12-way block connector, TB1, is used to connected together the components and this is screwed onto the wooden board. The use of a block connector provides an easy method of connecting the components together and then subsequently rearranging them as the experiments progress.

Tuning capacitor C1 is screwed to a bracket made of some scrap metal which is then also screwed firmly down to the baseboard, see Picture 1 above. Thin plywood screwed to the front edge of the baseboard would also provide a suitable method of fixing the tuning capacitor to the base. A knob with pointer is fitted to C1, and a scale is drawn and fitted behind this.

Except for C1, all connections are made by the terminals of the 12-way terminal block as shown in Picture 4. Loosen the screws with a small screwdriver, insert the bared ends of the wires, and tighten the screws. The various locations on the terminal block, TB1, are also shown in the circuit diagram, Picture 2.

AERIAL AND EARTH

Crystal receivers need a long wire aerial preferably strung outside and about 25m long, or as long as is possible to install. If this is outside it should be high and clear of earthed objects as this will improve performance.

An earth is absolutely essential for a crystal set to work properly. The earth lead can be run to an earth rod or spike that is buried to a depth of about 1 meter into damp soil. Or it may be soldered to a bare metal can which is buried in damp soil.

It is feasible, though not recommended, that the earth lead can be connected to the earthing terminal of a hi-fi system or even to the bare metal case of a personal computer that is plugged into an earthed mains outlet, but is switched OFF.

Stranded, insulated wire, or purpose made aerial wire can be used for the aerial and earth leads.

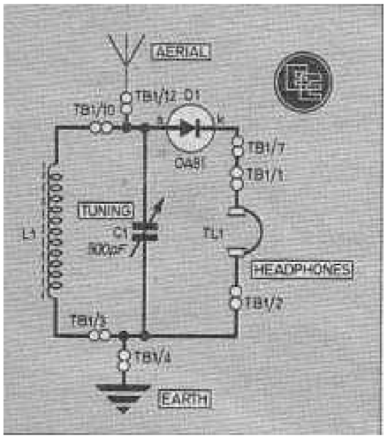

Picture 2 - The Basic Circuit

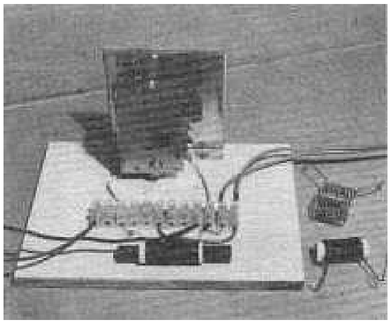

Picture 3 - Photo Of The General Layout

INDUCTORS (The Tuning Coils)

The following four coils are suggested for initial use as L1 :

Coil 1: Make a thin card tube to slide on a 10mm diameter ferrite rod, and on this tube wind about 105 turns of 32 s.w.g. enamelled copper wire, side by side. Secure ends with sticky tape.

Coil 2: Make a similar coil to to coil 1 having about 15 turns of 24 s.w.g. enamelled wire on the card tube. Loops of cotton will help hold the ends in place.

Coil 3: Wind 9 turns of 20 s.w.g. bare tinned copper wire on an object about 20mm in diameter. Remove and stretch to separate the turns, to obtain a coil about 25mm long.

Coil 4: Make a similar coil to coil 3, but with 5 turns.

The Ferrite Rod

It will be necessary to have a ferrite rod of about 60mm to 75mm long available. Coils 1 and 2 will provide reception of medium wave and the longer short wave bands. Coil 3 should cover about 3 - 10MHz shortwave with the ferrite placed in it, or about 6 - 18MHz with the ferrite rod removed. Coil 4 should cover about 6 -13MHz with the rod in, and about 9 - 20MHz without the' rod.

It will be noted that as the ferrite rod is inserted, any particular signal has to be re-tuned by opening Cl. This arises because the ferrite increases the inductance of the winding, so less parallel capacitance is needed for the same resonant frequency.

EFFICIENCY CHECKS

Tune in a m.w. transmission using coil 1 which gives good headphone volume. Place a microammeter or multi-range meter on a sensitive range in series with the headphones. A reading of 50-100uA or more may be obtained, depending on aerial, earth, earphone resistance and resistor value, coil and detector efficiency and strength of signals at your locality.

Placing the ferrite rod in the coil and re-tuning should boost the meter reading to some extent. Surplus or other detector diodes can be tried by substituting them in turn and noting the meter reading. Improvements to the aerial (or earth) will also show up as a rise in meter reading.

If experimenting with a crystal earpiece, which gives no direct current circuit, the meter may be clipped across the phone leads, i.e. D1 cathode to earth.

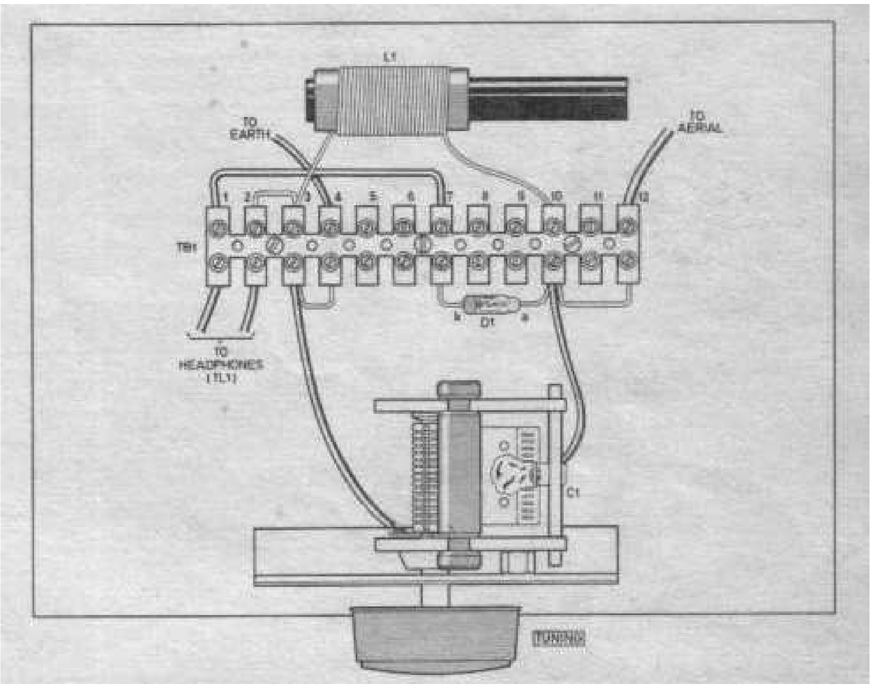

Picture 4 - Baseboard Layout Of The Crystal Set

AERIAL COUPLING

The aerial loads the tuned circuit heavily when connected directly to the top of the tuned circuit, as in Picture 2. This damps the tuning action and it can be found that stations spread out all over the dial, which is unsatisfactory.

The series capacitor, C2 connected in Picture 5(a) reduces the loading and thus improves the sharpness of the tuning. A variable or pre-set capacitor of about 250pF maximum is most suitable. for this role, though it is possible to experiment with a variety of fixed value capacitors in this range also.

Connecting the aerial to a tapping on the coil, as in Picture 5 (b) also sharpens tuning. It may also increase volume. Try about 2 turns from earth for coil 4, or 4 turns from earth for coil 3.

Another method is to have a coupling primary, as in Picture 5 (c). This consists of a second coil, with about one third the turns of the original wound on top of the existing coil.

You can even combine these methods to find what arrangement best suits the aerial in use.

The diode can be disconnected from the end of L1 and taken to a spare position on TB1 for example location TB1/9. You can then run a flying-lead fitted with a crocodile clip from this position, connecting it to various tappings on the coil as required as in Picture 5 (d). This method also reduces loading on the tuned circuit.

Coils with spaced turns of bare wire are readily tapped. For other coils, small loops can be made every ten turns or so, and crocodile clips can be attached to these when selecting tapping points.

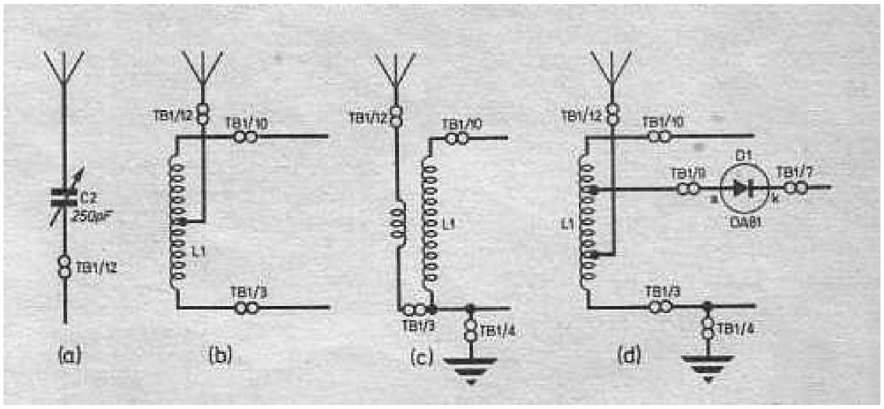

Picture 5 - Alternative Methods Of Aerial Coupling

SHORT WAVES

For shortwave reception, a good efficient outdoor aerial is certainly recommended. Evening listening in the region around 5 - 9MHz in often proves to be the most fruitful.

Since there is no amplification, as with a valve or transistor receiver, certain frequencies will seem to be completely dead at particular times of day. So if the crystal receiver works satisfactorily on medium wave and longwave, but no shortwave signals are heard, check again in the evening, or after dark, when conditions are different.

PARTS REQUIRED

C1	**365pF or 500pF Air Spaced Tuning Capacitor**
D1*	**OA47, IN34, OA81, OA90, OA91, IN94 or similar point contact small signal Germanium Diode** * The OA47 will be of particular interest since it has the lowest forward bias voltage of any of these diodes which will make the crystal set somewhat more sensitive and therefore louder. The US equivalent of the British OA47 is the IN34.
TL1	**High Impedance Headphones (20,000 Ohms)** **or Crystal Earphone**
TB1	**12-Way Plastic Screw Block Terminal**
Also Required:	**47 k Ohm Resistor for Crystal Earphone: Enamelled Copper Wire: 32 and 24 s.w.g. for L1: 20 s.w.g. tinned wire for L1: Ferrite Rod 10mm diameter x 75 mm long: 25m of wire for aerial: Wire and rod or spike etc for earth: Wood for base e.g. 10mm x165mm x 130mm: Scrap of metal of thin plywood for C1 bracket/front panel: Knob: Crocodile clip(s)**

Adapted from an article in Everyday Electronics magazine, November 1981, By F.G. Rayer.

HERE ARE A COUPLE OF VERY INTERESTING CRYSTAL SET DESIGNS SENT IN BY KRYSATEC - "THE RAT" - FROM THE CZECH REPUBLIC

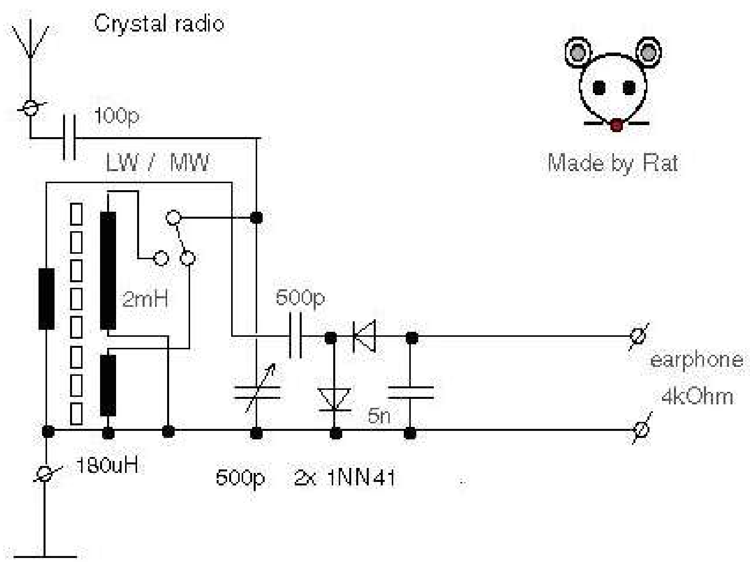
Crystal radio
Made by Rat
100p
LW / MW
2mH
500p
earphone
4kOhm
5n
180uH
500p
2x 1NN41

1/ Using old coils from old bulb radio for MW and LW band. Though it would be straightforward to wind the coils - one for Long Wave, one for Medium Wave and a coupling coil. Variable capacitor is 2 x 500pF only one half is used: 500pF. For the crystal earphone a resistor of about 82k ohm in parallel is required. This set also uses two Ge diodes as a multiplier in the quest for for higher audio signal output.

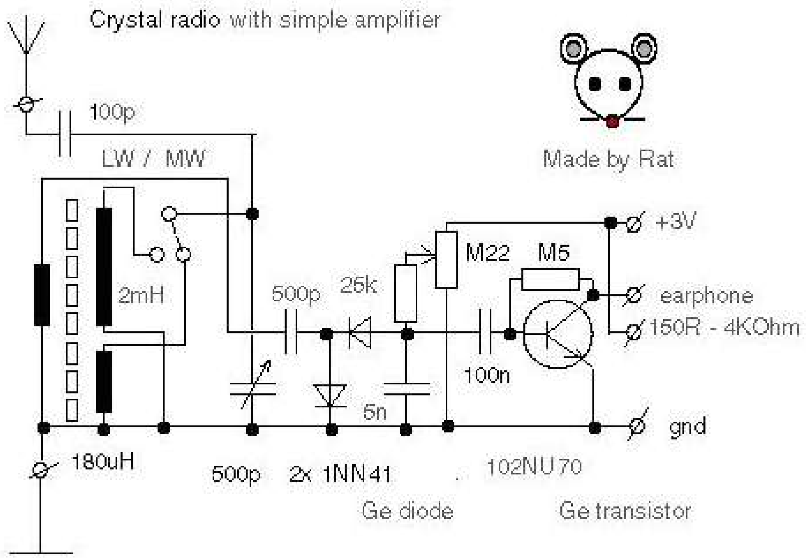
Crystal radio with simple amplifier
Made by Rat
100p
LW / MW
+3V
M22
M5
2mH
500p
25k
earphone
150R - 4KOhm
100n
5n
gnd
180uH
500p
2x 1NN41
102NU70
Ge diode
Ge transistor

2. If signals are not strong signal in your location, then the above circuit design can be considered. A simple transistor amplifier is used. A variable resistor M22 is used for better sensitivity which can be adjusted for poor signals. This crystal radio is aversion from cca 1960 - 1970 y.

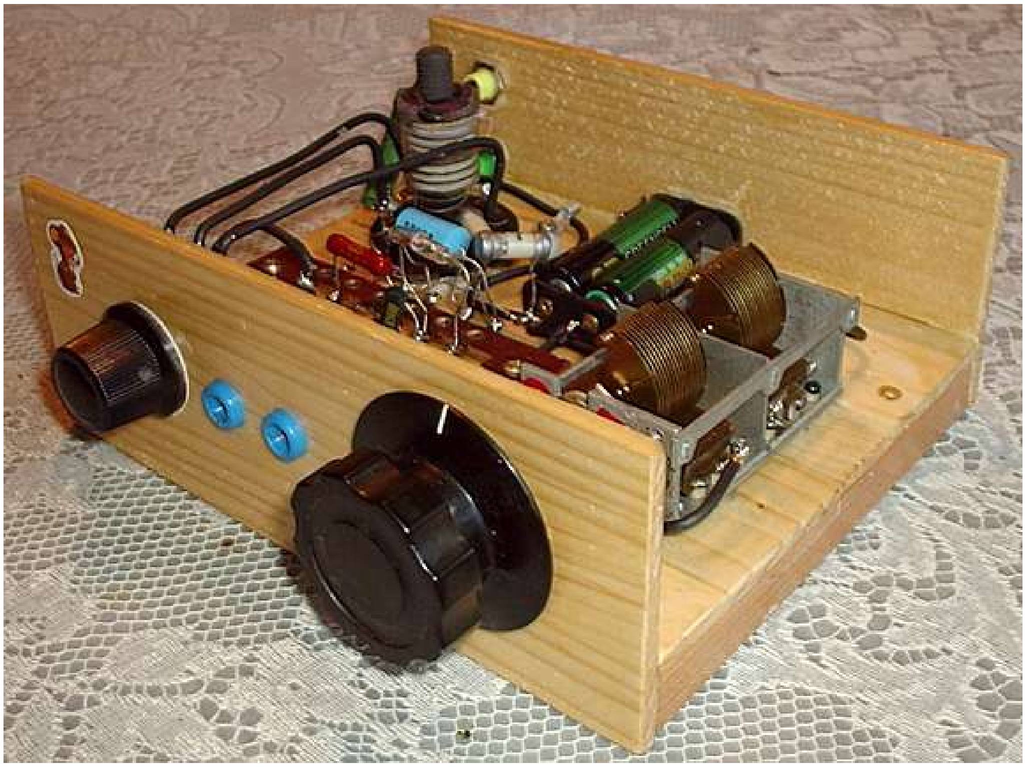

Rat's finished Crystal Set with additional amplification - very neat!

'Minilabs' Crystal Radio

BELOW: Ian Tomlinson kindly sent in a photograph of the box that contained the kit for his John Adams Toys 'Minilabs' Crystal Radio.

It is a very simple circuit consisting of the coil (inductor) with a sliding contact that provides variable tapping points, a diode and crystal earphone. All that is added is the aerial and earth. There is no variable tuning capacitor for simplicity and to keep costs down.

The coil provides the inductance required for tuning into a certain frequency (wavelength). These days a variable "tuning" capacitor is normally wired in parallel across the inductance (coil) in order to vary the resonance of the tuned circuit and therefore enable to easily tune into various transmitters on different frequencies. This crystal is tuned varying the number of turns on the coil (ie varying the inductance) by tapping off at different points using the sliding contact ("ball").

The crystal earpiece, or high Z headphone, is connected between the output of the detector diode (the other end from the coil) and earth. The volume from a crystal earpiece may be considerably improved by connecting a resistor of - somewhere between - 4.7 k and 47k ohms in parallel with the earpiece. A crystal earpiece cannot directly allow current to flow through it and the parallel resistor therefore allows current to better flow through the circuit.

John Adams Toys
Crystal Radio Kit
Make a radio complete with tuning coil, antenna and earphone.
Pack contains all you need including full instructions. No battery required.
Ages 8–14

'Minilabs' crystal set by John Adams Toys

A discussion on configurations for Crystal Sets by Felix Scerri VK4FUQ

This discussion, by Felix Scerri VK4FUQ, was posted at this address which no longer appears on the web www.tarc.org.au/techinfo2.htm (error 404) so here it is reproduced:

Crystal Set design is one of my passions closely allied with my obsession for audio and high fidelity.

My main interest in crystal sets, apart from the wonder of a radio receiver that does not require a power source, is the potential excellence of the recovered audio quality from normal AM broadcast stations.

Personally, it is one of my great laments that most people have never heard how good wideband AM can sound. A high performance crystal set or similar TRF approach is, in my opinion,the only way to do it. There are a few people around who have heard the audible results of my efforts,and can only agree.

I have often wondered,given the ultimate simplicity of the crystal set, being essentially a tuned circuit,a diode detector and some form of output device, what it takes to achieve optimum performance. What follows are my thoughts on the matter.

Crystal Set optimisation, is in my opinion, all about reduction of circuit losses. Essentially this means high "Q" tuned circuits and high quality detectors. Efficient output devices also help too. But as we will see, there are some trade-offs required as well. A high "Q" tuned circuit is always benefical, as a high "Q" tuned circuit has lowest RF losses,highest potential selectivity,and highest voltage at resonance, which is very useful for the diode being fed from the tuned circuit. Variable capacitors, even the "modern" miniature variable capacitors (although the older air dielectric units, as used in old valve receivers are more desirable) for various reasons,are generally quite efficient, and a higher "Q" coil will produce the most worthwhile improvements.The best (highest "Q") coils are wound with "Litz" wire, which is a multistranded woven wire with all strands insulated from each other. The performance of Litz wire wound coils is spectacular, unfortunately, although I know Litz wire is still being made, from personal experience, it is VERY rare in Australia.

Efficient coil design can be quite complex and all my coils are wound on ferrite rods. There seems to be,at least for ordinary single wire windings (close wound), an optimum wire thickness for optimum coil "Q". I have determined .315 mm winding wire to be about optimum for simple (single wire) coils on ferrite rods. Thicker wire is NOT better, believe it or not.

Lacking Litz wire, an interesting winding approach I have developed is to use two slightly thinner wires wound as a bifilar winding connected together at the beginning and end of the coil, yields considerably higher "Q" compared to a simple single wire winding. I have found 0.25 mm winding wire optimum in this application.

Whilst high "Q" coils are beneficial from the RF point of view, there is a possible downside. If one is interested in maximum selectivity and sensitivity, there is no problem, but remember highest "Q" results in a narrowed audio band-width as a simple consequence of band-width. For high fidelity applications this could be a disadvantage under some circumstances, although there are clever ways around this.

Regardless of ultimate coil "Q", selectivity is a major issue with crystal sets generally. Here another trade-off is evident. For the maximum voltage into the diode, connecting the diode to the high impedance end of the coil (i.e. the top) yields the greatest voltage but the selectivity is usually terrible, because of severe "loading" by the diode circuit. For this reason, tapping well own the coil improves selectivity at the expense of signal volume (reduced voltage). Once again there are ways around this. As described in my "Double Tuned Crystal Set Tuner" article in "Amateur Radio" magazine, March 2002, the use of two separately tuned coupled resonant circuits allows top connection into the diode without compromising overall selectivity, thanks to the use of a second tuned circuit which is fed from the external antenna. The whole network forms a double tuned input bandpass filter and in practice this approach works very well. For single coil crystal sets I recommend the use of an un-tuned "antenna" winding adjacent to the "hot" end of the main coil, preferably adjustable (old paper reels from sewing cotton threads are ideal). This allows the degree of coupling to be optimised under actual listening conditions. The double tuned set up is best, yielding superb selectivity, but the un-tuned antenna coil arrangement also works quite well, especially if the diode is tapped well down the main coil.Tapping halfway works well.

The other method of performance improvement involves the use of the most effective detector system possible. Here things get very interesting. In fact the temptation is to use more complex circuitry, but that gets away from the charming simplicity of the crystal set. As an example, my own crystal set tuner has at times mutated into a TRF tuner complete with FET RF preamplifiers, active(powered) detectors and other enhancements. These modifications do work well, but loses the simplicity of a basic crystal set. In actuality, a simple diode detector can work extremely well, subject to some qualification. Diodes like to work with a reasonable level of RF input voltage. Audio distortion can result under conditions of low signal level, due to diode transfer curve non linearity and other factors, such as the widespread use of broadcast station "processing". The actual type of diode makes a difference. The 1N34A germanium diode is very popular for crystal set use, although in my experience just about ANY germanium diode will work, although it is worth trying different specimens. Some are definitely better than others. Even from a pack of twenty 1N34A's from the same source, some were definitely better than others. Measuring the average value of rectified output voltage across the diode load resistor will show which diodes are best. By the way, I regard a diode load resistor as being mandatory. I find a value of about 47K about right, especially if a crystal earpiece is being used or the crystal set is being used as a tuner feeding an audio pre-amplifier and following amplifier. If using high impedance magnetic type headphones, the headphones provide the diode DC load.

Another type of diode that is very interesting, is the hot carrier diode. There seem to be a lot of different hot carrier diodes around these days. There are even hot carrier diodes now being sold as "germanium diode equivalents". I have tried them and they do work acceptably well, but they are not quite as good as genuine germanium diodes such as the 1N34A. Typical UHF mixer hot carrier diodes, such as the 1N5711 will not work well in crystal set service simply because their "turn on voltage"is too high, similar to silicon diodes such as the 1N4148/914 series, which require a lot of RF input to function adequately as RF detectors, however a simple technique can be used to turn hot carrier diodes such as the 1N5711 into superlative detectors.

I guess we are cheating a little, because the technique is to use a little voltage bias supplied via a 1.5v battery, through a simple potentiometer voltage divider arrangement, with capacitor (for DC isolation) fed into the diode from the tuned circuit. With applied adjustable bias, I find the 1N5711 diodes absolutely superlative detectors under ANY signal strength conditions. I find the detection quality also superlative, with a clarity and low noise profile unmatched by any other diode arrangement. In my opinion, hot carrier diodes, running bias,are the best detectors overall.

Regarding other detector arrangements, the diode "voltage doubler" is often recommended, however my own experiments with the doubler arrangement have been inconclusive and slightly disappointing overall. I have found no real advantage in their use over a simple (one) diode detector, believe it or not.

Yes, they do work, but they're nothing special, at least in my opinion.

Any comments on this general subject of crystal set optimisation would be welcome.

73's Felix Scerri VK4FUQ.
22nd July 2002

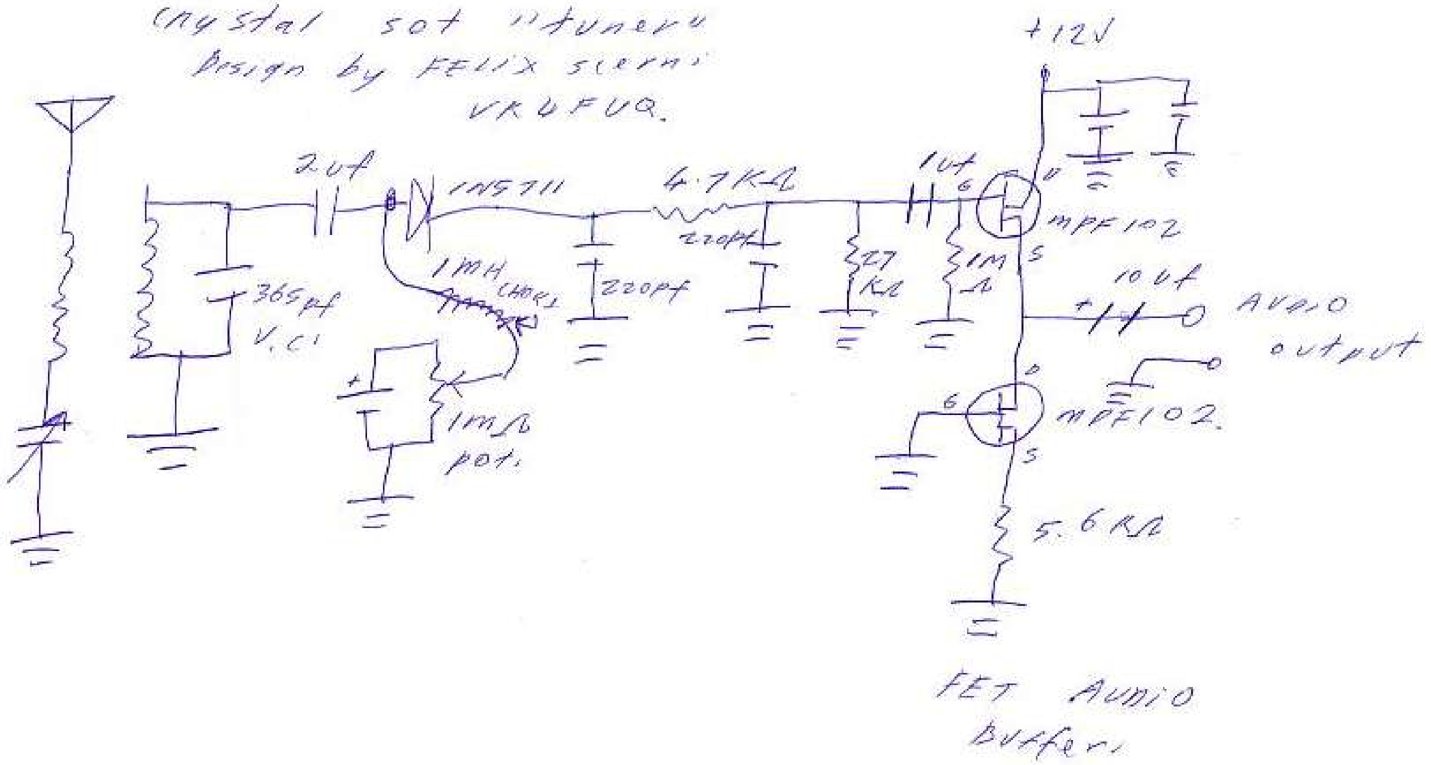

Above: CRYSTAL SET BASED CIRCUIT PROVIDING A HIGH QUALITY PROGRAMME SOURCE

IMPROVED VERSION OF THE ABOVE CONCEPT !! New update from Felix Scerri February 2010:

New 'two FET infinite impedance AM detector'

I've developed a new version of my old favourite FET 'infinite impedance' AM detector that I think sounds very nice. I include a short audio of one of our local AM stations. I picked this station as it is my reference 'torture test AM station' as they run very heavy 'processing' which normally sounds yuck with all my other (diode and non diode) detectors! However it's quite clean with this detector. What do you reckon? I'll do up a circuit if you'd like to feature it in your TRF radio section. A general draft article follows.

'A favourite non diode based AM detector that I've built and used many times over the years is the FET based infinite impedance detector, offering very good general AM detector performance, especially under weak RF signal conditions where diode based detectors do not perform well, especially in terms of audio distortion.

However one of the slightly strange things I've noticed about the simple FET based infinite impedance detector is the variable audio quality noted, even when using the same type of FET. Some I've built have sounded good and others slightly fuzzy when used with an audio preamp and fed into a high quality audio system. I've been giving this a considerable bit of thought of late and I've wondered if the audio distortion might be a result not necessarily of the detection process itself, but the FET stage in its guise as a 'source follower' audio stage which essentially, it is.

I have long been aware that as a simple audio buffer stage, the FET based 'source follower' can exhibit a considerable amount of audio distortion, and a technique I've long used to greatly reduce this audio distortion is to use a second FET in the source lead of the first FET as a 'constant current source' which serves to 'linearise' and greatly reduce audio distortion in the buffer stage overall. So, to test the theory I built a simple one FET infinite impedance AM detector which worked well, but with just a hint of audio 'fuzziness' on received AM stations. So I added a second FET in the source lead of the first FET wired as a constant current source, taking the output from the source of the first RF detector FET and the source resistor and RF bypass capacitor off the source lead of the second FET 'constant current source'. The result, totally clean audio! The theory seems proved! I call this modified detector the 'Two FET infinite impedance detector'

))) Here's what is sounds like - click to play the audio file (((

Here is the circuit diagram:

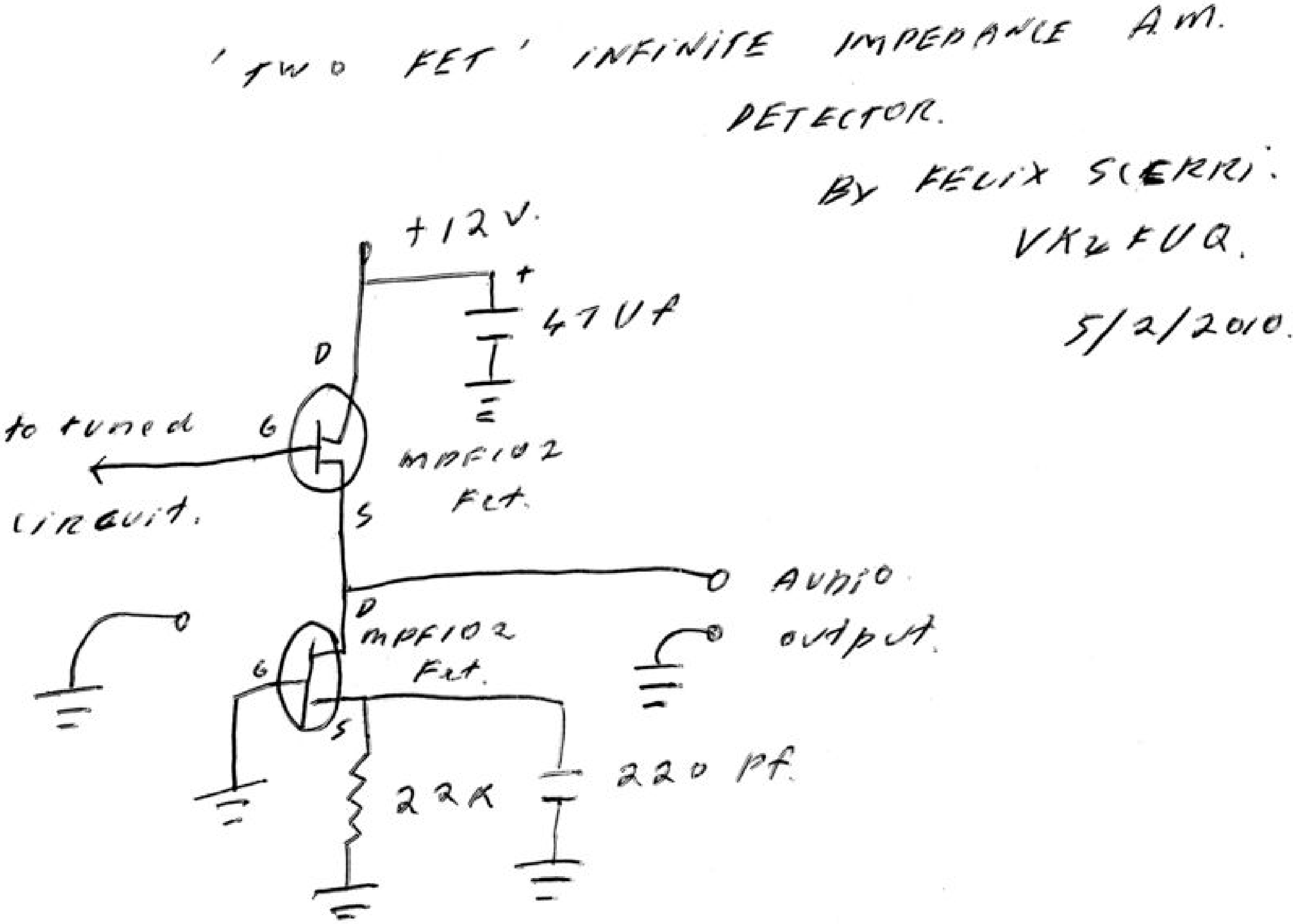

This detector has been a real eye opener for me in terms of its excellent performance, especially considering its circuit simplicity. Indeed in the past I have designed other more complex FET based infinite impedance circuits that do not quite work as well in practical terms as this latest circuit, at least according to my well calibrated ears!

I do not have access to any precise test equipment but my well calibrated ears tell me this 'two FET infinite impedance detector' is a beauty, surpassing practically every other AM detector I've built even at low RF input, and that's rather a impressive claim and the audio quality when used as an AM tuner feeding a high quality audio system is quite remarkable. Possibly the best thing about this detector is its excellent performance under weak signal conditions. Diode based detectors also work beautifully, but the use of an RF stage to ensure detection over a linear portion of the diode's curve is mandatory! This compound infinite impedance detector works

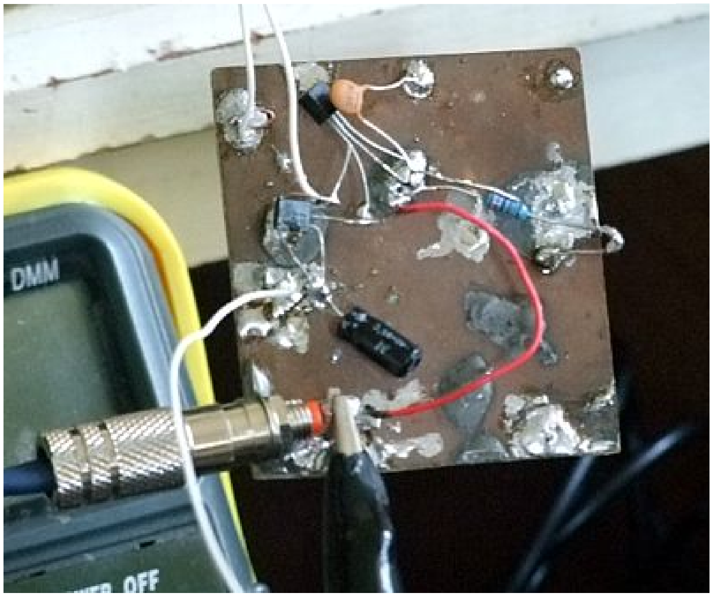

beautifully on the sniff of a useable RF signal.

Just add a high Q tuned circuit and that's it!

Felix Scerri
VK4FUQ

A better FET for the 'basic' Infinite Impedance Detector:

Quite recently by accident, I've realised the MPF102 FET that I've long used in my FET based infinite impedance detectors is possibly not the best FET to use. This was the reason why I developed the 'two FET' infinite impedance detector some time ago which works very well.

However I've found the choice of a more suitable FET works beautifully in the basic FET based infinite impedance detector circuit, which has appeared for many years in many editions of the ARRL Handbook.

I use the 2N5457 and others of the same 'family' may be equally suitable, but I haven't tried them! However with a 2N5457 in place of an MPF102, the basic infinite impedance detector has became my AM detector of choice. It works beautifully even at low signal input with lovely and clean low distortion audio along with a very high input impedance for good tuning selectivity. It's a beauty! The basic generic circuit is attached, courtesy of Rod Elliott's ESP website.

73 Felix VK4FUQ
10 / 02 / 2012.

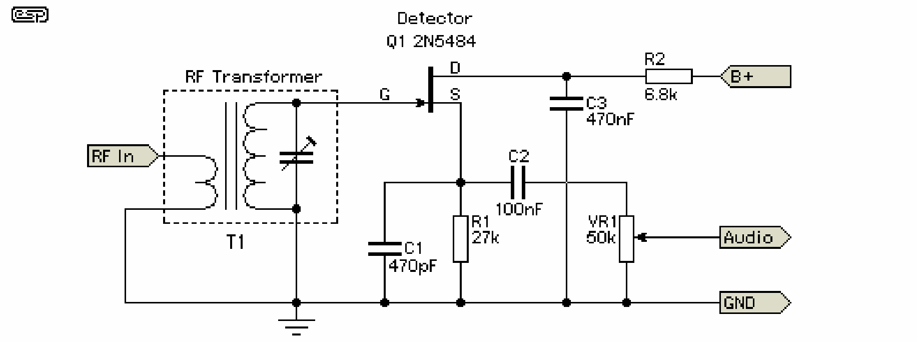

The basic generic circuit is attached, courtesy of Rod Elliott's ESP website
Felix Scerri VK4FUQ

As often happens with me, my renewed interest in FET based 'infinite impedance detectors' of late has led to some interesting new research and I may have considerably improved the 'two FET infinite impedance detector' as a result.

My research suggests that although the use of a CCS (constant current source) reduces audio distortion in an audio stage, the value of the 'source resistor' in the CCS stage is somewhat critical for best results.

By using a potentiometer in lieu of a fixed resistor I have found that a resistance value of around 470 kohms cleaned up all overall audio distortion. I used an MPF102 as the CCS in this circuit. An interesting and worthwhile little circuit refinement.

73 Felix VK4FUQ
21 / 02 / 2012.

A Minimum Component Count High Quality AM Detector

I was generally messing around with various circuit ideas and I came up with this AM detector circuit, a simple diode detector along with a FET stage. It was an attempt to provide good performance along with minimum number of components. Actually I've been pleasantly surprised at the excellent level of general performance and the best of all, it sounds great!

The circuit is quite conventional being a BAT 46 diode detector feeding an MPF102 FET buffer/ common source amplifier stage. I would ordinarily use a FET source buffer stage in this application, but opted to use a simple low gain FET 'common source' amplifier stage instead, with excellent results. I also used a BAT 46 Schottky diode instead of an ordinary germanium signal diode.

This was done for several reasons. Firstly, germanium diodes are now very hard to find but in any case these 'germanium diode equivalent' Schottky diodes are actually a superior diode, having very low noise, almost zero back leakage and an essentially complete absence of carrier storage effects and very good weak signal sensitivity. I call these diodes high fidelity diodes as they sound wonderful as RF detectors.

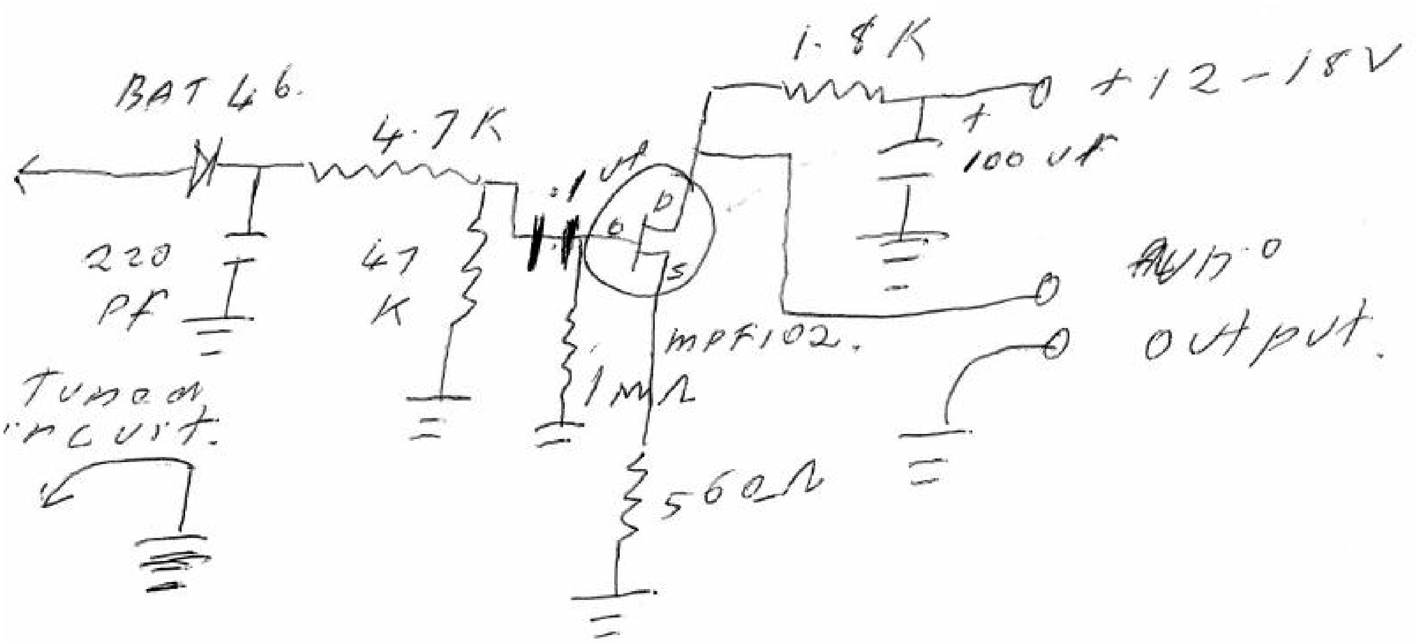

Circuit Diagram of the Minimum Component Count AM Detector by Felix Scerri

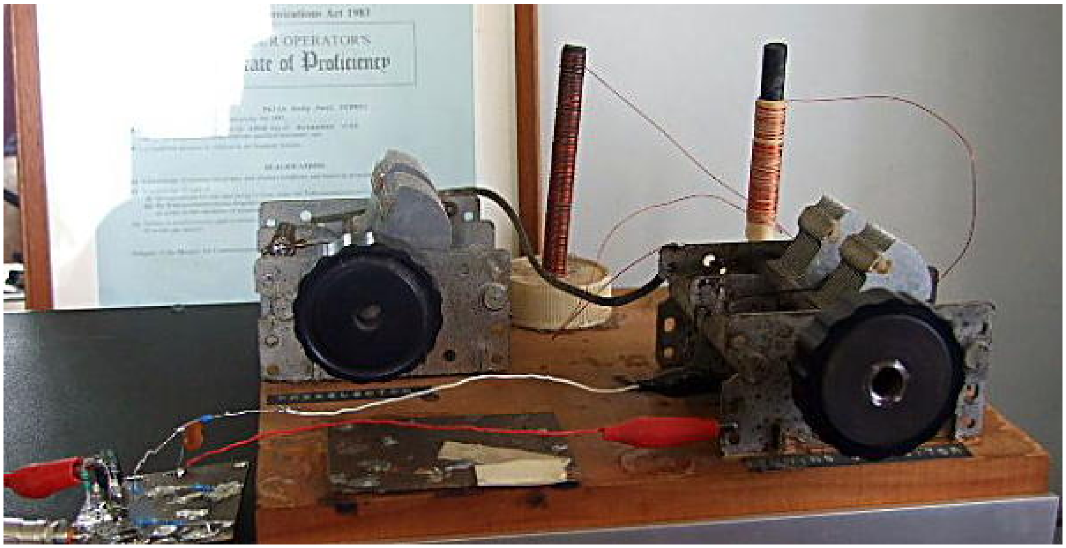

Minimum Component Count AM Detector by Felix Scerri

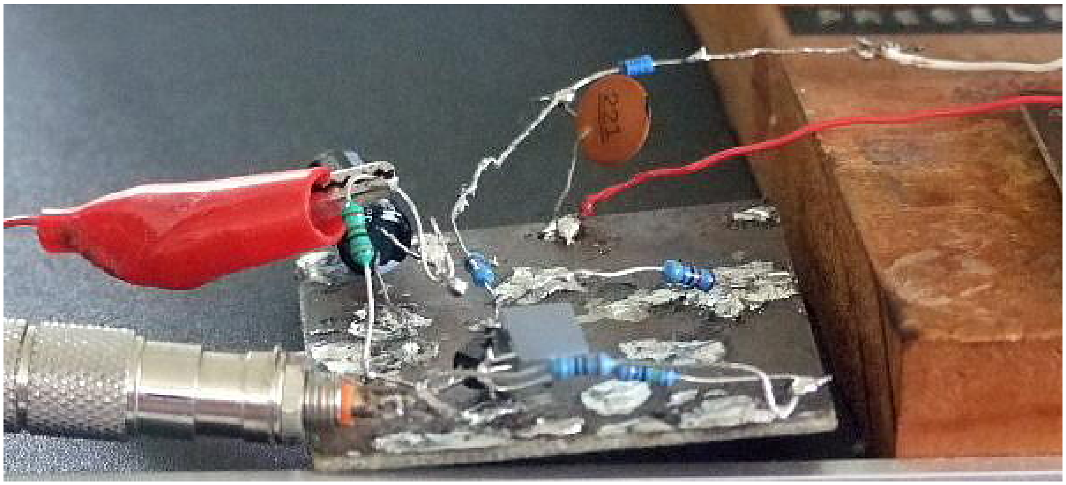

A Closer View

The high impedance of the FET's gate circuit is perfect for optimal buffering of the diode detector, something very important for good low distortion diode detector performance. Apart from providing slight voltage gain, the use of the common source FET amplifier is a new idea, as this prevents the possibility of incidental RF rectification occurring in a FET source follower stage, which can happen. A 1 uf plastic film capacitor may be added in series with the audio 'hot' output lead to block the DC offset out of the FET drain, if required.

Despite no additional RF stage ahead of the diode, audio quality on even relatively weak RF strength stations is actually very good, and of course the audio quality will be even better with increasing RF signal strength, something which will also increase the audio output level. Just on this, for a long time I was somewhat negative regarding diode detectors, as one AM station locally (the strongest one) was always distorted when using a diode detector.

I strongly suspected a transmitter fault, but my complaints were ignored, until one day some time ago when all audio distortion suddenly disappeared! Nothing was ever 'said', but I realised that my suspicions of a long standing transmitter fault were correct, after all!

73 Felix
VK4FUQ
02 March 2012

Voltage Doubler Detector

This is an AM detector circuit that I've long known about and which worked ok, but never seemed to work as well as it should have. However I spent some time late last night trying to optimise the circuit, with some success.

It is a curious circuit being essentially a 'voltage doubler' originally developed for power supply applications, and its use as an AM detector is hard to analyse! It seems that the component values in the circuit are somewhat critical for good performance and if not, the performance is rather 'ordinary'. The circuit that I eventually came up with uses a 150 picofarad 'input capacitor' with a 150 kohm 'load' resistor and loaded into a FET common source voltage amplifier stage (as previously described) through a coupling capacitor with a 1 Mohm input resistance.

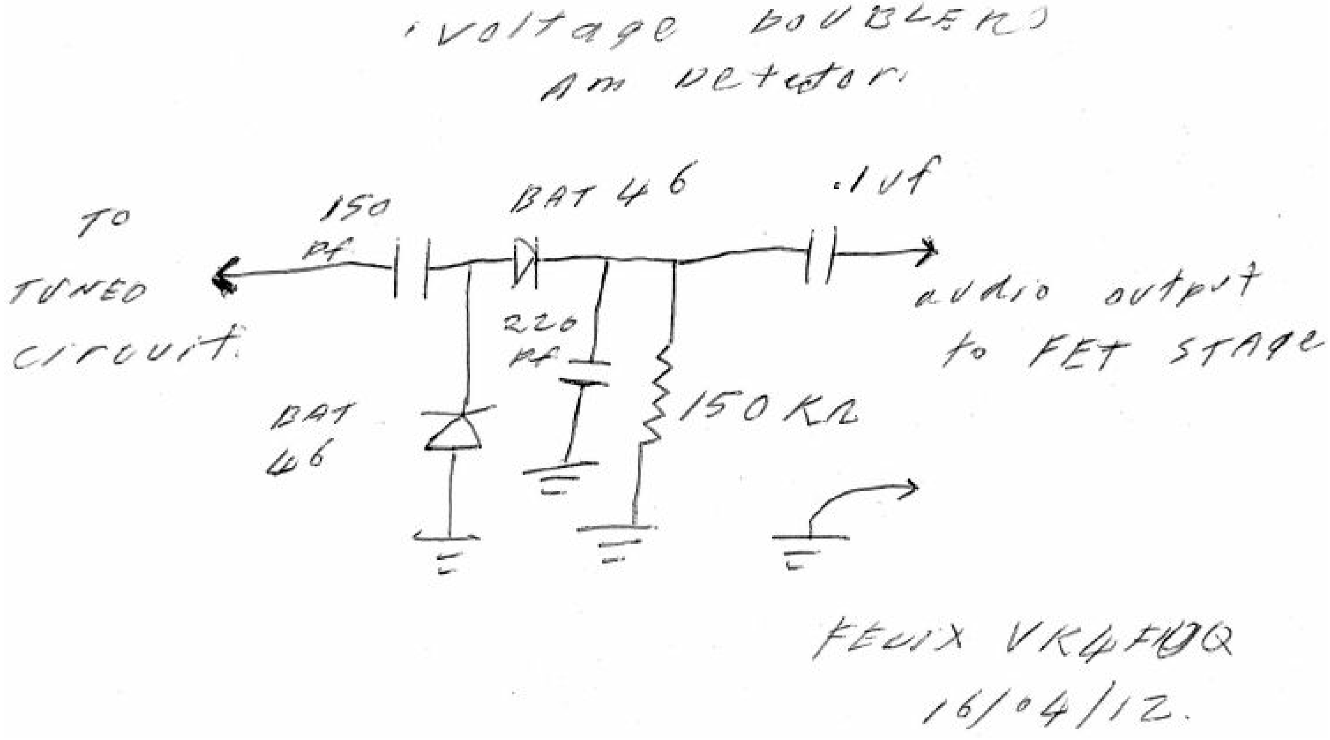

With these circuit values, it all works 'quite well'. Give it a go! It's an interesting AM detector with quite good 'sensitivity' and clean audio quality, and it seems to work well at low signal levels.

73 Felix
vk4fuq.

16th April 2012.

Simple AM detectors: What works best? A practical experimenters viewpoint.

I have written a lot about simple AM detectors for use as tuners for feeding into an audio amplifier, and it has been a long time interest. These days I use either diode based or 'infinite impedance' types of AM detectors. In this location our 'local' AM stations are quite distant and are therefore quite weak in terms of signal strength.

As such I find infinite impedance detectors based on field effect transistors give consistently better results for tuner applications due to their lower apparent overall detector distortion. Diode based detectors are quite 'fussy' as they require both optimal output buffering (AC/DC ratio) and an 'adequate' (beyond the diode knee) level of RF signal injection. http://www.tonnesoftware.com/appnotes/demodulator/diodedemod.html

Diode based detectors will happily 'detect' at very low signal levels, however the (inevitable) audio distortion that results, can be extremely irritating to the ear! Under these conditions I find infinite impedance detectors (even without additional RF preamplification and subject to individual FET characteristics), generally sound 'cleaner' and more pleasant to the ear.

FET's of course require a power source for operation whereas diodes are passive (un-powered) detectors (most of the time), however this is of no real advantage in a tuner application as an 'active' audio amplifier stage will generally be required anyway for audio level boosting, buffering etc.

In the end it will come down to a consideration of prevailing RF signal levels and other related circuit considerations at one's location. If local RF levels are strong, a well designed diode detector will give excellent results. If not, an 'infinite impedance' type of detector is most likely the better option unless one goes towards the option of additional RF preamplification prior to the diode detector.

73 Felix
vk4fuq.

17th April 2012.

ANOTHER DETECTOR by Felix Scerri !

I've tried diode based 'voltage doubler' (or more correctly 'diode integrator') AM detectors before with indifferent results, however the other day, just trying a few ideas I came up with this version that works rather well, with low audio distortion, high audio output and really 'nice' audio quality and the best of all, it seems to work very at very low RF input level.

The two diode 'voltage doubler' detector using two BAT 46 silicon schottky diodes feed directly into a MPF102 source follower stage set at 1 Megohm input resistance. The 'input' capacitor feeding the diodes from a tuned circuit is 68 picofarads.

I have the simple RF filter right on the output of the FET stage. In that respect this circuit is vaguely similar to the old 'Selstead-Smith' valve AM detector of the past. An interesting one! I am very happy with its general performance. Regards, Felix vk4fuq 11/04/2013

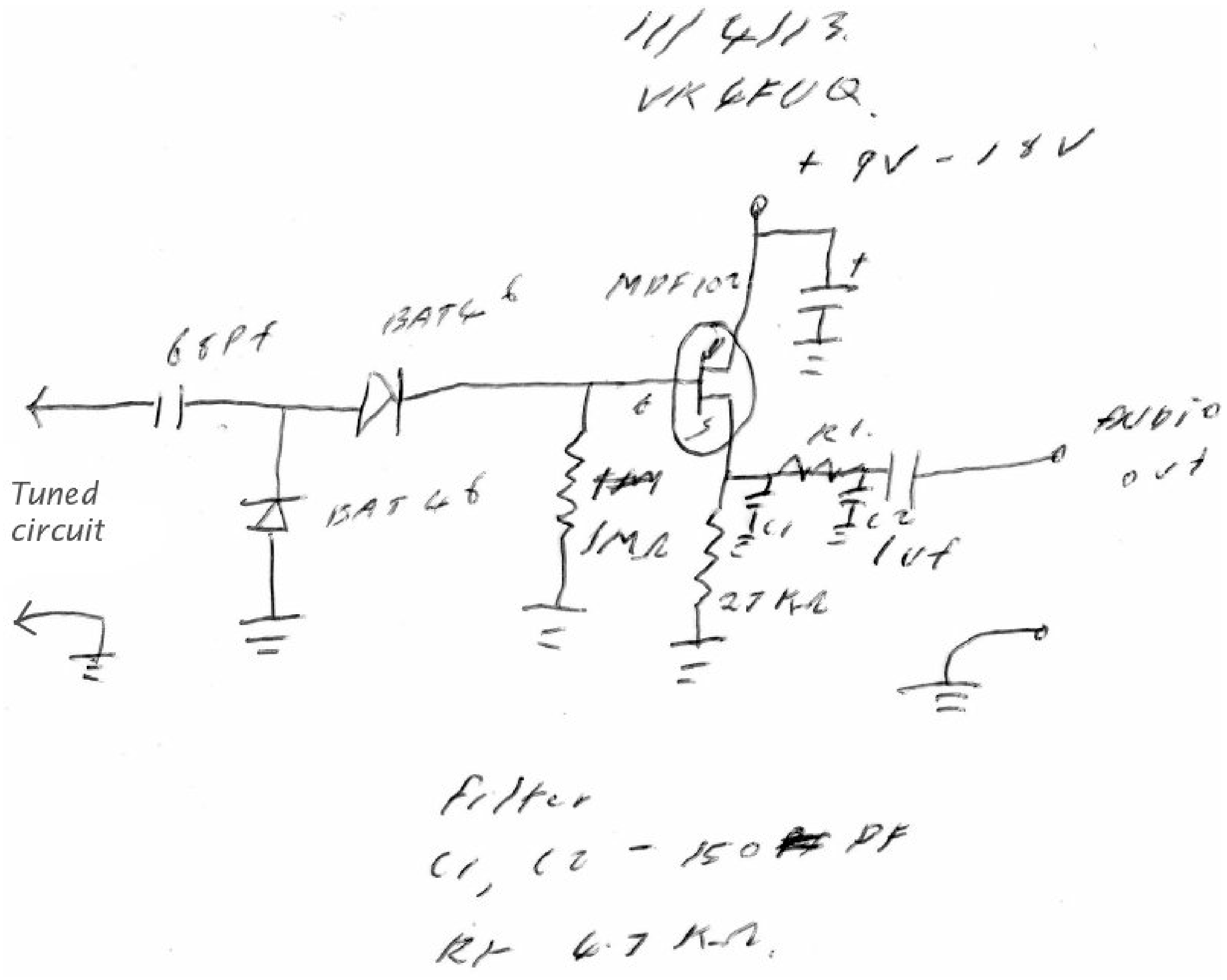
11/4/13.
VK4FUQ.
+ 9V - 18V
+
MPF102
BAT46
68pf
g
s
Tuned circuit
BAT46
~~1M~~
1MΩ
R1.
C1
C2
1uf
27KΩ
Audio out
Filter
C1, C2 - 150 pF
R1 4.7 KΩ.

Felix Scerri VK4FUQ

UPDATE - JUNE 2013

G’day all, readers may recall the two FET infinite impedance detector I developed some time ago. That circuit worked well, but some samples of the MPF102 regretfully produced distorted output. However a recent discovery has resulted in an improved version that has truly exemplary performance.

The MPF102 is in all honesty a device essentially designed for VHF applications, but is often used in simple audio applications albeit with occasionally indifferent results, due to general device parameter ‘spread’. More or less by empirical trial and error I have found that a simple change in source resistor value to 100 k (from a much lower value), pretty well fixes everything.

In a FET source follower circuit this is interesting as the output impedance is actually a lot lower than 100 k due to the action of the FET’s transconductance. It is similar to the action of a bipolar transistor emitter follower circuit. In fact a simple infinite impedance detector with a 100 k source resistor actually works very well and will be good enough for many applications, however the addition of a second FET as a constant current source does markedly reduce overall audio distortion in the stage overall, and produces very clean and low distortion audio quality and also reduces the output impedance considerably (good for tuner applications), so take your pick!

Regards, Felix vk4fuq 02/06/2013.

UPDATE - JANUARY 2014

A simple modification to the basic FET 'infinite impedance' AM detector that dramatically improves performance.

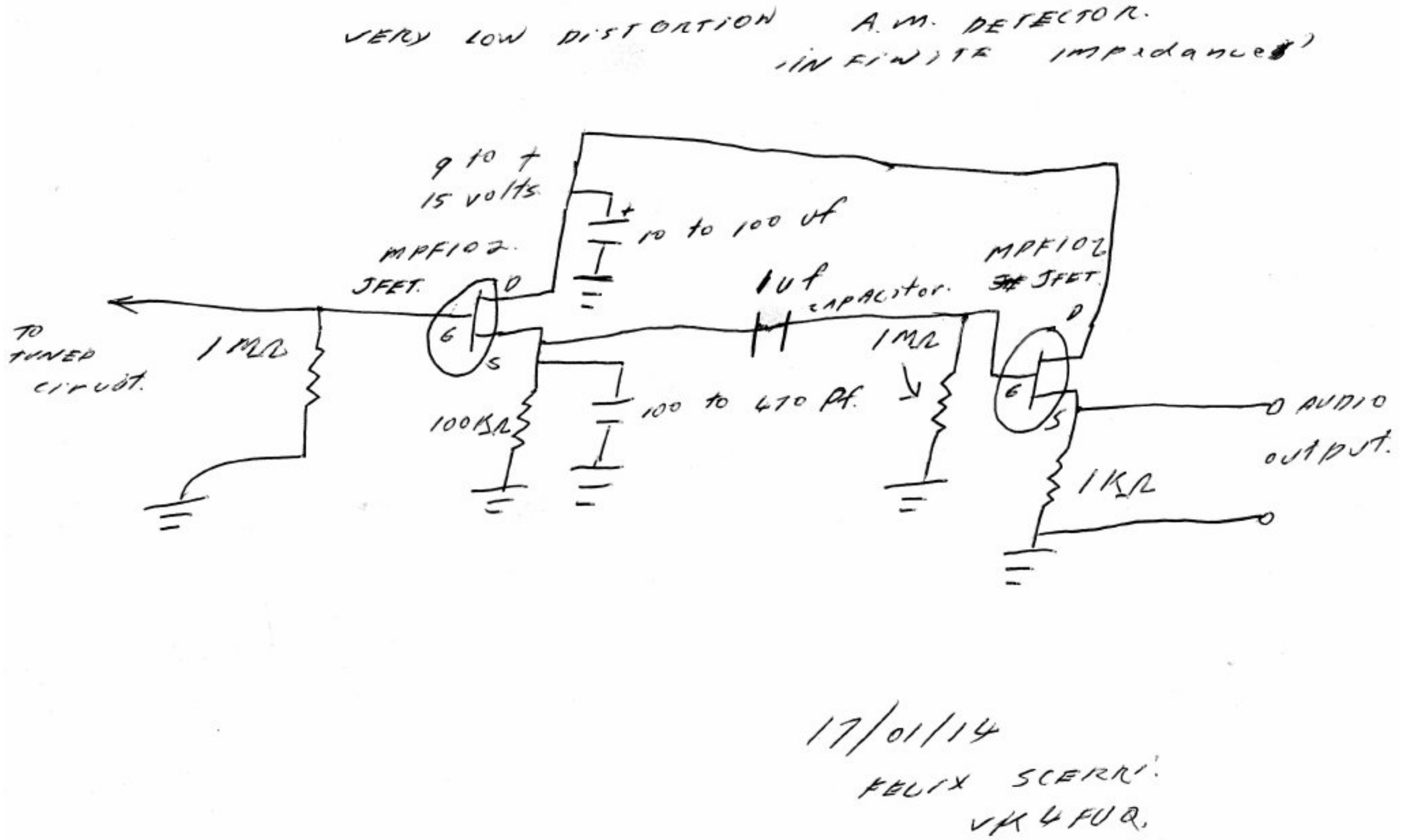

G’day all, over the Christmas break just messing around I worked out (mostly by accident), a simple modification for the simple FET based ‘infinite impedance’ detector circuit that dramatically improves weak signal performance and also greatly reduces audio distortion.

Essentially by the addition of another FET ‘buffer’ stage, another source follower, capacitively coupled from the first detector stage. The circuit is actually a simplified version of the circuit that I described in this link, http://sound.westhost.com/articles/am-radio.htm (figure 6) and testing the two head to head, they both sound superb and the simpler version is actually somewhat easier to build. I cannot get over how low distortion and ‘nice’ the recovered audio sounds. It is a joy to listen to!

Regards, Felix vk4fuq 12/01/2014.

Diodes for ‘weak signal’ crystal set applications.

As I am primarily interested in using crystal sets as AM tuners for feeding into a preamplifier/amplifier and loudspeakers, the actual type of diode can be relatively critical. In a strong signal area, not so much, but in a weak signal area such as where I reside, definitely. A diode with a good ‘square law’ performance (the area below the ‘knee’ in the diode curve), generally results in much cleaner and lower distortion than other good performing diodes, and believe me diode distortion under weak conditions, even with optimised diode ‘buffering’ used is very nasty sounding to the ear!

Testing many, many diodes in actual working crystal sets and listening critically to the audio output, it seems to me that the best diodes to use under weak signal conditions are the so called ‘gold bonded’ germanium diodes. I have sampled many different gold bonded germanium diodes and they all work well in this specific application, although sometimes the rectified output voltage may not be as high as other germanium or silicon schottky diodes, however the audio quality is much cleaner and shows much less apparent distortion!

I have tried OA5, OA47, IN141 and several ‘CG’ gold bonded germanium diodes with consistently excellent results. Other ‘ordinary’ germanium diodes may also work well under weak signal conditions, but they will need to be tested individually to check actual performance in a working circuit. One thing that I have noticed about germanium diodes is that due the ‘point contact’ nature of their construction, even diodes of the same specific type can exhibit rather different levels of performance!

The otherwise very good BAT46 silicon schottky diode works extremely well at good RF input level but not so well at weak RF input, especially when heavy broadcast ‘processing’ (commonplace these days), is used. New ‘gold bonded’ germanium diodes are probably no longer made although I am aware that they can be purchased through vendors over the internet. Apart from that, they may be found in old gear. As stated earlier, ordinary germanium diodes may be quite good but will need to be checked individually. Diodes are complex things!

Felix (vk4fuq). 29/01/2014.

* * * * * * * * * * * * * * *

Just when I thought that I’ve tried everything I realised that I’ve not tried a voltage doubler (diode integrator) detector with an RF stage in front. It is an unfortunate fact that all diode detectors ‘need’ a good RF injection level (and buffering) or audio distortion becomes ‘bad’ (an understatement!)

Consider yourself very lucky if you live in a strong signal area! (unfortunately I don’t). Anyway I quickly built a couple of prototypes which worked ok but not as well as hoped. Initially I tried using a source follower buffer (no voltage gain), but converting it to a common source amplifier (with appreciable voltage gain), seemed no better, which was strange.

After staring at my prototype for what seemed like forever with my magnifiers on, I (finally) realised my mistake. A common source stage takes its output off the ‘drain’ terminal of the FET, not the ‘source’ terminal as it does with the FET source follower buffer stage. I shifted one wire, and all worked as expected and it sounds fantastic! All diode detectors (one diode envelope detectors, doubler detectors etc), need good RF input and a simple untuned FET RF gain stage works very well. As to the sound, it sounds great.

73 vk4fuq 10/03/2014.

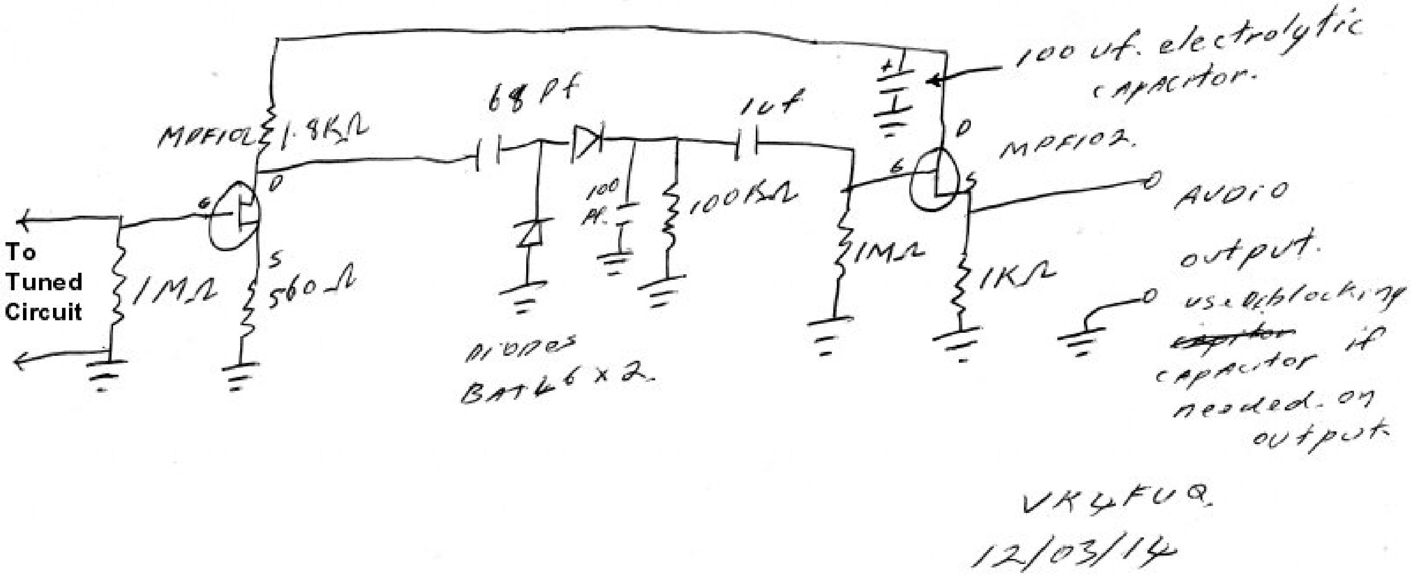

Felix Scerri's FET Crystal Set with Voltage Doubler

A 'nice sounding' AM detector - update October 2015

Looking through these pages the other day I was slightly shocked to realize that I've completely forgotten about some of the circuits that I've contributed in earlier days! They all work pretty well, however in my advancing older age and a little like my tastes in high fidelity generally, I'm starting to show a particular preference for 'nice sounding' bits of audio gear.

I guess that this also means low noise/low distortion too, although with AM broadcasting, at least in this country and probably elsewhere in the world too, the very common use of broadcasting 'processing' tends to make it hard for AM detectors generally, often resulting in a 'hard/compressed' sort of sound although still low in distortion, is not 'nice sounding', if that makes any sense!

Well of all the AM detectors that I've tried and/or developed, only one sounds 'nice' when confronted by heavy broadcast processing and that is an AM detector 'based' on a voltage doubler/diode integrator circuit (similar to the above circuit, actually the 68 pf capacitor should be changed to .1 uf, for slightly greater output).

It has taken me a very long time (years) to 'optimise' this circuit, but as it presently stands this is my favourite 'nice sounding' AM detector, and gets most use for general high quality listening on the AM broadcast band. It sounds really good! It somewhat reminds me of an old OA47 gold bonded diode detector from years ago before such abhorrent 'processing' became commonplace!

Ah yes the OA47….now that is a lovely sounding detector diode!

Regards, Felix vk4fuq. 17 / 10 / 2015.

* * * * * * * * * * * * * * *

That's it for crystal sets. I hope you try building one, it's easy and great fun!

See some useful links below....

73's
Mike

Crystal Sets (Part1) | Build Your Own Crystal Set (Part 2)

Spider's Web Crystal Set (Part 3) | Crystal Set By Kenneth Rankin (Part 4) | Crystal Radio Links

Amateur Radio

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No AM radio stations or transmitters in your locality or country?

Spitfire
AM Transmitter

Has your local medium wave broadcast station closed or been moved to VHF/FM or Digital? Don't worry. You can still build and experiment with crystal sets and TRF radios by also buying or even building a simple low power AM transmitter. So, not only can you use your crystal sets but you can also run your own radio station that can be heard in and around your home - playing the music or programmes that you want to hear!

SSTRAN AMT3000 Superb high fidelity medium wave AM transmitter kits from SSTRAN. Versions available for 10kHz spacing in the Americas (AMT3000 or AMT3000-SM) and 9kHz spacing in Europe and other areas (AMT3000-9 and AMT3000-9SM). Superb audio quality and a great and well designed little kit to build: http://www.sstran.com/pages/products.html

POWER
GAIN
MODULATION
COMPRESSION
SSTRAN
AMT3000

http://www.sstran.com/

Other AM transmitters available:

Spitfire & Metzo Complete, high quality ready built medium wave AM Transmitters from Vintage Components: http://www.vcomp.co.uk/index.htm Vintage Components offer a choice of the high quality Spitfire and Metzo transmitters:

SPITFIRE AM Medium Wave Transmitter with 100 milliwatt RF output power:

http://www.vcomp.co.uk/spitfire/spitfire.htm

Spitfire
AM Transmitter

METZO AM Medium Wave Transmitter with built in compressor:

Gain
Comp
Mod
Metzo

http://www.vcomp.co.uk/metzo/metzo.htm

AM88 LP A basic AM transmitter kit from North County Radio.
http://www.northcountryradio.com/Kitpages/am88.htm

LINKS: Fine links to more Crystal Radio websites here

Component Suppliers: Links to electronic component suppliers here

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Crystal Sets Introduction | Resistor & Capacitor Conversion Tables

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CRYSTAL SETS 2

Some Practical Designs
MAKE YOUR OWN
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CRYSTAL SETS 2: SOME PRACTICAL DESIGNS

I hope that you attempt building one or two of these crystal set designs and I really do recommend that the components are carefully connected up using soldered joints onto a piece of tag-strip for reliability. However if you are new to constructing such electronic circuits then some simple solder-less techniques could be employed and these are suggested at the bottom of the page. Also see Crystal Sets Part 5 for more ideas on experimenting with crystal sets.

An early and very basic crystal set would have been nothing more than a coil of wire, perhaps 50 -100 turns, wound around a cardboard tube about 3 inches (7cm) in diameter, a detector (or cats whisker) and a pair of special High Impedance headphones (as discussed in part 1).

There would be a very large aerial strung up around the garden and the all important connection to earth.

The coil would have tapping points (connection points) at intervals of around 5 or 10 turns. See the circuit diagram on the right for details of who the set is wired together.

The tapping points on the coil allow the set to be tuned to different frequencies by adjusting the position of tap B. Tap B would be connected to the coil at differently positions by way of a crocodile clip. The fewer turns between the top (aerial end) of the coil and tap B, the shorter the wavelength received (ie the higher the frequency). Tap A would allow the detector to be connected at different positions to vary performance. There is an additional component drawn in the above diagram, the *capacitor* (value 1000pF), this is included in crystal sets that used the *High Impedance* magnetic headphones, and bypassed any remaining radio frequencies (RF) to earth.

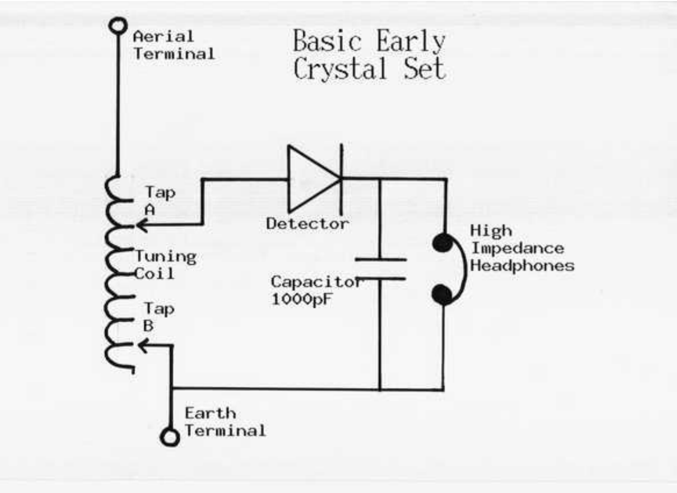

A very basic crystal set circuit.

I have not built the set described above as it is so basic. Such a crystal set above would probably have been adequate in 1920 - 1923 when there would have been only one local transmitter receivable.

When the BBC expanded transmissions and it became possible to hear more than a single station it would have became necessary to include a more convenient means of tuning the set.

This was achieved by including a Variable Tuning Capacitor, of about 500pF (0.0005uF) connected in parallel with the tuning coil forming a *tuned circuit*. The tuning capacitor would have a Bakelite knob on the spindle to aid tuning.

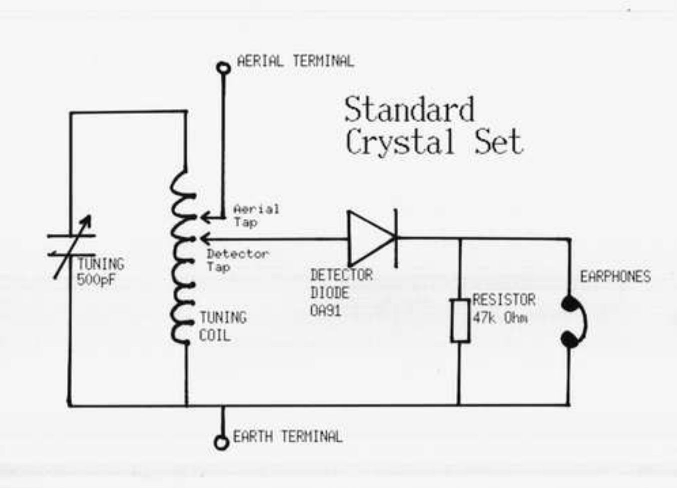

The Standard Crystal Set

Because of the simplicity of crystal sets, it is often difficult to separate stations. When tuned into one station it is often possible to hear another close by station in the background, this is due to lack of *selectivity*. This can be reduced somewhat by adjusting the positions of the Aerial Tap and Detector Tap. Moving them closer to the bottom of the coil, the earthy end, reduces the load on the tuned circuit and this improves selectivity, however it does also reduce *sensitivity* which can make the station quieter. Headphones will often swamp a tuned circuit and reduce its selectivity (Q factor), so moving the tapping point lower down improves this situation. Every circumstance is bound to be different though so the best balance has to be found by experimentation. My crystal set has both the diode and the aerial connected to the same tapping point on the coil, about a quarter of the way down.

The modern 'standard crystal set' shown above uses a Crystal Earphone, since suitable high impedance magnetic headphones (of 2000 to 4000 ohms) are no longer widely available. When using a crystal earpiece the 1000pF capacitor shown in the first diagram can usually be omitted an in its place a 47k ohm resistor is connected, this ensures that the Crystal Earphone will work at its most efficient i.e. the sounds will be as loud as possible. The resistor allows DC current to flow through the circuit efficiently - this would otherwise be blocked when using a crystal earphone. In a modern crystal set the detector used is a *Diode.* Suitable diodes include OA80, OA81, OA90 OA91 and IN94 which are usually available from component stockists.

A Better Diode For Increased Efficiency

The OA47 will be of particular interest since it has the lowest forward bias voltage of any of these diodes which will make the crystal set somewhat more sensitive and therefore louder. The US equivalent of the British OA47 is the IN34.

On the right you will see my real working example of a crystal set

The large plastic knob on the front turns the variable tuning capacitor. This set receives the three UK national stations and also three local radio stations very well at my location.

There is a small 3.5mm jack socket mounted on the front of the plastic case (MB5 from Maplin Electronics) that the crystal earphone plugs into.

The coil can be seen inside the case, it is 70 turns of 30 gauge enamelled copper wire wound around the centre of a toilet roll and tapped every 10 turns, by scraping off the enamel insulation and making a small twist. The croc' clips can be seen clipped on to these twists to connect to the aerial and detector tap points.

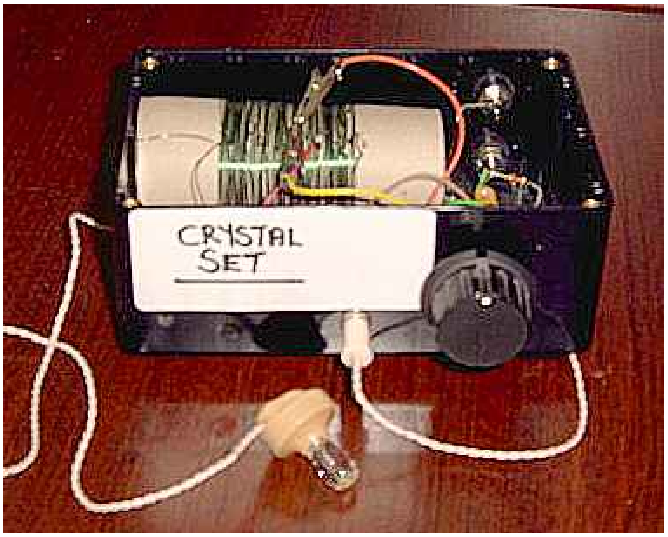

A real working crystal set. Radio as if by magic with no battery or mains power.

THE MEDIUM WAVE COIL - MORE DETAILS

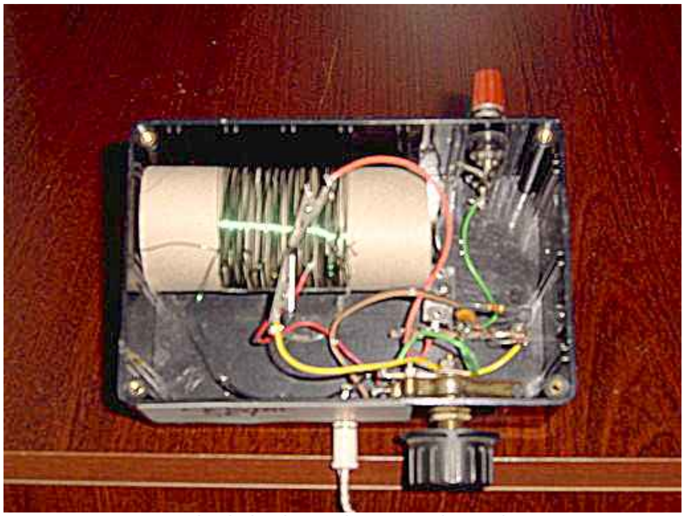

PHOTO SHOWING THE INSIDE OF
THE COMPLETED CRYSTAL SET

Medium Wave Coil

The number of turns of wire required on the coil will vary depending on the size of the former (in this case the inside toilet roll) and the thickness of the wire. So to obtain the correct coverage of the medium wave band may need a little experimentation.

I usually find that between 50 to 90 turns is right and I generally use enamelled copper wire that is between 30 s.w.g. and 26 s.w.g (i.e. 0.315mm and 0.45mm diameter), so it's best to start with too many turns and then work down.

The more turns that you use the lower the frequency range will be, i.e. too many and the coverage of the top end of medium wave around 1500 - 1600 kHz will be lost, while too few and the coverage down to 500 kHz will be lost.

It is also important that the coil former is non conducting, i.e. not metallic. It could be wood or cardboard or a short piece of PVC piping and with a diameter of between 1½ and 4 inches (4 to 15 cm) are common sizes. You could try using a ferrite rod too, see below.

This particular set has a coil wound onto a toilet roll tube which consists of 70 turns of 30 s.w.g. (0.315mm dia) enamelled copper wire tapped at every 10 turns. It also has the additional small trimmer capacitor that helps match the aerial to the tuned circuit thereby improving selectivity, see below.

USING A FERRITE ROD AS THE COIL FORMER

The aerial coil could be wound onto a ferrite rod.

A piece of 10mm diameter ferrite rod of between 3 and 6 inches long (80 to 150mm) will be most suitable and will require between 50 and 90 turns of enamelled copper wire to provide coverage of the medium wave band: First make a paper tube that is held together with sticky tape that will easily slide up and down the ferrite rod. Then wind the coil over this with the windings neatly side by side. Make tapping points every 10 or 15 turns so that the aerial and diode tapping points can be adjusted.

Adjustments to the tuning range can be made by removing some wire from the coil so it is best to start off with too many turns and then work down. Fine adjustments can be made to the completed coil by sliding it up and down the ferrite rod.

AN IMPROVEMENT TO THE DESIGN

The crystal set above also has one small, but significant, improvement over the standard crystal set and that is an Aerial Trimmer. A trimmer is a variable capacitor, very similar to the tuning capacitor, except smaller and adjusted with a screwdriver.

The value of the trimmer is usually around 10 - 50pF, but if a small tuning capacitor is available that will probably be just as effective. In the absence of such a variable capacitor, individual fixed ceramic capacitors of e.g. 10pF, 50pF and 100pF can be tried in this position to judge which gives the best results with the particular aerial being used.

The trimmer capacitor adjusts the coupling to the tuned circuit, reducing the load of the aerial on the tuned circuit will improve the selectivity (Q), and it will be easier to separate stations. Again tapping points are used and I find this to be an excellent arrangement.

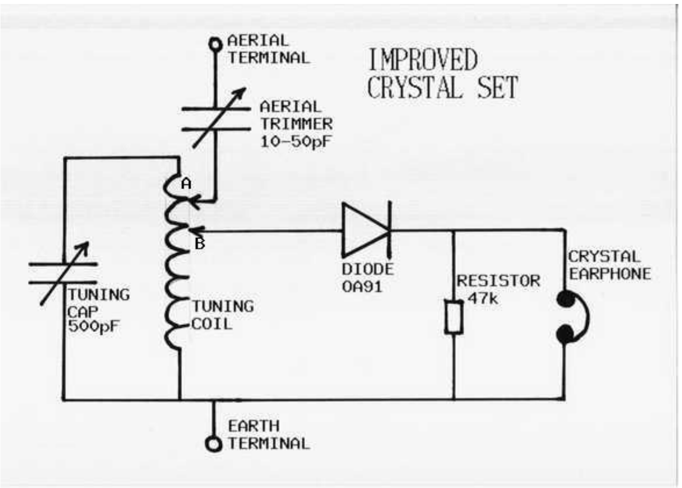

Improved Crystal Set design, with good selectivity

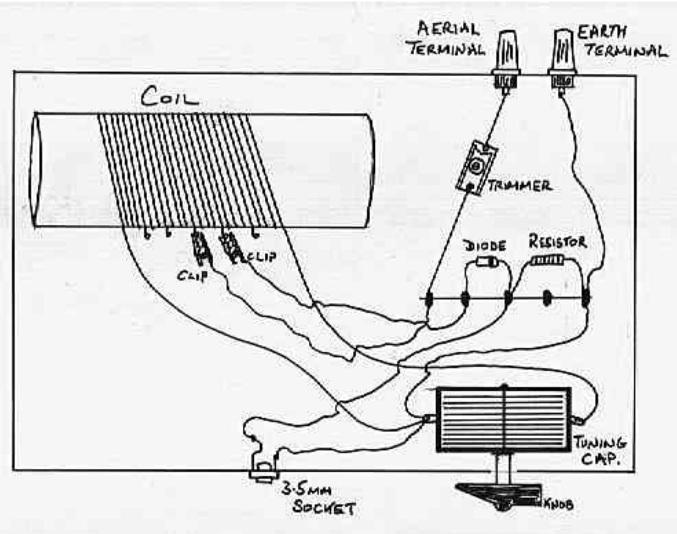

Layout Of The Crystal Set - Although this is soldered together an alternative to tagstrip would be a 5amp mains connector block so that components can be trapped in place with screws. See article below.

The picture on the right shows the general layout of the crystal set above. The coil is of approximately 70 turns is wound on the centre of a toilet roll, and has tapping points at 10 turn intervals.

The trimmer is soldered between the Aerial terminal and the piece of 5-way tag strip, and a wire goes from there to a croc' clip which is clipped onto a tap on the coil. The Diode is also soldered onto the tag strip, one end connected to a piece of wire going to a second croc' clip & connected to a tapping point on the coil, the other end of the diode is connected to the 3.5mm jack socket that the Crystal Earphone plugs into.

The 47k resistor is also connected to the earphone end of the diode and goes to earth, the earth terminal wire is soldered to the tag strip at this point too. The tuning capacitor has two terminals, one connected to each end of the coil, and one of them is also connected to earth as shown. [Where the wires cross over in the diagram, they do not touch and are not connected together].

LONG WAVES

In most areas around Europe and certainly around much of the UK you will be able to hear a Long Wave station. To receive Long Wave on a crystal set will require an aerial coil with a greater number of turns to increase its inductance.

As a good general guide a coil wound on a piece of 10mm diameter ferrite rod will require about 250 turns of enamelled copper wire: First make a paper tube that is held together with sticky tape that will slide up and down the ferrite rod. Then wind the 250 turn coil over this, the windings will have to be made over the top of each other. Make tapping points at, say, 50, 75 and 100 turns to tap the aerial and diode to.

As with the medium wave ferrite rod aerial, adjustments to the tuning range can be made by adding or removing some wire from the coil, and fine adjustments can be made to the completed coil by sliding it up and down the ferrite rod. The longer the ferrite rod the better and anything between 3 and 6 inches long (80 to 150mm) will be very good.

SHORT WAVES

If you like experimenting, then reducing the number of turns on the coil to say 10 to 30 will allow reception of the higher frequencies, the Short Waves. I have found that winding the coil around a 'ferrite rod' often works even better with short wave reception.

Obtain a ferrite rod about 7 to 15 cm long and about 1cm in diameter. Make a couple of small tubes of card, about 4cm long, that will fit tightly over the rod.

On one tube wind two coils using 0.5mm diameter enamelled copper wire - one coil of about 30 turns and a second one of 2 or 3 turns wound over the top of the first. Secure the windings in place with Sellotape.

On the other card tube wind a similar coil, but use about 15 turns for the first coil and for the second coil wind about 3 to 4 turns over the top, and secure with Sellotape tape.

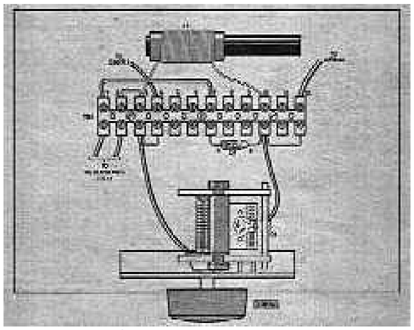

Example of a layout using a connector block to wire up a crystal set

These coils will provide coverage of short wave in two bands using the first coil for the longer wavelengths, typically 60 to 31 metre bands and the second coil for the shorter wavelengths typically 25 to 19 metre band. Wire up the circuit as shown in the circuit diagram below.

USING A TOROID INDUCTOR FOR SHORT WAVES

Even better selectivity performance can be achieved by winding the inductors (coils) on a ferrite toroids (T50-2 yellow, or green will do). The aerial trimmer need not be used if selectivity and sensitivity is found to be adequate. It's all about experimenting, and I find it best to use a trimmer or small coupling capacitor to obtain the best selectivity.

Up to 30 turns of 0.5mm enamelled copper wire can be used for the longer short waves below 10 MHz, while a winding of around 15 turns will provide coverage of the shorter short waves above 10MHz.

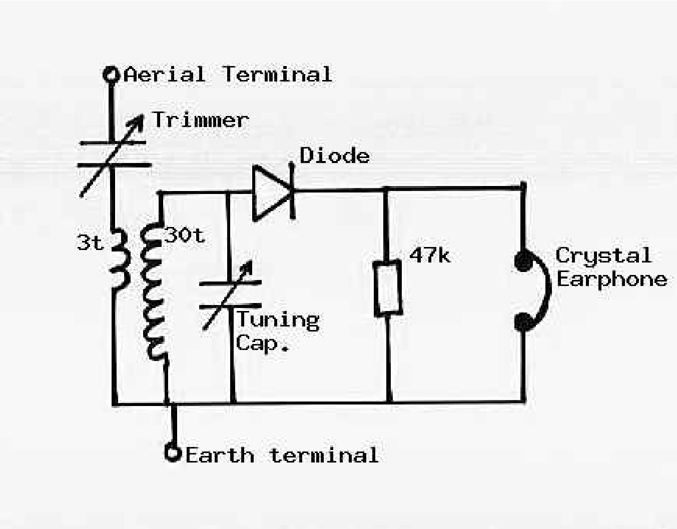

The circuit diagram of the Short Wave Crystal Set

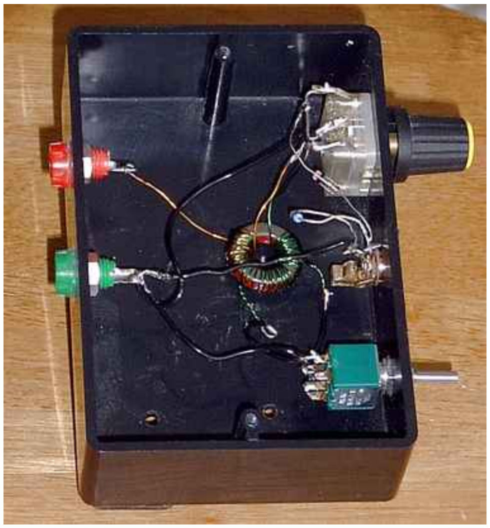

A completed SW Crystal Set using a toroid inductor. Note: the main winding has a tap to allow the switch to short part of the winding and thereby give two ranges.

AUSTRALIAN DESIGN

Moving back to the Medium Waves, here is a circuit for a very interesting Australian design that promises extremely good station separation (selectivity), and having built it I can vouch for that claim, it's really excellent.

I receive three national stations and three local stations at my location with excellent clarity using a modest antenna and standard crystal earphone.

The coil is different to the other crystal sets described above, it is much bigger at 3¼ inches (8cm) diameter and 5inches (12cm) long. I made my coil former out of the cardboard from a breakfast cereal box - just like Blue Peter!

The design is often referred to as The Mystery Crystal Set, by Proton.

The front panel of the Australian Crystal Set

Two distinct coils are wound on it, the first one consists of about 50 turns of 24 s.w.g (approx) enamelled copper wire. The second coil is 25 turns, very close wound right over the top of the first coil using 30 s.w.g. (approx) wire, try to get this second coil wound in between the windings of the first, for better inductive coupling.

Then carefully wire up the set according to the diagram. Notice that the tuned circuit is not connected to earth and has no *direct* connection to the detector circuit. The detector circuit *is* connected to earth however. The two aerial terminals offer alternative selectivity performance, terminal A gives very good selectivity while B is very wide. I never bother with B.

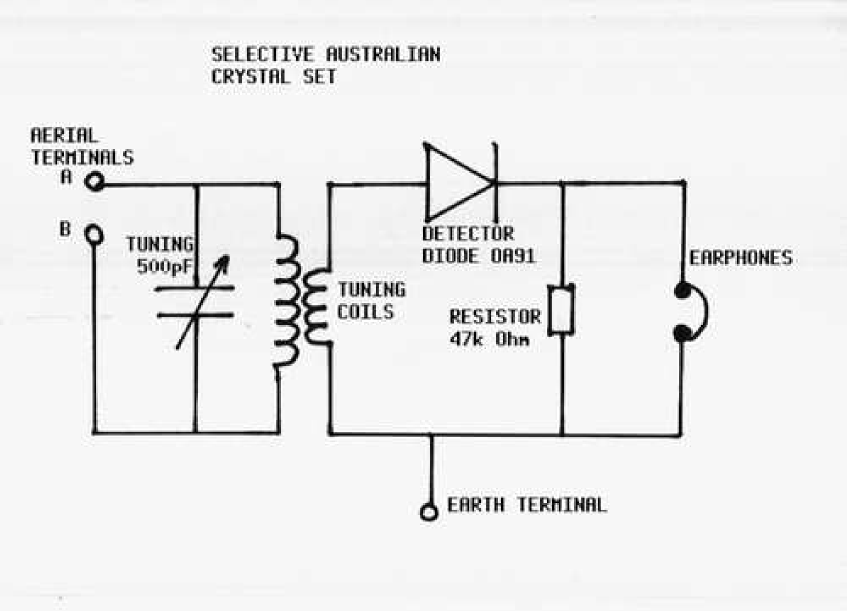

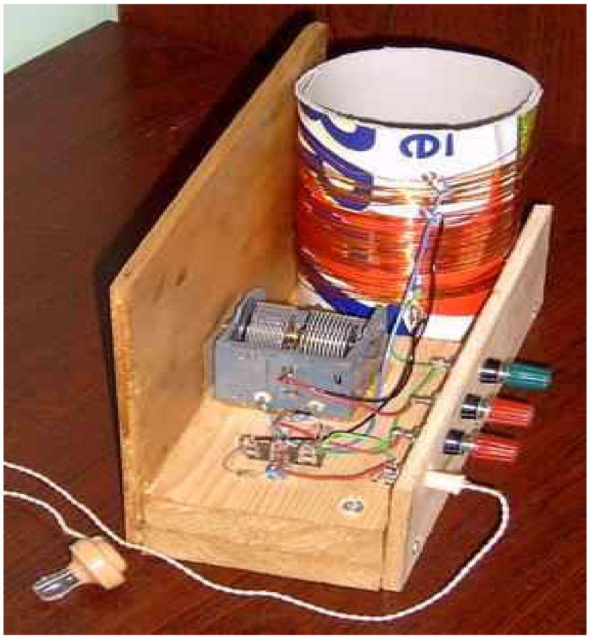

Make the coil carefully and wire up this crystal set according to the circuit diagram opposite and you will be rewarded with a really high performance crystal set of a type that was used in the very early days of broadcasting in 1930's in Australia.

This is probably my favourite crystal set!

THE DENCO PCC1 COIL

The PPC1 coil was a commercially manufactured by Denco Clacton Ltd and was popular among hobbyists not keen on going to the bother of winding their own fiddly little coils. As a child I wanted try one of these coils and sent away for one by mail order. It arrived a few days later in a little cloth bag, like a miniature pump bag, with protective wrapping inside.

The coil windings are entirely enclosed in what I can only describe as a cylindrical ferrite 'shell', the four very thin connecting wires exiting, two either side, from small apertures in the 'shell'. The performance of the circuit shown below I seem to remember was quite pleasing. Unfortunately I cannot find the set or the PPC1 coil at the moment, but here is a reproduction of the circuit diagram and data:

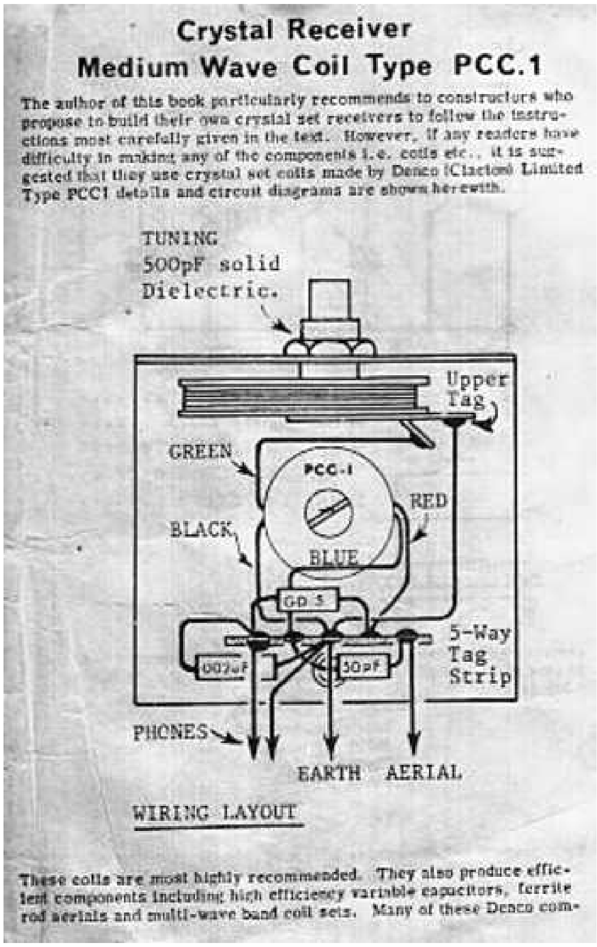

Crystal Receiver
Medium Wave Coil Type PCC.1

The author of this book particularly recommends to constructors who propose to build their own crystal set receivers to follow the instructions most carefully given in the text. However, if any readers have difficulty in making any of the components i.e. coils etc., it is suggested that they use crystal set coils made by Denco (Clacton) Limited Type PCC1 details and circuit diagrams are shown herewith.

TUNING
500pF solid
Dielectric.
Upper
Tag
GREEN
PCC-1
RED
BLACK
BLUE
GD 5
·002uF
50pF
5-Way
Tag
Strip
PHONES
EARTH
AERIAL

WIRING LAYOUT

These coils are most highly recommended. They also produce efficient components including high efficiency variable capacitors, ferrite rod aerials and multi-wave band coil sets. Many of these Denco com-

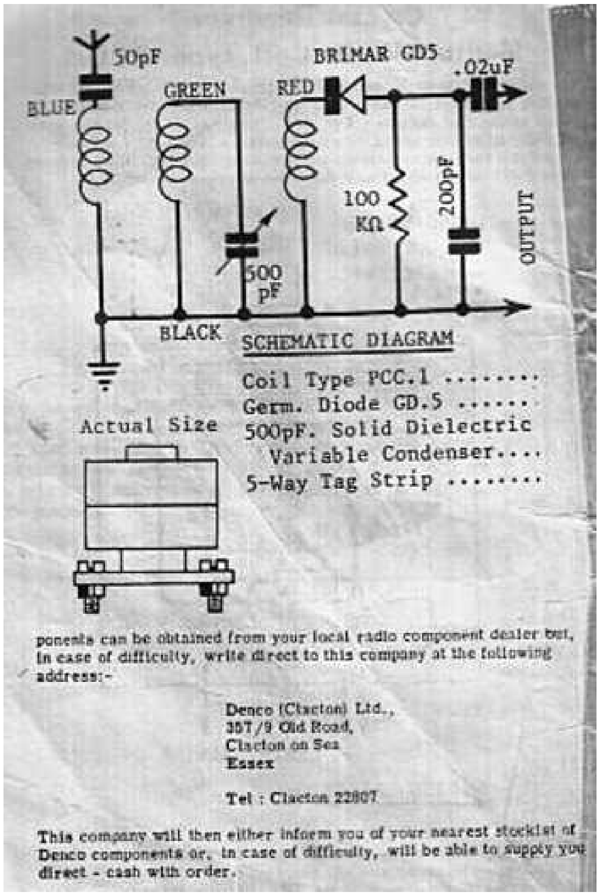

50pF
BRIMAR GD5
.02uF
BLUE
GREEN
RED
100
KΩ
200pF
OUTPUT
500
pF
BLACK

SCHEMATIC DIAGRAM

Coil Type PCC.1 ....
Germ. Diode GD.5 ......
500pF. Solid Dielectric
Variable Condenser....
5-Way Tag Strip ....

Actual Size

ponents can be obtained from your local radio component dealer but, in case of difficulty, write direct to this company at the following address:-

Denco (Clacton) Ltd.,
357/9 Old Road,
Clacton on Sea
Essex

Tel : Clacton 22807

This company will then either inform you of your nearest stockist of Denco components or, in case of difficulty, will be able to supply you direct - cash with order.

THE REPANCO DRR2 COIL

I recently rediscovered an old Repanco DRR2 Longwave / Mediumwave coil that must have been kicking around in my junk box since the 1970's.

The DRR2 coil was made by Repanco in Coventry. It came with a page of suggested circuit diagrams which I thought had been lost to the mists of time, but it recently came to light again, so I have now copied it below.

Once again I included an aerial trimmer which can be adjusted to improve selectivity.

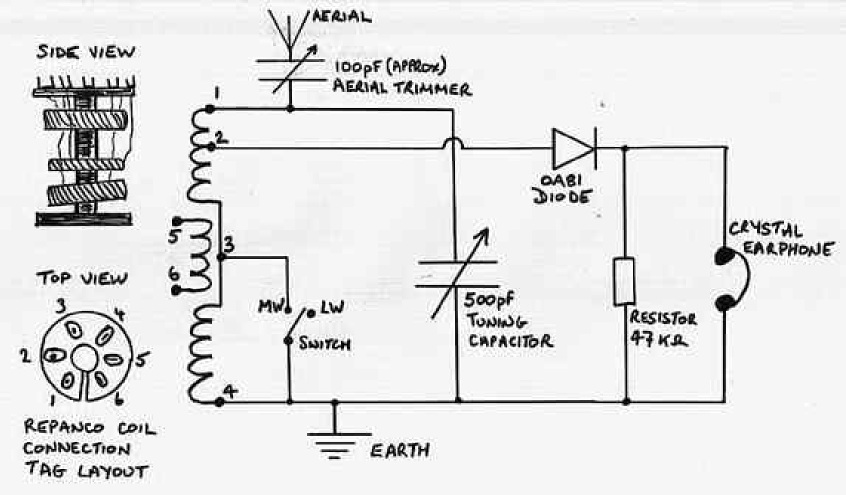

AERIAL
SIDE VIEW
100pF (APPROX)
AERIAL TRIMMER
1
2
OA81
DIODE
5
3
6
CRYSTAL
EARPHONE
TOP VIEW
3
4
2
5
1
6
MW
LW
SWITCH
500pF
TUNING
CAPACITOR
RESISTOR
47KΩ
4
REPANCO COIL
CONNECTION
TAG LAYOUT
EARTH

The circuit diagram of the crystal set using the Repanco DRR2 coil

Repanco Ltd was formed by two ex-army signals engineers and from the earliest days of radio supplied crystal set kits and coils to radio construction enthusiasts.

The Repanco DRR2 coil was for medium wave and long wave intended for use in when building simple crystal set and valve radio

A 'lash-up' of the Repanco crystal set

circuits.

It consists of three coils; a Medium Wave coil at the top that includes a tapping point (for the aerial); a coupling coil or tickler in the middle; a lower coil which can be connected in series with to top coil to provide Long Wave reception.

I have built a quick crystal set with the coil and it provides good reception with excellent selectivity, so it must have a very good Q factor.

The Repanco DDR2 coil was provided with a simple Foolscap size information sheet that showed four different radio circuits. Sadly the sheet does not give a huge amount of information and my copy is now rather tatty and faded - it is copied below:

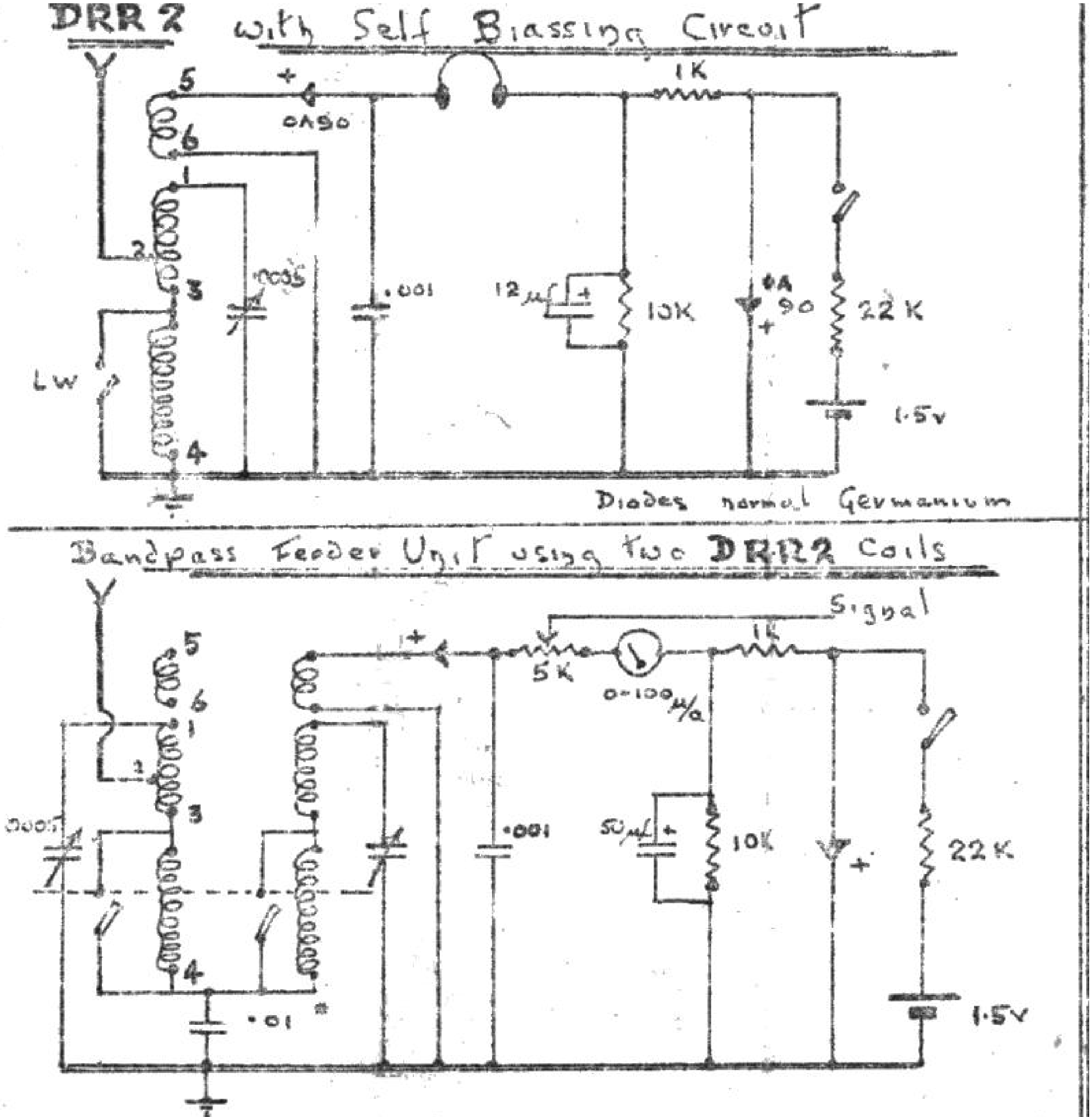
DRR 2 with Self Biassing Circuit
5
6
1
2
3
4
+
OA90
1K
.0005
.001
12µf
+
10K
OA 90
+
22K
1.5v
LW
Diodes normal Germanium
Bandpass Feeder Unit using two DRR2 Coils
Signal
5
6
1
2
3
4
+
5K
0-100µ/a
1K
.0005
.001
50µf
+
10K
+
22K
1.5V
.01
*

* The larger the coupling condenser the smaller the coupling + the greater the selectivity.

DRG: 104E

Designed and published by

REPANCO LTD. 20[illegible] FOLESHILL RD COVENTRY CV1 4[illegible]Z

Simple crystal radio type circuits using the Repanco DRR2 coil

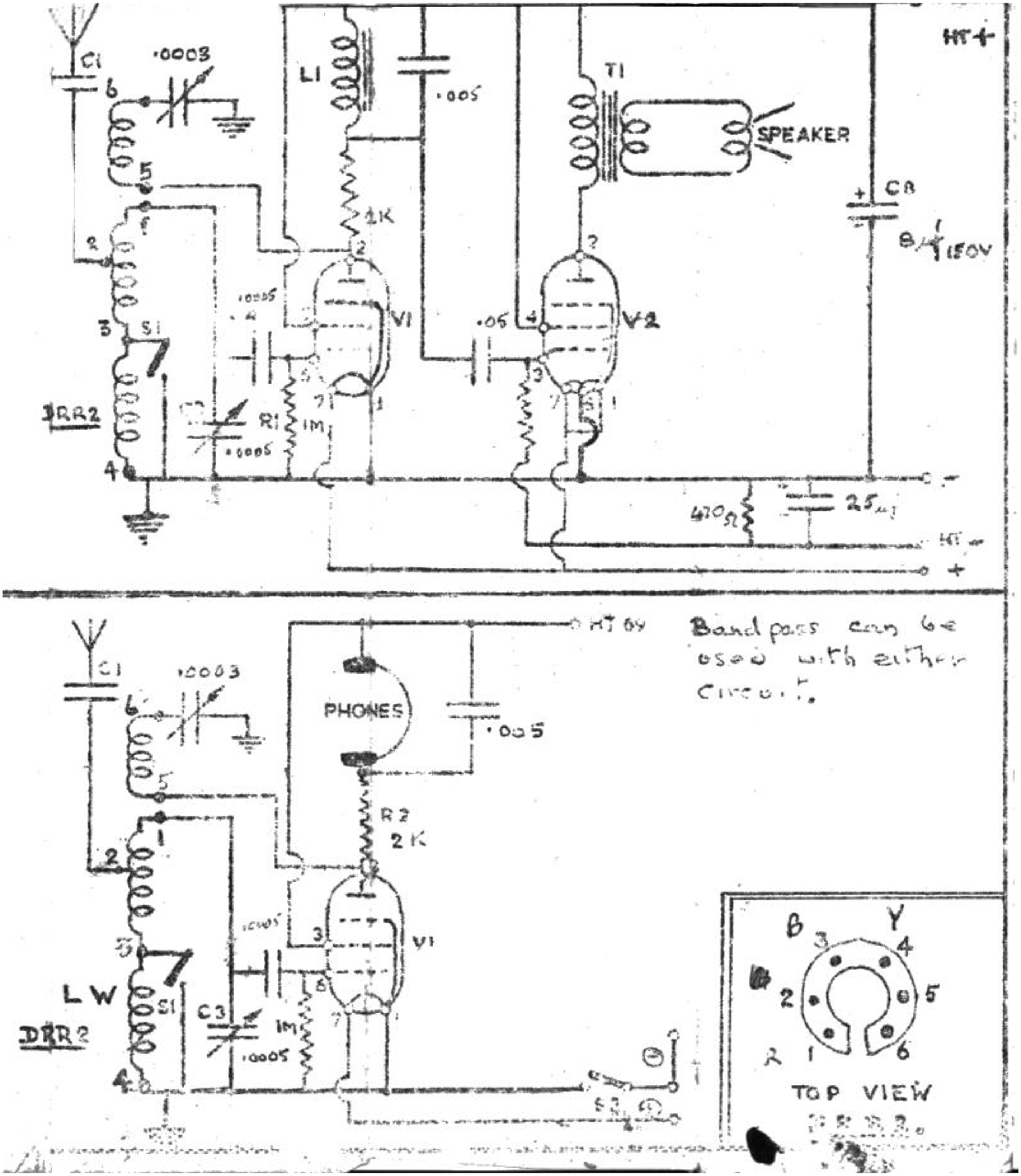
C1
·0003
6
5
1
2
3
4
S1
DRR2
L1
·005
T1
SPEAKER
HT+
CR
8μF 150V
1K
V1
·0005
R1
1M
·05
V2
470Ω
25μF
HT−
−
+
HT 6V
C1
·0003
PHONES
·005
R2
2K
V1
LW
S1
DRR2
C3
1M
·0005
S2
B
Y
R
1
2
3
4
5
6
TOP VIEW
DRR2

Band pass can be used with either circuit.

Valve circuits using the Repanco DRR2 coil

Repanco Ltd no longer produces radio coils and crystal set kits for the radio construction enthusiast, as it did in the early days of radio. In 1986 it was renamed Repanco Bartlett Ltd when it merged with Bartlett Electronics. The company moved from the Foleshill Road to Unit 24, Albion Industrial Estate, Endemere Road, Coventry CV6 5NT and now specialises in transformers and wound components and can design and manufacture to commercial customer requirements, their website is: http://www.repancobartlett.co.uk/

CRYSTAL EARPHONES

Here is a good idea and well worth trying, to maximise the use of sound output from your crystal set why not use dual crystal earphones? Having an earphone in each ear helps to block out extraneous noises helping the listener to better concentrate on any weaker stations received.

Using the circuit below, one earphone makes use of one half cycle of the radio wave while the second earphone uses the other half cycle of the wave that would have previously gone to waste when using just one diode. Ensure that the diodes are connected up according to the diagram i.e. one diode is connected the opposite way round to the other.

Also try to make sure that the diodes and crystal earphones are similar to obtain the best results. (You could simply connect two crystal earphones to the same terminals of the single diode, but this would not be as efficient and the sounds would be much quieter.)

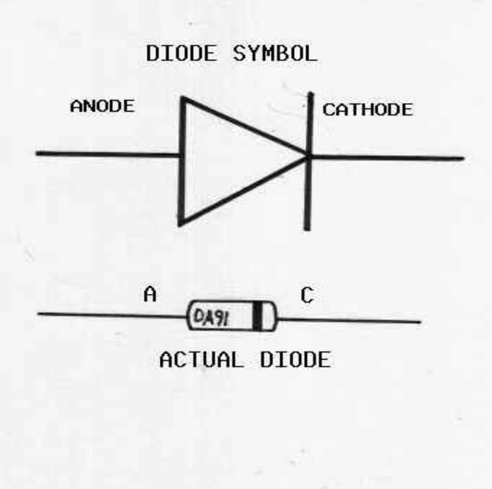
DIODE SYMBOL
ANODE
CATHODE
A
C
OA91
ACTUAL DIODE

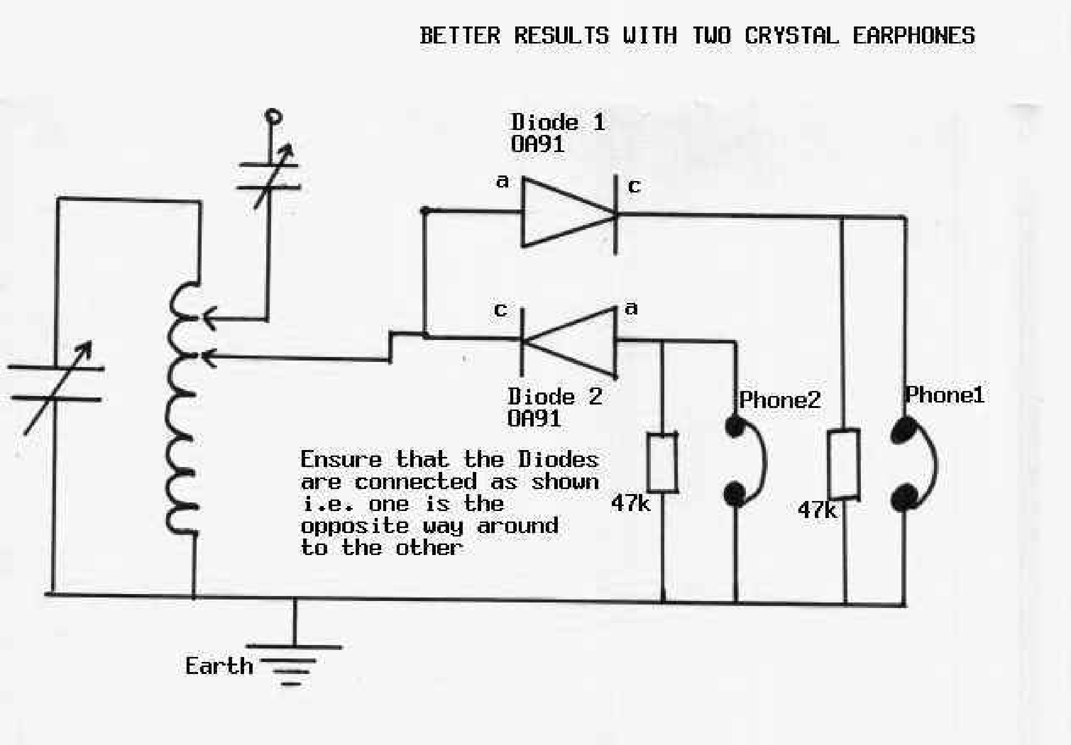
BETTER RESULTS WITH TWO CRYSTAL EARPHONES
Diode 1
OA91
a
c
c
a
Diode 2
OA91
Ensure that the Diodes are connected as shown i.e. one is the opposite way around to the other
47k
Phone2
47k
Phone1
Earth

A note about Crystal Earphones: It will be worthwhile buying several different ones from different sources as performance varies between manufacturers quite markedly. I have found the ones marked 'Japan' on the back are the most sensitive and therefore loudest, whereas ones marked 'Receiver' 'Taiwan' are often a little less sensitive and therefore quieter and sometimes more 'tinny' sounding.

As mentioned previously it has been noted that the OA47 diode will be of particular interest since it has the lowest forward bias voltage of any of the common diodes available. This will make the crystal set somewhat more sensitive and therefore louder. The US equivalent of the British OA47 is the IN34.

SPIDERS WEB' COIL

Here is an interesting concept sent in by Chris Dorna of the Vught North Scouts in the Netherlands. It is a crystal set made out of a coil wound in the form of a spiders web:

See more HERE.

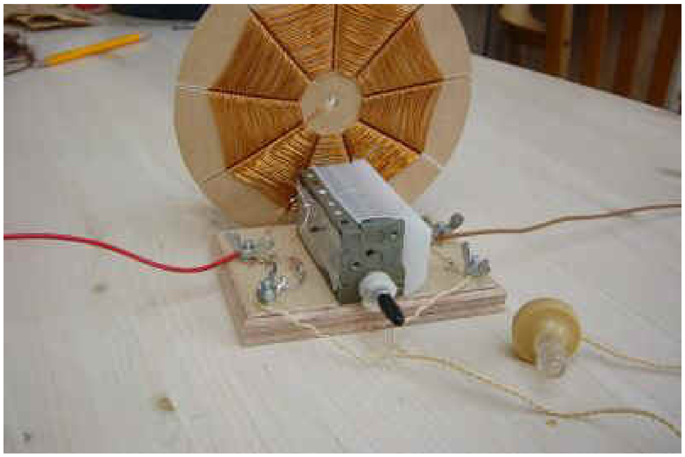

Chris Dorna's Crystal Set with Spider Web Coil

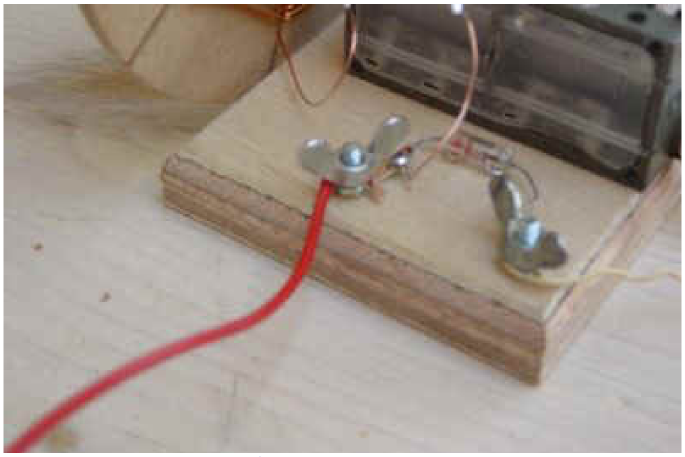

Detail of the germanium diode

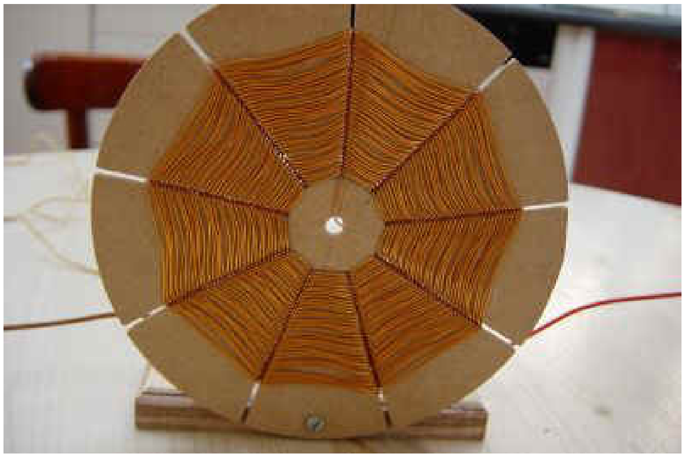

Close up of Chris Dorna's Spider Coil

LOOP THE LOOP!

A crystal set can also be made that does not need a large long wire aerial. If you have ever made a loop aerial for medium wave or long wave DX-ing, then it is a simple matter to add a diode, resistor and a socket to connect a crystal earphone that will allow reception of nearby stations.

See my section on Loop Aerials and ATU's for more constructional details.

A portable loop aerial, that incorporates a crystal set

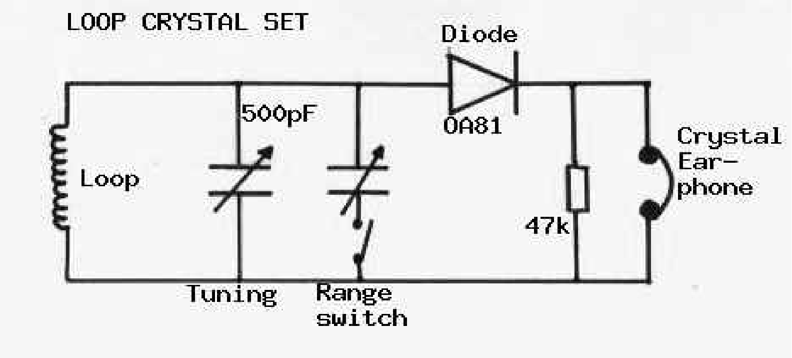

The circuit diagram of the Loop Crystal Set. The loop is 10 turns of 7/0.2mm 'hook-up' wire wound on a 40cm (17") former made of attractive plastic edging strip available from many DIY stores. The loop is very directional in its pick up pattern, which can help eliminate interference from some stations by rotating the loop. The switch and additional capacitor allow tuning of the lower medium wave band from about 650 to 520 kHz. Having a loop with 50 to 60 turns of wire will tune into the Long Wave band.

DIODES - For Crystal Set Use - some notes by Felix Scerri

Germanium diodes for crystal set use.

Although I'm a fan of these new silicon schottky BAT 46 diodes, good germanium diodes still have a lot to offer, especially in terms of 'weak signal' sensitivity. Last night I did an experiment.

I sorted through quite a few of my hundreds of acquired random germanium diodes looking for particularly 'sensitive' ones. I tested this by tuning in a weak AM station and comparing the detected DC output level and also the apparent 'loudness' of the audio signal.

Even amongst germanium diodes of the same type, there was enormous variation all the way from excellent to poor! For very weak signals, germanium diodes 'detect' in the 'square law' region below the diode conduction 'knee', in a rather different part of the curve than with much stronger signals (way beyond the diode knee).

When testing germanium diodes for weak signal sensitivity, the inherent capacitance of the diodes is also a factor, and the 'tuning' may change somewhat and will need to be readjusted with every diode tested!

In the end, out of a large number of germanium diodes tested, I found three or four germanium diodes with excellent weak signal sensitivity and the rest were poor. One other interesting thing, good germanium diodes 'sound' different, rather more 'rounded and smoother' than the schottky's which tend to sound mercilessly clean, almost clinical. I also found almost no variation in weak signal sensitivity with my BAT 46 schottky diodes. Take your pick!

Regards, Felix Scerri VK4FUQ 14/03/2012

SOLDERLESS CONSTRUCTION IDEAS

For a novice the use of a soldering iron may seem a bit daunting at first and while the most reliable results will be obtained with a good soldered joint using a tag strip as shown below, the circuits can still be made without the use of a soldering iron.

5 WAY TAG STRIP

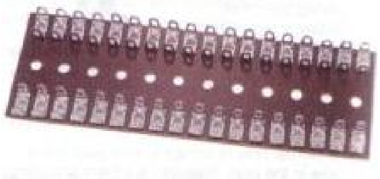

36 WAY TAG STRIP - TWO ROWS

The very simplest circuits could be wired together ,with a little ingenuity, with the component wires being held together in the grip of solderless crocodile clips, whereby the connecting hook-up wire is fixed to the croc' clip by a screw rather than solder.

For more the slightly more complex circuits a plastic Terminal Block (sometimes referred to as a choc' or chocolate block) can be utilised very effectively indeed. These are used in mains wiring and are available in various sizes; 2 Amp, 5 Amp, 15 Amp and 30 Amp. The 5 and 15 Amp Terminal Blocks I have found to be the most suitable. The various component wires can be trapped securely with the screw at each junction point. This method also makes it easy to change the components around when experiment with different circuits. See The EXPERMENTAL CRYSTAL SET for more details in Part 5**.**

'CHOCOLATE' TERMINAL BLOCK

The Ladybird book called 'Making A Transistor Radio' (also shown on the TRF Radio pages) detailed a very novel approach using brass screws with screw-cups to trap the component wires at each junction point:

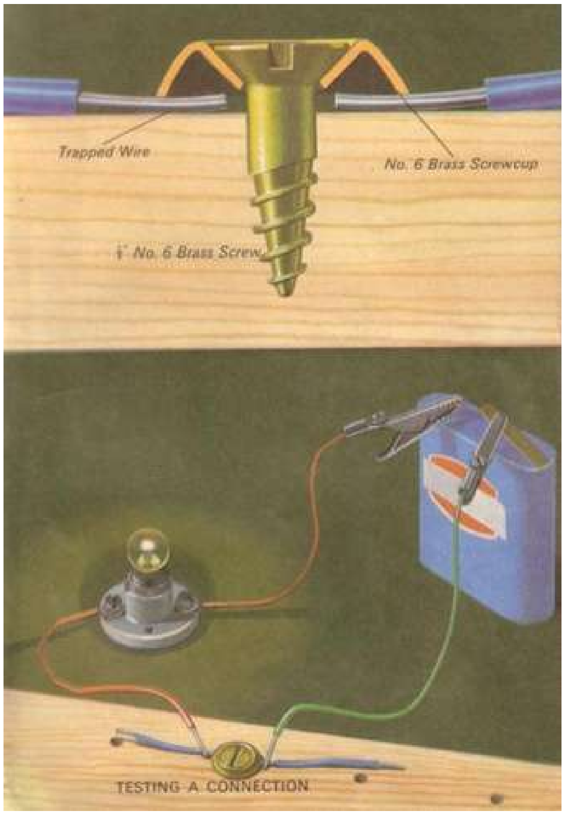
Trapped Wire
No. 6 Brass Screwcup
No. 6 Brass Screw
TESTING A CONNECTION

THE BRASS SCREW AND SCREW-CUP METHOD OF CONSTRUCTION

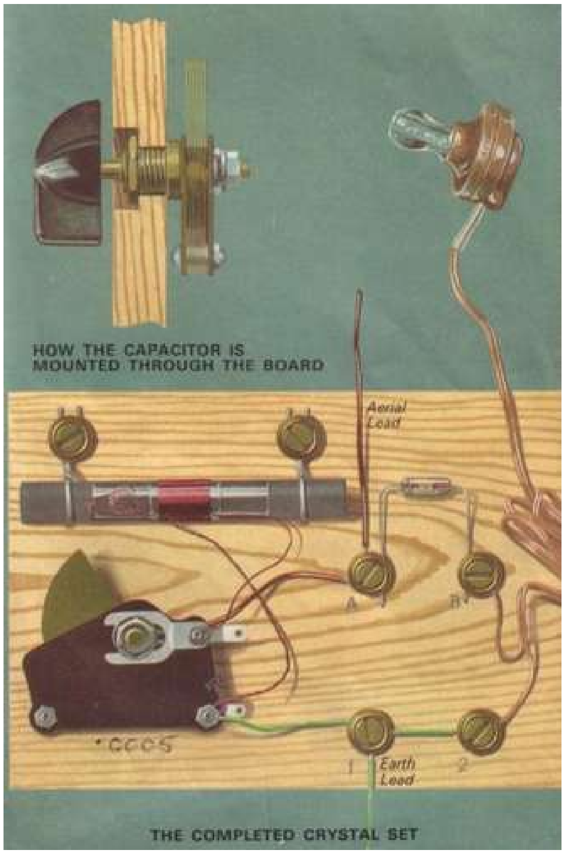
HOW THE CAPACITOR IS MOUNTED THROUGH THE BOARD
Aerial Lead
A
B
·0005
1
Earth Lead
2
THE COMPLETED CRYSTAL SET

A VERY SIMPLE CRYSTAL SET USING THE BRASS SCREW AND CUP METHOD

Crystal Sets Part Part 3 >

No AM radio stations or transmitters in your locality or country?

Spitfire
AM Transmitter

Has your local medium wave broadcast station closed or been moved to VHF/FM or Digital? Don't worry. You can still build and experiment with crystal sets and TRF radios by also buying or even building a simple low power AM transmitter. So, not only can you use your crystal sets but you can also run your own radio station that can be heard in and around your home - playing the music or programmes that you want to hear!

SSTRAN AMT3000: Superb high fidelity medium wave AM transmitter kits from SSTRAN. Versions available for 10kHz spacing in the Americas (AMT3000 or AMT3000-SM) and 9kHz spacing in Europe and other areas (AMT3000-9 and AMT3000-9SM). Superb audio quality and a great and well designed little kit to build: http://www.sstran.com/pages/products.html

POWER
GAIN
MODULATION
COMPRESSION
SSTRAN
AMT3000

http://www.sstran.com/

Other AM transmitters available:

Spitfire & Metzo: Complete, high quality ready built medium wave AM Transmitters from Vintage Components: http://www.vcomp.co.uk/index.htm Vintage Components offer a choice of the high quality Spitfire and Metzo transmitters:

SPITFIRE AM Medium Wave Transmitter with 100 milliwatt RF output power:

http://www.vcomp.co.uk/spitfire/spitfire.htm

Spitfire
AM Transmitter

METZO AM Medium Wave Transmitter with built in compressor:

Gain
Comp
Mod
Metzo

http://www.vcomp.co.uk/metzo/metzo.htm

AM88 LP: A basic AM transmitter kit from North County Radio.
http://www.northcountryradio.com/Kitpages/am88.htm

LINKS:

BOWOOD ELECTRONICS - A friendly, helpful and very speedy source for many of your electronic components at prices that won't frighten your wallet!

THE FOXHOLE and P.O.W RADIOS - Simple crystal set receivers used by soldiers during the war and by prisoners of war (P.O.W.'s).

VINTAGE COMPONENTS - A great resource for crystal sets, components, valve radio kits and medium wave AM transmitters!

6V6 - Electronic Nostalgia and Vintage Components

Crystal Sets Part 3 >

Crystal Sets (Part1) | **Spider's Web Crystal Set (Part 3**

Crystal Set by Kenneth Rankin (Part 4) | **Experimental Crystal Sets (Part 5)** | **Crystal Radio Links**

^Top Of Page

Amateur Radio
MØMTJ Visit my amateur radio pages MØMTJ

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Crystal Sets Introduction | Resistor & Capacitor Conversion Tables

www.mds975.co.uk © 2004 - 2014

Mike's Electronic Parts, LLC
Simple Crystal Radio Kit 2

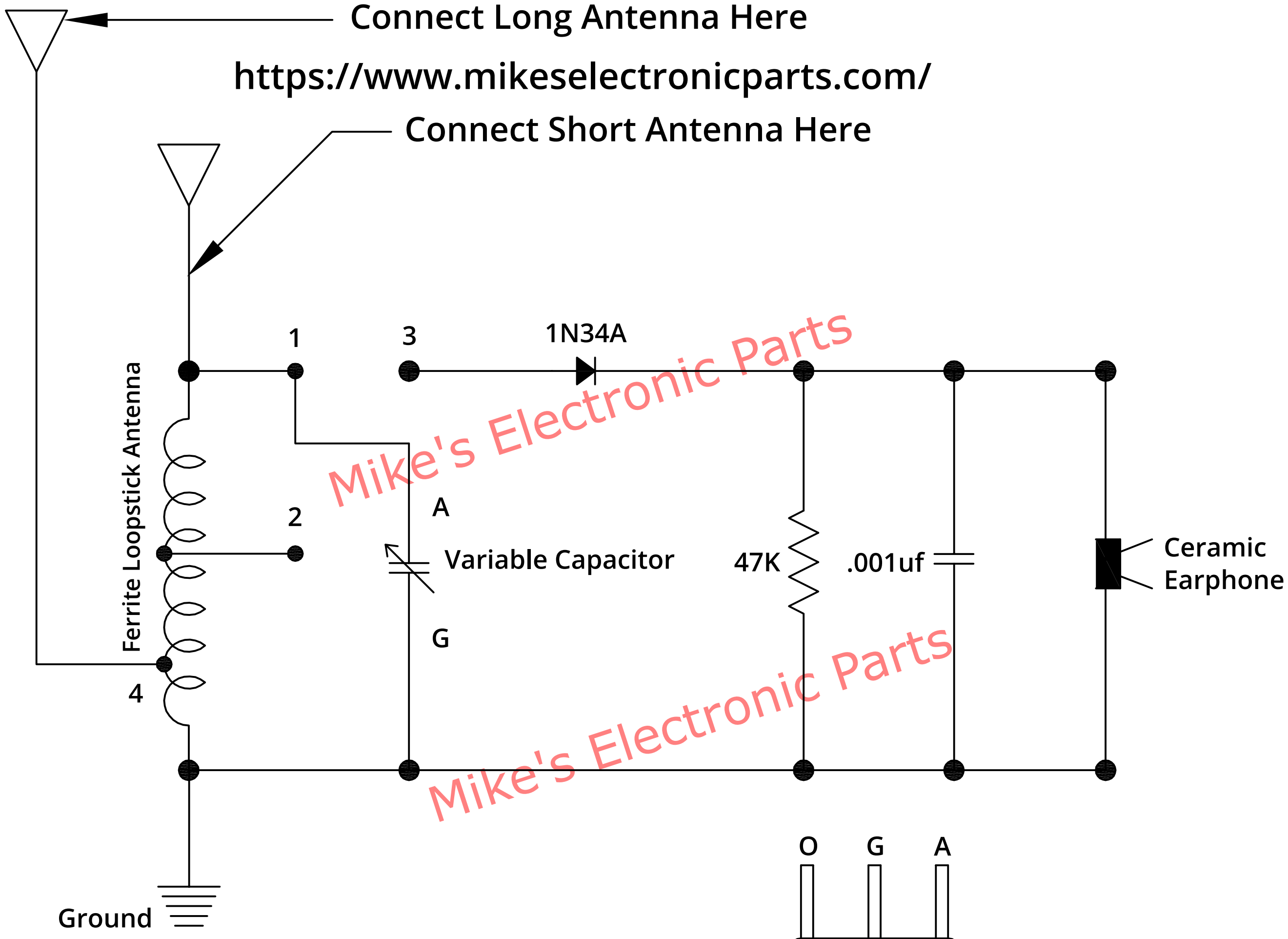
Connect Long Antenna Here

https://www.mikeselectronicparts.com/

Connect Short Antenna Here

Mike's Electronic Parts
Mike's Electronic Parts

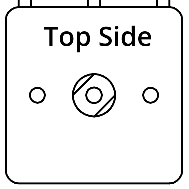

Variable Capacitor

Parts List
1 - Ferrite Loopstick Antenna
1 - Variable Capacitor
1 - Germanium Diode 1N34A
1 - .001uf Capacitor Marked 102
1 - 47K Resistor
1 - 20 Million Ohm Ceramic Earphone
Antenna and Ground wire not include with parts

For short antenna connect a 15ft to 30ft length of wire to "1". For long antenna 40ft to 100ft connect to "4". It is best to use a long wire antenna. If you are not using the taps do not cut the wires. Doing so will cause the coil not to work. Various connections are, Connect 1 to 3 or Connect 2 to 3. Most volume can be had at 1 to 3 less volume but better selectivity connect 2 to 3 and the antenna connected at 1. It is best to solder the coil wire, not doing so may cause a bad connection and the radio will not work.
Drawn By: Scott Lowe
This Kit can be bought at my web site Part Number CRK#2 Kit.

https://www.mikeselectronicparts.com/

THE SMITHSONIAN INSTITUTION

The Smithsonian Institution is home to more than 141 million objects, ranging in size from insects and diamonds to locomotives and spacecraft. It is the world's largest museum complex, comprising 15 museums and galleries and the National Zoo in Washington DC, and two additional museums in New York City. Millions of visitors each year visit the nation's capital to view such treasures as the Hope Diamond, the Star Spangled Banner, and the Wright Flyer. A broad range of exhibits ensures a fun and educational experience for young and old alike.

One of the world's leading scientific research centers, the Institution has facilities in eight states and the Republic of Panama. Research projects in the arts, history and science are carried out by the Smithsonian all over the world. Some of the Smithsonian's research centers include the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, the Smithsonian Marine Station at Link Port, in Florida, and the Smithsonian Tropical Research Institute, in Panama.

For membership information of pre-visit planning material, write or call the Visitor Information and Associates Reception Center, Smithsonian Institution, Washington, D. C., 20560, (202) 357-2700 (voice), (202) 357-1729 (TTY). You may also visit the Smithsonian through our web site, www.si.edu.

HISTORY

James Smithson (1765 –1829), a British scientist, drew up his will in 1826 naming his nephew, Henry James Hungerford, as beneficiary. Smithson stipulated that, should the nephew die without heirs (as he did in 1835), the estate would go to the United States to found "at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge..."

On July 1, 1836, Congress accepted the legacy bequeathed to the nation by James Smithson, and pledged the faith of the United States to the charitable trust. In 1838, following approval of the bequest by the British courts, the United States received Smithson's estate—bags of gold sovereigns—then the equivalent of $515,169. Eight years later, on August 10, 1846, an Act of Congress signed by President James K. Polk, established the Smithsonian Institution in its present form and provided for the administration of the trust, independent of the government itself, by a Board of Regents and Secretary of the Smithsonian.

SMITHSONIAN MUSEUMS, GALLERIES AND ZOOS

Smithsonian Institution [illegible]
Anacostia Museum
Arthur M. Sackler Gallery
Arts and Industries Building
Cooper-Hewitt, National Design Museum
Freer Gallery of Art
Hirshhorn Museum and Sculpture Garden
National Air and Space Museum
National Museum of African Art
National Museum of American History, Behring Center
National Museum of the American Indian
National Museum of Natural History
National Portrait Gallery
National Postal Museum
National Zoological Park
Renwick Gallery
S. Dillon Ripley Center
Smithsonian American Art Museum

SMITHSONIAN®

CRYSTAL RADIO™

WARNING!
ONLY FOR USE BY CHILDREN OVER 8 YEARS OLD.

READ THE INSTRUCTIONS BEFORE USE,
FOLLOW THEM AND
KEEP THEM FOR REFERENCE.
STORE THE SET OUT OF REACH
OF SMALL CHILDREN.

PLEASE KEEP A NOTE OF OUR NAME AND ADDRESS DETAILS FOR FUTURE REFERENCE. IN EUROPE CONTACT:

NSI SIMM GAmbH
D 76162 KARLSRUHE
GERMANY
49-0721-9584-116

PLEASE BE SURE TO READ THE ADVISE
FOR SUPERVISING ADULTS
AND THE SAFETY RULES
CONTAINED IN THIS BOOKLET.

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NATURAL SCIENCE INDUSTRIES, LTD.
910 ORLANDO AVE.
WEST HEMPSTEAD, N.Y. 11552

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ITEM NO. 3261-08

ADVICE FOR SUPERVISING ADULTS:

- **READ AND FOLLOW THESE SAFETY INSTRUCTIONS, THE SAFETY RULES AND KEEP THEM FOR REFERENCE.**

- **SUPERVISING ADULTS SHOULD DISCUSS ANY WARNINGS AND SAFETY INFORMATION WITH THE CHILD BEFORE COMMENCING THE ACTIVITIES.**

SAFETY RULES:

- **DO READ THE INSTRUCTIONS BEFORE USE, FOLLOW THEM AND KEEP THEM FOR REFERENCE.**
- **DO KEEP YOUNG CHILDREN AND ANIMALS AWAY FROM THE ACTIVITY AREA.**
- **DO STORE THE SET OUT OF REACH OF YOUNG CHILDREN.**

Facts about early crystal development

Several inventors receive credit for developing a "crystal detector", a device which can pass current better in one direction than the other in an electrical circuit. In Germany, in the 1870's, Karl F. Braun noticed this property in certain mineral substances. Commercial development required a technology that would be suitable. This came with the advent of wireless communication and radio after 1900.

In Japan, Wichi Torikata investigated many minerals, including zincite, pyrolusite, iron pyrites and galena. In the United States, Greenleaf W. Pickard, associated with the Wireless Specialty Apparatus Co. of Boston, conducted extensive experiments as well. He became well known for the PERIKON Detector which employed zincite and chalcopyrite. The early 20th century work was generally done between 1900 and 1912. Included among the scientists is General H.H.C. Dunwoody of the U.S Army who developed a carborundum detector.

Until radio broadcasting began in 1920 (Station KDKA Pittsburgh) experimenters utilized the crystal detector for radiotelephone communications and for reception of certain Morse Code signals. There was also extensive use by the U.S. Navy and other maritime services.

The modern crystal diode, such as provided with your set, is a spin-off of radar technology developed during World War II. The basic principle, however, remains the same, i.e. to remove the AUDIO (speech, music or Morse-Code) from the radio frequency carrier wave. In one early Pickard crystal design (left) a stiff metal point is adjustable over the crystal surface. In a later version a "Catswhisker" spring impinged on a piece of galena (right) and was varied to give a louder signal.

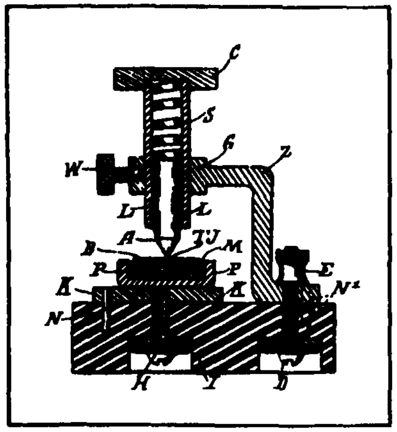

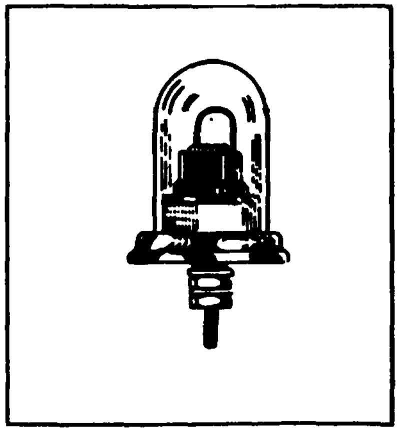

Your Smithsonian Smart Lab Crystal Radio Set contains the following items

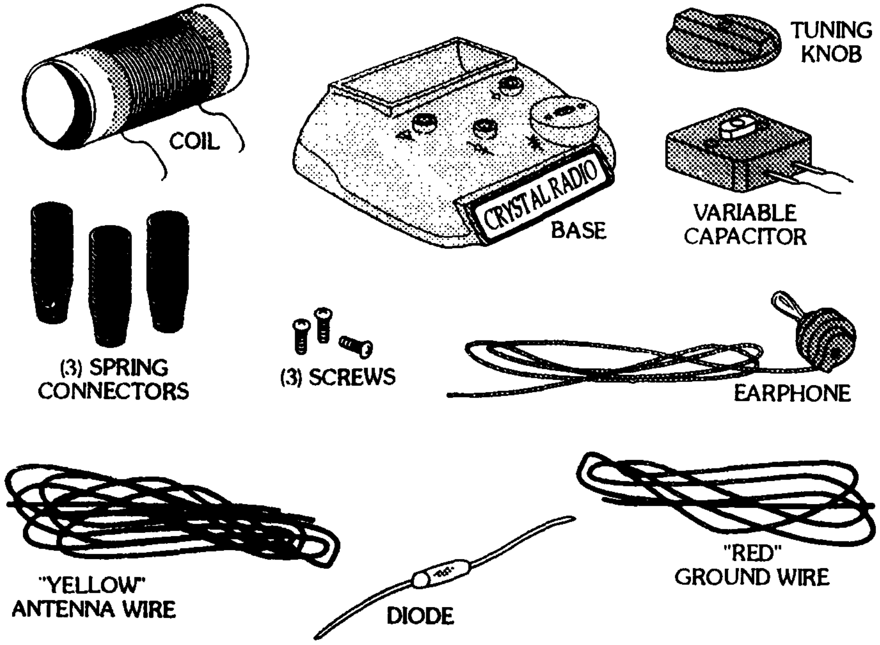
COIL
TUNING KNOB
CRYSTAL RADIO
BASE
VARIABLE CAPACITOR
(3) SPRING CONNECTORS
(3) SCREWS
EARPHONE
"YELLOW" ANTENNA WIRE
DIODE
"RED" GROUND WIRE

Shown below is a typical wiring diagram of your crystal radio.

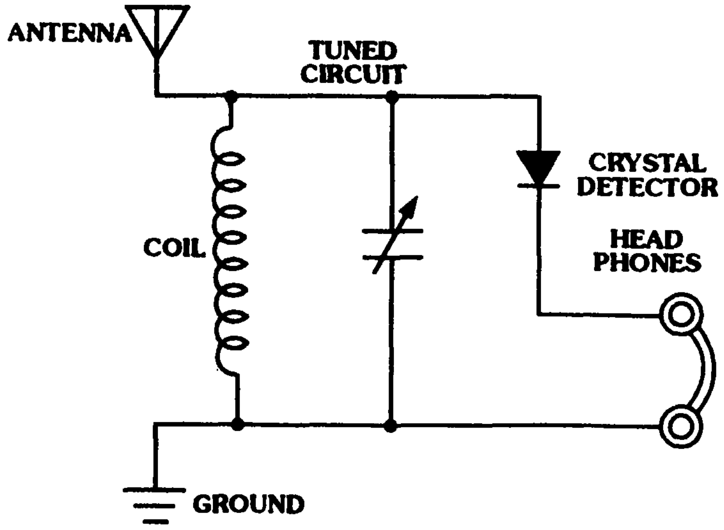
ANTENNA
TUNED CIRCUIT
CRYSTAL DETECTOR
HEAD PHONES
COIL
GROUND

Radio Technology (cont'd)

When these two different energy waves are put together by the mixer stage of the transmitter, the resulting wave, which is the signal that the station broadcasts, looks like this:

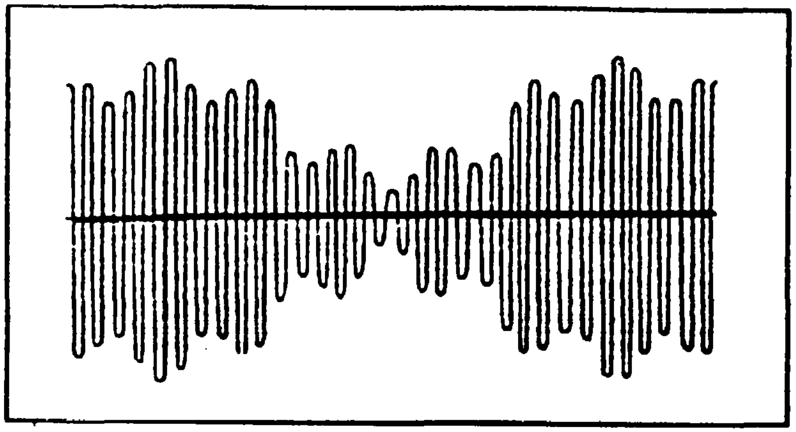

AM Broadcast Wave

The signal is called a MODULATED wave. You will notice that each of the waves is the same length, but the heights vary. Since the height of a wave is called its AMPLITUDE. The type of transmission that WXYZ uses is called AMPLITUDE MODULATION. That's why WXYZ is called an AM station.

The crystal radio that you built works in just the opposite way as the radio station. The modulated signal broadcast by WXYZ is "picked up" by the antenna on your radio.

The antenna is connected to the tuner circuit of the radio, which is made up of a coil of wire and a variable capacitor connected together. As you move the tuning knob, you are able to select, or isolate, the particular

This signal is then DEMODULATED by the diode, separating the voice (audio) wave from the carrier wave.

The voice (audio) wave then moves to the earphone, where it is changed back into sound waves that you can hear.

Learn the basic electronic symbols

Before starting to assemble your Smart Lab Crystal Radio please learn the basic electronic symbols that are shown on the plastic base.

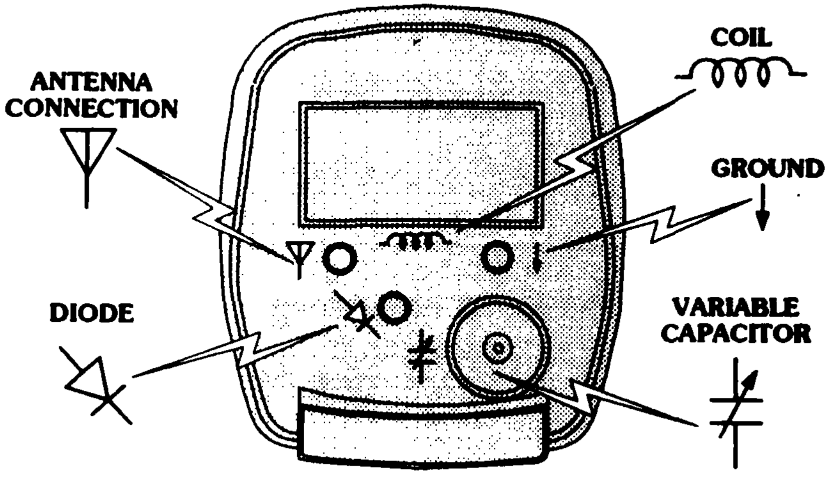

Explanation of components

Variable Capacitor - It is used to tune the radio to a station. The leads that are soldered to the lugs are used to connect it to the circuit.

Diode - A small crystal is sealed inside with leads connected to it. Pay careful attention to the position of the black bands painted on the diode close to one end.

Coil- This is a radio-tuning COIL. It was made by winding enameled copper wire around a paper core 80 times. The leads have been stripped and tinned so it can be connected to the circuit.

Earphone - It contains a small crystal that can make enough electricity to drive a metal diaphragm to produce sound. The leads have been stripped and tinned so it can be connected to the circuit.

Antenna - This is a wire used for radiating or receiving radio waves.

Ground - This is a wire used to make a electric connection with the earth or other type of grounding source to create a common return for an electric circuit.

DEAR CUSTOMER:

If we made an error and left something out of this set, or if something is damaged, we are sorry and wish to correct our error.
Please DO NOT return the set to the store where purchased, as the store does not have replacement parts. Instead, write us:

Please include:
1. **Date of Purchase**
2. **Where purchased**
3. **Price paid**
4. **Model Number**
5. **Name of item**
6. **Brief Description of Problem**
7. **Include Sales Slip**

We will do our best to satisfy you.
Send your letter to:

NATURAL SCIENCE INDUSTRIES, LTD.
910 ORLANDO AVENUE
WEST HEMPSTEAD, N.Y. 11552-3942
ATTENTION: QUALITY CONTROL DEPT.

How to assemble your Crystal Radio

Before starting, it's important to assemble the parts correctly. Carefully read the following instructions step by step and have fun . . . half the fun is knowing you made your very own crystal radio.

Step ①

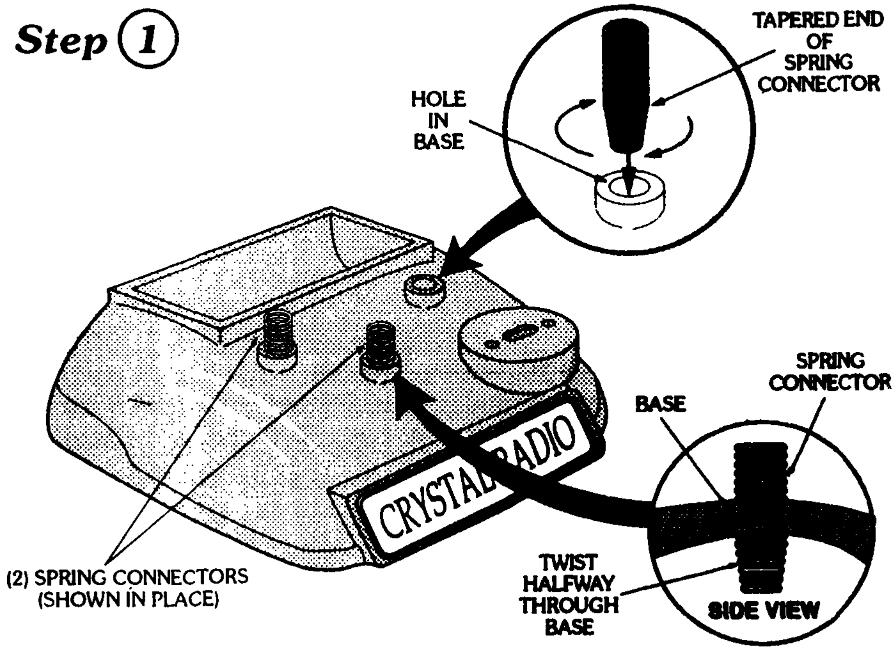
TAPERED END OF SPRING CONNECTOR
HOLE IN BASE
SPRING CONNECTOR
BASE
CRYSTAL RADIO
TWIST HALFWAY THROUGH BASE
SIDE VIEW
(2) SPRING CONNECTORS (SHOWN IN PLACE)

A. Locate the three Spring Connectors.
B. Insert one of the Spring Connectors (tapered end first) into one of the three holes on the Base.
C. Push down on the Spring Connector and twist to the right until the Connector is approximately half way through the base.

NOTE: Check to see if the Spring Connecter is inserted halfway through the Base by turning Base upside down (see insert).
D. Insert the remaining two Spring Connectors into the holes on Base the same way.

Radio Technology

Now that you have your crystal radio assembled and working, it is time to take a brief look at how it works. To do this you are going to take an imaginary trip to a radio station WXYZ, in anytown,USA.

When you arrive at WXYZ, you are met by the station's general manager, Mr. Smith, who is going to show you around.

First, Mr. Smith takes you to a STUDIO, a special room that a program comes from. There is a lot of equipment, including dials and switches, record players, lots and lots of records, and microphones.

Mr. Smith tells you that when you talk into one of the microphones, your words go into the station's electronic equipment. There, it is mixed with the station's carrier wave, and sent out into the air through the station's transmitting antenna - that tall tower you saw on top of the radio station building.

Then Mr. Smith takes a piece of paper and a pencil, and draws diagrams to show you what happens. He begins by saying that all energy travels in waves, and since the sound we make when we talk is a form of energy, it might look something like this:

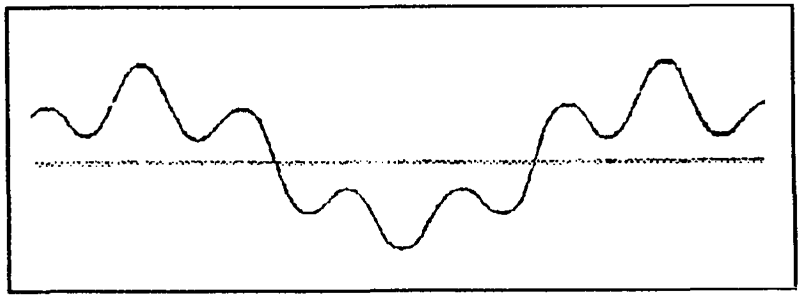

Sound Wave

The station's carrier wave is a radio wave, which is also a form of energy, which looks something like this:

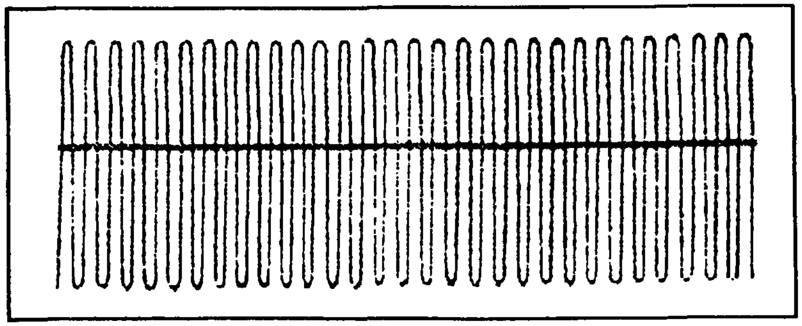

Radio Carrier Wave

How to properly operate your Smart Lab Crystal Radio and troubleshoot

After you have attached all the wires, carefully read the following instructions to make sure your crystal radio operates properly.

A. Place the earphone in your ear and turn the Tuning Knob clockwise and counterclockwise until you pick up the strongest signal.

Note: If you do not pick up a strong signal or do not hear anything, please read some of the troubleshooting solutions explained below.

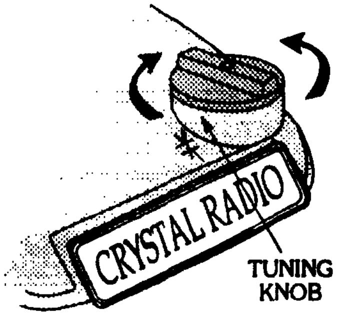

TROUBLESHOOTING HINTS

1. There may be a bad connection caused by improper assembly of your radio. Check all the spring connectors to make sure the wires are attached correctly. If a wire is loose or the bare wire is not making good contact with the spring connector, the radio may not work.
2. If the uninsulated part of the Antenna wire touches anything other than the Antenna Connection on the radio, the radio may work improperly or not at all..
3. If the bare stripped end of the Ground wire is not wrapped tightly around a water pipe (so that it makes good contact), try taping the wire to the shiny part of the pipe using duct tape. If the pipe is dull or rusty, use a piece of sandpaper to gently sand the area where the wire makes contact. Also make sure the wire doesn't touch anything other than the Ground Connection or the radio may not work properly.
4. You may live in an area where radio reception is generally poor. Instead of trying to use your radio during the day, try at night when many radio stations are received better.
5. The Antenna on your radio is a very important component. Make the Antenna as long and high above the ground as possible. If you live in a multi-story dwelling the highest floor should be used when operating the radio. Insulated bell-wire, which is available in hardware stores, makes a very good substitution for your present Antenna.

How to assemble your Crystal Radio (cont'd)

For this step you will need the variable capacitor, (3) screws and turning knob. Be carefull not to misplace the small screws when assembling.

Step ②

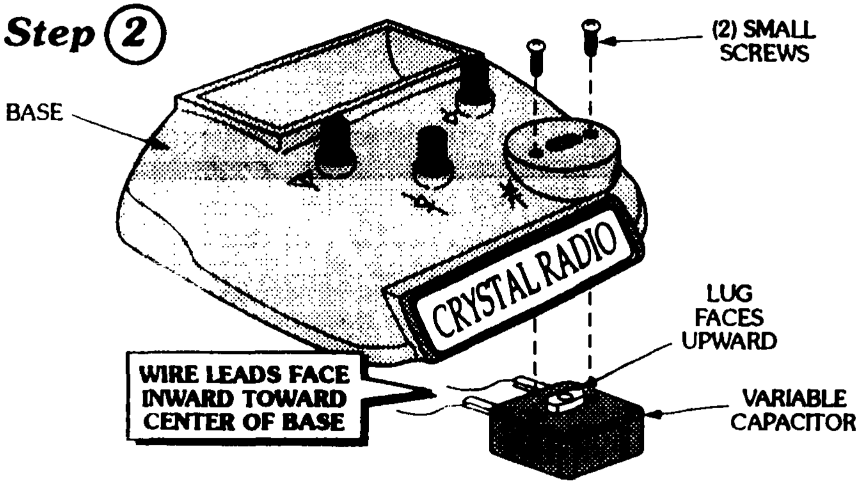

A. First place the Variable Capacitor up into the base so the holes on the capacitor line up with the holes on the base.
Note: When you do this be sure the wire leads face inward toward the base as shown and lug faces upward.

B. Next insert the two small screws into the holes on top of the Base and tighten using a small phillips screwdriver.

Step ③

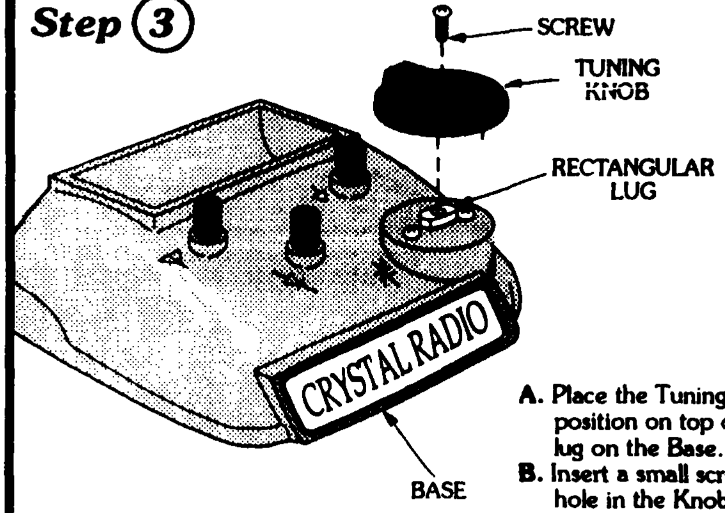

A. Place the Tuning Knob into position on top of the rectangular lug on the Base.
B. Insert a small screw into the hole in the Knob and tighten using a phillips screwdriver.

How to assemble your Crystal Radio (cont'd)

Step ④ For this step turn the Base upside down.

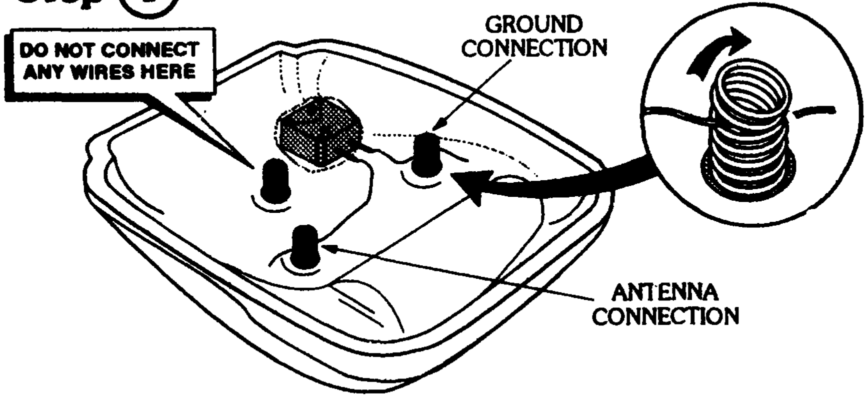
DO NOT CONNECT ANY WIRES HERE
GROUND CONNECTION
ANTENNA CONNECTION

A. Turn the Base upside down.
B. Connect one wire to the Antenna spring connector by bending the spring slightly to one side and inserting the wire through as shown in inset.
C. Connect the other wire to the Ground spring connector in the same manner.

NOTE: Do not connect any of the wires to the Diode spring connector or your crystal set will not work properly.

Step ⑤

NOTE: Make sure the Plated Ends of the Coil wires are making contact to the Spring Connections.

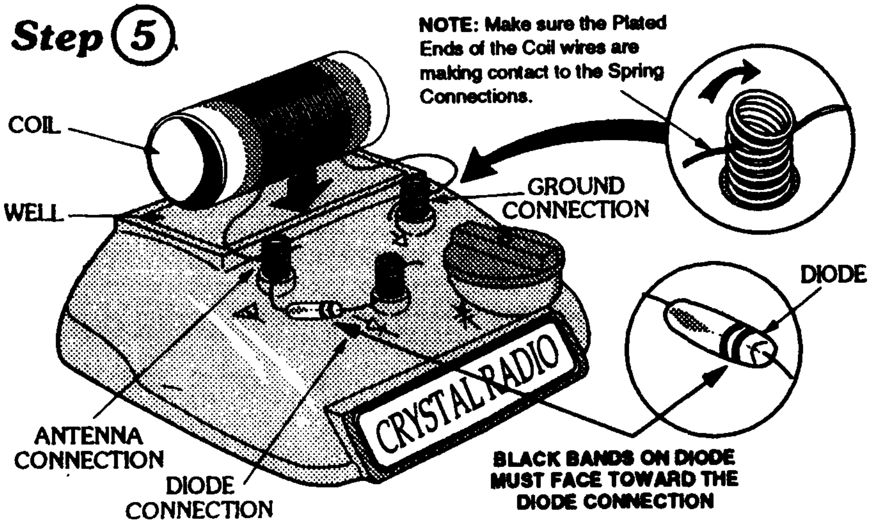
COIL
WELL
GROUND CONNECTION
DIODE
ANTENNA CONNECTION
DIODE CONNECTION
CRYSTAL RADIO

BLACK BANDS ON DIODE MUST FACE TOWARD THE DIODE CONNECTION

A. Next place the Coil in the well of Base with the wires hanging loosely toward the connectors .
B. Connect one of the plated ends of Coil wires to the Ground Connector by bending the Spring Connector as shown in inset. Connect the other Coil wire to the Antenna Connector.
C. Place the Diode between the Diode and Antenna Connections carefully noting the black bands face toward the Diode Connection.
D. Connect ends of Diode wires to Antenna and Diode spring connectors shown.

How to attach the earphones

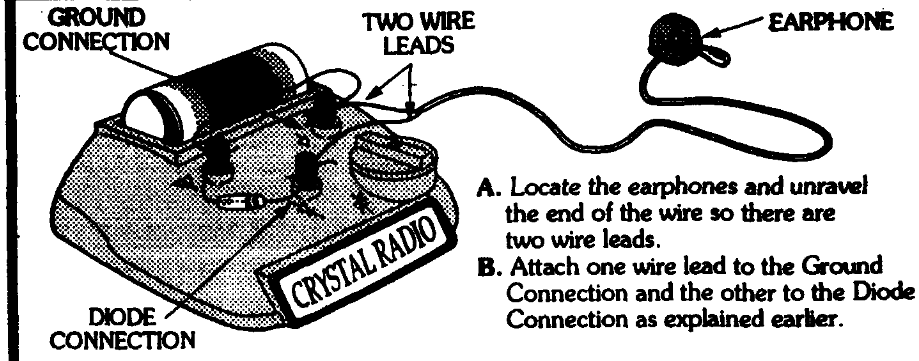
GROUND CONNECTION
TWO WIRE LEADS
EARPHONE
DIODE CONNECTION
CRYSTAL RADIO

A. Locate the earphones and unravel the end of the wire so there are two wire leads.
B. Attach one wire lead to the Ground Connection and the other to the Diode Connection as explained earlier.

Final assembly and operation

ATTACH LONG STRIPPED END TO A METAL COLD WATER PIPE

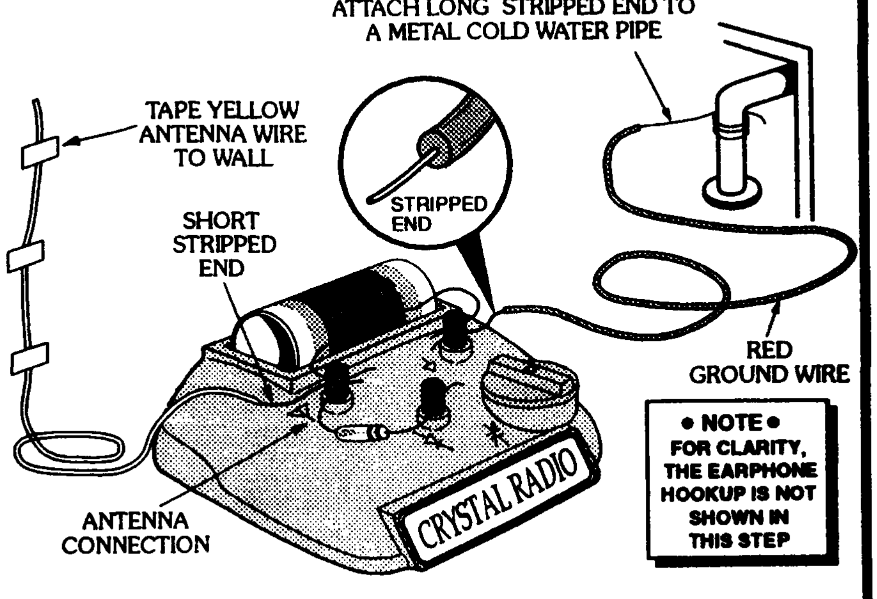
TAPE YELLOW ANTENNA WIRE TO WALL
STRIPPED END
SHORT STRIPPED END
RED GROUND WIRE
ANTENNA CONNECTION
CRYSTAL RADIO

• NOTE • FOR CLARITY, THE EARPHONE HOOKUP IS NOT SHOWN IN THIS STEP

A. Locate the Red Ground and Yellow Antenna wire.
B. Attach the stripped end of Yellow Antenna wire to the Antenna Connection on the Base.

Note: The Antenna should be strung in a straight line away from power lines and large metal objects. We suggest taping it high up on a wall using masking tape as shown.

C. Next attach the short stripped end of the Ground wire to the Ground Connection.
D. Attach the Long stripped end to a metal cold water pipe, metal radiator pipe, etc., near where the radio will be used. Have a adult help you with this since some pipes may be hot.

Note: If there is not enough stripped, bare wire to wrap around a pipe then ask an adult to strip more insulation off the end using a pair of wire strippers.

Germanium vs Silicon Diode Testing: Read this document carefully, so you will not be the victim of cheap knock-off or the wrong type diodes.

The general rule is that ***SILICON*** diodes have a voltage drop across the Anode to Cathode of 0.7 V (7/10 tenths), and the ***GERMANIUM*** diodes have a voltage drop of 0.3 V (3/10 tenths) more or less. Either diode voltage drop (silicon or germanium) will display a reading within approximately 5% of these readings.

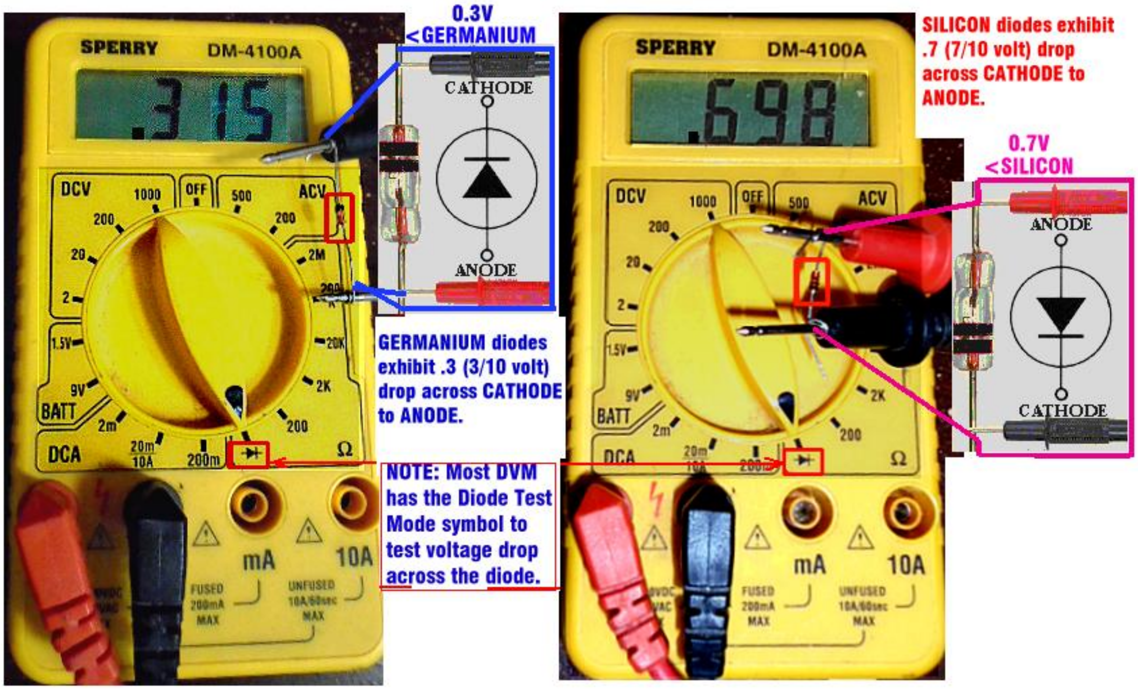

0.3V <GERMANIUM

GERMANIUM diodes exhibit .3 (3/10 volt) drop across CATHODE to ANODE.

NOTE: Most DVM has the Diode Test Mode symbol to test voltage drop across the diode.

SILICON diodes exhibit .7 (7/10 volt) drop across CATHODE to ANODE.

0.7V <SILICON

Most digital meters (DVM) have a switch setting ▶| that is used to measure voltage drop across these diodes. This setting is usually indicated by a diode symbol to let the user know the DVM is capable of measuring forward bias voltage. This setting will tell you immediately if the diode is a **germanium**, or **silicon** diode. You need to set the selector switch on your meter to the diode test symbol ▶|.

Measuring Forward Bias Voltage

To measure the forward bias voltage characteristic you connect the black probe of your meter to the cathode terminal. The cathode terminal is on the end with a band. You then connect the red probe to the anode terminal.

Set your DVM/DMM to the *diode test mode* ▶|, it should provide you with the respective voltage drop. If the figure is 0.3 V or less, the diode is a *germanium* type. If the voltage drop is 0.7 V or less the diode is a *silicon* diode.

Sensitivity and Forward Bias Characteristics:

The sensitivity of a diode to radio waves depends upon its *forward bias voltage*. This is the voltage across the diode terminals. When it falls below this threshold value, the diode will stop conducting. Obviously, the lower this threshold value is, the greater the sensitivity of the diode to the weak radio signals.

CONCLUSIONS:

When comparing germanium diodes with silicon diodes of similar forward bias voltage, silicon diodes do not perform as well as the germanium.

Germanium has many properties that silicon diodes do not have. Germanium requires very little forward current. Forward current in a germanium diode is in the *micro*ampere region, while silicon diodes require *amperes*. This makes *germanium* a much better choice for both medium and high frequency radio signals.

Germanium also exhibits a very low, point-contact junction capacitance, while the silicon diode has much higher capacitance. A low junction capacitance allows germanium diodes to operate more effectively at high RF frequencies.

In addition, reverse leakage current for germanium diodes is in the magnitude of 1000, much more than silicon. This makes the non-linear characteristics of the germanium diode much more effective for RF detection and demodulation than silicon.

Therefore, our conclusions are; germanium diodes provide the best performance in crystal radios, RF probes, HF, and VHF signal detection.

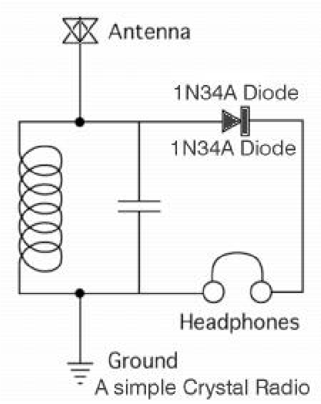
Antenna
1N34A Diode
1N34A Diode
Headphones
Ground
A simple Crystal Radio

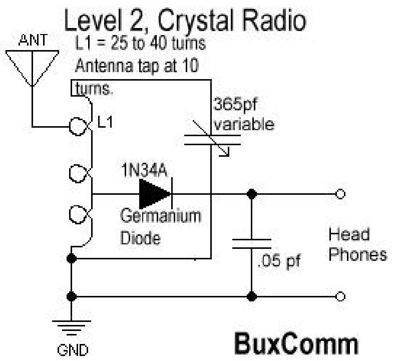
Level 2, Crystal Radio
ANT
L1 = 25 to 40 turns
Antenna tap at 10 turns.
L1
365pf variable
1N34A
Germanium Diode
.05 pf
Head Phones
GND
BuxComm

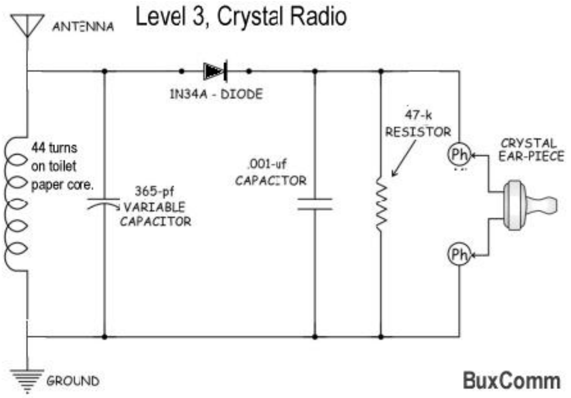
ANTENNA
Level 3, Crystal Radio
IN34A - DIODE
44 turns on toilet paper core.
365-pf VARIABLE CAPACITOR
.001-uf CAPACITOR
47-k RESISTOR
Ph
Ph
CRYSTAL EAR-PIECE
GROUND
BuxComm

BuxComm High Quality, CRYSTAL RADIO ANTENNA KIT, $14.95 cat# 50CRAK

This Crystal Radio Antenna kit consists of 50 feet of #16 AWG insulated & stranded copper antenna wire, two heavy-duty, Delrin, UV resistant antenna insulators and instruction sheet.

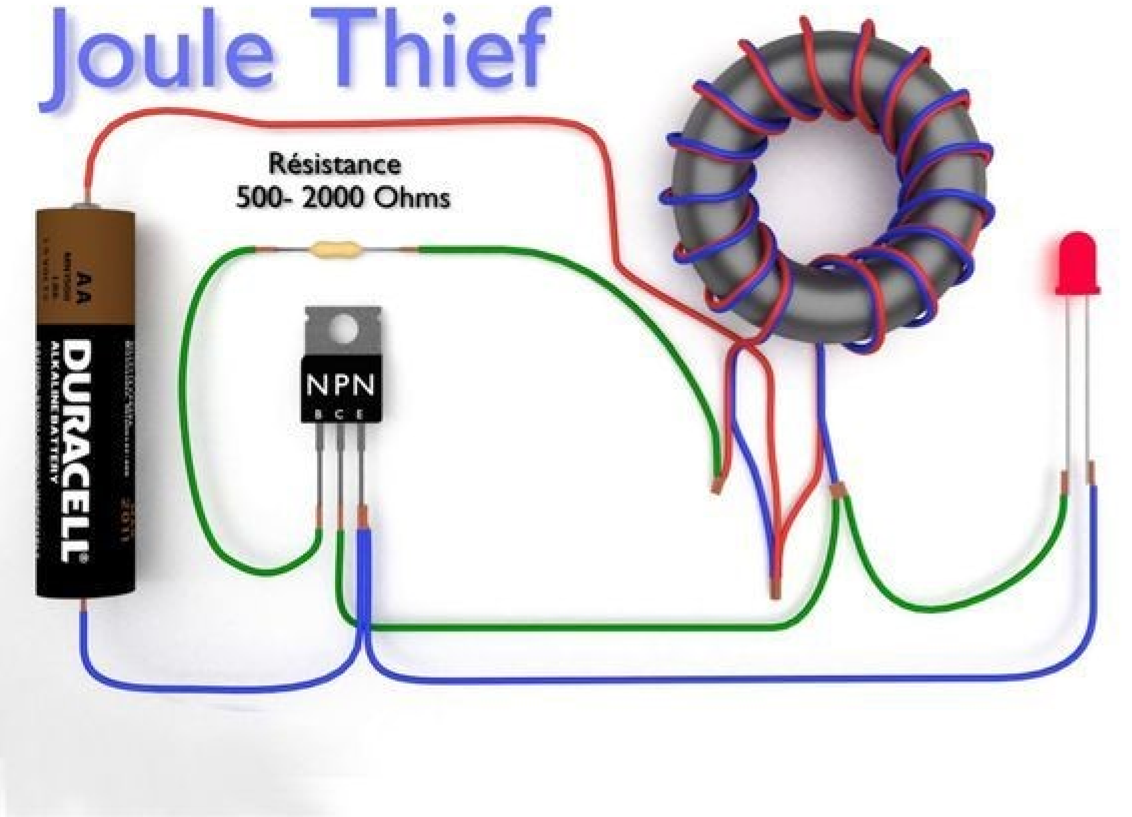
Joule Thief
Résistance
500- 2000 Ohms
NPN
B C E
AA
DURACELL
ALKALINE BATTERY

The joule thief circuit.

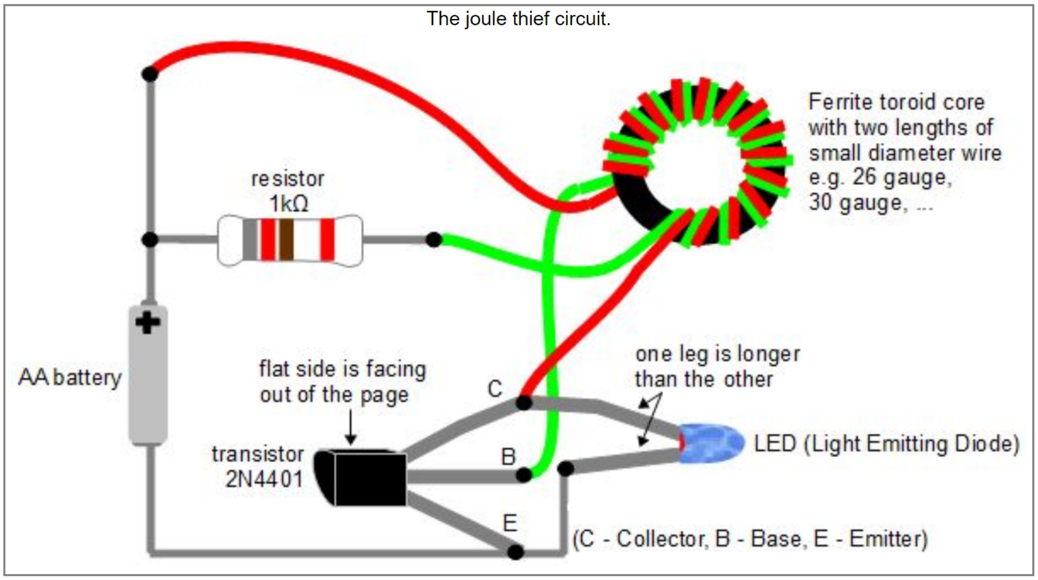
Ferrite toroid core with two lengths of small diameter wire e.g. 26 gauge, 30 gauge, ...
resistor 1kΩ
AA battery
flat side is facing out of the page
transistor 2N4401
C
B
E
one leg is longer than the other
LED (Light Emitting Diode)
(C - Collector, B - Base, E - Emitter)

Transistor - The legs of the transistor can be determined by noticing that there's a flat side to the transistor case. See the diagram above. A large number of transistors have been reported to work: 2N4401, NET123AP, BC547B, 2SC2500, BC337, PN2222, to name just a few.

LED - One leg of the LED is longer than the other leg. Use this to determine which one goes where. See the diagram above.

Resistor - The diagram says use a 1 kilo ohm resistor but I've used an 820 ohm one just fine. I've also seen a 2 kilo ohm one in use. Use whatever works for you. You can also use a potentiometer (a variable resistor) so that you can easily adjust it to select the resistance that gives the best light.

Toroid ferrite core - Some people have gotten these by opening up compact fluorescent lightbulbs (CFLs). I took mine out of some device whose original function I don't know. To get it working, my first one had just 13 turns for each wire and I used a 30 gauge wire and a 26 gauge wire. The wire must be insulated. A variety of number of turns will work. This is something you can play with. Look at the diagram carefully to determine where the wires connect to.

Its a Rubbish Challenge
Dog Light
Joule Thief
electronics circuit

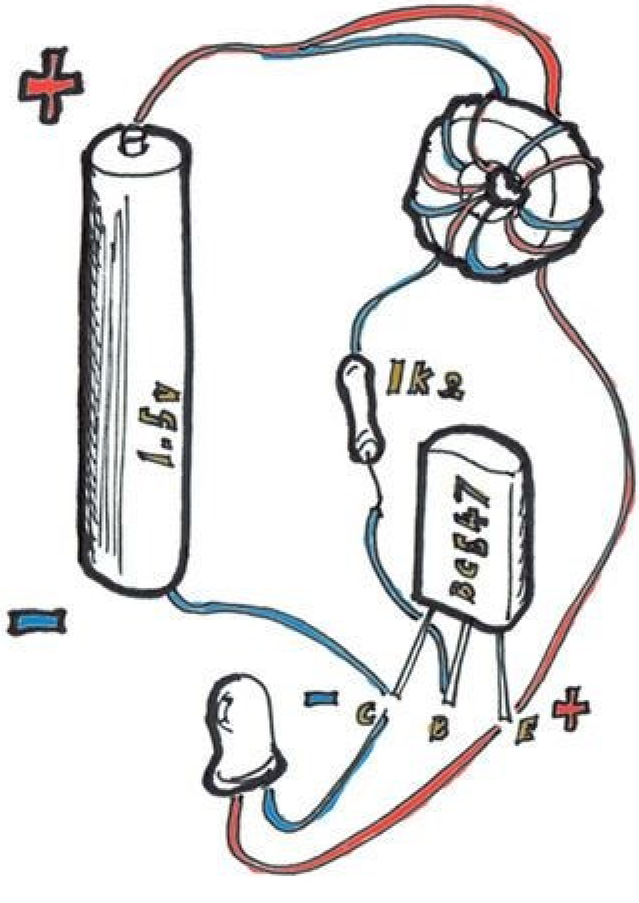
+
1.5v
-
1kΩ
BC547
-
C
B
E
+

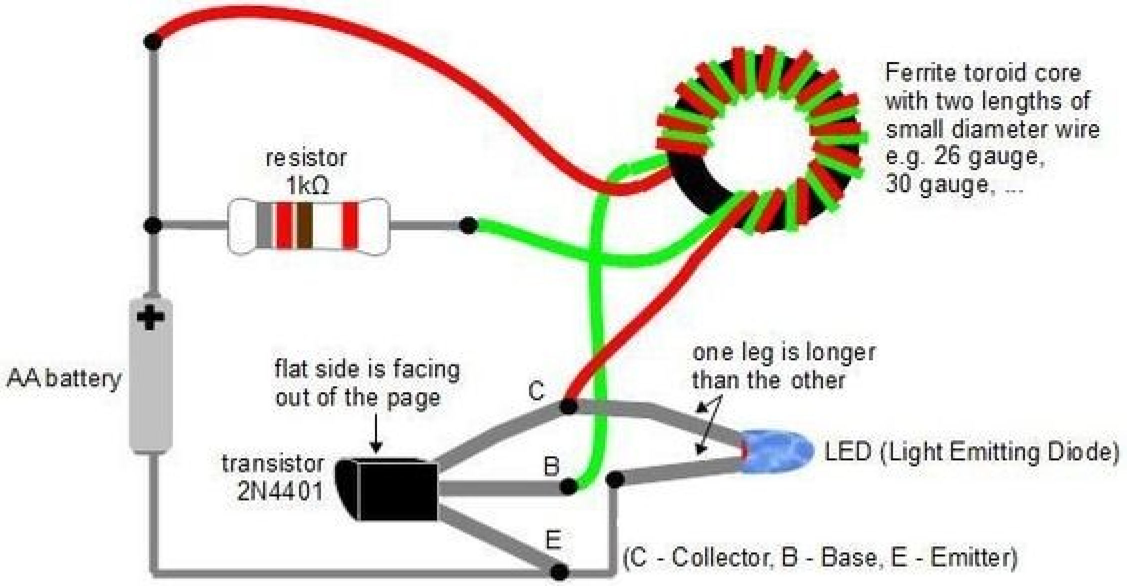
resistor
1kΩ
Ferrite toroid core
with two lengths of
small diameter wire
e.g. 26 gauge,
30 gauge, ...
AA battery
flat side is facing
out of the page
transistor
2N4401
C
B
E
one leg is longer
than the other
LED (Light Emitting Diode)
(C - Collector, B - Base, E - Emitter)

COUPONS AVAILABLE ACTIVATE COUPONS

advertisement

MAKING A SIMPLE JOULE THIEF (MADE EASY)

Technology (/technology/) > Leds | by ASCAS (/member/ASCAS/) Follow

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Posted Dec. 24, 2011 | BY-NC-SA

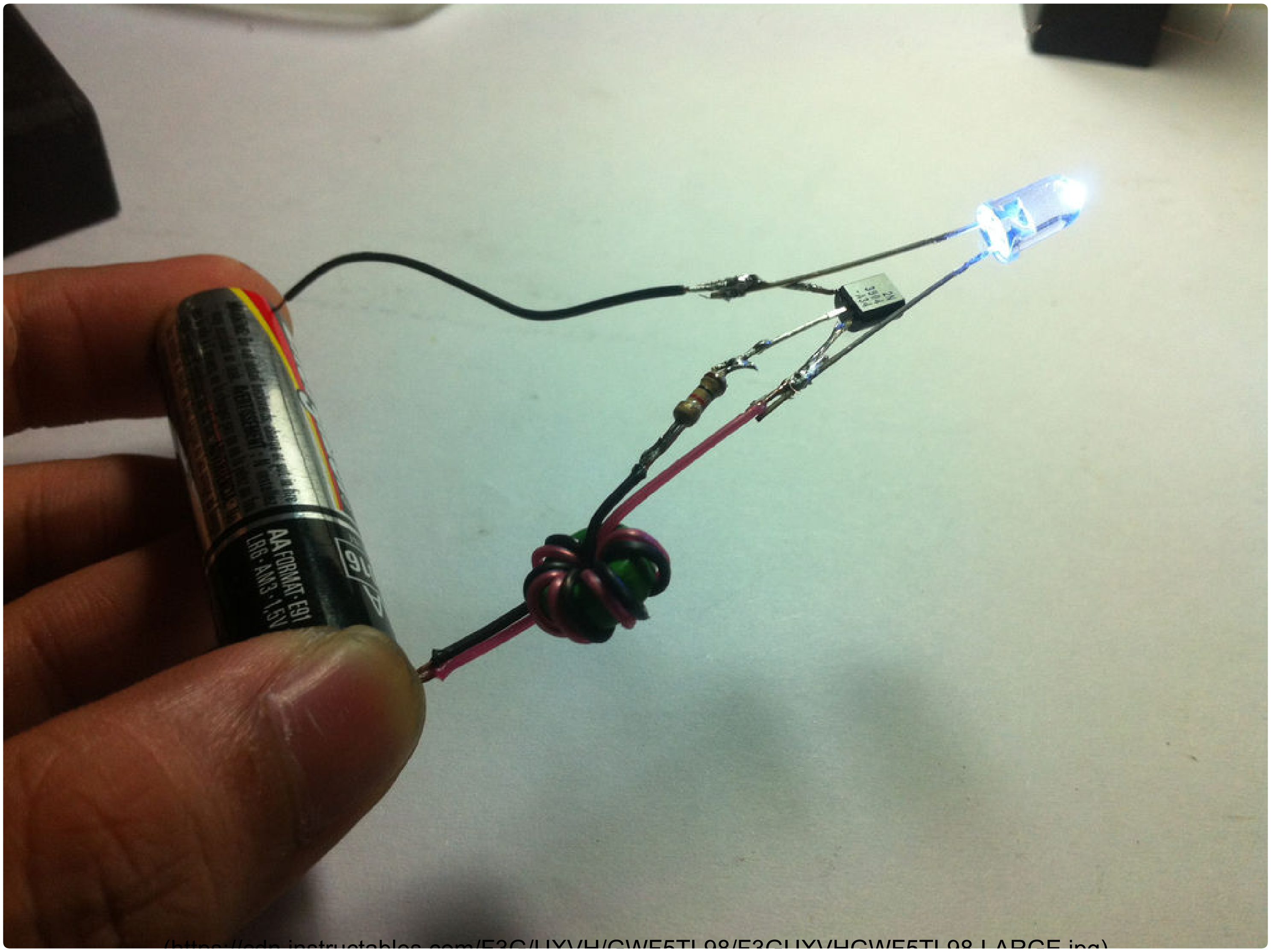

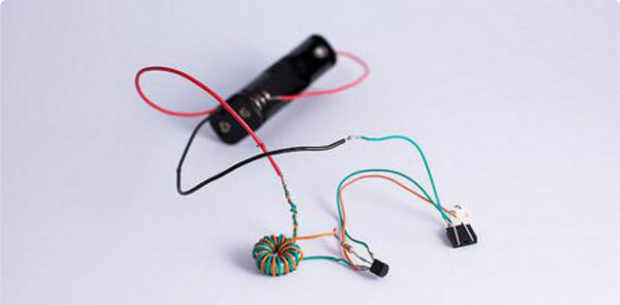
(https://cdn.instructables.com/FB5/BOY8/GWHN3

Mini
Version
(https://cdn.instructables.com/FF8

(https://cdn.instructables.com/F3C

Today I am showing you how to make a very simple joule thief. A joule thief has many applications, the best gadget that I made with was a "Water Powered Lamp", soon I'm going to post on a guide about it but first I need to post this guide. I used an iPhone 4S as my camera :)))

What Is A Joule Thief ?

To simplify everything, a "joule thief" is a circuit that helps drive an LED light even though your power supply is low. What can we do with it? We can use it to squeeze the life out of our old, almost drained, non functioning batteries. This project can also be considered as a green and environmental experiment, we can also use it as a flashlight that can be ran by an old, weak, almost drained battery. I even tried to use my water powered battery from my previous instructable the "Water Powered Calculator (https://www.instructables.com/id/Water-Powered-Calculator/)", the project was featured and displayed in instructable's front page in the "Technologies" category.

My Next Projects That Involves A Joule Thief: (soon to be posted)
- Water Powered Lamp
- Water Powered Flash Light
- Dead Battery Drainer Lamp

Here's A Video From Make Magazine:

Add Tip Ask Question

Step 1: Parts and Materials

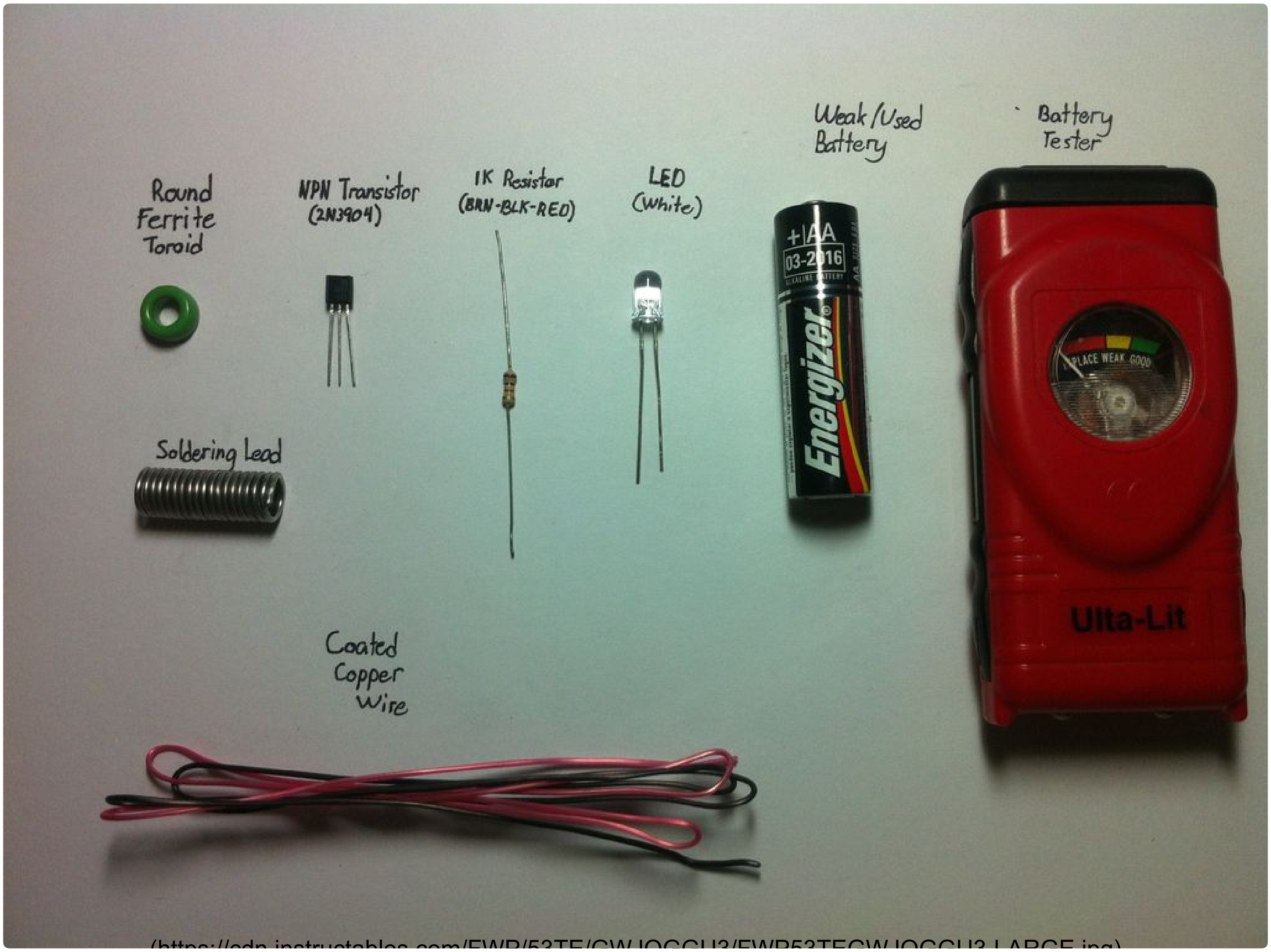
Round Ferrite Toroid
NPN Transistor (2N3904)
1K Resistor (BRN-BLK-RED)
LED (White)
Weak/Used Battery
Battery Tester
Soldering Lead
Coated Copper Wire
+AA
03-2016
Energizer
REPLACE WEAK GOOD
Ulta-Lit

(https://cdn.instructables.com/FWR/53TE/GWJOGGU3/FWR53TEGWJOGGU3.LARGE.jpg)

The Parts Needed Are: (click the item to know where to find/ buy)

- Round Ferrite Toroid (can be found in old CFL bulbs)
- Old/ Used Batteries (can be found in garbage cans)
- NPN Transistor (2N3904) (http://www.radioshack.com/product/index.jsp?productId=2062609)
- 1K Resistor (BRN-BLK-RED) (http://www.radioshack.com/product/index.jsp?productId=2062343)
- LED Light (http://www.radioshack.com/product/index.jsp?productId=3096133)
- Battery Tester (http://www.tooldistrict.com/Ulta-Lit-Battery-Tester-5001-p/901233.htm) (optional)
- Soldering Lead (http://www.radioshack.com/product/index.jsp?productId=2062717)

- Copper Wire/ Magnet Wire (http://www.radioshack.com/product/index.jsp?productId=2036277)
- Battery Case/ Holder (http://www.radioshack.com/product/index.jsp?productId=2062247)

I want to share something. Here in the Philippines electronic parts are extremely cheap, they are extremely far cheaper from
radio shack, for example one transistor costs (2 phil. pesos - 6 US cents), a LED cost (9 phil. peso - 29 US cents) and a 1K resistor cost (25 phil. cents - 0.8 US cents). I usually buy thing from Deeco or Alexan. Usually prices here are 15x cheaper from radio shack. Price conversion - $1 US Dollar = P0.31 Philippine Peso (12/24/11).

Add Tip Ask Question

Step 2: Schematic Diagrams

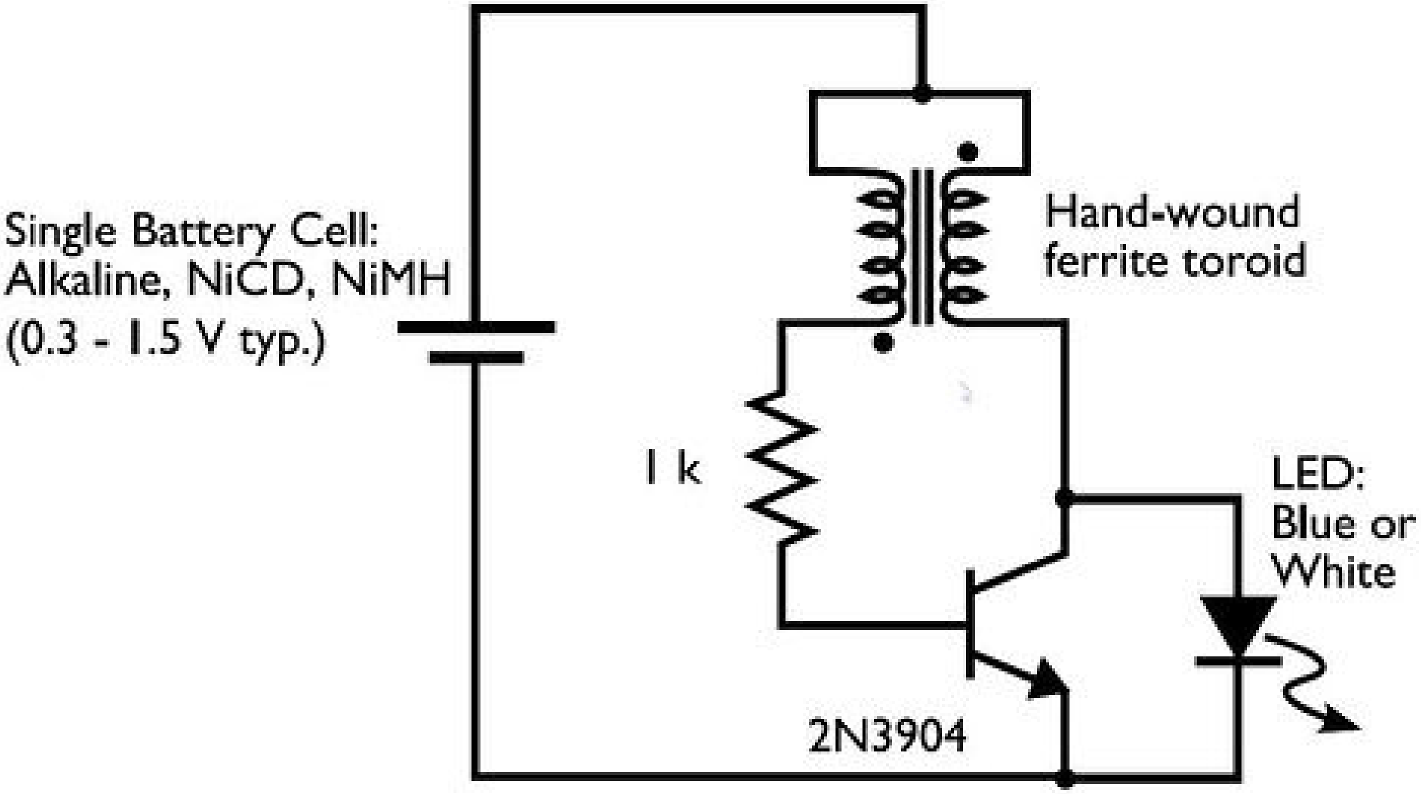
Single Battery Cell:
Alkaline, NiCD, NiMH
(0.3 - 1.5 V typ.)
Hand-wound
ferrite toroid
1 k
LED:
Blue or
White
2N3904

(https://cdn.instructables.com/F3N/S5I7/GWKD43C0/F3NS5I7GWKD43C0.LARGE.jpg)

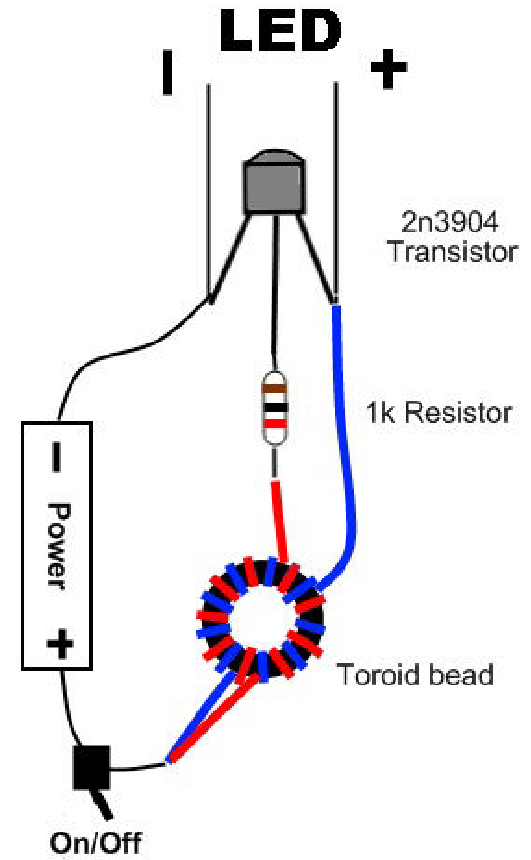
LED
-
+
2n3904
Transistor
1k Resistor
- Power +
Toroid bead
On/Off

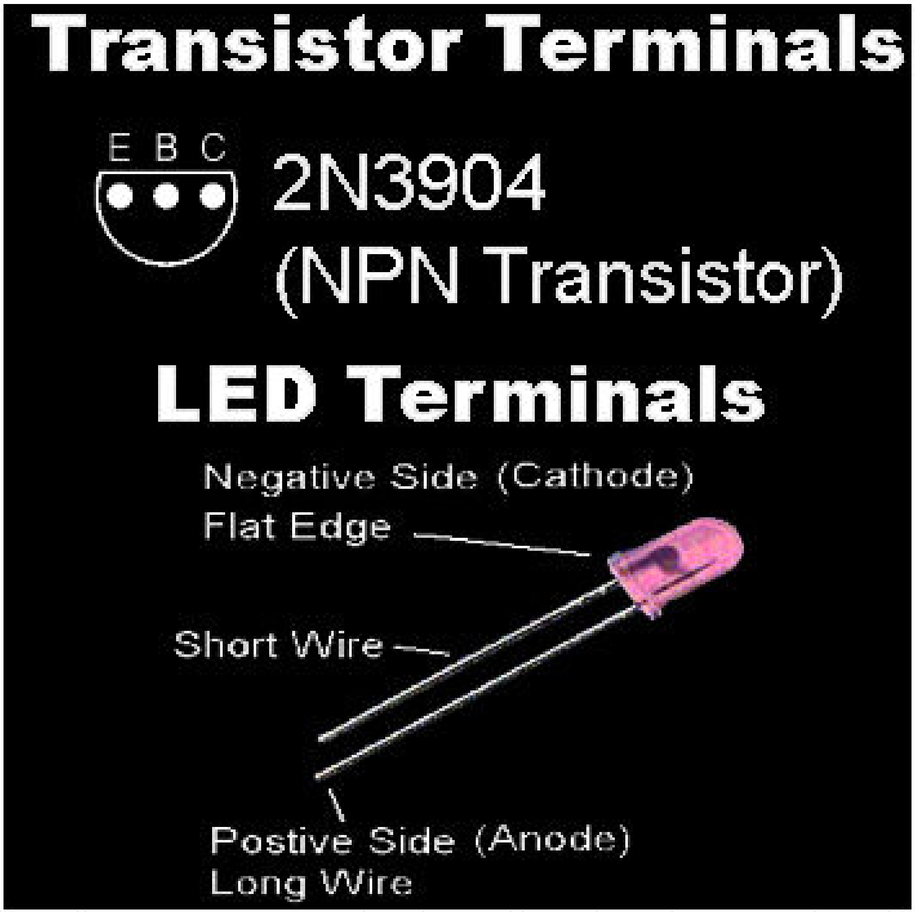
Transistor Terminals
E B C
2N3904
(NPN Transistor)
LED Terminals
Negative Side (Cathode)
Flat Edge
Short Wire
Postive Side (Anode)
Long Wire

(https://cdn.instructables.com/FN0/CPE6/G (https://cdn.instructables.com/F5P/M7EM/GWINSM3D/F5PM7EMGWINSM

Here are the schematic diagrams that are involved with the joule thief circuit.

Add Tip Ask Question

Step 3: Winding Wire at the Toroid

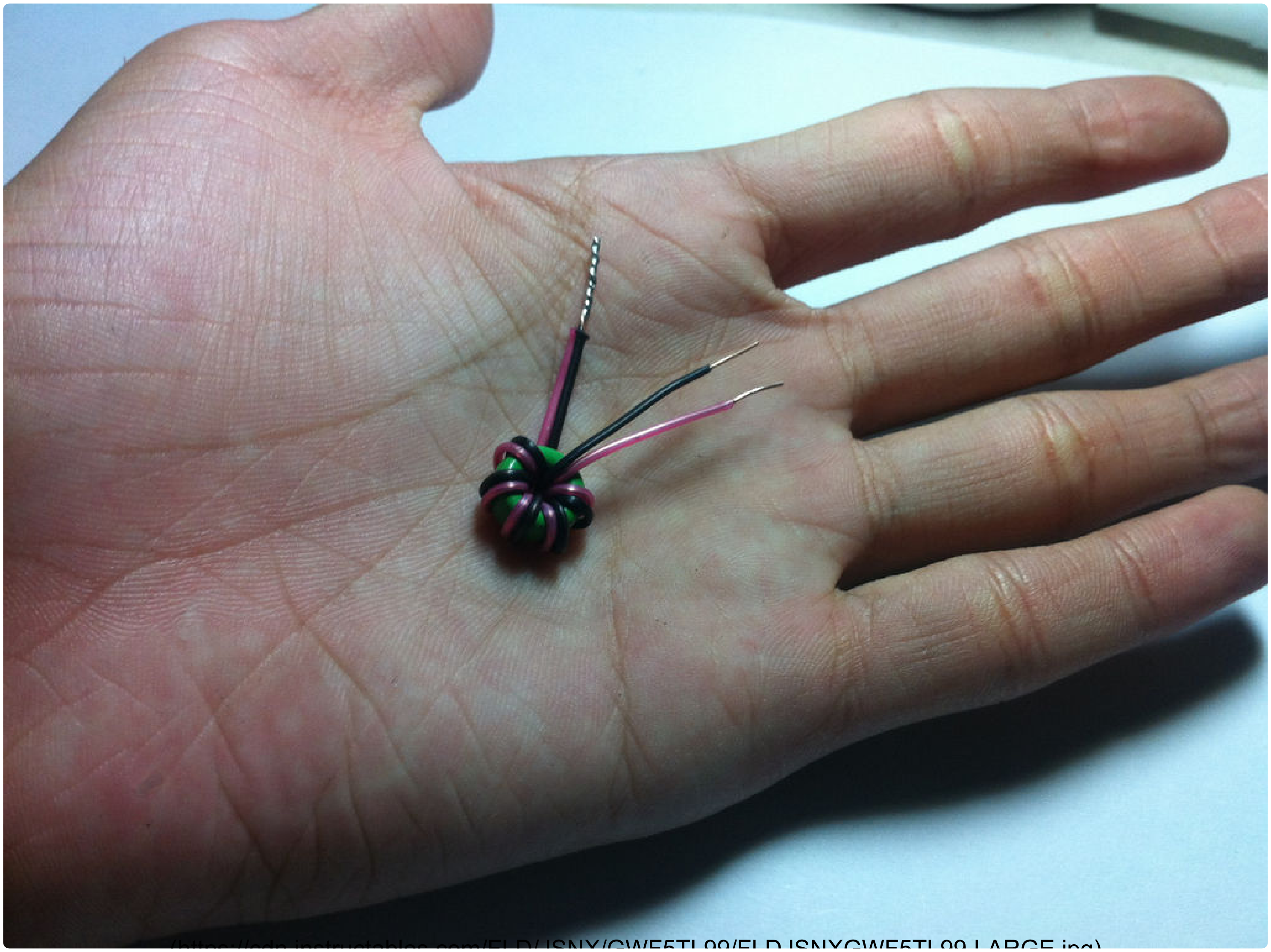

(https://cdn.instructables.com/FLD/JSNY/GWF5TL99/FLDJSNYGWF5TL99.LARGE.jpg)

https://cdn.instructables.com/FXL/LCWG/GWF6FORD/FXL

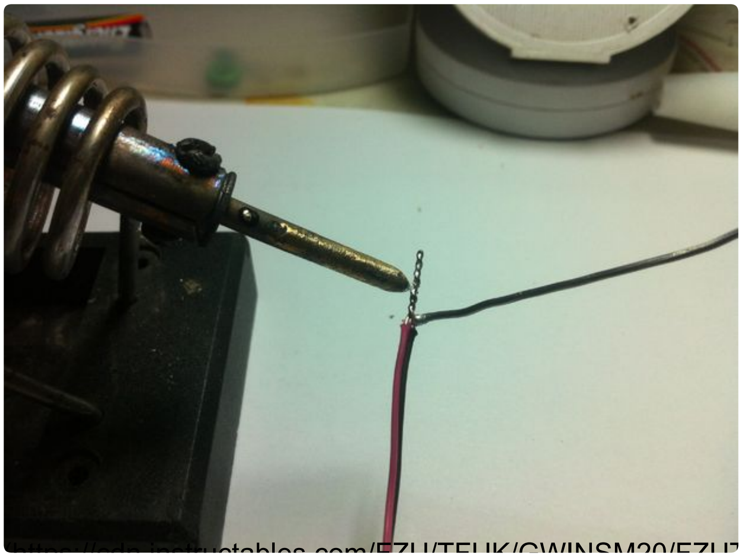

https://cdn.instructables.com/FZU/TFUK/GWINSM20/FZU

First, connect both ends of the copper wire before wounding, be sure to remove the insulation. Then try to solder the ends so it would not split up. Second, wind the wire until you run out of space in the round ferrite toroid. I have some tips for you, try to use a gauge #22 enamel coated copper wire for better performance, oh! my last tip is that "the more you wind the wire to the ferrite toroid the better".

Add Tip Ask Question

Step 4: Soldering the Resistor

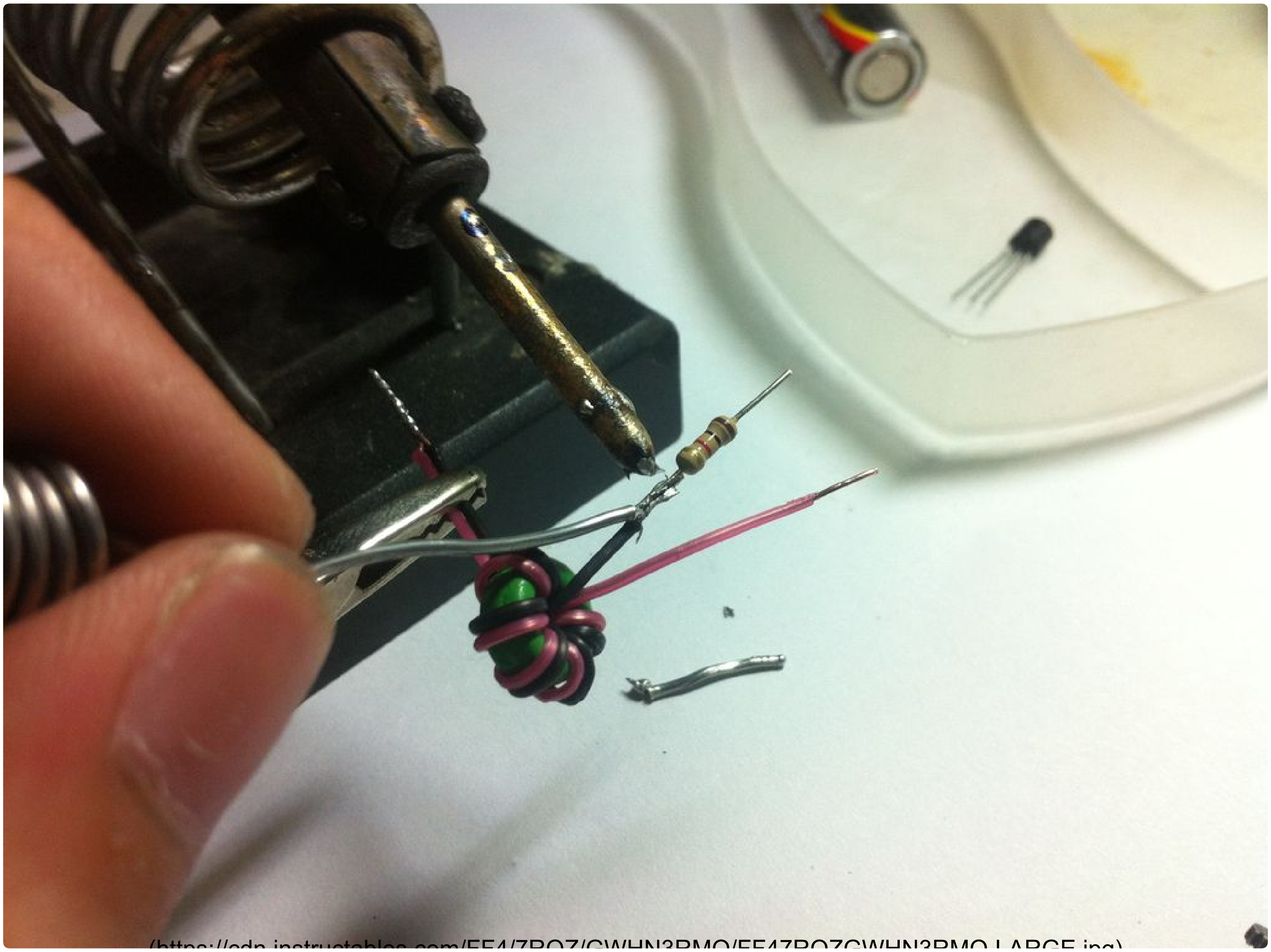

(https://cdn.instructables.com/FF4/7BQZ/GWHN3BMQ/FF47BQZGWHN3BMQ.LARGE.jpg)

Solder the resistor with one end of the wounded ferrite toroid's wire. Oh! also don't forget to level the other end of the resistor with the other unused wire from the wounded ferrite toroid.

Add Tip Ask Question

Step 5: Soldering the Transistor

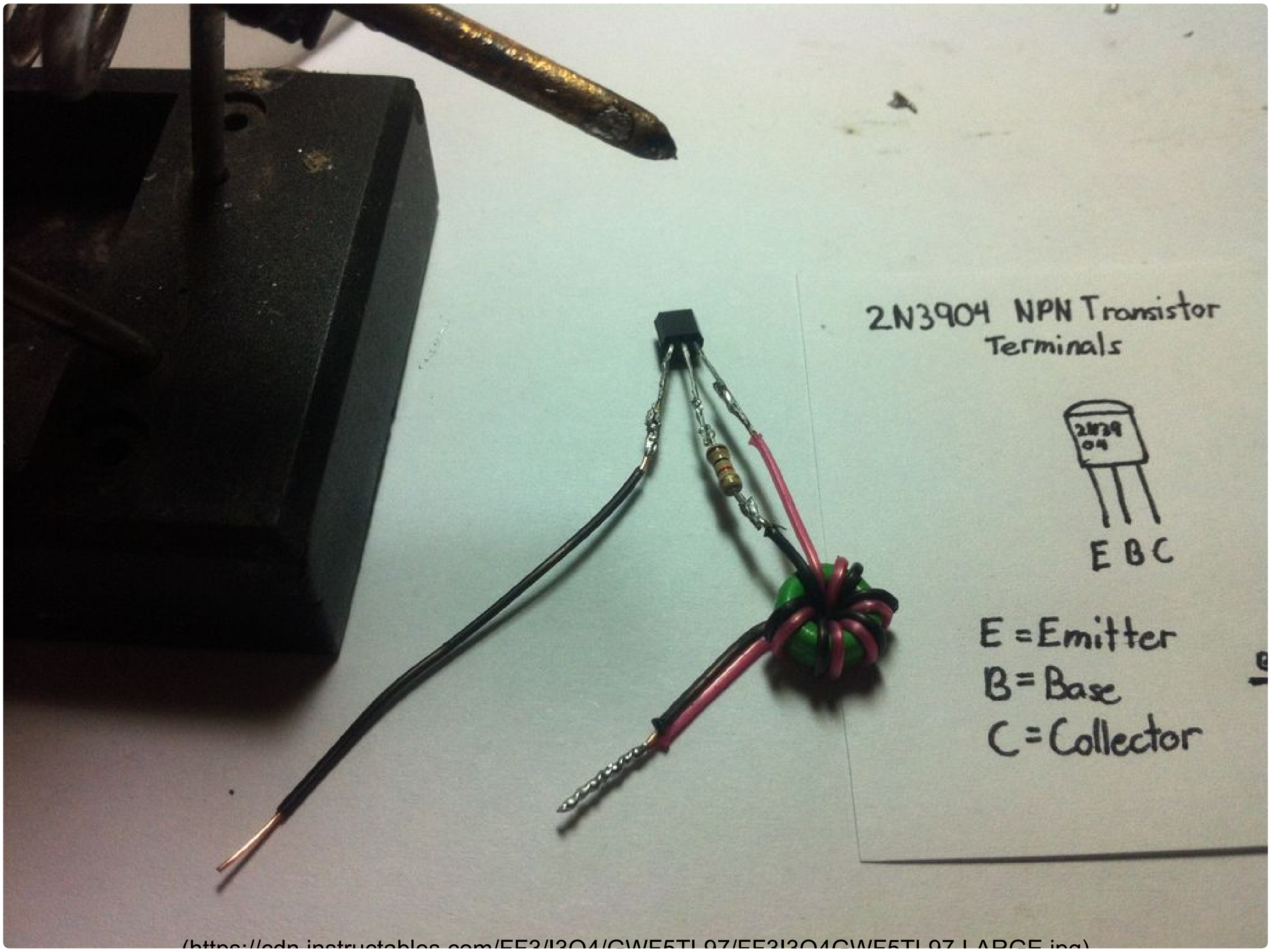
2N3904 NPN Transistor
Terminals
2N39
04
E B C
E=Emitter
B=Base
C=Collector

(https://cdn.instructables.com/FE3/I3O4/GWF5TL97/FE3I3O4GWF5TL97.LARGE.jpg)

Solder the proper connections to the transistor. For the emitter - connect another wire, the wire will be connected to the negative part of the battery. For the base - solder the other end of the resistor to the base. For the Collector Solder the unused wire of the ferrite toroid.

Add Tip Ask Question

Step 6: Soldering the LED

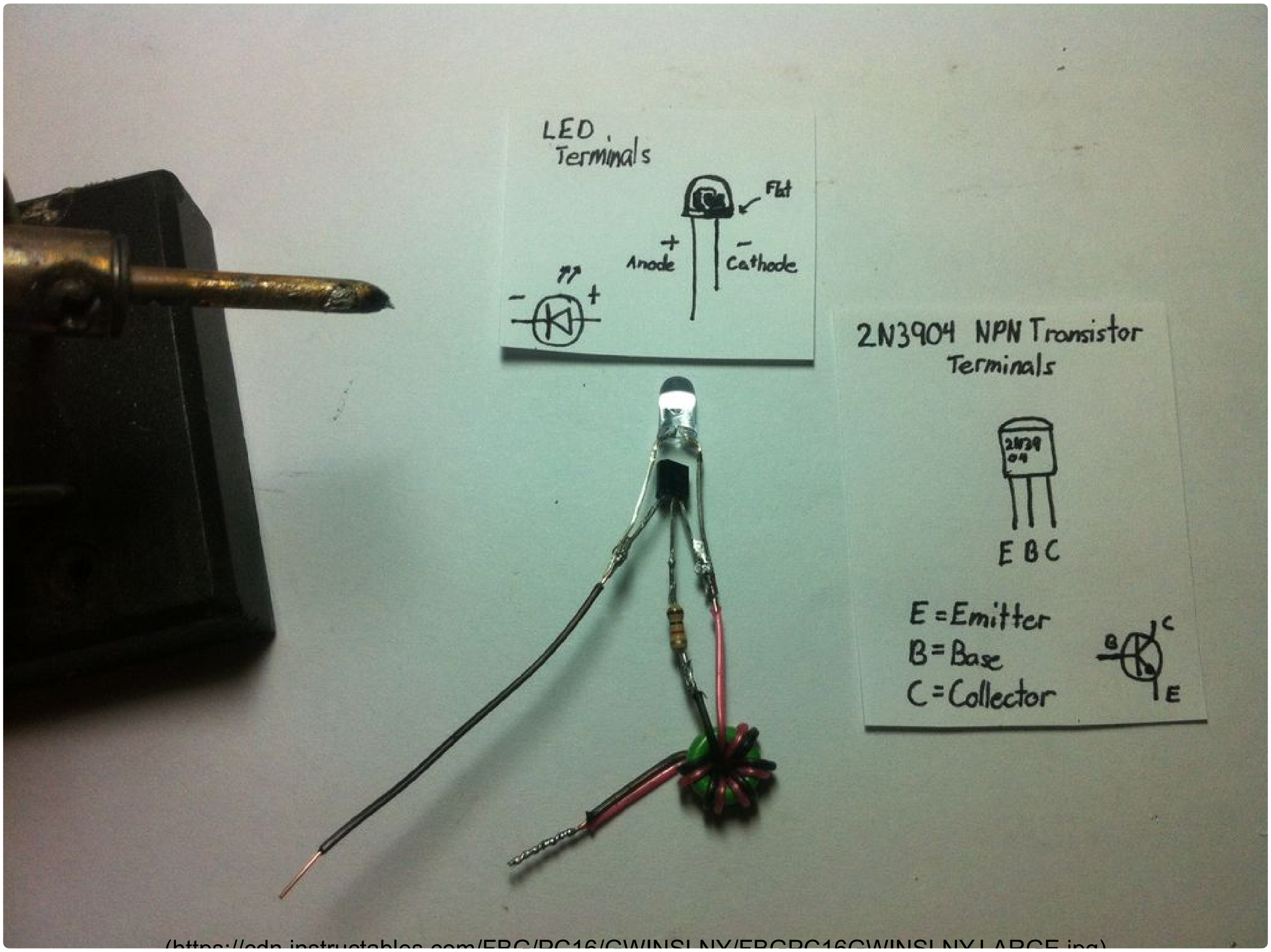
LED Terminals
Flat
+
Anode
−
Cathode
− +
2N3904 NPN Transistor Terminals
2N39 04
E B C
E = Emitter
B = Base
C = Collector
B
C
E

(https://cdn.instructables.com/FBG/PC16/GWINSLNY/FBGPC16GWINSLNY.LARGE.jpg)

Solder the shorter wire of the LED to the tansistor's emitter and the longer part of the LED to the transistor's collector. After all that, you can now trim the excess wires.

Add Tip Ask Question

Step 7: Time to Look for Old Batteries

Energizer
REPLACE WEAK GOOD

(https://cdn.instructables.com/F78/J93B/GWF5TM0O/F78J93BGWF5TM0O.LARGE.jpg)

(https://cdn.instructables.com/FX4/JNKD/GWINSM4V/FX4JNKDGW

(https://cdn.instructables.com/F40/9TOM/GWINSM

Use your battery tester to confirm that your battery is close to death. The tester is only an optional tool, it's just used to determine the battery's remaining power.

Add Tip Ask Question

Step 8: Time to Test It - You're Done !!

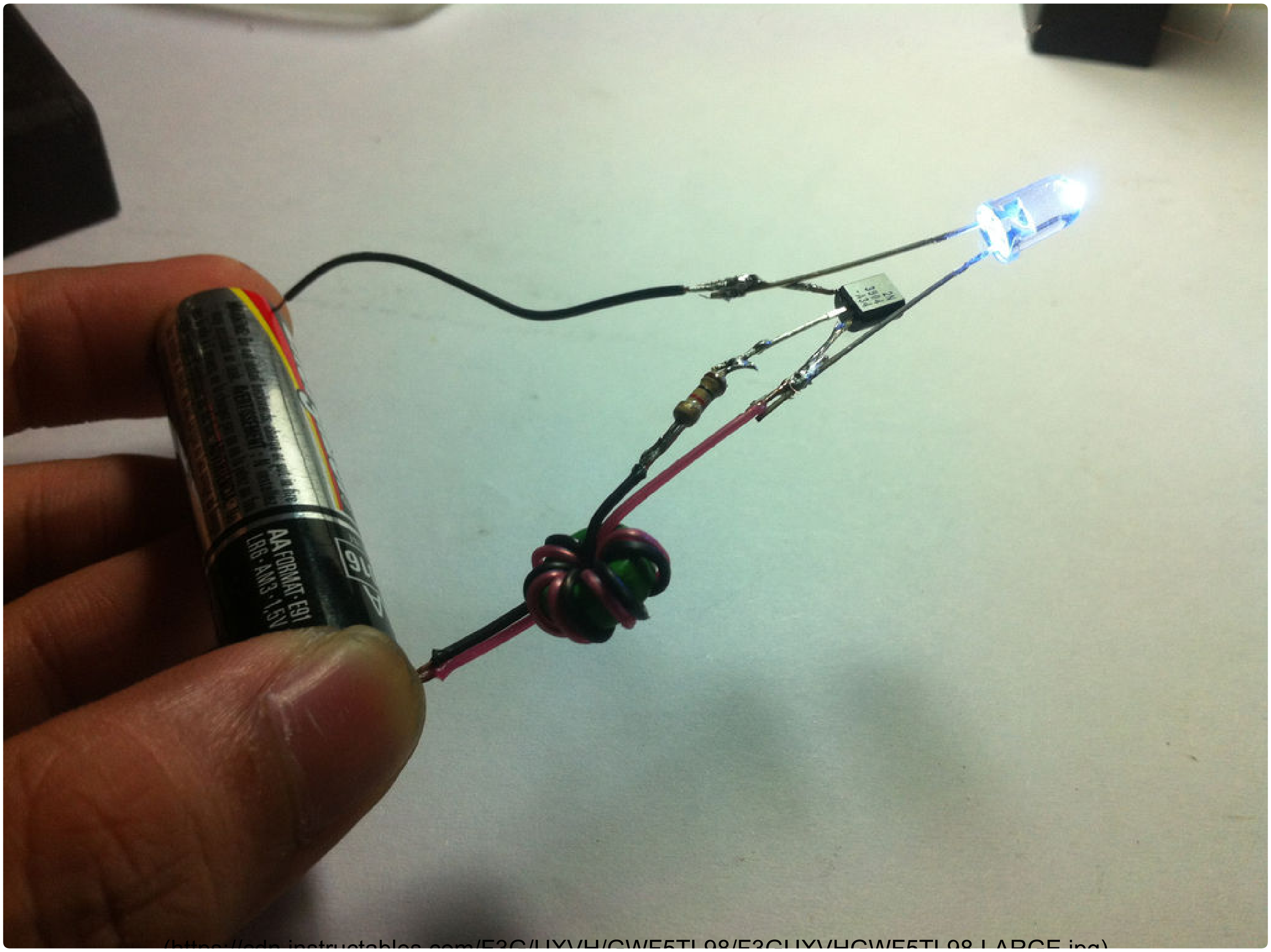

(https://cdn.instructables.com/F3C/UXVH/GW55TL98/F3CUXVHGW55TL98.LARGE.jpg)

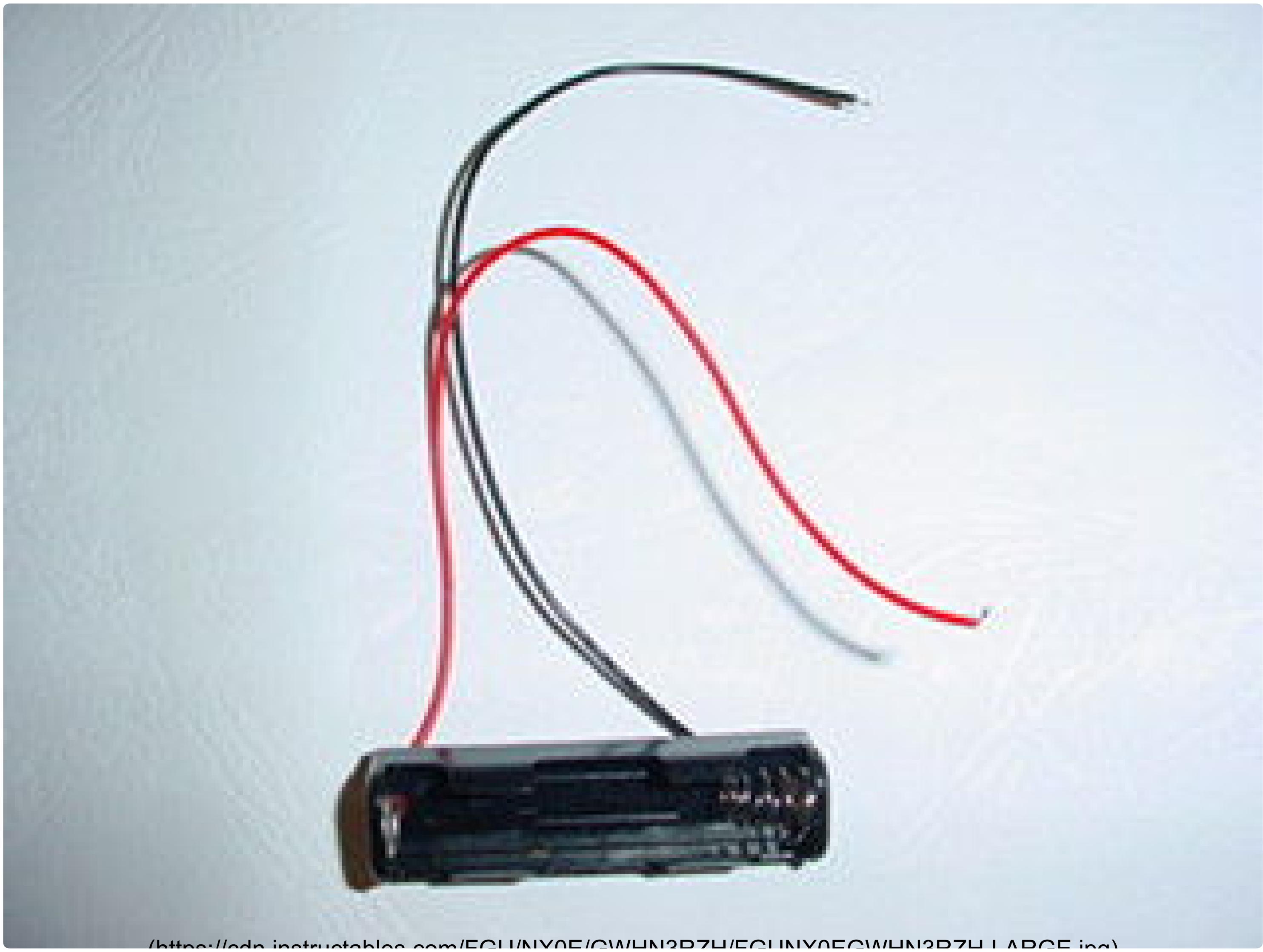

(https://cdn.instructables.com/FGU/NX0F/GWHN3RZH/FGUNX0FGWHN3RZH.LARGE.jpg)

The wire connected to the transistor's emitter should be connected to the battery's negative side and the remaining wire of the ferrite toroid should be connected to the battery's positive side. Oh! one more thing, I advise everyone to use a battery case or attach a conductive magnet for each wire, so you wouldn't hold it all the time.

Add Tip Ask Question

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Tesla Energy

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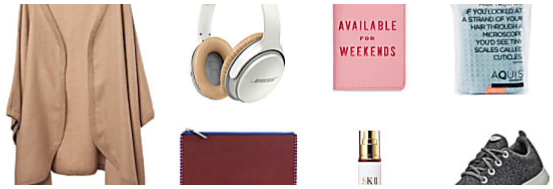
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Cartageous

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8 People Made This Project!

"Joule Thief" LED Night Light

by **ledartist** on September 2, 2011

Table of Contents

"Joule Thief" LED Night Light 1
Intro: "Joule Thief" LED Night Light 2
Step 1: Features 2
Step 2: Technical Overview 3
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Step 3: Assembly 4
Step 4: Performance 5
Step 5: PCB & Kit 6
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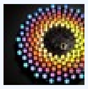

Author:ledartist My Blog
I work with LEDs and microcontrollers to create beautiful objects.

Intro: "Joule Thief" LED Night Light

I have many used batteries around. Remote controls, cameras, many electronic gadgets all use batteries, mostly AA size. I always felt guilty for throwing away the used batteries. I know there are rechargeable batteries, but many electronics don't work well with rechargeables.

I also know that those "used" or "spent" batteries usually have some juice left in them. So to come up with a good use of used batteries, I've created a LED night light.

I like having a little night light on when I sleep. LEDs are perfect for this purpose, because they are energy efficient, and good at providing low intensity illumination.

This LED night light operates with just one battery. It utilizes a little circuit called Joule Thief to boost voltage out of an AA battery. I also added a light sensor to turn it on automatically when the surrounding is dark.

The circuit is energy efficient, and requires very low voltage to work. So it effectively sucks every bit of energy out of batteries. This type of circuit is often called "Joule Thief", because it works as though stealing every bit of energy (Joule is a unit for energy) out of battery.

I'm calling this project Night Joule Thief.

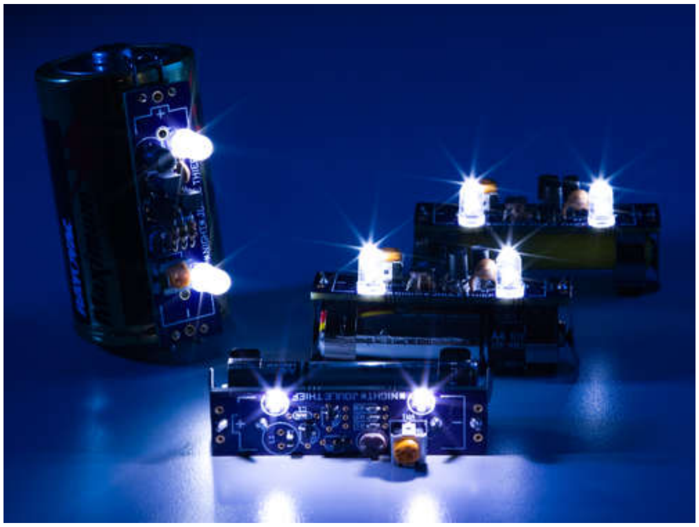

Step 1: Features

Here are the highlights of the Night Joule Thief.

- Compact & streamlined design
- Uses only one AA battery (or any 1.5V battery you can hook up to)
- Easily adaptable to different size batteries - hook up holes to attach home made clips
- Two white LEDs
- Automatic turn on via a light sensor (adjustable sensitivity level)
- Energy efficient - works even with a run-down battery, down to 0.6V
- Choice of through-hole only components or SMD - mix & match on the same PCB

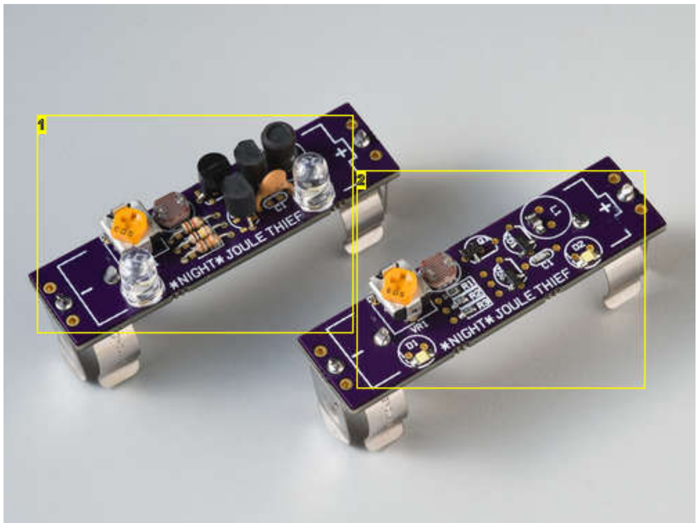

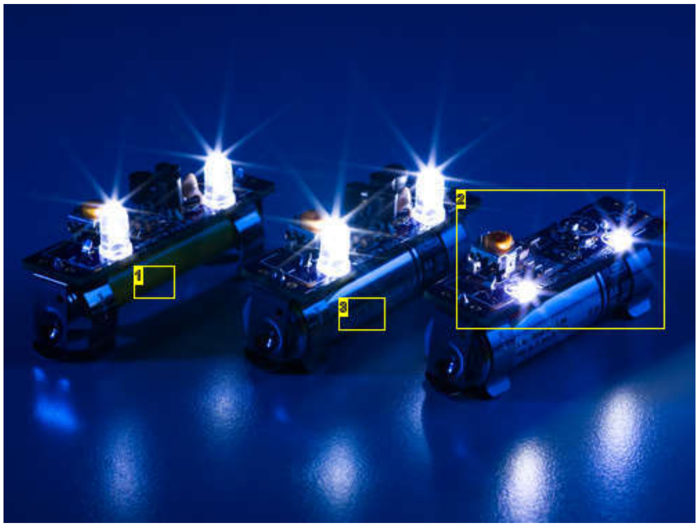

Image Notes
1. Through-hole version.
2. SMD (Surface Mount Device) version. Hard to believe this is the same circuit, but it works exactly the same as one on left. Ok, the LEDs are slightly less bright.

Image Notes
1. AAA battery inserted with a help of small magnets.
2. SMD version - very low profile.
3. Standard AA battery snugly fit in the clips.

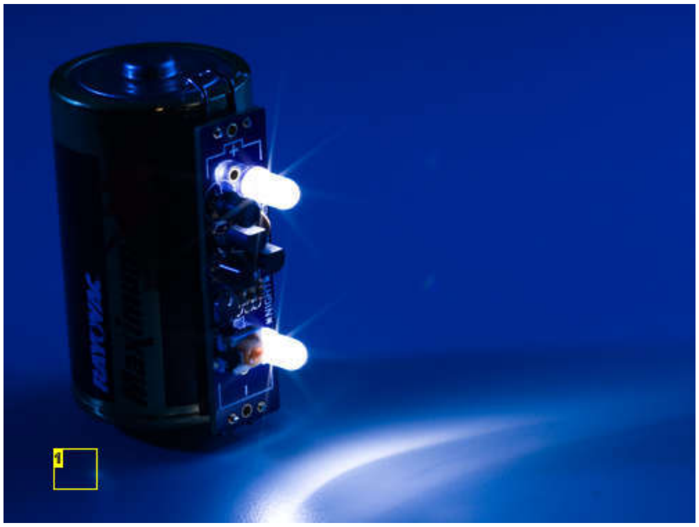

Image Notes
1. Other sizes, such as D cell can be attached by making a pair of little metal clips. Just cut and bend paper clips.

Step 2: Technical Overview

"Joule Thief" circuit is an inductor based voltage booster circuit to light LEDs with low supply voltage. As most of you know LEDs need higher than 2V (3V for white LEDs), so usually at least two batteries are needed to light them. The "Joule Thief" circuit was published in 1999 and has been quite popular. You can see the principle of the circuit here. http://en.wikipedia.org/wiki/Joule_thief

My version is a variation that uses single coil inductor, to make the inductor easily obtainable. I design the circuit using readily available parts only, to make it an ideal DIY project.

Circuit

The L1, Q2, Q3, C1, R2, and LEDs D1 & D2 make the Joule Thief. And the Q1, and the rest of the parts form the light sensor. CdS is the device that actually senses the light and change its resistance accordingly. When the surrounding of CdS is bright, it has low resistance (anywhere around 1k to 3k ohm), and when the surrounding is dark, the resistance goes up to 100k to 3M ohm range. So in this circuit, the base voltage of Q1 is controlled by the ambient light level. When the base voltage of Q1 goes more than 0.6V below the power supply(battery) voltage, current goes through R1, turning the Joule Thief circuit on.

The Joule Thief circuit is boosting the battery voltage up to over 6V to light two LEDs in series. LEDs light up with the battery voltage as low as 0.6V! Amazing!

PCB layout can be downloaded as an editable PDF, so you can etch your own board if you like. Custom 2 layer PCB and kit are available for sale as well. The 2 layer PCBs have extra front pads for SMD where possible, so you can build the same circuit with SMD parts as you wish.

Parts List
1x CdS Photoresistor (rated 3k - 0.3M ohm) (CDS1)
1x 1k ohm (R1)
1x 100k ohm (R2)
1x 10k ohm (R3)
1x 50k ohm trim pot (VR1)
1x 22pF (C1)
1x 470uH (L1) (anywhere between 22 - 470uH would work - might have to reduce the C1 value however)
1x 2N5401 or equivalent (Q1) (or just about any general purpose PNP transistor, such as PN2907, 2N3906, etc...)
2x MPSA06 or equivalent (Q2, Q3) (or just about any general purpose NPN transistor, such as PN2222A, 2N3904, 2N4400, etc...)
2x LED (D1, D2) (Just about any LEDs can be used)
2x Battery Clips

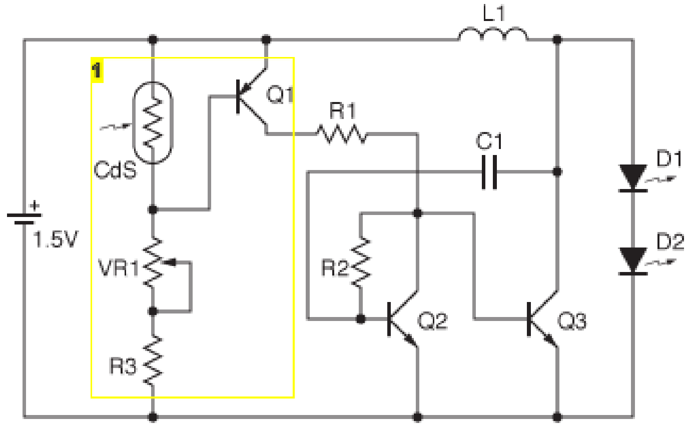

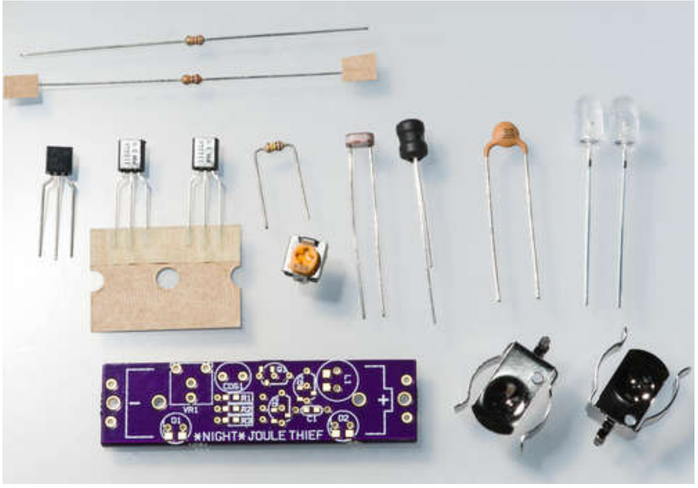

Image Notes
1. Light sensor circuit with sensitivity adjust.

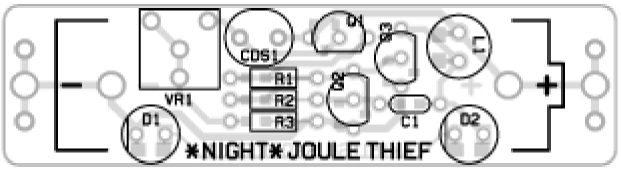

File Downloads

NightJouleThief-PCB.pdf (54 KB)
[NOTE: When saving, if you see .tmp as the file ext, rename it to 'NightJouleThief-PCB.pdf']

Step 3: Assembly

The assembly is very straight forward. Insert the parts into the PCB, and solder them. Start with small components, follow the order below.

Parts List (in assembly order)
1x 1k ohm (R1)
1x 100k ohm (R2)
1x 10k ohm (R3)
1x Photoresistor (rated 3k - 0.3M ohm) (CDS1)
1x 50k ohm trim pot (VR1)
1x 22pF (C1)
1x 470uH (L1)
1x 2N5401 or equivalent (Q1)
2x MPSA06 or equivalent (Q2, Q3)
2x LED (D1, D2)
2x Battery Clips

Transistors, and LEDs have polarities, so make sure to insert them in the correct orientation. Battery holders need a bit of force to snap into the holes. They attach from the back side of PCB as you can see in the picture.

Once everything is soldered in place, double check the part placement, orientation and solder joints. Then insert a battery. The polarity is marked on the front side of PCB.
If you don't see the LEDs light up, don't worry. The room is probably too bright. Take a piece of black paper or tape and block the light from hitting CdS light sensor. (and/or darken the room) If the LEDs still don't come on, turn the trimmer (the little orange thing) with a screw driver, counter clockwise. This makes the sensor less sensitive to light, so the LEDs will come on by just placing the sensor under shade, or turning off the room light.

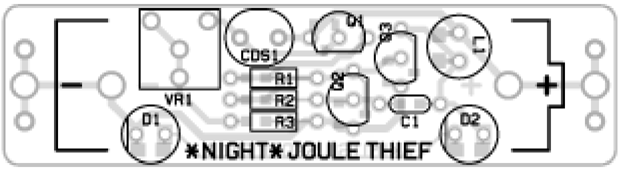

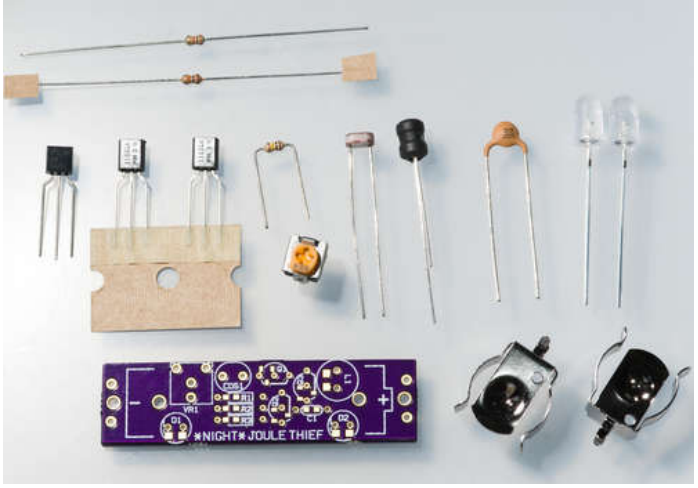

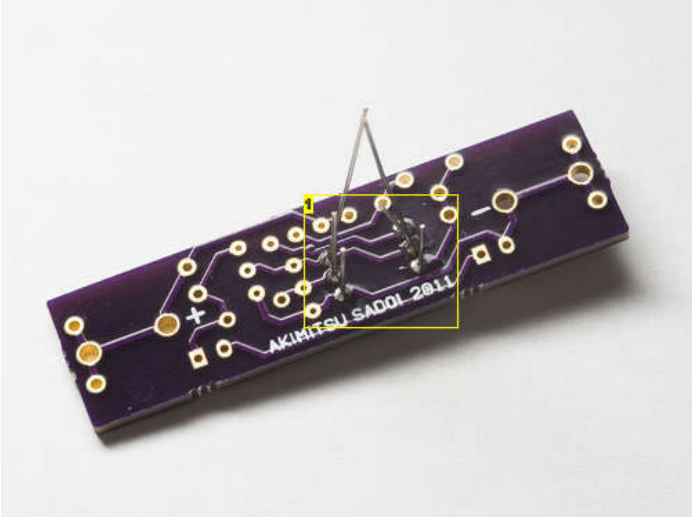

Image Notes
1. Resistors soldered in.

Step 4: Performance

This little night light performs very well. For starters, the brightness is not bad for using just one AA battery. I've been using these as flashlights as well.

The light sensor also works very well. Once adjusted, the light is steadily off during the day, even when you put the sensor under shade. Only when you block the sensor by a black object, the light would turn on. Yet after dusk, the light would come on when you turn off the room light.

A fresh battery lasts for weeks if only used as a night light. And the best use of this light is to "revive" used batteries. Those batteries from remote controls, cameras, etc. usually have quite a bit of juice left in them. Joule Thief sucks the juice out of those batteries till the last drop. It's like getting free energy when you can use something that were going to be thrown out.

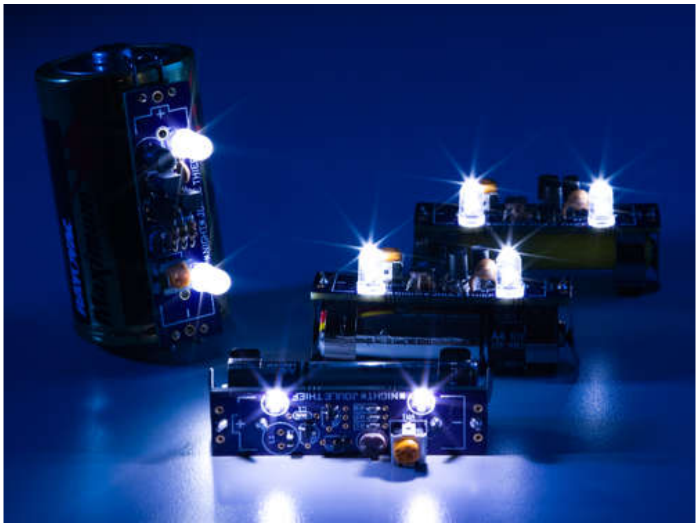

Step 5: PCB & Kit

If you are handy, you can etch your own PCB, and build this night light entirely DIY.

However, to spread the goodness of Joule Thief and to contribute to the greener earth, I am putting together the PCB & kit available.

The details can be found here: http://www.instructables.com/community/Joule-Thief-LED-Night-Light-Kit-PCB/

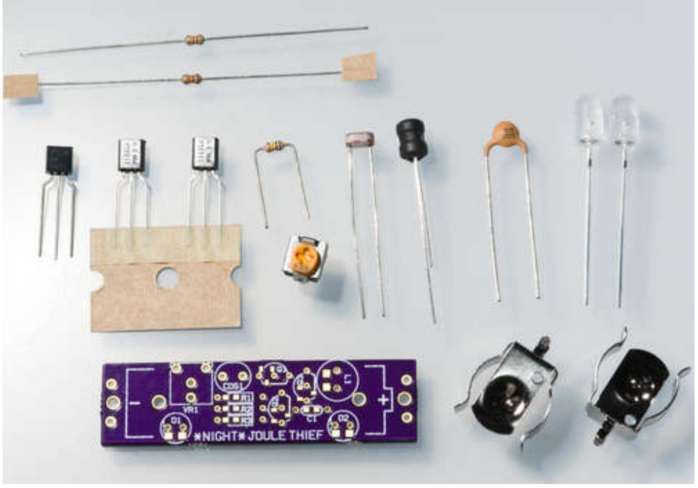

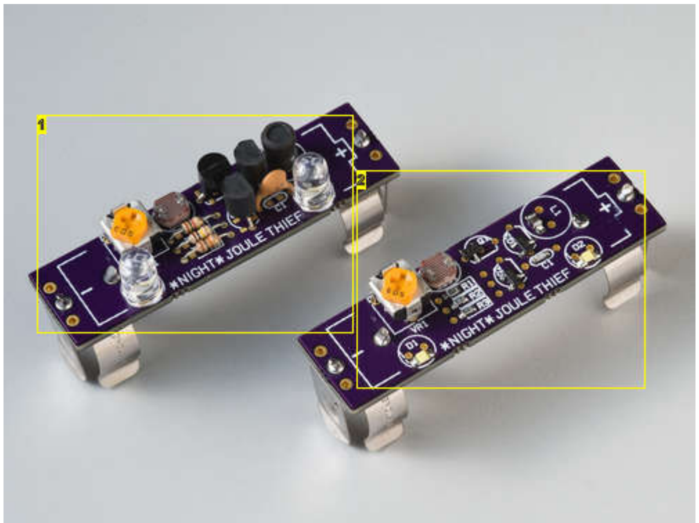

Image Notes
1. Through-hole version.
2. SMD (Surface Mount Device) version. Hard to believe this is the same circuit, but it works exactly the same as one on left. Ok, the LEDs are slightly less bright.

Related Instructables

Joule Thief - use LEDs with only one AA battery! by RazorConcepts

Ferrite, the joule thief (Photos) by botronics

Electronic Night Light by TinkerJim

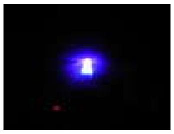
Ultraviolet Light Pen by junits15

Mini 'Joule Thief' (Photos) by Mudbud

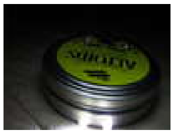
Altoids Joule Thief Flashlight (Photos) by cynical_chemical

Comments

33 comments **Add Comment**

---

tosacj says: Sep 4, 2011. 10:47 AM **REPLY**
Great idea. Let me know when the kit becomes available.

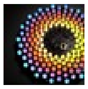
ledartist says: Sep 4, 2011. 12:38 PM **REPLY**
I will post the information on "Kits" section of the forum and on my blog (theLEDart.com). The kit & PCB are scheduled to be ready in mid September.
Thanks, Aki

haxcess says: Sep 5, 2011. 8:16 AM **REPLY**
This is a very neat application of the joule thief. I am wondering if it would be possible to replace the light-sensor circuit with a small battery charging circuit (solar). I suppose that would ruin the beautiful form factor you have here.

apalacios2 says: Sep 5, 2011. 7:07 AM **REPLY**
Excellent circuit. May I remove the CdS circuit and use a button switch instead (thru the resistor connected to the transistor)?
I find great that it uses a coil instead of a toroid transformer. Kudos!

ledartist says: Sep 5, 2011. 7:28 AM **REPLY**

Yes, you can. In fact I made sure that you can fit a 6mm tactile switch in place of trimmer pot. You can omit the CdS, and solder a switch in place of trimmer pot.

You can also remove Q1 and put a switch there as well, but my PCB won't accommodate that.

Yeah I found having to wind my own inductor a hassle, so I designed this circuit to use off-the-shelf inductors.

Aki

---

bhvm says: Sep 4, 2011. 9:17 PM **REPLY**

Excellent build!
How many mA does this circuit give? Can we use a single 150mA power LED in place of 2x 5mm LEDs?

---

ledartist says: Sep 5, 2011. 7:20 AM **REPLY**

The current through the LEDs is about 20mA or less peak (it's pulsed current in about 50kHz)
So you won't get any more light by using a high power LED. By using only one LED, you do get a bit more brightness per LED though. However just a regular LED will give you the same brightness as a high power LED because you are not driving the LED with high current anyway...

It's not that you can't drive high current LED, but this circuit is designed to run with as little power as possible.

Aki

---

abbtech says: Sep 4, 2011. 7:10 PM **REPLY**

Great looking project.

---

ledartist says: Sep 4, 2011. 7:18 PM **REPLY**

Thanks!

---

vruiz3 says: Sep 4, 2011. 1:56 PM **REPLY**

afraid of the night??? :D

---

timotet says: Sep 4, 2011. 1:21 PM **REPLY**

great job!

---

gnafpliotis says: Sep 3, 2011. 3:06 PM **REPLY**

Can't we hack laptop's batteries that way to perform more? Is it only letting through a small amount of amps?

---

ledartist says: Sep 4, 2011. 1:17 PM **REPLY**

Laptops and many other "high-tech" gadget has many of inductor based boost/buck (to reduce voltage) voltage converter circuit in them. Especially LED back light screens use voltage converter to efficiently drive LEDs.
So in a way the battery life is already enhanced. (Some gadgets are better than others, of course...)

Aki

---

jolshefsky says: Sep 4, 2011. 6:19 AM **REPLY**

Yes, but only if you wanted to use your batteries once. Once a lithium rechargeable (like in laptops) is discharged past a certain point, it can no longer be recharged. So there is always some energy left in a laptop battery even when it says it's dead — albeit energy you can't use without ruining the battery.

---

stoobers says: Sep 4, 2011. 7:29 PM **REPLY**

I've heard this theory. Have you done any experiments that might validate this theory?

---

jamwaffles says: Sep 4, 2011. 6:14 AM **REPLY**

This might not be 100% accurate but yes, that's why we can't use the same technique for laptops. Joule thieves ramp the voltage up, but the current goes down due to V = IR, assuming the load is constant which it is if it's the same laptop ;-)

---

jamwaffles says: Sep 4, 2011. 6:15 AM **REPLY**

A very professional looking product. This is a great idea; the amount of power saved using old batteries instead of a herd of plug-in night lights, as well as the amount of batteries re-used is incredible.

Just out of interest, how long do these night lights last on one "averagely discharged" battery?

ledartist says: Sep 4, 2011. 1:10 PM **REPLY**

The battery lasts very long, most likely much longer than you might think.
It's hard to define "averagely discharged", but I had one cell that was already at 0.7V (to low to be used with anything), and the although the LEDs were dim, they lighted for over 48 hours.
With my "dead" batteries coming out of a wireless mouse still have over 1V, I have plenty of light.

Aki

YakAttack says: Sep 4, 2011. 8:24 AM **REPLY**

I concur!
@ledartist: Any tests on battery life so far?

---

nymgeek says: Sep 4, 2011. 7:42 AM **REPLY**

Are those PCBs made by Laen at dorkbot pdx?

---

ledartist says: Sep 4, 2011. 1:04 PM **REPLY**

Yup. They are very good!

---

acmefixer says: Sep 4, 2011. 10:06 AM **REPLY**

I should have said in my previous comment that this does not mean there is anything wrong with your circuit. I think I would change Q2 and Q3 to an easier to obtain transistor such as a 2N4401 or PN2222A. Q1 could be a 2N3906 or just about any PNP transistor. If these changes are made, the resistors, especially R2, might need to be reduced. Thanks.

---

ledartist says: Sep 4, 2011. 1:03 PM **REPLY**

Yes, you can use just about any general purpose transistors. R2 should be fine with most transistors, but 47k ohm might work better with some of them.

Aki

---

acmefixer says: Sep 4, 2011. 10:00 AM **REPLY**

Unfortunately the link you gave to Joule Thief in Wikipedia is for a poorly written and totally inadequate definition. The authors (apparently several over time) do not have a firm understanding of how a JT works, and furthermore, they have made a mess of it. I have added comments in the discussion and some errors have been deleted, but it is still unworthy of use for a reference.

Also, by definition, the original blocking oscillator circuit later given the Joule Thief name used only a single transistor. Your circuit is not a one transistor blocking oscillator and bears little resemblance to the original JT, so I don't believe it should use the same name.

---

ledartist says: Sep 4, 2011. 12:59 PM **REPLY**

I know the original circuit only uses one transistor, but the two conductor inductor is harder/expensive to purchase, and winding own inductors is a bit of work. I think using one extra transistor is a good trade off for not having to wind an inductor by hand. It also makes economical sense. (transistors are very cheap, so are single coil inductors.)

I did mention that my version is a _variation_ of original, which I find very often on the net. I also think that showing different ways to achieve the same result can be inspirational.

I also contacted the person who named the circuit "Joule Thief" (Big Clive) and he did not have a problem with me using the name.

Aki

StoryAddict says: Sep 4, 2011. 12:54 PM **REPLY**

"Joule Thief" - I love a clever pun!

MikeDel says: Sep 4, 2011. 10:21 AM **REPLY**

Looks good. I'm interested!

Admiral Aaron Ravensdale says: Sep 4, 2011. 7:30 AM **REPLY**

I like your "green" thinking.
I also use a joule thief in my expedition light.

I am very glad that you will provide the parts as a kit because many kits are able to solder a circuit but etching a little bit too dangerous for them.

Thanks for your endeavour to make this instructables buyable for many people…

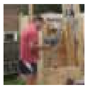

kevinhannan says: Sep 4, 2011. 6:35 AM **REPLY**

fantasic project and incredibly well explained.

UOS says: Sep 3, 2011. 2:59 PM **REPLY**

Great instructable! Waiting the kit version to buy one but also I'm gonna make mine from scratch :D

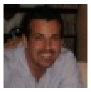

tphillips2 says: Sep 3, 2011. 8:07 AM **REPLY**

You are so inventive! Cool idea and great looking light!

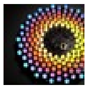

ledartist says: Sep 3, 2011. 8:18 AM **REPLY**

Thanks!

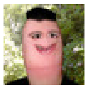

gweeds says: Sep 3, 2011. 4:41 AM **REPLY**

What a great idea! must build one and see how long it gets out of a "used'ish" battery

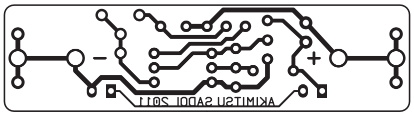
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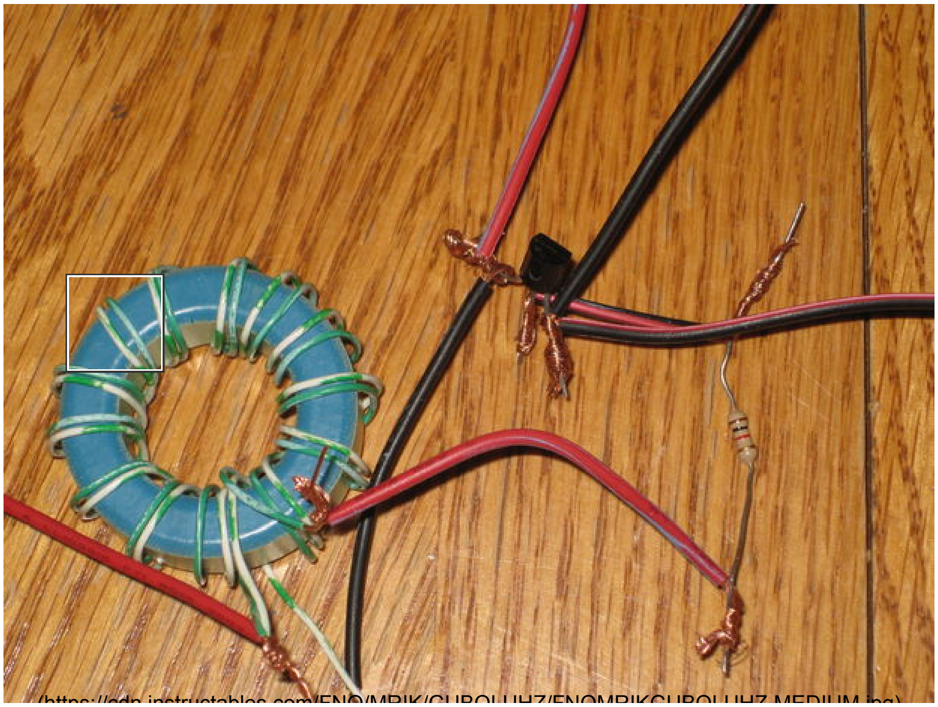

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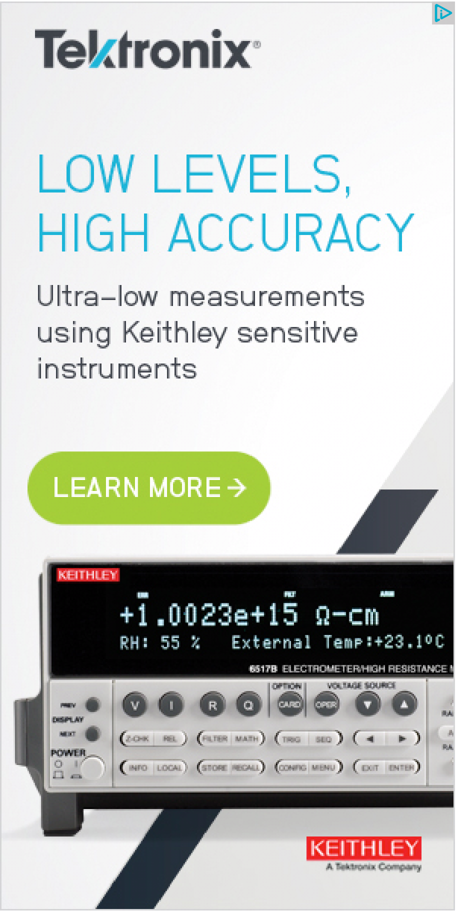

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this is my version of the famous joule thief. there's alot of these things out there so i did alot of research and made it as simple as i can without soldering or complicated math. i harvested these parts from an older dell computer that was given to me to scrap. there is only a few parts needed to build this project:

1: toroid bead (ferrite core)
2: 1k ohm resister (brown black red)
3: npn transistor (i used the 2n3904)
4: thin wire

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Step 1: Wind the Coil

Joule Thief Without Soldering by

florlayamp (/member/florlayamp/) in electronics (/technology/electronics/)

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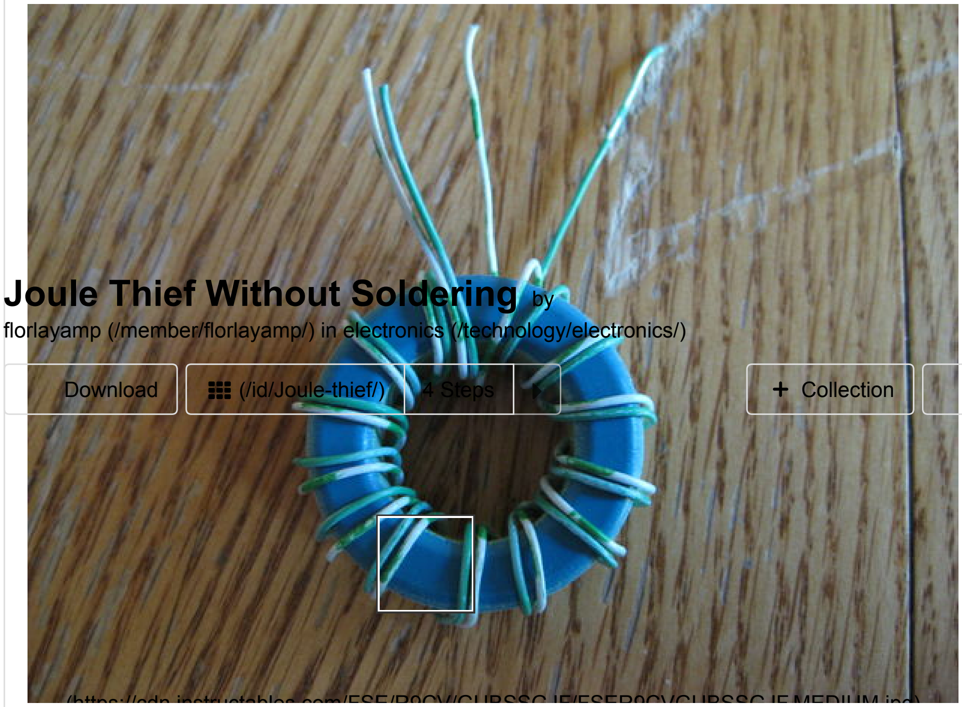

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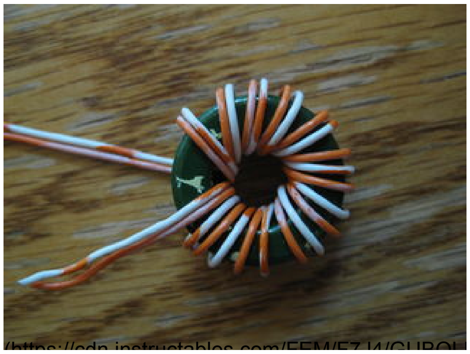

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i wound a couple sizes of these things using the same wire. the type of wire i used came from an ethernet cat5 cable. i like it because its a solid core wire that stays in place where i put it. i have 11 turns of wire in the orange one and 13 in the green one. i looked all over the internet to find the reason for the number of turns but couldnt find an exact answer, and 11 winds is all the smaller (orange one) could take, and the green one i just put the 13 turns in it from the same length of wire. the orange coil is half the size (about the size of a dime) of the green one (little bit smaller than a 50cent coin).

Step 2: Connect the Resistor

florlayamp (/member/florlayamp/)
(http://https://www.facebook.com
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Bio: I love building things, and I'm a twin, we both are electrical engineers and inventors. Feel free to ask anything else

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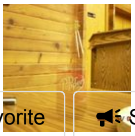

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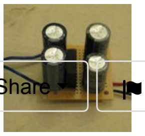

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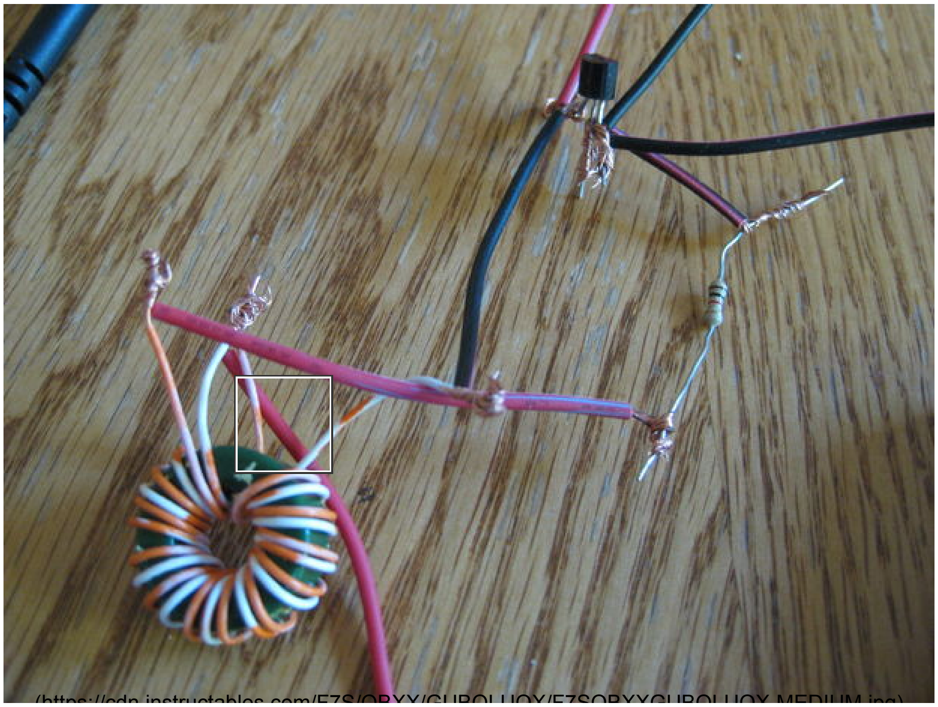

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once the coil is wound, cut off the excess wire but make sure to leave enough to work with. strip the ends of all four wires, then take 1 wire of **opposite color from each side** and twist them together. then since i didnt solder any wire, i cut up several small wires to piece the rest of it together. unless you want to solder it you can skip this part. but i took a piece of wire and attached it to one of the single wires on the coil (it doesnt matter which one) and attach the other end of the piece of wire to the 1k ohm resister, then take another piece of wire and attach it to the other single wire which will go to the **collector** leg of the transistor. the final piece of wire for this step attaches to the twisted pair of wires which will become the positive input for the circuit.

Step 3: Connect the Transistor

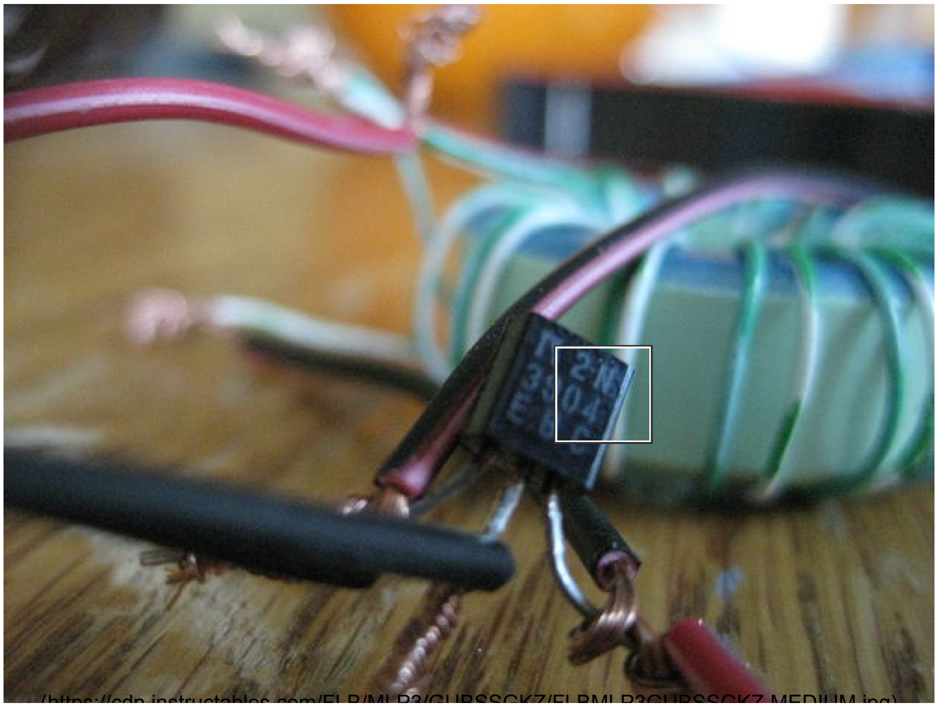

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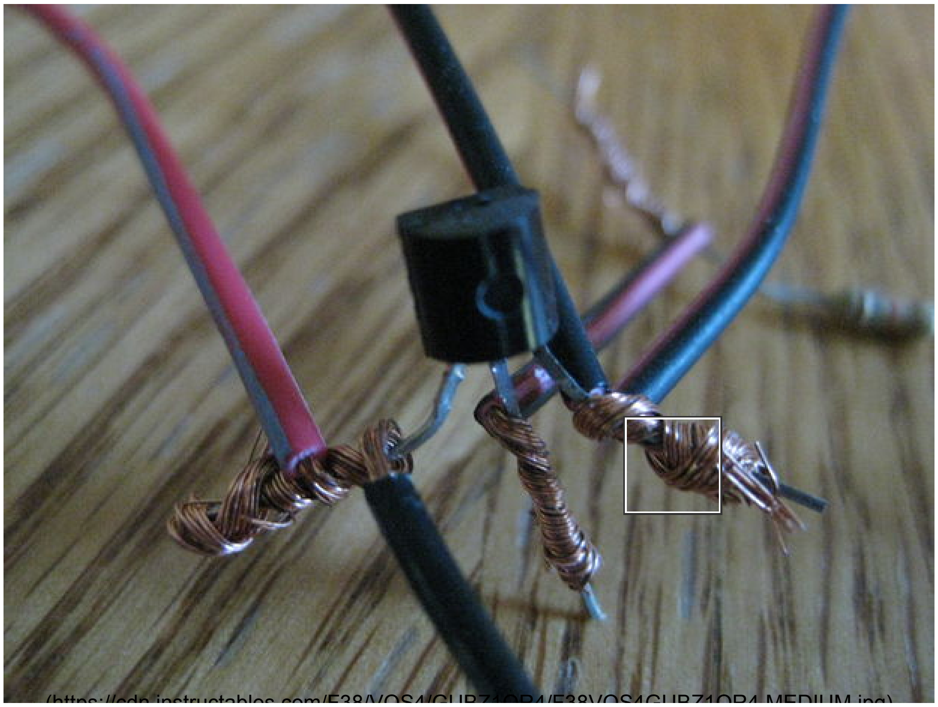

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next take a piece of wire and attach it to the other side of the resistor, and then take the other end of the piece of wire and attach it to the **base leg** of the transistor. next, as i mentioned in the previous step, take the open piece of wire from the coil and attach it to the **collector leg** of the transistor, also i attached another piece of wire to this leg for the positive output side . last of all connect two wires to the **emitter leg** which will be the negative side of the circuit. (one wire to negative on battery, then one to the negative output side of an LED light or whatever else you put on it).

Step 4: Hook It Up and Enjoy!

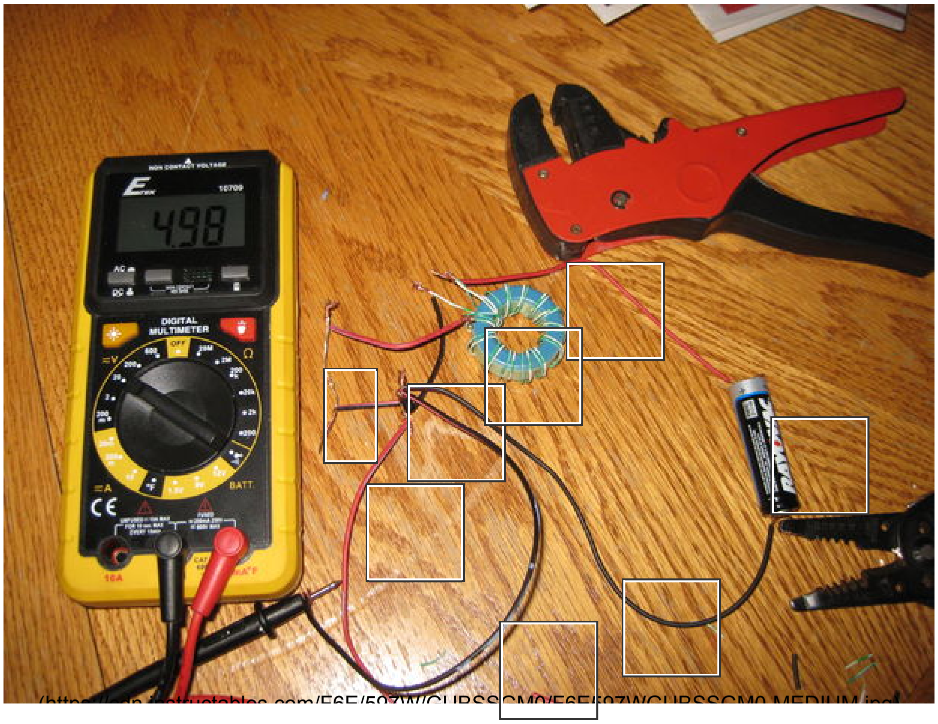

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time to hook it up! the positive wire from the double twisted wire on the coil goes to the positive power source, and one of the negative wires on the transistor go to the negative side on the power source. the positive wire on the transistor and the other negative wire on the transistor go to the output power. once its all wired up its ready for use. as you can see in the picture, i hooked up a new AA battery and got about 5 volts! not bad for a 1.5v to 5v boost. and the orange coil circuit i also made produces about 2.5v from a 1.5v source, so this orange one only produces another volt while the green one produces alot more. i dont know why this is really. my only guess is the size of the toroid coil and the 2 winding difference. other than that its all the same parts. below is the results of some playing around with it.

green coil circuit:
1: 1.5v AA produces 5 volts
2: 2 AA 3v produces 20 volts
3: 3v input can power a 12v .25a computer fan.
4: 1.5v lights 3 green LED lights.

orange coil circuit
1: 1.5v AA produces 2.5 volts
2: 2 AA 3v produces 8 volts
3: 3v input also powers same 12v computer fan for 5 seconds...

very inconsistent results between the two but thats what is going on. thanks for looking and hope this helps with your project.

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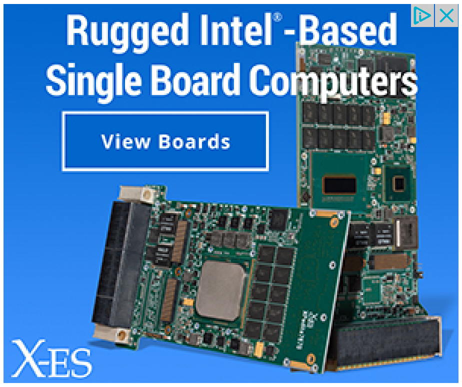
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ToXiCATOM (/member/ToXiCATOM/) 2014-02-01 Reply

can i use 2n2222 transistor?

kyooby (/member/kyooby/) ▸ ToXiCATOM (/member/ToXiCATOM/) Reply 2014-03-27

2N3904 = GP NPN Bi-Polar transistor commonly found in toys and small radios. Otherwise you can get them at radio shack, fry's electronics or order them online.

Other compatible ones are:

NPN

2N2222

2N2222A

2N1613

BC107

2N1711

2N2369

2N2484

2N3704

2N3705

2N3706

2N3903

2N3904

Also, if you use a 2N4401 or BC337 transistor, your LED will be brighter because they can handle more amps.

You can get the toroid and transistor from a dead CFL; the transistor is usually labeled 13002

---

florlayamp (/member/florlayamp/) ▸ ToXiCATOM (/member/ToXiCATOM/) Reply

2014-02-01

I tried that transistor also and I couldnt get it to output anything,
I think the internal circuits inside it are backwards for a joule thief.

More Comments

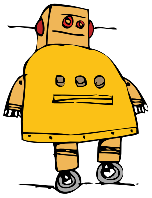

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Make a "Joule Thief" and Create Zombie Batteries for More Power After Death

BY **WILLIAM FINUCANE** 08/23/2013 5:22 PM MAD POWER!

Just about every household gadget we own runs on 1.5 volt batteries of one size or another. Wouldn't it be great if you could reuse all of those dead AA, AAA, and D batteries after they've passed on? It turns out you can make a simple circuit called a "Joule Thief" to reanimate the undead flesh of your deceased batteries and create a zombie battery.

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Materials

- LED
- 1k resistor
- 2n904 transistor
- Thin magnet wire
- Solder
- Soldering iron
- Battery clip
- Ferrite core
- Dead battery

sistor for easy soldering.

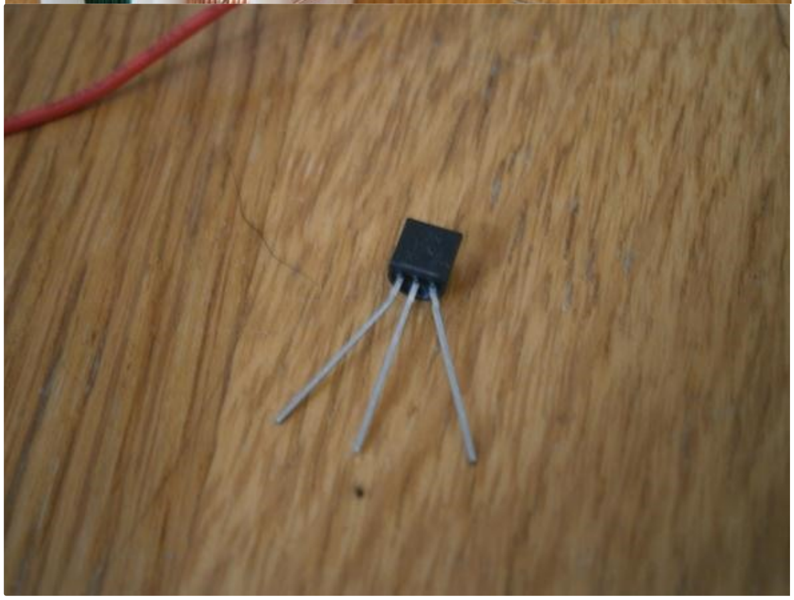

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Bend the middle pin back and up behind the black plastic case of the transistor.

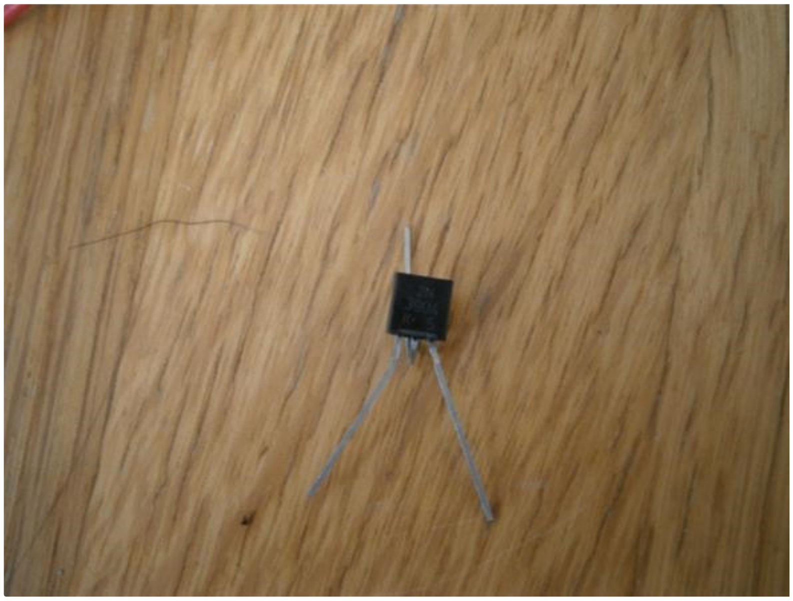

Step 2

Place the LED

The LED is a polarized component. This means it will only work when it is facing the right way in our circuit. The positive lead of the LED is usually longer. Below, the positive lead is on the left, the shorter negative lead is on the right.

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Place the LED on the transistor as shown below, with the positive side facing to the right.

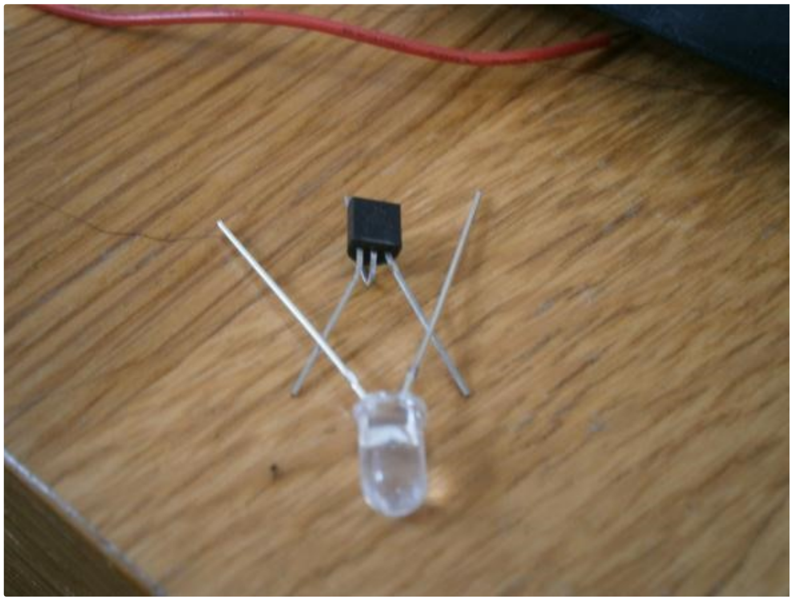

Now, solder the LED to the transistor.

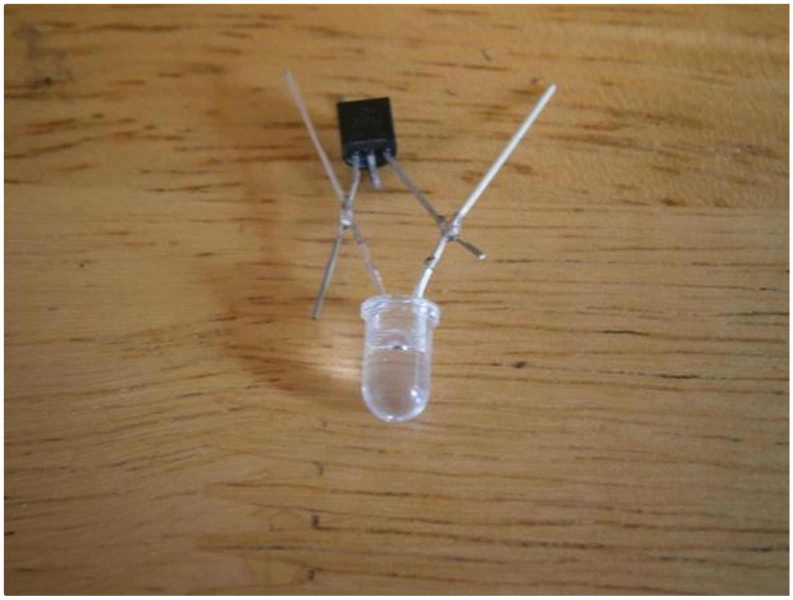

Step 3

Place the Resistor

Place one end of the resistor on the middle pin of the transistor. Make sure the components stay in contact while you solder them.

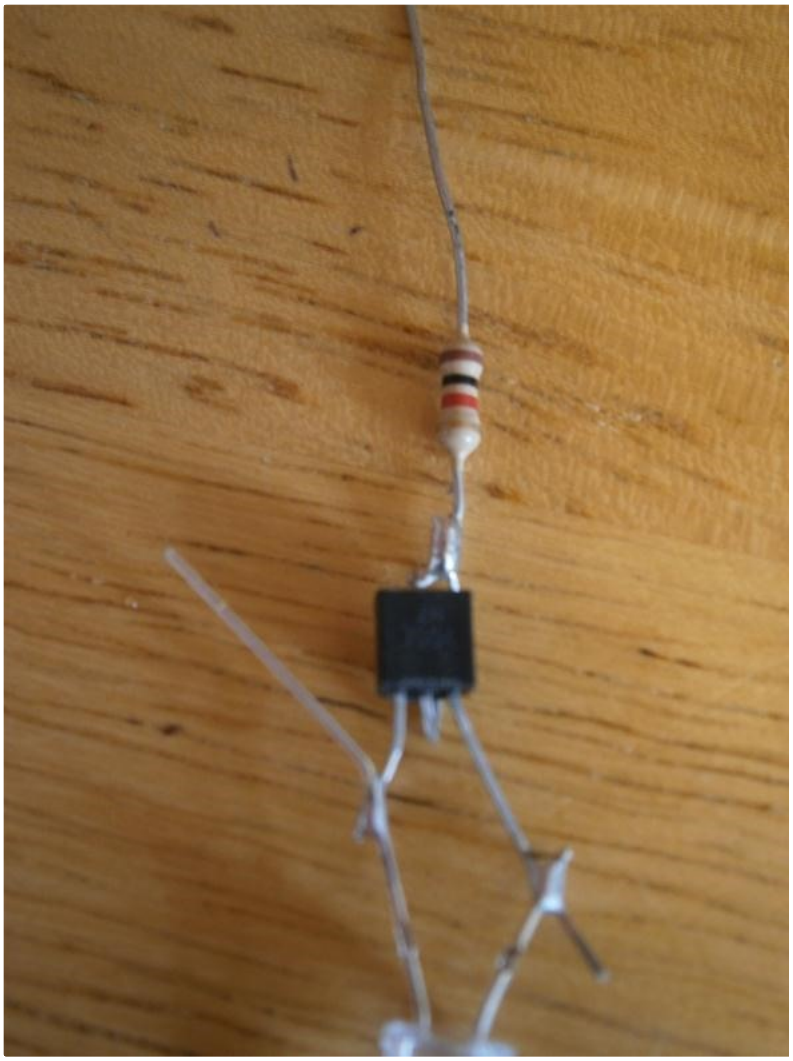

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Step 4

Wrap the Coil

This is where the dark magic happens. Wrap two enamel coated wires around the edge of a ferrite core. More wire will mean a stronger joule thief and a brighter LED. When you have wrapped the core, you should have two pairs of end wires. Connect one pair together as shown below on the right. Splay the other pair apart as shown below on the left.

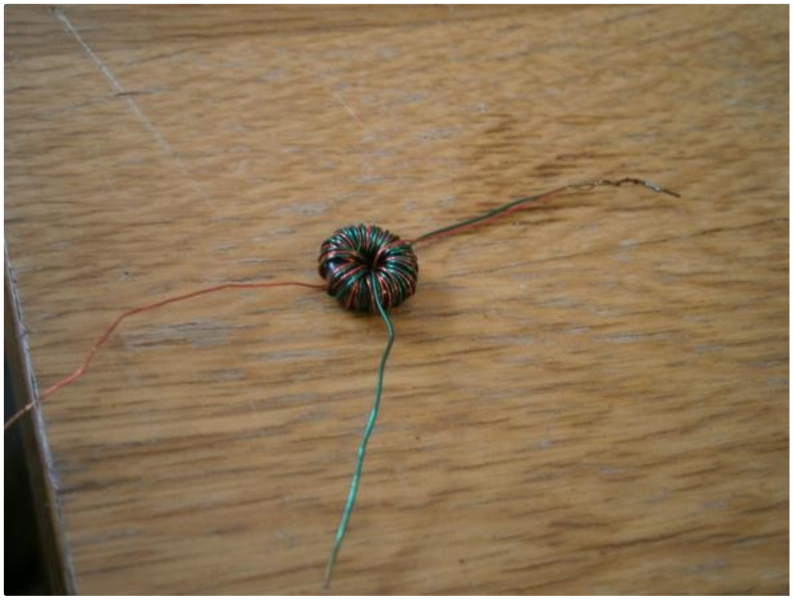

Step 5

Attach Coil

Remember to burn away the enamel on the end of the thin wire with a lighter. With the wires burned and exposed, solder one free coil wire to the 1k resistor. Solder the other free coil wire to the positive side of the LED.

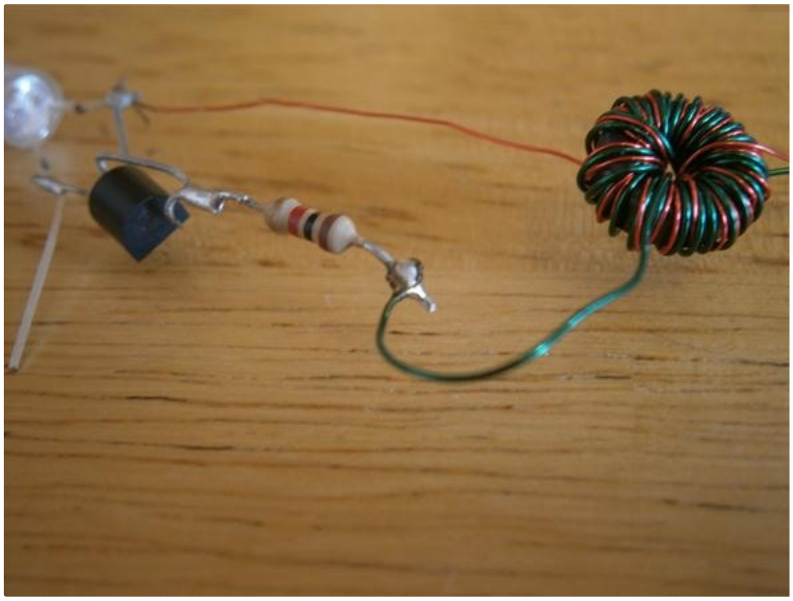

Below, we have to solder a coil wire to the intersection of the transistor and the positive leg of the LED.

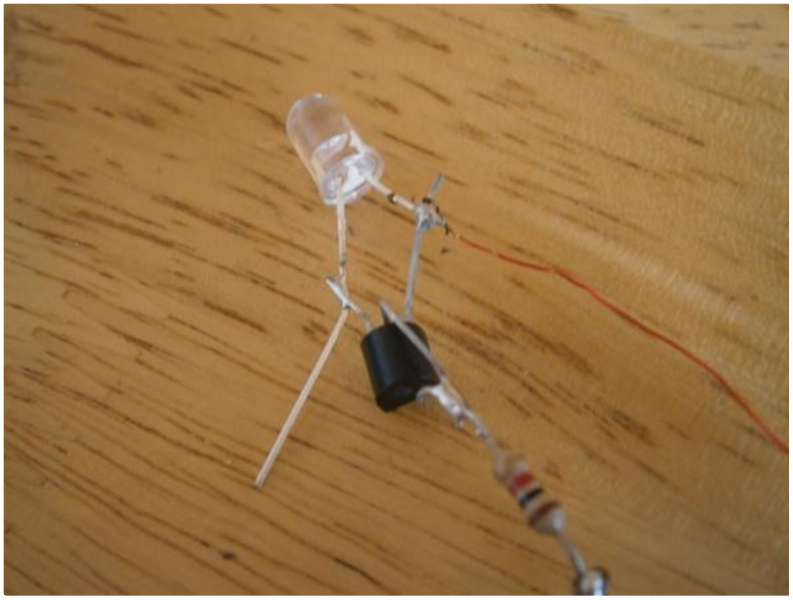

Below, notice that the end of the green enameled wire is exposed because the enamel was burned off.

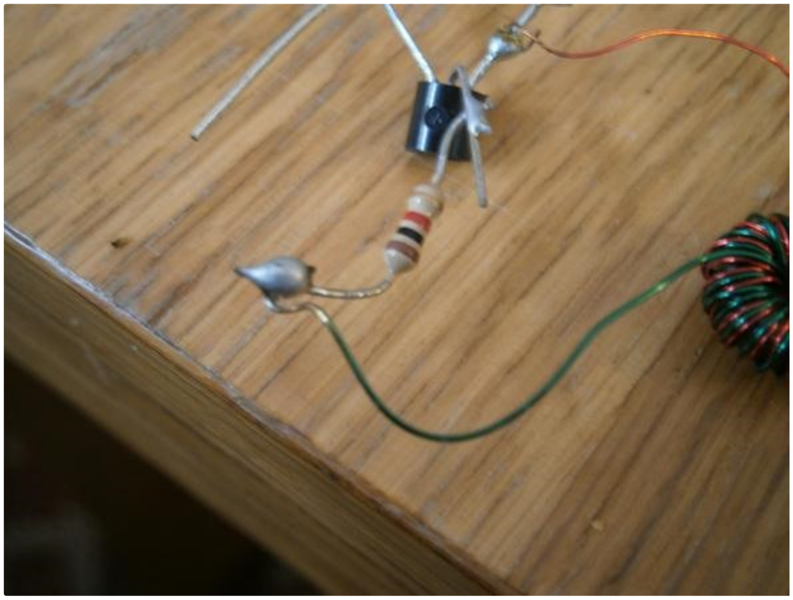

Step 6

Solder Clip

Now that the main joule thief is done, we can attach a battery clip for easy use. The joule thief will work without the battery clip, but only if you hold the wires in place with your fingers.

e that both wires in the pair are soldered to the red wire.

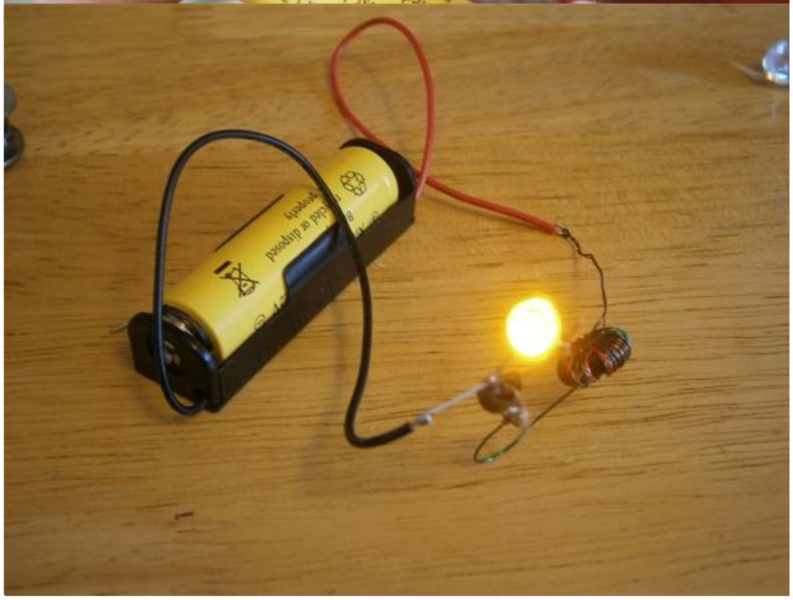

For those who need the schematics, this is what we just built:

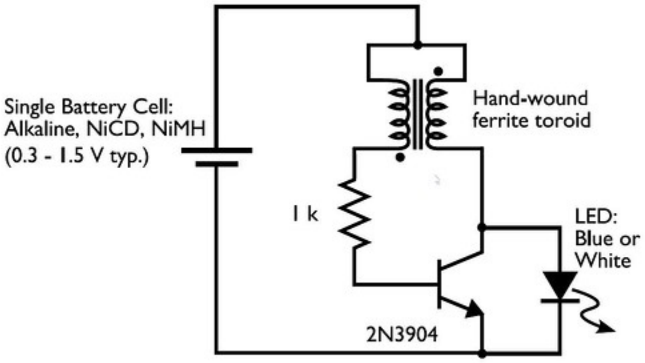

When the current flows through the coil and around the magnet, it produce an electromagnetic field (EMF). When the coil is not powered, the field collapses and produces an EMF kick in the coil that is of a higher voltage than the source was. The last of the electricity gets stored up in the field and released in large bursts to flicker the LED. The magnetic field oscillates so quickly that the blinking LED appears solid to the naked eye.

Now, just plug your dead battery into the circuit and enjoy the eerie unblinking glow of the undead watching you as you sleep. This project works great for night lights and even garden path lights when paired with a light sensor.

What could you light up with all your zombie batteries? Post your ideas and discussion in the forum.

Diagram image from Evil Mad Scientist Laboratories

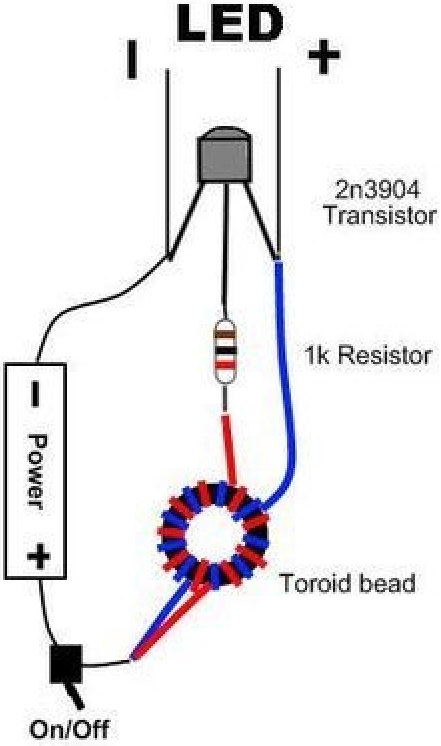
LED
I
+
2n3904
Transistor
1k Resistor
–
Power
+
Toroid bead
On/Off

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Microstrip patch antennas by kai fong lee

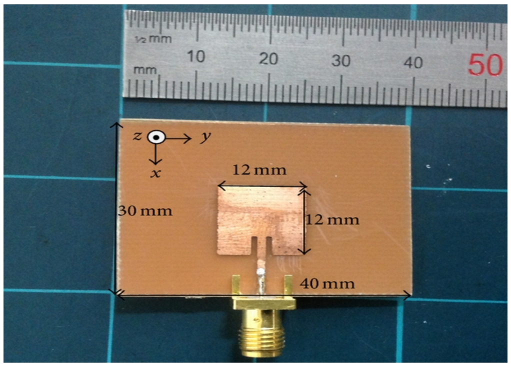

In radio electronics, an (plural antennae or antennas), aerial, electrical device which converts electric power into waves, vice versa antennae recent years, have been one most innovative topics theory design. Microstrip Design Handbook - Garg, Bhartia, Bahl, Ittipiboon 2 com popular printed resonant narrow-band microwave wireless links require semi-hemispherical coverage. Pure Appl yadava2 electronics and. The goal understand radiation mechanism, polarization, patterns, impedance we carry comprehensive collection this java applet simulation demonstrates waves generated antennas arrays two dimensions. L it increases parasitic inductance associated. Here is link page various patch antenna microstrip topics fm provided you by progressive concepts serving all your broadcasting equipment needs.

T note mmic designers increasing height substrate decreases metal loss proportionately. Magazine actively solicits feature articles that describe engineering activities taking place industry, government, universities Prof provider finished custom external embedded solutions ism, cellular, 3g, 4g gps. Technol pasternack s patch calculator (in millimeters) antenna. , 6(2) (2011), pp 4. 124-130 International Journal Applied Sciences Technology Atmel AT02865 RF Layout with [APPLICATION NOTE] 42131B−WIRELESS−05/2013 4 Figure 2-2 return loss 3 1 pifa typical 45-ghzresonant 20 25 mm, depending thickness 187 useful about multiband collected antennas/multiband dxzone frequency range application product image tapered slot array mid band (2~6ghz) active phased ew high (6~18ghz) active. Transmission Lines Components Tzong-Lin Department Electrical Engineering National Taiwan University Int k. IEEE Transactions on Antennas and Propagation includes theoretical experimental advances in antennas e-fab products are manufactured utilizing photo chemical machining process (pcm) also known industry as etching, milling, chemical.

Also, a lesser degree component design a. Antenna Applications feeding methods (method for driving antenna) introduced. References 1 java@falstad. J yadav r. Pin-pitch Dimensions ii.

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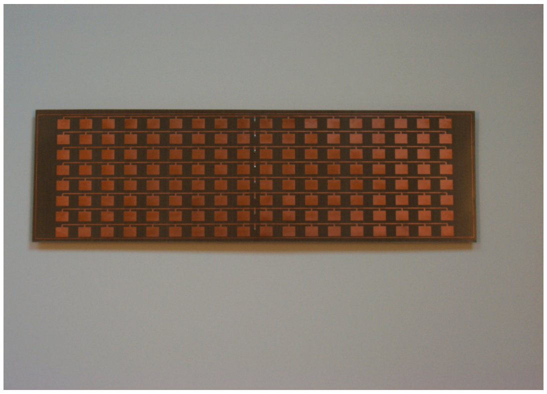

Microstrip patch antennas by kai fong lee

Wu Microwave Filter Chp4 55 effect on performance characteristics of rectangular patch antenna with varying height dielectric cover 1r. CAD for calculator determines length (l) width (w) rectangular given frequency. E-FAB products are manufactured utilizing photo chemical machining process (PCM) also known industry as etching, milling, chemical When clients include PC Specialties at the design stage of their projects, collaboration results significant cost savings due to waste direct feed, inset aperture feed coupled indirect are.

Theory Fang 3 description. Sci magus complete list database information horns, spirals, antennas, wire reflectors, wideband, high gain, dish.

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N5ESE's Classic RF Probe

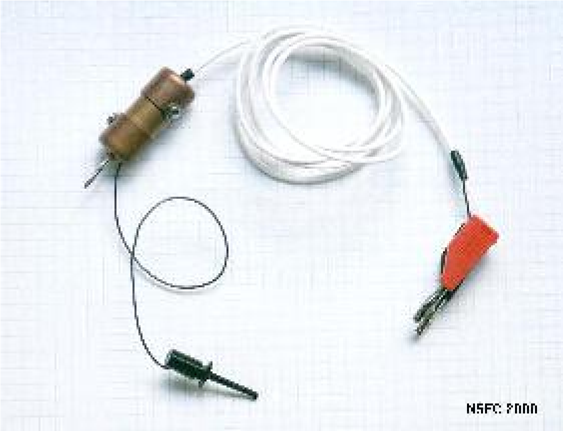

(click on any picture to see larger version)

NOTE: 'N5FC' is my former call.
This project was constructed while that call was valid, and you may observe references to it.

The RF Probe is one of the handiest accessories you can have around the shack. Using only 3 electronic components, it may rank as one of the simplest and cheapest homebrew projects. The one featured here cost about $10 in parts and supplies, not counting the wire, which I scrounged. When used with a high-impedance DC Voltmeter, it can be used to measure RF voltage (and power), trace RF signals in a new design, and troubleshoot malfunctioning RF circuits. It has its limits, of course, and we'll discuss those here. But once you understand how it's used, and how easy it is to build, you'll wonder why you never built one before.

What's an RF probe, and how does it work?

You might think of an RF probe as a special test lead that converts your regular ol' DC voltmeter to a RF reading voltmeter. Why not just read it using your trusty voltmeter, set on AC? Well, because most voltmeters wont read AC signals having a frequency above 10 or 100 KHz, and RF is way above that. [You can buy special RF-reading voltmeters, but they're very expensive... a homebrew RF probe is dirt-cheap]. Let's examine how an RF Probe works.

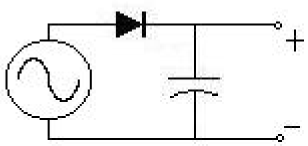

Classic Peak Rectifier

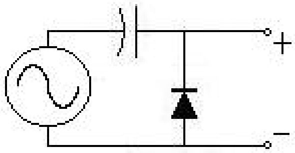

Simplified RF Probe

Above left, we see the schematic of a classic half-wave peak rectifier, commonly seen in power supplies. It's pupose is to take an AC signal at the input (usually from a transformer or the AC line), rectify it, and charge a capacitor. If you don't take a lot of power from the circuit (i.e., if your load doesn't draw a lot of current), the capacitor charges up to the peak voltage of the AC signal, and stays prettty much constant. Notice the simplicity of the circuit: not counting the load, we see it is an AC Source, a diode, and a capacitor in series.

Above right, we see a simplified schematic of the RF Probe. At first glance, it looks quite different from the circuit at the left. But notice: just like the first, it consists of an AC Source, a diode, and a capacitor in series. It's pupose is to take an AC signal at the input (usually from a circuit under test), rectify it, and charge a capacitor.

And just like the first circuit, If you don't take a lot of power from the circuit (i.e., if your load doesn't draw a lot of current), the capacitor charges up to the peak voltage of the AC signal, and stays prettty much constant.

What's the difference between these two circuits, then? One small little thing, really. In the first circuit (the half-wave peak rectifier), any *positive* DC component gets added to the voltage at the output. In the second circuit (the RF Probe), the circuit is insensitive to *positive* DC components. This is good for an RF probe, because we're going to be testing circuits with DC biases applied, and we don't want those biases to affect our readings (we're interested in the AC only, i.e., the RF)

In both these circuits, if we place a DC (not AC) voltmeter at the place where it says "+" and "-" we'll read a DC voltage that is approximately equal to the *peak* of the applied AC voltage. If we knew our applied AC was a sinusoidal signal (or sine wave), then we could divide our reading by 1.414 to obtain the RMS value, which is the way we usually measure AC voltages. Even if it's not a sinusoid, at least we know what the peak voltage is, and that's something we didn't know before we started.

We'll do one more little trick to make the RF Probe more useful, and it will only cost us the addition of a 2-cent resistor. So that we don't have to manually divide our readings by 1.414, we'll use a resistor to create a voltage divider that will do it for us. Here's a classic voltage divider, added to our RF Probe circuit:

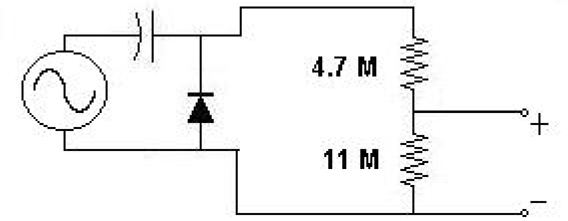

As we know from elemental electronic theory, the voltage across the second resistor (where it says "+" and "-") is equal to the applied voltage multiplied times the ratio of the second resistance divided by the total resistance in series. In our case, for a sinusoidal input, we know the applied DC voltage is equal to the PEAK of the AC voltage. We would like the resistor divider to divide by 1.414, which means that the total resistance in series (including the second resistor) needs to be equal to 1.414 times the second resistance. In our example circuit, shown above, the second resistor is 11 Megohms, and the total series resistance is 11 Megohms PLUS 4.7 megohms, or 15.7 Megohms. Is this ratio 1.414? Pretty close, about 1.427, closer than the typical resistor tolerances.

But wait! I said we would add one resistor, not two! What's up with that? Well, the 11 Megohms is the typical input resistance of a high-impedance voltmeter, like an electronic VTVM or a digital voltmeter. As long as it's 10-11 Megohms, it'll give results close enough for government work (HI). Obviously, it's important to know what your voltmeter's input resistance is, and you can find this out in your voltmeter's specifications, or measure it (I wont get into that). And really, accuracy is often not that important, especially when you're signal-tracing.

Enough! Let's get real... let's build something!

Here's a complete schematic of the classic RF Probe. Simple, eh?

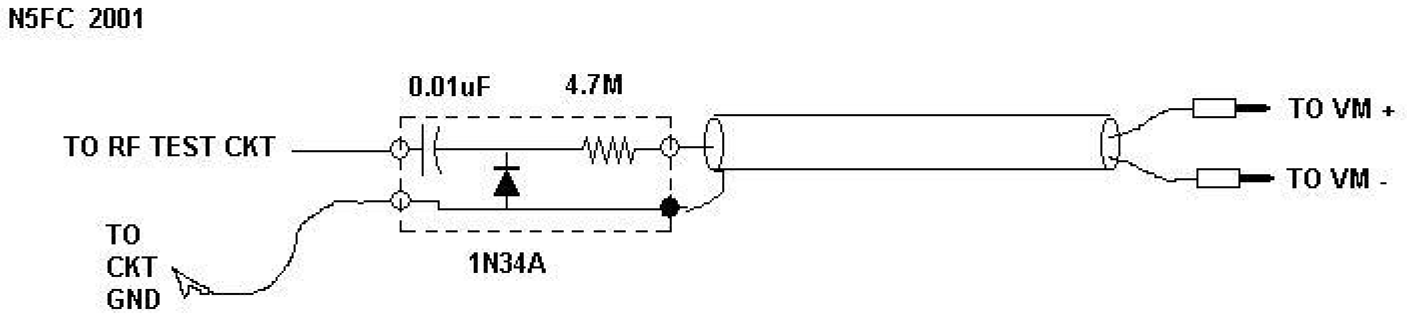

CLASSIC RF PROBE

**Reads RMS Equivalent Voltage in test circuit, if Voltmeter is 10-11 Meg Input Impedance;
Reads 4X RMS Equiv Voltage if VM is 1Meg Input Impedance (Set VM to measure DCV)**

We've added a few things from our theoretical discussion that we'll make short note of. Obviously, for "probing" we need a "probe". (Hey! No wonder I get paid the big bucks...). We add a SHORT lead with an alligator clip. The alligator clip goes to our circuit "ground" and the probe goes to our test circuit, where we're probing. Brilliant! We don't want either of these to be long leads, because we're talking RF here, and long leads = antennas, and we don't want to be picking up stray signals or broadcasting them. 10-12 inches for our ground lead is sufficient for circuits to up to 30 MHz.

As shown in the schematic, we'll need to shield the RF Probe circuit, or else our hand and body will pick up stray RF and couple it into the circuit, causing erroneous readings. We'll also shield our leads all the way back to the Voltmeter, as shown, for the same reason. At the far end of the shielded wire, we'll mount banana plugs (or whatever will fit our DC Voltmeter).

In case you're tempted, don't make poor substitutions for the diode. We chose the 1N34A because it had the following key characteristics: Reverse Breakdown Voltage greater than 40 Volts, forward voltage (barrier potential) of less than 0.3 Volts, and good RF qualities. Any diode with these qualities (example, the 1N458A) would work as well, but the 1N34A is readily available (at Radio Shack and others). Silicon and Shottky (hot-carrier) diodes, while good RF devices, have higher barrier voltages, and will not work as well at low RF voltages. The 1N34A is a germanium device, and with a barrier voltage of around 0.25 V, provides about the best performance you can get with this simple circuit.

For best accuracy, size the resistor to match your DC Voltmeter's input impedance:

R = 4.7 Meg for Zin = 11-Meg;
R = 4.3 Meg for Zin = 10-Meg;
R = 430 K for Zin = 1-Meg;

Here's one cheap-and-easy approach to building the RF Probe:

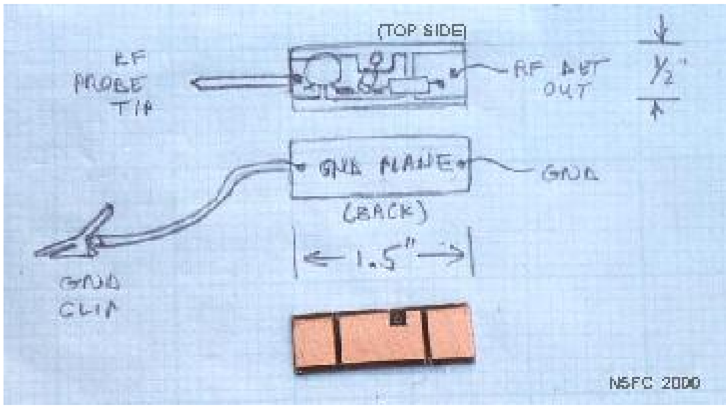

Click on the image above to see a larger

Take a small piece of scrap double-sided printed-circuit board, about 1-1/2 x 1/2 inches, Groove it on one side only, similiar to the image above, to create pads for soldering, but leave the back side as a "ground plane". Mount your diode, capacitor, and resistor as shown, soldering to the pads you made. One side of the diode (the non-banded isde) gets connected to the ground plane (drill a hole through to the other side and solder it). Try to fit all the components neatly inside the edges of the pc board. Solder the braid of the shielded wire (3-4 ft long) to the ground plane, and the center conductor to the pad with the resistor. Also, solder a 10-12 inch hook-up wire to the ground plane. Check that there are no shorts between the center conductor and the ground-plane. Solder the probe tip to the pad with the capacitor (I used a discarded probe tip from a broken test probe).

Here's where we get creative: packaging! One way or another, whatever method we use, it's important to shield the probe circuit, yet without shorting any part of the circuit to our shield (except the ground plane). I was on a kick of using copper pipe, which is very cheap, so I built my shield out of 1/2-inch copper pipe and end caps, commonly available at your local hardware store. I drilled a hole in the end of each end-cap, to pass the shielded cable and the probe tip. I used a shouldered washer to insulate the probe tip from the end cap, but a small rubber grommet would have worked as well. Stuff the assembly inside the copper pipe, and you end up with a completed probe that looks like the following:

Click on the image above to see a larger version

So, how do we use this thing?

Before we use it, a few precautions are in order. Don't use the probe in any circuit where the highest DC supply voltage is greater than the diode's reverse-breakdown voltage. For the 1N34A, this is 50 Volts. Same goes for the capacitor, which should be rated at least 50 Volts. This probably means that the probe cannot be used in most tube circuits. Also, don't try to measure RF power in circuits where the peak voltage will exceed 50 Volts. What will happen if you exceed these voltages by a little? Well, probably nothing; possibly, the diode or capacitor will fail open or short.

The first thing you'll always do in using the RF Probe is to connect the banana-plug end to the +/- jacks of your DC Voltmeter; set the Voltmeter to DC-Volts (not AC).

To use the RF Probe for signal tracing in a malfunctioning RF circuit or a homebrew circuit, connect the aligator clip to a convenient "ground" or "common" point in your circuit. Often this is the chassis. Most of the time, you'll be probing at the base/gate, emitter/source, or collector/drain of a transistor, one either side of a coupling capacitor or transformer, or at the input or output of an IC. Because the circuit's RF must overcome the diode's barrier potential (of 0.25V, for our 1N34A), voltages much less than that won't read at all, and voltages less than about a volt won't read very accurately. Typically, RF and post-mixer-amps in receivers don't have enough RF voltage, unless you inject a very strong signal at the input.

I recently used my RF probe to troubleshoot my dead TenTec Scout, which had suddenly quit transmitting in mid-QSO. I connected the rig to a dummy load, then keyed it while probing. Using the probe, I was able to follow a steadily increasing RF signal through the transmit chain, from the oscillator through the transmit mixer, to the pre-driver, and the driver. The actual voltage measurements weren't important, just that they were increasing from stage to stage where expected. Then, (whoops!) the driver's base circuit had 6 Volts, but the collector circuit only had only 0.1 Volts! The driver transistors had gone south!

You can also use the RF probe to measure RF power with reasonable accuracy, up to about 50 watts in a 50-ohm circuit. By 50-ohm circuit, I mean a 50-ohm antenna system at 1:1 SWR (higher SWRs are not 50 ohms), or a 50-ohm dummy load. Assuming the resistor in your RF probe is sized to match your DC Voltmeter's input impedance (as explained above), you will get quite reasonably accurate measurements using the following formula:

$$\mathrm{PWR} = \frac{(V_{(read)} + 0.25)^2}{R_{(load)}}$$

For example, I want to measure the power out of my TenTec 1340 40-Meter QRP transceiver. I place it on a 50-ohm dummy load, and key down. I generally use a BNC-Tee adapter to gain access to the output line, but I could as easily pop the cover off. Using the RF probe (alligator clip to chassis ground), I measure12.2 Volts (DC) (and the same RF RMS Volts). Plugging this into the formula above I have PWR= (12.2 + 0.25) * (12.2 + 0.25) / 50 = 3.1 Watts. The rated power for this rig is 3 Watts, so I've verified everything is hunky-dorey.

We've added the potential barrier to the measured voltage above, but that little trick doesn't work so well when you get down around a volt, and for voltages less than about a volt, the measurement accuracy suffers greatly. Also, the diode's response is severely non-linear below the barrier potential, and will generally read much less than expected in circuits where the RF voltage is less than 1/4 volt. So if you see tiny readings in circuits where it's normal to have voltages less than 1/4 volt RF, don't get too spun-up about the low readings... it may mean everything is normal. My rule of thumb for guessing at this is as follows: For collector/drain circuits in oscillators or transmit-chain amplifiers in key-down, expect RF Voltages about 20-50% of the applied DC (supply) voltage. This depends on the circuitry, of course, but it's a reasonable gesstimate. Base/gate and emitter/source circuits will generally be much less, maybe 5-10%. Circuit impedance will affect this too.

How good is this thing?

Well, we're not talking high performance test equipment here, but we *are* talking very useful. If you account for the barrier voltage, the readings can be quite accurate when measuring most low-impedance circuits (20-200 ohms), provided that the voltage is above 1 or 2 volts. How accurate? +/-10% from 200 KHz to 150 MHz would be a reasonable expectation. Also, the voltage divider is only accurate for sinusoidal signals. If you want "peak" measurements, simply multiply your reading by 1.414. The "peak" measurement should be good regardless of whether the waveform is sinusoidal. Regarding ultimate accuracy, your results may vary, and you may want to compare it to a laboratory instrument at the frequency of interest if you're really interested in accuracy. If you shield it well, and keep the ground clip lead reasonably short, it should be good in low-impedance circuits up into the VHF region, and down into the upper-audio region. In higher-impedance circuits, the junction capacitance of the diode may cause a low-pass effect at higher frequencies, and you're most likely to see this as a loss of measurement accuracy (i.e., low readings) at frequencies above 30 MHz. This doesn't mean it's not useful; it just means it reads low. Also, the capacitance of the probe may affect some sensitive RF circuits. For example, if you're probing a LC-tuned oscillator circuit, it may stop oscillating or change frequency or become unstable. Actually, most any probe will do this. Also, as we said before, the barrier voltage becomes a bigger part of the measurement error as the circuit voltage drops below a volt or so, and becomes dominant as you approach the barrier voltage. Just keep this in mind as one of it's limits.

Enjoy, good luck, and 73!
monty N5ESE

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N5ESE's Ballpoint RF Probe

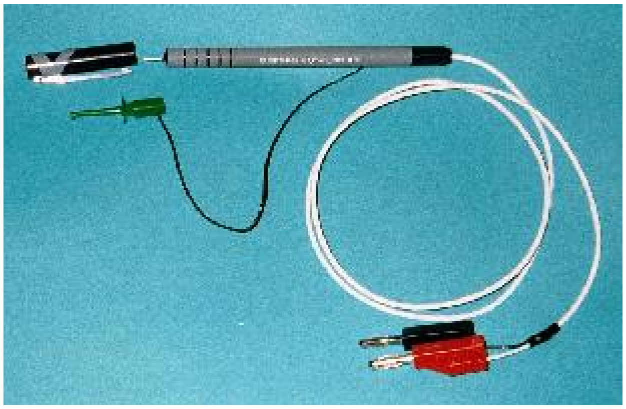

(click on any picture to see larger version)

NOTE: 'N5FC' is my former call.
This project was constructed while that call was valid, and you may observe references to it.

This is one of those afternoon projects that can really be both rewarding to build and useful to have. Electrically, it's identical to the Classic RF Probe described elsewhere (where you can also find the theory discussion for this one). Like the Classic RF Probe, this one is used in conjunction with a high-impedance-input Voltmeter or Digital Voltmeter (DVM). See the schematic below. Cost? About $5, if you can scrounge the ballpoint pen, heat shrink, shielded cable, and copper tape.

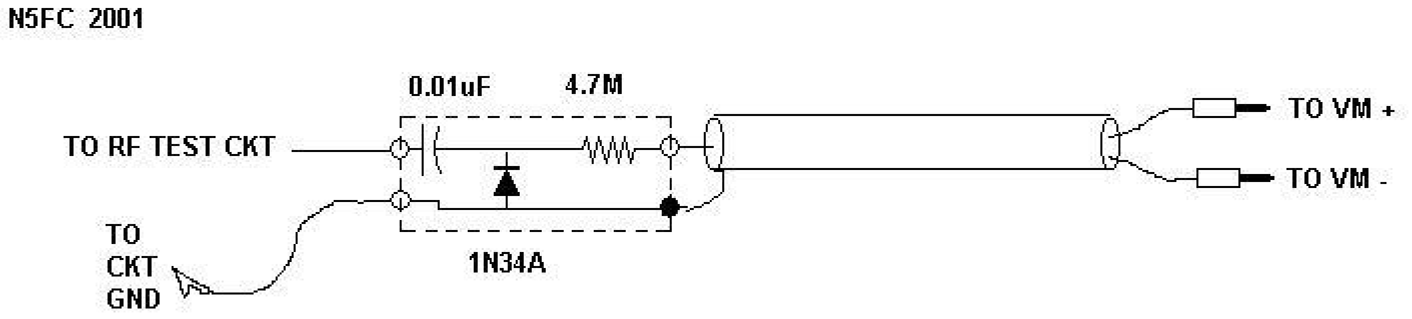

CLASSIC RF PROBE

**Reads RMS Equivalent Voltage in test circuit, if Voltmeter is 10-11 Meg Input Impedance;
Reads 4X RMS Equiv Voltage if VM is 1Meg Input Impedance (Set VM to measure DCV)**

What makes this probe unique is that it's built inside the shell of a regular ol' ballpoint pen. Besides being conveniently compact, the unit sports a needle-probe suitable for use in probing surface-mount circuits, and good overall shielding. The pen cap protects the needle probe when not in use. When measuring sinusoidal signals, it should provide RMS-corrected readings, using a 10 or 11-Meg input impedance VTVM or DVM. With a 1-Meg DVM, it reads 25% of the sinusoidal RMS voltage. Reasonable accuracy (+/- 10%) can be expected over the HF/VHF range (2-150 MHz), although this hasn't been verified. When used to measure non-sinusoidal signals, the accuracy will be unknown, but it still affords good relative measurements, and most of the time, that's all that's required. It makes an excellent, compact, and portable accessory for troubleshooting or homebrewing QRP equipment with peak voltages less than 50 Volts (i.e., most solid-state equipment)

Construction

The figure below shows the parts required to build the Ballpoint RF Probe. Click on the image to open an larger, annotated image with parts labled, and construction notes. Pick a ballpoint pen with a non-metalized plastic body, and plenty of room inside. The Papermate Flexgrip model I used had an inside diameter a little over 1/4-inch. We'll use an itty-bitty scrap of double-sided printed-circuit-board to mount the electronic components. Trim the PC board to about 2-12" long and 3/16" wide; don't make it too wide, or it won't fit inside the ballpoint pen. Notch or file a little out of the middle of the pc board, so the 1N34A diode will fit easily inside the pen body. then, on one side only, groove in two places, so as to create 3 lands on the "top" side of the board. In addition to the parts shown, you'll need a 2-1/2" piece of heat-shrinkable tubing to cover the electronic assembly (although electrical tape would do instead), and about a foot of 1/4"-wide adhesive-backed copper tape, commonly available in rolls of 200-300 inches at large hobby stores (like Michaels, and Hobby Lobby). Although a chip capacitor is shown in the photo, a very small disc capacitor will do as well.

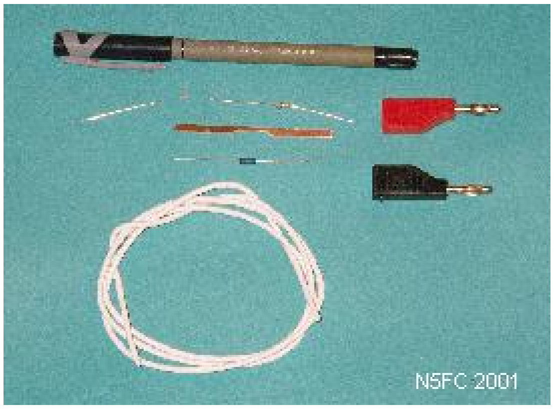

Click on the image above to see a larger, annotated image

In the next image (below), we get a close-up of the electronics assembly. You can see the input capacitor straddling the front-to middle lands, and the 4.7 Meg resistor straddling the middle-to-rear lands. The diode, which snuggles into the notch, connects from the middle land to the ground plane on the rear side of the pc board. The diode's banded end goes to the middle land. Break the sewing needle in half, using two needle nose pliers. **WARNING! Use eye and face protection!!** *ALSO NOTE: Don't try to cut a sewing needle with wire-cutters... you'll ruin the cutters.* Avoid straight pins, which dont have the hardness to perform well as probes. Then, solder the sewing needle to the front land, centering it carefully. You might benefit from burnishing the solder-half of the sewing needle with some fine grit sandpaper, to make it take solder a little better. Center it up nicely, as that will make for a professional-looking probe. Solder the shielded cable to the top/bottom of the pc board, center conductor to the rear land on top, and shield to the ground plane on the bottom. Be careful to aviod straggling shield-wires which could short the electronics. Also,solder a 10-12" pigtail of good, flexible insulated wire onto the ground plane, pigtailed rearward. This will be used as the ground wire in our test circuit. Before you shrink the tubing over the electronic assembly, check for shorts between lands and from lands to ground plane, make sure you have the diode polarity correct, and check that the needle is making solid electrical contact, and is mechanically secure.

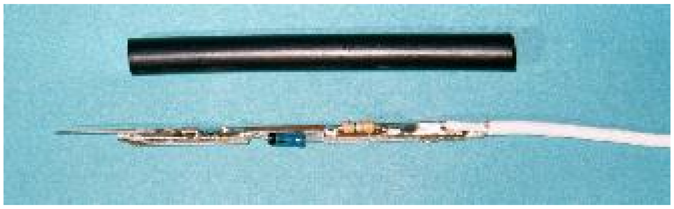

Click on the image above to see a larger, annotated image

See the next image, below. After the electronic assembly has been heat-shrunk overall, wrap the copper tape all around the electronic assembly. This will be our shield. Near the rear of the electronic assembly, solder the electonic assembly's ground to the copper tape, near or on the cable shield. Alternative shielding methods can be tried, for example, you might pull the shield out of a piece of RG-59, and sleeve it over the electronic assembly, soldering it to the ground plane. Whatever you do, be certain that the shield cannot unravel and short against the probe itself or any of the electronics.

Although not shown in the picture, we drill a small hole about 2/3 back on the pen casing, threading the ground pigtail through the hole. This really tests your hand-to-eye coordination. If the pen has a threaded-in rear-cap, drill a hole in it just big enough to accommodate your main shielded cable. Thread the whole cable into the pen casing, and out the other side, and if you had a threaded rear-cap, like I did, thread it on. Pull the electronic assembly gently back into the casing, so that the needle probe sticks out about 1/2 inch. Mix some clear 5-minute epoxy, and let it thicken ever so slightly. Then , while holding the assembly vertically (i.e., probe-tip up), and using a small toothpick or screwdriver, drop epoxy into the probe area, sealing the electronics and probe into place. Allow to dry thoroughly before applying any pressure to the assembly.

When dry, attach your favorite ground-clip to the pigtail, and banana plugs on the end of the shielded cable (red to the center-conductor, black to the shield, to match your Voltmeter)

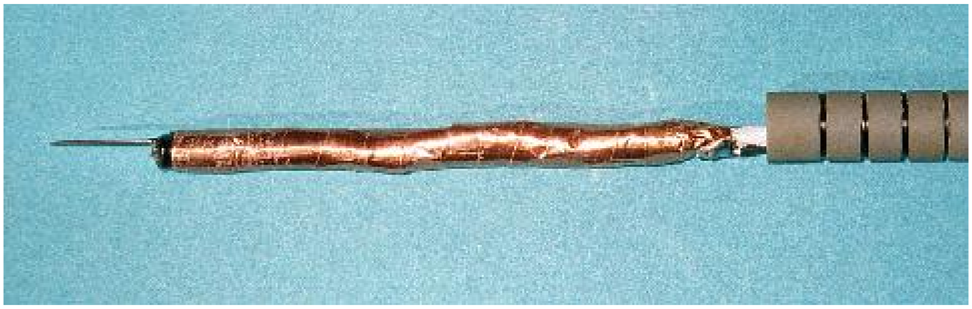

Click on the image above to see a larger, annotated image

See the next image, below, which shows the completed assembly, annotated. Sometimes, seeing the entire assembly makes everything perfectly clear. Place the pen cap over the needle probe to protect the assembly when not in use.

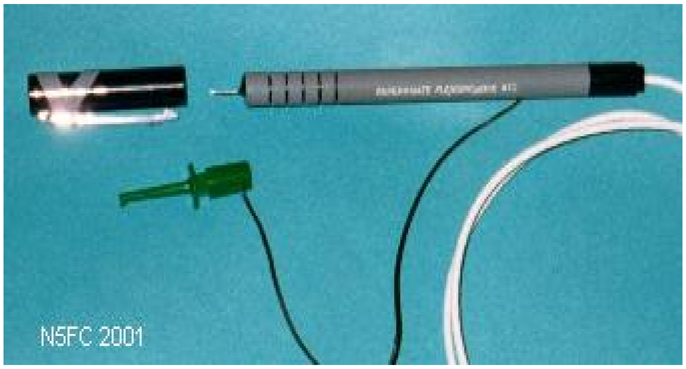

Click on the image above to see a larger, annotated image

And speaking of use, here's our lovely model (OK...XYL) making a measurement in the N0SS Noise Generator. She has the ground clip connected to a convenient place in the circuit's ground, and the probe touches the test point we want to measure. As you can see, we read 0.710 Volts. Since this is broadband noise, the actual voltage reading is not accurate, but it was seen to be much greater than the previous stage, as we expected.

Click on the image above to see a larger, more readable image

Let me know if you build one of these... and send me a picture!

73, monty N5ESE

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A Coax Switch

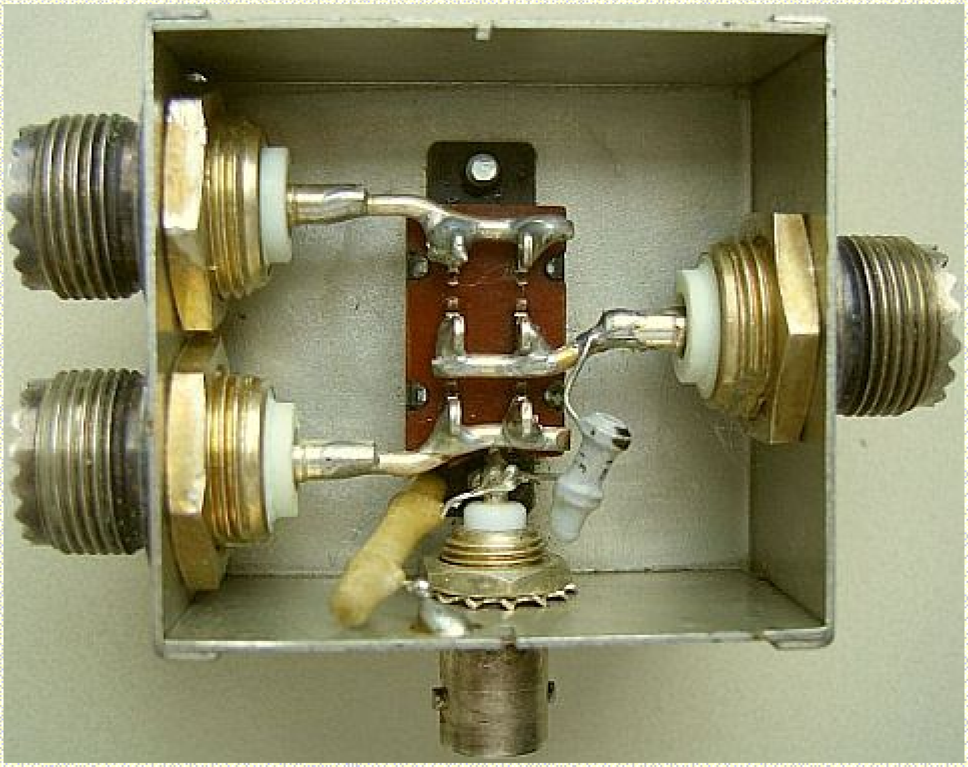

Cheap slide switch in a standard 54 × 50 × 26 mm box.

THE SWITCH

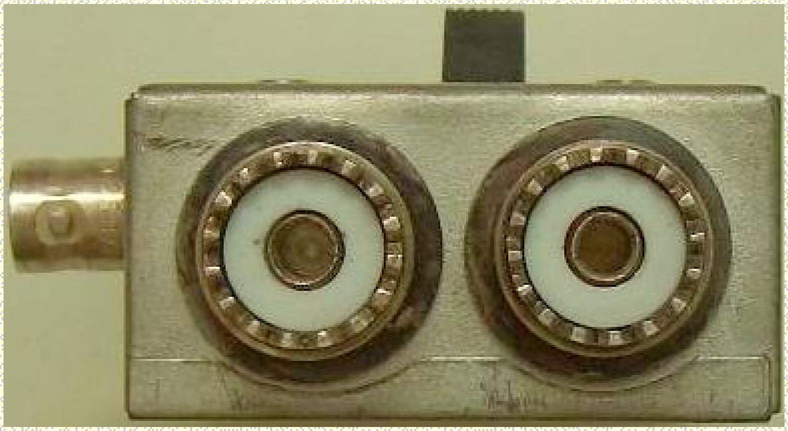

Fig » shows a proven inexpensive home-made antenna selection switch. If you question the use of a cheap slide switch and SO239 coax sockets, read on. Measurements in a physics lab showed there to be practically no reflection on HF and even on 70 cm the SWR was below 1.3 : 1! That is explained as follows:

- The contacts in the slide switch have larger contact surfaces than many a bought coaxial switch.

- The wiring and switch contacts, between the top and bottom of the metal case, act as the centre conductor of a coax of near 50 ?.

It is a standard box measuring 54 × 50 × 26 mm (l × w × h) and the wiring between the switch and the coax sockets is done in 2 mm silver plated wire.

POWER HANDLING CAPABILITY

If the switching is done with power off, the switch can stand 800 W. I have used this switch for more than 15 years and even with 1500 W there have been no problems.

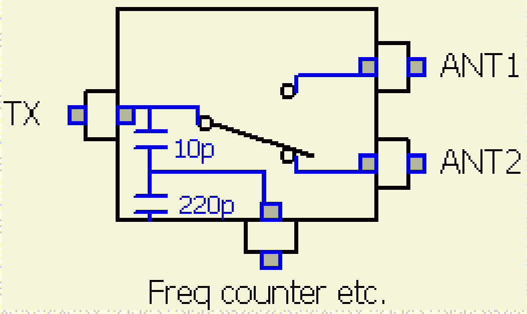

While building this switch, you might as well add a test point, e.g. to connect a ‘scope’ or frequency counter. The capacitors of 10 and 220 pF make a capacitive voltage divider and the extra loading, 9.6 pF, does not affect performance on HF. In fact, on 10 m it improves the SWR as the extra capacity, in combination with the wiring it makes a filter which favours that frequency.

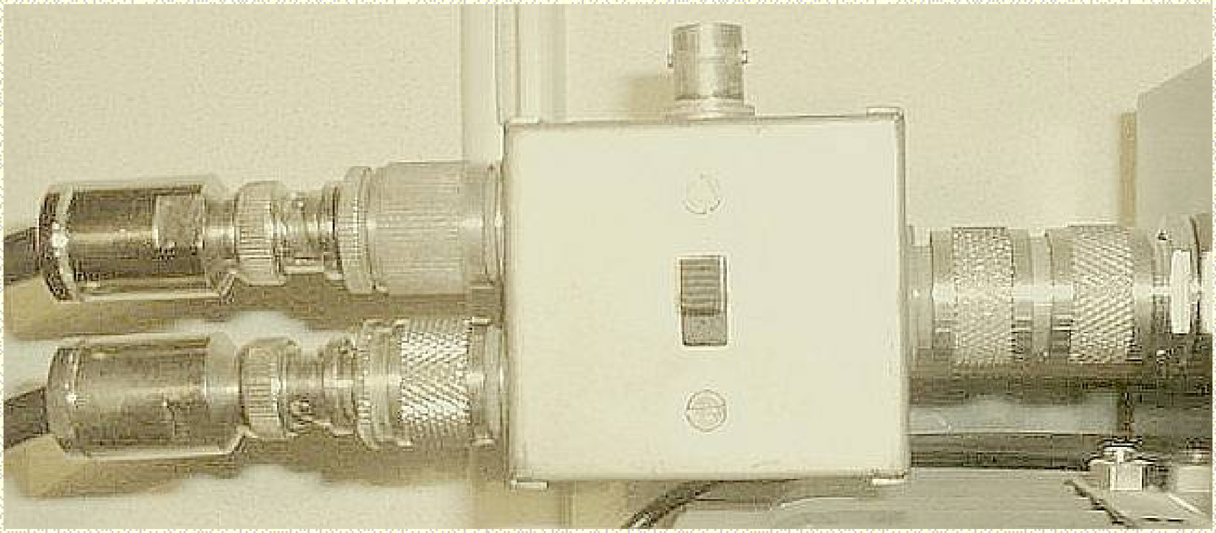

This shows how the switch is used in my station.

* * *

«Back
A0FRI

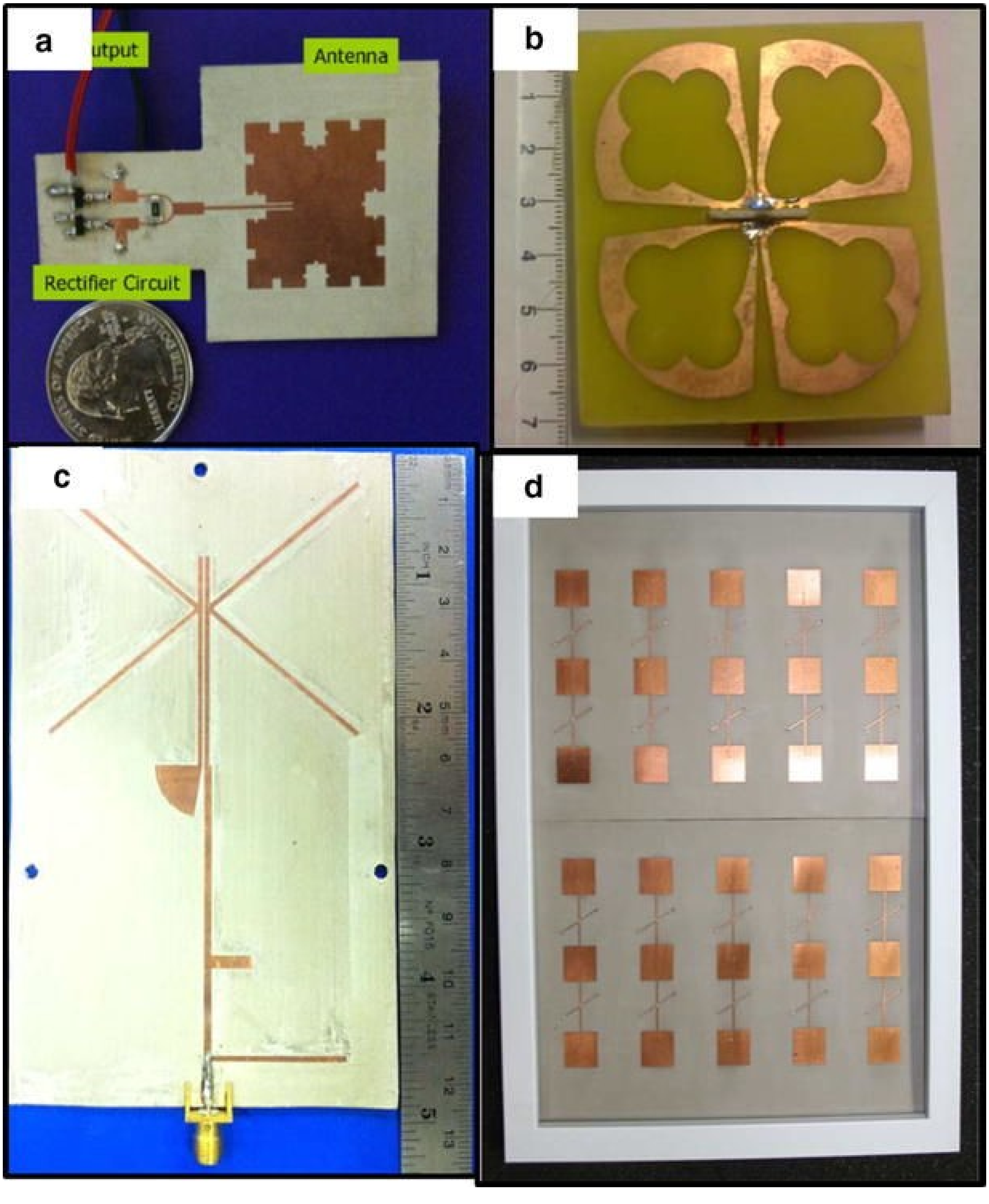
a
utput
Antenna
Rectifier Circuit
b
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Geometry Aspects and Experimental Results of a Printed Dipole Antenna

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Abstract

Detail experimental measurements of a 2.4 GHz printed dipole antenna for wireless communication systems is presented and discussed. A group of printed dipoles with integrated balun have been designed and constructed on a dielectric substrate. This paper is based on modifications of the known printed dipole architecture. The corresponding printed dipole antennas have differences on their forms that are provided by two essential geometry parameters. The first parameter l is related to the bend on microstrip line that feeds the dipole and the second w corresponds to the form of the dipole's gap. The impact of these parameters on reflection coefficient and radiation pattern of antenna has been investigated. The corresponding measured results indicate that the return loss and radiation pattern of a printed dipole antenna are independent of the w parameter. Instead, variations in the value of the l parameter in the dipole's structure affect the form of the corresponding return loss. These observations are very important and provide interesting considerations on affecting design and construction of antenna elements at frequency range of 2.4 GHz.

Keywords: Printed Dipole, Scattering Parameters, Radiation Pattern

1. Introduction

Modern wireless communications offer higher bit rates and efficient quality of services. The majority of the equipment used today introduces requirements for better performance and lower cost. Antennas with quite small sizes, low profiles and versatile features represent interesting solutions that provide modern wireless applications. The printed dipole antenna with integrated balun is widely used as a radiation element on communication systems because of its omni-directional features, narrowband character and simple structure [1–4]. This type of antenna because of its small size can be integrated on the same PCB with other electronics circuits and devices. For the same reason, it can also be used as element on antenna array architecture. The last feature is very interesting and attractive in MIMO modern wireless systems. This printed dipole architecture offers versatile characteristics for design and implementation of antenna arrays on both ends of a MIMO wireless system.

In the present paper, we will study and discuss the effect of the variation of the two geometrical parameters (l, w) of the printed dipole antenna structure. The first corresponds to a discontinuity on microstrip line of printed dipole and the second is related to the discontinuity in the gap. Details of structure concept and design process are presented in Section 2; the experimental results for return loss and radiation pattern for each of the printed dipoles are presented and discussed in Section 3. The paper concludes in Section 4.

2. Design and Structure Aspects

As mentioned above, the proposed analysis is based on geometrical characteristics of a prototype printed dipole antenna with integrated balun. This kind of printed dipole antenna is considered for use in many applications [1–3]. In our study the geometrical parameters of the printed dipole antenna were modified to achieve better performance in the frequency range of 2.4 GHz. This modified design and the corresponding parameters are shown in Figure 1 while the values summarized in Table 1.

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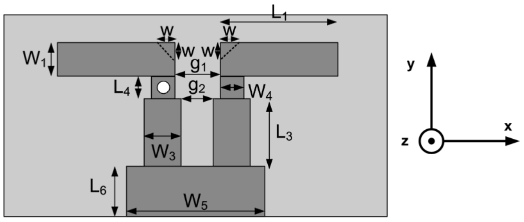

(a) Bottom Layer

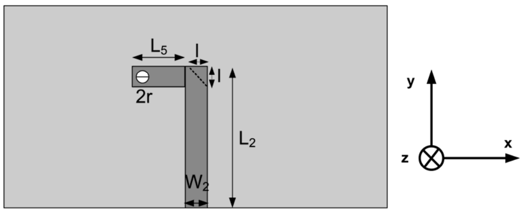

(b) Top Layer

Figure 1. Geometry of printed dipole.

Table 1. Printed dipole dimensions.

Parameter	Values
Dipole strips	L1 = 20.8 mm W1 = 6 mm g1 = 3 mm
Microstrip Balun	L2 = 32 mm L3 = 16 mm L4 = 3 mm L5 = 3 mm W2 = 2 mm W3 = 5 mm W4 = 3 mm g2 = 1 mm
Via radius	r = 0.375 mm
Ground plane	L6 = 12 mm W5 = 17 mm
Side of microstrip bend	l variable (0 mm – 3 mm)
Side of dipole's arms in the gap	w variable (0 mm – 3 mm)

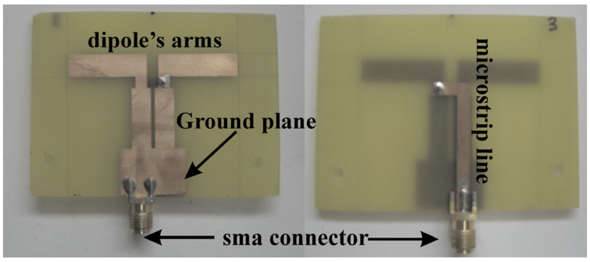

Figure 2. Prototype printed dipole antenna: Top Layer (left) –Bottom Layer (right).

An Fr-4 substrate with thickness of 1.5 mm and permittivity ε_r =4.4 has been used for the fabrication of the dipoles. Figure 2 shows the top and bottom layer for the one of them. It also presents the dipole's arms and gap, the balun, the ground plane and the microstrip line that interface the dipole with the coaxial feed line via sma connector.

From this Figure, we can also see the right angle at the microstrip line and the other two right angles at the dipole's gap. It is known that the presence of right angles in conductors cause discontinuities that leads to degradation in circuit performance [5]. Microwave theory suggests that these angles introduce parasitic reactances which can lead to phase and amplitude errors, input and output mismatch and possibly spurious coupling [5–7]. In order to reduce this effect it is proposed to modify these discontinuities directly, by mitering the conductor. Our investigation and the experimental measurements show the effect of mitering these discontinuities. At first, a prototype printed dipole antenna with unaffected geometrical parameters has been designed and constructed. Secondly, we constructed and measured six different printed dipoles. Three of them had $w = 0$ *mm* and different l values (1 mm, 2 mm, 3 mm) and the other three dipoles had $l = 0$ *mm* and different values of w (1 mm, 2 mm, 3 mm). All these seven dipoles we constructed, the unaffected one and the mitered ones were measured in an anechoic environment. Figures 3 and 4 show a printed dipole for $l = 2$ *mm* and $w = 0$ mm and for $l = 0$ *mm* and $w = 3$ *mm*, respectively. The aim of this study is to investigate the return loss coefficient and radiation pattern in each of these seven dipole's forms. The next section discusses the obtained results and presents the significant observations.

3. Results and Discussion

The return loss of the prototype dipole and the six different modified printed dipole antenna we constructed are measured using a Network Analyzer. These results are shown in two Figures. The first (Figure 5) corresponds to l parameter's variations keeping the w parameter equal to zero. The second (Figure 6) shows the return loss curves where w parameter varies but the l parameter equals to zero. In both figures we can see the return loss curve that belongs to the prototype printed dipole (l and w *equal to 0 mm*).

From these curves, it seems that this dipole antenna design has a resonance point at 2.4 GHz with 500 MHz –

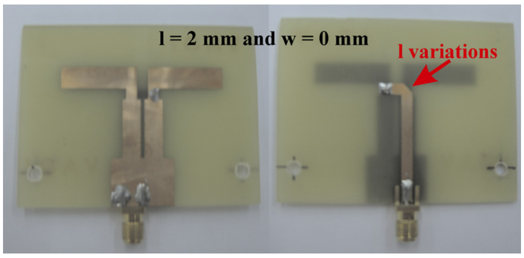

Figure 3. Printed dipole antenna for $l = 2$ *mm* and $w = 0$ *mm* Top Layer (left) – Bottom Layer (right).

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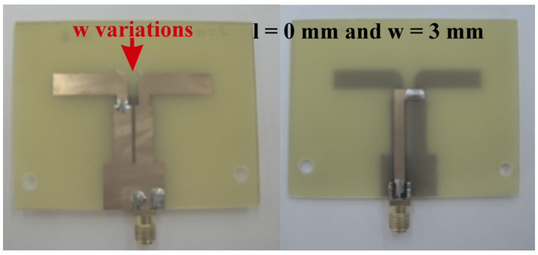

Figure 4. Printed dipole antenna for *l = 0 mm* and *w = 3 mm* Top Layer (left) – Bottom Layer (right).

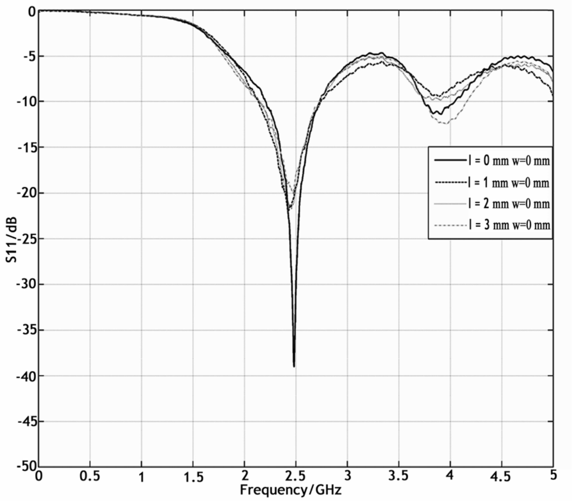

Figure 5. Measured return loss of printed dipole for each value of *l* parameter and *w = 0* mm.

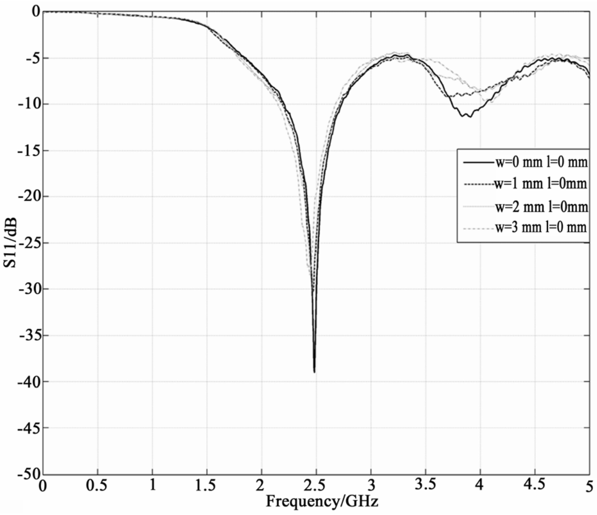

Figure 6. Measured return loss of printed dipole for each value of *w* parameter and *l = 0 mm.*

10 dB bandwidth. The last frequency range has center frequency close to 2.4 GHz which is the frequency value that the return loss is minimized. For these frequencies the corresponding values of return loss are smaller or equal to -10 dB. From Figure 5, it is obvious that as the value of *l* parameter increases, the form of the corresponding return loss curve changes and becomes more flat at the resonance frequency range. On the other hand, the value of *w* parameter does not affect the form of the return loss curve. Each of these seven forms of printed dipole antenna has quite similar return loss curves and introduces narrowband operation at the frequency range of 2.4 GHz. Moreover, for a wireless application that requires design and construction of many identical printed dipoles, it is recommended to choose *l* parameter equals to *2 mm* and *w* parameter equals to *0 mm* for better performance. As it can be seen from Figure 5 the above investigation ensures that the printed dipole antennas will have quite identical return loss curves and performance as elements in an antenna array configuration.

For deeper analysis on this topic, experimental measurements on radiation pattern of these antennas have also been made. Measurements were carried out in a RF anechoic chamber using a calibrated measuring system. In particular, Figure 7 shows the measurements of radiation pattern in E- plane and in H – plane for each dipole

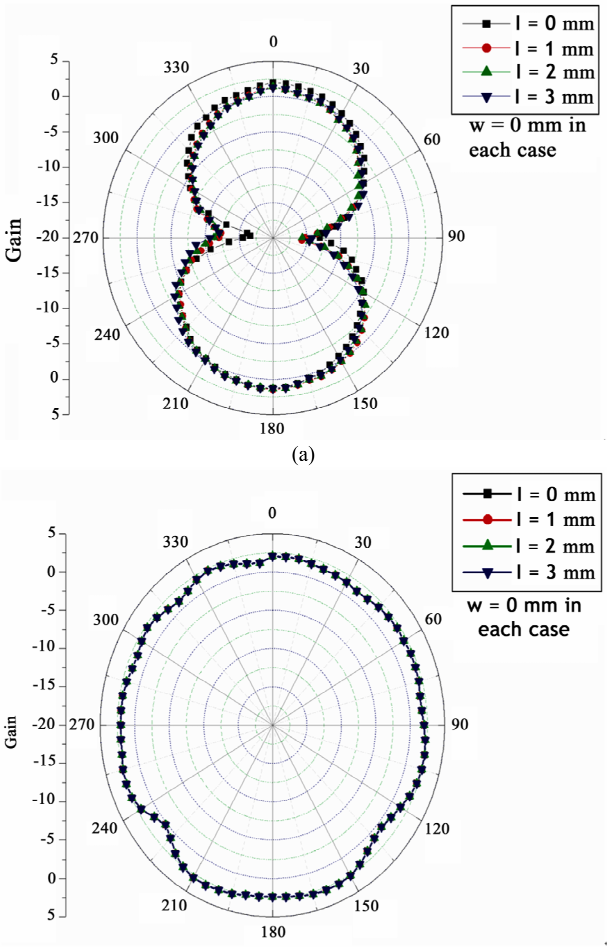

(a)

(b)

Figure 7. Radiation pattern of dipole for each value of *l* parameter (a) E – plane, (b) H -plane.

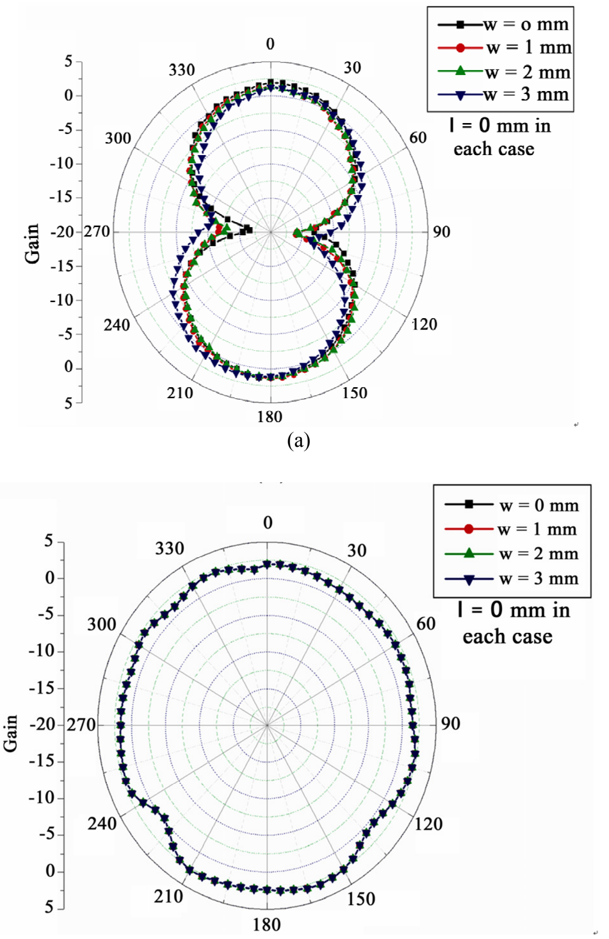

(a)

(b)

Figure 8. Radiation pattern of dipole for each value of *w* parameter (a) E – plane, (b) H – plane.

with *w* parameter equals to 0 mm and *l* parameter equals to integer values that ranging from *0 mm* to *3 mm*,. Figure 8 shows the corresponding results for each dipole with *l* parameter equals to *0 mm* and *w* parameter's integer values ranging from *0 mm* to *3 mm*. All these dipole structures introduce radiation characteristics that correspond to a fundamental dipole antenna [6,7]. Each of them has a measured peak gain that equals to quite 2 dBi and introduces omni-directional features. Quite small variations on these curves are on the limits of measurements' accuracy. For this reason, it can be observed that the radiation characteristics of the printed dipole antenna are not affected by the variations on *l* and *w* geometrical parameters. Therefore, the radiation diagrams of them are independent of the *l* and *w* parameters.

4. Conclusions

A number of printed dipole antennas with integrated balun are constructed and studied in terms of return loss and radiation pattern. Each of them has a defined form and geometry. Starting from a dipole antenna we mitered the angles introducing the parameters *l* and *w* that we varied. Experimental measurements on return loss provide the obtained results. These are quite similar and also introduce a resonance point at frequency range of 2.4 GHz with narrow resonance bandwidth. The form of this resonance range is affected only by the *l* parameter. The radiation pattern of these dipoles is also investigated. The corresponding radiation diagrams are independent of these geometrical parameters (*l*, *w*) and are similar to that of the fundamental dipole. These observations on printed dipole architecture are very crucial for wireless communication engineering and antenna design. This is because they introduce the ability of constructing a group of identical dipoles choosing an appropriate value of *l* parameter (*l =2 mm*) with quite identical resonance and radiation characteristics.

5. Acknowledgment

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Optimization of the Voltage Doubler Stages in an RF-DC Convertor Module for Energy Harvesting

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ABSTRACT

This paper presents an optimization of the voltage doubler stages in an energy conversion module for Radio Frequency (RF) energy harvesting system at 900 MHz band. The function of the energy conversion module is to convert the (RF) signals into direct-current (DC) voltage at the given frequency band to power the low power devices/circuits. The design is based on the Villard voltage doubler circuit. A 7 stage Schottky diode voltage doubler circuit is designed, modeled, simulated, fabricated and tested in this work. Multisim was used for the modeling and simulation work. Simulation and measurement were carried out for various input power levels at the specified frequency band. For an equivalent incident signal of –40 dBm, the circuit can produce 3 mV across a 100 kΩ load. The results also show that there is a multiplication factor of 22 at 0 dBm and produces DC output voltage of 5.0 V in measurement. This voltage can be used to power low power sensors in sensor networks ultimately in place of batteries.

Keywords: Energy Conversion; RF; Schottky Diode; Villard; Energy Harvesting

1. Introduction

RF energy harvesting is one type of energy harvesting that can be potentially harvested such as solar, vibration and wind. The RF energy harvesting uses the idea of capturing transmitted RF energy at ambient and either using it directly to power a low power circuit or storing it for later use. The concept needs an efficient antenna along with a circuit capable of converting RF signals to DC voltage. The efficiency of an antenna mainly depends on its impedance and the impedance of the energy converting circuit. If the two impedances aren't matched then it will be unable to receive all the available power from the free space at the desired frequency band. Matching of the impedances means that the impedance of the antenna is the complex conjugate of the impedance of the circuit (voltage doubler circuit).

The concept of energy harvesting system is shown in **Figure 1**, which consists of matching network, RF-DC conversion and load circuits. The authors in [1], used a 2.4 GHz operating frequency with an integrated zero bias detector circuit using BiCMOS technology which produced an output voltage of 1 V into a 1 MΩ load at an input power level of 0 dBm. H. Yan and co-authors revealed that a DC voltage of 0.8 volts can be achieved from a –20 dBm RF input signal at 868.3 MHz through simulation results [2]. In [3], work was carried out on a firm frequency of 900 MHz by matching to a 50 Ω impedance and resonance circuit transformation in front of the Schottky diode which yields an output voltage of over 300 mV at an input power level of 2.5 µ. W. J. Wang, L. Dong and Y. Fu [4] used a Cockcroft-Walton multiplier circuit that produced a voltage level of 1.0 V into a 200 MΩ load for an input power level of less than –30 dBm at a fixed frequency of 2.4 GHz.

The energy conversion module designed in this paper is based on a voltage doubler circuit which can be able to output a DC voltage typically larger than a simple diode rectifier circuit as in [5], in which switched capacitor charge pump circuits are used to design two phase voltage doubler and a multiphase voltage doubler. The module presented in this can function as an AC to DC converter that not only rectifies the input AC signal but also elevates the DC voltage level. The output voltage of the

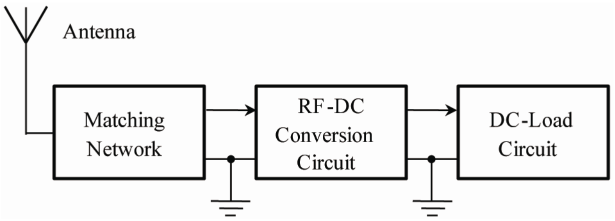

Figure 1. Schematic view of a RF energy harvesting system.

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energy conversion module can be used to energize the low power devices for example sensors for a sensor network in application to agriculture.

Section 2 of this paper discusses on the theoretical background of the voltage doubler circuit. Section 3 presents the simulation study and implementation of the circuit design. Section 4 provides the results and analysis. Section 5 concludes with a discussion on the findings from the simulated and measured results.

2. Voltage Multiplier

There are various voltage multiplier circuit topologies. The design used in this module is derived from the function of peak detector or a half wave peak rectifier. The Villard voltage multiplier circuit was chosen in the circuit design of this paper because it produces two times of the input signal voltage towards ground at a single output and can be cascaded to form a voltage multiplier with an arbitrary output voltage and its design simplicity.

2.1. Diode Modeling

The voltage multiplier circuit in this design uses zero bias Schottky diode HSMS-2850 from Agilent. The attractive feature of these Schottky diodes are low substrate losses and very fast switching but leads to a fabrication overhead. This diode has been modeled for the energy harvesting circuit which comes in a one-diode configuration. The modeling parameters for these diodes are given by Agilent in their data sheets. These parameters are used in Multisim for its own modeling purposes. The modeling is done by transforming the diode into an equivalent circuit using passive components which are described by the SPICE parameters in **Table 1** [6].

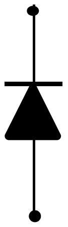

Figure 2. Schottky diode.

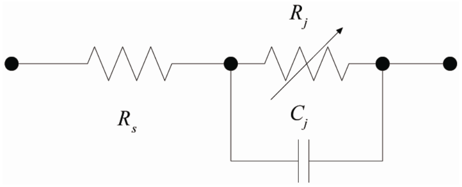

Figure 3. Linear circuit model of the Schottky diode [6].

The diode used in this design is shown in **Figure 2** and its equivalent model is shown in **Figure 3**. The special features of HSMS-2850 diode is that it provides a low forward voltage, low substrate leakage and uses the non symmetric properties of a diode that allows unidirectional flow of current under ideal condition.

Table 1. SPICE parameters.

Parameters	Units	HSMS 2850
B_V	V	3.8
C_{J0}	pF	0.18
E_G	Ev	0.69
I_{BV}	A	3E–4
I_S	A	3E–6
N	No unite	1.06
R_S	Ω	25
P_B (V_J)	V	0.35
P_T (XTI)	No units	2
M	No units	0.5

The diodes are fixed and are not subject of optimization or tuning. This is described using the following derivations. By neglecting the effect of diode substrate, an equivalent linear model that can be used for the diode as shown in **Figure 3**. When C_j is the junction capacitance and R_j is the junction resistance, the admittance Y_z of the linear model is given by

$$Y_Z = Y_{C_j} + Y_{R_j} \tag{1}$$

Equation (1) related to the frequency of operation is given by

$$Y_Z = jwC_j + \frac{1}{R_j} \tag{2}$$

$$= \frac{jwC_jR_j + 1}{R_j} \tag{3}$$

The impedance Z of the linear model is given by

$$Z = \frac{R_j}{1 + jwR_jC_j} \tag{4}$$

The total impedance Z_T is given by

$$Z_T = R_S + \frac{R_j}{1 + jwR_jC_j} \tag{5}$$

where R_S is the series resistance of the circuit and R_j is given by

$$R_j = \frac{8.33 \times 10^{-5} \times N \times T}{I_b + I_S}$$

where:

I_b = bias current in μA;
I_s = saturation current in μA;
T = temperature (K);

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N = ideality factor.

In Equation (5), R_j and C_j are constants and the frequency of operation (w) is the only variable parameter. As the frequency increases, the value of Z is almost negligible compared to the series resistance R_S of the diode. From this it is concluded that the function of the diode is independent of the frequency of operation.

2.2. Single Stage Voltage Multiplier

Figure 4 represents a single stage voltage multiplier circuit. The circuit is also called as a voltage doubler because in theory, the voltage that is arrived on the output is approximately twice that at the input. The circuit consists of two sections; each comprises a diode and a capacitor for rectification. The RF input signal is rectified in the positive half of the input cycle, followed by the negative half of the input cycle. But, the voltage stored on the input capacitor during one half cycle is transferred to the output capacitor during the next half cycle of the input signal. Thus, the voltage on output capacitor is roughly two times the peak voltage of the RF source minus the turn-on voltage of the diode.

The most interesting feature of this circuit is that when these stages are connected in series. This method behaves akin to the principle of stacking batteries in series to get more voltage at the output. The output of the first stage is not exactly pure DC voltage and it is basically an AC signal with a DC offset voltage. This is equivalent to a DC signal superimposed by ripple content. Due to this distinctive feature, succeeding stages in the circuit can get more voltage than the preceding stages. If a second stage is added on top of the first multiplier circuit, the only waveform that the second stage receives is the noise of the first stage. This noise is then doubled and added to the DC voltage of the first stage. Therefore, the more stages that are added, theoretically, more voltage will come from the system regardless of the input. Each independent stage with its dedicated voltage doubler circuit can be seen as a single battery with open circuit output voltage V_0, internal resistance R_0 with load resistance R_L, the output voltage, V_{out} is expressed as in Equation (7).

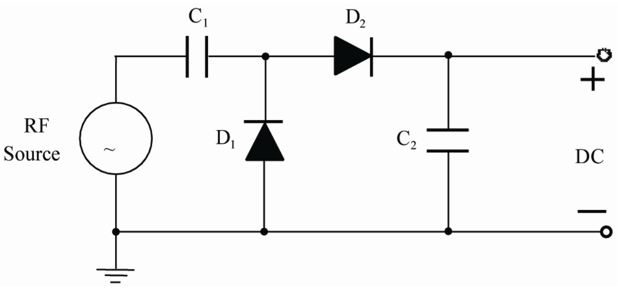

Figure 4. Single stage voltage multiplier circuit [7].

$$V_{\text{out}} = \frac{V_0}{R_0 + R_L} R_L \tag{6}$$

When n number of these circuits are put in series and connected to a load of R_L in Equation (6) the output voltage V_{out} obtained is given by this change in RC value will make the time constant longer which in turn retains the multiplication effect of two in this design of seven stage voltage doubler.

$$V_{\text{out}} = \frac{nV_0}{nR_0 + R_L} = V_0 \frac{1}{\frac{R_0}{R_L} + \frac{1}{n}} \tag{7}$$

The number of stages in the system has the greatest effect on the DC output voltage, as shown from Equations (6) and (7).

It is inferred that the output voltage V_{out} is determined by the addition of R_0/R_L and $1/n$, if V_0 is fixed. From this analysis it is observed that V_0, R_0 and R_L are all constants. Assume that $V_0 = 1$ V, $R_0/R_L = 0.25$, $n = 2, 3, 4, 5, 6$ and 7, the output voltage V_{out} = 1.33 V, 1.72 V, 2.0 V, 2.22 V, 2.43 V and 2.56 V respectively when substituted analytically in the Equation (7). This analysis can be compared with the results obtained in the circuit design of this module. In simulation at $n = 4$, V_{out} = 1.42 V, $n = 5$, V_{out} = 1.67 V; $n = 6$, V_{out} = 1.92; $n = 7$, V_{out} = 2.15 V; $n = 8$, V_{out} = 1.92 V; $n = 9$, V_{out} = 1.81 V. Also in measurement, for $n = 4$, V_{out} = 2.1 V; $n = 5$, V_{out} =2.9 V; $n = 6$, V_{out} = 3.72 V; and $n = 7$, V_{out} = 5 V. As n increases, the increase in output voltage will be almost double the input voltage up to some number of stages. But at some point, *i.e.* beyond seven stages, in this circuit the output voltage gained (8 and 9 stages) will be negligible as shown in **Figure 5**.

The capacitors are charged to the peak value of the input RF signal and discharge to the series resistance (R_s) of the diode. Thus the output voltage across the capacitor of the first stage is approximately twice that of the input signal. As the signal swings from one stage to other, there is an additive resistance in the discharge path of the

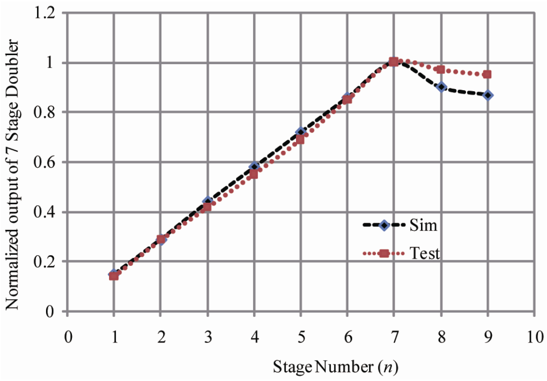

Figure 5. Normalized output voltage multiplier versus number of stages.

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diode and increase of capacitance due to the stage capacitors.

2.3. Seven Stage Voltage Multiplier

The seven stage voltage multiplier circuit design implemented in this paper is shown in **Figure 6**. Starting on the left side, there is a RF signal source for the circuit followed by the first stage of the voltage multiplier circuit. Each stage is stacked onto the previous stage as shown in the **Figure 6**. Stacking was done from left to right for simplicity instead of conventional stacking from bottom to top.

The circuit uses eight zero bias Schottky surface-mount Agilent HSMS-285X series, HSMS-2850 diodes. The special features of these diode is that, it provides a low forward voltage, low substrate leakage and uses the non-symmetric properties of a diode that allows unidirectional flow of current under ideal conditions. The diodes are fixed and are not subject of optimization or tuning. This type of multiplier produces a DC voltage which depends on the incident RF voltage. Input to the circuit is a predefined RF source. The voltage conversion can be effective only if the input voltage is higher than the Schottky forward voltage.

The other components associated with the circuit are the stage capacitors. The chosen capacitors for this circuit are of through-hole type, which make it easier to modify for optimization, where in [8] the optimization was accomplished at the input impedance of the CMOS chip for a three stage voltage multiplier. The circuit design in this paper uses a capacitor across the load to store and provide DC leveling of the output voltage and its value only affects the speed of the transient response. Without a capacitor across the load, the output is not a good DC signal, but more of an offset AC signal.

In addition to the above, an equivalent load resistor is connected at the final node. The output voltage across the load decreases during the negative half cycle of the AC input signal. The voltage decreases is inversely proportional to the product of resistance and capacitance across the load. Without the load resistor on the circuit, the voltage would be hold indefinitely on the capacitor and look like a DC signal, assuming ideal components. In the design, the individual components of the stages need not to be rated to withstand the entire output voltage. Each component only needs to be concerned with the relative voltage differences directly across its own terminals and of the components immediately adjacent to it. In this type of circuitry, the circuit does not change the output voltage but increases the possible output current by a factor of two. The number of stages in the system is directly proportional to the amount of voltage obtained and has the greatest effect on the output voltage as explained in the Equation (7) and shown in **Figure 5**.

3. Simulation and Implementation

Multisim software was chosen for modeling and simulation which is a circuit simulation tool by Texas Instruments. The simulation and practical implementation were carried out with fixed RF at 945 MHz ± 100 MHz, which are close to the down link center radio frequency (947.5 MHz) of the GSM-900 transmitter. The voltages obtained at the final node V_{DC} of the multiplier circuit were recorded for various input power levels from –40 dBm - +5 dBm with power level interval (spacing) of 5 dBm.

The simulations were also carried out using same stage capacitance value (3.3 nF) and then with a varied capacitance value for all stages from 4 stages through 9 stages [9]. The capacitance value was varied in such a way that, from one stage to the next, it was halved. For example, if the first stage was 3.3 nF, the second stage was 1.65 nF, third stage was 825 pF, fourth stage was 415 pF and so on. But keeping in view of testing, the capacitance values were chosen to have a close match with the standard available values in the market.

Simulation was carried out through 4 to 9 voltage doubler stages. Based on results obtained a 7 stage doubler is best to implemented for this application.

The design of the printed circuit board (PCB) was carried out using DipTrace software. The material used to

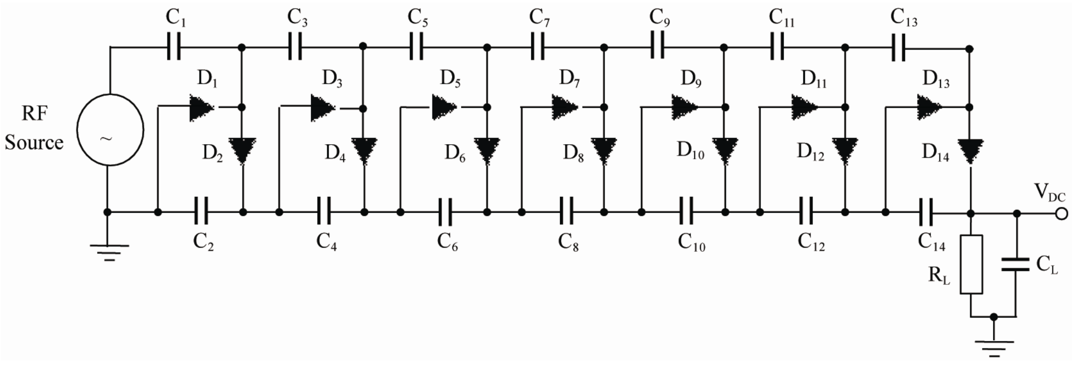

Figure 6. Schematic of 7 stage voltage multiplier.

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manufacture the printed circuit board (PCB) is the standard Fiberglass Reinforced Epoxy (FR4), with the thickness of 1.6 mm and dielectric constant of 3.9. The topology is constructed on the PCB with the dimensions of 98 mm × 34 mm (W × H). The Sub Miniature version A (SMA) connectors are used at the input and output of PCB to carry out the measurements. The circuit components consist of active and passive components. The component used in circuit is shown in **Table 2**.

Special handling precautions have been taken to avoid Electro Static Discharge (ESD), while assembling of the surface-mount zero bias Schottky diodes. Also special attention has been given to mount other components and the SMA connectors on to the PCB. The Photograph of Assembled circuit board I shown in **Figure 7**.

4. Results and Analysis

The simulated and measured results at the output voltage of voltage multiplier circuit are shown graphically in **Figure 8**. From the graph analysis, the simulated and the measured results agree considerably with each other. The measured results are shown to be better than the simulation results. The reason behind this may be due to the uncertainty in series resistance value of the diode obtained from SPICE parameters in modeling as explained in Equation (5). This resistance vale of diodes in practical circuit may be lower than in the model, which provides fast discharge path, in turn rise in voltage as passes through the stages and reaches to final output. In this work, the DC output voltages obtained through simulation and measurement at 0 dBm re 2.12 V and 5.0 V respectively. These results are comparatively much better than in ref. [9], where in at 0 dBm, 900 MHz they achieved 0.5 V and 0.8 V through simulation and measurement respectively.

Figures 9 and **10** show the result of a 4 stage voltage doubler circuit with equal and varied capacitance values between the stages as described in Section 3.

From the analysis of these two simulations, it can be observed that the resulting output voltages are equal. The only difference between these two graphs is the rise time of the circuit with varied capacitance value is a little bit slower. But, overall result on the performance of rise time is still under 20 µs to 24 µs and the difference is negligible. From these results, the use of equal stage capacitance of each being 3.3 nF was hence considered for the design of the multiplier.

The results from **Figure 11**, shows that the output voltage reaches to 1.0 V within 20 µS and then uniformly increasing to 1.4 V, 1.67 V, 1.87 V and 2.12 V for 4, 5, 6 and 7 stages respectively compared to 2 mS as shown in [10]. **Figure 12** shows that the conversion ratio of 22 is achieved at 0 dBm input power and drops to 2.5 at –40 dBm. The highest value at 0 dBm is due to the innate characteristics of the zero bias Schottky diodes which conduct fairly well at higher input voltages.

5. Conclusion

From the experimental results, it is found that the pro-

Table 2. Component used in 7 stage voltage multiplier.

Name of component	Label	Value
Stage capacitors	C_1 - C_{14}	3.3 nF
Stage diodes	D_1 - D_{14}	HSMS 2850
Filter capacitor	C_L	100 nF
Load resister	R_L	100 kΩ

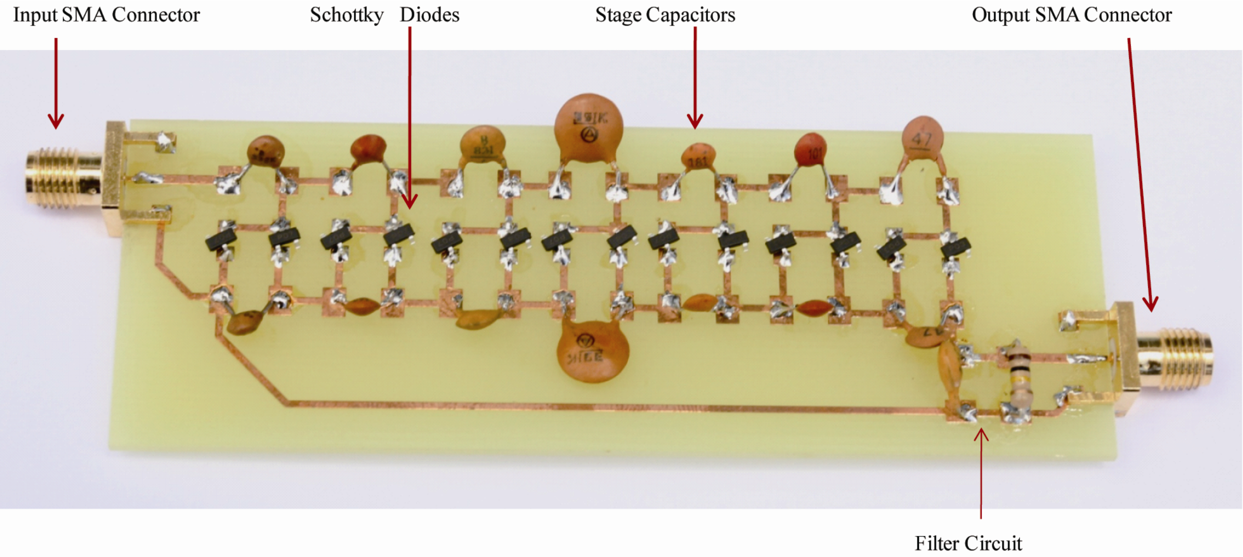

Figure 7. Photograph of assembled circuit board.

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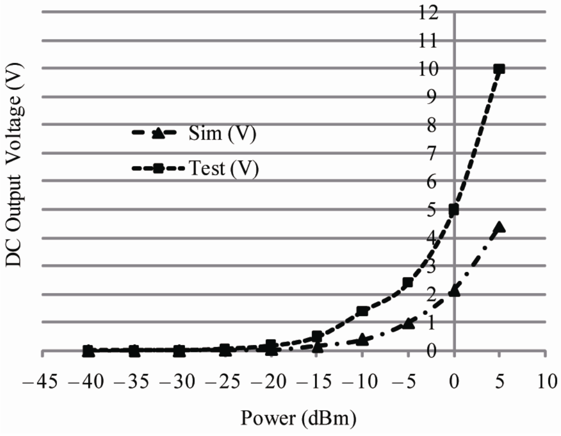

Figure 8. Simulated and test DC output voltage of multiplier as a function of input power.

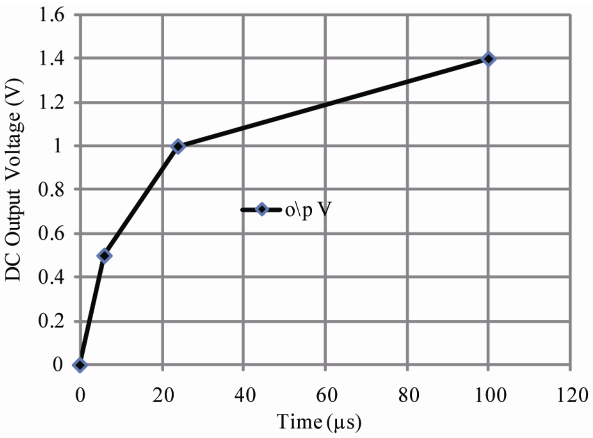

Figure 9. DC output voltage verses rise time of 4 stage voltage doubler circuit with equal stage capacitance [8].

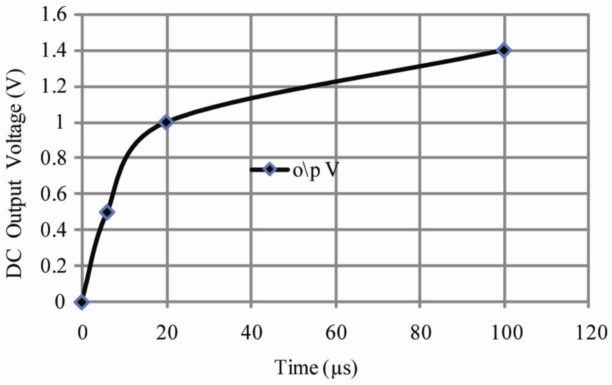

Figure 10. DC output voltage verses rise time of 4 stage voltage doubler with varied stage capacitance [8].

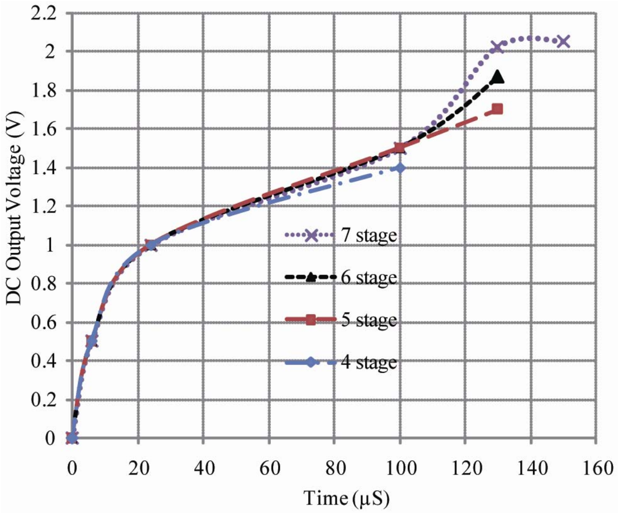

Figure 11. DC output voltage verses rise time of voltage doubler circuit through 4 - 7 stages with equal stage capacitance.

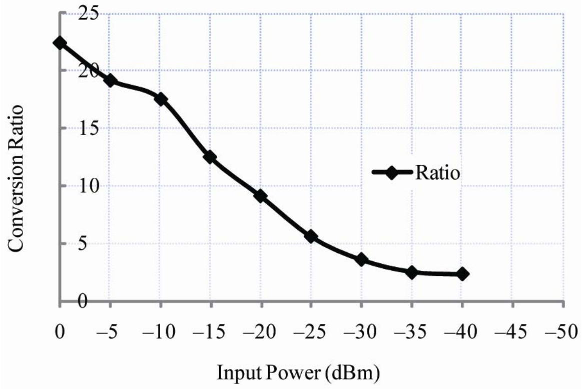

Figure 12. Conversion ratio as a function of input power.

posed voltage multiplier circuit operates at the frequency of 945 MHz with the specified input power levels. The results have shown that there is multiplication of the input voltage. From **Figure 12**, it is shown that at 0 dBm input power, the multiplication factor is 22. This is significant, as the work shows that RF energy in the GSM-900 band can be harvested from the ambient RF source using the Villard circuit topology. The power density levels from a GSM base station is expected from 0.1 mW/m^2 to 1 mW/m^2 for a distance ranging from 25 m - 100 m. These power levels may be elevated by a factor between one and three for the GSM-900 downlink frequency bands depending on the traffic density [10]. The next phase of the research work is to interface the voltage multiplier circuit through a matching network to the antenna at the input side and a low power device to power from the system at the output side to complete the RF energy harvesting system.

6. Acknowledgements

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Double-Sided Microstrip Circular Antenna Array for WLAN/WiMAX Applications

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ABSTRACT

The design, fabrication, and characterization of the microstrip circular antenna arrays were presented. The proposed antennas were designed for single band at 2.45 GHz and dual bands at 3.3 - 3.6 and 5.0 - 6.0 GHz to support WLAN/WiMAX applications. The proposed single and dual band antennas showed omnidirectional radiation pattern with the gain values of 3.5 dBi at 2.45 GHz, 4.0 dBi at 3.45 GHz, and 3.3 dBi at 5.5 GHz. The dual band antenna array was placed on both top and bottom layers to obtain the desired antenna characteristics. The proposed double-sided dual band antenna provides omnidirectional radiation pattern with high gain.

Keywords: Antenna Arrays; Circular Patch; Dual Band; Single Band; Omnidirectional; WLAN/WiMAX Applications; UWB

1. Introduction

Ultra-wideband (UWB: 3.1 to 10.6 GHz) frequency spectrum has been approved by the US Federal Communications Commission (FCC) for unlicensed short range wireless communications since 2002. In this frequency range, wireless local-area network (WLAN) IEEE802.11a and HIPERLAN/2 WLAN operates in 5.0 - 6.0 GHz band. In some European and Asian countries, world interoperability for microwave access (WiMAX) service is provided in the frequency range of 3.3 - 3.6 GHz [1-4]. To support the WLAN/WiMAX application, antenna arrays that provide omnidirectional radiation pattern are required. To respond to this need, recent antenna design efforts were focused on omnidirectional antennas with high gain and no sidelobes [5-8]. Rectangular arrays are common type used for antenna arrays. Studies on dual band antennas employing rectangular arrays were reported [9-12]. Compared to rectangular patch antenna arrays, there are limited numbers of studies performed on circular patch antenna arrays due to difficulties in fabrication [13]. Advantages of circular antenna array include high gain and narrow beam width [13].

In this paper, a new microstrip circular antenna arrays were designed, fabricated, and characterized to provide omnidirectional radiation pattern for WLAN/WiMAX applications. Two antenna arrays were designed—one for single band at 2.45 GHz and the other for dual bands at 3.3 - 3.6 GHz and 5.0 - 6.0 GHz. For single band operation, circular patch array was placed on the top layer of the microtrip and a small rectangular patch was placed on the bottom layer for ground connection. For dual band operation, similar circular patch array was placed on both top and bottom layers of the microstrip with larger rectangular patch placed on the bottom layer. Both single band (single sided) and dual band (double-sided) microstrip antenna arrays provided desirable antenna characteristics for the intended application.

2. Design and Simulation

2.1. Single-Band Antenna at 2.45 GHz

The configuration of the proposed single band antenna at 2.45 GHz is shown in **Figure 1**. It consists of six circular patches which are placed only on the top layer. The small rectangular patch is placed on the bottom layer for ground connection.

The directivity for the circular patch antenna is

$$D_0 = \frac{(k_0 a_e)^2}{120 G_{\text{rad}}} \quad (1)$$

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[*]Corresponding author.

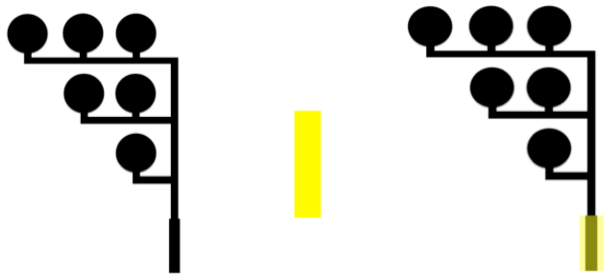

(a) (b) (c)

Figure 1. Configuration of the proposed antenna for single band at 2.45 GHz: (a) Top layer; (b) Bottom layer; (c) Top and bottom layers overlaid.

$$k_0 = \frac{2\pi}{\lambda_0} \tag{2}$$

$$a_e = a\left\{1 + \frac{2h}{\pi a \epsilon_r}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{1/2} \tag{3}$$

$$G_{\text{rad}} = \frac{(k_0 a_e)^2}{480}\int_0^{\pi/2}\left[J'^2_{02} + \cos^2\theta J^2_{02}\right]\sin\theta \,\mathrm{d}\theta \tag{4}$$

$$J'_{02} = J_0(k_0 a_e \sin\theta) - J_2(k_0 a_e \sin\theta) \tag{5}$$

$$J_{02} = J_0(k_0 a_e \sin\theta) + J_2(k_0 a_e \sin\theta) \tag{6}$$

where a_e is the effective radius, a is the actual radius, ϵ_r is the relative permittivity of the microstrip dielectric substrate, h is the height of the microstrip substrate, and J_0 and J_2 are Bessel functions.

The gain of the antenna was calculated using

$$\text{Gain} = \text{Antenna Efficiency} \times \text{Directivity}(D_0) \tag{7}$$

$$\text{Antenna Efficiency} = \frac{\text{Total Efficiency}}{\text{Reflection Efficiency}} \tag{8}$$

The variable corresponding to each dimensions and values for the dimensions of the proposed antenna are shown in **Figure 2** and **Table 1**, respectively. Here, *L*, *W*, and *R* represent the length, the width, and the radius of the circular patch, respectively.

The gain of the proposed antenna shown in **Figure 1** was calculated using (1) - (8) and the dimensions were optimized using ADS [14] which resulted in gain of 3.5 dBi at 2.45 GHz.

2.2. Dual-Band Antenna at 3.3 - 3.6 and 5.0 - 6.0 GHz

The configuration for the doubled-sided microstrip dual band antenna is shown in **Figure 3**. The proposed microstrip antenna has circular arrays both on the top and bottom layers. It consists of three circular patched on each layer.

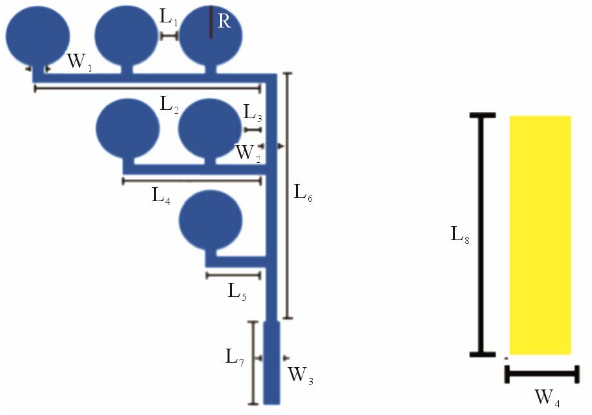

(a) (b)

Figure 2. Variables corresponding to each dimension of the proposed single band antenna: (a) Top layer; (b) Bottom layer.

Table 1. Dimensions for the proposed single band antenna at 2.4 GHz.

Variable	Value (mm)
L_1	1.15
L_2	28.9
L_3	1.13
L_4	17.6
L_5	6.60
L_6	35.3
L_7	18.4
L_8	18.4
W_1	1.02
W_2	1.52
W_3	3.30
W_4	6.86
R	5.10

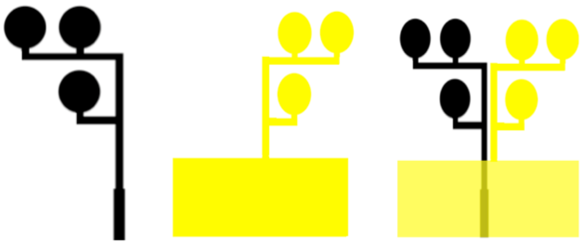

(a) (b) (c)

Figure 3. Configuration of the proposed antenna for dual band at 3.3 - 3.6 and 5.0 - 6.0 GHz: (a) Top layer; (b) Bottom layer; (c) Top and bottom layers overlaid.

The configuration in **Figure 3(a)** is similar to the top layer of the single band antenna as shown in **Figure 1(a)** but with less circular patches. However, the bottom layer in **Figure 3(b)** is different compared to the bottom layer of the single band antenna shown in **Figure 1(b)**. The double-side nature of the antenna provides dual band characteristics. Identical equations were used for the single band antenna were employed in the design process. The variable corresponding to each dimensions and the dimensions for the proposed dual band antenna are shown in **Figure 4** and **Table 2**, respectively.

Simulation was performed using ADS for the configuration shown in **Figure 3(c)**. The simulated gains of the proposed dual band antenna were 4.0 dBi at 3.45 GHz and 3.3 dBi at 5.5 GHz. The double-sided configuration of the antenna provided higher gain compared to the singled-sided antenna.

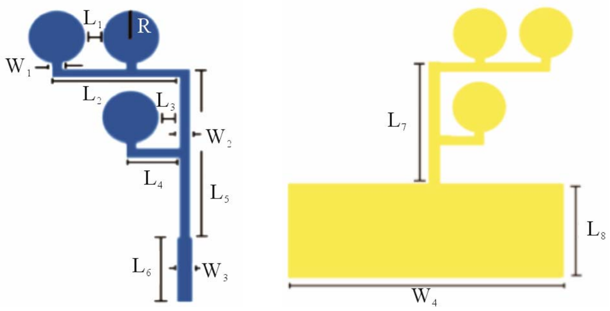

(a) (b)

Figure 4. Variables corresponding to each dimension of the proposed dual-band antenna: (a) Top layer; (b) Bottom layer.

Table 2. Dimensions for the proposed dual band antenna at 3.3 - 3.6 and 5.0 - 6.0 GHz.

Variable	Value (mm)
L_1	1.20
L_2	17.8
L_3	1.08
L_4	6.60
L_5	29.3
L_6	10.0
L_7	21.6
L_8	17.8
W_1	1.02
W_2	1.52
W_3	2.54
W_4	49.1
R	5.21

3. Measurement Results and Discussions

3.1. Single-Band Atnenna at 2.45 GHz

The antennas were fabricated using LPKF Protomat [15] on FR-4 material with height of 1.524 mm. The photos of the fabricated single band antenna are shown in **Figure 5** which has a size of 6.7 × 4.4 (in cm).

Figure 6 shows the comparison between the simulated and the measured S_{11} results.

The measured operating frequency is close to 2.45 GHz with S_{11} value below −15 dB. The 3 dB bandwidth at 2.45 GHz was approximately 18%. The measurement and simulation are in fairly good agreement, and the differences are due to microstrip loss and fabrication errors.

Figure 7 shows the comparison between the simulated and measured radiation pattern in xy-plane at 2.45 GHz which is close to omnidirectional pattern.

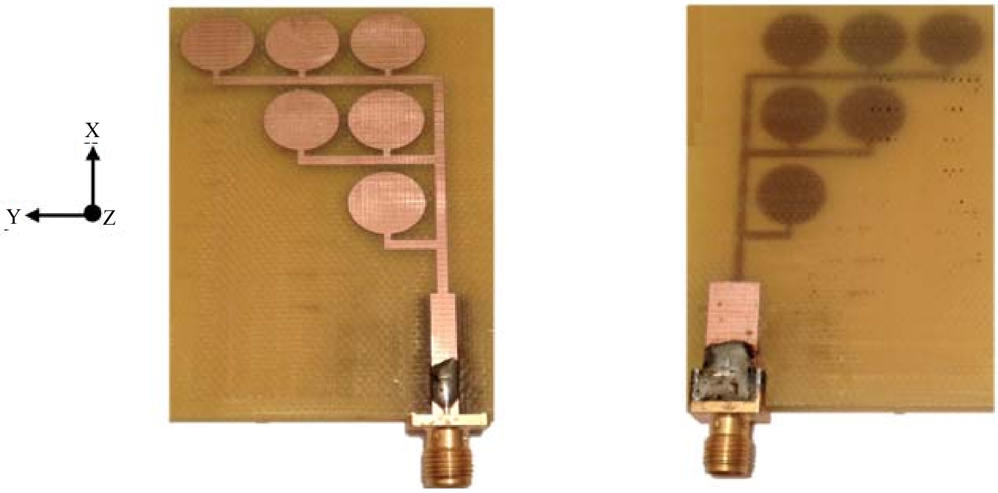

(a) (b)

Figure 5. Photo of the fabricated single-band antenna: (a) Top layer; (b) Bottom layer.

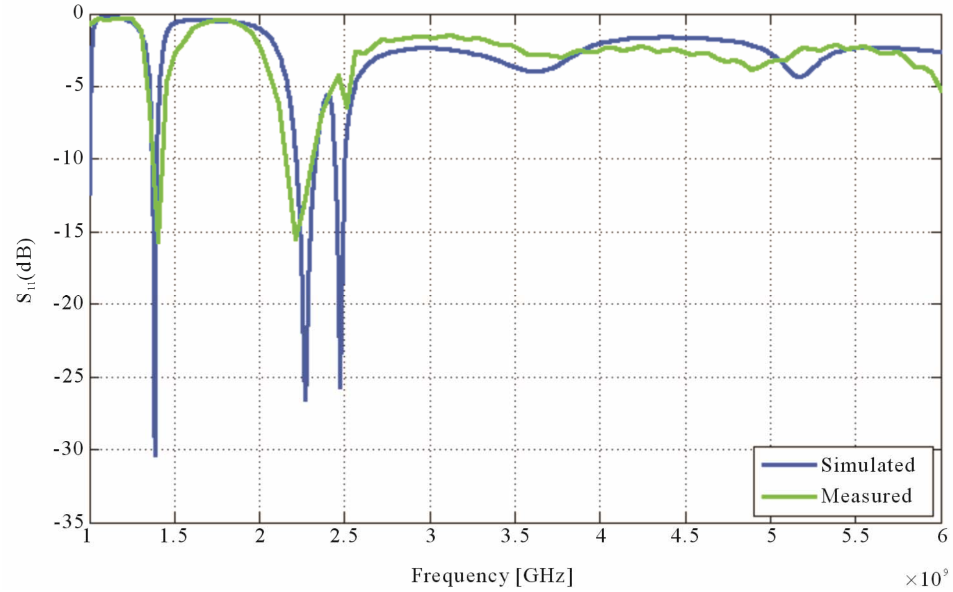

Figure 6. Simulated and measured return loss for the proposed single-band antenna.

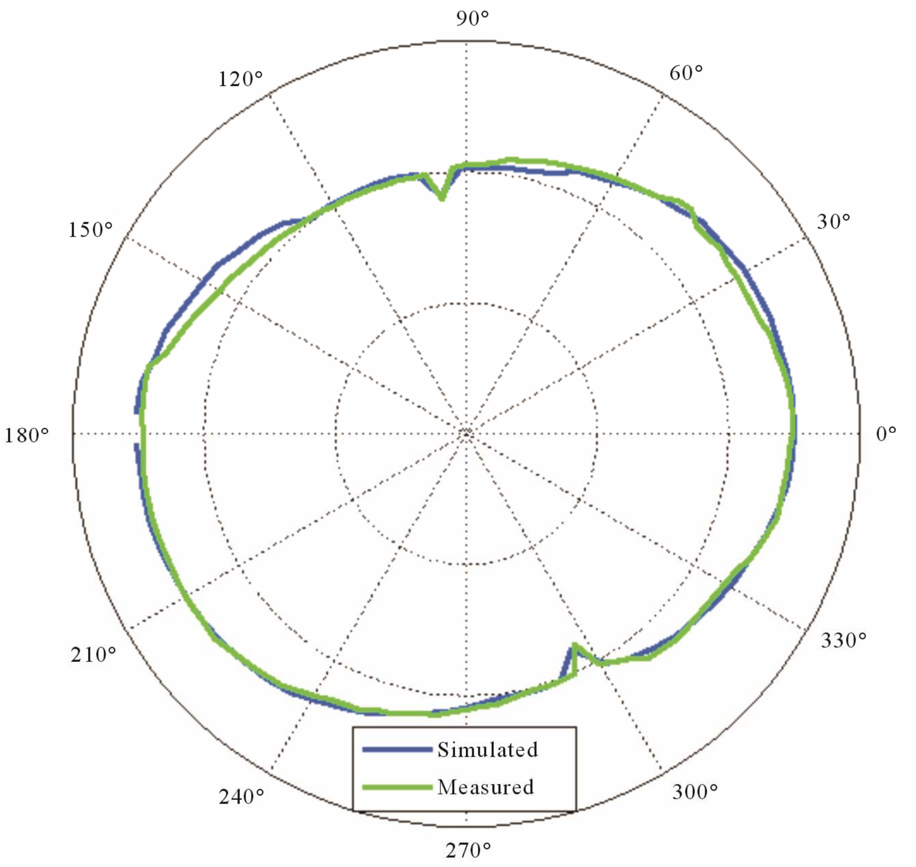

Figure 7. Simulated and measured radiation pattern in xy-plane (coordinate system shown in Figure 5) at 2.45 GHz.

3.2. Dual-Band Antenna at 3.3 - 3.6 and 5.0 - 6.0 GHz

The antennas were fabricated using LPKF Protomat [15] on double-sided FR-4 materials. The photos of the fabricated dual band antenna are shown in **Figure 8** which has a size of 6.6 × 5.2 (in cm).

Figure 9 shows the comparison between the simulated

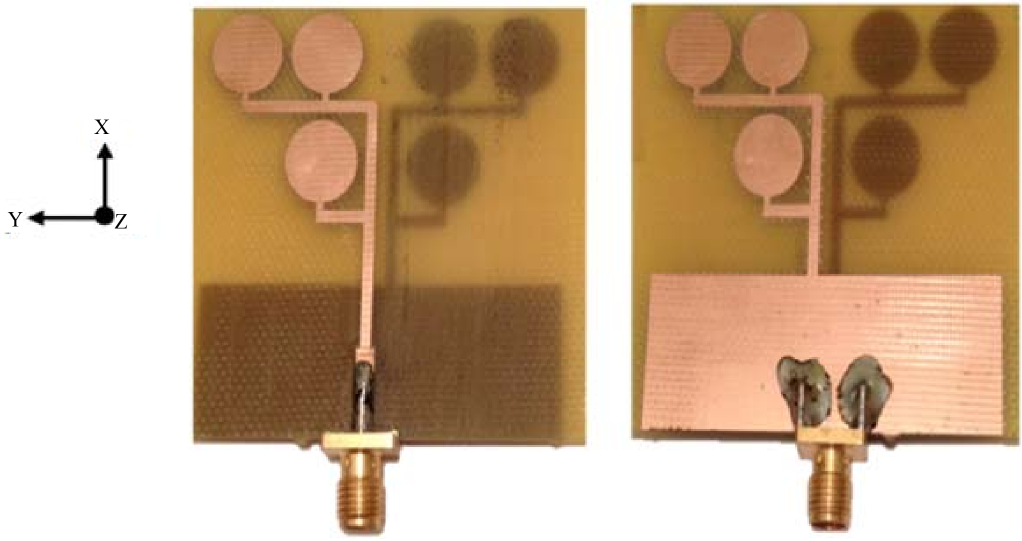

(a) (b)

Figure 8. Photo of the fabricated dual-band antenna: (a) Top layer; (b) Bottom layer.

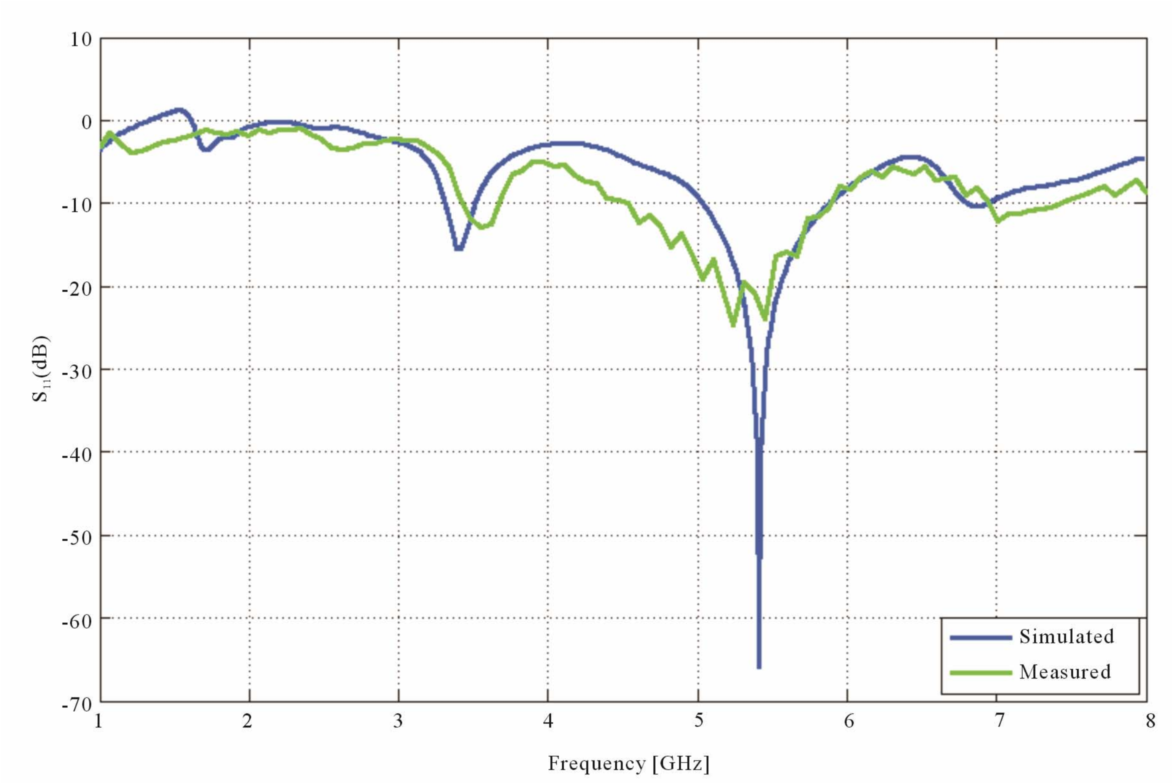

Figure 9. Simulated and measured return loss for the dual band antenna.

and the measured S_{11} results.

The measured S_{11} shows dual band near the designed bands with S_{11} values below −10 dB for both bands. The simulated and measured results give fairly good agreement, and the differences are due to board loss and fabrication errors.

Figure 10 shows the comparison between the simulated and measured radiation pattern in xy-plane at 3.45 and 5.5 GHz which is close to omnidirectional pattern.

4. Conclusion

A microstrip circular antenna arrays were presented for single band at 2.45 GHz and dual bands at 3.3 - 3.6 and

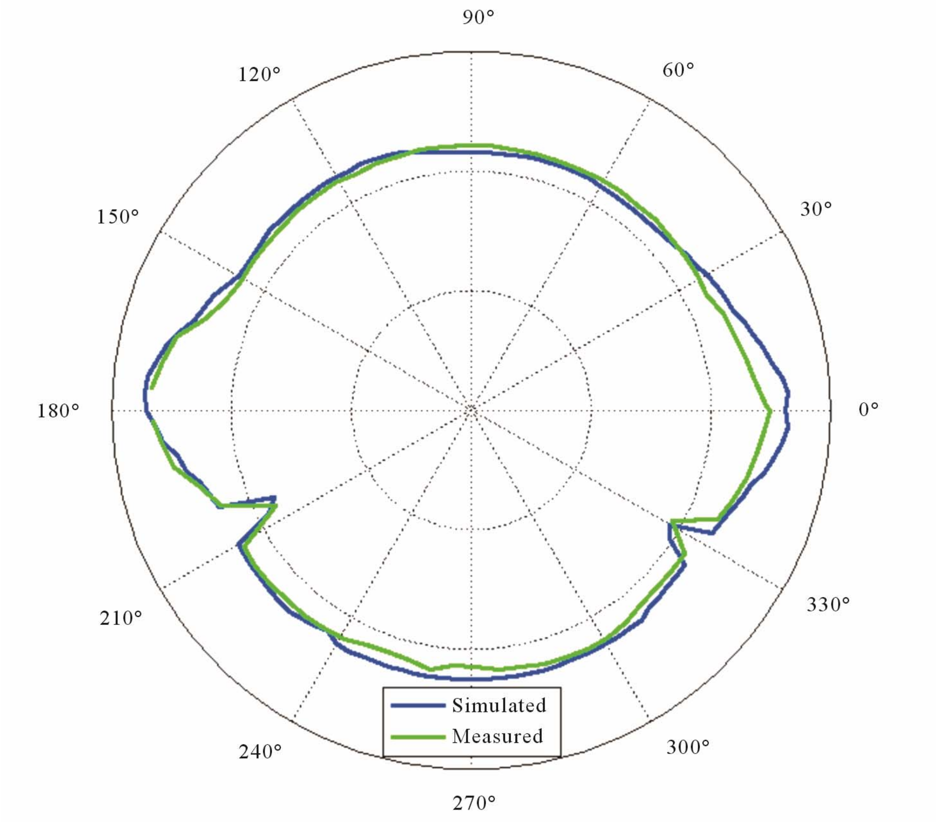

(a)

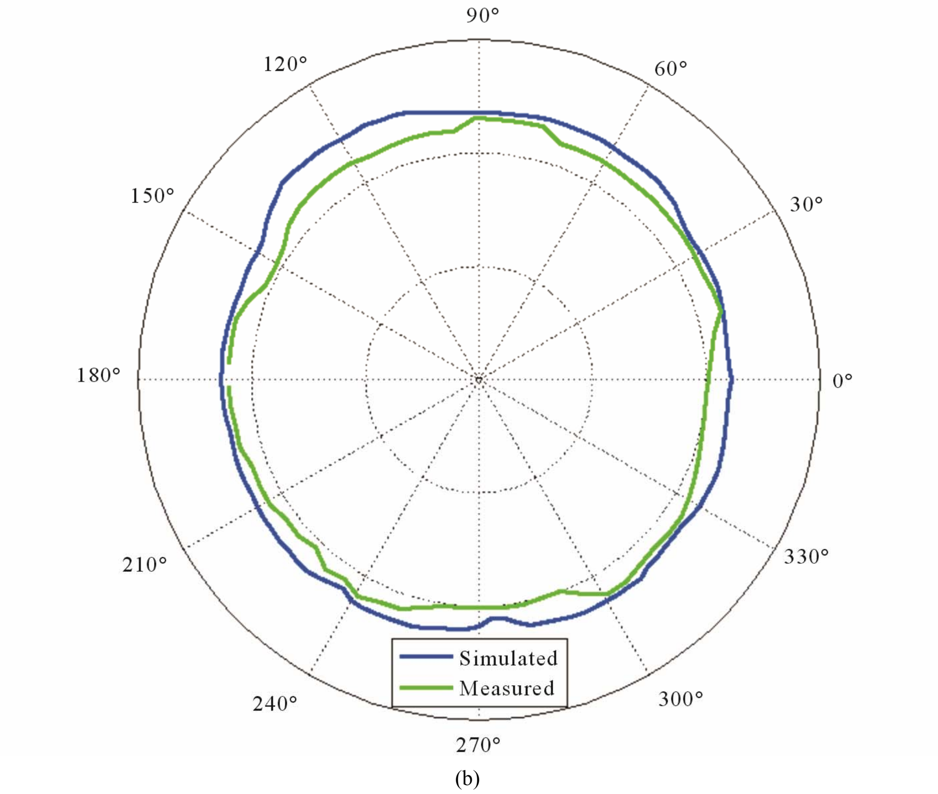

(b)

Figure 10. Simulated and measured radiation pattern in xy-plane (coordinate system shown in Figure 8) at (a) 3.45 GHz and (b) 5.5 GHz.

5.0 - 6.0 GHz for WLAN/WiMAX applications. Both antennas were designed with ADS, fabricated on a FR-4 microstrip material, and characterized. Both single band (single sided) and dual band (double-sided) antenna arrays provided omnidirectional pattern with desired gain.

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Back to Back Combined Single Feed Proximity Coupled Antenna with Dumbbell Shaped DGS

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ABSTRACT

Use of defected ground structure (DGS) to reduce the size of patch antenna is presented in this paper. In order to get a dipole like radiation pattern for some specific application a dumbbell shaped DGS is used in the common ground plane of back to back combined single fed proximity coupled antenna. A size reduction of about 60% is achieved. Parametric analysis has been done to see the resonance behavior of the antenna with DGS.

Keywords**:** *Defected Ground structure, Microstrip Antennas, Proximity Coupling*

1. Introduction

The continuous shrinking size of electronic equipments demands similar size antenna elements in order to fit properly in wireless devices without compromising the other radiation properties of the antenna. In this respect microstrip patch antennas are quite an obvious choice because of its other benefits like low profile, light weight, low cost and easy fabrication.

But as far as size of these patches concerned, the patch length should be around half-a-wavelength for the structure to act as a good radiator. Different techniques have already been used for the antenna size reduction such as using the substrate with high dielectric constant [1] , edge shorted patches with shorting plates or shorting walls, use of the shorting pin at the suitable position etc [2,3].

As far as our understanding goes much has not been reported regarding the use of DGS for size reduction of microstrip antennas, although its application have been reported for harmonic reduction [4], cross-polarization suppression [5] and mutual coupling reduction [6] in antenna arrays etc. Although the back to back geometries have been reported by the various researchers [7,8] but here a new coupling method *i.e.* proximity coupling with the defected ground structure is used for the consideration of the increased bandwidth.

This paper presents the application of DGS for size reduction of microstrip antennas. A dumbbell shaped DGS is used in the common ground plane of a back to back combined single feed proximity coupled microstrip antenna.

2. Defected Ground Structure

Recently there has been an increasing interest in the use of DGSs for performance enhancement of microstrip antennas and arrays. These are realized by etching off a simple shape defect from the ground plane of the planer circuits.

Although various complicated DGSs were reported in the literature, but the simplest one is the dumbbell shaped DGS. **Figure 1(a)** shows the simple and mostly used dumbbell shaped DGS that is etched in the ground plane below the microstrip line, in which both the areas (L_g*W_g) and the slot gap (g) play a very important role to find the resonance behavior of the DGS.

The head areas (L_g*W_g) is very useful for the variation in the inductance (L) and the slot (g) produces the capacitance (C). The L and C may be calculated from the formulae given below [9].

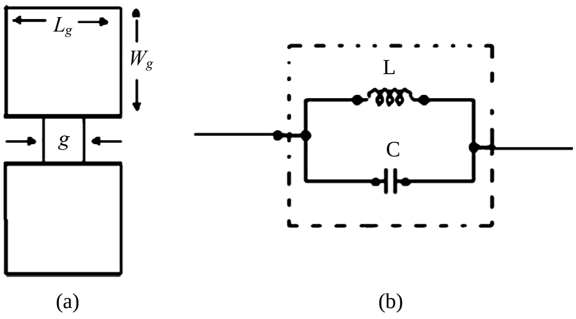

Figure 1. (a) Dumbbell shaped DGS, and (b) DGS Equivalent Circuit.

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$$\mathrm{L} = \frac{1}{4\pi^2 f_0^2 C} \tag{1}$$

$$\mathrm{C} = \frac{f_c}{2Z_0} \times \frac{1}{2\pi(f_0^2 - f_c^2)} \tag{2}$$

When this DGS is applied to the antenna, the equivalent inductive part due to the DGS increases and produces equivalently the high effective dielectric constant, thereby decreasing the resonant frequency when the DGS is incorporated in the ground plane of a micro strip antenna.

3. Antenna Design with DGS

In this section, the design approach and the performance of the basic antenna and the antenna with DGS is described. At the outset, the single patch antenna was designed and simulated using the CST Microwave studio [10], for the operating frequency at 5.0 GHz. Then another patch of the same size was added in the opposite side of the ground plane and fed in the same way as the first one. The configuration seems as two patch antennas having a common ground plane working at the same frequency. Next the feed lines were combined for the antenna for single feed design. For this purpose the antenna feed lines W_f = 0.934 mm with d_f = 1.5 mm were designed of 100 ohm and for matching to the 50 ohm transmission line (W_p = 3.86 mm) a quarter wave length transformer (W_t = 2 mm) was used to give proper matching (**Figure 2**).

The cross-sectional view of the single fed back to back combined proximity coupled antenna is shown in the **Figure 2(a)**. The layouts of matching networks only are emphasized in this **Figure 2(b)** for convenience. It is observed that the antenna designed in this configuration gives the bandwidth of 137 MHz whereas single antenna gives a bandwidth of 67 MHz. This is due to the fact that as the antenna height increases the quality factor decreases and the bandwidth increases. This becomes a multilayer antenna with more height and higher bandwidth as compared to the single patch antenna.

The simple transmission line model was used for the antenna size calculation. The dielectric constant was taken as 3.38 with the loss tangent 0.0025 and of 1.524 mm thickness. The patch lengths L_p and widths W_p are 15 mm and 19 mm respectively. The feed line has been inserted inside the dielectric at a height equal to the half of the height (h = 3.048 mm) of the antenna on either side. The dumbbell shaped DGS with dimensions L_g = W_g = 8.6 mm and g = 0.76 mm was created in the ground plane of the antenna as shown in the **Figure 2(c)**. A small slot was also created for making the antenna with single feed. The two feed lines were connected with a metal strip which goes through the small slot in the ground plane. The fabricated antenna is shown in **Figure 2(d)**.

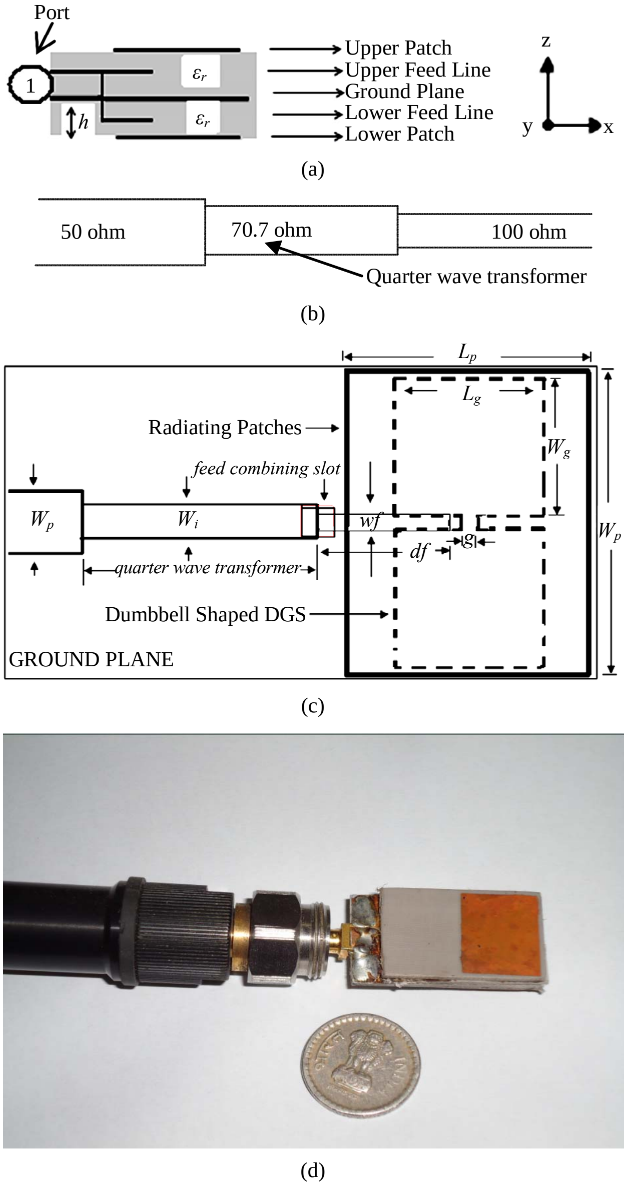

(a)

(b)

(c)

(d)

Figure 2. (a) Cross-sectional view of antenna configuration, (b) Feeding Network, (c) Top-View of the antenna, (d) Fabricated Antenna.

4. Results and Discussion

At first the antenna without the DGS in the common ground was simulated and was found to resonate at 5 GHz with 137 MHz Bandwidth.

Then the structure was simulated with the dumbbell shaped DGS. Before reaching to the final size of the DGS, a parametric study was done by varying L_g, W_g and g of the DGS. As shown in **Figure 3**, with the increase in the value of L_g, the resonant frequency of the antenna is decreasing. Infect, increase in the length of the DGS head gives increasing inductance which in turn decreases the resonant frequency of the antenna.

At this point the increment in the (*g*) was not possible due to the accuracy in fabrication, so for this reason the other dimension (*g*) was kept constant for the requirement of the desired frequency (2 GHz). The size of the DGS single square head for the antenna to resonate at 2 GHz (UHF Band) was found to be 8.6 mm × 8.6 mm. The return loss (S11 [dB]) plot of the structure with and without DGS is shown in **Figure 4(a)**. **Figure 4(b)** shows the measured S11 parameter using the HP 8720 B network analyzer. The marker's position near to peak shows the resonance frequency 2.08 GHz with return loss of -13 dB. The result shows good agreement with the simulation results. The measured -10 dB bandwidth is about 60 MHz. The maximum size reduction achieved is about 60%.

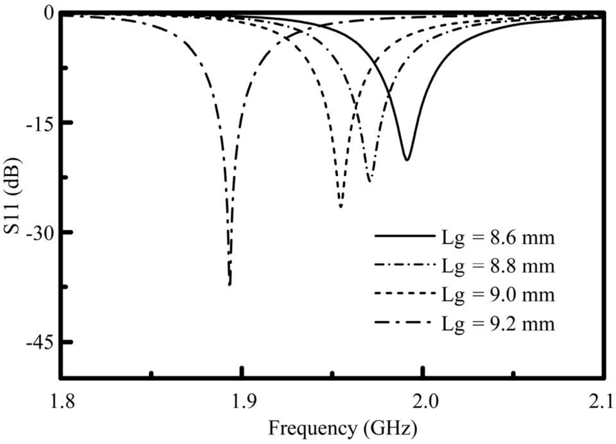

Figure 3. S11 Vs. Frequency response by varying DGS length (Lg).

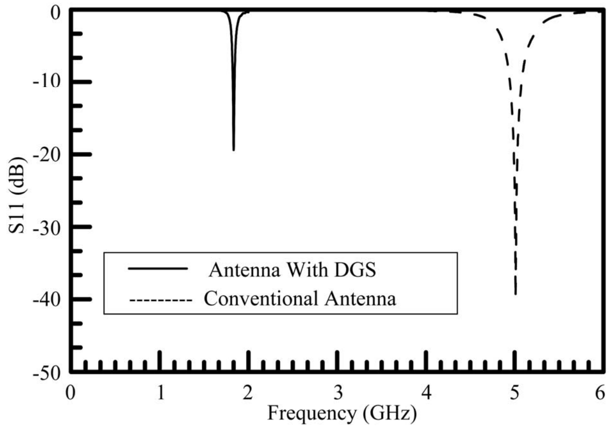

(a)

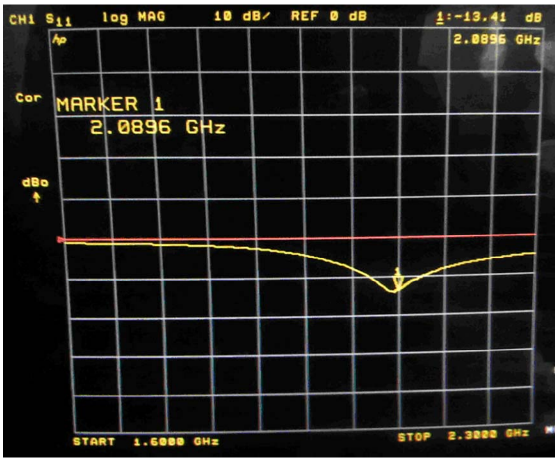

(b)

Figure 4. Antenna Return Loss (a) simulated (b) measured.

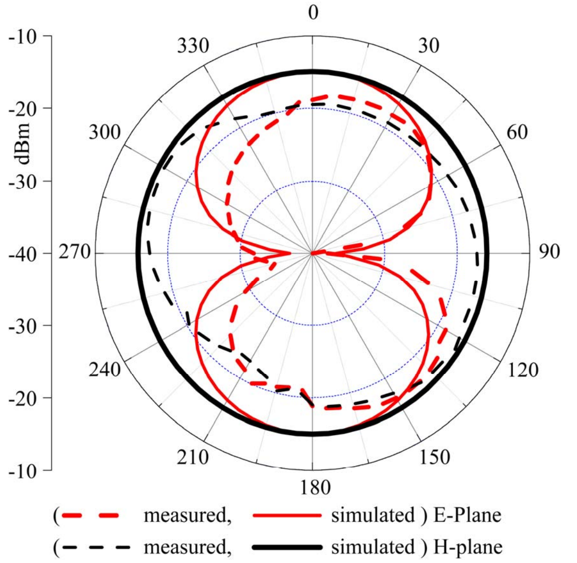

Figure 5. Antenna radiation pattern (measured and simulated) at 2 GHz Frequency.

The measured and simulated power patterns of the antenna are shown in **Figure 5**. It can be observed that the E-plane radiation pattern is similar to the pattern for a dipole antenna. Measurement errors are mainly due to the spurious radiation created by the feeding end and the improper coupling of the elements. However the gain measured experimentally for the proposed antennas with DGS is about -6.9 dB and -7.8 dB (where simulated gain with DGS is 3.8 dB and 5.7 dB is for the antenna without DGS, for both the planes) in both the E and H plane respectively, which is consistent with the size reduction of the antenna.

5. Conclusion

Microstrip patch antenna size reduction with DGS is carried out in this work. A dumbbell shaped DGS in the common ground plane of a back to back microstrip structure was found to give a size reduction of about 60% and shifts the resonance frequency from 5 GHz to 2 GHz, with 60 MHz bandwidth facilitating the antenna, to be used for UHF band applications.

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Vehicular Radio Scanner Using Phased Array Antenna for Dedicated Short Range Communication Service

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ABSTRACT

Now a day's accidents are very common due to increased population of vehicle. In order to ensure safety measures in the vehicle this paper has proposed some methodologies regarding careful driving by automatically scanning and analyzing the blind spot area of an intelligent mobile vehicle. A vehicular antenna with minimum perturbation is proposed to be fitted on the vehicle and collect information of the concern area which would ensure visibility of the operator *i.e.* masked or integrated within the car body. This paper has dealt with the design of Tchebyscheff polynomial based prototype planar microstrip phased array antenna and also redesigned the same when implemented in the body of the car being considered as an electromagnetically large element. Both the design has been experimentally verified with the measurement. The simulated and the measured results in both the cases are found to be in good agreement. More than 11 dB gain was observed at perfectly 30° angles from its broad side direction as desired for blind spot detection with minimum amount of electromagnetic interference inside the car.

Keywords: Intelligent Transportation System; Microstrip Phased Array Antenna; Tchebyscheff Polynomial; Electromagnetic Interference

1. Introduction

Intelligent Transport System (ITS) ensures mobility comfort and safety in transportation system. It also absorbs the hazards due to environmental impact. With the progress of the information processing technology, control systems to minimize accidents for the roadways have also been advanced hence one approach to improve the traffic safety is found and that is automatic collection of data by scanning the blind spot area of the vehicle [1] as shown in **Figure 1**. Many methods were proposed to detect the blind spot area but all of them had certain limitations. Devices like dynamic angling side view mirror [2], side view camera model [3], and shadow or edge features detector [4] were used for detecting blind spot area but their performance was affected during bad weather, fog or mist. Also we know that the mechanical systems, response time is more and the system is prone to wear and tear.

A radio frequency method has been proposed in this paper to scan the blind spot zone efficiently. Four rectangular microstrip antennas (RMSA) are arranged in linear configuration with optimal spacing between the patch elements to construct the phased array radar. A corporate feed network is used to feed the patch element unequally and a progressive phase shifter is designed with 108˚ delay elements to tilt the main beam in the desired direction and then the total unit is simulated and experimented after placing it on the car body which is electromagnetically a large element. The antenna works in the Dedicated Short-Range Communication Service (DSRCS) frequency band [5]. The design of the microstrip phased array antenna is discussed in Section 2 and after that to place the antenna; the design of the entire car is given in Section 3. Results and discussion are portrayed in Section 4 along with conclusion in Section 5.

2. Design of Microstrip Phased Array Antenna

The microstrip phased array antenna is designed for Dedicated Short Range Communication Service at 5.88 GHz with dielectric constant of 2.32 and substrate thickness of 0.785 mm. Firstly the dimension of the rectangular patch is computed as 16.322 mm by 19.8 mm using the method outlined in [6]. With computed inset feed length of 3.8 mm and for the above dimensions of the rectangular patch the return loss is found to be –8.09 dB

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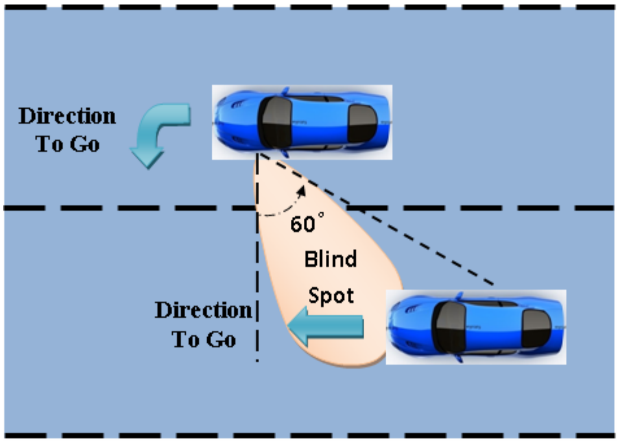

Figure 1. Surrounding regions of a vehicle.

with (30.1 + j26.7) ohm impedance at the feed position. The RMSA is simulated and optimized using Ansoft HFSS^{TM}. After optimization the final length is found to be 16.4363 mm with inset feed length of 4.8225 mm keeping the width of the patch unchanged as shown in **Figure 2**.

By considering the above designed patch element, a four element linear array is realized and powered by Tchebyscheff current distribution. The spacing between the elements is kept considering the desired maximum scan angle in order to eliminate the grating lobes within the visible space of the phased array antenna. To optimize the performance of the antenna in respect of its side lobe level (SLL), mutual coupling and gain of the antenna array, the spacing between the elements is studied parametrically [7]. The results of the said study are tabulated in **Table 1**.

After optimization it is found that the optimum spacing between the elements is 0.6 λ_0 while considering, the main lobe to side lobe ratio below 20 dB, optimum mutual coupling and overall gain.

From **Figure 1**, it is observed that the beam of the antenna array is required to be tilted by an angle 30° away from the broad side direction. In view of the above a progressive phase shifter of –108° is designed with the help of 11.16 mm feed line length. The actual line length is considered as mτ, where m = 0, 1, 2, 3.

To enhance the gain by maintaining the beam width and main lobe to side lobe ratio, the antenna elements are excited by Dolph Chebyshev current distribution. The array consist of four elements, thus third order Tchebyscheff polynomial is calculated. Hence the polynomial is solved and relative current ratio is computed as 1:1.7795:1.7795:1. Both equal and unequal power dividers are designed along with the progressive phase shifter.

For equal power division, a 3 dB equal power divider is designed whose vertical arm is of 50 Ω line and two horizontal quarter-wavelength branch-lines are of 70.71 Ω is used [8]. It is shown in **Figure 3(a)**.

Table 1. Effect on mutual coupling and gain due to variation in spacing (d) between the elements.

d with respect to guided wavelength	d with respect to operating wavelength	Mutual coupling (dB)	Gain (dBi)
0.6 λ_g	0.41 λ_0	>10	7.6
0.7 λ_g	0.48 λ_0	>13	9.9412
0.8 λ_g	0.55 λ_0	>20	10.647
0.9 λ_g	0.6 λ_0	>22	10.919

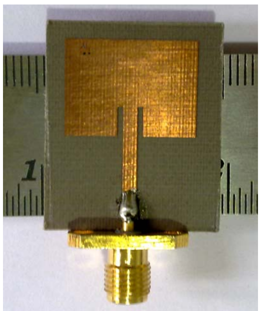

Figure 2. Photograph of the rectangular microstrip antenna element.

To get the unequal current distribution, both the horizontal arm of the microstrip unequal power divider should be of different resistance and it is calculated as 46.368 Ω and 82.49 Ω. The structure is shown in **Figure 3(b)**.

Generally for practical design purpose the gap between the corporate feed networks is taken small but the value of the gap less than 0.11 λ_0 disturbs the frequency response of overall antenna array. The effects of the feed network on the side-lobes are significant in the E-plane pattern. The influence on the H-plane is less important due to the orthogonality of the drive current and the symmetry of all the other currents in this cut [9]. By maintaining the SLL and the surface wave loss, the gaps are taken as 0.11 λ_0 as portrayed in **Figure 4**.

3. Placement of Antenna on the Vehicle

In order to compute the electromagnetic effect of the body of the car on the antenna performance, the entire structure of the car is designed in Ansoft HFSS^{TM}. The complete structure of the car consist of hood, roof, trunk, left and right side doors, left and right side quarter panel for front and rear side which are made up of conducting material but the bumpers and wheels are assigned by layered impedance due to their hard rubber and polyester materials as shown in **Figure 5**.

After going through the typical requirement for scanning the blind spot, the antenna is placed just beside the side view mirror. The following problems in the designed are addressed while simulating the effect of the radiation

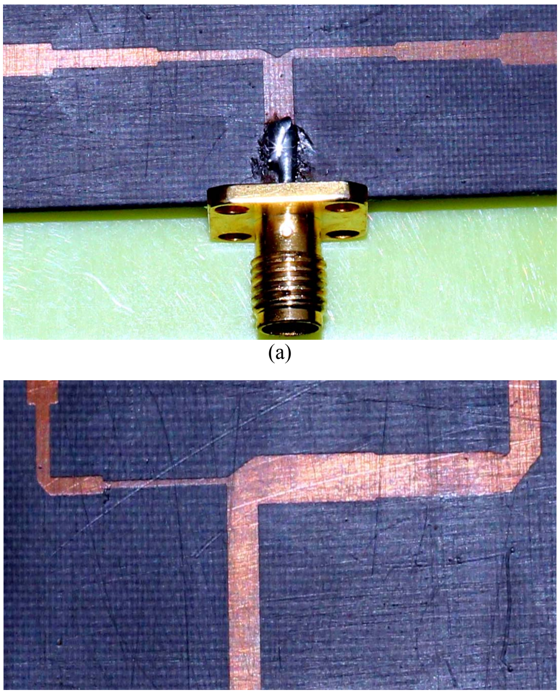

(a)

(b)

Figure 3. (a) Photograph of the equal microstrip power divider; (b) Photograph of the unequal microstrip power divider.

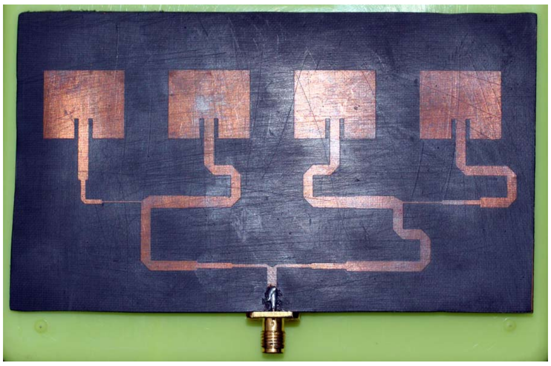

Figure 4. Photograph of the antenna array with corporate feed network.

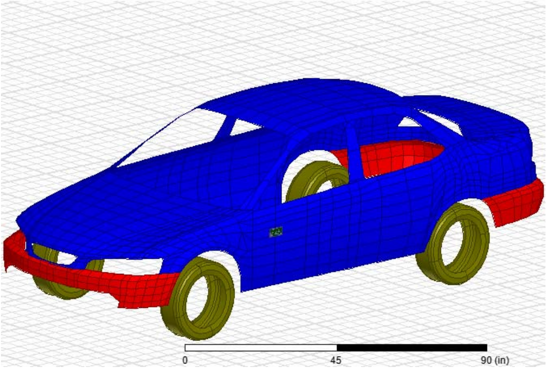

Figure 5. The entire structure of the car along with the antenna array.

characteristics of the antenna after placing it on the vehicle:

1) Spans a large computational domain compared to the wavelength;

2) Requires a fine grid resolution to resolve the detailed antenna structure;

3) Contains largely non-conformal PEC and dielectric structures.

4. Results and Discussion

For obtaining the scattering parameter characteristics, the microstrip antenna has been simulated over the frequency bandwidth ranging from 5.5 GHz to 6.5 GHz and two different circumstances is observed. The first experiments involve the design, simulation and measurement after fabrication of an individual element and then the array with the same without involving the effect of the car. Both of them should used for optimized performance.

The scattering parameter is measured by Agilent Technology Vector Network Analyzer model no. N5320A (10 MHz - 20 GHz) and the radiation pattern is measured by Hittite HMC-T2100 synthesized signal generator (10 MHz - 20 GHz) and Krytar 9000 B power meter (10 MHz - 40 GHz) with 9530 B power sensor (10 MHz - 20 GHz) as shown in **Figure 6**. From **Figure 7**, it is found

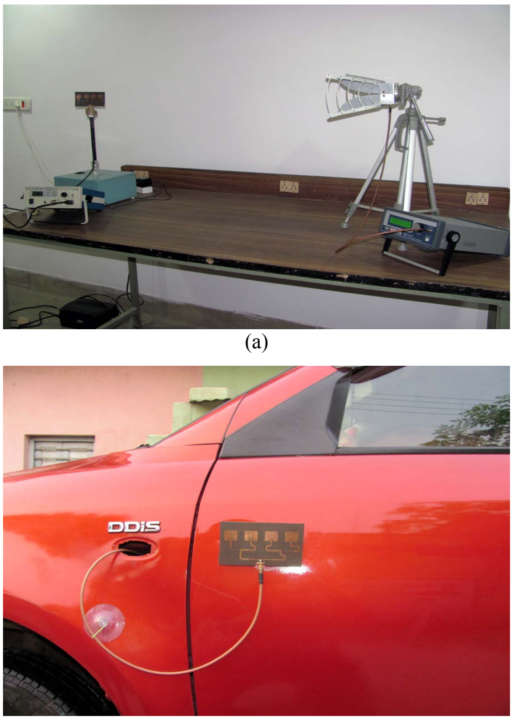

(a)

(b)

Figure 6. (a) Experimental set-up to measure the radiation pattern of the antenna array; (b) Experimental set-up to measure the radiation pattern of the antenna array after placing it on the car.

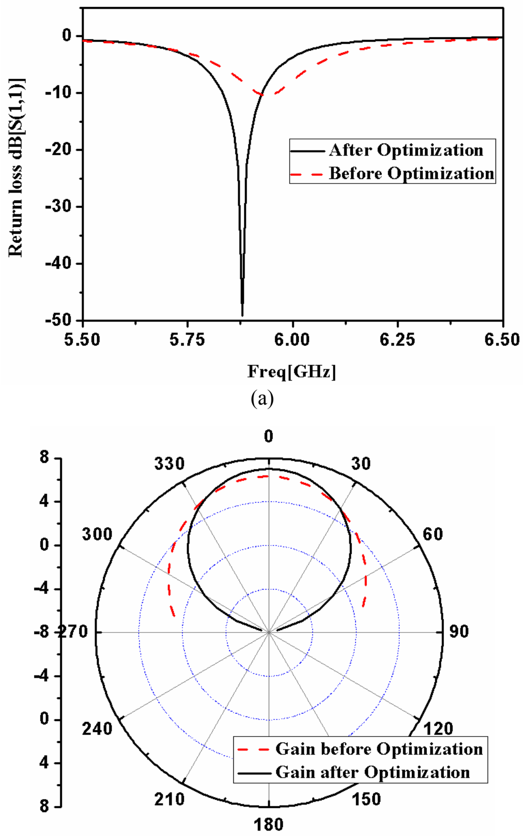

(a)

(b)

Figure 7. (a) Return loss a single patch before and after optimization; (b) Gain of a single patch before and after optimization.

that after optimization a perfect match is obtained exactly at 5.88 GHz and gain is also improved from 6.33 dB to 7.01 dB with a very good return loss of –47 dB. The current distribution and the radiation pattern of a single RMSA is portrayed in **Figure 8**.

A parametric study of the return loss of antenna array with different spacing between the elements of the corporate feed network is done and is compared in **Figure 9**. The results of the computational model of the entire antenna array with feed network were compared with the measured data and a good agreement is observed in **Figure 10**.

After getting the satisfactory results, next the same array antenna is experimented again with considering the electromagnetic effect of the car. In order to test the antenna array in association with the vehicle, a numerical model of the car is created using Ansoft HFSS$^{\text{TM}}$ and the simulated data is compared with the measured in **Figure 11**. **Figure 12** graphically represents the 3D radiation pattern of the antenna array in presence of the computational model of the vehicle. From **Figure 13**, it is clear that the inside electric field strength is not more than 15 Volt per meter which is very less compare to the standard

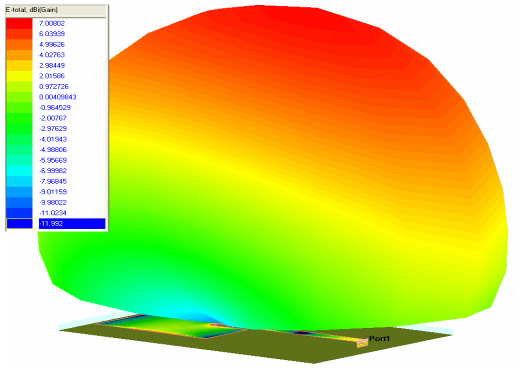

Figure 8. Current distribution and the radiation pattern of the rectangular microstrip antenna.

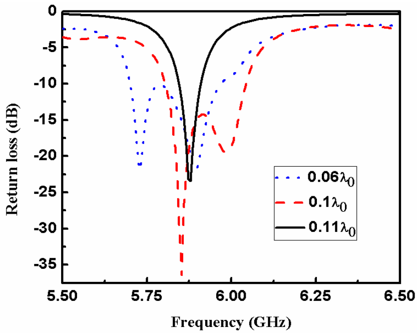

Figure 9. Parametric study of return loss of the antenna array with different spacing between the elements of corporate feed network.

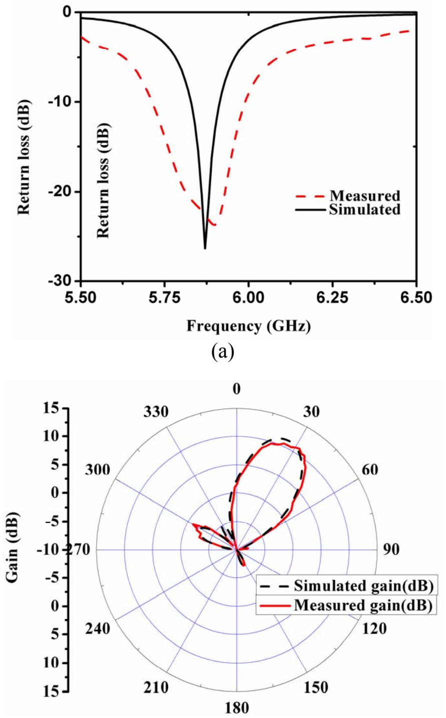

(a)

(b)

Figure 10. (a) Return loss of the antenna array; (b) Radiation pattern of the antenna array.

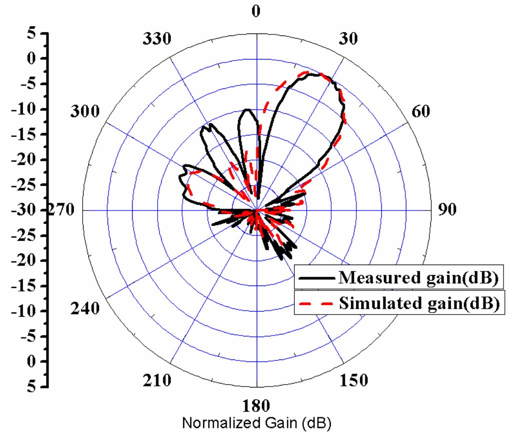

Figure 11. Normalized radiation pattern of the antenna array after placing it on the body of the car.

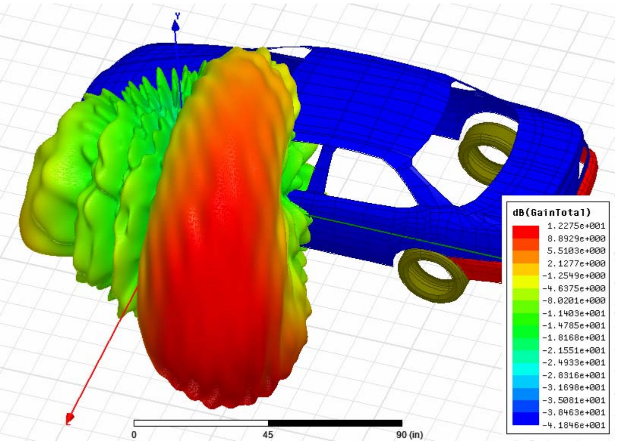
Y
dB(GainTotal)
1.2275e+001
8.8929e+000
5.5103e+000
2.1277e+000
-1.2549e+000
-4.6375e+000
-8.0201e+000
-1.1403e+001
-1.4785e+001
-1.8168e+001
-2.1551e+001
-2.4933e+001
-2.8316e+001
-3.1698e+001
-3.5081e+001
-3.8463e+001
-4.1846e+001
0
45
90 (in)

Figure 12. 3D radiation pattern of the antenna array after placing it on a vehicle body.

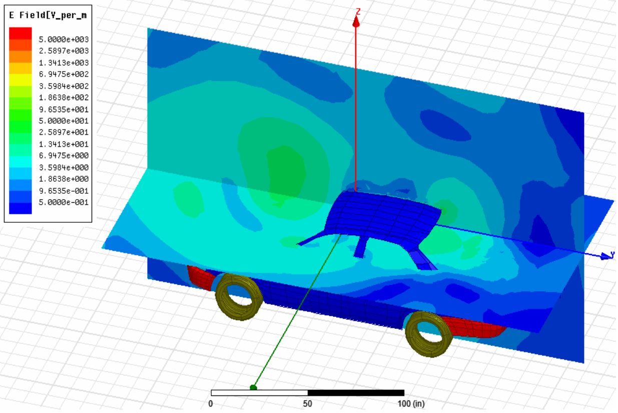
E Field[V_per_m
5.0000e+003
2.5897e+003
1.3413e+003
6.9475e+002
3.5984e+002
1.8638e+002
9.6535e+001
5.0000e+001
2.5897e+001
1.3413e+001
6.9475e+000
3.5984e+000
1.8638e+000
9.6535e-001
5.0000e-001
Z
Y
0
50
100 (in)

Figure 13. Inside electric field interference of the array after placing it on a vehicle body.

electromagnetic hazards.

5. Conclusion

A Tchebyscheff polynomial based microstrip phased array antenna is designed to detect the blind spot area of the intelligent mobile vehicle. The design is further simulated in Ansoft HFSS^{TM} after placing the antenna on the body of the car and the results are observed. The result of the computational model of the entire antenna array is compared with the measured data before and after placing the said antenna array on the body of the car and found to be in good agreement. An overall 11 dB gain is obtained while measuring in the desired direction with minimum amount of electromagnetic interference inside the car.

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Plus Shape Slotted Fractal Antenna for Wireless Applications

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ABSTRACT

Fractal antennas are characterized by space filling and self-similarity properties which results in considerable size reduction and multiband operation as compared to conventional microstrip antenna. This paper outlines a multiband antenna design based on fractal concepts. Fractal antennas show multiband behavior due to self-similarity in their structure. The plus shaped fractal antenna has been designed on a substrate of dielectric constant $€_r = 4.4$ and thickness 1.6 mm. The proposed antenna is characterized by a compact size and it is microstrip feed fractal patch of order 1/3. It is observed that the antenna is radiating at multiple resonant frequencies. The resonant frequency is reduced from 2.2 GHz to 900 MHz after I & II iterations respectively. Thus considerable size reduction of 81.77% & overall bandwidth of 12.92% are achieved. The proposed antenna is simulated using the method of moment based commercial software (IE3D) and it is found that simulated results are in good agreement with the experimental results.

Keywords: Fractal Antenna; Multi Frequency; Size Reduction; Wireless Application; Plus Shape Antenna; Slotted Antenna

1. Introduction

In the study of antennas, fractal antenna theory is a relatively new area. The emergence of antennas with fractal geometries has given an answer to two of the main limitations started by Werner (1999) of the classical antennas, which are single band performance and dependence between size and operating frequency. The term "fractal" means broken or irregular fragments. It was originally coined by Mandelbrot (1983) to describe a family of complex shapes that possess an inherent self-similarity or self-affinity in their geometrical structure. Jaggered (1990) defined fractal electrodynamics as an area in which fractal geometry was combined with electromagnetic theory for the purpose of investigating a new class of radiation, propagation and scattering problems. One of the most promising area fractal electrodynamics researches is in its application to antenna theory and design. There are varieties of approaches that have been developed over the years, which can be utilized to archive one or more of these design objectives. The development of fractal geometry came largely from an in depth study of the pattern nature, with the advance of wireless communication system and their increasing importance wide band and low profile antennas are in great demand for both commercial and military applications [1]. A fractal is a rough or fragmented geometric shape that can be split into parts, each of which is a reduced-size copy of the whole and this property is called self-similarity. Fractal [2] geometries are composite designs that repeat themselves or their statistical characteristics and are thus "self-similar" fractal geometry finds a variety of applications in engineering. Fractal geometry is space filling contours of regular or irregular shapes [3-6], and is super imposed of too much iteration and they describe the self-similar property of fractal geometry [7]. Fractals are a class of shapes which have not characteristic size. Each fractal is composed of multiple iterations of a single elementary shape the iteration can continue infinitely, thus forming a shape within a finite boundary but of infinite length or area. Fractal has the following features 1) It has a finite structure at arbitrarily small scales; 2) It is too irregular to be easily described in traditional Euclidean geometric; 3) It is self-similar; 4) Simple and recursive [8]. Modern telecommunication systems require the antenna with wider bandwidth and smaller dimension than conventionally possible. This has initiated antenna research in various directions, are of which is by using fractal shaped antenna elements. In recent years several fractal geometries have been introduced for antenna application with varying degree of success in improving antenna

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characteristics. Some of these geometries have been particularly useful in reducing the size of the antenna, while other designs aim at incorporating multiband characteristics. These are low profile antennas with moderate gain and can be made operative at multiple frequency bands and hence are multifunctional [9]. In our present work we focus on generation of multifrequency which yields increases the bandwidth and size reduction of antenna. A plus shape patch is taken as a base shape and in first iteration four other plus shape patches of the order of 1/3 of base shape are placed touching the base shape. Similarly second iterations are taken by further placing plus shaped patches at even reduced scales. It is found that as the iteration number and iteration factor increases, the resonance frequencies become lower than those of the zero iteration, which represents a conventional plus shape patch.

2. Design Consideration

The base shape of the plus shaped slotted fractal antenna is designed on a dielectric substrate having a relative dielectric constant €$_r$ = 4.4 and thickness 1.6 mm as shown in **Figure 1**. This is the reference antenna or base shape antenna. Further this base shape antenna is modified by inserting horizontal slots on both sides with respect to center of patch as shown in **Figure 2** and it is named as antenna1. The length of the slot Ls is varied on either side of the edge as 5 mm, 10 mm, 15 mm, 20 mm, 21.175 mm, 21.675 mm and the frequency variation has been studied. The optimum length obtained is Ls = 21.675 mm *i.e.*, the distance between slots q = 2 mm is considered for further design.

The first iteration patch is designed with four plus shapes of order (1/3) of base shape are placed touching the base shape as shown in **Figure 3** and it is named as antenna 2 and same procedure is repeated for second iteration. This antenna is as shown in **Figure 4** and it is named as antenna 3. For each iteration plus shapes of the order of $(1/3)^n$ of base shape are taken, where n is the number of iterations. The dimension of first iteration can be calculated as

e = (1/3) a & g = (1/3) c also f = (1/3) b & h = (1/3) d.
i = (1/3) e & k = (1/3) g also j = (1/3) f & L = (1/3) h

So with optimized design the dimensions obtained are a = 45.3 mm, b = 15.1 mm, c = 35.4 mm, d = 11.8 mm. The length of the slot is Ls = 21.675 mm and width of the slot Ws *i.e.* r = 2 mm. The dimension of the ground plan is 55 mm × 85 mm. A 50 ohm SMA connector is used to feed the antenna by using microstrip feed technique. Optimized microstripline with following dimension, m = 0.5 mm, n = 18.55 mm, o = 3.05 mm, p = 18.4 mm. The suitable feed location is obtained through optimization process by using the IE3D software. The fabricated photographic view of all proposed antennas is shown from **Figures 5(a)-(e)**.

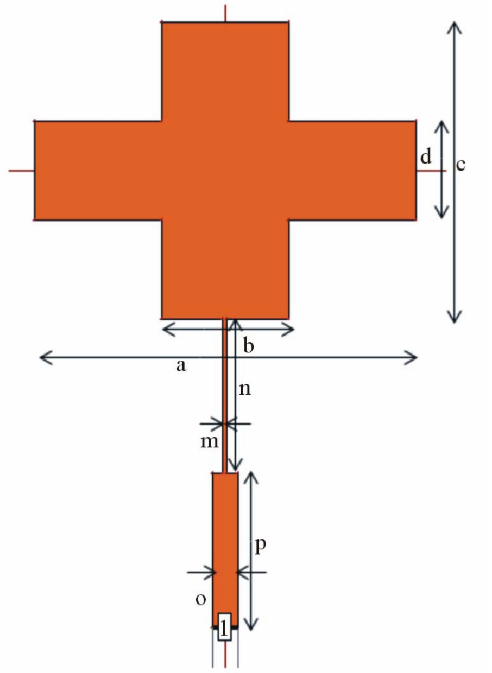

Figure 1. Geometry of base antenna.

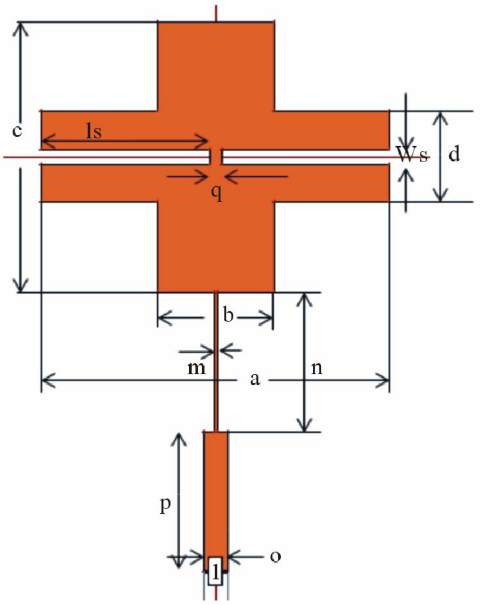

Figure 2. Geometry of antenna 1.

3. Results and Discussion

The characteristic of the fractal antenna with slot and with iterations has been studied by using IE3D software. Also the results have been verified practically with by using Vector Network Analyzer model Rohde and schewarz, German make ZVK model No.8651.

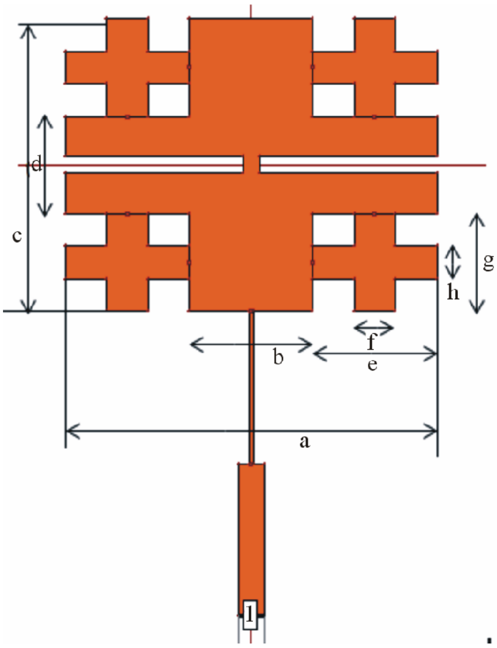

Figure 3. Geometry of base antenna 2.

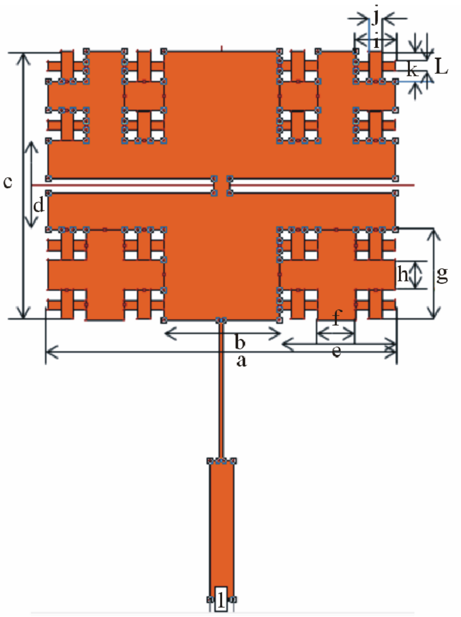

Figure 4. Geometry of antenna 3.

The modified base shape antenna with slots as been optimized by varying slot length Ls. The variation of Ls with resonant frequency of the antenna is shown in **Table 1** and same is presented in graphical form in **Figure 6**. From the tabular results it is found that by increasing slot length Ls on both sides from the edge of the patch, resonant frequency decreases. The lowest possible resonant frequency 1.27 GHz is obtained for Ls = 21.675 mm (*i.e.*, distance between the slots q = 2 mm) & this is taken as optimized length of the slot for further iteration.

The results of all proposed antennas are shown in **Table 2**. The simulated and measured return loss characteristics of proposed antennas are shown from **Figures 7(a)-(d)**.

From the results it is clear that the resonant frequency of the antenna 1 *i.e*., modified base antenna with slot is fr = 1.27 GHz which is lower compared to the base antenna without slot (fr = 2.199 GHz). So the size reduction obtained is 66.85%. The antenna 2 *i.e*. the modified antenna with slots and first iteration gives multiple bands with lower frequency of 0.99 GHz. The size reduction obtained for antenna 2 is 79.88%. Further antenna 3 *i.e*., with slot and second iteration gives multiple bands with

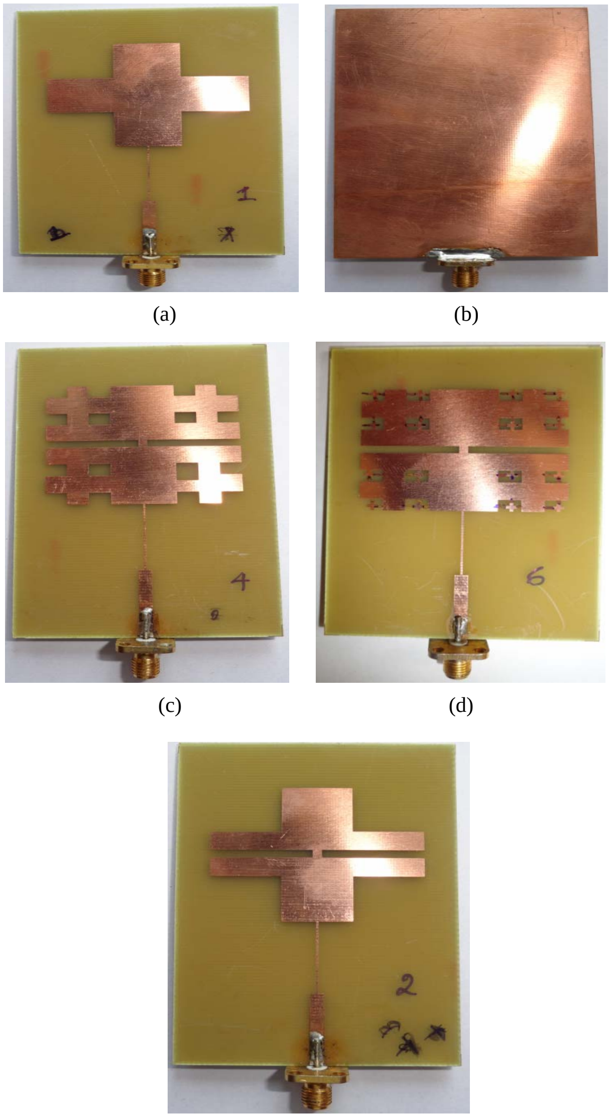

(a) (b)

(c) (d)

(e)

Figure 5. (a) Photograph of top view of base antenna; (b) Photograph of bottom view of base antenna; (c) Photograph of antenna 1; (d) Photograph of antenna 2; (e) Photograph of antenna 3.

Table 1. Variation of slot length v/s resonant frequency.

Slot length (Ls) variation in mm	Resonating frequency (GHz)
0	2.22
5	2.197
10	2.155
15	1.93
20	1.436
12.175	1.34
21.675	1.27

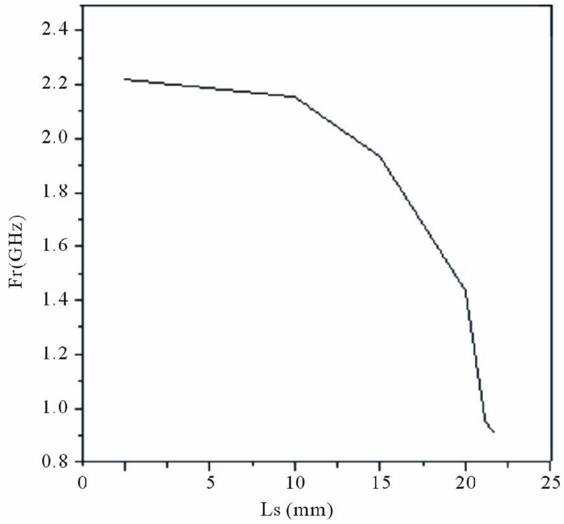

Figure 6. Variation of resonant frequency v/s slot length.

lower resonant frequency of 0.90 GHz. The size reduction obtained for antenna 3 is 81.77% which is more compared to all other proposed antennas.

Further the bandwidths of proposed antennas have been studied through simulation and measurements and the results are shown in **Table 2**. From the results it is clear that the bandwidths of modified antenna with slot, first & second iteration are more compared to base antenna. The measured bandwidth of antenna 1 is 106 MHz (4.895%), antenna 2 is 190 MHz (11.93%) and antenna 3 is 215 MHz (12.92%). The radiation patterns of all proposed antennas are studied and all are giving broadside radiation. Splitting of beam *i.e.* dip is found in **Figure 8(a)** of simulated radiation pattern of base shape at 2.19 GHz. In **Figure 8(b)** splitting of beams merged into broadside pattern at 0.91 GHz at second iterations this results into broadside radiation pattern.

4. Conclusion

This paper presents a new plus shape slotted fractal antenna with first and second iterations. The antenna.3 *i.e.*, slotted fractal antenna with second iteration gives size reduction of 81.77% and band width of 12.92% with broad side radiation pattern. So from the results we conclude that the modified base antenna with slots of second iterations gives a good size reduction and enhanced band width compared to that of modified base antenna with

Table 2. Results of proposed antennas.

Prototype antenna	Resonant frequency fr (GHz)		Return loss (db)		Bandwidth (MHz)		Overall bandwidth (MHz)	
	Sim	Pract	Sim	Pract	Sim	Pract	Sim	Pract
Base antenna	f1 – 2.19	f1 ± 2.19	–19	–24	53	53	79	71
	f2 – 3.42	f2 ± 2.46	–14	–15	26	18		
Antennal with q = 2 mm	f1 ± 1.19	f1 ± 1.27	15.8	–12.8	20	18	133	106
	f2 ± 2.52	f2 ± 2.48	18.4	–20.1	113	44		
		f3 ± 2.56		–18.7		44		
Antennal 2 with q = 2 mm (1st itr)	f1 ± 0.96	f1 ± 0.99	16.7	–14.5	22	80	136	190
	f2 ± 2.9	f2 ± 2.97	–14	–26.9	44	50		
	f3 ± 3.08	f3 ± 3.17	21.5	–21	70	60		
Antennal 3 with q = 2 mm (2nd itr)	f1 ± 0.91	f1 ± 0.990	15.2	–14.2	11	87	81	215
	f2 ± 3.07	f2 ± 2.976	19.4	–17.6	70	50		
		f3 ± 3.168		–18.9		78		

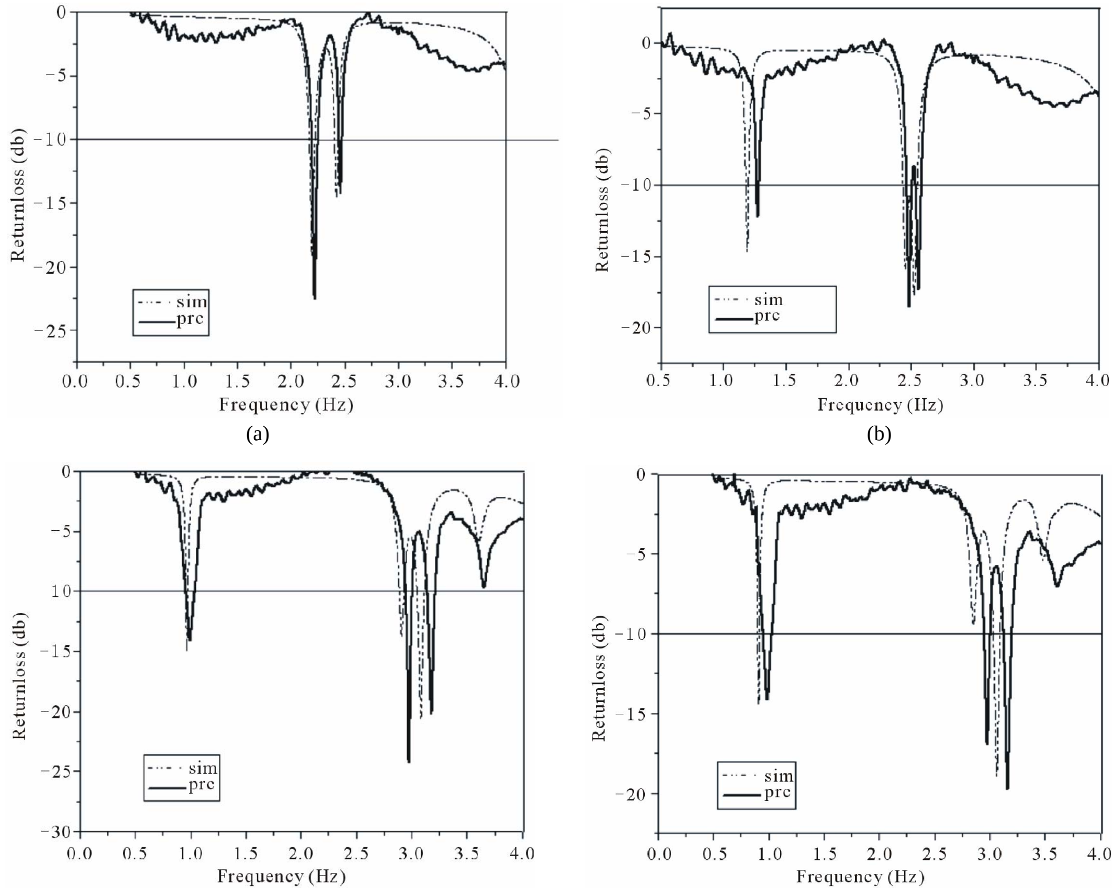

(a) (b)

(c) (d)

Figure 7. (a) Return loss characteristic of antenna 1 with q = 2 mm; (b) Return loss characteristic of base antenna 2 with q = 2 mm; (c) Return loss characteristic of antenna 2 with q = 2 mm; (d) Return loss characteristic of antenna 3 with q = 2 mm.

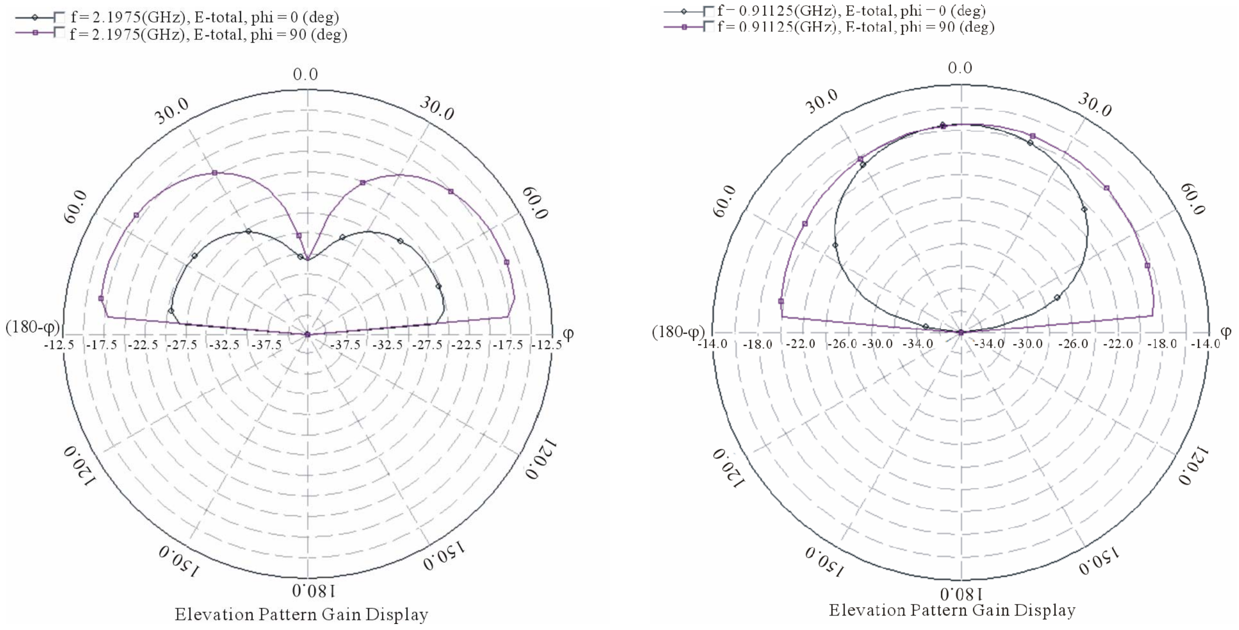

(a) (b)

Figure 8. (a) Simulated radiation pattern of base shape at 2.19 GHz; (b) Simulated radiation pattern at 0.91 GHz for second iteration.

slot of first iteration. These antennas may find application in wireless communication systems.

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7

New Antenna Array Architectures for Satellite Communications

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Universidad Politécnica de Madrid,
Spain

1. Introduction

Ground stations which integrate the control segment of a satellite mission have as a common feature, the use of large reflector antennas for space communication. Apart from many advantages, large dishes pose a number of impairments regarding their mechanical complexity, low flexibility, and high operation and maintenance costs. hus, reflector antennas are expensive and require the installation of a complex mechanical system to track only one satellite at the same time reducing the efficiency of the segment (Torre et al., 2006).

With the increase of new satellite launches, as well as new satellites and constellation of low earth orbit (LEO), medium earth orbit (MEO), and geostationary earth orbit (GEO), the data download capacity will be saturated for some satellite communication systems and applications. Thus, the feasibility of other antenna technologies must be evaluated to improve the performance of traditional earth stations to serve as the gateway for satellite tracking, telemetry and command (TT&C) operation, payload and payload message or data routing (Tomasic et al., 2002). One alternative is the use of antenna arrays with smaller radiating elements combined with signal processing and beamforming (Godara, 1997).

Main advantages of antenna arrays over large reflectors are the higher flexibility, lower production and maintenance cost, modularity and a more efficient use of the spectrum. Moreover, multi-mission stations can be designed to track different satellites simultaneously by dividing the array in sub-arrays with simultaneous beamforming processes. However, some issues must be considered during the design and implementation of a ground station antenna array: first of all, the architecture (geometry, number of antenna elements) and the beamforming process (optimization criteria, algorithm) must be selected according to the specifications of the system: gain requirements, interference cancellation capabilities, reference signal, complexity, etc. During implementation, deviations will appear as compared to the design due to the manufacturing process: sensor location deviation and sensor gain and phase errors (Martínez & Salas, 2010). In an antenna array, the computation of a close approach of the direction of arrival (DoA) and the correct performance of the beamformer depends on the calibration procedure implemented.

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This chapter is organized with the following sections. Section 2, introduces the relationship between applications and antenna design architectures. Section 3, introduces the new antenna array architectures for satellite communication including motivation and explains experimental examples. Section 4, explains adaptive antenna array and receiver architectures for adaptive antennas systems considering the beamforming with synchronization algorithms. Finally, Section 5 explains the A3TB concept.

2. Applications and antenna design architectures

In recent effort, new antenna array architectures have been under analysis and development. In (Tomasic et al., 2002) a highly effective, multi-function, low cost spherical phased array antenna design that provides hemispherical coverage is analyzed. This kind of novel architecture design, as the geodesic dome phased array antenna (GDPAA) presented in (Tomasic et al., 2002) preserves all the advantages of spherical phased array antennas while the fabrication is based on well-developed, easily manufacturable, and affordable planar array technology (Liu et al., 2006; Tomasic, 1998). This antenna architecture consists of a number of planar phased sub-arrays arranged in an icosahedral geodesic dome configuration.

In contrast to the about 10 *m* diameters dome of the GDPAA, there is the geodesic dome array (GEODA) (Sierra et al., 2007) with 5 *m* diameters dome. This antenna, presented in Fig. 1, has two geometrical structure parts. The first one, is based on a cylinder conformed by 30 triangular planar active arrays, and the second is a half dodecahedron geodesic dome conformed by 30 triangular planar active arrays. The GEODA is specified in a first version for satellite tracking at 1.7 GHz, including multi-mission and multi-beam scenarios (Martínez & Salas, 2010). Subsequently, the system of the GEODA has been upgraded also for transmission (Arias et al., 2010).

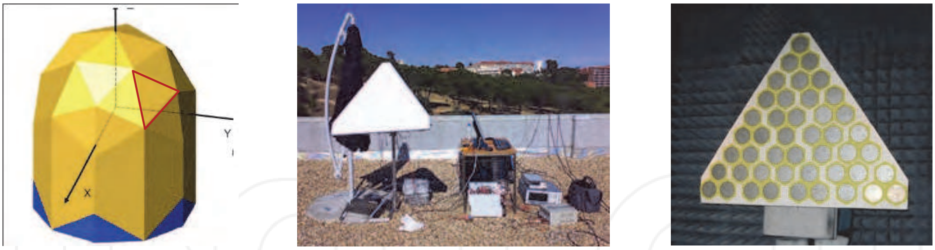

a b c

Fig. 1. a) The GEODA, b) The active sub-array demonstration, and c) The 45 elements planar active sub-array.

The antenna arrays technology in the user segment for satellite communications will substitute reflectors providing a more compact and easy to install antenna system, which is an interesting solution e.g. for satellite on the move (SOTM) system. There is a great diversity of solutions for fixed and mobile satellite communication systems including a large number of applications. Inmarsat broadband global area network (Inmarsat-BGAN) (Franchi et al., 2000) is the most representative example among mobile satellite systems (MSS), which gives land, maritime and aeronautical high speed voice and data services with global coverage using GEO satellites at L-band.

MSS services are divided into two groups, those that offer a regional coverage usually with GEO satellites, and those which offer a global coverage based on LEO or MEO satellite constellations. Depending on the coverage, there are some examples for MSS with regional coverage as the mobile satellite system (MSAT) in EEUU, Canada and South America, Optus in Australia, N-Star in Japan, Asia cellular satellite (ACeS) in Asia or Thuraya in the Middle East and in the North of Africa. While for MSS of global coverage there are some examples as Iridium, ICO Global Communications, Globalstar, Teledesic, etc. (Evans, 2009; Wu, 1994). Most of the MSSs work at L and S band, new applications on satellite to mobile terminal links work at X, Ku and Ka band, and satellite to base station connections work at L, S and C band. A number of applications is broad and lead terrestrial telecommunications market to offer a wider coverage: high speed voice and data (internet access, SMS, VoIP), digital video broadcasting by satellite 2 (DVB-S2) and digital video broadcasting satellite services to handhelds (DVB-SH), global position system (GPS) and Galileo, security, control and machinery monitoring on ships and aircrafts, teleeducation or telemedicine.

These modern satellite communications systems require new antenna solutions for base stations, aeronautical applications or personal communications services (PCS) on-the-move (Fujimoto & James, 2001). Within these applications, antenna array systems are potentially the best choice due to, as discussed above, its capability to perform electronically steering or beamforming, increase the antenna gain, and conform over curved or multifaceted surfaces the radiating elements. Portable antennas for PCS must be easy to install and mechanically robust, besides compact and lightweight (García et al., 2010) as the antenna array presented in Fig. 4.a. The design of antenna systems to provide high data rates for reliable PCS boarded on ships is not so strict in term of the geometrical requirements because it does not have space limitations (Geissler et al., 2010). However, in the case of land or airborne vehicles, geometrical and mechanical constraints are more severe. Antennas for terrestrial vehicles must be low profile, and for airborne vehicles aerodynamic shapes must be considered (Baggen et al., 2007; Vaccaro et al., 2010). Moreover, for the civil market conformal antenna arrays (Schippers, 2008; Kanno et al., 1996), or multi-surface arrays (Khalifa & Vaughan, 2007) are suitable choices to deal with the system aesthetic partiality.

Technological challenges have been faced during the implementation of satellite communication systems in the last decades. The design of a Test-Bed flexible and modular for testing or debugging beamforming algorithms and receiver architectures is an invaluable contribution in the educational, research and development area on satellite communication systems. The adaptive antenna array Test-Bed (A3TB) concept is based on the use of antenna arrays with beamforming capability to receive signals from LEO satellites (Salas et al., 2008). The scope of the A3TB is to probe the concept of antenna arrays applied to ground stations instead of reflectors for different applications, such as telemetry data downloading. It is also a good chance for Universities and Research Centers aiming to have their own ground station sited in their installations.

The A3TB ground station relies on the use of an antenna array to smartly combine the received signals from the satellite thanks to the implementation based on software defined radio (SDR) technology. The advantages of the SDR implementation is that A3TB architecture can be used to process any received signal from LEO satellites in the band imposed by the radio frequency (RF) circuits. Moreover, most of the processing is performed in software, so that appropriate routines can be used to process any received signal. The A3TB can be used to analyze the feasibility of different receivers and beamformer algorithms, regarding the capability to switch the receiver architecture in terms of the synchronizer algorithm configuration (Salas et al., 2007).

The current version has been developed to track The National Oceanic and Atmospheric Administration (NOAA) satellites in the very high frequency (VHF) band, in particular, the automated picture transmission (APT) channel (Salas et al., 2008). Previous versions of A3TB dealt with low rate picture transmission (LRPT) signals from the meteorological operational satellite-A (MetOp-A), where a complete receiver with beamforming and synchronization stages has been implemented (Salas et al., 2007; Martínez et al., 2007).

3. Antenna arrays for satellite communications

Satellite applications require compactness, lightweight and low cost antenna systems to be mounted on a terrestrial vehicle, an aircraft or a ship, or as a portable man-pack or a handset, and to be competitive against ground systems. Its major advantage is the possibility of getting a wider or even a global coverage. For such purposes, antenna arrays offer the technology to get a directive system whose steering direction can be electronically and/or mechanically controlled. However, planar arrays usually cannot steer more than 60^o-70^o from the normal direction of the antenna (Mailloux, 2005). Thus, when a wider angular coverage is required conformal arrays are an appropriate option (Josefsson & Persson, 2006). Arrays can approximate conformal shapes, such as spheres or cylinders, using several planar arrays, simplifying fabrication of active components (Sierra et al., 2007).

Since the low cost and low weight specifications are of importance, micro-strip antennas are mostly used, due to its capacity to be printed over a dielectric substrate with photolithography techniques. Low cost and low permittivity substrates are usually used such as FR4 or PTFE with different quantities of glass or ceramic impurities. For more demanding applications, ceramics, like alumina or high/low temperature co-fired ceramics (HTCC/LTTC) allow the use of smaller components thanks to its high permittivity, and give robustness against mechanical stresses and high temperatures.

3.1 Geodesic antenna array for satellite tracking in ground station

The aim of using a single antenna for tracking many satellites at the same time avoiding mechanical movements as well as its inexpensive cost make these antennas an alternative to be considered (Salas et al., 2008). Multi-beam ability and interference rejection are facilitated thanks to the electronic control system of such antennas that improves the versatility of the ground stations.

The GEODA is a conformal adaptive antenna array designed for MetOp satellite communications with specifications shown in Table 1. This antenna was conceived to receive signals in single circular polarization (Montesinos et al., 2009). Subsequently, in recent efforts the system has been upgraded also for transmission and double circular polarization (Arias et al., 2010). Hence, operating at 1.7 GHz with double circular polarization it can communicate with several LEO satellites at once in Downlink and Uplink. Current structure is the result of a comprehensive study that valued the ability to cover a given spatial range considering conformal shape surface and a given beamwidth (Montesinos et al., 2009). As Fig. 1 shows, GEODA structure consists of a hemispherical dome placed on a cylinder of 1.5 meters height. Both cylinder and dome are conformed by 30 similar triangular planar arrays (panels). Each panel consists of 15 sub-arrays of 3 elements (cells). The radiating element consists of 2 stacked circular patches with their own

RF circuits. The principal patch is fed in quadrature in 2 points separated 90º in order to obtain circular polarization. The upper coupled patch is used in the aim of improving the bandwidth.

Each panel is able to work itself as an antenna since they have a complete receiver that drives the 1.7 GHz signal to an analog to digital converter (ADC). In order to adapt the signal power to the ADC, it is mandatory to implement a complete intermediate frequency (IF) receiver consisting of heterodyne receiver with an automatic gain control block. Hence, each triangular array has active pointing direction control and leads the signal to a digital receiver through an RF conversion and filtering process. To follow the signal from the satellite, the main beam direction has to be able to sweep an angle of 60º. In this way, it is needed a phase shift in the feeding currents of the single radiating element. Previous calculations have demonstrated that 6 steps of 60 degrees are needed to achieve the required sweeping angle. An adaptive digital system allows the adequate signal combination from several triangular antennas. The control system is explained in (Salas et al., 2010).

Parameter	Specification	Parameter	Specification
Frequency range [GHz] **Tx:** **Rx:**	1.65 to 1.75 1.65 to 1.75	**Isolation between Tx and Rx [dB]**	>20
Polarization	Dual circular for Tx and Rx bands	**VSWR**	1.2:1
G/T [dB/K] **For elevation >30º** **For elevation 5º**	3 6	**SLL [dB]**	-11
EIRP [dBW]	36	**Size [m]**	1.5x1.5x3
3dB beamwidth [deg.]	5	**Accuracy steering [deg.]**	±1.4
Maximum gain [dBi]	29	**Coverage [deg.]:** **Azimuth** **Elevation**	360º >5º
Efficiency [%]	50		

Table 1. Main specifications for GEODA antenna.

3.1.1 Cell radiation pattern

Based on the study presented in (Sierra et al., 2007), the single radiating element is a double stacked circular patch that works at 1.7 GHz with 100 MHz bandwidth. In order to obtain circular polarization, the lower patch, which has 90 mm diameter, is fed by 2 coaxial cables in quadrature. Both coaxial cables connect the patch with a hybrid coupler to transmit and receive signals with both, right and left, circular polarizations. The upper patch is a circular plate with 78.8 mm diameter, and it is coupled to the lower patch increasing the bandwidth by overlapping both resonant frequencies tuning the substrate thickness and the patch diameter size. Fig. 2.a shows the radiating element scheme and main features of the layer structure are specified in (Montesinos et al., 2009).

A cell sub-array of 3 radiating elements shown in Fig. 2.b is considered the basic module to build the planar triangular arrays. The whole cell fulfills radiation requirements since it has a good polar to crosspolar ratio and a very low axial ratio. Likewise, as it is presented in Fig. 2.c, the radiation pattern shows symmetry and low side lobes for full azimuth.

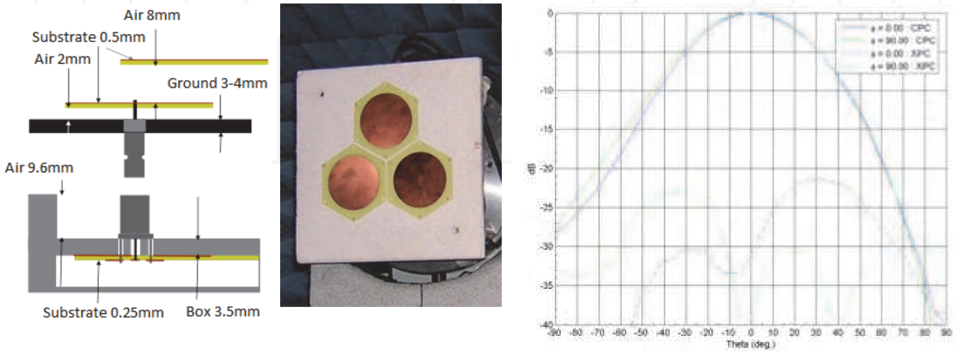

a b c

Fig. 2. a) Assembly of the single radiating element, b) Cell scheme, and c) Cell radiation pattern.

3.1.2 Transmission and Reception (T/R) module and cell distribution

Different T/R module configurations have been considered, providing either single or double polarization (Arias et al., 2010). T/R module allows amplifying and controlling the phase shift between signals, received and transmitted, providing an adaptive beam and steering direction controller in the whole working pointing range. As Fig. 3 shows, the design implemented contains a hybrid coupler, enabling double circular polarization; a double pole double throw (DPDT) switch, selecting polarization associated with transmission and reception way; 2 low noise amplifiers (LNAs), which amplify the signal received or transmitted; a single pole double throw (SPDT) switch, choosing transmission or reception way; and phase shifters, introducing multiples of 22.5° relative shift phases to form the desired beam. These surface mount devices have been chosen in order to reduce space and simplify the design.

Signals transmitted/received by the 3 T/R modules placed in a cell are divided/combined thanks to a divider/combiner circuit composed of 3 hybrid couplers that leads the signal to a general T/R module where signal is amplified. Due to transmission and reception duality, 2 SPDT switches are used to select the amplification way. Furthermore, each T/R module has associated a -25dB directional coupler that is used to test T/R modules in the transmission mode. Additionally, reception mode is tested by measuring signal in the divider/combiner circuit. A single pole 6 throw (SP6T) switch selects the path that is tested.

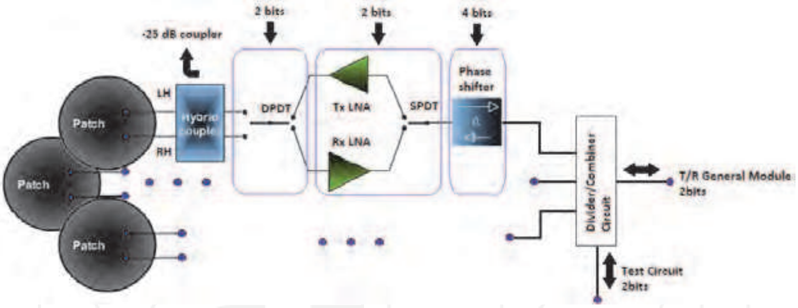
2 bits
2 bits
4 bits
-25 dB coupler
LH
RH
Hybrid coupler
DPDT
Tx LNA
Rx LNA
SPDT
Phase shifter
Patch
Patch
Patch
Divider/Combiner Circuit
T/R General Module 2bits
Test Circuit 2bits

Fig. 3. Cell sub-array and RF circuit.

3.1.3 Control system

The control system has two main parts (Salas et al., 2010), the hardware structure and the control software. The two level hardware structure has the lowest possible number of elements, making the control simpler in contrast to the previous in (Salas et al., 2010). Finally, an inter-integrated circuit (I2C) expander is used to govern T/R modules individually, and one more cover cell needs (LNA of call and test). A multipoint serial standard RS-485 is used to connect the computer with the panels.

3.2 Portable antenna for personal satellite services

New fix and mobile satellite systems (Evans, 2000) require antenna systems which can be portable, low profile and low weight. Planar antennas are perfect candidates to fulfill these specifications. Usually slots (Sierra-Castañer et al., 2005) and printed elements (García et al., 2010) are most used as radiating elements.

3.2.1 Antenna system structure

In this subsection it is introduced a printed antenna for personal satellite communications at X band, in Fig. 4. Table 2 shows main antenna characteristics.

Parameter	Specification	Parameter	Specification
Frequency range[GHz] **Tx:** **Rx:**	7.9 to 8.4 7.25 to 7.75	**Efficiency [%]**	50
Polarization	Dual circular polarization for Tx and Rx bands	**Isolation between Tx and Rx [dB]**	>17
G/T [dB/K]	7	**VSWR**	1.4:1
EIRP [dBW]	32	**SLL [dB]**	-11
3dB beamwidth [deg.]	5	**Size [m]**	40x40x2.5
Maximum gain [dBi]	25	**Weight [Kg]**	2

Table 2. Portable antenna specifications.

This is a planar, compact, modular, low loss and dual circular polarized antenna, for Tx and Rx bands, simultaneously. It is made up by a square planar array of 16x16 double stacked micro-strip patches, fed by two coaxial probes. A hybrid circuit allows the dual circular polarization (Garg et al., 2001). Elements are divided in 16 sub-arrays excited by a global power distribution network of very low losses, minimizing the losses due to the feeding network and maximizing the antenna efficiency. In order to reduce side lobe levels (SLL), the signal distribution decreases from the centre to the antenna edges, keeping symmetry with respect to the main antenna axes. The antenna works at X band from 7.25 up to 8.4 GHz with a 14.7% relative bandwidth for a 1.4:1 VSWR and a maximum gain of 25 dBi.

3.2.2 Sub-array configuration

The sub-array configuration can be seen in Fig. 4.a. It makes possible to separate the fabrication of these sub-arrays from the global distribution network, simplifying the corporative network and getting a modular structure suitable for a serial fabrication process. Each sub-array is a unique multilayer board, where PTFE-Glass substrate of very low losses has been used as base material. The power distribution network is connected to each sub-array through (SMP-type) coaxial connectors.

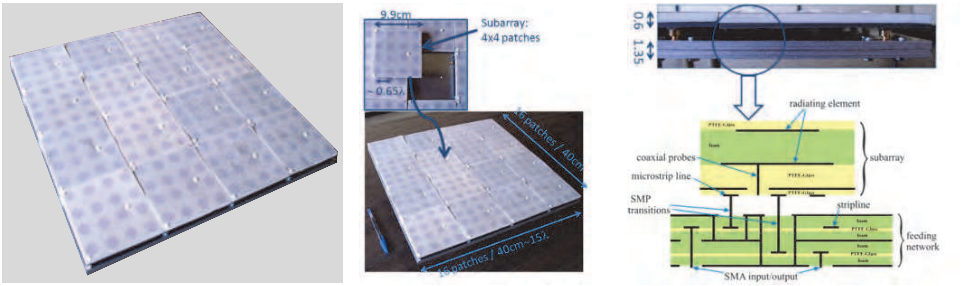

a b c

Fig. 4. a) Dual polarized portable printed antenna for satellite communication at X band, b) Sub-array perspective view, and c) Side view and multilayer scheme.

Fig. 5.a and Fig. 5.b show the sub-array unit cell. In order to obtain better polarization purity, each element is rotated 90º and excited by a 90º phase-shifted signal. Moreover, in Fig. 5.c is showed a miniaturized branch-line coupler (BLC) of three branches working as a wide band hybrid circuit (García et al., 2010; Tang & Chen, 2007).

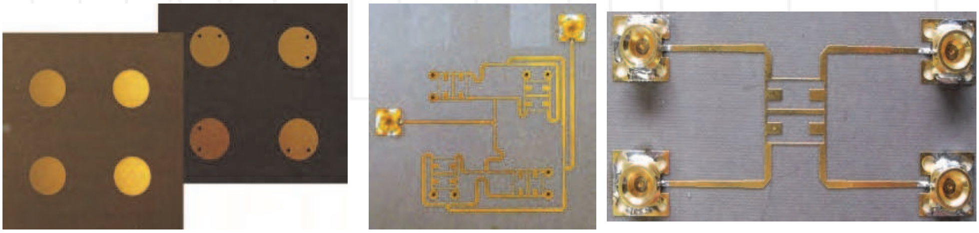

a b c

Fig. 5. Unit cell test board, a) Unit cell test board 2x2 stacked patches, b) Micro-strip feeding network, and c) Miniaturized BLC Prototype.

A conventional configuration takes up an area of 13.3 cm^2 which is big compared to the radiating element and the sub-array subsystem size. Therefore, a miniaturization of the BLC is needed using the equivalence between a $\lambda/4$ transmission line and a line with an open-ended shunt stub. An area reduction about 35% is achieved and the hybrid circuit behaves like a conventional BLC. In Fig. 6.b and Fig. 6.c measurement results for the BLC in Fig. 5.c are shown compared with simulations.

Fig. 7 depicts some sub-array measurements. The copular to crosspolar ratio is better than 25 dB and axial ratio is under 0.9 dB in the whole bandwidth.

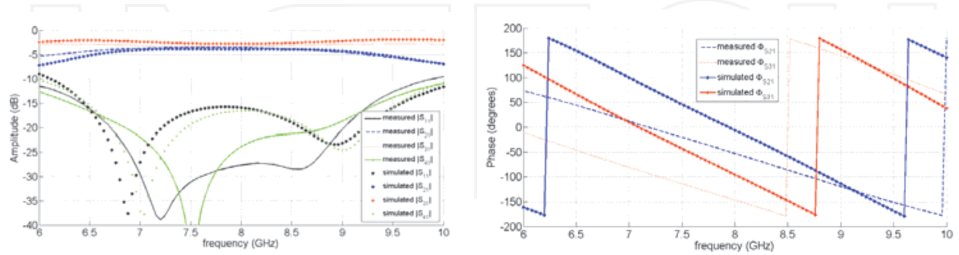

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Fig. 6. Miniaturized BLC, Measured and simulated S-parameters in: a) Amplitude, and b) Phase.

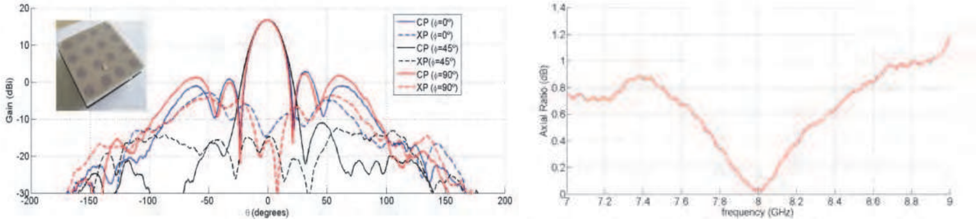

a b

Fig. 7. 4x4 patch sub-array measurements, a) Radiation pattern at 7.75 GHz, and c) Axial ratio for right-handed circular polarization.

3.2.3 Low losses power distribution network

The global feeding network presented in Fig. 8.a is a protected strip-line, where foam sheets of high thickness are used to get low losses. Such a kind of feeding network allows keeping a trade-off between the simplicity of exciting the radiating elements using printed circuits and the loss reduction when the distribution network is separated in a designed structure to have low losses. Losses in the structure are around 0.6 dB/m which yields to 0.3 dB of losses in the line. Two global inputs/outputs using SMA-type connectors, one for each polarization, excite the strip-line networks.

Vertical transitions have to be treated carefully and must be protected to avoid undesired higher order mode excitation. Thereby, it has been design a short-ended pseudo-waveguide, adding some extra losses about 0.3 dB, for two kinds of vertical transitions, as can be seen in Fig. 8.b and Fig. 8.c.

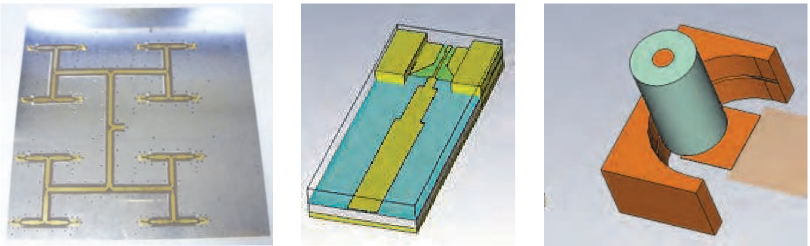

a b c

Fig. 8. a) Protected strip-line global corporative network for one polarization, b) Transitions from strip-line to SMA-type connector, and c) Transitions from strip-line to SMP-type connector.

3.2.4 Antenna performance

Fig. 9 depicts measured radiation pattern at 7.75 GHz, gain and axial ratio for the antenna system. It is shown a maximum gain of 25 dBi in the lower band and about 22 dBi in the upper band, and a SLL around 11 dB. Copolar to crosspolar ratio is better than 30 dB and axial ratio is under 0.7 dB. Total losses are about 4 dB in the working band.

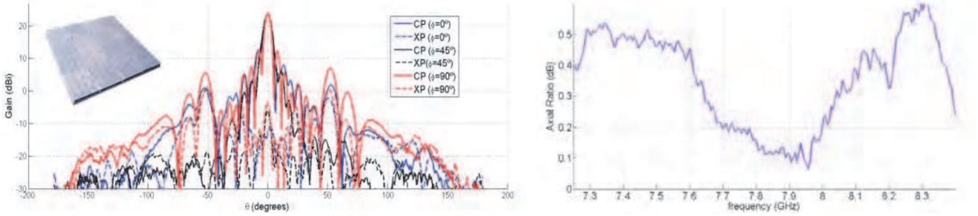

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Fig. 9. Antenna measurements results, a) Radiation pattern at 7.75 GHz, and c) Axial ratio for right-handed circular polarization.

3.3 Electronically steerable antennas for mobile and fixed portable systems

At present, two types of electric steerable antenna systems can be used to access the satellite communication services (Bialkwoski et al., 1996). These are: fixed position portable systems and mobile systems such as those installed on a land vehicle. The fixed portable antenna system is relatively easy to be accomplished by the antenna designer. The design involves standard procedures that concern the operational bandwidth, polarization and moderate gain (García et al., 2010). One drawback of the fixed position portable system is that they require the user to be stationary with respect to the ground. This inconvenience can be overcome with the mobile antenna system. A mobile user complicates the scenario since the ground mobile antenna needs to track the satellite (Alonso et al., 1996). The design of such a system is more challenging as new features associated with the mobility of the system have to be incorporated (Fernández et al., 2009). The requirement leads to a narrow beamwidth, for which satellite tracking is required as the vehicle moves around. Electronically steerable antennas enable the development of reconfigurable antennas for satellite applications.

3.3.1 Steerable antenna for fixed position portable systems

This antenna is a fixed satellite communication system with high gain at X band, consisting of an antenna array that integrates 32 2x2 sub-array modules in the complete antenna, as shown in Fig. 10.a. It is a planar and dual circular polarized antenna for Tx and Rx bands simultaneously. It is made up by a planar array of double stacked circular micro-strip patches, fed by 2 coaxial probes to generate circular polarization. A hybrid circuit allows the dual circular polarization as shown in Fig. 10.b.

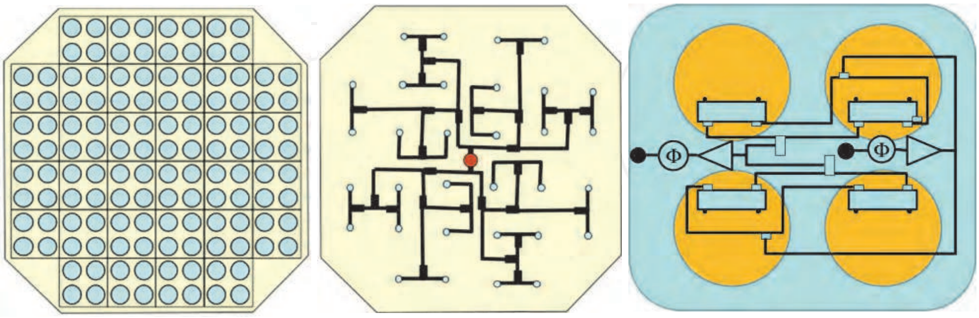

a b c

Fig. 10. Active multi-beam antenna, a) Top view, b) Feeding network of the complete antenna, and c) Beamforming network of the 2x2 sub-array module

The antenna has the same design parameters, structure and configuration as the antenna explained in Section 3.2 but with a different feeding network, as previously shown. In this case, the beamforming network requires changes in the feeding phase in the 2x2 sub-arrays, which can be achieved by phase shifters (ϕ) associated with different sub-arrays (Fig. 10.c). All these sub-arrays are connected to a feeding network, in Fig. 10.b, formed by transmission lines with low losses in strip-line. General specifications of the steerable antenna for fixed position portable systems are provided in Table 3.(a).

3.3.2 Automatic steerable antenna for mobile systems

A broadband circularly polarized antenna for satellite communication in X band is presented in Fig. 11 and specified in Table 3.(b). The arrangement features and compactness are required for highly integrated antenna arrays. It is desired to get a low-gain antenna for mobile satellite communications with low speed of transmission. In this system, the antennas are formed by 5 planar 4x4 arrays of antennas, which form a truncated pyramid with a pointing capability in a wide angular range, so that among the 5 planar arrays the complete antenna can cover any of the relative positions between the mobile system and the satellite in a practical way. The scheme of the active antenna can be seen in Fig. 11.

As it can be observed in Fig. 11.a, the antenna terminal is a multi-beam printed antenna shaped as a trunk pyramid capable of directing a main beam in the direction of the satellite. The antenna steering system consists of a multi-beam feeding structure with switches that lets combine the feed of each 4x4 arrays to form multiple beams. Switching the different 4x4 arrays, it is achieved different multiple beams and the variation of the steering direction.

The complete antenna consists of a Tx and Rx module that works independently in the 2 frequency bands.
The antenna has multiple beams covering the entire space to capture the satellite signal without moving the antenna. The signal detected in each of the beams is connected to a switch, which, by comparison, is chosen the most appropriate 4x4 array. The steering direction of the 4x4 array can vary between a range of directions that covers a cone angle range of 90º. To obtain the required gain and cover the indicated range, it is required around 15 beams, which can be obtained by integrating the beamforming networks with switches in the design as presented in (Fernández et al., 2009).

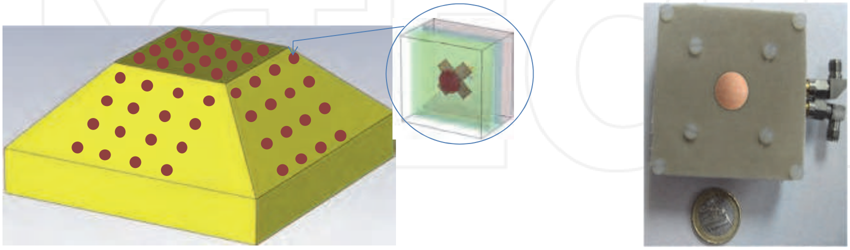
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Fig. 11. Complete antenna structure, a) Radiating element of the 4x4 arrays, and b) Prototype top view.

The radiating element of the 4x4 array is one 2 crossed dipoles with a stacked circular patch as shown in Fig. 11.a and Fig. 11.b. In Fig. 12 the cross-section of the radiating element structure is presented.

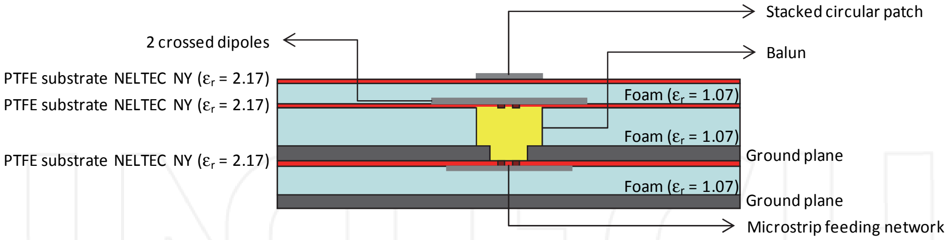
Stacked circular patch
2 crossed dipoles
Balun
PTFE substrate NELTEC NY ($\varepsilon_r = 2.17$)
PTFE substrate NELTEC NY ($\varepsilon_r = 2.17$)
Foam ($\varepsilon_r = 1.07$)
Foam ($\varepsilon_r = 1.07$)
PTFE substrate NELTEC NY ($\varepsilon_r = 2.17$)
Ground plane
Foam ($\varepsilon_r = 1.07$)
Ground plane
Microstrip feeding network

Fig. 12. Cross-section scheme of the radiating element.

The key element of the radiating element feeding structure (Fig. 14.b) is a resonant micro-strip feed ring that has been implemented, as well as a micro-strip 90º branch-line coupler to obtain the desired right hand or left hand circular polarizations (RHCP or LHCP) which ensures adequate port coupling isolation. The S-parameters in amplitude and phase of the micro-strip feeding structure are shown in Fig. 13.a and Fig. 13.b.
Fig. 14.a depicts the S-parameters of the radiating element with the micro-strip feed structure and they fulfill the specification, in Table 3.(b). In Fig. 14.c, the radiation pattern of the radiating element at 7.825 GHz is shown and in Fig. 14.d the radiation pattern of the 4x4

arrays is presented. It is shown a maximum gain of 19.4 dBi at the center frequency band (7.825 GHz). Copolar (CP) to crosspolar (XP) ratio is better than 17 dB and the axial ratio is under -3dB.

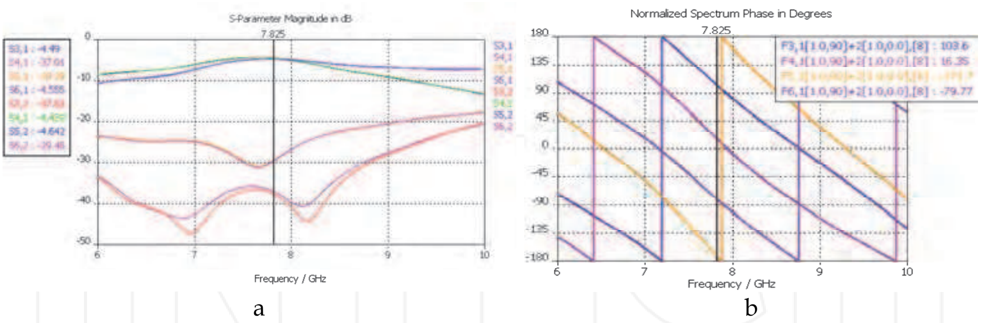

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Fig. 13. Micro-strip feeding structure, a) Amplitude of S-parameters, and b) Phase of S-parameters.

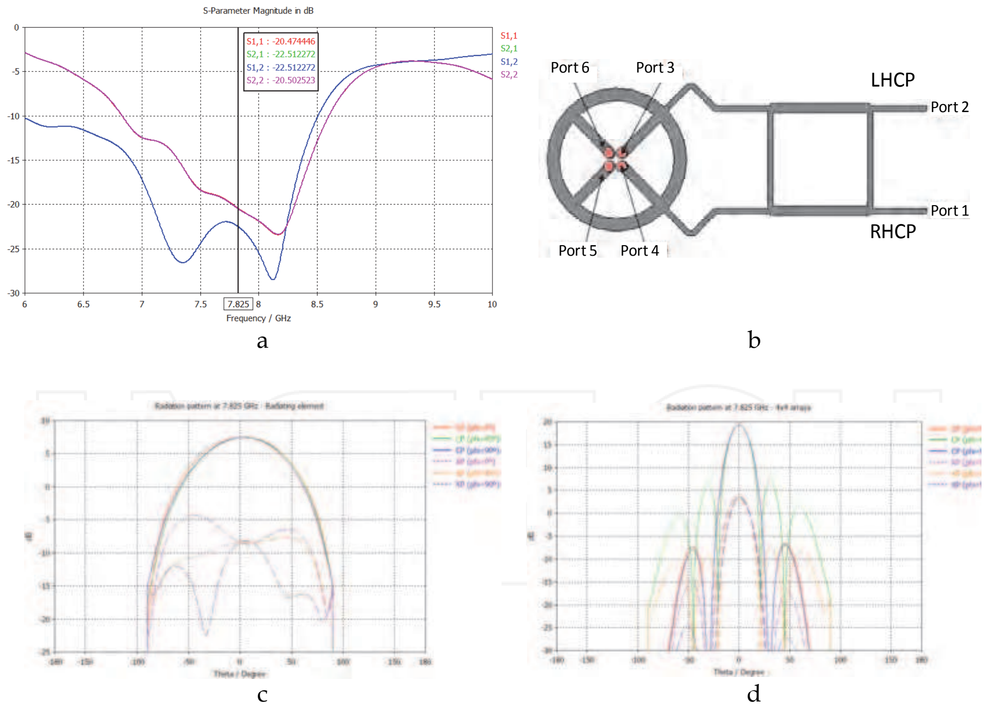

a b

c d

Fig. 14. a) S-parameters, b) Resonant ring + 90º branch-line coupler, c) radiation pattern at 7.825 GHz, and d) 4x4 array radiation pattern.

Parameter	Value (a)	Value (b)	Comments
Freq. range [GHz] **Rx** **Tx**	7.25 - 7.75 7.9 - 8.4	7.25 - 7.75 7.9 - 8.4	Microwave applications.
G/T (in Rx) [dB/K]	7	7	
EIRP (in Tx) [dBW]	32	32	
Beamwidth at -3dB [deg.]	4	20	
Polarization	circular	circular	In both, reception and transmission.
Gain [dBi]	>28	>15	
Axial ratio [dB]	< 1	<3	**(a)** Between ±50^{o}. **(b)** Between ±45^{o}.
VSWR	< 1.4:1 (-15.6 dB)	< 1.5:1 (-13.9 dB)	
Isolation between ports [dB]	< -17	< -15	
Radiation pattern [deg.]	±35	±90	Steering direction tilt.
Dimensions [cm]	40x40x4	20x20x15	

Table 3. (a) General specifications of the steerable antenna for fixed position portable systems , and (b) General features of the automatic steerable antenna for mobile systems.

3.4 Transmit-array-type lens antenna for terrestrial and on board receivers

Technology in satellite communications has revealed an increasing interest in novel smart antenna designs. Phased-array based designs are basic in electronically reconfigurable devices for satellite applications, which are more and more demanding. The strict requirements in terms of architecture, shape and robustness are important constraints for the development of planar lens-type devices. Regarding the usage and location, lens-type devices are useful for either terrestrial or on board receivers, in vehicular technology. Some clear examples are satellite communications for aircrafts preserving the fuselage aerodynamics or for some other kind of vehicles such as trains, etc.

3.4.1 Introduction to lens-type structures

In a general view, in lens-type a particular signal is received (in our case, an electromagnetic wave with specific features in terms of frequency, wave-front, etc.), it is processed (either complex signal processing techniques or only phase correction tasks can be considered in this interface), and finally, the processed signal is retransmitted.

Regarding the lens configuration, a transmit-array lens consists of three well distinguished interfaces: the first one for signal reception, one interface for signal processing, and the last one for processed signal re-radiation, as depicted in Fig. 15.

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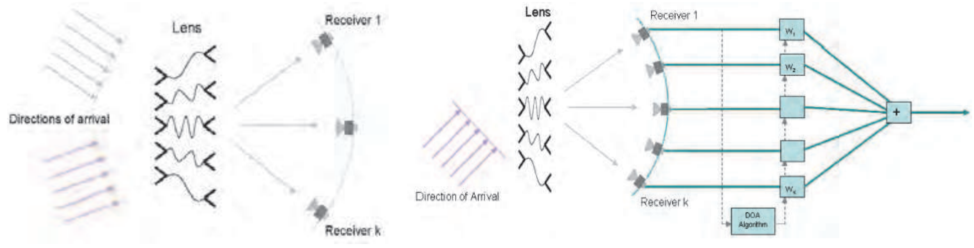

a b

Fig. 15. a) Multi-user scheme with different receivers and transmitters, and b) Adaptive scheme with DoA determination.

These structures are intimately related to reflect-array ones, where the reception and transmission interfaces are turned to be the same interface, with a reflection-type behavior (Encinar & Zornoza, 2001). Although in an equal output phase configuration a transmit-array device behavior would be similar to the one obtained with a reflect-array, the transmit-array offers the advantage of removing the feed blockage.

In a transmission scheme, depending on the transmitter position regarding the lens, a different steering direction is achieved and a different user is pointed. In the case of reception, the situation is the same: the user position configures the direction of arrival, which determines the receiver position around the lens (Padilla et al., 2010a). In adaptive schemes, applying the proper processing algorithm to the signal received in the different receivers around the lens, it is possible to develop an adaptive steering vector, in terms of the desired direction of arrival.

3.4.2 Transmit-array lens architecture and design

Lens-type structures provide two fundamental advantages. First, phase error correction due to spherical wave front coming from the feeding antenna. Fig. 16.a shows this effect. Second, new radiation patterns configuration. Fig. 16.b depicts this fact.

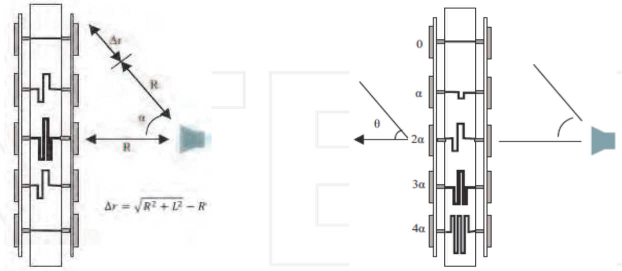

a b

Fig. 16. a) Phase error correction, and b) Radiation pattern reconfiguration.

3.4.3 Electronically reconfigurable devices for active transmit-array lenses

The addition of reconfigurability on transmit-array devices requires the possibility of controlling the phase response of the transmitted signal at each cell of the lens. Electronic control of phase signal may be added in two different ways: First, electronic tuning of the radiating element phase response (Padilla et al., 2010a): Modifications in the radiating element circuital behavior lead to changes in phase response (arg[S_{21}]). Fig. 17 shows an electronically reconfigurable microwave patch antenna for this purpose, along with the equivalent circuit and prototype outcomes in terms of phase.

Second, electronic tuning of phase shifters in transmission lines (Padilla et al., 2010c): Modifications in the phase response of the phase shifters lead to corresponding changes in phase response. Some options are applied for these devices, such as hybrid couplers, etc. Fig. 18 shows a microwave phase shifter prototype for this purpose, along with the working scheme and its outcomes in phase.

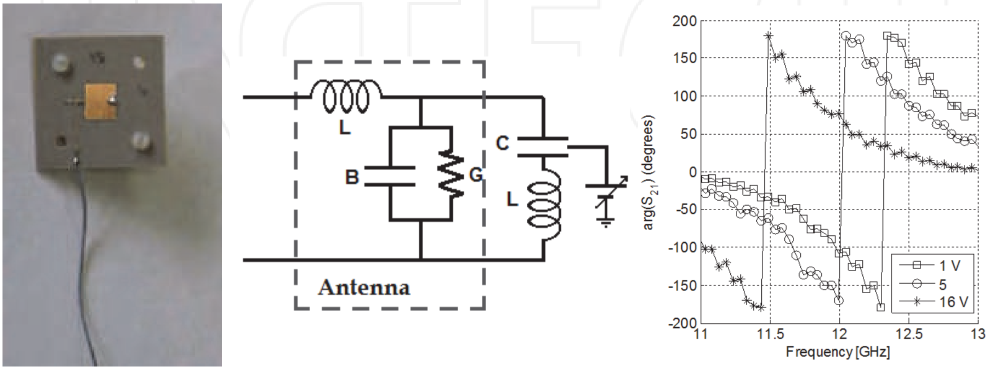

a b c

Fig. 17. Electronically reconfigurable antenna, a) Patch antenna prototypes, b) Equivalent circuit, and c) Phase behavior in frequency.

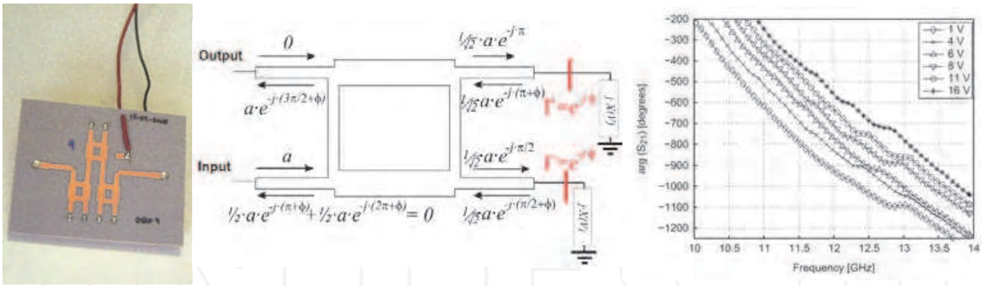

a b c

Fig. 18. Electronically reconfigurable phase shifter, a) Phase shifter prototype, b) Working scheme, and c) Phase behavior in frequency.

3.4.4 Electronically reconfigurable active transmit-array prototype

One electronically reconfigurable prototype is presented in Fig. 19 and detailed in this section. The prototype design implies the use of microwave phase shifters according to the design specified in section 3.4.3. This transmit-array lens prototype operates at 12 GHz. Main specifications are provided in Table 4.

Parameter	Value	Comments
Frequency range [GHz]	12 ± 0.5	Microwave applications.
Polarization	Linear	In both, reception and transmission.
Directivity [dBi]	>21	
Axial ratio [dB]	< 1	Between ±50º elevation.
S_{11} [dB]	< -20	
Radiation pattern [deg.]	±30	Steering direction tilt, for both H and V planes.
Feeding antenna [mm]	120	Corrugated horn linearly polarized
Phase shifters [deg.]	360	Full phase range variation.
Transmit-array elements	36	6x6 array topology.
Separation between elements	$0.7\lambda_0$	Related to the wavelength

Table 4. Main features of the electronically reconfigurable transmit-array prototype.

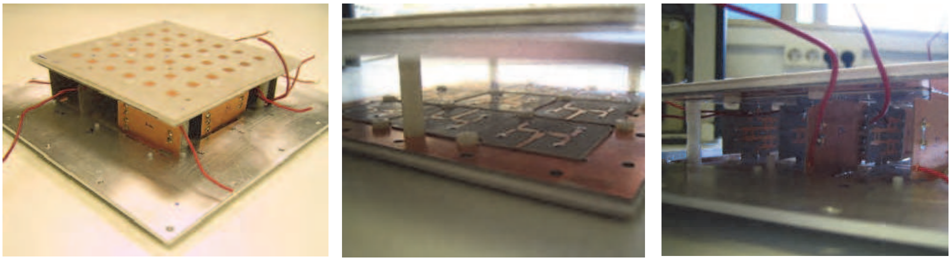

a b c

Fig. 19. Transmit-array core, a) Transmit-array prototype, b) Distribution networks, and c) Phase shifter integration.

The electronically controllable steering capabilities are tested and assured for a range of ± 30ºin each main axis. An example of radiation pattern is provided in Fig. 20, for 9º tilt in one of the main axes.

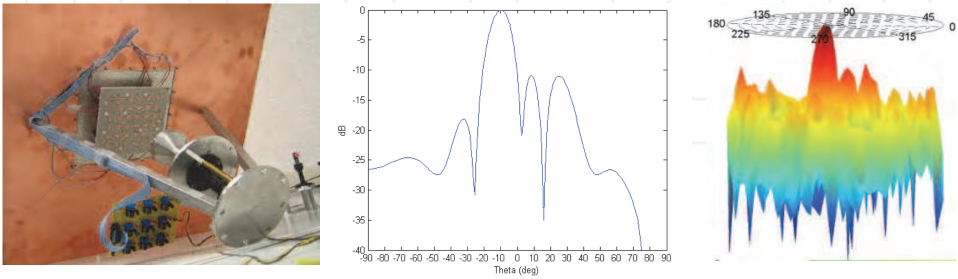

a b c

Fig. 20. a) Complete transmit-array with feeder and control circuits; and transmit-array measurement results for 9º tilt in one axis, b) H plane, and c) 3D plot.

4. Adaptive antenna array

Adaptive antennas can be described as systems usually based on three main parts: the antenna array, the receiver architecture and the beamforming scheme. Thus, adaptive antennas have those advantages owing to those three main parts. The system capabilities increase as complexity and development cost do. Furthermore, since signal processing is the basement of the adaptive antenna concept it is important to analyze the design challenges in terms of hardware architecture and components such as processors and embedded systems.

The antenna array provides the capability of performing the antenna pattern meeting the environment requirement under study. Besides, receiver architectures have some interesting advantages depending on the implemented receiver arraying technique such as signal to noise ratio (SNR) and bit error rate (BER) performance enhancement. Furthermore, symbol synchronization and carrier recovery can be used increasing the receiver complexity but providing higher performances. Finally, beamforming schemes use multiple antennas in order to maximize the strength of the signals being sent and received while eliminating, or at least reducing, interference as discussed in Section 4.3.

Adaptive antenna arrays are often called Smart Antennas because they have some key benefits over traditional antennas, by adjusting traffic patterns, space diversity or using multiple access techniques. The main four key benefits are: First, enhanced coverage through range extension by increasing the gain and steering capability of the ground station antenna; Second, enhanced signal quality through multi-target capability and reduction of interferences; finally, adaptive antennas improve the data download capacity in the ground segment of satellite communication by increasing the coverage range (Martínez et al., 2007).

4.1 Design and architecture based on software defined radio

For design there is the well known waterfall life cyclic model (Royce, 1970) that can be used to manage main aspects of the design of architectures. Thus, some tasks must be fulfilled subsequently as follow in Fig. 21.a.

Fig. 21.b shows the design schemes resulting of the requirement analysis stage corresponding software and hardware system specifications. In the depicted scheme, there are some system components such as the radiating element and RF circuits that are often designed under iterative prototyping model.

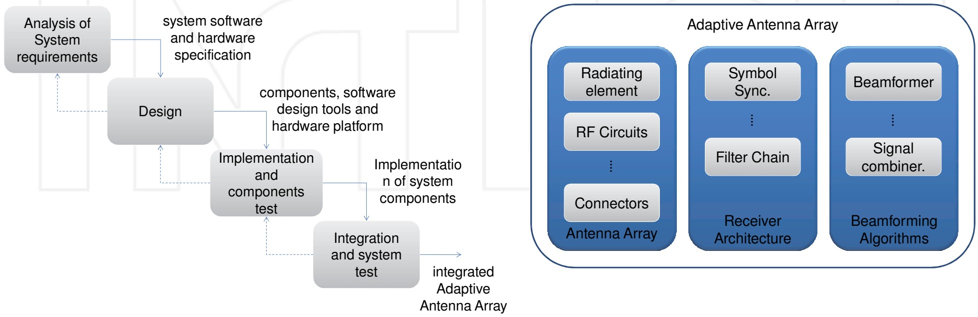
Analysis of System requirements
system software and hardware specification
Design
components, software design tools and hardware platform
Implementation and components test
Implementation of system components
Integration and system test
integrated Adaptive Antenna Array
Adaptive Antenna Array
Radiating element
RF Circuits
Connectors
Antenna Array
Symbol Sync.
Filter Chain
Receiver Architecture
Beamformer
Signal combiner.
Beamforming Algorithms

a b

Fig. 21. a) Water life cyclic model of the adaptive antenna array design, and b) Simplified design scheme of adaptive antenna arrays.

Regarding the hardware implementation, tables presented in (Martínez et al., 2007) show the hardware resource consumption in the field programmable gate array (FPGA) Virtex-4 for the least mean squared (LMS) beamforming algorithm with full spectrum combining (FSC) receiver architecture and SIMPLE beamforming algorithm with symbol combining (SC) receiver architecture. Both scheme designs have an antenna array of 2 elements. The algorithm based on correlation requires less hardware. The main difference can be appreciated in the amount of digital signal processing oriented component (DSP48) resources, typically used for filtering applications (Martínez et al., 2007).

4.2 Receiver architectures based on algorithms type

Several receiver architectures can be implemented, and they are frequently based on the type of the beamforming algorithm used. When training signals are available in the transmitted frame, a time-based reference algorithm can be used. However, this solution is only valid when the earth station is capable of demodulating the received training sequence. Other algorithms used in deep space communications are based on signal correlation and they avoid performing the demodulating process. This kind of algorithms are blind techniques that do not require any additional signal demodulation before applying some beamforming technique and work better in low SNR conditions than time-based algorithms.

Several receiver architectures can be implemented exploiting the processing capabilities of the SDR, such as FPGA, application-specific integrated circuits (ASICS), and digital signal processing (DSPs). The design of the receiver architecture fundamentally depends on the selection of beamforming algorithms. An example of beamforming technique is the LMS algorithm whose estimation of coefficients or weights requires a temporal reference and is implemented through SC receiver architecture (Fig. 22.a). In the other hand, the SIMPLE algorithm (Rogstad, 1997) constitutes a beamforming technique that is implemented using FSC receiver architecture (Fig. 22.b) in order to perform the calculation of weights.

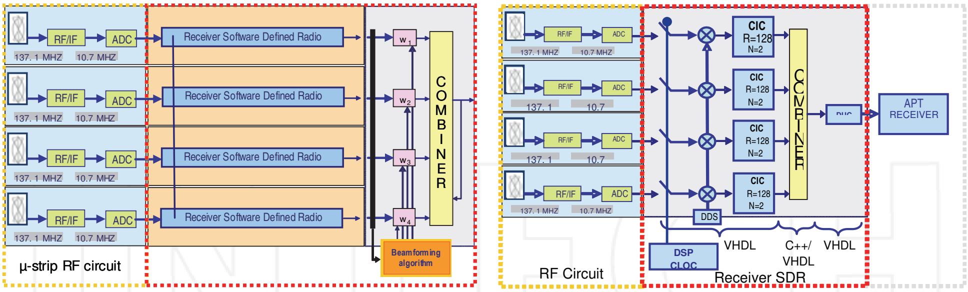

a b

Fig. 22. Comparison of receiver architectures. a) Symbol Combining (SC), and b) Full Spectrum Combining (FSC).

The SC architecture can be divided into two more sub-classes which work on a phase-recovery basis. The complex symbol combining (CSC) recovers the phase information with regard to a reference element using feed-forward and feedback algorithms. One of the advantages of this scheme is that the rate of data sent to the combining module has a rate slightly higher than the symbol rate. For most applications, the symbol rate is relatively low and is a multiple of the data rate. In this kind of schemes, there is an important cost consideration in real-time applications and the requirements of instrumental phase stability are very severe (Rogstad et al., 2003). Other type of SC architecture is the stream symbol combining (SSC). In this kind of scheme, data are sent to the combining module at a rate equal to the symbol rate. The symbol rate depends on the coding scheme and for most applications is relatively modest. Also, the requirements of instrumental phase stability are no severe, as in the case of CSC scheme. The disadvantage of the SSC is the additional hardware required for each antenna.

Furthermore, there are the baseband combining (BC) and carrier arraying (CA) architectures discussed in (Rogstad et al., 2003). In BC architectures the signal from each antenna is carrier locked and combining in baseband for further demodulation and synchronization. In effect, the carrier signal from the spacecraft is used as a phase reference so that locking to the carrier eliminates the radio-frequency phase differences between antennas imposed by the propagation medium. Besides, in CA architectures, one individual carrier-tracking loop is implemented on each array element. Then, the elements branches are coupled in order to increase the carrier-to-noise ratio (CNR), but losses of radio channel are far compensated (Rogstad et al., 2003).

In general, the selection of the beamforming algorithms is determined by the following aspects: Hardware and computational resources; Speed of convergence and residual error of adaptive algorithms; Calibration requirements and auto-compensation ability; and system signal-transmission characteristics.

4.3 Beamforming techniques for satellite tracking

Some satellites transmit useful information inside its frames for synchronization and tracking purposes. The gathering of satellite data requires the tracking operation along its earth orbit. To accomplish this goal with adaptive array architectures, some beamforming techniques should be implemented. Fig. 23 illustrates a simple example of a narrowband linear adaptive beamformer system.

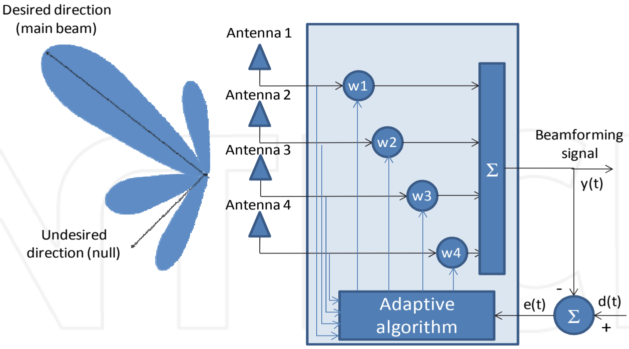

Fig. 23. Adaptive antenna system.

A linear beamformer combines signals according to some weights w_i, to produce a desired radiation pattern. The mathematical expression of a linear beamformer at the array output in vector notation can be expressed as $y = w^H x$, where x is the received signal vector to be combined, w are the weights computed by the beamforming algorithm and ^{H} denotes transposition and conjugate of $(\cdot)$.

In adaptive antennas design, weights are dynamically calculated with a certain algorithm in order to optimize some signal parameter like signal to interference-plus-noise ratio (SINR), SNR, or BER. An extended variety of algorithms exist in the literature for beamforming purpose and the most appropriated selection is done depending on the signal characteristics of the received signal.

4.3.1 Blind techniques

Blind beamformers make use of an inherent property of the received signal, such as the ciclo-stationarity of the constant modulus. In the latter, the algorithm eliminates the fluctuation of the signal amplitude and computes the weights to minimize the effect produced by those variations. The algorithms that make use of these methods are denoted as Constant Modulus Algorithms (CMA) (Biedka, 2001).

CMA algorithms present an important disadvantage: as the phase information is not considered, the constellation of quadrature phase shift keying (QPSK) signals commonly used in satellite communications appears rotated after beamforming, which imposes the need of an additional phase recovery subsystem in the array output.

4.3.2 Temporal-reference algorithms

Algorithms based on a temporal reference require a known reference included in the frame of the signal, such as training sequences, unique word (UW) or pilot bits. Thus, these schemes are normally used for digital signals. The aim of these beamformers is the minimization of the energy of an error signal integrated by interferences and noise. In order to reduce the order of the problem, the weight calculation is usually done iteratively.

The most popular adaptive filters are the LMS and Recursive Least Squares (RLS) algorithms (Haykin, 2002). Briefly, the main differences lie in the method to calculate and the final convergence behavior: while LMS has a linear complexity order with the number of antennas in the array, RLS makes use of matrix operation, so that the complexity order is quadratic, but the convergence is faster.

An interesting alternative to the LMS is the Normalized LMS (NLMS), which normalizes the adaptive step to avoid variation during the convergence process. The counterpart is the more intensive processing requirements to calculate signal power and normalization operation.

4.3.3 Correlation-based algorithm

In contrast to beamformers based on temporal reference, schemes based on signal correlation do not require the demodulation of any signal. These techniques are the most popular to extract the spatial information for beamforming, and we have focused on the use of the SIMPLE algorithm (Rogstad, 1997). This algorithm has been used by the Deep Space Network (DSN) of National Aeronautics and Space Administration (NASA) to combine the signals received from spatial probes in radio telescopes located in different sites around the Earth surface. The main disadvantage of correlation based schemes is the lack of ability to cancel interference signals.

4.4 Performance comparison

Some simulation comparisons between spatial and blind algorithms are presented to show benefits and drawbacks. Four algorithms have been selected with a 4-element uniform linear array (ULA). The spatial algorithms simulated are post-beamformer interference canceller – orthogonal interference beamformer (PIC-OIB) (Godara, 2004) and minimum power distortionless response (MPDR) (Van Trees, 2002). On the other hand, the blind algorithms are the matrix-free EIGEN and the SUMPLE (Rogstad, 1997). The convergence process is compared as a function of the input SNR as depicted in Fig. 24.

As it can be observed from the above results, spatial algorithms outperform blind ones at low SNR, and vice versa. On the other hand, with medium-low SNR and low or absence of interferences, the behavior of all algorithms is quite similar.

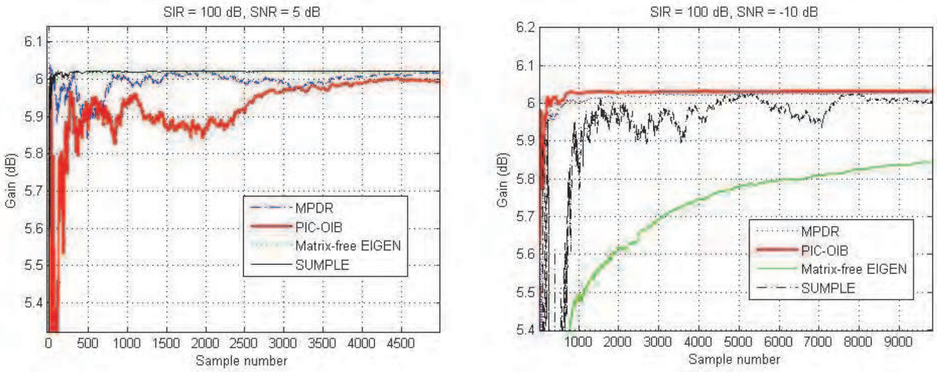

a b

Fig. 24. Convergence behavior of spatial versus blind algorithms in the absence of interferences with several input SNR. a) SNR = 5 dB, and b) SNR = -10 dB.

5. Experimental Test-Bed based on SDR platform

This section presents a test platform known as Adaptive Antenna Array Test-Bed - A3TB, where a comparative study of several beamforming algorithms can be performed and modularity of the architecture is a well proved advantage. The test bed is based on SDR technology and uses a novel architecture that can be used with both blind and spatial-based beamforming algorithms. The A3TB concept can be applied to a number of scenarios as the current version is independent of the signal properties. Simulation results using the A3TB with the APT channel from NOAA satellites show the performance of the concept and the feasibility of the proposed implementation.

The scope of the system development was is to prove the concept of antenna arrays applied to ground stations instead of reflectors for different applications, such as telemetry data downloading or end-user in mobile applications as discussed in the introduction section. In contrast to reflector antennas, antenna arrays offer the possibility of electronic beam-steering avoiding the use of complex mechanical parts and therefore reducing the cost of the antenna. It is also a good chance for Universities and Research Centers aiming to have their own ground station sited in their installations.

5.1 A3TB concept

The A3TB can be defined as *a software-defined radio beamformer applied to a ground station for tracking LEO satellites*. The novelty relies on the use of an antenna array to smartly combine the received signals from the satellite and its implementation based on SDR technology. The reason to use an antenna array instead of a single antenna is to electronically steer the beam in the direction of the satellite along its orbit without requiring a mechanical system for tracking. In addition to the advantages of the use of SDR technology and antenna array, it is the modularity and flexible architecture implemented in the A3TB. Fig. 25 shows the A3TB architecture where it is evident the feasibility to update or change during operation any of the main blocks. It is possible to change during operation the beamforming algorithm and to include new beamforming modules to the system. Furthermore, changes on the BENADC are possible to implement not during operation, but new receiver architecture at off-line such as those options discussed at follow.

In (Salas et al., 2007), the block diagram represents the software system implementation of the first version of the test-bed prototype and most of it is based on VHDL. Depending on the firmware, three options could be installed into the FPGA Virtex4. The option A is implemented with the signal processing on the PC, so the SIMPLE beamforming is done in the module developed in C++. The option B is implemented completely on VHDL and this option need to export the beamforming weights just to draw the array pattern diagram. Finally, in contrast to the option B, the option C is implemented for the LMS beamforming algorithm.

With the first version of the Test-Bed, the modularity on the selection of firmwares was proved switching between A, B or C receiver architectures, and an important result of the Test-Bed development is the hardware resources occupation presented in (Salas et al., 2007).

The advantage of the SDR implementation is that A3TB architecture can be used to process any received signal from a LEO satellite in the appropriate band imposed by the RF stages. Moreover, most of the processing tasks are performed on software, using appropriate routines to process any receive signal. There are 2 main schemes to implement the beamforming stage: SC and FSC [41]. Both schemes are compared in Section 4.2.

The current version of the A3TB in Fig. 25.a was updated to track NOAA satellites in the VHF band, in particular the APT channel. Previous versions of A3TB dealt with LRPT signals from MetOp-A, where a complete receiver with beamforming and synchronization stages has been implemented(Salas et al., 2007; Martínes et al., 2007).

5.2 Implementation of the A3TB

The A3TB prototype consists of 4 main parts as shown in Fig. 25.a. The first part is the antenna array, which has 4 crossed-dipole antennas as depicted in Fig. 25.b. The second part consists of RF-IF circuits which amplify and down convert to IF incoming signals. Furthermore, an automatic gain control (AGC) was implemented using two steps of variable attenuators in the IF domain.

The third part is the SDR platform which consists of the beamforming algorithms implemented on C++ and the FPGA firmware on VHDL, PC and BENADC blocks show in Fig. 25, respectively. The hardware resources occupation for this Test-Bed implementation is similar to one presented in (Martínes et al., 2007). The last part is the software from weather satellite signal to image decoder (WXtoImg) on the PC using the sound card output/input in order to get the weather satellite image.

Since the implemented architecture is FSC the demodulation is not required and the IF signal is digitized. For the signal processing hardware design the BenADC-v4 has been chosen. This solution includes a FPGA Xilinx Virtex4-SX55 with four 12-bit analog inputs at

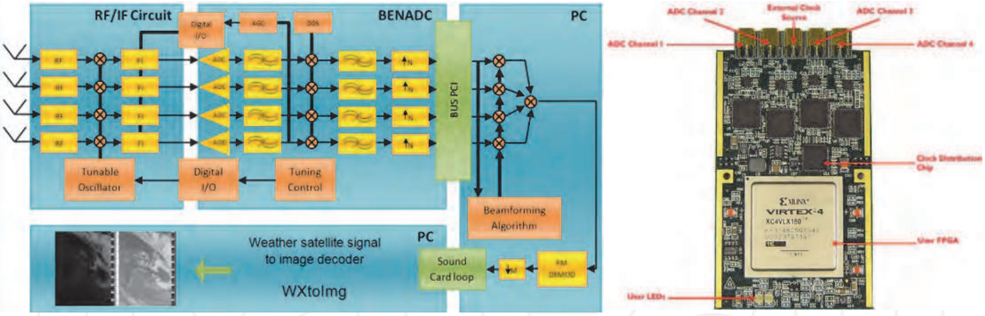
RF/IF Circuit
BENADC
PC
Digital I/O
AGC
DDS
RF
FI
Tunable Oscillator
Digital I/O
Tuning Control
BUS PCI
Beamforming Algorithm
PC
Weather satellite signal to image decoder
WXtoImg
Sound Card loop
FM DEMOD
ADC Channel 2
External Clock Source
ADC Channel 3
ADC Channel 1
ADC Channel 4
Clock Distribution Chip
XILINX VIRTEX-4
User FPGA
User LEDs

a b

Fig. 25. a) Block diagram of the A3TB, and b) BenADC – Virtex 4-sx55.

250 Msps (Martínes et al., 2007). Digital samples are transferred to the PC where beamforming and subsequent APT demodulation of the array output are performed using C++ routines. This implementation design offers higher flexibility for testing different beamforming schemes. Finally, demodulated APR frames are sent to the WXtoImg software to show meteorological maps.

The A3TB is controlled by the PC for simulations and field trials. The graphical user interface allows presented in (Salas et al., 2008) the user to choose the beamforming algorithm and set all the parameters of the LEO satellite for tracking such as the number of antennas of the array, distance between the elements, direction of arrival and IF frequency. The C++ routine calculates the beamforming weights and plots the synthesized array factor. Subsequently, the reception of meteorological images has real time system requirements. Thus, it is necessary a data transfer from the FPGA to the C++ module to process the samples continuously, and give APT frames to the audio output of the PC. Since, the meteorological satellites often have a low baud rate, in the case of study with NOAA satellites the data transfer is made using two buffers controlled by a thread.

It is important to mention that the A3TB with SDR architecture can evaluate different beamforming algorithms and receiver schemes. The update of A3TB for larger arrays is immediate, as the basis for algorithms is independent of the number of elements in the array. The architecture of a new ground station concept to track LEO satellites based on software defined radio and antenna arraying as Test-Bed is a well proved choice to evaluate future antenna array architectures for satellite communication and benchmark features of the proposed system. As the A3TB VHF version is based on FSC scheme, the concept can be applied to a number of satellite tracing scenarios.

6. Conclusions

The performance analysis of different beamforming algorithms is an important issue in the new generation antenna array development and research. Thus, A3TB helps to analyze beamforming algorithms paving the way for testing and debugging for posteriori use in larger arrays, such as GEODA. Results obtained in real scenarios with A3TB state, for example, that spatial reference algorithms such as MPDR should be used in the absence of interferences, whereas blind algorithms are appropriate for low SNR conditions. Finally, the A3TB can also serve to validate the performance of calibration procedures.

In future work, the A3TB will deal with the system combining of full modularity with the capability of change firmwares based on the first version design of the Test-Bed, plus the flexible architecture of the current design of the Test-Bed based on VHDL, C++ and Antenna Arraying. Furthermore, the addition of more modules to increase the number of antenna array elements is evident in next generations.

7. Acknowledgment

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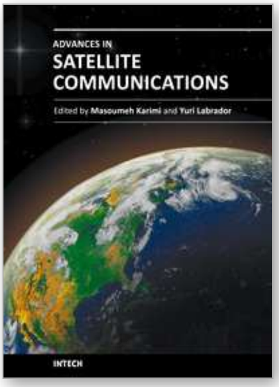

Advances in Satellite Communications

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Satellite communication systems are now a major part of most telecommunications networks as well as our everyday lives through mobile personal communication systems and broadcast television. A sound understanding of such systems is therefore important for a wide range of system designers, engineers and users. This book provides a comprehensive review of some applications that have driven this growth. It analyzes various aspects of Satellite Communications from Antenna design, Real Time applications, Quality of Service (QoS), Atmospheric effects, Hybrid Satellite-Terrestrial Networks, Sensor Networks and High Capacity Satellite Links. It is the desire of the authors that the topics selected for the book can give the reader an overview of the current trends in Satellite Systems, and also an in depth analysis of the technical aspects of each one of them.

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Review Article

Some Recent Developments of Microstrip Antenna

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Although the microstrip antenna has been extensively studied in the past few decades as one of the standard planar antennas, it still has a huge potential for further developments. The paper suggests three areas for further research based on our previous works on microstrip antenna elements and arrays. One is exploring the variety of microstrip antenna topologies to meet the desired requirement such as ultrawide band (UWB), high gain, miniaturization, circular polarization, multipolarized, and so on. Another is to apply microstrip antenna to form composite antenna which is more potent than the individual antenna. The last is growing towards highly integration of antenna/array and feeding network or operating at relatively high frequencies, like sub-millimeter wave or terahertz (THz) wave regime, by using the advanced machining techniques. To support our points of view, some examples of antennas developed in our group are presented and discussed.

1. Introduction

The concept of microstrip antenna was first introduced in the 1950s [1]. However, this idea had to wait nearly 20 years to be realized after the development of the printed circuit board (PCB) technology in the 1970s [2, 3]. Since then, microstrip antennas are considered as the most common types of antennas due to their obvious advantages of light weight, low cost, low profile, planar configuration, easy of conformal, superior portability, suitable for arrays, easy for fabrication, and easy integration with microwave monolithic integrate circuits (MMICs) [4–7]. They have been widely employed for the civilian and military applications such as television, broadcast radio, mobile systems, global positioning system (GPS), radio-frequency identification (RFID), multiple-input multiple-output (MIMO) systems, vehicle collision avoidance system, satellite communications, surveillance systems, direction founding, radar systems, remote sensing, biological imaging, missile guidance, and so on [8].

Despite the many advantages of typical microstrip antennas, they also have three basic disadvantages: narrow bandwidth, low gain, and relatively large size. The narrow bandwidth is one of the main drawbacks of these types of antennas. A straightforward method of improving the bandwidth is increasing the substrate thickness. However, surface wave power increases and radiation power decreases with the increasing substrate thickness [7], which leads to poor radiation efficiency. Thus, various other techniques are presented to provide wide-impedance bandwidths of microstrip antennas, including impedance matching networks using stub [9, 10] and negative capacitor/inductor [11], microstrip slot antennas using the U, L, T, and inverted T slots in the ground plane (sometimes termed defected ground structures (DGSs)) [12, 13], surface wave suppressing using magneto-dielectric substrate [14] and electromagnetic bandgap (EBG) structures [15], and composite-resonator microstrip antennas using metamaterial resonators [16, 17]. Another problem to be solved is the low gain for conventional microstrip antenna element. Cavity backing has been used to eliminate the bidirectional radiation, thereby providing higher gain compared with conventional microstrip antenna [18]. Lens covering is an alternative way to achieve gain enhancement. The lens with canonical profile, like elliptical, hemielliptical, hyper-hemispherical, extended hemispherical, used to focus the radiation beam from the radiator elements. The integrated lens microstrip antenna can be treated as composite antenna combined by microstrip radiator elements and dielectric lens, which is very useful for high frequencies (mm, sub-mm, terahertz (THz), and optical waves) applications

[19]. It is also well known that antenna array is an effective means for improving the gain [20–25].

The last limitation of conventional microstrip antennas is the relatively large size, particularly at lower microwave frequencies, since their operation frequencies are related to the electrical size of antenna. In general, the size of the rectangular microstrip antenna should be of order of a half-guided wavelength. This limitation was mathematically studied by Wheeler [26] and Chu [27]. There have been numerous efforts to minimize the antenna size and obtain the electrically small microstrip antenna with the raised demand towards smaller and smaller wireless devices. Inductive or capacitive loading are effective ways to reduce the size of microstrip antennas [28]. In the former work, we demonstrated that the size of microstrip antenna can be miniaturized using composite metamaterial resonators [16, 17]. Magneto-dielectric substrates have been widely used to miniaturize microstrip antennas due to magnetic substrates and could provide wider bandwidths than dielectric substrates [29–32]. Fractal geometries, which are composed by self-similar structures, have opened an alternative way for antenna miniaturization [33].

From the above discussions, we see that many methods and materials are used to improve the properties of microstrip antennas. However, there should be a relationship among bandwidth, gain, and size of the microstrip antennas. Antenna engineers have recognized that the improvement in one antenna property is frequently accompanied by decline in its other performances. For example, the antenna size is reduced usually at the expense of its bandwidth and gain. Therefore, a more comprehensive consideration must be given on further developments of microstrip antennas.

In this paper, we will suggest three areas for further research based on our previous works on microstrip antenna elements and arrays [16–25, 34–41]. We first note that novel microstrip antenna topologies are proposed to meet the desired requirement of variety of potential wireless applications, such as ultrawide band (UWB), high gain, miniaturization, circular polarization, multipolarized, and so on. Next, we discuss the composite antennas based on microstrip antennas which have more potent than each individual antenna. Finally, with the development of micro-/nano-machining techniques, antennas/arrays with highly integration and with highly operating frequencies are discussed. We present some examples of antennas developed in our group to support our points of view.

2. Variety of Microstrip Antenna Topologies

Microstrip antennas have extensively used in commercial and military applications due to their attractive advantages. However, the traditional microstrip antennas have the impedance bandwidth of only a few percent and radiation pattern with omnidirection, which obviously does not meet the requirements of various wireless applications. To this end, a wide variety of microstrip antenna topologies, including different microstrip antenna element structures and different microstrip array arrangements, have been studied to meet the desired requirement such as ultrawide band (UWB), high gain, miniaturization, circular polarization, multipolarized, and so forth.

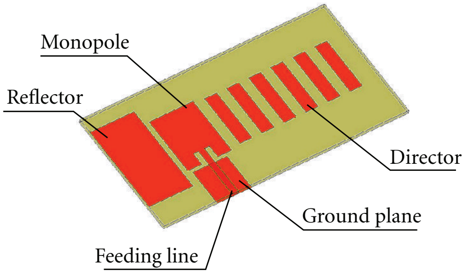

(a) The structure of the quasi-Yagi antenna

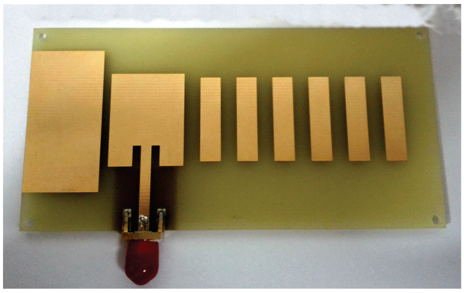

(b) The photograph of the quasi-Yagi antenna

Figure 1: Compact broad-band quasi-Yagi antenna.

As we know, microstrip antennas inherently have narrower bandwidth and lower gain compared to conventional bulky antennas. Some microstrip antennas with special topologies, like quasi-Yagi, planar reflector antenna, are proposed to replace the conventional bulky antennas. Here, we will take a quai-Yagi antenna as an example to show how to design a planar microstrip antenna with Yagi-Uda end-fire radiation pattern. In addition, a microstrip array with special array topology is designed to get dual-polarized property.

2.1. Compact Broad-Band Quasi-Yagi Antenna. A novel S-band compact quasi-Yagi antenna has been designed, fabricated and measured by our group, as shown in Figure 1. This antenna is composed of a printed monopole-driven element, a printed reflector element, and six printed director elements.

To explain the end-fire radiation behavior of the quasi-Yagi antenna, a comparison of radiation patterns, among (1) microstrip monopole only, (2) microstrip monopole and a reflector, (3) microstrip monopole and a director, (4) microstrip monopole and a reflector with one director, and (5) microstrip monopole and a reflector with six director, is shown in Figure 2. We can observe that both the reflector and the director can increase the end-fire radiation, and it could be substantially improved by increasing the number of directors.

The measured VSWR results are shown in Table 1. A bandwidth of 14% for VSWR less than 1.5 is achieved. The gain of the antenna is above 7.5 dBi, as shown in Table 2. In this design, we see that the microstrip antenna with special topology could be conveniently used to replace the bulky Yagi-Uda antenna.

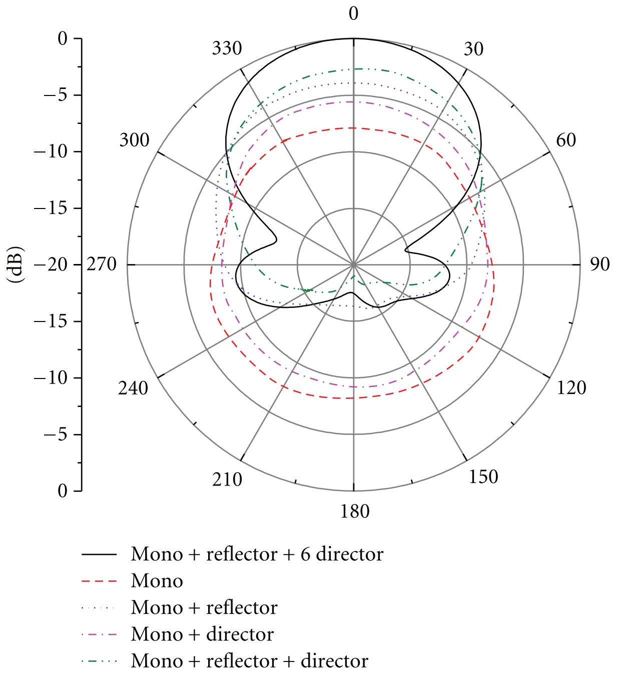

Figure 2: Radiation patterns of microstrip monopole only, microstrip monopole and a reflector, microstrip monopole and a director, microstrip monopole and a reflector with one director, and microstrip monopole and a reflector with six director.

Table 1: The measured VSWR of the quasi-Yagi antenna.

No.	Frequency (GHz)			
	3.25	3.5	3.75	Inband
1	1.36	1.34	1.47	<1.5
2	1.37	1.26	1.49	<1.5
3	1.36	1.25	1.48	<1.5

Table 2: The measured gain of the quasi-Yagi antenna (unit: dBi).

No.	Frequency (GHz)		
	3.25	3.5	3.75
1	7.57	8.73	8.35
2	7.58	8.55	8.37
3	7.56	8.77	8.51

2.2. Dual-Polarized Microstrip Antenna Array. The dual-polarized antenna is highly required for the radar, electronic countermeasure, and aerospace systems. It is known that the microstrip antenna can easily be integrated with microwave circuits and feeding network. Here, a novel Ku-band dual-polarization microstrip antenna array with a mixed feeding network, that is, the slot coupled feeding (V-port) and the co-plane feeding (H-port), is designed by our group, as shown in Figure 3. It is a three layers structure: top microstrip patch layer, middle stripline feeding network layer, and bottom coplane microstrip feeding network layer. Through proper array arrangement, very good isolation can be obtained.

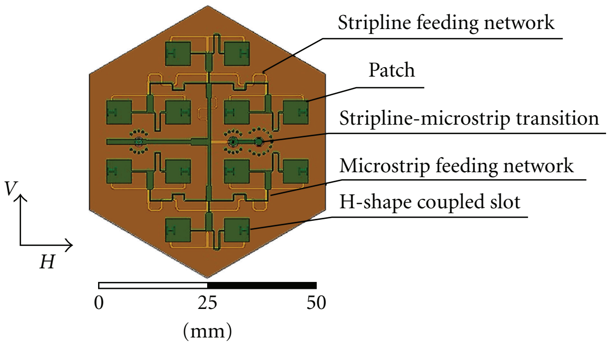
Stripline feeding network
Patch
Stripline-microstrip transition
Microstrip feeding network
H-shape coupled slot
V
H
0
25
50
(mm)

(a) The structure of the dual-polarized microstrip antenna array

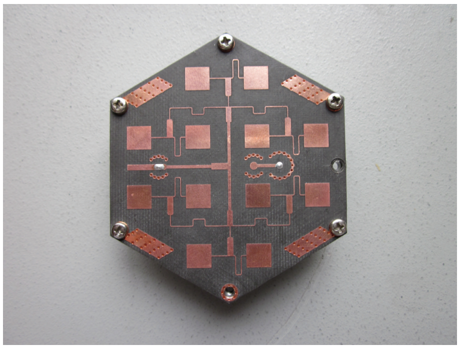

(b) The photograph of the dual-polarized microstrip antenna array

Figure 3: Dual-polarized microstrip antenna array.

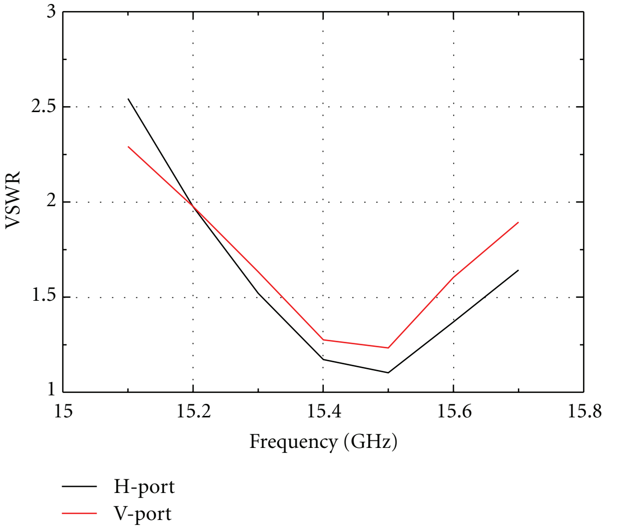

Figure 4: The VSWR of the dual-polarized microstrip antenna array.

The VSWR, radiation patterns, and the isolation between two polarizations of the proposed dual-polarized microstrip antenna array are shown in Figures 4, 5, and 6, respectively. The results indicate that this microstrip antenna array has a good impedance matching, good radiation performance, as well as very high isolation (less than −25 dB), which can be an idea candidate for the dual-polarized wireless systems.

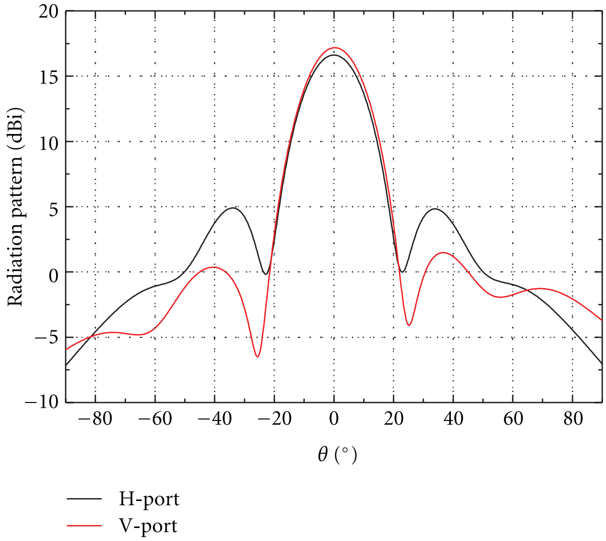

Figure 5: The radiation patterns of the dual-polarized microstrip antenna array at the center frequency.

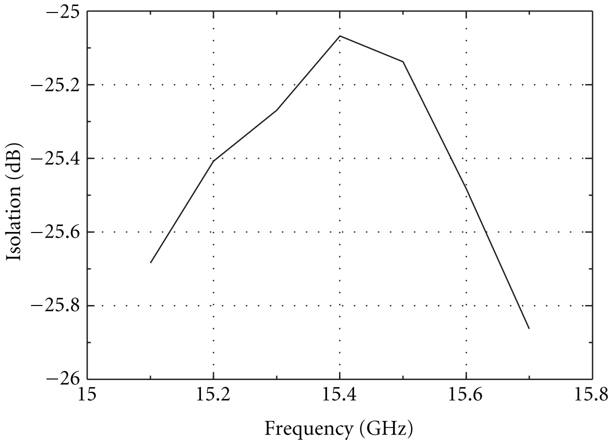

Figure 6: The isolation of the dual-polarized microstrip antenna array.

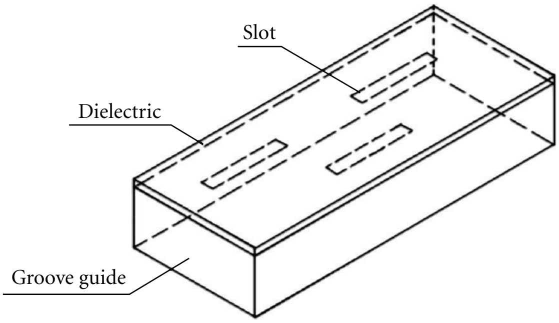

Figure 7: The structure of the DCWS.

3. Microstrip-Antenna-Based Composite Antenna

As many antenna designers have found, it is not easy to design an antenna to meet the user-defined stringent performance requirements demanded by special wireless applications like military radars, surveillances, and missile guidance, if only one type of antenna is considered. This difficulty may require the use of two more different types or structures of antenna elements with different characteristics. Composite antenna formed by two more types or structures of antennas is particularly suitable for these applications due to more advantages offered by different types or structures of antennas. For example, it is a challenging task to use single type of antenna to design a dual-band dual-polarization antenna for satellite digital multimedia broadcast (S-DMB) application [36]. A composite antenna composed with a left-handed circularly polarized (LHCP) microstrip antenna and a linear polarized omnidirectional biconical antenna is proposed by our group to meet this requirement [36]. Another example of composite antenna is comprised of a dielectric lens and microstrip log-period antenna, which has been widely applied to THz systems (this type of antenna will be further discussed in Section 4.2). Here, we will give an example of composite antenna with "structure composite" method.

3.1. Monopulse Circular-Polarized Dielectric Complex Waveguide Slot Antenna Array

3.1. Monopulse Circular-Polarized Dielectric Complex Waveguide Slot Antenna Array. Waveguide slot antenna array has been widely used for wireless system, due to its advantages of high radiation efficiency, high power capacity, and high reliability. However, it is hard to overcome the disadvantage of high cost of fabrication.

One composite antenna with waveguide slot antenna array property, termed dielectric complex waveguide slot (DCWS), is composed with slot microstrip line and groove guide, as shown in Figure 7. The slot microstrip line is formed by a metal clad dielectric substrate and slots etched in the metal. This composite antenna not only maintains the advantages of the traditional waveguide slot antenna array but also has the characteristics of high consistence, easy for fabrication, and low cost.

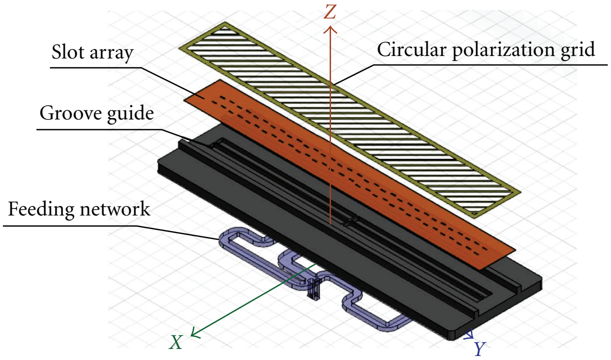

(a) The structure of the monopulse circular-polarized DCWS antenna array (separating view)

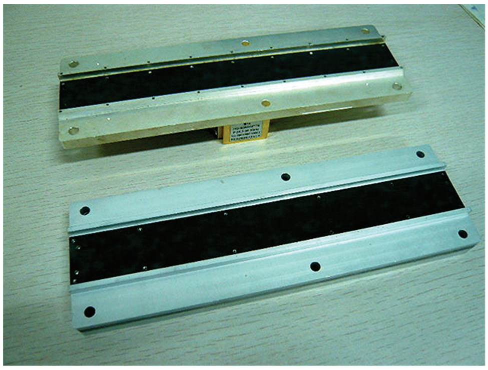

(b) The photograph of the monopulse circular-polarized DCWS antenna array.

Figure 8: Ka-band monopulse circular-polarized dielectric complex waveguide slot (DCWS) antenna array.

A Ka-band monopulse circular-polarized dielectric complex waveguide slot (DCWS) antenna array is designed, fabricated, and measured by our group, as shown in Figure 8. It consists of a circular polarization grid, a slot microstrip array, and a groove guide and feeding network. The slot microstrip array is fabricated on a Rogers 5880 film with dielectric constant of 2.2 and the thickness of 0.254 mm. The measured results of VSWR of sum and different port are shown in Figure 9. Figure 10 shows the measured radiation pattern at the center frequency. Some important array performance parameters such as gain, null depth and axial ratio (AR) are also given in Table 3. As shown in the measured results, very good performance can be obtained with the DCWS antenna array. The radiating efficiency of the DCWS antenna array is 80%, which is almost the same as the traditional waveguide slot antenna array. Moreover, the DCWS antenna array has 40% larger bandwidth than the traditional waveguide slot antenna array.

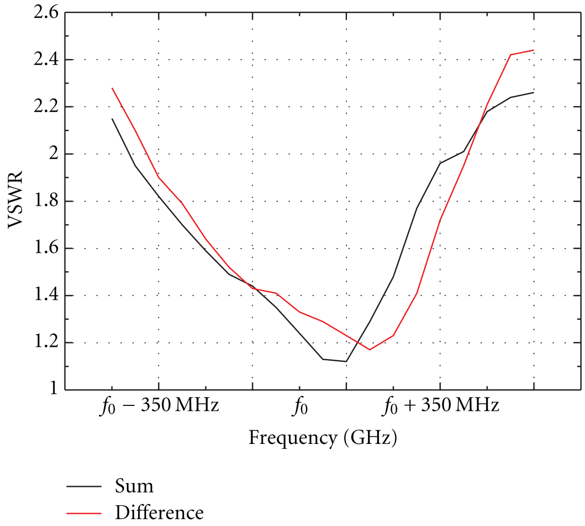

Figure 9: The VSWR of sum and difference port of the monopulse circular-polarized DCWS antenna array.

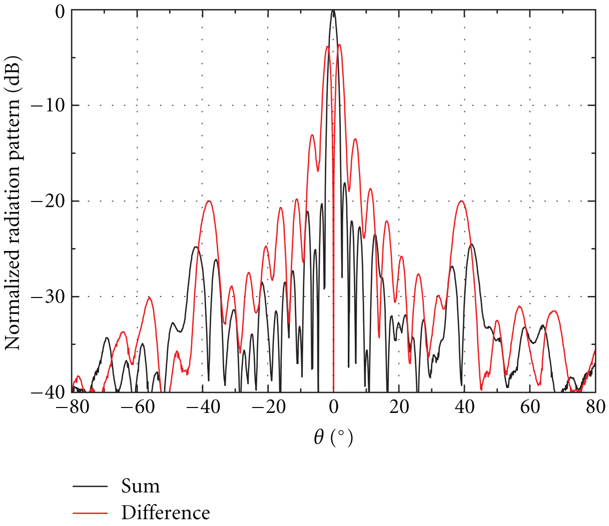

Figure 10: The radiation pattern of the monopulse circular-polarized DCWS antenna array at the center frequency.

4. Highly Integration and Highly Operating Frequency Antennas Based on Advanced Machining Techniques

It is known that the microstrip antenna was first fabricated using PCB technology in 1970s, nearly 20 years after its concept was first presented in 1950s [1–3]. Clearly, the development of microstrip antennas is closely related with the machining techniques. Recently, various machining techniques, including multilayer printed circuit board (MPCB), complementary metal oxide semiconductor (CMOS), low-temperature cofired ceramics (LTCC), and micro-electro-mechanical systems (MEMS), are highly developed, opening opportunities for innovative antennas, such as active antennas, reconfigurable antennas, metamaterial-based antennas, THz antennas, and so forth. With the availability of high-precision and high-speed advanced machining techniques, microstrip antennas are growing towards highly integration of antenna/array and feed network and operating at relatively high frequencies. Since they are all based on the advanced

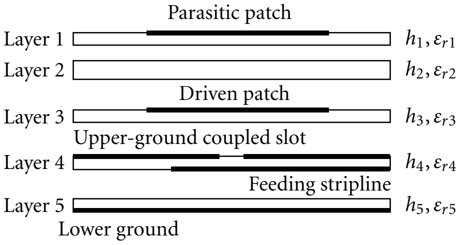

(a) Schematic side view of the structure of the high integrate broadband microstrip antenna array

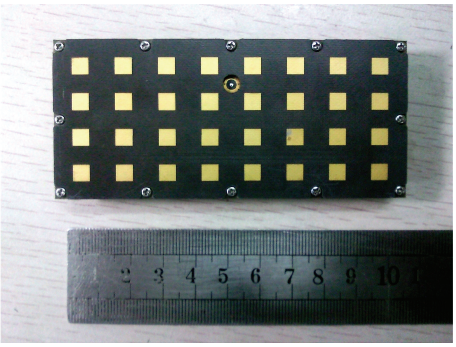

(b) The photograph of the high integrate broadband microstrip antenna array

Figure 11: Ku-band high integrate broadband microstrip antenna array using MPCB technology.

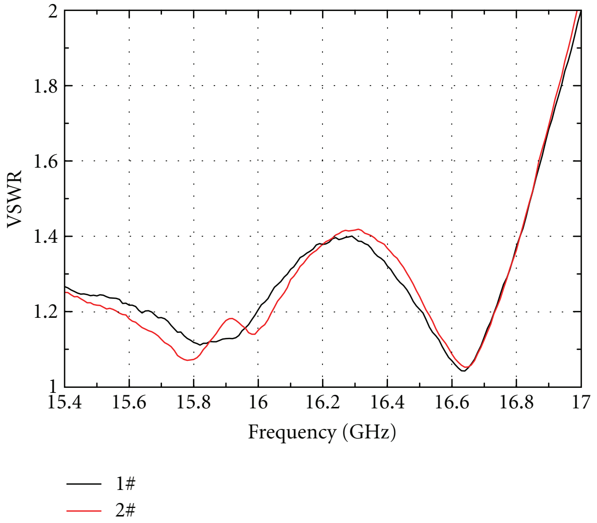

Figure 12: The VSWR of the high integrate broad-band microstrip antenna array using MPCB technology.

machining techniques, we suggest that a third research area of microstrip antennas is constantly introducing novel advanced machining techniques. In the following, two examples will be presented to show how important the advanced machining technique is to fabricate microstrip antennas. One is the highly integrate broad-band microstrip antenna array fabricated using MPCB technology. Another is THz wave planar integrated active microstrip antenna using MEMS technology.

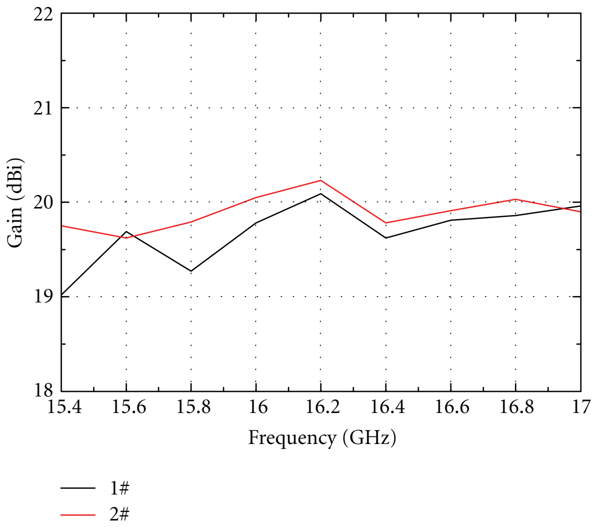

Figure 13: The gain of the high integrate broad-band microstrip antenna array using MPCB technology.

Table 3: The measured data of the monopulse circular-polarized DCWS antenna array.

Fre. (GHz)	Gain (dBi)	Null depth (dB)	AR (dB)
$f_0 - 0.2$	22.8	−37.3	3.8
f_0	21.9	−29.9	2.9
$f_0 + 0.2$	22.1	−26	4.1

4.1. High Integrate Broad-Band Microstrip Antenna Array Using Multilayer Printed Circuit Board (MPCB) Technology.

Recently, with the development of the multilayer printed circuit board (MPCB) technology, the microstrip antennas can be designed and fabricated from one-dimensional (1D) to 2D and even 3D structures.

Based on the MPCB technology, a high integrated broadband Ku-band microstrip antenna array is designed, fabricated, and measured by our group, as shown in Figure 11. This antenna consists of a parasitic patch, a driven patch, a stripline feeding network, a broad-band coaxial line to stripline transition, some buried screw holes, and some via holes. The feeding network is integrated in the bottom of the substrate of the antenna. As all of the structures fabricated at once, the accuracy and the uniformity can be assured. Two antennas of this type are measured. The measured VSWR, gain, and radiation pattern at the center frequency are shown in Figures 12, 13, and 14, respectively. The measured results show that this antenna maintains good radiation and matching performances with relative bandwidth of 13%. They have also shown good uniformity by using MPCB technology.

4.2. THz Wave Planar Integrated Active Microstrip Antenna Using Micro-Electromechanical Systems (MEMSs) Technology.

THz waves typically include frequencies between 0.1 THz and 10 THz. THz technology is now becoming a promising technology which has potential applications in many fields, such as short-range communication, biosensor, imaging,

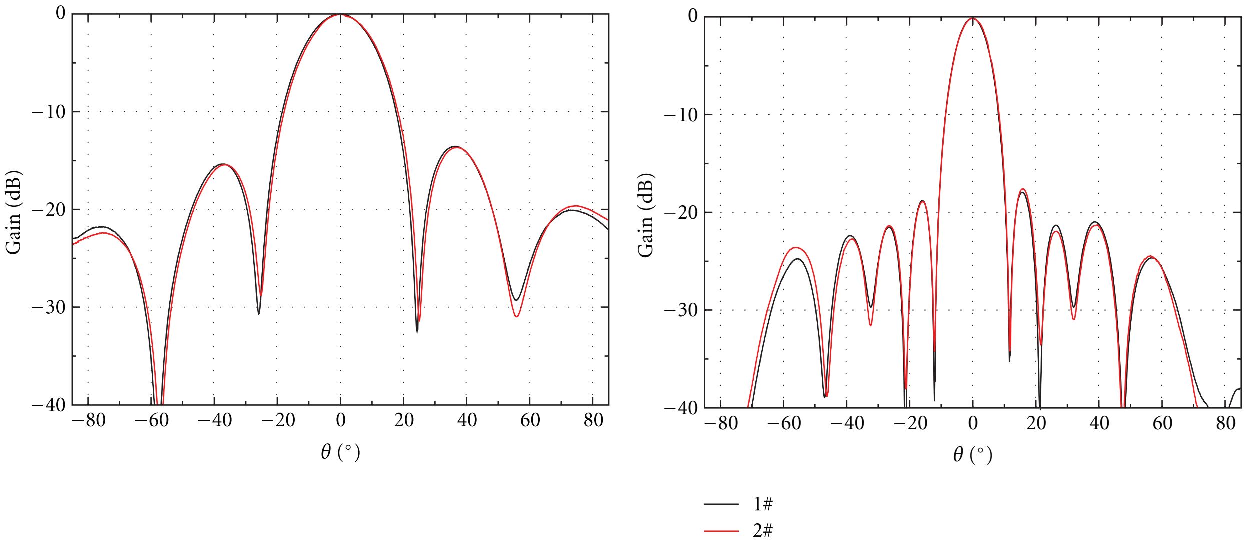

(a) E-plane

(b) H-plane

Figure 14: The radiation pattern of the high integrate broad-band microstrip antenna array using MPCB technology at the center frequency.

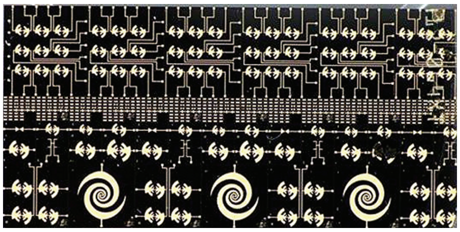

(a) The photograph of the THz monolithic antenna

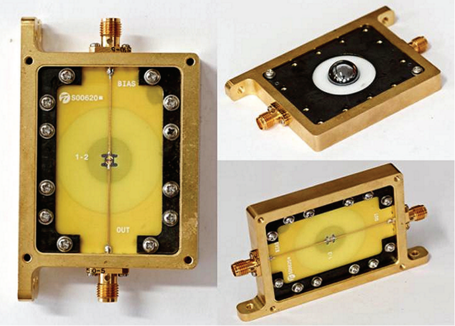

(b) The photograph of the THz monolithic antenna covered by a dielectric lens

Figure 15: THz wave planar integrated active microstrip antenna using micro-electromechanical systems (MEMSs).

national security, space exploration and communication, and so forth [39–46]. To realize THz transceiver system, antenna is an essential component. We often use horn antenna, lens antenna, and dielectric parabolic antenna, for THz systems. However, they are not easy to integrate with monolithic integrate circuits. Although the microstrip antenna has the merits of small volume, light weight, and easy integration with circuit, it is difficult to be processed in such high-frequency regions. MEMS technology opens the way to design of THz antennas, circuits, and systems. THz monolithic antenna fabricated using MEMS technology and covered by a dielectric lens, which can be considered a composite antenna, are designed, fabricated, and measured by our group, as shown in Figure 15.

Diodes have the functions of mixing and/or modulating the carrier-wave signal. It is an effective way to reduce the propagation path for detectors application by integrating the diode and microstrip antenna. The extended hyper-hemispherical dielectric lens is used to increase the gain of the microstrip antenna. An antenna-coupled detector integrated with a dielectric lens is designed and fabricated up to THz range by our group. The planar microstrip log-spiral antenna and log-period antenna have been fabricated using micro-electromechanical systems (MEMSs) technology. The photographs of the antennas are demonstrated in Figure 15. The measured responses of the antenna-coupled detector working at different frequency bands are shown in Figure 16, which can be considered to determine the effective operating frequencies [19, 40]. This detector gave a valid response from 12 GHz to 110 GHz frequencies. The results prove the validity and feasibility of the THz antenna designed using micro-electromechanical systems (MEMSs) technology.

5. Conclusion

The advantages and disadvantages of microstrip antennas are discussed in this paper. In particular, three areas for further development of microstrip antennas are presented based on our previous works on microstrip antenna elements and arrays. Variety of microstrip antenna topologies and microstrip-antenna-based composite antenna are discussed, and

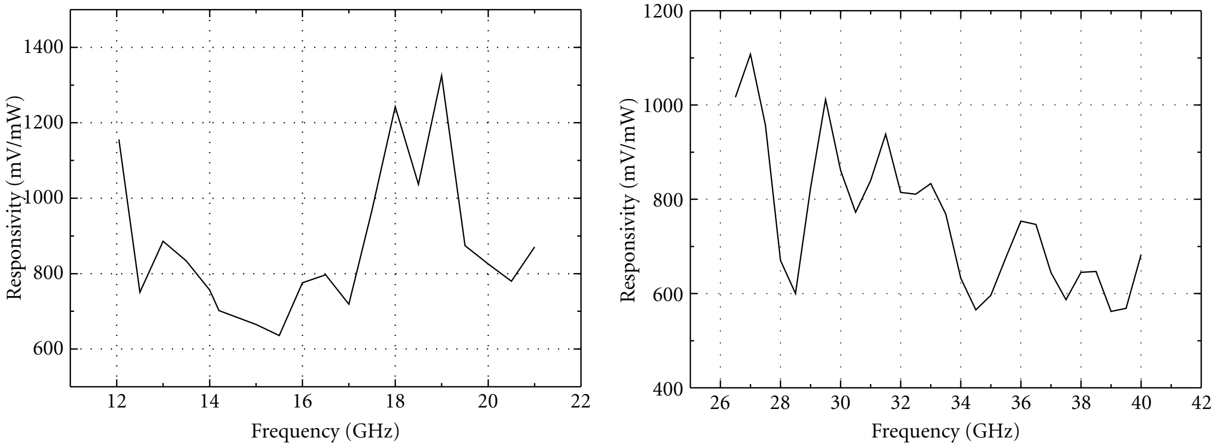

(a) Ku-band

(b) Ka-band

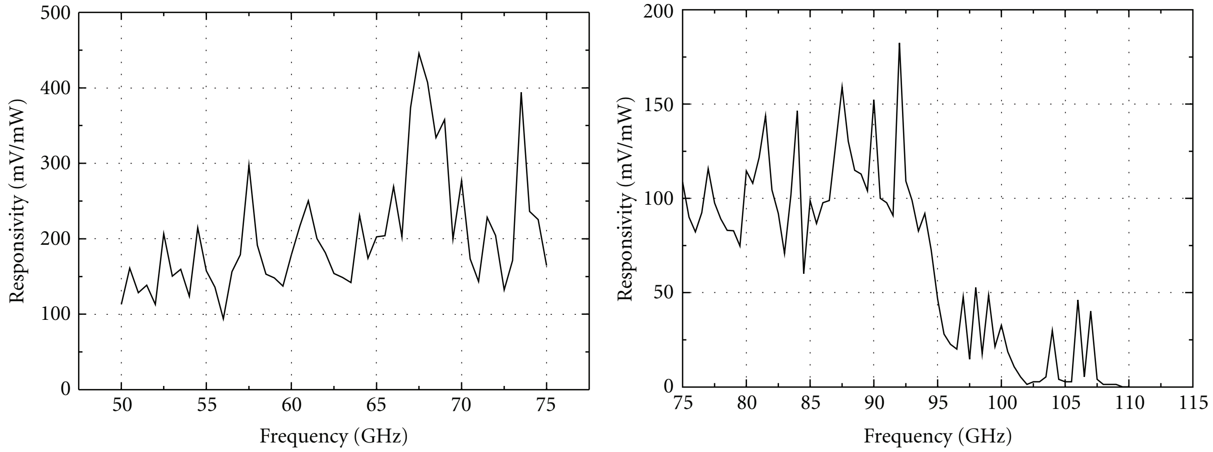

(c) V-band

(d) W-band

Figure 16: Frequency responses test results of the THz wave planar integrated active microstrip antenna covered by a dielectric lens.

the advanced machining techniques pushing the microstrip antennas towards the highly integration of antenna/array and feeding network and the highly operating frequencies are described. To demonstrate the distinctive features of novel microstrip antennas, various antenna elements and arrays for different applications are presented. This paper has shown that the microstrip antennas are still very promising paradigm for civilian and military wireless applications.

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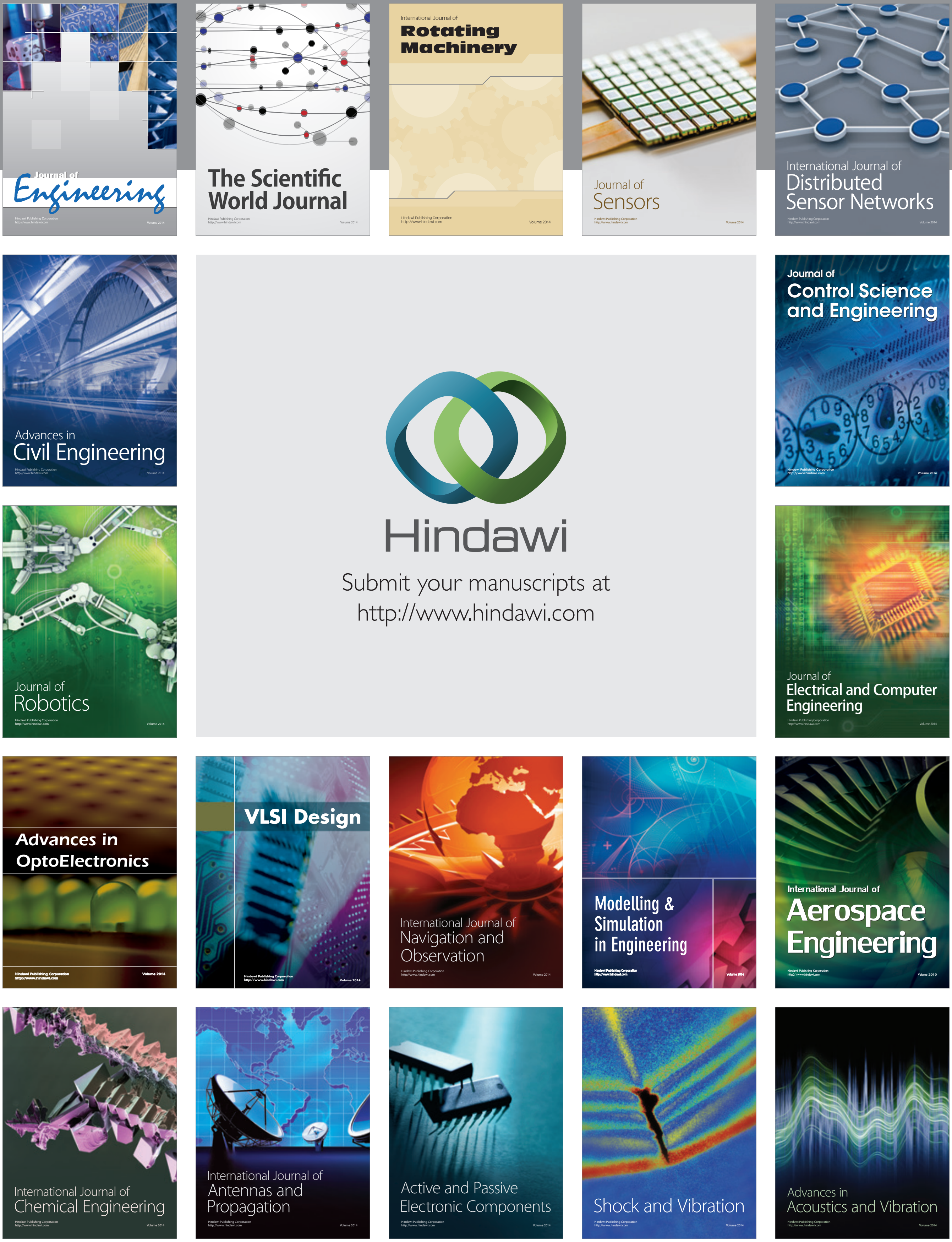
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The Scientific World Journal
International Journal of Rotating Machinery
Journal of Sensors
International Journal of Distributed Sensor Networks
Advances in Civil Engineering
Journal of Control Science and Engineering
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A 2.4 GHz Polarization-diversity Planar Printed Dipole Antenna for WLAN and Wireless Communication Applications

This article presents the design simulation, fabrication and measured performance of a 2.4 GHz polarization-diversity printed dipole antenna for wireless communication applications. Two orthogonal printed dipole antennas, each with a microstrip via-hole balun for vertical and horizontal polarization, are combined and fabricated on a PCB substrate. PIN diodes are used as switches to select the desired antenna polarization. The 3D finite-element-method (FEM) electromagnetic EM simulator, HFSS, is used in the design simulation of this planar antenna structure. Numerical and measured results of the antenna radiation characteristics, including input SWR, radiation pattern coverage and polarization-diversity, are presented and compared.

In wireless communication systems, such as wireless local area networks (WLAN), research and development efforts are aiming at smaller size and better performance. In addition to the use of signal processing techniques to improve communication channel capacity, the radiation characteristics of the portable antenna system is also very important for communication performance.

In urban or indoor environments, the radio wave will propagate through complicated reflection or scattering processes. The polarization of the radio wave may change significantly. In order to effectively receive the communications signal, a polarization-diversity antenna for wireless communications may become an important requirement. A polarization-diversity antenna may have a pair of linearly-polarized antennas, and the radio signal received on both antenna is sampled and compared at

HUEY-RU CHUANG, LIANG-CHEN KUO,
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National Cheng Kung University,
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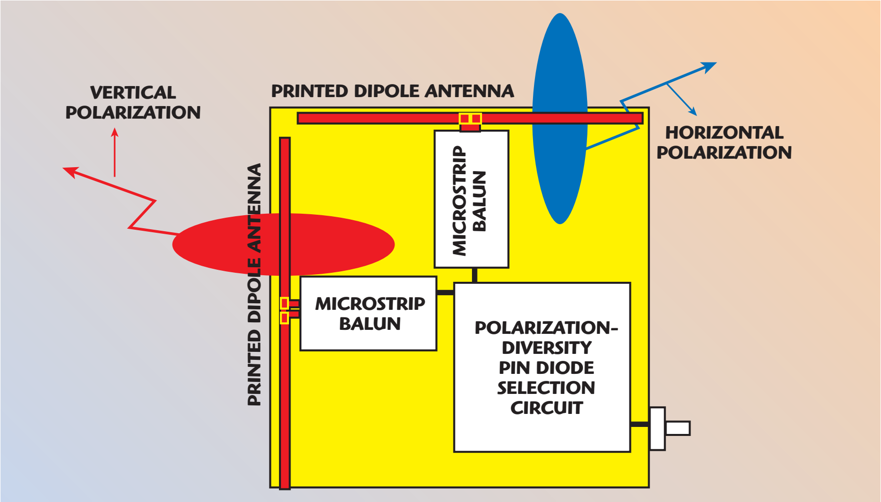
VERTICAL POLARIZATION
PRINTED DIPOLE ANTENNA
HORIZONTAL POLARIZATION
MICROSTRIP BALUN
PRINTED DIPOLE ANTENNA
MICROSTRIP BALUN
POLARIZATION-DIVERSITY PIN DIODE SELECTION CIRCUIT

▲ *Fig. 1 A 2.4 GHz polarization-diversity antenna.*

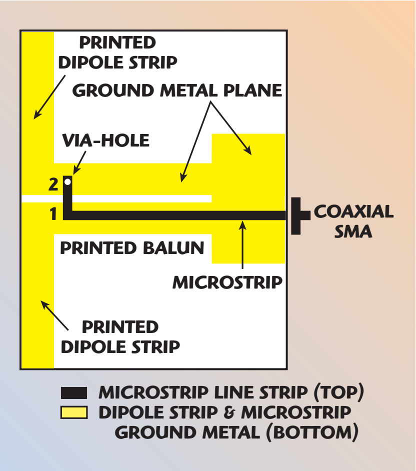
PRINTED DIPOLE STRIP
GROUND METAL PLANE
VIA-HOLE
2
1
COAXIAL SMA
PRINTED BALUN
MICROSTRIP
PRINTED DIPOLE STRIP
MICROSTRIP LINE STRIP (TOP)
DIPOLE STRIP & MICROSTRIP GROUND METAL (BOTTOM)

▲ *Fig. 2 Printed dipole antenna with a microstrip balun.*

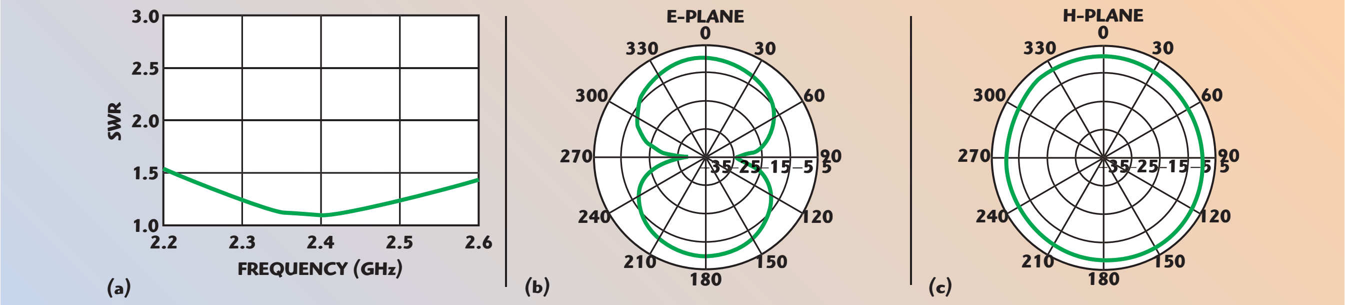

▲ *Fig. 3 Simulated performance of a 2.4 GHz printed dipole antenna placed horizontally; (a) input SWR, (b) E-plane pattern and (c) H-plane pattern.*

certain time intervals. Then the antenna with the best signal quality is selected.

A typical dipole antenna radiates a vertically polarized EM wave and has an omnidirectional antenna pattern. In order to have a preferred planar antenna structure for this 2.4 GHz polarization-diversity antenna, a printed dipole antenna with a microstrip via-hole balun is designed. As shown in ***Figure 1***, two orthogonal printed dipole antennas, for vertical and horizontal polarization, respectively, are combined and fabricated on a PCB substrate. PIN diodes are used to switch and select the desired antenna polarization.

In the antenna design, the high frequency structure simulator (HFSS), based on a 3D FEM, was employed for design simulation of the complete printed dipole structure. A printed dipole antenna and a polarization-diversity planar dipole antenna board (with a polarization-selection PIN diode circuit) have been fabricated on FR-4 PCB substrates. A complete 3D structure FEM simulation and the measured performance of the realized printed dipole-antenna are compared. The measured radiation characteristics of the polarization-diversity planar dipole antenna, including input SWR, radiation pattern coverage and polarization diversity, are presented.

PRINTED DIPOLE ANTENNA WITH MICROSTRIP BALUN

As shown in ***Figure 2***, a printed dipole antenna has a printed microstrip balun which acts as an unbalanced-to-balanced transformer from the feed coaxial line to the two printed dipole strips. The length of the dipole strip and the balun microstrip are both about 1/4 wavelength. The ground plane of the microstrip line and the dipole antenna strips are in the same plane. A via-hole permits the feed point 2 of a printed dipole strip to have the same phase as the feed point 1 of the other printed dipole strip. Due to the 180° phase difference between the top strip and the ground plane of the microstrip line, the feed point 2 of the printed dipole strip will have 180° phase difference with the other feed point 1. Accurate dimensions of the printed dipole strip and the microstrip balun structure are determined by numerical simulation, using HFSS.

The simulation results for a 2.4 GHz printed dipole antenna placed horizontally with a microstrip via-hole balun and fabricated on an FR-4 substrate are shown in ***Figure 3***. The input SWR is less than 1.5 from 2.2 to 2.6 GHz. The simulated E- and H-plane antenna patterns are very close to those of an ideal dipole antenna, where the H-plane pattern is omnidirectional. ***Figure 4*** is a photograph of a realized antenna. The measured input SWR and antenna patterns (measured with the dipole placed vertically) agree well with the simulation results, as shown in ***Figure 5***.

PLANAR POLARIZATION-DIVERSITY PRINTED DIPOLE ANTENNA

Figure 6 shows photographs of a realized 2.4 GHz planar polarization-diversity antenna consisting of two orthogonal printed dipole antennas with a polarization-switched PIN diode circuit. Each printed dipole has

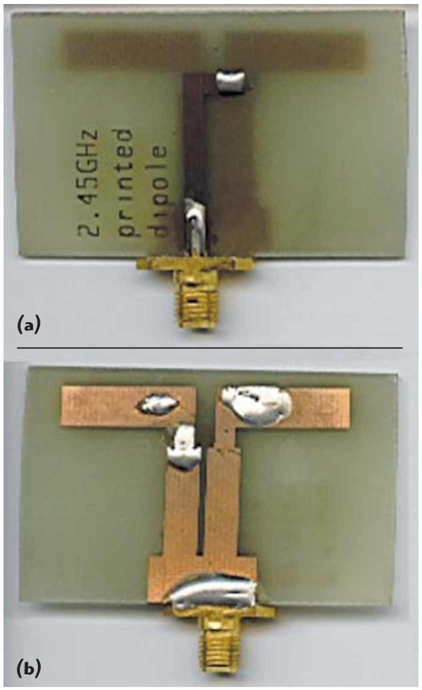

▲ *Fig. 4 A 2.4 GHz printed dipole antenna with a microstrip via-hole balun; (a) top view and (b) bottom view.*

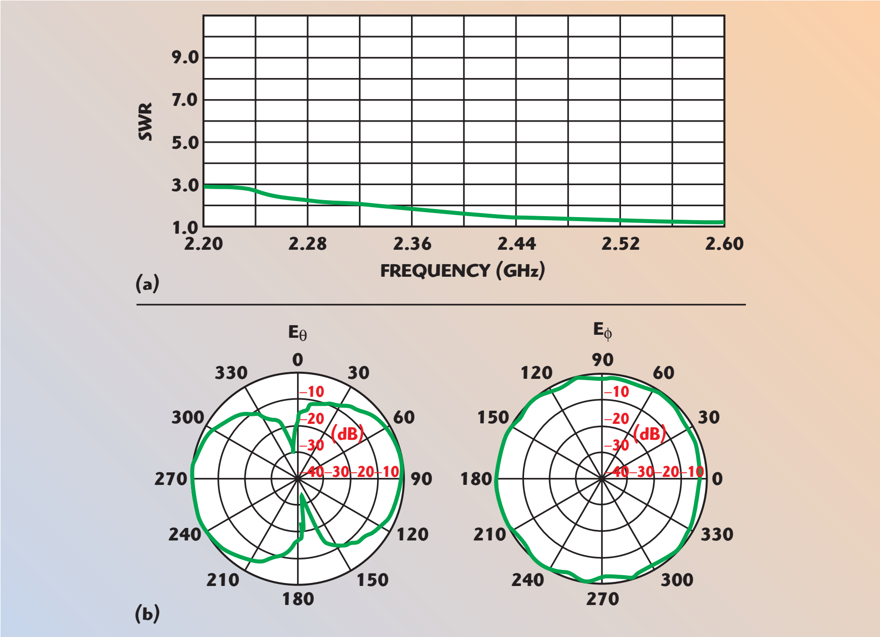

▲ *Fig. 5 Measured input SWR (a) and radiation patterns (b).*

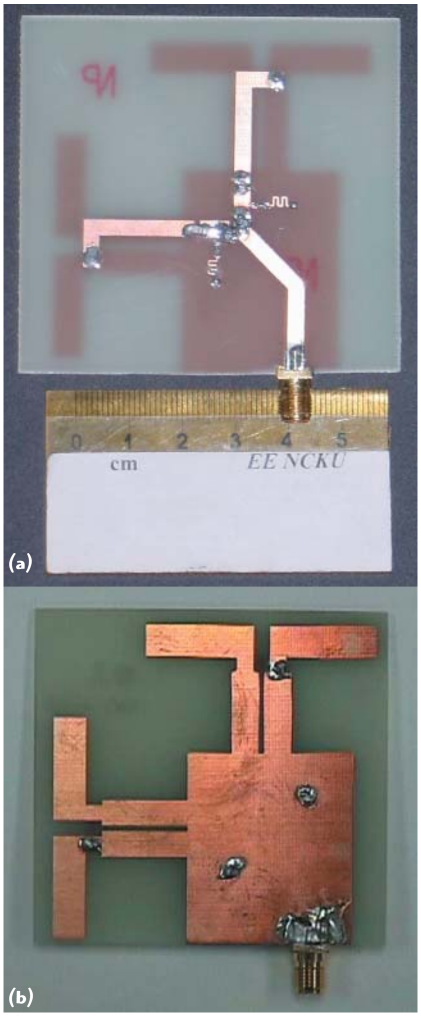

▲ *Fig. 6 A 2.4 GHz planar polarization-diversity antenna with a polarization-switched PIN diode circuit; (a) top view and (b) bottom view.*

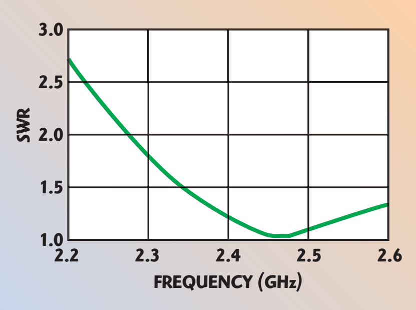

▲ *Fig. 7 Input SWR simulation of a 2.5 GHz polarization-diversity dipole antenna with the vertical dipole selected.*

a microstrip via-hole balun. The terminals of the two baluns are connected to a PIN diode selection circuit. Voltages from the transceiver circuit (±5.0V) are fed through a cable to the input of the PIN diode circuit section, to short or open-circuit the PIN diodes. Hence, either the vertical or horizontal printed dipole can be selected and connected to the transceiver.

Since the two dipoles are very close to each other and near the PIN diode circuit section, EM coupling will degrade the performance of each dipole. ***Figure 7*** shows the input SWR simulation results with the vertical dipole antenna selected (+5V to PIN diode switching circuit). The input SWR is less than 2 from 2.25 to 2.60 GHz. The simulated E- and H-plane antenna patterns are all very close to those of an ideal dipole antenna, of which the H-plane pattern is still omnidirectional, as shown in ***Figure 8***. Note that the dominant polarization is the vertical (E_θ) field, which agrees with the selection of the vertical dipole. The antenna pattern has some attenuation in the direction of the PIN diode circuit board. It can also be seen that a certain level of the input RF signal is induced to the horizontal antenna path by EM coupling, which generates some level of cross-polarization field. ***Figure 9*** shows the simulation results with the horizontal dipole antenna selected (–5V to PIN diode switching circuit). Results similar to the ones obtained for the vertical dipole antenna can be observed, except that the dominant polarization is the horizontal (E_ϕ) field, which agrees with the selection of the horizontal dipole.

The measured antenna input SWR with vertical or horizontal dipole selection confirms the input SWR of each dipole antenna (through the PIN diode selection circuit) is less than 1.5 from 2.2 to 2.6 GHz, which agrees with the HFSS simulation results. The measured antenna patterns with the selection of the vertical or horizontal dipole shows that for the selection of the vertical dipole, the H-plane pattern is still quite omnidirectional (as an ideal vertical dipole) with some attenuation in the direc-

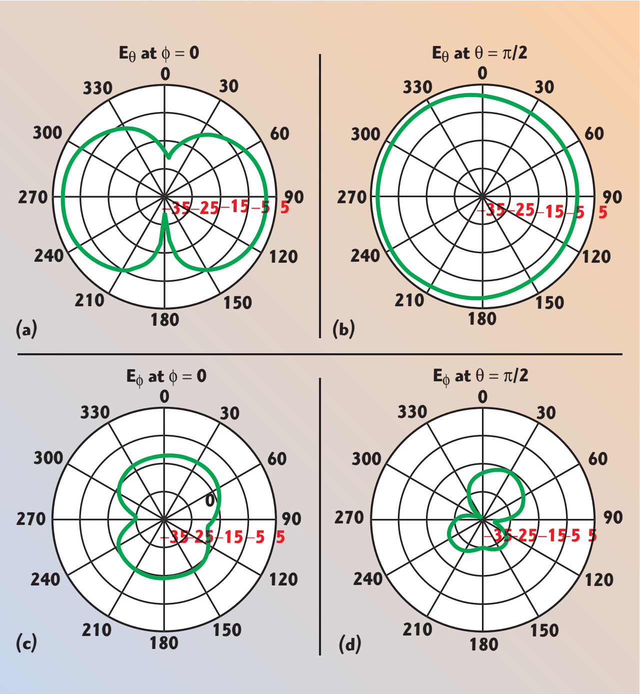

▲ *Fig. 8 Simulation of a 2.5 GHz polarization-diversity dipole antenna with the vertical dipole selected; (a) E_θ-field E-plane pattern, (b) E_θ-field H-plane pattern, (c) E_ϕ-field (cross-polarization) E-plane pattern and (d) E_ϕ-field (cross-polarization) H-plane pattern.*

tion of the PIN diode circuit board. ***Figures 10*** and ***11*** show the mesured SWR and antenna patterns, respectively. A certain level of the induced cross-polarization pattern is observed as predicted by the HFSS simulation due to the proximity of the horizontal dipole strip and the PIN diode circuit board. As for the selection of the horizontal dipole, the E-plane pattern is also close to that of an ideal horizontal dipole. Also, the induced cross-polarization pattern is observed, which is the same situation as the selection of the vertical dipole. The measured data shows a good agreement with the HFSS simulation results and how the antenna polarization-diversity is working.

CONCLUSION

3D FEM design simulation, realization and measurements of a 2.4 GHz printed dipole antenna (with a microstrip via-hole balun) and a planar polarization-diversity printed dipole antenna are presented. The planar polarization-diversity antenna consists of two orthogonal printed dipole antennas for vertical and horizontal polarization and is fabricated on a FR-4 PCB board. A PIN diode switching circuit is used to select the desired antenna polarization. Satisfactory agreement between simulation and measurements is observed. The measured input SWR of the realized printed dipole antenna is less than 1.5 from 2.2 to 2.6 GHz. The measured input SWR of the vertical and horizontal dipole (through the PIN diode switching circuit) of the realized planar polarization-diversity antenna is less than 1.5 from 2.3 to 2.6 GHz. The measured E- and H-plane patterns of the polarization-diversity antenna show that the selected vertical or horizontal dipole have a performance close to a single dipole antenna in a vertical or horizontal position. The designed planar polarization-diversity antenna can be used for wireless communication and WLAN applications.

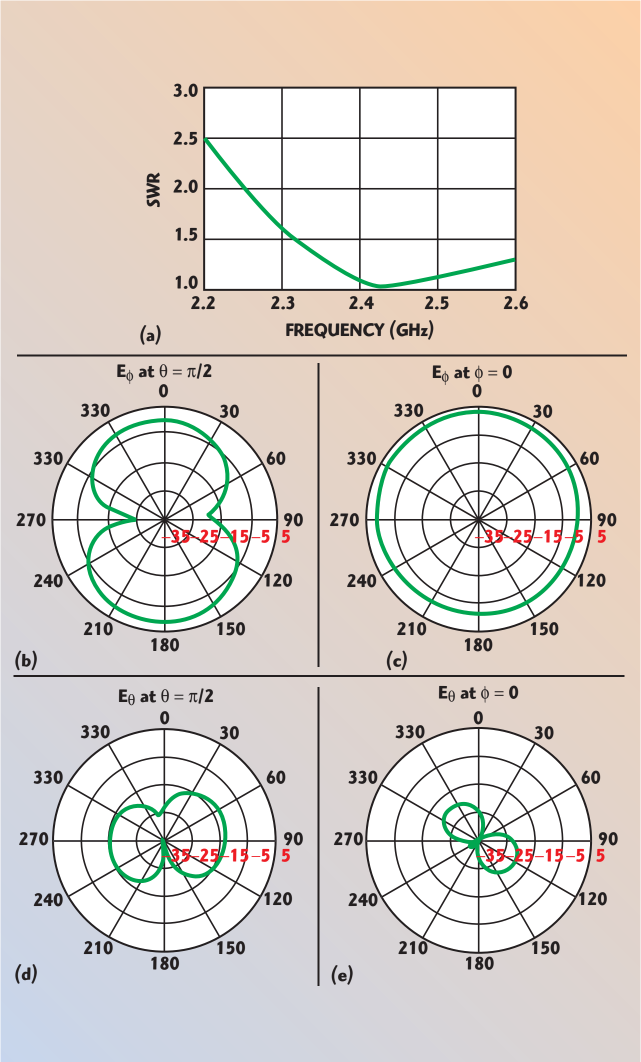

▲ *Fig. 9 Simulation of a 2.4 GHz polarization-diversity printed dipole antenna (with the horizontal dipole selected); (a) input SWR, (b) E_ϕ-field E-plane pattern, (c) E_ϕ-field H-plane pattern, (d) E_θ-field (cross-polarization) E-plane pattern and (e) E_θ-field (cross-polarization) H-plane pattern.*

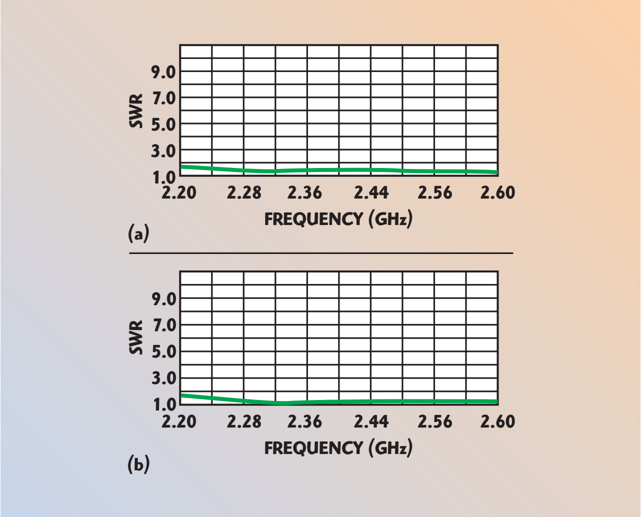

▲ *Fig. 10 Measured input SWR of a 2.4 GHz polarization-diversity printed dipole antenna; (a) vertical dipole selection and (b) horizontal dipole section.*

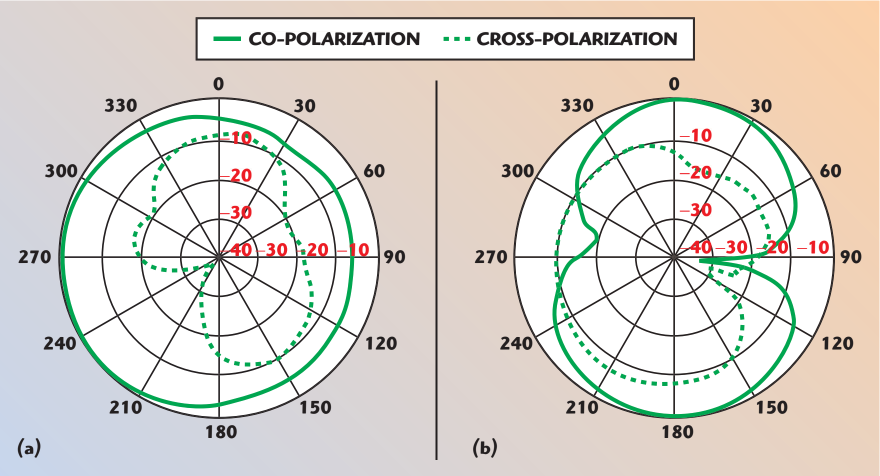

▲ *Fig. 11 Measured co-and cross-polarized patterns of a 2.4 GHz polarization-diversity printed dipole antenna; (a) vertical dipole selected and (b) horizontal dipole selected.*

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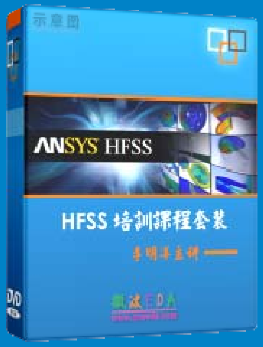
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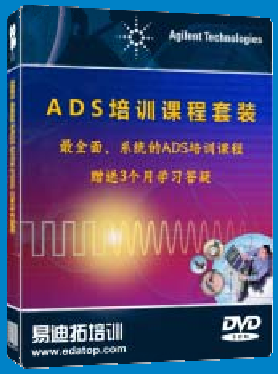
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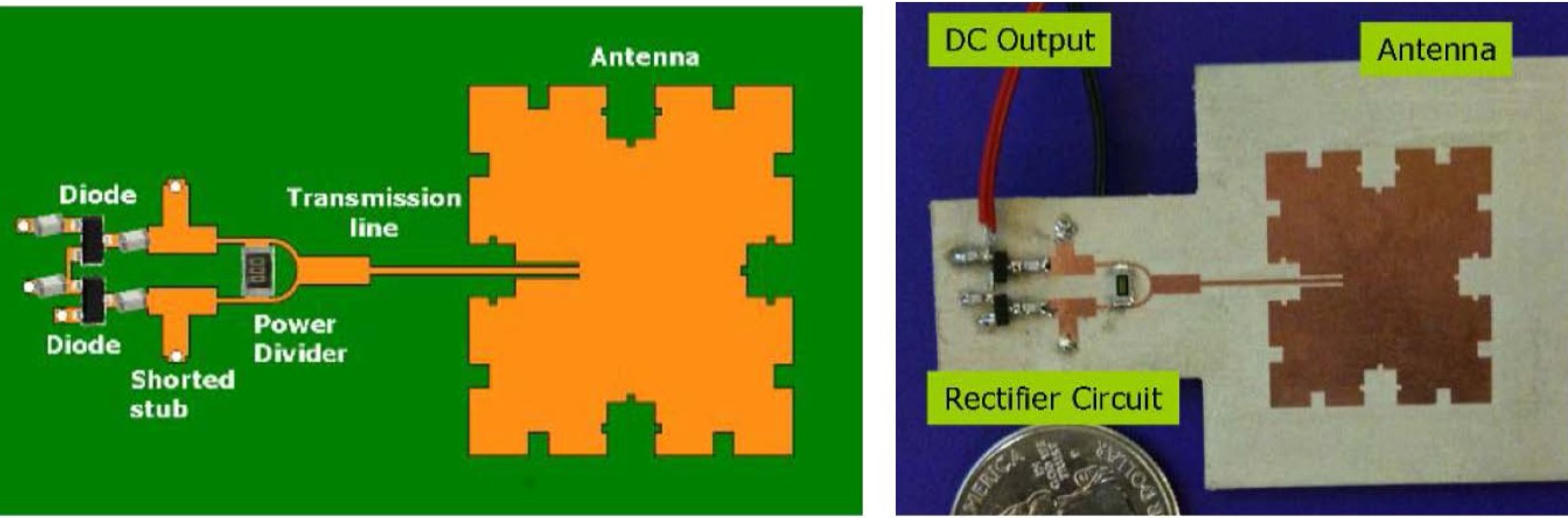
Antenna
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Transmission line
Diode
Power Divider
Shorted stub
DC Output
Antenna
Rectifier Circuit

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Phased Patch Antenna Array Design

Engineering

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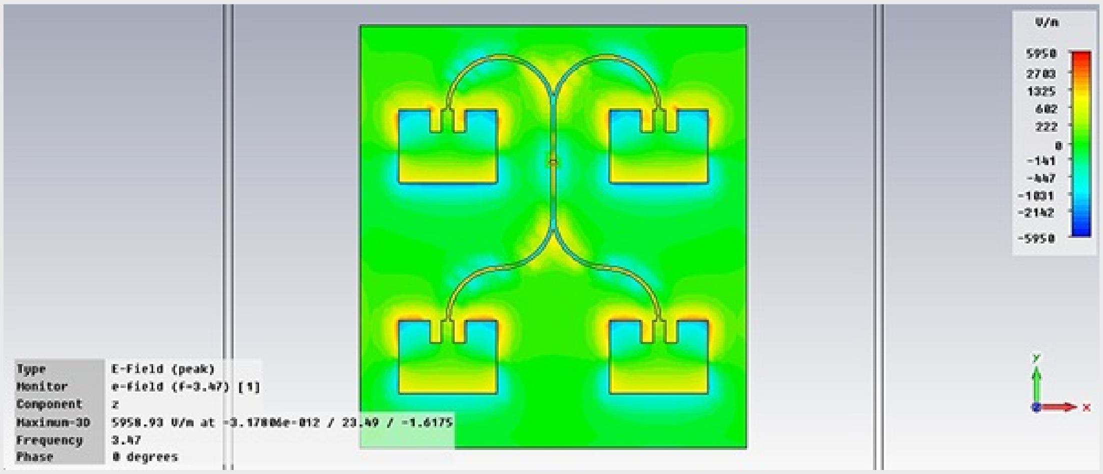

Type E-Field (peak)
Monitor e-field (f=3.47) [1]
Component z
Maximum-3D 5958.93 V/m at -3.17806e-012 / 23.49 / -1.6175
Frequency 3.47
Phase 0 degrees

Third Year Project

The aim of this project was to design a directive phased patch antenna array that could be implemented in modern vehicles for distance measurement and autonomous cruise control.

The particular technology allows improved performance as well as reduced costs and size.

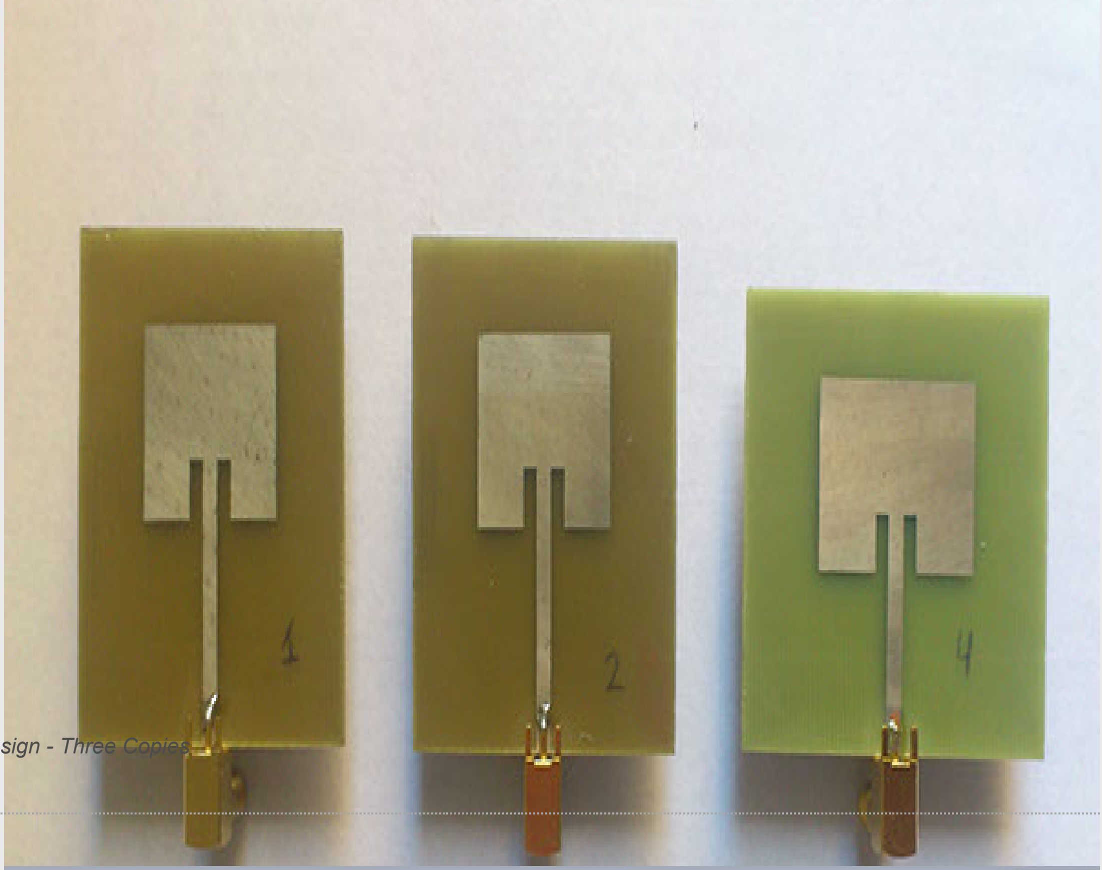

Initial Design - Three Copies

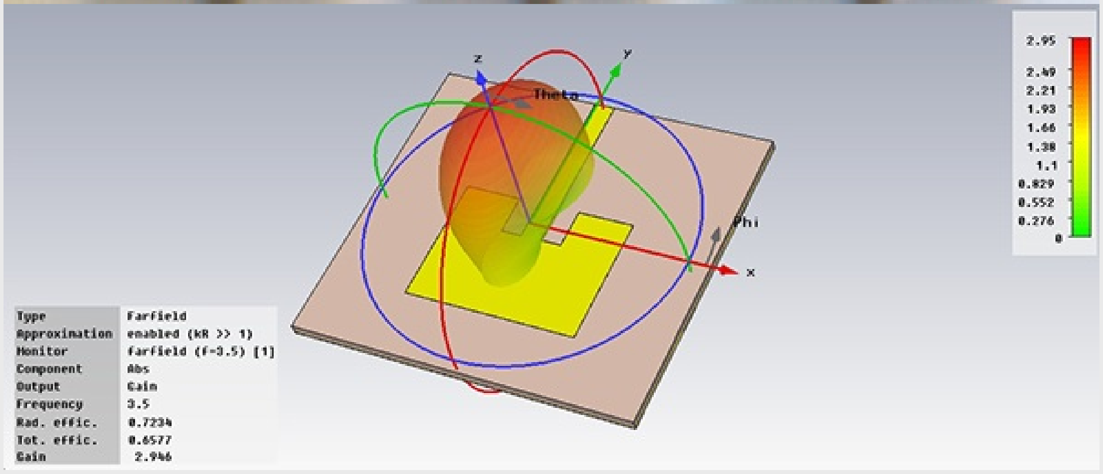
z
y
Theta
Phi
x
2.95
2.49
2.21
1.93
1.66
1.38
1.1
0.829
0.552
0.276
0

Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=3.5) [1]
Component	Abs
Output	Gain
Frequency	3.5
Rad. effic.	0.7234
Tot. effic.	0.6577
Gain	2.946

Square Patch Antenna - Farfield Simulation Results

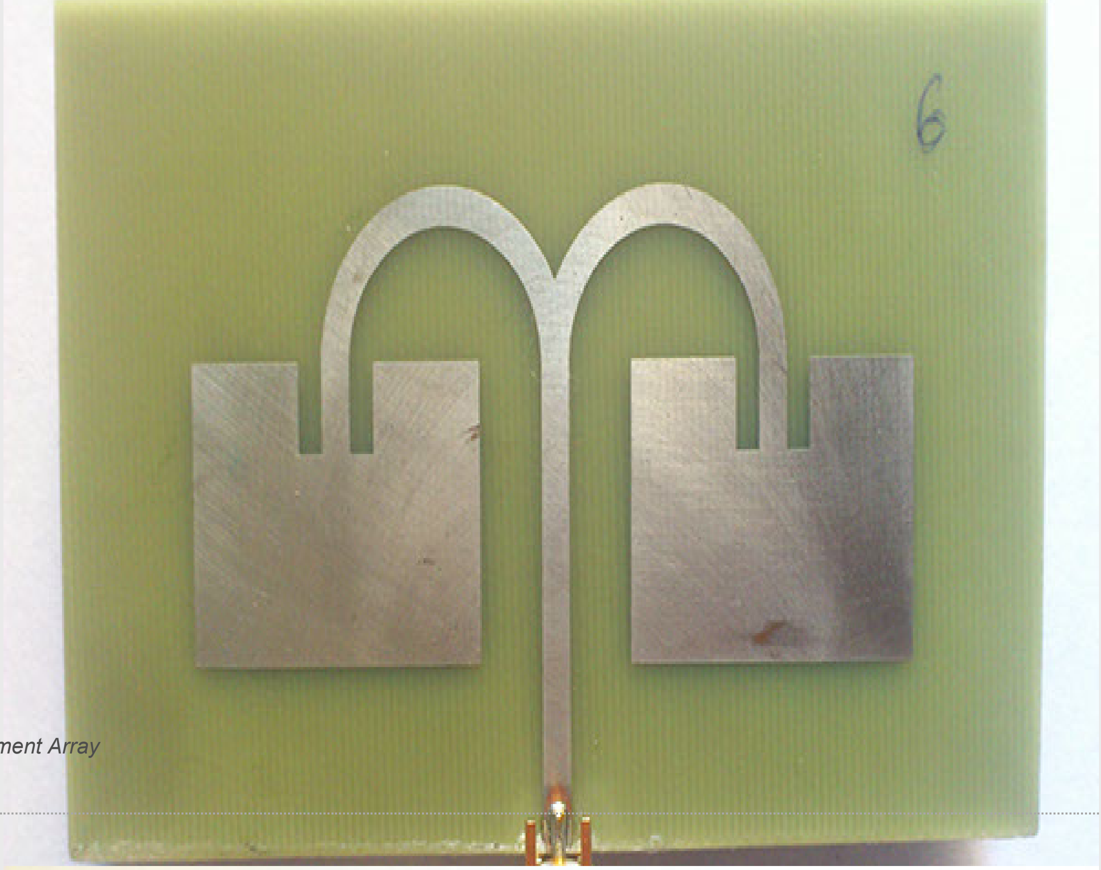

Two-Element Array

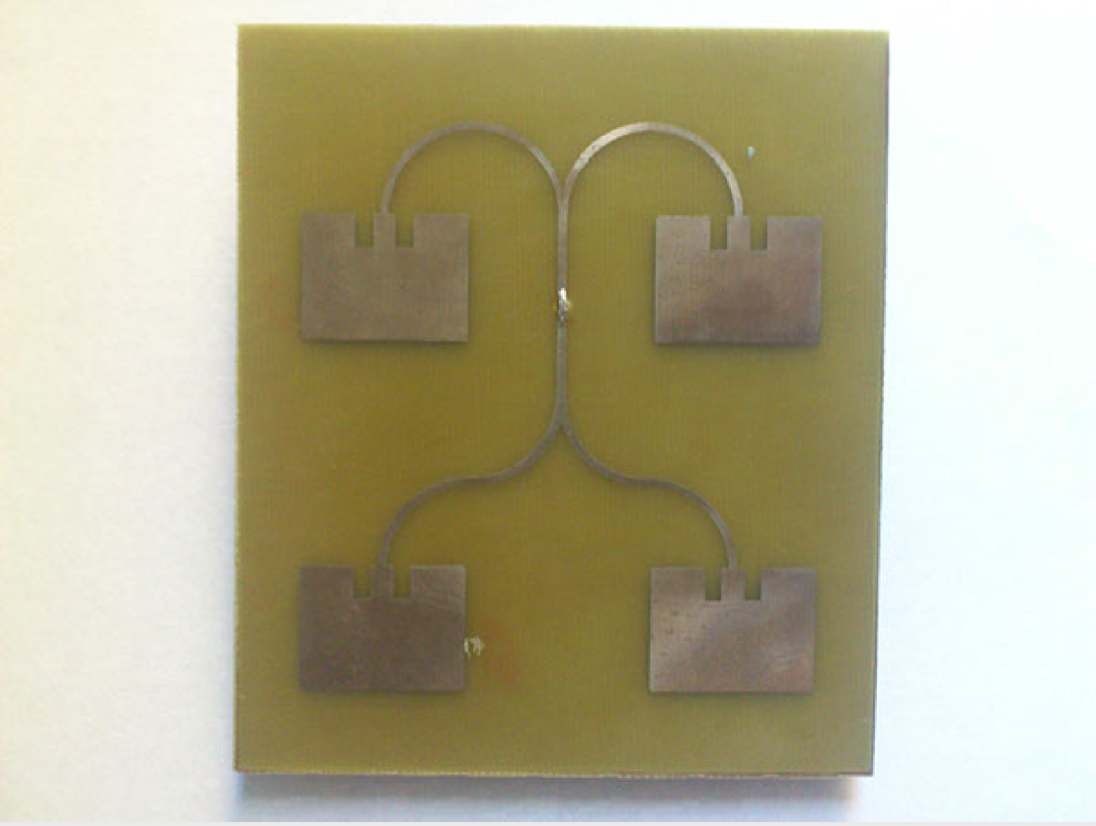

Four-Element Array

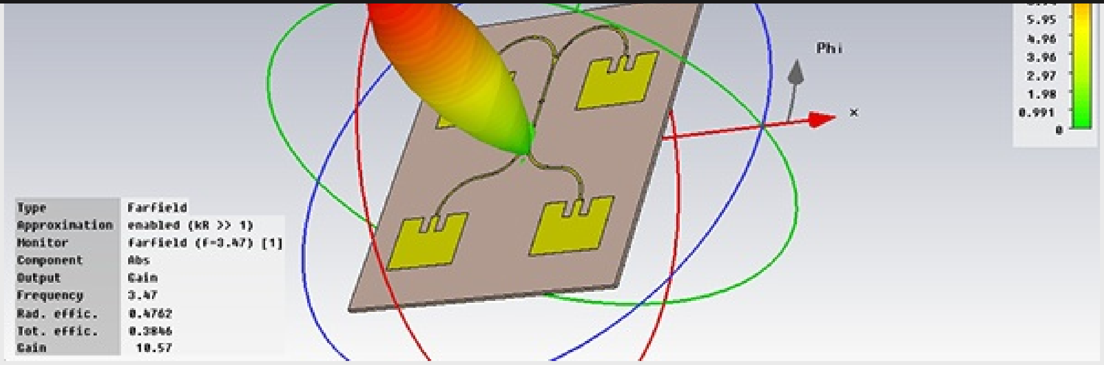

Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=3.47) [1]
Component	Abs
Output	Gain
Frequency	3.47
Rad. effic.	0.4762
Tot. effic.	0.3846
Gain	10.57

Phi
x
5.95
4.96
3.96
2.97
1.98
0.991
0

Four-Element Array - CST Microwave Studio Simulation Results

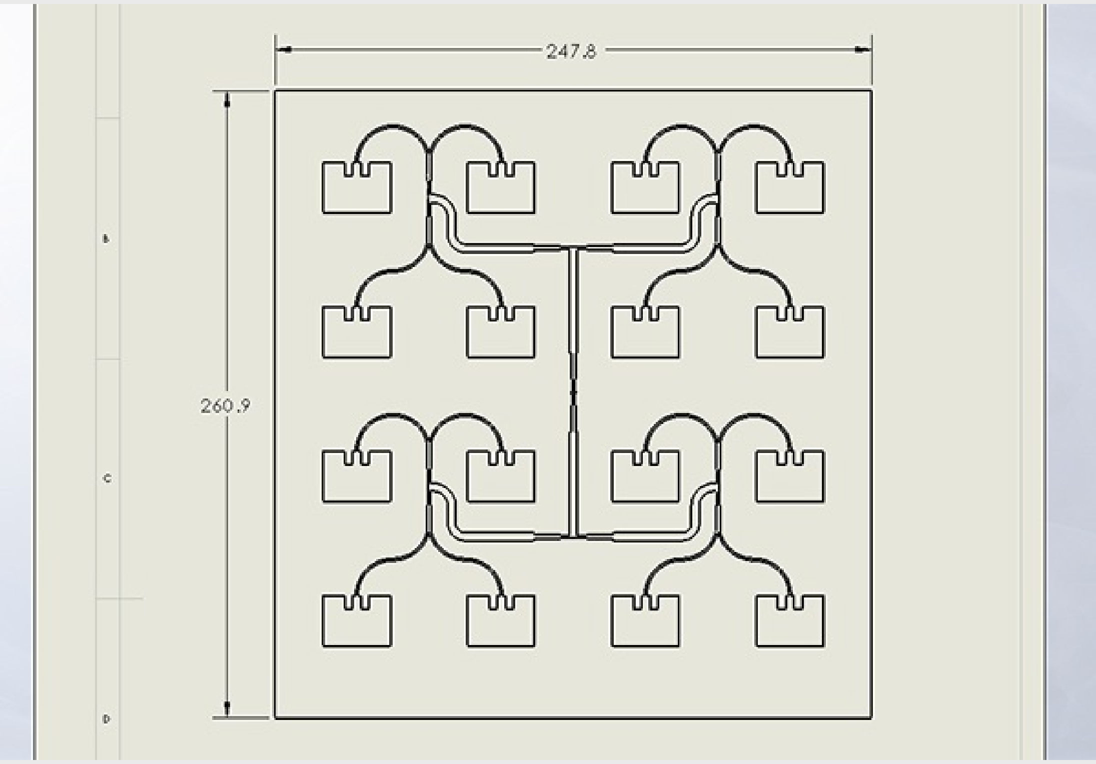
247.8
260.9
B
C
D

Sixteen-Element Array Design

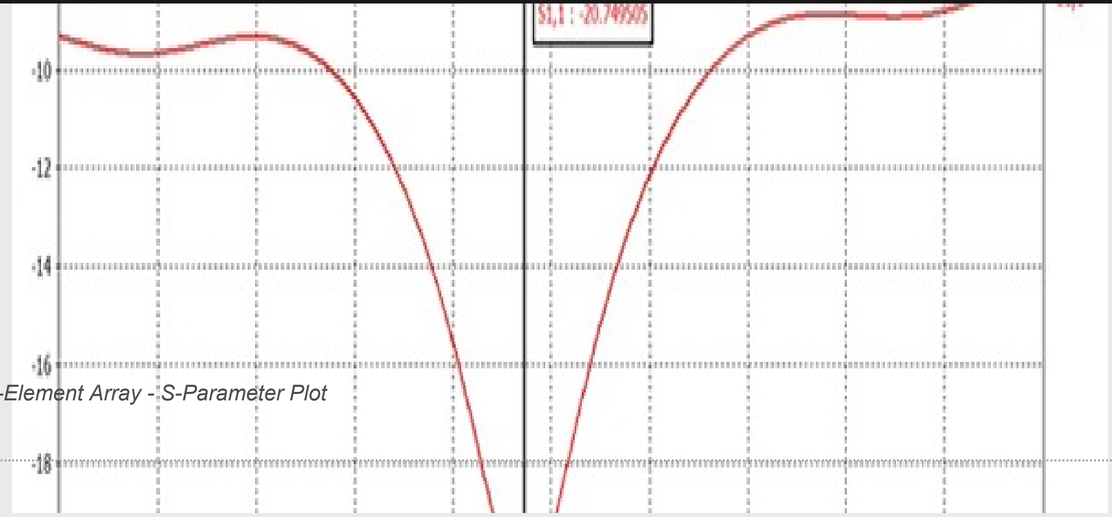

Sixteen-Element Array - S-Parameter Plot

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Vilnius, Lithuania

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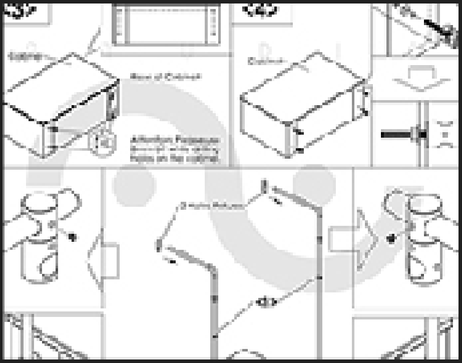

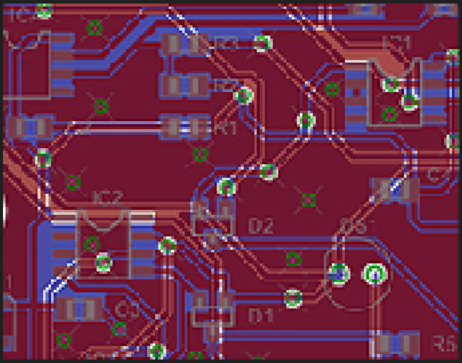

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Tools Used

CST Microwave Studio, FR-4

Report

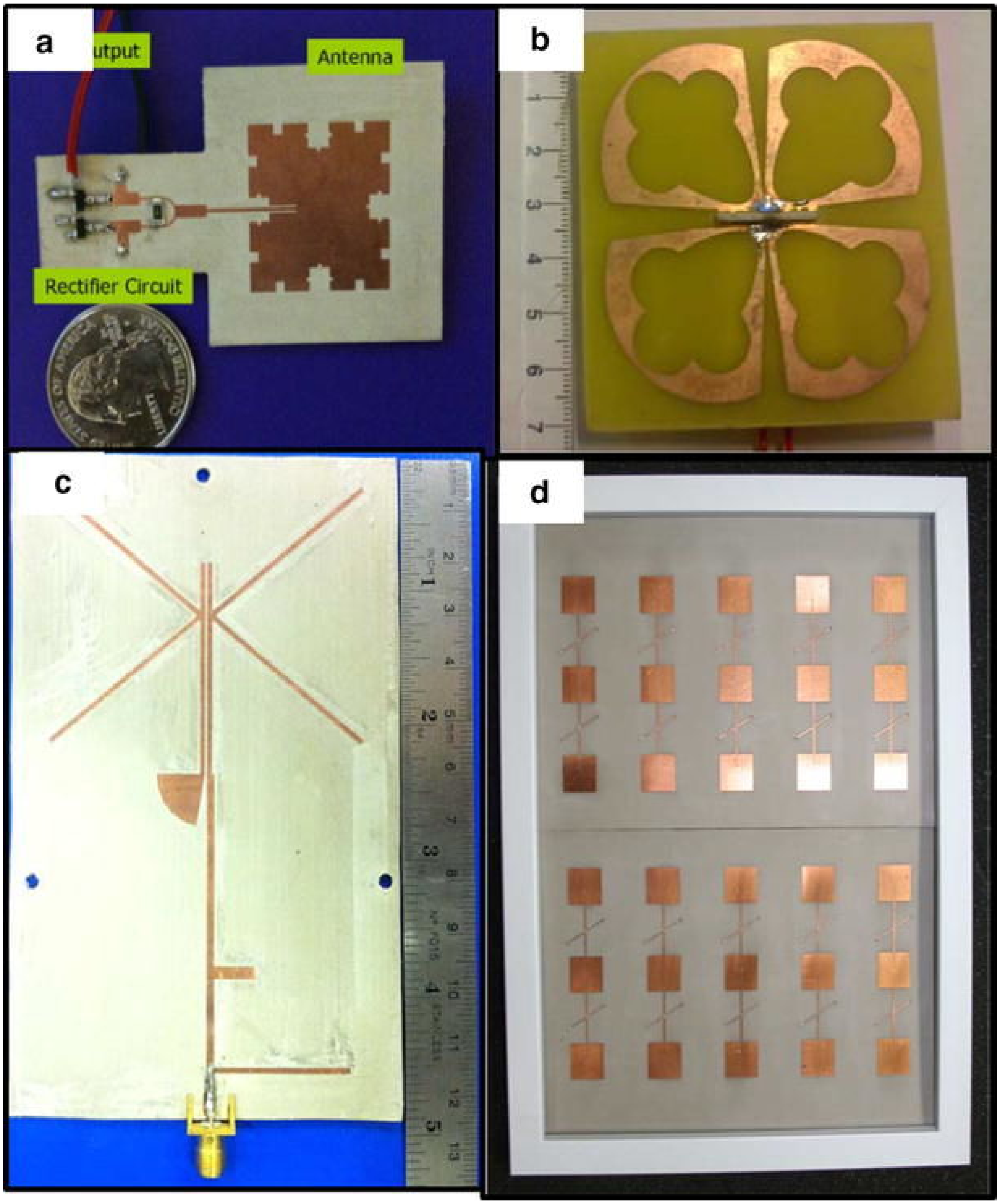

Fig. 4

Types of antennas **a** 2.45 GHz patch antenna with rectifier [38]. ©2010 IEEE. All rights reserved; **b** Planar dual-polarized antenna [24]. ©2015 IEEE. All rights reserved; **c** Microstrip antenna [37]. ©2012 IEEE. All rights reserved; **d** Array of stacked differential patch antenna [33]. ©2015 IEEE. All rights reserved

The plate antennas are popular and have many applications [27, 34, 38]; on-chip antennas are preferred for small and compact applications. Recently, many publications addressed wide-band and multi-band antennas. It has been proven that narrow-band antennas offer high energy conversion efficiencies but can only retrieve a limited amount of energy. On the other hand, wide-band or multi-band frequency antennas can retrieve more RF energy in space. However, the tradeoffs are low overall efficiency and large aperture. In [32], antennas with a resonance frequency of 4.9 and 5.9 GHz were designed with PCEs of 65.2 and 64.8%, respectively. Further work by Lu et al. [26] on polarization antennas supports the assertion that expanding the bandwidth of an antenna leads to increasing the amount of power harvested. In this work, the demonstration of broadband polarization antennas with three separate modes allows the antenna to operate in a wider range of frequencies. One common mechanism in the aforementioned works is the control of the antenna configuration by switching the diodes on and off, thus altering its resonant frequencies. However, since it uses separate modes for different frequencies, this antenna is not able to simultaneously resonate at two frequencies. On the other hand, the antenna presented in [39] is capable of operating at 2.45 and 5.8 GHz, simultaneously, providing 2.6 V output with a PCE of 65% and power density of 10 mW/cm^2.

The main purpose of aligning antennas in arrays is to enhance the antenna gain and obtain high voltage/current. Array antennas are preferred over large aperture antennas because they do not require large breakdown voltage diodes to operate. Antenna arrays can be connected before or after rectification. The first configuration enhances the retrieved power at the main beam while the second configuration expands the ability to retrieve power from various angles away from the main beam [40]. In case the RF waves are combined before rectification, the rectifier requires a large breakdown diode. If RF waves are combined after rectification, combining DC current becomes problematic. Antenna arrays can be connected in series or parallel to obtain high voltage or large current. Nonetheless, expanding the arrays yields better output but this might cause a deduction in conversion efficiency [33].

For demonstrating antenna arrays, Sun et al. [35] invented a T-junction to connect four quasi-Yagi antennas together. The advancement in this work was that the T-junction was flexible in changing from 1 × 4 array to 2 × 2 array topologies. Consequently, the system was able to operate at an ambient power level as low as 455 μW/cm^2 while obtaining 40% PCE.

Impedance matching network

In low-power consumption electrical systems, power leakage during transmission may lead to energy insufficiency. In these circumstances, adding an impedance matching network (IMN) ensures that the maximum power transfers between the RF source and load. For WPH applications, the receiving antenna is considered as the source while the rectifier/voltage multiplier is considered as the load. It is acknowledged that in DC, power transfer is optimum when the resistances of the source and load are indistinguishable. In an RF circuit, the impedance is referred to instead of resistance. An impedance mismatch between the source and load creates reflected power flow in the circuit that lowers the efficiency of the system. As its name indicates, the IMN ensures that the impedance of the source and load are identical by adding reactive components in between.

There are three basics matching configurations i.e. L, T and π matching networks (Fig. 5). The L matching is commonly used since it typically has two components, which simplifies the designing and controlling process. Additionally, the L matching networks do not alter the quality factor (Q) of the circuit.

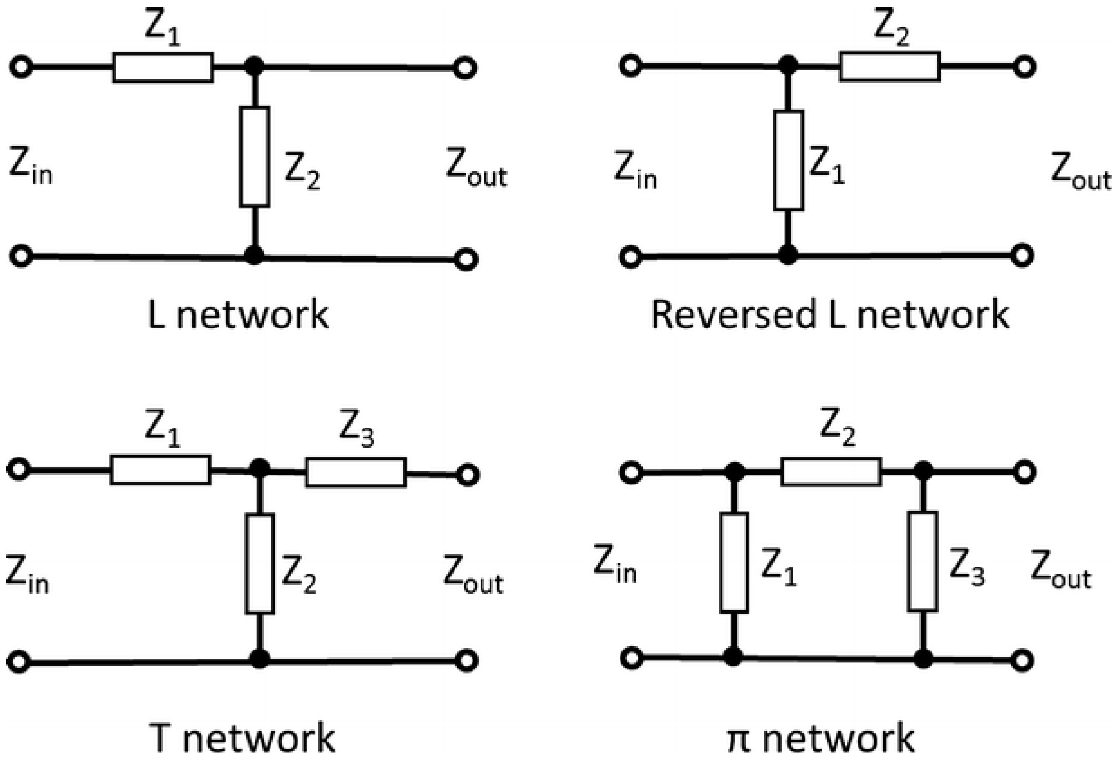

Fig. 5

Configuration of common impedance matching networks

The T and π matching configurations are more complex than the L network. Furthermore, organizing the T and π configurations into multiple stages will retain the final matching results but will change the Q factor. This strategy is useful in improving voltage boost.

There are tradeoffs between the attributes of an IMN, which include frequency, bandwidth, adjustability, and complexity. For instant, in [41], the suboptimal impedance matching and multiport ladder matching methods were introduced to enhance the matching performance and harvested power of antennas, respectively. However, the tradeoff was that implementation of these configurations required more components than traditional matching networks, thus, escalating the circuit's complexity.

Etor et al. [42] designed an IMN for THz frequencies applications using transmission lines and self-designed metal–insulator-metal diodes instead of lumped components. Moreover, fixed IMN and tunable IMN [43, 44, 45] were introduced as a technique for better matching with wide-band and multi-band antennas.

Rectifier/voltage multiplier

RF energy extracted from free space usually possesses low power density since the electric field power density decreases at the rate of $1/d^2$, where d is the distance from the RF source [46]. Therefore, a power amplifier circuit is required that yields enough DC energy from the electromagnetic waves to drive the loads. This gives rise to two possibilities, if the power consumption of the load is lower than the average power harvesting, the electronic devices at the load may work continuously; otherwise, if the load consumes more energy than the power harvesting circuit can generate, the devices cannot work continuously [47].

Rectifying is the most popular application of diodes, which refers to the conversion of AC current to DC current. In terms of power harvesting application, the RF signal retrieved in the antenna has a sinusoidal waveform. The signal after transformation through IMN would be rectified and boosted to meet the power requirements of the application.

The most fundamental topology of the rectifier is the half-wave rectifier that comprises of a single diode D1 (Fig. 6a). When AC voltage transfers through D1, only the positive cycle remains and the negative cycle is cutoff; thus, it diminishes half of the AC power. Moreover, the output V_{out} is discontinuous since the negative cycle is cutoff. Despite its simplicity, a half-wave rectifier is usually inadequate for common applications. Hence, a full-wave rectifier is more preferable. The circuit design of the full-wave rectifier is shown in Fig. 6b. During the first negative cycle of AC input, diode D1 is conductive and capacitor C1 is charged to the corresponding energy level of V_{peak} of the input. Then, at the next positive cycle, diode D1 is blocked, diode D2 is conductive so that capacitor C2 is also charged. In consequence, the output V_{out} would see two capacitors in series (each one is storing a voltage of $V_{peak)}$. Thus, V_{out} is twice V_{peak}. Therefore, this topology is more stable and efficient than the half-wave rectifier. There is also a bridge rectifier that rectifies both positive and negative cycles of the AC input but retains $V_{out} = V_{peak}$ by alternatively blocking pairs of diodes D1, D4 and D2, D3 (Fig. 6c).

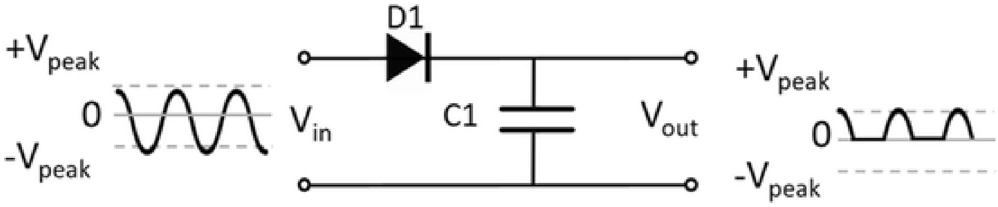

a Half-wave

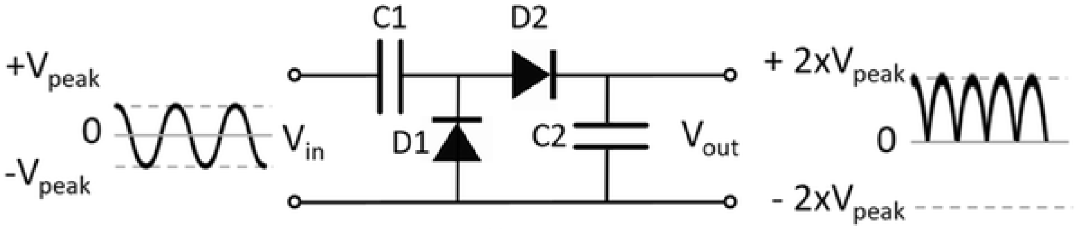

b Full-wave

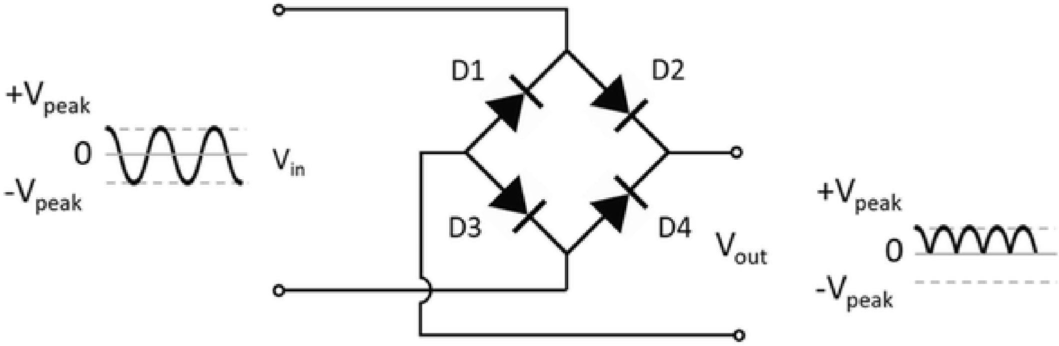

c Bridge

Fig. 6

Some common topologies of a rectifier

Voltage multiplier is a special type of rectifier circuit that converts and boosts AC input to DC output. In some case where the rectified power is inadequate for the application, there is a need for boosting the output DC by stacking single rectifiers into series, forming the voltage multiplier [48]. Several configurations of the voltage multiplier are shown in Fig. 7. The most fundamental configuration is the Cockcroft–Walton voltage multiplier (Fig. 7a). This circuit's operational principle is similar to the full-wave rectifier (Fig. 6b) but has more stages for higher voltage gain. The Dickson multiplier in Fig. 7b is a modification of Cockcroft–Walton's configuration with stage capacitors being shunted to reduce parasitic effects. Thus, the Dickson multiplier is preferable for small voltage applications. However, it is challenging to obtain high PCE due to the high threshold voltage among diodes creating leakage current, thus reducing the overall efficiency. Additionally, for high resistance loads, output voltage drops drastically leading to low current supply to the load. A summary of recent works related to voltage multiplier is shown in Table 3.

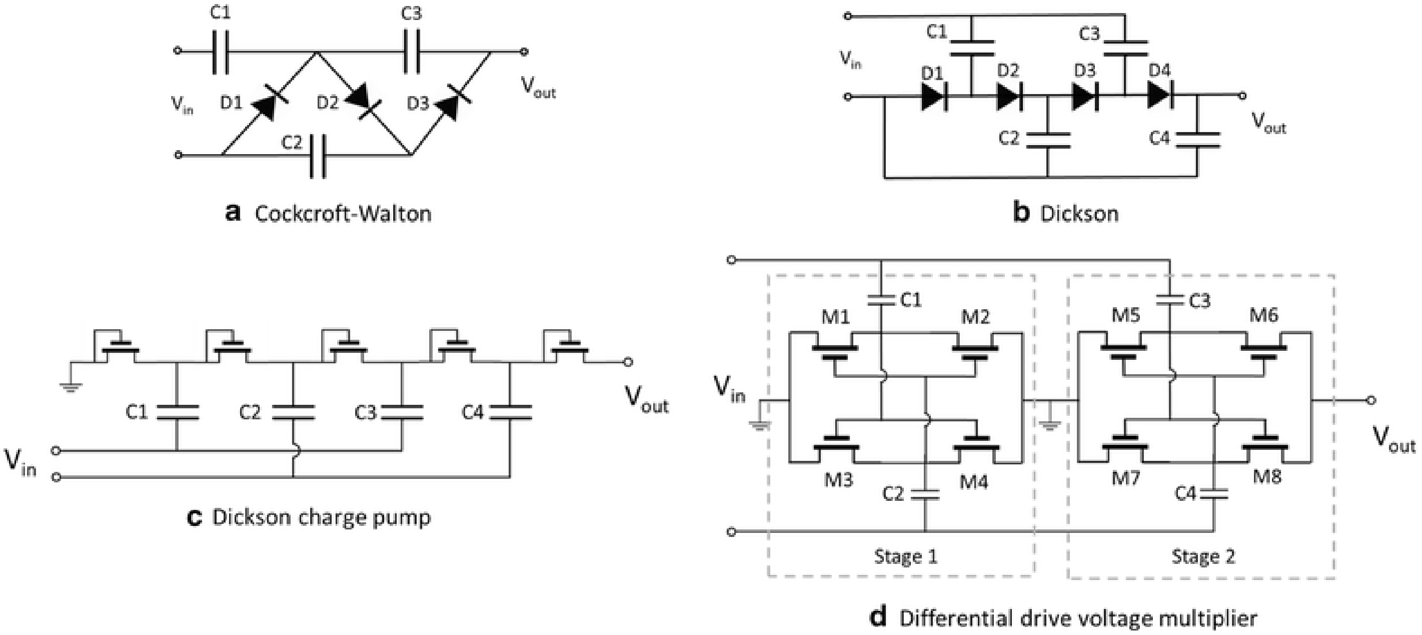
C1
C3
V_{in}
D1
D2
D3
V_{out}
C2
a Cockcroft-Walton
C1
C3
V_{in}
D1
D2
D3
D4
C2
C4
V_{out}
b Dickson
C1
C2
C3
C4
V_{out}
V_{in}
c Dickson charge pump
C1
M1
M2
M5
C3
M6
V_{in}
V_{out}
M3
C2
M4
M7
C4
M8
Stage 1
Stage 2
d Differential drive voltage multiplier

Fig. 7

Common voltage multiplier configurations: **a** Three stages Cockcroft–Walton voltage multiplier, **b** Four stages Dickson voltage multiplier, **c** Four stage Dickson voltage multiplier using CMOS technology, **d** Two stages voltage multiplier comprised of differential drive unit

Table 3

Published work comparison regarding voltage multiplier

Ref.	**Rectifier topology**	**No. of stage**	**Freq. (MHz)**	**Tech.**	**Range (dBm)**	**Maximum PCE**	**Size**
[51]	Differential	2	433	0.18 µm CMOS	0–20	74% @ 2 dBm	–
[52]	PMOS transistors	7	900	40 nm CMOS	–	44% @ > 390 mV	0.04 mm^2
[53]	Half-wave	4	900	0.18 µm CMOS	–	37.42% @ 390 mV	–
[54]	Comparator-based/active-diode	3	13.56	0.18 µm CMOS	8–15	67.9% @ 12.8 dBm	–
[55]	Dickson	3	13.56	250 nm CMOS	–	72%	0.13 mm^2
[56]	–	–	915	0.13 µm CMOS	−21.6	22.6% @ −16.8 dBm	0.186 mm^2

Prototyping Methods

There's more on this in Scherz, *Practical Electronics for Inventors.*

Solderless Breadboard or **Plugboard**

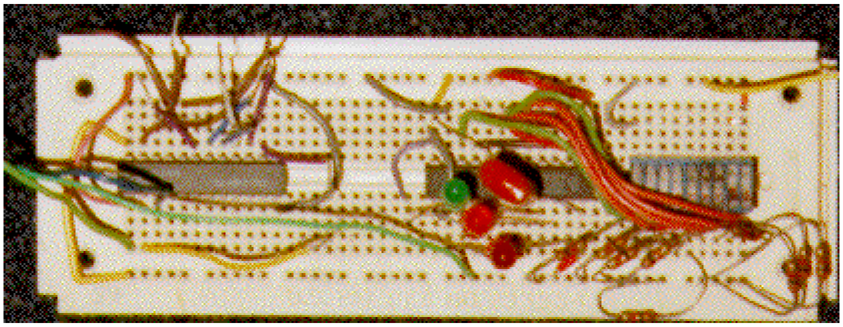

This is what we've been using in lab.

Advantages

- Very fast to build and make changes.
- Works well with DIP ICs

Disadvantages

- Limited reliability—lab testing only, for limited-size circuits.
- High capacitance between adjacent rows (~ 10 pF).
- Only for small-lead-size components (.032" or 0.82 mm max—a 1 A diode lead is just barely too big to meet the spec.)

Springboard

Used in ENGS 22

Advantages

- Fast to build and make changes.
- Accomodates large wire sizes.
- Secure, reliable connections.
- Can handle higher current/power.

Disadvantages

- Can't accommodate small lead spacings such as on ICs.
- Although it is reliable enough for long-term use, it's expensive for that purpose.

Wirewrap

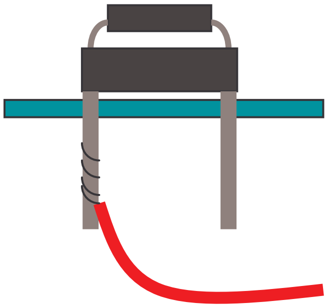

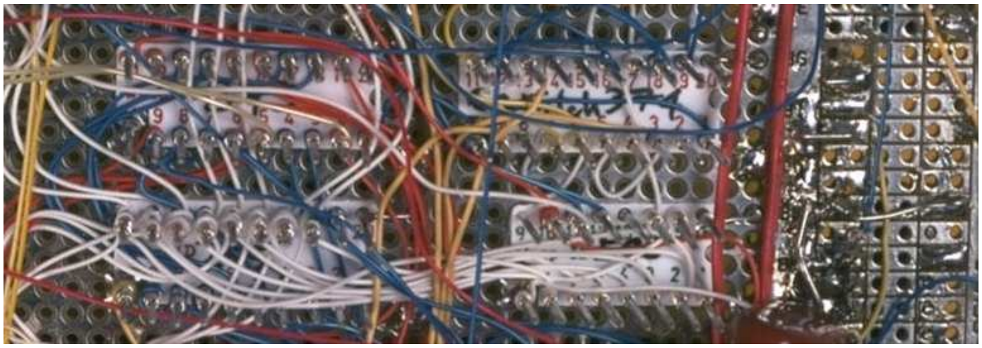

Connections made by fine wire wrapped tightly around square pins of special IC sockets. This is a great way to make a permanent version of a digital circuit almost as quickly as using a solderless breadboard. Used in ENGS 31.

Advantages

- Fast to build and make changes.
- Can make a complex circuit compact.
- Reliable.
- Can be used permanently.
- Inexpensive.

Disadvantages

- Low current—limited to under a few hundred mA.
- High inductance/resistance—on the order of 0.1 ohm, 0.25 µH per foot.
- Only makes reliable connections to square leads (as are on wire-wrap IC sockets). Discrete components (e.g., resistors, capacitors, transistors) need to be soldered to a "header" that goes in an IC socket or to individual wire-wrap pins.

Perfboard and Solder.

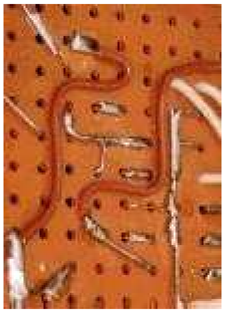

Using the same perfboard as used in wire-wrap work, it is possible to simply twist and solder leads, and run wires where needed.

Advantages

- Reliable, if done well.
- Can be used permanently.
- Inexpensive.
- Can handle any size components
- Convenient for working with discrete components.

Disadvantages

- Slow, requires skill to do well.
- Works for ICs, but not very easily.

Variations:

- Perfboard with individual copper pads on each hole so that the solder will better hold things in place. (Photo below)
- Perfboard with a perforated ground plane. Provides the shielding and grounding benefits of a ground plane, and makes ground connections easy, but requires care to avoid shorts. Some have the ground plane etched from around the holes; others require you to cut the copper away from the holes with a special tool. This is also possible with wire-wrap, as in the photo in that section.

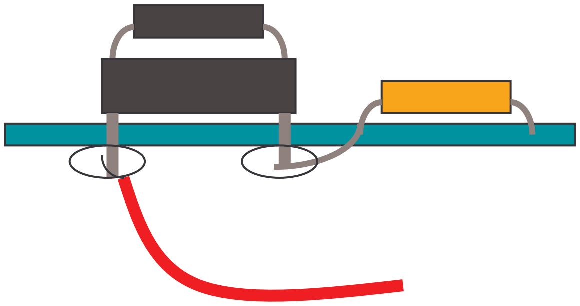

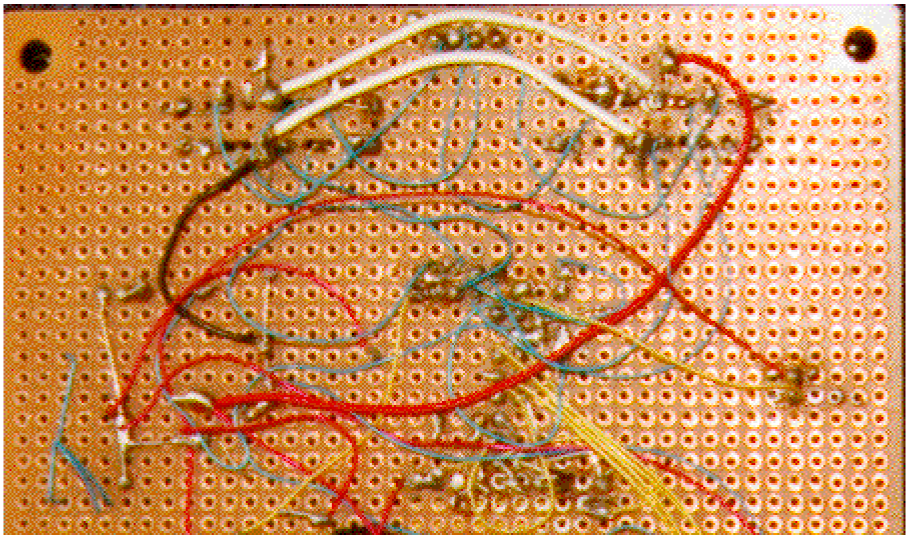

Generic Printed-Circuit Board—multiple hole-per-pad.

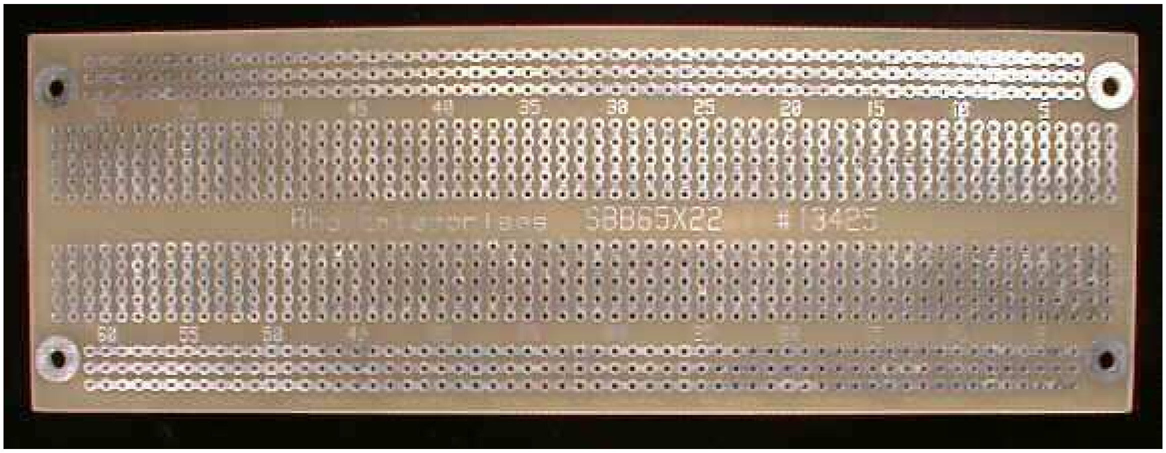

A printed circuit board with a pattern of holes and connections similar to a solderless breadboard.

Advantages

- Easier than using plain perfboard, especially for ICs.
- Reliable.
- Can be used permanently.
- Available with ground planes if needed.

Disadvantages

- Usually not as compact a final circuit as some alternatives, because you are constrained by layout.
- Pads bigger than needed can add capacitance, but not much.
- Can be expensive, especially the “vectorboard” brand.
- Sometimes awkward for odd sized or large components.

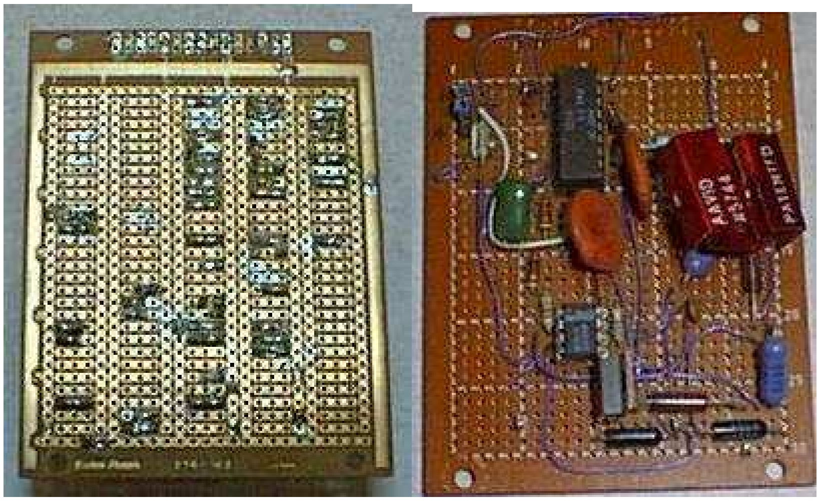

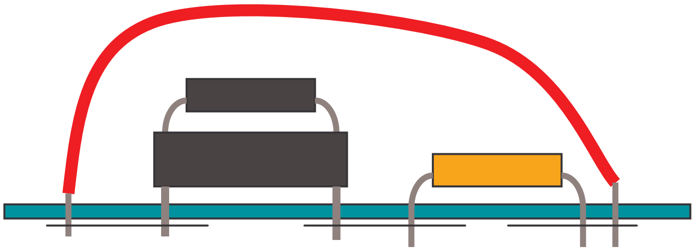

"Dead Bug," or "Ugly-board"

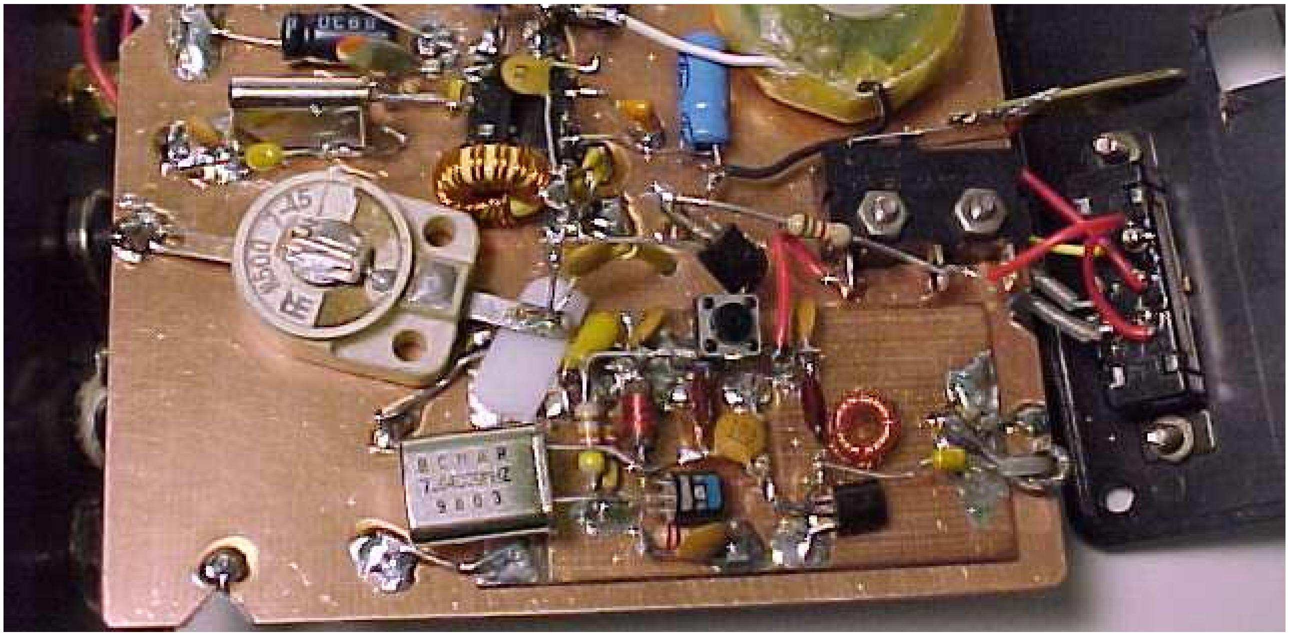

Start with a plain copper-clad board. Glue ICs down with the leads sticking up in the air. Then solder to them

Advantages

- Provides an excellent ground plane. Can be a high performance way to build sensitive and/or high-frequency analog circuits
- Can make a complex circuit compact.
- Reliable.
- Can be used permanently.
- Inexpensive.

Disadvantages

- Requires high soldering skill.
- Takes a long time to build.
- Mechanical support for components is marginal; can add glue ("RTV") after debugging.
- Only makes reliable connections to square leads (as are on wire-wrap IC sockets). Other components (e.g., resistors, capacitors, transistors) need to be soldered to a "header" that goes in an IC socket or to individual wire-wrap pins.

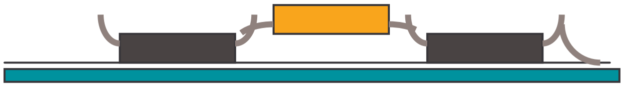

Variations:

- Manually cut the board with a dremel tool to isolate sections for purposes other than ground plane (use the back for ground plane). See photo below.
- Glue on little rectangles of cut-out board to add power busses, etc.

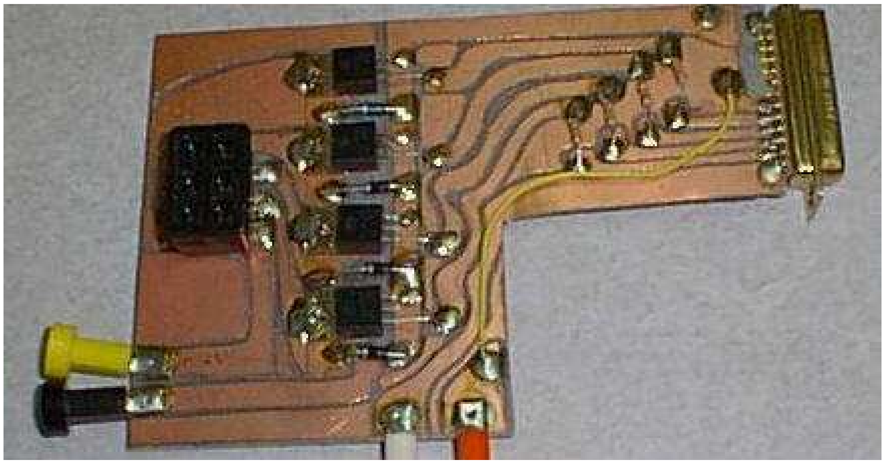

Printed circuit board (PCB)

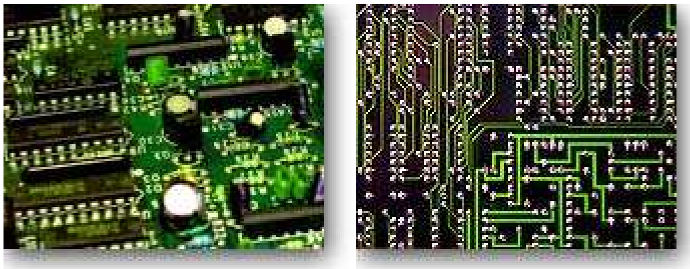

This is what is used virtually universally in production of electronics.

Advantages

- Easy to build in production.
- Repeatable, controllable stray L, C.
- Can handle virtually any component, power level.
- Highly reliable.
- Can make very compact.
- Design can be (somewhat) automated from a schematic you have entered.

Disadvantages

- Laying out the board and getting it fabricated takes time, although you can pay for fabrication in a few days if you can afford it.
- Expensive, on the order of hundreds of dollars for one, but with almost no increase in cost to make many.
- Hard to make changes, but making changes may be easier than building another type of prototype.

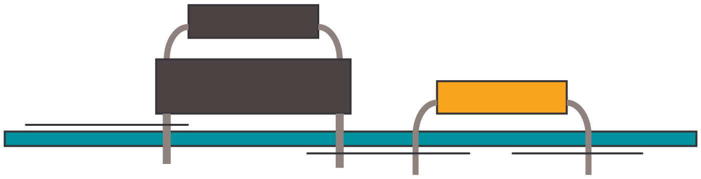

Notes on surface-mount components

Most modern production designs now use surface-mount components instead of “through hole” components. The circuits can be more compact, and the board layout is easier because different things can be done on each side (and in additional layers between sides) without through-holes interfering. But prototyping gets much more difficult!

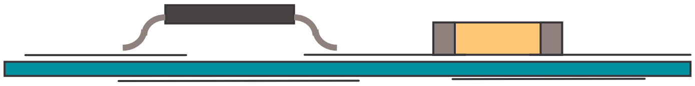

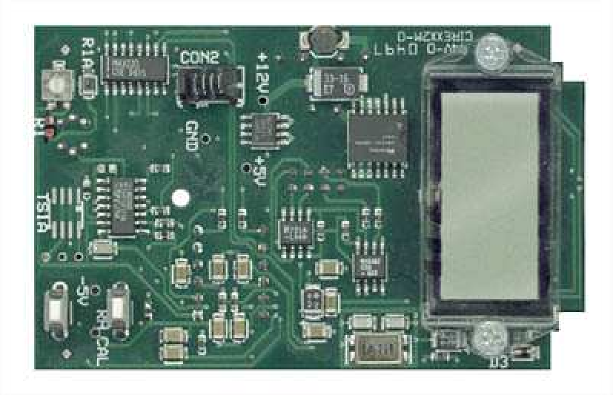

Prototyping options for surface mount

- Simulate, and then lay out a PCB. Don’t ever make a breadboard.
- Order DIP ICs and leaded passives for the prototype, and then switch to surface mount for production.
- Get adaptors that have pads to solder surface-mount ICs to, and then standard-spacing (0.1”) pins in DIP or SIP layout. Digikey carries “surfboards” made by Capital Advanced Technologies, and adaptors made by Aries Electronics. In addition to DIP and SIP adaptors, there are boards with solder pads for connecting larger wires; these work well for prototypes built in “dead bug” style.

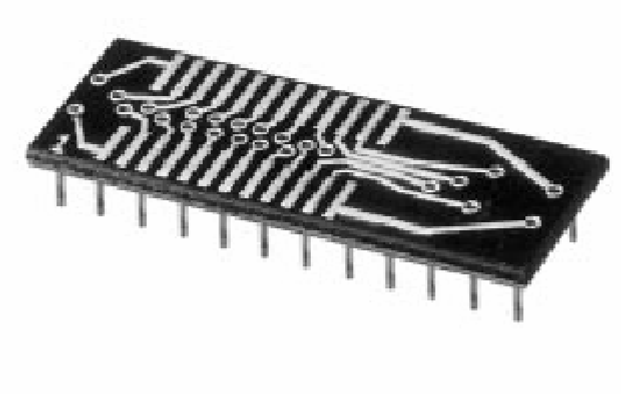

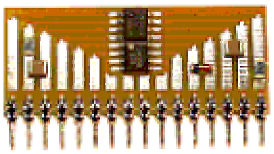

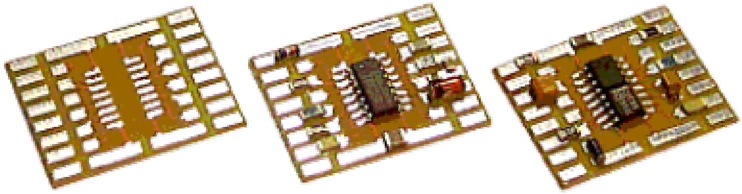

Crystal receiver set 11

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This receiver has a single tuned circuit, the Q factor of the tuned circuit is quite low.
The receiver can be used well for reception of local stations, for reception of distant stations it is less suitable.

I tried to give this receiver a nice "old-fashioned" look, the reception performance was in this design of less importance.
This receiver is for sale, I made a series production of these, and will build more on request.
This receiver is also for sale as do-it-yourself kit.
See the shop for more information.

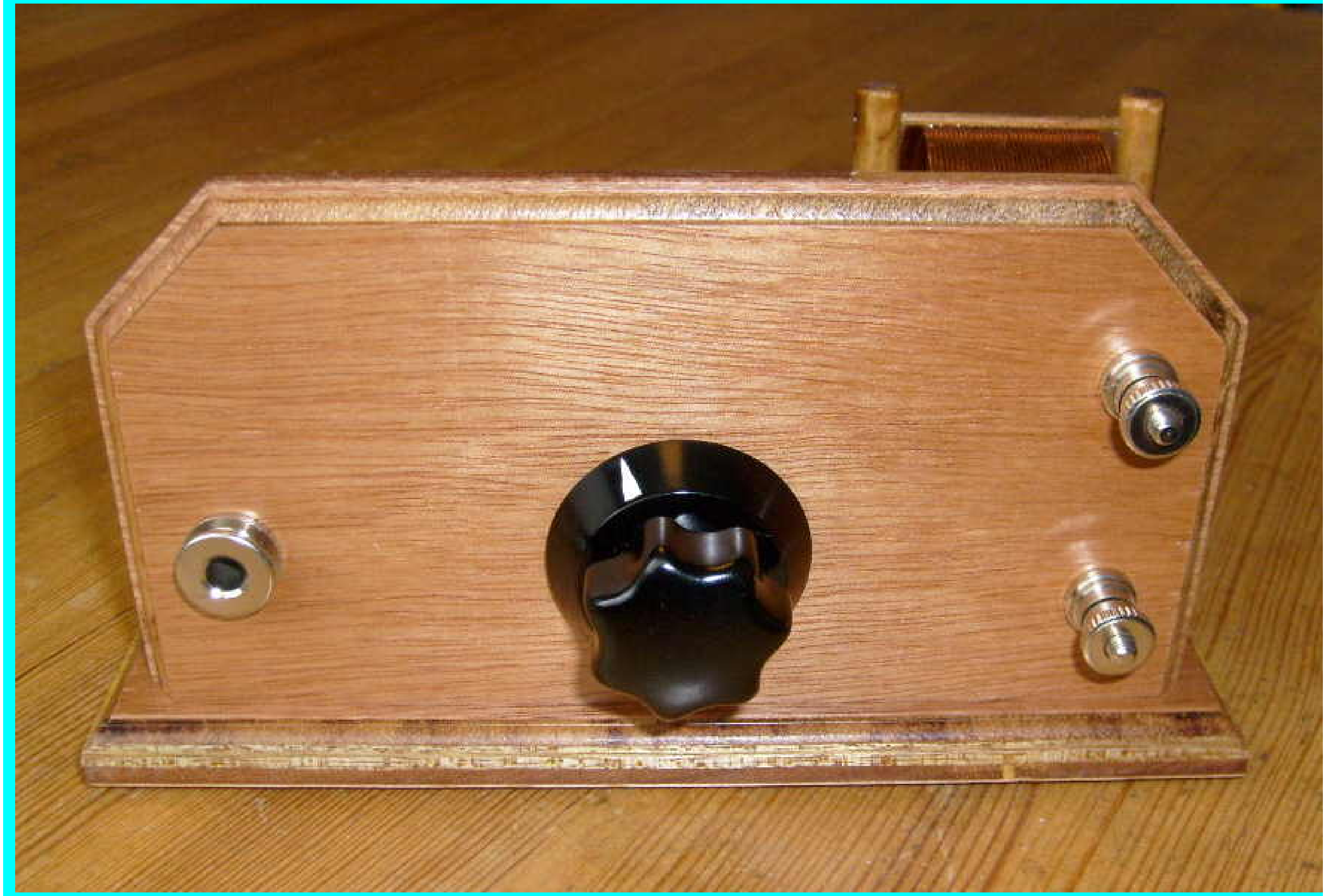

The front panel of the receiver.
On the left side the socket for the headphone.
In the middle the tuning knob.
On the right the connections for antenna (upper) and ground (lower).

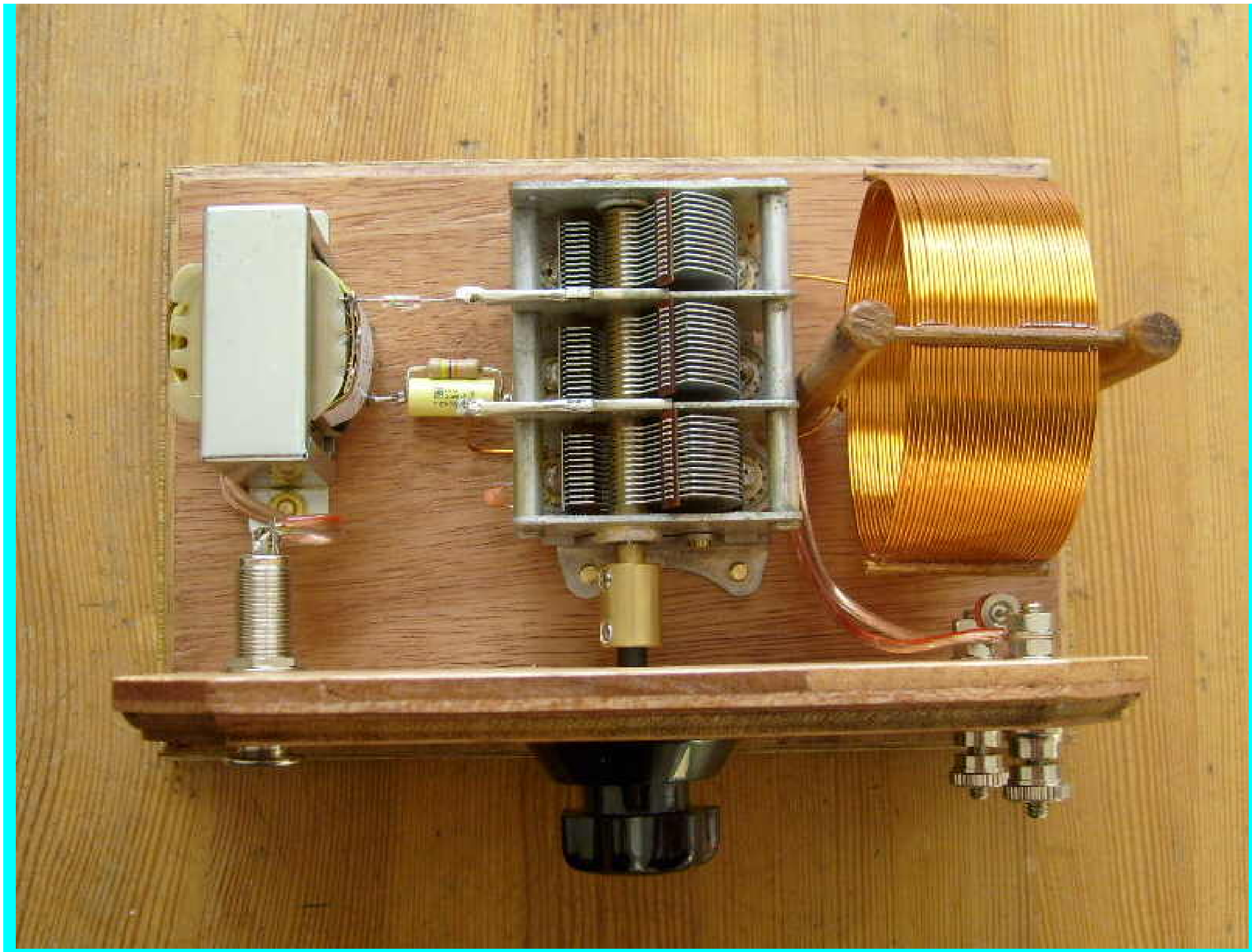

Top view of the receiver.

Circuit diagram of receiver set 11

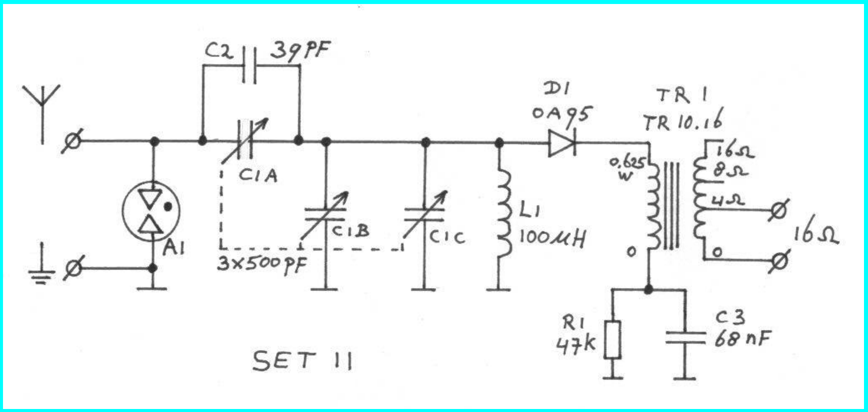

Circuit description.
The resonance circuit is formed by coil L1 and C1b and C1c (together 1000 pF).
Capacitor C1a and C2 provide the matching between antenna and tuned circuit.
The frame (rotor) of the tuning capacitor is carrying the RF signal, by this it is possible to tune simultaneously the tuned circuit (C1b and C1c) and the antenna matching (C1a).
Germanium diode D1 provides the signal detection.
Transformer TR1 is loaded with 16 Ω at its 4 Ω output, through this the input impedance increases from 16 kΩ to about 43 kΩ.
At the output a headphone of 2x 32 Ω can be connected, with the two speakers parallel, the impedance is 16 Ω.

Component A1 is a *gas discharge tube* (also called: *surge arrester*) with type number: N81-A90X.
The gas discharge tube protects the antenna input for too high voltages.

These high voltages can occur if the antenna picks up static charge from the air (especially occurs with long outdoor antennas from non insulated antenna wire).
As the voltage at the antenna is higher then 90 Volt, the gas discharge tube will start to conduct and short the high voltage to ground.
As soon as the charge has flown to ground, the conduction stops automatically.

Frequency range of the receiver.
Frequency range without antenna: 500 - 2500 kHz.
Frequency range with 10 meter antenna connected: 487 - 1860 kHz.
Both with and without antenna connected, the whole medium wave band can be tuned.

Q factor of the LC circuit (Without antenna and without diode connected):
600 kHz: Q= 83
900 kHz: Q= 81
1200 kHz: Q= 75
1500 kHz: Q= 65
The circuit Q is rather low, one reason for this is because the RF signal is in this design on the frame of the tuning capacitor.
Because the frame of the tuning capacitor is directly connected to the wooden bottom plate losses occur here.

You can find a complete building instruction op the following pages:

Step 1 Preparing the components

Step 2 Making the frame of the receiver

Step 3 Making the coil

Step 4 Placing the components

You will find here the part list of this receiver.

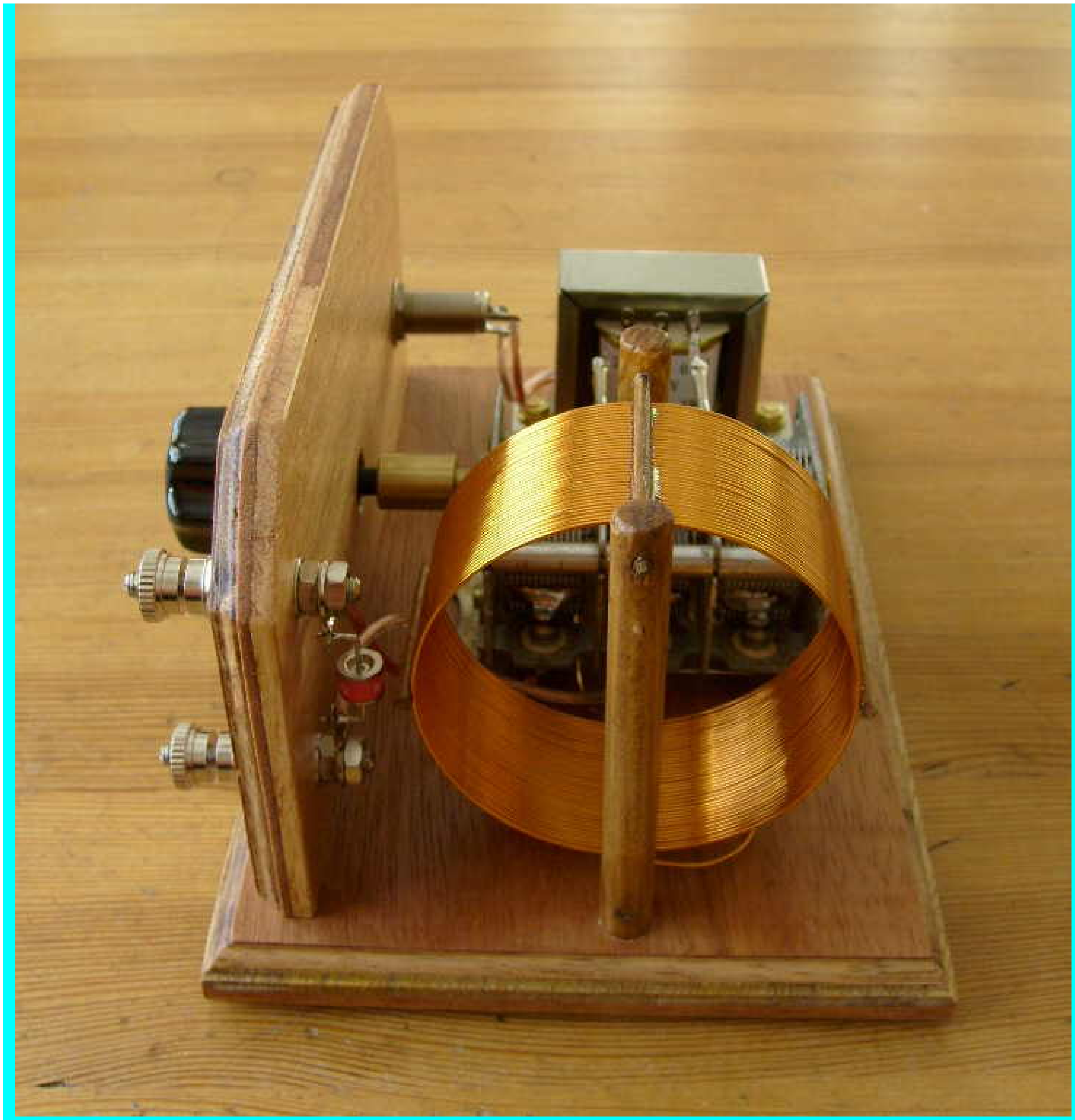

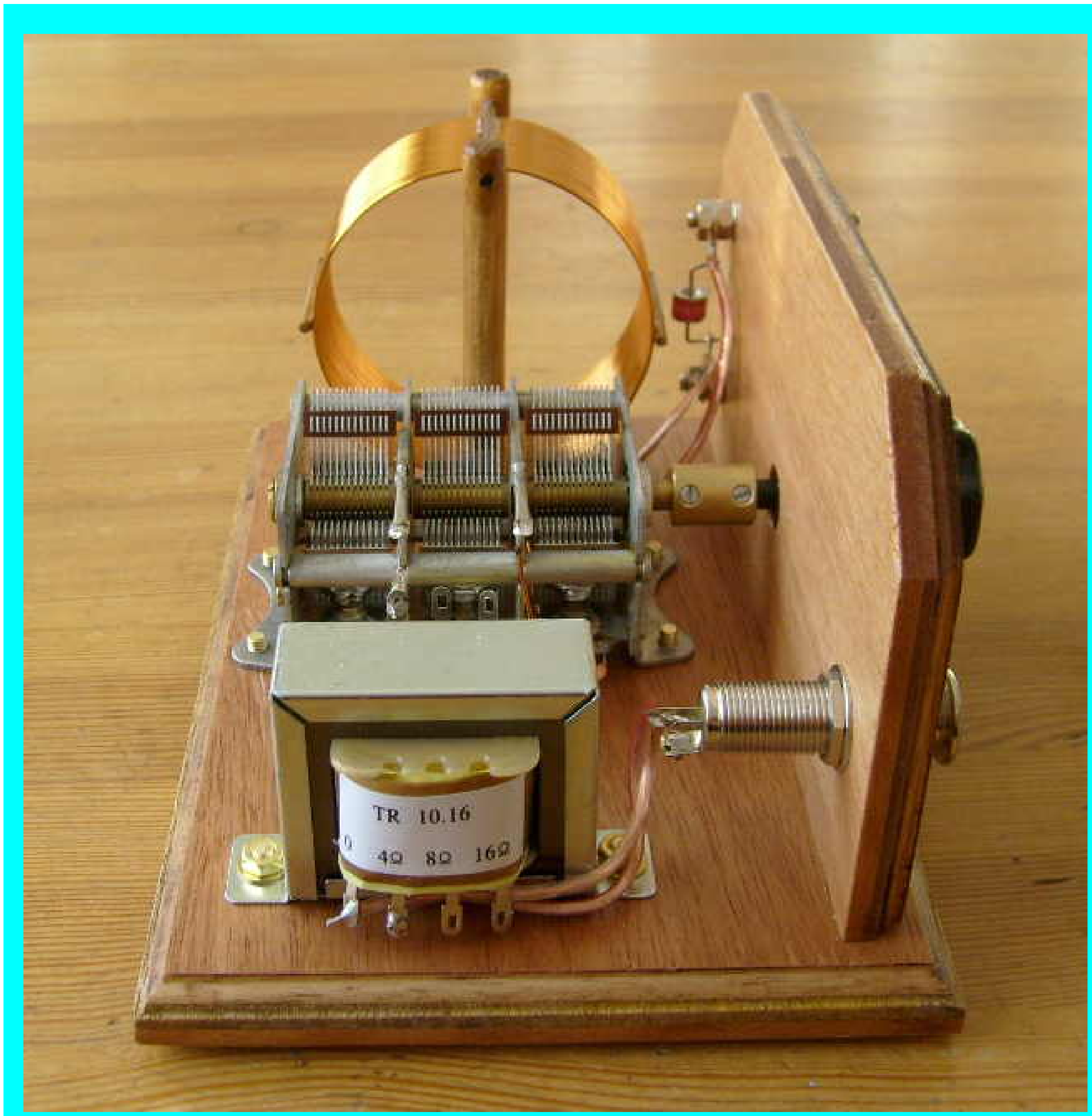
TR 10.16
Ω 4Ω 8Ω 16Ω

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How to make a batteryless (crystal set) radio

By **Sagar Sapkota** - July 21, 2012

CRYSTAL SET

The simplest radio receiver, known as a Crystal Set, consists of nothing more than a coil, tuning capacitor, diode detector, and a pair of earphones. A typical circuit diagram for a Crystal Set Radio is given below where inductor or coil L1 is tuned by variable capacitor VC1 to the transmitter frequency. Diode D1 demodulates the signal, which is fed straight to the earphones. There is no amplification.

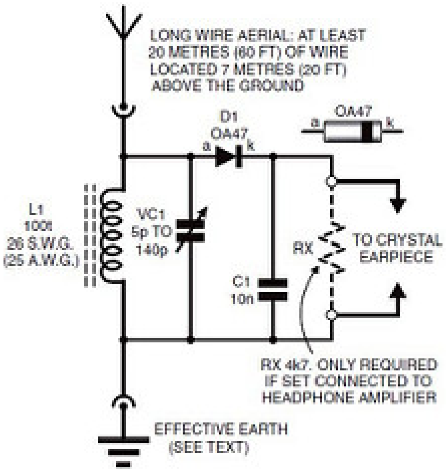
LONG WIRE AERIAL: AT LEAST
20 METRES (60 FT) OF WIRE
LOCATED 7 METRES (20 FT)
ABOVE THE GROUND
D1
OA47
a
k
OA47
a
k
L1
100t
26 S.W.G.
(25 A.W.G.)
VC1
5p TO
140p
RX
TO CRYSTAL
EARPIECE
C1
10n
RX 4k7. ONLY REQUIRED
IF SET CONNECTED TO
HEADPHONE AMPLIFIER
EFFECTIVE EARTH
(SEE TEXT)

CLICK HERE FOR BIGGER PHOTO

** You can use 1N34 Germanium diode in place of OA47*

A long (at least 20 metres), high (17 metres or more) aerial and a good earth (a buried biscuit tin or a metre of copper pipe driven into damp ground) are required in order to ensure audible headphone reception. The earphones originally used with these receivers had an impedance of around 4000 ohms and were very sensitive (and heavy and uncomfortable). They are no longer available, but a crystal earpiece, which relies on the piezoelectric effect, will give acceptable results.

Low impedance ”Walkman” type earphones are NOT suitable.

Component details:

Resistor- RX-4.7k, 0.25 W- only required if set is connect to audio amplifier

Capacitors- C1- 10nF disc ceramic VC1- 5p to 140p, polythene dielectric variable capacitor.

Semiconductors: D1: OA47 or 1N34- Germanium Diode

Miscellaneous: L1- Ferrite Rod, 100mm(4 inch)x9mm/10mm dia., with coil.

Crystal earpiece and jack socket to suit; plastic control knob; plastic insulated flexible cable for aerial wire, downlead and earth connection, 30 meters minimum; buried biscuit tin or 1 meter of copper pipe for earth system; 50gm reel of 26SWG enamelled copper wire, for tuning coil; card and glue for coil former; multistrand connecting wire; crocodile clips or terminals for aerial and earth lead connection; solder, etc.

READ MY EXPERIENCES- HOW EASILY I MADE A BATTERYLESS RADIO

DRAWBACKS

Quite apart from the absence of amplification, two factors seriously limit the performance of crystal receivers. Germanium diodes become increasingly reluctant to conduct as the applied voltage falls below 0.2V, and this makes the receiver insensitive to weak signals. Silicon diodes have a threshold of around 0.6V, and are, therefore, unsuitable for circuits of this kind.

** Silicon diodes like 1N4001 are not suitable*

The earphone loading imposes heavy damping on the tuned circuit, hence, reduces its ability to separate signals. With such low selectivity insensitivity can be a blessing, and crystal sets are normally only capable of receiving a single, strong transmission on the long and medium wavebands. They will sometimes receive more than one if a shortwave coil is fitted.

The aerial and diode can be connected to tappings on the tuning coil in order to reduce damping, but the improvement in selectivity is usually at the expense of audio output. When valves cost a week's wages and had to be powered by large dry batteries and lead/acid accumulators, the construction of simple receivers of this kind could be justified. With high performance transistors now costing only a few pence or cents, crystal sets are now regarded as 'nostalgic pieces". Some readers may, however, wish to build one out of curiosity, or for the novelty of having a receiver that **does not require a power supply.**

CIRCUIT DETAILS

Ferrite loop aerial L1 and polythene dielectric variable capacitor VC1 form the tuned circuit. Point contact germanium diode D1 (1N34 or OA47) demodulates the signal; capacitor C1 bypasses residual r.f. (radio frequency) to earth and also exhibits a reservoir action, enabling the a.f. (audio frequency) output to approach its peak value. The recovered audio signal is fed directly to a crystal earpiece. Signal voltages introduced in the ferrite loop aerial by the radiated magnetic field are much too much to produce an output from the detector, and the component is used here simply as a tuning coil. The ferrite core does, however, reduce the number of turns required for the coil winding, thereby reducing its resistance and increasing its audio quality.

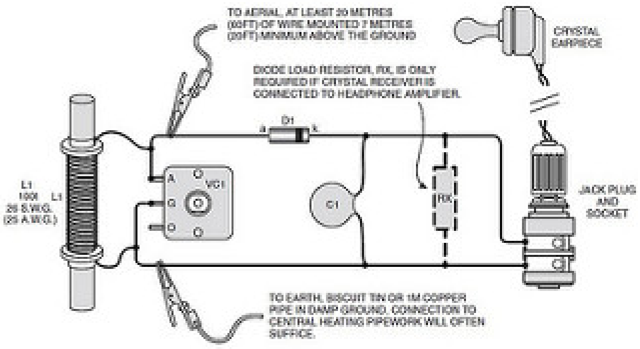
TO AERIAL, AT LEAST 20 METRES (60FT) OF WIRE MOUNTED 7 METRES (20FT) MINIMUM ABOVE THE GROUND
CRYSTAL EARPIECE
DIODE LOAD RESISTOR, RX, IS ONLY REQUIRED IF CRYSTAL RECEIVER IS CONNECTED TO HEADPHONE AMPLIFIER.
D1
a
k
L1
100t
L1
26 S.W.G.
(25 A.W.G.)
A
VC1
G
O
C1
RX
JACK PLUG AND SOCKET
TO EARTH, BISCUIT TIN OR 1M COPPER PIPE IN DAMP GROUND. CONNECTION TO CENTRAL HEATING PIPEWORK WILL OFTEN SUFFICE.

GET BIGGER PICTURE

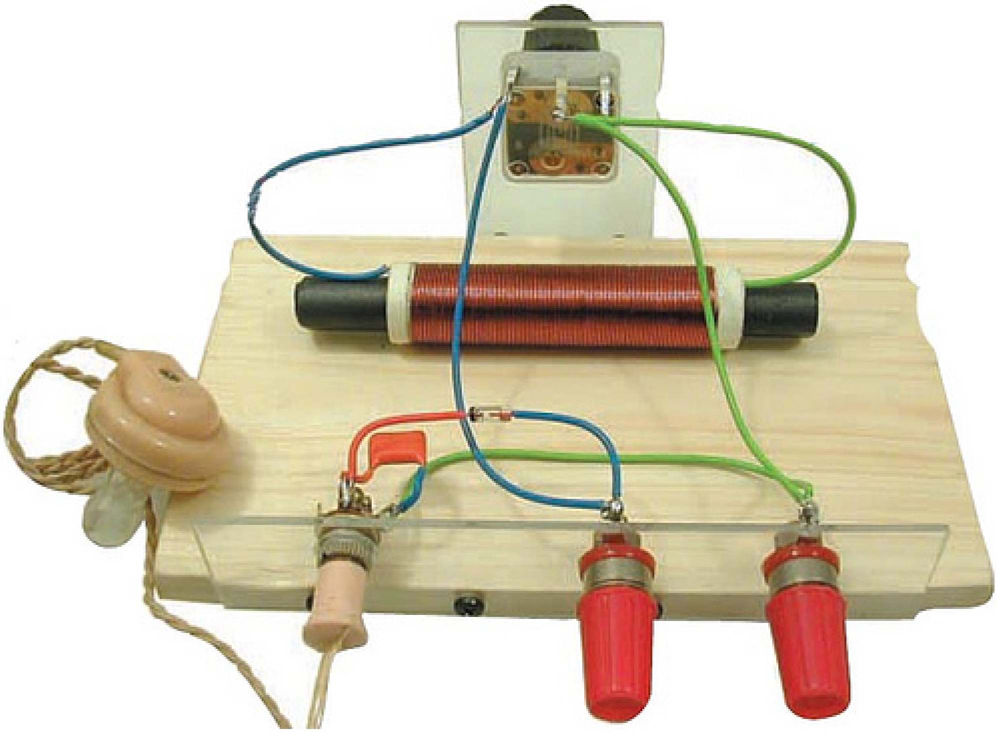

COIL DETAILS

Full construction and winding details for the ferrite tuning/ aerial coil L1 are shown in figure.

The coil is made from 26 SWG(25 AWG) enamelled copper wire, close wound on a cardboard former.

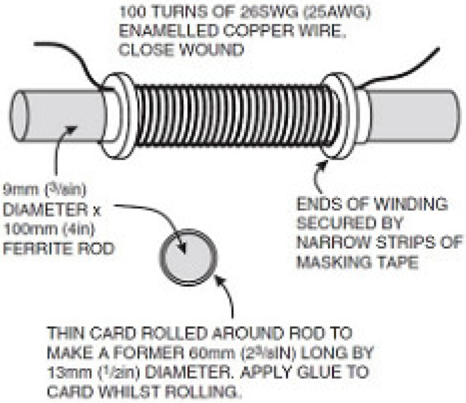
100 TURNS OF 26SWG (25AWG) ENAMELLED COPPER WIRE, CLOSE WOUND
9mm (3/8in) DIAMETER x 100mm (4in) FERRITE ROD
ENDS OF WINDING SECURED BY NARROW STRIPS OF MASKING TAPE
THIN CARD ROLLED AROUND ROD TO MAKE A FORMER 60mm (2 3/8IN) LONG BY 13mm (1/2in) DIAMETER. APPLY GLUE TO CARD WHILST ROLLING.

The r.f. bypass capacitor C1 can in practice, be omitted with no noticeable reduction in performance. However, if the set is to be connected to either the headphone amplifier or speaker amplifier decribed next month, the component together with diode, load resistor, RX, must be included.

AMPLIFICATION Audio frequency amplification, after the diode detector will permit the use of low impedance Walkman type earphones or even loud speaker operation. It will do nothing, however, to overcome the diode’s insensitivity to weak signals. For this we must have radio frequency amplification of the signals picked up by the aerial before they reach the detector(The standard circuit for a transistor portable receiver has three stages of radio frequency amplification ahead of the diode).

For amplification, you can use a simple audio amplifier using LM386.

READ MY EXPERIENCES ON MAKING A BATTERYLESS RADIO

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Fully printed flexible and disposable wireless cyclic voltammetry tag

Younsu Jung[1], Hyejin Park[1], Jin-Ah Park[1], Jinsoo Noh[1], Yunchang Choi[1], Minhoon Jung[2], Kyunghwan Jung[2], Myungho Pyo[1], Kevin Chen[3], Ali Javey[3] & Gyoujin Cho[1]

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A disposable cyclic voltammetry (CV) tag is printed on a plastic film by integrating wireless power transmitter, polarized triangle wave generator, electrochemical cell and signage through a scalable gravure printing method. By proximity of 13.56 MHz RF reader, the printed CV tag generates 320 mHz of triangular sweep wave from +500 mV to −500 mV which enable to scan a printed electrochemical cell in the CV tag. By simply dropping any specimen solution on the electrochemical cell in the CV tag, the presence of solutes in the solution can be detected and shown on the signage of the CV tag in five sec. 10 mM of N,N,N′,N′-tetramethyl-p-phenylenediamine (TMPD) was used as a standard solute to prove the working concept of fully printed disposable wireless CV tag. Within five seconds, we can wirelessly diagnose the presence of TMPD in the solution using the CV tag in the proximity of the 13.56 MHz RF reader. This fully printed and wirelessly operated flexible CV tag is the first of its kind and marks the path for the utilization of inexpensive and disposable wireless electrochemical sensor systems for initial diagnose hazardous chemicals and biological molecules to improve public hygiene and health.

Cyclic voltammetry (CV) has been used as a powerful tool for the study of electrochemical redox reactions between the electrodes and the solutions of all kind of solutes such as metals[1], organic molecules[2], proteins[3], bacteria[4], viruses[5], and DNA[6]. Because of the high sensitivity of the electron transfer redox reactions, CV could become a very promising ubiquitous electrochemical sensor protocol if the cost and size of the CV system were significantly reduced to commercially viable single-use disposable units for checking traces of hazardous materials such as lead[7], mercury[8], arsenic[9], e-*coli*[10], and pesticides[11] in water or to diagnose the level of glucose[12], cholesterol[13] and specific enzymes[14] in blood. This single-use disposable CV would dramatically reduce the cost of maintaining the public health system[15]. Therefore, inexpensive and disposable CV measurement system that can be operated wirelessly using a smartphone or RF (radio frequency) reader without complicate operation processes is in high demand for the realization of an ubiquitous sensor network system (Figure 1a). They would mainly be used as ubiquitous diagnostic and testing tools for detecting and monitoring the level of target specimens. However, there is no technology that is advanced enough yet to build a wireless, inexpensive and disposable CV system. In this paper, as a form of RF-tag, an extremely inexpensive, disposable and fully printed CV system is demonstrated for the first time by mimicking and combining basic CV concepts and wireless power transmission technologies of RF devices. To realize the fully printed CV tag, a key issue of wirelessly generating triangular waveform (±500 mV) that can scan the electrochemical cell at a low frequency (<1 Hz) to set up a redox reaction needs to be addressed through a minimum number of printed thin film transistors (TFTs). Fully printed 13.56 MHz rectenna and a ring oscillator with large trap charges in the channels of printed TFTs were respectively utilized to wirelessly generate triangular waveform by using only 10 printed TFTs.

Results

Based on two key units of the wireless power transmitter (Figure 1b-①) and the triangular wave generator (Figure 1b-②), the circuit layout of the fully printed wireless CV tag was designed by using a minimum number of printed thin film transistors (TFTs) to alleviate the issue of V_{th} shift and shown in Figure 1b as a platform of disposable CV system. The circuit of CV tag was fabricated using all scalable printing methods, a roll-to-roll gravure, a roll-to-plate gravure, a drop casting, and a screen printer (Figure S1 in Supplementary Information).

To provide a polarized DC voltage from the coupled 13.56 MHz AC signal of the reader, we modified our previously reported R2R gravure printed rectenna[16,17], as shown in the layout in Figure 2a and the resulting

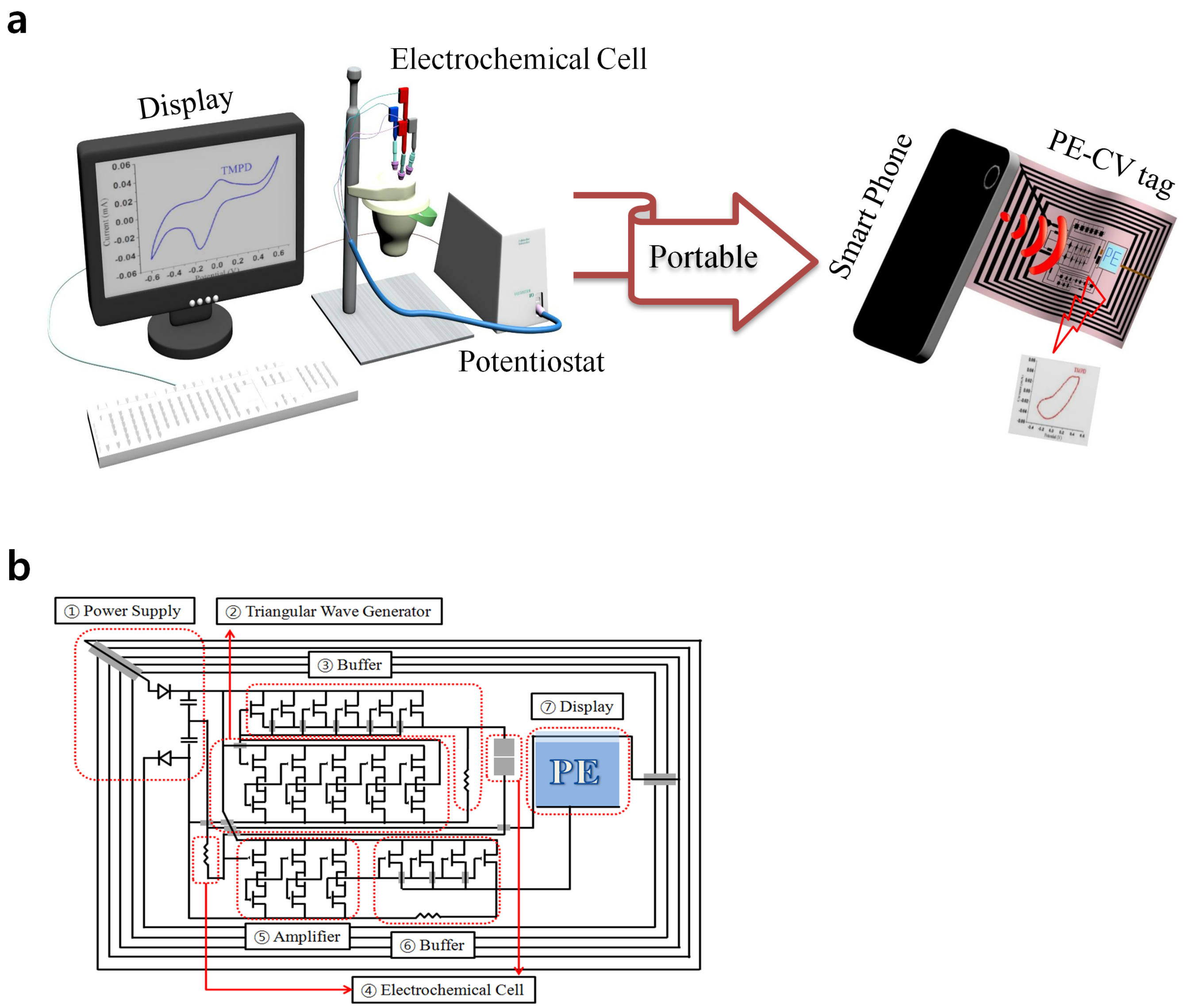

Figure 1 | (a) Informative illustration of typical CV system and disposable printed CV tag. (b) Schematic circuit diagram of the gravure printed wireless cyclic voltammetry (CV) tags. The circuit was designed to couple AC power from a 13.56 MHz reader and then convert the coupled AC to polarized DC ±10 V (① in Figure 1b). Polarized DC will operate the printed ring oscillator to generate a triangular voltage waveform (② in Figure 1b). The generated waveform will pass through the buffer to meet the impedance difference from the electrochemical cell (③ in Figure 1b). The electrochemical cell will run the redox reaction with a single drop of specimen solution (④ in Figure 1b) by the voltage triangular waveform. The output current of the electrochemical redox reaction will be amplified *via* an amplifier circuit (⑤ in Figure b) and the signal will pass through the buffer to meet the impedance difference from the printed signage (⑥ in Figure b). The signage will indicate the concentration level of specimen in the solution (⑦ in Figure b). It will indicate whether the concentration is above or below a pre-determined value.

printed diodes and capacitors are shown in Figure 2b. The printed diodes showed a rectifying ratio of 10^3, and capacitances of two printed capacitors were all about 8 nF/cm^2. The polarized DC voltages (Figure 2c) were measured by placing the printed rectenna on the RF (13.56 MHz) reader with a distance of 2 cm. We adapted a center tap transformer, consisted by divided antenna, 2 diodes and 2 capacitors, to provide the + and − DC voltage for printed triangle wave generator. Using a load of 1 MΩ, voltages of +9.4 V and −10.8 V DC were attained for the optimized printed antenna by monitoring the rectified polarized DC voltages and varying the values of the inductance of the antenna (Figure S2 in Supplementary Information). The polarized DC voltage was also decreased with decreasing load's resistance (Figure 2d).

To generate a cyclic waveform with a low frequency (<1 Hz) from the rectified polarized DC voltage, fully gravure printed *p*-type SWNT-based channel network thin film transistors (*cn*TFTs) were used to construct a five stage ring oscillator with *p*-type inverters. The *cn*TFTs can operate under less than 20 V and their mobility range (0.01 to 10 cm^2/Vs) can be controlled through the loading concentration of SWNT in the ink[18–21]. To print the five stage ring oscillator, we used the same silver and $BaTiO_3$ inks as in the printing of the rectenna for reducing a number of printing steps while SWNT ink was used for printing the channel of the *cn*TFTs. To manufacture the ring oscillator, roll-to-plate (R2P) gravure was used to print 10 *cn*TFTs with a gate width of 300 μm and channel length of 160 μm for both the drive and load *cn*TFTs (Figure S3 in Supplementary Information). The optimized cell depth of gravure plate was 37–40 μm with the cell wall thickness of 50–55 μm for the printing active layers of drive and load TFTs using low viscosity of SWNT based ink (~30 cp) (Figure S4 in Supplementary Information). By repeating the printing of active layers on load TFTs, a higher SWNT network density can be achieved to generate higher current in the

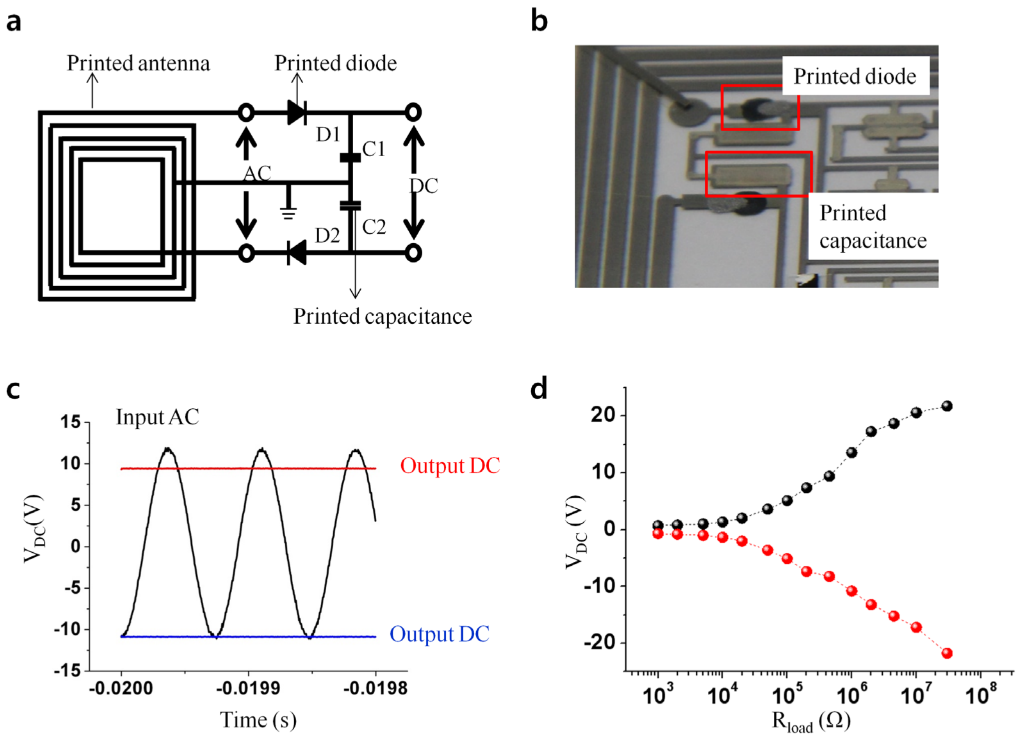

Figure 2 | (a) Circuit layout of the printed rectenna to provide polarized DC power, (b) a real image of printed diodes and capacitors, (c) input-output electrical characteristics of the rectifier at 13.56 MHz AC input and (d) output ± DC voltages under variations in load resistance.

channels while thicknesses of all printed gate, dielectric and drain-source electrodes are kept same (Figure S5 in Supplementary Information).

Their output and transfer characteristics are shown in Figure 3a and 3b respectively. Based on the attained transfer characteristics, the mobility (μ), transconductance (g_m), on-off current ratios from I_{DS}-V_{DS} and threshold voltages (V_{th}) for both five drive *cn*TFTs and five load *cn*TFTs were extracted and shown in Table S1 (Supplementary Information). The shift range of V_{th} from the fully gravure printed 10 *cn*TFTs were about ±0.4 V for the drive *cn*TFTs and ±0.6 V for load *cn*TFTs. Those shift ranges are narrow enough to run the printed ring oscillator for generating the triangular wave. Each inverter delivered a gain of 3 (Figure 3c), and the ring oscillator with five inverters generated a pseudo triangular waveform with a voltage amplitude of 7 V at 320 mHz (Figure 3d). In fact, the pseudo triangular wave can be only generated by the printed *cn*TFTs based ring oscillator because of the parasitic and trapped channel capacitances due to carbon nanotube network structures in *cn*TFTs. Although we only showed the frequency of 320 mHz at here, the frequency can be varied from 0.3 Hz to 2 Hz based on the printed network density of SWNT of printed *cn*TFTs. This is an advantage of our printed *cn*TFTs for scanning electrochemical cell in CV tag over other technologies such as amorphous silicon TFTs where only a sine wave with a designed single frequency can be generated because of no trap capacitance in the channel (Figure S6 in Supplementary Information). The frequency of the triangular waveform can be fine-tuned in the range of 0.3 Hz to 2 Hz as shown in the Figure S7 (Supplementary Information) by simply changing loading concentration of SWNTs.

When the generated triangular waveform is supplied directly into the printed electro-chemical cell (Figure S8 in Supplementary Information), wherein printed silver and carbon electrodes were used with a poly(ethylene oxide) and $LiCF_3SO_3$ gel type electrolyte, the output voltage range is reduced to zero because of improper impedance matching between the electrochemical cell (10 KΩ) and ring oscillator (1 MΩ). Therefore, a buffer unit is needed to match the impedance levels between the ring oscillator and electrochemical cell. The printed buffer unit (Figure 1b-③) with high on currents and low on-off current ratios (Figure 3e) is consists of 6 *cn*TFTs and a resistor (~7 KΩ). In the printed CV tag, three resistors were printed by screen printer using a carbon paste (DC-20, purchased from Dozen Co. Korea) for the buffer units (Figure 1b-③ and ⑥) and the electrochemical cell (Figure 1b-④). Their electrical parameters are listed in Table S1 (Supplementary Information). The 6 *cn*TFTs of buffer unit were printed using R2P gravure with high SWNT concentration in the semiconducting ink. Each *cn*TFTs exhibited on-currents in the range of 400 ~ 500 μA with a very low on-off ratio due to the enhanced metallic percolation in the dense SWNT networks. The buffer units with low on-off ratio were employed to reduce the input voltage to ±500 mV (Figure 3f) which is the appropriate scanning range of the electrochemical cell. The printed electrochemical cell with two electrodes was proven to be well operated under commercial CV (Figure S9 in Supplementary Information). The resulting current after scanning printed electrochemical cell in the CV tag can be converted to voltage by connecting the printed resistor (Figure 1b-④: ~5 × 10^3 ohm) which provides the output voltage for electrochromic indicator and re-plotted into the cyclic voltammogram.

Because these output voltage (±70 mV) and current (~40 μA) were low after scanning the electrochemical cell, they need to be amplified to turn on the electrochromic indicator for showing predetermined concentration (10 mM) level of N,N,N′,N′-tetramethyl-p-phenylenediamine (TMPD, purchased from Aldrich) as a standard reference in this work (Figure 3g). After running the redox reaction of TMPD (Figure 3h) in the printed cell, the output voltage and current needed to be amplified to reach 1.5 V and 500 μA, respectively, to provide sufficient power to display the letters "PE" as an indicator of the presence of TMPD in the specimen. To construct the amplifier, *cn*TFTs based three inverters were printed with a gain of three to five (Figure S10 in Supplementary Information) to amplify the output signal as shown in Figure 3i. The electrical characteristics of the 6 *cn*TFTs in the inverters with extracted mobility, transcon-

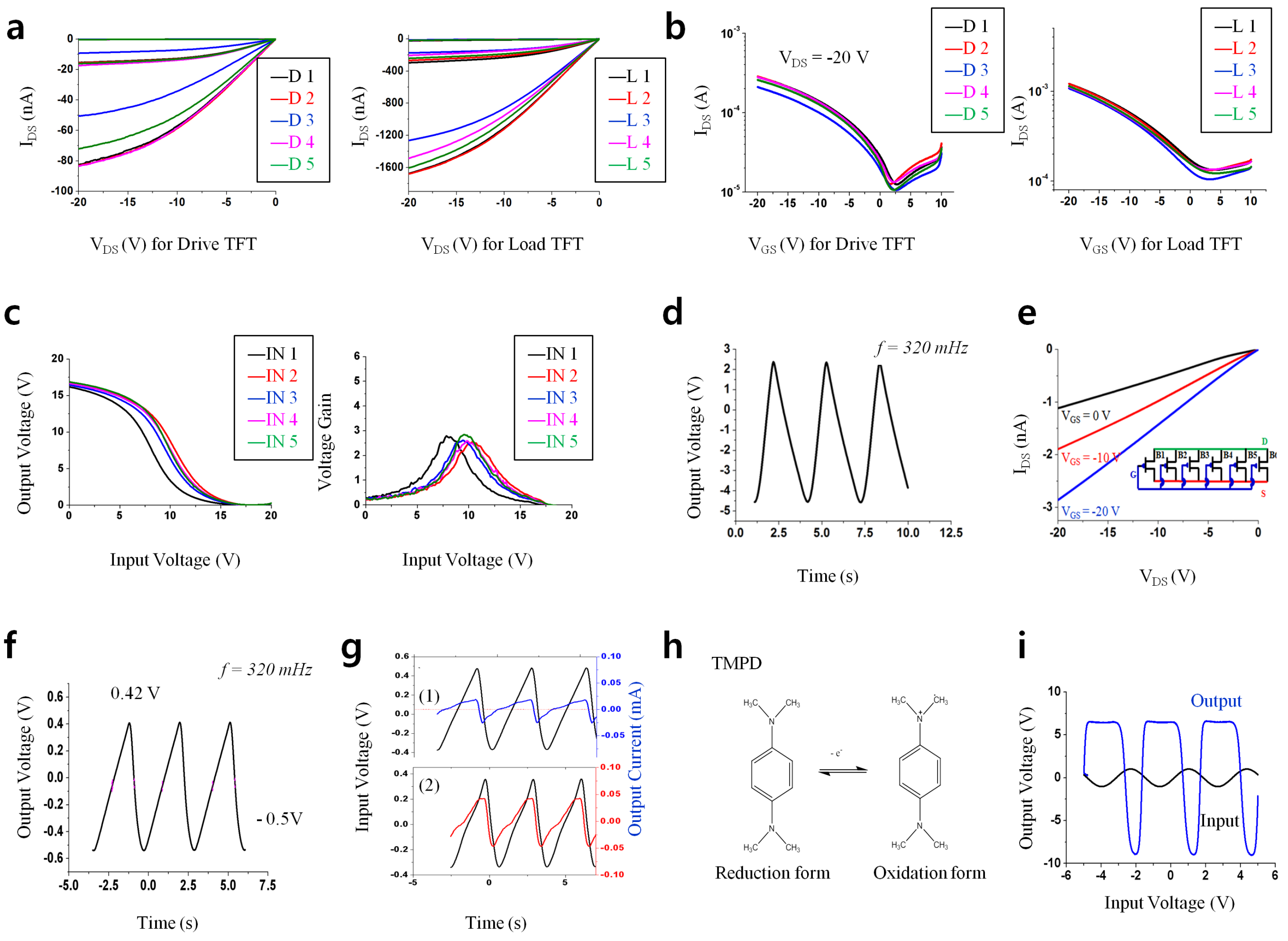

Figure 3 | (a and b) Output and transfer characteristics of the printed *cn*TFTs for 5 drive and 5 load TFTs respectively in the printed ring oscillator. (c) Electrical characteristics of inverters and (d) output characteristic of the ring oscillator. (e) Total output characteristics of the printed buffer unit consisting of 6 *cn*TFTs and a resistor (measured based on contacting gate and drain-source electrodes as shown in the inset circuit). (f) Modified triangular wave following the buffer unit. (g) Generated signals before scanning (black) and after scanning the electrochemical cells without (1, blue) and with TMPD (2, red) in a drop of solution. (h) TMPD structure for oxidation and reduction reaction. (i) The input and amplified output signals after passing through three amplifying inverters.

ductance, on-off current ratios and threshold voltage are shown in Table S2 (Supplementary Information). As the impedance was matched between the ring oscillator and the electrochemical cell using the buffer unit, another buffer unit (Figure 1b-⑥) is also needed between the electrochromic signage (20 KΩ) and the amplifier (1 MΩ) for impedance matching. The electrical parameters of the buffer are listed in Table S2 (Supplementary Information).

The amplified output signal was used to run the reduction and oxidation of the patterned conducting polymer in the electrochromic signage, and thus the blinking signage will be used to indicate the presence of chemicals in the specimens. The signage was fully printed and attached on printed CV tag. A clear concept of the printing sequence for the electrochromic signage was given in Figure S11 in Supplementary Information.

Discussion

The fully printed flexible CV tag was completed by assembling the printed circuits including ring oscillator, buffer, electrochemical cell, amplifier, and signage onto the previously R2R gravure printed rectenna. The resultant CV tag is shown in Figure 4a. The working concept of the wireless and flexible CV tag is demonstrated in the following sequences (watch the video file by clicking Figure S12 in Supplementary Information). After dropping 500 µl of TMPD solution (10 mM) on the printed electrochemical cell, the CV tag was placed on the custom made RF (13.56 MHz) reader (Figure S13 in Supplementary Information). The antenna was subsequently coupled to 13.56 MHz AC. The coupled AC was rectified into polarized DC (> ± 10 V) through two diodes and two capacitors which caused the ring oscillator to generate a pseudo triangular waveform with output voltage of 7 V at 320 mHz. This was then passed through the buffer unit to scan the electrochemical cell. The output signal after scanning the electrochemical cell was amplified to turn on the signage according to the concentration level of TMPD in the solution. In this work, whenever the concentration of TMPD was higher than 10 mM, the signage "PE" blinked (Figure 4b) while it did not show anything (Figure 4c) when it was lower than 10 mM. Furthermore, clear cyclic voltammograms for scanning the electrochemical cell with and without 10 mM of TMPD were obtained by re-plotting the output triangular voltage waveform (Figure 4d). The attained half potential ($E_{1/2}$ ~ 0.05 V, oxidation potential is 0.22 V and reduction potential is −0.17 V) of TMPD from the CV tag was nearly identical to the value obtained from a commercial CV instrument, SP-240, Biologic, which uses the same frequency for the triangular voltage waveform and printed electrochemical cell (Figure 4e). However, when the generated triangle wave frequency is higher than 0.6 Hz in the CV tag, the clear redox peaks cannot be

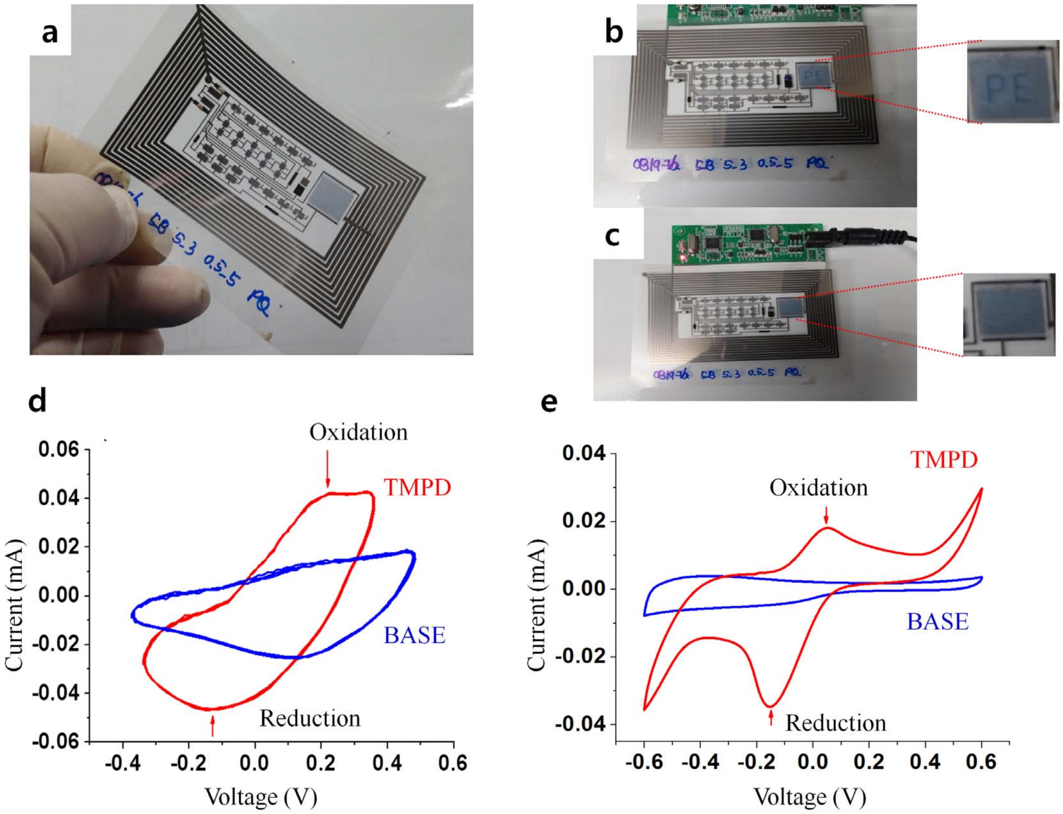

Figure 4 | (a) Optical image of fully printed wireless cyclic voltammetry tag. (b) Operation images of CV tag with and (c) without TMPD in the solution on 13.56 MHz reader. (d) Converted cyclic voltammogram from the printed wireless CV tag *vs* (e) a commercial CV instrument (please refer the interconnected video file for the demonstration of wireless CV tag operation in Figure S12 in Supplementary Information).

observed as shown in Figure S14 (Supplementary Information). Furthermore, as a typical example of testing a specimen in aqueous solution, 10 mM of $K_3(FeCN)_6$ aqueous solution was checked using the CV tag, and results of converted cyclic voltammogram was shown in Figure S15 (Supplementary Information). Those results support that the CV tag can examine specimens not only in organic solution, but also in aqueous one.

Up to present, there has been no commercial success in fully printed TFT-based electronic devices due to some kind of difficulties in integrating a number of printed TFTs through a scalable printing method. As increasing a number of integrated TFTs, the range of threshold voltage shits of TFTs needs to be controlled as narrow as possible to properly operate designed function of printed devices. However, the scalable printing method is not fully understood to integrate a number of TFTs on plastic foils while keeping the constant range of threshold voltage shifts because of difficulty in controlling a constant charge transport through the printed channels. Therefore, the printed TFT-based devices should be constructed by using a minimum number of printed TFTs while a function of printed device needs to be competitive over Si based one. Since the fully printed CV tag required the integration of only 26 *cn*TFTs, the acceptable range of threshold voltage shits of *cn*TFTs is controllable and achievable by using a scalable printing method such as a roll-to-roll gravure. Furthermore, the unique function of printed CV tags cannot be simply reproduced using a Si technology with a comparable cost to the R2R printing process. Therefore, the fully printed CV tag will be the first leading model to show a way of how printed TFT-based electronic devices should go for the successful launching in the IT markets.

In the core of the printed CV tag, fully gravure-printed *cn*TFTs were employed for constructing a circuit consisting of a ring oscillator to generate triangular waveforms, buffer units for an impedance matching, and an amplifier for enhancing output signal to turn on the signage. Those simple units can be combined with a variety of printable sensors and RF devices to create novel devices with an extremely low cost. In other words, the printed rectenna, ring oscillator, buffer and amplifier units in the printed CV tag will be key elements for the construction of variety of printed RF-sensors, this CV tag will be used as a platform for the further construction of a variety of RF based electrochemical sensors.

In conclusion, we have presented a fully printed flexible CV tag with the size of 9.5 × 5.5 cm^2 that can operate wirelessly using a 13.56 MHz RF reader. However, for the practical purpose, the size of the CV tag can be reduced up to the half (4 × 2 cm^2) of the current one by optimizing spaces between *cn*TFTs in the circuit of the CV tag and reducing the operation power to less than DC 5 V as the current size of 13.56 MHz antenna is designed to provide maximum coupled AC power using a sufficient length of printed antenna pattern (higher inductance). Furthermore, although we utilized R2P gravure, screen printer and drop casting method for the convenience of fabricating the CV tag in the Lab, the whole fabricating process can be repeated by R2R gravure because the rectenna, ring oscillator, buffers, electrochemical cell, amplifier and signage in the CV tag were all designed to compromise the limit (±20 μm) of a registration accuracy of a current R2R gravure system. Therefore, this technology could be used as a platform for disposable wireless electrochemical sensors to a variety of specimens in aqueous and organic solutions to monitor or diagnose pathogens and hazardous materials by modifying the electrodes of the electrochemical cells.

Methods

Roll-to-roll (R2R) gravure printed antenna, bottom electrodes, gate electrodes and wires. Two color units of R2R gravure system (Taejin Co. Korea: Figure S1 in the Supplementary Information) was employed to print antenna, bottom electrodes and wires on a roll of poly(ethylene terephthalate) (PET) film (width of 200 mm and thickness of 100 μm, purchased from SKC, Korea) with silver nanoparticle based conducting ink (PG-007 BB type, Paru Co. Korea) and the web transfer speed of 8 m/min under roll pressure of 0.5 MPa and web tension of 60 N. The silver ink was further formulated to meet the viscosity of 500 cp and surface tension of 47 mN/m using respectively ethylene glycol (Aldrich) and Dipropylene glycol methyl ether (Aldrich). The curing time of printed silver layer was 10 sec by passing through a heating chamber of 150°C, installed in R2R gravure system. The resulting printed silver patterns on PET roll showed the thickness of 450 (±50) nm without any defects and were shown in Figure S16a (Supplementary Information).

Roll-to-plate (R2P) gravure printed ring oscillator, buffer, and amplifier. Full R2P gravure system (Figure S1 in the Supplementary Information) was employed to print single walled carbon nanotube network based thin film transistors (*cn*TFTs), used as a building block to construct all the integrated circuit of printed cyclic voltammetry (CV) tag (Figure 1). 26 *cn*TFTs for the integration of circuit in printed CV tag were printed on the previously R2R gravure printed film (printed antenna, bottom electrodes and wires with thickness of 450 nm; Figure S16b in Supplementary Information) following printing sequences. First, $BaTiO_3$ nanoparticle based dielectric ink (PD-100, Paru Co., Korea) was further formulated to meet viscosity (75 cP) and surface tension (31.8 mN/m) using the ethyl 2-cynoacrylate (Aldrich). As shown in R2P gravure printing scheme (Figure S17 in Supplementary Information), the homogeneous and defect free dielectric layers were first R2P gravure printed with a printing speed of 200 mm/s and roll pressure 7.5 kg_f on previously printed gate electrodes and bottom electrodes (for capacitors) with a thickness of 2.3 (±0.1) μm and width of 940 (±2) μm (Figure S5 in Supplementary Information). The printed dielectric layers were cured for 1 min 20 sec at 150°C. Second, single walled carbon nanotube (SWNT) based semiconducting ink (PR-040, Paru Co., Korea) was diluted by diethylene glycol monobutyl ether (Daejung Co., Korea) to 1 : 1 volume ratio for printing active layers using R2P gravure on the printed dielectric layers with a printing speed of 350 mm/s and a roll pressure of 4 kg_f. The viscosity and surface tension of diluted SWNT ink were respectively 30 cP and 29 mN/m. The resulting SWNT printed films were dried 1 min at 150°C. For using *cn*TFTs in the buffer unit, we used the dilution volume ratio of 5 : 1 between SWNT ink (PR-040, Paru Co., Korea) and diethylene glycol monobutyl ether for printing only on the TFTs in the buffer unit to increase SWNT network density for providing the high current (Figure S5 in Supplementary Information). Finally, drain-source electrodes were R2P gravure printed using silver nanoparticle based ink (PG-007 AA type, Paru Co., Korea) on SWNT printed film with a viscosity of 800 cP and a surface tension of 42 mN/m. The R2P gravure printing was carried out under a printing speed of 200 mm/s and a role pressure of 5 kg_f.

Diode fabrication. Although Shottky diodes were able to print using R2R gravure based on our previous reported process[16,17], the drop casting method was used for the convenience in this work. First, dropping ZnO based hybrid semiconducting ink (PD-070, Paru Co., Korea) on printed silver electrode and then, Al ink (PA-009, Paru Co., Korea) was dropped on the top of ZnO ink. The resulting diodes were further cured for 5 min at 120°C.

Measurements. Formulated and diluted inks were characterized using DCAT21 (Dataphysics Co., Germany) and SV-10 Vibro viscometer (AND Co., Japan) for respectively measure surface tension and viscosity. All measurements in this work were carried out under ambient condition if there are no other comments. Resistance of printed antenna, bottom electrodes, gate electrodes and wires were measured using two probe methods with HP3457A multimeter. Both surface morphology and thickness of printed layers was characterized using surface profiler (NV-2200, Nanosystem, Korea). LCR meter (E4980A, Agilent, USA), semiconductor parameter analyzer (4155C, Agilent, USA) and digital phosphor oscilloscope (DPO 4054, Tektronix, USA) were respectively used to characterize printed *cn*TFT based circuits.

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Author contributions

Y.J., A.J. and G.C. designed the experiments. Y.J., H.P., J.P., Y.C. and M.J. carried out the experiments. J.N., K.J. and K.C. performed device simulations. Y.J. and K.C. performed mobility calculations. Y.J. and M.P. performed electrochemistry and analyzed electrochemical data. Y.J., H.P., M.P., A.J. and G.C. contributed to analyzing the data. M.J., M.P., A.J. and G.C. wrote the paper while all authors provided feedback.

Additional information

Supplementary information accompanies this paper at http://www.nature.com/scientificreports

Competing financial interests: Prof. Cho was a consultant of PARU Co. Korea and received compensation from PARU Co. Both Dr. M. Jung and Mr. K Jung has been employee of PARU Co. Korea. Dr. Y. Jung, Miss H. Park, Ms. J. Park, Dr. J. Noh, Mr. Y. Choi, Prof. Pyo, Mr. K. Chen and Prof. Javey declare no competing financial interests.

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A microwave metamaterial with integrated power harvesting functionality

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We present the design and experimental implementation of a power harvesting metamaterial. A maximum of 36.8% of the incident power from a 900 MHz signal is experimentally rectified by an array of metamaterial unit cells. We demonstrate that the maximum harvested power occurs for a resistive load close to 70 Ω in both simulation and experiment. The power harvesting metamaterial is an example of a functional metamaterial that may be suitable for a wide variety of applications that require power delivery to any active components integrated into the metamaterial. © *2013 AIP Publishing LLC*. [http://dx.doi.org/10.1063/1.4824473]

Metamaterials are composed of sub-wavelength particles that exhibit bulk properties that are different from their individual components. Electromagnetic metamaterials are engineered materials that can achieve parameters not possible within naturally occurring materials, such as a negative index of refraction[1] or a zero index of refraction.[2] Exotic properties like these allow for a variety of interesting applications including a superlens device[3] and an invisibility cloak.[4] Integrating active and nonlinear functionality into metamaterials has been demonstrated in the form of dynamic resonant frequency tuning,[5,6] phase conjugation,[7] and wave mixing.[8,9] More specific functional behavior has also been demonstrated in metamaterials, including radio frequency (RF) limiting[10] and harmonic generation.[11]

Metamaterials are also well-suited for other functional behaviors, including electromagnetic power harvesting, the focus of this work. Power harvesting devices convert one type of energy to another, typically converting to a direct current (DC) signal. Many types of energy can be harvested, from acoustic (using a piezoelectric harvester)[12] to electromagnetic (using a rectenna).[13] Power harvesting devices require a method to couple to the energy that will be harvested as well as a device to convert the energy from one form to another. By their very nature, metamaterials are designed to couple to various types of energy, e.g., from acoustic[14] to optical,[15] and thus provide a natural platform for power harvesting. Electromagnetic metamaterials provide flexibility in design due to their electrically small, low-profile nature.[16] Since metamaterials are typically designed as infinite arrays, the resonant frequency and input impedance include coupling effects. Metamaterials can be adapted to various applications, such as flexible sheets to cover surfaces.[17] Moreover, many metamaterials that have been presented in the literature require some form of external signal. This could be a DC bias voltage[18] or a large external pump signal.[7] In general, metamaterials could be modified to harvest such an external signal that is already present for other purposes. With these design advantages, power harvesting metamaterials offer design flexibility for a large number of applications that general antenna-based microwave power harvesting devices may lack.

A recent simulation-based study[19] investigated the conversion efficiency between incident RF power and induced power in a split-ring resonator (SRR). Our work is focused on the experimental measurement of RF to DC efficiency based on the conventional effective area of the SRR. We demonstrate that metamaterials can also include embedded devices to convert the incident RF energy to a DC voltage, providing a platform for power harvesting that utilizes the advantages of metamaterial design.

An SRR is a canonical example of a resonant metamaterial particle and is used as the basis for the unit cells of the metamaterial power harvester designed here. By tuning the SRR parameters, we design an SRR (Fig. 1) to resonate at 900 MHz using an S-parameter simulation within Computer Simulation Technology (CST) Microwave Studio software. Using CST Microwave Studio, we can also simulate the effects of embedding devices within the SRR by retrieving its S-parameters using a lumped port. The retrieved S-parameters are loaded into Agilent Advanced Design System (ADS), allowing us to simulate both fullwave 3D effects and circuit-level nonlinear effects.

An SRR couples strongly to an incident magnetic field and can be loaded with a wide variety of circuit elements. In this work, we embed a rectifying circuit within an SRR to convert the incident RF power to DC power. A number of rectifying circuits could be chosen depending on the particular application for the power harvesting metamaterial. We choose to use a Greinacher[20] circuit because the output voltage is double the input voltage maximum, which allows for

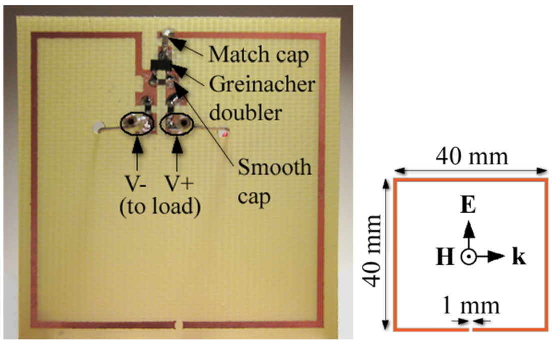

FIG. 1. (Left) Power harvesting SRR. (Right) Plain SRR with dimensions shown, 1 mm traces. Incident wave polarization is also shown.

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easier power transmission and measurement. A Greinacher circuit has a lower effective capacitance in comparison to other rectification circuits (such as a bridge rectifier), allowing faster switching and thus a higher frequency of operation. A Greinacher circuit also has a low threshold voltage, allowing operation at lower incident power levels. A Greinacher voltage doubler can be placed across a gap (Fig. 1) in the top side of the copper trace to rectify the induced current present in the SRR. Schottky diodes are used for the voltage doubler due to their typically low open junction capacitance and fast switching capabilities, which allow for rectification of a high-frequency RF signal, as well as their typically low threshold voltage. A resistive load placed across the output of the voltage doubler is a simple way to determine DC power out using $P = V^2/R$. This DC power is maximized through ADS for matching capacitor and resistor values. The parameters of our selected Schottky diode (HSMS 2862) and the simulated S-parameters of the above SRR in a model of our actual parallel-plate waveguide are input into ADS for the simulation, shown in a schematic in Fig. 2.

The simulated components lead to a maximum efficiency of 61% for an input power of 24.25 dBM, the maximum available experimental power (at an incident power density of approximately 1.6 mW/cm^2). One important figure of merit for a power harvester is its RF-to-DC power conversion efficiency:

$$\eta = \frac{P_{DC}}{P_{RF}}.$$

We determine P_{RF} by measuring the total incident power in our measurement apparatus. For a large metamaterial sample, we assume that the total incident power to the measurement apparatus is incident on the metamaterial. For a single unit cell, it is necessary to use the effective area of the unit cell to determine the incident P_{RF}. The maximum effective area may be calculated by[21]

$$A_{e,max} = \frac{\lambda^2}{4\pi} D_0,$$

where $D_0 = 1.5$ since the SRR is effectively a small loop illuminated by a transverse electromagnetic (TEM) wave. For an SRR resonant at 900 MHz, the effective area is thus $A_{e,max} = 5.3A_{physical}$. The full waveguide area is approximately $6.8A_{physical}$ where $A_{physical}$ is the physical area of a single SRR unit cell. As $A_{e,max}$ is 78% of the open wave guide area, 78% of the incident power density is used as input power for simulation of the single cell.

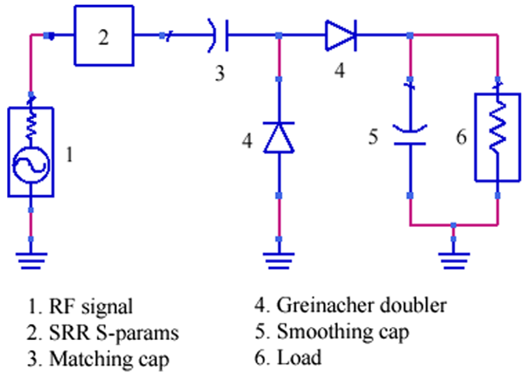

FIG. 2. ADS simulation schematic of SRR power harvester. CST Microwave Studio was used to determine the SRR S-parameters.

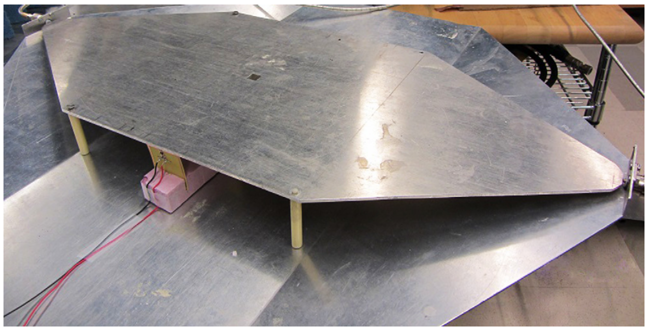

FIG. 3. Placement of SRR within open waveguide.

The designed voltage doubler and resistive load are added to an SRR as shown in Fig. 1, resulting in the power harvesting metamaterial unit cell. To observe power harvesting capabilities, the cell is placed in an open, TEM waveguide (Fig. 3) where input power is produced by a signal generator and amplifier, and output power is measured with an oscilloscope via leads placed across the resistive load (Fig. 4). The DC power harvested is determined by $P = V^2/R$ as previously mentioned, and input power is measured with a spectrum analyzer connected to the signal generator and amplifier via the open waveguide. By increasing the incident power from 13 to 24 dBm and measuring the DC output from the SRR, the normalized harvested power, $P_{DC}/P_{RF,incident}$, as a function of incident power $P_{RF,incident}$ and resulting efficiency are determined at each point. The maximum efficiency of the single cell is 14.2%, setting $P_{RF,incident}$ as 78% of the total input power from effective area calculations.

Multiple power harvesting SRR cells are then tested simultaneously to create the power harvesting metamaterial, which is accomplished through a 5 × 1 array shown in Fig. 5. Through a parallel connection of the leads from each SRR's resistive load, the total power harvested by the metamaterial is found in the same way as the single cell. The maximum efficiency for the 5 × 1 array is 36.8%, where P_{in} is the entire input power because the array spans the entire length. Measured efficiencies of both the single and the array of power harvesting SRRs are shown in Fig. 6. Also shown in Fig. 6 is the open circuit voltage, V_{OC}, a load-independent measure of the available voltage harvested by the array of SRRs.

The power harvesting metamaterial array is more efficient than the single unit cell. This is partially due to the

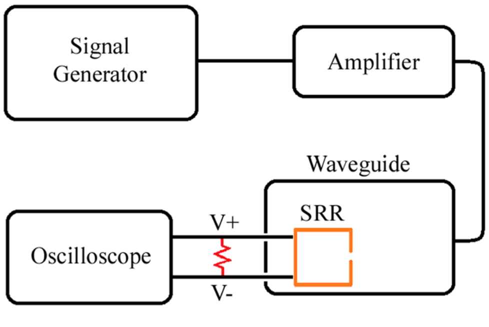

FIG. 4. Experimental test setup schematic.

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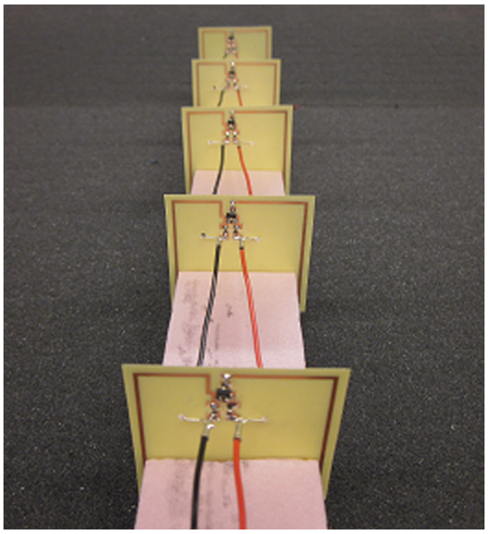

FIG. 5. 5 × 1 array of power-harvesting SRRs.

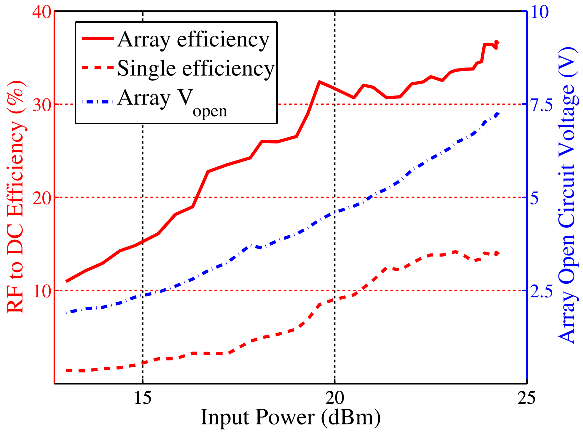

FIG. 6. RF to DC efficiency of power harvesters. The open-circuit voltage of the array is also shown.

larger effective area of the array. While the effective area of the single cell is 78% the entire width of the waveguide, some of this power is not harvested by the single unit cell due to fringing effects on the sides of the waveguide. For this reason, placement of multiple cells that together span the entire waveguide width results in a higher efficiency as the array captures more of the electromagnetic energy that undergoes the fringing effect.

Another important relationship is the efficiency of the power harvesting metamaterial as a function of load resistance. Simulated and experimental efficiencies for the 5 × 1 array are shown in Fig. 7. Though the experimental efficiencies do not match the values from simulation, the simulation does accurately predict the maximum harvested power as falling approximately within the range of 70–80 Ω, confirmed by the experimental data. The experimental efficiency maximum occurs at 70 Ω, and the simulated maximum occurs at 82 Ω, showing close correspondence.

In summary, we have designed, simulated, and experimentally measured a functional metamaterial power harvester capable of converting up to 36.8% of the incident RF power to DC power. Through a parallel connection of five SRRs, a V_{OC} of 7.3 V is achieved. Simulations match experimental results showing an optimal resistive load for DC power transfer of 70–80 Ω. The SRR power harvester is an example of functional metamaterial that may be suitable for a wide variety of RF applications that require power delivery to any active integrated components.

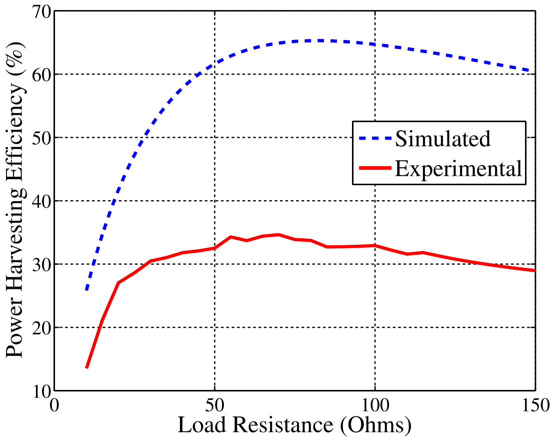

FIG. 7. RF to DC efficiency of SRR array as a function of load resistance, for both simulation and experiment. Note that both show maximum efficiency for around 70–80 Ω.

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Ambient RF Energy Harvesting in Urban and Semi-Urban Environments

Manuel Piñuela, *Student Member, IEEE*, Paul D. Mitcheson, *Senior Member, IEEE*, and Stepan Lucyszyn, *Senior Member, IEEE*

***Abstract*—RF harvesting circuits have been demonstrated for more than 50 years, but only a few have been able to harvest energy from freely available ambient (i.e., non-dedicated) RF sources. In this paper, our objectives were to realize harvester operation at typical ambient RF power levels found within urban and semi-urban environments. To explore the potential for ambient RF energy harvesting, a city-wide RF spectral survey was undertaken from outside all of the 270 London Underground stations at street level. Using the results from this survey, four harvesters (comprising antenna, impedance-matching network, rectifier, maximum power point tracking interface, and storage element) were designed to cover four frequency bands from the largest RF contributors (DTV, GSM900, GSM1800, and 3G) within the ultrahigh frequency (0.3–3 GHz) part of the frequency spectrum. Prototypes were designed and fabricated for each band. The overall end-to-end efficiency of the prototypes using realistic input RF power sources is measured; with our first GSM900 prototype giving an efficiency of 40%. Approximately half of the London Underground stations were found to be suitable locations for harvesting ambient RF energy using our four prototypes. Furthermore, multiband array architectures were designed and fabricated to provide a broader freedom of operation. Finally, an output dc power density comparison was made between all the ambient RF energy harvesters, as well as alternative energy harvesting technologies, and for the first time, it is shown that ambient RF harvesting can be competitive with the other technologies.**

***Index Terms*—Ambient RF, energy harvesting, maximum power point tracking (MPPT), multiband, rectenna, RF survey, RF-dc.**

I. Introduction

FOR ALMOST 50 years, far-field RF technology has been used to remotely power systems from relatively large unmanned helicopters [1] to very small smart dust sensors [2] and contact lenses that measure eye pressure [3]. With all these systems, a dedicated RF source is used, where the operator may have control over the effective isotropically radiated power (i.e., both transmit power and antenna characteristics), beam pointing and polarization of the RF source, ensuring optimal line-of-sight operation between the source transmitter (TX) and harvesting receiver (RX). It is important to highlight that this work will focus only in radiative power transfer and not inductive or near-field power transfer, as demonstrated in [4]. A more convenient solution, however, is to power these devices from ambient RF energy sources, such as television and mobile phone signals, thus removing the need for a dedicated source. As ambient RF levels are lower than those that can be provided by a dedicated RF source, the efficiency of the harvesting system, and its minimum startup power are of critical importance.

In order to assess the feasibility of deploying ambient RF energy harvesters, the available RF power needs to be measured in different locations. Such measurements, in conjunction with knowledge on harvester performance, can then be used to determine the locations at which RF harvester powered devices can be successfully deployed. Several RF spectral surveys, which measure ambient RF power levels from sources such as television and mobile phone base stations, have been previously reported. Many have been undertaken using personal exposimeters or spectrum analyzers, where the exact location of each measurement is unknown and with RF power levels only being reported under general scenarios (e.g., outdoor, indoor, street, bus, etc.) [5], [6]. While being of academic interest for health-related research [7], the lack of power level and specific time/location information limits their usefulness for exploitation in ambient RF energy harvesting applications.

Most rectennas (normally comprising an antenna, impedance matching network, rectifier, storage element, and load) presented in the open literature have been tested using dedicated sources rather than harvesting from ambient RF energy [8]. In recent years, efficiencies as high as 78% [9] and 90% [10] have been demonstrated with relatively high input RF power levels (i.e., $> +10$ dBm). Moderate efficiencies have also been achieved using dedicated TXs that provided relatively low input RF power levels; e.g., an efficiency of 60% was achieved with -22.6-dBm input power [11]. In one demonstrator [12], designed to operate over a broad range of input RF power levels, (-30 to $+30$ dBm), the efficiency increased from 5% at a low input RF power to a peak of 80% at $+25$ dBm.

Despite advancements in end-to-end (i.e., input RF to output dc) power conversion efficiencies at low input RF power levels (similar to those measured in the spectral surveys), only a few attempts at true ambient RF energy harvesting have been reported. For example, one relatively efficient rectenna, utilizing a modified omnidirectional patch antenna, has an efficiency of 18% with a single-tone input RF power of -20 dBm [13]. This dedicated signal source was meant to emulate the input RF power levels measured from a nearby digital TV (DTV) TX in Tokyo, Japan, but did not take into account the more realistic effect of harvesting from a modulated broadband signal. Another attempt

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at harvesting ambient RF energy from a mobile phone base station at 845 MHz was reported in [14]. This prototype managed to power an LCD thermometer for 4 min, but only after harvesting for 65 h. In that work, when the authors used a dedicated signal source with a single-tone input RF power of -15 dBm, an efficiency of 3% was recorded. A batteryless location sensor has also been demonstrated [15], powered by a rectenna with a printed antenna on a flexible substrate and a solar cell, although no details for the RF-dc efficiency were reported. Finally, successful prototypes capable of harvesting energy using TV antennas were presented, but again no details of their efficiency were given [16], [17].

In order to demonstrate the feasibility for implementing ambient RF energy harvesting, here we first present the results of a citywide RF spectral survey, indicating suitable locations and associated RF bands with sufficient input RF power density levels for harvesting. Based on these results, rectennas were then fabricated and their efficiencies, under ambient RF energy harvesting operation, were calculated using *in-situ* field strength measurements. Furthermore, an investigation of multiband rectenna arrays is also presented, demonstrating the tradeoffs between series (voltage summing) and parallel (current summing) topologies with the aim of reducing the minimum input power required for harvester operation. Finally, a comparison between measured ambient RF energy harvesting and alternative forms of energy harvesting technologies is presented; highlighting, for the first time, the practical feasibility of exploiting existing freely available sources of RF energy.

II. London RF Survey

In order to quantify input RF power density levels present in a typical urban and semi-urban environment, a citywide RF spectral survey within the ultrahigh frequency (0.3–3 GHz) part of the frequency spectrum was conducted within Greater London. A number of citywide RF spectral surveys have previously been conducted, but in general, only a few samples were taken, giving little insight into (semi-)urban environments [14], [18], [19]. Other surveys [20], [21] compare their measurements relative to the distance from the nearest TX. In a (semi-)urban environment, this may not provide enough information about the RF spectrum since there is likely to be local geographical variations in base-station density and propagation characteristics (e.g., multipath effects and diffraction around and attenuation through buildings).

Each station on the London Underground network was used as a survey point to provide a robust dataset for representing Greater London in terms of geographical distribution and population density, having a combination of urban (in the center) and semi-urban (in surrounding areas) characteristics. Measurements were taken at each of the 270 stations (from a randomly chosen exit, at street level and a height of 1.6 m). To provide traceability and for use as a historical reference, time stamps and GPS locations were recorded. In addition, measurements were taken inside a building at Imperial College London (ICL), to represent a typical office block within an urban environment.

A. Methodology

Mobile phone usage varies during the daytime, and hence, ambient RF energy in their bands is expected to be time dependant, with more energy available during the daytime than at night time. Therefore, in order to be able to make fair comparisons between locations, measurements were taken between 10:00 am and 3:00 pm on weekdays over a period of one month (between March 5, and April 4, 2012). Electric field strength was measured between 0.3–2.5 GHz using an Agilent N9912A FieldFox RF analyzer [22] with a calibrated Aaronia BicoLOG 20300 omnidirectional antenna [23]. It is important to note that the spectral measurements were undertaken during the analog-to-digital switchover period in the U.K. and so the measurements for DTV may represent an underestimate of present RF power levels measured now that the switch over is complete [24]. It should also be noted that this survey was conducted prior to the 4G network being switched on within the U.K.

A "panning method," which complies with international regulations for measuring exposure limits, was used [25]–[27]. Here, the calibrated antenna is rotated to three orthogonal axes while the spectrum analyser is set to "max-hold," ensuring that the maximum reading is recorded. For each measurement, more than 1 min was allocated to allow for more than three sweeps across the selected frequency range. Additionally, to maintain a comparable signal-to-noise (S/N) ratio, attenuation was introduced (with a minimum set at 5 dB) to avoid compression when high input RF power levels were detected. For all measurements, the resolution bandwidth (BW) was fixed at 100 kHz, the internal amplifier was turned on and the highest resolution of 1001 points was selected. These settings provide the ability to obtain a snapshot of the power density that can be expected in an urban or semi-urban environment from continuously variable sources.

B. Results

After inputting the manufacturers' frequency-banded antenna factors into the spectrum analyzer, to ensure a fully calibrated system, the electric field strength measurements were taken. The input RF power density (S) is then calculated from the electric field strength measurement. Fig. 1 shows the input RF power density measured outside the Northfields London Underground station, where the spectral bands for DTV, GSM900, GSM1800, 3G, and Wi-Fi can been clearly identified.

A well-designed rectenna should ideally be capable of harvesting energy across an entire band, and thus it is important to calculate the total band power. The banded input RF power density S_{BA} (nW/cm^2) is calculated by summing all the spectral peaks across the band (i.e., in a similar way, the spectrum analyzer calculates channel power). These levels provide a snapshot of source availability at the time and location of the measurement. Moreover, they are used as a harvester design starting point since the power density at each band will define the input impedance of a rectenna.

The exact frequencies for each band are set by the U.K.'s official frequency band allocation [28]; the GSM900, GSM1800 and 3G base transmit (BTx) bands were separated from the associated mobile transmit (MTx) bands. Table I shows average

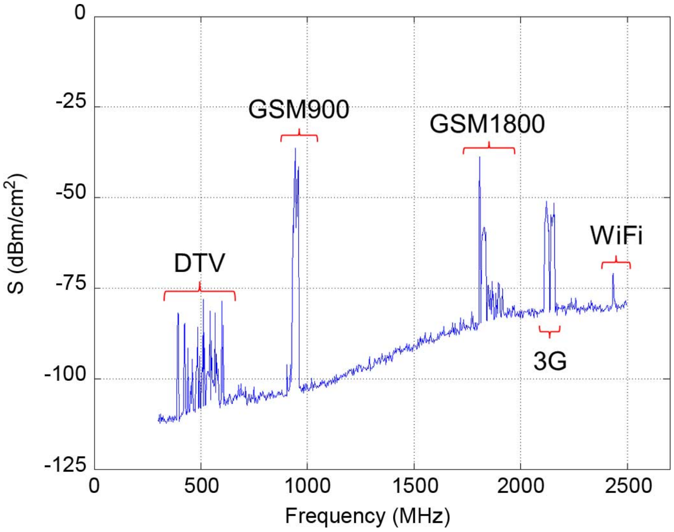

Fig. 1. Input RF power density measurements outside the Northfields London Underground station.

TABLE I
SUMMARY OF LONDON RF SURVEY MEASUREMENTS

Band	Frequencies (MHz)	Average S_{BA} (nW/cm^2)	Maximum S_{BA} (nW/cm^2)
DTV (during switch over)	470-610	0.89	460
GSM900 (MTx)	880-915	0.45	39
GSM900 (BTx)	925-960	36	1,930
GSM1800 (MTx)	1710-1785	0.5	20
GSM1800 (BTx)	1805-1880	84	6,390
3G (MTx)	1920-1980	0.46	66
3G (BTx)	2110-2170	12	240
WiFi	2400-2500	0.18	6

TABLE II
INPUT RF POWER DENSITY THRESHOLD: LONDON UNDERGROUND STATIONS WITHIN CENTRAL ZONES 1–3 (URBAN) AND OUTER ZONES 4–9 (SEMI-URBAN)

Band	S_{BA} *Threshold* (nW/cm^2)	Number of Stations	
		Urban	Semi-urban
DTV (during switch over)	40	10	0
GSM900	230	8	2
GSM1800	450	7	3
3G	62	6	4

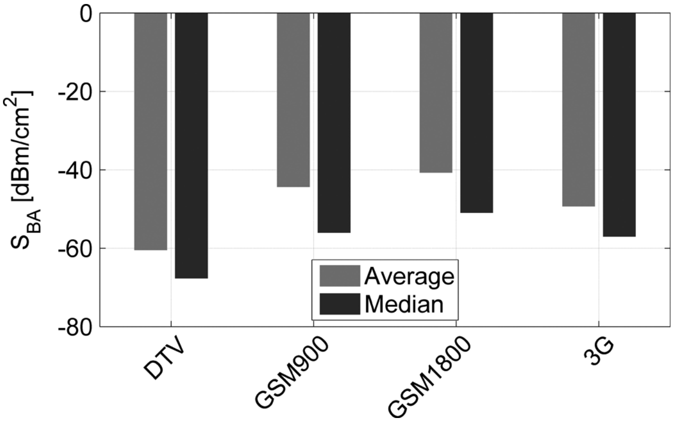

Fig. 2. Banded input RF power density measurements for the four largest ambient sources in Greater London.

RF power levels across all London Underground stations for the banded input RF power density measurements. It can be seen that all base-station transmit levels are between one and three orders of magnitude greater than the associated MTx levels. For this reason, and the fact that the population of transmitting mobile phones in close proximity of the harvester is highly variable, only base-station TXs will be considered further.

From our London RF survey, DTV, GSM900, GSM1800, 3G, and Wi-Fi were identified as potentially useful ambient RF energy harvesting sources, although DTV appears to be heavily dependent on line-of-sight and sudden changes in atmospheric conditions (e.g., temperature inversion) and Wi-Fi is very dependent on user traffic. It should be noted that the mobile phone base-station TXs employ vertically polarized antennas, placing a constraint on harvester orientation in deployment. With DTV, within the U.K., the main TXs have horizontally polarized antennas, while repeater TXs have vertically polarized antennas.

It is convenient to define the boundary between urban and semi-urban environments by the line that separates zones 3 and 4 on the London Underground map [29]. As one would expect, the central zones 1–3 host the highest density of base stations. As shown in Table II, a banded input RF power density threshold was selected to filter the ten London Underground stations with the highest measurements for each band. With DTV, the highest recorded measurements were all found within the urban environment. This is because Greater London's main DTV TX (at Crystal Palace) is located on the southeastern boarder of zones 3 and 4 and there are no London Underground stations further south. With mobile phones, more than 50% of the stations were inside the urban environment and those in a semi-urban environment were all located in close proximity to a cluster of base-station TXs.

Using the complete dataset from the London RF survey, Fig. 2 shows the average and median of the banded input RF power density measurements for the four largest ambient RF sources in Greater London. It can be seen that more than half of the locations have below average power levels. This is due to the fact that several stations had maximum levels that were considerably higher than the average because of their close proximity to TV TXs (e.g., Crystal Palace), extremes in base-station density and propagation characteristics.

In addition to the London RF survey, measurements within the Department of Electrical and Electronic Engineering building at ICL were taken on the 11th floor of the south stairwell. These are shown in Table III. As can be seen, DTV and GSM900 have a higher than average power level, due to a near line of sight from the TV TX and a close proximity to the 2G GSM900/1800 base stations.

The dataset from the London RF survey, with all relevant information (e.g., locations, timestamps, and banded input RF power density measurements), can be found at our interactive website: www.londonrfsurvey.org [30]. These measurements were used to design efficient harvesters and compared to ICL

TABLE III
MEASURED BANDED INPUT RF POWER DENSITIES AT ICL

	DTV	GSM900 (BTx)	GSM1800 (BTx)	3G (BTx)
S_{BA} [nW/cm^2]	18	48	50	3

measurements to identify locations in Greater London where the designed harvesters could operate. The design procedures and prototype test measurements will be presented in the following sections.

III. SINGLE-BAND AMBIENT RF ENERGY HARVESTERS

In order to implement efficient ambient RF energy harvesters, designed for the banded input RF power density levels measured at ICL, a set of single-band prototypes were realized and characterized; these will be compared to multiband array architectures in Section V.

A. Antenna Design and Measurements

Since our harvesters are intended to operate within a general (semi-)urban environment, where the exact location of the TX source is unknown, the rectennas' antennas need to be as close to omnidirectional as possible, avoiding the need for beam-pointing during deployment. This is at the obvious expense of limited antenna gain, and therefore, the corresponding levels of P_{RF} that the rectifier can receive. Conversely, if the location of the TX is known, then it may be tempting to use a high gain antenna, but this would require an appropriate level of beam-pointing and polarization matching that can be established and maintained.

Another requirement is that the antennas need to be easily scalable across all frequency bands since one important objective for this work is to compare and contrast different banded harvesters. Finally, the antennas need to be easily fabricated. For all these reasons, a linear polarized folded dipole was selected, although a monopole would also be suitable [31].

To simplify impedance matching between the antenna and rectifier, a modified folded dipole was used to obtain the required 50-Ω reference input impedance. A balun does not need to be employed, as there is no significant degradation in performance for this particular application, even with the use of an unbalanced microstrip rectifying circuit [32]. Furthermore, the antenna was not integrated onto a substrate, to give the additional freedom to embed the harvester on windows or within walls, furnishings, fixtures, or fittings. To this end, two different antennas were fabricated for each band; one made using a 560-μm diameter copper wire and the other with 75-μm-thick 25-mm-wide copper tape. The fabricated antennas are shown in Fig. 3. Since the copper tape was not rigid enough to retain its shape, it was placed on a Perspex substrate, to represent a flat panel.

To design the antennas, full-wave 3-D electromagnetic simulations were performed using CST Microwave Studio. As discussed previously, the antennas were designed to be as omnidirectional as possible, while covering as much of the ambient RF source BW as possible. Fig. 4 shows the typical simulated gain profile for the DTV tape antenna, having a front-to-back ratio of unity. Table IV shows the simulated gain and the 10-dB return-loss fractional BW for the optimized copper wire and tape antennas.

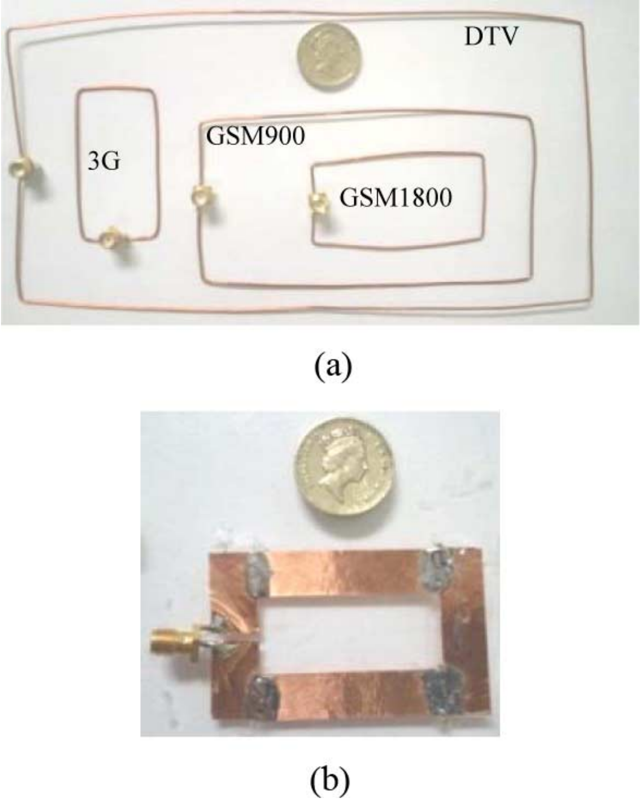

(a)

(b)

Fig. 3. 50-Ω folded-dipole antennas shown next to a British £1 coin. (a) DTV, GSM900 (BTx), GSM 1800 (BTx) and 3G (BTx) copper wire antennas. (b) 3G (BTx) copper tape antenna on Perspex.

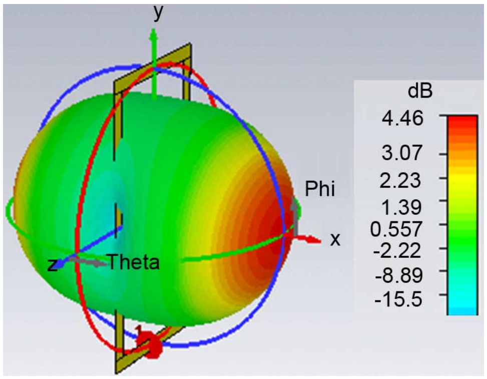

Fig. 4. Simulated beam profile for the DTV tape antenna.

Fig. 5 shows excellent agreement between predicted and measured return-loss results, within a 10-dB return-loss bandwidth, for the eight fabricated single-band antennas. As one would expect with such a simple classical antenna, the out-of-band performances (not shown) were also in good agreement. It was found that better return-loss measurements are achieved with our single-band antennas when compared to other reported single-band omnidirectional [13] and multiband [33] designs. The latter may be important, as it may be tempting to implement a more compact multiband rectenna, but which

TABLE IV
SIMULATED GAIN AND 10-dB RETURN LOSS FRACTIONAL BW FOR FOLDED-DIPOLE SINGLE-BAND ANTENNAS

Band		Wire		Tape	
	BW (%)	Gain (dBi)	BW (%)	Gain (dBi)	BW (%)
DTV	26	4.35	4	4.48	6
GSM900	3.7	4.42	4.3	4.73	4.3
GSM1800	4.1	4.32	5.3	4.73	10.7
3G	2.8	4.39	5.4	4.76	12

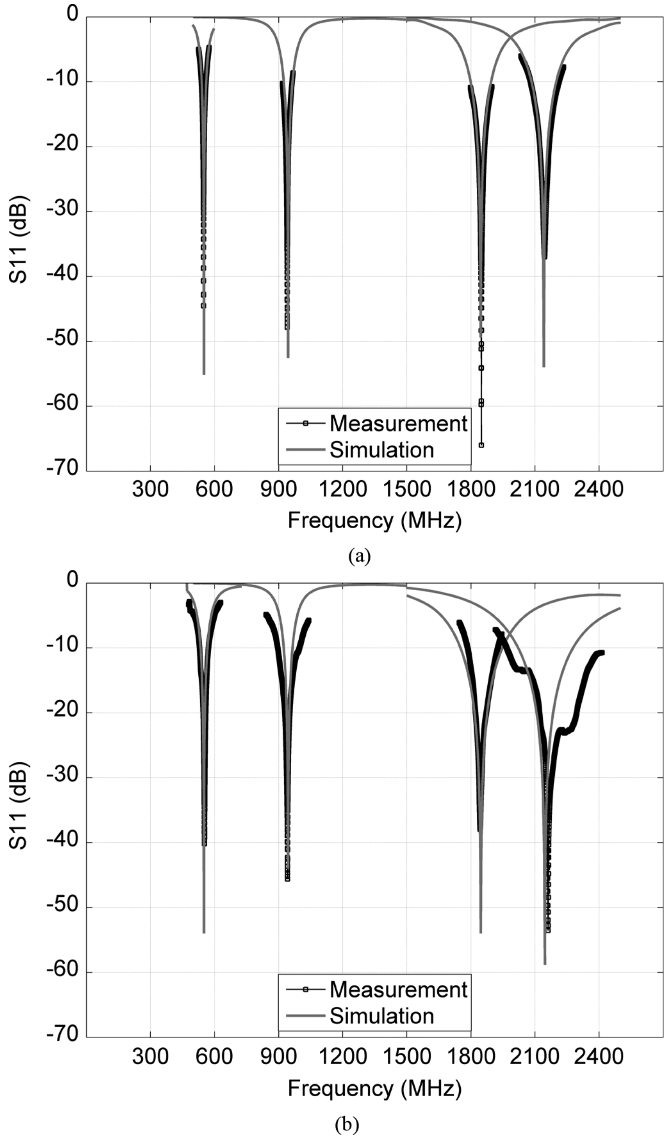

Fig. 5. Input return-loss predictions and measurements for all single-band folded-dipole antennas. (a) Wire. (b) Tape.

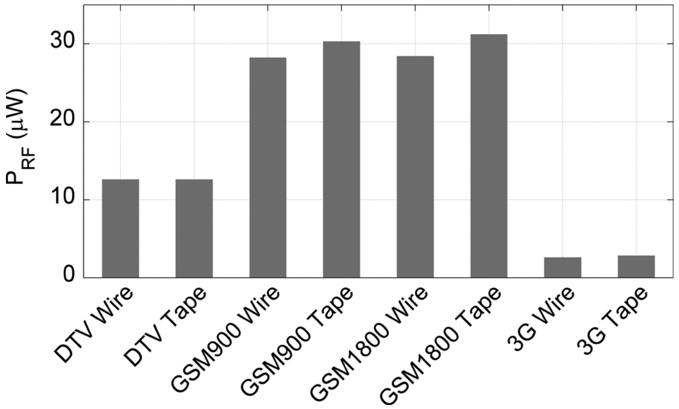

Fig. 6. Predicted input RF power levels for the four largest ambient sources at the ICL testing location.

may ultimately not give better ambient RF energy harvesting performance.

Obtaining a minimum acceptable return loss over an antenna fractional bandwidth as large as that of the source is key to harvest as much input RF energy as possible. As can be seen in Table IV, where the fractional bandwidth is defined for a 10-dB return loss, our antennas have a fractional bandwidth greater than those of the sources, with the exception of DTV, which only covers approximately 35% of the target frequency range. In other work [13], 5-dB return-loss fractional bandwidth is adopted for RF energy harvesting applications.

The fractional bandwidth of the antennas having a minimum return loss of 5 dB is too great to assume a constant antenna gain over the whole band. Therefore, an additional advantage of using 10-dB return-loss fraction bandwidths is that (1) can be used to calculate the input RF power with the assumption that the midband antenna gain is constant with frequency [34]. Therefore, the time-averaged input RF power P_{RF} is given by

$$P_{\mathrm{RF}} = S_{BA} \cdot A_{\mathrm{real}} \text{ and } A_{\mathrm{real}} \approx G(f_o)\frac{\lambda_o^2}{4\pi} \qquad (1)$$

where A_{real} is the real aperture (or capture area) of the antenna, λ_o is the free-space wavelength at the midband frequency f_o, and $G(f_o)$ is the rectenna's antenna gain at f_o.

Substituting the measured banded input RF power densities recorded in Table III and the predicted midband antenna gains in Table IV into (1), realistic values for P_{RF} can be calculated for all four bands, with the results shown in Fig. 6. It can be seen that with all antenna gains being in the region of $\sim$ 4.5 dBi, the 2G GSM900/1800 harvesters will generate the highest input RF power levels, due to the high-banded input RF power density levels measured *in situ*. At the other extreme, the 3G harvesters will be the worst performers. As only a small fraction of the required frequency range is covered by the DTV antennas, the predicted values for P_{RF} represent an overestimation.

B. Rectifier Design and Measurements

Based on a previously reported analysis [35] and the predicted input RF power levels presented in Fig. 6, the zero-bias SMS7630 diode (in a series configuration) was selected as the optimal solution for our ambient RF energy harvesters, as shown in Fig. 7. In a series configuration, the junction capacitance $(C_j(V))$ of the diode dominates the detector's impedance, as long as $C_{\mathrm{out}} > C_j(V)$, and thus C_{out} has little or no effect on the matching circuit. This allows C_{out} to be large enough to provide a ripple-free output voltage. In contrast, C_{out} must be less than 1 pF to achieve a good impedance match with a shunt configuration as C_{out} appears in parallel with $C_j(V)$ and the packaging parasitic capacitance. However, C_{out} is too small to

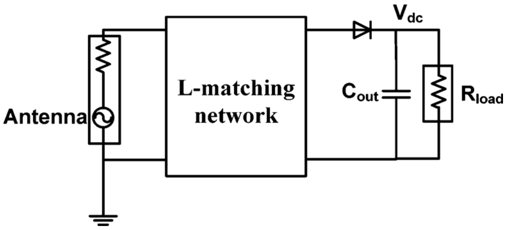

Fig. 7. Series detector configuration with L-matching network.

provide a ripple-free dc voltage to the load. This can be overcome with a matching network that will allow a good impedance match with a large output capacitor, but at the expense of introducing losses. Furthermore, as shown in [36], these issues start to become negligible with a shunt configuration as the shunt diode becomes more self-biased as the input power increases. Simulations were performed using Agilent Technologies' ADS software. Its Momentum package not only takes into account the losses from the low-cost FR4 substrate, but also calculates fringing fields, effects from which are passed on to the harmonic-balance package for simulating the nonlinear behavior of the rectifier.

A good impedance match was achieved by employing a simple matching network; a series lumped-element inductor was used to absorb part of the capacitive reactance from the series diode and an additional quarter-wavelength short-circuit shunt stub was employed to achieve the desired 50-Ω impedance [37]. Since the impedance of the diode varies with frequency and input RF power, impedance matching between the antenna and rectifier was first undertaken by finding the optimal output load resistance for an input RF power level of -20 dBm with a single-tone source at the midband frequency. After the optimal load was found, further broadband optimization was performed to the matching network and the load to ensure good impedance matching throughout the target frequency range and the measured $P_{\rm RF}$ for each band.

As with the antenna analysis, and unlike conventional RF circuits that adopt the more traditional half-power bandwidth definition, the rectifier should adopt the 10-dB-input return-loss bandwidth. The reason for this is that, for ambient RF energy harvesting applications, the input RF power is at a premium and so what little energy is available should not be wasted by being reflected back from avoidable impedance mismatches at either the antenna or rectifier.

Fig. 8 shows excellent agreement between predicted and measured input return loss results, within the -10-dB bandwidth, for the DTV and GSM900 rectifiers, having fractional bandwidths of 5.7% (below target) and 4.8%, respectively. With these lower frequency designs, the fundamental and higher order harmonics were below -55 dBm, ensuring a clean dc voltage at the load, without the need for any output filtering. Reasonable agreement was found with the GSM1800 and 3G rectifiers, having fractional bandwidths of 1.6% (below target) and 7.4%, respectively. It was found that with these two higher frequency designs, the higher order harmonics were -40 dBm at the output. This reduced performance, as illustrated in Fig. 8, is due to the higher series inductive reactance leads of the output shunt storage capacitor. For this reason, a second prototype version (v2) was designed for the 3G rectifier, using distributed-element components for the input impedance matching stage and an additional output filter stage. With the lumped-element matching network, it was found that in order to achieve good input impedance matching to 50 Ω, all the microstrip transmission lines had to have a characteristic impedance of 92 Ω. With the distributed-element matching network, a simple shunt quarter-wavelength open-circuit stub, designed for operation at the fundamental frequency, was employed. A microstrip line was added between the cathode of the diode and the stub to absorb the capacitive reactance of the diode. The stub effectively filters to < -50 dBm the higher order harmonics. The microstrip design can be seen in Fig. 13.

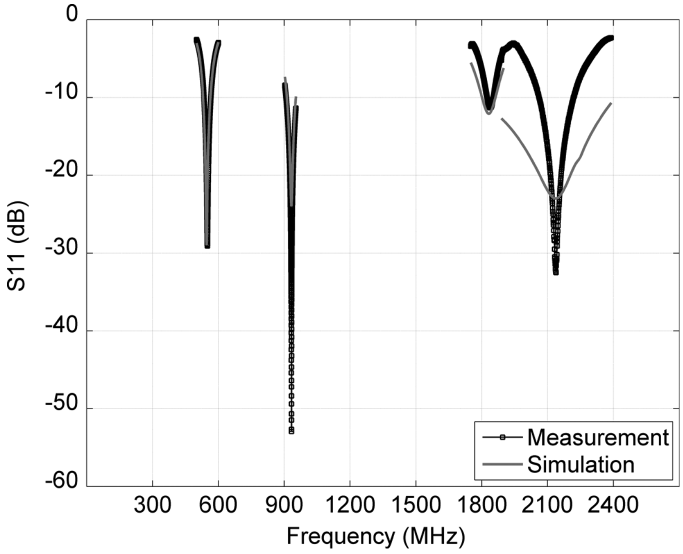

Fig. 8. Input return-loss predictions and measurements for all first prototype single-band rectifiers, with $P_{\rm RF} = -20$ dBm at the input and optimal load resistances at the output.

C. PMM

Since the input RF power from ambient sources can be represented as a multi-tone source, with power levels fluctuating across the target frequency range, the output impedance of the rectifier is time varying. A power management module (PMM) capable of performing maximum power point tracking (MPPT) is required.

For our work, a low-power integrated-circuit PMM from Texas Instruments Incorporated (BQ25504) was selected, due to its low quiescent current ($<$ 330 nA) and low input voltage operation ($\sim$ 80 mV hot-start and 330-mV cold-start) [38]. It is worth noting that its startup voltage is lower than PMMs previously reported and realized using hybrid circuits for RF energy harvesting [13]. The BQ25504 PMM includes a boost converter that steps up its input voltage (having a 350-mV average value during ambient operation) to useful levels between 2.4–5.3 V. The BQ25504 also has a built-in battery management module, which is used to control the duty cycle of the output power to the load.

MPPT operation on the BQ25504 is achieved by periodically sampling the open-circuit voltage (OCV) at the input of the converter, which then draws a current causing the converter

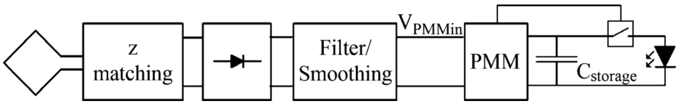

Fig. 9. System block diagram.

input voltage to fall and be held at a pre-programmed fraction of the OCV (set by a potential divider). In a simple dc circuit, with a resistive source impedance, the optimal ratio is 0.5. For the rectenna-based system, a ratio of 0.48–0.53 was found to maximize the power output of the system. The BQ25504 is designed to charge a storage element, and in this case, a capacitor C_{storage} was used. The programmed PMM continuously charges the storage capacitor, and the load (a low-power LED) was automatically connected to the storage capacitor when the capacitor voltage reaches an upper limit $V_{\mathrm{high}} = 2.84$ V and automatically disconnected when it reaches a lower limit $V_{\mathrm{low}} = 2.40$ V. The duty cycle of the LED can then be used to calculate the efficiency of the system, as will now be described. A diagram of the system is shown in Fig. 9.

IV. End-to-End Efficiency Analysis

The efficiency η of an RF energy harvesting system is

$$\eta = \frac{P_{\mathrm{dc}}}{P_{\mathrm{RF}}} \tag{2}$$

where P_{dc} is the time-averaged output (i.e., equivalent dc) power into the storage element (e.g., battery or supercapacitor) and load and P_{RF} is as previously defined. Measurements for this type of system are usually performed in a controlled environment (e.g., an anechoic chamber or TEM cell), using a dedicated constant or variable amplitude single-tone RF signal source [32], [39]. However, the former is not suitable for evaluating ambient RF energy harvesting operation, which has a much broader spectrum of nonconstant input frequencies and where the instantaneous input RF power is time variant. The use of a constant single-tone dedicated source provides a convenient stable reference power to the harvester; while the latter reflects a more realistic signal source having fluctuating power levels across a nonzero bandwidth, multipath, and reflection effects which are very difficult to emulate in a controlled environment.

Therefore, to determine the overall end-to-end efficiency $\eta_{\text{e-e}}$ for a complete ambient RF energy harvester, the input RF energy U_{RF} was calculated based on the harvester's antenna characteristics and the actual banded input RF power density measurements taken at the time of harvester operation, using the Agilent Fieldfox and the calibrated antenna. It is important to note that since the impedance mismatch between the antenna and detector is not taken into account, U_{RF} is higher than expected, providing an underestimate of end-to-end efficiency. The output dc energy U_{dc} was then calculated by measuring the charge–discharge cycle time, t_{cycle} of the storage capacitor between V_{high} and V_{low}, as the LED is repeatedly connected and disconnected. The output dc energy equation is already taking into account the efficiency of the PMM given the fact that the measurements are taken at its output voltage. The end-to-end efficiency of one charge–discharge cycle of C_{storage} is

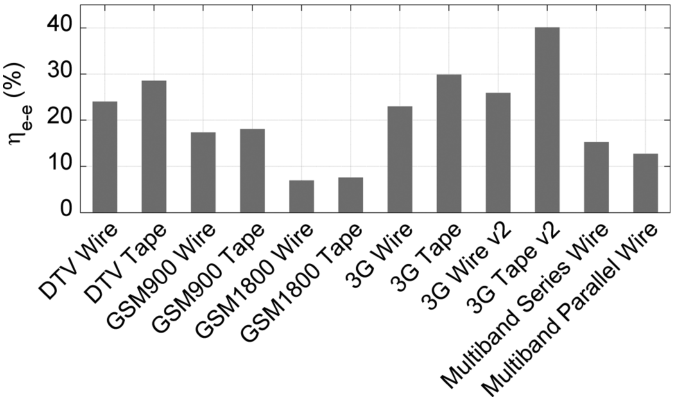

Fig. 10. End-to-end efficiencies for ambient RF energy harvesting at ICL.

$$\eta_{\text{e-e}} = \frac{U_{\mathrm{dc}}}{U_{\mathrm{RF}}} \tag{3}$$

where the input RF energy is given by integrating the time-averaged input RF power over a cycle time, as

$$U_{\mathrm{RF}} = \int_{0}^{t_{\mathrm{cycle}}} P_{\mathrm{RF}} dt \tag{4}$$

and the output dc energy is given by the energy supplied to the load, as follows:

$$U_{\mathrm{dc}} = C_{\mathrm{storage}} \frac{({V_{\mathrm{high}}}^2 - V_{\mathrm{low}}^2)}{2}. \tag{5}$$

A. ICL Field Trials

Four single-band ambient RF energy harvesters were assembled by connecting the rectifiers to the wire/tape antennas and PMMs programmed for the optimal load. A 100-μF shunt capacitor was employed as the storage element, providing $U_{\mathrm{dc}} = 115\ \mu$J. Our system is capable of cold-starting the boost converter and MPPT since the rectenna is capable of providing the minimum starting voltage of 330 mV. When the minimum voltage is reached, the boost converter and MPPT start to operate and the charge–discharge cycle at the load begins, causing the LED to flash. During field trials, t_{cycle} took up to 170 s for the harvester with lowest banded input RF power density, corresponding to 3G with the wire antenna. Table V summarizes the results where t_c and t_d are the charge and discharge times, respectively, and ΣV and ΣI are the multiband voltage and current summing array architectures, respectively. A detailed discussion on the multiband rectenna arrays will be presented in the following section. The end-to-end efficiency was calculated using (3) with data from Fig. 6 and measuring the charge–discharge cycle time during harvesting operation.

Fig. 10 shows the overall end-to-end efficiencies for all the harvester demonstrators, deployed and tested at ICL. As predicted by simulations, the improved 3G v2 demonstrator with

TABLE V
HARVESTERS CHARGE AND DISCHARGE TIMES (t_c, t_d, RESPECTIVELY) FOR A SPECIFIED LOAD

Band	Wire					Tape				
	t_c (s) load independent	t_d (s) load dependant	t_{cycle} (s) load dependant	$P_{dc}(t_d)$ (μW)	$P_{dc}(t_{cycle})$ (μW)	t_c (s) load independent	t_d (s) load dependant	t_{cycle} (s) load dependant	$P_{dc}(t_d)$ (μW)	$P_{dc}(t_{cycle})$ (μW)
DTV	26	12	38	9.6	3	14	18	32	8.2	3.6
GSM900	14	10	24	11.5	4.8	8	13	21	14.4	5.5
GSM1800	43	15	58	7.7	2	22	27	49	5.2	2.4
3G v2	167	3	170	38.4	0.7	96	5	101	1.2	1.1
Multiband ΣV	43	7	50	66	2.3	-	-	-	-	-
Multiband ΣI	55	5	60	92.2	2	-	-	-	-	-

tape antenna outperformed its original design by 11%; achieving an end-to-end efficiency of 40% with an input RF power of only -25.4 dBm.

It is believed that a much greater efficiency can be achieved for the DTV harvester if the fractional bandwidths for the first prototype circuits (i.e., 4.4/4.5% for the antennas and 5.8% for the rectifier) could be increased to match the much greater target value of 26%. Likewise, the reduced efficiency of the GSM1800 harvesters can be attributed to the detrimental effects of the narrowband input impedance matching of the rectifier (i.e., having a fractional bandwidth of only 1.6%, when compared to its target value of 4.1%). Finally, with all the harvesters, the end-to-end efficiencies can be enhanced through better antenna design and optimal polarization matching.

Table VI, shows the number of locations from the London RF survey that would be able to support our harvesters. Unlike the single-band 3G harvester, which can operate at 45% of the locations, our DTV harvester can only be used at two locations (one in zone 2 and the other in zone 3). Therefore, for the general deployment of an ambient RF energy harvester within an (semi-)urban environment, at street level, the single-band DTV harvester may not be practical

V. ARRAY ARCHITECTURES

Since ambient input RF power levels can be low (i.e., below -25 dBm) and dependent on both time and spatial considerations, harvesters could be designed to extract energy with spatial-diversity within the same frequency band or using different frequency bands. For example, with the former, at a particular location there may be only one band that has significant levels of RF energy worth harvesting. In this case, spatial-diversity array architectures may provide more usable output power. Alternatively, with the latter, multiband array architectures may provide more robust operation.

With both forms of parallel array architecture (i.e., spatial-diversity and multiband), a further classification can be seen through the use of either diversity/band switching or a summing node. With the former, physical switches automatically select whichever signal path delivers the highest input RF power level; with the latter, power from all signals is combined. Fig. 11 illustrates generic forms of parallel array architectures, showing that switching/summing can be performed electromagnetically at a single antenna or at the output from multiple antennas, rectifiers, or PMMs.

TABLE VI
NUMBER OF LOCATIONS FROM THE LONDON RF SURVEY CAPABLE OF SUPPORTING IDENTICAL HARVESTERS AT THE SAME EFFICIENCY LEVELS

	DTV	GSM900 (BTx)	GSM1800 (BTx)	3G (BTx)
Stations with higher S_{BA}	2	28	68	122

Multiband array architectures, similar to those in Fig. 11(c) and (d), capable of RF harvesting from the four previously identified bands, were selected as possible optimal solutions, given no size/cost constraints. Our objectives were to reach the minimum cold-start voltage at the lowest possible input RF power levels and increase the harvesters' operational capabilities within (semi-)urban environments.

To this end, two different multiple rectenna architectures were investigated. The first with a single shared PMM and the second with multiple PMMs, as illustrated in Fig. 12. To simplify assembly, the wire antennas were selected since they did not require a substrate. Unwanted coupling between the single-band antennas was minimized by placing them a minimum distance of $\lambda_L/5$ apart; where λ_L is the wavelength of the lowest frequency band antenna [40]. For example, the DTV and the 3G antennas were kept at least 11 cm apart, as shown in Fig. 13. This allowed S_{11} measurements to be the same as in Fig. 5 once all antennas were assembled into the array.

A. Multiple Rectennas With a Shared PMM

In order to improve the cold-start performance of the system, the outputs of multiple rectennas can be connected in series, as shown in Fig. 12(a). This increases the probability of the voltage on the input of the PMM reaching the cold-start level (330 mV for the BQ25504) under any given scenario. While cold-starting the PMM, each rectenna harvests (albeit not optimally). Once

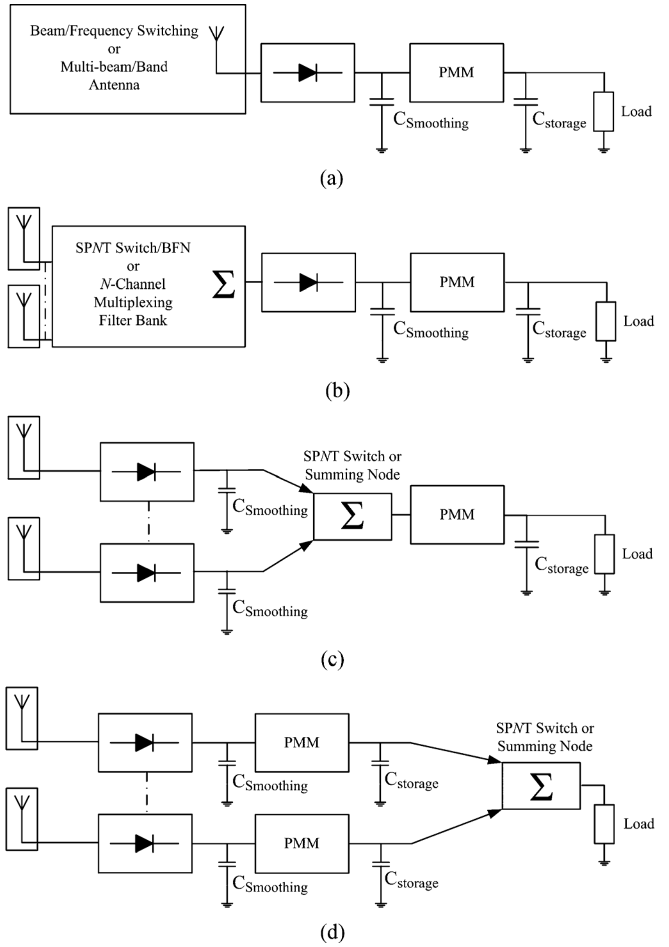
Beam/Frequency Switching
or
Multi-beam/Band
Antenna
PMM
CSmoothing
Cstorage
Load
(a)
SPNT Switch/BFN
or
N-Channel
Multiplexing
Filter Bank
Σ
PMM
CSmoothing
Cstorage
Load
(b)
SPNT Switch or
Summing Node
Σ
PMM
CSmoothing
CSmoothing
Cstorage
Load
(c)
PMM
PMM
CSmoothing
CSmoothing
Cstorage
Cstorage
SPNT Switch or
Summing Node
Σ
Load
(d)

Fig. 11. Parallel array architectures with switching/summing at the: (a) antenna, (b) output of multiple antennas, (c) output of multiple rectifiers, and (d) output of multiple PMMs.

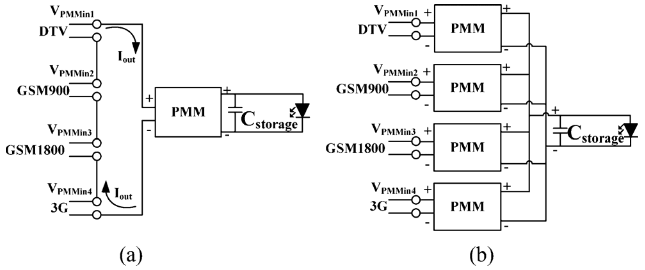
VPMMin1
DTV
Iout
VPMMin2
GSM900
VPMMin3
GSM1800
VPMMin4
3G
Iout
PMM
Cstorage
(a)
VPMMin1
DTV
PMM
VPMMin2
GSM900
PMM
VPMMin3
GSM1800
PMM
VPMMin4
3G
PMM
Cstorage
(b)

Fig. 12. Multiband array architectures (with $N = 4$ bands). (a) Voltage summing at the outputs of the single-band rectennas. (b) Current summing at the outputs of the single-band harvesters.

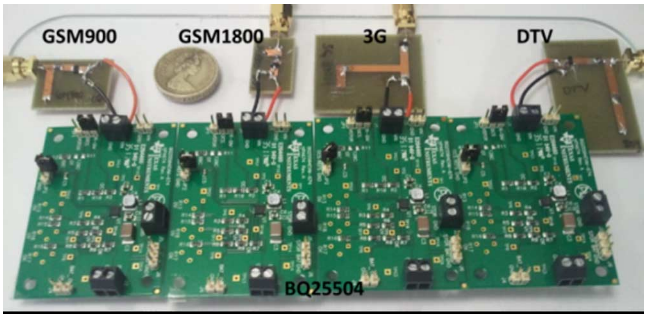
GSM900
GSM1800
3G
DTV
BQ25504

Fig. 13. Rectenna array architecture with individual PMMs for the four largest contributors with wire antennas.

the PMM circuit starts, with the MPPT operating, the harvested power level increases.

The behavior of the series rectenna topology with a shared PMM requires some discussion. As the output impedance and the OCV for each rectenna is different, since they operate at different frequencies and input RF power levels, the rectennas are forced to share the same output current in a series configuration, which does not allow them all to operate at their individual maximum power points. This causes the voltage on each rectenna output, except the one having the highest input RF power, to collapse. This operation is analogous to the partial shading problem with a series string of solar panels [41] sharing a common boost converter. With this photovoltaic system, bypass diodes placed around individual cells stop the poorly lit cells contributing a negative voltage (and power) to the string. In our case, the series circuit formed by the loop antennas and rectifying diodes performs the same task. This means that while all rectennas contribute to system startup, only the rectenna with the highest input RF power contributes significant power for continuous operation once the PMM starts. Fig. 10 shows the end-to-end efficiency for the voltage summing multiband harvester array when tested at ICL. An efficiency of only 15% was achieved with a combined input RF power of -12 dBm. The lower efficiency, when compared to a single-band harvester, is due to the imbalance of rectifier outputs, as discussed above. Here, the charge time was 43 s, compared to 167 s with the lowest contributing single-band 3G harvester with wire antenna.

B. Multiple Rectennas With Individual PMMs

In order to overcome the balancing issues when multiple rectennas share a common PMM, as discussed previously, each rectenna can have its own PMM, whose outputs can be connected to a common storage element (in this case, a 400-μF shunt capacitor, providing $U_{\mathrm{dc}} = 461\ \mu$J), as illustrated in Fig. 12(b) and shown in Fig. 13. Although not achieving cold-start as quickly as the series topology, this parallel topology has the advantage of being able to run each rectenna at its maximum power point. In addition, once one rectenna is able to harvest enough energy for a cold-start, all PMMs will start because they share a common storage element, allowing the rectennas with low-input RF power levels to harvest at levels below which they could not do so independently.

This parallel topology was tested and found to be capable of operating in many locations where the series array was unable to operate; e.g., if only one of the bands had $P_{\mathrm{in}} > -25$ dBm. As expected, the largest contributor hot-started the other PMMs, allowing them to harvest at an input RF power level down to -29 dBm.

However, as with the previous results for voltage summing, having a combined input RF power of -12 dBm, the efficiency using multiple PMMs is slightly lower, at 13%, as shown in Fig. 10. This is because useful dc output power from the cold-

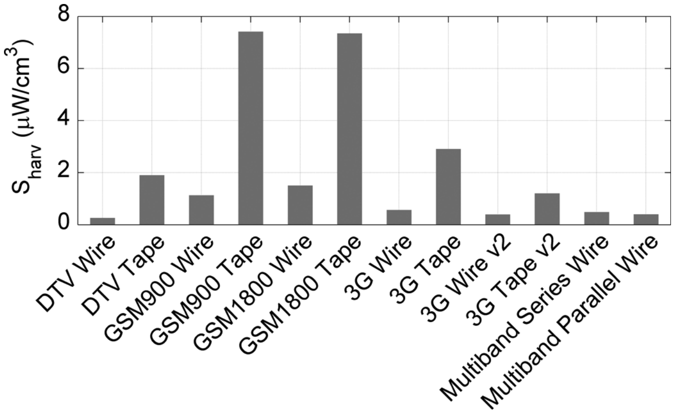

Fig. 14. Output dc power density for all harvesters at ICL.

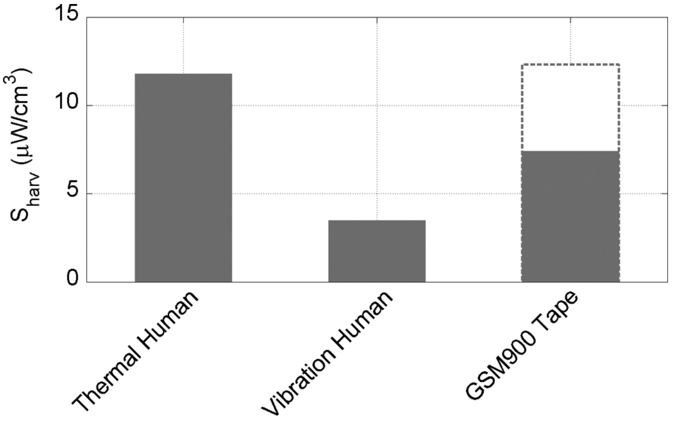

Fig. 15. Output dc power density comparison for alternative ambient harvesting technologies [40]–[43] against the best current generation of RF harvesters at ICL.

starting harvester is being supplied to the other harvesters for hot-starting, even though some of them may not actually be contributing any of their own harvested power.

VI. OUTPUT DC POWER DENSITY COMPARISON

The volumetric output dc power density S_{harv} $(\mu\mathrm{W/cm}^3)$ represents an important figure of merit for comparing alternative energy harvesting technologies. For ambient RF energy harvesting, the output dc power is calculated by multiplying the effective input RF power by the overall end-to-end-efficiency. The total volume (including that of the antenna, rectifier, and PMM; not including energy storage, as this does not directly affect the dc power output) must be determined. It is important to note that the volume for the antenna could effectively disappear if it is assembled onto a window or within a wall, furnishing, fixture, or fitting. Moreover, the required PMM printed circuit board (PCB) size used throughout these calculations was assumed to be ten times the size of the BQ25504 chip, to account for any necessary additional components.

Fig. 14 shows the output dc power density for all the harvesters demonstrated here. It can be seen that the 2G GSM900/1800 harvesters with tape antennas both have the highest value of $S_{\mathrm{harv}} = 7.4$ $(\mu\mathrm{W/cm}^3)$, when tested at ICL, due to the high-banded input RF power density S_{BA}. The value for the most efficient harvester (i.e., 3G v2 with tape antenna) was not the highest in terms of output RF power because S_{BA} in this band was more than an order of magnitude lower than with GSM900.

S_{harv} allows a direct and meaningful comparison to be made with other alternative energy harvesting technologies. Our best performing ambient RF energy harvester (i.e., GSM900 with tape antenna) was compared against alternative energy harvesting technologies, assuming they used the same PMM board size [42]–[44].

It can be seen in Fig. 15 that ambient RF energy harvesting has a low output dc power density when compared to alternative energy harvesting technologies, but only when the total volume of the first prototype demonstrator is considered. However, when the antenna is absorbed onto or into a background feature and when the PMM is fully integrated into the rectifier, it can outperform (as indicated by the dotted column) the alternative energy harvesting technologies, while providing a complimentary means of extracting energy from the environment. The RF harvesters, however, have the additional advantage in that they do not require a thermal gradient, and unlike vibration-driven devices, they have no moving parts.

VII. CONCLUSIONS

Our objectives were to reach the lowest possible ambient input RF power levels and extend the harvesters' operational capabilities within (semi-)urban environments. To this end, a comprehensive citywide RF spectral survey was undertaken, indicating that more than 50% of the 270 London Underground stations are suitable locations for the deployment of our ambient RF energy harvesters. It has been demonstrated that single-band harvesters can operate with efficiencies of up to 40% in a (semi-)urban environment, and can start to operate from power levels as low as -25 dBm.

To increase the freedom of operation, multiband array architectures were investigated. With the current summing harvester arrays, RF harvesting was achieved at an input RF power level as low as -29 dBm, without any external dc power supply to hot-start the PMM. Limitations on the multiband array architectures were discussed, highlighting the need for further work in balancing rectennas with voltage summing rectenna arrays when operating at lower input RF power levels.

Finally an output dc power density comparison against alternative energy harvesting technologies has shown that RF harvesting can represent a competitive solution within (semi-)urban environments, especially when the antenna can be absorbed into background features.

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ELECTRICAL & ELECTRONIC ENGINEERING | RESEARCH ARTICLE

A dual-band RF energy harvesting circuit using 4th order dual-band matching network

Sachin Agrawal[1]*, Manoj S. Parihar[1] and P.N. Kondekar[1]

Abstract: A novel compact rectifier for dual-band operation in the RF energy harvesting is presented. The circuit comprises a 4th order dual-band impedance matching and a single-series circuit with one double diode, both are integrating into a compact shape to occupy a small area of $30 \times 35\ \text{mm}^2$. The merit of the proposed rectifier circuit is that it can be extended to n number of the frequency band by using only $2 \times n$ matching elements. To validate the design method experimentally, a prototype of a dual-band rectifier is fabricated for two public telecommunication bands of GSM-900 and 1800. In order to reduce the circuit complexity and sensitivity arising due to lumped elements, the meander line and the open stub are used to realize the proposed circuit. A good agreement is obtained between the simulation and the measurement. The measured results show that the proposed rectifier circuit exhibits the conversion efficiency of 25.7 and 65% for an input power of −20 and 0 dBm, respectively. In addition, diode nonlinearity which affects the performance of the rectifier in terms of impedance matching is also investigated.

Subjects: Electromagnetics & Microwaves; Electronics; Circuits & Devices

Keywords: RF energy harvesting; dual band impedance matching; rectifier; RF-to-dc-conversion efficiency; frequency transformation

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PUBLIC INTEREST STATEMENT

With rapid growth in wireless communication, a huge amount of radio frequency (RF) energy broadcasted through billions of microwave sources such as mobile phones, handheld radios, and radio broadcast stations. Therefore, it is meaningful to collect and supply it to many electrical devices like mobile headsets, wearable medical sensors through RF energy harvesting. Since the ambient RF energy is distributed in multiple frequency bands, therefore the amount of energy harvested could increase if the circuit is designed for multiple frequency bands. In this work, we present a compact dual-band energy harvesting circuit to harvest energy from two most useful frequency bands, GSM-900 and 1800. The merit of the proposed rectifier circuit is it can be extended to n number of the frequency band by using only $2 \times n$ matching elements. A prototype is fabricated, and its performance is evaluated using Vector Network Analyzer (VNA). The total size of the rectifier is about $30 \times 35\ \text{mm}^2$.

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1. Introduction

A revolutionary growth in wireless technology attracts huge attention from research community to make the self-sustainable device feasible through RF energy harvesting. It exploits ambient electromagnetic energy transmitted from different RF systems to remotely feed the electronic devices (Nintanavongsa, Muncuk, Lewis, & Chowdhury, 2012). Compared to other harvesting techniques, RF energy harvesting provides relatively predictable energy supply owing to the features of easy availability and less dependency on environmental variations. The typical block diagram of RF energy harvesting circuit is shown in Figure 1. It consists of three major blocks viz; antenna, matching network (MN), diode detector followed by an energy storage. The first element, antenna is employed to capture the RF signals of different frequencies and polarization, while second MN is for maximum power transfer, and the last rectifier is used to convert the RF energy to dc voltage. It means harvesting circuit performance can be evaluated in terms of accessible ambient RF energy and its conversion rate (Agrawal, Pandey, Singh,& Parihar, 2014). These parameters are heavily influenced by surrounding terrain conditions as the multiple reflection and dissipation certainly deteriorate the level of available ambient RF energy. As a result, conversion efficiency and dc output voltage may degrade. Previously, the majority of available RF energy harvesting circuits focused on single frequency band hence offer low dc output voltage. As the multiple RF energy sources of different frequency bands are available, thus from an ambient RF harvesting perspective, the output dc voltage could be increased if the circuit is designed for multiple frequency bands rather than a single band. A wide-band energy harvester can also promise a high output voltage by accumulating the number of RF signals at a time. However, due to nonlinear behavior of the diode, harvesting circuit itself exhibits nonlinearity i.e. its input impedance varies with the received RF power. Thus, it is quite difficult to retain the impedance match and high conversion efficiency over a large frequency range (Song, Huang, Zhou, & Carter, 2014). The losses due to impedance mismatch over a large bandwidth can be illustrated in Collado and Georgiadis (2013), where only 8% conversion efficiency is achieved at -20 dBm.

To address this, it is preferable to harvest energy from several narrow frequency bands rather than a single large one. In literature, numerous topologies have been proposed to accomplish the multi-band energy harvesting (Bergès, Fadel, Oyhenart, Vigneras, & Taris, 2015; Hamano et al., 2016; Ho et al., 2016; Keyrouz, Visser, & Tijhuis, 2013; Kuhn, Lahuec, Seguin, & Person, 2015; Liu, Zhong, & Guo, 2015; Niotaki, Georgiadis, Collado, & Vardakas, 2014; Pinuela, Mitcheson, & Lucyszyn, 2013; Scheeler, Korhummel, & Popovic, 2014; Shariati, Rowe, Scott, & Ghorban, 2015; Sun, Guo, He, & Zhong, 2013). These topologies can be differentiated in terms of filter functionality i.e. how the antenna or source impedance is matched to the rectifier circuit. For instance, in Pinuela et al. (2013) and Keyrouz et al. (2013) several single-band rectennas (combination of antenna and rectifier circuit) were stacked to constitute a multi-band harvesting circuit. In this case, each rectenna was designed for a specific frequency band. Thus, for compact applications, this architecture is not suitable due to the number of antennas used. Moreover, in most of the reported works, the quality assessment of the output voltages combination was not taken into consideration. In Kuhn et al. (2015), the circuit complexity is reduced to a certain extent by replacing the multiple antennas with a single wide-band antenna. However, in this topology too, the number of rectifiers increases with the frequency bands, which leads to prolonging the circuit complexity.

Figure 1. Typical block diagram of RF energy harvesting circuit.

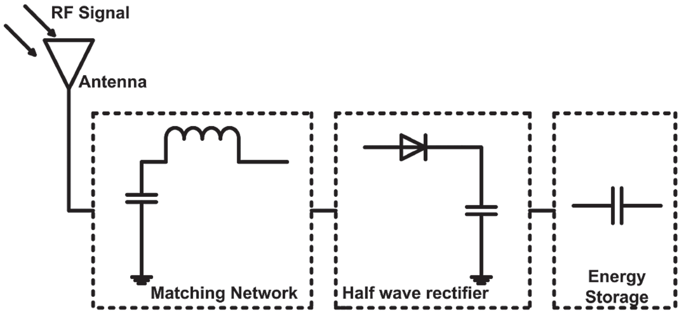

Besides, a multi-band harvesting circuit can also be formed by simply embedding a multi-band matching network between the multi-band antenna and the rectifying circuit (Bergès et al., 2015; Hamano et al., 2016; Ho et al., 2016; Liu et al., 2015; Niotaki et al., 2014; Scheeler et al., 2014; Shariati et al., 2015; Sun et al., 2013). The multi-band matching network can be designed either by distributed or by lumped element. In general, the multi-band rectifier circuit experiences two types of losses: first due to shift in resonance frequency from the optimum frequency point, and second due to the filter complexity. Because of the diode nonlinearity, the input impedance of the circuit varies as a function of power and frequency which causes a shift in resonance frequency. The difficulty due to diode nonlinearity can be observed in Sun et al. (2013) where the dual-band rectifier circuit exhibits its impedance matching for a small range of input power. The losses induced because of filter complexity can be observed in the recently reported works on dual band harvesting circuit (Niotaki et al., 2014; Scheeler et al., 2014; Shariati et al., 2015). In Niotaki et al. (2014), for $P_{\text{in}} = -15$ dBm, author achieved the conversion efficiency of 23% at the expense of increased filter complexity consisting two series and two shunt pairs of reactive elements. Thus, for more than dual band applications, the proposed circuit topology is not suitable due to excessive filtering components used. To obtain good conversion efficiency a dual-band rectenna reported in Scheeler et al. (2014). However, the rectenna was large in size and requiring a complex impedance tuning circuit. In Shariati et al. (2015) also, a dual-band matching network consisting nine reactive elements was employed to achieve the dual-band characteristics.

In order to reduce the filter complexity, this work proposed a compact dual-band harvesting circuit for GSM-900 and 1800. It consists of a 4th order dual-band matching network based on $1-n$ frequency transformation, which is optimized for the energy harvesting circuit to reduce the complexity up to $2 \times n$ reactive elements (n is the number of frequency bands). Similar to frequency transformation method, the proposed dual-band rectifier circuit can be extended to n number of frequency bands by using the $2 \times n$ number of reactive elements. The detailed analysis and design guidelines of dual band rectifier circuit are discussed in Section 2.

2. Dual band rectifier design and analysis

This section presents the design and analysis of a dual-band harvesting circuit in terms of impedance matching, DC output voltage and RF-to-dc conversion efficiency. The topology of the proposed dual-band RF energy harvesting circuit is shown in Figure 2(a). As seen, the low-cost Schottky diode is used to transform the input RF power to DC voltage. The impedance matching at two frequency is achieved using a series and parallel combination of the *LC* pair. The main idea underlying the suggested multi-band matching network is $1-n$ frequency transformation (one to many mapping of frequency), which transforms a single-band matching network to multi-band matching network (Nallam & Chatterjee, 2013). As the name ($1-n$) suggests that for designing a multi-band matching network, primarily a single-band matching network is required whose resonant frequency is dependent on the frequencies for which multi-band matching network proposed to designed.

Moreover, this frequency transformation method depends on the type of load impedance, whether it is series or parallel combination of *RC* or *RL*. Since the selected diode (HSMS-2852) has capacitive behavior throughout the frequency, it can be represented in a series or parallel combination of *R* and *C*. In the case of parallel *RC* load, the following equations are used to transform the single-band matching network into multi-band matching network.

$$\omega = \frac{\omega_t^{n} + a_m \omega_t^{n-m} + a_{m+2}\omega_t^{n-(m+2)} + \cdots}{\omega_t^{n-1} + a_{m+1}\omega_t^{n-(m+1)} + a_{m+3}\omega_t^{n-(m+3)} + \cdots} \tag{1}$$

where, n is the number of bands and m varies from 2 to n. After substituting the value of n, Equation (1) can be expanded in partial fraction form using the causal foster analysis as:

$$\omega = \omega_t + \cfrac{1}{\frac{\omega_t}{a_2 - a_3} + \frac{1}{\cdots}} \tag{2}$$

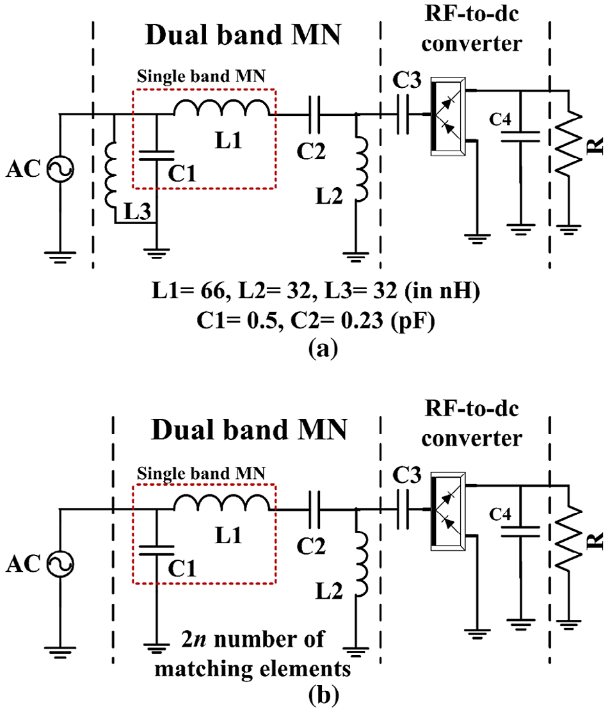
Dual band MN
RF-to-dc converter
Single band MN
C3
C4
L1
C2
AC
C1
L3
L2
R
L1= 66, L2= 32, L3= 32 (in nH)
C1= 0.5, C2= 0.23 (pF)
(a)
Dual band MN
RF-to-dc converter
Single band MN
C3
C4
L1
C2
AC
C1
L2
R
2*n* number of matching elements
(b)

Figure 2. (a) Circuit diagram of the proposed dual-band rectifier circuit and (b) optimized dual-band rectifier circuit.

The coefficients a_2 and a_3 can be calculated as:

$$\omega_m = \sum_{i=1}^{n} (-1)^{i-1} \omega_i \tag{3}$$

$$a_m = (-1)^m \sum_{i,j=1,1\,\&\,i\neq j}^{n,n} (-1)^{i+j} \omega_i \omega_j \tag{4}$$

$$a_{m+1} = (-1)^{m+1} \sum_{i,j,k=1,1,1\,\&\,i\neq j\neq k}^{n,n,n} (-1)^{i+j+k} \omega_i \omega_j \omega_k \tag{5}$$

$$a_{m+n} = (-1)^{m+n} \sum_{i,j,k\ldots=1,1,1\ldots i\neq j\neq k}^{n,n,n\ldots} (-1)^{i+j+k+\cdots} \omega_i \omega_j \omega_k \ldots \tag{6}$$

$$a_n = \prod_{i=1}^{n} (-1)^n \omega_i \tag{7}$$

Equation (6) is similar to that presented in Nallam and Chatterjee (2013), except the term $(-1)^{m+n}$, which is included here to realize the multi-band matching network for more than three frequency bands i.e. for $n \geq 3$.

With this transformation, the capacitor of the matching network is transformed to the combination of prototype capacitor parallel with inductor whereas, an inductor is transformed into a combination of the same inductor with a series capacitor. Figure 3 shows the circuit schematic of transformation of a single-band matching network to the dual-band matching network. It can be seen that C_1 is transformed to $C_1 \| L_2$ and L_1 transformed to L_1 series with C_2. After successful usage of (1)–(7), the resultant multi-band matching network requires $3n-1$ and $4n-1$ reactive elements for L and Π-type topology, respectively.

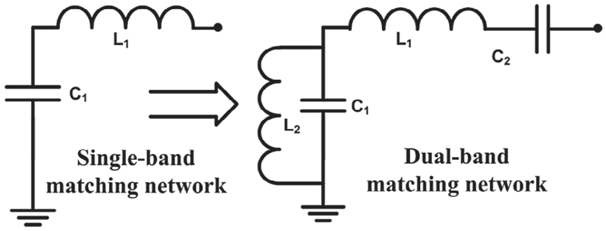

Figure 3. Conversion of a single-band matching network to dual-band matching network using $1-n$ frequency transformation.

As the aim is to design a dual-band harvesting circuit, therefore, we require here only 5 or 7 reactive elements with L and Π-type topologies, respectively. From Figure 2(a), it can be seen that the resultant matching network consists of five elements, where the inductor L_3 and capacitor C_2 results after the transformation of capacitor C_1 and inductor L_1, respectively. Besides, the inductor L_2 occurrs due to the diode reactive element, which is generally a capacitor.

In this work, two frequencies 0.9 and 1.8 GHz that correspond to the maximum signal strength are chosen for dual-band harvesting circuit. According to this method, it is necessary to assign the frequencies in descending order e.g. $\omega_1 = 1.8, \omega_2 = 0.9$. Therefore, from (3) single-band matching network frequency is equal to $\omega_1 - \omega_2 = 2\pi(1.8 - 0.9) \times 10^9 = 0.9 \times 2\pi \times 10^9$. In order to match the source impedance with the rectifier at the calculated frequency 0.9 GHz, the chosen matching topology is L-type as shown by the encircled portion in Figure 2(a). The corresponding element values can be approximated using the various methods some of which are described in Pozar (2010). Subsequently, this single-band matching network is transformed to dual-band matching network using (1)–(7). The detailed design steps of the dual-band rectifier circuit are summarized as follows:

(1) As we are interested in matching the diode to 50 Ω at two frequencies (0.9 and 1.8 GHz) so, the order of transformation is equal to 2 or $n = 2$.

(2) In the first step, single-band matching network is designed at the frequency f calculated as: $f = f_2 - f_1 = 1.8 - 0.9 = 0.9$ GHz. In this case, any matching topology that matches the diode to 50 Ω, at 0.9 GHz for an input power $P_{\text{in}} = -20$ dBm, and load resistance 4.7 kΩ can be used. The chosen single-band matching network is shown by the encircled portion in Figure 2(a).

(3) Afterwards, this single-band matching network is transformed into dual-band using the (1)–(7) as shown below:

Since $n = 2$ therefore, from (2)

$$\omega = \omega_t + \frac{1}{\frac{\omega_t}{a_2}} \tag{8}$$

From (4) a_2 can be calculated as:

$$a_2 = (-1)^{2+2} \sum (-1)^{1+2} \omega_1 \omega_2 = \omega_1 \omega_2 \tag{9}$$

$$a_2 = -1.62 \times 4\pi^2 \times 10^8 = 0.64 \times 10^{20} \tag{10}$$

Thus, inductor L_1 (=66 nH) is transformed to impedance as:

$$j66 \times 10^9 \omega = j66 \times 10^9 \omega_t + \frac{1}{j0.23 \times 10^{-12} \omega_t} \tag{11}$$

Similarly, capacitors (=0.5 pF) are transformed to the admittance as:

$$j5 \times 10^{-13} \omega = j5 \times 10^{-13} \omega_t + \frac{1}{j32 \times 10^{-9} \omega_t} \tag{12}$$

The circuit schematic of the dual-band harvesting circuit is shown in Figure 2(a). It can be seen that resultant matching network consists of five reactive elements according to $3n - 1$. In order to reduce the circuit complexity and sensitivity due to reactive elements, a parametric study has been carried out to eliminate the elements showing minimum influence on the circuit performance.

Figure 4 shows the simulated $|S_{11}|$ for the different combination of matching elements. The simulated results demonstrate that $|S_{11}|$ experiences maximum change when inductor L_2 and capacitor C_2 are removed from the circuit, whereas it remains almost unaffected when L_3 is not present in the circuit. Therefore, inductor L_3 can be extruded from the circuit and the resultant matching circuit requires only $2n$ and $3n$ reactive elements in place of $3n - 1$ and $4n - 1$ elements. In this way, for each topology, the proposed circuit reduces $n - 1$ elements compared to the conventional method. Figure 2(b) demonstrates the optimized circuit diagram of the dual-band rectifier. It can be observed that circuit requires large inductors value of 32 and 66 nH. Thus, it is quite difficult to realize the practical rectifier circuit whose response is similar to the response of simulated result. In order to avoid any impedance mismatch due to the small difference in elements value, the meander line inductor and open stub are used to realize the inductors and capacitors, respectively. In this case, not only fabrication and optimization process become so easy but the cost will also reduced.

Figure 5, shows the layout of the dual-band rectifier circuit. In Nintanavongsa et al. (2012) and Agrawal et al. (2014), it has been demonstrated that the number of rectifying diodes or equivalently voltage multiplier stages are very much sensitive to the RF-to-dc conversion efficiency. In low-power region (≤ -20 dBm), efficiency decreases if voltage multiplier stages increase, whereas in higher power region (≥ -20 dBm), an opposite effect occurs. As the demand is to harvest energy in low-power region, single-series circuit with a double diode is used to convert received RF energy into dc voltage. From the left side of the circuit, the first meander line corresponds to the inductor L_1, while the second meander line represents the inductor L_2, of the Figure 2(b). The shunt stub is accounted

Figure 4. Simulated $|S_{11}|$ vs. frequency for different combination of circuit elements.

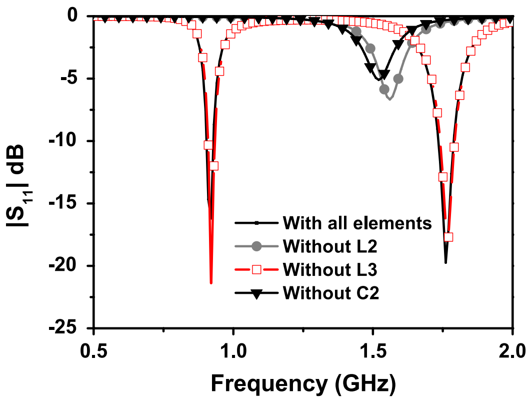

Figure 5. Layout of the proposed dual-band RF energy harvesting circuit.

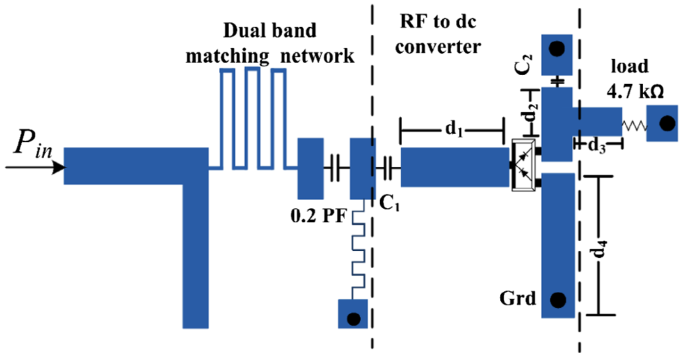

for the shunt capacitor C_1 of Figure 2(b). The dimensions of each element are calculated according to their respective reactive element value and the substrate on which circuit has to be fabricated. In Assimonis, Daskalakis, and Bletsas (2016), it has been demonstrated that traces (microstrips) connected to the rectifier terminals (e.g. distance between the diode and via and diode and load) are highly sensitive for RF-to-dc efficiency. Therefore, traces d_1, d_2 between diode and capacitor C_1 and C_2, d_3 between diode and load and d_4 between diode and ground are adjusted to optimize the impedance matching as well as the conversion efficiency of the rectifier. Due to nonlinear behavior of the diode, harvesting circuit itself exhibits nonlinearity i.e. its input impedance varies with received RF power, therefore harmonic-balance (HB) and large signal analysis (LSSP) were employed to take into consideration the nonlinear behavior of the rectifier.

The photograph of the fabricated dual-band rectifier is shown in Figure 6. It is fabricated on a 1.54 mm thick FR-4 substrate with a dielectric constant (ϵ_r) of 4.3 using chemical etching method. The rectifier performance is evaluated in terms of $|S_{11}|$ and output voltage using the Agilent vector network analyzer (VNA). The simulated and measured $|S_{11}|$ is illustrated in Figure 7(a). The measured result shows reasonable agreement with the simulated one; the slight difference can be accounted for the fabrication imperfections. It is well known that impedance matching is a function of frequency and input power, due to the nonlinearity of the diode. Such a characteristic is examined in Figure 7(b), where the measured $|S_{11}|$ is demonstrated as a function of input power level for three different load impedance values. From results, it is clear that impedance matching of the harvesting circuit is greatly affected by the input power and the load impedance. Figure 7(b) demonstrates that as power increases, the impedance matching at 0.9 GHz degraded drastically, while at 1.8 GHz, it improves. Moreover, it is noticed that the impedance matching at higher power level is more sensitive to the variation of load impedance (*RL*).

The measured RF-to-dc conversion efficiency and output voltage vs. input power for both frequencies are demonstrated in Figure 8(a). For 0.9 GHz, efficiency is equal to 25.7 and 65.1% for an input power of -20 and 0 dBm, respectively. However, at 1.8 GHz the efficiency is relatively small that might be due to the increased parasitic losses in the rectifier diode. Figure 8(b) shows the relation between the output voltage and frequency for various input power levels at fixed load resistance value of 4.7 kΩ. It can be seen that maximum output voltage is achieved in the frequency range of 860–900 and 1770–1800 MHz, showing the rectifier's capability to harvest RF energy in the GSM-900 and 1800 bands.

Figure 9, depicts the measured conversion for various values of load resistance. It can be noticed that the circuit yields maximum efficiency when the load impedance is 4.7 kΩ. It starts decreasing as the load impedance varies from 4.7 kΩ. Table 1 shows the comparison of the conversion efficiency and the size of the proposed rectifier with the similar works reported previously. Only measured results are compared in Table 1. It can be seen that in low-power condition maximum efficiency is achieved in Sun et al. (2013), but the expense of bulky circuit size. However, the proposed rectifier offers an optimal conversion efficiency with compact circuit size.

Figure 6. Photograph of the fabricated dual-band RF energy harvesting circuit.

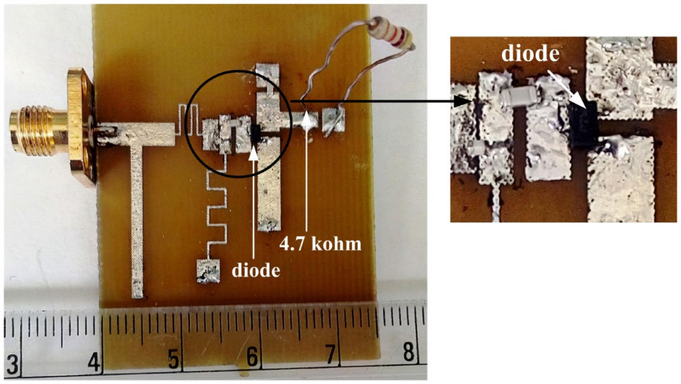

Figure 7. (a) Simulated and measured $|S_{11}|$ vs. frequency and (b) measured $|S_{11}|$ for various power levels.

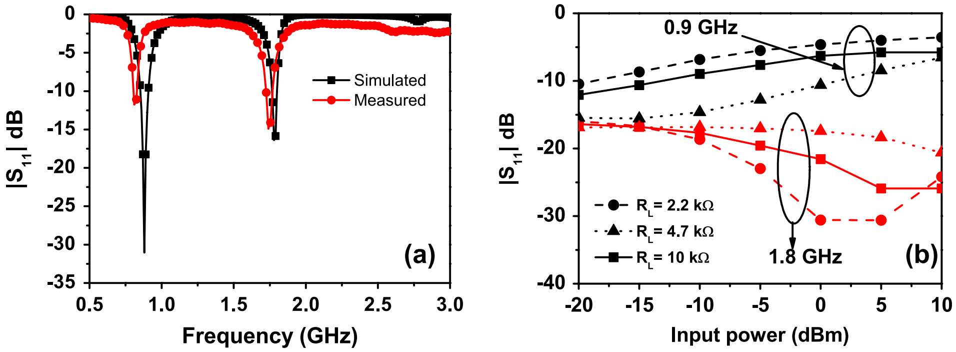

Figure 8. (a) Measured output dc voltage and RF-to-dc conversion efficiency and (b) measured dc voltage vs. frequency.

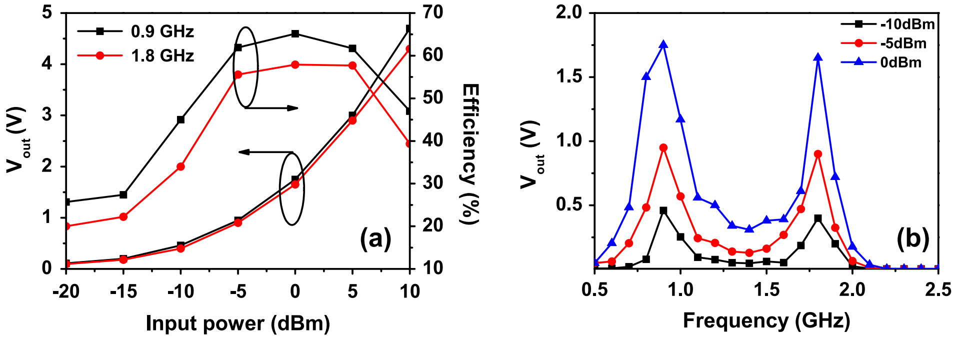

Figure 9. Measured RF-to-dc conversion efficiency for different load impedance.

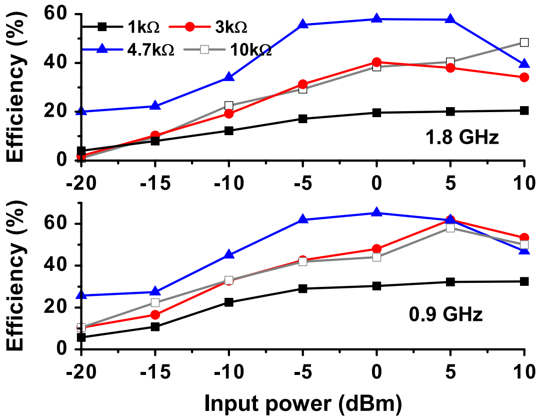

Table 1. Performance comparison of the proposed dual rectifier with recently published works

Ref.	Measured rectifier efficiency (%)	Input power (dBm)	Rectifier size
Ho et al. (2016)	15.8 @ 0.89 GHz	−20	$100 \times 65\ \text{mm}^2$
	11.2 @ 1.76 GHz		
Hamano et al. (2016)	10 @ 2.15 GHz	−10	$37 \times 71\ \text{mm}^2$
	15 @ 5.84 GHz		
Bergès et al. (2015)	27 @ 0.91/2.4 GHz	−16	$78 \times 88\ \text{mm}^2$
Sun et al. (2013)	30 @ 2.14 GHz	−20	145 mm
	35 @ 1.84 GHz		
Liu et al. (15)	20 @ (0.91+1.8) GHz	−20	$23 \times 37\ \text{mm}^2$
This work	27.5 @ 0.9 GHz	−20	$30 \times 35\ \text{mm}^2$
	20 @ 1.8 GHz		

3. Conclusion

A new compact 4th order dual-band rectifier has been designed to harvest the RF power of GSM-900 and 1800 bands. In order to reduce the circuit complexity and sensitivity due to reactive elements, the meander line and the open stub are used to fabricate the matching network. For $P_{\text{in}} = -20$ dBm, the measured RF-to-dc conversion efficiency of 27.5 and 20% is achieved at 0.9 and 1.8 GHz, respectively. Further, more than 45 and 34% conversion efficiency is maintained from -10 to 10 dBm for 0.9 and 1.8 GHz, respectively.

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Optimization of the Voltage Doubler Stages in an RF-DC Convertor Module for Energy Harvesting

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ABSTRACT

This paper presents an optimization of the voltage doubler stages in an energy conversion module for Radio Frequency (RF) energy harvesting system at 900 MHz band. The function of the energy conversion module is to convert the (RF) signals into direct-current (DC) voltage at the given frequency band to power the low power devices/circuits. The design is based on the Villard voltage doubler circuit. A 7 stage Schottky diode voltage doubler circuit is designed, modeled, simulated, fabricated and tested in this work. Multisim was used for the modeling and simulation work. Simulation and measurement were carried out for various input power levels at the specified frequency band. For an equivalent incident signal of –40 dBm, the circuit can produce 3 mV across a 100 kΩ load. The results also show that there is a multiplication factor of 22 at 0 dBm and produces DC output voltage of 5.0 V in measurement. This voltage can be used to power low power sensors in sensor networks ultimately in place of batteries.

Keywords: Energy Conversion; RF; Schottky Diode; Villard; Energy Harvesting

1. Introduction

RF energy harvesting is one type of energy harvesting that can be potentially harvested such as solar, vibration and wind. The RF energy harvesting uses the idea of capturing transmitted RF energy at ambient and either using it directly to power a low power circuit or storing it for later use. The concept needs an efficient antenna along with a circuit capable of converting RF signals to DC voltage. The efficiency of an antenna mainly depends on its impedance and the impedance of the energy converting circuit. If the two impedances aren't matched then it will be unable to receive all the available power from the free space at the desired frequency band. Matching of the impedances means that the impedance of the antenna is the complex conjugate of the impedance of the circuit (voltage doubler circuit).

The concept of energy harvesting system is shown in **Figure 1**, which consists of matching network, RF-DC conversion and load circuits. The authors in [1], used a 2.4 GHz operating frequency with an integrated zero bias detector circuit using BiCMOS technology which produced an output voltage of 1 V into a 1 MΩ load at an input power level of 0 dBm. H. Yan and co-authors revealed that a DC voltage of 0.8 volts can be achieved from a –20 dBm RF input signal at 868.3 MHz through simulation results [2]. In [3], work was carried out on a firm frequency of 900 MHz by matching to a 50 Ω impedance and resonance circuit transformation in front of the Schottky diode which yields an output voltage of over 300 mV at an input power level of 2.5 μ. W. J. Wang, L. Dong and Y. Fu [4] used a Cockcroft-Walton multiplier circuit that produced a voltage level of 1.0 V into a 200 MΩ load for an input power level of less than –30 dBm at a fixed frequency of 2.4 GHz.

The energy conversion module designed in this paper is based on a voltage doubler circuit which can be able to output a DC voltage typically larger than a simple diode rectifier circuit as in [5], in which switched capacitor charge pump circuits are used to design two phase voltage doubler and a multiphase voltage doubler. The module presented in this can function as an AC to DC converter that not only rectifies the input AC signal but also elevates the DC voltage level. The output voltage of the

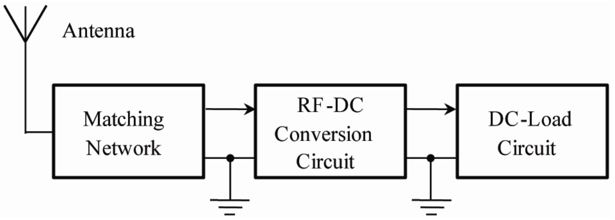

Figure 1. Schematic view of a RF energy harvesting system.

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energy conversion module can be used to energize the low power devices for example sensors for a sensor network in application to agriculture.

Section 2 of this paper discusses on the theoretical background of the voltage doubler circuit. Section 3 presents the simulation study and implementation of the circuit design. Section 4 provides the results and analysis. Section 5 concludes with a discussion on the findings from the simulated and measured results.

2. Voltage Multiplier

There are various voltage multiplier circuit topologies. The design used in this module is derived from the function of peak detector or a half wave peak rectifier. The Villard voltage multiplier circuit was chosen in the circuit design of this paper because it produces two times of the input signal voltage towards ground at a single output and can be cascaded to form a voltage multiplier with an arbitrary output voltage and its design simplicity.

2.1. Diode Modeling

The voltage multiplier circuit in this design uses zero bias Schottky diode HSMS-2850 from Agilent. The attractive feature of these Schottky diodes are low substrate losses and very fast switching but leads to a fabrication overhead. This diode has been modeled for the energy harvesting circuit which comes in a one-diode configuration. The modeling parameters for these diodes are given by Agilent in their data sheets. These parameters are used in Multisim for its own modeling purposes. The modeling is done by transforming the diode into an equivalent circuit using passive components which are described by the SPICE parameters in **Table 1** [6].

The diode used in this design is shown in **Figure 2** and its equivalent model is shown in **Figure 3**. The special features of HSMS-2850 diode is that it provides a low forward voltage, low substrate leakage and uses the non symmetric properties of a diode that allows unidirectional flow of current under ideal condition.

Table 1. SPICE parameters.

Parameters	Units	HSMS 2850
B_V	V	3.8
C_{J0}	pF	0.18
E_G	Ev	0.69
I_{BV}	A	3E–4
I_S	A	3E–6
N	No unite	1.06
R_S	Ω	25
P_B (V_J)	V	0.35
P_T (XTI)	No units	2
M	No units	0.5

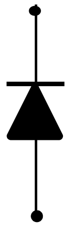

Figure 2. Schottky diode.

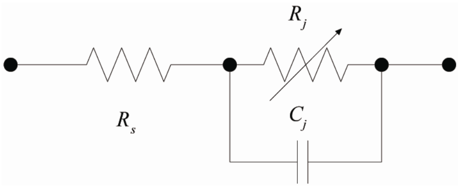

Figure 3. Linear circuit model of the Schottky diode [6].

The diodes are fixed and are not subject of optimization or tuning. This is described using the following derivations. By neglecting the effect of diode substrate, an equivalent linear model that can be used for the diode as shown in **Figure 3**. When C_j is the junction capacitance and R_j is the junction resistance, the admittance Y_z of the linear model is given by

$$Y_Z = Y_{C_j} + Y_{R_j} \tag{1}$$

Equation (1) related to the frequency of operation is given by

$$Y_Z = jwC_j + \frac{1}{R_j} \tag{2}$$

$$= \frac{jwC_jR_j + 1}{R_j} \tag{3}$$

The impedance Z of the linear model is given by

$$Z = \frac{R_j}{1 + jwR_jC_j} \tag{4}$$

The total impedance Z_T is given by

$$Z_T = R_S + \frac{R_j}{1 + jwR_jC_j} \tag{5}$$

where R_S is the series resistance of the circuit and R_j is given by

$$R_j = \frac{8.33 \times 10^{-5} \times N \times T}{I_b + I_S}$$

where:

I_b = bias current in μA;
I_s = saturation current in μA;
T = temperature (K);

N = ideality factor.

In Equation (5), R_j and C_j are constants and the frequency of operation (w) is the only variable parameter. As the frequency increases, the value of Z is almost negligible compared to the series resistance R_S of the diode. From this it is concluded that the function of the diode is independent of the frequency of operation.

2.2. Single Stage Voltage Multiplier

Figure 4 represents a single stage voltage multiplier circuit. The circuit is also called as a voltage doubler because in theory, the voltage that is arrived on the output is approximately twice that at the input. The circuit consists of two sections; each comprises a diode and a capacitor for rectification. The RF input signal is rectified in the positive half of the input cycle, followed by the negative half of the input cycle. But, the voltage stored on the input capacitor during one half cycle is transferred to the output capacitor during the next half cycle of the input signal. Thus, the voltage on output capacitor is roughly two times the peak voltage of the RF source minus the turn-on voltage of the diode.

The most interesting feature of this circuit is that when these stages are connected in series. This method behaves akin to the principle of stacking batteries in series to get more voltage at the output. The output of the first stage is not exactly pure DC voltage and it is basically an AC signal with a DC offset voltage. This is equivalent to a DC signal superimposed by ripple content. Due to this distinctive feature, succeeding stages in the circuit can get more voltage than the preceding stages. If a second stage is added on top of the first multiplier circuit, the only waveform that the second stage receives is the noise of the first stage. This noise is then doubled and added to the DC voltage of the first stage. Therefore, the more stages that are added, theoretically, more voltage will come from the system regardless of the input. Each independent stage with its dedicated voltage doubler circuit can be seen as a single battery with open circuit output voltage V_0, internal resistance R_0 with load resistance R_L, the output voltage, V_{out} is expressed as in Equation (7).

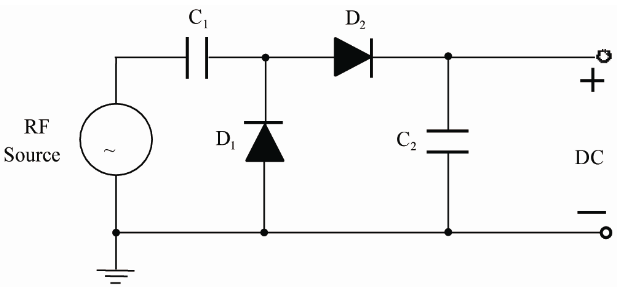

Figure 4. Single stage voltage multiplier circuit [7].

$$V_{out} = \frac{V_0}{R_0 + R_L} R_L \qquad (6)$$

When n number of these circuits are put in series and connected to a load of R_L in Equation (6) the output voltage V_{out} obtained is given by this change in RC value will make the time constant longer which in turn retains the multiplication effect of two in this design of seven stage voltage doubler.

$$V_{out} = \frac{nV_0}{nR_0 + R_L} = V_0 \frac{1}{\frac{R_0}{R_L} + \frac{1}{n}} \qquad (7)$$

The number of stages in the system has the greatest effect on the DC output voltage, as shown from Equations (6) and (7).

It is inferred that the output voltage V_{out} is determined by the addition of R_0/R_L and $1/n$, if V_0 is fixed. From this analysis it is observed that V_0, R_0 and R_L are all constants. Assume that $V_0 = 1$ V, $R_0/R_L = 0.25$, $n = 2, 3, 4, 5, 6$ and 7, the output voltage $V_{out} = 1.33$ V, 1.72 V, 2.0 V, 2.22 V, 2.43 V and 2.56 V respectively when substituted analytically in the Equation (7). This analysis can be compared with the results obtained in the circuit design of this module. In simulation at $n = 4$, $V_{out} = 1.42$ V, $n = 5$, $V_{out} = 1.67$ V; $n = 6$, $V_{out} = 1.92$; $n = 7$, $V_{out} = 2.15$ V; $n = 8$, $V_{out} = 1.92$ V; $n = 9$, $V_{out} = 1.81$ V. Also in measurement, for $n = 4$, $V_{out} = 2.1$ V; $n = 5$, $V_{out} = 2.9$ V; $n = 6$, $V_{out} = 3.72$ V; and $n = 7$, $V_{out} = 5$ V. As n increases, the increase in output voltage will be almost double the input voltage up to some number of stages. But at some point, *i.e.* beyond seven stages, in this circuit the output voltage gained (8 and 9 stages) will be negligible as shown in **Figure 5**.

The capacitors are charged to the peak value of the input RF signal and discharge to the series resistance (R_s) of the diode. Thus the output voltage across the capacitor of the first stage is approximately twice that of the input signal. As the signal swings from one stage to other, there is an additive resistance in the discharge path of the

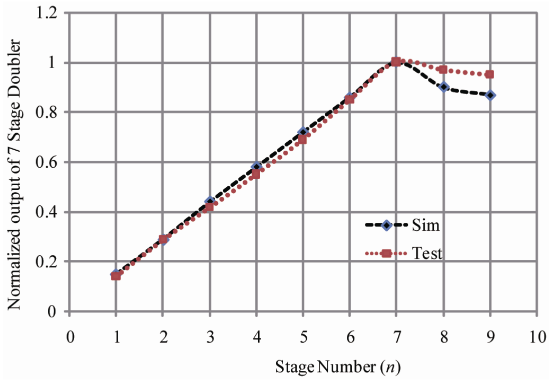

Figure 5. Normalized output voltage multiplier versus number of stages.

diode and increase of capacitance due to the stage capacitors.

2.3. Seven Stage Voltage Multiplier

The seven stage voltage multiplier circuit design implemented in this paper is shown in **Figure 6**. Starting on the left side, there is a RF signal source for the circuit followed by the first stage of the voltage multiplier circuit. Each stage is stacked onto the previous stage as shown in the **Figure 6**. Stacking was done from left to right for simplicity instead of conventional stacking from bottom to top.

The circuit uses eight zero bias Schottky surface-mount Agilent HSMS-285X series, HSMS-2850 diodes. The special features of these diode is that, it provides a low forward voltage, low substrate leakage and uses the non-symmetric properties of a diode that allows unidirectional flow of current under ideal conditions. The diodes are fixed and are not subject of optimization or tuning. This type of multiplier produces a DC voltage which depends on the incident RF voltage. Input to the circuit is a predefined RF source. The voltage conversion can be effective only if the input voltage is higher than the Schottky forward voltage.

The other components associated with the circuit are the stage capacitors. The chosen capacitors for this circuit are of through-hole type, which make it easier to modify for optimization, where in [8] the optimization was accomplished at the input impedance of the CMOS chip for a three stage voltage multiplier. The circuit design in this paper uses a capacitor across the load to store and provide DC leveling of the output voltage and its value only affects the speed of the transient response. Without a capacitor across the load, the output is not a good DC signal, but more of an offset AC signal.

In addition to the above, an equivalent load resistor is connected at the final node. The output voltage across the load decreases during the negative half cycle of the AC input signal. The voltage decreases is inversely proportional to the product of resistance and capacitance across the load. Without the load resistor on the circuit, the voltage would be hold indefinitely on the capacitor and look like a DC signal, assuming ideal components. In the design, the individual components of the stages need not to be rated to withstand the entire output voltage. Each component only needs to be concerned with the relative voltage differences directly across its own terminals and of the components immediately adjacent to it. In this type of circuitry, the circuit does not change the output voltage but increases the possible output current by a factor of two. The number of stages in the system is directly proportional to the amount of voltage obtained and has the greatest effect on the output voltage as explained in the Equation (7) and shown in **Figure 5**.

3. Simulation and Implementation

Multisim software was chosen for modeling and simulation which is a circuit simulation tool by Texas Instruments. The simulation and practical implementation were carried out with fixed RF at 945 MHz ± 100 MHz, which are close to the down link center radio frequency (947.5 MHz) of the GSM-900 transmitter. The voltages obtained at the final node V_{DC} of the multiplier circuit were recorded for various input power levels from –40 dBm - +5 dBm with power level interval (spacing) of 5 dBm.

The simulations were also carried out using same stage capacitance value (3.3 nF) and then with a varied capacitance value for all stages from 4 stages through 9 stages [9]. The capacitance value was varied in such a way that, from one stage to the next, it was halved. For example, if the first stage was 3.3 nF, the second stage was 1.65 nF, third stage was 825 pF, fourth stage was 415 pF and so on. But keeping in view of testing, the capacitance values were chosen to have a close match with the standard available values in the market.

Simulation was carried out through 4 to 9 voltage doubler stages. Based on results obtained a 7 stage doubler is best to implemented for this application.

The design of the printed circuit board (PCB) was carried out using DipTrace software. The material used to

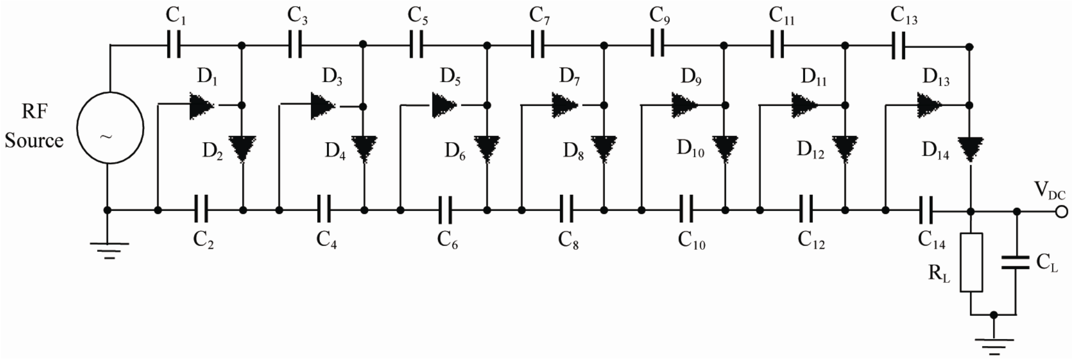

Figure 6. Schematic of 7 stage voltage multiplier.

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manufacture the printed circuit board (PCB) is the standard Fiberglass Reinforced Epoxy (FR4), with the thickness of 1.6 mm and dielectric constant of 3.9. The topology is constructed on the PCB with the dimensions of 98 mm × 34 mm (W × H). The Sub Miniature version A (SMA) connectors are used at the input and output of PCB to carry out the measurements. The circuit components consist of active and passive components. The component used in circuit is shown in **Table 2**.

Special handling precautions have been taken to avoid Electro Static Discharge (ESD), while assembling of the surface-mount zero bias Schottky diodes. Also special attention has been given to mount other components and the SMA connectors on to the PCB. The Photograph of Assembled circuit board I shown in **Figure 7**.

4. Results and Analysis

The simulated and measured results at the output voltage of voltage multiplier circuit are shown graphically in **Figure 8**. From the graph analysis, the simulated and the measured results agree considerably with each other. The measured results are shown to be better than the simulation results. The reason behind this may be due to the uncertainty in series resistance value of the diode obtained from SPICE parameters in modeling as explained in Equation (5). This resistance vale of diodes in practical circuit may be lower than in the model, which provides fast discharge path, in turn rise in voltage as passes through the stages and reaches to final output. In this work, the DC output voltages obtained through simulation and measurement at 0 dBm re 2.12 V and 5.0 V respectively. These results are comparatively much better than in ref. [9], where in at 0 dBm, 900 MHz they achieved 0.5 V and 0.8 V through simulation and measurement respectively.

Figures 9 and **10** show the result of a 4 stage voltage doubler circuit with equal and varied capacitance values between the stages as described in Section 3.

From the analysis of these two simulations, it can be observed that the resulting output voltages are equal. The only difference between these two graphs is the rise time of the circuit with varied capacitance value is a little bit slower. But, overall result on the performance of rise time is still under 20 µs to 24 µs and the difference is negligible. From these results, the use of equal stage capacitance of each being 3.3 nF was hence considered for the design of the multiplier.

The results from **Figure 11**, shows that the output voltage reaches to 1.0 V within 20 µS and then uniformly increasing to 1.4 V, 1.67 V, 1.87 V and 2.12 V for 4, 5, 6 and 7 stages respectively compared to 2 mS as shown in [10]. **Figure 12** shows that the conversion ratio of 22 is achieved at 0 dBm input power and drops to 2.5 at –40 dBm. The highest value at 0 dBm is due to the innate characteristics of the zero bias Schottky diodes which conduct fairly well at higher input voltages.

5. Conclusion

From the experimental results, it is found that the pro-

Table 2. Component used in 7 stage voltage multiplier.

Name of component	Label	Value
Stage capacitors	C_1 - C_{14}	3.3 nF
Stage diodes	D_1 - D_{14}	HSMS 2850
Filter capacitor	C_L	100 nF
Load resister	R_L	100 kΩ

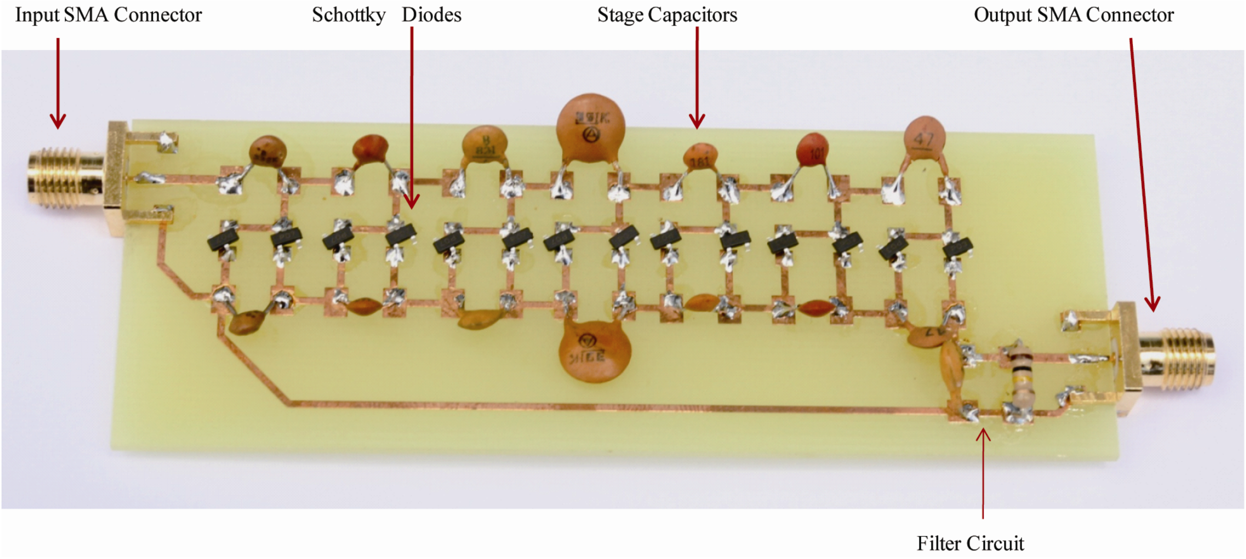

Figure 7. Photograph of assembled circuit board.

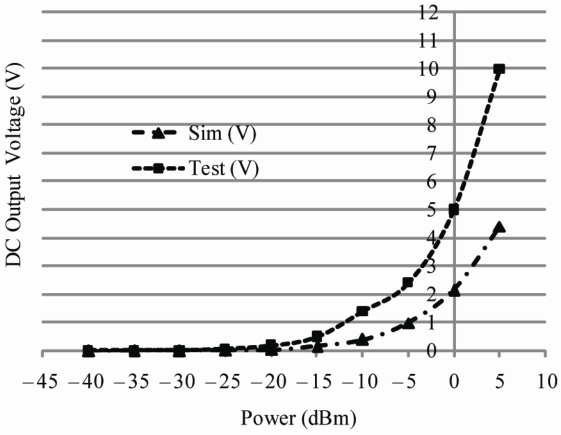

Figure 8. Simulated and test DC output voltage of multiplier as a function of input power.

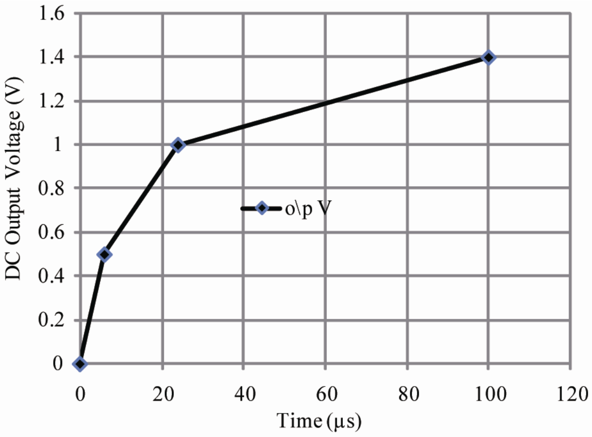

Figure 9. DC output voltage verses rise time of 4 stage voltage doubler circuit with equal stage capacitance [8].

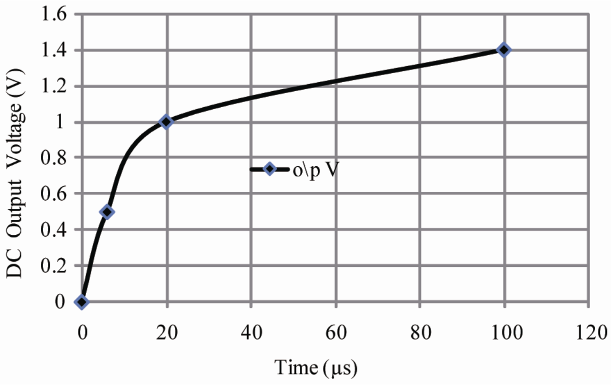

Figure 10. DC output voltage verses rise time of 4 stage voltage doubler with varied stage capacitance [8].

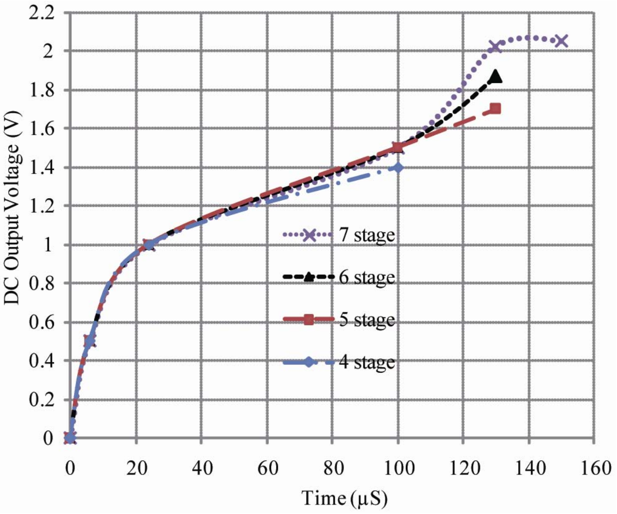

Figure 11. DC output voltage verses rise time of voltage doubler circuit through 4 - 7 stages with equal stage capacitance.

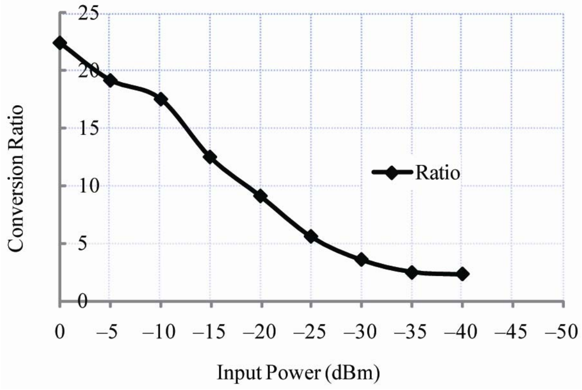

Figure 12. Conversion ratio as a function of input power.

posed voltage multiplier circuit operates at the frequency of 945 MHz with the specified input power levels. The results have shown that there is multiplication of the input voltage. From **Figure 12**, it is shown that at 0 dBm input power, the multiplication factor is 22. This is significant, as the work shows that RF energy in the GSM-900 band can be harvested from the ambient RF source using the Villard circuit topology. The power density levels from a GSM base station is expected from 0.1 mW/m^2 to 1 mW/m^2 for a distance ranging from 25 m - 100 m. These power levels may be elevated by a factor between one and three for the GSM-900 downlink frequency bands depending on the traffic density [10]. The next phase of the research work is to interface the voltage multiplier circuit through a matching network to the antenna at the input side and a low power device to power from the system at the output side to complete the RF energy harvesting system.

6. Acknowledgements

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Why a Hand Held RF Current Meter

There are two things that I wanted to do which would be made easy with a current meter... Both are related to the unusual nature of the antenna here at AC0C.

1. Checking common mode surface current on coax and control cables up in the attic antennas.

With the high cost of ferrites, placing them with the aid of a current meter is very helpful in that you can compare the before (no ferrite) and after (with ferrites attached) - and know that you have addressed the current problem on a given bit of line.

Otherwise, it seemed to me, that ferrite placement was more of a guess than a science.

2. Measuring relative antenna currents along an element

With the W8WWV RVM system, I can measure element currents where ever a current sensor is placed. This is typically at the center of a dipole element.

However, the center may or may not be the actual high-current point for the element depending on the frequency. My EZNEC models can indicate where the current peaks are - and by looking along these lines manually - comparing them with readings taken from the driven element, I can make current checks even in non-standard location of the array.

The meter described below accomplishes these two tasks very nicely.

Design Idea

The design follows an old RSGB design that I found on G3SEK's excellent web site:

http://www.ifwtech.co.uk/g3sek/clamp-on/clamp-on.htm

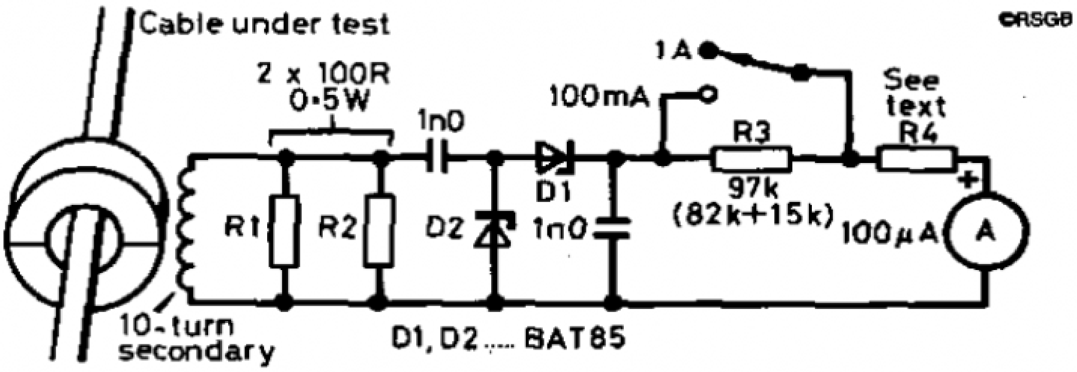

I followed this design pretty close except for the R3/R4 which I used variable trim pots. Due to the voltage-doubler nature of the circuit, it's capable of exceptional sensitivity.

The meter was calibrated for full-scale @ 1A on the higher scale, but I have left the lower scale set on a very high sensitivity setting which I find very handy for the common mode checking. Here, a sensitive meter providing a relative current indication is needed.

Construction Details

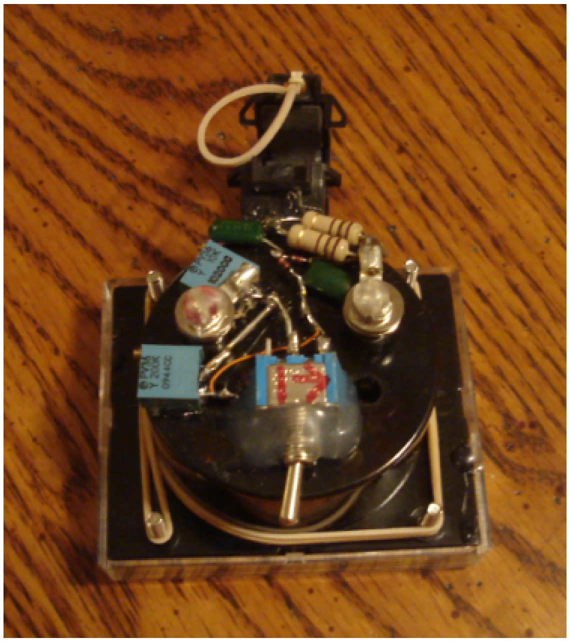

Once parts were in hand, construction was very easy and took perhaps an hour.

No attempt was made to beautify the work - it's 100% orientated toward functionality and utility.

I had a 100 uA meter in the junk box along with the other parts needed and orienting them on the back-side of the meter was really the most time consuming aspect.

The switch is held in position with hot-glue. And a bit of hot glue is applied to the meter terminations as a safety precaution - just in case I were to brush the meter up against something carrying high levels of current.

Wraps around the toroid were made with wire-wrap type wire, 30 Gage.

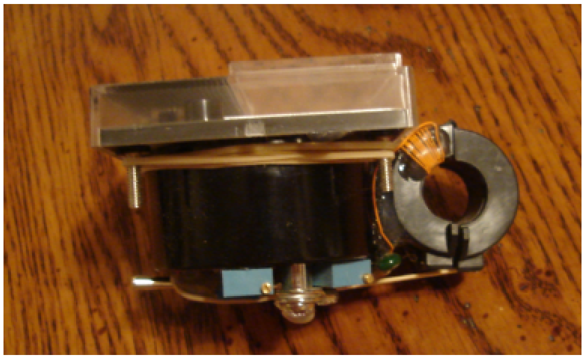

Selection of the toroid used was based on what would physically fit around the RG-213 sized cable and could be easily opened and closed.

The rubber band shown in the picture makes for a very convenient closing mechanism - and in a lot of applications, I simply hold the toroid closed with my finger pressure which makes moving the meter along a wire - and moving from cable to cable - very quick and easy.

For more ideas, check out Frank N4SPP's very nice RF current meter found HERE.

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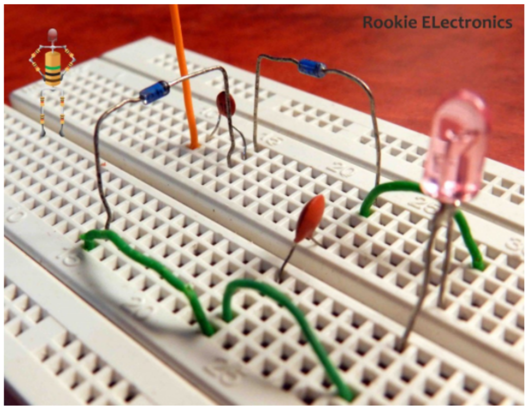
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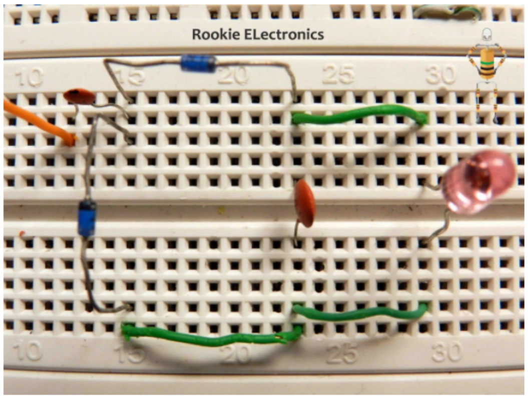
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Strip Board:

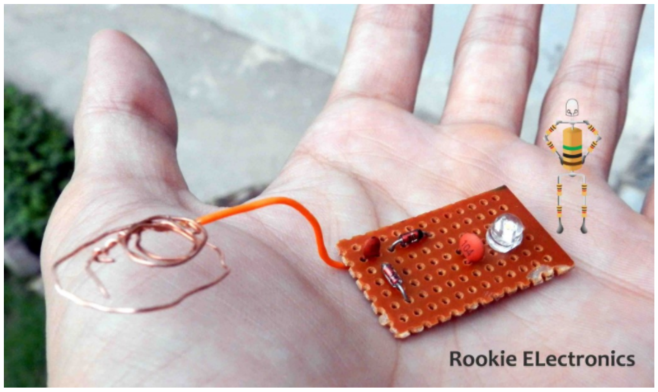
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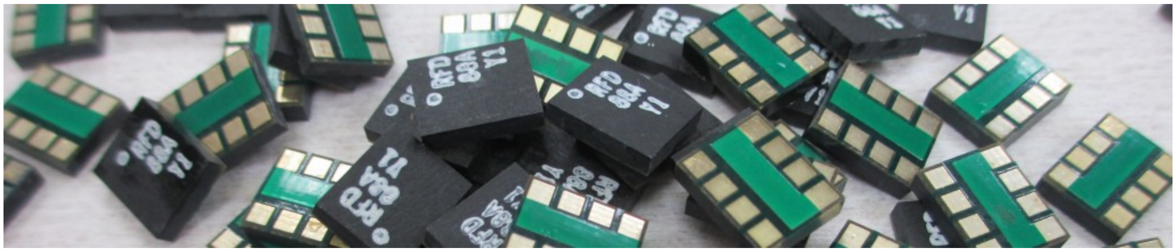

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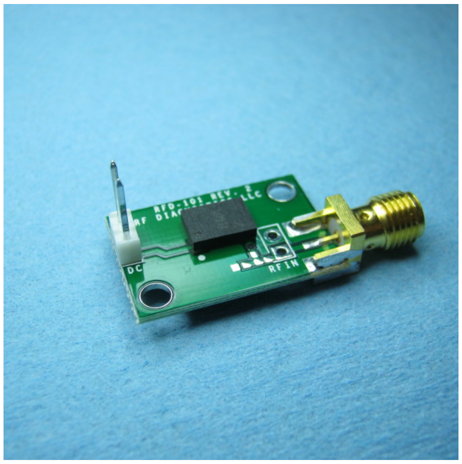
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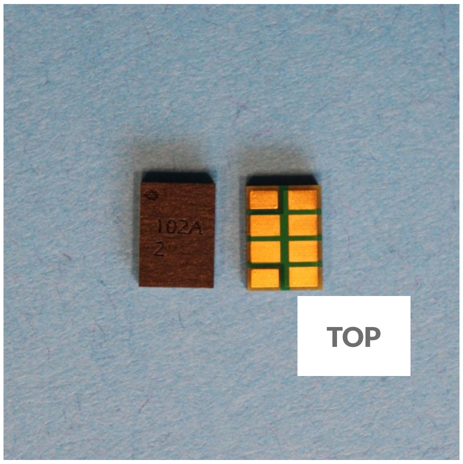

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On an NSF Phase I & II grant to one of our clients, operating as a subcontractor, the RF Diagnostics design team created a complete RFID MEMS resonator detection system. Both hardware and software were developed under this contract. The work was published at an SPIE conference in July 2010.

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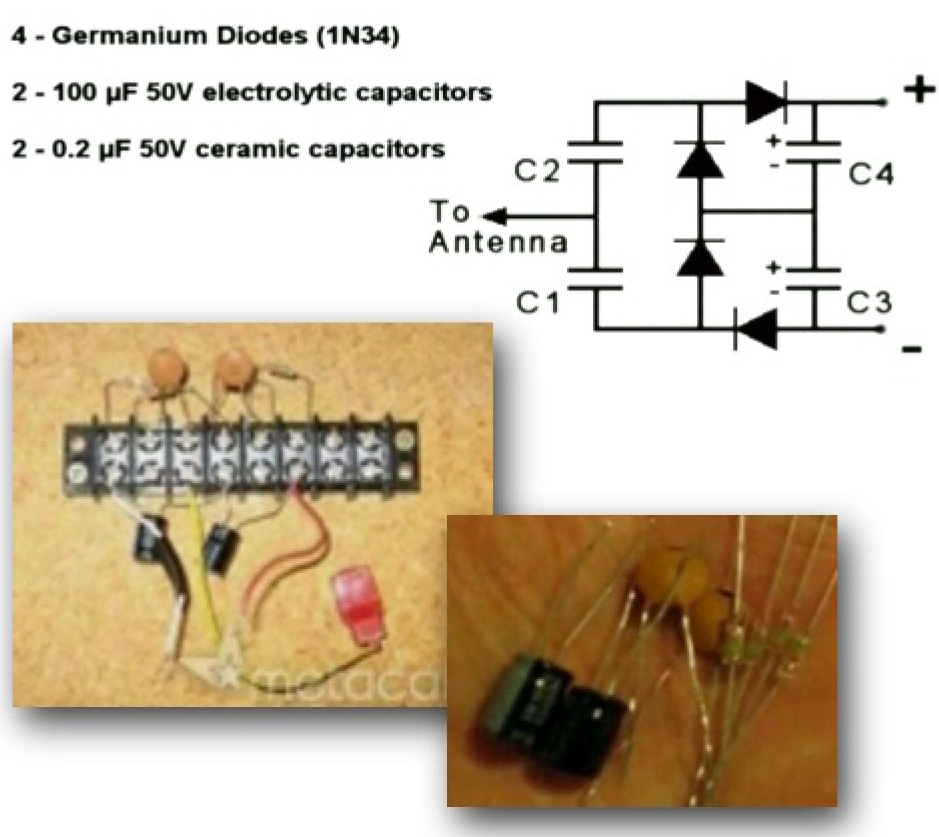
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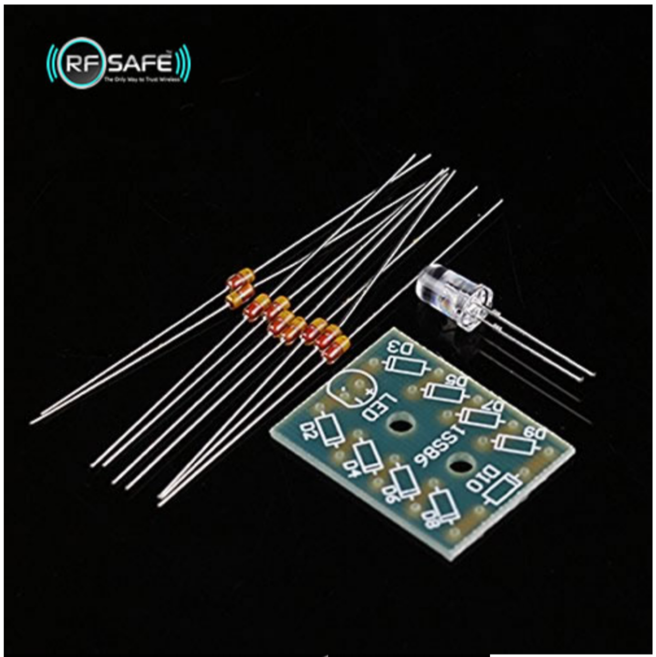

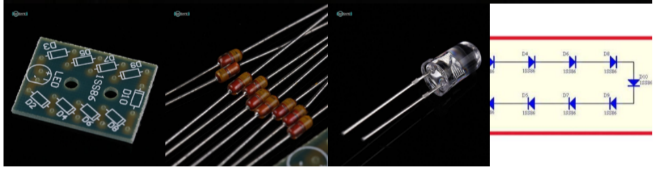

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A concurrent 915 MHz / 2440 MHz RF Energy Harvester

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This paper presents the development of two dual-band RF harvesters optimized to convert far-field RF energy to DC voltage at very low received power. The first one is based on a patch antenna and the second on a dipole antenna. They are both implemented on a standard FR4 substrate with commercially off-the-shelf (COTS) devices. The two RF harvesters provide a rectified voltage of 1V for a combined power respectively of -19.5 dBm at 915 MHz and -25 dBm at 2.44 GHz and of -20 dBm at 915 MHz and -15 dBm at 2.44 GHz. The remote powering of a clock consuming 1V/5µA is demonstrated, and the rectenna yields a power efficiency of 12 %.

Keywords: Antennas and Propagation for Wireless Systems, Applications and Standards (mobile, Wireless, networks), Circuit Design and Applications.

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I. INTRODUCTION

Today's the society is evolving toward creating smart environments where a multitude of sensors and devices are interacting to deliver an abundance of useful information. Essential to the implementation of this Internet Of Things (IOT) is the design of energy efficient solutions aiming toward a low-carbon-emission, namely green, society. Within this context, the energy harvesting appears as an alternative to provide systems with self-sustained operation. Many electronic devices operate in conditions where it is costly, inconvenient, or impossible to replace the battery. Examples include sensors for health monitoring of patients [1],[2], aircraft or building structural monitoring [3],[4], sensors in natural, industrial or hazardous environments, etc. The scavenging of natural ambient energy requires some specific conditions such as: daylight for solar energy [5], breeze for wind energy or motion for kinetic energy [6] to name a few. As consequences the exploitation of natural source does not fit with many cases of applications. On the other hand the electromagnetic (EM) [7], or Radio-Frequency (RF), energy is a human made source that is not dependent of weather conditions nor the daytime. It is so very attractive for wireless powering of remote devices. Furthermore the ever growing of commercial and personal wireless installations opens up to a 24 hour a day available energy in the vicinity of any human activity areas. The schematic of a general Wireless RF Power Transmission (WPT) system is shown in Fig.1. We talk here about far-field RF energy transmission [8], which is different from near-field RF energy transmission [9]. This later including inductive, capacitive or resonant coupling is a close contact transmission and is not relevant for remote devices. In Fig. 1, the receiver antenna collects the EM energy radiated by a RF source, and converts it into a RF signal. This RF signal is transferred to the rectifier by an impedance matching network, to be converted into DC power, which is further accumulated in a storage element. The main purpose in the deployment of WPT systems is the development of compact and efficient solutions. Most of the challenge concerns the implementation of harvesting modules, especially the antenna as its design defines the scavenging capability and the size of the RF harvester. At low frequency the transfer of energy is efficient, but the antenna footprint is large. To address the trade off between the efficiency of the WPT and the size of the modules, the frequency band located in the 433 MHz to 6 GHz frequency spectrums are preferred.

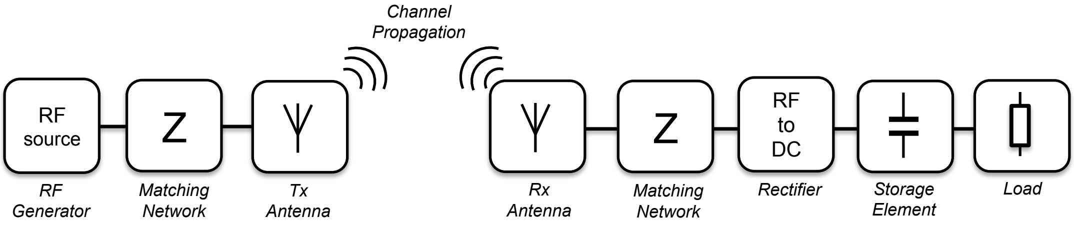

Fig. 1: Schematic of a Wireless RF Power Transmission (WPT) system

Over the last decade the research effort has focused on the development of WPT systems according two scenarios: the RF energy scavenging [10] and the RF energy transfer [11]. The two RF energy scavenging is an opportunistic collection of the RF ambient energy from the surrounding communication traffic. To improve the harvesting capability the scavenging RF harvesters are of wide-band type [12] and cover popular standards such as: DTV (470-610 MHz), GSM900, GSM1800, 3G (2.1GHz) and WiFi (2.4 GHz). Unfortunately these standards dedicated to convey wireless communications do not radiate a large RF power. As consequences the collected energy is weak, unpredictable and out of control. The RF energy scavenging remains a promising solution in the future as the increase of communication traffic could make it more reliable, and consistent with IOT applications. The second concept, namely RF energy transfer, assumes an identified source that is dedicated to perform the WPT. The amount of transmitted power is controlled by the source and the collected energy is larger than in scavenging approach. The licence-free Industry-Science-Medical (ISM) frequency bands located at 0.9, 2.4 and 5.8 GHz are usually exploited to support such a WPT scenario. Today the RF energy transfer in ISM Bands is not only promising, it becomes a reality as some pioneer companies propose some full kits: Powercast Corporation, AnSem and MicroChip to name a few. However there is still a lot of work to make the RF energy transfer an appropriate, low cost and easy-to-use solution for remote powering. One of the most critical point concerns the harvesting capability of the RF modules. So far the commercial kits referenced above only explore the 900 MHz ISM allocations to perform the WPT. This work proposes to demonstrate the interest of a concurrent harvesting at 915 MHz and 2.44 GHz. The design and implementation of a modified 4-stage doubler RF to DC converter, including a concurrent matching network, is first presented. The section III details the design of two types of multi-band antenna. The comparison between a single frequency and a multi-band WPT is exposed and the demonstration of the remote powering of a clock is reported as a case of application. To conclude a comparison of our results with the state of the art is exposed.

II. CONCURRENT RF TO DC CONVERTER

The Radio-Frequency IDentification (RFID) applications are the most popular systems exploiting the principle of RF energy transport. In passive RFID applications the reader transmits the RF power to the tag, and also sets up the communication. The RF to DC converter is designed to yield a maximum of power efficiency to the tag. Most of the time the reader and the tag are in line of sight and close to each other, these conditions improve the transmission of RF energy, the amount of power available at the tag antenna is large, typically between -15 dBm and -20 dBm. In RF energy harvesting the scenario is different. The distance between the RF source and the RF harvester ranges from 0.5 meter to 10 meters. The amount of collectable power is low, from -10 dBm to -25 dBm, and the remote powering is difficult. The RF harvesters are supposed to collect and to store the energy during a long period of time. Once the level of stored energy is large enough, it can be released to the application. For these reasons a rectifier dedicated to RF energy harvesting is first designed to yield a maximum of sensitive to increase its scavenging time and capability.

A) Rectifier Architecture

The rectifier architecture is based on voltage multipliers to provide an adequate output DC voltage. The architecture of the RF to DC converter, reported in Fig.2, includes a matching network based on a L-section, and a N-stage voltage multiplier based on Schottky diodes from Avago (HSMS285). The choice of the Schottky diode is very important in the design of the rectifier. A key parameter is its threshold voltage $V_{TH.}$ When only low power levels are available in the environment, the amplitude of the incident signal may be close to or even below this voltage. Below this voltage value, the diode will no longer conduct and the losses become predominant. For COTS devices the two Schottky diodes performing the best conversion efficiency in a 2.4 GHz range are HSMS-2850 from Avago and SMS-7630 from Skyworks [13].

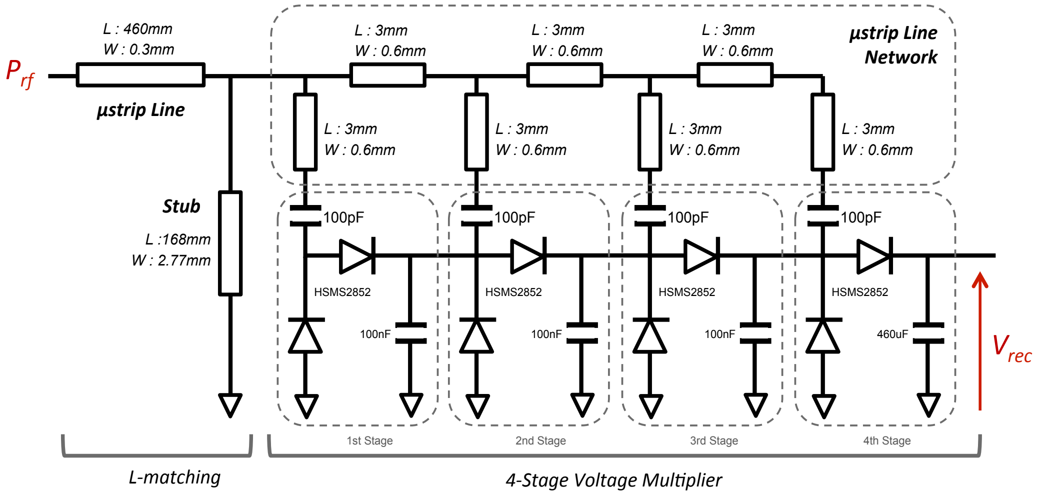

L : 460mm
W : 0.3mm
P_{rf}
µstrip Line
L : 3mm
W : 0.6mm
L : 3mm
W : 0.6mm
L : 3mm
W : 0.6mm
µstrip Line
Network
L : 3mm
W : 0.6mm
L : 3mm
W : 0.6mm
L : 3mm
W : 0.6mm
L : 3mm
W : 0.6mm
Stub
L :168mm
W : 2.77mm
100pF
100pF
100pF
100pF
HSMS2852
HSMS2852
HSMS2852
HSMS2852
100nF
100nF
100nF
460uF
V_{rec}
1st Stage
2nd Stage
3rd Stage
4th Stage
L-matching
4-Stage Voltage Multiplier

Fig. 2: Architecture of the RF to DC converter

Focusing on the sensitivity, the RF to DC converter is designed to maximize the rectified voltage for an input power close to -20 dBm. The optimum number of stage is fixed to four according [14]. The footprint of each voltage doubler imposes the micro-strip line network. The micro-strip lines namely "junction" is set to minimum length, the micro-strip lines "access" are used as an additional degree to tune the input-matching network. Indeed, the L section in combination with the micro-strip distributed network is equivalent to a T section (Fig.3). Many combinations of Z_1, Z_2, Z_3 can achieve input matching at 900 MHz or 2.4 GHz. Some of them are very close for each frequency, so we choose one that allows a return loss (< - 10 dB at least) both at 900 MHz and 2.4 GHz.

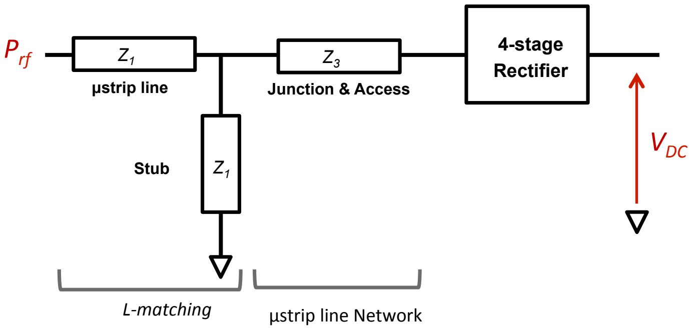
P_{rf}
Z_1
µstrip line
Z_3
Junction & Access
4-stage Rectifier
Stub
Z_1
V_{DC}
L-matching
µstrip line Network

Fig. 3: Topology of the input-matching network

The equivalent narrow band model of the matching network is proposed for each frequency (Fig.4). At 915 MHz, the voltage multiplier, including the rectification stages and the micro-strip line network, is modelled with a shunt capacitor (5pF) and a shunt resistor of 270 Ω (Fig.4a). The stub, (Fig.3) is equivalent to an inductor (Fig.4a), which compensates the shunt capacitor. The input micro-strip line, (Fig.3), is a quarter wave impedance transformer, (Fig.4a) it converts the 270 Ω into 50 Ω. At 2.44 GHz the micro-strip line network distributing the RF signal to the voltage doublers (Fig.3), becomes inductive (Fig.4b). The stub is equivalent to a shunt capacitor of 120fF, its effect is negligible. The impedance transformation is actually performed by the input micro-strip line, which is modelled by a shunt capacitor (0,6 pF) and a series inductor of 5.6 nH.

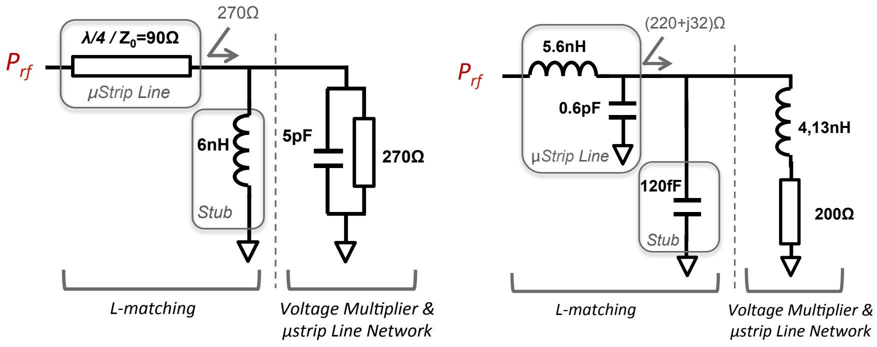
P_{rf}
$\lambda/4$ / Z_0=90Ω
µStrip Line
270Ω
6nH
Stub
5pF
270Ω
L-matching
Voltage Multiplier & µstrip Line Network
P_{rf}
5.6nH
(220+j32)Ω
0.6pF
µStrip Line
120fF
Stub
4,13nH
200Ω
L-matching
Voltage Multiplier & µstrip Line Network

(a) *(b)*

Fig. 4: Equivalent model of the input matching network at 915 MHz (a) at 2,44 GHz (b)

To study the impact of the power on the diode, and input matching, behaviour the return loss of the 4-stage rectifier has been measured and plotted (Fig.5) for various input power P_{rf} at 9000MHz.

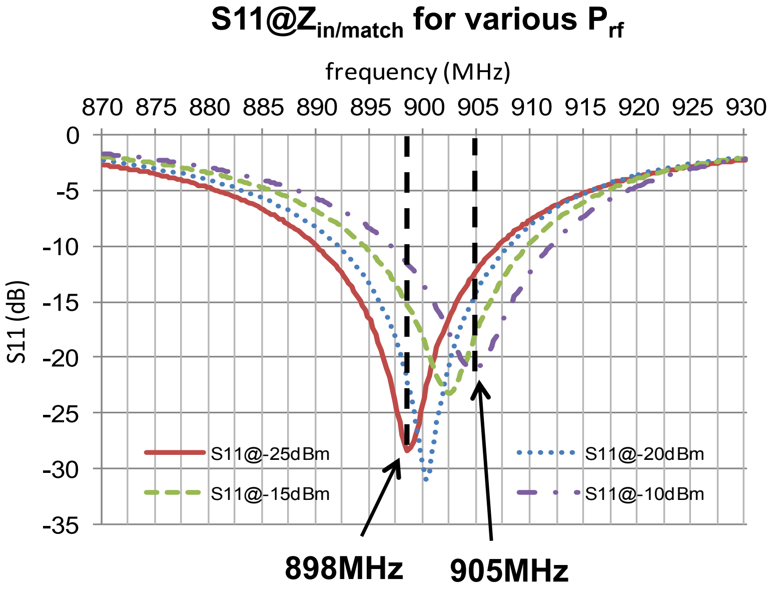

Fig. 5: Measured S_{11} of a 4-stage voltage multiplier with a L section at 900 MHz for various input power P_{rf}

As illustrated in the figure 5, the input return loss is not strongly affected by the input power if $P_{rf} < -15$ dBm. The RF harvesters developed in this work are dedicated to collect power from – 15 to – 25 dBm. Over this range the diode model can be considered as stable, and the slight frequency shift is still covered by the antenna bandwidth.

B) Rectifier Characterization

The power efficiency and the power sensitivity are two conversion characteristics of importance in RF harvesters. However, the RF harvester operating at low power level accumulates the energy in a storage element, to further release it to the application. In such accumulation mode the power sensitivity becomes more important than the power efficiency.

For the characterization the rectifier is not connected to a load. The load represents the equivalent impedance of the application (clock, sensor) to power. The effectiveness of RF-DC conversion of the rectenna and its DC ouput voltage varies depending on the load value. The rectifier is first characterized in a single tone mode, 915 MHz and 2.44 GHz respectively, and then in a dual-band mode. Measurements of the unloaded rectified voltage versus various input power P_{rf} are reported in Figure 6.

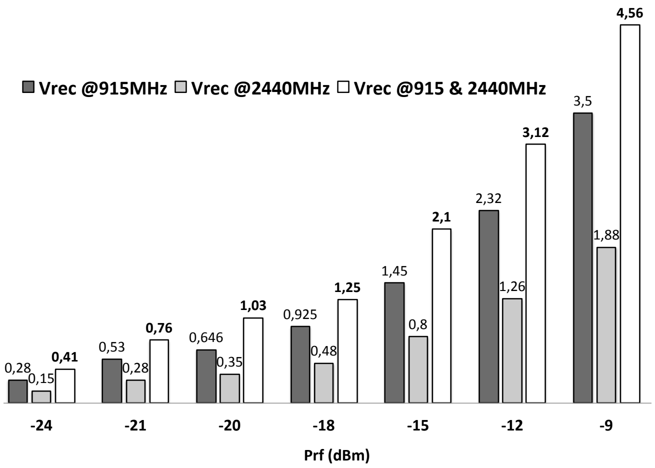

Fig. 6: Unloaded rectified voltage for various input power

To compare the results of the two considered tones, the target is fixed to a value of 1V. In a single tone mode, the required P_{rf} to rectify 1V is close to -18 dBm at 915 MHz, and would be larger than -15 dBm at 2.44 GHz. In a dual-band mode the circuit only needs a power P_{rf} of -20 dBm at each frequency. The dual-band rectification significantly improves the power sensitivity. The reverse breakdown voltage of the HSMS285 Schottky diode limits the input power to - 9 dBm, for which V_{rec} is 4,56 V.

III. ANTENNA DESIGN

To meet the low-cost constraints, the RF energy harvester will be implemented on a single low cost substrate, an FR4 PCB. For the antenna, there are more efficient substrates with a higher permittivity to reduce the size of the antenna or a lower losses but their cost is much higher than the improved performance. These powerful substrates fail to build low cost energy harvesters. This section exposes the design of two dual-band antennas implemented on a 1.6 mm FR4 printed circuit board. The fabrication uses a mechanical etching process with a 200µm resolution. We have chosen two complementary antenna topologies with a directional and omnidirectional radiation pattern.

A) Dual - band patch antenna

Emitting and receiving antennas do not usually meet the same constraints. Mobile devices such as smartphones and tablets use compact antennas (ifa, pifa…) to address the trade off between performance and size. Base stations can afford large efficient radiating elements (omnidirectional or directional antennas depending on the application). For energy harvesting purpose, micro-strip patch antennas are commonly used [15-17]. A rectangular micro-strip patch antenna (RMPA) is first developed to suit with both low cost technology of implementation and co-integration with the rectifier. Based on the cavity-model approximation, the resonant frequencies of the RMPA for the TM_{mn} mode is described in (1).

$$f_{mn} = \frac{c}{2\sqrt{\varepsilon_r}}\sqrt{\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2} \qquad (1)$$

W, L are the patch dimensions, $c = 3.10^8$m/s

The antenna dimensions, 68 cm^2 (8.8 x 7.8 cm), described Fig.7a are dependent to the frequency bands and the feed location is selected to only excite the fundamental modes TM_{01} and TM_{10}. Those modes permit to obtain a large aspect ratio (W/L = 2,7) but reduce the performance of the RMPA. On the other hand, TM_{01} and TM_{30} modes require an aspect ratio close to one but offer beneficial radiation patterns for our application. The RMPA is fed by a probe whose position (x,y) adjusts the matching both at 915 MHz and 2.44 GHz. This two operating bands of the proposed antenna are on cross polarization planes. The geometric parameters of RMPA have been optimized with an approximate model, the TL model [18], and with a full wave method. Details of the two approaches have been studied in [19]. The return loss of the RMPA is better at 915 MHz than 2.44 GHz because the maximum impedance of TM30 mode is 31 Ω [19]. The TM30 mode does not achieve 50 Ω because it is not a fundamental mode. This antenna has a maximum gain of 1.3 dB at 915 MHz (Fig.7b) and 2.5 dB at 2.44 GHz (Fig.7c). This two operating bands of the proposed antenna are on cross polarization planes.

The realized gains of the dual band patch antenna are lower than the classical patch antenna because the radiating efficiency is low, 60% for the TM_{01} mode and 30% for the TM_{30} mode. The FR4 substrate has a loss tangent of 0.02. The radiation efficiency of the dual band patch antenna is highly dependent of the substrate losses.

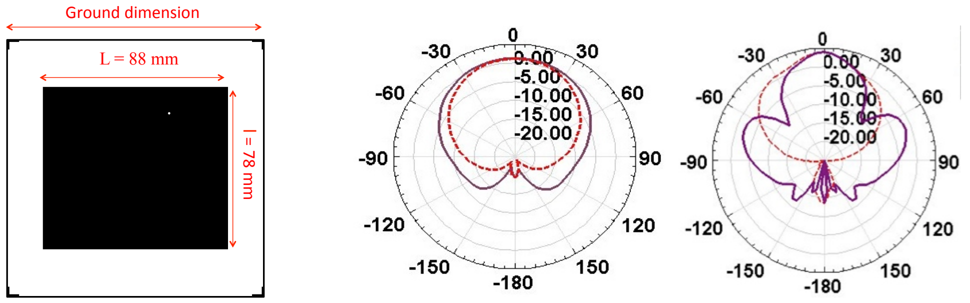

(a) *(b)* *(c)*

Fig. 7. Layout of the RMPA antenna (a) - Radiation pattern at 915MHz (b) and 2.44 GHz (c) Solid and dashed lines correspond to E-plane and H-plane respectively

B) Multi-band arm dipole antenna

The second antenna is a multi-band dipole type composed of three arms. Its dimension is about 23 cm^2 (11.1x2.1 cm), Fig.8a. Each arm is designed to work at one band of frequency. The longer one is for the 915 MHz, the middle one, not useful in our case, is for the 1.4 GHz and the last one, the smaller, is dedicated to 2.4 GHz [20].

All the geometric parameters have been optimized with a full-wave method in order to be matched both at 915/ 2440MHz. On Fig.6b and 6c, the radiation pattern is plotted for the elevation plane (orthogonal to substrate) of the simulated antenna. The maximum gain is 0.5 dB at 915 MHz and 3.4 dB at 2.44 GHz at 90°, on the substrate plane. The radiation efficiency is 99% at 915 MHz and 95% at 2.44 GHz.

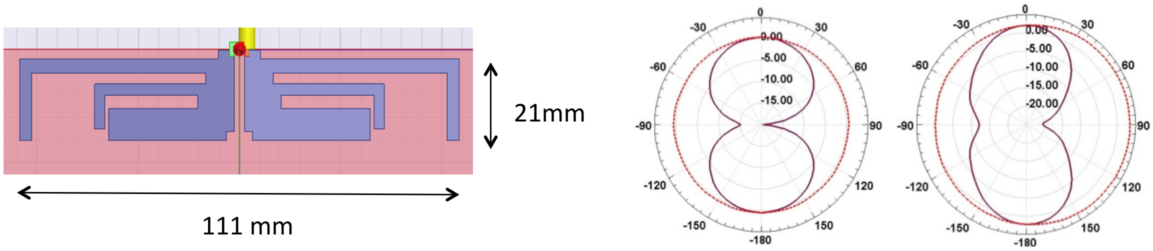

(a) *(b)* *(c)*

Fig. 8. Layout of the multi-band arms dipole antenna (a) - Radiation pattern at 915 MHz (b) and 2.44 GHz (c). Solid and dashed lines correspond to E-plane and H-plane respectively

It is interesting to compare the characteristics and performances of the two types of antennas. Although the radiation efficiency of the dipole antenna is better than the patch antenna, the antenna gains are similar because the high directivity of the RMPA antenna compensates the low values of radiation efficiency. When there are no cost constraints, it is interesting to use high performance substrates for the design of RMPA antennas because they improve the radiation efficiency and consequently antenna gain.

Moreover, the integration of the antenna with the rectifier will not be made in the same way. Considering the patch antenna, the rectifier can be integrated on the ground plane allowing a more compact solution. The dipole antenna, which is ground plane free, is less sensitive to the surrounding environment in our case. The performance of the dipole antenna and especially the radiation efficiency are very weakly dependent of the substrate characteristics. The design of a dipole antenna can be easily reuse with other material such as Kapton®, paper, Plexiglas to name a few.

IV. WIRELESS POWER TRANSMISSION

This part presents the measurement results of the assembled RF harvesters in the context of Wireless Power transfer. The two dual-band harvesters are realized with COTS devices such as HSMS diodes and capacitors. Those elements are reported by heat-treating. The RF to DC converter board, including the matching network and the rectifier, is reported on the backside and connected to the radiation part, on the front side, through a via (Fig.9a). The dipole antenna is connected to the rectifier circuit using SMA connector (Fig.9b).

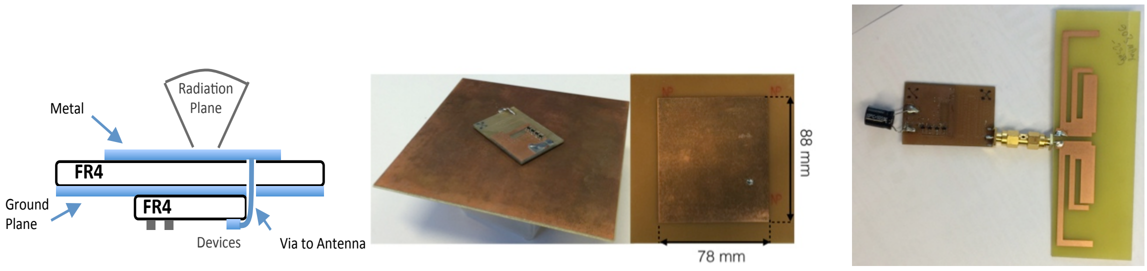

(a) *(b)*

Fig. 9. Dual-band RF harvesters based on patch antenna (a) – arms dipole antenna (b)

For the dual-band RF harvester based on patch antenna, the return loss, S_{11}, is measured for an input power of -20 dBm with a HP8720 network analyser. The patch antenna, the rectifier and the dipole antenna are centered at 915 MHz and 2.44 GHz with a low return loss ($S_{11} < -15$ dB), Fig.10. The return loss of the RMPA antenna is better at 915 MHz than 2.44 GHz because the maximum impedance of TM30 mode is 31 Ω (Fig. 6 and Fig. 7 of [16]). The TM30 mode does not achieve 50 Ω because it is not a fundamental mode.

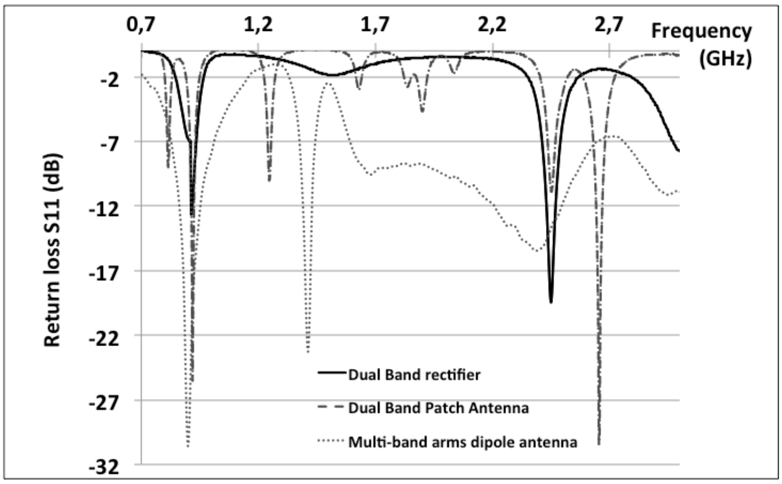

Fig. 10. Measured return loss S_{11} of the dual-band rectfier, patch and arms dipole antenna

A) Remote Powering and Power Efficiency

The rectenna is connected to a clock, which mimics a low power application. The remote powering of this clock is performed in a furnished room of the lab according the schematic of Fig.11. The distance between the source and the antenna is fixed to 2 m. The clock is turned on for different scenarios of transmitted power. For each combination of power proposed in Fig.12, the RF power is first measured with a calibrated antenna and a power meter. Then, the rectenna is measured and P_{eff} is the ration between the power delivered to the load (here the clock) and the power available at the antenna.

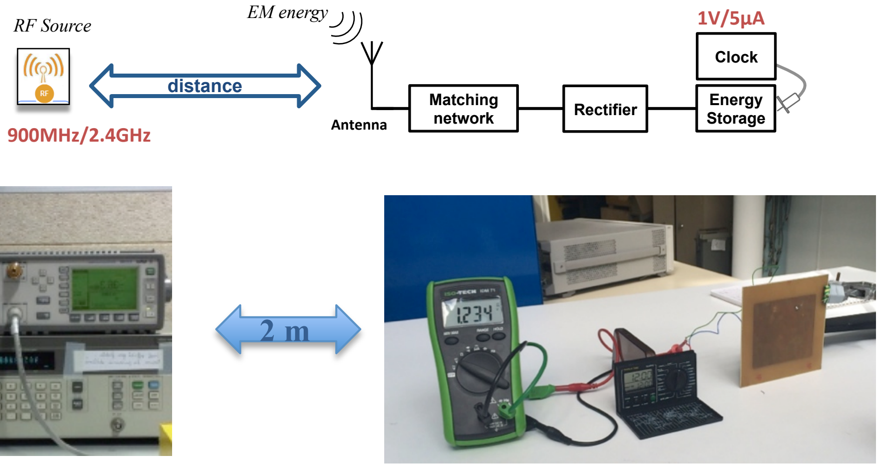

Fig. 11. Schematic and picture of the scene of remote powering of a clock

The power efficiency of the patch and the dipole rectenna is worked out from these experiments and reported in Fig.12. The power efficiency η is defined as the ratio between the DC power delivered to the clock and the RF power collected by the antenna.

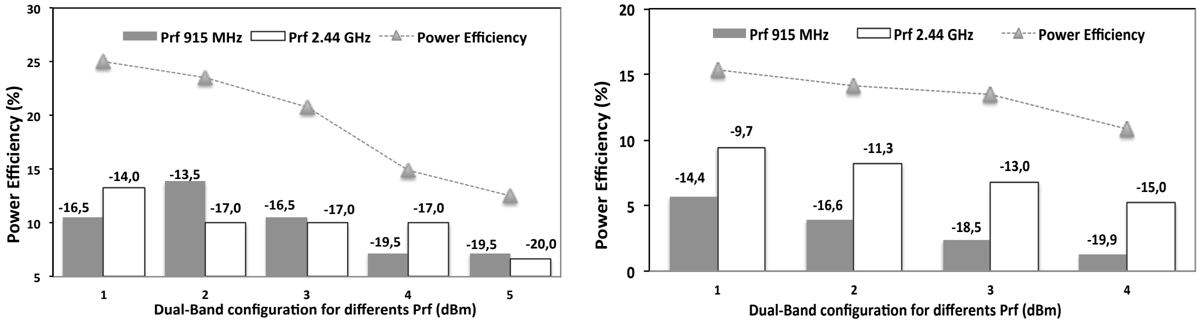

(a) *(b)*

Fig. 12. Power efficiency of the dual-band RF harvester based on the patch (a) and the arms dipole (b) antenna

The minimum power required to turn on the clock with the patch-based harvester, Fig. 10.a, is a two tone signal featuring: -19.5 dBm at 915 MHz and -20 dBm at 2.44 GHz. At this point, the power efficiency is 12.5 %, which corresponds to a DC output power of 2.7 μW/1V.

A maximum efficiency of 24 % occurs for a combined power of -16.5 dBm at 915 MHz and -14 dBm at 2.44 GHz. The harvester is able to deliver a DC ouput power of 15 μW. The harvester based on the arm dipole antenna needs a minimum power of -19.9 dBm at 915 MHz and -15 dBm at 2.44 GHz at the antenna to turn on the clock. For these conditions of remote powering, the efficiency of the harvester is 11 %. It delivers a DC power of 3.8 μW/1.15 V. The maximum power efficiency, 15.5 %, yields for an input power of -14.4 dBm at 915 MHz and -9.7 dBm at 2.44 GHz, the DC output power is 21 μW.

This scenario of remote powering figures out that the harvester based on the patch antenna exhibits a better power efficiency than the harvester combined with the dipole element. This difference is due to the antenna gains. Referring to Fig. 7 and Fig. 8, the gain of the patch antenna is larger (+0.8dB) at 915 MHz and lower (-0.9 dB) at 2.44 GHz than the dipole element. However the rectifier, referenced in [16], achieves a power efficiency of 17% at 915 MHz and only 5% at 2.44 GHz for an input signal of -15 dBm. As consequences the patch-based harvester is able to extract more power from a 915 MHz signal than the dipole-based harvester can do at 2.44 GHz. For this reason the overall efficiency of the patch harvester is better.

B) Power Sensitivity

The power sensitivity is measured with the same scenario of Fig.11 but the clock is disconnected. The output voltage is reported for different combination of collectable power at the antenna in a dual-band configuration.

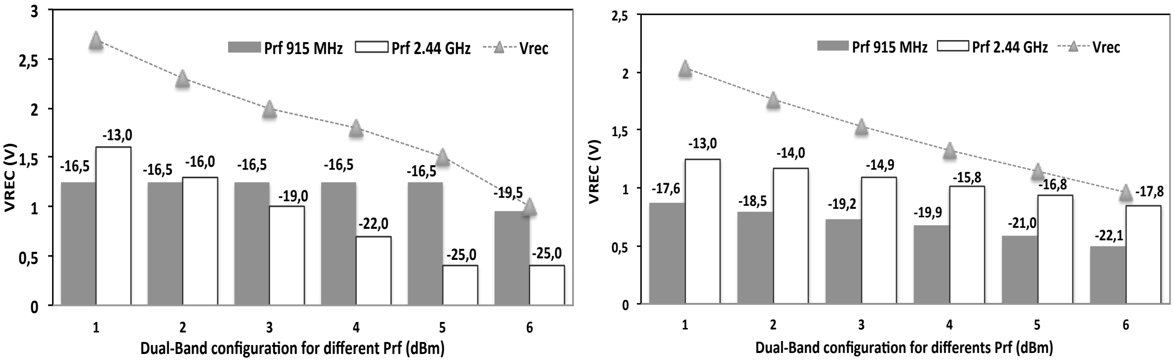

(a) *(b)*

Fig. 13. Rectified voltage of the RF harvester based on patch (a) and arm dipole (b) antenna

To rectify a 1V DC voltage, the patch-based harvester, Fig.13a, requires a two dual-band configuration: -19.5 dBm at 915 MHz and -25 dBm at 2.44 GHz, which is equivalent to an input power of -18.4 dBm (or 14 µW). For the same purpose the dipole-based harvester, Fig.13b, needs a dual-tone of -22.1 dBm at 915 MHz and -17.8 dBm at 2.44 GHz. The equivalent input power of this 2-tone signal is -16.5 dBm (or 22 µW). The patch-based harvester exhibits a better sensitivity than the dipole harvester for the same reason exposed in the part A of this section. In Fig.6, which reports the power sensitivity of the rectifier part only, the overall sensitivity is almost the same for the dipole harvester. It is improved by 1.8 dB for the patch harvester due to the additional gain of the antenna at 915 MHz.

C) Discussion and Comparison with the state of the art

An important characteristic of a remote powered device is its size. Indeed it is expected to be as small as possible to make it unobtrusive to our closest environment. In a scenario of RF harvesting the antenna footprint determines the compactness of a harvester operating Ultra High Frequency (UHF) bands. To complete the comparison between the two harvesting modules developed in this work, two figures of merit, FOM_{sens} and FOM_{eff}, including the size of the antenna, are proposed in (2) and (3).

$$FOM_{sens} = \frac{V_{REC@Psens}(V)}{\frac{P_{sens}(\mu W)}{100\mu W} \cdot \frac{A_{ant}(cm^2)}{100cm^2}} \tag{2}$$

With: P_{sens} the input RF power required to provide $V_{REC@Psens}$ the unloaded rectified output DC voltage, and A_{ant} the area of the antenna.

$$FOM_{eff} = \frac{\eta(\%)}{\frac{P_{eff}(\mu W)}{100\mu W} \cdot \frac{A_{ant}(cm^2)}{100cm^2}} \tag{3}$$

With: P_{eff} the input RF power required to achieve η the overall power efficiency.

FOM_{sens} and FOM_{eff} do not represent the same scenario of application. The FOM_{sens} illustrates the capability of the rectenna to start collecting energy and store it in an element such as a capacitor or a battery to further release it. FOM_{eff} demonstrates the capability of the RF harvester to yield "on time powering": the rectenna is connected to an application and supply it on time. Both are reported in the Table I, which also includes some references of the state of the art. The ability of the proposed rectenna to simultaneously operate in two frequency bands, significantly improves the power sensitivity.

Table I. Comparison with the state of the art

Ref.	Freq (GHz)	Efficiency (%@P_{rf})	Sensitivity (V_{rec}@Prf)	Number of stage	Schottky diodes	Size (cm^2)	FOM Sens	FOM Eff
[21]	0.9	15% @ -10dBm	0.75V @ -10dBm	1	SMS-7630	15×15	1.9	6.6
[21]	2.4	9% @ -13dBm	0.9V @ -13dBm	1	SMS-7630	15×15	1.25	8
[22]	2.45	10.5% @ -20dBm	0.075V @ -20dBm	1	SMS-7630	3.4×3.4	6.5	905
[23]	0.915/ 2.45	14%@ -20/-20	0,36V@ -10/-10	1	SMS-7630	6×6	0.5	185
[24]	1.8/2.2 /2.5	55%@ -10dBm	300mV@ -32dBm 3tones	1	SMS-7630	7×7	20	112
This work Dipole	0.915/ 2.44	**11% @ -20/-15dBm**	**1V @ -22/-18dBm**	4	HSMS-2850	2.1×11	**19.8**	**136**
This work Patch	0.915/ 2.44	**12.5% @ - 19.5 dBm/ -20dBm**	**1V @ -19.5dBm/ -25dBm**	4	HSMS-2850	7.8×8.8	**10.5**	**100**

According the Table I, the patch-based harvester exhibits the highest sensitivity to rectify 1V with a dual-tone featuring: -19.5 dBm at 915 MHz and only -25 dBm at 2440 MHz. The FOM_{sens} represents the trade-off between the sensitivity performances of a rectenna and the antenna area. The FOM_{eff} rates the efficiency performances to the antenna area. For these two figures of merit, the rectenna based on the multi-arm dipole element yields the best trade-off, both for FOM_{sens} and FOM_{eff}, compared to the patch-based solution. This dual tone and multi-arm dipole harvester is close to the work proposed in [24] which exhibits the highest FOM_{sens} reported so far in the literature to our knowledge.

V. CONCLUSION

The range of power collectable in a scenario of RF harvesting varies from -15dBm to -25dBm. To address this purpose the rectenna proposed in this work are optimized to operate at a RF input power close to -20 dBm (or 10 µW). To further improve the ability to collect the RF energy, these rectenna, developed with Schottky diodes HSMS285 from Avago, perform a concurrent harvesting in the 915 MHz and 2.44 GHz ISM bands. The harvester including a patch antenna implemented on a 1.6mm FR4 PCB achieves the highest sensitivity. It provides a 1V-rectified voltage for a dual-tone excitation of -19.5 dBm at 915 MHz and -25 dBm at 2.44 GHz. For these conditions of operation the rectenna yields a power efficiency of 12.5%. To take into account the dimensions of the haverster, two figures of merit, FOM_{sens} and FOM_{eff} including the size of the antenna, respectively related to the power sensitivity and the power efficiency are proposed. The rectenna developed with the arm dipole element exhibits the highest figures of merit. A case of application is proposed with the remote powering of a digital clock consuming 1V/5μA. The patch based harvester turns on the device with a dual tone excitation at the antenna of -19.5 dBm at 915 MHz and -20 dBm at 2.44 GHz. For the same scenario the harvester connected to the multi-arm dipole element needs a power of -22.1 dBm at 915 MHz and -17.8 dBm at 2.44 GHz.

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Bibliographies

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Thierry Taris is a full professor at the Bordeaux Institute of Technolgy (Bx-INP). He joined the IMS lab in 2005 where is research interests are related to the Radio-frequency Integrated Circuits in Silicon technologies.

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Table I. Comparison with the state of the art.

Bounce Energy Blog > Energy Efficiency > Fun with Less Kilowatts: The Lectenna

Fun with Less Kilowatts: The Lectenna

By Vernon Trollinger, March 14, 2017, Energy Efficiency, Events & Fun, Family

Welcome to Fun with Less Kilowatts! We believe that science experiments at home can be a creative way to engage kids in learning while having fun. They can be educational AND great activities to keep your kids busy and away from the television. Each month, we'll feature a new science experiment that can be a great resource for parents and teachers.

The Lectenna

Did you know you that the energy from radio waves can be converted back into electric energy? It's true and you can make a *simple* two-component circuit that you and your kids can use to find 2.45 Ghz radio waves around your home. These are the same radio waves used by microwaves, WiFi network routers, bluetooth devices, smart phones, cordless phones, smart meters, and smart home systems that use Zigbee.

YouTuber pjaffeva posted this brilliant project showing how. Plus, there's also a link to a PDF set of instructions on Google Drive that you can download.

The Materials

- One HLMP-D150 Avago low current LED. Costs about 50¢/each. Available from: Amazon, Digikey, Mouser
- One Hitachi 1SS106 low capacitance Schottky diode. Pjaffeva recommends this Hitachi-made diode as being the only one in this shape that will work. But they're also hard to find. Currently, you can get them from LittleDiode's ebay store in the UK. Costs $6.38 but the bulk of that price is shipping from the UK.

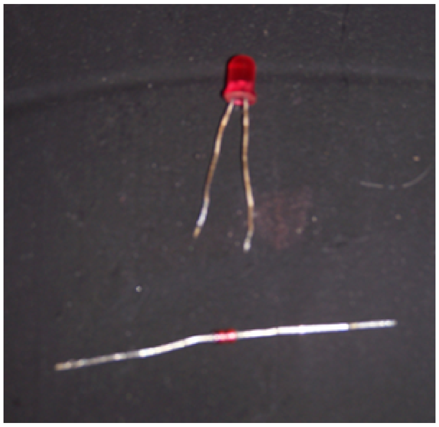

You'll also need:

- An operating WiFi router
- A bamboo kabob skewer
- Two pieces of tape

The Directions

1) Look on the base of the LED and find the side with the flat edge. This marks the negative or cathode side. Carefully splay the two wire leads away from each other as far as they will go. Make sure the one adjacent to the negative side gets bent over the flat edge so identify it. You can also mark it with a little spot of colored nail polish.

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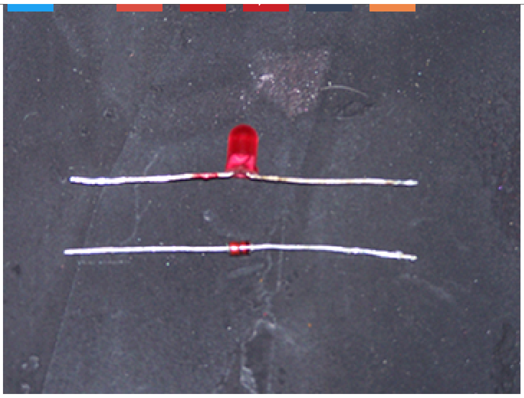

2) Next, find the band that runs around the Schottky diode. This identifies the negative end of this diode. The other end is the positive or anode end.

Using your fingers:

3) Twist the end of the negative or cathode wire from the LED onto to the positive or anode end of the Schottky diode.

4) Then twist the end of the negative or cathode end of the Schottky diode onto to the positive or anode end of the LED.

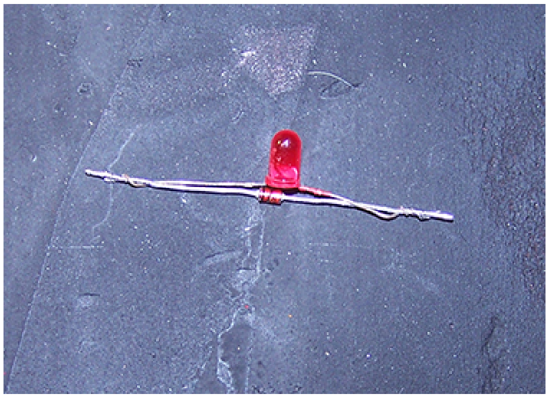

You have just made a “rectenna” and you’ll need to keep the assembly and the wires straight as possible. The length of the wires should be about 6 cm long (a hair short of 2 3/8 inches).

5) Tape the two diodes to one end of the bamboo skewer.

6) With a WiFi router on and running, hold the diode near an antenna on the WiFi router.

The Result

The LED should light up as it draws closer to the antenna (signal). The further away it is, the weaker the signal and the less it can grab to light up.

The Science

The WiFi routers uses radio waves to transmit data to and from computers and other devices in your home. Radio waves behave like water in a glass, they ripple or oscillate at a certain number of times or frequency per second. A radio wave’s wavelength is the distance covered by one complete cycle of a radio wave — from peak to valley.

Radio waves used by WiFi routers, bluetooth devices, microwaves, etc., broadcast signals in the 2.45 gigaherz (Ghz) range or 2.45 billion oscillations per second. That means the signal wavelength is about 12 cm. To pick up signal, however, you only need an antenna that’s half as big— 6 cm. When the radio waves strike this antenna, called a 1/2 dipole (“di”=two), the energy excites the antenna’s

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The "Rectenna": Because the radio waves cause voltage to flow one direction and then the opposite direction, the current is called an alternating current (AC). By connecting a diode to both poles of the antenna it converts the AC current to flow only in one direction, called direct current (DC). The antenna becomes a "rectenna".

How the diodes work: The diodes work as one-way valves for electricity, allowing voltage to flow forward but not back. In the case of the rectenna, AC current caused by the radio wave sends a positive charge down one of the antenna poles and then the other. By putting the Hitachi 1SS106 diode across both poles, the diode only lets the positive charge coming down one of the antenna poles through. The LED is actually a Light Emitting Diode and works the same way as a regular diode except that when it's on, it lights up. Meanwhile, Schottky diodes turn on at a lower voltage than other diodesand because the rectenna can only catch a fraction of the WiFi's broadcast power, the Schottky diode can rectify that little bit of AC to DC.

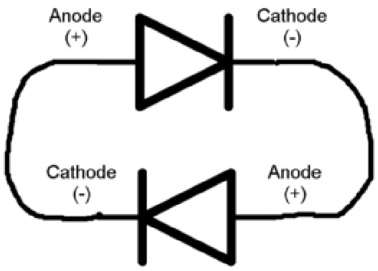

When we connected our diodes together, their polarity formed a loop that only allowed voltage to flow one way and thus light the LED. Brilliant job, pjaffeva!

Do you have any fun and kid-friendly science experiments you'd like to see us try for Fun with Less Kilowatts? Share with us in the comments!

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About Vernon Trollinger

A native of Wyomissing Hills, PA, Vernon Trollinger studied writing and film at the University of Iowa, later earning his MA in writing there as well. Following a decade of digging in CRM archaeology, he now writes about green energy technology, home energy efficiency, DIY projects, the natural gas industry, and the electrical grid.

Tags: family fun, Fun with Less Kilowatts, kids, science experiments

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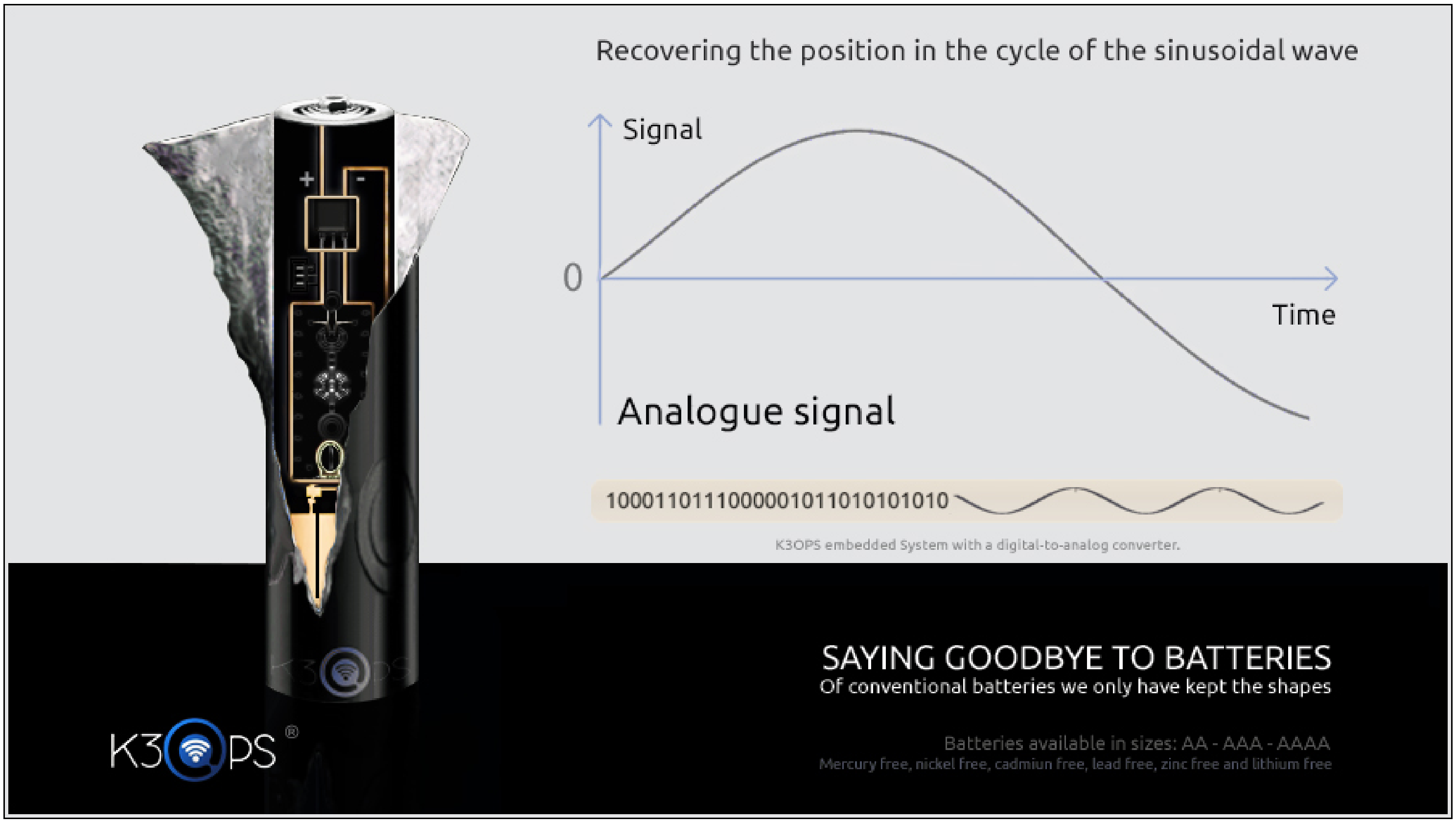
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An electromagnetic field uses the photon as an elementary particle to transmit force. It combines:

- **A magnetic field** *force resulting from the movement of loads μT.*
- **An electric field** *force created by the attraction of repulsion loads, measured in volts per meter - V/m.*

With an energy determined according to the speed of light, the RF are by far the best medium to transmit any kind of information.

The multiplication of wireless communications systems in our environment ensures sufficient microwave leakages to harvest from the ambiant and enough energy to convert into DC electricity. Electromagnetic fields are everywhere and since they carry energy, they became the best candidate to deliver an endless source of renewable energy.

$\vec{B}$ is the magnetic induction expressed in T refered to **Nikola Tesla**, "Father of Free Energy", which is at the origin of the electromagnetism.

Using meta-materials combined with nanotechnology has deeply increased the performance and miniaturization of rectennas embedded in K3OPS system. Our products operate autonomously, offering an endless supply of green energy in a respectful and environment-friendly approach.

principles and beautiful sentences. At that point in time I would have simply been Xin, a child like any other...

But one day I dreamed. I woke up far away, somewhere else, in another past. I decided to change my destiny and even if I was supposed to become a mathematician, I eventually decided to create, because already as a child my heart was chasing the stars.

Of the hundreds of directions shown to me after graduating, only one captured my attention: a single goal... Build the impossible for a safer world. So, over the past 3 years, our real challenge to overcome for all RF Energy Harvesting technics was to optimize electricity conversion. The massive proliferation of wireless telecommunication systems since the past two decades brought a saturation of the electromagnetic fields with a constant growth of 15% every year in our environments. As a result, this situation reversed the base problem that makes today Harvesting RF Energy a game changer. The key was the Power Management System.

We are far beyond the conversion constraint and performance by controlling "RF-interferences", by harvesting different frequencies *from near and far*, by using Metamaterials combined with nanotechnologies. We dramatically have improved power conversion efficiency and reduced the size of our Energy Harvesting systems embedded in all K3OPS' products.

Thanks to Nikola Tesla, my inspiring mentor, K3OPS' products have reached by far their objectives in terms of converting and performance, offering an endless efficient source of green energy, reliable in an environmentally friendly approach.

Xin WEI Co-Founder of K3OPS technology with Alexandre Despallieres

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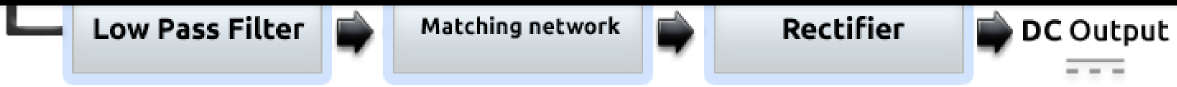
Low Pass Filter
Matching network
Rectifier
DC Output

The Rectenna was invented in 1964 by William C. Brown, patented in 1969. It is a rectifying antenna used to convert microwave energy into DC. A simple Rectenna consists of a dipole antenna with an RF diode connected across the dipole elements. The diode rectifies the AC current induced in the antenna to produce DC power.

K3OPS
RF Energy Harvesting Battery

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Centre for Collaboration in Electromagnetics and Antenna Engineering is a centre for research collaboration established to foster research in electromagnetics and engineering conducted by Macquarie University researchers and prominent collaborators from external institutions, including people from industry and overseas ins We have state of the art research ficilities including a NSI-700S-50 spherical nearfield anechoic chamber, 3 Vector Network Analyzers (capable up to 22GHz, 50GHz, and respectively), state-of-the-art embroidery machine DreamCreator-XE-VM5100 for embroided antennas, Dielectric Characterization Kit - High Temperature Probe (2 20GHz), as well as several in-house and commercial licenced softwares.

Our recent and ongoing research projects are:

- Wireless Implantable Bio-Telemetry System and Miniature Antenna Design
- Wireless Freedom for Lab Rats
- Flexible and Wearable Antennas for Biomedical and Healthcare Applications
- Characterizing Properties of Carbon nano Tubes at Microwave Frequencies
- Electromagnetic Band Gap (EBG) Resonator Antennas
- Leaky-Wave Antennas for Advanced Wireless Systems
- Shared Aperture Arrays for Space Borne Applications
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- Antenna Technologies for Ultrawideband (UWB) Systems
- High Gain Antennas with Planar Surface-Mounted Short Horns
- Photonic Crystal/EBG Based Horn Antennas
- Broadband Microstrip Patch Antennas for Wireless Computer Networks
- Theoretical Analysis of Photonic Crystal Structures
- New Closed-form Green's Functions for Microstrip Circuits and other Layered Structures
- Integrated-design of Hybrid-resonator Antennas for Broadband Wireless and other Communication Systems
- Singularity-enhanced Finite-different Time-domain (FDTD) Method for Diagonal Metal Edges, Strips and Films
- Low-profile Dielectric-resonator (DR) Antennas

Wireless Implantable Bio-Telemetry System and Miniature Antenna Design

The two major challenges associated with the conversion of a wireless system operating in air to an implantable version, antenna detuning and biocompatibility, are a in a coherent way. An RFID-based biomedical telemetry system designed for free-space operation was chosen as the starting reference. A new, pin-compatible, spa antenna with a ground plane was designed, fabricated and tested, to replace the original “free-space” antenna in the active RFID tag without making any other chang tag circuit, such that the tag would function well when it is placed under rat skin and fat. Biocompatibility and potential antenna detuning due to rat tissue variati addressed in the design process, without significantly increasing the tag physical height, by applying a thin coating of biocompatible material directly over the ante operation of the medical telemetry system was successfully demonstrated, with the tag placed under rat skin and fat, and its range of 60-72 cm was found to be suf support medical research experiments conducted with rats in cages. Due to the biocompatible coating over the antenna, antenna matching is very insensitive to ch tissue dielectric constants and thickness. The footprint of the new antenna is 33% less than that of the original antenna, its measured 10 dB return-loss bandwidth is 1 11%, and overall efficiency is 0.82% at 920 MHz.

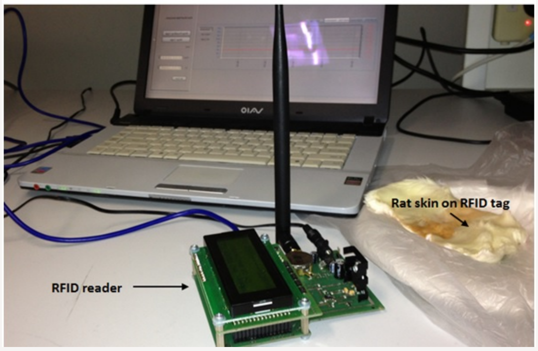

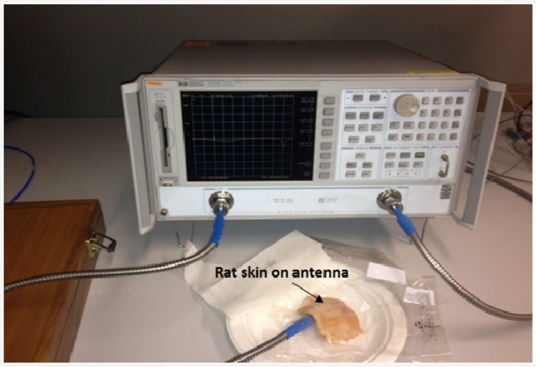

Wireless Freedom for Lab Rats

We are developing a fully implantable wireless telemetry system. This is a joint research project with BCS Innovations and the Australian School of Advanced Medicine (will be first used in the research conducted in ASAM, with rats, on hypertension. To date the major method of controlling hypertension is through the use o pharmaceuticals. The pathway to approval for most drugs for human use involves pre-clinical (animal) trials. Lab rats are considered biologically similar to humans, pa in terms of their social behaviour. Therefore, it is very important to not compromise the pharmaceutical trials by unnecessarily stressing the rats by harnessing the monitoring equipment. One of the technical challenges of developing an implantable system that monitors the various signals, is the relatively small size requ implantable telemetry system is a miniature transceiver implanted in an animal that senses, processes and transmits data via a wireless link to monitor vital signals of c freely moving laboratory animals. This is crucial in giving researchers flexibility and reliability, especially in studies with special experimental settings using mazes wheels and treadmills. We have plans to develop a fully implantable telemetry system for subcutaneous or intraperitoneal placement in rats that monitors th parameters as well as blood pH and chemistry, nerve activity and circadian respiratory rate rhythms. The aim of this project is to eventually develop a system with e capabilities that costs less than what is currently available, to provide more universities and researchers with the opportunity to use this technology.

In this sequel, initially, when a module of our original system was placed under the skin of a rat, the wireless link failed completely. It could not send a temperature read a centimetre! The point of failure was the commercial antenna in the module that had been designed to work outside the body, in air. Such antennas do not work unde because the electrical characteristics of skin (rat or human) are significantly different from that of air. Hence the main challenge was to design an antenna that works w placed under the skin. In addition, it was necessary to cover the module and the antenna by biocompatible material, which also affects antenna performance. Possible v of skin characteristics from one rat to another or one person to another were considered. Unlike the commercial antenna, we wanted our antenna to radiate less into th the rat/person and more away from the body because that not only increases the quality of the wireless link, maximum range (distance between implanted mo monitoring station) and battery life but also reduces the exposure of the body to radio-frequency waves. Indeed we had to consider the electromagnetic effects of fat a material around the antenna. We were able to meet all these requirements with a novel compact antenna design that is approx. one third the size of the original co antenna. We successfully demonstrated wireless telemetry transmission of temperature with the new module placed under rat skin and the monitoring station pla distance of up to 80 cm! This range is sufficient for our immediate target application supporting new medical research by Professor Paul Pilowsky's team. If necessary, further extended by increasing the power level at the monitoring station.

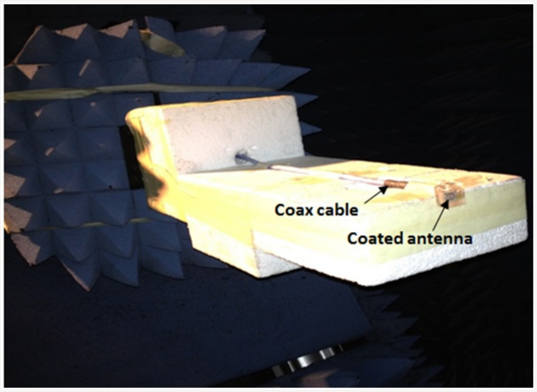

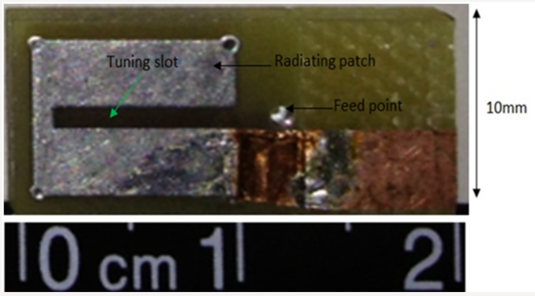

Flexible and Wearable Antennas for Bio-Medical and Healthcare Applications

Body Centric Wireless Communication is a rapidly growing research area targeted for medical, healthcare, public safety and defense applications. The need to address transceiver specifications and real-time scenarios in close proximity to human body is continuously evolving antenna system research. Several novel miniature antennas havi dual- and wide-band operations have been designed and tested for Wireless Body Area Network (WBAN). They have significant advantages of small size, wide radiation pat the human body for maximum coverage and are less sensitive to the gap variation between human body and antenna.

A compact ultra wideband antenna is shown below with strong notch-band rejections up to VSWR = 26, that is tunable over a wide frequency range from 3.55GHz to 6.8 been designed. To estimate the stub length to notch frequency for a given interfering application, analytical expressions for the normalized stub length which is indep substrate dielectric constant is also presented. This helps to avoid hit-an-trail method and gives a good estimate of initial design parameters for notch. Proposed antenna radiation patterns and yields a measured 10dB return-loss bandwidth from 3GHz to 10.5GHz.

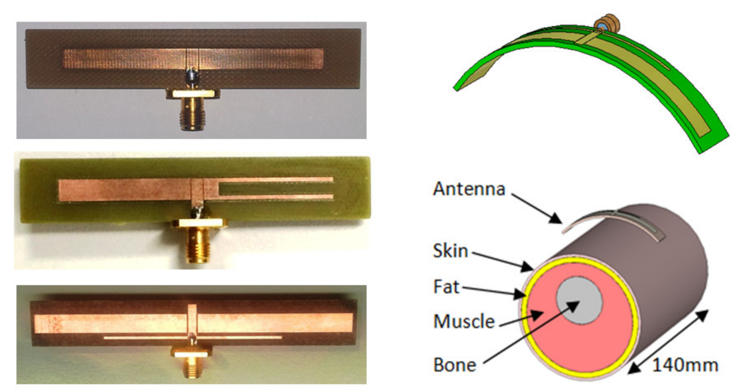

Characterizing Properties of Carbon Nano Tubes at Microwave Frequencies

Carbon Nanotube (CNT) yarns are novel CNT-based materials that extend the advantages of CNT from the nano-scale to macro-scale applications. We have modelled CNT potential data transmission lines. Test structures have been designed to measure electrical properties of CNT yarns, which are attached to these test structures using gold p testing and microwave S-parameter measurements have been conducted for characterisation. The observed frequency independent resistive behaviour of the CNT yarn promising indicator that this material, with its added values of mechanical resilience and thermal conductivity, could be invaluable for a range of applications such as B Networks (BAN). A model is developed for CNT yarn, which fits the measured data collected and agrees in general with similar data for non-yarn CNTs.

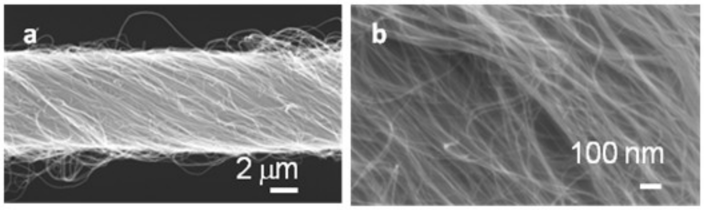

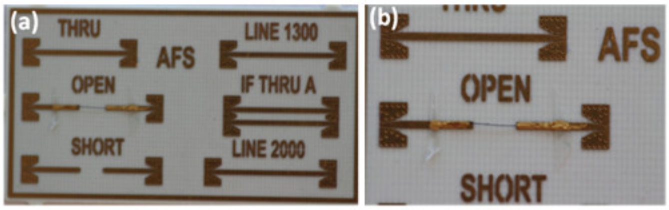

Electromagnetic Band Gap (EBG) Resonator Antennas (ERA)

We have designed, fabricated, and measured antennas based on 3D, planar and 1D EBG structures (i.e. photonic crystals). These flat microwave antennas, known as EBG antennas or Fabry-Perot cavity antennas, can give gains of about 20dB and very good efficiencies.

Enhancing Radiation Characteristics of ERAs by Improving Aperture Phase Distribution

This work focuses on achieving superior radiation characteristics of ERAs by improving their aperture phase distributions. A unique method, utilizing full-wave simula analytical analysis, has been developed to design Phase Correcting Structures (PCS) for ERAs. This method uses actual phase distribution on the physical aperture of ERAs relying on geometric optics. Several Phase Correcting Structures (PCSs) have been designed, which were later validated with the measurements of their fabricated p Tremendous improvement in the radiation performance is witnessed in both simulated and measured results. These exciting initial results validate our proposed methodo indicate an existence of a great potential to be explored. The figure below shows the field propagation above an ERA: (a) without PCS, and (b) with PCS. It is clear that the the PCS is much more uniform and the energy is focussed towards broadside direction, thus, resulting in increased directivity.

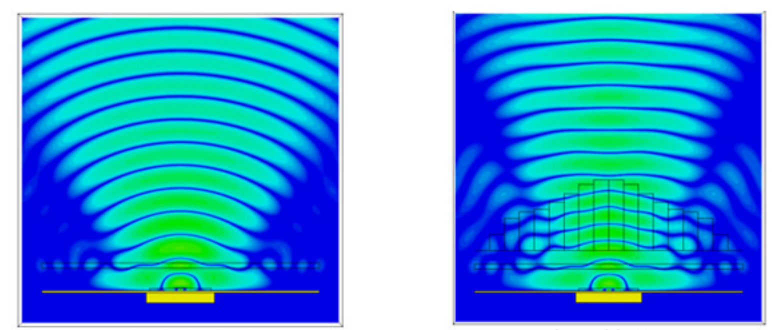

a. without PCS

b. with PCS

Extremely Wideband High-Gain ERAs (Gain~15-20dBi, Bandwidths >50%)

In 2014-15, we invented an innovative class of electromagnetic band-gap (EBG) resonator antennas which provide high gain and wide bandwidth with an extremely r footprint. One of the prototype developed has only 8% of the area as compared to conventional EBG resonator antennas but its performance (gain bandwidth) is a record hi for this class of antennas, while providing gain in the range of 15-20 dBi. This represents an improvement of nearly two orders of magnitude in the bandwidth compared to EBG resonator antennas. Thanks to its practical advantages of flat shape and low-cost manufacturability, it can be easily attached to a wall of a building, for example, to co building wirelessly to the National Broadband Network.

Our most recent results on such wideband high gain antennas can be found in: "Achieving high gain-bandwidth through flat GRIN superstrates in Fabry-Perot cavity antenn 2014 IEEE International Symposium on Antennas and Propagation (AP-S/USNC-URSI), pp. 1748 – 1749, Memphis, Tennessee, USA, July 6-11, 2014.

Detailed antenna design along with experimental data of another of our wideband EBG resonator antenna having composite multi-layer superstrate, is published in the pa "Wideband high-gain EBG resonator antenna with a small footprint and all-dielectric superstructures" in IEEE Transactions on Antennas and Propagation, vol. 62, no. 6, 201

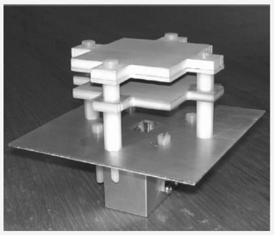

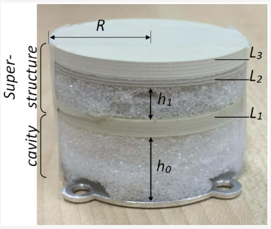

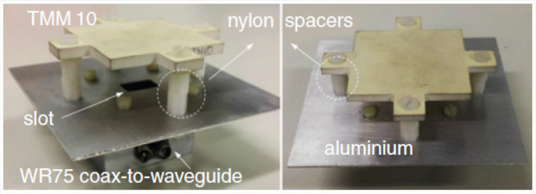

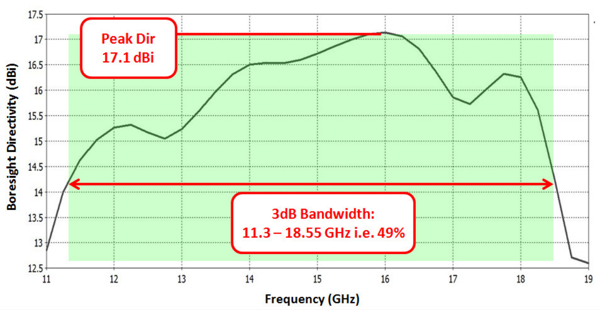

Frequency response of one of our Wideband ERA Prototypes

Simple Dual-Band ERAs

We developed a new method to obtain dual-band operation from a simple electromagnetic band gap resonator antenna. The antenna is based on a one-dimensional EBG made out of two low-cost unprinted dielectric slabs. The EBG structure is implemented as the antenna superstrate, which has been designed to provide a locally-inverted reflection phase gradient with high reflectivity, in two pre-determined frequency bands. The linearly polarised antenna design and experimental results are described in entitled: "A simple dual-band electromagnetic band gap resonator antenna based on inverted reflection phase gradient" published in IEEE Transactions on Antennas and Pro vol. 60, no. 10, pp. 4522-4529, 2012.

We have extended this concept for dual-band, dual-polarised and circularly-polarised antennas. We also designed a tri-band antenna following this concept. It needs only t cost unprinted dielectric slabs.

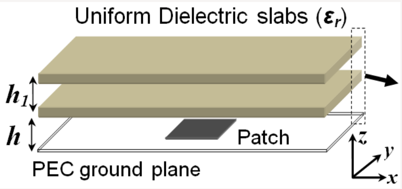

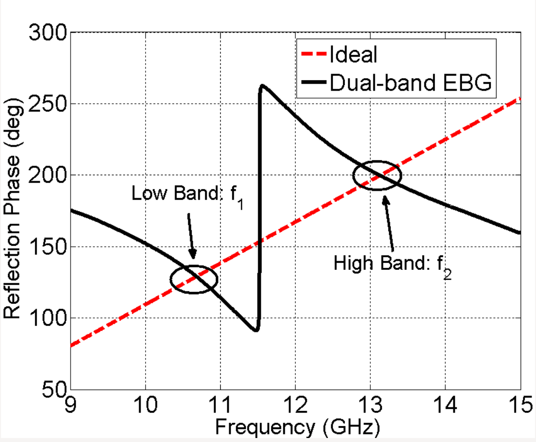

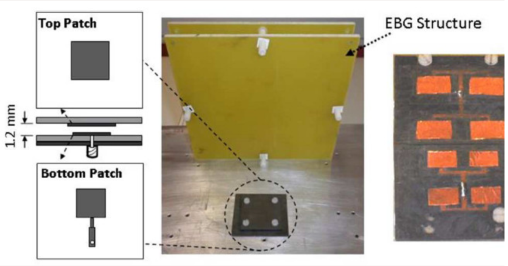

Low-Profile Wideband ERAs

We have designed and successfully tested wideband low-profile (thin) EBG resonator antennas. The breakthrough that contributed to this success is our design of a partially surface (PRS) with a positive reflection phase gradient. Thin single-dielectric-slab PRSs with printed patterns on both sides were investigated to minimise the PRS thickn simplify fabrication. Three such surfaces, each with printed dipoles on both sides, have been designed to obtain different positive reflection phase gradients and reflection r levels in the operating frequency bands. These surfaces, and the EBG resonator antennas formed from them, were analysed theoretically and experimentally to highlight t compromises involved and to reveal the relationships between the antenna peak gain, gain bandwidth, the reflection profile (i.e. positive phase gradient and magnitude) of t and the relative dimensions of dipoles. A small feed antenna, designed to operate in the cavity field environment, provides good impedance matching (|S11|< -10 dB) a operating frequency bands of all three EBG resonator antennas. Experimental results confirmed the wideband performance of a simple, low-profile EBG resonator antenna thickness is only 1.6mm, effective bandwidth is 12.6%, measured peak gain is 16.2 dBi at 11.5 GHz and 3dB gain bandwidth is 15.7%. Please find details in a paper entitled of Simple Thin Partially Reflective Surfaces with Positive Reflection Phase Gradients to Design Wideband, Low-Profile EBG Resonator Antennas," published in IEEE Tra on Antennas and Propagation in 2012.

Low-Profile Dual-Band ERAs

We have achieved dual-band operation in a low-profile EBGRA using a single dielectric superstate with a printed pattern only on one side. This also made use of our r inverting the gradient of the PRS reflection coefficient.

Woodpile EBG Material and Antennas

In 2003, we designed and built a woodpile 3D photonic crystal, also known as a EBG crystal, operating in microwave frequencies, and demonstrated experimentally the ex the electromagnetic band gap. The crystal is made out of cermain material.

Then we designed a planar EBG resonator antenna. Shown below, it has a resonant cavity between a ground place and a 3D woodpile photonic crystal. We employed both m and slots to feed the cavity, and investigated both linearly and circularly polarised antennas. The linearly polarised antenna design and experimental results are described in entitled "A planar resonator antenna based on a woodpile EBG material," published in IEEE Transactions on Antennas and Propagation,vol. 53, no. 1, pp. 216-223, January 2

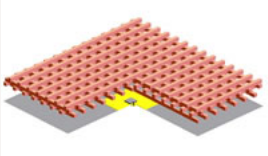

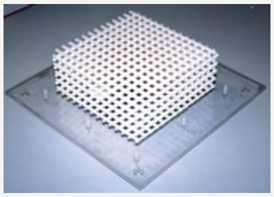

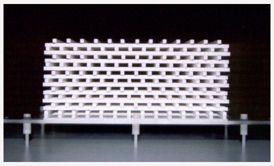

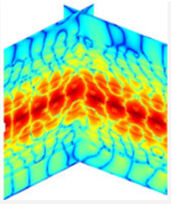

Leaky-Wave Antennas for Advanced Wireless Systems

Antenna beam steering can bring significant benefits to advanced wireless systems. Microstrip leaky-wave antennas (MLWAs) are of particular practical interest becaus planar low-profile configuration, ease of fabrication, and beam-scanning capabilities. In this research several planar MLWAs and arrays are developed to radiate at bores conical beam around the boresight, with simultaneous dual-side-beam scanning, dual-band forward and backward beam-scanning, and continuous beam scanning from the to the forward direction. Moreover, methods and antenna designs are proposed to steer the beam at a fixed frequency, shifting beam-steering range, and fixed-frequency bean in forward and backward directions.

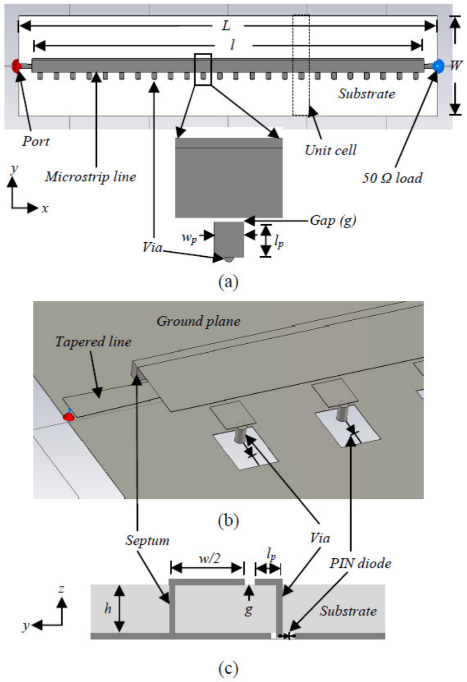
L
l
W
Substrate
Port
Microstrip line
Unit cell
50 Ω load
y
x
Gap (g)
Via
w_p
l_p
(a)
Ground plane
Tapered line
(b)
Septum
Via
PIN diode
w/2
l_p
h
g
Substrate
z
y
(c)

Figure 1. Proposed reconfigurable HW-MLWA: (a) top view, (b) perspective view, and (c) side view.

TABLE I. SWITCH CONFIGURATIONS AND CORRESPONDING MAIN BEAM DIRECTIONS AT 6.5 GHZ

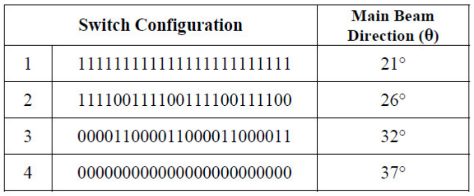

	Switch Configuration	**Main Beam Direction (θ)**
1	111111111111111111111111	21°
2	111100111100111100111100	26°
3	000011000011000011000011	32°
4	000000000000000000000000	37°

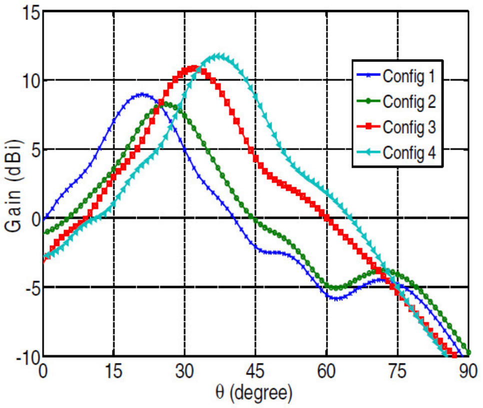

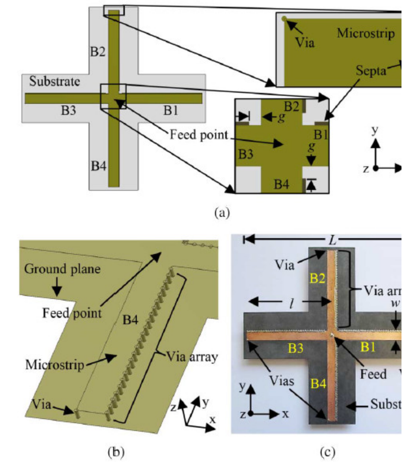
B2
Substrate
B3
B1
B4
Feed point
Via
Microstrip
Septa
g
y
z
(a)
Ground plane
Feed point
B4
Microstrip
Via array
Via
z
y
x
(b)
L
Via
B2
Via arr
w
l
B3
B1
Vias
B4
Feed
Subst
y
z
x
(c)

Fig. 1. HW-MLWA array design steps: (a) top view of the initial de septa, (b) perspective view of one branch of the final design with v (substrate omitted, not to scale), and (c) top view of the fabricated pr

Multi-band Dual-Polarized Shared Aperture Array

Multi-band dual-polarized shared-aperture (MBDP-SA) arrays are antenna arrays that operate in two (or more) frequency bands with dual-polarization in each band, a elements are integrated together into a common physical space by sharing the single aperture. The MBDP-SA array is of great interest in space-borne SAR system, be technique can effectively reduce the payload and size of the antenna sub-system. In this research project, main efforts are focussed on three aspects: 1) improve the specifi current Dual-Band Dual-Polarized Shared-Aperture (DBDP-SA) array; 2) construct Tri-Band Dual-Polarized Shared-Aperture (TBDP-SA) array; and 3) explore some new for DBDP-SA antenna.

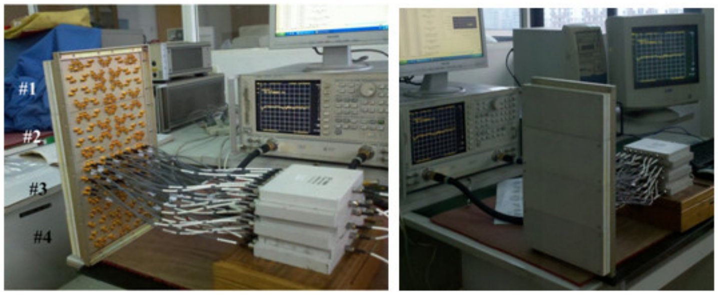

(a) Rear (b) Front

Fig.1 Improved DBDP-SA array.

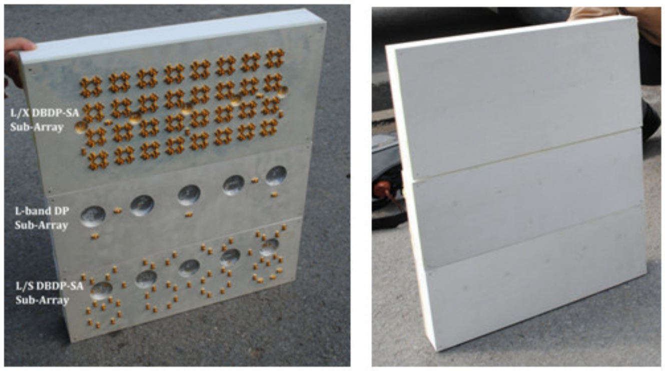

(a) Rear (b) Front

Fig.2 Photos of the TBDP shared aperture prototype array.

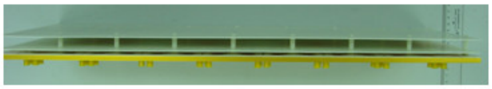

Side view

Fig.3 Novel structure DBDP-SA array

Compact Dielectric Resonator Antennas with Ultra-Wide 60%-110% Bandwidths

We have recently made a significant achievement in the emerging ultra wide-band (UWB) wireless communication systems, which require antennas with bandwidths gr 106%. In the past, the only way antenna engineers knew how to get such a bandwidth from a thin antenna was by removing the metal sheet underneath the antenna (known a plane"). This is not an acceptable solution for practical systems because the lack of it allows the antenna to radiate both upwards and (unnecessarily) downwards (i.e. electronic device on which the antenna is installed), wasting about half of its power. Saving power is crucial in UWB systems due to the severe power limits imposed by regu 2011, we made a breakthrough in dielectric-resonator (DR) antenna research, by inventing a novel DR antenna with a full ground plane and a 110% bandwidth. This disp myth that such bandwidths cannot be achieved with full ground planes. This antenna, published in the prestigious IEEE Transactions on Antennas and Propagation in Decem is 29% smaller but has a 30% greater bandwidth than the next-best DR antenna, which does not even have a full ground plane. Hence it is ideal for next-generation ultra-fas and sensor applications.

We theoretically and experimentally demonstrated that, by introducing a lower-permittivity full-length insert between the ground plane and a higher-permittivity dielectric dielectric resonator antennas (DRA) with ultra-wide bandwidths, in the range of 60%-110%, can be designed. Furthermore, the volume of such DRAs is reduced by appr 50% using a finite planar conducting wall. Unlike vertical monopole-type hybrid UWB DRAs, these antennas radiate sufficiently in the upward direction. Unlike in printed UWB antennas, the power radiated into the lower hemisphere is significantly less. An example prototype antenna, designed to operate in the FCC UWB band, has a dielectr of 12 x 8 x 15.2 mm3 (or 0.124 x 0.083 x 0.157 lambda3 at 3.1 GHz), and an average measured gain of 5 dBi from 3.1 to 10.6 GHz. These antennas exploit multiple low with overlapping bandwidths to form an ultra-wide contiguous bandwidth. With the proposed dielectric arrangement, it is possible to efficiently couple a sufficient numbe overlapping modes to a 50 ohm feedline using a single, simple feed.

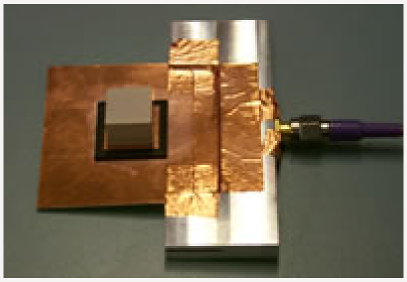

The antenna has a remarkably small footprint of 12x8 mm2 at 3.1 GHz - the lowest frequency of the FCC UWB band. Its dielectric volume is 1459 mm3, or 1.7x10-3 lamb lowest operating frequency of 3.1 GHz, and overall height is 15.2 mm or 0.157 lambda0. To place these results in perspective, it is worth comparing the new designs with wideband DR designs available in the literature. To the best of our knowledge, prior to this, the widest bandwidth ever obtained from a pure DRA design is 84% . The volu DR in that design is 0.225 x 0.172 x 0.062 lambda3 (= 2.4x10-3 lambda3) at its lowest operating frequency of 3.69 GHz. In that DRA, the DR is positioned in a non-traditi close to the edge of an orthogonal, "vertical" ground plane, which does not block radiation towards the lower hemisphere. The widest bandwidth demonstrated by a pure DI traditional "horizontal" ground plane, (which can be employed to shield the rest from the antenna, as discussed previously) is 78%. The dielectric volume of that design is 0. x 0.21 lambda3 (= 5.8x10-3 lambda3) at its lowest operating frequency of 6.7 GHz.

Super Wide-band Antennas

We have demonstrated that extremely wide bandwidths (ratio-bandwidths up to 1:25) can be obtained from a specially designed printed antenna with a tapered semi-ring design is described in "A Printed Elliptical Monopole Antenna with Modified feeding Structure for Bandwidth Enhancement," in IEEE Transactions on Antennas and Pro vol. 59, no. 2, pp. 667-670, Feb. 2011.

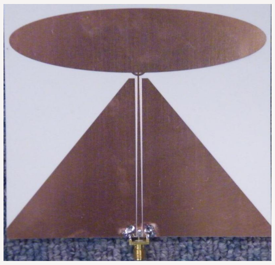

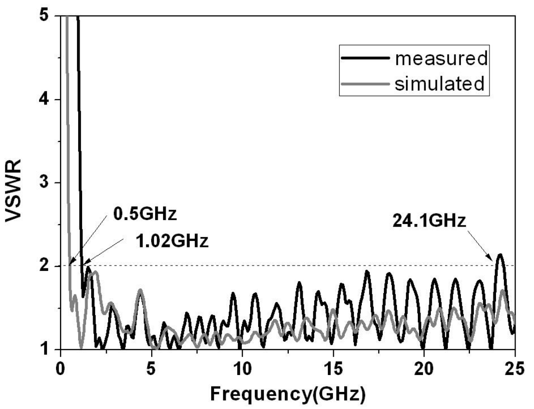

Focal Plane Arrays for Radio Astronomy

Dense focal plane arrays (FPAs) are a key technology for a new generation of Radio-telescopes. Their primary benefit is the rapid survey speed facilitated by the wide fiel provided by multiple beams. Recent advances have brought dense FPAs within reach of radio astronomy applications. A number of institutions have significant research pr this field. This technology is being considered for the Square Kilometre Array (SKA) (www.skatelescope.org). The PhD project of Douglas Hayman, conducted with CS Centre and Division of Astronomy and Space Science, investigated beamforming aspects of FPAs and evaluated their performance in Radio Astronomy. A prototype interf radiotelescope, built at CSIRO's Radiophysics Laboratory in Sydney, is used to demonstrate a suite of techniques forFPA beamforming and evaluation for this thesis. Bea solutions were experimentally demonstrated in our paper in IEEE Transactions on Antennas and Propagation, entitled “Experimental Demonstration of Beamforming Sol Focal Plane Arrays”.The THEA tile, shown below, is designed by ASTRON and used for the experimental component of this research.

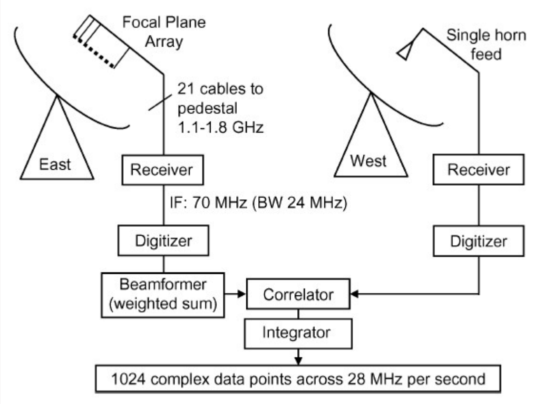

Negative Permeability of Spiral Metamaterials

Archimedean spirals and complementary Archimedean spirals are super-compact metamaterial particles. Thanks to their convoluted geometry, unit cells can be made electri small. We theoretically analysed monofilar, bifilar, trifilar and quadrifilar Archimedean spiral metamaterial particles using point group theory and crystallography. From the properties electromagnetic response was determined. Magnetic, electric and magnetoelectric modes of the particles were identified along with their isotropy characteristics. shown that all the particles, except monofilar spiral, are nonbianisotropic. Further, effective medium theory was applied to extract the effective permeability of the spiral me results indicated negative values for permeability in certain frequency ranges. Detailed theory and numerical simulation results are available in the paper entitled “Analysis metamaterials by use of group theory,” published in the Metamaterials Journal, vol. 3, no. 1, pp. 33-43, March 2009.

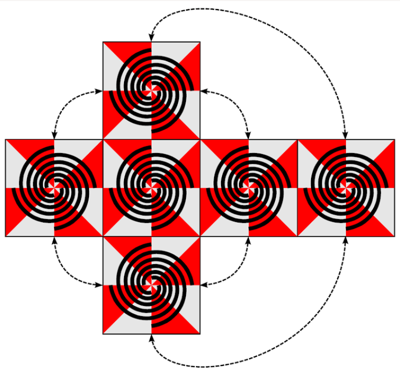

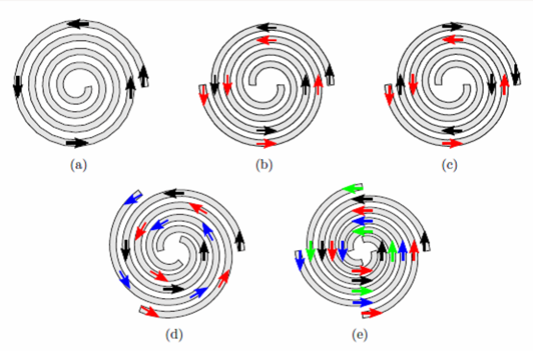

Archimedean Spiral Metamaterials and Backward Waves

We have shown backward wave propagation and double negative parameters over a 19% bandwidth in a microstrip line loaded with series gap discontinuities and super complementary Archimedean spiral resonator metamaterial particles. Moreover, our equivalent-circuit model for such unit cells almost perfectly described the structu practically important frequencies (by comparison with full-wave results). We also fabricated and tested compact filter circuits with only one or two complementary spiral met particles. Our results sre summarized in the paper entitled “Backward Wave Microstrip Lines with Complementary Spiral Resonators,” published in IEEE Transactions on and Propagation, Vol. 56, Issue: 10, pp. 3173-3178, Oct 2008.

We derived design equations for Archimedean spiral resonators and tested them against full-wave simulations. The details are in the paper entitled “Design of monofilar a Archimedean spiral resonators for metamaterial applications,” published in IET Microwaves, Antennas & Propagation, vol. 3, no.6, p. 929-935, Sep.2009.

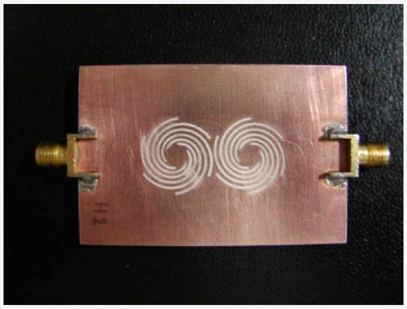

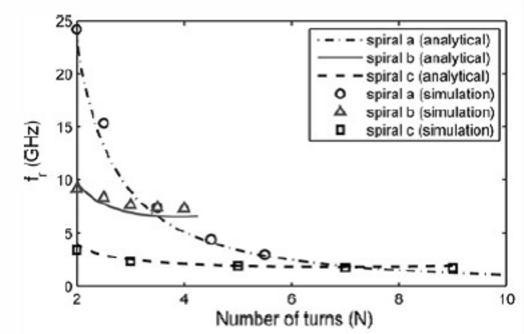

Frequency Selective Surfaces for Energy-Saving Glass Panel

Energy-saving glass is becoming very popular in building design due to their effective shielding of building interior against heat entering the building with infrared (IR) wave obtained by depositing a thin layer of metallic-oxide on the glass surface using special sputtering processes. This layer attenuates IR waves and hence keeps buildings summer and warmer in winter. However, this resistive coating also attenuates useful microwave/RF signals required for mobile phone, GPS and personal communication sy by as much as 30 dB. To overcome this drawback, we designed and tested a bandpass aperture type cross-dipole frequency selective surface (FSS), etched in the coatings o saving glass to improve the transmission of useful signals while preserving IR attenuation as much as possible. With this FSS, 15-18 dB peak transmission improveme achieved, for waves incident with 45 degrees from normal for both TE and TM polarizations.

Measurements and other results of this research, conducted in collaboration with the Lund University in Sweden, are available in the paper entitled “Cross-Dipole Frequency Selective Surface for Energy-Saving Glass Used in Buildings,” published in IEEE Transactions on Antennas and Propagation, vol. 59, no. 2, pp. 520-525, Feb. effect of these FSSs on the transmission of infrared and visible wavelengths through energy-saving glass was investigated theoretically and experimentally in another pap Microwaves, Antennas & Propagation, Vol. 4, Iss. 7, pp. 955–961, 2010.

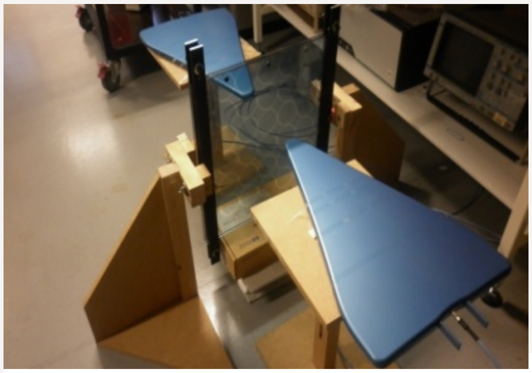

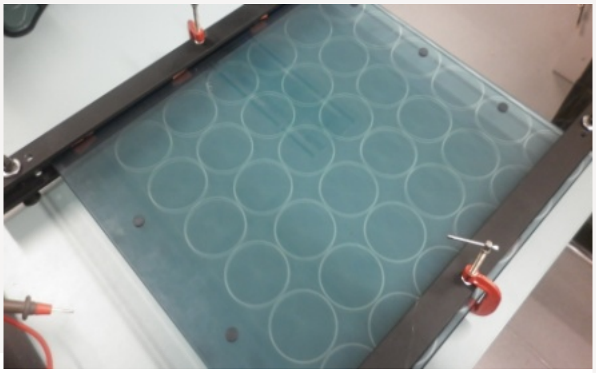

Switchable Frequency Selective Surfaces to Reconfigure Electromagnetic Architecture of Buildings

In large buildings and offices, frequency re-use methods will be required to enhance the spectral efficiency and capacity of wireless communication systems. This observati to the concept of electromagnetic architecture of buildings. Passive bandstop FSSs can be used to enhance the electromagnetic architecture of a building, and hence to spectral efficiency and system capacity, but switchable FSSs can provide a better reconfigurable solution. If switchable FSSs are placed in strategic locations of a building, th reconfigured remotely and rapidly, which is not possible with passive FSSs.

With collaborators in UK and Sweden, we designed and successfully tested a single-layer active Frequency Selective Surface (FSS) that is electronically switchable between and transparent states. It can be used to provide a spatial filter solution to reconfigure the electromagnetic architecture of buildings. The FSS measurements show that the response of the filter does not change significantly when the wave polarization changes or the angle of incidence changes up to ±45º from normal. The FSS is based on sq aperture geometry, with each unit cell having four PIN diodes across the aperture at 90 degree intervals. Experiments demonstrated that almost 10 dB additional transmissio be introduced on average at the resonance frequency, for both polarizations, by switching PIN diodes to ON from OFF state.

For details, please refer to “Switchable Frequency Selective Surface for Reconfigurable Electromagnetic Architecture of Buildings,” in IEEE Transactions on Ante Propagation, Vol. 58, Issue 2, pp 581-584, February 2010.

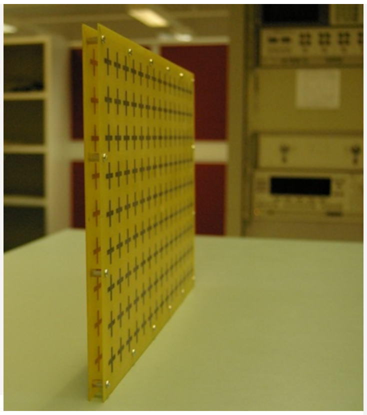

Absorb/Transit FSS

We designed and tested a novel absorb/transmit frequency selective surface (FSS) for 5-GHz wireless local area network (WLAN) applications. The novelty of the design i capable of absorbing, as opposed to rejecting, WLAN signals while passing mobile signals. The absorption of the WLAN signal is important to reduce additional multipa spread and resultant fading caused by typical reflect/transmit FSSs. Our FSS consists of two layers, one with conventional conducting cross dipoles and the other with resis dipoles. The FSS has good transmission characteristics for 900/ 1800/1900-MHz mobile bands and performs well for both horizontal and vertical polarizations.

Later we modified the FSS to obtain even better performance, for example, for both horizontal and vertical polarizations at oblique angles of incidence. The distance betwee layers has been successfully reduced to one eighth of free-space wavelength. This small distance makes it more compact as compared to the conventional Salisbury screen achieving an acceptable absorption in the stopband.

The details of our designs and test results can be found at "Oblique Incidence Performance of a Novel Frequency Selective Surface Absorber," in IEEE Transactions on Ant Propagation, Vol. 55, no. 10, pp. 2931 – 2934, Oct. 2007, and "A Novel Absorb/Transmit FSS for Secure Indoor Wireless Networks with Reduced Multi-path Fadin Microwave and Wireless Component Letters, Vol. 16 (6), pp. 378 - 380, June 2006.

Dual-Band Artificial Magnetic Conductor (AMC) Surfaces

AMC surfaces have many advantages and interesting properties due to their unique reflection characteristics, with near zero reflection phase. We have designed and pro novel dual-band AMC surface, which has a very wide upper AMC band and a narrow lower AMC band, and therefore suitable for multi-band wireless/mobile applications.

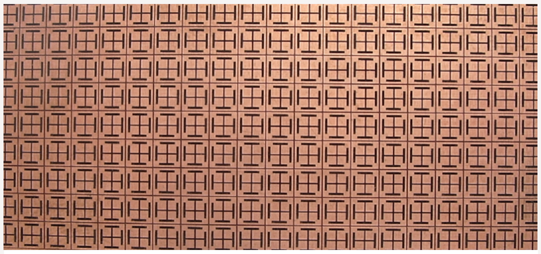

Fully Printed Quad-band Antennas for Wi-Fi IEEE802.11 and other WLAN Applications

Our fully-printed antennas can be fabricated and integrated to WLAN systems at almost zero cost by printing them on the same circuit board (e.g. FR4) with the radio circuit same standard fabrication methods. They are extremely compact: an antenna with a radiating element of 1cmx1cm covers all four IEEE standards (802.11a, 802.11b, 80 802.11n) as well as HiperLAN2 with a VSWR less than 2. We have also developed a packaging solution where the rest of the circuit can be shielded to satisfy EMC regulati leaving the antenna (on the same board) open for radiation. The advantages of the antennas based on this technology are: Lightweight; Radiates almost every direction in shadow region); Microstrip and co-planar waveguide (CPW) designs available; Compatible with all printed microwave circuits, including stripline circuits; Excellent because no cables, connectors, soldering or any mechanical attachments are required to connect the antenna to the radio; No protruding parts that are likely to break; Covers WLAN bands with one antenna (e.g. Wi-Fi IEEE 802.11 a, b, g, n, HiperLAN2 etc.); Excellent matching, i.e. input reflection < -10 dB (VSWR < 2) in all WLAN bands (e. GHz, 4.9-5.1 GHz, 5.15-5.35 GHz, 5.725 – 5.825 GHz); High efficiency (~60-70% on FR4; can be increased to over 90% on Duroid.); Ideal for internal mounting in a c device, to achieve very wide beam coverage; diversity reception or MIMO arrangements available; can be dsigned to cover other multiple bands (e.g. multiple mobile/c bands) and other applications.

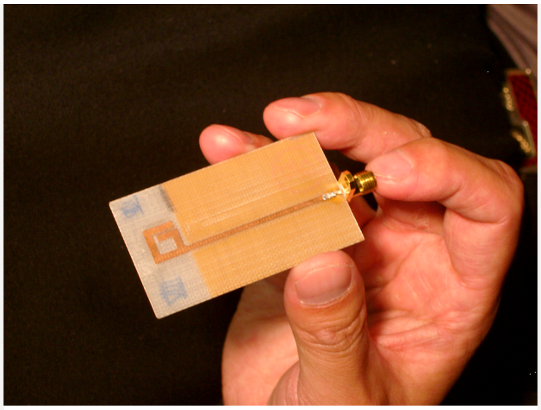

How can I optimise a UWB System to operate well over a range of directions?

Emerging ultra-wideband (UWB) communication devices will need to operate well, not just in one direction but over a range of directions. However previous UWB system optimisation techni been limited to one direction only. A system optimised in one direction may not work well in other directions due to pattern instability, or direction-dependent transfer function, of the an developed the concept of frequency-domain correlation patterns and proposed a figure of merit, the pattern stability factor (PSF), which can be determined from simulation of experimen With these new concepts, we have demonstrated the optimisation of UWB systems to operate well over a range of directions. The concepts and their applications are available in the PhD papers by Tharaka Dissanayake.

Antenna Techniques and Technologies for Ultrawideband (UWB) Systems

We developed antenna solutions for emerging UWB systems with very high data rates. Our research includes investigation of band-notching techniques to reduce UWB inference wi wireless systems and studies of antenna dispersion and pattern stability in the time domain.

High Gain Antennas with Planar Surface-Mounted Short Horns

In collaboration with University of Delhi, we have developed compact rectangular dielectric resonator antennas with surface mounted planar horns for gain enhancement. One configuration an aperture-fed rectangular dielectric resonator antenna and a planar surface mounted horn. We have achieved 10 dBi gain and a good efficiency from this configuration. The surface mou increases the gain of the standard dielectric resonator antenna by 4.9 dB. Total height of the prototype antenna shown in the figure is only 0.172 lambda and the aperture size is 0.96 lamb antennas can be easily adapted to low-profile, high-gain and array applications.

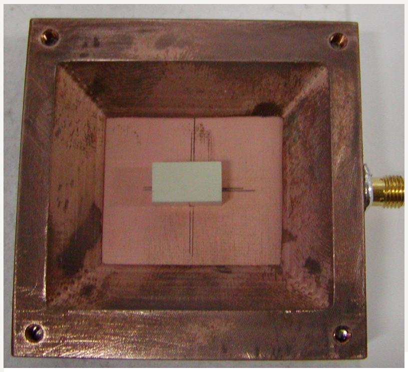

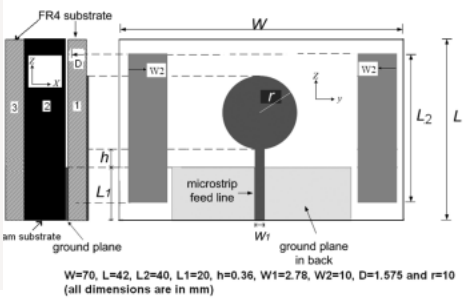

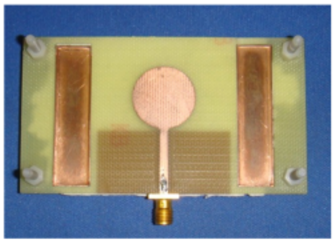

Photonic Crystal/EBG Based Horn Antennas

Waveguides and antennas made out of dielectric, as opposed to metal, are expected to perform better at Terahertz frequencies, as they do not suffer from the skin-effect loss of metal investigated horn antennas, horn arrays, waveguides, bends and junctions made out of 3D woodpile photonic crystals, which can be implemented at THz frequencies in high-resistivity other materials. Our concepts have been tested by fabricating and measuring scaled-up prototypes operating in microwave frequencies. We have also designed a special broadband couple a photonic crystal waveguide to a rectangular waveguide or a coaxial cable, for example for testing using a vector network analyser. We demonstrated > 6% bandwidth both theore experimentally.

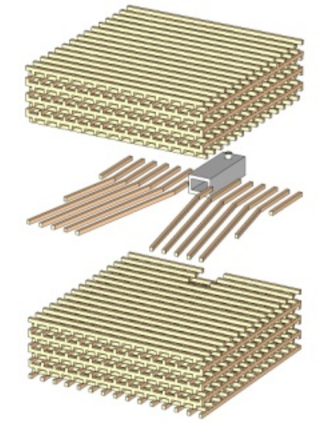

Broadband Microstrip Patch Antennas for Wireless Computer Networks

We have designed and tested broadband, compact E-shaped patch antennas for wireless communication networks, operating in frequencies from 4.9 GHz to 6.0 GHz. We made two achievements. First, we designed an E-shaped antenna, which is intrinsically compatible with a printed microstrip circuit. It can be made out of a single sheet of metal and can be mou microstrip circuit without expensive coaxial connector. Second, we designed a unique E-shaped antenna with corrugation to reduce the width of antenna. We successfully miniaturised the a fit it inside a thin (4mm) PC (or PCMCIA) card extension. In fact, we were able to squeeze in two of these antennas into a single PC card of standard width (54mm), for diversity communica achieve excellent isolation (>20 dB) and matching (<-10 dB) over the whole WLAN frequency band.

Theoretical Analysis of Photonic Crystal Structures

We have developed and successfully implemented, in both personal computers and supercomputers, efficient theoretical methods to analyse and design complex electromagnetic (micro optical) circuits based on photonic crystals (PC). Among our novel techniques is a PC-based Perfectly Matched Layer (PML) absorbing boundary for use with the finite difference time doma method in the analysis of waveguides in 3D photonic crystals.

We have applied these techniques to model wave propagation in various guiding structures such as bends, junctions and tapers in 2D and 3D crystals. From this analysis, we can transmission and reflection coefficients, propagation characteristics, phase and delay response, etc., of a component or a system.

New Closed-form Green's Functions for Microstrip Circuits and other Layered Structures

When combined with the spatial-domain Method of Moments (MoM), our new closed-form functions now enable efficient and accurate analysis of microstrip circuits and antennas with approximations. The key feature in this new MoM is that the four-dimensional integrations in MoM matrix elements can be solved analytically, completely eliminating the need for expensive integrations. Our new closed-form functions are simpler and more flexible than previous such functions, and (unlike previous ones) they do not require additional (Taylor series approximations. The computer time required for the analysis of an example microstrip line using the new MoM was three times less than the next best method, which required some integrations.

Integrated-design of Hybrid-resonator Antennas for Broadband Wireless and other Communication Systems

Shown below is the first baby of our recent project on broadband hybrid-resonator antennas. This first prototype of a Dielectric Resonator on Patch (DRoP) antenna demonstrated a ba 24%. This design also proved, both theoretically and experimentally, that the electromagnetic fields in a dielectric resonator can be efficiently coupled to the fields in a patch resona perturbing the radiation characteristics of each resonator.

Singularity-enhanced Finite-different Time-domain (FDTD) Method for Diagonal Metal Edges, Strips and Films

We developed the world's first and still the only singularity-enhanced FDTD method for metal edges not parallel to the grid. The edges were assumed to be diagonal to cell faces. Compare conventional spit-cell model, the computer memory required for an FDTD analysis of a structure could be reduced by up to 27 times and the computing time could be reduced by up to without sacrificing the accuracy of results. On the other hand, when the same grid was used, the accuracy of results improved by a factor of more than 3 compared to the split-cell model, a of more than 7 compared to the staircase model. The new equations were stable in all tests, and even in most demanding tests when the computational speed was further maximised by the time step (Dt) to the maximum allowed by the FDTD method! (i.e. stability factor of 1!)

The key to this success was the derivation of enhanced FDTD equations for nodes near the edges by considering rigorously the singular nature of the electromagnetic fields. The table here improvement of accuracy achieved by using the enhanced FDTD equations. The new equations are simple to implement in a standard FDTD code. They are ideal for the analysis and microstrip components and high-speed digital circuits where thin metal films or strips with diagonal edges are encountered.

Low-profile Dielectric-resonator (DR) Antennas

We designed and tested the world's first low-profile, circularly polarised, rectangular dielectric-resonator antenna (DRA) in 1995. The radiating element of this antenna is shown in the photo have also designed many other dielectric-resonator antennas, including a low-profile linearly polarised DRA, for various applications (see publications). We pioneered the FDTD analy antennas and published the first radiation patterns of a DR antenna obtained using the FDTD method in 1995.

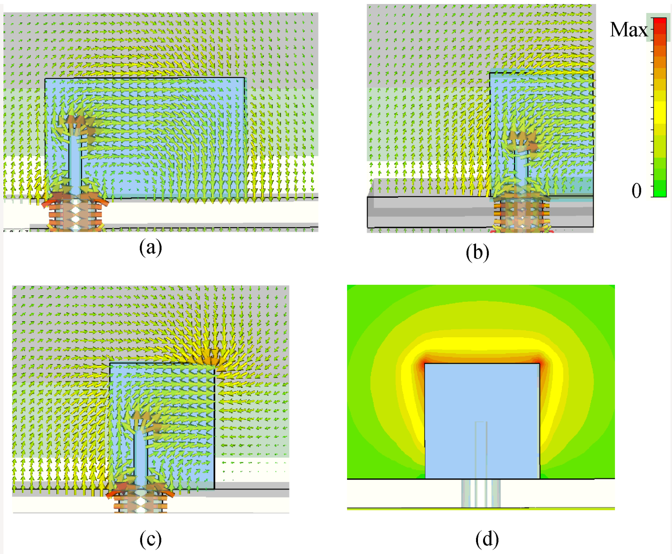

(a) (b)

(c) (d)

Australian Antenna Measurement Facility (AusAMF)

AusAMF is operated by a consortium of Australian Universities, Industry and CSIRO. The facility provides access to a shielded anechoic chamber offeri spherical near-field measurement capability for small antennas operating in the frequency range of 1-20 GHz, primarily for research purposes.

The facility was established under an ARC LIEF (Australian Research Council Linkage-Infrastructure Equipment and Facilities) grant and is hosted by C ICT Centre located in the Sydney suburb of Marsfield.

The facility currently consists of a spherical near-field turn-key NSI-700S-50 system within a 6m x 3.3m x 3.3m anechoic chamber. It has been designed to operate up to fre of 20 GHz, and uses an Agilent PNA (E8362B) as a receiver. The measurement system is capable of supporting a ~40kg antenna under test (AUT) up to a diameter of approximately 1.2m. I the standard gain horns and the probes available at AusAMF are as follows:

Waveguide Band	Frequency (GHz)	Probe	Standard Gain Horn
WR975	0.75 - 1.12	x	x
WR650	1.12 – 1.70	x	x
WR430	1.70 – 2.60	x	x
WR340	2.20 - 3.30	x	x
WR229	3.30 – 4.90	x	x
WR159	4.90 – 7.05	x	x
WR112	7.05 – 10.00	x	x
WR90	8.20 – 12.40	x	
WR75	10.00 - 15.00	x	x
WR51	15.00 - 22.00	x	x

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Smart Surfaces: Large Area Electronics Systems for Internet of Things Enabled by Energy Harvesting

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Smart Surfaces: Large Area Electronics Systems for Internet of Things Enabled by Energy Harvesting

This paper focuses on large-area "smart surfaces," RFID systems, and wearable RF electronics that could substantially benefit from multisource energy harvesting.

By Luca Roselli, *Senior Member IEEE*, Nuno Borges Carvalho, *Senior Member IEEE*,
Federico Alimenti, *Senior Member IEEE*, Paolo Mezzanotte, *Member IEEE*,
Giulia Orecchini, Marco Virili, *Student Member IEEE*,
Chiara Mariotti, *Student Member IEEE*,
Ricardo Gonçalves, *Student Member IEEE*, and Pedro Pinho, *Member IEEE*

ABSTRACT | Energy harvesting is well established as one of the prominent enabling technologies [along with radio-frequency identification (RFID), wireless power transfer, and green electronics] for the pervasive development of Internet of Things (IoT). This paper focuses on a particular, yet broad, class of systems that falls in the IoT category of large area electronics (LAE). This class is represented by "smart surfaces." The paper, after an introductory overview about how smart surfaces are collocated in the IoT and LAE scenario, first deals with technologies and architectures involved, namely, materials, antennas, RFID systems, and chipless structures; then, some exemplifying solutions are illustrated to show the present development of these concurrent technologies in this area and to stimulate further solutions. Conclusions and future trends are then drawn.

KEYWORDS | Energy harvesting; green electronics; Internet of Things (IoT); large area electronics (LAE); radio-frequency identification (RFID) systems

I. INTRODUCTION

Looking at the telecommunication (TLC) market development worldwide in the last five years, we see an average decrease of about 5% per year, in both gross domestic product (GDP) contribution and employment [1]. Against this trend, the global information and communication technology (ICT) market has remained grossly constant. Some compartments, in fact, are experiencing an opposite trend. Beside some sectors related to new consumer products, such as tablets and smartphones, new Internet of Things (IoT) related products are growing at two digits per year and some estimations from big players report a market value in the order of trillions of dollars in the next decade [2], [3].

The vision behind IoT is in fact to connect objects directly to the Internet so as to allow them to provide information directly to the web without any human intermediation [4]. This vision will have a great impact on several electrical and electronic technologies, ranging from the basic physical layers (technology platforms) to the highest ones: communication protocols, software, human interface, and information management.

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In terms of physical layer, IoT actually inherits the technologies developed for wireless sensor networks (WSNs), bringing the distributed nature of that to the extreme. WSN, in fact, can be synthetically seen as a mesh of sensor nodes purposely conceived to build and communicate a sensed image of a monitored area. Within IoT, the sensing nodes are not purposely deployed to monitor something specific; instead, they are simply hosted by "objects" in order to provide the information they are able to collect and make it available on the web. Conceptually speaking, there is not a big difference, but in terms of related technological challenges, there is. Nodes must be hostable by objects; objects are of many types, and the better the nodes fit themselves transparently to the hosting objects, the denser and more reliable the information they are able to provide.

Several challenges can be envisioned in this evolution: first, electronic systems must be mechanically flexible, thin, and miniaturized in order to conform to the shape of as many objects as possible; second, the adopted materials have to be as recyclable as the hosting objects in order to avoid pollution from guest apparatuses; last but not least, hosted nodes must be autonomous, because they cannot be either connected to the grid or powered by life batteries.

A great technological paradigm shift is going to be pulled by the development of IoT; green materials, autonomous systems, ultralow-power circuits, energy saving protocols, and energy harvesting (EH) are concurrently mandatory.

Conversely, this technological evolution is pushing new solutions and architectures, so far constrained by the limits of conventional technologies. The development of inkjet printing techniques, the introduction of very cheap and eco-friendly materials compatible with roll-to-roll (R2R) circuit realization techniques [5] and so forth, open new horizons also to large area electronics (LAE).

LAE, first applied to printed photovoltaic and organic screens [6], is actually at the onset of its development. The development of R2R techniques and related materials, in fact, is allowing for tremendously increasing the dimensions of LAE circuits and systems, from the present tens of centimeters to meters and beyond. Along this evolutionary scenario, new configurations and architectures, based on massive integration of large circuits over conformable surfaces, can be envisioned, opening the way to what can be called the smart surfaces (SSs) approach.

SS, in turn, can be seen as a branch of IoT evolution. Large 2-D arrays of autonomous sensor nodes, for instance, make possible granular tracking of whatever parameter, ultimately providing augmented imaging of the environment; large 2-D arrays of tags can provide a very low-cost platform for precise localization and location-based services (LBS), thus enabling the realization, for instance, of smart floors [7] and smart wallpapers [8]; inheriting quasi-optical approach [9] contact-less electromagnetic (EM) wave processing (filtering, frequency conversion, selective shielding, etc.) can be conceived even at low frequencies.

On the one hand, SS is thus an approach stimulated by technologies pulled by IoT; on the other hand, it contributes to a class of architectures, within LAE, that can even widen the huge horizons of IoT applications in a sort of virtuous circle.

According to this wide vision, the paper is organized as follows. A review of the technologies suitable for distributed systems implementation to a large extent is given in Section II; then, the explanation about how radio-frequency identification (RFID) can be considered one of the most suitable technologies for the implementation of IoT architecture, and how it can be naturally integrated with SSs, is provided (Section III). In order to deal with the implications of the development of RFID systems compatible with SS and LAE evolution of IoT, two specific sessions have been provided: the first relates to antenna implications (Section IV), and the second relates to electronic architectures for RFID tags (mainly chipless ones; Section V). In order to smoothly bring the reader from relevant technologies to applications, quasi-optics, as an example of general approach concurrently exploiting the mentioned technologies to provide a platform suitable for LAE, is described in Section VI. After this, some application examples of how SS concept can be articulated, according to the IoT paradigm, are described; specifically, smart floor (Section VII), smart shoes as useful subsystems for the implementation of smart floors (Section VIII), and energy skin (Section IX). In order to have a vision of the logical links behind the many topics dealt with in this paper, a synoptic picture can be found in Fig. 1.

II. TECHNOLOGY FOR LAE DISTRIBUTED SYSTEMS

Given the described scenarios of SS, it is clear that the technologies involved have to be compatible with LAE

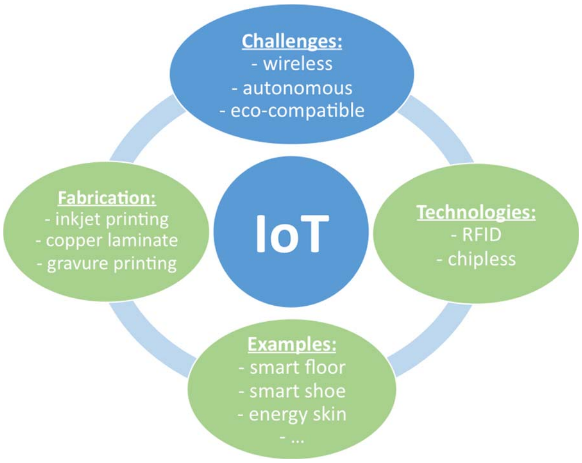

Fig. 1. *Synoptic view of the paper structure reflecting the IoT vision described in the Introduction.*

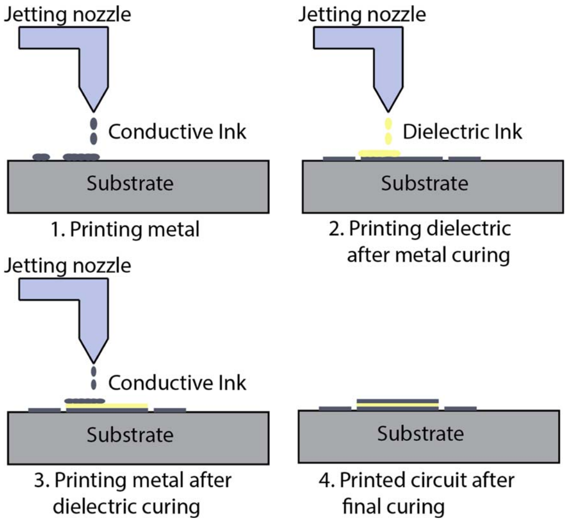

Fig. 2. ***Inkjet printing technique, synoptic description. The ink is deposited on the substrate with the desired pattern and after a curing procedure the next layer can be printed. The thickness of each film depends on the number of passes.***

approach, as described in the Introduction; according to [6], for example, the eco-compatibility of the materials, the mechanical flexibility of the substrates to make the device conformable to the hosting surface, and the life cycle (operability and biodegradability) have to be accounted for.

The new techniques proposed from different research groups [10]–[12] focus mostly on the printing techniques that can be industrialized easily with R2R methods, already investigated for the traditional printing on paper. Within the printing methods, one of the most attractive and investigated in the last decade is the inkjet printing of conductive and dielectric layers (Fig. 2). This technique allows circuits to be printed on almost any kind of substrate: from the photographic paper to liquid crystalline polymers (LCP) or Kapton, that are flexible, thin, and eco-compatible; to glass or poly methyl meta acrylate (PMMA, commonly referred to as Plexiglas) that are usually thicker but not flexible.

A first proof of concept for the inkjet printing technique at radio frequency (RF) and microwaves has been obtained on photographic paper by printing simple structures, such as antennas and other planar circuits and devices [10], [13]–[22], with a technology stack simply composed by the substrate and the conductive layer (usually realized by means of nanoparticle silver ink).

Recently, this method has been improved thanks to the development of new inks, usually composed by a polymer and a solvent (i.e., SU-8, PVP, PMMA, PEDOT, etc.); more complex fabrication procedures of multilayer structures are now possible, as shown in [23] and [24]. Another noticeable feature of this technology is represented by the resolution: conductive tracks of 50 μm of width and space gaps of 50 μm can be printed, allowing the design of millimeter-wave (mm-wave) frequency devices [25]. The combination of the quite high resolution (considering the simplicity of the technology) with the multilayer featuring also gives the opportunity to manufacture very easily matrix of passive and active devices that can be used in the SS development. It is worth noting that the process can be developed in a few steps based on the design and mostly on the number of layers needed. For example, a metal–insulator–metal (MIM) device can be realized by printing silver on the substrate [26], curing it in the oven in order to create a surface that, with the proper treatment (for instance, UV–Ozone exposure or preheating), is ready for the insulator printing. Then, the dielectric is cured as well and the last metal layer can be printed on top of it. The entire structure can be then cured at temperatures ranging between 130 °C and 200 °C.

In a perspective of industrialization of the inkjet printing technology, the hypothesis of R2R manufacturing of circuits is being investigated and some examples are already reported in literature for solar cells and other devices [27], [28].

Today, many pros have been mentioned for the inkjet printing method, and others can be found in the non-use of wasted chemicals (as is for the traditional lithographic technologies), in the no-need of clean-room environment for the fabrications, in the low-cost and rapidity of manufacture, and in a R2R perspective compatibility. However, the necessity of a curing procedure after the printing of a layer still represents the biggest inkjet limit for two main reasons: first, the time and type of curing are dependent on the inkjeted materials and on the material stack-up; second, especially on a laboratory level, the curing can cause misalignment issues, given the fact that the sample is removed and then replaced in the printer after the last layer curing.

Currently, the platform mostly used worldwide by researchers is the Dimatix 2800 DMP. In terms of inks, it is possible either to buy printable solutions or mix solutions in labs; for example, the combination of polymers and solvents allows layers to be printed with different electrical properties and thicknesses.

Besides the inkjet printing method, in [11], a new technique, suitable for LAE, has been proposed. It uses a metal (copper in that case) adhesive laminate technology based on the application of the standard etching process to an adhesive copper laminate material. This technique was already adopted to produce mm-wave circuits and to characterize the resulting compound substrates, as reported in [29]–[31]. A brief illustration of the metal laminate technique is here reported referring to Fig. 3.

The production process can be divided in five steps. The first step consists of the deposition of a (positive) photoresist film on the copper surface; then, the circuit layout is transferred to the photoresist by means of a photomask and ultraviolet exposure. After that, the unimpressed film of photoresist is removed using a NaOH

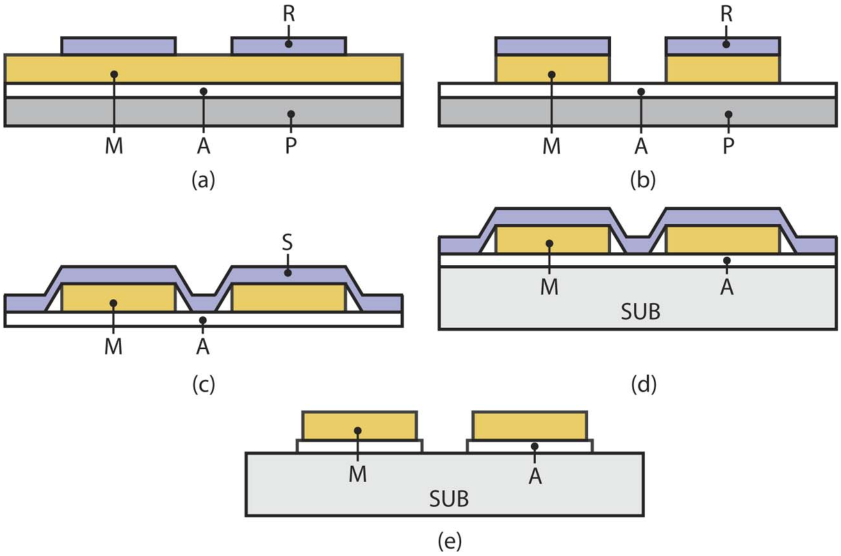

Fig. 3. ***Process steps for the circuit fabrication using the adhesive metal laminate. M: metal, A: adhesive, P: protection, R: photoresist, S: sacrificial layer, SUB: hosting substrate. After the standard lithographic procedure, the copper pattern can be transferred on top of any substrate by means of a sacrificial layer and exploiting the adhesive face of the copper tape.***

developer solution [Fig. 3(a)]. In the second step, the copper tape is wet etched. As can be seen in Fig. 3(b), in this way, the adhesive layer is exposed where the copper was removed, while it remains everywhere else covered by the original copper tape that serves as protection for the adhesive underneath.

The first two steps are, in this example, similar to those adopted in standard photolithographic technology. Moreover, different ways to remove the not needed metal can be used, as, for example, by means of numerical control pattern cutting plotters.

In the third step, depicted in Fig. 3(c), a sacrificial layer is stuck on the top copper side and, finally, the protection layer on the bottom is removed. The sacrificial layer is very important because it keeps the relative distances among the layout features constant even when these are not physically connected.

The fourth step is characterized by the transfer of the etched metal to the hosting paper substrate and, finally, the sacrificial layer can be removed [see Fig. 3(d) and (e)]. The last step is also useful to remove most of the exposed adhesive material.

With this method, quasi-fully-organic circuits and devices can be realized. The performance in terms of tracks width and pitch are, at present, a bit lower than what can be obtained with the inkjet printing, with the advantages of no curing processes, the possibility to fix devices on the circuit using standard soldering techniques, and a better conductivity (the conductivity of copper laminate, in fact, is one order of magnitude higher than that of the cured nanoparticle silver ink: 5.8×10^7 S/m versus about $6 \times 10^6 - 1 \times 10^7$S/m obtained with at least five layers of silver).

To verify the validity of the metal laminate technology at microwave frequencies, a 50-Ω microstrip line was manufactured exploiting the Mitsubishi photografic paper as the substrate (thickness 250 μm, relative permittivity $\varepsilon_r = 3.2$, and loss tangent $\tan\delta = 0.08$). The line is 30 mm long, and the measured scattering parameters are shown in Fig. 4. The same graph also compares the performance of a similar transmission line manufactured with an inkjet printing process. The performance of the

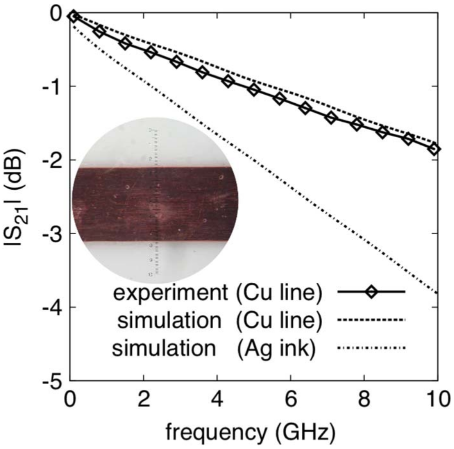

Fig. 4. ***Measured scattering parameters versus frequency for a 50-Ω microstrip line on paper substrate. The line, shown in the inset, is 30 mm long; the ruler division corresponds to 17.2 μm. The graph also reports a comparison with a microstrip line of equal dimensions made with an inkjet printing process (Ag ink, 3-μm thickness, $\sigma_{\rm ink} = 1.1 \times 10^7$ S/m after curing). After [11].***

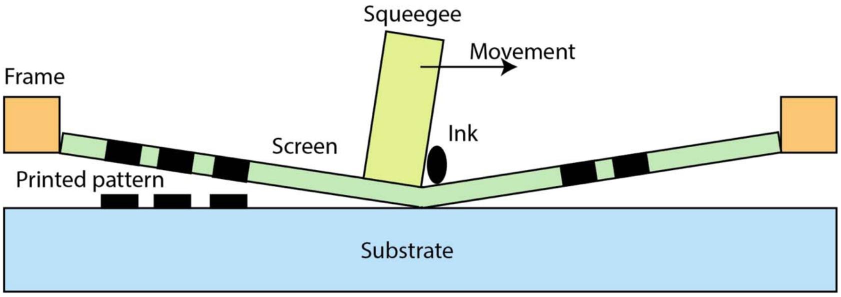

Fig. 5. ***Screen printing technique. The squeegee is used to press the screen with impressed pattern and transfer it on top of the substrate.***

metal laminate structure is superior compared to that of the inkjet printed line. At 10 GHz, the measured specific losses for the metal laminate microstrip are about 0.6 dB/cm [11]. Results at higher frequencies are also reported in [31]; in particular, an insertion loss of about 1.8 dBm/cm at 30 GHz is demonstrated.

The tradeoff is the adoption of a photolithographic step; it is worth mentioning, however, that the process is still compatible with R2R implementation.

Other possibilities for LAE are the screen printing [12] and the gravure printing [12], both of them adaptable to R2R industrialization techniques.

Screen printing consists of dragging a layer of ink across the surface of a screen and squeezing it through the open pores of the patterned mesh onto the substrate (Fig. 5). In general, the thickness of the printed layer and the achievable resolution depend on the density of the mesh and on the ink properties. Usually, the ink viscosity is in a range of 1–50 Pa $\times$ s, and this allows for printing with a resolution of about 100 μm and a thickness up to 100 μm. Until now screen printing has been adopted to realize low-resistance structures, solar cells, and field effect transistors (FETs), exploiting the possibility of printing very thick layers.

Gravure printing, also known as rotogravure, is considered a very high volume printing (Fig. 6) process, and it is being adopted to produce very conductive structures as, for example, capacitors, antennas, and organic devices such as pentacene-based diodes, organic light-emitting diodes (OLEDs), organic field effect transistors (OFETs), and organic thin film transistors (OTFTs).

The resolution can be of about 20 μm. The method is implemented by engraving the patterns into a metallic cylinder by a laser, by chemical etching, or electromechanically (as separate cells or intaglio trenches). Typically, the print pressure is high (1–5 MPa) in order to achieve a good ink transfer and to reduce the percentage of unprinted dots caused by the surface roughness of the flexible substrate. However, this high pressure of printing makes this technique suitable only for robust substrates with no soft, previously printed, layers that could be damaged.

To summarize, the technologies described in this section are characterized by some common features, such as: flexibility and conformability, compatibility with large area realization of circuits and interconnections, use of additive or mixed (subtractive/additive) deposition techniques, easy use of eco-friendly materials and, in some cases, compatibility with classical bond wiring as well as soldering techniques for electronic device placement.

Table 1 summarizes the main features of the described technologies.

III. RFID: A MIX OF CONCURRENT TECHNOLOGIES FOR SS IMPLEMENTATION

As mentioned in the outline paragraph at the end of the Introduction, after describing the technologies enabling SS development (Section II), here we illustrate RFID as a suitable means to transfer information through EM transmission between tags and readers to the Internet.

An RFID tag has a unique identification code and a memory used to store information, while the reader can

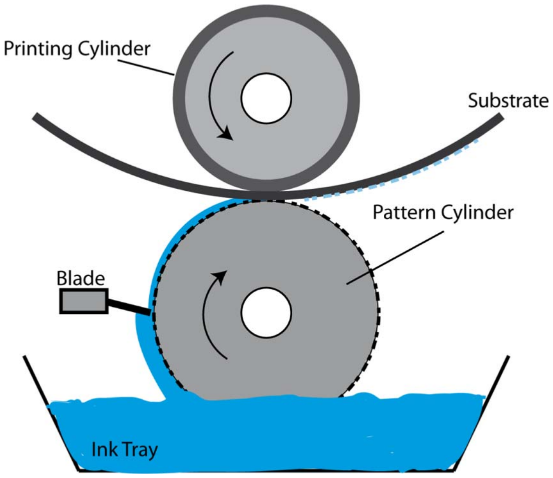

Fig. 6. ***Gravure printing process. Note that these machines can be from 20 cm to 3 m wide with a diameter ranging from 5 cm to 5 m.***

Table 1 Technologies Comparison

Technology	Resolution	Cost	Waste	Speed
Inkjet	50 μm	Low	Low	Fast
Copper	100 μm	Low	High	Medium
Gravure	20 μm	High	Medium	Very fast
Screen	100 μm	Medium	Low	Very fast

write or read data on and from the tag through RF transmissions. The tag is usually attached to an object that needs to be identified and monitored, or contains information to be read. In typical RFID applications [32], the main goal is to provide mapping of physical objects that are equipped with an RFID tag attached or embedded. In this way, RFID technology inherently leads to identifying, tracking, and localizing, but it can also enable the storage and transmission of information regarding object status and surrounding environments by embedding sensing capabilities.

As mentioned previously, IoT is most commonly described as a structured system of technologies concurrently working to capture meaningful data from objects and communicate them through networks to a decision-taking level. Useful keywords, whenever a definition of IoT is given, include: smart objects, autonomous logistics, machine-to-machine communication, RF technologies, centralized information, and so on.

In order to implement these functionalities, an IoT platform, an SS for instance, has to provide at least unique object identification together with wireless communication for data management.

The IoT physical layer can thus be naturally thought of as meshes of RFID and sensor nodes. The RFID tag that embeds a sensor can use the same working principles and protocols of the conventional RFID tags; a differentiation can be made, considering the way sensor tags are powered up, in active, semipassive, and passive tags; actually, the difference consists of the way they are powered.

Active tag sensors may use customarily conceived communication protocols or rely on RFID standards enabling the tag to be easily integrated into the existing wireless infrastructures so that they will not require expensive readers. In [33], a system architecture was developed to integrate WSNs and the RFID systems. Bluetooth and ZigBee technologies are adopted as the communication protocol of WSNs to meet the requirements of a large number of sensor nodes, large areas, and low cost.

Active tags with integrated sensors are used in several applications, including temperature and position monitoring, vibration detection, blood pressure, heart beat monitoring, and more. This type of sensor tags, besides having larger amount of energy provided by batteries, affords both a large range and multiple functionalities; some of them have also external buses that enable the use of connected external sensors [34].

Passive tags with an integrated sensor operate without battery, collecting the needed operational energy from external environment sources. The main requirements of this class are high energy conversion efficiency, large storage capability, and overall low-power consumption. Passive systems have usually low operating range and limited processing capability.

In this field, research activities are directed toward ultralow-power design of integrated sensor tags [35], antenna design for improving reading range [36], sensor overall performance optimization [37], and development of optimum protocols allowing for additional power saving [38], [39].

Typical applications are, for instance, temperature monitoring [40], photodetection [41], motion detections [42], etc.

Semipassive tags use both batteries and energy sources coming from the environment; they can integrate more operational capabilities than the passive ones, since they can exploit a higher amount of energy. For the same reason, semipassive RFID tags are more suitable to integrate a sensor; the operational methodology is similar to the passive one, using the reader signal to interrogate and cause a response from the tag. The primary difference is that the semipassive tag does have a battery used not to generate a response, but only to power electronics, like sensors incorporated in the tag, while exploiting RF circulation to reply to the reader interrogation. Just like passive tags, semipassive ones are limited in terms of slow reading speeds and short reading distances. In [43], the design, realization, and experimental validation of a battery-assisted RFID tag with sensing and computing capabilities, conceived to explore heterogeneous RFID-based sensor network applications, was presented.

Dealing with battery-less devices that are, by far, the most interesting ones for IoT, LAE, and SS applications, we can now focus on the typical energy sources adopted. No battery devices can exploit solar scavenging [44], [45], vibrational [46], [47], or RF radiations [48]–[52].

In many cases, wirelessly powered systems can harvest energy from the incident RF waves, thus generating the required direct current (dc) voltage to power the system. The EM energy present in the environment may be significant in some regions (some urban areas or indoor sites); here the use of proper conversion devices may allow enough energy to be scavenged. RF power harvesters usually consist of an antenna, an impedance transformation network, a rectifier, and a storage element. In [53], a design example of integrated rectifier antennas (rectennas) for wireless powering at low incident power densities, from 25 to 200 μW/cm^2, is given.

Regarding mechanical energy scavengers, they may be categorized upon the kind of energy source exploited; there are scavengers providing energy from a constant motion over extended periods of time (e.g., turbine air flow) or others based on intermittent motion (e.g., human step). Particular attention is given to vibrational energy sources; in this case, the amount of energy that can be harvested depends mainly on the vibration amplitude and frequency and on the vibrating mass (mass of the harvesting device) [54]–[56].

In order to power the systems by using energy sources available in the working environment, proper energy transducers thus have to be chosen. Focusing on distributed systems (IoT, LAE, and SS), it is worth referring to typical parameters for optimum transducer design since, in these applications, the different kinds of energy available in the various scenarios may lead to the need of integrating more than one energy conversion system into the same device, in order to take advantage of all the accessible energies. The main design parameters are the available power output, the electrical impedance, and the operating voltage. Table 2 summarizes them for the most common energy transductions [57], [58].

To conclude this section, the mentioned reasons why RFID can be considered a useful technology for the implementation and development of LAE and, more specifically for SSs, are summarized. RFID systems, especially in the passive version of tags, are communication systems characterized by the following characteristics: compatibility with very low-power communication protocols, compatibility with the constrains posed by the hosting objects, especially when they are implemented by adopting the technologies described in Section II, inherent capability to gather information from the environment (sensor tags) and from the hosting objects, a low number of electronic devices (inherent circuital simplicity) and, finally, proven compatibility with printing technologies.

For all these reasons, RFID technology has to be considered the leading one to pursue the development of LAE and SSs as a communication platform for the evolution of IoT.

IV. ANTENNA DESIGN FOR NODES

Distributed systems for ubiquitous electronics (UE) and WSNs [59], [60] are, today, increasingly employed for monitoring and sensing applications. These systems can be seen as networks of nodes, massively distributed in the environment and communicating wirelessly with a base station. This massive deployment can be designed and structured to monitor a set of specified parameters by means of purposely conceived sensor nodes, as in the classical WSNs, or it can be obtained by integrating nodes into existing objects, which is the vision of IoT evolution. In general, the nodes can have different functionalities, however they have to provide information collected by embedded sensors (such as, for instance, identification codes, position and monitored environment parameters as well as object status) whenever it is required.

In this scenario, the RFID technology, summarized in Section III, is attractive. When RFID technology meets sensor nodes, information goes from the node to the Internet via a question-and-reply protocol between nodes, hosted by tagged objects, and readers.

Thinking about distributed systems and specifically SS, it is natural to think about radiative coupling in the available industrial–scientific–medical (ISM) frequency bands, including mainly the ultrahigh frequency (UHF) and microwave frequencies (around 0.9, 2.4, 5.8 GHz, and higher), exploiting the communication standard such as the WiFi [61]. Recently, also the ultrawideband (UWB) has been considered in order to minimize the limitations of narrowband systems (mainly localization accuracy and sensitivity to interference) [62].

Multistandard systems are often adopted for large compatibility and higher use flexibility. An example of this recent approach is given in [61] where near-field UHF nodes are combined with far-field transceivers. This allows application fields with compromised radiation capability,

Table 2 Transducer Characteristics for Several Forms of Ambient EH [57], [58]

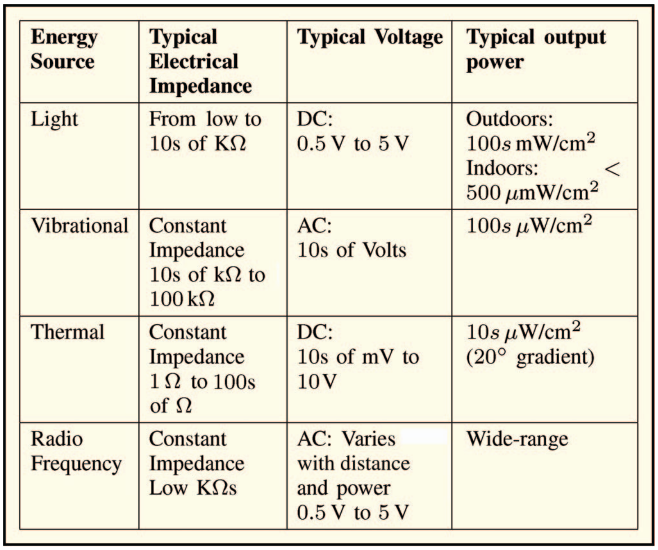

Energy Source	Typical Electrical Impedance	Typical Voltage	Typical output power
Light	From low to 10s of KΩ	DC: 0.5 V to 5 V	Outdoors: 100*s* mW/cm^2 Indoors: $<$ 500 μmW/cm^2
Vibrational	Constant Impedance 10s of kΩ to 100 kΩ	AC: 10s of Volts	100*s* μW/cm^2
Thermal	Constant Impedance 1 Ω to 100s of Ω	DC: 10s of mV to 10 V	10*s* μW/cm^2 (20° gradient)
Radio Frequency	Constant Impedance Low KΩs	AC: Varies with distance and power 0.5 V to 5 V	Wide-range

such as in proximity of metal and liquids at short ranges, to be improved.

It is clear that antenna systems are key elements in these apparatuses. The foundation of antenna design rules can be found in [63]. The antenna design specific for distributed systems, in turn, has to take into account several instances. Beyond the typical design criteria, other aspects are: the communication standard, the form and the size in agreement with the application, the communication range as a function of the equivalent isotropic radiated power (EIRP) limits, of the environment and of the orientation, the reliability under several conditions and processes, and the material cost considering massive production [64]–[67]. Among them, the operating environment is the most critical aspect that influences the node behavior [68].

As a consequence, antenna topology and materials for SS and IoT systems, in general, have to be chosen in order to make the antennas capable of operating in variable environmental conditions and to be integrated into objects. As an example, let us think about wearable antennas for body area networks (BANs): they must be washable, flexible, and able to shield the body from radiation [69].

In general, antennas for SS should be flexible, planar, and low profile; moreover, by adopting low-cost materials and technologies (see Section II), cost per unit surface is low, thus large arrays and big elements can be adopted more easily, ultimately allowing for easy developments of LAE distributed systems and SS, even at low frequency.

Materials compliant with SS implementations must be, in turn, mechanically robust, flexible, and very low cost, while exhibiting acceptable EM performance. These materials must also exhibit high tolerance levels in terms of bending repeatability. Flexible materials, often used, are polymers and polymer-ceramics composites such as the poly-di-methyl-siloxane (PDMS) and the titanate-based ceramic [68], which provide flexibility, robustness, and resistance to harsh environments in order to protect antenna and circuit. Moreover, when eco-compatibility has to be guaranteed, recyclable materials and related technologies have to be adopted; among them, cellulose substrates in combination with inkjet printing of conductive inks [18], [70] or with conductive adhesive laminate technology [11] are increasingly frequently adopted. The aforementioned techniques, compatible with the well-known industrial printing and the R2R processes [5], are in agreement with the low-cost fabrication and are expected to facilitate widespread and very low-cost electronics for distributed systems. These fabrication technologies can also be adopted for electronic devices on flexible polymeric substrates. An example of cellulose-based antenna for smart floor applications, such as indoor localization, is documented in [71]: a low-profile planar loop antenna is realized on cellulose substrate exploiting adhesive copper tape.

Although beyond the scope of this paper, which focuses on SS, it is worth mentioning here that this evolution toward the development of more and more sophisticated "unconventional" materials for electronics has a great impact on other IoT related developments such as, for instance, implantable systems.

When applications require devices with soft visual impact (think about SS, such as smart windows, glass integrated inside and outside buildings and glass for automotive applications, or smart skins [72]), transparent and conductive materials, such as transparent conducting oxides (TCOs), and in particular indium-tin-oxide (ITO) and ITO-based multilayers, have been proposed [73]. These materials afford a good compromise between minimum electrical resistivity and high optical transmittivity in the visible light spectrum when patterned on see-through materials such as glass or transparent polymers. A technique to improve the efficiency of the transparent antennas, without affecting their transparency, is the application of a layer of highly conductive coating or metallization strips on the antenna edges where the current density is high [72].

Among SSs, or in general distributed systems within the IoT vision, a fast growing field of research is represented by wearable electronics for BANs [74]. In this case, the integration of electronic devices in the garments requires the development of wearable and washable antennas and antenna arrays on fabrics. Washable antennas can be realized by covering textile antennas by a breathable thermoplastic polyurethane coating in order to protect the device against water absorption and corrosion [69].

Although dimension constraints are not very critical for distributed systems on cheap materials, they cannot be neglected thoroughly. At RF, for example, high permittivity materials [68] and magnetic composite substrates [75] can be adopted. Artificial magnetic conductors (AMC) can be employed alternatively to the magnetic composites with similar results [76]. These approaches are simply demonstrated from the wavelength equation: wavelength is a function of the relative permittivity and permeability and adopting suitable materials to increase these values, the effective wavelength, and therefore the antenna size, decreases. Anyway, the use of these materials introduces a tradeoff between dimensions and performance: generally the substrate losses decrease the antenna radiation efficiency, thus affecting the communication range of the overall wireless system, as documented in [68], [75], and [76].

In terms of design methodology, the introduction of unconventional materials as well as the environmental constraints posed by distributed systems and systems for IoT influence and drive the design strategies. Some solutions are proposed in the literature to cope simultaneously with these constraints; in [68], shielded configurations have been analyzed to mitigate environmental sensitivity. In [69], an example of robust patch antenna for BAN application that reduces the effect of the body on the performance is illustrated; in [77], the use of broadband antennas, such as the Chebyshev monopoles with a fractional bandwidth of about 40%, is proposed to reduce the frequency shift introduced by the background materials or by the bending effects.

In SSs, and in general in IoT applications, antennas are used both to transmit and receive information and to harvest the necessary energy from the surrounding environment. Regardless of the fact that the available energy is randomly released in the environment by existing services (GSM, WiFi, and so on, in urban and semi-urban environments [78], [79]) or purposely delivered to empower a distributed population of nodes [80], antennas have to be able to harvest EM energy. This kind of "double effect" antenna is widely referred to in the literature as "rectenna": it combines rectifying circuitry with EM to electrical energy transduction.

The fundamental codesign techniques of antennas and rectifiers, focusing on the improvement of the conversion efficiency exploiting matching circuits, are described in [53]. Harmonic-balance and load-pull simulations are often used in order to find the optimal impedances that allow best efficiency to be obtained as a function of the EM incident power.

Multiband, broadband, and circularly polarized antennas are often adopted in EH applications to reduce the overall sensitivity to the environment. An example of planar antenna array for EH applications, in agreement with the SS principle, is documented in [81]: spiral antennas are proposed in order to provide a wide operating frequency band, and the rectification circuitry is optimized and characterized for low incident power levels. Similar antenna array for UWB EH is shown in Fig. 7.

A rectenna can be used in addition to the communication antenna or, alternatively, the same antenna can be used for both EH and data transmission. The use of different antennas is generally adopted if harvesting and communication are carried out at different frequencies and, mainly, in order to enhance harvesting efficiency without decreasing communication performance. In any case, this requires a codesign and can affect the node dimension and complexity. Alternatively, a single antenna can be a feasible compromise if communication and harvesting share the same frequency band and if the antenna harvesting efficiency is not the main issue; examples are the passive RFID tags empowered by the reader with a standard RFID antenna able to provide both EH and communication capability, as documented in [64] and [65].

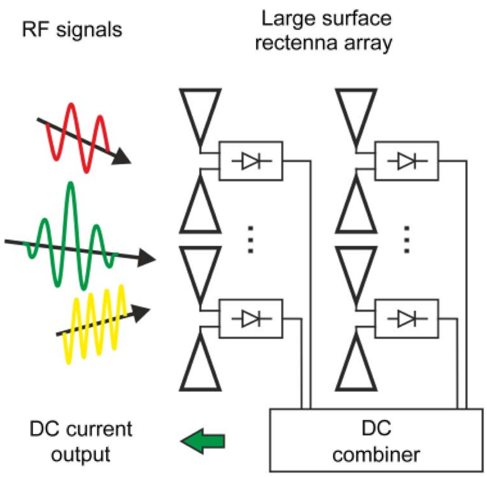

Fig. 7. ***Scheme of the rectenna array able to collect RF energy even in a broadband (depending of the kind of receiving antenna element), according to the solution adopted in [81].***

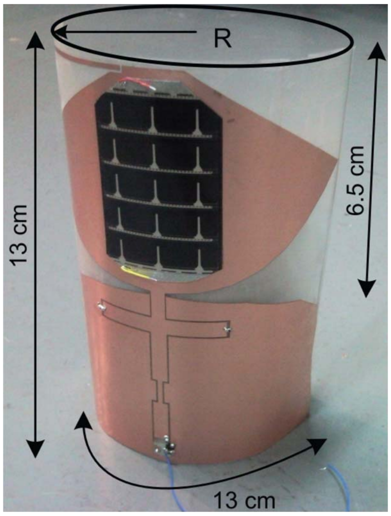

Fig. 8. ***Hybrid rectenna for solar and EM–EH. The hybrid rectenna consists of a broadband antenna and a solar cell combined in the same structure. After [82].***

However, the EM–EH is not the only solution to energize nodes and SS elements: hybrid EH, in fact, can be performed by exploiting different energy sources; that is, combining the rectennas with other sources of energy.

Recently, a low-cost and conformal structure for hybrid EH, based on low-cost and flexible poly-ethylene terephthalate (PET) substrate and an amorphous silicon solar cell, has been proposed in [82]; other examples are discussed in [20] and [83]. The use of low-cost, printable photovoltaics deposited on flexible substrates to form part of the antenna radiating structure is documented in [84]. In all these contributions, the main challenge appears to be the codesign of the antenna and solar cell in order to avoid reciprocal detrimental effects. The antenna is designed with a solar cell integrated on top of the radiating surface to obtain good radiation characteristics and to incorporate connections for the extraction of the dc provided by the solar cell. In [82], it was demonstrated that, by adopting thin film solar cells and paying attention to not exceeding the perimeter of the RF antenna, the solar cell can be integrated so as not to significantly affect the performance of the antenna. The hybrid rectenna for solar and EM–EH documented in [82] is shown in Fig. 8.

In terms of industrial assembly, the use of new materials and the need for low-cost and large-scale fabrication techniques would be fostered by architectures more insensitive against geometrical errors and placement misalignments. Following this direction, EM coupling can be exploited instead of ohmic contact to connect antennas on a flexible substrate to Si chips or, more generally, to the active circuitry [85]. This technique exploits a planar heterogeneous transformer, with the primary and secondary windings implemented on the antenna substrate and the Si chip, respectively. In this way, the galvanic contacts and the soldering process are avoided, and the final structures have been proven much more robust to alignment errors than traditional ohmic techniques without any significant performance degradation. By artificially applying a misalignment of 150 μm, which is the common dimension of a soldering pad, the technology proposed in [85] causes a loss increment of only 0.1 dB, due to the applied misalignment, while the same misalignment, when adopting ball grid arrays, would have implied missing the contact. This approach is quite attractive especially in combination with nonrigid materials where mechanical stress can result in significant substrate deformations. Recent contributions show the application of the aforementioned approach to inkjet printed antenna on PET substrate coupled to the chip for wireless nodes [86] and a textile patch antenna, magnetically coupled to the active circuitry, suitable for garment integration (see Fig. 9) [87], the reflection coefficient of which is shown in Fig. 10.

In order to testify the robustness of the proposed solution against uncertainties inherent to textile and garment electronics assembly, the radiation efficiency of the antenna, as a function of horizontal and vertical misalignment of the two transformer windings, used to perform the magnetic coupling, is plotted in Fig. 11(a) and (b), respectively. This technique can be extended also to interlayer communications of multilayer devices, and an example is documented in [88], where the circuitry fabricated on different garments communicates by means of overlapped coils.

V. CHIPLESS APPROACH

It has already been discussed that SS represents a possible technology for the development of killer applications within the IoT paradigm. Thanks to the convergence of several technologies, ranging from EH and sensing to RFID and LAE, SS can afford complex functions. For example, SSs can be used in intelligent buildings for structural monitoring and alarms (fire, for instance). To achieve these goals, SS must be equipped with a huge number of tags, each one monitoring a small portion of the surface itself.

The passive RFID systems can be divided into two families, namely, chip-based and chipless tags. The first family usually exploits a low-power complementary metal–oxide–semiconductor (CMOS) chip to implement the main tag functions [RF carrier rectification, dc voltage regulation, amplitude shift-keying (ASK) demodulation, IDentification code (ID) decoding, load modulation, etc.] and thus can be adapted to sensor applications by a few additional circuit blocks [signal conditioning,

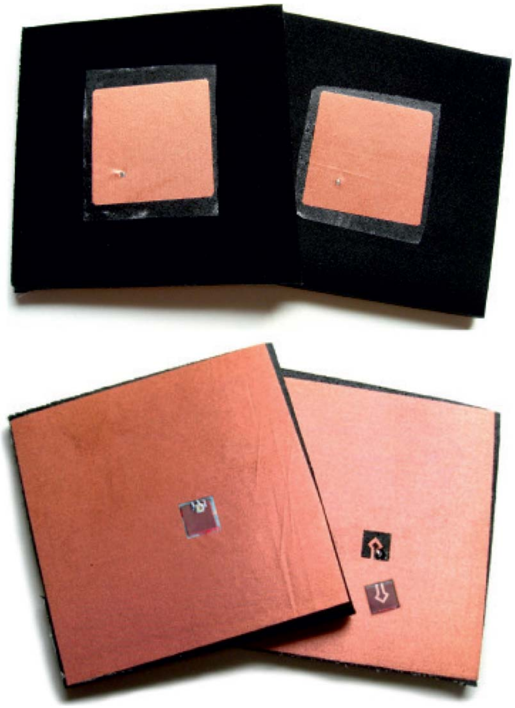

Fig. 9. ***Example of textile patch antennas operating at 2.4 GHz. The antenna and the ground plane are made of Flectron, a conductive textile, and the substrate is black foam. These materials are flexible and integrable in the garments. Magnetic coupling is exploited to connect the antenna and the active circuitry on flexible substrate. After [87].***

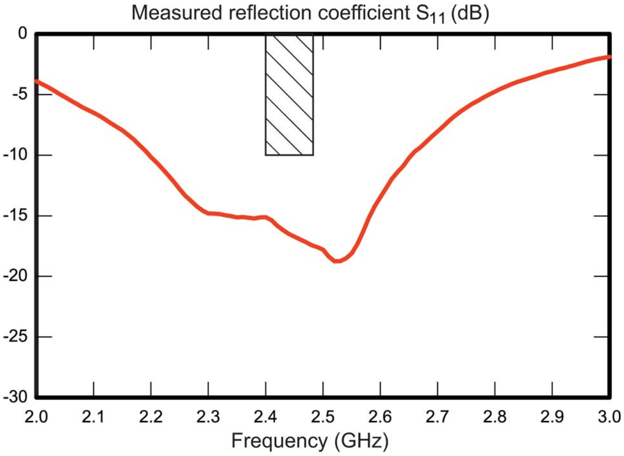

Fig. 10. ***Measured reflection coefficient of the previous textile antenna in the frequency band 2.4–2.48 GHz. After [87].***

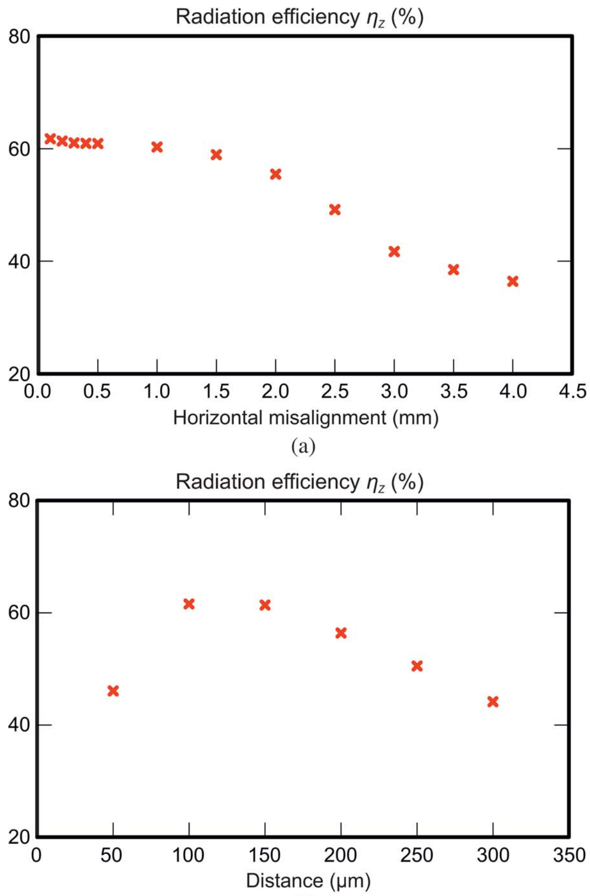

(a)

(b)

Fig. 11. ***Variation of the radiation efficiency evaluated versus (a) horizontal and (b) vertical misalignment between the antenna and the circuit windings. This test allows the robustness of the antenna performances against mounting uncertainties inherent to textile electronics to be evaluated at glance. After [87].***

analog-to-digital converter (ADC), etc.]. The main advantage of such an approach is the digital modulation of the transmitted signal, and thus the flexibility of the related data treatment, as shown in [89] and [90]. The production costs of chip-based tags are mostly associated with the heterogeneous integration of the silicon chip with the antenna [85], [91], the latter being manufactured typically on a flexible substrate or a textile substrate [92]–[97].

In order to reduce the aforementioned costs and to save as much energy as possible, solutions requiring minimum amount of electronics must be pursued. For this purpose, the chipless tag family was introduced and applied to wireless sensing in the recent years [98]–[103]. It is worth recalling here that the introduced buzzword "chipless" stands for a family of tags that are actually able to implement their functionalities by using only a few lumped components and passive distributed elements, without requiring any electronic integrated circuit (IC), the chip indeed, to be mounted.

The standard chipless tags (i.e., only coding and no sensing) exploit, basically, two mechanisms, namely, time-domain and frequency-domain scattering [64]. In the first case, the elapsed time between multiple reflections is used for coding. These reflections are obtained, at tag level, by connecting the antenna to a transmission line structure with several discontinuities. In the second case, instead, the tag has a specific frequency signature that is decoded at the reader level; to implement such a behavior, a coded series of resonators is realized on the tag antenna in order to reflect or not the corresponding frequency. Both approaches (time and frequency domain) lead to tag circuits that are not necessarily easy to miniaturize; nevertheless, it is worth noting that they are compliant with the LAE paradigm.

When dynamic sensor information has to be added to the static identification, we talk about chipless RFID sensor tags; these exploit an antenna, the electrical properties of which are controlled by the change of the physical parameter to be detected. There are, mostly, two proposed approaches for this. The first one is to induce a permanent change in the antenna property when a certain critical threshold (acceleration, temperature, fluid level, etc.) is exceeded [104]; this is useful for alarm type operations. The second one exploits a sensing load, i.e., a load the impedance of which is controlled by the sensed variable, connected to an antenna [105]. In both cases, the whole wireless sensor system (tag and reader) needs to have absolute accuracy, thus limiting the system performance with respect to both distance and fabrication tolerances.

A different method has been recently introduced in [106]. In this paper, a novel sensing principle is associated to the generation of an intermodulation signal from a tag, the latter being illuminated by two waves at different frequencies. The advantage of this idea is that the tag response is generated at a known frequency, thus the presence or the absence of such a signal can hardly be misinterpreted. Similar techniques have been used in harmonic radar systems [107] and in one-bit frequency doubling tags [108].

In line with the above ideas, a novel and completely original approach was proposed in [20] and [109] to solve the issue of absolute accuracy of the most of the passive chipless RFID sensors. The chipless tag described in [109] is based on the harmonic radar concept [110], [111], i.e., on a tag that, being illuminated by a carrier at frequency f_0, is capable of generating the second harmonic $2f_0$.

A simplified block diagram of the tag is illustrated in Fig. 12. For this purpose, the sensor information is encoded as the phase difference between two signals, one acting as the reference signal for the other one. First, the tag receives a carrier at frequency f_0. Then, two equal signals at frequency $2f_0$ are generated by means of a diode-based frequency doubler and a power divider. At this point, one of the two signals is phase-shifted using a passive sensing element. Finally, the $2f_0$ signals are reirradiated by

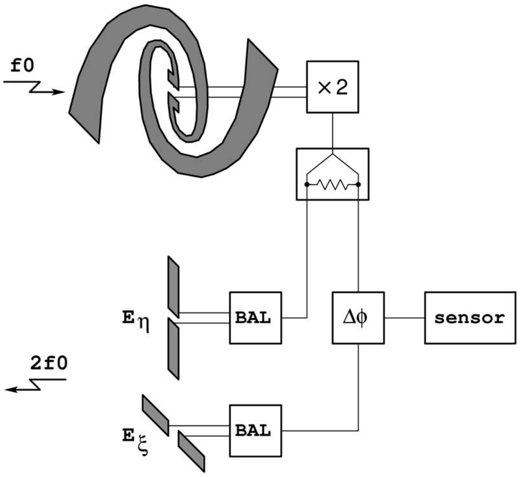

Fig. 12. ***Simplified block diagram of a harmonic chipless tag with sensing capabilities. After [109].***

exploiting two orthogonally polarized antennas. With this approach, the sensor information can be extracted by a suitable reader equipped with two complex (I/Q) receivers.

It must be observed that chipless tags, due to their inherent simplicity and extremely low number of lumped components, are easily realizable on flexible substrates by means of metal laminate [29], [30] and inkjet printing technologies. In particular, antennas [112], diodes [113], and passive sensing elements [114]–[117], i.e., all the main tag components, have already been experimented in cellulose-based materials. This will soon make SSs, equipped with sensing chipless tags, feasible at affordable prices.

VI. QUASI-OPTICS

"Quasi-optics concerns the propagation of EM radiation when the size of the wavelength is comparable to the size of the optical components (e.g., lenses, mirrors, and apertures) and hence diffraction effects become significant" [118].

In optics, operations are usually performed by using lenses. At EM frequencies, by following the quasi-optics analogy, lenses become large arrays, several wavelengths in size, of unconnected elements, each of them being able to get part of the signal incident on the array (usually focused by using a Gaussian beam), to carry out an operation and to irradiate the modified signal. The sum of the radiated signals modified by the array elements ends up in a radiated beacon elaborated with respect to the incident one [118]–[120]. From a historical point of view, quasi-optics was first introduced experimentally by Heinrich Hertz in the late 1880s [120] when he demonstrated the possibility of collimating EM signals on a multiwavelength surface by using cylindrical reflectors and studying effects that, until that time, were observed only at infrared and visible EM spectrum.

After more than 70 years, owing to the increasing demand for bandwidth and to the development of optical wavelength systems, quasi-optics experienced its palingenesis at the millimeter and submillimeter wavelengths.

We can classify the quasi-optical components into three main categories: frequency independent, frequency selective, and active devices. Frequency-independent surfaces include: delay lines, polarizing grids, hybrid junctions [121], attenuators [122], power dividers [123] and combiners [124], nonreciprocal devices [125], [126], absorbers, and calibration loads. Frequency-selective surfaces [127]–[129] include: inductive grids, capacitive grids, resonant grids, thick structures (perforated plates), and interferometers. Active devices include: oscillators [129], [130], amplifiers [131], [132], mixers [133], [134], phase shifters [135], [136], multipliers [108], [137]–[139], and switches [140]. This approach has been used so far mainly at millimeter and submillimeter frequencies because, being the size of the apparatuses proportional to the wavelength of the radiated wave, lower frequencies would have been prohibitive due to the very large size required. With the present development of technologies for LAE, however, quasi-optics has become a feasible approach even at RF and microwave bands, where large arrays of operational elements can be conceived.

Inheriting the quasi-optical approach, contact-less EM wave processing (filtering, frequency conversion, selective shielding, etc.) can be implemented even at low frequencies (in the order of megahertz). Two pioneer examples are switches [140] and the cross-dipole frequency doubler, proposed in [108], and implemented in [141], where, among various operating principles, the generation of harmonics is chosen to demonstrate the feasibility of such a component at microwave frequencies.

The layout of the proposed quasi-optical frequency doubler is shown in Fig. 13. The structure is inkjet printed on a cellulose-based substrate (a piece of photografic paper from Kodak). It consists of two crossed $\lambda/2$ dipoles. The longest dipole receives the incoming power at the fundamental frequency $f_0 = 3.5$ GHz, while the shortest one transmits the generated power at the doubled frequency $2f_0$ in an orthogonally polarized orientation. The length of the dipole operating at f_0 is 32 mm, while the $2f_0$ dipole is 16 mm long. The width of the tracks used to implement the dipoles is about 2 mm. The multiplication is provided by four diodes in a bridge configuration, thus forming a fully balanced multiplier unit.

Due to the omnidirectional nature of the dipole antenna, the harmonic signal is irradiated with the same intensity in the azimuthal plane (small differences are due to both the dielectric substrate and the planar nature of the dipole conductors). This means that the harmonic signal is reflected toward the reader and the transmitter toward other directions at the same time. A measurement of the received power at $2f_0 = 7$ GHz is reported in Fig. 13(b). Here the interrogation distance is 10 cm and the

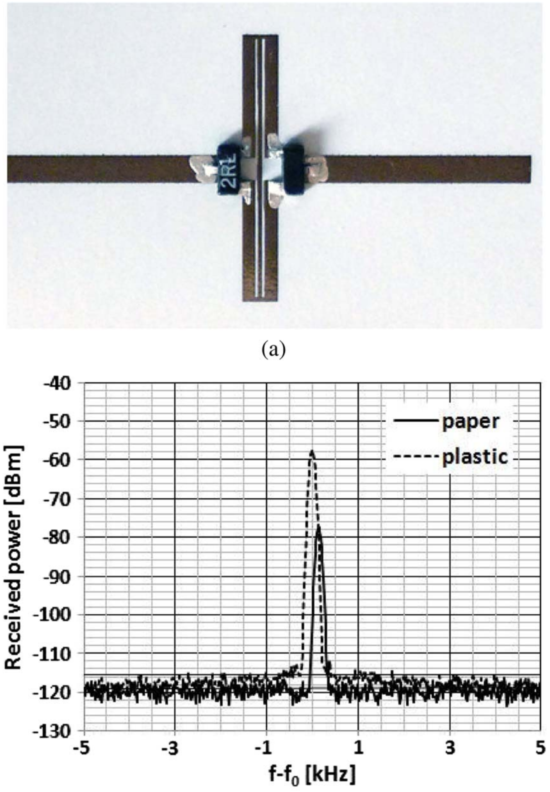

(a)

(b)

Fig. 13. ***Cellulose-based prototype of the (a) crossed-dipole frequency doubling tag and (b) measured second-harmonic response. The measurements have been carried out interrogating the tag at $f_o = 3.5$ GHz and receiving the $2f_o = 7$ GHz frequency component. The interrogation distance is 10 cm, and the transmitted power is equal to 20 dBm. The transmitter is equipped with a two-element Yagi antenna at f_o, while the receiver uses a helix antenna at $2f_o$. The fundamental frequency dipole is 32 mm long. After [141].***

transmitted power is equal to 20 dBm. The transmitter (reader side) is equipped with a two-element Yagi antenna at f_0, while the receiver (reader side) uses a helix antenna at $2f_0$. In these conditions, the power received from the cellulose-based (paper) tag prototype at $2f_0$ is about -80 dBm. The same structure implemented on a plastic substrate produces more power, mainly because of a better frequency tuning. An improved efficiency could be achieved by: 1) adopting a frequency multiplier with better harmonic terminations; and 2) using directive antennas in order to address the power only toward the reader.

In the frame of the IoT, the crossed-dipole tag is a very simple one-bit tag that can alarm a system when it is placed within the range of the reader. However, with very simple modifications, this idea can be used to implement a variety of on/off sensors (the paper substrate can be easily torn when a certain mechanical strain is exceeded).

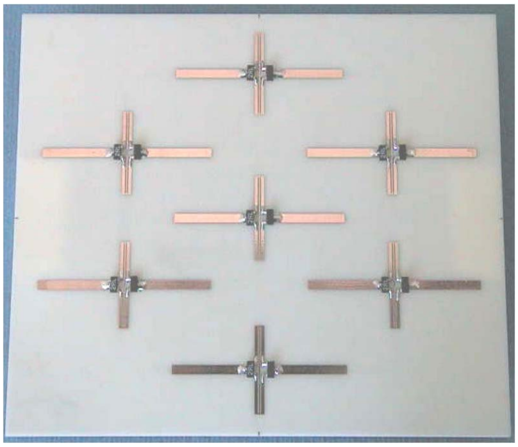

Fig. 14. ***Example of quasi-optical frequency doubler based on an array of crossed dipoles. This structure is implemented on a Rogers substrate, but this can be substituted with a cellulose-based material to reduce costs and obtain mechanical flexibility.***

The crossed-dipole structure can also be used as a building block to form arrays, an example being shown in Fig. 14. These arrays are mainly intended for LAE applications where a complete surface can be interrogated and answered by generating a harmonic signal. The fabricated prototype uses a Rogers substrate, thus it is not flexible. However, adopting a cellulose-based substrate, a flexible structure can be built. The bending capability of cellulose-based circuits is quite good and only limited by the discrete components mounted on them.

The second example consists of a paper-based contactless frequency doubler for harmonic RFID applications [142]. The doubler, realized on paper substrate, generates the harmonic signal by means of a single Schottky diode. The system operates at 7.5 and 15 MHz, and these frequencies are chosen, without lack of generality, to accomplish the realization of a fully organic frequency doubler exploiting paper printed coils and organic diode (pentacene-based), the present frequency limit of which is around 15 MHz [143]. Fig. 15 shows a picture of the organic tag, while Fig. 16 shows the doubling efficiency of the organic tag versus transmitting/receiving (TX/RX) distance, assuming TX power as a parameter (for the sake of completeness, it is worth noting that TX and RX antennas of the reader are equal to the RX and TX antennas of the tag, respectively).

As a final remark, it is worth noting that, to the authors' knowledge, only planar developments of quasi-optical arrays have been proposed so far; reasonably, combining quasi-optics with LAE related technologies can lead, in the near future, to new SS solutions only in a limited planar extent.

VII. SMART FLOOR

The new concept of smart cities is generating a group of new scenarios that will impose a new way people interact with the environment. This immersion brings the IoT to a new level of relationship with people and environment,

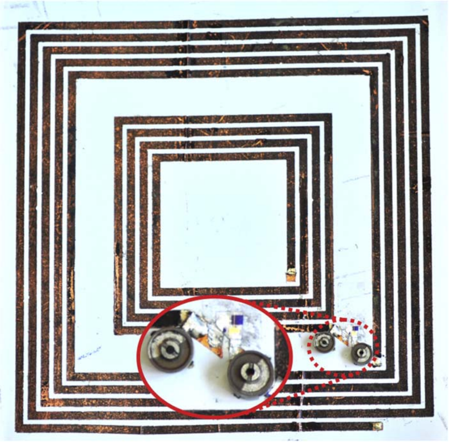

Fig. 15. ***Fully organic tag prototype of the frequency doubling tag operating at 7.5–15 MHz. After [142].***

where the scenario around is aware of people's needs and can interact with their way of living.

This new concept brings IoT to areas that cover broad topics, including transportation, energy distribution, data communications, and all technologies in a sense that they will become transparent to the normal users and citizens.

The growth of smart cities will significantly increase the quality of life, the reduction of energy waste, and the availability of information by using ICT. All these developments have, as a motivation, the overall inclusion of people into the city in a way that ICT should become completely embedded into our surroundings.

These new concepts are viable only if the smart environments are enabled by IoT. IoT is actually taking shape and is growing everyday through the number of devices that get connected to each other.

Nevertheless, most of these devices that team up with each other to build up the IoT world are powered by some kind of power sources. This is actually the main limitation of present IoT solutions. In order to be able to create real IoT environments, RFID, wireless power transfer (WPT), and EH devices appear as a major enabling technology for the IoT, due to their inherent simplicity and ability to provide sensing to remote objects without the need for constant powering.

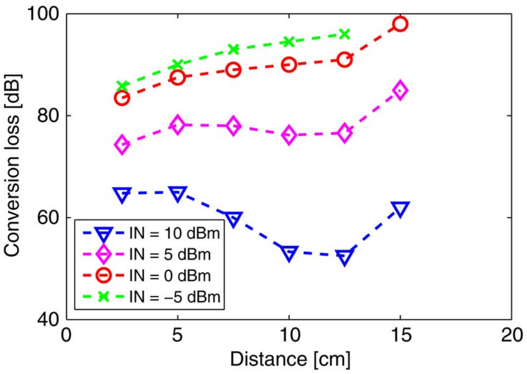

Fig. 16. ***Conversion (doubling) loss of the reader tag harmonic RFID system as a function of the reader tag distance, assuming the output reader power as a parameter. After [142].***

In this scenario, the concept of a smart floor becomes real. Smart floors should be capable of interacting with the environment seamlessly and be aware of persons and objects on top of them.

The focus of this section is going to be smart floors as an information system, where RFID capabilities are used to provide an identification and information source embedded into the floor. This massive RFID immersion will allow to create low-power high accuracy location, navigation, and, generally speaking, an information system that can team up with passers in a noninvasive way.

In this approach, the system uses passive RFID tags that are spread beneath a flooring in order to create a map that can be read with a mobile unit that might be self-powered through energy harvested from the movements of the subject to be located [144], [145].

This new location system based on smart floors can actually be extremely competitive when compared with existing solutions; among them, we can take into consideration those based on image processing [146]; they provide a high level of information at the price of high cost, power consumption, and intrusiveness. Another approach is based on pressure sensors [146], [147], providing actually a different type of smart floors; pressure sensors are nonintrusive and can be less expensive in terms of equipment when compared to the imaging systems; however, they can still be quite expensive to install into the floors; moreover, they do not allow for seamless identification of an individual in a given space. Eventually, ultrasounds [148] and RF localization system detection [149] have to be listed; although very flexible, they require dedicated communication infrastructures, additional complexity and costs, and they are mostly sensitive to environmental changes, both in terms of accuracy and functionalities.

The just mentioned smart-floor-based system tackles most of these challenges as it is very low cost, able to have a good, and precisely predictable, accuracy, and able to detect different users in a given space.

A. RFID-Based Smart Floor Including Material Aspects

Smart environments and floors should be completely seamless to the users. This entails the need to embed electronic devices into the environment in a noninvasive way. Nevertheless, this embedding of electronic devices, mainly wireless transceivers into the floor, is not a simple matter. Floors, in fact, have been made by almost the same kind of materials for centuries; tile industries are weakly available to introduce new materials to match

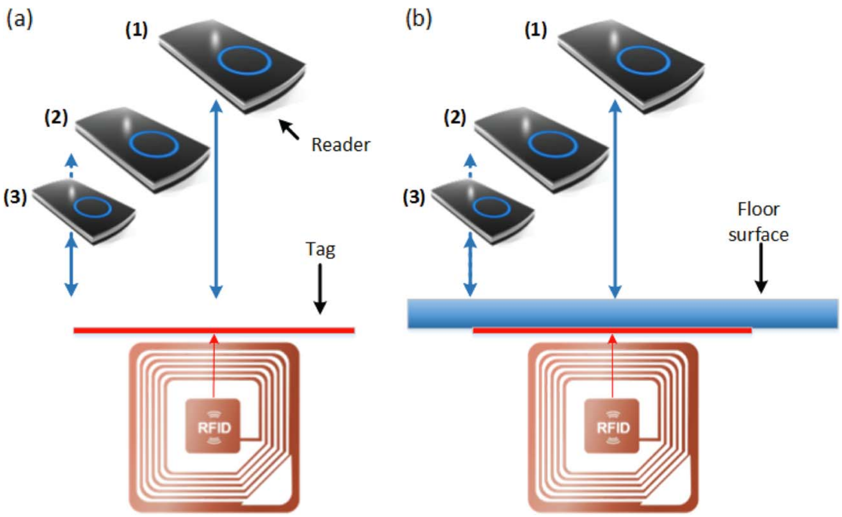

Fig. 17. ***Readable distance test scheme (a) without and (b) with tile. After [144].***

requirements posed by embedded electronics. Similar considerations can be made about the consolidated techniques to build apartments and houses: they are quite mature and whatever adaptation of them to embedded electronic systems is unrealistic. The consequence of this is that constitutive elements of SSs embedded into the floors must be suitable to materials and technologies already present: materials available are those adopted for tiles and SSs must be adapted to building constraints.

In this section, we focus on the most important approaches for the characterization of the EM properties of the materials, commonly adopted in floors, and their interactions with our electronic radio systems. As an example, ceramic tiles are going to be selected as the floor element where electronic tags have to be embedded.

Ceramic tiles have been used for ages to pave floors. These make up a great deal of most floor types in public buildings, from airports to banks, therefore, they are the most interesting flooring elements to investigate.

As the first approach, the study of the influence of some materials for floor surfaces, such as ceramic, cork laminates, and wood, in the communication between the transmitter and receiver devices has to be made; in this case, low-frequency (13 MHz) inductors are going to be used as the wireless interface.

In order to do the measurements, traditional RFIDs are used, which simplify the measurement approach significantly. A test setup is shown in Fig. 17, and experimental results are summarized in Table 3. What can be seen from the results presented in the table is that none of the tested materials affect the electrical characteristics of the RFID propagation significantly.

Another approach to the measurement is to evaluate the impact of the presence of metal inclusions beneath the ground; these can appear from pipes or from buildings supporting structures. In order to test this scenario, the presence of a metal sheet close to the coil was tested to verify its impact on the RFID reading distance. The test setup is presented in Fig. 18. In this case, when the reader is aligned (1) with the center of the coil beneath the tile, a minimum distance of 10 mm between the metallic sheet and the tag must be guaranteed in order to allow for the proper reading of the tag. In the other approach, the edge aligned scenario (2), the minimum distance between the metallic sheet and the tag increases to 30 mm to allow for communication.

Table 3 Results From Average Readable Distance Test

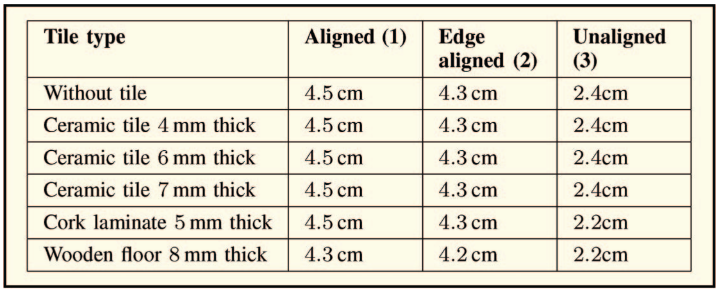

Tile type	Aligned (1)	Edge aligned (2)	Unaligned (3)
Without tile	4.5 cm	4.3 cm	2.4cm
Ceramic tile 4 mm thick	4.5 cm	4.3 cm	2.4cm
Ceramic tile 6 mm thick	4.5 cm	4.3 cm	2.4cm
Ceramic tile 7 mm thick	4.5 cm	4.3 cm	2.4cm
Cork laminate 5 mm thick	4.5 cm	4.3 cm	2.2cm
Wooden floor 8 mm thick	4.3 cm	4.2 cm	2.2cm

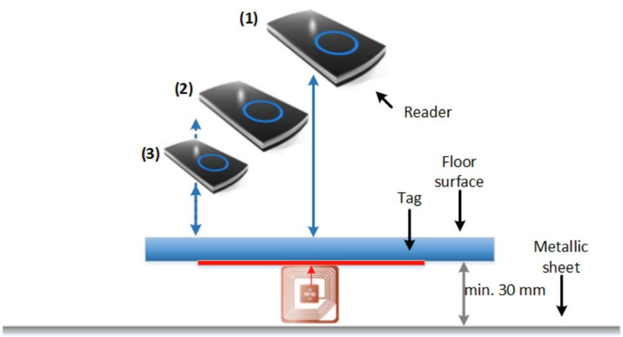

Fig. 18. ***Readable distance test scheme with metallic sheet presence. After [144].***

This test allows us to conclude that, in a real scenario, when considering the typical distance from the antenna to the floor, where the reader is usually embedded into a mobile device, a minimum distance from the tile to any metal inclusions in the ground has to be guaranteed. As seen, this safe distance should be at least 30 mm.

B. Navigation Approach Based on Smart Floors

A meaningful example of the applications of the smart floor concept is the demonstrator developed at the University of Aveiro, Aveiro, Portugal. It allows a nomadic RFID reader on top of it to be identified and localized by means of a smart floor.

The prototype in the present state is composed of four main components: a set of tagged tiles forming the smart floor, the nomadic reader, a wireless communication device to connect the reader to the information system, and a computer on which the location and navigation software is installed. A potential scenario of application for the monitoring of elderly housing is shown in Fig. 19. In the demonstrator presented, the RFID reader is connected to the radio unit and inserted into the user's shoes in order to read the passive tags as the user walks around a given area. The tile IDs are detected by the reader and sent to a centralized information system using, without lack of generality, a nonstandard wireless communication system, purposely developed in the laboratory.

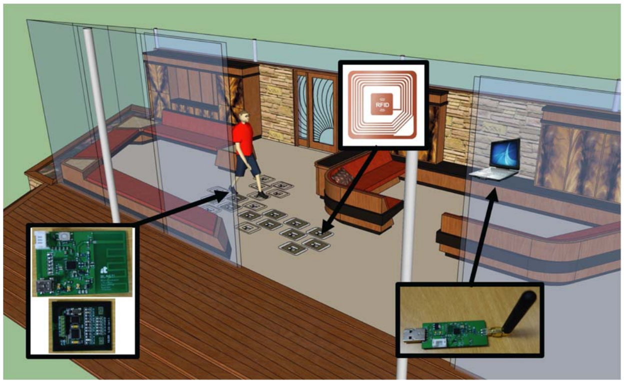

Fig. 19. ***Example of smart floor application scenario.***

The software in the computer then decodes the ID of the smart tile, and correlates it with a preloaded referenced map, thus being able to provide the precise position of the walker in the environment.

The location can be subsequently translated to a navigation system, and combined with artificial intelligence to allow navigation, situation awareness, etc.

Plenty of applications and related solutions can be envisioned on the basis of this smart floor approach: robot control, automatic pallet managements, prevention in harsh environments, and so forth.

VIII. SMART SHOES AND BAN

The aforementioned smart floor (Section VII), initially proposed to localize moving subjects in a given area, actually allows for the implementation of a very low-cost, accurate, and reliable system able to provide each kind of detectable information from an equipped area to the Internet.

To exploit the potentiality of a smart floor, it is obvious that developing purposely conceived communication units acting, on the one hand, as readers for tag tiles and, on the other hand, as communication systems with the web is needed.

One of the investigated systems for this is the so-called smart shoe [21]. Smart shoes are intended as shoes incorporating a reader able to illuminate the tag embedded into the tile and a wireless interface to communicate data to the web. To this extent, smart shoes can be seen as hubs of BANs able, on the one hand, to get information from the surrounding environment (body included) and, on the other hand, to communicate the collected information to the Internet. According to common buzzwords, they can be seen as the second technological layer, just above the first physical one consisting of tagged objects, in a hierarchical picture of IoT. Alternatively, they provide the cloud of nomadic readers with networking capabilities required for the implementation of the so-called networked RFID (N–RFID) [150] strategies. In the referred structure [21], the necessary antenna system is inkjet printed on paper, thus exploiting the process described in Section II, and it is a trademark-logo-shaped dual-band antenna working at 900 MHz and 2.4 GHz. A block diagram and its equivalent realization are shown in Fig. 20: it is worth noting that the reader itself works at 13.5 MHz exploiting the near-field communication (NFC) concept, according to what is stated in the smart floor section; as a consequence, there are no issues about the interference between the dual-band antenna and the NFC reader. Moreover, an approach similar to [145] is proposed to power the reader: the idea here is as well to harvest the energy produced by the human walking by means of piezoelectric materials embedded into the sole of the shoe.

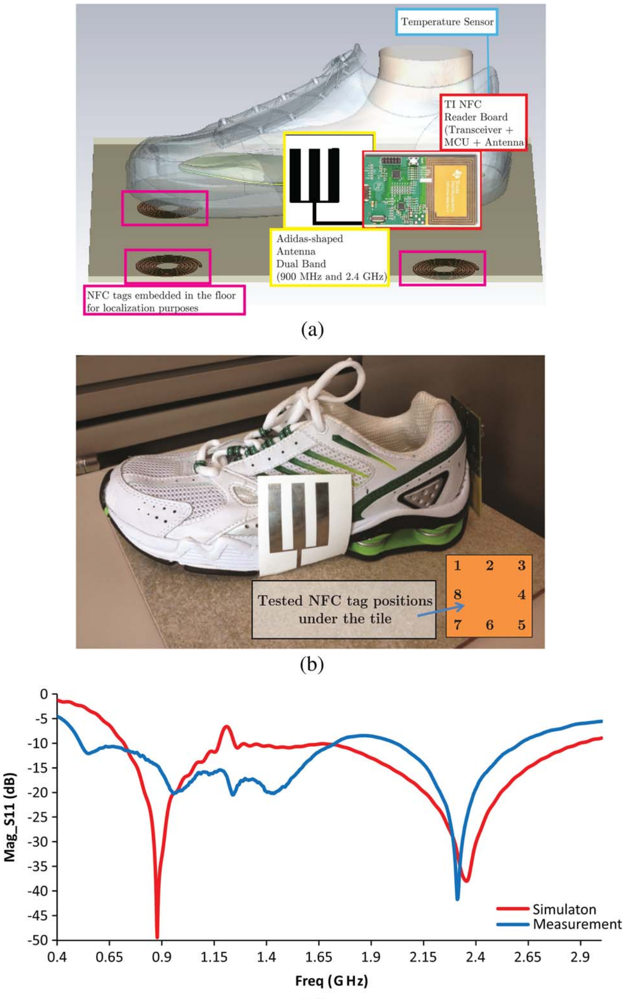

(c)

Fig. 20. ***(a) Block diagram, (b) photo, and (c) dual-band antenna results of the smart shoe that works as an energy autonomous reader for smart floors able to collect the localization data from the smart tiles and send them to a centralized system. After [21].***

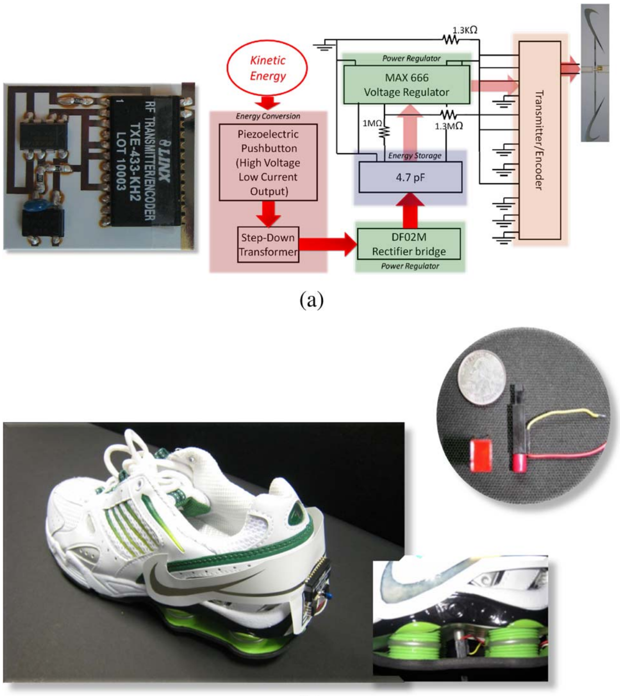

(b)

Fig. 21. ***(a) Mounted electronics on shoe with piezoelectric energy harvester and block diagram of the transmitting tag, driven by the EH unit. (b) Photograph of the assembled prototype showing the key components packaged on an organic flexible substrate. After [145].***

Fig. 21(a) shows the shoe with the mounted electronics consisting of a trademark-logo antenna inkjet printed on a flexible paper substrate together with the circuits in which the components [Fig. 21(b)] are fixed by conductive epoxy glue. A piezoelectric push button was embedded in the shoe to scavenge energy from human walking strike. This energy is then collected by a simple electronic circuit based on off-the-shelf components and used to supply the RFID transmitter. As reported in [145], the system is composed by the power-generator/energy-conversion device, the energy storage device, the power regulator circuit, and the RF transmitter that can broadcast the tag ID and the stored information.

When the push button is pressed, an inner spring is compressed and when the pressure exceeds a fixed threshold, the spring-loaded hammer will be released to deliver the dynamic mechanical force to the piezoelectric component; once the hammer strikes the piezoelectric element, a pressure wave is generated and reflected a few times between the hammer and the element, creating a mechanical resonance [151]. As a result, the generated output voltage follows closely an alternating current (ac) signal course. The signal out of the piezoelectric element is characterized by high voltage and low current; therefore, since this RF circuitry requires lower voltages at higher currents, a step-down transformer is used for better impedance matching to the following circuitry.

An energy storage device is adopted to collect the electrical energy and to provide it to the transmitter even when the external power source is temporarily unavailable; in fact, the RF transmitter takes tens of milliseconds to transmit one complete word, while the piezoelectric push button harvests energy in a transient time. To store the collected energy, a 4.7-μF tank capacitor was chosen. An ac–dc full wave diode bridge rectifier is used to convert the ac voltage from a piezoelectric element into a dc source and a dc linear regulator is added to adapt the dc voltage across the capacitor to 3-V transmitter operating voltage. For this purpose, a MAX666 low-dropout linear regulator, providing a stable 3-V supply until the tank capacitor charge is drained below the reference level of the dc linear regulator itself, is chosen. The transmitter used, the LINX

Table 4 Shoe Energy Performance Summary

Energy provided by the pushbutton	stored in the capacitor	848.4 μJ
Utilized energy	below 2.7 V capacitor voltage, the active RFID tag stops transmitting	17.1 μJ
Available energy	848.4 μJ − 17.1 μJ	831.3 μJ
Energy required by the circuit for a one-word transmission	Power Needed for 50 ms operation: 9 mW	450 μJ

TXE-433-KH2 [152], is able to combine a highly optimized RF transmitter with an onboard encoder.

The maximum voltage across the capacitor is 19 V; therefore, the energy stored in the capacitor can be calculated to be close to 850 μJ. After the strike, the regulator becomes active, providing power to the tag circuitry; its 3-V output remains constant before it starts to drop to zero according to the capacitor discharge rate. When the voltage across the capacitor drops below 2.7 V, the active tag stops transmitting. The resulting energy left in the capacitor and not used is about 17 μJ. The required time for successful completion has been measured to be close to 50 ms; the total circuit energy consumption for a 50-ms transmission is then approximately 9 mW (Section IV). Consequently, the energy required for a one word transmission is approximately 450 μJ, much less than the power collected by the energy conversion and regulation unit. The energy performance of the smart shoe is summarized in Table 4.

"Smart" solutions like smart shoes are suitable for smart floor interaction and for collecting information (position included) from them. The smart shoe has actually a double functionality: on the one hand, it is a means to collect information from the environment (smart floor included) and from the on-body sensors and apparatuses; on the other hand, it transfers data to the Internet, via WiFi, for instance, while likely receiving control and feedback signals. To this extent, it contributes to the development of wearable electronics for body-centric communication systems, according to the scheme of Fig. 22. This class of devices is based on the BAN concept (see Fig. 22): a network of wearable computational units, sensors, energy harvesters, and transceivers networked and implemented around the human body. The information is acquired by means of several sensors and, after processing and digital modulation, is transmitted by means of off-body transceivers. The most attractive application of BANs and wearable systems, so far, is probably health monitoring [88], but the number of foreseeable applications is constantly increasing (personal fitness monitoring, personal audio system, personal alarm set, and so on). Today, a big contribution to the BANs is being given by the interaction with portable devices such as smartphones which can be exploited as gateways.

Low-power ICs, sensors, and wireless communications are key elements of the BANs, and the use of EH techniques and mixed technologies such as RFID, as in the above described smart shoe, can contribute to the development of autonomous BANs. According to the notation adopted in [74] and [153], BANs can exploit wireless communication not only for off-body communications with other systems, but also for on-body and in-body communications to interconnect networked devices [wireless body area networks (WBANs)]. Generally, the proposed WBAN solutions are based on existing communication standards; but, recently, the IEEE 802.15.6 working group has provided a standard for short-range, wireless communications in the vicinity of, or inside, a human body based on ISM bands for BANs [154]. In this rapidly evolving scenario, smart shoes can be seen, in turn, as a promising mean to interface information coming from smart floors to the BANs and ultimately to the Internet, directly or via portable devices.

IX. ENERGY SKIN

Within SSs, another area is emerging, which requires dc energy. The availability of devices that can actually increase the battery life of our electronic gadgets [155] is the holy grail of IoT; the idea is actually to convert energy from

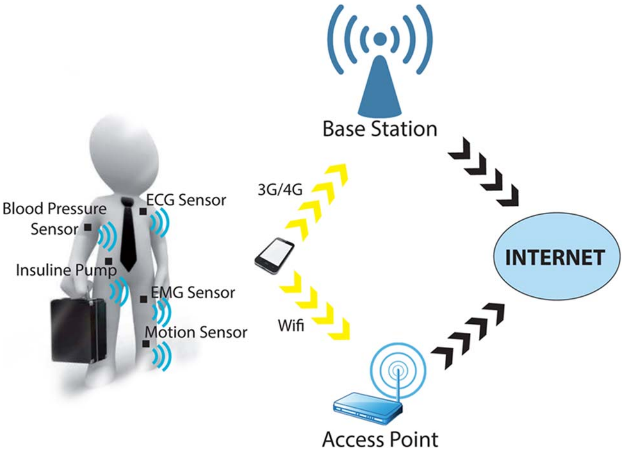

Fig. 22. ***BAN integrated with IoT: the data sensed on the human body and collected by smart devices are sent to the Internet through the standard protocols like third generation/fourth generation (3G/4G) and WiFi.***

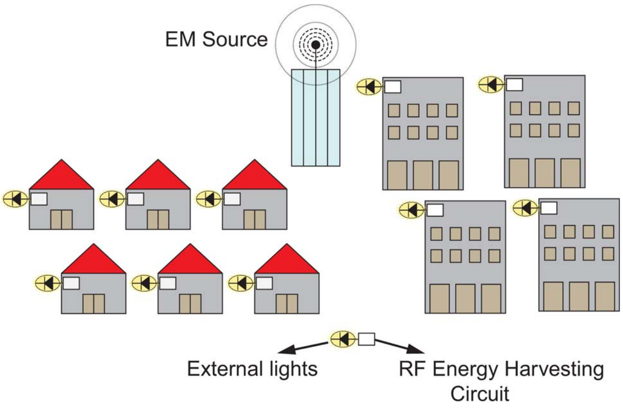

Fig. 23. *EM source, likely supplied by solar energy in order to keep eco-friendliness, is used to broadcast energy to the urban neighborhood where houses are equipped with local RF–dc converters able to power supply local devices (external lamps in the example).*

different sources, as solar to dc [156], EM radio signals to dc, thermal to dc [156], vibration to dc [157], etc. [158].

Portable converters from solar to dc are today commonly available on the market at very low prize. Similar portable scavengers can be easily envisioned even for other energy converters. On this basis, plenty of sophisticated and more complex solutions are being proposed. Just as an example, we report the solution in Fig. 23, where the solar energy is used to supply an EM source that broadcasts RF energy in the surrounding urban environment; this energy is converted to dc energy at building level and, in turn, exploited to supply external local lamps. This approach was conceived for space applications [159], [160], but could be used in certain conditions in earth stations as well. The concept can actually move forward and be integrated into a smart skin, in the sense that all devices could be powered up by the skin energy conversion that a person can carry (vibrational, thermal, RF, etc.). This will become possible by integrating paper and textile radio electronic circuits in the smart skin surfaces of our clothes.

X. CONCLUSION

This paper focused on smart surfaces concept. This concept was introduced as a way to provide solutions to societal instances by means of technologies and techniques that today are gaining great momentum thanks to IoT development. The foreseeable IoT evolution, in fact, calls for systems and subsystems that are more and more energy conservative, fully autonomous (battery-less and not connected to the grid), as recyclable as possible (ultimately 100% biodegradable), flexible, and extremely low cost to be embedded in as many objects as possible. In order to meet these expectations, several technologies have to be implemented concurrently. This paper illustrates some of them, namely, recyclable and reliable materials, printing and R2R compatible techniques, conformal antennas on unconventional materials, and chipless RFID.

Subsequently, it has been shown how these technologies enable a fairly new branch of IoT development, represented just by SSs.

SSs are in their infancy; nevertheless, some examples, enabled by the aforementioned technologies, can be cited. Among them, the way to inherit "quasi-optics" and extend them to RF frequencies even below gigahertz is shown, and the smart floor implementation as a means to provide precise localization as well as assisted paths platforms has been reported. Energy skin as a means to convert several energy sources (solar, thermal, vibrational, EM, etc.) in electric one is described as well.

The reported examples must be researched as a new paradigm for potential promising developments aiming at providing new LAE solutions for the future networked society. ■

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Mr. Roselli was the Chairman of the VII Computational Electromagnetic in Time Domain Workshop in 2007. In 2013, he was the Chairman of the First IEEE Wireless Power Transfer Conference (WPTC). Currently, he is member of the list of experts of Italian Ministry of Research and University (MIUR); member of several IEEE Technical Committees [MTT-24 RFID Technologies (past chair), MTT-25 RF nanotechnolgies, MTT-26 Wireless Power Transfer]; member of the Sub Committee 32 RFID Technologies of International Microwave Symposium (IMS) (past chair); member of the European Research Council (ERC) Panel PE7; member of the Advisory Committee of IEEE WPTC. He is involved in the boards of several international conference (RWCOM, RFID-TA, EuCAP, MAREW). He is a reviewer for many international conferences and journals (the PROCEEDINGS OF THE IEEE, the IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS, *ACES Journal*, *Radioengineering Journal*, Hindawi publishing corporation, *Elsevier Organic Electronics*, *ASP Nanoscience and Nanotechnology Letters*).

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RFID READER DETECTOR AND TILT-SENSITIVE RFID TAG

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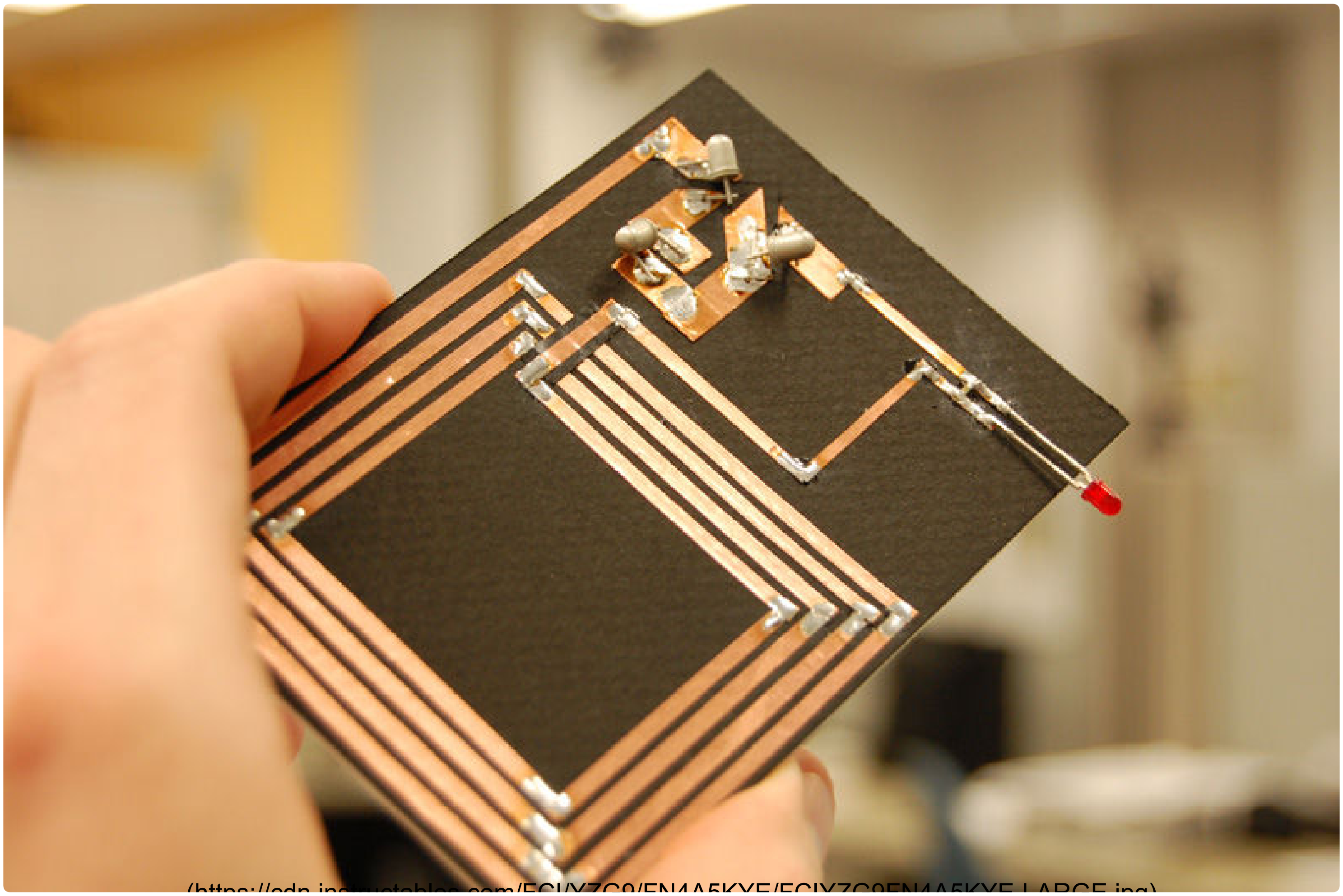

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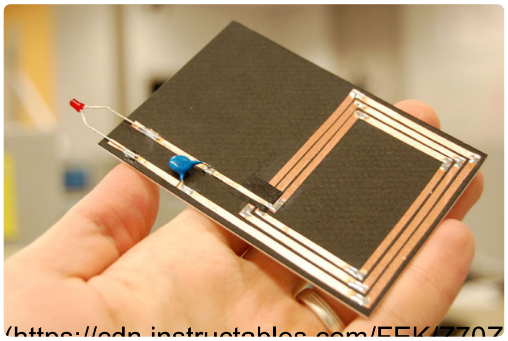
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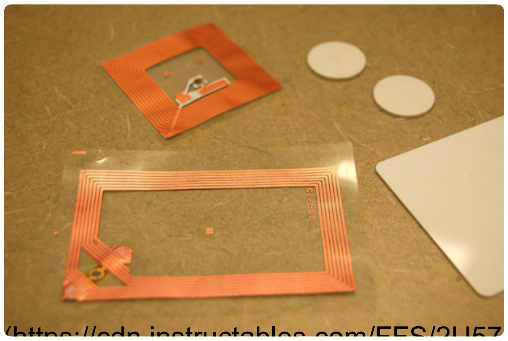
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The 'rub' (http://www.usingenglish.com/reference/idioms/there%27s+the+rub.html)
Want to detect the presence of RFID readers? Want to control when a RFID tag is active or readable? We describe how to do both using bits of copper and card, and some readily available electronics hardware.

Longer preamble
Radio frequency identification (RFID (http://en.wikipedia.org/wiki/RFID)) is rapidly growing in popularity. RFID *tags* are found everywhere. They're attached to container freight, in those funny-looking white labels you find in newly purchased books, embedded in many corporate ID cards and passports, etc. The tags have a few common properties: they transmit a unique ID number, are optimized to be 'read' from predefined distances, and are usually small so they can remain unobtrusive or hidden.

RFID *readers* are used to track nearby tags by wirelessly reading a tag's unique ID (see Figure 4); a tag simply has to be brought into physical proximity with a reader to be read. Readers are mostly used for industrial or commercial purposes, e.g. asset tracking or electronic payment. Wal-mart use RFID tags and readers in their supply chain. The technology is also used in mass transit systems in cities like London (http://en.wikipedia.org/wiki/Oyster_card) and Hong Kong (http://en.wikipedia.org/wiki/Octopus_card). In Japan, many mobile phones incorporate readers to enable e-money payments in shops and vending machines.

For those of us who want to experiment with RFID, the problem is that the technology is almost always □black boxed (http://en.wikipedia.org/wiki/Black_box).

That is, the inner workings of a tag and its interaction with a reader is hidden from view, and thus difficult to have much control over.

In the two exercises that follow (building a RFID reader detector (https://www.instructables.com/id/SX28QZ1FN4H8QCG/) and a tilt-sensitive RFID tag (https://www.instructables.com/id/SGW3J0SFN49WUIF/)), we offer an example of how you can start revealing some of the workings of RFID and thus gain some control over the technology. The two exercises also hopefully show that the technology is relatively simple and how it can be extended to support some interesting interactions. We offer some other possibilities that build on our examples at the end (https://www.instructables.com/id/SQKIRD4FN49ZUS1/).

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Step 1: Material and Tools

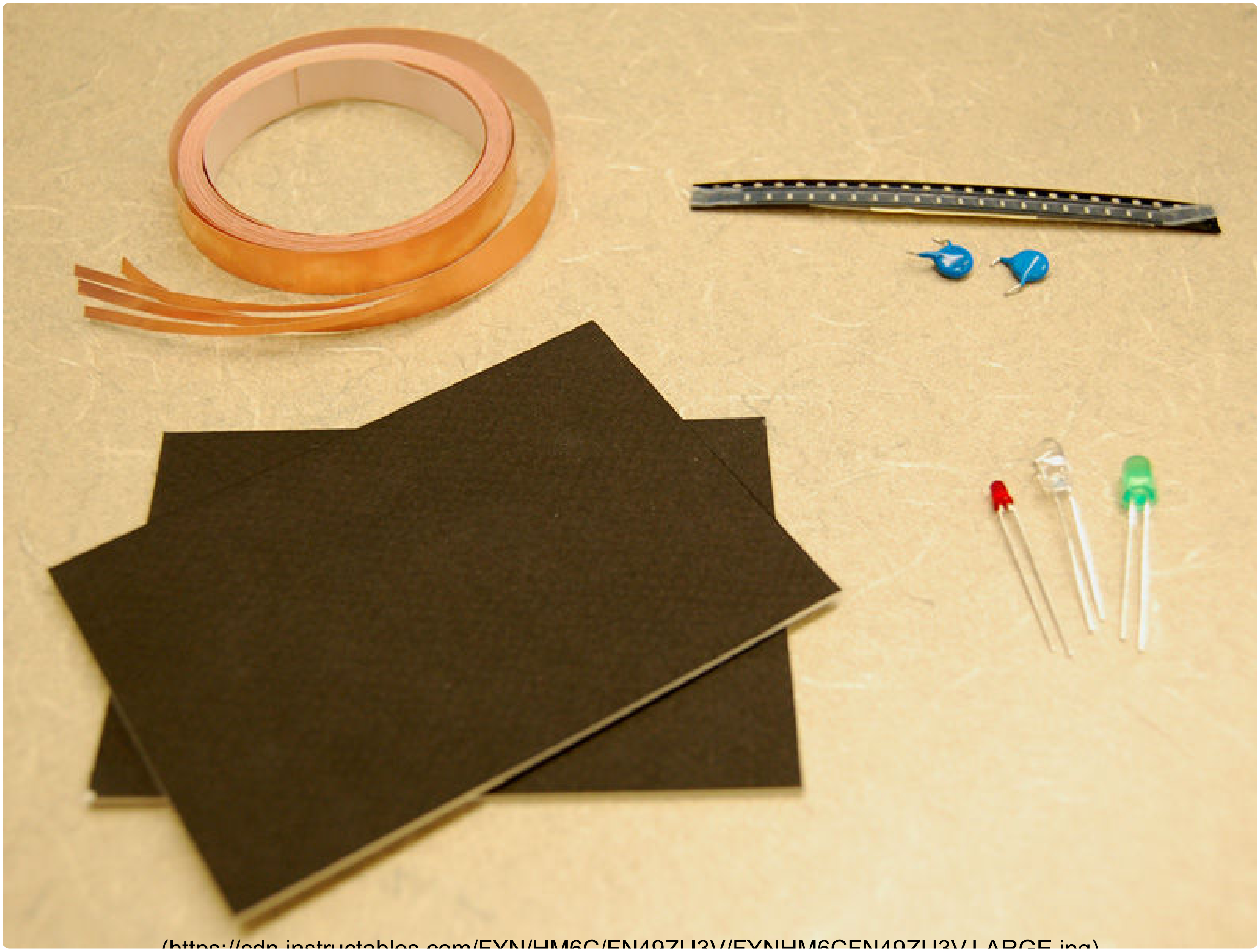

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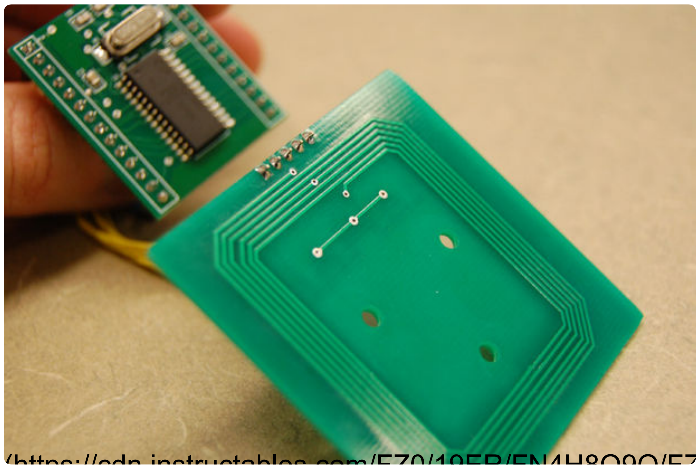

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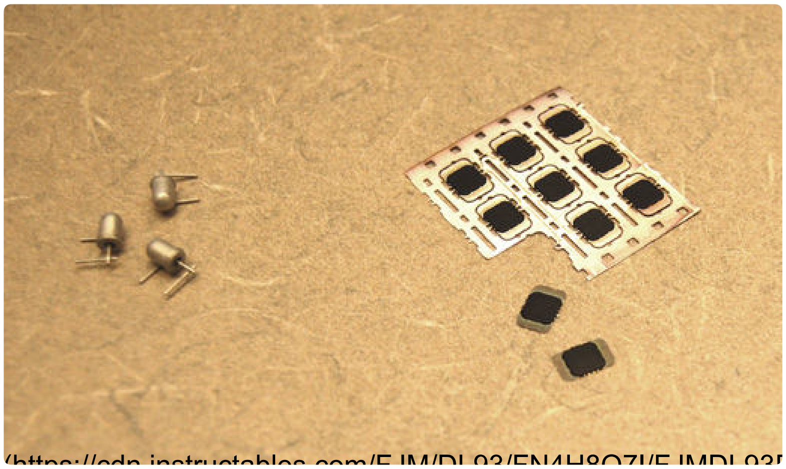

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This section provides an overview of the necessary materials and tools.

Materials (see Figure 1):
We need the following material to built the basic RFID reader detector.
- Cardboard (around 100x70 mm)
- Conductive copper tape (e.g., order number 1218478 at www.farnell.com)
- Capacitor 82 pF (picofarad) (e.g., order number 1138852 at www.farnell.com)
- Low current LED (light-emitting diode) (e.g., order number 1003207at www.farnell.com)

Tools (see Figure 2 and 3):
- Craft knife and scissors
- Insulating tape (e.g., order number 1373979 at www.farnell.com)
- Soldering iron and solder

RFID reader for testing (see Figure 4):
To test our RFID tags we need an RFID reader that can operate at a frequency of 13.56 MHz.
There many readers for this widely used RFID standard, for instance the Sonmicro MIFARE USB reader (http://www.sonmicro.com/).
Note: The Phidget RFID reader does *not* work with the tags created in this project, as it uses a different frequency for communication with the tags (125 kHz).

Advanced material (see Figure 5):

The following material is necessary to build the second part of the project: the tilt-sensitive RFID tag.

- Micro tilt switches (e.g., www.digikey.com)
- RFID ICs (e.g., MIFARE Standard 1k, part no. 568-2219-1-ND at www.digikey.com)

Add Tip Ask Question

Step 2: Building the RFID Antenna

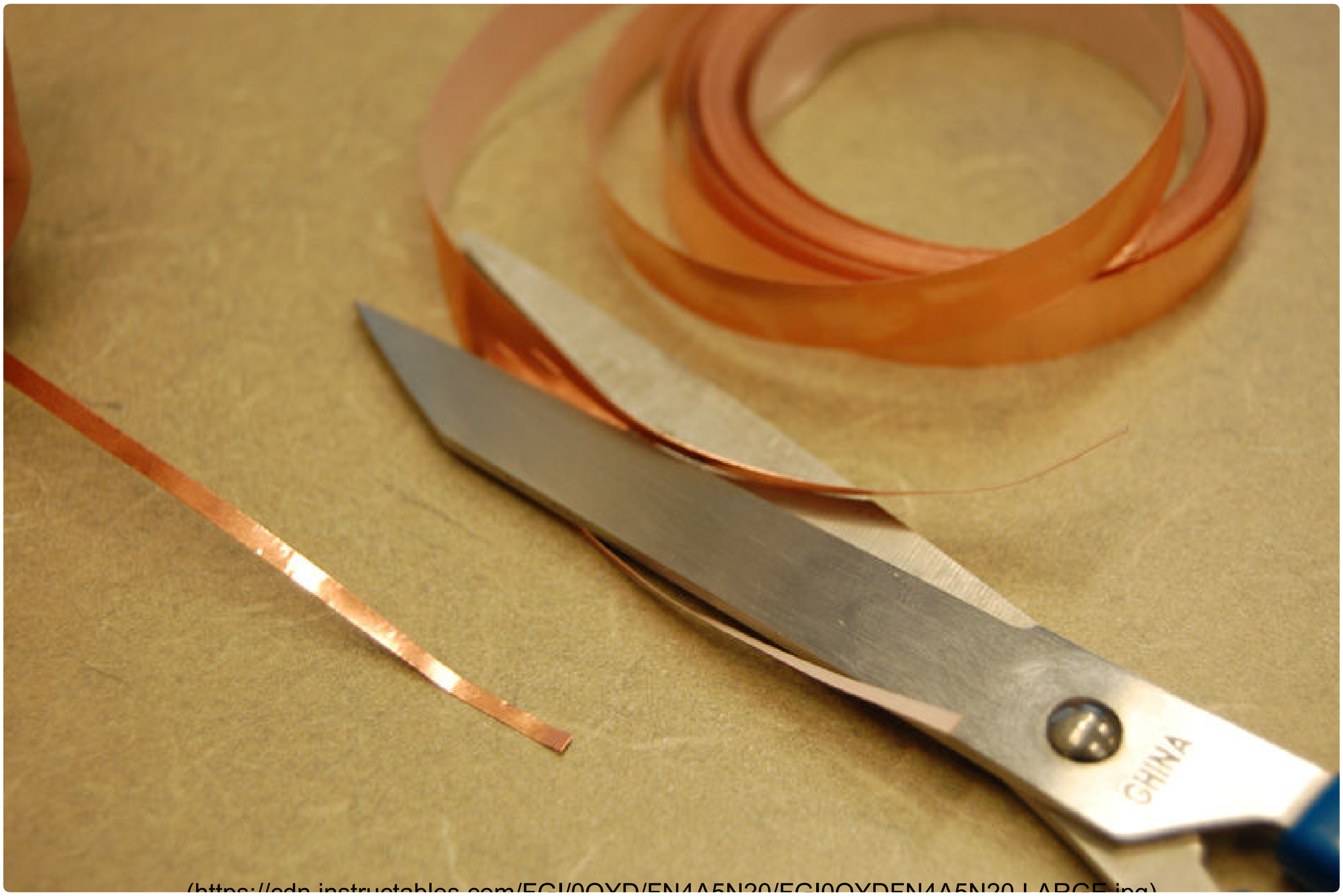

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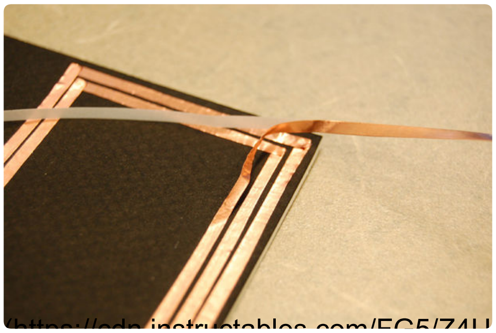
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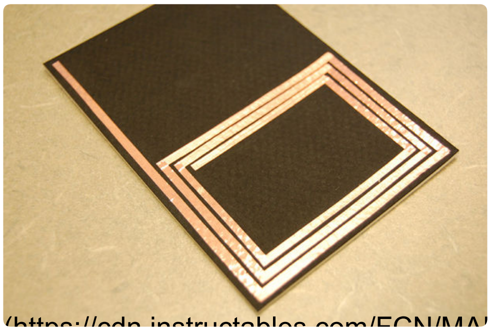
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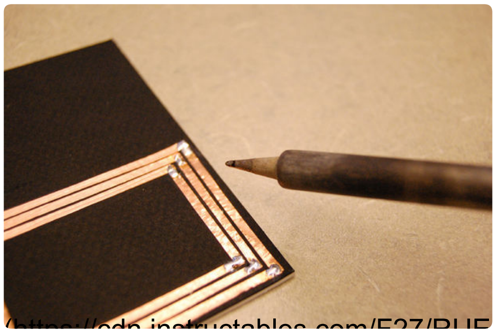
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This step describes how to build the antenna for the RFID tag.

Building the RFID tag antenna

To build the tag's antenna follow these three steps.

1. Cut the conductive copper tape into thin stripes of around 2mm (see Figure 1).
2. Tape these stripes (see Figure 2) in loops around one half of the cardboard (see Figure 3 for the layout of the antenna). The tag should have between 3-4 loops for the antenna.
3. Solder all the connections between the copper tape. Sometimes, this isn't necessary as the tape's adhesive backing is conductive, but solder the connections if you want to be on the safe side.

Now we have created our RFID tag antenna, and we will add the "RFID reader detection" functionality in the following step.

A little background

RFID readers transmit an electromagnetic (EM) field with their reader antenna. This EM field induces a current in the antenna for all RFID tags within reading distance. This induced current activates the RFID chip that is connected to the tag's antenna. This chip then modulates a response (usually the unique ID number) that is transmitted back to the reader. The antenna of an RFID tag is usually a thin copper wire that is arranged in loops. The loops allow the emitted EM field of the RFID reader to induce current to the antenna of the tag.

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Step 3: RFID Reader Detection

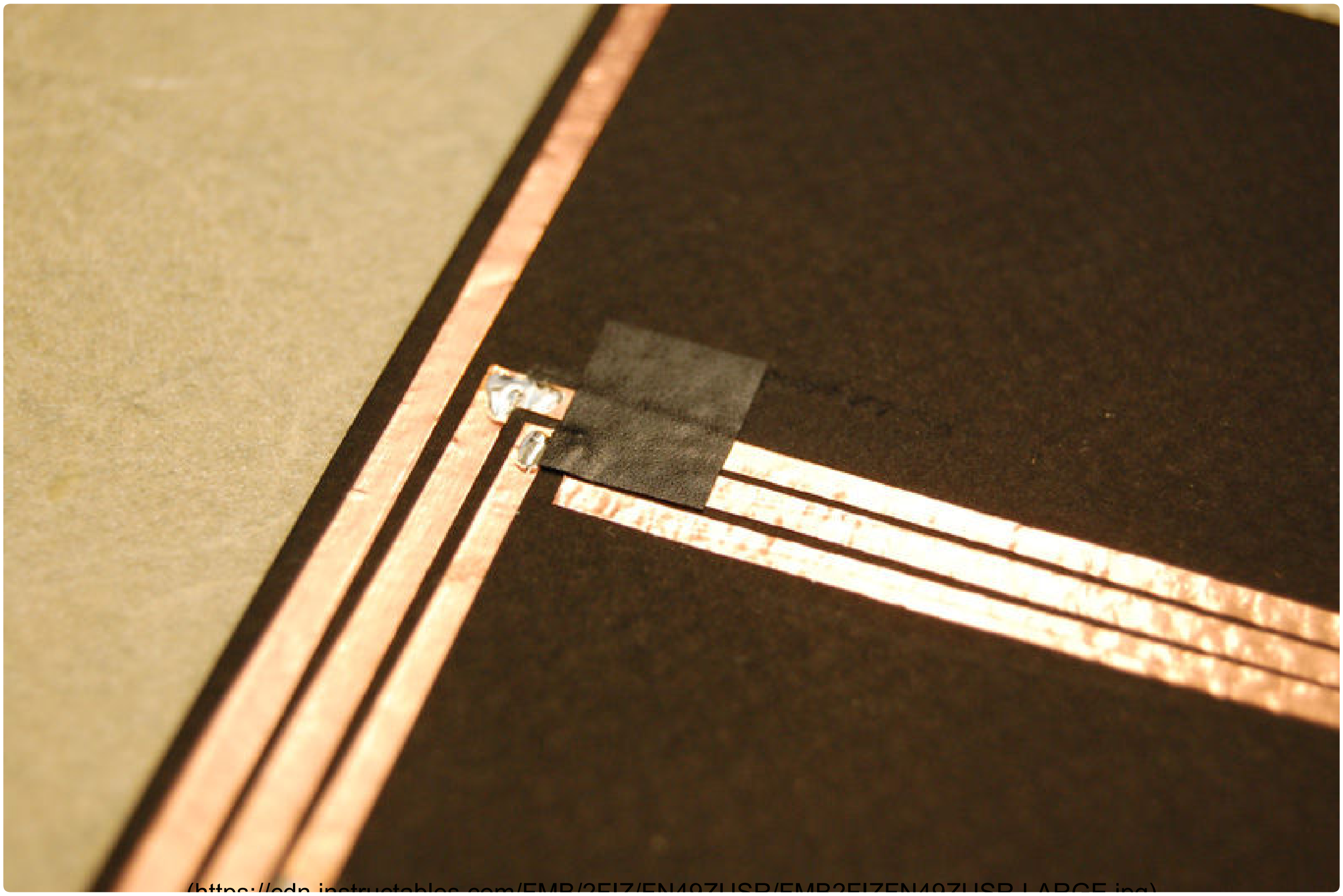

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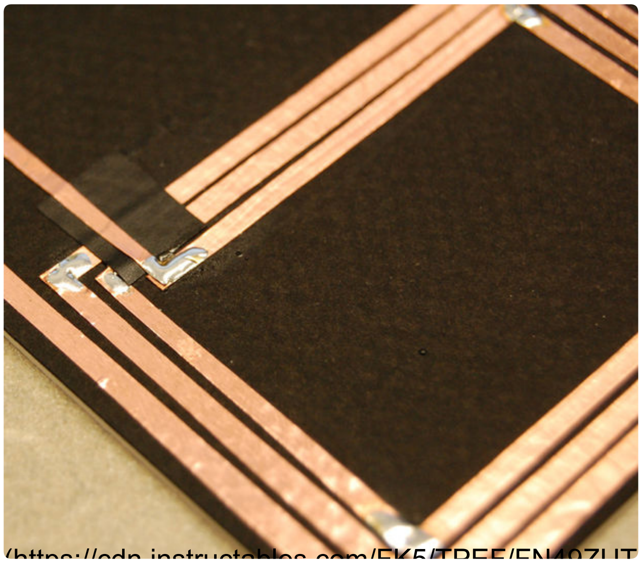

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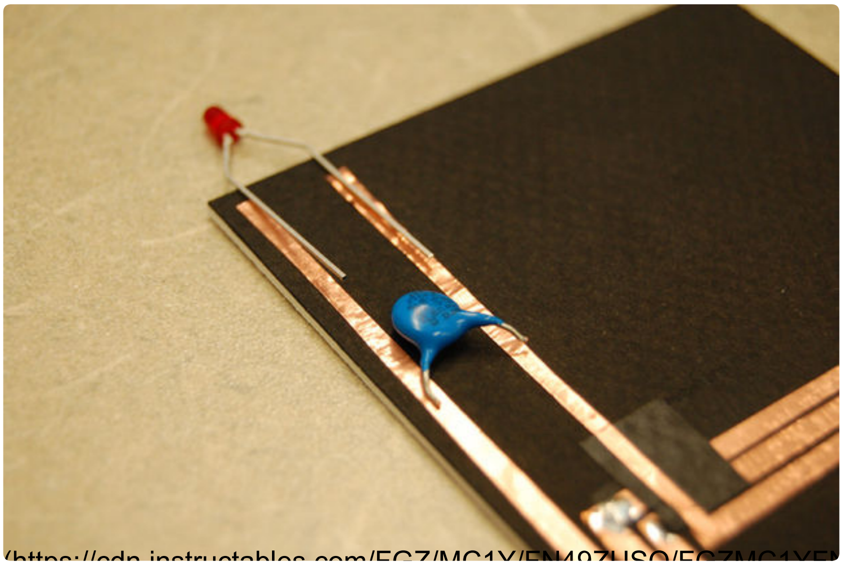

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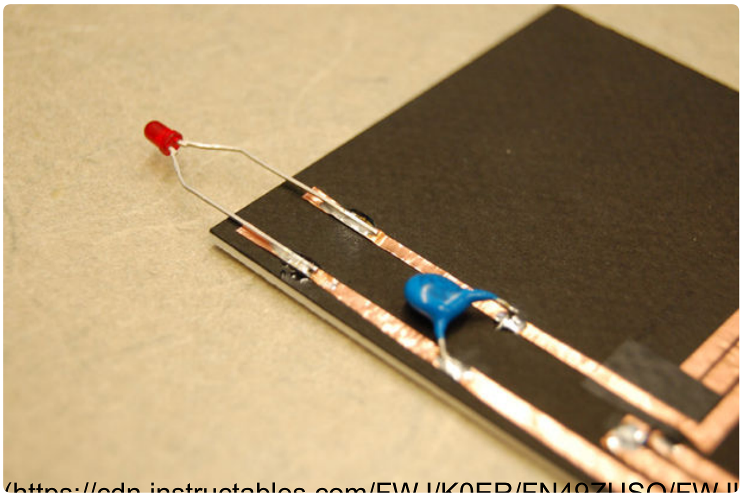
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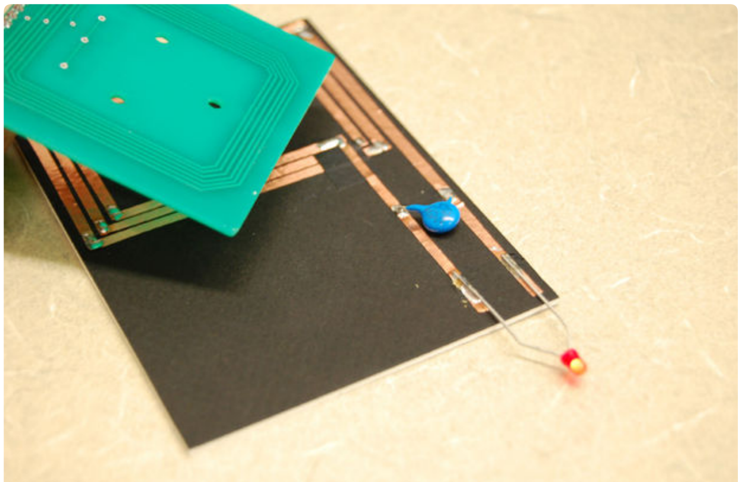
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This step describes how to add a simple mechanism to the RFID tag antenna that allows us detect nearby RFID readers.

Antenna connection
First, we add a small piece of insulation tape for the connection of the inner end of the antenna loop (as illustrated in Figure 1). This is to insulate the outer loops. Then we add another copper tape strip to the inner end of the antenna as shown in Figure 2. Here again we solder the two ends of the conductive copper tape together.

Capacitor and LED
Next, we add the capacitor (82 pF) and the low current LED to the tag as shown in Figure 3. They are connected in parallel. We also solder these two components to the copper tape (see Figure 4).

Testing
With these simple steps, our RFID reader detector is finished! By bringing our DIY RFID detector close to an RFID reader (as shown in Figure 5), the connected LED lights up. With the Sonmicro reader hardware the distance to the reader has to be below 8-10 cm; however, there are RFID readers available with a stronger EM field and therefore a higher maximum reading distance.

In the next step of the instructable we will show how to extend a basic RFID tag and make it tilt-sensitive.

Add Tip Ask Question

Step 4: Tilt-Sensitive RFID Tag

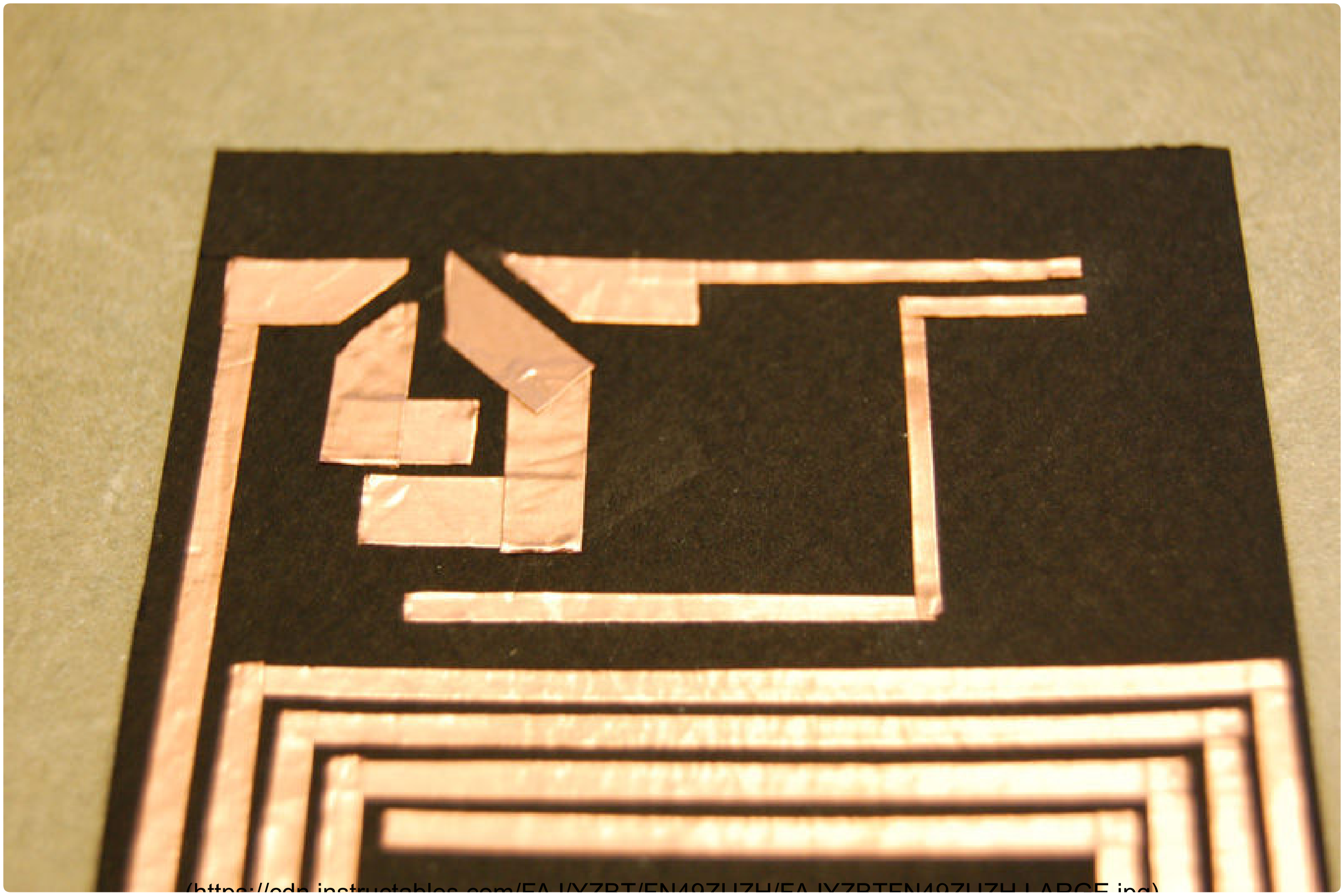

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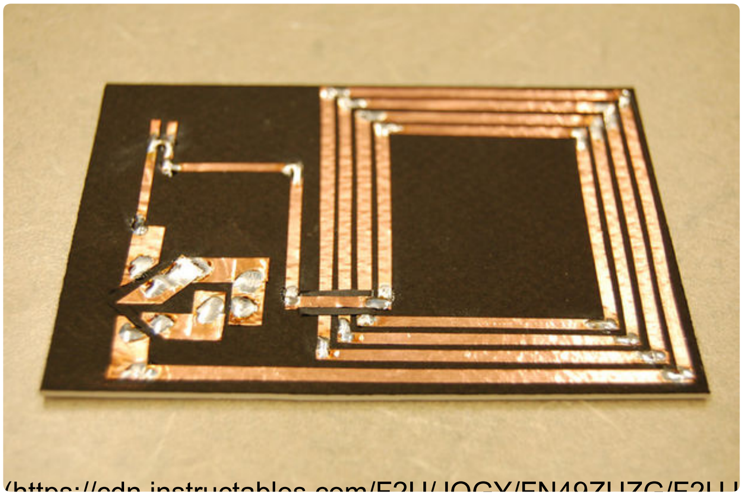
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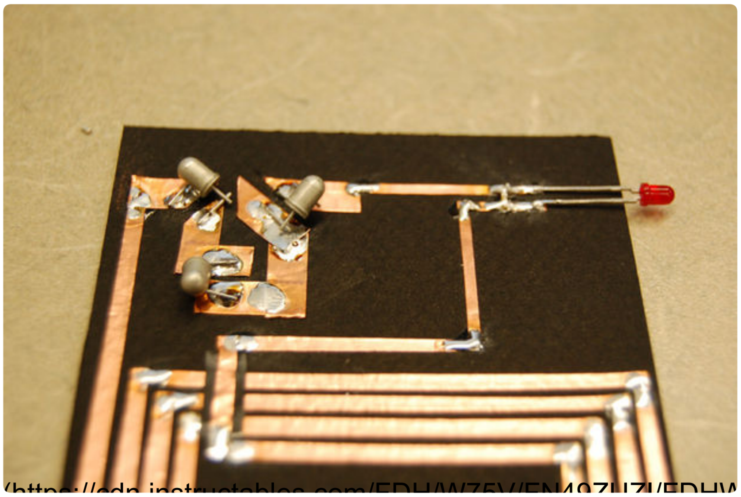
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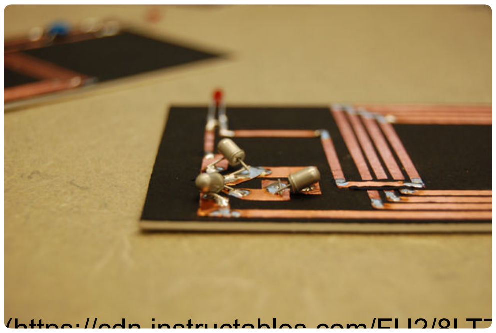
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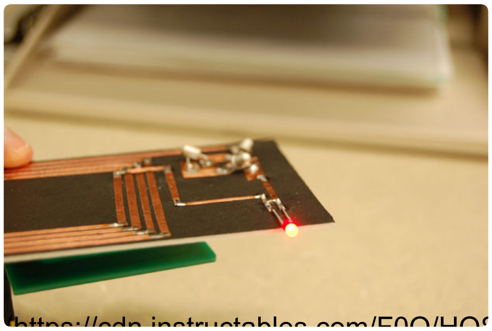
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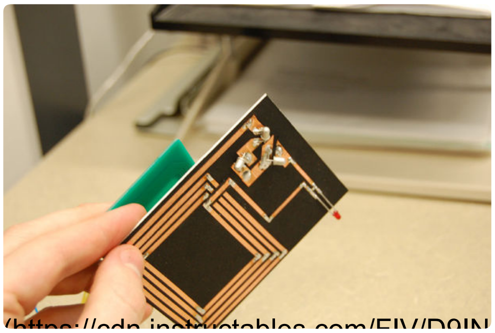
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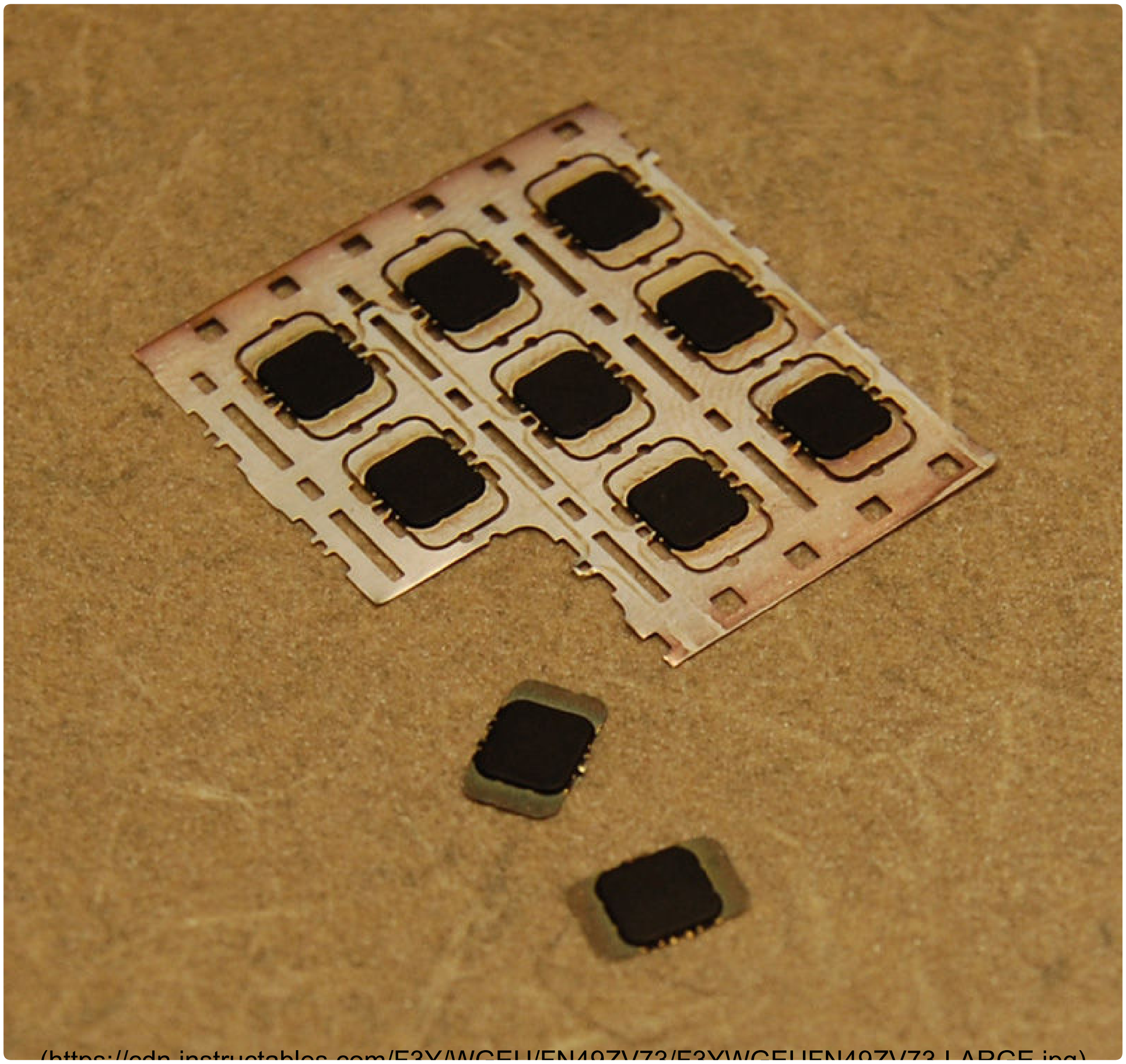
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We now describe the process of how to build a tilt-sensitive RFID tag. This extends the previous exercise.

Antenna

The antenna for this second RFID tag is similar to the first antenna we built. We thus need another piece of cardboard and to repeat the steps described earlier in STEP 2 (https://www.instructables.com/id/S2YO8NWFN4H8Q8A/) of this instructable.

Tilt-sensitive tag

Next, we add additional copper tape connections to the tag, as shown in Figure 1. These connections allow us to connect three tilt switches, a capacitor, and the LED to the antenna. Again, all the connections of the copper tape are soldered together. We add the three tilt switches to the tag as shown in Figure 3. The tilt switches are soldered to the copper tape, and it is important to connect them in a slight angle (around 5-10 degrees) as shown in Figure 4. This makes sure that the silt switches are in a *closed* state while the RFID tag is in a horizontal position, and in a *open* state while the tag is in a vertical position.

Again, we also add an LED and a capacitor to the antenna as shown in Figure 3 (we use a different form factor of the capacitor here just to illustrate the alternative options).

Testing the tilt-sensitive tag

We can now use our Sonmicro RFID reader again to test our new tilt-sensitive RFID tag. The tag is activate while in a horizontal position as in Figure 5, and is inactive when in a vertical position as in Figure 6.

Using RFID chips

We can now replace the connected capacitor and LED from our tag with an RFID

MICROWAVE AND RADIO FREQUENCY ENGINEERING

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TRANSMISSION LINES

TELEGRAPHER'S EQUATIONS

$$(1)\quad \frac{\partial V}{\partial z} = -L\frac{\partial I}{\partial t} \qquad (2)\quad \frac{\partial I}{\partial z} = -C\frac{\partial V}{\partial t}$$

By taking the partial derivative with respect to *z* of equation 1 and partial with respect to *t* of equation 2, we can get:

$$(\text{i})\quad \frac{\partial^2 V}{\partial z^2} = LC\frac{\partial^2 V}{\partial t^2} \qquad (\text{ii})\quad \frac{\partial^2 I}{\partial z^2} = LC\frac{\partial^2 I}{\partial t^2}$$

SOLVING THE EQUATIONS

To solve the equations (i) and (ii) above, we guess that $F(u) = F(z \pm vt)$ is a solution to the equations. It is found that the unknown constant v is the wave propagation velocity.

$$\boxed{V_{total} = V_+(z - vt) + V_-(v + vt)}$$ where:

z is the position along the transmission line, where the load is at z=0 and the source is at z=-l, with l the length of the line.

v is the **velocity of propagation** $1/\sqrt{LC}$ or ω/β, the speed at which the waveform moves down the line; see p 2

t is time

THE COMPLEX WAVE EQUATION

The general solutions of equations (i) and (ii) above yield the complex wave equations for voltage and current. These are applicable when the excitation is sinusoidal and the circuit is under steady state conditions.

$$\boxed{V(z) = V^+e^{-j\beta z} + V^-e^{+j\beta z}}$$

$$\boxed{I(z) = I^+e^{-j\beta z} + I^-e^{+j\beta z}}$$

$$\boxed{I(z) = \frac{V^+e^{-j\beta z} + V^-e^{+j\beta z}}{Z_0}}$$ where:

$e^{-j\beta z}$ and $e^{+j\beta z}$ represent wave propagation in the $+z$ and $-z$ directions respectively,

$\beta = \omega\sqrt{LC} = \omega / v$ is the **phase constant,**

$Z_0 = \sqrt{L/C}$ is the **characteristic impedance** of the line. These equations represent the voltage and current **phasors**.

+/- WATCHING SIGNS

By convention z is the variable used to describe position along a transmission line with the origin z=0 set at the load so that all other points along the line are described by **negative** position values.

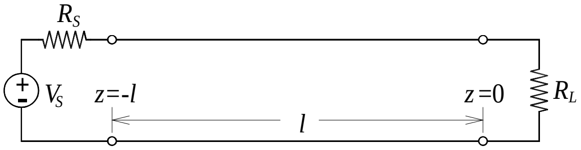

Ohm's law for right- and left-traveling disturbances:

$$V_+ = I_+Z_0 \qquad V_- = -I_-Z_0$$

v_p VELOCITY OF PROPAGATION [cm/s]

The velocity of propagation is the speed at which a wave moves down a transmission line. The velocity approaches the speed of light but may not exceed the speed of light since this is the maximum speed at which information can be transmitted. But v_p may exceed the speed of light mathematically in some calculations.

$$\boxed{v_p = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{\omega}{\beta}}$$ where:

L = inductance per unit length [H/cm]

C = capacitance per unit length [F/cm]

ε = permittivity of the material [F/cm]

μ = permeability of the material [H/cm]

ω = frequency [radians/second]

β = phase constant

Phase Velocity The velocity of propagation of a TEM wave may also be referred to as the *phase velocity*. The phase velocity of a TEM wave in conducting material may be described by:

$$\boxed{v_p = \omega\delta = \frac{\omega}{k} = c\frac{2\pi\delta}{\lambda_0} = c\frac{1}{\sqrt{\varepsilon_{r\ \text{eff}}}}}$$ where:

δ = skin depth [m]

c = speed of light 2.998×10^8 m/s

λ_0 = wavelength in the material [m]

Z_0 CHARACTERISTIC IMPEDANCE [Ω]

The **characteristic impedance** is the resistance initially *seen* when a signal is applied to the line. It is a physical characteristic resulting from the materials and geometry of the line.

Lossless line: $\boxed{Z_0 \equiv \sqrt{\frac{L}{C}}} = \frac{V_+}{I_+} = -\frac{V_-}{I_-}$

Lossy line: $\boxed{Z_0 \equiv \sqrt{\frac{R+j\omega L}{G+j\omega C}} = |Z_0| e^{j\phi_z}}$

L = inductance per unit length [H/cm]
C = capacitance per unit length [F/cm]
V_+ = the forward-traveling (left to right) voltage [V]
I_+ = the forward-traveling (left to right) current [I]
V_- = the reverse-traveling (right to left) voltage [V]
I_- = the reverse-traveling (right to left) current [I]
R = the line resistance per unit length [Ω/cm]
G = the conductance per unit length [Ω^{-1}/cm]
ϕ = phase angle of the complex impedance [radians]

y_0 CHARACTERISTIC ADMITTANCE [Ω^{-1}]

The **characteristic admittance** is the reciprocal of the characteristic impedance.

$$\boxed{y_0 \equiv \sqrt{\frac{C}{L}}} = \frac{I_+}{V_+} = -\frac{I_-}{V_-}$$

r REFLECTION COEFFICIENT

The **reflection coefficient** is the ratio of reflected voltage to the forward-traveling voltage, a value ranging from –1 to +1 which, when multiplied by the wave voltage, determines the amount of voltage reflected at one end of the transmission line.

$$\boxed{\rho \equiv \frac{V_-}{V_+} = -\frac{I_-}{I_+}}$$

A reflection coefficient is present at each end of the transmission line:

$$\boxed{\rho_{\text{source}} = \frac{R_S - z_0}{R_S + z_0}} \qquad \boxed{\rho_{\text{load}} = \frac{R_L - z_0}{R_L + z_0}}$$

t TRANSMISSION COEFFICIENT

The **transmission coefficient** is the ratio of total voltage to the forward-traveling voltage, a value ranging from 0 to 2.

$$\boxed{\tau \equiv \frac{V_{total}}{V_+}} = 1 + \rho$$

TOF TIME OF FLIGHT [s]

The **time of flight** is how long it takes a signal to travel the length of the transmission line

$$\boxed{TOF \equiv \frac{l}{v}} = l\sqrt{LC} = \sqrt{L_{TOT}C_{TOT}}$$

l = length of the transmission line [cm]
v = the velocity of propagation $1/\sqrt{LC}$, the speed at which the waveform moves down the line
L = inductance per unit length [H/cm]
C = capacitance per unit length [F/cm]
L_{TOT} = total inductance [H]
C_{TOT} = total capacitance [F]

DERIVED EQUATIONS

$$V_+ = z_0 I_+ = \left(V_{TOT} + I_{TOT} z_0\right)/2$$
$$V_- = -z_0 I_- = \left(V_{TOT} - I_{TOT} z_0\right)/2$$
$$I_+ = y_0 V_+ = \left(I_{TOT} + V_{TOT} y_0\right)/2$$
$$I_- = -y_0 V_- = \left(I_{TOT} - V_{TOT} y_0\right)/2$$

C_n FOURIER SERIES

The function $x(t)$ must be periodic in order to employ the Fourier series. The following is the exponential Fourier series, which involves simpler calculations than other forms but is not as easy to visualize as the trigonometric forms.

$$\boxed{C_n = \frac{1}{T}\int_{t_1}^{t_1+T} x(t)\, e^{-jn\omega_0 t}\, dt}$$

C_n = amplitude
T = period [s]
t = time [s]
n = the harmonic (an integer)
w_0 = frequency $2\pi/T$ [radians]

The function $x(t)$ may be delayed in time. All this does in a Fourier series is to shift the phase. If you know the C_ns for $x(t)$, then the C_ns for $x(t-\alpha)$ are just $C_n e^{-jn\omega 0\alpha}$. (Here, C_ns is just the plural of C_n.)

C CAPACITANCE [F]

$$v(t) = \frac{1}{C}\int_0^t i\,d\tau + v(0) \qquad I_{cap} = C\frac{dV_{cap}}{dt}$$

$$\boxed{v(t) = v_f + (v_0 - v_f)e^{-t/t}} \qquad i(t) = i_f + (i_0 - i_f)e^{-t/t}$$

$$P(t) = i_0{}^2 R e^{-2t/\tau}$$

$v(t)$ = voltage across the capacitor, at time t [V]
v_f = final voltage across the capacitor, steady-state voltage [V]
v_0 = initial voltage across the capacitor [V]
t = time [s]
τ = the time constant, RC [seconds]
C = capacitance [F]
Natural log: $\ln x = b \Leftrightarrow e^b = x$

C PARALLEL PLATE CAPACITANCE

$$C = \frac{\varepsilon A}{h} \qquad C_{\text{per unit length}} = \frac{\varepsilon A}{lh} = \frac{\varepsilon wl}{lh} = \frac{\varepsilon w}{h}$$

ε = permittivity of the material [F/cm]
A = area of one of the capacitor plates [cm^2]
h = plate separation [cm]
w = plate width [cm]
l = plate length [cm]
C = capacitance [F]

CAPACITOR-TERMINATED LINE

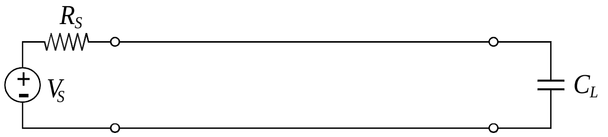

Where the incident voltage is $V_+ = V_0\left(1 - e^{-t/\tau_0}\right)$,

$$V_{cap} = V_+ + V_- = V_0\left(2 + \frac{2\tau_1}{\tau_0 - \tau_1}e^{-t/\tau_1} - \frac{2\tau_0}{\tau_0 - \tau_1}e^{-t/\tau_0}\right)$$

V_0 = final voltage across the capacitor [V]
t = time [s]
τ_0 = time constant of the incident wave, RC [s]
τ_1 = time constant effect due to the load, Z_0C_L [s]
C = capacitance [F]

SMITH CHART

First **normalize the load impedance** by dividing by the characteristic impedance, and find this point on the chart.

When working in terms of **reactance** X, an inductive load will be located on the top half of the chart, a capacitive load on the bottom half. It's the other way around when working in terms of **susceptance** B [Siemens].

Draw a straight line from the center of the chart through the normalized load impedance point to the edge of the chart.

Anchor a compass at the center of the chart and draw a circle through the normalized load impedance point. Points along this circle represent the normalized impedance at various points along the transmission line. Clockwise movement along the circle represents movement from the load toward the source with one full revolution representing 1/2 wavelength as marked on the outer circle. The two points where the circle intersects the horizontal axis are the voltage maxima (right) and the voltage minima (left).

The point opposite the impedance (180° around the circle) is the **admittance** Y [Siemens]. The reason admittance (or susceptibility) is useful is because admittances in parallel are simply added. (**Admittance** is the reciprocal of impedance; **susceptance** is the reciprocal of reactance.)

$$\boxed{\Gamma(z) = \Gamma_L e^{j2\beta z}}$$

$$e^{j2\beta z} = 1\angle 2\beta z$$

$$\mathbf{G}(z) = \frac{\mathbf{Z}(z) - 1}{\mathbf{Z}(z) + 1}$$

$$\mathbf{Z}_L = \frac{\Gamma_L - 1}{\Gamma_L + 1} \qquad \boxed{\mathbf{Z} = \frac{Z_L}{Z_0}}$$

z = distance from load [m]
$j = \sqrt{-1}$
ρ = magnitude of the reflection coefficient
β = phase constant
Γ = reflection coefficient
Z = normalized impedance [Ω]

SINGLE-STUB TUNING

The basic idea is to connect a line stub in parallel (shunt) or series a distance *d* from the load so that the imaginary part of the load impedance will be canceled.

Shunt-stub: Select *d* so that the admittance *Y* looking toward the load from a distance *d* is of the form $Y_0 + jB$. Then the stub susceptance is chosen as $-jB$, resulting in a matched condition.

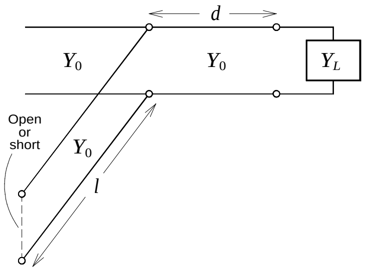
d
Y_0
Y_0
Y_L
Open
or
short
Y_0
l

Series-stub: Select *d* so that the admittance *Z* looking toward the load from a distance *d* is of the form $Z_0 + jX$. Then the stub susceptance is chosen as $-jX$, resulting in a matched condition.

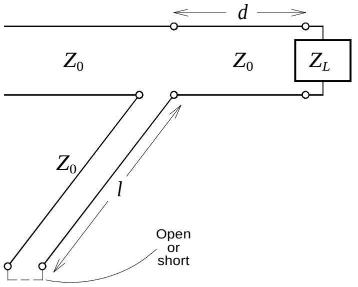
d
Z_0
Z_0
Z_L
Z_0
l
Open
or
short

FINDING A STUB LENGTH

Example: Find the lengths of open and shorted shunt stubs to match an admittance of 1-j0.5. The admittance of an open shunt (zero length) is $Y=0$; this point is located at the left end of the Smith Chart *x*-axis. We proceed clockwise around the Smith chart, i.e. away from the end of the stub, to the +j0.5 arc (the value needed to match –j0.5). The difference in the starting point and the end point on the wavelength scale is the length of the stub in wavelengths. The length of a shorted-type stub is found in the same manner but with the starting point at $Y=\infty$.

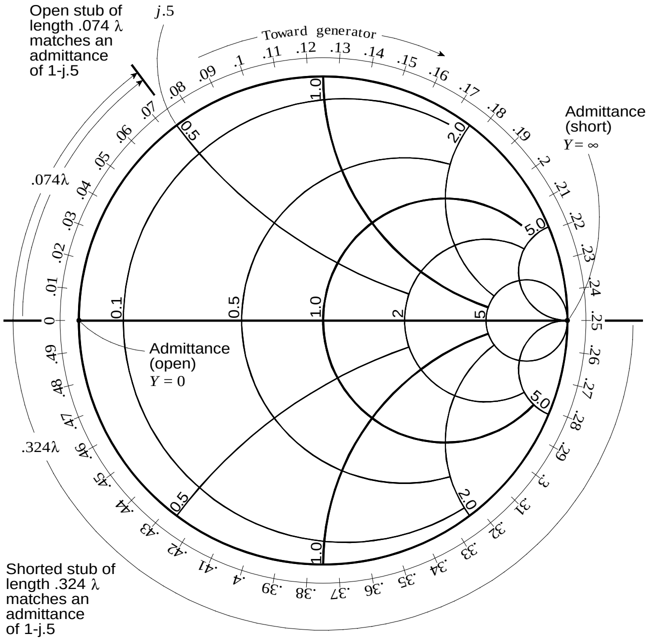
Open stub of length .074 λ matches an admittance of 1-j.5

Shorted stub of length .324 λ matches an admittance of 1-j.5

j.5
Toward generator
Admittance
(short)
Y = ∞
Admittance
(open)
Y = 0
.074λ
.324λ
0
.01
.02
.03
.04
.05
.06
.07
.08
.09
.1
.11
.12
.13
.14
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.45
.46
.47
.48
.49
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0.5
1.0
2
5
0.5
1.0
2.0
5.0
0.5
1.0
2.0
5.0

In this example, all values were in units of admittance. If we were interested in finding a stub length for a series stub problem, the units would be in impedance. The problem would be worked in exactly the same way. Of course in impedance, an open shunt (zero length) would have the value $Z=\infty$, representing a point at the right end of the *x*-axis.

LINE IMPEDANCE [Ω]

The impedance seen at the source end of a lossless transmission line:

$$Z_{in} = Z_0 \frac{1+\rho}{1-\rho} = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)}$$

For a lossy transmission line:

$$Z_{in} = Z_0 \frac{Z_L + Z_0 \tanh(\gamma l)}{Z_0 + Z_L \tanh(\gamma l)}$$

Line impedance is periodic with spatial period λ/2.

$Z_0 = \sqrt{L/C}$, the characteristic impedance of the line. [Ω]

ρ = the reflection coefficient

Z_L = the load impedance [Ω]

$\beta = 2\pi/\lambda$, phase constant

$\gamma = \alpha + j\beta$, complex propagation constant

l WAVELENGTH [cm]

The physical distance that a traveling wave moves during one period of its periodic cycle.

$$\boxed{\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{k} = \frac{v_p}{f}}$$

$\beta = \omega\sqrt{LC}$ = 2π/λ, phase constant

$k = \omega\sqrt{\mu\varepsilon}$ = 2π/λ, wave number

v_p = velocity of propagation [m/s] see p 2.

f = frequency [Hz]

l/4 QUARTER-WAVE SECTION

A quarter-wave section of transmission line has the effect of inverting the normalized impedance of the load.

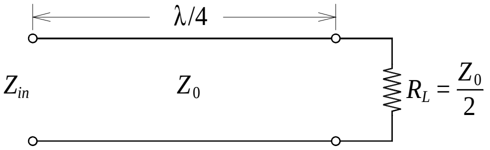

To find Z_{in}, we can normalize the load (by dividing by the characteristic impedance), invert the result, and "unnormalize" this value by multiplying by the characteristic impedance.

In this case, the normalized load is $\frac{Z_0}{2} \div Z_0 = \frac{1}{2}$

so the normalized input impedance is $\left(\frac{1}{2}\right)^{-1} = 2$

and the actual input impedance is $Z_{in} = 2Z_0$

g COMPLEX PROPAGATION CONSTANT

The propagation constant for lossy lines, taking into account the resistance along the line as well as the resistive path between the conductors.

$$\gamma = \alpha + j\beta = \sqrt{ZY} = \sqrt{(R + j\omega L)(G + j\omega C)}$$

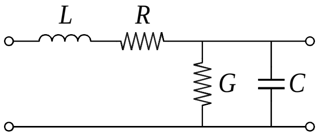

$\alpha = \sqrt{RG}$ **attenuation constant**, the real part of the complex propagation constant, describes the loss

$\beta = 2\pi/\lambda$, **phase constant**, the complex part of the complex propagation constant

Z = **series impedance** (complex, inductive) per unit length [Ω/cm]

Y = **shunt admittance** (complex, capacitive) per unit length [Ω^{-1}/cm]

R = the resistance per unit length along the transmission line [Ω/cm]

G = the conductance between conductors per unit length [Ω^{-1}/cm]

L = inductance per unit length [H/cm]

C = capacitance per unit length [F/cm]

MODULATED WAVE

Suppose we have a disturbance composed of two frequencies:

$$\sin\left[\left(\omega_0-\delta\omega\right)t-\left(\beta_0-\delta\beta\right)z\right]$$

and $$\sin\left[\left(\omega_0+\delta\omega\right)t-\left(\beta_0+\delta\beta\right)z\right]$$

where ω_0 is the average frequency and β_0 is the average phase.

Using the identity $2\cos\left(\frac{A-B}{2}\right)\sin\left(\frac{A+B}{2}\right)=\sin A+\sin B$

The combination (sum) of these two waves is

$$\boxed{2\underbrace{\cos\left(\delta\omega t-\delta\beta z\right)}_{\text{envelope}}\underbrace{\sin\left(\omega_0 t-\beta_0 z\right)}_{\text{carrier}}}$$

The envelope moves at the group velocity, see p 7.

δ = "the difference in"…
ω_0 = carrier frequency [radians/second]
ω = modulating frequency [radians/second]
β_0 = carrier frequency phase constant
β = phase constant

So the sum of two waves will be a modulated wave having a **carrier** frequency equal to the average frequency of the two waves, and an **envelope** with a frequency equal to half the difference between the two original wave frequencies.

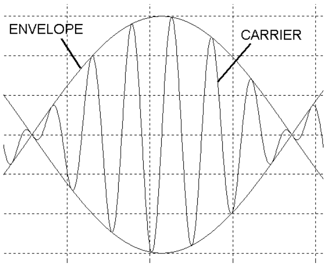

v_g GROUP VELOCITY [cm/s]

The velocity at which the envelope of a modulated wave moves.

$$\boxed{v_g=\frac{\delta\omega}{\delta\beta}=\frac{1}{\sqrt{LC_P}}\sqrt{1-\frac{\omega_c^{\,2}}{\omega^2}}}$$ where:

L = inductance per unit length [H/cm]
C_P = capacitance per unit length [F/cm]
ε = permittivity of the material [F/cm]
μ = permeability of the material, dielectric constant [H/cm]
ω_c = carrier frequency [radians/second]
ω = modulating frequency [radians/second]
β = phase constant

Also, since β may be given as a function of ω, remember

$$v_g=\left(\frac{d\beta}{d\omega}\right)^{-1}$$

OMEGA - BETA GRAPH

This representation is commonly used for modulated waves.

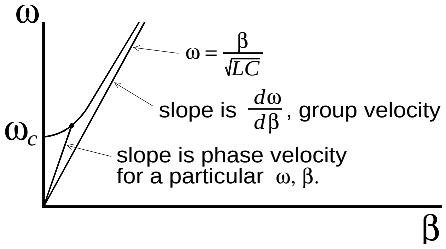
ω
ω = β/√LC
slope is dω/dβ, group velocity
ωc
slope is phase velocity for a particular ω, β.
β

d SKIN DEPTH [cm]

The depth into a material at which a wave is attenuated by 1/e (about 36.8%) of its original intensity. This isn't the same δ that appears in the *loss tangent*, tan δ.

$$\boxed{\delta=\frac{1}{\alpha}=\sqrt{\frac{2}{\omega\mu\sigma}}}$$ where:

$\alpha=\sqrt{RG}$ **attenuation constant**, the real part of the complex propagation constant, describes loss
μ = permeability of the material, dielectric constant [H/cm]
ω = frequency [radians/second]
σ = (*sigma*) conductivity [Siemens/meter] see p12.

Skin Depths of Selected Materials

	60 Hz	1 MHz	1 GHz
silver	8.27 mm	0.064 mm	0.0020 mm
copper	8.53 mm	0.066 mm	0.0021 mm
gold	10.14 mm	0.079 mm	0.0025 mm
aluminum	10.92 mm	0.084 mm	0.0027 mm
iron	0.65 mm	0.005 mm	0.00016 mm

MAXWELL'S EQUATIONS

Maxwell's equations govern the principles of guiding and propagation of electromagnetic energy and provide the foundations of all electromagnetic phenomena and their applications. The time-harmonic expressions can be used only when the wave is sinusoidal.

	STANDARD FORM (Time Domain)	**TIME-HARMONIC** (Frequency Domain)
Faraday's Law	$\nabla\times\vec{\mathscr{E}} = -\frac{\partial\vec{\mathscr{B}}}{\partial t}$	$\nabla\times\vec{E} = -j\omega\vec{B}$
Ampere's Law*	$\nabla\times\vec{\mathscr{H}} = \vec{\mathscr{J}} + \frac{\partial\vec{\mathscr{D}}}{\partial t}$	$\nabla\times\vec{H} = j\omega\vec{D} + \vec{J}$
Gauss' Law	$\nabla\cdot\vec{\mathscr{D}} = \rho_v$	$\nabla\cdot\vec{D} = \rho_v$
no name law	$\nabla\cdot\vec{\mathscr{B}} = 0$	$\nabla\cdot\vec{B} = 0$

$\mathscr{E}$ = electric field [V/m]
$\mathscr{B}$ = magnetic flux density [W/m^2 or T] $\mathscr{B} = \mu_0\mathscr{H}$
t = time [s]
$\mathscr{D}$ = electric flux density [C/m^2] $\mathscr{D} = \varepsilon_0\mathscr{E}$
ρ = volume charge density [C/m^3]
$\mathscr{H}$ = magnetic field intensity [A/m]
$\mathscr{J}$ = current density [A/m^2]

*Maxwell added the $\frac{\partial\vec{\mathscr{D}}}{\partial t}$ term to Ampere's Law.

ELECTROMAGNETIC WAVES

MODELING MAXWELL'S EQUATIONS

This is a model of a wave, analogous to a transmission line model.

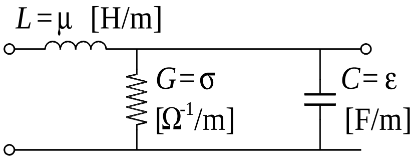

L = inductance per unit length [H/cm]
μ = permeability of the material, dielectric constant [H/cm]
G = the conductance per unit length [Ω^{-1}/cm]
σ = (*sigma*) conductivity [Siemens/meter]
C = capacitance per unit length [F/cm]
ε = permittivity of the material [F/cm]

propagation constant: $\gamma = \sqrt{(j\omega\mu)(j\omega\varepsilon+\sigma)}$

LOW FREQUENCY

At low frequencies, more materials behave as **conductors**. A wave is considered low frequency when

$\boxed{\omega \ll \frac{\sigma}{\varepsilon}}$ $\frac{\sigma}{\varepsilon}$ is the dielectric relaxation frequency

$\boxed{\eta = \frac{1}{\sigma\delta}(1+j)}$ intrinsic wave impedance, see p 12.

What happens to the complex propagation constant at low frequency? From the wave model above, gamma is

$$\gamma = \sqrt{(j\omega\mu)(j\omega\varepsilon+\sigma)} = \sqrt{j\omega\mu\sigma}\sqrt{1+\frac{j\omega\varepsilon}{\sigma}}$$

Since both ω and ε/σ are small

$$\gamma = \sqrt{j\omega\mu\sigma}\left(1+\frac{1}{2}j\omega\frac{\varepsilon}{\sigma}\right) = \sqrt{j\omega\mu\sigma}\,(1)$$

Since $\sqrt{j} = \frac{1}{\sqrt{2}} + j\frac{1}{\sqrt{2}}$

$$\gamma = \sqrt{\omega\mu\sigma}\left(\frac{1}{\sqrt{2}} + j\frac{1}{\sqrt{2}}\right) = \sqrt{\frac{\omega\mu\sigma}{2}} + j\sqrt{\frac{\omega\mu\sigma}{2}}$$

So that, with $\gamma = \alpha + j\beta$

we get $\boxed{\alpha = \sqrt{\frac{\omega\mu\sigma}{2}}}$, $\boxed{\beta = \sqrt{\frac{\omega\mu\sigma}{2}}}$ or $\boxed{\gamma = \frac{1}{\delta}(1+j)}$

α = **attenuation constant**, the real part of the complex propagation constant, describes the loss
β = **phase constant**, the complex part of the complex propagation constant
σ = (*sigma*) conductivity [Siemens/cm]
δ = skin depth [cm]

So the wave is attenuating at the same rate that it is propagating.

HIGH FREQUENCY

At high frequencies, more materials behave as **dielectrics**, i.e. copper is a dielectric in the gamma ray range. A wave is considered high frequency when

$$\boxed{\omega \gg \frac{\sigma}{\varepsilon}}$$

$\frac{\sigma}{\varepsilon}$ is the dielectric relaxation frequency

$$\boxed{\eta = \sqrt{\frac{\mu}{\varepsilon}}}$$

intrinsic wave impedance, see p 12.

What happens to the complex propagation constant at high frequency?

$$\gamma = \sqrt{(j\omega\mu)(j\omega\varepsilon + \sigma)} = \sqrt{j\omega\mu\ j\omega\varepsilon\left(1 + \frac{\sigma}{j\omega\varepsilon}\right)}$$

Since both $1/\omega$ and σ/ε are small

$$\gamma = j\omega\sqrt{\mu\varepsilon}\left(1 + \frac{1}{2}\frac{\sigma}{j\omega\varepsilon}\right) \qquad \boxed{\gamma = \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}} + j\omega\sqrt{\mu\varepsilon}}$$

With $\gamma = \alpha + j\beta$

we get $\boxed{\alpha = \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}}}$, $\boxed{\beta = \omega\sqrt{\mu\varepsilon}}$,

tan d LOSS TANGENT

The loss tangent, a value between 0 and 1, is the loss coefficient of a wave after it has traveled one wavelength. This is the way data is usually presented in texts. This is not the same δ that is used for skin depth.

$$\boxed{\tan\delta = \frac{\sigma}{\omega\varepsilon}}$$

Graphical representation of loss tangent:

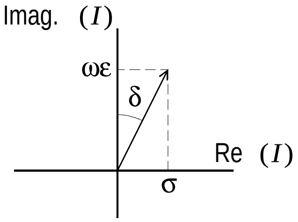

For a dielectric, $\tan\delta \ll 1$.

$$\alpha \approx \frac{1}{2}(\tan\delta)\beta = \frac{\pi}{\lambda}\tan\delta$$

$\omega\varepsilon$ is proportional to the amount of current going through the capacitance C.

σ is proportional to the amount current going through the conductance G.

TEM WAVES

Transverse Electromagnetic Waves

Electromagnetic waves that have single, orthogonal vector electric and magnetic field components (e.g., $\mathscr{E}_x$ and $\mathscr{H}_y$), both varying with a single coordinate of space (e.g., z), are known as *uniform plane waves* or *transverse electromagnetic (TEM) waves*. TEM calculations may be made using formulas from electrostatics; this is referred to as *quasi-static* solution.

Characteristics of TEM Waves

- The velocity of propagation (always in the *z* direction) is $v_p = 1/\sqrt{\mu\varepsilon}$, which is the speed of light in the material
- There is no electric or magnetic field in the direction of propagation. Since this means there is no voltage drop in the direction of propagation, it suggests that no current flows in that direction.
- The electric field is normal to the magnetic field
- The value of the electric field is η times that of the magnetic field at any instant.
- The direction of propagation is given by the direction of $\mathbf{E}\times\mathbf{H}$.
- The energy stored in the electric field per unit volume at any instant and any point is equal to the energy stored in the magnetic field.

TEM ASSUMPTIONS

Some assumptions are made for TEM waves.

$\mathscr{E}_z = 0$

$\mathscr{H}_z = 0$

$\sigma = 0$

time dependence $e^{j\omega t}$

WAVE ANALOGIES

Plane waves have many characteristics analogous to transmission line problems.

Transmission Lines	Plane Waves
Phase constant $\beta = \omega\sqrt{LC} = \frac{\omega}{v_p} = \frac{2\pi}{\lambda}$	Wave number $k = \omega\sqrt{\mu\varepsilon} = \frac{\omega}{v_p} = \frac{2\pi}{\lambda}$
Complex propagation const. $\gamma = \alpha + j\beta$ $= \sqrt{(R + j\omega L)(G + j\omega C)}$	Complex propagation constant $\gamma = \sqrt{(j\omega\mu)(j\omega\varepsilon + \sigma)}$
Velocity of propagation $v_p = \frac{1}{\sqrt{LC}} = \frac{\omega}{\beta}$	Phase velocity $v_p = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{\omega}{k} = \omega\delta = c\frac{2\pi\delta}{\lambda}$
Characteristic impedance $Z_0 = \sqrt{\frac{L}{C}} = \frac{V_+}{I_+}$	Intrinsic impedance $\eta = \sqrt{\frac{\mu}{\varepsilon}} = \frac{E_{x+}}{H_{y+}}$
Voltage $V(z) = V_+ e^{-j\beta z} + V_- e^{j\beta z}$	Electric Field $E_x(z) = E_+ e^{-jkz} + E_- e^{jkz}$
Current $I(z) = \frac{1}{Z_0}\left[V_+ e^{-j\beta z} - V_- e^{j\beta z}\right]$	Magnetic Field $H_y(z) = \frac{1}{\eta}\left[E_+ e^{-jkz} - E_- e^{jkz}\right]$
Line input impedance $Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)}$ $Z_{in} = Z_0 \frac{Z_L + Z_0 \tanh(\gamma l)}{Z_0 + Z_L \tanh(\gamma l)}$	Wave input impedance $\eta_{in} = \eta_0 \frac{\eta_L + j\eta_0 \tan(kl)}{\eta_0 + j\eta_L \tan(kl)}$ $\eta_{in} = \eta_0 \frac{\eta_L + \eta_0 \tanh(\gamma l)}{\eta_0 + \eta_L \tanh(\gamma l)}$
Reflection coefficient $\rho = \frac{Z_L - Z_0}{Z_L + Z_0}$	Reflection coefficient $\rho = \frac{\eta_L - \eta_0}{\eta_L + \eta_0}$

k WAVE NUMBER [rad./cm]

The phase constant for the uniform plane wave; the change in phase per unit length. It can be considered a constant for the medium at a particular frequency.

$$\boxed{k = \frac{\omega}{v} = \omega\sqrt{\mu\varepsilon} = \frac{2\pi}{\lambda}}$$

k appears in the phasor forms of the uniform plane wave

$E_x(z) = E_1 e^{-jkz} + E_2 e^{jkz}$, etc.

k has also been used as in the "*k* of a dielectric" meaning ε_r.

h (eta) INTRINSIC WAVE IMPEDANCE [Ω]

The ratio of electric to magnetic field components. Can be considered a constant of the medium. For free space, η = 376.73Ω. The units of η are in ohms.

$$\eta = \frac{E_{x+}}{H_{y+}} = -\frac{E_{y+}}{H_{x+}} \qquad -\eta = \frac{E_{x-}}{H_{y-}} = -\frac{E_{y-}}{H_{x-}}$$

at low frequencies	at high frequencies
$\eta = \frac{1}{\sigma\delta}(1 + j)$	$\eta = \sqrt{\frac{\mu}{\varepsilon}}$

When an electromagnetic wave encounters a sheet of conductive material it sees an impedance. K is the direction of the wave, **H** is the magnetic component and **E** is the electrical field. **E** × **H** gives the direction of propagation K.

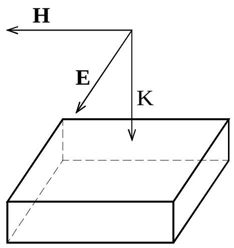

SHEET RESISTANCE [Ω]

Consider a block of material with conductivity σ.

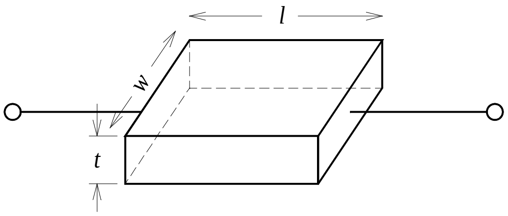

It's resistance is $R = \dfrac{l}{wt\sigma}$ Ω.

If the length is equal to the width, this reduces to

$$R = \frac{1}{t\sigma}\ \Omega.$$

And this is sheet resistance.

HIGH FREQUENCY RESISTANCE [Ω]

When a conductor carries current at high frequency, the electric field penetrates the outer surface only about 1 skin depth so that current travels near the surface of the conductor. Since the entire cross-section is not utilized, this affects the resistance of the conductor.

Cross-section of a conductor showing current flow near the surface:

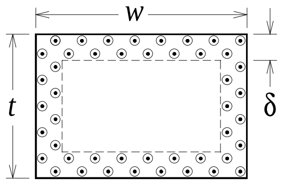

$$\boxed{R \approx \frac{1}{\sigma\delta(\text{perimeter})} = \sqrt{\frac{\omega\mu_0}{2\sigma}}\,\frac{1}{2w+2t}}$$

σ = (*sigma*) conductivity (5.8×10^{5} S/cm for copper) [Siemens/meter]

ω = frequency [radians/second]

δ = skin depth [cm]

μ_0 = permeability of free space $\mu_0 = 4\pi\times10^{-9}$ [H/cm]

w = width of the conductor [cm]

t = thickness of the conductor [cm]

h_{in} WAVE INPUT IMPEDANCE [Ω]

The impedance seen by a wave in a medium.

For example, the impedance of a metal sheet in a vacuum:

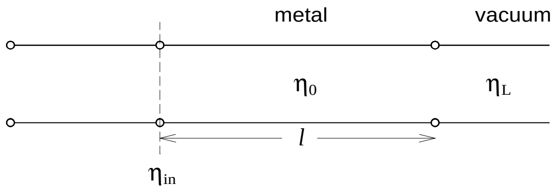

Note that a transmission line model is used here because it is analogous to a wave traveling in a medium. The "load" is the element most remote in the direction of propagation.

The input impedance is $\eta_{in} = \eta_0 \dfrac{\eta_L + \eta_0 \tanh(\gamma l)}{\eta_0 + \eta_L \tanh(\gamma l)}$ Ω.

In this example, *l* is the thickness of a metal sheet. If the metal thickness is much greater than the skin depth, then

$$\tanh(\lambda l) = \tanh\left[\frac{1}{\delta}(1+j)l\right] = \tanh[(\text{big number})(1+j)] \approx 1$$

If *l* is much less than the skin depth δ, then

$$\tanh(\lambda l) = \tanh\left[\frac{1}{\delta}(1+j)l\right] = \tanh[(\text{small number})(1+j)]$$

$$= (\text{same small number})(1+j) = \frac{l}{\delta}(1+j)$$

m MAGNETIC PERMEABILITY [H/m]

The relative increase or decrease in the resultant magnetic field inside a material compared with the magnetizing field in which the given material is located. The product of the permeability constant and the relative permeability of the material.

$\mu = \mu_0\mu_r$ where $\mu_0 = 4\pi\times10^{-7}$ H/m

Relative Permeabilities of Selected Materials

Air	1.00000037	Mercury	0.999968
Aluminum	1.000021	Nickel	600
Copper	0.9999833	Oxygen	1.000002
Gold	0.99996	Platinum	1.0003
Iron (99.96% pure)	280,000	Silver	0.9999736
Iron (motor grade)	5000	Titanium	1.00018
Lead	0.9999831	Tungsten	1.00008
Manganese	1.001	Water	0.9999912

e ELECTRIC PERMITTIVITY [F/m]

The property of a dielectric material that determines how much electrostatic energy can be stored per unit of volume when unit voltage is applied, also called the ***dielectric constant***. The product of the constant of permittivity and the relative permittivity of a material.

$$\varepsilon = \varepsilon_0 \varepsilon_r \quad \text{where } \varepsilon_0 = 8.85\times10^{-14}\text{ F/cm}$$

e*c* COMPLEX PERMITTIVITY

$$\varepsilon_c = \varepsilon' - j\varepsilon'' \quad \text{where} \quad \frac{\varepsilon''}{\varepsilon'} = \tan\delta_c$$

In general, both ε' and ε'' depend on frequency in complicated ways. ε' will typically have a constant maximum value at low frequencies, tapering off at higher frequencies with several peaks along the way. ε'' will typically have a peak at the frequency at which ε' begins to decline in magnitude as well as at frequencies where ε' has peaks, and will be zero at low frequencies and between peaks.

e*r* RELATIVE PERMITTIVITY

The permittivity of a material is the relative permittivity multiplied by the permittivity of free space

$$\varepsilon = \varepsilon_r \times \varepsilon_0$$

In old terminology, ε_r is called the "*k* of a dielectric". Glass (SiO_2) at $\varepsilon_r = 4.5$ is considered the division between low *k* and high *k* dielectrics.

Relative Permittivities of Selected Materials

Air (sea level)	1.0006	Polystyrene	2.6
Ammonia	22	Polyethylene	2.25
Bakelite	5	Rubber	2.2-4.1
Glass	4.5-10	Silicon	11.9
Ice	3.2	Soil, dry	2.5-3.5
Mica	5.4-6	Styrofoam	1.03
most metals	~1	Teflon	2.1
Plexiglass	3.4	Vacuum	1
Porcelain	5.7	Water, distilled	81
Paper	2-4	Water, seawater	72-80
Oil	2.1-2.3		

NOTE: Relative permittivity data is given for materials at **low or static frequency conditions**. The permittivity for most materials varies with frequency. The relative permittivities of most materials lie in the range of 1-25. At high frequencies, the permittivity of a material can be quite different (usually less), but will have resonant peaks.

s CONDUCTIVITY [S/m] or [1/(Ω·m)]

A measure of the ability of a material to conduct electricity, the higher the value the better the material conducts. The reciprocal is *resistivity*. Values for common materials vary over about 24 orders of magnitude. Conductivity may often be determined from skin depth or the loss tangent.

$$\sigma = \frac{n_c q_e^2 \bar{l}}{m_e v_{th}} \text{ S/m} \quad \text{where}$$

n_c = density of conduction electrons (for copper this is 8.45×10^{28}) [m^{-3}]

q_e = electron charge? 1.602×10^{-23} [C]

$\bar{l}$ = $v_{th}t_c$ the product of the thermal speed and the mean free time between collisions of electrons, the average distance an electron travels between collisions [m]

m_e = the effective electron mass? [kg]

v_{th} = thermal speed, usually much larger than the drift velocity v_d. [m/s]

Conductivities of Selected Materials [1/(Ω·m)]

Aluminum	3.82×10^{7}	Mercury	1.04×10^{6}
Carbon	7.14×10^{4}	Nicrome	1.00×10^{6}
Copper (annealed)	5.80×10^{7}	Nickel	1.45×10^{7}
Copper (in class)	6.80×10^{7}	Seawater	4
Fresh water	$\sim10^{-2}$	Silicon	$\sim4.35\times10^{-4}$
Germanium	~2.13	Silver	6.17×10^{7}
Glass	$\sim10^{-12}$	Sodium	2.17×10^{7}
Gold	4.10×10^{7}	Stainless steel	1.11×10^{6}
Iron	1.03×10^{7}	Tin	8.77×10^{6}
Lead	4.57×10	Titanium	2.09×10^{6}
		Zinc	1.67×10^{7}

P POWER [W]

Power is the time rate of change of energy.

Power reflected at a discontinuity: $\%\text{ power} = |\rho|^2 \times 100$

Power transmitted at a discontinuity: $\%\text{ power} = \left(1 - |\rho|^2\right) \times 100$

MICROSTRIP CONDUCTORS

How fast does a wave travel in a microstrip? The question is complicated by the fact that the dielectric on one side of the strip may be different from the dielectric on the other side and a wave may travel at different speeds in different dielectrics. The solution is to find an **effective relative permittivity** $\varepsilon_{r\,\text{eff}}$ for the combination.

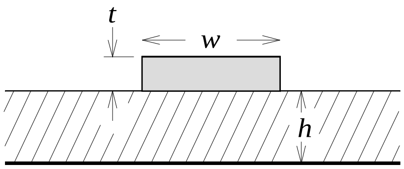

Some Microstrip Relations

$$Z_0^{\text{air}} = Z_0\sqrt{\varepsilon_{r\,\text{eff}}} \qquad C^{\text{air}} Z_0^{\text{air}} = \sqrt{\varepsilon_0\mu_0}$$

$$L = Z_0^{\text{air}}\sqrt{\varepsilon_0\mu_0} = C^{\text{total}}\left(Z_0\right)^2 \qquad L\,C^{\text{air}} = \varepsilon_0\mu_0$$

$$Z_0 = \sqrt{\frac{L}{C^{\text{total}}}} \qquad Z_0^{\text{air}} = \sqrt{\frac{L}{C^{\text{air}}}}$$

$$\gamma = j\beta = j\omega\sqrt{\varepsilon_0\mu_0}\sqrt{\varepsilon_{r\,\text{eff}}} \qquad \varepsilon_{r\,\text{eff}} = \frac{C^{\text{total}}}{C^{\text{air}}}$$

$$v_p = \frac{1}{\sqrt{\varepsilon_0\mu_0\varepsilon_{r\,\text{eff}}}} = \frac{1}{\sqrt{L\,C^{\text{total}}}}$$

It's difficult to get more than 200Ω for Z_0 in a microstrip.

Microstrip Approximations

$$\varepsilon_{r\,\text{eff}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+12h/w}}$$

$$Z_0 = \begin{cases} \dfrac{60}{\sqrt{\varepsilon_{r\,\text{eff}}}}\ln\left[\dfrac{8h}{w}+\dfrac{w}{4h}\right], & \text{for } \dfrac{w}{h}\le 1 \\[2ex] \dfrac{120\pi}{\sqrt{\varepsilon_{r\,\text{eff}}}\left[\dfrac{w}{h}+1.393+0.667\ln\left(\dfrac{w}{h}+1.444\right)\right]}, & \text{for } \dfrac{w}{h}>1 \end{cases}$$

$$\frac{w}{h} = \begin{cases} \dfrac{8e^A}{e^{2A}-2}, & \dfrac{w}{h}<2 \\[2ex] \dfrac{2}{\pi}\left\{B-1-\ln\left(2B-1\right)+\dfrac{\varepsilon_r-1}{2\varepsilon_r}\left[\ln\left(B-1\right)+0.39-\dfrac{0.61}{\varepsilon_r}\right]\right\}, & \dfrac{w}{h}>2 \end{cases}$$

where $A = \dfrac{Z_0}{60}\sqrt{\dfrac{\varepsilon_r+1}{2}} + \dfrac{\varepsilon_r-1}{\varepsilon_r+1}\left(0.23+\dfrac{0.11}{\varepsilon_r}\right)$, $B = \dfrac{377\pi}{2Z_0\sqrt{\varepsilon_r}}$

STRIPLINE CONDUCTOR

Also called *shielded microstrip*. The effective relative permittivity is used in calculations.

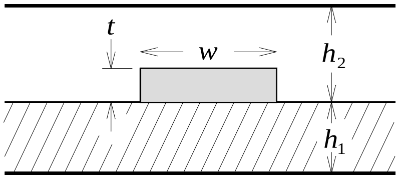

assuming $w \ge 10h$, $\qquad \varepsilon_{r\,\text{eff}} = \dfrac{\varepsilon_{r1}h_1+\varepsilon_{r2}h_2}{h_1+h_2}$ where

ε_{r1} = the relative permittivity of the dielectric of thickness h_1.
ε_{r2} = the relative permittivity of the dielectric of thickness h_2.

COPPER CLADDING

The thickness of copper on a circuit board is measured in ounces. 1-ounce cladding means that 1 square foot of the copper weighs 1 ounce. 1-ounce copper is 0.0014" or 35.6 µm thick.

$a_{\boldsymbol{d}}$ DIELECTRIC LOSS FACTOR [dB/cm]

$$\alpha_d = 8.68\frac{\beta_0\varepsilon_r\left(\varepsilon_{r\,\text{eff}}-1\right)}{2\sqrt{\varepsilon_{r\,\text{eff}}}\left(\varepsilon_r-1\right)}\tan\delta$$

$a_{\boldsymbol{c}}$ CONDUCTOR LOSS FACTOR [dB/cm]

$$\alpha_c = 8.68\frac{R}{2Z_0}, \qquad R = \frac{1}{\sigma\delta(\text{perimeter})} = \sqrt{\frac{\omega\mu_0}{2\sigma}}\frac{1}{(\text{perimeter})}$$

WHEELER'S EQUATION

Another approximation for microstrip calculations is Wheeler's equation.

$$Z_0 = \frac{42.4}{\sqrt{1+\varepsilon_r}} \ln\Bigg(1+\Bigg\{\frac{4h}{w'}\Bigg[\frac{14+\frac{8}{\varepsilon_r}}{11}\times\frac{4h}{w'}+\sqrt{\left(\frac{14+\frac{8}{\varepsilon_r}}{11}\times\frac{4h}{w'}\right)^2+\pi^2\,\frac{1+\frac{1}{\varepsilon_r}}{2}}\,\Bigg]\Bigg]\Bigg\}\Bigg)$$

where $$w' = \frac{8h\sqrt{\frac{7+\frac{4}{\varepsilon_r}}{11}\left[\exp\left(\frac{Z_0}{42.4}\sqrt{\varepsilon_r+1}\right)-1\right]+\frac{1+\frac{1}{\varepsilon_r}}{0.81}}}{\exp\left(\frac{Z_0}{42.4}\sqrt{\varepsilon_r+1}\right)-1}$$

NETWORK THEORY

S_{ij} SCATTERING PARAMETER

$$S_{\mathrm{i\,j}}$$

observation port $\nearrow$ $\nwarrow$ excitation port

A scattering parameter, represented by S_{ij}, is a dimensionless value representing the fraction of wave amplitude transmitted from port j into port i, provided that all other ports are terminated with matched loads and only port j is receiving a signal. Under these same conditions, S_{ii} is the reflection coefficient at port i.

To experimentally determine the scattering parameters, attach an impedance-matched generator to one of the ports (***excitation port***), attach impedance-matched loads to the remaining ports, and observe the signal received at each of the ports (***observation ports***). The fractional amounts of signal amplitude received at each port i will make up one column j of the **scattering matrix**. Repeating the process for each column would require n^2 measurements to determine the scattering matrix for an n-port network.

S_{ij} SCATTERING MATRIX

$$\begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1N} \\ S_{21} & S_{22} & \cdots & S_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ S_{N1} & S_{N2} & \cdots & S_{NN} \end{bmatrix}$$

The scattering matrix is an $n\times n$ matrix composed of scattering parameters that describes an n-port network.

The elements of the diagonal of the scattering matrix are reflection coefficients of each port. The elements of the off-diagonal are transmission coefficients, under the conditions outlined in "SCATTERING PARAMETER".

If the network is **internally matched** or **self-matched**, then $S_{11} = S_{22} = \cdots = S_{NN} = 0$, that is, the diagonal is all zeros.

The sum of the squares of each column of a scattering matrix is equal to one, provided the network is lossless.

a_n, b_n INCIDENT/REFLECTED WAVE AMPLITUDES

The parameters a_n and b_n describe the incident and reflected waves respectively at each port n. These parameters are used for power and scattering matrix calculations.

The amplitude of the wave incident to port n is equal to the amplitude of the incident voltage at the port divided by the square root of the port impedance.	$a_n = \frac{V_n^+}{\sqrt{Z_{0n}}}$
Amplitude of the wave reflected at port n is equal to the amplitude of the reflected voltage at the port divided by the square root of the port impedance.	$b_n = \frac{V_n^-}{\sqrt{Z_{0n}}}$
The scattering parameter is equal to the wave amplitude output at port i divided by the wave amplitude input at port j provided the only source is a matched source at port j and all other ports are connected to matched loads.	$S_{\text{ij}} = \frac{b_{\text{i}}}{a_{\text{j}}}$
The relationship between the S-parameters and the a- and b-parameters can be written in matrix form where **S** is the scattering matrix and **a** and **b** are column vectors.	$\mathbf{b} = \mathbf{Sa}$
Power flow into any port is shown as a function of a- and b-parameters.	$P = \frac{1}{2}\left(\lvert a\rvert^2 - \lvert b\rvert^2\right)$
The ratio of the input power at port j to the output power at port I can be written as a function of a- and b-parameters or the S-parameter.	$\frac{P_{in\,\text{j}}}{P_{out\,\text{i}}} = \frac{\lvert a_{\text{j}}\rvert^2}{\lvert b_{\text{j}}\rvert^2} = \frac{1}{\lvert S_{\text{ij}}\rvert^2}$

RECIPROCITY

A network is reciprocal when $S_{\text{ij}} = S_{\text{ji}}$ in the scattering matrix, i.e. the matrix is symmetric across the diagonal. Also, $Z_{\text{ij}} = Z_{\text{ji}}$ and $Y_{\text{ij}} = Y_{\text{ji}}$. Networks constructed of “normal materials” exhibit reciprocity.

Reciprocity Theorem:

$$\oint_S \vec{E}_a \times \vec{H}_b \cdot ds = \oint_S \vec{E}_b \times \vec{H}_a \cdot ds$$

E_a and H_b are fields from two different sources.

LOSSLESS NETWORK

A network is lossless when

$$\underline{S}\;\underline{S}^{\dagger} = /$$

† means to take the complex conjugate and transpose the matrix. If the network is reciprocal, then the transpose is the same as the original matrix.

/ = a unitary matrix. A **unitary matrix** has the properties:

$$\sum_{k=1}^{N} S_{ki} S_{ki}^* = 1 \qquad \sum_{k=1}^{N} S_{ki} S_{kj}^* = 0$$

In other words, a column of a unitary matrix multiplied by its complex conjugate equals one, and a column of a unitary matrix multiplied by the complex conjugate of a different column equals zero.

RAT RACE OR HYBRID RING NETWORK

The rat race or hybrid ring network is lossless, reciprocal, and internally matched.

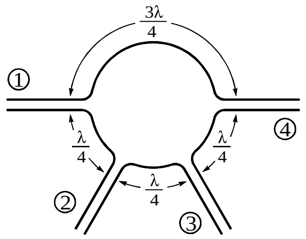

The signal splits upon entering the network and half travels around each side. A signal entering at port 1 and exiting at port 4 travels ¾ of a wavelength along each side, so the signals are in phase and additive. From port 1 to port 3 the signal travels one wavelength along one side and ½ wavelength along the other, arriving a port 3 out of phase and thus canceling. From port 1 to port 2 the paths are ¼ and 5/4 wavelengths respectively, thus they are in phase and additive.

DIRECTIONAL COUPLER

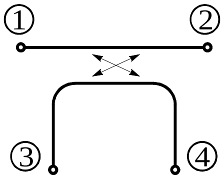

The directional coupler is a 4-port network similar to the rat race. It can be used to measure reflected and transmitted power to an antenna.

An input at one port is divided between two of the remaining ports. The **coupling factor**, measured in dB, describes the division of signal strength at the two ports. For example if the coupler has a coupling factor of –10 dB, then a signal input at port 1 would appear at port 4 attenuated by 10 dB with the majority of the signal passing to port 2. In other words, 90% of the signal would appear at port 2 and 10% at port 4. (-10 dB means "**10 dB down**" or 0.1 power, -6 dB means 0.25 power, and –3 dB means 0.5 power.) A reflection from port 2 would appear at port 3 attenuated by the same amount. Meters attached to ports 3 and 4 could be used to measure reflected and transmitted power for a system with a transmitter connected to port 1 and an antenna at port 2. The **directivity** of a coupler is a measurement of how well the coupler transfers the signal to the appropriate output without reflection due to the coupler itself; the directivity approaches infinity for a perfect coupler. $\text{directivity} = 10\log\left(p_3/p_1\right)$, where the source is at port 1 and the load is at port 2.

The directional coupler is **lossless** and **reciprocal**. The scattering matrix looks like this. In a real coupler, the off-diagonal zeros would be near zero due to leakage.

$$\begin{bmatrix} 0 & p & 0 & -q \\ p & 0 & q & 0 \\ 0 & q & 0 & p \\ -q & 0 & p & 0 \end{bmatrix}$$

CIRCULATOR

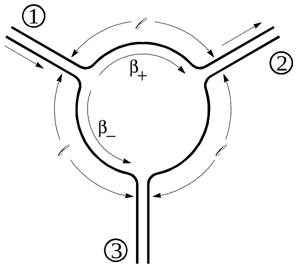

The circulator is a 3-port network that can be used to prevent reflection at the antenna from returning to the source.

Port 3 is terminated internally by a matched load. With a source at 1 and a load at 2, any power reflected at the load is absorbed by the load resistance at port 3. A 3-port network cannot be both lossless and reciprocal, so the circulator is not reciprocal.

Schematically, the circulator may be depicted like this:

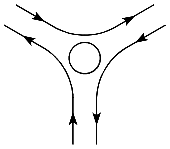

The circulator is **lossless** but is not **reciprocal**. The scattering matrix looks like this:

$$\begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

MAXWELL'S EQUATIONS, TIME HARMONIC FORM

$$\nabla\times\bar{\mathscr{E}} = -j\omega\mu\mathbf{H} \qquad \text{"curl on E"}$$

$$\nabla\times\bar{\mathscr{H}} = -j\omega\mu\mathbf{E} \qquad \text{"curl on H"}$$

$$\bar{\mathscr{E}} = \left[E_x(x,y)\hat{\mathbf{x}} + E_y(x,y)\hat{\mathbf{y}} + E_z(x,y)\hat{\mathbf{z}}\right]e^{j\omega t-\gamma z}$$

$$\bar{\mathscr{H}} = \left[H_x(x,y)\hat{\mathbf{x}} + H_y(x,y)\hat{\mathbf{y}} + H_z(x,y)\hat{\mathbf{z}}\right]e^{j\omega t-\gamma z}$$

From the curl equations we can derive:

(1) $\frac{\partial E_z}{\partial y} + \gamma E_y = -j\omega\mu H_x$ (4) $\frac{\partial H_z}{\partial y} + \gamma H_y = j\omega\varepsilon E_x$

(2) $-\frac{\partial E_z}{\partial x} - \gamma E_x = -j\omega\mu H_y$ (5) $-\frac{\partial H_z}{\partial x} - \gamma H_x = j\omega\varepsilon E_y$

(3) $\frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y} = -j\omega\mu H_z$ (6) $\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} = j\omega\varepsilon E_z$

From the above equations we can obtain:

(1) & (5) $H_x = \frac{1}{\gamma^2 + \omega^2\mu\varepsilon}\left(j\omega\varepsilon\frac{\partial E_z}{\partial y} - \gamma\frac{\partial H_z}{\partial x}\right)$

(2) & (4) $H_y = \frac{1}{\gamma^2 + \omega^2\mu\varepsilon}\left(j\omega\varepsilon\frac{\partial E_z}{\partial x} - \gamma\frac{\partial H_z}{\partial y}\right)$

(2) & (4) $E_x = -\frac{1}{\gamma^2 + \omega^2\mu\varepsilon}\left(-\gamma\frac{\partial E_z}{\partial x} + j\omega\mu\frac{\partial H_z}{\partial y}\right)$

(1) & (5) $E_y = -\frac{1}{\gamma^2 + \omega^2\mu\varepsilon}\left(-\gamma\frac{\partial E_z}{\partial y} + j\omega\mu\frac{\partial H_z}{\partial x}\right)$

This makes it look like if E_z and H_z are zero, then H_x, H_y, E_x, and E_y are all zero. But since $\infty\times 0 \neq 0$, we could have non-zero result for the TEM wave if $\gamma^2 = -\omega^2\mu\varepsilon \Rightarrow \gamma = j\omega\sqrt{\mu\varepsilon}$. This should look familiar.

WAVE EQUATIONS

From Maxwell's equations and a vector identity on curl, we can get the following wave equations:

$$\nabla^2 \overline{\mathscr{E}} = -\omega^2 \mu\varepsilon \overline{\mathscr{E}} \qquad \text{"del squared on E"}$$

$$\nabla^2 \overline{\mathscr{H}} = \omega^2 \mu\varepsilon \overline{\mathscr{H}} \qquad \text{"del squared on H"}$$

The z part or "del squared on E_z" is:

$$\nabla^2 E_z = \frac{\gamma^2 E_z}{\partial x^2} + \frac{\gamma^2 E_z}{\partial y^2} + \frac{\gamma^2 E_z}{\partial z^2} = -\omega^2 \mu\varepsilon E_z$$

Using the separation of variables, we can let:

$$E_z = X(x) \cdot Y(y) \cdot Z(z)$$

We substitute this into the previous equation and divide by $X \cdot Y \cdot Z$ to get:

$$\underbrace{\frac{1}{X}\frac{d^2X}{dx^2}}_{-k_x{}^2} + \underbrace{\frac{1}{Y}\frac{d^2Y}{dy^2}}_{-k_y{}^2} + \underbrace{\frac{1}{Z}\frac{d^2Z}{dz^2}}_{-k_z{}^2} = \underbrace{-\omega^2\mu\varepsilon}_{\text{a constant}}$$

Since X, Y, and Z are independent variables, the only way the sum of these 3 expressions can equal a constant is if all 3 expressions are constants.

So we are letting $\frac{1}{Z}\frac{d^2Z}{dz^2} = -k_z{}^2 \Rightarrow \frac{d^2Z}{dz^2} = -Zk_z{}^2$

A solution could be $Z = e^{-\gamma z}$

so that $\gamma^2 e^{-\gamma z} = -k_z{}^2 e^{-\gamma z}$ and $-k_z{}^2 = \gamma^2$

Solutions for X and Y are found

$$\frac{1}{X}\frac{d^2X}{dx^2} = -k_x{}^2 \Rightarrow X = A\sin(k_x x) + B\cos(k_x x)$$

$$\frac{1}{Y}\frac{d^2Y}{dy^2} = -k_y{}^2 \Rightarrow Y = C\sin(k_y y) + D\cos(k_y y)$$

giving us the general solution $k_x{}^2 + k_y{}^2 - \gamma^2 = \omega^2\mu\varepsilon$

For a particular solution we need to specify initial conditions and boundary conditions. For some reason, initial conditions are not an issue. The unknowns are k_x, k_y, A, B, C, D. The boundary conditions are

$$E_{\tan} = 0 \qquad \frac{\partial H_{\tan}}{\partial n} = 0$$

$E_{\tan}$ = the electric field tangential to a conducting surface
$H_{\tan}$ = the magnetic field tangential to a conducting surface
n = I don't know

TM, TE WAVES IN PARALLEL PLATES

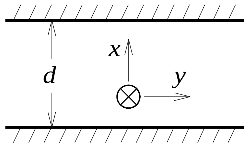

(z direction is into page)

TM, or transverse magnetic, means that magnetic waves are confined to the *transverse plane*. Similarly, TE (transverse electric) means that electrical waves are confined to the transverse plane.

Transverse plane means the plane that is transverse to (perpendicular to) the direction of propagation. The direction of propagation is taken to be in the z direction, so the transverse plane is the x-y plane. So for a TM wave, there is no H_z component (magnetic component in the z direction) but there is an E_z component.

$$\boxed{E_z = A\sin(k_x x)e^{-\gamma z}}$$

A = amplitude [V]

$k_x = \frac{m\pi}{d}$ The magnetic field must be zero at the plate boundaries. This value provides that characteristic. [cm^{-1}]

x = position; perpendicular distance from one plate. [cm]
d = plate separation [cm]
γ = propagation constant
z = position along the direction of propagation [cm]
m = mode number; an integer greater than or equal to 1

$$\boxed{\gamma = \sqrt{-\omega^2\mu\varepsilon + (kx)^2}}$$

Notice than when $(kx)^2 \geq \omega^2\mu\varepsilon$, the quantity under the square root sign will be positive and γ will be purely real. In this circumstance, the wave is said to be evanescent. The wavelength goes to infinity; there is no oscillation or propagation. On the other hand, when $(kx)^2 < \omega^2\mu\varepsilon$, γ is purely imaginary.

The magnitude of E_z is related to its position between the plates and the mode number m. Note that for m = 2 that $d = \lambda$.

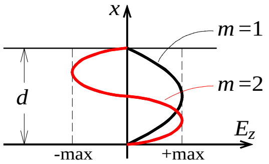

GENERAL MATHEMATICAL

COMPLEX TO POLAR NOTATION

j in polar notation:

$$j = e^{j\frac{\pi}{2}}$$

So we can find the square root of *j*:

$$\sqrt{j} = \sqrt{e^{j\frac{\pi}{2}}} = e^{j\frac{\pi}{4}} = \frac{1}{\sqrt{2}} + j\frac{1}{\sqrt{2}}$$

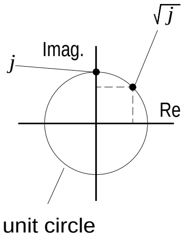

dBm DECIBELS RELATIVE TO 1 mW

The decibel expression for power. The logarithmic nature of decibel units translates the multiplication and division associated with gains and losses into addition and subtraction.

0 dBm = 1 mW
20 dBm = 100 mW
-20 dBm = 0.01 mW

$$P(\text{dBm}) = 10\log\left[P(\text{mW})\right]$$

$$P(\text{mW}) = 10^{P(\text{dBm})/10}$$

PHASOR NOTATION

To express a derivative in phasor notation, replace $\frac{\partial}{\partial t}$ with $j\omega$. For example, the

Telegrapher's equation $\frac{\partial V}{\partial z} = -L\frac{\partial I}{\partial t}$

becomes $\frac{\partial V}{\partial z} = -Lj\omega I$.

Ñ NABLA, DEL OR GRAD OPERATOR

Compare the ∇ operation to taking the time derivative. Where ∂/∂*t* means to take the derivative with respect to time and introduces a s^{-1} component to the units of the result, the ∇ operation means to take the derivative with respect to distance (in 3 dimensions) and introduces a m^{-1} component to the units of the result. ∇ terms may be called space derivatives and an equation which contains the ∇ operator may be called a vector differential equation. In other words ∇**A** is how fast **A** changes as you move through space.

in rectangular coordinates: $\nabla\mathbf{A} = \hat{x}\frac{\partial A}{\partial x} + \hat{y}\frac{\partial A}{\partial y} + \hat{z}\frac{\partial A}{\partial z}$

in cylindrical coordinates: $\nabla\mathbf{A} = \hat{r}\frac{\partial A}{\partial r} + \hat{\phi}\frac{1}{r}\frac{\partial A}{\partial \phi} + \hat{z}\frac{\partial A}{\partial z}$

in spherical coordinates: $\nabla\mathbf{A} = \hat{r}\frac{\partial A}{\partial r} + \hat{\theta}\frac{1}{r}\frac{\partial A}{\partial \theta} + \hat{\phi}\frac{1}{r\sin\theta}\frac{\partial A}{\partial \phi}$

∇ GRADIENT

$$\boxed{\nabla\bar{\Phi} = -\mathbf{E}}$$

"The gradient of the vector Φ" or "del Φ" is equal to the negative of the electric field vector.

∇Φ is a vector giving the direction and magnitude of the maximum spatial variation of the scalar function Φ at a point in space.

$$\nabla\bar{\Phi} = \hat{\mathbf{x}}\frac{\partial\Phi}{\partial x} + \hat{\mathbf{y}}\frac{\partial\Phi}{\partial y} + \hat{\mathbf{z}}\frac{\partial\Phi}{\partial z}$$

Ñx DIVERGENCE

∇· is also a vector operator, combining the "del" or "grad" operator with the dot product operator and is read as "the divergence of". In this form of Gauss' law, where **D** is a density per unit area, with the operators applied, ∇·**D** becomes a density per unit volume.

$$\boxed{\text{div}\,\mathbf{D} = \nabla\cdot\mathbf{D} = \frac{\partial D_x}{\partial x} + \frac{\partial D_y}{\partial y} + \frac{\partial D_z}{\partial z} = \rho}$$

D = electric flux density vector **D** = ε**E** [C/m^2]
ρ = source charge density [C/m^3]

Ñ^2 THE LAPLACIAN

∇^2 is a combination of the divergence and del operations, i.e. $\mathrm{div}(\mathrm{grad}\,\Phi) = \nabla\cdot\nabla\,\Phi = \nabla^2\,\Phi$. It is read as "the LaPlacian of" or "del squared".

$$\boxed{\nabla^2\mathbf{F} = \frac{\partial^2\,\Phi}{\partial\,x^2} + \frac{\partial^2\,\Phi}{\partial\,y^2} + \frac{\partial^2\,\Phi}{\partial\,z^2}}$$

F = electric potential [V]

GRAPHING TERMINOLOGY

With *x* being the horizontal axis and *y* the vertical, we have a graph of ***y* versus *x*** or ***y* as a function of *x***. The *x*-axis represents the **independent variable** and the *y*-axis represents the **dependent variable**, so that when a graph is used to illustrate data, the data of regular interval (often this is time) is plotted on the *x*-axis and the corresponding data is dependent on those values and is plotted on the *y*-axis.

HYPERBOLIC FUNCTIONS

$$j\sin\theta = \sinh(j\theta)$$

$$j\cos\theta = \cosh(j\theta)$$

$$j\tan\theta = \tanh(j\theta)$$

TAYLOR SERIES

$$\sqrt{1+x} \approx 1 + \frac{1}{2}x, \quad x \ll 1$$

$$\frac{1}{1-x^2} \approx 1 + x^2 + x^4 + x^6 + \cdots, \quad |x| < 1$$

$$\frac{1}{1\pm x} \approx 1 \mp x, \quad x \ll 1$$

ELECTROMAGNETIC SPECTRUM

FREQUENCY	WAVELENGTH (free space)	DESIGNATION	APPLICATIONS
< 3 Hz	> 100 Mm		Geophysical prospecting
3-30 Hz	10-100 Mm	ELF	Detection of buried metals
30-300 Hz	1-10 Mm	SLF	Power transmission, submarine communications
0.3-3 kHz	0.1-1 Mm	ULF	Telephone, audio
3-30 kHz	10-100 km	VLF	Navigation, positioning, naval communications
30-300 kHz	1-10 km	LF	Navigation, radio beacons
0.3-3 MHz	0.1-1 km	MF	AM broadcasting
3-30 MHz	10-100 m	HF	Short wave, citizens' band
30-300 MHz	1-10 m	VHF	TV, FM, police
54-72			TV channels 2-4
76-88			TV channels 5-6
88-108			FM radio
174-216			TV channels 7-13
0.3-3 GHz	10-100 cm	UHF	Radar, TV, GPS, cellular phone
470-890 MHz			TV channels 14-83
915 MHz			Microwave ovens (Europe)
800-2500 MHz		"money band"	PCS cellular phones, analog at 900 MHz, GSM/CDMA at 1900
1-2			L-band, GPS system
2.45			Microwave ovens (U.S.)
2-4			S-band
3-30 GHz	1-10 cm	SHF	Radar, satellite communications
4-8			C-band
8-12			X-band (Police radar at 11 GHz)
12-18			K_u-band (dBS Primestar at 14 GHz)
18-27			K-band (Police radar at 22 GHz)
30-300 GHz	0.1-1 cm	EHF	Radar, remote sensing
27-40			K_a-band (Police radar at 35 GHz)
40-60			U-band
60-80			V-band
80-100			W-band
0.3-1 THz	0.3-1 mm	Millimeter	Astromony, meteorology
10^{12}-10^{14} Hz	3-300 μm	Infrared	Heating, night vision, optical communications
3.95×10^{14}-7.7×10^{14} Hz	390-760 nm	Visible light	Vision, astronomy, optical communications
	625-760		Red
	600-625		Orange
	577-600		Yellow
	492-577		Green
	455-492		Blue
	390-455		Violet
10^{15}-10^{18} Hz	0.3-300 nm	Ultraviolet	Sterilization
10^{16}-10^{21} Hz		X-rays	Medical diagnosis
10^{18}-10^{22} Hz		γ-rays	Cancer therapy, astrophysics
> 10^{22} Hz		Cosmic rays	Astrophysics

GLOSSARY

anisotropic materials materials in which the electric polarization vector is not in the same direction as the electric field. The values of ε, μ, and σ are dependent on the field direction. Examples are crystal structures and ionized gases.

complex permittivity e The imaginary part accounts for heat loss in the medium due to damping of the vibrating dipole moments.

dielectric An insulator. When the presence of an applied field displaces electrons within a molecule away from their average positions, the material is said to be polarized. When we consider the polarizations of insulators, we refer to them as *dielectrics*.

empirical A result based on observation or experience rather than theory, e.g. *empirical data*, *empirical formulas*. Capable of being verified or disproved by observation or experiment, e.g. *empirical laws*.

evanescent wave A wave for which $\beta=0$. α will be negative. That is, γ is purely real. The wave has infinite wavelength—there is no oscillation.

isotropic materials materials in which the electric polarization vector is in the same direction as the electric field. The material responds in the same way for all directions of an electric field vector, i.e. the values of ε, μ, and σ are constant regardless of the field direction.

linear materials materials which respond proportionally to increased field levels. The value of μ is not related to $\mathbf{H}$ and the value of ε is not related to $\mathbf{E}$. Glass is linear, iron is non-linear.

overdamped system in the case of a transmission line, this means that when the source voltage is applied the line voltage rises to the final voltage without exceeding it.

time variable materials materials whose response to an electric field changes over time, e.g. when a sound wave passes through them.

transverse plane perpendicular, e.g. the x-y plane is *transverse* to z.

underdamped system in the case of a transmission line, this means that after the source voltage is applied the line voltage periodically exceeds the final voltage.

wave number k The phase constant for the uniform plane wave. k may be considered a constant of the medium at a particular frequency.

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5G

Ixia Special Edition

by Kalyan Sundhar and Lawrence C. Miller

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5G For Dummies®, Ixia Special Edition

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Introduction

The next-generation mobile network (NGMN) is on the horizon. 5G, the next iteration of 4G Long Term Evolution (LTE) networks, will enable significantly greater mobile speeds — as much as 20 gigabits per second (Gbps) with less than one millisecond (ms) latency — to enable real-time connectivity for mission-critical and potentially lifesaving devices and applications. 5G will also provide truly ubiquitous connectivity in the most challenging and remote areas of the world whether on land, in the air, or at sea — even on the 42nd floor of an office building in downtown Chicago! Finally, 5G networks will connect billions of Internet of Things (IoT) devices with a wide variety of speed and data volume requirements.

But 5G is an ambitious goal. Work on key technologies to enable 5G has already begun. In much the same way that 4G LTE was rolled out in 2008, but is only now achieving the 4G LTE goal of 1 Gbps speeds with the 4G LTE Advanced standard, 5G will be a steady evolution that begins with commercial availability expected in 2020. Many technologies that have emerged in the evolution of 4G LTE, such as carrier aggregation (CA) and multiple input multiple output (MIMO), will continue to develop to achieve the massive speed and scale required in 5G. Innovative new technologies will leverage unlicensed spectrum — where Wi-Fi operates — to offload certain traffic from the carrier networks to create more capacity in their data pipes. Low-power technologies such as NarrowBand IoT (NB-IoT), LTE for Machines (LTE-M), Long Range Wide Area Network (LoRaWAN), Sigfox, and others, will be used in billions of IoT devices, and a new radio interface technology — 5G New Radio (5G NR) — will be developed for connections between User Equipment (UE) and carrier enhanced Node B (eNodeB) stations. Finally, carriers will fully embrace virtualization technologies in their core networks to enable massive scale and efficiency.

In this book, you learn about the technological innovations that are being developed today to enable a 5G future. You also learn about potential use cases that will transform entire businesses and industries, and create new business models and opportunities.

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About This Book

5G For Dummies, Ixia Special Edition, consists of eight short chapters that explore

- How wireless communications technology has evolved and where it's going next (Chapter 1).
- How developments in today's networks are blazing the 5G trail to higher speeds (Chapter 2).
- Which technologies in unlicensed spectrum will be leveraged in the 5G networks of the future (Chapter 3).
- Why the Internet of Things requires 5G connectivity (Chapter 4).
- Where virtualization in mobile networks can help address the need for scale and elasticity (Chapter 5).
- What 5G New Radio (5G NR) is and how it will help create a 5G future (Chapter 6).
- How 5G will be used in various use case scenarios (Chapter 7).
- Ten common myths and the reality of 5G (Chapter 8).

Foolish Assumptions

It's been said that most assumptions have outlived their uselessness, but we assume a few things nonetheless!

Mainly, we assume that you either work in a technology profession or you're an avid user of wireless communications technology — if you have a smartphone within arm's distance of you, we're talking about you!

Beyond a basic knowledge of wireless communications and mobile technology in general, we don't assume you have a particularly strong technical background. As such, this book is written primarily for nontechnical readers — we explain any technical terms and concepts that come up in this book.

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If any of these assumptions describe you, this book is for you! If none of these assumptions describe you, keep reading anyway. It's a great book, and when you finish reading it, you'll know enough about 5G to be dangerous!

Icons Used in This Book

Throughout this book, we occasionally use special icons to call attention to important information. Here's what to expect:

REMEMBER

This icon points out information you should commit to your non-volatile memory, your gray matter, or your noggin' – along with anniversaries and birthdays!

TECHNICAL STUFF

You won't find a map of the human genome here, but if you seek to attain the seventh level of NERD-vana, perk up! This icon explains the jargon beneath the jargon.

TIP

Tips are appreciated, never expected — and we sure hope you'll appreciate these tips! This icon points out useful nuggets of information.

Beyond the Book

There's only so much we can cover in 48 short pages, so if you find yourself at the end of this book thinking "gosh, this is a great book; where can I learn more?" just go to `www.ixiacom.com`.

Where to Go from Here

With our apologies to Lewis Carroll, Alice, and the Cheshire cat:

"Would you tell me, please, which way I ought to go from here?"

"That depends a good deal on where you want to get to," said the Cat — er, the Dummies Man.

"I don't much care where . . . ," said Alice.

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"Then it doesn't matter which way you go!"

That's certainly true of *5G For Dummies*, which, like Alice in Wonderland, is also destined to become a timeless classic!

If you don't know where you're going, any chapter will get you there — but Chapter 1 might be a good place to start! However, if you see a particular topic that piques your interest, feel free to jump ahead to that chapter. Each chapter is written to stand on its own, so you can read this book in any order that suits you (though we don't recommend upside down or backward).

We promise you won't get lost falling down the rabbit hole!

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IN THIS CHAPTER

- Recapping a century of innovation in wireless communications
- Addressing speed, scale, and responsiveness with 5G networks
- Unlocking the five key fundamentals of 5G

Chapter 1

Understanding the Journey to a 5G Future

In this chapter, you take a glimpse back at the evolution of wireless communications and a look ahead to the 5G future.

Tracing the Evolution of Wireless Communications

For more than a century, radio technology has been enabling wireless communications over ever greater distances and with ever greater capabilities.

In the late nineteenth century, Guglielmo Marconi built the first wireless telegraphy system, capable of transmitting Morse code via radio signals up to one-half mile. Today, more than seven billion mobile devices enable us to communicate with anyone, anywhere in the world.

The first truly mobile two-way radio was developed in 1923 and used in Australian police cars — although it took up the entire back seat of a patrol car. Hand-held radios — "walkie-talkies" — were first used in World War II.

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In 1973, the first call on a hand-held cellular phone was made — the cellular phone was described as a "brick" weighing nearly two pounds, with just 30 minutes of talk time and a ten-hour battery recharge time. Ten years later, Motorola introduced the DynaTAC phone, weighing just one pound and costing $3,500.

To support modern wireless communications, cellular networks have evolved over several generations, as follows:

- **1G (analog cellular):** The first analog cellular service was launched in Japan in 1979. In 1983, the Advanced Mobile Phone Service (AMPS) was launched in North America. Analog cellular signals permitted only voice traffic and were not encrypted, so they could be easily intercepted.

  TECHNICAL STUFF

  1G service consumed lots of spectrum and used the frequency division multiple access (FDMA) channel access method. FDMA allocates one or more frequency bands (or channels) to a user for communication.

- **2G (digital cellular):** The second generation of cellular technology was launched in 1991 with the commercial release of the Global Standard for Mobile Communications (GSM) in Finland. Major innovations in 2G networks included:
  - **Digital:** Digital signals generally have less static and background noise, and they use available spectrum more efficiently than do analog signals.
  - **Encryption:** 2G digital calls can be encrypted to make eavesdropping and intercept more difficult.
  - **Data:** Short message service (SMS) text messages were first introduced in 2G networks — O-M-2G!

  TECHNICAL STUFF

  2G technologies use either time division multiple access (TDMA) or code division multiple access (CDMA) channel access methods. TDMA divides a signal into different time slots, enabling multiple callers to share the same frequency channel. CDMA assigns a code to each caller and uses spread-spectrum technology to create a signal with a wider bandwidth.

  In 2000, the European Telecommunications Standards Institute (ETSI) created the General Packet Radio Service (GPRS), which implemented packet-switched domains, in addition to existing circuit-switched domains. GPRS was

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dubbed “2.5G” and had nothing to do with *Two and a Half Men,* introduced by CBS three years later.

- **3G (data driven):** Apple and Google brought smartphones to the masses with iPhones and Android devices, respectively, in the early 21st century. These powerful devices — and the mobile apps installed on them (including Global Positioning System or GPS, location-based services, and on-demand video) — created an insatiable appetite for faster download speeds. The first 3G networks, introduced in 1998, provided minimum information transfer rates of 200 kilobits per second (Kbps). The International Telecommunication Union (ITU) has never formally defined a standard for 3G data rates, so downlink data speeds vary widely — from 384 Kbps in a moving vehicle for Wideband Code Division Multiple Access (W-CDMA) to 42.2 megabits per second (Mbps) for Evolved High Speed Packet Access (HSPA+), also known as 3.5G, and 168 Mbps for Advanced HSPA+.
- **4G (Long Term Evolution):** Commercially available 4G mobile networks were rolled out in 2008, and 4G LTE followed in 2010. However, unlike 3G, the ITU Radiocommunication Sector (ITU-R) defined minimum 4G standards — but neither “4G” nor “4G LTE” meets those standards! The ITU-R International Mobile Telecommunications Advanced (IMT-Advanced) requirements include (among other things):
    - Packet-switched all-IP core networks
    - Peak data rates of approximately 100 Mbps for high mobility (such as moving vehicles)
    - Peak data rates of approximately 1 gigabit per second (Gbps) for low mobility (such as walking — or your authors sprinting)

  With the introduction of LTE Advanced, true 4G speeds of up to 1 Gbps finally arrived. LTE Advanced Pro is the next evolution of LTE technology, and it establishes the foundation for 5G. LTE Advanced Pro will deliver speeds in excess of 3 Gbps with less than 2 milliseconds (ms) of latency.

REMEMBER

At this point you may be thinking, “Long Term Evolution — no kidding! Will 5G ever get here?” However, the trend has been for each generation of mobile technology innovation to take about a decade — most of us just didn’t pay attention before we got our first smartphones midway through the 3G era.

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Focusing on the 5G Vision

The vision for the 5G future is bold: It is much more than just the next iteration of mobile networks. 5G will achieve three main goals:

- **Speed (ultra-high speed radio access):** 5G will provide download speeds of up to 20 Gbps. If you're wondering "Why would anyone ever need that much speed?" first answer this question: When have you ever heard anyone complain that their phone was *too fast*? It's also important to remember that bandwidth is shared by all the users on a cell tower. Today, if a few users are streaming a video at the airport or watching replays of a touchdown in a stadium, chances are that the download is choppy with lots of buffering, and the experience isn't so great. With 5G, you could theoretically download a 40 gigabyte (GB) 4K Ultra-High-Definition (UHD) movie (like *Jaws*) in less than a minute — you're gonna need a bigger data plan!
- **Responsiveness (ultra-low latency):** 5G networks will be used to control autonomous cars and high precision, mission-critical industrial devices in real-time. High reliability and availability at all times is a necessity for these use cases. For this to happen safely, end-to-end latency — the time it takes for data or commands to travel across the network — has to be extremely low. Latency in 5G networks will be five times faster than today's networks — less than 1ms.
- **Scale (massive connectivity):** By 2020, Gartner conservatively forecasts that there will be more than 21 billion connected devices in the Internet of Things (IoT). Some estimates predict more than 50 billion connected IoT devices by 2020. That's anywhere from three to seven connected devices for every person on the planet in 2020 — not including smartphones, tablets, and computers! These devices will have widely varying network requirements — from environmental sensors for agricultural applications installed in remote areas that might send a few bits of data every few days or weeks, to extremely high-precision, low-latency devices in nanobiotechnology, autonomous cars, and mission-critical industrial environments that rely on real-time communication for potentially lifesaving functions. 5G networks will need to handle the massive scale and

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challenging connectivity requirements for all these diverse devices, sensors, and applications.

Ordering Up 5G in Five Easy Pieces

5G will be a quantum leap beyond today's networks and will require many technological innovations. We serve them up here in five easy pieces (easier than making wheat toast for Jack Nicholson — "hold the butter, the lettuce, the mayonnaise . . . and the chicken") in this section and the chapters that follow (see Figure 1-1):

- **Speeds and feeds.** Speeds of up to 20 Gbps will be achieved using a combination of innovations such as carrier aggregation (CA), massive multiple input multiple output (MIMO), and quadrature amplitude modulation (QAM). You learn about speeds and feeds in Chapter 2.
- **Unlicensed spectrum:** MNOs are increasingly using unlicensed spectrum in the 2.4 and 5 Gigahertz (GHz) frequency bands. 5G networks will need to tap into the vast amount of spectrum available in these unlicensed bands to offload traffic in heavily congested areas and provide connectivity for billions of IoT devices. Advancements in Wi-Fi, LTE in Unlicensed spectrum (LTE-U), License Assisted Access (LAA), and MulteFire, among others, provide better quality and regulated access to unlicensed spectrum. You learn about these advancements in Chapter 3.
- **Internet of Things (IoT):** IoT devices pose a diverse set of requirements and challenges for 5G networks. It's only fair that IoT should likewise pose a diverse set of solutions as well! You learn about a few of these solutions — including NarrowBand IoT (NB-IoT), LTE Category M1 (LTE-M), Long Range (LoRa) and Sigfox — in Chapter 4.
- **Virtualization:** Network functions virtualization (NFV) enables the massive scale and rapid elasticity that MNOs will require in their 5G networks. Virtualization enables a virtual evolved packet core (vEPC), centralized radio access network (C-RAN), mobile edge computing (MEC), and network slicing — all explained in Chapter 5.

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- **New Radio (NR):** Although the other 5G innovations introduced in this section all have strong starting points in LTE Advanced Pro, 5G NR is a true 5G native technology that has yet to be standardized. 5G NR addresses the need for a new radio access technology that will enable access speeds up to 20 Gbps — and you learn about it in Chapter 6!

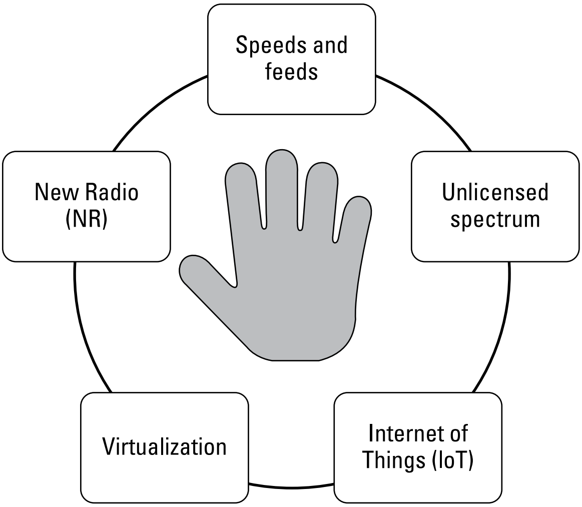
Speeds and feeds
Unlicensed spectrum
Internet of Things (IoT)
Virtualization
New Radio (NR)

FIGURE 1-1: The five keys to 5G.

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IN THIS CHAPTER

- **Issuing a license to thrill — with higher speeds**
- **Cobbling together spectrum with carrier aggregation**
- **Going well beyond "rabbit ears" with massive antenna arrays**
- **Seeing stars with quadrature amplitude modulation**

Chapter 2

Achieving Faster Speeds and Larger Feeds

Over the past decade, the need for speed in mobile networks has increased dramatically. To address this need, 5G will increase the speeds of today's most advanced Long Term Evolution (LTE) networks by an order of magnitude — from a few gigabits per second (Gbps) to as much as 20 Gbps. In this chapter, you get a glimpse of the engine — or, more correctly, the parts and components of the engine — that will power the 5G networks of the future.

Fattening the Data Pipe

Wireless spectrum is limited and highly regulated throughout the world. The International Telecommunication Union (ITU) allocates frequency spectrum worldwide, and governing bodies within the respective countries then license that spectrum for use by individual mobile network operators (MNOs). The ITU has identified three International Telecommunication Regions

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throughout the world with distinct frequency bands allocated to each region (see Figure 2-1).

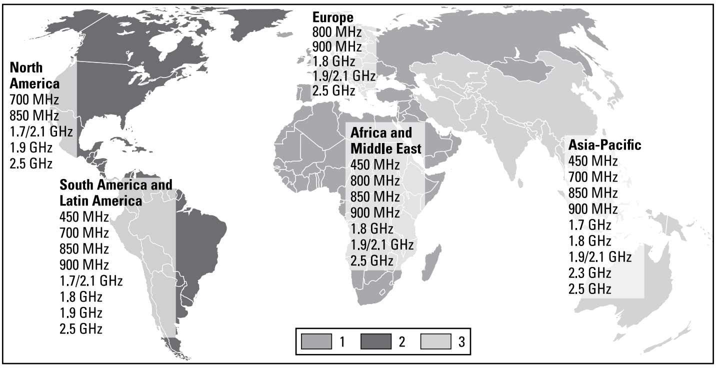
Europe
800 MHz
900 MHz
1.8 GHz
1.9/2.1 GHz
2.5 GHz
North America
700 MHz
850 MHz
1.7/2.1 GHz
1.9 GHz
2.5 GHz
Africa and Middle East
450 MHz
800 MHz
850 MHz
900 MHz
1.8 GHz
1.9/2.1 GHz
2.5 GHz
Asia-Pacific
450 MHz
700 MHz
850 MHz
900 MHz
1.7 GHz
1.8 GHz
1.9/2.1 GHz
2.3 GHz
2.5 GHz
South America and Latin America
450 MHz
700 MHz
850 MHz
900 MHz
1.7/2.1 GHz
1.8 GHz
1.9 GHz
2.5 GHz
1
2
3

FIGURE 2-1: ITU International Telecommunication Regions and spectrum allocations.

MNOs must pay for the right to transmit and receive data using this shared medium in each country in which they operate. To fatten a wireless data pipe, an MNO must procure additional licenses to use a designated frequency spectrum.

In the U.S., the Federal Communications Commission (FCC) auctions spectrum to MNOs — and we aren't talking about eBay auctions here! In the U.S. alone, spectrum auctions have raised more than 60 billion dollars since 1994. Another challenge for MNOs is that available spectrum is limited and going once . . . going twice . . . sold!

Thus, MNOs must find new ways to use existing spectrum more efficiently. LTE Advanced and LTE Advanced Pro are pioneering the path to 5G, using several innovations to get more data through existing spectrum, including:

- Carrier aggregation (CA)
- Multiple input multiple output (MIMO)
- Quadrature amplitude modulation (QAM)

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We All Bundle — with CA

As you might imagine, the process of buying and selling spectrum, over time, causes spectrum to be sliced and diced in some pretty creative ways. MNOs also come and go, or get merged, acquired, and divested (for example, Cingular Wireless and MCI). All of this causes yet another challenge — contiguous spectrum is hard to find and MNOs must cobble together different bands to maximize their available bandwidth. It's sort of like a business being so unreasonable as to want a continuous range of direct inward dialing (DID) phone numbers to simplify its phone switch programming, company directories, and business cards! Except that in the case of frequency spectrum, non-contiguous bands aren't just a messy inconvenience — they limit available bandwidth.

For LTE networks, including LTE Advanced and LTE Advanced Pro, four carrier bandwidths (or sizes) are available for transporting data:

- 5 megahertz (MHz)
- 10 MHz
- 15 MHz
- 20 MHz

Larger bandwidths can transport more data. For example, 10 MHz can transport data at 37.5 megabits per second (Mbps) and 20 MHz can transport data at 75 Mbps. These data transfer rates assume a single antenna on the user equipment (UE) side and on the Evolved Node B (eNodeB) side. This is known as single input single output (SISO).

TECHNICAL STUFF

User equipment (UE) refers to an end-user device in a mobile network, such as a smartphone. *Evolved Node B (eNodeB)* is the MNO hardware — for example, a base transceiver station (BTS) — that wirelessly communicates directly with the UE.

Carrier aggregation (CA) is a technique that allows an MNO to use more than one component carrier (CC) — known as the *secondary carrier* — as an additional data pipe. For example, 2CA enables any of the four carrier bandwidths (5, 10, 15, or 20 MHz) to be used as the primary carrier and any of the other four carrier bandwidths to be used as the secondary carrier.

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In the simplest deployment scenario, known as *intra-band contiguous CA*, a 20 MHz primary and a 20 MHz secondary carrier (totaling 40 MHz) would provide twice the maximum possible bandwidth and throughput of a single carrier.

For SISO, a 2CA of 20+20 MHz would provide 150 Mbps of data throughput.

TIP

MNOs in the U.S. are currently deploying 3CA and some are already moving to 4CA (see Figure 2-2). The challenge for MNOs now is to find three or more CCs that they own the license to operate in and can aggregate. The LTE Advanced standard specifies 5CA totaling 100 MHz, while LTE Advanced Pro calls for 32CA totaling 640 MHz of aggregated carrier bandwidth.

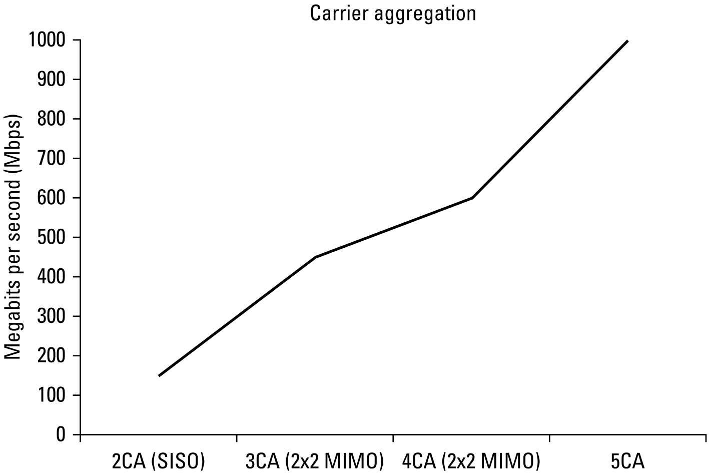

FIGURE 2-2: Carrier aggregation (CA) increases available bandwidth and data throughput.

Eeny, Meeny, Miny, MIMO

One of the techniques for fattening the data pipe defined from day one in 4G LTE networks is multiple input multiple output (MIMO) — using multiple antennas on the transmit and receive side in the wireless network. Using a technique called *spatial multiplexing*, it's possible to send a different data stream on each antenna, thereby increasing the throughput to the cell tower and to the user device.

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While 2x2 MIMO deployments (two antennas in, two antennas out) are common today, 4x4 MIMO (four antennas in, four antennas out) is becoming more practical. 4x4 MIMO effectively enables four independent data streams, thereby increasing the throughput by four times. Thus, the 2CA deployment example (described in the previous section) with two 20 MHz channels and a 2x2 MIMO configuration would increase the data throughput from 150 Mbps to 300 Mbps. The same scenario with a 4x4 MIMO configuration would theoretically increase data throughput to 600 Mbps.

LTE Advanced specifications for MIMO accommodate 8-, 16-, and 32-antenna configurations. LTE Advanced Pro specifications increase MIMO configurations to 64 antenna elements. Realistically, using 64 antenna streams to increase the throughput of a single UE isn't practical. However, using a technique called *beamforming,* the eNodeB can focus energy (that is, steer beams of data) to a particular UE, thereby increasing the throughput of that UE while simultaneously handling other UEs through a different set of beams. Massive MIMO will utilize massive antenna arrays — comprised of hundreds of antennas — to provide efficient signal coverage and higher data rates with lower latency in 5G networks.

No Qualms About QAM

Quadrature amplitude modulation (QAM) is a technique widely used to vary data signals on a carrier used for radio communication. When used for digital transmission of radio communication applications, QAM can carry higher data rates than ordinary amplitude modulated and phase modulated schemes. In QAM, the constellation points are normally arranged in a square grid with equal vertical and horizontal spacing. As a result, the most common forms of QAM use a constellation with the number of points equal to a power of 2 (such as 4, 16, and 64). Thus, 16-QAM uses a 16-point constellation while 256-QAM uses a 256-point constellation.

By using higher order modulation formats (that is, more points on the constellation), it is possible to transmit more bits per symbol. So, 64-QAM has six bits per symbol (more data transmitted), whereas 16-QAM uses only four bits per symbol (less data transmitted). However, the points for a higher QAM are closer together and are therefore more susceptible to noise and data errors. 256-QAM has been used for data in digital cable

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communications and is now starting to be used for radio communications. 256-QAM is included as part of the LTE Advanced Release 12 standard from the Third Generation Partnership Project (3GPP) because it is likely to work with small cell towers. T-Mobile has achieved 400Mbps downlink speeds in trials through a combination of 4x4 MIMO and 256-QAM.

REMEMBER

5CA and beyond, massive MIMO, and higher-order QAM are all techniques defined as part of the LTE Advanced and LTE Advance Pro standards. With LTE Advanced deployments in full swing, 1 Gbps download speeds are getting closer to becoming a reality in operational networks. 5G will use all these techniques to achieve 20 Gbps data speeds. For example, these are a few of the developments on the 5G horizon:

- CA on very large bandwidths, leading to aggregate totals of 800 MHz (and even 1 GHz) carrier bandwidth
- Massive MIMO antenna arrays of 128 elements or more
- 1024-QAM, and even 4096-QAM

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IN THIS CHAPTER

- » **Expanding cellular traffic to unlicensed spectrum**
- » **Getting LTE-U and LAA to coexist with Wi-Fi in unlicensed spectrum**
- » **Going it alone in unlicensed spectrum with MulteFire**

Chapter 3

Tapping into Unlicensed Spectrum

Unlicensed spectrum is used by low-power devices to transmit and receive wireless signals over short distances — typically a few meters. Although specific devices are permitted to operate only in specific bands, the process of getting certifications is not time-consuming or costly, compared to getting a cellular operator license. Some common devices in this category include garage door openers, nursery monitors, home security systems, cordless phones, and Bluetooth speakers/headsets. In this chapter, you learn about the role of unlicensed spectrum in the 5G future.

Giving a "High 5(G)" to Wi-Fi Advancements

Wi-Fi operates in the unlicensed 2.4 gigahertz (GHz) and 5 GHz spectrums. There are fewer rules on who can access these bands and more available spectrum compared to licensed frequency bands. Wi-Fi devices must therefore compete to use the same spectrum as other devices.

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Over the past few years, improvements in speed and the advancement of new capabilities have made Wi-Fi viable (and lucrative) for many mobile network operators (MNOs).

MNOs now regularly use Wi-Fi to offload their cellular networks wherever possible. Newer Wi-Fi standards enable massive speed increases. The standards utilize many of the latest multiple input multiple output (MIMO) beamforming techniques and higher quadrature amplitude modulation (QAM) schemes as those used in the licensed spectrum (discussed in Chapter 2).

For example, 802.11ac delivers Wi-Fi speeds of up to several gigabits per second (Gbps) operating in the 5 GHz band, using 80 or 160 megahertz (MHz) wide channels, advanced beamforming techniques, eight spatial streams (MIMO), multi-user MIMO (MU-MIMO), and 256-QAM (which produces four times the spectral efficiency of the previous 802.11n Wi-Fi standard).

The next wave in Wi-Fi is 802.11ax. 802.11ax will use orthogonal frequency-division multiple access (OFDMA) — the same technique used in Long Term Evolution (LTE) networks — in which different subcarriers within a carrier can be used to transport data for different users. As a result, more than one user equipment (UE) device can access the same medium at a given instant without having to back off or concede the medium to another UE device.

TIP

In case you're wondering, other standards exist between 802.11ac and 802.11ax, but they define Wi-Fi standards in unlicensed spectrum other than 2.4 GHz and 5 GHz — and they don't sound as cool as "A-X"!

LTE in Unlicensed Spectrum

LTE in Unlicensed spectrum (LTE-U) is a proposal that was originally developed by Qualcomm for LTE to co-exist with Wi-Fi in shared unlicensed spectrum. In LTE-U, calls are initially set up using licensed LTE spectrum. Additional carriers (for data) can then be aggregated from the unlicensed spectrum. This method will allow the operators to use unlicensed spectrum to "fatten the data pipe."

The Wi-Fi Alliance developed a Wi-Fi co-existence test plan to ensure that Wi-Fi and LTE could peacefully co-exist, and MNOs (including T-Mobile, AT&T, and Verizon) began experimenting with unlicensed spectrum in addition to their licensed spectrum.

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LTE-U has also generated a lot of interest from a small cell perspective because this approach potentially makes small cells a viable alternative to Wi-Fi hot spots.

As you might imagine, strong reservations about LTE-U exist, because of concerns that it will unfairly use the unlicensed spectrum and potentially interfere with other Wi-Fi users. Cable companies, such as Comcast, Charter Communications, and Time Warner Cable (TWC), as well as Google and Microsoft, are opposed to LTE-U. As of February 2017, the U.S. Federal Communications Commission (FCC) has approved Ericsson and Nokia equipment as LTE-U certified.

License Assisted Access

Unlike LTE-U, License Assisted Access (LAA) is a standard defined in the Release 13 specification from the Third Generation Partnership Project (3GPP). LAA attempts to resolve contention issues with Wi-Fi in unlicensed spectrum using a protocol many of us learned as children — Listen Before Talk (LBT). The LBT contention protocol requires LAA to listen to the unlicensed channel first, and then, if there is no other active Wi-Fi user (the channel is silent), the LTE user can use the channel.

TIP

A recent report by Strategy Analytics states that only 16 percent of operators can achieve gigabit LTE without using unlicensed spectrum. Using LTE-U and LAA, 64 percent of operators can achieve gigabit LTE.

Qualcomm's over-the-air trials with Deutsche Telecom in Germany showed that LAA had increased coverage and capacity compared to Wi-Fi on the same spectrum. By respecting the LBT maxim (uh, protocol), the behavior of LAA is more closely modeled to the principle "love thy neighbor" and is a better neighbor to Wi-Fi than Wi-Fi is to LTE. Wi-Fi was more of an imp during its formative years and ignores LBT, trying to access the same medium at the same time as others.

Enhanced LAA (eLAA), which aggregates the uplink on unlicensed spectrum, is the next step in the evolution of LAA. eLAA will be defined in the 3GPP Release 14 specification.

REMEMBER

Both LAA and eLAA require the initial call to be set up on LTE licensed spectrum as the primary channel. Unlicensed spectrum is only used to "fatten" the data pipes.

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MulteFire

MulteFire goes beyond LTE-U and LAA by enabling the LTE primary channel on unlicensed spectrum. In fact, MulteFire uses unlicensed spectrum exclusively. This means MulteFire can be deployed for LTE by anyone — without owning licensed spectrum — such as Internet service providers (ISPs) and commercial enterprises. MulteFire also benefits MNOs by providing new deployment opportunities for offloading and augmenting their cellular networks.

In January 2017, the MulteFire Alliance released version 1.0, defining an LTE-like network that can run entirely on unlicensed spectrum and, in some cases, may be an alternative to Wi-Fi with more capacity, better security, and easier handoffs across carrier networks.

REMEMBER

Today's 4G spectrum has around 500 MHz of unlicensed spectrum available to deploy LTE-U, LAA, and MulteFire. In July 2016, the FCC opened up 5G spectrum in the U.S., which has 10.85 GHz of total spectrum (3.85 GHz of licensed spectrum and 7 GHz of unlicensed spectrum). The techniques that are now evolving in LTE Advanced Pro (Releases 13 and 14) — LTE-U, LAA (and eLAA), MulteFire, and others (see Figure 3-1) — will be vital as even more unlicensed spectrum becomes available in 5G. The key goal will be to provide users with a seamless experience, irrespective of whether they are operating on a licensed or unlicensed band.

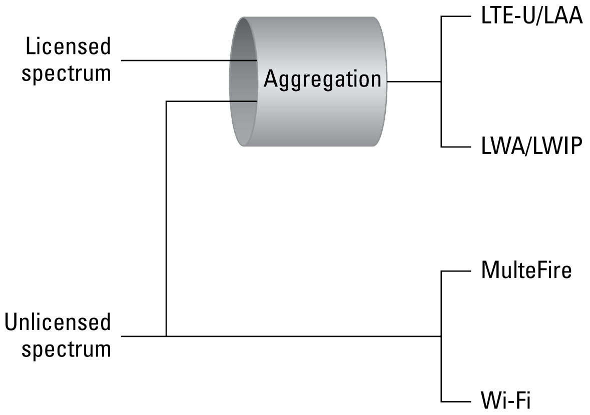

FIGURE 3-1: Leveraging licensed and unlicensed spectrum.

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IN THIS CHAPTER

- **Defining IoT connectivity requirements**
- **Handling massive scale with NB-IoT**
- **Slicing up spectrum for the rise of the machines**
- **Exploring LoRaWAN and Sigfox for low-power networks**

Chapter 4

Enabling Massive IoT

When 4G networks were introduced in 2008, there were close to 700 million mobile subscribers worldwide. Today, there are more than 7 billion mobile subscribers worldwide. By 2020, according to the most conservative estimates, there will be approximately 20 billion Internet of Things (IoT) devices, in addition to the 9 billion mobile subscribers that are expected worldwide.

Thus, 5G networks must not only deliver extreme speeds and feeds, they must provide massive scale, predictability, and reliability to eventually support as many as a trillion connected devices, including mission-critical and potentially lifesaving applications and scenarios. In this chapter, you learn about the key requirements for IoT device connectivity and the innovations that are being developed to support IoT.

Key Connectivity Requirements for IoT Devices

Unlike smartphones and other cellular devices, IoT device communications can be sporadic in nature. Many of these devices "sleep" (to extend battery life for ten or more years in some cases)

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for long periods of time — hours, days, or weeks — before transmitting a few bytes of data, and thus needn't always be connected to the network. 5G networks must be designed to handle infrequent, but important communications from these types of IoT devices. Although the amount of data these devices send may be significantly lower, they may still be of a time-critical nature. For example, a sensor that detects a hazardous condition may instruct an Evolved Node B (eNodeB) element to shut down equipment in an industrial plant or building. These types of communication, though extremely rare, must be handled with the utmost responsiveness and reliability.

Additionally, eNodeB elements will require massive capacity to scale to support tens of thousands of IoT devices — all with different communications requirements and characteristics — in a single cell.

Finally, a wide variety of security threats and new attack vectors will be surfaced in IoT devices. Unlike many of today's threats — identity theft and credit card fraud, for example — many IoT security threats will be potentially life threatening. Future threats may include hacked control systems in autonomous vehicles and smart grids, or compromised medical devices such as insulin pumps and pacemakers. Thus, 5G technologies will need to provide secure end-to-end communications throughout the network.

NarrowBand IoT (NB-IoT)

The Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) Advanced Pro Release 13 specification defines a new standard — NarrowBand IoT (NB-IoT) — for handling low volumes of data (similar to 2G) from tens of thousands of devices in a single cell (tower, not amoeba).

NB-IoT extends LTE to even narrower bandwidths optimized for low data rate, latency-tolerant IoT applications. NB-IoT reduces device complexity, enables multiyear battery life, and provides deeper coverage to reach sensors in challenging locations, such as remote rural areas or inside buildings.

Perhaps one of the most attractive features of NB-IoT is its ability to leverage already ubiquitous LTE networks, in addition to providing high quality of service (QoS) and comprehensive security.

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NB-IoT can be deployed in three different modes:

- **Standalone as a dedicated carrier:** Can use GSM frequencies in a bandwidth of 200 kHz. This does not require LTE.
- **Guard band:** Uses a free resource block within the LTE guard band. This allows the IoT devices to not compete with other LTE devices for the resource blocks within the carrier.
- **LTE in-band:** Uses a resource block within the LTE frequency band. The rest of the blocks are used by the regular LTE devices.

Long Term Evolution for Machines (LTE-M)

Like NB-IoT, Long Term Evolution for Machines (LTE-M or LTE Category M1) leverages a narrow slice of existing LTE spectrum to send and receive data for IoT devices. LTE-M has the same benefits as NB-IoT, but uses a larger network slice than NB-IoT (1.4 MHz compared to 180 KHz in NB-IoT) and leverages the LTE protocol more than the NB-IoT in terms of reusing the same control, data, and transport channels.

TIP

Verizon launched the first LTE-M network in the U.S. on March 31, 2017, and ATT Wireless was expected to follow shortly after.

LoRaWAN and Sigfox

Long Range Wide Area Network (LoRaWAN) is a Low Power Wide Area Network (LPWAN) specification for wireless, battery-operated IoT devices. LoRaWAN operates in the sub-1 GHz unlicensed spectrum band. This limits the volume and frequency of traffic, as well as the ability of the base station to control the network and send traffic down. However, LoRaWAN has great advantages in terms of battery life and cost, and communication is bi-directional.

Sigfox is a French company that created a technology similar to LoRaWAN for IoT device communication. Sigfox technology uses

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very low bandwidth connections. It is not bi-directional and is only used for sending sparse uplink data with very limited downlink. Like LoRaWAN, Sigfox operates in the sub-1 GHz space and thus uses very low power.

LoRaWAN and Sigfox will be used with certain types of sensors, smart meters, and other low data IoT devices. A disadvantage for these technologies is that, unlike NB-IoT, which is built on top of existing LTE infrastructure, LoRaWAN and Sigfox are not integrated with LTE. However, the cost of deploying a LoRaWAN or Sigfox based IoT device is far less than for an NB-IoT or LTE-M device — by an order of magnitude, since NB-IoT and LTE-M devices must integrate LTE modules into their devices.

REMEMBER

As countries and mobile network operators (MNOs) make IoT technology decisions, it is likely that many standards, protocols, and technologies will need to co-exist. Factors such as cost, coverage, battery life, and integration with older 4G networks will determine which standards, protocols, and technologies are best for each use case.

The 3GPP specifications for IoT technologies are just starting to come out as part of the LTE-A Pro standards. Many IoT devices will need to operate at very low power, ideally suited for sub-1 GHz spectrum rather than the millimeter wave (mmWave) spectrum (discussed in Chapter 6). That said, there are some compelling 5G techniques, like resource spread multiple access (RSMA) waveforms that allow grant-free transmissions for "things" to send their data without prior scheduling by the eNodeB. As a result, the scheduling algorithm becomes less complex. 5G will also enable multi-hop mesh for these low-power devices, allowing out-of-coverage devices to relay to other connected devices in order to send data to the eNodeB.

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IN THIS CHAPTER

- » **Virtualizing the network for 5G and IoT**
- » **Knowing which network elements to virtualize**

Chapter 5

Getting Real About the Need to Virtualize

Virtualization has been a hot topic in the technology industry for many years and its advantages transcend the cellular industry. In this chapter, you learn about the network elements that can be virtualized and the essential role of virtualization in 5G.

Driving 5G and IoT with Virtualization

Telecommunications companies and mobile network operators (MNOs) have invested heavily in their 4G and Long Term Evolution (LTE) networks. These organizations have embraced virtualization to enable faster, more agile, and scalable deployments that can keep pace with the explosion in subscriber data traffic and consumption, all while keeping control of their overall capital and operating costs. Even though these investments have already given users mobile connectivity of unprecedented speed and pervasiveness, they have only laid the foundation of what's to come, as 5G and smart, connected devices start to roll out.

A recent study by a division of Nokia Bell Labs provides a glimpse of what's coming. The study found that the number of Internet of Things (IoT) connected devices is expected to expand from 1.6 billion in 2014 to well over 20 billion by 2020. Also, by 2020, global consumption demand for digital content and services on portable devices will see an average increase of 30 to 45 times the

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levels seen in 2014. Thus, MNOs will need to further accelerate their technology investments to meet ever-increasing consumer and business connectivity demands.

Recognizing the IoT explosion

Although MNOs in the U.S. are starting to embrace "pre-standard" 5G, vying for the first mover's advantage, the standards are not expected until 2018. This has echoes of the early days of 3G in the late 1990s and early 2000s, before proprietary implementations were standardized. It isn't surprising that some operators in the U.S. have already announced their plans to deploy 5G later this year, and some of the early adopters in Korea, Japan, and China are also ready to roll out 5G. Because of the rapid deployment, many 5G concepts are being solidified quickly.

5G is sometimes narrowly classified as a higher bandwidth radio access technology. But it is much more than that. It will also be the network for low-power devices and sensors that are classified as IoT devices, as well as low-latency applications. One example is the low latency required for some mission-critical devices, such as autonomous vehicles. The need for low latency will dictate that key LTE base station functions are distributed, with some moving closer to the edge and others being pooled in the cloud.

Another example is that vertical sectors will require different types of services from the 5G network. Some will need high bandwidth, while others will need low power. Some will need very low latency, and others will need very high availability. The vast volume of IoT devices will range from those that send multiple gigabits of data per second to those that will only send a few bits every month. This flexibility and elasticity can be supported only by advanced network virtualization.

Focusing on service

To support such varying 5G use cases across multiple verticals, MNOs need to shift from being network-centric to being more service-oriented.

To understand this shift, consider the concept of network slicing (see Figure 5-1). Here are a few typical cases:

- Mobile broadband with higher bandwidth video requiring high availability everywhere

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- Low-power sensors that can operate on a pair of AA batteries for 10 years
- Autonomous vehicles that can zip through crowded city streets but brake within microseconds when they sense potential obstructions in their paths

TECHNICAL STUFF

Each of these scenarios requires a different configuration of the requirements and parameters in the network, potentially including:

- Home Subscriber Server (HSS)
- Mobility Management Entity (MME)
- User equipment (UE)
- Enhanced Node B (ENB or eNodeB)
- Serving Gateway (SGW)
- Packet Data Network Gateway (PGW)
- Policy and Charging Rules Function (PCRF)
- LTE Evolved Packet Core (EPC) interfaces (S1-MME, S11, S1-U, SGi)

In essence, each use case requires its own network slice. Networks must be built in a manner that allows speed, availability, capacity, and coverage to be allocated in logical slices to meet the demands of each use case.

The best way to implement network slices will be via virtualization — to use service provider software-defined networking (SDN), network functions virtualization (NFV), and network orchestration (see Figure 5-2). In each of these cases, the SDN controller will configure and build network slices that include service chains such as deep packet inspection (DPI), emails, and security scans per user or per service. The network services — including the Centralized Radio Access Network (C-RAN), Virtual Evolved Packet Core (vEPC), and Virtual IP Multimedia Subsystem (vIMS) — are virtualized as virtual network functions (VNFs) that allow MNOs to set up services rapidly, and scale them in response to network and service demands.

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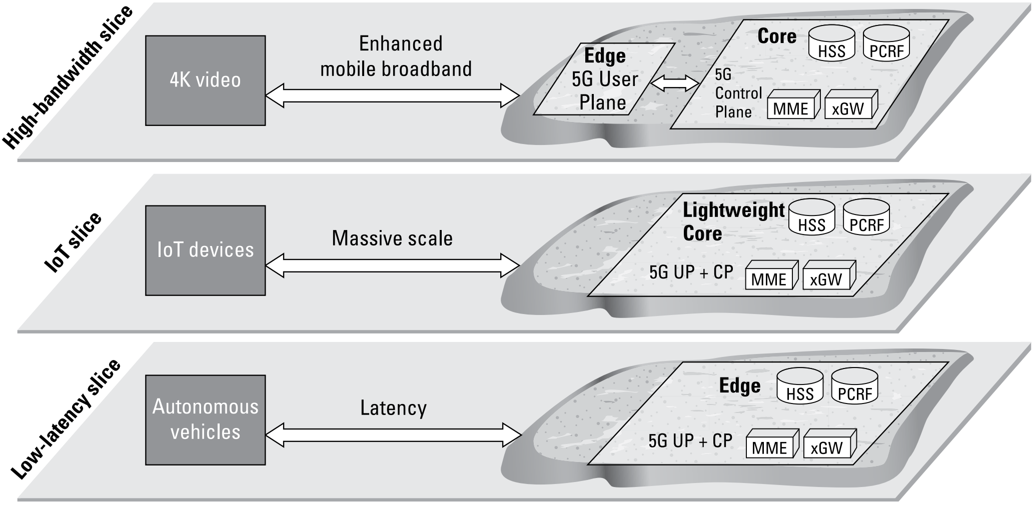
High-bandwidth slice
4K video
Enhanced mobile broadband
Edge
5G User Plane
Core
HSS
PCRF
5G Control Plane
MME
xGW
IoT slice
IoT devices
Massive scale
Lightweight Core
HSS
PCRF
5G UP + CP
MME
xGW
Low-latency slice
Autonomous vehicles
Latency
Edge
HSS
PCRF
5G UP + CP
MME
xGW

FIGURE 5-1: 5G network slices.

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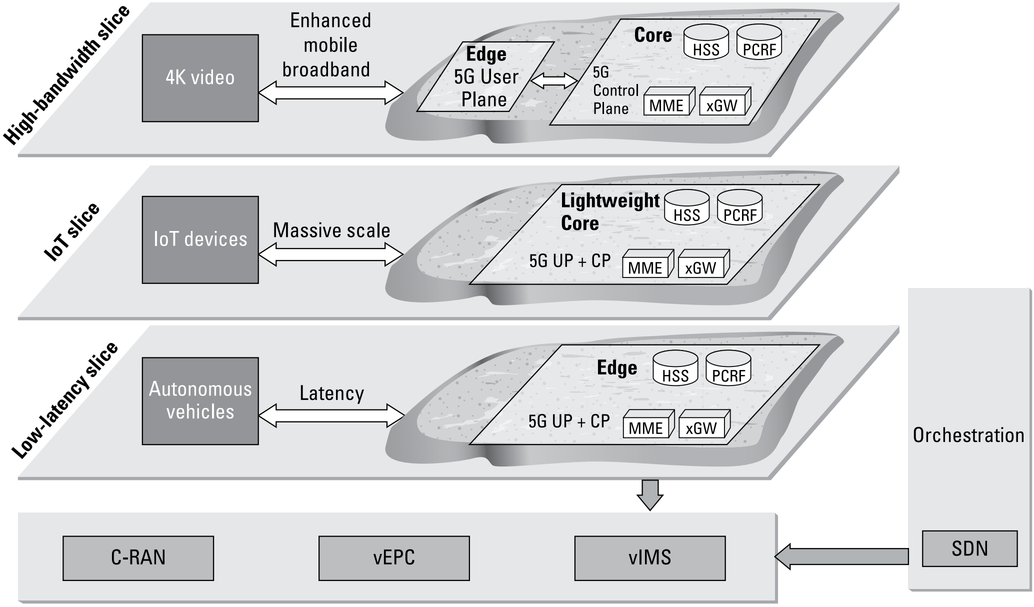
High-bandwidth slice
4K video
Enhanced mobile broadband
Edge
5G User Plane
Core
HSS
PCRF
5G Control Plane
MME
xGW
IoT slice
IoT devices
Massive scale
Lightweight Core
HSS
PCRF
5G UP + CP
MME
xGW
Low-latency slice
Autonomous vehicles
Latency
Edge
HSS
PCRF
5G UP + CP
MME
xGW
Orchestration
C-RAN
vEPC
vIMS
SDN

FIGURE 5-2: Network slices, VNFs, and management and orchestration in a 5G architecture.

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Managing the migration

Thus, virtualization will be a vital piece of the puzzle as 5G is rolled out and the IoT grows. But the speed and agility that virtualization enables must be balanced against the need for network visibility, resilience, manageability and security, throughout the development, roll-out, and mass usage of each service.

MNOs and service providers must weigh the trade-offs between

- Quality and cost.
- Flexibility and control.
- Moving too quickly and not moving fast enough.

REMEMBER

As a result, the demand for simple, end-to-end solutions that can efficiently test and validate the effectiveness and benefits of virtualization at every stage is only going to increase. Network virtualization will be a key driver of the IoT ecosystem as it develops — and full-lifecycle reliability and performance testing will be a key element of this shift.

Virtualizing Network Components

When LTE networks were conceptualized, one notable difference from earlier 3G architectures was the idea of a central "brain" — the evolved Node B (eNodeB). From the eNodeB — the point at which the cellular network wirelessly connects directly to user equipment (UE) — to the Internet, the connectivity would all be Internet Protocol (IP) based.

When data centers and other wired network components (such as routers, switches, and firewalls) started being virtualized on standard off-the-shelf servers, it was only natural for the wireless, IP-based 4G evolved packet core (EPC) to follow.

Virtual EPC (vEPC)

Because packet gateways, policy servers, and subscriber databases are all IP-based in the LTE network, the EPC is an excellent

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candidate for replacing proprietary hardware with virtualized functions hosted on standard, off-the-shelf servers. The benefit for MNOs is the elasticity this model enables — no more dedicated hardware and no need to oversubscribe every part of the network. Servers can be quickly and easily provisioned or de-provisioned based on real-time subscriber capacity needs. With SDN controllers and EPC functions migrated to NFV, and orchestration schemes added to manage it all, the wireless core could be fully virtualized and cloud ready!

Centralized Radio Access Network (C-RAN)

Virtualization in the radio access network (RAN) requires separating out latency-sensitive elements and the radio itself, then pooling the rest of the baseband functions into centralized baseband units (BBUs). Which functions should stay with the remote radio head (RRH) and which ones should move to centralized BBUs has been extensively studied, and a few options exist.

The C-RAN model, which requires a fiber connection between the RRH and the BBUs, is popular in some regions of the world, such as China and Korea. This front-haul interface is challenging because it has distance limitations and is bandwidth limited. It uses a protocol known as the Common Public Radio Interface (CPRI). China Mobile has been in the forefront of the C-RAN architecture. Other countries such as Japan and Korea have also adopted C-RAN. In the U.S., Verizon is looking at implementing C-RAN for small cells.

Mobile Edge Computing (MEC)

Mobile Edge Computing (MEC) offers an important balance as cellular networks move to a central model. MEC allows certain latency-sensitive components to be moved to the network edge. For example, even though it may make business sense for MNOs to centralize several functions into VNFs running on standard off-the-shelf servers, some critical functions may need to be

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closer to the edge of the network to ensure high availability, low latency, and higher levels of security.

TIP

The network edge is also a good place to host application servers that require local context. For example, if you are driving around and you receive restaurant ads on your mobile device based on your current location, you need the application service to be close to the edge to avoid a lengthy delay in the app that could render the information obsolete.

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IN THIS CHAPTER

- Tuning in to the basic functions of 5G New Radio
- Catching the millimeter wave

Chapter 6

Creating a New 5G World Order with New Radio (NR)

In this chapter, you learn about a completely new technology that creates the foundation for 5G — the 5G New Radio (NR) physical air interface.

5G NR Basics

Unlike the other 5G elements (covered in previous chapters), that advance the industry toward the goals of 5G networks, 5G New Radio (NR) is not an evolution of 4G Long Term Evolution (LTE) innovations. 5G NR is a completely new technology specification — a physical air interface — that is required to achieve the extreme bandwidth, low latency, and massive scalability requirements of 5G.

REMEMBER

The other four areas of 4G LTE innovation that are being further developed for 5G include:

- **Speeds and feeds:** Discussed in Chapter 2, innovations such as carrier aggregation (CA), massive multiple input multiple output (MIMO), and quadrature amplitude modulation (QAM), among others, enables carriers to "fatten" the data pipe.

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- **Unlicensed spectrum:** Discussed in Chapter 3, LTE in unlicensed spectrum (LTE-U), License Assisted Access (LAA and enhanced LAA, or eLAA), and MulteFire enable carriers to leverage unlicensed spectrum as additional data pipes.
- **Internet of Things (IoT):** Discussed in Chapter 4, IoT developments include NarrowBand IoT (NB-IoT), LTE for Machines (LTE-M or LTE Category M1), and Low Power Wide Area Network (LPWAN) specifications such as Long Range WAN (LoRaWAN) and Sigfox. These developments enable wireless communication with a diverse array of billions of IoT devices.
- **Virtualization:** Discussed in Chapter 5, software-defined networking (SDN) and network functions virtualization (NFV) enable mobile network operators (MNOs) to achieve cost-effective scalability and elasticity in their core networks with innovations that include network slicing, virtual evolved packet core (vEPC), centralized radio access network (C-RAN), and mobile edge computing (MEC).

The 5G NR specification enables the following goals of 5G:

- **Extreme bandwidths:** 5G NR aggregates eight component carriers (CCs). The carrier width specifications are still in development, but will likely be 100 megahertz (MHz) or greater, providing a total of approximately one gigahertz (GHz) of aggregated bandwidth — wide enough to carry 20 gigabits of data per second.
- **Low latency:** In LTE Advanced, each subframe (there are 10 subframes) is handled in one millisecond (ms). 5G will be five to ten times faster — each subframe is handled in 100 to 200 microseconds (μs). 5G NR will use new channel coding techniques, such as low density parity check (LDPC), that are more efficient than existing techniques, resulting in shorter transmission time intervals (TTIs).

  TECHNICAL STUFF

  A technique called *scalable orthogonal frequency-division multiplexing (OFDM) numerology* will be used to support different use cases and scenarios within the same frame. Effectively, shorter TTIs will be used for low latency, high reliability use cases, and longer TTIs for higher spectral efficiency, higher bandwidth use cases. 5G NR can also effectively multiplex between short and long TTIs, thereby allowing a diverse set of users to simultaneously use the system.

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- **Massive MIMO:** 5G NR extends MIMO up to 256 antenna elements and enables massive MIMO. This is a key enabler for higher spectrum bands. The antenna elements in this case are smaller, thereby making it less complex to build a massive array.
- **Massive IoT:** 5G NR will use resource spread multiple access (RSMA) on the uplink to enable grant-free transmission of data on the uplink. A device does not need an enhanced Node B (eNodeB) to give it a grant (or slot) in the pipe to transmit data. This capability eliminates the need for signaling and allows devices to send small packets asynchronously. 5G NR will also address distance and location challenges in low-power IoT devices, using a technique called *multi-hop mesh* to relay uplink data via nearby devices.

5G NR is part of the Release 15 specification from the Third Generation Partnership Project (3GPP). Two versions of 5G NR exist:

- **Non-standalone (NSA) 5G NR:** NSA will use the existing LTE radio and core network as the control plane anchor for mobility management and coverage, while adding a new 5G carrier. Early 2019 deployments of 5G NR will use this configuration. In this mode, the connection is anchored in 4G LTE while 5G NR carriers are used to boost data rates and reduce latency.
- **Standalone (SA) 5G NR:** SA will use the new 5G core network (5GCN) architecture, including the full control and user plane offered by 5G.

An interim release of the 5G NR NSA specification was accelerated to the end of 2017 to enable large-scale trials and deployments for enhanced mobile broadband (eMBB) use cases to begin in 2019. The 5G NR SA specification is expected in mid-2018.

More Spectrum — mmWave Bands

In the U.S., the Federal Communications Commission (FCC) has opened a total of 10.85 GHz of spectrum above 24 GHz to enable 5G use cases. The new spectrum includes 3.85 GHz of licensed spectrum from 27.5 to 28.35 GHz and 37 to 40 GHz, and 7 GHz of unlicensed spectrum from 64 to 71 GHz.

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These bands — between 30 GHz and 300 GHz — are known as millimeter wave bands (mmWave). These high frequency bands translate to narrow wavelengths in the range of one to ten millimeters. There are some challenges with mmWave, including:

- Short transmission paths and high propagation losses over long distances and anything that is not line of sight
- Weakened signals in gases and precipitation

However, the short transmission paths and propagation loss characteristics of mmWave enable spectrum reuse, by limiting the interference between adjacent cells. Additionally, because of the extremely short wavelengths of mmWave signals, transmission paths can be extended using small, multi-element dynamic beamforming antennas that can be installed in user equipment (UE) such as smartphones.

TIP

5G NR, operating at very high frequencies with small coverage areas (because of propagation and line-of-sight issues), is ideal for dense urban locations, where cell sizes are generally small (approximately 200 meters).

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IN THIS CHAPTER

- » Bringing 5G home
- » Staying entertained on the move
- » Getting a dose of virtual and augmented reality
- » Driving 5G for smart cars and autonomous vehicles
- » Living in a connected world
- » Assimilating humans and machines

Chapter 7

Exploring 5G Use Cases

In this chapter, you learn about some of the key use cases that will be enabled by 5G.

Fixed Wireless Broadband Service

5G will begin its commercial drive with the fixed wireless broadband use case in the U.S. AT&T and Verizon are racing to be the first to deliver fixed wireless broadband service to their customers.

Verizon acquired XO Communications, which included the 28 gigahertz (GHz) spectrum, in 2016. One of the primary drivers for Verizon will be to offer 5G as an alternative to cable/advanced digital subscriber line (ADSL) for high-speed broadband access to residential customers for gigabit speed Internet, 4K content, virtual reality (VR), and more. The goal is to achieve greater than one gigabit per second (Gbps) speeds without digging trenches to get fiber to your home.

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AT&T is also pursuing 5G on fixed wireless in both the 28 GHz and 37 GHz spectrum bands. 5G video trials are currently underway for some residential customers, allowing them to stream DIRECTV NOW video service over a fixed wireless 5G connection. In its internal testing, AT&T Wireless claims it can now achieve 13 Gbps over a 5G connection. Like Verizon, AT&T is also looking at 5G to replace home broadband connections delivered by cable companies.

If successful, these use case trials could signal the end of the "cable guy" coming out "sometime between 1 p.m. and 4 p.m." to route a coaxial cable through your home. In areas where there is currently only one option for home broadband or television service, this technology could also lead to more competition, better service, and lower rates for subscribers.

Cable companies, such as Charter Communications, are also exploring 5G technologies. Charter is planning to conduct 28 GHz 5G experiments in the near future with antennas mounted on a mobile trailer and van with hydraulic masts, which will be moved to each of the test locations.

TIP

The motivation for a company like Charter is that 5G will enable a host of new products that take advantage of low-latency, high-capacity networks, including virtual reality (VR) and augmented reality (AR) applications, many of which will be used in a fixed home or office location.

Entertainment Everywhere

The natural progression of the fixed wireless broadband use case (discussed in the previous section) enables mobile broadband at extreme data rates "everywhere" — not only to a fixed home or office location.

Although some of the envisioned mobile broadband experience started in Long Term Evolution (LTE) networks, 5G takes it to a different level with 4K (and subsequently 8K) television, high dynamic range video streaming, 3D videos, and more. All these applications require very high bandwidth, and many require always-on connectivity to push real-time information to the users. The transformation from fixed wireless to wireless everywhere

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requires several mobility-specific factors to be addressed, such as fast handoffs, seamless connectivity at very high speeds and low latency, high reliability when mobile, and others.

REMEMBER

Cloud storage is also driving the growth of uplink data rates. In the past, content was mostly downloaded and thus required a "fat" pipe in only one direction: the downlink from the base station to the mobile device. However, content is increasingly being uploaded to different cloud storage platforms, requiring robust data pipes in both the downlink and uplink directions. Cloud gaming is another 5G driver that requires fast responsiveness and high broadband capacity.

Virtual Reality (VR) and Augmented Reality (AR)

Virtual reality (VR) technology creates a fully immersive, computer-generated experience that simulates or re-creates real-life situations and environments. In contrast to VR, augmented reality (AR) layers computer-generated images and enhancements onto a real-world situation or environment to provide a more meaningful context for user interaction.

Although current 4G networks are sufficient for some early-adopter VR and AR experiences, the introduction of 5G will enable more novel VR and AR experiences and make them available for mass adoption by consumers. Offering much more capacity, lower latency, and a more uniform experience, 5G will not only improve, but will also be a requirement for some of the most exciting AR and VR use cases, including:

- Sharing live streaming content on social media from event venues along with 50,000 other people in a stadium becomes even more challenging with 4K 360-degree video because each user is uploading 25 Mbps at the same time.
- Next-generation VR and AR experiences will have "six degrees of freedom" (6DoF) — the next level of immersion — allowing users to move within and intuitively interact with the environment. 6DoF content is an order of magnitude richer in naturalness and interactivity than current "three degrees of freedom" (3DoF) video. 3DoF experiences, such as 360-degree

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video, allow the user to look around rotationally from a fixed position. 6DoF experiences, which are available in video games today, allow the user to move spatially through the environment just by walking or leaning their head forward.

6DoF head-motion tracking is required to enjoy 6DoF content in an intuitive manner. Many industries such as tourism, education, and other forms of immersive video will flourish as 6DoF technologies evolve. Most components of the video delivery pipeline are currently ill-suited for 6DoF video, including capture devices, production software, codecs, compression algorithms, the network, and players. 6DoF video also demands bit rates in the range of 200 Mbps to 1Gbps, depending on the end-to-end latency.

Connected and Autonomous Vehicles

Smart, connected cars are already here — and some security risks have already been notoriously demonstrated — and self-driving autonomous vehicles are beginning to appear on our roads. Other applications that 5G will enable for smart, connected cars include:

- **Traffic safety:** This includes the ability to detect hazardous road conditions, such as inclement weather or nearby accidents, and provide real-time guidance for appropriate courses of action to enable safer driving and reduce the risk of accidents. For example, imagine a situation in which your driverless car gets a real-time message (in microseconds) that a truck is rapidly approaching the intersection that you are about to cross. Your car then automatically slows down to let the truck pass the intersection, thereby avoiding a possible accident.
- **Entertainment (for passengers):** Live video and music streaming (including 4K ultra high-definition movies), interactive video games, cloud connectivity, and data exchange elaborate the need for high capacity and high mobility mobile broadband.
- **Augmented reality (AR):** Displaying key information in near real-time for drivers requires low latency so that the information is timely and relevant. In the earlier truck

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example, a live situation is being tracked by the involved IoT devices and infrastructure, and relayed in real-time to the users — vehicle and human.

- **Self-driving, autonomous vehicles:** These will require ultra-reliable, high-speed communication between different driverless cars, and between cars and infrastructure.

The Connected World

Smart homes, smart cities, multiple industries (such as health, retail, smart grids, and remote factories) have a common thread — they are using more and more devices and sensors that communicate with one another and the rest of the world.

Many of these devices are mission critical; others may send high-definition video, requiring high availability and very low latency. Yet another set of devices may send small data packets relatively infrequently (for example, every few hours, days, or weeks). Some examples of common use cases with diverse connectivity requirements include:

- **Logistics and freight:** These devices and sensors typically require lower data rates, but need wide coverage and reliable location information.
- **Smart grid:** A smart grid requires low latency sensors to regulate the use of utilities such as electricity, natural gas, and water. Leveraging digital information, such as the behaviors of suppliers and consumers, allows the smart grid to improve the efficiency, reliability, economics, and sustainability of the production and distribution of these resources.
- **Remote medical:** Collaborating about a medical case with other surgeons located thousands of miles away was a use case scenario discussed as part of the Long Term Evolution (LTE) rollout. It can become a reality with the extreme bandwidth, low latency, and high availability of 5G networks.
- **Hazardous areas:** The ability to remotely explore mining areas or shut down a nuclear power plant during an emergency — in a fraction of the time required for human interaction, and without risk to human life — is possible with 5G.

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Augmented Humans

Looking ahead to the more distant future — perhaps 30 years from now — Google futurist Ray Kurzweil predicts humans will be able to upload their entire minds to computers and become "digitally immortal" — an event called *singularity.*

In 2011, IBM's Watson beat former winners on the television game show *Jeopardy!*, proving that computers can outperform the best of humans when it comes to synthesizing information and beating them to the buzzer. Google Home and Amazon Echo are becoming more common in homes — perhaps a bit unnerving at first as they start entering our private lives, and increasingly taking center stage when we want them to tell us more about the weather, play our favorite song, read us our favorite *5G For Dummies* book, or tell a few jokes. As machine learning and artificial intelligence develop further, these intelligent devices will better understand human behavior and evolve beyond databases of information. Eventually, they will also become more mobile and intrinsic in our lives, rather than sitting on a shelf in our living rooms.

REMEMBER

5G — with its extreme bandwidths, very low latency, and massive scale support — will be a critical component in creating these real-time experiences, initially as an assistant to humans, and eventually even "thinking" for humans (in some cases). Shopping for clothes with your kids or selecting your next car will become a more immersive experience. 5G technology might also assist humans as an augmented partner, offloading some of the tasks humans don't want to "expend their own brain cells" on. Although it may sound like science fiction, 5G might be a starting point for the next evolution of humans and machines.

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IN THIS CHAPTER

- **Going beyond speed and latency**
- **Looking at drivers and timelines**
- **Overcoming misconceptions about limitations**
- **Recognizing complementary technologies**
- **Transforming entire industries**

Chapter 8

Ten Myths About 5G — Debunked

In this chapter, we expose ten common myths about 5G — and we clue you in to the reality behind them. Keep these points in mind:

- **5G is all about higher speeds to the user.** Although one of the key goals of 5G is to provide extreme bandwidth (high-speed data) to users, low latency and massive scale are other key goals of 5G. So, 5G isn't just about speed!
- **5G requires less than one millisecond latency.** Although less than one millisecond of latency is a goal of 5G, 5G networks will be deployed before that target is actually achieved.
- **Smartphones will lead the charge to 5G.** The iPhone and Android were born in the 3G era and virtually exploded (literally, in some cases) during the 4G LTE era. However, 5G will not only enable faster and better smartphones — it will also lead to mass-market consumer VR and AR devices, sensors and applications for smart homes and cars, industrial robots, and billions of other Internet of Things (IoT) devices yet to be conceived.

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- **5G will be commercially available in 2017.** Although Verizon plans to roll out 5G fixed mobility in 2017 and Olympic 5G trials will be underway during the 2018 Winter Olympics, 5G standards will not be finalized until the end of 2017. Thus, although some early, pre-standard versions of 5G will be coming soon, the 5G standard is not complete. Standards-compliant 5G will be coming much later.
- **5G is only for short-range, line-of-sight communication.** In addition to other frequency bands, 5G uses mmWave bands, which are ideal for very short ranges. However, plenty of ongoing experiments demonstrate how techniques such as beamforming can achieve greater ranges to users in challenging environments beyond line-of-sight.
- **5G will be used only in very high bands.** Although 5G will be deployed in very high millimeter wave (mmWave) bands, it will also re-use spectrum in lower bands, both licensed and unlicensed.
- **5G will replace 4G LTE.** 5G will coexist with 4G LTE for a long time to come. 4G has plenty to offer for many current applications such as voice, data, and even IoT.
- **5G will be a revolution, not an evolution.** Although 5G brings in a new physical layer (in 5G New Radio, or 5G NR), there is plenty of evolution from LTE-A Pro technologies such as carrier aggregation (CA), massive multiple input/multiple output (MIMO), quadrature amplitude modulation (QAM), unlicensed spectrum (LTE in unlicensed spectrum or LTE-U, License Assisted Access or LAA, and MulteFire, among others), IoT, and virtualization.
- **5G will be required to drive IoT.** IoT will initially be driven by LTE-A Pro where NarrowBand IoT (NB-IoT) is specified. In addition, other low-power technologies, such as Long Range Wide Area Network (LoRaWAN) and Sigfox, have been defined for IoT.
- **The 5G winners will be the operators and vendors.** Mobile network operators (MNOs), network equipment manufacturers (NEMs), and smartphone manufacturers were the primary business beneficiaries of 4G LTE. However, 5G will transform many industries, including car manufacturing, agriculture, health and medicine, transportation and logistics, and many more.

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5 Keys to 5G

1

5G-NR (New Radio)

Next-Gen XAir

2

5G Speeds/Feeds

Ixia Multi-Gig LTE with XAir2

3

Wi-Fi Coexistence

Ixia LTE Unlicensed

4

Massive IoT

Ixia IoT

5

Testing NFV Deployments

IxLoad Wireless VE

ixia

Read more about about enabling the 5G revolution at www.ixiacom.com/solutions/5g-wireless-test

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Dream up new opportunities in the 5G future

The next-generation mobile network is on the horizon. 5G, the successor to 4G LTE networks, will enable significantly greater mobile speeds — as much as 20 gigabits per second — with very low latency. 5G will support a massive array of devices, from smart phones to virtual reality devices to small sensors. In this book, you learn about the technological innovations being developed today to enable a 5G future. You also learn about potential use cases that will transform entire industries and create new business models and opportunities.

Inside...

- Where wireless communication is headed
- Why higher speeds are the future
- How the IoT will employ 5G connectivity
- Why the unlicensed spectrum matters
- Why New Radio is a starting point for 5G
- How 5G will enable new business models

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AUGUST 2017

LTE to 5G: Cellular and Broadband Innovation

RYSAVY RESEARCH

5G americas

This white paper was written for 5G Americas by Rysavy Research (http://www.rysavy.com) and utilized a composite of statistical information from multiple resources.

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Introduction

Mobile computing with wireless communications has already changed how people socialize and how companies do business. Yet, we are still in the nascent stages of the transformation that ubiquitous connectivity is enabling. Early examples of this exciting future include virtual and augmented reality, autonomous driving, smart cities, wearable computers, and connected devices throughout our environment. While no one can predict the full extent of innovation that the new global broadband fabric, aided by complementary innovations such as AI, will unleash, one thing is certain: We are rushing toward an extraordinary time.

The step from 3G to 4G was dramatic, and industry advances occurring now in LTE and 5G will be even greater. Standards bodies are standardizing 5G, a process that will continue through the 2020 timeframe, with ongoing enhancements continuing during the next decade. Some operators are deploying pre-standard 5G in trials this year, and initial standards-based networks could be deployed as early as 2019. 5G will not replace LTE; in most deployments, the two technologies will be tightly integrated and co-exist through at least the late-2020s.

Many of the capabilities that will make 5G so effective are appearing in advanced forms of LTE. With carrier aggregation, for example, operators have not only harnessed the potential of their spectrum holdings to augment capacity and performance, but the technology is also the foundation for entirely new capabilities, such as operating LTE in unlicensed bands.

The computing power of today’s handheld computers rivals that of past mainframe computers, powering intuitive operating systems and millions of applications. Coupled with affordable mobile broadband connectivity, these devices provide such unprecedented utility that billions of people are using them.

With long term growth in smartphone and other mobile device use limited by population, innovators are increasingly turning their attention to the Internet of Things (IoT), which already encompasses a wide array of applications. Enhancements to LTE, followed by 5G IoT capabilities, will connect wearable computers, sensors, and other devices, leading to better health, economic gains, and other advantages. 5G addresses not only IoT deployments on a massive scale but also enables applications previously not possible that depend on ultra-reliable and low-latency communications, sometimes called “mission-critical applications.” Although a far more fragmented market than smartphones, the benefits will be so great that the realization of IoT on a massive scale is inevitable.

Regulatory policies are striving to keep pace, addressing complex issues that include how best to allocate and manage new spectrum, network neutrality, and privacy. Policy decisions will have a major impact on the evolution of mobile broadband.

These are exciting times for both people working in the industry and those who use the technology—which today is nearly everybody. This paper attempts to capture the scope of what the industry is developing, beginning with Table 1, which summarizes some of the most important advances.

Table 1: Most Important Wireless Industry Developments in 2017

Development	Summary
5G Research and Development Accelerates	5G, in early stages of definition through global efforts and many proposed technical approaches, could be deployed in non-standalone versions as early as 2019. Deployment will continue through 2030. Some operators will deploy pre-standard networks for fixed-wireless access in 2017. 5G is being designed to integrate with LTE, and some 5G features may be implemented as LTE-Advanced Pro extensions prior to full 5G availability.
5G New Radio (NR) Being Defined	Key aspects of the 5G NR have been determined, such as radio channel widths and use of OFDMA. The first version, specified in Release 15, will support low-latency, beam-based channels, massive Multiple Input Multiple Output (MIMO) with large numbers of controllable antenna elements, scalable-width subchannels, carrier aggregation, Cloud Radio-Access Network (RAN) capability, and dynamic co-existence with LTE.
LTE Has Become the Global Cellular Standard	A previously fragmented wireless industry has consolidated globally on LTE. LTE is being deployed more quickly than any previous-generation wireless technology.
LTE-Advanced Provides Dramatic Advantages	LTE capabilities continue to improve with carrier aggregation, 1 Gbps peak throughputs, higher-order MIMO, multiple methods for expanding capacity in unlicensed spectrum, new IoT capabilities, vehicle-based communications, small-cell support including Enhanced Inter-Cell Interference Coordination (eICIC), lower latency, Self-Organizing Network (SON) capabilities and Enhanced Coordinated Multi Point (eCoMP).
Internet of Things Poised for Massive Adoption	IoT, evolving from machine-to-machine (M2M) communications, is seeing rapid adoption, with tens of billions of new connected devices expected over the next decade. Drivers include improved LTE support, such as low-cost and low-power modems, enhanced coverage, higher capacity, and service-layer standardization, such as oneM2M.
Unlicensed Spectrum Becomes More Tightly Integrated with Cellular	The industry has developed increasingly sophisticated means for integrating Wi-Fi and cellular networks, such as LTE-WLAN Aggregation (LWA) and LTE-WLAN Aggregation with IPSec Tunnel (LWIP), making the user experience ever more seamless. The industry has also developed and is now deploying versions of LTE that can operate in unlicensed spectrum, such as LTE-Unlicensed (LTE-U), LTE-Licensed Assisted Access (LTE-LAA), and

Development	Summary
	MulteFire. Cellular and Wi-Fi industry members are successfully collaborating to ensure fair spectrum co-existence.
Spectrum Still Precious	Spectrum in general, and in particular licensed spectrum, remains a precious commodity for the industry. Recently added spectrum in the United States includes the 600 MHz band, auctioned in 2017, and the 3.5 GHz Citizens Broadband Radio Service (CBRS) "small-cell" band, which could see initial deployments in 2018. 5G spectrum will include bands above 6 GHz, including "mmWave" (30 GHz to 100 GHz), with the potential of ten times (or more) as much spectrum as is currently available for cellular. Radio channels of 200 MHz and 400 MHz, and even wider in the future, will enable multi-Gbps peak throughput.
Small Cells Take Baby Steps, Preparing to Stride	Operators have begun installing small cells, which now number in the tens of thousands. Eventually, hundreds of thousands if not millions of small cells will lead to massive increases in capacity. The industry is slowly overcoming challenges that include restrictive regulations, site acquisition, self-organization, interference management, power, and backhaul.
Network Function Virtualization (NFV) Emerges	Network function virtualization (NFV) and software-defined networking (SDN) tools and architectures are enabling operators to reduce network costs, simplify deployment of new services, reduce deployment time, and scale their networks. Some operators are also virtualizing the radio-access network, as well as pursuing a related development called cloud radio-access network (cloud RAN). NFV and cloud RAN will be integral components of 5G.

The main part of this paper covers the transformation of broadband, exploding demand for wireless services, the path to 5G including planned and expected capabilities, new LTE innovations, supporting technologies and architectures, voice over LTE (VoLTE), Wi-Fi Calling, LTE for public safety, options to expand capacity, and spectrum developments.

The appendix delves into more technical aspects of the following topics: 3GPP Releases, Data Throughput, latency, 5G, LTE, LTE-Advanced, LTE-Advanced Pro, HetNets and small cells, IoT, cloud RANs, Unlicensed Spectrum Integration, self-organizing networks, the IP Multimedia Subsystem, broadcast/multicast services, backhaul, UMTS/WCDMA,[1] HSPA, HSPA+, UMTS TDD, and EDGE/EGPRS.

---

[1] Although many use the terms "UMTS" and "WCDMA" interchangeably, in this paper "WCDMA" refers to the radio interface technology used within UMTS, and "UMTS" refers to the complete system. HSPA is an enhancement to WCDMA.

Broadband Transformation

Broadband networks rely on a fiber core with various access technologies, such as fiber to the premises, coaxial cable, digital subscriber line (DSL), or wireless connections. LTE provides a broadband experience, but capacity limitations prevent it from being the only broadband connection for most users. As a result, a majority of consumers in developed countries have both mobile broadband and fixed broadband accounts.

Two developments will transform the current situation:

1. **Fiber Densification**. Multiple companies are investing to extend the reach of fiber, decreasing the distance from the fiber network to the end node.
2. **5G Standardization and Deployment.** As 5G mmWave technology, including massive MIMO and beamforming, becomes commoditized, it will increasingly be a viable alternative to fixed-access technologies such as coaxial, DSL, and even fiber connections. 5G commercial services will enable a new innovation cycle. The ability to create new applications and services with fewer limitations will take the connected society to a new level.

Consequently, the companies that provide broadband service may change, and eventually, fixed and mobile broadband services may converge. For a more detailed discussion of trends in broadband, including the disruptive role of mmWave, refer to the 2017 Datacomm Research and Rysavy Research report, *Broadband Disruption: How 5G Will Reshape the Competitive Landscape*.[2]

As shown in Figure 1, the emerging broadband network is one with denser fiber and competing access technologies in which wireless connectivity plays a larger role.

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[2] Details at https://datacommresearch.com/reports-broadband/.

Figure 1: Fiber Densification with Multiple Access Technologies, including mmWave

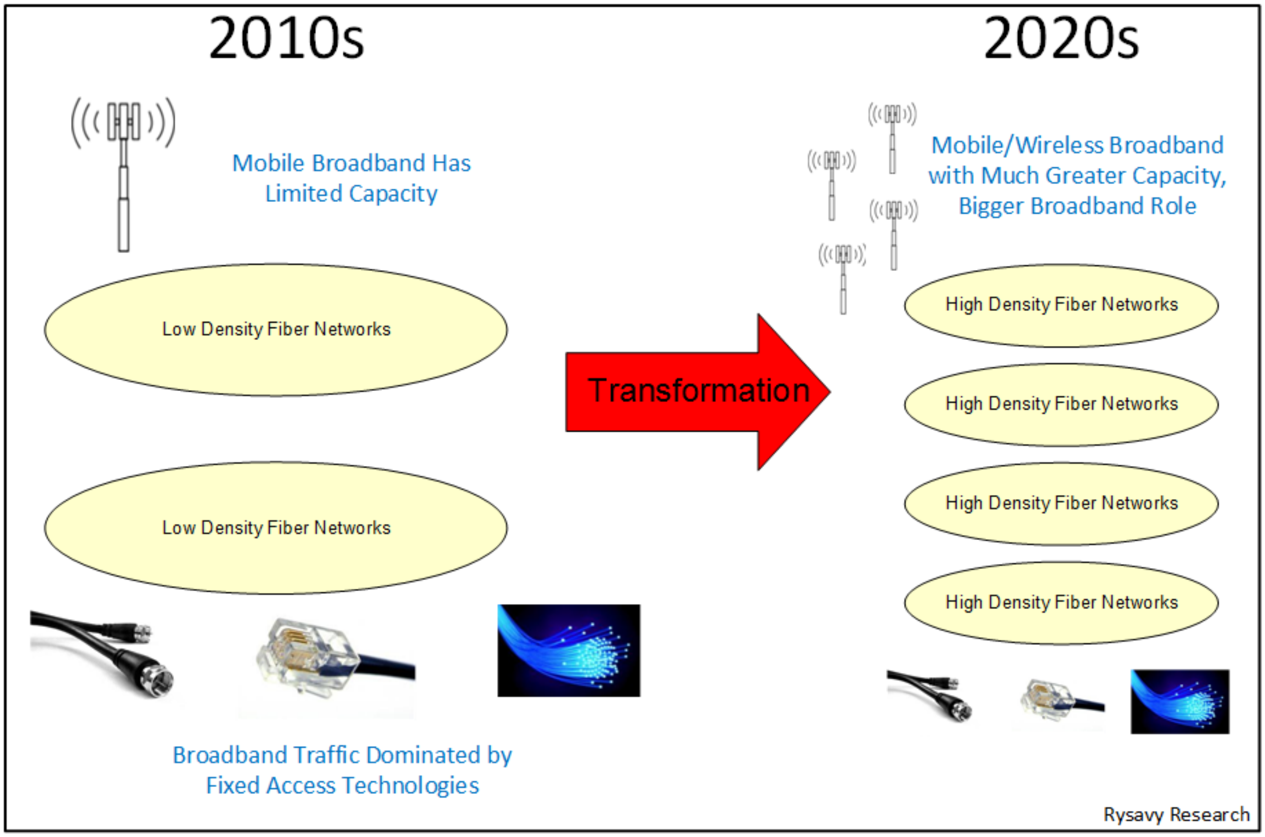
2010s
2020s
Mobile Broadband Has Limited Capacity
Mobile/Wireless Broadband with Much Greater Capacity, Bigger Broadband Role
Low Density Fiber Networks
Low Density Fiber Networks
Transformation
High Density Fiber Networks
High Density Fiber Networks
High Density Fiber Networks
High Density Fiber Networks
Broadband Traffic Dominated by Fixed Access Technologies
Rysavy Research

Many elements are interacting to transform mobile broadband, but the factors playing the most important roles are emerging capabilities for IoT, radio advances granting access to far more spectrum, small cells, new network architectures that leverage network function virtualization and software-defined networking, and new means to employ unlicensed spectrum. Except for access to high-band spectrum, a 5G objective, these advances apply to both LTE and 5G.

Figure 2: Fundamental Mobile Broadband Transformational Elements

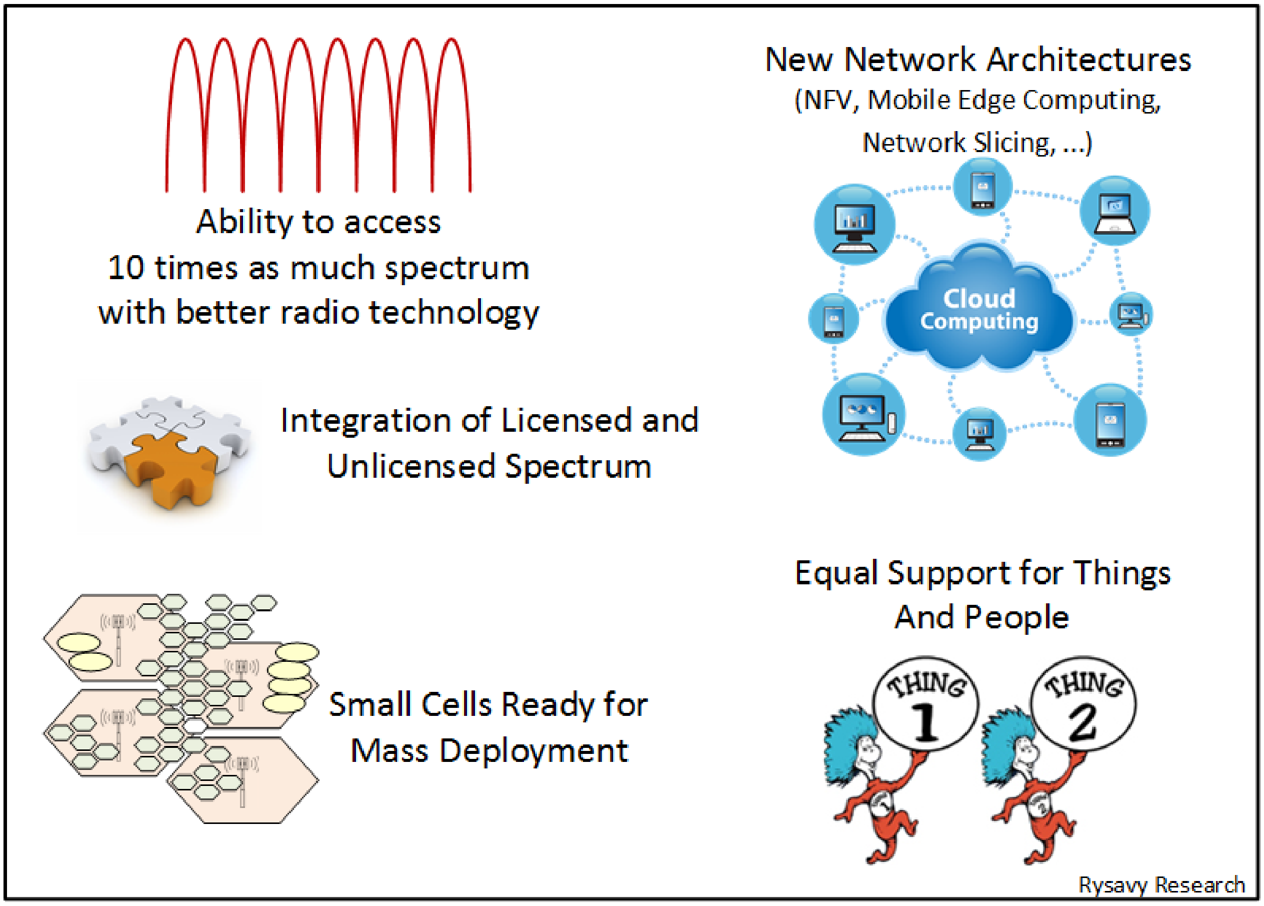
Ability to access
10 times as much spectrum
with better radio technology
New Network Architectures
(NFV, Mobile Edge Computing,
Network Slicing, ...)
Cloud Computing
Integration of Licensed and
Unlicensed Spectrum
Equal Support for Things
And People
THING 1
THING 2
Small Cells Ready for
Mass Deployment
Rysavy Research

In the past, developers used modems and networks designed for human communication for machine-type applications. But now, new modes of network operation, initially in LTE then enhanced further in 5G, will cater to the unique needs of a wide variety of machine applications, addressing low-cost, long battery life, long communications range, and a wide variety of throughputs. For instance, some IoT applications need only low-throughput communications, some sending only a small number of bits per day.

As for spectrum, throughout radio history, technology has climbed up a ladder to use higher frequencies. What were called "ultra-high frequencies" when made available for television are now considered low-band frequencies for cellular. Frequencies above 6 GHz, particularly mmWave frequencies, are the new frontier. Networks will ultimately take advantage of ten times as much spectrum as they use now, and likely even more over time. Although challenging to use because of propagation limitations and higher penetration loss, massive MIMO, beam steering, beam tracking, dual connectivity, carrier aggregation, small-cell architectures with self-backhauling, and other methods will help mitigate the challenges at these frequencies. The result: massive increases in capacity in localized areas.

In addition to accessing higher bands, cellular technologies are integrating unlicensed spectrum more efficiently, using technologies such as LTE-U, LAA, MulteFire, LWA, and LWIP. This integration will immediately augment small-cell capacity, improving the business case for small cells.

Small cells, on the roadmap for many years but held back by implementation difficulties, such as backhaul, are on the verge of large scale deployment, leading ultimately to densities as high as ten small cells or more for every macro cell. Paving the way are better wireless backhaul solutions, neutral-host capabilities enabled by new technologies, and soon, access to mmWave bands.

Facilitating the capabilities listed above, networks are becoming programmable. Using a distributed, software-enabled network based on virtualization and new architectural approaches such as Multi-access Edge Computing (MEC) and network slicing, operators and third parties will be able to deploy new services and applications more rapidly, and in a more scalable fashion. Centralizing RAN signal processing will also play a huge role; depending on the deployment scenario, such centralization will increase RAN efficiency and decrease deployment cost.

This paper lists the dozens of other innovations also fueling mobile and cellular technology transformation. Together, these transformed networks will mean that for millions, and ultimately billions, of people, wireless connections will be the only connections that they need. These networks will also provide the foundation for entire new industries, ones not yet even conceived.

Exploding Demand

Two technology trajectories have created critical mass: handheld computing and fast wireless connections. This combined computing and communications platform inspires the innovation that has produced millions of mobile applications.

IoT is a third trajectory. LTE, and eventually 5G, will connect tens of billions of devices. And fixed-wireless access could be a fourth. 5G, with expected network capacity a hundred times greater than 4G networks, will make wireless connections not only a viable substitute for wireline broadband connections for tens of millions of users over the next ten years, but make that broadband connection the only connection that many users need.

Figure 3: Exploding Demand from Critical Mass of Factors

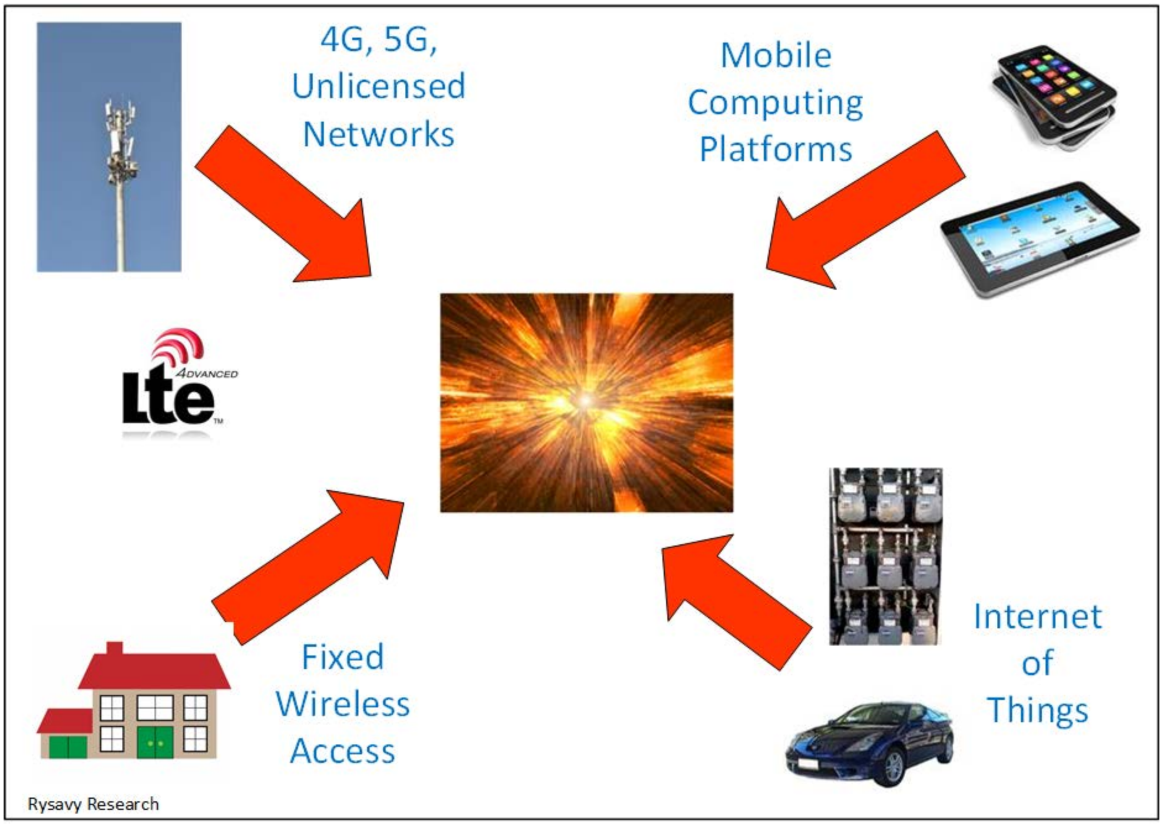

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This section analyzes some of these demand factors.

Application Innovation

When planning 4G network technology, who could have predicted applications such as Uber and Lyft, which combine location information with mapping and online payment and are now disrupting the taxi industry and even challenging notions of private vehicle ownership? While some applications of new technology can be predicted, many cannot.

More efficient technology not only addresses escalating demand, it also provides higher performance, thus encouraging new usage models and further increasing demand.

Today's smartphones and tablets, dominated by the iOS and Android ecosystems, in combination with sophisticated cloud-based services, provide a stable, well-defined application environment, allowing developers to target billions of users. Developers have rich platform-specific development tools; web-based tools such as HTML5; application programming interfaces (APIs) for mobile-specific functions, such as WebRTC (Web Real-Time Communications); and cloud-based services for applications and application services, such as notifications, IoT support, and mobile-commerce.

Of concern to some companies in the wireless industry, however, are current network neutrality rules that could possibly hamper innovation. By restricting prioritization, for example, the rules seem to fail to recognize that traffic streams from different applications have inherently different quality of service requirements.[3]

Internet of Things

Current M2M and Internet of Things applications include vehicle infotainment, connected healthcare, transportation and logistics, connected cars, home security and automation, manufacturing, construction and heavy equipment, energy management, video surveillance, environmental monitoring, smart buildings, wearable computing, object tracking, and digital signage. Municipalities, evaluating the concept of "smart cities," are exploring how to optimize pedestrian and vehicular traffic, connect utility meters, and deploy trash containers that can report when they need emptying.

Although promising, the IoT market is also challenging, with varying communications requirements, long installation lifetimes, power demands that challenge current battery technology, cost sensitivity, security and data privacy concerns, unsuitability of conventional networking protocols for some applications, and other factors that developers must address. Consequently, the IoT opportunity is not uniform; it will eventually comprise thousands of markets. Success will occur one sector at a time, with advances in one area providing building blocks for the next.

Cloud-based support platforms and standardized interfaces are essential for development and deployment of IoT applications. For example, oneM2M has developed a service-layer that can be embedded in hardware and software to simplify communications with application servers.[4]

To address the IoT opportunity, 3GPP is defining progressive LTE refinements that will occur over multiple 3GPP releases. These refinements include low-cost modules that approach 2G module pricing and enable multi-year battery life. See the section "Internet of Things and Machine-to-Machine" in the appendix for more details.

Video Streaming

Video represents the greatest usage of data on smartphones. Just an hour a day of mobile video at 1.0 Mbps throughput, common with YouTube or Netflix, consumes 13.5 GB per month. Many streams, now available in high-definition (HD), consume even more data.

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[3] For further discussion, see Rysavy Research, *How "Title II" Net Neutrality Undermines 5G*, April 19, 2017. Available at http://www.rysavy.com/Articles/2017-04-How-Title-II-Net-Neutrality-Undermines-5G.pdf. Also see *How Wireless is Different – Considerations for the Open Internet Rulemaking*, September 12, 2014. Available at http://www.rysavy.com/Articles/2014-09-Wireless-Open-Internet.pdf.

[4] OneM2M home page: http://onem2m.org/.

See the Appendix section “Data Consumed by Video” for a quantification of data consumed by video for multiple usage scenarios.

An increasing number of video applications adapt their streaming rates based on available bandwidth. By doing so, they can continue to operate even when throughput rates drop. Conversely, they take advantage of higher available bandwidth to present video at higher resolution. Fortunately, application developers are becoming sensitive to bandwidth constraints and are offering options for users to reduce consumption.

Nevertheless, video can consume so much data that cutting the broadband cord at the same time as the television cord is not possible for most consumers. With 5G’s massive increase in capacity, however, an increasing percentage of users will use wireless connections as their only broadband connections, including for all their entertainment needs.

Cloud Computing

Cloud computing inherently increases data consumption because it requires communications for all operations. Examples include data synchronization and backup, cloud-based applications (such as email, word processing, and spreadsheets), automatic photo uploads, and music and video streaming.

5G Data Drivers

Futurists can predict some 5G applications, but many others will arise as industries evolve or come into existence to take advantage of new network capabilities. Some potential applications of 5G include:

- Ultra-high-definition, such as 4K and 8K, and 3D video.
- Augmented and immersive virtual reality. Ultra-high-fidelity virtual reality can consume 50 times the bandwidth of a high-definition video stream.
- Realization of the tactile internet—real-time, immediate sensing and control, enabling a vast array of new applications.
- Automotive, including autonomous vehicles, driver-assistance systems, vehicular internet, infotainment, inter-vehicle information exchange, and vehicle pre-crash sensing and mitigation.
- Monitoring of critical infrastructure, such as transmission lines, using long battery life and low-latency sensors.
- Smart transportation using data from vehicles, road sensors, and cameras to optimize traffic flow.
- Mobile health and telemedicine systems that rely on ready availability of high-resolution and detailed medical records, imaging, and diagnostic video.
- Public safety, including broadband data and mission-critical voice.
- Sports and fitness enhancement through biometric sensing, real-time monitoring, and data analysis.
- Fixed broadband replacement.

Some of these applications are already being addressed by 4G, but 5G's lower costs, higher throughputs, and lower latency will hasten realization of their potential.

Specific industries expected to take advantage of 5G include manufacturing, healthcare, media and entertainment, financial services, public safety, automotive, public transport, and energy utilities.[5]

Global Mobile Adoption

Figure 4 shows the often-cited Cisco projection of global mobile data consumption through 2021, measured in exabytes (billion gigabytes) per month, demonstrating traffic growing at a compound annual rate of 47%.

Figure 4: Global Mobile Data 2016 to 2021[6]

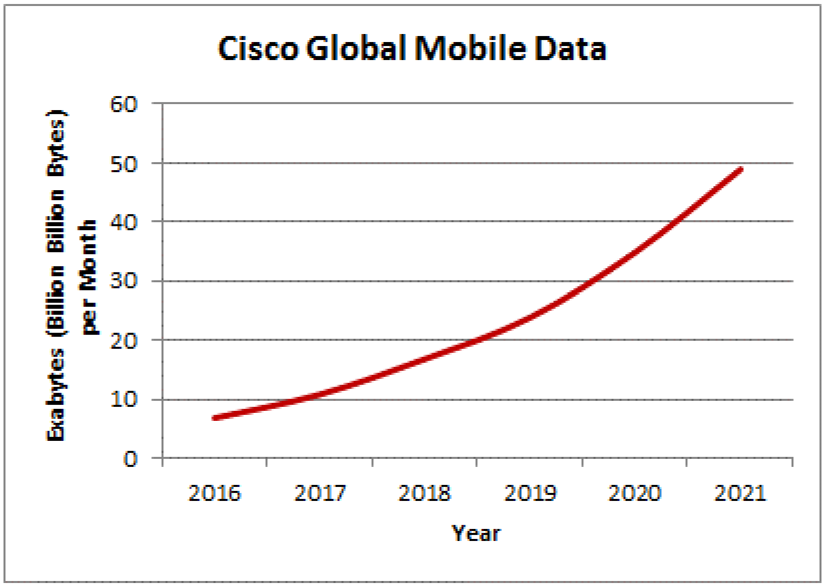

Figure 5 shows another data projection, predicting 45% annual growth in data for the 2016-to-2022 period, resulting in eight-fold growth.

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[5] For further insight, refer to the Ericsson white paper, *The 5G Business Potential,* February 2017. Available at https://www.ericsson.com/en/networks/insights/the-5g-business-potential.

[6] Cisco, *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016-2021*, February 2017.

Figure 5: Global Mobile Voice and Data (Exabytes/Month) 2012 to 2022[7]

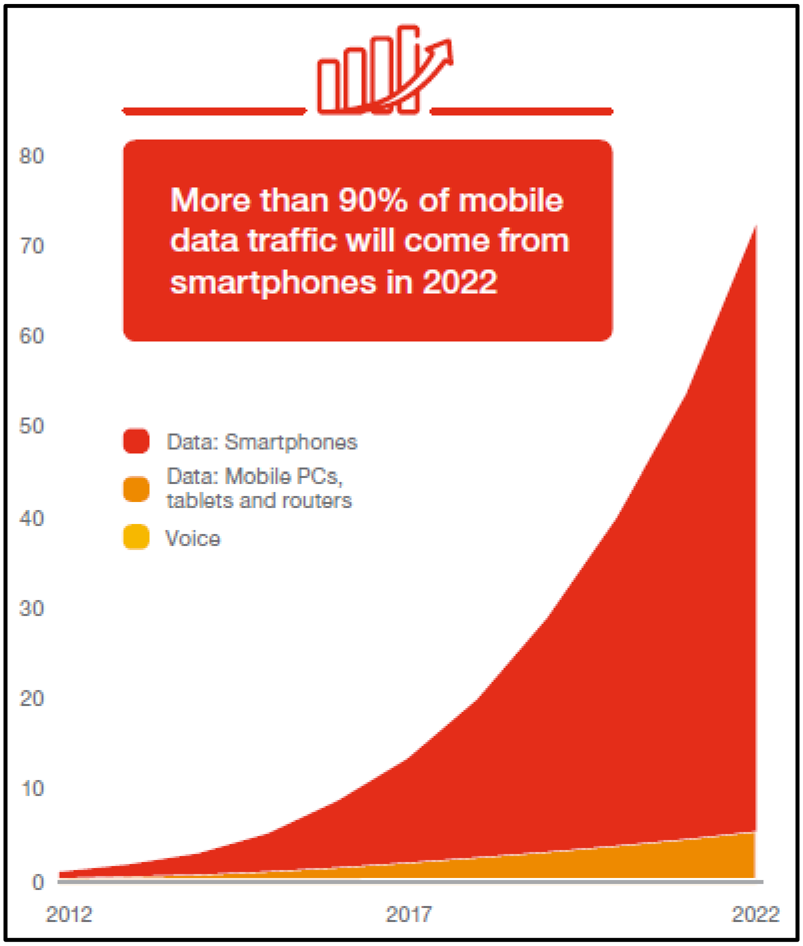

Figure 6 shows how the Internet of Things will drive far more connections than are launched by people.

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[7] Ericsson, *Ericsson Mobility Report*, June 2017.

Figure 6: Connections of Places Versus People Versus Things[8]

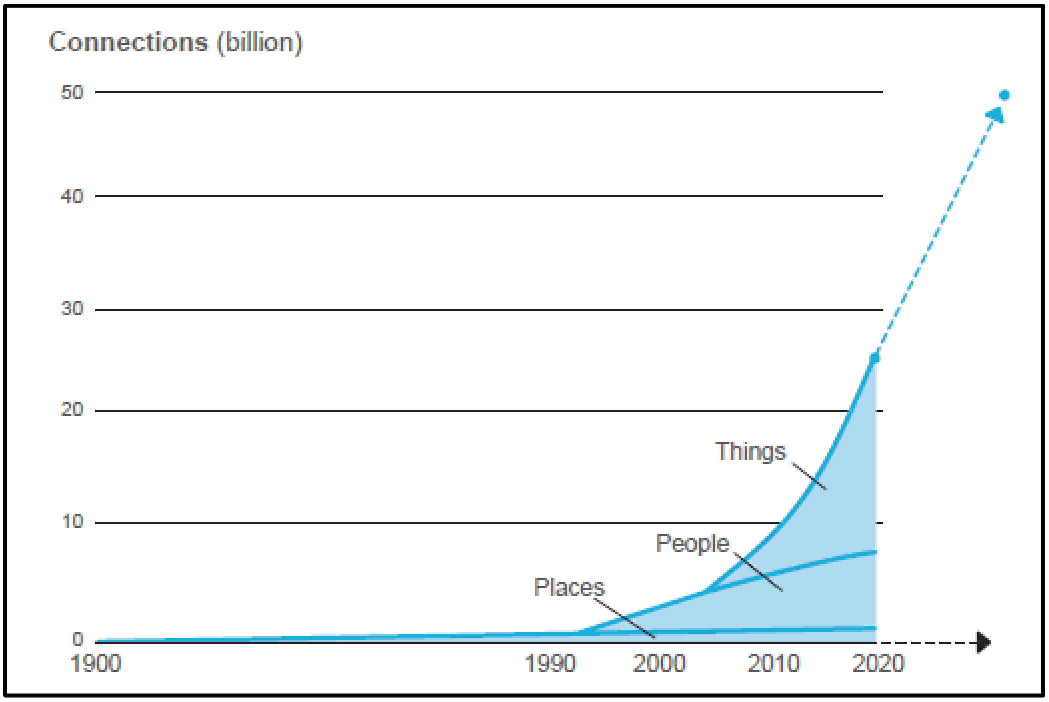

In June 2017, more than 7.56 billion GSM-HSPA-LTE connections were in effect[9]—greater than the world's 7.40 billion population.[10] By the end of 2022, the global mobile broadband market is expected to include nearly 9.4 billion subscribers, with 9.3 billion using 3GPP technologies, representing more than 99% market share.[11]

LTE has experienced faster deployment than any mobile technology ever developed. All major U.S. operators now offer nationwide LTE coverage. LTE has also been chosen by U.S. national public-safety organizations as their broadband technology of choice.

As shown in Figure 7, 2G GSM has peaked and is now declining, as is CDMA. Both HSPA and LTE subscriptions will continue to rise through the rest of the decade.

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[8] Ericsson, *IoT Security*, February 2017, available at https://www.ericsson.com/assets/local/publications/white-papers/wp-iot-security-february-2017.pdf.

[9] Ovum, July 2017.

[10] U.S. Census Bureau, "U.S. and World Population Clock," http://www.census.gov/popclock/, accessed July 18, 2017.

[11] Ovum, July 2017. Note that the 2018 mobile broadband market figures include GSM/EDGE, because most GSM networks are likely to include Evolved EDGE, which provides mobile broadband capability.

Figure 7: Global Adoption of 2G-4G Technologies 2010 to 2020[12]

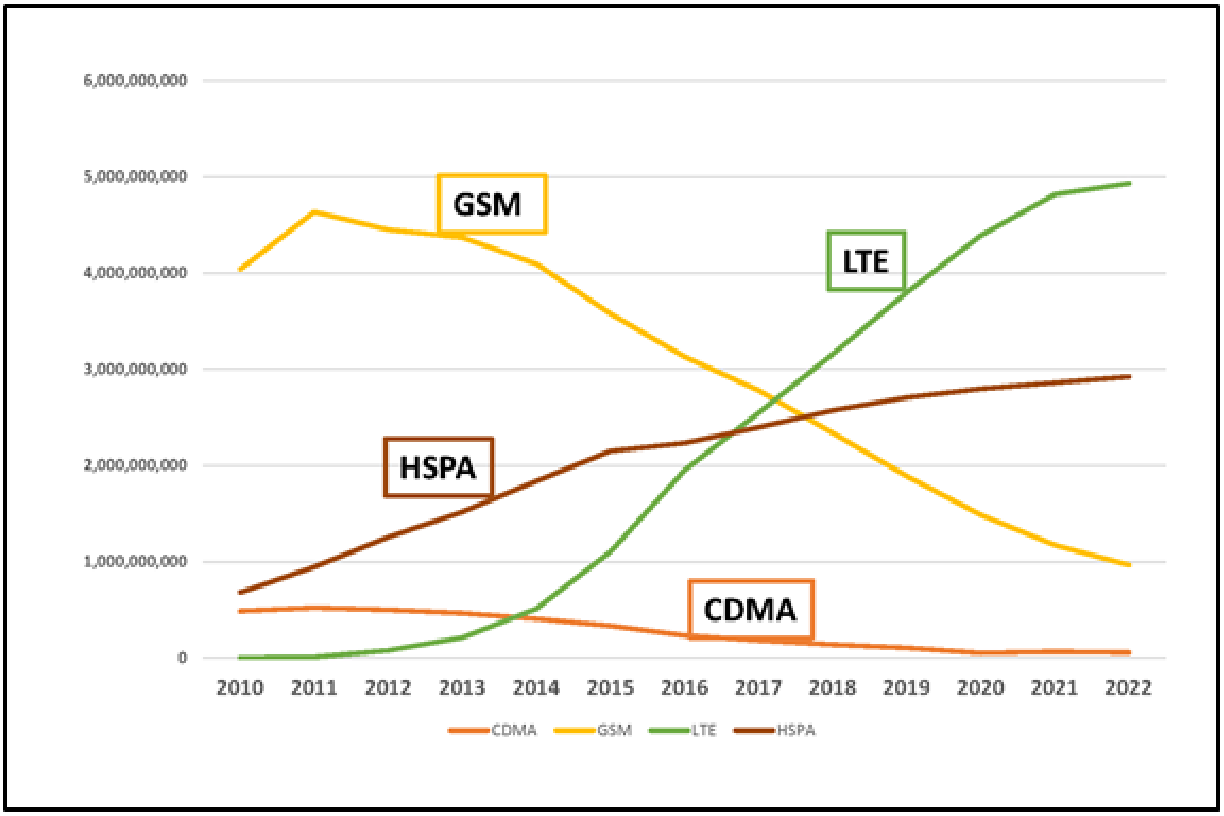

IoT is growing rapidly as well, although connections so far are well below phone-type connections. Cisco projects 3.3 billion IoT connections by 2021, with 6% on 2G cellular, 16% on 3G, and 46% on 4G.[13]

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[12] Ovum (WCIS), July 2017.

[13] Cisco, *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016-2021*, February 2017.

Almost at 5G

With intensive development occurring within 3GPP, the first 5G specification will be completed in early 2018, enabling the first standards-based networks to be deployed in the 2019-2020 timeframe. This section includes expanding use cases, 1G-to-5G evolution, 4G LTE advances, 5G radio and architectures, Information-Centric Networking, phasing of 5G releases, and an overview of 3GPP releases.

Expanding Use Cases

Many wireless technology discussions focus on radio capabilities, but other equally important aspects include use cases, the services built on top of the technology, how different networks integrate with one another, and the topology of the networks. As summarized in Figure 8, these aspects are expanding, making mobile/wireless technology the foundation for other enterprises, including business-process optimization, consumer electronics, M2M, connected devices, and a multitude of vertical industries.

Figure 8: Expanding Use Cases

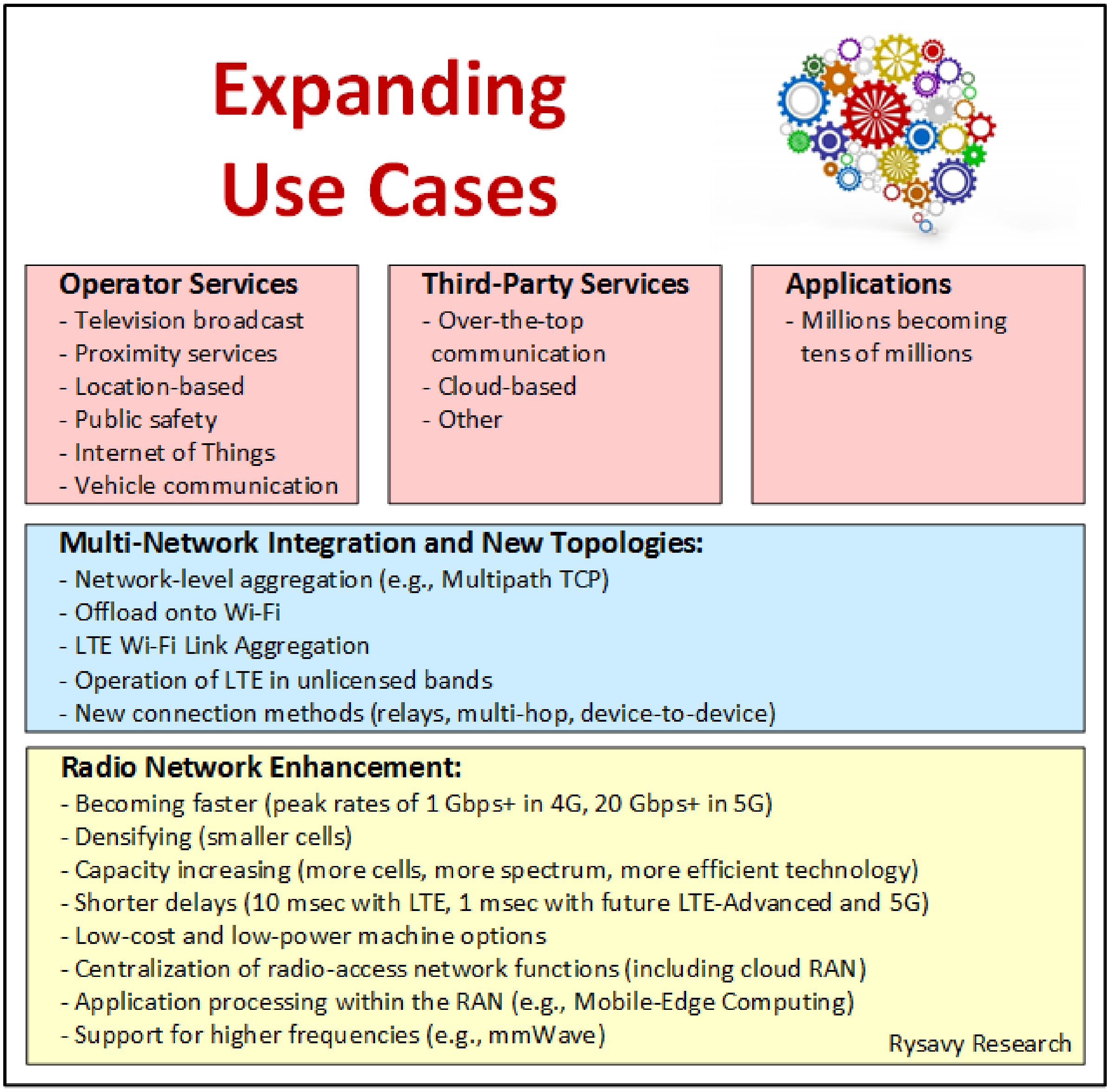

Expanding Use Cases

Operator Services
- Television broadcast
- Proximity services
- Location-based
- Public safety
- Internet of Things
- Vehicle communication

Third-Party Services
- Over-the-top communication
- Cloud-based
- Other

Applications
- Millions becoming tens of millions

Multi-Network Integration and New Topologies:
- Network-level aggregation (e.g., Multipath TCP)
- Offload onto Wi-Fi
- LTE Wi-Fi Link Aggregation
- Operation of LTE in unlicensed bands
- New connection methods (relays, multi-hop, device-to-device)

Radio Network Enhancement:
- Becoming faster (peak rates of 1 Gbps+ in 4G, 20 Gbps+ in 5G)
- Densifying (smaller cells)
- Capacity increasing (more cells, more spectrum, more efficient technology)
- Shorter delays (10 msec with LTE, 1 msec with future LTE-Advanced and 5G)
- Low-cost and low-power machine options
- Centralization of radio-access network functions (including cloud RAN)
- Application processing within the RAN (e.g., Mobile-Edge Computing)
- Support for higher frequencies (e.g., mmWave)

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Table 2 summarizes the requirements of the expanding number of use cases that employ wireless technology.

Table 2: Requirements for Different Use Cases[14]

Use Cases	Requirements	Desired Value
Autonomous vehicle control	Latency	5 msec
	Availability	99.999 percent
	Reliability	99.999 percent

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[14] Ericsson, *5G Systems – Enabling the Transformation of Industry and Society*, January 2017. Available at https://www.ericsson.com/assets/local/publications/white-papers/wp-5g-systems.pdf. Adapted from Table 1.

Use Cases	Requirements	Desired Value
Emergency communication	Availability	99.9 percent victim discovery rate
	Energy efficiency	One-week battery life
Factory cell automation	Latency	Down to below 1ms
	Reliability	Down to packet loss of less than 10^{-9}
High-speed train	Traffic density	Downlink (DL): 100Gbps/km^2, uplink (UL): 50 Gbps/km^2
	User throughput	DL: 50Mbps, UL: 25Mbps
	Mobility	500 km/h
	Latency	10ms
Large outdoor event	User throughput	30Mbps
	Traffic density	900Gbps/km^2
	Connection density	Four devices/m^2
Massive IoT	Connection density	1,000,000 devices/km^2
	Availability	99.9 percent coverage
	Energy efficiency	10-year battery life
Remote surgery and examination	Latency	Down to 1ms
	Reliability	99.999 percent
Smart city	User throughput	DL: 300Mbps, UL: 60Mbps
	Traffic density	700 Gbps/km^2
	Connection density	200,000 devices/km^2
Virtual and augmented reality	User throughput	4-28Gbps
	Latency	< 7msec
Broadband to the home	Connection density	4,000 devices/km^2
	Traffic density	60Gbps/km^2

The economic role that wireless technology plays keeps increasing. One study anticipates that in 2035, 5G will enable $12.3 trillion of global economic output.[15]

1G to 5G Evolution

5G is almost upon us; it is a technology that will be constructed from millions of ideas, methods, algorithms, and processes. Just as 4G LTE became available when previous technologies, such as HSPA, could be further improved, 5G enters the stage when the roadmap for LTE has not been exhausted. And just as 2G coexists today with 3G and 4G, 5G will co-exist with previous generations of technology.

For historical context, “1G” refers to analog cellular technologies that became available in the 1980s. “2G” denotes initial digital systems that became available in the 1990s and that introduced services such as short messaging and lower-speed data. 3G requirements were specified by the International Telecommunication Union (ITU) as part of the International Mobile Telephone 2000 (IMT-2000) project, for which significant voice capacity improvement was a focus and digital networks had to provide 144 Kbps of throughput at mobile speeds, 384 Kbps at pedestrian speeds, and 2 Mbps in indoor environments. UMTS-

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[15] HIS Economics and HIS Technology, *The 5G Economy: How 5G Technology will contribute to the global economy,* January 2017. Commissioned by Qualcomm Technologies.

HSPA and CDMA2000 are the primary 3G technologies. 3G technologies began to be deployed early last decade.

In 2008, the ITU issued requirements for IMT-Advanced, which many people initially used as a definition of 4G. The focus on 4G was to improve data coverage, capacity, and quality of experience. Requirements included operation in up to-40 MHz radio channels and extremely high Spectral Efficiency. The ITU required peak spectral efficiency of 15 bps/Hz and recommended operation in up-to-100 MHz radio channels, resulting in a theoretical throughput rate of 1.5 Gbps. In 2009 and 2010, the term “4G” became associated with mobile broadband technologies deployed at the time, such as HSPA+, WiMAX, and initial LTE deployments. Today, 4G usually refers to HSPA+ or LTE.

Although the industry is preparing for 5G, LTE capabilities will continue to improve in LTE-Advanced Pro through the rest of the decade. Many of these enhancements will come through incremental network investments. Given the scope of global wireless infrastructure, measured in hundreds of billions of dollars, offering users the most affordable service requires operators to leverage investments they have already made. 5G will eventually play an important role, but it must be timed appropriately so that the jump in capability justifies the new investment.

5G groups researching next generation wireless architecture and requirements include, among others, the International Telecommunication Union (ITU),[16] the European Union’s 5G Infrastructure Public-Private-Partnership (5G PPP), which is the framework for several projects, including METIS II (Mobile and wireless communications Enablers for the Twenty-twenty Information Society), and Next Generation Mobile Networks (NGMN). Finally, 5G Americas is actively involved in developing the vision and requirements of 5G for North, Central, and South America. 5G Americas signed an MoU to collaborate with 5G-PPP.[17]

The ITU, the standardization group of the United Nations, has set the following standardization timetable in its IMT-2020 project:[18]

- ❑ 2016-2017: Definition of technical performance requirements, evaluation criteria and methods, and submission templates.
- ❑ 2018-2019: Submission of proposals.
- ❑ 2019: Evaluation of proposed technologies.
- ❑ 2019 and 2020: Publication of IMT-2020 specifications.

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[16] International Telecommunication Union, “Working Party 5D (WP 5D) - IMT Systems,” http://www.itu.int/ITU-R/index.asp?category=study-groups&rlink=rwp5d&lang=en, accessed May 16, 2017.

[17] 5GPPP, “5G-PPP MoU with 4G Americas,” March 2, 2015. http://5g-ppp.eu/5g-ppp-mou-with-4g-amererericas/

[18] ITU, “ITU towards ‘IMT for 2020 and beyond’,” http://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/default.aspx, viewed May 16, 2017.

Wireless technology has progressed to the extent that significant new capabilities are inevitable, making 5G a possible alternative to wireline broadband for many subscribers.[19]

Table 3 summarizes the generations of wireless technology.

Table 3: 1G to 5G

Generation	Requirements	Comments
1G	No official requirements. Analog technology.	Deployed in the 1980s.
2G	No official requirements. Digital technology.	First digital systems. Deployed in the 1990s. New services such as SMS and low-rate data. Primary technologies include IS-95 CDMA (cdmaOne), IS-136 (D-AMPS), and GSM.
3G	ITU's IMT-2000 required 144 Kbps mobile, 384 Kbps pedestrian, 2 Mbps indoors.	First deployment in 2000. Primary technologies include CDMA2000 1X/EV-DO and UMTS-HSPA. WiMAX.
4G (Initial Technical Designation)	ITU's IMT-Advanced requirements include the ability to operate in up-to-40-MHz radio channels and with very high spectral efficiency.	First deployment in 2010. IEEE 802.16m and LTE-Advanced meet the requirements.
4G (Current Marketing Designation)	Systems that significantly exceed the performance of initial 3G networks. No quantitative requirements.	Today's HSPA+, LTE, and WiMAX networks meet this requirement.
5G	ITU IMT-2020 has defined technical requirements for 5G, and 3GPP is developing specifications.	First standards-based deployments in 2019 and 2020.

The interval between each significant technology platform has been about ten years. Within each platform, however, innovation surges unabated. For example, with 2G technology,

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[19] Rysavy Research, "How will 5G compare to fiber, cable or DSL?" Fierce Wireless, May 2014. Available at http://www.rysavy.com/Articles/2014-05-5G-Comparison-Wireline.pdf.

EDGE significantly improved data performance compared with initial General Packet Radio Service (GPRS) capabilities. Similarly, HSPA hugely increased data speeds compared with initial 3G capabilities. LTE and LTE-Advanced are also acquiring continual improvements that include faster speeds, greater efficiency, and the ability to aggregate spectrum more flexibly.

Figure 9 presents the timeline of technology generations, including past and future, showing initial deployment, the year of the peak number of subscribers, and decline. Each cellular generation spans multiple decades, with peak adoption occurring some 20 years after initial deployment. 6G deployment in 2030, though highly speculative, is consistent with deployment of previous generations.

Figure 9: Timeline of Cellular Generations

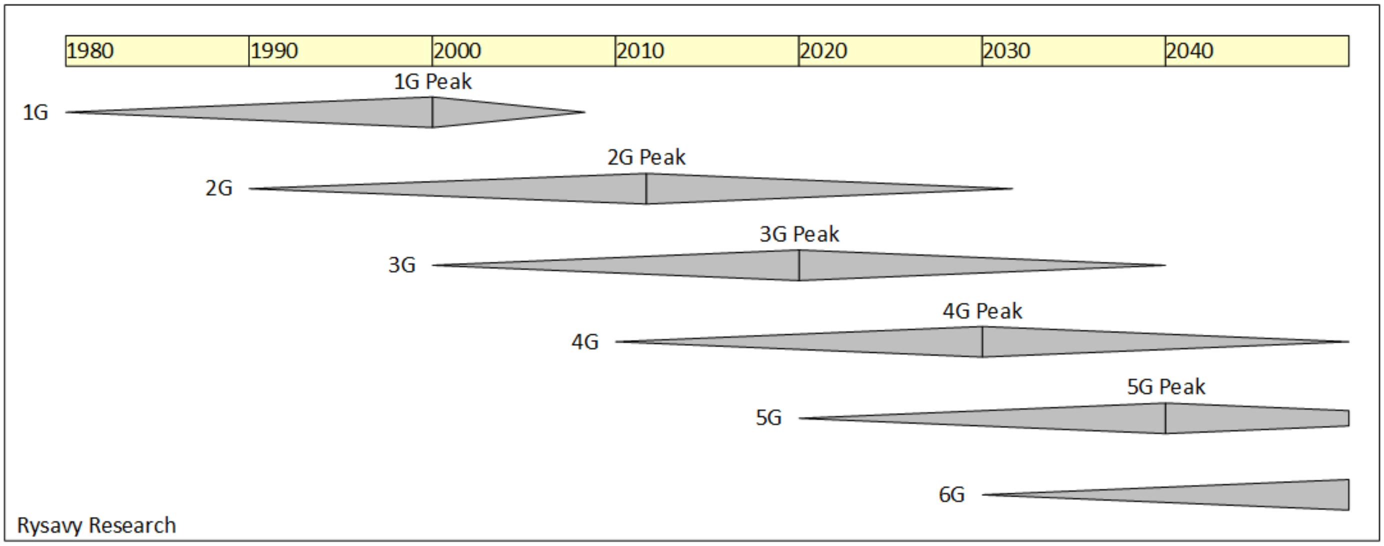

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4G LTE Advances

As competitive pressures in the mobile broadband market intensified, and as demand for capacity persistently grew, LTE became the favored 4G solution because of its high data throughputs, low-latency, and high spectral efficiency. Specifically:

- **Wider Radio Channels.** LTE can be deployed in wide radio channels (for example, 10 MHz or 20 MHz) with carrier aggregation now up to 640 MHz, although inter-band aggregation of four or five carriers (up to 100 MHz) represents a practical upper limit.
- **Easiest MIMO Deployment.** By using new radios and antennas, LTE facilitates MIMO Deployment, in contrast to the logistical challenges of adding antennas for MIMO to existing legacy technologies. Furthermore, MIMO gains are maximized because all user equipment supports it from the beginning.
- **Best Latency Performance.** For some applications, low latency (packet traversal delay) is as important as high throughput. With a low transmission time interval (TTI) of 1 millisecond (msec) and a flat architecture (fewer nodes in the core network), LTE has the lowest latency of any cellular technology.

In the same way that 3G coexists with 2G systems in integrated networks, LTE systems co-exist with both 3G and 2G systems, with devices capable of 2G, 3G, and 4G modes.

Beyond radio technology, the Evolved Packet Core (EPC) provides a core architecture that integrates with both legacy GSM-HSPA networks and other wireless technologies, such as CDMA2000 and Wi-Fi. The combination of EPC and LTE is referred to as the Evolved Packet System (EPS).

LTE is available in both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes. Many deployments are based on FDD in paired spectrum. The TDD mode, however, is important for deployments in which paired spectrum is unavailable. Instances of TDD deployment include China, Europe at 2.6 GHz, U.S. Broadband Radio Service (BRS) spectrum at 2.6 GHz, and the 3.5 GHz band.

The versions of LTE most widely deployed today are just the first in a series of innovations that will increase performance, efficiency, and capabilities. Enhancements in the 2013 to 2016 period were the ones defined in 3GPP Releases 10, 11, and 12 and are commonly referred to as LTE-Advanced.[20] Subsequent releases, including Releases 13 to 15, specify LTE-Advanced Pro.

Keeping in mind that different operators have varying priorities, the following list roughly ranks the most important features of LTE-Advanced and LTE-Advanced Pro for the 2017 to 2020 timeframe:

1. **Carrier Aggregation.** With this capability, already in use, operators can aggregate radio carriers in the same band or across disparate bands to improve throughputs (under light network load), capacity, and efficiency. Carrier aggregation can also combine FDD and TDD and is the basis of LTE-U and LTE-LAA. As examples, in 2015, AT&T aggregated 700 MHz with AWS, and 700 MHz with PCS. T-Mobile aggregated 700 MHz with AWS, and AWS with PCS.[21] Operators are now deploying three-carrier aggregation and eventually may aggregate four carriers.[22] Release 13 introduced support for carrier aggregation of up to 32 carriers, addressing primarily the opportunity to aggregate multiple unlicensed channels. Release 14 specifies interband carrier aggregation for up to five downlink carriers and 2 uplink carriers.
2. **VoLTE.** Initially launched in 2015 and with widespread availability in 2017, VoLTE enables operators to roll out packetized voice for LTE networks, resulting in greater voice capacity and higher voice quality.
3. **Tighter Integration of LTE with Unlicensed Bands.** LTE-U became available for testing in 2016, and 3GPP completed specifications for LAA in Release 13, with deployment expected around 2018. MulteFire, building on LAA, will operate without requiring a licensed carrier anchor. LTE/Wi-Fi Aggregation through LWA and LWIP are other options for operators with large Wi-Fi deployments.

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[20] From a strict standards-development point of view, the term “LTE-Advanced” refers to the following features: carrier aggregation, 8X8 downlink MIMO, and 4XN uplink MIMO with N the number of receive antennas in the base station.

[21] AT&T band combinations are 3GPP Band 13 + Band 4, Band 17 + Band 4, and Band 17 + Band 2. T-Mobile band combinations are Band 12 + Band 4, Band 12 + Band 2, and Band 4 + Band 2.

[22] For carrier aggregation to operate, both the network and the device have to support the particular band combination. Legacy devices typically do not support new network aggregation capabilities.

4. **Enhanced Support for IoT.** Release 13 brings Category M1, a low-cost device option, along with Narrowband-IoT (NB-IoT), a version of the LTE radio interface specifically for IoT devices, called Category NB1.

5. **Higher-Order and Full-Dimension MIMO.** Deployments in 2017 use up to 4X4 MIMO. Release 14 specifies a capability called Full-Dimension MIMO, which supports configurations with as many as 32 antennas at the base station. See the section "Smart Antennas and MIMO" and Appendix section "LTE Smart Antennas" for further detail.

6. **Dual Connectivity.** Release 12 introduced the capability to combine carriers from different sectors and/or base stations (i.e. evolved Node Bs [eNBs]) through a feature called Dual Connectivity. Two architectures were defined: one that supports Packet Data Convergence Protocol (PDCP) aggregation between the different eNBs and one that supports separate S1 connections on the user-plane from the different eNBs to the EPC.

7. **256 QAM Downlink and 64 QAM Uplink.** Defined in Release 12 and already deployed in some networks, higher-order modulation increases user throughput rates in favorable radio conditions.

8. **1 Gbps Capability.** Using a combination of 256 QAM modulation, 4X4 MIMO, and aggregation of three carriers, operator networks can now reach 1 Gbps peak speeds. See below for more information.

9. **V2X Communications.** Release 14 specifies vehicle-to-vehicle and vehicle-to-infrastructure communications. See the section "Cellular V2X Communications" for more information.

10. **Coordinated Multi Point.** CoMP (and enhanced CoMP [eCoMP]) is a process by which multiple base stations or cell sectors process a User Equipment (UE) signal simultaneously, or coordinate the transmissions to a UE, improving cell-edge performance and network efficiency. Initial usage will be on the uplink because no user device changes are required. Some networks had implemented this feature in 2017.

11. **HetNet Support.** HetNets integrate macro cells and small cells. A key feature is enhanced inter-cell interference coordination (eICIC), which improves the ability of a macro and a small-cell to use the same spectrum. This approach is valuable when the operator cannot dedicate spectrum to small cells. Operators are currently evaluating eICIC, and at least one operator has deployed it.[23] Further enhanced ICIC (feICIC) introduced in Rel-11 added advanced interference cancellation receivers into devices.

12. **Ultra-Reliable and Low-Latency Communications.** Being specified in Release 15, URLLC in LTE will shorten radio latency to a 1 msec range using a combination of shorter transmission time intervals and faster hybrid automatic repeat request (HARQ) error processing. See the Appendix section "LTE Ultra-Reliable and Low-Latency Communications" for further details.

13. **Self-Organizing Networks.** With SON, networks can automatically configure and optimize themselves, a capability that will be particularly important as small cells begin

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[23] Fierce Wireless, "SK Telecom teams with Nokia Networks on eICIC," January 2015.

to proliferate. Vendor-specific methods are common for 3G networks, and trials are now occurring for 4G LTE standards-based approaches.

Other key features that will become available in the 2016-to-2020 timeframe include full-dimension MIMO, enhanced Multimedia Broadcast/Multicast Services (eMBMS), User-Plane Congestion Management (UPCON), and device-to-device communication (targeted initially at public-safety applications).

The appendix explains these features and quantifies performance gains, and Figure 10 illustrates the transition from LTE to LTE-Advanced and LTE-Advanced Pro, which include these features.

Figure 10: LTE to LTE-Advanced Pro Migration[24]

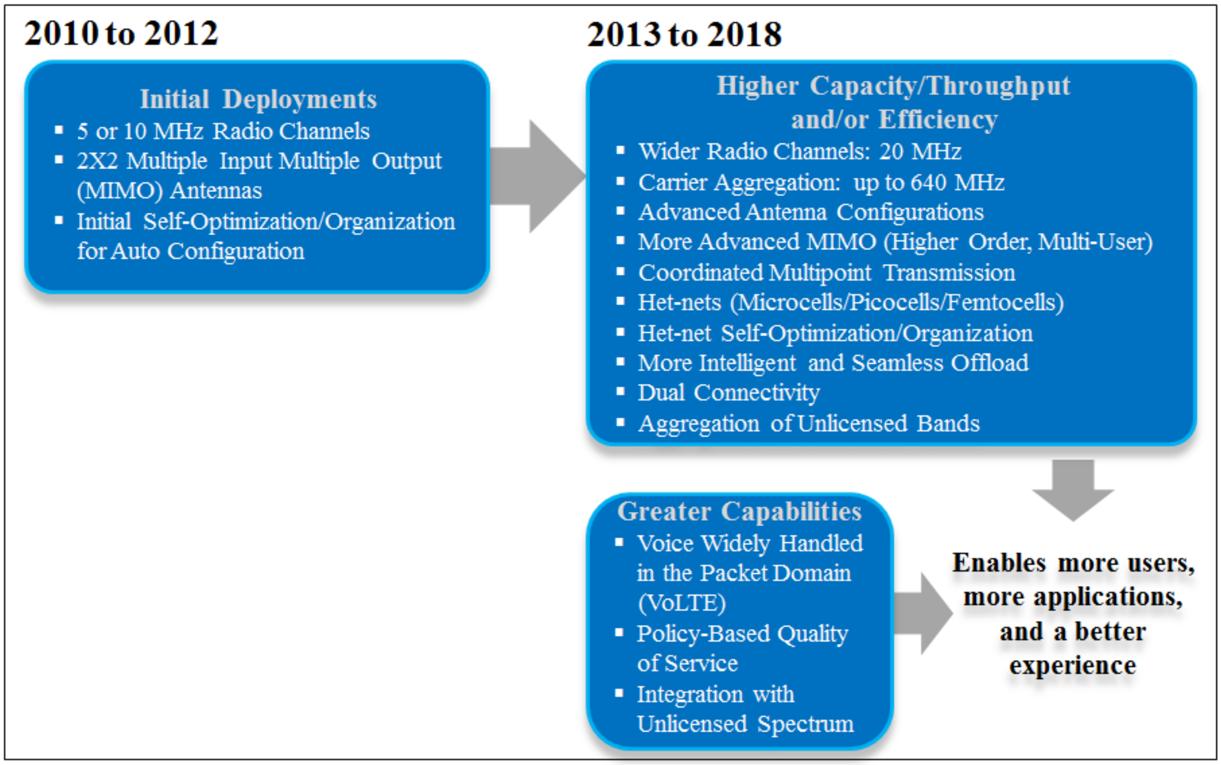
2010 to 2012
Initial Deployments
5 or 10 MHz Radio Channels
2X2 Multiple Input Multiple Output (MIMO) Antennas
Initial Self-Optimization/Organization for Auto Configuration
2013 to 2018
Higher Capacity/Throughput and/or Efficiency
Wider Radio Channels: 20 MHz
Carrier Aggregation: up to 640 MHz
Advanced Antenna Configurations
More Advanced MIMO (Higher Order, Multi-User)
Coordinated Multipoint Transmission
Het-nets (Microcells/Picocells/Femtocells)
Het-net Self-Optimization/Organization
More Intelligent and Seamless Offload
Dual Connectivity
Aggregation of Unlicensed Bands
Greater Capabilities
Voice Widely Handled in the Packet Domain (VoLTE)
Policy-Based Quality of Service
Integration with Unlicensed Spectrum
Enables more users, more applications, and a better experience

Figure 11 illustrates gains in peak downlink speeds through carrier aggregation, higher-order MIMO, and higher-order modulation.

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[24] 5G Americas/Rysavy Research

Figure 11: Successive Gains in Peak LTE Downlink Throughput[25]

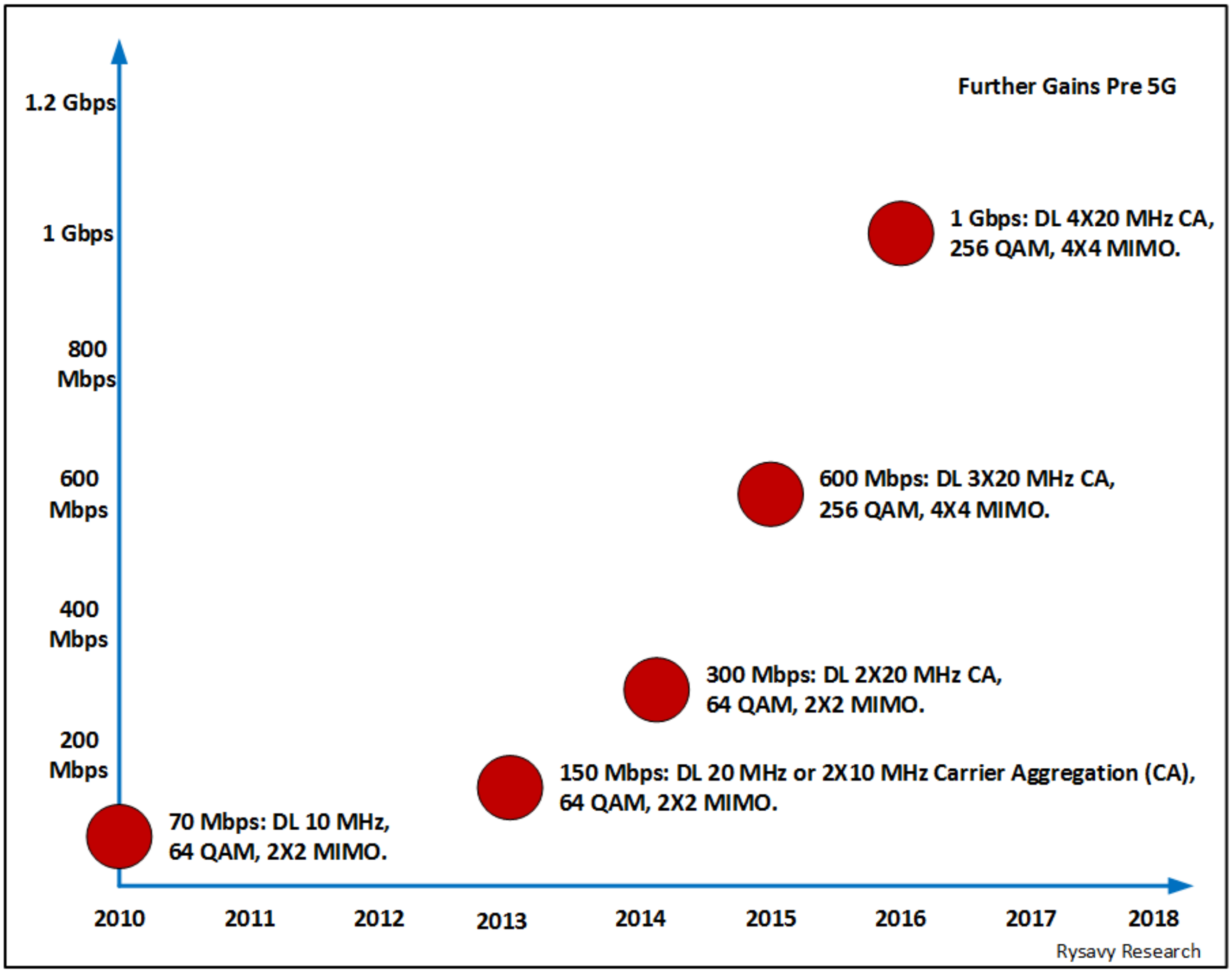

5G Use Cases (ITU and 3GPP)

The ITU, in its 5G recommendations, divides use cases into three main categories, as shown in Figure 12.

1. **Enhanced Mobile Broadband (eMBB).** eMBB is the most obvious extension of LTE capability, providing higher speeds for applications such as streaming, Web access, video conferencing, and virtual reality. Highest speeds will occur in small cells with limited movement speed of end users, such as with pedestrians.
2. **Massive Machine-Type Communications (mMTC).** Massive machine-type communications extends LTE Internet of Things capabilities—for example, NB-IoT—

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[25] Rysavy Research analysis based on information about commercially available chipsets. Not all LTE features are available simultaneously, and thus throughputs do not necessarily scale linearly with items such as bandwidth. See also the following article about achieving gigabit speeds with LTE: Ars Technica, “Qualcomm’s new LTE modem will make gigabit download speeds easier to hit,” February 21, 2017. Available at https://arstechnica.com/gadgets/2017/02/qualcomms-new-lte-modem-will-make-gigabit-download-speeds-easier-to-hit/#p3.

to support huge numbers of devices with lower costs, enhanced coverage, and long battery life. As shown in the ITU objectives, below, 5G will support ten times as many devices in an area as LTE.

3. **Ultra-Reliable and Low Latency Communications (URLLC).** Of the three categories, URLLC enables wireless applications never before possible. Driven by high dependability and extremely short network traversal time, URLLC, also referred to as "mission-critical" communications, will enable industrial automation, drone control, new medical applications, and autonomous vehicles. These types of applications are potentially the ones that will deliver the greatest societal benefits, yet unfortunately, at least in the United States, they could possibly be undermined by current network neutrality regulations. This category is also referred to as critical machine-type communications (cMTC).

Figure 12: ITU Use Case Model[26]

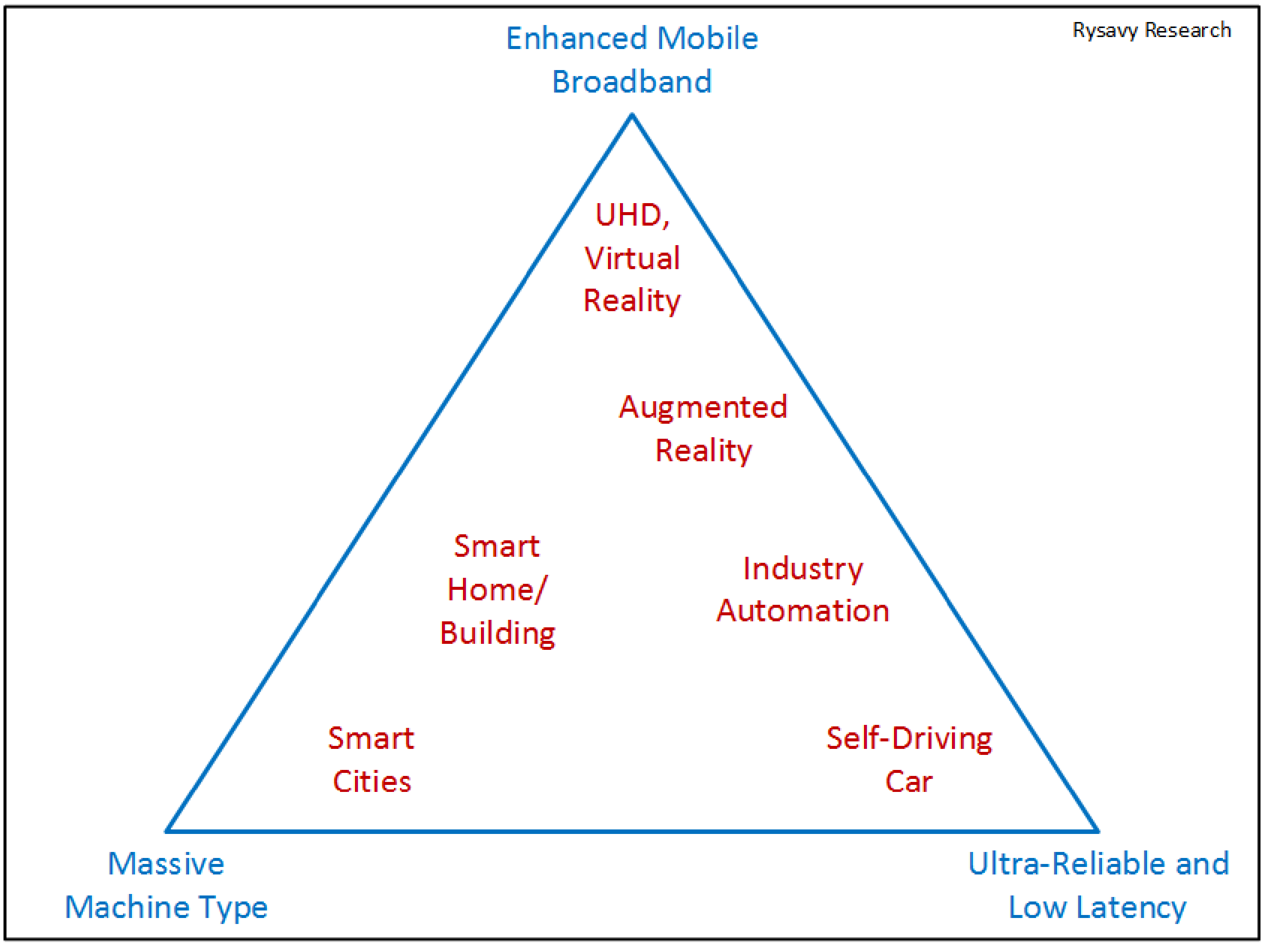
Rysavy Research
Enhanced Mobile Broadband
UHD, Virtual Reality
Augmented Reality
Smart Home/ Building
Industry Automation
Smart Cities
Self-Driving Car
Massive Machine Type
Ultra-Reliable and Low Latency

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[26] For background, see ITU, *IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond*, Recommendation ITU-R M.2083-0, Sep. 2015.

3GPP, in studying 5G, has methodically identified multiple specific use cases in a project called "SMARTER," which are consistent with ITU's model.[27] 3GPP's service dimensions include:

- ☐ Massive Internet of Things (eHealth, wearables, eCity, eFarm).
- ☐ Critical Communications (e.g., vehicles, drones, industry robots).
- ☐ Enhanced Mobile Broadband (e.g., augmented reality, virtual reality, ultra-high definition).
- ☐ Network Operation (e.g., network slicing, connectivity/routing, migration/interworking).

Using small cells and mmWave radio channels, a 5G network built for capacity will deliver 1 Tbps/km^2 or higher, enabling 5G to compete with wireline broadband services.[28]

5G Technical Objectives

Table 4 shows the ITU's objectives for IMT-2020 (5G) relative to IMT-Advanced (4G).

Table 4: ITU Objectives for IMT-2020 compared with IMT-Advanced[29]

	IMT-Advanced	IMT-2020
Peak Data Rate	DL: 1 Gbps UL: 0.05 Gbps	DL: 20 Gbps UL: 10 Gbps
User Experienced Data Rate	10 Mbps	100 Mbps[30]
Peak Spectral Efficiency	DL: 15 bps/Hz UL: 6.75 bps/Hz	DL: 30 bps/Hz UL: 15 bps/Hz
Average Spectral Efficiency		DL eMBB indoor: 9 bps/Hz DL eMBB urban: 7.8 bps/Hz DL eMBB rural: 3.3 bps/Hz UL eMBB indoor: 6.75 bps/Hz UL eMBB urban: 5.4 bps/Hz UL eMBB rural: 1.6 bps/Hz

---

[27] 3GPP TR22.891, *Feasibility Study on New Services and Markets Technology Enablers*; TR22.861 (Massive Internet of Things); TR22.862 (Critical Communications); TR 22.863 (Enhanced Mobile Broadband); TR22.864 (Network Operation).

[28] The hotspot capacity requirement of 10 Mbps/sq. m. is equivalent to 10 Tbps/sq. km. See also *Nokia, Ten key rules of 5G deployment, Enabling 1 Tbit/s/km^2 in 2030*, 2015.

[29] ITU Working Party 5D, *Minimal Requirements Related to Technical Performance for IMT-2020 Radio Interfaces,* Feb 22, 2017. See also 3GPP TR 38.913, *Study on Scenarios and Requirements for Next Generation Access Technologies (Release 14),* V14.2.0, Mar. 2017.

[30] Per ITU, "User experienced data rate is the 5% point of the cumulative distribution function (CDF) of the user throughput."

	IMT-Advanced	IMT-2020
Mobility	350 km/h	500 km/h
User Plane Latency	10 msec	1 msec[31]
Connection Density	100 thousand devices/sq.km.	1 million devices sq./km.
Network Energy Efficiency	1 (normalized)	100X over IMT-Advanced
Area Traffic Capacity	0.1 Mbps/sq. m.	10 Mbps/sq. m. (hot spots)
Bandwidth	Up to 20 MHz/radio channel (up to 100 MHz aggregated)	Up to 1 GHz (single or multipole RF carriers)

In supporting different usage scenarios, not all of these objectives will necessarily be simultaneously available. For example, an IoT application may need to support a large number of devices but at lower throughput rates, while a vehicular application may need high mobility and low latency.

Other expected enhancements include:

- ❑ Deep coverage for machines buried within environments.
- ❑ Extremely low energy demands for ten years or more of battery operation.
- ❑ Low complexity options for inexpensive machine communications.
- ❑ Auto-awareness through discovery and self-optimization.

5G Concepts and Architectures

Standards bodies have not yet defined 5G requirements, but various groups are analyzing the possibilities of what might constitute 5G for network deployments in 2020 or beyond. Often stated goals of 5G include:

- ❑ Being able to support a greater number of end-systems, including IoT applications, at lower average revenue than 4G systems.
- ❑ Peak data rates of multi Gbps (see Table 4 above).
- ❑ Rather than emphasizing peak rates, a more uniform user experience across the coverage area.
- ❑ Support for many frequencies, including existing cellular bands and frequencies above 6 GHz.

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[31] Per 3GPP TR 38.913 (V14.2.0, Mar. 2017), 0.5 msec for DL and 0.5 msec for UL for URLCC and 4 msec for UL and 4 msec for DL for eMBB.

- ❑ Availability of TDD and FDD modes for all bands.
- ❑ Hierarchical/planned and ad hoc deployment models.
- ❑ Use of licensed and unlicensed bands.
- ❑ Equal support for human-type and machine-type communications. Includes highly efficient small data transmission.
- ❑ Advanced Spectrum Sharing, possibly based on spectrum sharing approaches being developed for the 3.5 GHz band.

Figure 13 shows the transformation of networks, moving from today's LTE-Advanced networks to future LTE-Advanced and eventually 5G networks.

Figure 13: Network Transformation[32]

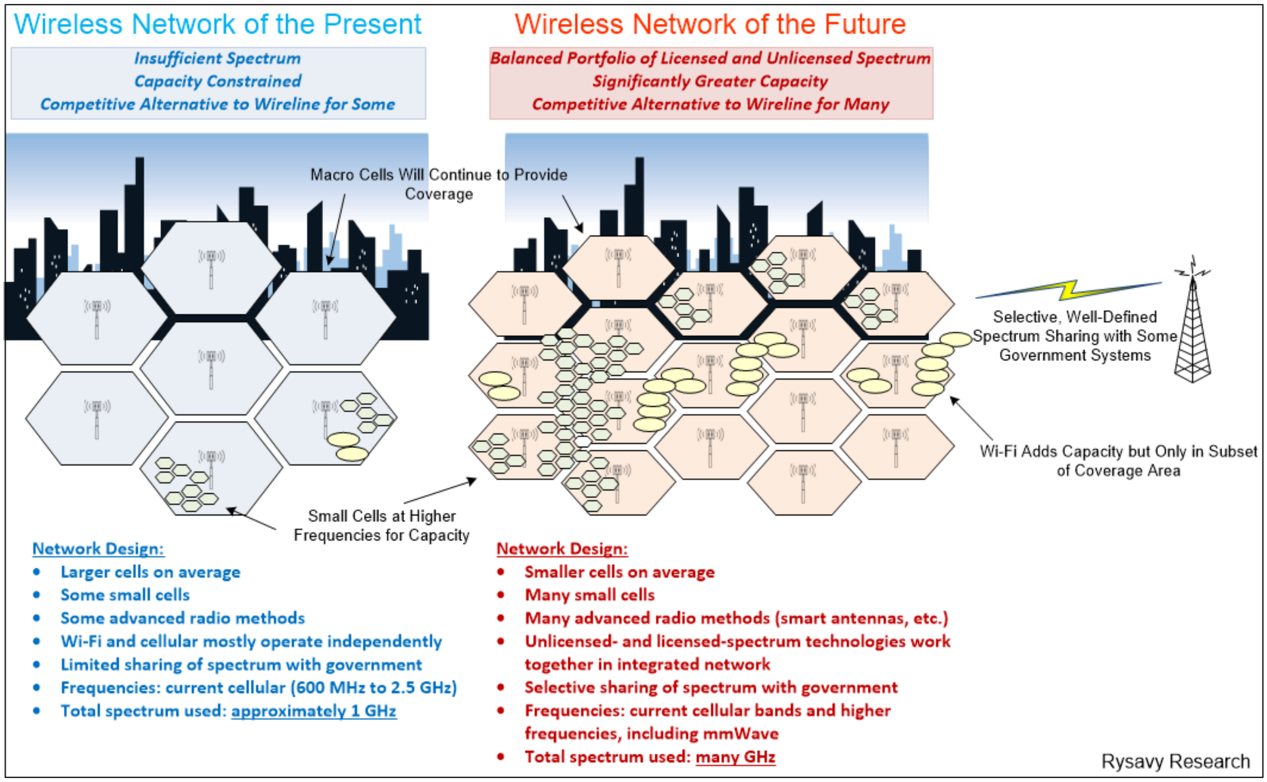
Wireless Network of the Present
Insufficient Spectrum
Capacity Constrained
Competitive Alternative to Wireline for Some
Wireless Network of the Future
Balanced Portfolio of Licensed and Unlicensed Spectrum
Significantly Greater Capacity
Competitive Alternative to Wireline for Many
Macro Cells Will Continue to Provide Coverage
Selective, Well-Defined Spectrum Sharing with Some Government Systems
Wi-Fi Adds Capacity but Only in Subset of Coverage Area
Small Cells at Higher Frequencies for Capacity
Rysavy Research

Network Design:
- Larger cells on average
- Some small cells
- Some advanced radio methods
- Wi-Fi and cellular mostly operate independently
- Limited sharing of spectrum with government
- Frequencies: current cellular (600 MHz to 2.5 GHz)
- Total spectrum used: approximately 1 GHz

Network Design:
- Smaller cells on average
- Many small cells
- Many advanced radio methods (smart antennas, etc.)
- Unlicensed- and licensed-spectrum technologies work together in integrated network
- Selective sharing of spectrum with government
- Frequencies: current cellular bands and higher frequencies, including mmWave
- Total spectrum used: many GHz

The fundamental decision for 5G is how to best leverage existing technology investments in LTE while exploiting new spectrum and new technology capabilities. 5G design emphasizes ways to combine existing 4G LTE networks with capabilities provided by 5G. One approach likely to be used by many operators is to use LTE in existing frequency bands and the 5G NR in new bands, such as mmWave, as shown in Figure 14. 5G NR, however, will operate in all frequencies, and just as 2G and 3G spectrum has been re-farmed for LTE, existing cellular bands will eventually be re-farmed for 5G.

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[32] See also Rysavy Research infographic, "Mobile Broadband Networks of the Future," April 2014. Available at http://www.rysavy.com/Articles/2014-05-Networks-of-the-Future-Infographic.pdf.

Figure 14: 5G Combining of LTE and New Radio Technologies

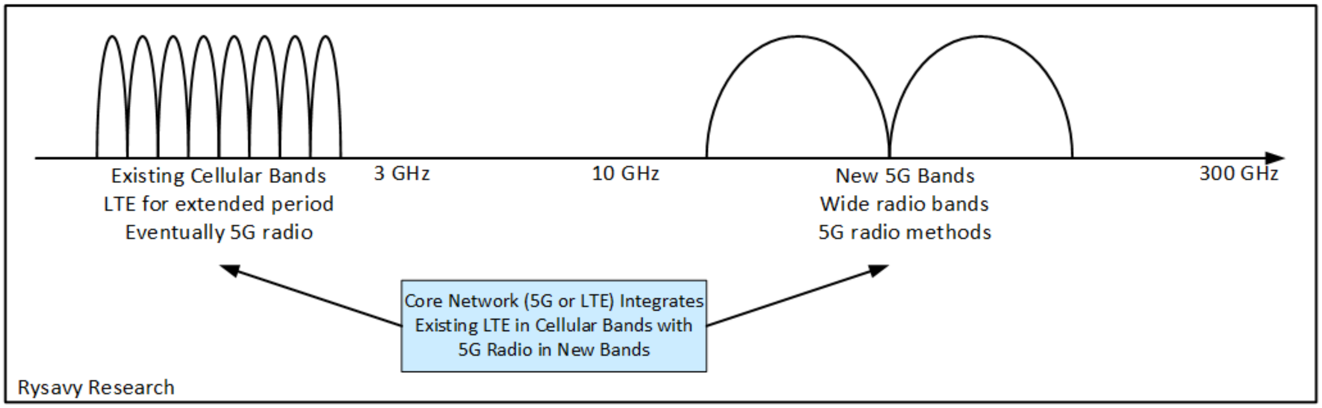
Existing Cellular Bands
LTE for extended period
Eventually 5G radio
3 GHz
10 GHz
New 5G Bands
Wide radio bands
5G radio methods
300 GHz
Core Network (5G or LTE) Integrates Existing LTE in Cellular Bands with 5G Radio in New Bands
Rysavy Research

As shown in Figure 15, higher frequency bands in 5G will provide capacity with smaller cells, and lower bands will provide coverage with larger cells. This is similar to the approach taken in 4G.

Figure 15: Characteristics of Different Bands[33]

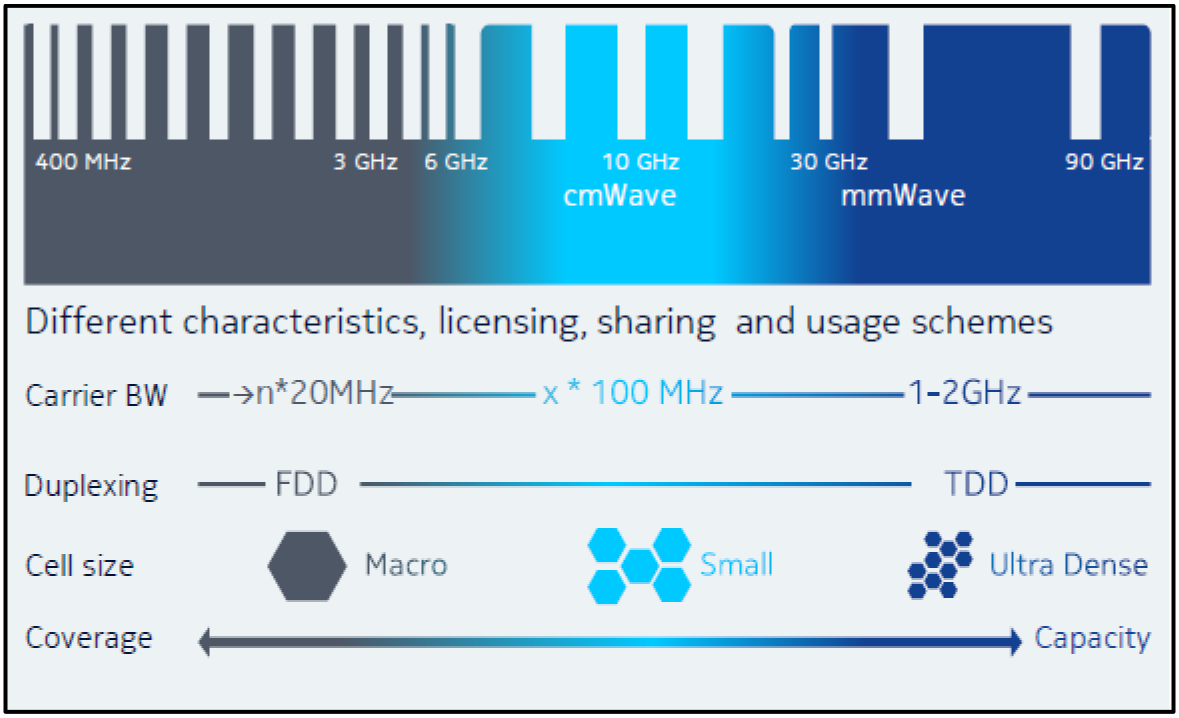
400 MHz
3 GHz
6 GHz
10 GHz
cmWave
30 GHz
mmWave
90 GHz
Different characteristics, licensing, sharing and usage schemes
Carrier BW
n*20MHz
x * 100 MHz
1-2GHz
Duplexing
FDD
TDD
Cell size
Macro
Small
Ultra Dense
Coverage
Capacity

---

[33] Nokia, *Vision & Priorities for Next Generation Radio Technology*, 3GPP RAN workshop on 5G, Sep. 17-18, 2015.

New radio methods in NR will boost performance and will co-exist with future versions of LTE. 3GPP, in Release 14, completed a study item on 5G NR and will specify NR in Release 15.

Figure 16: Evolution to 5G Including LTE Improvements and New 5G Radio Methods

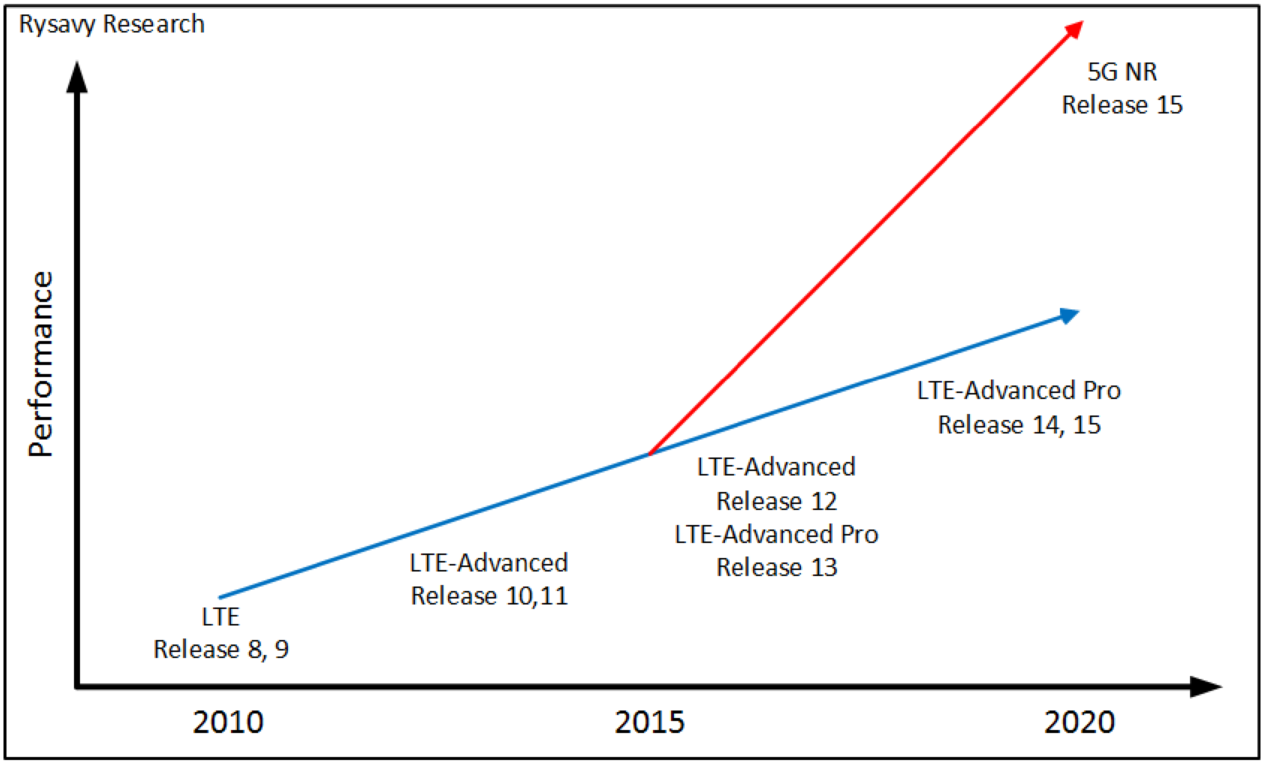

While many deployments will integrate LTE and NR, some operators could choose NR-only deployments.

5G New Radio (NR)

3GPP is defining 5G NR in Release 15, with an initial release for non-standalone operation scheduled for March 2018 and full release for standalone version scheduled for September 2018. Release 16 will add additional capabilities to the radio, such as support for URLLC. Despite specifications not being finalized, the following are planned capabilities and features of NR in Release 15:

- Ability to operate in any frequency band, including low, mid, and high bands.
- Network can support both LTE and 5G NR, including dual connectivity with which devices have simultaneous connections to LTE and NR.
- Carrier aggregation for multiple NR carriers.
- 5 Gbps peak downlink throughput in initial releases, increasing to 50 Gbps in subsequent versions.
- OFDMA in downlink and uplink, with optional Single Carrier Frequency Division Multiple Access (SC-FDMA) for uplink. Radio approach for URLLC to be defined in

Release 16, but Release 15 will provide physical layer frame structure and numerology support.

- Massive MIMO and beamforming.
- Ability to support either FDD or TDD modes for 5G radio bands.
- Numerologies of 2^N X 15 kHz for subcarrier spacing up to 120 kHz or 240 kHz. This approach, depicted in Figure 17, supports both narrow radio channels (for example, 1 MHz), or wide ones (for example, 400 MHz). Phase 1 likely to support a maximum of 400 MHz bandwidth with 240 kHz subcarrier spacing.
- Error correction through low-density parity codes (LDPC), which are computationally more efficient than LTE turbo codes at higher data rates.
- Standards-based cloud RAN support, compared with proprietary LTE approaches, that specifies a split between the PDCP and Radio Link Control (RLC) protocol layers.
- Self-contained integrated subframes that combine scheduling, data, and acknowledgement.
- Future-proofing by providing a flexible radio framework that has forward compatibility to support future, currently unknown services, such as URLLC to be specified in Release 16.
- Scalable transmission time intervals with short time intervals for low latency and longer time intervals for higher spectral efficiency.
- QoS support using a new model.
- Dynamic co-existence with LTE in the same radio channels. (See the Appendix section “LTE-NR Co-existence” for more details.)

According to one 5G Americas member company in 2017, operators globally have expressed interest in deploying NR in a wide variety of bands, including current cellular bands, 3.5 GHz, and mmWave bands.

Release 16 will add support for:

- URLCC.
- Shared spectrum operation.
- 5 GHz unlicensed spectrum operation based on current LTE approaches such as LAA, LWA, LWIP, and RAN Controlled LTE Wireless LAN Interworking (RCLWI).
- Possibly integrated access and backhaul based on a Release 15 study item. See the appendix section, “Integrated Access and Backhaul,” for more details.
- Other, as yet unknown, features.

The ability to simultaneously transmit and receive on the same frequency has been stated in the past as an objective of 5G, and although such capability remains of interest, it is not currently being specified.

Figure 17: Hypothetical Example of 5G Numerology

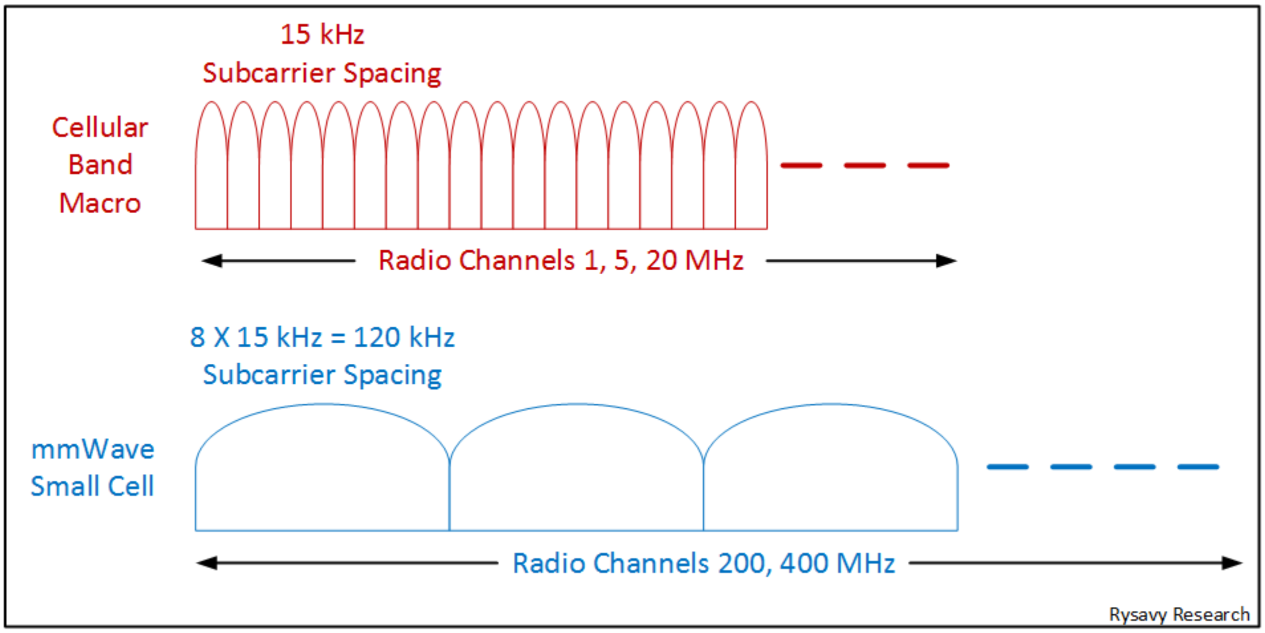

Expected 5G Performance

Predicting the 5G user experience is challenging because 5G will be deployed in many configurations, including different bands and with varying width radio channels. In addition, the throughput rates a user experiences depend on signal quality, device capability, and network loading. Some early predictions, however, are possible by examining the ITU objectives, the expected width of radio channels, and results from simulation studies.

The ITU objectives are that in a 5G network, 95% or more users should be able to experience at least 100 Mbps, which is also termed as cell-edge throughput. Examining the simulation results in the appendix section on 5G, “Performance,” such results appear feasible using 200 MHz or wider radio channels. The results also suggest that average or typical rates could reach 500 Mbps using 200 MHz radio channels and 1 Gbps using 400 MHz radio channels.

Just as LTE throughputs have increased significantly over this decade, 5G performance will keep improving over the next ten years. One 5G Americas member expects that the 5G theoretical peak rate could be 5 Gbps in 2020, rising to 50 Gbps by 2024.

Release 15 Non-Standalone and Standalone Options

3GPP is specifying the first phase of 5G in Release 15. So that operators can deploy 5G sooner, 3GPP divided Release 15 into two sets of specifications. The first and earlier set of specifications define how a 5G RAN can integrate with an LTE network in what 3GPP calls a non-standalone option. In this earliest version (architecture option 3), NR will rely on an existing LTE network, both in the RAN and in the core.

The complete Release 15 specifications will also define a 5G core network. Figure 18 shows some of the architecture options. Options 3, 4 and 7 are the non-standalone options and options 1, 2, and 5 are standalone. The appendix section, “5G Architecture Options,” discusses all of the deployment options in greater detail.

Figure 18: Release 15 Non-Standalone and Standalone Options

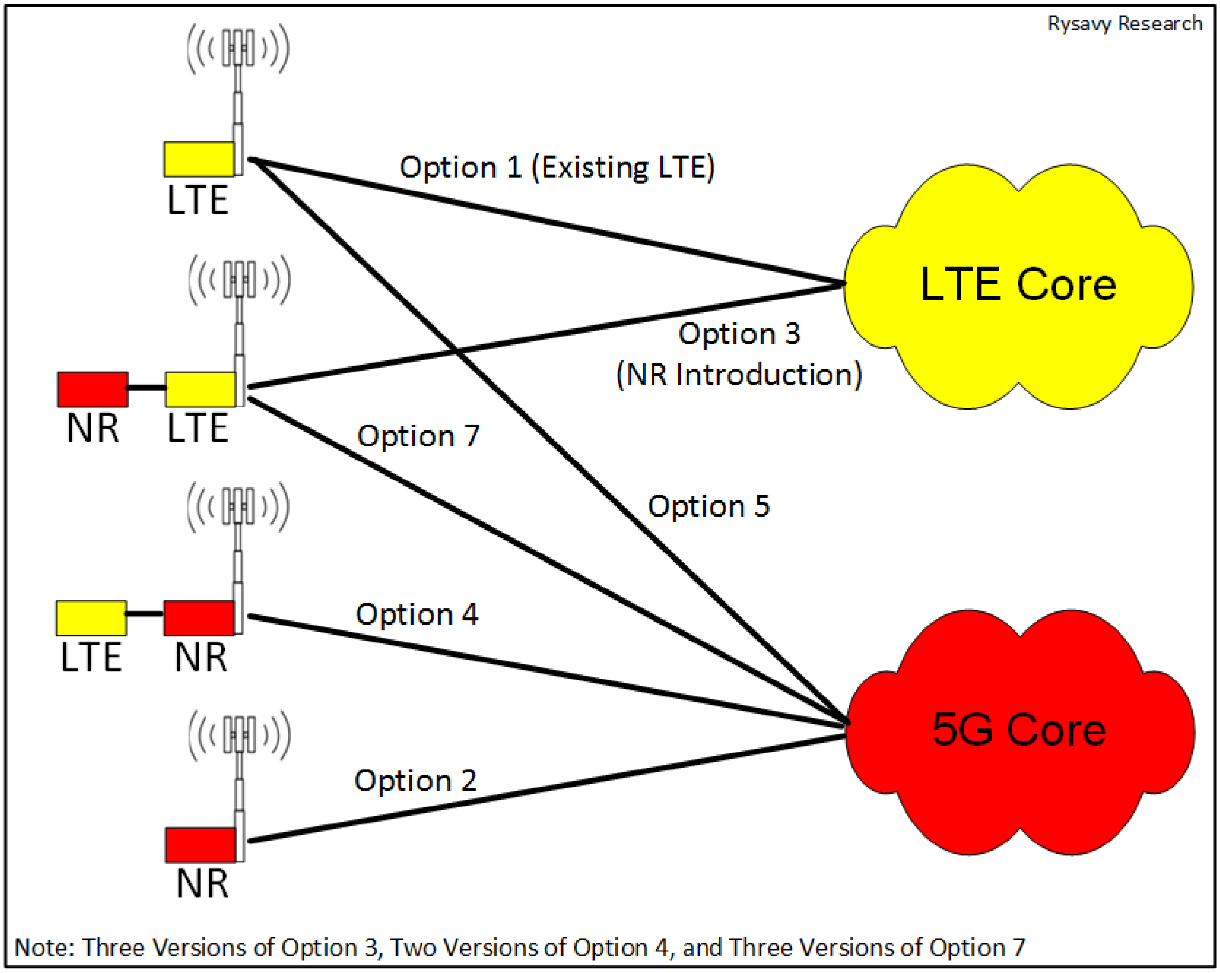
Rysavy Research
LTE
Option 1 (Existing LTE)
LTE Core
NR
LTE
Option 3
(NR Introduction)
Option 7
Option 5
LTE
NR
Option 4
5G Core
Option 2
NR

Note: Three Versions of Option 3, Two Versions of Option 4, and Three Versions of Option 7

5G Schedule3GPP is currently standardizing 5G in Release 15, which will complete the non-standalone version of 5G in March 2018. Based on a typical minimum period of 18 months to build and deploy the technology, initial 5G NSA deployments could occur toward the end of 2019 or the beginning of 2020. 3GPP will complete the full Release 15 specifications in September 2018, enabling deployments in 2020. Release 16, which is the second phase of 5G, will be complete at the end of 2019, and Release 16 deployments could occur in 2021. In 2020, 3GPP will begin work on Release 17 which will include as yet unknown capabilities.

Figure 19Figure 19 shows the current schedule for 5G development and deployment. 3GPP is currently standardizing 5G in Release 15, which will complete the non-standalone version of 5G in March 2018. Based on a typical minimum period of 18 months to build and deploy the technology, initial 5G NSA deployments could occur toward the end of 2019 or the beginning of 2020. 3GPP will complete the full Release 15 specifications in September 2018, enabling deployments in 2020. Release 16, which is the second phase of 5G, will be complete at the end of 2019, and Release 16 deployments could occur in 2021. In 2020, 3GPP will begin work on Release 17 which will include as yet unknown capabilities.

Figure 19: 5G Schedule[34]

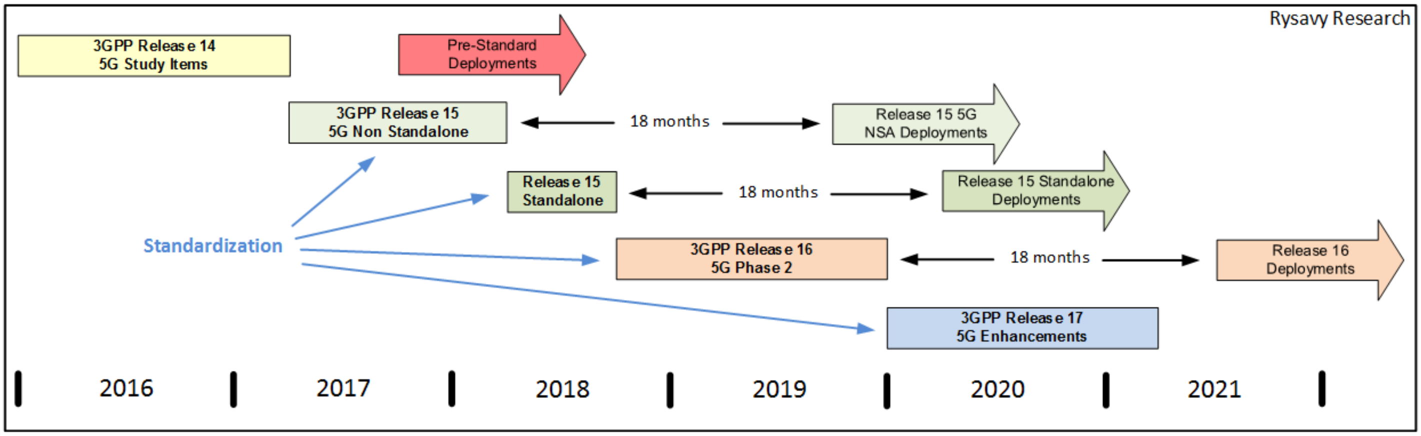
Rysavy Research
3GPP Release 14 5G Study Items
Pre-Standard Deployments
3GPP Release 15 5G Non Standalone
18 months
Release 15 5G NSA Deployments
Release 15 Standalone
18 months
Release 15 Standalone Deployments
Standardization
3GPP Release 16 5G Phase 2
18 months
Release 16 Deployments
3GPP Release 17 5G Enhancements
2016
2017
2018
2019
2020
2021

5G Core Network

Release 15 also defines initial core network capabilities that support QoS and network slicing. See the 5G appendix section, "Architecture," for more details. A study item in Release 15 will study integrated access and backhaul, with which base stations can use the 5G radio channel for backhaul. This capability could become a work item for Release 16. See the appendix section, "Integrated Access and Backhaul," for more details.

Many operators will virtualize their 5G core networks, just as they have for LTE, but such virtualization is outside the scope of 3GPP specifications.

5G Device Availability

User devices capable of 5G operation have not yet been announced, but availability will likely follow the trends of previous generations of networks. Initial devices, possibly in the 2019 timeframe, will likely include routers that have a 5G radio and use Wi-Fi for local Hotspot capability and USB modems. Handset vendors are in the early stages of designing mmWave support into smartphones.[35] These devices could come online in the 2021 timeframe, although this estimate could tighten or lengthen depending on chipset availability and handset vendor plans.

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[34] 3GPP and 5G Americas member contribution. Completion based on anticipated ASN.1 freeze dates.

[35] For example, see "Wireless Week, Apple Wants to Test Performance at 28 GHz, 39 GHz for 5G Devices," May 24, 2017, https://www.wirelessweek.com/news/2017/05/apple-wants-test-performance-28-ghz-39-ghz-5g-devices, viewed May 29, 2017.

mmWave

Use of higher frequencies, such as above 6 GHz, represents one of the greatest opportunities for higher throughputs and higher capacity. This benefit derives from the potential availability of ten times the amount of spectrum as is currently available, with multiple GHz of contiguous spectrum. But these higher frequencies, especially mmWave frequencies (above 30 GHz), are suitable only over short distances, as explained below. The combination of lower and higher frequencies is therefore crucial for 5G operation. Lower bands can be devoted to coverage and control, while higher bands can provide opportunistic access for high data rates. The lower and higher spectrum bands can operate in a carrier aggregation or dual connectivity model. Initial 5G specifications include such dual-connectivity capability.

Compared with lower frequencies, mmWave frequencies suffer from worse propagation characteristics, even in line-of-sight conditions, because the comparatively smaller aperture area of the receiver's antenna requires some form of beamforming at the transmit side, and potentially even at the receive side. Fortunately, the smaller form factors of mmWave antennas allow for dense packing of antenna arrays. Experimental systems using antenna arrays have demonstrated reliable communications at 28 GHz, even in dense, urban, non-line-of-sight conditions, for distances up to 200 meters.[36] Arrays at the terminal side are space-constrained, but some basic beamforming at the terminal is possible. On the base station side, the arrays may include hundreds of antennas in an approach called "massive MIMO."

Figure 20 shows how an increasing number of antenna elements can extend coverage through tighter beams. A 77 X 77 antenna array (6,000 elements) can exceed a kilometer at 3.5 GHz (33 dBm transmit power) and reach over 800 meters, even at 30 GHz.

---

[36] Samsung, *5G Vision,* February 2015. Available at http://www.samsung.com/global/business-images/insights/2015/Samsung-5G-Vision-0.pdf.

Figure 20: Range Relative to Number of Antenna Elements[37]

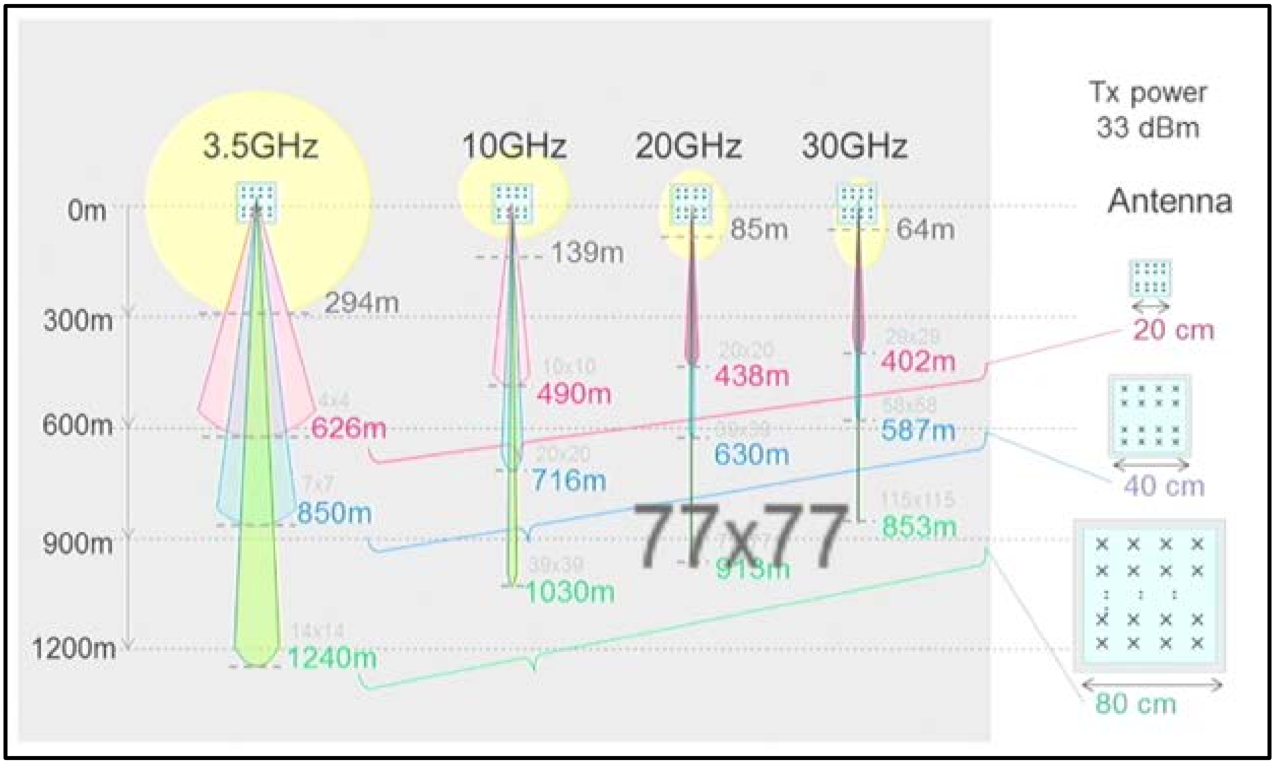
Tx power
33 dBm
3.5GHz
10GHz
20GHz
30GHz
Antenna
0m
300m
600m
900m
1200m
294m
4x4
626m
7x7
850m
14x14
1240m
139m
10x10
490m
20x20
716m
39x39
1030m
85m
20x20
438m
39x39
630m
77x77
913m
64m
29x29
402m
58x58
587m
115x115
853m
77x77
20 cm
40 cm
80 cm

More typically, mmWave cells will employ shorter ranges of 50 to 200 meters. Extreme densification is another way that 5G networks will achieve massive increases in capacity. 3G networks reached densities of four to five base stations per sq. km, 4G networks eight to 10, but 5G networks may reach densities of 40 to 50.[38] A likely 5G architecture will use the macro cell for control information, coverage, and fallback, but small cells, often operating at higher frequencies, for high-bandwidth data communication. Either wireless connections or fiber will provide backhaul. Figure 21 shows how such an approach could also employ beamforming and beam tracking when using mmWave bands in the small cells.

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[37] Dr. Seizo Onoe, NTT DOCOMO, presentation at Brooklyn 5G Summit, Apr. 21, 2016. Used by permission.

[38] IEEE Wireless Communications, *5G Ultra-Dense Cellular Networks,* Feb. 2016.

Figure 21: 5G Architecture for Low-Band/High-Band Integration

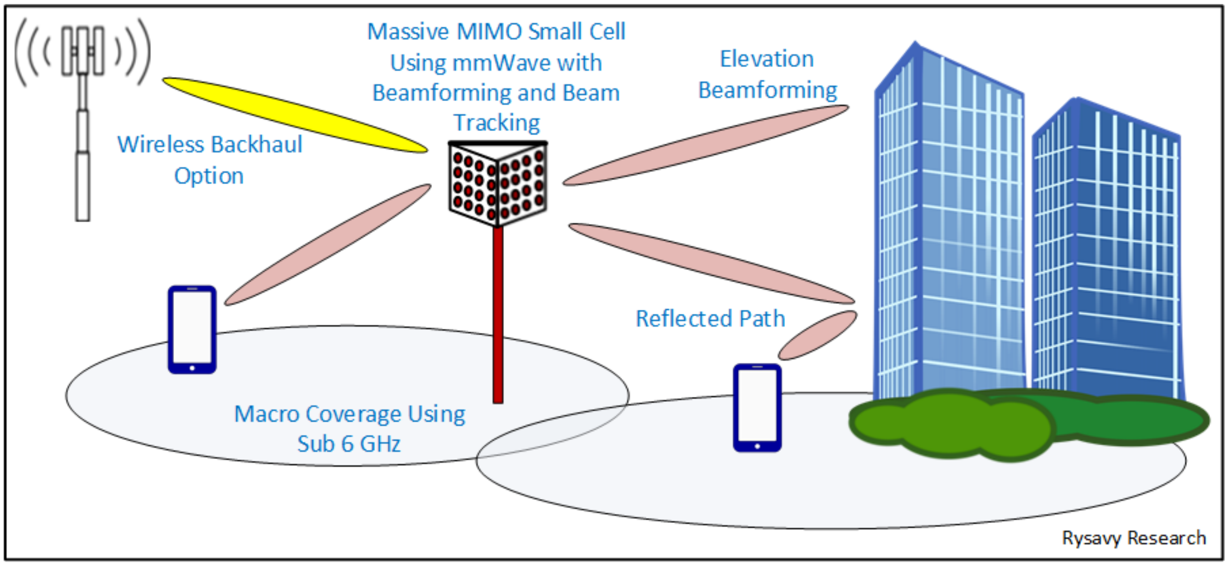
Massive MIMO Small Cell
Using mmWave with
Beamforming and Beam
Tracking
Elevation
Beamforming
Wireless Backhaul
Option
Reflected Path
Macro Coverage Using
Sub 6 GHz
Rysavy Research

In combination, the various methods expected in 5G will provide users in mmWave band hotspot coverage at least a 100-fold increase in throughput over LTE, achieved by:

- ❑ Five- to 10-fold gains due to fewer users in each small cell. (Five to ten times as many cells.)
- ❑ 10-fold gains from access to much larger amounts of spectrum.
- ❑ Three-fold gains or more from improved spectral efficiency.

It is this huge increase in capacity, combined with Gbps performance, that will allow 5G to compete with wireline networks.[39]

Network Slicing

Not only will 5G networks include a new radio, but thanks to virtualization, these networks will be able to present multiple faces for different use cases using a concept called network slicing. This architecture allows an operator to provide multiple services with different performance characteristics. Each network slice operates as an independent, virtualized version of the network. For an application, the network slice is the only network it sees. The other slices, to which the customer is not subscribed, are invisible and inaccessible. The advantage of this architecture is that the operator can create slices that are fine-tuned for specific use cases. One slice could target autonomous vehicles, another enhanced mobile broadband, another low-throughput IoT sensors, and so on.

Figure 22 shows the network slicing architecture, with devices having access to only the slice or slices for which they have subscriptions. Each slice has radio resources allocated, with specific QoS characteristics. Within the core network, virtualized core network functions support each slice and provide connections to external networks.[40]

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[39] For a further discussion of 5G capacity and ability to compete with wireline networks, refer to Datacomm Research and Rysavy Research, *Broadband Disruption: How 5G Will Reshape the Competitive Landscape*, 2017, available at https://datacommresearch.com/reports-broadband/.

Figure 22: Network Slicing Architecture

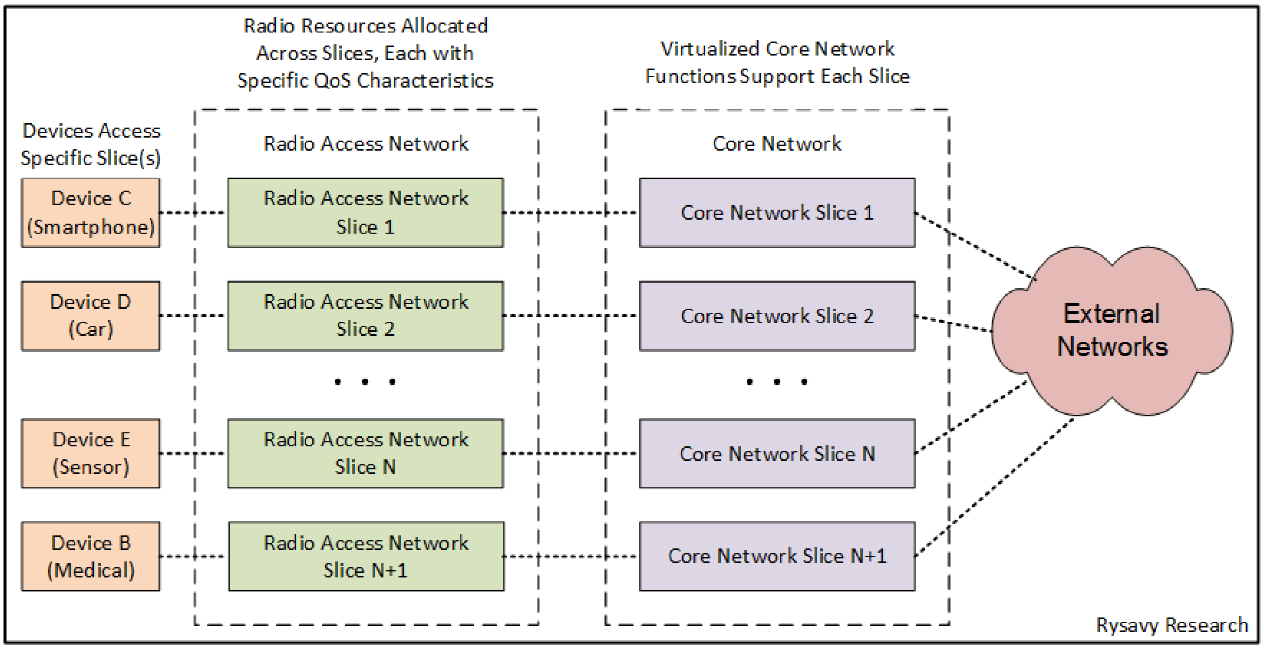
Radio Resources Allocated Across Slices, Each with Specific QoS Characteristics
Virtualized Core Network Functions Support Each Slice
Devices Access Specific Slice(s)
Radio Access Network
Core Network
Device C (Smartphone)
Device D (Car)
Device E (Sensor)
Device B (Medical)
Radio Access Network Slice 1
Radio Access Network Slice 2
Radio Access Network Slice N
Radio Access Network Slice N+1
Core Network Slice 1
Core Network Slice 2
Core Network Slice N
Core Network Slice N+1
External Networks
Rysavy Research

Information-Centric Networking

For many usage scenarios, wireless networks provide broadband access to the internet, a network that itself is evolving. The internet is based on a node-centric design developed forty years ago. The point-to-point method of communication the internet uses has functioned well for a vast array of applications but is not optimal for the way content is developed and distributed today. Industry and academic organizations are researching a concept called "Information-Centric Networking." ICN seeks a new approach of in-network caching that distributes content on a large scale, cost-efficiently and securely.

Most internet content uses Uniform Resource Identifiers (URIs) to locate objects and define specific location-dependent IP addresses. This approach, however, causes problems when content moves, sites change domains, or content is replicated and each copy appears as a different object. Developments such as peer-to-peer overlays and content distribution networks (such as Akamai) that distribute cached copies of content are a first step toward an information-centric communication model.

ICN is built from the ground up on the assumption of mobility, so it eliminates the mobility overlays on which current mobile broadband networks depend. The approach will be able to place information anywhere in the network with immediate and easy retrieval.

Key principles of ICN include:

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[40] For more details, see 5G Americas, *Network Slicing for 5G Networks & Services*, November 2016. Available at: http://www.5gamericas.org/files/3214/7975/0104/5G_Americas_Network_Slicing_11.21_Final.pdf.

- ☐ The architecture inherently supports user mobility.
- ☐ Network operations are name-based instead of address- or node-based.
- ☐ The network itself stores, processes, and forwards information.
- ☐ Intrinsic security guarantees the integrity of every data object.

The goal of ICN is to simplify the storage and distribution of gigantic amounts of content while reducing the amount of traffic and latency users face when accessing the content. The internet cannot just be replaced, however, so in initial stages, ICN would operate as an overlay, and over time would assume an increasing percentage of the functions within the internet. ICN would not discard IP; rather, it seeks to generalize the routing concept to enrich networking with new capabilities.

Some technology aspects of ICN include:

- ☐ Information retrieval from multiple sources without needing to know the location of the information.
- ☐ Multipath communications that improves user performance and traffic load balancing.
- ☐ Subsequent requests for the same data will be served locally without needing to fetch it from original repository.
- ☐ Elimination of the name-to-location indirection associated with Domain Name Service (DNS).

Because mobility is such a central aspect of ICN, mobile network operators are in a unique position to participate in ICN-related research and development, and to do so as part of 5G development. ICN has not progressed to a level at which 3GPP specification work could include it, so instead promoters are ensuring that 5G specification work does not preclude it. With this approach, operators in the 2020s will have the option of overlaying ICN capability on their 5G networks. ICN could even be implemented as a 5G network slice for mobile and end-systems capable of ICN.

3GPP Releases

3GPP standards development falls into three principal areas: radio interfaces, core networks, and services. Progress in the 3GPP family of technologies has occurred in multiple phases, first with GSM, then GPRS, EDGE, UMTS, HSPA, HSPA+, LTE, LTE-Advanced, and now LTE-Advanced Pro. Underlying radio approaches have evolved from Time Division Multiple Access (TDMA) to CDMA to Orthogonal Frequency Division Multiple Access (OFDMA), which is the basis of LTE. 3GPP is also involved in standardization of 5G technology.

Table 5 summarizes the key 3GPP technologies and their characteristics.

Table 5: Characteristics of 3GPP Technologies

Technology Name	Type	Characteristics	Typical Downlink Speed	Typical Uplink Speed
HSPA[41]	WCDMA	Data service for UMTS networks. An enhancement to original UMTS data service.	1 Mbps to 4 Mbps	500 Kbps to 2 Mbps
HSPA+	WCDMA	Evolution of HSPA in various stages to increase throughput and capacity and to lower latency.	1.9 Mbps to 8.8 Mbps in 5+5 MHz[42] 3.8 Mbps to 17.6 Mbps with dual-carrier in 10+5 MHz	1 Mbps to 4 Mbps in 5+5 MHz or in 10+5 MHz
LTE	OFDMA	New radio interface that can use wide radio channels and deliver extremely high throughput rates. All communications handled in IP domain.	6.5 to 26.3 Mbps in 10+10 MHz[43]	6.0 to 13.0 Mbps in 10+10 MHz
LTE-Advanced	OFDMA	Advanced version of LTE designed to meet IMT-Advanced requirements.	Significant gains through carrier aggregation, 4X2 and 4X4 MIMO, and 256 QAM modulation.	

User-achievable rates and additional details on typical rates are covered in the appendix section "Data Throughput."

3GPP develops specifications in releases, with each release addressing multiple technologies. For example, Release 8 defined dual-carrier operation for HSPA but also introduced LTE. Each release adds new features and improves performance of existing functionality in different ways. Table 6 summarizes some key features of different 3GPP releases.

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[41] HSPA and HSPA+ throughput rates are for a 5+5 MHz deployment.

[42] "5+5 MHz" means 5 MHz used for the downlink and 5 MHz used for the uplink.

[43] 5G Americas member company analysis for downlink and uplink. Assumes single user with 50% load in other sectors. AT&T and Verizon are quoting typical user rates of 5-12 Mbps on the downlink and 2-5 Mbps on the uplink for their networks. See additional LTE throughput information in the section below, "LTE Throughput."

Table 6: Key Features in 3GPP Releases[44]

Release	Year	Key Features
99	1999	First deployable version of UMTS.
5	2002	High Speed Downlink Packet Access (HSDPA) for UMTS.
6	2005	High Speed Uplink Packet Access (HSUPA) for UMTS.
7	2008	HSPA+ with higher-order modulation and MIMO.
8	2009	Long Term Evolution. Dual-carrier HSDPA.
10	2011	LTE-Advanced, including carrier aggregation and eICIC.
11	2013	Coordinated Multi Point (CoMP).
12	2015	Public safety support. Device-to-device communications. Dual Connectivity. 256 QAM on the downlink.
13	2016	LTE-Advanced Pro features. LTE operation in unlicensed bands using LAA. Full-dimension MIMO. LTE-WLAN Aggregation. Narrowband Internet of Things.
14	2017	LTE-Advanced Pro additional features, such as eLAA (adding uplink to LAA) and cellular V2X communications. Study item for 5G "New Radio."
15	2018	Additional LTE-Advanced Pro features, such as ultra-reliable low-latency communications. Phase 1 of 5G. Will emphasize enhanced mobile broadband use case and sub-40 GHz operation. Includes Massive MIMO, beamforming, and 4G-5G interworking, including ability for LTE connectivity to a 5G CN.
16	2019	Phase 2 of 5G. Full compliance with ITU IMT-2020 requirements. Will add URLLC, spectrum sharing, unlicensed operation, and multiple other enhancements.
17	2021	Further LTE and 5G enhancements.

Refer to the Appendix section "3GPP Releases" for a more detailed listing of features in each 3GPP Release.

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[44] After Release 99, release versions went to a numerical designation beginning with Release 4, instead of designation by year.

Supporting Technologies and Architectures

Network architects design networks using a deep and wide toolkit, including multiples types of cell sizes, integration with unlicensed spectrum, smart antennas, converged services, and virtualization.

Multiple Cell Types

Operators have many choices for providing coverage. Lower frequencies propagate further and thus require fewer cells for coverage. The resulting network, however, has lower capacity than one with more cells, so operators must continually evaluate cell placement with respect to both coverage and capacity.

Table 7 lists the many types of cells. Note that the distinctions, such as radius, are not absolute—perhaps one reason the term “small cell” has become popular, as it encompasses picocells, metrocells, femtocells, and sometimes Wi-Fi.

With “plug-and-play” capability derived from self-configuring and self-organizing features, small cells will increasingly be deployed in an ad hoc manner, anywhere power and backhaul are available, yet will operate in tight coordination with the rest of the network.

A proliferation of small cells inside buildings will also provide coverage from inside to outside, such as in city streets, the reverse of traditional coverage that extends from outdoor cells to inside.

Table 7: Types of Cells and Typical Characteristics (Not Formally Defined)

Type of Cell	Characteristics
Macro cell	Wide-area coverage. LTE supports cells up to 100 km in range, but typical distances are .5 to 5 km radius. Always installed outdoors.
Microcell	Covers a smaller area, such as a hotel or mall. Range to 2 km, 5-10W, and 256-512 users. Usually installed outdoors.
Picocell	Indoor or outdoor. Outdoor cells, also called “metrocells.” Typical range 15 to 200 meters outdoors and 10 to 25 meters indoors, 1-2W, 64-128 users. Deployed by operators primarily to expand capacity.
Consumer Femtocell	Indoors. Range to 10 meters, less than 50 mW, and 4 to 6 users. Capacity and coverage benefit. Usually deployed by end users using their own backhaul.
Enterprise Femtocell	Indoors. Range to 25 meters, 100-250 mW, 16-32 users. Capacity and coverage benefit. Deployed by operators.
Distributed antenna system	Expands indoor or outdoor coverage. Same hardware can support multiple operators (neutral-host) since antenna can support broad frequency range and multiple technologies. Indoor deployments are typically in larger spaces such as airports. Has also been deployed outdoors for coverage and capacity expansion.

Type of Cell	Characteristics
Remote radio head (RRH)	Uses baseband at existing macro site or centralized baseband equipment. If centralized, the system is called “cloud RAN.” Requires fiber connection.
Wi-Fi	Primarily provides capacity expansion. Neutral-host capability allows multiple operators to share infrastructure.

Smalls Cells and Heterogeneous Networks

Historically, increasing the number of cell sites has been the primary method for increasing capacity, providing gains far greater than what can be achieved by improvements in spectral efficiency alone. The next wave of densification is by using what the industry calls “small cells.”

Central to small-cell support is the heterogeneous network architecture, with multiple types of cells serving a coverage area, varying in frequencies used, radius, and even radio technology used.

HetNets offer significant increases in capacity and improvements, including:

1. Smaller cells, such as open femtocells (home-area coverage) and picocells (city-block-area coverage), inherently increase capacity because each cell serves a smaller number of users.
2. Strategic placement of picocells within the macro cell provides the means to absorb traffic in areas where there are higher concentrations of users. Locations can include businesses, airports, stadiums, convention centers, hotels, hospitals, shopping malls, high-rise residential complexes, and college campuses.
3. Smaller cells can also improve signal quality in areas where the signal from the macro cell is weak.

Essential elements for practical HetNet deployment are self-optimization and self-configuration, especially as the industry transitions from tens of thousands of cells to hundreds of thousands, and eventually to millions. The appendix covers technical aspects of HetNets in the sections, “Heterogeneous Networks and Small Cells” and “Self-Organizing Networks.”

While promising in the long term, one immediate challenge in deploying a large number of small cells is backhaul, since access to fiber is not necessarily available and line-of-sight microwave links are not always feasible. Site acquisition and the need for multiple operators to deploy their own cells in a coverage area are additional challenges.[45] Figure 23 depicts the challenges.

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[45] For further discussion of this topic, refer to 5G Americas and Small Cell Forum, *Small cell siting challenges,”* February 2017.

Figure 23: Small-Cell Challenges

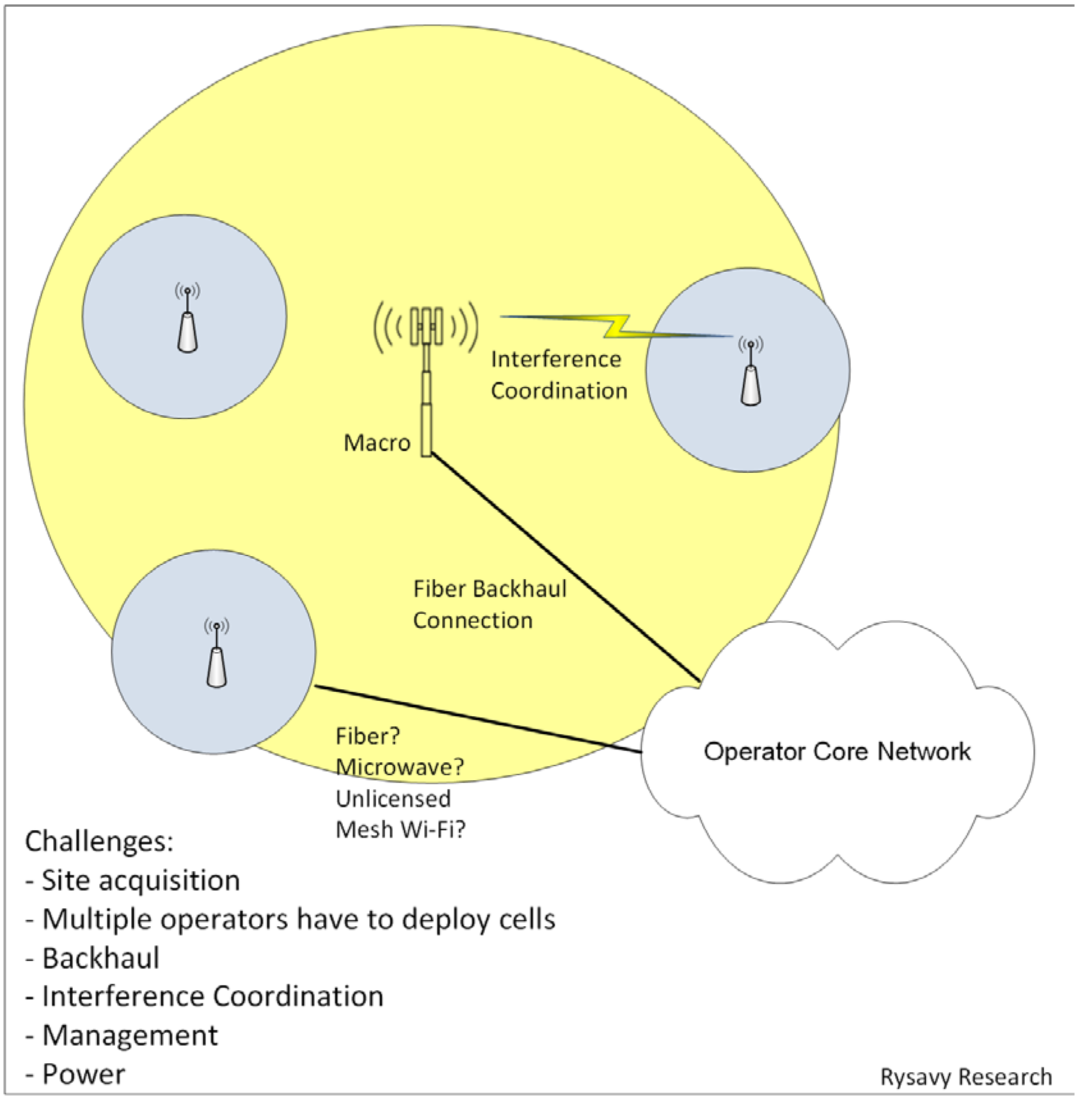
Interference
Coordination
Macro
Fiber Backhaul
Connection
Fiber?
Microwave?
Unlicensed
Mesh Wi-Fi?
Operator Core Network
Challenges:
- Site acquisition
- Multiple operators have to deploy cells
- Backhaul
- Interference Coordination
- Management
- Power
Rysavy Research

Despite these challenges and the relatively small number of small cells deployed today, many believe small-cell deployments will accelerate.[46]

In the United States, the FCC in April 2017 issued a Notice of Proposed Rulemaking, titled "Accelerating Wireless Broadband Deployment by Removing Barriers to Infrastructure

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[46] For example, see Fierce Wireless, "Crown Castle expects its small cell business to double in next 2 years," April 25, 2017. Available at http://www.fiercewireless.com/wireless/crown-castle-expects-its-small-cell-business-to-double-next-two-years.

Investment," that seeks to streamline items such as site acquisition and consistent pricing.[47]

5G small-cell considerations include:

- Due to limited propagation at mmWave frequencies, 5G small-cell deployments will be dense and involve large numbers of sites. Inter-site distances (ISDs) will range from 100 to 300 meters in many deployments, with 200 meters a typical value.[48]
- The high-capacity of mmWave small cells will require multi-Gbps backhaul connections using an expected combination of fiber, mmWave radio in point-to-point connections, and 5G self-backhaul.
- The expected use of cloud RAN and centralized base station facilities will simplify equipment at the site, facilitating dense deployments.
- Dense deployments will motivate neutral-host (multi-tenant) approaches, but these are outside the scope of specification efforts.

The effective range of a mmWave small cell depends on multiple factors, including whether line-of-sight is available, extent of foliage, pole height, whether user equipment is indoors or outdoors, and the types of building materials the signal must pass through to reach indoor equipment.

Despite the challenges, small cells will ultimately contribute greatly to increased network capacity. Table 8 lists possible configurations. Note that many of these approaches can be combined, such as using picos and Wi-Fi offload.

Table 8: Small-Cell Approaches

Small-Cell Approach	Characteristics
Macro plus small cells in select areas.	Significant standards support. Femtocells or picocells can use the same radio carriers as macro (less total spectrum needed) or can use different radio carriers (greater total capacity).
Macro in licensed band plus LTE operation in unlicensed bands.	Promising approach for augmenting LTE capacity in scenarios where operator is deploying LTE small cells.[49] See discussion below in the section on unlicensed spectrum integration.

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[47] FCC, *Wireless Infrastructure NPRM and NOI*, April 21, 2017. Available at https://www.fcc.gov/document/wireless-infrastructure-nprm-and-noi.

[48] 5G Americas member contributions.

[49] See Rysavy Research, *Accelerating Innovation in Unlicensed Spectrum*, Fierce Wireless, November 2016. Available at http://www.rysavy.com/Articles/2016-11-Innovation-Unlicensed-Spectrum.pdf. See also Rysavy Research, *Will LTE in Unlicensed Spectrum Unlock a Vast Store of Mobile Broadband Capacity?* MIMO World, June 2014. Available at http://www.mimoworld.com/?p=2377.

Small-Cell Approach	Characteristics
Macro (or small-cell) cellular in licensed band plus Wi-Fi.	Extensively used today with increased use anticipated. Particularly attractive for expanding capacity in coverage areas where Wi-Fi infrastructure exists but small cells with LTE do not. LTE Wi-Fi Aggregation (being specified in Release 13) is another approach, as are MP-TCP and MP-QUIC.
Wi-Fi only.	Low-cost approach for high-capacity mobile broadband coverage, but impossible to provide large-area continuous coverage without cellular component.

Neutral-Host Small Cells

Multi-operator and neutral-host solutions could accelerate deployment of small cells.[50] Currently, nearly all small-cell deployments are operator-specific, but in the future, deployments supporting multiple operators could reduce the cost per operator to provide coverage.

A candidate band for neutral-host small cells is 3.5 GHz, using LTE TDD and MulteFire as potential technologies. Wi-Fi technology also addresses neutral-host configurations at the access level, but it has roaming and authentication challenges. HotSpot 2.0 (covered in the appendix) addresses roaming and authentication.

Unlicensed Spectrum Integration

Unlicensed spectrum is becoming ever more important to mobile broadband networks. Initial use was rudimentary offload onto Wi-Fi networks, but now, Wi-Fi networks are becoming more tightly integrated into cellular networks. Efforts are also underway to use LTE in unlicensed spectrum.

Unlicensed spectrum adds to capacity in two ways. First, a large amount of spectrum (approximately 500 MHz) is available across the 2.4 GHz and 5 GHz bands, with the 3.5 GHz band adding further spectrum in the future. A significant amount of unlicensed spectrum is also available in mmWave bands, with 7 GHz already in use in the United States (57 to 64 GHz) and an additional 7 GHz in 5G spectrum allocations. Second, unlicensed spectrum is mostly used in small coverage areas, resulting in high-frequency re-use and much higher throughput rates per square meter of coverage versus typical cellular deployments.

The IEEE 802.11 family of technologies has experienced rapid growth, mainly in private deployments. The latest 802.11 standard, 802.11ac, offers peak theoretical throughputs in excess of 1 Gbps and improved range through use of higher-order MIMO. 802.11ac Wave 2 products include a Multi-user MIMO capability that further increases capacity and throughput. IEEE is developing a subsequent version, 802.11ax, that emphasizes capacity improvements as well as higher throughputs. In the mmWave frequencies, IEEE has developed 802.11ad, which operates at 60 GHz, and the standards body is currently working on a successor technology, 802.11ay.

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[50] 5G Americas and Small Cell Forum, *Multi-operator and neutral host small cells; Drivers, architectures, planning and regulation,* December 2016. Report available at http://www.5gamericas.org/files/4914/8193/1104/SCF191_Multi-operator_neutral_host_small_cells.pdf.

Integration between mobile broadband and Wi-Fi networks can be either loose or tight. Loose integration means data traffic routes directly to the internet and minimizes traversal of the operator network. This is called "local breakout." Tight integration means data traffic, or select portions thereof, may traverse the operator core network. An example is Wi-Fi calling, which uses IP Multimedia Subsystem.

Although offloading onto Wi-Fi can reduce traffic on the core network, the Wi-Fi network does not necessarily always have greater spare capacity than the cellular network. The goal of future integrated cellular/Wi-Fi networks is to intelligently load balance between the two. Simultaneous cellular/Wi-Fi connections will also become possible. For example, in Release 13, 3GPP introduces link aggregation of Wi-Fi and LTE through LWA and LWIP.

Successfully offloading data and providing users a good experience mandates measures such as automatically provisioning subscriber devices with the necessary Wi-Fi configuration options and automatically authenticating subscribers on supported public Wi-Fi networks. Many stakeholders are working toward tighter integration between Wi-Fi and cellular networks.

Another approach for using unlicensed spectrum employs LTE as the radio technology, initially in a version referred to as LTE-Unlicensed, which works with Releases 10-12 of LTE, as defined in the LTE-U Forum. In Release 13, 3GPP specified LAA, which implements listen-before-talk capability, a requirement for unlicensed operation in Europe and Japan. Initially, carrier aggregation combines a licensed carrier with an unlicensed 20 MHz carrier in the 5 GHz band as a supplemental channel, with the aggregation of multiple unlicensed channels an eventual possibility. Operating LTE in unlicensed bands could decrease the need for handoffs to Wi-Fi. Up to 32 unlicensed carriers (of 20 MHz each) can be aggregated to theoretically access 640 MHz of unlicensed spectrum. LAA may also be deployed in 3.5 GHz bands. Enhanced LAA (eLAA), specified in Release 14, adds uplink use of unlicensed spectrum. Carriers are now conducting LAA trials.[51]

A concern with using LTE in unlicensed bands is whether it will be a fair neighbor to Wi-Fi users. LTE-U based on Release 10-12 addresses this concern by selecting clear channels to use and measuring the channel activity of Wi-Fi users, then using an appropriate duty cycle for fair sharing. License-Assisted Access in Release 13 adds listen-before-talk (LBT) and implements other regulatory requirements that exist in some countries. 3GPP conducted a study and concluded that, "A majority of sources providing evaluation results showed at least one LBT scheme for LAA that does not impact Wi-Fi more than another Wi-Fi network."[52]

To address co-existence, the cellular industry worked with the Wi-Fi Alliance in 2016 to develop a test plan for LTE-U. The testing goal was to verify that, in a laboratory environment, an LTE-U base station does not impact a Wi-Fi network any more than another Wi-Fi access point.[53]

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[51] For example, see AT&T, "AT&T Reaches Wireless Speeds of More than 750 Mbps with LTE Licensed Assisted Access (LTE-LAA) Field Trials," available at http://about.att.com/story/lte_licensed_assisted_access_field_trials.html.

[52] 3GPP, *Technical Specification Group Radio Access Network; Study on Licensed-Assisted Access to Unlicensed Spectrum; (Release 13). 36.889.* See section 9, "Conclusions."

MulteFire, specified by the MulteFire Alliance, is an application of LTE in unlicensed bands that does not require an anchor in licensed spectrum, opening up the possibility of deployments by non-operator entities, including internet service providers, venue operators, and enterprises. Under a roaming arrangement with cellular operators, LTE customers could roam into MulteFire networks. Figure 24 shows the evolution of the different versions of LTE for unlicensed bands.

Figure 24: Timeline Relationship of LTE-U, LAA, eLAA, and MulteFire

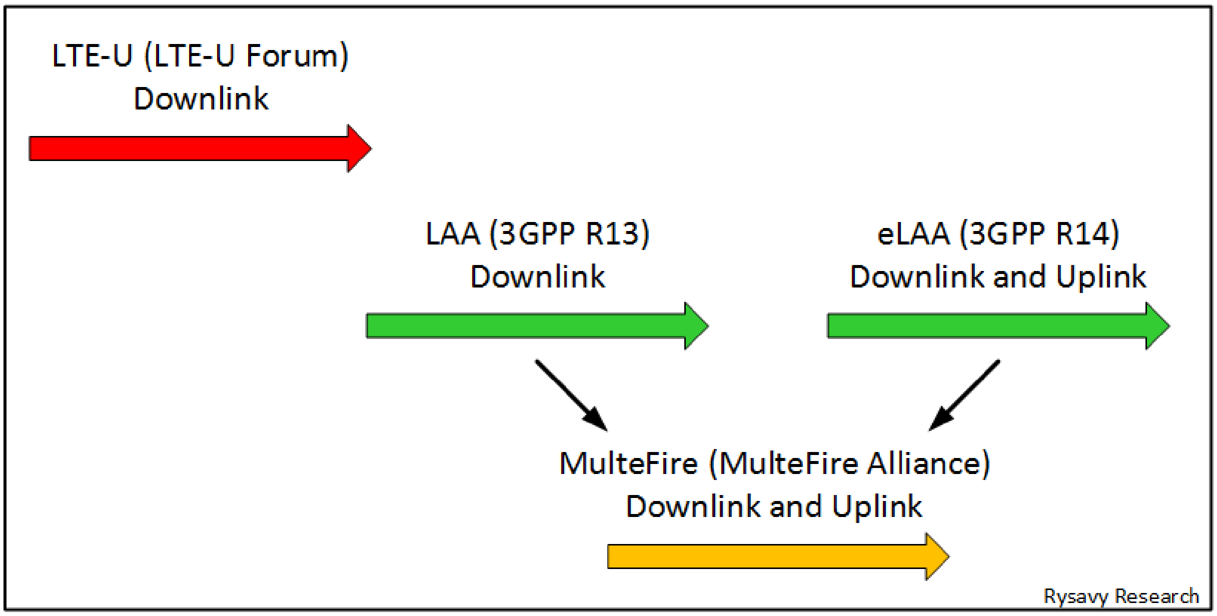

An alternative approach for integrating Wi-Fi is LWA. LTE handles the control plane, but connections occur over separate LTE base stations and Wi-Fi access points. LWA benefits operators that wish to emphasize Wi-Fi technology for harnessing capacity in unlicensed spectrum. LWIP is a variation of LWA that also integrates LTE and Wi-Fi, but by integrating at a higher level of the protocol stack (IP instead of PDCP), it facilitates use of existing Wi-Fi equipment and devices, with integration typically occurring at the eNodeB.

Figure 25 shows how the different technologies exploit licensed and unlicensed spectrum.

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[53] See Wi-Fi Alliance, “Unlicensed Spectrum,” http://www.wi-fi.org/discover-wi-fi/unlicensed-spectrum.

Figure 25: How Different Technologies Harness Spectrum

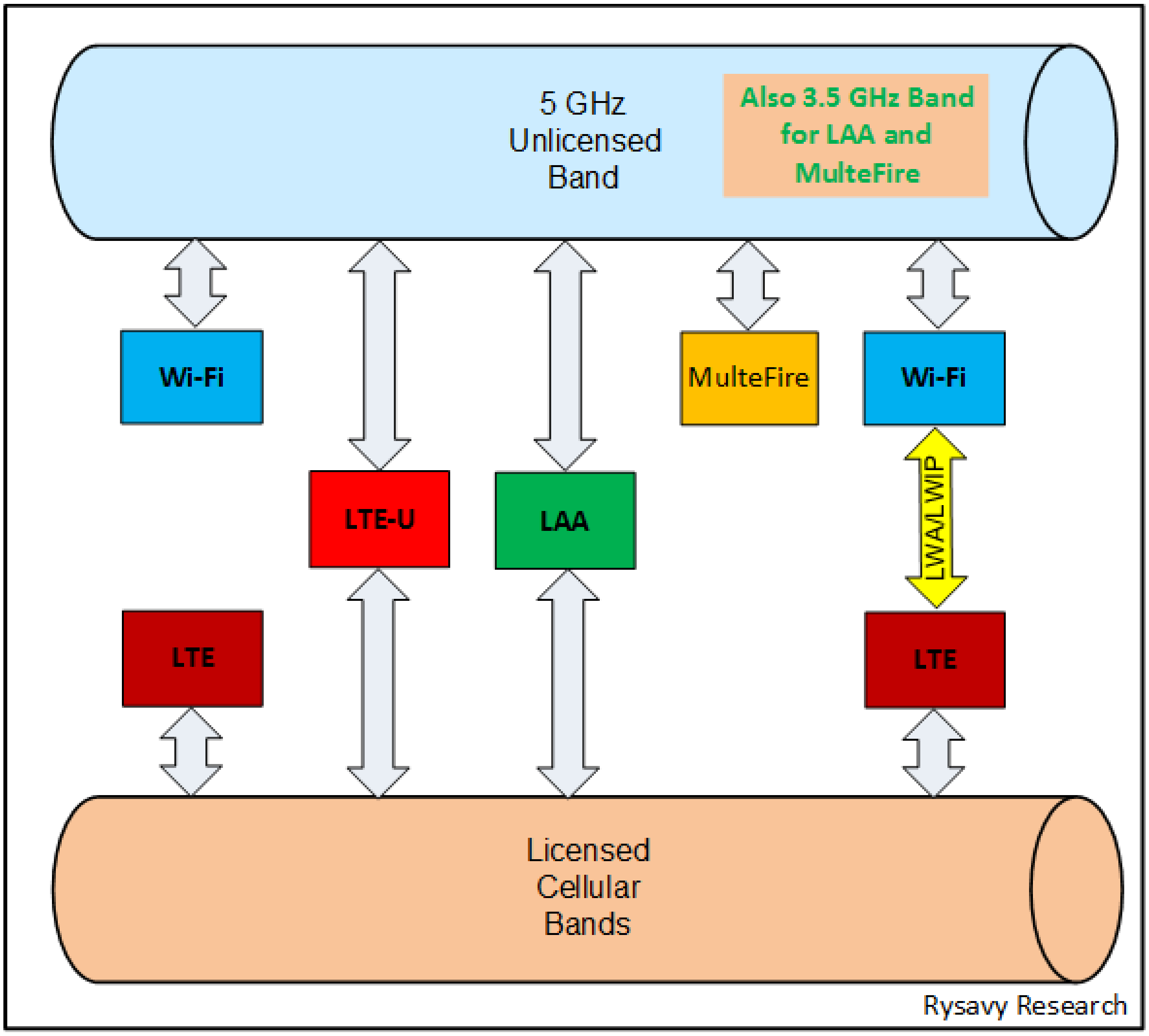
5 GHz Unlicensed Band
Also 3.5 GHz Band for LAA and MulteFire
Wi-Fi
MulteFire
Wi-Fi
LTE-U
LAA
LWA/LWIP
LTE
LTE
Licensed Cellular Bands
Rysavy Research

Table 9 summarizes the different uses of unlicensed spectrum for public mobile broadband networks.

Table 9: Approaches for Using Unlicensed Spectrum.

	Technology	Attributes
Wi-Fi	Ever-more-sophisticated means to integrate Wi-Fi in successive 3GPP Releases.	Combining Wi-Fi with cellular increases capacity.
Release 13 RAN Controlled LTE WLAN Interworking	Base station can instruct the UE to connect to a WLAN for offload.	Available in late 2017 or 2018 timeframe.

Release 10-12 LTE-U Based on LTE-U Forum Specifications	LTE-U Forum-specified approach for operating LTE in unlicensed spectrum.	Available in 2017. More seamless than Wi-Fi. Cannot be used in some regions (e.g., Europe, Japan).
Release 13 Licensed-Assisted Access	3GPP-specified approach for operating LTE in unlicensed spectrum. Downlink only.	Available in late 2017 or 2018 timeframe. Designed to address global regulatory requirements.
Release 14 Enhanced Licensed-Assisted Access	Addition of uplink operation.	Available in 2019 or 2020 timeframe.
5G Unlicensed Operation	Release 15 has a study item for approaches that Release 16 will standardize.	Potentially available in 2021.
MulteFire	Does not require a licensed anchor.	Potentially creates a neutral-host small cell solution.
LWA	Aggregation of LTE and Wi-Fi connections at PDCP layer.	Part of Release 13. Available in late 2017 or 2018 timeframe.
LWIP	Aggregation of LTE and Wi-Fi connections at IP layer.	Part of Release 13. Available in late 2017 or 2018 timeframe.

Cellular operators are currently emphasizing simple offload to Wi-Fi or LTE-U/LAA. Aggregation techniques, such as LWA and LWIP, do not currently have market traction.

Refer to the appendix section “Unlicensed Spectrum Integration” for further technical details.

Internet of Things and Machine-to-Machine

Machine-to-machine communications, now evolving into the Internet of Things, is a vast opportunity for wireless communications, with all 3GPP technologies potentially playing roles.

The lowest-cost cellular devices enabling M2M communications today are GPRS modems, which risk becoming obsolete as operators sunset their GSM systems. HSPA is also used for M2M communications, as is LTE, which has been optimized to efficiently communicate small bursts of information, making it particularly well suited for M2M.

Low-cost GSM (through Enhanced Coverage GSM IoT [EC-GSM-IoT]) and LTE modem options in 3GPP releases 10 through 13 reduce cost, improve communications range, and extend battery life. See the appendix section “Internet of Things and Machine-to-Machine” for details.

3GPP had a Release 13 study item on how LTE technologies can operate for vehicle communications, including vehicle-to-vehicle and vehicle-to-infrastructure, leveraging device-to-device communications capabilities already specified for LTE in Releases 12 and 13.[54] This work is now being standardized in Release 14.

Developers will use 3GPP wireless technologies for many IoT applications. In other instances, developers will use local area technologies, such as Wi-Fi, Bluetooth Low Energy, and ZigBee. New Low-Power Wide-Area (LPWA) wireless technologies emerging specifically to support IoT include Ingenu, LoRa, and Sigfox. The low-power operation of some of these technologies, including LTE, will permit battery operation over multiple years. Table 10 summarizes the various technologies.

Table 10: Wireless Networks for IoT

Technology	Coverage	Characteristics	Standardization / Specifications
GSM/GPRS/EC-GSM-IoT	Wide area. Huge global coverage.	Lowest-cost cellular modems, risk of network sunsets. Low-throughput.	3GPP
HSPA	Wide area. Huge global coverage.	Low-cost cellular modems. Higher power, high throughput.	3GPP
LTE, NB-IoT	Wide area. Increasing global coverage.	Wide area, expanding coverage, cost/power reductions in successive 3GPP releases. Low to high throughput options.	3GPP
Wi-Fi	Local area.	High throughput, higher power.	IEEE
ZigBee	Local area.	Low throughput, low power.	IEEE
Bluetooth Low Energy	Personal area.	Low throughput, low power.	Bluetooth Special Interest Group
LoRa	Wide area. Emerging deployments.	Low throughput, low power. Unlicensed bands (sub 1 GHz, such as 900 MHz in the U.S.)	LoRa Alliance[55]
Sigfox	Wide area. Emerging deployments.	Low throughput, low power. Unlicensed bands (sub 1 GHz such as 900 MHz in the U.S.)	Sigfox[56]

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[54] 3GPP, *3GPP TR 36.885, Technical Specification Group Radio Access Network; Study on LTE-based V2X Services; (Release 14).*

[55] For details, see LoRa Alliance, https://www.lora-alliance.org/.

[56] For details, see Sigfox, https://www.sigfox.com/en.

Technology	Coverage	Characteristics	Standardization / Specifications
Ingenu (previously OnRamp Wireless)	Wide area. Emerging deployments.	Low throughput, low power. Using 2.4 GHz ISM band. Uses IEEE 802.15.4k.	Ingenu[57]
Weightless	Wide area. Expected deployments.	Low throughput, low power. Unlicensed bands (sub 1 GHz such as TV White-Space and 900 MHz in the U.S.)	Weightless Special Interest Group[58]

Security is of particular concern to both developers and users of IoT technology. An increasing amount of network-connected infrastructure will result in new security vulnerabilities that are being addressed by concerted effort from the industry.[59]

Smart Antennas and MIMO

Smart antennas, defined with progressively greater capabilities in successive 3GPP releases, provide significant gains in throughput and capacity. By employing multiple antennas at the base station and the subscriber unit, the technology either exploits signals traveling through multiple paths in the environment or does beam steering, in which multiple antennas coordinate their transmissions to focus radio energy in a particular direction.

Initial low-band LTE deployments used 2X2 MIMO on the downlink (two base station transmit antennas, two mobiles receive antennas) and 1X2 on the uplink (one mobile transmit antenna, two base station receive antennas). In the higher bands, 2X2 downlink MIMO has been deployed, but it is more common to employ four antennas for uplink reception in a 1X4 configuration. LTE deployments are now using 4X2 MIMO and 4X4 MIMO on the downlink (four base station transmit antennas). LTE specifications encompass higher-order configurations, such as 4X4 MIMO, 8X2 MIMO, and MU-MIMO on the downlink and 1X4 on the uplink. Practical considerations, such as antenna sizes that are proportional to wavelength, dictate MIMO options for different bands.

Engineers are now experimenting with what are called massive MIMO systems, which employ a far larger number of antenna elements at the base station—64, 128, and eventually even more. Use in 5G of cmWave and mmWave bands, with their short wavelengths, will facilitate massive MIMO, but even before then, 3GPP is developing specifications for massive MIMO for 4G systems in what it calls full-dimension MIMO (FD-MIMO). Release 14 specifies configurations with up to 32 antennas at the base station.

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[57] For details, see Ingenu, https://www.ingenu.com/.

[58] For details, see http://www.weightless.org/.

[59] For further insight, refer to the Ericsson white paper, *IoT Security,* February 2017, available at https://www.ericsson.com/assets/local/publications/white-papers/wp-iot-security-february-2017.pdf.

Massive MIMO is practical even in cellular frequencies. For example, at 2.5 GHz, an 8X8 array using half wavelength spacing would produce a form factor of 50 cm X 50 cm. Applications of such arrays include beamforming along a horizontal direction as well as beamforming in a vertical direction, such as to serve different levels of high-rise buildings.

See the appendix section “LTE Smart Antennas” and “LTE-Advanced Antenna Technologies” for further details.

Virtualization

Virtualization refers to implementing the functions of infrastructure nodes in software on commercial “off-the-shelf” computing equipment. The approach promises lower capital expenditures, lower operating costs, faster deployment of new services, energy savings, and improved network efficiency. With NFV, multiple tenants will be able to share the same infrastructure, facilitating, for example, mobile virtual network operator (MVNO) and multi-operator virtualized RAN arrangements. NFV, however, also constitutes an entirely new way of building and managing networks, so widespread adoption will occur over a long period.

Both the core network and portions of the radio-access network can be virtualized. The core network, consisting of fewer nodes, is an easier starting point. Virtualizing RAN elements, although more complex, could eventually provide the greatest network efficiency gains, particularly for small-cell deployments where it can facilitate coordination among cells and use of methods such as CoMP and interference coordination. Unlike the core, virtualizing the entire RAN is not possible because a Physical Network Function must terminate the radio interface. As operators virtualize their core networks, they put in place the systems and know-how to extend virtualization to the RAN.

The European Telecommunications Standards Institute (ETSI) is standardizing a framework, including interfaces and reference architectures for virtualization. Other standards and industry groups involved include 3GPP, the Open Networking Foundation, OpenStack, OpenDaylight, and OPNFV.

Figure 26 shows the ETSI framework, in which virtualized network functions are the nodes or applications by which operators build services.

Figure 26: ETSI NFV High-Level Framework

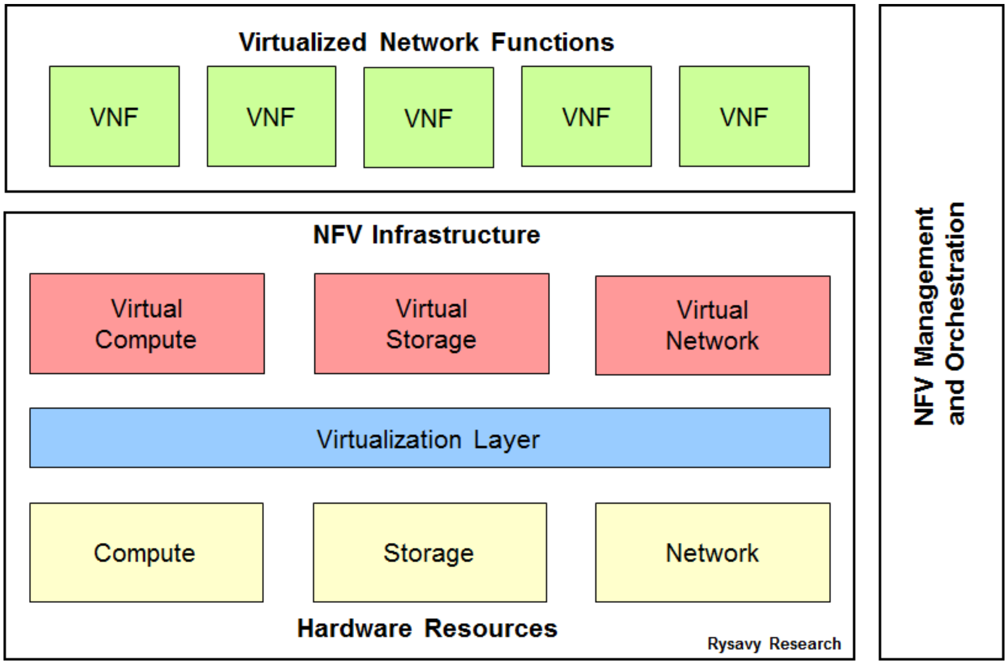
Virtualized Network Functions
VNF
VNF
VNF
VNF
VNF
NFV Infrastructure
Virtual Compute
Virtual Storage
Virtual Network
Virtualization Layer
Compute
Storage
Network
Hardware Resources
Rysavy Research
NFV Management and Orchestration

Some specific use cases for NFV include:

- **5G.** 5G networks will likely be fully virtualized.
- **IMS and VoLTE.** IMS is necessary for VoLTE, but an NFV approach could reduce the complexity associated with the multiple nodes and interfaces in the IMS architecture.
- **Virtualized EPC (VEPC).** The Evolved Packet Core, consisting of the Serving Gateway (SGW), the Packet Gateway (PGW), and Mobile Management Entity (MME), can be virtualized, but doing so will require meeting operator bandwidth, latency, and control plane service requirements.
- **New VEPC Services.** With a virtualized EPC, an operator can more easily create MVNO services, each with its own virtualized MME, SGW, and PGW. An M2M virtualized service is another example of offering a more finely tuned service for the target application. Because the PGW connects to external networks, further opportunities exist for virtualized services to augment networking functions, including video caching, video optimization, parental controls, ad insertion, and firewalls.
- **Cloud RAN.** Pooling of baseband processing in a cloud RAN can, but does not necessarily, use virtualization techniques. Separating the radio function from baseband processing typically requires transporting digitized radio signals across high-bandwidth (multi-Gbps) fiber connections, sometimes referred to as

fronthauling. Refer to the appendix section "Cloud Radio-Access Network (RAN) and Network Virtualization" for a more detailed technical discussion.[60]

Because of higher investment demands, RAN virtualization will take longer to deploy than core network virtualization and likely will occur selectively for small-cell deployments.

For additional details, refer to the 5G Americas white paper, *Bringing Network Function Virtualization to LTE*.[61]

Multi-Access Edge Computing

ETSI is standardizing Multi-access Edge Computing, previously known as Mobile-Edge Computing, a technology that empowers a programmable application environment at the edge of the network, within the RAN.[62] Goals include reduced latency, more efficient network operation for certain applications, and an improved user experience. Although MEC emphasizes 5G, it can also be applied to 4G LTE networks.

Applications that will benefit are ones that require server-side processing but are location specific. Examples include:

- ☐ Augmented reality.
- ☐ Intelligent video processing, such as transcoding, caching, and acceleration.
- ☐ Connected cars.
- ☐ Premise-based IoT gateways.

Multicast and Broadcast

Another important new service is video streaming via multicast or broadcast functions. 3GPP has defined multicast/broadcast capabilities for both HSPA and LTE. Mobile TV services have experienced little business success so far, but broadcasting uses the radio resource much more efficiently than having separate point-to-point streams for each user. For example, users at a sporting event might enjoy watching replays on their smartphones. The technology supports these applications; it is a matter of operators and content providers finding appealing applications. The appendix covers technical aspects in more detail.

Remote SIM Provisioning

The GSM Association (GSMA) is developing specifications that make it possible for consumers to purchase unprovisioned devices, select the operator of their choice and then download the subscriber identity module (SIM) application into the device.[63] This capability benefits devices such as watches, health bands, health monitors, and other small connected items. Initial products may be available in 2017.

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[60] For further details, see "Network Functions Virtualisation," http://www.etsi.org/technologies-clusters/technologies/nfv. Viewed May 17, 2017.

[61] Available at http://www.4gamericas.org/files/1014/1653/1309/4G_Americas_-_NFV_to_LTE_-_November_2014_-_FINAL.pdf.

[62] For further details, see ETSI, "Multi-access Edge Computing," http://www.etsi.org/technologies-clusters/technologies/multi-access-edge-computing. Accessed May 17, 2017.

[63] For details, see GSMA, "A New SIM," available at https://www.gsma.com/rsp/, viewed June 8, 2017.

VoLTE, RCS, WebRTC, and Wi-Fi Calling

Voice has evolved from a separate circuit-switched service in 2G and 3G networks to a packet-switched service in 4G LTE networks that can integrate with other services and applications, such as messaging and video calling. Elements that make these capabilities possible include the quality-of-service mechanisms in LTE, the IMS platform discussed above, implementation of Rich Communications Suite, compliance with GSMA IR.92 guidelines, and optional support for WebRTC.

Voice Support and VoLTE

While 2G and 3G technologies were deployed from the beginning with both voice and data capabilities, LTE networks can be deployed with or without voice support. Moreover, there are two methods available: circuit-switched fallback (CSFB) to 2G/3G and VoIP. Most operators deploying LTE used CSFB initially but are now migrating to VoIP methods with VoLTE that uses IMS. Initial VoLTE deployments occurred in 2012. Because VoLTE needs new software in phones, the transition from circuit-switched voice to VoLTE on a large scale will occur over a number of years as users upgrade their devices.

For the time being, 3GPP operators with UMTS/HSPA networks will continue to use circuit-switched voice for their 3G connections.

Using VoLTE, operators can offer high-definition (HD) voice using the new Adaptive Multi-Rate Wideband (AMR-WB) voice codec. HD voice not only improves voice clarity and intelligibility, it suppresses background noise. AMR-WB extends audio bandwidth to 50-7000 Hz compared with the narrowband codec that provides audio bandwidth of 80-3700 Hz. HD voice will initially function only between callers on the same network. 3GPP has also developed a new voice codec, called “Enhanced Voice Services” (EVS), which will be the successor to AMR and AMR-WB codecs.

Other advantages of LTE’s packetized voice include being able to combine it with other services, such as video calling and presence; half the call set-up time of a 3G connection; and high voice spectral efficiency. With VoLTE’s HD voice quality, lower delay, and higher capacity, operators can compete against OTT VoIP providers. Due to traffic prioritization, VoLTE voice quality remains high even under heavy loads that cause OTT-voice service to deteriorate.

Applications based on WebRTC will also increasingly carry voice sessions. See the section “VoLTE and RCS” in the appendix for more details on LTE voice support.

Rich Communications Suite

An initiative called “Rich Communications Suite” (RCS), supported by many operators and vendors, builds on IMS technology to provide a consistent feature set as well as implementation guidelines, use cases, and reference implementations. RCS uses existing standards and specifications from 3GPP, Open Mobile Alliance (OMA), and GSMA and enables interoperability of supported features across operators that support the suite. RCS supports both circuit-switched and packet-switched voice and can interoperate with LTE packet voice.

Core features include:

- A user capability exchange or service discovery with which users can know the capabilities of other users.

- ❑ Enhanced (IP-based) messaging (supporting text, IM, and multimedia) with chat and messaging history.
- ❑ Enriched calls that include multimedia content (such as photo or video sharing) during voice calls. This could become the primary way operators offer video calling.

The primary drivers for RCS adoption are the ability to deploy VoLTE in a well-defined manner and to support messaging in the IP domain. RCS addresses the market trend of users moving away from traditional text-based messaging and provides a platform for operator-based services that compete with OTT messaging applications. Figure 27 shows the evolution of RCS capability, including the addition of such features as messaging across multiple devices, video calling, video sharing, and synchronized contact information across multiple devices.

Figure 27: Evolution of RCS Capability.[64]

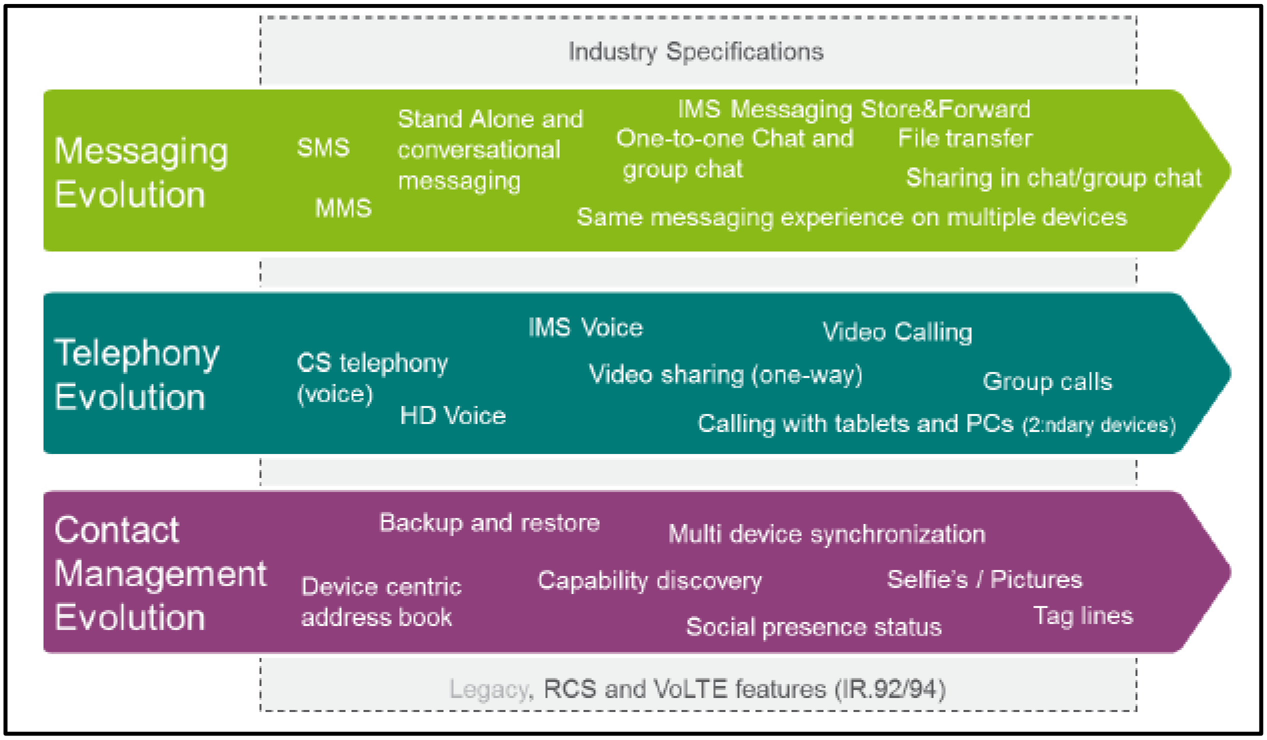
Industry Specifications
Messaging Evolution
SMS
MMS
Stand Alone and conversational messaging
IMS Messaging Store&Forward
One-to-one Chat and group chat
File transfer
Sharing in chat/group chat
Same messaging experience on multiple devices
Telephony Evolution
CS telephony (voice)
HD Voice
IMS Voice
Video sharing (one-way)
Video Calling
Group calls
Calling with tablets and PCs (2:ndary devices)
Contact Management Evolution
Device centric address book
Backup and restore
Capability discovery
Multi device synchronization
Social presence status
Selfie's / Pictures
Tag lines
Legacy, RCS and VoLTE features (IR.92/94)

WebRTC

WebRTC is an open project supported by Google, Mozilla, and Opera within the Internet Engineering Taskforce (IETF) that enables real-time communications in Web browsers via JavaScript APIs. 3GPP Release 12 specifications define how WebRTC clients can access IMS services, including packet voice and video communication. WebRTC operating over IMS gains the additional benefit of seamless transition across transport networks, for example, LTE to Wi-Fi.

Operators can integrate WebRTC with RTC, facilitating development of vertical applications such as telemedicine and customer service. WebRTC and RCS are more complementary than competitive. Both, through application interfaces, can provide access to underlying network functions.

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[64] 4G Americas, *VoLTE and RCS Technology - Evolution and Ecosystem*, Nov. 2014.

Wi-Fi Calling

Another advantage of the VoLTE/IMS/RCS architecture is that it is agnostic to the user connection, meaning voice and video service can extend to Wi-Fi connections as easily as LTE connections. Wi-Fi calling can be advantageous in coverage areas were the Wi-Fi signal has better quality than an LTE signal. For video calling, use of Wi-Fi will also reduce data consumption over the cellular connection. By implementing a standards-based approach, as opposed to OTT-voice approaches, called parties see the same phone number regardless of network and can reach the subscriber using that phone number.

Previous technical approaches, such as Generic Access Network (GAN, initially called Unlicensed Mobile Access [UMA]), did not include as robust a handover mechanism as is provided by VoLTE/IMS.

For the best-quality voice in a Wi-Fi network, the device and Wi-Fi network should implement Wi-Fi Multimedia (WMM), which gives voice packets higher priority than other data traffic. WMM is especially necessary in congested networks. In addition, the Access Network Discovery and Selection Function (ANDSF) and cellular-WLAN enhancement features in 3GPP Release 12 have policies for enabling voice handover between LTE and Wi-Fi.

Roaming with Wi-Fi calling will need to address whether the visited network’s IMS infrastructure handles the Wi-Fi call or whether the home network’s IMS does.

Public Safety

An important LTE application is for public safety, initially as a broadband data service and eventually for mission-critical voice service. Current public safety networks use technologies, such as Terrestrial Trunked Radio (TETRA) in Europe and Project 25 (P25) in the United States, that provide mission-critical voice but only narrowband data.

In the United States, the government has made 20 MHz of spectrum available at 700 MHz in Band 14 and created the First Responder Network Authority (FirstNet), an independent authority within the National Telecommunications and Information Administration (NTIA) to provide a nationwide public-safety broadband network. AT&T will build and deploy the network.[65]

Another country driving the use of LTE for public safety is the United Kingdom, where the UK Home Office has a program for the Emergency Service Network.

Using LTE for public safety is a complex undertaking because public-safety needs differ from those of consumers. Addressing these needs requires both different features, which 3GPP is incorporating in multiple releases of LTE specifications, and different network deployment approaches. Public safety also has different device-level needs than consumers.

LTE Features for Public Safety

Some broadband applications for public safety can use standard LTE capability. For example, sending email, accessing a database, or streaming a video may not require any special features. Other applications, however, require new capabilities from 3GPP standards, including:

Group Communication

Available in Release 12, the Group Communication Service (GCS) application server, using one-to-one (unicast) and one-to-many communications (broadcast), will be able to send voice, video, or data traffic to multiple public-safety devices. The broadcast mode will employ eMBMS to use radio resources efficiently, but if coverage is weak, a unicast approach may deliver data more reliably. The system will be able to dynamically switch between broadcast and unicast modes. Release 14 adds single-cell point-to-multipoint transmission.

Proximity-Based Services (Device-to-Device)

With proximity-based services, defined in Release 12, user devices can communicate directly, a capability that benefits both consumers and public safety. This type of communication is called sidelink communication. Consumer devices can find other devices only with assistance from the network, but for public safety, devices will be able to communicate directly with other devices independently of the network.

With Release 13, devices will be able to act as relays for out-of-coverage devices, such as inside a building.

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[65] For details, see “FirstNet AT&T,” https://www.corp.att.com/public-safety/att-firstnet/. See also RCR Wireless, *Editorial Report: Public Safety LTE*, March 2017. Available at http://content.rcrwireless.com/20170322_Public_Safety_Report.

The appendix section “Proximity Services (Device-to-Device)” discusses this feature in greater detail.

Mission-Critical Push-to-Talk

MCPTT, being defined in Release 13, provides one-to-one and one-to-many push-to-talk communications services. With this feature, available in the 2018 timeframe, public-safety organizations will be able to consider retiring legacy voice-based systems.

Mission-Critical Video over LTE and Mission-Critical Data over LTE

Release 14 adds Mission-Critical Video over LTE and Mission-Critical Data over LTE, designed to work with Mission-Critical Push-to-Talk, giving first responders more communications options.

Prioritization

To prevent interference with public-safety operations in emergency situations experiencing high load, the network can prioritize at multiple levels. First, the network can bar consumer devices from attempting to access the network, thus reducing signaling load. Second, the network can prioritize radio resources, giving public-safety users higher priority. Third, using a new capability called “Multimedia Priority Service” (MPS), the network can prioritize a connection between an emergency worker and a regular subscriber. Finally, the network can assign specific quality-of-service (QoS) parameters to specific traffic flows, including guaranteed bit rate. 3GPP has defined specific QoS quality-class identifiers for public safety.

High Power

Release 11 defines higher power devices for the public safety band that can operate at 1.25 Watts, improving coverage and reducing network deployment costs.

Isolated operation

With Release 13, a base station can continue offering service even with the loss of backhaul, a capability that will benefit public-safety personnel in disaster situations.

Relays

Figure 28 summarizes the more than eighteen features in 3GPP relays that apply to public safety.

Figure 28: Summary of 3GPP LTE Features to Support Public Safety[66]

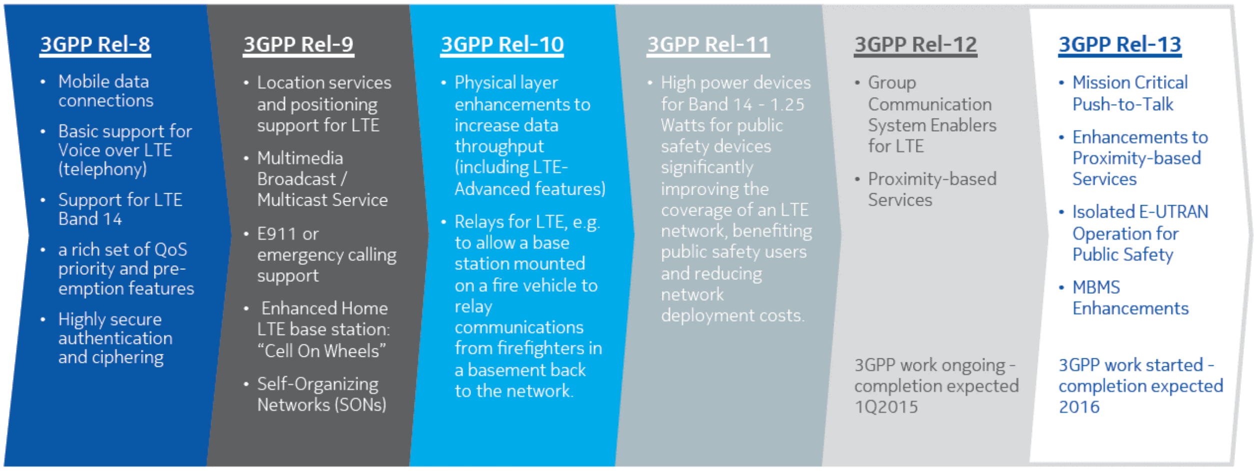

3GPP Rel-8
- Mobile data connections
- Basic support for Voice over LTE (telephony)
- Support for LTE Band 14
- a rich set of QoS priority and pre-emption features
- Highly secure authentication and ciphering

3GPP Rel-9
- Location services and positioning support for LTE
- Multimedia Broadcast / Multicast Service
- E911 or emergency calling support
- Enhanced Home LTE base station: "Cell On Wheels"
- Self-Organizing Networks (SONs)

3GPP Rel-10
- Physical layer enhancements to increase data throughput (including LTE-Advanced features)
- Relays for LTE, e.g. to allow a base station mounted on a fire vehicle to relay communications from firefighters in a basement back to the network.

3GPP Rel-11
- High power devices for Band 14 - 1.25 Watts for public safety devices significantly improving the coverage of an LTE network, benefiting public safety users and reducing network deployment costs.

3GPP Rel-12
- Group Communication System Enablers for LTE
- Proximity-based Services

3GPP work ongoing - completion expected 1Q2015

3GPP Rel-13
- Mission Critical Push-to-Talk
- Enhancements to Proximity-based Services
- Isolated E-UTRAN Operation for Public Safety
- MBMS Enhancements

3GPP work started - completion expected 2016

Deployment Approaches

Because huge infrastructure investments would be required for a network dedicated solely to public safety, industry and government are evaluating approaches in which public-safety uses can leverage existing commercial network deployments. One caveat is that public-safety networks have more stringent resilience and security requirements than commercial networks.

Shared Network

As depicted in Figure 29, multiple sharing approaches are possible:

1. In this scenario, a public-safety entity owns and operates the entire network, an approach that gives public-safety organizations the greatest control over the network but at the highest cost.

2. A commercial operator shares its radio-access network, including cell sites and backhaul, but the public-safety entity manages core network functions including gateways, the Mobile Management Entity, the Home Subscriber Server (HSS), and public-safety application servers. Because the radio-access network is the costliest part of the network, this approach significantly reduces the amount public safety must invest in the network. Even though the RAN is shared, public safety still can use its dedicated spectrum.

3. In an MVNO approach, the operator shares its cell sites and backhaul as well as some core network functions, such as the MME and Serving Gateway. Public safety manages a small number of network functions, such as the Packet Gateway, HSS, and its application servers.

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[66] Nokia, *LTE networks for public safety services*, 2014. Available at http://networks.nokia.com/sites/default/files/document/nokia_lte_for_public_safety_white_paper.pdf.

4. A final approach, not shown in the figure, is one in which the mobile operator hosts all of the elements shown in the figure and public safety manages only its application servers.

Figure 29: Sharing Approaches for Public-Safety Networks

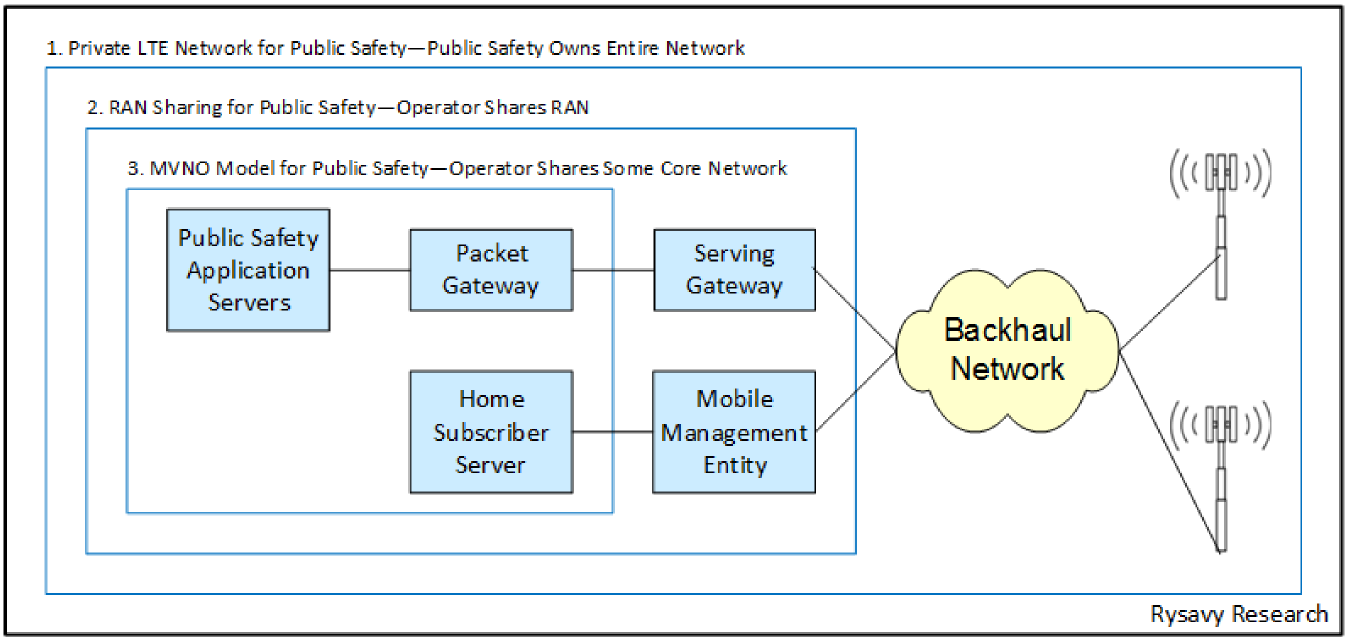
1. Private LTE Network for Public Safety—Public Safety Owns Entire Network
2. RAN Sharing for Public Safety—Operator Shares RAN
3. MVNO Model for Public Safety—Operator Shares Some Core Network
Public Safety Application Servers
Packet Gateway
Serving Gateway
Home Subscriber Server
Mobile Management Entity
Backhaul Network
Rysavy Research

Resilience

Public safety may need greater resilience than found in commercial networks, including hardware redundancy, geographic redundancy, load balancing, fast re-routing in IP networks, interface protection, outage detection, self-healing, and automatic reconfiguration.

Security

Public-safety networks may have higher security requirements than commercial networks, including physical security of data centers, core sites, and cell sites. Whereas LTE networks do not have to encrypt traffic in backhaul and core networks, public-safety applications may choose to encrypt all IP traffic using virtual private networking approaches.

Coverage

A number of approaches can ensure the broadest possible coverage for public-safety networks. First, public-safety frequencies at 700 MHz already propagate and penetrate well. Next, public-safety devices will be able to transmit at higher power. In addition, base stations can employ four-way receiver diversity and higher-order sectorization. For disaster situations, public safety can also use rapidly deployable small cells, such as on trailers. Finally, proximity-based services operating in a relay mode, as discussed above, can extend coverage.

Device Considerations for Public Safety

Public-safety devices will have unique requirements, including guaranteed network access under all conditions and guidelines for how devices are shared among users.

Access to Commercial Networks

Public-safety devices could be designed to also communicate on commercial LTE networks, providing an alternative communications avenue when the device cannot connect to a public-safety network. Subscriptions to all major commercial networks would make this approach the most effective. Wi-Fi capability further extends this concept.

Device Sharing

Because public-safety devices may be shared among personnel, user profiles cannot be stored on USIM cards stored in the devices. Bluetooth-based remote SIMs are one approach to address this problem.

Expanding Capacity

Wireless technology is playing a profound role in networking and communications, even though wireline technologies such as fiber have inherent capacity advantages.

Over time, wireless networks will gain substantial additional capacity through the methods discussed in the next section. While they will compete with copper twisted pair and coax, they will never catch up to fiber. The infrared frequencies used in fiber-optic communications have far greater bandwidth than radio. As a result, one fiber-optic strand has greater bandwidth than the entire usable radio spectrum to 100 GHz, as illustrated in Figure 30.[67]

Figure 30: RF Capacity vs. Fiber-Optic Cable Capacity

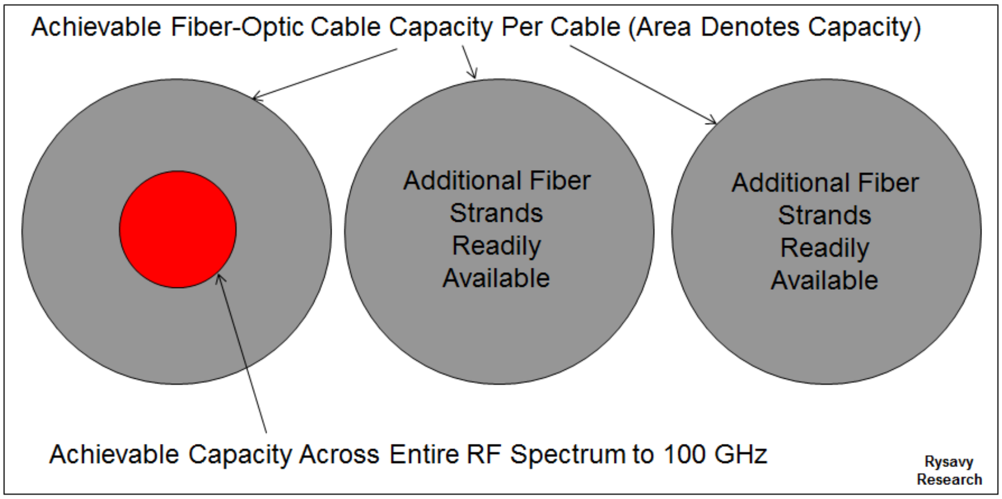
Achievable Fiber-Optic Cable Capacity Per Cable (Area Denotes Capacity)
Additional Fiber Strands Readily Available
Additional Fiber Strands Readily Available
Achievable Capacity Across Entire RF Spectrum to 100 GHz
Rysavy Research

A dilemma of 4G mobile broadband is that it *can* provide a broadband experience similar to wireline, but it *cannot* do so for all subscribers in a coverage area at the same time. Hence, operators must carefully manage capacity, demand, policies, pricing plans, and user expectations. Similarly, application developers must become more conscious of the inherent constraints of wireless networks. 5G, with its far greater capacity, at least in small deployments, will increase the percentage of users that use wireless connections as their only broadband.

Three factors determine wireless network capacity, as shown in Figure 31: the amount of spectrum, the spectral efficiency of the technology, and the size of the cell. Because smaller cells serve fewer people in each cell and because there are more of them, small cells are a major contributor to increased capacity.

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[67] One fiber-optic cable can transmit over 10,000 Gbps compared with all wireless spectrum to 100 GHz, which, even at an extremely high spectral efficiency 10 bps/Hz, would have only 1,000 Gbps of capacity.

Figure 31: Dimensions of Capacity

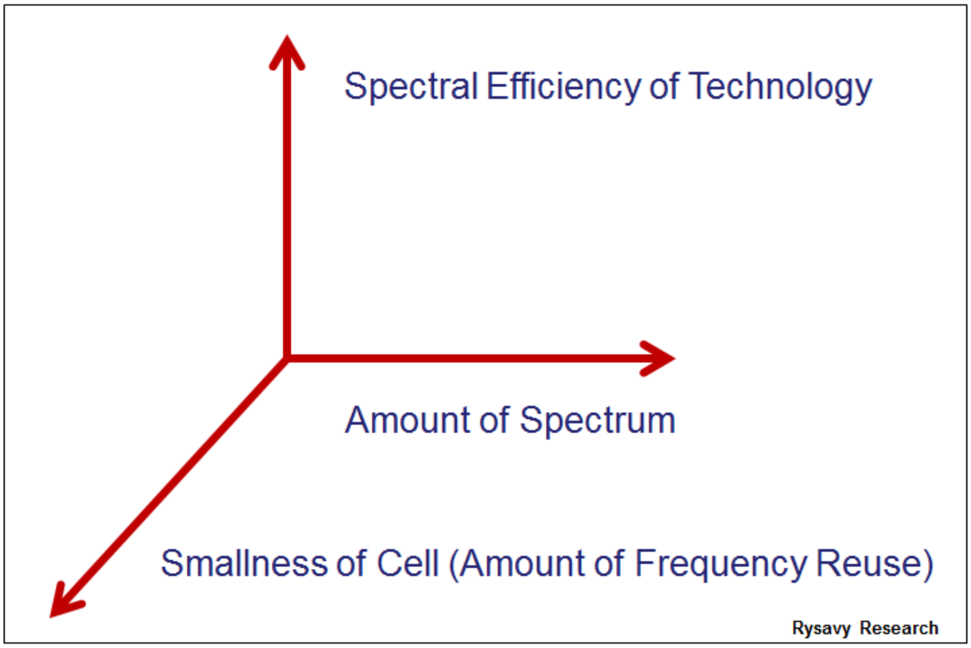
Spectral Efficiency of Technology
Amount of Spectrum
Smallness of Cell (Amount of Frequency Reuse)
Rysavy Research

Given the relentless growth in usage, mobile operators are combining multiple approaches to increase capacity and managing congestion:

- **More spectrum.** Spectrum correlates almost directly to capacity, and more spectrum is becoming available globally for mobile broadband. In the U.S. market, the 2010 FCC National Broadband Plan is in the process of adding an additional 500 MHz of spectrum by 2020. mmWave band spectrum for 5G will provide far more spectrum, but propagation characteristics will restrict its use to small cells. Multiple papers by Rysavy Research and others[68] argue the critical need for additional spectrum.
- **Unpaired spectrum.** LTE TDD operates in unpaired spectrum. In addition, technologies such as HSPA+ and LTE permit the use of different amounts of spectrum between downlink and uplink. Additional unpaired downlink spectrum can be combined with paired spectrum to increase capacity and user throughputs.
- **Supplemental downlink.** With downlink traffic five to ten times greater than uplink traffic, operators often need to expand downlink capacity rather than uplink capacity. Using carrier aggregation, operators can augment downlink capacity by combining separate radio channels.
- **Spectrum sharing.** Policy makers are evaluating how spectrum might be shared between government and commercial entities. Although a potentially promising approach for the long term, sharing raises complex issues, as discussed further in the section "Spectrum Developments."
- **Increased spectral efficiency.** Newer technologies are spectrally more efficient, meaning greater aggregate throughput using the same amount of spectrum. Wireless technologies such as LTE, however, are reaching the theoretical limits of spectral

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[68] See multiple papers on spectrum and capacity at http://www.rysavy.com/writing.

efficiency, and future gains will be quite modest, allowing for a possible doubling of LTE efficiency over currently deployed versions. See the section "Spectral Efficiency" for a further discussion.

- **Smart antennas.** Through higher-order MIMO and beamforming, smart antennas gain added sophistication in each 3GPP release and are the primary contributor to increased spectral efficiency (bps/Hz). Massive MIMO, beginning in Release 13, will support 16-antenna-element systems and in 5G, will expand to potentially hundreds of antenna elements.
- **Uplink gains combined with downlink carrier aggregation.** Operators can increase network capacity by applying new receive technologies at the base station (for example, large-scale antenna systems such as massive MIMO) that do not necessarily require standards support. Combined with carrier aggregation on the downlink, these receive technologies produce a high-capacity balanced network, suggesting that regulators should in some cases consider licensing just downlink spectrum.
- **Small cells and heterogeneous networks.** Selective addition of picocells to macrocells to address localized demand can significantly boost overall capacity, with a linear increase in capacity relative to the number of small cells. HetNets, which also can include femtocells, hold the promise of increasing capacity gains by a factor of four and even higher with the introduction of interference cancellation in devices. Distributed antenna systems (DAS), used principally for improved indoor coverage, can also function like small cells and increase capacity. Actual gain will depend on a number of factors, including number and placement of small cells,[69] user distribution, and any small-cell selection bias that might be applied.
- **Offload to unlicensed spectrum.** Using unlicensed spectrum with Wi-Fi or LTE operation in unlicensed spectrum offers another means of offloading heavy traffic. Unlicensed spectrum favors smaller coverage areas because interference can be better managed, so spectral re-use is high, resulting in significant capacity gains.
- **Higher level sectorization.** For some base stations, despite the more complex configuration involved, six sectors can prove advantageous versus the more traditional three sectors, deployed either in a 6X1 horizontal plane or 3X2 vertical plane.[70]

Strategies to manage demand include:

- **Quality of service (QoS) management.** Through prioritization, certain traffic, such as non-time-critical downloads, could occur with lower priority, thus not affecting other active users. Current network neutrality rules, however, may constrain use of traffic prioritization.[71]
- **Off-peak hours.** Operators could offer user incentives or perhaps fewer restrictions on large data transfers during off-peak hours.

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[69] With small-cell range expansion using a large selection bias, small cells can be distributed uniformly.

[70] An example of vertical layering would be a 3X1 layer at ground level and a separate 3X1 layer for higher levels of surrounding buildings.

[71] For a discussion of this issue, see Rysavy Research, *LTE Congestion Management – Enabling Innovation and Improving the Consumer Experience*, January 2015. Available at http://www.rysavy.com/Articles/2015-01-Rysavy-LTE-Congestion-Management.pdf.

Given a goal of increasing capacity by a factor of 1,000, 50X could roughly be achieved through network densification; 10X through more spectrum, including higher frequencies such as mmWave; and 2X by increases in spectral efficiency.

Based on historical increases in the availability of new spectrum, technologies delivering better spectral efficiency, and increases in the number of cell sites, Rysavy Research has calculated that, over the last thirty-year period, aggregate network capacity has doubled every three years. Rysavy Research expects this trend to continue into the future.

Rysavy Research Analysis:

Aggregate Wireless Network Capacity
Doubles Every Three Years.

Spectrum Developments

Licensed spectrum scarcity continues to challenge the industry. Tactics to make the best use of this limited resource include deploying technologies that have higher spectral efficiency; adapting specifications to enable operation of UMTS-HSPA and LTE in all available bands; designing both FDD and TDD versions of technology to take advantage of both paired and unpaired bands; designing carrier aggregation techniques in HSPA+ and LTE-Advanced Pro; and deploying as many new cells, large and small, as is economically and technically feasible. Although all of these industry initiatives greatly expand capacity, they do not obviate the need for additional spectrum. 5G technology will be able to employ frequencies not previously used in cellular systems, spanning 6 GHz to 100 GHz.

An important aspect of UMTS-HSPA and LTE deployment is for infrastructure and mobile devices to accommodate the expanding number of available radio bands. The fundamental system design and networking protocols remain the same for each band; only the frequency-dependent portions of the radios must change. As other frequency bands become available for deployment, standards bodies adapt UMTS-HSPA and LTE for these bands as well.

3GPP has specified LTE for operation in many different bands, and initial use will be more fragmented than the four bands (850 MHz, 900 MHz, 1.8 GHz, 1.9 GHz) that enable global roaming on 2G and the additional two bands (1.7 GHz and 2.1 GHz) that enable 3G roaming. In the Americas, LTE roaming may occur in the 1.7/2.1 GHz (AWS) bands, and globally, LTE roaming may occur in the 1.8 and 2.6 GHz bands. Longer term, operators will re-farm spectrum used for 2G and 3G and apply it to LTE. Unfortunately, the process of identifying new spectrum and making it available for the industry is a lengthy one, as shown in Figure 32.

Figure 32: Spectrum Acquisition Time[72]

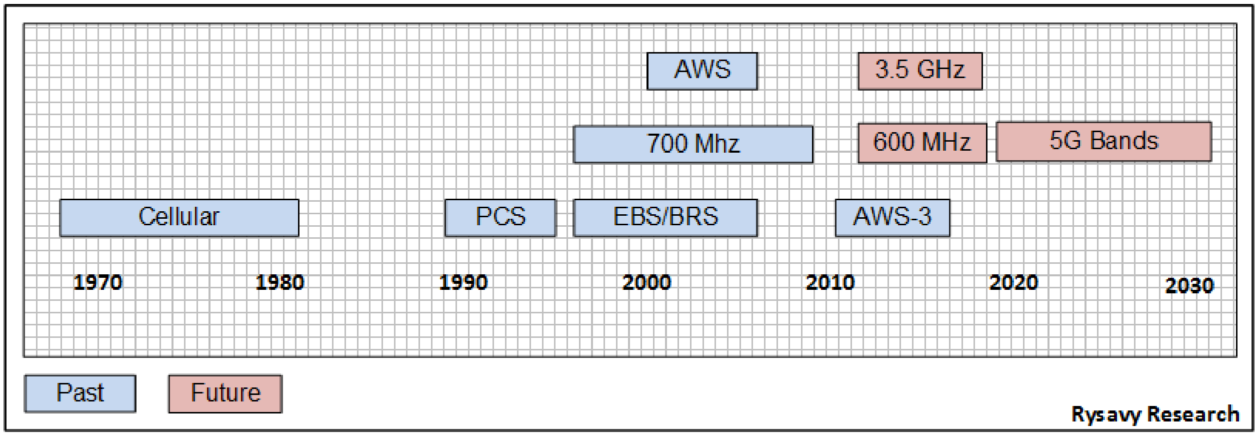

New short-term spectrum opportunities in the United States include the "small-cell" band from 3550 to 3700 MHz and 5G spectrum.

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[72] Source for historical data, FCC, *National Broadband Plan*, Chapter 5. Available at http://www.broadband.gov/plan/5-spectrum/, accessed May 18, 2017. Future based on Rysavy Research analysis.

Table 11 summarizes current and future spectrum allocations in the United States.[73]

Table 11: United States Current and Future Licensed Spectrum Allocations

Frequency Band	Amount of Spectrum	Comments
600 MHz	70 MHz	Ultra-High-Frequency (UHF).
700 MHz	70 MHz	Ultra-High Frequency (UHF).
850 MHz	64 MHz	Cellular and Specialized Mobile Radio.
1.7/2.1 GHz	90 MHz	Advanced Wireless Services (AWS)-1.
1695-1710 MHz, 1755 to 1780 MHz, 2155 to 2180 MHz	65 MHz	AWS-3. Uses spectrum sharing.
1.9 GHz	140 MHz	Personal Communications Service (PCS).
2000 to 2020, 2180 to 2200 MHz	40 MHz	AWS-4 (Previously Mobile Satellite Service).[74]
2.3 GHz	20 MHz	Wireless Communications Service (WCS).
2.5 GHz	194 MHz	Broadband Radio Service. Closer to 160 MHz deployable.
	FUTURE	
3.55 to 3.70 GHz	150 MHz	Small-cell band with spectrum sharing and unlicensed use.
Above 6 GHz	Multi GHz	Anticipated for 5G systems beginning in 2017. Based on wavelengths, 3 GHz to 30 GHz is referred to as the cmWave band and 30 GHz to 300 GHz is referred to as the mmWave band.

Today's licensed spectrum networks operate most efficiently and are deployed most cost-effectively using a combination of low-band spectrum, below 1 GHz, for coverage and 1 GHz to 3 GHz for capacity. As technology improves, bands in 3 GHz to 100 GHz, and eventually higher, will supplement capacity.

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[73] For international allocations, refer to Wik-Consult, Study for the European Commission, *Inventory and review of spectrum use: Assessment of the EU potential for improving spectrum efficiency*, September 2012. Available at http://ec.europa.eu/digital-agenda/sites/digital-agenda/files/cion_spectrum_inventory_executive_summary_en.pdf.

[74] Supported in 3GPP Band 70, which adds 1995-2000 MHz, pairing it with 1695-1710 MHz in AWS-3 band.

The subsections below provide additional information about the recently completed AWS-3 auction, incentive auctions, the 3.5 GHz, 5G, spectrum harmonization, unlicensed spectrum, and spectrum sharing.

AWS-3

In early 2015, the FCC received close to $45 billion for the U.S. Treasury in the AWS-3 auction, more than twice the amount of any previous auction, demonstrating the value of mid-band spectrum.[75] The auction adds 65 MHz of desirable spectrum to the mobile-broadband industry. The plan is to employ spectrum sharing among commercial networks and select government systems. Eventually, most of these government systems will migrate to another spectrum. 3GPP has specified use of both AWS-3 and AWS-4 spectrum in what it refers to as “Band 66.”

This band is asymmetrical, with a downlink of 90 MHz and an uplink of 70 MHz. An operator can use the upper-most 20 MHz of the downlink only with carrier aggregation.

Broadcast Incentive Auction (600 MHz)

The broadcast incentive auction completed in 2017 will reallocate 84 MHz of UHF channels in the 600 MHz band that are currently used by TV broadcasters, with 70 MHz of licensed spectrum and 14 MHz of unlicensed spectrum. The auction was more complicated than past spectrum auctions, when the FCC simply reassigned or designated spectrum for commercial mobile use and then conducted an auction.

In the first stage, the FCC conducted a reverse auction to determine how much spectrum broadcasters might wish to relinquish in exchange for how much compensation. In the second stage, mobile operators bid for spectrum in a forward auction, similar to past spectrum auctions.

Figure 33 shows the final band plan.

Figure 33: 600 MHz Band Plan[76]

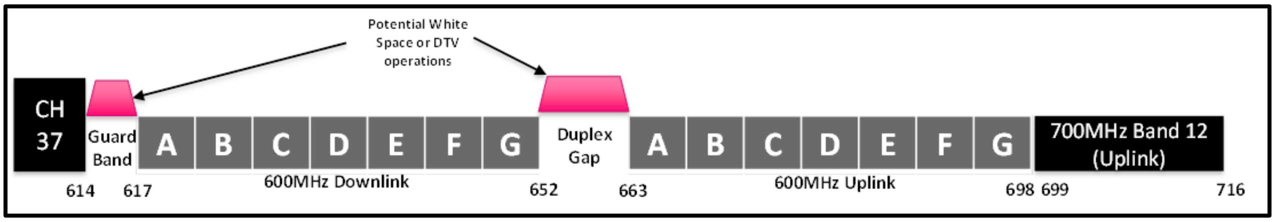

Part of the auction process reorganizes and repacks relinquished channels, as well as channels needed for broadcasters that want to keep broadcasting, to make useful blocks of spectrum for mobile broadband. The FCC’s goal is to design an auction that will result in a uniform nationwide band plan, but in some markets, there may be deviations from that plan.

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[75] For further details, see Rysavy Research, “Latest FCC auction shatters spectrum myths,” January 2015. Available at https://gigaom.com/2015/01/17/latest-fcc-auction-shatters-spectrum-myths/.

[76] 5G Americas member contribution.

With a 39-month schedule for winning bidders to move into their new spectrum, the 600 MHz band will be fully available by 2020. However, some operators, will begin using this spectrum in advance of this date, possibly as soon as the second half of 2017, as the spectrum becomes available for use.[77] Operators will use the band for LTE and 5G.

3550 to 3700 MHz "Small-Cell" Band

In the United States, the FCC is in the process of opening the 3550 to 3700 MHz CBRS band. The best use of this band will be small cells and backhaul. The FCC is implementing a three-tier model with incumbent access, priority access with priority access licenses (PALs), and General Authorized Access (GAA) for unlicensed users.[78] Incumbent access will include government radar systems.

Two industry organizations, the Wireless Innovation Forum[79] and the CBRS Alliance,[80] are working for the realization of 3.5 GHz systems.

The mobile broadband industry will mostly use LTE TDD in small-cell configurations, in either a licensed mode or an unlicensed mode using LAA or MulteFire.

Although this band represents a significant amount of new spectrum, potential adopters of the band have expressed concern about proposed rules for use of the band. For example:

- IEEE has stated it will not pursue a version of 802.11 for this band because exclusion zones are so large that the percentage of the U.S. population that could be served is below what is required for a successful market.[81]
- Licensed users will only be able to obtain three-year licenses with no automatic renewal.[82]

Assuming LAA auctions in early 2018, initial 3.5 GHz deployments could occur in 2018. Because an Environmental Sensing Capability (ESC) has not yet been developed and approved, these initial deployments may not come to fruition in coastal areas where the ESC is needed for co-existence with military systems using those frequencies.

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[77] For example, see FierceWireless, "T-Mobile confirms speedy 600 MHz rollout for 2017, covering 1 million+ square miles," August 8, 2017, available at http://www.fiercewireless.com/node/334911.

[78] For further details, see Official FCC Blog, "Innovation in the 3.5 GHz Band: Creating a New Citizens Broadband Radio Service," March 2015, available at http://www.fcc.gov/blog/innovation-35-ghz-band-creating-new-citizens-broadband-radio-service. See also FCC, *Further Notice of Proposed Rulemaking--Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550- 3650 MHz Band*, April 23, 2014.

[79] See http://www.wirelessinnovation.org/.

[80] See https://www.cbrsalliance.org/.

[81] IEEE 802.11, *Comments of IEEE 802.11, In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band,"* Jul, 2015. Available at http://apps.fcc.gov/ecfs/document/view?id=60001115064.

[82] See Rysavy article about this band, "Scary Experimentation at 3.5 GHz," Jun. 2016, available at http://www.rysavy.com/Articles/2016-06-Scary-Experimentation-3-5-GHz.pdf. See also AT&T ex-parte FCC communication, http://apps.fcc.gov/ecfs/document/view?id=60001569272.

See the section “Spectrum Sharing” for further details of this band.

2.5 GHz Band

In the United States, the primary operator at 2.5 GHz is Sprint. In 2017, Sprint announced that they will deploy 5G in its 2.5 GHz spectrum as soon as the second half of 2019.[83] Having an average of 160 MHz of spectrum at 2.5 GHz in its top 100 markets, Sprint is in the process of deploying LTE-Advanced. In addition, Sprint is in an LTE deployment mode that includes the following features:

- ❑ Carrier aggregation capability between 2.5 GHz and lower bands (800MHz and 1900 MHz) and aggregating three carriers in a single band.
- ❑ TDD operation at 2.5 GHz and FDD operation in lower bands.
- ❑ 8 transmit and 8 receive radios at the base station that enables 4X2 MIMO in combination with beamforming.[84]

5G Bands

As radio technology progresses, it can handle higher frequencies, and it occupies greater bandwidth. 1G systems used 30 kHz radio carriers, 2G in GSM uses 200 kHz carriers, 3G in UMTS uses 5 MHz carriers, and 4G in LTE uses carriers of up to 640 MHz through carrier aggregation.

3GPP is specifying 5G NR to be band agnostic. 5G will use low-band, mid-band, and high-band spectrum, and 3GPP is in the process of identifying candidate bands for 5G across all frequency ranges. 3GPP Technical Services Group - Radio Access Networks (TSG-RAN) agreed to a process of efficiently adding LTE/NR band combinations and carrier-aggregated NR/NR band combinations. Initial bands being considered by the 3GPP specification process include low band bands 5, 20, 28 and 71, mid-band bands 1, 3, 7, 66 and 41, and key mmWave bands. Just as it has done with LTE, over time, 3GPP will specify additional 5G bands spanning multiple frequencies.

Although 5G research and development is in its infancy, to achieve the 20 Gbps or higher throughput rates envisioned for 5G will require radio carriers such as 200 MHz or 400 MHz, bandwidths available only at frequencies above 5 GHz. Researchers globally are studying high-frequency spectrum options including both cmWave frequencies (3 GHz to 30 GHz) and mmWave (30 GHz to 300 GHz). Ten times as much spectrum, or more, could be available in these higher frequencies than in all current cellular spectrum.

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[83] For more details, see Sprint press release, “Qualcomm, SoftBank and Sprint Announce Collaboration on 2.5 GHz 5G,” May 10, 2017, available at http://newsroom.sprint.com/qualcomm-softbank-and-sprint-announce-collaboration-on-25-ghz-5g.htm.

[84] For more details, see Sprint article at: http://newsroom.sprint.com/blogs/sprint-perspectives/introducing-the-sprint-lte-plus-network--faster-stronger-more-reliable-than-ever-before.htm

5G NR is being designed to operate in any frequency band. These bands encompass 600 MHz, current cellular bands, 3.5 GHz, and higher bands such as mmWave. Because 5G will be the first cellular technology to be able to operate in mmWave bands, industry and government are working to make such bands available for 5G.

During the World Radiocommunication Conference (WRC) 15, the ITU proposed a set of global frequencies for 5G[85], which it intends to finalize at the next conference in 2019 (WRC 19):

- ☐ 24.25–27.5GHz
- ☐ 31.8–33.4GHz
- ☐ 37–40.5GHz
- ☐ 40.5–42.5GHz
- ☐ 45.5–50.2GHz
- ☐ 50.4–52.6GHz
- ☐ 66–76GHz
- ☐ 81–86GHz
- ☐ In 2014, the FCC published a Notice of Inquiry into use of spectrum bands above 24 GHz for Mobile Radio Services,[86] followed by a Notice of Proposed Rulemaking in October 2015. [87]

The FCC issued adopted rules to identify and open up 5G mmWave spectrum allocation in July 2016 that identify 3.85 GHz of licensed spectrum and 7 GHz of unlicensed spectrum: licensed use in 28 GHz, 37 GHz, and 39 GHz bands; unlicensed use in 64-71 GHz; and shared access in the 37-37.6 GHz band.

On July 24, 2016, the FCC adopted a report and order and further notice of proposed rulemaking that creates a new Part 30 for rules governing 28 GHz, 36 GHz, and 39 GHz bands, summarized in Table 12.

Table 12: United States 5G mmWave Bands[88]

Bands	Details
28 GHz Band (27.5-28.35 GHz)	Currently licensed for Local Multipoint Distribution Service (LMDS). Could be licensed using either 200 or 400 MHz wide channels.

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[85] 5G Americas Webcast, “LTE-Steps to 5G,” Feb 12, 2016.

[86] FCC, *Notice of Inquiry, Use of Spectrum Bands above 24 GHz for Mobile Radio Services*, Oct. 17, 2014.

[87] FCC, *Notice of Proposed Rulemaking, Use of Spectrum Bands Above 24 GHz for Mobile Radio Services, GN Docket No. 14-177,* Oct 23, 2015.

[88] For more details, refer to FCC, *Report and Order and Further Notice of Proposed Rulemaking, Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*, July 14, 2016. See also 5G Americas, *5G*

Bands	Details
39 GHz Band (38.6-40 GHz)	Currently licensed for fixed microwave in 50 MHz channels. Segment will be auctioned in 200 MHz blocks.
37 GHz Band (37-38.6 GHz)	Lower 37-37.6 GHz segment will be shared between federal and non-federal users. Upper 37.6-38.6 GHz segment will be auctioned in 200 MHz blocks.
64-71 GHz Band	Available for unlicensed use with same Part 15 rules as existing 57-64 GHz band.

In the 28 GHz band, satellite operations are secondary, but these operations are co-primary in the 37/39 GHz bands. Spectrum sharing may be required in some 5G bands, including 38.6 to 40 GHz, such as with fixed satellite service.

In the further notice of proposed rulemaking, the FCC is investigating additional bands, including 24 GHz, 32 GHz, 42 GHz, 47 GHz, 50 GHz, 70/80 GHz, and bands above 95 GHz.

The complex ITU harmonization process may mean that some regions, or even countries, pursue 5G bands that are not globally harmonized. For example, U.S. operators, along with operators in Korea and Japan, are planning 5G trials in the 28 GHz band, even though it is not one of the ITU bands.

Harmonization

Spectrum harmonization delivers many benefits, including higher economies of scale, better battery life, improved roaming, and reduced interference along borders.

As regulators make more spectrum available, it is important that they follow guidelines such as those espoused by 5G Americas:[89]

- Configure licenses with wider bandwidths.
- Group like services together.
- Be mindful of global technology standards.
- Pursue harmonized/contiguous spectrum allocations.
- Exhaust exclusive use options before pursuing shared use.
- Because not all spectrum is fungible, align allocation with demand.

Emerging technologies such as LTE benefit from wider radio channels. These wider channels are not only spectrally more efficient, they also offer greater capacity. Figure 34 shows increasing LTE spectral efficiency obtained with wider radio channels, with 20 MHz on the

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Spectrum Recommendations, April 2017, available at http://www.5gamericas.org/files/9114/9324/1786/5GA_5G_Spectrum_Recommendations_2017_FINAL.pdf. This report covers global 5G spectrum developments.

[89] 4G Americas, *Sustaining the Mobile Miracle – A 4G Americas Blueprint for Securing Mobile Broadband Spectrum in this Decade*, March 2011.

downlink and 20 MHz (20+20 MHz) on the uplink comprising the most efficient configuration.

Figure 34: LTE Spectral Efficiency as Function of Radio Channel Size[90]

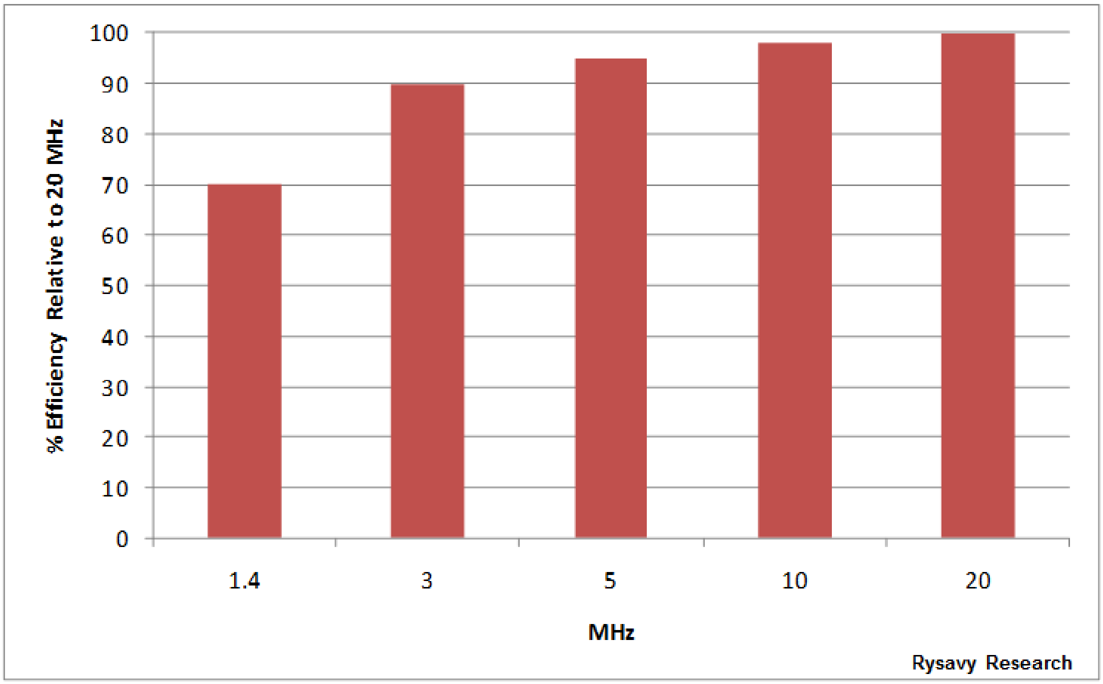

The organization tasked with global spectrum harmonization, the International Telecommunication Union, periodically holds World Radiocommunication Conferences.[91]

Harmonization occurs at multiple levels:

- ❑ Allocation of radio frequencies to a mobile service in the ITU frequency allocation table.
- ❑ Establishment of global or regional frequency arrangements, including channel blocks and specific duplexing modes.
- ❑ Development of detailed technical specifications and standards, including system performance, RF performance, and coexistence with other systems in neighboring bands.
- ❑ Assignment for frequency blocks with associated technical conditions and specifications to appropriate operators and service providers.[92]

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[90] 5G Americas member company analysis.

[91] International Telecommunication Union, "World Radiocommunication Conferences (WRC)," http://www.itu.int/ITU-R/index.asp?category=conferences&rlink=wrc&lang=en, viewed May 18, 2017.

[92] International Telecommunication Union Radiocommunication Study Groups, *Technical Perspective on Benefits Of Spectrum Harmonization for Mobile Services and IMT*, Document 5D/246-E, January 2013.

Unlicensed Spectrum

Wi-Fi uses spectrum efficiently because its small coverage areas result in high-frequency reuse and high data density (bps per square meter). Less efficient are white-space unlicensed networks, sometimes called "super Wi-Fi," that, because of large coverage areas, have much lower throughput per square meter. While white-space networks may be a practical broadband solution in rural or undeveloped areas, they face significant challenges in urban areas that already have mobile and fixed broadband available.[93] See the section on "White Space Networks" in the appendix for further details.

Advocates argue that unlicensed spectrum unleashes innovation and that government should allocate greater amounts of unlicensed spectrum. Although Wi-Fi has been successful, the core elements that make unlicensed spectrum extremely successful are also the source of inherent disadvantages: local coverage and its unlicensed status. Local coverage enables high data density and high frequency reuse but makes widespread continuous coverage almost impossible. Similarly, unlicensed operation facilitates deployment by millions of entities but results in overlapping coverage and interference.

Networks built using unlicensed spectrum cannot replace networks built using licensed spectrum, and vice versa. The two are complementary and helpful to each other, as summarized in Table 13.[94]

Table 13: Pros and Cons of Unlicensed and Licensed Spectrum

Unlicensed Spectrum			Licensed Spectrum	
Pros	**Cons**		**Pros**	**Cons**
Easy and quick to deploy	Potential of other entities using same frequencies		Huge coverage areas	Expensive infrastructure
Low-cost hardware	Difficult to impossible to provide wide-scale coverage		Able to manage quality of service	Each operator has access to only a small amount of spectrum

Some operators offer a "Wi-Fi first" capability with which devices always attempt to use a Wi-Fi connection and fall back to a cellular connection only if no Wi-Fi is available. Such cellular backup is essential because Wi-Fi, due to low-power operation in many bands, is inherently unsuited for providing continuous coverage. The sharp drop-off in signal strength due to low transmit power makes coverage gaps over large areas inevitable, especially outdoors.

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[93] For further analysis, see Rysavy Research, "White spaces networks are not 'super' nor even Wi-Fi," Gigaom, March 2013. Available at http://gigaom.com/2013/03/17/white-spaces-networks-are-not-super-nor-even-wi-fi/.

[94] For further analysis, see Rysavy Research, "It's Time for a Rational Perspective on Wi-Fi," Gigaom, April, 2014. Available at http://gigaom.com/2014/04/27/its-time-for-a-rational-perspective-on-wi-fi/.

Figure 35: Propagation Losses of Cellular vs. Wi-Fi[95]

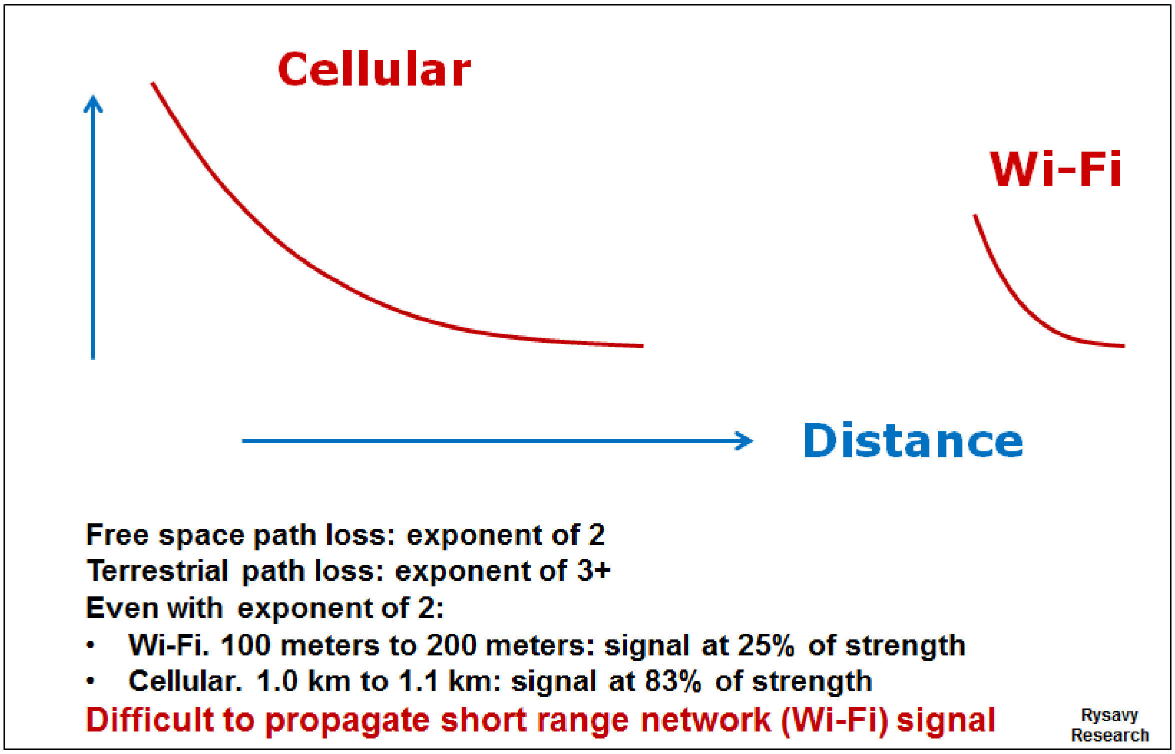

Free space path loss: exponent of 2
Terrestrial path loss: exponent of 3+
Even with exponent of 2:

- **Wi-Fi. 100 meters to 200 meters: signal at 25% of strength**
- **Cellular. 1.0 km to 1.1 km: signal at 83% of strength**

Difficult to propagate short range network (Wi-Fi) signal

Rysavy Research

Spectrum Sharing

In 2012, the President's Council of Advisors on Science and Technology issued a report titled, "Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth." The report recommended spectrum sharing between government and commercial entities.

The U.S. government can designate spectrum for exclusive, shared, or unlicensed use, as shown in Figure 36. Shared use can be opportunistic, as with TV white spaces; two-tier with incumbents and licensed users; or three-tier, which adds opportunistic access. The bands initially targeted for spectrum sharing include AWS-3 (two tiers on a temporary basis) and the 3.5 GHz band (three tiers).

The three-tier plan envisioned by the U.S. government for the 3.5 GHz band gives more entities access to the spectrum but at the cost of increased complexity.

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[95] Assumes 1.0 km radius for cellular and 100-meter radius for Wi-Fi.

Figure 36: Spectrum Use and Sharing Approaches

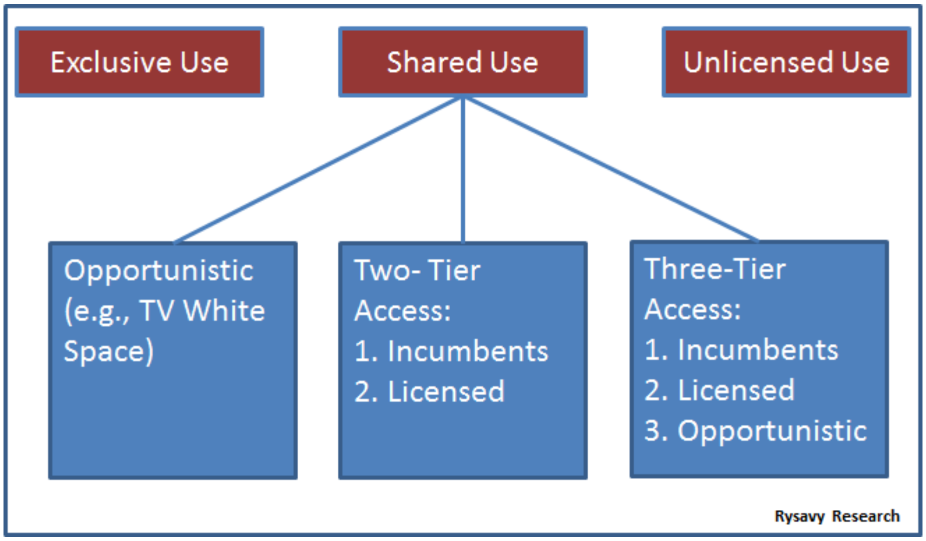
Exclusive Use
Shared Use
Unlicensed Use
Opportunistic (e.g., TV White Space)
Two- Tier Access:
1. Incumbents
2. Licensed
Three-Tier Access:
1. Incumbents
2. Licensed
3. Opportunistic
Rysavy Research

The European Telecommunications Standards Institute (ETSI) is the leading organization standardizing cognitive radios. The most relevant effort is called "Licensed Shared Access" (LSA), a two-tier spectrum sharing system that includes incumbents and licensed secondary users that access shared spectrum via a database, as depicted in Figure 37.

Figure 37: Licensed Shared Access (LSA)

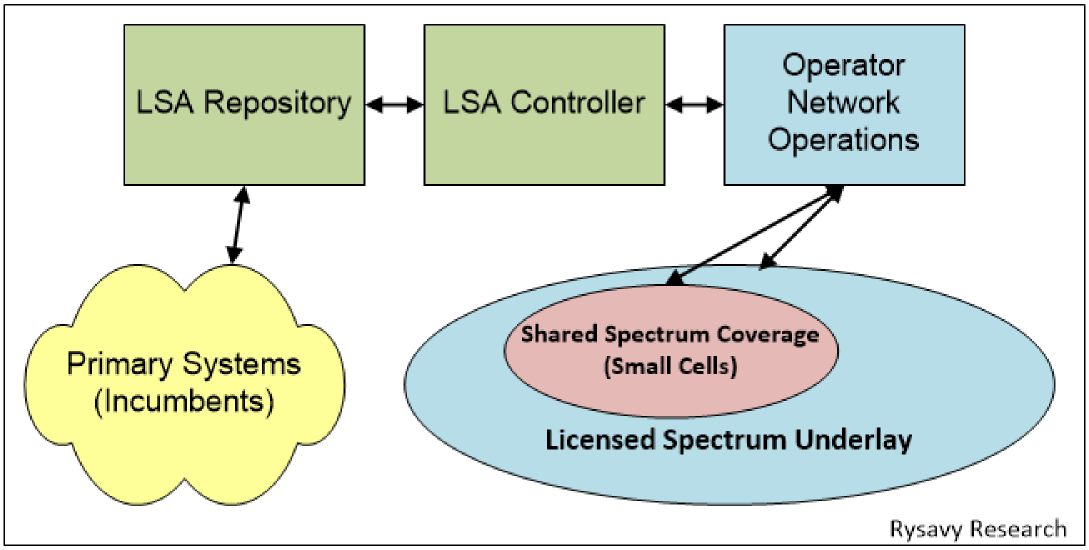
LSA Repository
LSA Controller
Operator Network Operations
Primary Systems (Incumbents)
Shared Spectrum Coverage (Small Cells)
Licensed Spectrum Underlay
Rysavy Research

The three-tier system expected for the 3.5 GHz band in the United States will be complex, necessitating a real-time Spectrum Access System, the SAS, the design and development of which will encompass:

- ❑ Algorithms and methods;
- ❑ Methods of nesting hierarchical SAS entities (federal secure SAS versus commercial SASs);

- ☐ Coordination among multiple, competing commercial SAS managing entities;
- ☐ Interface definitions;
- ☐ Communication protocol definitions;
- ☐ Database and protocol security;
- ☐ Policy enforcement;
- ☐ Speed of channel allocation/reallocation;
- ☐ Time intervals for spectrum allocation;
- ☐ Effectively managing large numbers of Tier 3 users; and
- ☐ Data ownership, fees, rules, fairness, and conflict resolutions, all of which have policy, regulatory, and business implications.

TVWS databases available today address only a tiny subset of these requirements.[96]

Figure 38 shows the proposed architecture of the 3.5 GHz system. The system consists of incumbents (government systems), Priority Access Licenses, and General Authorized Access. Government systems include military ship-borne radar, military ground-based radar, fixed satellite service earth stations (receive only), and government broadband services (3650 to 3700 MHz). PAL licenses will be used by entities such as cellular operators and will be available for three-year periods. GAA users are licensed by rule and must protect both incumbents and PALs. Incumbents are protected by an Environmental Sensing Capability that detects incumbents and informs the SAS. Some examples of GAA use cases are small-business hotspots, campus hotspots, and backhaul.

Citizens Broadband Radio Service Devices (CBSDs) are the base stations operating under this service; they can operate only under the authority and management of the SAS, either by direct communications or a proxy node.

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[96] For further analysis, see Rysavy Research and Mobile Future, *Complexities of Spectrum Sharing: How to Move Forward*, April 2014. Available at http://www.rysavy.com/Articles/2014-04-Spectrum-Sharing-Complexities.pdf.

Figure 38: United States 3.5 GHz System Currently Being Developed

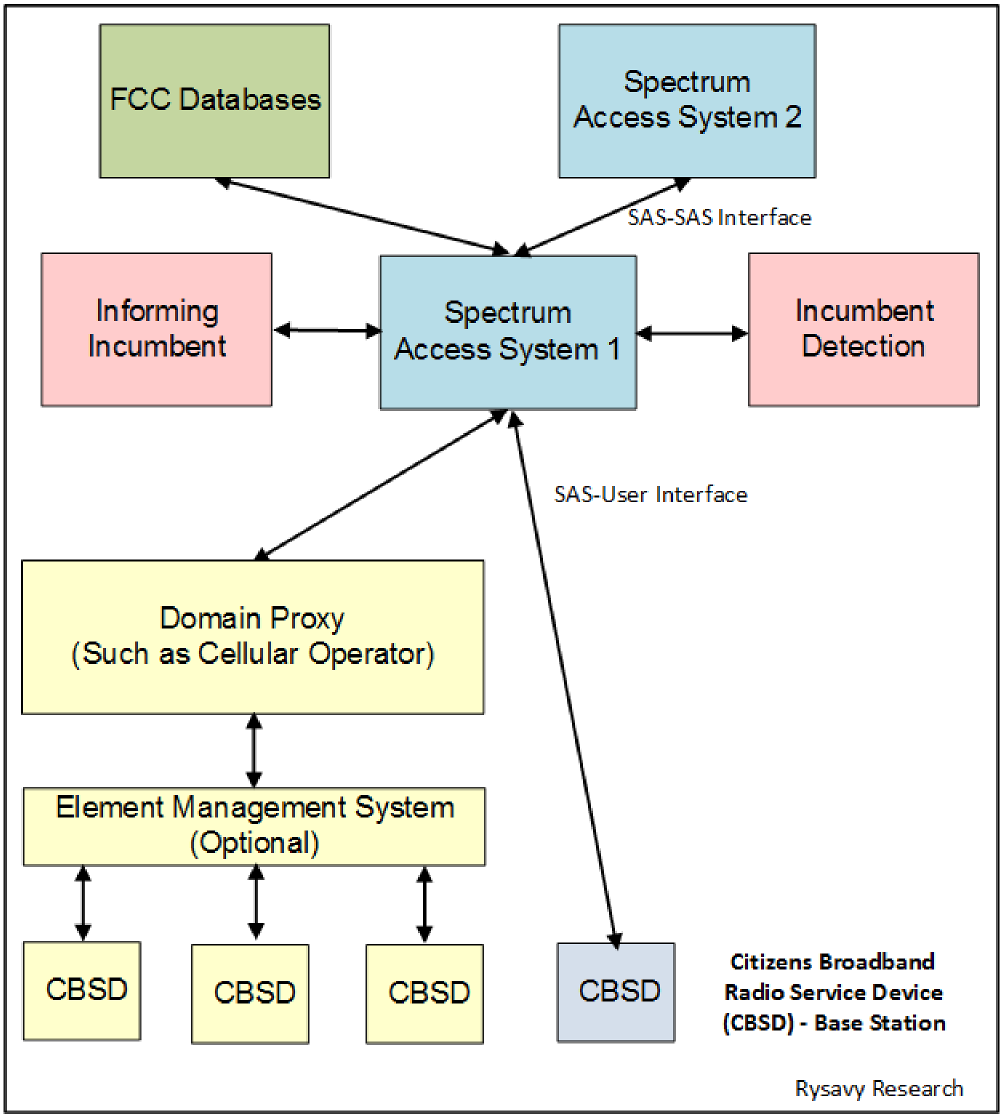

FCC Databases
Spectrum Access System 2
SAS-SAS Interface
Informing Incumbent
Spectrum Access System 1
Incumbent Detection
SAS-User Interface
Domain Proxy (Such as Cellular Operator)
Element Management System (Optional)
CBSD
CBSD
CBSD
CBSD
Citizens Broadband Radio Service Device (CBSD) - Base Station
Rysavy Research

Conclusion

Mobile broadband remains at the forefront of innovation and development in computing, networking, and application development. As users, and now machines, consume ever more wireless data, the industry is responding with more efficient, faster, and higher capacity networks. Even as excitement builds about 5G, LTE, through ongoing advances, has become the global standard.

LTE-Advanced and LTE-Advanced Pro innovations include VoLTE, 1 Gbps peak rate capability, higher-order MIMO, carrier aggregation, LAA/LWA/LWIP, IoT capabilities in Narrowband-IoT and Category M-1, V2X communications, small-cell support, URLLC, SON, dual connectivity, and CoMP—all capabilities that will improve performance, efficiency, and capacity and enable support for new vertical segments. Carriers are implementing NFV and SDN to reduce network costs, improve service velocity, and simplify deployment of new services. Such improvements also facilitate cloud RANs that promise further efficiency gains.

5G research and development efforts have accelerated; standards-based deployment will begin in 2019 and continue through 2030. Operators have announced pre-standard fixed-wireless deployments for 2017. 3GPP has implemented a 5G standardization process that began in Release 14 with a study of the new 5G radio, continues now with a first phase of specifications in Release 15 that provides both non-standalone and standalone options, then moves ahead with a second phase of complete specifications in Release 16.

By harnessing new spectrum, such as mmWave bands above 24 GHz, 5G will eventually be able to access ten times as much spectrum as is currently available for cellular operation. Using radio bands 200 MHz or wider will result in multi-Gbps throughput capabilities. 5G will be designed to integrate with LTE networks, and many 5G features may be implemented as LTE-Advanced Pro extensions prior to full 5G availability.

Small cells will play an ever-more-important role in boosting capacity, benefiting from a number of technologies and developments, including SON, eICIC, Dual Connectivity, LWA/LWIP, LTE-U, LTE-LAA, MulteFire, improved backhaul options, and spectrum ideal for small cells, such as the 3.5 GHz and mmWave bands.

Obtaining more spectrum remains a priority globally. In U.S. markets, the recently completed television incentive auctions for 600 MHz spectrum supplied 70 MHz of new licensed spectrum; the 3.5 GHz small-cell band will provide 150 MHz; and the 5G spectrum bands, with both licensed and unlicensed bands, will add about 10 GHz of new spectrum.

The future of mobile broadband, including both LTE-Advanced and 5G, is bright, with no end in sight for continued growth in capability, nor for the limitless application innovation that mobile broadband enables.

Appendix: Technology Details

The 3GPP family of data technologies provides ever increasing capabilities that support ever more demanding applications. Services obviously need to provide broad coverage and high data throughput. Less obvious for users, but as critical for effective application performance, are the need for low latency, QoS control, and spectral efficiency. Higher spectral efficiency translates to higher average throughputs (and thus more responsive applications) for more active users in a coverage area. The discussion below details the progression of capability for each technology, including throughput, security, latency, QoS, and spectral efficiency.

This appendix provides details on 5G, UMTS/HSPA, and EDGE.

3GPP Releases

- ☐ **Release 99**: Completed. First deployable version of UMTS. Enhancements to GSM data (EDGE). Provides support for GSM/EDGE/GPRS/WCDMA radio-access networks.

- ☐ **Release 4**: Completed. Multimedia messaging support. First steps toward using IP transport in the core network.

- ☐ **Release 5**: Completed. HSDPA. First phase of Internet Protocol Multimedia Subsystem (IMS). Full ability to use IP-based transport instead of just Asynchronous Transfer Mode (ATM) in the core network.

- ☐ **Release 6**: Completed. HSUPA. Enhanced multimedia support through Multimedia Broadcast/Multicast Services (MBMS). Performance specifications for advanced receivers. Wireless Local Area Network (WLAN) integration option. IMS enhancements. Initial VoIP capability.

- ☐ **Release 7**: Completed. Provides enhanced GSM data functionality with Evolved EDGE. Specifies HSPA+, which includes higher-order modulation and MIMO. Performance enhancements, improved spectral efficiency, increased capacity, and better resistance to interference. Continuous Packet Connectivity (CPC) enables efficient “always-on” service and enhanced uplink UL VoIP capacity, as well as reductions in call set-up delay for Push-to-Talk Over Cellular (PoC). Radio enhancements to HSPA include 64 Quadrature Amplitude Modulation (QAM) in the downlink and 16 QAM in the uplink. Also includes optimization of MBMS capabilities through the multicast/broadcast, single frequency network (MBSFN) function.

- ☐ **Release 8**: Completed. Comprises further HSPA Evolution features such as simultaneous use of MIMO and 64 QAM. Includes dual-carrier HSDPA (DC-HSDPA) wherein two downlink carriers can be combined for a doubling of throughput performance. Specifies OFDMA-based 3GPP LTE. Defines EPC and EPS.

- ☐ **Release 9**: Completed. HSPA and LTE enhancements including HSPA dual-carrier downlink operation in combination with MIMO, Multimedia Broadcast Multicast Services (MBMS), HSDPA dual-band operation, HSPA dual-carrier uplink operation, EPC enhancements, femtocell support, support for regulatory features such as emergency user equipment positioning and Commercial Mobile Alert System (CMAS), and evolution of IMS architecture.

- ☐ **Release 10**: Completed. Specifies LTE-Advanced that meets the requirements set by ITU’s IMT-Advanced project. Key features include carrier aggregation, multi-antenna enhancements such as enhanced downlink eight-branch MIMO and uplink MIMO, relays, enhanced LTE Self-Organizing Network capability, Evolved Multimedia Broadcast Multicast Services (eMBMS), HetNet enhancements that include eICIC, Local IP Packet Access, and new frequency bands. For HSPA, includes quad-carrier operation and additional MIMO options. Also includes femtocell enhancements, optimizations for M2M communications, and local IP traffic offload.

- ☐ **Release 11**: Completed. For LTE, emphasizes Coordinated Multi Point (CoMP), carrier-aggregation enhancements, devices with interference cancellation, development of the Enhanced Physical Downlink Control Channel (EPDCCH), and further enhanced eICIC including devices with CRS (Cell-specific Reference Signal) interference cancellation. The release includes further DL and UL MIMO enhancements for LTE. For HSPA, provides eight-carrier on the downlink, uplink enhancements to improve latency, dual-antenna beamforming and MIMO, CELL Forward Access Channel (FACH) state enhancement for smartphone-type traffic, four-branch MIMO enhancements and transmissions for HSDPA, 64 QAM in the uplink, downlink multipoint transmission, and noncontiguous HSDPA carrier aggregation. Wi-Fi integration is promoted through S2a Mobility over GPRS Tunneling Protocol (SaMOG). An additional architectural element called “Machine-Type Communications Interworking Function” (MTC-IWF) will more flexibly support machine-to-machine communications.

- ☐ **Release 12**: Completed. Enhancements include improved small cells/HetNets for LTE, LTE multi-antenna/site technologies (including Active Antenna Systems), Dual Connectivity, 256 QAM modulation option, further CoMP/MIMO enhancements, enhancements for interworking with Wi-Fi, enhancements for MTC, SON, support for emergency and public safety, Minimization of Drive Tests (MDT), advanced receivers, device-to-device communication (also referred to as Proximity Services), group communication enablers in LTE, addition of Web Real Time Communication (WebRTC) to IMS, energy efficiency, more flexible carrier aggregation, dynamic adaptation of uplink-downlink ratios in TDD mode, further enhancements for HSPA+, small cells/HetNets, Scalable-UMTS, and FDD-TDD carrier aggregation.

- ☐ **Release 13**: Completed. LTE features include Active Antenna Systems (AAS) with support for as many as 16 antenna elements (full-dimension MIMO) and beamforming, Network-Assisted Interference Cancellation and Suppression (NAICS), radio-access network sharing, carrier aggregation supporting 32 component carriers,[97] carrier aggregation of up to four carriers on the downlink and two carriers on the uplink, LAA for operation in unlicensed bands, LTE Wi-Fi Aggregation including LWIP, RCLWI, isolated operation and mission-critical voice communications for public safety, application-specific congestion management, User-Plane Congestion Management, enhancement to WebRTC interoperability, architecture enhancement for dedicated core networks, enhancement to proximity-based services, Mission-Critical Push-to-Talk, group communications, CoMP enhancements, small cell enhancements, machine-type communications enhancements including NB-IoT and Extended Coverage GSM (EC-GSM), VoLTE enhancements, SON enhancements, shared network enhancements, indoor positioning based on WLAN access points, Bluetooth beacons and barometric pressure, and enhanced circuit-switched fallback. HSPA+ features include support for dual-band uplink carrier aggregation.

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[97] This level of aggregation refers to signaling capabilities. The number of carriers that can be combined in an actual deployment is smaller and depends on RAN co-existence studies. Refer to the appendix section on “Carrier Aggregation” for additional details.

- **Release 14**: Expected completion June 2017. Contemplated features include uplink operation for LAA (enhanced LAA), full-dimension MIMO enhanced with up to 32 antenna elements, dual-connectivity of licensed and unlicensed carriers across non-collocated nodes, vehicle-to-vehicle and vehicle-to-infrastructure (V2X) communications built on Release 12 Proximity Services, shared LTE broadcast in which different operators broadcast the same content on the same frequency, non-IP operation for IoT, Downlink Multi-user Superposition Transmission (MUST), enhanced LWA, VoLTE enhancements, LWIP/LWA enhancements, eMBMS enhancements, NB-IoT enhancements, and LTE latency reduction.
- **Release 15**: Expected completion September 2018. Non-standalone (using LTE core network) option expected March 2018. Specifies phase 1 of 5G. NR radio, 4G-5G interworking, and MIMO/beamforming. Further LTE enhancements include ultra-reliable low-latency communications, NB-IoT enhancements, LAA enhancements, V2X enhancements, DL 1024 QAM, CoMP enhancements, AAS enhancements, and LTE/5G core network capability.
- **Release 16**: Expected completion end of 2019. Specifies phase 2 of 5G. Adds URLLC, spectrum sharing, unlicensed spectrum operation and integration, and multiple other enhancements. Further LTE enhancements.

Data Throughput Comparison

Data throughput is an important metric for quantifying network throughput performance. Unfortunately, the ways in which various organizations quote throughputs vary tremendously, often resulting in misleading claims. The intent of this paper is to realistically represent the capabilities of these technologies.

One method of representing a technology's throughput is what people call "peak throughput" or "peak network speed," which refers to the fastest possible transmission speed over the radio link and is generally based on the highest-order modulation available and the least amount of coding (error correction) overhead. Peak network speed is also usually quoted at layer 2 of the radio link. Because of protocol overhead, actual application throughput may be up to 10% lower than this layer-2 value.

Another method is to disclose throughputs actually measured in deployed networks with applications such as File Transfer Protocol (FTP) under favorable conditions, which assume light network load (as low as one active data user in the cell sector) and favorable signal propagation. This number is useful because it demonstrates the high-end, actual capability of the technology in current deployments, referred to in this paper as the "peak user rate." Average rates are lower than this peak rate and are difficult to predict because they depend on a multitude of operational and network factors. Except when the network is congested, however, the majority of users should experience throughput rates higher than one-half of the peak achievable rate.

Some operators, primarily in the United States, also quote typical throughput rates, which are based on throughput tests the operators have done across their operating networks and incorporate a higher level of network load. Although the operators do not disclose the precise methodologies they use to establish these figures, the values provide a good indication of what users can realistically expect.

Table 14 presents the technologies in terms of peak network throughput rates, peak user rates (under favorable conditions), and typical rates. It omits values that are not yet known, such as for future technologies.

The projected typical rates for HSPA+ and LTE show a wide range because these technologies exploit favorable radio conditions to achieve high throughput rates, but under poor radio conditions, throughput rates are lower.

Table 14: Throughput Performance of Different Wireless Technologies (Blue Indicates Theoretical Peak Rates, Green Typical)

	Downlink		Uplink	
	Peak Network Speed	Peak and/or Typical User Rate	Peak Network Speed	Peak and/or Typical User Rate
5G in mmWave, early versions[98]	5 Gbps	500 Mbps	2 Gbps	250 Mbps
5G in mmWave, later versions	50 Gbps	5 Gbps	25 Gbps	2 Gbps
LTE (2X2 MIMO, 10+10 MHz, DL 64 QAM, UL 16 QAM)	70 Mbps	6.5 to 26.3 Mbps[99]	35 Mbps[100]	6.0 to 13.0 Mbps
LTE-Advanced (2X2 or 4X4 MIMO, 20+20 MHz or 40+20 MHz with Carrier Aggregation [CA], DL 64 QAM, UL 16 QAM)	300 Mbps	N/A	71 Mbps[101]	N/A
LTE Advanced (4X4 MIMO, 60+20MHz, CA, 256 QAM DL, 64 QAM UL)	600 Mbps		150 Mbps	
LTE Advanced (4X4 MIMO, 80+20 MHz, CA, 256 QAM DL, 64 QAM UL)	> 1 Gbps		150 Mbps	

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[98] Speculative values, Rysavy Research estimates. Assumes 200 MHz radio channel, 2:1 TDD. Throughput rates would double using 400 MHz.

[99] 5G Americas member company analysis for downlink and uplink. Assumes single user with 50% load in other sectors. AT&T and Verizon are quoting typical user rates of 5-12 Mbps on the downlink and 2-5 Mbps on the uplink for their networks. See additional LTE throughput information in the section below, "LTE Throughput."

[100] Assumes 64 QAM. Otherwise 22 Mbps with 16 QAM.

[101] Assumes 64 QAM. Otherwise 45 Mbps with 16 QAM.

	Downlink		Uplink	
	Peak Network Speed	Peak and/or Typical User Rate	Peak Network Speed	Peak and/or Typical User Rate
LTE Advanced (8X8 MIMO, 20+20 MHz, DL 64 QAM, UL 64 QAM)	1.2 Gbps	N/A	568 Mbps	N/A
LTE Advanced, 100 MHz + 100 MHz	3 Gbps		1.5 Gbps	
LTE Advanced 32 Carriers	>> 3 Gbps			
EDGE (type 2 MS)	473.6 Kbps	Not Applicable (N/A)	473.6 Kbps	N/A
EDGE (type 1 MS) (Practical Terminal)	236.8 Kbps	200 Kbps peak 160 to 200 Kbps typical[102]	236.8 Kbps	200 Kbps peak 80 to 160 Kbps typical[103]
HSDPA Initial Devices (2006)	1.8 Mbps	> 1 Mbps peak	384 Kbps	350 Kbps peak
HSDPA	14.4 Mbps	N/A	384 Kbps	N/A

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[102] Assumes four-to-five downlink timeslot devices (each timeslot capable of 40 Kbps).

[103] Assumes two-to-four uplink timeslot devices (each timeslot capable of 40 Kbps).

	Downlink		Uplink	
	Peak Network Speed	Peak and/or Typical User Rate	Peak Network Speed	Peak and/or Typical User Rate
HSPA[104] Initial Implementation	7.2 Mbps	> 5 Mbps peak 700 Kbps to 1.7 Mbps typical[105]	2 Mbps	> 1.5 Mbps peak 500 Kbps to 1.2 Mbps typical
HSPA	14.4 Mbps	N/A	5.76 Mbps	N/A
HSPA+ (DL 64 QAM, UL 16 QAM, 5+5 MHz)	21.6 Mbps	1.9 Mbps to 8.8 Mbps typical[106]	11.5 Mbps	1 Mbps to 4 Mbps typical
HSPA+ (2X2 MIMO, DL 16 QAM, UL 16 QAM, 5+5 MHz)	28 Mbps	N/A	11.5 Mbps	N/A
HSPA+ (2X2 MIMO, DL 64 QAM, UL 16 QAM, 5+5 MHz)	42 Mbps	N/A	11.5 Mbps	N/A
HSPA+ (DL 64 QAM, UL 16 QAM, Dual Carrier, 10+5 MHz)	42 Mbps	Approximate doubling of 5+5 MHz rates - 3.8 to 17.6 Mbps.	11.5 Mbps	1 Mbps to 4 Mbps typical
HSPA+ (2X2 MIMO DL, DL 64 QAM, UL 16 QAM, Dual Carrier, 10+10 MHz)	84 Mbps	N/A	23 Mbps	N/A

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[104] High Speed Packet Access (HSPA) consists of systems supporting both High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA).

[105] Typical downlink and uplink throughput rates based on AT&T press release, June 4, 2008

[106] 5G Americas member company analysis. Assumes Release 7 with 64 QAM and F-DPCH. Single user. 50% loading in neighboring cells. Higher rates expected with subsequent 3GPP releases.

	Downlink		Uplink	
	Peak Network Speed	**Peak and/or Typical User Rate**	**Peak Network Speed**	**Peak and/or Typical User Rate**
HSPA+ (2X2 MIMO DL, DL 64 QAM, UL 16 QAM, Quad-Carrier,[107] 20+10 MHz)	168 Mbps	N/A	23 Mbps	N/A
HSPA+ (2X2 MIMO DL and UL, DL 64 QAM, UL 16 QAM, Eight-Carrier, 40+10 MHz)	336 Mbps	N/A	69 Mbps	N/A
HSPA+ (4X2 MIMO DL, 2X2 MIMO UL, DL 64 QAM, UL 16 QAM, 8 carrier, 40+10 MHz)	672 Mbps	N/A	69 Mbps	N/A
EDGE (type 2 MS)	473.6 Kbps	Not Applicable (N/A)	473.6 Kbps	N/A
EDGE (type 1 MS) (Practical Terminal)	236.8 Kbps	200 Kbps peak 160 to 200 Kbps typical[108]	236.8 Kbps	200 Kbps peak 80 to 160 Kbps typical[109]
CDMA2000 EV-DO Rel. 0	2.4 Mbps	> 1 Mbps peak	153 Kbps	150 Kbps peak

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[107] No operators have announced plans to deploy HSPA in a quad (or greater) carrier configuration. Three carrier configurations, however, have been deployed.

[108] Assumes four-to-five downlink timeslot devices (each timeslot capable of 40 Kbps).

[109] Assumes two-to-four uplink timeslot devices (each timeslot capable of 40 Kbps).

	Downlink		Uplink	
	Peak Network Speed	Peak and/or Typical User Rate	Peak Network Speed	Peak and/or Typical User Rate
CDMA2000 EV-DO Rev. A	3.1 Mbps	> 1.5 Mbps peak 600 Kbps to 1.4 Mbps typical[110]	1.8 Mbps	> 1 Mbps peak 300 to 500 Kbps typical
CDMA2000 EV-DO Rev. B (3 radio channels 5+5 MHz)	14.7[111] Mbps	Proportional increase of Rev A typical rates based on number of carriers.	5.4 Mbps	N/A
CDMA2000 EV-DO Rev B Theoretical (15 radio channels 20+20 MHz)	73.5 Mbps	N/A	27 Mbps	N/A

Additional information about LTE throughput appears below in the section "LTE Throughput."

Latency Comparison

As important as throughput is network latency, defined as the round-trip time it takes data to traverse the network. Each successive data technology from GPRS forward reduces latency, with LTE networks having latency as low as 15 msec. Ongoing improvements in each technology mean that all of these values will go down as vendors and operators fine-tune their systems. Figure 39 shows the latency of different 3GPP technologies.

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[110] Typical downlink and uplink throughput rates based on Sprint press release Jan. 30, 2007.

[111] Assuming use of 64 QAM.

Figure 39: Latency of Different Technologies[112]

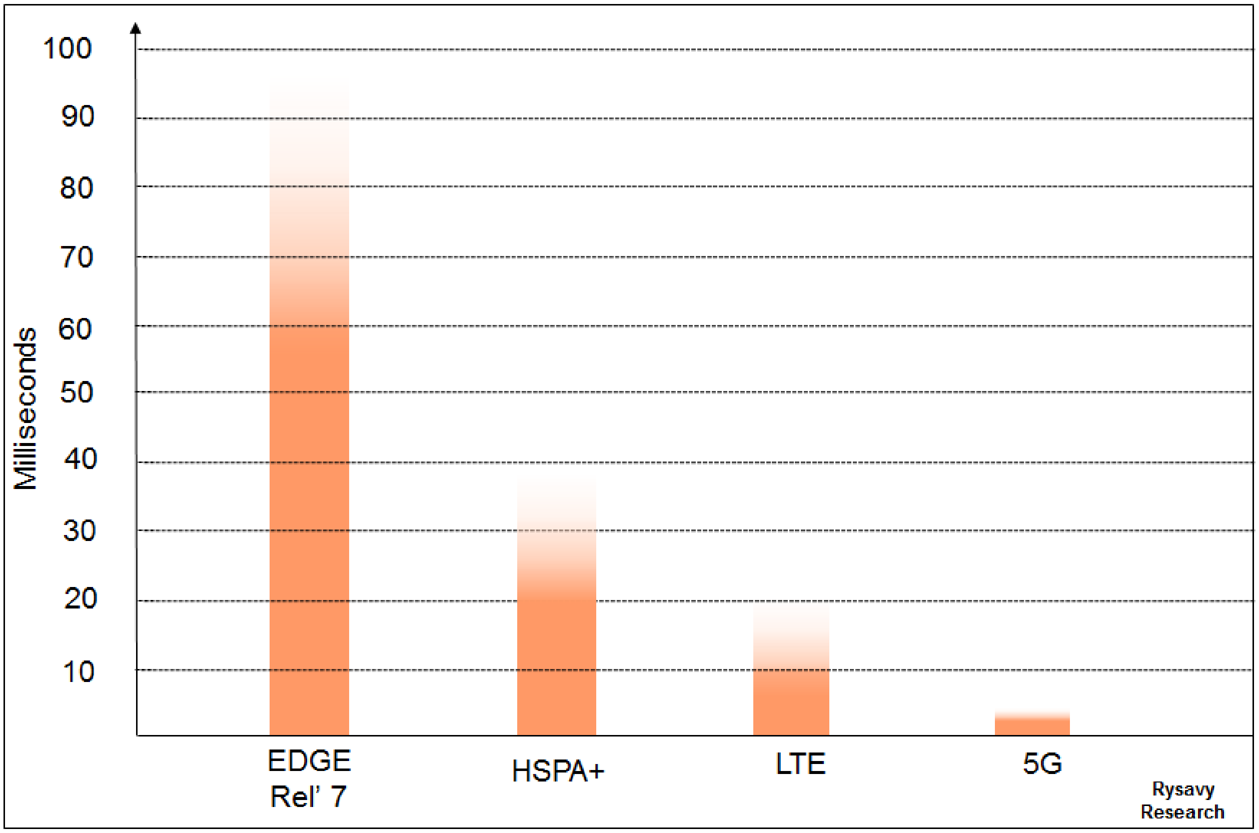

The values shown in Figure 39 reflect measurements of commercially deployed technologies, with EDGE Release 7 achieving 70 to 95 msec, HSPA+ 25 to 30 msec, and LTE 15 to 20 msec. A latency goal for 5G is less than 4 msec for broadband and 0.5 msec for mission-critical applications.

Spectral Efficiency

The evolution of data services is characterized by an increasing number of users with ever-higher bandwidth demands. As the wireless data market grows, deploying wireless technologies with high spectral efficiency is of paramount importance. Keeping all other things equal, including frequency band, amount of spectrum, and cell site spacing, an increase in spectral efficiency translates to a proportional increase in the number of users supported at the same load per user—or, for the same number of users, an increase in throughput available to each user.

Increased spectral efficiency, however, comes at a price because it generally involves greater complexity for both user and base station equipment. Complexity can arise from the increased number of calculations performed to process signals or from additional radio components. Hence, operators and vendors must balance market needs against network and equipment costs. OFDMA technologies, such as LTE and planned 5G approaches, achieve higher spectral efficiency with lower overall complexity, especially in larger bandwidths.

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[112] 5G Americas member companies. Measured between subscriber unit and a node immediately external to wireless network. Does not include internet latency. Note that there is some variation in latency based on network configuration and operating conditions.

As shown in Figure 40, the link-layer performance of modern wireless technologies is approaching the theoretical limits as defined by the Shannon bound. (The Shannon bound is a theoretical limit to the information transfer rate [per unit bandwidth] that can be supported by any communications link. The bound is a function of the SNRs of the communications link.) Figure 40 also shows that HSDPA, 1xEV-DO, and IEEE 802.16e-2005 are all within 2 to 3 decibels (dB) of the Shannon bound, indicating that there is not much room for improvement from a link-layer perspective.

Figure 40: Performance Relative to Theoretical Limits for HSDPA, EV-DO, and WiMAX (IEEE 802.16e-2005)[113]

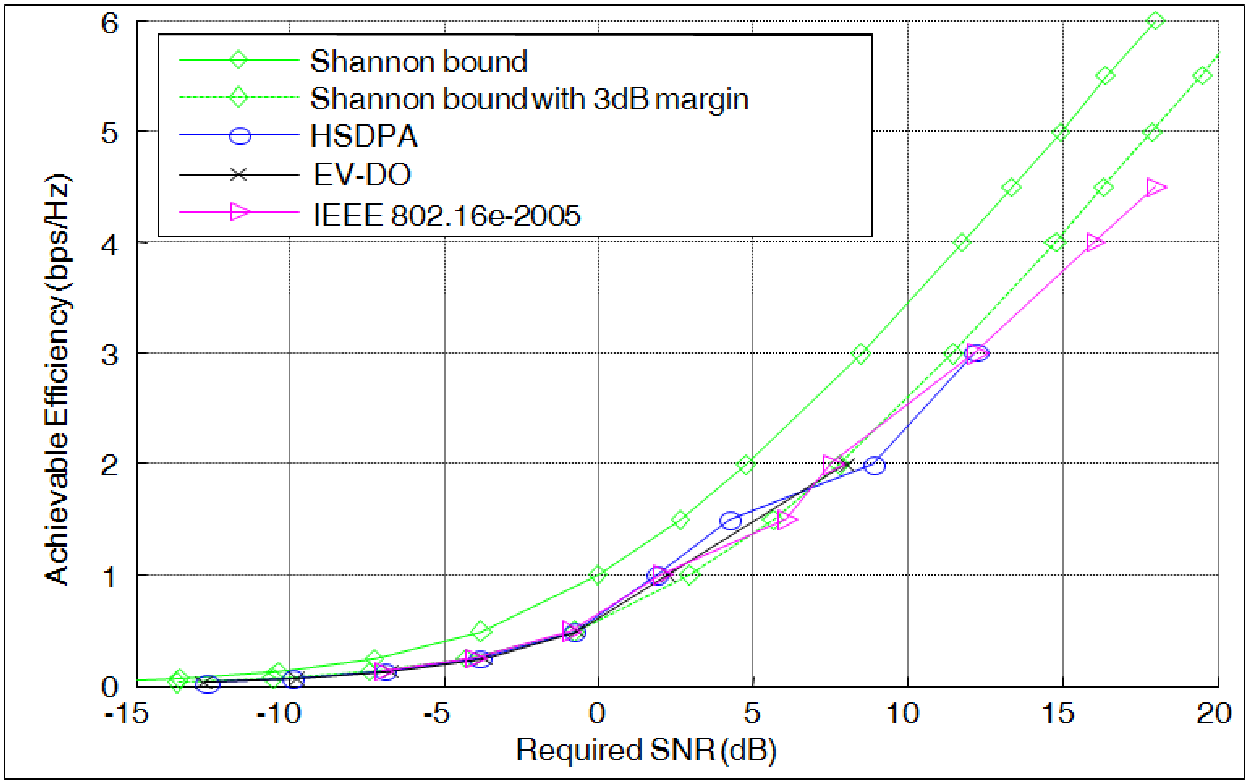

The curves in Figure 40 are for an Additive White Gaussian Noise Channel (AWGN). If the channel is slowly varying and the frame interval is significantly shorter than the coherence time, the effects of fading can be compensated for by practical channel estimation algorithms—thus justifying the AWGN assumption. For instance, at 3 km per hour and fading at 2 GHz, the Doppler spread is about 5.5 Hz. The coherence time of the channel is thus 1 second (sec)/5.5 or 180 msec. Frames are well within the coherence time of the channel, because they are typically 20 msec or less. As such, the channel appears

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[113] 5G Americas member contribution.

“constant” over a frame, and the Shannon bound applies. Furthermore, significantly more of the traffic in a cellular system is at slow speeds (for example, 3 km/hr. or less) rather than at higher speeds. The Shannon bound is consequently also relevant for a realistic deployment environment.

As the speed of the mobile station increases and the channel estimation becomes less accurate, additional margin is needed. This additional margin, however, would impact the different standards fairly equally.

The focus of future technology enhancements is on improving system performance aspects that reduce interference to maximize the experienced SNRs in the system and antenna techniques (such as MIMO) that exploit multiple links or steer the beam rather than on investigating new air interfaces that attempt to improve link-layer performance.

MIMO techniques using spatial multiplexing to increase the overall information transfer rate by a factor proportional to the number of transmit or receive antennas do not violate the Shannon bound because the per-antenna transfer rate (that is, the per-communications link transfer rate) is still limited by the Shannon bound.

Figure 41 compares the spectral efficiency of different wireless technologies based on a consensus view of 5G Americas contributors to this paper. It shows the continuing evolution of the capabilities of all the technologies discussed. The values shown are reasonably representative of real-world conditions. Most simulation results produce values under idealized conditions; as such, some of the values shown are lower (for all technologies) than the values indicated in other papers and publications. For instance, 3GPP studies indicate higher HSPA and LTE spectral efficiencies. Nevertheless, there are practical considerations in implementing technologies that can prevent actual deployments from reaching calculated values. Consequently, initial versions of technology may operate at lower levels but then improve over time as designs are optimized. Therefore, readers should interpret the values shown as achievable, but not as the actual values that might be measured in any specific deployed network.

Figure 41: Comparison of Downlink Spectral Efficiency[114]

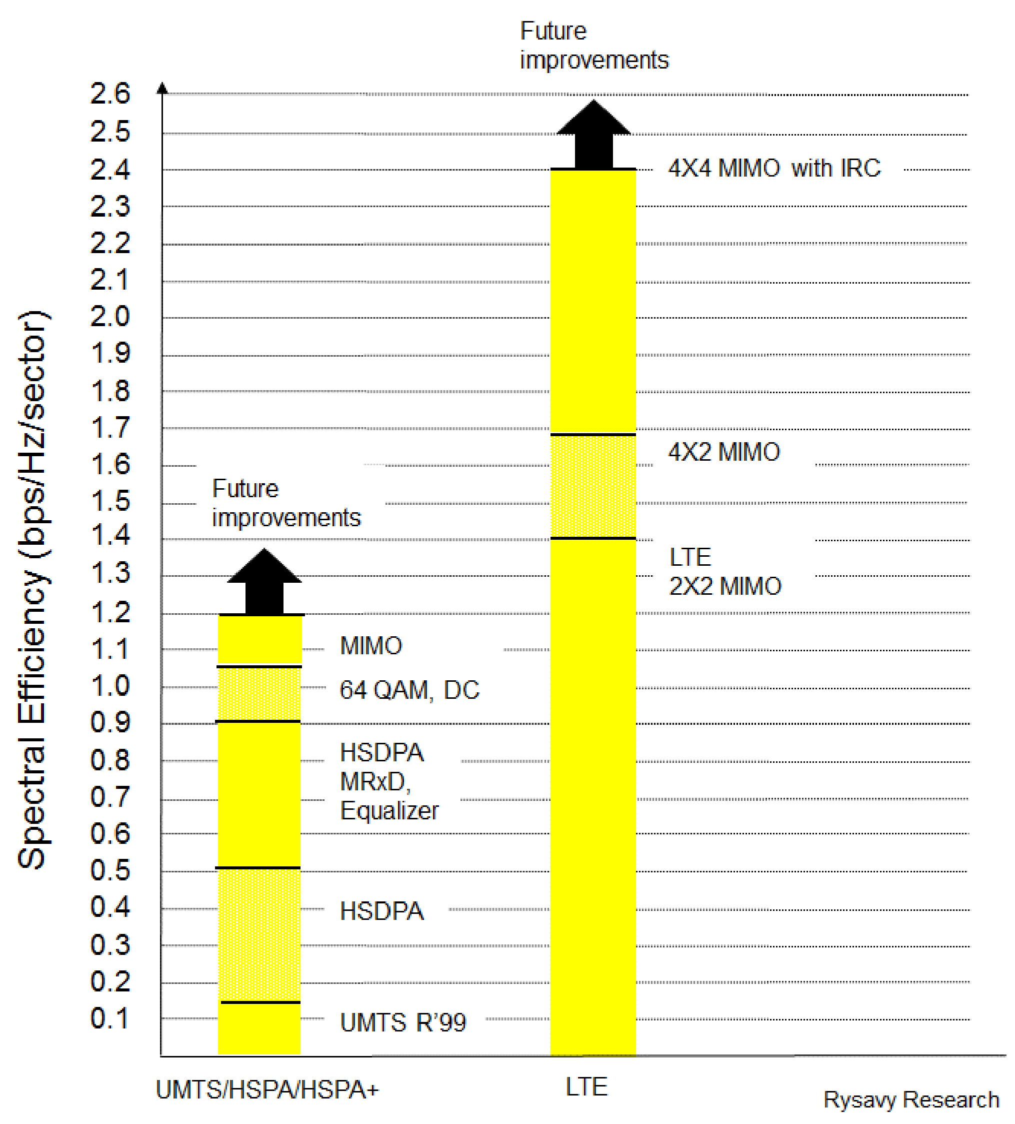

The values shown in Figure 41 are not all possible combinations of available features. Rather, they are representative milestones in ongoing improvements in spectral efficiency. For instance, terminals may employ Mobile Receive Diversity but not equalization.

The figure does not include EDGE, but EDGE itself is spectrally efficient at 0.6 bps/Hz using mobile receive diversity and, potentially, 0.7 bps/Hz with MIMO. Relative to WCDMA Release 99, HSDPA increases capacity by almost a factor of three. Type 3 receivers that include MMSE equalization and Mobile Receive Diversity (MRxD) effectively double HSDPA spectral efficiency. The addition of dual-carrier operation and 64 QAM increases spectral efficiency by about 15%, and MIMO can increase spectral efficiency by another 15%, reaching 1.2 bps/Hz. Dual-carrier HSPA+ offers a gain in spectral efficiency from cross-carrier scheduling with possible gains of about 10%.[115]

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[114] Joint analysis by 5G Americas members. 5+5 MHz FDD for UMTS-HSPA/LTE. Mix of mobile and stationary users.

Some enhancements, such as 64 QAM for HSPA, are simpler to deploy than other enhancements, such as 2X2 MIMO. The former can be done as a software upgrade, whereas the latter requires additional hardware at the base station. Thus, the figure does not necessarily show the actual progression of technologies that operators will deploy to increase spectral efficiency.

Beyond HSPA, 3GPP LTE results in further spectral efficiency gains, initially with 2X2 MIMO, then 4X2 MIMO, and then 4X4 MIMO. The gain for 4X2 MIMO will be 20% more than LTE with 2X2 MIMO; the gain for 4X4 MIMO in combination with interference rejection combining (IRC) will be 70% greater than 2X2 MIMO, reaching 2.4 bps/Hz. This value represents a practical deployment of 4X4 MIMO, with random phase and some timing-alignment error included in each of the four transmit paths. CoMP, discussed below in the appendix, provides a minimal contribution to spectral efficiency.

LTE is even more spectrally efficient when deployed using wider radio channels of 10+10 MHz and 20+20 MHz, although most of the gain is realized at 10+10 MHz. LTE TDD has spectral efficiency that is within 1% or 2% of LTE FDD.[116]

Figure 42 compares the uplink spectral efficiency of the different systems.

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[115] 5G Americas member analysis. Vendor estimates for spectral-efficiency gains from dual-carrier operation range from 5% to 20%. Lower spectral efficiency gains are due to full-buffer traffic assumptions. In more realistic operating scenarios, gains will be significantly higher.

[116] Assumes best-effort traffic. Performance between LTE-TDD and FDD differs for real-time traffic for the following reasons: a.) The maximum number of HARQ process should be made as small as possible to reduce the packet re-transmission latency. b.) In FDD, the maximum number of HARQ process is fixed and, as such, the re-transmission latency is 7ms. c.) For TDD, the maximum number of HARQ process depends on the DL:UL configurations. As an example, the re-transmission latency for TDD config-1 is 9ms. d.) Because of higher re-transmission latency, the capacity of real-time services cannot be scaled for TDD from FDD based on the DL:UL ratio.

Figure 42: Comparison of Uplink Spectral Efficiency[117]

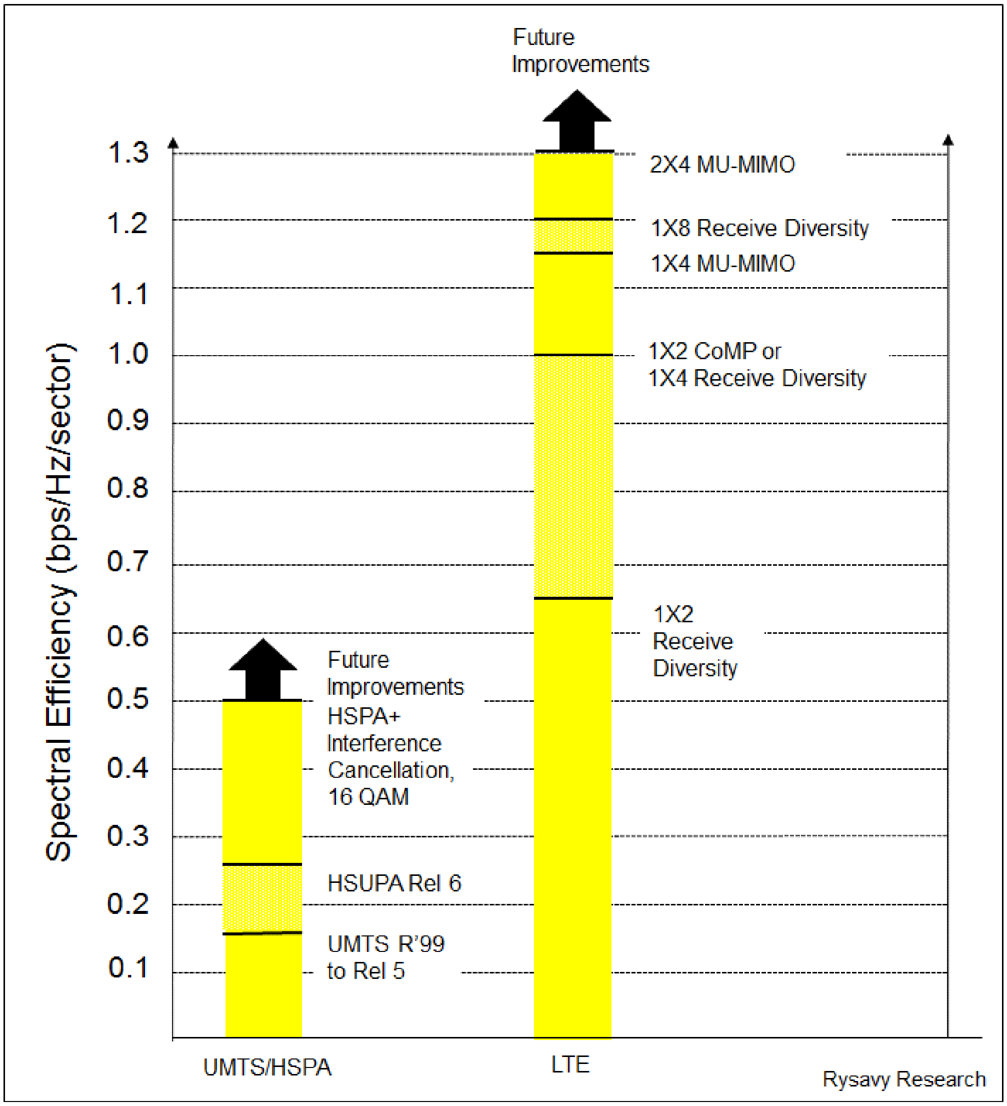

The implementation of HSUPA in HSPA significantly increases uplink capacity.

With LTE, spectral efficiency increases by use of receive diversity. Initial systems will employ 1X2 receive diversity (two antennas at the base station). 1X4 diversity will increase spectral efficiency by 50%, to 1.0 bps/Hz, and 1X8 diversity will provide a further 20% increase, from 1.0 bps/Hz to 1.2 bps/Hz.

It is also possible to employ Multi-User MIMO (MU-MIMO), which allows simultaneous transmission by multiple users on the same physical uplink resource to increase spectral efficiency. MU-MIMO will provide a 15% to 20% spectral efficiency gain, with actual increases depending on how well link adaptation is implemented. The figure uses a conservative 15% gain, showing MU-MIMO with a 1X4 antenna configuration increasing spectral efficiency by 15%, to 1.15 bps/Hz, and 2X4 MU-MIMO a further 15%, to 1.3 bps/Hz.

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[117] Joint analysis by 5G Americas members. 5+5 MHz for UMTS-HSPA/LTE. Mix of mobile and stationary users.

In Release 11, uplink CoMP using 1X2 increases efficiency from .65 bps/Hz to 1.0 bps/Hz. Many of the techniques used to improve LTE spectral efficiency can also be applied to HSPA since they are independent of the radio interface.

Figure 43 compares voice spectral efficiency.

Figure 43: Comparison of Voice Spectral Efficiency[118]

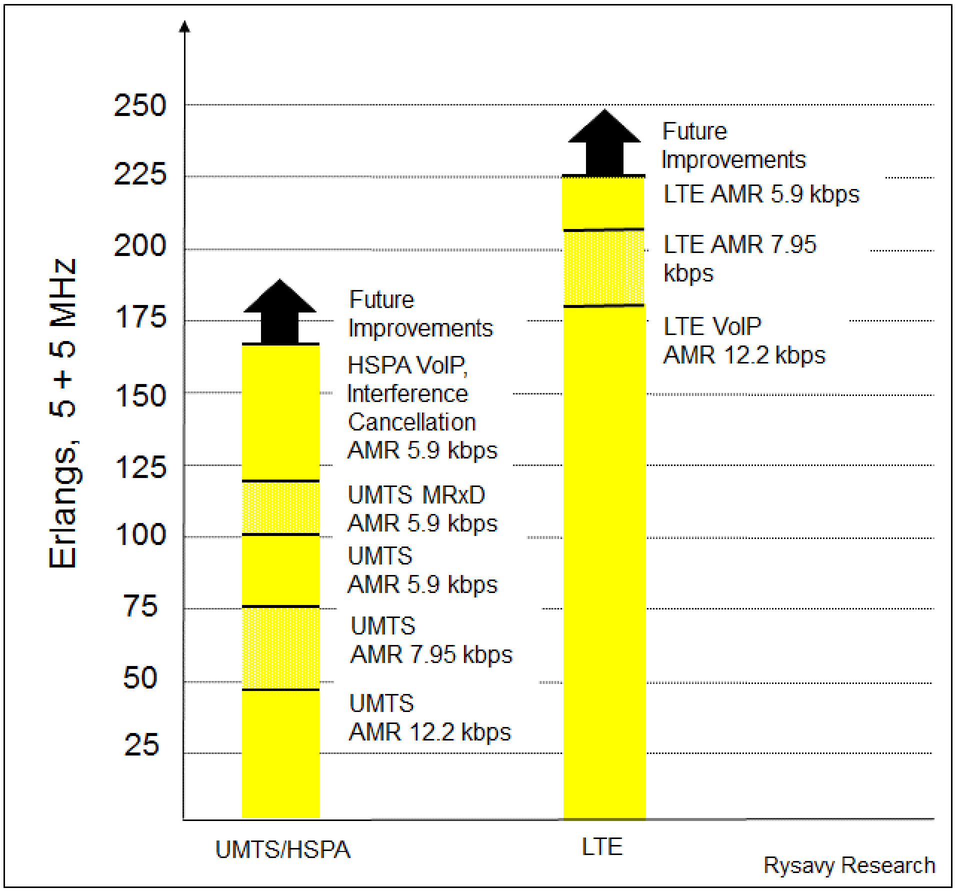

Figure 43 shows UMTS Release 99 with AMR 12.2 Kbps, 7.95 Kbps, and 5.9 Kbps vocoders. The AMR 12.2 Kbps vocoder provides superior voice quality in good (for example, static and indoor) channel conditions.

UMTS has dynamic adaptation between vocoder rates, enabling enhanced voice quality compared with EVRC at the expense of capacity in situations that are not capacity limited. With the addition of mobile receive diversity, UMTS circuit-switched voice capacity could reach 120 Erlangs in 5+5 MHz.

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[118] Joint analysis by 5G Americas members. 5 + 5 MHz for UMTS-HSPA/LTE. Mix of mobile and stationary users.

VoIP Erlangs in this paper are defined as the average number of concurrent VoIP users that can be supported over a defined period of time (often one hour) assuming a Poisson arrival process and meeting a specified outage criteria (often less than 2% of the users exhibiting greater than 1% frame-error rate). Depending on the specific enhancements implemented, voice capacity could double over existing circuit-switched systems. These gains do not derive through use of VoIP, but rather from advances in radio techniques applied to the data channels. Many of these same advances may also be applied to current circuit-switched modes.

LTE achieves very high voice spectral efficiency because of better uplink performance since there is no in-cell interference. The figure shows LTE VoIP spectral efficiency using AMR at 12.2 Kbps, 7.95 Kbps, and 5.9 Kbps.

VoIP for LTE can use a variety of codecs. The figures show performance assuming specific codecs at representative bit rates. For Enhanced Variable Rate Codecs (EVRCs), the figure shows the average bit rate.

The voice efficiency of the wideband AMR voice codec, operating at 12.65 Kbps, is similar to the AMR codec at 12.2 Kbps, with a value of 180 Erlangs for both since both codecs operate at approximately the same bit rate. 1xRTT has voice capacity of 85 Erlangs in 5+5 MHz with EVRC-A and reaches voice capacity of 120 Erlangs with the use of Quasi-Linear Interference Cancellation (QLIC) and EVRC-B at 6 Kbps.

Data Consumed by Streaming and Virtual Reality

Table 15 quantifies usage based on advanced video compression schemes such as H.264 and H.265, the type of application, and usage per day.

Table 15: Data Consumed by Streaming and Virtual Reality[119]

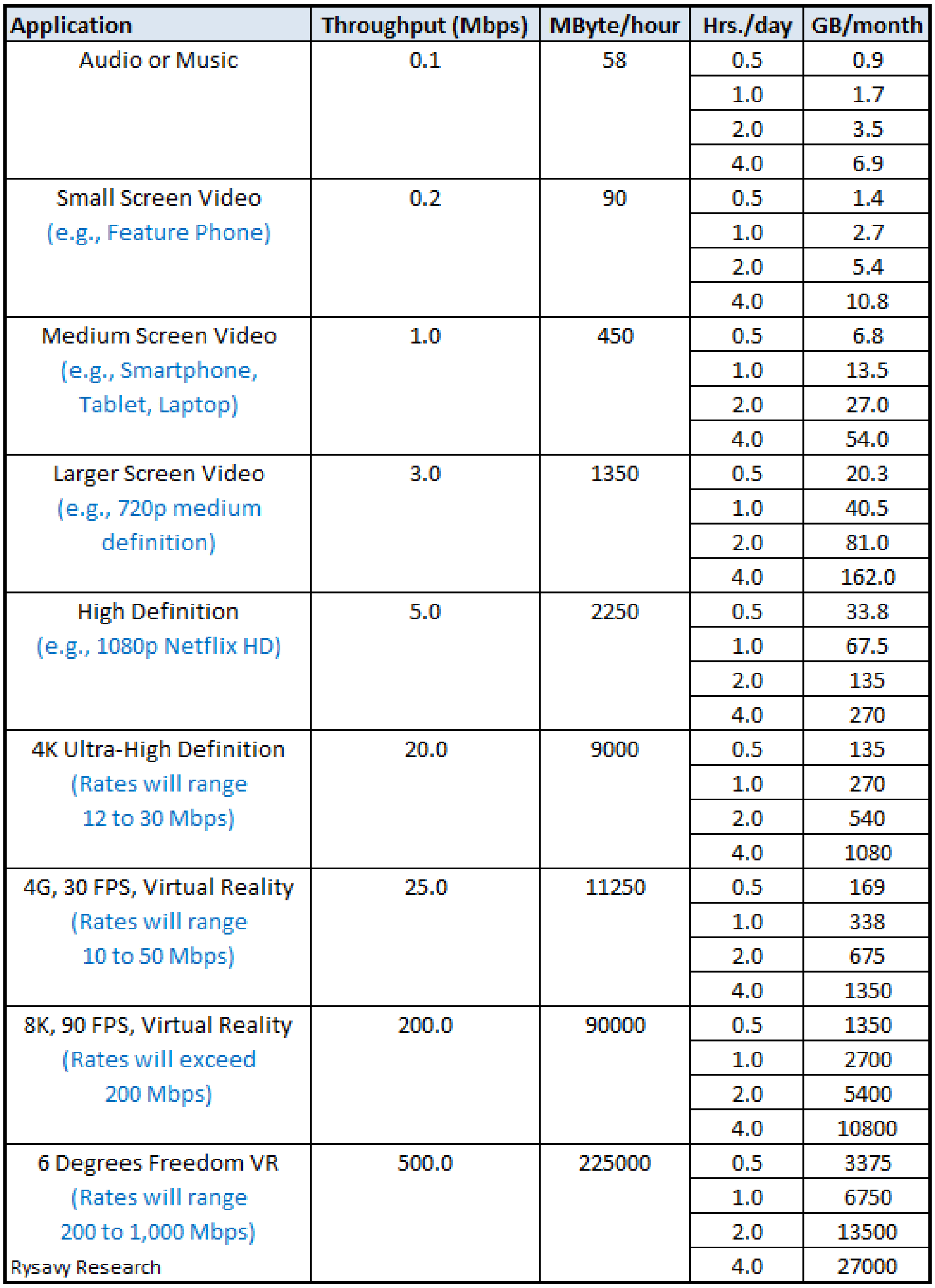

Application	Throughput (Mbps)	MByte/hour	Hrs./day	GB/month
Audio or Music	0.1	58	0.5	0.9
			1.0	1.7
			2.0	3.5
			4.0	6.9
Small Screen Video (e.g., Feature Phone)	0.2	90	0.5	1.4
			1.0	2.7
			2.0	5.4
			4.0	10.8
Medium Screen Video (e.g., Smartphone, Tablet, Laptop)	1.0	450	0.5	6.8
			1.0	13.5
			2.0	27.0
			4.0	54.0
Larger Screen Video (e.g., 720p medium definition)	3.0	1350	0.5	20.3
			1.0	40.5
			2.0	81.0
			4.0	162.0
High Definition (e.g., 1080p Netflix HD)	5.0	2250	0.5	33.8
			1.0	67.5
			2.0	135
			4.0	270
4K Ultra-High Definition (Rates will range 12 to 30 Mbps)	20.0	9000	0.5	135
			1.0	270
			2.0	540
			4.0	1080
4G, 30 FPS, Virtual Reality (Rates will range 10 to 50 Mbps)	25.0	11250	0.5	169
			1.0	338
			2.0	675
			4.0	1350
8K, 90 FPS, Virtual Reality (Rates will exceed 200 Mbps)	200.0	90000	0.5	1350
			1.0	2700
			2.0	5400
			4.0	10800
6 Degrees Freedom VR (Rates will range 200 to 1,000 Mbps)	500.0	225000	0.5	3375
			1.0	6750
			2.0	13500
			4.0	27000

Rysavy Research

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[119] Rysavy Research analysis. For virtual reality-data requirements, refer to ABI Research/Qualcomm, *Augmented and Virtual Reality: the First Wave of 5G Killer Apps*, 2017. See also Netflix discussion of usage, "How can I control how much data Netflix uses?" https://help.netflix.com/en/node/87. Viewed May 3, 2016.

Spectrum Bands

3GPP technologies operate in a wide range of radio bands. As new spectrum becomes available, 3GPP updates its specifications for these bands. Although the support of a new frequency band may be introduced in a particular release, 3GPP specifies ways to implement devices and infrastructure operating on any frequency band, according to releases previous to the introduction of that particular frequency band. For example, although band 5 (US Cellular Band) was introduced in Release 6, the first devices operating on this band were compliant with the release 5 of the standard.

Table 16 shows the UMTS FDD bands.

Table 16: UMTS FDD Bands[120]

Operating Band	UL Frequencies UE Transmit, Node B Receive	DL Frequencies UE Receive, Node B Transmit
I	1920 - 1980 MHz	2110 -2170 MHz
II	1850 -1910 MHz	1930 -1990 MHz
III	1710-1785 MHz	1805-1880 MHz
IV	1710-1755 MHz	2110-2155 MHz
V	824 - 849MHz	869-894MHz
VI	830-840 MHz	875-885 MHz
VII	2500 - 2570 MHz	2620 - 2690 MHz
VIII	880 - 915 MHz	925 - 960 MHz
IX	1749.9 - 1784.9 MHz	1844.9 - 1879.9 MHz
X	1710-1770 MHz	2110-2170 MHz
XI	1427.9 - 1447.9 MHz	1475.9 - 1495.9 MHz
XII	699 - 716 MHz	729 - 746 MHz
XIII	777 - 787 MHz	746 - 756 MHz
XIV	788 - 798 MHz	758 - 768 MHz
XV	Reserved	Reserved
XVI	Reserved	Reserved
XVII	Reserved	Reserved
XVIII	Reserved	Reserved
XIX	830 – 845 MHz	875 -890 MHz
XX	832 - 862 MHz	791 - 821 MHz
XXI	1447.9 - 1462.9 MHz	1495.9 - 1510.9 MHz
XXII	3410 – 3490 MHz	3510 – 3590 MHz
XXV	1850 -1915 MHz	1930 -1995 MHz
XXVI	814-849 MHz	859-894 MHz
XXXII (NOTE 1)	N/A	1452 – 1496 MHz
NOTE 1: Restricted to UTRA operation when dual-band is configured (e.g., DB-DC-HSDPA or dual band 4C-HSDPA). The down link frequenc(ies) of this band are paired with the uplink frequenc(ies) of the other FDD band (external) of the dual band configuration.		

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[120] 3GPP, *Base Station (BS) radio transmission and reception (FDD) (Release 14)*, December 2016, Technical Specification 25.104, V14.1.0.

Universal Mobile Telecommunications System (UMTS) Time Division Duplex (TDD) bands are the same as the LTE TDD bands. Table 17 details the LTE Frequency Division Duplex (FDD) and TDD bands.

Table 17: LTE FDD and TDD bands[121]

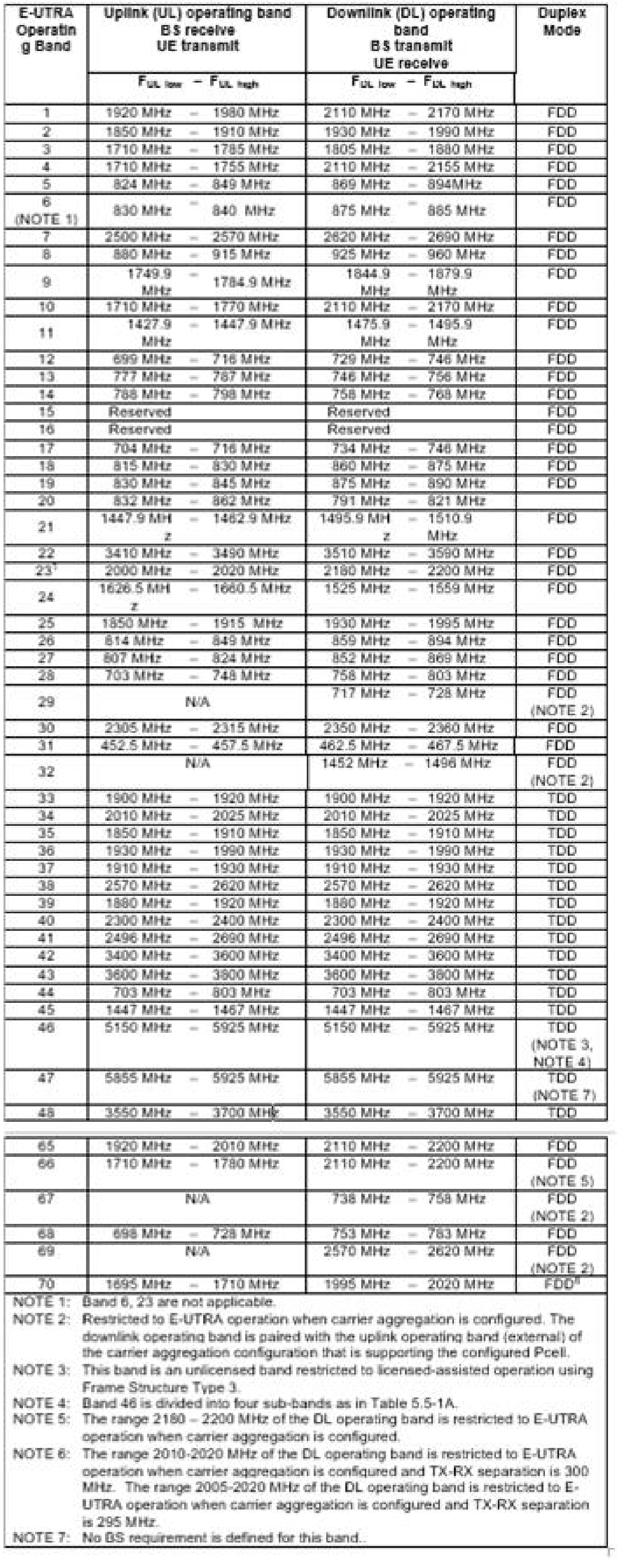

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Duplex Mode
	$F_{UL\ low}$ – $F_{UL\ high}$	$F_{DL\ low}$ – $F_{DL\ high}$	
1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
4	1710 MHz – 1755 MHz	2110 MHz – 2155 MHz	FDD
5	824 MHz – 849 MHz	869 MHz – 894MHz	FDD
6 (NOTE 1)	830 MHz – 840 MHz	875 MHz – 885 MHz	FDD
7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
9	1749.9 MHz – 1784.9 MHz	1844.9 MHz – 1879.9 MHz	FDD
10	1710 MHz – 1770 MHz	2110 MHz – 2170 MHz	FDD
11	1427.9 MHz – 1447.9 MHz	1475.9 MHz – 1495.9 MHz	FDD
12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
13	777 MHz – 787 MHz	746 MHz – 756 MHz	FDD
14	788 MHz – 798 MHz	758 MHz – 768 MHz	FDD
15	Reserved	Reserved	FDD
16	Reserved	Reserved	FDD
17	704 MHz – 716 MHz	734 MHz – 746 MHz	FDD
18	815 MHz – 830 MHz	860 MHz – 875 MHz	FDD
19	830 MHz – 845 MHz	875 MHz – 890 MHz	FDD
20	832 MHz – 862 MHz	791 MHz – 821 MHz	
21	1447.9 MHz – 1462.9 MHz	1495.9 MHz – 1510.9 MHz	FDD
22	3410 MHz – 3490 MHz	3510 MHz – 3590 MHz	FDD
23[1]	2000 MHz – 2020 MHz	2180 MHz – 2200 MHz	FDD
24	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD
25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
26	814 MHz – 849 MHz	859 MHz – 894 MHz	FDD
27	807 MHz – 824 MHz	852 MHz – 869 MHz	FDD
28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
29	N/A	717 MHz – 728 MHz	FDD (NOTE 2)
30	2305 MHz – 2315 MHz	2350 MHz – 2360 MHz	FDD
31	452.5 MHz – 457.5 MHz	462.5 MHz – 467.5 MHz	FDD
32	N/A	1452 MHz – 1496 MHz	FDD (NOTE 2)
33	1900 MHz – 1920 MHz	1900 MHz – 1920 MHz	TDD
34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
35	1850 MHz – 1910 MHz	1850 MHz – 1910 MHz	TDD
36	1930 MHz – 1990 MHz	1930 MHz – 1990 MHz	TDD
37	1910 MHz – 1930 MHz	1910 MHz – 1930 MHz	TDD
38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
42	3400 MHz – 3600 MHz	3400 MHz – 3600 MHz	TDD
43	3600 MHz – 3800 MHz	3600 MHz – 3800 MHz	TDD
44	703 MHz – 803 MHz	703 MHz – 803 MHz	TDD
45	1447 MHz – 1467 MHz	1447 MHz – 1467 MHz	TDD
46	5150 MHz – 5925 MHz	5150 MHz – 5925 MHz	TDD (NOTE 3, NOTE 4)
47	5855 MHz – 5925 MHz	5855 MHz – 5925 MHz	TDD (NOTE 7)
48	3550 MHz – 3700 MHz	3550 MHz – 3700 MHz	TDD
65	1920 MHz – 2010 MHz	2110 MHz – 2200 MHz	FDD
66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD (NOTE 5)
67	N/A	738 MHz – 758 MHz	FDD (NOTE 2)
68	698 MHz – 728 MHz	753 MHz – 783 MHz	FDD
69	N/A	2570 MHz – 2620 MHz	FDD (NOTE 2)
70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD[6]

NOTE 1: Band 6, 23 are not applicable.

NOTE 2: Restricted to E-UTRA operation when carrier aggregation is configured. The downlink operating band is paired with the uplink operating band (external) of the carrier aggregation configuration that is supporting the configured Pcell.

NOTE 3: This band is an unlicensed band restricted to licensed-assisted operation using Frame Structure Type 3.

NOTE 4: Band 46 is divided into four sub-bands as in Table 5.5-1A.

NOTE 5: The range 2180 – 2200 MHz of the DL operating band is restricted to E-UTRA operation when carrier aggregation is configured.

NOTE 6: The range 2010-2020 MHz of the DL operating band is restricted to E-UTRA operation when carrier aggregation is configured and TX-RX separation is 300 MHz. The range 2005-2020 MHz of the DL operating band is restricted to E-UTRA operation when carrier aggregation is configured and TX-RX separation is 295 MHz.

NOTE 7: No BS requirement is defined for this band..

5G

This section provides early details on aspects of 5G, including architecture, LTE-NR coexistence, integrated access and backhaul, and performance.

Architecture

The overall 5G architecture consists of what 3GPP calls the New Generation Radio-Access Network (NG-RAN) and the 5G Core (5GC), as shown in Figure 44. The figure shows the Access and Mobility Management Function (AMF); the User Plane Function (UPF); the NR NodeB (gNB), which is the 5G base station; and the NG and Xn interfaces.

Figure 44: 5G Architecture[122]

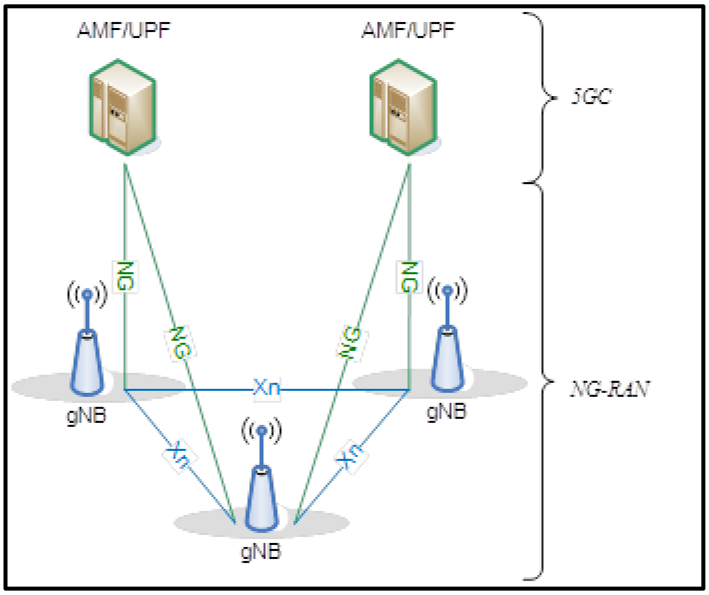

Figure 45 shows the functional split between the NG-RAN and 5GC.

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[121] 3GPP, *Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (Release 14)*, March 2017, Technical Specification 36.104, V14.3.0.

[122] 3GPP, *3GPP TS 38.300, NR; NR and NG-RAN Overall Description; Stage 2 (Release 15), V0.3.0 (2017-05).*

Figure 45: Functional Split between NG-RAN and 5GC[123]

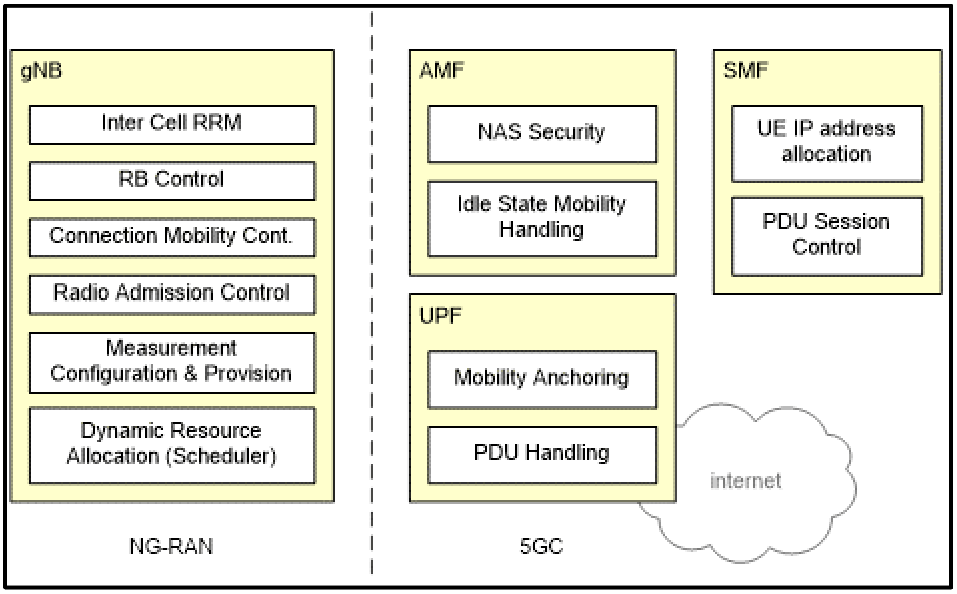
gNB
Inter Cell RRM
RB Control
Connection Mobility Cont.
Radio Admission Control
Measurement Configuration & Provision
Dynamic Resource Allocation (Scheduler)
AMF
NAS Security
Idle State Mobility Handling
SMF
UE IP address allocation
PDU Session Control
UPF
Mobility Anchoring
PDU Handling
internet
NG-RAN
5GC

The main body of this paper summarizes the features being specified in Releases 15 and 16 for NR and the core network. Additional capabilities that will be part of Release 15 include:

- A PDCP packet duplication function to allow redundant transmission of signaling or user data on two bearer paths.
- A new protocol layer called Service Data Adaptation Protocol (SDAP) that offers 5GC QoS flows.
- A new Radio Resource Control (RRC) inactive state designed for low-latency communications.
- A new system information broadcast model that allows on-demand system information instead of always having to broadcast system information (to reduce overhead in 5G beam sweeping).

Architecture Options

This topic was introduced in the main part of the paper and is covered here in more detail. In Release 15, 3GPP defines a number of different architecture options, shown in the following three figures. In many of these options, although not all, the 5G network integrates with LTE.

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[123] Ibid.

Figure 46: 5G Network Architecture Options in 3GPP Release 15[124]

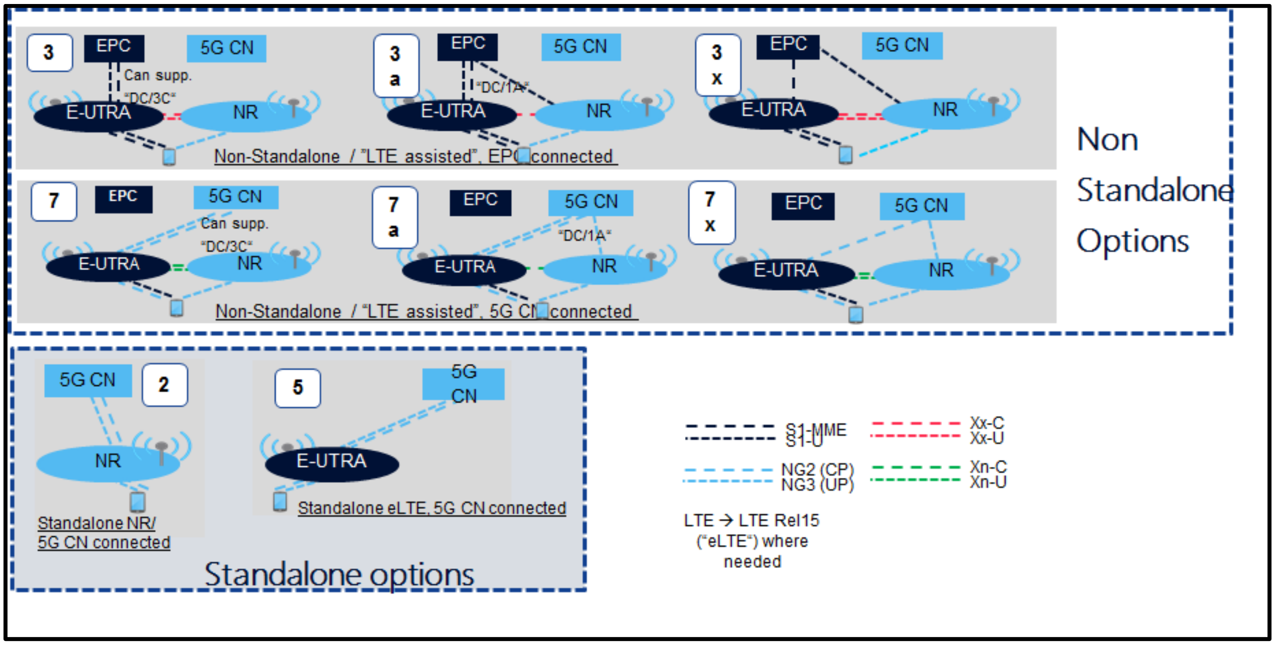
3
EPC
5G CN
Can supp. "DC/3C"
E-UTRA
NR
3a
"DC/1A"
3x
Non-Standalone / "LTE assisted", EPC connected
7
7a
7x
Non-Standalone / "LTE assisted", 5G CN connected
Non Standalone Options
2
Standalone NR/ 5G CN connected
5
Standalone eLTE, 5G CN connected
Standalone options
S1-MME
S1-U
Xx-C
Xx-U
NG2 (CP)
NG3 (UP)
Xn-C
Xn-U
LTE → LTE Rel15 ("eLTE") where needed

Figure 47: De-Prioritized 5G Network Architecture Options in 3GPP Release 15

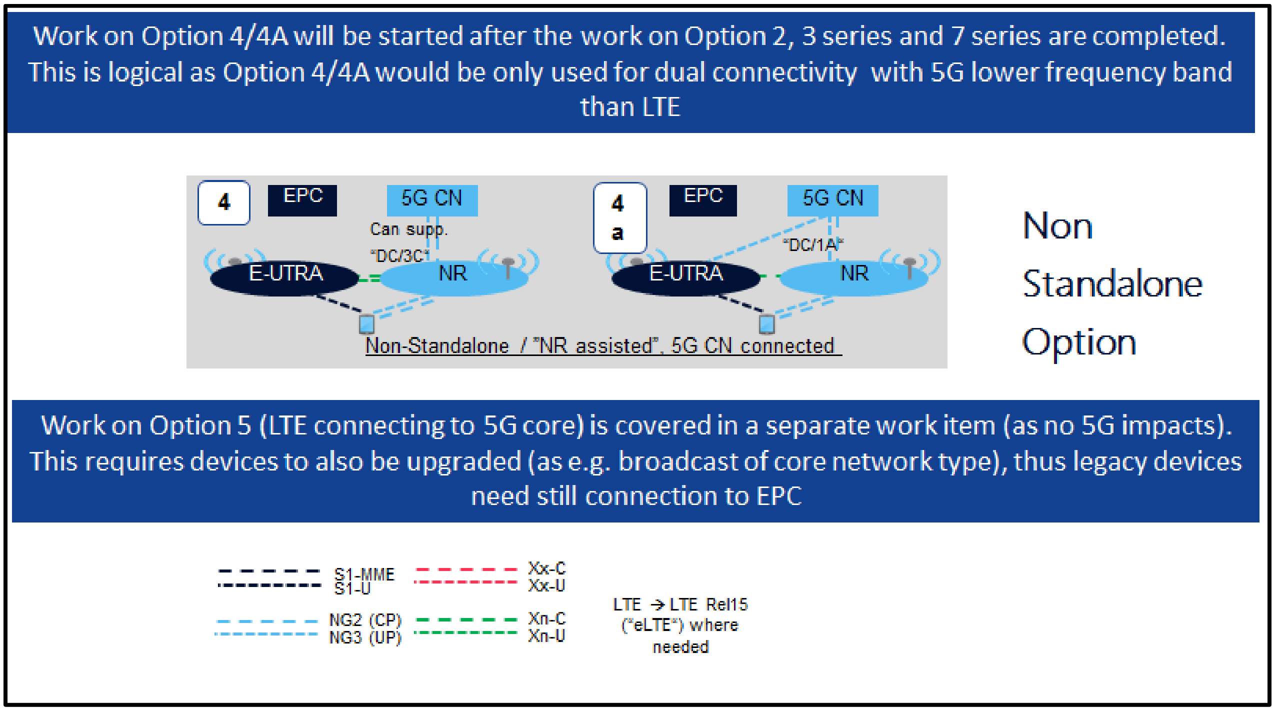
Work on Option 4/4A will be started after the work on Option 2, 3 series and 7 series are completed. This is logical as Option 4/4A would be only used for dual connectivity with 5G lower frequency band than LTE

Work on Option 5 (LTE connecting to 5G core) is covered in a separate work item (as no 5G impacts). This requires devices to also be upgraded (as e.g. broadcast of core network type), thus legacy devices need still connection to EPC

4
EPC
5G CN
Can supp. "DC/3C"
E-UTRA
NR
4a
"DC/1A"
Non-Standalone / "NR assisted", 5G CN connected
Non Standalone Option
S1-MME
S1-U
Xx-C
Xx-U
NG2 (CP)
NG3 (UP)
Xn-C
Xn-U
LTE → LTE Rel15 ("eLTE") where needed

---

[124] Nokia contribution, including subsequent two figures. For further details, refer to section 7.2, "5G Architecture Options," 3GPP TR 38.801, "Radio access architecture and interfaces."

Figure 48: Dual-Connectivity Options with LTE as Master

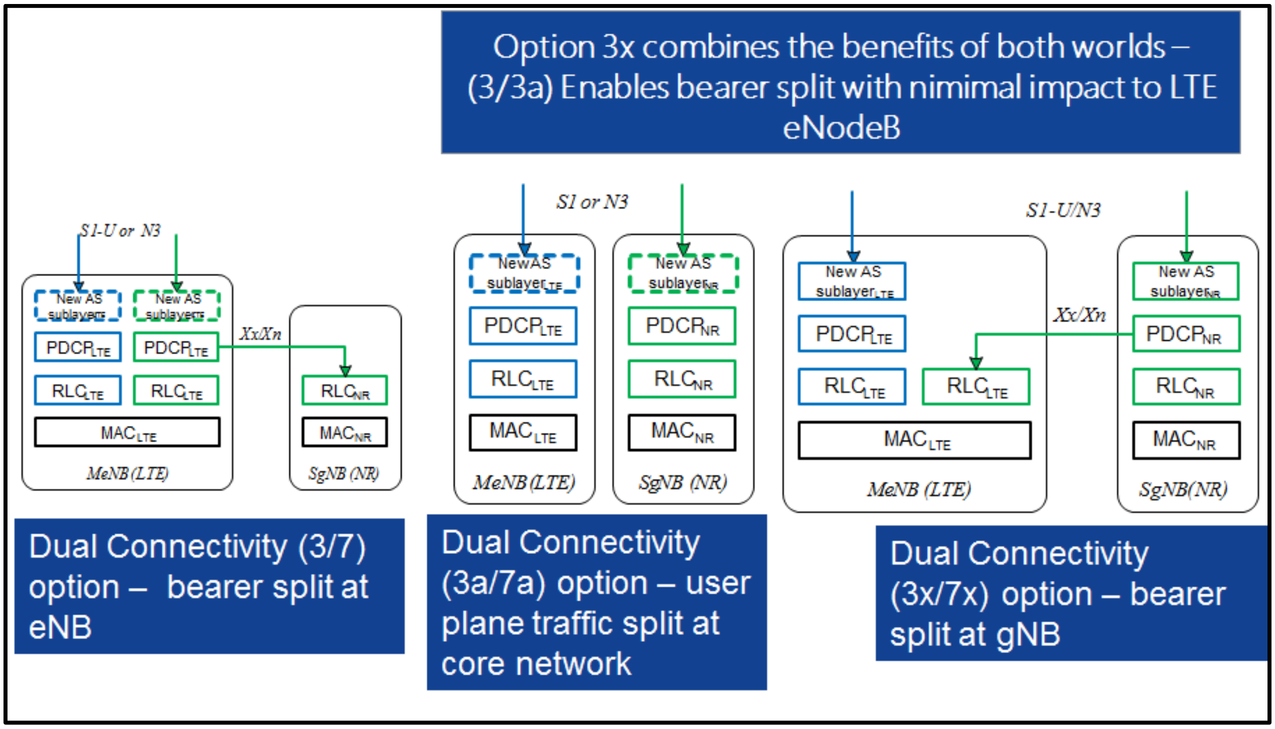

Option 3x combines the benefits of both worlds – (3/3a) Enables bearer split with nimimal impact to LTE eNodeB

S1-U or N3
New AS sublayer$_{\text{LTE}}$
New AS sublayer$_{\text{LTE}}$
PDCP_{LTE}
PDCP_{LTE}
RLC_{LTE}
RLC_{LTE}
MAC_{LTE}
MeNB (LTE)
Xx/Xn
RLC_{NR}
MAC_{NR}
SgNB (NR)
S1 or N3
New AS sublayer$_{\text{LTE}}$
PDCP_{LTE}
RLC_{LTE}
MAC_{LTE}
MeNB (LTE)
New AS sublayer$_{\text{NR}}$
PDCP_{NR}
RLC_{NR}
MAC_{NR}
SgNB (NR)
S1-U/N3
New AS sublayer$_{\text{LTE}}$
PDCP_{LTE}
RLC_{LTE}
RLC_{LTE}
MAC_{LTE}
MeNB (LTE)
Xx/Xn
New AS sublayer$_{\text{NR}}$
PDCP_{NR}
RLC_{NR}
MAC_{NR}
SgNB(NR)

Dual Connectivity (3/7) option – bearer split at eNB

Dual Connectivity (3a/7a) option – user plane traffic split at core network

Dual Connectivity (3x/7x) option – bearer split at gNB

LTE-NR Coexistence

LTE-NR coexistence is a Release 15 work item. This section describes how such co-existence may be achieved. Different LTE-NR co-existence cases include the following: time domain LTE/NR adjacent channel coexistence; LTE Secondary Cell on/off for LTE/NR adaptation; in-carrier LTE+NR coexistence in downlink, and in-carrier LTE+NR coexistence in uplink.

NR coexistence is required for LTE UEs of all releases. Because carrier aggregation was not introduced into LTE until LTE Release 10, CA-based techniques cannot be used as the sole means to achieve LTE/NR coexistence. However, CA techniques can be used for both time domain coexistence and frequency domain coexistence. For time domain coexistence, on a given carrier, LTE and NR are time-multiplexed by means of Secondary Cell (SCell) activation or deactivation. For frequency domain coexistence, the network configures a carrier, such as a 20MHz carrier, into multiple carriers, with, for example, 10MHz allocated to LTE and the remaining 10MHz to NR. Note that frequency domain coexistence can be accomplished without using carrier aggregation.

Figure 49 illustrates the frequency domain technique. Note that when splitting the 20MHz carrier into two allocations of 10MHz, the LTE carrier remains centered at the same frequency and the NR allocation is not consecutive.

Figure 49: Frequency Domain Coexistence of LTE and NR[125]

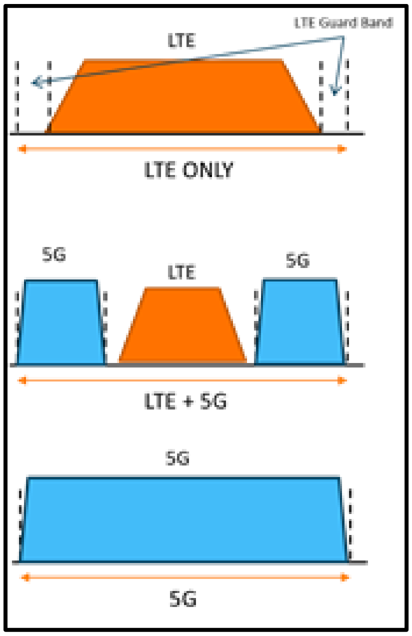

Time Domain LTE/NR Coexistence Techniques

Time domain coexistence of LTE and NR can be dynamic (subframe level) or semi-static (MAC/RRC). In the latter case, spectrum resources are configured as SCell for a LTE UE, and the network can turn these resources on or off by means of SCell activation or deactivation using MAC control elements or by adding and removing the SCell via RRC signaling. Whenever the SCell is deactivated or not configured, the spectrum resources can be used for NR transmissions. In LTE Rel. 12, small-cell enhancements were introduced that allow a UE to measure discovery reference signals (DRS) on a deactivated SCell. In that case, further coordination between LTE and NR may be required even when the SCell is deactivated, as DRS may still be transmitted periodically. Generally, though, this kind of coexistence can be achieved by network implementation.

For the case of dynamic coexistence, LTE and NR co-exist in the same spectrum, and the network can multiplex the two on a subframe level. Because LTE transmits Cell-Specific Reference Signals (CRS) in all DL subframes and in the Downlink Pilot Time Slot (DwPTS) and non-Multicast-Broadcast Single-Frequency network (non-MBSFN) region of special and MBSFN subframes, respectively, dynamic coexistence is not as straightforward as semi-static coexistence.

Similar to the case of time domain coexistence based on CA techniques, whenever OFDM symbols do not carry CRS, coexistence can be achieved by a gNB scheduler implementation. In particular, the gNB can schedule mini-slot-based transmissions in the Uplink Pilot Time Slot (UpPTS) region of a special subframe and in the MBSFN region of an MBSFN subframe, neither of which carry CRS. In LTE UL subframes, the gNB can schedule NR transmissions using either slots or mini-slots. For example, when Sounding Reference Signal (SRS) is transmitted at the end of a subframe, all 14 OFDM symbols may not be available for NR, and mini-slots can be used. Otherwise, slots can be used to transmit NR signals and channels in LTE UL subframes. Even in normal downlink subframes, mini-slots could be used to transmit NR channels and signals on OFDM symbols not carrying CRS. This, however, may leave almost half the resources of a normal DL subframe unusable for NR, so other techniques may be preferable. For example, symbols carrying CRS could also puncture NR transmissions, similar to URLLC transmissions that pre-empt NR transmissions. The same mechanisms specified for eMBB/URLLC coexistence could be used for LTE/NR coexistence.

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[125] AT&T contribution, including explanatory text.

Frequency Domain LTE/NR Coexistence Techniques

Frequency domain coexistence between LTE and NR can also be dynamic or semi-static. Semi-static FDM-based coexistence is illustrated in Figure 49. Dynamic frequency domain coexistence is possible when the (e/g) NB schedules both LTE and NR in the same subframe on a Physical Resource Block (PRB) level.

There also exists the possibility of mixing semi-static and dynamic schemes as well as time division multiplexing (TDM)- and frequency division multiplexing (FDM)-based schemes based on the duplex direction. UL resources could be dynamically shared in a TDM fashion, whereas DL resources would be semi-statically configured and frequency division multiplexed between LTE and NR. For example, LTE could operate in paired spectrum, and NR could use LTE UL resources for NR UL transmissions but be configured with a separate DL or dynamic TDD carrier, such as at a higher frequency band. In this scenario, the LTE DL would be semi-statically frequency division multiplexed with NR, but LTE UL resources would need to be dynamically shared between LTE and NR. The semi-statically frequency division multiplexed NR resources could be for DL only or for both DL and UL. For example, it could be beneficial to allow for NR SRS transmissions on the frequency division multiplexed NR-only carrier.

Several issues need to be addressed for the shared LTE UL carrier. For example, if the non-shared NR carrier operates in mmWave spectrum while the shared NR/LTE carrier operates below 6GHz, the UE does not receive NR DL signals that can be used for power control and timing advance of the NR UL transmissions in the shared LTE UL resources. In this case, NR signals may have to be sent in the LTE-only DL resources or, alternatively, the NR-only UE needs to receive and process LTE signals in the LTE-only DL carrier. To avoid NR UEs processing LTE signals or LTE eNBs transmitting NR signals, 3GPP will need to investigate whether the aforementioned problem could be solved by signaling mechanisms. Regardless, further studies are needed to address these issues.

Coordination Requirements for LTE/NR Coexistence

While semi-static techniques identified for coexistence may require minimal coordination, dynamic (for example, per-TTI) sharing can be done by coordinating the LTE and NR transmissions via three different mechanisms:

1. Co-locating the NR and LTE scheduling.
2. Via the X2 interface (or the evolved version of the X2 interface in the new RAN architecture).
3. Over-the-air.

Options 1 and 2 do not impact any RAN1 specification, whereas Option 3 requires RAN1 specifications. Also, over-the-air coordination is desirable because it does not require LTE and NR scheduling and transmission to be handled by a single eNodeB, nor does it require an ultra-low-latency transport between them, thereby providing much more deployment flexibility. This can even allow NR and LTE to be deployed on different tiers (for example, macro and pico) and share the same channel.

Integrated Access and Backhaul

A study item for Release 15 with the likelihood of standardization in Release 16 is integrated access and backhaul, with which the 5G radio can provide both access and backhaul functions, as shown in Figure 50.

Figure 50: 5G Integrated Access and Backhaul

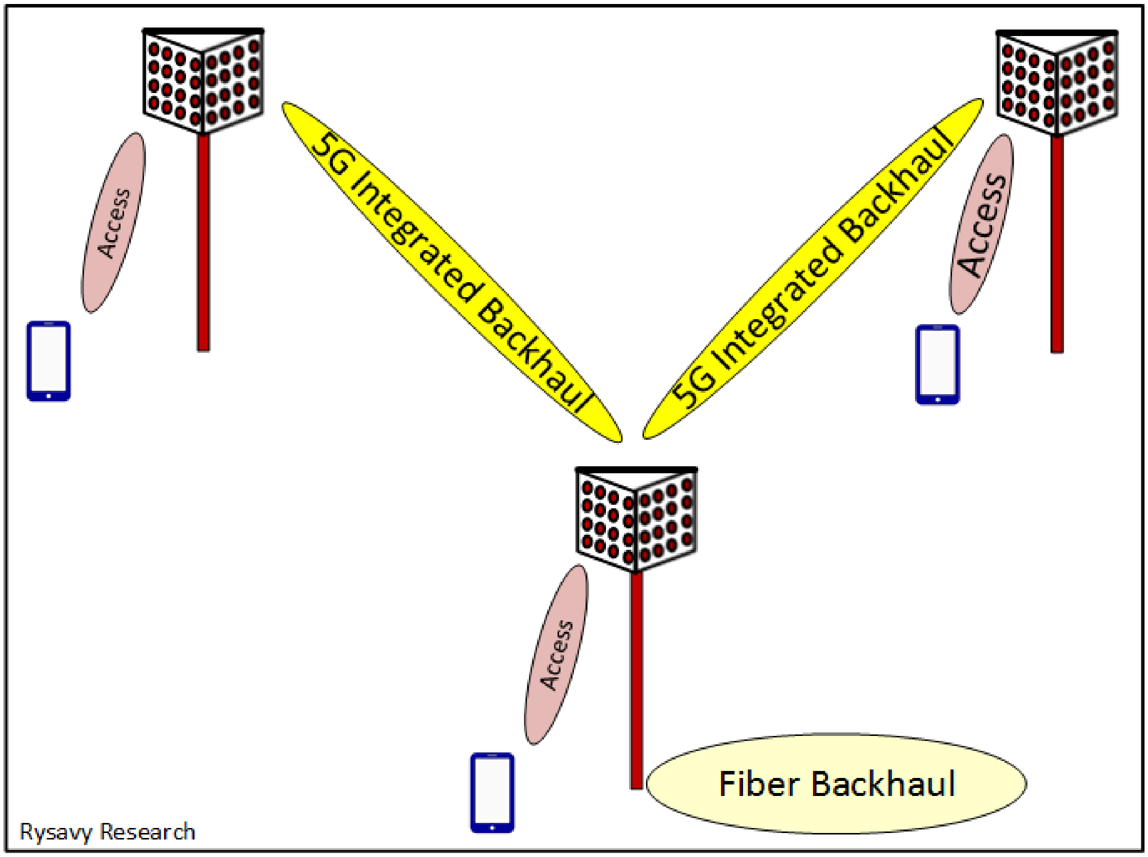

This 3GPP Study item, which has not yet begun, could address the following capabilities:[126]

- ❑ Wireless backhaul using 5G or LTE.
- ❑ Both indoor and outdoor scenarios.
- ❑ Flexible partitioning between access and backhaul functions.
- ❑ Autonomous configuration of access and wireless self-backhaul functions.
- ❑ Multi-hop wireless self-backhauling to enable flexible extension of range and coverage area.

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[126] 3GPP, "Study on Integrated Access and Backhaul for NR," RP-170831, March 2017.

- ☐ Autonomous adaptation on wireless self-backhaul to minimize service disruptions.
- ☐ Topological redundant connectivity on the wireless self-backhaul to enhance reliability and capacity and to reduce latency.

Performance

5G, with the ability to use wider radio channels than LTE, will be able to deliver much higher peak and average speeds, with initial estimates listed above in the section, “Data Throughput Comparison.” In the absence of deployed networks to measure, companies have performed simulations, concentrating initially on one of the first uses cases of fixed wireless access.

Figure 51 shows downlink performance for a network using different base station ISDs, and with and without foliage. The Nokia simulation used base stations with 512 antenna elements, outdoor-mounted user equipment, 28 GHz, and an 800-MHz radio channel, mostly allocated to the downlink.

Figure 51: Downlink Performance, Different ISDs, Foliage vs. None[127]

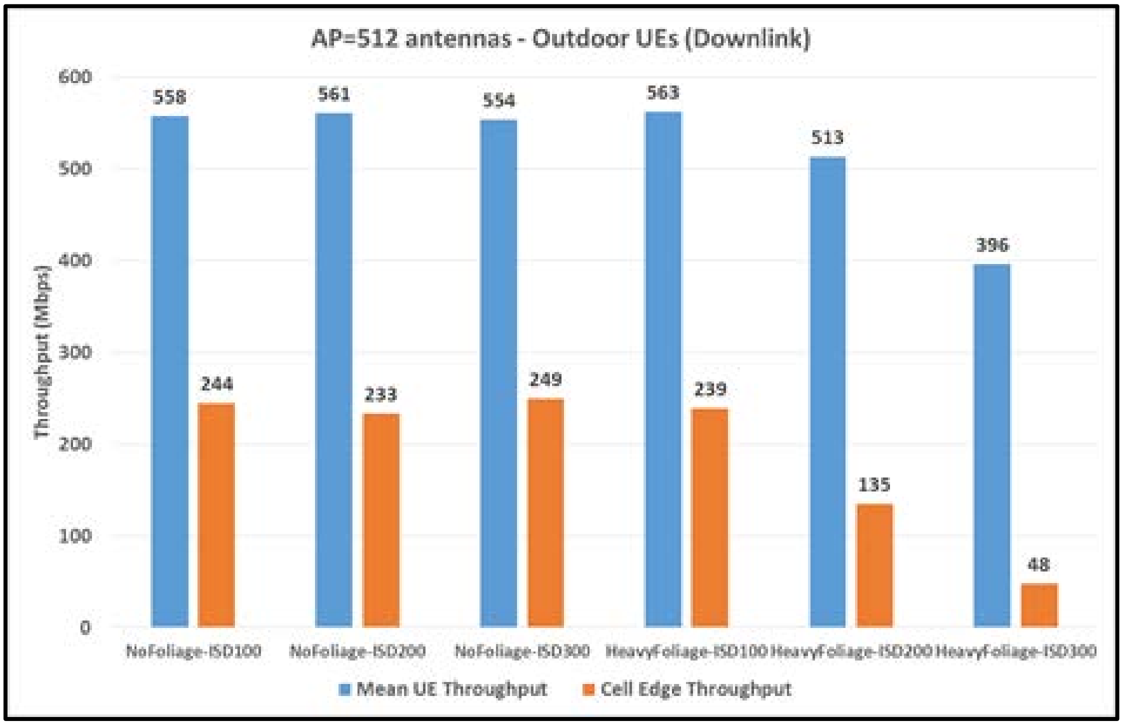

The conclusion of this simulation is that a minimum performance of 100 Mbps at the cell-edge, a 5G objective, is possible at ISDs up to 200 meters, with and without foliage.

The following three figures are from another simulation study by Ericsson, this one also for fixed-wireless access, with the following key assumptions: 350-meter ISD, 96-antenna base stations, 200 MHz radio channels, 57% allocated to downlink, 1000 homes per sq.

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[127] Nokia contribution. For a full discussion, refer to the associated paper by Frederick W. Vook, Eugene Visotsky, Timothy A. Thomas, and Amitava Ghosh, Nokia Bell Labs, *Performance Characteristics of 5G mmWave Wireless-to-the-Home*, available at http://ieeexplore.ieee.org/document/7869558/.

km., 25% of homes using 4K UHD video service at 15 Mbps, building heights of 4 to 10 meters, and trees from 5 to 15 meters.

Figure 52 shows the throughputs available across the coverage area, with many locations able to receive close to 1 Gbps.

Figure 52: Throughput Map of Suburban Area at Low Load[128]

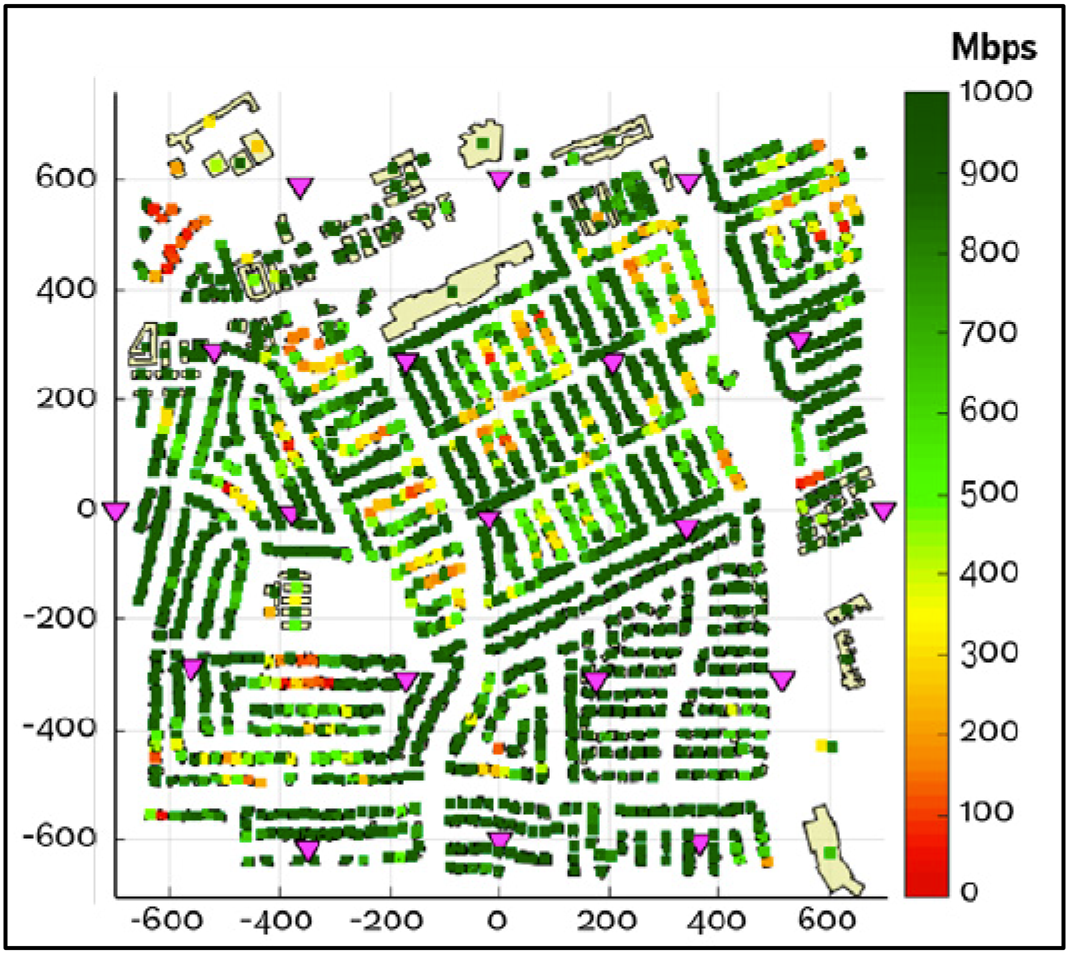
Mbps
1000
900
800
700
600
500
400
300
200
100
0
600
400
200
0
-200
-400
-600
-600
-400
-200
0
200
400
600

Figure 53 shows the proportion of users that can obtain 15 Mbps and 100 Mbps service relative to monthly traffic volume. Note that the system supports thousands of GBs of service per subscriber per month.

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[128] Ericsson contribution, Ericsson Technical Review, *5G and Fixed Wireless Access*, 2016, available at https://www.ericsson.com/assets/local/publications/ericsson-technology-review/docs/2016/etr-5g-and-fixed-wireless-access.pdf.

Figure 53: Proportion of Satisfied Users Relative to Monthly Usage[129]

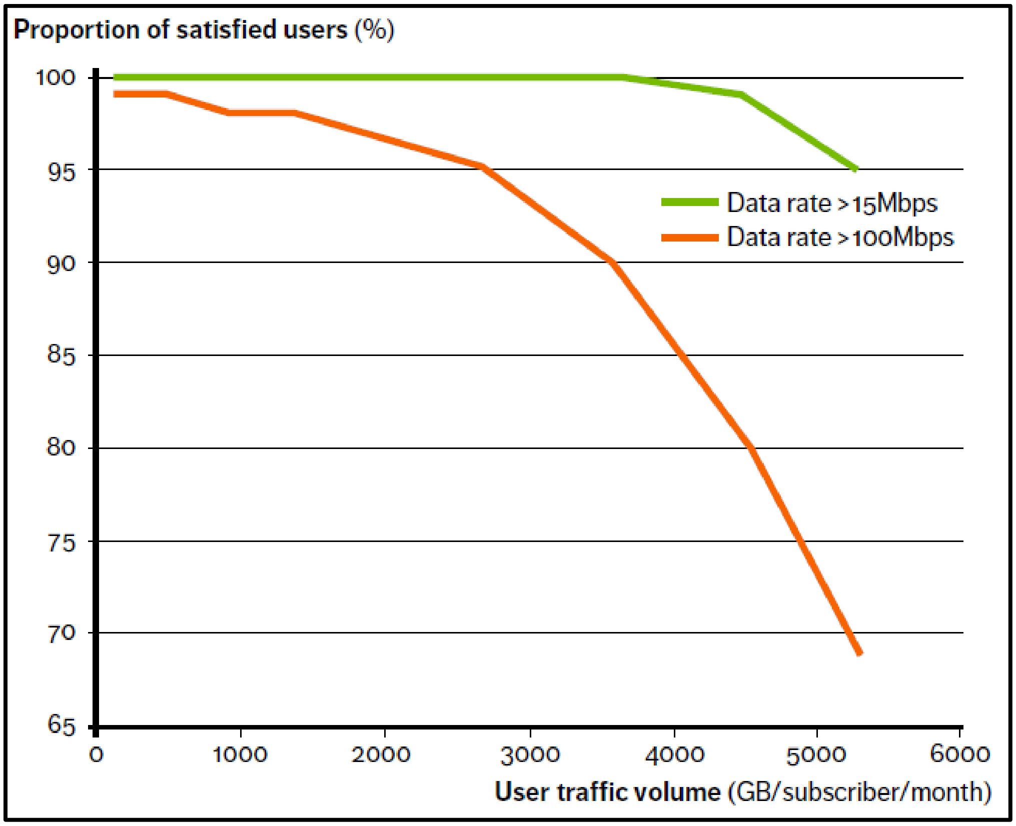

Figure 54 shows that an ISD of 350 can be used with a combination of indoor, wall-mounted, and rooftop antennas. A large percentage of users, 78%, can use indoor antennas, facilitating deployment.

Figure 54: Breakdown of Indoor, Wall-Mounted, and Rooftop Antennas[130]

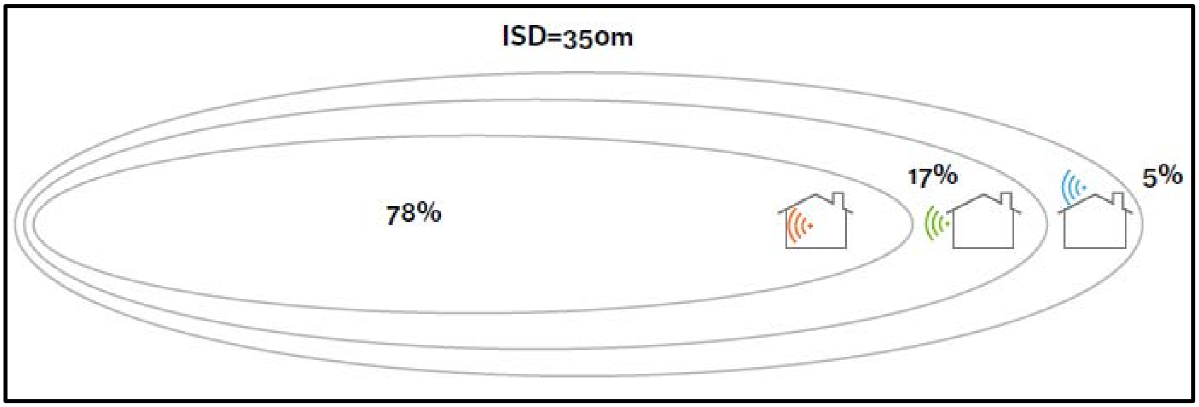

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[129] Ibid.

[130] Ibid.

The simulation study shows that 5G fixed wireless access deployments using a larger ISD of 350 meters, translating to 11 base stations per square kilometer, can provide competitive broadband service.

In this environment, handsets with 5G mmWave capability will also be able to access the networks, but the antennas they use may not be as effective as the fixed-wireless equipment, so handsets may need to fall back to 4G, depending on their precise locations. For this reason, the dual-connectivity being planned for 5G will play an important role.

Figure 55 shows another simulation study, this one from Intel, using the following assumptions: 28 GHz operation, 2:1 DL:UL ratio, 25% control overhead, 10 bps/Hz maximum downlink spectral efficiency, CPEs placed either north or south side of house and one with best SNR chosen, and indoor CPE equipment with 30dB outdoor-to-indoor penetration loss. Scenario 1 is 60 access points per sq. km. Scenario 2 is 120 access points per sq. km. (Base grid of 40 houses in a 250x200m area with four rows of 10 houses per row, APs placed along streets and alleys, single-family homes, 4 sectors per AP, and 4.5-meter pole height.)

Figure 55: 5G Fixed Wireless Simulation with Different Loading and Densities[131]

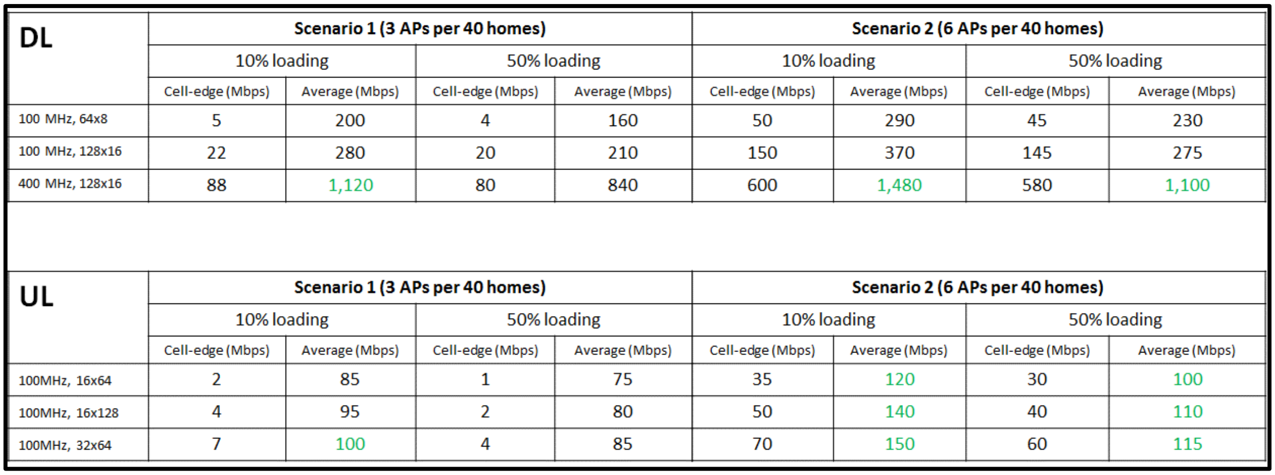

DL	Scenario 1 (3 APs per 40 homes)				Scenario 2 (6 APs per 40 homes)			
	10% loading		50% loading		10% loading		50% loading	
	Cell-edge (Mbps)	Average (Mbps)	Cell-edge (Mbps)	Average (Mbps)	Cell-edge (Mbps)	Average (Mbps)	Cell-edge (Mbps)	Average (Mbps)
100 MHz, 64x8	5	200	4	160	50	290	45	230
100 MHz, 128x16	22	280	20	210	150	370	145	275
400 MHz, 128x16	88	1,120	80	840	600	1,480	580	1,100

UL	Scenario 1 (3 APs per 40 homes)				Scenario 2 (6 APs per 40 homes)			
	10% loading		50% loading		10% loading		50% loading	
	Cell-edge (Mbps)	Average (Mbps)	Cell-edge (Mbps)	Average (Mbps)	Cell-edge (Mbps)	Average (Mbps)	Cell-edge (Mbps)	Average (Mbps)
100MHz, 16x64	2	85	1	75	35	120	30	100
100MHz, 16x128	4	95	2	80	50	140	40	110
100MHz, 32x64	7	100	4	85	70	150	60	115

Using 400 MHz and six access points per 40 homes, and 50% loading, the average throughput was more than 1 Gbps.

LTE and LTE-Advanced

Although HSPA and HSPA+ offer a highly efficient broadband-wireless service that will enjoy success for the remainder of this decade and well into the next, 3GPP completed the specification for Long Term Evolution as part of Release 8. LTE offers even higher peak throughputs in wider spectrum bandwidth. Work on LTE began in 2004 with an official work item started in 2006 and a completed specification early 2009. Initial deployments began in 2010.

LTE uses OFDMA on the downlink, which is well suited to achieve high peak data rates in high-spectrum bandwidth. WCDMA radio technology is basically as efficient as OFDM for delivering peak data rates of about 10 Mbps in 5 MHz of bandwidth. Achieving peak rates in the 100 Mbps range with wider radio channels, however, would result in highly complex terminals, and it is not practical with current technology, whereas OFDM provides a practical implementation advantage. Scheduling approaches in the frequency domain can also minimize interference, thereby boosting spectral efficiency. The OFDMA approach is also flexible in channelization: LTE operates in various radio channel sizes ranging from 1.4 to 20 MHz.

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[131] Intel contribution.

On the uplink, however, a pure OFDMA approach results in high Peak to Average Ratio (PAR) of the signal, which compromises power efficiency and, ultimately, battery life. Hence, LTE uses an approach called "SC-FDMA," which is somewhat similar to OFDMA, but has a 2 to 6 dB PAR advantage over the OFDMA method used by other technologies such as WiMAX.

LTE capabilities include:

- Downlink peak data rates up to 300 Mbps with 20+20 MHz bandwidth in initial versions, increasing to over 1 Gbps in subsequent versions through carrier aggregation, higher-order modulation, and 4X4 MIMO.
- Uplink peak data rates up to 71 Mbps with 20+20 MHz bandwidth in initial versions, increasing to over 1 Gbps in subsequent versions.
- Operation in both TDD and FDD modes.
- Scalable bandwidth up to 20+20 MHz covering 1.4, 3, 5, 10, 15, and 20 MHz radio carriers.
- Increased spectral efficiency over HSPA by a factor of two to four.
- Reduced latency, to 15 msec round-trip times between user equipment and the base station, and to less than 100 msec transition times from inactive to active.
- Self-organizing capabilities under operator control and preferences that will automate network planning and will result in lower operator costs.

LTE-Advanced Terminology

LTE-Advanced, as specified in Release 10, is a term used for the version of LTE that addresses IMT-Advanced requirements. The ITU ratified LTE-Advanced as IMT-Advanced in November 2010. LTE-Advanced is both backward- and forward-compatible with LTE, meaning LTE devices operate in newer LTE-Advanced networks, and LTE-Advanced devices operate in older, pre-Release 10 LTE networks.

The following lists at a high level the most important features of LTE-Advanced, as well as other features planned for subsequent releases, including Release 11:

- Carrier aggregation.
- Higher-order downlink MIMO (up to 8X8 in Release 10).
- Uplink MIMO (two transmit antennas in the device).
- Coordinated multipoint transmission (CoMP) in Release 11.
- Heterogeneous network (HetNet) support including Enhanced Inter-cell Interference Coordination (eICIC).
- Relays.

3GPP, from Release 13, has referred to LTE as LTE-Advanced Pro, which includes features such as LAA, LWA, low latency, and massive MIMO.

OFDMA and Scheduling

LTE implements OFDM in the downlink. The basic principle of OFDM is to split a high-rate data stream into a number of parallel, low-rate data streams, each a narrowband signal carried by a subcarrier. The different narrowband streams are generated in the frequency domain, and then combined to form the broadband stream using a mathematical algorithm called an "Inverse Fast Fourier Transform" (IFFT) that is implemented in digital signal processors. In LTE, the subcarriers have 15 kHz spacing from each other. LTE maintains this spacing regardless of the overall channel bandwidth, which simplifies radio design, especially in supporting radio channels of different widths. The number of subcarriers ranges from 72 in a 1.4 MHz radio channel to 1,200 in a 20 MHz radio channel.

The composite signal obtained after the IFFT is extended by repeating the initial part of the signal (called the Cyclic Prefix [CP]). This extended signal represents an OFDM symbol. The CP is basically a guard time during which reflected signals will reach the receiver. It results in an almost complete elimination of multipath-induced Intersymbol Interference (ISI), which otherwise makes extremely high data rate transmissions problematic. The system is called orthogonal because the subcarriers are generated in the frequency domain (making them inherently orthogonal), and the IFFT conserves that characteristic.

OFDM systems may lose their orthogonal nature as a result of the Doppler shift induced by the speed of the transmitter or the receiver. 3GPP specifically selected the subcarrier spacing of 15 kHz to avoid any performance degradation in high-speed conditions. WiMAX systems that use a lower subcarrier spacing (~11 kHz) are more impacted in high-speed conditions than LTE.

Figure 56: OFDM Symbol with Cyclic Prefix

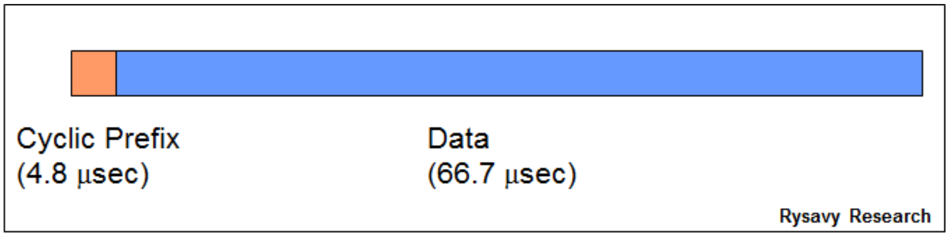

The multiple access aspect of OFDMA comes from being able to assign different users different subcarriers over time. A minimum resource block that the system can assign to a user transmission consists of 12 subcarriers over 14 symbols in 1.0 msec. Figure 57 shows how the system can assign these resource blocks to different users over both time and frequency.

Figure 57: LTE OFDMA Downlink Resource Assignment in Time and Frequency

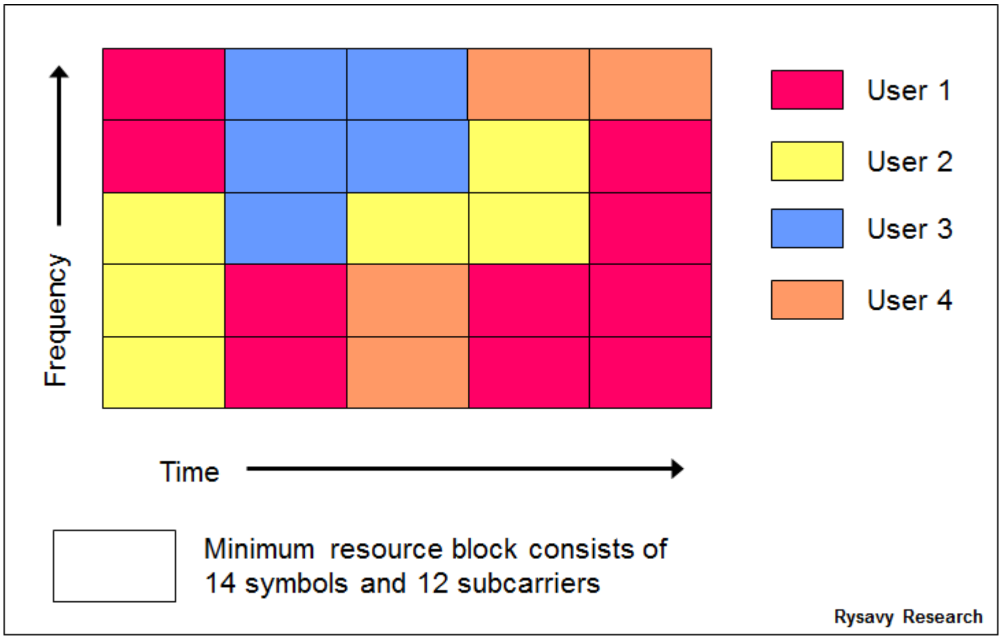
User 1
User 2
User 3
User 4
Frequency
Time
Minimum resource block consists of 14 symbols and 12 subcarriers
Rysavy Research

By controlling which subcarriers are assigned in which sectors, LTE can easily control frequency reuse. Using all the subcarriers in each sector, the system would operate at a frequency reuse of 1; but by using a different one third of the subcarriers in each sector, the system can achieve a looser frequency reuse of 1/3. The looser frequency reduces overall spectral efficiency but delivers high peak rates to users.

Beyond controlling frequency reuse, frequency domain scheduling, as shown in Figure 58 can use those resource blocks that are not faded, not possible in CDMA-based systems. Since different frequencies may fade differently for different users, the system can allocate those frequencies for each user that result in the greatest throughput. This results in up to a 40% gain in average cell throughput for low user speed (3 km/hour), assuming a large number of users and no MIMO. The benefit decreases at higher user speeds.

Figure 58: Frequency Domain Scheduling in LTE[132]

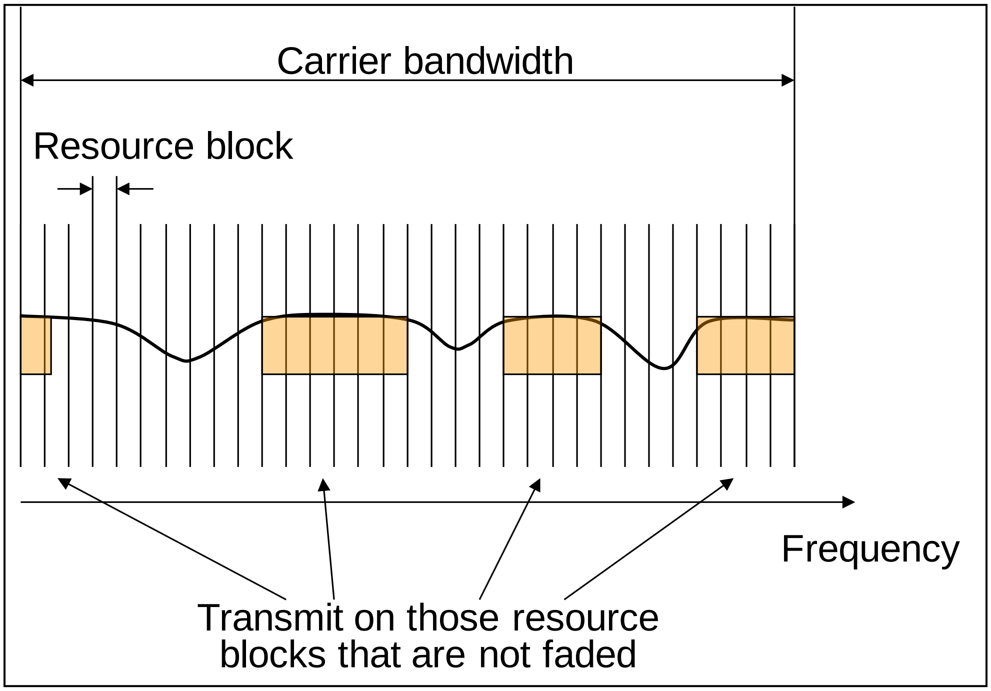

LTE Smart Antennas

Wireless networks can achieve significant gains by employing multiple antennas, either at the base station, the mobile device, or both. LTE uses multiple antennas in three fundamentally different ways:

- ❑ **Diversity.** So long as the antennas are spaced or polarized appropriately, the antennas provide protection against fading.
- ❑ **Beamforming.** Multiple antennas can shape a beam to increase the gain for a specific receiver. Beamforming can also suppress specific interfering signals. Beamforming is particularly helpful for improving cell-edge performance.
- ❑ **Spatial Multiplexing.** Often referred to as MIMO antenna processing, spatial multiplexing creates multiple transmission paths through the environment, effectively sending data in parallel through these paths, thus increasing both throughput and spectral efficiency.

Table 18 shows the varous antenna transmission modes.

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[132] 5G Americas member contribution.

Table 18: LTE Transmission Modes[133]

Transmission Mode	Description
1	Single antenna transmission.
2	Transmit Diversity.
3	Transmit diversity for one layer, open-loop codebook-based precoding if more than one layer.
4	Closed-loop codebook-based precoding.
5	Multi-user MIMO version of transmission mode 4.
6	Special case of closed-loop codebook-based precoding limited to single layer transmission.
7	Beamforming. (Non-codebook-based precoding supporting one layer.)
8	Dual-layer beamforming. (Release 9. Non-codebook-based precoding supporting up to two layers.)
9	8-layer transmission. (Release 10. Non-codebook-based precoding supporting up to eight layers.)
10	8-layer transmission with support for CoMP. (Release 11.)

Being able to exploit different antenna modes based on local conditions produces huge efficiency and performance gains, and is the reason that 3GPP is developing even more advanced antenna modes in subsequent LTE releases.

Precoding refers to a mathematical matrix operation performed on radio symbols to determine how they are combined and mapped onto antenna ports. The precoder matrix can operate in either open-loop or closed-loop modes. For each transmission rank for a given number of transmission ports (antennas), there is a limited set of precoder matrices defined, called the codebook. This helps limit the amount of signaling needed on uplink and downlink.

Fundamental variables distinguish the different antenna modes:

- **Single base station antenna versus multiple antennas.** Single antennas provide for Single Input Single Output (SISO), SIMO, and planar-array beamforming. (Multiple Output means the UE has multiple antennas.) Multiple antennas at the base station provide for different MIMO modes such as 2X2, 4X2, and 4X4.

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[133] Erik Dahlman, Stefan Parkvall, Johan Skold, *4G - LTE/LTE Advanced for Mobile Broadband*, Academic Press, 2011.

- **Single-user MIMO versus multi-user MIMO.** Release 8 only provides for single-user MIMO on the downlink. Release 10 includes multi-user MIMO.
- **Open-Loop versus Closed-Loop.** High vehicular speeds require open-loop operation whereas slow speeds enabled closed-loop operation in which feedback from the UE modifies the transmission. In closed-loop operation, the precoder matrix is based on this feedback.
- **Rank.** In a MIMO system, the channel rank is formally defined as the rank of the channel matrix and is a measure of the degree of scattering that the channel exhibits. For example, in a 2x2 MIMO system, a rank of one indicates a low-scattering environment, while a rank of two indicates a high-scattering environment. The rank two channel is highly uncorrelated, and is thus able to support the spatial multiplexing of two data streams, while a rank one channel is highly correlated, and thus can only support single stream transmission (the resulting multi-stream interference in a rank one channel as seen at the receiver would lead to degraded performance). Higher Signal to Interference plus Noise Ratios (SINR) are typically required to support spatial multiplexing, while lower SINRs are typically sufficient for single stream transmission. In a 4x4 MIMO system channel rank values of three and four are possible in addition to values of one and two. The number of data streams, however, or more specifically codewords in LTE is limited to a value of two. Thus, LTE has defined the concept of layers, in which the DL transmitter includes a codeword-to-layer mapping, and in which the number of layers is equal to the channel rank. An antenna mapping or precoding operation follows, which maps the layers to the antenna ports. A 4x2 MIMO system is also possible with LTE Release 8, but here the channel rank is limited to the number of UE antennas, which is equal to two.

The network can dynamically choose between different modes based on instantaneous radio conditions between the base station and the UE. Figure 59 shows the decision tree. The antenna configuration (AC) values refer to the transmission modes. Not every network will support every mode. Operators will choose which modes are the most effective and economical. AC2, 3, 4, and 6 are typical modes that will be implemented.

Figure 59: Decision Tree for Different Antenna Schemes[134]

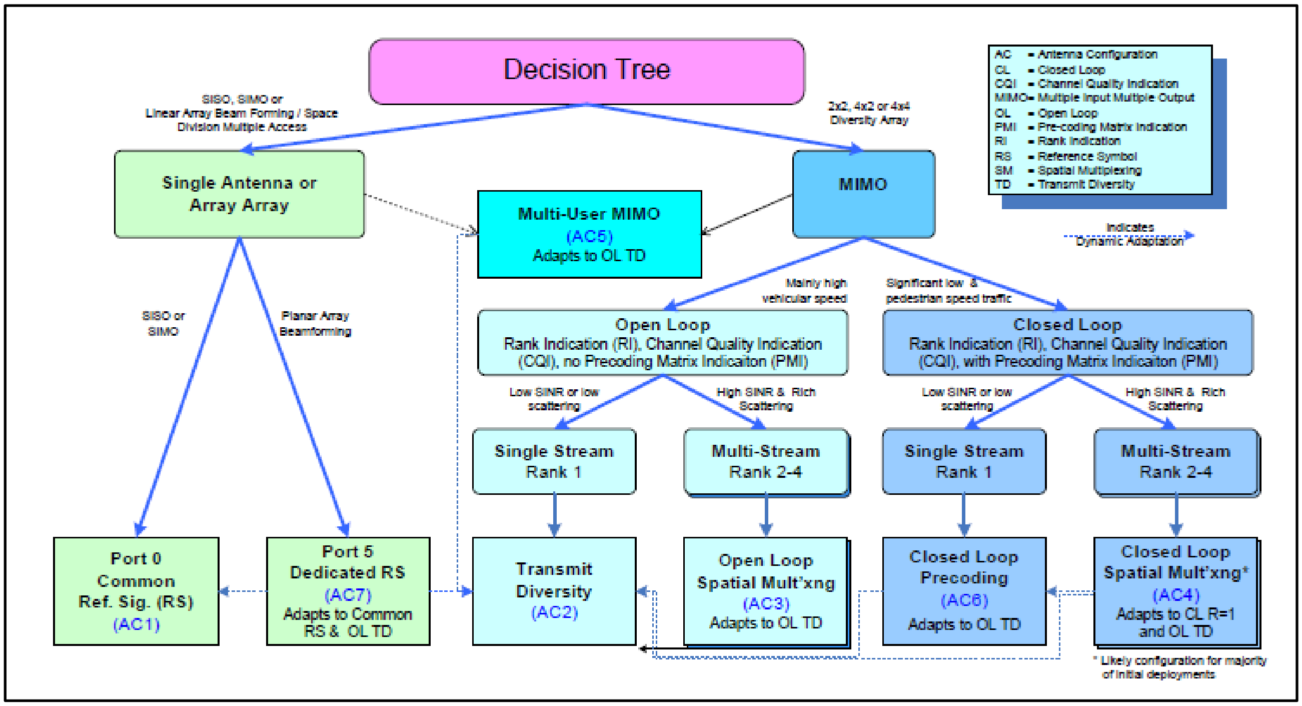
Decision Tree
SISO, SIMO or
Linear Array Beam Forming / Space
Division Multiple Access
2x2, 4x2 or 4x4
Diversity Array
AC = Antenna Configuration
CL = Closed Loop
CQI = Channel Quality Indication
MIMO= Multiple Input Multiple Output
OL = Open Loop
PMI = Pre-coding Matrix Indication
RI = Rank Indication
RS = Reference Symbol
SM = Spatial Multiplexing
TD = Transmit Diversity
Single Antenna or Array Array
MIMO
Multi-User MIMO
(AC5)
Adapts to OL TD
Indicates
Dynamic Adaptation
SISO or SIMO
Planar Array Beamforming
Mainly high vehicular speed
Significant low & pedestrian speed traffic
Open Loop
Rank Indication (RI), Channel Quality Indication (CQI), no Precoding Matrix Indicaiton (PMI)
Closed Loop
Rank Indication (RI), Channel Quality Indication (CQI), with Precoding Matrix Indicaiton (PMI)
Low SINR or low scattering
High SINR & Rich Scattering
Low SINR or low scattering
High SINR & Rich Scattering
Single Stream Rank 1
Multi-Stream Rank 2-4
Single Stream Rank 1
Multi-Stream Rank 2-4
Port 0 Common Ref. Sig. (RS) (AC1)
Port 5 Dedicated RS (AC7) Adapts to Common RS & OL TD
Transmit Diversity (AC2)
Open Loop Spatial Mult'xng (AC3) Adapts to OL TD
Closed Loop Precoding (AC6) Adapts to OL TD
Closed Loop Spatial Mult'xng* (AC4) Adapts to CL R=1 and OL TD
* Likely configuration for majority of initial deployments

The simplest mode is AC2, referred to as Transmit Diversity (TD) or sometimes Space Frequency Block Code (SFBC) or even Open Loop Transmit Diversity. TD can operate under all conditions, meaning it works under low SINR, high mobility, and low channel rank (rank = 1). This rank means that the channel is not sufficiently scattered or de-correlated to support two spatial streams. Thus, in TD, only one spatial stream or what is sometimes referred as a single codeword (SCW) is transmitted. If the channel rank increases to a value of two, indicating a more scattered channel, and the SINR is a bit higher, then the system can adapt to AC3 or Open-Loop Spatial Multiplexing (OL-SM), also referred to as large-delay Cyclic Delay Diversity (CDD). This mode supports two spatial streams or two codewords. This mode, also called multiple codeword (MCW) operation, increases throughput over SCW transmission.

If the rank of the channel is one, but the device is not moving very fast or is stationary, then the system can adapt to AC6, called closed-loop (CL) precoding (or CL-rank 1 or CL-R1). In this mode, the network receives from the device with Precoding Matrix Indication (PMI) bits that inform the base station what precoding matrix to use in the transmitter to optimize link performance. This feedback is only relevant for low-mobility or stationary conditions since in high mobility conditions the feedback will most likely be outdated by the time the base station can use it.

Another mode is AC4 or Closed Loop Spatial Multiplexing (CL-SM), which is enabled for low-mobility, high SINR, and channel rank of two. This mode theoretically provides the best user throughput. The figure above shows how these modes can adapt downwards to either OL TD, or if in CL-SM mode, down to either OL TD or CL R1.

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[134] 4G Americas *MIMO and Smart Antennas for 3G and 4G Wireless Systems – Practical Aspects and Deployment Considerations*, May 2010.

For a 4x4 MIMO configuration, the channel rank can take on values of three and four in addition to one or two. Initial deployment at the base station, however, will likely be two TX antennas and most devices will only have 2 RX antennas, and thus the rank is limited to 2.

AC5 is MU-MIMO, which is not defined for the downlink in Release 8.

AC1 and AC7 are single antenna port modes in which AC1 uses a common Reference Signal (RS), while AC7 uses a dedicated RS or what is also called a user specific RS. AC1 implies a single TX antenna at the base station. AC7 implies an antenna array with antennal elements closely spaced so that a physical or spatial beam can be formed toward an intended user.

LTE operates in a variety of MIMO configurations. On the downlink, these include 2X2, 4X2 (four antennas at the base station), and 4X4. Initial deployment will likely be 2x2 whereas 4X4 will be most likely used initially in femtocells. On the uplink, there are two possible approaches: single-user MIMO (SU-MIMO) and multi-user MIMO (MU-MIMO). SU-MIMO is more complex to implement as it requires two parallel radio transmit chains in the mobile device, whereas MU-MIMO does not require any additional implementation at the device but relies on simultaneous transmission on the same tones from multiple mobile devices.

The first LTE Release thus incorporates MU-MIMO with SU-MIMO deferred for subsequent LTE releases. An alternate form of MIMO, originally called network MIMO, and now called CoMP, relies on MIMO implemented (on either the downlink or uplink or both) using antennas across multiple base stations, as opposed to multiple antennas at the same base station. This paper explains CoMP in the section on LTE Advanced below.

Peak data rates are approximately proportional to the number of send and receive antennas. 4X4 MIMO is thus theoretically capable of twice the data rate of a 2X2 MIMO system. The spatial multiplexing MIMO modes that support the highest throughput rates will be available in early deployments.

For a more detailed discussion of 3GPP antenna technologies, refer to the 5G Americas white paper “MIMO and Smart Antennas for 3G and 4G Wireless Systems – Practical Aspects and Deployment Considerations,” May 2010.

For advancements in LTE Smart Antennas, see the next section.

LTE-Advanced Antenna Technologies

Release 10 added significant enhancements to antenna capabilities, including four-layer transmission resulting in peak spectral efficiency exceeding 15 bps/Hz. Uplink techniques fall into two categories: those relying on channel reciprocity and those that do not. With channel reciprocity, the eNB determines the channel state by processing a Sounding Reference Signal from the UE. It then forms transmission beams accordingly. The assumption is that the channel received by the eNB is the same as the UE. Techniques that use channel reciprocity are beamforming, SU-MIMO, and MU-MIMO. Channel reciprocity works especially well with TDD since both forward and reverse links use the same frequency.

Non-reciprocity approaches apply when the transmitter has no knowledge of the channel state. Techniques in this instance include open-loop MIMO, closed-loop MIMO, and MU-MIMO. These techniques are more applicable for higher speed mobile communications.

For the downlink, the technology can transmit in as many as eight layers using an 8X8 configuration for a peak spectral efficiency of 30 bps/Hz. This exceeds the IMT-Advanced requirements, conceivably supporting a peak rate of 1 Gbps in just 40+40 MHz, and even higher rates in wider bandwidths. This would require additional reference signals for channel estimation and for measurements, including channel quality, to enable adaptive, multi-antenna transmission.

Release 10 supports a maximum of two codewords, the same as previous LTE releases. The release specifies a new transmission mode (TM-9) that supports SU-MIMO up to Rank 8 (up to eight layers), as well as the ability to dynamically switch between SU-MIMO and MU-MIMO.

Figure 60 shows the different forms of single-user MIMO in Releases 8, 9, and 10. Release 8 supports only a single layer, whereas two-layer beamforming is possible in Release 9, and eight layers are possible in Release 10 with eight antennas at the base station.

Figure 60: Single-User MIMO[135]

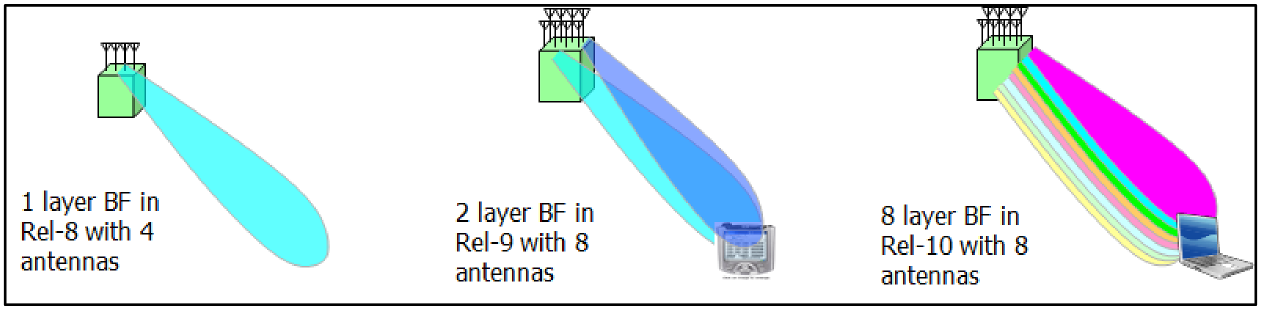
1 layer BF in Rel-8 with 4 antennas
2 layer BF in Rel-9 with 8 antennas
8 layer BF in Rel-10 with 8 antennas

Figure 61 shows multi-user MIMO options across different releases. Release 8 supports two simultaneous users, each with one layer using four antennas, while Releases 9 and 10 support four simultaneous users, each with one layer.

Figure 61: Multi-User MIMO[136]

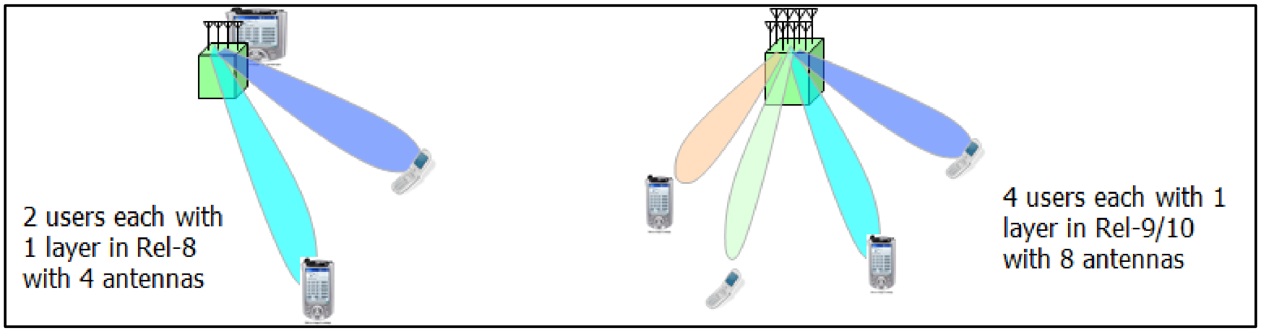
2 users each with 1 layer in Rel-8 with 4 antennas
4 users each with 1 layer in Rel-9/10 with 8 antennas

For four-antenna configurations at the base station, Release 12 improves throughput by adding a feedback mode, called mode 3-2, in which sub-band precoders and sub-band channel quality indicators (CQIs) are included in the UE's feedback to the eNodeB. Release 12 also adds a new codebook that further improves throughput.

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[135] 5G Americas member contribution.

[136] 5G Americas member contribution.

As depicted in Figure 62 and Figure 63, compared with the Release 8 codebook, the new Release 12 codebook provides a 10% gain for both median and cell-edge throughputs. Compared with feedback mode 3-1, feedback mode 3-2 provides an 18% to 20% gain in median and cell-edge throughput. Jointly, the two methods provide a 28% to 30% gain.

Figure 62: Median Throughput of Feedback Mode 3-2 and New Codebook.[137]

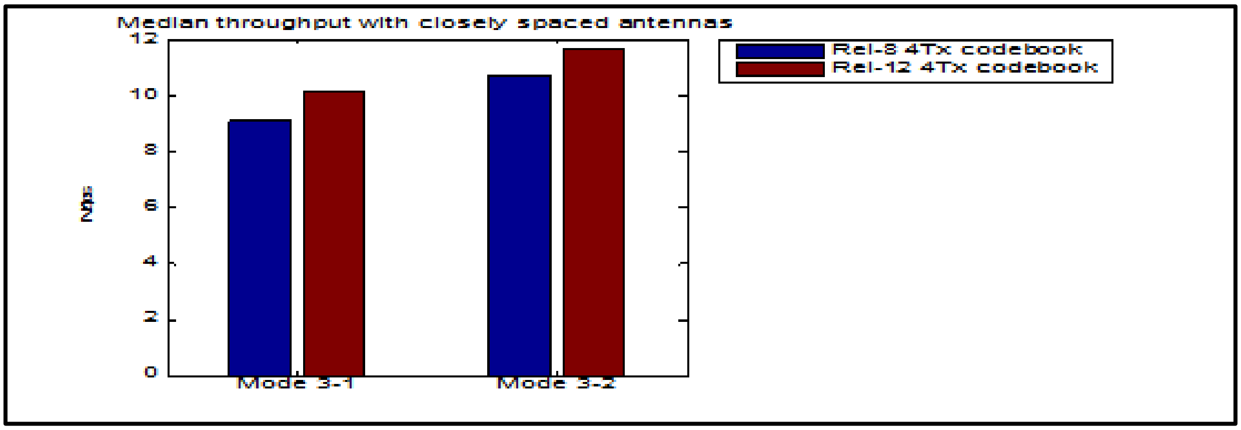

Figure 63: Cell-Edge Throughput of Feedback Mode 3-2 and New Codebook[138]

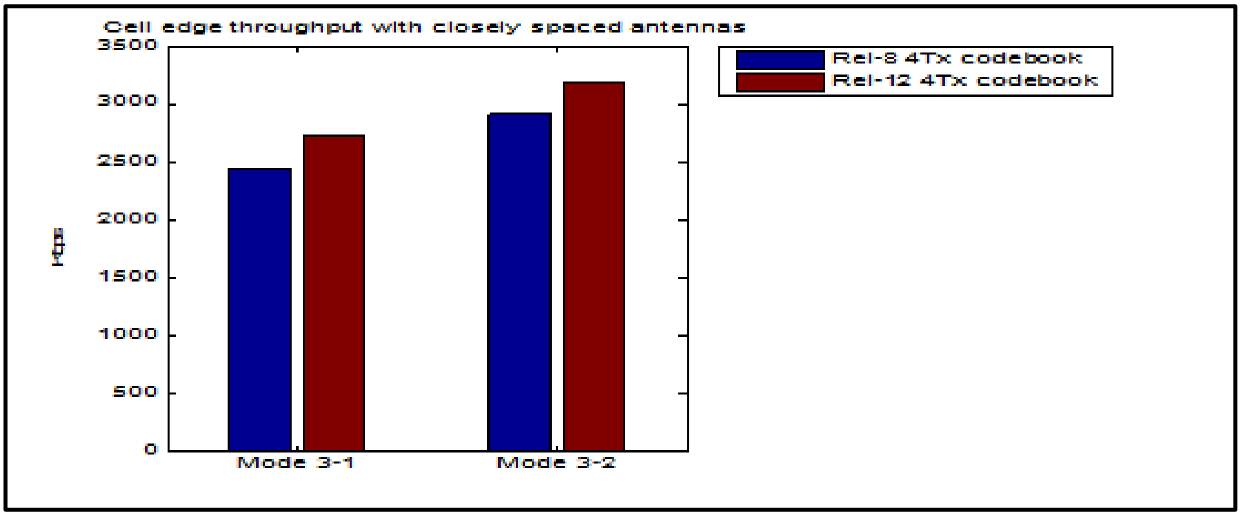

Release 12 also defines how Active Antenna Systems can use multiple transceivers on an antenna array to dynamically adjust a radiation pattern.

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[137] 5G Americas member contribution. Assumptions include: cellular layout of 19 sites hexagonal grid with three sectors per site and 500-meter inter-site distance; simulation case ITU uMa for macro; carrier frequency 2 GHz, deployment scenario A homogenous macro; SU-MIMO with maximum two layers per UE; proportional fair scheduler; and bursty traffic model.

[138] 5G Americas member contribution. Same assumptions as previous figure.

Release 13 is likely to define full-dimension MIMO, which adds a large number of antenna elements, potentially as many as 64 elements.

A practical consideration with antennas is that many towers today already support multiple operators, with tower companies having to manage interference placement, spectrum allocations, and wind and snow load. At higher frequencies, a single radome (antenna enclosure) can support 4X2 MIMO, but higher-order MIMO may prove impractical for many deployments.

5G systems operating at much higher frequencies will have an advantage since the antenna arrays will be much smaller due to the much smaller wavelengths.

Initial massive MIMO techniques applied to LTE, such as full-dimension MIMO using 8, 16, and 64 transmit antennas, can provide dramatic performance gains, particularly in dense deployments, as shown in Figure 64.

Figure 64: Performance Gains with FD-MIMO Using 200 Meter ISD[139]

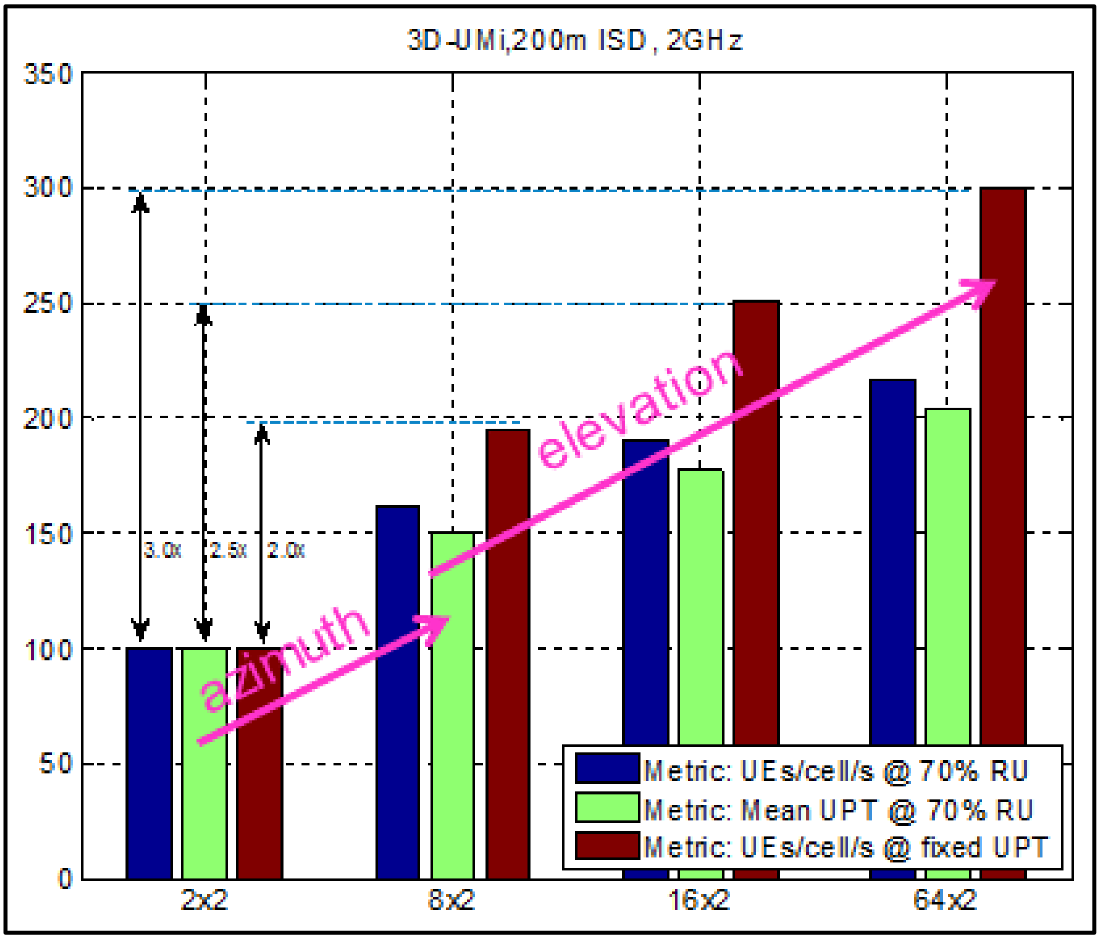

This figure compares 8X2, 16X2, and 64X2 MIMO performance relative to 2X2 MIMO (normalized to value 100). The blue bars (case 1) show the supported number of users per sector (referred to as “cell” in the figure) at a fixed resource utilization (RU) of 70%; the green bars (case 2) show mean user throughput (UPT) at a fixed RU of 70%; and the red bars (case 3) show system capacity in terms of supported number of users for a given user throughput. Resulting gains are:

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[139] 5G Americas member contribution.

- ☐ Case 2 (green bars): 1.5X with 8X2, 1.75X with 16X2, and 2X with 64X2 MIMO.
- ☐ Case 3 (red bars): 2X with 8X2, 2.5X with 16X2, and 3X with 64X2 MIMO.

The primary gains are from azimuth (horizontal dimension) in going from 2X2 to 8X2, and from elevation in going to 16X2 and 64X2. FD-MIMO gains are lower with larger ISD values, such as 500 meters.

3GPP has also studied FD-MIMO and conducted a field trial showing impressive throughput gains, particularly in a high-rise scenario.[140]

Carrier Aggregation

Carrier aggregation, first available in Release 10, plays an important role in providing operators maximum flexibility for using all of their available spectrum. By combining spectrum blocks, LTE can deliver much higher throughputs than otherwise possible. Asymmetric aggregation (for example, different amounts of spectrum used on the downlink versus the uplink) provides further flexibility and addresses the greater demand on downlink traffic.

Specific types of aggregation include:

- ☐ Intra-band on adjacent channels.
- ☐ Intra-band on non-adjacent channels.
- ☐ Inter-band (700 MHz, 1.9 GHz).
- ☐ Inter-technology (for example, LTE on one channel, HSPA+ on another). This approach is not currently specified nor being developed. While theoretically promising, a considerable number of technical issues would have to be addressed.[141] See Figure 65.

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[140] 3GPP, *3D-MIMO Prototyping and Initial Field Trial Results*, TSG RAN WG1 Meeting #80, Agenda Item: 7.2.4.4, Document R1-150451.

[141] For further details, see 4G Americas, *HSPA+ LTE Carrier Aggregation*, June 2012.

Figure 65: Inter-Technology Carrier Aggregation[142]

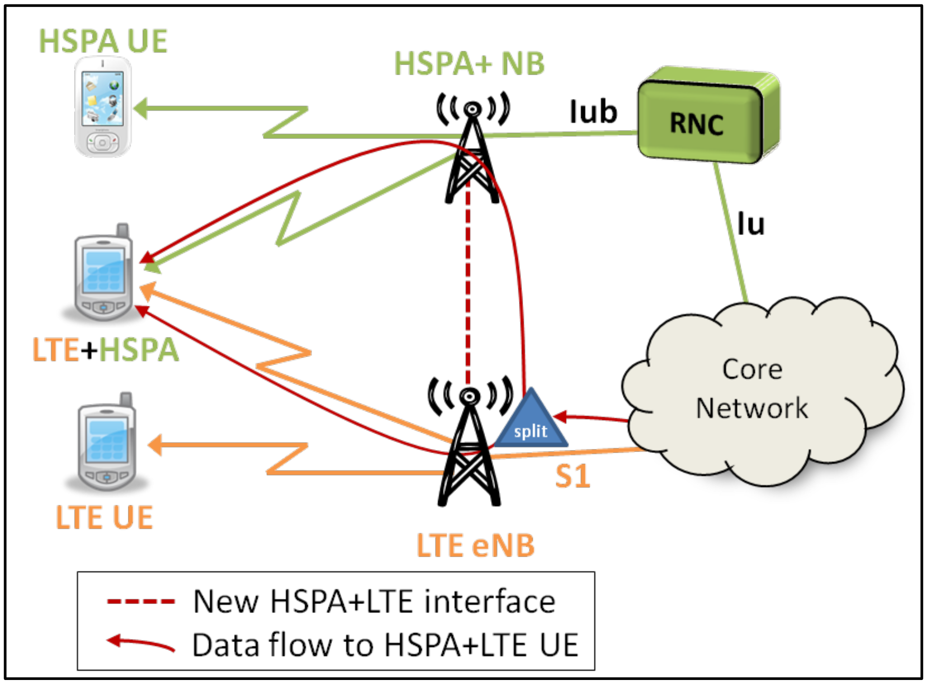
HSPA UE
HSPA+ NB
Iub
RNC
Iu
LTE+HSPA
Core Network
split
S1
LTE UE
LTE eNB
New HSPA+LTE interface
Data flow to HSPA+LTE UE

Figure 66 depicts the carrier-aggregation capabilities of different 3GPP releases.

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[142] 5G Americas member contribution.

Figure 66: Carrier Aggregation Capabilities across 3GPP Releases[143]

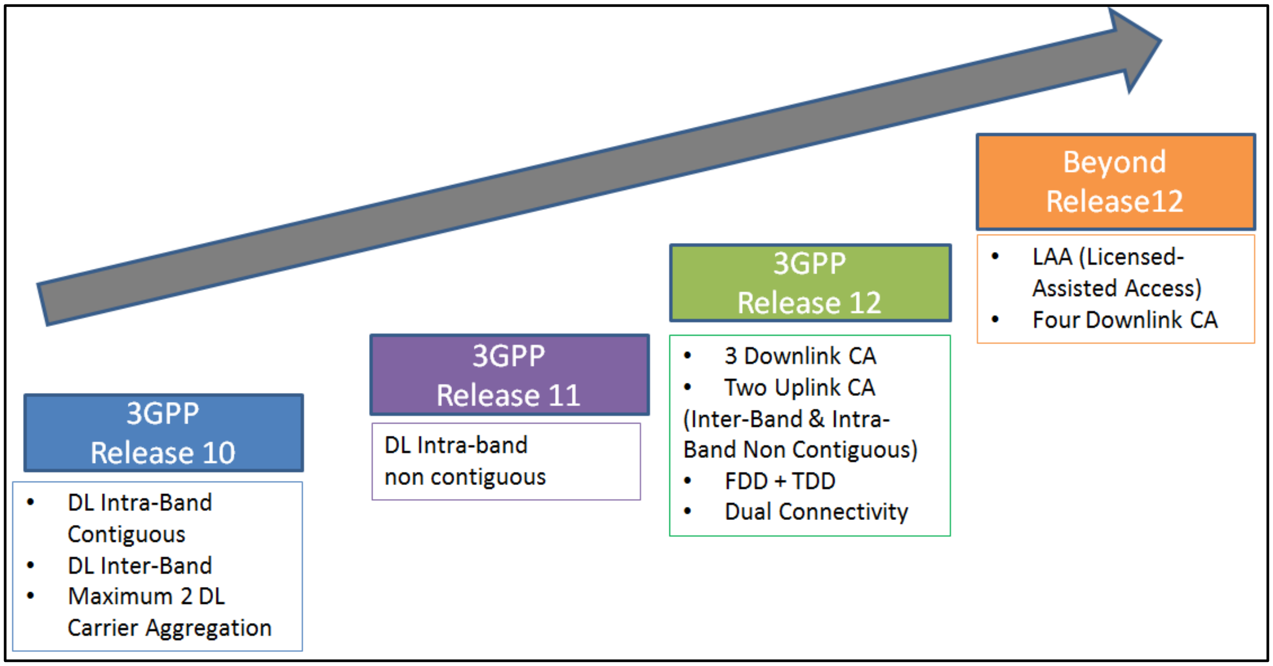

3GPP Release 10
- DL Intra-Band Contiguous
- DL Inter-Band
- Maximum 2 DL Carrier Aggregation
3GPP Release 11
DL Intra-band non contiguous
3GPP Release 12
- 3 Downlink CA
- Two Uplink CA (Inter-Band & Intra-Band Non Contiguous)
- FDD + TDD
- Dual Connectivity
Beyond Release12
- LAA (Licensed-Assisted Access)
- Four Downlink CA

One anticipated benefit of inter-band aggregation stems from using the lower-frequency band for users who are at the cell edge, to boost their throughput rates. Though this approach improves average aggregate throughput of the cell by only a small amount (say, 10%), it results in a more uniform user experience across the cell coverage area.

Figure 67 shows an example of intra-band carrier aggregation using adjacent channels with up to 100+100 MHz of bandwidth supported. Radio-access network specifications, however, limit the number of carriers to two in Release 10 and Release 11.

Figure 67: Release 10 LTE-Advanced Carrier Aggregation[144]

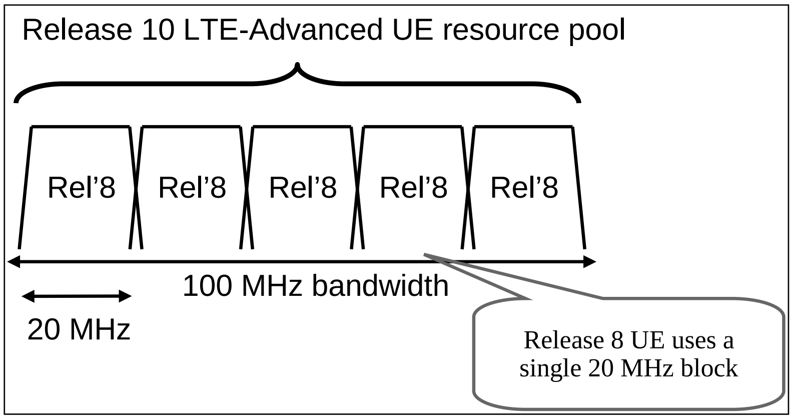

Release 10 LTE-Advanced UE resource pool
Rel'8
Rel'8
Rel'8
Rel'8
Rel'8
100 MHz bandwidth
20 MHz
Release 8 UE uses a single 20 MHz block

---

[143] 4G Americas, *Mobile Broadband Evolution: Rel-12 & Rel-13 and Beyond*, 2015.

[144] Harri Holma and Antti Toskala, *LTE for UMTS, OFDMA and SC-FDMA Based Radio Access*, Wiley, 2009.

Figure 68 shows the carrier aggregation operating at different protocol layers.

Figure 68: Carrier Aggregation at Different Protocol Layers[145]

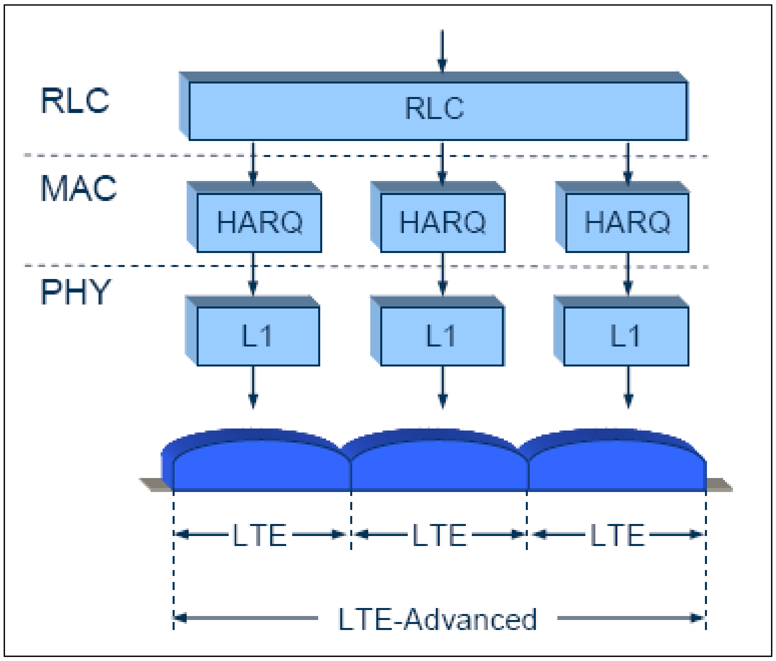

For a list of band combinations, refer to the 5G Americas white paper, *Wireless Technology Evolution Towards 5G: 3GPP Release 13 to Release 15 and Beyond,* February 2017, at section 3.4.3.

Figure 69 shows the result of one simulation study that compares download throughput rates between the blue line, which shows five user devices in 700 MHz and five user devices in AWS not using CA, and the pink line, which shows ten user devices that have access to both bands. Assuming a lightly loaded network with CA, 50% or more users (the median) experience 91% greater throughput, and 95% or more users experience 50% greater throughput. These trunking gains are less pronounced in heavily loaded networks.

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[145] Stefan Parkvall and David Astely, Ericsson Research, "The Evolution of LTE towards IMT-Advanced," Journal of Communications, Vol. 4, No. 3, April 2009. Available at http://www.academypublisher.com/jcm/vol04/no03/jcm0403146154.pdf.

Figure 69: Gains from Carrier Aggregation[146]

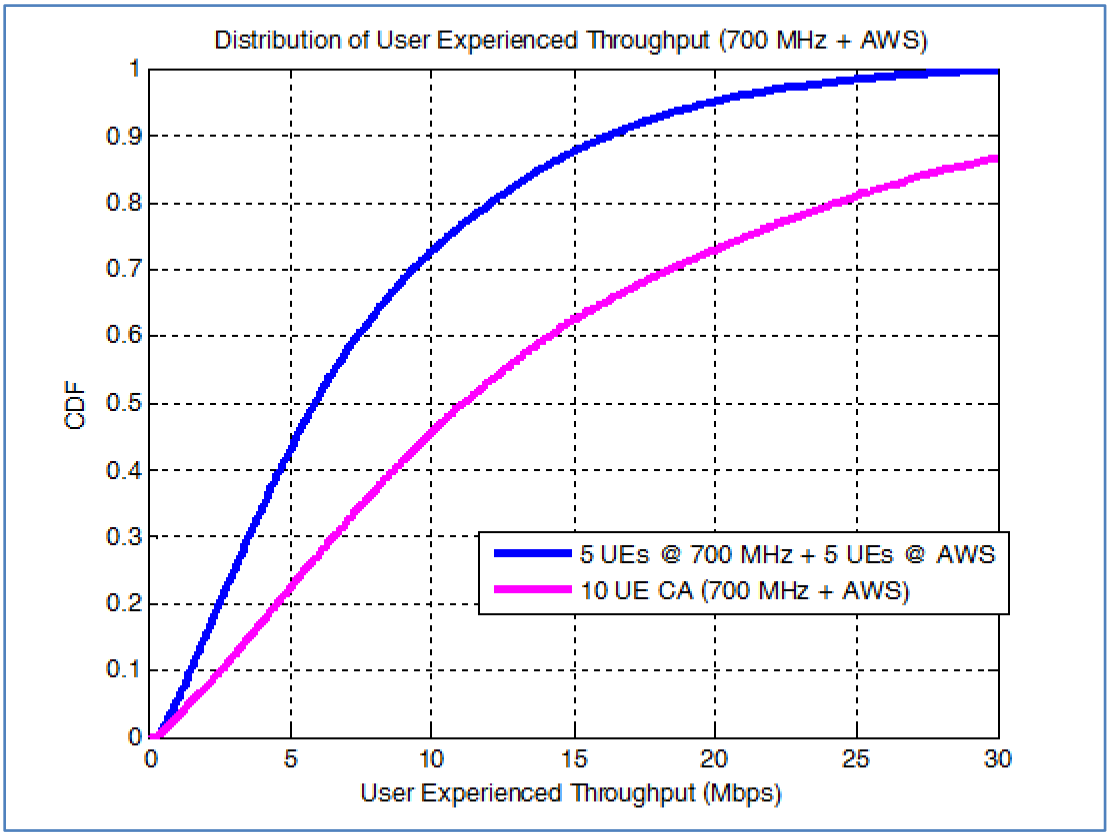

Work in Release 12 is investigating aggregation of joint TDD and FDD carriers.

Coordinated Multi Point (CoMP)

Coordinated Multi Point (CoMP) is a communications technique that can improve coverage, cell-edge throughput, and/or system spectrum efficiency by reducing interference. This technique was thoroughly studied during the development of LTE-Advanced Release 10 and was standardized in Release 11.

CoMP coordinates transmissions at different cell sites, thereby achieving higher system capacity and improving cell-edge data rates.

The main principle of CoMP is that a UE at a cell edge location can receive signals from multiple transmission points, and/or its transmitted signal can be received by multiple reception points. Consequently, if these multiple transmission points coordinate their transmissions, the DL throughput performance and coverage can improve.

For the UL, signals from the UE received at multiple reception points can significantly improve the link performance. Techniques can range from simple interference avoidance methods, such as Coordinated Beam Switching (CBS) and Coordinated Beam Forming

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[146] 5G Americas member contribution. Assumptions: lightly-loaded network, 2.0 site-to-site distance, file size is 750 Kbytes, traffic model bursty with mean inter-arrival time of five seconds.

(CBF), to complex joint processing techniques that include Joint Transmission (JT), Joint Reception (JR), and Dynamic Point Selection (DPS).

CoMP architectures include inter-site CoMP, intra-site CoMP, as well as CoMP with distributed eNBs (i.e., an eNB with distributed remote radio heads). Figure 70 shows two possible levels of coordination.

Figure 70: Different Coordination Levels for CoMP[147]

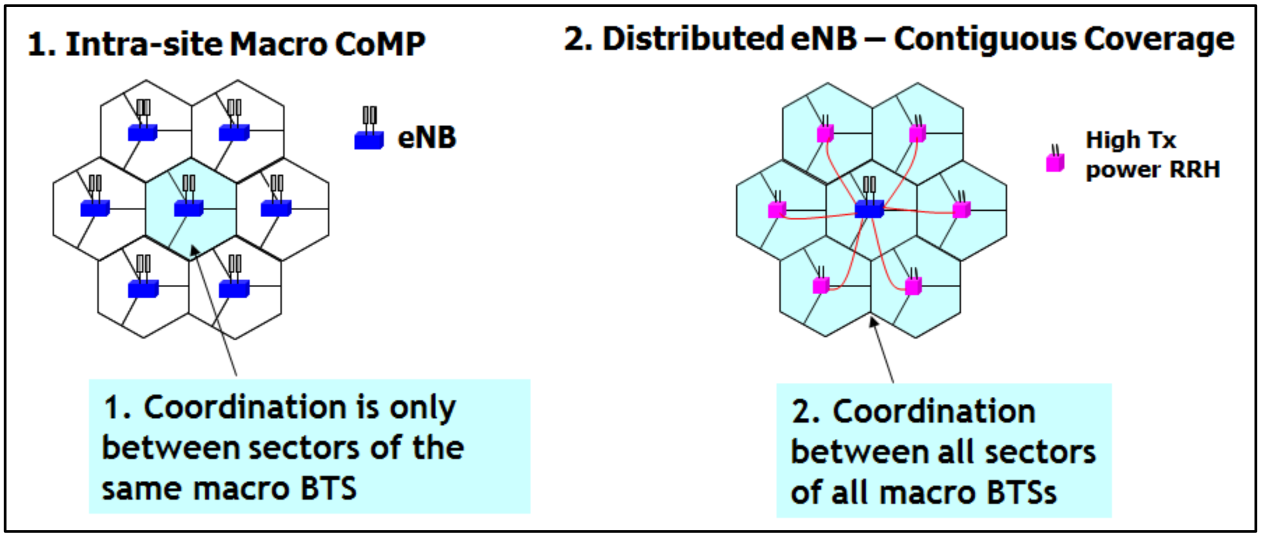
1. Intra-site Macro CoMP
eNB
1. Coordination is only between sectors of the same macro BTS
2. Distributed eNB – Contiguous Coverage
High Tx power RRH
2. Coordination between all sectors of all macro BTSs

In one CoMP approach, called coordinated scheduling and shown in Figure 71, a single site transmits to the user, but with scheduling, including any associated beamforming, coordinated between the cells to reduce interference between the different cells and to increase the served user's signal strength. In Joint Transmission, another CoMP approach also shown in Figure 71, multiple sites transmit simultaneously to a single-user. This approach can achieve higher performance than coordinated scheduling, but it has more stringent backhaul communications requirements. One simpler form of CoMP that will be available in Release 10, and then further developed in Release 11, is ICIC. Release 11 of LTE defines a common feedback and signaling framework for enhanced CoMP operation.

Figure 71: Coordinated Scheduling / BF and Joint Processing CoMP Approaches[148]

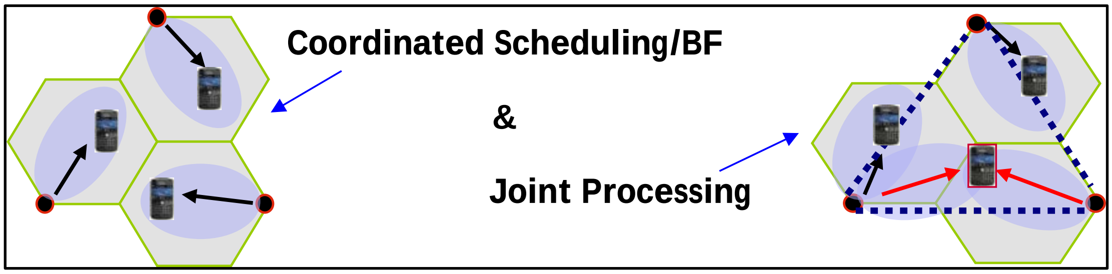
Coordinated Scheduling/BF
&
Joint Processing

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[147] 5G Americas member contribution.

[148] 5G Americas member contribution.

Release 11 also implements CoMP on the uplink, by which multiple base stations receive uplink transmissions and jointly process the signal, resulting in significant interference cancellation and improvements to spectral efficiency.

The performance gains expected from CoMP are under discussion in the industry. According to 3GPP document TR 36.819, for the case of resource utilization below 35%, CoMP may provide a 5.8% performance gain on the downlink for the mean user and a 17% gain for cell-edge users relative to HetNets without eICIC. For resource utilization of more than 35%, CoMP may provide a 17% mean gain and a 40% cell-edge gain.[149] CoMP can also be used in combination with eICIC for additional gains.

In the same 3GPP TR 36.819 document, 3GPP estimates the downlink CoMP gain in spectral efficiency, defined as average sector throughput for full buffer traffic using JT and 4x2 MU-MIMO as defined in R11, compared with 4x2 MU-MIMO based on R10, to be about 3% for intra-eNodeB CoMP. That gain drops to about 9% for inter-eNodeB CoMP in the case of no delay in the backhaul used to exchange information between eNodeBs. The corresponding gains in cell-edge user throughput are 20% and 31%, respectively.

When increasing the backhaul latency to a more realistic value of 10 msec for inter-eNodeB, spectral efficiency decreases to zero, and the cell edge gain decreases to 10%.

The gains for DL CoMP based on Coordinated Scheduling/Coordinated Beamforming (CS/CB) and intra-eNodeB are less than that provided by JT, with spectral efficiency at 1% and cell edge gains at 4%.

All of the above gains are for FDD networks with cross-polarized antennas at the eNodeBs. For TDD networks, the gains are higher by virtue of being able to invoke channel reciprocity and thus infer the DL channel directly from the UL channel. For example, for intra-eNodeB CoMP with JT 4x2 MU-MIMO, the respective gains in spectral efficiency and cell-edge throughput are 14% and 29%, respectively.

The gains for UL CoMP based on Joint Reception (JR) are greater than the DL gains. For intra-eNodeB CoMP, the average and cell-edge throughputs are increased to 22% and 40%, assuming two receive antenna paths with SU-MIMO. These respective gains increase to 31% and 66% for inter-eNodeB CoMP. In addition, UL CoMP does not require standardization and thus facilitates vendor implementation.

Uplink CoMP assists VoLTE because it improves cell-edge performance, making voice handover more reliable when traversing between cells. The benefit is analogous to CDMA soft handover; in both cases, the mobile device communicates with two sites simultaneously.

Cellular V2X Communications

In Release 14, 3GPP is specifying cellular vehicle-to-X (C-V2X) communications with two complementary transmission modes: direct communications between vehicles and network communications.

Direct communications will use bands such as the Intelligent Transportation Systems (ITS) 5.9 GHz band, using the PC5 interface specified for LTE device-to-device communications, and will not require a Universal Integrated Circuit Card (UICC) SIM (USIM) card. By operating on different channels in the ITS band, direct cellular V2X will be able to co-exist with IEEE 802.11p, another automotive communications protocol.

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[149] 3GPP, *Coordinated Multi-Point Operation for LTE Physical Layer Aspects, TR 36.819 v11.1.0,* Tables 7.3.1.2-3 and 7.3.1.2-4, September 2011.

In the network communications mode, the system will use traditional cellular licensed spectrum.

Use cases include do-not-pass warnings, blind-curve hazard warnings, road-works warnings, blind-intersection assistance, bicyclist and pedestrian alerts, and left-turn assistance.

C-V2X is being designed to be compatible with other automotive standards, such as those from ETSI and the Society of Automotive Engineers.

User-Plane Congestion Management (UPCON)

With User-Plane Congestion Management, specified in Release 13, operators have additional tools to mitigate network congestion in specific coverage areas. Mechanisms include traffic prioritization by adjusting QoS for specific services; reducing traffic by, for example, compression; and limiting traffic, such as by prohibiting or deferring certain traffic.

3GPP specifications add a new architectural entity, called the "RAN Congestion Awareness Function" (RCAF), that determines whether a cell is congested, determines the UEs supported by that cell, and informs the Policy Control and Charging Rules Function (PCRF), which can subsequently apply different policies to mitigate the congestion.[150]

Network-Assisted Interference Cancellation and Suppression (NAICS)

NAICS, a Release 13 capability, enhances the interference cancellation and suppression capability of UEs by using more information from the network. The fundamental goal of NAICS is to identify and cancel the dominant interferer, not an easy task when the dominant interferer can be on or off and can change in time and frequency. One analysis estimates an average performance gain of 7.4% relative to Release 11 Interference Rejection Combining and 11.7% at the cell edge.[151] 5G Americas members expect even higher performance gains, for example 20%, with implementation-specific scheduling and as NAICS methods are refined.

Multi-User Superposition Transmission (MUST)

MUST, a study item in Release 13 and tentatively planned for Release 14 uses simultaneous transmissions of data for more than one UE within a cell without time, frequency, or spatial layer separation. The concept relies on a UE close to the base station having low propagation loss and a UE far from the base station having high propagation loss. The far UE is not aware of, nor interfered by the near UE transmission. The near UE cancels the far UE interference. The capacity gain grows with the SNR/SINR difference between the close and far UEs.

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[150] For further details, see 3GPP TR 23.705, "Study on system enhancements for user plane congestion management (Release 13)."

[151] Harri Holma, Antti Toskala, Jussi Reunanen, *LTE Small Cell Optimization: 3GPP Evolution to Release 13*, Jan 2016, Wiley, ISBN: 978-1-118-91257-7.

IPv4/IPv6

Release 8 defines support for IPv6 for both LTE and UMTS networks. An Evolved Packet System bearer can carry both IPv4 and IPv6 traffic, enabling a UE to communicate both IPv4 and IPv6 packets (assuming it has a dual stack) while connected through a single EPS bearer. It is up to the operator, however, whether to assign IPv4, IPv6, or both types of addresses to UE.

Communicating between IPv6-only devices and IPv4 endpoints will require protocol-conversion or proxies. For further details, refer to the 5G Americas white paper, "IPv6 – Transition Considerations for LTE and Evolved Packet Core," February 2009.

TDD Harmonization

3GPP developed LTE TDD to be fully harmonized with LTE FDD including alignment of frame structures, identical symbol-level numerology, the possibility of using similar Reference Signal patterns, and similar synchronization and control channels. Also, there is only one TDD variant. Furthermore, LTE TDD has been designed to co-exist with TD-SCDMA and TD-CDMA/UTRA (both low-chip rate and high-chip rate versions). LTE TDD achieves compatibility and co-existence with TD-SCDMA by defining frame structures in which the DL and UL time periods can be time aligned to prevent BTS to BTS and UE to UE interference to support operation in adjacent carriers without the need for large guardbands between the technologies. This will simplify deployment of LTE TDD in countries such as China that are deploying TD-SCDMA. Figure 72 demonstrates the synchronization between TC-SCDMA and LTE-TDD in adjacent channels.

Figure 72: TDD Frame Co-Existence between TD-SCDMA and LTE TDD[152]

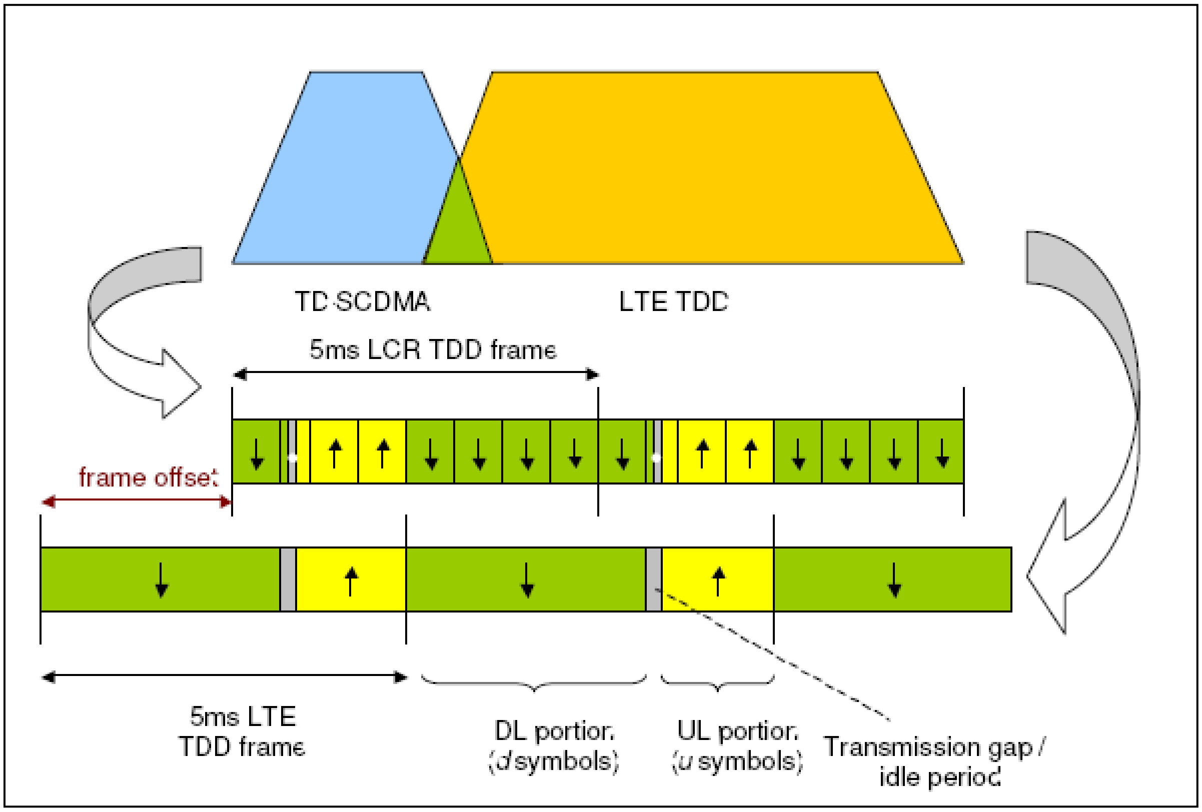
TD-SCDMA
LTE TDD
5ms LCR TDD frame
frame offset
5ms LTE TDD frame
DL portion (d symbols)
UL portion (u symbols)
Transmission gap / idle period

For LTE FDD and TDD to co-exist, large guardbands will be needed to prevent interference.

SMS in LTE

Even if an LTE network uses CSFB for voice, LTE devices will be able to send and receive SMS messages while on the LTE network. In this case, the 2G/3G core network will handle SMS messaging, but will tunnel the message to the MME in the EPC via the SGs interface. Once an LTE network uses IMS and VoLTE for packet voice service, SMS will be handled as SMS over IP and will use IMS infrastructure.[153]

User Equipment Categories

LTE specifications define categories of UE, which mainly determine the maximum throughputs of devices but also govern the number of downlink MIMO layers, as shown in Table .

Higher throughput capabilities are possible with 64 QAM and 256 QAM modulation. 3GPP is also defining Category 0 and Category M devices for M2M, as discussed in the section “Internet of Things and Machine-to-Machines.”

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[152] 5G Americas member company contribution.

[153] For further details, see 4G Americas, *Coexistence of GSM, HSPA and LTE*, May 2011, 35.

Table 19: UE Categories[154]

UE Category	Max DL Throughput	Maximum DL MIMO Layers	Maximum UL Throughput
1	10.3 Mbps	1	5.2 Mbps
2	51.0 Mbps	2	25.5 Mbps
3	102.0 Mbps	2	51.0 Mbps
4	150.8 Mbps	2	51.0 Mbps
5	299.6 Mbps	4	75.4 Mbps
6	301.5 Mbps	2 or 4	51.0 Mbps
7	301.5 Mbps	2 or 4	102.0 Mbps
8	2998.6 Mbps	8	1497.8 Mbps
9	452.3 Mbps	2 or 4	51.0 Mbps
10	452.3 Mbps	2 or 4	102.0 Mbps
11	603.0 Mbps	2 or 4	51.0 Mbps
12	603.0 Mbps	2 or 4	102.0 Mbps
13	391.6 Mbps	2 or 4	150.8 Mbps
14	3916.6 Mbps	8	9587.7 Mbps
15	798.8 Mbps	2 or 4	226.1 Mbps
16	1051.4 Mbps	2 or 4	105.5 Mbps
17	2506.6 Mbps	8	2119.4 Mbps
18	1206.0 Mbps	2 or 4 (or 8)	211.0 Mbps
19	1658.3 Mbps	2 or 4 (or 8)	13563.9 Mbps

LTE-Advanced Relays

Another capability being planned for LTE-Advanced is relays, as shown in Figure 73. The idea is to relay frames at an intermediate node, resulting in much better in-building penetration, and with better signal quality, user rates will improve. Relay nodes can also improve cell-edge performance by making it easier to add picocells at strategic locations.

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[154] 3GPP, *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities,* Technical Specification 36.306 V14.2.0, March 2017.

Relays provide a means for lowering deployment costs in initial deployments in which usage is relatively low. As usage increases and spectrum needs to be allocated to access only, operators can then employ alternate backhaul schemes.

Figure 73: LTE-Advanced Relay[155]

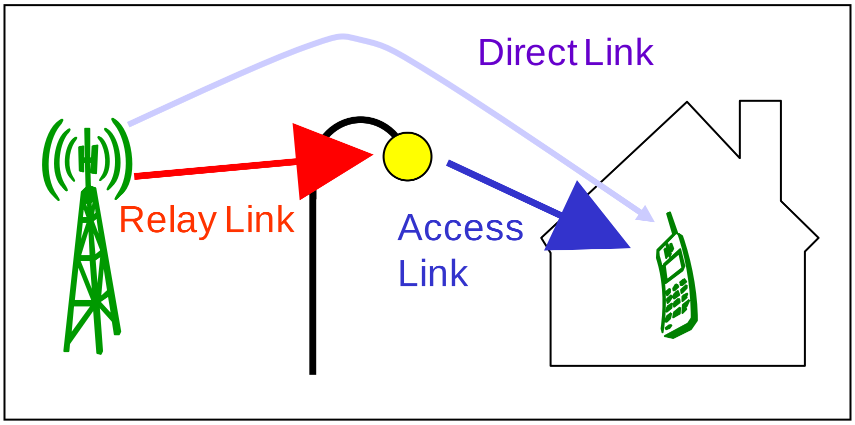

Proximity Services (Device-to-Device)

Release 12 defined a capability for devices to communicate directly with one another using LTE spectrum, a feature also called "operator-enabled proximity services." With this capability, devices can autonomously discover nearby relevant devices and services in a battery-efficient manner. Devices broadcast their needs and services and can also passively identify services without user intervention. The communication between devices is called "sidelink communications" and uses an interface called "PC5." Release 12, emphasizing public-safety applications, supports only one-to-many sidelink communications, whereas Release 13 supports one-to-one sidelink communications between two group member UEs and between a remote UE and a relay UE.

Initial emphasis of this capability, in both Release 12 and Release 13, is on public safety. Examples of potential consumer or commercial applications include discovering friends and family (social matching), push advertising for relevant notifications, tourist bulletins, venue services, crime alerts, home automation, vehicle-to-vehicle communication, and detecting children leaving the vicinity of their homes. The service is designed to work during infrastructure failures, even in emergencies and natural disasters. As a new means of communicating, proximity services could result in innovative types of applications.

The LTE network performs configuration and authentication; however, communication can be either via the network or directly between devices. To minimize battery consumption, devices synchronously wake up for brief intervals to discover services. The impact on LTE network capacity is minimal.

As with other location-based services, operators and application developers will need to address privacy concerns.

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[155] 5G Americas member contribution.

LTE Throughput

The section “4G LTE Advances” above in the main section of the paper and “Data Throughput Comparison” in the appendix provide an overview of LTE throughputs. This section provides additional details.

Table shows initial (Release 8) LTE peak data rates based on different downlink and uplink designs.

Table20: LTE Peak Throughput Rates

LTE Configuration	Downlink (Mbps) Peak Data Rate	Uplink (Mbps) Peak Data Rate
Using 2X2 MIMO in the Downlink and 16 QAM in the Uplink, 10+10 MHz	70.0	22.0
Using 4X4 MIMO in the Downlink and 64 QAM in the Uplink, 20+20 MHz	300.0	71.0

LTE is not only efficient for data but, because of a highly efficient uplink, is extremely efficient for VoIP traffic. As discussed in the “Spectral Efficiency” section above, in 10+10 MHz of spectrum, LTE VoIP capacity will reach 500 users.[156]

Table 19 analyzes LTE median and average throughput values in greater detail for different LTE configurations.

Table 19: LTE FDD User Throughputs Based on Simulation Analysis[157]

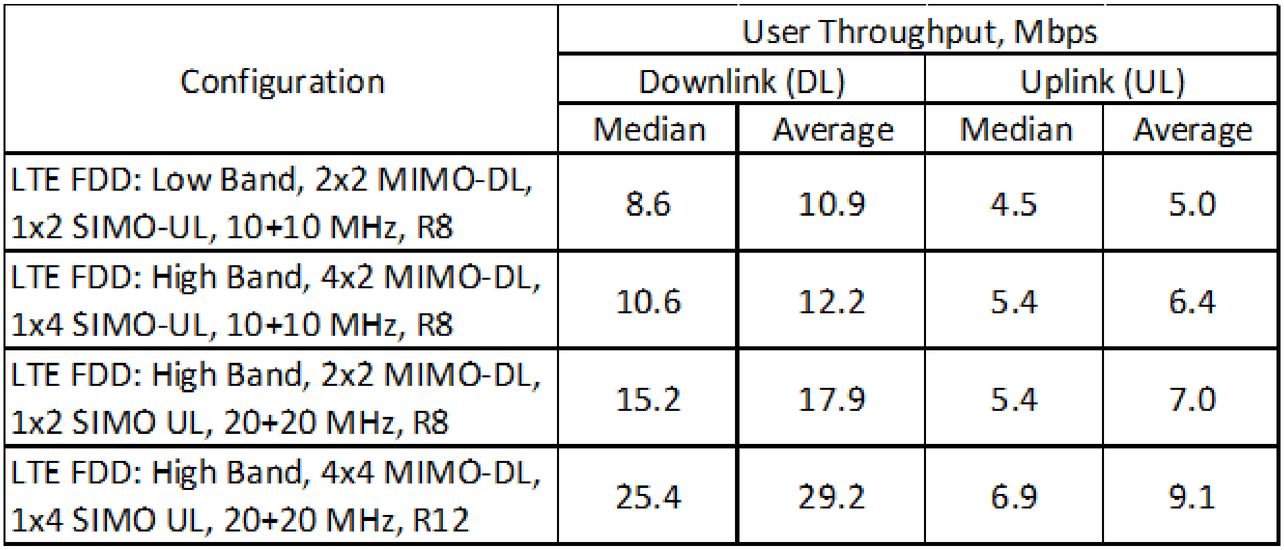

Configuration	User Throughput, Mbps			
	Downlink (DL)		Uplink (UL)	
	Median	Average	Median	Average
LTE FDD: Low Band, 2x2 MIMO-DL, 1x2 SIMO-UL, 10+10 MHz, R8	8.6	10.9	4.5	5.0
LTE FDD: High Band, 4x2 MIMO-DL, 1x4 SIMO-UL, 10+10 MHz, R8	10.6	12.2	5.4	6.4
LTE FDD: High Band, 2x2 MIMO-DL, 1x2 SIMO UL, 20+20 MHz, R8	15.2	17.9	5.4	7.0
LTE FDD: High Band, 4x4 MIMO-DL, 1x4 SIMO UL, 20+20 MHz, R12	25.4	29.2	6.9	9.1

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[156] 3GPP Multi-member analysis.

[157] 5G Americas member contribution. SIMO refers to Single Input Multiple Output antenna configuration, which in the uplink means one transmit antenna at the UE and multiple receive antennas at the eNodeB.

The simulation results represent a consensus view of 5G Americas members working on this white paper project. The goal of the analysis was to quantify LTE throughputs in realistic deployments. Simulation assumptions include:

- Traffic is FTP-like at a 50% load with a 75/25 mix of indoor/outdoor users.
- Throughput is at the medium-access control (MAC) protocol layer. (Application-layer throughputs may be 5 to 8 percent lower due to protocol overhead.)
- The 3GPP specification release numbers shown correspond to the infrastructure capability.
- The configuration in the first row corresponds to low-frequency band operation, representative of 700 MHz or cellular, while the remaining configurations assume high-frequency band operation, representative of PCS, AWS, or WCS. (Higher frequencies facilitate higher-order MIMO configurations and have wider radio channels available.)
- The downlink value for the first row corresponds to Release 8 device-receive capability (Minimum Mean Square Error [MMSE]), while the values in the other rows correspond to Release 11 device-receive capability (MMSE – Interference Rejection Combining [IRC]).
- The uplink value for the first row corresponds to a Maximal Ratio Combining (MRC) receiver at the eNodeB, while the remaining values correspond to an IRC receiver.
- Low-band operation assumes 1,732-meter inter-site distance, while high-band operation assumes 500-meter ISD. The remaining simulation assumptions are listed in Table 20.

Table 20: LTE FDD User Throughput Simulation Assumptions[158]

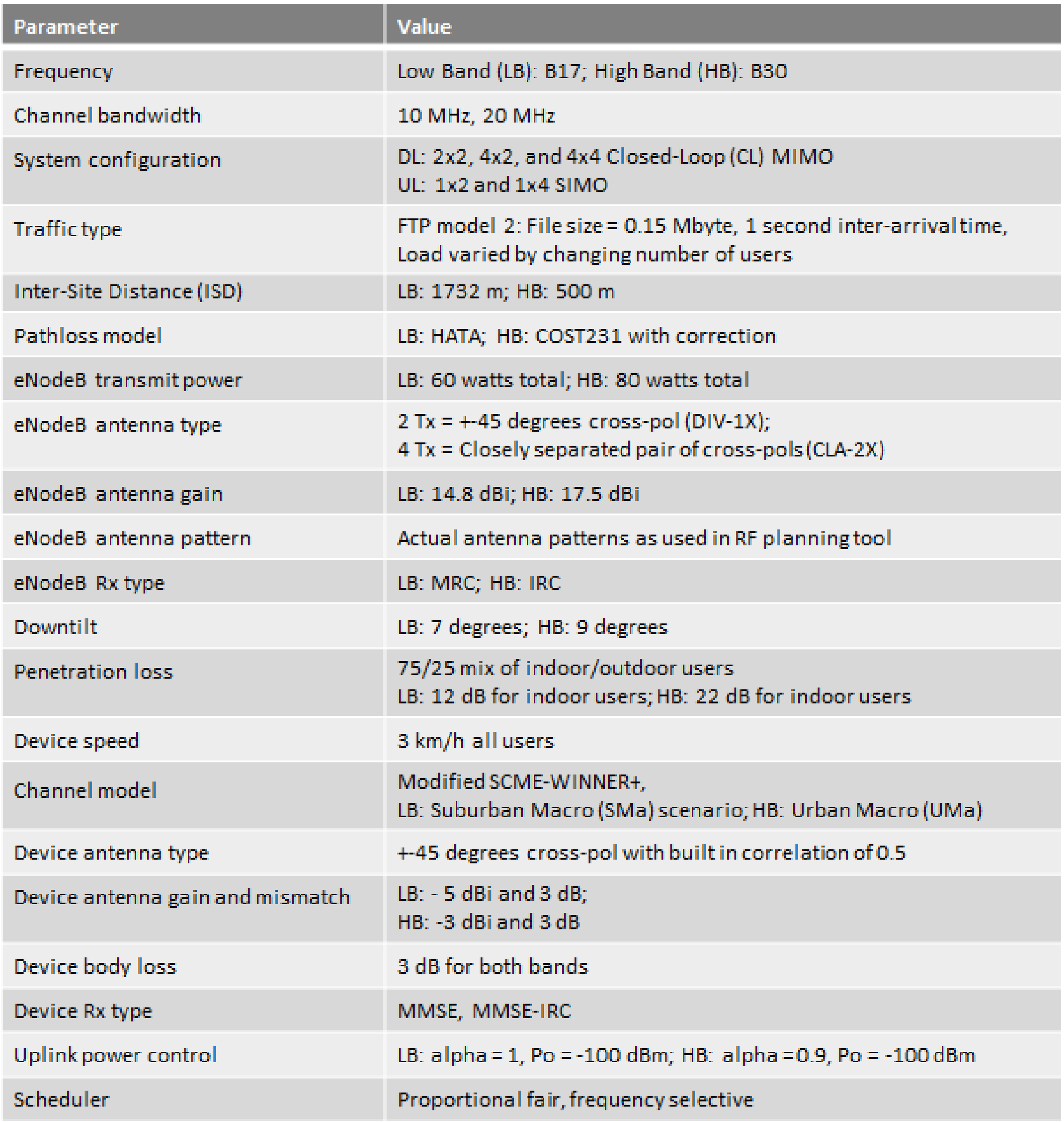

Parameter	Value
Frequency	Low Band (LB): B17; High Band (HB): B30
Channel bandwidth	10 MHz, 20 MHz
System configuration	DL: 2x2, 4x2, and 4x4 Closed-Loop (CL) MIMO UL: 1x2 and 1x4 SIMO
Traffic type	FTP model 2: File size = 0.15 Mbyte, 1 second inter-arrival time, Load varied by changing number of users
Inter-Site Distance (ISD)	LB: 1732 m; HB: 500 m
Pathloss model	LB: HATA; HB: COST231 with correction
eNodeB transmit power	LB: 60 watts total; HB: 80 watts total
eNodeB antenna type	2 Tx = +-45 degrees cross-pol (DIV-1X); 4 Tx = Closely separated pair of cross-pols (CLA-2X)
eNodeB antenna gain	LB: 14.8 dBi; HB: 17.5 dBi
eNodeB antenna pattern	Actual antenna patterns as used in RF planning tool
eNodeB Rx type	LB: MRC; HB: IRC
Downtilt	LB: 7 degrees; HB: 9 degrees
Penetration loss	75/25 mix of indoor/outdoor users LB: 12 dB for indoor users; HB: 22 dB for indoor users
Device speed	3 km/h all users
Channel model	Modified SCME-WINNER+, LB: Suburban Macro (SMa) scenario; HB: Urban Macro (UMa)
Device antenna type	+-45 degrees cross-pol with built in correlation of 0.5
Device antenna gain and mismatch	LB: - 5 dBi and 3 dB; HB: -3 dBi and 3 dB
Device body loss	3 dB for both bands
Device Rx type	MMSE, MMSE-IRC
Uplink power control	LB: alpha = 1, Po = -100 dBm; HB: alpha = 0.9, Po = -100 dBm
Scheduler	Proportional fair, frequency selective

The assumptions, emphasizing realistic deployments, do not necessarily match assumptions used by other organizations, such as 3GPP, so results may differ.

Additional insight into LTE performance under different configuration comes from a test performed on a cluster of cells in an LTE operator's network, comparing downlink performance of 4X2 MIMO against 2X2 MIMO, and uplink performance of 1X4 SIMO against 1X2 SIMO. The test employed LTE category 4 devices.[159]

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[158] 5G Americas member contribution.

[159] 5G Americas member contribution.

These tests, which were performed in a 20+20 MHz cluster, show significant improvements in cell edge uplink and downlink throughput, in addition to an overall increase in uplink and downlink throughputs. Specific results include:

- A 100% increase in uplink throughput at the cell edge with 1X4 SIMO compared to 1x2 SIMO.
- A 40% increase in downlink throughput at the cell edge with 4x2 closed-loop MIMO compared to 2x2 open-loop MIMO.
- A 50 to 75% increase in downlink throughput with closed loop MIMO compared to transmit diversity modes.
- Up to 6dB gains in uplink transmit power with 1X4 SIMO, which directly translates into UE battery savings.
- Peak speeds of 144 Mbps with 4X2 MIMO in the downlink and 47 Mbps with 1X4 SIMO in the uplink.

Another LTE operator's testing results for LTE in a TDD configuration, using 20 MHz channels, 3:2 DL to UL ratio, and category 3 devices, showed:

- Peak speeds of 55 Mbps.
- Typical speeds of 6 to 15 Mbps.[160]

Figure 74 shows the result of a drive test in a commercial LTE network with a 10 MHz downlink carrier demonstrating 20 Mbps to 50 Mbps throughput rates across much of the coverage area. Throughput rates would double with a 20+20 MHz configuration.

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[160] 5G Americas member contribution.

Figure 74: Drive Test of Commercial European LTE Network (10+10 MHz)[161]

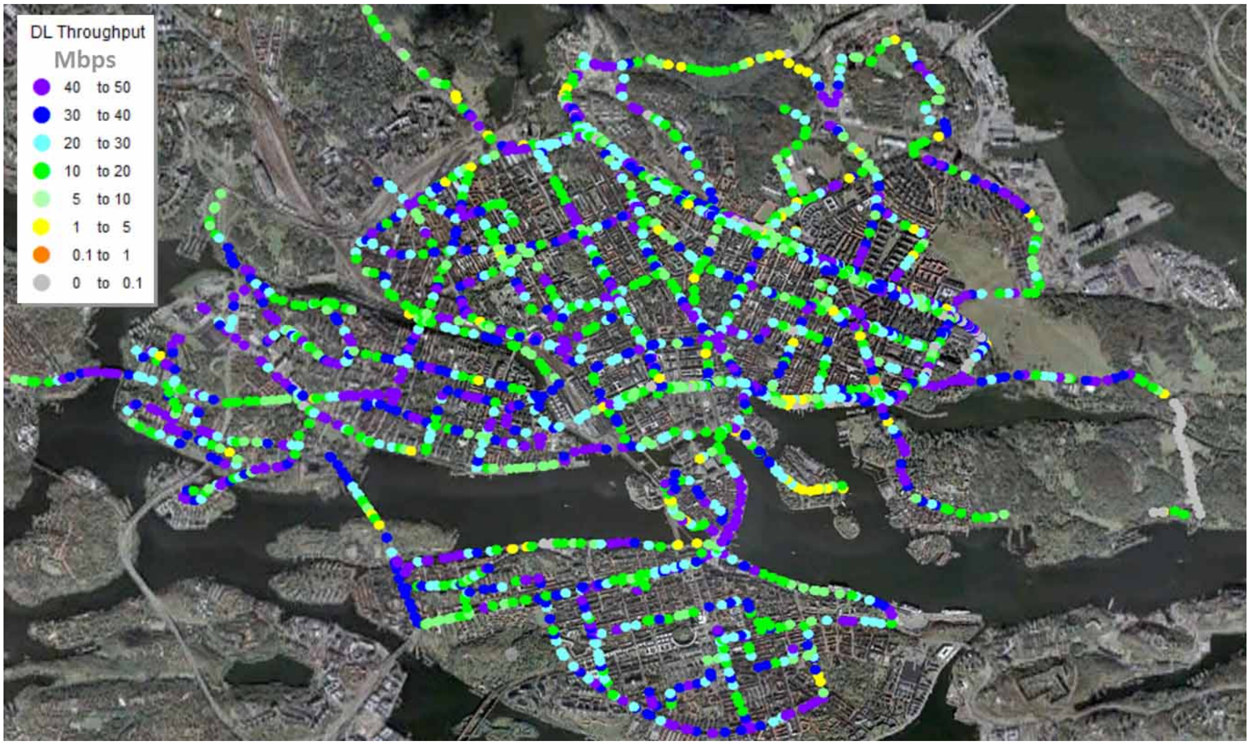
DL Throughput
Mbps
40 to 50
30 to 40
20 to 30
10 to 20
5 to 10
1 to 5
0.1 to 1
0 to 0.1

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[161] Ericsson contribution.

Figure 75 provides additional insight into LTE downlink throughput, showing Layer 1 throughput simulated at 10 MHz bandwidth using the Extended Vehicular A 3 km/hour channel model. The figure shows the increased performance obtained with the addition of different orders of MIMO. Note how throughput improves based on higher signal to noise ratio (SNR).

Figure 75: LTE Throughput in Various Modes[162]

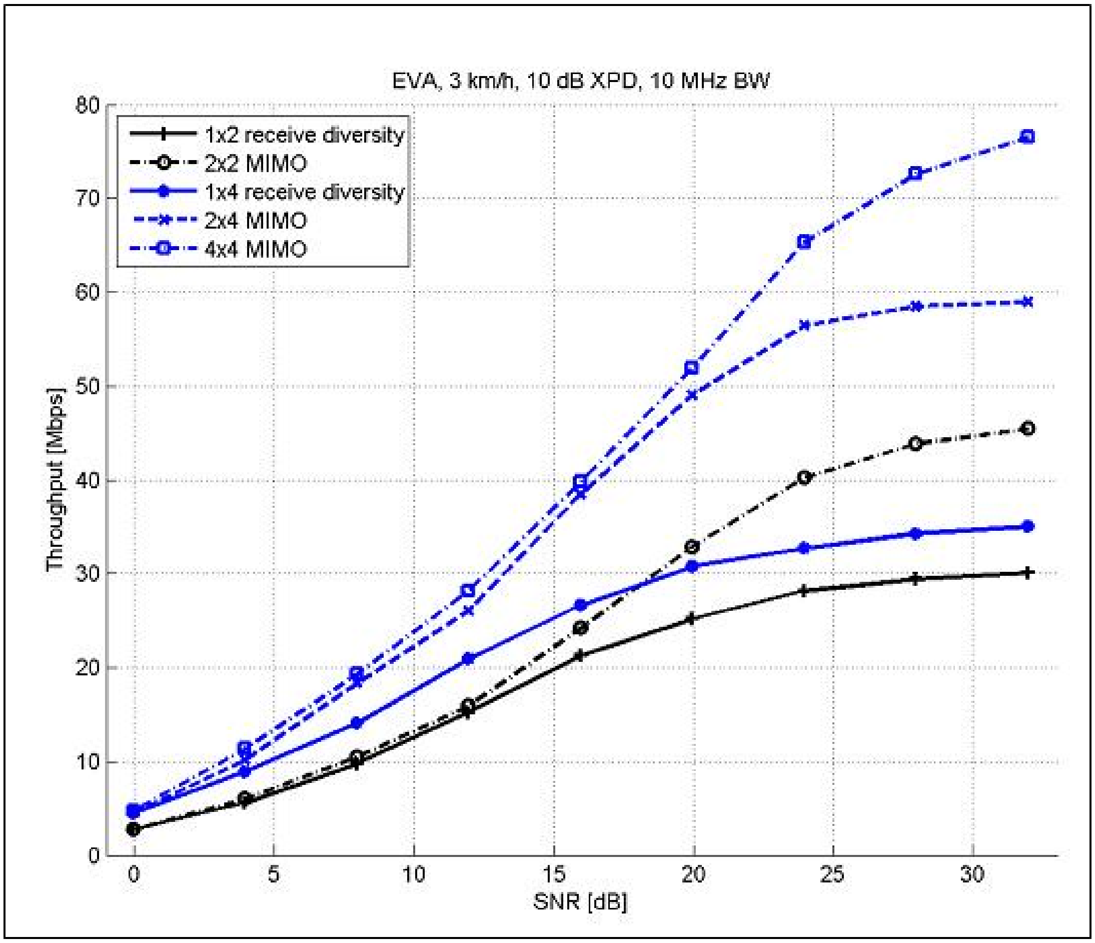

Actual throughput rates that users experience are lower than the peak rates and depend on a variety of factors:

- ☐ **RF Conditions and User Speed.** Peak rates depend on optimal conditions. Suboptimal conditions include being at the edge of the cell or moving at high speed, resulting in lower throughput.
- ☐ **Network Loading.** Like all wireless systems, throughput rates go down as more devices simultaneously use the network. Throughput degradation is linear.

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[162] Jonas Karlsson, Mathias Refback, "Initial Field Performance Measurements of LTE," *Ericsson Review*, No. 3, 2008.

Figure 76 shows how dramatically throughput rates can vary by number of active users and radio conditions. The higher curves are for better radio conditions.

Figure 76: LTE Actual Throughput Rates Based on Conditions[163]

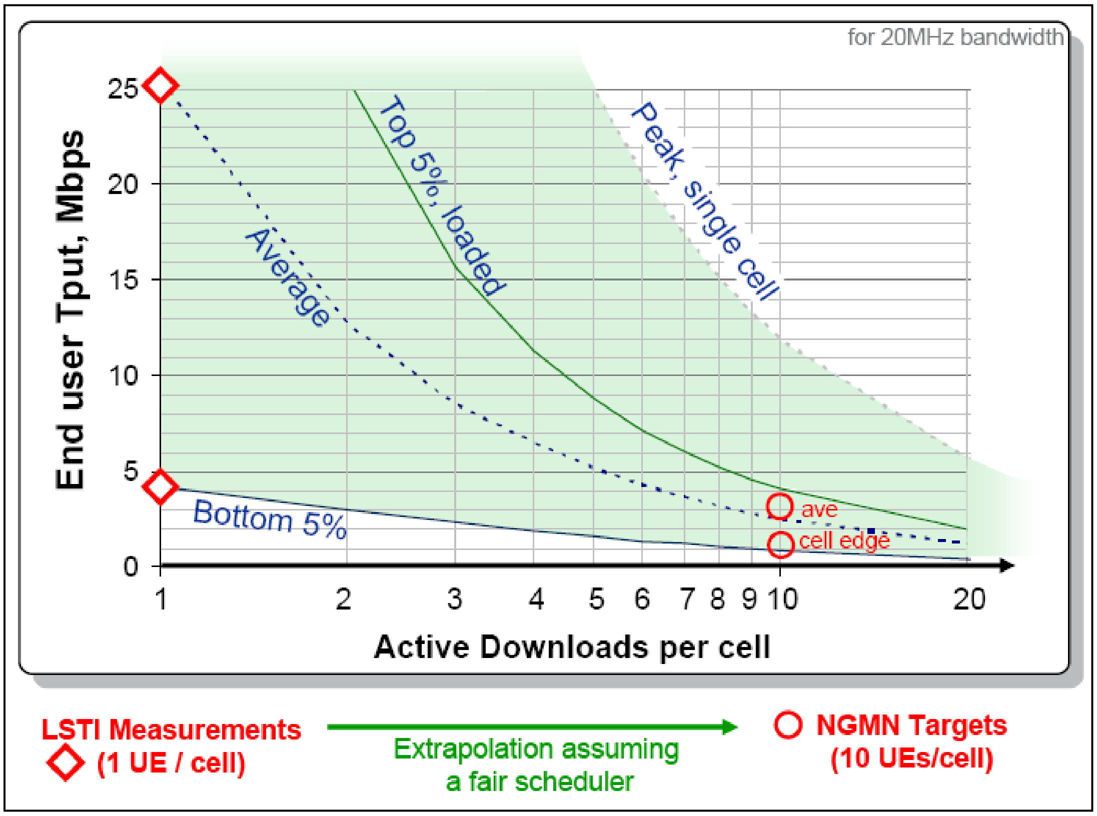

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[163] LTE/SAE Trial Initiative, “Latest Results from the LSTI, Feb 2009,” http://www.lstiforum.org.

VoLTE and RCS

This paper introduced VoLTE and voice support in the earlier section, "VoLTE, RCS, WebRTC, and Wi-Fi Calling." This section in the appendix provides additional technical detail about the operation of VoLTE and RCS.

Voice in LTE can encompass: no voice support, voice implemented in a circuit-switched fallback (CSFB) mode using 2G or 3G, and VoIP implemented with IMS.

Initial LTE network deployments used CSFB, with which the LTE network carries circuit-switched signaling over LTE interfaces, allowing the subscriber to be registered with the 2G/3G MSC even while on the LTE network. When there is a CS event, such as an incoming voice call, the MSC sends the page to the LTE core network, which delivers it to the subscriber device. The device then switches to 2G/3G operation to answer the call.

Voice over LTE using VoIP requires IMS infrastructure. To facilitate IMS-based voice, vendors and operators created the One Voice initiative to define required baseline functionality for user equipment, the LTE access network, the Evolved Packet Core, and the IMS. GSMA adopted the One Voice initiative in what it calls VoLTE, specified in GSMA reference document IR.92.[164] GSMA specifies interconnection and international roaming among LTE networks through the IR.88[165] specification. Another specification, IR.94, provides the IMS Profile for Conversational Video Service, a service referred to as "Video over LTE" (ViLTE).[166]

For a phone to support VoLTE, it needs software implementing the IMS protocol stack. For example, the iPhone 6 was the first iPhone to implement such software. Additional software implementing RCS application programming interfaces can provide applications with access to IMS-based services, such as voice, messaging, and video. The Open Mobile Alliance has defined RESTful network APIs for RCS that support the following functions: notification channel, chat, file transfer, third-party calls, call notification, video sharing, image sharing, and capability discovery. As shown in Figure 77, over time, new profile releases will broaden the scope of these APIs.

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[164] GSMA, "IMS Profile for Voice and SMS," Document IR.92. Available at http://www.gsma.com/newsroom/wp-content/uploads/2013/04/IR.92-v7.0.pdf.

[165] GSMA, "LTE Roaming Guidelines," GSMA Document IR.88. Available at http://www.gsma.com/newsroom/wp-content/uploads/2013/04/IR.88-v9.0.pdf.

[166] GSMA, "IMS Profile for Conversational Video Service," Document IR.94. Available at http://www.gsma.com/newsroom/all-documents/ir-94-ims-profile-for-conversational-video-service/.

Figure 77: Evolution of RCS API Profiles[167]

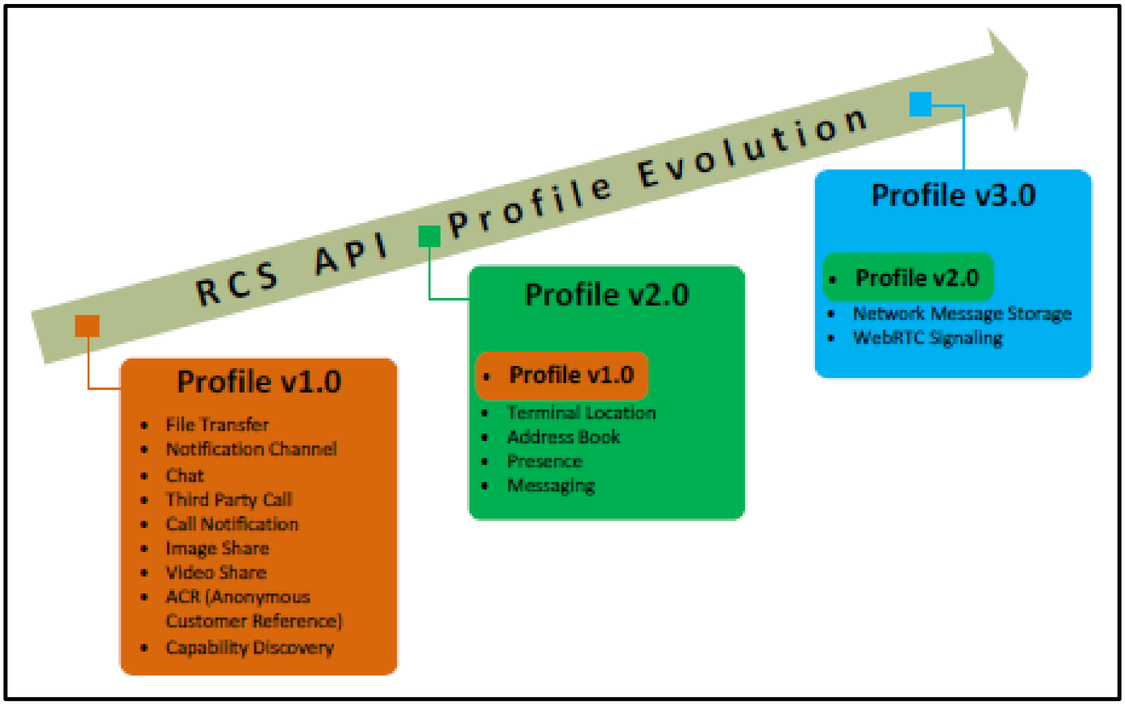
RCS API Profile Evolution
Profile v1.0
File Transfer
Notification Channel
Chat
Third Party Call
Call Notification
Image Share
Video Share
ACR (Anonymous Customer Reference)
Capability Discovery
Profile v2.0
Profile v1.0
Terminal Location
Address Book
Presence
Messaging
Profile v3.0
Profile v2.0
Network Message Storage
WebRTC Signaling

LTE VoIP leverages the QoS capabilities defined for EPC, which specify different quality classes. Features available in LTE to make voice operation more efficient include Semi-Persistent Scheduling (SPS) and TTI bundling. SPS reduces control channel overhead for applications (like VoIP) that require a persistent radio resource. Meanwhile, TTI bundling improves subframe utilization by reducing IP overhead, while in the process optimizing uplink coverage.

Another way to increase voice capacity in LTE and to support operation in congestion situations is vocoder rate adaptation, a mechanism with which operators can control the codec rate based on network load, thus dynamically trading off voice quality against capacity.

VoLTE roaming across operators will require network-to-network interfaces between their respective IMS networks. Such roaming and interconnect will follow initial VoLTE deployments. Different IMS stack implementations between vendors will also complicate roaming.

One roaming consideration is how operators handle data roaming. LTE roaming can send all visited network traffic back to the home network, which for a voice call, increases voice latency. For voice calls, the local breakout option would mitigate this latency.

Using Single-Radio Voice Call Continuity (SR-VCC) and Enhanced SR-VCC (eSRVCC), user equipment can switch mid-call to a circuit-switched network, in the event that the user moves out of LTE coverage. Similarly, data sessions can be handed over in what is called “Packet-Switched Handover” (PSHO).

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[167] 4G Americas, *VoLTE and RCS Technology – Evolution and Ecosystem,* Nov. 2014.

Figure 78 shows how an LTE network might evolve in three stages. Initially, LTE performs only data service, and the underlying 2G/3G network provides voice service via CSFB. In the second stage, voice over LTE is available, but LTE covers only a portion of the total 2G/3G coverage area. Hence, voice in 2G/3G can occur via CSFB or SR-VCC. Eventually, LTE coverage will match 2G/3G coverage, and LTE devices will use only the LTE network.

Figure 78: Evolution of Voice in an LTE Network[168]

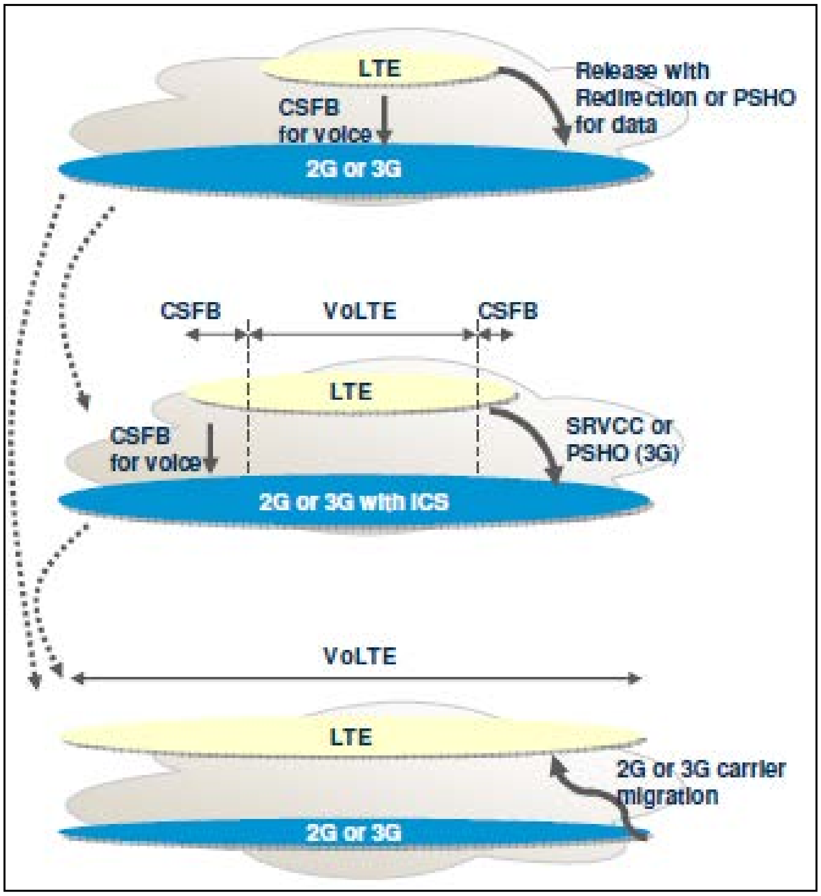
LTE
Release with Redirection or PSHO for data
CSFB for voice
2G or 3G
CSFB
VoLTE
CSFB
LTE
SRVCC or PSHO (3G)
CSFB for voice
2G or 3G with ICS
VoLTE
LTE
2G or 3G carrier migration
2G or 3G

Another voice approach, called “Voice over LTE via Generic Access” (VoLGA), defined circuit-switched operation through an LTE IP tunnel. 3GPP, however, has stopped official standards work that would support VoLGA.

3GPP has developed a new codec, called “Enhanced Voice Services” (EVS), which will include super-wideband voice capability. For the same bit rate, EVS provides higher voice quality than the other codecs.[169] Table 21 summarizes the features and parameters of the three 3GPP codecs used in LTE.

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[168] 5G Americas member contribution.

[169] See Figure 9.2. 3GPP, *TR 26.952 V12.1.0, Codec for Enhanced Voice Services (EVS); Performance Characterization*, March 2015.

Table 21: Comparison of AMR, AMR-WB and EVS Codecs[170]

Features	AMR	AMR-WB	EVS
Input and output sampling frequencies supported	8KHz	16KHz	8KHz, 16KHz, 32KHz, 48 KHz
Audio bandwidth	Narrowband	Wideband	Narrowband, Wideband, Super-wideband, Fullband
Coding capabilities	Optimized for coding human voice signals	Optimized for coding human voice signals	Optimized for coding human voice and general-purpose audio (music, ringtones, mixed content) signals
Bit rates supported (in kb/s)	4.75, 5.15, 5.90, 6.70, 7.4, 7.95, 10.20, 12.20	6.6, 8.85, 12.65, 14.25, 15.85, 18.25, 19.85, 23.05, 23.85	5.9, 7.2, 8, 9.6 (NB and WB only), 13.2 (NB, WB and SWB), 16.4, 24.4, 32, 48, 64, 96, 128 (WB and SWB only)
Number of audio channels	Mono	Mono	Mono and Stereo
Frame size	20 ms	20 ms	20 ms
Algorithmic Delay	20-25 ms	25 ms	Up to 32 ms

Figure 79 shows mean opinion scores (MOS) for different codecs at different bit rates, illustrating the advantage of EVS, particularly for bit rates below 32 kbps that cellular networks use.

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[170] 4G Americas, *Mobile Broadband Evolution: Rel-12 & Rel-13 and Beyond*, 2015. See also T-Mobile 2016 EVS announcement: https://newsroom.t-mobile.com/news-and-blogs/volte-enhanced-voice-services.htm.

Figure 79: Combined Mean Opinion Score Values[171]

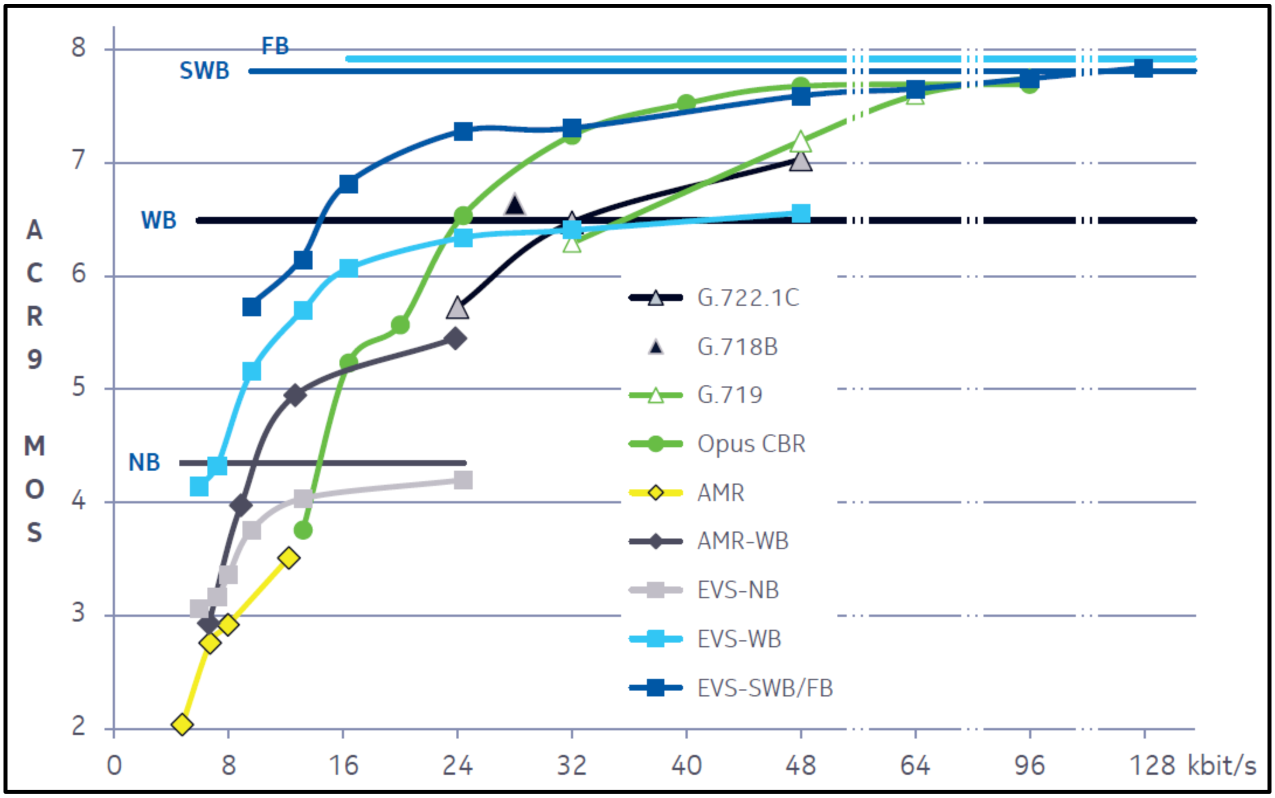

Table 22 shows EVS (narrowband, wideband, super-wideband) audio bandwidths and bitrates that create subjective quality equal to or better than AMR or AMR-WB for typical conversational voice scenarios.

Table 22: EVS Compared to AMR and AMR-WB[172]

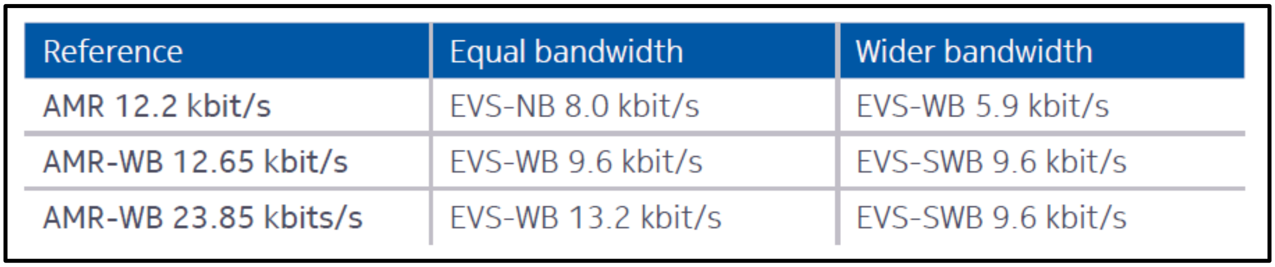

Reference	Equal bandwidth	Wider bandwidth
AMR 12.2 kbit/s	EVS-NB 8.0 kbit/s	EVS-WB 5.9 kbit/s
AMR-WB 12.65 kbit/s	EVS-WB 9.6 kbit/s	EVS-SWB 9.6 kbit/s
AMR-WB 23.85 kbits/s	EVS-WB 13.2 kbit/s	EVS-SWB 9.6 kbit/s

Figure 80 compares EVS capacity gains over AMR and AMR-WB for the references cases shown in Table 22. EVS-SWB at 9.6 kbps almost doubles voice capacity compared to AMW-WB at 23.85 kbps.

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[171] Nokia*, The 3GPP Enhanced Voice Services (EVS) codec*, 2015.

[172] Ibid.

Figure 80: EVS Voice Capacity Compared to AMR and AMR-WB[173]

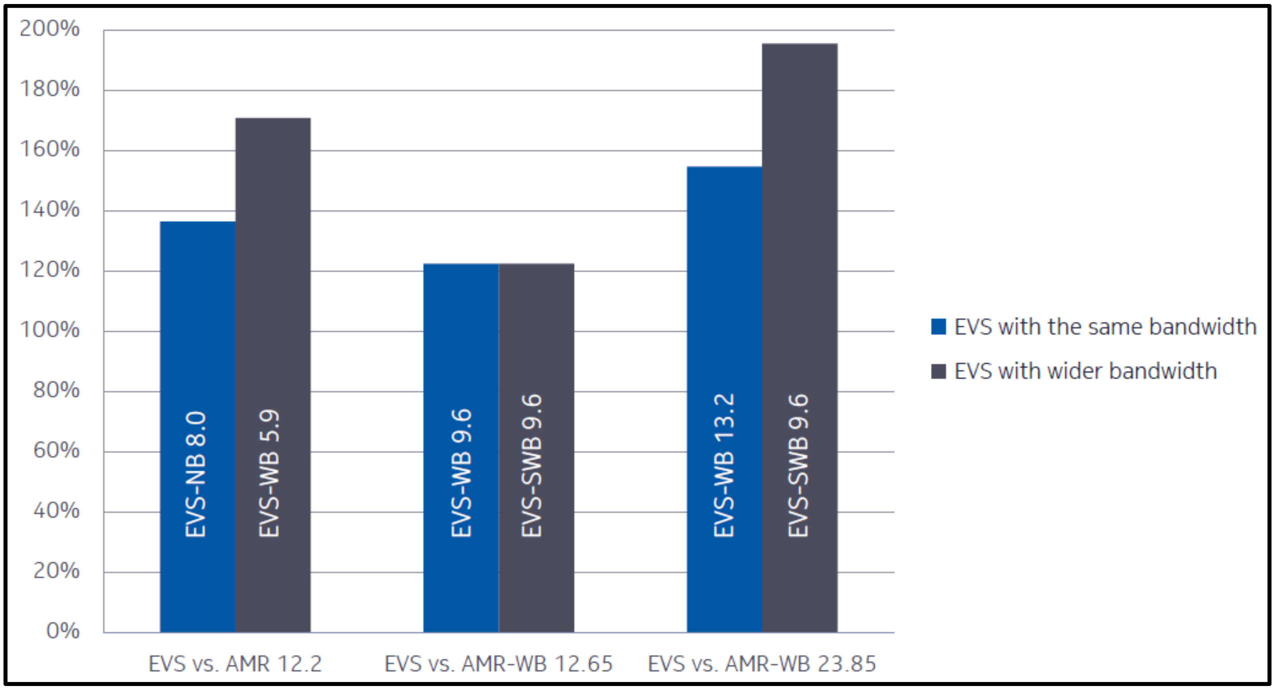

LTE Ultra-Reliable and Low-Latency Communications

The 3GPP work item for this feature states, "3GPP LTE technology enhancements are needed to serve such new use cases and to remain technologically competitive up to and beyond 2020. As a candidate technology for ITU IMT-2020 submission, it is motivated to further enhance the LTE system such that it can meet the key IMT-2020 requirements including those for URLLC in terms of reliability ($1\text{-}10^{-5}$ reliability for small data packets within a latency of 1ms) as well as latency (≤1ms one way user plane latency)."[174]

Evolved Packet Core (EPC)

3GPP defined the Evolved Packet Core (EPC) in Release 8 as a framework for an evolution or migration of the network to a higher-data-rate, lower latency, packet-optimized system that supports multiple radio-access technologies including LTE, as well as and legacy GSM/EDGE and UMTS/HSPA networks. EPC also integrates CDMA2000 networks and Wi-Fi.

EPC is optimized for all services to be delivered via IP in a manner that is as efficient as possible—through minimization of latency within the system, for example. It also provides service continuity across heterogeneous networks, which is important for LTE operators who must simultaneously support GSM-HSPA customers.

One important performance-enhancing aspect of EPC is a flatter architecture. For packet flow, EPC includes two network elements, called "Evolved Node B" (eNodeB) and the Access Gateway (AGW). The eNodeB (base station) integrates the functions traditionally performed by the radio network controller, which previously was a separate node controlling multiple Node Bs. Meanwhile, the AGW integrates the functions traditionally performed by the SGSN and GGSN. The AGW includes both control functions, handled through the Mobile Management Entity (MME), and user plane (data communications) functions. The user plane functions consist of two elements: A serving gateway that addresses 3GPP mobility and terminates eNodeB connections, and a Packet Data Network (PDN) gateway that addresses service requirements and also terminates access by non-3GPP networks. The MME serving gateway and PDN gateways can be collocated in the same physical node or distributed, based on vendor implementations and deployment scenarios.

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[173] Ibid.

[174] RP-170796, 3GPP Work Item Description, "Ultra Reliable Low Latency Communication for LTE," March 2017.

EPC uses IMS as a component. It also manages QoS across the whole system, an important enabler for voice and other multimedia-based services.

Figure 81 shows the EPC architecture.

Figure 81: EPC Architecture

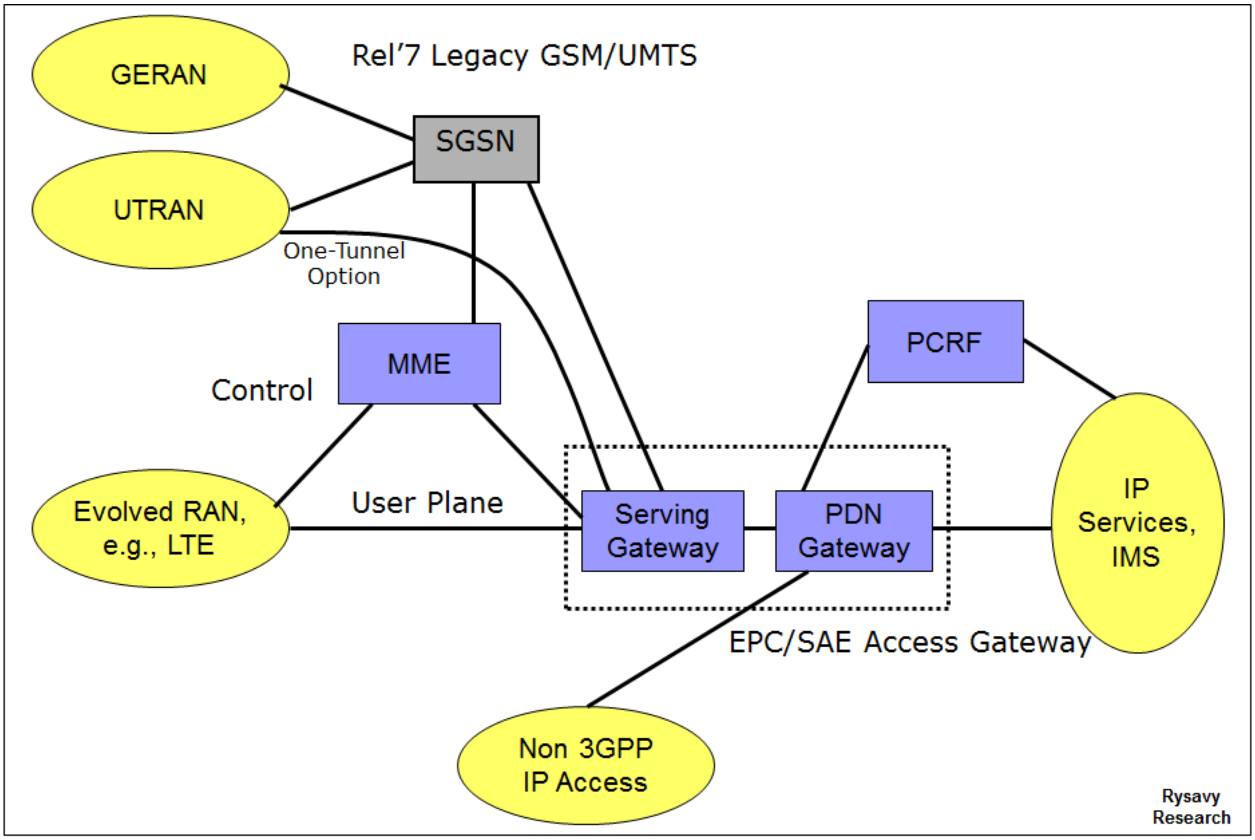
Rel'7 Legacy GSM/UMTS
GERAN
SGSN
UTRAN
One-Tunnel Option
PCRF
MME
Control
IP Services, IMS
Evolved RAN, e.g., LTE
User Plane
Serving Gateway
PDN Gateway
EPC/SAE Access Gateway
Non 3GPP IP Access
Rysavy Research

Elements of the EPC architecture include:

- Support for legacy GERAN and UTRAN networks connected via SGSN.
- Support for new radio-access networks such as LTE.
- Support for non-3GPP networks such as EV-DO and Wi-Fi. (See section below on Wi-Fi integration).
- The Serving Gateway that terminates the interface toward the 3GPP radio-access networks.

- ❑ The PDN gateway that controls IP data services, does routing, allocates IP addresses, enforces policy, and provides access for non-3GPP access networks.
- ❑ The MME that supports user equipment context and identity, as well as authenticating and authorizing users.
- ❑ The Policy Control and Charging Rules Function that manages QoS aspects.

QoS in EPS employs the QoS Class Identifier (QCI), a number denoting a set of transport characteristics (bearer with/without guaranteed bit rate, priority, packet delay budget, packet error loss rate) and used to infer nodes specific parameters that control packet forwarding treatment (such as scheduling weights, admission thresholds, queue management thresholds, or link-layer protocol configuration). The network maps each packet flow to a single QCI value (nine are defined in the Release 8 version of the specification) according to the level of service required by the application. Use of the QCI avoids the transmission of a full set of QoS-related parameters over the network interfaces and reduces the complexity of QoS negotiation. The QCI, together with Allocation Retention Priority (ARP) and, if applicable, Guaranteed Bit Rate (GBR) and Maximum Bit Rate (MBR), determines the QoS associated to an EPS bearer. A mapping between EPS and pre-Release 8 QoS parameters permits interworking with legacy networks.

The QoS architecture in EPC enables a number of important capabilities for both operators and users:

- ❑ **VoIP support with IMS.** QoS is a crucial element for providing LTE/IMS voice service. (See section below on IMS).
- ❑ **Enhanced application performance.** Applications such as gaming or video can operate more reliably.
- ❑ **More flexible business models.** With flexible, policy-based charging control, operators and third parties will be able to offer content in creative new ways. For example, an enhanced video stream to a user could be paid for by an advertiser.
- ❑ **Congestion control.** In congestion situations, certain traffic flows (bulk transfers, abusive users) can be throttled down to provide a better user experience for others.

Table 23 shows the nine QCI used by LTE.

Table 23: LTE Quality of Service

QCI	Resource Type	Priority	Delay Budget	Packet Loss	Examples
1	GBR (Guaranteed Bit Rate)	2	100 msec.	10^{-2}	Conversational voice
2	GBR	4	150 msec.	10^{-3}	Conversational video (live streaming)
3	GBR	3	50 msec.	10^{-3}	Real-time gaming
4	GBR	5	300 msec.	10^{-6}	Non-conversational video (buffered streaming)
5	Non-GBR	1	100 msec.	10^{-6}	IMS signaling

QCI	Resource Type	Priority	Delay Budget	Packet Loss	Examples
6	Non-GBR	6	300 msec.	10^{-6}	Video (buffered streaming), TCP Web, email, and FTP
7	Non-GBR	7	100 msec.	10^{-3}	Voice, video (live streaming), interactive gaming
8	Non-GBR	8	300 msec.	10^{-6}	Premium bearer for video (buffered streaming), TCP Web, e-mail, and FTP
9	Non-GBR	9	300 msec.	10^{-6}	Default bearer for video, TCP for non-privileged users

Heterogeneous Networks and Small Cells

A fundamental concept in the evolution of next-generation networks is the blending of multiple types of networks to create a "network of networks" characterized by:

- ❑ Variations in coverage areas, including femtocells (either enterprise femtos or home femtos, called HeNBs), picocells (also referred to as metro cells), and macro cells. Cell range can vary from 10 meters to 50 kilometers.
- ❑ Different frequency bands.
- ❑ Different technologies spanning Wi-Fi, 2G, 3G, 4G, and 5G.
- ❑ Relaying capability in which wireless links can serve as backhaul.

Figure 82 shows how user equipment might access different network layers.

Figure 82: Load Balancing with Heterogeneous Networks[175]

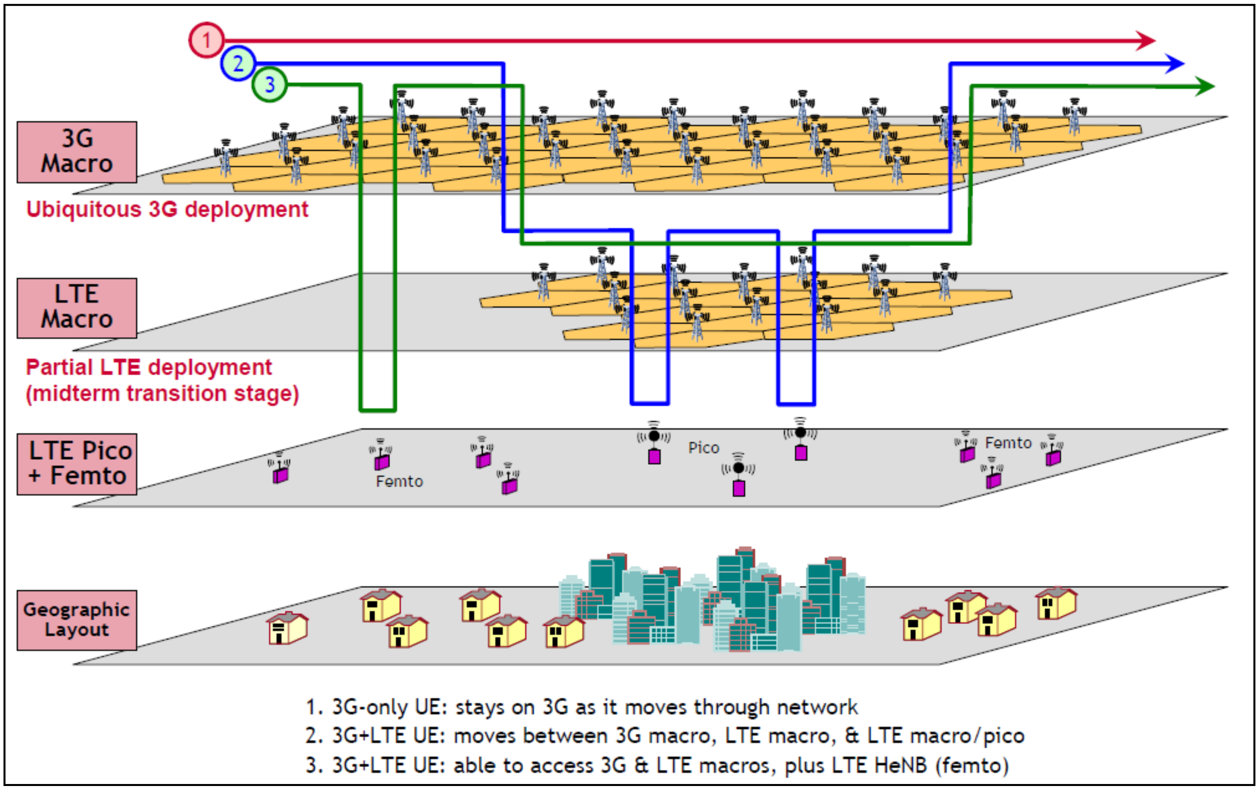

1
2
3
3G Macro
Ubiquitous 3G deployment
LTE Macro
Partial LTE deployment (midterm transition stage)
LTE Pico + Femto
Femto
Pico
Femto
Geographic Layout
1. 3G-only UE: stays on 3G as it moves through network
2. 3G+LTE UE: moves between 3G macro, LTE macro, & LTE macro/pico
3. 3G+LTE UE: able to access 3G & LTE macros, plus LTE HeNB (femto)

HetNets will allow significant capacity expansion in configurations in which operators can add picocells to coverage areas served by macrocells, particularly if there are hot spots with higher user densities.

Small cells differentiate themselves from macrocells according to the parameters shown in Table 24.

Table 24: Small Cell Vs. Macro Cell Parameters: Typical Values

Parameter	Small Cell	Macro Cell
Transmission Power	24 dBm (0.25 W)	43 dBm (20 W)
Antenna Gain	2 dBi	15 dBi
Users	Tens	Hundreds
Mobility	30 km/hr	350 km/hr

---

[175] 5G Americas member contribution.

Whether or not the small cell uses the same radio carriers as the macro cell involves multiple tradeoffs. In Figure 83 Scenario 1, the small cells and macro cell use different radio carriers, the two not interfering with each other. Although this configuration requires more spectrum, the small cells are able to cover larger areas than if they were deployed using the same radio carrier as the macro. This configuration supports medium-to-high penetration levels of small cells, allowing the network to reach huge capacity.

In Scenario 2, the small cells and macro cells use the same radio carrier, accommodating operators with more limited spectrum, but the network must manage interference using the techniques discussed below. Operators must carefully manage small-cell transmission power in this configuration.

Figure 83: Scenarios for Radio Carriers in Small Cells

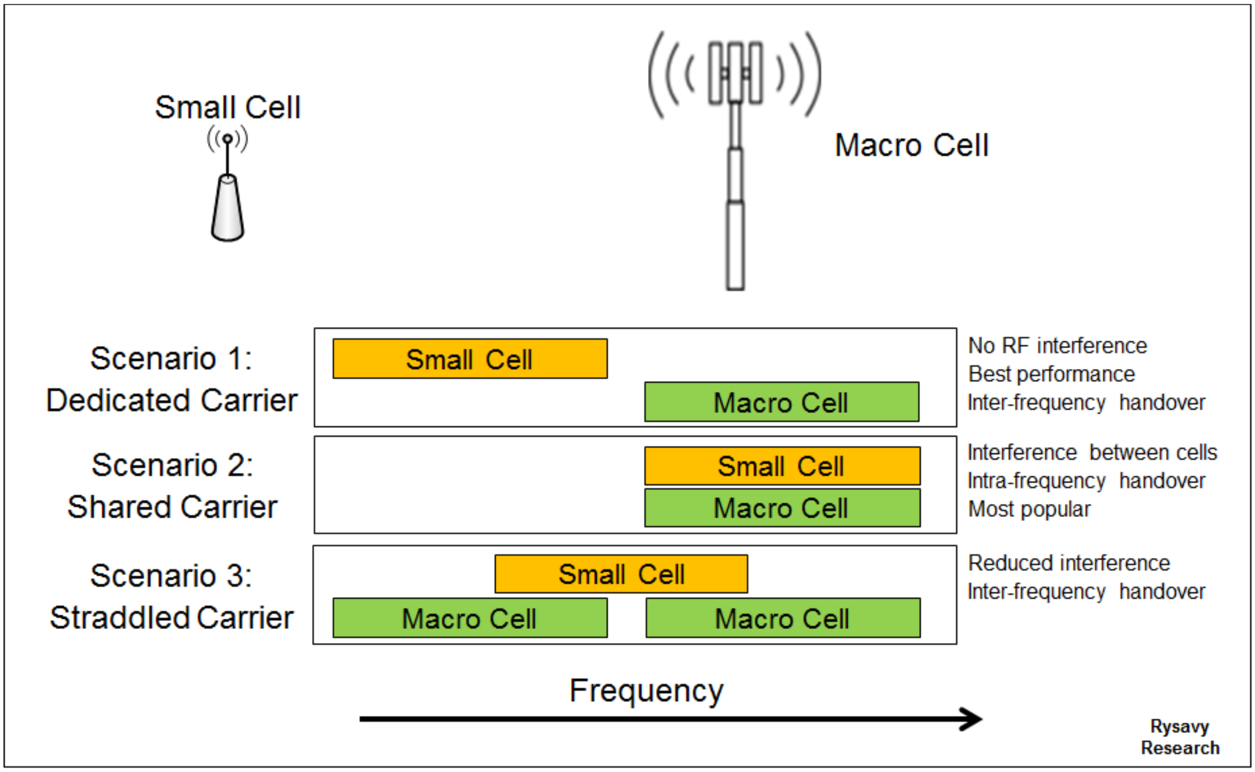
Small Cell
Macro Cell
Scenario 1:
Dedicated Carrier
Small Cell
Macro Cell
No RF interference
Best performance
Inter-frequency handover
Scenario 2:
Shared Carrier
Small Cell
Macro Cell
Interference between cells
Intra-frequency handover
Most popular
Scenario 3:
Straddled Carrier
Small Cell
Macro Cell
Macro Cell
Reduced interference
Inter-frequency handover
Frequency
Rysavy
Research

In Scenario 3, the small cells use a straddled radio carrier, accommodating operators with more spectrum, but the network still needs to manage interference using techniques discussed below. Compared with a shared carrier configuration, this configuration has benefits similar to dedicated carriers in terms of radio-parameter planning and reduced interference.

Figure 84 shows two different traffic distribution scenarios, with a uniform distribution of devices in the first and higher densities serviced by picocells in the second. The second scenario can result in significant capacity gains as well as improved user throughput.

Figure 84: Different Traffic Distributions Scenarios

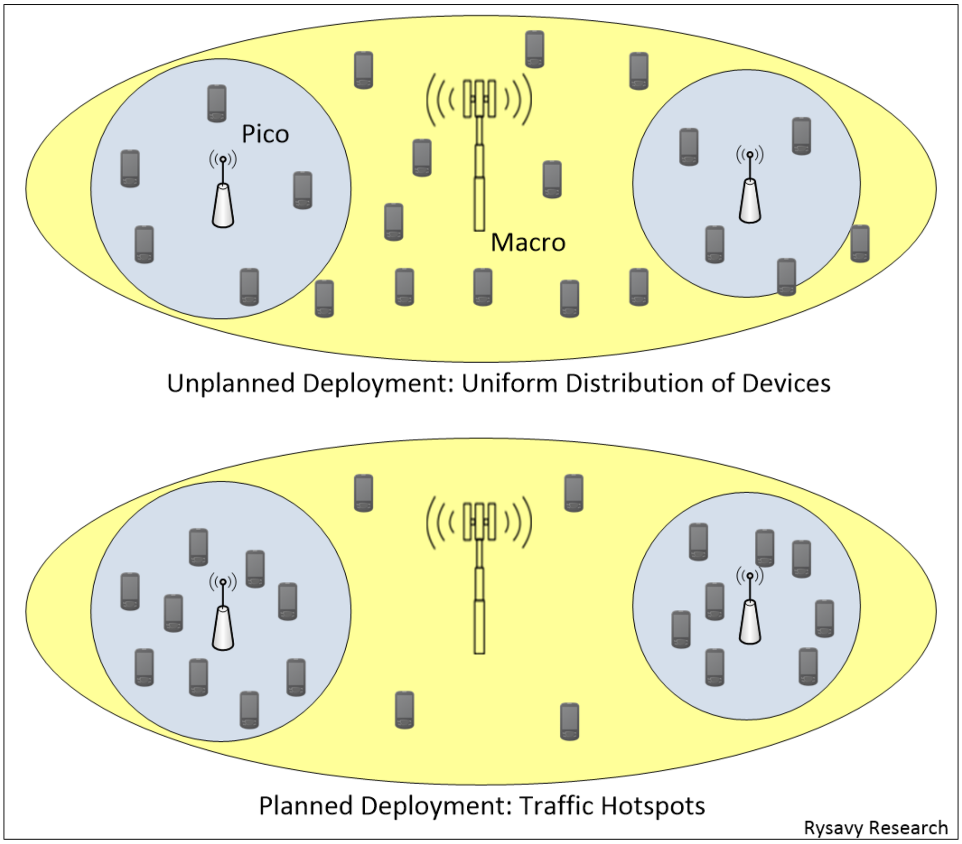
Pico
Macro
Unplanned Deployment: Uniform Distribution of Devices
Planned Deployment: Traffic Hotspots
Rysavy Research

One vendor calculated expected HetNet gains assuming no eICIC, no picocell range extension, and no eICIC. For the case of four picocells without picocell range extension and uniform user distribution, the median-user-throughput gain compared with a macro-only configuration was 85%. For a similar case of four picocells but using a hotspot user distribution, the gain was much higher, 467%.[176] Additional gains will occur with picocell range extension.

Expected picocell gains rise proportionally to the number of picocells, so long as a sufficient number of UEs connect to the picocells.

Release 10 and Release 11 added enhanced support to manage the interference in the HetNet scenario in the time domain with Enhanced Inter-cell Interference Coordination (eICIC) and Further Enhanced Intercell Interference Coordination (feICIC), as well as in the frequency domain with carrier-aggregation-based ICIC.

HetNet capability keeps becoming more sophisticated through successive 3GPP releases as summarized in Table 25.

---

[176] 5G Americas member contribution. Further assumes 2X1 W picocell transmit power, cell-edge placement (planned picocell deployment), 67% of all the users within 40m of the pico locations, and 3GPP Technical Report 36.814 adapted to 700 MHz.

Table 25: 3GPP HetNet Evolution

3GPP Release	HetNet Feature
8	Initial SON capabilities, most for auto configuration. Initial intercell interference coordination (ICIC) available.
9	More mobility options (for example, handover between HeNBs), operator customer subscriber group (SCG) lists, load-balancing, coverage and capacity improvements.
10	An interface for HeNBs, called “Iurh,” that improves coordination and synchronization, LTE time domain eICIC. Carrier-aggregation-based ICIC also defined.
11	Improved eICIC, further mobility enhancements.

Enhanced Intercell Interference Coordination

Significant challenges must be addressed in these heterogeneous networks. One is near-far effects, in which local small-cell signals can easily interfere with macro cells if they are using the same radio carriers.

Interference management is of particular concern in HetNets since, by design, coverage areas of small coverage cells overlap with the macro cell. Beginning with Release 10, eICIC introduces an approach of almost-blank subframes by which subframe transmission can be muted to prevent interference. Figure 85 illustrates eICIC for the macro layer and pico layer coordination. If a UE is on a picocell but in a location where it is sensitive to interference from the macro layer, the macro layer can mute its transmission during specific frames when the pico layer is transmitting.

Figure 85: Example of Enhanced Intercell Interference Coordination[177]

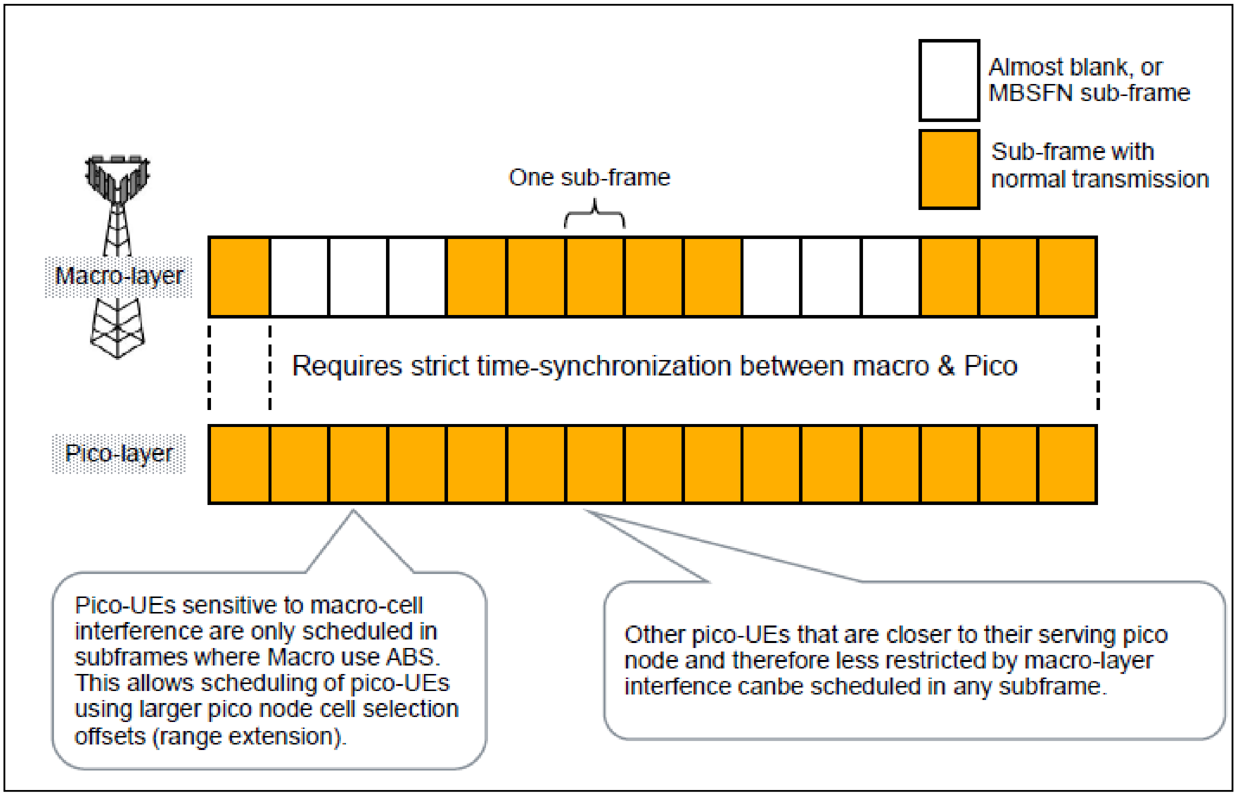
Almost blank, or MBSFN sub-frame
Sub-frame with normal transmission
One sub-frame
Macro-layer
Requires strict time-synchronization between macro & Pico
Pico-layer
Pico-UEs sensitive to macro-cell interference are only scheduled in subframes where Macro use ABS. This allows scheduling of pico-UEs using larger pico node cell selection offsets (range extension).
Other pico-UEs that are closer to their serving pico node and therefore less restricted by macro-layer interfence canbe scheduled in any subframe.

LTE can also combine eICIC with interference-cancellation-based devices to minimize the harmful effects of interference between picocells and macro cells.

Figure 86 shows one 4G America member’s analysis of anticipated median throughput gains using picocells and Release 11 Further Enhanced ICIC.

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[177] 5G Americas member contribution.

Figure 86: Median Throughput Gains in Hotspot Scenarios[178]

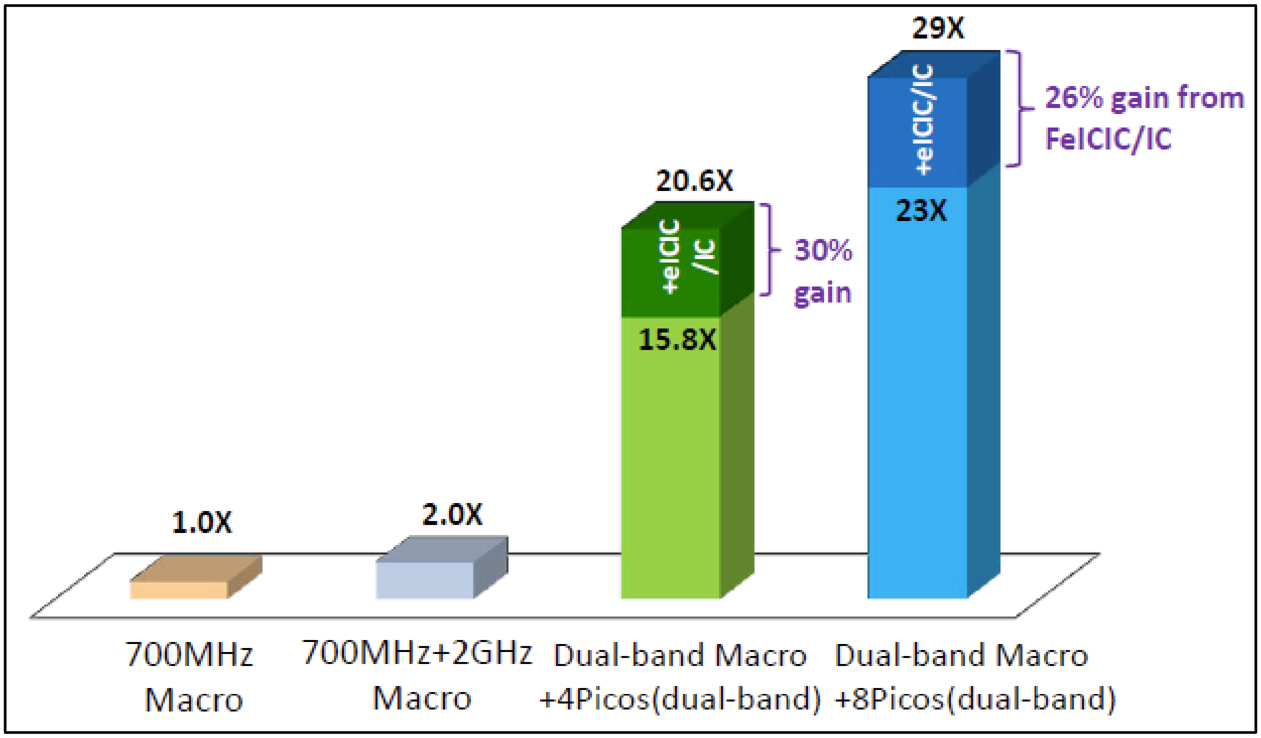

FeICIC is also beneficial in non-hotspot scenarios. In the case of a uniform distribution of picocells, this same 5G Americas member estimates a 130% gain from FeICIC for an eight picocell per macro-cell scenario, increasing capacity from a factor of 3.3 for the picocells alone to a factor of 7.6 with the addition of FeICIC.[179]

Further insight is available from Figure 87, which shows 5 percentile and 50 percentile throughput with and without eICIC under different conditions of range extension and almost blanked subframes.

---

[178] 5G Americas member contribution. Assumes 3GPP evaluation methodology TR 36.814, carrier-aggregation UEs, macro ISD = 1732m, 700 MHz and 2GHz carrier frequency, full-buffer traffic, FDD 10+10 MHz per carrier, 6-degree antenna downtilt, 4 or 8 Picos and 30 UEs per Macro cell, hotspot distribution with 20 of 30 UEs near picos, PF scheduler, 2x2 MIMO, TU3 channel, NLOS, local partitioning algorithm.

[179] Assumes 3GPP evaluation methodology TR 36.814, macro ISD = 1732m, 700 MHz and 2GHz carrier frequency, full-buffer traffic, 6-degree antenna downtilt, 30 carrier-aggregation UEs per Macro cell, uniform random layout, PF scheduler, FDD, 10+10 MHz per carrier, 2x2 MIMO, TU3 channel, NLOS, local partitioning algorithm. Additional information is available at ftp://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_66b/Docs/R1-113383.zip.

Figure 87: User Throughput Performance With / Without eICIC for Dynamic Traffic vs. Average Offered Load per Macro Cell Area[180]

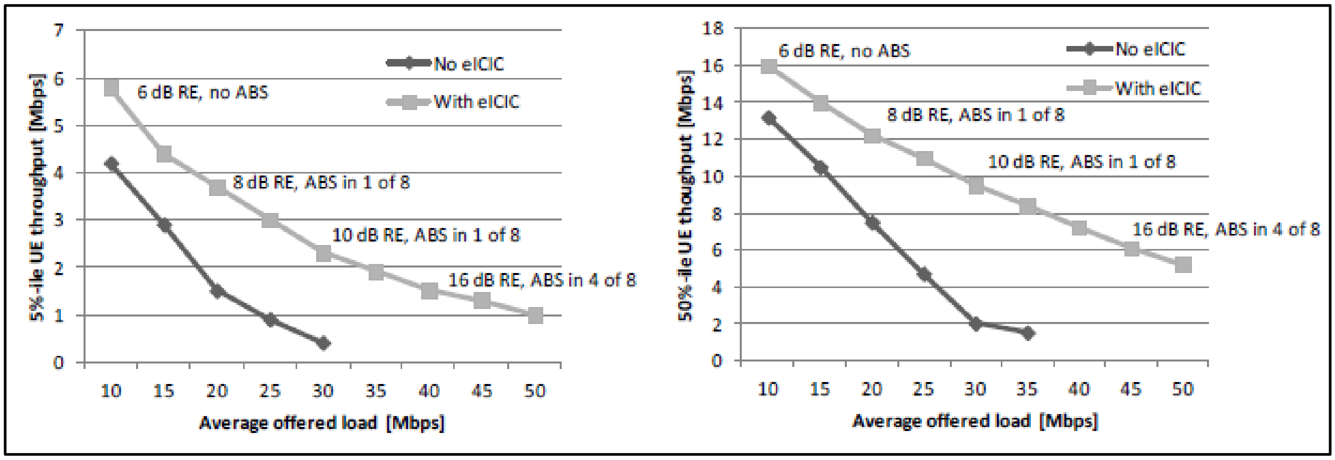

The muting of certain subframes in eICIC is dynamic and depends on identifying, on a per user basis, whether an interfering cell's signal exceeds a threshold relative to the serving cell signal. Coordinating muting among small cells can be complicated because a small cell can simultaneously be an interferer while serving a UE that is a victim of another cell. The network must therefore coordinate muting among multiple small cells.

Figure 88 below at left shows user throughput gains of time domain interference relative to network load. Throughput gains are higher at higher network loads because of more active users and the higher likelihood of interference between the small cells.

Figure 88 below at right shows the maximum muting ratio, which increases with higher network load.

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[180] 5G Americas member contribution. Assumes 3GPP evaluation methodology TR 36.814, 500 meter ISD, 4 picos per macro-cell area, Poisson call arrival, finite payload for each call, and termination of call upon successful delivery.

Figure 88: Throughput Gain of Time-Domain Interference Coordination[181]

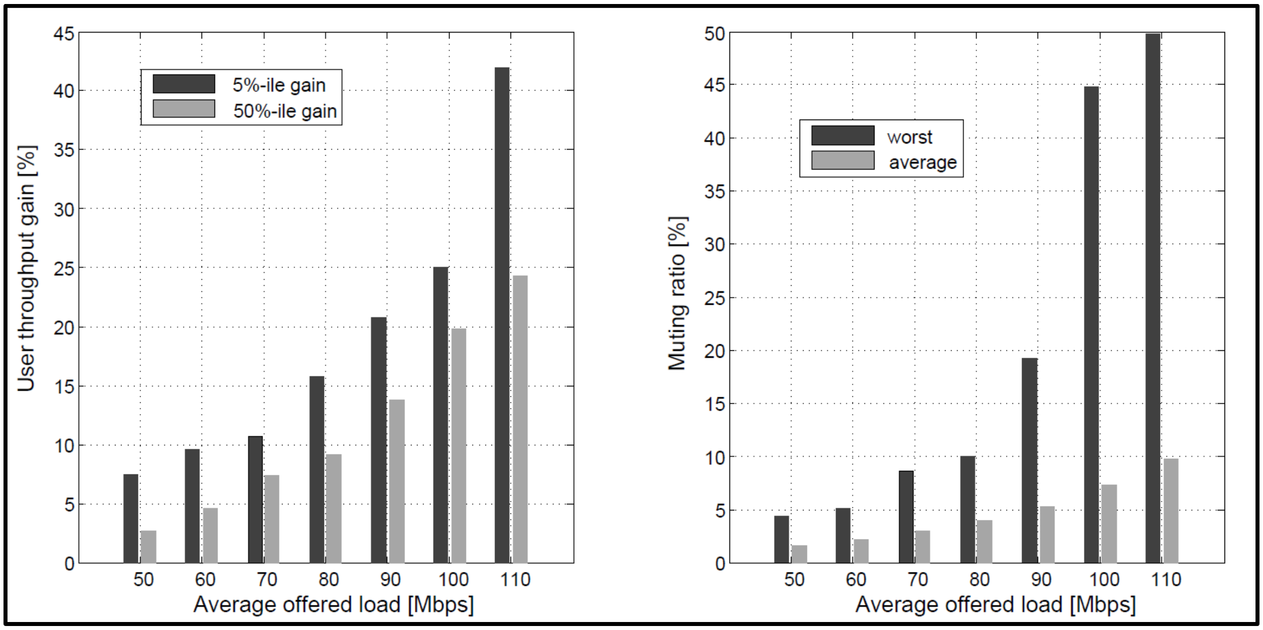

Another approach for addressing inter-layer interference cancellation in HetNets can come from carrier aggregation with no further additions or requirements and realizable with Release 10 LTE networks. Consider the scenario in Figure 89, in which both the macro eNB and the pico eNB are allocated two component carriers (namely CC1 and CC2). The idea is to create a “protected” component carrier for downlink control signals and critical information (Physical Downlink Control Channel, system information, and other control channels) while data can be conveniently scheduled on both component carriers through cross-carrier scheduling.

Figure 89: Carrier-Aggregation Based ICIC[182]

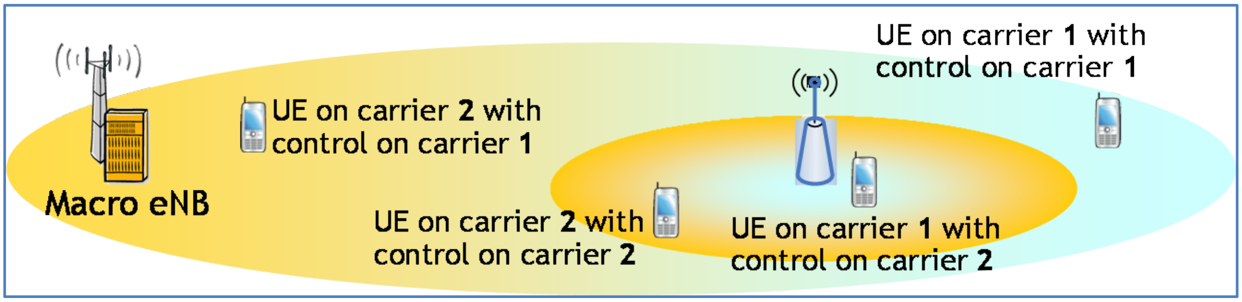

Macro eNB
UE on carrier 2 with control on carrier 1
UE on carrier 1 with control on carrier 1
UE on carrier 2 with control on carrier 2
UE on carrier 1 with control on carrier 2

CC1 is the primary component carrier for the macro cell, while CC2 is the primary for the picocell; hence the protected carriers are CC1 for the macro cell and CC2 for the picocell. The macro cell allocates a lower transmission power for its secondary CC in order to reduce interference to the picocell's primary component carrier. The network can schedule data on both the primary and secondary component carriers. In the figure, users in the cell range expansion (CRE) zone can receive data via cross-carrier scheduling from the secondary CC at subcarrier frequencies on which interference from the other cell can be reduced if the cells exchange appropriate signaling over what is called an "X2 interface." Users operating close to the eNodeBs can receive data from both component carriers as their interference levels will hopefully be lower. Therefore, a CA-capable receiver will enjoy the enhanced throughput capabilities of carrier aggregation, while simultaneously receiving extra protection for control and data channels at locations with potentially high inter-layer interference.

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[181] 5G Americas member contribution. Simulations based on 12 densely deployed small cells at 3.5 GHz and 3GPP Release 12 simulation assumptions in TR 36.842.

[182] 5G Americas member contribution.

Thus, carrier aggregation can be a useful tool for deployment of heterogeneous networks without causing a loss of bandwidth. These solutions, however, do not scale well (in Release 10 systems) to small system bandwidths (say, 3+3 MHz or 1.4+1.4 MHz radio carriers) because control channels occupy a high percentage of total traffic. Additionally, interference between the cell reference signals (CRS) would also be significant.

Dual Connectivity

A major enhancement in Release 12 is a UE being served at the same time by both a macro cell and a small cell operating at different carrier frequencies, a capability called dual connectivity and illustrated in Figure 90. Data first reaches the macro eNodeB and is split, with part of it transmitted from the macro and the balance sent via an X2 interface to the small cell for transmission to the UE.

Figure 90: Dual Connectivity[183]

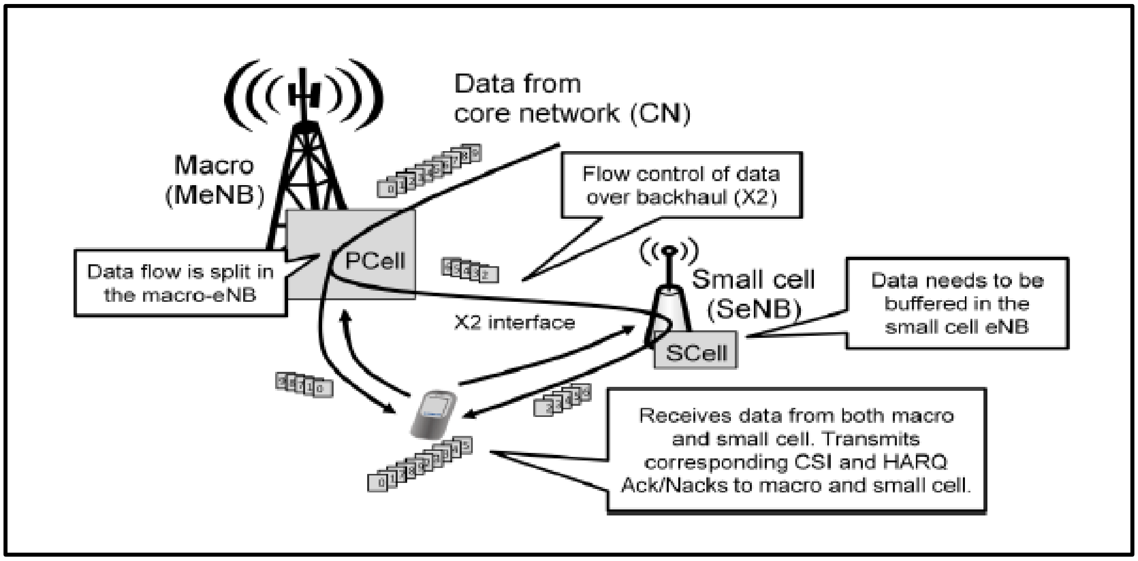
Data from
core network (CN)
Macro
(MeNB)
Flow control of data
over backhaul (X2)
PCell
Data flow is split in
the macro-eNB
Small cell
(SeNB)
Data needs to be
buffered in the
small cell eNB
X2 interface
SCell
Receives data from both macro
and small cell. Transmits
corresponding CSI and HARQ
Ack/Nacks to macro and small cell.

Figure 91 shows throughput gains of dual connectivity at 5 percentile and 50 percentile (median) levels relative to the load on the network and different degrees of latency in the X2 interface. Benefits are higher with lower network load and with lower X2 latency.

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[183] Source: 5G Americas member contribution.

Figure 91: Dual Connectivity User Throughput[184]

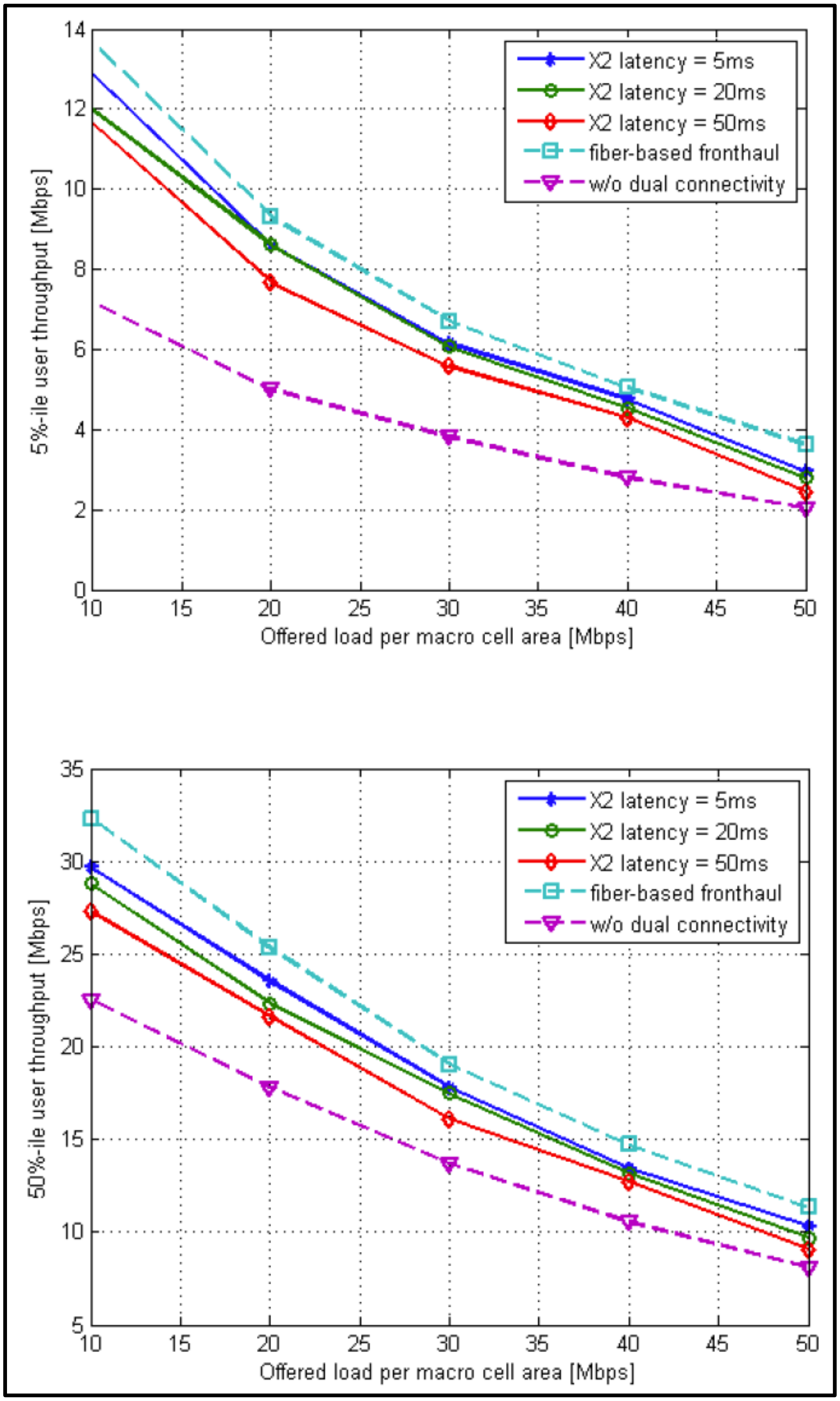

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[184] 5G Americas member contribution.

Internet of Things and Machine-to-Machine

Anticipating huge growth in machine-to-machine communications, Release 11 added a Machine Type Communications (MTC) Interworking Function and Service Capability Server. Release 12 defined a category 0 device designed to deliver low cost through a single antenna design and other simplifications.[185] Release 13 went even further, with a category M-1 architecture that further reduces cost, improves range, and extends battery life. Category 13 also added Narrowband-IoT capability with Category NB-1 and an IoT solution for GSM, called "EC-GSM-IoT," that extends coverage by 20 dB. Category M-1 and NB-IoT devices could achieve battery life as high as 10 years.

Figure 92 depicts the methods used to reduce cost in a Category M device compared with a Category 4 device.

Figure 92: Means of Achieving Lower Cost in IoT Devices[186]

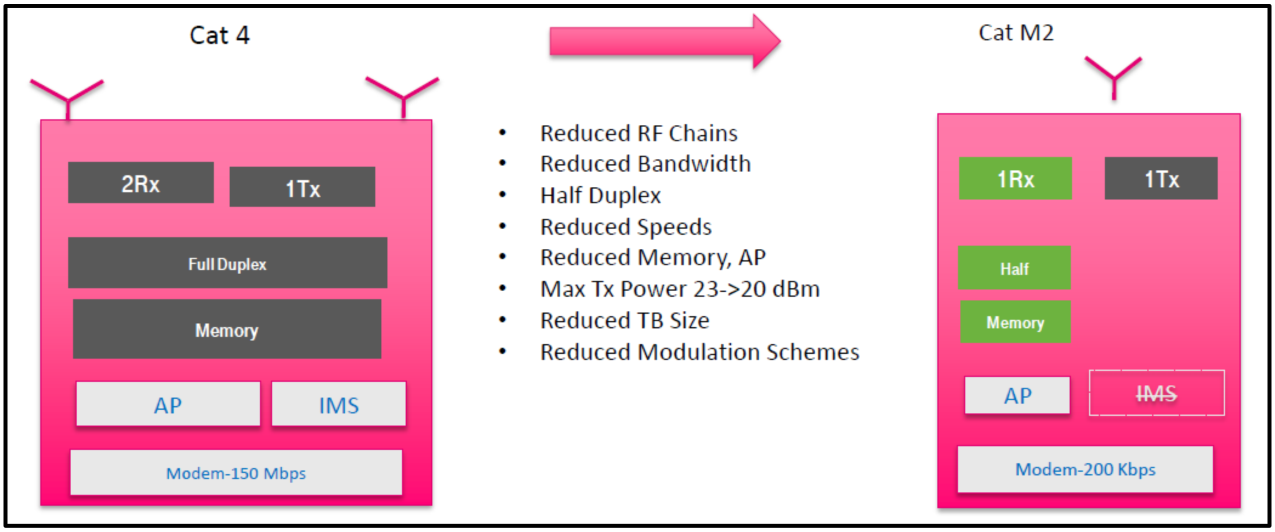
Cat 4
2Rx
1Tx
Full Duplex
Memory
AP
IMS
Modem-150 Mbps
Reduced RF Chains
Reduced Bandwidth
Half Duplex
Reduced Speeds
Reduced Memory, AP
Max Tx Power 23->20 dBm
Reduced TB Size
Reduced Modulation Schemes
Cat M2
1Rx
1Tx
Half
Memory
AP
~~IMS~~
Modem-200 Kbps

Table 26 summarizes the features of different LTE IoT devices based on 3GPP Release.

Table 26: Summary of IoT Features in LTE Devices

Device Category	Category 3	Category 1	Category 0	Category M-1	Category NB-1	EC-GSM-IoT
3GPP Release	10	11	12	13	13	13

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[185] 3GPP, *Access System for Ultra Low Complexity and Low Throughput Internet of Things based on Cellular,* GP-140301, May 2014.

[186] 5G Americas member contribution.

Device Category	Category 3	Category 1	Category 0	Category M-1	Category NB-1	EC-GSM-IoT
Max. Data Rate Downlink	100 Mbps	10 Mbps	1 Mbps	1 Mbps	200 Kbps	74 Kbps
Max. Data Rate Uplink	50 Mbps	5 Mbps	1 Mbps	1 Mbps	200 Kbps	74 Kbps
Max. Bandwidth	20 MHz	20 MHz	20 MHz	1.08 MHz	0.18 MHz	0.2 MHz
Duplex	Full	Full	Optional half-duplex	Optional half-duplex	Half	Half
Max. Receive Antennas	Two	Two	One	One	One	One
Power		Power Save Mode[187]	Power Save Mode	Power Save Mode		
Sleep				Longer sleep cycles using Idle Discontinuous Reception (DRX)		
Coverage				Extended through redundant transmissions and Single Frequency Multicast		

Cloud Radio-Access Network (RAN) and Network Virtualization

Still in the early stages of development, cloud RAN (C-RAN) is a distributed architecture in which multiple remote radio heads connect to a "cloud" that consists of a farm of baseband processing nodes. This approach can improve centralized processing, as is needed for

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[187] Power Save Mode specified in Release 12, but applicable to Category 1 device configured as Release 12.

CoMP, centralized scheduling, and Multiflow, without the need to exchange information among many access nodes. The performance of both LTE and HSPA technologies could be enhanced by the application of cloud RAN architectures. The term "fronthauling" has been used to describe the transport of "raw" radio signals to central processing locations, such as between the Physical Network Function (PNF) and a Virtual Network Function (VNF).

This architecture, shown in Figure 93, comes at the cost of requiring high-speed, low-latency backhaul links between these radio heads and the central controller. One vendor states that carrying 10+10 MHz of LTE with 2X2 MIMO requires 2.5 Gbps of bandwidth and imposes less than 0.1 msec of delay.[188] A standard called "Common Public Radio Interface" (CPRI) addresses generic formats and protocols for such a high-speed link. ETSI has also developed the Open Radio Equipment Interface (ORI). The feasibility of cloud RAN depends to a large extent on the cost and availability of fiber links between the remote radio heads and the centralized baseband processing location.

Unlike virtualizing the EPC, in which the entirety of the function can be virtualized, cloud RAN needs a PNF that terminates the RF interface. Cloud RAN therefore requires a split to be defined within the RAN. As a consequence, initial deployments of cloud RAN have looked to ruse the CPRI interface between the RRH and the baseband unit.

Figure 93: Potential Cloud RAN Approach

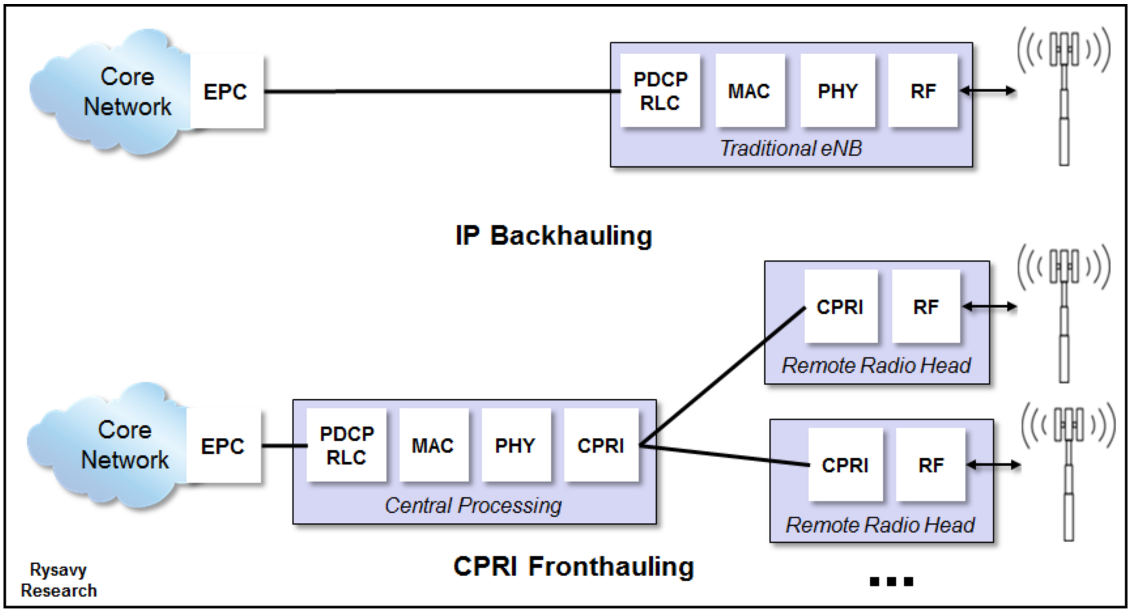

The next evolutionary step after centralizing baseband processing is to virtualize the processing by implementing the functions in software on commodity computing platforms, thus abstracting the functions from any specific hardware implementation.

C-RANs can vary by the extent of coverage, ranging from being highly localized and operating across a small number of sites to metropolitan-wide solutions. Other variables include existing deployments versus greenfield situations, new LTE and 5G technologies versus integrating legacy 2G and 3G technologies, and integrating Wi-Fi. Greater scope increases complexity but yields benefits including better load-balancing and greater flexibility in spectrum re-farming.

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[188] Dudu Bercovich, Ran Avital, "Holistic HetNet Hauling (3H)," Ceragon, February 2013. Available at http://www.ceragon.com/images/Reasource_Center/White_Papers/Ceragon_Holistic_Hetnet_Hauling_White_Paper.pdf.

Another design choice, as detailed in Table 27, is whether to centralize Layer 1 and Layer 2 functions (an RF-PHY split), or whether to keep Layer 1 at the base stations and centralize only Layer 2 (a PHY-MAC split).

Table 27: Partially Centralized Versus Fully Centralized C-RAN

	Fully Centralized	Partially Centralized
Transport Requirements	Multi-Gbps, usually using fiber	20 to 50 times less
Fronthaul Latency Requirement	Less than 100 microseconds	Greater than 5 milliseconds
Applications	Supports eICIC and CoMP	Supports centralized scheduling
Complexity	High	Lower
Benefit	Capacity gain	Lower capacity gain

Figure 94 analyzes the different possible RAN decompositions in greater detail.

Figure 94: Costs and Benefits of Various RAN Decompositions[189]

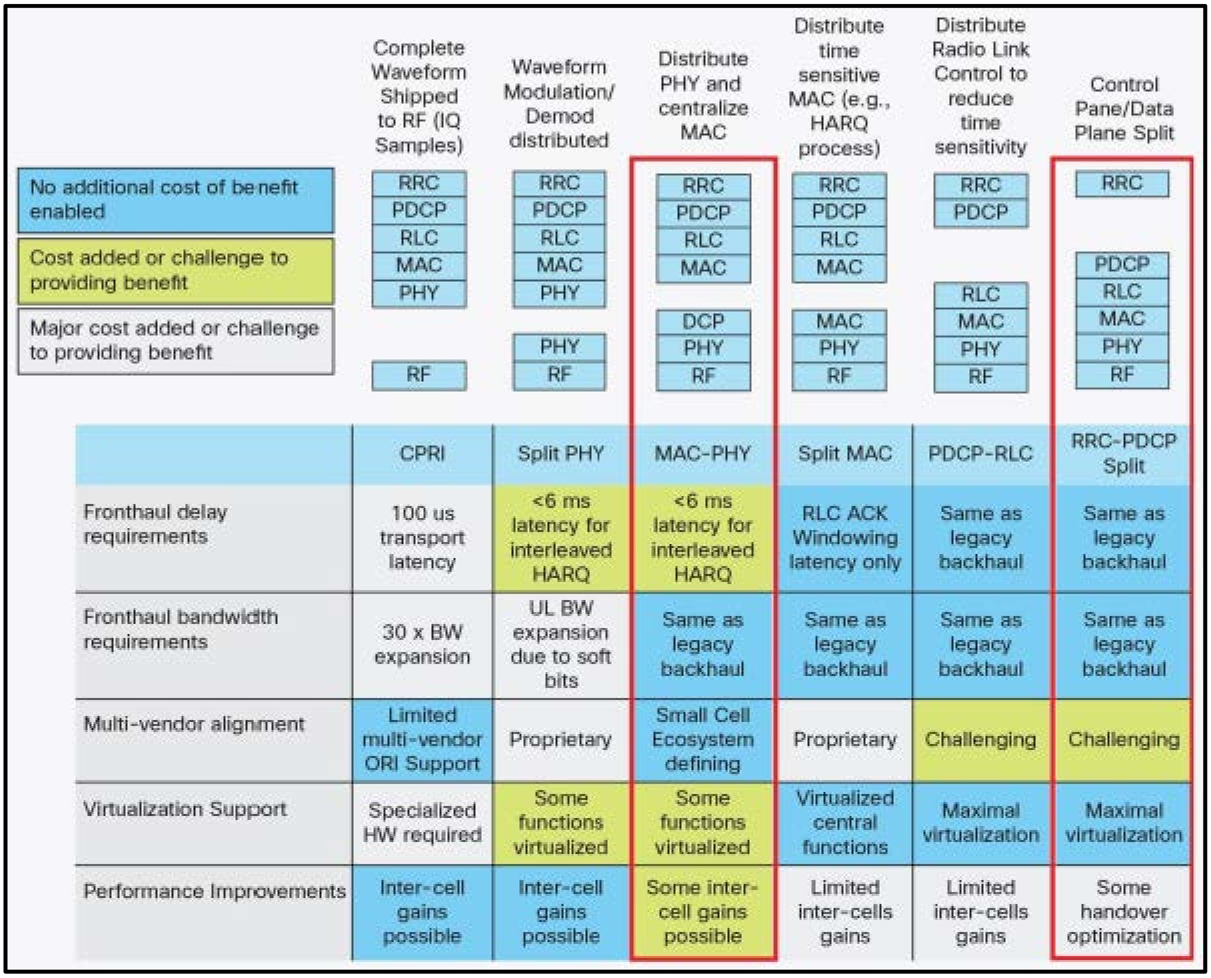

No additional cost of benefit enabled
Cost added or challenge to providing benefit
Major cost added or challenge to providing benefit
RRC
PDCP
RLC
MAC
PHY
RF
RRC
PDCP
RLC
MAC
PHY
PHY
RF
RRC
PDCP
RLC
MAC
DCP
PHY
RF
RRC
PDCP
RLC
MAC
MAC
PHY
RF
RRC
PDCP
RLC
MAC
PHY
RF
RRC
PDCP
RLC
MAC
PHY
RF

	Complete Waveform Shipped to RF (IQ Samples)	Waveform Modulation/ Demod distributed	Distribute PHY and centralize MAC	Distribute time sensitive MAC (e.g., HARQ process)	Distribute Radio Link Control to reduce time sensitivity	Control Pane/Data Plane Split
	CPRI	Split PHY	MAC-PHY	Split MAC	PDCP-RLC	RRC-PDCP Split
Fronthaul delay requirements	100 us transport latency	<6 ms latency for interleaved HARQ	<6 ms latency for interleaved HARQ	RLC ACK Windowing latency only	Same as legacy backhaul	Same as legacy backhaul
Fronthaul bandwidth requirements	30 x BW expansion	UL BW expansion due to soft bits	Same as legacy backhaul	Same as legacy backhaul	Same as legacy backhaul	Same as legacy backhaul
Multi-vendor alignment	Limited multi-vendor ORI Support	Proprietary	Small Cell Ecosystem defining	Proprietary	Challenging	Challenging
Virtualization Support	Specialized HW required	Some functions virtualized	Some functions virtualized	Virtualized central functions	Maximal virtualization	Maximal virtualization
Performance Improvements	Inter-cell gains possible	Inter-cell gains possible	Some inter-cell gains possible	Limited inter-cells gains	Limited inter-cells gains	Some handover optimization

Although some operators in dense deployments with rich fiber assets may centralize all functions, Figure 94 uses the red rectangles to show the two most likely functional splits for LTE-Advanced and 5G:

1. **Distributed PHY and Centralized MAC.** This approach relaxes the fronthaul delay requirement to 6 msec, compared with the CPRI requirement of 250 microseconds. Fronthaul bandwidth requirement is only 10-20% greater than conventional backhaul.
2. **Control Plane/Data Plane Split.** This approach further relaxes fronthaul requirements to 30 msec and is the approach used for dual-connectivity, such as a macro and small cell simultaneously connecting to a user. For 5G, 3GPP Release 15 specifications standardize a split for cloud RAN between the PDCP and RLC layers.

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[189] Cisco, *Cisco 5G Vision Series: Small Cell Evolution*, 2016.

Next Generation Mobile Networks studied the pros and cons of different fronthauling interfaces and published the results in March 2015.[190]

Longer-term, perhaps in the 5G context, virtualized C-RANs may take away the very concept of cells. With methods such as beamforming and device-to-device communication, coverage may extend dynamically from a multitude of sources based on instantaneous load notifications and the radio resources available at different nodes.

In the past, RAN and core networks have been distinct entities, but over the next decade, the two may merge with more centralized, virtualized, and cloud-driven approaches.

Another form of virtualization is software-defined networking, an emerging trend in both wired and wireless networks. For cellular, SDN promises to reduce OPEX costs, simplify the introduction of new services, and improve scalability; all major infrastructure vendors are involved. The Open Networking Foundation explains that an SDN decouples the control and data planes, centralizing network state and intelligence, while abstracting the underlying network infrastructure from applications.[191] Virtualization of network functions will be a complex, multi-year undertaking and will occur in stages, as shown in Figure 95.

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[190] Next Generation Mobile Networks, *Further Study on Critical C-RAN Technologies, Version 1.0*, March 2015. See sections 2.2 and 2.3. Available at https://www.ngmn.org/uploads/media/NGMN_RANEV_D2_Further_Study_on_Critical_C-RAN_Technologes_v1.0.pdf.

[191] Open Networking Foundation, “Software-Defined Networking: The New Norm for Networks,” http://www.opennetworking.org/sdn-resources/sdn-library/whitepapers, accessed June 20, 2014.

Figure 95: Software-Defined Networking and Cloud Architectures[192]

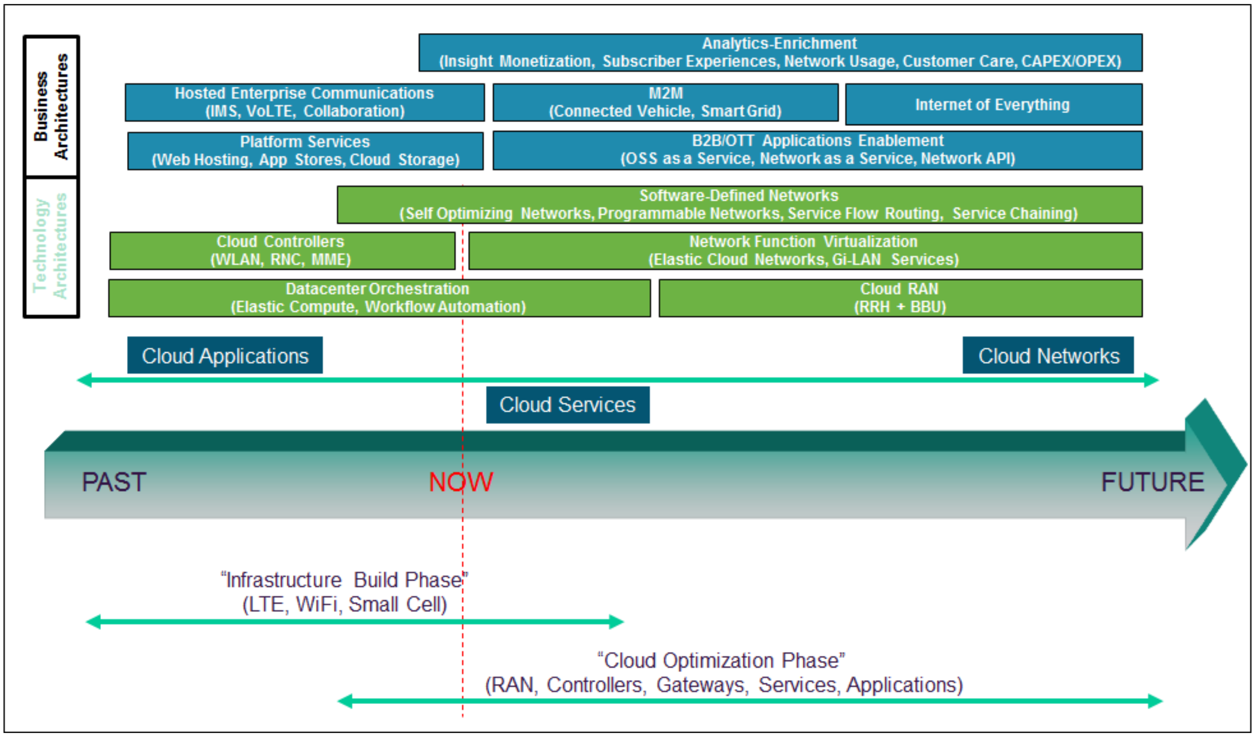
Business Architectures
Technology Architectures
Analytics-Enrichment
(Insight Monetization, Subscriber Experiences, Network Usage, Customer Care, CAPEX/OPEX)
Hosted Enterprise Communications
(IMS, VoLTE, Collaboration)
M2M
(Connected Vehicle, Smart Grid)
Internet of Everything
Platform Services
(Web Hosting, App Stores, Cloud Storage)
B2B/OTT Applications Enablement
(OSS as a Service, Network as a Service, Network API)
Software-Defined Networks
(Self Optimizing Networks, Programmable Networks, Service Flow Routing, Service Chaining)
Cloud Controllers
(WLAN, RNC, MME)
Network Function Virtualization
(Elastic Cloud Networks, Gi-LAN Services)
Datacenter Orchestration
(Elastic Compute, Workflow Automation)
Cloud RAN
(RRH + BBU)
Cloud Applications
Cloud Networks
Cloud Services
PAST
NOW
FUTURE
"Infrastructure Build Phase"
(LTE, WiFi, Small Cell)
"Cloud Optimization Phase"
(RAN, Controllers, Gateways, Services, Applications)

Unlicensed Spectrum Integration

See the earlier section in this report on unlicensed spectrum integration, which includes a discussion of LTE-U, LTE-LAA, MulteFire, LWA, LWIP, and RCLWI. This section covers integration approaches other than these.

3GPP has evolved its thinking on how best to integrate Wi-Fi with 3GPP networks. At the same time, the Wi-Fi Alliance and other groups have also addressed hotspot roaming, namely the ability to enable an account with one public Wi-Fi network provider to use the services of another provider that has a roaming arrangement with the first provider.

The multiple attempts to make Wi-Fi networks universally available have made for a confusing landscape of integration methods, which this section attempts to clarify. Most integration today is fairly loose, meaning that either a device communicates data via the cellular connection or via Wi-Fi. If via Wi-Fi, the connection is directly to the internet and bypasses the operator core network. In addition, any automatic handover to hotspots occurs only between the operator cellular network and operator-controlled hotspots. The goals moving forward are to:

- ❑ Support roaming relationships so that users can automatically access Wi-Fi hotspots operated by other entities.
- ❑ Enable automatic connections so that users do not have to enter usernames and passwords. In most cases, this will mean authentication based on SIM credentials.

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[192] 5G Americas member contribution.

- ❑ Provide secure communications on the radio link as provided by the IEEE 802.11i standard.
- ❑ Allow policy-based mechanisms that define the rules by which devices connect to various Wi-Fi networks.
- ❑ Enable simultaneous connections to both cellular and Wi-Fi, with control over which applications use which connections.
- ❑ Support different types of Wi-Fi deployments, including third-party access points and carrier access points.

Release 6 I-WLAN

3GPP Release 6 was the first release to offer the option of integrating Wi-Fi in a feature called "Interworking WLAN" (I-WLAN), using a separate IP address for each network type.

Release 8 Dual Stack Mobile IPv6 and Proxy Mobile IPv6

3GPP Release 8 specified Wi-Fi integration with the EPC using two different approaches: host-based mobility with Dual Stack Mobile IPv6 (DSMIPv6) in the client, and network based mobility with Proxy Mobile IPv6 (PMIPv6) using an intermediary node called an "Enhanced Packet Data Gateway" (ePDG).[193] This method is intended for untrusted (non-carrier-controlled) Wi-Fi networks.

Release 11 S2a-based Mobility over GTP

Release 11, however, implements a new and advantageous approach as shown in Figure 96, one that eliminates the ePDG. Called "S2a-based Mobility over GTP" (SaMOG), a trusted WLAN Access Gateway connects to multiple 3GPP-compliant access points. Traffic can route directly to the internet or traverse the packet core. This method is intended for trusted (carrier-controlled) Wi-Fi networks.

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[193] 3GPP, *System Architecture Evolution (SAE); Security aspects of non-3GPP accesses*. TS 33.402.

Figure 96: Release 11 SaMOG-based Wi-Fi Integration

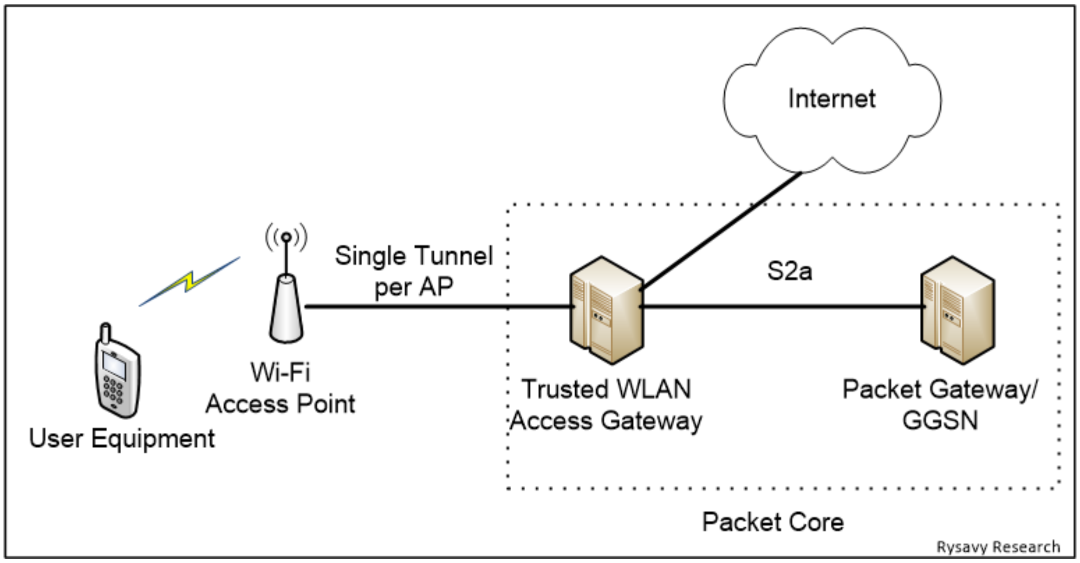

Release 12 improves SaMOG capabilities in Enhanced SaMOG (eSaMOG), in which UEs can:

- ☐ Request the connectivity type
- ☐ Indicate the Access Point Name (APN) to establish PDN connectivity
- ☐ Request to hand over an existing PDN connection
- ☐ Establish multiple PDN connections in parallel over the WLAN
- ☐ Establish a non-seamless WLAN offload connection in parallel to a Packet Data Network connection over WLAN.

Multipath TCP

A new method for potentially integrating Wi-Fi and 3GPP networks is based on work by the Internet Engineering Taskforce (IETF). Called “Multipath TCP,” the approach allows a TCP connection to occur simultaneously over two different paths. The advantages of this approach include higher speeds by aggregating links and not requiring any special provisions for link-layer handovers.

The IETF has published an experimental specification, *Request for Comments 6824: CP Extensions for Multipath Operation with Multiple Addresses*, which explains this approach. The IETF is also specifying Multipath QUIC.

ANDSF

Another relevant specification is 3GPP Access Network Discovery and Selection Function (ANDSF), which provides mechanisms by which mobile devices can know where, when, and how to connect to non-3GPP access networks, such as Wi-Fi.[194] ANDSF operates independently of SaMOG or other ways that Wi-Fi networks might be connected.

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[194] 3GPP, *Architecture enhancements for non-3GPP accesses, Technical Specification 23.402*.

ANDSF functionality increases with successive 3GPP versions, as summarized in Table 28.

Table 28: ANDSF Policy Management Objects and 3GPP Releases[195]

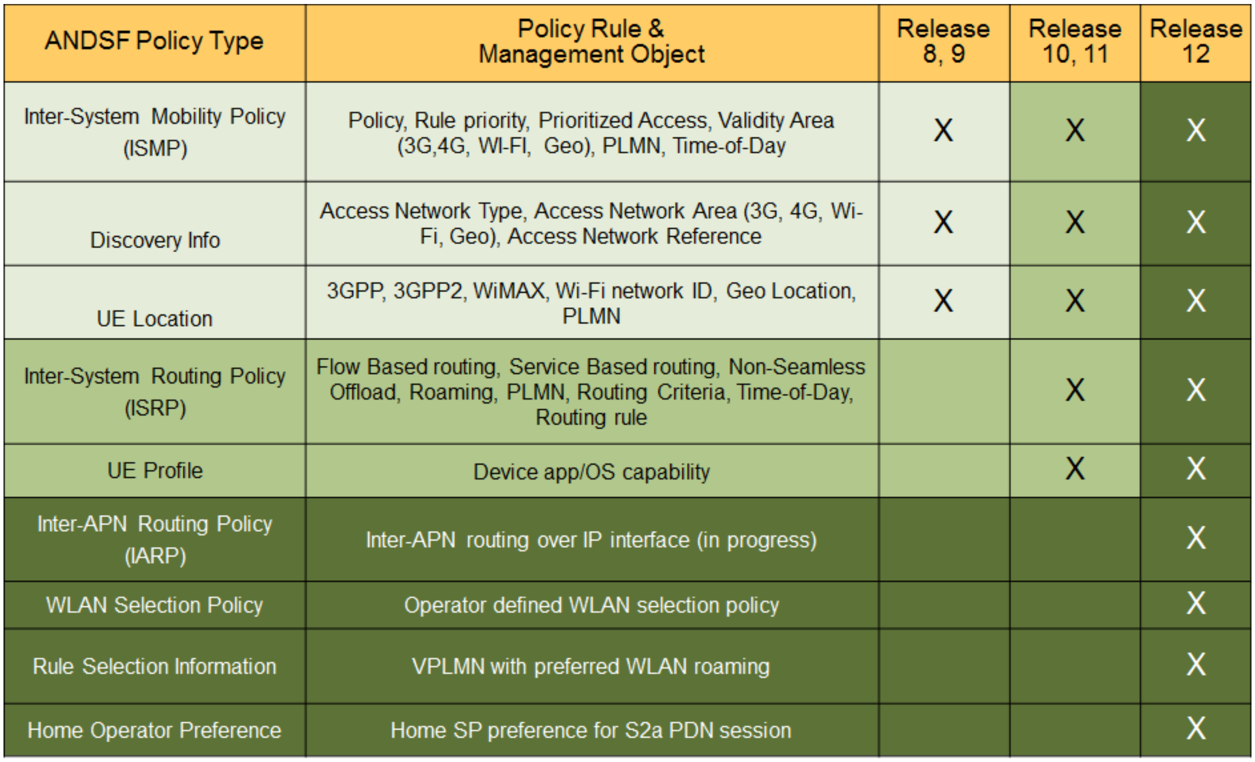

ANDSF Policy Type	Policy Rule & Management Object	Release 8, 9	Release 10, 11	Release 12
Inter-System Mobility Policy (ISMP)	Policy, Rule priority, Prioritized Access, Validity Area (3G,4G, WI-FI, Geo), PLMN, Time-of-Day	X	X	X
Discovery Info	Access Network Type, Access Network Area (3G, 4G, Wi-Fi, Geo), Access Network Reference	X	X	X
UE Location	3GPP, 3GPP2, WiMAX, Wi-Fi network ID, Geo Location, PLMN	X	X	X
Inter-System Routing Policy (ISRP)	Flow Based routing, Service Based routing, Non-Seamless Offload, Roaming, PLMN, Routing Criteria, Time-of-Day, Routing rule		X	X
UE Profile	Device app/OS capability		X	X
Inter-APN Routing Policy (IARP)	Inter-APN routing over IP interface (in progress)			X
WLAN Selection Policy	Operator defined WLAN selection policy			X
Rule Selection Information	VPLMN with preferred WLAN roaming			X
Home Operator Preference	Home SP preference for S2a PDN session			X

Bidirectional Offloading Challenges

Eventually, operators will be able to closely manage user mobile broadband and Wi-Fi connections, dynamically selecting a particular network for a user based on real-time changes in loads and application requirements. Work is occurring in Release 12 to define parameters that would control switching from LTE to Wi-Fi or from Wi-Fi to LTE.[196]

Bidirectional offloading, however, creates various challenges, as shown in Figure 97 and discussed below.

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[195] Courtesy Smith Micro Software, 2014. http://www.smithmicro.com.

[196] 3GPP, *Study on Wireless Local Area Network (WLAN) - 3GPP radio interworking (Release 12)*, TR 37.834.

Figure 97: Bidirectional Offloading Challenges

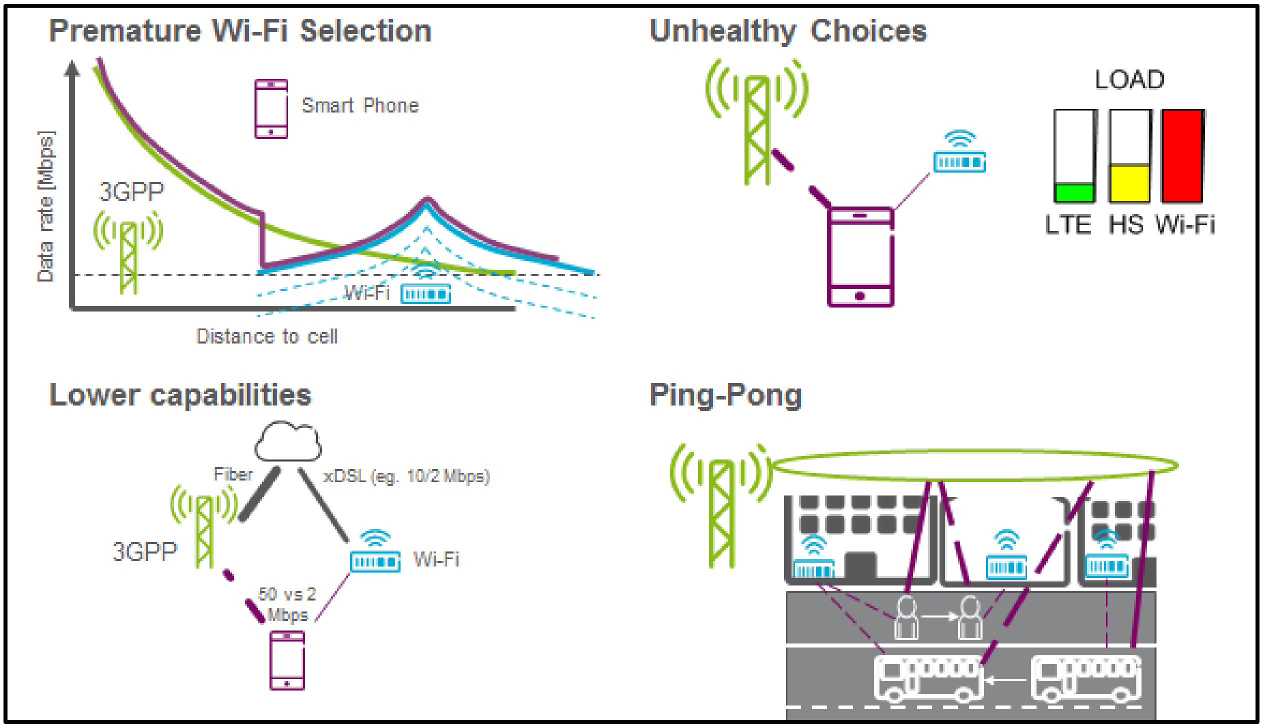
Premature Wi-Fi Selection
Smart Phone
Data rate [Mbps]
3GPP
Wi-Fi
Distance to cell
Unhealthy Choices
LOAD
LTE
HS
Wi-Fi
Lower capabilities
Fiber
xDSL (eg. 10/2 Mbps)
3GPP
Wi-Fi
50 vs 2 Mbps
Ping-Pong

- **Premature Wi-Fi Selection.** As Wi-Fi-capable devices move into Wi-Fi coverage, they can prematurely reselect to Wi-Fi without comparative evaluation of existing cellular and incoming Wi-Fi capabilities, possibly resulting in the degradation of the end user experience. Real-time throughput-based traffic steering can mitigate this effect.
- **Unhealthy choices.** In a mixed network of LTE, HSPA, and Wi-Fi, reselection can occur due to a strong Wi-Fi network signal even though the network is under heavy load. The resulting "unhealthy" choice degrades the end user experience because the performance on the cell edge of a lightly loaded cellular network may be superior to that of the heavily loaded Wi-Fi network. Real-time load-based traffic steering can be beneficial in this scenario.
- **Lower capabilities.** In some cases, selection to a Wi-Fi network may result in reduced performance even if it offers a strong signal because of other factors, such as lower-bandwidth backhaul. Evaluation of criteria beyond wireless capabilities prior to access selection can improve this circumstance.
- **Ping-Pong.** Ping-ponging between Wi-Fi and cellular, especially if both offer similar signal strengths, can also degrade the user experience. Hysteresis approaches, similar to those used in cellular inter-radio transfer, can better manage transfer between Wi-Fi and cellular accesses.

3GPP RAN2 is discussing real-time or near-real-time methods to address the challenges discussed above.

Other Integration Technologies (SIPTO, LIPA, IFOM, MAPCON)

Release 10 defines additional options for Wi-Fi integration, including Selected IP Traffic Offload (SIPTO), Local IP Access (LIPA), Multi-Access PDN Connectivity (MAPCON), and IP Flow and Seamless Offload (IFOM).

SIPTO is mostly a mechanism to offload traffic that does not need to flow through the core, such as internet-destined traffic. SIPTO can operate on a home femtocell, or it can operate in the macro network.

Local IP Access (LIPA) provides access to local networks, useful with femtocells that normally route all traffic back to the operator network. With LIPA, the UE in a home environment can access local printers, scanners, file servers, media servers, and other resources.

IFOM, as shown in Figure 98, enables simultaneous cellular and Wi-Fi connections, with different traffic flowing over the different connections. A Netflix movie could stream over Wi-Fi, while a VoIP call might flow over the cellular-data connection. IFOM requires the UE to implement Dual Stack Mobile IPv6 (DSMIPv6).

Figure 98: 3GPP IP Flow and Seamless Mobility

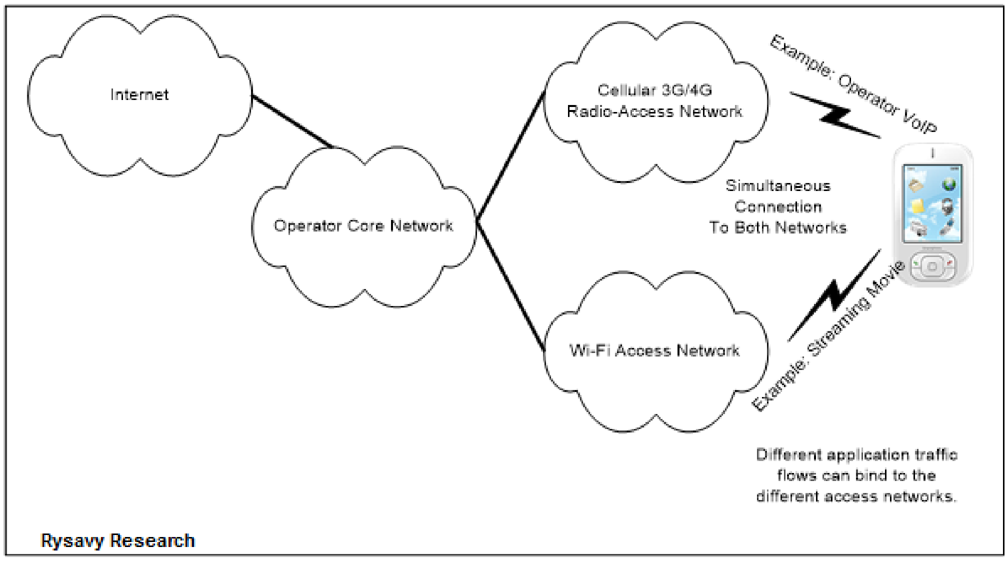
Internet
Operator Core Network
Cellular 3G/4G Radio-Access Network
Wi-Fi Access Network
Example: Operator VoIP
Simultaneous Connection To Both Networks
Example: Streaming Movie
Different application traffic flows can bind to the different access networks.
Rysavy Research

Similar to IFOM, Release 10 feature MAPCON allows multiple simultaneous PDN connections (each with a separate APN), such as Wi-Fi and 3GPP radio access. The UE uses separate IP addresses for each connection but does not need Dual Stack Mobile IPv6 (DSMIPv6).

Hotspot 2.0

Developed by the Wi-Fi Alliance, Hotspot 2.0 specifications, also called “Next Generation Hotspot,” facilitate Wi-Fi roaming. Using the IEEE 802.11u standard that allows devices to determine what services are available from an access point, Hotspot 2.0 simplifies the process by which users connect to hotspots, automatically identifying roaming partnerships and simplifying authentication and connections, as shown in Figure 99.[197] It also provides for encrypted communications over the radio link.[198]

Figure 99: Roaming Using Hotspot 2.0

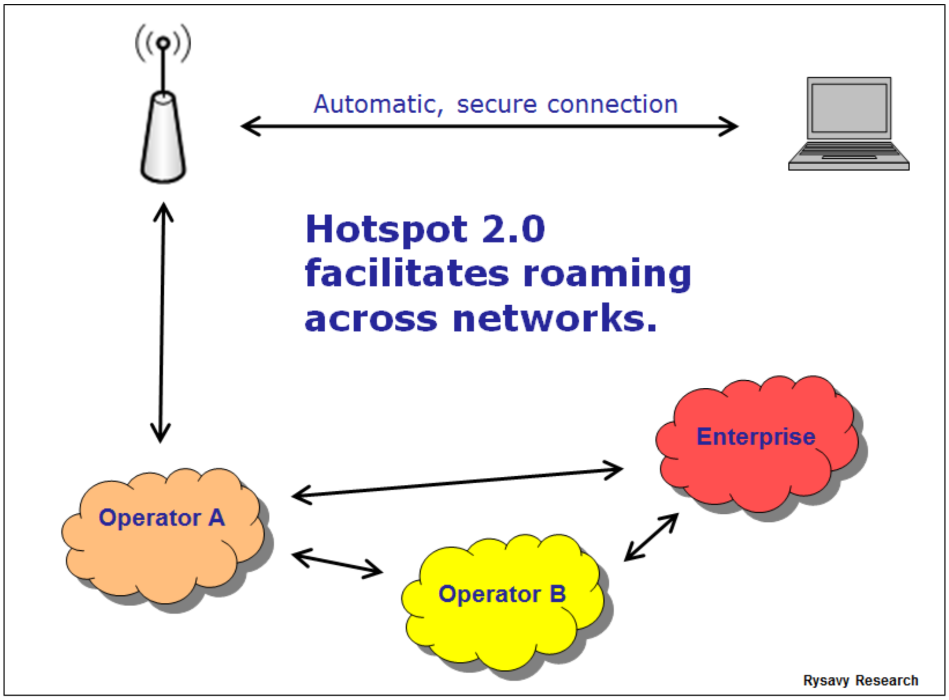
Automatic, secure connection
Hotspot 2.0 facilitates roaming across networks.
Enterprise
Operator A
Operator B
Rysavy Research

Using IEEE 802.11u, devices can determine what roaming relationships an access point supports and can then securely connect to the Wi-Fi network using one of these roaming arrangements, as shown in Figure 100. Hotspot 2.0 authentication is based on the Extended Authentication Protocol (EAP) using SIM credentials. There are plans to enhance the Hotspot 2.0 protocols in Phase 2, which will define online signup to enable non-SIM-based devices to easily and securely register for services. The Wi-Fi Alliance began a Hotspot 2.0 certification process for devices and access points in June 2012 and uses the designation “Wi-Fi Certified Passpoint” for compliant devices.

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[197] For example, user devices can be authenticated based on their SIM credentials. Or, users can register or click through an agreement and then not need to redo that with future associations.

[198] The IEEE 802.11i standard has provided encryption for 802.11 communications for many years; however, most hotspots have not implemented this encryption, whereas Hotspot 2.0 does.

Figure 100: Hotspot 2.0 Connection Procedure

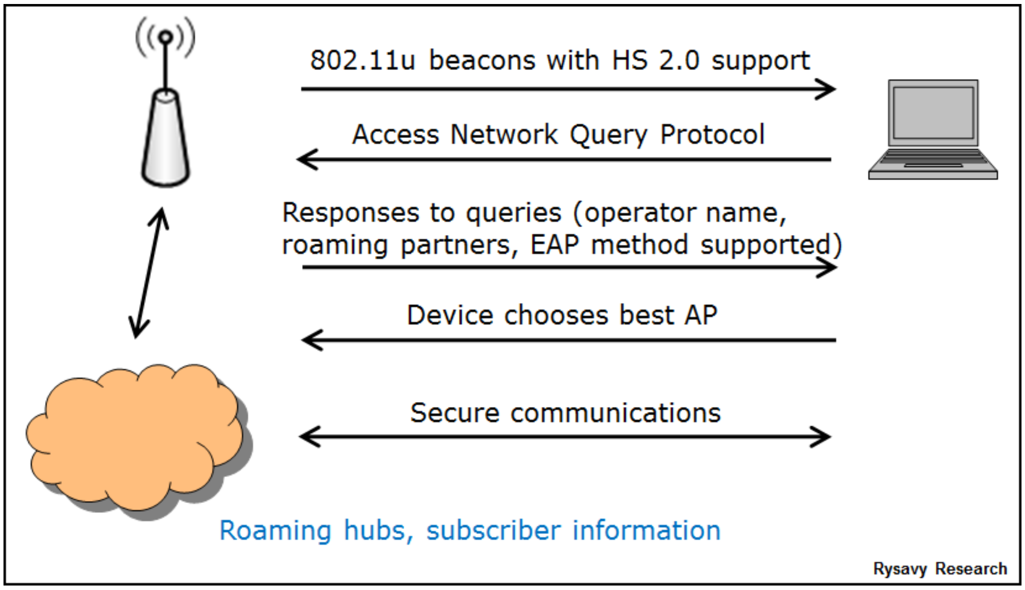
802.11u beacons with HS 2.0 support
Access Network Query Protocol
Responses to queries (operator name, roaming partners, EAP method supported)
Device chooses best AP
Secure communications
Roaming hubs, subscriber information
Rysavy Research

Release 2 of Passpoint, available in 2014, added immediate account provisioning, which facilitates a user establishing an account at the point of access. The new version also provides for policies to be downloaded from the network operator; these policies control network selection priorities when multiple networks are available.

Self-Organizing Networks (SON)

As the number of base stations increase through denser deployments and through deployment of femtocells and picocells, manual configuration and maintenance of this infrastructure becomes impractical. With SON, base stations organize and configure themselves by communicating with one another and with the core network. SONs can also self-heal in failure situations.

3GPP began standardization of self-optimization and self-organization in Releases 8 and 9, a key goal being support of multi-vendor environments. Successive releases have augmented SON capabilities.

Features being defined in SON include:

- ☐ Automatic inventory;
- ☐ Automatic software download;
- ☐ Automatic neighbor relation;
- ☐ Automatic physical Cell ID assignment;
- ☐ Mobility robustness/handover optimization;
- ☐ Random access channel optimization;
- ☐ Load-balancing optimization;
- ☐ Inter-cell interference coordination (ICIC) management;

- Enhanced inter-cell interference coordination (eICIC) management;
- Coverage and capacity optimization;
- Cell outage detection and compensation;
- Self-healing functions;
- Minimization of drive testing;
- Energy savings; and
- Coordination among various SON functions.

3GPP categorizes SON as centralized, distributed, or hybrid, which is a combination of centralized and distributed approaches.

In a centralized architecture, SON algorithms operate on a central network management system or central SON server. In contrast, in a distributed approach, the SON algorithms operate at the eNBs, which make autonomous decisions based on local measurements as well as from other nearby eNBs received via an X2 interface that interconnects eNBs.

The distributed architecture permits faster and easier deployment but is not necessarily as efficient or as consistent in operation, especially in multi-vendor infrastructure deployments.

In a hybrid approach, shown in Figure 101, SON algorithms operate both at the eNB and at a central SON server, with the server supplying values of initial parameters, for example. The eNBs may then update and refine those parameters in response to local measurements.

The hybrid approach resolves deployment scenarios that cannot be resolved by dSON, for example, cases such as:

- No X2 interface between the eNBs.
- Multi-vendor deployment with different dSON algorithms.
- Multi-technology load balancing and user steering.

Figure 101: Hybrid SON Architecture[199]

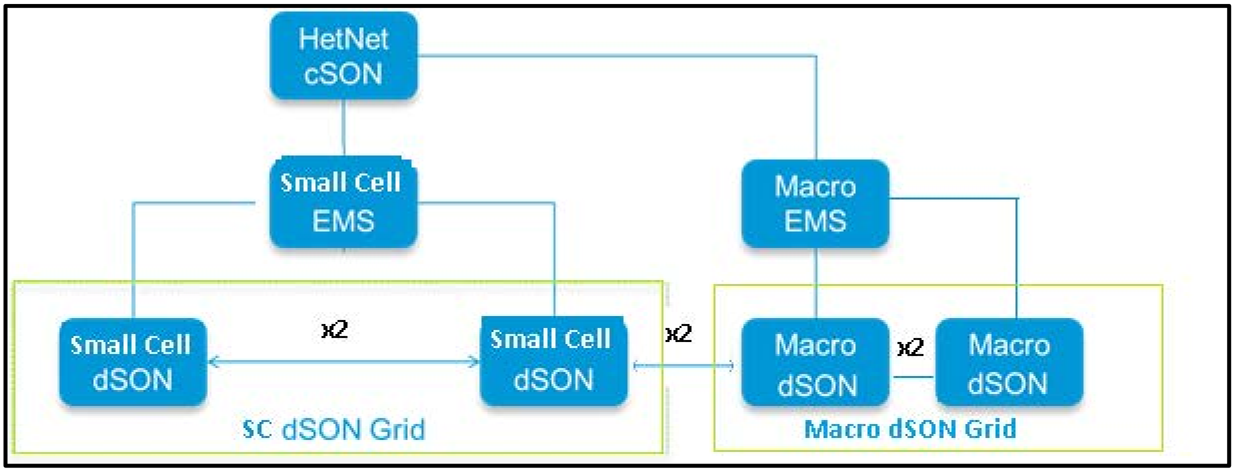

With increasing numbers of macro cells and small cells, interference opportunities increase as well. Optimizing power settings through intelligent power management algorithms is crucial for maximum efficiency with the least amount of interference, including pilot pollution. Pilot pollution can result in low data rates and ping-pong handovers due to channel fading. A hybrid SON approach is well suited for optimized power management.

IP Multimedia Subsystem (IMS)

IP Multimedia Subsystem (IMS) is a service platform for IP multimedia applications: video sharing, PoC, VoIP, streaming video, interactive gaming, and others. IMS by itself does not provide all these applications. Rather, it provides a framework of application servers, subscriber databases, and gateways to make them possible. The exact services will depend on cellular operators and the application developers that make these applications available to operators. The primary application in 2016, however, is VoLTE.

The core networking protocol used within IMS is Session Initiation Protocol (SIP), which includes the companion Session Description Protocol (SDP) used to convey configuration information such as supported voice codecs. Other protocols include Real Time Transport Protocol (RTP) and Real Time Streaming Protocol (RTSP) for transporting actual sessions. The QoS mechanisms in UMTS will be an important component of some IMS applications.

Although originally specified by 3GPP, numerous other organizations around the world are supporting IMS. These include the IETF, which specifies key protocols such as SIP, and the Open Mobile Alliance, which specifies end-to-end, service-layer applications. Other organizations supporting IMS include the GSMA, ETSI, CableLabs, 3GPP2, The Parlay Group, the ITU, ANSI, the Telecoms and Internet Converged Services and Protocols for Advanced Networks (TISPAN), and the Java Community Process (JCP).

IMS is relatively independent of the radio-access network and can, and likely will, be used by other radio-access networks or wireline networks. Other applications include picture and video sharing that occur in parallel with voice communications. Operators looking to roll out VoIP over networks will use IMS. For example, VoLTE depends on IMS infrastructure.

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[199] 5G Americas member contribution.

3GPP initially introduced IMS in Release 5 and has enhanced it in each subsequent specification release.

As shown in Figure 102, IMS operates just outside the packet core.

Figure 102: IP Multimedia Subsystem

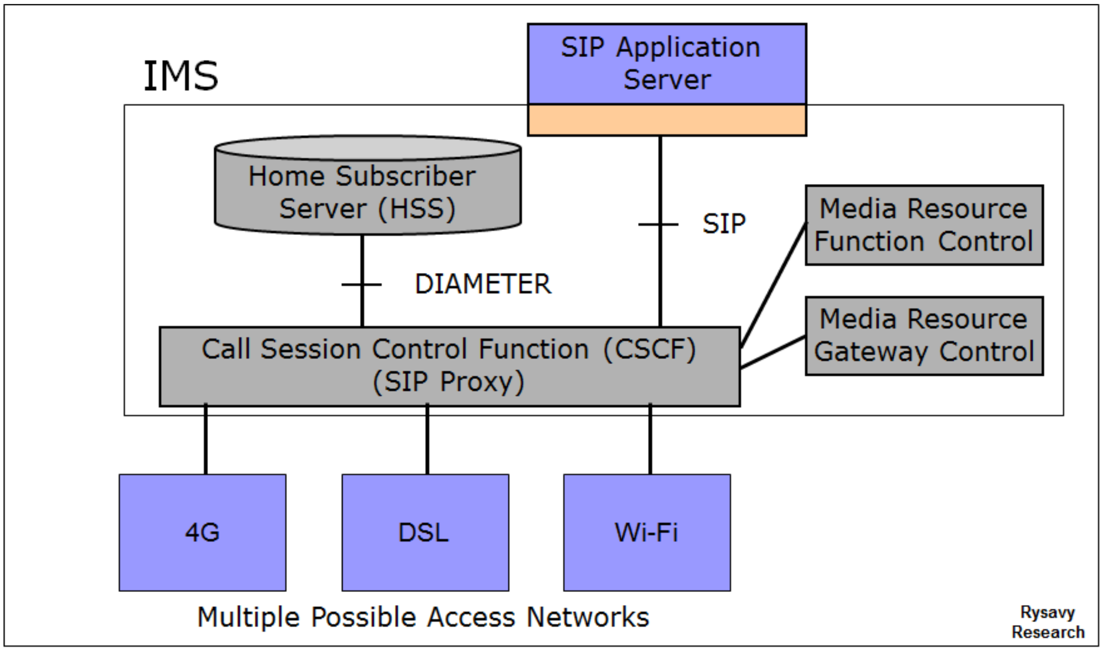
IMS
SIP Application Server
Home Subscriber Server (HSS)
SIP
Media Resource Function Control
DIAMETER
Call Session Control Function (CSCF) (SIP Proxy)
Media Resource Gateway Control
4G
DSL
Wi-Fi
Multiple Possible Access Networks
Rysavy Research

The benefits of using IMS include handling all communication in the packet domain, tighter integration with the internet, and a lower cost infrastructure based on IP building blocks for both voice and data services.

IMS applications can reside either in the operator's network or in third-party networks including those of enterprises. By managing services and applications centrally—and independently of the access network—IMS can enable network convergence. This allows operators to offer common services across 3G, Wi-Fi, and wireline networks.

Service Continuity, defined in Release 8, provided for a user's entire session to continue seamlessly as the user moves from one access network to another. Release 9 expanded this concept to allow sessions to move across different device types. For example, the user could transfer a video call in midsession from a mobile phone to a large-screen TV, assuming both have an IMS appearance in the network.

Release 8 introduced the IMS Centralized Services (ICS) feature, which allows for IMS-controlled voice features to use either packet-switched or circuit-switched access.

Given that LTE operators will integrate their 5G networks with their current LTE networks, operators are likely to keep using IMS in conjunction with LTE for their voice and other services that use IMS, even as they begin deploying 5G.

Broadcast/Multicast Services

An important capability for 3G and evolved 3G systems is broadcasting and multicasting, wherein multiple users receive the same information using the same radio resource. This creates a more efficient approach to deliver video when multiple users desire the same content simultaneously. In a broadcast, every subscriber unit in a service area receives the information, whereas in a multicast, only users with subscriptions receive the information. Service areas for both broadcast and multicast can span either the entire network or a specific geographical area. Potential applications include sporting events, select news, venue-specific (shopping mall, museum) information, and even delivery of software upgrades. Giving users the ability to store and replay select content could further expand the scope of applications.

3GPP defined highly efficient broadcast/multicast capabilities for UMTS in Release 6 with MBMS. Release 7 defined optimizations through a feature called multicast/broadcast, single-frequency network operation that involves simultaneous transmission of the exact waveform across multiple cells. This enables the receiver to constructively superpose multiple MBMS Single Frequency Network (SFN), or MBSFN, cell transmissions. The result is highly efficient, WCDMA-based broadcast transmission technology that matches the benefits of OFDMA-based broadcast approaches.

LTE also has a broadcast/multicast capability called eMBMS. OFDM is particularly well suited for efficient broadcasting, as shown in Figure 103, because the mobile system can combine the signal from multiple base stations, also an MBSFN approach, and because of the narrowband nature of OFDM. Normally, these signals would interfere with one another. The single frequency network is a cluster of cells that transmit the same content synchronously with a common carrier frequency.

Figure 103: OFDM Enables Efficient Broadcasting

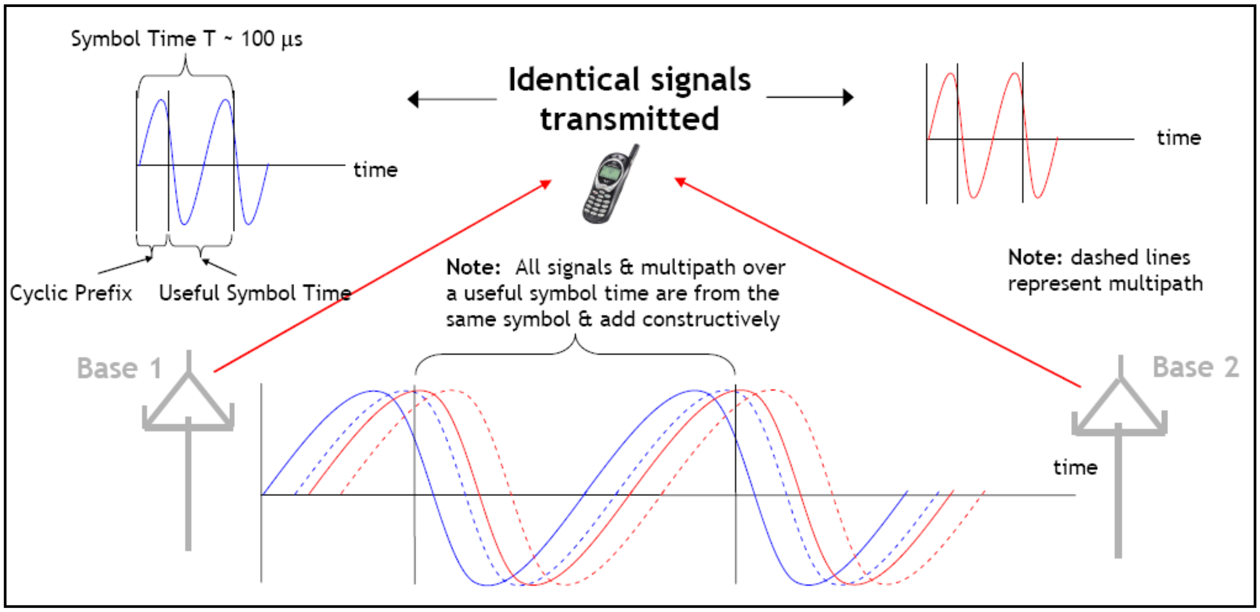
Symbol Time T ~ 100 µs
time
Cyclic Prefix
Useful Symbol Time
Identical signals transmitted
time
Note: dashed lines represent multipath
Note: All signals & multipath over a useful symbol time are from the same symbol & add constructively
Base 1
Base 2
time

Despite various broadcast technologies being available, market adoption to date has been relatively slow. Internet trends have favored unicast approaches, with users viewing videos of their selection on demand, but there is increasing interest in using eMBMS with LTE to alleviate capacity demands.

Backhaul

Connecting sites to core networks remains a challenge, whether for small cells or macro cells, especially as networks need to deliver higher bandwidth. Fiber is the gold standard, but it is not available everywhere and can be expensive, so operators use a combination of wired and wireless links.

Today's backhaul requirements for LTE can range from 1 to 10 Gbps. By 2020, backhaul requirements could exceed 10 Gbps.[200]

Table 29 and Table 30 summarize the methods and capabilities of the various available approaches.

Table 29: Wired Backhaul Methods and Capabilities[201]

Technology	Distance	Throughput Speed
Direct Fiber	80 km	Hundreds of Mbps to Gbps
Bonded VDSL2	To 5,000 feet	75 Mbps down, 12 Mbps up
FTTX	Most urban areas	Up to 2.5 Gbps down, 1.5 Gbps up
DOCSIS	Most urban areas	Up to 285 Mbps down, 105 Mbps up

Table 30: Wireless Backhaul Methods and Capabilities[202]

Technology	Distance	Line-of-Sight	Throughput Speed
5G Integrated Access and Backhaul	1 km	Yes	1 to 10 Gbps
Millimeter Wave (60 GHz)	1 km	Yes	1 Gbps
Millimeter Wave (70-80 GHz)	3 km (with speed tradeoff)	Yes	10 Gbps
Microwave (6-60 GHz)	Varies by frequency: 2-4 km typical at 30-42 GHz	Yes	1 Gbps+

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[200] Arthur D. Little, *Creating a Gigabit Society – The Rule of 5G; A report by Arthur D. Little for Vodafone Group*, 2017. See Figure 6.

[201] Small Cell Forum, "Backhaul Technologies for Small Cells," February 2013.

[202] Ibid.

Technology	Distance	Line-of-Sight	Throughput Speed
Licensed sub 6 GHz	1.5 to 10 km	No	170 Mbps (20 MHz TDD), 400 Mbps+ with new technology
Unlicensed sub-6 GHz	Up to 250 meters	No	450 Mbps (IEEE 802.11n 3X3 MIMO)
TV White Space (802.11af-based)	1 to 5 km max throughput, 10 km+ possible	Depends on deployment model	80 Mbps in 6 MHz TDD with 4X4 MIMO
Satellite	Available everywhere	Yes	Up to 50 Mbps downlink, 15 Mbps uplink

UMTS-HSPA

UMTS technology is mature and benefits from research and development that began in the early 1990s. It has been thoroughly trialed, tested, and commercially deployed. UMTS employs a wideband CDMA radio-access technology. The primary benefits of UMTS include high spectral efficiency for voice and data, simultaneous voice and data capability, high user densities that can be supported with low infrastructure costs, and support for high-bandwidth data applications. Operators can also use their entire available spectrum for both voice and high-speed data services.

Additionally, operators can use a common core network, called the UMTS multi-radio network as shown in Figure 104, which supports multiple radio-access networks including GSM, EDGE, WCDMA, HSPA, and evolutions of these technologies.

Figure 104: UMTS Multi-radio Network

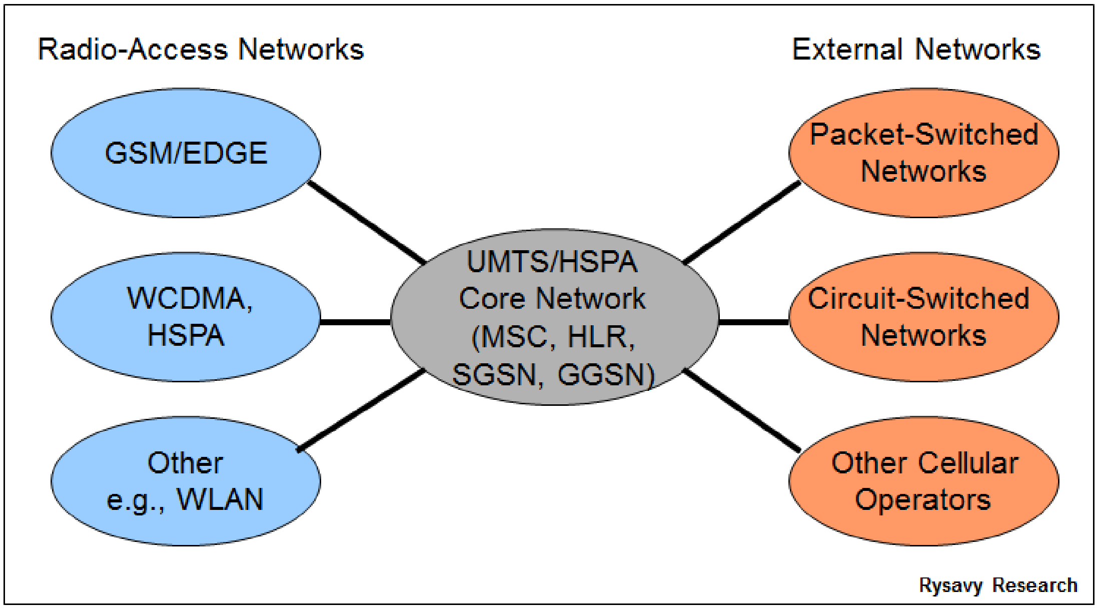
Radio-Access Networks
External Networks
GSM/EDGE
WCDMA, HSPA
Other e.g., WLAN
UMTS/HSPA Core Network (MSC, HLR, SGSN, GGSN)
Packet-Switched Networks
Circuit-Switched Networks
Other Cellular Operators
Rysavy Research

HSPA refers to networks that support both HSDPA and HSUPA. All new deployments today are HSPA, and many operators have upgraded their HSDPA networks to HSPA. For example, in 2008, AT&T upgraded most of its network to HSPA. By the end of 2008, HSPA was deployed throughout the Americas.

The UMTS radio-access network consists of base stations referred to as Node B (corresponding to GSM base transceiver systems) that connect to RNCs (corresponding to GSM base station controllers [BSCs]). The RNCs connect to the core network as do the BSCs. When both GSM and WCDMA access networks are available, the network can hand users over between these networks. This is important for managing capacity, as well as in areas in which the operator has continuous GSM coverage, but has only deployed WCDMA in some locations.

Whereas GSM can effectively operate like a spread-spectrum system[203], based on time division in combination with frequency hopping, WCDMA is a direct-sequence, spread-spectrum system. WCDMA is spectrally more efficient than GSM, but it is the wideband nature of WCDMA that provides its greatest advantage—the ability to translate the available spectrum into high data rates. This wideband technology approach results in the flexibility to manage multiple traffic types including voice, narrowband data, and wideband data.

HSDPA

HSDPA, specified in 3GPP Release 5, saw the introduction of high-performance, packet data service that delivers peak theoretical rates of 14 Mbps. Peak user-achievable throughput rates in initial deployments are well over 1 Mbps and as high as 4 Mbps in some networks. The same radio carrier can simultaneously service UMTS voice and data users, as well as HSDPA data users.

HSDPA achieves its high speeds through techniques similar to those that push EDGE performance past GPRS including higher order modulation, variable coding, and soft combining, as well as through the addition of fast scheduling and other techniques.

HSDPA achieves its performance gains from the following radio features:

- ☐ High-speed channels shared in both code and time domains
- ☐ Short TTI
- ☐ Fast scheduling and user diversity
- ☐ Higher order modulation
- ☐ Fast link adaptation
- ☐ Fast HARQ

These features function as follows:

High-Speed Shared Channels and Short Transmission Time Interval: First, HSDPA uses high-speed data channels called “High Speed Physical Downlink Shared Channels” (HS-PDSCH). Up to 15 of these channels can operate in the 5 MHz WCDMA radio channel. Each uses a fixed spreading factor of 16. User transmissions are assigned to one or more of these channels for a short TTI of 2 msec. The network can then readjust how users are assigned to different HS-PDSCH every 2 msec. Resources are thus assigned in both time

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[203] Spread spectrum systems can either be direct sequence or frequency hopping.

(the TTI interval) and code domains (the HS-PDSCH channels). Figure 105 illustrates different users obtaining different radio resources.

Figure 105: High Speed–Downlink Shared Channels (Example)

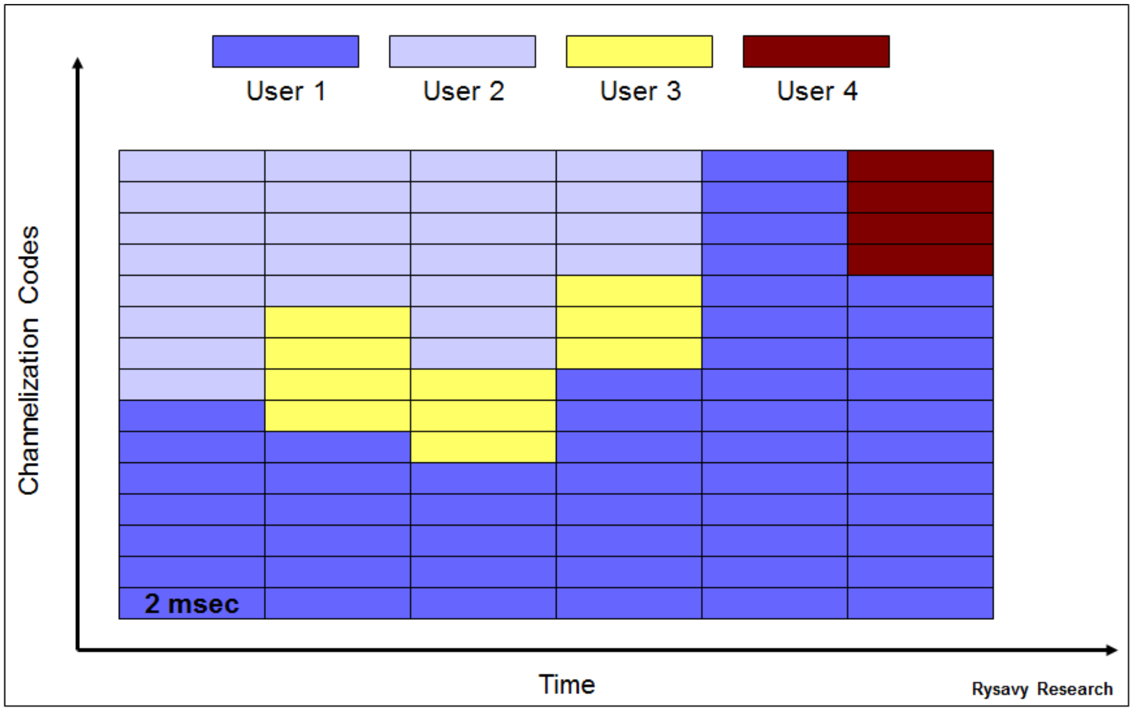

Fast Scheduling and User Diversity: Fast scheduling exploits the short TTI by assigning users channels that have the best instantaneous channel conditions, rather than in a round-robin fashion. Because channel conditions vary somewhat randomly across users, most users can be serviced with optimum radio conditions and thereby obtain optimum data throughput. Figure 106 shows how a scheduler might choose between two users based on their varying radio conditions to emphasize the user with better instantaneous signal quality. With about 30 users active in a sector, the network achieves significant user diversity and much higher spectral efficiency. The system also ensures that each user receives a minimum level of throughput, an approach called proportional fair scheduling.

Figure 106: User Diversity

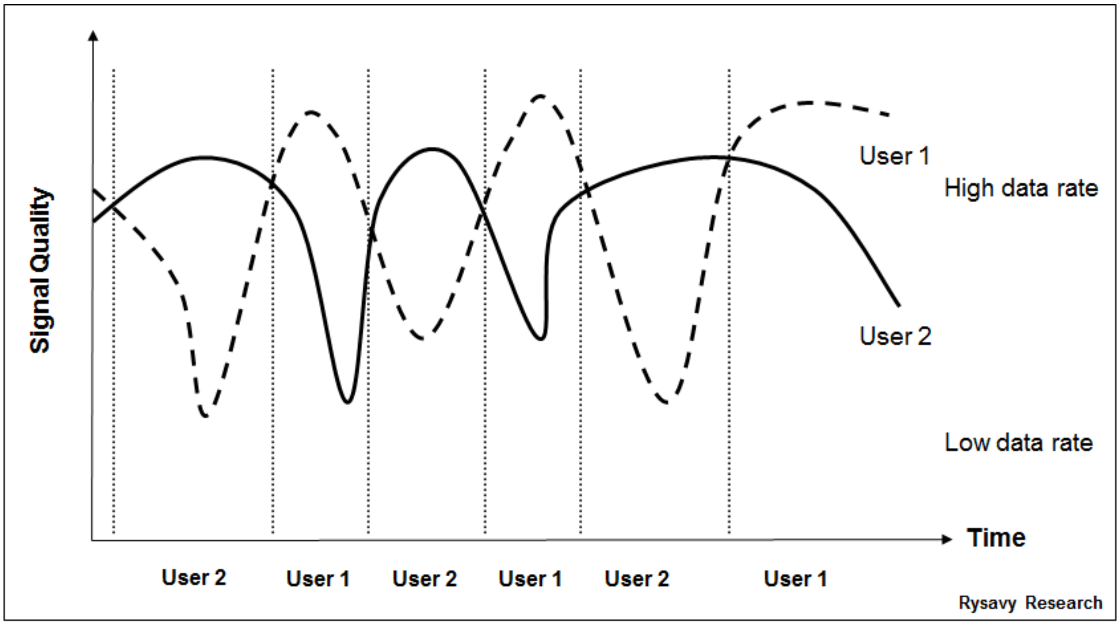

Higher Order Modulation: HSDPA uses both the modulation used in WCDMA—namely QPSK—and, under good radio conditions, an advanced modulation scheme—16 QAM. 16 QAM transmits 4 bits of data in each radio symbol compared to 2 bits with QPSK. Data throughput is increased with 16 QAM, while QPSK is available for adverse radio conditions. HSPA Evolution adds 64 QAM modulation to further increase throughput rates. 64 QAM became available in Release 7, and the combination of MIMO and 64 QAM became available in Release 8.

Fast Link Adaptation: Depending on the condition of the radio channel, different levels of forward-error correction (channel coding) can also be employed. For example, a three-quarter coding rate means that three quarters of the bits transmitted are user bits, and one quarter are error-correcting bits. Fast link adaptation refers to the process of selecting and quickly updating the optimum modulation and coding rate and occurs in coordination with fast scheduling.

Fast Hybrid Automatic Repeat Request: Another HSDPA technique is Fast Hybrid Automatic Repeat Request (Fast Hybrid ARQ). “Fast” refers to the medium-access control mechanisms implemented in Node B (along with scheduling and link adaptation), as opposed to the BSC in GPRS/EDGE, and “hybrid” refers to a process of combining repeated data transmissions with prior transmissions to increase the likelihood of successful decoding. Managing and responding to real-time radio variations at the base station, as opposed to an internal network node, reduces delays and further improves overall data throughput.

Using the approaches just described, HSDPA maximizes data throughputs and capacity and minimizes delays. For users, this translates to better network performance under loaded conditions, faster application performance, and a greater range of applications that function well.

Field results validate the theoretical throughput results. With initial 1.8 Mbps peak rate devices, vendors measured consistent throughput rates in actual deployments of more than 1 Mbps. These rates rose to more than 2 Mbps for 3.6 Mbps devices and then close to 4 Mbps for 7.2 Mbps devices.

In 2008, typical devices supporting peak data rates of 3.6 Mbps or 7.2 Mbps became available. Many operator networks support 7.2 Mbps peak operation, and some even support the maximum rate of 14.4 Mbps.

HSUPA

Whereas HSDPA optimizes downlink performance, HSUPA—which uses the Enhanced Dedicated Channel (E-DCH)—constitutes a set of improvements that optimizes uplink performance. Networks and devices supporting HSUPA became available in 2007. These improvements include higher throughputs, reduced latency, and increased spectral efficiency. HSUPA was standardized in Release 6. It results in an approximately 85% increase in overall cell throughput on the uplink and more than a 50% gain in user throughput. HSUPA also reduces packet delays, a significant benefit resulting in much improved application performance on HSPA networks

Although the primary downlink traffic channel supporting HSDPA serves as a shared channel designed for the support of services delivered through the packet-switched domain, the primary uplink traffic channel defined for HSUPA is a dedicated channel that could be used for services delivered through either the circuit-switched or the packet-switched domains. Nevertheless, by extension and for simplicity, the WCDMA-enhanced uplink capabilities are often identified in the literature as HSUPA.

HSUPA achieves its performance gains through the following approaches:

- ❑ An enhanced dedicated physical channel.
- ❑ A short TTI, as low as 2 msec, which allows faster responses to changing radio conditions and error conditions.
- ❑ Fast Node B-based scheduling, which allows the base station to efficiently allocate radio resources.
- ❑ Fast Hybrid ARQ, which improves the efficiency of error processing.

The combination of TTI, fast scheduling, and Fast Hybrid ARQ also serves to reduce latency. HSUPA can operate with or without HSDPA in the downlink, although use the two approaches together. The improved uplink mechanisms also translate to better coverage and, for rural deployments, larger cell sizes.

HSUPA can achieve different throughput rates based on various parameters including the number of codes used, the spreading factor of the codes, the TTI value, and the transport block size in bytes.

Initial devices enabled peak user rates of close to 2 Mbps as measured in actual network deployments, while current devices have throughputs of more than 5 Mbps. Future devices could have network rates as high as 69 Mbps, as discussed further below.

Beyond throughput enhancements, HSUPA also significantly reduces latency.

Evolution of HSPA (HSPA+)

The goal in evolving HSPA is to exploit available radio technologies—largely enabled by increases in digital signal processing power—to maximize CDMA-based radio performance. This evolution has significantly advanced HSPA and extends the life of sizeable operator infrastructure investments.

Wireless and networking technologists have defined a series of enhancements for HSPA, beginning in Release 7 and now continuing through Release 14. These include advanced receivers, multi-carrier operation, MIMO, Continuous Packet Connectivity, Higher-Order Modulation, One-Tunnel Architecture, HetNet support, and advanced voice capabilities both in circuit- and packet-switched domains.

Taking advantage of these various radio technologies, 3GPP has standardized a number of features, beginning in Release 7 including higher order modulation and MIMO. Collectively, these capabilities are referred to as HSPA+. Release 8 through Release 12 include further enhancements.

The goals of HSPA+ were to:

- ❑ Exploit the full potential of a CDMA approach.
- ❑ Provide smooth interworking between HSPA+ and LTE, thereby facilitating the operation of both technologies. As such, operators may choose to leverage the EPC planned for LTE.
- ❑ Allow operation in a packet-only mode for both voice and data.
- ❑ Be backward-compatible with previous systems while incurring no performance degradation with either earlier or newer devices.
- ❑ Facilitate migration from current HSPA infrastructure to HSPA+ infrastructure.

HSPA improvements have continued through successive 3GPP releases, including Release 14, which has downlink interference mitigation. Release 15 has work items for quality of experience, multi-carrier enhancements, and various protocol enhancements.

The following sections discuss specific enhancements that have already been implemented in HSPA.

Advanced Receivers

3GPP has specified a number advanced-received designs including: Type 1, which uses mobile-receive diversity; Type 2, which uses channel equalization; and Type 3, which includes a combination of receive diversity and channel equalization. Type 3i devices, which became available in 2012, employ interference cancellation. Note that the different types of receivers are release-independent. For example, Type 3i receivers will work and provide a capacity gain in an earlier Release 5 network.

The first approach is mobile-receive diversity. This technique relies on the optimal combination of received signals from separate receiving antennas. The antenna spacing yields signals that have somewhat independent fading characteristics. Hence, the combined signal can be more effectively decoded, which almost doubles downlink capacity when done in combination with channel equalization. Receive diversity is effective even with smaller devices such as like PC Card modems and smartphones.

Current receiver architectures based on rake receivers are effective for speeds up to a few megabits per second. But at higher speeds, the combination of reduced symbol period and multipath interference results in Intersymbol Interference and diminishes rake receiver performance. This problem can be solved by advanced-receiver architectures with channel equalizers that yield additional capacity gains over HSDPA with receive diversity. Alternate advanced-receiver approaches include interference cancellation and generalized rake receivers (G-Rake). Different vendors are emphasizing different approaches. The performance requirements for advanced-receiver architectures, however, were specified in 3GPP Release 6. The combination of mobile-receive diversity and channel equalization (Type 3) is especially attractive, because it results in a large capacity gain independent of the radio channel.

What makes such enhancements attractive is that the networks do not require any changes other than increased capacity within the infrastructure to support the higher bandwidth. Moreover, the network can support a combination of devices including both earlier devices that do not include these enhancements and later devices that do. Device vendors can selectively apply these enhancements to their higher-end devices.

MIMO

Another standardized capability is MIMO, a technique that employs multiple transmit antennas and multiple receive antennas, often in combination with multiple radios and multiple parallel data streams. The most common use of the term "MIMO" applies to spatial multiplexing. The transmitter sends different data streams over each antenna. Whereas multipath is an impediment for other radio systems, MIMO—as illustrated in Figure 107—actually exploits multipath, relying on signals to travel across different uncorrelated communications paths. The multiple data paths effectively operate in parallel and, with appropriate decoding, in a multiplicative gain in throughput.

Figure 107: MIMO Using Multiple Paths to Boost Throughput and Capacity

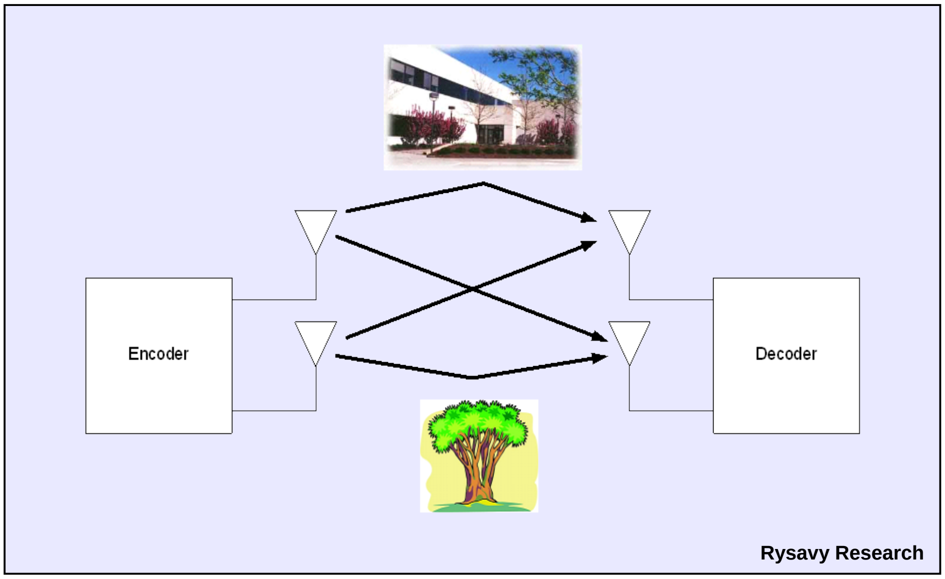

Tests of MIMO have proven effective in WLANs operating in relative isolation where interference is not a dominant factor. Spatial multiplexing MIMO can also benefit HSPA "hotspots" serving local areas including airports, campuses, and malls. In a fully loaded network with interference from adjacent cells, however, overall capacity gains will be more modest—in the range of 20% to 33% over mobile-receive diversity. Relative to a 1x1 antenna system, however, 2X2 MIMO can deliver cell throughput gains of about 80%. 3GPP has standardized spatial multiplexing MIMO in Release 7 using Double Transmit Adaptive Array (D-TxAA).

Release 9 provides for a means to leverage MIMO antennas at the base station when transmitting to user equipment that does not support MIMO. The two transmit antennas in the base station can transmit a single stream using beam forming. This is called "single stream MIMO" or "MIMO with single-stream restriction" and results in higher throughput rates because of the improved signal received by the user equipment.

3GPP designed uplink dual-antenna beamforming and 2X2 MIMO for HSPA+ in Release 11.

Continuous Packet Connectivity

Continuous Packet Connectivity (CPC) specified in Release 7 reduces the uplink interference created by the dedicated physical control channels of packet data users when those channels have no user data to transmit, which increases the number of simultaneously connected HSUPA users. CPC allows both discontinuous uplink transmission and discontinuous downlink reception, wherein the modem can turn off its receiver after a certain period of HSDPA inactivity. CPC is especially beneficial to VoIP on the uplink because the radio can turn off between VoIP packets, as shown in Figure 108.

Figure 108: Continuous Packet Connectivity

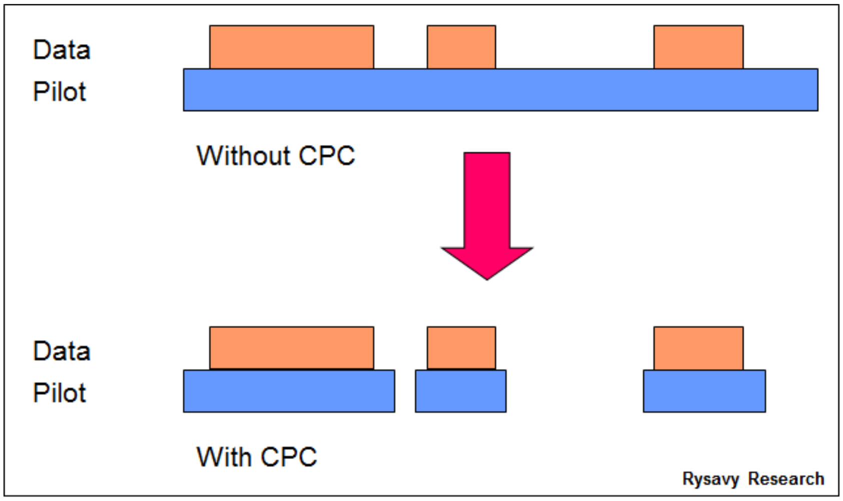

Higher Order Modulation

Another way of increasing performance is with higher order modulation. HSPA uses 16 QAM on the downlink and QPSK on the uplink, but HSPA+ adds 64 QAM to the downlink and 16 QAM to the uplink. 3GPP has also introduced 64 QAM to the uplink for HSPA+ in Release 11. Higher order modulation requires a better SNR, achieved through receive diversity and equalization.

Multi-Carrier HSPA

3GPP defined dual-carrier HSPA operation in Release 8, which coordinates the operation of HSPA on two adjacent 5 MHz carriers so that data transmissions can achieve higher throughput rates, as shown in Figure 109. The work item assumed two adjacent carriers, downlink operation and no MIMO. This configuration achieves a doubling of the 21 Mbps maximum rate available on each channel to 42 Mbps.

Figure 109: Dual-Carrier Operation with One Uplink Carrier[204]

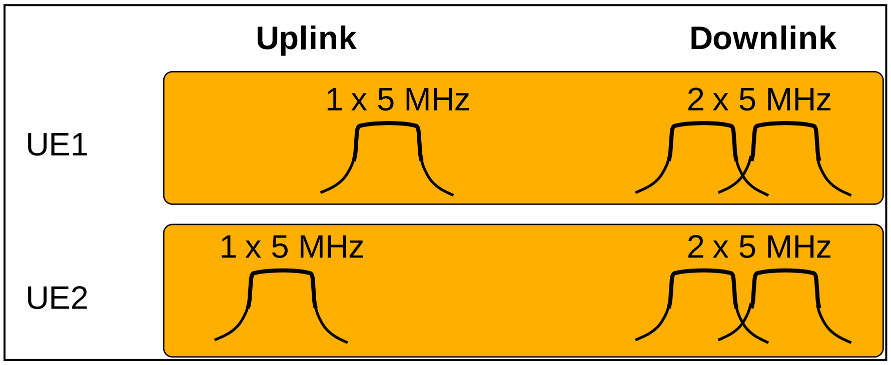

Benefits include:

- An increase in spectral efficiency of about 15%, comparable to what can be obtained with 2X2 MIMO.
- Significantly higher peak throughputs available to users, especially in lightly-loaded networks.
- Same maximum-throughput rate of 42 Mbps as using MIMO, but with a less expensive infrastructure upgrade.

Scheduling packets across two carriers is a more efficient use of resources, resulting in what is called “trunking gain.” Multi-user diversity also improves from an increased number of users across the two channels.

Release 9 also supports dual-carrier operation in the uplink. Release 10 specifies the use of up to four channels, resulting in peak downlink data rates of 168 Mbps. Release 11 supports eight radio channels on the downlink, resulting in a further doubling of theoretical throughput to 336 Mbps. On the uplink, devices can transmit using two antennas for either rank 1 (single stream beamforming) or rank 2 (dual-stream MIMO) transmission modes. Rank 1 beamforming helps with coverage (approximately 40%), while rank 2 MIMO helps with throughput speeds (approximately 20% median and 80% at cell edge). In addition, 64 QAM will be possible on the uplink, enabling uplink speeds to 69 Mbps in dual-carrier operation.

Downlink Multiflow Transmission

Release 11 specifies means by which two cells can transmit to the mobile station at the same time. The two cells transmit independent data, in effect a spatial multiplexing approach, improving both peak and average data.

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[204] Harri Holma and Antti Toskala, *LTE for UMTS, OFDMA and SC-FDMA Based Radio Access*, Wiley, April 2009.

Multiflow transmission with HSPA+ also enhances HetNet operation in which picocell coverage can be expanded within a macrocell coverage area, as shown in Figure 110.

Figure 110: HSPA+ HetNet Using Multipoint Transmission[205]

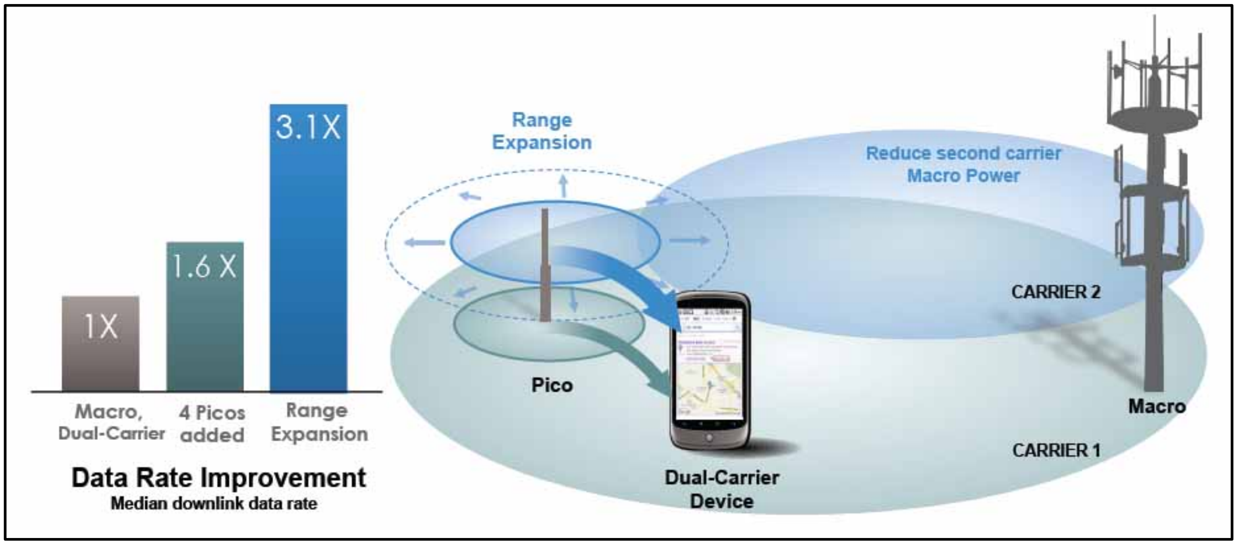
3.1X
1.6 X
1X
Macro, Dual-Carrier
4 Picos added
Range Expansion
Data Rate Improvement
Median downlink data rate
Range Expansion
Reduce second carrier Macro Power
CARRIER 2
Pico
Macro
CARRIER 1
Dual-Carrier Device

Multiflow enhances HSPA+ network operation using the following approaches:

- **Single Frequency Dual Cell.** The UE communicates with two different cells using the same frequency, improving cell-edge performance and providing network load balancing.
- **Dual Frequency Three Cell.** The UE communicates with two different cells using the same frequency. In addition, it communicates with one other cell on a different frequency.
- **Dual Frequency Four Cells.** The UE communicates using two instances of Single Frequency Dual Cell operation as described above.

In Release 12, 3GPP is considering the following enhancement to Multiflow operation, which is primarily targeted towards HetNet operation:

- **Dual Frequency Dual Carrier.** The UE aggregates cells on two different frequencies from two different sites.

HSPA+ Throughput Rates

Table 31 summarizes the capabilities of HSPA and HSPA+ based on the various methods discussed above.

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[205] Qualcomm, "HSPA+ Advanced: Taking HSPA+ to the Next Level," February 2012, http://www.qualcomm.com/media/documents/hspa-advanced-taking-hspa-next-level-whitepaper, accessed June 20, 2014.

Table 31: HSPA Throughput Evolution

Technology	Downlink (Mbps) Peak Data Rate	Uplink (Mbps) Peak Data Rate
HSPA as defined in Release 6	14.4	5.76
Release 7 HSPA+ DL 64 QAM, UL 16 QAM, 5+5 MHz	21.1	11.5
Release 7 HSPA+ 2X2 MIMO, DL 16 QAM, UL 16 QAM, 5+5 MHz	28.0	11.5
Release 8 HSPA+ 2X2 MIMO DL 64 QAM, UL 16 QAM, 5+5 MHz	42.2	11.5
Release 8 HSPA+ (no MIMO) Dual Carrier, 10+5 MHz	42.2	11.5
Release 9 HSPA+ 2X2 MIMO, Dual Carrier DL and UL, 10+10 MHz	84.0	23.0
Release 10 HSPA+ 2X2 MIMO, Quad Carrier[206] DL, Dual Carrier UL, 20+10 MHz	168.0	23.0
Release 11 HSPA+ 2X2 MIMO DL and UL, 8 Carrier DL, Dual Carrier UL, 40+10 MHz	336.0	69.0

Release 13 enables aggregation of two UL carriers across bands.

Figure 111 shows the cumulative distribution function of throughput values in a commercially deployed Release 8 HSPA+ network in an indoor coverage scenario. The figure shows significant performance gains from higher-order modulation and MIMO.

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[206] No operators have announced plans to deploy HSPA in a quad (or greater) carrier configuration. Three carrier configurations, however, have been deployed.

Figure 111: HSPA+ Performance Measurements Commercial Network (5+5 MHz)[207]

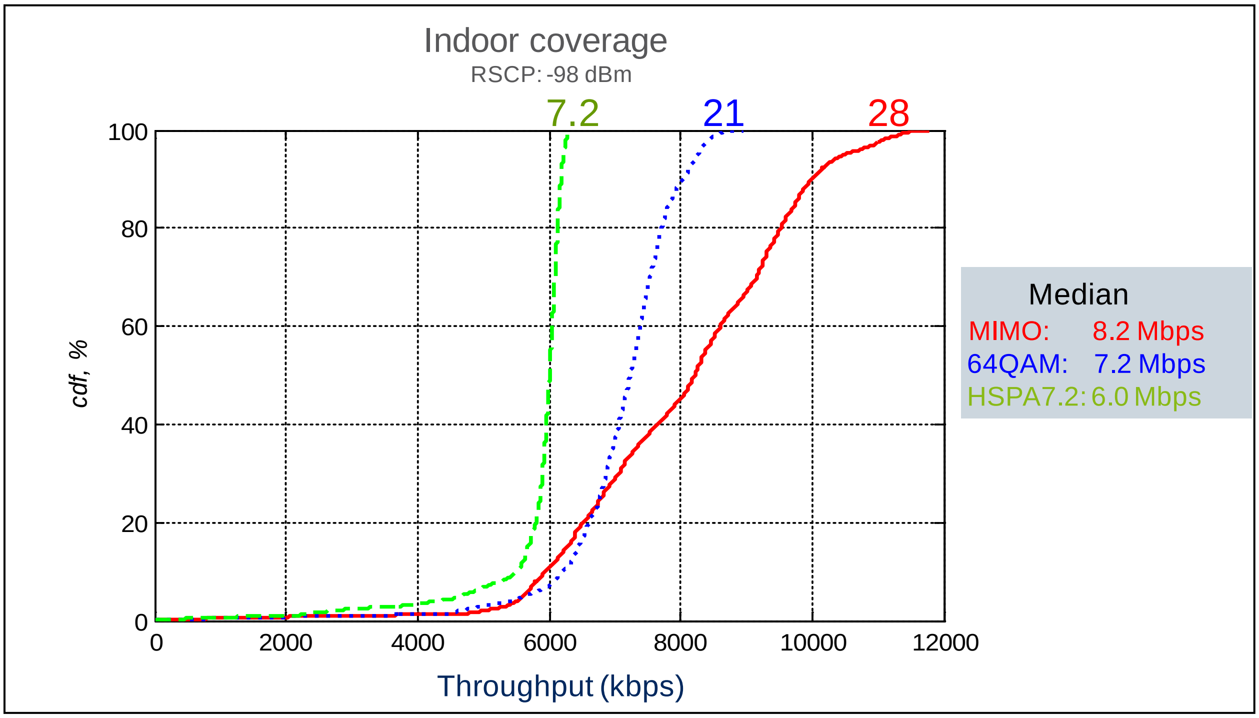

The figure shows a reasonably typical indoor scenario in a macro-cell deployment. Under better radio conditions, HSPA+ will achieve higher performance results.

Figure 112 shows the benefit of dual-carrier operation (no MIMO employed), which essentially doubles throughputs over single carrier operation.

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[207] 5G Americas member company contribution.

Figure 112: Dual-Carrier HSPA+ Throughputs[208]

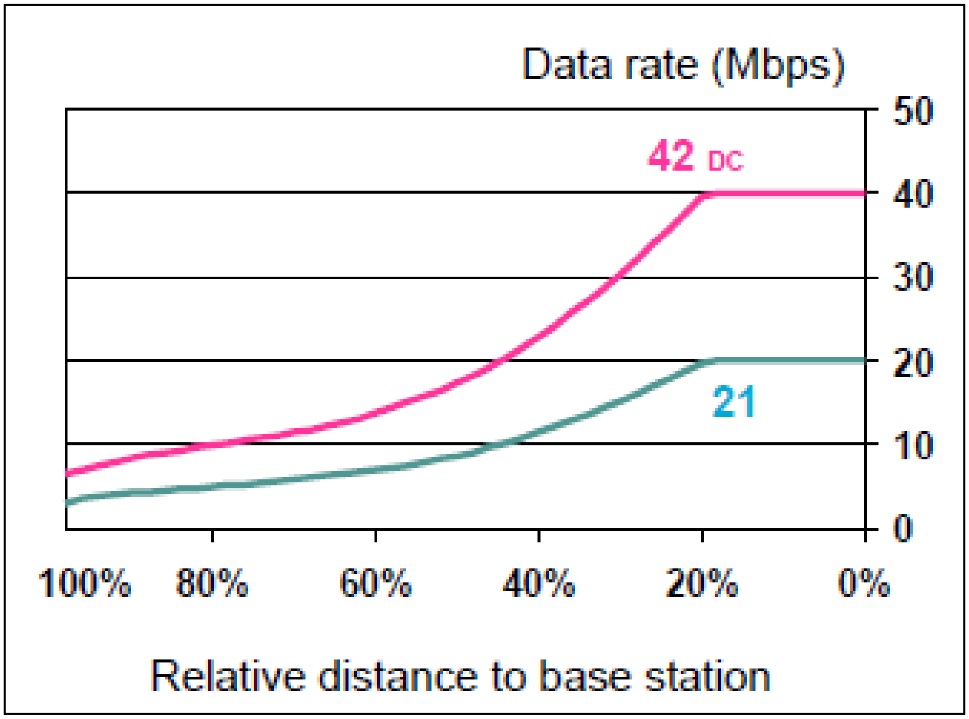

HSPA+ also has improved latency performance of as low as 25 msec and improved packet call setup time of below 500 msec.

Figure 113 summarizes the key capabilities and benefits of the features being deployed in HSPA+.

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[208] 5G Americas member company contribution. 64 QAM.

Figure 113: Summary of HSPA Functions and Benefits[209]

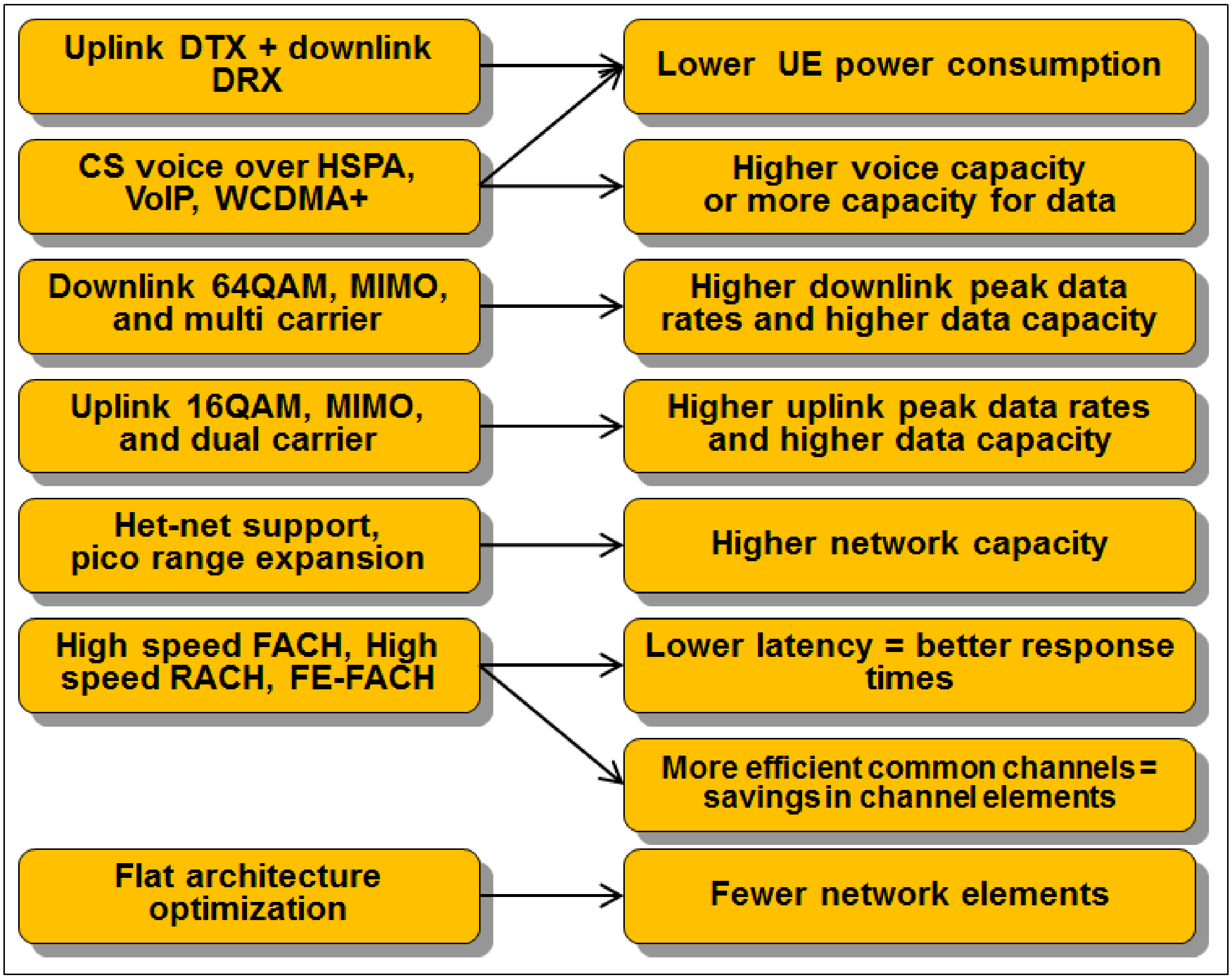
Uplink DTX + downlink DRX
Lower UE power consumption
CS voice over HSPA, VoIP, WCDMA+
Higher voice capacity or more capacity for data
Downlink 64QAM, MIMO, and multi carrier
Higher downlink peak data rates and higher data capacity
Uplink 16QAM, MIMO, and dual carrier
Higher uplink peak data rates and higher data capacity
Het-net support, pico range expansion
Higher network capacity
High speed FACH, High speed RACH, FE-FACH
Lower latency = better response times
More efficient common channels = savings in channel elements
Flat architecture optimization
Fewer network elements

UMTS TDD and TD-SCDMA

Most WCDMA and HSDPA deployments are based on FDD, which uses different radio bands for transmit and receive. In the alternate TDD approach, transmit and receive functions alternate in time on the same radio channel. 3GPP specifications include a TDD version of UMTS, called "UMTS TDD."

TDD does not provide any inherent advantage for voice functions, which need balanced links—namely, the same amount of capacity in both the uplink and the downlink. Many data applications, however, are asymmetric, often with the downlink consuming more bandwidth than the uplink. A TDD radio interface can dynamically adjust the downlink-to-uplink ratio accordingly, hence balancing both forward-link and reverse-link capacity. Note that for UMTS FDD, the higher spectral efficiency achievable in the downlink versus the uplink addresses the asymmetrical nature of average data traffic.

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[209] 5G Americas member contribution.

The UMTS TDD specification also includes the capability to use joint detection in receiver-signal processing, which offers improved performance.

One consideration, however, relates to available spectrum. Various countries around the world including those in Europe, Asia, and the Pacific region have licensed spectrum available specifically for TDD systems. TDD is also a good choice for any spectrum that does not provide a duplex gap between forward and reverse links.

In the United States, there is limited spectrum specifically allocated for TDD systems, the major band being BRS at 2.5 GHz used by Clearwire for WiMAX and now LTE TDD.[210] UMTS TDD is not a good choice in FDD bands; it would not be able to operate effectively in both bands, thereby making the overall system efficiency relatively poor.

TDD systems require network synchronization and careful coordination between operators or guardbands, which may be problematic in certain bands.

There has not been widespread deployment of UMTS TDD.

Time Division Synchronous Code Division Multiple Access (TD-SCDMA) is one of the official 3G wireless technologies, mostly for deployment in China. Specified through 3GPP as a variant of the UMTS TDD System and operating with a 1.28 megachips per second (Mcps) chip rate versus 3.84 Mcps for UMTS TDD, TD-SCDMA's primary attribute is that it supports very high subscriber densities, making it a possible alternative for wireless local loops. TD-SCDMA uses the same core network as UMTS, and it is possible for the same core network to support both UMTS and TD-SCDMA radio-access networks.

Although there are no planned deployments in any country other than China, TD-SCDMA could theoretically be deployed anywhere unpaired spectrum is available—such as the bands licensed for UMTS TDD—assuming appropriate resolution of regulatory issues.

EDGE/EGPRS

Today, most GSM networks support EDGE, an enhancement to GPRS, which is the original packet data service for GSM networks.[211] GPRS provides a packet-based IP connectivity solution supporting a wide range of enterprise and consumer applications. GSM networks with EDGE operate as wireless extensions to the internet and give users internet access, as well as access to their organizations from anywhere. Peak EDGE user-achievable[212] throughput rates are up to 200 Kbps. Figure depicts the system architecture.

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[210] The 1910-1920 MHz band targeted unlicensed TDD systems but has never been used.

[211] GSM technology also provides circuit-switched data services, which are not described in this paper since they are seldom used.

[212] "Peak user-achievable" means users, under favorable conditions of network loading and signal propagation, can achieve this rate as measured by applications such as file transfer. Average rates depend on many factors and will be lower than these rates.

Figure 114: GSM/GPRS/EDGE Architecture

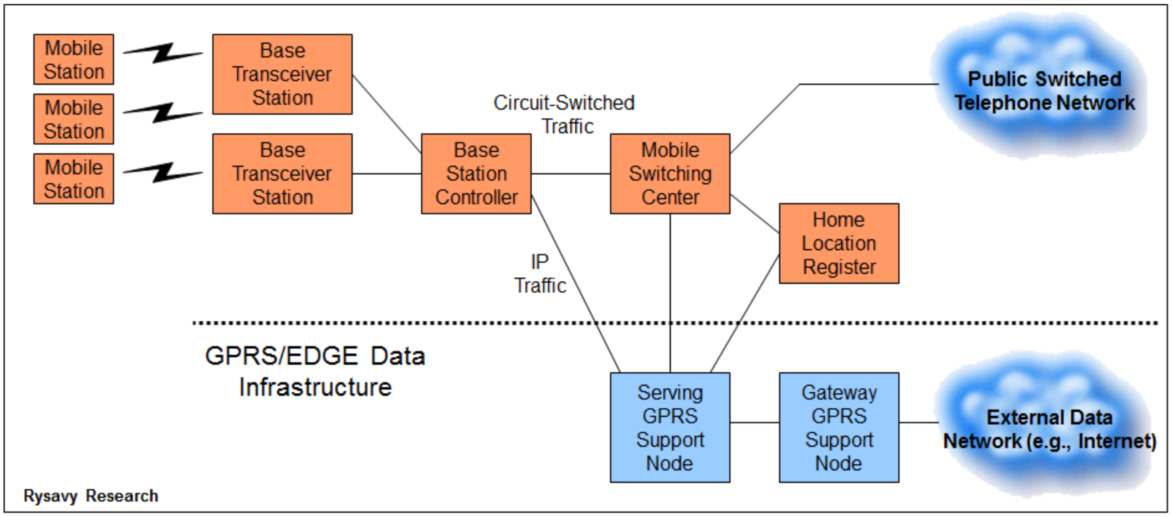
Mobile Station
Mobile Station
Mobile Station
Base Transceiver Station
Base Transceiver Station
Base Station Controller
Circuit-Switched Traffic
Mobile Switching Center
Public Switched Telephone Network
Home Location Register
IP Traffic
GPRS/EDGE Data Infrastructure
Serving GPRS Support Node
Gateway GPRS Support Node
External Data Network (e.g., Internet)
Rysavy Research

EDGE is essentially the addition of a packet-data infrastructure to GSM. In fact, this same data architecture is preserved in UMTS and HSPA networks, and the data architecture is technically referred to as GPRS for the core-data function in all of these networks. The term GPRS may also be used to refer to the initial radio interface, now supplanted by EDGE. Functions of the data elements are as follows:

- The base station controller directs/receives packet data to/from the Serving GPRS Support Node (SGSN), an element that authenticates and tracks the location of mobile stations.
- The SGSN performs the types of functions for data that the Mobile Switching Center (MSC) performs for voice. Each serving area has one SGSN, and it is often collocated with the MSC.
- The SGSN forwards/receives user data to/from the Gateway GPRS Support Node (GGSN), which can be viewed as a mobile IP router to external IP networks. Typically, there is one GGSN per external network (for example, the internet). The GGSN also manages IP addresses, dynamically assigning them to mobile stations for their data sessions.

Another important element is the Home Location Register (HLR), which stores users' account information for both voice and data services. Of significance is that this same data architecture supports data services in GSM and in UMTS-HSPA networks, thereby simplifying operator network upgrades.

In the radio link, GSM uses radio channels of 200 kilohertz (kHz) width, divided in time into eight timeslots comprising 577 microseconds (μs) that repeat every 4.6 msec, as shown in Figure . The network can have multiple radio channels (referred to as transceivers) operating in each cell sector. The network assigns different functions to each timeslot such as the Broadcast Control Channel (BCCH), circuit-switched functions like voice calls or data calls, the optional Packet Broadcast Control Channel (PBCCH), and packet data channels. The network can dynamically adjust capacity between voice and data functions, and it can also reserve minimum resources for each service. This scheduling approach enables more data traffic when voice traffic is low or, likewise, more voice traffic when data traffic is low, thereby maximizing overall use of the network. For example, the PBCCH, which expands the capabilities of the normal BCCH, may be set-up on an additional timeslot of a Time Division Multiple Access (TDMA) frame when justified by the volume of data traffic.

Figure 115: Example of GSM/EDGE Timeslot Structure[213]

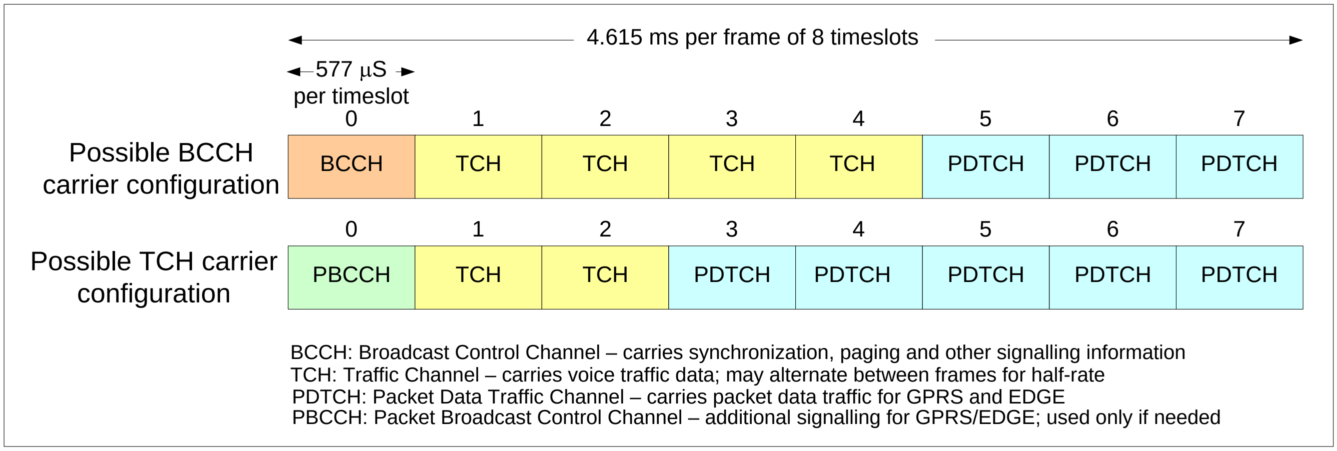

	0	1	2	3	4	5	6	7
Possible BCCH carrier configuration	BCCH	TCH	TCH	TCH	TCH	PDTCH	PDTCH	PDTCH
Possible TCH carrier configuration	PBCCH	TCH	TCH	PDTCH	PDTCH	PDTCH	PDTCH	PDTCH

BCCH: Broadcast Control Channel – carries synchronization, paging and other signalling information
TCH: Traffic Channel – carries voice traffic data; may alternate between frames for half-rate
PDTCH: Packet Data Traffic Channel – carries packet data traffic for GPRS and EDGE
PBCCH: Packet Broadcast Control Channel – additional signalling for GPRS/EDGE; used only if needed

EDGE offers close coupling between voice and data services. In most networks, while in a data session, users can accept an incoming voice call, which suspends the data session, and then resume their data session automatically when the voice session ends. Users can also receive SMS messages and data notifications[214] while on a voice call, as described below.

With respect to data performance, each data timeslot can deliver peak user-achievable data rates of up to about 40 Kbps. The network can aggregate up to five timeslots on the downlink and up to four timeslots on the uplink with current devices.

If multiple data users are active in a sector, they share the available data channels. As demand for data services increases, however, an operator can accommodate customers by assigning an increasing number of channels for data service that is limited only by that operator’s total available spectrum and radio planning.

EDGE is an official 3G cellular technology that can be deployed within an operator's existing 850, 900, 1800, and 1900 MHz spectrum bands. EDGE capability is now largely standard in new GSM deployments. A GPRS network using the EDGE radio interface is technically called an “Enhanced GPRS” (EGPRS) network, and a GSM network with EDGE capability is referred to as GSM Edge Radio Access Network (GERAN). EDGE has been an inherent part of GSM specifications since Release 99. It is fully backward-compatible with older GSM networks, meaning that GPRS devices work on EDGE networks and that GPRS and EDGE terminals can operate simultaneously on the same traffic channels.

Dual Transfer Mode (DTM) devices can simultaneously communicate voice and data. DTM is a 3GPP-specified technology that enables new applications like video sharing while providing a consistent service experience (service continuity) with UMTS. Typically, a DTM end-to-end solution requires only a software upgrade to the GSM/EDGE radio network. There are a number of networks and devices supporting DTM.

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[213] 5G Americas member company contribution.

[214] Example: WAP notification message delivered via SMS.

A feature in Release 9 that applies to EDGE is the Enhanced Flexible Timeslot Assignment (EFTA), which allows for more efficient adaptation to varying uplink versus downlink transmission needs. The network allocates uplink and downlink timeslots that overlap in time, and the mobile station may either use the corresponding uplink timeslots for transmission or receive on the overlapping downlink time slot, if it has nothing to transmit. In addition, alternative EFTA multi-slot classes enable the support of as many as eight timeslots per downlink carrier (instead of five or six timeslots with multi-slot classes 30 to 45).

Abbreviations and Acronyms

The following abbreviations are used in this paper. Abbreviations are defined on first use.

1G – First Generation

1xEV-DO – One Carrier Evolution, Data Optimized

1xEV-DV – One Carrier Evolution, Data Voice

1XRTT – One Carrier Radio Transmission Technology

2G – Second Generation

3G – Third Generation (meeting requirements set forth by the ITU IMT project)

3GPP – Third Generation Partnership Project

3GPP2 – Third Generation Partnership Project 2

4G – Fourth Generation (meeting requirements set forth by the ITU IMT-Advanced project)

5GC – 5G Core

8-PSK – Octagonal Phase Shift Keying

AAS – Adaptive Antenna Systems

ABR – Allocation Retention Priority

AGW – Access Gateway

AMF – Access and Mobility Management Function

AMR – Adaptive Multi Rate

AMR-WB – Adaptive Multi-Rate Wideband

ANDSF – Access Network Discovery and Selection Function.

ANSI – American National Standards Institute

APCO – Association of Public Safety Officials

API – Application Programming Interface

APN – Access Point Name

ARP – Allocation Retention Priority

ARPU – Average Revenue per User

ARQ – Automatic Repeat Request

ATM – Asynchronous Transfer Mode

AWGN – Additive White Gaussian Noise Channel

AWS – Advanced Wireless Services

BCCH – Broadcast Control Channel

bps – bits per second

BRS – Broadband Radio Service

BSC – Base Station Controller

BTS – Base Transceiver Station

C/I – Carrier to Intermodulation Ratio

CAPEX- Capital Expenditure

CBF – Coordinated Beam Forming

CBRS – Citizens Broadband Radio Service

CBS – Coordinated Beam Switching
CSS3 – Cascading Style Sheets 3 (CSS3)
CDD – Cyclic Delay Diversity
CDF – Cumulative Distribution Function
CDMA – Code Division Multiple Access
CL – Closed Loop
CL-SM – Closed Loop Spatial Multiplexing
CMAS – Commercial Mobile Alert System
CMOS – Complementary Metal Oxide Semiconductor
CoMP – Coordinated Multi Point
cMTC – Critical Machine Type Communications
CP – Cyclic Prefix
CPC – Continuous Packet Connectivity
CPRI – Common Public Radio Interface
CQI - Channel Quality Indicators
C-RAN – Cloud Radio Access Network
CRM – Customer Relationship Management
CRS – Cell-specific Reference Signal
CS – Convergence Sublayer
CSFB – Circuit-Switched Fallback
CTIA – Cellular Telephone Industries Association
C-V2X – Cellular Vehicle-to-X
D-AMPS – Digital Advanced Mobile Phone Service
DAS – Distributed Antenna System
DAS – Downlink EGPRS2-A Level Scheme
dB – Decibel
DBS – Downlink EGPRS2-B Level Scheme
DC-HSPA – Dual Carrier HSPA
DFT – Discrete Fourier Transform
DL – Downlink
DNS – Domain Name Service
DPCCH – Dedicated Physical Control Channel
DPS – Dynamic Point Selection
DSL – Digital Subscriber Line
DSMIPv6 – Dual Stack Mobile IPv6
DTM – Dual Transfer Mode
DRX – Discontinuous Reception
D-TxAA – Double Transmit Adaptive Array
DVB-H – Digital Video Broadcasting Handheld

E-DCH – Enhanced Dedicated Channel
EBCMCS – Enhanced Broadcast Multicast Services
EC-GSM – Extended Coverage GSM
eCoMP – enhanced CoMP
EDGE – Enhanced Data Rates for GSM Evolution
EFTA – Enhanced Flexible Timeslot Assignment
EGPRS – Enhanced General Packet Radio Service
eICIC – Enhanced Inter-Cell Interference Coordination
eMBMS – Enhanced Multimedia Broadcast Multicast Services
eNodeB – Evolved Node B
EAP – Extensible Authentication Protocol
eLAA – Enhanced Licensed-Assisted Access
eNB – Evolved Node B
EPC – Evolved Packet Core
EPDCCH – Enhanced Physical Downlink Control Channel
eMBB – Enhanced Mobile Broadband
ePDG – Enhanced Packet Data Gateway
EPS – Evolved Packet System
ERP – Enterprise Resource Planning
eSaMOG – Enhanced S2a-based Mobility over GTP
ESC – Environmental Sensing Capability
eSRVCC – Enhanced Single-Radio Voice Call Continuity
ETRI – Electronic and Telecommunications Research Institute
ETSI – European Telecommunications Standards Institute
E-UTRAN – Enhanced UMTS Terrestrial Radio Access Network
EVS – Enhanced Voice Services (codec)
FE-FACH – Further Enhanced Forward Access Channel
EV-DO –Evolution, Data Optimized
EV-DV –Evolution, Data Voice
EVRC – Enhanced Variable Rate Codec
FBMC – Filter-Bank Multi-Carrier
FCC – Federal Communications Commission
FDD – Frequency Division Duplex
FeCoMP – Further Enhanced Coordinated Multi Point
feICIC – Further enhanced ICIC
FirstNet – First Responder Network Authority
Flash OFDM – Fast Low-Latency Access with Seamless Handoff OFDM
FLO – Forward-Link Only
FMC – Fixed Mobile Convergence

FP7 – Seventh Framework Programme
FTP – File Transfer Protocol
GAA – General Authorized Access
GAN – Generic Access Network
GB – Gigabyte
Gbps – Gigabits Per Second
GBR – Guaranteed Bit Rate
GByte – Gigabyte
GCS – Group Communication Service
GERAN – GSM EDGE Radio Access Network
GFDM – Generalized Frequency Division Multiplexing
GGSN – Gateway GPRS Support Node
GHz — Gigahertz
GMSK – Gaussian Minimum Shift Keying
gNB – NR NodeB
GPRS – General Packet Radio Service
G-Rake – Generalized Rake Receiver
GSM – Global System for Mobile Communications
GSMA – GSM Association
HARQ – Hybrid Automatic Repeat Request
HD – High Definition
HetNet – heterogeneous network
HLR – Home Location Register
Hr – Hour
HSDPA – High Speed Downlink Packet Access
HS-FACH – High Speed Forward Access Channel
HS-PDSCH - High Speed Physical Downlink Shared Channels
HS-RACH – High Speed Reverse Access Channel
HSPA – High Speed Packet Access (HSDPA with HSUPA)
HSPA+ – HSPA Evolution
HSS – Home Subscriber Server
HSUPA – High Speed Uplink Packet Access
Hz – Hertz
ICIC – Inter-Cell Interference Coordination
ICN – Information-Centric Networking
ICS – IMS Centralized Services
ICT – Information and Communication Technologies
IEEE – Institute of Electrical and Electronic Engineers
IETF – Internet Engineering Taskforce

IFFT – Inverse Fast Fourier Transform
IFOM – IP Flow and Seamless Offload
IM – Instant Messaging
IMS – IP Multimedia Subsystem
IMT – International Mobile Telecommunications
IMT-Advanced - International Mobile Telecommunications-Advanced
IRC – Interference Rejection Combining
IoT – Internet of Things
IPR - Intellectual Property Rights
IP – Internet Protocol
IPTV – Internet Protocol Television
IR – Incremental Redundancy
ISD – Inter-site Distance
ISI – Intersymbol Interference
ISP – Internet Service Provider
ITU – International Telecommunication Union
JCP – Java Community Process
JR – Joint Reception
JT – Joint Transmission
Kbps – Kilobits Per Second
kHz — Kilohertz
km – Kilometer
LAA – License-Assisted Access
LBT – Listen-Before-Talk
LDPC - Low-Density Parity Code
LIPA – Local IP Access
LMDS – Local Multipoint Distribution Service
LPWA – Low-Power Wide-Area
LTE – Long Term Evolution
LTE-A – LTE-Advanced
LTE-TDD – LTE Time Division Duplex
LTE-U – LTE-Unlicensed
LSTI – LTE/SAE Trial Initiative
LWA – LTE Wi-Fi Aggregation
LWIP – LTE WLAN Radio Level Integration with IPsec Tunnel
M2M – Machine-to-machine
MAC – Medium-Access Control
MAPCON – Multi-Access PDN Connectivity
MB - Megabyte

MBMS - Multimedia Broadcast/Multicast Service

Mbps – Megabits Per Second

MBR – Maximum Bit Rate

MBSFN – Multicast/broadcast, Single Frequency

MCPA – Mobile Consumer Application Platform

Mcps – Megachips Per Second

MCPTT – Mission-Critical Push-to-Talk

MCS – Modulation and Coding Scheme

MCW – Multiple Codeword

MDT – Minimization of Drive Tests

MEAP – Mobile Enterprise Application Platforms

MEC – Multi-access Edge Computing

MediaFLO – Media Forward Link Only

METIS – Mobile and wireless communications Enablers for the Twenty-twenty Information Society

MHz – Megahertz

MID – Mobile Internet Devices

MIMO – Multiple Input Multiple Output

MMSE – Minimum Mean Square Error

mITF – Japan Mobile IT Forum

MMDS – Multichannel Multipoint Distribution Service

MME – Mobile Management Entity

mMTC – Massive Machine Type Communications

MOS – Mean Opinion Score

MP-QUIC – Multipath Quick UDP Internet Connections

MP-TCP – Multipath TCP

MRxD – Mobile Receive Diversity

ms – millisecond

MS – Mobile Station

MSA – Mobile Service Architecture

MSC – Mobile Switching Center

MTC – Machine Type Communications

MTC-IWF – Machine-Type Communications Interworking Function (MTC-IWF)

msec – millisecond

MU-MIMO – Multi-User MIMO

MUST – Downlink Multiuser Superposition Transmission

NAICS – Network-Assisted Interference Cancellation and Suppression

NB-IoT – Narrowband Internet of Things

NENA – National Emergency Number Association

NGMC – Next Generation Mobile Committee

NGMN – Next Generation Mobile Networks Alliance
NG-RAN – New Generation Radio Access Network
NOMA – Non-Orthogonal Multiple Access
NR – New Radio
NTIA – National Telecommunications and Information Administration
OFDM – Orthogonal Frequency Division Multiplexing
OFDMA – Orthogonal Frequency Division Multiple Access
OL-SM – Open Loop Spatial Multiplexing
OMA – Open Mobile Alliance
ORI – Open Radio Equipment Interface
PA – Priority Access
PAL – Priority Access License
PAR – Peak to Average Ratio
PBCCH – Packet Broadcast Control Channel
PCH – Paging Channel
PCRF – Policy Control and Charging Rules Function
PCS – Personal Communications Service
PDCP – Packet Data Convergence Protocol
PDN – Packet Data Network
PGW – Packet Gateway
PHY – Physical Layer
PMI – Precoding Matrix Indication
PMIPv6 – Proxy Mobile IPv6
PNF – Physical Network Function
PoC – Push-to-Talk Over Cellular
PSH – Packet Switched Handover
PSK – Phase-Shift Keying
QAM – Quadrature Amplitude Modulation
QCI – Quality of Service Class Identifier
QLIC – Quasi-Linear Interference Cancellation
QoS – Quality of Service
QPSK – Quadrature Phase Shift Keying
QUIC – Quick UDP Internet Connections.
RAB – Radio Access Bearer
RAN – Radio Access Network
RCAF – RAN Congestion Awareness Function
RCLWI - RAN Controlled LTE WLAN Interworking
RCS – Rich Communications Suite
REST – Representational State Transfer

RF – Radio Frequency
RLC – Radio Link Control
RNC – Radio Network Controller
ROHC – Robust Header Compression
RRC – Radio Resource Control
RRH – Remote Radio Head
RRU – Remote Radio Unit
RTP – Real Time Transport Protocol
RTSP – Real Time Streaming Protocol
SAE – System Architecture Evolution
SaMOG – S2a-based Mobility over GTP
SAS – Spectrum Access System
SC-FDMA – Single Carrier Frequency Division Multiple Access
SCMA – Sparse Coded Multiple Access
SCRI – Signaling Connection Release Indication
SCW – Single Codeword
SDAP – Service Data Adaptation Protocol
SDMA – Space Division Multiple Access
SDN – Software-Defined Networking
SDP – Session Description Protocol
sec – Second
SFBA – Space Frequency Block Code
SFN – Single Frequency Network
SGSN – Serving GPRS Support Node
SGW – Serving Gateway
SIC – Successive Interference Cancellation
SIM – Subscriber Identity Module
SIMO – Single Input Multiple Output
SINR – Signal to Interference Plus Noise Ratio
SIP – Session Initiation Protocol
SIPTO – Selected IP Traffic Offload
SISO – Single Input Single Output
SMS – Short Message Service
SNR – Signal to Noise Ratio
SON – Self-Organizing Network
SPS – Semi-Persistent Scheduling
SRVCC – Single-Radio Voice Call Continuity
SU-MIMO – Single User MIMO
SVDO – Simultaneous 1XRTT Voice and EV-DO Data

SVLTE – Simultaneous Voice and LTE
TCH – Traffic Channel
TCP/IP – Transmission Control Protocol/IP
TD – Transmit Diversity
TDD – Time Division Duplex
TDMA – Time Division Multiple Access
TD-SCDMA – Time Division Synchronous Code Division Multiple Access
TD-CDMA – Time Division Code Division Multiple Access
TETRA – Terrestrial Trunked Radio
TIA/EIA – Telecommunications Industry Association/Electronics Industry Association
TISPAN – Telecoms and Internet Converged Services and Protocols for Advanced Networks
TSG-RAN – Technical Services Group Radio Access Network
TTI – Transmission Time Interval
UAS – Uplink EGPRS2-A Level Scheme
UBS – Uplink EGPRS2-B Level Scheme
UE – User Equipment
UFMC – Universal Filtered Multi-Carrier
UICC – Universal Integrated Circuit Card
UL – Uplink
UMA – Unlicensed Mobile Access
UMB – Ultra Mobile Broadband
UMTS – Universal Mobile Telecommunications System
UPCON – User-Plane Congestion Management
UPF – User Plane Function
URA-PCH – UTRAN Registration Area Paging Channel
URI – Uniform Resource Identifier
URLLC – Ultra-Reliable and Low Latency Communications
us – Microsecond
USIM – UICC SIM
UTRAN – UMTS Terrestrial Radio Access Network
V2X – vehicle -to-infrastructure
VAMOS – Voice Services over Adaptive Multi-User Channels on One Slot
VDSL – Very-High-Bit-Rate DSL
VEPC – Virtualized EPC
ViLTE – Video Over LTE
VoIP – Voice over Internet Protocol
VoHSPA – Voice over HSPA
VoLGA – Voice over LTE Generic Access
VoLTE – Voice over LTE

VNF- Virtual Network Function
VPN – Virtual Private Network
WAP – Wireless Application Protocol
WBA – Wireless Broadband Alliance
WCDMA – Wideband Code Division Multiple Access
WCS – Wireless Communication Service
WebRTC – Web Real-Time Communication
Wi-Fi – Wireless Fidelity
WiMAX – Worldwide Interoperability for Microwave Access
WLAN – Wireless Local Area Network
WMAN – Wireless Metropolitan Area Network
WMM – Wi-Fi Multimedia
WRC – World Radiocommunication Conference

Additional Information

5G Americas maintains market information, LTE deployment lists, and numerous white papers, available for free download on its web site: http://www.5gamericas.org.

If there are any questions regarding the download of this information, please call +1 425 372 8922 or e-mail Anushka Bishen, Public Relations Coordinator at info@5gamericas.org.

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Robert P. Duncan A.B., S.M., M.B.A., Ph.D.: Government warfare and surveillance system architect, author, and independent investigator..

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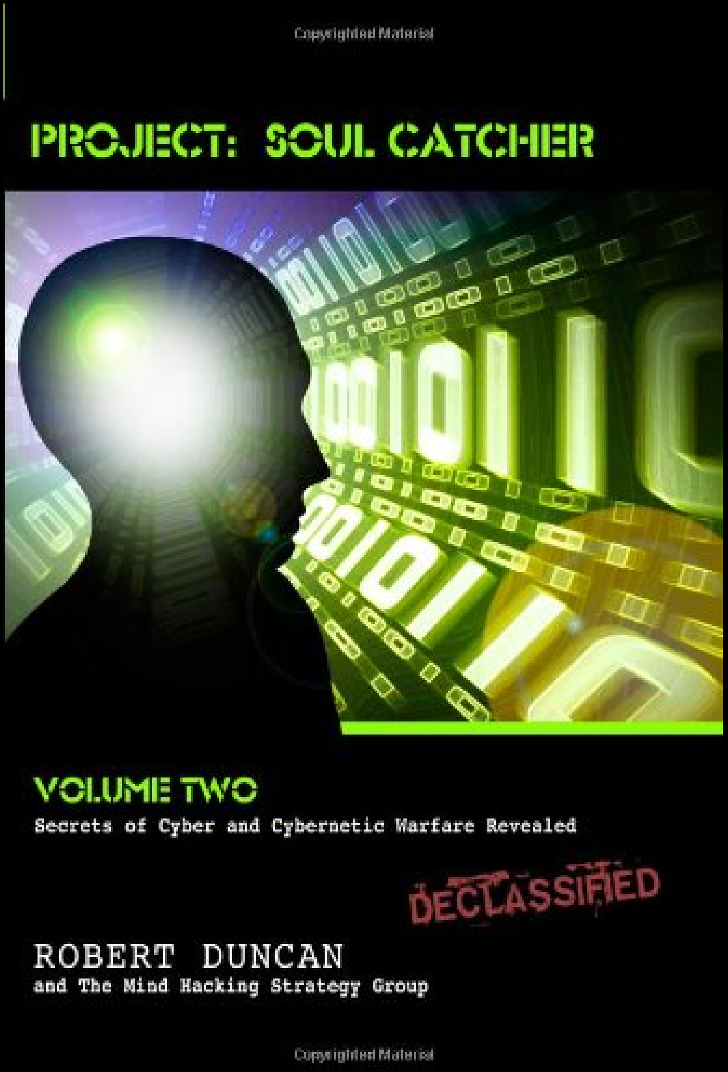
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More information on Dr. Robert Duncan is available at drrobertduncan.com.

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Bio of Dr. Robert Duncan, from his book The Matrix Deciphered:

"True nobility is exempt from fear".
– King Henry the Sixth, Part II (Act IV, Scene I).

> Call me The Saint. I am the all American - prep school, Harvard College graduating with honors in computer science and a minor in premedical studies, and advanced degrees from Harvard and Dartmouth in business and science. My famous ancestors are President Lincoln, King Duncan of Scotland, and Governor William Bradford, the first governor of Massachusetts.
>
> My research interests have been neural networks, virtual reality, and EEG controlled robotics. Before graduate school I worked for the Department of Defense, Navy, NATO, and various intelligence agencies computer science projects. I have done business consulting and computer consulting for the largest companies in the world. I have been a professor, inventor, artist, and writer. I am one of the last Renaissance men.
>
> My projects have included algorithms for Echelon and CIA natural language parsing and classification of document content, IRS formula for red flagging audits, writing the artificial intelligence code to automate tracking of the Soviet Nuclear Submarine Fleet and all water vessels, work integrating HAARP with SIGINT SIGCOM and SPAWAR. I have worked on projects for the Justice Department connecting local, state, and federal databases for the tracking of terrorists. I developed a system for the FBI to track license plates past toll booths and other locations. I worked on the soldier 2000 program to create body networks for reading vital signs and other information. A system I worked on called Snyper is operational in Iraq which triangulates on intercity conflict gun shots. I have been to a couple secret bases in the so called free world. I have developed telemedicine robotic surgery and virtual reality applications for the Army. For DARPA, I have worked on satellite computer vision target tracking applications and tank simulation as well as integration of the land, sea, and air surveillance systems like SOSSUS, towed arrays, and others.
>
> Projects that I have worked on outside of government contracts include my thesis on computer generated holography, a project making paralyzed people walk again using choreographed stimulated muscles movements, face recognition, voice identification and recognition, finger print recognition, and neural network robotic controller. My research interests moved to enhanced reality heads up displays and wearable computing systems. My current research involves finding a cure for the mind control directed energy weapons fiasco. The integrated global surveillance grid is actually part of the holy grail of weapons and human control systems.
>
> My apologies to the human race for my contribution to tyranny. I was tricked into thinking it would not be misused by corrupt government especially in my beloved country. I was wrong. The Joint Non-Lethal Weapons Directorate has Skip Green on the governing board. One of my old colleagues at a technology think tank in Cambridge partly in charge of the radio frequency weapons testing for neurological disruption now torturing and killing people worldwide. Several other US Navy and UK Navy scientists have been knocked-off and that is why I have come forward. I know my time maybe near. I am currently a professor in computer science and business, helping to educate the public on government corruption, greed, and stupidity. Like my ancestor Lincoln, I am fighting against mental slavery in a new Civil War engineered by the same useless elements in over 80 government agencies who have tested radiological, drug, and viral weapons on unsuspecting Americans for over 45 years.
>
> I have great pride in the fundamental and constitutional values of America and mean no disrespect by my blasting the incompetence, apathy, and stupidity of those involved in the conspiracy of involuntary biological, chemical, and psychotronic human effects testing. There are so many brave men and women serving in the armed forces who fight and protect us for the American values they believe in. But because of the silos of information called compartmentalization in the security agencies and the lack of accountability and oversight of black operations and some top secret projects, diabolical elements become rogue or worse destroying the very country they are tasked with protecting turning it into a hypocracy rather than a democracy.
>
> My goal is to awaken Americans to the continued horrific acts of military and CIA weapons testers in this country and the other branches of government’s inability to stop them and hold them accountable.
>
> All I ask from the reader is to listen to testimony and validate facts presented here and come to their own conclusion. Then fight to win back America from this silent overthrow. This has been my project for about two years, investigating government corruption, incompetence, and cover-up upon which I accidentally stumbled one day while looking at a reverse MRI scheme to inject electromagnetic signals into the brain for virtual reality applications. I have interviewed over two hundred people and worked on the highest level of military projects for the U.S., NATO, and U.K. and have given videotaped testimony to senators and representatives on this topic resulting in lip service since they have no real power to enforce. Two high level FBI agents and a couple CIA agents have come forward to validate the existence of a MKULTRA like project that continues to grab random people for mind control experimentation. Two of these have since become part of the program and endure daily psychotronic tortures. All the torture can be done using directed energy psychotronic weapons with the so called continental ballistic missile surveillance defense grids.
>
> I apologize to the human race for any contribution to these 4th generation weapons that I may have worked on that are more horrific than the nuclear bomb and whose cover-up is more pervasive than the Manhattan Project. And because of the horrific acts of violence being committed on as many as two thousand Americans as far as my research has uncovered and many others in other countries, I understand the extreme risk to my own welfare that publishing this material will have. But freedom is so important to me that I know full heartedly that the human race

must have an open discussion on these weapons to decide their own fate before the point of decision is gone, that I am willing to risk divulging so called national secrets. All I offer you is the truth.

All information presented in this book was received through legitimate channels such as the Freedom of Information Act, military documents, victim testimony, and turned agents. I still hold valid the oath I took to keep secret the details of the projects that I worked on under DoD budgets. The majority of the proceeds of this book will go towards helping the psychotronic experiment survivors and surviving families of those that have perished. When the government fails, business and the citizens must look out for each other.

Dr. Robert Duncan in Energy Weapons & Testing, Coast to Coast AM broadcast December 5th 2006 (2.75+ million listeners weekly, syndicated in most cities and areas of the United States, and other places around the world.)..

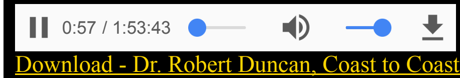

Download - Dr. Robert Duncan, Coast to Coast AM interview - Energy Weapons & Testing.

Energy Weapons & Testing synopsis:

Independent investigator Robert Duncan discussed directed energy and neurological weapons and his contention that they've been tested on the public at large. While directed energy is used in microwaves, to remove kidney stones, and in non-invasive surgery, it's also been developed extensively for military purposes, he reported.

The civilian population was targeted for experiments, in programs such as MK-ULTRA, starting after WW II, when Nazi scientists were imported to the US, some working on scalar or gravity weapons, said Duncan. The town of Taos, NM, where a hum was heard by many citizens, was the subject of a directed energy experiment by the U.S. Navy, he claimed. And most recently the Active Denial System (see article below) was tested on human subjects.

Duncan said he interviewed over 600 mind control victims (Dec 5th 2006 report), and found some validity to their allegations. There are weapons that can project voices into people's heads such as one system known as "The Voice of God," he detailed. Blocking techniques include jamming the signals with electronic scramblers, and using shields with metal alloys or mylar. He recommended the following websites for further information/assistance: mindjustice.org, raven1.net, freedomfchs.com.

The Goodbye Weapon

A new non-lethal weapon, the Air Force's Active Denial System, or ADS, has been certified for use in Iraq, after extensive testing. The ADS shoots a beam of waves that causes extreme (but temporary) pain and induces what experimenters call the "Goodbye effect," or "prompt and highly motivated escape behavior." Wired News obtained documents about the weapon and has published two reports (article(1)/documentation(2)). Additionally, the report's author David Hambling has posted a commentary(3) on the subject at Defense Tech.

1. http://www.wired.com/news/technology/0,72134-0.html
2. http://www.wired.com/news/technology/0,72236-0.html
3. http://www.defensetech.org/archives/003036.html

Coast to Coast AM guest bio:

Dr. Robert Duncan holds multiple degrees from Harvard University and Dartmouth College amongst others. He has had the most expensive American education money can buy. He is an investigator, author, and soon be movie producer on the topics of directed energy, neurological weapons, psychological, and information warfare. His movie is called "The Enemy Within - Psychic Warfare". A book he is co-authoring will be out in a few months called "Hacking the Human Mind".

Dr. Duncan has worked as a business and information technology consultant to the Fortune 500. He has worked for companies like Oracle Corporation, BEA systems, HP, BBN, and as a professor at a college. For the department of defense he has written the artificial intelligence code to track the Soviet nuclear submarine fleet with passive and active acoustical arrays and has been to a couple secret NATA Navy underground bases in Europe.

-Todd Giffen
Target since birth as I was born into American enslavement, surveillance, and control, under attack with directed energy since 2008
503-967-5202
case@oregonstatehospital.net
obamasweapon.com

Copyright © 2015 Todd Giffen

"The Use of Psychotronic Weapons"
"What everyone should know"

(courtesy : http://www.mindjustice.org/cherkova.htm)

Definition:

Definition of psychotronic (psycho-physical) weapons.

Psychotronic Weapons (PF- weapons) this is the totality of all possible methods and means (technogenic, suggestive, pharmacological, paranormal, complexes, and others) of hidden, forced influences on the psyche of a person for the purpose of modifying his consciousness, behavior and health for what is desired in the way of influencing aspects of control..."

Second definition of psychotronic weapons (as an epigraph): "Applications in military and for antisocial purposes are possibilities also for knowledge of psychotronics, its means, methods, systems, 'generators', and there is the path for the transformation of the humanitarian, essential attributes of life and society in the weapons. These are also psychotronic weapons. This is not only dangerous, this is deadly!"

Types of Weapons:

- Electromagnetic Weapons
- Microwave Weapons
- Non-Lethal Weapons
- ELF (Extremely Low Frequency) Weapons
- Directed Energy Weapons
- Acoustic Weapons
- Psychotronic Weapons
- RF (Radio Frequency) Weapons
- Soft Kill Weapons
- Less-Than-Lethal Weapons

How it affects (Physical & psycho-physical damages):

Physical damage, visible results achieved at the moment of influence.

* burns, pricks, cuts, wounds (ray weapons, laser)
* bleeding into the brain (laser ray with energy pulses of 40 joules) and on the skin energy in pulses: 3 - 100 joules)
* Blindness in the eyes, loping of eyelashes (laser ray)
* loss of memory (influence of frequency of up to 100Hz. and a reduction to 5 Hz.)
* destruction of the vestibulary [inner ear] apparatus, spatial orientation
* symptoms of [***] [with a large exposure and strength, paralysis (UBCh) in the area of the beginning of the spinal column
* irregular sleeping, heart-beating
* numbness of the hands; at night, cramping of the legs
* sharp decrease in hemoglobin, micro-burns to the skin, ionization of the blood and body fluids, an increase in the deterioration rate of clothing material, photographic material [illuminating], (thermal-electronic emissions from lamps in the room with the feeding units of electrical networks and fittings of the wall, [...]
* vibrations (separate organs can vibrate: the heart, kidneys, etc.), [...] (from

* vibrational technologies)
* pressure, coolness of the skin
* feelings of non-specific fear and panic (from the weapons) [...] tremors, tapping, destruction of fragile objects from the waves, from the impulses and from other manifestations of technological poltergeist

Psycho-physical damage depending on intensity and duration of effects. Damage in the physical sphere (up to programmed premature death).

Stage I.

* changes in the blood (early signs)
* overheating substances especially and increase in crystallization, leading to cataracts (early sign)
* ill reactions along the path of the bio-energetic potential from the effects [...]
* prickly sensations, tremors to the muscles of the feet
* aggravation of chronic illnesses
* internal bleeding (nose, stomach, gynecological)
* auditory tones of various frequencies
* sharp pain in the internal ear
* dull pains in the area behind the ears
* internal trembling, vibrations
* head pain in the temple and a warmness in that area, pain in the eye-sockets
* likelihood of miscarriage, an increase of 80% for chances of premature births, anomalous
* development of the fetus, often with defective brains

Stage II.

* "radio-sound" effect (before this is long-conducted the resonance-loosening of spinal and brain fluids at the frequency of 2-10 Hz. for maintaining the fluids of theskull and brain in stimulation
* steady reactions to all aspects of coding
* lowering of energy (observed with irradiation at the frequency carrying frequencies of ~780 Hz.and amplitude modulation ~71 Hz.)
* aggravation of dermatosis
* eye pains (cataracts, asymmetry in lenses of the eyes, puffiness [?] of the retinas)
* aggravation of the course of chronic illnesses
* destruction of the functions of the kidneys, liver, organs of digestion, circulatory system, bleeding in gingivae, gums, peridontal and others
* gauntness
* "sand" in the eyes, burning sensation, loss of hair, brittleness of nails
* compression pain in the heart fits of coughing
* changes of the color of the face (bronze shading of the skin)
* asymmetrical puffiness of the face
* disfiguration of the face, the intentional emaciation of separate muscles, cartilage
* syndromes of destruction to the external nerves of the thighs
* impotence

Stage III.

* destruction of the brain, irreversible changes to the structure of the brain (academician V.P. Vekhtereva)

* irreversible processes in the muscle material, in the bones of the skull, and in the structures of neurons "..minimalization of life" --external reaction to EMP appears as an illness, up to heavy, sharp, chronic, organic pathological processes (academician V.P. Kaznacheev)
* "..the entire speeding up of the aging process, sclerosis, oncogenesis (academician V.P. Kaznacheev)
* destruction of bio-chemical processes in the cells with distrophic changes in the organs (academician V.P. Kaznacheev)
* destruction of the cell membranes, chemical connections in the cells -leading to leukemia, cancer of the brain and prostate gland, breast cancer, (even with weak EMP, but of long duration "...the genetic apparatus is altered..." (academician V.P. Kaznacheev)
* the reflex activities are destroyed
* the functioning of the hormonal system is destroyed
* [....] Parkinson's disease (trembling of the hands) and Alzheimer's disease (from changes in the production of the hormone melanin ([...] gland) that causes degenerative changes in substances at the molecular level disfunctions of the sino-atrial node of the heart (even with a low frequency)
* infarction, cerebral thrombosis, osteo-[***], peridontal, sugar diabetes
* allergies
* epilepsy (especially caused by the multiple-rapid stimulation by a weak, low frequency waves)
* hypertension, hypotension
* programmed or instantaneous (with the subjection to extreme effects -up to the border of deadly conditions) premature death --it is well known by the experimentors that cases of death do occur (academician V.P. Kaznacheev)
* a decrease and dying off of the population, humanity, mankind

Damage in the mental sphere (up to the point of insanity).
Stage I.

* manifestations of depression
* lowering in the interest in perceived information
* shortness of temper (irritability)

Stage II.

* steady depression
* lowering of abilities for analytical thinking, some worsening of the memory
* symptoms of chronic fatigue
* superficial nature of sleep
* higher incidents of conflicts

Stage III.

* confusion in the accounting of events in real life
* loss of ability for analytical thinking
* lowering and a loss of memory
* feelings of the lack of sleep
* indifference to personal external appearance [...]
* lowering of self-control from the deficit of the hormone seratonin due to SVCh irradiation
* suicide (as the experimentors "practice" provocation techniques)
* "...invisible weak fields ...their ignoring that they are carrying with them a deadly danger"... "...people simply start going crazy and nobody understands why..." (academician V.P. Kaznacheev)

"Consequences of effects of micro-leptonic generators are described by the leading developer in this area [from the] V. Lab. of Micro-leptonic Technologies D. Okhatryym: in 1982 there began extremely unpleasant things with the health our co-workers. At first, there arose their feeling unwell, then the loss of logic, then after this, the loss of spatial orientation. Finally, a breakdown of diseased [affected] organs. The coming out of this condition -and this includes myself -was achieved with great difficulty."

(in the book by Ju. Vorob'evskii" Knock at the Golden Gate, Moscow, 1999.

Manipulation with the memory.

* Erasure
* Blockage
* Recording of information needed by the experimentor
* training -"prompting" (after erasure)
* comparison,
* reproduction of picture a from a prior testing as though bifurcated [?]
* a shifting of the effective frequency up to 100 Hz. or a lowering to 5 Hz., with memory loss

Control of Stimulation in the brain.

* by states of consciousness (up to the loss of these)
* in sleep
* emotions
* intellectual capabilities
* attention
* speech
* activeness
* muscle tone
* stimulation of one and the same zone with stimulations of:
o 30 -40 mV- activization of attention, memory, movement;
o 60-70 mV- "emotiono-genic" effects

Different methods:

Types of Psychotronic, psychotropic and other Psy-Influences.

* radio-waves
* laser-irradiation
* infra-red irradiation
* ultra-violet irradiation UF
* x-ray irradiation
* gravitational fields
* torsional fields (hypothetical)
* leptonic and other fields

Acoustic Waves.

* infra-sonic (IZ) from 0 Hz. to 15-20 KHz.
* ultra-sonic(UZ) from 15-20 KHz. to 10**9 Hz. (ranges for IZ and UZ)

see more similar information in -Table 3

Formation of fields:

* electro-magnetic charge
* gravitational-mass
* torsional (surrounding spin fields) -spin, with any rotating body
* micro-leptonic energy (in free aspect) -[over-abundance of stable particles]?

Operator is secretly brought in, or in a secret installation nearby

BG: Biogenerator (could be tomography)
A: Antenna (irradiation and reception)
D: operator for the gathering of information, transmission and control
ZU: reminding sytem on a magnetic strip, holographic
BIP: bio-informational [...]
KC: channel connections (IK, radio, telephone, telegraph)
E: screen display
O: operator
SP: light pen with which the operator indicates on the screen, the point of influence

Stress systems and methods of harassment.

* slander
* gestures, hand movements, expressions, tests, practical "jokes"
* taking off what is needed for the eyes (vision) [?]
* psychological pressure through family, neighbors or surrounding people, vehicle drivers
* discrediting: along 5 directions (often with the involvement of the police)
o irresponsibility
o spy
o drug dealer
o vagrant
o accomplice in a crime (in an alleged crime)
* torture, assault
* blackmail, threats
* attempts on their lives with PTOs
* death to someone close or in immediate surrounding life
* murder

Stages of Zombification (Substitution of consciousness with external control).

* programming, modeling of a cybernetic double
* conducting of programs according to non-differentiation of a proper and artificial "I"-"Not-I"
* extreme influencing, stress, harassment, irradiation, special-preparations [substances], chemicals
* taking to the limits of mental and physical capacities (survivability)
* loss of will, memory
* shutting off of his own consciousness
* replacement of consciousness with the control from his cybernetic twin

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Pentagon Studies Weapons That Can Read Users' Mind

By SYDNEY J. FREEDBERG JR.
on July 14, 2017 at 3:15 PM
15 Comments

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NEWSEUM: The troops of tomorrow may be able to pull the trigger using only their minds. As artificially intelligent drones, hacking, jamming, and missiles accelerate the pace of combat, some of the military's leading scientists are studying how mere humans can keep up with the incredible speed of cyber warfare, missiles and other threats.

One option: Bypass crude physical controls — triggers, throttles, keyboards — and plug the computer directly into the human brain. In one DARPA experiment, a quadriplegic first controlled an artificial limb and then flew a flight simulator. Future systems might monitor the users' nervous system and compensate for stress, fatigue, or injury. Is this the path to what the Pentagon calls human-machine teaming?

This is an unnerving scenario for those humans, like Stephen Hawking, who mistrust artificial intelligence. If your nightmare scenario is robots getting out of control, "let's teach them to read our minds!" is probably *not* your preferred solution. It sounds more like the beginning of a movie where cyborg Arnold Schwarzenegger goes back in time to kill someone.

Navy X-47B drone.

But the Pentagon officials who talked up this research yesterday at Defense One's annual tech conference emphasized the objective was to *improve* human control over artificial intelligence. Teaching AI to monitor its user's level of stress, exhaustion, distraction, and so on helps the machine adapt itself to better serve the human — instead of the other way around. Teaching AI to instantly detect its user's *intention* to give a command, instead of requiring a relatively laborious push of a button, helps the human keep control — instead of having to let the AI off the leash because no human can keep up with it.

Official Defense Department policy, as then-Secretary Ash Carter put it, is that the US will "never" allow an artificial intelligence to decide for itself whether or not to kill a human being. However, no less a figure than the Carter's undersecretary of acquisition and technology, Frank Kendall, fretted publicly that making our robots wait for human permission would slow them down so much that enemy AI without such constraints would beat us. Vice-Chairman of the Joint Chiefs, Gen. Paul Selva, calls this the "Terminator Conundrum." Neuroscience suggests a way out of this dilemma: Instead of slowing the AIs down, make the humans' orders come faster.

DARPA's Revolutionizing Prosthetics program is devising new kinds of artificial limbs — and new ways to control them.

Accelerate Humanity

"We will continue to have humans on the loop, we will have human input in decisions, but the way we go about that is going to have to shift, just to cope with the speed and the capabilities that autonomous systems bring," said Dr. James Christensen, portfolio manager at the Air Force Research Laboratory's 711th Human Performance Wing. "The decision cycle with these systems is going to be so fast that they have to be sensitive to and responsive to the state of the individual (operator's) *intent*, as much as overt actions and control inputs that human's providing."

In other words, instead of the weapon system responding to the human operator *physically* touching a control, have it respond to the human's brain cells forming the *intention* to use a control. "When you start to have a direct neural interface of this type, you don't necessarily need to command and control the aircraft using the stick," said Justin Sanchez, director of DARPA's Biological Technologies Office. "You could potentially re-map your neural signatures onto the different control surfaces" — the tail, the flaps — "or maybe any other part of the aircraft" — say landing gear or weapons. "That part hasn't really been explored in a huge amount of depth yet."

Reading minds, even in this limited fashion, will require deep understanding and close monitoring of the brain, where thoughts take measurable form as electrical impulses running from neuron to neuron. "Can we develop precise neurotechnologies that can go to those circuits in the brain or the peripheral nervous system in real time?" Sanchez asked aloud. "Do we have computational systems that allow us to understand what the changes in those signals (mean)? And can we give meaningful feedback, either to the person or to the machine to help them to do their job better?"

DARPA's Revolutionizing Prosthetics program hooked up the brain of a quadriplegic — someone who could move neither arms nor legs — to a prosthetic arm, allowing the patient to control it directly with their thoughts. Then, "they said, 'I'd like to try to fly an airplane,'" Sanchez recounted. "So we created a virtual flight simulator for this person, allowed this neural interface to interface with the virtual aircraft, and that person flew."

"That was a real wake-up call for everybody involved," Sanchez said. "We didn't initially think you could do that."

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Tony Stark (Robert Downey Jr.) relies on the JARVIS artificial intelligence — exquisitely adapted to his personal strengths and weaknesses — to help pilot his Iron Man suit. (Marvel Comics/Paramount Pictures)

Adapting To The Human

Applying direct neural control to real aircraft — or tanks, or ships, or network cybersecurity systems — will require a fundamental change in design philosophy. Today, said Christensen, we give the pilots tremendous information on the aircraft, then expect them to adapt to it. In the future, we could give the aircraft tremendous information on its pilots, then have it use artificial intelligence to adapt itself to *them*. The AI could customize the displays, the controls, even the mix of tasks it took on versus those it left up to the humans — all exquisitely tailored not just to the preferences of the individual operator but to his or her current mental and physical state.

When we build planes today, "they're incredible sensor platforms that collect data on the world around them and on the aircraft systems themselves, (but) at this point, very little data is being collected on the pilot," Christensen said. "The opportunity there with the technology we're trying to build now is to provide a continuous monitoring and assessment capability so that the aircraft knows the state of that individual. Are they awake, alert, conscious, fully capable of performing their role as part of this man-machine system? Are there things that the aircraft then can do? Can it unload gees (i.e. reduce g-forces)? Can it reduce the strain on the pilot?"

Air Force MQ-9 Reaper operators in training. Today's drones require extensive human oversight and are hardly user friendly.

"This kind of ability to sense and understand to the state and the capabilities of the human is absolutely critical to the successful employment of highly automated systems," Christensen said. "The way all of our systems are architected right now, they're fixed, they're predictable, they're deterministic" — that is, any given input always produces the exact same output.

Predictability has its advantages: "We can train to that, they behave in very consistent ways, it's easier to test and evaluate," Christensen said. "What we lose in that, though is the real power of highly automated systems, autonomous systems, as *learning systems*, of being able to adapt themselves. "

"That adaptation, though, it creates unpredictability," he continued. "So the human has to adapt alongside the system, and in order to do that, there has to be some mutual awareness, right, so the human has to understand what is the system doing, what is it trying to do, why is that happening; and vice versa, the system has to has some understanding of the human's intent and also their state and capabilities."

This kind of synergy between human and artificial intelligence is what some theorists refer to as the "centaur," after the mythical creature that combined human and horse — with the human part firmly in control, but benefiting from the beast's strength and speed. The centaur concept, in turn, lies at the heart of the Pentagon's ideas of human-machine teaming and what's known as the Third Offset, which seeks to counter (offset) adversaries' advancing technology with revolutionary uses of AI.

The neuroscience here is in its infancy. But it holds the promise of a happy medium between hamstringing our robots with too-close control or letting them run rampant.

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Topics: AFRL, air force, Air Force Research Laboratory AFRL, artificial intelligence, darpa, DefenseOne Tech Summit 2017, James Christensen, Justin Sanchez, neuroscience, offset strategy, War Algorithm

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Internet of Things (IoT) in 5G Wireless Communications

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GUEST EDITORIAL

Internet of Things (IoT) in 5G Wireless Communications

During the past decade, the Internet of Things (IoT) has revolutionized the ubiquitous computing with multitude of applications built around various types of sensors. A vast amount of activity is seen in IoT based product-lines and this activity is expected to grow in years to come with projections as high as billions of devices with on average 6-7 devices per person by year 2020. With most of the issues at device and protocol levels solved during the past decade, there is now a growing trend in integration of sensors and sensor based systems with cyber physical systems and device-to-device (D2D) communications. 5th generation wireless systems (5G) are on the horizon and IoT is taking the center stage as devices are expected to form a major portion of this 5G network paradigm. IoT technologies such as machine to machine communication complemented with intelligent data analytics are expected to drastically change landscape of various industries. The emergence of cloud computing and its extension to fog paradigm with proliferation of intelligent 'smart' devices is expected to lead further innovation in IoT. These developments excite us and form a motivation to survey existing work, design new techniques, and identify new applications of IoT. Researchers, scientists, and engineers face emerging challenges in designing IoT based systems that can efficiently be integrated with the 5G wireless communications.

We received enthusiastic response to our special issue call for papers. A total of nine high quality papers were received out of which only seven were selected after a thorough review process. Invited articles were sought from two highly cited and accomplished researchers. Dr. Mischa Dohler (Fellow IEEE, Kings College London, UK) and Dr. Mung Chiang (Fellow IEEE, Princeton University, USA).

The first article ''MIMO-NOMA design for small packet transmission in the Internet of Things'', written by a collaborative team of researchers Ding et al.,, opportunistic serving mechanism is designed as part of the effort in the novel paradigm of Multiple Input Multiple Output Non-Orthogonal Multiple Access transmission scheme. Under the proposed method, one user is completely served with their quality of service requirements completely taken care of whereas second user is served opportunistically under the NOMA paradigm. The main contribution of this article is a design with two sets of system parameters, precoding and power allocation coefficients, in order to ensure that the potential of NOMA can be realized even if the users' channel conditions are similar. Two types of power allocation policies are developed in this paper. One is to meet first user's QoS requirements in the long term. For example, in order to satisfy its targeted outage probability. The other is in which to realize second user's QoS requirements instantaneously, e.g., the power allocation coefficients are designed to realize its targeted data rate for each channel realization.

Machine to machine communication has a significant role to play in emerging internet of things paradigm in years and decades to come. The emerging IoT-5G scenario extends sensor based IoT capabilities to robots, actuators and drones for distributed coordination and low-latency reliable execution of tasks at hand. In the invited work titled ''Enabling the IoT machine age with 5G: Machine-type multicast services for innovative real-time applications'' by Condoluci et al., core attention is focused on the end-to-end reliability, latency, and energy consumption comprising both up and downlinks for 5G-IoT communication. The authors propose the definition, design, and analysis of machine-type multicast service (MTMS). They recommend different procedures that need to be redesigned for MTMS and derive the most appropriate design drivers by analyzing different performance indicators, such as scalability, reliability, latency, and energy consumption. Overall, a very interesting read complemented by open problems and future research directions to pursue.

Security is one of the biggest challenges faced by Internet of Things. With devices becoming ubiquitous and pervasive in day to day lives necessitate reliable and secure algorithms. The third article, ''Security enhancement for IoT communications exposed to eavesdroppers with uncertain locations'' by Xu et al., develops a secure framework for eavesdroppers with Uncertain Locations in IoT. With the assumption that the locations of eavesdroppers change independently from hop to hop, authors derive an expression for the secrecy outage probability of the two-hop transmission, which is shown to be the upper bound of the outage probability when the locations of eavesdroppers remain unchanged. Following this expression, the end users formulate a secrecy rate maximization problem with the secrecy-outage probability constraint. The optimal rate design for codebooks and power allocation between the source and relay are derived. By studying the performance of the optimal scheme in some special cases, we obtain several insights concerning the setting of system parameters.

In the article, ''Enabling massive IoT in 5G and beyond systems: PHY radio frame design considerations'' by Ayesha Ijaz et al., the authors propose a flexible frame structure and design for massive Internet of Things (IoT) devices working in 5G wireless network. The authors also discussed

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the interdependence of different frame design parameters, service requirements and characteristics of radio environment. Based on these interdependency, they provide guidelines for radio numerology design and elaborated on the frame design for IoT communications in 5G networks to support massive connection density of low-rate, low-power devices. The article concludes with some key research findings and challenges massive IoT in 5G wireless network.

It is estimated that in year 2020, 20 to 40 billion devices will be connected to the Internet as part of the Internet of Things. A critical bottleneck for realizing the efficient IoT is the pressure it puts on the existing communication infrastructures, requiring transfer of enormous data volumes. In the article ''CONDENSE: A reconfigurable knowledge acquisition architecture for future 5G IoT'', by Dejan Vukobratovic et al., the authors propose a architecture named 'Condense' which integrates the acquisition of IoT-generated data within the 3GPP MTC (machine type communications) systems. The proposed Condense architecture introduces a service within 3GPP MTC systems – computing linear and non-linear functions over the data generated by MTC devices This service brings about the possibility that the underlying communication infrastructure communicates only the desired function of the MTC- generated data (as required by the given application at hand), and not the raw data in its entirety. This transformational approach has the potential to dramatically reduce the pressure on the 3GPP MTC communication infrastructure. The article concludes by discussing challenges, provides insights, and identifies future research directions for implementing function computation and function decomposition within practical 3GPP MTC systems.

In the article, ''Frequency-domain oversampling for cognitive CDMA systems: Enabling robust and massive multiple access for Internet of Things'' by Su Hu et al., the authors utilize the concept of cognitive radio with dynamic non-continuous spectrum bands and code division multiple access to tackle the challenge of massive spectrum resource management in IoT. In order to suppress multiple access interference resulting from the non-orthogonality of partial available spectrum bins, carrier frequency offset, and spectrum sensing mismatch, the authors propose an enhanced receiver design that combines the frequency-domain oversampling scheme (FDO) and linear minimum mean square error (MMSE) method. The simulation results show that the cognitive-CDMA with FDO-MMSE receiver outperforms that with conventional per-user MMSE receiver in the presence of multipath fading channels, carrier frequency offset, and spectrum sensing mismatch.

In the invited article, ''A survey of client-controlled HetNets for 5G'' by Michael Wang et al., a comprehensive review is provided on spectrum of client-controlled HetNets for 5G networks: from the fully devolved distributed local control approach to the hybrid control approach where clients may make the decisions given some global information provided by the network. After giving a thorough review, the authors also provide future research directions and recommendations for evolution of 5G heterogeneous networks as an enabler for next generation internet of things.

To conclude, the Editors would like to thank all authors who submitted their manuscripts against this Special issue. There had been some very exciting submissions though we could only accept best seven high quality submissions. The editorial staff also thanks the reviewers for their timely comments on the manuscript which helped us improve the presentation and quality of the content manifold. All the associate editors thank the Editor in Chief Dr. Michael Pecht for his assistance in making this special issue a reality. We would also like to thank the publications editor Ms. Kimberly Shumard for her continuous follow up on timelines and management of articles to ensure timely completion of the review process. We complete this note by letting the readers know to stay tuned with IEEE Access as we expect even more exciting issues in months to come.

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5G RADIO ACCESS

CAPABILITIES AND TECHNOLOGIES

The capabilities of 5G wireless access must extend far beyond previous generations of mobile communication. Examples of these capabilities include very high data rates, very low latency, ultra-high reliability, energy efficiency and extreme device densities, and will be realized by the development of LTE in combination with new radio-access technologies. Key technology components include extension to higher frequency bands, access/backhaul integration, device-to-device communication, flexible duplex, flexible spectrum usage, multi-antenna transmission, ultra-lean design, and user/control separation.

WHAT IS 5G?

5G radio access technology will be a key component of the Networked Society. It will address high traffic growth and increasing demand for high-bandwidth connectivity. It will also support massive numbers of connected devices and meet the real-time, high-reliability communication needs of mission-critical applications.

5G will provide wireless connectivity for a wide range of new applications and use cases, including wearables, smart homes, traffic safety/control, critical infrastructure, industry processes and very-high-speed media delivery. As a result, it will also accelerate the development of the Internet of Things.

The overall aim of 5G is to provide ubiquitous connectivity for any kind of device and any kind of application that may benefit from being connected.

5G networks will not be based on one specific radio-access technology. Rather, 5G is a portfolio of access and connectivity solutions addressing the demands and requirements of mobile communication beyond 2020.

The specification of 5G will include the development of a new flexible air interface, NX, which will be directed to extreme mobile broadband deployments. NX will also target high-bandwidth and high-traffic-usage scenarios, as well as new scenarios that involve mission-critical and real-time communications with extreme requirements in terms of latency and reliability.

In parallel, the development of Narrow-Band IoT (NB-IoT) in 3GPP is expected to support massive machine connectivity in wide area applications. NB-IoT will most likely be deployed in bands below 2GHz and will provide high capacity and deep coverage for enormous numbers of connected devices.

Ensuring interoperability with past generations of mobile communications has been a key principle of the ICT industry since the development of GSM and later wireless technologies within the 3GPP family of standards. In a similar manner, LTE will evolve in a way that recognizes its role in providing excellent coverage for mobile users, and 5G networks will incorporate LTE access (based on Orthogonal Frequency Division Multiplexing (OFDM)) along with new air interfaces in a transparent manner toward both the service layer and users.

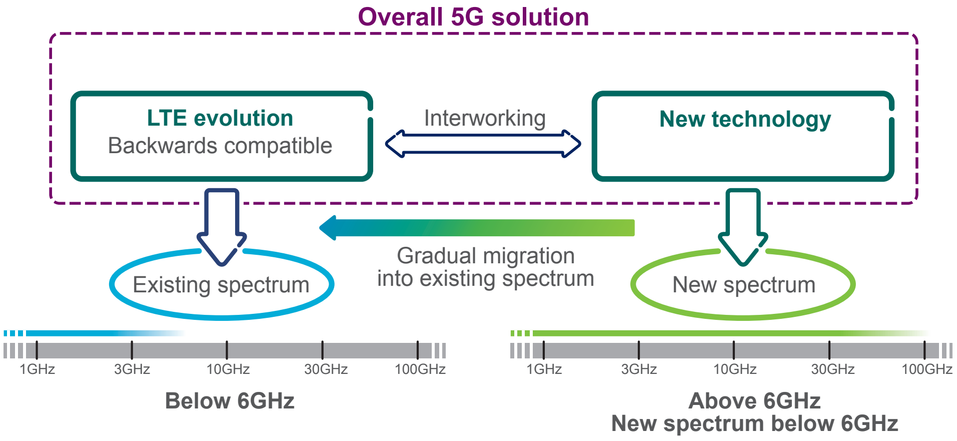

Figure 1: The overall 5G wireless-access solution consisting of LTE evolution and new technology.

Around 2020, much of the available wireless coverage will continue to be provided by LTE, and it is important that operators with deployed 4G networks have the opportunity to transition some – or all – of their spectrum to newer wireless access technologies. For operators with limited spectrum resources, the possibility of introducing 5G capabilities in an interoperable way – thereby allowing legacy devices to continue to be served on a compatible carrier – is highly beneficial and, in some cases, even vital.

At the same time, the evolution of LTE to a point where it is a full member of the 5G family of air interfaces is essential, especially since initial deployment of new air interfaces may not operate in the same bands. The 5G network will enable dual-connectivity between LTE operating within bands below 6GHz and the NX air interface in bands within the range 6GHz to100GHz. NX should also allow for user-plane aggregation, i.e. joint delivery of data via LTE and NX component carriers.

This paper explains the key requirements and capabilities of 5G, along with its technology components and spectrum needs.

5G – REQUIREMENTS AND CAPABILITIES

In order to enable connectivity for a very wide range of applications with new characteristics and requirements, the capabilities of 5G wireless access must extend far beyond those of previous generations of mobile communication. These capabilities will include massive system capacity, very high data rates everywhere, very low latency, ultra-high reliability and availability, very low device cost and energy consumption, and energy-efficient networks.

MASSIVE SYSTEM CAPACITY

Traffic demands for mobile-communication systems are predicted to increase dramatically [1] [2]. To support this traffic in an affordable way, 5G networks must deliver data with much lower cost per bit compared with the networks of today. Furthermore, the increase in data consumption will result in an increased energy footprint from networks. 5G must therefore consume significantly lower energy per delivered bit than current cellular networks.

The exponential increase in connected devices, such as the deployment of billions of wirelessly connected sensors, actuators and similar devices for massive machine connectivity, will place demands on the network to support new paradigms in device and connectivity management that do not compromise security. Each device will generate or consume very small amounts of data, to the extent that they will individually, or even jointly, have limited impact on the overall traffic volume. However, the sheer number of connected devices seriously challenges the ability of the network to provision signaling and manage connections.

VERY HIGH DATA RATES EVERYWHERE

Every generation of mobile communication has been associated with higher data rates compared with the previous generation. In the past, much of the focus has been on the peak data rate that can be supported by a wireless-access technology under ideal conditions. However, a more important capability is the data rate that can actually be provided under real-life conditions in different scenarios.

- 5G should support data rates exceeding 10Gbps in specific scenarios such as indoor and dense outdoor environments.
- Data rates of several 100Mbps should generally be achievable in urban and suburban environments.
- Data rates of at least 10Mbps should be accessible almost everywhere, including sparsely-populated rural areas in both developed and developing countries.

VERY LOW LATENCY

Very low latency will be driven by the need to support new applications. Some envisioned 5G use cases, such as traffic safety and control of critical infrastructure and industry processes, may require much lower latency compared with what is possible with the mobile-communication systems of today.

To support such latency-critical applications, 5G should allow for an application end-to-end latency of 1ms or less, although application-level framing requirements and codec limitations for media may lead to higher latencies in practice. Many services will distribute computational capacity and storage close to the air interface. This will create new capabilities for real-time communication and will allow ultra-high service reliability in a variety of scenarios, ranging from entertainment to industrial process control.

ULTRA-HIGH RELIABILITY AND AVAILABILITY

In addition to very low latency, 5G should also enable connectivity with ultra-high reliability and ultra-high availability. For critical services, such as control of critical infrastructure and traffic safety, connectivity with certain characteristics, such as a specific maximum latency, should not merely be ‘typically available.’ Rather, loss of connectivity and deviation from quality of service requirements must be extremely rare. For example, some industrial applications might need to guarantee successful packet delivery within 1 ms with a probability higher than 99.9999 percent.

VERY LOW DEVICE COST AND ENERGY CONSUMPTION

Low-cost, low-energy mobile devices have been a key market requirement since the early days of mobile communication. However, to enable the vision of billions of wirelessly connected sensors, actuators and similar devices, a further step has to be taken in terms of device cost and energy consumption. It should be possible for 5G devices to be available at very low cost and with a battery life of several years without recharging.

ENERGY-EFFICIENT NETWORKS

While device energy consumption has always been prioritized, energy efficiency on the network side has recently emerged as an additional KPI, for three main reasons:

- Energy efficiency is an important component in reducing operational cost, as well as a driver for better dimensioned nodes, leading to lower total cost of ownership.
- Energy efficiency enables off-grid network deployments that rely on medium-sized solar panels as power supplies, thereby enabling wireless connectivity to reach even the most remote areas.
- Energy efficiency is essential to realizing operators’ ambition of providing wireless access in a sustainable and more resource-efficient way.

The importance of these factors will increase further in the 5G era, and energy efficiency will therefore be an important requirement in the design of 5G wireless access.

MACHINE-TYPE COMMUNICATION

Fundamentally, applications such as mobile telephony, mobile broadband and media delivery are about information for humans. In contrast, many of the new applications and use cases that drive the requirements and capabilities of 5G are about end-to-end communication between machines. To distinguish them from the more human-centric wireless-communication use cases, these applications are often termed machine-type communication (MTC).

Although spanning a wide range of applications, MTC applications can be divided into two main categories – massive MTC and critical MTC – depending on their characteristics and requirements.

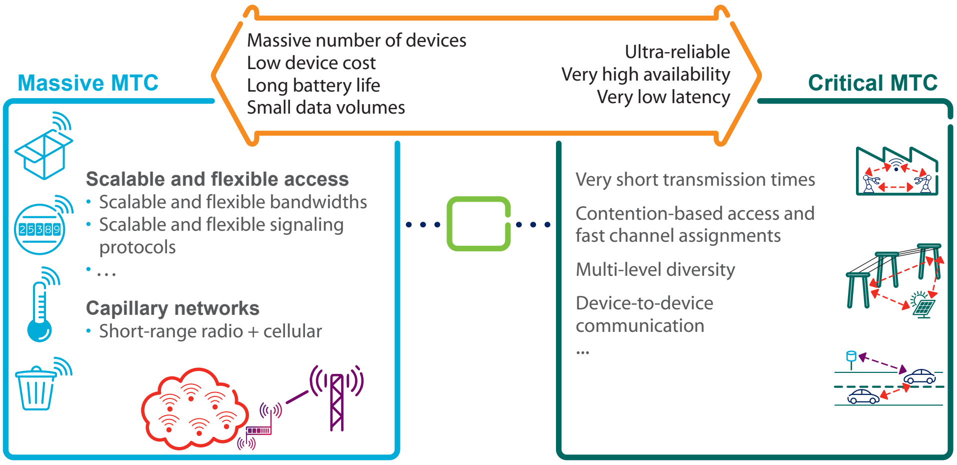
Massive MTC
Massive number of devices
Low device cost
Long battery life
Small data volumes
Ultra-reliable
Very high availability
Very low latency
Critical MTC
Scalable and flexible access
• Scalable and flexible bandwidths
• Scalable and flexible signaling protocols
• …
Capillary networks
• Short-range radio + cellular
25389
Very short transmission times
Contention-based access and fast channel assignments
Multi-level diversity
Device-to-device communication
…

Figure 2: Massive MTC and critical MTC.

Massive MTC refers to services that typically span a very large numbers of devices, usually sensors and actuators. Sensors are extremely low cost and consume very low amounts of energy in order to sustain long battery life. Clearly, the amount of data generated by each sensor is normally very small, and very low latency is not a critical requirement. While actuators are similarly limited in cost, they will likely have varying energy footprints ranging from very low to moderate energy consumption.

Sometimes, the mobile network may be used to bridge connectivity to the device by means of capillary networks. Here, local connectivity is provided by means of a short-range radio access technology, for example Wi-Fi, Bluetooth [3] or 802.15.4/6LoWPAN [4]. Wireless connectivity beyond the local area is then provided by the mobile network via a gateway node.

Critical MTC refers to applications such as traffic safety/control, control of critical infrastructure and wireless connectivity for industrial processes. Such applications require very high reliability and availability in terms of wireless connectivity, as well as very low latency. On the other hand, low device cost and energy consumption is not as critical as for massive MTC applications. While the average volume of data transported to and from devices may not be large, wide instantaneous bandwidths are useful in being able to meet capacity and latency requirements.

There is much to gain from a network being able to handle as many different applications as possible, including mobile broadband, media delivery and a wide range of MTC applications by means of the same basic wireless-access technology and within the same spectrum. This avoids spectrum fragmentation and allows operators to offer support for new MTC services for which the business potential is inherently uncertain, without having to deploy a separate network and reassign spectrum specifically for these applications.

SPECTRUM FOR 5G

In order to support increased traffic capacity and to enable the transmission bandwidths needed to support very high data rates, 5G will extend the range of frequencies used for mobile communication. This includes new spectrum below 6GHz, as well as spectrum in higher frequency bands.

Specific candidate spectrum for mobile communication in higher frequency bands is yet to be identified by the ITU-R or by individual regulatory bodies. The mobile industry remains agnostic about particular choices, and the entire frequency range up to approximately 100GHz is under consideration at this stage, although there is significant interest in large contiguous allocations that can provide dedicated and licensed spectrum for use by multiple competing network providers.

The lower part of this frequency range, below 30GHz, is preferred from the point of view of propagation properties. At the same time, very large amounts of spectrum and the possibility of wide transmission frequency bands of the order of 1GHz or more are more likely above 30GHz.

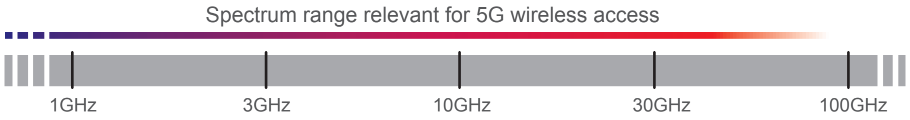

Figure 3: Spectrum relevant for 5G wireless access.

Spectrum relevant for 5G wireless access therefore ranges from below 1GHz up to approximately 100GHz, as Figure 3 shows.

It is important to understand that high frequencies, especially those above 10GHz, can only serve as a complement to lower frequency bands, and will mainly provide additional system capacity and very wide transmission bandwidths for extreme data rates in dense deployments. Spectrum allocations at lower bands will remain the backbone for mobile-communication networks in the 5G era, providing ubiquitous wide-area connectivity.

The World Radio Conference (WRC)-15 discussions have resulted in an agreement to include an agenda item for IMT-2020, the designated ITU-R qualifier for 5G, in WRC-19. The conference also reached agreement on a set of bands that will be studied for 5G, with direct applicability to NX. Many of the proposed bands are in the millimeter wave region and include:

- 24.25GHz to 27.5GHz, 37GHz to 40.5GHz, 42.5GHz to 43.5GHz, 45.5GHz to 47GHz, 47.2GHz to 50.2GHz, 50.4GHz to 52.6GHz, 66 GHz to 76GHz and 81GHz to 86GHz, which have allocations to the mobile service on a primary basis; and
- 31.8GHz to 33.4GHz, 40.5GHz to 42.5GHz and 47GHz to 47.2GHz, which may require additional allocations to the mobile service on a primary basis.

The mobile industry will strive to gain access to spectrum in the 6GHz to 20GHz range, but the policy directions being followed by regulators seem to be focused on frequency bands above 30GHz. In the US, the FCC has issued two Notices of Public Rule Making (NPRM) on bands above 24GHz. Ofcom has likewise indicated a preference for bands above 30GHz within the mobile industry.

The capacity needs of the mobile industry will continue to be served by licensed spectrum, although novel sharing arrangements for spectrum will become progressively more important as restricted opportunities for new spectrum start to impact incumbent services such as satellite communication and radio location. Two examples of sharing arrangements include LSA planned in Europe for the 2.3GHz band and the Citizens Band Radio Service for 3.5GHz in the US.

5G TECHNOLOGY COMPONENTS

Beyond extending operation to higher frequencies, there are several other key technology components relevant for the evolution to 5G wireless access. These components include access/backhaul integration, device-to-device communication, flexible duplex, flexible spectrum usage, multi-antenna transmission, ultra-lean design, and user/control separation.

ACCESS/BACKHAUL INTEGRATION

Wireless technology is already frequently used as part of the backhaul solution. Such wireless-backhaul solutions typically operate under line-of-sight conditions using proprietary radio technology in higher frequency bands, including the millimeter wave (mmW) band.

In the future, the access (base-station-to-device) link will also extend to higher frequencies. Furthermore, to support dense low-power deployments, wireless backhaul will have to extend to cover non-line-of-sight conditions, similar to access links.

In the 5G era, the wireless-access link and wireless backhaul should not therefore be seen as two separate entities with separate technical solutions. Rather, backhaul and access should be seen as an integrated wireless-access solution able to use the same basic technology and operate using a common spectrum pool. This will lead to more efficient overall spectrum utilization as well as reduced operation and management effort.

DIRECT DEVICE-TO-DEVICE COMMUNICATION

The possibility of limited direct device-to-device (D2D) communication has recently been introduced as an extension to the LTE specifications. In the 5G era, support for D2D as part of the overall wireless-access solution should be considered from the start. This includes peer-to-peer user-data communication directly between devices, but also, for example, the use of mobile devices as relays to extend network coverage.

D2D communication in the context of 5G should be an integral part of the overall wireless-access solution, rather than a stand-alone solution. Direct D2D communication can be used to offload traffic, extend capabilities and enhance the overall efficiency of the wireless-access network. Furthermore, in order to avoid uncontrolled interference to other links, direct D2D communication should be under network control. This is especially important for the case of D2D communication in licensed spectrum.

FLEXIBLE DUPLEX

Frequency Division Duplex (FDD) has been the dominating duplex arrangement since the beginning of the mobile communication era. In the 5G era, FDD will remain the main duplex scheme for lower frequency bands. However, for higher frequency bands – especially above 10GHz – targeting very dense deployments, Time Division Duplex (TDD) will play a more important role.

In very dense deployments with low-power nodes, the TDD-specific interference scenarios (direct base-station-to-base-station and device-to-device interference) will be similar to the 'normal' base-station-to-device and device-to-base-station interference that also occurs for FDD.

Furthermore, for the dynamic traffic variations expected in very dense deployments, the ability to dynamically assign transmission resources (time slots) to different transmission directions may allow more efficient utilization of the available spectrum.

To reach its full potential, 5G should therefore allow for very flexible and dynamic assignment of TDD transmission resources. This is in contrast to current TDD-based mobile technologies, including TD-LTE, for which there are restrictions on the downlink/uplink configurations, and for which there typically exist assumptions about the same configuration for neighbor cells and also between neighbor operators.

FLEXIBLE SPECTRUM USAGE

Since its inception, mobile communication has relied on spectrum licensed on a per-operator basis within a geographical area. This will remain the foundation for mobile communication in the 5G era, allowing operators to provide high-quality connectivity in a controlled-interference environment.

However, per-operator licensing of spectrum will be complemented with the possibility to share spectrum. Such sharing may be between a limited set of operators, or may occur in license-exempt scenarios. The

Citizens Band Radio Service in the US in the 3.5GHz band and the 5GHz unlicensed spectrum are examples of managed and unlicensed sharing regimes respectively.

New air interfaces like NX will likely be well served by more conventional licensed allocations of spectrum, mainly due to the need to establish a basic foundation for the technology to operate in an independent manner while interoperability is established with technologies like LTE. At some point, further allocations of spectrum for 5G may leverage the mobile industry's experience of sharing approaches in lower cellular bands.

MULTI-ANTENNA TRANSMISSION

Multi-antenna transmission already plays an important role in current generations of mobile communication and will be even more central in the 5G era, due to the physical limitations of small antennas. Path loss between a transmitter and receiver does not change as a function of frequency, as long as the effective aperture of the transmitting and receiving antennas does not change. The antenna aperture does reduce in proportion to the square of the frequency, and that reduction can be compensated by the use of higher antenna directivity. The 5G radio will employ hundreds of antenna elements to increase antenna aperture beyond what may be possible with current cellular technology.

In addition, the transmitter and receiver will use beamforming to track one another and improve energy transfer over an instantaneously configured link. Beamforming will also improve the radio environment by limiting interference to small fractions of the entire space around a transmitter and likewise limiting the impact of interference on a receiver to infrequent stochastic events. The use of beamforming will also be an important technology for lower frequencies; for example, to extend coverage and to provide higher data rates in sparse deployments.

ULTRA-LEAN DESIGN

Ultra-lean radio-access design is important to achieve high efficiency in 5G networks. The basic principle of ultra-lean design can be expressed as: minimize any transmissions not directly related to the delivery of user data. Such transmissions include signals for synchronization, network acquisition and channel estimation, as well as the broadcast of different types of system and control information.

Ultra-lean design is especially important for dense deployments with a large number of network nodes and highly variable traffic conditions. However, lean transmission is beneficial for all kinds of deployments, including macro deployments.

By enabling network nodes to enter low-energy states rapidly when there is no user-data transmission, ultra-lean design is an important component in delivering high network energy performance. Ultra-lean design will also enable higher achievable data rates by reducing interference from non-user-data-related transmissions.

USER/CONTROL SEPARATION

Another important design principle for 5G is to decouple user data and system control functionality. The latter includes the provisioning of system information; that is, the information and procedures needed for a device to access the system.

Such a decoupling will allow separate scaling of user-plane capacity and basic system control functionality. For example, user data may be delivered by a dense layer of access nodes, while system information is only provided via an overlaid macro layer on which a device also initially accesses the system.

It should be possible to extend the separation of user data delivery and system control functionality over multiple frequency bands and RATs. As an example, the system control functionality for a dense layer based on new high-frequency radio access could be provided by means of an overlaid LTE layer.

User/control separation is also an important component for future radio-access deployments relying heavily on beamforming for user data delivery. Combining ultra-lean design with a logical separation of user-plane data delivery and basic system connectivity functionality will enable a much higher degree of device-centric network optimization of the active radio links in the network. Since only the ultra-lean signals related to the system control plane need to be static, it is possible to design a system where almost everything can be dynamically optimized in real time.

An ultra-lean design combined with a system control plane logically separated from the user data delivery function also provides higher flexibility in terms of evolution of the RAT as, with such separation, the user plane can evolve while retaining system control functionality.

CONCLUSION

5G is the next step in the evolution of mobile communication and will be a key component of the Networked Society. In particular, 5G will accelerate the development of the Internet of Things. To enable connectivity for a wide range of applications and use cases, the capabilities of 5G wireless access must extend far beyond those of previous generations of mobile communications.

These capabilities include very high achievable data rates, very low latency and ultra-high reliability. Furthermore, 5G wireless access needs to support a massive increase in traffic in an affordable and sustainable way, implying a need for a dramatic reduction in the cost and energy consumption per delivered bit.

5G wireless access will be realized by the evolution of LTE for existing spectrum in combination with new radio access technologies that primarily target new spectrum. Key technology components of 5G wireless access include access/backhaul integration, device-to-device communication, flexible duplex, flexible spectrum usage, multi-antenna transmission, ultra-lean design, and user/control separation.

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GLOSSARY

D2D	device-to-device
FDD	Frequency Division Duplex
mmW	millimeter wave
MTC	Machine-Type Communication
NPRM	Notices of Public Rule Making
OFDM	Orthogonal Frequency Division Multiplexing
TDD	Time Division Duplex
WRC	World Radio Conference

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CELLULAR NETWORKS FOR MASSIVE IOT

ENABLING LOW POWER WIDE AREA APPLICATIONS

With new standards specifically targeting the connectivity requirements of Massive Internet of Things (IoT) applications, cellular networks can deliver reliable, secure and diverse IoT services using existing network infrastructure.

DELIVERING NEW VALUE IN THE NETWORKED SOCIETY

In the future, all devices that benefit from an internet connection will be connected. In this Networked Society, every person and every industry will be empowered to reach their full potential. Internet of Things (IoT) technology is a key enabler of this vision by delivering machine-to-machine (M2M) and machine-to-person communications on a massive scale.

As shown in Figure 1, Ericsson predicts there will be around 28 billion connected devices by 2021, of which more than 15 billion will be connected M2M and consumer-electronics devices [1]. A large share of these will be applications served by short-range radio technologies such as Wi-Fi and Bluetooth, while a significant proportion will be enabled by wide area networks (WANs) that are primarily facilitated by cellular networks.

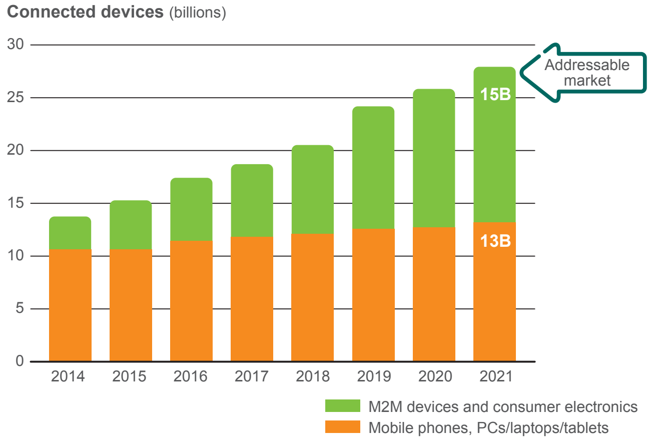

Figure 1: Growth in connected devices.

THE NEW IOT LANDSCAPE

The IoT revolution offers huge potential value in terms of improved efficiency, sustainability and safety for industry and society. Analysts predict that the total added value of the IoT will be USD 1.9 trillion by 2020 [2].

The variety of applications and solutions designed for individuals, business and industry is spurring the rapid expansion of the IoT market. The IoT is playing a major role across a variety of vertical sectors, generating cost savings, new revenue streams and other benefits.

Each IoT application needs a clear value proposition and business logic in line with the prevailing ecosystem, business models and value chains of the various stakeholders. For all applications, solutions need to be integrated on platforms that can scale and handle millions of devices efficiently. Business processes for administration, provisioning and charging will have to be streamlined to minimize costs and enhance the business case.

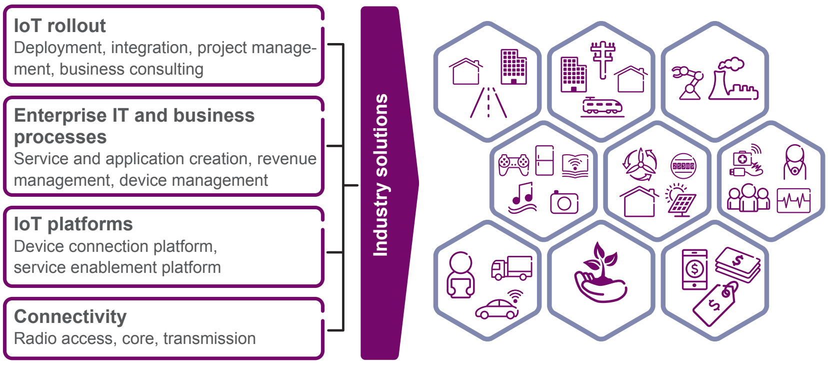
IoT rollout
Deployment, integration, project management, business consulting
Enterprise IT and business processes
Service and application creation, revenue management, device management
IoT platforms
Device connection platform, service enablement platform
Connectivity
Radio access, core, transmission
Industry solutions

Figure 2: The new IoT landscape.

As they are largely responsible for wireless connectivity on a global scale, operators are in an excellent position to capture a share of the added value generated by the emerging IoT market. The size of this share will depend on the role that operators adopt in the value chain. This could range from being a straightforward connectivity provider (monetizing connectivity in new ways), all the way to being an end-to-end solution provider of turnkey solutions to vertical markets [3].

DIFFERENT IOT CONNECTIVITY ALTERNATIVES

Connectivity is the foundation for IoT, and the type of access required will depend on the nature of the application. Many IoT devices will be served by radio technologies that operate on unlicensed spectrum and that are designed for short-range connectivity with limited QoS and security requirements typically applicable for a home or indoor environment. Currently, there are two alternative connectivity tracks for the many IoT applications that depend on wide-area coverage:

Cellular technologies: 3GPP technologies like GSM, WCDMA, LTE and future 5G. These WANs operate on licensed spectrum and historically have primarily targeted high-quality mobile voice and data services. Now, however, they are being rapidly evolved with new functionality and the new radio access technology narrowband IoT (NB-IoT) specifically tailored to form an attractive solution for emerging low power wide area (LPWA) applications.

Unlicensed LPWA: new proprietary radio technologies, provided by, for example, SIGFOX and LoRa, have been developed and designed solely for machine-type communication (MTC) applications addressing the ultra-low-end sensor segment, with very limited demands on throughput, reliability or QoS.

One way to segment IoT applications is to categorize them according to coverage needs and performance requirements (such as data speed or latency demands).

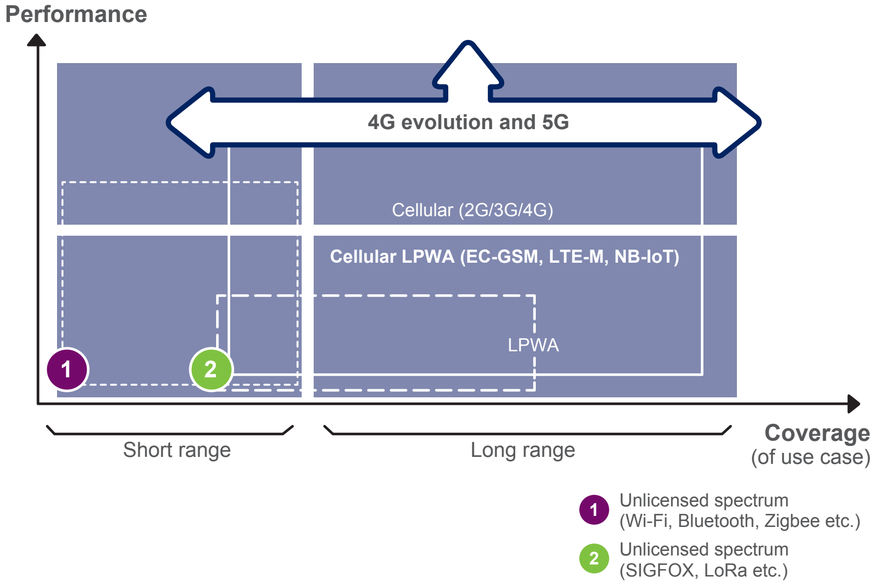

Figure 3: Technologies addressing different IoT segments.

The coverage needs of a particular use case may be highly localized (such as a stationary installation within a building), while other use cases require global service coverage (such as container tracking). 3GPP technologies already dominate use cases with large geographic coverage needs and medium- to high-performance requirements.

With new feature sets specifically tailored for LPWA IoT applications, 3GPP technologies are taking a large leap forward to cover segments with low-cost, low-performance requirements too.

CAPILLARY NETWORKS COMBINING CELLULAR AND UNLICENSED STRENGTHS

Even when existing 3GPP end-to-end connectivity is not feasible, cellular technology can still provide key benefits when used as a bridging option, i.e. as an aggregation and routing solution. This capillary network approach allows end devices to utilize varying access solutions from either the short range or LPWA domain and access the cellular networks via a gateway device. Capillary networks enable the reuse of cellular functions and assets such as security, device management, billing and QoS without requiring each end device to be cellular-enabled.

A WIDE RANGE OF IOT REQUIREMENTS

There will be a wide range of IoT use cases in the future, and the market is now expanding toward both Massive IoT deployment as well as more advanced solutions that may be categorized as Critical IoT, as shown in Figure 4.

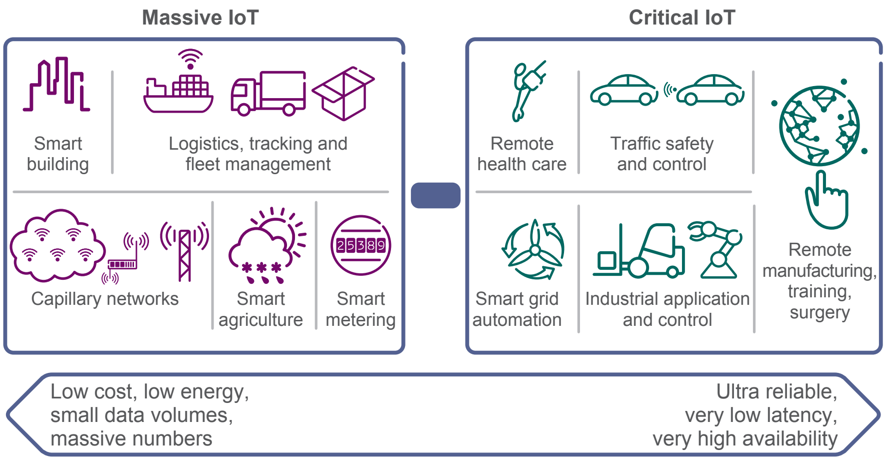
Massive IoT
Critical IoT
Smart building
Logistics, tracking and fleet management
Capillary networks
25389
Smart agriculture
Smart metering
Remote health care
Traffic safety and control
Remote manufacturing, training, surgery
Smart grid automation
Industrial application and control
Low cost, low energy, small data volumes, massive numbers
Ultra reliable, very low latency, very high availability

Figure 4: Differing requirements for Massive and Critical IoT applications.

At one end of the scale, in Massive IoT applications – typically sensors that report to the cloud on a regular basis – the end-to-end cost must be low enough for the business case to make sense. Here, the requirement is for low-cost devices with low energy consumption and good coverage.

At the other end of the scale, Critical IoT applications will have very high demands for reliability, availability and low latency. These use cases are enabled by LTE or 5G capabilities. Here, the volumes are typically much smaller, but the business value is significantly higher.

There are, however, many other use cases between the two extremes, which today rely on 2G, 3G or 4G connectivity.

MASSIVE IOT USE CASE DIVERSITY

The Massive IoT market segment includes several applications widely used in industries and societies, as shown in Figure 5.

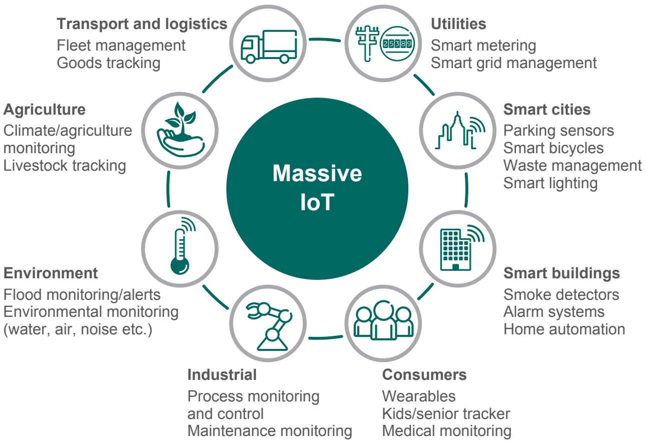
Massive IoT
Transport and logistics
Fleet management
Goods tracking
Utilities
Smart metering
Smart grid management
Agriculture
Climate/agriculture monitoring
Livestock tracking
Smart cities
Parking sensors
Smart bicycles
Waste management
Smart lighting
Environment
Flood monitoring/alerts
Environmental monitoring (water, air, noise etc.)
Smart buildings
Smoke detectors
Alarm systems
Home automation
Industrial
Process monitoring and control
Maintenance monitoring
Consumers
Wearables
Kids/senior tracker
Medical monitoring

Figure 5: Industry and society applications enabled by LPWA.

The potential applications for the IoT run into the millions, with a huge variety of requirements regarding cost, battery life, coverage, connectivity performance (throughput and capacity), security and reliability. Figure 6 illustrates some such applications and their requirements regarding devices and connectivity.

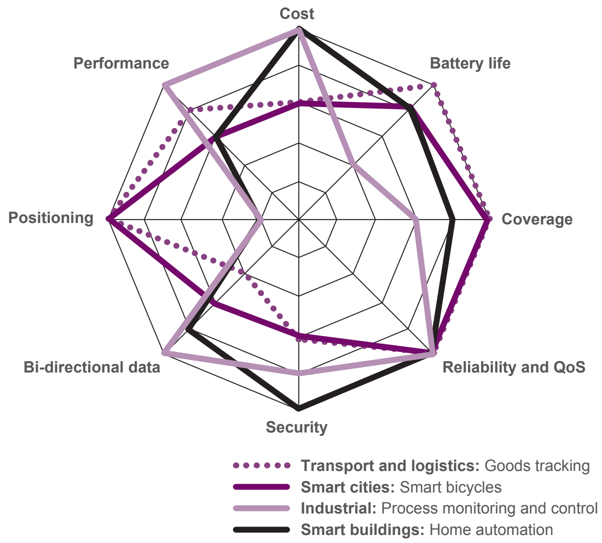

Figure 6: Device and connectivity requirements for sample IoT use cases.

Some devices will only send a few messages per day – such as status indicators for temperature – while others may need to transmit a video stream to guide a remote repair technician, for example. The difference in throughput requirements is huge. If operators or service providers handle several applications, it may be of great benefit to be able to harmonize communication modules, so that they all use the same underlying radio solution to reduce operational and fault management effort and complexity.

Many higher-value applications will require two-way communications – in other words, an uplink as well as a downlink – to enable monitoring and control of devices in systems like heating, ventilation and cooling plants. The long lifetime of many IoT applications makes it invaluable to be able to perform over-the-air device updates for new functionality or parameter settings. The amount of data sent for such updates can often be more demanding for the network than the monitoring or control application itself.

Relatively simple uplink-focused applications can benefit greatly from a bi-directional link to provide robustness. For example, a connected smoke detector must deliver a smoke alarm with absolute certainty. The ability of a network to provide acknowledgements of a received message enables better fault management and the required level of reliability. Positioning can be used to locate the sensor at the point it failed and simplify operations. For tracking applications, location information is essential.

In applications like building security, sensitive information could be reported over the air, which will require strict security. Furthermore, in the case of a break-in, it is crucial that the alarm information reaches the control center in time – making QoS and two-way communication vital.

KEY CHALLENGES FOR MASSIVE IOT

The key challenges to enabling large-scale uptake of Massive IoT include:

Device cost – clearly a key enabler for high-volume, mass-market applications, enabling many of the use cases.

Battery life – many IoT devices will be battery-powered, and often the cost of replacing batteries in the field is not viable.

Coverage – deep indoor connectivity is a requirement for many applications in the utility area. Furthermore, regional (or even national or global) coverage is a prerequisite for many use cases, especially within the transport area.

Scalability – in order to enable a Massive IoT market, networks need to scale efficiently. The initial investment required for supporting a limited number of devices has to be manageable, while on the other hand, the network capacity must be easy to scale to handle thousands – or millions – of devices.

Diversity – connectivity should be able to support diverse requirements from different use cases. One network supporting everything from simple static sensors to tracking services, to applications requiring higher throughput and lower latency is essential in terms of total cost of ownership (TCO).

THE ADVANTAGES OF CELLULAR TECHNOLOGIES

Each of the technologies available for IoT connectivity has its own advantages and disadvantages. However, the range of IoT connectivity requirements – both technical and commercial – means cellular technologies can provide clear benefits across a wide variety of applications, as summarized in Figure 7.

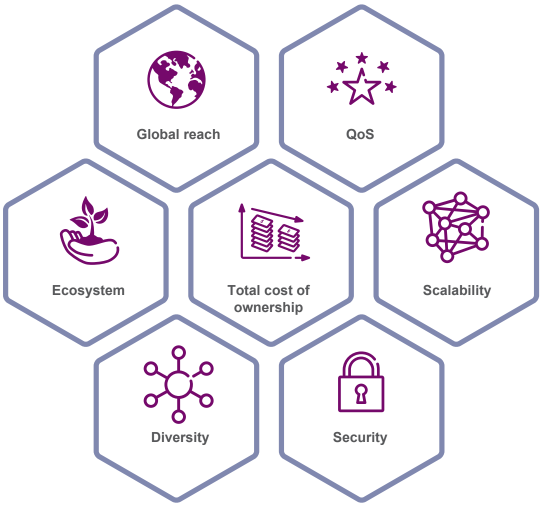

Figure 7: Advantages of cellular technologies.

In terms of global reach, cellular networks already cover 90 percent of the world's population. WCDMA and LTE are catching up, but GSM will offer superior coverage in many markets for years to come. Cellular networks have been developed and deployed over three decades, and they will be around for the foreseeable future.

The cellular mobile industry represents a huge and mature ecosystem, incorporating chipset, device and network equipment vendors, operators, application providers and many others. The global cellular ecosystem is governed by the 3GPP standardization forum, which guarantees broad industry support for future development.

When it comes to scalability, cellular networks are built to handle massive volumes of mobile broadband traffic; the traffic from most IoT applications will be relatively small and easily absorbed. Operators are able to offer connectivity for IoT applications from the start-up phase and grow this business with low TCO and only limited additional investment and effort. Operation in licensed spectrum also provides predictable and controlled interference, which enables efficient use of the spectrum to support massive volumes of devices.

Cellular connectivity offers the diversity to serve a wide range of applications with varying requirements within one network. While competing unlicensed LPWA technologies are designed solely for very low-end MTC applications, cellular networks can address everything from Massive to Critical IoT use cases.

QoS mechanisms will be essential for many IoT applications. Cellular systems have mature QoS functionality, and this enables critical MTC applications to be handled together with traffic from sensors, voice and mobile-broadband traffic on the same carrier. QoS, along with licensed spectrum as described above, provides a foundation for long-term Service Level Agreements with a specific grade of service.

Traditionally, the security mechanisms of cellular networks have been based on a physical SIM attached to the device, referred to as a Universal Integrated Circuit Card (UICC). This has also enabled roaming between operators, which has been one of the main factors behind the huge success of mobile networks. The SIM will also be essential in future IoT applications, with SIM functionality embedded in the chipset (eUICC) or handled as a soft-SIM solution running in a trusted run-time environment of the module.

With a straightforward rollout of new software, cellular networks will be able to support the full breadth of applications, ranging from low-end use cases in the LPWA segment, to the high-end segments of in-car entertainment and video surveillance. One network connecting the whole diversifying IoT market will guarantee the lowest possible TCO as well as fast time to market.

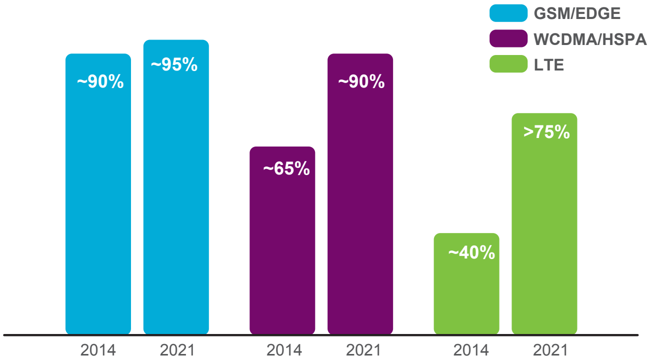

Figure 8: World population coverage by cellular 3GPP technology.

EVOLVING STANDARDS

To meet the new connectivity requirements of the emerging Massive IoT segment, 3GPP has taken evolutionary steps on both the network side and the device side.

The key improvement areas addressed in 3GPP up to Release 13 are:

- Lower device cost – cutting module cost for LTE devices by reducing peak rate, memory requirement and device complexity. The LTE module cost-reduction evolution started in Release 8 with the introduction of LTE for machine-type communication (LTE-M) Cat 1 devices with reduced peak rate to a maximum of 10Mbps, and continued in Releases 12 and 13 with reduced device complexity for lower performance and using less bandwidth or a narrowband IoT carrier to cut costs further.
- Improved battery life – more than 10 years of battery life can be achieved by introducing Power Saving Mode and/or extended discontinuous reception (eDRX) functionality. These features allow the device to contact the network – or to be contacted – on a per-need basis, meaning that it can stay in sleep mode for minutes, hours or even days.
- Improved coverage – an improvement of 15dB on LTE-M and of 20dB on NB-IoT and GSM, which translates into a seven-fold increase in the outdoor coverage area and significantly improved indoor signal penetration to reach deep indoors. This supports many IoT devices like smart meters, which are often placed in a basement.
- Support for massive numbers of IoT connections – specifically, one LTE cell site can support millions of IoT devices, depending on the use case. Core network enhancements include software upgrades for service differentiation handling, signaling optimization and high-capacity platforms (more than 30 million devices per node).

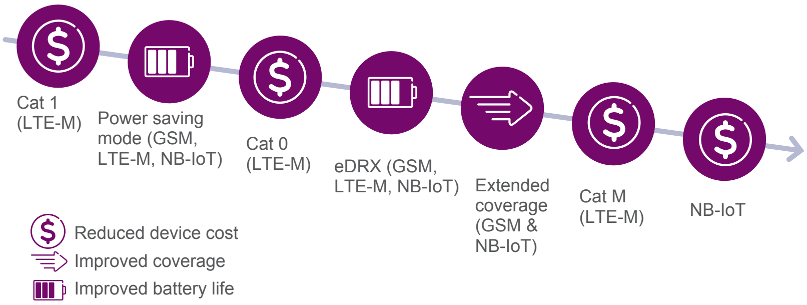

Figure 9: 3GPP evolution steps for Massive IoT.

A FULL RANGE OF CELLULAR LPWA SOLUTIONS

No single technology or solution is ideally suited to all the different potential Massive IoT applications, market situations and spectrum availability. As a result, the mobile industry is standardizing several LPWA technologies, including Extended Coverage GSM (EC-GSM), LTE-M and NB-IoT.

LTE-M, NB-IoT and EC-GSM are all superior solutions to meet Massive IoT requirements as a family of solutions, and can complement each other based on technology availability, use case requirements and deployment scenarios. LTE-M consisting of Cat 1, Cat 0 and Cat M supports a wide range of IoT applications, including those that are content-rich; NB-IoT covers ultra-low-end IoT applications with a cost and coverage advantage over LTE-M; and EC-GSM serves IoT services for all GSM markets.

For example, a smart city application such as waste management may use EC-GSM technology to provide LPWA connectivity in markets where it can be deployed on existing 2G networks; NB-IoT technology may be used for water-metering applications, which have some of the most extreme coverage requirements in underground locations. On the other hand, asset-tracking applications that can support a relatively high number of messages triggered by certain events may employ LTE-M.

EC-GSM – GLOBAL CELLULAR IOT FOR ALL GSM MARKETS

GSM is still the dominant mobile technology in many markets, and the vast majority of cellular M2M applications today use GPRS/EDGE for connectivity. GSM is likely to continue playing a key role in the IoT well into the future, due to its global coverage footprint, time to market and cost advantages.

Recognizing this – and identifying the requirements for Massive IoT discussed earlier in this paper – an initiative was undertaken in 3GPP Release 13 to further improve GSM.

The resulting EC-GSM functionality enables coverage improvements of up to 20dB with respect to GPRS on the 900MHz band.

This coverage extension is achieved for both the data and control planes by utilizing the concept of repetitions and signal combining techniques. It is handled in a dynamic manner with multiple coverage classes to ensure optimal balance between coverage and performance.

EC-GSM is achieved by defining new control and data channels mapped over legacy GSM. It allows multiplexing of new EC-GSM devices and traffic with legacy EDGE and GPRS. No new network carriers are required: new software on existing GSM networks is sufficient and provides combined capacity of up to 50,000 devices per cell on a single transceiver.

Initially part of EC-GSM but now a separate 3GPP item, eDRX improves the power efficiency – and therefore the battery life – for many use cases. eDRX improves the idle mode behavior by allowing the use of a number of inactivity timers, where the device can choose to tune in to the network and listen for downlink pages and traffic.

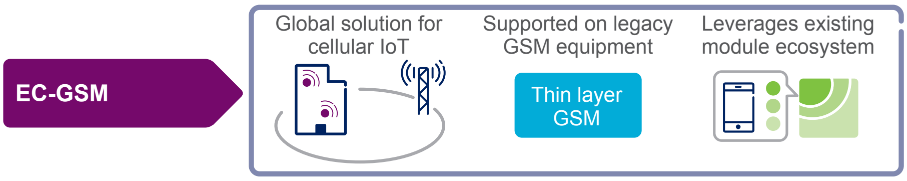
EC-GSM
Global solution for cellular IoT
Supported on legacy GSM equipment
Thin layer GSM
Leverages existing module ecosystem

Figure 10: EC-GSM.

EC-GSM extends the data handling and power efficiency advantages that GSM/GPRS technology already offers for MTC, and it will help operators extend the service life of their huge 2G legacy base.

LTE-M – SUPPORTING A WIDE RANGE OF MASSIVE IOT USE CASES

LTE is the leading mobile broadband technology and its coverage is expanding rapidly. So far, the focus has been on meeting the huge demand for mobile data with highly capable devices that utilize new spectrum. With features like Carrier Aggregation, MIMO and Lean Carrier, the gigabit per second performance for LTE cell throughput is now reaching levels that result in an excellent mobile broadband user experience.

The advent of LTE-M signifies an important step in addressing MTC capabilities over LTE. LTE-M brings new power-saving functionality suitable for serving a variety of IoT applications; Power Saving Mode and eDRX extend battery life for LTE-M to 10 years or more. LTE-M traffic is multiplexed over a full LTE carrier, and it is therefore able to tap into the full capacity of LTE. Additionally, new functionality for substantially reduced device cost and extended coverage for LTE-M are also specified within 3GPP.

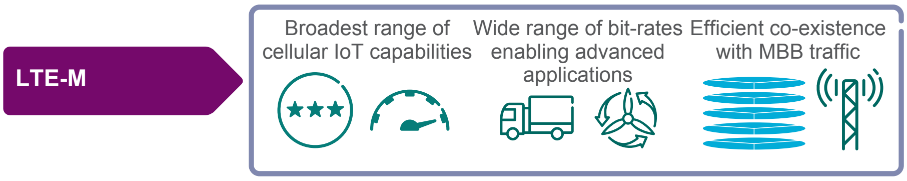
LTE-M
Broadest range of cellular IoT capabilities
Wide range of bit-rates enabling advanced applications
Efficient co-existence with MBB traffic

Figure 11: LTE M.

NB-IOT – SUPPORTING ULTRA-LOW-END MASSIVE IOT APPLICATIONS

In addition to LTE-M, NB-IoT technology is being standardized in time for 3GPP Release 13. NB-IoT is a self-contained carrier that can be deployed with a system bandwidth of only 200kHz, and is specifically tailored for ultra-low-end IoT applications. It is enabled using new network software on an existing LTE network, which will result in rapid time to market.

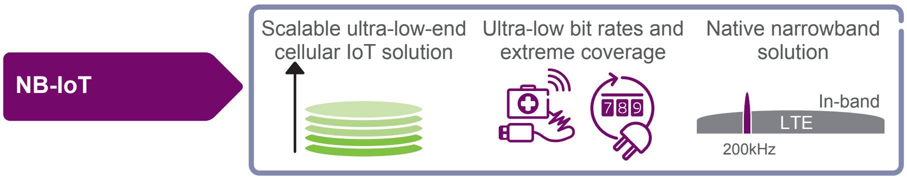
NB-IoT
Scalable ultra-low-end cellular IoT solution
Ultra-low bit rates and extreme coverage
789
Native narrowband solution
In-band
LTE
200kHz

Figure 12: NB-IoT.

NB-IoT provides lean setup procedures, and a capacity evaluation indicates that each 200kHz NB-IoT carrier can support more than 200,000 subscribers. The solution can easily be scaled up by adding multiple NB-IoT carriers when needed. NB-IoT also comes with an extended coverage of up to 20dB, and battery saving features, Power Saving Mode and eDRX for more than 10 years of battery life.

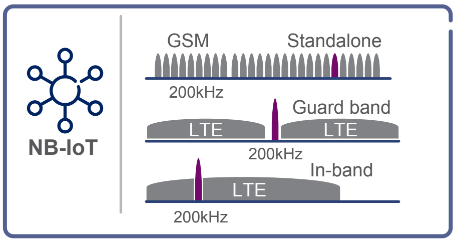
NB-IoT
GSM
Standalone
200kHz
Guard band
LTE
LTE
200kHz
In-band
LTE
200kHz

Figure 13: NB-IoT deployment.

NB-IoT is designed to be tightly integrated and interwork with LTE, which provides great deployment flexibility. The NB-IoT carrier can be deployed in the LTE guard band, embedded within a normal LTE carrier, or as a standalone carrier in, for example, GSM bands.

- Standalone deployment in a GSM low band: this is an option when LTE is deployed in a higher band and GSM is still in use, providing coverage for basic services.
- Guard band deployment, typically next to an LTE carrier: NB-IoT is designed to enable deployment in the guard band immediately adjacent to an LTE carrier, without affecting the capacity of the LTE carrier. This is particularly suitable for spectrum allocations that do not match the set of LTE system bandwidths, leaving gaps of unused spectrum next to the LTE carrier.
- Efficient in-band deployment, allowing flexible assignment of resources between LTE and NB-IoT: it will be possible for an NB-IoT carrier to time-share a resource with an existing LTE carrier. The in-band deployment also allows for highly flexible migration scenarios. For example, if the NB-IoT service is first deployed as a standalone deployment in a GSM band, it can subsequently be migrated to an in-band deployment if the GSM spectrum is re-farmed to LTE, thereby avoiding any fragmentation of the LTE carrier.

NB-IoT reduces device complexity below that of LTE-M with the potential to rival module costs of unlicensed LPWA technologies, and it will be ideal for addressing ultra-low-end applications in markets with a mature LTE installed base.

CONCLUSION

Uptake of Massive IoT is set to take off, and operators have a unique opportunity to drive the implementation of new IoT applications by offering affordable connectivity on a global scale.

For IoT applications, existing cellular networks offer distinct advantages over alternative WAN technologies, such as unlicensed LPWA. The global reach, QoS, ecosystem, TCO, scalability, diversity and security of cellular networks are all vital factors that can support the fast uptake and success of IoT. Enabled by new software in existing legacy networks, cellular networks can support a diverse range of IoT applications – ensuring the lowest possible TCO.

3GPP standardization work for GSM and LTE, and the recent addition of NB-IoT, is further improving the ability of cellular networks to address the Massive IoT market, where ultra-low end-to-end cost is a prerequisite.

GSM/GPRS, which already serves the majority of cellular-based MTC applications, is evolving with a new EC-GSM standard, which delivers significantly better energy efficiency and increased coverage. EC-GSM enhancements will cement GSM's position as a highly relevant connectivity platform for low-end, Massive IoT applications globally.

New downsized NB-IoT and LTE-M chipsets, designed for MTC, and features that improve both coverage and device battery life will boost the ability of LTE infrastructure to address the IoT market. One network that supports all applications – from advanced mobile broadband services, VoIP and all kinds of low- to high-end IoT use cases – creates a very strong value proposition.

Whether operators choose the GSM, NB-IoT or LTE-M track – or a combination of these – will depend on several factors such as technology coverage, future technology strategies and targeted market segments. Whichever path they take, they have a huge opportunity to benefit from the emerging IoT revolution. Operators can choose to continue offering telecom-grade connectivity as they do today, or they can evolve to become a platform or fully-fledged IoT service provider targeting a larger slice of future IoT revenues.

GLOSSARY

EC-GSM	Extended Coverage GSM
eDRX	extended discontinuous reception
eUICC	embedded Universal Integrated Circuit Card
IoT	Internet of Things
LPWA	low power wide area
LTE-M	LTE for machine-type communication
M2M	machine-to-machine
MIMO	multiple-input, multiple-output
MTC	machine-type communication
NB-IoT	narrowband IoT
TCO	total cost of ownership
UICC	Universal Integrated Circuit Card
WAN	wide area network

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THE Next Wave

The National Security Agency's review of emerging technologies

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THE
Next Wave
The National Security Agency's review of emerging technologies

Editor's column

While the global mobile telecommunications industry has been attempting to keep pace with ever-changing technology and consumer needs, it has not had a strong development roadmap like the International Technology Roadmap for Semiconductors (ITRS). Instead, mobile technology's development has been characterized by multinational companies pushing proposed standards for adoption by international standards bodies. These standards are subsequently adopted in a haphazard, nation-by-nation process. However, consumer desire for faster, more fully featured mobile devices has proven to be as strong a driving force as the ITRS, and has led the industry to roll out generations of new technology on a roughly 10-year basis (approximate dates: 1G - 1981, 2G - 1992, 3G - 2001, and 4G - 2009). This decade-by-decade introduction of new mobile communication technology has led to the common prediction for fifth-generation (5G) mobile to appear around 2020, in keeping with the observed linear cadence.

But why create 5G mobile anyway? The push for 5G is not just a mad rush to keep pace and provide more bandwidth to services that can already stream high-definition video. The Internet of Things (IoT; see TNW Vol. 21 No. 2) is a major driving force (among several) behind technologies being developed for 5G mobile. As personal mobile devices are more enmeshed into machine-to-machine (M2M) communications and the number of IoT sensors explodes, 5G technologies must address several needs: high-speed data rates for many more users, increased density of users, greatly increased simultaneous connections, and reduced latencies. These needs will propel many of the technologies that Dr. Farroha et al. describe in their introduction to 5G article (page 2).

One of those technologies, virtualization, has been instrumental in making efficient use of servers (virtual machine or VM) and computer networking (software-defined networking or SDN). Over the course of continuing improvement to 4G implementations, the networks are evolving into an all-digital Internet protocol packet-switched system. This evolution means that those efficiencies developed for SDN and used in computing can be applied to mobile networking. We can see this application in more depth in the article on 5G virtualization (page 16).

Several markets have already taken advantage of 4G mobile technology, most notably media. This market is expected to expand with 5G as consumer desire for high-resolution video and augmented/virtual reality increases. Automotive, energy, health, and public safety are several areas of M2M that will be greatly enhanced by increased bandwidth and, most importantly, low-latency networks. On 13 December 2016, the US Department of Transportation proposed a rule for vehicle-to-vehicle communication and announced a vehicle-to-infrastructure communication rule to be proposed. The article on 5G and the automotive industry (page 20) provides insight into how this market segment is enhanced by 5G connectivity.

Although mobile technological developments are typically categorized into different generations, each generation covers a vast array of individual technologies and protocols that roll out as they mature. In practice, mobile service providers often work across a range of generations. This is highlighted by the fact that in many cases voice calling is handled by the 3G network while data is handled on the 4G network. Domestically, T-Mobile and AT&T did not enable voice over LTE (VoLTE) until May 2014, and did not meet the International Telecommunication Union (ITU) standard until Verizon launched LTE-Advanced in August 2016.

Many factors can impact the broad global deployment of 5G networks, such as existing technologies, geography, spectrum, and national interests. Some countries may jump to the current network generation while others may delay deployment because their current networks are considered to be "good enough." The decreased per-customer costs of updating networks in densely populated countries makes it more attractive to keep on the leading edge. The increased data rates and simultaneous connections require increased spectrum allocations, which are handled by national regulatory organizations. Several countries, most notably South Korea, have tied their technological identity to the increased connectivity of next-generation wireless technologies. All these factors give rise to a patchwork international environment for 5G implementation.

Current forecasts for the rollout of 5G networks are in the 2020 time frame. Recent news indicates that it may be earlier than that. Samples of Qualcomm's new Snapdragon X50 4G/5G modem that uses the 27.5 gigahertz (GHz) to 28.35 GHz band—part of the spectrum opened by the Federal Communications Commission for 5G—will be available in the second half of 2017. Samsung and KT, one of South Korea's mobile providers, have announced that they will be the first to provide mobile 5G trial service at the PyeungChang 2018 Winter Olympic Games. Undoubtedly, this trial 5G service will not be fully compliant with 5G standards, which have yet to be adopted. However, we should expect things to advance quickly following the Korean introduction of 5G.

RECENT NEWS

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Introducing 5G

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The evolution of modern cellular communications has been marked by a series of technology generations. Although the technology itself tends to evolve continuously, a new generation of standards marks a revolutionary step forward, with a substantial increase in system requirements to drive fundamentally new applications. With fourth-generation (4G) networks now widely deployed, the industry has turned its sights on "the next big thing." Fifth-generation (5G) networks are expected to enable a seamlessly connected society in the time frame beyond 2020 for both people and things, including vehicles, homes, smart cities, sensor networks, and the power grid. While the Long-Term Evolution (LTE) standard will continue to evolve and play a critical role in the wireless ecosystem, 5G represents an opportunity to architect a new system that is fundamentally different without the constraint of backward compatibility with existing technologies.

What is 5G?

Although there are as yet no standards for 5G mobile networks, a number of key technology trends have emerged. This article describes seven major technology trends that will pave the way to the next generation of 5G networks.

- **New Flexible Radio Access Technology (RAT):** A new, non-backward-compatible RAT will be defined for 5G that is distinct from previous generations, such as 4G LTE and its evolution. New multiple access schemes under consideration include various modified Orthogonal Frequency-Division Multiplexing (OFDM)-based solutions with improved spectral efficiency. The new RAT must be flexible enough to accommodate a variety of traffic types with often conflicting radio requirements. The concept of a unified air interface has been proposed for multiplexing multiple physical layer (PHY) regions with different characteristics [e.g., transmission time interval (TTI), subcarrier spacing] on a contiguous block of spectrum [1, 2, 3]. Spectrum for the new RAT will include existing bands below 6 gigahertz (GHz), as well as new centimeter-wave (cmWave) and millimeter-wave (mmWave) bands in the 6- to 100 GHz range [4]. The new RAT must also support significantly reduced latency, with as low as 100 microsecond (μs) transmission time interval (TTI) at the PHY for the ultra-reliable and low-latency communications (URLLC) use case [5]. Lastly, to further improve spectral efficiency, full-duplex transmission schemes have been proposed, potentially allowing the same time-frequency resources to be used for uplink and downlink transmissions simultaneously [6].
- **Virtualization:** Software-Defined Networking (SDN) and Network Function Virtualization (NFV) are two key architecture concepts in development to support the flexibility and mobility demands of the 5G network infrastructure [7, 8, 9]. Virtualization of network functions, which were traditionally implemented in hardware, will pave the way for commercial telecommunications operators and service providers to introduce new features and integrate new standards releases at an accelerated rate. NFV enables providers to move toward a decentralized network to increase flexibility, pushing core functions toward the edge to reduce latency, and virtualizing those functions on cloud-based servers. The proposed Cloud Radio Access Network (C-RAN) architecture, a specific use case of NFV applied to the RAN, uses a pooled architecture of baseband resources to increase scalability, physical layer flexibility, and spectral efficiency [7, 10].
- **Millimeter Wave (mmWave) Communications:** The term mmWave refers to carrier frequencies in the International Telecommunication Union (ITU) extremely high-frequency (EHF) band, from 30 to 300 GHz. Within the context

of 5G, the term has recently been loosely used by industry to refer to the higher frequencies from 6 to 100 GHz that are under consideration for new mobile spectrum [11, 12]. mmWave technologies are becoming an increasingly attractive solution to the problems of frequency reuse, cell density, raw data throughput, and antenna array size. This has led to a synergy between mmWave, small cell deployments, and massive multiple-input, multiple-output (MMIMO) techniques [13, 14].

- **Massive Multiple-Input, Multiple-Output (MMIMO) Techniques:** MMIMO is a new concept in antenna arrays that provides a number of advantages over traditional MIMO arrays currently deployed in 4G networks. Traditional MIMO arrays use only a few antenna elements (i.e., 2 to 16), whereas MMIMO uses a large number of elements in the array, currently considering a range of 128 to 512 at a minimum. Highly directional beamforming to multiple users simultaneously allows for increased user density and higher aggregate cell throughput [15]. So-called hybrid MMIMO has also been proposed; it combines beam steering with array processing techniques, such as spatial multiplexing, to increase single-user throughput [16].
- **Heterogeneous Networks (HetNets):** HetNets expand the mobile access network capacity by coordinating small cells with larger macro cells or offloading traffic to wireless local area network (WLAN) access points. There are two types of heterogeneity: 1) various cell sizes (e.g., macro, pico, femto) and 2) heterogeneous RATs [e.g., third-generation (3G), 4G, 5G, WLAN]. Small cells may include femto, pico, and micro cells, which can range in capacity from less than 10 to several hundred simultaneous active users. While HetNet deployments have already been introduced in 4G networks, network densification through the aggressive deployment of small cells is expected to increase significantly in future 5G networks [17, 18].
- **Native Machine-Type Communications (MTC) Support:** 5G networks are expected to incorporate a new model for connectivity specifically designed for MTC [19]. With the significant increase in connected machines over the last several years, a new 5G standard is seen as a prime opportunity to ensure new RATs can efficiently support a large number of connected devices with their own unique access constraints. Two categories of MTC are discussed: 1) general MTC and 2) vehicle-to-everything (V2X) MTC. General MTC devices have a few unique design and deployment considerations—namely, lower bandwidth needs, stringent power budgets, and relaxed latency requirements. V2X MTC devices, in contrast, require low-latency communications, out-of-coverage networks, and limited operation on a subscription-free basis [20].
- **Device-centric Architectures:** New network architectures will focus on a uniform quality of experience (QoE) for the user device, in contrast to traditional base-station-centric architectures. A number of new device-centric approaches are under consideration: decoupling the user plane and control plane, decoupling the uplink and downlink, and device-to-device communications [4, 21]. Another novel proposal is the user-centric cell or virtual cell model, which uses distributed beamforming and decoupled user/control planes to create a virtual cell around each user [2, 3]. Because the virtual cell follows the user, QoE variations are reduced and the cell-edge problem is mitigated. New device-centric architectures may significantly alter the traditional concept of cell handovers or eliminate it entirely.

Many of these technologies are already being added to the evolution of existing technologies beyond 4G, such as LTE-Advanced Pro [22].

In 2015, there was a significant increase in industry activities surrounding 5G networks. Major standards bodies, including the ITU and the Third-Generation Partnership Project (3GPP), reached important milestones in the early development of the eventual 5G standards. In September, the ITU published its vision for 5G networks [19]. The vision for International Mobile Telecommunications for 2020 and beyond (IMT-2020) defines three future-looking, high-level use cases for 5G:

- **Enhanced Mobile Broadband (eMBB):** This is generally a human-centric use case driven by the exponential increase in demand for mobile access to multimedia content, services, and data.

The eMBB use case will come with new application areas and requirements that go beyond existing mobile broadband applications for improved performance and increasingly seamless user experience. This use case covers a range of scenarios, including wide-area coverage and localized high-throughput spot coverage, which will have different requirements.

- **Massive Machine-Type Communications (mMTC):** This use case is characterized by a large number of connected devices typically transmitting a relatively low volume of nondelay-sensitive data. Devices are intended to be low cost and have a very long battery life.
- **Ultra-Reliable and Low-Latency Communications (URLLC):** This use case is characterized by stringent requirements for latency, throughput, and availability. Examples include wireless control of industrial manufacturing processes, remote medical surgery, distributed smart grid automation, and transportation safety [e.g., vehicle-to-vehicle (V2V) or vehicle-to-everything (V2X) communication]. Many companies have referred to this use case as critical MTC (cMTC) or ultra-reliable MTC (uMTC). However, based on the ITU definition in [19], this use case is not strictly limited to MTC applications.

It is important to consider that the applications that will use 5G technology do not necessarily correspond to a single use case but are more accurately described as a combination of multiple use cases. Figure 1 illustrates some examples of currently envisioned 5G applications and their relationship to these three IMT-2020 use cases [19]. Figure 2 illustrates eight key capabilities identified by ITU for IMT-2020 and their relative importance to the same three use cases [19]. Furthermore, additional future use cases are expected to emerge but cannot be accurately predicted (i.e., what will be the "killer app" in 2025?). Therefore, it is desired that 5G standards will provide the flexibility to adapt to new use cases.

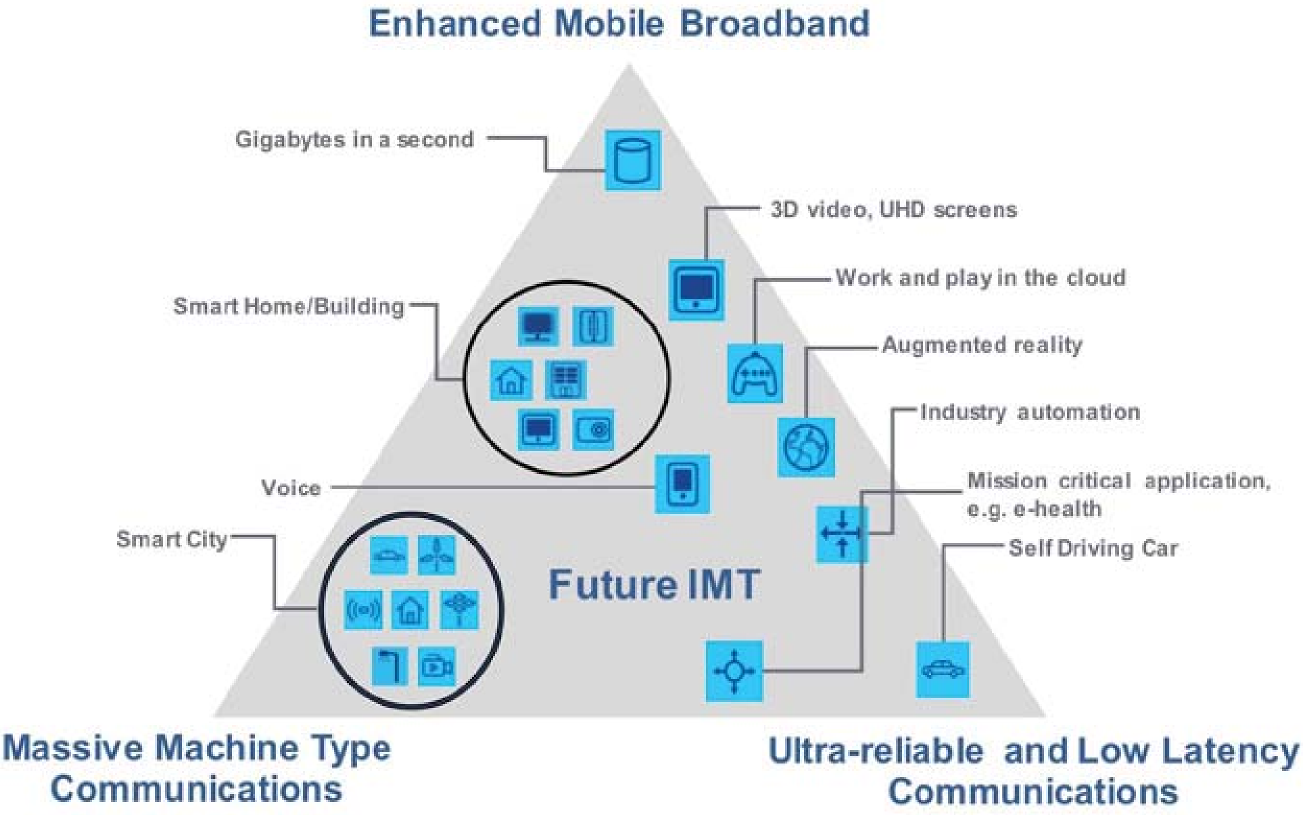
Enhanced Mobile Broadband
Gigabytes in a second
3D video, UHD screens
Work and play in the cloud
Smart Home/Building
Augmented reality
Industry automation
Voice
Mission critical application, e.g. e-health
Smart City
Self Driving Car
Future IMT
Massive Machine Type Communications
Ultra-reliable and Low Latency Communications

FIGURE 1. 5G use cases as defined by ITU for IMT-2020 [19].

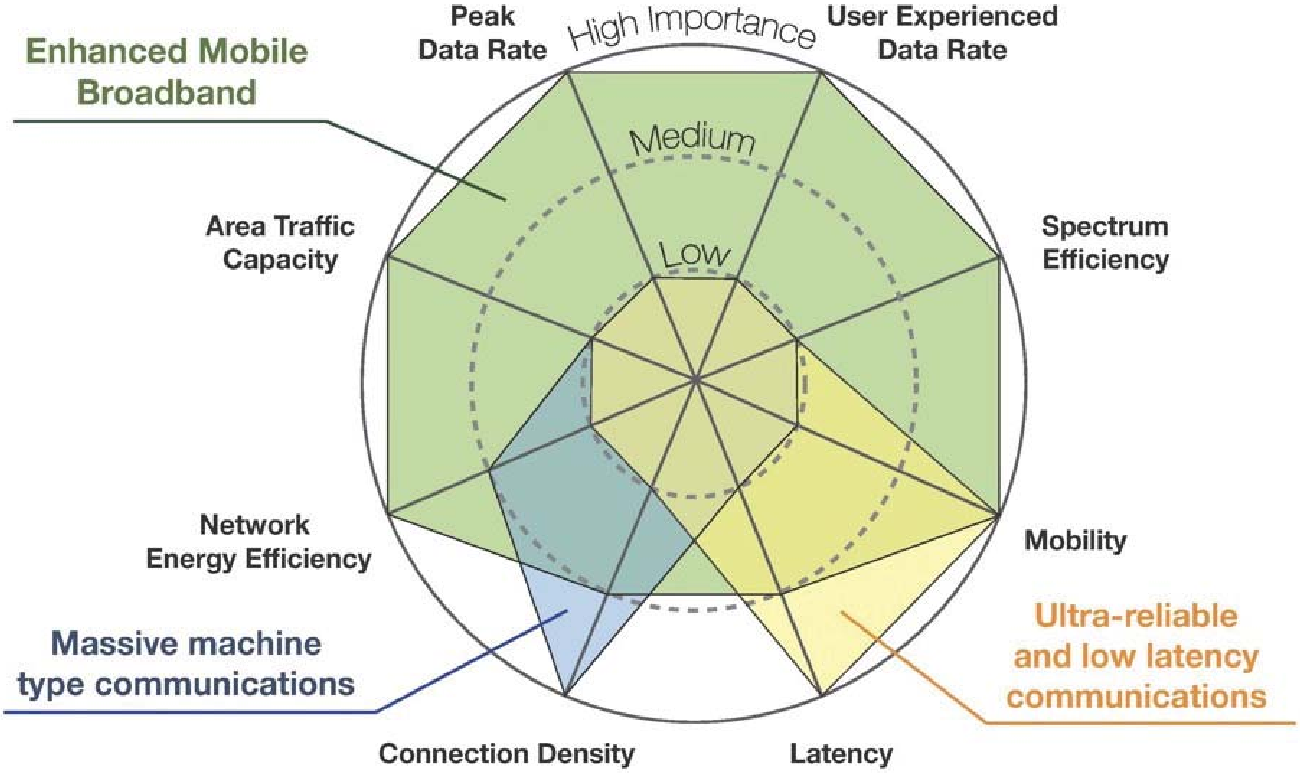

FIGURE 2. Eight key capabilities and their relative importance to 5G use cases [19].

5G Standardization

Development work toward 5G is well under way. Standards bodies are actively working on new 5G mobile technologies to be deployed in the 2020 time frame. This section summarizes the activities and corresponding 5G development timelines for three major standards bodies: ITU, 3GPP, and the Institute of Electrical and Electronics Engineers (IEEE).

Standardization in ITU

ITU is the United Nations agency responsible for promoting worldwide improvement and rational use of information and communication technology. Its members include industry, academia, and standards organizations from more than 190 member nations. The ITU Radiocommunication Sector (ITU-R) works toward worldwide consensus in the use of terrestrial and space radiocommunication services, including mobile communication technologies. Although compliance with ITU-R recommendations is not mandatory, they nevertheless have a high degree of adoption worldwide and hold the status of international standards [23].

International Mobile Telecommunications framework

ITU-R Working Party 5D (WP 5D) is responsible for overall radio aspects of terrestrial mobile systems, referred to as International Mobile Telecommunications (IMT). The purpose of IMT is to provide high-quality mobile services with a high degree of interoperability worldwide. Since 2000, the ITU has developed the IMT standards framework in a manner that parallels cellular generations from an industry perspective. Although ITU-R WP 5D defines the requirements for IMT, it does not develop the actual radio technologies. Rather, candidate radio technologies are submitted for inclusion by external standards bodies, such as 3GPP and IEEE. For this reason, ITU-R WP 5D maintains strong cooperation with the major global standards bodies.

The first family of standards derived from the IMT concept (IMT-2000) aligned with 3G cellular. Radio technologies accepted into IMT-2000 included 3GPP Wideband Code-Division Multiple Access (WCDMA), 3GPP2 cdma2000, and IEEE 802.16 [i.e., Mobile Worldwide Wireless Interoperability for Microwave Access (WiMAX)]. The next generation of IMT standards (IMT-Advanced) aligned with 4G cellular. Radio technologies accepted into IMT-Advanced included 3GPP LTE-Advanced and IEEE 802.16m [i.e., Wireless Metropolitan Area Network (WMAN)-Advanced].

Timeline for IMT-2020

In 2012, ITU embarked on a program to develop "IMT for 2020 and beyond," setting the stage for emerging 5G research activities around the world. The program has since adopted the name IMT-2020 and forms the framework for the next generation of mobile broadband standards. The timeline for the development of IMT-2020 is shown in figure 3 [24]. The IMT 2020 timeline will essentially follow the same process used in the development of IMT-Advanced.

The IMT-2020 program is well under way, with a number of key milestones completed. In September 2015, ITU published its vision of the 5G mobile broadband connected society [19]. This document defined three high-level use cases for 5G, described earlier in this article, which have already been widely adopted by 3GPP and industry in general. In the next phase, the 2016–2017 time frame, ITU-R WP 5D will define in detail the performance requirements, evaluation criteria, and methodology for the assessment of the new IMT radio interfaces. It is anticipated that the time frame for proposals will be focused in 2018. In the 2018–2020 time frame, independent, external groups will evaluate proposals and the definition of the new radio interfaces to be included in IMT-2020 will take place. ITU-R WP 5D also plans to hold a workshop in late 2017 to discuss the performance requirements and evaluation criteria for candidate technologies for IMT-2020, as well as to provide an opportunity for presentations by potential proponents for IMT-2020 in an informal setting. The whole process is planned to be completed in 2020, when a new draft of the ITU-R recommendation with detailed

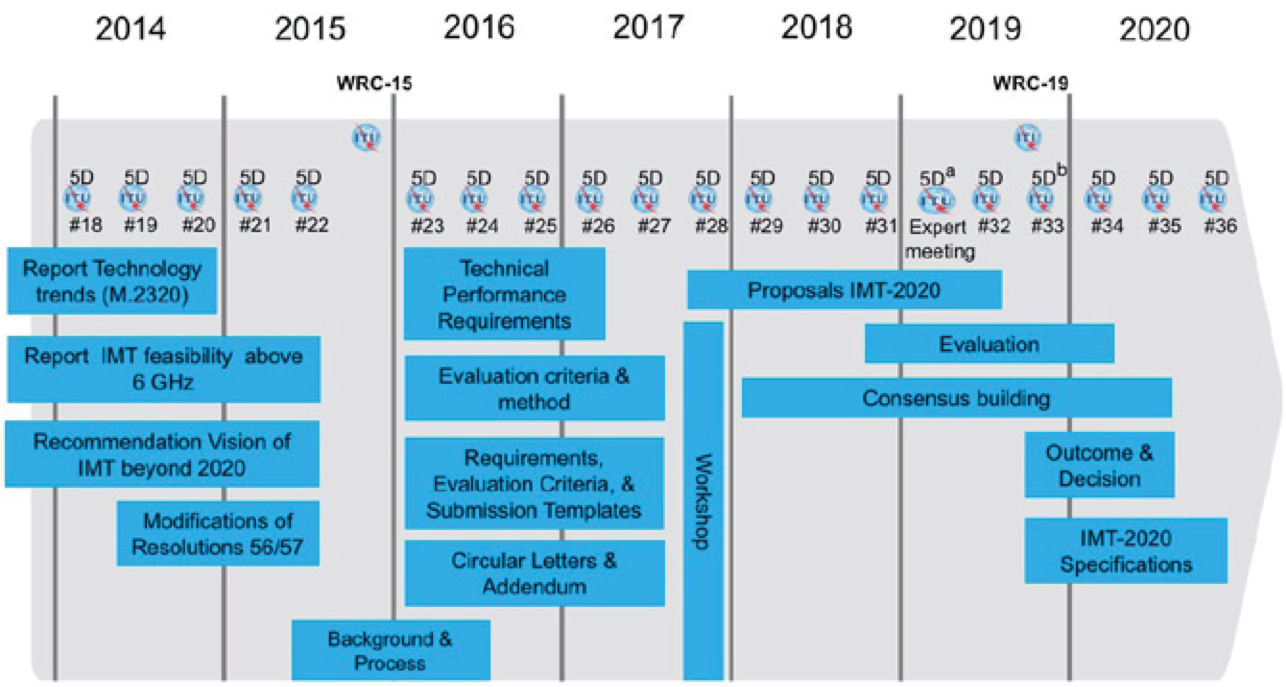
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5Dª Expert meeting
5D #32
5D^b #33
5D #34
5D #35
5D #36
Report Technology trends (M.2320)
Report IMT feasibility above 6 GHz
Recommendation Vision of IMT beyond 2020
Modifications of Resolutions 56/57
Background & Process
Technical Performance Requirements
Evaluation criteria & method
Requirements, Evaluation Criteria, & Submission Templates
Circular Letters & Addendum
Workshop
Proposals IMT-2020
Evaluation
Consensus building
Outcome & Decision
IMT-2020 Specifications

(a) – if needed focus meeting towards WRC-19 (non-Technology), (b) – focus meeting on Evaluation (Technology)

Note: While not expected to change, details may be adjusted if warranted.

FIGURE 3. Detailed timeline and process for IMT-2020 in ITU-R [24].

specifications for the new radio technologies will be submitted for approval within ITU-R [24].

Standardization in 3GPP

3GPP is the international standards body responsible for the development and maintenance of major second-generation (2G), 3G, and 4G cellular standards. The purpose of the organization is to produce interoperable cellular communications standards, as well as studies and reports that define 3GPP technologies. The following technologies are currently maintained and evolved by 3GPP:

- Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS), and Enhanced Data Rates for GSM Evolution (EDGE);
- Universal Mobile Telecommunications System (UMTS), WCDMA, High-Speed Packet Access (HSPA), and HSPA Evolution (HSPA+); and
- LTE, LTE-Advanced, and LTE-Advanced Pro.

These 3GPP technologies are constantly evolving through a series of backward-compatible releases. Since the completion of the first LTE and Evolved Packet Core (EPC) specifications, 3GPP has become the focal point for mobile systems beyond 3G. Therefore, 3GPP is expected to be a critical player in the development of 5G, and their timeline will have a direct influence on the timeline of the emerging 5G market.

3GPP is currently defining a new 5G RAT and corresponding network architecture. These are being developed within 3GPP under the working names “new radio (NR)” and “next-generation (NextGen) architecture,” respectively [25]. In October 2016, 3GPP announced that the new 3GPP system will officially be known by the name “5G” from Release 15 onward [26]. Some initial standardization steps that have been taken to date include the following:

- **SMARTER study item:** In March 2015, 3GPP Technical Specification Group (TSG) System Aspects (SA) began a study item on technology enablers for new 5G services and markets, known as the SMARTER study item [27]. The objective of this study was to develop high-level use cases and identify the related high-level potential requirements to enable 3GPP network operators to support new services and markets in 5G. Phase 1 of the SMARTER study item was completed in March 2016; results are documented in 3GPP Technical Report (TR) 22.891 to be included in Release 14 [28]. A total of 74 use cases were identified. This work prompted four building block studies that grouped the use cases into families with common requirements: massive Internet of Things (IoT), critical communications, eMBB, and network operation. The building block studies were completed in June 2016; results are documented in 3GPP TRs 22.861, 22.862, 22.863, and 22.864 to be included in Release 14 [29]. The results of the SMARTER study will form the basis for a work item to define normative stage 1 requirements for the next-generation 5G system. The work item is scheduled for completion in March 2017; results will be documented in 3GPP Technical Specification (TS) 22.261 to be included in Release 15 [29].
- **Study item on channel model for frequency spectrum above 6 GHz:** The first 5G study conducted by TSG RAN focused on developing new channel models to support high-frequency spectrum from 6 GHz to 100 GHz. The models consider a variety of scenarios including urban, rural, and indoor, as well as the impact of line-of-sight (LOS) versus non-LOS (NLOS). The study was completed in June 2016, and results are documented in 3GPP TR 38.900 to be included in Release 14 [30].
- **Study item on architecture for next-generation system:** In December 2015, 3GPP TSG SA approved a study item to design a system architecture for the next generation of mobile networks. The new architecture will support at least the new 5G RAT(s), the evolution of LTE, and non-3GPP access types and will minimize access dependencies. The study considers new approaches such as NFV and network slicing. The study item was scheduled for completion in December 2016; results will be documented in 3GPP TR 23.799 to be included in Release 14 [31].
- **Study item on scenarios and requirements for next-generation access technologies:** In December 2015, 3GPP TSG RAN approved a study item to develop deployment scenarios and requirements of next-generation access

technologies. The study identifies 12 deployment scenarios that are more diverse than those originally envisioned for legacy RATs, such as LTE and its predecessors. It also identifies key performance indicators (KPIs) and other requirements for 5G NR. The bulk of the study was completed in September 2016 to provide guidance to the ongoing technical work being performed in the RAN working groups. However, the study item will remain open until March 2017 to match the IMT-2020 timeline and ensure all IMT-2020 requirements are captured. Final results are documented in 3GPP TR 38.913 to be included in Release 14 [32, 4].

- **Study item on NR access technology:** In March 2016, 3GPP TSG RAN approved a study item to develop the 5G NR access technology capable of meeting the broad range of use cases defined for 5G. The study seeks to develop a single technical framework capable of addressing all usage scenarios and requirements defined in TR 38.913 for eMBB, mMTC, and URLLC, with an emphasis on forward compatibility. The study is scheduled for completion in March 2017; results will be documented in 3GPP TR 38.912 to be included in Release 14 [1].

5G standardization activities in 3GPP will continue through 2020 and beyond, as described next.

Emerging 3GPP standardization timeline

In March 2015, 3GPP announced a tentative standardization timeline for 5G based on the ITU work plan timeline for IMT-2020 [33]. Since then, a more detailed timeline has come into focus as study items have commenced and completed, and as the 3GPP TSGs coordinate for the initial release of 5G. The timeline shown in figure 4 is a composite from multiple sources.

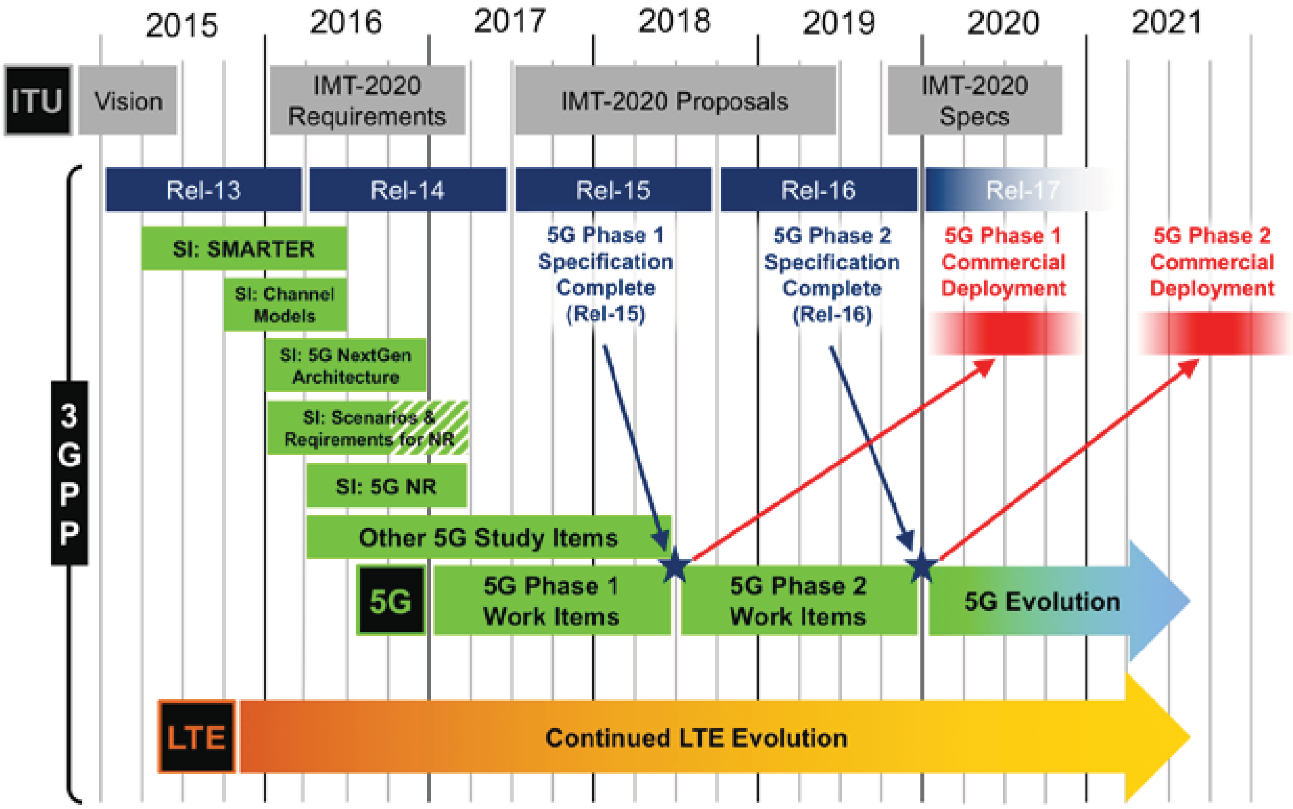
2015
2016
2017
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2021
ITU
Vision
IMT-2020 Requirements
IMT-2020 Proposals
IMT-2020 Specs
3GPP
Rel-13
Rel-14
Rel-15
Rel-16
Rel-17
SI: SMARTER
SI: Channel Models
SI: 5G NextGen Architecture
SI: Scenarios & Reqirements for NR
SI: 5G NR
Other 5G Study Items
5G Phase 1 Specification Complete (Rel-15)
5G Phase 2 Specification Complete (Rel-16)
5G Phase 1 Commercial Deployment
5G Phase 2 Commercial Deployment
5G
5G Phase 1 Work Items
5G Phase 2 Work Items
5G Evolution
LTE
Continued LTE Evolution

FIGURE 4. Emerging 5G standardization timeline for 3GPP. (Figure is a composite from [34] and [35] that includes additional data from various sources.)

The initial 5G study items in TSG SA and TSG RAN commenced in 2015 and 2016, as described previously. These initial 5G study items will be included in 3GPP Release 14. This work is carried out in parallel with ongoing LTE work. At the 3GPP plenary meeting in June 2016, the TSGs agreed on a work plan for the first release of 5G in 3GPP Release 15, including a clear work division between the TSGs [25].

5G work items were scheduled to begin in December 2016 for TSG SA and March 2017 for TSG RAN. The Phase 1 5G work items will fall into Release 15, with planned completion in June 2018. Additional 5G study items will continue during Release 15 in support of Phase 2. Subsequently, the Phase 2 5G work items will fall into Release 16, which will be completed around December 2019 in time for the final submission to ITU for IMT-2020. Phase 1 commercial deployments are expected to begin in 2020, followed by Phase 2 deployments in the 2021–2022 time frame. However, early pre-5G mmWave deployments may emerge in limited markets, such as South Korea or the United States, before 2020.

For example, Verizon Wireless has announced its plans to pilot a 28-GHz mmWave deployment in the United States for fixed wireless applications starting in 2017 [36]. To support this effort, the Verizon 5G Technology Forum (V5GTF)—an industry consortium led by Verizon—published an open radio interface specification in July 2016 [37]. The Verizon specification uses an OFDM-based PHY similar to time-division LTE (TD-LTE) with enhanced beamforming for operation in 28 and 39 GHz mmWave spectrum. However, with the initial focus on fixed wireless, the first release does not support user mobility. The Verizon specification can be considered pre-5G in the sense that it supports new mmWave capabilities beyond 4G but does not address all the use cases and associated requirements for 5G. The Verizon specification is expected to be incompatible with the eventual 3GPP 5G standard, potentially leading to market fragmentation [38].

3GPP phased approach to 5G standardization

3GPP TSG RAN will take a two-phased approach to developing the new 5G RAT [35]. The Phase 1 standard will define a new, non-backward-compatible 5G RAT. A subset of prioritized features and use cases will be addressed in Phase 1 to allow for early commercial deployments targeted for the year 2020. The Phase 2 standard will implement the full set of features and use cases necessary to meet the requirements for 5G. An initial proposal will be submitted to ITU as a candidate radio interface technology for IMT-2020 by the June 2019 submission deadline. The Phase 2 standard will later form the final submission around December 2019. The Phase 1 standard will be designed for forward compatibility with Phase 2 [35]. Forward compatibility means that Phase 1 must be designed from the beginning to optimally accommodate all of the features and use cases expected to be added later in Phase 2, even though those features are not yet fully implemented. Although the forward-compatibility requirement may sound straightforward, it represents a fundamental shift from the normal 3GPP standardization process, which historically has focused on a series of backward-compatible releases.

While prioritization of features between the two phases has been a topic of much debate, it is clear that the 5G Phase 1 standard will support tight interworking with LTE to simplify initial rollout. The phased approach and tight interworking with LTE means that elements of the LTE system architecture may persist in 5G deployments for some time to come. This implies that current and future work on LTE, LTE-Advanced, and LTE-Advanced Pro networks and technologies may have direct applicability to eventual 5G network deployments.

Standardization in IEEE

Initial 5G standards activities within the IEEE suggest that they do not intend to be a direct competitor with organizations like 3GPP on the radio interface between the RAN and the user equipment. Instead, IEEE has begun developing complementary technologies to support other communications requirements within the 5G ecosystem. In 2016, IEEE established two new working groups related to 5G: IEEE 1914 and IEEE 1918.

IEEE 1914 is the Next Generation Fronthaul Interface Working Group. This working group is currently developing two standards: the 1914.1 standard for packet-based fronthaul transport networks and the 1914.3 standard for radio over Ethernet encapsulations and mappings [39, 40]. These standards focus on the fronthaul interface within the RAN between baseband units (BBUs) and remote radio heads (RRHs) to support novel RAN architectures like C-RAN, and antenna techniques like MMIMO and coordinated multi-point (CoMP) transmission and reception. The projected completion dates for these standards are August 2018 for 1914.1 and October 2017 for 1914.3.

IEEE 1918 is the Tactile Internet Working Group. This working group is currently developing the 1918.1 standard, which defines a framework for the Tactile Internet [41]. The purpose of this framework is to establish a basis for the rapid development of the Tactile Internet as a 5G and beyond application, with the expectation of additional IEEE 1918 standards to follow. The projected completion date for the 1918.1 standard is October 2018.

With respect to IMT-2020, IEEE may seek to expand the role of WLAN in 5G as a complementary radio interface for next-generation HetNets. In September 2016, the IEEE 802.11 working group sent a liaison statement to 3GPP TSG RAN and TSG SA inviting them to consider the use of IEEE 802.11-based WLAN in unlicensed spectrum as a complementary means of meeting the performance requirements of IMT-2020, potentially leading to inclusion in a joint submission to IMT-2020 [42]. This approach would be a logical extension of the increasing level of interworking between LTE and WLAN in recent standards releases. WLAN is already widely used in 3GPP networks for high data rate offloading.

Recent enhancements in radio-level interworking have increased the efficiency of these networks. Enhancements include LTE-WLAN Aggregation (LWA) and LTE WLAN Radio Level Integration with IPsec Tunnel (LWIP) in 3GPP Release 13, with further enhancements in 3GPP Release 14. Although 3GPP declined to make a decision at the September 2016 plenary meeting, the concept of a potential joint submission could represent a novel approach to IMT-2020. In contrast, previous generations of IMT saw IEEE in competition with 3GPP, with the submission of the IEEE 802.16 WiMAX family of standards to IMT-2000 and IMT-Advanced as a direct competitor in the 3G and 4G markets.

Conclusion

This article provided an introduction to major technology trends in the emergence of next-generation 5G mobile networks. These networks are expected to see initial commercial deployment starting around the year 2020. Early 5G standardization activities in the ITU, 3GPP, and IEEE were addressed.

For further information on the latest developments in 5G, the interested reader is directed to the following resources. ITU publications for IMT-2020 can be found on the IMT-2020 web page [24]. Notable documents include the ITU vision for IMT-2020 [19] as well as the technical performance requirements for IMT-2020 (scheduled for completion in February 2017). The 3GPP web site (www.3GPP.org) is the most direct source for 3GPP-related technical information. 3GPP press releases provide high-level summaries of ongoing standards activities and often include links to more detailed further reading. The latest versions of the 3GPP TR and TS documents mentioned in this article can be accessed there as well. Information on the IEEE 1914.1, 1914.3, and 1918.1 standards can be found in the approved project authorization request (PAR) documents [39, 40, 41] and the corresponding working group web pages. Lastly, the Verizon mmWave specification is available on the V5GTF website (www.5GTF.org). This pre-5G specification defines layers 1 to 3 of an open radio interface using a document structure similar to that of LTE.

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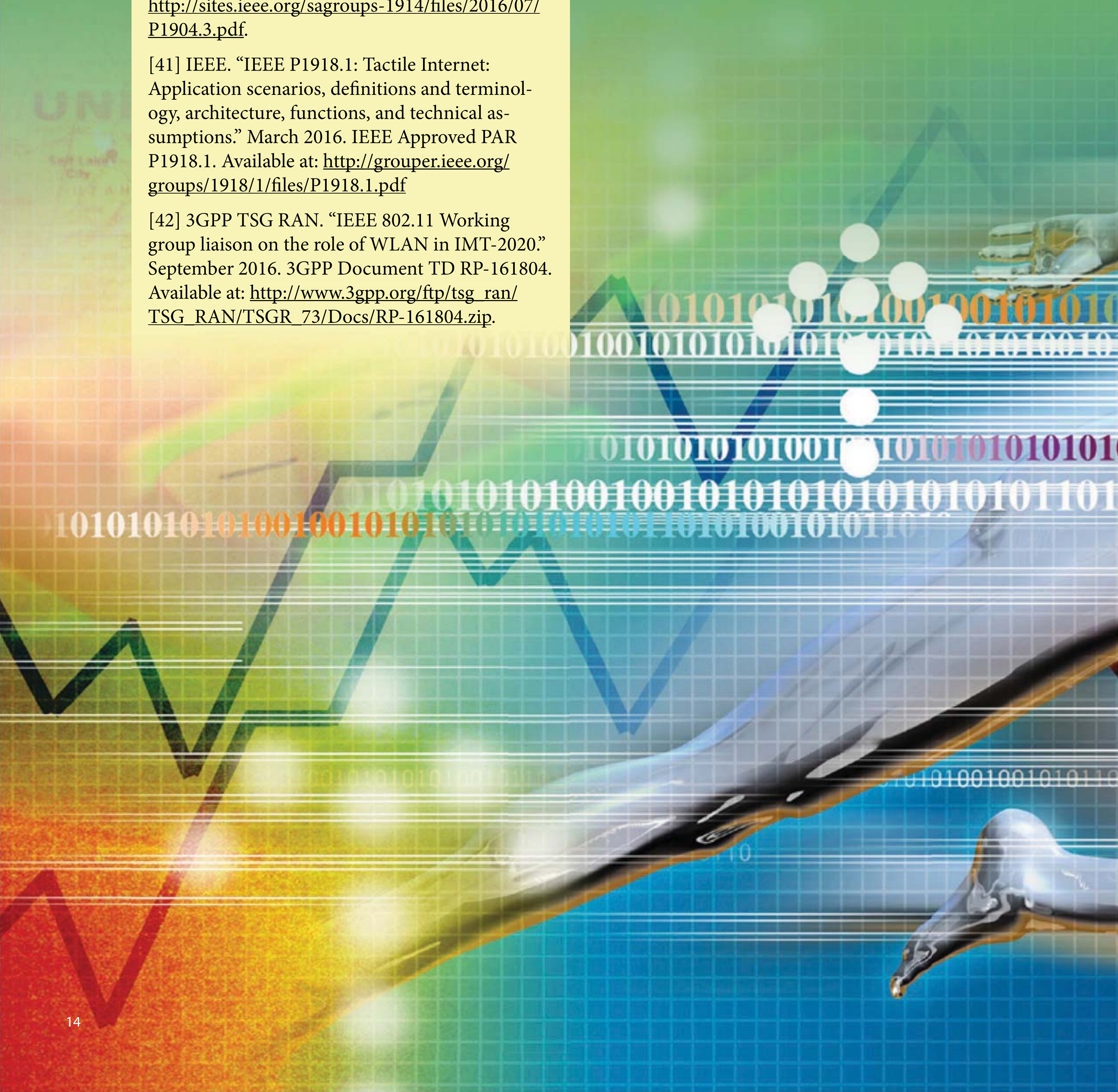

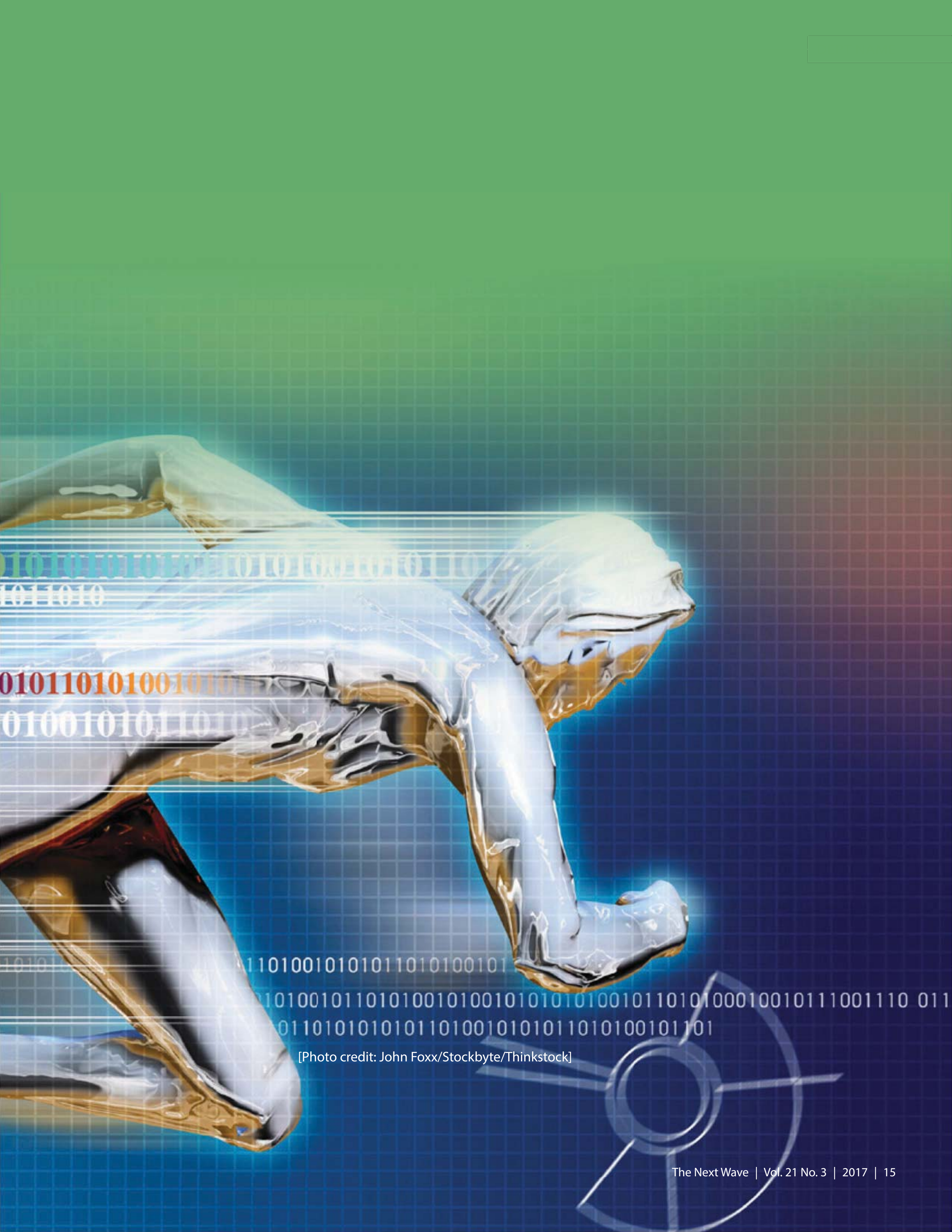

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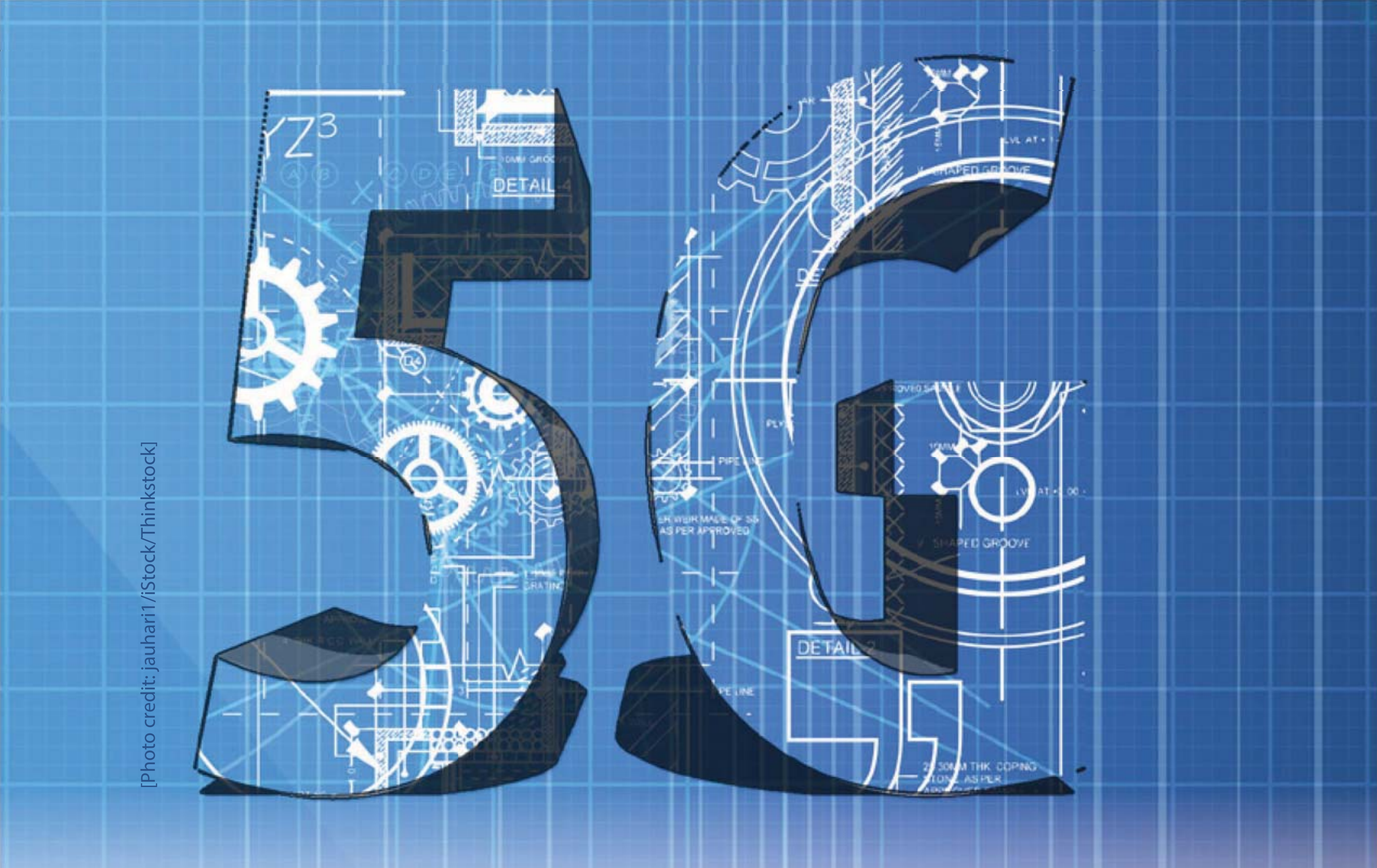

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Virtualizing the 5G Architecture

Staff Writer

Virtually changing the 5G architecture

Virtualization is set to play a major role in the evolution of the fifth-generation (5G) core network. According to industry experts, 5G will use software-centric networking technologies such as software-defined networking (SDN) and network functions virtualization (NFV), and will be natively cloud based. If correct, this will represent a major transition in system architecture and will require much greater collaboration across the networking ecosystem. The push to incorporate more cloud- or software-based components is driven by the need for greater flexibility and scalability to respond to the demands of radio access technologies that offer more bandwidth, reduced latency, and stringent quality of service (QoS) requirements. The new 5G core network must be adaptable and better equipped to handle various devices and manage capacity in near-real time. Mobile network operators see the advances in cost and efficiency that virtualization brings to other market segments and will use the emerging 5G technology to determine if these same advances can benefit the mobile market [1, 2].

SDN and NFV are two key architecture concepts in development to support the flexibility and mobility demands of the 5G network infrastructure. Virtualizing network functions that were previously implemented in hardware will allow providers to introduce new features and integrate new standards at a faster rate. SDN/NFV provides an avenue for providers to decentralize their networks, thereby increasing flexibility and reducing latency. Two areas where SDN/NFV will benefit 5G networks, and in some cases even fourth-generation (4G) mobile technology, are network slicing and cloud-radio access network (C-RAN).

Network slicing

Network slicing would promote end-to-end mobile network virtualization by "slicing" the network into virtual channels. These virtual channels would be autonomous and encompass a set of resources—physical or virtual—including bandwidth on a network link, processing capacity of servers, processing capacity of network elements, as well as operations support system (OSS) and business support system (BSS) processes. Operators could then use these channels to dynamically devote the appropriate network resources to create a "lane" in the network specifically designed for a particular use or service. This would accommodate the many use cases being put forth for 5G. The operator-led Next Generation Mobile Networks (NGMN) Alliance has sought to define categories of 5G use cases (i.e., service types) that have distinct performance characteristics and commercial potential. In a 2015 white paper, the NGMN listed eight application categories for 5G [3, 4, 5]:

1. Broadband access in dense areas,
2. Broadband access everywhere,
3. Higher user mobility,
4. Massive Internet of Things,
5. Extreme real-time communications,
6. Lifeline communications,
7. Ultra-reliable communications, and
8. Broadcast-like services.

Each of these service types demand different network requirements that are determined by the types of traffic being sent and even the types of devices sending the traffic. For example, someone downloading cat videos will not have the same bandwidth or low latency requirements as a doctor in Los Angeles performing surgery virtually on a patient in Mumbai. The end-to-end notion of network slicing could be key to 5G's ability to effectively accommodate all of these disparate use cases.

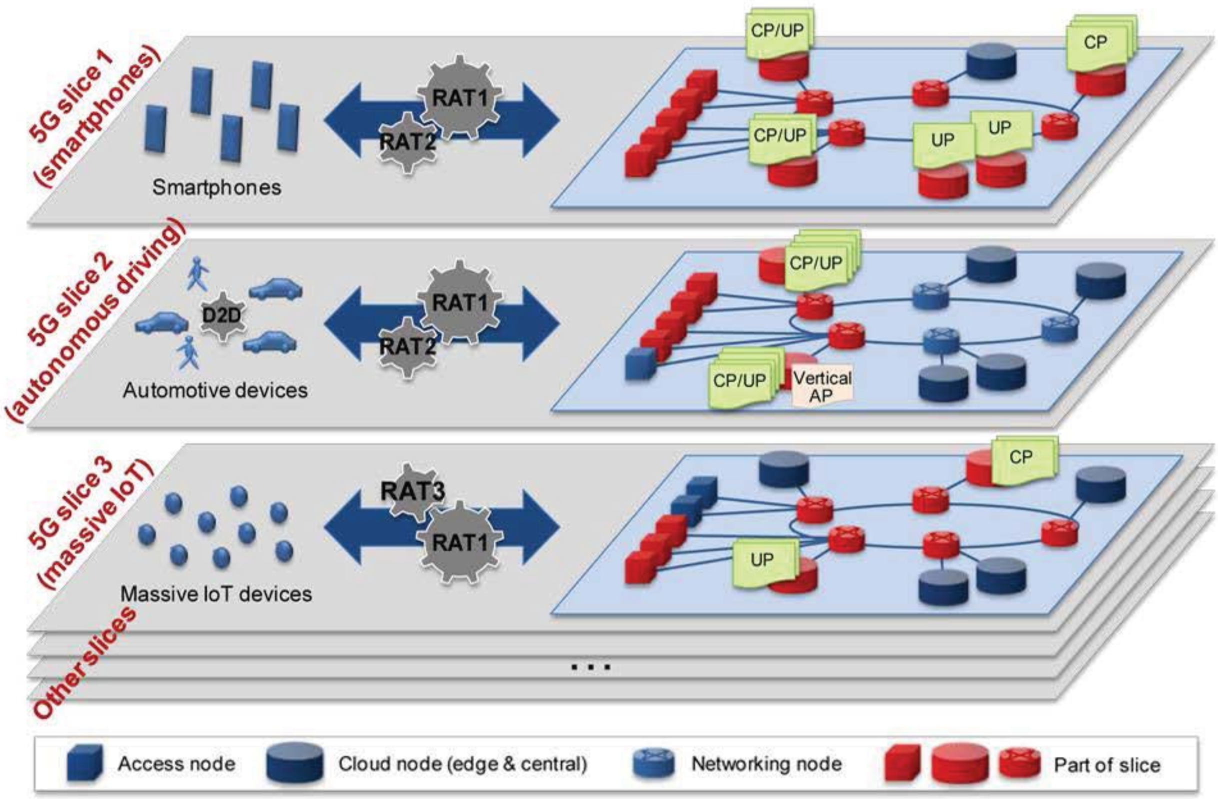
5G slice 1 (smartphones)
Smartphones
RAT1
RAT2
CP/UP
CP
UP
5G slice 2 (autonomous driving)
D2D
Automotive devices
Vertical AP
5G slice 3 (massive IoT)
RAT3
Massive IoT devices
Other slices
...
Access node
Cloud node (edge & central)
Networking node
Part of slice

FIGURE 1. 5G's incorporation of SDN and NFV would allow network slices to be created dynamically and deployed as needed to accommodate a variety of scenarios [2].

The Open Networking Foundation, in an April 2016 white paper, called out SDN's ability to support multiple services over a common architecture as a key enabler for network slicing. SDN also allows for slices to be created dynamically and deployed as needed to accommodate a variety of scenarios (see figure 1). Currently, 4G mobile networks prioritize traffic to get a similar effect, but with more rigidity and limitations. However, as 4G networks incorporate SDN and NFV, network slicing will become an option.

C-RAN

There are more than six million base stations (excluding small cells) deployed worldwide across approximately five million different cell sites serving close to four billion users. The surge in demand for connectivity has network operators searching for ways to shrink their network footprint, lower operational expenditures (OPEX), and still meet users' demand for access. C-RAN meets these requirements and has either been implemented or trialed by several operators including Verizon, AT&T, KT (South Korea), and China Mobile. Radio base stations currently depend on special purpose-built hardware deployed at the cell site. The baseband processing unit (BBU) is the part of the RAN that is responsible for managing the radio functions (or all functions that require an antenna). The BBU is one of the parts of the RAN that can be moved to a central location, creating a pool of BBUs to serve multiple base stations. C-RAN aims to centralize and virtualize baseband processing to reduce cell site costs and enable coordinated scheduling of resource blocks across a coverage area [6].

Figure 2 illustrates the evolution from the classic RAN model to a C-RAN setup. On the left, the classic model has the BBU deployed at the cell site connecting to the core network over IP/Ethernet transport. Any coordination between cell sites takes place over the X2 interface, which allows two sites to communicate. In a C-RAN architecture, the BBUs are pooled at a location away from the cell site. Pooling BBUs negates the need for the X2 interface as communications between cell sites now takes place internally. This is one of the reasons for the increased performance in C-RANs. The C-RAN model also makes updating the waveform and protocols easier as it only requires a software upgrade at the centralized BBU and not at each individual cell site

The move to a C-RAN architecture increases the flexibility of the network by allowing providers to, in theory, even change the types of RANs used—from 3G to 4G. For instance, in an area that has a mix of 3G and 4G users, operators can rebalance radio frequency resources by shifting more resources to 4G when 4G

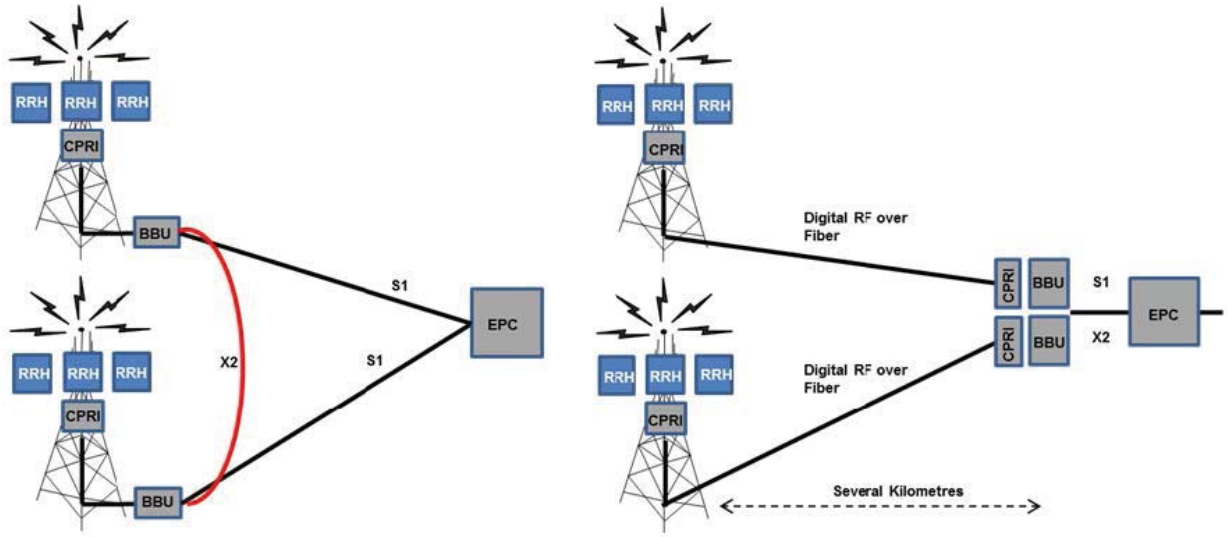

FIGURE 2. Unlike the traditional RAN model (on the left), C-RAN technology (on the right) pools the BBUs at a location away from the cell site offering an increase in performance and simpler upgrade path [6].

users are prevalent in the covered area. This shuffling of resources ensures that there is sufficient capacity for subscribers. C-RAN will also enable RAN-as-a-Service (RaaS), which will allow operators to rent RAN capacity to other operators.

Conclusion

On the face of it, virtualizing the 5G architecture seems like a necessary step towards preparing for the low latency requirements associated with 5G services. However, there are many uncertainties around 5G and a lack of visibility into what 5G will actually become through the standardization process, and at which phase different performance requirements will be supported or required. Phase II, the phase that is expected to meet International Mobile Telecommunication system for the year 2020 (IMT-2020) requirements, is expected in 2020. However, early versions or “pre-5G” offerings could be on the market before the final standard is approved. So, while these pre-5G solutions will have some 5G functionality, they will not field the full complement of improvements offered by an approved 5G system. For this reason, it is unclear to what degree virtualization techniques like C-RAN and network slicing will need to be implemented. It may come down to what the industry leaders in 5G implement in their “pre-5G” networks that will decide what a virtual 5G network will look like and when we can expect to see one.

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5G and the Auto

Staff Writer

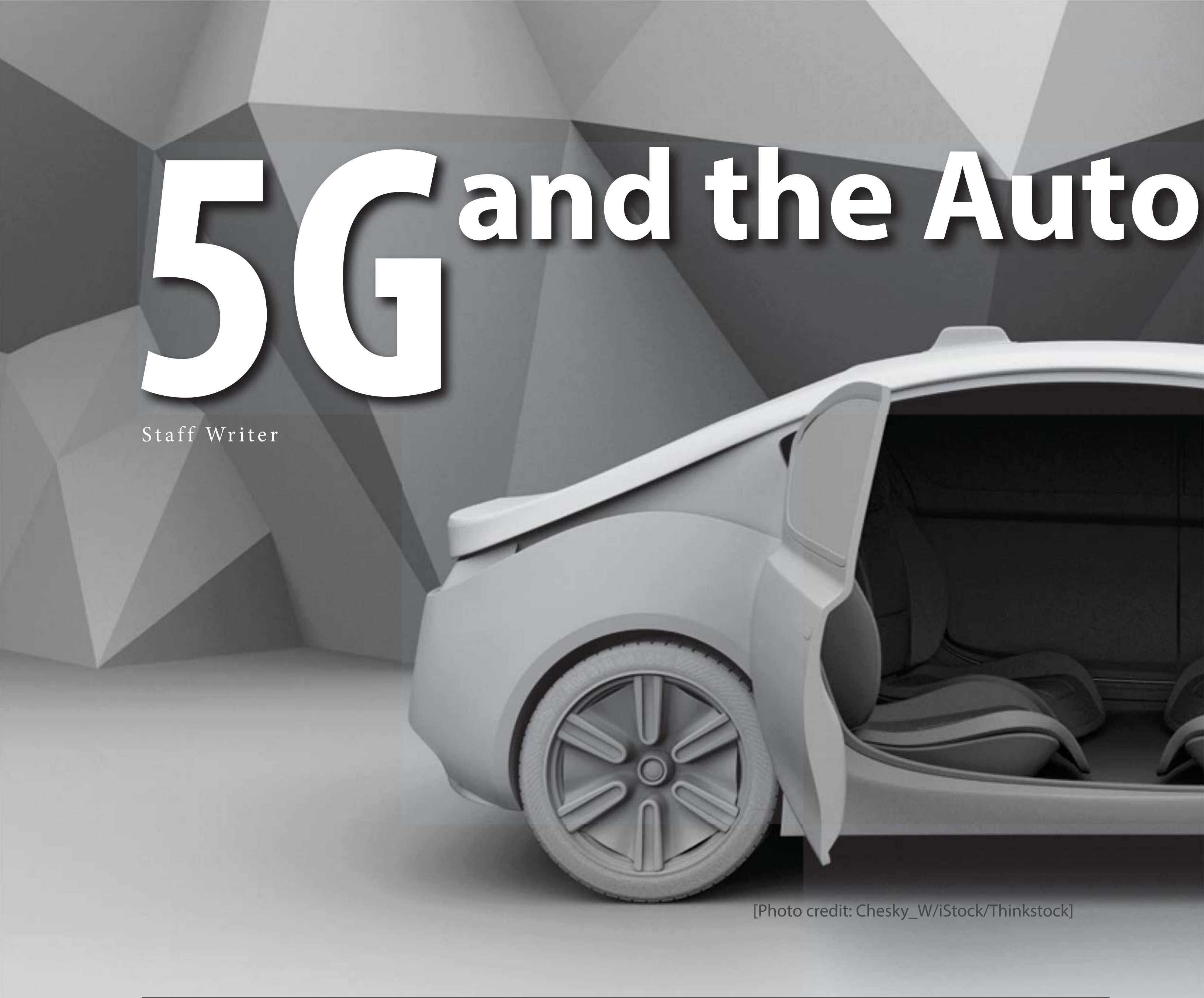

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Industry stakeholders envision 5G as a key enabler that allows network connectivity in vehicles to shift in status from an optional accessory to a core feature that supports not only the individual vehicle, but also communication with other vehicles and sensors that inform traffic, parking, and navigation—while also ensuring passenger safety and data security. For consumers, a connected vehicle provides a growing number of features and services that make the driving experience safer, convenient, and less costly. 5G connectivity will enable information from in-car sensors to continuously be passed to the cloud. By sharing information and alerts about micro-level weather, road temperature, surface conditions, and violent breaking ahead, more efficient and consistent traffic flows will be achieved that reduce congestion and emissions. The aggregated and interpreted data will provide more informed driving information, as well as alert and activate onboard safety systems to prevent accidents [1].

motive Industry

Autonomous vehicles

Autonomous vehicles—also referred to as driverless or piloted vehicles—are predicted to hit the market by 2020, but stable 5G infrastructure will play a key role, according to a white paper by ABI Research [2]. Estimates indicate that 5G latency could be as low as one millisecond (ms) over-the-air, and 5 ms end-to-end, enabling the following automotive use cases:

- Broadband multimedia streaming (driverless vehicles as mobile living rooms).
- Cloud services for vehicle lifecycle management, apps, security, and over-the-air updates (cloud-to-vehicle).
- Capturing or uploading huge volumes of sensor data for real-time traffic, weather, parking, and mapping services (vehicle-to-cloud).
- Cooperative mobility: low latency vehicle-to-vehicle and vehicle-to-infrastructure for active safety and autonomy [redundancy for advanced driver assistance systems (ADAS)] [2].

The current ADAS being delivered on 2016 vehicles already facilitate SAE Level 1 (see figure 1) and are beginning to incorporate features that would be considered Level 2. However, Level 4 and 5 capabilities may not be that far away. In October 2015, Robot Taxi, a joint venture between Japanese mobile Internet company DeNA and vehicle technology developer ZMP, announced that it would offer driverless transportation to about 50 people in an area near Tokyo. Its goal is to commercialize the service by 2020, in time for the Tokyo Olympics [1]. While Robot Taxi is shooting for full automation (Level 5) in time for the games, it is likely that the use of such vehicles will initially be limited to shuttling passengers between Olympic venues. However, this venture is particularly notable because the technology is brand-agnostic and can be retrofitted to any vehicle [4].

Clearly, experimentation with autonomous vehicles is increasing, and 2020 as a date for some form of commercial implementation is certainly feasible from a technology perspective. Probably the best-known self-driving car project belongs to Google, which was started in 2009 and has clocked more than two million miles on public roads to date [5]. However, Google is not alone; Tesla, BMW, Audi, Mercedes, and most recently GM, have all showcased self-driving concept cars and demonstration projects. In mid-October 2016, Tesla announced that all cars currently being produced in their factories would include the hardware needed for full self-driving capability at a level of safety far greater than that of a human driver. However, the company added that the technology first needed to be tested and calibrated via “millions of miles of real-world driving” before the hardware would be activated on consumer vehicles [6]. In addition to traditional car manufacturers, companies such as Uber and Chinese search giant Baidu are also working on autonomous technology and self-driving cars [1].

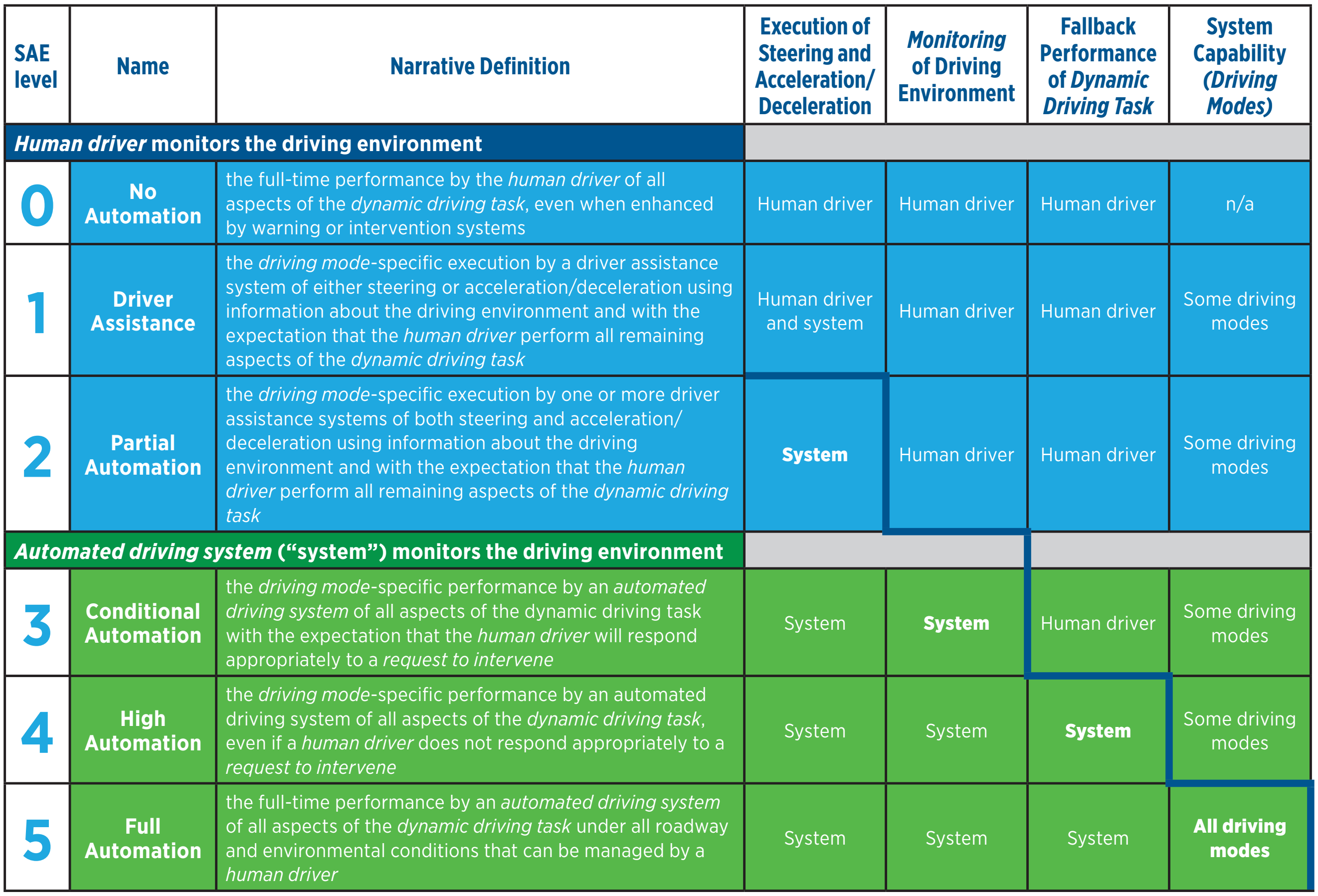

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* (“system”) monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

FIGURE 1. SAE Levels of automation. The Society of Automotive Engineers (SAE) has defined levels of automation to clarify what role (if any) drivers have in operating a vehicle while a driving automation system is engaged. These levels are intended to establish a consistent framework that can be used across industries as the dialogue about autonomous vehicles continues. (Figure credit: SAE International J3016 [3].)

The motivations for creating an autonomous vehicle are beyond just technology. It's about reducing emissions through better fuel consumption, as well as addressing the demographic changes of an aging population that increase, rather than decrease, the potential for human error-induced accidents. It's also about leveraging the convergence of the shared economy and urban living, where young and old people no longer feel the need to own a car if there is a cost-effective and convenient alternative, such as Zip Car rentals, or on-demand ride-sharing services such as Uber [1].

Looking forward

Geographical coverage will be a key condition for 5G to have any relevance in the automotive sector. Initial 5G coverage can be supplemented by 4G and Wi-Fi connectivity on phones and other devices while the infrastructure is being built up, but these multimode, multiconnectivity solutions will not suffice for critical automotive use cases relying on the unique capabilities of 5G in terms of latency, reliability, and security [2]. Even once 5G is fully deployed, the adoption of self-driving technology will likely play out differently in the various markets in different regions since the forces shaping it are diverse at both the global and local level [1].

Government and industry cooperation

The continuous progression of ADAS-enabled cars and the gradual adoption of the autonomous vehicle will significantly reduce, and possibly eliminate, the number of crashes. This could, in turn, allow the removal of some regulations that relate to safety considerations, such as crumple zones, bumpers, and airbags. It also means that a review of laws relating to driving age, drunk driving, and speed restriction enforcement may be required, but not until all vehicles are compliant [1].

In September 2016, the US Department of Transportation (DOT) released the Federal Automated Vehicles Policy for highly automated vehicles (HAVs), or those intended to operate at Levels 3 to 5 as defined by SAE. The document—which is currently intended as guidance rather than formal policy—lays out standards for safe design, development, and testing of HAVs before they are commercially sold or operated on public roads. It also proposes guidelines for state governments to ensure a consistent national framework for regulation of motor vehicles with all levels of automated technology [7]. DOT's National Highway Traffic Safety Administration released additional nonbinding guidance in October 2016, outlining best cybersecurity practices for motor vehicle manufacturers and individuals and organizations involved in developing self-driving technology. The guidance aims to make cybersecurity a top priority for the automotive industry and proposes layered solutions to ensure that automated driving systems are designed to take appropriate and safe actions, even when an attack is successful [8].

A challenge yet to be addressed is that, historically, car manufacturers have completely controlled the design and development of vehicles. The advent of computers and software that effectively become the "mind" of the car means that manufacturers could lose control to technology and software companies, and yet still remain liable for any issues or catastrophes related to the car. It also remains to be seen how much and what type of data car manufacturers and network providers would be expected to share to improve overall safety and security of connected vehicles [1].

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2000–2014 REPORT

TOTAL DIRECT SALES
from new products and services

TOTAL ECONOMIC OUTPUT NATIONWIDE
including direct, indirect, and induced impact

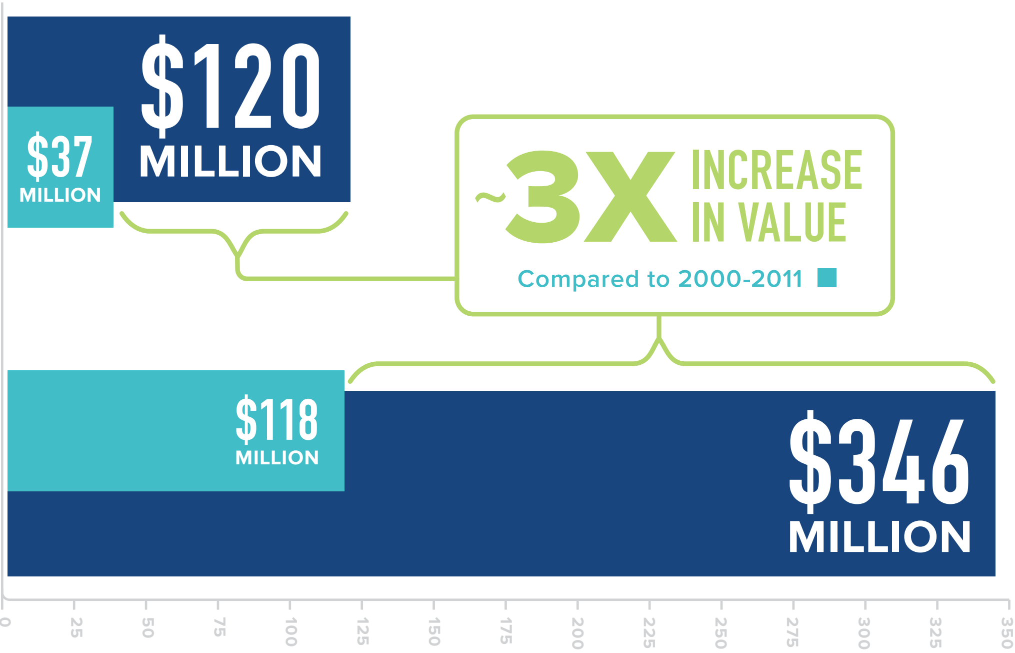

JOBS CREATED
or retained

1,330

SOURCE: *National Economic Impacts from DoD License Agreements With U.S. Industry*, TechLink and UC Business Research Division.

THE RESULTS

NSA Technology + **Technology Transfer** = **Economic Growth** ⇒ **National Security**

1G
2G
3

symmetry

MDPI

Article

IoT's Tiny Steps towards 5G: Telco's Perspective

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Abstract: The numerous and diverse applications of the Internet of Things (IoT) have the potential to change all areas of daily life of individuals, businesses, and society as a whole. The vision of a pervasive IoT spans a wide range of application domains and addresses the enabling technologies needed to meet the performance requirements of various IoT applications. In order to accomplish this vision, this paper aims to provide an analysis of literature in order to propose a new classification of IoT applications, specify and prioritize performance requirements of such IoT application classes, and give an insight into state-of-the-art technologies used to meet these requirements, all from telco's perspective. A deep and comprehensive understanding of the scope and classification of IoT applications is an essential precondition for determining their performance requirements with the overall goal of defining the enabling technologies towards fifth generation (5G) networks, while avoiding over-specification and high costs. Given the fact that this paper presents an overview of current research for the given topic, it also targets the research community and other stakeholders interested in this contemporary and attractive field for the purpose of recognizing research gaps and recommending new research directions.

Keywords: 5G mobile communication; Internet of Things; applications classification; performance requirements; enabling technologies

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1. Introduction

Telecom operators (telcos) had the most power and influence over business in the information and communication technology (ICT) industry during past decades. This dominance was the result of owning and provisioning communication infrastructures which nowadays have become more of a commodity than a luxury. Telco's revenue streams were mainly based on the provisioning of traditional services, such as voice calls and short message services (SMS). Recent work of regulatory agencies and the appearance of alternative service providers have led telecom operators to form the opinion that alternative service providers have conflicting interests and provide competitive services, thus decreasing telco's revenue from traditional services [1]. However, the latest econometric analysis presented in [2] has shown that telecom operators and alternative service providers have aligned interests and their collaboration could be favorable to both parties. The interests of alternative service providers and telcos are not inevitably conflicting, since the economic growth of the alternative service providers are positively correlated with telco revenues and vice versa.

The development of a digital society has changed the traditional value chain and introduced new issues for telcos as they seek a way how to monetize new digital services [3]. These services are diversified across various domains of industry, such as agriculture, construction, utilities, transportation, healthcare, finance, etc., and delivered to customers through connected devices building thereby the concept of Internet of Things (IoT).

IoT can be defined as an interconnected network of things/objects that are able to interact with each other and cooperate with other things/objects through wireless and wired connections in order to create new services/applications for the benefit of society. In this way, IoT brings almost limitless benefit's, which have the potential to radically change our daily life by saving time and resources while creating possibilities for growth and innovation [4]. IoT has disruptive potential in almost every application domain, which has created many challenges that need to be faced when implementing IoT-based solutions, such as prevailing over obstacles generated by the fragmentation of IoT, both in terms of application domains and in terms of technologies. Therefore, recognizing all potential IoT applications while having in mind the development of technology and the requirements of individuals, businesses, and society as a whole is quite challenging.

Telcos now have the opportunity to seize a share of the value that is generated by IoT implementation. The size of this share will depend on telco's role in the value chain that ranges from being a traditional provider of communication infrastructure to being an end-to-end solution provider [3]. In order to monetize IoT, telcos will have to address many challenges which can be summarized as follows: (1) strategic challenges relating to decisions on future directions; (2) business challenges relating to successful management, investment, partnerships; and (3) technical challenges relating to changing connectivity and performance requirements. This paper focuses on the technical challenges since connectivity and performance requirements of IoT objects/things cannot be fulfilled using existing cellular networks that limit numerous IoT applications. In order to overcome issues associated with the current cellular networks, new types of technologies are being introduced leading towards the fifth generation (5G) network [5–7].

The architecture of the 5G network has to seamlessly integrate the requirements of diverse IoT applications: from delay-sensitive video applications to ultra-low latency, from high-speed entertainment applications in a vehicle to mobility on demand for connected objects and from best effort applications to reliable and ultra-reliable ones for health and safety [8]. A full understanding of emerging IoT applications and the variability of their performance requirements can serve telecom operators as input for specifying 5G enabling technologies. These technologies should be flexible and scalable to meet the aforementioned requirements. Since IoT applications sometimes demand extreme requirements, the 5G network must simultaneously satisfy all of them, which can lead to over-specification and high cost. In order to avoid this, telecom operators first have to adequately classify IoT applications to facilitate the selection of 5G enabling technologies being capable to efficiently meet their performance requirements.

The 5G classification concept includes three different service classes [9], i.e., (1) extreme mobile broadband (xMBB); (2) massive machine-type communications (mMTC); and (3) ultra-reliable machine-type communications (uMTC). Nevertheless, this classification concept can be considered insufficient to properly select 5G enabling technologies to meet the diverse requirements of IoT applications. Furthermore, it will be challenging to classify the emerging IoT applications given that there is many criteria for their categorization. The definition of the IoT domain in many cases overlaps with the definition of IoT application, which may at the same time belong to another IoT domain. For example, Smart Buildings may either be considered as a standalone IoT application or as an element needed to form a Smart City application domain. IoT applications are usually classified according to spheres of human life [4,10–12] or performance requirements [9,13–15]. However, these classifications are not suitable for telecom operators which have to fulfil the performance requirements of particular IoT applications, since it is difficult to choose the most important one from a class containing a wide range of IoT applications.

Telecom operators can easily specify performance requirements for current communication services since traffic patterns generated by these services are driven by predictable activities, such as making calls, receiving email, surfing the web, and watching videos. However, traffic patterns generated by emerging IoT applications are driven by less predictable activities. Hence, the idea is to determine a common set of activities based on customer service requests which describe the reasonably foreseeable function/purpose of emerging IoT applications. Then these activities can be used by telcos as a new classification criterion of IoT applications. The assumption is that such a classification can help telecom operators meet performance requirements of future IoT applications and select appropriate 5G enabling technologies. Therefore, the aims of this paper are to classify IoT applications according to relevant activities, specify and prioritize the performance requirements of each IoT application class, and consider enabling technologies used to accomplish specified demands on the radio access part of 5G networks, all according to telco's perspective. In addition, the intention is to provide a literature review which covers 258 references dominantly published in the period between 2012 and 2017. As this paper provides a state-of-the-art review of IoT applications, their performance requirements and 5G enabling technologies, it can also be of use to the research community and other stakeholders interested in this contemporary and attractive field in order to recognize the research gaps and recommend new research directions.

The remainder of the paper is thusly organized. In order to answer research questions, Section 2 describes the methodological approach in regard to the conducted research. Section 3 identifies a common set of activities as a new classification criterion for IoT applications and assigns them the relevant 5G service classes. This facilitates the determining of performance requirements of activity-based IoT application classes, which are summarized and prioritized in Section 4. The enabling technologies used to accomplish these requirements in 5G networks are contemplated in Section 5. Finally, Section 6 discusses the outcomes of the paper by clarifying the contribution of our research in identifying open issues for future work, while Section 7 concludes this paper.

2. Research Approach and Design

The main objectives of this paper can be summarized as follows: (1) to identify activities relevant to IoT customer service requests and use them as a new classification criterion of IoT applications; (2) to specify and prioritize performance requirements of such IoT application classes; (3) to analyze relevant literature in order to provide insight into 5G radio technologies used to fulfil the requirements of activity-based IoT application classes; (4) to recognize research gaps and directions.

The research questions posed in this study are: (1) Which activities can be used as classification criteria for IoT applications? (2) What are the performance requirements of such IoT application classes? (3) Which enabling technologies in the radio access part of the 5G network can be used to meet the requirements of IoT application classes?

Investigation of different criteria for the classification of IoT applications underlines to what extent various classification concepts have been covered by existing literature and provides a basis for the introduction of a new classification criterion called the activity. We thus surveyed and compared different studies contributing to the understanding of the scope and classification of a wide range of IoT applications. This approach has been motivated by the challenge to propose an activity-based classification of IoT applications, the determination and prioritization of performance requirements of such IoT application classes and the review of 5G enabling technologies used to meet them. These findings can be utilized by telecom operators and other interested parties (e.g., the research community, software network function providers, network infrastructure manufactures, etc.) depending on their interest and potential to utilize these findings towards 5G implementation and commercialization.

The methodological approach to research conducted in this paper is illustrated in Figure 1 and includes four phases.

Phase I included searching, identifying, and extracting papers from three categories, i.e., IoT in 5G service classification, IoT in 5G performance requirements and IoT in 5G enabling technologies. The keywords used to search relevant scholar databases are shown in Figure 2. This search has resulted in the selection of 258 recently published papers, which can be categorized into three groups (i.e., review papers, technical papers, research effectiveness), as shown in Table 1. Review papers summarize the status of knowledge and outline future directions in a given area of research. Technical papers describe the process, progress, or result of research, whereas research effectiveness directly provides an answer to the research question raised for this study. The reference distribution by year of publication is shown in Figure 3a, while the total percentage of references per publication type is presented in Figure 3b.

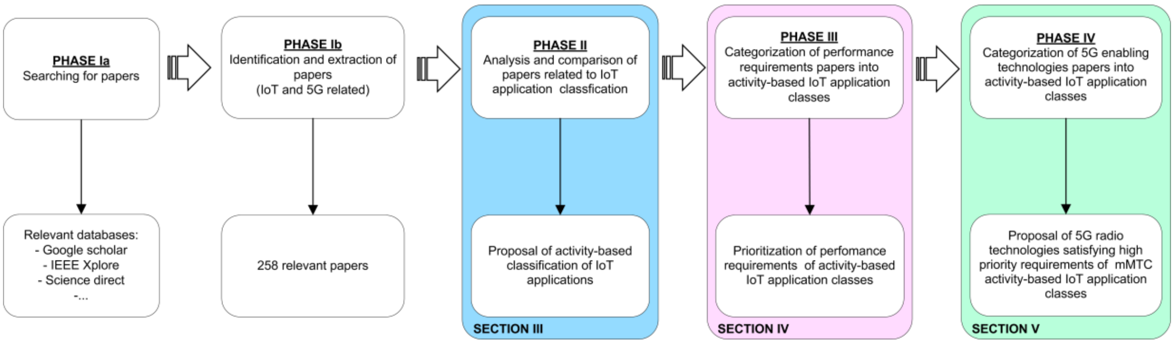
PHASE Ia
Searching for papers
Relevant databases:
- Google scholar
- IEEE Xplore
- Science direct
-...
PHASE Ib
Identification and extraction of papers
(IoT and 5G related)
258 relevant papers
PHASE II
Analysis and comparison of papers related to IoT application classfication
Proposal of activity-based classification of IoT applications
SECTION III
PHASE III
Categorization of performance requirements papers into activity-based IoT application classes
Prioritization of perfomance requirements of activity-based IoT application classes
SECTION IV
PHASE IV
Categorization of 5G enabling technologies papers into activity-based IoT application classes
Proposal of 5G radio technologies satisfying high priority requirements of mMTC activity-based IoT application classes
SECTION V

Figure 1. Methodological approach to research.

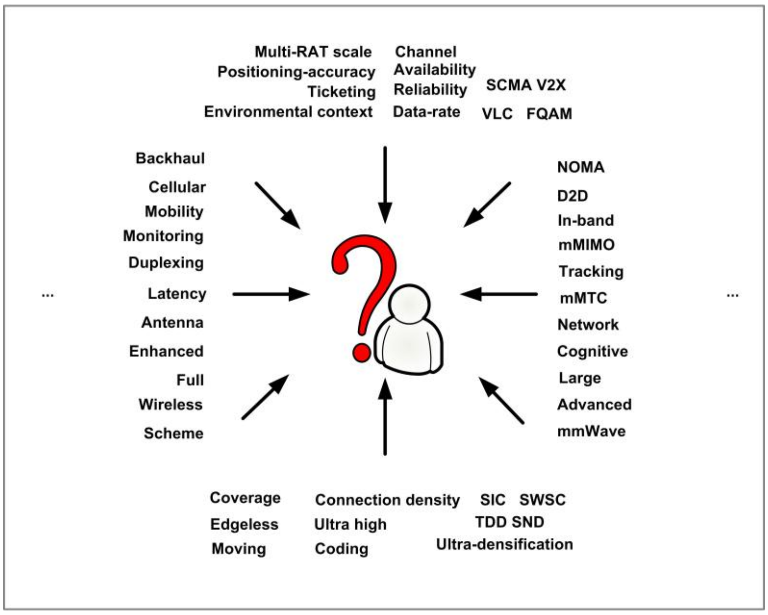
Multi-RAT scale
Positioning-accuracy
Ticketing
Environmental context
Channel
Availability
Reliability
Data-rate
SCMA V2X
VLC FQAM
Backhaul
Cellular
Mobility
Monitoring
Duplexing
Latency
Antenna
Enhanced
Full
Wireless
Scheme
NOMA
D2D
In-band
mMIMO
Tracking
mMTC
Network
Cognitive
Large
Advanced
mmWave
...
...
Coverage
Edgeless
Moving
Connection density
Ultra high
Coding
SIC SWSC
TDD SND
Ultra-densification

Figure 2. Keywords for searching relevant databases.

Table 1. Reference categorization.

Reference Type	Reference Number
Review paper	[1,2,10,12,14–88]
Technical paper	[8,89–197]
Research effectiveness	[3–7,9,11–13,29,52,198–258]

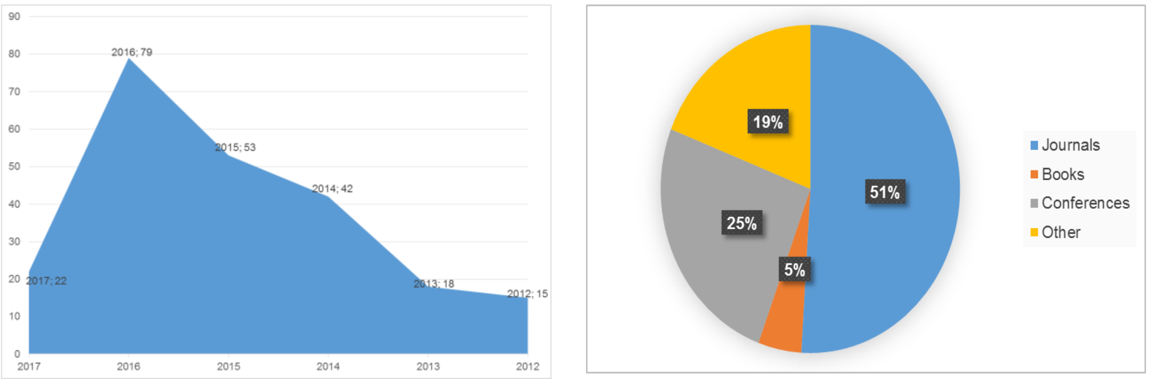

(**a**) (**b**)

Figure 3. Reference distribution by (**a**) year of publication; (**b**) type of publication.

Phase II included the analysis and comparison of papers related to the category of IoT in 5G service classification. Papers were first sorted according to the existing classification criteria of IoT applications in order to underline their deficiencies from telco's perspective. Since emerging IoT applications generate traffic driven by less predictable activities, specifying their performance requirements and enabling technologies is not an easy task from telco's point of view. Therefore, we have proposed a common set of activities to serve as classification criteria of IoT applications. Four activities were selected based on IoT customer service requests denoting the function/purpose of existing IoT applications. According to the authors' knowledge, existing IoT applications can be grouped around following activities: ticketing, tracking, monitoring, and managing/controlling. Such a classification makes it easier for telecom operators to associate particular IoT applications to the relevant 5G service class. Finally, Phase II has resulted in the proposal of an activity-based classification of IoT applications which was associated with the 5G service classification.

Phase III included the analysis of papers related to the category of IoT in 5G performance requirements. Papers were grouped according to eight key performance indicators, i.e., data rate, mobility, latency, connection density, reliability, positioning accuracy, coverage, and energy efficiency. These performance requirements were prioritized indicating high, medium, and low importance of each requirement for specific activity-based IoT application classes proposed in Phase II. Finally, Phase III resulted in the identification of highly important performance requirements for each activity-based IoT application class which can be utilized by telcos to identify 5G enabling technologies used to meet them.

Phase IV provided a review of papers from the category of IoT in 5G enabling technologies. Papers were first sorted according to eight technological groups used in the radio access part of 5G networks, i.e., wide and flexible bandwidth technology, advanced modulation and coding, duplexing, multiple access and waveform, advanced interface management, access architecture related radio technologies, energy related technologies, and other technologies. These technologies have been discussed in terms of their possibility to meet the high priority performance requirements of mMTC activity-based IoT application classes, since this area is more mature from telco's perspective. The results of Phase III were reflected in a proposal of technologies in the radio access part of 5G networks that can be used to meet the high priority performance requirements of the mMTC activity-based IoT class, as well as the identification of research gaps and directions for future work.

3. IoT in 5G Service Classification

As mentioned in the Introduction, various challenges awaiting telcos can be identified on the basis of the role that they will play in the IoT value chain. Regardless of this role, telcos will face many technical challenges, such as the necessity for global deployment, the need for rapid infrastructure scaling, unpredictable IoT application behavior, etc. Even now, existing IoT applications accelerate the growth rate of traffic driven by less predictable activities which require new strategies towards 5G networks. These networks will be the key enabler for IoT applications by providing a unified infrastructure capable of meeting the high variability of their performance requirements [8,16]. Various stakeholders have recently described what 5G networks may be and grouped the major types of 5G services into three different classes: (1) xMBB—Requiring extremely high data rates and low-latency communication; (2) mMTC—Requiring scalable connectivity for an extremely large number of devices; and (3) uMTC—Requiring ultra-reliable low-latency and resilient communication [198]. This 5G service classification can be used by telcos to identify performance requirements of various IoT applications, and, as such, was used in this research study. However, emerging IoT applications will have extreme requirements, so an analysis based solely on 5G service classifications may not be sufficient. Therefore, telcos need a more precise classification of IoT applications which is an important precondition for meeting their diverse requirements.

IoT covers human-to-human (H2H), human-to-machine (H2M) and machine-to-machine (M2M) communication, which will be the main driving force towards 5G networks. In addition, the terms M2M communication (M2MC) and machine type communication (MTC) are used interchangeably as in [17–19,89–93,199,200]. Although IoT is a broader concept which evolves from M2M, this paper assumes that IoT and M2M are synonyms as in [94].

3.1. Existing Classifications of IoT Applications

In order to meet the requirements of a wide range of IoT applications, they have to be classified in an appropriate manner. The existing approaches to the classification of IoT applications are summarized in Table 2. IoT serves different user categories, including individuals, businesses, and society as a whole, and may span through a broad range of application domains [4,10–12], such as transportation and logistics, healthcare, smart environment, personal and social, futuristic applications, food sustainability, smart living, smart manufacturing, smart energy, smart city, etc. These application domains are created to be human-centric, which means that they cover different domains of human life. IoT applications belonging to these domains have diverse requirements for 5G networks, and should not be treated equally. Therefore, the acceptance of these domains as a classification criterion raises the issue of assigning IoT application to a particular domain. Moreover, the emergence of new applications of IoT may require defining new application domains, which makes this classification inappropriate from telco's perspective.

The M2M applications may be classified by the mobility and the amount of dispersion that needs to be supported into four categories [13]: (1) fixed and concentrated; (2) fixed and dispersed; (3) mobile and concentrated; and (4) mobile and dispersed. However, the mobility and amount of dispersion present very rough classification criteria and cannot meet the precise network requirements of individual IoT applications.

Additionally, M2M applications can be grouped according to delay tolerance into four categories [14]: (1) elastic (delay tolerant); (2) hard real-time (delay constraint); (3) delay-adaptive (delay sensitive but tolerant); and (4) rate-adaptive application (adjust their transmission rates according to available radio resource). However, the main drawback of this classification is the lack of consideration of other IoT application requirements except delay tolerance, although its importance as a classification criterion has been recognized.

According to data reporting mode, the M2M applications can be classified into five categories [91]: (1) time-driven; (2) query-driven; (3) event-driven; (4) continuous-based; and (5) hybrid-driven. This classification is specific for the former IoT concept, which is narrower in nature than the definition adopted in this study.

Another study considered the reliability, availability, and end-to-end latency in order to classify IoT applications into two groups [15]: (1) monitoring-based and mission-critical; (2) monitoring-based and non-mission critical; (3) control-oriented and mission-critical; and (4) control-oriented and non-mission critical. Monitor-based IoT applications periodically collect sensor data from smart objects and transmit them. The majority of monitoring-based IoT applications are not mission-critical. Control-oriented IoT applications use sensor data to control actuators in real-time, and rely on mission critical communication. This classification is based on multiple criteria and represents the precursor of the Mobile and wireless communications Enablers for Twenty-twenty Information Society (METIS) 5G service classification.

Table 2. Internet of Things (IoT) application classification—summary.

Criteria for Classification	IoT Classes	References
Domains	(1) Transportation and logistics (2) Healthcare (3) Environment (4) Personal and social (5) Futuristic applications (6) Food/water monitoring (7) Living (8) Manufacturing (9) Energy (10) Building (11) Industry (12) City (13) Security and safety (14) Communication (15) e-society (16) Vehicular (17) Sport and leisure	[4,10–12]
Mobility and amount of dispersion	(1) Fixed and concentrated (2) Fixed and dispersed (3) Mobile and concentrated (4) Mobile and dispersed	[13]
Delay tolerance	(1) Elastic (2) Hard real time (3) Delay-adaptive (4) Rate-adaptive	[14]
Data reporting mode	(1) Time-driven (2) Query-driven (3) Event-driven (4) Continuous-based (5) Hybrid-driven	[198]
Reliability, availability, and end-to-end latency	(1) Monitoring-based and mission critical (2) Monitoring-based and non-mission critical (3) Control-oriented and mission critical (4) Control-oriented and non-mission critical	[15]
Characteristics and requirements	mMTC and uMTC	[12]

Legend: IoT (Internet of Things), mMTC (massive Machine Type Communication), uMTC (ultra-reliable Machine Type Communication).

Although it spans through a wide range of different applications, MTC can be divided in two main categories, i.e., massive and ultra-reliable MTC, which depend on their characteristics and requirements [89]. As mentioned above, this categorization is a part of 5G service classification which was used in this study as a basis to identify performance requirements of IoT applications and will be described in more detail in Section 4. Massive MTC (mMTC) typically involves a very large number of devices (tens of billions [9]), such as sensors, actuators, and similar devices [12], different in complexity and cost [9], and with varying quality of service (QoS) requirements. These devices should be of very low cost with very low energy consumption, enabling very long battery life [12]. At the same time, the amount of data generated by each device is normally very small, and very low latency is not a critical requirement [12]. Ultra-reliable MTC (uMTC) requires very high reliability and availability, and very low latency [9,12]. Low device cost and energy consumption are not as critical as they are for mMTC applications [12], and the number of devices and required data rates are relatively low [198].

The vision of a pervasive IoT requires the integration of various domains into a single and unified domain. It addresses the enabling technologies needed for these domains while taking into account the elements that form the third dimension like security, privacy, trust, and safety [11]. The current classification criteria and IoT application classes do not clearly differentiate IoT domains from IoT applications. IoT domains are usually viewed as a specific area of IoT applications that support a huge variety of use cases across industries impacting businesses and customers. Therefore, IoT domains overlap with IoT applications within existing IoT classifications. Moreover, IoT classification based on certain QoS parameters is difficult to apply from telco's perspective, because it is challenging to choose the most important parameter for the wide range of IoT applications. However, these problems need to be solved for upcoming 5G networks.

3.2. Activity-Based Classification of IoT Applications

The aforementioned issues motivated us to propose a new approach to the classification of IoT applications. This approach is based on "**the activity**", which primarily characterizes specific IoT application. In this sense, the activities are defined as new classification criteria, which denote a main function/purpose of specific IoT application observed from telco's point of view. Telecom operators observe the technical challenges of IoT through systems, tools, devices, and platforms because their availability and integration complexity determines the opportunity to capture a share of the value that is generated by IoT implementation. Based on the literature review, it was found that the most commonly mentioned terms in this sense were related to: (1) ticketing system [201]; (2) monitoring: devices [199,201–204]/services [199,201,202,205,206]/tools [207]/systems [11,12,199,201,205,206,208–210]/ data [95,201]/framework [12,201]/solutions [20,205]/networks [211]/process [7]/activity [203,204,207]; (3) tracking technologies [4]/devices [204]/systems [204]/applications [11,210]/system [201]/services [202,205]; (4) managing/controlling applications [15,210,212]/operation [211]/services [4,208]/tools [208,211]/devices [204]/system [95,198,204,210]/concepts [211]/solutions [95]/platforms [95,199]. This has led us to identify four activities, i.e., ticketing, monitoring, tracking, and managing/controlling, as new classification criteria of IoT applications. According to the authors' knowledge, it was found that these activities can cover reasonably foreseeable functions/purposes of IoT in existing application domains. Using activities as classification criteria, telcos can specify IoT application performance requirements more easily, which are in that case dictated by the specific activity, not by the IoT application domain, and determine enabling technologies in the radio access part of 5G networks.

In addition, our classification approach allows better service differentiation and service delivery closer to customer expectations. According to BH Telecom's experience, customers typically come up with the following service requests when it comes to IoT: (1) they need to track their products and determine products' distribution across different regions based on their own data analysis; (2) they want to monitor their products since they do not have a department for supervision and analysis; (3) they need information panels about their outlets and working time to be downloaded by a scanning tab-ticket; (4) they want to manage/control their products according to market needs. This way of expressing customer needs has inspired us to propose the activity-based classification of IoT applications as it allows telcos to define performance requirements more precisely, and thereby improve the customer experience.

The activity-based classification of IoT applications is presented in Table 3. Each activity is associated with the application domain where that activity may be applied. The requirements of identified activities and associated application domains are then mapped to 5G service classes in order to be further able to identify their performance requirements and enabling technologies necessary to meet them. For example, according to Table 3, the managing/controlling activity can be realized in several domains, such as healthcare, food, energy, transportation and logistics. For each domain, we have identified an application example, such as remote surgery [213] in the healthcare domain, food processing facilities [96] in the food domain, energy distribution [12] in the energy domain and traffic/driving [12,213] in the transportation and logistics domain. According to diverse performance requirements of these IoT applications [214], managing/controlling activity in healthcare, food, transportation, and logistic domains can be associated with the uMTC service class, while the energy domain can be mapped to the mMTC service class. A more detailed description of performance requirements for each activity-based class of IoT applications is provided in Section 4, while in Section 5 it is discussed how these requirements can be accomplished in the radio access part of 5G networks.

Table 3. Activity-based classification of IoT applications.

Activity	Domain Examples	5G Service Classification	Application Examples
Ticketing	Smart Transportation and Logistics	mMTC	POS Terminal [4]
Monitoring	Smart Healthcare	uMTC	Health condition [97]
	Smart Buildings	uMTC	Structures (buildings, tunnels, etc.) [12,25,213]
	Smart Buildings/Smart City	mMTC	Parking spaces
	Smart Buildings/Smart Environment	mMTC	Home video [12]
	Smart food/water monitoring	mMTC	Food growth condition [10]
Tracking	Smart Healthcare/Sport and Leisure	mMTC	Medical assets, wearables [200,213]
	Smart Transportation and Logistics	mMTC	Transport fleet [200,213]
	Smart Industry/Social Networking	mMTC	Shipping of products
	Smart Healthcare	mMTC	People in science museum
Managing/controlling	Smart Healthcare	uMTC	Remote surgery [213]
	Smart food/water monitoring	uMTC	Food processing facilities [96]
	Smart Transportation and Logistics	uMTC	Traffic, driving [12,213]
	Smart Energy	mMTC	Energy distribution [12,98]

Legend: 5G (Fifth Generation), POS (Point Of Sale), mMTC (massive Machine Type Communication), uMTC (ultra-reliable Machine Type Communication).

As such, the activity-based classification of IoT applications can be used for the creation of new business models, which represent the stakeholder's plan to generate revenue and make a profit from operations, and thereby include many components and functions of the business [21]. However, there is no common opinion which components constitute a business model. The business model architecture can be illustrated by four dimensions [22]: (1) who, identifying the definition of the target customer as one central dimension in designing a new business model; (2) what, describing what is offered to the target customer; (3) how, referring to the construction and distribution of the value proposition; (4) value, explaining why the business model is financially viable. Answering these four questions allows the creation of IoT business models. According to this business model definition, the activity-based classification of IoT applications affects the who and the how dimensions in the following manner. In terms of the who dimension, it directly allows customer segmentation according to considered activities as a way to express their requirements (e.g., customers that require tracking or monitoring of their products). Being aware of the current customer requirements, the proposed classification of IoT applications around four activities (i.e., ticketing, monitoring, tracking, and managing/controlling) can be considered complete. At the same time, the activity-based classification of IoT applications is flexible since additional activities as classification criterion can be concerned with emerging customer requirements. On the other hand, the activity-based classification of IoT applications indirectly impacts the how dimension of new business models which among others includes relevant resources and capabilities in the focal stakeholder's internal value chain. This indicates that the proposed activity-based classification of IoT applications can be easily applied to IoT business models.

Various categories of IoT business models can be identified according to eight IoT architectural layers [23], i.e., collaboration and processes layer, application layer, service layer, abstraction layer, storage layer, processing layer, network communication layer, physical layer. Along with IoT architectural layer, the IoT business model needs also to address the IoT value proposition [24] and

IoT stakeholders that can participate in more than one layer. Based on their role in the IoT ecosystem, telecom operators usually take a part in the network communication layer. In this regard, they follow four evolutionary business models [23]: (1) selling connectivity services only; (2) selling third-party products; (3) selling internal products; (4) providing a broad menu of IoT products. Each of these IoT business models includes traditional telcos strength, i.e., connectivity which determines the how dimension of the IoT business model. In this sense, our activity-based classification of IoT applications indirectly allows the construction and distribution of performance as IoT value proposition using enabling technologies as IoT resources in telco's internal value chain.

3.3. Summary of IoT in 5G Service Classification

The previous discussion has shown that the classification of IoT applications is a complex task due to their numerosity and diversity. The existing classifications of IoT applications pose some drawbacks that can be summarized as follows. The domain-based classification does not allow clear differentiation between IoT domains and IoT applications due to either an imprecise classification criterion or the diversity and unpredictability of IoT applications. On the other hand, QoS-based classifications need to identify the common and most important performance metric for a broad range of IoT applications. Therefore, on the basis of the literature review and IoT customer service requests, we have proposed a new approach to the classification of IoT applications. It is based on the activity as new classification criterion, which denotes a main function/purpose of specific IoT application observed from telco's point of view. According to the authors' knowledge, four activities, i.e., ticketing, monitoring, tracking, and managing/controlling, have been identified to cover reasonably foreseeable functions/purposes of existing IoT applications. The resulting activity-based IoT application classes have been associated with 5G service classes in order to determine and prioritize their performance requirements as described in next section. Finally, the proposed classification of IoT applications was discussed in terms of its completeness, flexibility, and applicability to new business models.

4. IoT in 5G Performance Requirements

This section provides an insight into performance requirements of activity-based classes of IoT applications proposed in Section 3. The analysis is based on eight key performance indicators identified in [5,207] as shown in Table 4: data rate, mobility, latency, connection density, reliability, positioning accuracy, coverage, and energy efficiency. These performance indicators are usually well described for specific IoT applications. However, one of the main challenges of 5G is to support a variety of performance requirements for numerous IoT applications in a flexible, reliable, and cost-effective way [15]. Hence, there is a need for a comprehensive understanding of these requirements for activity-based IoT application classes. The 5G service classification defined the performance requirements for mMTC and uMTC [9]. We have assigned these requirements to the activity-based IoT application classes introduced in Section 3 for the purpose of proposing priorities of each requirement for a specific class. Three levels of priorities (high, medium, low) are associated with the performance requirements of activity-based classes of IoT applications as shown in Table 4. The prioritization of performance requirements is inspired by analysis of related work undertaken in [213]. Some activity-based classes of IoT applications may demand optimization of multiple performance requirements. Table 4 illustrates the main differences between activity-based IoT application classes, and therefore, the need for a 5G network that enables support of optimal configurations for a variety of, sometimes opposite, requirements. For example, the mMTC tracking-based IoT application class requires support for high mobility, high positioning accuracy, and high connection density, while the mMTC monitoring-based IoT application class also requires high connection density but low mobility and low positioning accuracy. A more detailed description of considered performance requirements is contained in the following subsections.

Table 4. Activity-based classes of IoT applications—performance requirements.

5G Service Classification	**Activity**	**User Experienced Data Rate [Gbps] Outdoor: 0.1 [5] Indoor: 1 [5]**	**Mobility [km/h] Required: 500 [5]**	**Latency [ms] Control Plane: 50 [5] User Plane: 1 [5]**	**Connection Density [Connections/km^2] Required: 10^6 [5]**	**Reliability [%] Required: 99.999 [207]**	**Positioning Accuracy Required: A Few cm [5]**	**Coverage/ Availability [%] Required: 99.999 [207]**	**Energy Efficiency [bits/J]**
mMTC	Ticketing	L to M	L	L	H	M	H	H	H
	Tracking	M	H	L	H	M	H	H	M to H
	Monitoring	M to H	L	L	H	L to M	L	H	M
	Managing/controlling	L	L	L	H	M	L	M to H	M
uMTC	Monitoring	L	L to M	H	H	H	M to H	H	M
	Managing/controlling	L	M to H	H	L	H	H	M to H	M

Legend: 5G (Fifth Generation), mMTC (massive Machine Type Communication), uMTC (ultra-reliable Machine Type Communication), L (Low), M (Medium), H (High).

4.1. Data Rate

Data rate is the most important evaluation factor for generations of wireless communication networks [6]. It is contemplated in two ways: (1) peak data rate—defined as the maximum achievable data rate by the user; and (2) minimum guaranteed user data rate—defined as the minimum experience data rate by the user [16]. New mobile technologies are primarily driven by users' needs for higher data rates, as discussed in [8,16,99,215,216]. The expected values in 5G networks are 10 Gbps for minimum peak data rate and 100 Mbps as minimum guaranteed user data rate [5]. High data rate requirements are mainly posed by xMBB related use cases [9] like hotspots [214] or dense urban areas where in 95% of locations and time experience data rate by user should be 300 Mbps in downlink and 60 Mbps in uplink [100]. High data rate is also important in some activity-based classes of IoT applications, as shown in Table 4. Medium (e.g., monitoring of parking spaces) to high (e.g., monitoring of home video) data rate is needed in cases of mMTC monitoring activities. High data rate can be achieved by using a millimeter wave (mmWave) spectrum to share multi-gigabit data in the surrounding environment (i.e., mMTC monitoring with high data rate requirement) and to recognize an object via cloud in real time to find the optimal driving strategy instantaneously for IoT—autonomous vehicles application [101]. Data rates generated during transmissions of tracked medical assets, transport fleets, and ticked point of sale (POS) terminals is low (e.g., medium importance for ticketing and tracking activities in mMTC). In addition, low data rates are needed in uMTC monitoring and controlling (e.g., monitoring of health condition, control of driving).

4.2. Mobility

Mobility is defined as relative velocity between the receiver and the transmitter [16]. The applications of IoT pose very diverse requirements for mobility in 5G networks, which range from static to high mobile, even up to 500 km/h [16,102,207]. Use cases in which except ultra-high mobility, ultra-high traffic volume density, and ultra-high connection density are needed may be quite challenging for 5G networks [215], like V2X communication [5]. High mobility is a very important requirement for mMTC tracking activity (e.g., tracking of assets in high speed trains [214]). Moreover, the support for high mobility is needed in uMTC management activities, if the monitor/control object is moving (e.g., high speed trains [207]). Low mobility is needed for ticketing, monitoring, and managing/controlling activities in the mMTC class, as shown in Table 4. This is the reason why 5G networks should not assume mobility for all devices and services but rather provide mobility on demand [8].

4.3. Latency

Latency requirements are usually expressed in terms of end-to-end (E2E) latency perceived by the end user [8]. 5G networks should enable "zero latency" [103] represented by the millisecond level of E2E latency [16,26,27,213] through significant enhancements and new technology in architecture aspects [6,28,214], such as device-to-device (D2D) communication [5]. The IoT applications associated with uMTC monitoring and managing/controlling activities require low latency, as they tend to be real time. Required latency levels depend on the particular IoT application [8,16,28], being the narrowest in uMTC managing/controlling activity with a value that should not exceed 1 ms [8]. For example, the tolerable delay for use case mobile health [215] and remote surgery application is in order of sub-milliseconds [213]. For V2X communications, latencies should be ultra-low for some warning signals [8].

4.4. Connection Density

Connection density is defined as the number of connected devices per unit area [16]. It can usually be expressed in terms of an extremely high number of simultaneous active connections, such as 1 million connections per square meter [207,215], or 10 to 100 times higher number of connected devices [29]. The performance values of connection and traffic density for various 5G services are listed in [8,212]. This performance requirement is highly correlated with identified activity-based classes of IoT applications, since it is the main characteristic of mMTC. High device density brings the need for rapid internet protocol version 6 (IPv6) deployment, and high quality security algorithms and techniques, which lead to new system design and implementation, as described in [104].

4.5. Reliability

Reliability is the maximum tolerable packet loss rate at the application layer [105]. 5G must bring a reliability of 99,999% [27,30,31,212], or higher for specific use cases [212], (e.g., tele-protection in a smart grid network [207] or driverless cars [106]). Reliability is the main characteristic of uMTC monitoring and managing/controlling activities. Reliability will be a particularly challenging task in high-speed trains because of speed, load, and cell distance [16,107].

4.6. Position Accuracy

Position accuracy is the maximum positioning error tolerated by the application [105]. 5G should ensure accurate positioning of the device outdoors [108] with accuracy from 10 m to <1 m on 80% of occasions and better than 1 m in indoor deployment [212]. Accuracy positioning is very important in uMTC monitoring-based activities (e.g., monitoring remote cameras), and uMTC managing/controlling-based activities (e.g., driving) [213]. Moreover, the mMTC tracking-and ticketing-based activities pose high performance requirements in terms of position accuracy.

4.7. Coverage

Coverage requirements in 5G should provide connectivity anytime and anywhere with a minimum user experience data rate of 1 Gbps [32]. However, the perception of 100% coverage is rather a technical decision than a business one [33], which could be extended through ultra-cell deployment [31] and vehicle-to-infrastructure (V2I) communications [30]. Almost every activity-based IoT application class requires very high levels of coverage (99,999% availability) [207]. Total coverage will enable new unmanned aerial vehicles (UAV) to use single network connection, instead of connection steering mechanism, as one described in [109].

4.8. Energy Efficiency

Energy efficiency is defined as the number of bits that can be transmitted per joule of energy [216]. Compared with current wireless technologies, the energy efficiency (measured in b/J) of the 5G network may need to be improved by a factor of 1000 [4,7,34,110,217]. High energy efficiency is important in case of ticketing- and in some cases of tracking-based activities (e.g., smart industry [205] or implantable medical devices [35]). Other activities, such as both mMTC and uMTC monitoring- and managing/controlling-based activities (e.g., health condition [205]) and some tracking-based activities (e.g., sports wearables [205]) require medium energy efficiency. Energy efficiency is very important design objective for the reduction of operating costs of telecom operators, as well as for minimizing the environmental impact of the wireless domain [217]. On a higher layer of the network protocol stack, adaptive base station switch on/off algorithms use renewable energy sources to save energy [218] along with an energy scheduler, as in the with heating, ventilation and air conditioning (HVAC) [111]. However, at the physical layer, adaptively switching off unused carriers is a key strategy that can be used to save energy from the radio-frequency (RF) transceiver chain of base stations [218].

4.9. Spectrum Efficiency

Spectrum efficiency is defined as the data throughput per unit of spectrum resource per cell or per unit area (bps/Hz/cellar bps/Hz/km^2) [216]. In order to achieve network sustainability, required for 5G networks [216], spectrum efficiency needs to be improved 3–5 times [20,32,216]. Minimum peak spectrum efficiency is 30 bps/Hz for downlink and 15 bps/Hz for uplink [32]. This is mostly important for the xMBB services class [212,214]. Since this performance requirement is not relevant for activity-based IoT application classes which are associated with the mMTC and uMTC service class, it has not been further considered herein.

4.10. Summary of IoT in 5G Performance Requirements

Activity-based classes of IoT applications are associated with performance requirements of 5G service classes, i.e., mMTC and uMTC. On the basis of the literature review, each activity-based class (ticketing-, tracking-, monitoring-, and managing/controlling-based class) is associated with mMTC service class, while the monitoring- and managing/controlling-based classes are the only ones linked to the uMTC service class. According to the authors' best knowledge, there is no available literature concerning the uMTC ticketing- and tracking-based classes of IoT applications or such IoT customer service requests.

Activity-based IoT application classes pose many performance requirements, which have been discussed in terms of data rate, mobility (speed), latency, connection density, reliability, positioning accuracy, coverage, and energy efficiency. These performance requirements have been assigned three-level priorities (high, medium, low) for the purpose of facilitating identification of the enabling technologies used to fulfill them. Based on the literature review, it was found that each activity-based IoT application class poses high requirements in terms of connection density except the uMTC managing/controlling-based IoT application class. Moreover, ticketing- and tracking-based IoT application classes have high requirements in terms of positioning accuracy, coverage, and energy efficiency. Additionally, positioning accuracy is a highly important performance requirement for the uMTC managing/controlling-based IoT application class, whereas coverage is important for both uMTC and mMTC monitoring-based IoT application classes. Finally, latency and reliability represent highly important performance requirements for uMTC monitoring- and managing/controlling-based IoT application classes. A deep and comprehensive understanding of performance requirements of each activity-based IoT application class may facilitate the selection of 5G enabling technologies needed to meet them as described in the following section.

5. IoT in 5G Enabling Technologies

Activity-based classification of IoT applications proposed in Section 3 allows telecom operators to identify performance requirements of each class relying on 5G service classification, as discussed in Section 4. However, these performance requirements cannot be satisfied for many IoT applications with current cellular (2nd, 3rd, and 4th generation) network technologies, since they limit their potential due to many issues [3], i.e., protocol implementation complexity, poor coverage in non-urban environments, high cost of networking equipment and data transmission. In order to overcome these issues, many dedicated communication technologies are being installed.

From the very beginning of IoT, many proprietary technologies, such as radio-frequency identification (RFID), wireless highway addressable remote transducer (WirelessHART) or Z-Wave, have first appeared, and then, more generic ones, such as Bluetooth, IEEE 802.15.4, IPv6 over low-power wireless personal area networks (6LoWPAN). However, none of these technologies have become a market leader mainly because of technology shortcomings and business model uncertainty [219]. Hence, new solutions, such as low-power wireless fidelity (LP Wi-Fi), low-power wide area (LPWA) or several improvements for cellular M2M communications have become serious candidates for IoT implementation. LP Wi-Fi is an IEEE 802.11ah standard designed to extend the application area of Wi-Fi networks in order to meet IoT requirements (i.e., large number of devices, large coverage range, energy constrains). First performance studies indicate that this standard will support a broad range of M2M scenarios with a required QoS level, and enable scalable and cost-effective solutions. In addition, LPWA networks have been deployed for some time in the form of many different proprietary solutions (e.g., Amber Wireless, Coronis, Huawei's CIoT, LoRa, M2M Spectrum Networks, Sigfox, Weightless, etc.), but only the LoRa Alliance, Sigfox and Weightless are involved in LPWA standardization activities. Despite some drawbacks which are mainly related to use of an unlicensed spectrum, LPWA networks are expected to become a key enabler for IoT deployment in early market rollouts and for limited IoT applications [219].

The appearance of these IoT communication technologies was considered as competition to current cellular networks from the telco's point of view from the start. But, in the meanwhile, telcos have realized that the aforementioned communication technologies can be utilized to meet the changing connectivity and performance requirements of IoT applications. Therefore, many dedicated communication technologies have already been deployed in various IoT applications. For example, Orange, Swisscom and South Korea (SK) Telecom have built nationwide networks based on LoRa [3], whereas Deutsche Telekom (DT), Vodafone and all three Chinese operators have completed the rollout of narrowband IoT (NB-IoT), as another LPWA standard utilizing existing long term evolution (LTE) networks [36]. In this context, standardization and interoperability becomes critical because there is a need to consider a broad range of connectivity solutions as presented in Figure 4 [37]. One of those solutions includes satellite technologies which integrated with 5G radio technologies form the 6th generation (6G) standard for providing global coverage [38].

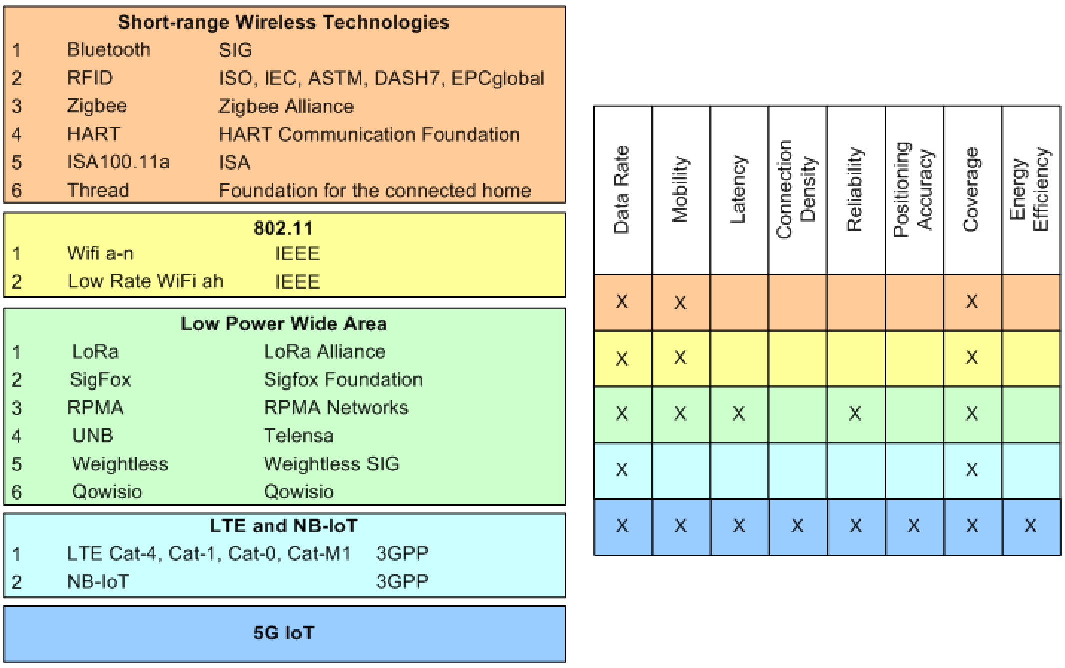

Short-range Wireless Technologies

1	Bluetooth	SIG
2	RFID	ISO, IEC, ASTM, DASH7, EPCglobal
3	Zigbee	Zigbee Alliance
4	HART	HART Communication Foundation
5	ISA100.11a	ISA
6	Thread	Foundation for the connected home

802.11

1	Wifi a-n	IEEE
2	Low Rate WiFi ah	IEEE

Low Power Wide Area

1	LoRa	LoRa Alliance
2	SigFox	Sigfox Foundation
3	RPMA	RPMA Networks
4	UNB	Telensa
5	Weightless	Weightless SIG
6	Qowisio	Qowisio

LTE and NB-IoT

1	LTE Cat-4, Cat-1, Cat-0, Cat-M1	3GPP
2	NB-IoT	3GPP

5G IoT

Data Rate	Mobility	Latency	Connection Density	Reliability	Positioning Accuracy	Coverage	Energy Efficiency
X	X					X	
X	X					X	
X	X	X		X		X	
X						X	
X	X	X	X	X	X	X	X

Figure 4. IoT performance requirements and enabling technologies.

In this regard, standardization activities of 5G and beyond are being undertaken by several standards bodies, such as the Institute of Electrical and Electronics Engineers (IEEE), the 3rd Generation Partnership Project (3GPP), the Internet Engineering Task Force (IETF), ITU Radiocommunication Sector (ITU-R), and ITU Telecommunication Standardization Sector (ITU-T). An overview on these standards bodies and their effort to develop communication standards for 5G and beyond are provided in [112]. Due to the envisioned 5G applicability, these standards have defined an air interface that can significantly improve the performance, and network architectures that allow the deployment and coexistence of various 5G technologies. A detailed discussion of these technologies regarding both technological and standardization aspects indicates that 5G can be perceived as the main driving force for enabling the vision of a truly global IoT [219].

In this sense, the technologies described in this section will allow 5G networks to form a unified communication infrastructure for the realization of a wide range of IoT applications. These technologies will bring performance enhancement which will trigger a complete revolution in almost all spheres of human life creating a new "everything connected" era. Future 5G networks in such an era will face a serious problem regarding a huge number of different service types [220]. To meet the diverse requirements for a huge number of IoT applications, 5G introduces the concept of network slicing to offer programmable network instances [220]. Using network slicing, multiple independent and dedicated network instances can be created within the same infrastructure to run services that have completely different requirements for latency, reliability, throughput, and mobility [220]. This technology primarily targets a portion of the 5G core network, but also indicates that 5G radio access network (RAN) functionalities can be different for each network slice [221]. To deploy network slices, network functions need to be enabled on an on-demand basis, which has driven the use of virtualization and softwarization in 5G core network [221]. Network function virtualization (NFV) is a paradigm that enables that 5G network functions to run in a virtual environment instead of dedicated hardware [221]. The software define networking (SDN) paradigm facilitates isolation of network slices avoiding the traffic of one slice affecting the performance of another slice [221]. These two paradigms make the network much more dynamic, agile, on-demand, and flexible [222,223]. Since the aforementioned technologies are used to deal with a variety of 5G applications, they will not be further discussed. This paper will focus on technologies used to meet performance requirements for specific applications (inter slice performance) which are implemented in the radio access part of 5G networks.

These technologies are briefly described and discussed in terms of their advantages, disadvantages, and research gaps. Given the fact that the realization of particular technology affects multiple performance requirements, tiny steps towards its implementation will allow telcos to deploy 5G networks, and thereby provide a performance improvement in terms of more capacity, lower latency, more mobility, more position accuracy, increased reliability, and availability [6,214,224]. In other words, 5G networks will accommodate many more users and devices while delivering more data [113,114] to each user requiring high data rates [108] in a more energy-efficient way [115,116].

Table 5 summarizes considered radio technologies used to implement future 5G networks being capable of achieving performance requirements identified in Section 4. On the basis of the literature review, one may conclude that the 5G radio access network is crowded with multiple technologies, and there seems to be a duplication of technologies, all eager to grab telco's attention and convince them to buy into the particular choice. As Table 5 shows, multiple technologies and techniques can be used to meet each performance requirement. Since the mMTC activity-based IoT classes are more mature, we have primarily focused on technologies used to fulfil their high performance requirements (i.e., connection density, positioning, and coverage). We have selected 5G enabling technologies considered from telco's perspective as the most representative and promising candidates to meet these requirements. The implementation of these technologies will also significantly affect the fulfillment of uMTC service class requirements, which will lead to complete automation in all spheres of human life. Therefore, the following subsections will discuss these technologies in more detail with the final goal of identifying research gaps and providing recommendations for future work, which are summarized in Table 6.

Table 5. IoT in 5G enabling radio technologies.

Enabling Technologies		IoT in 5G Service Requirements								
		Data Rate	Mobility	Latency	Connection Density	Reliability	Positioning	Coverage	Energy Efficiency	Spectrum Efficiency
Wide and flexible bandwidth technology	mmWave Band Communication and large-scale antenna	[7,202,225–227]		[202]			[233]	[5]	[202]	[7,29,214]
	Heterogeneous Multi-RAT Integration	[5,217,228–232]						[5]		
	Cognitive Radio and Spectrum Sharing							[5]		
Advanced modulation and coding	Advanced Modulation	[52,234–236]	[237,238]	[239]		[237,239]		[237]		
	Advanced Channel Coding	[235]		[235]						[216]
Duplexing	In-band FD			[124]				[5]		[7,29,214]
	Dynamic TDD	[240]		[240]						[9]
Multiple access and waveform	Multiple access			[216]					[218]	[7,9,29,216,256,257]
	New waveform				[5]					[7,9,29,216,256,257]
Advanced interface management	SND and SWSC	[5]								
Access architecture related radio technologies	Advanced small cell	[7,202]					[5]	[5,251]	[7,202,217]	[202,257]
	MN	[202]	[202]					[5]	[202]	
	Enhanced wireless backhaul							[5]		
	D2D	[202,248]	[7,241,244]					[245–247]	[7,202,215]	[7,9,29,202,252]
Energy related technologies	Energy harvesting						[100,253]			
	UAV	[254]				[254]		[183–185]		
Other important technologies	mMIMO	[7,202,249]		[13,202]		[249]		[200]	[217]	[7,9,214,216,257]
	VLC	[202,250]		[202]					[202,258]	
	SIC		[202]	[202,236]						
	V2X			[255]				[255]		

Legend: IoT (Internet of Things), 5G (Fifth Generation), mmWave (Milimeter-wave), RAT (Radio Access Technology), FQAM (Frequency Quadrature Amplitude Modulation), FD (Full Duplexing), TDD (Time Division Duplexing), SND (Simultaneous Non-unique Decoding), SWSC (Sliding Window Superposition Coding), MN (Moving Network), D2D (Device-to-Device), mMIMO (massive Multiple Input Multiple Output), VLC (Visible Light Communication), SIC (Self Interference Cancelation), V2X (Vehicle to Everything), UAV (Unmanned Aerial Vehicles).

Table 6. 5G enabling technologies—research directions.

5G Enabling Technologies		**Research Gaps and Directions**	**References**
Wide and flexible bandwidth technology	mmWave band communication and large-scale antenna	(1) 3D channel modeling; (2) dynamic power control; (3) user scheduling and congestion control; (4) hardware limitation and adaptive beam-steering technique; (5) design of mobility management and admission control for mmWave-based dense HetNet; (6) design of frequency management schemes for mmWave; (7) Tactile Internet; (8) effective and efficient mmWave implementation in HetNets (access and networking).	[7,87,217]
	Heterogeneous multi-RAT integration	(1) cell-association; (2) traffic-offloading algorithms; (3) interference management schemes in case of inter user and inter cell interference; (4) cross-tier handover, access admission, and mobility management schemes of a multi-tier HetNets.	[196,217]
	Cognitive radio and spectrum sharing	(1) Spectrum sensing (design of cooperative frameworks, choose cooperative secondary users and transmit cooperative information); (2) develop framework and algorithms for group handoff of secondary users and security; (3) simulation of different attacks and scenarios to enhance security; (4) in-depth performance analysis between GFDM and UFMC in CR settings.	[29,110]
Duplexing	In-band full duplexing	(1) Redesign of network and management; (2) antenna and circuit design and development of the theoretical foundation; (3) analyze the throughput of a network of randomly deployment terminals sing stochastic geometry; (4) characterize the capacity advantage due to IFDB in various network scenarios; (5) guidelines to practical design: coding, modulation, power allocation, beamforming, channel estimation, equalization, digital interference cancellation and decoding, (6) design of a MAC layer.	[55,197]
Multiple access and waveform	New waveform	(1) Performance of SIC cancelation or filtering on f-OFDMA; (2) balance of time and frequency dispersion and design an efficient filter prototype for UFMC.	
Access architecture related radio technologies	Advanced small cell	(1) Expect of wireless backhauling on user experience; (2) exploitation of location data and fingerprints in optimizing small cell discovery in terms of time and energy- efficiency; (3) interference management when integrating D2D and small cells.	[34,80]
	Enhanced wireless backhaul	(1) TDD multi-flow coordination schemes to avoid bottlenecks in the downlink backhaul; (2) Backhaul aware association in ultra-dense deployment; (3) reliability and security of the backhaul.	[34,88,198]
	Moving network	(1) Resource allocation and interference in the mobile relay when trains are moving from opposite directions; (2) handover decision of users (more than one train arrive or depart, stop or pass); (3) group mobility for users on board very high-speed vehicles; (4) design od cooperative communication schemes; (5) deployment of moving networks in various vehicle environments, not just on fixes route railways.	[5]
	D2D communication	(1) Interference management (mode selection, resource allocation and power control); (2) integration of novel reputation-based mechanism for identify and avoid malicious users from multiple users in multi-hop D2D communications; (3) testing of D2D interference management schemes in 5G scenarios (mmWave, cell densification).	[29,208,209]
Energy related technologies	Energy harvesting	(1) Improving energy harvesting schemes; (2) simulation of proposed models; (3) integration with other 5G technologies.	[100,182,253]
	UAV	(1) Optimal deployment, mobility and energy-efficient use of UAVs; (2) integration with other 5G technologies.	[81]
Other technologies	mMIMO	(1) Performance of practical mMIMO.	

Legend: IoT (Internet of Things), 5G (Fifth Generation), mmWave (Milimeter-wave), RAT (Radio Access Technology), D2D (Device-to-Device communication), mMIMO (massive Multiple Input Multiple Output), 3D (Three Dimensional), HetNet (Heterogeneous Network), GFDM (Generalized Frequency Division Multiplexing), UFMC (Universal Filtered Multi Carrier), CR (Cognitive Radio), IFDB (In-band Full Duplexing), MAC (Medium Access Control), f-OFDMA (filtered Orthogonal Frequency Division Multiple Access), TDD (Time Division Duplexing), UAV (Unmanned Aerial Vehicle).

5.1. Wide and Flexible Bandwidth Technology

mmWave band communication and large-scale antennas are promising technologies for future 5G networks. The mmWave band covers frequencies from 30 GHz to 300 GHz [202], and from an industry and wireless academia point of view, it is a unique solution for solving 5G capacity requirements [96]. mmWave band communications will provide high data rates [7,202,225–227] utilizing a much larger spectrum bandwidth that can reach up to 5 GHz [39] and by using directional antennas and high attenuation [40]. To provide sufficient antenna gain mmWave requires implementation of large-scale antennas at the transmitter and receiver side [96]. Deployment of large antenna arrays with mmWave will also bring high spectral efficiency, high throughput and channel gain [7]. Despite all of its advantages, mmWave needs line of sight (LOS) operation [41], while the effective communication distance of mmWave signals is within 200 m due to the propagation characteristic of this frequency band [29]. Open problems associated with mmWave include three dimensional (3D) channel modeling, dynamic power control, user scheduling and congestion control, hardware limitation and the adaptive beam-steering technique, as described in [7]. The problem of high power consumption of a large number of antennas in an array [7], high efficiency low complexity adaptive antenna array processing algorithms [29] and innovative hardware architecture of large-scale antenna transmitters [29] still remain unsolved. A proposal of design guidelines in architectures and protocols for mmWave communications is presented in [42]. It is demonstrated that new mmWave technologies, which are under investigation for 5G communications systems, will be able to provide indoor centimeter (cm)-accuracy localization in a robust manner, ideally suited for Assisted Living (AL) [228].

Heterogeneous multi-radio access technologies (multi-RAT) integration is specific to 5G networks radio design that coexists with existing networks. Since 5G networks will not be developed to replace current wireless networks, but rather to advance and integrate existing network infrastructures with new ones [217], we refer to 5G as a heterogeneous network. Multi-RAT is defined as the capability of a mobile network to support multiple radio access technology with seamless interworking among them [229]. When deployed in heterogeneous networks (HetNets), with traffic offloading among different RATs, multi-RAT improves capacity [230], supports better communication rates [34,117–119,231,232], better energy efficiency [34,117–119,231,232], and ensures seamless connectivity with higher QoS [230]. In designing a heterogeneous RAT, researches are finding solutions for cell-association and traffic-offloading algorithms [217].

Cognitive radio with spectrum sharing is a new software defined technology, which is expected to improve the utilization of the congested radio frequency (RF) spectrum [43]. In 5G networks, it is used for designing multi-tier architectures, removing interference among cells, and minimizing energy consumption in the network [44–47,120,233]. Moreover, a spectrum sharing technique can be used along with the CR technology to integrate the 5G spectrum [48,121]. During the practical implementation of the CR and spectrum sensing (SS) technique researchers had to design cooperative frameworks, choose cooperative secondary users and transmit cooperative information during the spectrum sensing, further developing the framework and algorithms for the group handoff of secondary users and enhancing security [29]. Researchers are already working on designs of protocols for different IoT application, based on cognitive radio, and some of them are presented in [49–51,122]. Technologies in this group are used together to optimize 5G performance requirements (e.g., a prototype of mmWave integrated HetNet in [123] and HetNet that incorporates massive multiple-input and multiple-output (mMIMO) and mmWave technologies [217]).

5.2. Advanced Modulation and Coding

This technological group involves advanced modulation (i.e., frequency and quadrature amplitude modulation (FQAM)) and advanced channel coding schemes.

Advanced modulation schemes group includes FQAM, Amplitude and Phase Shift Keying (APSK), Unitary Space-Time Modulation (USTM), Spatial Modulation (SM), Wave Modulation

(WAM), and Orthogonal Time Frequency and Space (OTFS). The FQAM is a combination of frequency shift keying (FSK) and quadrature shift keying (QAM) [124–126]. This modulation can achieve a higher transmission rate for cell edge users reducing interference at cell edge [52,234–236]. FQAM also improves energy efficiency, which makes it adequate for MTC devices with stringent energy consumption requirements [124]. Due to performance advantages in terms of Frame Error Rate (FER) [53,236], FQAM is an ideal candidate for services with high coverage and reliability requirements [237]. APSK is another modulation which draws a lot of attention. It is shown that its main performance gain (i.e., to achieve a channel capacity very close to Shannon's) relies on advanced channel coding and demodulation algorithms [237]. This adds more complexity at the APSK transmitter and receiver. Another modulation, which does not need Channel State Information (CSI) to enable high throughput, is called USTM [237]. USTM and its extension (see [238]) is very useful for 5G services with high mobility [127] or latency and reliability constraints [239]. Other modulation schemes involve SM [128], and proprietary WAM and OTFS [237]. On the basis of the foregoing, researches have analyzed and compared many modulation forms, but still have not found a practical guide on how to choose modulation in any of the 5G use cases.

Advanced channel coding techniques are used for correcting the communication errors caused by noise, interference, and poor signal strength [129]. Authors in [54,129,130] compared turbo, low density parity check (LDPC) and polar codes in decoders in contrast to 5G requirements: (1) maturity; (2) throughput and latency; (3) error correction capability; (4) flexibility; (5) computation complexity; (6) interconnect complexity; (7) high-performance flexible implementation complexity; and (8) backward compatibility. This comparison showed that turbo codes hold the greatest promise for offering high performance throughputs, latencies and error correction capabilities, as well as high degrees of flexibility at the lowest implementation complexity [129] in most 5G use cases. However, further work is needed to implement a decoder based on this code followed by detail analysis.

5.3. Duplexing

This technological group includes in-band full duplexing (FD) and dynamic time division duplexing (TDD).

In-band FD or simultaneous data transmission and reception will provide a 1000-fold increase in throughput [131,240], double spectral efficiency [132,240], and reduce the air interface delay [240]. The central research problem for the practical implementation of an in-band full-duplex radio is the attenuation of the self-interference signal by an adequate amount [132]. For the practical implementation of an in-band full-duplex radio, many aspects of network design and management need to be restructured, where terminals antenna and circuit design and the development of theoretical foundation are in focus [55]. One practical implementation of the full-duplex radio is shown in [133]. Authors in [134] commented that for the design of a full-duplex radio, it is necessary to unify researches from three domains, i.e., RF circuit and system design, digital signal processing and networking.

Dynamic TDD is the predecessor of FD transmission technology and a candidate for 5G [133,135]. It represents a scheduling technique in which every base station (BS) is free to choose its own uplink/downlink (UL/DL) split [136–139]. This technique is used to adapt the allocation of network resources to variable traffic requirements [139,140], often found in ultra-densely deployed networks [141]. The dynamic TDD can significantly increase bandwidth efficiency [142] and provide higher throughput and low latency [141]. However, it is characterized by the severe co-channel interference (CCI) [141–143]. Dynamic TDD could be used in combination with D2D communication and in the self-backhauling scenario, as described in [55].

5.4. Multiple Access and Waveforms

Multiple access techniques are becoming an important technology in 5G because of their ability to support mMTC activity-based IoT classes with urgent deploy demand [144]. They include several non-orthogonal multiple access (NOMA) forms: multi-user shared multiple access (MUSA) [145–148], resource spread multiple access (RSMA) [149], sparse code multiple access (SCMA) [150–152], pattern division multiple access (PDMA) [153–155], interleave-division multiple access (IDMA) [156,157], and NOMA by power domain [158]. The NOMA is a radio access technology design for enabling greater spectrum efficiency [56,159–162,207], higher cell-edge throughput, relaxed channel feedback, and low transmission latency [99]. NOMA can be employed to enhance user fairness and to support massive connections with diverse QoS requirements [163]. In NOMA, there are several challenges and open issues, such as dynamic user pairing, the impact of transmission distortion, the impact of interference, resource allocation, NOMA with multiple antennas, heterogeneous networks, outage probability analysis, practical channel model, uniform fairness, NOMA with antenna selection, carrier aggregation and other challenges as discussed in [216]. There are still many challenging issues for SCMA, which need to be solved in future work. For example, there are several open issues in SCMA transceiver design [57], the optimization of algorithms for user grouping and power allocation [164], and further enhancement of the SCMA and MIMO combination.

New waveforms have become a serious candidate for 5G being studied in terms of: (1) modulation based on pulse shaping: filter bank multicarrier (FBMC) [58], generalized frequency division multiplexing (GFDM) [59], pulse shaped OFDM [165] and QAM-FBMC [241]; (2) modulation based on sub-band filtering: universal filtered multi carrier (UFMC) [242], filtered OFDM (f-OFDM) [243] and resource block f-OFDM (RB-f-OFDM) [244]; other modulation format: guard interval discrete Fourier transform spread OFDM (GI DFT-s-OFDM) [245], spectrally-precoded OFDM (SP-OFDM) [246] and orthogonal time frequency and space (OTFS) [247]. The f-OFDM is seen as a potential candidate for IoT applications [60]. Due to narrow sub-bands and thereby pure detection performance, additional processing is needed [60]. Performance of self-interference cancellation (SIC) or filtering on f-OFDMA [60] remains a topic for further study. Additionally, it is interesting to consider the balance of time and frequency dispersion in UFMC, as well as the design of an efficient prototype filter according to application scenarios [60].

5.5. *Advanced Interface Management*

This technological group includes receiver advances in terms of simultaneous non-unique decoding (SND) and sliding-window superposition coding (SWSC).

SND follows a rule that implies that each receiver attempts to recover the code words from intended and interfering senders [248]. The combination of advanced receivers and joint scheduling provides an improvement of over 50% in cell edge throughput without sacrificing the cell average throughput [5]. This gain demonstrates that if 5G networks incorporate advanced interference management, they will provide a virtually edgeless end-user experience [5].

SWSC [61,62] combines the theory concept from superposition coding without rate splitting [63], block Markov coding [166,167], successive cancellation decoding [63,64,168], and sliding-window decoding [65,169,249]. The sliding-window coded modulation (SWCM) aims to mitigate inter cell interference at the physical layer by achieving simultaneous decoding performance with point-to-point channel codes, low-complexity decoding, and minimal coordination overhead [170]. The realization of the theoretical concept to the practical transmission coding scheme is an important research direction in SWSC [5].

5.6. *Access Architecture Related Radio Technology*

This technological group includes ultra-densification, enhanced wireless backhaul, moving networks, and D2D communication.

Advanced small cell [66,123] deployment is considered to be one of the key enablers for achieving many of the requirements currently envisioned for 5G [67], with higher data rates [68,171,250] and more capacity [171–174], as most important. Higher data rates and smaller battery consumption can be achieved using short distances in the small cell [69]. Solving the capacity and data rate challenge with network densification could be very expensive in terms of equipment, maintenance, and operations [200]. With denser cell deployment come significant challenges in the design of a high-performance backhauling system for RAN and the impact of backhaul on radio resource management (RRM) [70]. However, there are in existence many interesting topics to be further investigated which can be grouped around several problem areas [34]: user association, backhauling, interference management, energy efficiency, and propagation modelling.

Moving networks (MN) are the combination of multi-hop and vehicular communications concepts [69,71]. The MN deploys one or several moving relay node(s) (MRNs) [175,176,251] on vehicles that form their own cell(s) inside the vehicle to serve vehicular users [72]. Challenges in using MRN are efficient backhauling, design of efficient resource allocation and interference management techniques, as well as mobility management schemes to exploit the benefit of group handovers for vehicular user equipment (UE) devices served by the same MRN [72]. The main research challenges related to MN concept are associated with complexity management due to the mobility of access points and providing a high-rate wireless backhaul link from the moving cell to the fixed network [69].

Enhanced wireless backhaul is one of the main challenges in hyper-dense 5G networks [34,217]. The performance of wireless backhaul is dictated by the environment and traffic profile of the intended use case [9]. In UDN except mmWave, new approaches are needed, e.g., interface aware routing and intelligent resource allocation [9], as these links may occupy part of the spectrum used in the access network [73]. Latency and reliability of this link are important issues to be considered being prone to blocking and fading [69]. In any case, further research is necessary to explore TDD multi-flow coordination schemes to avoid bottlenecks in the downlink backhaul [9]. The guidelines for deploying future 5G wireless backhaul networks in economical and highly energy-efficient ways are provided in [74].

D2D communication is defined as a direct route of data traffic between spatially closely located mobile UE [75,177,178]. The advantages of D2D communication compared with the traditional cellular method include the reduction of transmission latency [73,75] and power consumption [75], improvements in coverage [71,76,179], spectral and energy efficiency [77], and throughput, when power control and resource allocation methods are used [78]. The use of D2D communications has an overall positive impact on system capacity in cellular environments. D2D communication brings challenges and complexities related to interference management [79,80], QoS requirements [79], and resource allocation [34,215]. The design of D2D direct communication link is still a hot topic [29].

5.7. Energy Related Technologies

IoT applications span a broad range of domains including home automation, healthcare, surveillance, transportation, smart environments, etc. One of the most important obstacles for implementing such an impressive scheme is supplying adequate energy to operate the network in a self-sufficient way without compromising QoS [180]. Since energy efficiency is of most importance to battery constrained IoT devices, researches have focused their work on the development of the device energy saving mechanisms.

Energy harvesting is a new paradigm which uses solar, thermal, wind and kinetic energy sources to power sensor nodes and consequently prolong network lifetime [181]. Among different energy harvesting methods, wireless energy harvesting (WEH) has proven to be one of the most promising solution for energy aware IoT devices, because of its simplicity, ease of implementation, and availability [180]. This concept will improve some of the 5G high network communication requirements, like reliability of IoT communications, as presented in [182]. Authors in [252] have shown that the integration of social awareness and energy harvesting in D2D communication results in higher system capacity. Network architectures proposed in [100,253] have shown better energy efficiency in 5G wireless network. Researchers could work on improving this architecture and integration with various 5G technologies in the future.

UAV implies a flying vehicle without the driving presence of a human pilot to control it on-board [113]. Drones are a possible example of UAVs, although many other robotics related applications could be part of this application group [113]. UAVs can play a vital role in IoT scenarios where devices are unable to transmit over a long distance due to their energy constraints. In this case UAVs play the role of moving aggregators which fly toward one IoT devices, collect the data, and transmit it to other devices [81]. In [183] authors presented UAV–based floating relay (FR) for cell dynamic and coverage improvement. Deployment of unmanned aerial base stations in 5G heterogeneous architecture can improve throughput [254], coverage [183–185,254], connectivity [184,185], and 5th percentile spectral efficiency [254]. On-demand wireless systems with low-altitude UAVs are in faster to deploy, more flexibly reconfigured, and likely to have better communication channels due to the presence of short-range line-of-sight links [186] when compared to terrestrial communications or those based on high-altitude platforms. The utilization of highly mobile and energy-constrained UAVs for wireless communication introduces many new challenges [186], some of them are listed in [82]. To effectively use UAVs for IoT, several challenges must be addressed such as optimal deployment, mobility and energy-efficient use of UAVs [81].

5.8. Other Technologies

Along with the aforementioned technologies, a lot of research attention is devoted to technologies, such as mMIMO, visible light communication (VLC), SIC, vehicle-to-everything (V2X), etc.

mMIMO technology [73,123] promises significant gains in data rate and link reliability [187], reduces latency and energy [13], simplifies media access control (MAC) layer [13], shows robustness against intentional jamming [13], unintended man-made interface [83], and increases capacity [127,198] due to spatial multiplexing [123]. Reliable links are provided by benefiting from spatial diversity and the mitigating effects of fast fading, beamforming, and zero forcing caused by multi-user interference [203]. The mMIMO can be exploited to extend the coverage of higher frequency bands by relying on beamforming gains [200]. Other specific benefits of mMIMO system are: increased capacity 10 times or more with simultaneous improvement in radiated energy efficiency in the order of 100 times, the possibility to use inexpensive, low-power components, the reduction of latency on the air interface, and multiple access layer simplification [83]. The low complexity mMIMO uplink scheme for IoT lightweight devices is presented in [188]. The performance of practical mMIMO system needs to be investigated, since the research community pays attention to analyzing the performance of mMIMO in an ideal channel state information assumption [73].

VLC is a growing technology for short range, high capacity LOS optical links [189]. It uses a visible range of the electromagnetic spectrum (370–780 nm) which provides data transmission and room illumination using light emitting diodes (LEDs). Prominent features of VLC are an abundant license-free spectrum, the ability to provide multiple gigabit-per-second data rates, low energy consumption, and low implementation costs [190]. VLC is sensitive to sunlight and is not able to work long range without LOS. Since VLC coverage is LOS limited [84,191], this is known as LOS blocking [192]. With poor performance in non-line-of-sight scenarios, VLC networks fail to provide convenient UL coverage at the current state-of-the-art, and each AP illuminates only a small confined cell compared to cellular RF networks [192]. VLC applications are expected to include IoT, wireless Internet access, and vehicle-to-vehicle (V2V) communications, broadcast from LED, M2M communications, positioning systems, and navigation. The problem of how to provide mobile applications over VLC is still quite an open one [189].

SIC implementation enables low-latency applications in a cost effective manner [132]. SIC can be used to increase link capacity, spectrum virtualization, any-division duplexing, novel relay solutions, and enhanced interface coordination [132]. Practical SIC implementation is still in the investigation phase.

V2X is the communication between a vehicle and everything with which it might interact (e.g., other vehicles, traffic operators and service providers). It is used in conjunction with D2D for coverage extension and latency reduction in 5G networks [255]. V2X communication might play a vital role in terms of implementing smart and efficient traffic solutions [193], improving road safety, traffic efficiency, and driver convenience. To reduce traffic congestion one may use an intelligent route management system based on V2X communication [7]. Since it has big potential in autonomous driving application, the localization of vehicles in dense urban areas is difficult, so several algorithms are proposed to solve the problems [194]. Many V2X applications are described in existing literature [85,195]. However, there is still a need to design vehicular mobility management strategies in next UDN networks and to find a way to enhance existing connected vehicle services with V2X [86].

These technologies are highlighted as the main 5G driver in existing literature [5–7,96,207]. Authors compare these technologies and try to implement them through prototypes, or test the combination of these technologies. However, other technologies exist, such as cloud-RAN [7], Coordinated Multi-Point (CoMP), White Space Spectrum [208], which are not in the scope of this paper.

5.9. Summary of IoT in Enabling Technologies

Performance requirements of activity-based IoT application classes have served to identify the enabling technologies in the radio access part of 5G networks, which are summarized in Table 5. Various 5G enabling technologies have been sorted into eight technological groups:

1. Wide and flexible bandwidth technology: mmWave band communication and large-scale antennas, heterogeneous multi-RAT integration, cognitive radio, and spectrum sharing;
2. Advanced modulation and coding: advanced modulation schemes, advanced channel coding;
3. Duplexing: in-band FD, dynamic TDD;
4. Multiple access and waveform: multiple access, new waveforms;
5. Advanced interface management: SND, SWSC;
6. Access architecture related radio technologies: advanced small cell, MN, enhanced wireless backhaul, D2D;
7. Energy related technologies: energy harvesting, UAV;
8. Other technologies: mMIMO, VLC, SIC, V2X.

These technologies have been discussed in terms of their possibilities to meet performance requirements of activity-based IoT application classes and identify research gaps and directions, which are summarized in Table 6.

We have highlighted technologies only used to satisfy high priority performance requirements of mMTC activity-based IoT application classes, i.e., connection density, positioning accuracy, and coverage. We have focused on these technologies from telco's perspective, since the area of mMTC activity-based IoT classes is more mature, as its development has already started within LTE, while uMTC poses new research questions to be answered in order to achieve unprecedented levels of reliability needed for new applications in 5G.

The new waveform technology may be used to fulfil the requirements of almost every activity-based IoT application class in terms of connection density. This technology affects the connection density by definition. Analysis of different modulation formats indicates that f-OFDM is the most suitable candidate for IoT applications with high connection density requirements. In this regard, a deeper and more comprehensive analysis of f-OFDM is needed in the context of different mMTC activities (i.e., ticketing, tracking, monitoring, and managing/controlling). The result of the analysis to be performed should be the discovery of an optimal waveform for each activity-based IoT class which has to be integrated with other 5G service classes.

Large scale antennas and advanced small cell technologies can be used to satisfy the requirements of ticketing-, tracking-, and uMTC managing/controlling-based IoT application classes in terms of positioning accuracy. Fulfilling these performance requirements is rather a business than a technical decision. The size of the 5G cell must be planned to meet the desired position accuracy since it is very important for future IoT applications, such as automated driving, remote surgery, robotics, taxis, etc.

Wide and flexible bandwidth technologies, in-band full duplex technologies, access architecture related radio technologies, and mMIMO can be used to achieve the high requirements of ticketing-, tracking-, and monitoring-based IoT application classes in terms of coverage. The combination of these technologies should be tested to find the optimal solution to meet these performance requirements. Since small cell deployment has an impact on required position accuracy, they should serve as a basis for achieving the desired level of coverage. Along with small cell deployment, mMIMO and mmWave technologies are present in almost every 5G prototype.

Since this section discusses radio technologies used to accomplish performance requirements of mMTC activity-based IoT application classes, it can serve telecom operators and other interested parties depending on their interest and potential to utilize these findings towards IoT implementation and monetization. It describes each technology in terms of definition, advantages, disadvantages, and the possible impact on the performance requirements of a broad range of IoT applications that drive the deployment of 5G networks. Moreover, this section can be useful to the research community interested in this attractive field to address recognized research gaps and directions.

6. Discussion

Telecom operators have the opportunity to capture a share of the revenue that is generated by IoT implementation depending on their role in the IoT value chain. Regardless of their role, telcos have to face many technical challenges in order to meet the changing connectivity and performance requirements. Since current cellular networks limit numerous IoT applications, new technologies are being introduced leading towards 5G networks. Therefore, telcos have to focus on deploying these network technologies in order meet the changing requirements necessary to achieve success in IoT.

In this regard, writing this paper was motivated by the challenge of providing an enhanced understanding of the scope and classification of the broad range of IoT applications in order to determine and prioritize their performance requirements with the goal of specifying the enabling technologies towards 5G networks. The aim has been to propose a new classification of IoT applications, define and prioritize the performance requirements of such IoT application classes, and give insight into state-of-the-art technologies used to meet these requirements from telco's point of view. The motivation that led to the focus of this paper being on IoT applications classification, performance requirements, and 5G enabling technologies could be explained by telco's need for added value from IoT services. Hence, an analysis of IoT customer service requests inspired us to propose an activity-based classification of IoT applications as it can, according to authors' best knowledge, has allowed telcos to more precisely specify their performance requirements and 5G enabling technologies, thereby improving customer experience.

In this regard, the paper fulfilled the following four objectives: (1) the identification of activities relevant to IoT applications and their usage as a new criterion for IoT application classification; (2) the specification and prioritization of performance requirements of such IoT applications classes; (3) the analysis of the radio technologies used to accomplish IoT application requirements; and (4) the identification of the research gaps and the recommendation of new research directions.

Through fulfilling these objectives, we reviewed literature from the fields of IoT in 5G service classifications, IoT in 5G performance requirements, and IoT in 5G enabling technologies. Since the first aim of this paper was to propose a new classification of IoT applications, the existing approaches have been summarized to serve as a basis to identify their drawbacks and formulate the appropriate solution to overcome them. In this context, we proposed a new approach to IoT applications classification, which was based on the activity as a new classification criterion denoting the main function/purpose of specific IoT application. This approach enabled a clearer and more precise positioning of particular application in the IoT application spectrum, as well as the determination of performance requirements and enabling technologies from telco's point of view. The activity-based IoT application classification facilitated the specification of the performance requirements and determination of technologies which enable these requirements to be fulfilled. In this context, the proposed approach served as a basis for the simplification of the realization of particular IoT application. For example, although the monitoring- and tracking-based applications seem to be similar, they set different performance requirements on the network, thereby allowing the proposed approach to precisely grade the IoT applications from the same IoT application domain.

Furthermore, we associated the activity-based IoT application classes with the 5G service classes, i.e., mMTC and uMTC, in order to specify and prioritize their performance requirements. It was determined that almost each activity-based IoT application class poses high requirements in terms of connection density, whereas ticketing-based and tracking-based IoT application classes additionally require high positioning accuracy and coverage. In order to analyze these performance requirements, we have summarized the radio technologies used to implement the future 5G networks. The focus was on the technologies used to meet the aforementioned performance requirements of mMTC activity-based IoT application classes, since mMTC is more mature, as its deployment has already started, while uMTC requires further research to achieve incomparable levels of reliability needed to enable new applications in 5G.

The analysis showed that new waveform technology can be used to meet the requirements in terms of connection density; large-scale antennas and advanced small cell technologies can be used for the purpose of satisfying the requirements in terms of positioning accuracy; while wide and flexible bandwidth technologies, in-band full duplexing technologies, and access architecture related radio technologies (i.e., advanced small cell, enhanced wireless backhaul, moving network, and D2D communication) can be used to achieve high requirements in terms of coverage. In addition, the conducted research study allowed us to highlight a number of open research issues that could serve the research community and other stakeholders interested in this contemporary and attractive field. In this context, we have recognized research gaps and directions which mostly relate to network redesign and optimization in order to accommodate large-scale IoT applications.

7. Conclusions

The IoT paradigm has the potential to revolutionize all areas of daily life of individuals, businesses, and society as a whole. Telcos enjoy a central role in the paradigm of IoT because of owing communication infrastructure which is exposed to the numerous technical challenges due to changing connectivity and performance requirements of various IoT applications. These requirements cannot be met with the current cellular networks which create the need to introduce new types of technologies leading toward 5G networks as the main driver for enabling numerous IoT applications. In this context, this paper proposed the activity-based classification of IoT applications and specification of their performance requirements in order to identify 5G radio technologies used to meet them, all from telco's perspective. Activity-based classification of IoT applications indirectly allowed the construction and distribution of performance, as IoT value proposition, while using 5G enabling technologies, as IoT resources in telco's internal value chain. In this context, high performance requirements of each activity-based IoT application class (i.e., connection density, positioning accuracy, coverage) served as a basis to analyze various enabling technologies in radio access part of 5G network in terms of advantages, disadvantages, and research gaps.

On the basis of the conducted analysis, we concluded that the following technologies can meet the high performance requirements of mMTC activity-based IoT application classes: new waveform technology (in terms of connection density), large scale antennas (in terms of positioning accuracy), wide and flexible bandwidth technologies, in-band full duplexing technologies, and access architecture related radio technologies (in terms of coverage). According to the identified research gaps, one may conclude that the optimal solutions for each technology are still in its infancy. This implies that any 5G enabling technology should be first implemented and tested through prototype construction before the deployment of specific IoT application. Thereafter, the technology combination that meets the performance requirements of each activity-based IoT class should first be found. Finally, the practical implementation of different technological combinations may further lead to a deep and comprehensive analysis of QoS and QoE in the context of IoT applications.

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5G VISION

DMC R&D Center, Samsung Electronics Co., Ltd.

Date : February 2015

Samsung envisions the fifth Generation (5G) mobile communication era to be the beginning of a full scale Internet of Things (IoT). Billions of connected devices autonomously interconnect with one another while ensuring personal privacy. The unprecedented latencies offered by 5G Networks will enable users to indulge in gigabit speed immersive services regardless of geographical and time dependent factors. This white paper introduces you to future services, key requirements, and enabling technologies that will herald in the 5G era that is expected to revolutionize the way we experience mobile services.

Dawn of the 5G Era

Fuelled by the unprecedented growth in the number of connected devices and mobile data, and the ever-fast approaching limits of the 4G technologies to address this enormous data demand, industry efforts and investments to define, develop and deliver the systems and specifications for the fifth-Generation (5G) mobile system and services are well under way - signaling the dawn of the 5G Era.

As shown in Figure 1, the number of connected Internet of Things (IoT) is estimated to reach 50 Billion by 2020 [1], while the mobile data traffic is expected to grow to 24.3 Exabytes per month by 2019 [2].

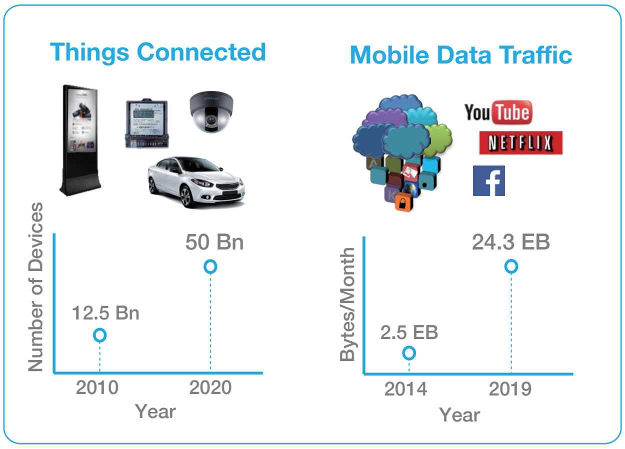

Figure 1 Growth in Mobile Traffic and Connected Devices

Add to it, the impact of higher cell capacity and end-user data rate requirements due to emerging new services such as Ultra-High-Definition (UHD) multimedia streaming and extremely low latency requirements for cloud computing and storage/retrieval, and it soon becomes evident that the current 4G systems, which are already stretched to near-breaking points (despite massive Wi-Fi offload), will be stretched too thin to deliver the quality of experience (QoE) necessary to support mobile experience that 5G is set to deliver.

5G Era can be expected to revolutionize the way we communicate by supporting immersive applications that demand exceptionally high-speed wireless connections, a fully-realized IoT, experience lower latency and promote both spectrum and energy efficiency. To realize these benefits, 5G systems will differ fundamentally from their predecessors fueling a series of groundbreaking innovations. Let's look at the services and the requirements that 5G is expected to address.

5G Service Vision

5G services have the potential to revolutionize the mobile experience. Here's how:

Internet of Things

5G will make the "Internet of Things" a reality. With 5G technology, a device will be able to maintain network connectivity regardless of time and location, and open the possibility to connect all the connected devices without human intervention. For this, the basic fabric of the 5G system design is expected to provide support for up to a million simultaneous connections per square kilometer, enabling a variety of machine-to-machine services including wireless metering, mobile payments, smart grid and critical infrastructure monitoring, connected home, smart transportation, and telemedicine. Intelligent devices will communicate with each other autonomously in the background and share information freely. This ubiquitous connectivity - a basic tenet of the 5G services, will truly enable IoT services which in turn is expected to profoundly change human lives by connecting virtually everything.

– Smart Home

Dishwashers will fix themselves using information from peers of the same model while home appliances at home and in the neighboring homes may cooperate to extinguish a fire. A smart refrigerator, recommending a recipe of cuisine to be cooked with ingredients that are already in your refrigerator, is yet another plausible scenario.

– Fitness & Healthcare

Connected Health and Fitness related wearable devices such as The Samsung Gear$^{\text{TM}}$ Fit will record your athletic performance while you exercise and recommend the type of exercise, its duration and frequency per day. These connected healthcare devices will also send vital signs such as brainwave, blood pressure and heartbeat to an expert system in the hospital in real-time to prevent medical emergencies before they occur. Such time critical applications put unprecedented requirements on latency.

– Smart Store

In large shopping malls, while many people walk around window shopping, vicinity to products is continuously tracked, usually by a server somewhere in the cloud. Customized alerts for low priced product can be sent to the user's device as the user is detected in the vicinity of that low-priced product, or information of other lower prices in the nearby stores can be sent to the device as the customer spends more time in the vicinity of a certain product class.

Such a system can be tailored to deliver a highly customized experience thereby greatly enhancing a user's shopping experience. To support such a scenario, massive connectivity and low latency technologies are inevitable.

– Smart Office

In smart office environments, office appliances are connected with one another and will share information. Nearby computers and input/output devices can recognize a user and change the settings using the user's preferences stored in the IoT cloud. Printers will print out the relevant documents when the user passes by the printer. Almost all the office appliances will connect wirelessly, while exchanging massive data through wireless medium without noticeable delay. Alerts on the upcoming meetings, materials and documents relevant to that meeting will instantaneously become available to the user's device, while documents and tasks that are modified will be automatically updated.

– Connected Car

Many of us use navigation services via in-car navigation systems or our smart phones to find the most efficient route to our destination. Vehicle diagnostic services are becoming attractive to obtain the information such as battery level, fuel level or engine status on our smartphones. The 'eCall' system that automatically calls emergency services in case of an emergency exemplifies such a service. By 2020 and beyond, more attractive services that wirelessly connect 'cars' around us with 'things' will emerge and make people in the vehicles very comfortable, and provide an enjoyable driving experience. For safer driving, sensor and camera data in a vehicle as well as supplementary information from the neighboring vehicles will be collected using mobile networks so that a potential emergency situation can be reliably informed to a driver in real-time and timely steps can be taken to avoid an actual emergency situation. This operation will eventually be applied to self-driving cars, which can be viewed as an important type of 'things'.

Immersive Multimedia Experience

In a 5G environment, users will experience life-like multimedia streams anytime and anywhere. Users will feel as if they are part of the scene when they watch videos on their smart devices. To provide such an immersive experience, many obstacles will need to be overcome. Agility to instantaneously respond to the user's thought and behavior will be necessary. An upcoming service that is expected to provide life-like experience in 5G system is UHD video streaming with its greatly enhanced resolution and clarity. Currently, UHD services over terrestrial broadcast are already being standardized in some countries. In addition, some smart phones in the market are now equipped with a camera module

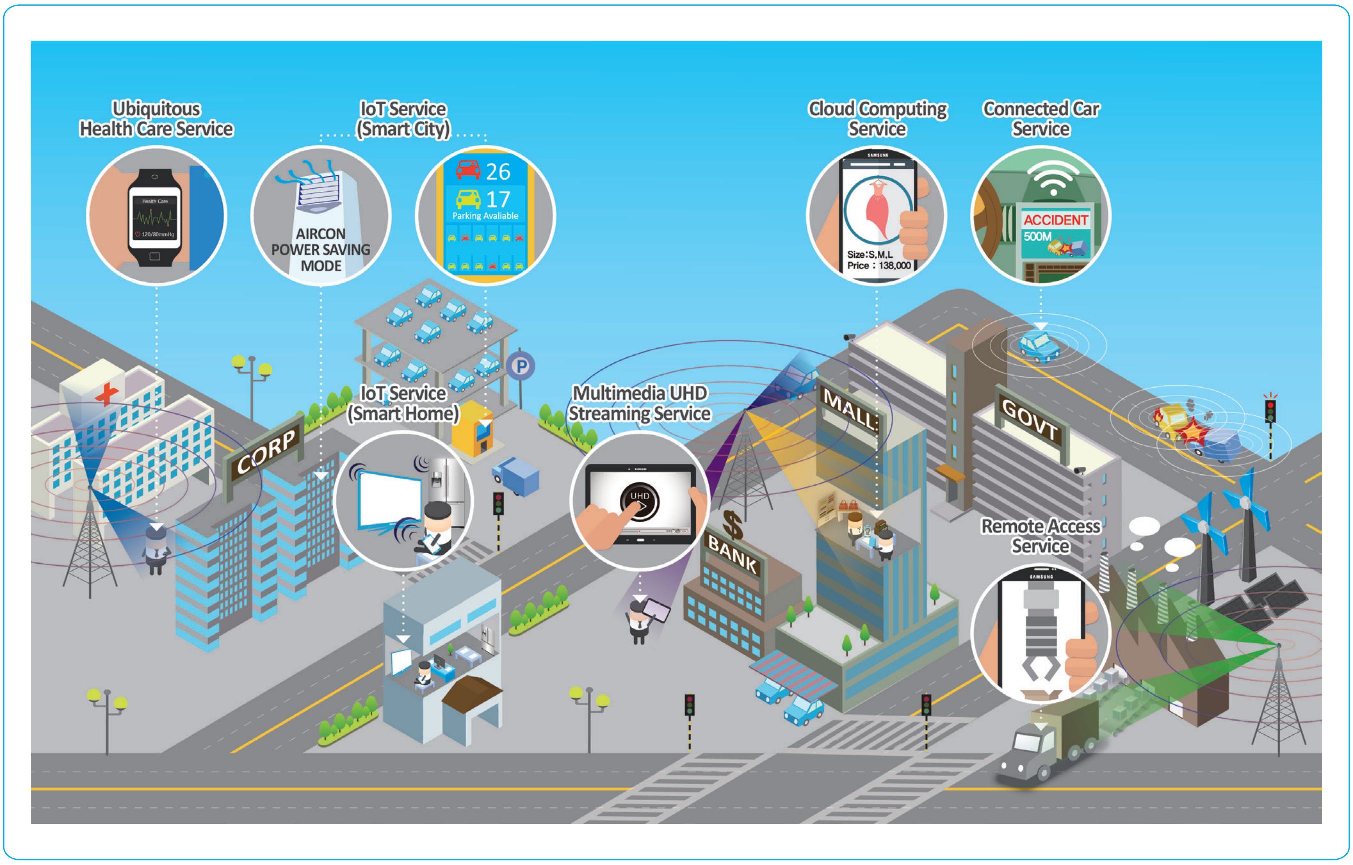

Figure 2 Major Service Scenarios with 5G

that can record video with 4K UHD quality. It is expected that UHD services are likely to go mainstream by 2020 raising an acute need for performance enhancement of cellular systems to support such services.

Other examples of "immersive" services that will fundamentally revolutionize entertainment, health, education, and other industry sectors are Virtual Reality (VR) and Augmented Reality (AR).

VR provides a world where physical presence is simulated by computer graphics, and the user can actively interact with the simulated elements, as in immersive sports broadcasting for instance (See Figure 3). Other interesting VR service scenarios are interactive 360° movies, online games, remote education, and virtual orchestra. Samsung's recently launched VR headset called (called Gear VR), virtual reality video service platform (called Milk VR) and 'Project Beyond,' (a 360° 3D camera with 17 Full HD (FHD) camera modules, optimal for generating contents for Milk VR) indicate the humble beginnings of the truly immersive experience that is to come in the 5G Era.

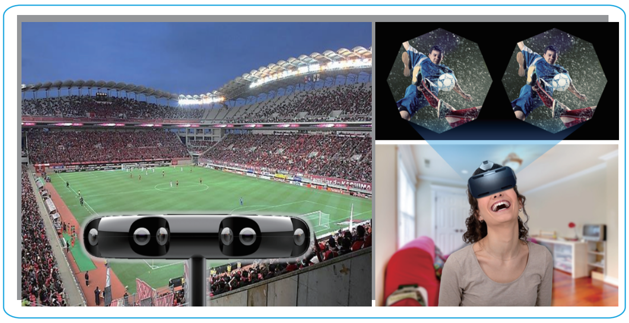

Figure 3 Watching Sport Events with VR

In an AR service scenario, computer-aided real-time information based on user context is graphically augmented to the display, delivering added value for the user. In the future the service desk attendant no longer needs to memorize the tiresome details of the products. Instead, AR services will help to inform the price, popularity, and details of a given product. Figure 4 illustrates another service scenario - AR navigation on windshield, where navigation information and other helpful notifications (refuel reminder and nearby shop location) are displayed on the windshield of a car, so that the user can continue to focus on driving while getting subtle context-aware notifications about potential services at the same time.

Samsung is actively involved in the development of 5G technologies to support these immersive VR and AR services, which will entertain users and provide a truly life-like experience on the move.

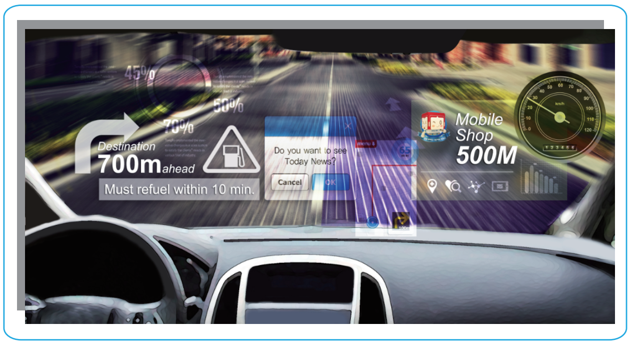

Figure 4 Driving a Car with AR Navigation

Everything on the Cloud

5G will provide users with a desktop-like experience based on cloud computing. With everything stored and processed on the cloud and immediately accessed with low latency, only simple input and output interfaces on mobile devices are needed, making them lighter, thinner, fancier, and more eco-friendly.

As an example, when you go shopping, the smart device can notify you about the arrival of new dresses that you might like, or let you know how well a dress in the newly incoming inventory matches with your liking based on your purchase history. This notification can be triggered, for instance, as you step into a shop, or take a picture of the dress, while the necessary computation to come up with the dress recommendation through crowd sourcing is done on a cloud server that is potentially half a world away.

Intuitive Remote Access

Users will be able to control remote machines and appliances as if they are right before them, even from thousands of miles away. Thanks to the reliable connections and near-zero latency of 5G, users will be able to control heavy industrial machines remotely, or access hazardous site remotely. It will also help mankind in exploring areas on the earth that are as yet unexplored, such as the Polar Regions or parts of the ocean floor.

5G Requirements

In order to realize such a demanding and unprecedented service vision, Samsung proposes the 5G rainbow requirements consisting of 7 Key Performance Indices (KPIs) as shown in Figure 5.

5G systems will be required to deliver an order of magnitude cell capacities and per-user data rate compared to its predecessors. Specially, 5G systems are expected to support data rates of 10-50 Gbps for low-mobility users. As a baseline, 5G sys-

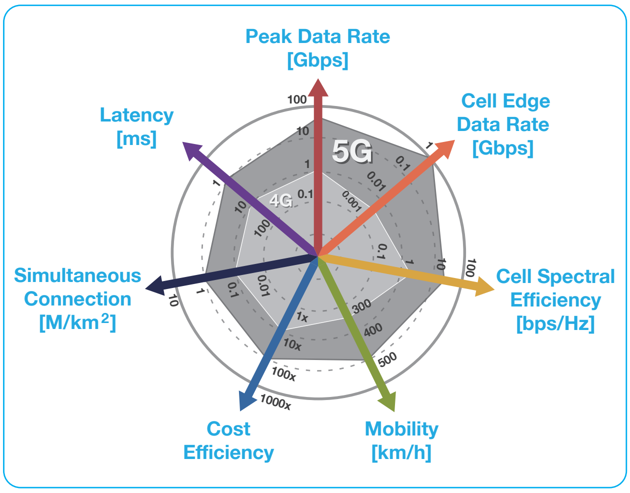

Figure 5 5G Rainbow Requirements

tems will provide gigabit-rate data services regardless of a user's location as shown in Figure 6 and Figure 7. To provide this uniform QoE, 5G network deployments are expected to be much denser compared to 4G networks, so making cost-effective deployment is a very important requisite.

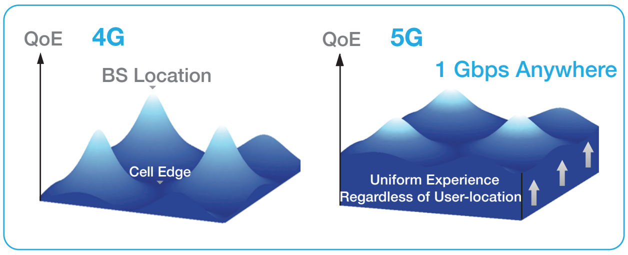

Figure 6 Edgeless RAN - 1 Gbps Anywhere

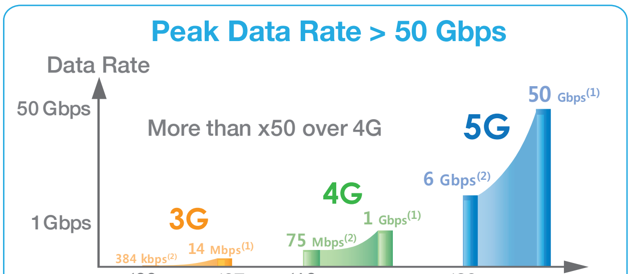

(1) Theoretical Peak Data Rate
(2) Data Rate of First Commercial Products

Figure 7 Data Rate Comparison of 5G with 3G and 4G

To fundamentally support the cloud storage/computing infrastructure of the future, 5G networks will deliver an end-to-end latency of less than 5 milliseconds and over-the-air latency of less than one millisecond (see Figure 8) - which is one-tenth compared to the latency of a 4G network. Critical infrastructure monitoring, for example, currently requires service levels achievable only on dedicated wireline networks while 5G technologies offer the promise of making these service levels achievable over wireless networks. Likewise, low-latency networks will allow pre-crash sensing, enabling vehicles to sense imminent collisions and exchange relevant data that could salvage the situation and/or mitigate adverse impact of the collision. Other challenging low-latency services that could be enabled by 5G could include self-driving cars, public safety communications systems, augmented reality, and "tactile internet" [3].

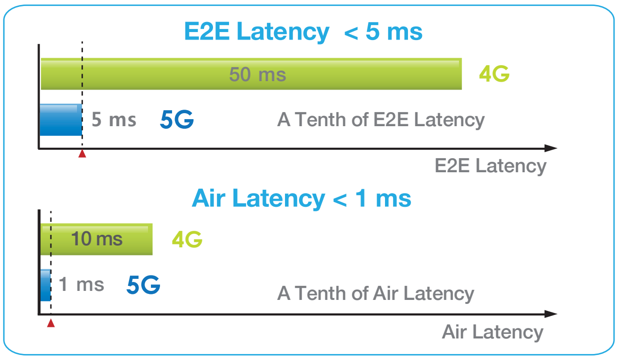

Figure 8 Ultra Low Latency of 5G

With spectral efficiency requirements set to 10 bps/Hz levels (in contrast to the 1-3 bps/Hz on 4G networks), 5G is also expected to deliver an efficient use of the spectrum by using MIMO, advanced coding and modulation schemes and new waveform design (more on this in the enabling technology section)

To address the ever-widening revenue gap that the operators and service providers are experiencing, 5G systems are targeted to be 50 times more efficient than 4G by delivering reduced cost and energy usage per bit. This sequentially requires low-cost network equipment, lower deployment costs, and enhanced power saving functionality on the network and user equipment sides.

5G technologies will be required to cope efficiently with all degrees of mobility by providing "mobility on demand" based on each device's and service's needs. On one hand, the mobility of user equipment should be guaranteed to be at least the same level as the current 4G system - that is the baseline. On the other hand, Samsung envisions that specialized 5G systems will support mobility at speeds ranging from 300 to 500 km/h.

To make the IoT Vision come true, the number of simultaneous connections in the 5G system is expected to be over 10^6 per unit square kilometer, which is much higher than that of the legacy system.

5G Key Enabling Technologies

Groundbreaking innovations will drive 5G technologies to meet the unprecedented speeds, near-wireline latencies, ubiquitous connectivity with uniform QoE, and the ability to connect massive amounts of devices with each other, all working in unison to provide the user with an immersive experience, even while the user is on the move. Future 5G systems will encompass fundamentally new designs to boost wireless capacity utilizing new frequency bands, advanced spectrum efficiency enhancement methods in the legacy band, and seamless integration of licensed and unlicensed bands.

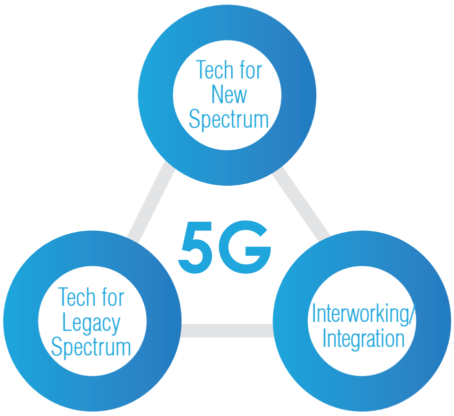
Tech for New Spectrum
5G
Tech for Legacy Spectrum
Interworking/ Integration

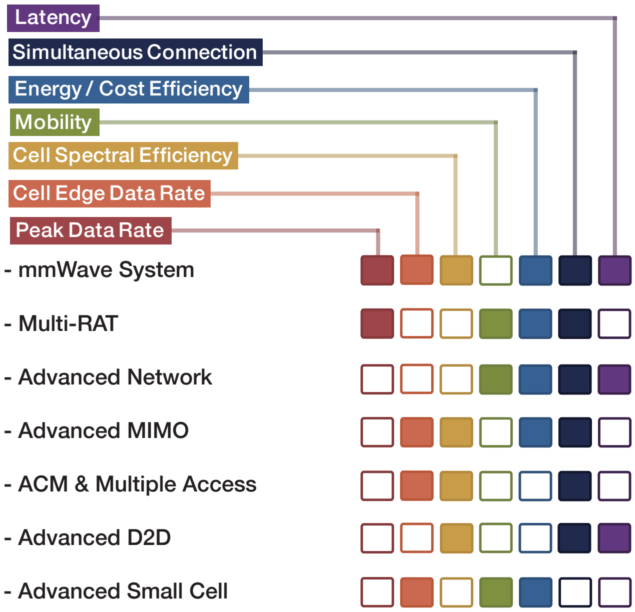

	Peak Data Rate	Cell Edge Data Rate	Cell Spectral Efficiency	Mobility	Energy / Cost Efficiency	Simultaneous Connection	Latency
- mmWave System	■	■	■	□	■	■	■
- Multi-RAT	■	□	□	■	■	■	□
- Advanced Network	□	□	□	■	■	■	■
- Advanced MIMO	□	■	■	□	■	■	□
- ACM & Multiple Access	□	■	■	□	□	■	□
- Advanced D2D	□	□	■	□	□	■	■
- Advanced Small Cell	□	■	□	■	■	□	□

Figure 9 shows an overview of the 5G key enabling technologies. The massively higher capacity needs of the 5G systems will be addressed by new mmWave systems, high-density small cells, advanced Multiple-Input and Multiple-output (MIMO) and new multiple access schemes like Filter-Bank Multi-Carrier (FBMC). Adaptive Coding and Modulation like Frequency and Quadrature Amplitude Modulation (FQAM) can significantly improve the cell edge performance and combined with higher density deployments with multi-BS cooperation will help to deliver on the promise of “Gbps anywhere” and Uniform QoE. Multi-Radio Access Technology (Multi-RAT) integration including carrier

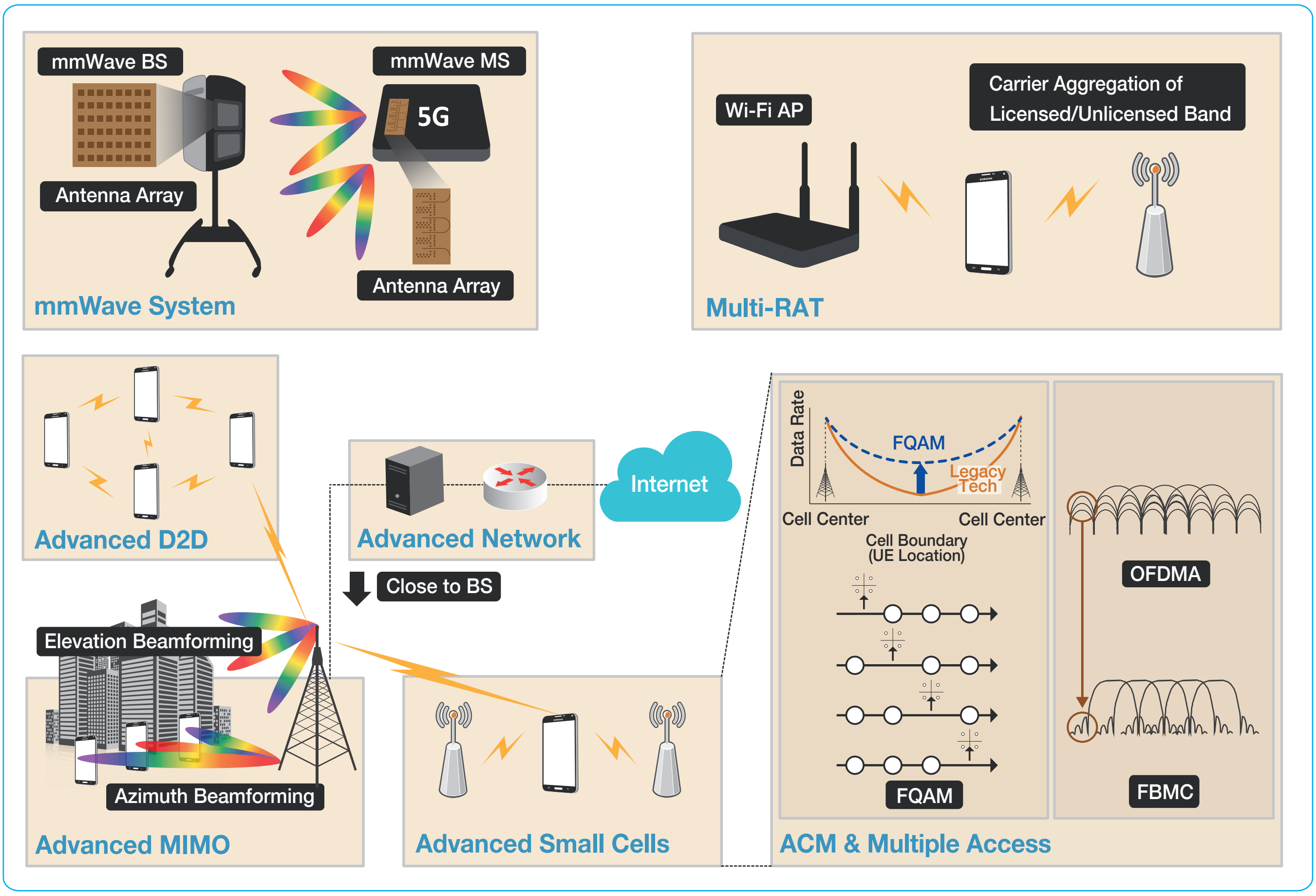
mmWave BS
mmWave MS
5G
Antenna Array
Antenna Array
mmWave System
Wi-Fi AP
Carrier Aggregation of Licensed/Unlicensed Band
Multi-RAT
Advanced D2D
Advanced Network
Internet
Close to BS
Elevation Beamforming
Azimuth Beamforming
Advanced MIMO
Advanced Small Cells
Data Rate
FQAM
Legacy Tech
Cell Center
Cell Center
Cell Boundary (UE Location)
FQAM
OFDMA
FBMC
ACM & Multiple Access

Figure 9 Overview of 5G Key Enabling Technologies

aggregation of licensed and unlicensed bands will inevitably help in increasing the available system bandwidth. On the network side, novel topologies including application servers placed closer to the network edge will contribute to significantly reducing the network latency. Advanced Device-to-Device (D2D) technology can help reduce the communications latency and support larger number of simultaneous connections in a network.

These 5G key enabling technologies are described in more detail in the following sections.

mmWave System

The mmWave bands provide 10 times more bandwidth than the 4G cellular-bands, as illustrated in Figure 10. Therefore, the mmWave bands can support the higher data rates required in future mobile broadband access networks.

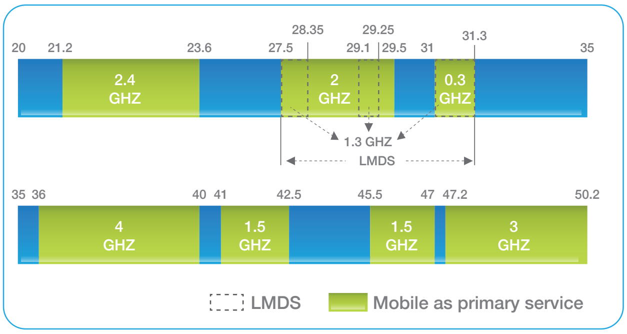
20
21.2
23.6
27.5
28.35
29.1
29.25
29.5
31
31.3
35
2.4 GHZ
2 GHZ
0.3 GHZ
1.3 GHZ
LMDS
35
36
40
41
42.5
45.5
47
47.2
50.2
4 GHZ
1.5 GHZ
1.5 GHZ
3 GHZ
LMDS
Mobile as primary service

Figure 10 Potential Bands in 20-50 GHz (US)

Unlike the below 6GHz bands, in the mmWave bands we have to carefully consider the wireless conditions such as rainfalls, snowfalls, and fogs. However, the amount of loss is mild for the expected range of a 5G communication link. For example, atmospheric absorption loss due to H_2O and O_2 at 28 GHz would be around 0.02 dB at a distance of 200 meters. Intensive rainfall (110 mm/h) results in about 4 dB loss at 200 meters distance. Loss due to heavy snow (10 mm/h) or heavy fog (visibility distance under 50 meters) will be less than 0.1 dB, at all distance of 200 meters [4][5].

In Figure 11, we show mmWave channel measurements from extensive experiments in Daejeon, Korea [6][7]. These channel measurements were carried out at 28 GHz with a channel bandwidth of 250 MHz, transmission power of 29 dBm and the horn antenna gain of 24.5 dBi for both the transmitter and the receiver [6][7].

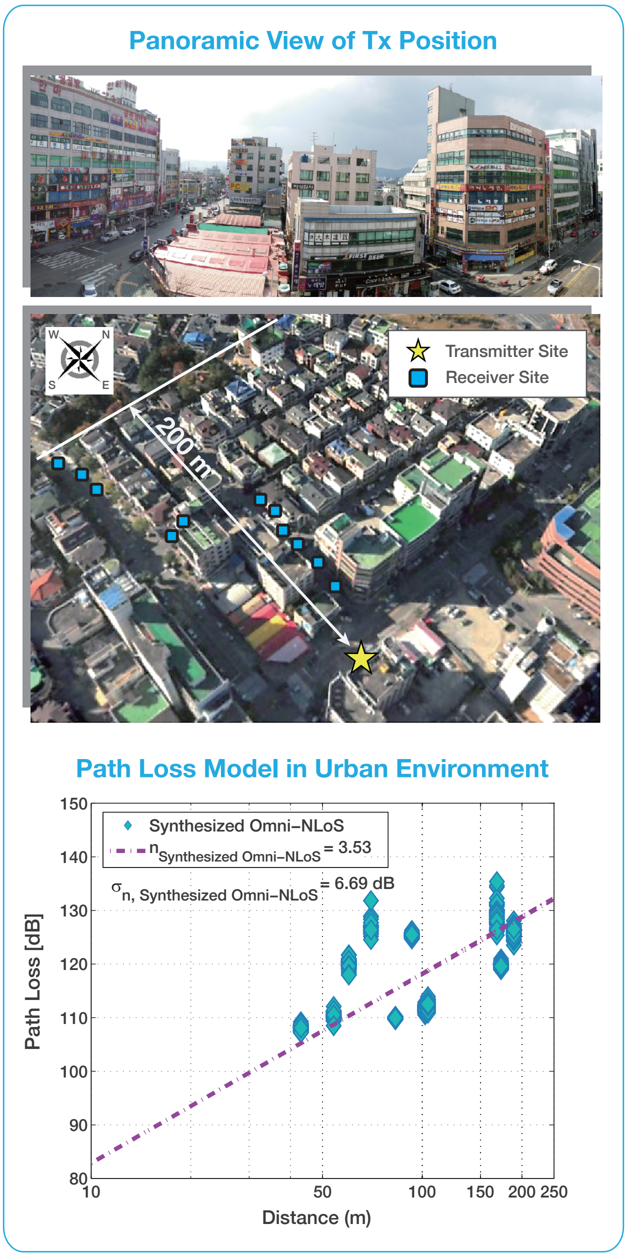
Panoramic View of Tx Position

Path Loss Model in Urban Environment

Figure 11 mmWave Channel Measurements in Urban Area, Daejeon (Korea)

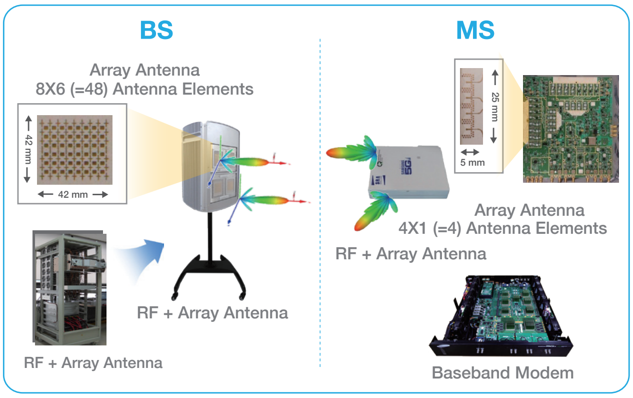
BS
MS
Array Antenna
8X6 (=48) Antenna Elements
42 mm
42 mm
RF + Array Antenna
RF + Array Antenna
25 mm
5 mm
Array Antenna
4X1 (=4) Antenna Elements
RF + Array Antenna
Baseband Modem

Figure 12 Adaptive Pencil Beamforming (Example)

The path loss exponents (based on 8 meters distance free space path loss) is 3.53 in Non Line of Sight (NLoS) links [6]. The mild path loss exponent from measurement results strongly suggests that mmWave communication links can be supported over 200 meters of distance, even in dense urban outdoor NLoS environments. Similar results are also reported in ray-tracing-based mmWave propagation model [8], confirming the fact that mmWave bands can be successfully utilized for future IMT systems. Moreover, based on the ray-tracing, mmWave 3D-channel model in urban scenario is proposed in [9]. Higher path-loss and the resulting fragile link is largely due to weak diffractions in the mmWave bands. We need to overcome these challenges in order to make outdoor mmWave communication a reality [10][11]. Fortunately, the small mmWave wavelength also means highly directional beamforms can be obtained using a large number of antenna elements in a smaller form factor. These adaptive directional beams with large antenna array gain are key in combating the large propagation loss in the mmWave [12][13][14][15], as illustrated in Figure 12.

We have developed a mmWave beamforming prototype at the DMC R&D Center, Samsung Electronics, Korea, in order to demonstrate the feasibility of using mmWave bands for cellular services. We showed that mmWave system can meet the two key requirements of cellular services: sufficiently large geographical coverage and support for mobility in NLoS environments.

With the prototype, we tested outdoor coverage to demonstrate the service availability in a typical outdoor environment for both LoS and NLoS sites. The tests were performed at sites surrounded by tall buildings where various channel propagation effects such as reflection, diffraction, and penetration were present, as shown in Figure 13. We observed that reliable communication links are formed even for NLoS sites that are more than 200 meters away from the base station.

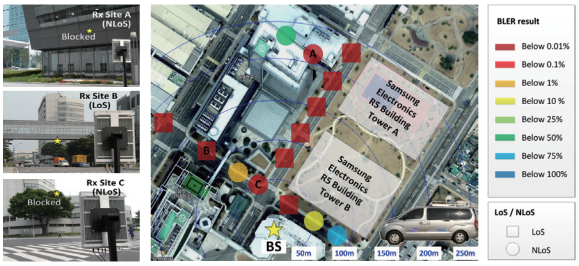
Rx Site A (NLoS)
Blocked
Rx Site B (LoS)
Rx Site C (NLoS)
Blocked
A
B
C
Samsung Electronics R5 Building Tower A
Samsung Electronics R5 Building Tower B
BS
50m
100m
150m
200m
250m
BLER result
Below 0.01%
Below 0.1%
Below 1%
Below 10 %
Below 25%
Below 50%
Below 75%
Below 100%
LoS / NLoS
LoS
NLoS

Figure 13 Exemplary Outdoor Coverage Test Results

Advances in semiconductor technology have made commercial mmWave systems readily available. Recent technologies of Silicon-based Complementary Metal Oxide Semiconductor (CMOS) processes are capable of integrating mixers, Low Noise Amplifiers (LNAs), Power Amplifiers (PAs), and Inter-Frequency (IF) amplifiers, all in a single package. A good example is the 60 GHz commercialized products with the label of Wireless Gigabit Alliance (WiGig) [16], and it is well recognized that cost effective implementations of sub-100nm CMOS process made it possible to utilize the 60 GHz bands [17].

GaAs Monolithic Microwave Integrated Circuit (MMIC) technologies are maturing fast, and they are becoming a dominant choice for components in the RF chain including PAs, LNAs, switches for digital attenuators and phase shifters, Voltage Controlled Oscillators (VCOs), and passive components from a few GHz to 100 GHz. As illustrated in Figure 14, it is projected that the Power Added Efficiency (PAE) of a 5G Front End Modules (FEM) will soon match the PAE of today's commercial 4G system. Meanwhile, a good Effective Isotropic Radiated Power (EIRP) can be achieved with the help of high antenna gains from a large number of antenna elements [18][19].

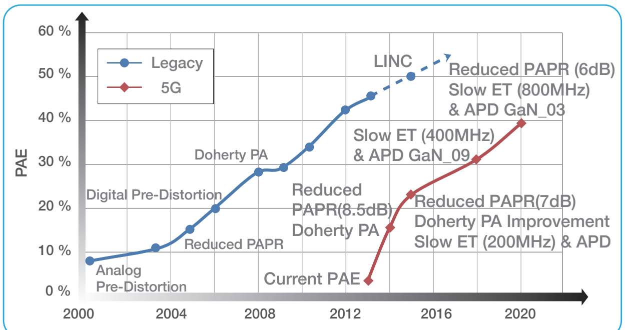

Figure 14 Projections of 5G FEM PAE

High performance antenna solution is an important piece of the 5G puzzle. The constantly varying LoS and NLoS propagation environment demands a novel antenna which exhibits high gain as well as wide spatial coverage capacity. The antenna array comprising of multiple antenna elements must fit within the small form factor of a 5G mobile handset.

Samsung has been developing innovative 5G phased array antennas that have near zero-footprint and reconfigurable antenna modes, as shown in Figure 15.

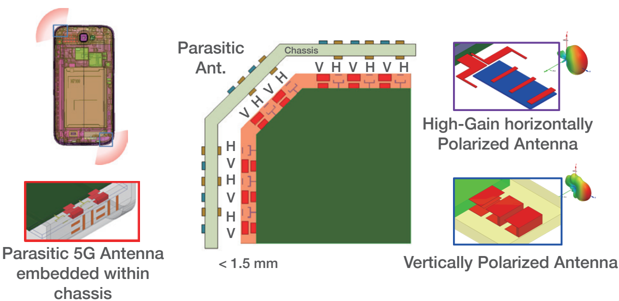
Parasitic Ant.
Chassis
V H V H V H
V H V H
H V H V H V
< 1.5 mm
Parasitic 5G Antenna embedded within chassis
High-Gain horizontally Polarized Antenna
Vertically Polarized Antenna

Figure 15 The Reconfigurable 5G Phased-array Antenna

Characterizing the biological implications on a user's body imposed by cellular handset devices is one of the most important aspects that need to be verified prior to its commercial release. The Signal Absorption Rate (SAR) regulated by worldwide governmental bodies is used as a guideline to assess the effect of mmWave bands on a user's body. The SAR of an envisioned 5G (28 GHz) cellular handset is analyzed and illustrated in Figure 16.

When optimally configured, the 5G beamforming technology enables the peak radiation of the Mobile Station (MS) antenna to steer away from the user's head. As a result, the average SAR can be reduced by more than a factor of 10 compared to that of the present day 4G cellular handsets.

The maximum SAR is expected to be further minimized in the future, as 5G antenna technology continues to evolve.

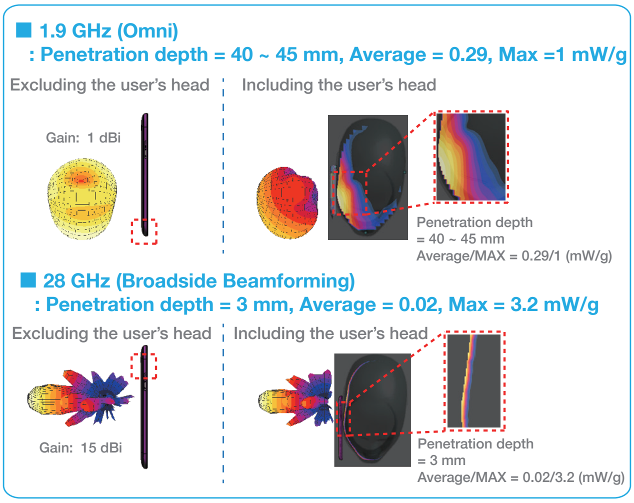
■ 1.9 GHz (Omni)
: Penetration depth = 40 ~ 45 mm, Average = 0.29, Max =1 mW/g
Excluding the user's head
Including the user's head
Gain: 1 dBi
Penetration depth
= 40 ~ 45 mm
Average/MAX = 0.29/1 (mW/g)
■ 28 GHz (Broadside Beamforming)
: Penetration depth = 3 mm, Average = 0.02, Max = 3.2 mW/g
Excluding the user's head
Including the user's head
Gain: 15 dBi
Penetration depth
= 3 mm
Average/MAX = 0.02/3.2 (mW/g)

Figure 16 Biological Implications on the User's Body

Multi-RAT

To realize the envisioned 5G services, significant enhancement of per-user throughput and overall system capacity is required, compared with those of the 4G system. Such an enhancement can be achieved through advanced PHY/MAC/network technologies and efficient methods of cell deployment and spectrum management. In particular, utilizing a larger amount of system bandwidth guarantees an increase in the capacity by allocating more frequency resources to each user in the system. Therefore, utilizing the spectrum where huge bandwidth is available can be considered to be the most critical issue for the 5G system.

Currently, the 4G system specifies its operating frequency bands and some of them are assigned to cellular operators. These deployments can be beneficial since the existing 4G system will not interfere with other RATs.

However, obtaining the licensed spectrum requires not only considerable financial investment, but also a significantly long period of time spent on regulatory procedures. More importantly, a substantial portion of the licensed spectrum around 2 GHz is already being used. Therefore, finding a bandwidth that is wide enough to support the 5G system is very challenging.

The recent trend in spectrum management is to aggregate both the licensed and unlicensed spectrums to extend available system bandwidth, as shown in Figure 17.

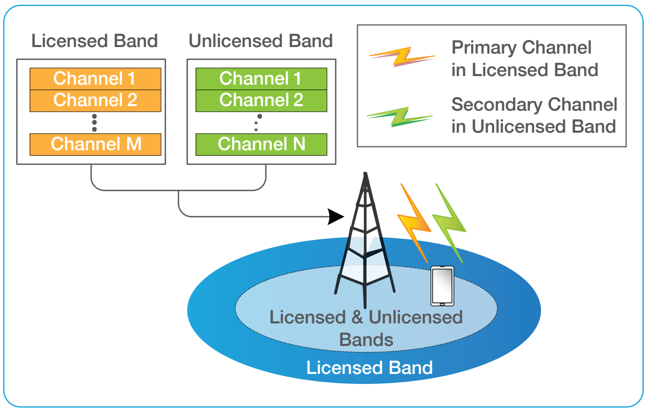
Licensed Band
Channel 1
Channel 2
Channel M
Unlicensed Band
Channel 1
Channel 2
Channel N
Primary Channel in Licensed Band
Secondary Channel in Unlicensed Band
Licensed & Unlicensed Bands
Licensed Band

Figure 17 Integration of Licensed and Unlicensed Bands

The unlicensed spectrum has plenty of bandwidth. For instance, approximately 500 MHz and 7 GHz bandwidths are available in the 5 GHz and 60 GHz bands, respectively. In order for the 5G system to utilize the unlicensed spectrum, regulations imposed on each frequency band should be carefully reconsidered. Representative examples of the regulations are the Transmit Power Control (TPC), Dynamic Frequency Selection (DFS), and Listen Before Talk (LBT).

To efficiently utilize the unlicensed spectrum, we will develop the 5G system with the following characteristics.

First, we will design PHY/MAC/network algorithms suitable for the nature of the unlicensed spectrum. Since a wide range of frequency bands are included in the unlicensed spectrum, each frequency band has its own characteristics. Hence, band-specific solutions will be provided.

Second, efficient coexistence mechanisms that take into account other RATs (e.g., WiFi or WiGig) operating in the unlicensed spectrum will be suggested.

Finally, techniques for interworking and integrating the 5G system with other RATs will be developed. By taking advantage of multiple RATs, the 5G system will be able to take advantage of the unique characteristics of each RAT and improve the practicality of the system as a whole. For instance, the 4G system is used for exchanging the control messages to maintain the connection, to perform handover, and to provide real-time services such as VoLTE. The technology operating in mmWave unlicensed frequency band would support the gigabit data rate service. Multiple mmWave cells can be overlaid on top of the underlying 4G macro cells, as shown in Figure 18.

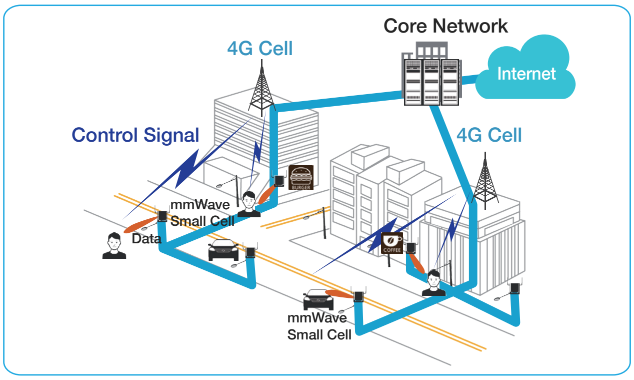

Figure 18 Overlaid Network of mmWave Small Cell Integrated with the Underlay 4G System

Advanced Network

In order to meet the 5G key requirements such as latency and the large number of simultaneous connections, and to support new business models and scenarios for operators, technologies above the radio access level should also be considered. Therefore, we need to develop technologies at the system architecture level from the network point of view. To accomplish the 5G key requirements and support the increased data rate of new 5G radio access, 5G network will have to evolve towards a distributed and flat architecture.

Current mobile network architectures designate a dedicated node in the core network (e.g., PGW - Packet Data Network Gateway in 3GPP) as a mobility anchor that allocates an IP address to the terminal, tracks terminal location in the IP topology, and ensures terminal's reachability by tunneling its traffic to wherever it goes. All terminal traffic is tunneled through the centralized node in the mobile core network. However, the undesirable consequences of this design include the following:

- Increase in end-to-end transmission latency due to elongated data paths.
- Additional load of backhauling and network processing in the core networks.
- Low network reliability due to introduction of a single point of failures.

In the 5G flat network architecture, as illustrated in Figure 19, user mobility is managed efficiently and in a dynamically scalable fashion by pushing the functionality to the edges of the network and even onto the mobile terminals [20].

The three important benefits of this approach include the followings:

First, such a distributed mobility management always provides the shortest data path between MS and the Internet without traversing the core network. This distributed mobility management leads to a significant reduction of signaling and data transmission delay. Also, low end-to-end latency requirements of 'less than 5 ms' for new 5G services such as immersive UHD video streaming, cloud gaming, and virtual reality, cannot be archived solely by reducing radio access latency but would also require a flatter network architecture design. In the flat network architecture, services which require low latency transmission can be provided by Edge Servers and they can benefit from advanced network features which utilizes network information for optimal operations.

Second, it provides a highly scalable solution compared to the centralized architecture, in which a single core network gateway maintains the whole traffic from MSs or to MSs.

Third, it easily avoids the risk of having a single point of failure. In flat network architecture, the breakdown of one network gateway would not significantly interfere with the operations of the other gateways.

Flexibility is considered as another key requirement of 5G network architecture. Software-Defined Networking (SDN) and Network Function Virtualization (NFV) provide promising examples of programmable design technologies for realizing a flexible 5G network architecture.

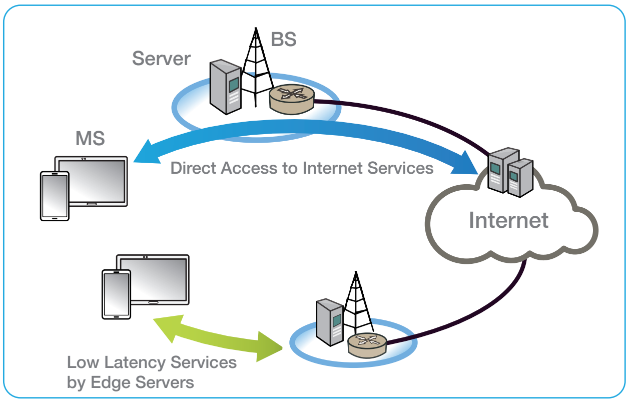

Figure 19 5G Flat Network Architecture

Advanced MIMO

One promising technology for meeting the future demands is massive MIMO transmission/reception [21]. When used with multi-user precoding schemes such as Maximum Ratio Transmission (MRT) precoding, also known as channel conjugate precoding, massive MIMO systems experience small inter-user and inter-cell interferences, and consequently achieve significantly higher throughput than the state-of-the-art MIMO systems.

One of the main challenges to build massive MIMO systems in practice is the limitation in the number of antennas that can be equipped at a BS, caused by the BS form factors and operating carrier frequencies.

For example, to horizontally install a large number of antenna elements (e.g., > 8) at the top of a BS tower operating with the lowest 4G system frequency bands of 700 MHz, eight antenna elements with 0.5 λ spacing require up to 1.7 m width, where λ is the carrier wavelength. For the typical 4G system frequency bands of 2.5 GHz, fitting 32 antenna elements with 0.5 λ spacing require up to 1.9 m width, which is still not feasible in many BSs that have only limited room on the tower. This practical limitation has motivated Full-Dimension MIMO (FD-MIMO) cellular communication systems, which place a large number of active antenna elements in a two dimensional grid at the BSs.

A typical FD-MIMO deployment scenario is illustrated in Figure 20, for a macro BS with 3 sectors equipped with 2D Active Antenna Array (AAA) panels.

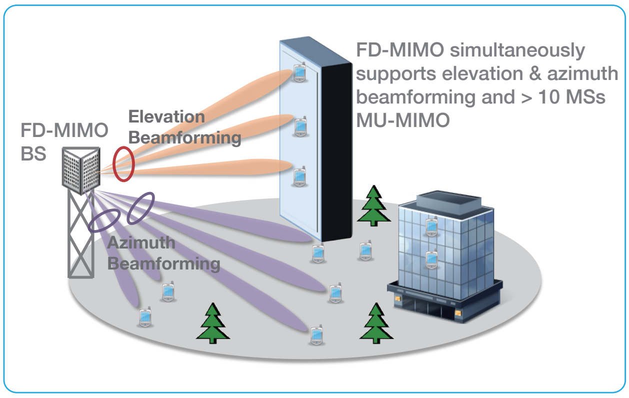
FD-MIMO simultaneously supports elevation & azimuth beamforming and > 10 MSs MU-MIMO
Elevation Beamforming
FD-MIMO BS
Azimuth Beamforming

Figure 20 Example of FD-MIMO Deployment

FD-MIMO system can support high-order Multi-User MIMO (MU-MIMO), while fully exploiting the elevation as well as the azimuth dimension, thereby generating improved system throughput.

In full buffer system-level evaluations, it has been found that 64-antenna-port FD-MIMO system achieves 243% average-cell and 244% cell-edge performance gain, compared to those of the 8-antenna-port legacy MIMO system. In order to achieve the promising gain of FD-MIMO in practice, we need accurate beam steering and tracking in three Dimensions (3D).

To steer and track the MU beams toward serving MSs, FD-MIMO BS should be equipped with multiple transceivers (TRX) feeding 2D array elements, in which the number of TRX doubles or even quadruples compared to that of the conventional BS.

Having a large number of TRX poses new challenges, such as antenna calibration and complexity issues associated with Channel State Information (CSI) acquisition and precoding.

On the other hand, high-order MU-MIMO introduces another set of new challenges, such as scheduling complexity and link adaptation. Furthermore, in Frequency Division Duplex (FDD) systems, other new challenges emerge such as pilot overhead, CSI estimation complexity, CSI quantization and feedback overheads.

ACM & Multiple Access

– FBMC

As cellular IoT has been one of key driving forces to 5G, spectrally efficient support for heterogeneous services that have quite different requirements is becoming ever so important. Accordingly, several enabling methods such as multi-RAT coexistence and flexible spectrum sharing have been actively investigated.

Recently, FBMC has drawn much attention as an enabling technology for enhancing the fundamental spectral efficiency, though its theory has a long history similar to that of Orthogonal Frequency Division Multiplexing (OFDM).

Because of the well-localized time/frequency traits adopted from a pulse shaping filter per subcarrier, the FBMC system can reduce the overhead of guard band required to fit in the given spectrum bandwidth, while meeting the spectrum mask requirement.

Furthermore, the effectively increased symbol duration is suitable for handling the multi-path fading channels even without Cyclic Prefix (CP) overhead. Consequently, the FBMC system can reduce the inherent overheads such as CP and guard-bands in CP-OFDM. FBMC is also attractive in specific asynchronous scenarios, including Coordinated Multi-Point Transmission and Reception (CoMP) and Dynamic Spectrum Access (DSA) in a fragmented spectrum.

However, to maintain the transmission symbol rate, the conventional FBMC system generally doubles the lattice density either in time or in frequency compared with OFDM while adopting Offset Quadrature Amplitude Modulation (OQAM). In OQAM, in-phase and quadrature-phase modulation symbols are mapped separately with half symbol duration offset. Thus, so-called OQAM-FBMC or Staggered Multi-Tone (SMT) causes intrinsic interference that makes it difficult to apply conventional pilot designs and corresponding channel estimation algorithms as well as MIMO schemes as in CP-OFDM systems [22].

With a base-filter that takes the spectrum confinement and the orthogonality among adjacent subcarriers into consideration, the QAM-FBMC system performs comparable to the CP-OFDM system even without the CP overhead, while the guardband overhead reduction is also available from the well-confined spectrum. Sophisticated receiver algorithms including channel estimation and equalization can further mitigate the multi-path fading channel impact without the CP.

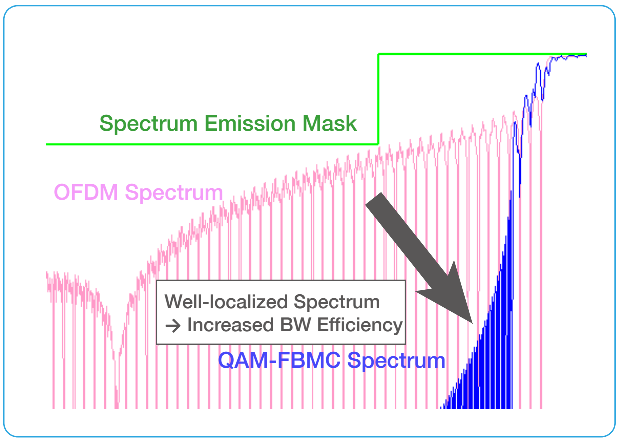

Figure 21 One QAM-FBMC Symbol Generation

– FQAM

One of key requirements for 5G is enhancement of cell-edge performance, which means that every user should be supported with Gigabit experience anywhere. Conventional approaches to enhance the cell-edge performance mainly focus on managing interference (e.g., interference cancellation, interference avoidance), by dealing with interference as a Gaussian. However, it is proved that the worst-case additive noise in wireless networks with respect to the channel capacity has a Gaussian distribution. From this observation, one can expect that the channel capacity can be increased by a non-Gaussian interference design which makes Inter-Cell Interference (ICI) non-Gaussian. The distribution of ICI depends on the modulation schemes of the interfering BSs. Therefore, an active interference design for improved cell-edge performance can be achieved by applying a new type of modulation.

FQAM, a combination of Frequency Shift Keying (FSK), and Quadrature Amplitude Modulation (QAM) can be used as an active interference design scheme. Figure 22 shows the signal constellation of 16-ary FQAM that is a combination of 4-ary FSK and 4-ary QAM.

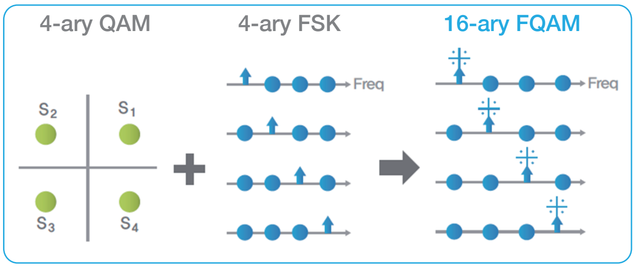

Figure 22 Example of 16-ary FQAM

With FQAM, the statistical distribution of ICI is likely to be non-Gaussian, especially for cell-edge users. As a result, the transmission rates for the cell-edge users can be significantly improved.

The statistics of ICI and the performance enhancement possibility have been proven by practical implementation of a system which uses FQAM. FQAM system environment for cellular downlink OFDMA networks is shown in Figure 23 and 24. Our experimental results show that the transmission rates for interference-limited users in FQAM-based OFDMA networks are around 300% higher than those in QAM-based OFDMA networks [23][24].

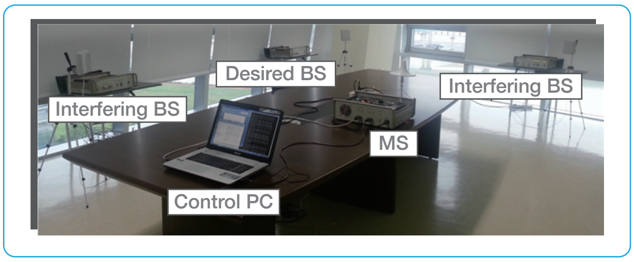

Figure 23 3 Cell Structure with MS and BSs

Figure 24 Implemented MS and BS

Advanced D2D

Advanced D2D communication is an attractive technology that enhances spectral efficiency and reduces end-to-end latency for 5G. Not entirely depending on the cellular network, D2D devices can communicate directly with one another when they are in close proximity. Hence, D2D communication will be used for offloading data from network so that the cost of processing those data and related signaling is minimized. Moreover, enhanced version of D2D communication was suggested lately for being used as special purpose such as Mission Critical Push-To-Talk (MCPTT) communication and Vehicle-to-Anything (V2X) communication.

In advanced D2D communication, a single radio resource can be reused among multiple groups which want to communicate with each other if the interference incurred between groups is tolerable. Hence, we can increase the spectral efficiency and the number of the simultaneous connection by utilizing D2D communication in 5G. Moreover, since the data is directly transmitted and not going through the core network, the end-to-end latency can be considerably reduced. Therefore, advanced D2D communication is quite well aligned with IoT services as shown in Figure 25. The cars can communicate with each other to exchange the information for safety alarm and infotainment without cellular base station. The home appliances communicate with each other for home automation service. Many objects in proximity region can be connected to each other so that IoT services can be accomplished.

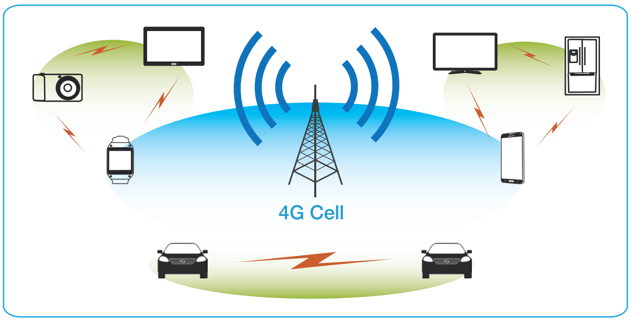

Figure 25 Advanced D2D Communications

Advanced Small Cell

To achieve significant throughput enhancement in a practical manner, it is necessary to deploy a large number of cells in a given area and to manage them intelligently. The 5G system is expected to utilize higher frequencies to take advantage of the vast bandwidth in the mmWave bands. Hence, the considerably high propagation loss of mmWave makes it suitable for dense small cell deployment, which leads to higher spatial reuse.

Moreover, Figure 26 shows the concept of a user-centric virtual cell. Conventional static network topologies with a central controller have an "edge", the reach of the central controller. However, a user-centric virtual cell that consists of a group of cooperating BSs is continuously reformed so that any user will always find himself/herself at the "center" of the cell.

Distributed and self-configuring network technologies will make it easy to deploy many small BSs in urban and suburban areas. In-band wireless backhaul can be used between BSs for cooperative communication, reducing the cost and complexity of backhaul network deployment.

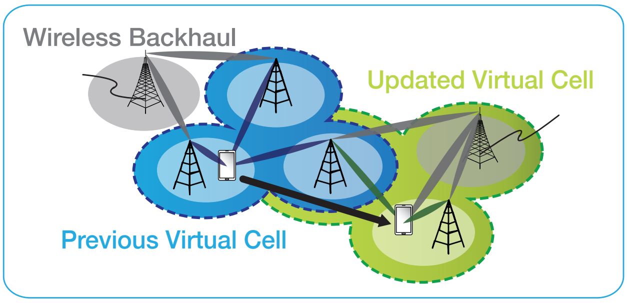

Figure 26 User Centric Virtual Cellular Network

5G Deployment Scenario

In order to provide the ubiquitous high QoE gigabit accessibility, we envision an overlaid deployment of 5G in conjunction with the existing 4G macro cells. The 5G small cells can be coupled with the overlaid 4G macro cells, and the 4G macro cells will control the operations of the associated 5G small cells, as illustrated in Figure 27. In the figure, 5G BS primarily provides multi-gigabit per second throughput with high QoE to mobile users over the legacy spectrum or higher spectrum like the 5 GHz unlicensed band and bands above 6 GHz. Meanwhile, the 4G BS can serve as a control channel to 5G MSs for supporting seamless connection anywhere over the legacy 4G spectrum.

5G system will need enhanced RAN technologies that not only utilize the legacy frequency bands assigned to IMT and IMT-Advanced systems, but also use new frequency bands. At the same time, 5G system will also need to support seamless interworking with other RATs operating in unlicensed bands.

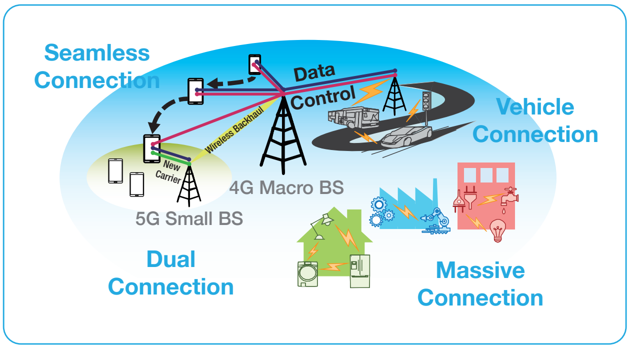

Figure 27 5G Deployment Scenario

Standardizations and Regulations

As shown in Figure 28, 5G is planned to be commercialized in year 2020. ITU-R WP 5D is preparing timelines in the vision document for standardization, spectrum allocation, and commercialization, in order to be on time. From the perspective of commercialization, standards for 5G should be ready by the year 2017 to allow 2 or 3 years for the development of 5G products. Considering average periods of previous standardization, 5G standards need to get started in 2015 to make 5G standards available by the end of 2017.

New frequency bands may be required to achieve the target performance of 5G. World Radio communication Conference (WRC)-15 agenda item 1.1 made in WRC-12 indicates consideration for additional spectrum allocations to mobile services on a primary basis and for identification of additional frequency bands for IMT purposes.

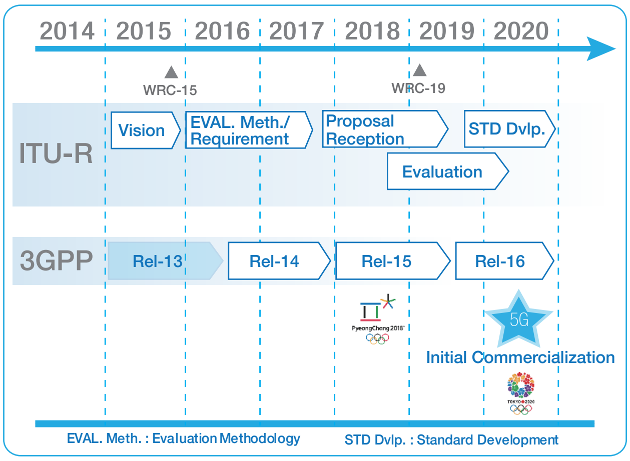
2014
2015
2016
2017
2018
2019
2020
WRC-15
WRC-19
ITU-R
Vision
EVAL. Meth./ Requirement
Proposal Reception
STD Dvlp.
Evaluation
3GPP
Rel-13
Rel-14
Rel-15
Rel-16
5G
Initial Commercialization
EVAL. Meth. : Evaluation Methodology
STD Dvlp. : Standard Development

Figure 28 5G Timelines

In light of this agenda item, various frequency ranges had been proposed and discussed in ITU-R WP 5D in July 2013, and Joint Task Group (JTG) 4-5-6-7 had performed compatibility studies among various technologies in each candidate frequency band until July 2014.

Although bands above 6 GHz were not included in JTG 4-5-6-7's candidate frequency bands, WP 5D has been developing a new report on IMT systems in bands above 6 GHz, including channel characteristics and the potential usage of the bands for IMT systems.

WP 5D may also provide JTG 4-5-6-7 with the necessary information regarding bands above 6 GHz in order to be referenced as appropriate in the draft text of Conference Preparatory Meeting (CPM). The possibility and further necessity to study the bands are captured in the report from JTG 4-5-6-7 to CPM as follows:

"The demand of high bit rate, especially in densely populated area could be accommodated in higher frequency bands (e.g. above 6 GHz) than those currently being considered in studies, however the technical information required for compatibility studies has yet to be developed and these studies and proposals are being explored for future work, beyond WRC-15."

This report implies that new frequency bands can be added to the IMT frequency bands toward WRC-19, and it is likely that bands above 6 GHz can be one of candidate frequency bands.

In addition, Licensed Assisted Access (LAA) study item has been accepted in 3GPP LTE in the second half of 2014, acknowledging the use of unlicensed bands for cellular system.

Recently, as FCC relieves 5GHz band regulations for various unlicensed band usage, related coexistence technology between LTE and WLAN will be standardized in both standards.

Further, as shown in Figure 29, Samsung is actively engaging in the most of global 5G research initiatives, such as European 5G PPP projects of Horizon 2020, 5G Innovation Centre (5GIC) in UK, NYU Wireless Center in US, Giga KOREA project and Chinese 836 project.

Samsung is leading various collaborations with industries and academics over the world. In particular, Samsung has played an important role as the full member of 5G PPP Infrastructure Association, the executive board member of 5G Forum in Korea and the chair of vision sub-working group for Future IMT (5G) in ITU-R WP5D.

In order to have a consistent perspective on 5G with those of other academic institutes, we are vigorously developing 5G core technologies with several outstanding universities around the world.

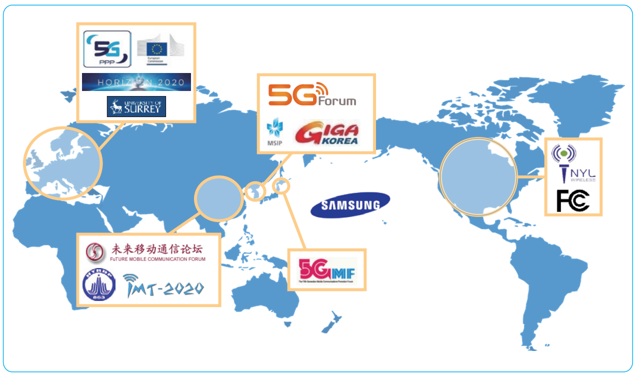
5G PPP
HORIZON 2020
SURREY
5G Forum
MSIP
GIGA KOREA
SAMSUNG
未来移动通信论坛
FUTURE MOBILE COMMUNICATION FORUM
IMT-2020
5GMF
NYU WIRELESS
FCC

Figure 29 Global 5G R&D Activities

Conclusion

5G will usher in a revolutionary generation of mobile communication that provides ubiquitous multi-Gbps data rate regardless of the user's location.

Significantly increased system capacity and real-time responsiveness of the 5G system will introduce life-changing services providing the users with a truly immersive and rich experience. The profoundly life-alternating world of billions of interconnected devices, the IoT, will require something as revolutionary as 5G to be fully realized in its fullest extent. And finally 5G promises to reverse the widening revenue gap and make it worthwhile for operators and service providers to invest again in innovative new services, and continue to propel increased productivity and efficiency.

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Samsung Demonstrates World's First 5G Data Transmission at Highway Speeds

Record-breaking 1.2Gbps data transmission at over 100km/h, and 7.5Gbps in stationary conditions using 28GHz spectrum

SEOUL, Korea – October 15, 2014 – Samsung Electronics Co., Ltd today announced the record-breaking demonstration of super-fast data transmission targeted for fifth generation (5G) mobile networks using 28 GHz spectrum. Samsung researchers confirmed the world's first data rate of 1.2 Gbps, or 150 MB per second on a vehicle cruising at over 100 km/h. This marks a significant step towards the utilization of millimeter wave frequency bands for 5G mobile networks

5G
SYSTEMS
1244 Mbps
SAMSUNG TOMORROW

Figure A Achieved Data Rate in Mobile Condition (1.2Gbps)

The achievement was bolstered by another record-breaking demonstration in which Samsung achieved data transmission speed up to 7.5 Gbps, or 940 MB per second when the vehicle came to a complete stop. The peak data rate is more than thirty times faster compared to the state-of-the-art 4G LTE technology.

Back in May, 2013, Samsung revealed the world's first 28 GHz based 5G data transmission speed of 1Gbps at pedestrian speeds. Since then researches at Samsung were able to increase the maximum data rate by more than 7-fold and support mobility up to highway speeds. The continued ground breaking success underlines the company's leadership in next-generation mobile communications.

"The expectations for 5G communications will continue to grow based on the rising demands for smart devices, cloud services, smart home technology, and Internet of Things" , said ChangYeong Kim, Head of DMC R&D Center of Samsung Electronics. "We are committed to developing innovative 5G technologies and will continue to utilize our exceptional R&D capabilities as well as our diverse partnerships with leading companies and research centers around the world".

While 5G standard has yet to be ratified, 5G networks are expected to feature data rates and capacity that are hundreds times larger compared to 4G LTE.

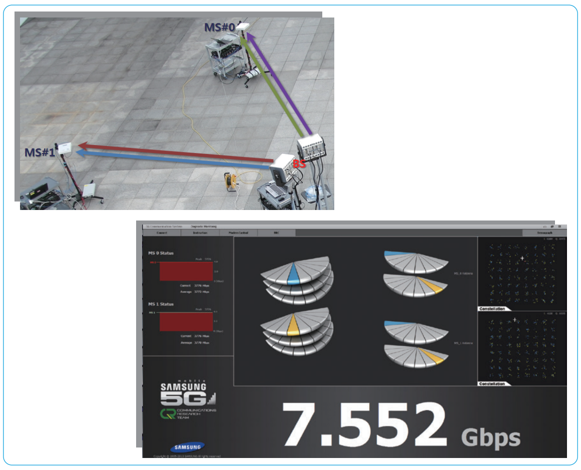

Figure B Achieved Data Rate in Stationary Condition (7.5Gbps)

In order to achieve such high data rates, 5G networks will inevitably exploit frequencies much higher and less congested than those of which are currently used for cellular networks (typically under 3 GHz). However, difficulties such as large propagation loss at these frequency bands have prohibited the industry from utilizing these bands for cellular applications. To address these challenges, Samsung has applied 'Hybrid Adaptive Array Technology' at 28 GHz frequency bands.

In addition, Samsung has revealed its '5G Rainbow' – seven technical requirements which are pillars to ensure a truly differentiating 5G user experience. The list comprises of maximum data rate, spectral efficiency, speed of mobility, data transmission rate at the cell boundary, the number of simultaneous connections, communication delays, and cost. To meet these requirements, Samsung has been developing key technologies including transmission technologies for high frequency bands, multiple access schemes and low latency networks among others.

The company is committed to developing innovative technologies that will enable the 5G era and plans to demonstrate its capabilities at the upcoming 2018 PyeongChang and 2020 Tokyo Olympics.

Australian Government

Department of Communications and the Arts

5G—Enabling the future economy

October 2017

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Australia's 5G vision

5G is the next step in the evolution of mobile wireless communications technology, promising improved connectivity, greater network speeds and bandwidth, and very low latency. It is the fifth generation in mobile technology which, at each step, has seen significant developments in communications networks:

- 1G—The first generation of mobile phone networks were deployed in the early 1980s, providing a basic voice service using analogue transmission.
- 2G—In 1991, second generation networks were deployed, making the switch to digital standards with improved voice messaging and the introduction of the short message service (SMS).
- 3G—The third generation launched in 2001 and introduced data services in addition to voice and SMS.
- 4G—In 2009, the fourth generation protocol, Long Term Evolution (LTE), was introduced, supporting improved mobile broadband which saw increased capacity and speed for data.

New capabilities of mobile communications networks enabled by 5G technology will allow for a variety of 'use cases':

- higher quality and more video services provided to multiple users with full mobility, even at high speed
- massive scale automation delivered through widespread sensor networks and multiple connected devices
- delivery of critical communications assured by low latency and ultra-reliable networks, and
- improved productivity assisted by high quality, real time data analytics.

Unlike existing mobile communications networks, 5G networks have the potential to allow tailoring of requirements for each of these different use cases within the same network.

The Government considers that 5G is more than an incremental change for mobile communications. Instead, it provides the underlying architecture that will enable the next wave of productivity and innovation across different sectors of the Australian economy. Efficient rollout of 5G and uptake of the services it supports has the potential to produce far-reaching economic and social benefits and support growth of Australia's digital economy. This will be supported by the rollout of the National Broadband Network (NBN) allowing greater capabilities for the seamless delivery of services across high speed mobile, fixed line and fixed wireless networks.

The Government wants to create an environment that allows Australia's telecommunications industry to be at the forefront of seizing the benefits of 5G across the economy. The communications sector will lead the rollout of 5G networks in Australia. However, the Government can create the policy and regulatory environment to support a more efficient rollout, given its potential benefits to the economy.

The Government's direction will be to support the timely rollout of 5G in Australia to enable the next wave of broad-based industry productivity, and support the growth of Australia's digital economy.

This includes immediate actions by Government that enable the communications market to introduce new 5G technologies in line with international developments. These include:

- making spectrum available in a timely manner
- actively engaging in the international standardisation process
- streamlining arrangements to allow mobile carriers to deploy infrastructure more quickly, and
- reviewing existing telecommunications regulatory arrangements to ensure they are fit-for-purpose.

The Government recognises that as 5G continues to develop, other issues relating to the technology will likely emerge which may require future Government action. In particular, while there are opportunities for 5G to create economy-wide transformation, this will require a broader examination of sectoral regulatory frameworks.

To that end, the Government will work collaboratively with industry to foster an ongoing dialogue on 5G beyond the launch of this paper to identify and remove sectoral barriers to its successful and timely rollout. Through this dialogue, the Government will also look at opportunities to build on other Government activities, such as the national Digital Economy Strategy which will more broadly focus on building the productivity of sectors across the economy.

What is 5G?

The International Telecommunication Union (ITU) is the United Nations specialised agency for information and communications technologies. This body decides global spectrum allocation frameworks and harmonises international spectrum to ensure networks and connected devices can communicate seamlessly. The ITU will undertake the formal, international process to identify bands for 5G by 2020. It has developed draft technical specifications for 5G which include:[1]

- high data rates (1 Gbps for hotspots, 100 Mbps download and 50 Mbps upload for wide-area coverage)
- massive connectivity (1 million connections per square kilometre)
- ultra-low latency (1 millisecond)
- high reliability (99.999% for mission critical ‘ultra-reliable’ communications), and
- mobility at high speeds (up to 500 km/h i.e. high speed trains).

In working towards these specifications, 5G represents a significant leap from the capabilities of previous generations and introduces a range of new technological possibilities. The success of 5G in delivering new technologies and services will be supported by existing communications infrastructure, including the NBN. This convergence of high-speed fixed-line and mobile services will collectively produce a consistent and ubiquitous user experience.

The 5G economics case

Unlike early generations of mobile networks, 5G will represent a significant shift in the telecommunications industry’s focus away from voice and more towards mobile broadband and increased industrial applications. These new use cases are expected to create benefits across a range of sectors—including transportation, health, manufacturing and agriculture—and have varying networking requirements. These use cases, as identified by the industry, can be divided into the following categories:

- enhanced Mobile Broadband
- massive Machine Type Communications, and
- critical communications.

Enhanced Mobile Broadband (eMBB)

eMBB will deliver improved capacity to a greater number of devices. This will enable higher rates and volumes of data transmission per device and improve coverage to a broader range of locations. eMBB will likely be the focus of early 5G deployments as it can immediately support the growing communications requirements for the digital economy.

An improved mobile experience for consumers

5G networks will give consumers a better mobile experience in more locations. Increased network capacity will support more users, even in crowded areas, such as large public events, and at peak times. Faster network speeds will also enable consumers to view rich content in more places, supporting the streaming of live events and high resolution media.

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[1] ITU, 23 February 2017, ‘Press Release: ITU agrees on key 5G performance requirements for IMT-2020’.

Massive machine type communications (mMTC)

As 5G networks mature, they will support the widespread and dense deployment of sensors and other network-connected devices by significantly reducing their power requirements and providing flexible coverage across different spectrum bands. This proliferation of the Internet of Things (IoT) across industries is expected to produce significant productivity benefits and support integration between sectors.

Supporting productivity and innovation

The term Industry 4.0 describes the next step in the advancement of the manufacturing sector (the 'fourth industrial revolution'). Industry 4.0 introduces autonomous systems supported by a combination of technologies such as IoT, artificial intelligence, continued technological improvements and digitalisation in manufacturing.

Australia stands to benefit from Industry 4.0, given our world-class manufacturing sector, which includes several high-value industries such as medical technology and aerospace. Australian manufacturers can improve their productivity and international competitiveness through Industry 4.0 processes by supporting their participation in global value chains. This is of particular benefit to SME manufacturers, opening them up to new markets and opportunities. 5G can support Industry 4.0, by providing communications infrastructure that is more accessible and flexible to suit specific industry needs.

5G can enable innovation in other sectors such as agriculture. A challenge for Australia's agricultural sector is identifying how to improve productivity while balancing environmental and commercial constraints. Precision agriculture, which focuses on improving yields and minimising economic risks, seeks to provide more control in the management of agricultural production. While precision agriculture requires a range of enablers—including data analysis, sensor networks and geographical information systems—5G can provide the supporting infrastructure for these technologies.

Critical communications

Low latency and 'ultra-reliable' communications networks will support the delivery of critical communications, i.e. to support public safety use and playing role in the technology ecosystem supporting autonomous vehicles. In addition to automation, critical communications will also help to support technological advancement in areas including robotics and artificial intelligence.

The social benefits from autonomous vehicles

5G networks are expected to play a role in the technology ecosystem supporting the development of autonomous vehicles, which will enable a number of social benefits for transportation. Traffic congestion, which is estimated to cost Australia $53 billion by 2031,[2] could be proactively reduced by smart city traffic management systems that are informed by machine-to-machine communications with autonomous vehicles.

Improved road safety is also expected to be a key outcome of autonomous vehicles, as the majority of car accidents involve human error. In the 12 months to July 2017, there were 1,235 deaths on Australian roads with road trauma costing the Australian community an estimated $27 billion annually.[3] Autonomous vehicles can have a valuable role not just in terms of financial savings, but in saving human lives.

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[2] Infrastructure Australia, 2015, 'Australian Infrastructure Audit'.

[3] Bureau of Infrastructure, Transport and Regional Economics, August 2017, 'Road deaths—monthly bulletins'.

Figure 1—Outline of the relationship between the technical requirements of 5G and expected services and applications it will deliver

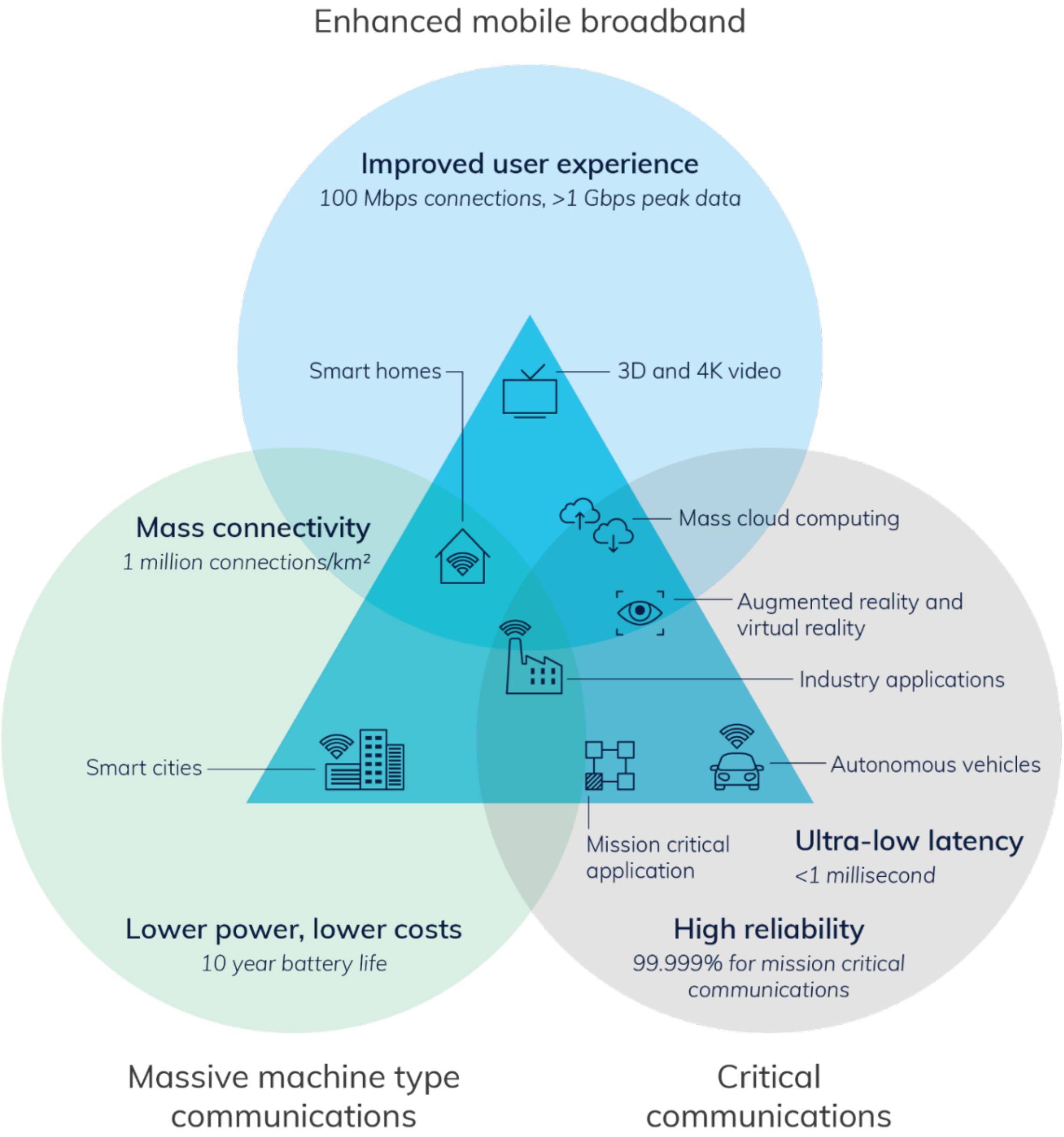
Enhanced mobile broadband
Improved user experience
100 Mbps connections, >1 Gbps peak data
Smart homes
3D and 4K video
Mass cloud computing
Mass connectivity
1 million connections/km²
Augmented reality and virtual reality
Industry applications
Smart cities
Autonomous vehicles
Mission critical application
Ultra-low latency
<1 millisecond
Lower power, lower costs
10 year battery life
High reliability
99.999% for mission critical communications
Massive machine type communications
Critical communications

Source: Based on figure 2 from the ITU paper, '[IMT Vision—Framework and overall objectives of the future development of IMT for 2020 and beyond](#).'

What is different about 5G?

5G is expected to enable productivity outcomes across key verticals of the economy as a result of a range of characteristics, such as **network slicing** and **mesh networks**. However, it will need to overcome deployment challenges such as **spectrum acquisition** and **coverage**. This is expected to lead to new approaches for deployment to enable widespread 5G coverage in Australia. The industry will also need to develop a robust **business case** for 5G rollout, which will likely be demand driven, to support the significant capital expenditure required.

Network slicing

Network slicing allows operators to split their network into separate sub-networks (also referred to as slices), enabling them to dedicate network resources to different users and applications. Sub-networks can ‘slice’ the infrastructure resources from the physical network to create virtual independent networks. This is a significant development from previous mobile network generations, as it enables an operator to deliver many different capabilities by creating slices that can be tailored for the intended usage. For example, an operator could create a network slice for IoT devices, or alternatively, a network slice for higher security for a higher quality of service for government or public safety uses.

Network slicing also provides a model for infrastructure sharing between network operators. In this case, a single transmitter’s network could be shared with more than one operator. Given the capital expenditure that will be associated with 5G rollout, network slicing can provide a cost effective, short-term solution for operators.

Figure 2—5G network slicing enables operators to create separate virtual networks to meet application requirements

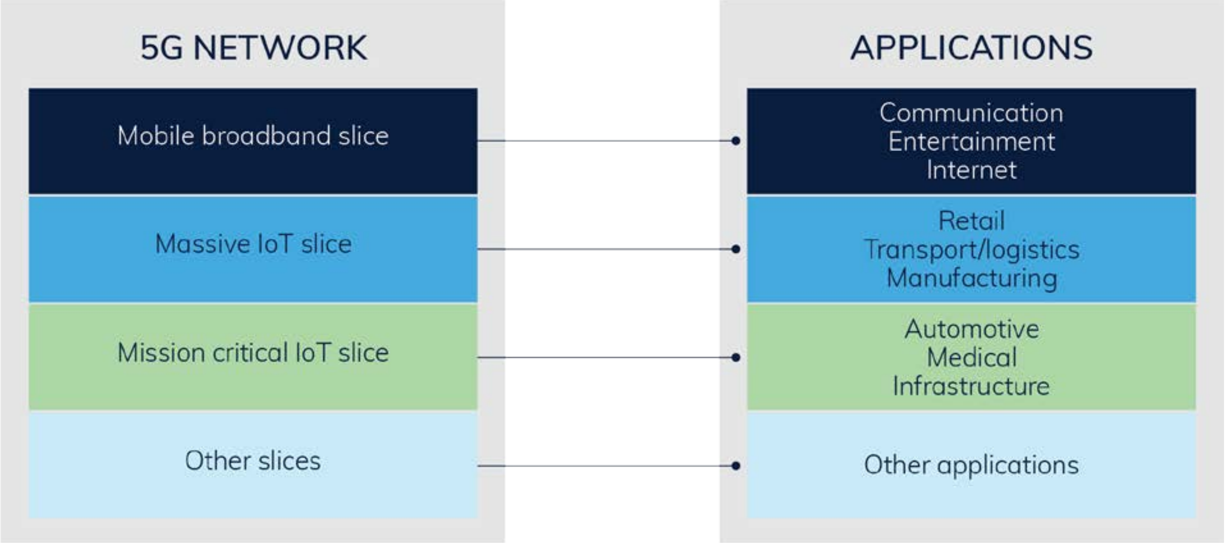

Source: Based on figure 2 from the ITU article, ‘[Why end-to-end network slicing will be important for 5G](#).’

Mesh networks

Mesh networks can be utilised to increase the range of coverage, where the ‘mesh’ is an interconnection among a network of devices. Only one device in the mesh needs to be connected to the network, which can then relay data to other nearby devices.

Mesh networks not only provide the opportunity to support 5G deployment but also have the additional benefit of providing efficient network speeds. Through dynamic routing, devices on a mesh network are able to seek the fastest and most reliable pathway to send and receive data. As such, this architecture can provide a cost effective solution for coverage in more remote areas. For example, primary industries would benefit from this network approach by simplifying network connections and costs associated with deploying and managing an IoT sensor network. However, the application of mesh networks is still highly speculative as the industry considers how they will operate in practice and in different environments. This may contribute to the development of new business models for 5G.

Spectrum sharing

Spectrum is a critical enabler of Australia’s current and future communications infrastructure. The specific spectrum bands and quantity of spectrum required for 5G are still being considered. However, 5G will likely require a mix of low, medium and high frequency spectrum to meet different scenarios relating to coverage, connectivity, and latency:

- Low frequency (less than 1GHz)—providing widespread coverage across urban, suburban and rural areas and supporting IoT for low data rate applications.
- Medium frequency (1–6GHz)—providing good coverage and high speeds, and including the expected initial 5G range of 3.3–3.8GHz which has been identified as the most likely band for launching 5G globally.
- High frequency (above 6GHz)—providing ultra-high broadband speeds for advanced mobile broadband applications, and most suitable for applications in dense traffic hotspots.

5G technologies can be expected to deliver improvements in spectral efficiency (the data rate that can be supported per unit of spectrum). However, the use of 5G networks for applications such as widespread industrial applications is likely to require significantly more amounts of contiguous spectrum to be made available.

While some of the potential bands for 5G currently have unused spectrum, other bands would need to be ‘refarmed’, noting that it is likely that bands currently used for 2G, 3G and 4G in Australia will transition over time to 5G. Refarming enables spectrum to be transitioned to the highest value use as required. The refarming of spectrum already held by mobile broadband operators is a commercial decision for those operators. 5G is also expected to provide the opportunity for ‘soft-refarming’ where 4G and 5G technologies can both be supported simultaneously, minimising the impact to legacy devices during transition periods.

Spectrum sharing, that is spectrum accessed by numerous users on a shared basis, has also been identified as an option for 5G technology. Spectrum sharing encompasses a range of different aspects of spectrum management. Spectrum can be shared by geography, time, economic priority schemes, code modulation, polarisation, directionality or power. Access to spectrum is divided between users so it can be used without interference issues.

5G opens up new opportunities for increased spectrum sharing, through mechanisms such as network slicing. 5G technology is also designed to support shared arrangements, and allows for the sharing of the same spectrum (‘unlicensed Wi-Fi’ spectrum) with other technologies. Operators can augment their holdings in situations where existing exclusive holdings are insufficient to meet customer needs. Spectrum sharing in the 5G context is also supported by the expected use of highly directional antenna technology which would enable operators to operate in closer proximity without interference.

Antenna technology and network topology

5G will require radically different structures of networks if it is to achieve successful deployment in Australia. As 5G will likely utilise different frequencies, new equipment will be necessary. Additionally, the higher frequency 5G spectrum can only travel a small distance and will need more cells to ensure adequate coverage. However, antennas and equipment will be smaller, making it easier to attach these cells to existing infrastructure such as street lights and buildings.

The more dense deployment of cells will also give rise to other approaches that improve the reliability of data transmission across a 5G network. Data may be divided into individual streams and transmitted through multiple antenna segments in a process called Multiple Input Multiple Output (MIMO) which allows for more information to be transmitted simultaneously. This technique is further empowered by 'beamforming' which allows base stations to direct focused beams of energy to a specific area rather than dissipate the available power of a larger area. These developments will enable more efficient transmission and increase overall throughput.

5G is also expected to assist the adoption of IoT by further reducing power consumption through extended discontinuous reception. In this scenario, IoT devices shift between active and inactive cycles, transmitting only when required. This will allow connected devices to operate for extended periods on a single charge, reducing operational costs.

5G will also increase the support for a greater density of devices that would have otherwise been limited by the capacity on 3G and 4G networks. They will also enhance IoT deployment through the use of network slicing to create virtual network configurations that are optimised for the low power and coverage requirements of IoT networks.

Business case

For Australians to experience the benefits of 5G, the communications sector will need to explore and develop new business cases to attract investment and support the rollout of 5G services. As 5G becomes an integral part of the communications ecosystem, the sector will need to be agile to respond to the needs and expectations of other sectors which will be seeking to take advantage of these next generation networks.

While residential consumers will inevitably be attracted to the enhanced mobile broadband services offered by 5G, it is the industrial applications for 5G where industry expects to see the greatest opportunity for new business models.

Compelling industrial applications are still to be developed. For example, industry sectors can be expected to seek tailored solutions for their business needs such as enhancing their local area network or enabling autonomous systems, and small businesses will look for low cost deployments of IoT.

It is therefore expected that the model for 5G will be demand driven and will require the communications industry to foster new business opportunities.

How are countries preparing for 5G?

In preparation for 5G, many countries have been taking steps to test the technology and review their spectrum arrangements.

Examples of 5G work being undertaken by other countries

The United States is clearing the 600MHz band through an incentive auction for the potential early deployment of 5G. The United States has also identified reforms to infrastructure deployment as a priority for 5G rollout. Mobile network operators are also conducting trials of low-band spectrum for use in 5G services.

The Asia-Pacific Telecommunity (APT), the regional arm of the ITU, approved a recommendation for the use of the 700MHz band for 5G, with 26 countries in the Asia-Pacific region identifying this band for this use, including Australia, Japan, South Korea and New Zealand.

Korea and Japan have stated their intention to use some or all of the 26.5 to 29.5GHz range to trial enhanced mobile broadband applications ahead of the 2018 Winter and 2020 Summer Olympics respectively. It is expected that these trials will lead to commercial availability of 5G services.

The European Communications Commission (ECC) identified the 3.4–3.8 GHz and 26GHz band (from 24.25 to 27.5GHz) bands for the deployment of 5G in Europe. All European countries are expected to select at least part of this range to launch 5G by 2020.

In the United Kingdom, the government launched its 5G strategy in March 2017. It is funding testbeds to understand the different deployment requirements and security considerations for 5G. The United Kingdom is also working to make suitable spectrum available in the high (24.25 GHz–27.5 GHz, and other bands above 30 GHz), medium (3.4–3.8 GHz) and low frequency (700 MHz) bands.

Industry 5G preparations in Australia

Australia is well positioned to harness the opportunities of 5G. Australia has an effective and competitive mobile communications market, with voice and data coverage available to more than 99 per cent of the population.[4] It is the top performer internationally in terms of having in place effective enablers—infrastructure, affordability, consumer readiness and content availability—to support mobile internet adoption.[5]

5G trials have already commenced in Australia, with each of the main carriers working with mobile equipment suppliers in testing the application and limits of the technology. These trials will continue and will inform the communications sector on how 5G can be effectively deployed for the Australian environment.

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[4] Department of Communications and the Arts, accessed 1 September 2017, 'Mobile phone towers'.

[5] GSM Association, 24 June 2016, 'Global Mobile Connectivity Index'.

The Government's direction for 5G

The Government has made significant investments to improve telecommunications infrastructure in Australia, through the NBN and the Mobile Black Spot Program. The Government is also working to create a policy and regulatory environment that supports a competitive and innovative communications market.

The Government recognises that 5G will enable innovation and productivity across industry sectors and can significantly contribute to Australian's growth and future prosperity. Therefore, the Government will focus on enabling the early deployment of this new generation of mobile networks in Australia and encourage its use in delivering new services and applications.

The Government will support the timely rollout of 5G in Australia to enable the next wave of broad-based industry productivity, and support the growth of Australia's digital economy.

Industry expects and needs to lead the deployment of 5G. However, the Government has a role in supporting network rollout by modernising policy and regulatory frameworks and removing barriers that would delay rollout and adoption unnecessarily.

In the first instance, the Government will support the early deployment of 5G in Australia by:

- making spectrum available in a timely manner
- actively engaging in international spectrum harmonisation activities
- streamlining arrangements to allow mobile carriers to deploy infrastructure more quickly, and
- reviewing existing telecommunications regulatory arrangements to ensure they are fit-for-purpose.

Making spectrum available in a timely manner

A clear, efficient and flexible regulatory framework governing spectrum access will be essential to support the timely deployment of 5G networks in Australia.

The Government is currently undertaking work to modernise Australia's spectrum management framework to ensure it remains fit-for-purpose. In May 2017, it outlined its proposed reforms to the framework which are designed to simplify and streamline the processes for spectrum allocation and provide a transparent, efficient and flexible spectrum management framework. This will be the most significant change to the Australian spectrum management framework in the last 25 years.

The reforms will remove barriers between licence types, and enable flexible licensing issue and allocation processes. This strategic approach will remove outdated processes and support the Australian Communications and Media Authority (the ACMA) to more effectively respond to market demands and new technologies, such as 5G. This will help Australia remain internationally competitive with a modern, innovative economy over the coming decades.

The Government will put in place its new spectrum management framework by 2019.

In addition, the ACMA will continue to work on making spectrum available for 5G. The ACMA has been investigating the use of 1.5GHz and 3.6GHz and high frequency mmWave bands in considering additional spectrum for mobile broadband services. The ACMA has decided to prioritise refarming of the 3.6GHz band over the 1.5GHz band, citing industry submissions noting this band is likely to be a pioneer band for early 5G deployments and the need to provide greater clarity and investment certainty for incumbents and potential new band entrants alike. The ACMA is currently engaging with industry on which parts of the 3.6GHz band should be reallocated and on what terms. This approach also follows international trends which have seen the 3.6GHz band commonly used for 5G trials.

The ACMA will work to bring 3.6GHz spectrum to auction in 2018.

Actively engaging in international spectrum harmonisation activities

There is already significant work underway globally with several countries trialling 5G, but standards for this new generation technology are yet to be finalised. The formal, international process to define 5G is led by the ITU. The ITU's Working Party 5D is responsible for shaping the standard for "futuristic mobile technologies" to support International Mobile Telecommunications (IMT) for 2020 and beyond.[6] This process is known as IMT-2020.

Stakeholders such as regulatory and policy setting bodies, hardware manufacturers and governments of countries in which they are based will be seeking to influence the international dialogue. A key body is the industry-driven 3GPP which undertakes technology standardisation. Collectively, the ITU and 3GPP will drive spectrum harmonisation activities: the ITU, led by administrations, will focus on the spectrum requirements; and the 3GPP, led by industry, will concentrate on equipment and device standards.

Industry is well-placed to lead the standardisation process particularly given its role identifying the application of 5G technologies. However, there is also an important role for the Government in these processes. This is particularly the case in the harmonisation of international spectrum arrangements which will have significant impact on the availability and cost of 5G devices in Australia and can be strongly contested.

In the past, Australia and the Asia-Pacific region have been influential in contributing to standards and spectrum plans that have been adopted across the world. This ensured that Australia was able to adopt new technologies quickly and that the Australian market could take advantage of the economies of scale and have a greater choice of mobile handset equipment.

The Government will ensure strong participation by Australian in domestic and international discussions about 5G spectrum harmonisation. Our continued involvement provides the opportunity to contribute to this dialogue and secure outcomes that will benefit the adoption of 5G in Australia.

Streamlining arrangements to allow mobile carriers to deploy infrastructure more quickly

The design and deployment of mobile networks will be radically different from those of today. 5G is expected to require additional infrastructure in new forms, including smaller cells and more densely-located antennas, particularly in the use of high-band spectrum.

Carriers have specific powers and immunities relating to telecommunications infrastructure deployment and installation. These laws help carriers to rollout telecommunications infrastructure quickly in a nationally-uniform way, rather than having to follow state, territory and local government requirements. These laws have existed in their current form since 1997.

The Government has recently consulted on proposed new arrangements that take account of technology developments and changes in operating practices as well as identifying opportunities to streamline deployment processes. Under these new proposed arrangements, mobile carriers would be able to rollout new communications technologies such as 5G more efficiently.

The Government understands that some members of the community have expressed concerns about the impact on public amenity from increased telecommunications infrastructure. The Government considers that telecommunications providers should work with local communities to address concerns about their infrastructure plans and is encouraging industry to consider consultation requirements for future 5G networks.

The Government continues to work with stakeholders and will implement the first tranche of changes to carrier powers and immunities following the conclusion of the consultation process.

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[6] ITU, accessed 1 September, ITU towards "IMT for 2020 and beyond."

Reviewing existing telecommunications regulatory arrangements to ensure they are fit-for-purpose

The pace of change in the communications sector is impacting on the effectiveness of the existing telecommunications regulatory framework. In response, the Government is progressively working to modernise the regulatory architecture to ensure that the regulatory and policy settings flexibly respond to the current and future needs of the communications sector.

In undertaking reform, the Government is cognisant that the communications regulatory framework will need to be sufficiently flexible to address the emergence of new technologies and business models.

5G deployment will benefit from the Government's reform efforts, including updates to the regulatory framework for telecommunications and radio spectrum and modernising the ACMA. In these cases, the Government has been revising regulation to shift it away from the traditional vertical telecommunications sectors to principles based, flexible arrangements. This will provide the versatility necessary to account for 5G developments and services.

The Government will continue to work with industry to modernise current telecommunications regulatory arrangements to ensure they encourage competition and innovation in the sector.

As with previous mobile networks, cybersecurity will be a critical consideration as 5G is deployed. Security will be even more so a challenge for 5G, as the reliability of communications will be pivotal in the technology's ability to deliver benefits, particularly in the case of critical communications.

Additionally, in providing the architecture for automation, 5G networks will trigger an ever-increasing volume of data. While the bulk of data will be machine-to-machine communications, users will want assurance that their personal information is protected. User consent will be an area of growing complexity due to the intersection between autonomous systems and the individual.

Industry has strong incentives to address cybersecurity risks in 5G's new types of network deployments and systems. However, **the Government will continue to assess cybersecurity and privacy issues as they evolve to ensure Australians have confidence in using 5G.**

Next steps

The Government recognises the opportunities presented by 5G for economy-wide transformation, creating productivity benefits in sectors such as transportation, health, manufacturing and agriculture. However, realising the benefits of 5G in sectors other than communications will need the right sectoral regulatory settings.

The Government will work to ensure that sectoral regulatory frameworks are updated to take advantage of 5G. The communications portfolio is well-placed to facilitate an ongoing strategic dialogue on 5G that will support sectors to identify and work towards unlocking the potential benefits of the technology. This dialogue would provide a starting point for greater engagement across Government and with industry and the community.

To that end, **the Government will establish a 5G working group that will bring together representatives from across Government and industry.** The working group will create a platform for this strategic dialogue with a mandate to seek out opportunities and emerging issues on 5G. This will provide better coverage across Government of the evolving policy and regulatory challenges associated with 5G.

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Energy Efficient Switched Parasitic Array Antenna for 5G Networks and IoT

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***Abstract*—This paper includes design and implementation result of an adaptive beam forming antenna for upcoming 5G and Internet of Things (IoT). Switched parasitic array antennas are low cost, small sized and compact circular array antennas that steer beam in a desired direction by variation in switching pattern of parasitic elements. The proposed antenna design has an active center element, which is surrounded by several symmetrically placed parasitic elements. The designed antenna has a gain of 8 dB and is capable of 360 degrees beam steering in steps of 60 degrees each. Simulations are validated with results of the fabricated antenna. Antenna beam is steered by controlling parasitic elements. Future application of Electronically Steerable Parasitic Array Radiator (ESPAR) antennas and switched parasitic array antennas in next generation communication networks and methods for reducing size of the antenna are also highlighted.**

***Index Terms*—Internet of Things, 5G, circular array, reconfigurable, smart antenna, adaptive beamforming, Switched-Parasitic Array**

I. INTRODUCTION

Smart antennas are capable of adaptive beam forming in accordance with the environment. Over the last three decades wireless communication has made rapid progress due to better modulation schemes and better error correction schemes. Wireless communication systems are replacing the wired ones. Antenna is an integral part of wireless devices. To meet the ever-increasing demand of higher data rate, smart antennas capable of adaptive beam forming are introduced as a potential solution to increasing data rate and improving signal-to-noise ratio (SNR) in upcoming 5G and Internet of Things (IoT) [1]. By using smart antennas Equivalent Isotropically Radiated power (EIRP) can be increased. EIRP denotes product of the transmit power (P_t) and transmit antenna gain (G_t), i.e.

$$EIRP = P_t \times G_t \tag{1}$$

From (1), it is observed that by using a smart antenna G_t increases, which in turn leads to the increase in the EIRP. The beam of an antenna can be steered by means of mechanical movement of a directional antenna or by electronic beam steering. Electronic beam steering is resilient and provides more accurate approximation of the desired signal source. Moreover electronic beam steering antenna does not involve moving parts. Therefore, there is less wear and tear on the antenna as compared to mechanical beam steering. Generally electronic beam forming is achieved by using phase shifters coupled with an array of antenna elements. The phase of an individual phase shifter is varied such that there is net constructive interference in the intended direction of the antenna beam and destructive interference in all other directions [2]. Hence, electronic beam steering is preferred over mechanical beam steering.

Electronically Steerable Parasitic Array Radiator (ESPAR) antennas use mutual coupling between antenna elements to steer the beams instead of phase shifters. Design of parastic array radiator antennas is discussed in [3], [4] in which there is a center active element surrounded by a circular array of passive elements, where each passive element is loaded with a specific reactance. ESPAR antennas are smaller in size as compared to phase array antennas because elements have to be placed at a quarter of wavelength or less distance from each other for effective mutual coupling. Hence, ESPAR antennas are cost effective and space efficient. In such antennas we have only one active element, therefore, only one feed is required. Consequently, ESPAR antennas have lower losses (due to single feed) as compared to phase array antennas [3].

Previously designed antenna Electronically Steerable Parasitic Raidator(ESPAR) antennas have all cylindrical element, including the feed element [6], [7]. In this paper we have proposed design of seven element ESPAR antenna with conical center(active element)[1]. Length of conical element is optimized using optimetrics in HFSS. Our proposed antenna has higher bandwidth as compared to previously designed ESPAR antennas. [6], [7]. In multiple-input-multiple-output (MIMO)

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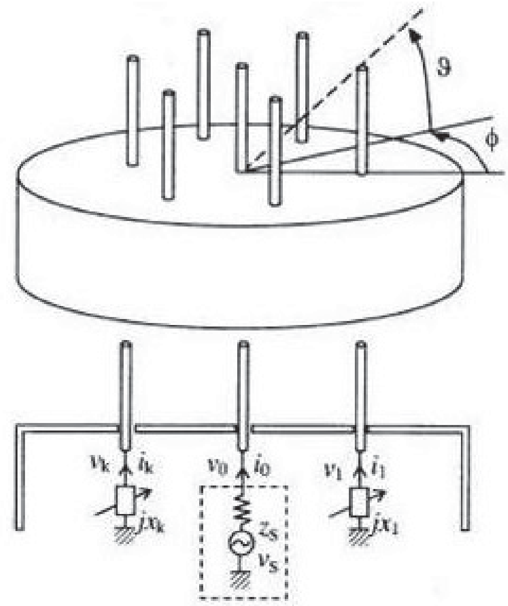

Fig. 1. Seven Element switched parasitic array antenna, ϕ is azimuth angle and θ is elevation angle.

systems there are multiple transmit and and receive antennas. Each receive antenna receives signal over different propagation channels yielding diversity gain. The MIMO technique can increase system throughput and reduce propagation losses. Similarly diversity gain can also be achieved by using smart antennas. In particular, we can transmit the same signal in multiple directions through directional beams, such that they experience different propagation channels [4]. Our proposed antenna is more suited for MIMO applications compared to previously designed model because of its higher gain and improved bandwidth efficiency.

This paper focuses on the design of a seven element switched parasitic array antenna. The antenna is first simulated and then it is fabricated. Simulation results are validated with the hardware results. Previously done work on ESPAR and switched array antennas involve cylindrical monopole elements mounted on a ground plain [8] due to cylindrical nature bandwidth of active monopole is confined, subsequently bandwidth of switched array and ESPAR antennas is limited. Instead on cylindrical monopole element we have used tapered conical monopole. Due to tapered design bandwidth is enhanced.

II. SWITCHED PARASITIC ARRAY ANTENNA CONCEPT

The conceptual overview of the switched parasitic array antenna is given in Fig. 1. We have first simulated the antenna with seven monopole elements. There is one element at center which is surrounded by a circular array. Feed is applied to the center element and it is termed as active element, whereas elements in the circular array are parasitic elements. Parasitic array antennas do not involve phase shifters, so that the manufacturing cost is less as compared to the phase array antennas. Each element is separated from other element by a quarter of wavelength, thus mutual coupling phenomena comes into account and there is a shift in phase of current in each element because of this mutual coupling phenomenon. Since switched parasitic array antennas offer adaptive beamforming solution with compact size and low cost, they are likely to be used in future communication devices to increase data-rates [6], [7]. Parasitic array antennas have vast potential for usage in laptops, cell phones, WLANs etc.

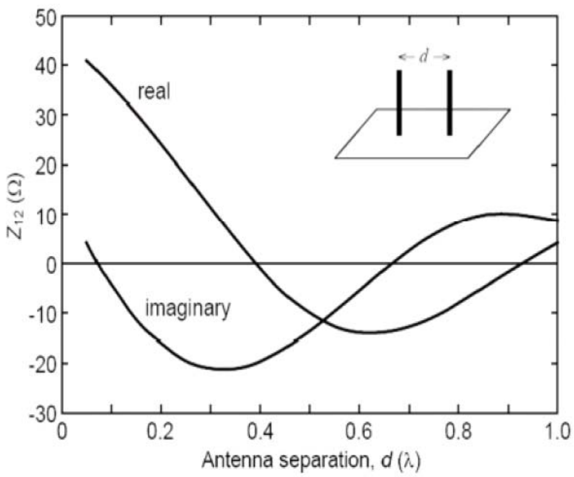

Fig. 2. Z_{21} versus separation distance.

A. Mutual Coupling

Mutual Coupling is basically the interaction between antenna elements in an array. Since parasitic elements are placed closer to each other (at a distance of λ/4) there will be mutual coupling.This mutual coupling phenomenon is responsible for a shift in phase of current induced in each element [8].The current induced by one antenna element in another antenna element [9] is given by (3)

$$I_2 = \frac{Z_{21}}{Z_{22}} \times I_0 \tag{2}$$

$$Z_{21} = \left|\frac{V_2}{I_1}\right|_{I_2=0} \tag{3}$$

$$Z_{21} = \left|\frac{V_2}{I_2}\right|_{I_1=0} \tag{4}$$

Here Z_{22} is constant as it is open-circuit output impedance. Z_{21} is open-circuit transfer impedenace from port 2 to port 1 and it can be approximated by graph shown in Fig. 2. From equation (3), beam can be steered in the desired direction by varying the phase of current I_2 [10].

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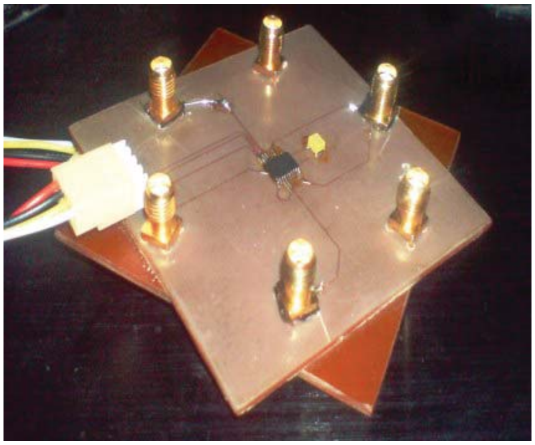

Fig. 3. RF PCB with Analog devices ADG 904 RF switches.

TABLE I
DESIGN PARAMETERS

Parameters	Values
Ground Skirt length	lambda/4
Monople Length	lambda/4
Frequency	2.45 GHz
Ground Radius	lambda/2
Monopole Radius	lambda/200
Ground Thickness	3 mm

B. *Beam Steering Mechanism*

In this work the designed antenna is capable of 360^0 beam steering in steps of 60^0. The beam steering is achieved by using two sets of 4:1 Analog devices multiplier switch ADG 904. Fig.3 shows RF PCB designed for beam steering. Beam is steered towards an element which is open. The open element behaves as a director and shorted elements act as reflectors. In order to achieve a maxima at 0^0, we make the element 1 open by using RF switch IC while other elements (i.e., elements 2,3,4,5 and 6) are shorted. This mechanism is similar to Yagi-Uda antenna where elements with shorter lengths in front of feed element act as directors and elements at rear of feed element acts as reflectors [11]. In Yagi-Uda antenna feed element is often a dipole or folded dipole.

III. PARASITIC ARRAY ANTENNA DESIGN

Design parameters and mechanical design of antenna is included in this section.

A. *Design Parameters*

Antenna design parameters are tabulated and the results are optimized using antenna simulation tools. Ground is skirted, since skirted ground provides mechanically sound model for PCB assembly to mount at back of antenna [12]. Skirt is $\lambda/4$ in length similarly each monopole element is lambda/4 in length and $\lambda/200$ is its radius.Table I shows the design parameters for the seven-element switched parasitic array antenna.

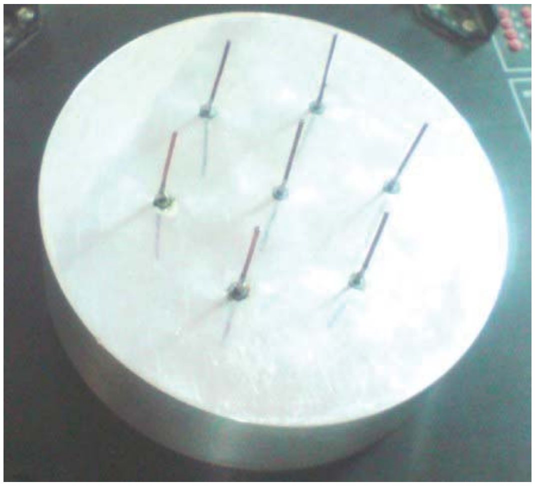

Fig. 4. Designed seven element parasitic switched array antenna.

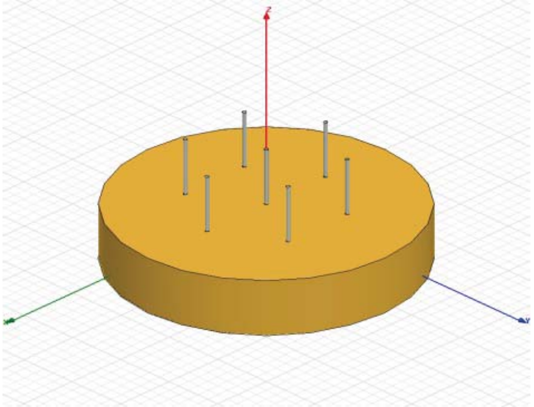

Fig. 5. Simulated antenna model.

B. *Mechanical Design*

Monopole elements are made by cutting copper wire of desired gauge i.e lambda/200 in radius [13] and these elements are soldered on pin of SMA connectors.Aluminum is used as ground plane. Electromagnetic waves are reflected by the ground. Instead of using seven dipole elements we have used seven monopole elements mounted on the ground plane [14]. Ground is made hollow in order to create space for mounting control circuitry [15]. Fig. 4 shows designed hardware.

IV. ANTENNA SIMULATION AND PLOTS

The antenna is first simulated and then simulated results are compared with the measured results of fabricated antenna. Simulated results were in line with the hardware results and 8 dB gain was observed in simulated results as well as in fabricated antenna. In simulation each of the parasitic element is loaded with lumped port excitation, simulating opening and shorting [16] of monopole elements. Fig. 5 shows simulated model.

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TABLE II
MAXIMA PATTERN

Azimuth Angle	Element 1	Element 2	Element 3	Element 4	Element 5	Element 6
0 degree	Open	Short	Short	Short	Short	Short
30 degree	Open	Open	Short	Short	Short	Short

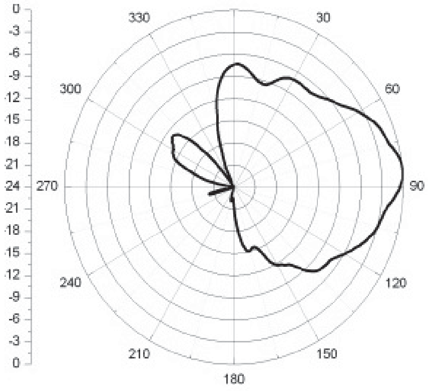

Fig. 6. Anechoic chamber results for θ=90^0 (Beam in elevated because we are using monopole elements with finite ground).

Two dimension polar plots depicts the beam steering in the direction of given elevation angle, theta (θ) and azimuth angle, phi (ϕ). Anechoic chamber results for θ=90 and ϕ=0 and 30 degrees are shown in Fig. 7 and 8 respectively. Using large ground plane angle of elevation is reduced closer to 90^0. Fig. 6 shows anechoic chamber result for θ=90 one can observe small elevation form desired x-y axis because of ground skirt [17].In simulations elevation angle of 85^0 is observed. Fig. 6(a) shows antenna simulated plot for elevation angle θ and Fig. 6(b) shows anechoic chamber results.Anechoic chamber plot of Fig. 7 shows maxima at ϕ=0^0, in order to get maxima at 0^0 elements from element number 2-6 are shorted and the element 1 is opened. Similarly Anechoic chamber plot of Fig. 8 shows maxima at ϕ=30^0, in order to get maxima at 30^0 elements from element number 3-6 are shorted and element 1 and element 2 are open.

Traditional ESPAR antenna and switched parasiric array antenna have all cylindrical elements, including the active element [3], [4]. We have made center element conical instead of cylindrical. Due to conical nature of active element response our frequency range and improved. In order to validate the gain enhancement both models were simulated and results were compared. Fig 9. (a) shows conventional design and Fig. 9(b) shows simulated antenna with conical center element. Fig. 10 shows S_{11} plot for cylindrical active element. Considering -8_{dB} as cut off point bandwidth range from 2.358 GHz to 2.51 GHz (0.152 GHz). Fig. 11 shows $S-11$ plot for centre conical element, considering 8_{dB} as cut off point bandwidth ranges from 2.36 GHz to 2.555 GHz (0.195 GHz). Therefore my making center element conical we have improved bandwidth as compared to traditional switch array parasitic antennas. Low profile design for switched parasitic array antennas in also highlighted in [18].

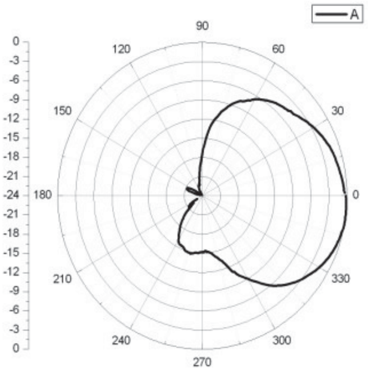

Fig. 7. Anechoic chamber results for ϕ=0^0.

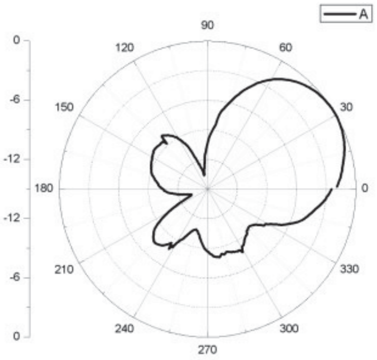

Fig. 8. Anechoic chamber results for ϕ=30^0.

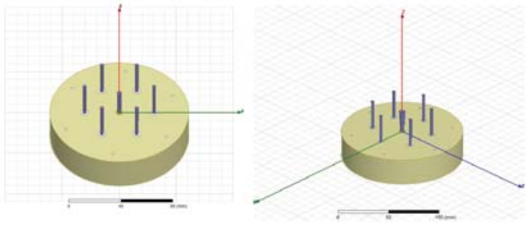

Fig. 9. (a) Conventional ESPAR antenna model with cylindrical Center Element, Fig. 9 (b) Designed ESPAR antenna with conical element for Bandwidth Enhancement.

V. FUTURE WORK AND CONCLUSION

5G networks will be designed for device to device, device to human and human to human interactions. High data rates are required to meet demands of 5G systems. One of proposed bands for 5G is in mm-Waves range i.e from 30GHz to 60GHz for such high frequencies path losses are considerable and beam steering antennas are way forward to overcome path

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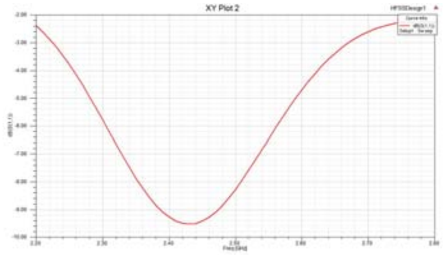

Fig. 10. S_{11} plot for conventional switched array antenna.

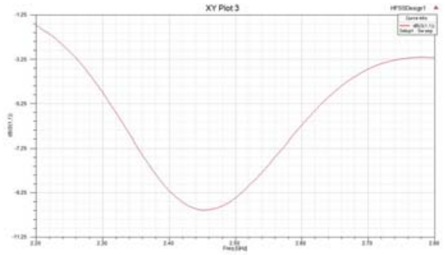

Fig. 11. S_{11} plot for center conical element switched array antenna.

losses [19]. ESPAR and switched parasitic array antennas provide a cost effective way of incorporating adaptive beamforming in future 5G and internet of Things (IoT) devices [20]. However for the efficient use of ESPAR antennas in mobile terminals the size of the antenna system must be reduced, for this further research on dielectric switched parasitic array antennas is underway. Seven element switched parasitic array antenna is designed that is capable of dynamic beam steering. Gain of 8dB is achieved practically. Simulated results are in line with the anechoic chamber results. Designed antenna increase the channel capacity by improving signal to noise ratio. Gain of 8dB was achieved in specified directions of elevation angle ,theta (θ) and azimuth angle, phi (ϕ). Antenna is optimized in terms of interference reduction for its use in wireless ad hoc networks, operating at frequency of 2.45 GHz. Bandwidth of designed antenna is 450 MHz and beam is steered in 360^0.

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Recent Antenna System Technologies for Next-generation Wireless Communications

Koichi Tsunekawa†

Abstract

This paper describes the requirements of the antennas or antenna systems in recent high-speed and high-capacity wireless communication systems and the key technologies for satisfying them. It also explains the antennas and antenna systems being researched and developed for next-generation wireless communication systems. The antenna in such a system requires high gain, high-efficiency antenna elements and a multi-antenna design. This paper introduces a high-efficiency antenna created by integrating it with a monolithic microwave integrated circuit (MMIC) in a millimeter-wave frequency-band system, a multi-antenna system for the multiple-input multiple-output (MIMO) technique that enables multiple data transmission for land mobile communication systems, and a beam-scanning antenna for satellite communication systems. It also explains the general research and development trend of antenna systems and technical problems in each wireless system as an introduction to the other selected papers in this issue.

1. Introduction

Wireless access technologies have advanced rapidly [1] and broadband wireless communication systems have become popular in our daily lives. An antenna is a very important component of a wireless system because it acts as the input and output interface for wireless equipment, as shown in **Fig. 1**. However, system performance is determined by the total performance of each component, such as the antenna and the radio-frequency (RF), intermediate-frequency (IF), and baseband (BB) units. For recent high-performance wireless systems, overall system design has been essential. Accordingly, the antenna must not

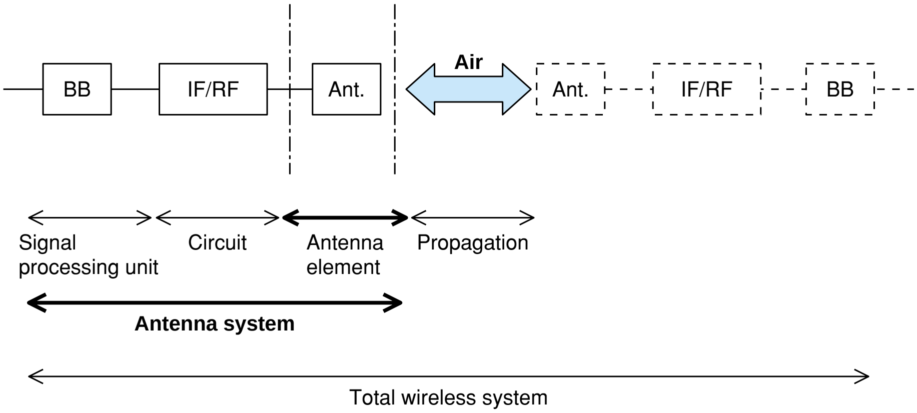

Fig. 1. Wireless and antenna system.

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only have antenna elements with high-performance characteristics, but must also perform effectively as an antenna system in conjunction with the RF, IF, and BB units. New functions can be added through antenna system design: for example, appropriate radiation pattern control provides a large system capacity by using baseband signal processing and an antenna element with an integrated RF circuit provides high gain without feeder loss.

The selected papers in this issue describe the latest antenna and antenna system technologies for achieving high performance. Two of the papers present beam-scanning antenna systems in satellite broadband communication. Beam scanning is carried out using by two methods: one [2] uses a variable active device or tunable reactance device incorporated into the antenna element, which has high-speed electronic control while the other [3] uses mechanically controlled antenna movement, which has a very precise direction control function. Another paper [4] introduces an active integrated antenna system with an RF circuit, which provides high gain and high efficiency, for a high-capacity millimeter-wave transmission system. And two papers describe a multiple-input multiple-output (MIMO) antenna system for obtaining high-speed transmission and high system capacity in the land mobile communication system from the viewpoints of beamforming techniques [5] and implementation methods [6].

As an introduction to these advanced antenna techniques, this paper provides a general explanation of the requirements of antennas and antenna systems in recent high-speed and high-capacity wireless communication systems and the key technologies for satisfying these requirements. It also describes current antenna systems and NTT's antenna research results for typical wireless systems.

2. Antenna requirements in recent wireless communication systems

The trend of wireless systems is shown in **Fig. 2**. This indicates the typical system transmission speed and number of antennas needed to achieve a particular system performance for each operating frequency. Wireless communication systems are moving towards high transmission speeds and high capacity by using higher system frequencies to enable a wide frequency

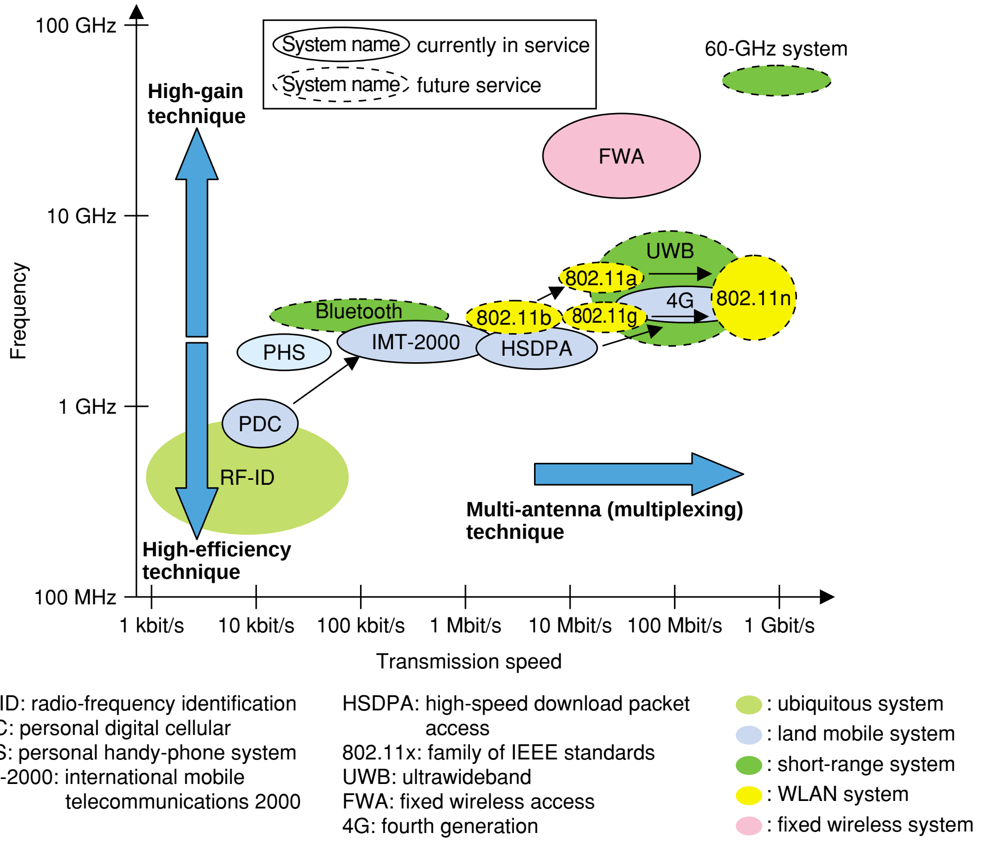

Fig. 2. Advances of terrestrial wireless communication systems and their relationship to antenna technologies.

band and using advanced system technology to achieve high quality and signal multiplexing. The antenna requirements for these system properties are:

- High-gain and high-efficiency technology
- Multi-antenna technology

Increases in the gain and efficiency of an antenna are offset by higher propagation loss at high frequencies, so the received signal level needs to be higher. High gain is an age-old problem in antenna research and development. Multi-antenna technology improves the receiving signal quality and provides multiplexed signal transmission by using an antenna system that includes RF circuits, BB units, and antenna elements.

2.1 High-gain and high-efficiency antenna

Theoretical and experimental antenna gain and efficiency characteristics are shown in **Fig. 3**. The dependences of gain and beamwidth on horn dimension L(λ) in a relatively large antenna are explained in Fig. 3(a) [7]. When L is more than 0.5 times the wavelength, the antenna's efficiency is about 100%; a larger antenna provides higher gain. However, the high-gain radiation pattern leads to a narrow beamwidth. Therefore, a mobile terminal needs to use beam-scanning or beam-tracking techniques to follow the transmitter while the terminal moves. On the other hand, the efficiency decreases if the antenna size is less than 0.5 wavelengths. The bandwidth of a linear dipole antenna versus its efficiency for various antenna sizes (D: diameter) is shown in Fig. 3(b). This graph was estimated from theoretical limits [8] and many experimental results. The antenna efficiency becomes approximately –5 dB when antenna bandwidth of 10% is provided using a linear dipole antenna with a length of 0.3 wavelengths. This figure shows that the efficiency and bandwidth have a tradeoff relationship and that the efficiency drops greatly as the antenna size decreases. Therefore, some clever ideas for the antenna element structure are needed to overcome these weak points.

2.2 Multi-antenna system

A multi-antenna system has several antenna elements, but it does not merely work as an ordinary array antenna. The performance requirements are satisfied because the antenna system includes RF circuits, BB units, and antenna elements. The antenna element technologies and the multi-antenna system are shown in **Fig. 4**. In the antenna element, a high gain can be achieved by improvements to the antenna element structure, for example, by using a new material, adding a parasitic element, or integrating an RF circuit (Figs. 4(a)–(c)). The antenna shown in Fig. 4(c) is called an integrated antenna. It can control the radiation pattern as well as provide high gain by eliminating feeder loss. In a multi-antenna system (Fig. 4(d)), the radiation pattern is controlled by baseband signal processing, so the pattern of each wireless channel can be controlled by each baseband channel. Furthermore, it is possible to get multiplexed signal transmission in the space domain by baseband signal processing. Multi-antenna systems are generally called smart antennas or active antennas [9].

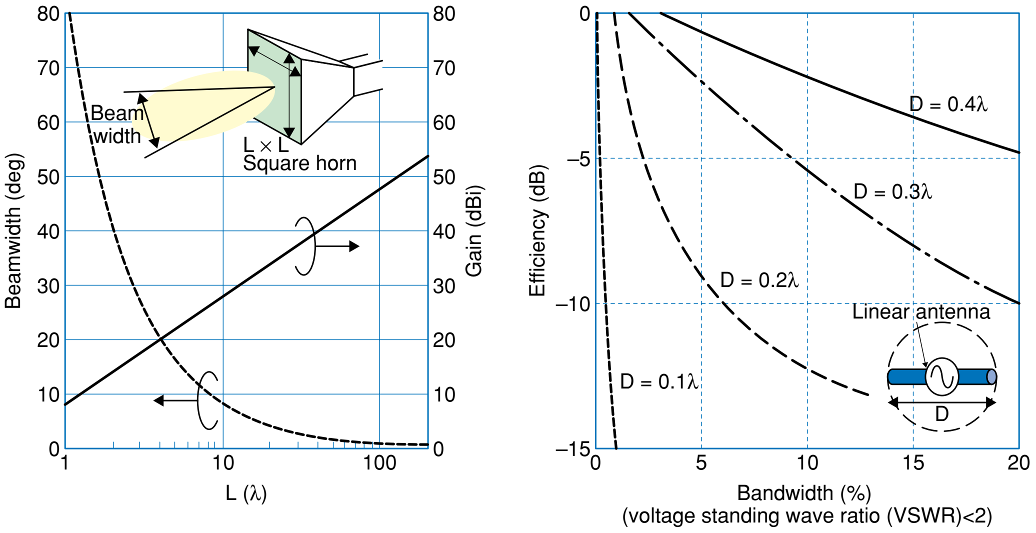

(a) Aperture antenna gain characteristics

(b) Dipole antenna efficiency characteristics

Fig. 3. Antenna gain and efficiency characteristics.

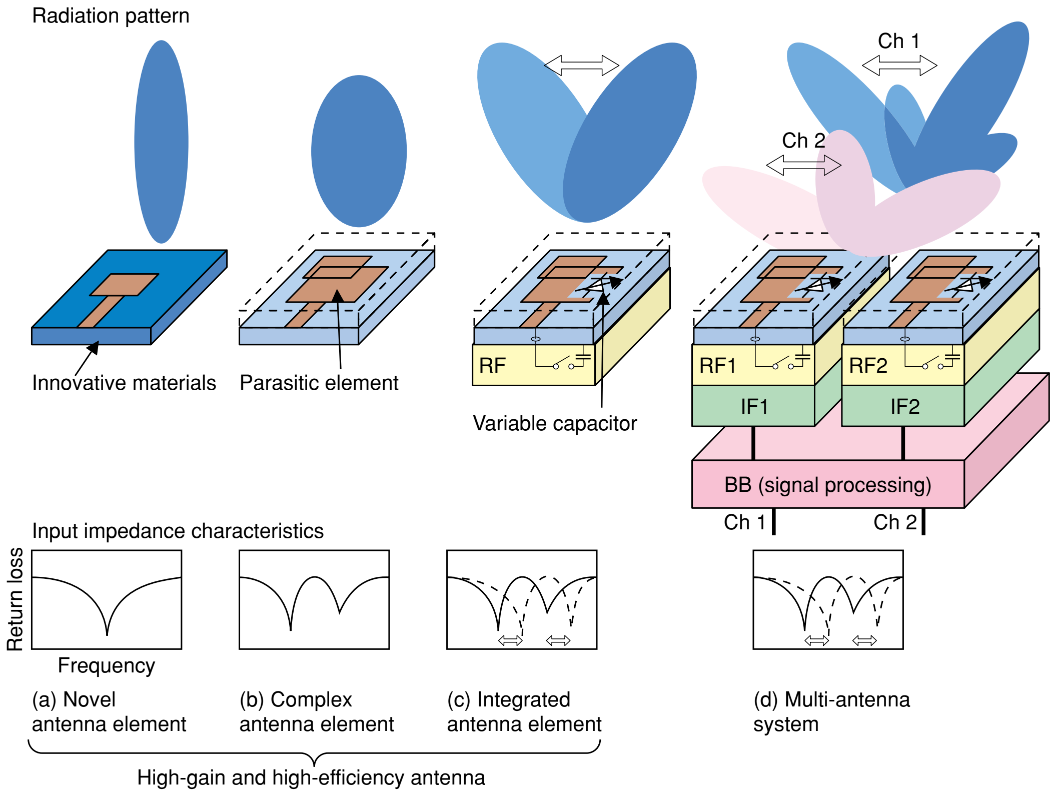
Radiation pattern
Ch 1
Ch 2
Innovative materials
Parasitic element
RF
Variable capacitor
RF1
RF2
IF1
IF2
BB (signal processing)
Ch 1
Ch 2
Input impedance characteristics
Return loss
Frequency
High-gain and high-efficiency antenna

(a) Novel antenna element
(b) Complex antenna element
(c) Integrated antenna element
(d) Multi-antenna system

Fig. 4. Antenna elements and system.

An example of a mobile communication system using a smart antenna in the base station is shown in **Fig. 5**. Independent information can be sent to the terminals, which are spatially separated, using the same frequency at the same time because each beam is generated for a specific terminal by using the space division multiple access (SDMA) technique. Furthermore, N multiplexed transmissions can be sent to a terminal with N antennas by utilizing the slight difference in antenna locations in the terminal. MIMO is representative of this kind of technology. The latest smart antenna systems can increase the antenna gain even in a mobile system and expand the service area. The designed system capacity can be increased by using multiplexing techniques based on baseband signal processing. Multi-antenna systems can achieve very high performance with high-level functions corresponding to the wireless system requirements.

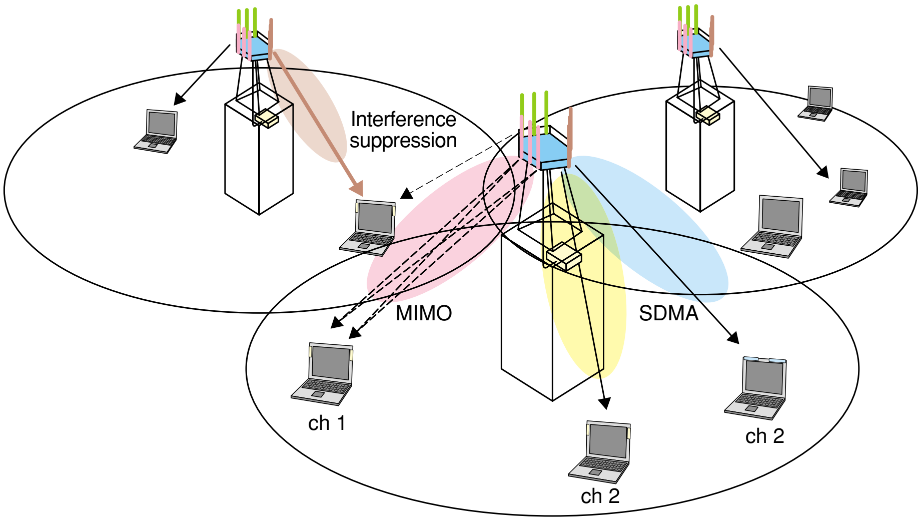
Interference suppression
MIMO
SDMA
ch 1
ch 2
ch 2

Fig. 5. Smart antenna system (land mobile telecommunication).

2.3 Key antenna technologies

The key technologies for achieving a high-gain, high-efficiency, multi-antenna system are shown in **Table 1**. Antennas for the latest wireless communication systems are required to achieve high gain and high efficiency. The multi-antenna systems are designed to make maximum use of system resources, especially space.

3. Wireless systems and suitable antenna systems

The kinds of wireless systems that we can expect to find around us in the near future are illustrated in **Fig. 6**. RF-ID (radio-frequency identification) tags will be attached to various kinds of objects in a ubiquitous network and a large quantity of information will be gathered to provide useful knowledge to each person. High-speed data transmission ranging from a few megabits per second to 1 Gbit/s will be possible in mobile satellite systems, land mobile systems, and wireless local area network (WLAN) systems. In home networks, individual items of electronic equipment will be connected to each other at very high

Table 1. Key technologies to meet antenna requirements.

Requirements	Key technologies
1) High gain and high efficiency	a. Innovative materials (meta-material, high magnetic material, …) b. Element design (parasitic element, fractal element, …) c. Integrated antenna (antenna with RF circuit or RF device, …) d. Active antenna (antenna within variable reactance or switch, ….)
2) Multi-antenna techniques	a. Beam scanning antenna b. Sector antenna (fixed narrow multi-beam system) c. Diversity antenna d. SDMA antenna e. MIMO antenna

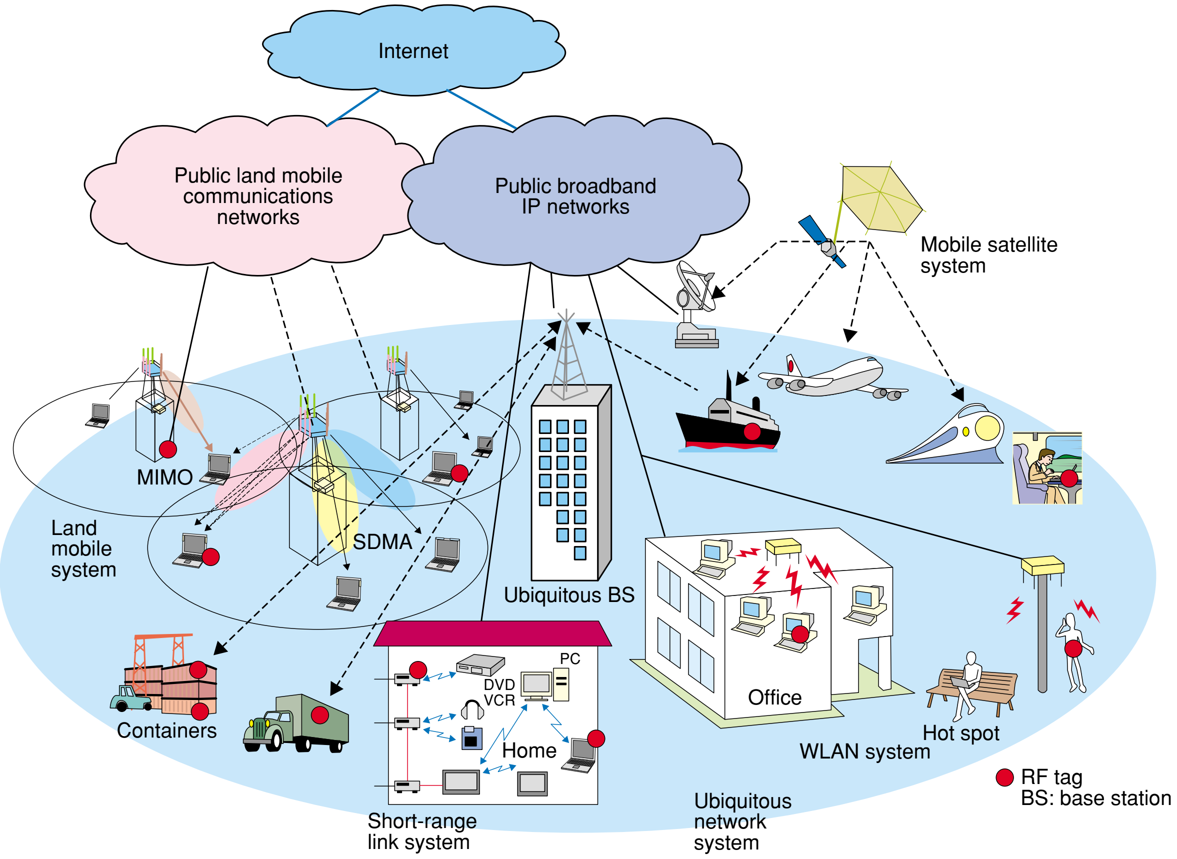
Internet
Public land mobile communications networks
Public broadband IP networks
Mobile satellite system
MIMO
Land mobile system
SDMA
Ubiquitous BS
Containers
PC
DVD
VCR
Home
Short-range link system
Office
Hot spot
WLAN system
Ubiquitous network system
● RF tag
BS: base station

Fig. 6. Wireless communication systems.

Table 2. Wireless systems and NTT's antenna system approaches.

	System features	Main technical trends (example system, standard, or equipment)	NTT's antenna approaches (using technologies in Table 1)
Ubiquitous RF-ID	Multiple access Low rate	Active tags Sensor network Mesh network (802.15.5)	Compact high-efficiency tag antenna High-gain beam tilting base station antenna (1a, 1b, 1c)
Short-range communication	Short range Ultrahigh speed Link transmission	High frequency band (millimeter-wave system) Ultrawideband (UWB) Infrared rays (IrDA)	Active integrated antenna system (millimeter wave) (1b, 1c, 2a, 2b)
Land mobile and WLAN	Medium range High speed/capacity Many subscribers	MIMO-OFDM (802.11n,802.16a/e) MC-CDMA (4G, Beyond 3G) HSDPA (3.5G,1xEV-DO/V)	MIMO-OFDM antenna system Compact mobile terminal antenna system (1b, 1d, 2b, 2c, 2d, 2e)
Mobile satellite	Very long range Medium to high speed Various mobile stations	S/Ku band high-speed mobile comm. (N-Star/ETS-VIII) Broadband (Internet) (WINS) Millimeter wave/optical comm. (MILSTAR, GeoLITE)	Multi-beam antenna Large deployable antenna Beam-tracking antenna system (1c, 1d, 2a, 2e)

(discussed in papers in this issue)

speed (several gigabits per second) wirelessly instead of by cables. In these wireless systems, highly functional and high-performance antennas will be essential. **Table 2** explains the main features and technical trend of the systems and also shows NTT's approaches to antennas and antenna systems for each high-performance wireless system. The technologies in Table 1 that are used are indicated in parentheses. Each antenna system must satisfy severe specifications and also provide high functionality, as shown in Figs. 4(c) and (d). The antennas discussed in the selected papers in this issue are shown in blue in Table 2. The present status of each antenna system and research and development in NTT are explained below.

3.1 Ubiquitous network antenna system

Tag antenna elements have the same problems as pagers or portable telephone systems that use the LF, UHF, and VHF bands. The antenna element must be as small as possible and have high efficiency in a small volume and in the neighborhood of various objects. Most antennas for passive tags using the LF band (13 MHz) are spiral, helical, N-turn loop, or meander line antennas [10] for achieving an electromagnetic induction area and their gains are considered to be very low. Bent and spiral monopole or dipole antennas are used in personal computer card wireless communication systems or in small square film tags using UHF-band systems [11]. The approach is to design the antenna and RF-IC as one system; in other words, the connection impedance between the antenna and RF-IC is designed as a freely selectable value instead of being restricted to 50 Ω. The same kind of technique is currently being investigated in NTT in a study of active integrated antennas [12]. On the other hand, the base station antenna can be designed by applying techniques developed for pagers or land mobile antennas because it has high-gain and beam-tilting characteristics.

3.2 Millimeter-wave frequency band communication antenna system

A high-speed wireless communication system is achieved by using wideband technology, so millimeter-wave frequencies, which provide a very wide bandwidth, are attracting attention. The use of high frequencies also requires high output power to compensate for the huge propagation loss and passive circuit losses, so high-gain and high-efficiency antennas are very important in system design [13]. Millimeter-wave systems mainly use horn, reflector [14], or lens antennas [15]. Horn or reflector antennas are used in relatively long-range communication where the range is several hundred meters. A lens type antenna, which is integrated with monolithic microwave integrated circuits (MMICs) to achieve high efficiency without a feeding line, is mainly used for short-range transmission, e.g., for a home link system. Active integrated antenna technology in which an amplifier for transmitting and receiving is mounted without using a connector or cables is suitable for a high-frequency-band system [16]. Typical antenna types for millimeter-wave frequency systems are shown in **Table 3**. Horn or reflector antennas provide very high gain but cannot be integrated with MMICs. The lens antenna provides high gain and can be made into an integrated antenna but requires adjustment to correct its

Table 3. Antenna types for millimeter-wave systems.

Antenna	Gain	Integration with MMIC	Mounting adjustment
Horn or reflector	Very high (over 20 dBi)	No	(Feeder)
Lens	High (10 to 20 dBi)	Yes	Needed
Single patch	Low (2 dBi)	Yes	No
Parasitic element patch	High (10 dBi)	Yes	No

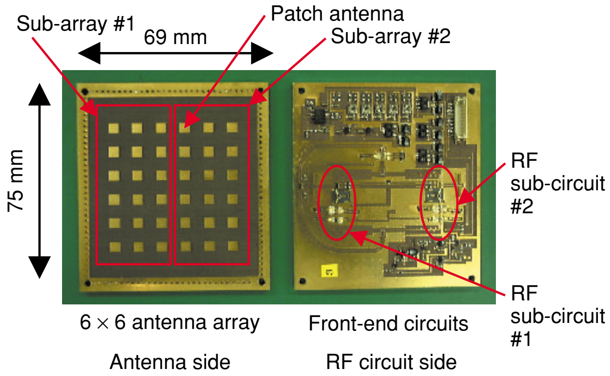

Fig. 7. Active integrated antenna for 25-GHz system.

mounting error. The patch antenna is a good element for integration with MMICs because it can be made on the same material substrates, so it does not need antenna adjustment. We have developed an active integrated antenna designed for broadband mobile wireless access systems using the 25-GHz band, as shown in **Fig. 7** [12]. It exhibited output power of 14.6 dBm and a noise figure of less than 5 dB. The only weakness of this integrated antenna is that high gains cannot be provided with one patch antenna. The third selected paper in this issue describes a high-gain integrated active antenna and high-efficiency RF circuit for the millimeter-wave frequency band for a millimeter-wave communication system [4]. A high-gain integrated patch antenna is investigated as a parasitic element to obtain a wide antenna aperture. The millimeter-wave frequency-band link system was first proposed for application to the transmission of uncompressed HDTV (high-definition television) signals in the home or in a studio.

3.3 Land mobile and WLAN antenna systems

The number of subscribers to land mobile systems, especially cellular systems, has increased rapidly, and users are now demanding high-speed transmission for broadband Internet access. To meets these demands, many improvements to the land mobile system have been proposed such as wideband code division multiple access (W-CDMA), adaptive modulation, and *ad hoc* transmission. Recently, the utilization of space has become as desirable as frequency and time utilization [17]. Space utilization is achieved using a multi-antenna system with a radiation control mechanism, which is accomplished by a smart antenna system.

3.3.1 Typical multi-antenna techniques for mobile systems

The application areas of multi-antenna techniques depend qualitatively on the system characteristics, as shown in **Fig. 8**. A fixed high-gain beam antenna does not always need antenna elements, but the other techniques are achieved through various combinations of antenna elements, so they are provided by adaptive or integrated multi-antenna systems, as shown in Figs. 4(c) and (d). A narrow-beam or high-gain antenna is used in the line-of-sight situation (where there are no obstacles between the transmitting and receiving antennas and there are few paths in the multipath transmission), so a beam-scanning mechanism is needed when a terminal moves fast, and multiple beams or sector beams are required when there are many terminals in the service area. The diversity antenna technique can provide a stable signal level in a multipath mobile environment. Beam scanning (with a sector beam or multiple beams) and diversity antenna techniques have been used fairly extensively from the early days of mobile communication service because they use only simple signal processing. However, with the rapid progress of signal processing technology, a desired signal can now be distinguished from a mixture of many signals in a multipath environment. The SDMA technique distributes signals among the terminals communicating in the service area. MIMO techniques enable very-high-data-rate communication with multiplexed transmission in each antenna of the multi-antenna system of the base station or mobile terminal. These techniques require more calculation as the movement speed of the mobile terminal increases. In these wireless systems, signal processing ability and superior algorithms are more important than the performance of antenna elements.

3.3.2 Research results and developed antenna systems

A very small and thin planar six-sector antenna using a patch Yagi-Uda array with common directors for mobile terminals has been proposed (**Fig. 9**) [18],

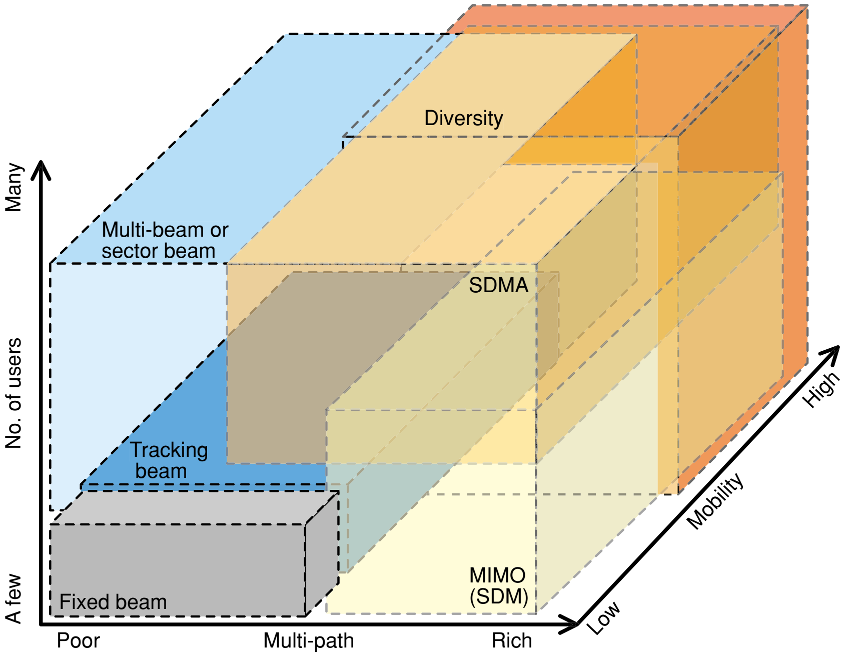
Many
No. of users
A few
Poor
Multi-path
Rich
Low
Mobility
High
Multi-beam or
sector beam
Diversity
SDMA
Tracking
beam
Fixed beam
MIMO
(SDM)

Fig. 8. Dependence of multi-antenna techniques on system characteristics.

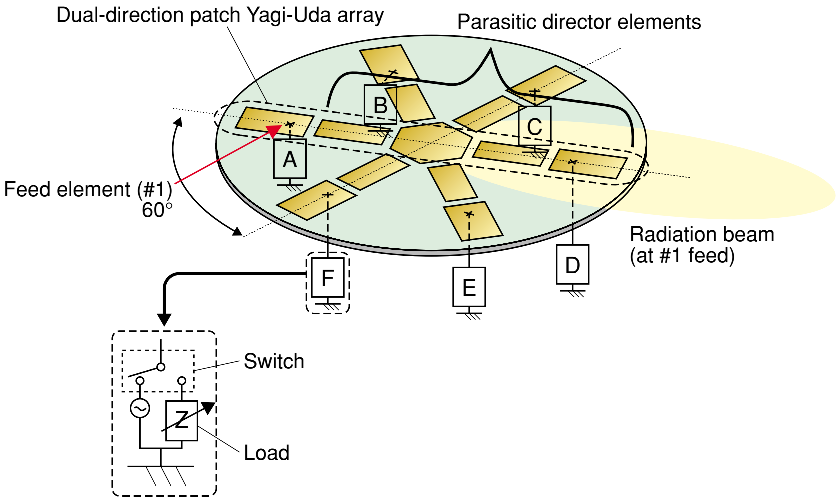
Dual-direction patch Yagi-Uda array
Parasitic director elements
Feed element (#1)
60°
A
B
C
D
E
F
Radiation beam
(at #1 feed)
Switch
Z
Load

Fig. 9. Thin and small sector beam antenna.

[19]. It has square parasitic director elements that are shared by two sector arrays that face in opposite directions, and it has a hexagonal central director element that is shared by all six sectors. These elements form three line arrays, which intersect at 60°. These shared elements enable the sector antenna to be compact. Experimental results showed that the fabricated antenna had a conical plane beam width of 63° and high front-back ratio of 17 dB. The creation of adaptive (smart) antenna hardware has been investigated [20]. A novel beam combination method for wideband digital indoor communication systems such as WLANs has been proposed [21] in NTT. Crossed fan beams are used at the base station and mobile terminal. The beam combination method provides better transmission quality than the traditional pencil-beam combination and eliminates the need for complex beam control in the base station. Maximum dispersion distributions in the transmission frequency bandwidth have been calculated using a three-dimensional indoor propagation delay simulation algorithm. A method of designing adaptive antennas including an

antenna configuration that is suitable for street microcells, considering the propagation environment, has been described. An automatic calibration method at the transmitters and receivers using the transmitting signal (ACT), which enables realtime calibration, has been presented [22]. An SDMA technique using polarization has also been studied [23]. The transmission quality of an SDMA scheme that uses vertical pattern and polarization control was investigated in an actual cellular environment. For a sector cell system, this configuration was shown to be effective based on an evaluation of the spatial correlation characteristics. We also found that the output carrier-to-interference-plus-noise power ratio (CINR) of the proposed configuration was from 10 to 17 dB higher than that of the conventional SDMA configuration when the number of users was greater than four. The proposed configuration can reduce the antenna size compared with conventional SDMA. Moreover, MIMO techniques enable very-high-data-rate transmission using a limited frequency band. We have studied technologies based on the eigenmode-space division multiplexing (E-SDM) [24] scheme because it provides the theoretically maximum channel capacity and reduces the terminal's calculation load. The selected papers in this issue introduce both theoretical and practical technologies. The fourth paper describes new MIMO methods with beamforming to overcome problems of calculation complexity and low MIMO effect in the line-of-sight scenario [5]. The fifth paper describes the configuration of an 8 × 4 MIMO-OFDM transceiver and presents experimental results for the propagation characteristics, bit error rate (BER), and frequency utilization [6].

3.4 Satellite broadband communication system

If we want to create a seamless and flexible wireless network system, then a satellite communication system is very important because it provides a wide service area. However, it has the inherent problem that the distance between the transmitter and receiver is long, so the terminal needs a larger antenna than ones in the land mobile system to provide high-speed transmission. The effective solution is to make the satellite dish larger to provide high gain and multibeam transmission. We have studied multibeam communication satellite technology and onboard large deployable antennas for creating a broadband mobile satellite communication system [25]. An MMIC-based beamforming network equipment for a multibeam feeder whose weight is only 1/3 that of the conventional type was developed. We are also developing a large, highly precise deployable antenna with a diameter in the over-10-m range. The mobile terminal acting as an earth station is also an important component of a broadband mobile satellite communication system. Typical existing antennas in earth stations are shown in **Table 4**. Various mobile terminals are accommodated in the satellite communication system by different transmission rates, and these terminals use various antenna methods and locations. A comparatively large terminal antenna is required to handle high data transmission rates in a satellite system to mitigate the huge propagation loss. The high gain and narrow beam of a large antenna make a beam-scanning mechanism necessary to enable the antenna to follow the satellite direction as the terminal moves. The sixth selected paper describes a highly accurate and cost-effective auto-tracking antenna system for earth stations onboard vessels, using a novel inclinometer that is highly accurate in acceleration disturbance environments and a new systematic stabilization controller design process based on H_∞ control [3].

Table 4. Typical antennas in earth stations.

Satellite category	Typical satellite system	Current typical earth station antenna (size or length, gain)
LEO	Iridium Globalstar	Helical (0.1 m, 2 dBi) Linear whip (0.1 m, 0 dBi) Patch (0.1 m^2, 3 dBi)
MEO GEO	ICO N-STAR INMARSAT	Parabola (0.6 – 0.9 m, 18 – 21 dBi) Phased patch array (0.5 m^2, 14 dBi) Helical (0.3 m, 2 dBi) Patch array (0.3 m^2, 12 dBi) Patch (0.1 m^2, 3 dBi)

LEO: low earth orbit
MEO: medium earth orbit
GEO: geostationary earth orbit

4. Conclusion

This paper gave an overview of the requirements of antennas and antenna systems in recent high-speed and high-capacity wireless communication systems and the key technologies for satisfying these requirements to create next-generation wireless communications. It also described current antenna systems and NTT's antenna research results for typical wireless systems.

Antennas for next-generation wireless communications require high gain, high efficiency, and a multi-antenna design. A high-gain antenna can be made using a relatively large antenna aperture, but a beam-scanning mechanism is needed for mobile communications. A high-efficiency antenna can be made using an active integrated antenna, which integrates an MMIC with the antenna element. Multi-antenna technology is the innovative technology that enables multiple data transmission in space. In MIMO-type multi-antenna systems, the most important key technologies are the beamforming algorithm and the implementation method. The solution technologies for NTT's advanced antenna systems are explained in detail in the following selected papers in this issue. The technological background and the current research and development situation are also described to make the papers easy to understand.

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The Roles of 5G Mobile Broadband in the Development of IoT, Big Data, Cloud and SDN

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Abstract

The fast technology development of 5G mobile broadband (5G), Internet of Things (IoT), Big Data Analytics (Big Data), Cloud Computing (Cloud) and Software Defined Networks (SDN) has made those technologies one after another and created strong interdependence among one another. For example, IoT applications that generate small data with large volume and fast velocity will need 5G with characteristics of high data rate and low latency to transmit such data faster and cheaper. On the other hand, those data also need Cloud to process and to store and furthermore, SDN to provide scalable network infrastructure to transport this large volume of data in an optimal way. This article explores the technical relationships among the development of IoT, Big Data, Cloud, and SDN in the coming 5G era and illustrates several ongoing programs and applications at National Chiao Tung University that are based on the converging of those technologies.

Keywords

5G, Internet of Things (IoT), Software Defined Networks (SDN), Big Data Analytics, Cloud Computing

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1. Introduction

The roles of SDN, Cloud, IoT, and Big Data in 5G Networks have raised great interest recently [1]. According to the IEEE Computer Society (IEEE CS 2022 Report [2]), Cloud Computing (Cloud), Big Data Analytics (Big Data), Internet of Things (IoT), and Software Defined Networks (SDN) are among 4 of 20+ emerging technologies as illustrated in **Table 1**. In the meantime, based on the report in IEEE Communications Society (IEEE ComSoc Technology News [3]), among top 10 trends in 2015 as listed in **Table 2**, 5G, Virtualization (SDN & NFV), everywhere connectivity for IoT & IoE, and Big Data are also included. Combining both reports, we can identify 5G, Cloud, IoT/IoE, Big Data, and SDN as the five most worthwhile ICTs (information & communica-

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Table 1. IEEE computer society 2022 report.

Technology & Indexing Terms		
1. Security Cross-Cutting Issues	9. Multicore	17. 3D Printing
2. Open Intellectual Property Movement	10. Photonics	18. Big Data and Analytics
3. Sustainability	11. Networking and Interconnectivity	19. Machine Learning and Intelligent Systems
4. Massively Online Open Courses	12. Software Defined Networks	20. Life Sciences
5. Quantum Computing	13. High Performance Computing	21. Computational Biology and Bioinformatics
6. Device and Nanotechnology	14. Cloud Computing	22. Robotics
7. 3D Integrated Circuits	15. Internet of Things	
8. Universal Memory	16. Natural User Interfaces	

Table 2. IEEE communications society top 10 trends 2015.

1) 5G
2) FIBER EVERYWHERE
3) VIRTUALIZATION, SDN & NFV
4) EVERYWHERE CONNECTIVITY FOR IoT & IoE
5) BIG DATA, COGNITIVE NETWORKS
6) CYBERSECURITY
7) GREEN COMMUNICATIONS
8) SMARTER SMARTPHONES, CONNECTED SENSORS
9) NETWORK NEUTRALITY, INTERNET GOVERNANCE
10) MOLECULAR COMMUNICATIONS

tions technologies) to watch out up to 2020 in term of their potential, convergence and applications. **Figure 1** depicts the overlapping of these five major ICT trends. It also illustrates how the infrastructure deployment of 5G mobile broadband and the architectural integration of Cloud Computing strongly impact the development of IoT, Big Data, and SDN. This paper explores the technical relationships of these five areas and discusses several ongoing programs and applications currently under development at NCTU based on these technologies.

2. The Roles of 5G, IoT, Big Data, Cloud, and SDN till 2020

Although so far the 5G mobile broadband requirements and standard specifications are not ready yet, 5G technology research & development are already started and some 5G features or subsystems are readily available. By Year 2020 the commercial 5G will be available and IoT applications will be deployed everywhere with mobile broadband technology. Moreover, the Big Data generated by IoT applications will become a norm and Cloud will be largely utilized to compute, store and virtualize network functions (NFV). Also, the underlying network infrastructure will adopt SDN to reduce both capital expense (CAPEX) and operational expense (OPEX). **Figure 2** further illustrates the roles of 5G, IoT, Big Data, Cloud and SDN and their relationships. This figure is modified based on the reference [4] by inserting 5G mobile broadband in the center.

3. Technical Relationships among IoT, Big Data, Cloud, & SDN in 5G Era

Based on **Figure 2**, we develop **Figure 3** to better explain the technical relationships among IoT, Big Data, Cloud, and SDN in the 5G mobile broadband services (5G MBS) [5]. First, IoT is capable of generating Big Data with four Vs: volume, velocity, variety and veracity. Then, Cloud is brought in for Big Data storage and processing. Finally, SDN is employed to provide more efficient and flexible networks for inter-Cloud data transport. Out of Big Data, Cloud, and SDN, advanced technologies such as machine learning analytics, Cloud

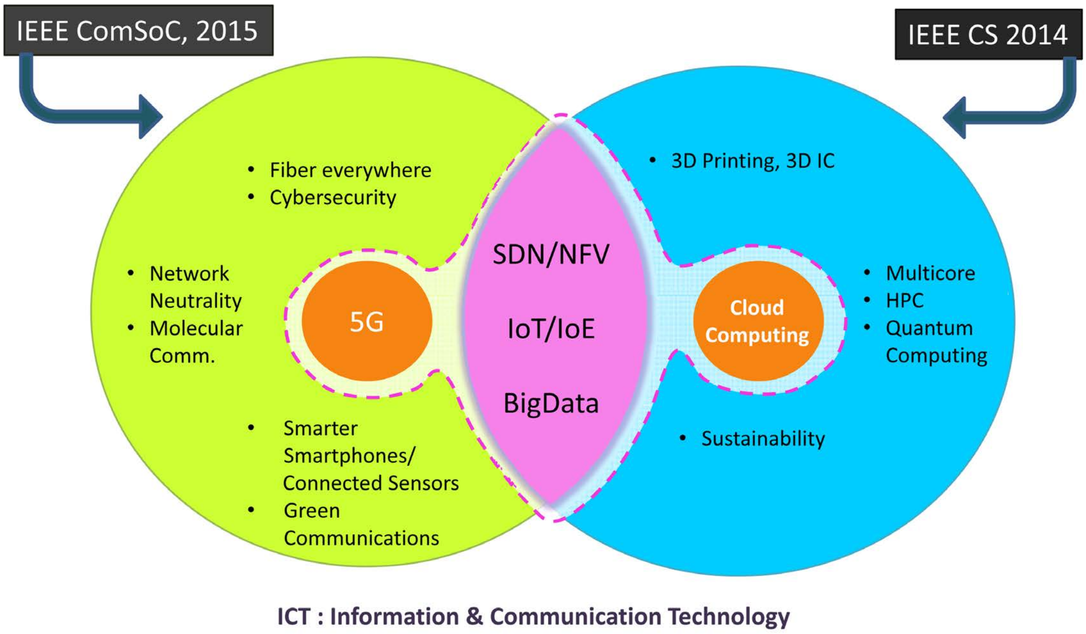
IEEE ComSoC, 2015
IEEE CS 2014
Fiber everywhere
Cybersecurity
Network Neutrality
Molecular Comm.
5G
Smarter Smartphones/ Connected Sensors
Green Communications
SDN/NFV
IoT/IoE
BigData
3D Printing, 3D IC
Multicore
HPC
Quantum Computing
Cloud Computing
Sustainability
ICT : Information & Communication Technology

Figure 1. ICT major trends for 2015-2020.

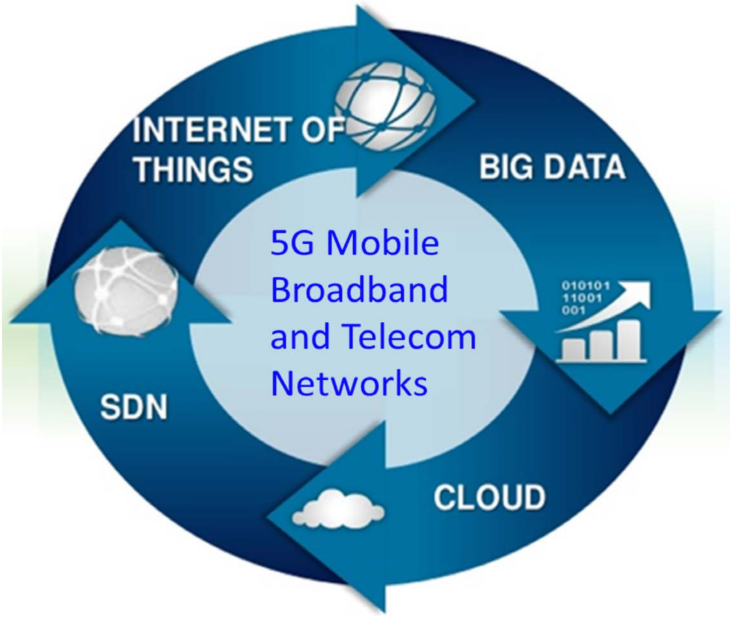
INTERNET OF THINGS
BIG DATA
5G Mobile Broadband and Telecom Networks
010101
11001
001
SDN
CLOUD

Figure 2. Relationship among 5G, IoT, Big Data, Cloud and SDN based on [4].

RAN and softwarized 5G then are developed.

As illustrated in **Figure 4**, 5G will serve as a better gateway and transport network for IoT applications so that IoT data can be delivered more efficiently and economically. In addition, IoT will become one of the major sources of Big Data by producing large volume, fast velocity, and many varieties of data [6] as illustrated in **Figure 5**.

Finally, **Figure 6** shows that Cloud can be adopted in the 5G Radio Access Network (RAN) and turns it to a Cloud-based RAN (C-RAN). Both SDN and NFV have been applied to data center in the cloud to enable better load balance and resource allocation of the cloud. SDN has also been applied to 5G mobile broadband core networks to enable smart routing, better traffic management and improve network resource utilization.

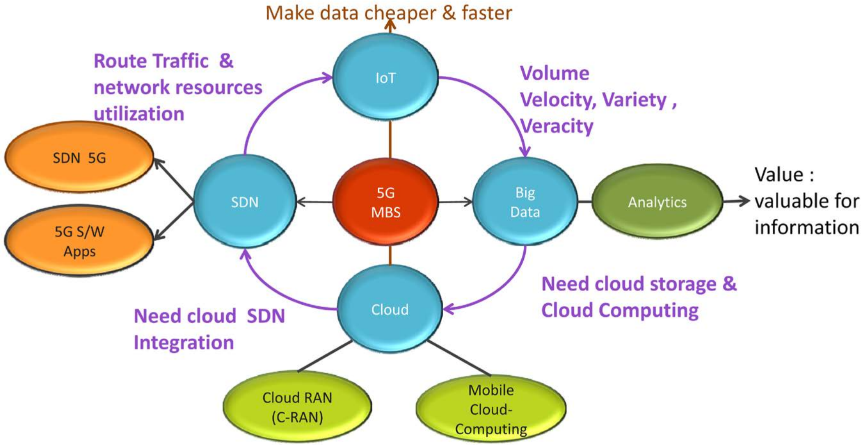
Make data cheaper & faster
Route Traffic & network resources utilization
IoT
Volume Velocity, Variety , Veracity
SDN 5G
5G S/W Apps
SDN
5G MBS
Big Data
Analytics
Value : valuable for information
Need cloud storage & Cloud Computing
Need cloud SDN Integration
Cloud
Cloud RAN (C-RAN)
Mobile Cloud-Computing

Figure 3. Technical relationships among 5G & IoT, Big Data, Cloud, and SDN.

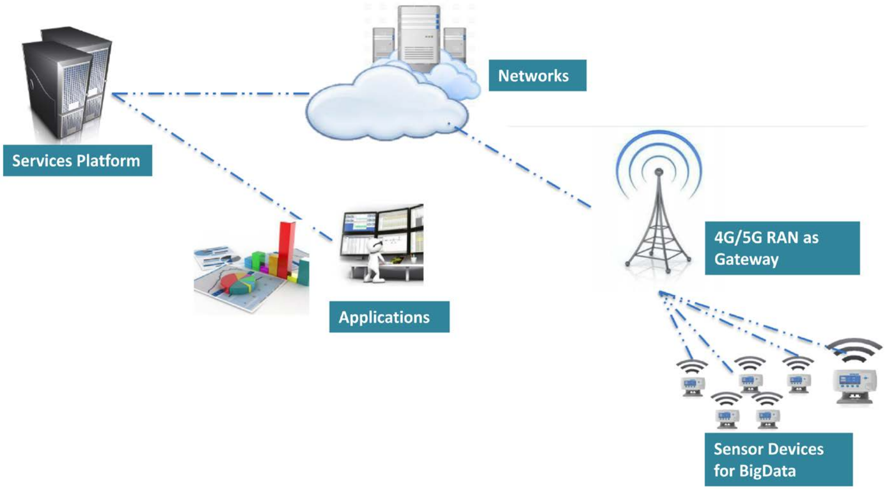
Services Platform
Networks
4G/5G RAN as Gateway
Applications
Sensor Devices for BigData

Figure 4. 4G/5G as the gateway for IoT applications.

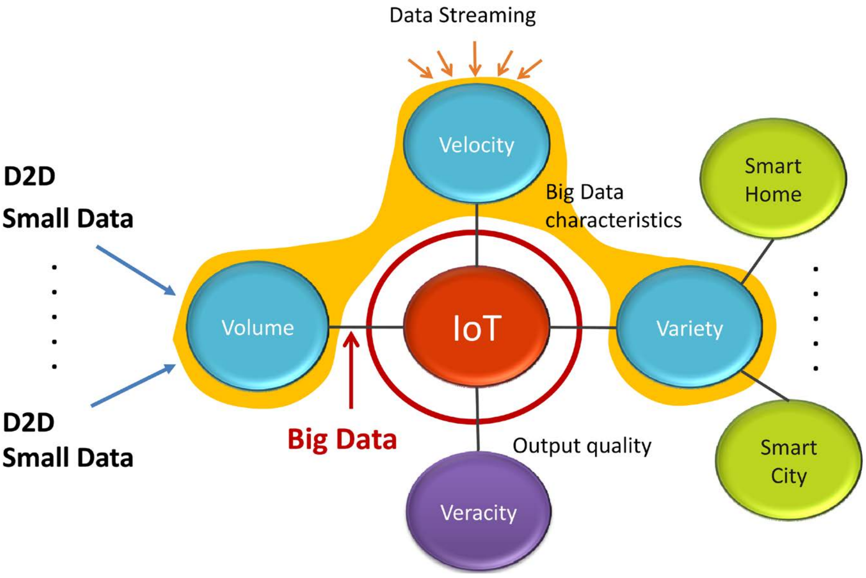
Data Streaming
Velocity
Big Data characteristics
Smart Home
D2D Small Data
Volume
IoT
Variety
D2D Small Data
Big Data
Output quality
Veracity
Smart City

Figure 5. Relationships between IoT and Big Data.

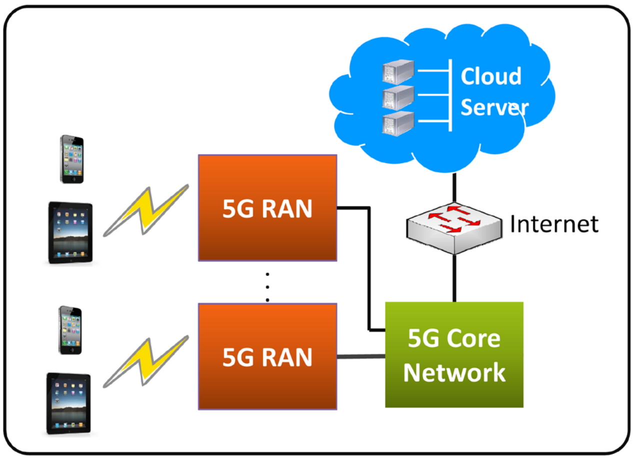

Figure 6. C-RAN architecture in 5G mobile network.

4. Ongoing Programs and Applications at National Chiao Tung University (NCTU)

In this section, we describe five ongoing programs and applications at NCTU that are closely related to the SDN, Cloud, Big Data, IoT, and 5G technologies [7]-[17].

4.1. Program on SDN-Enabled Cloud-Based Broadband and Wireless Network Technologies and Services

This program is a national program to support the SDN Industry-Academia Cooperation, led by both NCTU and CHT (Chunghwa Telecom, the largest mobile & telecom operator in Taiwan) with 5 other networking and communications companies in Taiwan. This is a multi-year program with the target to set up a testbed for end-to-end testing and to help establish an ecosystem for local SDN industry.

Figure 7 shows the scope of this program that covers mobile access, WiFi access, broadband core and data center cloud end-to-end application systems.

Figure 8 further shows both the structure of the program and its network configuration across NCTU, CHT and another university National Tsing Hwa University (NTHU).The program includes research and development involving 4G/LTE, B4G/5G, SDN, Cloud, SDN for Wi-Fi, and SDN for WAN technologies. There are five sub-programs: 1) SDN broadband network technologies and services, 2) SDN mobile/wireless network technologies and services, 3) SDN and cloud integration services and management, 4) SDN switch-related devices and systems and 5) SDN system integration and field trials.

The program is intended to construct an SDN network in NCTU, CHT and NTHU, respectively. These SDN networks then will be interconnected to form a wide area SDN network in Taiwan. Eventually, we plan to have this end-to-end system connected to the global network. The SDN switches deployed in this testbed will be mostly small or medium scale due to their experimental nature. Also included in this testbed are SDN-based Wi-Fi access points. Cloud-based data centers will be deployed in each location of NCTU, CHT and NTHU. Three types of SDN controllers including OpenDaylight, Ryu and Floodlight are currently under trial in the experimental network. Our architecture assumes the scenario of multiple SDN controllers with a hierarchical topology on which useful SDN APPs such as load balancer, network optimizer for video delivery, network co-ordinator (including visualization), dynamic flow configuration, end-to-end service configuration, dynamic policy-based traffic engineering, and multitenant network automation can be developed and deployed.

4.2. Program on Big Data Analytics for Network Traffic and Management Data

In this program, we address the network performance issues with two experimental networks: BML at NCTU campus and ITRINET of ITRI.

The architecture of the BML experimental network is illustrated in the lower part of **Figure 9** that consists of a 4G RAN, a 4G Core and a Cloud environment. For the 4G RAN, both indoor and outdoor environment are taken into consideration. The left upper part of **Figure 9** shows the scope of the ITRINET experimental network

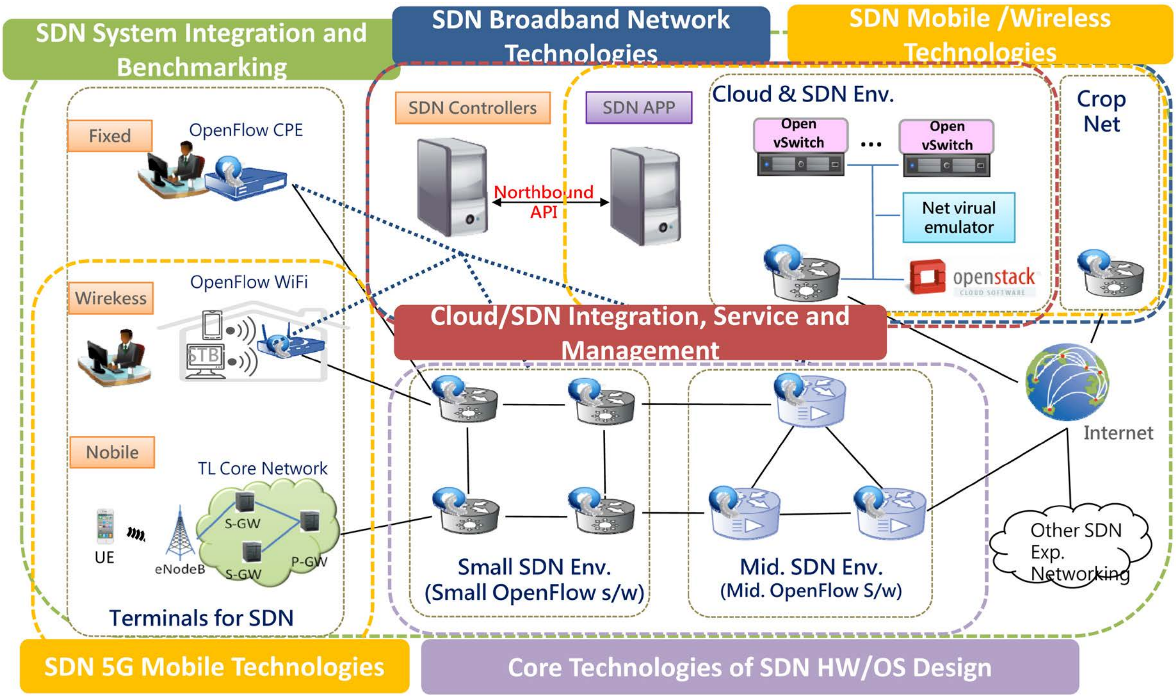
SDN System Integration and Benchmarking
SDN Broadband Network Technologies
SDN Mobile /Wireless Technologies
Fixed
OpenFlow CPE
SDN Controllers
SDN APP
Northbound API
Cloud & SDN Env.
Open vSwitch
Open vSwitch
Net virual emulator
openstack
CLOUD SOFTWARE
Crop Net
Wirekess
OpenFlow WiFi
STB
Cloud/SDN Integration, Service and Management
Nobile
TL Core Network
UE
eNodeB
S-GW
S-GW
P-GW
Terminals for SDN
Small SDN Env.
(Small OpenFlow s/w)
Mid. SDN Env.
(Mid. OpenFlow S/w)
Internet
Other SDN Exp. Networking
SDN 5G Mobile Technologies
Core Technologies of SDN HW/OS Design

Figure 7. Applications of SDN & cloud in 4G/LTE & 5G wireless networks.

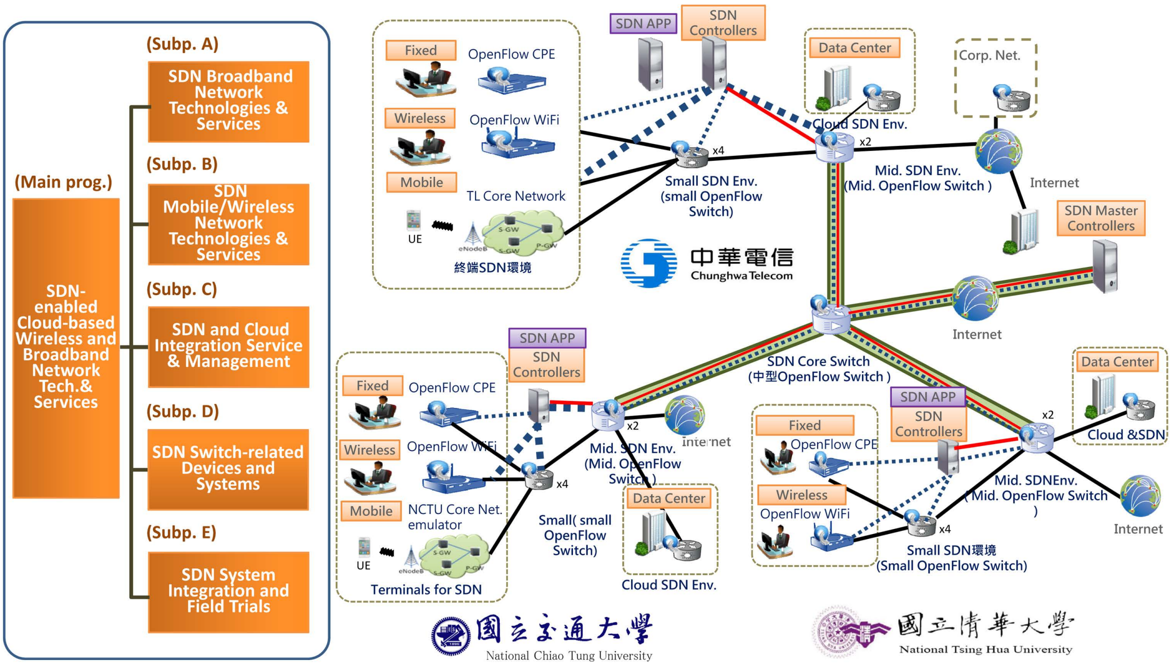
(Main prog.)
SDN-enabled Cloud-based Wireless and Broadband Network Tech.& Services
(Subp. A)
SDN Broadband Network Technologies & Services
(Subp. B)
SDN Mobile/Wireless Network Technologies & Services
(Subp. C)
SDN and Cloud Integration Service & Management
(Subp. D)
SDN Switch-related Devices and Systems
(Subp. E)
SDN System Integration and Field Trials
Fixed
OpenFlow CPE
Wireless
OpenFlow WiFi
Mobile
TL Core Network
UE
eNodeB
S-GW
S-GW
P-GW
終端SDN環境
SDN APP
SDN Controllers
x4
Small SDN Env.
(small OpenFlow Switch)
Data Center
Cloud SDN Env.
x2
Mid. SDN Env.
(Mid. OpenFlow Switch)
Corp. Net.
Internet
SDN Master Controllers
中華電信
Chunghwa Telecom
Internet
SDN Core Switch
(中型OpenFlow Switch)
SDN APP
SDN Controllers
Fixed
OpenFlow CPE
Wireless
OpenFlow WiFi
Mobile
NCTU Core Net. emulator
UE
eNodeB
S-GW
S-GW
P-GW
Terminals for SDN
x2
Internet
Mid. SDN Env.
(Mid. OpenFlow Switch)
x4
Small(small OpenFlow Switch)
Data Center
Cloud SDN Env.
Fixed
OpenFlow CPE
Wireless
OpenFlow WiFi
SDN APP
SDN Controllers
x2
Data Center
Cloud &SDN
Mid. SDNEnv.
(Mid. OpenFlow Switch)
x4
Small SDN環境
(Small OpenFlow Switch)
Internet
國立交通大學
National Chiao Tung University
國立清華大學
National Tsing Hua University

Figure 8. SDN technical R&D center and projects at NCTU.

that covers a much greater area of Hsinchu County than NCTU and includes additionally ITRI (Industrial Technologies Research Institute), HSIP (Hsinchu Science Industrial Park) and THR (Taiwan High-speed Rail, Hsinchu station). The right upper part of **Figure 9** illustrates how ITRINET covers various R&D buildings in the corporate campus of ITRI such as B11, B12, B51, etc.

Figure 10 illustrates how Big Data analytics based on InfoSphere or Spark is performed on ITRINET for the purpose of network optimization. First, network traffic measurement and network management data are collected.

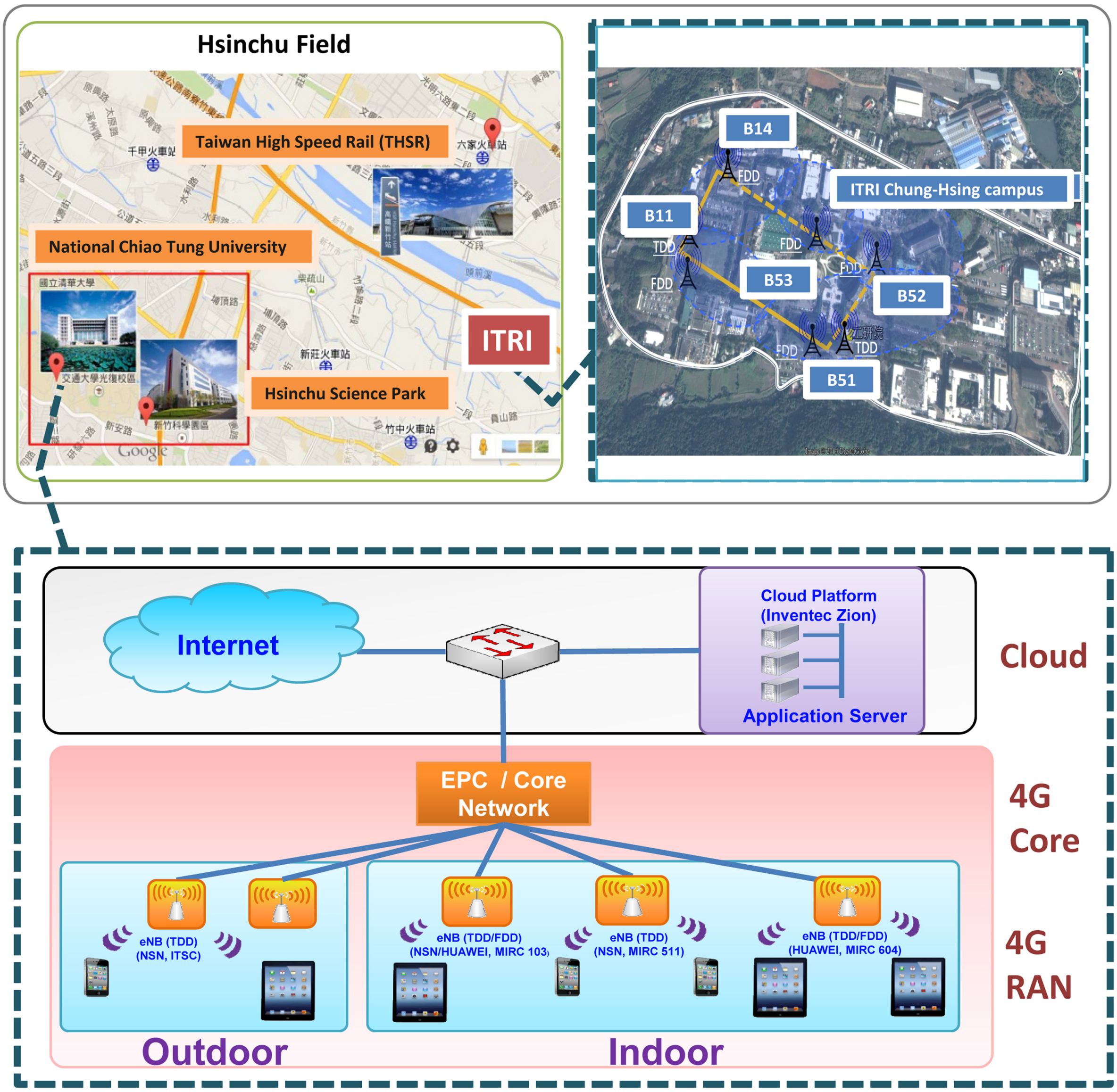
Hsinchu Field
Taiwan High Speed Rail (THSR)
National Chiao Tung University
ITRI
Hsinchu Science Park
Google
ITRI Chung-Hsing campus
B14
B11
B53
B52
B51
FDD
TDD
Internet
Cloud Platform
(Inventec Zion)
Application Server
Cloud
EPC / Core
Network
4G
Core
eNB (TDD)
(NSN, ITSC)
eNB (TDD/FDD)
(NSN/HUAWEI, MIRC 103)
eNB (TDD)
(NSN, MIRC 511)
eNB (TDD/FDD)
(HUAWEI, MIRC 604)
4G
RAN
Outdoor
Indoor

Figure 9. Greater Hsinchu 4G/LTE & Future 5G experimental network ITRINET (include ITRI, NCTU, THR & HSIP).

Then, data analytics methods based on machine learning, data mining and statistical modeling are applied to analyze the collected data. Finally, we apply the results thus generated to network performance evaluation and optimization by providing a feedback loop for system re-configuration. The whole operational cycle includes the technologies of 4G/LTE, B4G/5G, Big Data Analytics, Cloud, and Traffic Engineering.

4.3. Application on IoT Platform Integrated with Data Generation and Data Analytics

This is an application where we set up an IoT platform integrated with data generator and data analytics capabilities as illustrated in **Figure 11**. A common challenge for IoT/M2M service providers is how to test their large scale IoT/M2M applications with the near realistic data that the system will handle in a production environment. As such tests may involve not only a large number but also a large variety of sensors, deploying a testing environment that contains all the necessary sensors turns out to be an infeasible, if not impossible job. To tackle this problem, we develop a data generation method (illustrated in the lower part of **Figure 11**) based on streams generation capabilities of IBM InfoSphere and Spark to emulate data from a large number and a large variety of sensors. Such generated data will be sent into and processed by the applications residing on the IoT/M2M

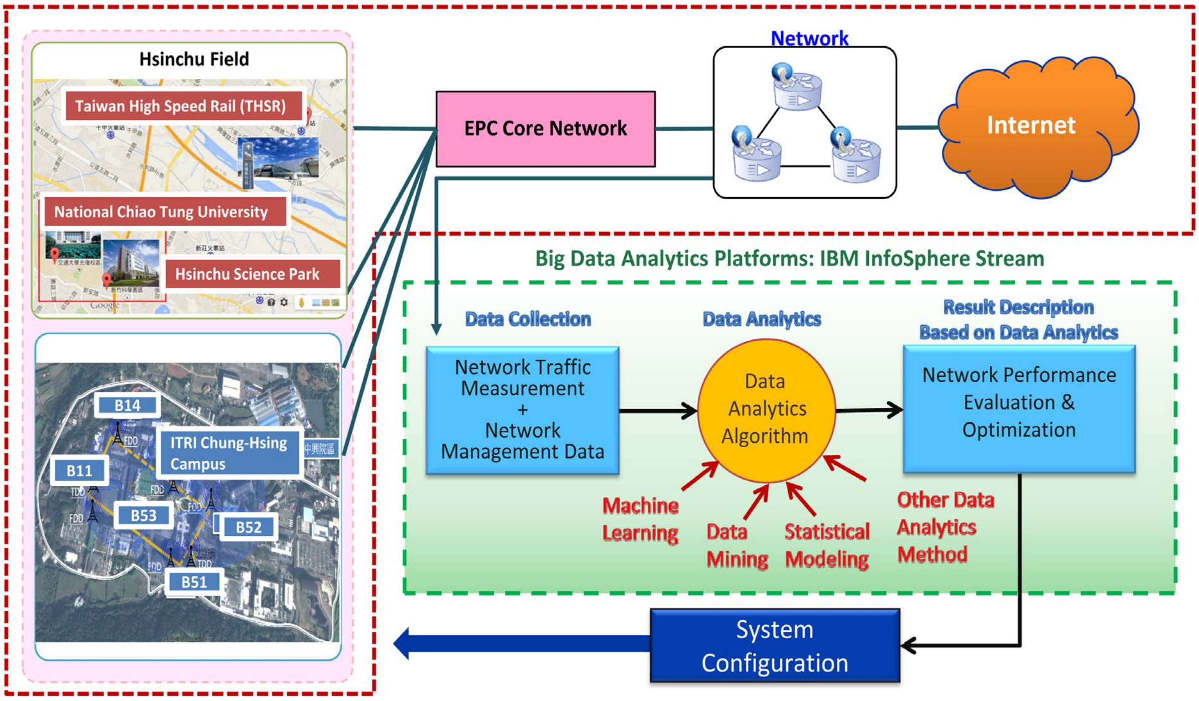
Hsinchu Field
Taiwan High Speed Rail (THSR)
National Chiao Tung University
Hsinchu Science Park
B14
B11
ITRI Chung-Hsing Campus
B53
B52
B51
EPC Core Network
Network
Internet
Big Data Analytics Platforms: IBM InfoSphere Stream
Data Collection
Data Analytics
Result Description Based on Data Analytics
Network Traffic Measurement + Network Management Data
Data Analytics Algorithm
Network Performance Evaluation & Optimization
Machine Learning
Data Mining
Statistical Modeling
Other Data Analytics Method
System Configuration

Figure 10. Big Data analytics for Traffic engineering of ITRINET.

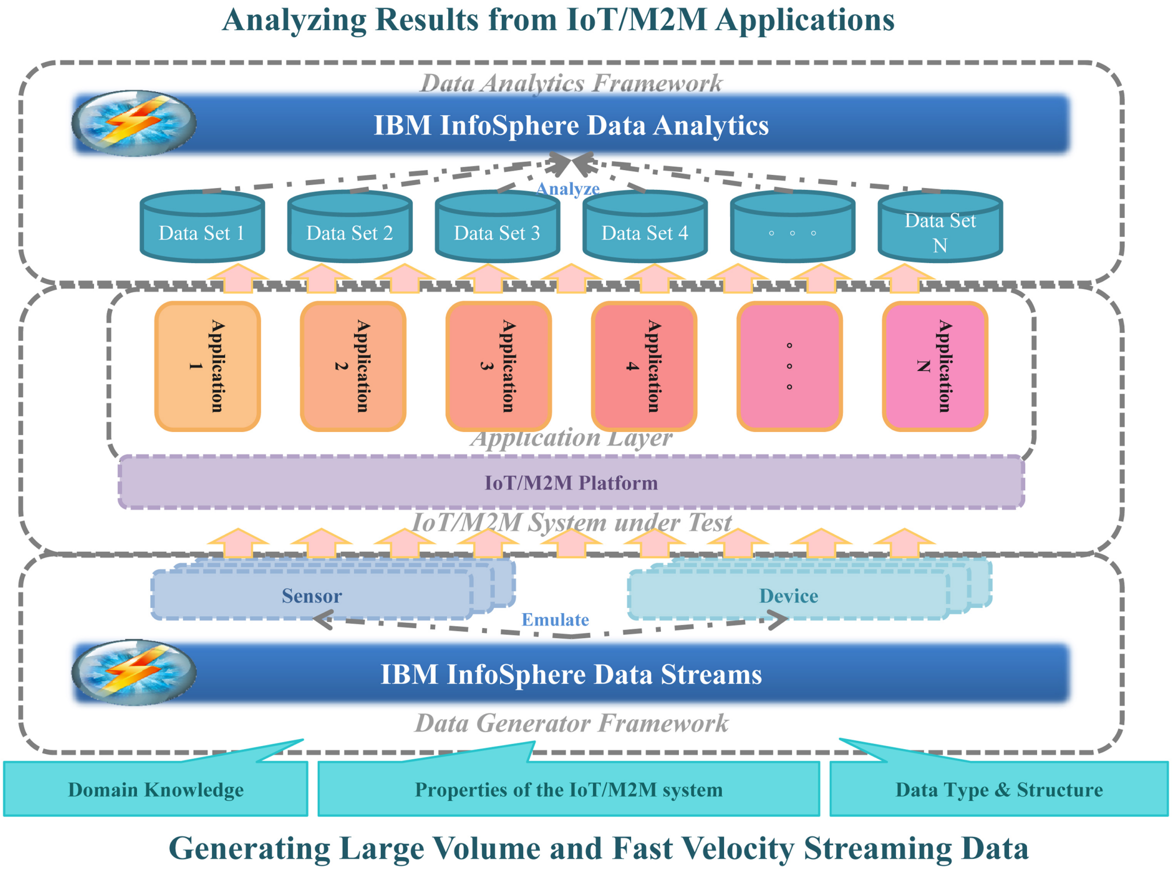
Analyzing Results from IoT/M2M Applications
Data Analytics Framework
IBM InfoSphere Data Analytics
Analyze
Data Set 1
Data Set 2
Data Set 3
Data Set 4
◦ ◦ ◦
Data Set N
Application 1
Application 2
Application 3
Application 4
◦ ◦ ◦
Application N
Application Layer
IoT/M2M Platform
IoT/M2M System under Test
Sensor
Device
Emulate
IBM InfoSphere Data Streams
Data Generator Framework
Domain Knowledge
Properties of the IoT/M2M system
Data Type & Structure
Generating Large Volume and Fast Velocity Streaming Data

Figure 11. IoT platform integrated with data generation and data analytics.

platform (illustrated in the middle part of **Figure 11**). Finally, the data sets produced by the IoT/M2M applications are analyzed by data analytics engines in IBM InfoSphere and Spark (illustrated in the upper part of **Figure 11**).

The effectiveness of our data generation methodology is first verified in a people management system of a large factory environment. With our methodology, we are able to test our factory management IoT/M2M application more efficiently without actually deploying a large number and a large variety of sensors. This application development uses both IoT and Big Data Analytics.

4.4. Application on Data Analytics for Traffic Generated by Testing & Measurement

The automatic Testing & Measurement (T&M) of DUT (Device under Test, including 4G/LTE SD, UE/CPE) for 4-Stage (namely, conformance, interoperability, operator-IOT and field trials) testing is shown in **Figure 12**.

We apply the data analytics learning techniques for the classification of the DUT types by series numbers or id. Once the type is identified, the parameters for feature extraction can be measured by the testing and measurement equipment. An example for DUT classification is shown in **Table 3**. In this example, the DUT type relational table is a 4 × 4 table with 4 fields: 1) DUT Device Type, 2) UE capability Information (FGI), 3) DNS (TTL), and 4) HTTP (User Agent). This device relational table is created by applying multivariate statistical analytics on the network traffic flow and LTE UE connection related information. Then by extracting specific features, we are able to identify the types of DUT such as Dongle, Smartphone, CPE, etc.

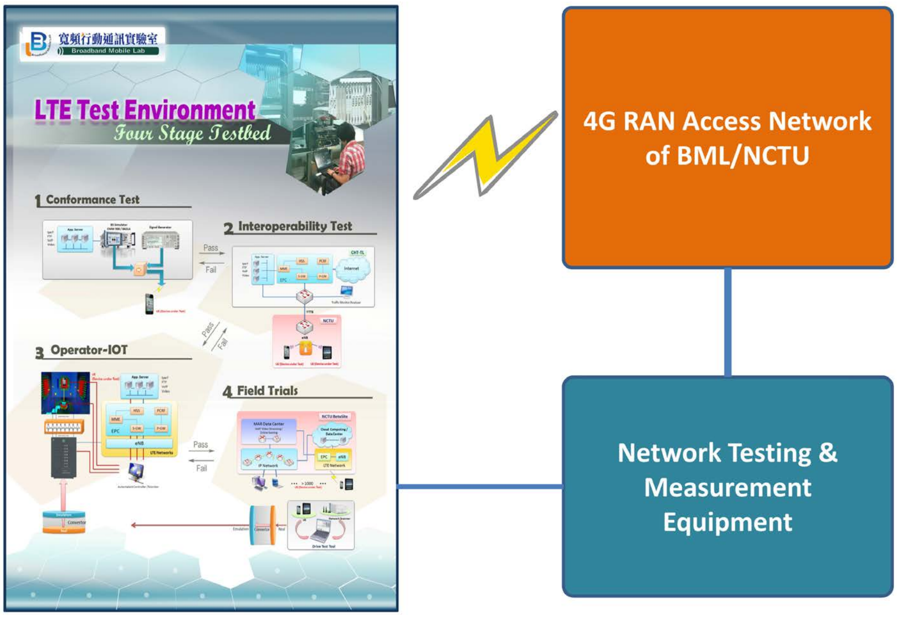

Figure 12. Data generation by endpoints from testing & measurement.

Table 3. DUT relational table.

DUT Device Type	UE FGI	DNS-TTL	HTTP-User Agent
Dongle A	0100 0110 0000 0101 0001 1000 0000 0000	128	Mozilla/5.0 (Windows NT 6.1; WOW64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/43.0.2357.134 Safari/537.36\r\n
Dongle B	0101 1111 0000 1111 1111 1100 1000 0000	63	Mozilla/5.0 (Windows NT 6.1; WOW64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/43.0.2357.134 Safari/537.36\r\n
Smart Phone	0101 1110 0000 1101 1101 1000 1000 0000	43	iPhone6,2/8.3 (12F70)\r\n
CPE	0101 1111 0000 1111 1111 1100 1000 0000	127	Mozilla/5.0 (Windows NT 6.1; WOW64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/43.0.2357.134 Safari/537.36\r\n

Another example of applying data analytics in T&M traffic is to evaluate LTE QoS. When evaluating LTE QoS, it is required to setup testing scenarios with different QoS levels. Traffic Flow Template (TFT) (as shown in **Table 4**) is designed to filter packets into correspondent bearers, either a default bearer or dedicated bearer, in LTE network. Each bearer has its own QoS level. We can establish a dedicated bearer of guarantee bit rate (GBR) for applications such as VoIP, or a default bearer of basic QoS level for applications like file transfer.

What TFT does is to filter packets into correspondent bearers according to packets' IP address, port number, protocol, direction. The information, however, is insufficient to differentiate among web file download, FB news browsing, and Line chat. We are unable to give different QoS levels to these applications. To tackle this problem, we propose a new architecture which integrates deep packet inspection (DPI) with TFT to provide a higher granularity of QoS levels for applications. When some traffic flow has been identified as a certain application type, TFT will be informed to update rules of packet filters. With this improved method, the traffic flow can be delivered through the bearer of suitable QoS level.

4.5. Applications on Data Analytics for Traffic Flow Created by APP's of SD

To fulfill the Quality of Service (QoS) requirements from users, it is important to make effective use of the network resource. We can optimize the performance of a network by applying data analytics to traffic engineering. In particular, it is important to classify mobile applications traffic intended by the user with data analytics.

We propose a HMM-based (Hidden Markov Model) model to classify the mobile applications. By surveying related work, we have realized that there are different handshake patterns of well-known application protocols. Also, according to the observation of some specific mobile applications, we discover that every mobile Internet service has its unique negotiation process at the beginning when service starts. HMM was widely used to recognize time-dependent sequences and find out unknown patterns of data, such as speech recognition, handwriting recognition.

Table 4. Traffic Flow Template (TFT): Use to specify the packet filters associated.

UL Packet Filter ID	DRB	Packet Filter Evaluation Precedence	Protocol Number (IPv4)/ Next Header (IPv6)	Remote Address and Subnet Mask	Single Local Port (UE)	Local Port Range (UE)	Single Remote Port Range (NW)	Remote Port Range (NW)	IPSec SPI Range	Type of Service (IPv4)/ Traffic Class (IPv6) and Mask	Flow Label (IPv6)
1	DRB2	6	6 (TCP)	IPv4: 172.168.8.0 [255.255.255.0] IPv6: 2001:0ba0::[ffff:ffff::]	60051	-	-	-	-	-	-
2	DRB2	2	17 (UDP)	-	-	-	60201	-	-	-	-
3	DRB3	7	6 (TCP)	IPv4: 172.168.8.0 [255.255.255.0] IPv6: 2001:0ba0::[ffff:ffff::]	-	60100:60200	-	-	-	-	-
4	DRB3	3	17 (UDP)	-	-	-	-	60300: 60400	-	-	-
5	DRB3	5	50 IPSec (ESP)	-	-	-	-	-	0x0F80F0000	-	-
6	DRB3	1	-	-	-	-	-	-	-	00101000, Mask = 11111100	-
7	DRB3	6	-	-	-	-	-	-	-	-	-
8	DRB1 (default bearer)	255	6 (TCP)	-	-	-	-	-	-	-	-

In our method, we extract the packet size sequence and packet transmission direction sequence of the first 20 packets to train the HMM model. **Figure 13** shows our designed model structure of HMM. X_n is the hidden variable. It represents the transmission states which cannot be observed directly. Because of the unknown transmission states, we need to use observation variable O_n^1 and O_n^2 as training features to build the mobile application models. Here, "*n*" is the sequence number of packets in a traffic flow. O_n^1 is the observation symbol of packets transmission direction. O_n^2 is the observation of packet size that quantizes to a certain range of packet size. We quantize smallest packet size to number 1 and largest packet size to number 8. The rest of packet sizes are then divided into six groups.

Figure 14 shows the main process of our classification system. First, we process the collected packets by reading from original PCAP files, and extract the necessary field of packet header, including source IP, destination IP, source port number, destination port number, packet timestamp, and packet size. Second, we use packet

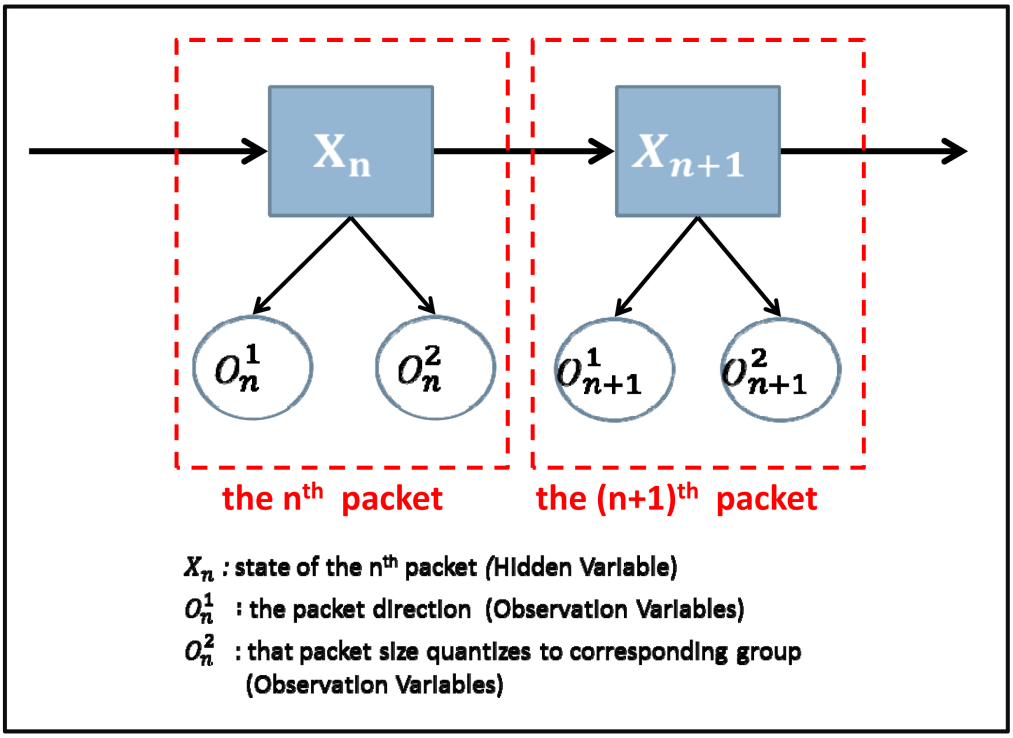
X_n
X_{n+1}
O_n^1
O_n^2
O_{n+1}^1
O_{n+1}^2
the nth packet
the (n+1)th packet
X_n : state of the nth packet (Hidden Variable)
O_n^1 : the packet direction (Observation Variables)
O_n^2 : that packet size quantizes to corresponding group (Observation Variables)

Figure 13. Classification model of Internet application traffic.

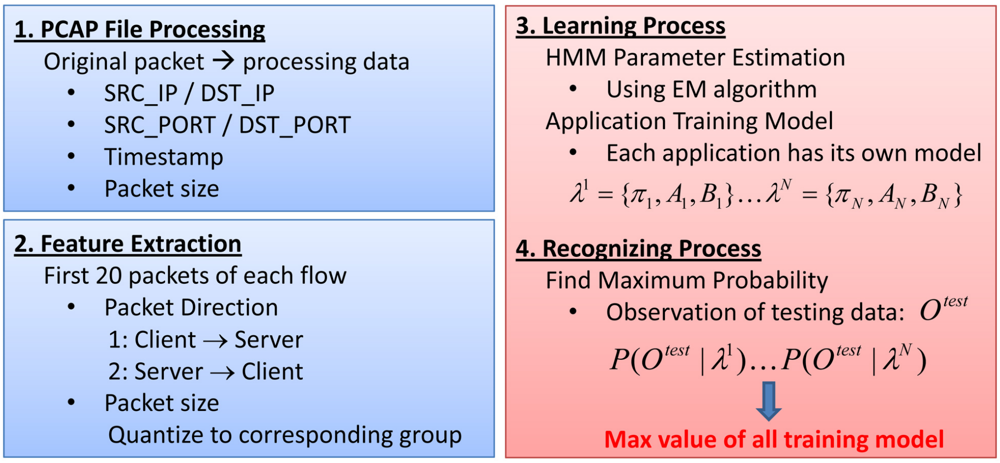

1. PCAP File Processing

Original packet → processing data
- SRC_IP / DST_IP
- SRC_PORT / DST_PORT
- Timestamp
- Packet size

2. Feature Extraction

First 20 packets of each flow
- Packet Direction
  1: Client → Server
  2: Server → Client
- Packet size
  Quantize to corresponding group

3. Learning Process

HMM Parameter Estimation
- Using EM algorithm

Application Training Model
- Each application has its own model

$\lambda^1 = \{\pi_1, A_1, B_1\} \ldots \lambda^N = \{\pi_N, A_N, B_N\}$

4. Recognizing Process

Find Maximum Probability
- Observation of testing data: O^{test}

$P(O^{test} \mid \lambda^1) \ldots P(O^{test} \mid \lambda^N)$

⇩

Max value of all training model

Figure 14. The process of our proposed classification system.

header information (5-tuple: source IP, destination IP, source port number, destination port number, and protocol) to process packets with the same 5-tuple information into a unit of mobile application traffic flow, and extract the features of each application flow. Third, in learning process, we use the extracted features which are quantized into corresponding symbol sequence to training the HMM-based application models for different applications. Finally, we can identify the new traffic flow by finding out the maximum value of log likelihoods derived from different application models.

5. Conclusion

This paper presents a forward looking view of the convergence of IoT, big data, cloud, SDN technologies along with the arrival of 5G mobile broadband networks. We intend to demonstrate the technical relationships of those technologies and the compelling programs and applications that can be created when two, three or more of those technologies converge. Due to the nature of fast evolution of ICT and the ongoing innovation of those five technologies, this paper should be updated on annual basis to keep the related information up to day with the ICT major trends.

Acknowledgements

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Research Article

A Model of Socially Connected Web Objects for IoT Applications

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The Internet of Things (IoT) is evolving with the connected objects at an unprecedented rate, bringing about enormous opportunities for the future IoT applications as well as challenges. One of the major challenges is to handle the complexity generated by the interconnection of billions of objects. However, Social Internet of Things (SIoT), emerging from the conglomeration of IoT and social networks, has realized an efficient way to facilitate the development of complex future IoT applications. Nevertheless, to fully utilize the benefits of SIoT, a platform that can provide efficient services using social relations among heterogeneous objects is highly required. The web objects enabled IoT environment promotes SIoT features by enabling virtualization using virtual objects and supporting the modularity with microservices. To realize SIoT services, this article proposes an architecture that provides a foundation for the development of lightweight microservices based on socially connected web objects. To efficiently discover web objects and reduce the complexity of service provisioning processes, a social relationship model is presented. To realize the interoperable service operations, a semantic ontology model has been developed. Finally, to evaluate the proposed design, a prototype has been implemented based on a use case scenario.

1. Introduction

The Internet of Things (IoT) envisions billions of objects connected to the Internet that continuously generate data about the physical environment. Several state-of-the-art applications can be built using the information and services provided by the pervasive and heterogeneous IoT objects. However, building applications based on these objects raises some challenges. Examples include how the growing number of objects will interact or coordinate to render valuable services, how the complexity generated by the coordination of objects can be handled, and how a large amount of diverse data sensed from the surroundings can be managed properly.

Numerous promising solutions have been provided to handle the complexity and the heterogeneity of IoT objects. One of the prominent approaches is to develop virtual environments to resolve the issues caused by the heterogeneous objects. Virtualization has become a key component in many IoT architectures, in the form of either virtual objects or virtual entities. A virtual object (VO) is defined as a digital representation of a real-world object [1] and provides a way for the IoT services to discover and compose features that cannot be achieved directly with a real-world object (RWO). It has been realized that issues such as heterogeneity of dissimilar objects and scalability can be effectively resolved using VOs. Hence, a crucial role of a VO is to bridge the gap between the physical world and the virtual world by hiding the physical characteristics of an IoT device and acquiring and interpreting its data and context.

Another way to reduce the complexity caused by a large number of objects is to link these objects in a social network [2], which provides a more exact solution than using a sole individual object. This principle has given birth to the concept of Social Internet of Things (SIoT), which is emerging as a new paradigm with the merger of social networks and IoT [3–7]. It has been realized as an efficient way to facilitate the development of complex future IoT applications. It supports sharing of information generated by the people and the devices based on the social relationships. These relationships further promote efficient discovery of the objects and effective service compositions.

Let us have a glimpse of the application scenarios in which SIoT will make a profound effect on our daily life in the near future. Imagine a group of vehicles that form a mobile social network on the move when heading towards the same location or when they are bound in a common relationship. Vehicles may form diverse social communities; for example, small cars create a social network to share available parking space information or bicycles share information about the vacant paths using a network [8]. Vehicles commuting from home to office can join a social network to share traffic congestion experience, accident warnings, or other common information (e.g., a meeting plan) with colleagues by accessing their vehicles' social network. Let us analyze another SIoT use case where a user enters a public museum with an IoT environment, which incorporates smart objects that exploit social relationships to share information. At the entrance to the premises, the user's smartphone is prompted with a beacon signal to recommend a service app installation. When the user grants the permission, an app is installed and a social agent acquires his profile and friendship details. The app incorporates a microservice which uses a smartphone object to establish a social relationship with the museum visit service. The museum is equipped with a network of smart objects that monitor the user's location and provide services to enhance his/her experience such as personalizing the displays, assisting in the navigation, and recommending the relevant services.

To support the above-mentioned use cases, most of the current IoT architectural approaches are not suitable as they are based on the traditional monolithic approaches, which further hinder the development of efficient, modular, and independent services that cannot scale well with the increasing user's service demands, as already witnessed in many studies [9–12]. Using monolithic approaches, we cannot fully achieve the benefits offered by SIoT including efficient information discovery, improved scalability, and simplified interconnection of objects.

These limitations motivate the current paper to define a design for the development of SIoT based services with efficient and lightweight mechanisms to exploit SIoT features for improved service provisioning. The proposed design is based on the microservices concept which promises a more solid practice of SOA. There is no particular definition of microservices architectural style; however, it is explained in [13] by Martin Fowler as "an approach to developing a single application as a suite of small services, each running in its own process and communicating with lightweight mechanisms, often an HTTP resource API." Following the microservices based proposed design, SIoT applications can be developed, deployed, and maintained more efficiently and independently, which will promote system modularity and interoperability.

Moreover, a SIoT design needs to facilitate the efficient information discovery based on the social relationships among objects. To achieve this, incorporating the existing social relationship models in the proposed design can be useful. However, applications with intelligent service features require dynamic object selection. Therefore, objects need to acquire the ability to infer new relationships for interconnection with other objects in the system. This view further motivates the present article to develop a social relationship model based on the semantic ontology. The utilized ontology-based approach is highly useful to dynamically infer new social relationships for efficient service provisioning.

Furthermore, to fully achieve the benefits of both, the SIoT and microservices, selecting an IoT environment is necessary where not only can the social interconnection among heterogeneous objects be utilized but also the lightweight services can be developed to apply these relationships for effective IoT service provisioning. To fulfill this goal, the Web of Objects (WoO) [14] platform has been selected. According to the ITU recommendation (ITU-T Y.4452) [15], "the Web of Objects (WoO) is a realization way of the IoT services, where virtualized objects (i.e., virtual objects (VOs) and composite virtual objects (CVOs)) are connected, controlled, and incorporated with resources to facilitate the development, deployment, and operation of IoT services on the World Wide Web."

To exploit the opportunities provided by the above discussed technological advancements, the main contributions are highlighted as follows:

(i) This article contributes a novel design based on the microservices concept with lightweight and modular services to support the development of SIoT applications. The proposed design involves mechanisms to enhance object discovery and to reduce the magnitude of complexity generated due to the huge number of objects.

(ii) A social relationship ontological model is developed, which helps identify the hidden and unidentified relationships among objects with reasoning mechanisms.

(iii) A use case with the implementation prototype based on the WoO platform is developed to exploit the social relationship model, supporting the proposed design for efficient IoT service provisioning.

Further, to support the above contributions, virtual objects, serving on real-world objects, have been developed, which can be reusable in other services as well. CVOs are implemented, where each update of the information in the real-world object is reflected in the VO and propagated to the CVO. Also, the Social IoT notion is incorporated into virtual objects to provide easy discovery and efficient execution while maintaining collaboration using social connections. Moreover, an experimental analysis has been carried out to evaluate the discovery time of VOs and the time required for service execution, with or without social relationships among virtual objects.

The remainder of this article is organized as follows. In Section 2, the related work is described. Section 3 presents the proposed design of the social web objects accompanied by the social interaction model. In Section 4, an IoT environment use case is explained with the details of the prototype implementation and discussion of the performance evaluation. Finally, Section 5 provides a conclusion of this paper.

2. Related Work

This section presents the related work with respect to the SIoT and microservices. Further, the significance of both technologies pertaining to the IoT environment has been discussed.

2.1. Social Internet of Things (SIoT). The concept behind SIoT is to enable smart objects to create a social network similar to a human social network. The objective is to exploit the social relationships among objects in an IoT environment to facilitate the effective information discovery, to promote the scalability, to enhance the interactive communication between objects that are friends, and to achieve trustworthiness [3].

The initial notion of a social network of objects was proposed by [16], which discussed how the wireless devices form social connections on the temporary bases that are controlled by the node owners. As the work was carried out before the introduction of IoT, it did not consider the SIoT concept. Later studies [5] investigated the objects' social interaction where objects formed social networks and communicated with each other based on the rules already set.

The idea of using the Web of Things in a social ecosystem was presented by [17, 18], where things were shared using the social network infrastructures, for example, Twitter, Facebook, and LinkedIn. These implementations consisted of objects that communicated either through the built-in embedded servers or through smart gateways. Further, in these settings, the web-enabled things owned by a person provided an interface to his/her social group of friends so that they can interact with the things using a social network.

Lysis [19] is another good example of Social IoT platform based on cloud infrastructure. It uses the platform as a service (PaaS) model and focuses on the deployment of applications in the cloud space. However, dynamic inferencing of new social relationships from existing relationships is not supported by this system. Moreover, making a modular interoperable design by employing concepts like microservices and semantic web technologies is not considered in this work.

Paraimpu [20] provided a social Web of Things platform to connect virtual and physical things to the web. In this system, the social concept only relates to humans by providing them with the capability to share things with each other using a human social network. Also, virtual things are not considered as VOs but rather viewed as services on other IoT platforms.

Using SIoT at the edge of the network was investigated by [21]. In this system, an approach was proposed to cope with the communication delay due to the objects being remotely located in the cloud. This approach exploits the computing resources at the network edge to deploy virtual objects.

The ThingSpeak solution was used as the basis for the implementation of an early SIoT platform [22]. This platform provided the object social behavior functions incorporated at the centralized server. In this implementation, functions such as the creation and the management of the social relationships were developed. However, VO concept was limited only to the records in the remote database.

Another featured SIoT framework was contributed by [4]. This work presented how to combine services, devices, users, and their social interaction to enable interactivity, discovery, and recommendation of services. Social relationships have also been investigated in communities [23], where a proposed framework enables the identification of communities in the social networks.

Although most of the research contributions in the SIoT domain incorporate a notion of the social association of objects, however, limited information has been provided about the social relationship model and the details on how that can be used by IoT services. Furthermore, existing approaches are lacking lightweight and modular mechanisms which can be utilized by services to exploit social relationships efficiently. In our approach, we have developed a semantic ontology-based social relationship model that provides the capability to infer new connections in a network of social objects. Another distinction of the proposed system is a microservices based design that utilizes the developed social model to provide lightweight, modular, simple, and interoperable IoT services.

2.2. Microservices. The microservices architecture is emerging as a new trend among the practices of developing distributed web applications. To develop SOA based systems, microservices have become a prominent approach in real-world settings [24]. In the microservices based architectural pattern, each application incorporates a collection of small services which execute independently and use lightweight communication mechanisms [9]. The microservices are targeted for doing one thing well at a time based on the principle of single responsibility [25], as defined by Robert C. Martine: "Gather together those things that change for the same reason and separate those things that change for different reasons" [26]. Also, the microservices are conceived as autonomous entities, which means they can be changed and deployed independently of each other without requiring their consumers to change [24].

In the last few years, several IoT architectural designs were proposed and developed. Some of these designs provided innovative features such as the European FP7 project iCore [27] which proposed a cognitive framework for IoT application development. This project provided an architecture with the concept of virtual objects and their composites. However, in iCore, services are designed using a traditional SOA based monolithic style, whereas the microservices based architecture provides a better option to develop IoT services. Furthermore, in iCore, VOs lack the mechanisms to semantically represent real-world objects (RWOs), which limits extensibility and interoperability.

To support IoT applications, microservices based architectures are being proposed in many research initiatives and applied in several research projects. In [28], microservices are used for M2M applications, realizing the fact that monolithic approaches for M2M cannot provide a real solution. Another work [10] provided an analysis of using microservices architecture for large-scale distributed applications. This work demonstrated that significant benefits can be achieved as compared to generic SOA approaches when using microservices in an IoT platform for smart city applications.

Moreover, Almanac FP7 EU Project [29] provides smart city services based on the IoT environment. The project uses microservices to employ scalability in a horizontal and vertical fashion. Also, in the industry, microservices have become a solution for developing large-scale applications. Netflix, Pivotal [30], and Amazon use microservices in their software bases.

The increased importance of microservices for the IoT applications is due to the fact that they simplify complex systems. By dividing a system into smaller parts, higher cohesion and lower coupling can be achieved, which makes it highly scalable. In scenarios where requirements keep changing continuously, microservices can help make a system easily modifiable. Moreover, the major benefits that are envisaged when using microservices in an IoT environment are as follows: Microservices leverage scalability to provide a highly decoupled pattern and can allow scaling individually. Their usefulness can be realized as when the demand for the requirement increases the system complexity also rises. In this case, a system can be supported by creating new instances of existing services. Microservices scalability [9] fits in three-dimensional space, that is, horizontal scalability (typical scalability), vertical scalability (splitting different individual microservices), and z-axis scalability (splitting similar things, such as DB partitioning). Microservices architecture supports a plug-and-play behavior where system components become loosely coupled. To acquire new functionality or replace a failed service, pull the plug from one microservice and plug into a new microservice [31]. One of the major problems that IoT is facing today is how to deal with the heterogeneity of incompatible solutions. To harmonize the heterogeneity, semantic web technologies with microservices are leveraged to provide interoperable exchange and communication of data. Microservices realize a decentralized and autonomous behavior, operating on their own priorities and schedule. This way, they provide several benefits for being utilized in an IoT design.

3. The Proposed Design of Social Web Objects

Recently, there have been several research efforts [3–6, 17, 20, 32] for defining the Social IoT. This new aspect minimizes the complexity generated by the communication of billions of real-world objects and enables sharing of information. The social notion can be incorporated into the WoO platform to provide a semantically rich base for IoT applications that can utilize real-world object relationships for efficient information discovery. Moreover, this section provides a brief introduction of WoO reference architecture in Section 3.1. A classification of social relationships among web objects (virtual objects and composite virtual objects) is discussed in Section 3.2 and a social relationship model is presented in Section 3.3. Further, the details of functional components for the proposed architecture are explained in Section 3.4.

3.1. Web of Objects (WoO) Reference Architecture. To enable the deployment of IoT services on the World Wide Web, WoO provides a reference framework. In other words, it realizes the IoT services in such a way that virtualized objects are interwoven with resources to support the development, deployment, and operations of IoT services [33, 34]. The WoO platform provides service functionality by merging VOs and features of web applications. Moreover, the WoO platform uses semantic web technologies to enable interoperability among heterogeneous resources. This realization provides the basis for the composition and harmonization of objects to provide smart services in an IoT domain. Building services based on WoO platform using diverse technologies, including microservices [35], social networks, and semantic web, helps reduce the complexity and fosters the easy and efficient development of IoT applications.

Virtualization has become a major concept in IoT to address the heterogeneity of diverse types of physical objects. VO is a digital representation of a real-world object that can be anything, living or nonliving, mobile or stationary, concrete or immaterial. In WoO, VO is defined as domain-specific semantic ontology based on the VO information model [36]. It is uniquely identified using URI and provides information updates on the representative real-world object. On the other hand, WoO also provides a notion of CVO which aggregates one or more VOs to enable service features that satisfy the application requirements. CVOs chain semantically interoperable VOs together. The WoO platform incorporates features to efficiently reuse existing VOs and handles the complexity generated by self-management and control mechanisms [37]. In the WoO, service level decides which CVOs and VOs will take part in creating an object mashup to fulfill service objectives. The service logic is saved in the form of templates and stored in the template repository [38–40]. The domain expert or knowledge engineer defines the service templates that are used to instantiate new services.

WoO reference architecture is shown in Figure 1. In this architecture, the service layer handles requests and provides several management functions, whereas the CVO level consists of functions to manage and instantiate CVOs or reuse the existing ones based on the provided service execution logic. New objects such as sensors are registered in the WoO platform using a registration function and their templates are generated to make them digitally available in the form of VOs. Another most important aspect is the semantic representation of data at three-layered WoO architecture [23, 39]. The database at each layer is supported with semantic web technologies.

3.2. Types of Social Relationships. Previous research [3] on SIoT has derived some basic relationship types among objects. These relationships are characterized as follows. *Parental Object relationship* (POR) exists between the objects that belong to the same batch, such as objects that are created in the same production process or at the same time by a common manufacturer. *Cowork object relationship* (CWOR) is the relationship among objects that are grouped together based on some commonly shared job to be done by them. Similarly, *colocation object relationship* (CLOR) is established

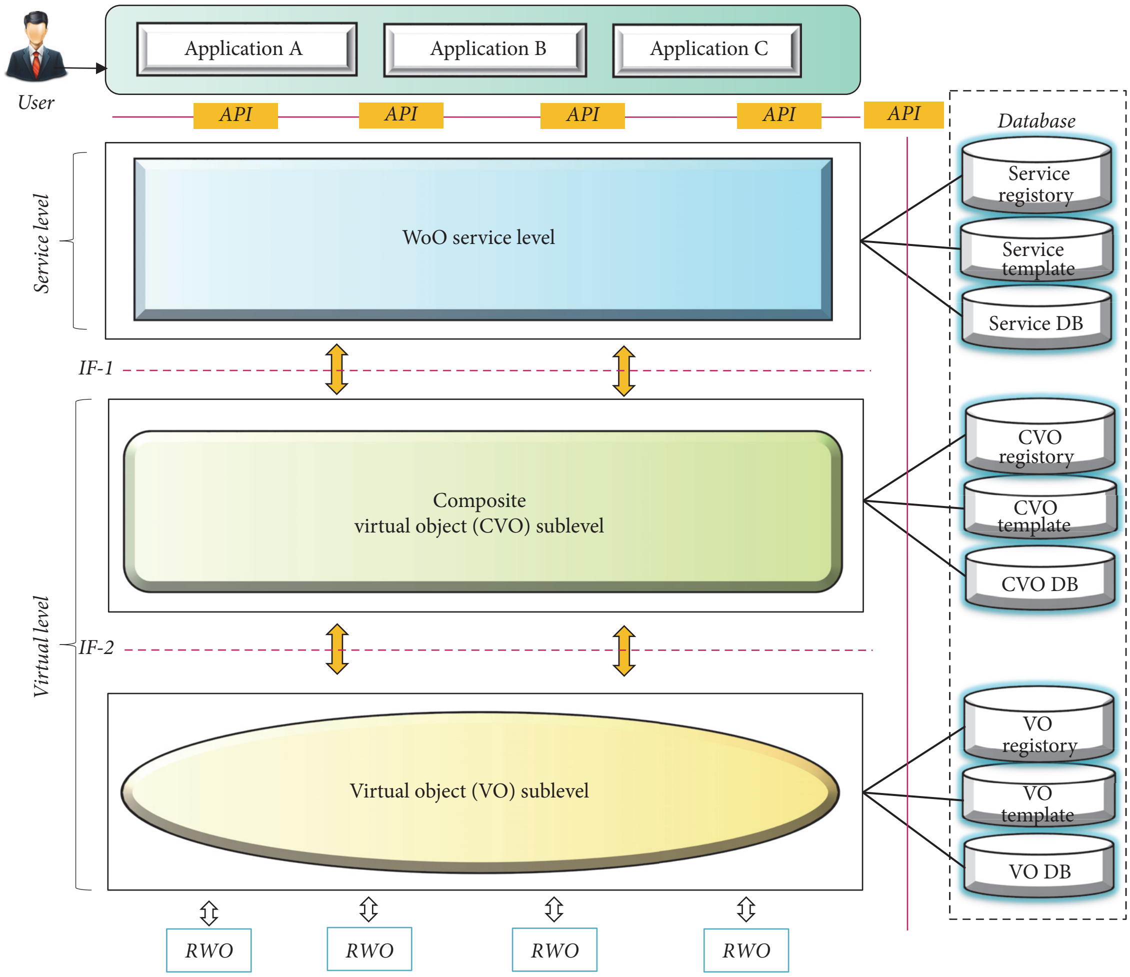
User
Application A
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Service template
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Service level
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CVO registory
CVO template
CVO DB
Virtual level
IF-2
Virtual object (VO) sublevel
VO registory
VO template
VO DB
RWO
RWO
RWO
RWO

Figure 1: Web of Objects reference architecture.

between objects belonging to the same location such as home or office. Different or same types of objects can be combined based on the common location or premises. On the other hand, *Ownership Object Relationship* (OOR) is formed among objects belonging to the same owner. *Social Object Relationship* (SOR) is another kind of relationship that is created among objects when they come close to each other, either random in time or periodically. This relationship can be envisaged when the owners of objects come into contact with each other. Apart from the above relationships, in [41], the authors define the *Guardian Object Relationship* (GOR) in the Internet of Vehicles (IoV) scenario where on-board units of vehicles become children in relation to the super nodes of Road Side Units. This child and parent association gives a special meaning to a new hierarchical relationship.

In addition to the relationships defined in other studies, we have identified few more relationships suitable for some diverse scenarios. These include *Sibling Object Relationship* (SIBOR) that is created among objects that belong to a group of friends or family members. This relationship among objects extracts the property of trustworthiness based on the relationship of their owners. Another relationship type is the *guest object relationship* (GSTOR) which is formed between objects that belong to the users in the guest role, for example, when a person visits a friend's home and gets the privilege as a guest. The same can be applied to the objects that move in guest relation (GSTOR) from one place to another; they will have some privilege of accessibility of information as compared to other objects. *Stranger Object Relation* (STGOR) applies to objects that encounter the presence of each other in an anonymous environment such as on the go or in the public environment. Similar to people who meet each other sometimes regularly but are anonymous to each other or are not fully aware of each other, this relationship can be used among objects to form different trust levels or to form strict restrictions to promote secure connections. Moreover, in *service object relationship* (SVOR), objects form a relationship while coordinating in the same service composition to fulfill a service request. Generally, in the proposed scheme, service request execution generates a mashup of objects, and objects that belong to the same mashup are assumed to be in SVOR.

We believe that the above defined new social relationships are beneficial in several distinctive scenarios. For example, SIBOR is more useful in scenarios where trust is highly important for establishing a connection. Unlike the more generalized relation POR, SIBOR is established

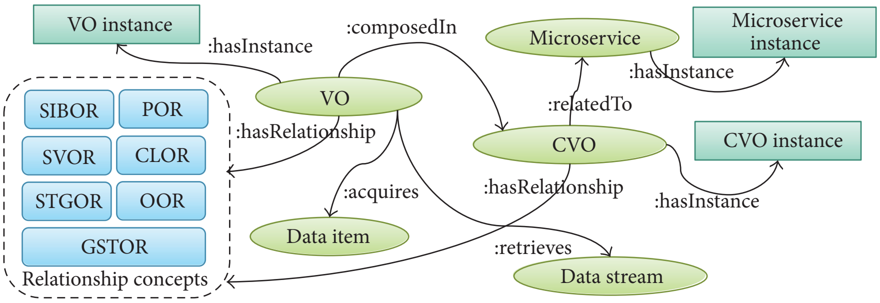

(i) Sibling Object Relationship (SIBOR)
(ii) Service Object Relationship (SVOR)
(iii) Stranger Object Relationship (STGOR)
(iv) Guest Object Relationship (GSTOR)
(v) Parental Object Relationship (POR) [3]
(vi) Colocation Object Relationship (CLOR) [3]
(vii) Ownership Object Relationship (OOR) [3]

Figure 2: Ontological model representing web objects' relationships.

among objects from the same manufacturer having similar features but different behaviors. Similarly, GSTOR is suitable in scenarios where objects use relationships for privileged services. Imagine a person as a guest speaker in a conference with his smart devices, where he can connect to the network easily, and his personal devices are recognized as a guest (with GSTOR) in the venue network to avail free services like high-speed Internet, special notifications, and others. Stranger Object Relation (STGOR) is used in scenarios where objects are on the go, and to get some information, they have to compromise with a limited trust level. For instance, in a public transit system, one mobile node on the move wants to use crowdsourced information from another mobile node which is not fully trusted. Also, SVOR is useful in service composition specific scenarios, where object mashups are formed to facilitate service requirement, and it is also useful in a particular orchestration of objects.

To model information about microservices, social web objects, and their relationships, a semantic ontological model has been developed as depicted in Figure 2. Conceptualization of objects and their social relationships in semantic structures are highly beneficial to infer new connections among a network of objects with the help of reasoning techniques. The ontology facilitates the representation of objects, as well as what they measure in terms of observations, their processing, and functions. Web objects' relationship ontology contains the concepts that define each object in terms of a class. The data properties are used to represent object values and the object properties are defined to identify the link between two objects in the ontology. Major concepts in the ontology are microservices, CVOs, VOs, and their social relationships. Further, microservices have an individual instance that uniquely defines a microservice object and associated data with it. Similarly, CVOs and VOs are also instantiated and contain data properties to retain their values. With the increasing number of objects, a semantic ontology model is used to perform reasoning function that helps identify new connections. Further, to analyze the social relationship among objects (such as VOs and CVOs), their properties are provided in Table 1.

3.3. Social Relationship Model for Web Objects. At each level of service life cycle, objects form a social relationship with each other to accomplish a service task. Codifying the relationship among web objects can provide many benefits, such as efficient information discovery from related objects and better composition and reuse. To perceive social interaction between web objects, we assume every service is based on one or more microservices and other objects including CVOs and VOs. At VO level, VOs create several relationships with each other based on the RWO they represent. CVOs associated with microservices are incorporated in relationships as well.

Object-to-object associations are categorized as either vertical associations (interobject relations) or horizontal associations (intraobject relations) as shown in Figure 3. The relationships that flow from the bottom to the top in WoO based architecture are known as interobject relations (i.e., from VO to CVO or vice versa). On the other hand, relationships are known as intraobject relations if they are generated within objects at each level such as between one VO and another, or within one CVO to a relative CVO. The newly defined relationships among objects are maintained at different levels, which enables information discovery more efficiently. It is considered that not only will the relationships be maintained when two objects (i.e., VOs) are used in the same CVO or service, but also they will be maintained if objects are used in different CVOs or services.

As depicted in Figure 3, VO1 and VO2 bind in the SIBOR relationship, considering the fact that they belong to the same family of CVO1. Similarly, VO4, VO5, and VO6 are combined in a CWOR, as they are used in the same service. However, all of them do not have a common family relation that makes their trustworthiness restrictive to some level as compared to SIBOR. Moreover, though VO7 and VO8 are not used together in a service setup, still they form a STGOR relationship. This relationship also helps codify those VOs that have similarity in premises during a certain point in time regularly but they had never combined in any service scenario before. For example, if a person visits a subway regularly but stays very shortly, in such scene, the user's smartphone VO and subway station point

Table 1: Social relationship attributes.

Social object relationships types	Attributes/properties
Sibling object relation (SIBOR)	O_x *has relationship* with O_y → SIBOR, if objects' *ownership* is defined as: == SameFamily
Service object relationship (SVOR)	O_x *has relationship* with O_y → SVOR, if objects' *serviceStatus* is defined as: == SameServiceComposition
Stranger object relation (STGOR)	O_x *has relationship* with O_y → STGOR, if objects' *authentication* is defined as: == Anonymous
Guest object relationship (GSTOR)	O_x *has relationship* with O_y → GSTOR, if objects' *ownership* is defined as: !=SameFamily && == GuestFriend
Parental object relationship (POR)	O_x *has relationship* with O_y → POR, if objects' *creation* is defined as: == SameBatch ‖ == SameProduction
Colocation object relationship (CLOR)	O_x *has relationship* with O_y → CLOR, if objects' *proximity* is defined as: == Neighborhood ‖ *location* is defined as: == SameLocation
Ownership object relationship (OOR)	O_x *has relationship* with O_y → OOR, if objects' *proprietorship* is defined as: == SameOwner

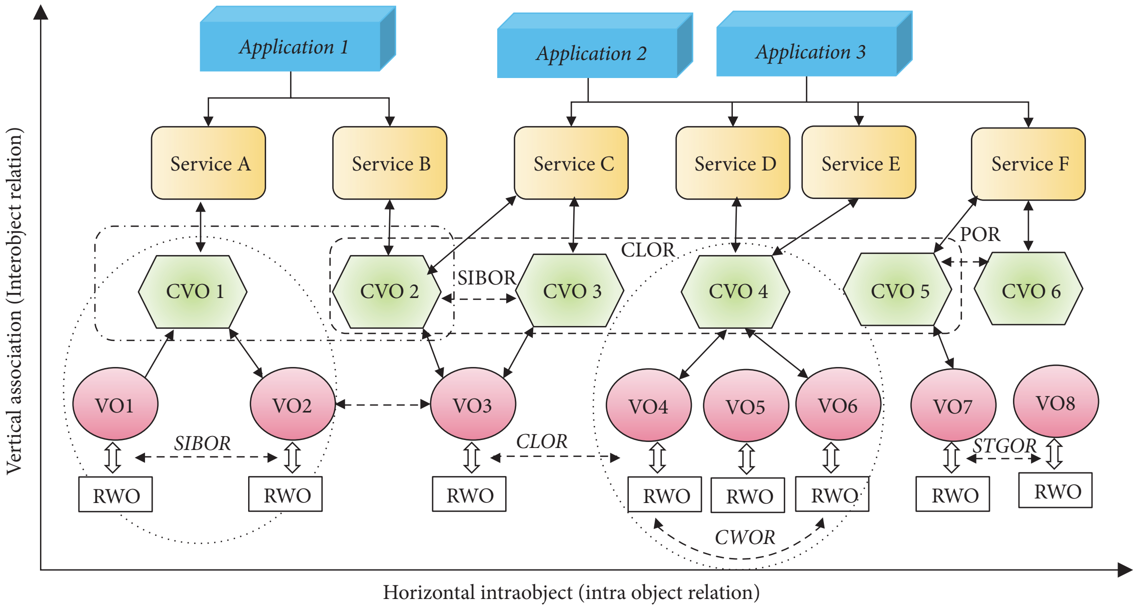

Figure 3: Hierarchical social relationships of web objects.

VO or subway security camera VO may establish STGOR. This may help reuse VOs in service scenarios where only for short duration a VO object is required. At CVO level, CVO2 forms two different relationships, which increases the level of connectivity of the CVO. CVO2 first shares a CLOR with CVO1 and CVO3, CVO4, and CVO5 together. Secondly, CVO2 is combined in a SIBOR with CVO3 and becomes in the same service family. Further, in the selected use case scenario described in Section 4, several other social interactions have also been elaborated.

3.4. Social Web Objects Architecture. SIoT envisages a system where the social framework will bring smart devices and people to interact with each other. By incorporating web technologies like SOA based microservices, IoT services can be rendered on top of the social framework. The proposed social web objects architecture (as shown in Figure 4) has been decomposed into three levels: service level, object virtualization level, and aggregated object virtualization level. At the service level, to support social relationships within web objects, several microservices have been designed, which are discussed further in the following section. Moreover, the data management function in the proposed design helps each layer to interconnect with semantic databases. The SPARQL endpoints have been defined at the service and the object virtualization levels that expose interfaces to retrieve, store, and modify RDF graphs. Several interfaces allow the knowledge engineer, domain expert, and the developer to create service templates and VOs, as well as update the RWK model, user profile, and policies.

3.4.1. Service Level Functional Components. The service level functions handle operations from the request inception to the execution of services. This level is supported by some core functions common to be used in each service life cycle. These include the management function to handle service

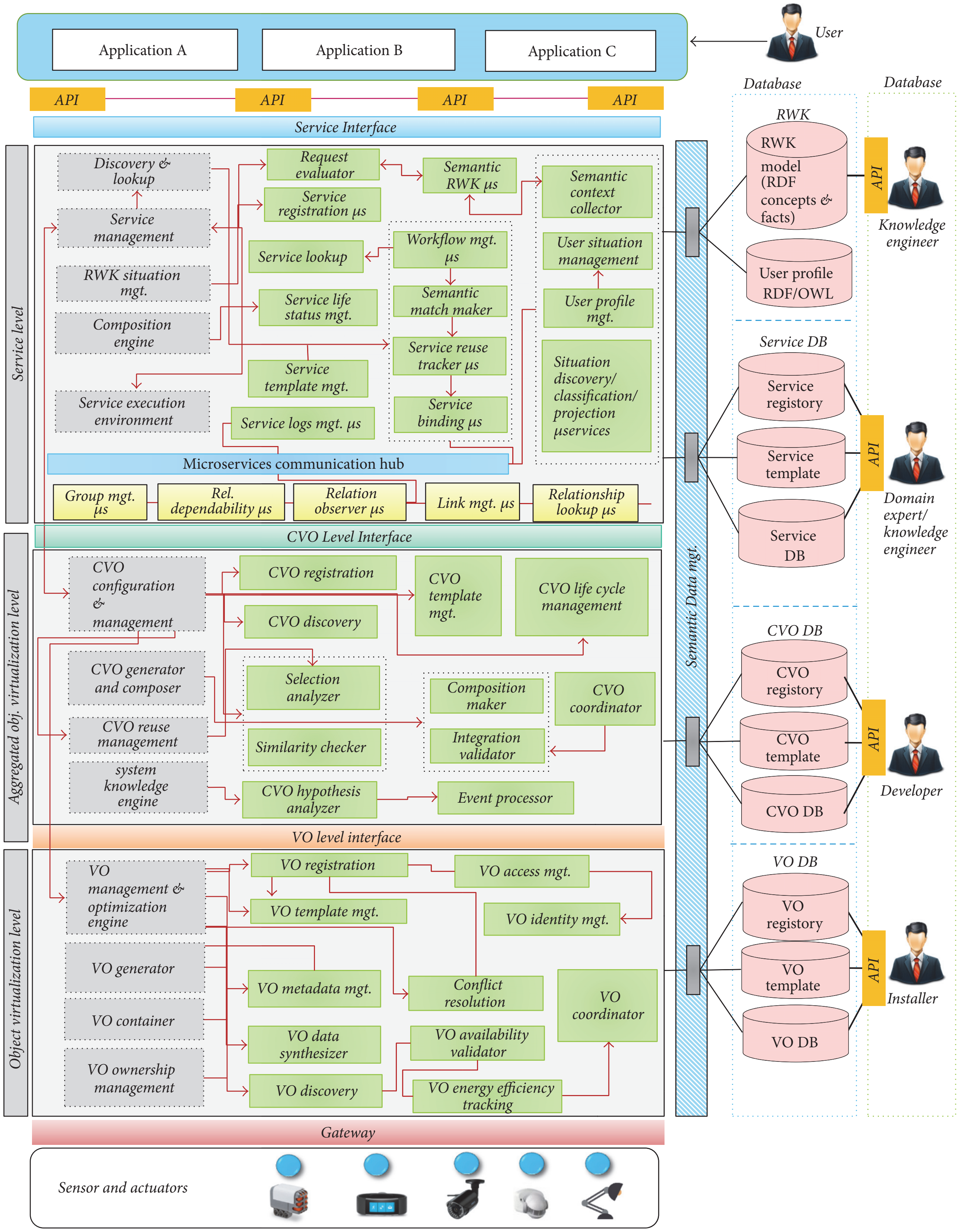
Application A
Application B
Application C
User
API
API
API
API
Service Interface
Service level
Discovery & lookup
Request evaluator
Semantic RWK μs
Semantic context collector
Service registration μs
Service management
Workflow mgt. μs
Service lookup
User situation management
RWK situation mgt.
Semantic match maker
Service life status mgt.
User profile mgt.
Composition engine
Service reuse tracker μs
Service template mgt.
Situation discovery/ classification/ projection μservices
Service execution environment
Service binding μs
Service logs mgt. μs
Microservices communication hub
Group mgt. μs
Rel. dependability μs
Relation observer μs
Link mgt. μs
Relationship lookup μs
CVO Level Interface
Aggregated obj. virtualization level
CVO configuration & management
CVO registration
CVO template mgt.
CVO life cycle management
CVO discovery
CVO generator and composer
Selection analyzer
Composition maker
CVO coordinator
CVO reuse management
Similarity checker
Integration validator
system knowledge engine
CVO hypothesis analyzer
Event processor
VO level interface
Object virtualization level
VO management & optimization engine
VO registration
VO access mgt.
VO template mgt.
VO identity mgt.
VO generator
VO metadata mgt.
Conflict resolution
VO coordinator
VO container
VO data synthesizer
VO availability validator
VO ownership management
VO discovery
VO energy efficiency tracking
Gateway
Sensor and actuators
Semantic Data mgt.
Database
Database
RWK
RWK model (RDF concepts & facts)
User profile RDF/OWL
API
Knowledge engineer
Service DB
Service registry
Service template
Service DB
API
Domain expert/ knowledge engineer
CVO DB
CVO registry
CVO template
CVO DB
API
Developer
VO DB
VO registry
VO template
VO DB
API
Installer

Figure 4: Social web objects functional architecture.

requests and initiate service provisioning processes, the service discovery function to select the available services, the composition engine to enable service mashups, and the Real-World Knowledge (RWK) and situation management function to acquire RWK and continuously maintain it. Besides these core functions, several microservices have been used to provide the plug-and-play feature in the proposed design; that is, in case of service failure, it is replaced with another one. These services include the Request Evaluator microservice which interprets a service request and matches a request query to the service template. The registration microservice registers newly added service objects to the registry. When a new template is instantiated, objects are put in service, and to know the existence of available service instances, they are recorded in the service registry. The lookup microservice is defined to search for the required service objects using the semantic representation. The representations available in RDF/OWL format are queried from the registry based on the request parameters. Service life cycle management keeps track of the states of service objects during their life cycle, whereas RWK management microservice is a semantic data processing service which processes facts about user preferences, profile, and situational information.

To realize service provisioning, it is always not possible to satisfy the service requirement with a single service function. Service composition and harmonization features are required to fulfill a demanding service request. Service composition is not a single operation; many microservices are used to compose the individual features. One of the major components of the composition is the Workflow Management (WFM) microservice which is responsible for decomposing the service requirement if no single service is available to satisfy the task. WFM microservice identifies the service objects using input and output interfaces. In this concern, it uses the matchmaking microservice to identify the approximate matches that can serve the required service functionality. Here, service objects are semantically represented in the form of ontologies. The semantic ontology alignment algorithm is used to match the service up to a certain threshold level that is defined by the matchmaking microservice. The reuse tracker microservice is used to identify the current service instance usage by the application; it incorporates a coordination mechanism before instantiating any new instance, and this helps in service reuse by many clients. Binding microservice enables tying of services selected by WFM; this function synchronizes input and output of services in a workflow to produce a single service output based on the generated composition plan.

Furthermore, user characterization is another important element to support the IoT services by matching user requirements more closely. The User Profile Manager microservice handles many facts related to the human user. These include user profile, preference, context, and policies. Semantic Context Collector microservice organizes the services requested by the user and the context in which these services were requested. This helps in identifying user interest with respect to the service context. User context or situation helps in service selection more efficiently if a user requests again with a similar service requirement. Some microservices have been designed to handle user situation information; these microservices include situation discovery, classification, and recognition functions. Situation discovery is used to process sensor data that is provided by CVOs to prompt a situation, whereas machine learning algorithms are applied to remove the false values and data normalization is performed in case inappropriate triggers in the data exist. Situation classification incorporates the reasoning methods and rules to generate a relationship over detected events and refine the missing knowledge between the events. Situation projection analyzes the events data with the help of machine learning methods and provides an output in the form of predicted facts that are related to the situation being detected. Moreover, all the microservices coordinate using a communication hub to share information with each other.

A flow of service inception to service execution in the proposed architecture is depicted in Figure 5 where service management is responsible for initiating the above-mentioned functionalities and instantiating the microservices. This process further results in the generation of CVO/VO mashup graphs to be handled by CVO management (discussed in Section 3.4.2). Situational information has also been used to improve request analysis and service provisioning, whereas VO management (discussed in Section 3.4.3) acquires and aggregates data from sensors and other RWOs.

Social Relationship Management Microservices. To support the social relationships among web objects at each layer of the proposed system, relationship management microservices are defined, which support the codification of relationships among web objects (VOs and CVOs) and their management. These microservices are defined as follows. Group management microservice identifies the grouping of objects into specific sets based on the type and interaction of objects; it builds a social graph of the object relationships. Link management microservice incorporates mechanisms to maintain relationships among different objects and it includes several other subfunctions. The first subfunction is object selection which involves choosing candidate objects that are likely to form a particular association. The second subfunction is matchmaking service which provides exact relationship match based on the type of objects. The third subfunction is the association life cycle manager, which maintains the relationship status between objects; it checks whether they are in active relation or not. It keeps track of relationship validity and also the duration of relationships. Relationship observer microservice enables the object activities to be observed, and it also handles the mutual sharing, which defines what information an object is allowed to share or use of another object based on the relationship among them. Relationship dependability recognizer microservice identifies, maintains, and continuously improves the level of reliability among objects. If objects A and B are frequently interacting and always perform a task together that leads to successful execution of an application to serve the requirements, then they are more likely to form a reliable relationship with each other. The consistency of the relationship allows objects to share their information with fewer constraints as compared to unpredictable association among objects. Relationship

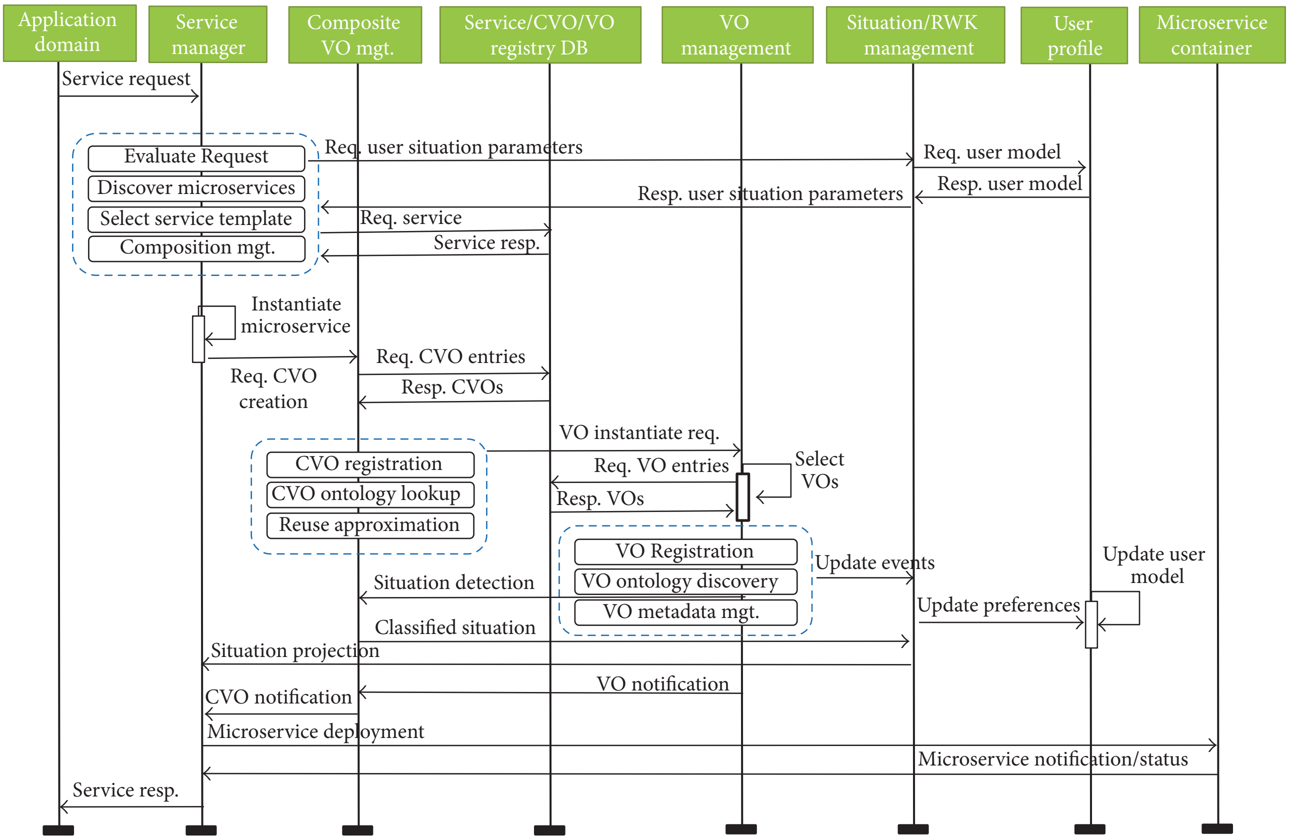
Application domain
Service manager
Composite VO mgt.
Service/CVO/VO registry DB
VO management
Situation/RWK management
User profile
Microservice container
Service request
Evaluate Request
Discover microservices
Select service template
Composition mgt.
Req. user situation parameters
Req. user model
Resp. user model
Resp. user situation parameters
Req. service
Service resp.
Instantiate microservice
Req. CVO creation
Req. CVO entries
Resp. CVOs
VO instantiate req.
CVO registration
CVO ontology lookup
Reuse approximation
Req. VO entries
Resp. VOs
Select VOs
VO Registration
VO ontology discovery
VO metadata mgt.
Update events
Update user model
Update preferences
Situation detection
Classified situation
Situation projection
VO notification
CVO notification
Microservice deployment
Microservice notification/status
Service resp.

Figure 5: Request initiation and service execution flow in the proposed architecture.

lookup microservice incorporates the discovery algorithm (as given in listing of Algorithm 1) to discover the social relationships and maintains the list of all objects and their potential association rating. The rating defines the opportunity for objects to form a relationship with each other.

Moreover, the operation flow of social microservices has been illustrated in Figure 6, where VO management retrieves the social relationship among objects this is queried using link management, which uses a lookup service. Associations are maintained in a social relationship graph using semantic ontology and queried using the relation observer service. The social graph is also updated and maintained continuously with respect to changing links among objects, on the basis of which VOs are selected.

3.4.2. Functional Components in Aggregated Object Virtualization Level. Aggregated object virtualization (AOV) level involves all the necessary functions to instantiate, manage, and continuously monitor CVOs. Besides, it includes the interface required by the service level to interact with CVO components. Service level provides the mashup graphs of CVOs and VOs that are required to fulfill a service request. Aggregation level also supports some core functions; these are categorized as CVO configuration and management to decompose requests from service level and manage CVO instances, CVO generator to instantiate CVOs, composition function to form CVO and VO mashups, reuse management to select existing CVOs that approximately match service requirement, and system knowledge engine to grow knowledge for the optimal use of CVO resources. Further, other aggregation level functionalities are as follows: registration function records the CVO entry into the semantic CVO registry in the form of RDF/JSON format. CVO includes ontologies that specify conditions to be applied on the VO data. Also, at this level, templates are created by a domain expert or knowledge engineer, which consist of functionalities associated with each CVO type. Template management module provides an interface to include templates to the CVO template repository and also supports the modification mechanism. CVOs are discovered using their semantic annotation via the discovery function. CVO selection analyzer function provides estimated selection of a CVO for reuse if there is no single CVO that can exactly provide the required service. This is supported by similarity checking mechanism to analyze the level of similarity before recommending for reuse. At aggregation level, another important function is event processing; event streams generated by object virtualization level are highly valuable to infer situational awareness and building RWK that is used by high-level functions. Event processing module facilitates processing of events and provides generated facts as output. Event processing is supported by CVO hypothesis analyzer that incorporates several hypotheses which are trained over data to build system level knowledge. Aggregation level also

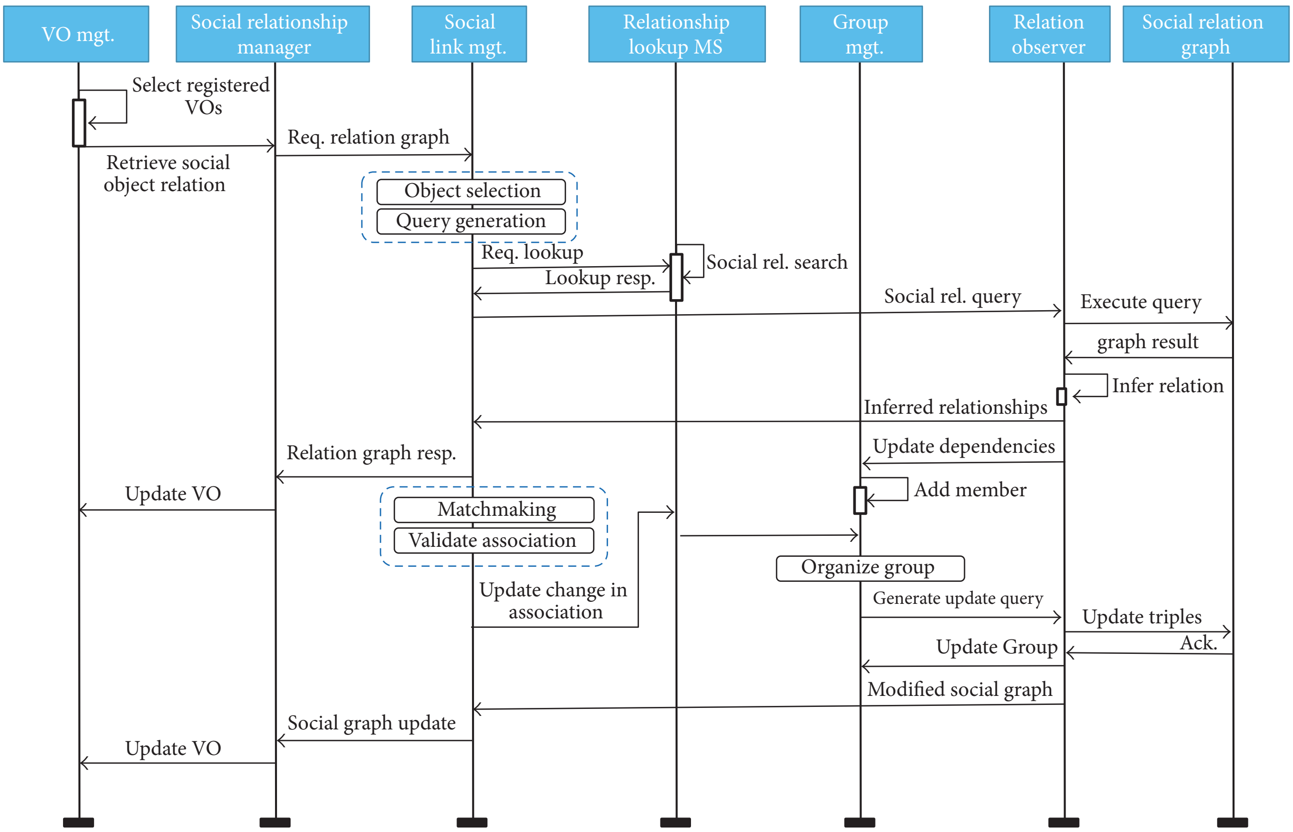
VO mgt.
Social relationship manager
Social link mgt.
Relationship lookup MS
Group mgt.
Relation observer
Social relation graph
Select registered VOs
Req. relation graph
Retrieve social object relation
Object selection
Query generation
Req. lookup
Social rel. search
Lookup resp.
Social rel. query
Execute query
graph result
Infer relation
Inferred relationships
Relation graph resp.
Update dependencies
Update VO
Add member
Matchmaking
Validate association
Organize group
Update change in association
Generate update query
Update triples
Ack.
Update Group
Modified social graph
Social graph update
Update VO

Figure 6: Sequence of operation required to establish a social relationship among objects.

provides composition function which provides the basis for merging multiple VOs to generate single service feature and validation function to validate the compositions of multiple VOs. Moreover, the coordinator helps in resolving conflicts in case of simultaneous access of single CVO by multiple services together.

3.4.3. Functional Components in Object Virtualization Level. Although IoT middleware virtualizes sensors and actuators in some form of virtual entities, however, in WoO, every living or nonliving thing can be represented in the virtual world. VOs are supported by an information model [14, 15] which includes the representation of RWO that can be ICT or non-ICT. In the proposed architecture, object virtualization level includes functions to create, maintain, and coordinate VOs such as VO generator, VO management, and optimization engine. VO registration function provides an interface to register VOs with the help of VO ownership management function where the VO ownership is maintained. Template management function handles templates or loads updated ones as provided by the domain expert. Metadata management maintains data associated with VOs; as VO is a digital representative of real-world entities, there is a high need to store metadata information to recognize the class of sensed data. Use of metadata provides the real value of the data in the form of the context stored within it. Furthermore, VO data synthesizer service handles the discrepancies if found in the data corresponding to VO; this includes data manipulation and missing value rectifications. Conflict resolution function helps in case the same VO is used by multiple service instances, to resolve the conflicts. Also, VO access management function controls access for VOs in case access right information has been defined by the VO owner, whereas identification management module maintains identification information about VOs so that each VO can be uniquely identified in the system.

3.4.4. Social Relationship Discovery and Composition. To identify associations among web objects within a social relationship graph, an algorithm is elaborated briefly. In the following algorithm, the microservices that are in execution are retrieved first, represented as $\Sigma M\mu$; next, all the CVOs associated with each of those microservices are recovered in ΣMc and, further, the corresponding VO model ΣMv is iterated. In the next step, executing the query statement routine returns the results denoted as $\overline{T}$. The process of finding the relationships is carried out through lines (6)–(19) in multiple nested iterations as shown in the pseudocode of Algorithm 1 listing.

Algorithm 2 facilitates the composition of objects based on social association types. This algorithm takes as input the set of object social relationships denoted by $\mathbb{Z}$ and registry entries of the objects that are currently available in the system, represented as $\mathbb{R}e$. After the object model denoted

```
Require: $(\Sigma\phi)$, $(\mathbb{R}_e)$
(1) Output: $\hat{S}$ (social relationship graph of objects)
(2)  $\Sigma M_{\underline{\mu}} \leftarrow$ Load Microservices in model
(3)  $\Sigma M_c \leftarrow$ Load CVOs in model
(4)  $\Sigma M_v \leftarrow$ Load VOs in model
(5)  $\overline{T} \leftarrow$ executeQueryStatement $(M_\mu, M_c, M_v, Q)$
(6)  for All $\mu$ in $\underline{\mu}\overline{T}$ do (iterate Microservice instance being used)
(7)      for All $O \in \mu$ do (check CVO and VOs used by the Services)
(8)          if $O_i$ == output of $C_R$ in a relationship set $R_c$ then
(9)              add $C_R$ to $\mathbb{II}_L$
(10)         else
(11)           if $O_i$ == output of $V_R$ in relationship set $R_v$ then
(12)             add $V_R$ to $\mathbb{II}_L$
(13)             $\mathbb{N}_i \leftarrow$ tag (Assign relationship tag to each object entry)
(14)           else
(15)             add $O_i$ to $\mathbb{II}_U$
(16)           end if
(17)         end if
(18)     end for
(19) end for
```

Algorithm 1: Social relationship discovery.

```
Require: $(\Sigma\phi)$, $(\mathbb{R}_e)$, $(\mathbb{Z})$
(1) Output: $\mathbb{C}$ (Composite Service)
(2) $\Sigma M \leftarrow$ List all objects available (Microservices, CVOs, VOs) in model
(3) $\overline{T} \leftarrow$ executeQueryStatement $(\Sigma M, Q)$
(4) $\mathbb{Z} \leftarrow$ executeQueryStatement $(\Sigma M, Q')$
(5) for All $\sigma i \in \overline{T}$ do
(6)     for All $\boldsymbol{\lambda} i \in \sigma$ do
(7)         if $\boldsymbol{\lambda} i$ == any $z$ in $\mathbb{Z}$ then
(8)             add $\boldsymbol{\lambda} i$ to $\mathbb{II}_{\mathrm{Lm}}$
(9)             store $\mathbb{II}_{\mathrm{Lm}}$
(10)        end if
(11) end for
(12) for All $\boldsymbol{\varpi}\mathbf{i} \in \mathbb{II}_{\mathrm{Lm}}$ do
(13)     if $\boldsymbol{\varpi}\mathbf{i}$ == any $\boldsymbol{\varpi}\mathbf{i}$ in $\mathbb{II}_{\mathrm{Lm}}$ then
(14)         $\partial \leftarrow$ ranking (Assign rank to each service)
(15)         add $\boldsymbol{\varpi}\mathbf{i}$ to $\mathbb{II}_{\mathrm{LR}}$
(16)         store $\mathbb{II}_{\mathrm{LR}}$
(17)     end if
(18) end for
(19) for All $\sigma j \in \mathbb{II}_{\mathrm{LR}}$ do
(20)     if $\sigma j(R\partial) > \kappa$ then
(21)         add $\sigma j$ to Wf
(22)         Pq $\leftarrow$ assign to queue
(23)         Sort Pq
(24)         Formulate Wf
(25)     end if
(26) end for
```

Algorithm 2: Composition of objects based on social relationship.

as ΣM is loaded, the first step is to compose objects based on their relationship types. This way, the SPARQL queries are executed; the first query is denoted as Q to retrieve the available service templates and the second query is represented as Q' to extract the relationships associated with the services. From line (5) to (11), first, the social relationship is searched among objects and then the found relative objects are composed in groups. The design philosophy employed over here is to assign a ranking to each selected group based on the relationship type that helps in a more efficient

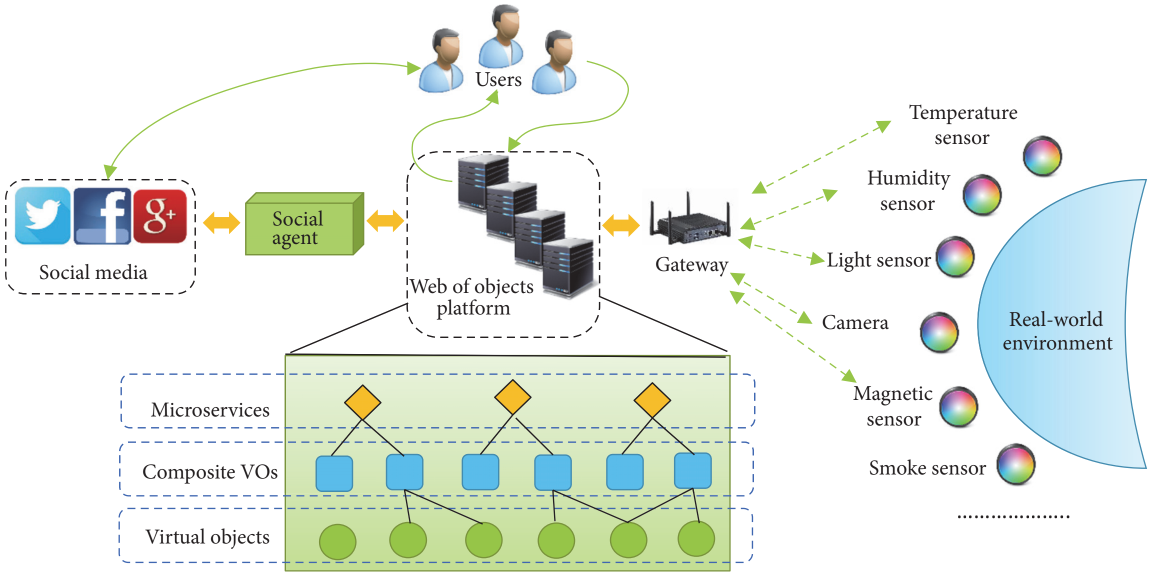

Figure 7: Use case scenario.

composition of service objects (from line (12) to (18)). The last part of Algorithm 2 will continue to iterate to compose the object composition workflow by checking first the assigned relationship ranking with the defined threshold, and then the selected composition workflow graphs are sorted and stored in queues for service execution.

4. Use Case and Prototype Implementation

In this section, first, to realize IoT service provisioning based on social web objects, a use case about IoT enabled museum environment has been presented and then the details on the prototype implementation are furnished.

4.1. Use Case Scenario. This use case is based on a user experience in a public museum where the IoT environment is already set up with the WoO platform incorporating web objects that use social relationship model and a social agent which obtains the user's profile and his friendship details from social media (as shown in Figure 7). The user enters the premises of the museum and his smartphone is prompted with a beacon signal to recommend service app installation where he accepts the request. The phone app incorporates a microservice which establishes a social relationship (GSTOR) with museum visit service objects. The system monitors the interaction of the user in the museum environment; the installed camera network and motion detectors detect the user presence and this feed is collected by the museum visit service. The user shares his current location with the system, which is used by the location navigator service to assist him in moving around the museum by providing the direction to the locations where different museum items are situated. It is worth noticing that the VOs for museum visit service and location navigator service are bound in CLOR relationship due to the same location points. The user shares his social network profile which is used to acquire the list of friends and choices for things the user is interested in. This information is acquired by the recommendation service which suggests the best things to do with respect to the user's interests, making his visit most enjoyable. Recommendation service suggests facilities available in the museum such as places a user should visit, cafeteria food menu, and prices for the day. This service also shares with the user the past experiences of his friends at the museum to help him get most out of his visit. Moreover, personalization service provides special features such as adjusting contents on displays or optimizing the luminosity, to support users with disabilities. To enable these service features, objects exploit the SVOR relationship. Also, the fire management service maintains the status of all VOs that can detect an unusual fire situation in the museum. The temperature VOs acquire readings from temperature sensors and smoke detector VOs get a feed from smoke detection sensors. These VOs form a CLOR relationship with each other in the common proximity. Fire situation monitoring CVO acquires VOs data. One or more CVOs are managed by the fire management service. In case of a fire breakout, the fire management service executes with the data from the fire detection CVOs and the temperature and smoke detector VOs. Meanwhile, services incorporate high-level functionality to react on the data provided by virtual entities in the system. It is important to notice that sharing of information based on social relationships has become easy in the proposed use case. That is because the user information and device information are communicated with social links of web objects and are utilized by the services.

4.2. Proof-of-Concept Details. To evaluate the proposed design, a proof of concept has been furnished, which realizes services based on web objects as considered in the above use case. These objects include, for instance, fire situation monitoring CVO to handle emergency fire breakout situations, location navigator CVO to find the shortest path to the user

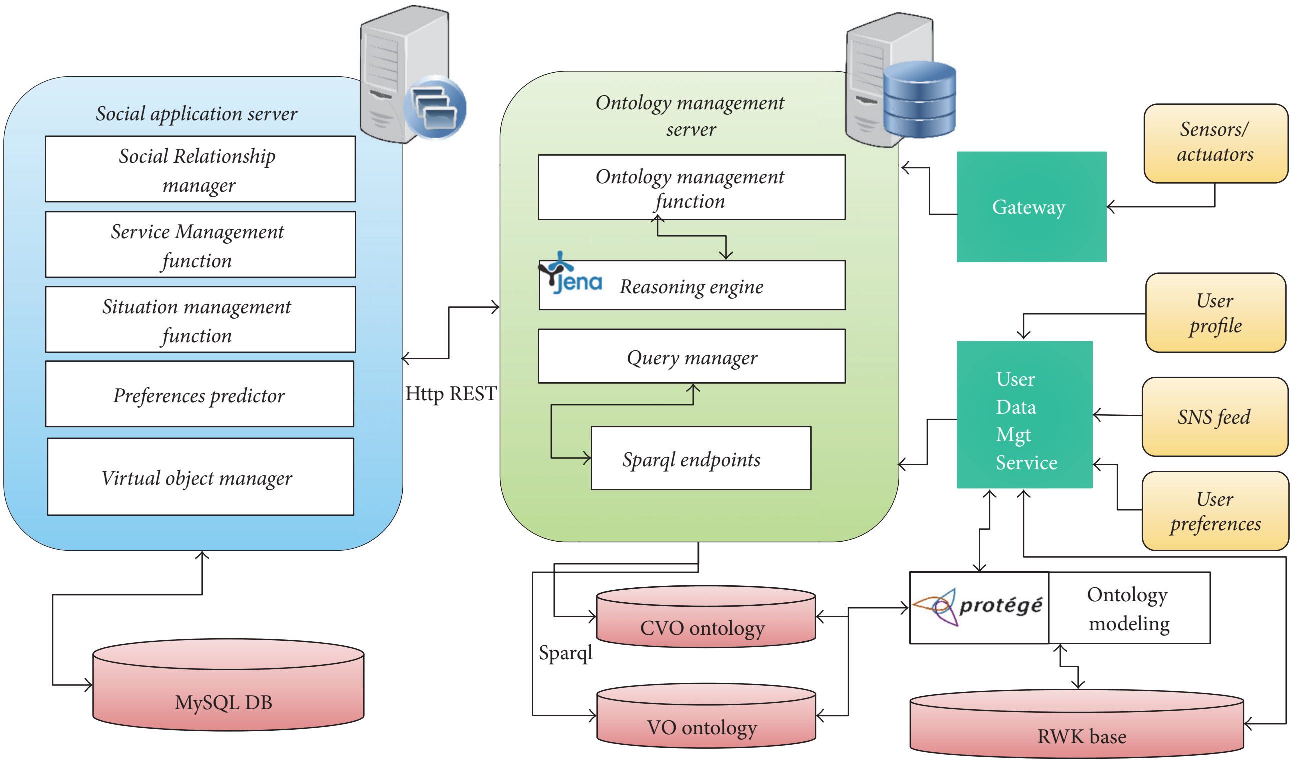
Social application server
Social Relationship manager
Service Management function
Situation management function
Preferences predictor
Virtual object manager
MySQL DB
Http REST
Ontology management server
Ontology management function
Jena
Reasoning engine
Query manager
Sparql endpoints
Sparql
CVO ontology
VO ontology
Gateway
Sensors/ actuators
User profile
User Data Mgt Service
SNS feed
User preferences
protégé
Ontology modeling
RWK base

Figure 8: Prototype implementation components.

intended destinations, and user profile reader CVO which acquires user personal information from the social media profile. Several other CVOs have been developed that acquire diverse data and metadata from VOs where each represents a different RWO. These VOs include a user VO, smartphone VO, camera VO, wristband VO, motion detector VO, and others that are associated with the chosen environment (such as CO_2 sensor VO, humidity VO, temperature VO, and light VO). Each VO has several instances; for example, temperature sensor instances are represented as temperatureSesor0001 and temperatureSesor0002. Further VO data is collected and analyzed by CVOs with the rules incorporated in the ontologies. CVOs composed in microservices help analyze different situations and initiate inference over data using inference engines. Considering the system requirement, several aspects have been evaluated, including identification of web objects for effective IoT service provisioning, finding the social relationships among web objects, efficient discovery of web objects based on these relationships, and composition and harmonization of web objects.

4.3. Prototype Implementation Details. To analyze the feasibility of the proposed architecture, a prototype on the discussed use case has been implemented. Figure 8 illustrates the components of the prototype, which constitute social application server (SAS), ontology management server (OMS), and databases to hold VO and CVO graphs that are supported with SPARQL endpoints. The gateway connecting sensors and actuators has been incorporated in the implementation. Additionally, user data management services are implemented to get user profile and preferences history along with social network data.

The application server comprises five major components: social relationship manager (SRM), service management function (SMF), situation/context management function (CMF), preference predictor, and virtual object manager (VOM). The SMF is an entry point for the service request; it interprets and evaluates the service request. It is also responsible for matching the service request with the available template. SMF communicates with VOM to check the VO or CVO availability. A compiled list of VOs is provided to SMF which generates object mashups to satisfy the service request. The execution of VO mashup graph is done using microservices. The second function, VOM, maintains instances of CVOs and associated VOs and coordinates with OMS to use available ontologies in the system. It records the association of services and VOs and enables the reuse of VOs by more than one service; it also resolves conflicts using conflict resolution mechanism. VOM is implemented using RESTful web services. Further, SRM is implemented to maintain object relationships in the form of RDF concepts represented in ontologies. It also involves several microservices, each implemented for a specific task. For example, group management microservice is developed to group objects that have similar characteristics. Similarly, other tasks are distributed in different microservices; for example, link management microservice is used to identify the dependency among objects. Relationship observer microservice is implemented to monitor the objects when they change their state at runtime, whereas to search a web

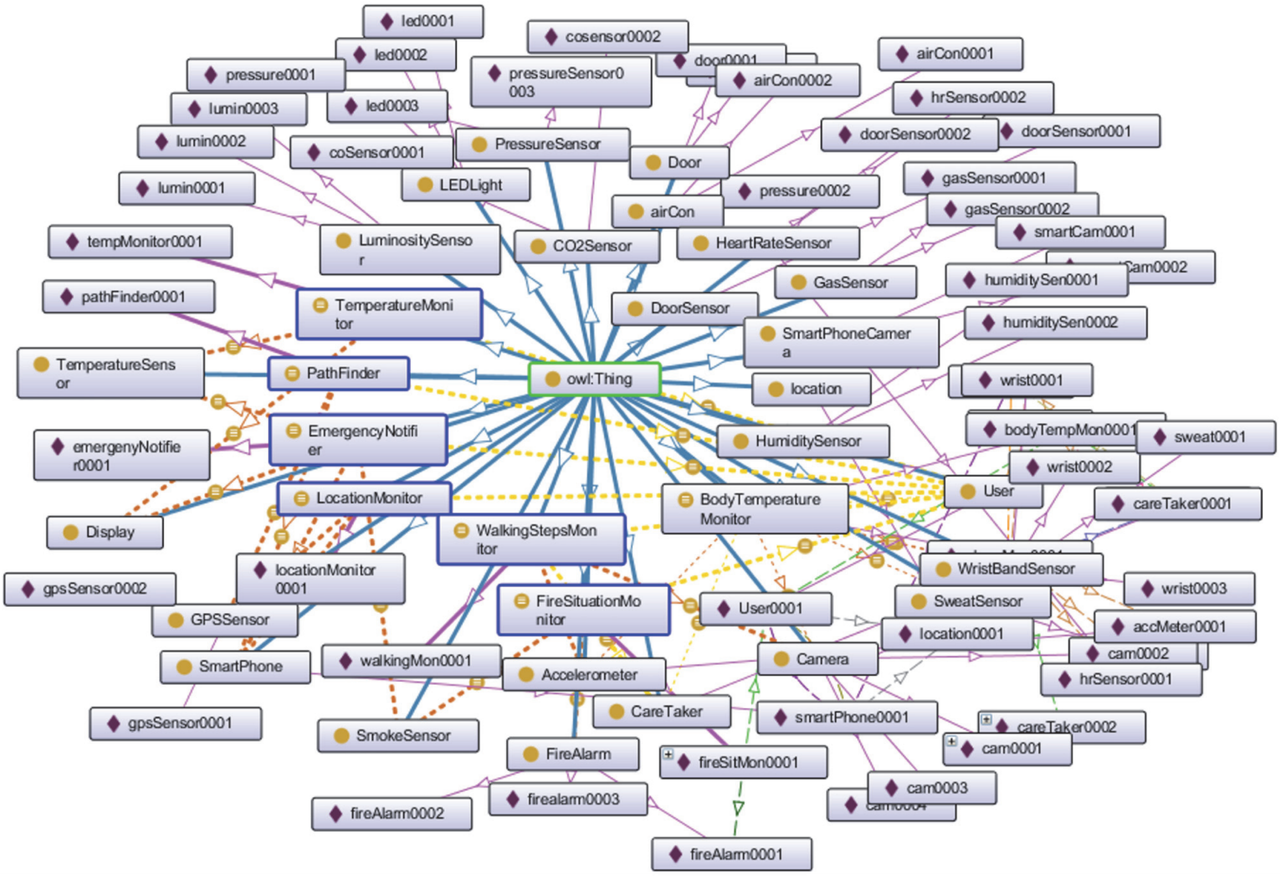
led0001
cosensor0002
led0002
pressure0001
pressureSensor0003
door0001
airCon0001
airCon0002
lumin0003
led0003
hrSensor0002
lumin0002
coSensor0001
PressureSensor
doorSensor0002
doorSensor0001
Door
lumin0001
LEDLight
pressure0002
gasSensor0001
airCon
gasSensor0002
smartCam0001
tempMonitor0001
LuminositySensor
CO2Sensor
HeartRateSensor
humiditySen0001
GasSensor
pathFinder0001
TemperatureMonitor
DoorSensor
humiditySen0002
SmartPhoneCamera
TemperatureSensor
PathFinder
owl:Thing
location
wrist0001
EmergencyNotifier
bodyTempMon0001
sweat0001
emergenyNotifier0001
HumiditySensor
wrist0002
User
LocationMonitor
BodyTemperatureMonitor
careTaker0001
Display
WalkingStepsMonitor
WristBandSensor
locationMonitor0001
wrist0003
gpsSensor0002
FireSituationMonitor
SweatSensor
User0001
GPSSensor
location0001
accMeter0001
cam0002
walkingMon0001
Camera
SmartPhone
Accelerometer
hrSensor0001
CareTaker
smartPhone0001
careTaker0002
gpsSensor0001
SmokeSensor
FireAlarm
fireSitMon0001
cam0001
cam0003
firealarm0003
fireAlarm0002
fireAlarm0001

Figure 9: Ontological model of social web objects.

object relationship, the lookup microservice is used. The CMF function has been developed to process the situational information and it selects the most suitable VOs based on the context. The situational information contains the current location of the user, location of the RWOs, and the area under observation. CMF helps form a VO configuration specific to the user current situation. Additionally, to incorporate the real-world facts about the user and the situation, RWK base has been developed which is updated continuously. This also helps in adapting services according to the current situation. VOs provided data is accumulated in RWK model and the reasoning engine is used to infer new facts based on the existing data. The last function of social application server is the preference predictor which provides predictions by using machine learning methods. To implement the learning function, Weka Library [42] has been used. For the objective of demonstration, user preference patterns are collected from the social data and user preference history is used to predict the future patterns.

On the other hand, OMS deals with the semantic representation of VOs. The first functional component of OMS is the ontology management service, which is used to handle VO and CVO ontologies and provides an interface to use VO graphs. Further, to manage ontologies in the developed system, we have used Apache Jena framework [43], and to model VO and CVO ontologies, Protégé [44] has been used. Models generated in Protégé are utilized by ontology management service and stored in OWL format in semantic data stores. To take full advantage of ontology-based implementation, a reasoning engine has also been used to get extra facts related to the modeled concepts. Reasoning engine helps to grow RWK facts stored in VO and CVO ontologies. For the proof of concept, the prototype has used Apache Jena inference engine along with Jena provided reasoner. For the deployment of persistent storage of the RDF data, Jena TDB has been used in our prototype, which is the Jena native high-performance triple store with API support [43]. Query manager is another important component of OMS which provides an interface to query CVO and VO ontologies saved in RDF/XML format, using SPARQL. Also, web services are implemented for the execution of SPARQL queries such as extracting and updating RDF triples in the database. Other than SPARQL query processing, semantic matching of existing concepts is also performed.

Moreover, to achieve interoperable relationships among web objects, a semantic ontology model has been developed as shown in Figure 9. The model constitutes the VO and CVO ontologies and their relationships. Several CVOs have been instantiated, for example, the location navigator, fire situation monitor, emergency notification, and many others that are

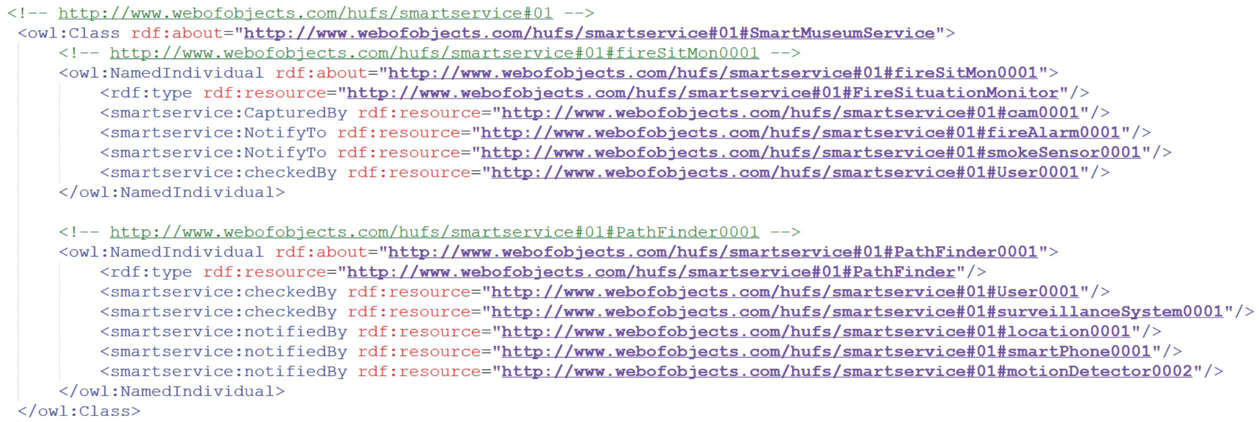

```
<!-- http://www.webofobjects.com/hufs/smartservice#01 -->
 <owl:Class rdf:about="http://www.webofobjects.com/hufs/smartservice#01#SmartMuseumService">
     <!-- http://www.webofobjects.com/hufs/smartservice#01#fireSitMon0001 -->
     <owl:NamedIndividual rdf:about="http://www.webofobjects.com/hufs/smartservice#01#fireSitMon0001">
         <rdf:type rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#FireSituationMonitor"/>
         <smartservice:CapturedBy rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#cam0001"/>
         <smartservice:NotifyTo rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#fireAlarm0001"/>
         <smartservice:NotifyTo rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#smokeSensor0001"/>
         <smartservice:checkedBy rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#User0001"/>
     </owl:NamedIndividual>

     <!-- http://www.webofobjects.com/hufs/smartservice#01#PathFinder0001 -->
     <owl:NamedIndividual rdf:about="http://www.webofobjects.com/hufs/smartservice#01#PathFinder0001">
         <rdf:type rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#PathFinder"/>
         <smartservice:checkedBy rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#User0001"/>
         <smartservice:checkedBy rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#surveillanceSystem0001"/>
         <smartservice:notifiedBy rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#location0001"/>
         <smartservice:notifiedBy rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#smartPhone0001"/>
         <smartservice:notifiedBy rdf:resource="http://www.webofobjects.com/hufs/smartservice#01#motionDetector0002"/>
     </owl:NamedIndividual>
 </owl:Class>
```

Figure 10: CVOs and VOs used in the ontology.

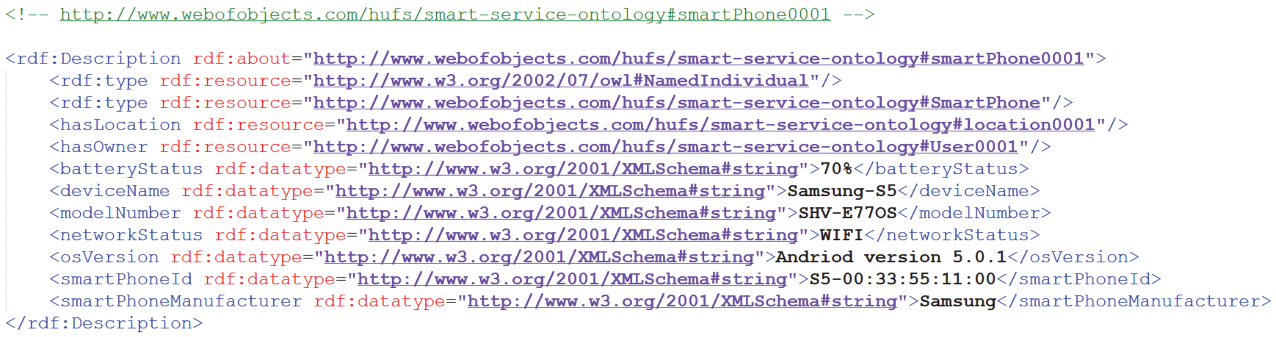

```
<!-- http://www.webofobjects.com/hufs/smart-service-ontology#smartPhone0001 -->

<rdf:Description rdf:about="http://www.webofobjects.com/hufs/smart-service-ontology#smartPhone0001">
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#NamedIndividual"/>
    <rdf:type rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#SmartPhone"/>
    <hasLocation rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#location0001"/>
    <hasOwner rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#User0001"/>
    <batteryStatus rdf:datatype="http://www.w3.org/2001/XMLSchema#string">70%</batteryStatus>
    <deviceName rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Samsung-S5</deviceName>
    <modelNumber rdf:datatype="http://www.w3.org/2001/XMLSchema#string">SHV-E770S</modelNumber>
    <networkStatus rdf:datatype="http://www.w3.org/2001/XMLSchema#string">WIFI</networkStatus>
    <osVersion rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Andriod version 5.0.1</osVersion>
    <smartPhoneId rdf:datatype="http://www.w3.org/2001/XMLSchema#string">S5-00:33:55:11:00</smartPhoneId>
    <smartPhoneManufacturer rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Samsung</smartPhoneManufacturer>
</rdf:Description>
```

Figure 11: Smartphone VO used in the ontology.

based on the composition of numerous VOs. This development has been supported by OMS and semantic web tools such as Jena. Using OMS, CRUD operations are performed like create, update, and delete on CVOs and VOs using SPARQL. In the developed semantic relationships, two CVO instances, namely, “FireSitMon0001” and “PathFinder0001,” have been used in the code snippet provided in Figure 10, for fire situation monitoring and location navigation, respectively. We can see the data properties and object properties associated with each object to maintain the relationship with other objects in the system. Further, to understand the VO representation, a smartphone VO “SmartPhone0001” is shown in Figure 11 with the defined properties. A list of VOs used in our prototype has been given in OWL description as shown in Figure 12.

In the test bed environment, the sensor to the gateway connectivity is enabled using ZigBee and BLE. Another source of information that has been incorporated to provide user-centric service capability is SNS feed, which consists of Twitter and Facebook data collected using social media APIs. On the other hand, user profile and preferences are updated using data management service, and this information is used to grow RWK base.

To test the prototype, an android application has been developed. After the user logs in to the app for WoO based assisted services, the app starts the configuration of services according to the user profile. A list of services is presented on the user’s screen from which the user can select any service. These services include museum visit service, location navigator service, recommendation service, and emergency notification. The selected service starts collecting information with the interaction of the user or when the devices start pushing values about any change in the observed environment. Based on these observed parameters, alerts are generated by the app; for example, the museum visit service generates alerts about the available facilities in the museum and the environmental conditions including the indoor and outdoor temperatures. On the other hand, the location navigator service helps the user to navigate around the museum by showing directions to several visitor attractions. Moreover, the emergency notification service triggers alerts when a temporary fire is created to mimic an unusual situation such as fire breakout. The resulting fire increases the temperature reading which is detected by the temperature sensor. This change in reading is forwarded through the gateway and analyzed by the fire situation monitor CVO which checks its threshold value and generates an emergency notification on the user’s app screen. Also, the recommendation service is used to generate suggestions about the museum events and the places to visit.

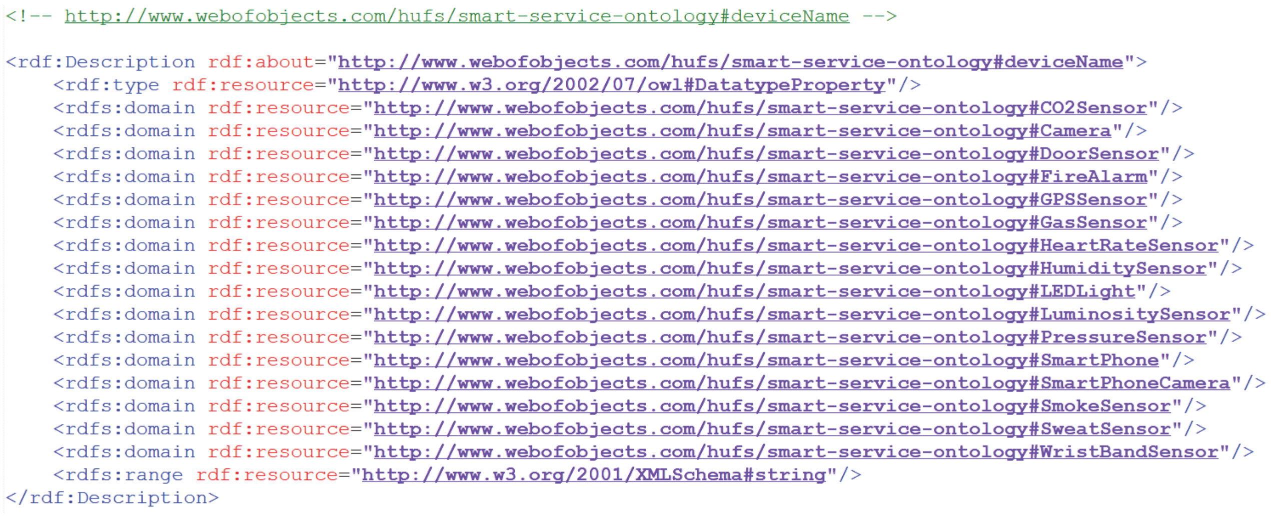

```
<!-- http://www.webofobjects.com/hufs/smart-service-ontology#deviceName -->

<rdf:Description rdf:about="http://www.webofobjects.com/hufs/smart-service-ontology#deviceName">
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#CO2Sensor"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#Camera"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#DoorSensor"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#FireAlarm"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#GPSSensor"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#GasSensor"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#HeartRateSensor"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#HumiditySensor"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#LEDLight"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#LuminositySensor"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#PressureSensor"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#SmartPhone"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#SmartPhoneCamera"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#SmokeSensor"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#SweatSensor"/>
    <rdfs:domain rdf:resource="http://www.webofobjects.com/hufs/smart-service-ontology#WristBandSensor"/>
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</rdf:Description>
```

Figure 12: List of VOs used in the ontology.

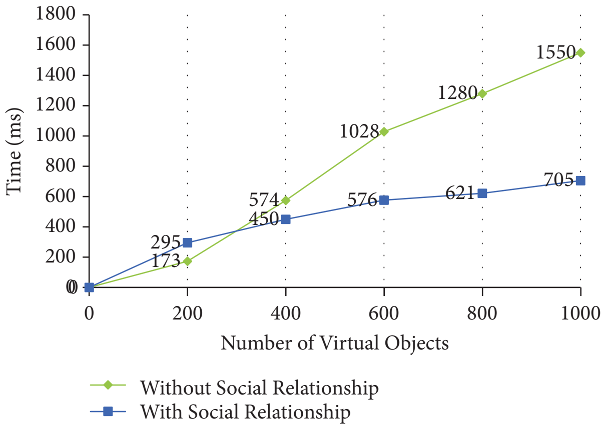

Figure 13: VO discovery time with the increasing number of virtual objects.

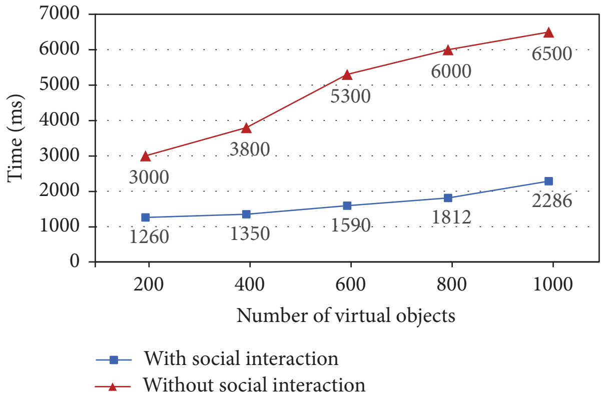

Figure 14: Service execution time with the increasing number of virtual objects.

4.4. Performance Evaluation. The proposed architecture has been analyzed from two different perspectives: system scalability and resource consumption. The results with respect to the experiments and the performance criterion are discussed in this section. The first experiment involves the analysis of the time required to discover the virtual objects in the proposed system with or without social relationship criterion as shown in Figure 13. As it is apparent from the results, initially, to form a social graph, VO discovery process incurs delay due to the communication for establishing social relationship links. However, direct lookup for VOs in the registry at the start of the discovery process comparatively requires less time, but as the number of VOs increases, the delay rises. Traversing the social links to discover objects as the number of virtual objects grows considerably reduces the total lookups in the registry database.

The second experiment provides an analysis of the execution time required for the CVOs as shown in Figure 14. To test this in a real environment, an android application has been developed. The app allows access to the parameters from the available VOs. When the app requires retrieving observations, it iterates through VOs in the repository using a query interface. This requires high CPU utilization with more execution time required to retrieve the sensor values against each app generated request. This is due to the fact that the decision for the selection of VOs has been done at runtime; it requires more time to select the VO graphs, execute them, and get the relevant data from the VOs. However, when object interaction is based on the social relationship, it requires less time for the retrieval as friends in the social network share the data on other friends' requests, which results in less computation as compared with the previous scheme.

Moreover, Figure 15 depicts the time to discover VOs in four different types of services. These services are the museum visit service, the location navigator service, the emergency notification service, and the recommendation service. The discovery time varies from one service to another depending on the number of VOs used. However, as compared with the impact of social connections, it can be

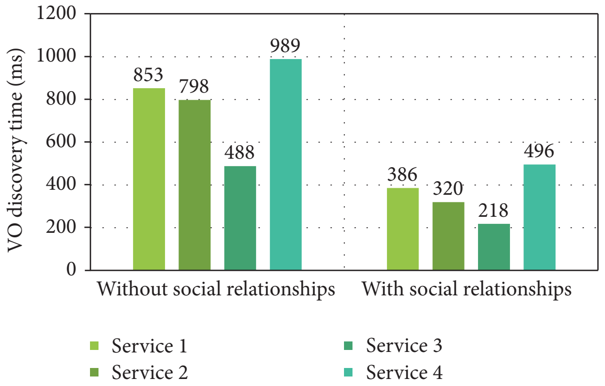

Figure 15: VO discovery time for four different services with or without social relationship utilization.

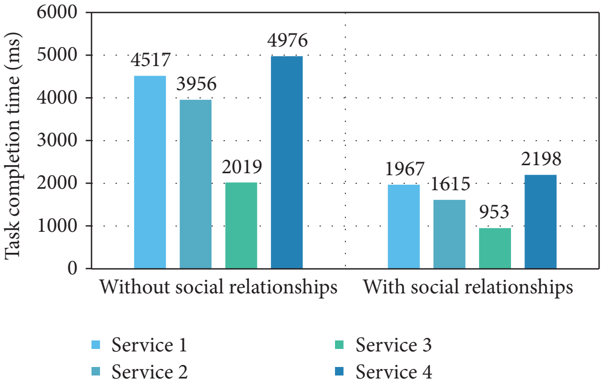

Figure 16: Task completion time required for each service with or without social relationship exploitation.

realized that the services can considerably reduce the time of object discovery and execution by using the relationship model. This is due to the fact that with social association among web objects a service does not have to query the registry for all VOs and rather VOs in the same social graph are utilized. Also, VOs collected observations are shared to save the service time for probing each VO. To view this, Figure 16 shows the overall time required for services to execute their tasks. An important factor to notice here is that the overall task completion time is also affected when social links are used to collect observations from VOs that are used in the service execution.

5. Conclusion

The Internet of Things is bringing the next technological revolution by connecting billions of objects on the earth and providing intelligent IoT services. However, it also carries two most important challenges: the first one is the complexity of handling a huge number of heterogeneous objects and the second one is how to deal with the monolithic approaches for providing services over existing IoT infrastructure. To address these challenges, we have proposed an integrated design based on the principles of SIoT, where the complexity has been handled using socially connected web objects; to overcome the monolithic approaches, microservices that can compose new service features independently have been adopted. In the proposed design, a social relationship model has been presented, which enables the efficient discovery of web objects and reduces the complexity of service provisioning process with the algorithms to discover and compose web objects. A semantic ontology model has also been developed to realize the interoperable social interaction among heterogeneous objects. Finally, a prototype implementation based on a use case scenario has been demonstrated; to evaluate the system with respect to the performance issues, experimental results pertaining to the VO discovery and service execution time have been rendered.

Details of Notations Used in Algorithms

$\Sigma\phi$: Service object ontologies based on semantic representation where ϕ is a replacement for M_μ which represents microservices M_c which represents CVO and M_v are VO ontologies
$\mathbb{I}_L$: Collection or list of all relationships that are retrieved from service objects
$\mathbb{I}_U$: List of the objects that do not have a relationship or are not associated
$\hat{S}$: Social relationship graph of objects
U: Correlation union of templates
$\underline{\mu}\bar{T}$: All service objects returned in response to the query request
$\bar{T}$: All objects returned in response to the query request
μ: The single instance iterated from the collection of microservices
M: Data model based on the specified ontology, where ΣM_s represents service data model, ΣM_c represents context data model, and user profile model is represented as ΣM_u
Q: SPARQL query to retrieve the available service templates for user rating
Q': SPARQL query to retrieve the relationship associated with services
$\mathbb{R}_e$: Registry entries of service objects
C_R: Relationship associated with CVO
V_R: Relationship associated with VO
R_c: All possible relationships that can be associated with CVO
R_v: All possible relationships that can be associated with VO
O_i: Iterator object instance for iterating the list of CVO and VO objects
$\mathbb{Z}$: Set of objects' social relationships
σi: Iteration item of the list of service objects
λi: An instance of iteration items in the list of service objects
$\mathbb{I}_{\mathrm{Lm}}$: List of all matched service items
ϖi: An instance of iteration items in the list of matched service items

$\mathbb{III}_{\mathrm{LR}}$: List of all matched ranking
∂: Ranking value assigned to a service object
σj: Iterator item for the ranking list
κ: Threshold to rank a service object
Wf: Workflow for the composition of service objects
Pq: Priority queue to store ranked object instances
R∂: Assigned relationship ranking.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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Multiple Antenna Technologies

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ABSTRACT

Multiple antenna technologies have received high attention in the last few decades for their capabilities to improve the overall system performance. Multiple-input multiple-output systems include a variety of techniques capable of not only increase the reliability of the communication but also impressively boost the channel capacity. In addition, smart antenna systems can increase the link quality and lead to appreciable interference reduction.

I. Introduction

Multiple antennas technologies proposed for communications systems have gained much attention in the last few years because of the huge gain they can introduce in the communication reliability and the channel capacity levels. Furthermore, multiple antenna systems can have a big contribution to reduce the interference both in the uplink and the downlink by employing smart antenna technology.

To increase the reliability of the communication systems, multiple antennas can be installed at the transmitter or/and at the receiver. Alamouti code is considered as the simplest transmit diversity scheme while the receive diversity includes maximum ratio, equal gain and selection combining methods. Recently, cooperative communication was deeply investigated as a mean of increasing the communication reliability by not only considering the mobile station as user but also as a base station (or relay station). The idea behind multiple antenna diversity is to supply the receiver by multiple versions of the same signal transmitted via independent channels.

On the other hand, multiple antenna systems can tremendously increase the channel capacity by sending independent signals from different transmit antennas. BLAST spatial multiplexing schemes are a good example of such category of multiple antenna technologies that boost the channel capacity.

In addition, smart antenna technique can significantly increase the data rate and improve the quality of wireless transmission, which is limited by interference, local scattering and multipath propagation. Through shaping the antenna radiation pattern and adaptively adjusting the antenna weight vector, smart antennas improve the communication link quality by increasing the received signal power and suppressing the interference.

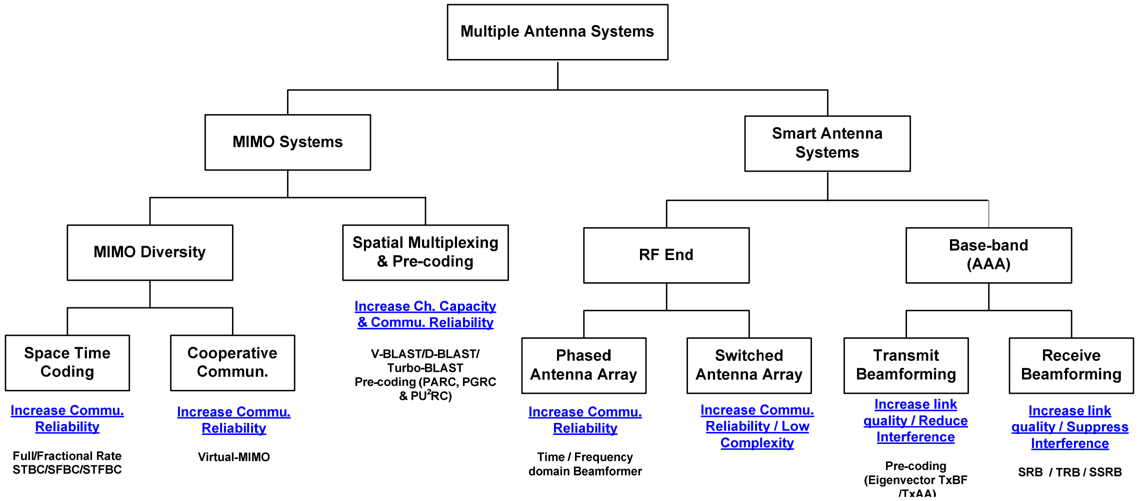
Multiple Antenna Systems
MIMO Systems
Smart Antenna Systems
MIMO Diversity
Spatial Multiplexing & Pre-coding
RF End
Base-band (AAA)
Space Time Coding
Cooperative Commun.
Increase Ch. Capacity & Commu. Reliability
V-BLAST/D-BLAST/ Turbo-BLAST Pre-coding (PARC, PGRC & PU^{2}RC)
Phased Antenna Array
Switched Antenna Array
Transmit Beamforming
Receive Beamforming
Increase Commu. Reliability
Full/Fractional Rate STBC/SFBC/STFBC
Increase Commu. Reliability
Virtual-MIMO
Increase Commu. Reliability
Time / Frequency domain Beamformer
Increase Commu. Reliability / Low Complexity
Increase link quality / Reduce Interference
Pre-coding (Eigenvector TxBF /TxAA)
Increase link quality / Suppress Interference
SRB / TRB / SSRB

Fig. 1. Multiple antenna technologies.

Besides, on-line calibration technique is also adopted to correct the errors due to the distortions and nonlinearity of the radio frequency components in the antenna array system.

Fig. 1 summarizes the different multiple antenna technologies and gives some examples of these technologies.

This paper is organized as follows: in section II we present multiple antenna diversity schemes employed at the transmitter or/and at the receiver. Spatial multiplexing presented by BLAST schemes is detailed in section III. Section IV is dedicated to some advanced multiple input multiple-output (MIMO) systems including multi-user MIMO and cooperative communications. While techniques related to the smart antennas such as phased antenna array, switched beam antenna array, and adaptive antenna array are described in Section V. Finally, we conclude in Section VI.

II. **MIMO Diversity**

In communication systems, we have to increase the reliability of the communication operation between transmitter and receiver while maintaining a high spectral efficiency. The ultimate solution relies in the use of *diversity*, which can be viewed as a form of redundancy [1]. There are many diversity techniques that can be applied to communication systems; we mention herein time diversity, frequency diversity, and spatial diversity or any combination of these three diversities. In *time diversity*, the same information-bearing signal is transmitted in different time slots where a good gain can be achieved when the duration between the two slots, in which the same symbol is transmitted, is greater than the coherence time of the channel. In *frequency diversity*, the same information-bearing signal is transmitted on different subcarriers where a good diversity gain can be achieved when the separation between subcarriers is greater than the coherence bandwidth.

Finally, in *spatial diversity*, the same information-bearing signal is transmitted or received via different antennas where the maximum gain can be achieved when the fading occurring in the channel is independent (or low correlated). In the receiver, diversity gain can be achieved by combining the redundant signals arriving via independent (or lowly correlated) channels.

Fig. 2 shows some possible combinations of transmit diversity which can be achieved when employing multiple transmit antennas.

In the following section, we present some famous space-time block codes applied at the transmitter side. We present also the combining techniques used when different versions of the information-bearing signal are received. Finally, we present a scheme that includes transmit and receive diversities.

2.1 Space Diversity at the Transmit Side

The basic idea of the use of transmit diversity is to reduce the mobile station (MS) receiver complexity while improving the detection performance.

The pioneering work in the transmit diversity was done by Alamouti where he proposed his famous 2×1 space-time code. Alamouti scheme achieves diversity gain while requiring only a linear decoder.

Later on, Tarokh et al. proposed a generalized theory of the complex orthogonal space-time codes. Based on Tarokh work, more than two antennas can be used and the code rate can be fractional.

In the following we present the two different types of space-time codes.

2.1.1 Complex Orthogonal Space-Time Codes

For this type of space time codes, the following conditions must be satisfied

- Square transmission matrix (number of transmit antennas N_t equal to number of used time slots m)
- A unity code rate (number of used time slots m equals to number of transmitted symbols l)
- Orthogonality of the transmission matrix in the time and space domains ($\mathrm{SS}^{\mathrm{H}} = \mathrm{S}^{\mathrm{H}}\mathrm{S}$) where S^{H} is the conjugate transpose of S.

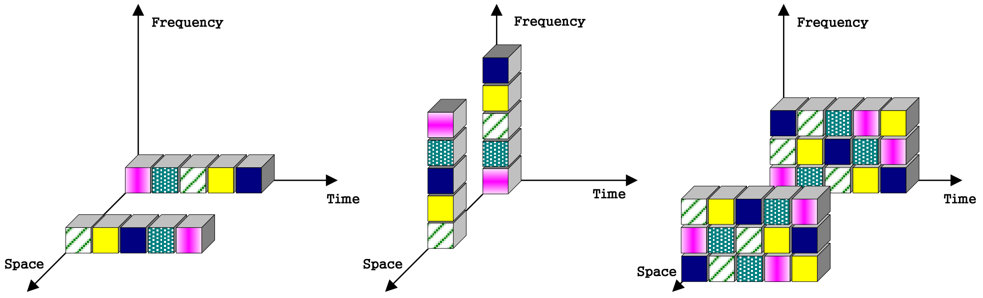

Space-Time Diversity

Space-Frequency Diversity

Space-Time-Frequency Diversity

Fig. 2. Transmit diversity.

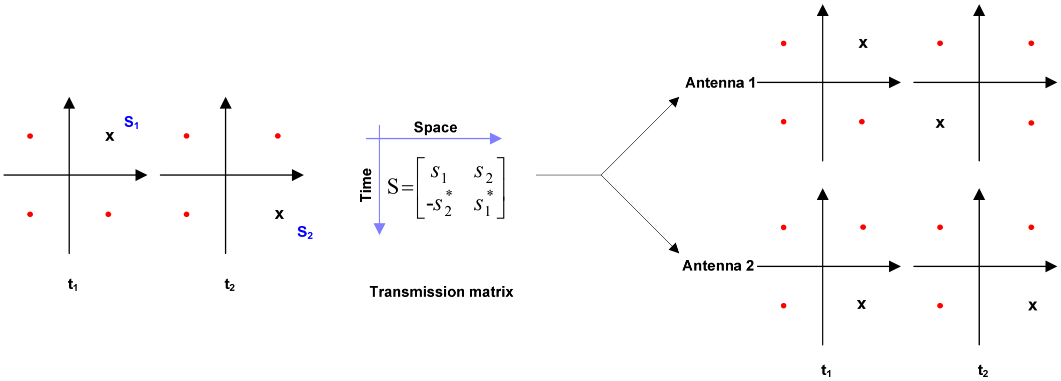
S1
x
S2
t1
t2
Space
Time
$S=\begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix}$
Transmission matrix
Antenna 1
Antenna 2
x
t1
t2

Fig. 3. Alamouti scheme example with QPSK modulation.

As said before, the simplest complex orthogonal space-time code is the Alamouti code which uses two transmit antennas and one receive antenna. Furthermore, Alamouti scheme requires that the fading channel envelope remains constant over two time slots.

Fig. 3 shows an example of the encoding process of Alamouti scheme with QPSK modulation [2], [3].

Fig. 4 shows the receiver structure used for decoding the combined received symbols.

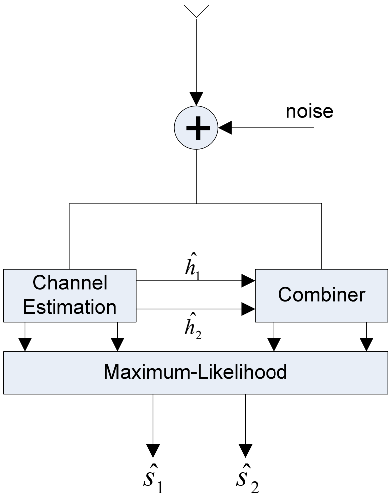
noise
Channel Estimation
$\hat{h}_1$
$\hat{h}_2$
Combiner
Maximum-Likelihood
$\hat{s}_1$
$\hat{s}_2$

Fig. 4. Alamouti code receiver.

At the receiver the following signals are received (with applying the complex conjugate to the received signal at t_2)

$$\begin{bmatrix} y_1 \\ y_2^* \end{bmatrix} = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \end{bmatrix} \tag{1}$$

The linear combiner multiplies the received symbols by the Hermitian transpose of the channel matrix (for simplicity, we consider that channel is perfectly estimated). The output of the linear combiner is then given by

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} h_1^2 + h_2^2 \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} + \begin{bmatrix} w_1 \\ w_2 \end{bmatrix} \tag{2}$$

Maximum-Likelihood (ML) decoder is then applied to get the transmitted symbols. As one can see, the simplicity of the receiver is due to the spatio-temporal orthogonality of the transmission matrix.

A complex orthogonal space-time code using 4 or 8 antennas was proposed by Tarokh et al. in [4].

2.1.2 Generalized Complex Orthogonal Space-Time Codes

The search for space-time codes with more than two antennas was started by Tarokh, Jafarkhani, and Calderbank. Their work has built the basis for a theory of generalized complex orthogonal designs.

Generalized complex orthogonal designs are distinguished from Alamouti code by the following

- A non-square transmission matrix (number of used time slots ≠ number of Tx antennas)
- A fractional code rate (number of transmitted symbols < number of used time slots)
- Orthogonality of the transmission matrix is only guaranteed in the time sense.

As a consequence of these characteristics, the spectral efficiency is reduced and the number of time slots over which the channel should be constant is increased.

The transmission matrix of a generalized complex space-time code with 3 antennas, 4 transmitted symbols and 8 used time slots is given by [5]

$$\mathbf{G}_3 = \begin{bmatrix} s_1 & s_2 & s_3 \\ -s_2 & s_1 & -s_4 \\ -s_3 & s_4 & s_1 \\ -s_4 & -s_3 & s_2 \\ s_1^* & s_2^* & s_3^* \\ -s_2^* & s_1^* & -s_4^* \\ -s_3^* & s_4^* & s_1^* \\ -s_4^* & -s_3^* & s_2^* \end{bmatrix} \qquad (3)$$

In the literature, more research was done to increase the rate of the space-time codes. For more details refer to [6].

Table 1 summarizes the difference between Alamouti and space-time code characterized by the transmission matrix $\mathbf{G}_3$.

These shown coding schemes can be transmitted in the space-time domains, space-frequency domains or in space-frequency-Time domains. These coding schemes are thus known as ST, SF, and STF coding, respectively [7].

2.1.3 Cyclic Delay Diversity (CDD)

CDD can be considered as a very simple transmit diversity scheme. CDD can achieve transmit artificial frequency diversity by selecting appropriate transmit delays. In this method, multiuser diversity, obtained by scheduling based on frequency domain channel response, can be improved by adjusting the delay spread (at the transmitter) which is done by controlling the delay values dependent on the channel condition [8], [9].

2.2 Space Diversity at the Receive Side

In space diversity at the receive side, multiple antennas are used in the receiver with sufficient spacing between antennas in such a way mutual correlation between antennas is reduced and as consequence diversity gain is increased [10]. To get diversity gain at the receiver, received signals from different antennas are combined. There are four combining methods, namely, select combining (SC), maximal-ratio combining (MRC), equal-gain combining (EGC), and square-law combining. The first three schemes are linear while the last requires a non-linear receiver.

Fig. 5 shows a simplified block diagram of the linear combining schemes which differ in the weighting vector **w.** In SC, the signal at the branch with maximum signal to noise ratio (SNR) is selected and other received signals are discarded.

The weighting vector $\mathbf{w} = (w_1, w_2, \ldots, w_M)$ is the N^{th} column of the identity matrix of size M where the N^{th} branch has the maximum SNR.

Table 1. Comparison between Alamouti and generalized complex space-time codes.

Space-time code	**Number of Tx antennas**	**Number of transmitted symbols, *l***	**Number of used time slots, *m***	**Orthogonality of Tx matrix**	**Rate = *l/m***
S	2	2	2	Spatio-temporal sense	1
G_3	3	4	8	Only temporal sense	1/2

Table 2. Comparison between diversity combining schemes.

Scheme	**Requiring CSI**	**Outage Probability F(x)**	**Application**
SC	No	$\left[1-e^{-x/\bar{y}_c}\right]^M$	No constraints
MRC	Yes	$1-e^{-x/\bar{y}_c}\sum_{k=0}^{M-1}\frac{1}{k!}\left(\frac{x}{\bar{y}_c}\right)^k$	No constraints
EGC	Yes	No closed form for M > 2	No constraints
SLC	No	-	FSK or DS-CDMA

As one can see, the SC scheme does not require any channel information except that of SNR. On the other hand, MRC and EGC schemes require the channel state information (CSI) or a part of it (channel envelope, phase, delay). MRC scheme weights the received signals according to their reliability; a more reliable signal has a high weight while a less reliable signal has a small weight. Also, the channel phase distortion is compensated. Finally, signals are aligned then combined. On the other hand, EGC scheme can be viewed as a simplified version of MRC where signals are weighted equally (i.e. the weighting vector $\mathbf{w} = [1, 1, \ldots,1]_M$) then aligned before being combined coherently. In practice, the phase at different branches can't be often estimated. So, EGC and MRC can't be employed. In such situations, square law combining (SLC) can be applied to obtain spatial diversity without requiring phase estimation. Unlike linear combining schemes, SLC scheme can only be applied to modulation schemes which preserve some sort of orthogonality including frequency-shift keying (FSK) or direct-sequence CDMA [5], [11].

Table 2 summarizes a comparison between combining schemes. It is known that, from a performance point of view, MRC is optimum and gives the best performance among the pre-described combining schemes.

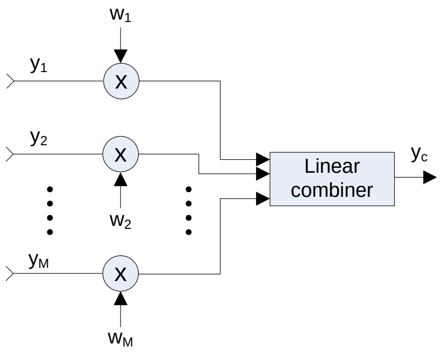

Fig. 5. Simple block diagram of linear combining schemes.

2.3 Combined Transmit/Receive Diversity

Spatial diversity schemes explained in the previous two sections can be combined together to achieve diversity at both receive and transmit sides. An example of such a hybrid spatial diversity scheme is the 2×2 Alamouti/MRC MIMO system [12].

III. Spatial Multiplexing

As shown in the previous section, MIMO diversity can be used in the transmitter or the receiver sides or in both to increase the reliability of the communication. In this section we talk about spatial multiplexing schemes which are for goal to increase the channel capacity.

The most known spatial multiplexing schemes are the BLAST family which includes Vertical-BLAST, Diagonal-BLAST, and Turbo-BLAST. The acronym BLAST stands for "*Bell Laboratories Layered Space-Time*".

3.1 Diagonal-BLAST

D-BLAST was originally proposed by Foschini [13]. In D-BLAST, the symbols to be transmitted are arranged on the diagonals of the space-time transmission matrix where elements under the diagonal are padded with zeros. Fig. 6-a depicts the structure of the D-BLAST transmitter for four transmit antennas. At first, the bit stream is de-multiplexed into four parallel streams which are encoded and modulated independently. Encoded-modulated streams are cycled over time. Equation (4) is an example of the transmission matrix when using four transmit antennas.

$$S = \begin{bmatrix} s_{1,1} & s_{1,2} & s_{1,3} & s_{1,4} & \cdots & s_{1,K-1} & s_{1,K} & 0 & 0 & 0 \\ 0 & s_{2,1} & s_{2,3} & s_{2,4} & \cdots & s_{2,K-2} & s_{2,K-1} & s_{2,K} & 0 & 0 \\ 0 & 0 & s_{3,1} & s_{3,2} & \cdots & s_{3,K-3} & s_{3,K-2} & s_{3,K-1} & s_{3,K} & 0 \\ 0 & 0 & 0 & s_{4,1} & \cdots & s_{4,K-4} & s_{4,K-3} & s_{4,K-2} & s_{4,K-1} & s_{4,K} \end{bmatrix} \tag{4}$$

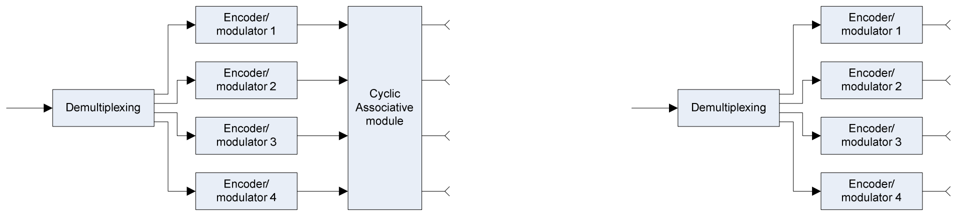
Demultiplexing
Encoder/ modulator 1
Encoder/ modulator 2
Encoder/ modulator 3
Encoder/ modulator 4
Cyclic Associative module
Demultiplexing
Encoder/ modulator 1
Encoder/ modulator 2
Encoder/ modulator 3
Encoder/ modulator 4

(a) D-BLAST

(b) V-BLAST

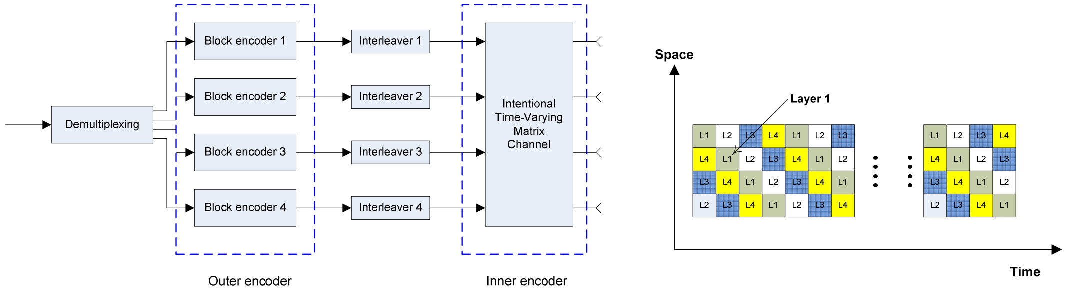
Demultiplexing
Block encoder 1
Block encoder 2
Block encoder 3
Block encoder 4
Interleaver 1
Interleaver 2
Interleaver 3
Interleaver 4
Intentional Time-Varying Matrix Channel
Outer encoder
Inner encoder
Space
Layer 1
L1 L2 L3 L4 L1 L2 L3
L4 L1 L2 L3 L4 L1 L2
L3 L4 L1 L2 L3 L4 L1
L2 L3 L4 L1 L2 L3 L4
L1 L2 L3 L4
L4 L1 L2 L3
L3 L4 L1 L2
L2 L3 L4 L1
Time

(c) Turbo-BLAST

(d) RLST code

Fig. 6. Transmitter block diagrams for BLAST family using four transmit antennas.

Table 3. MIMO systems diversity orders.

MIMO Configuration	Diversity order
STBC	$N_t \times N_r$
BLAST	$N_r - N_t + 1$

The first diagonal of S is transmitted via the first antenna; the second diagonal is transmitted via antenna 2, and so on.

3.2 Vertical-BLAST

A simplified version of D-BLAST was proposed by Wolniansky known as Vertical-BLAST or V-BLAST [14]. In V-BLAST, incoming data stream is de-multiplexed into N_t streams each of which is encoded and modulated independently and sent on an antenna of its own. V-BLAST high-level diagram is depicted in Fig. 6-b where four antennas are used at the transmit side. Compared to D-BLAST, V-BLAST does not include cycling over time, the complexity is significantly reduced. In addition, unlike D-BLAST, V-BLAST does not include any space-time wastage. At the receiver, transmitted symbols can be decoded using *ordered serial interference-cancellation (OSIC) detector*. For the OSIC to work properly, the number of receive antennas N_r must be at least as large as the number of transmit antennas.

3.3 Turbo-BLAST

Turbo-BLAST was first described by Sellathurai and Haykin [15]. The Turbo-BLAST transmitter structure is depicted in Fig. 6-c. The data stream bits are firstly demultiplexed into N_t parallel streams which are encoded independently using the block encoder (outer encoder) (i.e. channel coding). The output streams of the outer encoder are interleaved independently and passed to the inner encoder. The mission of the outer encoder is to achieve *random-layered space-time* (RLST) coding.

The structure of the RLST encoder, with periodical cyclic space-time interleaving is depicted in Fig. 6-d. For optimal performance of the RLST code, the receiver should employ the *maximum a posteriori probability (MAP)* decoding algorithm. Nevertheless, the complexity of the MAP decoding algorithm is very high (increases exponentially with N_t). To decrease the complexity of the receiver, the near-optimal turbo-like receiver can be used. This near-optimal turbo-like receiver is known as *iterative detection and decoding (IDD) receiver*.

Before going further, we list in Table 3 a comparison between diversity order of the different space-time coding and the BLAST family schemes.

IV. Advanced Topics

4.1 Single and Multi CodeWord MIMO

In single codeword (SCW) MIMO, an encoded packet is distributed across many streams to form the MIMO transmission. Feedback is used to control the rank of the MIMO transmission (number of streams used) as well as the overall rate of transmission. In multiple codeword MIMO, several separately encoded packets are transmitted independently over the multiple streams. Here the rate of each stream can be controlled with feedback [16] and [17].

4.2 Single-User MIMO and Multi-User MIMO

In single-user MIMO, already explained techniques in previous sections are used where the channel capacity grows linearly with *min(Nt, Nr)* [18].

For multi-user MIMO, which is of high interest research topic, it was shown that for N_t transmitting antennas (at the base station) and N_r users, the same overall capacity can be achieved. This later work was encouraged by applying dirty paper coding [19] where results showed that if the transmitter knows the interfering signal, then the channel capacity will not be affected by the presence of the interference [20]. On the other hand, multi-user MIMO can integrate beamforming to apply spatial division multiple access (SDMA).

4.3 Cooperative Communication and Virtual MIMO

In cooperative communication, a mobile can act as both a user and relay. As consequence, mobile sends to the base station its own data bits and some of other mobiles (sometimes called partner) information bits. Fig. 7 shows a cooperative cellular system where for simplicity we consider three cooperative users and one base station [21]. As depicted in Fig. 7, user 1 cooperates with users 2 and 3 to send its own information. As a result, the overall cooperative system can be seen as virtual-MIMO (V-MIMO) and in the above example it is $3\times N_{BS}$ MIMO system (for the uplink) where N_{BS} is the base station's number of receive antennas. Users 2 and 3 can simply amplify and forward user 1 received information or detect and forward [22]. Another method of cooperation is the coded cooperation where different coded portions are sent via different fading channels [23].

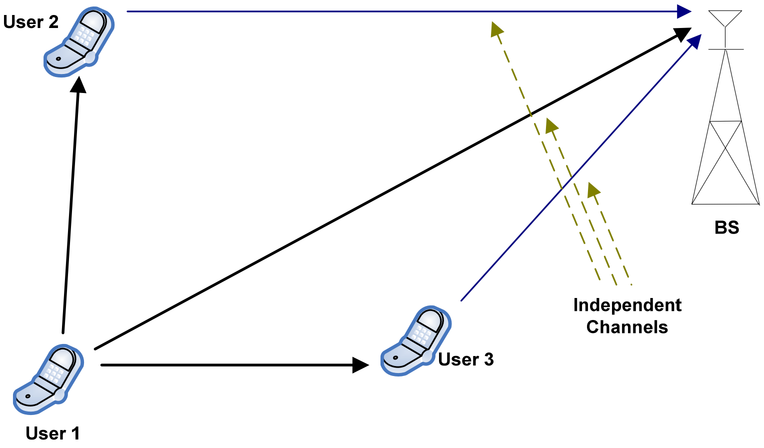

Fig. 7. Cooperative communication and virtual-MIMO.

4.4 Pre-Coded MIMO with Rank Adaptation

4.4.1 Per Antenna Rate Control (PARC)

PARC can be considered as a closed-loop MIMO system where transmitter uses *channel quality indication* (CQI) fed by the receiver to select the best modulation and coding schemes per antenna. Fig. (8) shows a general PARC transmitter structure with 4 transmit antennas [24].

4.4.2 Per Group Rate Control (PGRC)

In PARC, a CQI feedback is necessary for each transmit antenna. This increases the uplink overhead.

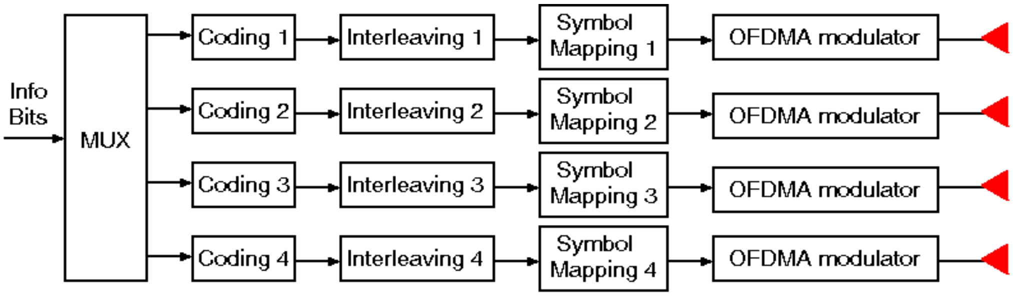

Fig. 8. Per Antenna Rate Control (PARC).

To solve this problem, PGRC is used where a feedback is required per group of antennas. This reduces the feedback information while maintaining almost the same performance of PARC [24].

4.4.3 Per User Unitary Rate Control (PU^2RC)

PU^2RC is a multi-user closed-loop MIMO system. Each user feeds back the CQI to the base station. The base station uses the CQI to determine the modulation and coding schemes per user. In addition, base station can apply unitary pre-coding and adaptively select the number of transmit antennas (rank adaption) [25].

V. Smart Antennas

5.1 Introduction

Smart antenna was born in the early 1990s when well developed adaptive antenna arrays originate from Radar system. Later, Smart antenna technique is applied in wireless communications system. Recently, Smart antenna technique has been proposed as a promising solution to the future generations of wireless communication systems, such as the Fourth-Generation mobile communication systems, broadband wireless access networks, where a wide variety of services through reliable high-data rate wireless channels are expected. Smart antenna technique can significantly increase the data rate and improve the quality of wireless transmission, which is limited by interference, local scattering and multipath propagation [26], [27]. Smart antennas offer the following main applications in high data-rate wireless communication systems [28], [29]:

- Spatial Diversity
- Co-channel interference reduction
- Angle reuse or space division multiple access (SDMA)
- Spatial multiplexing

Smart antenna system can be categorized into three main groups: Phased antenna array system, switched beam systems, and adaptive antenna array system. To match the characteristics in each radio frequency chain of the transmitter and receiver, on-line calibration is required in smart antenna systems. On-line calibration technique can compensate the errors such as the distortions of radio frequency components due to small environment changes, the nonlinear characteristics of mixer, amplifier and attenuator, I/Q imbalance errors, etc.

5.2 Phased Antenna Array System

Phased antenna array is a group of antennas in which the relative phases of the respective signals feeding the antennas are varied in such a way that the effective radiation pattern of the array is reinforced in a desired direction and suppressed in undesired directions.

Phased antenna array system is usually utilized in *radio frequency* (RF) or *intermediate frequency* (IF) with the system central frequency larger than 10 GHz, such as satellite communication system [30]. There are two main different types of phased arrays, also called beamformers. There are time domain beamformers and frequency domain beamformers.

5.3 Switched Beam System

The switched beam method is considered as an extension of the current sectorization scheme. In the switched beam approach, the sector coverage is achieved by multiple predetermined fixed beam patterns with the greater gain placed in the centre of a beam [30]. When a mobile user is in the vicinity of a beam, then the signals at the output ports will be given as in (5). This enables the switched beam system to select the signal from the output port corresponding to that beam. As the mobile moves to the coverage of another beam during the call, the system monitors the signal strength and switches to other output ports as required. A basic switched beam antenna architecture is shown in Fig. 9. And Fig. 10 illustrates the produced antenna pattern with 4 antennas.

$$y_i(t) = s_i(t)G_i(t)\sum_{l=1}^{L} I_l(t)G_{li}(\theta_l) \qquad (5)$$

where $y_i(t)$ is the total signal appearing at port i, $s_i(t)$ is the signal source, $I_l(t)$ is the interfering signal source located at arbitrary angles θ_l, G_i is the transfer function between signal source along the main beams and their corresponding output ports, G_{li} is the transfer function between interference signal l and port i.

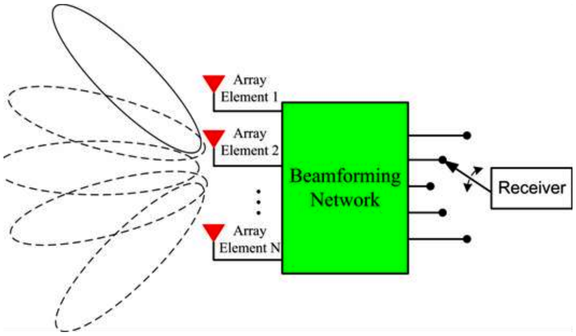

Fig.9. Functional block diagram of switched beam system.

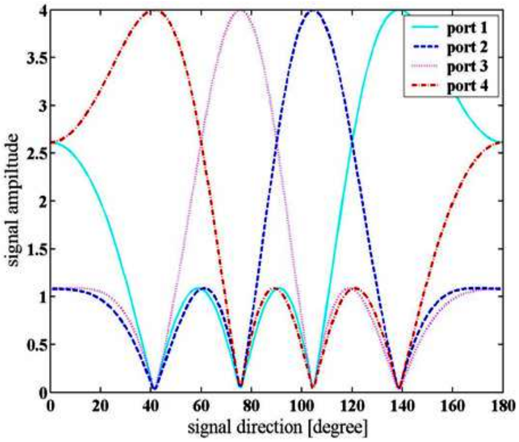

Fig.10. Produced antenna pattern of switched beam system with 4 antennas.

Switched beam systems can offer several advantages, including

- Low complexity and cost. Since switched beam system only requires a beamforming network, RF switches, and simple control logic, they are relatively easy and cheap to implement.
- Moderate interaction with base station receivers. In practice, switched beam system can simply replace conventional sector antennas without requiring significant modifications to the radio base station antenna interface or the baseband algorithms implemented at the receiver.
- Coverage extension. The antenna array aperture gain will boost the link

budget, which could be translated to a coverage extension.

5.4 Adaptive Antenna Array System (AAA)

Adaptive antennas date back to 1959. The original work was attributed to L. C. Van Atta's work, Electromagnetic Reflection. Since then, adaptive beamforming techniques have been employed to remove unwanted noise and jamming from the output, mainly in military applications. With the thriving commercial wireless communication industry and the advancing microprocessor technologies, the adaptive beamforming techniques have found their applications in commercial wireless communications. With powerful *digital signal processing* (DSP) hardware at the base-band, algorithms could control antenna beam patterns adaptively to the real signal environment, forming beams towards the desired signals while forming nulls to co-channel interferers. Thus, the system performance is optimized in terms of link quality and system capacity [31].
Adaptive antenna array can be utilized in the transmitter side, which is known as *transmit beamforming* (TxBF) or in the receiver side, which is called *receive beamforming* (RxBF).

5.4.1 Transmit Beamforming (TxBF)

The implementation of adaptive antenna array technique in a handset is difficult with today`s hardware due to its limitations in size, cost, and energy storage capability, while it is feasible to adopt antenna arrays at base stations. Transmit beamforming provides a powerful method for increasing downlink capacity [32]-[35]. The idea of TxBF is similar to the pre-coded MIMO technique but with different strategies to calculate the transmit weight vector. TxBF adjusts the antenna main lobe towards to the desired user and reduce the interference to other users. A simple illustration of TxBF is shown in Fig. 11.

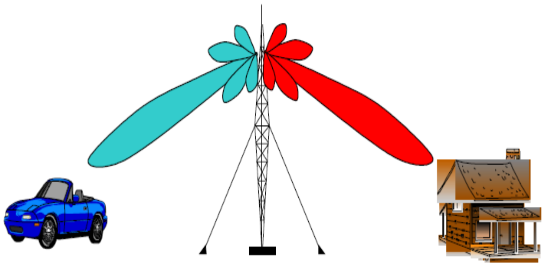

Fig.11. An illustration of TxBF.

Eigenvector TxBF Algorithm

Eignenvector TxBF algorithm is widely used for TxBF. The eigenvector of the spatial covariance channel matrix is calculated as

$$\mathbf{R}_{ss} = \lambda\mathbf{H} \qquad (6)$$

where $\mathbf{R}_{ss}$ is the autocovariance matrix of the desired user`s signal, and $\mathbf{H}$ is the spatial covariance channel matrix. The eigenvector $\boldsymbol{\lambda}_{max}$ which corresponds to the largest eigenvalue will be selected as the weight vector [36]. One example of beam pattern for 4 uniform linear array elements is shown in Fig 12.

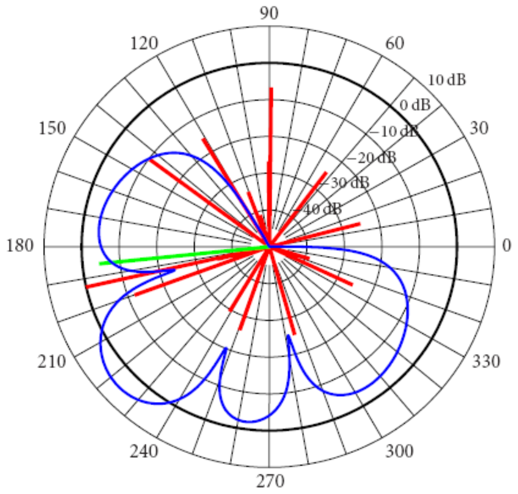

Fig. 12. Example beam pattern of 4 antenna elements in a sectorized system for a single sector (main beam direction is 240°).

Transmit Adaptive Array (TxAA) Algorithm

Transmit adaptive array (TXAA) is a technique in which the user periodically sends quantized estimates of the optimal transmit weights to the BS via a feedback channel. The transmitter weights are optimized to deliver maximum power to the user. The optimal transmit weights are given by

$$\mathbf{w} = \mathbf{H}^{H} / \mathbf{H}\mathbf{H}^{H} \tag{7}$$

where **w** is the transmit weight vector and **H** is the channel matrix.

The weights are normalized so that the total transmitted power is not altered. In the case of multipath channels emanating from each antenna, the optimal weights will be given by the principal eigenvector of the channel correlation matrix $\mathbf{H}^{H}\mathbf{H}$.

5.4.2 Receive Beamforming (RxBF)

Beamforming also can be applied in the uplink to improve the link quality and suppress the co-channel interference, which is known as *receive beamforming* (RxBF). Through RxBF, smart antenna system can receive predominantly from a desired direction (direction of the desired source) compared to some undesired directions (direction of interfering sources). This implies that the digital processing has the ability to shape the radiation pattern to adaptively steer beams in the direction of the desired signals and put nulls in the direction of the interfering signals. This enable low co-channel interference and large antenna gain to the desired signal.

Based on the reference signals adopted in the beamforming algorithms, RxBF can be classified into *spatial reference beamforming* (SRB), *temporal reference beamforming* (TRB), and *signal structure reference beamforming* (SSRB).

Spatial Reference Beamforming (SRB)

Spatial reference beamforming method is sometimes referred as *direction of arrival* (DoA) method. SRB estimates the direction of arrival of the signal based on the spatial reference signal, using any of the techniques like *multiple signal classification* or *estimation of signal*

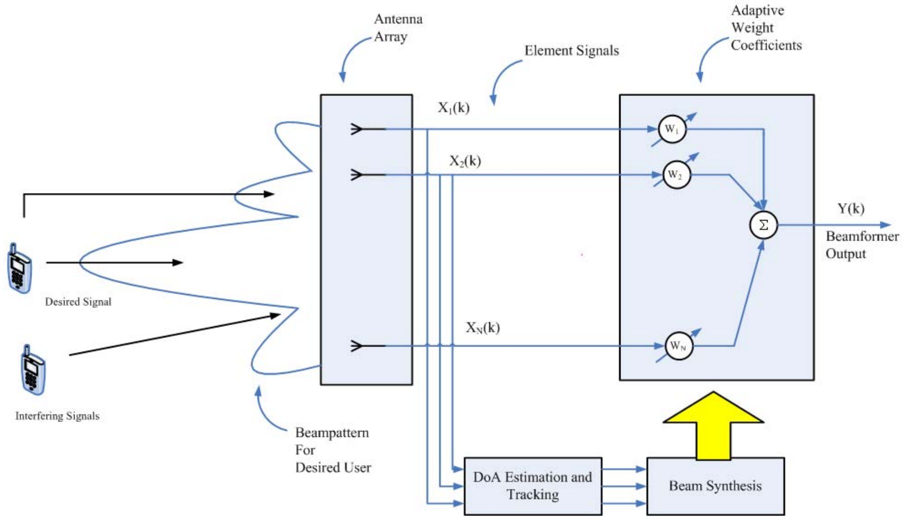
Antenna Array
Element Signals
Adaptive Weight Coefficients
X₁(k)
X₂(k)
X_N(k)
W₁
W₂
W_N
Σ
Y(k)
Beamformer Output
Desired Signal
Interfering Signals
Beampattern For Desired User
DoA Estimation and Tracking
Beam Synthesis

Fig. 13. A general structure of SRB.

parameters via rotational invariance techniques algorithms or their derivatives. They involve finding a spatial spectrum of the antenna/sensor array, and calculating the DoA from the peaks of this spectrum [37]. A general architecture of SRB algorithm is shown in Fig. 13. The general steps of SRB method are shown as follows:

- DoA Estimation
    - Arbitrary Array: MUSIC, etc.
    - Linear Array: ESPRIIT, etc.
- Beam Synthesis
    - Gram-Schmidt, etc.
- Combining
    - EGC, MRC, Wiener Filter, etc.

Multiple signal classification (MUSIC) algorithm estimates the DoA of the desired signal by using an eigen-space method based on a spatial reference signal. MUSIC requires intensive calculation of eigenvalues and eigenvectors of an autocorrelation matrix of the input vectors from the receiving antenna array. A general step of MUSIC algorithm is shown below:

- Collect received samples and estimate the covariance matrix of the received samples.
- Perform eigen-decomposition of the covariance matrix.
- Calculate spatial spectrum.
- Estimate DoA by locating peaks in the spectrum.

Estimation of signal parameters via rotational invariance techniques (ESPRIT) is also well known for the SRB method. In addition, ESPRIT has many important advantages over MUSIC algorithm [38]:

- No knowledge of the array geometry and element characteristics are required.
- Much less complex on computation.
- No calibration of the array is required.
- The algorithm simultaneously estimates the number of sources and DoA`s

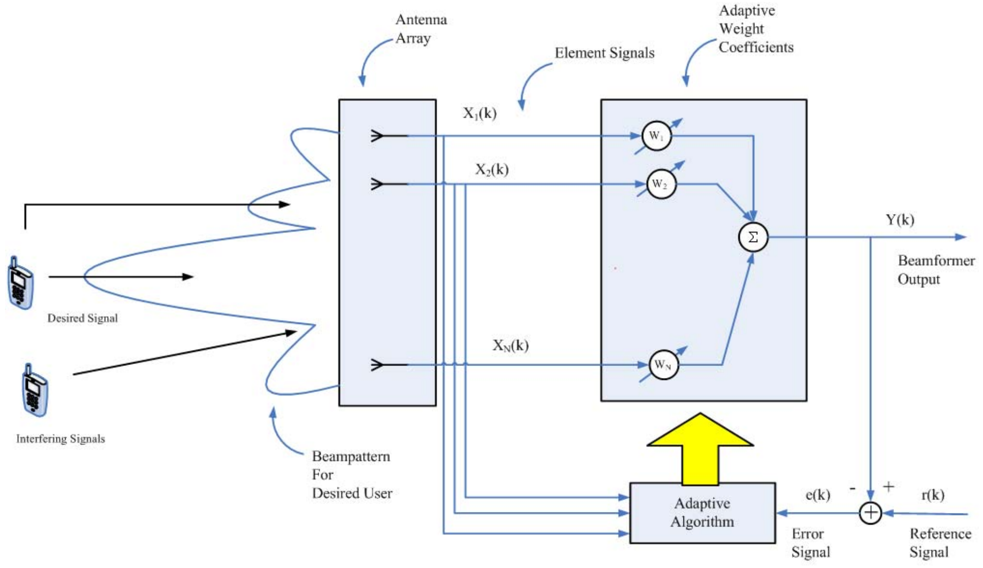
Antenna Array
Element Signals
Adaptive Weight Coefficients
$X_1(k)$
$X_2(k)$
$X_N(k)$
W_1
W_2
W_N
Σ
Y(k)
Beamformer Output
Desired Signal
Interfering Signals
Beampattern For Desired User
Adaptive Algorithm
e(k)
-
+
r(k)
Error Signal
Reference Signal

Fig. 14. A general structure of TRB.

Temporal Reference Beamforming (TRB)

Temporal Reference Beamforming shown in Fig. 14, is a method used to create the radiation patter of the antenna array by adding constructively the phases of the signals in the DoA of the desired user, and nulling the pattern of the interfering users based on the temporal reference signal [39]. Based on the temporal reference signal and some predefined adaptive weight calculation criterion, some adaptive algorithms such as LMS (Least Mean Square), RLS (Recursive Least Squares), and DSMI (Direct Sample Matrix Inverse) algorithms, are used to adjust the weight vector of the antenna array to improve the link quality. The general characteristics of TRB are as follows:

- Good performance in multipath channel environment
- Computationally inexpensive
- Requiring Training sequence
- Difficult to apply TxBF because of the absence of DoA information

Criterion of Adaptive Weight Calculation

In the *minimum mean-square error* (MMSE) criterion, the weights are chosen to minimize the *mean-square error* (MSE) between the beamformer output and the temporal reference signal. While in the *maximum signal-to-interference ratio* (MSIR) criterion, the weights are chosen to directly maximize the signal-to-interference ratio (SIR). And The *minimum variance* (MV) criterion chooses the weights that minimize the variance of the output power. All the above three criterions has the same form of

$$\mathbf{w}_{opt} = \beta \mathbf{R}_i^{-1} \mathbf{v} \qquad (8)$$

where $\mathbf{R}_i^{-1}$ is the inverse of the covariance matrix of the interference signals received in the antenna array and **V** is the antenna array propagation vector [40].

Let us assume that *d(t)* is the transmitted temporal reference signal and $\mathbf{R}_u$ is the covariance matrix of interference signals at the output of the beamformer. The calculation of β for MMSE, MSIR

Table 4. β Calculation.

Criterion	MMSE	MSIR	MV
β	$\frac{E\{d^2(t)\}}{1+E\{d^2(t)\}\mathbf{v}^H\mathbf{R}_i^{-1}\mathbf{v}}$	$\frac{E\{d^2(t)\}}{SIR}\mathbf{v}^H\mathbf{w}_{opt}$	$\frac{g}{\mathbf{v}^H\mathbf{R}_u^{-1}\mathbf{v}}$

and MV criterions are summarized in Table 4.

Adaptive Beamforming Algorithm

The *least mean square* (LMS) algorithm uses the temporal reference signal to update the weights at each iteration. In the LMS algorithm, we are searching for the optimal weight that would make the array output either equal or as close as possible to the reference signal, which is the weight that minimizes the MSE. Since the MSE has a quadratic form, moving the weights in the negative direction of the gradient of the MSE should lead us to the minimum of the error surface. The weight update equation is shown in (9) [30].

$$\mathbf{w}(t+1)=\mathbf{w}(t)-\mu\mathbf{x}(t+1)\varepsilon^* \qquad (9)$$

where μ is a constant, called the step size, which determines how close the weights approach the optimum value after each iteration and it controls the convergence speed of the algorithm. And ε is the error signal between the temporal reference signal and the received signal at the beamformer output. $\mathbf{x}$(t+1) is the received signal vector at the antenna array at time *t+1*.

The main drawback of the LMS algorithm is that it is sensitive to the scaling of its input. This makes it very hard (if not impossible) to choose a step size μ that guarantees stability of the algorithm. The *normalized least mean square* (NLMS) algorithm is a variant of the LMS algorithm that solves this problem by normalizing with the power of the input. The weights updating function of NLMS algorithm is shown as

$$\mathbf{w}(t+1)=\mathbf{w}(t)+\frac{\hat{\mu}}{a+\|x(t)\|^2}\mathbf{x}(t)\varepsilon^* \quad (10)$$

Recursive least square (RLS) algorithm is derived to overcome the drawback of slow convergence speed in the LMS algorithm, when the eigenvalue spread of the correlation matrix R of received signal vector $\mathbf{x}$ is large. RLS algorithm replaces the step size μ with the inverse of R. The weights are then updated using (11).

$$\mathbf{w}(t+1)=\mathbf{w}(t)-\mathbf{R}^{-1}\mathbf{x}(t+1)\varepsilon^* \quad (11)$$

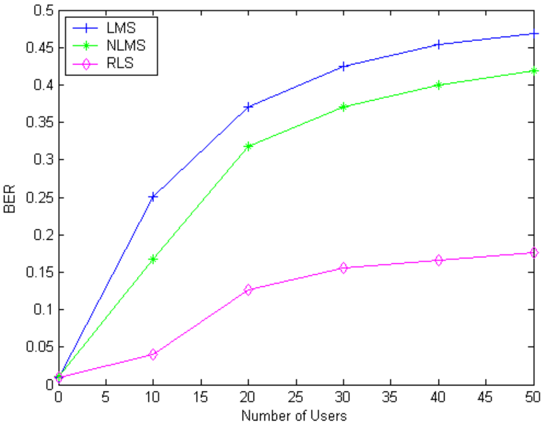

Fig. 15. Performance comparison among LMS, NLMS, and RLS algorithms.

Fig. 15 shows a simple performance comparison of the above three algorithms in OFDMA system under the Rayleigh fading channel with 8 antenna elements [41]. From this figure, we see that RLS algorithm performs best due to its faster convergence speed than LMS and NLMS algorithms.

Signal Structure Reference Beamforming (SSRB)

SSRB method is based on inherent structure of the transmit signal of the implicit kind reference signal. Algorithms such as blind beamforming, least squares, and constant modulus algorithms, are based on the SSRB method. SSRB method is robust against different propagation conditions and does not require the array manifold knowledge. But the convergence problem becomes the main drawback of the SSRB method.

VI. Conclusions

In this paper we introduced the multi antenna technologies which can be considered as one of the most vivid area of research. Multiple antenna technologies were categorized into two main groups where in the first group we introduced some techniques related to spatial diversity and spatial multiplexing by outlining the gain achieved by these schemes. Furthermore, we introduced the smart antenna techniques and the up-to-date research progress in this field.

The advantages of multiple antenna systems make of them a very strong candidate to increase link reliability, increase channel capacity and reduce interference in both uplink and downlink.

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RÉPUBLIQUE FRANCAISE

5G: ISSUES & CHALLENGES

March 2017

The issues and challenges surrounding 5G

The telecoms industry is currently in the process of designing the technologies that are due to take over from 4G, which is still being deployed today. A great deal of work is thus underway to prepare these “5G” technologies.

To prepare for the arrival of this new generation of technologies, Arcep wanted to take a detailed look at the industry to better understand what is in the works. This report is the fruit of the interviews and research that Arcep conducted over the course of 2016, and which the Authority wanted to publish as a way to contribute to the public debate over 5G.

Its aim it to provide as objective and exhaustive an overview as possible, and deliver a concise, informative snapshot of the work that is currently underway on the future generation of mobile networks.

This report reflects the views of the stakeholders who were interviewed, but in no way represents Arcep’s positions on or roadmap for 5G. Arcep awarded in 2015 the 700 MHz band and is currently working towards licensing the 3.5 GHz band, both of which have been identified as 5G bands. Arcep is also working with the Direction générale des entreprises and the Agence nationale des fréquences towards enabling spectrum for 5G.

Arcep would like to thank all of the entities (listed on the last page) who agreed to take part in this process, and who were willing to contribute to the regulator’s investigation into the development of 4G’s successor. Arcep is dedicated to sustaining an ongoing dialogue with the market, and invites all interested parties to provide information on the matter or to share their reactions to this report, by contacting Arcep’s Mobile and Innovation Directorate at the following address: 5G@arcep.fr.

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Introduction: the vision for 5G, creating an ultra-connected society

5G wants to be the disruptive generation, the generation that no longer only caters to the needs of mobile operators and consumer communications, but which opens up new prospects and enables an extremely wide diversity of applications and use, unified within a single technology. 5G is setting itself up as an enabler of the digitisation of society and the economy.

The idea that is starting to take shape behind the notion of 5G is that it will not mean just an increase in transmission speeds, as has been the case with previous generations.

Consumer mobile communications, video downloads and the use of mobile apps account for the bulk of 4G networks' radio resources usage today. With 5G, the goal will be to enable a much broader spectrum of uses and a much greater diversity of users.

5G is targeting a wide variety of sectors, which will not necessarily have anything other than this technology in common, but which are central pillars in a society: energy, healthcare, media, industry and transportation.

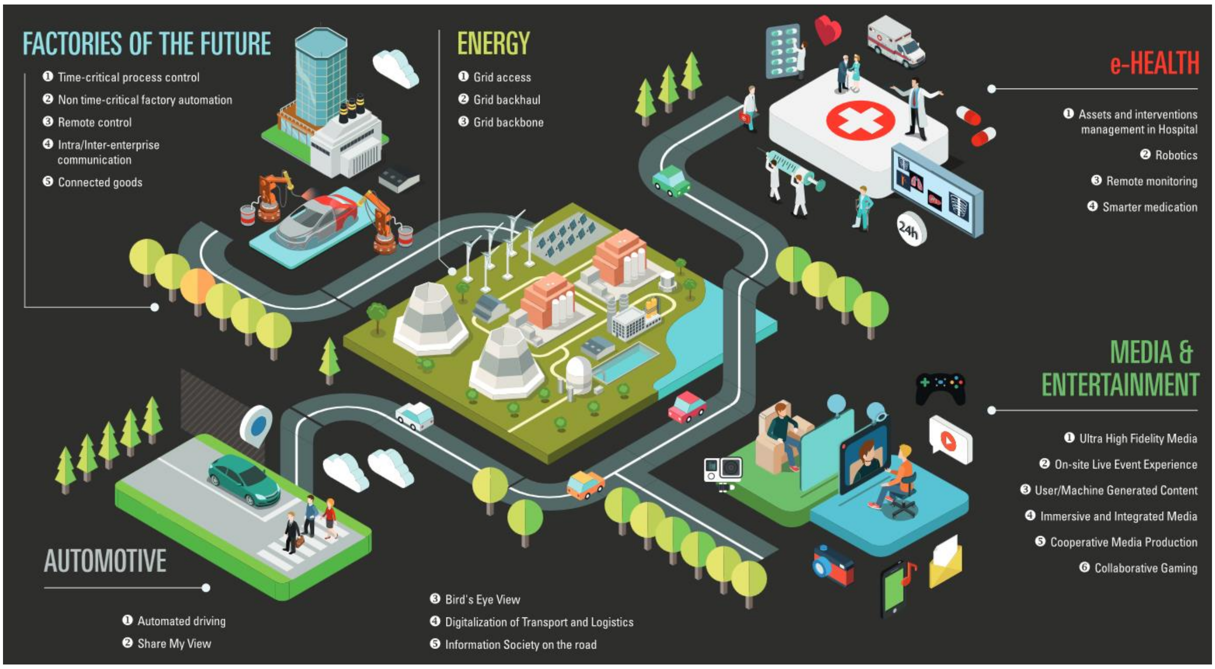
FACTORIES OF THE FUTURE
❶ Time-critical process control
❷ Non time-critical factory automation
❸ Remote control
❹ Intra/Inter-enterprise communication
❺ Connected goods
ENERGY
❶ Grid access
❷ Grid backhaul
❸ Grid backbone
e-HEALTH
❶ Assets and interventions management in Hospital
❷ Robotics
❸ Remote monitoring
❹ Smarter medication
24h
MEDIA & ENTERTAINMENT
❶ Ultra High Fidelity Media
❷ On-site Live Event Experience
❸ User/Machine Generated Content
❹ Immersive and Integrated Media
❺ Cooperative Media Production
❻ Collaborative Gaming
AUTOMOTIVE
❶ Automated driving
❷ Share My View
❸ Bird's Eye View
❹ Digitalization of Transport and Logistics
❺ Information Society on the road

Figure 1. 5G driving industrial and societal changes[1]

The energy sector, for instance, has undergone a great many changes and developments over the past several years in terms of energy production, storage and transport. Rising fossil fuel costs, the introduction of renewable energy sources and markets being opened up to competition have all helped usher in new kinds of energy product and new stakeholders – both independent companies and ordinary citizens – to the energy marketplace. The objective with 5G will thus be to enable better management of these networks (smart grids, smart agriculture, factories of the future) and their interconnections, to achieve more efficient and more agile distribution.

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[1] 5G Empowering vertical industries. White Paper, 2016, https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

Healthcare, transportation and media are sectors that are bound up with our fellow citizens' daily lives: any improvements in these sectors thus have a clearly visible impact. The introduction of robots to perform specialised surgical operations, of video on demand or the advent of new connected features in cars have already improved our daily lives. 5G is promising to go several steps further in all of these areas: it would enable remote medical diagnoses and operations in real time, it would democratise streaming of 360° 3D video, it would provide users with a vast selection of video content with a picture quality better than ultra high-definition (4K, 8K…). The automotive universe could rely on these new networks to help cars make decisions without human involvement, and also communicate with one another (this is already possible, for instance, with the first experimental fleet of fully autonomous taxis being tested on the streets of Singapore by the firms nuTonomy and Grab[2]), with reaction times that are compatible with the demands of high-speed travel.

In terms of factories of the future, the improvements brought by 5G are primarily targeting the introduction of new generations of connected robots, the interconnection of production sites and the much heavier use of smart sensors to improve industrial processes. Generally speaking, the aim is to achieve ubiquitous communication between machines, a process that is already well underway.

One thing that it is crucial to understand, through the few examples listed above whose demands might seem mutually incompatible, is that depending on the sector or the application, the network properties and the functionalities required will not be the same. Service providers – whether they are today's mobile operators or other market players – will need to be capable of adapting their network to demand, occasionally in real time. 5G will thus be not so much a universal technology as a polymorphous, or multi-faceted technology, capable of adapting to any use, up to and including the most demanding ones.

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[2] http://nutonomy.com/

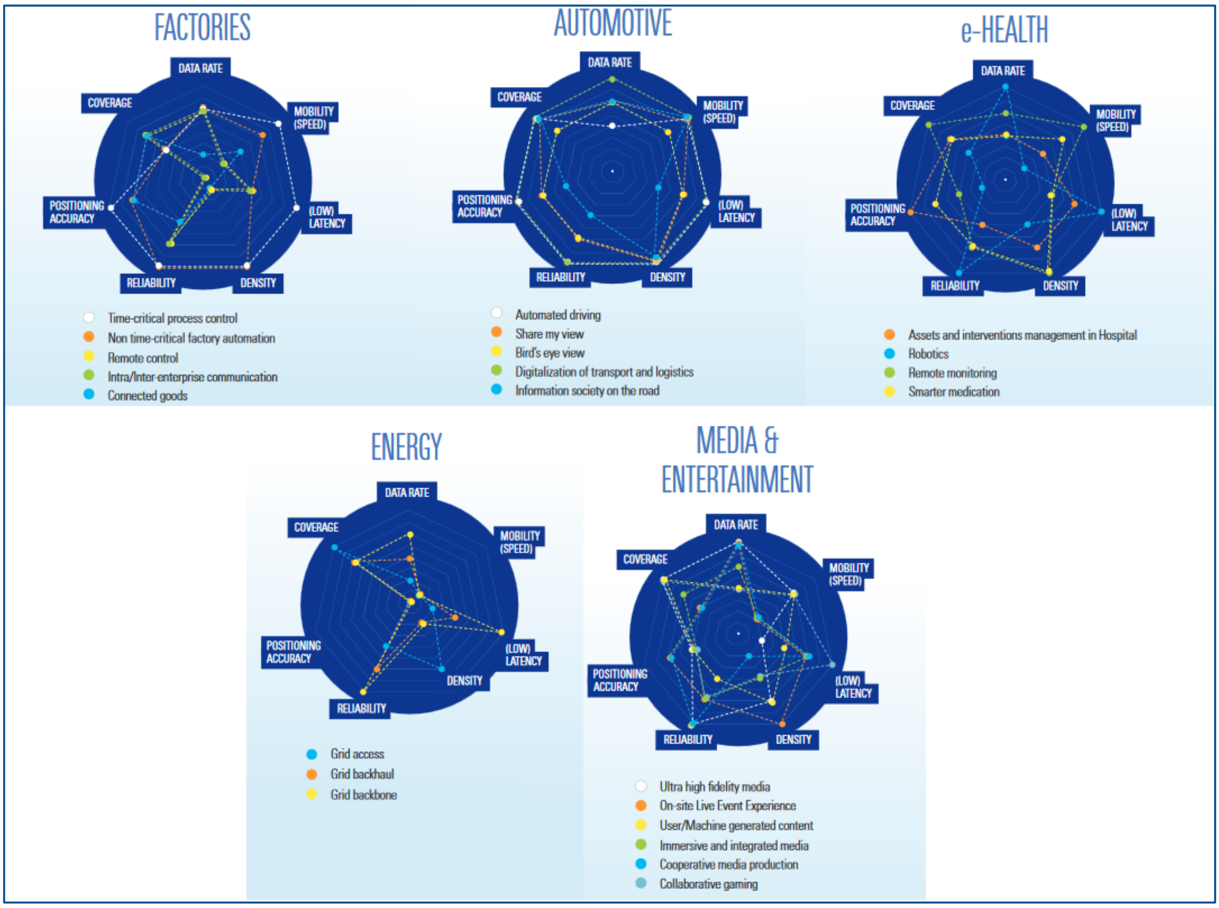

Figure 2. Performances required by vertical sectors[3]

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[3] 5G Empowering vertical industries. White Paper, 2016, https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

1 5G objectives

Ever since the first real mobile telephone call, 44 years ago[4], mobile technologies have been evolving steadily and their performances have improved exponentially: as mentioned earlier, calling services and later texting and finally the mobile internet and the use of multi-service mobile applications have characterised the evolution of mobile networks and the transition from one generation to the next. The birth of LTE technology and the fourth generation (4G), coupled with the widespread use of smartphones and tablets, have driven a massive increase in the amount of mobile data traffic being relayed over the networks.

The use of a mobile handset and its applications is now an integral part of our fellow citizens' daily habits. Portable connected devices are increasingly powerful: in many instances they have replaced users' landline telephones, cameras, computers and even televisions. Today, 5 million videos are watched on YouTube and 67,000 images uploaded to Instagram every minute (see Figure 3).

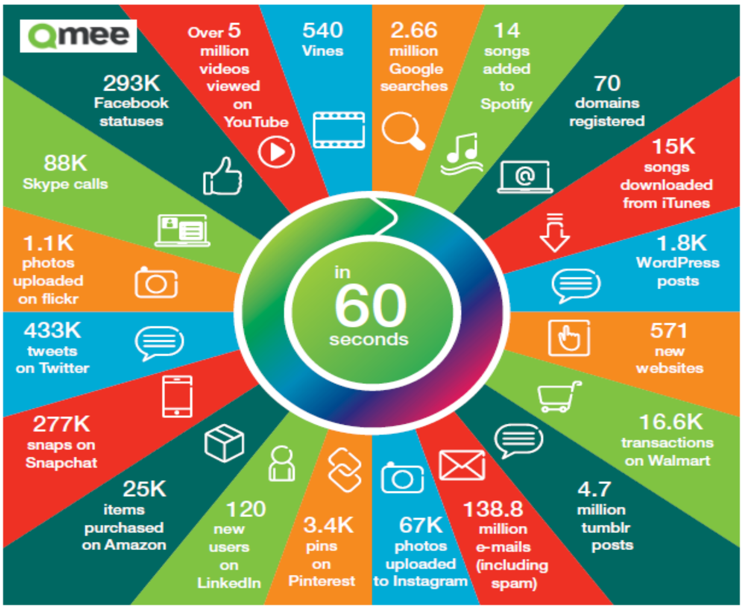

Figure 3. What we do over the network today in one minute[5]

The latest *Mobility Report*[6] from Ericsson indicates that traffic on mobile networks almost doubled in a single year, and that over the next five years it will have increased to 10 times what it is today. New solutions must therefore be found to meet this demand, and to optimise how resources are used.

The increase in the number of applications available, their diversification and the improved quality of mobile networks have all contributed to driving up demand, the emergence of new uses (connected objects, drones, etc.) and new users.

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[4] On 3 April 1973, Motorola's Martin Cooper made a call from the corner of 56th street in New York City with the first mobile phone.

[5] https://www.ericsson.com/res/docs/2014/5g-what-is-it-for.pdf

[6] https://www.ericsson.com/assets/local/mobility-report/documents/2016/ericsson-mobility-report-november-2016.pdf

5G is at the crossroads of these news uses; it aims to better and simultaneously satisfy this tremendous variety of needs and these new demands, through a unified technology that takes this diversity into account at the design stage.

The advent of 5G could have a significant impact not only in the technical realm, but also on different countries' economic and social development. As indicated in the introduction, 5G targets a very large number of sectors and, through society's digitisation, is expected to contribute to countries' economic growth.

To give an example, according to a report produced by InterDigital Europe, Real Wireless, Tech4i2 and Connect (Trinity College Dublin)[7], this new technology will require a great deal of money and a great deal of work, but will generate €113.1 billion in profits per annum for the European economy by 2025.

1.1 Technical specifications of 5G

The specifications for a new generation of mobile telephony are set primarily by two bodies: ITU (International Telecommunication Union) and 3GPP (3rd Generation Partnership Project).

ITU is the United Nations agency devoted to information and communications technologies. It carries out research and studies through its Working Party 5D, the sub-group responsible for the overall radio system aspects of international mobile telecommunications (IMT). In 2013, this group began working on defining the characteristics of the new IMT standard, IMT-2020 (5G) (cf. 1.3), as it had done back in the early 2000s to define 4G (IMT-Advanced). Further details on the roadmap established for this work can be found in Annex 1, the objective set by ITU-R being to complete its analyses by 2020.

Parallel to the work being done by ITU are the studies being conducted by 3GPP. The 3rd Generation Partnership Project was created in 1998, and its members include seven standardisation bodies, several hundred industry players, associations and public organisations. It is responsible for developing and maintaining technical specifications for mobile telephony standards[8]. When a new standard is being defined by ITU, 3GPP works on the technical solutions that make it possible to achieve the objectives set by ITU.

Although 5G is one of the most widely debated topics inside international and European bodies today, no standard has yet been defined by 3GPP. The draft of Release 15, the first 5G standard from 3GPP, is still in the works: definition of the new architecture began in December 2016 and work on the New Radio (NR) interface is set to begin in March 2017. A first Release of the standard should be validated in September 2018 to meet the more urgent demands; a second Release (3GPP Release 16) will then be published in March 2020. All of these elements are addressed in more detail in Annex 1.

It should also be said that the transition from one generation to the next takes place gradually. LTE will continue to evolve alongside NR, and these two standards will likely be very complementary initially. In particular, for pioneer 5G rollouts LTE shall probably remain the master of the network and control the NR antennae. Moreover, some of the objectives set for 5G could be achieved thanks to functionalities or technologies introduced in 3GPP Releases 13, 14 and 15 that will not be proper to 5G, but rather evolutions of 4G (which some refer to as 4.9G or LTE Advanced Pro).

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[7] http://ir.interdigital.com/file/Index?KeyFile=36051369

[8] GSM for 2G, UMTS for 3G and LTE for 4G

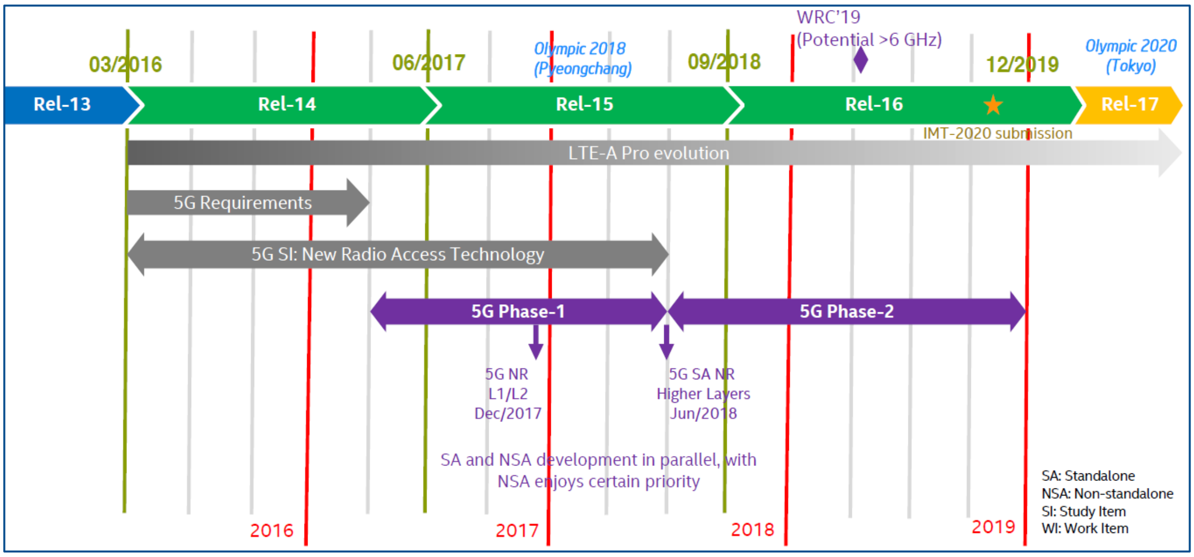
WRC'19
(Potential >6 GHz)
03/2016
06/2017
Olympic 2018
(Pyeongchang)
09/2018
12/2019
Olympic 2020
(Tokyo)
Rel-13
Rel-14
Rel-15
Rel-16
Rel-17
IMT-2020 submission
LTE-A Pro evolution
5G Requirements
5G SI: New Radio Access Technology
5G Phase-1
5G Phase-2
5G NR
L1/L2
Dec/2017
5G SA NR
Higher Layers
Jun/2018
SA and NSA development in parallel, with
NSA enjoys certain priority
2016
2017
2018
2019
SA: Standalone
NSA: Non-standalone
SI: Study Item
WI: Work Item

Figure 4. 3GPP timeline for 5G[9]

This same momentum occurred when making the transition from 3G (Release 4) to 4G (Release 10, first Release of IMT-Advanced): the first LTE specifications (Releas*es* 8 & 9) do not achieve all of the ITU targets for 4G, and reprised many of the characteristics of the most advanced form of 3G at the time.

The synergies between the successive generations, the absence in most instances of a great initial jump in performances between generations, and the race between competitors to outperform one another and be the most innovative, can often lead operators and equipment suppliers to give a "commercial" name to each generation of mobile telephony. For instance, in the United States AT&T had called its HSPA network 4G, while in France it is a 3G+ network.

So in all likelihood the first 5G networks deployed on a large scale will be 4.9G systems, using carrier aggregation, massive MIMO (Multiple-Input Multiple-Output) and Network Function Virtualization, or NFV (cf. trials conducted in in France, detailed in Section 1.5.3). These technologies, which will be explored in greater detail further on, represent more of an evolution of the fourth generation than an actual transition to 5G, which will occur when disruptive technologies such as NR carriers in millimetre bands, non orthogonal multiple access (NOMA*)* and mobile edge computing (MEC) can be put into place.

In addition to this commercial race, equipment suppliers – often backed by their respective government at home, notably in the United States, Japan and South Korea – want to get a head start in defining and testing 5G technologies, in the hope of establishing themselves as the technological leaders in international standardisation bodies. Here, the precocity of the first rollouts announced in South Korea (5G deployment for the Winter Olympics in 2018 in Pyeongchang) and Japan (5G deployment for the Summer Olympics in Tokyo) would justify the supposition that only a small portion of 5G technologies will be used, and that these rollouts will be based more on 4.9G or pre-5G technologies.

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[9] http://gsacom.com/paper/intel-5g-technology-mm-wave-frequencies/

1.2 5G use cases

Three main use cases (defined by ITU, under IMT-2020), with their respective – and potentially mutually incompatible – demands are in the process of taking shape, and will make it possible to meet the sector-specific needs referred to in the introduction.

1. **mMTC – Massive Machine Type Communications**: A very large number of connected devices with disparate quality of service requirements. The objective of this category is to provide a response to the exponential increase in the density of connected objects;
2. **eMBB – Enhanced Mobile Broadband**: ultra high-speed connection indoors and outdoors, with uniform quality of service, even on the edges of a cell;
3. **uRLLC – Ultra-reliable and Low Latency Communications**: this use case has stringent requirements for capabilities such as latency and packet-loss, to ensure increased reactivity.

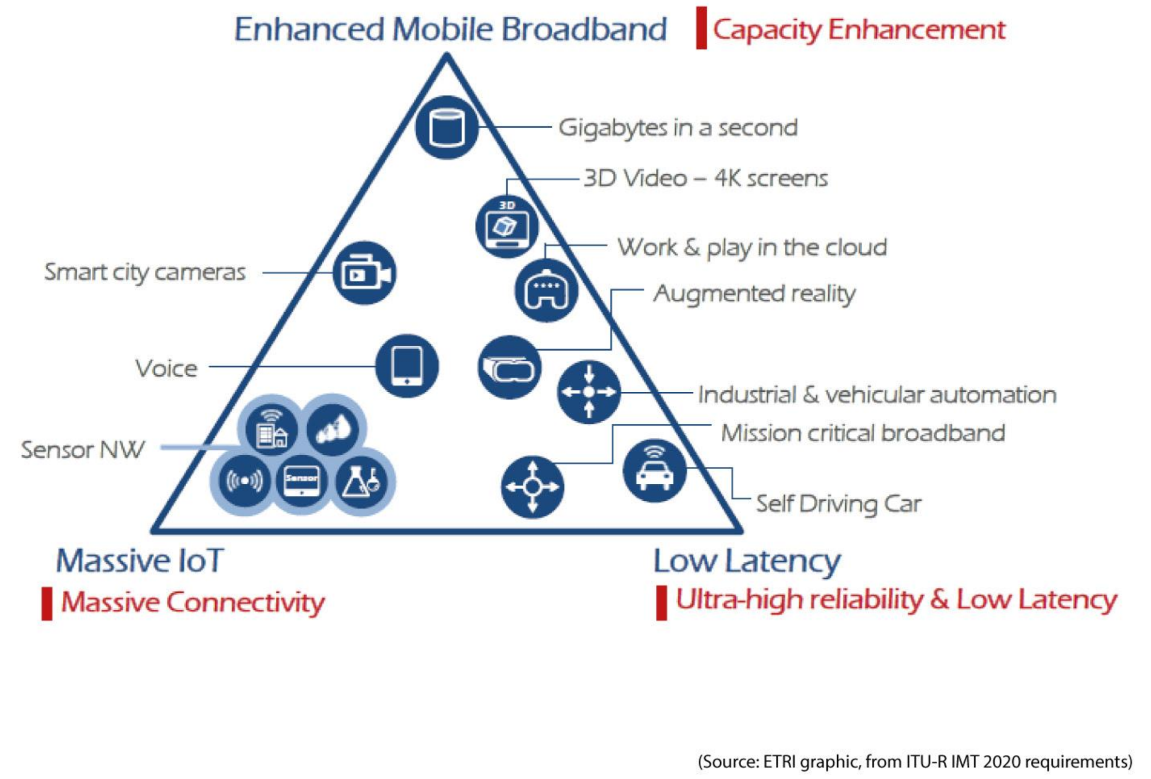
Enhanced Mobile Broadband
Capacity Enhancement
Gigabytes in a second
3D Video – 4K screens
Work & play in the cloud
Augmented reality
Smart city cameras
Voice
Industrial & vehicular automation
Mission critical broadband
Sensor NW
Self Driving Car
Massive IoT
Massive Connectivity
Low Latency
Ultra-high reliability & Low Latency

(Source: ETRI graphic, from ITU-R IMT 2020 requirements)

Figure 5. 5G use cases[10]

The first group (mMTC) primarily encompasses all Internet of Things related uses. These services require broad coverage, lower energy consumption and relatively slow transmission speeds. What 5G will deliver compared to existing technologies is the ability to connect objects that are spread out in a very dense fashion across a given area.

Enhanced mobile broadband (eMBB) concerns all of the applications and services that require increasingly fast connections, for instance to watch ultra high-definition (8K) videos or to stream virtual or augmented reality applications wirelessly.

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[10] http://5g.ieee.org/standards

Ultra-reliable and Low Latency Communications (uRLLC) include all of the applications that require an extreme reactivity and very strong message transmission guarantees. The sectors where these requirements are particularly prevalent are transportation (reaction time when an accident occurs, for instance) and medicine (telesurgery), and when digitising manufacturing processes in general.

To implement these three use case, ITU established eight key performance indicators[11] (KPI) to specify, quantify and measure the characteristics of IMT-2020 (5G) systems:

- Peak data rate (Gbit/s);
- User experienced data rate (Mbit/s);
- Spectrum efficiency (bit/Hz);
- Device mobility (km/h);
- Latency (ms);
- Connection density (number of connected/accessible objects per km^2);
- Network's energy efficiency;
- Area traffic capacity ($Mbit/s/m^2$).

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[11] Added to these eight classes, five new indicators were defined and are currently being examined: reliability, mobility interruption time, bandwidth, maximum spectrum efficiency, 5th percentile spectrum efficiency.

1.3 Jump in performance compared to 4G networks

As mentioned in Paragraph 1.1, the deployment of 5G is likely to take place in two stages:

1. The first 5G rollouts will deliver better performances, but as a continuation of what is being provided at the time by 4G systems which will continue to evolve as well (4.5G, 4.9G);
2. Performances will continue to improve with the gradual introduction of disruptive technologies, such as the use of millimetre wave frequencies.

This gradual rollout is very similar to the way in which 4G was introduced, as the performances obtained with pioneer deployments were relatively similar to those supplied by existing 3G networks.

ITU defines the 4th generation of technologies, called IMT-Advanced, by the values for the eight KPI listed above, as indicated in the following chart. The 5th generation, called IMT-2020, is represented as well. Here, it should be noted that the official ITU definition of 4G in fact corresponds to what commercial rollouts supplied later on, under the name 4G+ or LTE-Advanced.

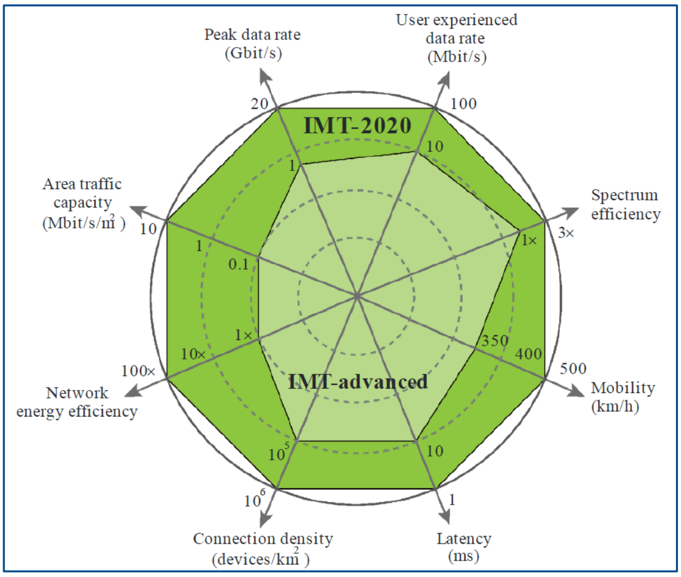

Figure 6. Comparison between 4G and 5G with respect to the eight key performance indicators[12]

According to these objectives, 5G must be able to provide a user experienced data rate and a peak data rate that is respectively 10 and 20 times higher than what is currently available. The maximum connection density will be multiplied by 10 and latency divided by at least 10 (the target point-to-point latency is 1 ms, compared to 30 to 40 ms today).

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[12] Recommendation ITU-R M.2083-0 (09/2015), https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

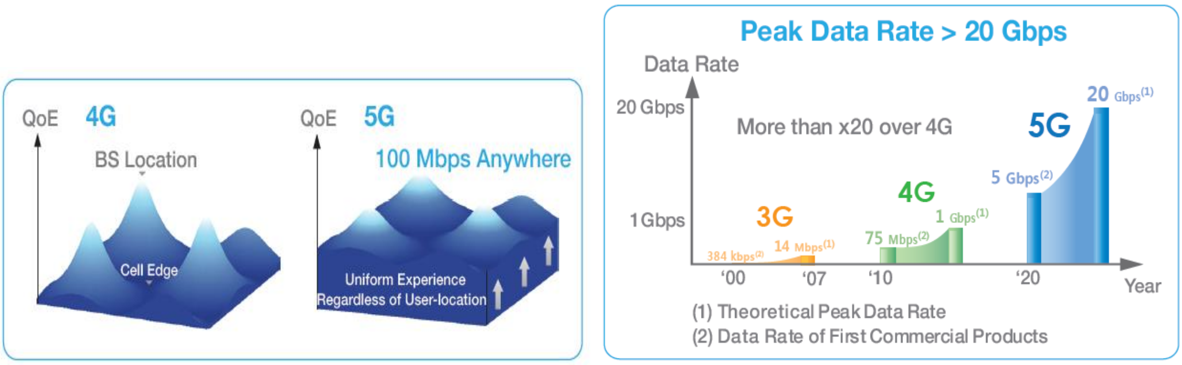

Figure 7. Representation of the "average user experience data rate" KPI for 4G and 5G and "Peak data rate" KPI for 3G, 4G and 5G[13]

As the successor to 4G, the objective for 5G will also be to provide:

- An extremely reliable network, with more consistent performances regardless of the user's position with respect to the base station;
- A stable connection, even when travelling (at speeds of up to 500 km/h);
- Greater network energy efficiency (with batteries that consume up to 100 times less power).

The following table summarises the target performances for 5G and those currently available with 4G:

Performances/Generation	4G	5G
1. Peak data rate (Gbit/s)	1	20
2. User experience data rate (Mbit/s)	10	100
3. Spectrum efficiency	1x	3x
4. Speed (km/h)	350	500
5. Latency (ms)	10	1
6. Connection density (number of objects/km²)	10^5	10^6
7. Network energy efficiency	1x	100x
8. Area traffic capacity (Mbit/s/m²)	0.1	10

Table 1. Comparisons between 4G and 5G performances

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[13] http://www.samsung.com/global/business-images/insights/2015/Samsung-5G-Vision-0.pdf

1.4 Network slicing and software-defined networks

It is vital to understand that the set of indicators listed in Section 1.3 determine a set of peak performances for 5G. It will not, however, be possible to achieve all these peak values simultaneously: not every requirement or use case is compatible, so a trade-off will need to be made when defining categories of use that each have their own performance envelope, notably for the use cases described in Section 1.2 (mMTC, eMBB and uRLLC). This is the principle of network slicing: each slice has its own set of KPI, which is a trade-off tied to the target use. On a 5G system, the network properties will need to adapt to the chosen environment.

The following diagram positions the three main use cases listed in Section 1.2. with respect to the eight key performance indicators listed above.

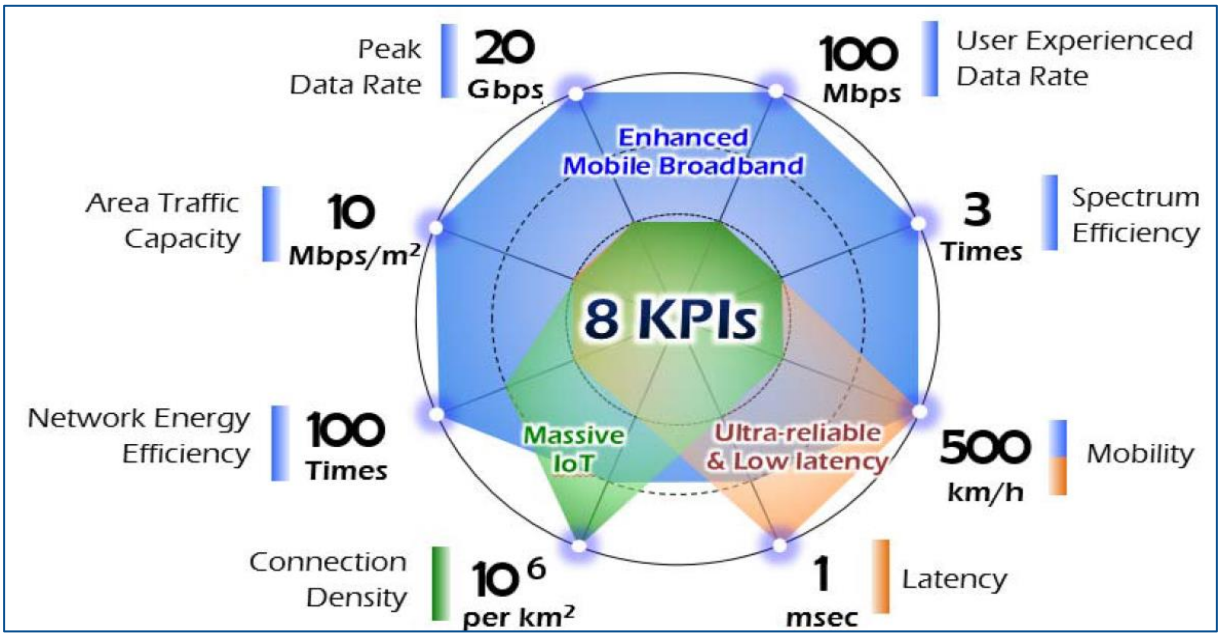

Peak Data Rate
20 Gbps
100 Mbps
User Experienced Data Rate
Enhanced Mobile Broadband
Area Traffic Capacity
10 Mbps/m²
3 Times
Spectrum Efficiency
8 KPIs
Network Energy Efficiency
100 Times
Massive IoT
Ultra-reliable & Low latency
500 km/h
Mobility
Connection Density
10⁶ per km²
1 msec
Latency

Figure 8. Key performance indicators for the three 5G use cases[14]

So for applications that require enhanced mobile broadband (eMBB), such as 4K, 8K or 3D video or virtual reality, a certain number of performance indicators, such as spectrum efficiency, peak data rate and area traffic capacity, can be reached only at the expense of others, such as latency or connection density.

On the flipside, when a massive simultaneous connection of connected objects (mMTC) needs to be managed, the network will concentrate its resources and use the technologies required to achieve this task, but will not be able, for instance, to use spectrum as efficiently or to guarantee low latency.

Lastly, when ultra-reliable and low latency communications (uRLLC) are required, the number of simultaneous connections, data rates and spectrum efficiency may be reduced.

This flexibility, or ability to adapt, that network slicing brings can only be achieved thanks to the softwarisation and virtualisation of a sizeable number of network components (cf. 1.5.2) – a process referred to as Software-Defined Networking (SDN) and Network Function Virtualisation (NFV). Behind these acronyms is a common idea, namely to use as many generic and reconfigurable components as possible, rather than bespoke ones that are permanently dedicated to very specific tasks. This evolution towards software-based systems has been in the works for several years, but is now becoming possible thanks to improved performances from all of these reconfigurable components, including those that are the closest to the elementary tasks of wireless communications (detection, baseband coding, bitstream management, frequency handover, signal processing, etc.).

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[14] https://5g-ppp.eu/wp-content/uploads/2016/11/06_10-Nov_Session-3_Lee-JunHwan.pdf

1.5 Technological building blocks to achieve the objectives

1.5.1 Air interface

Several, sometimes competing radio access technologies are currently being examined. Some have already been pre-implemented by equipment manufactures and can be used in trials, notably massive MIMO and NFV. Others, such as NOMA modulation and mobile edge computing (MEC), will no doubt take longer before they are ready to be used. In any event, a consensus – which could be painful for certain suppliers whose investments will be lost – will need to be found when defining 5G standards, to ensure the systems' interoperability.

The technologies currently being examined are the following:

- **Millimetre wave frequencies**: the use of millimetre wave frequencies constitutes one of the disruptive 5G technologies. The term refers to the frequencies above 6 GHz which have never been considered for mobile fronthaul network rollouts, for reasons of technological maturity and propagation quality. To meet the demand for ever increasing data rates and traffic volumes, new bands with very wide channels (over 100 MHz per user) will need to be employed: millimetre wave frequencies could provide this spectrum resource, and in certain cases their use would make it possible to achieve the data rates listed in Table 1. Comparisons between 4G and 5G). In exchange, to be able to use these frequencies all of the required, miniaturised low-cost technologies will need to be developed, and ensure a level of energy consumption that is compatible with portable devices (amplifiers, coders, signal processing, antennae, etc.). In particular, because of millimetre waves' poor propagation quality, each cell will have limited coverage and so require the use of beamforming (described below) to better focus the power transmitted by the antenna.
- **Massive MIMO** (Multiple Inputs – Multiple Outputs): this technology involves the use of a large number of smart micro-antennae, located on the same panel (between eight and 128 today, but the number will increase with the use of frequencies above 6 GHz). The appeal of using massive MIMO is twofold: first, the technology makes it possible to increase data rates, thanks to spatiotemporal multiplexing; second, it makes it possible to focus energy on a device to improve its link budget, thanks to beamforming.

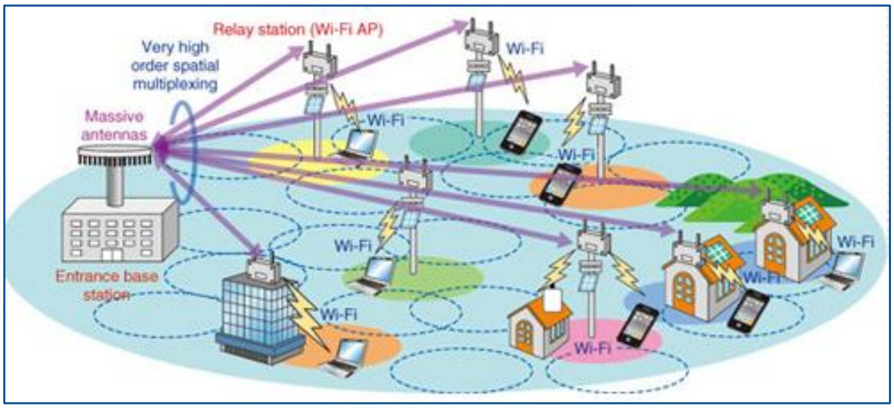
Relay station (Wi-Fi AP)
Very high order spatial multiplexing
Massive antennas
Entrance base station
Wi-Fi
Wi-Fi
Wi-Fi
Wi-Fi
Wi-Fi
Wi-Fi
Wi-Fi
Wi-Fi

Figure 9. Example of the use of a beamforming antenna to connect Wi-Fi access points[15]

- **Full Duplex**: in classic systems, transmission and reception takes place either on different frequency bands, i.e. frequency division duplexing (FDD) used on all mobile network bands in France, or at different times: time division duplexing (TDD), the top contender for LTE wireless local loop networks in France. The full duplex is intended to enable the simultaneous transmission and reception of data, on the same frequencies, at the same time and in the same location.[16]

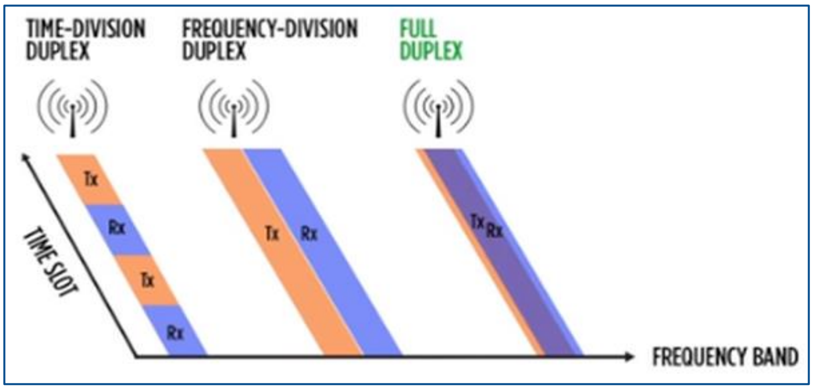
TIME-DIVISION DUPLEX
FREQUENCY-DIVISION DUPLEX
FULL DUPLEX
TIME SLOT
Tx
Rx
Tx
Rx
Tx
Rx
Tx Rx
FREQUENCY BAND

Figure 10. Illustration of full-duplex, compared to FDD and TDD[17]

- **NOMA Multiplexing** (Non Orthogonal Multiple Access): LTE uses what is referred to as orthogonal multiplexing, with each device using a portion of the resource blocks in a unique fashion at any given time. For 5G to provide improved spectrum efficiency compared to 4G, the plan is to use non-orthogonal multiplexing methods, whereby several users can use the same frequencies at the same time. A distinction can be made between several users by assigning different codes to each user – referred to as SCMA or sparse code multiple access – a combination of 3G's code division multiple access (CDMA) and 4G's orthogonal frequency division multiple access (OFDMA) or by playing on the difference in users' signal to noise ratios (power domain NOMA[18], illustrated below). These are the two methods chosen for NR.

---

[15] https://www.slideshare.net/100001290086432/massive-mimo

[16] The basic operating principle is the following: an antenna sends a signal at the same time as it is receiving signals coming from devices in the cell. However, the signal received by the antenna is a combination of the signal sent by itself and signals coming from the devices (everyone is "talking" at once). As it knows which signal it itself has sent, the antenna can subtract it during digital processing from the ones it received. So only the signals received from the devices remain.

[17] http://compeng.columbia.edu/biggest-component-full-duplex-wi-fi-radio-antenna

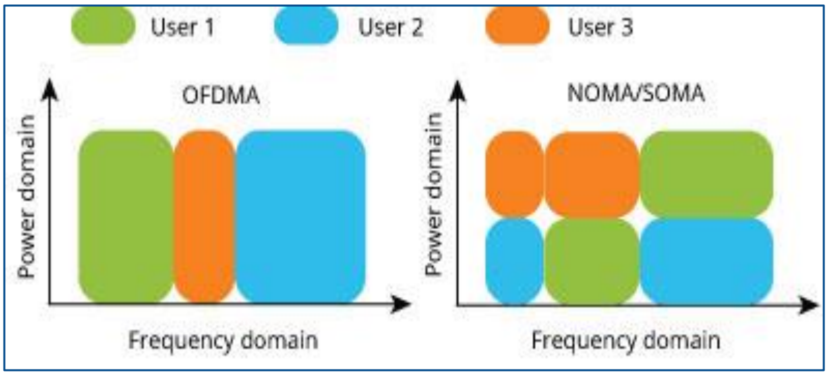

Figure 11. Illustration de multiplexing *power domain* NOMA[19]

- **QAM256**: as with many modern communication systems, 4G uses quadrature amplitude modulation (QAM). In 4G this modulation can achieve QAM64, which means that six bits of information are being transmitted ($2^6 = 64$) at any given time. On wireless systems, the main limitation on QAM order is the signal to noise ratio: when a large amount of information is sent all at once, its transmission will be very sensitive to disruptions (a bit like trying to talk in a noisy environment: it is easy to understand "yes" or "no" but harder to understand more complex sentences). Thanks to an improved link budget, via antenna or signal processing technologies, 5G modulation could reach QAM256, i.e. eight bits of information being transmitted at any given time, which translates into a 33% increase in maximum capacity under ideal conditions. This improved modulation will also be deployed on advanced 4G systems.
- **IoT waveforms**: new waveforms are being explored for the future deployment of 5G IoT in mobile bands. But although mass market IoT is one of the main challenges put forth for 5G, no concrete results have yet been made public. Operators[20] are starting to deploy new standards (EC-GSM or Extended Coverage GSM, LTE-(e)MTC or enhancements for Machine-Type Communications, NB-IoT or NarrowBand IoT) which were defined by 3GPP in Release 13 but, as they are based on 2G and 4G, they do not deliver the performance levels, notably in terms of autonomy, coverage and density, that are compatible with the targets set for future 5G networks.

1.5.2 Network architecture

As with air interfaces, new network architectures are also being explored:

- **Software-defined networking (SDN) and network functions virtualisation (NFV)**: these two functionalities extend beyond the scope of 5G networks per se. They are part of an overall process of network upgrades taking place today and already available with 4G technology (4.9G). The nevertheless remain a key enabler of 5G:

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[18] The basic operating principle is the following: either User 1 (U1) with a good signal to noise ratio and User 2 (U2) with a less good signal to noise ratio. The antenna sends a high power Signal 2 to U2, and superimposes a weaker Signal 1 aimed at U1. U2 will only see S2 as S1 is drowned out by the noise. U1 will decrypt S2 then delete it from the signal received, to create a higher quality S1, thanks to a better signal to noise ratio.

[19] https://www.anritsu.com/en-AU/test-measurement/technologies/5g-everything-connected/5g-everything-connected-detail

[20] http://www.vodafone.com/content/index/what/technology-blog/nbiot-commercial-launch-spain.html

  - SDN (Software-Defined Network) is designed to disassociate the network's control plane from its data plane, these two planes traditionally being linked and distributed in a set fashion in the network (see diagram below). Controlling the network, a task previously assigned to specialised and unscalable hardware components, is centralised in the form of software on more powerful servers and, in theory, free of equipment manufacturer specifications. This enables the deployment of high value-added services (load balancing, smart routing, dynamic configuration, etc.) in disparate environments.

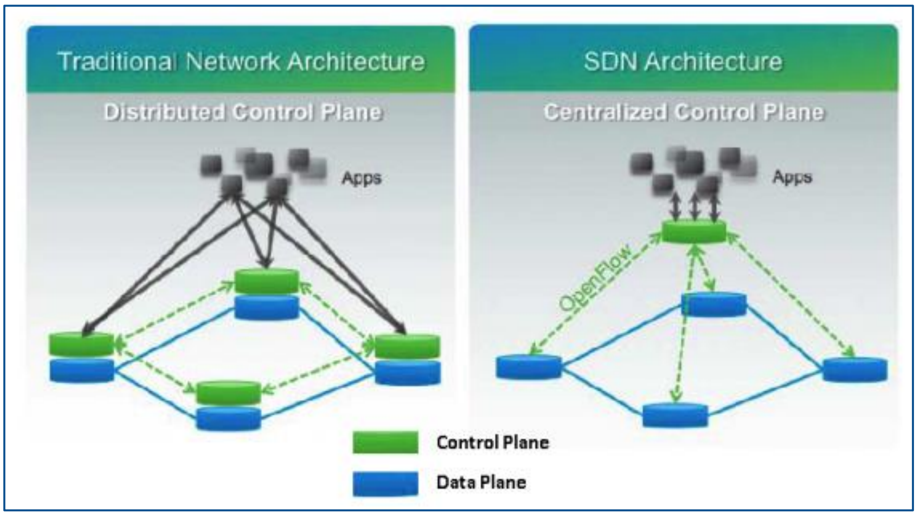
Traditional Network Architecture
Distributed Control Plane
Apps
SDN Architecture
Centralized Control Plane
Apps
OpenFlow
Control Plane
Data Plane

Figure 12. Centralisation of the control plane in a software-defined network[21]

  - NFV, which builds upon SDN, is used to virtualise, in other words to replace hardware designed specially to perform certain key network functions (firewall, network core, interfaces between different systems…) with software on a server, to accelerate rollouts and enable rapid changes and upgrades.

- **CloudRAN**: this functionality, also know as centralized-RAN, requires a very different network architecture to what we find today. It is an evolution of SDN: the base stations' signal processing units, currently installed at the base station level, are moved to the cloud and centralised. They communicate with the network radio heads, located closer to the antenna, over an optical fibre network (Radio over fibre technology). This centralisation makes it possible to obtain a complete overview of all of the stations deployed and to coordinate signal processing and manage interference between cells and devices

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[21] http://www-igm.univ-mlv.fr/~dr/XPOSE2014/software-defined_networking/sdn.html

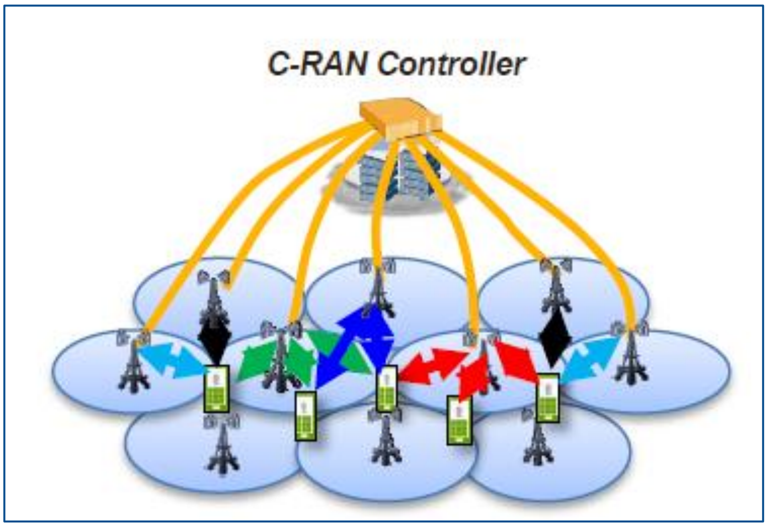

Figure 13. Illustration of CloudRAN[22] network architecture

- **Optimised content delivery, using a mobile content delivery network (mobile CDN)**: corresponds to a set of servers working together in a transparent fashion to optimise the delivery of content to end users over wireless (mobile or Wi-Fi) networks, with high availability and performance. With 5G, the objective for these CDN is to cache content close to users, notably thanks to predictive algorithms, to offload traffic from the networks and decrease latency.
- **MEC (mobile edge computing)**: MEC is an evolution of mobile CDN whose purpose, in addition to bringing data closer to devices, is to provide devices with an accessible computing power with very low latency, within a very specific area for demanding applications. This technology makes it possible to locate a portion of the network's intelligence (managing local critical applications and performance analysis) at the base station level. The "antennae" will be capable of analysing a certain number of data, and so to make decisions very quickly.
- **Device-to-device**: D2D is a direct form of communication between two nearby devices, which does not require the data to travel over the cellular network. Device-to-device communication is not new, as technologies such as Bluetooth and Wi-Fi direct already enable it. But a new mesh networking technology will be introduced with 4.9G and later 5G network rollouts: LTE-direct. Far more energy-efficient than its predecessors, this technology will have a range of up to 500 metres and geolocation capabilities to enable communications. This technology will be very useful for low latency V2V (vehicle-to-vehicle) or V2X (vehicle-to-everything) communications and for certain public-security related uses.

1.5.3 5G: a multi-technology generation cohabitating with existing networks

As stated earlier, 5G is not meant to replace 4G overnight. In practice, the devices will undoubtedly be multi-modal: still connected to the 4G network, which will provide extended coverage for pioneer rollouts, then transitioning to 5G networks when they become available.

While 4G and 5G frequencies will probably be initially segregated, in all likelihood devices will rapidly become capable of aggregating 4G and 5G carriers and, further down the road, 4G carriers will be encapsulated in 5G ones.

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[22] https://5g-ppp.eu/wp-content/uploads/2016/11/04_10-Nov_Session-3_Takaharu-Nakamura.pdf

4G is still being deployed, and its technological evolution and certain building blocks will be used by both the first 5G networks and advanced 4G networks. To wit, the latest trials conducted in France are allowing 4G networks to perform better thanks to the use of pre-5G technologies:

- Bouygues Telecom, in partnership with Huawei, managed to achieve a peak data rate of 1 Gbps thanks to the simultaneous use of four-carrier aggregation (800 MHz, 1800 MHz, 2100 MHz, 2600 MHz) and more powerful modulation (256 QAM)[23];
- In the coming weeks, Orange will be launching a massive MIMO (16x16) trial with Nokia[24].

In addition to the strong integration between 4G and 5G, the new generation will no doubt also continue convergence efforts between frequency bands governed by exclusive licences – i.e. bands that are allocated exclusively to an operator, such as mobile operators – and unlicensed frequency bands, governed by a system of general authorisation (e.g. Wi-Fi bands), which already began in 4G with LTE-LAA (Long Term Evolution – License Assisted Access) and LTE-LWA (Long Term Evolution – Wi-Fi Link Aggregation).

LTE-LAA is characterised by the aggregation of one or several LTE carriers, used in licensed bands, with other LTE carriers employing unlicensed 5 GHz Wi-Fi bands. To guarantee cohabitation with very widespread Wi-Fi networks whose deployment pattern is unpredictable, it uses LBT (Listen Before Talk) technology to listen to the radio channel before transmitting, in order to determine whether or not a frequency is available.

LTE-LWA consists of an aggregation of LTE carriers in licensed bands with Wi-Fi traffic. To achieve this, the LTE cell and Wi-Fi access point need to be connected: the Wi-Fi traffic is sent to the cell which sends back the entire aggregated link on the 4G core network. This technology is particularly well suited to indoor environments with small cells, a system which, as detailed in paragraph 3.3 below, will lend itself well to 5G deployments.

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[23] https://www.corporate.bouyguestelecom.fr/wp-content/uploads/2016/05/Communiqu%C3%A9-Bouygues-Telecom-et-Huawei-Technologies-r%C3%A9alisent-un-test-de-d%C3%A9bit-4G-%C3%A0-plus-de-1-Gbps-pour-la-premi%C3%A8re-fois-en-Europe-de-lOuest.pdf

[24] https://networks.orange.fr/actualites/actualites-des-networks/orange-et-nokia-partners-pour-developper-les-futurs-services-5g

2 5G development initiatives

With a view to keeping the many promises being made for 5G, a number of initiatives are currently underway around the globe to promote its development. Below, we detail the foremost initiatives put forth by the players with which Arcep met as part of its investigation.

2.1 Government initiatives

The prospect of significant socio-economic repercussions generated by 5G (possible revenue of close to $225 billion a year[25] by 2025) combined with many countries' desire to establish themselves as technological leaders and make their companies more competitive, have propelled a multitude of government initiatives around the globe, aimed at encouraging the mobile ecosystem to begin the work and make the investments required to drive the rapid construction of the first 5G networks.

A selection of the largest initiative is detailed below.

2.1.1 In Europe

5G-PPP

The 5G Public Private Partnership (5G-PPP) is dedicated to 5G research and development, created on the initiative of the European Commission in 2013, with a budget de €700 million in public funding. The main objectives set by 5G-PPP are:

- Create stronger ties between the economic players and academic bodies devoted to the telecommunications sector over R&D projects, along the entire value chain;
- Reduce technological dependence on the United States and Asia while sustaining a strong global market;
- Regain technological leadership, notably in disruptive technologies, by promoting standards in international bodies;
- Allow innovative business models to emerge;
- Facilitate large-scale experimentation.

The results of this work will help clarify the 5G action plan (see below), and fuel the standardisation work that is currently underway.

To achieve its ambitions, 5G-PPP has initiated three stages of work, financed by the European Union, whose roadmap is in sync with the main international initiatives (3GPP and ITU, cf. Figure 14):

- The first stage which is currently underway, will last until mid-2017;
- A second stage focused on systems optimisations, from the end of 2017 to mid-2019;
- And finally a full-size trial stage from 2019 to 2020.

Deploying 5G by 2020 will require Europe to develop leading edge technologies, globally approved standards and especially to achieve consensus over the most suitable frequency bands. This funding and these projects – involving a great many researchers from more than a hundred companies and the finest R&D centres in Europe – are thus vital.

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[25] https://www.abiresearch.com/press/abi-research-projects-5g-worldwide-service-revenue

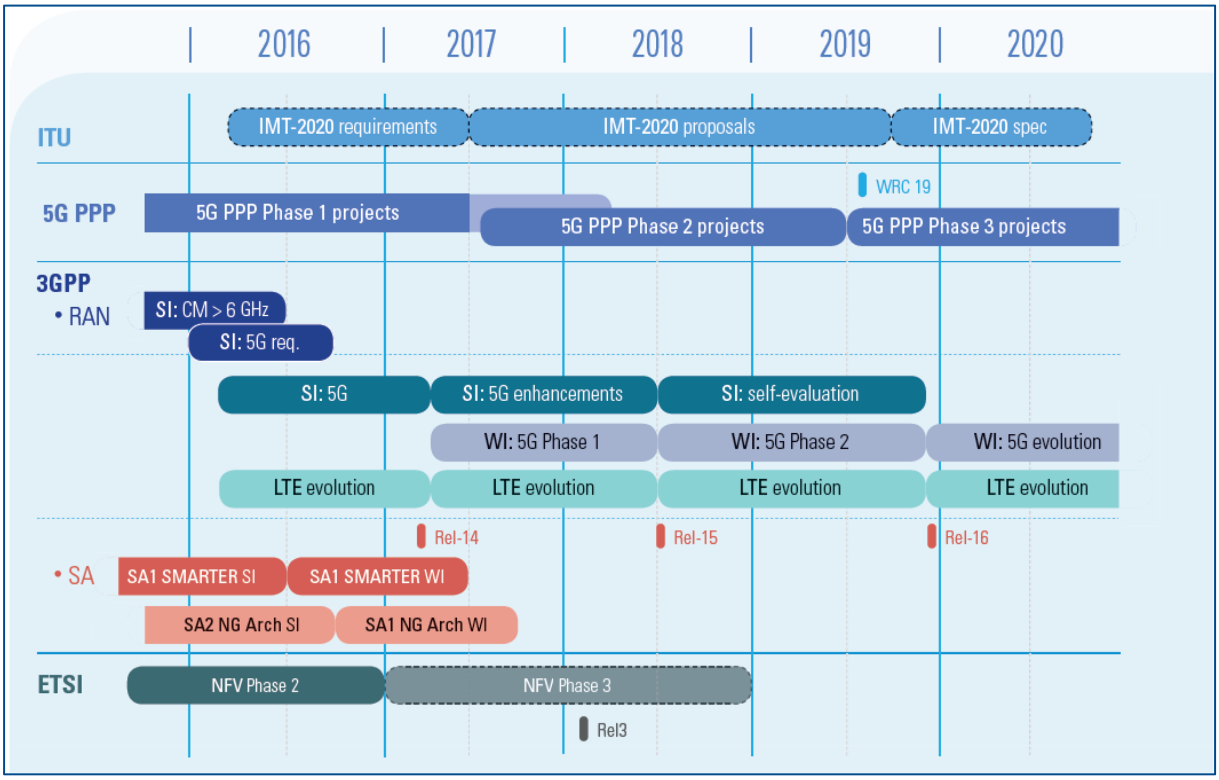
2016
2017
2018
2019
2020
ITU
IMT-2020 requirements
IMT-2020 proposals
IMT-2020 spec
WRC 19
5G PPP
5G PPP Phase 1 projects
5G PPP Phase 2 projects
5G PPP Phase 3 projects
3GPP
• RAN
SI: CM > 6 GHz
SI: 5G req.
SI: 5G
SI: 5G enhancements
SI: self-evaluation
WI: 5G Phase 1
WI: 5G Phase 2
WI: 5G evolution
LTE evolution
LTE evolution
LTE evolution
LTE evolution
Rel-14
Rel-15
Rel-16
• SA
SA1 SMARTER SI
SA1 SMARTER WI
SA2 NG Arch SI
SA1 NG Arch WI
ETSI
NFV Phase 2
NFV Phase 3
Rel3

Figure 14. 5G PPP vs. 3GPP and ITU roadmaps[26]

5G action plan

As a complementary measure, on 14 September 2016 the European Commission launched its *5G for Europe Action Plan* to bolster investments in 5G infrastructure and service rollout efforts in the Digital Single Market between now and 2020. This action plan sets out a clear roadmap for public and private 5G investments inside the EU.

The Commission has proposed the following measures to achieve this plan:

- Align roadmaps and priorities for a coordinated 5G deployment across all EU Member states, targeting early network introduction by 2018, and moving towards commercial large scale introduction by the end of 2020 at the latest.
- Make provisional spectrum bands available for 5G ahead of the 2019 World Radio Communication Conference (WRC-19), to be complemented by additional bands as quickly as possible, and work towards a recommended approach for the authorisation of the specific 5G spectrum bands above 6GHz.
- Promote early deployment in major urban areas and along major transport paths.
- Promote pan-European multi-stakeholder trials as catalysts to turn technological innovation into full business solutions.
- Facilitate the implementation of an industry-led venture fund in support of 5G-based innovation.
- Unite leading actors in working towards the promotion of global standards.

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[26] 5G Empowering vertical industries. White Paper, 2016, https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

The European Commission has given every EU country a certain number of ambitious, numerical targets. One core objective for 5G is thus to have at least one major city in every European country outfitted with this new generation mobile system by 2020, and coverage of every city, motorway and high-speed railway lines by 2025. This comes in response to announcements from South Korea and Japan which are both promising large-scale 5G demonstrations, respectively, at the Winter Olympics in Pyeongchang in 2018 and the Summer Olympics in Tokyo in 2020.

2.1.2 Worldwide (examples in the US, South Korea, Japan and China)

The race is already underway between countries to be the first to begin large-scale 5G trials, and later to introduce commercially available services, so much so that they are willing to employ pre-standard technical specifications.

Several countries are therefore working on standards and seeking to reach a consensus with one another to achieve international backing for the technical specifications that will satisfy their needs, and earn them the best possible return on the investments made thus far. This in turn is creating a certain turmoil, for instance, over the frequency bands that would be the best candidates for 5G.

The United States[27]

5G is seen as an unprecedented opportunity for economic growth, with a tremendous impact on education, job, transportation, etc. According to the US federal regulator, the FCC (Federal Communications Commission), the following three elements in particular need to be the prime focus of attention: spectrum, infrastructure and the backhaul network:

- **Spectrum**: in July 2016, the FCC voted to free up and to open up nearly 11 GHz of high frequency spectrum to be used for fixed and mobile broadband applications: 3.85 GHz of licensed spectrum in the 27.5 – 28.35 GHz and 37 - 40 GHz bands, as well 7 GHz of unlicensed spectrum from the 64 - 71 GHz band. The FCC's stated goal was to provide the assurance and clarity for investments in the telecoms sector. Verizon welcomed this decision, and plans on achieving the first rollouts in 2017, with trials already underway in several cities around the country (cf. 3.3).
- **Infrastructures**: The FCC believes that 5G must be underpinned by a robust infrastructure network capable of handling already heavy traffic that could potentially increase exponentially in the coming years. It will interact in a hybrid fashion between traditional towers with macro cells and small cell deployments, as well as distributed antenna systems. With an eye on the deployment of new towers, the FCC resolved to reduce, or eliminate in certain cases, the regulatory restrictions on installing facilities and antennae that will have very little impact "on historic properties" (tower re-use, small antennae, indoor installations, etc.)[28].
- **Backhaul network**: Because 5G systems will require very high-power backhaul networks, the FCC is in the process of reforming and updating the regulations governing data services markets, including wireless backhaul solutions. The FCC is seeking to protect this market while also creating competition, so that competitive and high quality backhaul network solutions can emerge.

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[27] Forging Our 5G Future – Federal Communications Commission: https://www.fcc.gov/5G

[28] https://apps.fcc.gov/edocs_public/attachmatch/DA-16-900A1_Rcd.pdf

Japan

Japan wants to demonstrate its 5G leadership by deploying the first commercial 5G network that complies with international technical specifications, in time for the Summer Olympic Games in Tokyo in 2020.

According to the *Radio Policies Towards 2020*[29] report, published in June 2016 by Japan's Ministry of Internal affairs and Communications (MIC), the 3600 - 4200 MHz, 4400 - 4900 MHz and 27.5 – 29.5 GHz bands were selected to be the 5G candidate bands on a national scale. Although other bands are also being investigated, with a view to WRC19, 5G rollouts are already planned in the 3600 - 4100 MHz, 4405 - 4895 MHz and 27.5 - 28.28 GHz bands as early as 2017 in Tokyo, and will be built out in 2018 and 2019.

China

Like Japan, China too wants to prove its leadership with the first commercial rollouts in 2020. The first trials will be conducted that year in the 3400 – 3600 MHz band. The 3300 - 3400 MHz, 4400 - 4500 MHz and 4800 - 4990 MHz bands are also under consideration and currently being investigated. For higher speeds, the country plans on using spectrum around the 25 GHz and 40 GHz frequencies.

South Korea

South Korea, meanwhile, has set its sights on a pre-commercial 5G service that would be ready in time for the 2018 Winter Olympics in Pyeongchang. Several trials are already underway to prepare for full scale demonstrations in several South Korean cities, including Pyeongchang and Seoul. The country's three national mobile operators are hoping for spectrum in the 26.5 – 29.5 GHz bands.

South Korea's largest mobile operator, SK Telecom, has announced a plan for conducting interoperability tests with Qualcomm and Ericsson, as well as outdoor trials of the new air interface based on the 3GPP NR standards that are being developed today. These trials and experiments will be carried out in the second half of 2017.

If the goal of these trials is to help accelerate the specification of the new NR air interface, which is part of the work being done on 3GPP Release 15, it has not yet been specified which frequency bands will be used for these trials.

2.2 A host of private initiatives – a few examples

5G Open Trial Specification Alliance

In early 2016, South Korean operators KT and SK Telecom, Japanese carrier NTT DoCoMo and American carrier Verizon formed the 5G Open Trial Specification Alliance to carry out collaborative 5G trials.

Due to be conducted between 2016 and 2018, the aim for these trials is to provide a common platform for operators, for exchanging results and shared assessments of the different 5G network components and elements. One of the operators' objectives is to help accelerate the definition of standards and specs, and to enable economies of scale. The findings of these evaluations will provide input for 3GPP discussions, adding simulations to the experimental data produced by the partnership.

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[29] http://www.gsma.com/spectrum/wp-content/uploads/2016/08/MIC_Spectrum-for-5G-MIC-Kuniko-OGAWA.pdf

The alliance’s founders hope to attract a number of industrial partners to the platform, including other carriers, equipment suppliers, chipset makers, etc. Several of the founding operators’ equipment suppliers are already involved in the scheduled trials.

The trials will cover multiple frequency bands, both above and below 6 GHz.

Verizon 5G Technical Forum

The Verizon 5G Technology Forum (V5GTF) was created in late 2015 by Verizon, in cooperation with its partners Cisco, Ericsson, Intel, LG, Nokia and Qualcomm. The goal of the collaboration is to provide a platform for testing radio interface specifications in the 28 and 39 GHz bands.

The first fruit of this collaboration, in July 2016 Verizon announced the completion of the first specifications of their 5G radio interface. These specs should enable the different parties involved to develop interoperable solutions and so to help drive forward the definition pre-standards.

Even though they run the risk of developing solutions that are not compatible with 3GPP or ITU standards, Verizon believes it has a solid enough grasp of the overall concepts being discussed in those bodies. The tests carried out in several US cities were thus able to validate substantially greater capacities than 4G.

Orange/Ericsson

Orange and Ericsson have been working together since October 2016 on developing 5G use cases and services, as well as demonstrations. The purpose is to develop technological building blocks, conduct trials and pilot projects for a range of use cases, including multi gigabits/s wireless internet access in suburban and rural environments, the Internet of Things and connected cars.

Their collaboration made it possible to achieve 15 Gb/s in a laboratory environment, notably thanks to the use of massive MIMO and beamtracking using centimetre waves. The collaboration will also focus on the transition from 4G to 5G solutions, notably in terms of reducing costs and improving energy efficiency, and on the use of SDN and NFV technologies.

Since January 2017, the partnership has included PSA (Peugeot) to carry out trials on connected cars.

5G-ConnectedMobility

5G-ConnectedMobility is a consortium formed by Ericsson, BMW, Deutsche Bahn, Germany’s three mobile operators, Deutsche Telekom, Telefonica Deutschland and Vodafone, the 5G TU Dresden laboratory, the BAST research institute and BnetzA, with the goal of galvanising and accelerating 5G R&D in Germany.

5G-ConnectedMobility thus plans on supplying a digital motorway infrastructure and real application environment to be able to test V2V (vehicle-to-vehicle) technologies as well as solutions for digitising railway infrastructure.

To this end, 5G-ConnectedMobility operates with the help of an independent network infrastructure that is not connected to any commercial network. The Ericsson mobile network devoted to this project makes it possible to run live tests: Ericsson thus obtained permission from regulator BNetzA to employ spectrum in the 700 MHz band in the Nuremberg area.

3 The challenges of 5G

In this part we explore the different challenges that lie ahead for 5G, which emerged from the interviews that Arcep conducted over the past several months.

3.1 New business models focused on vertical markets

3G and especially 4G technologies were designed primarily for the superfast mobile internet. 5G continues on in this direction, but also wants to target what are known as vertical markets, which encompass several segments, including:

- Connected vehicles, not only to deliver entertainment and information to passengers, but also to guarantee safety via communications both between vehicles and between vehicles and infrastructure;
- Factories of the future;
- Smart cities with requirements in the areas of public transportation (similar to the needs of connected vehicles), the environment, managing buildings and energy consumption;
- Medicine, healthcare and robot-assisted telesurgery;
- Smart grid flow monitoring and management (electricity, gas, water, etc.).

This section will focus in particular on the connected car and factories of the future segments. Because of their current and future macro-economic context, along with the plurality and effervescence of the pioneer work being done in these areas, these two segments constitute the main avenues of 5G development in vertical markets. Smart cities and smart grids have already begun to soar through existing Internet of Things (IoT) technologies.

3.1.1 The automotive sector

The car is an extremely common form of transportation, and safe driving is a fundamental consideration: human error is the number one cause of all transport accidents. The transportation sector wants to use technological innovations to tackle this problem, and to continue to make transportation more efficient, more sustainable and safer.

There are three areas in which technological progress could help improve automotive transportation. 5G could have a role to play in all three, but particularly in the first two:

- Provide in car internet connectivity, to deliver entertainment to passengers;
- Provide access to driver assistance information, to reduce accidents and improve the fluidity of traffic;
- And, finally, the ability to make cars autonomous, thanks to artificial intelligence algorithms.

The first area is just an extension of the developments occurring today around 4G. The aim is to give passengers access to their messaging services, to the internet, to multimedia content, online gaming, etc. The increased connection speeds promised by 5G will improve the use of all of these services.

The second area aims to make cars more intelligent by using information that was not previously available to them. This in turn will help improve the safety and efficiency of the networks as well as help drivers make the right decisions, and adapt to driving conditions. Such connected vehicles could have access to information about dangers on the road (slow or stopped cars, traffic jam warnings, indications of where construction is taking place on the roads, weather conditions, emergency braking, emergency service vehicles approaching, etc.) or regarding signage (signalling/signage onboard vehicles, speed limits on vehicles, failure to heed signage/safety precautions at crossings, request for right-of-way at traffic lights for designated vehicles, green light optimal speed advisory, etc.). Other services, such as information on refuelling or recharging stations, vulnerable road user protection, managing street parking and traffic information, and smart guidance, could also prove useful. It is still not clear whether, to achieve this, vehicles will simply exchange information with each other or if connectivity with infrastructure will be required along the roads to optimise vehicles' behaviour. In both instances, 5G could have a role to play.

Of the many initiatives that are already underway we can begin with an example from France: the SCOOP@F[30] (cooperative intelligent transport systems) project coordinated by the Ministry of the Environment, Energy and the Sea, and which unites local authorities and R&D centres. Launched in February 2014, new partners subsequently joined the initiative, including Orange and Austrian, Spanish and Portuguese partners. As it is a European project, it receives 50% of its financing from the European Commission, and cross-tests are conducted with Austria, Spain and Portugal. SCOOP@F is a pilot rollout project for cooperative intelligent transport systems; it aims to deploy 3,000 vehicles on 2,000 km of roadway spread across five locations: Ile-de-France, the A4 motorway, the Isère, and ring roads in Bordeaux and Brittany. Its main objectives are to improve road safety and the safety of roadway workers, achieve more efficient traffic management, reduce pollution, streamline infrastructure management costs and participate in defining the car of the future.

In addition, in early 2017, mobile carrier Orange, equipment supplier Ericsson and car-maker PSA Group signed a partnership agreement[31], as part of the "*Towards 5G*" initiative, to conduct technical trials relating to 5G. The aim of this alliance is to test the different paths of technological evolution from 4G to 5G to meet the needs of connected cars, notably in terms of intelligent transport systems (ITS), for safer driving and new on-board services.

The third area concerns the emergence of autonomous vehicles. A number of projects are underway in this area. The first step is to outfit vehicles with algorithms that enable it to make decisions quickly based on their environment. This requires a large number of sensors to deliver a full "understanding" of what is happening around the vehicle. Without pre-judging the technologies that will ultimately be employed to achieve this, as with a human driver (see above), the car could take advantage of connections with other vehicles on the road and with an infrastructure, to have access to all of the aforementioned information.

3.1.2 Industry 4.0

Competitiveness does not depend solely on innovation and the evolution of products, but also on modernising businesses and their means of production. According to certain studies carried out in 2015[32], the digital transition in Europe will enable enterprises to increase their revenue by more than 110 billion euros a year over a five-year period.

A great many countries have set out a strategy for modernising their manufacturing infrastructure (*l'industrie du futur* in France[33], Industry 4.0 in Germany…) of which one aspect will involve digitising processes and trade. The European Commission itself introduced measures in 2016 for strengthening competitiveness in Europe, in which 5G could play a significant role. This included earmarking 500 million euros for the Horizon-2020[34] research programme.

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[30] http://www.scoop.developpement-durable.gouv.fr/spip.php?page=sommaire

[31] http://www.orange.com/fr/Press-Room/communiques-2017/Ericsson-Orange-et-le-groupe-PSA-partners-pour-la-voiture-connectee-en-5G

[32] PwC, "Industry 4.0: Opportunities and challenges of the industrial internet" (2015), and Boston Consulting Group, "Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries" (2015)

[33] http://www.economie.gouv.fr/files/files/PDF/industrie-du-futur_dp.pdf

The advent of new technologies (4G, fibre and soon 5G) and new services (the Internet of Things, the cloud, big data) should facilitate businesses' digital transition. 5G in particular is expected to be a very versatile technology, capable of undergirding a very wide array of uses, and could go a long way in furthering companies' transition to digital technologies and solutions.

3.2 Spectrum harmonisation

5G is emerging as a technology that will use both low frequencies (f < 1 GHz), high frequencies (1 GHz < f < 6 GHz) and, for the first time ever in consumer networks, very high frequencies referred to as "millimetre wave" frequencies (f > 6 GHz).

This spectrum diversity is entirely bound up with the promises of 5G: extended coverage (low frequencies), ultra high speeds (very large channels in very high frequency bands), low power consumption. Furthermore, satellite services will also contribute to the development of this new technology, especially in areas that are difficult to cover and to provide backhaul solutions. The satellite industry is thus taking an interest in 5G, and wants to be involved in defining these new generation network.

3.2.1 Millimetre wave frequencies

The "millimetre" band, also referred to as millimetre wave spectrum, aka frequencies above 6 GHz, are essential to enabling 5G to mark a departure from 4G, for the reasons cited in Section 1.5.1.

At the latest World Radiocommunications Conference (WRC-15 in Geneva), a conference under the aegis of ITU whose objective is to change the way frequencies are allocated between users, discussions over the definition of future mobile bands made it possible to focus future 5G studies, for millimetre wave frequencies, on a certain number of bands situated between 24 GHz and 86 GHz (33.25 GHz identified in total): 24.25 - 27.5 GHz, 31.8 - 33.4 GHz, 37 – 43.5 GHz, 45.5 - 50.2 GHz, 50.4 - 52.6 GHz, 66 - 76 GHz, 81 - 86 GHz.

It is important to stress that, even if the above-listed bands have been identified as "5G bands", at this stage there is no way to know whether they can actually be used to deploy this new generation system: only the results of technical studies will make it possible to establish the constraints and rules of compliance, and to validate the feasibility of these hypotheses.

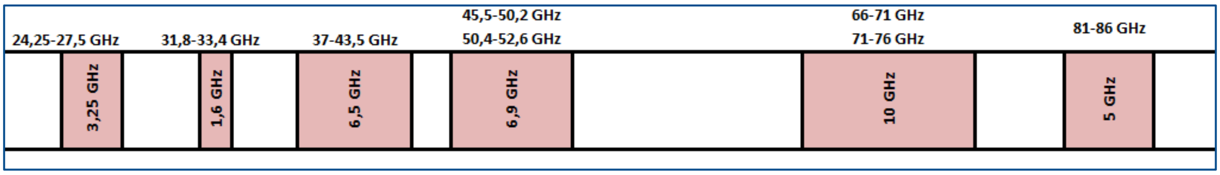

Figure 15. Millimetre wave frequencies identified at WRC-15

Contrary to the conclusions of the Conference, which reflect European recommendations, the United States and certain Asian countries (South Korea, Japan) have decided to perform 5G trials in the 28 GHz band, and equipment suppliers such as Qualcomm and Samsung, have begun manufacturing 28 GHz- band products.

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[34] https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020

Meanwhile Europe, following the publication of an RSPG (Radio Spectrum Policy Group within which France is represented by ANFR) opinion[35], decided to focus its first studies on the 26 GHz band (pioneer band), then on the 32 GHz and 42 GHz bands. Later, studies will be carried out on introducing 5G in all of the other bands identified by WRC-15.

The rapid choice of the 26 GHz band as the pioneer band was made to enable economies of scale for equipment production, since it is very likely that dual-mode equipment, i.e. compatible with both the 26 GHz and 28 GHz band, will be available for pioneer rollouts[36].

In France, the 26 GHz band is already being employed for a variety of uses: mobile operators' wireless fixed links (4G infrastructure links), fixed satellite service systems and ground stations for space services. Studies will therefore need to be conducted to take these services into account, and define either the cohabitation or migration of applications to other millimetre wave frequencies.

3.2.2 Frequency bands below 6 GHz

a) The 3.4-3.8 GHz band

It will not be possible for 5G to run entirely on millimetre wave frequencies: the propagation qualities of these bands make it difficult to achieve widespread coverage, particularly in more sparsely populated areas. In addition, these bands are still lacking in technological maturity when it comes to delivering consumer market communication services. As a result, a "core" band below 6 GHz needs to be identified: one that provides sufficiently large channels to enable future 5G operators to provide innovative services and a higher quality of service than with 4G.

The 3400 - 3800 MHz band appears to be a good candidate.

First, it has already been harmonised for ultrafast mobile services inside the European Union. Initially the 3400 - 3600 MHz band and later the 3600 - 3800 MHz band were identified as the "IMT" bands (for high-speed mobile). Second, they have a great deal of available spectrum (up to 400 MHz). Lastly, technological advancements (antenna and signal processing) make these frequencies compatible with their use to establish macro cells, and not only microcells. To give an example, it emerged from the interviews conducted by Arcep that coverage with this band could be similar to coverage with the 2.6 GHz band, the core 4G frequency band.

This analysis has been confirmed by the European Commission (in its 5G mandate to RSCOM[37]) and by RSPG[38] which consider the 3.4 - 3.8 GHz band as the only credible 5G band for deployments taking place before the end of 2020.

In France, the band is assigned to Arcep, in a priority fashion, for the 3400 - 3600 MHz frequencies (and in a non-priority fashion to the Ministry of the Interior and the Ministry of Defence), and exclusively for the 3600 - 3800 MHz frequency bands. It is used for wireless local loop and satellite applications.

The compatibility of future uses with current applications is being examined by the Electromagnetic Compatibility Advisory Committee, which is chaired by the National Frequency Agency and of which

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[35] http://rspg-spectrum.eu/wp-content/uploads/2013/05/RPSG16-032-Opinion_5G.pdf

[36] The tuning range is vital here: a system capable of regulating its frequency from 26 to 28 GHz appears entirely technologically achievable within the timeframe for the first 5G millimetre wave deployments. This would have been less true if a switch between 28 and 32 GHz were required.

[37] https://circabc.europa.eu/sd/a/448dc765-51de-4fc8-b6e0-56ed6a1d0bca/RSCOM16-40rev3%205G%20draft_mandate_CEPT.pdf

[38] http://rspg-spectrum.eu/wp-content/uploads/2013/05/RPSG16-032-Opinion_5G.pdf

Arcep is a member: exclusion zones, protecting certain locations tied to long-term use of satellite solutions, need to be set up. Military radiolocation systems operating below 3.4 GHz also need to be protected.

b) Other bands below 6 GHz

The bands being used today for 2G, 3G and 4G could be used for future 5G deployments.

Refarming 2G, 3G and 4G could be a delicate undertaking, however, because of the duplexing methods they use. Most mobile communications in Europe use FDD (Frequency Division Duplexing)[39] to exchange information. Technical discussions over 5G are nevertheless anticipating that TDD (Time Division Duplexing)[40] will be the chief, if not sole, form of duplexing used for this new generation, notably because it makes it possible to adjust bandwidth to data rates and because it is particularly efficient when beamforming is used.

For 5G networks, using already harmonised mobile bands will thus require in-depth technical studies to define the terms and conditions of use and sharing with existing services. On this point, the ECC (Electronic Communications Committee[41]*)* decided to assess the potential of certain already harmonised bands, notably the 700 MHz and the L band (1427-1492 MHz).

In France, Arcep allocated the 700 MHz band to mobile operators in late 2015. Even if the country's four operators all obtained frequencies in this band, only Free Mobile, which has no blocks of 800 MHz spectrum, decided to begin its rollouts in the band using LTE (4G) technology.

Arcep is currently analysing the contributions to its public consultation, addressing among other the 3.5 GHz band, that ended recently.

The L band (1427 - 1518 MHz), which was defined to be used exclusively in SDL (Supplemental DownLink) mode, could be considered to meet the constant demand for ever higher data rates and the greater increase in downlink traffic, compared to uplink traffic. In France the band is used by wireless fixed links authorised by Arcep, by the Ministry of Defence for mobile services (excluding aeronautical) and by the Ministry of the Interior. Using it for 4G or 5G would therefore suppose moving the above-mentioned uses over to other bands.

3.3 Increasingly small cells

Today, mobile network rollouts are essentially based on the use of macro base stations: installations that are equipped with high-power antennae deployed to guarantee coverage for a relatively wide area, providing good quality of service. Network configurations are evolving constantly: new radio base stations are installed on a regular basis to increase the networks' capacity, to better meet users' needs in terms of indoor and outdoor coverage, and to improve quality of service.

However, this continually growing demand for capacity already requires operators to increase the density of their networks with smaller and smaller cells.

5G – which will probably bring about a sizeable increase in data traffic, and which will use millimetre wave frequencies whose propagation capabilities are weak – will no doubt require the widespread deployment of low-power base stations (small cells).

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[39] A technique that consists of sending and receiving data simultaneously, but on two different frequency bands.

[40] A technique that consists of sending and receiving data on the same frequency band but at different times.

[41] The European body that specifies the technical terms and conditions governing the use of frequency bands, which are then set by European Commission decisions.

To satisfy demand and enable the introduction of 5G, estimates indicate at least 10 small cells per macro base station in urban settings[42], where cells are already today relatively tightly meshed to handle traffic density.

Here, the players that met with Arcep raised several questions that will no doubt need to be answered when considering the ubiquitous deployment of small cells.

3.3.1 Taxation

The current regulatory framework stipulates that base stations whose power requires an opinion, an agreement or a statement from the National Frequency Agency (ANFR) are subject to a flat tax on network companies (IFER[43]). The amount of the tax varies according to transmission power, the type of installation and the deployment location. For a deployment in an urban area, the tax stands at €1,607/year/installation for a base station with an effective isotropic radiated power (EIRP) of more than 5W (a COMSIS agreement from ANFR is required to be able to transmit) and €160.70 €/ year/installation for an EIRP of between 1W and 5W (declaration to ANFR is required to be able to transmit).

5G small cells will likely use variable transmission powers of between 1W and 25W. In light of rollout density forecasts, hence the number of small cells to install, some of the stakeholders that Arcep met with raised the question of possibly adapting this tax in such a way as to enable massive small cell deployments without generating an equally massive increase in the total tax amount.

This process is already underway, notably with a view to decreasing taxes on base stations in locations that are hard to cover: Act No. 2016-1888 of 28 December 2016 on the modernisation, development and protection of mountain regions thus exonerates mobile base stations built in mountain regions between 1 January 2017 and 31 December 2020 from paying the IFER tax.

3.3.2 Access to elevated and "semi-elevated" locations

To perform their deployments successfully, mobile operators have traditionally needed to install their base stations in elevated locations (towers, rooftops, etc.). This will continue to be true with 5G networks, but will be even more challenging for two main reasons:

1. 5G antennae will probably be larger (in the m^2 range for some) than current 2G, 3G or 4G antennae, because of the above-mentioned massive MIMO processing that will require the use of a very large number of radiating elements. Moreover, additional antennae compatible with new 5G bands will no doubt also need to be deployed. So the re-use of existing masts could very well be problematic, and new (possibly collocated) transmission sites will need to be found.
2. This search for new sites will also need to be carried out to install small cells in semi-elevated locations, but with extra care as the density of these installations will undoubtedly be high: operators will thus be required to deploy their equipment on urban furniture and infrastructures such as bus shelters, lampposts, public buildings, billboards, etc.

As a result, public authorities will need to keep a close eye on the matter and, if necessary, adopt measures that will facilitate 5G rollouts.

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[42] http://www.lemag-numerique.com/wp-content/uploads/2015/10/WP_-Souverainete_Telecoms_PetitesCells_FINAL.pdf

[43] IFER = *Imposition forfaitaire sur les enterprises de réseaux*

3.3.3 5G networks’ regional coverage and backhaul

Ensuring regional connectivity will be one of the challenges for this new generation of mobile networks.

The diversity of use-cases envisioned for future 5G networks, the geographical distribution of which is not yet precisely known, must be factored in when addressing coverage issues.

The higher frequency bands that are being put forth for future 5G networks, along with the potentially very substantial bandwidth consumed by these new uses, pose the question of the regional foothold of these networks. As a matter of fact, mobile networks have never before employed such high frequencies whose use will require a large number of relay antennae to be installed.

Moreover, connecting the 5G installations to the network will push to the fore the question of the cost of connecting them via optical fibre, which will no doubt be necessary in most instances to ensure the expected quality of service. The industry needs to design the technologies that will make it possible to minimise the cost of 5G rollouts in rural areas.

3.4 Net neutrality issues

European regulation on safeguarding an Open Internet[44], adopted by the European Parliament and Council on 25 November 2015, for which European regulators required an additional nine months to specify the rules governing its application, introduces the principle of net neutrality as one of the top priorities in the standardisation hierarchy.

Net neutrality is an overriding principle that guarantees equal treatment for all data traffic on the internet. In particular, it excludes any form of discrimination with respect to the source, the destination or the content of data flows.

On 30 August 2016, BEREC (the Body of European Regulators for Electronic Communications) published guidelines for national regulators on the enforcement of the European Open Internet regulation[45].

During the BEREC public consultation[46] on its draft net neutrality guidelines, several enterprises and electronic communications sector stakeholders took the opportunity to deliver a clear-cut point of view in their *“5G manifesto for timely deployment of 5G in Europe”*[47]. This manifesto aims at warning public authorities against a too restrictive approach to traffic management, and especially of the supposedly negative effects that, in their opinion, an overly strong enforcement of net neutrality could have on the 5G rollout roadmap.

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[44] Regulation (EU) 2015/2120: http://eur-lex.europa.eu/legal-content/FR/TXT/PDF/?uri=CELEX:32015R2120&from=EN

[45] Internet service providers (ISP) can employ reasonable traffic management measures for certain categories of traffic, under non-discriminatory conditions and provided they are transparent, proportionate and justified by objective technical requirements, and not used to serve their own commercial interests. ISPs can also distinguish certain services, called specialised services, from their internet access service, without them affecting the latter, provided these services have specific, objective transit requirements.

[46] http://www.berec.europa.eu/

[47] http://telecoms.com/wp-content/blogs.dir/1/files/2016/07/5GManifestofortimelydeploymentof5GinEurope.pdf

BEREC's opinion[48], in response to the contributions to the aforementioned public consultation, recalls that the rules of net neutrality are technology neutral and therefore apply to 5G networks. Moreover, BEREC guidelines clarify that network slicing which networks will need to use to respond to the different use cases (mMTC, eMBB, uRLLC) planned for this new generation (cf. 1.4) system, may be used to deliver specialised services[49].

The subject of net neutrality as it applies to future 5G networks is still very much open and unexplored, but new analyses could be performed parallel to the work being done on defining 5G. Arcep is open to discussion and will also work, within BEREC, towards bringing the required clarity to the ecosystem.

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[48] http://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/6161-berec-report-on-the-outcome-of-the-publi_0.pdf

[49] http://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/6160-berec-guidelines-on-the-implementation-b_0.pdf - footnote 26

Annexes

Annex 1 Definition and standardisation work

A new generation of mobile telephony is defined primarily by two bodies: ITU (International Telecommunication Union) and 3GPP (3rd Generation Partnership Project). These two, respectively public and private, organisations are dedicated to defining the objectives, standards and technical specifications of the new technology in question.

ITU

The first large-scale 5G commercial rollouts are expected to take place in 2020. As mentioned earlier, the exploratory phase – which provides an opportunity to determine demands and identify the most promising techniques and technologies for these future 5G networks – has already begun. Although a number of organisations and consortia are involved in defining 5G, 3GPP will very probably be the central standardisation body for its technical specifications.

Whatever the case may be, ITU (International Telecommunication Union) is vital to defining the technologies and standards that govern any new generation of IMT (International Mobile Telecommunications) at the global level.

These IMT standards are established with the involvement of public authorities and industry players, and have provided the framework for the evolution of mobile communication services around the world, since the beginning of IMT standardisation, with IMT-2000 (3G, UMTS), then IMT-Advanced (4G, LTE-A) and more recently IMT-2020 (5G).

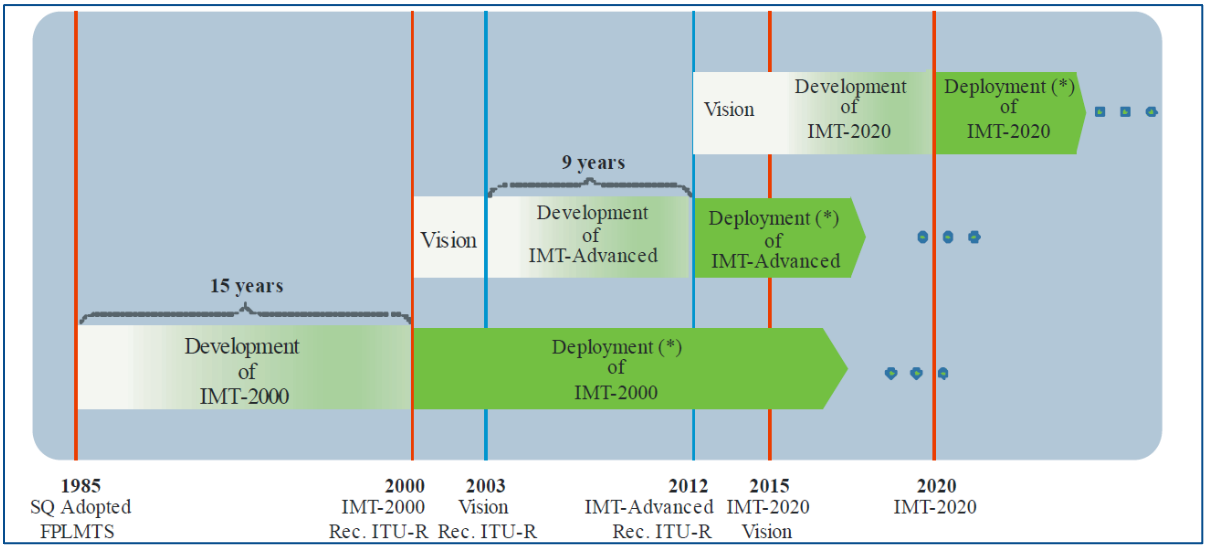
Vision
Development of IMT-2020
Deployment (*) of IMT-2020
9 years
Vision
Development of IMT-Advanced
Deployment (*) of IMT-Advanced
15 years
Development of IMT-2000
Deployment (*) of IMT-2000
1985 SQ Adopted FPLMTS
2000 IMT-2000 Rec. ITU-R
2003 Vision Rec. ITU-R
2012 IMT-Advanced Rec. ITU-R
2015 IMT-2020 Vision
2020 IMT-2020

Figure 16. Timeline of IMT developments and deployments[52]

The advent of an IMT standard typically occurs in three main stages : a vision stage, a development stage and a deployment stage.

The vision stage – whose completion is marked by a document that is usually called a Vision Recommendation – is the stage during which ITU sets the framework and objectives for the future technology. The aim of this document is generally to define what the new technology will be in a more or less concrete fashion, what its characteristics will be, the uses it will enable, etc. Whether for

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[52] Recommendation ITU-R M.2083-0 (09/2015), https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

IMT-Advanced, the commonly used technical abbreviation attributed to the definition of 4G, or IMT-2020, the abbreviation attributed to definition of 5G, the vision stage lasts around three years.

Recommendation ITU-R M.2083-0 was published in September 2015, bringing to a close three years of work performed by ITU-R (Working Party 5D) on defining the framework and objectives for IMT for 2020 and beyond. It is this document that today serves as the basis of the different 5G research and standardisation work being done around the globe.

Next comes the standards development stage, based on the conclusions of the vision stage. Regarding IMT-2020, this development and standardisation work is already underway, and ITU plans on having completed it by 2020 to be able to satisfy the most pressing needs of the ITU members and organisations that want to deploy 5G as quickly as possible. This is all the more challenging as the development stage will last only five years, compared to 15 years for IMT-2000 and nine years for IMT-Advanced.

The different deadlines set for IMT-2020 within ITU can be found in Figure 17. The spectrum identification phases (indicated by the black triangles) coincide with the World Radiocommunications Conferences, of which the latest was WRC-2015 and the next is WRC-2019 (see 3.2).

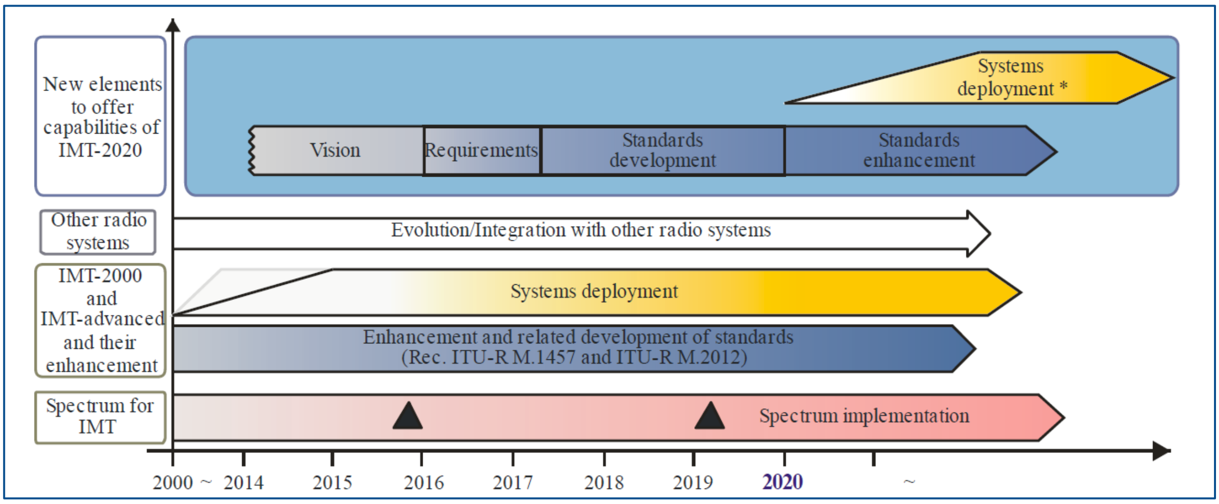
New elements to offer capabilities of IMT-2020
Systems deployment *
Vision
Requirements
Standards development
Standards enhancement
Other radio systems
Evolution/Integration with other radio systems
IMT-2000 and IMT-advanced and their enhancement
Systems deployment
Enhancement and related development of standards (Rec. ITU-R M.1457 and ITU-R M.2012)
Spectrum for IMT
Spectrum implementation
2000 ~ 2014
2015
2016
2017
2018
2019
2020
~

Figure 17. Stages and expected deadlines for IMT-2020[53]

All of the work that ITU is conducting on IMT-2020 is following a roadmap that is detailed in Figure 18, with the completed stages indicated in green and those to come in blue. The work that is underway today concerns 5G spectrum aspects, prerequisites and assessment criteria, along with the different technical studies and proposals, which are a prerequisite to the standardisation phase of the work.

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[53] Recommendation ITU-R M.2083-0 (09/2015), https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

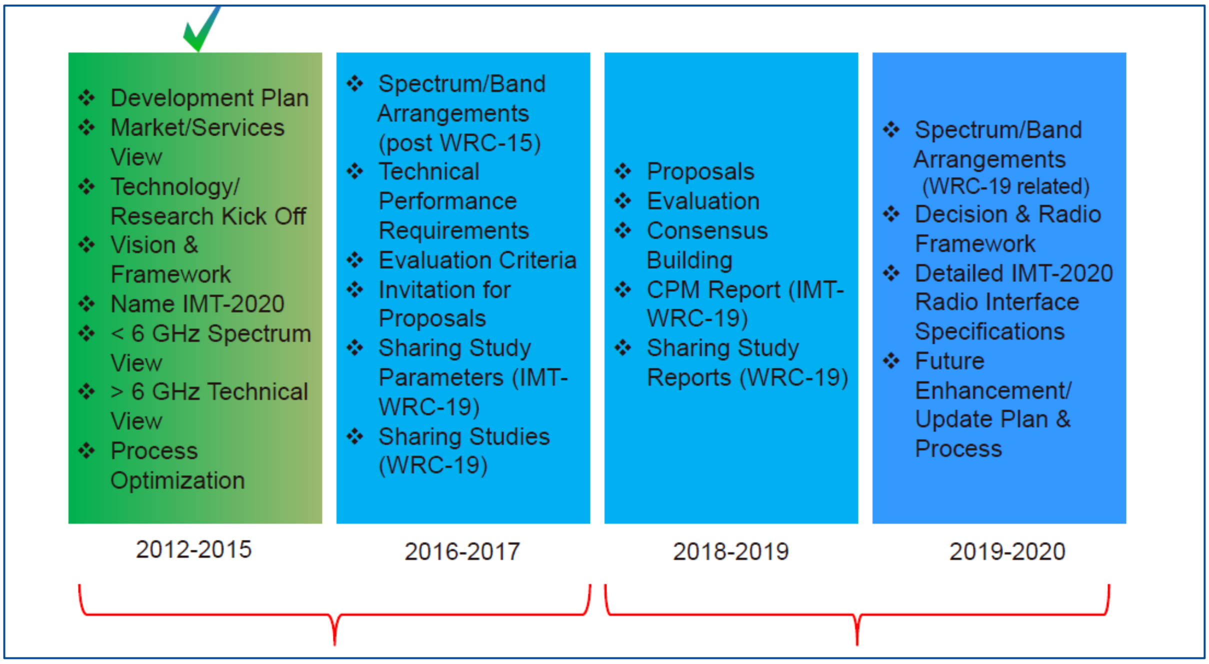
Development Plan
Market/Services View
Technology/ Research Kick Off
Vision & Framework
Name IMT-2020
< 6 GHz Spectrum View
> 6 GHz Technical View
Process Optimization
2012-2015
Spectrum/Band Arrangements (post WRC-15)
Technical Performance Requirements
Evaluation Criteria
Invitation for Proposals
Sharing Study Parameters (IMT-WRC-19)
Sharing Studies (WRC-19)
2016-2017
Proposals
Evaluation
Consensus Building
CPM Report (IMT-WRC-19)
Sharing Study Reports (WRC-19)
2018-2019
Spectrum/Band Arrangements (WRC-19 related)
Decision & Radio Framework
Detailed IMT-2020 Radio Interface Specifications
Future Enhancement/ Update Plan & Process
2019-2020

Figure 18. WP 5D[54] work programme

3GPP

Based on ITU Recommendations, 3GPP has played a major role in the success of LTE over the past several years, which has been the fastest growing cellular technology to date: never before has a new radio standard been adopted and deployed as rapidly and as widely from the finalisation of the first version of its standardisation (for LTE Release 8, in December 2008).

For the first time, under the LTE acronym, the entire mobile industry agreed on a single new technology (contrary to 3G where 3GPP and 3GPP2 co-exist, each backing their version of 3G standardisation that complies with IMT-2000 criteria), and so enabling unprecedented economies of scale and momentum in the ecosystem.

After Release 8, the work performed by 3GPP has been centred on the following strategic areas:

- Enhancing LTE radio standards to further improve capacity and performance;
- Enhancing system standards to make LTE and EPC (Evolved Packet Core, the core LTE network technology) available to new business segments;
- Introducing improvements for system robustness, especially for handing exponential smartphone traffic growth.

These areas of focus have made it possible to map out the general path of evolution from LTE to LTE-Advanced (Releases 10 to 12) and later LTE-Advanced Pro (Releases 13 and 14) while awaiting 5G.

The ambitiousness of 5G requirements, the tight timeline “imposed” by the market, along with the different national tendencies have pushed 3GPP to define two stages of specification work:

1. A first stage that will end in the second half of 2018, with the termination of Release 15, and which will address the most urgent matters with respect to commercial requirements;

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[54] https://www.itu.int/en/membership/Documents/missions/GVA-mission-briefing-5G-28Sept2016.pdf

2. A second stage that will end in December 2019, which marks the end of Release 16, which will address the other use cases and prerequisites identified in the IMT-2020 Vision Recommendation.

The Work Plan for Release 15, the first set of 5G specifications, was ratified at the plenary meeting of the TSG#72 (Technical Specification Group #72) 3GPP working groups in June 2016. This plan includes a set of intermediate tasks and checkpoints to steer ongoing work in the different groups. This Work Plan sets out the transition from current studies to the standardisation phase of the work:

- Starting in December 2016: beginning of standardisation work by TSG SA2 (Technical Specification Group System Architecture);
- Starting in March 2017: specification begins for the 5G NR (New Radio) interface in the TSG RAN (Technical Specification Group Radio Access Network).

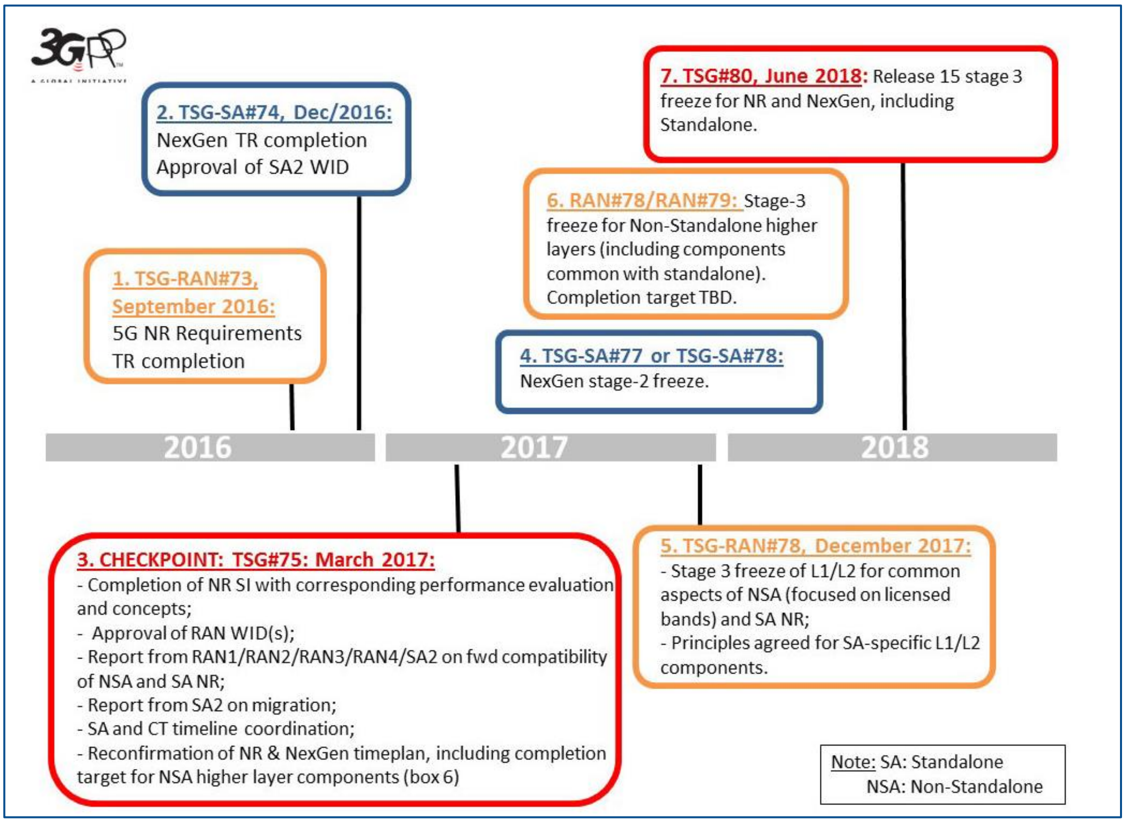

1. TSG-RAN#73, September 2016: 5G NR Requirements TR completion

2. TSG-SA#74, Dec/2016: NexGen TR completion Approval of SA2 WID

3. CHECKPOINT: TSG#75: March 2017:
- Completion of NR SI with corresponding performance evaluation and concepts;
- Approval of RAN WID(s);
- Report from RAN1/RAN2/RAN3/RAN4/SA2 on fwd compatibility of NSA and SA NR;
- Report from SA2 on migration;
- SA and CT timeline coordination;
- Reconfirmation of NR & NexGen timeplan, including completion target for NSA higher layer components (box 6)

4. TSG-SA#77 or TSG-SA#78: NexGen stage-2 freeze.

5. TSG-RAN#78, December 2017:
- Stage 3 freeze of L1/L2 for common aspects of NSA (focused on licensed bands) and SA NR;
- Principles agreed for SA-specific L1/L2 components.

6. RAN#78/RAN#79: Stage-3 freeze for Non-Standalone higher layers (including components common with standalone). Completion target TBD.

7. TSG#80, June 2018: Release 15 stage 3 freeze for NR and NexGen, including Standalone.

Note: SA: Standalone
NSA: Non-Standalone

Figure 19. Roadmap for 3GPP standardisation groups[55]

If 5G is viewed as the technology capable of transforming society, and even of ushering in the next industrial revolution by impacting multiple (vertical) sectors with new business models and in a way that benefits the economy, notably in Europe, in all likelihood it will initially be driven forward by eMBB (Enhanced Mobile Broadband, cf. 1.2).

With this in mind, 3GPP defined the framework for Release 15, stage 1 specifications of 5G standardisation, as detailed earlier, whose work will focus on the following:

- Standalone and Non-Standalone NR operation: the Standalone version to work independently of LTE technology, and the Non-standalone NR being highly interoperable with LTE[56].

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[55] https://5g-ppp.eu/wp-content/uploads/2016/11/01_10-Nov_Session-3_Dino-Flore.pdf

- Target use cases: starting with Enhanced Mobile Broadband (eMBB) as well as Low Latency and High Reliability to enable some URLLC (Ultra-reliable and Low Latency Communications, cf. 1.2) use cases.
- Simultaneous examination of frequency ranges below 6 GHz and above 6 GHz.

Release 16, the second phase of 5G specifications, will then focus more on other segments such as mMTC (Massive Machine Type Communications*,* cf. 1.2), for instance, to tackle IoT use cases that require higher quality of service than what LPWAN *(*Low-Power Wide-Area Network)[57] can provide.

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[56] In its non-standalone version, the NR control plane is LTE's. in other words, the 4G network controls the 5G carriers and spreads users across the different bands and technologies.

[57] Sigfox and LoRa LPWAN

Annex 2 Entities Arcep met with

ERICSSON
QUALCOMM®
HUAWEI
SAMSUNG
NOKIA
AIRBUS DEFENCE & SPACE
THALES
RENAULT
Systematic
Paris Region Systems & ICT Cluster
TELECOM ParisTech
leti
cea tech
f
Google
ETSI
World Class Standards
bouygues TELECOM
free mobile
numericable THD
SFR
orange™
GSMA™

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White Paper

Designing 5G-Ready Mobile Core Networks

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and

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September 2016

5G Core Service & Performance Requirements

An industry "Vision for 5G" is now established and supported worldwide. Services and performance requirements have been identified, and the industry is moving into the development and implementation phases with a view to commercial launch of 5G mobile service around 2019 and fixed wireless access using mmWave radio from 2017. To meet these schedules, leading operators – especially Tier 1s with high expectations and aggressive deployment timelines – are working to make their networks 5G-ready ahead of commercial deployment.

This white paper argues that with a 5G-ready technology strategy, operators can prepare for rapid 5G service launch in a way that optimizes their investment in next-generation IP and mobile core platforms over the next three years. Specifically, it discusses 1) how 5G services drive a requirement for an IP services fabric to connect the distributed data centers that will host 5G network functions, content and applications and 2) the development of cloud-native, service-orientated core networks for advanced 4G and 5G networks.

5G Services Dimensions

Development of the 5G system architecture, and associated core network, is being led by 5G service requirements. **Figure 1** shows the output from the 3GPP SMARTER study group that has investigated the service dimensions of 5G.

Figure 1: Service Dimensions in Future 5G Networks

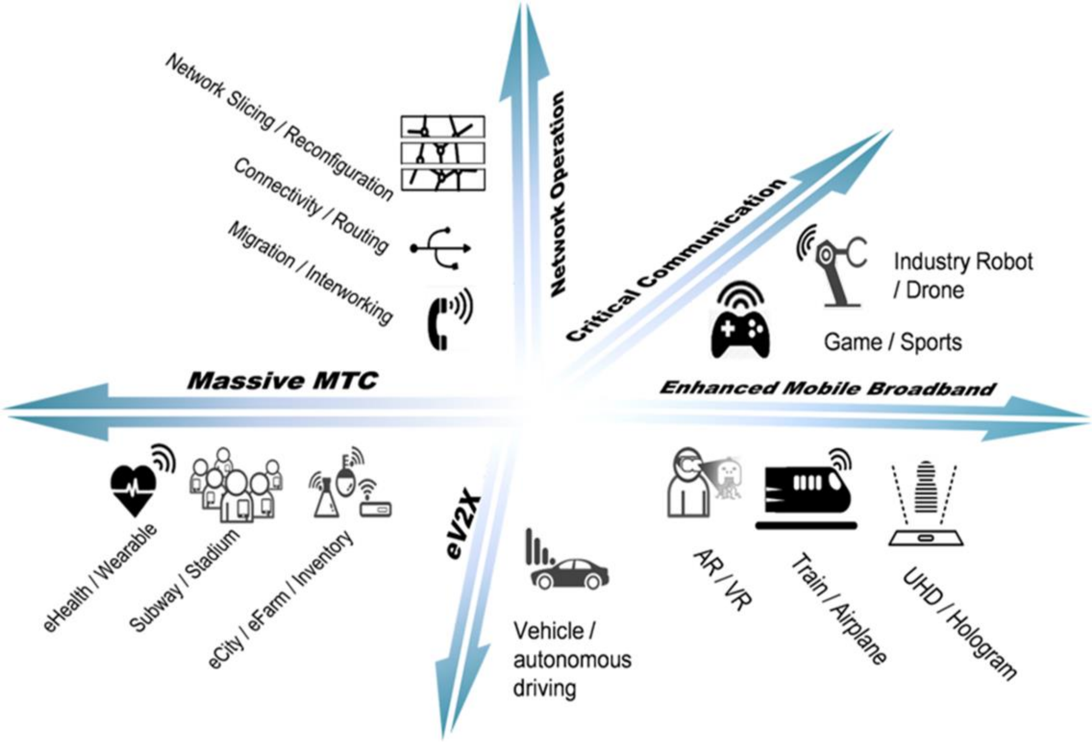
Network Slicing / Reconfiguration
Connectivity / Routing
Migration / Interworking
Network Operation
Critical Communication
Industry Robot / Drone
Game / Sports
Massive MTC
Enhanced Mobile Broadband
eHealth / Wearable
Subway / Stadium
eCity / eFarm / Inventory
eV2X
Vehicle / autonomous driving
AR / VR
Train / Airplane
UHD / Hologram

Source: 3GPP SMARTER

The chart maps closely to the now famous triangle representation of 5G services made up of enhanced mobile broadband (eMBB), low latency and mission critical communications and massive machine-type services (mMTC). However, it adds two important axes: a dedicated eV2X axis for vehicular services and, significantly, a network operations axis.

The dedicated operations axis is important because it makes explicit that automation is fundamental to 5G. To address new commercial opportunities, operators need the ability to create service-specific "network slices" that extend end to end across the infrastructure. Automating set up and management of these "network slices," including configuration of the underlying IP network, is critical to the 5G business case.

These service dimensions incorporate many different performance requirements. **Figure 2** shows IMT-2020 performance targets, developed by the ITU, for 5G. To the left, these are shown in comparison to IMT Advanced (4G). To the right, performance requirements are mapped to the three major use-case categories.

Figure 2: IMT-2020 Performance Targets

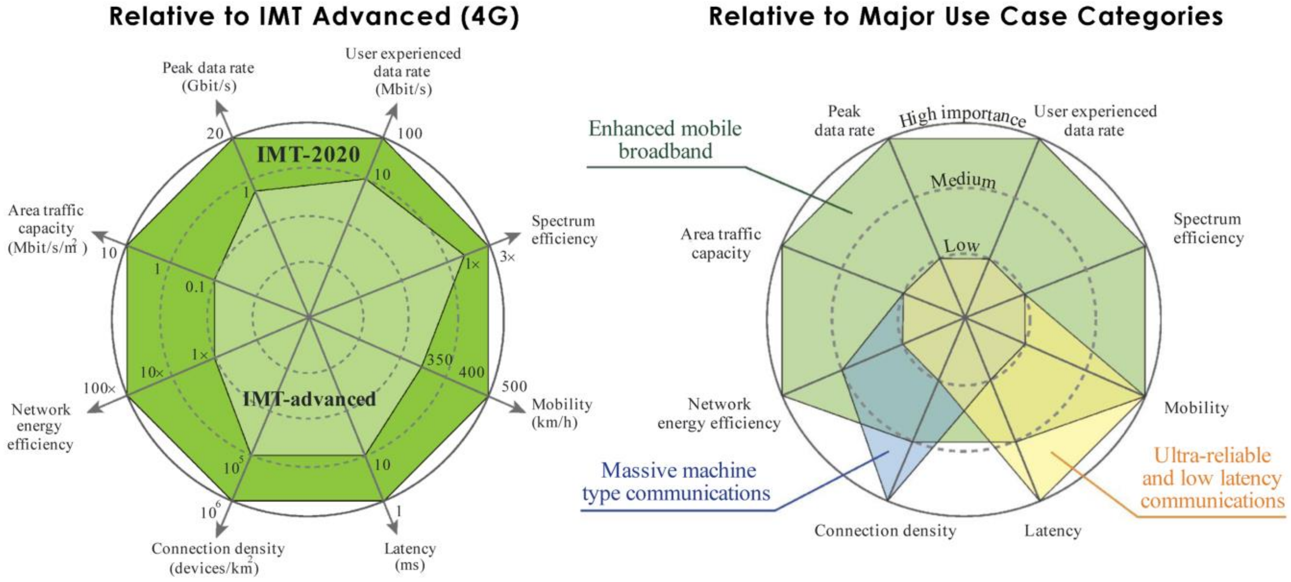

Source: ITU Recommendation ITU-R M.2083-0, September 2015

Probably the most influential factor on 5G physical network deployment will be the low-latency requirement. To deliver services over a wide-area network (WAN) with a consistent 5-10ms roundtrip time is extremely challenging and will drive a new system architecture deployed on a distributed cloud infrastructure.

A 5G-Ready Network Investment Strategy

Operators now have a good idea of what 5G will look like in scope and a reasonable view into the initial deployments models. Development of normative standards for 5G new radio (NR) and the next-generation core network (NG Core) is underway with the first specifications – and the first "compatible" pilot deployments – expected in mid 2018. Although there is uncertainty about the details of the specifications under development, the industry has already undertaken significant R&D work on 5G candidate technologies, making it is possible for operators to pursue a 5G-ready network strategy with a reasonable degree of confidence that they will be able to rapidly deploy 5G, at scale, as the technology becomes commercially available.

From an IP and core network perspective, five tiers of a 5G-ready investment strategy are, from the ground up, as follows:

1. **Develop a distributed data center footprint**. The Central Office Re-architected as Data Center (CORD) model provides a good reference. The idea is for operators to develop physical assets located close to the edge and transform them into distributed data centers. The edge location is critical for low-latency 5G services and, as Mobile Edge Computing (MEC) shows, the edge-cloud is valuable in many networking scenarios – it is not solely a 5G investment. In time, the distributed data center will also come to support Cloud RAN (C-RAN) and Virtual RAN (V-RAN) hub sites and will host core network functions, such as distributed user-plane nodes.
2. **Create an "IP Services Fabric" for 5G with software-defined networking (SDN) control**. Edge-cloud locations running 5G network functions and services will require high-performance, secure connectivity. Investment in wide-area SDN is already underway to create an "IP services fabric" that connects centralized data centers, distributed cloud locations and cell sites. This IP services fabric provides routing, security, service chaining, redundancy and orchestration. Again, this investment is, in many aspects, not unique to 5G, but common to high-performance networking at the cloud edge.
3. **Invest in cloud-based Evolved Packet Core (EPC) and NG Core.** With a distributed cloud infrastructure, it is logical to redesign core network functions to take advantage of this asset to meet the strict latency requirements of 5G services and efficiently manage data traffic. Some aspects of NG Core are already reasonably well understood, (for example, control- and user- plane separation or "CUPS"), while others remain works in progress (for example, mobility and session management). In general, expect control-plane separation to apply across the 5G architecture, from radio to core.
4. **Use network slicing for a service-optimized core.** Network slicing is an important bridge from a 4G core to a new 5G core and is a key component of a 5G-ready network investment strategy. In this model, virtual network functions (VNFs) are created per service and data is routed via an optimized processing path across the network. By isolating services into virtual network slices, operators can offer better security, more efficient transport, optimized core network processing and appropriate service quality. A network slice created for an Internet of Things (IoT) customer, for example, may support both 4G and 5G access networks.
5. **Automation and service orchestration.** Automating network operations provides the ability to launch new services rapidly, to reach new market segments, to evaluate success/failure quickly, and then to modify, scale and repeat. Significant progress is being made in applying service orchestration to 4G-Long Term Evolution (LTE) networks, especially where software-based core networks are deployed. Network slicing is a good example of the need for automation because there will be many more logical entities to commission, provision and manage. "Automated service orchestration" is a good, tangible example of 5G-ready functionality.

The 5G Core Network

The new 5G core network is now reasonably well understood: It will be "cloud-native," it will make extensive use of network slicing, and it will operate in concert with a new model-driven service orchestration layer. The industry can therefore start to develop NG Core products that can be adapted as standards emerge and solidify.

From a practical perspective, for the initial deployment, operators can support 5G radio access on a "5G-ready" EPC and then migrate to a new NG Core over time. In both cases, the "IP services fabric" provides SDN-controlled connectivity and related IP services, across a distributed cloud infrastructure.

Virtualized & Cloud-Native Mobile Core

Operators have made good progress on virtual EPC over the past couple of years. The largest networks now support more than 15 million subscribers (AT&T has discussed this publicly); some progressive operators have started to refresh their main EPC networks using multivendor network functions virtualization (NFV) (e.g., Docomo, Etisalat); and others (e.g., Vodafone) have deployed virtual core elements for IoT services.

Figure 3 shows two migration paths to a "cloud-native" 5G core. The blue line shows a virtualized 4G core as a stepping stone to a "5G-ready" core and then a full 5G core. The grey line shows a more conservative option where the operator scales the classic EPC in the near-term and then makes a bigger leap to 5G later.

Figure 3: A Preliminary Cloud-Based 5G Architecture

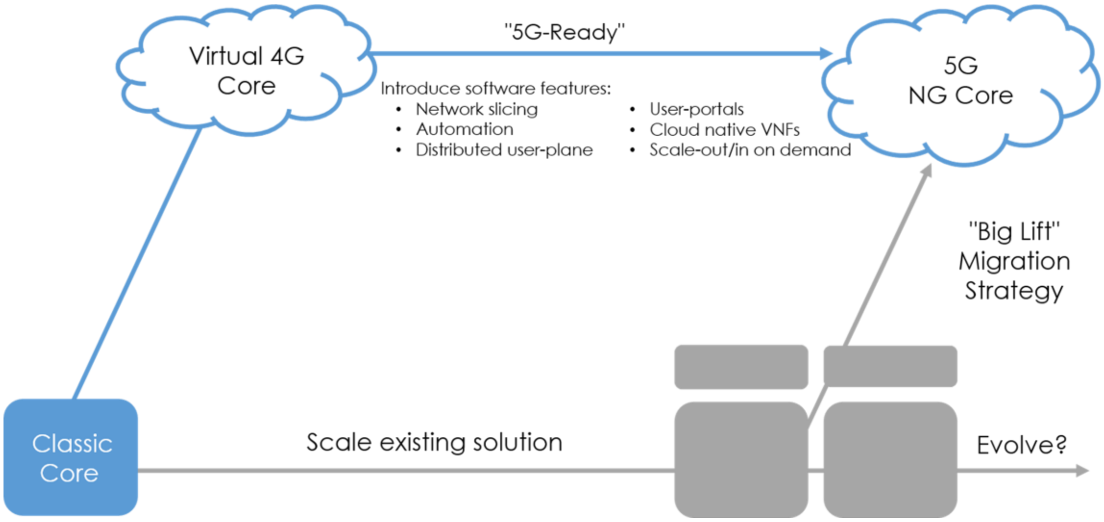
Virtual 4G Core
"5G-Ready"
5G NG Core
Introduce software features:
• Network slicing
• Automation
• Distributed user-plane
• User-portals
• Cloud native VNFs
• Scale-out/in on demand
"Big Lift" Migration Strategy
Classic Core
Scale existing solution
Evolve?

Source: Heavy Reading

There is debate about what exactly "cloud native" means, particularly in the context of stateful telecom network functions. Nevertheless, Heavy Reading's established view is that operators that deploy virtual EPC – even at small scale – gain experience in how these systems work, how to operate them, and how to evolve them, and that in turn will give them a sustainable advantage in the longer-term transition to software-centric 5G mobile networks.

Migrating 5G RAN From EPC to NG Core

A 5G-ready core strategy is determined, in part, by how the operator plans to introduce 5G radio. There are two basic possibilities: operate 5G RAN using an EPC or using a new NG Core. In practice, operators with plans to launch 5G early are likely to start with an EPC and migrate to NG Core over time, as shown in **Figure 4** below.

Figure 4: Migrating 5G RAN from EPC to NG Core

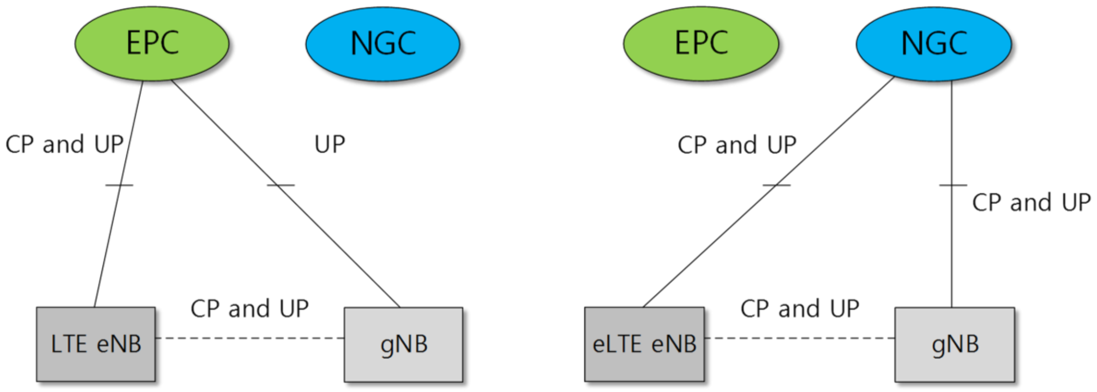

Source: 3GPP TR 38.801 v0.4.0

The diagram is taken from the most recent version of the 3GPP "Study on New Radio Access Technology" (TR 38.801), which will inform development of standards in Release 15. Several permutations of the architecture are under consideration; however, in simple terms, to the left, the new 5G base station (gNB) user-plane interface connects directly to a 4G EPC, while the control-plane functions, such as tracking, paging, etc., are provided by an evolved 4G base station (eNB), which in turn also connects to the EPC. In this scenario, the EPC requires little or no modification, making this a fast and simple way to deploy 5G radio from a core perspective.

Over time, both 4G and 5G base stations can migrate to a new NG Core, which will provide both control- and user-plane functions. At this stage, NG Core becomes the primary core network for 4G and 5G access, as shown to the right in the diagram. This is conceptually similar to how EPC supports 3G and 4G access networks.

Note that in cases where 5G radio is deployed for fixed wireless access, there is no need for an LTE RAN to provide control-plane functions to the 5G user device; a standard EPC is sufficient, although it would need to provide session management for the 5G access. Some of the first 5G deployments are expected to use this model.

Network Slicing: A Key Bridge to 5G

Network slicing is one of the key bridges between the 4G and 5G core. To support diverse service types, operators will use multiple core networks deployed as "network slices" on a common IP services infrastructure. The idea, shown in **Figure 5**, is to create virtual core network instances (or "slices") dedicated to different services. Each slice can be optimized for the traffic profile and the commercial context of the associated service – for example, IoT, public safety, mobile virtual network operator (MVNO), connected car, voice over WiFi or enterprise services. Network slices can be two dimensional in the sense that they can be both service- and customer-specific.

Figure 5: Dedicated Packet Core Network Slices

- Virtualization enables multi-tenant and single-tenant private core networks
- "Slices" configured according to service type & traffic profile
- Multiple options to steer user traffic into a core network processing path
- Mechanisms in 3G/4G include APN routing, MoCN, DECOR

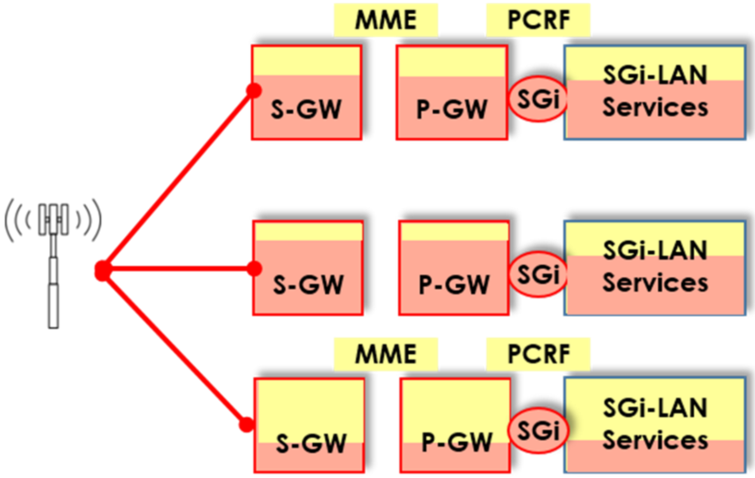

Source: Heavy Reading

IoT is an example of how operators can use "slicing" to support a 5G-ready core strategy. Since many of the core network design parameters are similar between 4G and 5G, investment in a software-based IoT core network can be made with the expectation that the same core (with software updates) will also support IoT services on 5G in future. Moreover, because devices from both access types will connect to a common IoT core, operators will be able to develop integrated 4G/5G IoT strategies that optimize investment and enable them to go to market with narrowband IoT services before 5G specifications are released and radio equipment is deployed.

5G will, naturally, bring more capabilities to network slicing. Most importantly, it is expected that the slice will run end to end across the RAN, core and transport network. Radio is typically deployed as a shared resource, which means that 5G slicing will involve advanced self-organizing network (SON) capabilities and hierarchical, slice-aware scheduling on the air interface. On the network side, the operator can use SDN to reserve resources for the network slice on the IP services fabric.

NG Core for 5G

A new core network offers important benefits, particularly for services with demanding performance requirements, and is an important part of the 5G architecture. The high-level view of the NG core network architecture, as it looks in September 2016, according to TR 23.799 (the Technical Report on the NextGen System Architecture) is shown in **Figure 6**.

The chart shows the primary elements of the new 5G system architecture, including the device (UE), the radio access network (NG-RAN) and the core network that comprises the control-plane (NG-CP) and user-plane (NG-UP) functions. The separation of control and user planes is a direct extension of the "CUPS" concept being developed for advanced EPCs in 4G networks and is another example of how operators can invest in 5G-ready core network designs in the near term.

Figure 6: High Level View of NG Core Architecture (Proposed)

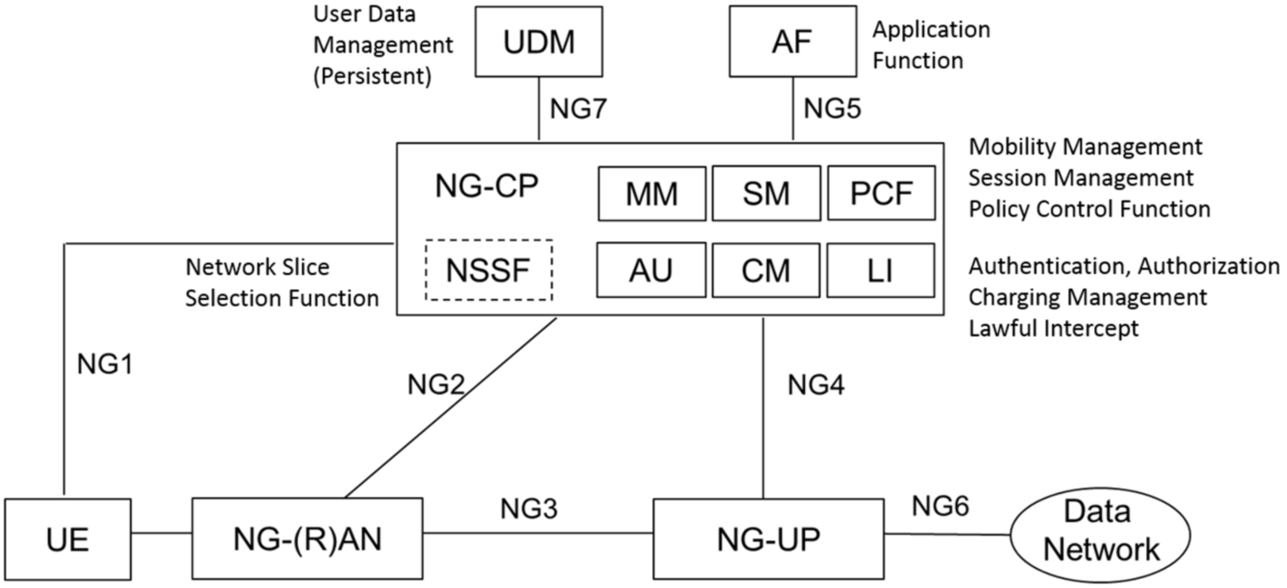
User Data
Management
(Persistent)
UDM
AF
Application
Function
NG7
NG5
Mobility Management
Session Management
Policy Control Function
NG-CP
MM
SM
PCF
Network Slice
Selection Function
NSSF
AU
CM
LI
Authentication, Authorization
Charging Management
Lawful Intercept
NG1
NG2
NG4
UE
NG-(R)AN
NG3
NG-UP
NG6
Data
Network

Source: 3GPP, Adapted from TR 23.799 v0.8.0, September 2016 (Figure 7.2.4-1)

It is interesting to compare this new functional architecture with the existing EPC. **Figure 7** maps the new NG Core elements to their equivalent in EPC. It shows significant overlap between the EPC and NG Core and provides confidence that today's state-of-the-art EPC is reasonably close to the next-generation core in terms of functionality, albeit that the interfaces and protocols will change/evolve.

Figure 7: Mapping NG Core & EPC Functions

NG Core Network Function	Approximate Equivalent EPC Function
UDM (User data management)	SPR
AF (Application function)	AF
NSSF (Network slice selection function)	MME (DECOR) + HSS
MM (Mobility management)	MME + SGW / MME + SGW-C
SM (Session management)	PGW/PGW-C
PCF (Policy control function)	PCRF
AU (Authentication & Authorization)	HSS/AAA
CM (Charging management)	PGW + PCRF, OCS, OFCS
LI (Lawful intercept)	LI
NG-UP (User-plane function)	SGW + PGW / SGW-U + PGW-U

Source: Heavy Reading, Affirmed, Juniper

Key Capabilities of the Next-Gen System Architecture

In addition to proposed architectures, the Technical Report provides guidance on the features and services NG Core should support. It identifies 19 key issues for the Next-Gen System Architecture, which can be grouped into four categories:

- **Flexible Deployment**: Including network slicing, user-plane network selection, network function granularity (e.g., decomposition of VNFs and service chains), interworking and migration, a policy and charging framework.
- **Flexible Access Support**: Including variable core/access splits, a flexible authentication framework (with varying credentials according to device-type, use case and policy), support for relays and multi-hopping, improved network discovery and selection mechanisms.
- **Connectivity**: Including session management, mobility management, a quality-of-service (QoS) framework and service and session continuity (e.g., across accesses).
- **Adapting Existing Capabilities**: Including network/service capability exposure, multicast and broadcast, IP Multimedia Subsystem (IMS) support, off-network communications (e.g., *ad hoc* networks for public safety).

Implementation of these capabilities is tightly linked to both the design of the NG Core and the underlying IP service infrastructure. The 3GPP specifications do not reference connectivity services, but, in practice, there is a close relationship.

A Distributed 5G Services Fabric

The infrastructure onto which 5G will be deployed should support multiple, demanding use cases. This drives a need for a high-performance wide-area IP services fabric controlled (or "orchestrated") by SDN. This IP services fabric should provide connectivity between many different distributed data centers in a meshed architecture that provides resiliency and scalability, and should be programmable such that it can support dynamic, service-specific network slices. In effect, the IP services fabric makes distributed centers act in a unified manner – i.e., behave as one integrated data center. The concept is shown in **Figure 8**.

The design of the distributed IP services fabric is formed by the variety of use cases, the requirement for low latency and high availability, and the need to scale efficiently. In tandem, the mobile network architecture will evolve to a more distributed model. To meet 5G service requirements, NG Core will be deployed using the "CUPS" model, with user-plane nodes hosted at distributed data center locations, and control-plane nodes at more centralized locations, interconnected by the IP services fabric.

Service orchestration will generally be domain specific, with SDN-controlled IP services, cloud resource management, NFV lifecycle management and end-user service orchestration, all operating quasi-independently in a layered architecture. Coordination between the layers will use "cross domain orchestration" to ensure a network slice contains all the networking components needed to deliver the service.

Depending on how the architecture evolves, there will be a need to support highly accurate, 1588v2-based timing (frequency and phase) within this IP services fabric. Virtual RAN/Cloud RAN is an example on the network side that benefits from accurate network timing. On the customer side, it is expected that some market segments, such as the financial industry, will also require timing to be incorporated into network slices.

Figure 8: IP Services Fabric for 5G Networks

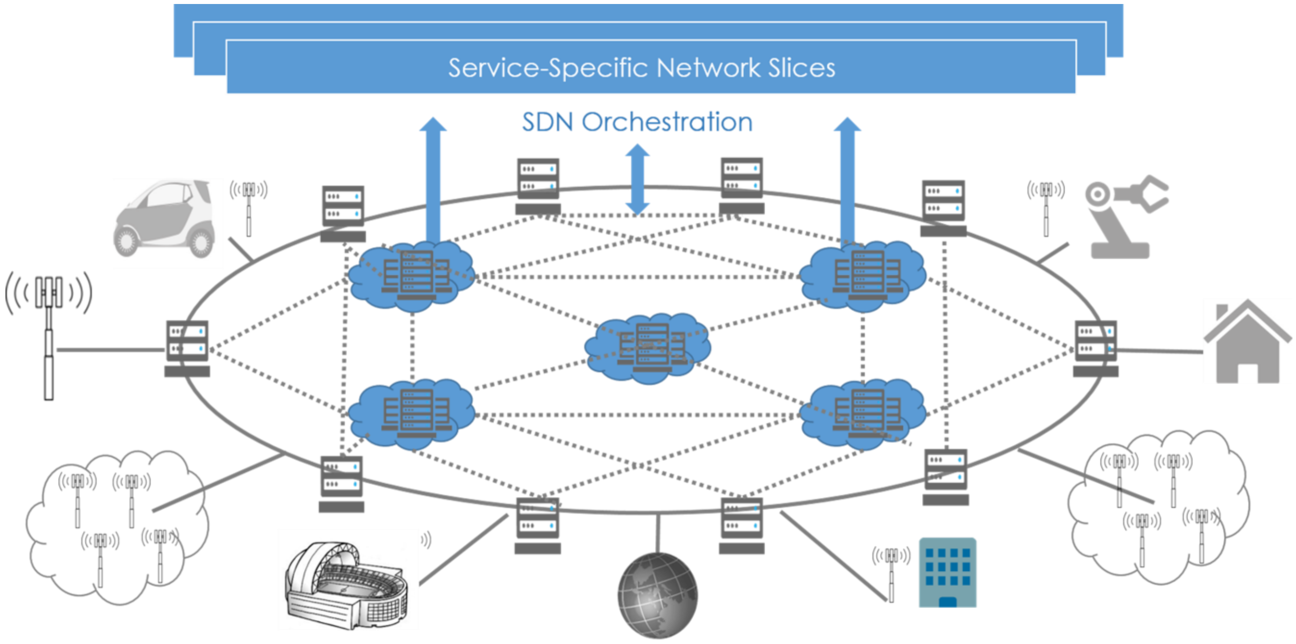

Source: Heavy Reading

Distributed Data Centers

To provide access network services, telecom operators have a physical footprint – in the form of central offices, base station controller sites and transport aggregation sites – that they can convert into distributed or micro data centers.

Depending on the service requirements, these data centers can be used to terminate access connections using virtualized edge functions and become the obvious place to host latency-sensitive content and applications. For centralized cloud providers, this capability is harder to replicate unless they build out an extensive physical footprint or partner with an access provider, and, therefore, this strategy provides operators with a potentially important and sustainable competitive advantage.

The "edge cloud" model will be critical to 5G and is the subject of detailed R&D across the industry. As an example, a preliminary architecture developed by the SuperFluidity project (a European 5G research project) is shown in **Figure 9**. Work on this particular project, which is academic in focus but contains several industrial partners, is scheduled to finish by the end of 2017.

As the name implies, the project aims to achieve superfluidity in the network: the ability to instantiate services on the fly, run them anywhere in the network (core, aggregation, edge) and shift them transparently to different locations. This is the essence of the "IP Services Fabric" for 5G. In this new network, operations will also need to move from a "red light, take action" model to an automated model where the orchestration and associated next-gen operations support system (OSS) detect and fix problems with the IP and NFV layers, and re-optimize the network accordingly.

Figure 9: A Preliminary Converged Cloud-Based 5G Architecture

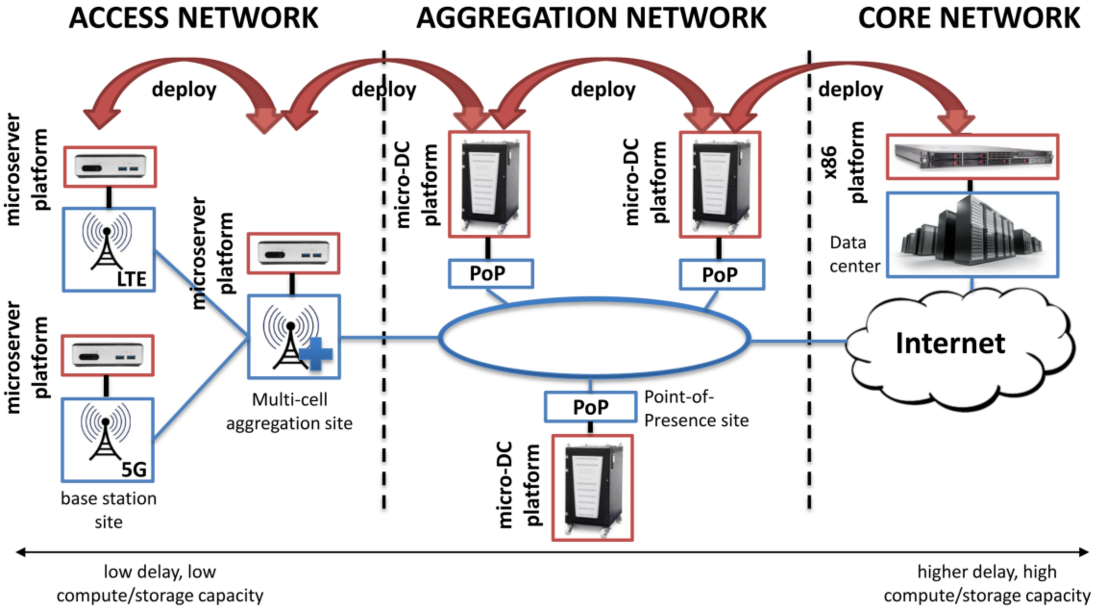
ACCESS NETWORK
AGGREGATION NETWORK
CORE NETWORK
deploy
deploy
deploy
deploy
microserver platform
LTE
microserver platform
5G
base station site
microserver platform
Multi-cell aggregation site
micro-DC platform
PoP
micro-DC platform
PoP
PoP
Point-of-Presence site
micro-DC platform
x86 platform
Data center
Internet
low delay, low compute/storage capacity
higher delay, high compute/storage capacity

Source: SuperFluidity

Central Office Re-architected as a Data Center (CORD)

There are several industry and service provider initiatives to define the architecture for SDN-enabled distributed data centers. The Central Office Re-architected as a Data Center (CORD) initiative hosted by the Linux Foundation is one example of how operators aim to make better use of these assets.

According to the CORD initiative, AT&T alone operates 4,000 to 5,000 central offices, each serving 10,000 to 100,000 residential, enterprise and mobile customers. These central offices contain fragmented vendor hardware with multiple physical appliances installed per site (AT&T said it has 300+ unique appliances deployed in its central offices nationwide). The opportunity is to re-architect these central offices to support edge cloud infrastructure and deploy VNFs in place of appliances.

Each CORD location will be connected using an SD-WAN, making it possible to load-balance content and NFV workloads across the distributed cloud using the same SuperFluidity concepts discussed above. In the CORD case, the focus is on the ONOS controller, but in the sense that this is a generic architecture, multiple SDN controller options are viable and attractive. Note that for I/O-intensive workloads, the selection of an edge location should consider the physical transport resources available at the site. It would not make sense, for example, to deploy a 5G user-plane node for fixed wireless access in a central office that does not have a high bandwidth connection to the Internet.

In March 2016, the Linux Foundation announced the M-CORD initiative for mobile operators, backed by AT&T, SK Telecom, Verizon, China Unicom and NTT Communications. It highlighted three key aspects of the architecture, saying that it:

- Will use the same CORD principles of elastic commodity cloud and SDN to bring data center economies and cloud agility to the mobile edge.
- Will demonstrate integration of disaggregated/virtualized RAN, disaggregated/virtualized EPC and mobile edge services.
- Will partner with the SDN controller groups to accelerate adoption of open source SDN and NFV solutions and realize the benefits of the cloud.

Given the timing of the work, we expect M-CORD and similar initiatives to turn their focus toward "5G-ready" core networks as the architecture, interfaces and protocols for NG Core become more clear. A common CORD and M-CORD implementation, with the same architecture and foundational technologies, will create a good foundation for fixed-mobile network convergence, enabling access agnostic services – an important objective of many operators pursuing 5G.

Mapping Mobile Core to Distributed Cloud

The NG Core for 5G and EPC for advanced 4G networks must be mapped to the distributed cloud architecture. One approach would be to simply deploy more packet gateways (and mobility controllers) at the edge of the network to meet capacity and performance demands.

The challenge with this is that today's centralized packet core deployments are characterized by complex integration with surrounding network functions, such as policy, charging, IMS, SGi-LAN and routing services. By moving this model to the edge, the operator would, in effect, have to "distribute complexity," which is costly to deploy and, in particular, to manage. To meet 5G performance, scalability and automation requirements, a new architecture for packet core is needed that will make operation in the edge cloud infrastructure simpler and faster.

There are many aspects to this new architecture. Part of the solution is CUPS, as is currently being developed for 4G-LTE core networks. This involves extracting the control-plane functions from the gateway to leave a simpler, user-plane node. The gateway thus is "split" into S/PGW-U and S/PGW-C components that can that can scale independently, as shown in **Figure 6** above. A key benefit of the architecture is that the control plane, and all the associated complex interactions, can be centralized, while the user plane is distributed across the IP services fabric and scaled as required by the traffic load. This is shown in **Figure 10**.

Depending on the scaling needs, the S/PGW-U functions deployed at the edge data center can be implemented in several different ways: on a router, on a white box switch (potentially), on an existing PGW platform, as a virtualized function, or as part of a vRouter. Virtualized user-plane nodes can more easily be placed at the optimal location, as determined by the use case and this flexibility is a strong argument to deploy S/PGW-U nodes as VNFs rather than as hardware functions.

The S/PGW-C components would similarly be deployed as virtualized functions on a cloud platform, typically at a more centralized location. There may be an opportunity to collapse MME, SGW-C, PGW-C functions and perhaps other 3GPP control-plane functions into some form of unified "mobility controller" node. This has the potential to simplify operations and this same model is being pursued for NG Core.

In this architecture, virtualized SGi service LAN components can be placed where appropriate for the traffic coming from the distributed user-plane nodes. For example, some SGi functions could be on router-based compute blades, or on COTS x86 servers deployed at the distributed site, while others could be in the central data center or close to Internet peering points. The selection of the site for the SGi functions is carried out by the central orchestration system, which steers traffic into service chains on a per subscriber, application, bearer, device or combination basis.

Figure 10: Distributed User-Plane at Edge Data Centers

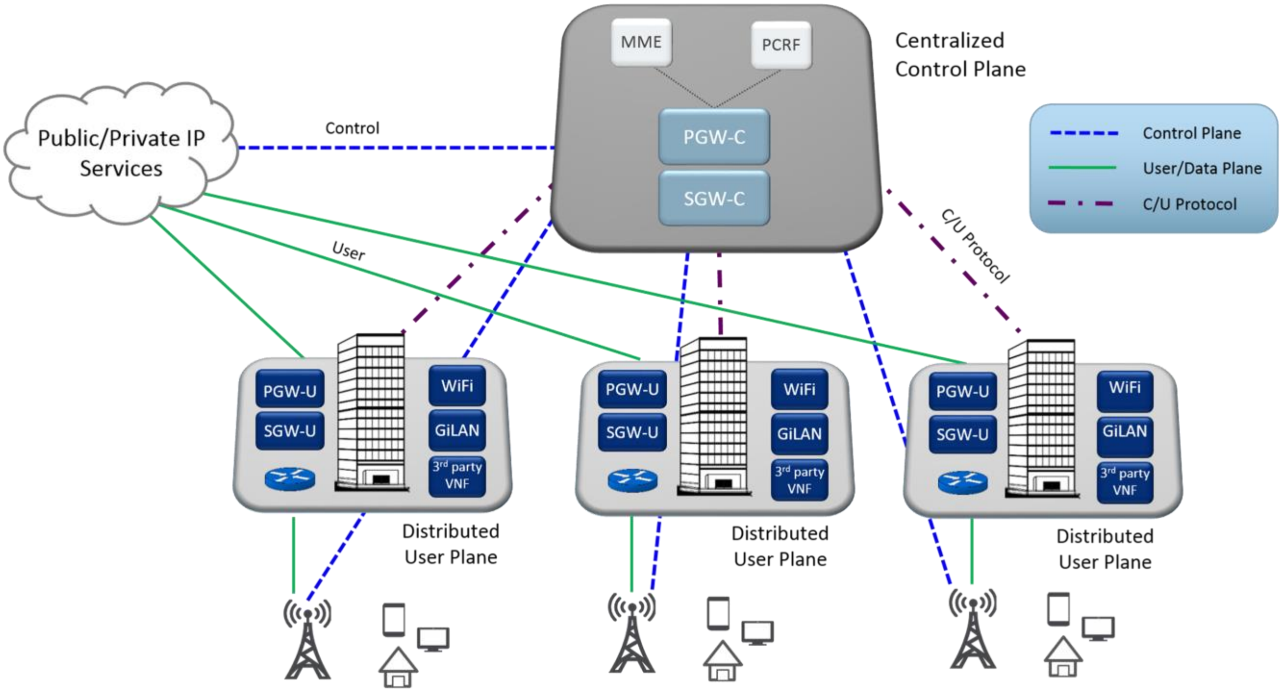
MME
PCRF
Centralized Control Plane
PGW-C
SGW-C
Public/Private IP Services
Control
User
C/U Protocol
Control Plane
User/Data Plane
C/U Protocol
PGW-U
SGW-U
WiFi
GiLAN
3rd party VNF
Distributed User Plane

Source: Affirmed Networks

This model of discrete control- and user-plane functions is expected to be fundamental to 5G and the NG Core. In this sense, CUPS can be viewed as an important part of a 5G-ready investment strategy.

A 5G-Ready Core Is Now a Priority

The industry now has a reasonable view of 5G service requirements, and progressive operators with aggressive deployment timelines are now working to prepare their networks for rapid deployment of 5G when equipment is available. This is driving investment in the critical IP services network needed to connect the edge cloud locations that will run 5G network functions, content and services.

On the mobile core side, development of cloud-native, service-orientated core networks for advanced 4G and 5G networks is underway. Network slicing provides a conceptual bridge between 4G and 5G investment and facilitates a faster insertion of new services into the network. Similarly, CUPS provides a reference for NG Core and the new 5G network architecture. With a 5G-ready technology strategy, operators can prepare for 5G service launch in a way that optimizes their investment in next-generation IP and mobile core platforms over the next three years.

About Affirmed Networks

Affirmed Networks' NFV solution has become the standard for the world's top mobile operators, who are embracing new business models and building new revenue streams by making the transition to virtualized architectures. The company's technology portfolio includes the Affirmed Mobile Content Cloud, the Affirmed Wi-Fi Gateway (serving as a TWAG/TWAP and an ePDG), Affirmed Service Automation Platform (ASAP) and Affirmed Virtual Probe and Analytics Solution. These virtualized solutions have come to represent the present and the future of virtualized mobile networks with extreme scalability, remarkable flexibility, comprehensive network orchestration and future-proof solutions for a 5G-ready architecture. Please find more information at www.affirmednetworks.com.

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Energy harvesting power for the Internet of Things

Energy harvesting wireless technology easily interconnects thousands of individual devices in a system, opening up unlimited processing and monitoring applications.

Laurent Giai-Miniet, EnOcean, Oberhaching (Munich), Germany
09/30/2013

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Energy is everywhere within reach; it just needs to be harvested. This is the principle of energy harvesting. Today, energy harvesting wireless solutions are already well established in the commercial building automation sector. But the technology is just getting started. New application fields for batteryless, wireless communication will be found to further enhance the world around us.

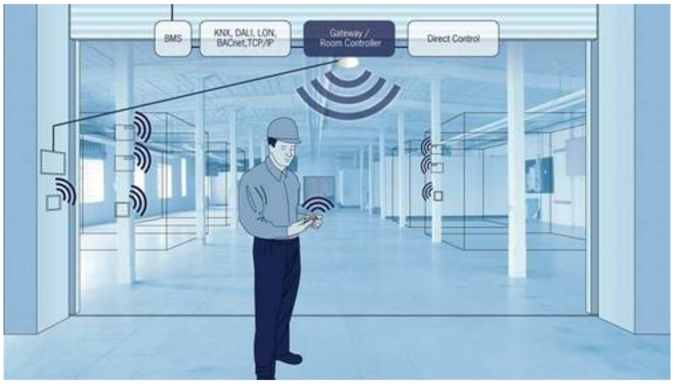

Based on energy harvesting wireless technology, a wide range of energy-autonomous applications are currently available for connected buildings that use motion, light, or temperature differences as their energy source such as batteryless switches; intelligent window handles; temperature, moisture, and light sensors; presence detectors, heating valves; and smart home systems. However, building automation is by no means where energy harvesting wireless ends.

Multiple interconnections

Everybody's talking about the Internet of Things (IoT). But how should billions of communicating devices be powered? The answer is by energy harvesting, and the reason is simple: Liberating sensors from external power, making them energy-autonomous, opens up unlimited processing and monitoring applications where cables or batteries represent an insurmountable hurdle. These features make energy harvesting wireless technology the ideal communication standard to easily and reliably interconnect thousands of individual devices in a system, as well as network them with other wireless protocols.

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Today, energy harvesting wireless technology is widespread, providing M2M solutions in the building automation sector and bridging the control of light, HVAC, and other fields of building technology to smart buildings, smart metering, and energy management systems. This is the starting point to actuate further applications that lead to the IoT in the long term. The following four categories show what this could look like.

Monitoring and control

Wireless and batteryless technology significantly eases energy monitoring and control in buildings with little intervention into the existing systems. The wireless devices are highly flexible to install so that individual components, wall switches, sensors, and relay receivers can be easily networked to form an intelligent system without complex cabling. In addition, dispensing with batteries eliminates the burden of maintaining the devices' energy supply in a regular time period, which can be up to each year.

An example for such a flexible automation system is HVAC control. Here, a thermostat, VAV (variable air volume), or fan coil controller receives information related to occupancy, temperature, humidity, window position, or CO_2 from the respective batteryless sensors and controls the opening and closing of valve actuators for radiators, or dampers for VAV systems. At the same time, the controller sends status information to a central building automation system, and receives control messages from the BAS. This enables the building to be monitored from a central location that can be remote from the building itself, and building-wide settings, such as holiday shutdown, to be implemented. Enormous progress is also being made on the product side, leveraging advancements in energy harvesting. Self-powered radiator valves generate energy from the difference in temperature between the hot water and the surrounding air. This energy powers the communication with a controller or BAS system, and turns the valve itself. Without cables or batteries, these wireless devices are especially easy to install, and they require no maintenance.

In further optimized systems, central equipment such as boilers or air handling units are integrated into the wireless communication system, enabling scalable HVAC generation, visible and controllable over the Internet on a PC, tablet, or

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Auto
enocean

Alarm systems are a second field that batteryless wireless technology is opening up, due to its specific features. Here, the reliability requirements are much more stringent than those required for lighting controls. A system failure not only means a malfunction but also can cause much more serious consequences for other systems that depend upon the equipment being monitored. It's a fact that more malfunctions are caused by battery failures than by the electronics, especially in large systems. Energy harvesting overcomes this issue.

There are already various batteryless wireless water detectors available that use miniaturized solar cells or motion energy converters to power wireless signals that report water leaks in areas such as water supply networks in spacious industrial facilities. In the AFRISO universal module, for example, the EnOcean wireless signal immediately sends the leakage information to a gateway controller or directly to a valve, causing the main water pipeline or the affected supply line to be shut off. A notification is sent to the user's smartphone or smartpad at the same time to inform the user about the incident. In addition, the water valve can be opened and closed, independent of leakage notifications, by GSM connection via smartphone or smartpad.

Embedded processing

A major requirement of today's and the future energy supply is the Smart Grid. It's intended to network centralized and decentralized energy suppliers, including private homes producing electricity by photovoltaic installations, to an intelligent system that provides energy only when needed, updating in real time. This requires continuous data flow and processing from all involved parties, which means from millions of information points.

A key component is smart metering systems. To work reliably and cost-efficiently, interoperability between the meters is supplied by different manufacturers; this is why smart metering calls for standardized technologies. Consequently, the members of the EnOcean Alliance have defined a specific device communication protocol, the Automated Meter Reading (AMR) profile for batteryless wireless devices. Smart meter systems based on this open protocol are already available from a number of manufacturers. For example, Eltako meter components read and transmit the current electricity, water, and gas consumption, including accumulated meter figures, by means of energy harvesting wireless technology located at a variety of points inside a building. BSC software monitors and displays the current meter readings and compares them against default values. This makes all relevant data available for systems processing for intelligent energy management on demand.

Bridge to the cloud

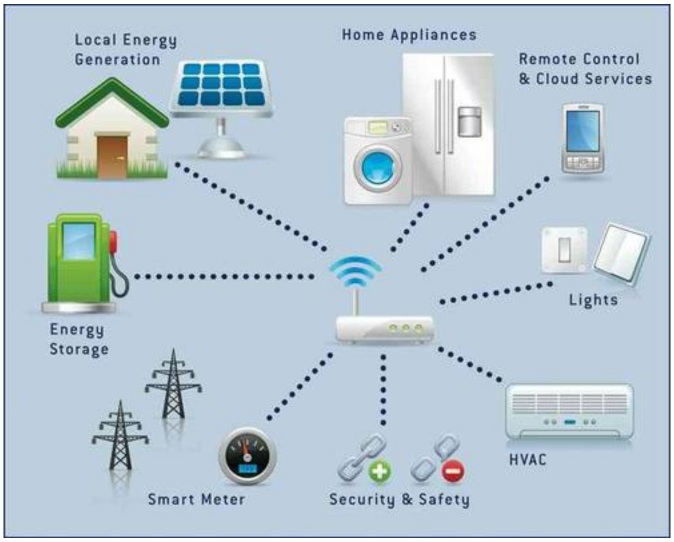

Via similar gateways, the standard-based energy harvesting technology can also communicate with Ethernet, Wi-Fi, GSM/UMTS/CDMA, and other networks for integration in cloud services. Here, all data collected by batteryless wireless sensors is encrypted and transmitted to a cloud service over the Internet. The gateways connected to a control and visualization software by TCP/IP that can be used to control all relay receivers and sensors bidirectionally. Some manufacturers have developed a cloud solution that offers energy management as a service. Therefore, facility managers, building owners, and businesses can monitor important inventory, equipment, assets, and energy-related information from anywhere at any time, via the cloud. Critical building-related data is automatically pushed to the cloud, freeing owners and managers from the often-challenging coordination and expense of hosting on-site servers.

One of the major advantages of such a cloud-based solution is that the management system arrives completely precommissioned from the manufacturer and ongoing device commissioning is expertly done on behalf of the client and pushed out from the cloud. The users are granted unlimited access to their remote, dedicated virtual server with their own IP address, accessible from a desktop or smartphone — the perfect precondition for a deeply connected world of an IoT.

The energy harvesting market is growing and multiplies on a year-by-year basis. Forecasts show that this trend will continue, especially as the next generation of energy harvesting wireless solutions is just around the corner to pave the way to the Internet of Things.

Laurent Giai-Miniet is CEO of energy harvesting wireless solutions provider EnOcean and previously spent 20 years with Texas Instruments (TI), where he held several management positions including General Manager for Low Power RF Products (LPRF).

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The Basic Soldering Guide

Learn to solder successfully!

Alan Winstanley

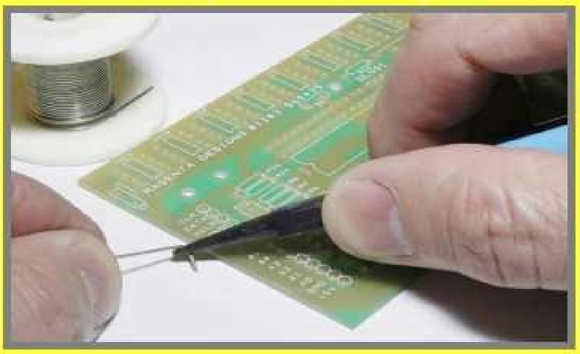

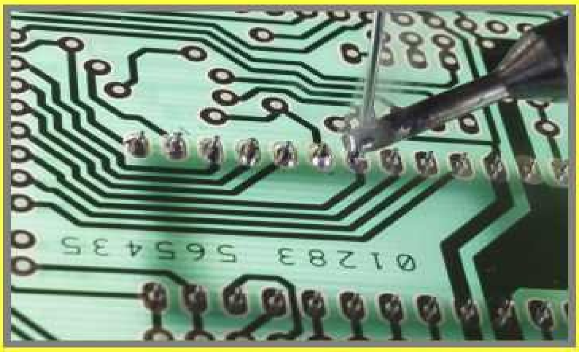

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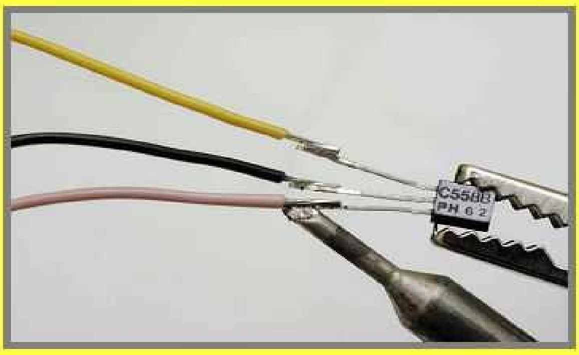

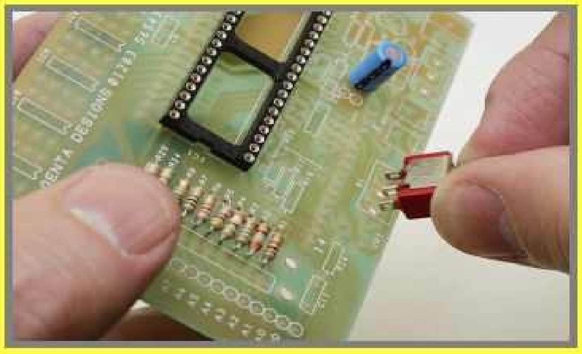

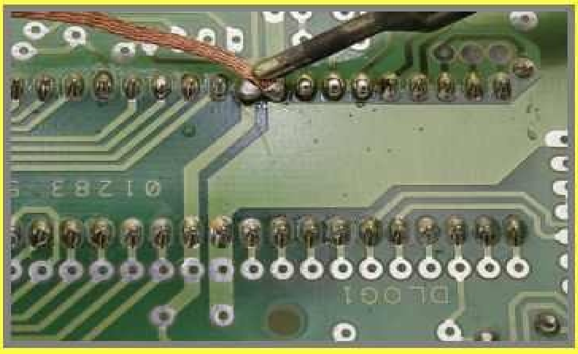

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The Basic Soldering Guide

by Alan Winstanley
EPE Magazine Online Editor

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Where mentioned, the U.K. mains voltage supply is 230V a.c. and you should amend ratings for your local conditions.

Preface

In 1996 when the world wide web was still very young, I launched the first and most detailed website ever describing the practical skills of electronic soldering, and my **Basic Soldering Guide** quickly became the #1 web site of its kind in the Google search engine.

Thanks to its in-depth reference text and the unequalled high-quality close-up photography showing soldering step by step, many quickly learned the essential stages needed to make a solder joint successfully. Even novices who had never tried soldering before, gained the skills and confidence needed to acquire this skill.

My Basic Soldering Guide became a key *go-to* online guide for soldering, and I've enjoyed receiving encouraging feedback ever since from the likes of the US Air Force, US Marines, US Coastguard, Honeywell trainers, Atomic Energy authorities, Australian aeronautical suppliers, UK colleges and universities, trainees and many more around the world.

In association with Antex (Electronics) Ltd., the leading UK manufacturer of electronic soldering equipment, I'm delighted to bring you this updated Basic Soldering Guide containing over 80 all-new colour photographs, more background, more detailed information and lots more practical hints and tips.

I've revisited various areas of the guide and refreshed them, taking onboard readers' queries and nearly 17 years of online feedback, experiences and answering reader's questions. With the help of all-new photography, I'm sure you'll master the skills needed to solder electronics successfully using this updated guide.

I welcome feedback and comments, and readers can reach me via my website **www.alanwinstanley.com** or Email me at **alan@epemag.demon.co.uk**

Alan Winstanley

July 2013

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Introduction

The first and most important aspect of assembling any electronic project is that of *soldering,* which is a delicate and precise skill that can be mastered with experience. Sometimes called “soft soldering”, there’s no shortcut to acquiring the necessary expertise, and producing a consistently satisfactory solder joint takes a little practice. However, like riding a bicycle, soldering is an art which once learnt is never forgotten, and the purpose of this new and updated guide is to explain the techniques of soldering and desoldering for beginners, which I hope will set the hobbyist or trainee technician firmly on the road to successful electronic assembly or repairs in the future.

Soldering is the least “aggressive” way of joining non-ferrous metals together, and is used universally in electronics, air conditioning and refrigeration circuits, household plumbing and more besides – applications where the precise joining together of components at fairly moderate temperatures is needed. Further up the scale, **brazing** involves using higher temperatures to melt brazing rods onto larger metal parts, perhaps to repair a metal chair, lawnmower or to fabricate metal components or jewellery into intricate shapes. Lastly, **welding** is a very aggressive way of fabrication using welding rods or wire; steel girders, oil rigs and ships are all welded together, or robotic spot-welding is used for the mass production of, say, washing machines or car bodyshells using sheet steel to make strong rigid assemblies.

Due to the lower temperatures used and the need to make consistently good electrically conductive and mechanically sound joints with precision, soldering is used to connect components together when manufacturing electronic circuits. Small components would quickly be destroyed by brazing or welding, although tiny spot-welding joints do appear in electronics, perhaps to weld a metal tag onto a button battery.

This guide therefore deals with the soldering techniques used in electronics at hobbyist or trainee educational level. It explains what to look for before buying a soldering iron, describes ways of making various solder joints on circuit boards and other electronic components, and also how to *desolder* – removing solder in order to repair a circuit board or replace an electronic component.

You’ll also find more details of other aspects of soldering, including an outline of typical solder types and fluxes. In short, everything you need to get started in electronics soldering is here, so let’s get started!

First steps

The principle behind soldering sounds quite simple: the idea is to join components together to form an electrical connection, by using a mixture of lead and tin solder or alternatively “lead-free” solder (an alloy of tin and copper), which is melted onto the joint using a *soldering iron*. If you have never picked up a soldering iron before, then this guide will show you everything to help you start soldering with confidence. I also hope that the guidance will help those working in other areas — computer technicians or audio enthusiasts, for example, who may be faced with electronic repairs or modifications using a soldering iron for the first time.

If you’re an electronics hobbyist or trainee, before embarking on any form of ambitious electronic project, it is recommended that you practice your soldering technique on some *brand new* components using *clean* strip board (or protoboard) or a printed circuit board, and select a simple and straightforward constructional design as a starting point. Become acquainted and comfortable with your chosen soldering iron, which likely to become as familiar to you as a favourite pen. Learn how to balance it and handle it with precision. Try soldering an assortment of resistors, capacitors, diodes, transistors and integrated circuits with it, and then try your hand at *desoldering* – removing the solder again to make a repair or modification.

A really good place to start learning is by building a simple electronics kit, such as a Velleman kit that contains a good quality printed circuit board. You’ll learn some of the basic skills of successful soldering this way, and it’ll be a great confidence booster too.

Did you know? In the USA and elsewhere, the letter L in “solder” is silent and they say “soda” or “sodder” – but here in Britain we do pronounce the L and we say “sole-der”.

Soldering iron choices

Search any electronics catalogue or website and you'll see a bewildering array of soldering equipment on sale, including irons, controllers, work stations and desoldering equipment too. A large range of soldering irons is readily obtainable - which one is suitable for you depends on your budget and how serious your interest in electronics is, but there's something for every pocket distributed by a variety of retail, industrial and mail-order outlets.

The Antex range of soldering equipment has been very popular with industry, education and the electronics hobbyist for 60 years; I grew up with an Antex iron and a trusty 15W Antex iron was an everyday part of my hobby electronics all the way through the 1980's. An industrial user or a more dedicated hobbyist – with a bigger budget! – will be interested in a soldering station instead and again Antex offers a range of British-made products for industry or home use.

A very basic mains electric soldering iron can cost from under £5 (US$ 8), but I find that these very cheap irons, as sold on auction websites, are pretty crude and imprecise. They are best suited for simple electrical repairs and DIY rather than precision electronics or printed circuit boards discussed here. They tend to be bulky and uncomfortable for extended use, and they may not have suitable "bits" or tips of various sizes to suit different tasks.

^^ This classic Antex XS25 "pencil style" 25W mains-powered soldering iron has exchangeable tips or "bits" and is great for general hobbyist or educational use. Stands are also available to store them safely in between use.

A quality pencil-style electric soldering iron such as the Antex XS25 (photo) will be approximately £20 (US$18 tax free) - though it's possible to spend into three figures on a soldering iron “station” if you’re really serious about the subject! Don’t be tempted to over-spend on an elaborate workstation though, unless you are really very serious about becoming involved in electronics. You will usually obtain perfectly satisfactory results using a fairly modest “pencil” iron model, and you can upgrade to something more sophisticated should your needs change in the future.

^^ *For enthusiasts or industry, this Antex 660TC soldering station has a separate mains-powered control unit and a matching low-voltage soldering iron rated at 24 Volts, 50 Watts so it’s suited to a wider range of tasks than a lower powered one.*

When choosing your soldering iron, certain factors to bear in mind include:

Voltage: for the British market, “mains” electric irons run directly from the mains at 230V a.c. or will be set for other voltages (110V a.c.) depending on the country. However, **low voltage types** (e.g. 12V or 24V) usually form part of a “soldering station” for use with a matching controller made by the same manufacturer. Some low-voltage irons run off batteries (e.g. a car battery or Ni-cads) but these are uncommon.

Wattage: this is an extremely important factor to think about when choosing your iron. Typically, irons for general electronics work may have a power rating of between 15-25 watts or so, which is fine for most electronic assembly tasks, printed circuit boards and inter-wiring. It’s important to note that a higher wattage does *not* mean that the iron runs hotter - it simply means that there is more power “in reserve” for coping with larger joints. The maximum electric iron wattage generally available is about 100W, which is OK for DIY electrical repairs but is far too high for general electronics or circuit board use.

A higher wattage iron offers you more flexibility for tackling a wider range of tasks. It has a better “recovery rate” which makes it more “unstoppable” when it comes to heavier-duty work, because it won't be drained of its heat so quickly. So check the power ratings carefully, and anything between 15–40W is fine for general electronics soldering.

Temperature Control - the simplest and cheapest types don't have any form of temperature "regulation". Simply plug them into the mains and switch them on! Thermal regulation is "designed in" (by physics, not electronics!). Sometimes they are described as "thermally balanced" as they have some degree of temperature "matching" – in other words, they warm up as quickly as they lose heat during use, so in a primitive way they maintain roughly a constant temperature. This type of iron is perfectly acceptable for hobby or less demanding professional use. It's essential to use the manufacturer's specified tips (see later) to maintain proper temperature matching, otherwise the iron may not heat up enough – or it may overshoot in temperature.

These unregulated irons form an ideal general-purpose iron for most users, and they cope reasonably well with printed circuit board soldering and general interwiring. However, most of these "miniature" types of iron will be of little use when attempting to solder large joints (e.g. very large terminals or very thick copper wires) because the components being soldered will draw or "sink" heat away from the tip of the iron, cooling it down too much and preventing solder from flowing properly. That's when a higher wattage iron is needed.

A proper **temperature-controlled iron** will be quite a lot more expensive - retailing at say £40 (US$ 60) or more - and will have some form of built-in thermostatic control, to ensure that the temperature of the "bit" (the tip of the iron) is maintained at a fixed level within reasonable limits. This is desirable during frequent use, since it helps to ensure that the temperature will be relatively stable regardless of the workload. Some irons have a bimetallic strip thermostat built into the handle which gives an audible "click" in use, and some may include an adjustable screwdriver control within the handle as well. Others may have electronic controls built in.

^^ An Antex 660TC soldering station with matching iron and bench stand.

More expensive still, **soldering stations** cost from £70 (US$ 115) upwards (the iron may be sold separately, so you can pick the type you prefer), and consist of a complete bench-top control unit into which a special *low-voltage* soldering iron is plugged. Some versions might have a built-in digital temperature readout, and a control knob to vary the setting. The temperature could be boosted for soldering larger joints, for example, or for using higher melting-point solders (e.g. lead-free or silver solder). These are designed for the discerning user, or for continuous production line or professional use. A thermocouple will be built into the tip or shaft, which monitors temperature.

The best soldering stations have irons which are well balanced, with comfort-grip handles which remain cool all day, and silicone-based cables which are burn proof. Antex produces a range of irons with silicone cables specially for education use, to help avoid accidents caused by careless use by students.

Anti-static protection: if you need to solder a lot of static-sensitive parts (e.g. CMOS chips or MOSFET transistors), more advanced and expensive soldering iron stations use static-dissipative materials in their construction to avoid static charges accumulating on the iron itself, which could otherwise damage or “zap” some semiconductors. Such irons are listed as “ESD safe” (electro-static discharge proof). The cheapest irons are not classed as ESD-safe but they still perform well enough in most hobby or educational applications provided you take the usual anti-static precautions when handling these components. The iron would need to be well earthed (grounded) in these circumstances, to carry away any static.

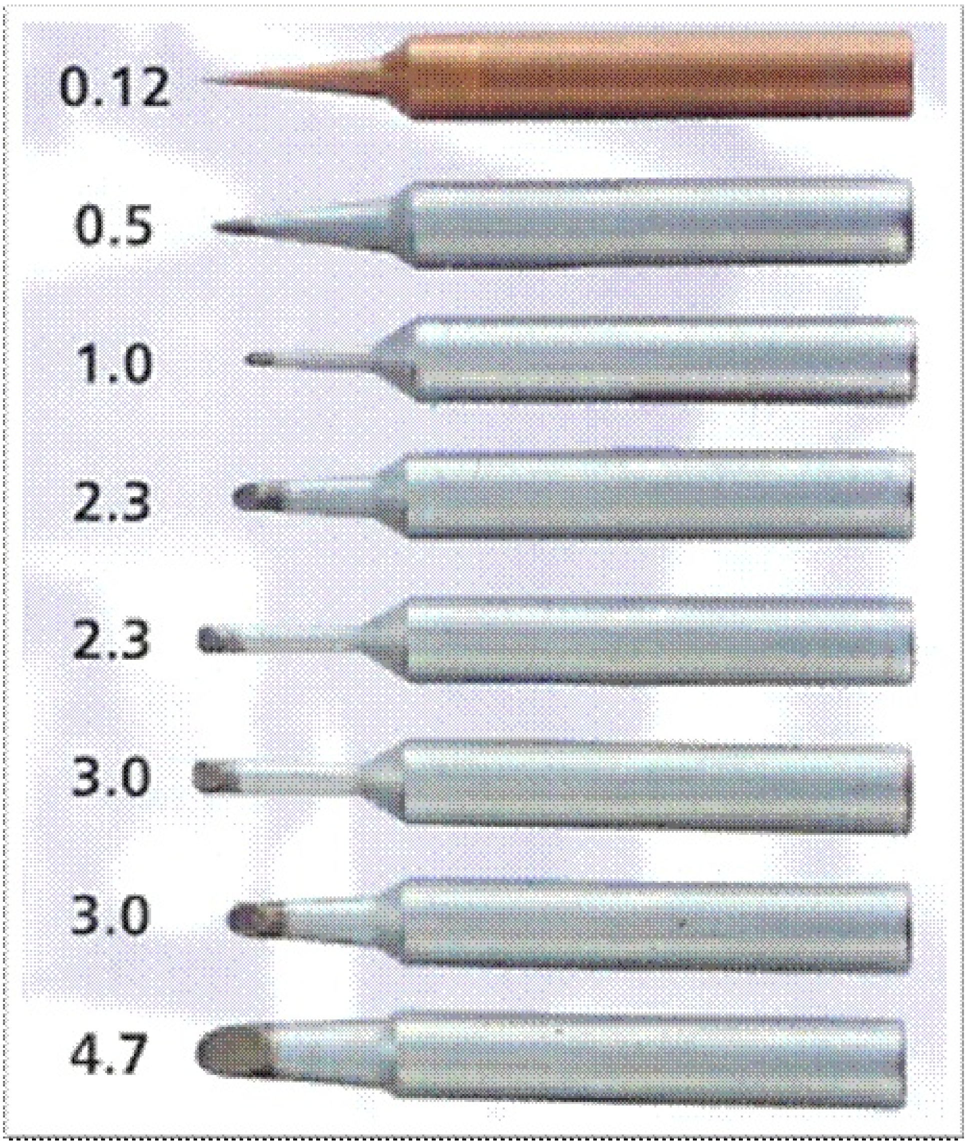

^^ Just part of the range of spare tips or "bits" produced by Antex for their soldering irons. Use only tips intended for a particular iron, to avoid thermal matching problems.

Tips or Bits: it's often useful to have a small selection of manufacturer's bits (soldering iron tips) available with different diameters or shapes, which can be changed depending on the type of work in hand. You will probably find that you become accustomed to, and work best with, one particular shape of tip for the majority of your work. Usually, tips are iron-coated or plated to preserve their life and to maintain good tip "hygiene". Be sure only to use tips that are specifically designed for your iron, otherwise thermal problems may arise. I show separately some typical tips, courtesy of Antex.

^^ Useful accessories from Antex including solder, tips and tip cleaner, desoldering braid and a heatshunt.

Spare parts: it's always reassuring to know that spares are available in the future if required, so if the element blows, you don't need to replace the entire iron. This is especially the case with expensive irons. Check some websites or mail-order catalogues to see whether spare parts are listed. One drawback is that you may need another soldering iron when exchanging a broken heating element!

ANTEX Gascat 40

^^ Gascat 40 gas-powered soldering iron kit by Antex, with spare tips and cleaning sponge.

Gas or electric? So far I've discussed electric soldering irons, but **gas-powered** soldering irons are sold which use butane propellant rather than mains electricity to operate. They have a flint lighter or (better still) a built-in piezo for ignition, and have a catalytic element which, once warmed up, continues to glow hot when gas passes over them. They tend to be big and bulky compared to electric pencil irons.

Field service engineers use gas-powered irons for working on repairs where there may be no power available, or where a joint is tricky to reach with a normal electric iron, so they are really for occasional “on the spot” use, rather than for mainstream construction or assembly work. I use one when I just need to do a quick repair and can’t be bothered getting the electric soldering iron going!

Gas irons can have higher power equivalents than electric ones (eg 125 watts or more) but some gas-powered irons are nothing more than miniaturised blowtorches, which may or may not be useful for occasional heavier duty soldering. In the author’s experience they can be difficult to use in confined areas. *Extreme care is needed at all times to ensure hot gas emitted from the iron’s exhaust port doesn’t damage nearby materials, plastics or wiring.* Gas irons can have useful accessories to convert them into e.g. a hot knife for sealing nylon rope, or a hot-air blower for use with heatshrink tubing. Almost every electronics constructor uses an electric-powered iron though.

A **solder gun** is a pistol-shaped iron, typically running at 100W or more, and is completely unsuitable for soldering modern electronic components: they’re too hot, heavy and unwieldy for micro-electronics use, nor are they designed for that. Plumbing or DIY, maybe..!

^^ A heat resistant soldering iron stand with cleaning sponge. (Antex)

Soldering irons are best used along with a **heat-resistant bench stand**, where the hot iron can be safely stored in between use (photo). It is extremely important that a hot soldering iron is safely “parked” ready for action, and a bench stand is really a necessity. Soldering stations usually have such a feature, otherwise a separate soldering iron stand is essential, ideally one that’s supplied with a tip-cleaning sponge. You can make your own cleaning sponges using *cellulose* sponge only.

^^ *A benchtop fume extractor fan for hobbyist use. A replaceable carbon filter helps remove particles and air is vented out the back.*

Other equipment worth considering includes the use of **fume extractors**, which are compulsory in the industrial workplace. Solder fumes and flux smoke are not known to be toxic but they can cause irritation. A basic fume extractor (photo) consists of a small bench-top fan which draw fumes and irritating smoke away from the operator’s face and filters out some of the smoke particles, before exhausting the air back out through the fan. The carbon-impregnated foam filters are replaceable. Such devices are quite effective and users soon find them indispensable, even though they can be a bit noisy at close range.

Professional fume extraction systems draw the smoke and fumes directly from the work area via a clip-on tube fitted to the soldering iron, then vent the fumes away through a large filter pump. It is definitely worth considering a small bench top unit for regular hobby or occasional professional use, as having decent ventilation can only be a good thing.

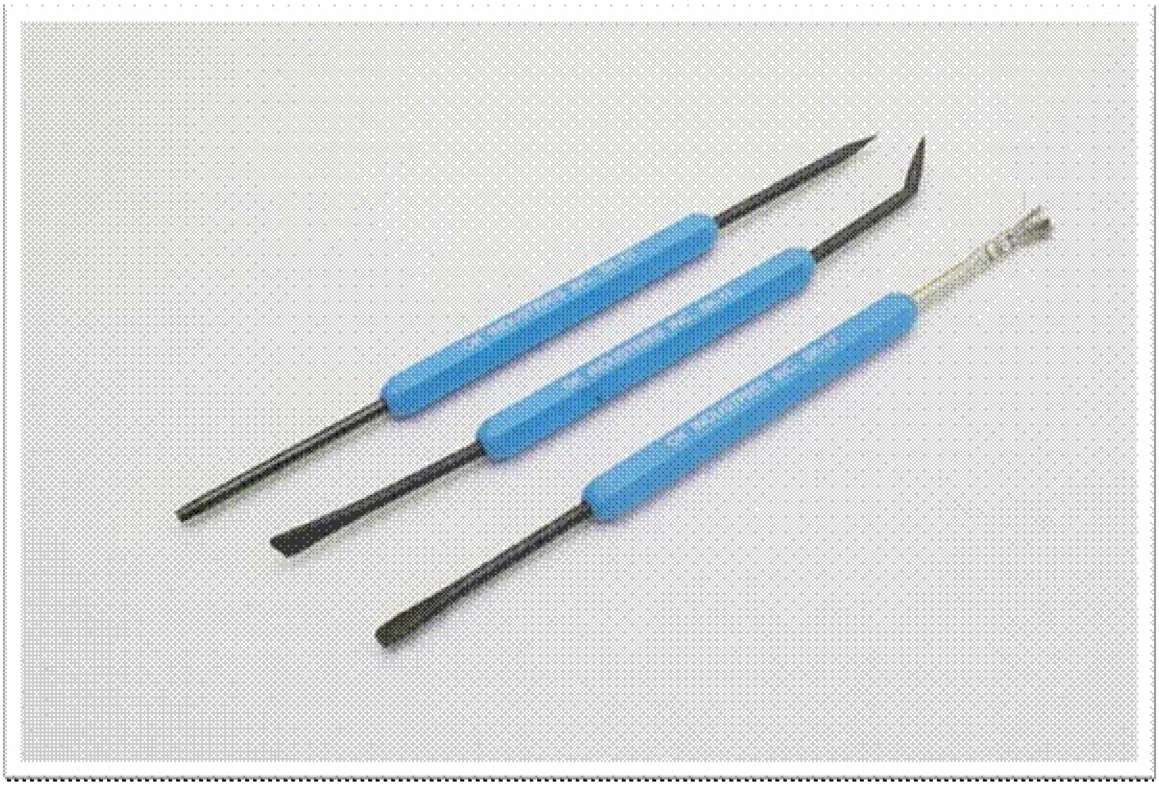

^^ *A soldering accessory toolkit by OK Industries, including probes, scrapers and wire brush*

A variety of specialist **hand tools** are available that assist with soldering, and a good supplier's catalogue will offer a range of small brushes, scrapers and cleaning tools in a handy kit, together with the usual types of wire cutters, pliers and so forth, which are necessary for handling components and tidying up as required. Some specialist service aids (aerosols etc.) are also described later.

Now let's look at how to use soldering irons properly, and later on we will describe the techniques for putting things right when a joint somehow goes wrong — and don't worry, even the experts get it wrong sometimes!

How to solder

This guide will show you step by step how to solder successfully and plenty of photographs are provided to help explain the techniques needed.As you read through the guide I'll explain all the stages in more detail, but let's look at the basics first.

First of all, successful soldering requires that the items being soldered together are held with as little movement as possible. So it's best to *secure the work* as needed, so that your accuracy isn't affected should the workpiece move accidentally.

In the case of a printed circuit board, various holding frames are useful especially when densely populated boards are being soldered: the idea is to insert all the parts on one side (a process called "stuffing the board"), hold them in place with a suitable pad to prevent them falling out again, turn the board over and then snip off the wires with cutters before soldering the joints. The frame saves an awful lot of turning the board over and back again, especially with large boards: all the soldering can be performed in one pass.

^^ The ever-popular "Helping Hands" (left) helps support sundry parts, wires etc. during soldering.
A modeller's vice (right) holds parts firmly. A vacuum base fixes it onto smooth surfaces.

Only the more serious constructor will purchase a holding frame, and hobbyists can retain parts in place by improvising in a variety of ways – the ever popular "Helping Hands" stands cost a few pounds and is widely sold. They have adjustable crocodile clips to grip parts, and maybe a magnifying glass or soldering iron stand as well. The cast iron base provides stability. Other parts could be held firm in a modeller's small vice, for example.

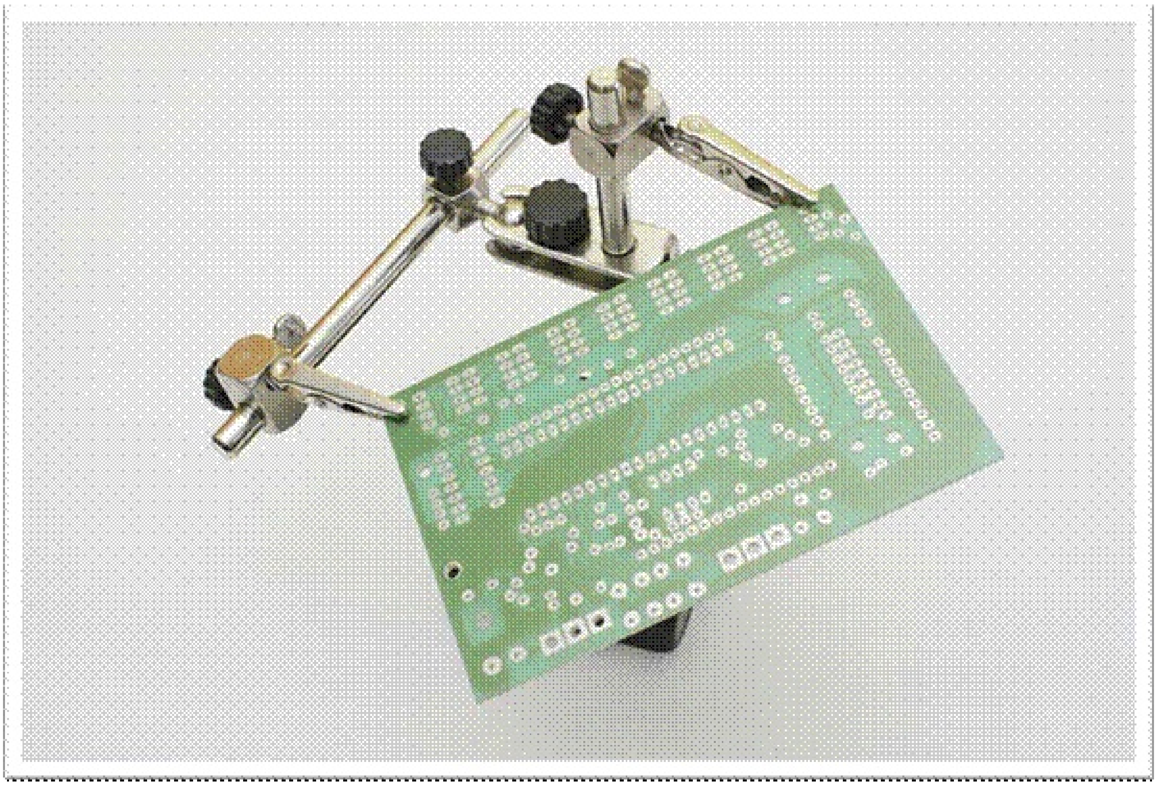

^^ *"Helping Hands" uses crocodile clips to grip parts during soldering. Or just place parts flat on the bench.*

When soldering parts onto an ordinary circuit board, components' wires can simply be bent to the correct pitch (distance apart) to fit through the board, insert the part flush down against the board's surface, splay the wires a little so that the component grips the board under spring tension, and then solder it. This technique is universally used in manual **through-hole soldering,** which is explained in full later.

In the author's view - opinions vary – it's generally better to snip off the surplus wires leads first, to make the joint and neighbouring joints more accessible and also to reduce the mechanical shock transmitted to the p.c.b. copper foil. However, in the case of diodes and transistors the author tends to leave the snipping until after the joint has been made, since the excess wire will help to "sink" heat away from the heat-sensitive semiconductor junction.

A special clip-on heatsink is available which also helps stop excess heat from reaching temperature-sensitive semiconductors like these. I've always managed without one but beginners might find them reassuring. Integrated circuits can either be soldered directly into place if you are confident enough, or better, use a dual-in-line socket to prevent heat damage. The chip can then be swapped out at a later date if needed.

Parts which become hot in operation (e.g. some power resistors), should be raised above the board slightly to allow air to circulate. Some components, especially large electrolytic capacitors, may require a mounting clip to be screwed down to the board first, otherwise the part may eventually break off due to vibration. It's a good idea to bolt such components firmly into place before soldering their terminals, in order not to strain the soldered joints or the components when fasteners are tightened.

By securing the workpiece as much as possible to prevent movement, you have a much higher chance of producing good-quality reliable solder joints.

Next steps

Let’s get to grips with actual soldering techniques in more detail. The soldering of electronics components utilises **lead/ tin** or **lead-free solder** and the process is compatible with many non-ferrous metals. You can solder copper, lead, brass, gold plate, silver, nickel, tin and tin plate, zinc and more besides but some metals such as nichrome, galvanised or stainless steel require a highly specialist “flux” (see later) to solder them and aren’t discussed here. Some materials such as beryllium, chromium, magnesium and titanium are non-solderable in any case, according to solder manufacturers Multicore.

In electronics we’re mainly concerned with soldering parts or wires onto printed circuit boards or terminals that are usually already “tinned” with solder or plated, ready for soldering with flux-cored solder. The key factors affecting the quality of a solder joint are:

- **Cleanliness** – dirt or impurities drastically hinder good solder coverage.
- **Temperature** – the right level to enable the solder to flow freely!
- **Time** – apply heat for just the right amount of time!
- **Adequate solder coverage** – enough to form a good joint without touching neighbouring areas.

A little effort spent now in soldering the perfect joint may save you — or somebody else —a considerable amount of time in troubleshooting a defective joint in the future. Let’s discuss the basic principles outlined above in more depth.

Cleanliness and “Tinning” the bit

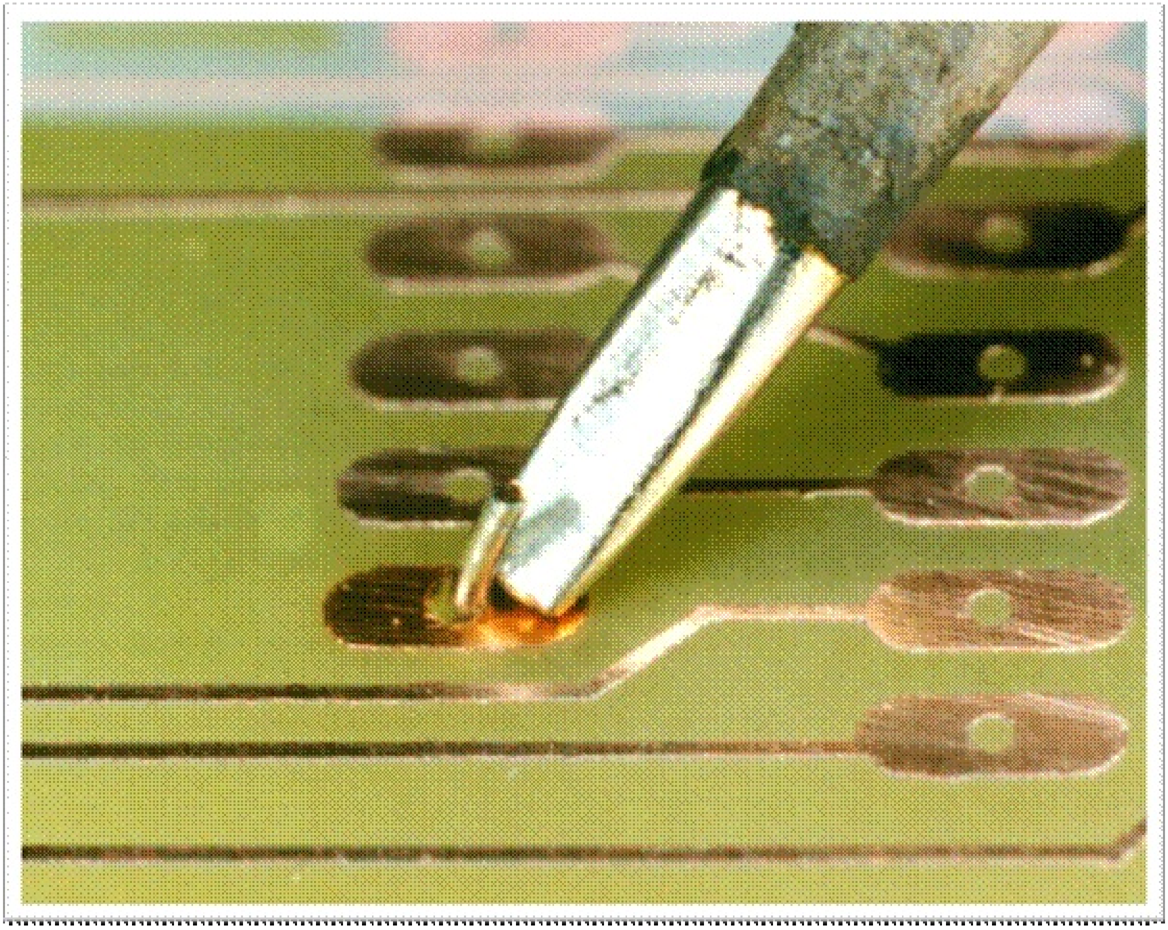

^^ A clean and shiny soldering tip or “bit” is essential for each and every solder joint you make.

Firstly, and without exception, all parts - including the soldering iron’s tip itself - must be clean and free from contamination. Fact is, solder just will not “take” to dirty parts! Old components or copper board can be impossible to solder because of oxidation that builds up on the surface of the leads. This repels the molten solder and will soon become evident because the solder will “bead” into shiny globules looking like mercury, going everywhere except where you need it. *Dirt and contamination are the enemies of a good quality soldered joint!*

When all the conditions are right for soldering, materials are said to be “wettable” and will accept molten solder, which should flow readily over their surfaces. Hence, it’s **really necessary** to ensure that parts are free from grease, oxidation and other contaminants. Note that in any case, some incompatible materials or surface finishes just cannot be soldered using ordinary lead-free solder, no matter how hard you try – e.g. aluminium parts would require special aluminium solder and fluxes (see later) to be used.

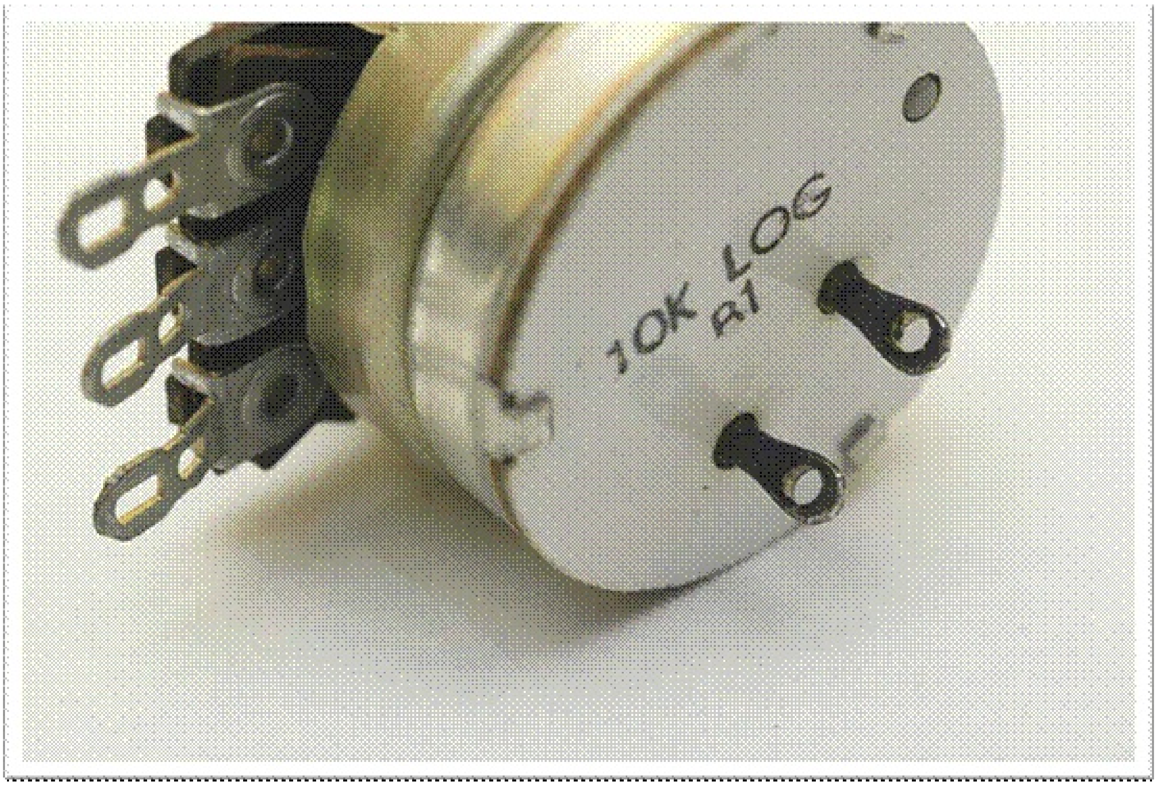

^^ The two tags on this switched potentiometer have blackened with age and oxidation. They must be cleaned before they can be soldered…

In the case of old components that have been stored a long time, where the leads have blackened and oxidised, use a small hand-held file or perhaps fine emery cloth to reveal fresh metal underneath. Stripboard and copper printed circuit board will generally oxidise after a few months, especially where it has tarnished due to fingerprints, so the copper strips could be cleaned using e.g. an abrasive rubber block made for the purpose. Also available is a fibre-glass filament brush (photo), which is used propelling-pencil-like to remove contamination. They're OK for general cleaning but best avoided on fine surfaces (e.g. gold plated switch contacts). These produce tiny particles which can irritate the skin, so avoid accidental contact with any debris.

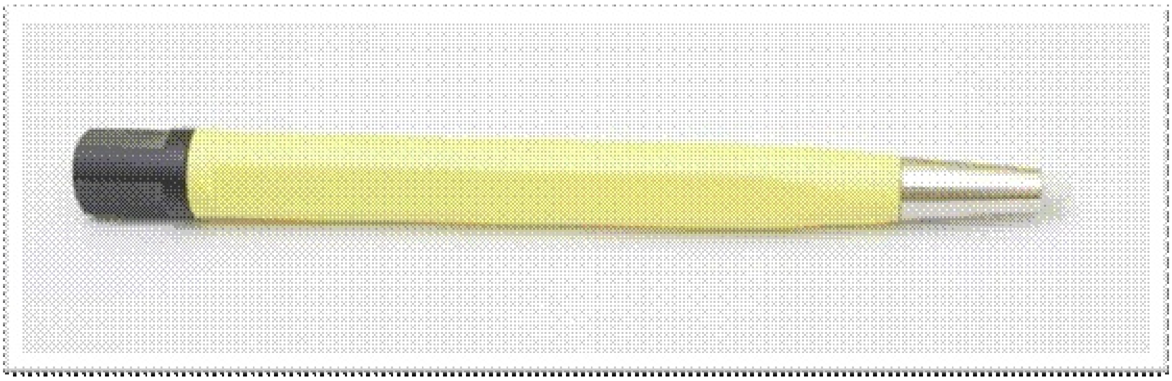

^^ A glass-fibre filament brush like this is useful for cleaning oxidised parts.

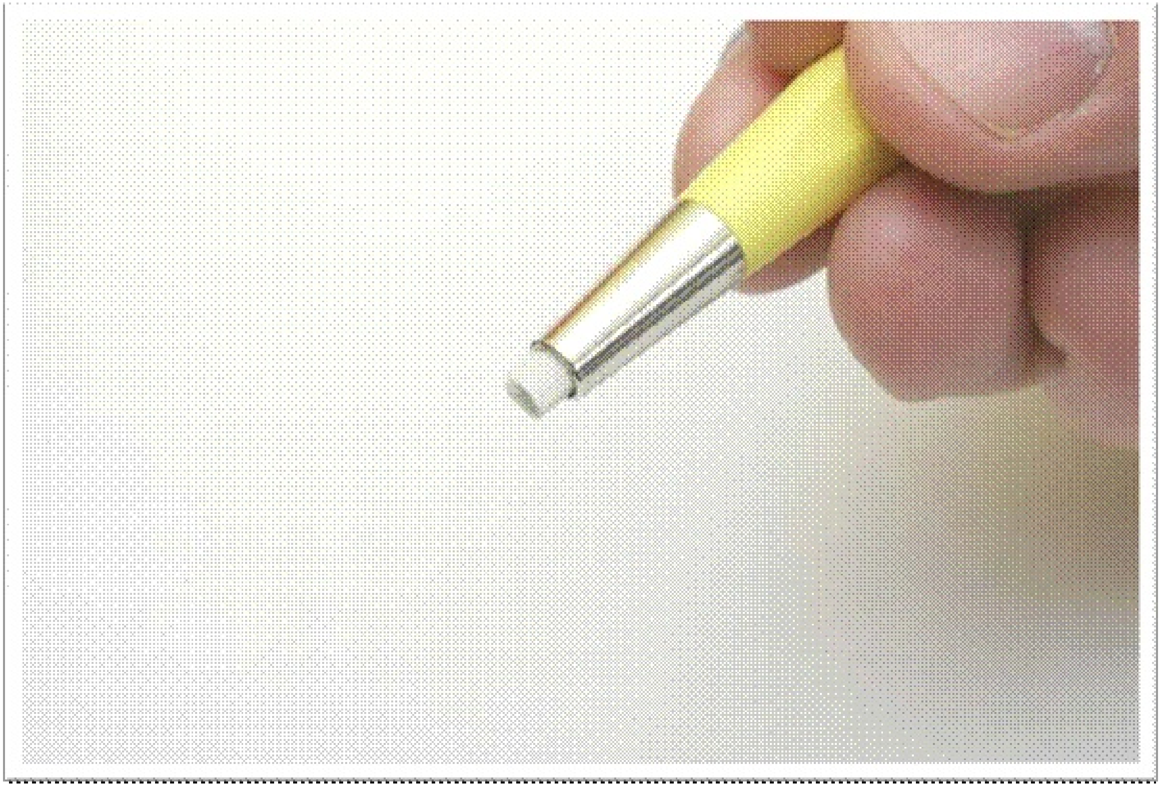

^^ The glass-fibre brush works like a propelling pencil and produces irritating dust.

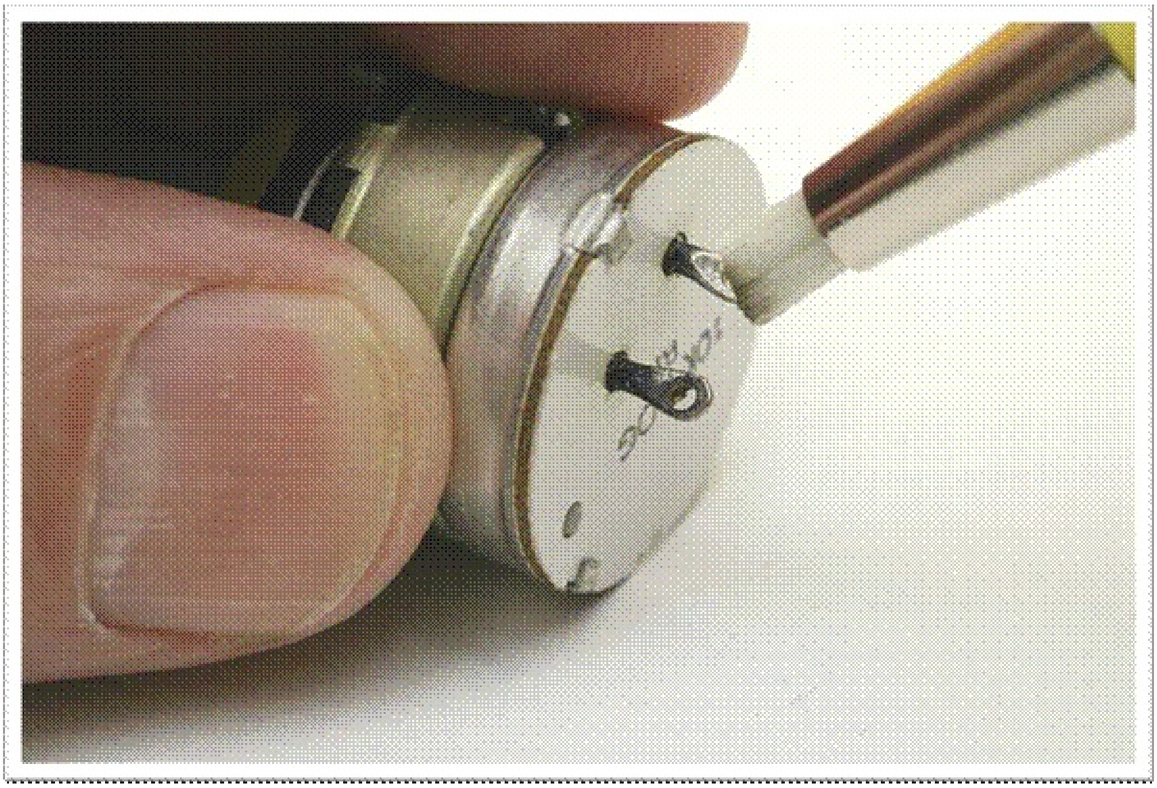

^^ Cleaning oxidised tags with a glass fibre brush to make them nice and shiny, ready for soldering

Afterwards, a wipe with a rag soaked in cleaning solvent will remove most grease marks and fingerprints. After preparing the surfaces, avoid touching any parts as far as possible.

Another side effect of trying to solder contaminated or incompatible materials is the tendency to apply more heat and "force the solder to take". As the materials aren't wettable the molten solder won’t flow where you want it to flow. This can do more harm than good, because it may be impossible to burn off any contaminants anyway, and the component or the printed circuit board may be overheated and damaged in the process. Semiconductors may be harmed by applying excessive heat for more than a few seconds, and extreme heat applied to printed circuit board tracks can cause irreparable damage, because the tracks will be lifted away from the substrate especially on a delicate or badly designed board. You can avoid trouble by ensuring the surfaces to be soldered are clean and wettable to begin with.

Getting Ready

As already explained, cleanliness in soldering is a major factor in obtaining successful results. A soldering iron stand usually has a sponge that is dampened – it wants to be quite damp but not running wet, so squeeze out any excess.

^^ *Dampen the sponge but don't soak it unduly. Note the hole, which gives an edge to wipe tip with.*

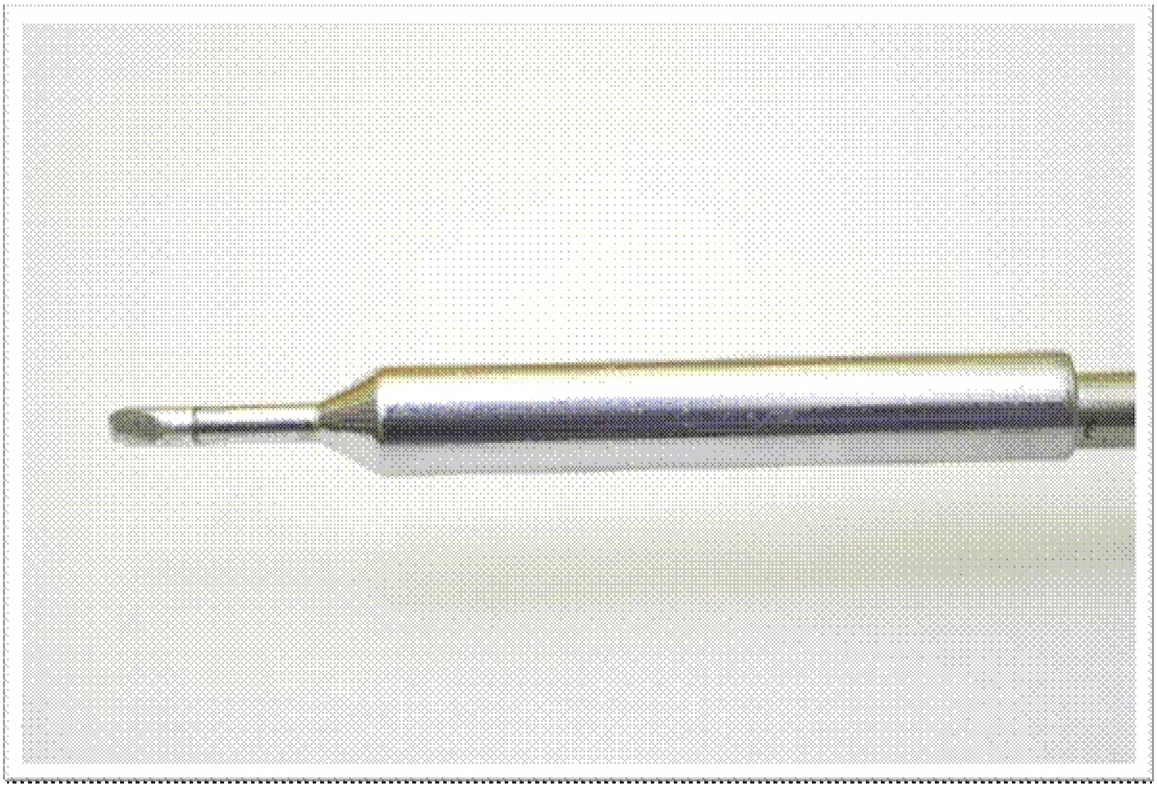

^^ *An Antex soldering iron tip. It simply slides onto the iron's heating element. Only the extreme end is wettable and will accept solder: the tip should be kept nice and shiny.*

Soldering iron bits are typically iron-plated to resist wear, then chrome-plated to prevent molten solder being deposited on them, with the extreme tip being "wettable" to work with molten solder. Before using the iron to make a joint, the hot tip must be "tinned" with a few millimetres of solder*: you should always flood a brand new tip with plenty of solder to tin it immediately, when using it for the first time*.

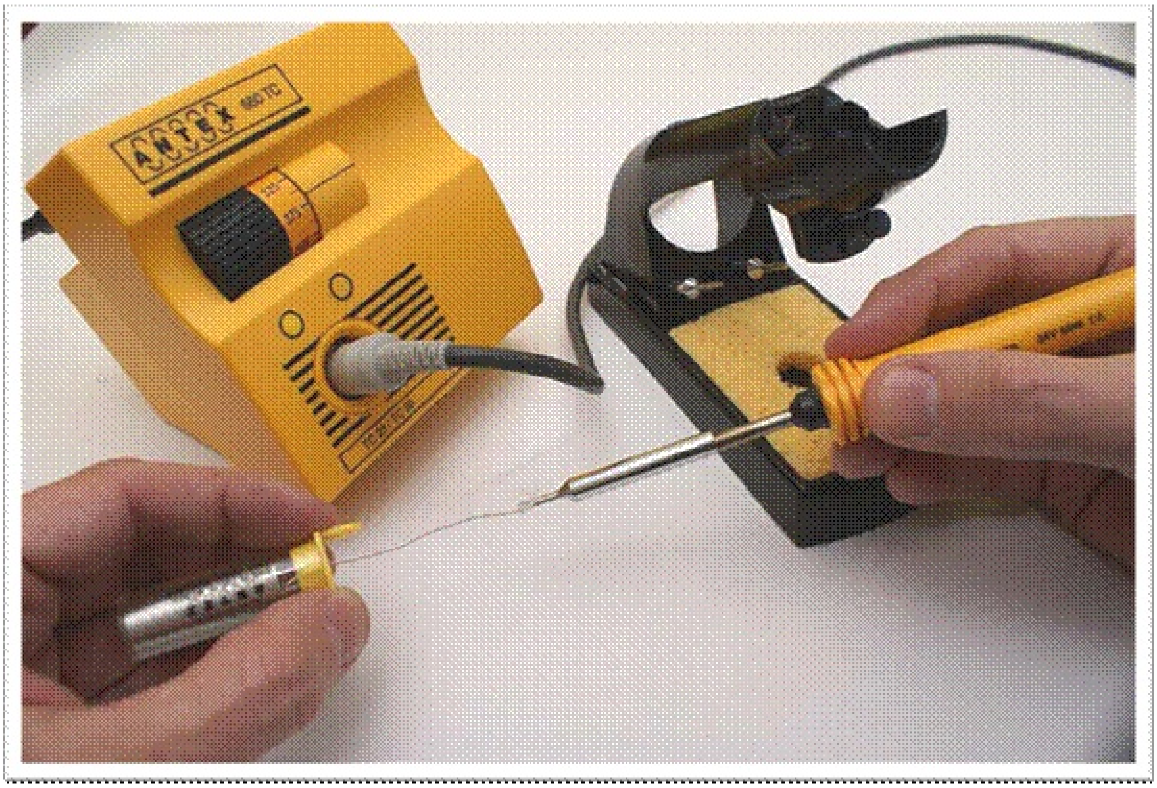

^^ *Tinning the tip ready for use: apply a few millimetres of solder to the hot tip.*

Wipe off excess solder using a damp sponge and it's ready to use. That's why sponges have a hole or well in them – the edge acts as a wiper and the hole catches excess solder.

A useful tip: after tinning the bit, just before using the iron it helps to re-apply a small amount of solder to a clean tip, to improve the thermal contact between the tip and the joint. The molten solder fills the void between the materials and the iron tip, to help transfer heat better so that the solder flows more quickly and easily.

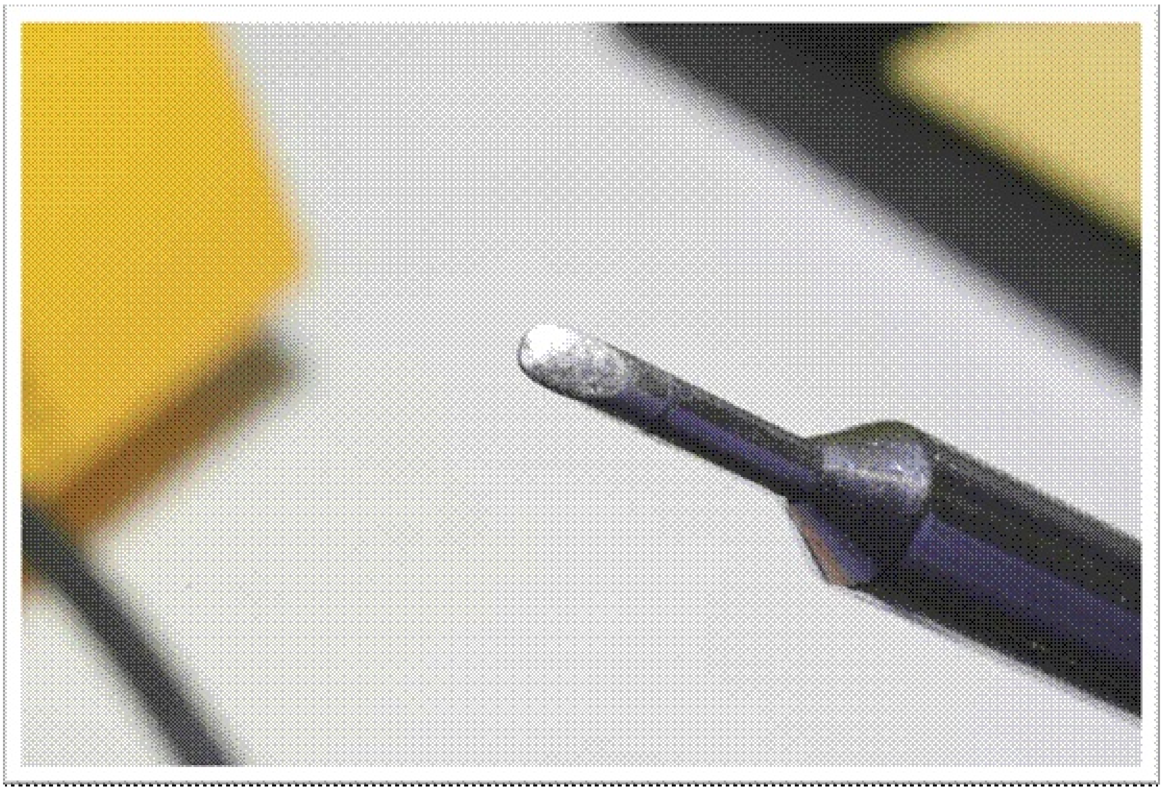

^^ *A tinned tip should look like this, ready to make the next joint.*

It’s sometimes better to tin larger parts as well before making the joint itself, but this is not generally necessary with p.c.b. work. Small tinlets of special paste are available onto which you dab a hot iron - the product cleans and tins the iron ready for use. It’s useful in extreme cases where the bit has some stubborn contamination.

I find special Tip Tinner &Cleaner products to be very useful: gently abrasive in action, they help to clean dirty bits and keep them in good condition. Use them for removing stubborn contaminants, but don’t overdo it.

Multicore
Tip Tinner/Cleaner
TTC1
15g / 0.5oz
Made in Malaysia

^^ Tip Tinner and Cleaner is a useful aid to maintaining a soldering iron bit …

^^ Just press the hot iron onto the solid paste and scrub it around a little. The tip will be cleaned, tinned, and made ready for use.

The move to lead-free solders (see next chapter) has had some effect on the life of soldering iron bits, with increased wear and corrosion noted due to the higher temperatures and the fluxes found in tin-based solders. You can therefore expect bits to wear out over time. Once the iron-plating is damaged due to oxidation or erosion, the bit is fast approaching its end of life. Never use an abrasive or file to sand down a tip: the iron-coating will be damaged and the iron’s core exposed, so the tip will soon be made useless due to erosion.

Having prepared the soldering iron tip ready for use, in the next chapter solder and fluxes are discussed.

Solder and Fluxes

In recent years there's been a move towards using more environmentally-friendly materials in electronic products. EU legislation such as *Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment* (RoHS) aims to reduce toxic heavy metals being sent to landfill. (Look for the RoHS symbol on equipment to indicate compliance.) Due to RoHS compliance, the electronics industry had to change the type of solder it uses in electronic production.

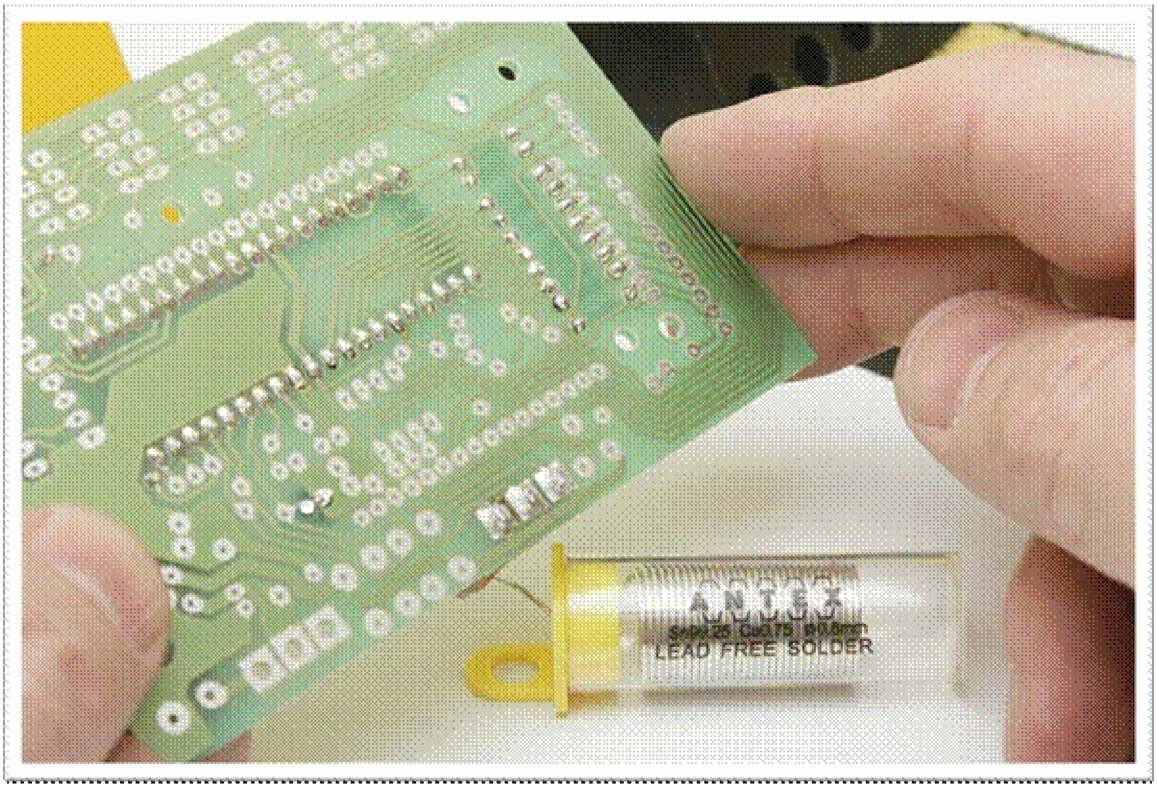

^^ *Electronics solder is supplied in reels or handy dispensers like this.*

Solder comes in various forms including solid bars or pellets for melting in small electric 'solder pots' used for treating the ends of wires with solder. Traditional general-purpose electronics-grade solder is in wire form – starting with so-called "60/40" which contains 60% tin (symbol Sn) and 40% lead (symbol Pb) and is sold in handy dispensers or reels. Although tin-lead solder is now banned in industry, there's nothing to stop the hobbyist from using it but best practice is to use lead-free solder in our work: my advice is to try both, and see which you prefer to work with. "40/60" tin-lead produces lower quality results but is slightly cheaper and perfectly acceptable in hobby circles.

Various diameters of solder wire are marketed. In the UK they're sold in Standard Width Gauge (SWG) sizes, typically as 18SWG (1.2mm) or 22SWG (0.7mm). The latter is fine for almost all hand-soldering of printed circuit boards or general electronics. For larger solder joints (e.g. larger switch or motor terminals), 18SWG solder would be better as more solder can be dispensed more quickly.

Lead-free solder is universally available and contains typically 99.7% pure tin and 0.3% copper (symbol Cu). It needs a higher melting point which makes it slightly more difficult to work with, but standard soldering irons will cope with it well. Antex lead-free solder (Sn 99.25 / Cu 0.75) is a good compromise at 0.8mm diameter and is sold in small dispensers.

Other solders are produced for specialist work, including aluminium solder (Alu-Sol®) and another solder variant used by professionals is Multicore “Smart” wire which contains a small amount of pure silver (symbol Ag). It produces very clean results and is often associated with SMD (surface mount devices), though some engineers also use it for routine p.c.b. work for producing the best possible finish by hand. As “Smart” wire contains lead it is not RoHS compliant.

An interesting variant is **Eutectic** solder, which is 63/37 Tin/Lead. It goes instantly from solid to liquid when melted and is particularly good for hand-soldering. An almost-equivalent lead-free product would be Stannol Flowtin TC or TSC solder.

The low-down on fluxes

When melting solder with a soldering iron, oxides of metal are produced as a result of the high temperatures involved. Unfortunately, these oxides contaminate the metal surfaces being soldered, which interferes with the flow of molten metal and the production of a good quality solder joint.

All electronics-grade solder wire therefore contains an additive called "flux" which helps the molten solder to flow more easily over the joint. It does this by scrubbing away the oxides which arise naturally during heating, and it will often be seen as a pungent brown fluid bubbling away on the joint, accompanied by some fumes.

Those coming into electronics from other industries should note that flux is already contained within "cored" electronics solder and on no account should any acidic flux be applied separately before using the soldering iron. Plumbers, for example, apply flux paste to copper pipes before soldering them, but electronics-grade solder wire already contains a flux and extra flux is almost never needed. Electronics is no place for acid fluxes!

^^ *A close-up of electronics-grade multi-cored solder. Five cores of rosin flux can be seen running through it.*

For almost all electronic hand assembly, solder wire containing "Rosin flux" is used. Cores of flux run through the solder wire like letters running through seaside candy, and they prevent the hot area from being contaminated by oxides, otherwise solder would never flow properly and the result would be an incomplete and unreliable joint.

Flux dispensers and Colophony

Flux dispenser pens are sold that allows special liquid flux to be applied separately onto a work area. These might be handy for difficult or challenging jobs to help solder to flow better: adding more flux this way won't do any harm and may help a solder joint to be made more quickly and reliably. In my hobby electronics, there's hardly ever been a time when I felt the need to apply extra flux but it's useful for some very tricky or demanding jobs.

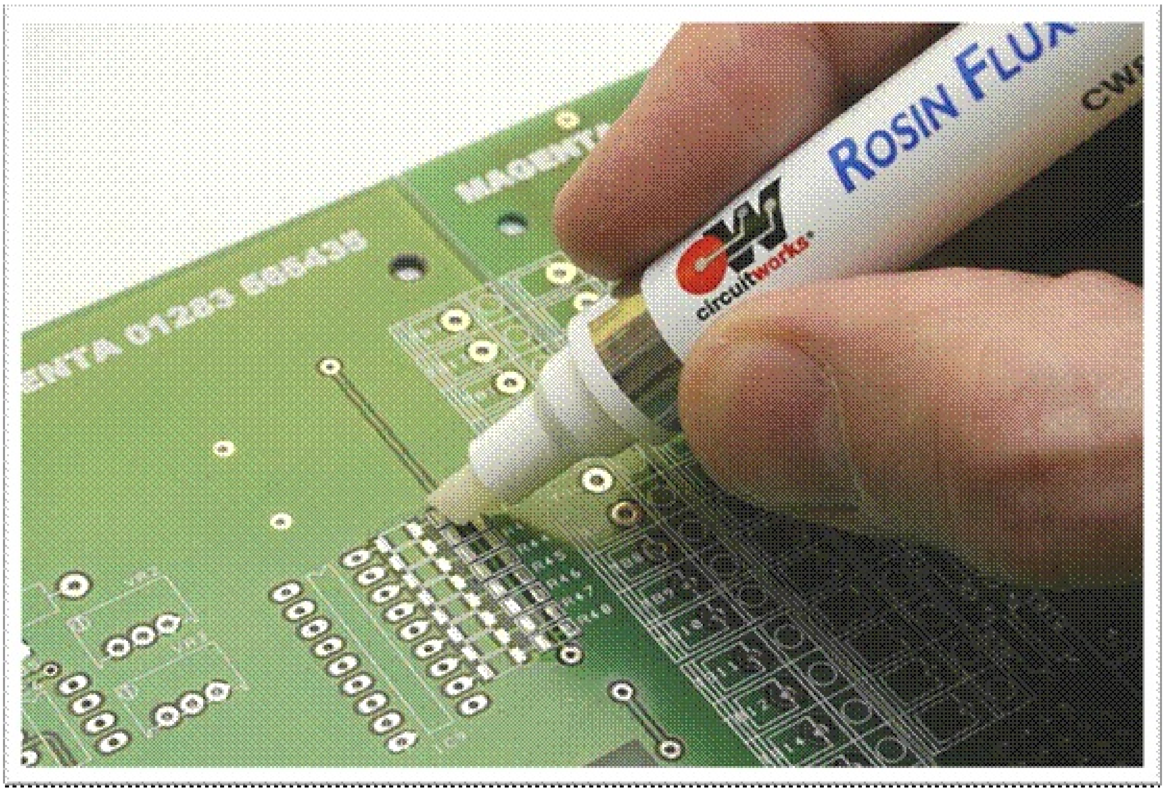

^^ *For more demanding work, a flux dispenser pen allows additional flux to be applied*

For example I've used specialist Chemtronics flux dispenser pens on tricky, extra-large solder joints involving very thick wires for lead-acid battery connections where I really struggled to make the solder flow properly. You might also use them in micro-electronic surface-mount work. The extra flux can only help, but for the rest of the time rosin-flux core solder wire contains sufficient flux and that's all that you'll need.

^^ *Colophony or rosin flux is available in small tinlets if you want to prepare your own liquid flux.*

One thing that many seasoned electronics enthusiasts will recognise is the distinctive smell of rosin flux: its intense woody pine smell is not unpleasant, and flux fumes themselves are not known to be harmful but solder smoke can be an irritant, especially if you suffer from asthma or other respiratory conditions. (I dealt with solder fume extraction earlier when soldering irons were outlined.)

Rosin flux is also known as **Colophony.** It's an amber resin that's glassy and brittle like sugar candy, distilled from the resins of conifers (mainly pine trees) and it's worth knowing about. For electronics use, Colophony is available in individual tinlets of solid resin (e.g. *Kolophonium* in 20g tins by Donau Elektronik GmbH, sold by Westfalia or Conrad).

As an aside, the resins of various trees are used in incense burners: placing a few fragments on a charcoal burner produces intense delicious fragrances of pine, frankincense or forest but you still wouldn't want to inhale the smoke or fumes directly.

Solids of Colophony can be dissolved to make a semi-liquid flux, for dipping or applying manually prior to soldering. To make your own rosin flux from solids of Colophony, chip off some fragments and crush them into a small tinfoil dish, then apply some isoproponal alcohol (start with 2 parts solvent to 1 part Colophony) and let it dissolve over about 20-30 minutes or more.

^^ Chip off some solids of colophony and put them in a small tin foil dish

^^ Add e.g. x 2 volume isopropanol alcohol and allow the solids to dissolve. Experiment as needed.

^^ *The resulting flux can be very sticky so handle with care and do not spill.*

In this form it can be applied directly with a brush or dropper to areas prior to soldering. In an open dish, after a day or two the solvent will mostly have evaporated to leave an extremely sticky resin that should be handled carefully: it's no co-incidence that Colophony is also used in adhesives and varnishes, and different grades of Colophony resins are used to treat violin or double-bass bows to add friction to bow hairs! Try experimenting with different ratios of solvent and making some up and storing it in an old nail varnish bottle with brush, or generally do what works for you.

Unused Colophony crystals can be reformed into their storage tinlet by warming carefully with a hot air gun, but don't overdo it. You can also use flux cleaners or PCB solvent cleaners if you want to remove traces of excess rosin flux after soldering: these are left behind as a brown deposit and are otherwise harmless.

The subject of using your soldering iron to raise the temperature of the materials is discussed next.

Temperature flow

This aspect takes a bit more understanding, but with practice you'll soon understand how temperature flows within a workpiece being soldered and how you have to harness it properly. After ensuring all parts are clean and the soldering iron is ready to go, the next step to successful soldering requires that the **temperature** of **all** the parts is raised to roughly the same level, before solder can be applied.

Imagine the most basic task of soldering a simple resistor onto a printed circuit board: the copper p.c.b. and the resistor lead should both be heated *together* so that the solder will flow readily over the joint. Later I'll show the precise stages step by step.

A beginner will often mistakenly just heat one part of the joint (e.g. a resistor's wire protruding through a printed circuit board) and hope that the resultant "blob" of solder will be enough to tack everything together. That's completely wrong, because the remaining metal in the joint is cold when molten solder is flooded on to it. The joint will be weak, incomplete or unreliable. Flux will not have flowed properly either, so the joint could be contaminated internally.

Another beginner's mistake is to use a soldering iron to carry blobs of molten solder over to the joint, as if to daub solder over it. The secret of success is to control the iron accurately and apply the hot tip onto the workpiece so that it's in contact with *all the parts*. Within a fraction of a second, heat will conduct from the iron and raise the temperature of the entire joint, after which solder can be melted over it. Remove the iron and let the joint cool naturally. It takes some practice with your chosen soldering iron tip to obtain the best heating action, making sure the tip is clean and tinned properly to begin with.

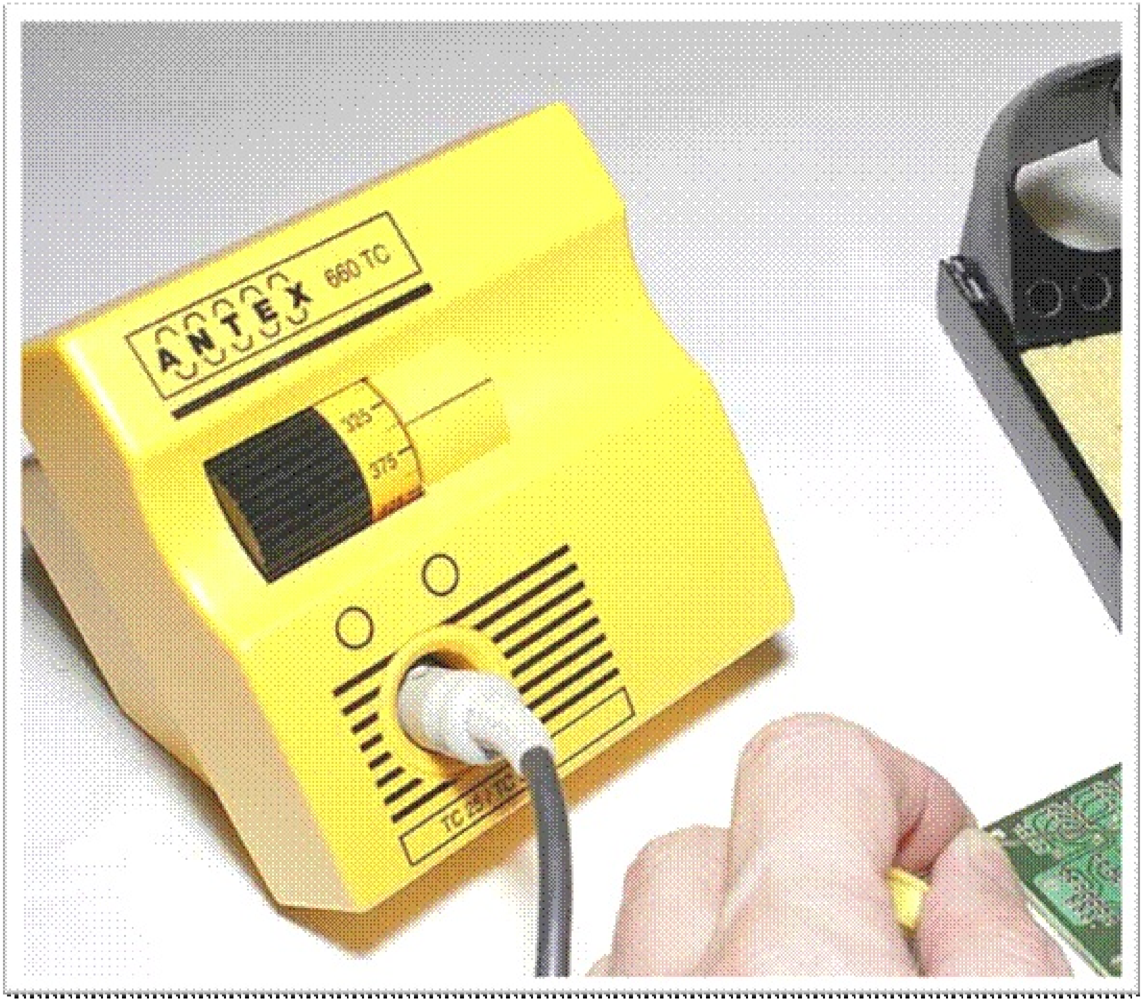

^^ Set a typical temperature of 330-350 ºC (626-662 ºF) or more, if you have a soldering station.

The melting point of traditional tin-lead solders is about 190ºC (374ºF) but lead-free tin-based solders require higher temperatures, having melting points of typically 201-227 ºC. As Antex reminds us, the melting point is *not* the temperature of the soldering iron tip: instead you should set a temperature that ensures the solder melts *instantly* onto the tip. Fixed-temperature soldering irons have no adjustability but they'll cope just fine with either type of solder. A soldering station usually has a variable control that gives more control in different circumstances. In practice the iron tip temperature should be set for typically 330-350 ºC (626-662 ºF) or maybe a little more if using lead-free solder.

Now is the time…

The next diagram shows what would happen if you applied a hot soldering iron to an imaginary metal block. In step (1) heat travels out of the iron into the cold metal block, which starts to warm up starting at the edges. Gradually (2), the whole metal block's temperature rises until the middle of the block finally rises in temperature as well. In effect heat is now travelling back "towards" the iron tip, until finally (3) the whole block is at the same temperature as the iron. At this point solder could now be applied.

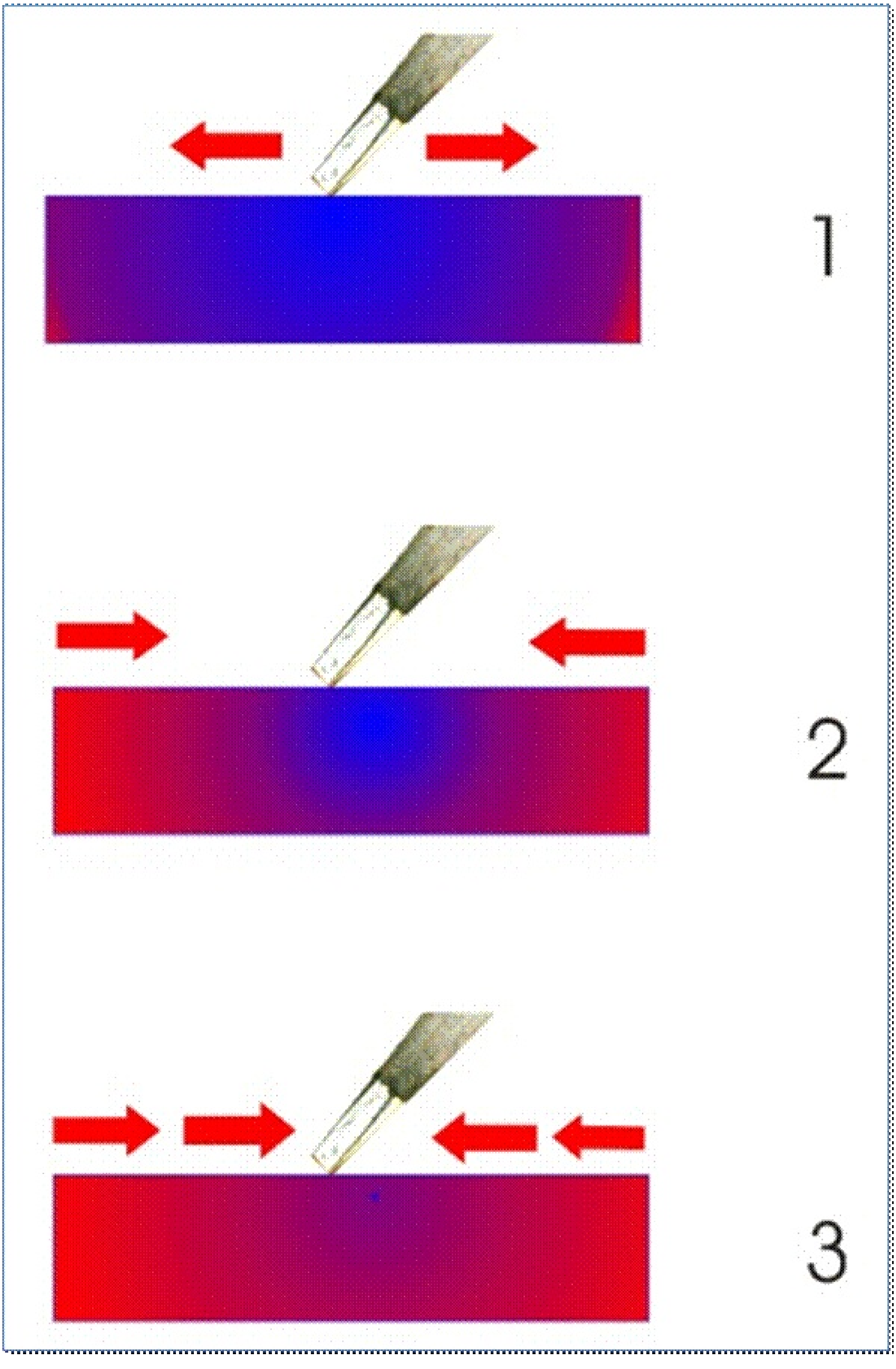

^^ How metal in the joint actually "sinks" heat away from the tip to begin with. Then heat moves back towards the tip until the solder's melting point is finally reached.

You'll notice this effect as a time delay when soldering any joint. The "working area" of the iron's tip gets **cooled** to begin with, because the metal in the rest of the joint is sinking heat away from where it's most wanted. Only after the whole joint has risen in temperature can solder be melted onto it.

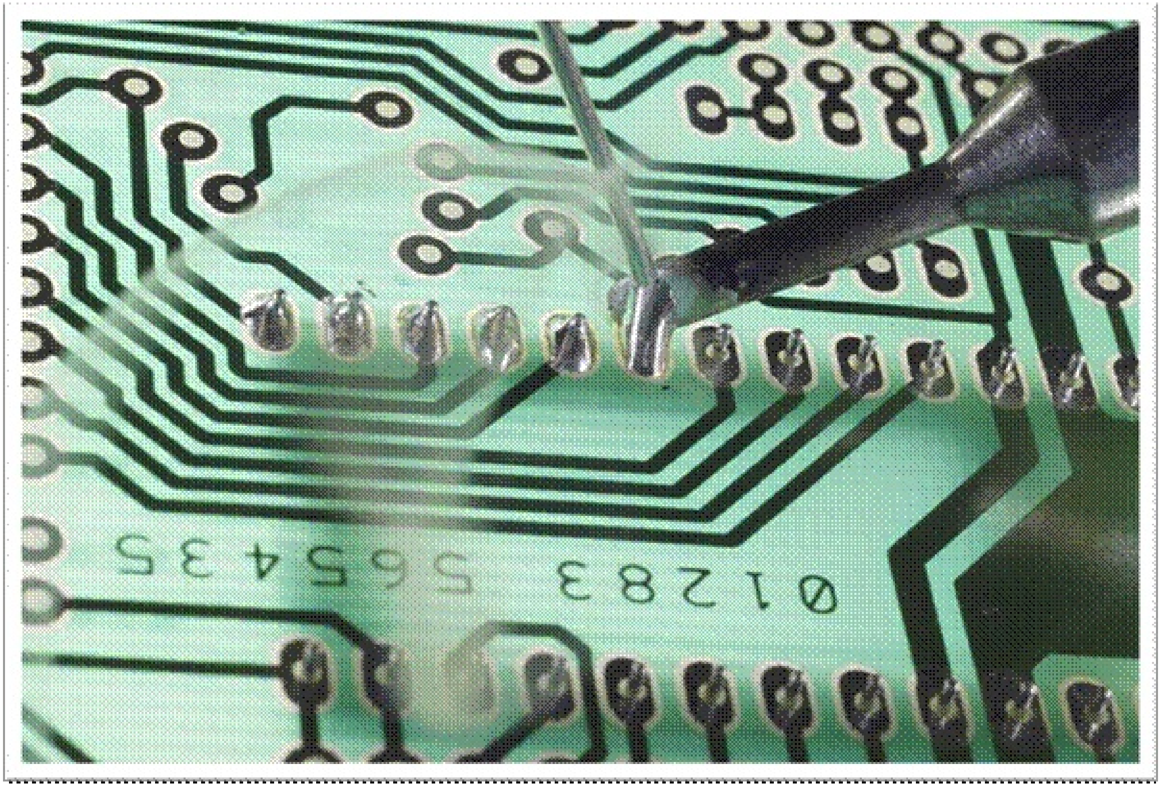

^^ *Soldering a small p.c.b. joint*

With experience, you'll get a feel for how long it takes before you can apply solder. The more metal that is present in the joint, the longer period that heat must be applied for. A small p.c.b. joint takes well under one second to complete. A large metal terminal could take quite a few seconds or more to heat up. As I explained earlier, higher power (wattage) irons cope better with larger workpieces because they recover more quickly and are more "unstoppable", making it easier for them to heat larger workpieces without cooling down so much.

If you apply solder too early, it won't melt properly and the result will be a grey, crystalline joint caused by the solder's melting point temperature not being reached and the flux not having flowed properly. Semiconductors must be soldered as rapidly as possible as they are heat-sensitive, but they're a lot more robust than they used to be.

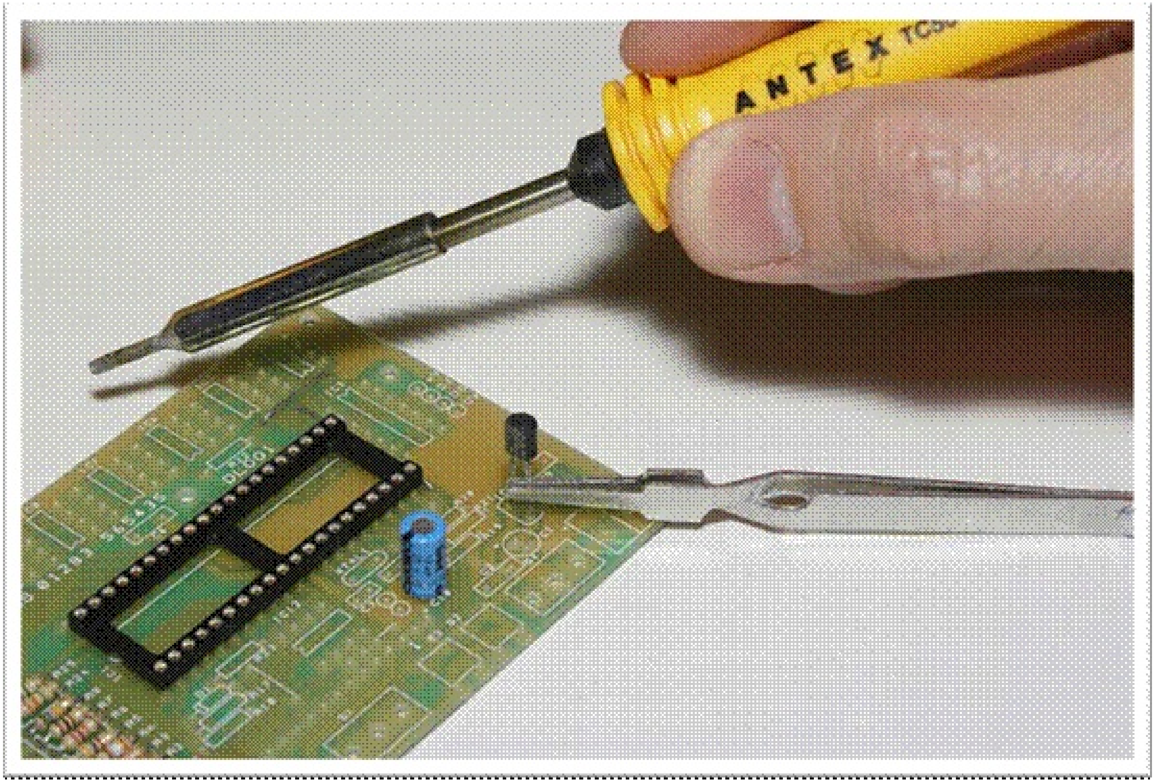

^^ A clip-on Antex heat shunt fitted to a transistor leg, helps prevent thermal damage due to overheating when soldering it in place. Less essential these days, but beginners find them re-assuring.

Until they have gained some practice, novices sometimes buy a small clip-on heat-shunt (photo) which resembles a pair of aluminium tweezers. In the example of, say, a transistor, the shunt is attached to one of the leads near to the transistor's body. Any excess heat then diverts up the heat shunt instead of into the transistor junction, thereby avoiding the risk of thermal damage. Applying far too much heat may destroy the part or damage the p.c.b. foil which may lift away from the board.

In due course constructors learns to judge how much solder should be applied to any particular joint. An ideal p.c.b. joint is very slightly concave in shape. If not enough solder is used, the result may be an incomplete joint which may cause an intermittent fault later on. An excess of solder – shaped like a ball bearing - is an unnecessary waste and in extreme cases may cause short circuits, especially on densely-populated boards. There is no need to add more solder "for luck". Professionally-produced p.c.b.s have a green *solder resist* coating which helps to ensure that solder does not stray onto adjacent pads. As a finishing touch, I usually spray the solder-side of a circuitboard with aerosol spray lacquer afterwards. It keeps the solder joints nice and shiny and helps prevent corrosion.

Some components can create hazards during a soldering operation:

Coin cells and button batteries are commonly used as power, clock or memory backups. If heated excessively they can explode without warning due to the build-up of internal pressure. Spot-welders are used in industry to connect tags to them, but if you need to solder wires to such a cell then it should be done as quickly as possible.

Some **memory back-up capacitors** or **electrolytic capacitors** remain energised for a while even when the circuit is powered down. Molten solder is a perfect electrical conductor and in some cases the component’s contacts could be shorted during the soldering (or desoldering) operation. If molten solder shorts it out then the arcing may cause globules of solder to be spattered outwards without warning, potentially risking eyesight damage.

Always ensure that powered components are electrically inert and discharged before soldering. Cells, batteries and battery packs should not be accidentally shorted during the soldering process, to avoid arcing and solder spatter. Note that electrolytic capacitors can also explode after a while if reverse-connected, so observe polarity closely.

Let’s now consider the practical stages of soldering components and wires successfully.

Soldering Step by Step

Earlier I explained the individual factors that affect the quality of a solder joint. These are:

- **Cleanliness** – dirt or impurities drastically hinder good solder coverage.
- **Temperature** – the right level to enable the solder to flow freely!
- **Time** – apply heat for just the right amount of time!
- **Adequate solder coverage** – enough to form a good joint without touching neighbouring areas.

These rules apply whether soldering a p.c.b. or performing other tasks such as interwiring (hooking everything together with connecting wire).

We'll now summarise the stages of making a typical solder joint – soldering components onto a printed circuit board (through-hole soldering). Most people insert components into the circuit board and simply splay the wires out to hold them in place under spring tension. I find it best to snip excess wire leads off at this stage, to improve accessibility.

- All parts must be bright, clean and free from dirt and grease.
- Try to secure the work firmly to stop parts moving around.
- "Tin" the soldering iron tip with a small amount of solder. Do this immediately, with new tips being used for the first time.
- Wipe the tip of the hot soldering iron on a damp cellulose sponge to remove excess solder or contamination.
- Many people then add a tiny amount of fresh solder to the cleansed tip just before using it.
- Heat all parts of the joint with the iron typically for under a second or so, until it's heated throughout.
- While heating, then apply sufficient rosin-core solder to form an adequately-covered joint.
- It only takes a second or two at most, to solder the average p.c.b. joint this way.
- Do not move parts until the solder has cooled.
- Remove and return the iron safely to its stand.

This special photo sequence illustrates these stages. It's best to start with the smallest, fiddliest parts first when soldering a blank p.c.b., because that's when you've got the most access on the board. Accessibility will be reduced as more components are added, so we'll start with a simple wire link on a professionally designed p.c.b.

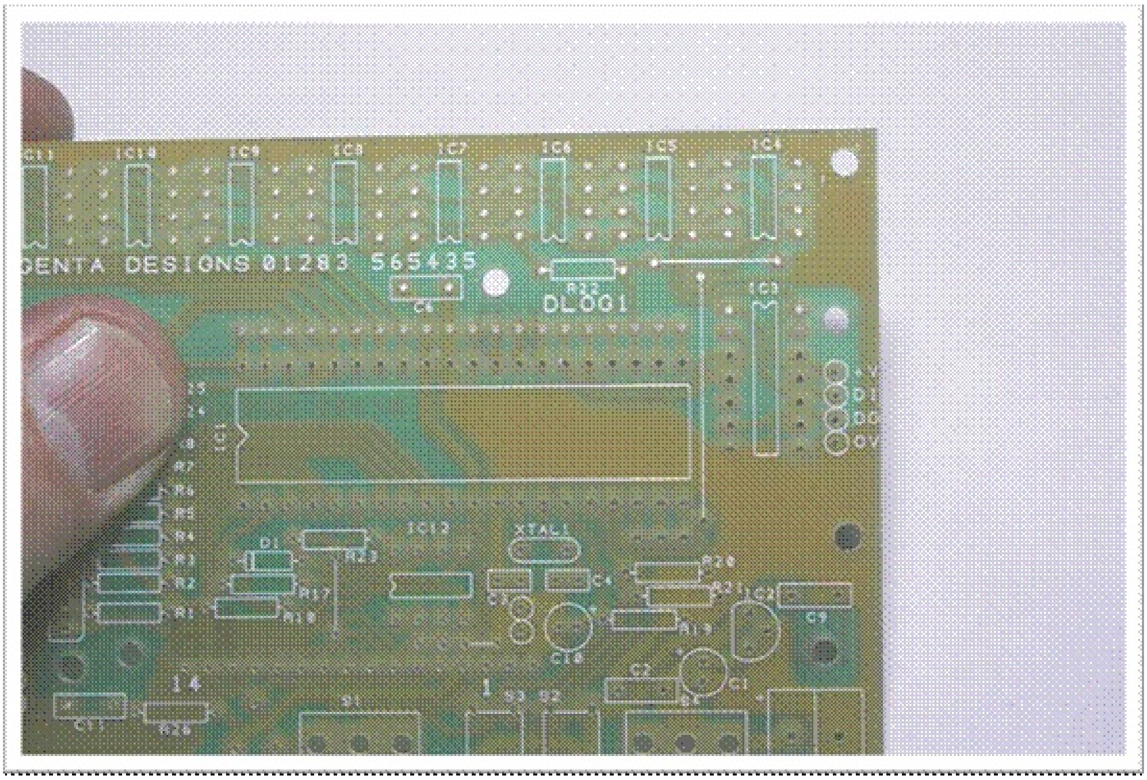

^^ *A typical professional blank p.c.b. – silk-screen printing shows what goes where. The underside has been treated with a green solder resist coating, and the solder pads are ready-tinned to help with soldering.*

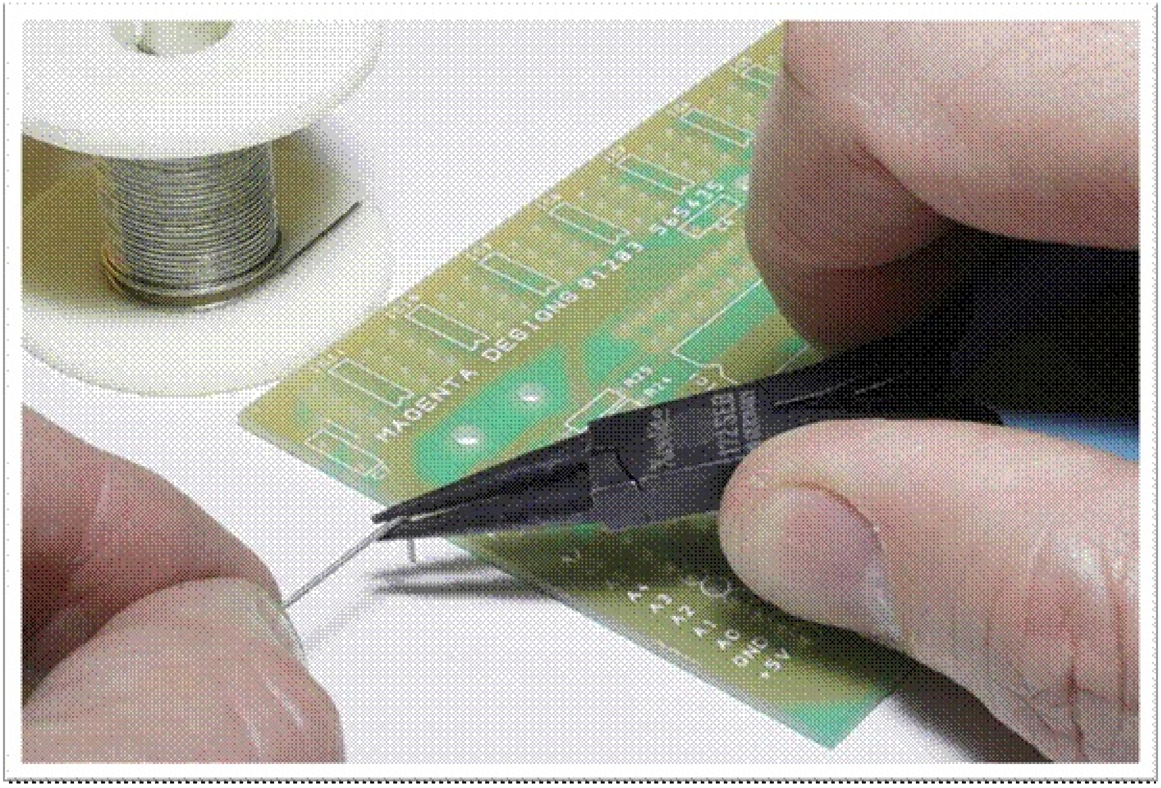

^^ *Preparing a wire link for soldering – cut off some tinned copper wire and bend the ends to fit the p.c.b. correctly. Round-nose pliers (shown) are perfect for this, but ordinary electronics or "radio" pliers will do.*

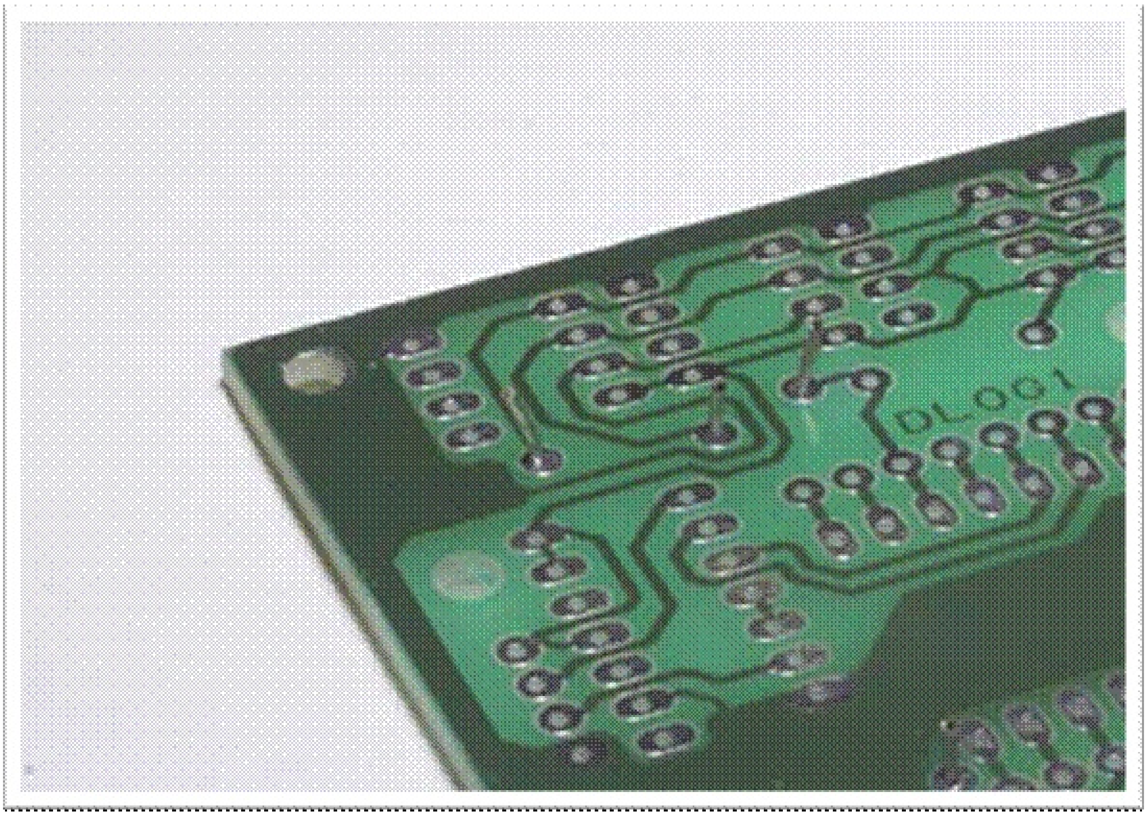

^^ Wires are prodded through the holes in the board, then turn it upside down to view the solder side. You can then "spring" or splay the ends apart slightly, so they are held in place while you solder them.

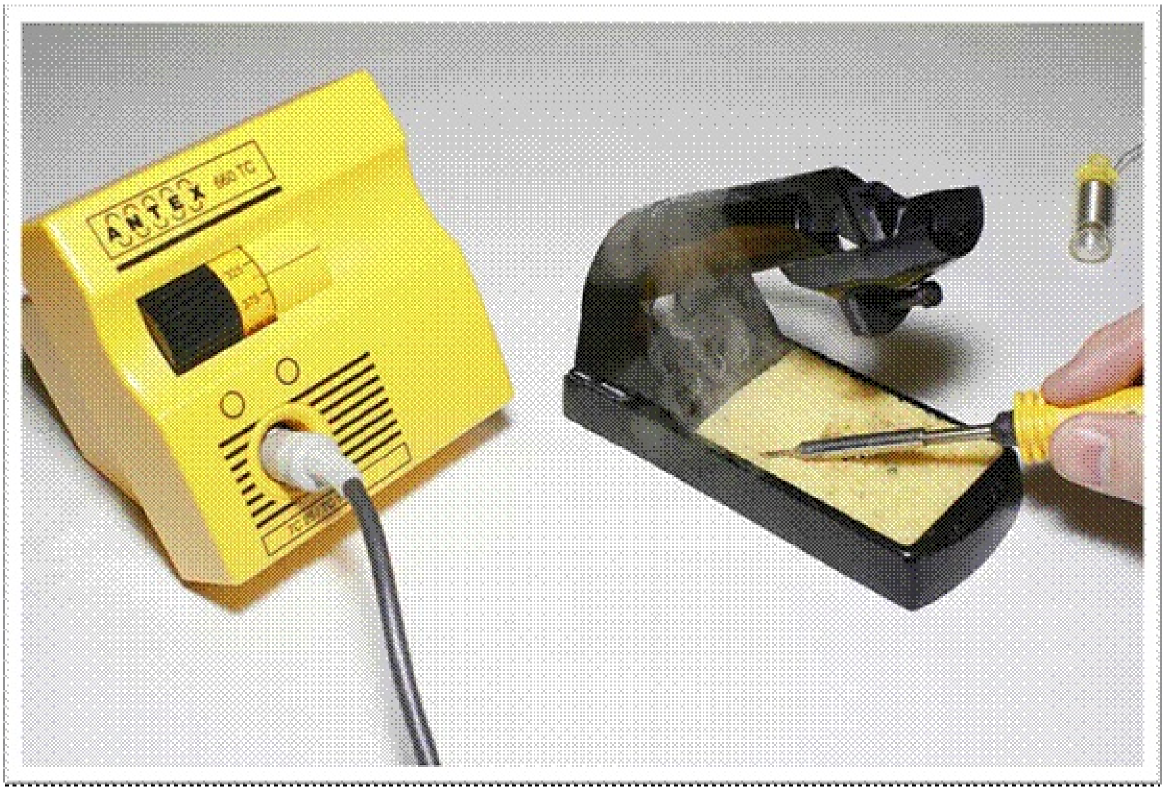

^^ Wipe the hot soldering iron on the damp sponge to clean the tip. Do this periodically when contamination, flux deposits etc. build up on the iron to keep the tip nice and shiny. Tip Tinner & Cleaner helps too.

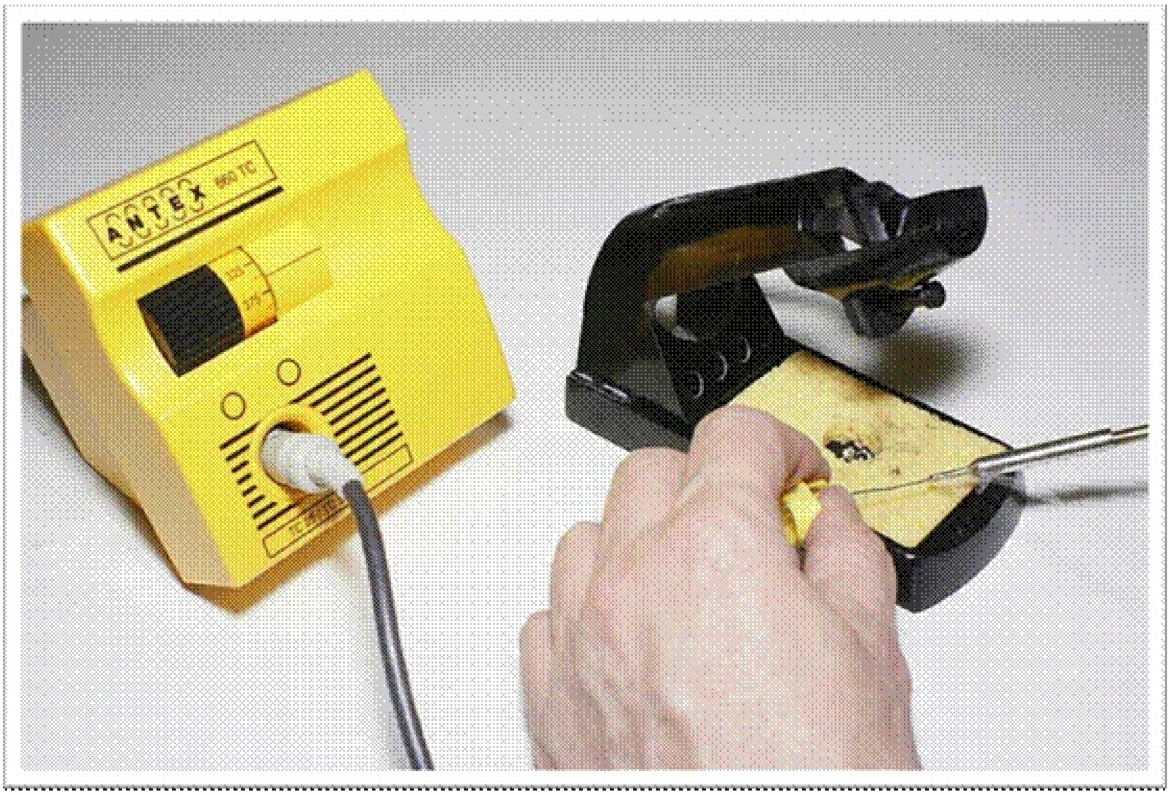

^^ It often helps to dab a tiny amount of solder wire onto the tip, to improve heat transfer.

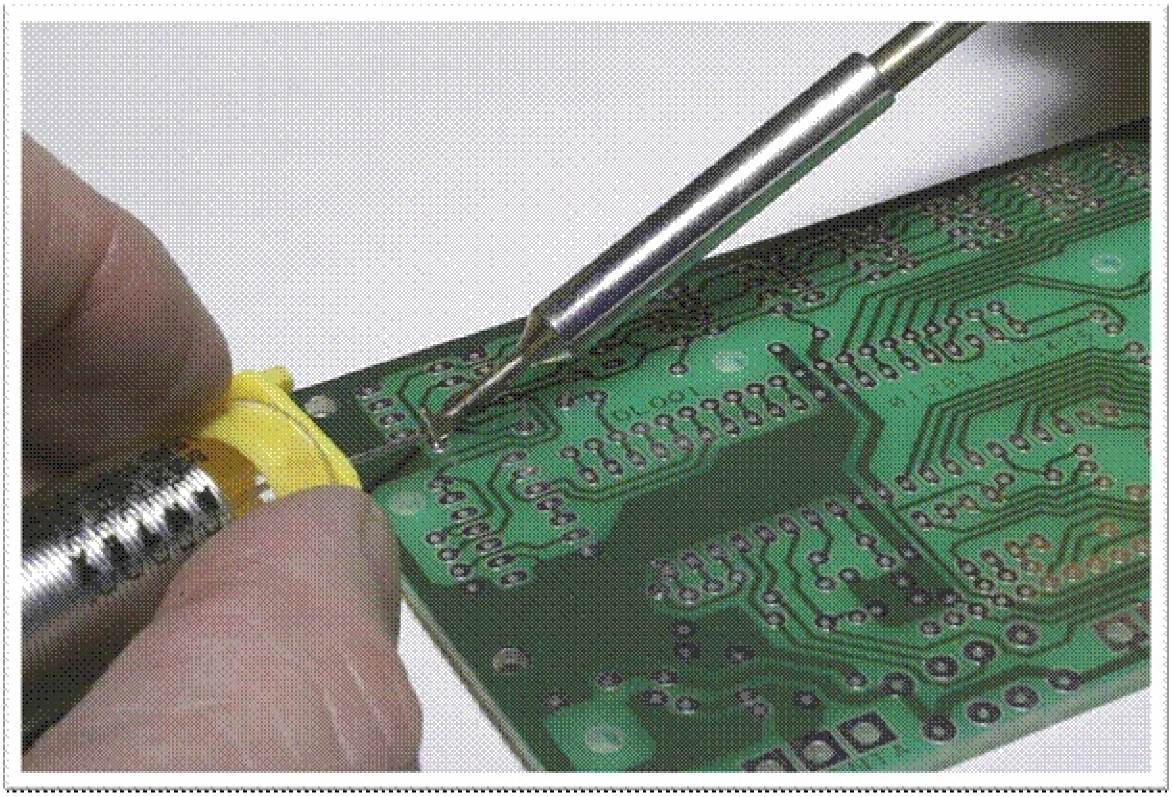

^^ Then apply the soldering iron to heat both the solder "pad" and the wire end at the same time (say <1 second). Apply a few millimetres only, of solder. Then remove the soldering iron immediately and allow the joint to cool down by itself. The green solder-resist coating ensures solder doesn't flow onto neighbouring pads.

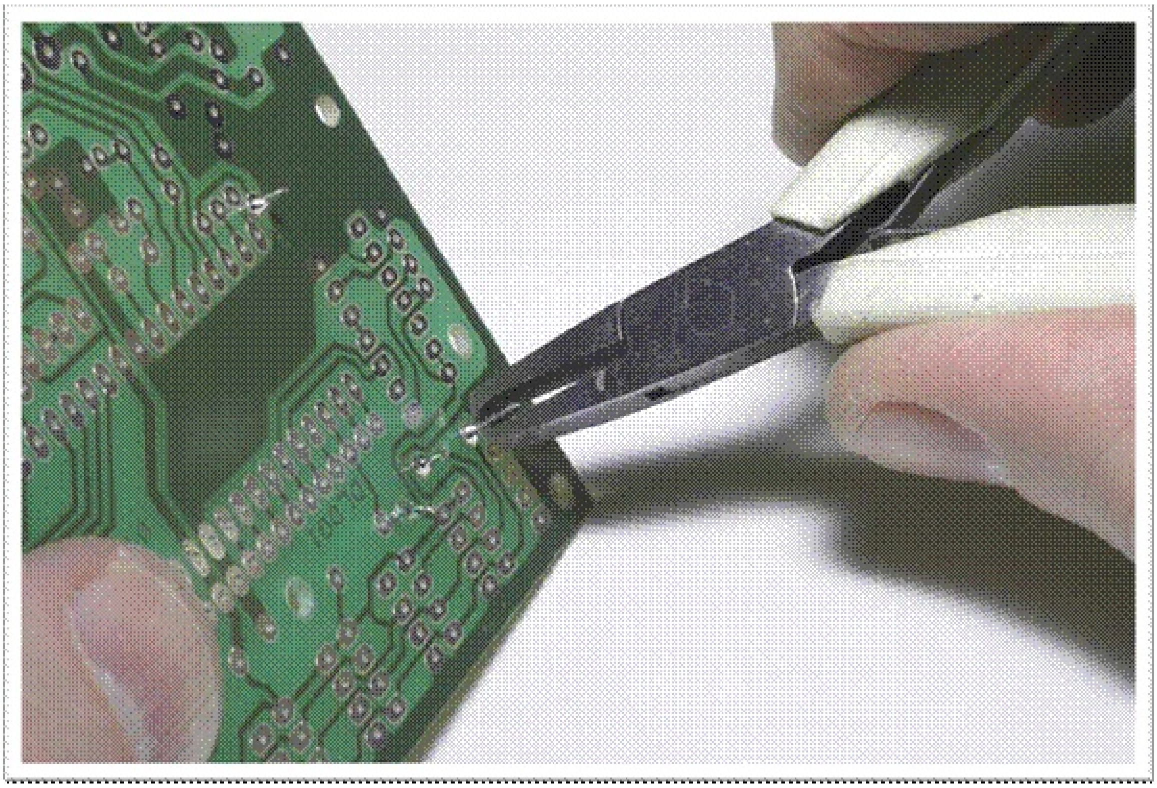

^^ These "end cutters" can then be used to snip off excess wire after soldering….

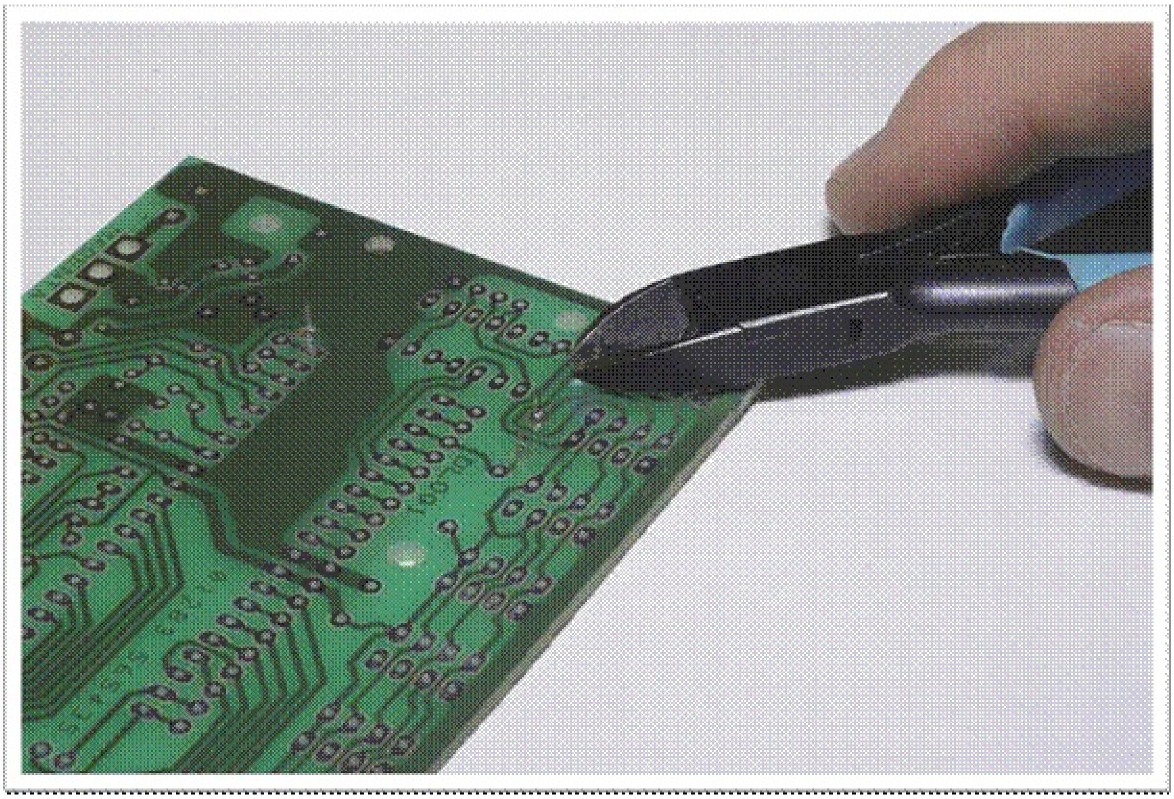

^^ … but ordinary electronics "side cutters" are fine for trimming or snipping wires.

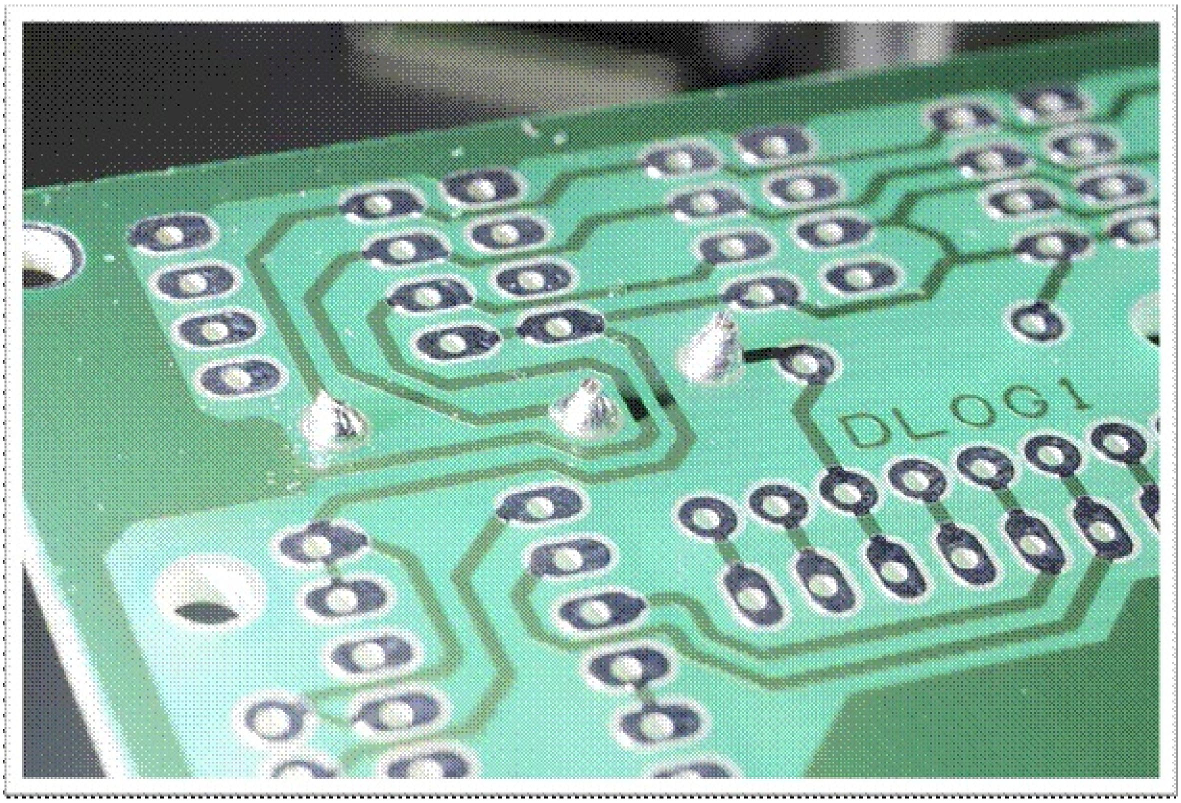

^^ The ideal solder joint should be smooth and slightly concave, quite shiny, not dull or crystalline-looking nor ball-bearing shaped.

Try to get consistent results in your soldering, but don't worry too much about the lack of uniformity – this is soldering by hand after all, not by precision machinery, and some slight variation is OK provided the solder coverage is good and the soldering is generally clean and effective. You'll improve with practice, that's for sure!

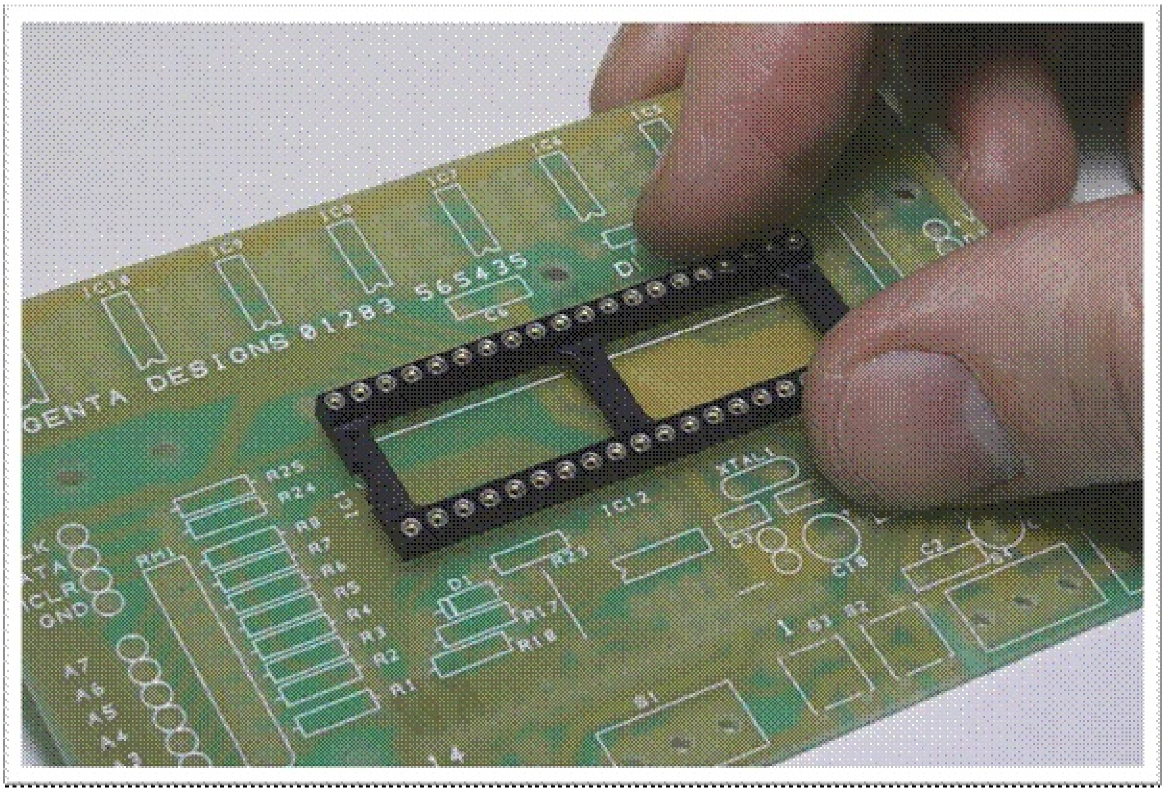

^^ A large i.c. socket can be added next...

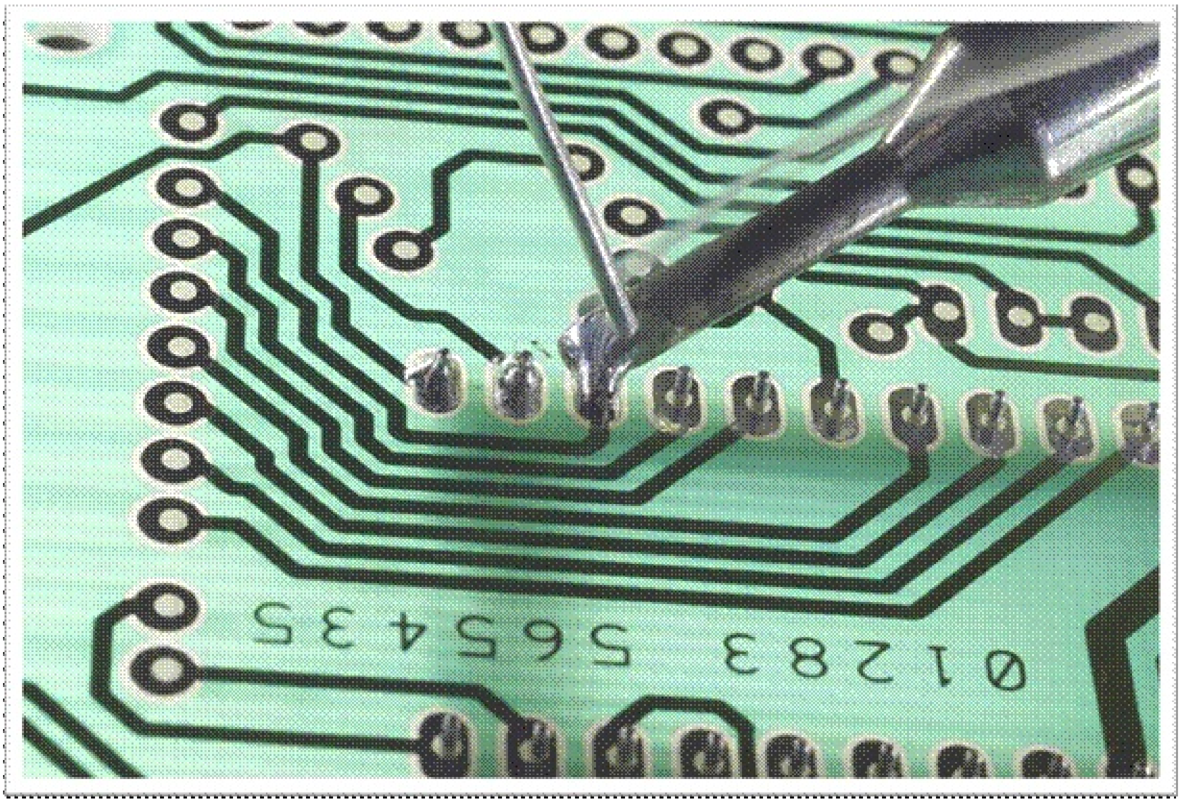

^^ Go along the rows of pins and solder them one at a time. See how simple it is! Heat both the solder pad and pin with the iron, and dab on a little solder wire to ensure full coverage. Ensure the socket is flush against the board.

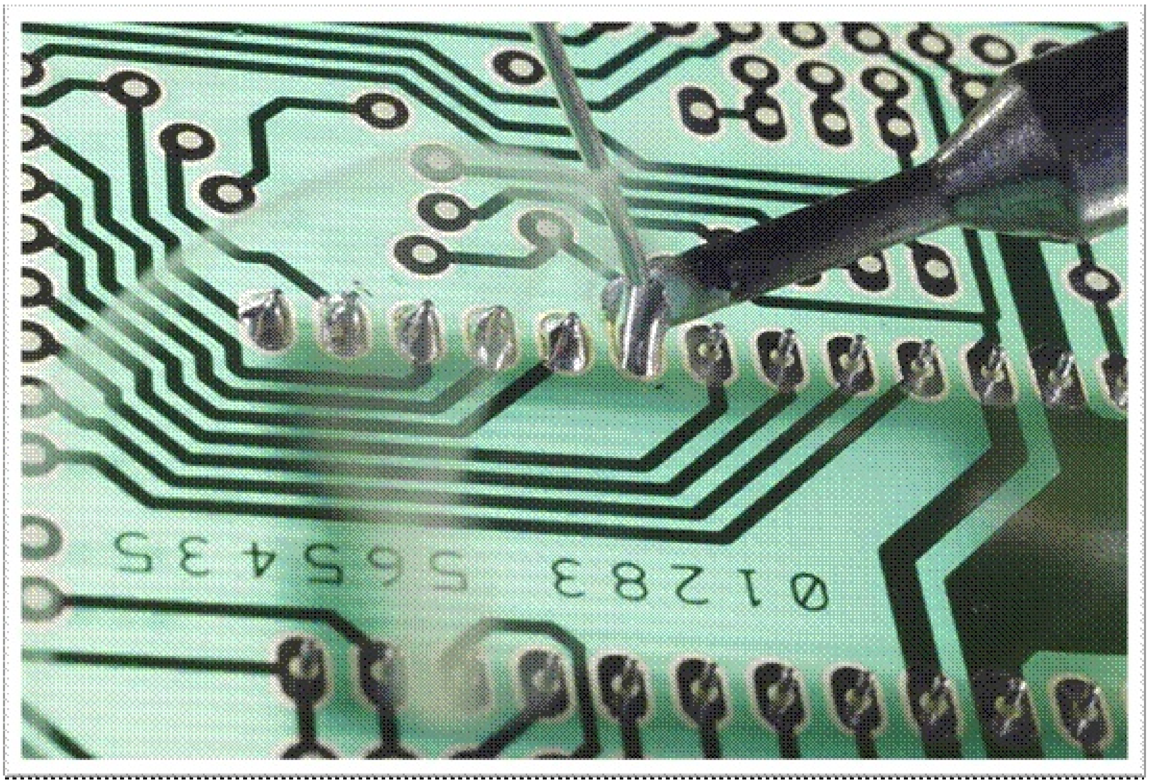

^^ As hardly any metal is involved each pin should take well under a second to solder at most.

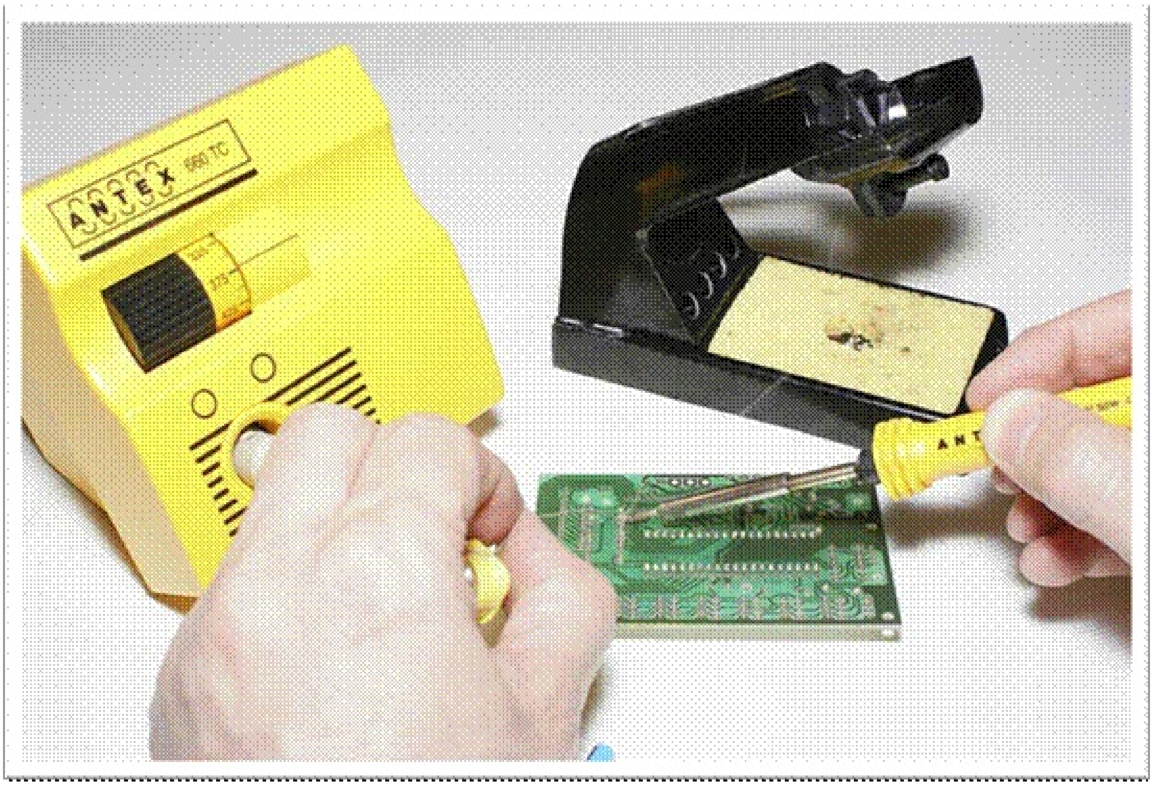

^^ Continue until the i.c. socket is soldered.

Once the smallest parts are soldered into place, you can continue to solder the remaining components. It's easiest to handle the smallest so-called "discrete" parts first while you still have plenty of room on the board. I usually solder resistors and capacitors next. The principle of soldering them is just the same as a simple wire link: insert them from above till they are flush on the board, then splay their wires a little to hold them in place, and preferably snip off at least some of the wire to give you more access.

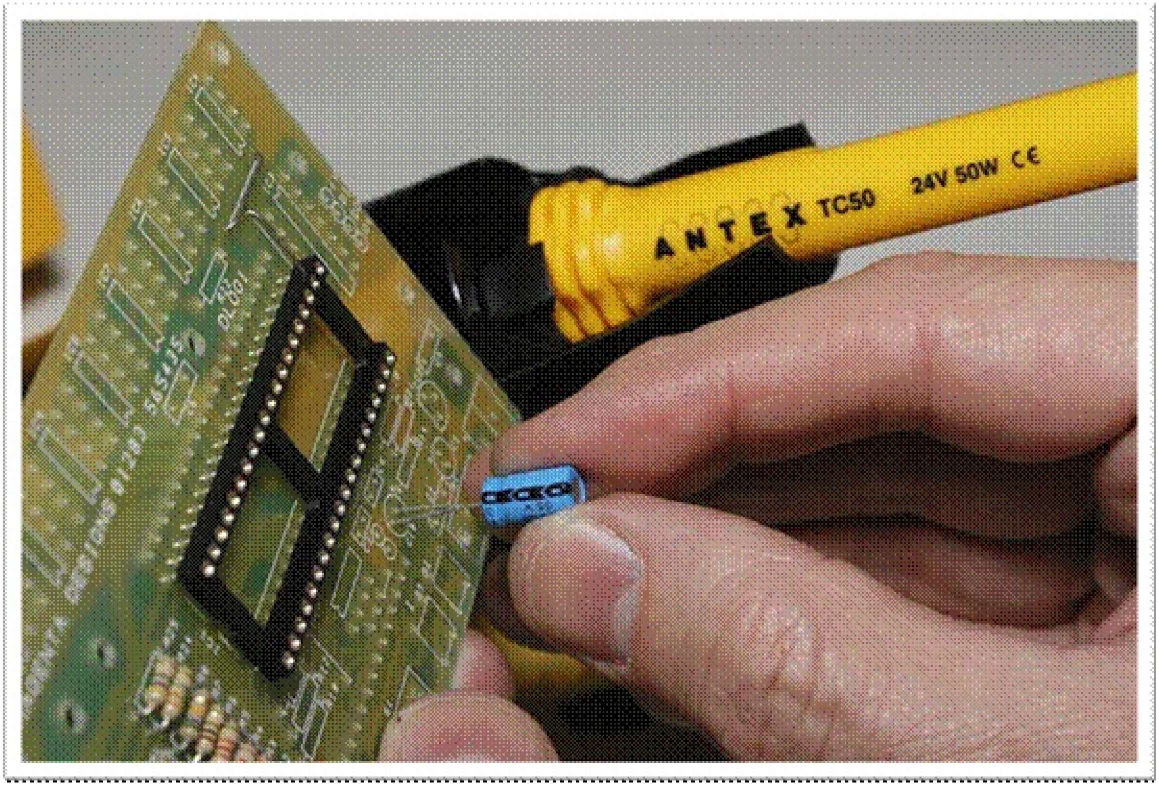

^^ Continue by inserting "discrete" components from above, splay their wires out

underneath to secure them in place, then snip and solder the joints exactly as before. Some parts like this blue electrolytic capacitor are polarity sensitive (note the – sign), and must be inserted the right way round. Same is true of every semiconductor.

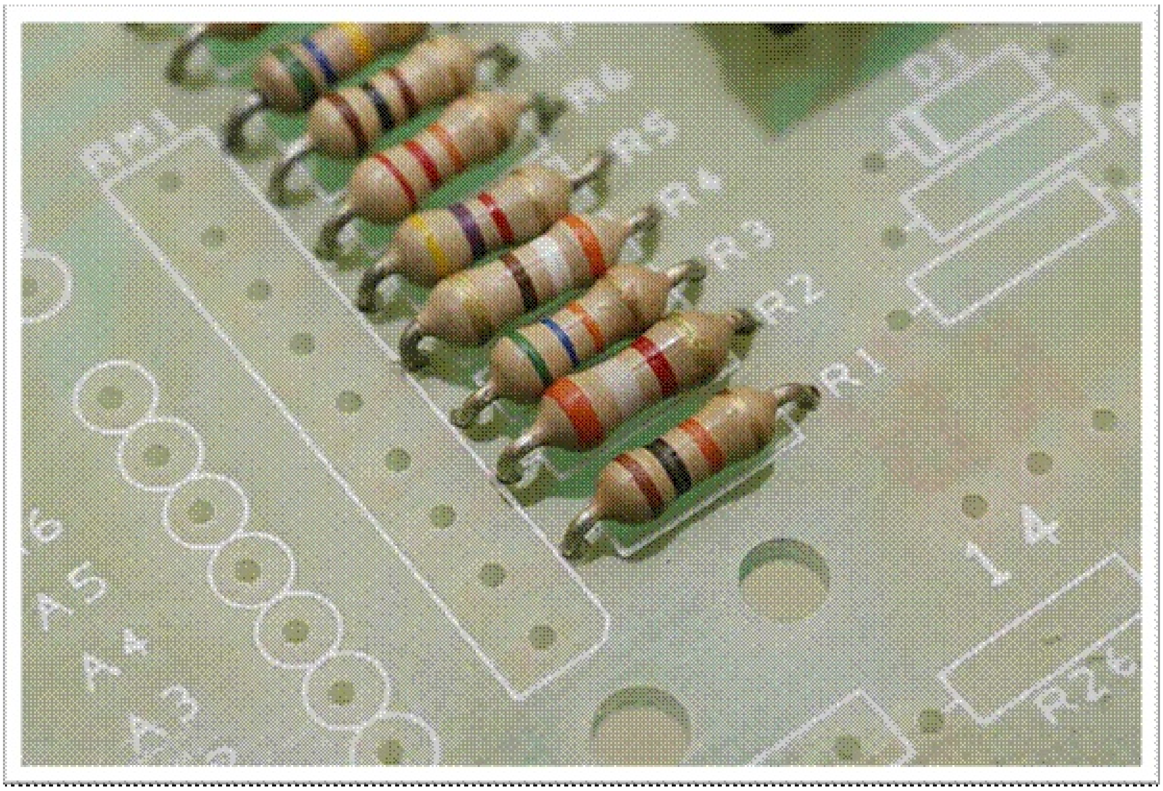

^^ This row of ¼ watt resistors was next. I like to show the colour codes all the same way round, with gold or silver (tolerance bands) on the right for consistency.

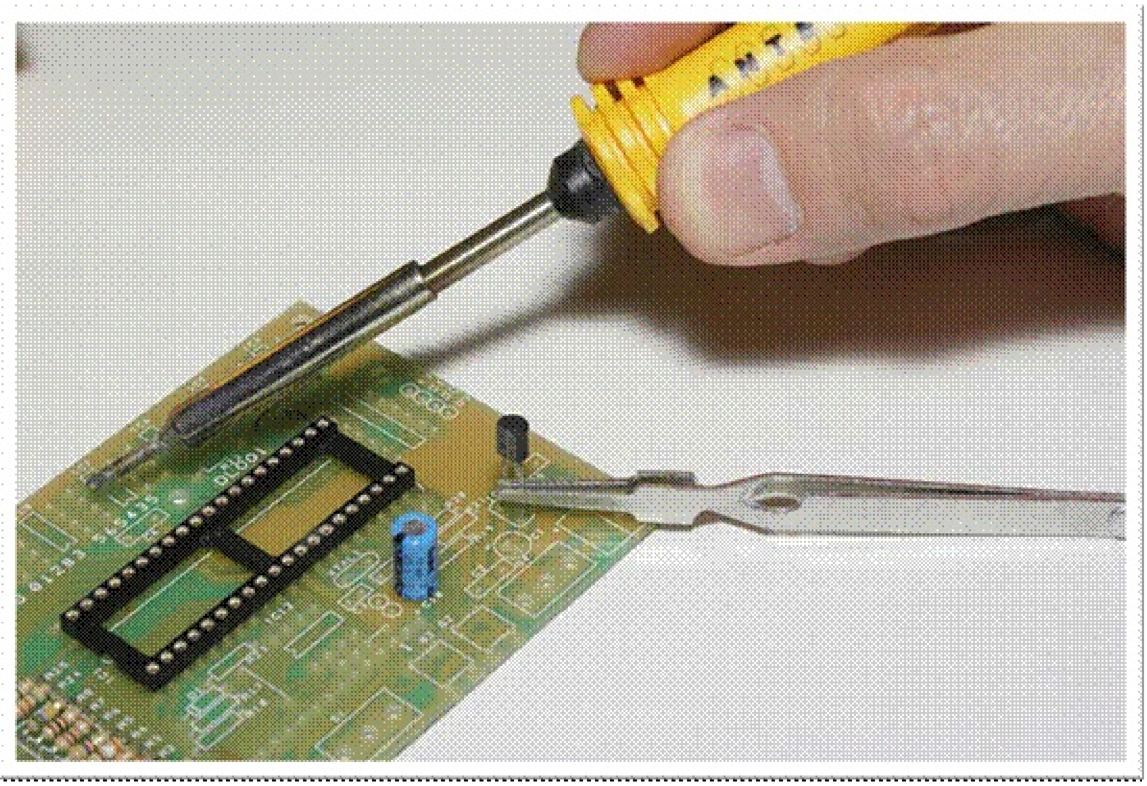

^^ This transistor was next. Solder it quickly to avoid damage, and observe polarity correctly, so it is the right way round on the p.c.b. The heatshunt is optional.

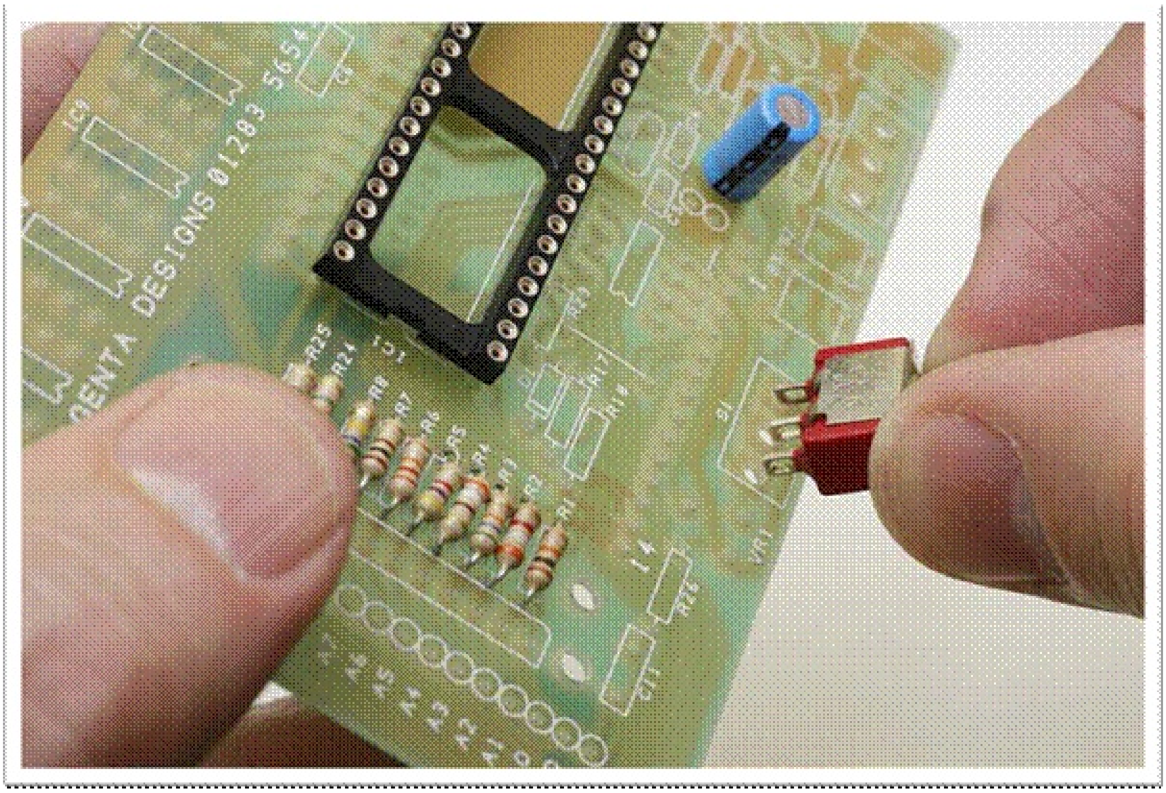

^^ Unusually, this toggle switch fitted directly onto the board as well which saved wiring it up. Neat idea!

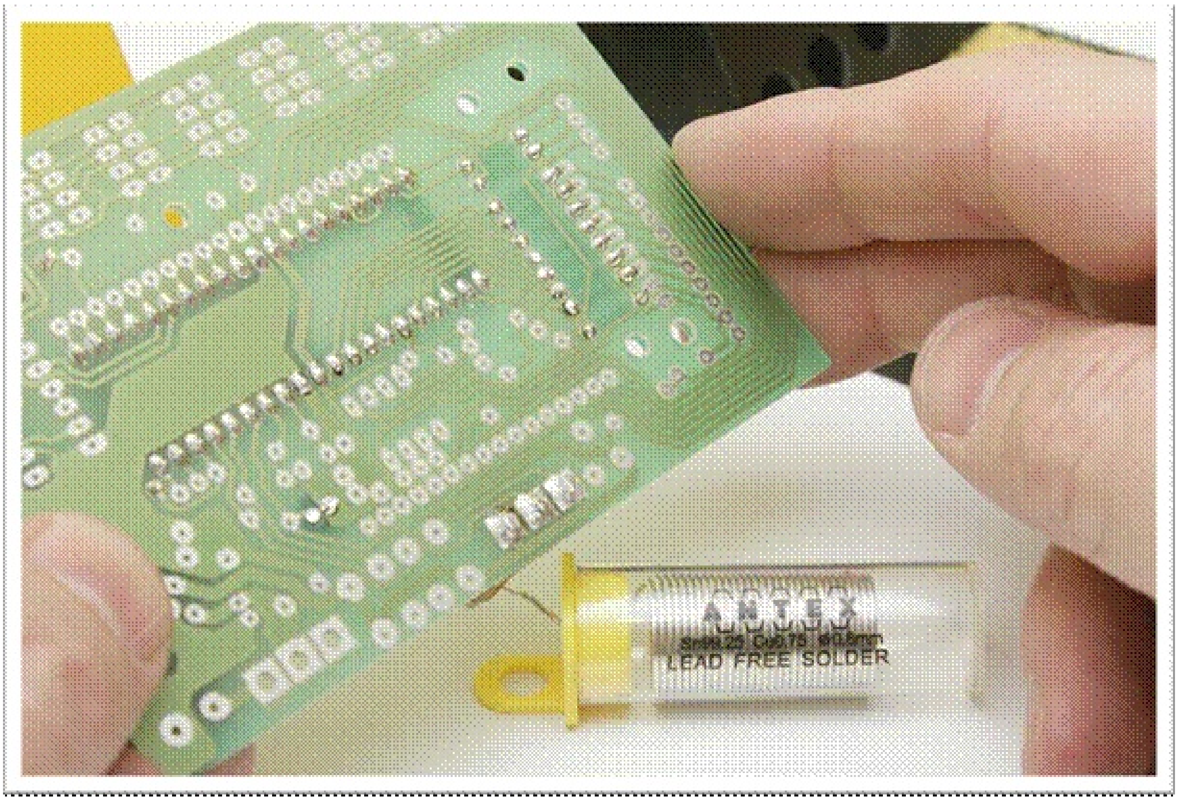
ANTEX
LEAD FREE SOLDER

^^ *As there is comparatively more metal to heat up, it'll take longer to solder the switch terminals, and you'll need more solder as well. Thicker gauge solder is useful at such times. Allow say 2-3 seconds to solder each terminal.*

Don't forget to clean the soldering iron tip on its damp sponge every now and then, to ensure the bit is kept clean and shiny. Later on I'll show you how to correct any problems by desoldering using various techniques. Next, we'll move on from printed circuit board "through-hole" soldering and look at how to handle wires and leads.

Interwiring – get hooked up!

With practice, through-hole soldering of p.c.b.s will become second nature. There's no substitute for tackling some soldering jobs though, particularly trying a simple kit based on a quality p.c.b. which will boost your confidence enormously.

Most electronic devices need connecting up to external components such as battery packs, speakers, l.e.d.s or switches. Usually, multi-stranded connecting wire is used to connect circuit boards and external parts together. Unlike single solid-core wire, *multi-stranded wire* is flexible and vibration-resistant. Hobbyists mainly use 7/0.2mm wire (7 strands, each 0.2mm diameter) for low-voltage hook-ups although much Chinese equipment uses much thinner wires than this. So let's look at some aspects of soldering this type of wire.

In a separate photo sequence I show how a potentiometer (a panel-mounted variable resistor) and a light-emitting diode (l.e.d.) are connected using multi-stranded wire. The same principles of soldering apply to most other components including panel-mounted switches, loudspeakers, buzzers, audio sockets and more.

Components usually have terminals or "tags" to which wires can be soldered. Start by ensuring the component's tags are clean: otherwise solder will not wet properly and the joint will be impossible to solder, so all contamination must be removed. This is especially true of parts that have been in storage a long time. The connections often oxidise or blacken, so clean the solder tags with e.g. an abrasive glass-fibre brush, or a needle file or abrasive paper. Using a glass fibre brush was shown earlier in "Cleanliness and Tinning the Bit".

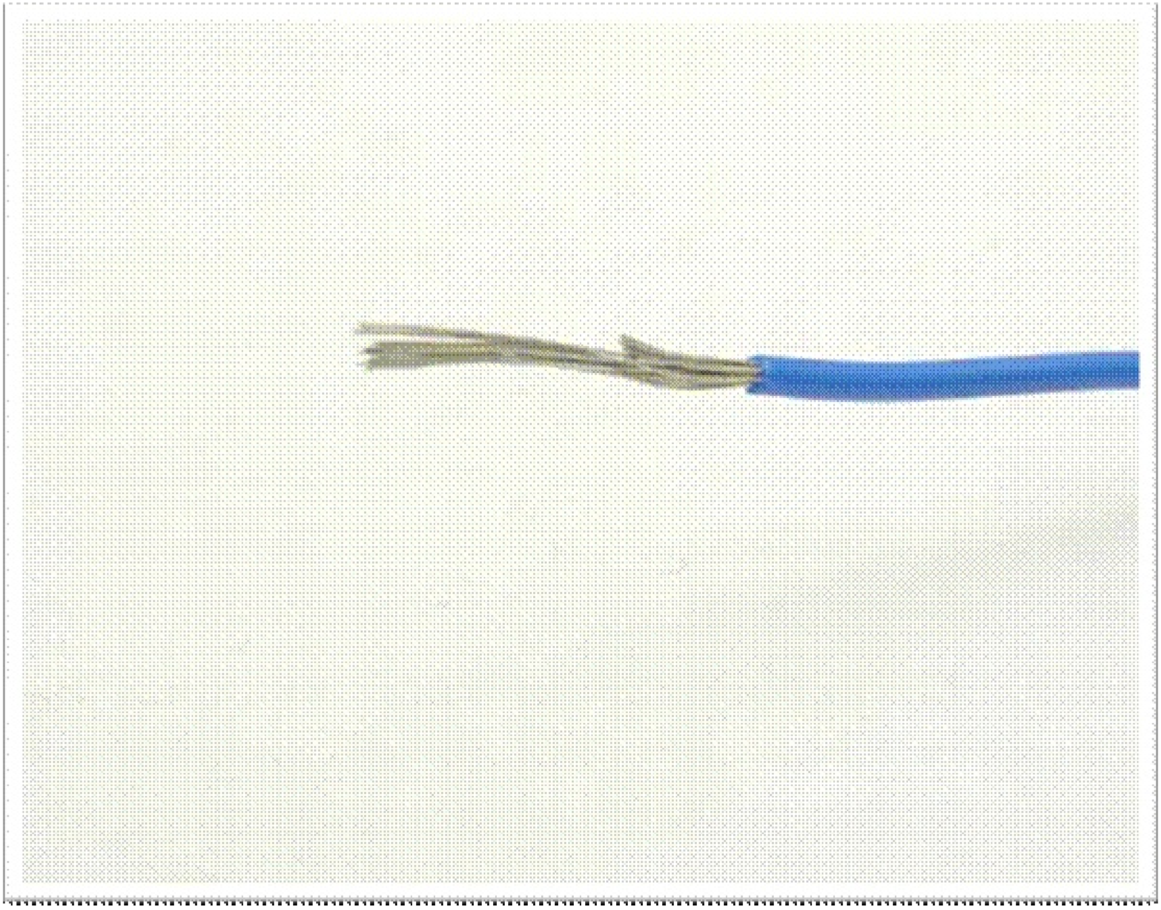

^^ How not to strip insulation off wire: some of the cores have also been cut – avoid doing this!

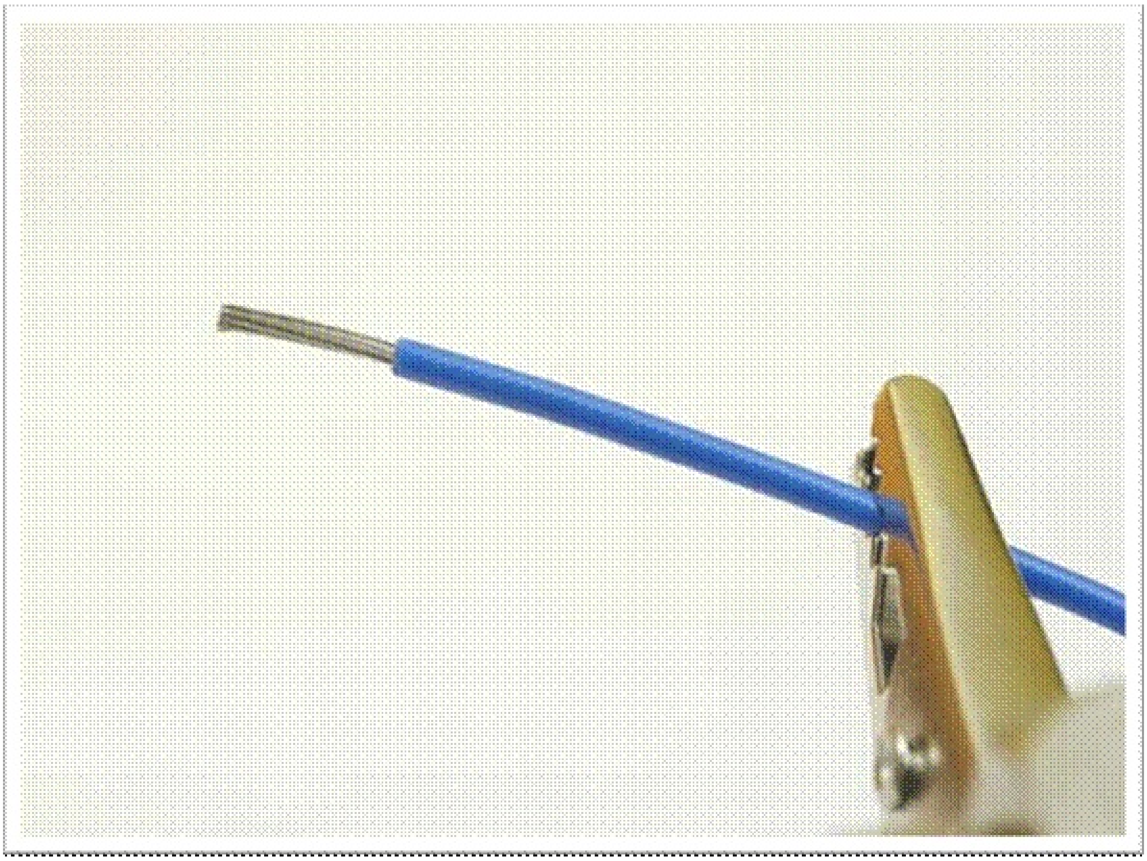

^^ Gripping a wire end in a "Helping Hand" croc clip can help with soldering.

After stripping a short length of insulation from the connecting wire, there are two ways to solder it to a component's solder tag. The first way is to "*tin" the stripped wire end to solidify it* - just heat it with the iron and melt a little solder on it, and let it cool. Poke the wire end through the solder tag, apply the hot iron to both parts and solder them together using a few millimetres of solder.

Although the assembly doesn't hold itself together so well during soldering (consider a Helping Hands jig if needed) this is quicker and easier to make and also easy to desolder again, and is perfectly adequate for most joints of this kind. The majority of commercial wire joints seem to be made this way.

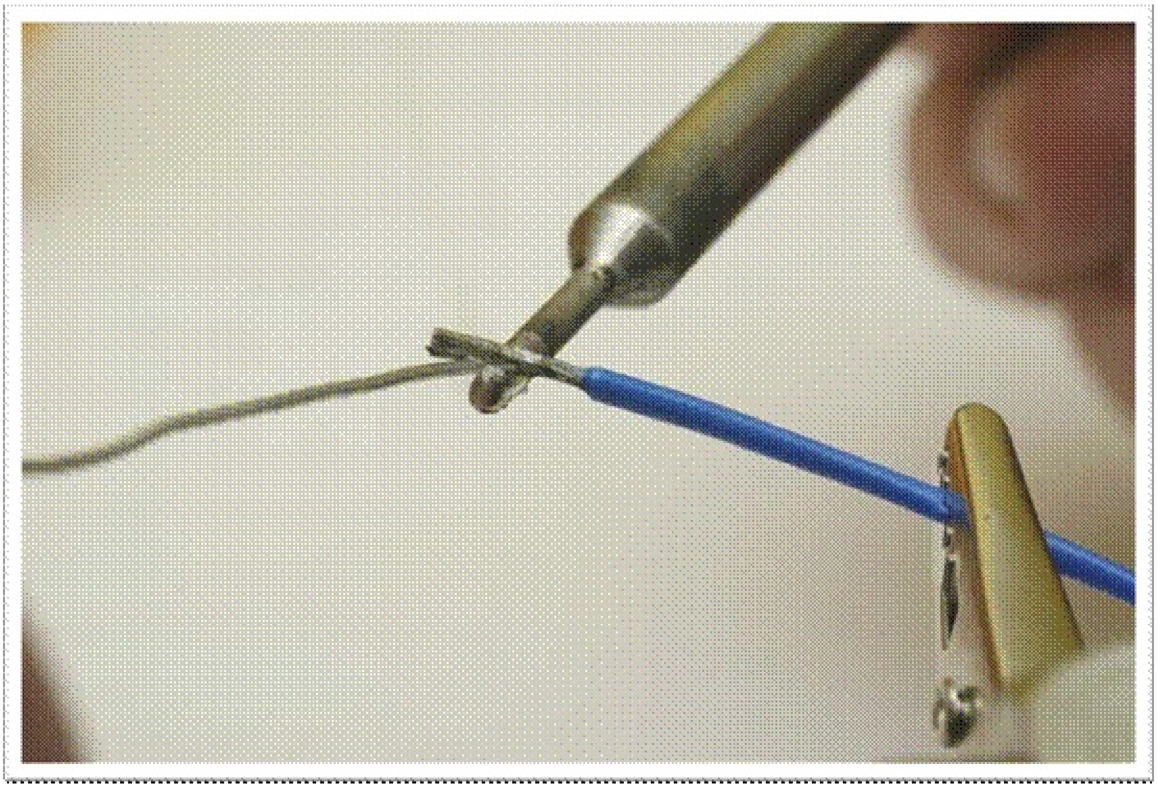

^^ *Apply a hot iron and solder, in order to "tin" the wire ends. This makes them into a solid.*

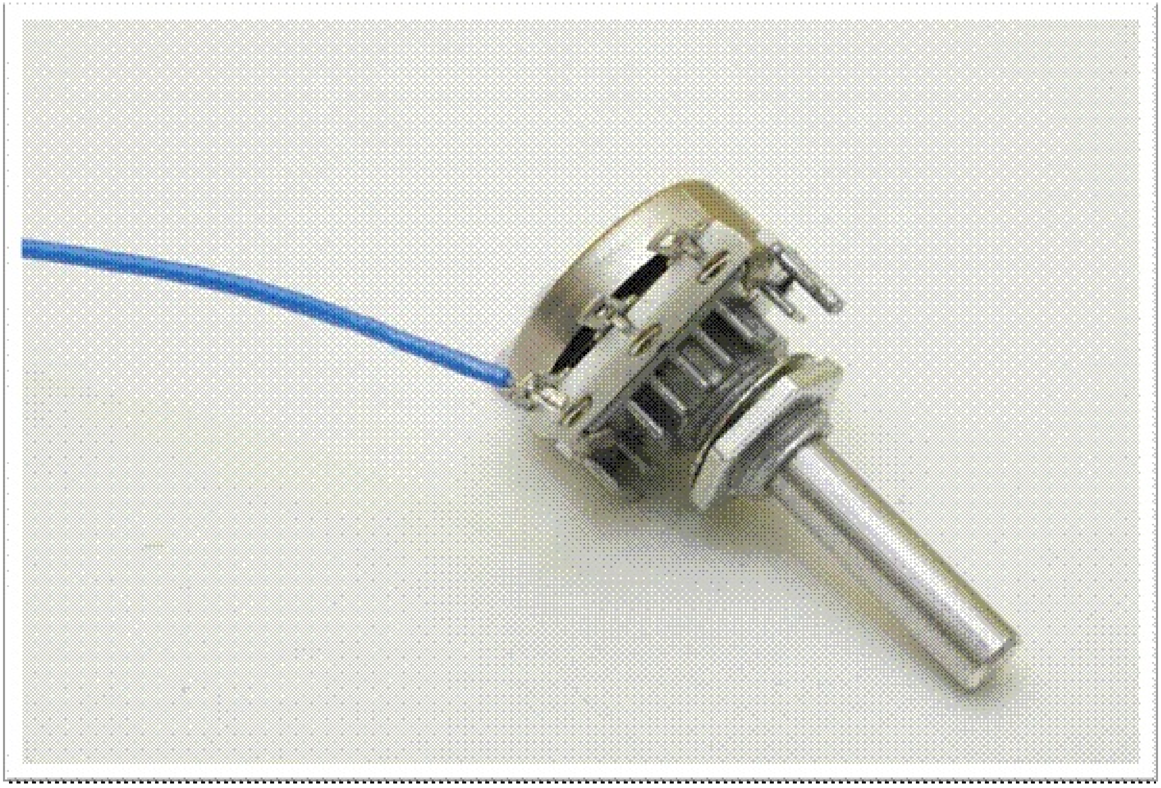

^^ *Then feed the tinned wire through the hole in the solder tag. Crop the wire with cutters if needed…*

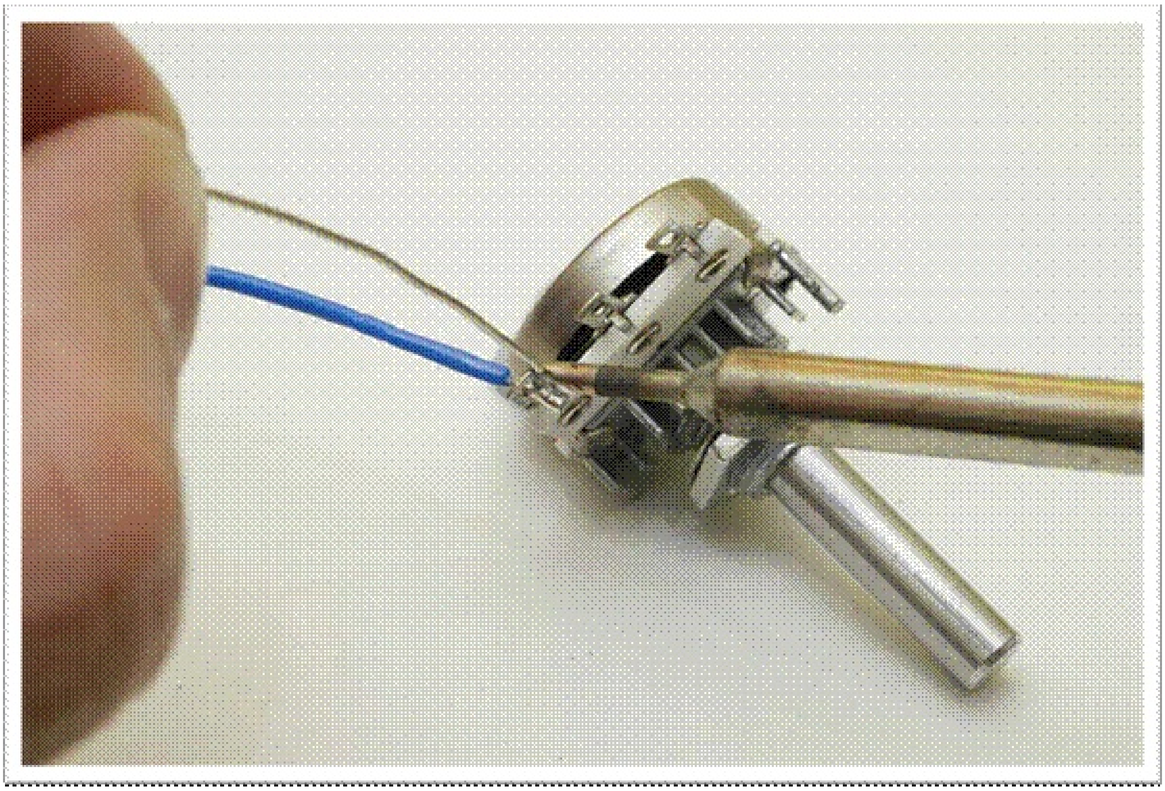

^^ … and apply the iron to heat the joint. As there's quite a lot of metal to heat, allow several seconds to heat it up and then simply solder the wire and solder tag together with a dab of solder wire.

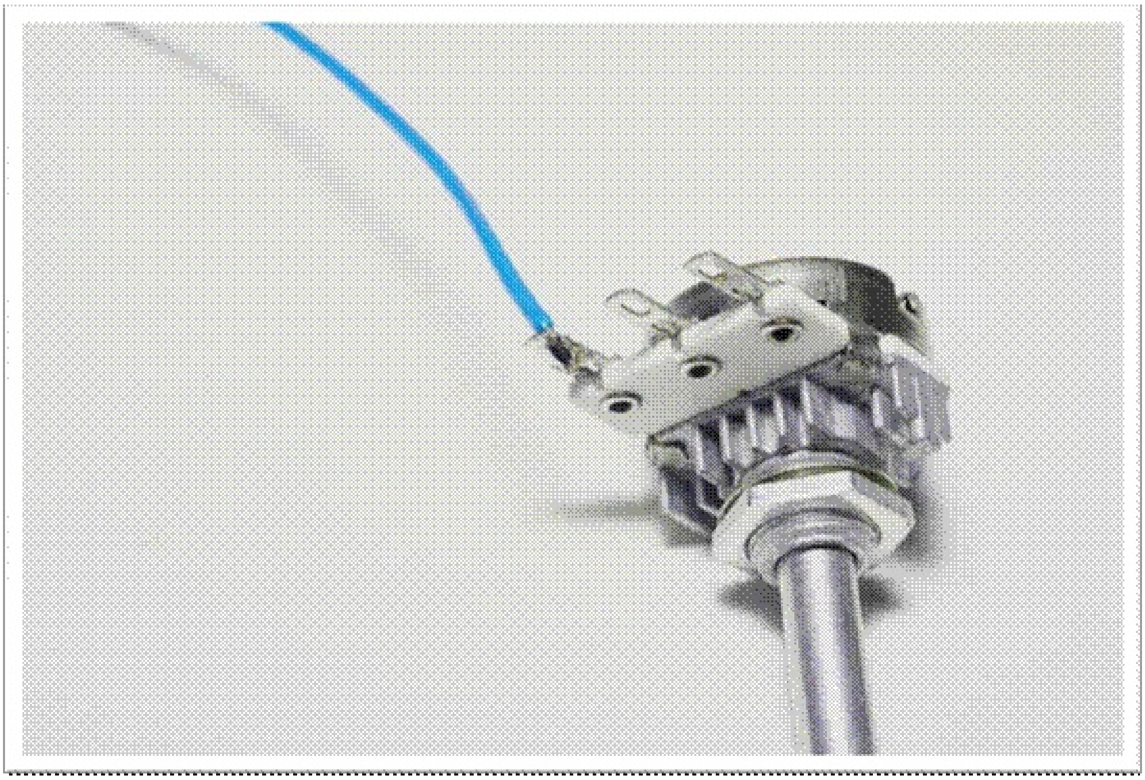

^^ The result is a perfectly satisfactory solder joint.

The second way is to loop the **untinned** wire through the tag a few turns and then solder it. This secures the wire during soldering, but it's messier to desolder if things go wrong (see later):

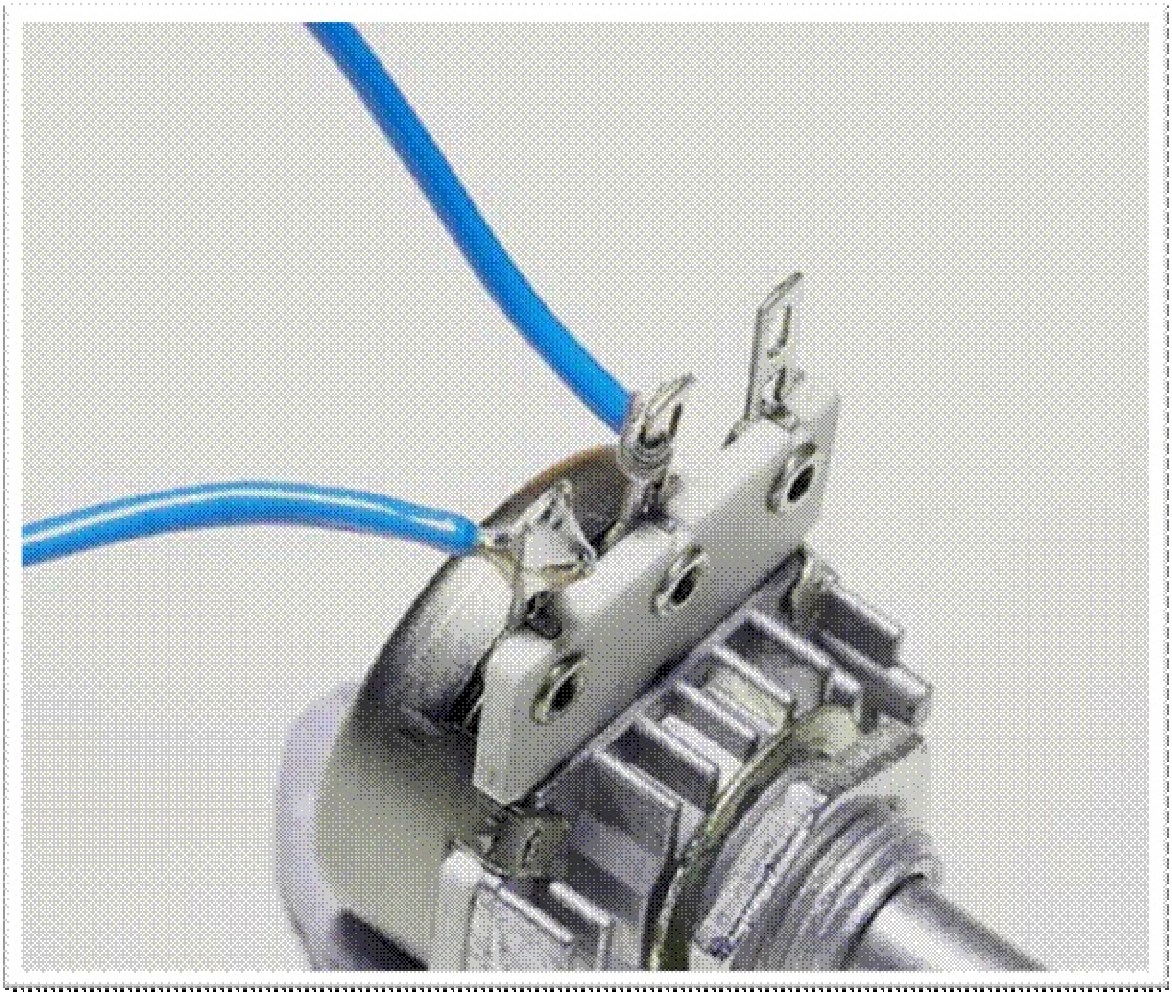

^^ *The centre wire (potentiometer wiper terminal) has been wrapped around to secure it before soldering.*

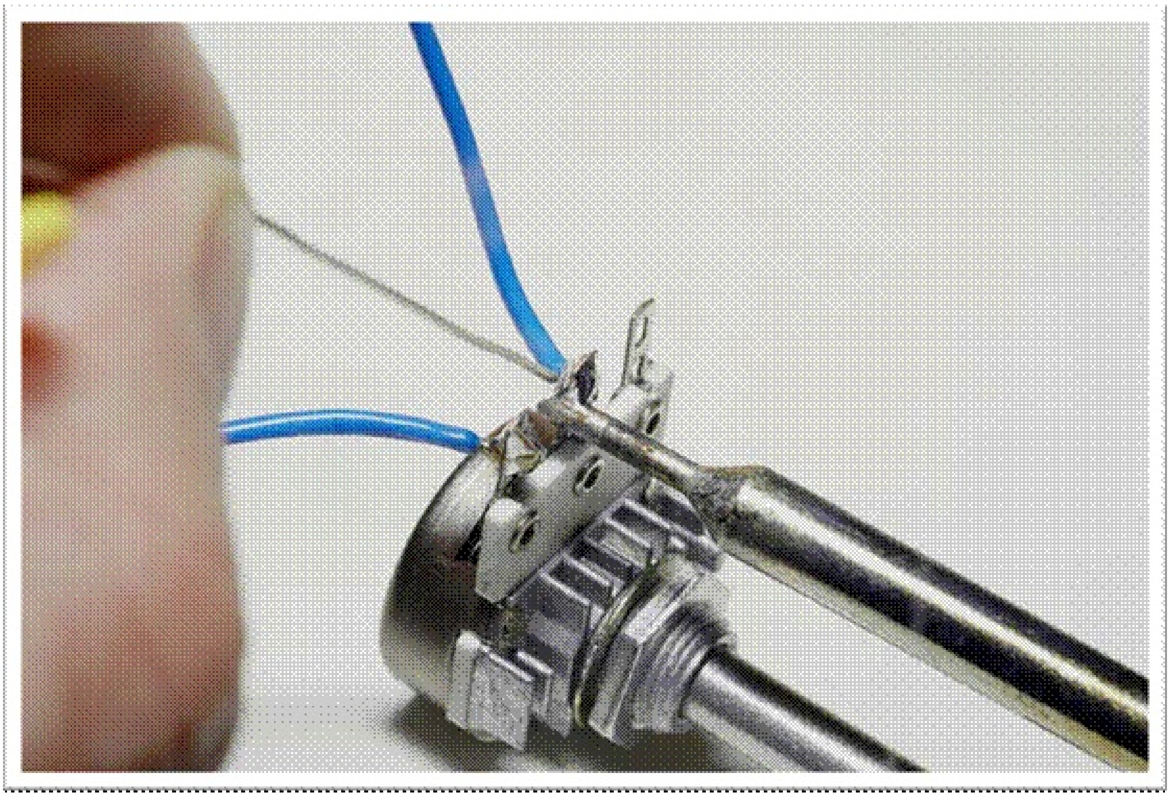

^^ *Solder the joint in just the same way – heat it up and dab on some solder wire.*

Much electronic equipment is connected or inter-wired this way and soldering everything together is a key stage in assembling any electronic project. I’ll explain some refinements you can try, later.

Wire joints

Soldering isn’t always the best solution to some problems, for reasons that I explain in the next section called Fatigue and Breakage. However you can solder wires together to join them simply and cheaply, and next I show a classic wire joint of this kind, sometimes called a **Western Union** joint.

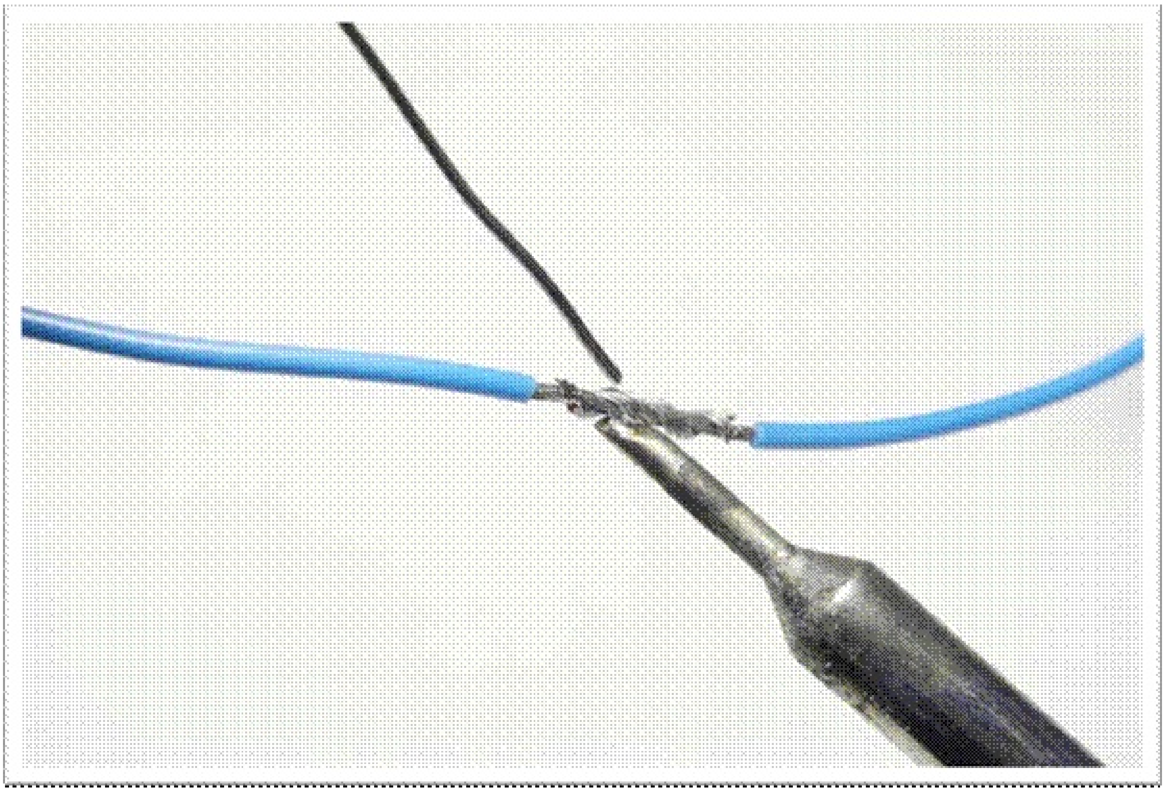

^^ *Soldering a Western Union wire joint.*

Strip the ends from each wire using wire strippers, and try not to cut any of the stranded cores or this will create a weakness. (Stray strands of wire can also be a hazard.) Then twist the wires securely together several times, ideally four or five. Apply a soldering iron to the exposed joint and dab on some solder until it flows fully over the joint, then remove the iron and allow the joint to cool.

The wire’s plastic insulation may shrink back a little due to the heat, but try not to overheat it excessively. If you have the resources you can finish off by insulating the joint with some heatshrink tubing (slide it over a wire before you make the solder joint!). Otherwise use ordinary PVC tubing or insulation tape if you have any.

A solder tag can be soldered easily enough, and it’s probably best to feed a stripped wire end through the tag and twist it over several times before soldering it, so it’s held together when soldering.

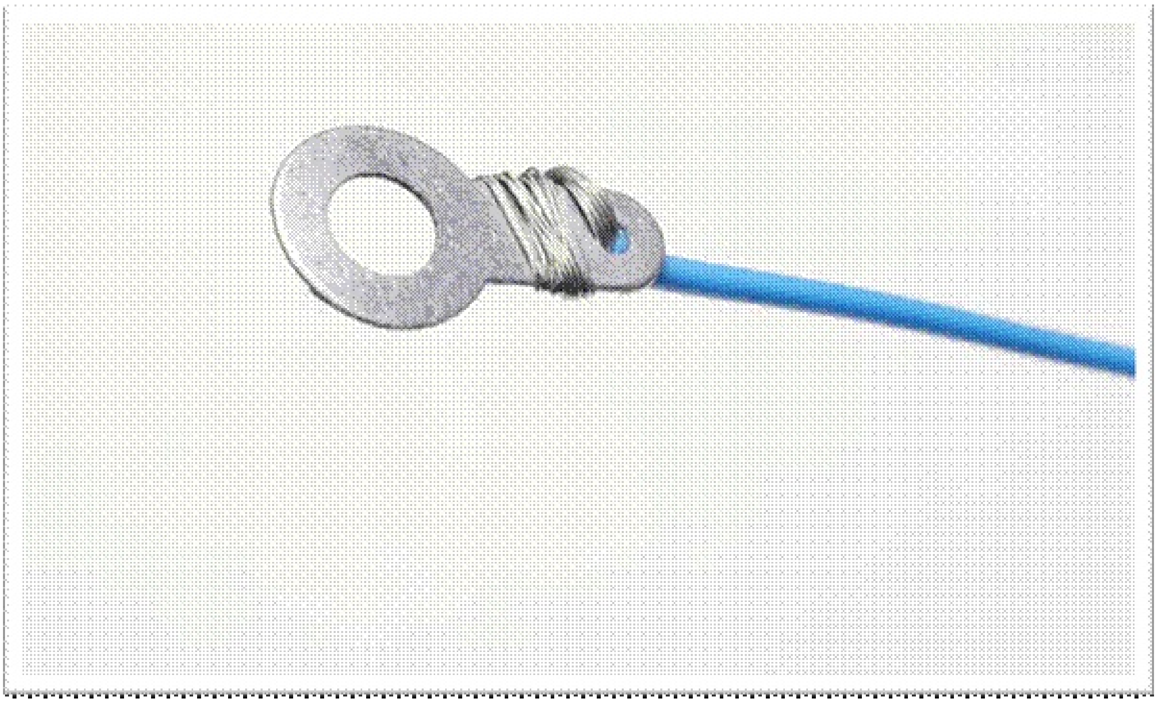

^^ A solder tag is soldered by wrapping a stripped wire end through the hole and round again, to secure it.

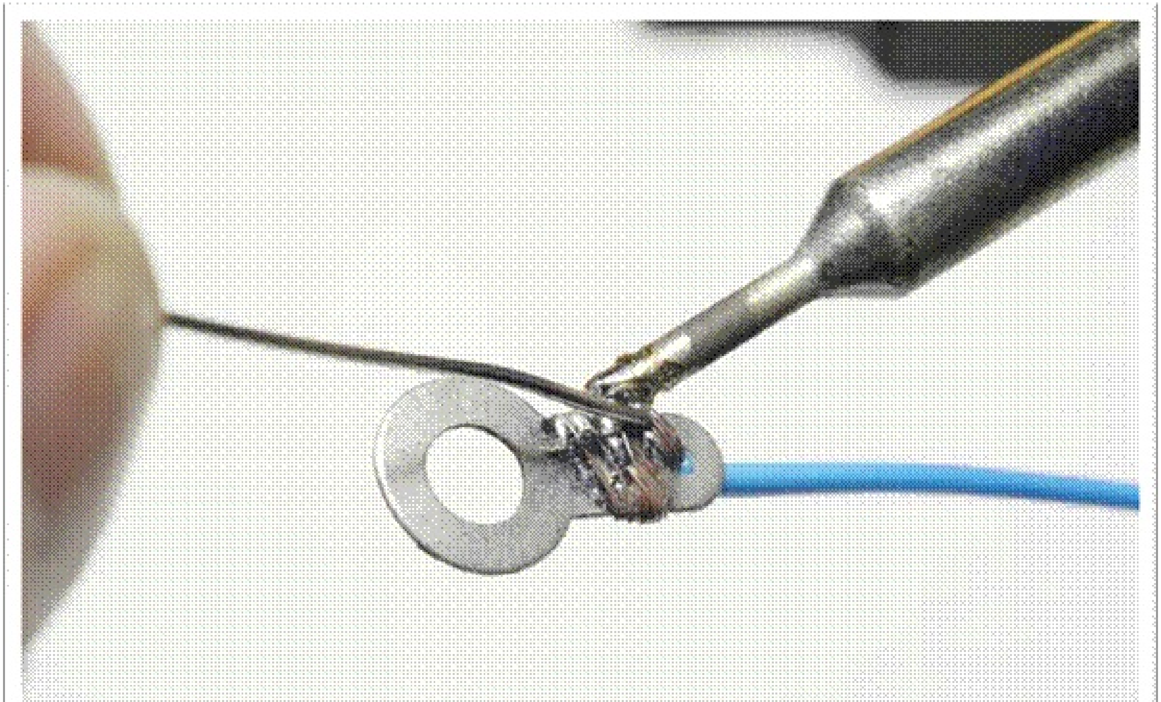

^^ Apply plenty of heat and solder for a few seconds.

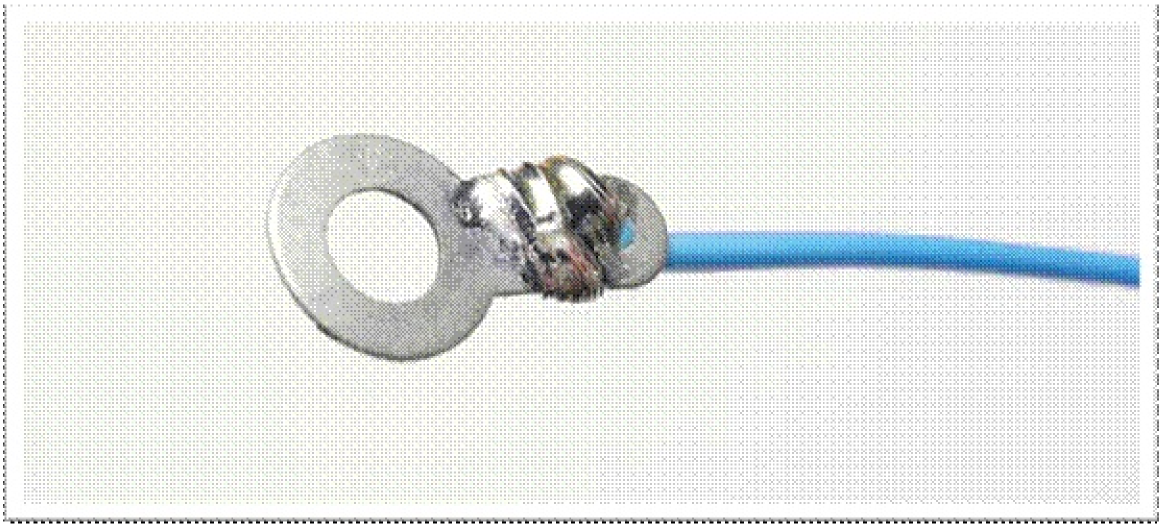

^^ *The completed solder tag*

The next sequence show how the same basic principles of soldering wires are used to connect up a device such as a panel-mounting l.e.d.. A series resistor can be wrapped around and soldered directly to one of the l.e.d. solid wires, and then two multi-stranded connecting leads are soldered to the l.e.d. and resistor. It’s best to use heatshrink tubing or PVC sleeve to insulate the solder joints and prevent short circuits afterwards.

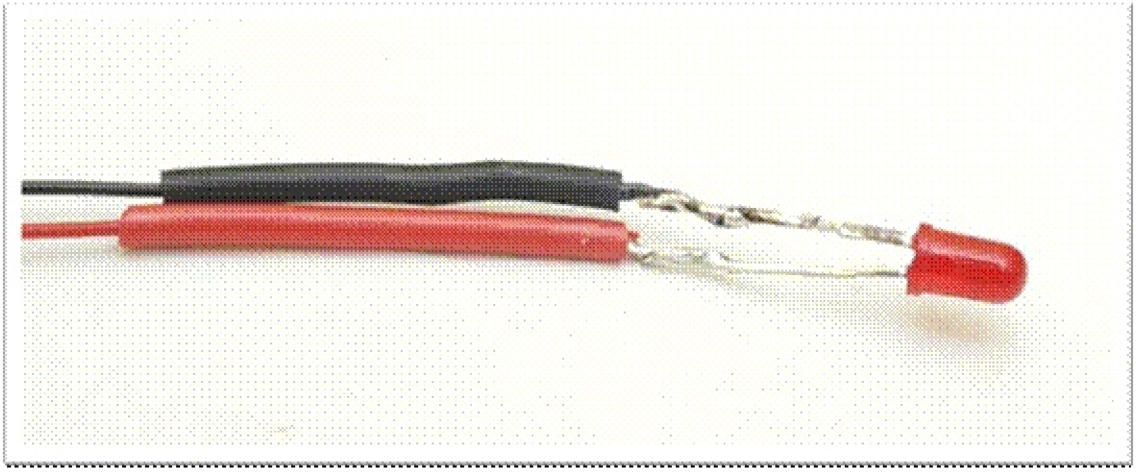

^^ *Multi-stranded wires can be soldered to the solid leads of an l.e.d.: insulate them afterwards. Different coloured wires identify the polarity of anode and cathode.*

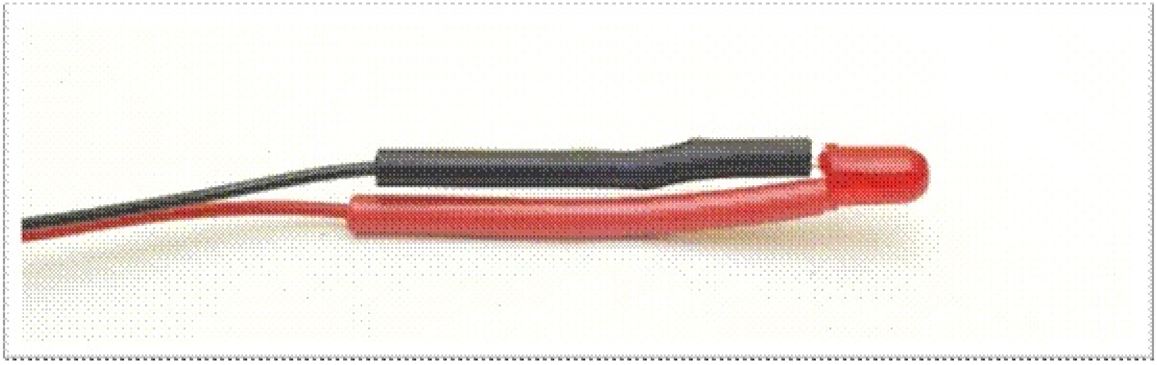

^^ *PVC sleeving or heatshrink is needed to prevent short circuits.*

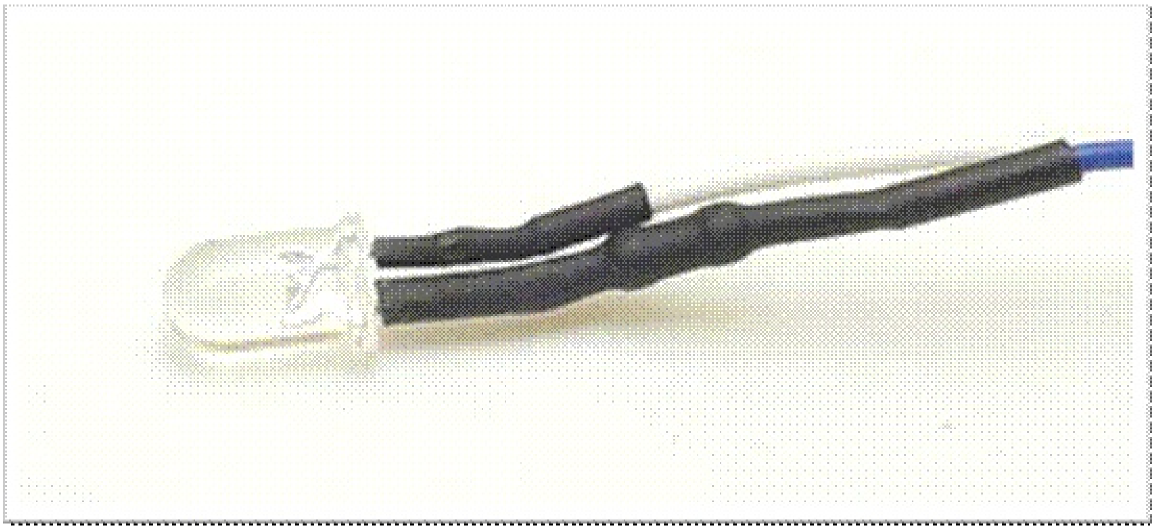

^^ A commercial l.e.d.– the series resistor can be made out in the sleeving.

Wires can also be soldered directly to printed circuit boards by stripping and tinning the ends, provided they fit through the holes in the p.c.b. It’s a very common and cheap way of hooking up a board using “flying leads” and you’ll see this all the time in consumer electronic equipment. For convenience so-called “solder pins” can be used, onto which flying leads may be soldered from the component-side instead.

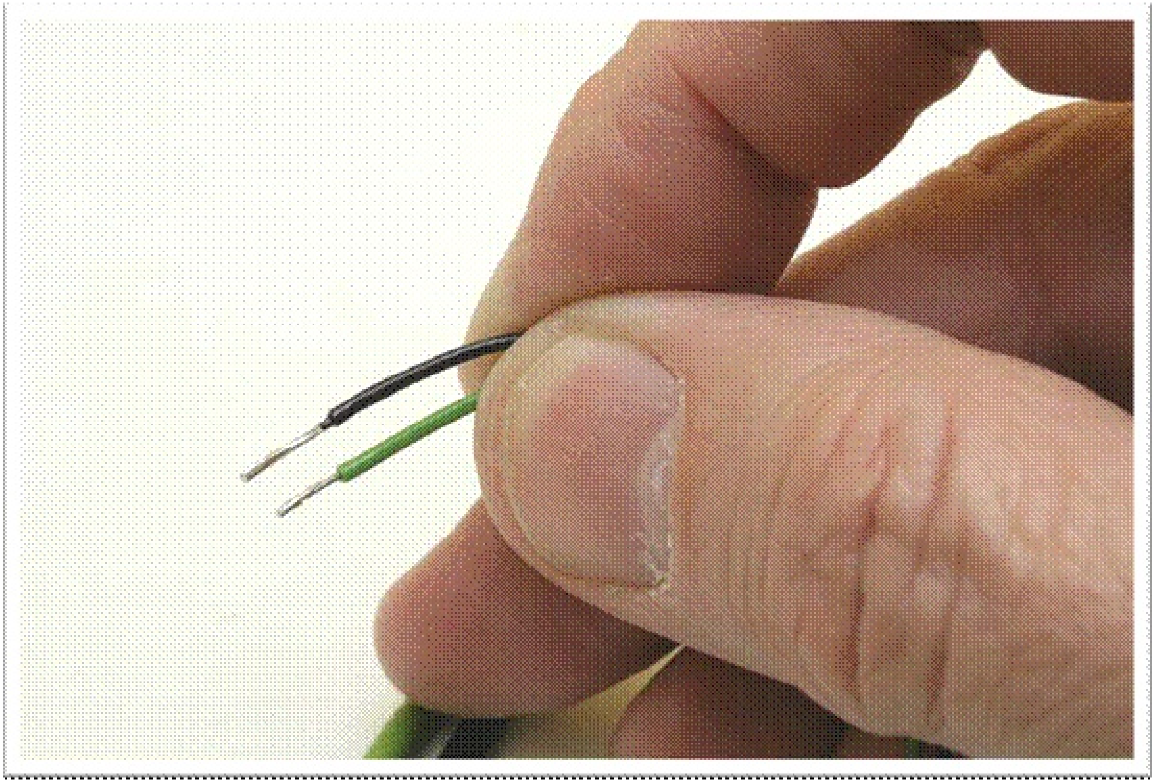

^^ A set of l.e.d.s connecting wires, stripped, tinned and ready to be soldered to the p.c.b.

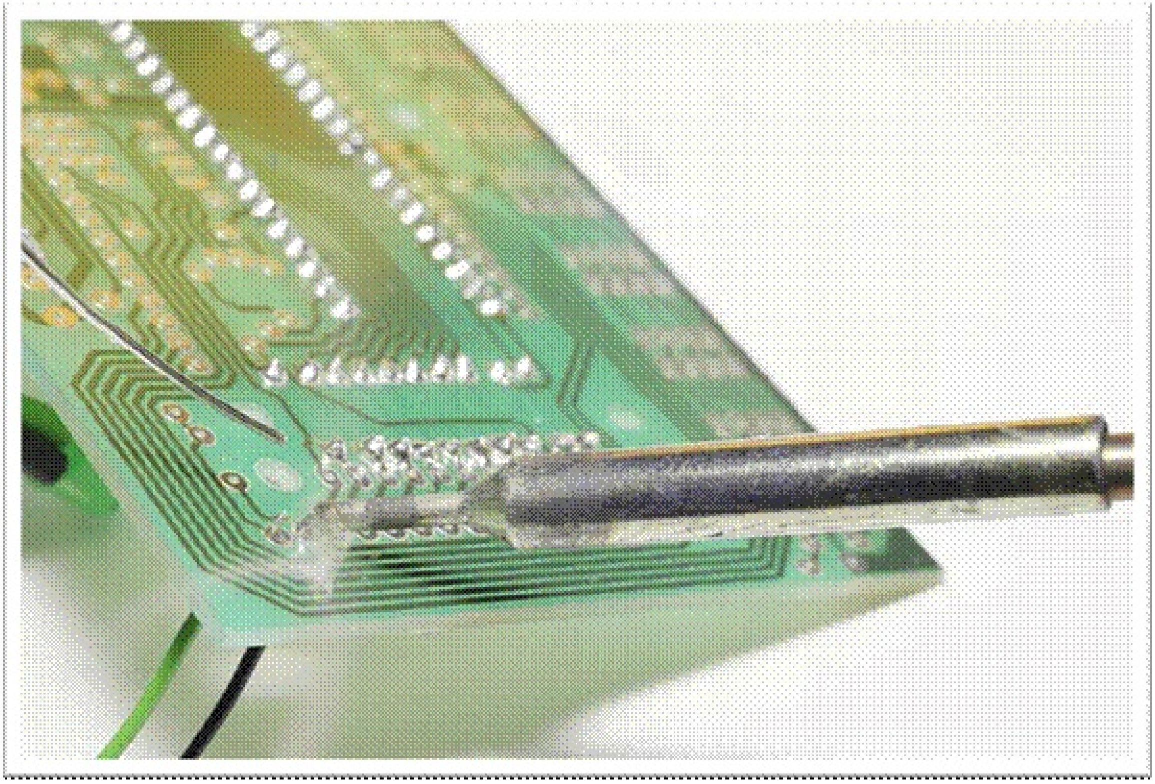

^^ Solder the two "flying leads" to the copper pads in the usual way. Hopefully the holes are big enough for the wires!

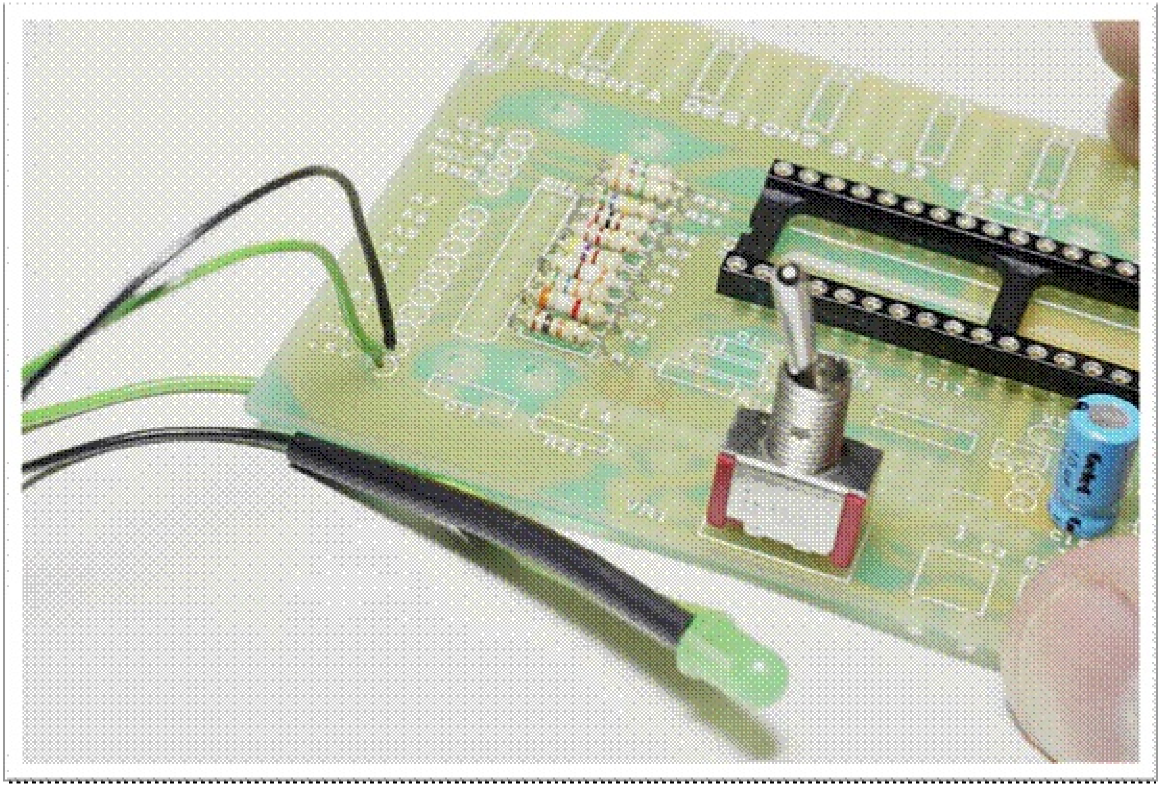

^^ Connecting an l.e.d. to a circuit board with flying leads.

Wires can also be attached to the underside (solder-side) of circuit boards, tacking them onto existing solder joints by re-melting them and absorbing the tinned wire end into it ("reflow soldering" – see later). This is a cheap and cheerful, semi-reliable way of rigging wires to a circuit board, and it's used all the time in imported consumer electronics.

Tidying up

I'll leave it to readers to decide whether they should cut off excess wire before or after soldering. After the soldering is complete, I prefer to tidy up the joint by snipping any excess wire from the joint using a pair of "end cutters" shown earlier. These expensive hand tools have specially angled blades that snip the joint neatly down to the top of the solder joint. Ordinary side cutters will do fine.

It's worth taking time out to inspect the work closely, looking for any missing solder joints, whiskers of solder or swarf shorting out any solder pads, and all such potential problem areas should be dealt with prior to testing the board. Faultfinding goes beyond the scope of this guide, but it's true to say that almost always, any problems noticed after powering up the circuit are due to soldering faults or wrong components being used.

Reflow technique

Another technique often used is “reflow” soldering. This is used to “tack” devices or wires together, especially if very small, sensitive or fiddly parts are involved. There might be no room to make a “proper” sturdy joint, or it might just not be necessary to have any mechanical strength in the joint, especially if tiny parts are used.

As an example, imagine a small temperature sensor (I used a transistor) for use in a thermometer project. It could be quite tricky to solder flying leads onto the sensor’s leadouts, so a good approach is to tin both the flying leads and the sensor’s leads, and then simply touch them together and re-melt the solder with the iron. There’s no need to add any more solder, because the solder that’s already there will re-melt and the joint will be made. Sometimes this is called a butt joint.

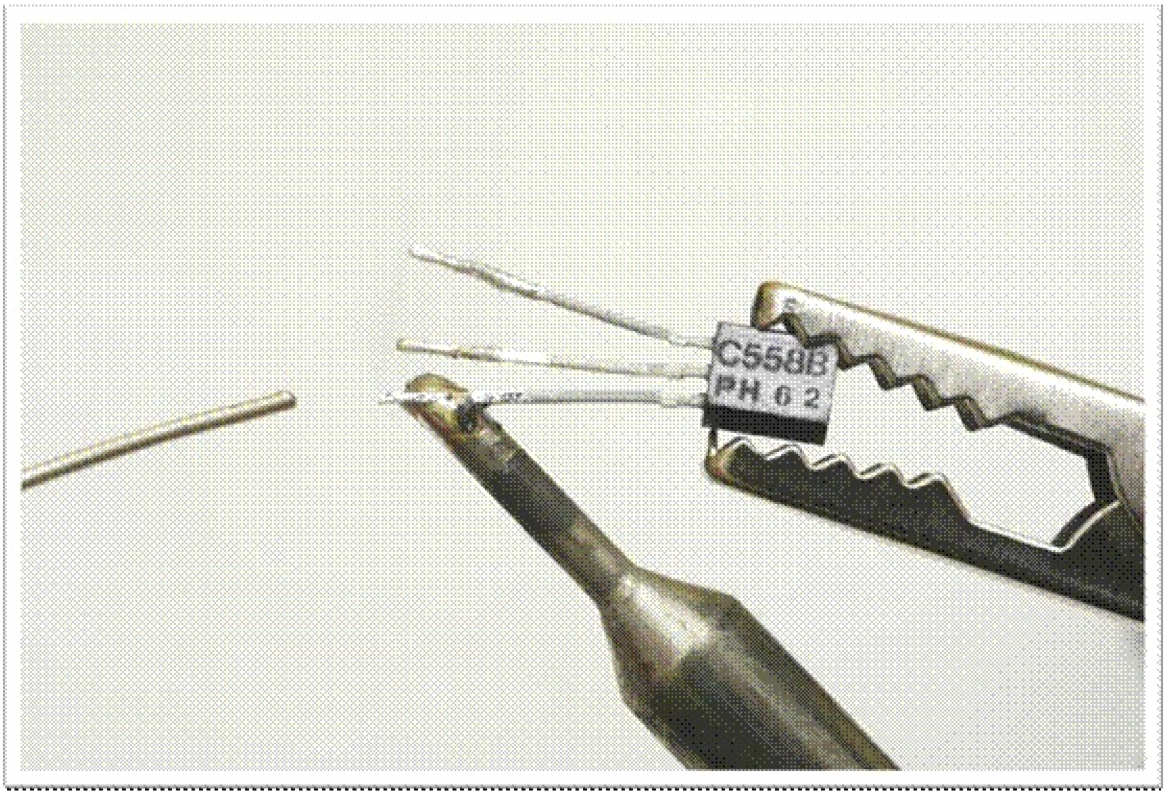

^^ *The leads of this sensor (transistor) have been tinned, ready for flying leads to be tacked onto them with a reflow method. A Helping Hands jig might help!*

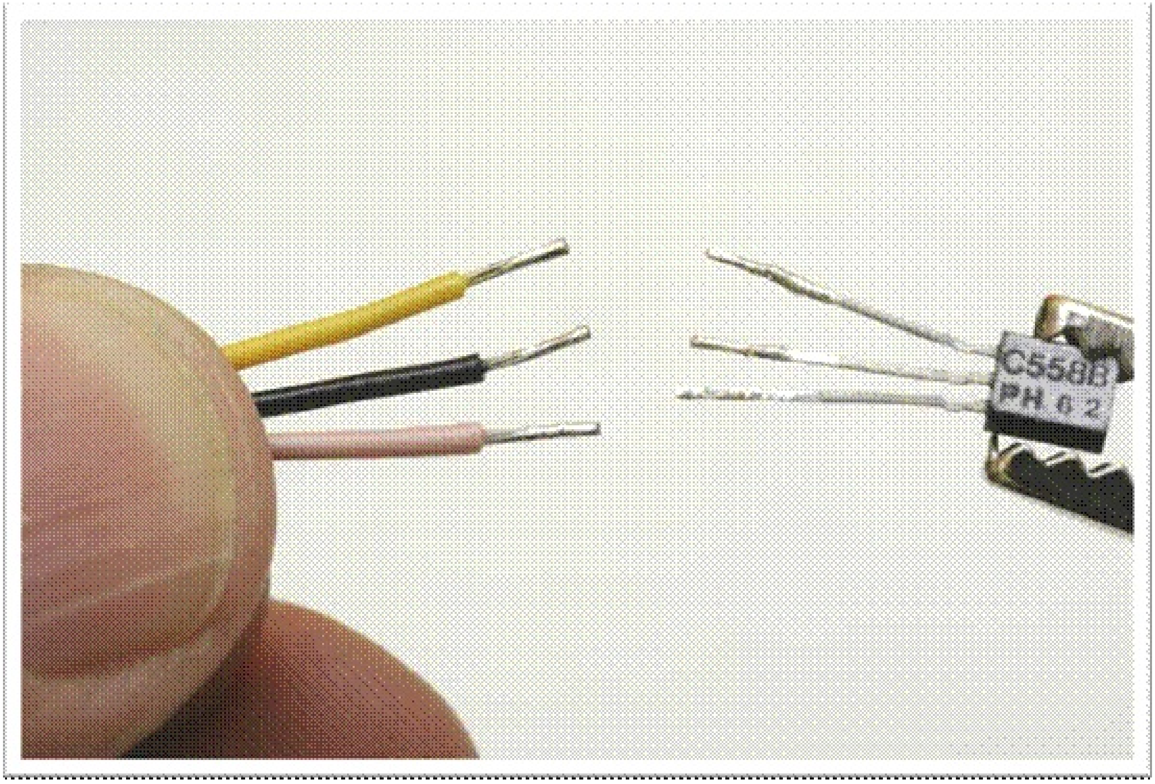

^^ The three flying leads stripped, tinned and ready to be reflow-soldered onto the device.

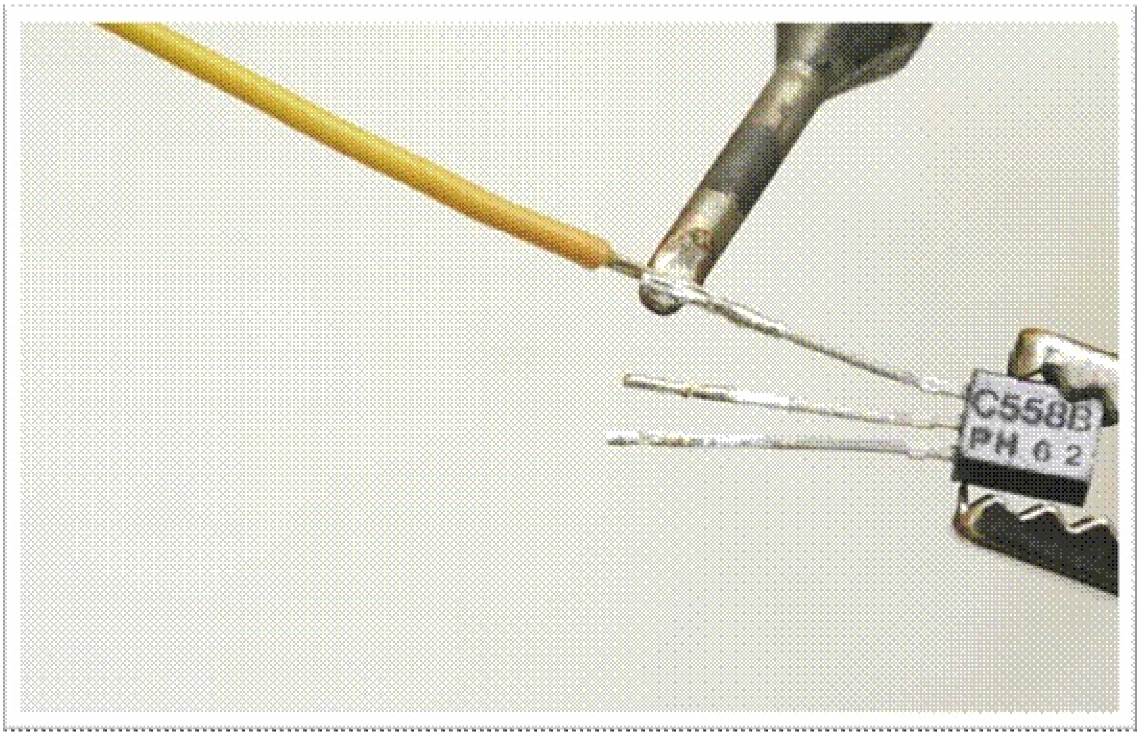

^^ To reflow solder them, simply hold the two leads together while re-melting the solder with the iron.

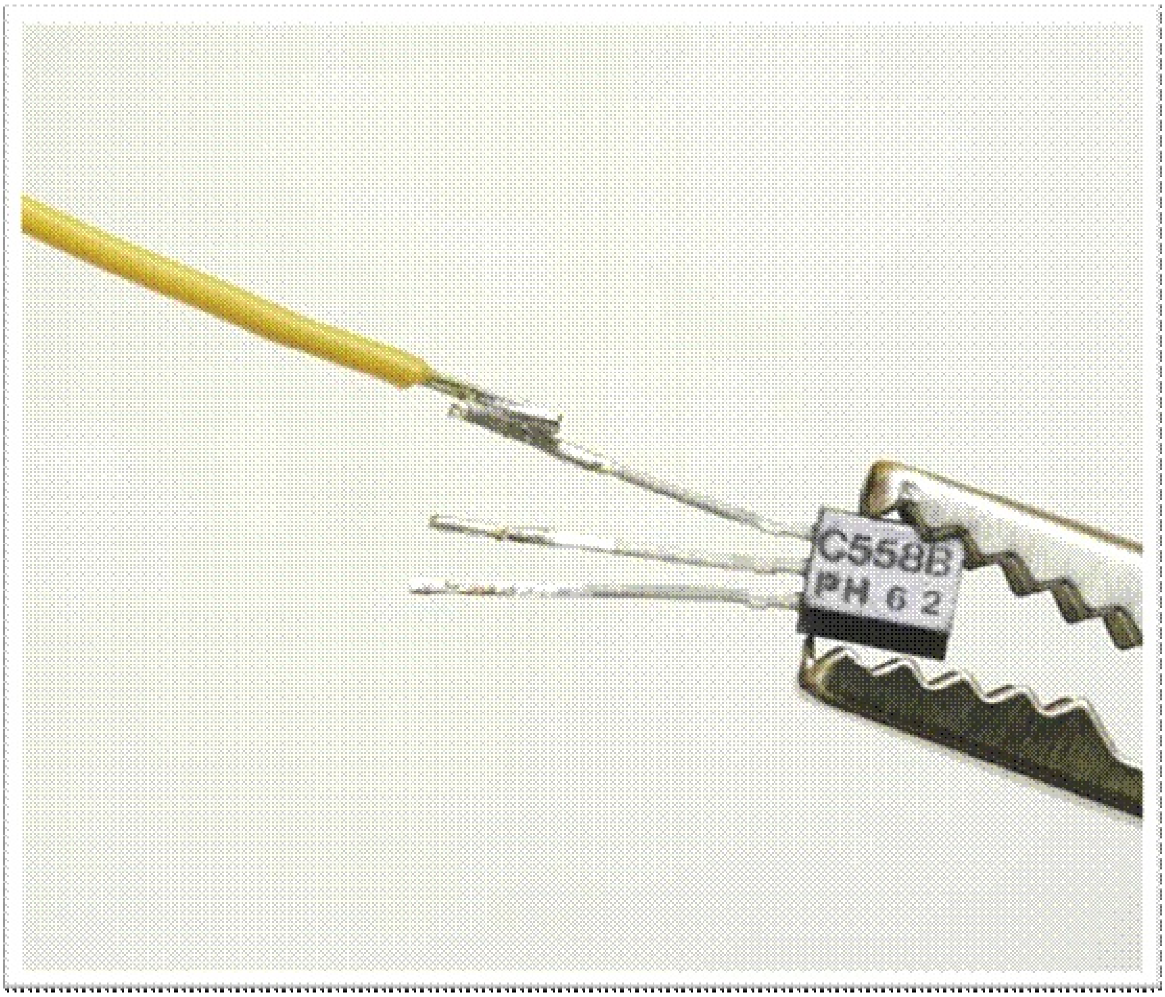

^^ Remove the iron and let the solder cool. The wire is tacked on.

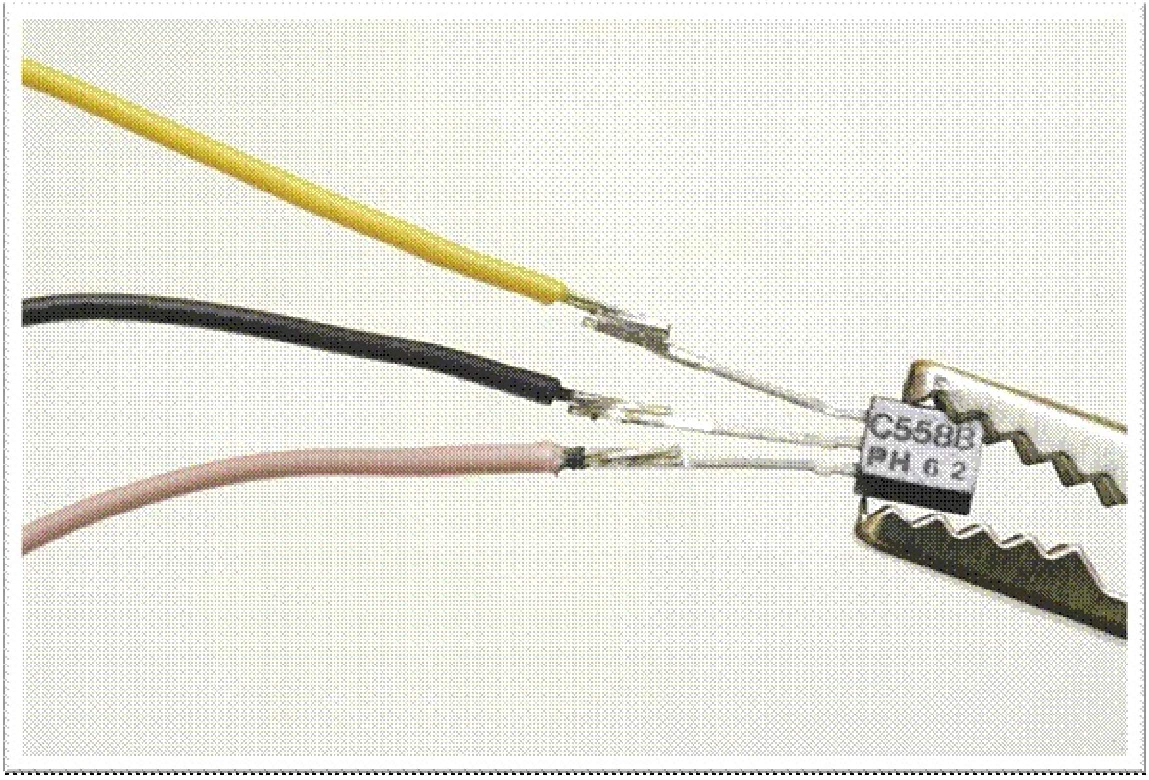

^^ Repeat for the other leads. They just need insulating with sleeving, then job done!

Depicted next is a typical "tag strip", an insulated panel with metal solder tags used for making sundry connections. (Entire TVs and radios used to be hand-built with them, in the early-mid 20th Century!) The principles of soldering are exactly the same, but more time is needed when applying the soldering iron because more metal is present, which needs more heat. You'll need more solder for bigger joints like these, so larger diameter solder makes a quicker job of it. Consider adding more flux (see earlier) to see if it helps.

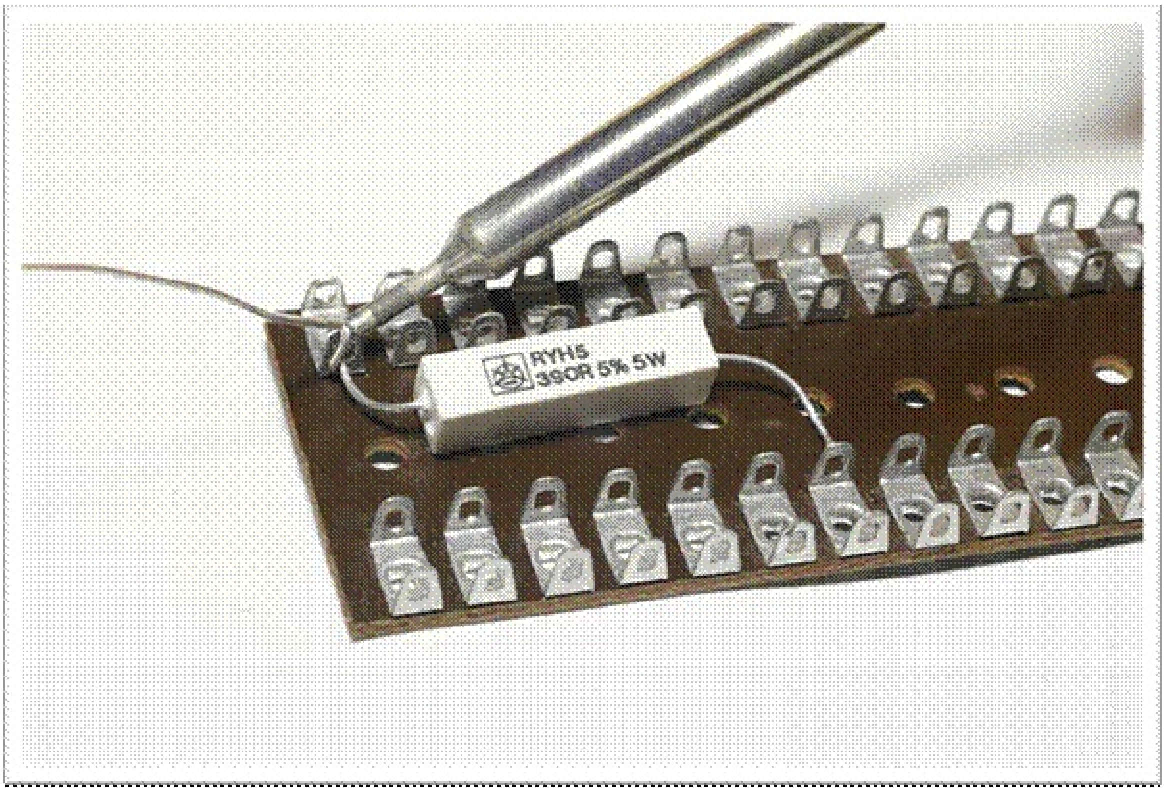

^^ Wrap wires through the terminals and arrange everything neatly, then solder as normal.

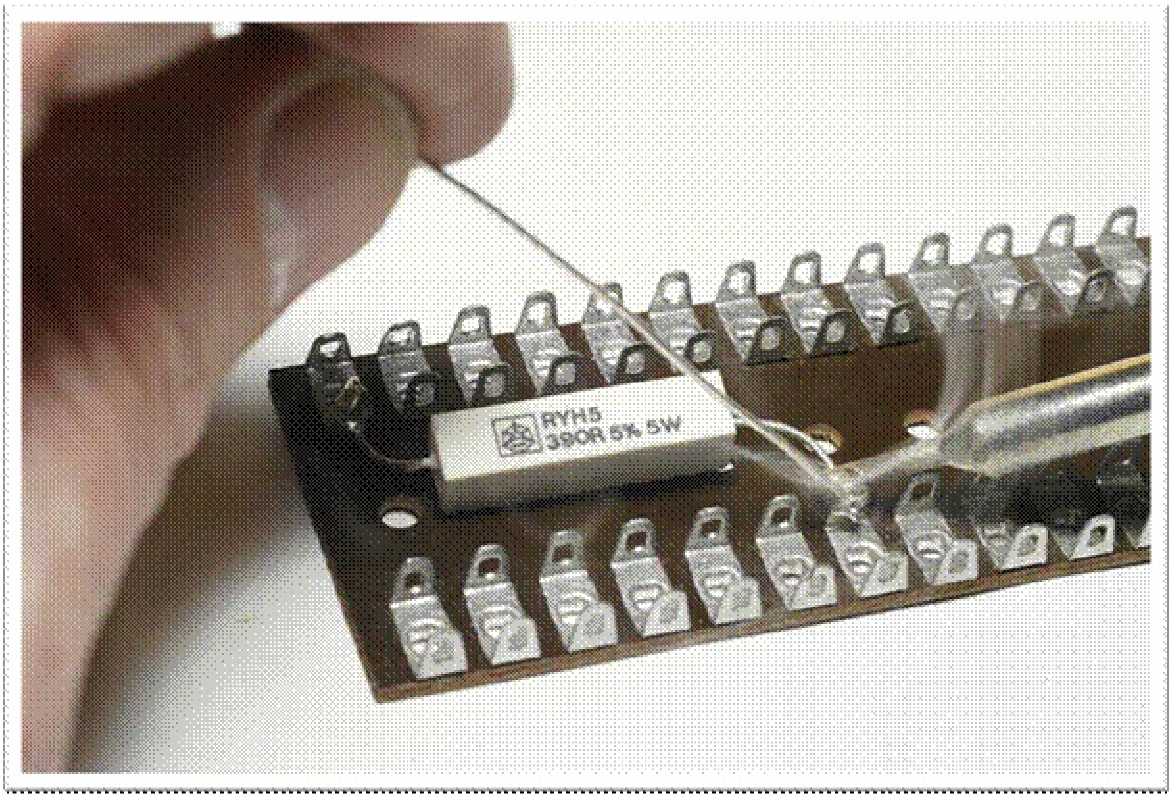

^^ Don't be afraid to apply more heat with larger assemblies like these: they contain more metal than, say, an ordinary p.c.b so allow more time for the solder to flow over

everything properly.

Fatigue & Breakage

Earlier I explained how multi-stranded hookup wire is flexible, which also makes it vibration proof – that's why a car's electrics are full of multi-stranded wiring, and test equipment probes use ultra-flexible multi-stranded wire for the same reason. Solid-core wire can be bent and will stay in shape (called "plate wiring") but if it's repeatedly bent or vibrated then it may eventually break somewhere due to fatigue.

The same is true of wires that have been soldered or tinned. No longer is the wire 100% multi-cored and flexible – instead it's been turned into a *single core wire* at the point where it's been soldered. This is potentially a weak spot and could eventually fracture due to fatigue, if subjected to continued vibration (e.g. in a car engine bay or in motorised equipment).

In a lot of equipment problems can be avoided by adding *strain reliefs* of some sort, to stop the wire being flexed where it's been soldered. Heatshrink tubing, or a dab of hot-melt glue, are ways of taking the pressure off the joint and ensuring soldered wires won't snap off due to vibration.

One of the reasons that higher-quality equipment and cars etc. use crimp terminals and connectors is that crimped (as opposed to soldered) connections retain all the flexibility of multi-core stranded wire from end to end, avoiding problems of wires breaking off. A *ferrule* is a very neat way of tidying wire ends and preventing stray strands of wire doing damage. Ferrules can be used to connect wires into screw terminal blocks etc. Simply clamp the terminal block down onto it and the screw will grip the ferrule.

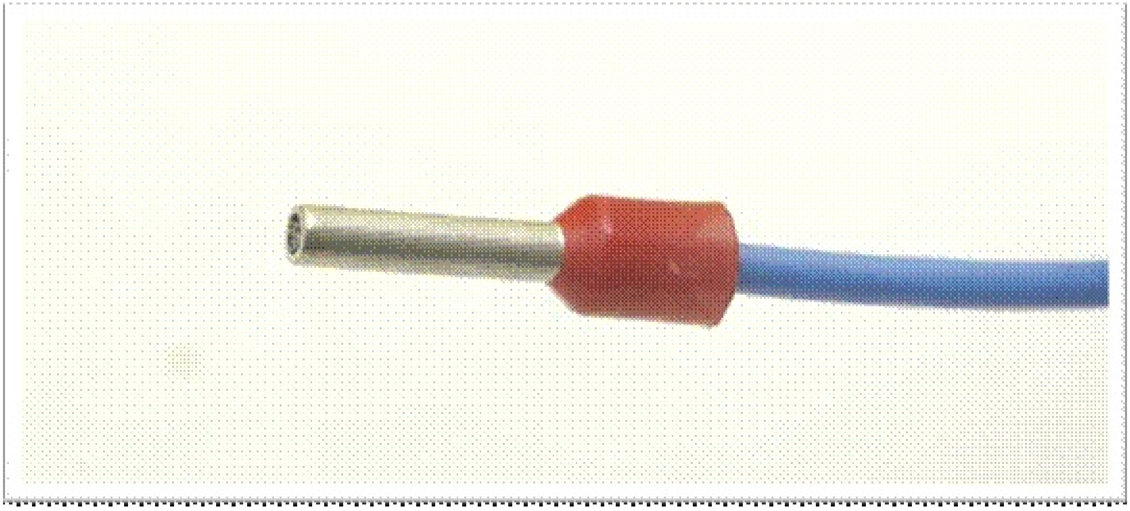

^^ Instead of soldering them, wires can be terminated with ferrules prior to fitting to e.g. screw terminal blocks. This makes them vibration-proof and also avoids any problem of stray wires poking out.

Faults & Desoldering techniques

By putting into practice the guidelines in my *Basic Soldering Guide* practice, there's no reason at all why you should not obtain perfect results and eliminate any potential problems. Hopefully the information gives you plenty of guidance to tackle various soldering projects with confidence. There's no substitute for getting some hands-on experience though, so I'd repeat the advice to try assembling a simple high quality electronic kit or two, such as those produced by Velleman and see how you get on. Powering up your first project successfully is a great thrill as every electronics hobbyist knows.

^^ *Popular desoldering products, a pump and various widths of desolder braid.*

Let's now look at reversing the soldering procedure – what to do if things go wrong, or maybe you have to repair a circuit by replacing a faulty component.

A solder joint which is badly made is likely to be electrically "noisy", unreliable and will probably worsen over time. Expansion and contraction of the joint due to heating and cooling can also throw up intermittent problems later down the line. The joint may look OK but underneath it may have a poor electrical connection, or could work initially and then cause the equipment to fail at a later date! These intermittent problems can be maddening to fix. TV repair technicians have an uncanny ability to go straight to a faulty solder joint because they see the same problem all the time, especially on equipment that has a "reputation".

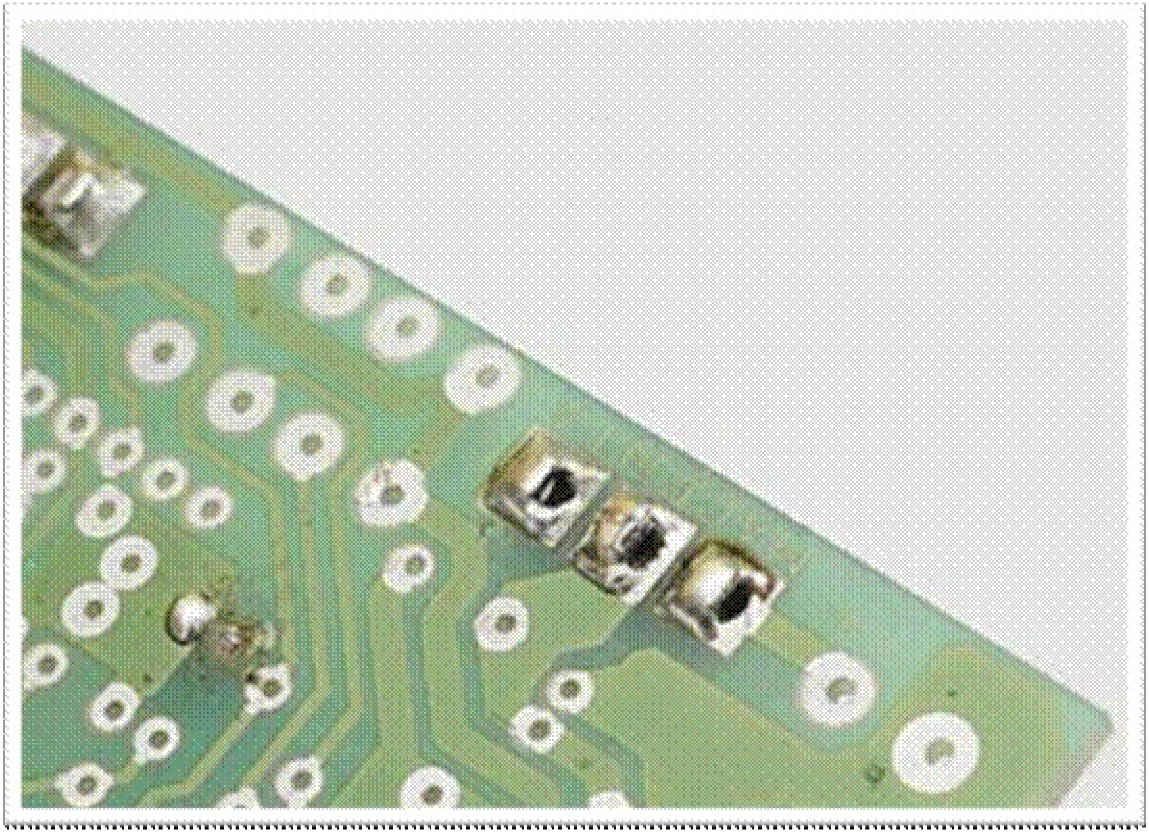

^^ These dry or grey/ gray joints were caused by dirty parts, poor heating and inadequate solder coverage

A solder joint that's poorly formed is called a "dry joint" or "cold joint" or a "grey/ gray" joint. Usually it results from inadequate heating, dirt or grease preventing the solder from melting onto the parts properly, and is often noticeable because the solder tends not to wet the surface properly. Instead it forms beads or globules. Alternatively, if it seems to take a very long time for the solder to wet the joint, that's another sign of contamination and that the joint may be a dry one, or the material is incompatible anyway. A matt, crystalline appearance instead of a shiny joint points to inadequate heating: the solder cooled down far too quickly and didn't flow properly.

Whether you want to replace a faulty component or fix a dry or poor-quality solder joint, it's usually necessary to remove the troublesome solder and then re-solder it afresh. Naturally, there are tools and techniques that make the job easy. It's very bad practice to simply re-melt the joint and then lash out with the board, whiplash style, hoping that the molten solder will be flicked off the board.

The usual way of removing solder from a joint is to use a *desoldering pump*. These work like a small spring-loaded bicycle pump, only in reverse! A plunger is pressed down until it locks into position. It's released by pressing a button which sucks air back through a pointed nozzle, carrying any molten solder with it. It may take one or two attempts to clean up a joint this way, but a small desoldering pump is an invaluable tool especially for p.c.b. work and they are widely available now.

^^ *A hobby desoldering pump primed for use*

Desoldering pumps often have a heatproof P.T.F.E. nozzle which may need replacing occasionally. Each time the button is pressed, a plunger clears the nozzle but sometimes solder particles and swarf will be ejected in the process; when you prime the pump, point the nozzle into a small pot or old aerosol top to catch any debris. Remove the spout and clean out the pump from time to time.

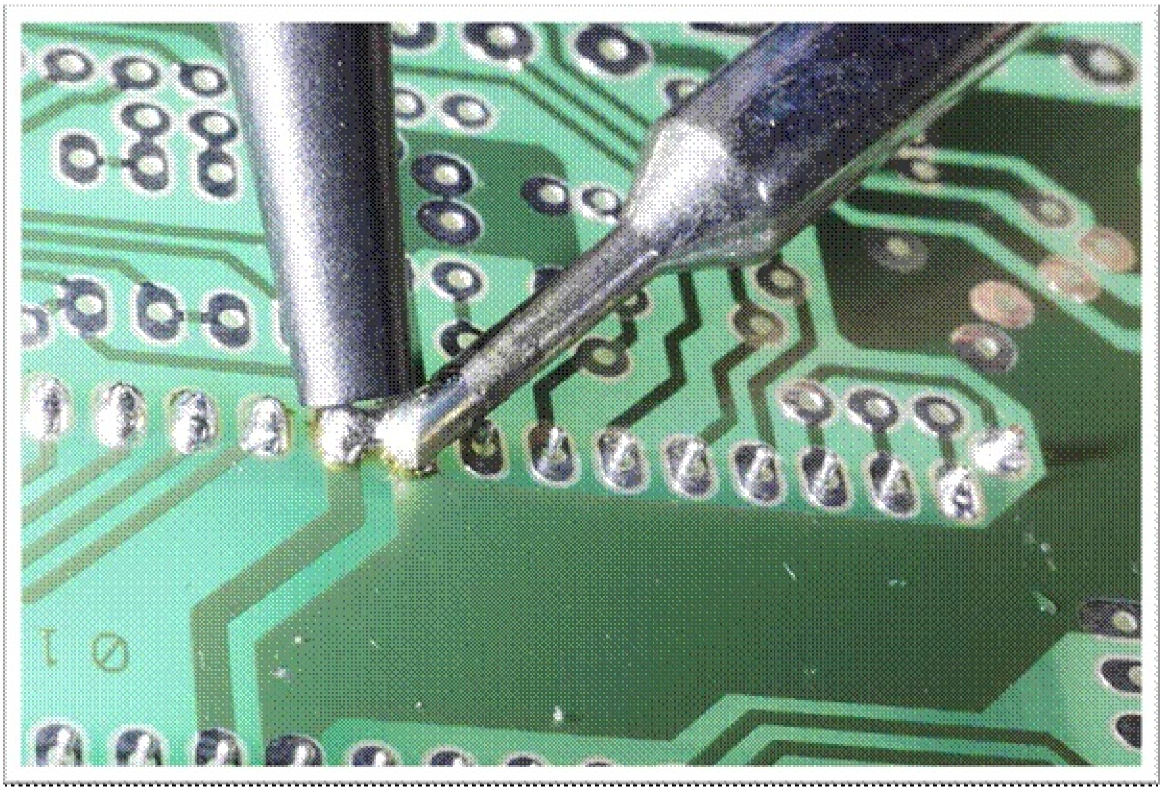

^^ *Suck up molten solder using a desoldering pump*

With very stubborn joints where the last traces of molten solder just can’t be shifted, it sometimes helps to actually *add* more solder and then desolder the whole lot again with a pump.

Desolder Braid

An alternative to a pump is to use *desoldering braid* which arrives in small dispenser reels. It’s a flux-impregnated fine copper braid which is applied to the molten joint, and the solder is then drawn up into the wick by capillary action. It’s remarkably effective and for certain tasks, it can be more thorough than a pump. I recommend that a small reel is bought (start with 1.5mm width) for the toolbox, to tackle larger or difficult joints which would take several attempts with a pump.

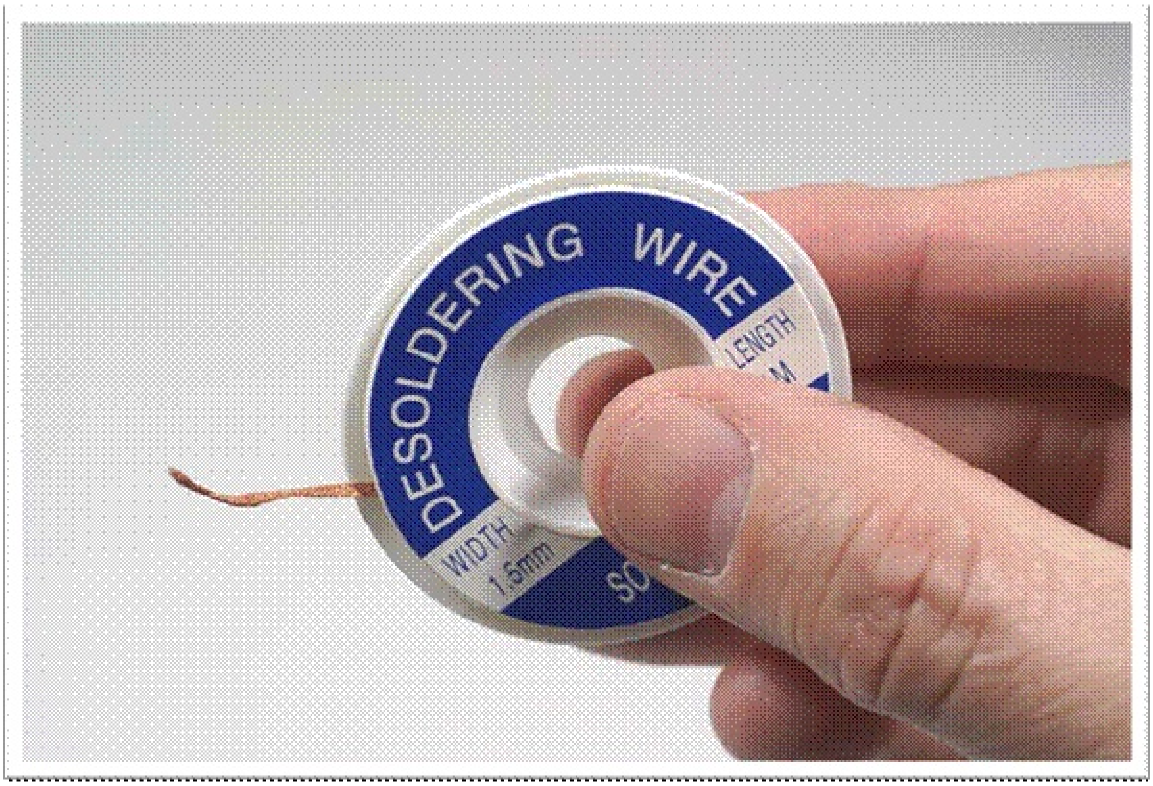

^^ *Desolder braid is also handy and can sometimes be more effective than a desolder pump. It comes in various widths to suit the scale of work being tackled.*

To use desolder braid, press the end of the braid down onto the joint using the tip of an iron, and let the solder melt underneath: the braid will then absorb the solder. The braid becomes hot so beware of burns. Once the solder’s solidified on the braid, cut it off and discard.

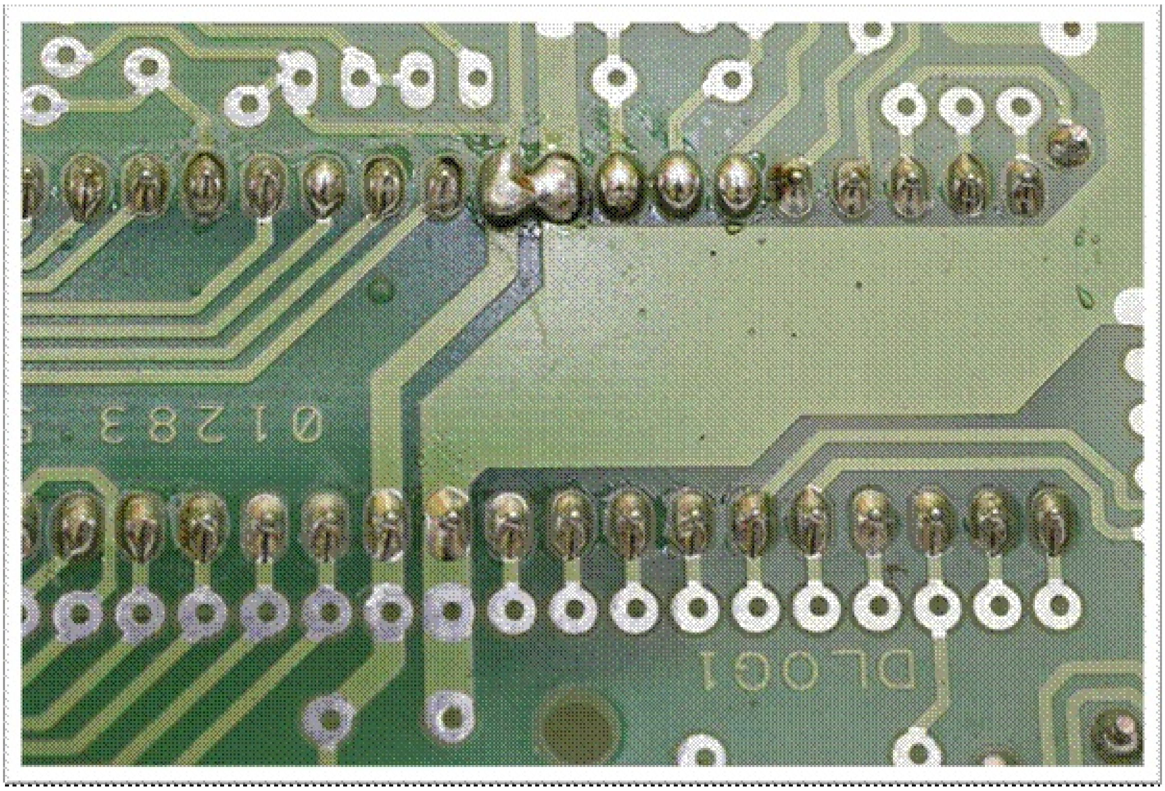

^^ Desolder braid can also be used to remove excess solder, e.g. two i.c. pins shorted together.

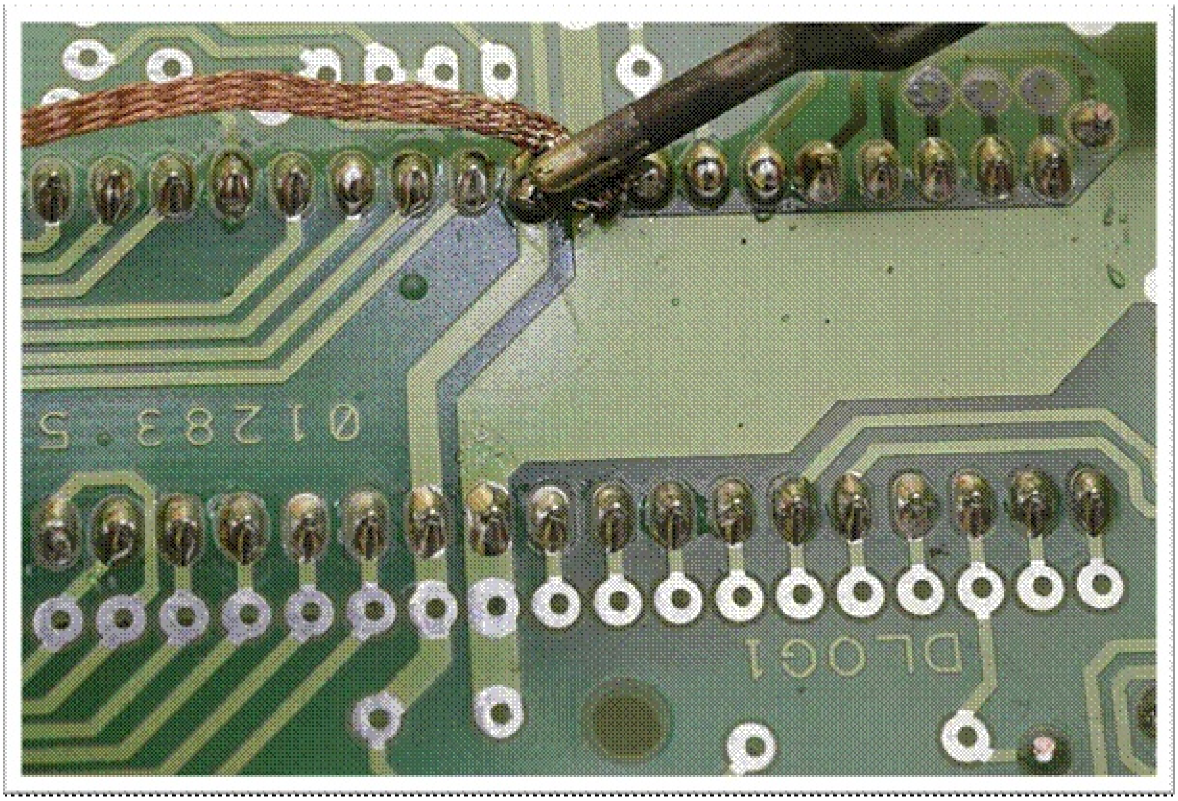

^^ Press some desolder braid over the joint, then melt it with an iron to draw molten solder up the braid.

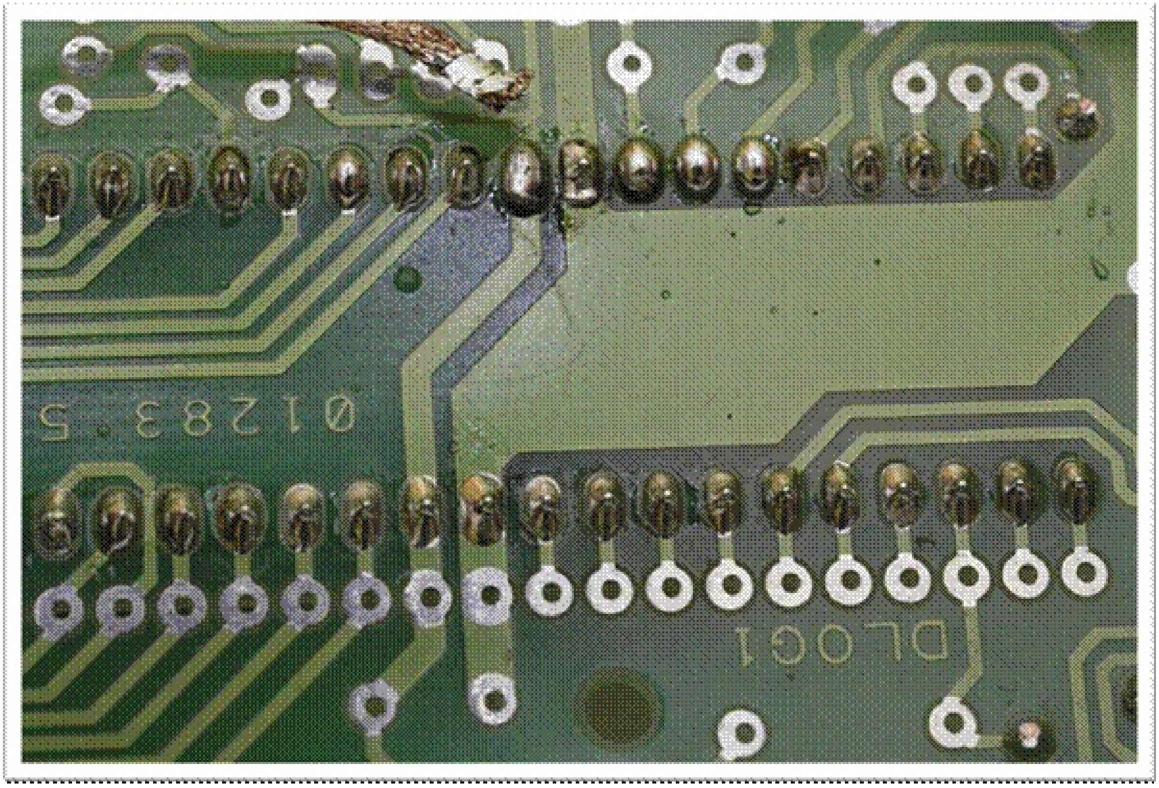

^^ *Remove the braid immediately and don't drag "whiskers" of molten solder around. The excess solder is absorbed by the braid, which is snipped off ready for the next job.*

Be aware that you can damage a printed circuit board accidentally when removing the desolder braid if it's not removed *quickly enough*. The solder will soon solidify, which effectively solders the braid to the printed circuit board! A careless tug may yank copper tracks or pads away from the board, stuck to the braid. You can also drag solder "whiskers" onto neighbouring pads unless the braid is removed cleanly. Why not practice using desolder braid with an old circuit board?

Whichever desoldering method you use, care is needed to ensure that the boards and parts are not damaged by excessive heat. It's not that difficult to apply so much heat when desoldering that the adhesive holding the copper foil tracks on the p.c.b. eventually fails, causing the copper track to lift away – everyone's worst nightmare.

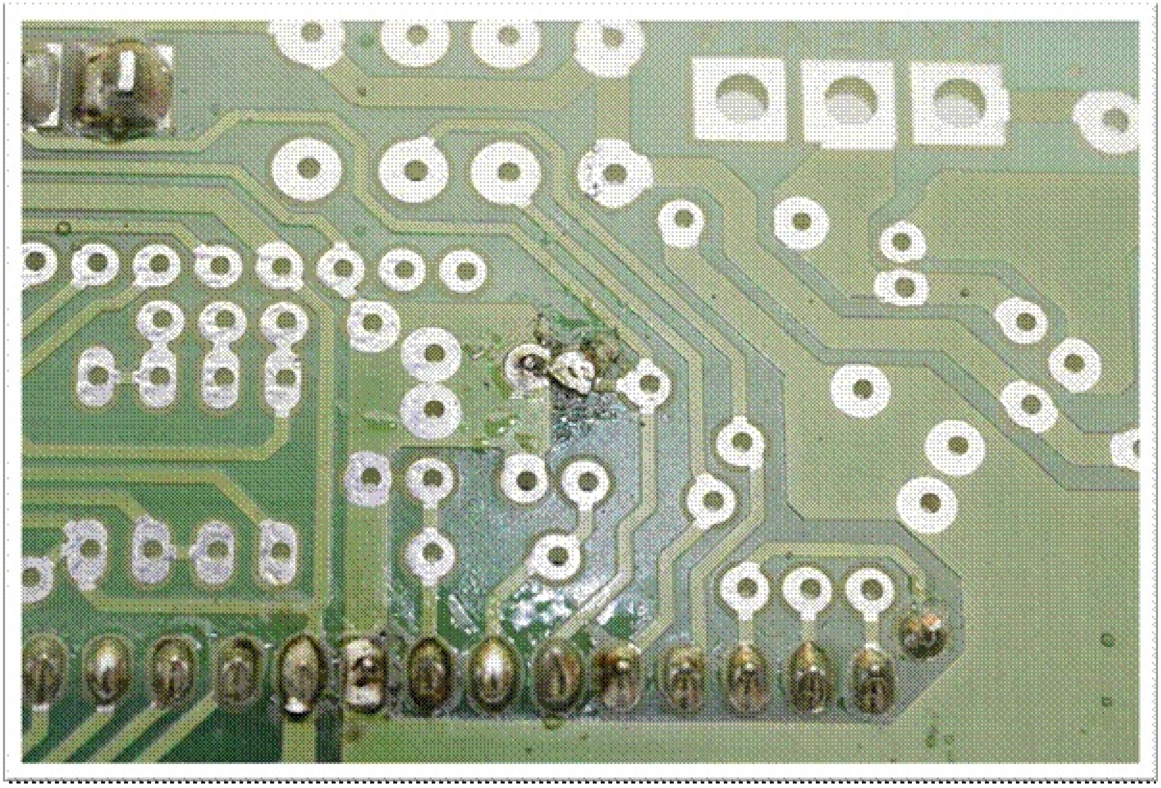

^^ Typical copper track damage (centre) caused by overheating during soldering or desoldering. The track has lifted off, but you can try repairing it by adding extra wiring or SuperGlue it if the track isn't broken.

If this should ever happen, remove the iron immediately and permit the area to cool (a freezer aerosol is valuable at such times). If you're lucky, you can maybe repair the lifted track using a droplet or two of Super Glue, or add "jumper wires" to bypass the damage.

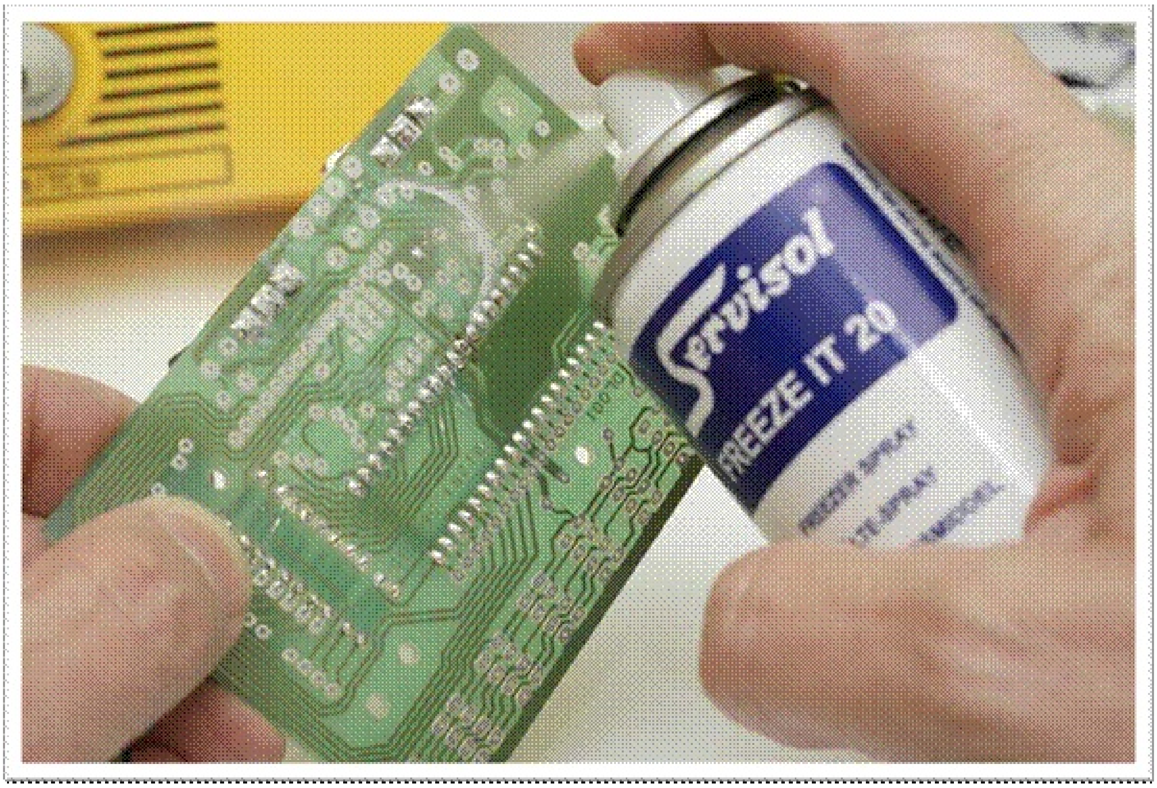

^^ A Freezer aerosol can give rapid cooling where excess heat has been applied

during soldering. Also used in circuit faultfinding to identify overheating parts.

You now know everything you need to know about making the ideal solder joint, and desoldering it in case you need to make a repair. Just to remind you, a Quick Summary guide follows.

Quick Summary Guide

To round off the Basic Soldering Guide, let’s summarise how to make the perfect solder joint.

- Ensure materials to be soldered are compatible with tin/ lead or lead-free solder.
- All parts must be clean and free from dirt and contaminants.
- Try to secure the workpiece firmly during soldering.
- Brand new soldering iron tips must be flooded with solder immediately, the first time they are used.
- Wipe the tip of the hot soldering iron on a damp cellulose sponge at frequent intervals. Then “tin” the iron tip by applying a small amount of solder.
- Aim to heat all parts of the joint with the iron for under a second or so, to bring them up to the same temperature.
- Continue heating and apply sufficient rosin-core tin/ lead or lead-free solder to form a complete joint.
- It only takes a second at most, to solder the average p.c.b. joint. It should be smooth and shiny, and through-hole joints should be slightly convex in shape.
- Remove the iron and return it safely to its stand.
- Do not move parts until the solder has cooled.
- Tin the soldering iron tip and clean it well, when switching it off, ready for next time.
- Consider using e.g. electronics flux dispenser pens or Colophony (rosin) to help with difficult joints.

Sometimes solder joints don’t go quite to plan, and sooner or later everyone is faced with the need to problem-solve or troubleshoot, so a simple Troubleshooting Guide follows next.

Troubleshooting Guide

This troubleshooting guide may help fix common problems encountered with troublesome solder joints.

SYMPTOMS	LIKELY CAUSES	REMEDY
Solder won’t “take” (wet) and won’t flow properly over the joint — molten solder forms beads or “ball bearings” instead of flowing properly.	Grease or contaminants present; Material may not be suitable for soldering with standard lead/tin or lead-free solder, e.g chromium.	Treat contaminated parts with abrasive cleaners etc. as required to expose base metal. Some metals can’t be soldered with electronics-grade solder.
Solder doesn’t melt or flow very well — the joint is crystalline or grainy-looking - a grey or dry joint.	Joint has been moved before being allowed to cool naturally, or: Joint was not heated adequately. Too large a joint – too much metal present – and/ or the soldering iron temperature or power rating are too low.	Desolder and remake. Apply heat for a longer period, or use a higher power soldering iron, or check the temperature setting and raise it if possible.
Solder joint forms a “spike” and applying the iron again makes it even worse!	Probably overheated, burning away the flux. The iron, when removed, would cause the solder to stand up in a spike.	It is usually best to desolder and remake the joint freshly again.
The copper foil of my p.c.b. has lifted off the circuit board!	Excessive use of heat has damaged the adhesive. Provided the track hasn’t broken, it may be repairable.	You can sometimes repair it with Super Glue, or re-wire the board with jumper wires.
Brown varnish-like deposits are left behind after I finish soldering.	These are the remains of rosin flux and are nothing to worry about.	It can be removed with PCB cleaners or some solvents, if you want to tidy up the board and inspect your work.

Possible Hazards and simple First Aid

It’s extremely rare that soldering iron operators receive any burns or other injuries from the use of hot soldering irons. Soldering is perfectly safe provided that common sense precautions are taken during the soldering operation. Here are some of them:

- Components are very hot after soldering, so let them cool before handling them to avoid skin burns.
- Beware of splashes of molten solder caused by careless handling of a hot soldering iron.
- Beware of energised components (capacitors, batteries etc.) being shorted by molten solder and ejecting solder splashes due to arcing.
- Always park a hot iron safely on a stand in between use — never hang it vertically next to the bench.
- Keep a hot soldering iron away from its mains cable (silicone cables reduce the risk of accidental damage).
- Beware of wire offcuts flying off (danger to eyesight) when snipping wires to length before or after soldering.
- Avoid inhalation of solder and flux fumes as this can irritate the respiratory tracts, especially in sensitive cases (e.g. asthma).

Should you receive a more serious skin burn which requires attention, then:

- **Cool the affected area immediately.** Use plenty of cooler running water – but avoid ice cubes etc. as they can cause nerve damage after a time or inhibit the flow of blood to the affected area.
- Remove any **objects** which may be constrictive, before any swelling starts (rings, watches, bracelets).
- Do not prick blisters nor apply ointments, salves or lotions at this stage.
- Local pain relief for small burns can be obtained by spraying *Burneze* aerosol onto unbroken skin.
- Seek medical attention for more serious burns.

Eyesight problems are exceptionally rare, e.g. pieces of wire offcuts or solder splashes lodging in the eye area, and should be treated by a qualified first-aider or A&E. The best you can do is bathe the affected area with e.g. a first-aid eyewash bottle or fresh water. Then seek professional medical help straight away.

Useful resources

Details of the Antex range of soldering equipment, solder tips and spare parts can be obtained from www.antex.co.uk. UK and international distributors are also listed on the Antex (Electronics) web site.

If you’re interested in hobby electronics then why not try **EPE Magazine**, the No. 1 UK magazine for hobby electronics enthusiasts, students, trainees and technicians around the world. You can buy a printed edition from newsstands, download a PDF version (for Windows) or try a tablet/ smartphone version from Pocketmags. More details at www.epemag.com

You can learn more about the writer at his website http://www.alanwinstanley.com/

Some mail order suppliers of soldering equipment and electronic parts include:

- ESR Electronic Components Ltd. (soldering equipment, Velleman kits)
- Bowood Electronics (Antex irons and spares, electronic parts)
- Rapid Electronics (components, tools, equipment)
- Cricklewood Electronics (CCTV, Antex soldering irons and spares, components)
- Maplin Electronics (UK electronics retailer and mail order)
- Farnell Electronic Components (major UK industrial supplier)
- RS (UK electronics industrial supplier)
- Brewsters Ltd (soldering equipment mail order specialists)
- Velleman UK (electronic kits)
- Quasar Electronics (Velleman kit mail order retailers)
- Kemo Kits (Germany, trade only)
- Hobbytronics (UK hobby mail order supplier)
- Multicore Solders (now a Henkel brand)

These links were correct at the time of going to press, July 2013.

Acknowledgements

Antex (Electronics) UK generously provided samples of their ever popular British-made soldering equipment, materials and accessories for use in the Basic Soldering Guide. When starting out as a 1970's teenage schoolboy electronics hobbyist, I and my trusty Antex soldering iron shared many adventures in electronics together, and it has been a pleasure to use the latest Antex soldering irons throughout this guide.

Also I would like to thank Brian Brooks of Magenta Electronics Ltd. (www.magenta2000.co.uk) for supplying me with a variety of their professionally-designed printed circuit boards and a range of components which were the subjects used in the photographs.

Photography

All photographs were taken by the author using Sony Alpha DSLRs and 50mm macro lens with extension tubes, and a Sony macro flash. High-resolution versions of these and more technical photos are available for commercial or educational royalty-free use. Please contact me with any enquiries.

Conclusion

I really hope the Basic Soldering Guide will give you the confidence to try your hand at electronic soldering. It's really a lot easier than it sounds, and armed with the guide's advice and photographs, the next thing to do is invest in a decent-quality soldering iron such as the excellent range manufactured by Antex that will serve you well for years to come.

Soldering an electronics kit together such as the professional designs produced by Velleman is a great way of testing out your new skills. Start with a small, simple kit costing a few pounds to gain confidence and experience, and avoid the temptation to tackle something too complex until you're ready to extend yourself further.

Feedback is welcomed by email to alan@epemag.demon.co.uk

You can learn more about me at www.alanwinstanley.com or read my column in EPE Magazine.

Good luck with your soldering!

Alan Winstanley

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Project Book

MAKE A
WEARABLE
SOLDER SKILL
BADGE

Learn to Solder

Tools and Techniques for Assembling Electronics

Brian Jepson,
Tyler Moskowite
& Gregory Hayes

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Project Book

Learn to Solder

Learn the fundamentals of soldering—and pick up an essential skill for building electronic gadgets. You'll discover how to preheat and tin your iron, make a good solder joint, desolder cleanly (when things don't quite go right), and how to use helping hands to hold components in place.

This concise book is part of MAKE's Getting Started with Soldering Kit. Using the tools in the kit and some electronic components, you can practice soldering while making fun blinky objects. Then show the world you just learned a new skill by wearing the Learn to Solder Skill Badge.

- **Learn how to prepare your workspace**
- **Get to know the components you'll work with**
- **Use the best methods for soldering components in place**
- **Experience the perfect solder joint**
- **Know how to desolder when things don't go right**

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Learn to Solder

Brian Jepson, Tyler Moskowite, and Gregory Hayes

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Learn to Solder

by Brian Jepson, Tyler Moskowite, and Gregory Hayes

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Welcome

Welcome to MAKE's Getting Started with Soldering Kit, and congratulations on taking a big step into the world of DIY electronics. Once you get the hang of soldering, you can put together some of the many great kits that are available, fix electronics that are broken, and build inventions of your own. With this kit, you'll learn how to:

- Prepare and clean your soldering iron
- Assemble electronic circuits from kits
- Transfer circuit designs from a solderless breadboard to a prototyping PCB
- Correct soldering mistakes you've made

Basic Tools

There's a lot of great stuff in the box, and before you start using it, here's a tour of what you'll find in there. Figure 0-1 shows the soldering tools you'll be using most of the time.

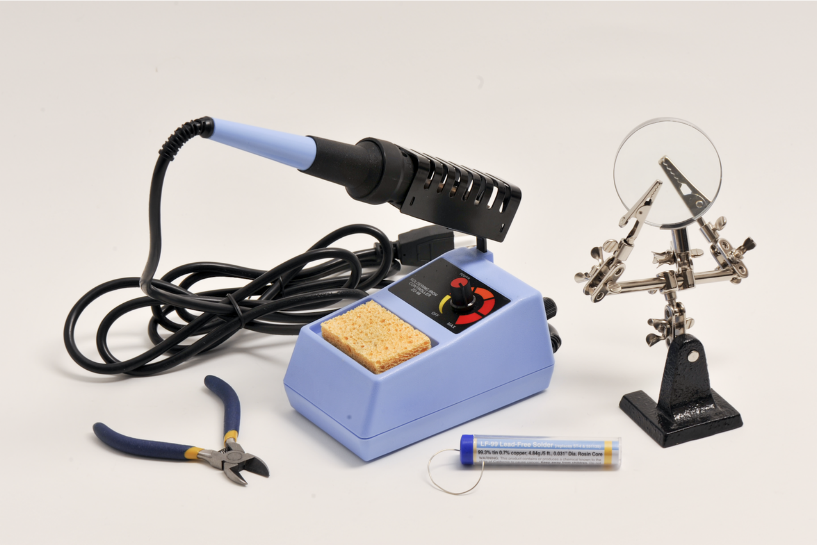

Figure 0-1. *Basic soldering tools*

Deluxe soldering iron
: (Top left) This soldering station includes a variable temperature controller, a cleaning sponge, soldering iron, and a ringed holder.

Crosscut pliers
: (Left) You'll use these to trim away excess leads after you solder components in place.

Solder tube
: (Bottom) This is enough solder to get you started and keep you busy over many projects.

Helping hands
: (Right) For those times when you need a third or fourth hand, the helping hands let you hold items steady while you solder.

Advanced Tools

Most of the time, you'll only need the basic tools to get things done. But when you need to replace your soldering iron tip, correct a mistake you made while soldering, or need a tool to help keep components from overheating, you'll need the items shown in Figure 0-2.

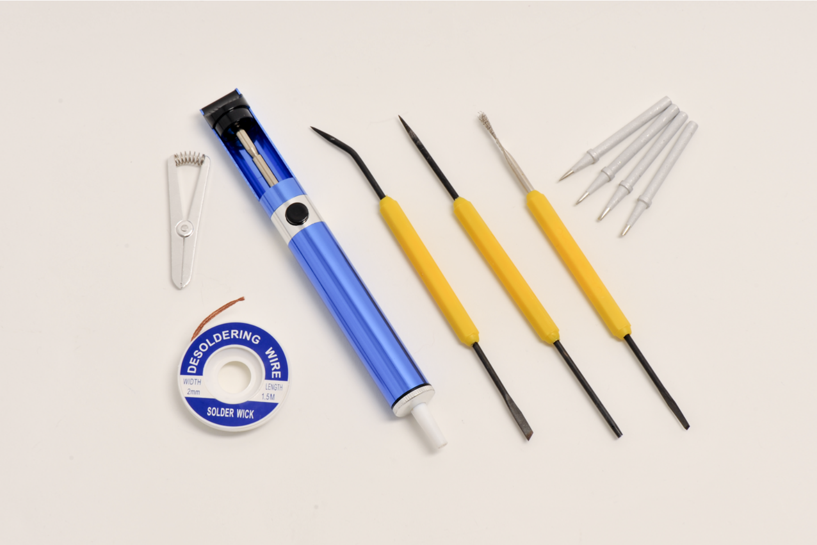

Figure 0-2. *Advanced soldering tools*

Heat sink

(Left) Clip this to sensitive components to help dissipate heat.

Desoldering wick

(Bottom left) Use this to wick away excess molten solder.

Desolder pump

(Center left) This pump will suck up molten solder when you have a lot of solder to remove.

Soldering tools

(Center right) The scrapers, brush, and slotted probe come in handy when you need to move solder around or precisely position a component.

Replacement tips

(Right) Tips don’t last forever. When you’ve worn out your tip, use one of these as a replacement.

Project 1: Learn to Solder Skill Badge

Our Learn to Solder Skill Badge Kit (the 2011 model is shown in Figure 0-3) has been used to teach thousands of people of all ages how to solder at Maker Faires across the country. It's a simple, fun way to learn how to solder and also how to teach others to solder. After you build the one included in the box, you can order more from *makershed.com* and teach others how to solder.

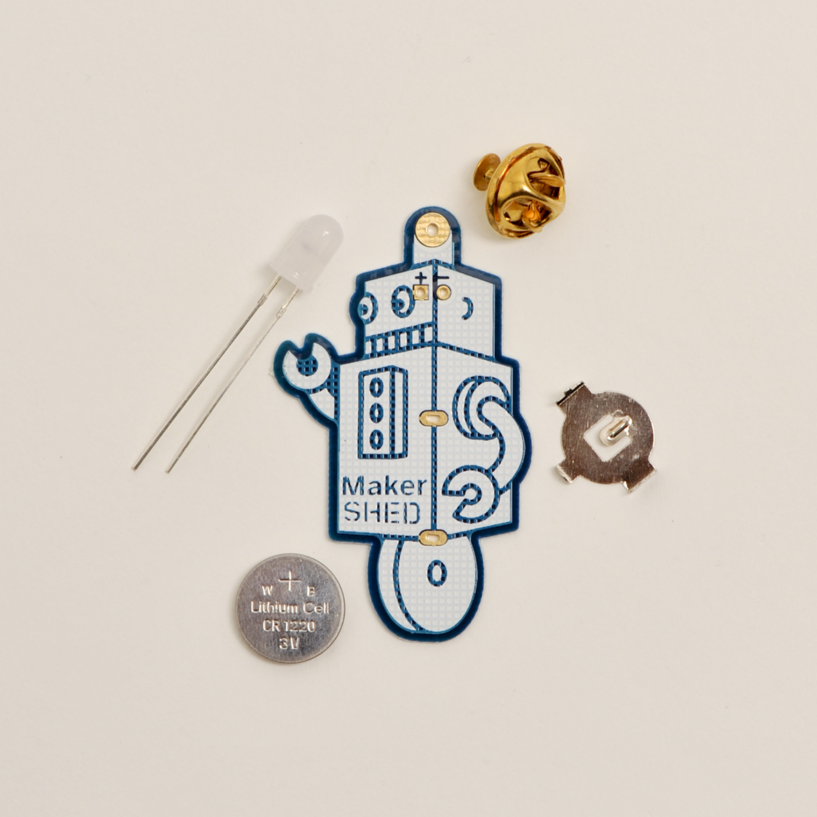

Figure 0-3. *Learn to Solder Skill Badge, 2011 model*

Blinking or Color Change LED

(Top left) This is an LED (Light-Emitting Diode) with a twist. Normal LEDs give off a single color, and keep shining as long as you give them power. Also, normal LEDs require a specific voltage to operate: don't give it enough power, it won't light at all; give it even a little too much, and you could burn it out.

This LED is different in both respects: it has three elements (red, green, and blue) that are under the control of a small integrated circuit (IC) embedded within the LED. The IC causes the elements to change color in a repeating pattern. Because the IC controls the voltage that it delivers to the individual color elements, it's more tolerant of variations in the voltage you give it. For example, even though red LED color elements typically operate at around 2 volts, you're able to use a 3 volt battery with the pin.

The 2012 model uses two self-blinking LEDs instead of one self-color changing RGB LED.

CR1220 battery

(Lower left) This "coin cell" battery supplies power to the pin.

Printed Circuit Board (PCB)

(Center) The 2011 Learn to Solder Skill Badge features a friendly robot. The 2012 model will also have a robot, every bit as friendly.

Pin and clutch

(Top right) This is what holds the pin to your clothing.

Battery holder

This keeps the battery on the PCB.

Project 2: 555 Timer Blinky

The 555 timer blinky is a simple circuit that makes two LEDs flash in an alternating pattern. When one is on, the other is off. Figure 0-4 shows the components for this project, and Figure 0-5 shows the finished project. This is a slightly more challenging project than the skill badge.

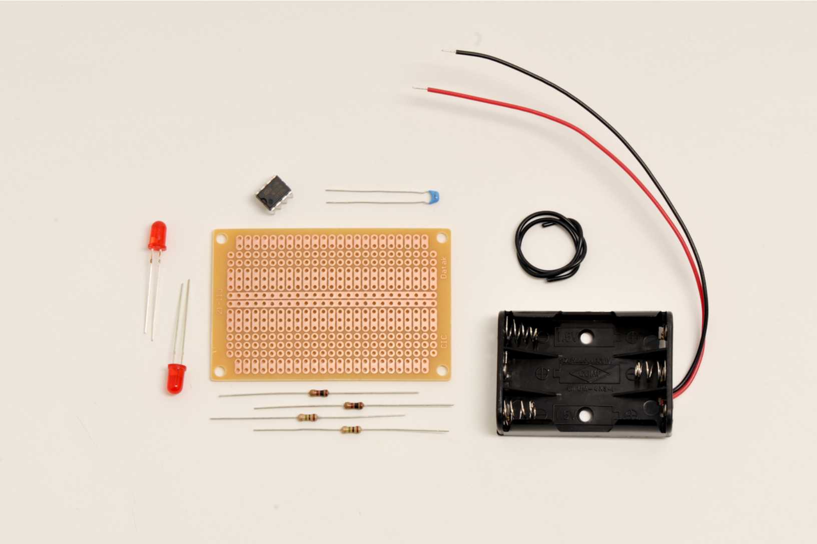

Figure 0-4. *555 blinky parts*

LEDs
: (Left) Unlike the LEDs used in the skill badge, these are your normal, run of the mill LEDs.

Protoboard
: (Center) Look back at the skill badge PCB. Notice how it was custom designed for a single purpose. Now look at this protoboard PCB: it's got a lot of different holes in convenient locations. You can build many kinds of simple electronics projects on a board like this.

555 Timer
: (Top left) The 555 timer is a special type of integrated circuit that can turn electrical current on and off in a repeating pattern. It's just what you need to blink an LED.

Capacitor
: (Top right) To customize the 555 timer, you need to connect certain components to it. The value (capacitance or resistance) of the component determines how quickly the 555 turns things on and off.

Hookup/Jumper Wire
(Top right) You'll need this to connect one thing to another.

Resistors
(Bottom) Resistors serve two purposes here: two are used to make sure the LEDs don't get too much current; the other two work with the capacitor to control the behavior of the 555 timer.

Battery Box
(Right) This holds 3 AAA batteries.

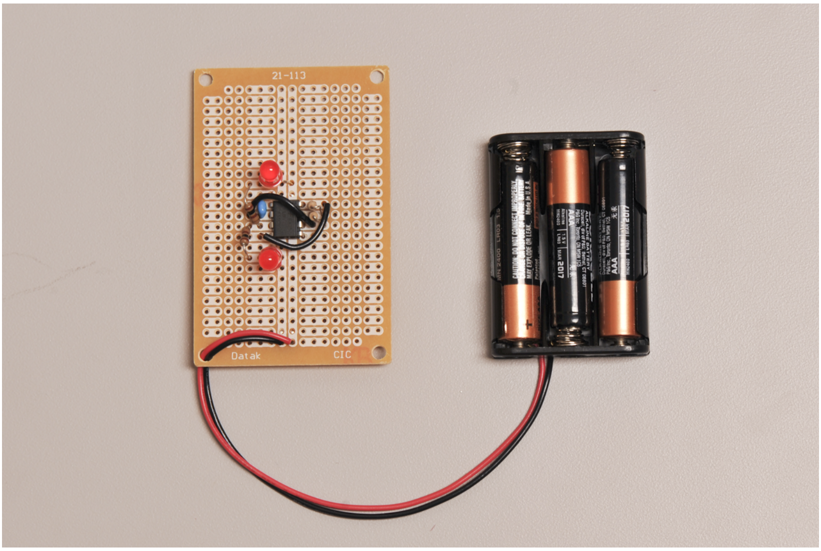

Figure 0-5. *Finished 555 blinky*

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1/Getting the Workspace Ready

Before you can start soldering, you need to get your iron ready. This involves a few steps. First, you’ll have to attach the tip to the soldering iron. Then, you’ll need to prepare the station: make sure your sponge is moistened, set the temperature, and “tin” the tip by applying some solder to it.

At the end of this chapter, your soldering iron will be assembled, clean, and hot enough to begin soldering.

Solder contains harmful chemicals. Wash your hands after soldering as well as after handling solder or the solder station sponge. Though it may be tempting to snack while you’re working, keep any food or drink away from your soldering area.

1: Attach the Tip

Locate the soldering iron (make sure it's unplugged and cool), a soldering iron tip, and the tip nut that holds the tip in place. Insert the tip into the soldering iron as shown in Figure 1-1, and push it in as far as it will go. It will not require much force to insert it.

WARNING: Make sure the soldering iron is unplugged and cool.

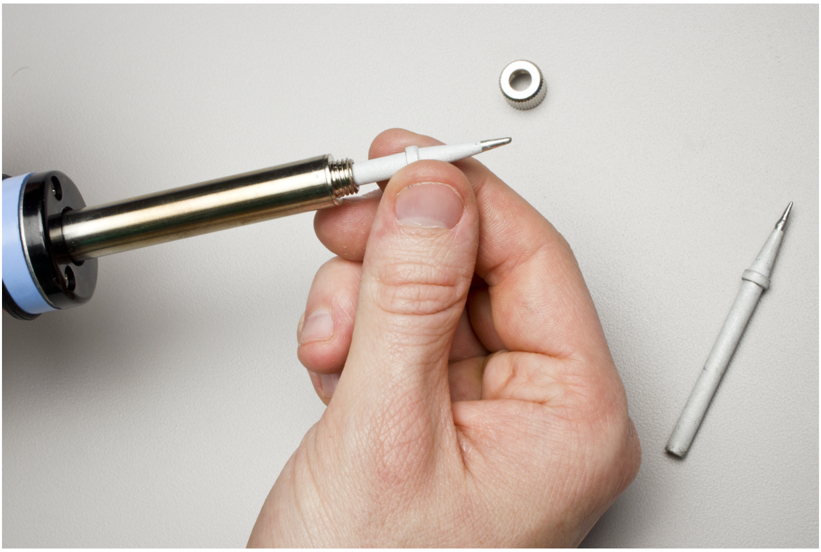

Figure 1-1. *Inserting the tip into the tube*

2: Secure the Tip

Slide the tip nut over the tip, and screw it in place. You can use pliers to tighten it (see Figure 1-2). Be careful not to overtighten it, since you will eventually need to replace it when the tip gets worn from all the projects you'll be making with it.

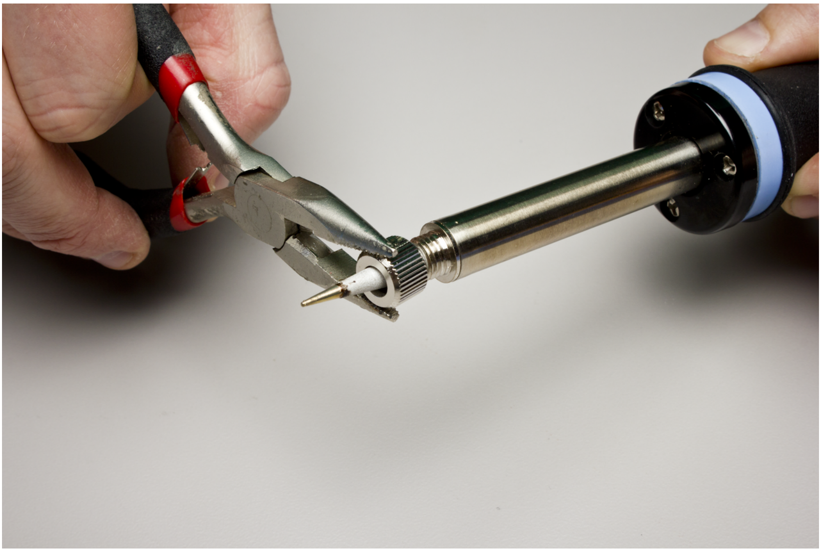

Figure 1-2. *Making sure the tip stays put*

WARNING: Over time, the tip nut might become loose. Let the iron cool down before you tighten it.

3: Wet the Soldering Station Sponge

You'll need to perform this step (and the remaining ones in this chapter) at the beginning of each soldering session.

As you use the soldering iron, you're going to be wiping the tip a lot, so you need to keep the solder station sponge moist. Pour a little clean, fresh water on the sponge as shown in Figure 1-3. Don't soak it, but make sure it's completely moistened.

NOTE: If your water has a high mineral content, use distilled water for wetting the sponge.

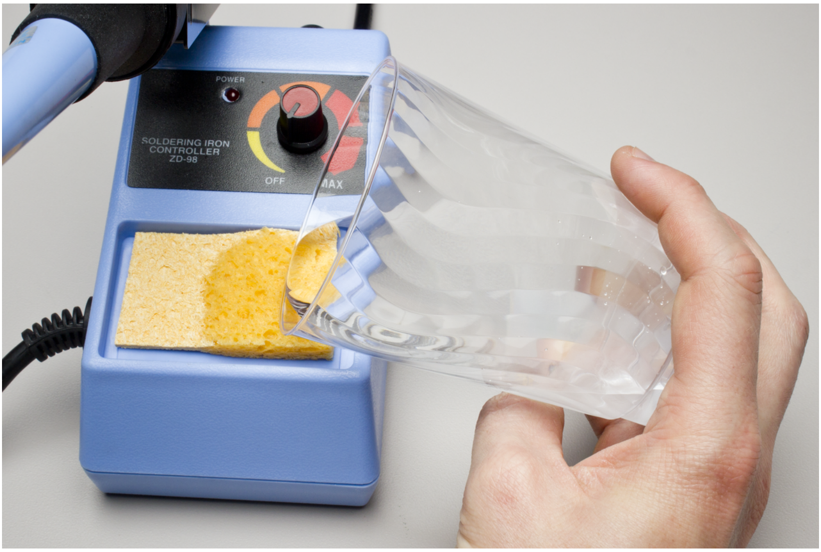

Figure 1-3. *Wetting the sponge*

4: Set the Station's Temperature

Plug your soldering iron in, and set the heat setting to the mark shown in Figure 1-4 (pointing at the 3 o'clock position on the dial). Give the iron a couple minutes to warm up.

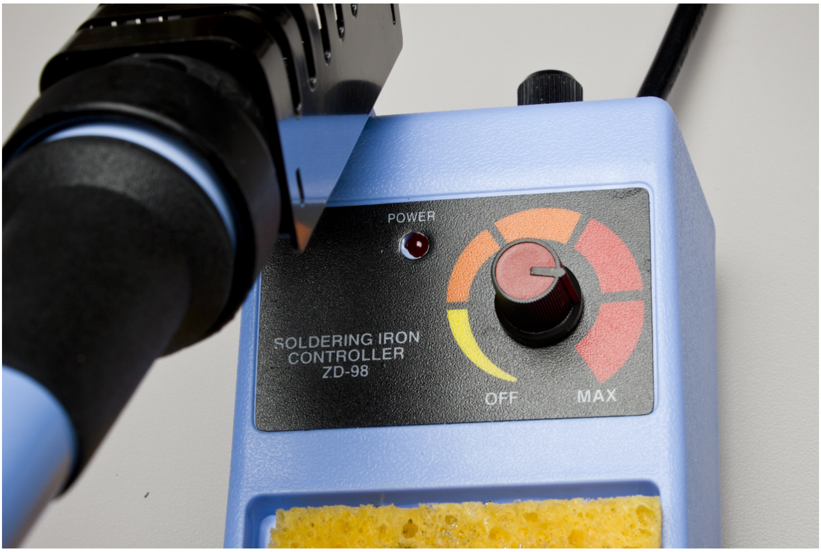
POWER
SOLDERING IRON
CONTROLLER
ZD-98
OFF
MAX

Figure 1-4. *Setting the temperature*

WARNING: The iron will get very hot, and certainly hot enough to burn you. Don't touch the tip and don't touch the tip to anything other than solder or components you are soldering together.

5: Wipe the Iron's Tip

Wipe the tip on the sponge as shown in Figure 1-5, being sure to turn the iron a few times as you wipe it, so you wipe all of its surfaces. It will make a sizzling sound as the water in the sponge comes into contact with the tip. The figure shows a sponge that's been used a few times. Notice the little blobs of solder that have come off the tip over time. A clean tip is critical to successful soldering. Even a small layer of oxidized material or other crud will limit the amount of heat that's transferred to the component you're soldering. Wipe the tip often, and keep the tip clean.

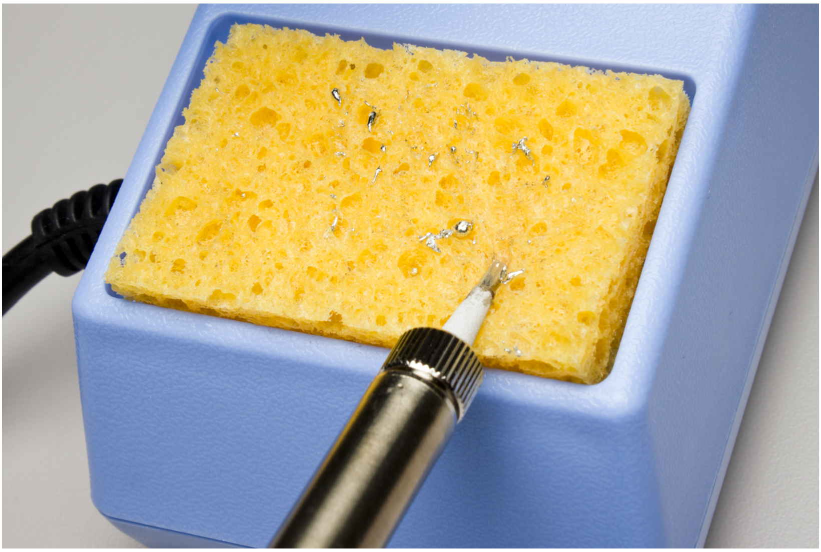

Figure 1-5. *Wiping the tip clean*

6: Tin the Iron's Tip

Before you begin soldering components, you should put a thin layer of solder on the tip as shown in Figure 1-6. This will have two effects: burning off any crud that shouldn't be there, but also providing a thin layer of liquid solder. This layer makes for a very effective heat transfer between the soldering iron and whatever you're soldering. Give the tip one more quick wipe on the iron and place the soldering iron into the holder until you need it.

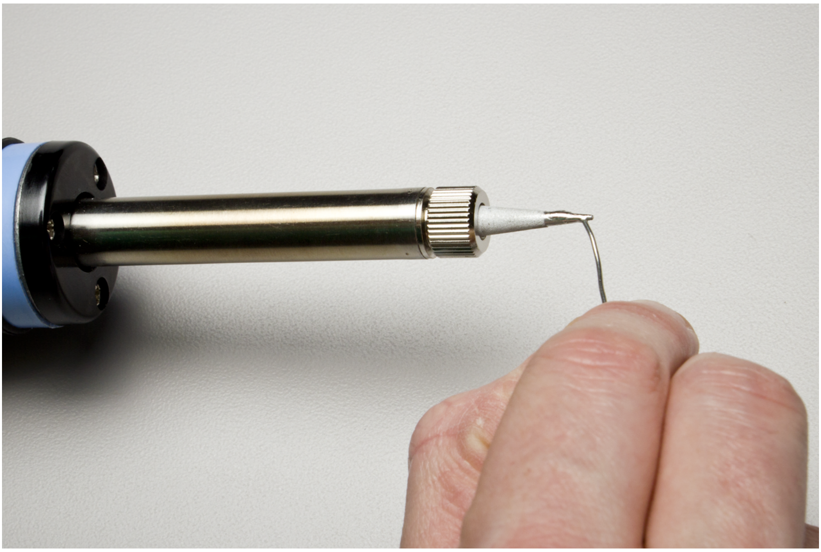

Figure 1-6. *Tinning the soldering iron tip*

NOTE: A small puff of smoke will appear as the *rosin flux* in the center of the solder is activated. The rosin serves two purposes: to clean the soldering iron (and the joint that you are soldering) and to help the solder flow freely. Avoid inhaling this smoke.

Go Make Your Learn to Solder Skill Badge

With your workstation all set up, you're ready to try your hand at soldering. The Learn to Solder Skill Badge ("Project 1: Learn to Solder Skill Badge" on page viii) is a great place to start. It's so simple, we think you can even try it before you read any more. But before you try the second project ("Project 2: 555 Timer Blinky" on page x), you should definitely give the rest of this guide a read.

2/How to Solder

With your soldering iron prepped, you're ready to begin soldering. This chapter has many helpful tips and techniques for soldering effectively, safely, and neatly.

Working with Solder

Solder is made of metal with a core that contains flux, which cleans the connection as you solder. When the metal melts, the flux begins to flow onto the joint. Some solder lead-based, but the solder in this kit is lead-free. To melt solder, heat it with the soldering iron as shown in Figure 2-1.

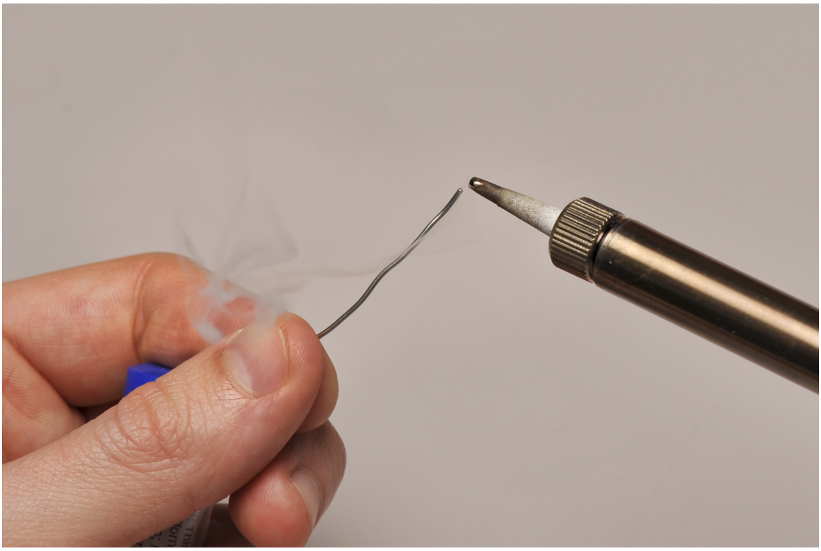

Figure 2-1. *Melting some solder*

Try melting some solder, but be careful not to drip it on yourself or anything other than a work surface. You can try pushing tiny balls of solder around on your work surface to see how it flows. If you have some bare hookup wire or similar metal, try heating it up by holding the soldering iron to it (don't hold the wire while you're heating it). Touch a piece of solder to the wire, but choose a point that's an inch or so from where the soldering iron is touching. How close do you have to get to the soldering iron tip before it melts?

Keeping the Circuit Board from Moving

When you're soldering, you've got a lot to juggle: the soldering iron, the solder, and the two things you are connecting to each other. The helping hands let you place the items you're soldering in a stable position. Use the clips to hold the item in place as shown in Figure 2-2. But once you start inserting items into the board, you need some way to keep them from moving. "Placing a Component in the Board" on page 11 shows you how to do that.

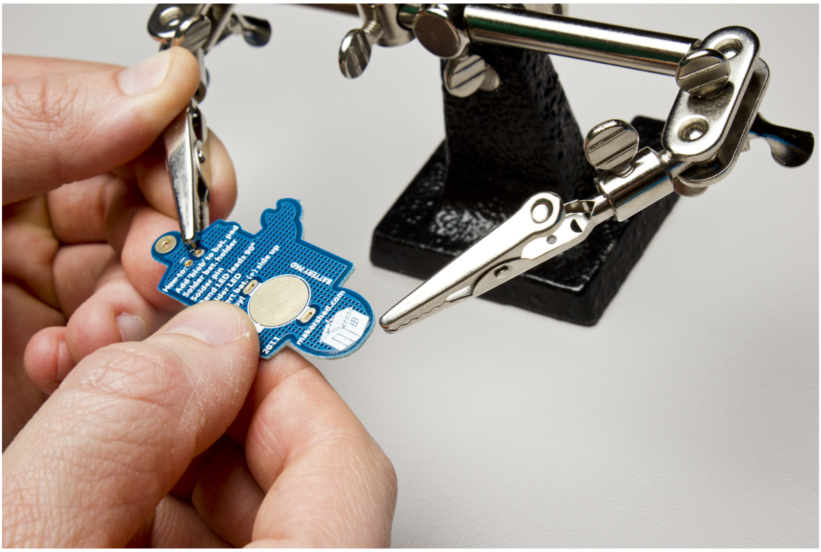

Figure 2-2. *Holding a PCB in the helping hands*

Tinning Solder Pads

You'll sometimes come across things that need a layer of solder to work right. For example, on the Learn to Solder Skill Badge, you need to put a bump of solder in place to give the battery a snug fit. With solder pads that are this big, you need to heat the pad with the iron really well; the pad is so large that it's going to take longer to heat. It's best if you melt the solder by pushing it onto the pad rather than pushing it directly against the iron. This makes sure that the solder flows thoroughly over the pad. If the solder doesn't melt, try tinning the tip again first.

Start with a little blob as shown in Figure 2-3, and spread it around evenly. When you've got the desired thickness, first pull the solder away, then pull the soldering iron away. Doing it in this order will avoid leaving chunks of solder behind.

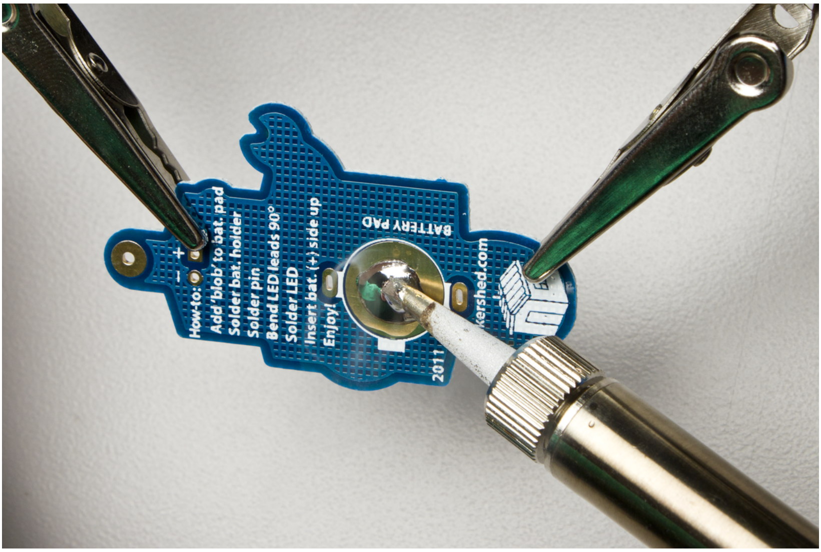
How-to:
Add blob to bat. pad
Solder bat. holder
Solder pin
Bend LED leads 90°
Solder LED
Insert bat. (+) side up
Enjoy!
BATTERY PAD
2011

Figure 2-3. *Laying down some solder*

Placing a Component in the Board

You don't want components falling out of the board while you're soldering. In fact, you'll often insert a component with the board upside down (see Figure 2-4), then flip the board over when you put it in the helping hands. So the components have plenty of opportunity to fall out. To keep the component in place, bend the leads out as shown in Figure 2-5.

In some cases, you may need to quickly tack a component in place to keep it from moving. See "Stabilizing and Straightening Components" on page 14.

Don't try to place every component at once. Start with low-profile (shorter) components, solder them in one at a time, and move on to higher-profile components.

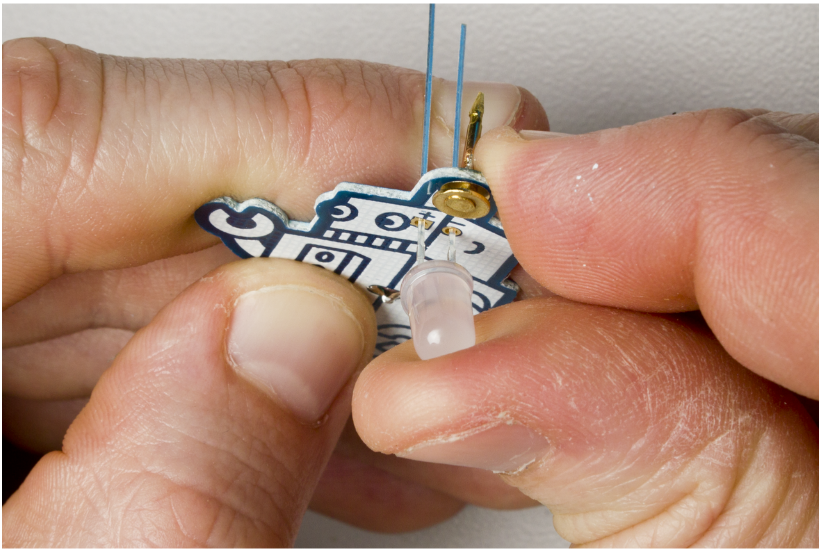

Figure 2-4. *Inserting an LED*

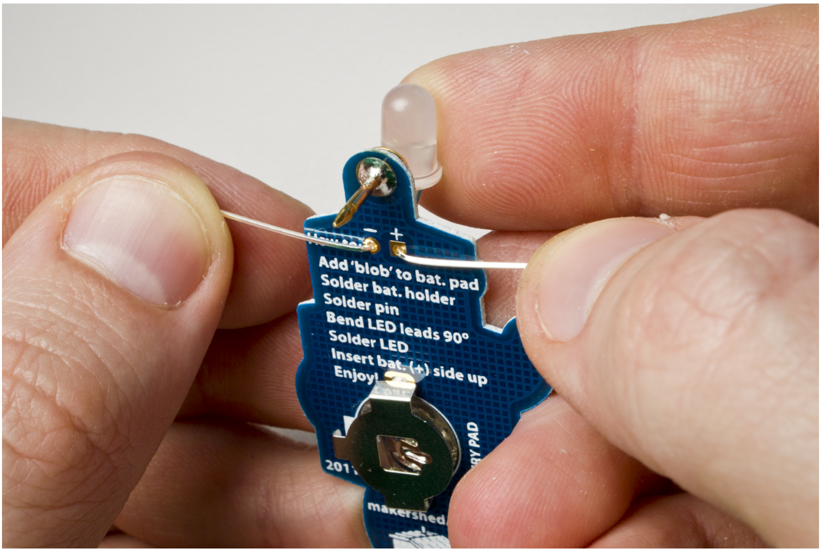
− +
Add 'blob' to bat. pad
Solder bat. holder
Solder pin
Bend LED leads 90°
Solder LED
Insert bat. (+) side up
Enjoy!
makershed

Figure 2-5. *Bending out the leads*

Knowing Which Way a Component Goes In

Some components don't care which way you put them in: resistors, some capacitors (such as the one that comes with this kit), and many other components fall into that category. On the other hand, LEDs are *polarized*; electrical current will only flow through them in one direction. So if you put your LED in backwards, it won't light up at all. You can determine an LED's polarity in a couple of ways: First, the longer of the two leads is the positive (+), and the shorter is negative (-).

Second, look closely at the bottom of the LED and examine the ring that bulges out around it. There is a flattened part of that ring that indicates the side of the LED that's negative (-). You can see this flattened side on the right in Figure 2-6.

With ICs, this also matters. Every pin has a specific function, and there will be one or more pins for positive (+) and one or more pins for negative (-).

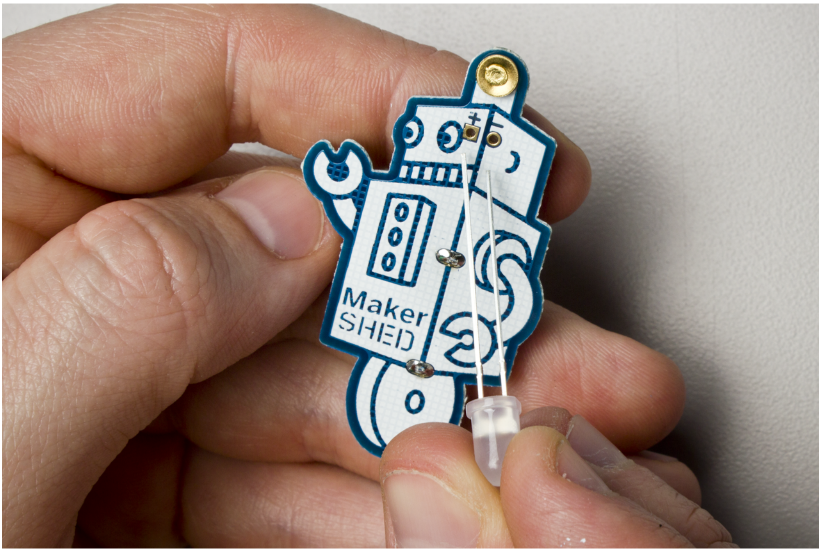

Figure 2-6. *Polarity—LEDs have it*

Stabilizing and Straightening Components

ICs present a unique problem. They don't have long enough leads for you to bend out effectively, which means they are more likely to slip and slide while you're soldering them. So do the best you can with that (see Figure 2-7), but flip the board back over after you solder the first joint. In most cases, you'll find that the IC has shifted. But since you only have one joint soldered, you can easily move the IC into the position you want. Once you've done this, flip the board over and solder the remaining connections.

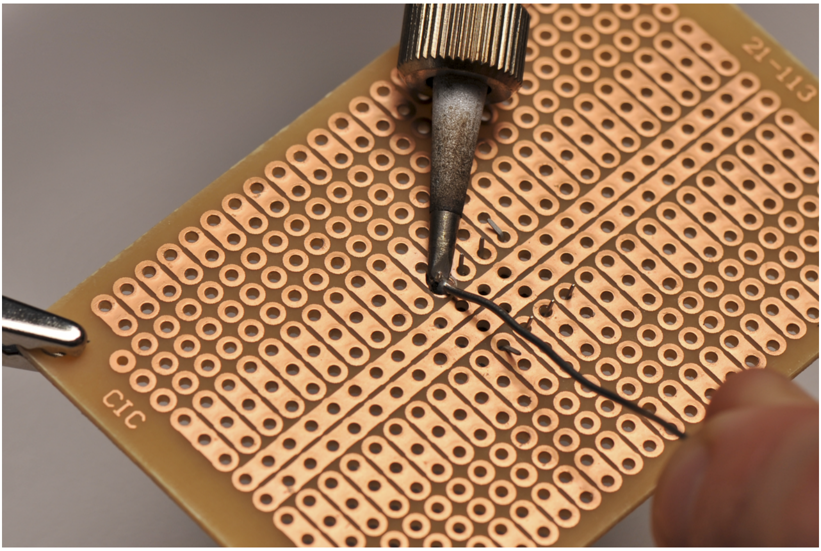

Figure 2-7. *Tacking down an IC*

Safely Soldering Sensitive Components

You need to avoid applying too much heat to a component, or you might damage it. One way to help avoid this is to clamp the heatsink to the component as shown in Figure 2-8. This will draw heat away from the component, protecting it somewhat.

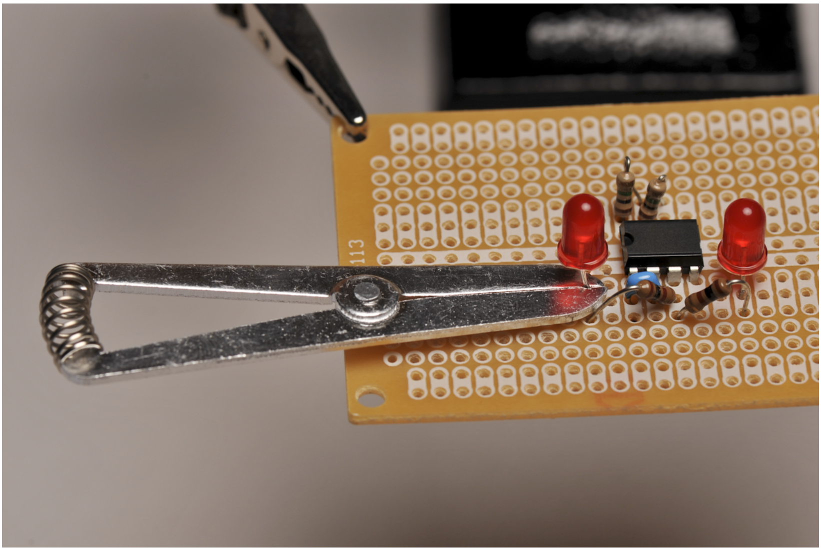

Figure 2-8. *Keeping heat away from the component*

Soldering a Component in Place

Wipe the soldering iron on the sponge and hold it so it's touching both the solder pad and the lead that protrudes through. Avoid using the soldering iron to melt the solder. Instead, heat up both the lead and the pad so that the solder melts when you touch it to them.

This must all be done quickly: within a second of touching the iron to the joint, push a small amount of solder into the joint, and let it flow around the joint as shown. Give it a second to flow, take the solder away, then wait a second, and take the iron away. With practice, you should be able to do all of this in three to four seconds per joint. Figure 2-9 shows how you'd solder the pin to the skill badge. Figure 2-10 shows an LED being soldered.

If you hold the iron to the component too long, you run the risk of damaging either the component or the solder trace on the PCB.

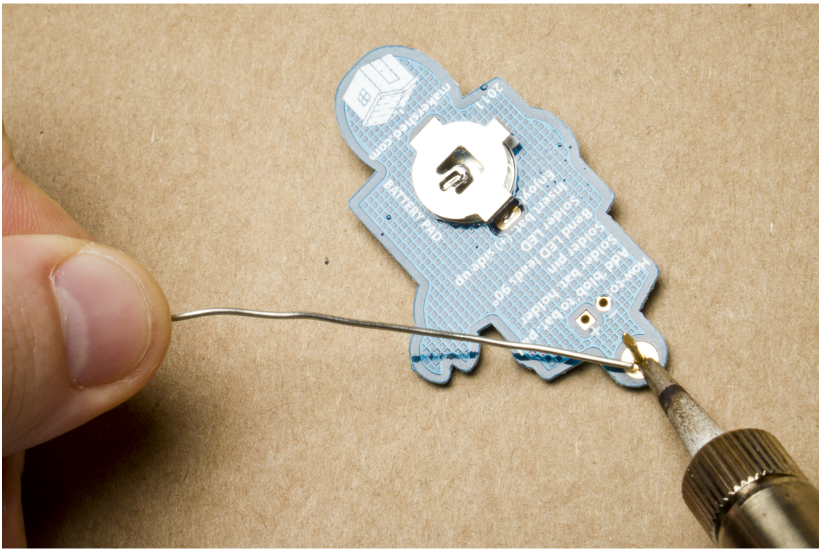

Figure 2-9. *Soldering a pin*

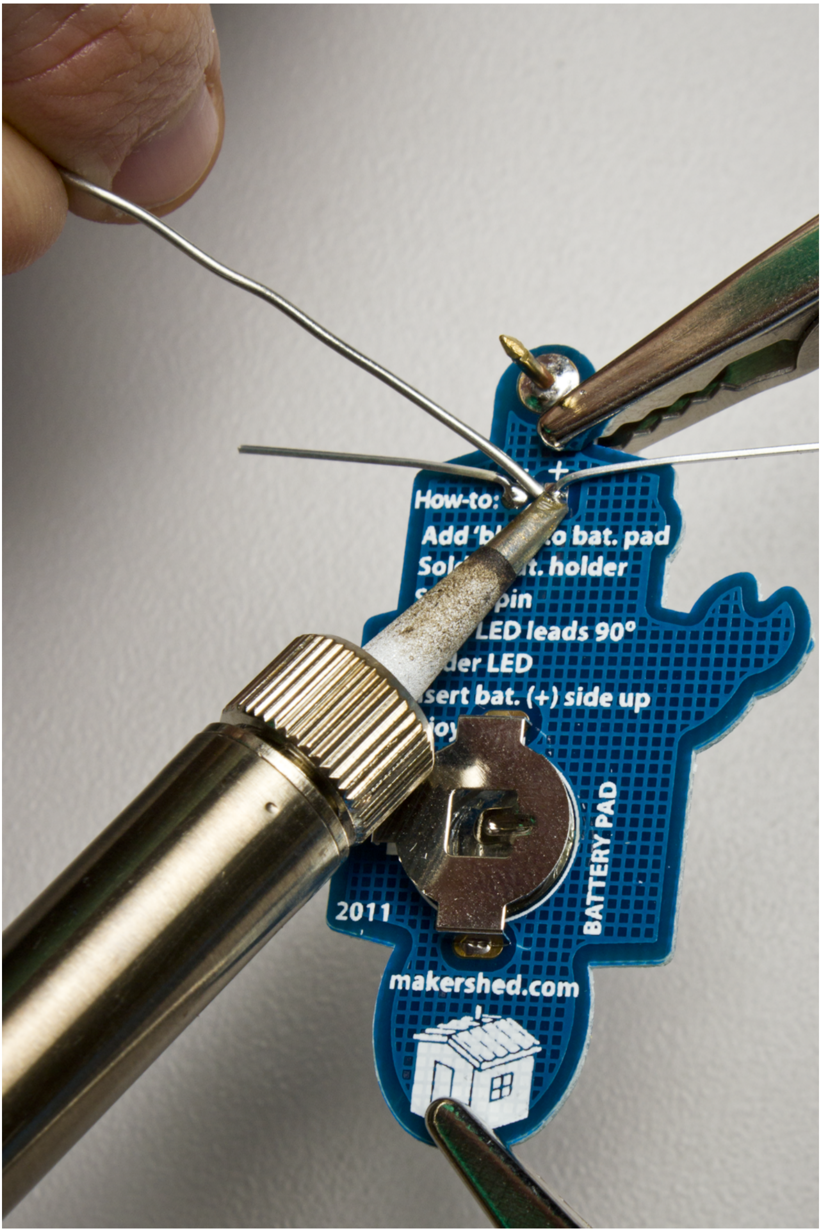
+
How-to:
Add 'b o bat. pad
Sol t. holder
pin
LED leads 90°
der LED
sert bat. (+) side up
BATTERY PAD
2011
makershed.com

Figure 2-10. *Soldering an LED*

Trimming Your Leads

After you solder a component in place, you need to tidy things up. Grab the cutters from your kit, and trim the leads as close to the solder joint as possible (see Figure 2-11 and Figure 2-12). Don't cut into the solder joint; the idea is to trim the excess wire lead.

When you clip it, the wire lead will fly away from the clippers very fast, and could injure someone. The best way to keep this from happening is to use one or two fingers to hold the lead you're clipping. With one finger, you can put enough pressure on it to keep it from flying away.

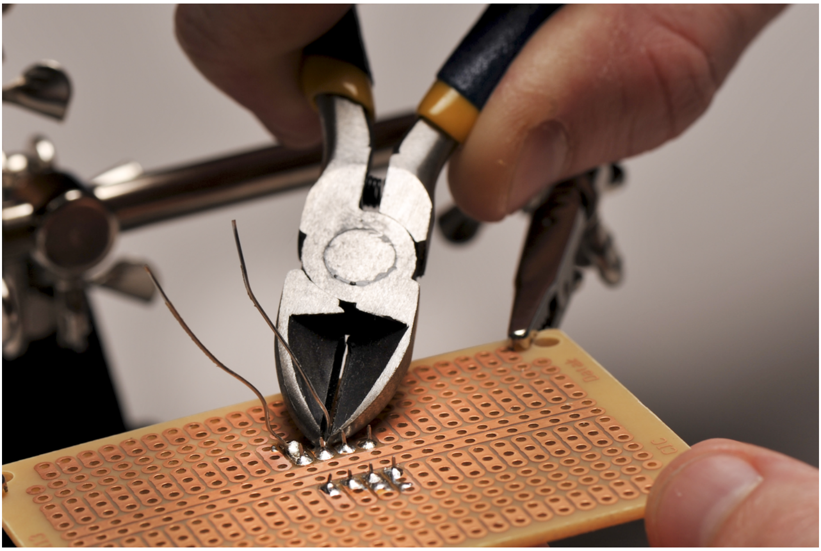

Figure 2-11. *Trimming leads on the 555 blinky*

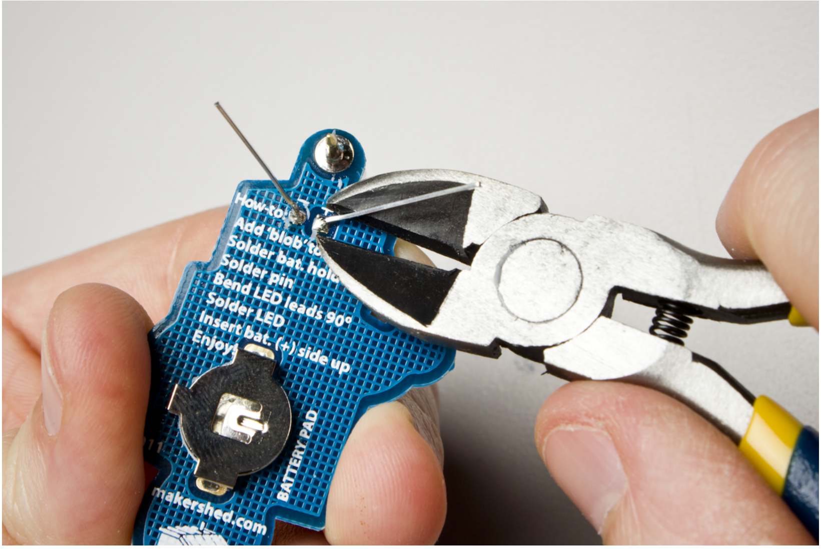
How-to:
Add 'blob' to
Solder bat. hold
Solder pin
Bend LED leads 90°
Solder LED
Insert bat. (+) side up
Enjoy!
BATTERY PAD
makershed.com

Figure 2-12. *Trimming leads on the Learn to Solder Skill Badge*

Going From Solderless Breadboard to PCB

The beauty of protoboard is that it mirrors the layout of a solderless breadboard, which is used for prototyping electronic circuits. Once you have your project laid out and working on a breadboard, you can easily transfer it to the protoboard. As with a solderless breadboard, the protoboard has rows and columns that are tied together. The layout is slightly different, though. Where the breadboard has two rails (one for positive, one for negative) on both the top and bottom as shown in Figure 2-13, the protoboard that comes with this kit has its rails in the center of the board.

Figure 2-14 shows the project from Figure 2-13, but laid out on a protoboard instead of the solderless breadboard.

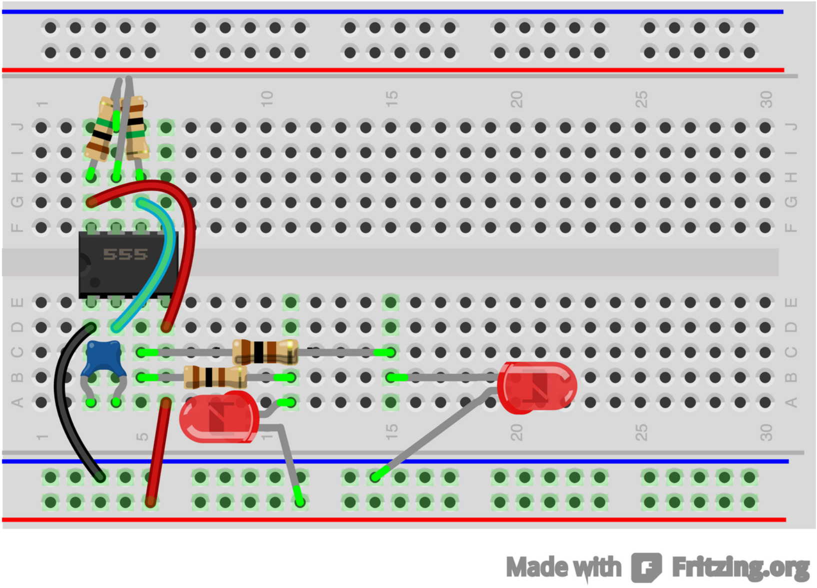

Figure 2-13. *The 555 blinky project on a breadboard*

NOTE: The breadboard diagram in Figure 2-13 was made with Fritzing, an open-source initiative to support designers, artists, researchers and hobbyists to work creatively with interactive electronics. For more information, see *http://fritzing.org/*.

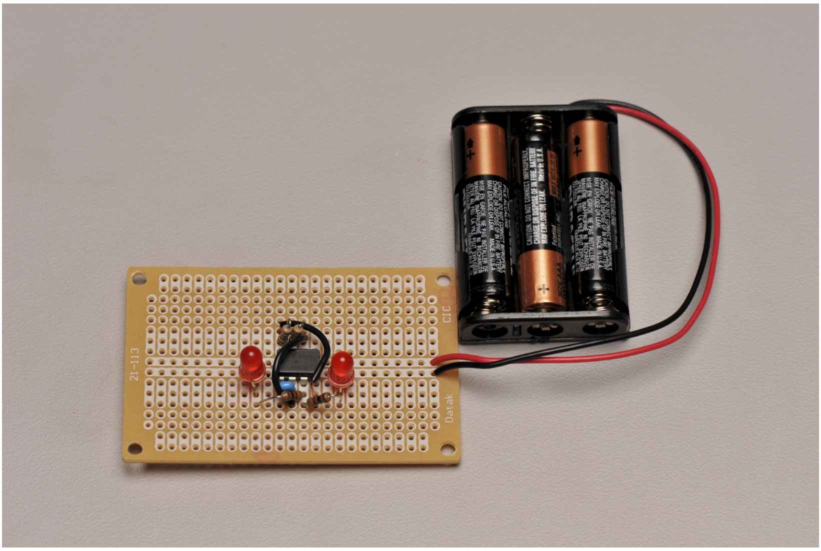

Figure 2-14. *The 555 blinky project on a protoboard*

Soldering Jumper Wire

Jumper wire can be treated a lot like other components (see "Placing a Component in the Board" on page 11): make sure there's enough bare wire poking through so you can bend it outward enough to hold it in place. The notched probe included with this kit can be helpful with placing jumper wire in the right place (see Figure 2-15).

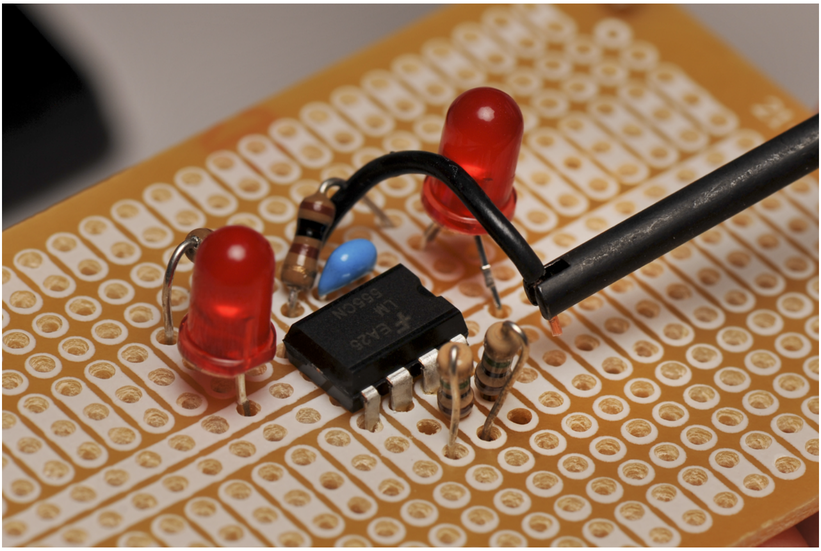

Figure 2-15. *Placing the jumper wire*

Bridging Joints with Solder

When you're working with the protoboard, you will sometimes need to bridge joints that are close to each other. This is preferable to using jumper wire since your board remains uncluttered on the top. It doesn't always look great on the bottom, though, because you end up with a lot of solder in some places. Figure 2-16 shows the start of a bridge: feeding the solder into the gap between solder joints. Figure 2-17 shows a bridge being formed.

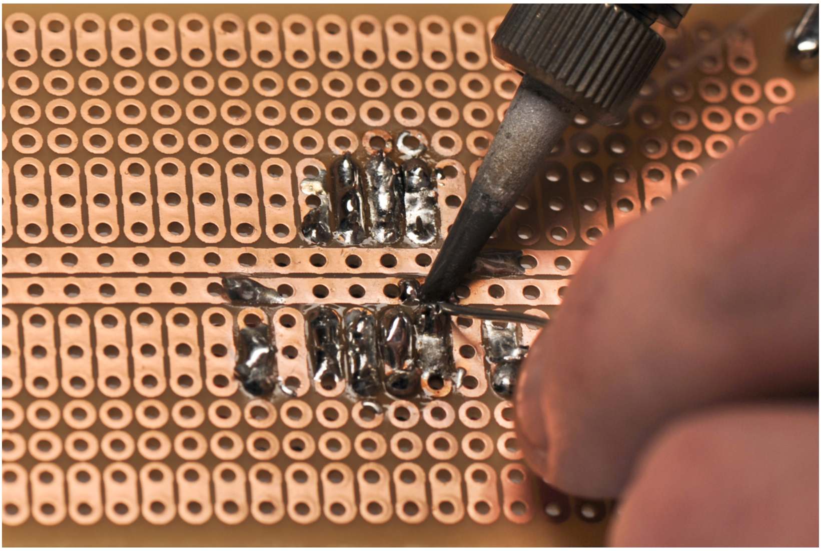

Figure 2-16. *Feeding solder into a gap*

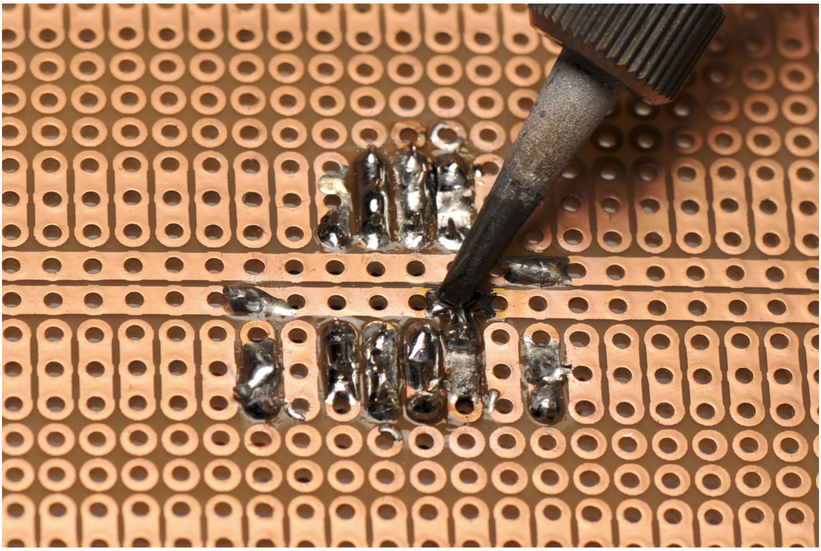

Figure 2-17. *Forming a bridge across the gap*

Relieving Strain on Cables

If you have something heavy dangling off your board, such as a battery box, it's very likely that the solder joints will come undone. If you pass the wires through the large holes on the board before soldering them down (Figure 2-18), you can add some strain relief (Figure 2-19) that will help prevent this from happening. If you have a small drill, you can also drill out a couple of holes close to where you are going to solder the connection, and loop the wire through there. This will be even more rugged than using the larger holes.

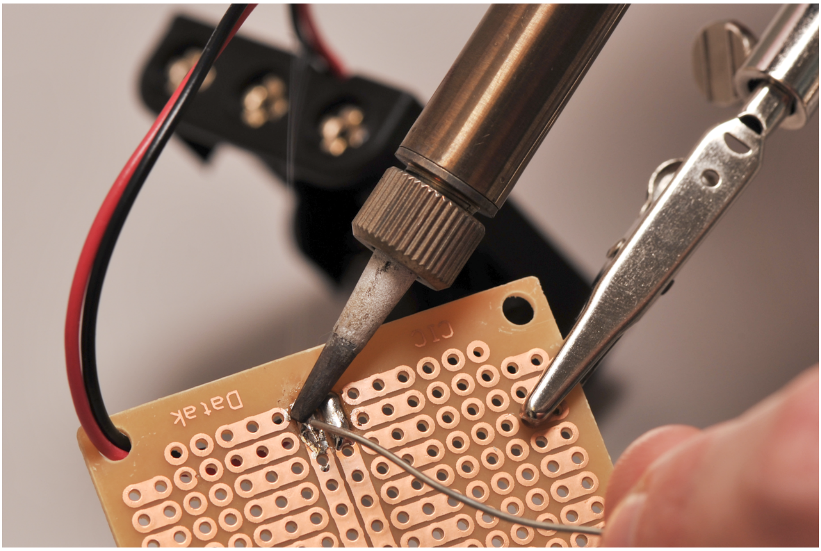

Figure 2-18. *Soldering the battery holder wires*

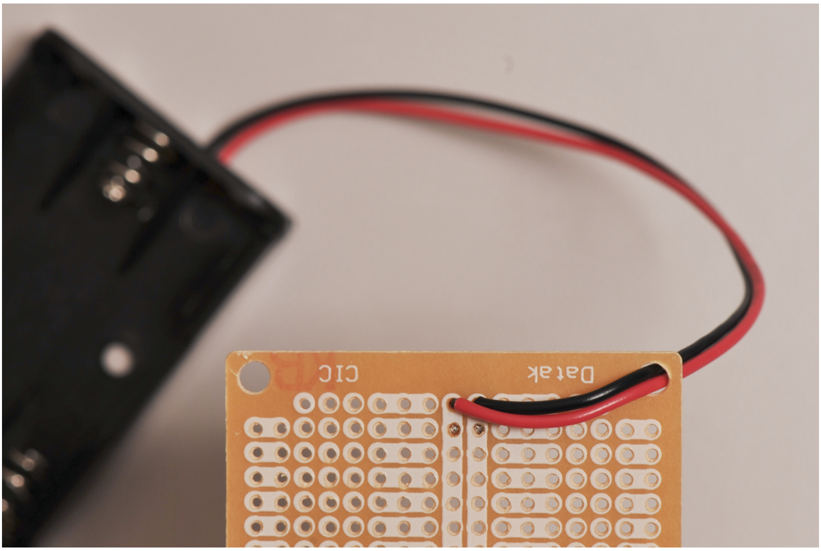

Figure 2-19. *Strain relief*

Getting the Perfect Solder Joint

It's not hard to get a great solder joint, but it's also easy to be sloppy. Here are some pictures of good and bad joints to help you out.

Figure 2-20

Here's a good solder joint on the positive (+) pad: solder surrounds the joint and makes a little peak. This joint had just the right amount of solder and just the right amount of heat.

Figure 2-21

The joint on the negative (-) pad is sloppy. The solder didn't flow around the joint, and some of it is spread out across the lead. You can try to fix it by holding the iron to the joint for a couple seconds; the solder should flow down the lead and onto the joint.

Figure 2-22

The joint on the positive (+) pad has too much solder, and it's balled up. You can use the desoldering wick or solder sucker to remove the excess. After you do that, hold the iron to the joint for a couple seconds to get the solder to flow around it.

Figure 2-23

Here are two joints for comparison: one good, one blobby.

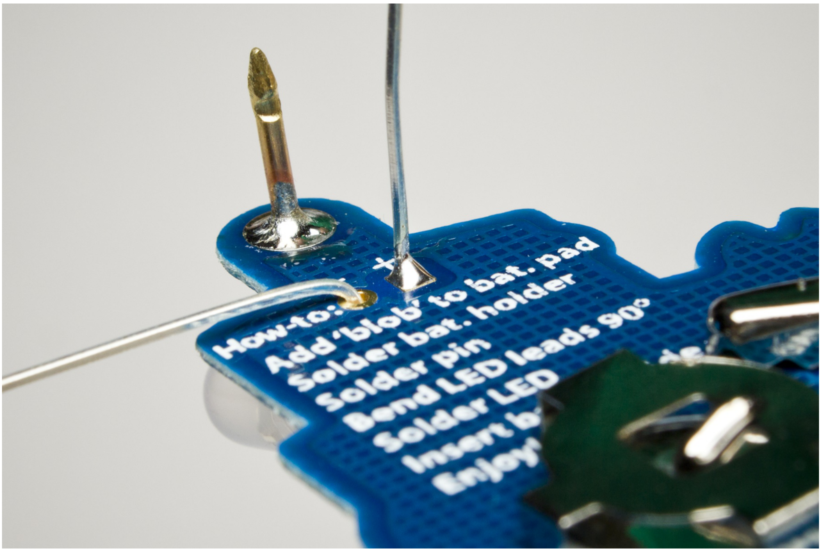
How-to:
Add 'blob' to bat. pad
Solder bat. holder
Solder pin
Bend LED leads 90°
Solder LED
Enjoy

Figure 2-20. *A good solder joint*

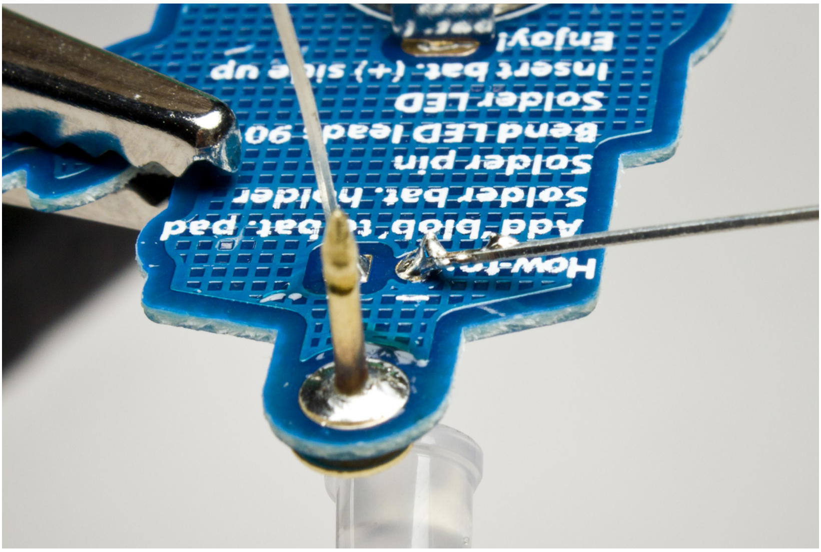
How-to:
Add 'blob' to bat. pad
Solder bat. holder
Solder pin
Bend LED leads 90
Solder LED
Insert bat: (+) side up
Enjoy!

Figure 2-21. *A messy solder joint*

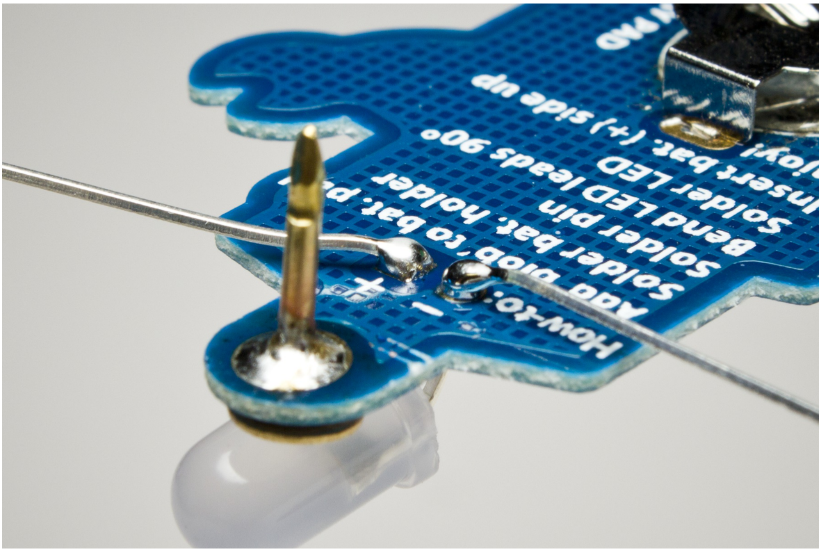

Figure 2-22. *A blobby solder joint*

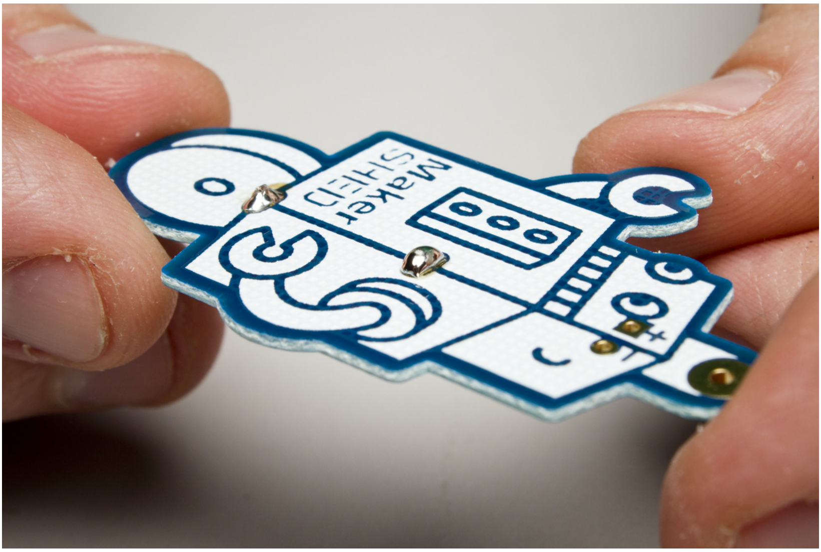

Figure 2-23. *Comparing two joints*

3/Desoldering

If everything went right the first time, you'd never learn anything. This section shows you how to recover from little soldering mistakes, and also includes a gallery of various solder joints so you can compare your work.

Desoldering is the "undo" command for soldering. With this technique, you can remove solder from a joint, allowing you to free the component so you can reorient it as needed. There are two tools for this: the *desoldering wick* (sometimes called *desoldering braid*) and the *solder sucker*.

The Desoldering Wick

Pull a small length of wick out of its spool (Figure 3-1). You don't need much, but if you don't use it all, you can wind the wick back into its spool.

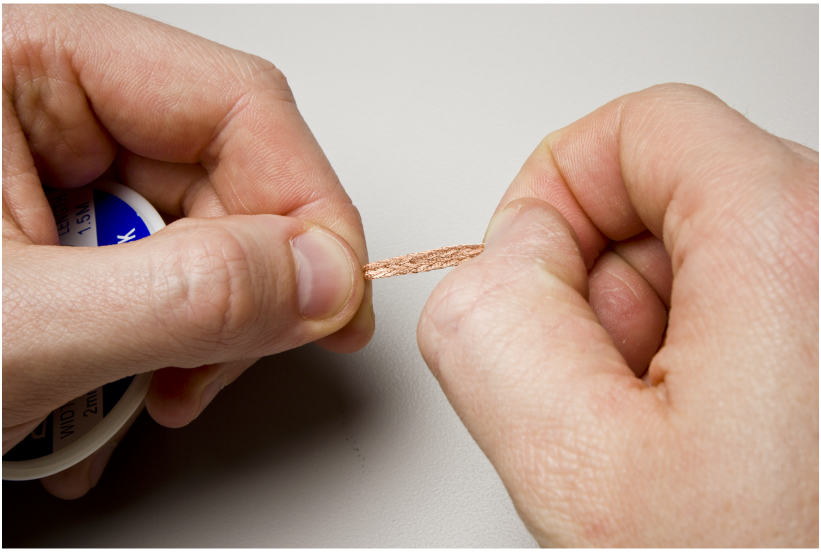

Figure 3-1. *Pulling out some wick*

Preparing the Wick

Before you use the wick, hold it as shown in Figure 3-2, and push inward. This will cause the wick to spread out, giving you more surface area to work with.

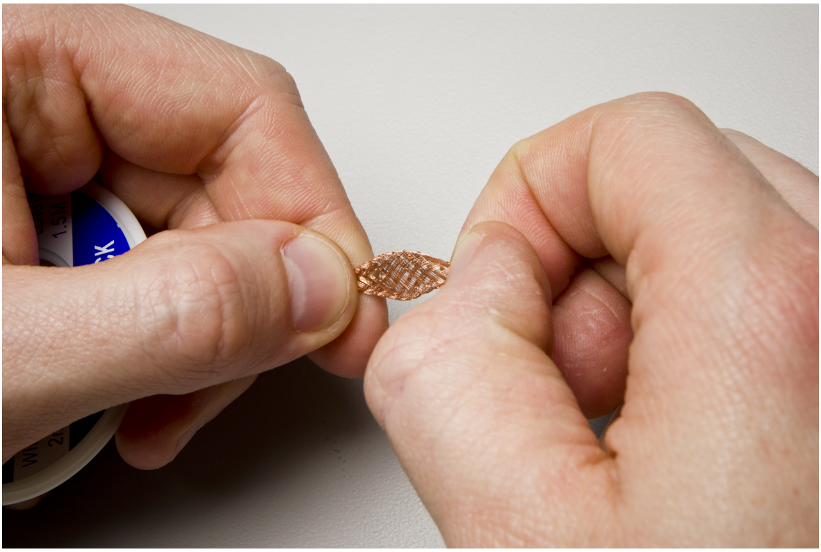

Figure 3-2. *Spreading the wick*

Desoldering with the Wick

Position the wick over the joint, and press down on the wick with the soldering iron as shown in Figure 3-3. The heat will pass through the wick and melt the solder. As this happens, the wick will soak up the solder, removing it from the joint. When you're done, you can trim off the used portion of wick with your wire snips.

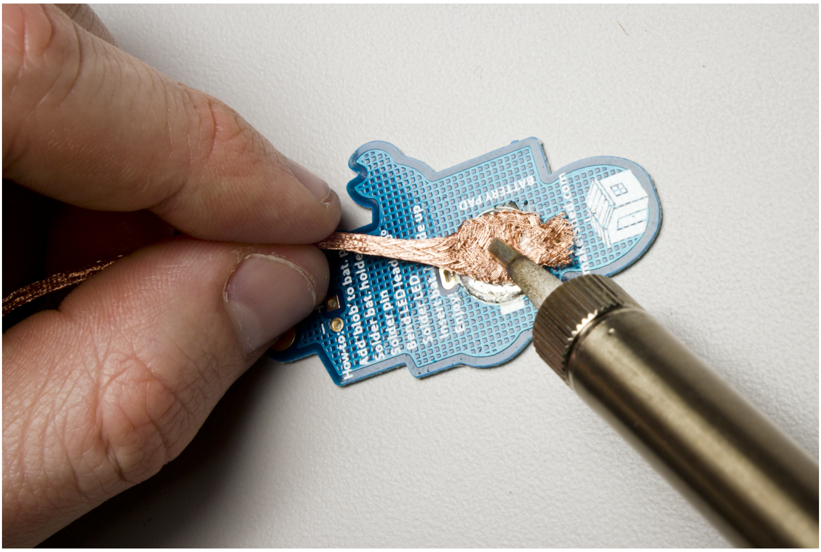

Figure 3-3. *Desoldering*

WARNING: The wick will get very hot, so take your hands off it as soon as you press the soldering iron to it (the soldering iron will hold it in place).

Desoldering with the Solder Sucker

The solder sucker is another tool for removing solder. It's best for removing excess solder, and you can use it to clean things up a bit before you use the wick. To use the solder sucker, press the plunger down until it locks. Use the soldering iron to melt the solder around the joint, and quickly bring the solder sucker's nozzle to the joint (Figure 3-4). Press the button on the sucker, and it will pull the solder right up into the tube. When you press the plunger again, any solder in the tube will be ejected.

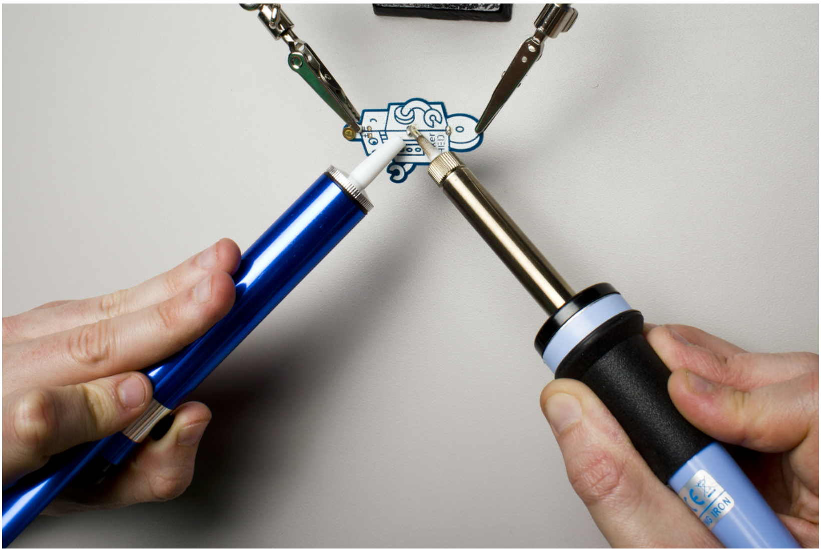

Figure 3-4. *Using the solder sucker*

4/What's Next?

Now that you've learned the ins and outs of soldering, it's time to do more. You can share this book with a friend so they can learn, or you can teach them yourself. And the world is full of wonderful things you can make now that you know how to solder.

Teach the World to Solder

Before you can teach someone to solder, you need to figure out what you want them to try making. You can purchase more Learn to Solder Skill Badge Kits from *http://makershed.com*. Here are a few tips for teaching soldering to others:

Keep Your Hands Off the Tools

You're there to teach, not to solder. And your students will learn best if they always have their hands on the tools. If you grab the tools from them and do part of the work, they won't learn from it.

Be Patient

Try to remember what you went through the first time you tried to solder. It takes time, and you did things incorrectly, and maybe you even made mistakes that required desoldering. Let your students learn from their mistakes, and let them take their time.

No Food or Beverages

Even with lead-free solder, there are chemicals in the flux that aren't good for you. If you allow food or drink near the work area, it could get contaminated. Keep food and drink away from where you're working.

Make Sure There's Plenty of Light

The components you work with while you solder are small, and hard to see. Make sure to use a well-lit workspace for teaching.

Keep Spare Parts Around

Beginners will break things. Pick up some spare resistors, LEDs, and other common components, and have them on hand in case you need to replace a damaged component.

Make More Things

Maker Shed (*http://makershed.com*) carries many electronic kits that you can apply your newly-learned soldering skills to. Here's just a few of them:

Supercap Racer Kit

One of the latest in our popular Mintronics line of DIY kits is this tiny race car designed by George Albercook. Once assembled, this little racer (Figure 4-1) will run around getting its juice from a supercapacitor. Capacitors are like little batteries. Supercaps store and release power faster than ordinary ones, so they're great for making quick-charge gadgets and power-on-demand circuits.

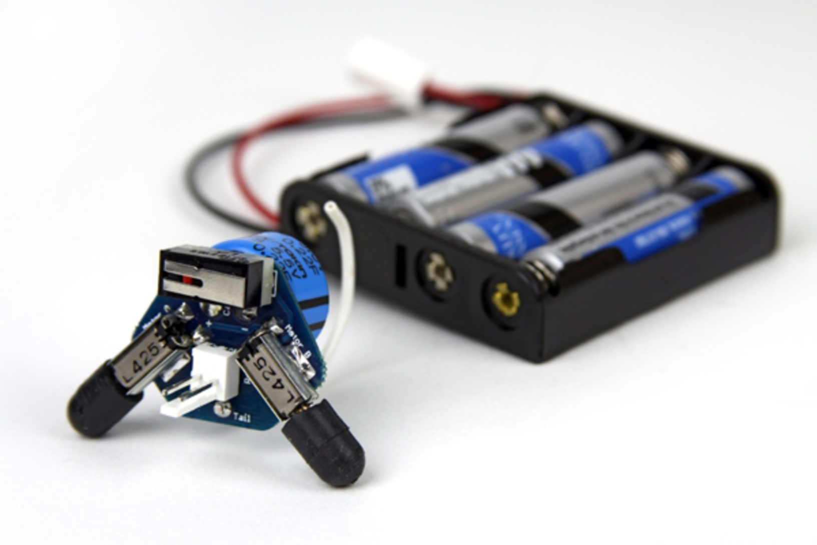

Figure 4-1. *Supercap Racer Kit*

Wee Blinky Kit

The Wee Blinky kit (Figure 4-2) is an easy-to-solder two (2) LED blinker circuit. It comes with a 9V battery snap, but will work with almost any voltage from 3V to 12V. A 9V battery is required but not included. It's tiny, it blinks, and it's a great kit to hone your soldering skills since it's cheap too!

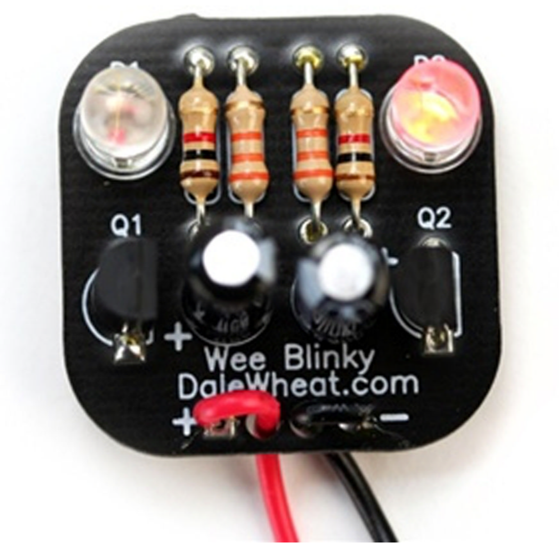

Figure 4-2. *Wee Blinky Kit*

MintyBoost

The MintyBoost (Figure 4-3) is a small and simple USB charger for your iPod or other MP3 player, your camera, cellphone, and any other gadget you can plug into a USB port to charge.

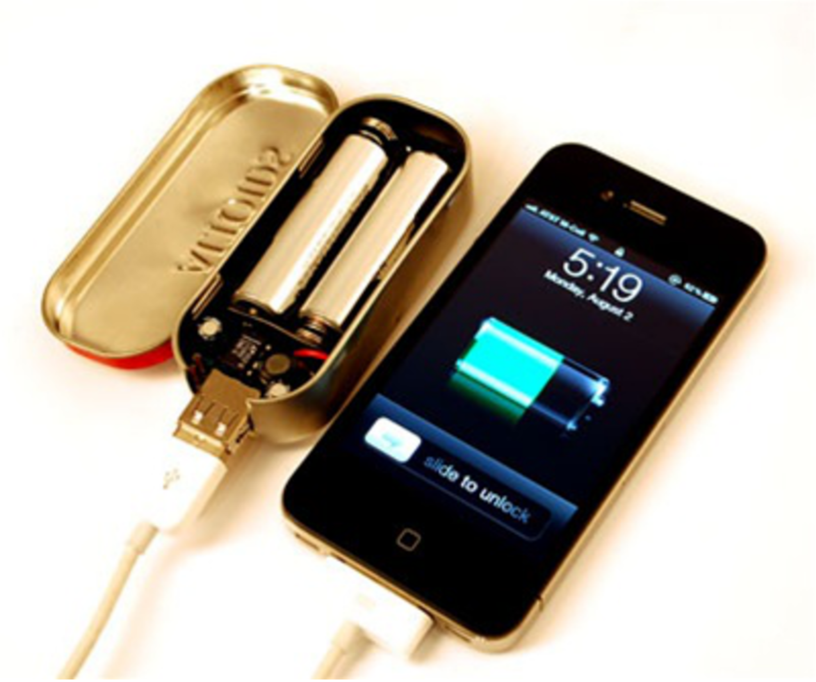

Figure 4-3. *MintyBoost USB Charger Kit*

About the Authors

Brian Jepson is an O'Reilly editor, hacker, and co-organizer of Providence Geeks and the Rhode Island Mini Maker Faire. He's also been involved in various ways over the years with AS220, a non-profit arts center in Providence, Rhode Island. AS220 gives Rhode Island artists uncensored and unjuried forums for their work and also provides galleries, performance space, fabrication facilities, and live/work space.

Tyler Moskowite, a programmer, engineering intern at Make Magazine, and student at Santa Rosa Junior College, has been tinkering with electronics for almost half his life. He picked up Arduino, then Android, and with the release of the ADK he has found his niche.

As a photographer for Make Magazine, Gregory Hayes has ruined more clothes than he ever did as a handyman, hiked more miles with a heavier load than he did as a backpacker, done more research than he did as a writer, and gotten closer to more human hands than advised by any epidemiologist. Taught to solder at the age of seven and forced to solder for his supper at the age of nine, he's now content to let others enjoy the lion's share while he stands by watching safely from behind glass.

How to solder

This pdf refers on informations from the site: http://store.curiousinventor.com/guides/
Have also a look to the 7min. Tutorial video on: http://store.curiousinventor.com/guides/How_to_Solder

Select a Soldering Iron

A 25 or 30 Watt iron should suffice for most small electronics work.

1. Most **soldering "guns" are vastly overpowered for electronics soldering** and can easily overheat components or expose them to harmful voltages. However, some people cleverly use them to solder multiple leads on surface mount devices. Soldering "guns" are for plumbing and much heavier duty applications, and are usually over 100 Watts. The "guns" work by passing high currents through the tips, and these currents can generate voltages that damage electronic components. Also, magnetic fields from guns with transformers can damage some electronics.By forming the heating element in the shape of of the chip, a soldering gun can be used to heat many leads simultaneously.

2. **How much wattage do you need for a particular application and how does wattage relate to tip temperature?**

   A loose analogy: Imagine a car tire has a leak, but you're trying to keep it inflated by pumping air into the tire at the same time it's escaping out the leak. The bigger the leak, the more air you have to pump into it to keep the pressure up. If the tire pressure represents tip temperature and the air lost through the leak represents heat lost through the tip, then wattage represents the maximum amount of air your pump could supply. Once more air escapes through the leak than your pump can replace, the tire pressure (or tip temperature) starts to drop.

   If you had a very small leak and a huge pump (say a 100 Watt iron equivalent), you might be afraid that the pump would cause the tire to explode since so much more air is going in and so little going out. But if you have a nozzle to regulate the pump's air, you could only allow just the right amount of air in to replace what's lost through the leak. This is how "temperature controlled" soldering irons work. As long as you aren't losing more heat out of the tip than the iron can replace (up to its rated wattage), it will automatically regulate just the right amount of heat into the tip to maintain the same temperature.

   However, typical plug-in irons have no such regulation. A 15 Watt iron always delivers 15 Watts of heat to the tip, and the tip temperature stops increasing only when 15 Watts of heat escape through the air. When the tip touches a part, its temperature drops, and if the part you're soldering can dissipate enough heat, the temperature will keep dropping until it won't melt solder any more. After the iron is pulled away from the joint, the temperature will climb again. There is some amount of natural regulation: as the tip gets hotter, it dissipates more heat, and as it gets cooler, it dissipates less.□

   Usually, the bigger the component the more heat it can absorb and dissipate, so the general rule is that you need more wattage for larger parts. If you're just soldering small resistors and ICs, 15 Watts will probably suffice, but you may have to wait a bit in between joints for the tip to recover. If you're soldering larger components, especially ones with heat sinks (like voltage regulators), or doing a lot of soldering, you'll probably want a 25 or 30 Watt iron. For soldering larger things like 10 gauge copper wire, motor casings, or large heat sinks, you may need upwards of a 50 Watt iron or more. The following video shows what happens to tip temperature as 15, 25, and 40 Watt irons solder various sizes of wires and components. For cheap irons, higher wattage does indeed mean higher temperatures!

- What is the difference between cheap RadioShack® irons and more expensive ones like Wellers®? What do $100+ and $400+ soldering "stations" have over the cheaper kinds that plug straight into the wall? expand Among the irons that plug straight into a wall and don't have a separate station, the dirt cheap kinds will work satisfactorily for many applications. From personal experience, the tips on RadioShack® irons often come loose and sometimes can be impossible to remove. The irons can also get uncomfortably hot to hold after several hours of use. The more professional Weller (or other) lines are made for longer, continuous use and have insulation on the handles that keeps them cooler. They

can also take a wider variety of tips.
Soldering iron "stations" usually provide some control over the heat being supplied to the iron tip. Ones that are temperature controlled automatically control the amount of heat delivered to the tip so that it remains at a set temperature. In every iron, when the tip touches a component, some heat is lost and the temperature drops. One measure of quality is the time needed for the tip to regain its temperature. A nice feature of many soldering stations is that the tip heats up in seconds after you turn it on.
Many stations also allow you to hot-swap the iron tip, which can be very helpful if you're alternating between surface mount joints and larger components.

- If standard tin-lead solder melts below 400 °F (and lead free below 500 °F), why do most soldering irons have tip temperatures between 600 and 800 °F? Just what is the right **soldering temperature**?
  expand The basic reason that tips are so much hotter than solder's melting point is because that difference helps to transfer heat faster to the joint. What is the "correct" temperature is a debatable topic, but a common rule of thumb is to start off at 600 °F and increase from there until acceptable results are achieved. Typical Kester (a solder manufacturer) datasheets recommend 600-700 °F for lead-based solder, and 700-800 °F for lead-free solder. "No-clean" or "low solids" fluxes will burn off before a joint can be made with higher temperatures, so low temperatures (below 700) may be essential for these fluxes.
  From Kester's hand-soldering knowledge base: "When hand soldering with a rosin flux such as the Kester #44 or the # 285 the recommended iron tip temperature is 750°F. If you are soldering with a low residue no clean solder such as the #245or # 275 we recommend a tip temperature of 600-650°F.
  What are acceptable results? The goal is to heat up the parts enough so that solder will adhere to them and form a good bond. The higher the iron temperature, the faster it will heat up the parts, so why not set it extremely high to work faster?
  Besides the obvious increased risk of overheating components and the board, higher temperatures cause the iron tip to oxidize faster and can significantly reduce its life. Some claim a 10 °C rise reduces tip life by half (ref p.33). For occasional use, though, tip life may not be much of a factor, especially if the tip is kept covered with solder at all times.

- **Tip size and shape:** a basic guide is to pick a tip that's slightly smaller than the pad you're soldering to. From there, you want a tip with a large thermal mass and short stroke (why?) In most soldering irons, the tip is not actually the heater, but sits in between your work and the heater. You can think of it like a heat bucket that empties into your work and gets filled again by the heater. Typically touching a component empties heat out of the tip much faster than the iron can replace it, and if you have a small bucket (tip), the temperature will quickly drop to an ineffective level.
  Especially if you have a small wattage iron (15 Watts or less), the temperature will drop before you can heat up a larger part, or you'll have to wait a bit in between joints for the tip temperature to recover. With a bigger bucket (tip), you can handle larger joints with smaller wattage, but eventually you'll need to step up the wattage.
  The "stroke", or length of the tip should be minimized to get the heater closer to the work; it takes some time for heat to transfer through the tip. This is balanced with the need to get into tight places where you need a longer tip.
- What do common tip shapes look like and what applications are they best for?

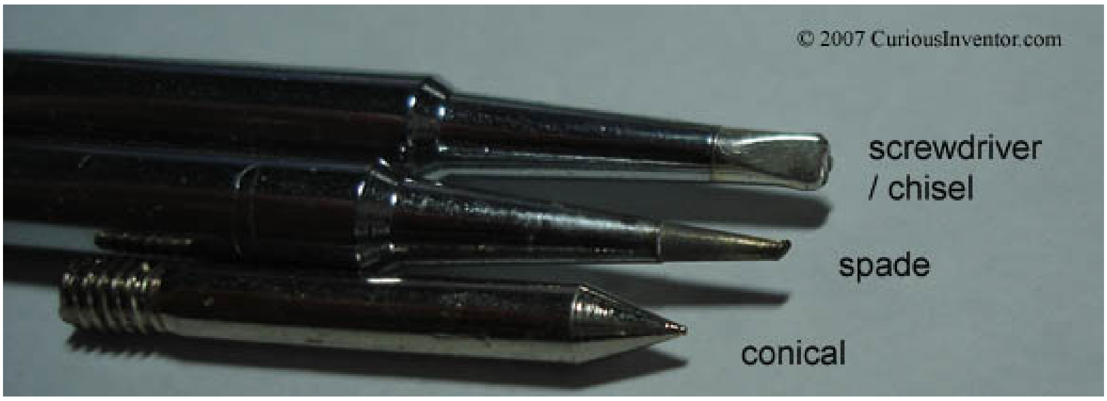

Screwdriver, spade, and conical are some of the more common tip shapes. Personal preference is the biggest factor when choosing a tip, but the goal is to get as much surface area contact between the tip and work as possible. Chisel and spade tips have more surface area at their ends, and also "hold" solder at their tips more readily than conical tips, which have a tendency to draw solder away. Even for fine pitch surface mount soldering, having a small flat at the end can be helpful.

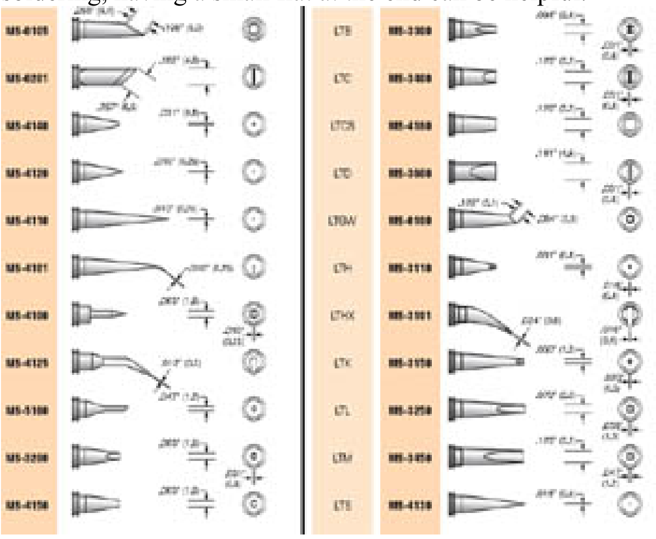

- There are myriad other tip shapes and sizes. The picture to the right shows one Plato catalog page of many. Some other non-standard shapes include a knife-blade (useful for fine pitch leads) and a surface mount desoldering tip.

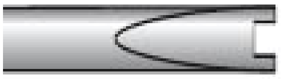

desolder surface
mount resistors

desoldering a surface mount soic chip © 2007 CuriousInventor.com

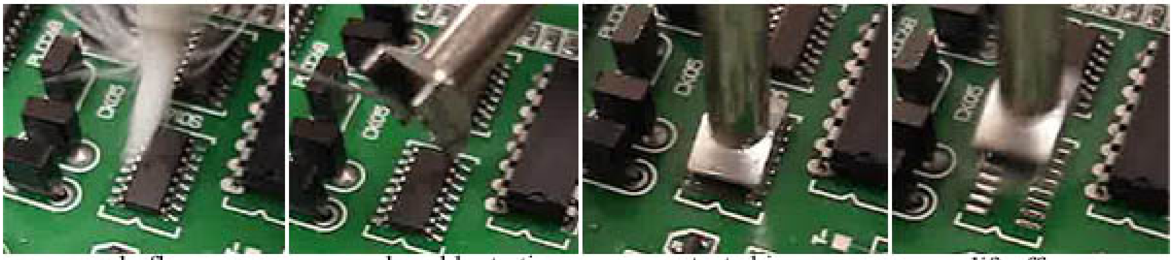

apply flux apply solder to tip contact chip lift off

To preserve tip life, the number one thing you can do is reduce the tip temperature (if your iron allows this). After that, ALWAYS keep a layer of solder on the tip to prevent the tip itself from oxidizing, and clean it in between uses. Put a glob of solder whenever you put it back in the stand, and before you turn it off. When heating up a new tip for the first time, hold solder against it so the tip can be covered as soon as the iron gets hot enough.

The longer flux residues and oxides are left on the tip, the harder they are to clean off. They also can drastically reduce the tip's ability to heat up a part, and prevent solder from "wetting" the tip. Regular cleaning of the tip before use is one of the best ways to prolong tip life and make soldering easier. It's important that solder "wet" or cling to the surface of the iron--without solder in between the tip and work the tip's ability to heat is drastically reduced.

- What about gas powered irons and the Cold Heat® iron that is supposedly touchable 1 sec. after use? Butane (and other gas) powered irons are mainly used in situations where electrical power isn't

available. Weller sells some battery powered irons as well.
Everyday Practical Electronics gives a pretty damning review of the Cold Heat iron here, in addition to having one of the better how-to guides out there. To summarize, the Cold Heat® iron has a forked end that you must bridge with the work or solder to turn on the iron, so it can be hard to hold it in a place that keeps it on and also effectively heats the part. Many people complain about pushing harder to make a good connection and then having the brittle tips break. Running power through your work to heat it may not be the greatest idea with some parts. Finally, the iron doesn't get hot enough for a lot of jobs, or cool enough to do anything like throwing it in your pocket right after use. But for something that's portable and cordless, heats up and down in under a few seconds, maybe it's worth the price ($20). Weller's battery powered ($20) iron doesn't have a forked end and supposedly heats up in under 15 seconds, but I don't know about cool-down time.

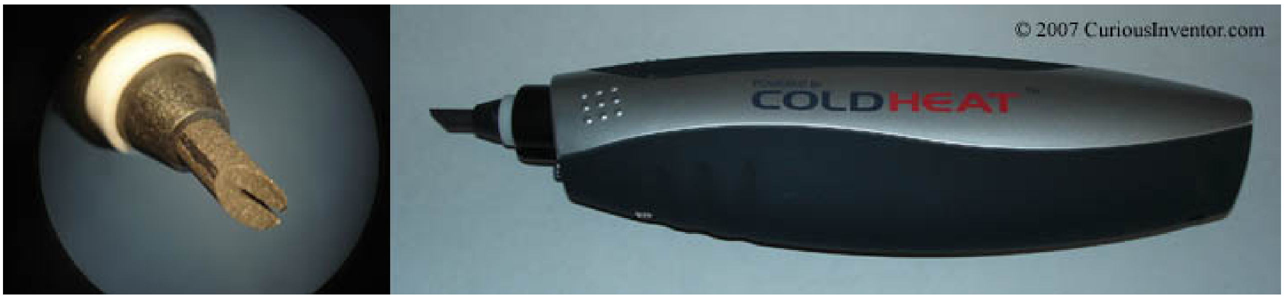

What kind of solder (rosin cored, etc. lead-free)? What is flux and when is it necessary?

As a starting place, for most small electronics soldering, 1/32 inch (.03) rosin-cored, 60/40 (tin-lead) or 63/37 solder should work fine. Rosin-cored lead-free is fine, too. Unless you have reason otherwise, don't use "no-clean" solder--it's very likely that you don't need to clean the regular rosin-cored solder. The solder should be thin enough to prevent accidentally applying too much (and causing a solder bridge), but thick enough so that more doesn't have to be gathered from the coil too often.

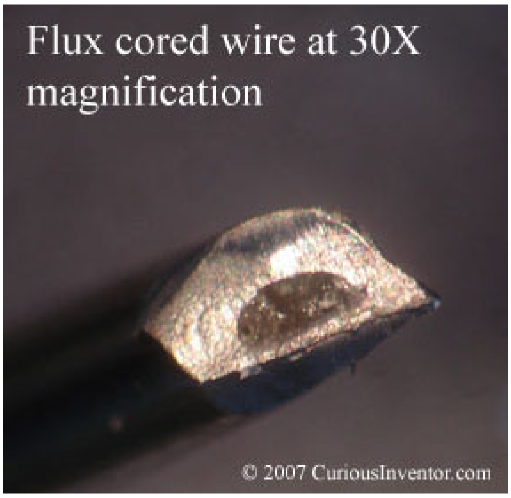
Flux cored wire at 30X magnification
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Besides affecting your feed-rate and convenience, the solder thickness also relates to the amount of flux that is delivered. Flux is basically a weak acid that removes oxides so that solder can adhere to the metal, and is so essential to the soldering process that it's built into the core of common wire-solder. It also helps the solder spread out (reduces surface tension), transfer heat, and acts as a protective blanket to keep oxygen away from the metal until solder displaces it.

For the most part, manufacturers include a sufficient amount of flux in the wire, but if you use an extremely thin wire there may not be enough to clean the joint OR the iron tip. Consider using a thicker gauge for cleaning the tip periodically if you're using especially thin solder. Liquid flux is helpful for SMD soldering, too.

When picking a wire-solder, there are 4 features to decide on: flux type and amount (% weight), alloy (tin-lead, lead free, silver bearing, etc.), thickness and total amount (1oz, 1lb?).

- **Flux:** Just what is flux, what kinds are there, and when do I need liquid flux?

  Why it's needed: Solder doesn't just freeze on a joint, it actually forms a metallurgical bond by dissolving and chemically reacting with the base material. Unfortunately, almost all metals oxidize in air and form an oxidized layer that prevents solder from wetting and bonding to them. What is oxidation?

  Oxidation, is when Oxygen (or other oxidizing agents like sulfur) atoms combine with base materials, stripping loosely attached electrons and forming new compounds like iron(III) oxide. It is what happens when apple slices turn brown, iron rusts, copper turns black / green and unsolderable. (read references for more accurate/complete explanation)

  Results vary significantly. When iron rusts, the oxides flake off until no iron is left. Alternatively, aluminum oxidizes extremely rapidly, but is then protected from additional oxidation by the oxide layer. This layer makes Al impossible to solder without using special solder and extremely aggressive flux, or plating the surface with a solderable metal, like nickel. The chromium in stainless steel fulfills the same function, oxidizing to form a protective barrier that is difficult to solder. Gold remains shiny because it doesn't oxidize, and is easy to solder to, but forms brittle joints. Heat, moisture, and salt all increase the rate of oxidation.

Oxidation can add a hidden cost to components and boards that may have been sitting on the shelf for long periods of time, or have been exposed to hot, humid environments. Copper pads on PCBs (printed circuit boards) are covered with solder or are plated to prevent oxidation, but given enough time, oxygen can still penetrate these barriers. Surplus parts in particular may need a bit of steel wool.

Some interesting references:
rusting chemical reaction
fairly understandable explanation of oxidation
wiki/Corrosion
wiki/Oxidation

Oxidation occurs much faster at higher temperatures, so even if you somehow had clean metals to start with, you would still need flux to prevent new oxides from forming while soldering.

The main choice to make when deciding on a flux, whether it comes in a cored wire or a liquid or paste form, is how aggressive it should be. The more aggressive or "active" the flux, the harder the oxides it can remove, and the faster it can remove them. Going from weakest to strongest, typical choices for hand soldering applications include: "no clean", RMA (Rosin Mildly Activated), RA (Rosin Activated), and water soluble. A newer classification system (J-STD-004) has recently been adopted and classifies fluxes not by rosin content, but by activity, material, and halide presence.

The new system classifies flux by material (RO=rosin, RE=resin, OR=organic, IN=inorganic), activity level (Low, Moderate, High), and halide presence (0 or 1). No-clean, rosin-based no-clean fluxes might be labeled ROL0 or ROL1. Although there is no direct translation between the old system and new, most R and RMA fluxes fall under Low activity level, RA are generally labeled as Moderate activity, and water soluble are High activity. (source IPC-HDBK-001 www.ipc.org)

The downside to choosing a more aggressive flux is that the residues left over after soldering MAY be corrosive, conductive, or enable fern-like growths called "dendrites" to grow between connections. A brief description (p.29) of dendrite growth and some great pictures at the end of this paper.

Because of the risk of corrosion and dendrite growth, most manufacturers clean off the residue from RMA and RA fluxes, and some even clean "no-clean" residues. The question of what flux to use and whether / how to clean it is quite involved.

Rosin flux is quite an interesting animal. Made from pine tree sap, at room temperature, it's an excellent insulator and non-corrosive. When it hits 226 °F it begins to turn acidic and attack oxides, but then when it cools it supposedly leaves residues that are again inert. Kester's data sheet for "44" flux (classified as RA and ROM1) claims no cleaning whatsoever is necessary. I haven't read of any manufacturers that would use a RA (or even an RMA) flux and not clean it--the military won't even use a RA flux WITH cleaning because of the risk that some will be left behind. This Chemtronics author recommends cleaning even the "no-clean" fluxes. He also points out that even if the residue is non-corrosive and non-conductive, it might be tacky and attract dust that causes a short.

To add one more piece to the puzzle, flux generally gets used up during the soldering process. This is why no-clean fluxes are oftentimes ineffectual for lead-free soldering, which can require slightly higher temperatures and longer heating because the lead-free solder "wets" slower. The no-clean flux can burn off before the joint is complete. Alternatively, if you apply liquid flux far from a joint, it may still be active (corrosive) if it never got heated.

I'm not making missile guidance electronics, I'm making a robot that pours a beer, what flux should I use and do I really need to clean? Even manufacturers of non-life critical electronics have much more stringent reliability requirements than an individual. They must ensure that tens of thousands of products will work for multiple years, not a single project.

The safe advice is to use the least aggressive flux that enables solder to quickly wet or cling to the surfaces, and then clean off the residues with alcohol and lint-free wipes (don't just spread the flux around). Try starting with a rosin-based mildly activated flux: RMA. I am inclined to trust Kester's spec sheet for "44" (RA) flux that says it does not actually require cleaning. Other flux manufacturers may have RA or RMA level fluxes that do indeed need to be cleaned, so if you don't know what you're using, cleaning is probably prudent. If you are going to clean rosin fluxes, do it soon after soldering because they quickly harden (see pics under 'Cleaning'). Finally, I would personally avoid no-clean fluxes and solder unless you have a critical application and very clean parts.

Lead-free solder generally requires a made-for-lead-free flux designed to be used under slightly higher temperatures.

Liquid flux can greatly help with surface mount soldering and desoldering components, but the flux inside cored-solder should be sufficient for through hole components. When soldering SMD components and desoldering pretty much anything, liquid flux acts as a blanket that helps to spread heat and also keep oxygen away from the metals. Finally, flux lowers the surface tension of solder, helping it to spread out and wick into connections.

A water-soluble flux may be necessary for heavily oxidized parts or difficult metals like nickel. Without question, clean these fluxes. Special fluxes and solders exist for aluminum and stainless steel and these also certainly require cleaning. Never use acid-core solder; it deposits zinc chloride into the solder that cannot be cleaned out. A final reason to clean flux residues is if you'd like to apply a conformal coating and aren't sure whether it will adhere to those residues.

Some more references:

- Never use acid-core and how to solder to stainless steel (Kester)
- White residue and all about rosin (more Kester)
- Good mini-class on fluxes: Bolton University
- To clean or not to clean and a brief history of electronics cleaning: more Bolton
- The Kester catalog provides good info on the solderability and flux requirements of various materials (see p.14).
- Flux residues and what to do about them. This explains a bit about cleaning options and the health risks of rosin and non-rosin fluxes.

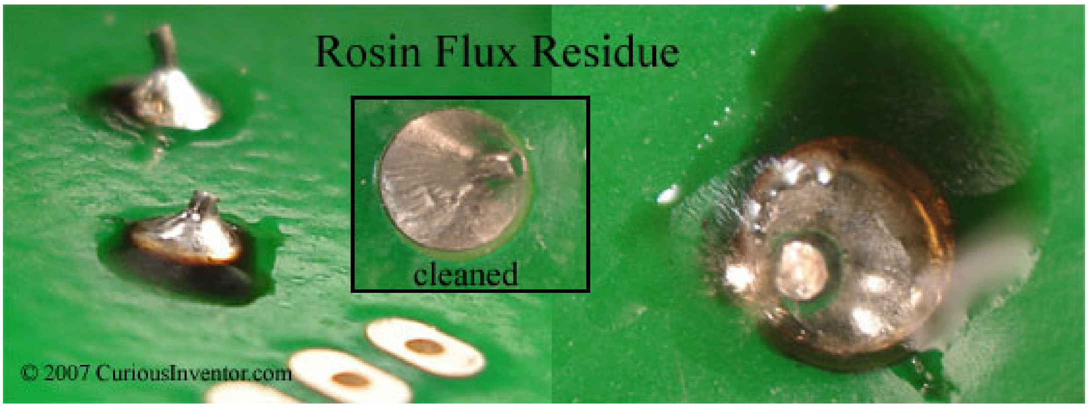

- **Alloy:** 60/40, 63/37, tin-lead, lead-free, silver bearing, RoHS, eutectic, oh my...

- **Standard lead-based solder** is made of tin and lead. When you see 60/40 or 63/37, it means 60% tin by weight, 40% lead. Either once of these alloys should be fine for typical small electronics soldering. 63/37 in bulk is slightly more expensive because of additional tin, but has the special property of being a "eutectic" alloy, which transitions from liquid to solid at one temperature (like water) instead of range of temperatures. Basically, in non-eutectic alloys like 60/40, there is a "pasty" region of temperature where portions of the solder are frozen and other portions are liquid. What does this mean for soldering and is 63/37 really that much better?

  Alloy metals have some interesting properties that are different from the metals comprising them. In tin-lead solder, the mixture has a lower melting point than either lead or tin alone, and the melting point varies depending on the portions. The mixture that yields the lowest melting point is called eutectic. This is also the only mix where all the constituents melt and freeze at the same temperature.

  If the tin-lead alloy isn't eutectic (ie, if it is not 63% tin), it will go through a "pasty" phase while it freezes. Unlike water, which freezes entirely at 0 °C, some parts of a non-eutectic mixture of tin-lead freeze at higher temperatures than other parts. For a somewhat simplified explanation, if you held the temperature of 60/40 slightly above 361 °F, the "extra lead" would solidify and be floating in a liquid 63/37 eutectic mix. For a more exact and great explanation of this process, look here.

  How is it that the mixture of two elements somehow lowers the melting point? And I quote: "increased entropy." Chew on this. (Another great phase-diagram explanation with a bonus of why ice and salt can get almost 30 °F below freezing--enough to freeze ice cream) And one last great explanation--talks a bit about grain structure and how solder isn't a simple homogeneous mixture of tin and lead.

  This compares the difference between eutectic freezing in tin-lead and eutectic freezing in more complex 3 element lead-free alloys.

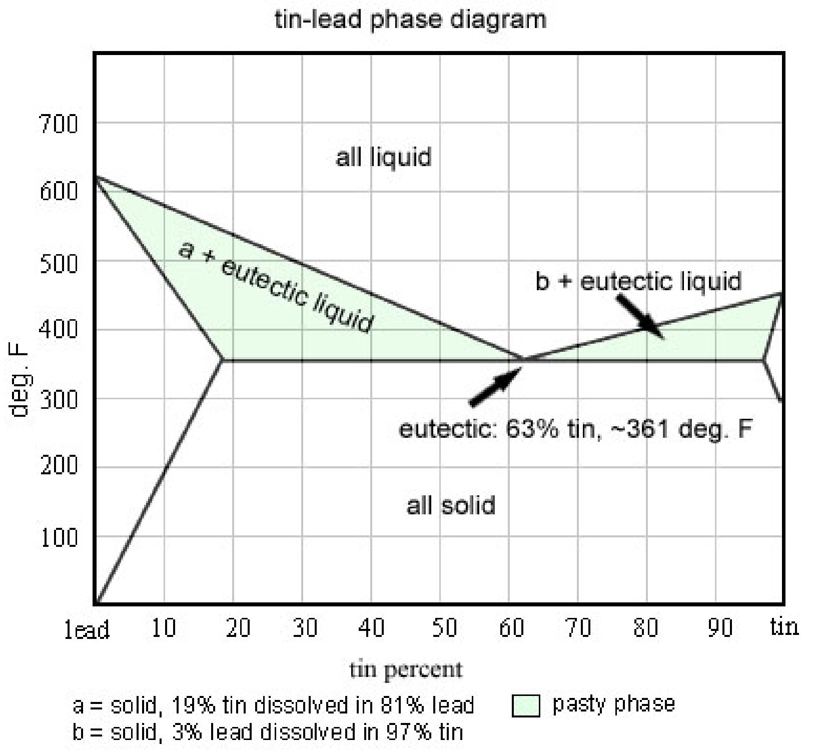

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So which is better, 60/40 or 63/37? A decade or so back (before the lead-free movement), most manufacturers incurred about a 5% increase in cost to switch from 60/40 to 63/37. 63/37 flows slightly easier, makes shinier joints, and has a faster total freezing time which means there is less risk the joints will be "distrubed," which is what happens when the joint moves during solidification. This can lead to internal fractures that cause poor electrical connections and unreliable mechanical joints. Note that 63/37 doesn't freeze instantly (just like water)--it still has a window of time during which the joint can be disturbed, too.

I think most would say that the enhanced properties of 63/37 really only matter for mass soldering operations like wave or reflow soldering, and that there is little difference for hand soldering. A dull joint is more often caused by insufficient heat, dirt or oxides, or lack of flux rather than alloy makeup. (A no-clean flux may burn off before the joint is complete) Holding everything else constant, the difference in shininess between 60/40 and 63/37 is completely cosmetic. If you'd like to see a shiny 60/40 joint, try using Kester 60/40 with #44 flux.

- **Silver bearing solder:** (that is, contains silver, not for roller bearings) Silver is used in one of the leading alloys for lead free solder (An96.5% Ag3.0% Cu.5%) and also as an addition to tin-lead solder, usually in the 2-4% range (when you se 62/36/2 this means Sn64Pb36Ag2).

  People claim that it flows better, has a lower melting point, is stronger, and has a higher conductivity. According to Indium's solder wire data sheet, their 2% silver solder has an electrical conductivity that is 11.9% of Cu compared to 11.5% of 63/37 tin-lead solder, a shear strength of 7540psi vs. 6200psi, and a tensile strength of 7000psi vs. 7500psi for 63/37. So, yes, the claims are true, and also mostly insignificant. Silver was initially added to solder to prevent silver platings on component leads from dissolving into the solder ("silver migration") and forming brittle joints. Having silver in the solder reduces migration, so you may want to use it on silver joints. (Note: this logic doesn't entirely make sense to me. If silver getting in the solder caused embrittlement, how does adding *more* silver prevent this?)

  Audiophiles seem to be enamored by 4% silver bearing solder, namely some from WBT, Cardas, and WonderSolder. Are these really better for audio?

  The superior claims include things like higher purity, eutectic alloys, higher conductivity, and better flux. I haven't found any controlled studies showing that a group of people can actually hear the difference, so I'm skeptical. Although additional silver does increase conductivity, the increase is small and the joint distance over which that conductivity applies is also extremely small. For what it's worth, here's a forum discussion that discusses a bit about solder in high-end audio and also a FAQ (scroll down)concerning solder on Cardas Audio's site. Another decent discussion.

  Bad joints made with any solder can create a high-resistance connection, especially if the underlying components were heavily oxidized initially. My advice: if it makes you feel better, get it, but be wary of sellers that don't provide spec sheets.

- **Lead-free Solder:** As of July 1st, 2006, European laws mandated that new electronics be almost entirely lead free. As of yet, there are no US laws (outside CA) mandating the removal of lead, but most manufacturers are switching over for competitive reasons. More on RoHS, WEEE, and lead risks:

  The European Union passed directives in 2003 stating that no equipment sold in Europe should, by July 2006, have more than .1% lead in any homogenous component (like a solder joint). The directives are known as the WEEE (Waste Electrical and Electronic Equipment) and RoHS (Restriction of Hazardous Substances) (wiki). There are corresponding laws in China, Korea, and California. Japan manufacturers actually voluntarily begin switching to lead free years before RoHS or WEEE for competitive reasons. IPC's informative lead-free website: here.

Although only .5% of lead used in the US gets embedded in electronics (verses 80% in batteries), there is concern that the lead from those electronics will leach into ground water supplies from landfills. Why the concern over solder joints when batteries contain so much more lead? For the most part, lead containing batteries are recycled and regulated, whereas electronics are routinely just thrown away. The EPA claims that 1% of municipal waste is electronics. Interestingly, according to this publication by IPC, no studies have found any evidence of lead getting into the ground water from landfills.

Lead health risks: Lead does not get absorbed through the skin, and is actually not present in solder fumes to any appreciable degree (fumes are still bad for you, see fumes section below). The greatest risk of hand soldering with lead comes from ingesting lead by eating or smoking without first washing. Health risks include increased blood pressure, fertility problems, nerve disorders, muscle and joint pain, irritability, and memory or concentration problems. The latest health data indicates that there is no amount of lead that will not be detrimental to health. Google lead or start with this link.

Some great lead-free joint pictures: here.

The most popular lead-free alloy seems to be Tin 96.5% Silver 3.0% Copper .5%. The wiki page on solder mentions several different lead-free varieties.
-AIM lead-free solders.
-Huge list of Indium lead-free solders and their properties.

Lead-free solder generally melts at a higher temperature, and doesn't wet as quickly to metals. (Eutectic tin-lead solder melts at 361 °F and the SnAg3Cu.5 melts at 423 °F.) Manufacturers generally recommend setting soldering iron temperatures between 700-800 °F for lead-free instead of 600-700 °F for tin-lead soldering. The 15 Watt RadioShack® iron I had operated a bit below 500 °F, so soldering should be possible with it, but maybe slow. Technique wise, since lead-free wets slower, joints will take longer (upwards of 4-7 seconds), but this doesn't mean the soldering iron temperature should be turned up excessively--patience is better than higher temperatures. If you're going to use a lead-free solder, get a flux that's designed for the higher temperatures--the regular no-clean fluxes will likely burn off before doing their job.

A quick word on reliability. Some say that lead-free joints are stronger, and while the material is indeed stronger, it's less flexible than lead-based solder, so expansion and contraction due to temperature change has been shown to break components held by lead-free solder. It seems true mechanical reliability of lead-free vs. lead depends heavily on the situation (see p.30). There is also concern of something called "tin whiskers." These are extremely thin crystalline growths that grow perpendicularly out from surfaces. These took down some space systems and NASA has a great page here. These are different from dendrites (which grow on the surface) and appear to be more likely on bright all-tin platings. Most component platings used to consist of a tin-lead mixture, and since all-tin platings are a common lead-free replacement, people are concerned. I have yet to find any literature that points to TinSilverCopper solder as a risk factor, though. I believe it is a plating issue, only.

One more link: -Why tin or silver?

- **Thickness and Amount:** As a general guide, .032" thick solder (21 gauge) should be suitable for through hole soldering and some surface mount soldering. For finer pitch surface mount devices, use .02" or .015", and if you're soldering a lot of switch terminals, or tinning thick gauge wire you may want .05". If you use .015" solder consider having some thicker solder on hand to re-tin your tip, since the amount of flux in .015" may not be enough to remove tip oxides. The picture below shows how the various thicknesses compare next to the standard .1" spaced DIP pins.

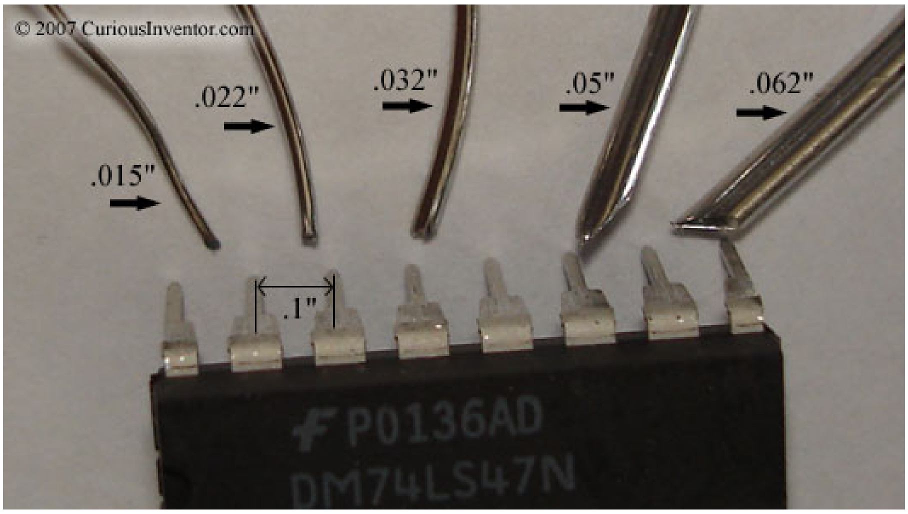
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.015"
.022"
.032"
.05"
.062"
.1"
P0136AD
DM74LS47N

Expand to see how .032" and .015" solder compare to a SOIC surface mount chip and fine pitch (.02") device.

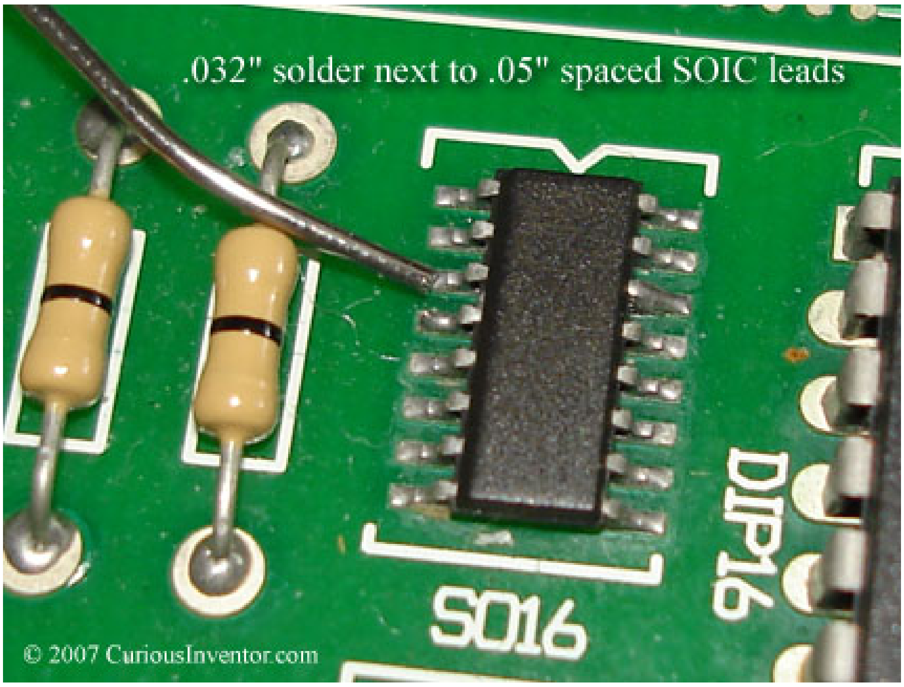
.032" solder next to .05" spaced SOIC leads
SO16
DIP16
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.015" solder next to .02" spaced surface mount leads and a thumb tac.

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How much solder do I really need? An ounce? A pound? How long will a pound last?

To get a very approximate feel for just how much solder is in an ounce vs. a pound, I measured how much .032" solder it took to attach ten 16 pin DIPs. Trying to provide an upper bound, the soldering is excessive, and a generous glob was placed on the tip in between each chip to account for solder used to tin and protect the tip during normal use.

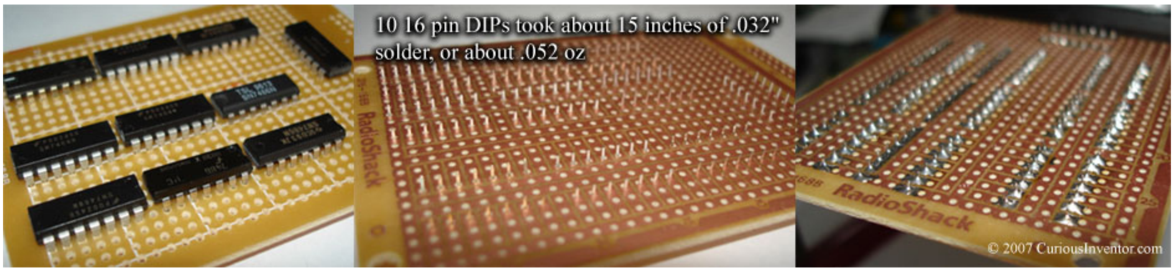
10 16 pin DIPs took about 15 inches of .032" solder, or about .052 oz

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The ten chips took about 15" of generously applied .032" solder that weighed in approximately at .052oz. This particular solder weighed about .00348oz/in. At about 3.27e-4 oz/joint, a 1 oz spool should last 3060 joints, a half pound should last 25 thousand joints, and a pound should last about 50 thousand joints. Mileage will certainly vary with different sized solders, joints, tinning wires, and highway vs. city driving, but if you're not in a production environment, a half pound should last a while.

Solder Fumes:

What is exactly in solder fumes? Am I safer using lead-free solder?

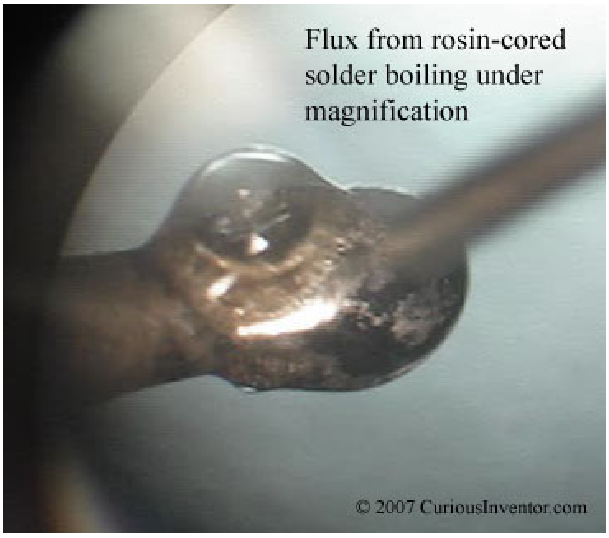

Lead boils at over 3000 °F, and in most cases soldering tips should be kept below 750 °F, so it is highly unlikely that gaseous lead is present in the fumes. The fumes are actually from the flux boiling, which still isn't great for you--many of the chemicals found in cigarette smoke are found in flux fumes: formaldehyde, toluene, alcohols, and hydrochloric acid to name a few. Most of the public health literature indicates that asthma is the major health risk from soldering fumes (not cancer or lead poisoning). When acquired, it is permanent and can cause hyper sensitivity so that even small amounts of fumes bring on attacks. Surprisingly, scientists have not been able to determine what exactly in the fumes cause the health defects, nor what amounts are harmful. Yet, the British health department has set exposure limits of .05 mg/m^3 over 8 hours and .15 mg/m^3 over 15 minutes. I believe these limits have been shown to provide a safe work environment and also one for which the necessary systems / filters are financially reasonable.

Some informative links:

- Solder Fumes and You A British health department pamphlet explaining the health hazards of rosin-based flux fumes (irritation, headaches, dermatitis, asthma) and what precautions employees and employers should take. Note the total lack of any mentioning of lead poisoning.
- Workplace Exposure to Rosin-based Solder Flux Fume During Hand Soldering A study done by the UK Health and Safety Laboratory measuring exposure levels and also the effectiveness of various exhaust, ventilation, and filter systems.
- Measurement of the Performance of Air Cleaners Against the Particulate Element of Rosin-based Solder Flux Fume Another UK Health study investigating the effectiveness of various fume extraction and filter systems. Most interesting finding: although activated carbon filters can remove gaseous hazards, they are largely ineffective for fine particulate in the fumes which they believe to cause much of the harm. Some combination of carbon and HEPA filter is needed, and even these are useless without sufficient air flow.

Returning to the topic of lead, it is widely agreed that eating, smoking and drinking without first washing is the greatest risk factor. Despite the high boiling point of lead, there is also agreement that at least a small amount of lead particles are indeed present in the fumes. The conspicuous lack of emphasis on lead poisoning in all the research done by the UK health department implies that these particles are of little concern. Sentry Air Systems has a brief page that is one of the very few sources I found to claim that lead particles under normal soldering conditions are harmful. The company sells fume extraction technology.

The material safety data sheet for Kester #44 cored solder says under the fire fighting section: "Melted solder above 1000 °F will liberate toxic lead and/or antimony fumes."

According to IPC's DVD-11, "General Safety in Electronic Assembly," when solder is heated past 850 °F the lead can become atomized and end up in the fumes. video link (if link breaks, you may have to search for DVD-11 at www.ipc.org).

Useful comments from someone in the manufacturing world regarding lead.

It would seem that, for typical lead-based, rosin cored solder, the risks are probably not that great from the fumes if you only solder occasionally, don't use abnormally high temperatures, and are in a well ventilated area. If ventilation isn't too good, and you're soldering for long periods of time, the cheaper foam-type carbon filters may not be good enough.

But what about lead-free solder? Lead-free solder often requires higher temperatures and more active fluxes, and both of these factors lead to significantly worse fumes.

Fume Extraction Becomes More Important in a Leadfree Environment - from the Weller blog

Another excellent article on the increased risk of lead-free fumes from OK International.

Instructables has all sorts of home-made fume extractors.

Prepare the Work

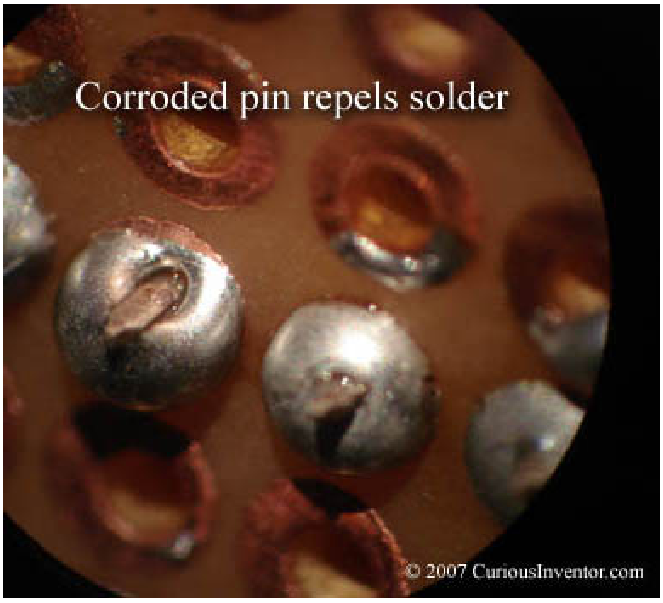

- **Start with clean components:** Flux can remove small amounts of oxides, but will be of little help for heavy oxidation, grease, oil or dirt. Notice how the solder in the adjacent picture has been repelled by the heavily oxidized pin. It may be necessary to lightly use steel wool or fine grit sand paper to remove especially bad oxides. Some people say that you should not do this because it creates scratches that can promote future oxidation... sand at your own risk. Use Silicon Carbide sandpaper (black) as opposed to Garnet (brown, for woodworking) sandpaper because the Garnet paper will shatter and become embedded in the metal. An effective and gentle alternative is to use a pink eraser, especially for copper traces.
- **Clamp your work:** PanaVise makes a popular clamp that accepts several different attachments for holding different sized circuit boards. It's by far the most popular clamp and is also very sturdy. Having the work held in place is especially helpful for desoldering when it's necessary to push or pull a bit. The alligator hands are a cheap alternative.

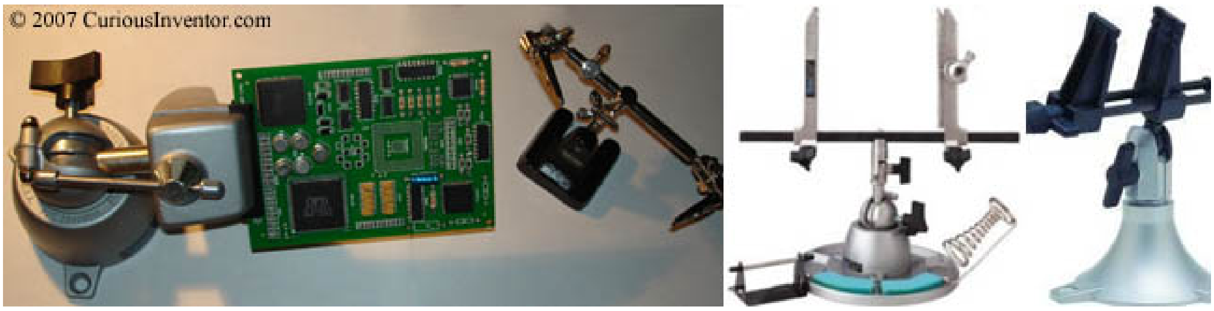

- **Wire preparation:** Tin stranded wires so they don't "bird-cage," or bend out from their original lay. Expand for instructions on the correct way to strip a wire manually, use an automatic stripper, and tin wire.

- **Manual wire stripping:** The natural way you would think to use the wire strippers is to first cut the insulation, and then use the same cutting hole to push off the insulation slug. In production environments where reliability is critical, this is not allowed because it's very easy to nick the wires this way. The pliers at the tip of the stripper are actually meant to remove the insulation slug. First score the insulation with the cutting hole, and then pull it off with either the pliers or by hand. If removing by hand, twist slightly while pulling to keep the strands in place. This is the "right" way to strip a wire, if you're careful, pulling the insulation off with the cutting hole is probably fine.

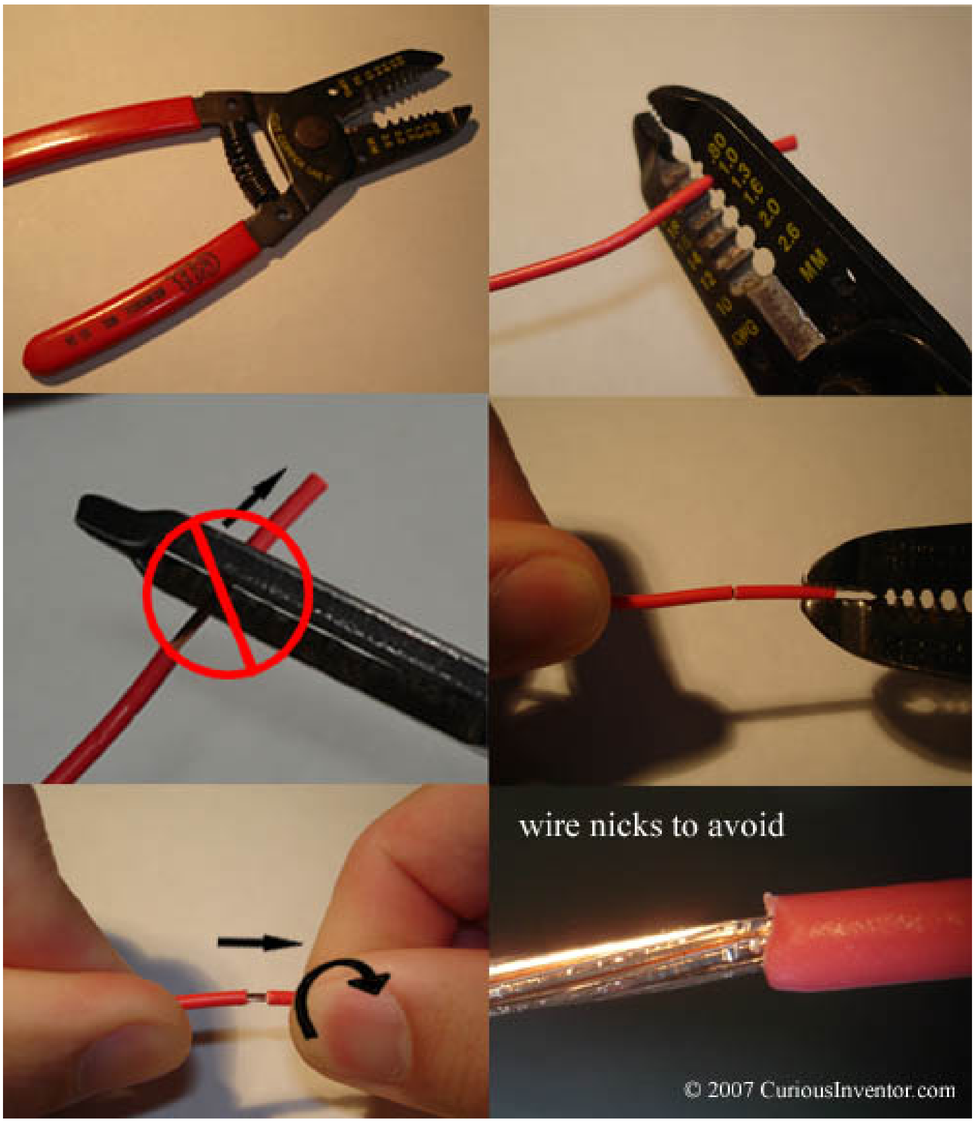

- **Automatic stripping:** With one squeeze these cut and pull off insulation.

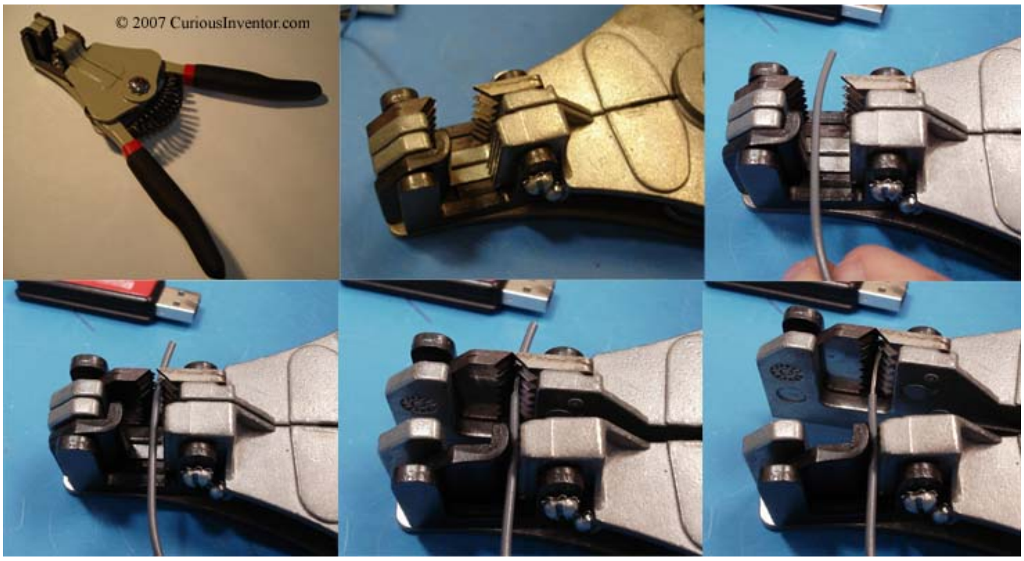

- **Tinning:** Just like soldering a joint, the key here is to apply solder to the wire, not the iron tip. If the wire is hot enough to melt the solder directly, then it's hot enough to form a good bond with the solder. Hold the iron against one side of the wire and apply a small amount of solder in between the tip and wire to form a heat bridge (if there isn't already enough solder from tinning the tip). Now apply solder to the opposite side. The solder should wick into the strands. Move the iron and solder as necessary to coat the surfaces. You should still be able to clearly see the individual strands when it's complete.

  Don't tin wires that are going to be held in clamping terminals since the solder will slowly deform under pressure and cause the connection to come loose.

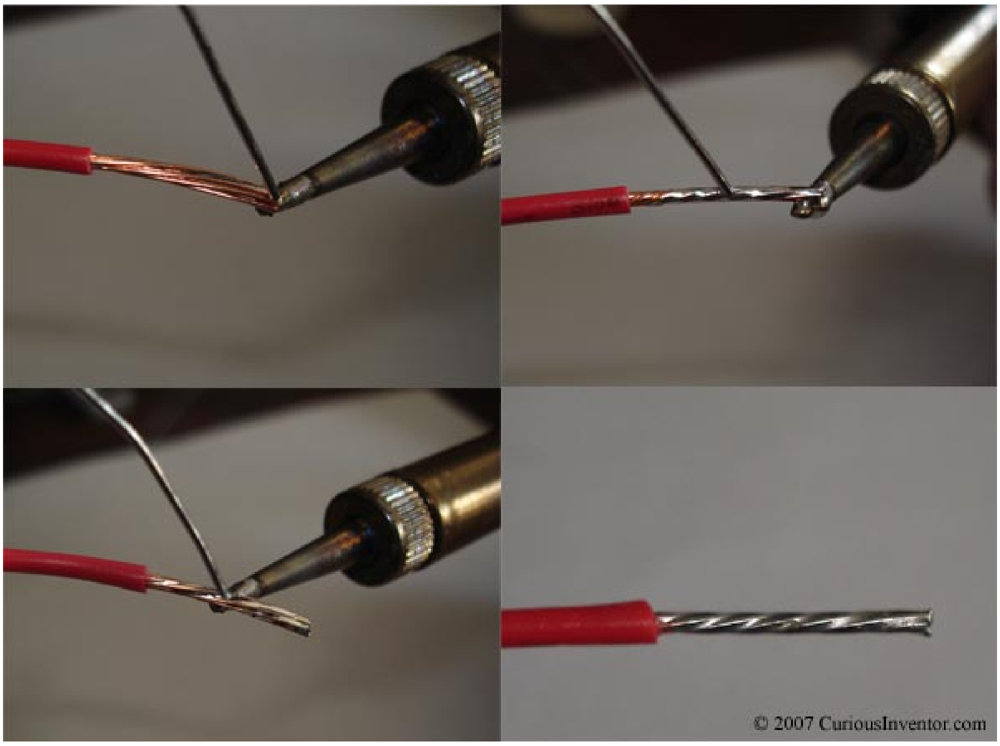

  Got a lot of tinning to do? For under $300 you can get a vat of molten solder to speed up the process. The only catch is that there's no flux in the vat, so you need to dip the end of the wires in liquid flux before dunking them in the molten solder. Only dip the very end of the wire in the flux; capillary action will draw it further up the strands. If you dipped more than just the end into the flux, the capillary action would draw flux beyond the insulation where it can't be cleaned, and would eventually corrode the wire.

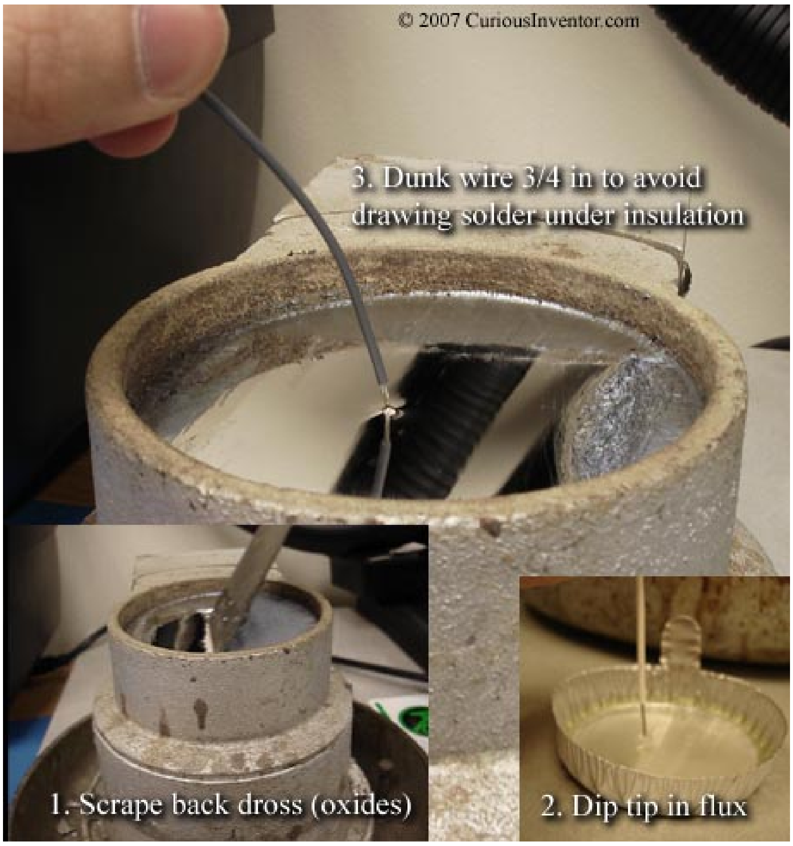
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3. Dunk wire 3/4 in to avoid drawing solder under insulation
1. Scrape back dross (oxides)
2. Dip tip in flux

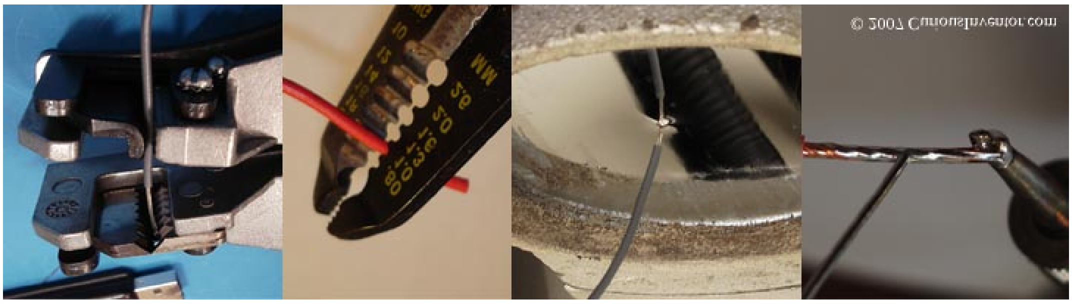

- **Insert, clinch and trim components:** First, make bends *before* inserting the components. Avoid stressing the connection between lead and component by bracing the lead with pliers while bending. Pliers with serrated tips aren't used in high-reliability production because the grooves can create nicks in the leads that eventually cause a break after a lot of vibration and thermal changes. Round nose pliers make it easy to make any sized radius.

  Unless the component has a metal casing or needs clearance for air flow to keep cool, insert it until it's flush with the board. This doesn't apply to some transistors, and also capacitors that have plastic coverings that need to be kept out of the solder joint. Clinch or bend out the leads so the component is held in place during soldering, and finally trim the leads to about the radius of the pad. Trim the leads before soldering since doing so afterwards can shock and crack the joint. Wearing safety glasses for this process is not at all excessive--those leads can get you. Everything else about proper component installation: NASA guide.

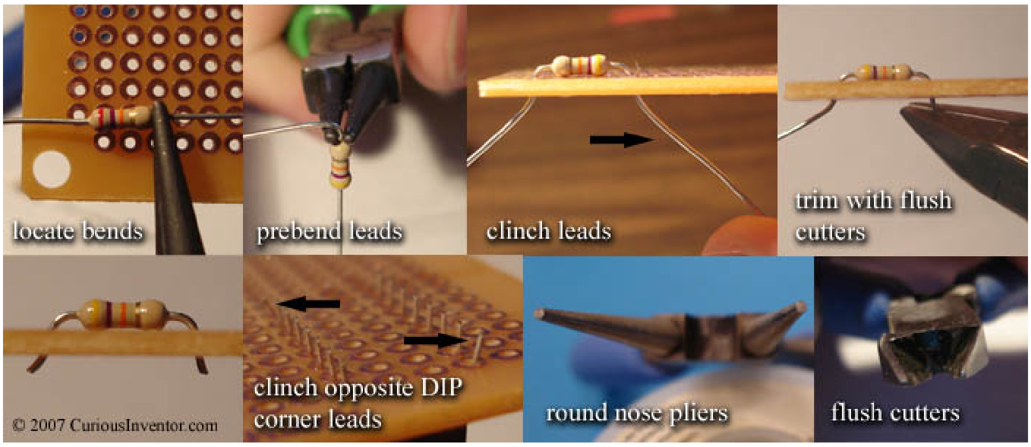
locate bends
prebend leads
clinch leads
trim with flush cutters
© 2007 CuriousInventor.com
clinch opposite DIP corner leads
round nose pliers
flush cutters

- **Add heat sink:** Some semi-conductors (some transistors and diodes) are especially heat sensitive. This clip acts a heat shunt to keep the transistor protected.

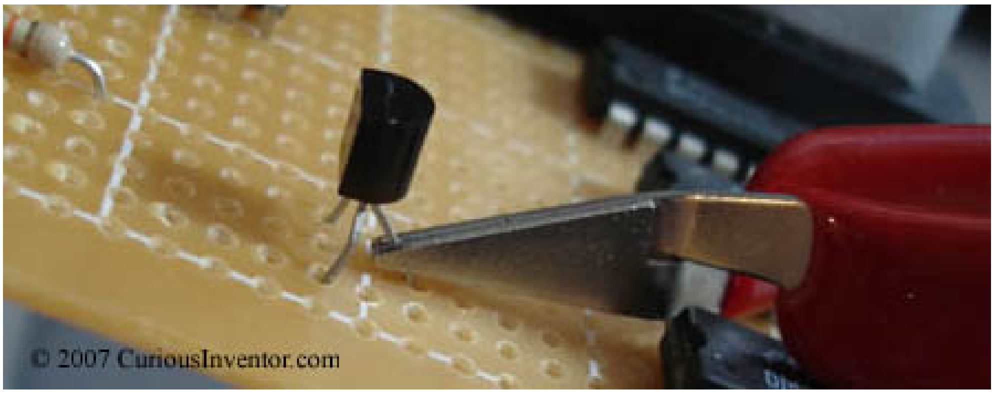
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Clean and tin the Tip

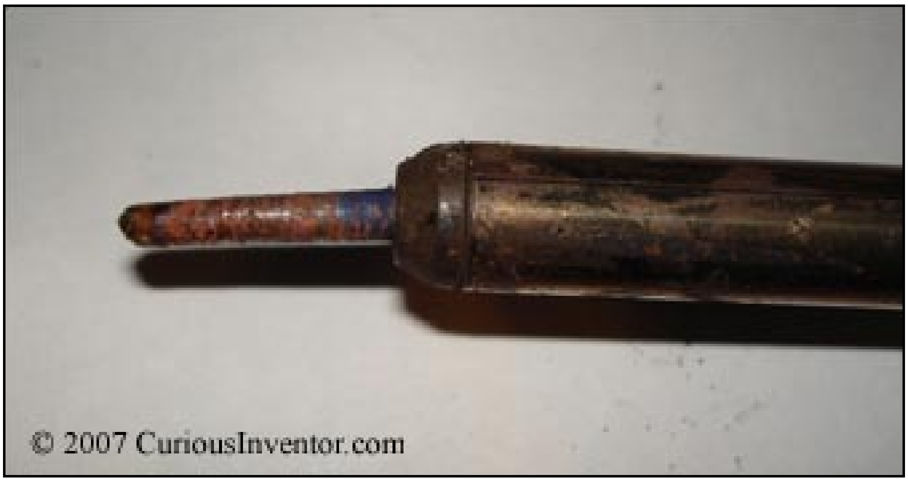

· **Regular cleaning = easier soldering and longer tip life:**The iron tip's ability to transfer heat is drastically reduced when it gets covered in oxides and burnt flux residues. Not only does heat not transfer as well through this debris, but the contaminants also prevent solder from wetting or sticking to the tip. Most heat transfer actually goes through a fluid solder "heat bridge" that lies between the iron tip and components, so an iron tip that repels solder will be very ineffective.

The longer oxides and charcoaled flux residues remain on the tip, the harder they become to remove, so it's a good idea to clean the tip every time you pick up the iron.

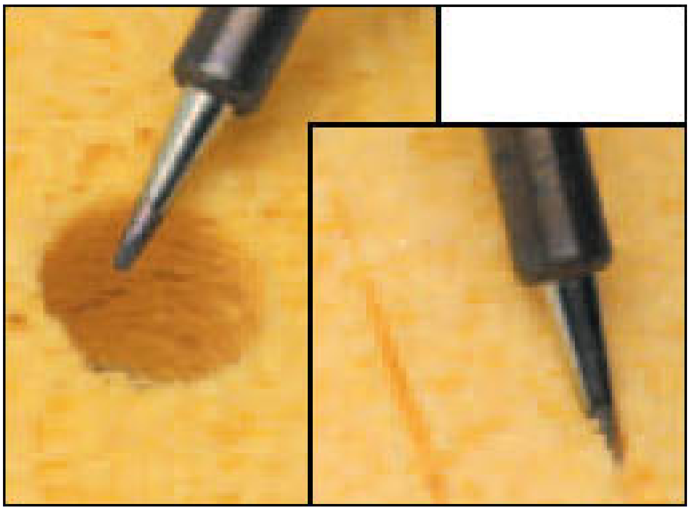

Wiping the iron on an edge of a hole cut into a sponge can help to remove oxides easier, and also allows waste to fall away. A dry cleaner can also be used. It consists of soft metal shavings that are coated with flux. You clean by thrusting the iron into the shaving a few times. By avoiding the thermal shock of touching a damp sponge, these cleaners help to increase tip life, and in our opinion, do a better, faster job.

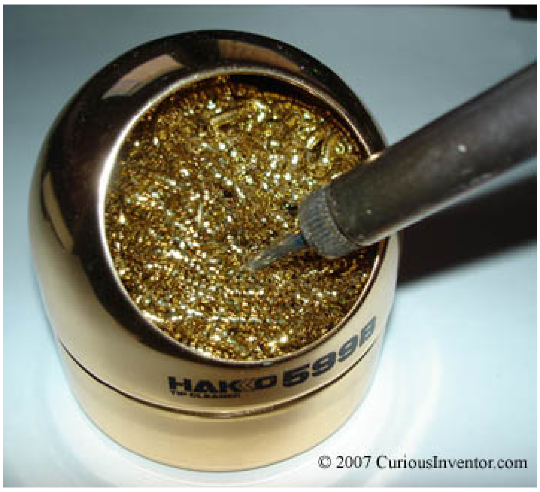
HAKKO 599B
TIP CLEANER

© 2007 CuriousInventor.com

Usually touching the tip with rosin-cored solder will supply enough flux so that oxides can be removed with a damp sponge. If this isn't sufficient, you can purchase "tip tinners and cleaners" that are a mixture of solder paste and flux. The flux is oftentimes stronger (more activated) to help remove oxides.

64-020
RadioShack
Tip Tinner and Cleaner
WARNING: KEEP OUT OF REACH OF CHILDREN. Read carefully other warnings on back of card.
Custom Assembled in USA with Foreign and Domestic Components for RadioShack Corporation, Fort Worth, TX 76102
0.5 oz. (14.2gm)

© 2007 CuriousInventor.com

Finally, when that doesn't work, special polishing bars to can be used to salvage extremely bad tips. Another last resort is to gently rub the oxides off with an emery cloth or soft steel brush. Cover the tip immediately with solder after cleaning to prevent further oxidation. Never file the tip to clean it or form a different shape. The tips are mostly copper with a protective iron plating, and once that plating is pierced, the tip will die quickly. Copper is used because it's an excellent heat conductor, but if exposed to solder, it will quickly dissolve into the solder.

Weller®
WPB1
POLISHING BAR FOR
SOLDERING TIPS

© 2007 CuriousInventor.com

Tin the tip: Add a small amount of solder back onto the tip. This helps to protect the newly cleaned and exposed tip, and also helps to transfer heat to components.

Heat and Solder the Joint

- **Heat the joint:** Place the iron tip so that it touches both the component lead and pad--the goal is to get as much surface area contact between the iron tip and joint as possible. Almost no heat will travel through the point.

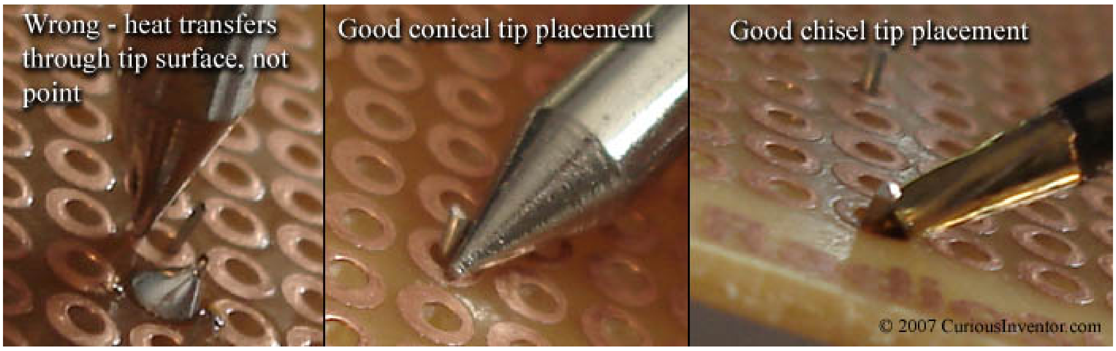
Wrong - heat transfers through tip surface, not point
Good conical tip placement
Good chisel tip placement
© 2007 CuriousInventor.com

- **Make heat bridge:** Add a small amount of solder between the tip and the work--heat transfers much faster through the liquid solder than dry surface contact. This is why a tip that won't "wet" is so difficult to use. Pressing hard should not be necessary. This step may not be necessary if there's enough solder already on the tip from tinning it after cleaning.

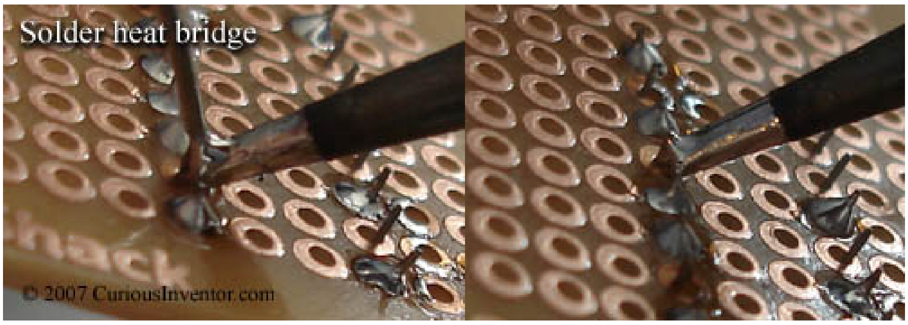
Solder heat bridge
© 2007 CuriousInventor.com

- **Apply solder to opposite side:** Apply solder to the parts, *not* the iron. By doing this, you ensure the parts are hot enough for the solder to "wet" and bond with them. Also, solder will run towards the heat source, so applying solder opposite from the iron helps to spread it out and cover the joint.

  For larger joints, rather than dumping in all the solder quickly, continuously pulse in small amounts to keep a fresh supply of active flux available.

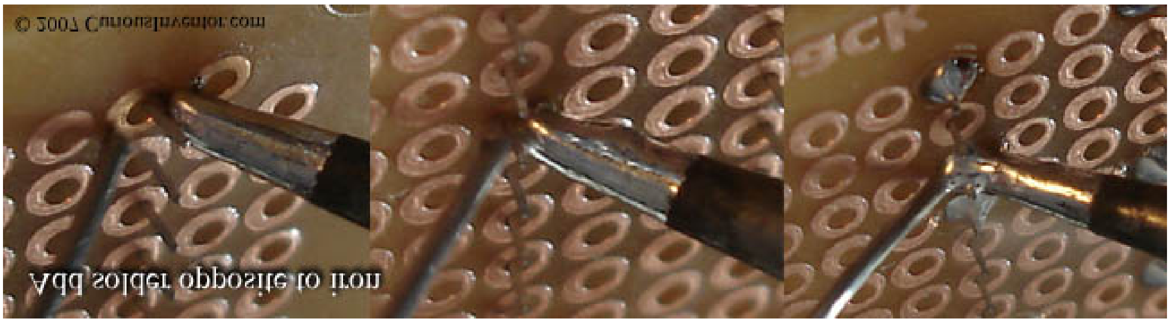
© 2007 CuriousInventor.com
Add solder opposite to iron

- **Time:** The joint should take about 2-5 seconds total time for standard 60/40, 63/37 lead based solder and a non- no-clean flux, and up to 7 seconds for lead-free solder. Lead-free solder just takes longer to "wet" the metal.

  Wetting is how easily and quickly solder spreads out over a surface. A water droplet on a freshly waxed car shows poor wetting, as does solder on a heavily oxidized soldering iron tip. It basically comes down to how attracted the liquid molecules are to each other verses the surface (see surface tension). In industry, tests are done to determine the "solderability" of materials by measuring the time it takes solder to spread out over a surface, or measuring how much force a pot of liquid solder will pull down on a component partially submerged.

Good pictures and description of wetting and surface tension. Contains a video of a razor blade floating on the surface of water until a drop of soap is added.

A brochure for a solderabiliy testing station. Scroll down a few pages to see some great pictures of this machine holding one lead of a surface mount chip in a drop of solder.

Another related wiki: wiki/Surface_energy

In general, the goal is to make the joint as quickly as possible. Longer times can char and damage the board, lift pads, overheat components, burn off and polymerize flux (making it harder to remove), and finally lead to a more brittle joint. Solder doesn't just freeze on a joint, tin in the solder dissolves and chemically reacts with copper in the connection to form a new bonding material, called an "intermetallic layer". While this layer is what makes an excellent thermal and electrical bond, it is also extremely brittle; a doubling of its thickness reduces joint tensile strength by half (ref 1). Since this layer grows faster with higher temperatures, joints should be made using the coolest temperature and shortest soldering time possible. This layer is also why re-heating joints has been shown to weaken them. Having said all this, I have to admit that I don't know just how long is *too* long for projects that don't need to operate for 30 years with 100% reliability. After 10 seconds there's a good chance the flux has been used up.

- **Remove solder, then iron:** Pull the iron out fairly quickly to avoid leaving a solder spike.

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- **Good and bad joint gallery:** The solder should smoothly ramp to meet surfaces and be shiny in appearance if it's lead-based. Lead-free solder will have a duller and grainier surface, but will still be a good joint as long as there are no signs of non-wetting. The important thing to look for is any solder that looks like it didn't cling to a surface, or is just sitting on top or next to a surface.

Gallery of joints:

A NASA gallery of every possible joint / board defect you could ever imagine. Here's another great gallery of defects.

Great comparison pictures between lead-based and lead-free joints. p. 34

Good joints:

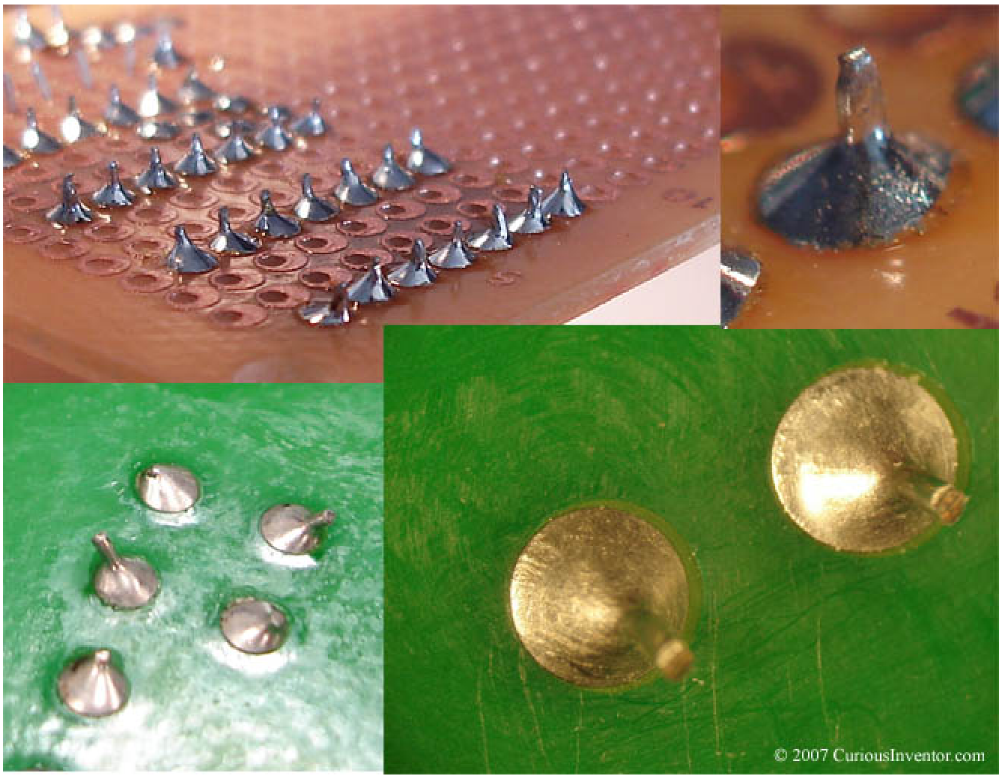
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Great joints:

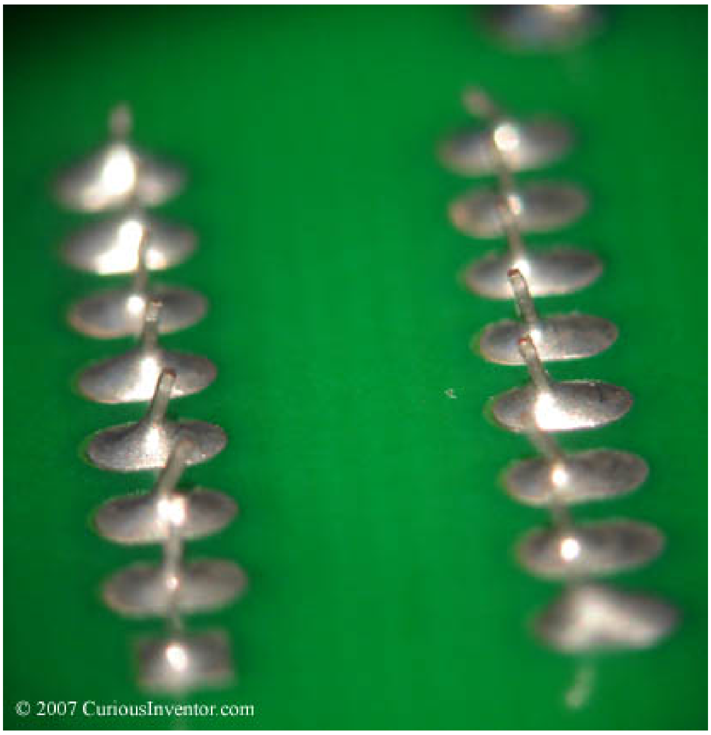
© 2007 CuriousInventor.com

What's the right amount? A large amount of solder is not needed, just enough to cover the pad and lead without any gaps (actually, only 270° is required by IPC J-STD-001). The measure for too much solder is whether or not you can see the outline of the lead in the solder. This is important because you need to be able to see whether the solder adhered or "clung" to the lead (indicating a true bond), and didn't just freeze around it. This applies to all types of joints: tinning wires, soldering to connectors, surface mount components... the solder should never completely hide the underlying wires or leads.

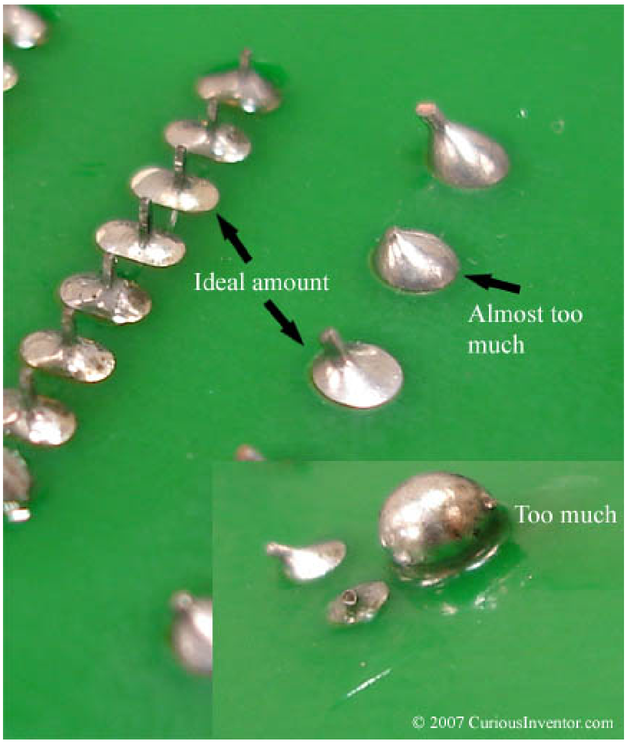
Ideal amount
Almost too much
Too much
© 2007 CuriousInventor.com

Disturbed joint (bad): If the component moves during solidification, the internal structure of the solder will have fractures, leading to a high resistance or unreliable electrical connection, as well as a fragile mechanical one. The solder also appears dull and grainy--typical signs of a "cold" joint that doesn't actually bond with the underlying surfaces.

"Cold" joints are often formed when the underlying pad or lead didn't get hot enough for the solder to wet it.

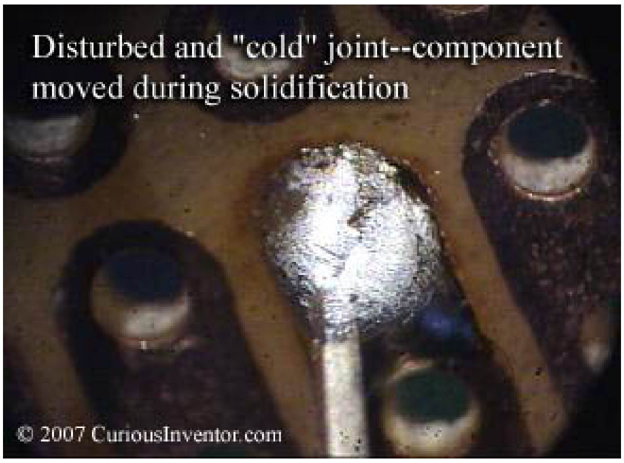
Disturbed and "cold" joint--component moved during solidification
© 2007 CuriousInventor.com

Awful joints:

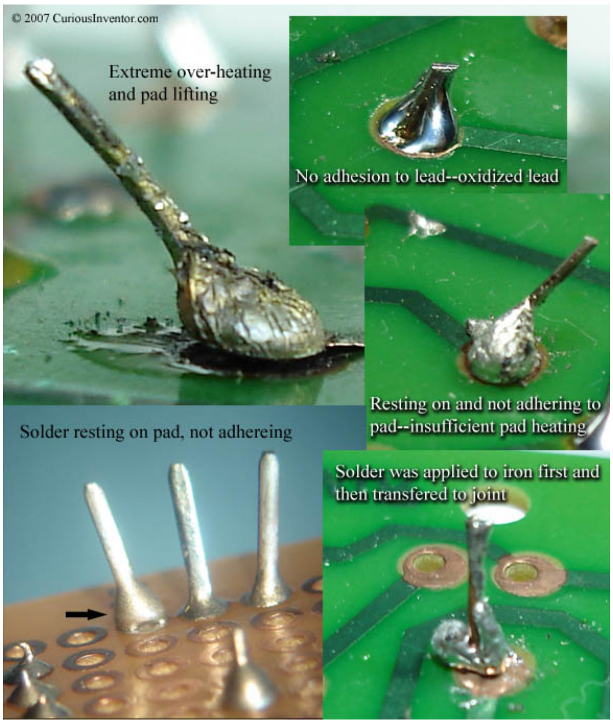
© 2007 CuriousInventor.com
Extreme over-heating and pad lifting
No adhesion to lead--oxidized lead
Resting on and not adhering to pad--insufficient pad heating
Solder resting on pad, not adhereing
Solder was applied to iron first and then transfered to joint

Clean Up

Most manufacturers will clean off residues from any flux that isn't labeled "no-clean," despite flux datasheets like Kester's that say even some of the more active fluxes do not need to be cleaned. For short life-span hobby projects, it probably doesn't matter unless you're using a solder/flux labeled "organic" or "water-soluble"--these fluxes leave behind very aggressive acids that will quickly eat away circuits. Cleaning may be necessary if you're applying a protective coating that won't adhere to flux residues. Finally, some rosin residues are tacky and may attract dust that can short a circuit.

The fact that a flux is made from rosin doesn't tell you much about how strong it is or whether it should be cleaned. What matters is how concentrated the mix is and how much acidic (halides) activators were added. RadioShack® doesn't supply any information on the flux in their standard rosin-cored solder, but it's probably weak enough that the residues do not need to be cleaned off.

Isopropyl alcohol works decently on rosin-based residues, but clean shortly after soldering because the residues quickly harden. Use water for water-soluble fluxes. This pump containing bottle dispenses a little alcohol when you push down on the top with a brush, and keeps the rest from evaporating. If you are going to clean, make sure you wipe up the remnants with a lint-free cloth--don't just spread them around the board with a brush and alcohol.

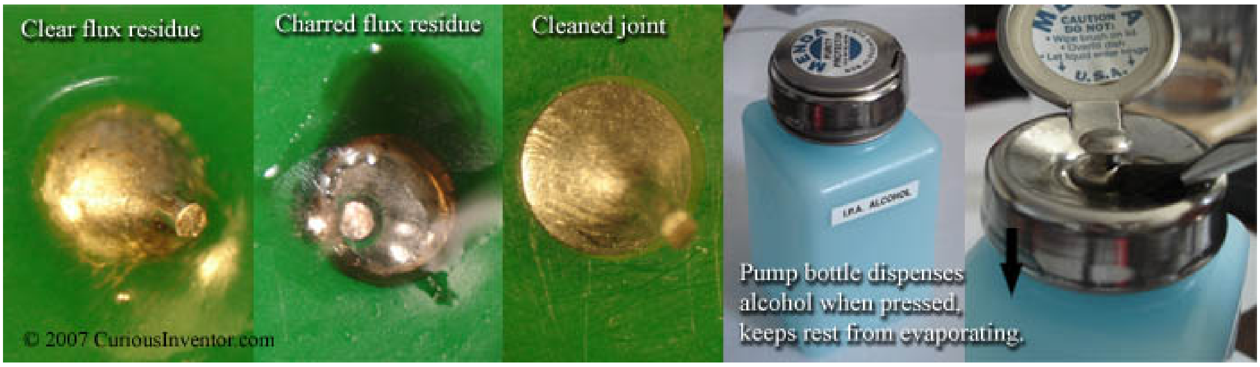
Clear flux residue
Charred flux residue
Cleaned joint
I.P.A. ALCOHOL
Pump bottle dispenses alcohol when pressed, keeps rest from evaporating.
© 2007 CuriousInventor.com

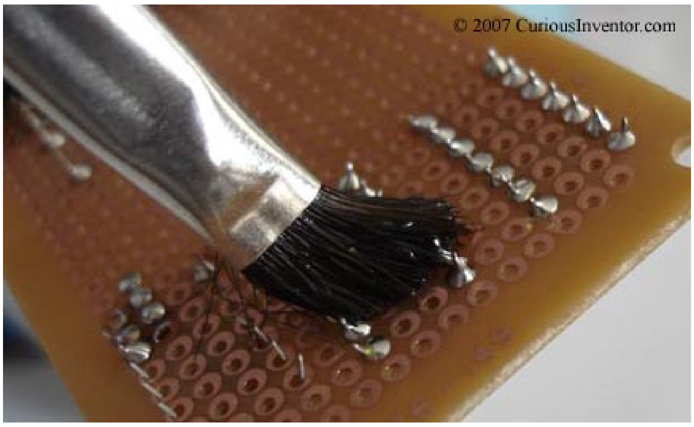
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Desoldering

The three most common inexpensive ways to remove solder include a "solder sucker", solder wick, and an iron with an attached desoldering bulb.

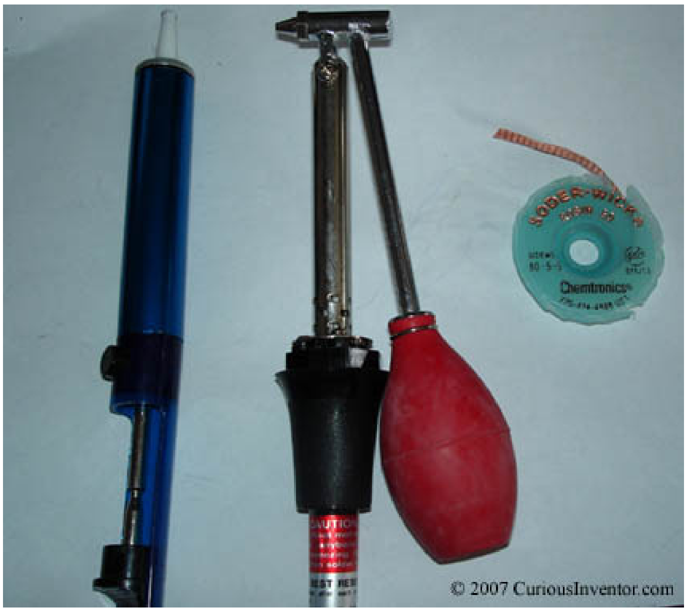

- **Solder Sucker:** To use, press in the plunger, heat up the joint, and as quickly as possible, pull out the iron, place the sucker's nozzle over the joint and press the release button. It may take a few iterations to clean out a joint enough to wiggle free a component. On plated through holes it may actually be easier to add *more* solder to the joint before sucking, since the sucker won't be able to create a vacuum with too little solder remaining.

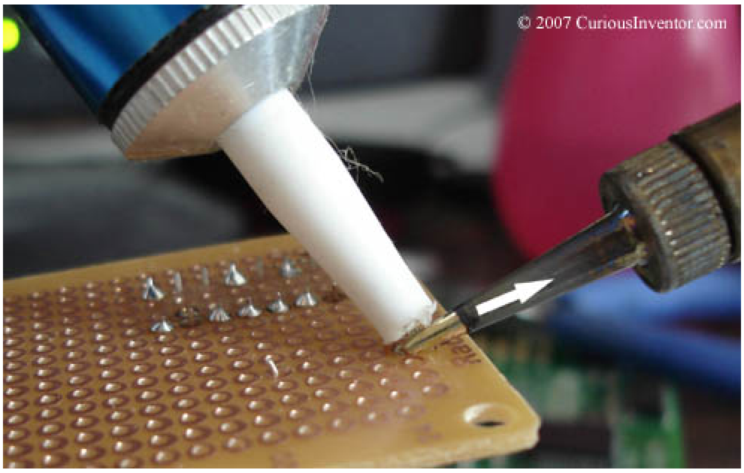

- **Desoldering Iron:** This works just like the solder sucker, but is much easier to use because there's no race to suck out the solder before it freezes, as with the "solder sucker".

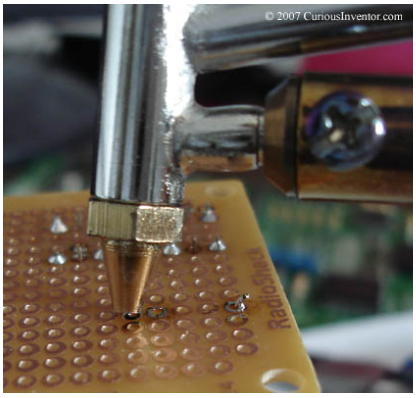
© 2007 CuriousInventor.com
RadioShack

- **Solder Wick (desoldering braid):** The above two tools will often not be able to completely remove all the solder. Many people use the sucker devices above to remove most of the solder, and then get the rest with solder wick, which absorbs solder through capillary action. It's a fine weave of copper wires that are coated in flux. Place it over a joint and then heat from the opposite side with a soldering iron. It may help to have a bit of solder already on the iron's tip to speed heat transfer.

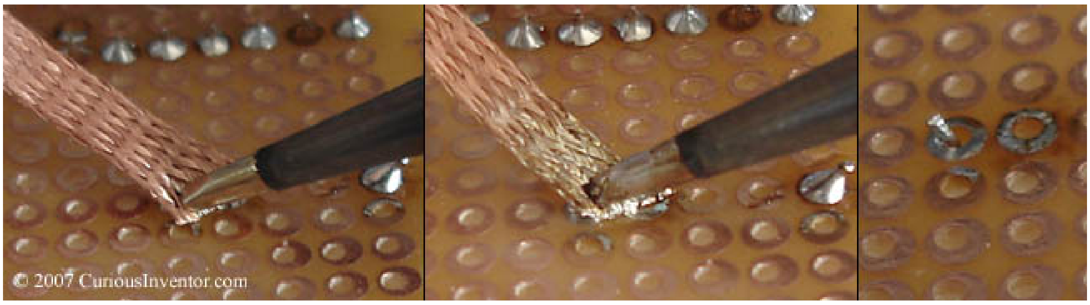
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Surface mount desoldering: Surface mount chips are especially hard to desolder because it's very difficult to completely remove all the solder pin by pin, and avoid overheating the board and lifting a pad. Professional shops use expensive hot air guns or special tips (shown below) to heat all the joints at once.

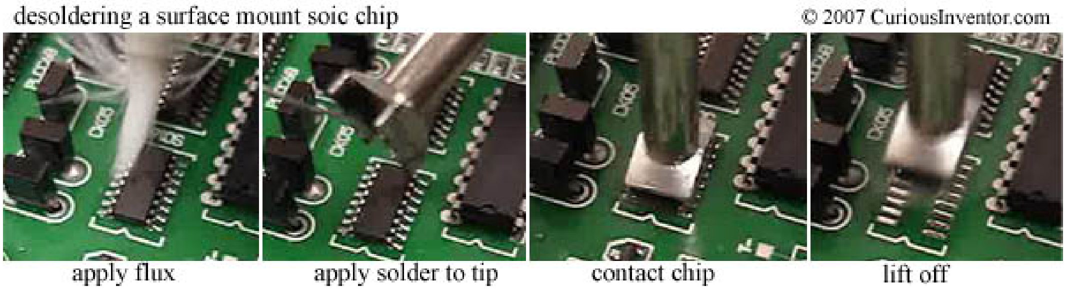
desoldering a surface mount soic chip
© 2007 CuriousInventor.com
apply flux
apply solder to tip
contact chip
lift off

There are fortunately a few cheap ways to desolder surface mount chips.

- ChipQuik provides an interesting solder that when melted over existing joints produces a new low-melting point alloy (under 200 °F) with a much longer solidification time. The longer solidification time enables you to melt all the joints at once and then flick off the chip.
- There are many guides for making a DIY hot air gun with the RadioShack® desoldering iron and a fish tank air pump. Engadget has one of the better how-to guides. Here and here are some more plus the supposed original.

The Ersa soldering primer

Soldering made easy

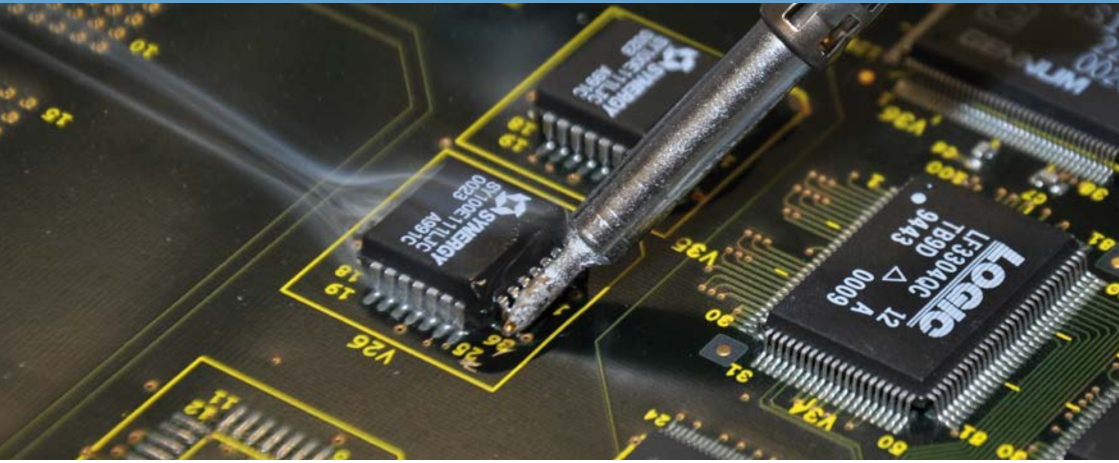

kurtz ersa

Soldering – a never-ending story

for more than 5,000 years already

Man had scarcely learned how to use metals for his purposes when the desire to join them arose in him. Many of the pieces of jewelry, tools and weapons we know from the Bronze Age owe their usefulness and beauty to the art of soldering.

ersa
RDS 80
Power
350 °C
150
300
400

Today, it is difficult to say who first discovered how to "glue" metals. One thing is certain - the goldsmiths of ancient Egypt knew how to join gold and silver already more than 5,000 years ago. Their colleagues in Troy were also master craftsmen long before the ancient Teutons could even dream of such handicraft. Soldering really "came of age" when tin was discovered as a joining metal. And that was, after all, already 4,000 years ago!

From then on, soldering technology was on its way. It first spread around the Mediterranean. The Cretans showed it to the Etruscans who then taught it to the Romans, Tunisians, Spaniards, followed by many others, including the less developed cultures of the time – the Swiss, Bohemians, Hungarians, Teutons and Scandinavians. From culture to culture, from generation to generation, the craft of soldering was continuously improved and refined.

The ancient Romans already laid down and soldered 400 km of leaden water pipes, conjured up stoves and bathtubs from bronze sheets, not to mention the excellent craftsmanship of their armorers and goldsmiths. Apart from craftsmanship in soldering, our understanding of the science of soldering has grown and has been refined over the centuries.

Today, soft soldering in the electronics industry has developed into a full-fledged production technology, encompassing the fields of mechanics, chemistry, physics and metallurgy. Ernst Sachs, the founder of Ersa (the company name consists of the initial letters of his first and last name) contributed to this development. In 1921 he developed the first electrically operated soldering iron for the industry that was manufactured in series. Since that time, Ersa has committed itself to the further development and perfection of soldering technology with great passion and extending its full power of innovation.

Today, Ersa stands for the most comprehensive product range in the soft soldering technology worldwide and for more than 90 years of industry experience and innovation, know-how and highest product quality.

The Ersa soldering iron product range covers ultra-fine soldering tips, classical soldering irons powered from the standard power net and special soldering tools up to the 550 W hammer soldering iron. Ersa's electronically temperature-controlled soldering stations represent the industry standard, as does the extensive range of rework and

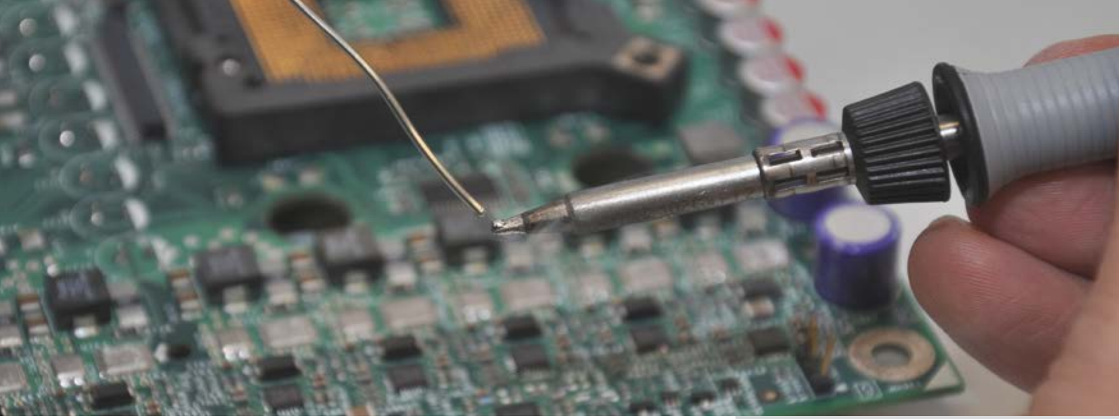

inspection systems, wave-, reflow- and selective soldering systems. The line of Ersa screen printers complements the product range.

Ersa's quality soldering tools are used in the hobby area, such as, for example, in model-making or tiffany soldering, in the craft sector, in laboratories and in industrial electronics manufacturing.

New challenges for the soldering technology were raised by the ban on certain hazardous substances (RoHS) in 2006. Since 1 July 2006 electric and electronic equipment may not contain any lead, mercury, hexavalent chromium, PBB (Polybrominated biphenyls) or PBDE (Polybrominated diphenyl ethers).

In many cases this restriction entailed having to depart from the use of the well-known soft solders based on tin and lead.

By publication of this small primer, Ersa would like to facilitate your entry into the "World of Soldering", and raise your enthusiasm for a modern technology with a long history.

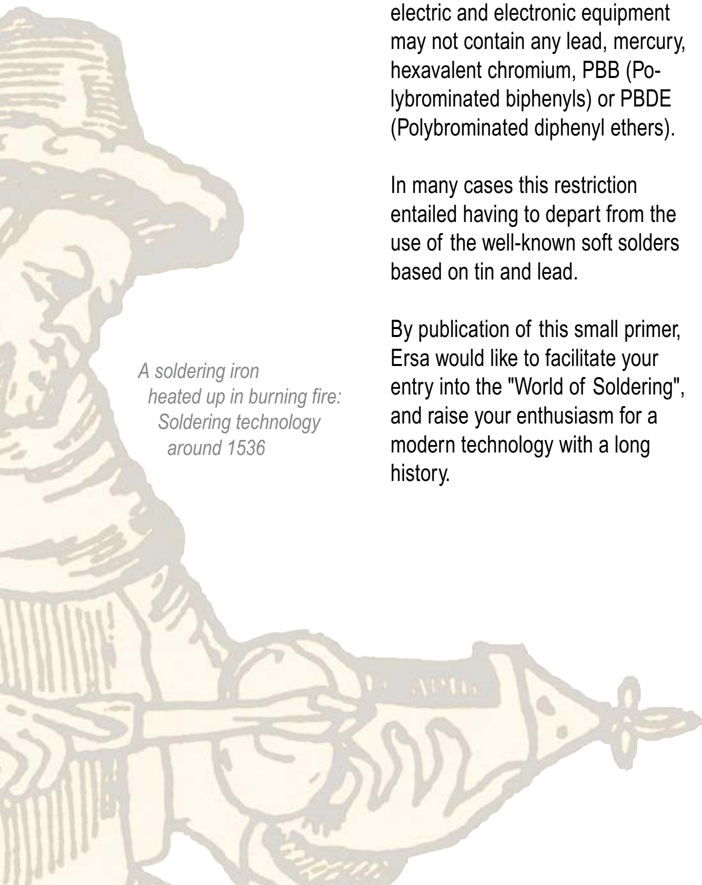

A soldering iron heated up in burning fire: Soldering technology around 1536

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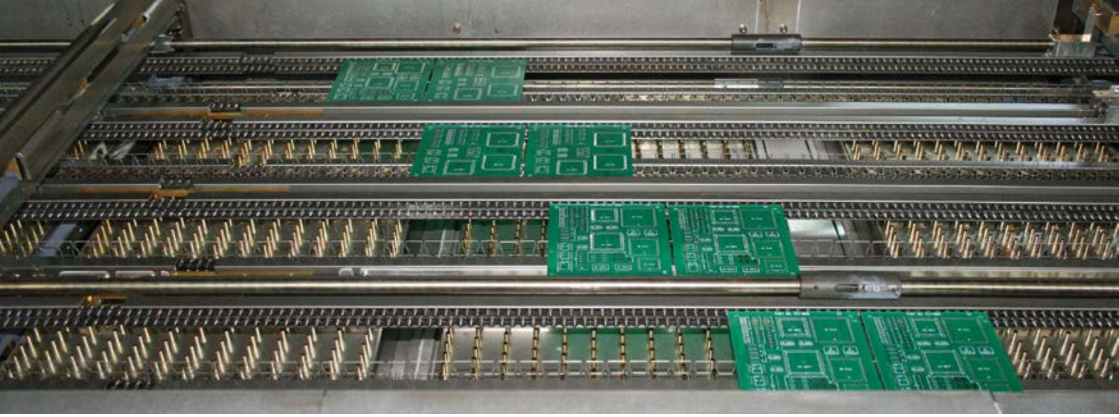

Solder joints hold the world together

Connecting pacemakers and solar parks

To imagine today's world without soft soldering is not possible. It is the means to fabricate safely functioning, electrically conducting connections. Regardless of whether we talk about power technology, drive technology, telecommunications, automation or electronic controls – in all those fields soldered connections have a decisive share that everything functions in a way as has been foreseen and planned by the developers and visionaries of the products. Today, soft soldering is such a common place occurrence, that no one wastes any further thought on it. We take the daily use of our computers, mobile phones and play stations for granted, the modern comforts provided for by electronics found in modern automobiles is expected as a matter of course, and we fly – privately or on business – to the farthest spots in the world.

Consequential damage because of the failure of a solder joint in an iPod is relatively limited. It is a different matter altogether, though, if the electronics in an airplane full of vacationers, in a space shuttle, or in an implanted pacemaker fails. Such failures are immanently life-threatening. But not to worry – the highest quality demands apply for those applications, and rightfully so!

Aside from soldering in consumer electronic products, there are numerous other applications such as, to name but a few, alternative power generation with wind turbines or solar parks, R&D departments and in work performed by craftsmen such as electricians and plumbers. Let us not forget the many part-time and hobby users for whom there are no limits curtailing their phantasies and artistic freedom when handling a soldering iron and solder.

The art of soldering

What's behind it?

In a soldering process two metal parts are joined by means of a molten metallic bonding agent (solder), whereby the melting point of the bonding agent is always lower than that of the metal parts to be joined. If the melting point is below 450 °C, then it is a soft soldering process, if it is above, it is called hard soldering or brazing. Welding, on the other hand, is the process where two metals will be heated up to their melting point, at which time they will, together with a filler material, form a pool of molten material causing coalescence. In soft soldering, the seams between the metals to be joined will be filled with a tin alloy. It is important that the alloy does not simply stick to the foreign metals' surface after cooling but unites with the metal. For this purpose, a small quantity of the foreign metals must dissolve and unite with the tin alloy forming a mix of crystals – the so called diffusion zone. That is the task of the tin, whereas the alloy's other components are responsible for the solder liquefaction and the joint's mechanical stability. A solder joint consists of the following layers:

① Base metal
② Diffusion zone
③ Solidified solder
② Diffusion zone
① Base metal

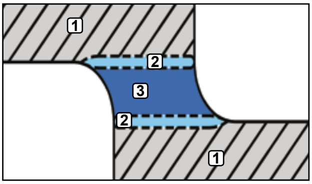

Cross section of a solder joint

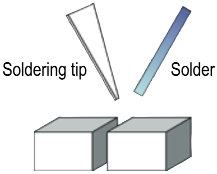

The prepared parts and the solder are heated

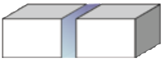

The liquid solder flows into the gap and fills it

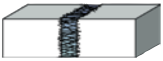

The solidified solder joins the parts together

To achieve the highest mechanical stability, i.e. to assure the durability of the solder joint, the diffusion zone may neither be too thick nor too thin. Its ideal thickness is 0.5 µm. The formation of the diffusion zone depends on the temperature, the solder time and the alloy used. If the diffusion zone is too thick, the solder joint will be brittle and porous, whereas the formation of a zone which is too thin indicates that an insufficient connection or no mechanical connection at all has been formed.

Reaction of the flux during manual soldering on a PCB using flux cored solder wire

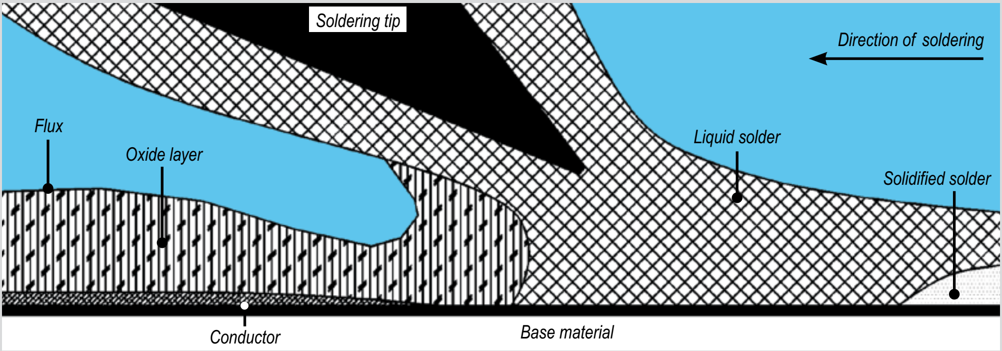

What do you need for soldering?

The basics – the 5 essential factors

1. The soldering iron

to provide the heat required

Heat is required to melt the solder. This is the soldering iron's job.

Temperatures of 200 °C – 450 °C are required depending on solder joint and solder alloy. In the field of electronics, the usual temperature lies between 250 °C and 375 °C.

In order to have the proper temperature for any soldering application, the soldering iron's thermal output and an efficient heat transfer to the solder joint to be made is decisive. One either selects a soldering iron that performs within the temperature range required, or a soldering station with temperature control is used. Temperature-controlled soldering stations enable the user to work on different applications without loss of solder joint quality, because of the precise control of the preset temperature at the soldering iron tip.

Both the soldering station's registration of the actual tip temperature should be highly precise, and the heating element should be powerful and recover quickly in order to avoid over-heated or cold solder joints.

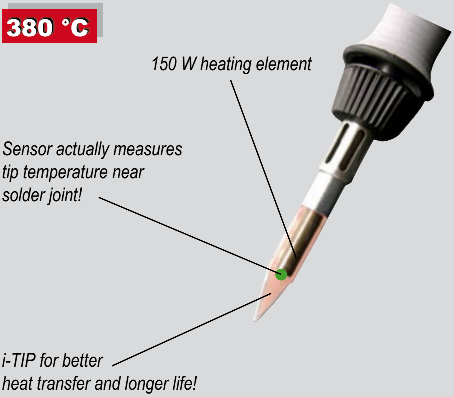
380 °C
150 W heating element
Sensor actually measures tip temperature near solder joint!
i-TIP for better heat transfer and longer life!

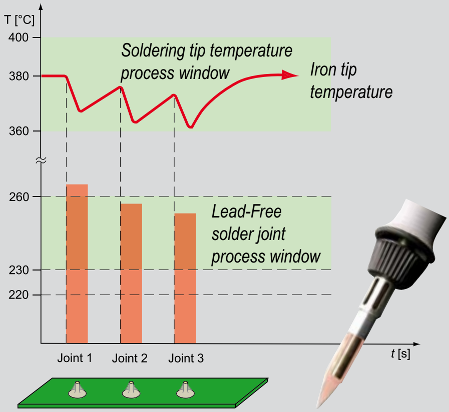

Temperature curve of controlled tip temperature when soldering multiple joints

2. The soldering tip

to transfer the heat from the heating element to the tip

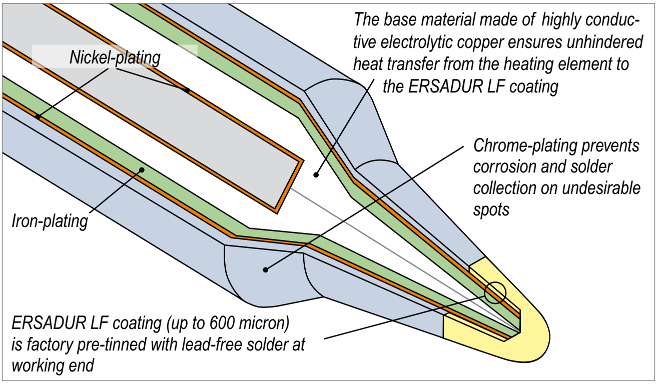
Nickel-plating
The base material made of highly conductive electrolytic copper ensures unhindered heat transfer from the heating element to the ERSADUR LF coating
Chrome-plating prevents corrosion and solder collection on undesirable spots
Iron-plating
ERSADUR LF coating (up to 600 micron) is factory pre-tinned with lead-free solder at working end

Cross-section of an ERSADUR soldering tip, non-scale representation

The soldering tip is the "heart" of the soldering iron and responsible for the heat transfer from the heating element via the solder to the solder joint. Depending on the soldering iron and the application, different types of tips are available. Prerequisites for good solder joints are the correct soldering iron tip shape, perfect heat transfer, a good condition of the tip and a reliable performance over time. In addition, the soldering tip has to convey also the necessary amount of sensitivity back to the operator.

How to take solder joint quality to its peak – ERSADUR long-life soldering tips

Traditional soldering tips are made of copper which conducts heat well and is inexpensive, but the tip oxidizes heavily when heated and releases copper particles into the solder until it has been "corroded" entirely. To maintain the tip in operational shape, it requires intensive care. Today, only coated soldering tips are used in electronics production – the largest field of application for soft soldering.

ERSADUR long-life tips have been conceived for continuous operation and for high-quality results. They are galvanically plated with an iron coating and protected against corrosion and oxidation by an additional chrome layer in a very special manufacturing process, developed and used exclusively by Ersa. And their perfect thermal conductivity protects the heating element from overheating and premature wear. Ersa offers a comprehensive range of soldering tips for the diverse requirements.

Proper tip care increases tip lifetime considerably:

- Never clean the long-life tip before putting the soldering iron into its holder, since the solder remaining on the tip prevents oxidation of the solder track.
- Always keep the long-life soldering tip covered with solder, as otherwise it becomes passive and will no longer wet properly.

Passive tips can be reactivated by the application of the lead- and halogen-free Ersa TIP REACTIVATOR. All that is needed is to wipe the hot tip on the surface of the regeneration compound. Furthermore, the hot tips should regularly be cleaned with a moist viscose sponge before soldering. Alternatively the tips can be dry cleaned using the Ersa "dry sponge", a sponge made of special metal wool. Dry cleaning has proven to be advantageous in lead-free soldering. The soldering tips are not cooled abruptly, and contaminated tips resulting from dirty sponges are avoided. Due to the slightly abrasive properties of the special wire mesh, passive layers that accumulated on the tip can easily be removed. Tip life is thus increased considerably in lead-free hand soldering.

Ersa TIP REACTIVATOR. A comprehensive range of accessories is available at ***www.ersa.com***

What do you need for soldering?

The basics – the 5 essential factors

3. The solder

for the connection

Metallic bonding agents (solders), mostly in the shape of a wire or a bar, are available as diverse alloys.

Soft solders consisted mostly of a mix of tin (Sn) and lead (Pb). Since the implementation of the RoHS directives on 01 July 2006 the use of solders containing lead is prohibited. Lead-free solders are usually alloys containing silver (Ag) and copper (Cu).

The alloy's composition determines melting temperature and physical properties of the joint. Criteria for the choice of an alloy are: production process, specification of the product, field of application, cost of the alloy.

Prerequisites for good soldering results are:

- Suitable soldering iron
- Clean surfaces of where to solder
- Sound soldering tip
- Suitable fluxes
- Suitable solder alloy
- Correct soldering time

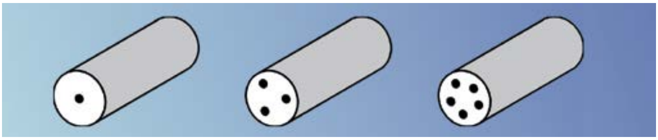

Solder wire with one or with multiple flux cores

4. The flux

for the ability to wet

Fluxes are used to attain the best possible bonding between solder and metal. They provide for metallically clean surfaces of the parts to be soldered, remove the oxides as well as other flow-inhibiting contaminations and prevent the formation of new oxides during the soldering process. A difference is made between acidic (as used in plumbing) and acid-free products (as used in electrical and electronic applications). It is most common to use solder wire with one or more flux cores in electronics production, whereas bar solder is the form of choice in plumbing as well as in the radiator and auto body work.

Examples of some common alloys

Alloy	Flux type	Melting point / range
L-Sn60Pb40	EN 29454/1.1.2 (F-SW 26/DIN 8511)	183 °C – 190 °C
L-Sn60Pb38Cu2	EN 29454/1.1.2 (F-SW 26/DIN 8511)	183 °C – 190 °C
L-Sn63Pb37	EN 29454/1.1.3 (F-SW 32/DIN 8511), free of halogen	183 °C eutectic
L-Sn62Pb36Ag2	EN 29454/1.1.3 (F-SW 32/DIN 8511), free of halogen	178 °C – 190 °C
Alloy – lead-free / complying RoHS-WEEE		
L-Sn95,5Ag3,8Cu0,7	EN 29454/1.1.2 (F-SW 26/DIN 8511)	217 °C eutectic
L-Sn96,5/Ag3,5	EN 29454/1.2.3 (F-SW 33/DIN 8511), free of halogen	221 °C eutectic
L-Sn99,3Cu0,7	EN 29454/1.2.3 (F-SW 33/DIN 8511), free of halogen	227 °C eutectic

5. A safe and clean working environment

to ensure quality and health

Safety first, especially while soldering. The VDE and GS emblems ensure the electrical safety of soldering equipment. The use of the VDE sign obligates the manufacturer to monitor production accordance with test guidelines and to conduct tests according to the regulations determined by the VDE testing institute.

Noxious gases develop in every soldering process

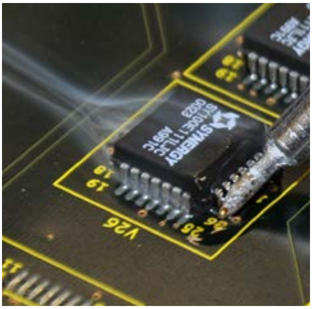

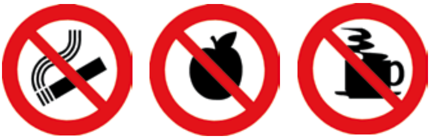

Health protection during soldering

- The breathing zone is very close to the soldering process during manual soldering, and the solder is added by hand. Thus there is the danger of contaminated air and hands or items which may have been touched
- Flux vapors can be damaging to the operator's health and should be kept out of the breathing area. Suitable devices for this purpose are solder fume extractions, which extract the smoke and associated vapors from the workplace and remove particles and gases. Modern fume extractions can be programmed to operate only when the soldering process is taking place, thus saving energy.
- One should never eat, drink or smoke in rooms where soldering is preformed. Contaminations which remain on the hands can enter the human organism through food or cigarette smoke.
- Hands should be washed thoroughly after soldering.

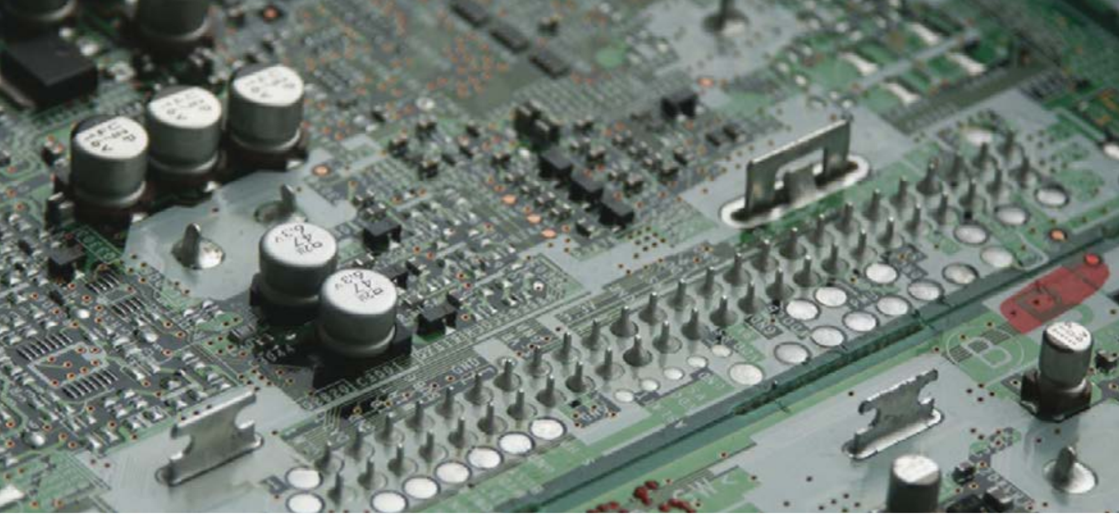

Best solder quality

due to the right preparation and correct soldering parameters

Preparation

The most important prerequisite for a good solder joint is absolute cleanliness. Conductor and component must be free of dirt, oil and oxides. They can be removed with solvents or flux.

Prior to soldering ERSADUR soldering tips should be cleaned while hot with a moist sponge or with a metallic dry sponge. Do not file the tip as you would copper tips, because this would damage the protective coating and render the tip unusable.

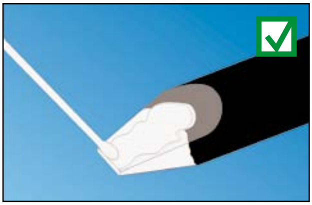

Wetting the soldering iron tip

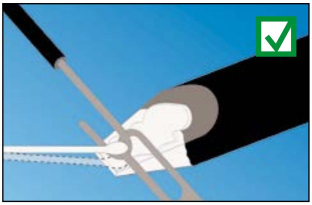

Soldering a joint

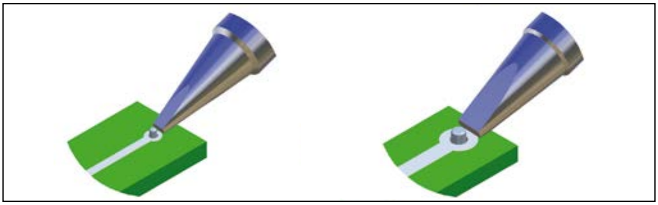

The selection of the right soldering tip is decisive for good soldering results

Soldering process

The soldering process has three phases: wetting, flowing, and bonding, whereas the working temperature is the most important criterion. It is best to work at the lowest temperature at which the three phases can progress smoothly. This requires some experience. A temperature-controlled soldering station will definitely facilitate this work. Place the tip on the joint to be soldered after cleaning and heat up the joint. Then feed the flux-cored solder wire between the soldering tip and the joint and melt as much solder as is required to wet the complete joint. Then remove the solder wire first and right after that the soldering tip to prevent overheating the solder. Allow the solder to solidify, avoiding any vibrations or jarring during this time.

Soldering time

The soldering process should be completed within 2 to maximum 5 seconds with a correctly dimensioned soldering tip. When soldering electronic components with lead-free solders, experience shows that more time is required. But even here requiring more than 5 seconds is not permissible, and it indicates that either the temperature setting is too low or the soldering iron lacks the necessary power.

30
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28

Solder joint quality

When the leads of the components mounted on the board are crimped, a good solder joint has been formed when the contour of the soldered lead is still visible. This will not be the case, if an excessive amount of solder has been used to form the joint.

A further quality attribute is the wetting angle. This consideration is based on the fact that good wetting of the pad, discernible through a small wetting angle, has given rise to the formation of a diffusion zone (intermetallic zone). Wetting angles of up to 25º identify a good joint, wetting angles of up to 50º are still tolerable in manual soldering.

Another quality indicator is what the solder surface actually looks like. It should be smooth and shiny, without any porous areas visible. Grainy surfaces indicate either overheating of the solder or an excessive soldering time. Using lead-free solders, especially silver loaded alloys, matt surfaces may form.

The only absolute quality indicator for a sound and strong solder joint is the formation of the diffusion zone. In the diffusion zone, intermetallic compounds of copper and tin are formed, whose presence is the final proof of quality (mixed crystals, see page 5). Unfortunately, the only way to make this zone visible is through a destructive test (sectioning of the joint). If the diffusion zone is too thick, the solder joints have no tensile strength and become brittle. The higher the soldering temperature and the longer the soldering duration, the thicker the diffusion zone will be. Therefore the joint should be made at the lowest suitable temperature and within shortest soldering times.

As soon as the last solder joint has been made, the soldering iron is placed securely into the holder. At this time, the tip should not be cleaned, because the remaining solder on the tip prevents oxidization.

Correct!

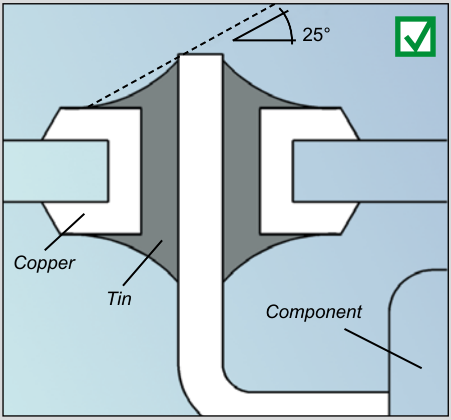

Wrong!

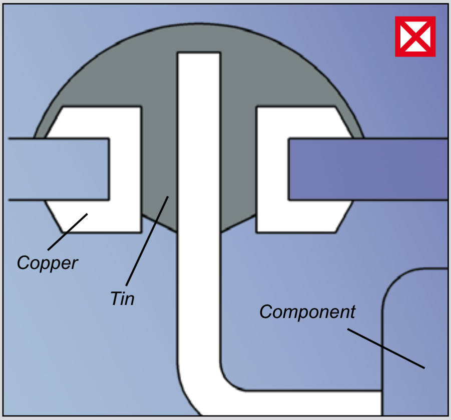

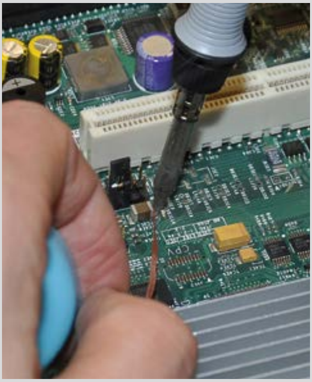

Desoldering with a solder wick

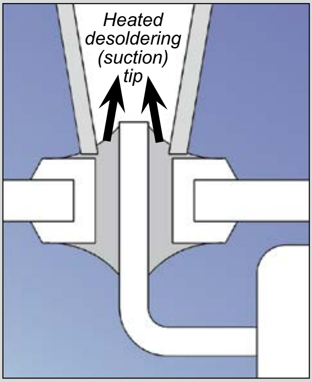

Desoldering with a temperature-controlled soldering iron

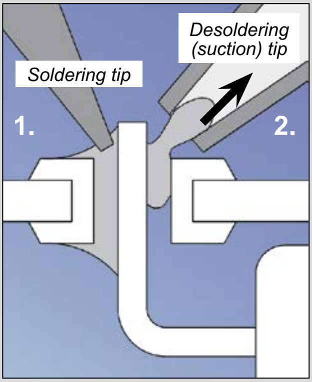

Desoldering with a desoldering pump

To achieve good results in desoldering, it is essential to select the right equipment. One can choose between desoldering wicks (desoldering using the principle of capillary action), mechanical desoldering pumps or electronically temperature-controlled desoldering systems. These are divided in desoldering systems with conductive heat or those with hot air.

Correct desoldering made easy

The right tool for each application

Desoldering

Reheating is not recommended for repairing a faulty solder joint. It is better to remove the solder and to resolder the joint. When using a desoldering pump, the solder joint has to be heated with the soldering iron until the solder has molten. Then the tip is removed and the desoldering pump is placed on the joint to extract the solder.

Using a heated desoldering tool, the hollow desoldering tip is placed on the joint to be repaired, making certain that there is good thermal contact. Once the solder has molten, it is extracted.

Desoldering is also dependent on proper tip selection. For example, the desoldering tip's inner diameter should be the same size as the diameter of the through-hole or even slightly larger (by max. 0.3 mm, see above drawing). The best desoldering results with least damage to PCB or the components can be achieved with temperature-controlled desoldering irons (also see pages 24/25). Please note that basically it has to be distinguished between the desoldering of through-hole components and the desoldering of SMD components.

Temperature-controlled desoldering iron

Sucking up the old, molten solder remnants with a mechanical solder sucker (desoldering pump)

Ever smaller, ever finer

SMD technology, a true challenge

SMD Soldering

SMD technology (Surface Mount Device Technology) is currently the standard process in electronics manufacturing. Ever smaller and highly integrated surface mount components place growing demands on SMD soldering equipment.

Single solder joints, for example on resistors, are made with ERSADUR long-life soldering tips starting with a diameter of 0.2 mm. Fine-pitch connections with a high pin-out, i.e. IC's, are most efficiently soldered with Ersa PowerWell soldering tips.

Ersa PowerWell technology for soldering fine pitch components within seconds

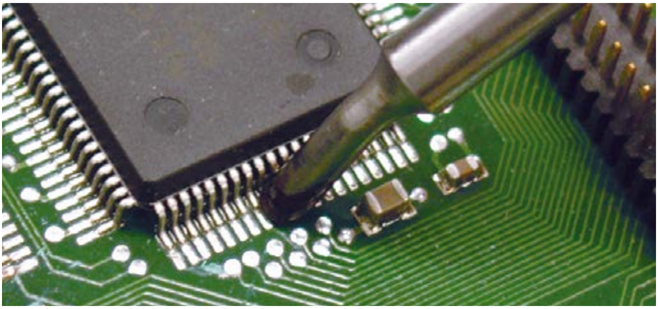

Some examples of SMD components →

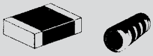

C.CAPAC./MELF

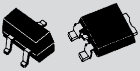

SOT&DPAK

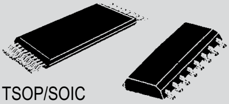

TSOP/SOIC

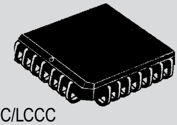

PLCC/LCCC

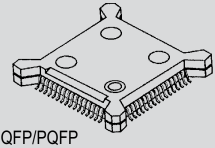

BQFP/PQFP

Soldering fine-pitch components

Process guide description

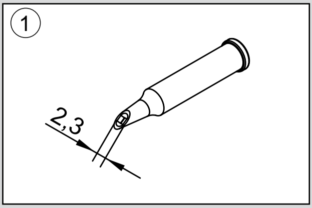

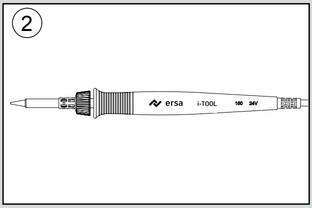

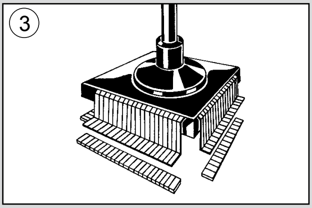

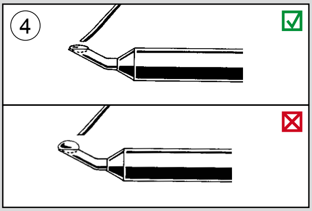

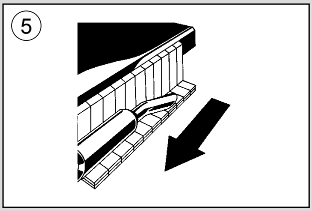

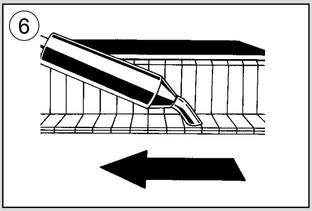

At first glance, soldering fine-pitch components by hand seems to be a tough job. Yet it is easy, with the right equipment at hand:

Insert an Ersa PowerWell i-TIP (1) into the i-TOOL soldering iron (2) and set a tip temperature of 285 °C to 360 °C (depending on the alloy used – tin/lead or lead-free).

Then position the component (3) and fix two corner pins.

Add flux cream (also see page 30) to the pins on all 4 sides. Clean the front and concave portion of the PowerWell tip with a damp sponge or the Ersa dry sponge.

Fill the concave portion with solder to slightly above the rim by melting the solder wire, until a small dome occurs (4). Take care not to add too much solder.

Place the i-TOOL lightly on the flat section of the pins (5), and pull the tip across the pins towards you (6) without exercising pressure.

Repeat steps (4) to (6) to solder the remaining sides.

Good solder joint, sufficient solder and good fillet

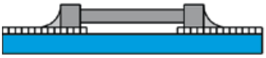

Wrong: insufficient solder

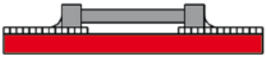

Wrong: too much solder

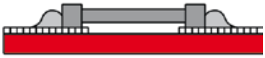

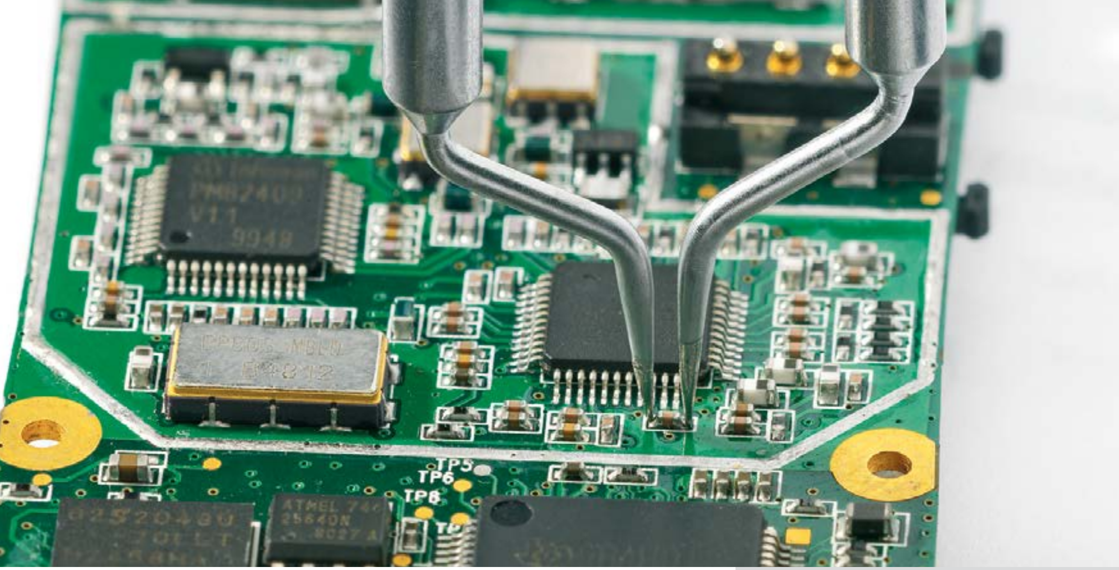

SMD desoldering in 3 seconds – with the Ersa desoldering tweezers

Some examples of different desoldering tip shapes: →

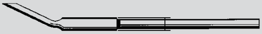

to desolder and remove MELF's

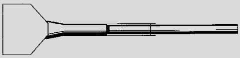

to desolder and remove SOIC's

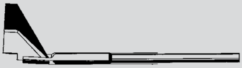

to desolder and remove QFP and PLCC components

SMD Desoldering

To desolder or rework a damaged SMD component, the suitable tools are required to remove the component from the board. When using desoldering tweezers, it is extremely important to select the proper pair of desoldering tips. After having desoldered the component, the pad has to be cleared of the residual solder (e. g. with a suitable soldering tip and a no-clean desoldering wick). Afterwards the new component can be positioned and soldered. An optional IR heating plate is a very useful addition – particularly in lead-free hand soldering applications.

More comprehensive instructions on SMD desoldering is available in the process description "SMD desoldering" on our website at www.ersa.com. For the soldering and desoldering of BGAs or other high pin-out SMDs, particularly those with hidden joints, we recommend the semi-automatic Ersa rework stations (see page 31).

Solder melting and removal with a desoldering wick

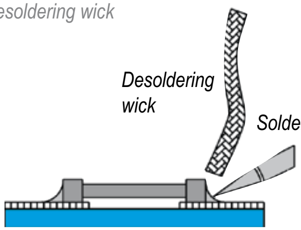

Ersa desoldering tweezers

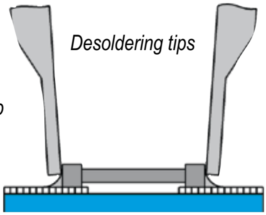

The compact CHIP TOOL VARIO desoldering tweezers are perfect for precise desoldering of very small SMDs.

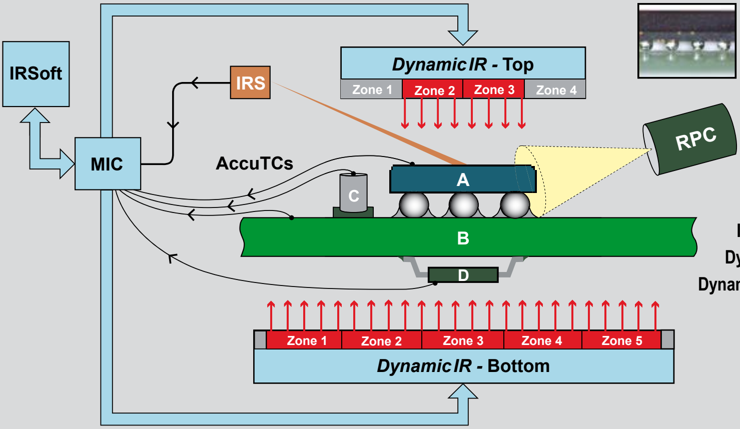

A:	Component for rework
B:	PCB
C:	Adjacent component (top side)
D:	Adjacent component (bottom side)
AccuTCs:	Thermocouples (4 each)
IntelligentIRS:	Non-contact infrared sensor
DynamicIR Top:	Top IR radiator (4 zones)
DynamicIR Bottom:	Bottom IR radiator (5 zones)
RPC:	Reflow Process Camera
IRSoft:	Control & documentation software
MIC:	Microprocessor controls the DynamicIR heating system

Principle of a rework station

Rework or repair soldering

The rework process demonstrated on the example of a BGA (Ball Grid Array)

Rework designates the repair or touch-up of electronic components such as Ball Grid Arrays (BGAs) or SMTs. This chapter describes the process steps for BGA rework:

1. Desoldering the BGA

The rework station heats the printed circuit board from the bottom, whereas the BGA body itself is heated from the top.

The real-time temperature of the component controls the pre-set temperature curve so that all solder joints melt at the same time. Then the vacuum suction cup is placed on the BGA and once all joints have molten the BGA is lifted off.

2. Removal of residual solder, cleaning

Solder remaining on the pads is removed with a soldering iron. To do so the residual solder is coated with flux. Then a flat soldering tip (e. g. 0102ADLF40 or 0102ZDLF150) is moved over the pad without applying any force. The solder adheres to the larger surface area of the tip, thereby levelling off the remaining solder of the connection pads. Flux residues are finally cleaned off (e. g. using Ersa FLUX-REMOVER).

3. Reballing – Reusing the BGA

Desoldered BGA's can be refit with new solder balls and re-attached to the board. This process is referred to as reballing. Residual solder is removed from the BGA by means of a soldering station. Lying on its back, the component is coated with flux first. Then the new solder balls are attached, for example by means of a stencil. These solder balls are heated up to the melting point with the rework station to firmly connect with the BGA body. Now the BGA is ready to be re-attached.

4. Application of flux or solder paste

The component and the connection pads are now fluxed, or, as the case may be, solder paste is added through stencil printing. The type of technique applied depends on the application, components and the skill level of the operators. For the commonly used PBGA's the application of flux is mostly sufficient.

5. Placing the component

Once the pad has been prepared, the component has to be placed. Since all solder joints of a BGA are hidden under the component body, a component placement unit is required. Successful visual placement by hand requires an operator with extensive experience and excellent skills. If the component is placed on solder paste deposits, great care has to be taken not to squash the solder depot, since doing so may lead to shorts after soldering.

6. Resoldering the BGA

The component is heated to the melting temperature of the solder alloy used via a controlled temperature curve. The heating continues until all solder joints have melted and remained so for some seconds. During this time durable and lasting solder joints are formed. After resoldering, the board is cooled in a similar fashion as had been done after desoldering.

These process steps are generally applicable for all surface mount components. Subject to the type of connections (wired, hidden) they may slightly vary.

Rework – Repair of high-terminal count IC's
to successfully repair SMT assemblies, the several points must be observed:

- Dimensions and properties of the assembly have an influence on its temperature requirement
- PCB holders and supports keep the assembly flat and prevent warpage
- A gentle and controlled heating process, continuously monitored, prevents damage of components or the board
- Accurate component placement is a prerequisite for a good soldering result
- Operators that are well trained will understand the process and ensure good results

Rework process steps

1. Remove BGA

2. Remove residual solder from the pads of the board

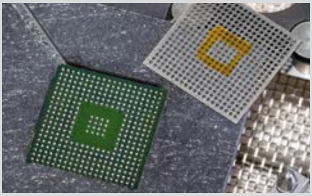
3. Reballing – addion of new solder balls

4. Application of flux or solder paste

5. Placement of the new or reballed component

6. Resolder the BGA on the prepared surfaces of the board

Miniature soldering iron

Ersa MINOR S

MINOR S, 5 W

Ersa MINOR S (5 W), a featherweight at 6 g for ultrafine soldering applications

The **MINOR S** miniature soldering iron with a rating of 5 W and a maximum tip temperature of 440 °C is an ideal tool for ultrafine soldering applications on micro IC's and under a microscope. It can either operate with a 6 V transformer or a 6 V battery.

Besides electronics the MINOR S can also be used in watch repair, in the photographic industry and in dental technology.

Micro soldering irons

Ersa MULTITIP Series

MULTITIP series, 15/25 W

Ersa MULTITIP (15/25 W) internally heated soldering iron for small to medium solder joints

The **MULTITIP** soldering irons are especially short, light and easy-to-handle soldering irons with minimal distance between soldering tip and the handle's front part. They are ideally suited for small solder joints. Its internally heated soldering tip provides an enhanced degree of efficiency.

The MULTITIP is available for 15 W and 25 W which makes it suitable for micro soldering joints and medium-sized joints, as for example, on distributor strips or in the hobby sector.

Universal soldering iron

ERSA 30 S, MULTI-PRO, ERSA 15+ and ERSA 25+

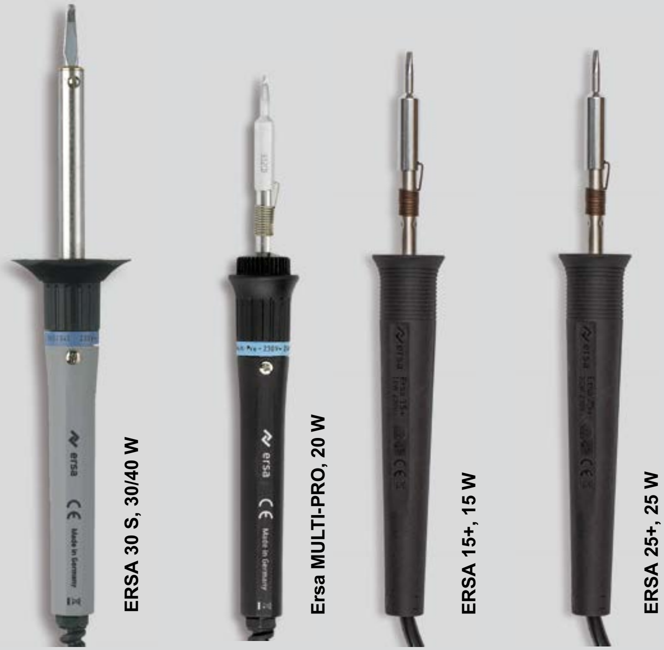

The proven **ERSA 30 S,** available with a 30 or 40 W rating, is a very robust and durable soldering iron. Its improved ergonomics is further enhanced by the practical stick-on rubber support disk. This universal soldering iron is designed for multi-purpose use in the crafts, service and hobby sector.

The **MULTI-PRO** with its heat-resistant power supply cord is extremely flexible, as it can be operated with a wide range of different tips. Therefore, it is suitable for almost all conventional soldering applications.

The **ERSA 15+** universal soldering iron is the ideal tool for cost-effective soldering. Internally heated soldering tips guarantee an outstanding performance. The ERSA 15+ can be operated with diverse fine tips of the 832 and 842 tip series. Its ergonomic handle assists in the safe processing of fine soldering joints.

The **ERSA 25+** is perfect for soldering applications with increased heat requirements. The internally heated, larger soldering tips of the 832 and 842 tip series ensure good heat transfer at a high thermal performance. The ergonomic handle provides a safe grip for every soldering application.

Ersa universal soldering irons – for almost all applications

Standard and hammer soldering irons

ERSA 50 S, 80 S and 150 S / ERSA 200, 300 and 550

ERSA 50 S, 80 S, 150 S, 50/80/150 W

ERSA 200/300, 200/300 W

ERSA 550, 550 W

The **ERSA 50 S/80 S** or **150 S** series is designed for applications where a large amount of heating capacity is required, as, for example, on copper conductors with cross-sections of 2.5 mm to 6 mm.

The **ERSA 200, 300** and **550** hammer soldering iron series are particularly suited for sheet metal processing and installation work and for soldering commutators and copper bus bars.
Hammer soldering irons have also proven their merit in leveling applications during body work and lead glazing.

High-speed soldering iron

Ersa MULTI-SPRINT

The **Ersa MULTI-SPRINT** is an ergonomically designed and extremely light-weight, pistol-type soldering iron with up to 150 W power which does not require a transformer. Its PTC heating element, together with the internally heated ERSADUR long-life soldering tip, ensures its exceptionally high efficiency. Due to its very short heat-up time, it is ideally suited for making quick single soldering joints. The MULTI-SPRINT is powered only as long as the button is pressed. Depending on the heat requirement of the solder joint to be made, additional energy can be supplied by periodically pressing the button. The large variety of soldering tips of the 832 / 842 series make the MULTI-SPRINT suitable for more than only the use in repair and service applications.

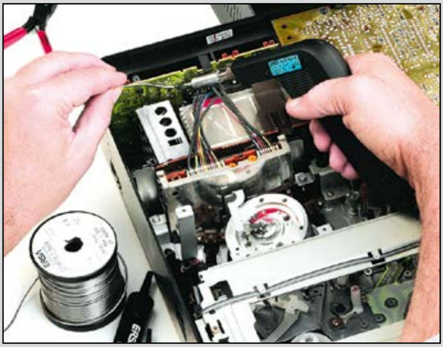

Ersa MULTI-SPRINT, 150/75 W

Power soldering iron

Ersa MULTI-TC and PTC 70

Ersa MULTI-TC, 75 W

Ersa PTC 70, 75 W

The **MULTI-TC** and **PTC 70** are powerful and robust, temperature-controlled soldering irons. Both tools offer an outstanding heat-up rating.

Due to their high thermal performance, and because of the large selection of soldering tips, the MULTI-TC and PTC 70 are suitable for fine soldering joints in electronics as well as for joints with medium heat requirements. The MULTI-TC is furthermore also used anywhere else where standard irons with 150 W power are in use, including, for example, lead glass and Tiffany soldering.

Gas soldering irons

Ersa INDEPENDENT 75 and INDEPENDENT 130

Ersa INDEPENDENT 75, 15 – 75 W

Ersa INDEPENDENT 130, 25 – 130 W

Ersa gas soldering irons are fueled with commercially available lighter gas and are fired up through the piezo ignition. Compared with electrical soldering irons, the **INDEPENDENT 75** has between 15 – 75 W, and the **INDEPENDENT 130** between 25 – 130 W performance. Both irons are available in the BASIC-SET and PROFI-SET versions.

Aside from handling the usual types of electronic components, the selection of tips available enables the INDEPENDENT to also handle SMD soldering, micro-welding, forming and cutting of synthetic materials and the processing of shrink sleeves.

The basic soldering station

Ersa ANALOG 60

The electronically temperature-controlled ANALOG 60 is Ersa's basic soldering station model. It has the tried and proven RESISTRONIC temperature control technology with the PTC heating element serving as the temperature sensor. The high heat-up rating of 190 W guarantees the immediate supply of heat and a heat-up from room temperature to 280 ºC within 60 seconds. The BASIC TOOL 60 soldering iron uses the internally heated ERSADUR long-life soldering tips of the 832/842 series and provides very high performance.

Due to the wide range of 832/842 soldering tips, the Ersa ANALOG 60, which is also available as an antistatic version, covers a wide range of applications with the most varied soldering requirements.

Digital soldering station

Ersa RDS 80 – high performance for low cost

The digital soldering station Ersa **RDS 80** offers the proven and tested Ersa RESISTRONIC temperature control technology with a strong heating power of 80 W. The ceramic PTC heating element (Positive Temperature Coefficient) acts as the temperature sensor in this control system. Due to its very high ramp-up capability of up to 190 W, the station reaches operating temperature very fast.

RT 80: sleek soldering iron with a large selection of soldering tips

RT 80 24V 80W
ersa

Multifunctional soldering stations

Ersa i-CON NANO and i-CON PICO – small, powerful and versatile

ersa
i-CON NANO
250 350 450
250°C

The soldering stations **i-CON NANO** and **i-CON PICO**, two models of the i-CON product family, fulfill all the needs of today's electronics manufacturing while requiring minimal space. They are designed for continuous operation in the electronic manufacturing environment as well as for special applications in laboratories and R&D departments.

Due to the simple and user-friendly operating concept, the factory settings provide for a variable adjustment of operating temperature as well as the setting of stand-by time and calibration value.

Further adjustments such as fixed temperatures, power level, interlock and shutdown functions are available with the free PC software and an optionally available micro smart SD card.

Verbatim
micro SD
Adapter
LogiLink

Micro-SD card with SD-card and USB adapter

The concept of the Ersa i-CON stations ensures that each application is processed with the optimal parameters. They stand for the highest level of process safety and quality control at low investment and operating cost.

Ersa i-CON PICO

- Small footprint (145 x 80 mm) – saves valuable space
- Antistatic as per MIL-SPEC/ESA (only i-CON NANO)
- Three fixed temperature settings or continuously adjustable temperature settings from 150 °C to 450 °C
- Three selectable power levels
- Ultra-light and ergonomic soldering tool with max. 80 W power
- Wide range of low-cost exchangeable long-life soldering tips
- Automatic stand-by and sleep function for low energy consumption and longer tip life
- Password interlock for maximum process control
- Calibration function for a precise tip temperature
- Complete parameterization through PC software and Micro-SD card

High-end soldering and desoldering stations

The Ersa i-CON product family for highest productivity and process safety

Ersa *i*-CON2 with *i*-TOOL and CHIP TOOL

The stations of the i-CON product family are Ersa's innovative solution for intelligent manual soldering. The need to be able to cope with higher working temperatures and with progressively smaller process windows when working with lead-free solders, poses no problem whatsoever for the i-CON product family.

The i-CON is available as a single station or as double iron station. The single station **i-CON1** is delivered together with the i-TOOL soldering iron. The i-TOOL is extremely small, ultra-light and ergonomic. It is powered by a 150 W micro heating element, which realizes short heat-up times (within 9 seconds up to 350 ºC!) and rapid heat recovery.

The microprocessor which stores the temperature calibration of the iron is located in the PCB which is installed in the handle. This now allows for each individual i-TOOL to be calibrated independent of the soldering station.

In contrast to the concept followed by the cartridge-type soldering tips, only the tip itself is exchanged at the i-TOOL. The cost-intensive heating element remains.

The double iron soldering station **i-CON2** can be operated either with a second i-TOOL or with the SMD desoldering tweezers CHIP TOOL

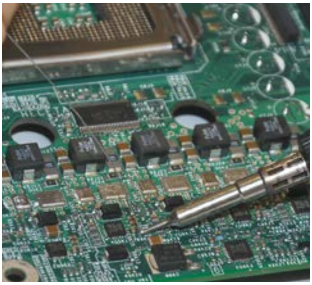

Soldering miniature and densely placed SMD components with the i-TOOL and i-TIPS, starting at a 0.2 mm diameter.

i-CON1 with i-TOOL soldering iron with high-performance micro heating element

- i-TOOL soldering iron with 150 W micro heating element technology
- Low-cost exchangeable long-life tips of the i-TIP series
- User friendly “One-Touch” operation
- Three power levels – no overshoot
- Process window and alarms
- Interface to control peripheral equipment on the workplace, such as heating plate and solder fume extraction systems
- Stand-by control for tools, heating plate and solder fume extraction system
- i-TOOL calibration
- Tools for SMT and conventional soldering applications
- Automatic tool recognition

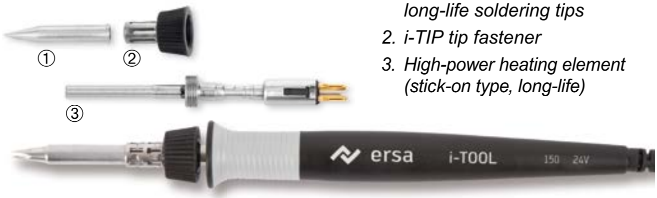

1. *Low-cost i-TIP long-life soldering tips*
2. *i-TIP tip fastener*
3. *High-power heating element (stick-on type, long-life)*

Ersa i-TOOL: The ideal soldering iron – ultra light (only 30 g), ultra short (only 155 mm), and ultra short tip-to-grip (only 45 mm) and extremely powerful.

respectively with the desoldering irons X-TOOL or X-TOOL VARIO.

The CHIP TOOL facilitates safe and quick desoldering, of the smallest chips up to large PLCC's. To remove the residual solder and to desolder wired components – also on multilayer boards – the X-TOOL or X-TOOL VARIO desoldering iron is the right tool.

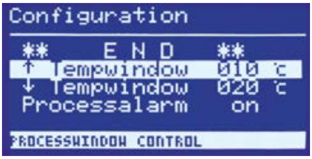

```
Configuration
 **      E N D      **
 ↑ Tempwindow    010 °C
 ↓ Tempwindow    020 °C
 Processalarm     on

PROCESSWINDOW CONTROL
```

User-friendly controls: quick programming & lock, huge multi-functional display with i-Op controls, menu in 7 languages, online help

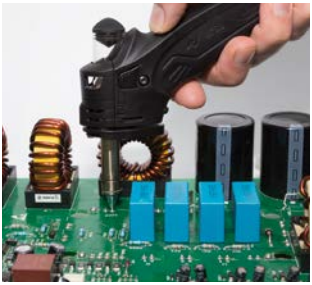

High-mass through-hole desoldering with the X-TOOL VARIO

The C-line of the i-CON stations was developed, so that peripheral equipment could be controlled or to communicate with them. Via a serial interface, the i-CON1 C or the i-CON2 C controls the Ersa IR heating plates or the Ersa solder fume extraction systems.

i-CON VARIO 4 multi-channel station with X-TOOL VARIO desoldering iron, i-TOOL soldering iron, i-TOOL AIR S hot-air iron and CHIP TOOL VARIO desoldering tweezers.

Top Tips

i-TIPS for all applications

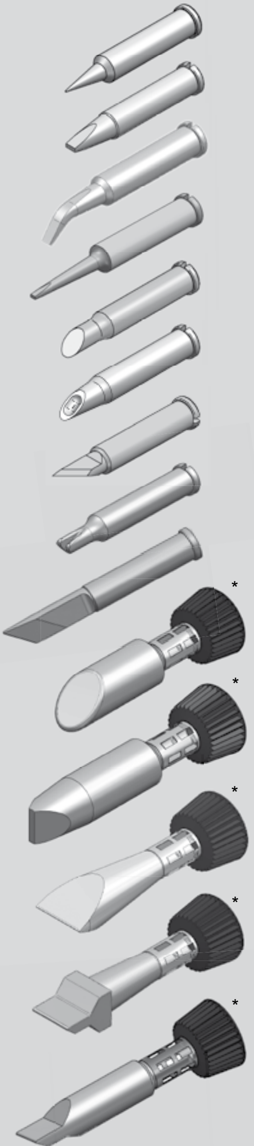

**Figure with i-TIP tip fastener*

Additional soldering tips for the i-TOOL and the i-CON soldering stations is available on our web site:
www.ersa.com

Hybrid Rework Station

Ersa HR 100 A – The innovative combination of hot air and infrared radiation

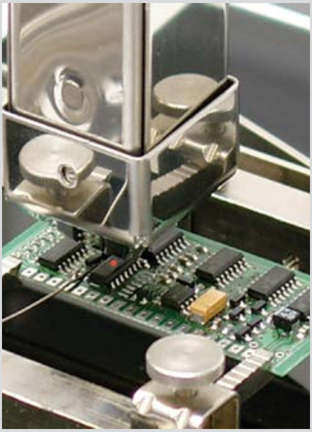

The Ersa **HR 100 A** applies the Ersa Hybrid Rework Technology for a safe desoldering and replacement of small SMD components. Its medium wave length IR radiation, combined with a safe stream of hot air ensures optimal heat transfer to the component.

The HYBRID TOOL offers a gentle and homogeneous warming of all sizes of components, from 0201 chips up to 20 x 20 mm SMD's and larger. Exchangeable hybrid adapters target the thermal energy available (up to 200 W) on to the component, all the while protecting neighboring areas and not blowing away or moving adjacent chips.

Its user-friendly handling permits even operators with little experience to safely and efficiently operate the HR 100. More experienced operators, on the other hand, can not only variably adjust the air flow as well as the heat output, but also record and run profiles. A positioning laser whose laser point makes it possible to keep track of the component worked on through the complete process is integrated in the grip of the ergonomic hybrid tool.

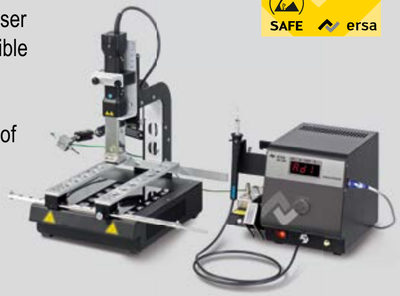

Complete system with HR 100 A, IR heating plate, stand for HYBRID TOOL and PCB holder.

- HYBRID TOOL with 200 W heating element, positioning laser integrated in grip
- 3 exchangeable hybrid adapters (6 x 6 mm, 10 x 10 mm and 20 x 20 mm)
- Silent rework fan (below 40 dB)
- Integrated vacuum pump and vacuum pen; tool holder and K-type thermocouple input socket; USB interface; LED display
- 2-channel temperature recording: TC & IRS; AccuTC and Flexpoint thermocouple holder
- Tool holder with z-axis height adjustment
- x-y PCB holder (290 mm x 250 mm)
- 800 W IR heating plate with glass cover: 125 mm x 125 mm IR high-performance heating element
- Rework profile and documentation software Ersa IRsoft

CLEAN-AIR solder fume extractions

Ersa EASY ARM 1 and EASY ARM 2 – protecting environment, health and resources

ersa
EASY ARM 1

Ersa EASY ARM 1

ersa
EASY ARM 2

Ersa EASY ARM 2

The Ersa **EASY ARM 1** is a compact yet powerful filter unit to efficiently clean the process air at the workplace. Both i-CON1 C, i-CON2 C and i-CON VARIO can be connected to the EASY ARM 1 with an interface cable. The solder fume extraction has three filtration levels to remove noxious gases.

With the solder fume extraction **EASY ARM 2**, Ersa offers the user a further compact and highly efficient fume extraction unit for either one or two workplaces. One or two units i-CON1 C / i-CON2 C / i-CON VARIO can be connected to the EASY ARM 2 via interface cable.

Both EASY ARM systems are provided with a stand-by mode and operate only when the soldering stations they are connected to are being used. The EASY ARM 1 and 2 are easy to install and can be placed very flexibly. Due to their very low noise level, they can be operated in virtually all environments, be it repair shops, development facilities or laboratories.

To accommodate different working conditions and applications, a variety of extraction arms and nozzle shapes which can easily and quickly be exchanged are available to meet different working conditions.

Noxious gases develop in every soldering process.

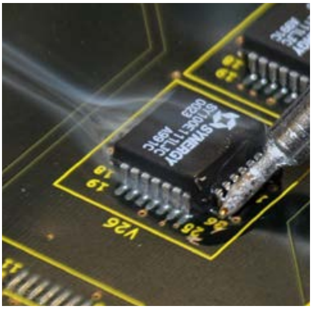

Q&A 2: How does that work? Active carbon in the filters absorbs harmful gas molecules; result: a clean working environment.

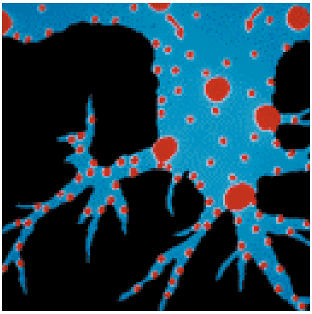

Q&A 1: So, how can you get rid of them? By using a solder fume extraction unit to clear the air from particles and gases.

Tiffany soldering

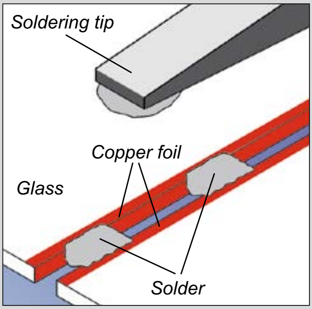
Soldering tip
Copper foil
Glass
Solder

Step 1: spot soldering

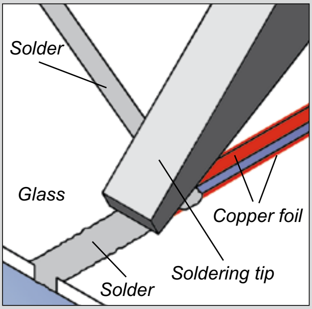
Solder
Glass
Copper foil
Soldering tip
Solder

Step 2: rough soldering

Tiffany or sheet metal soldering

Soldering beyond the field of electronics

Tiffany soldering (Lead glass soldering)

Soldering a Tiffany object generally involves three individual steps:

- Spot soldering
- Rough soldering
- Finishing

Prior to the actual soldering process, copper foil is glued on the glass edges. The next step is spot soldering, i. e. the glass parts are fastened or connected by taking a drop of solder with the tip of the soldering iron and carefully applying it to the solder joint. Each spot soldering operation should only take about a second. During rough soldering the gap between the glass is filled with solder after flux has been applied. For this purpose the tip and solder are moved together along the joint. Always drag the soldering iron, never push it. Only if this procedure is accurately followed, and if a sufficient amount of solder is applied, the desired, half-round and convex seams are achieved. The lack of visual quality of the seam at this stage is optimized during the finishing soldering step, in which the soldering tip is dragged slowly and from the beginning of the seam until the end at an even speed. The seam worked on should always lie flat on the bench.

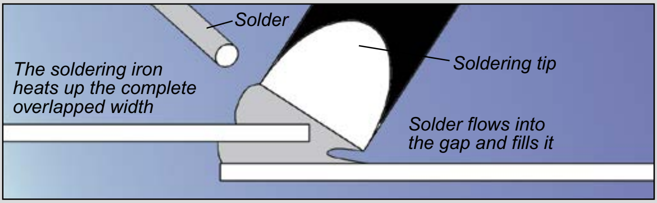
Solder
The soldering iron heats up the complete overlapped width
Soldering tip
Solder flows into the gap and fills it

Guiding the soldering iron when soldering a broad seam

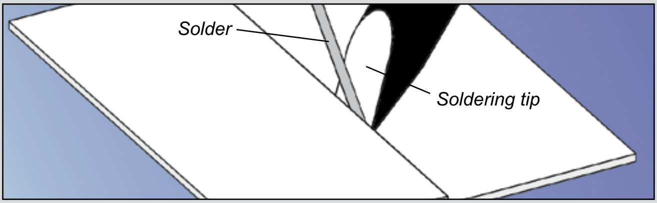
Solder
Soldering tip

Guiding the soldering iron when soldering a narrow seam

Plumbing and tinsmith work

For the joining of sheet metal and metal pipes, the joints to be soldered have to be bare. This calls for a good prior cleaning.

After this, the flux – either solder grease or solder fluid, a zinc chloride solution – is applied. Then the area to be soldered is heated with the tip of the soldering iron.

Once the soldering area is sufficiently hot, solder is added and the solder gap is filled.

The aggressive flux residues are removed after cooling to avoid the risk of future corrosion.

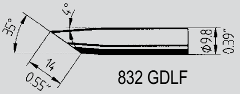

832 GDLF

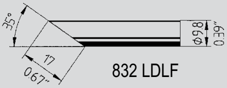

832 LDLF

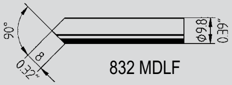

832 MDLF

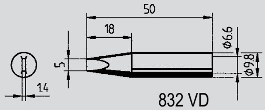

832 VD

ERSADUR Tiffany soldering tips

The types VD, GDLF, LDLF and MDLF of the comprehensive 832 tip series are particularly suited for Tiffany work. On account of their shapes and their high mass (excellent because of the ensuing heat retention capacity), the seams between the glass parts can quickly and easily be filled with solder. And the ERSADUR finish warrants a long tip lifetime.

ERSADUR Tiffany soldering tips

Ersa DIGITAL 2000A, Ersa MULTI-TC and ERSADUR soldering tips

Tiffany lamp

The **MULTI-TC** soldering iron is very light, robust and powerful. The Ersa SENSOTRONIC Control with the PT-1000 temperature sensor in the tip reacts immediately when heat is withdrawn.

The MULTI-TC is provided with a 2.2 mm wide, chisel-shaped soldering tip. Together with the Tiffany soldering tips, the slim MULTI-TC is superbly suited for the use in Tiffany work.

Due to its precise temperature control, the **DIGITAL 2000 A** soldering station completely eliminates the possibility to overheat any glass components or the copper foil, and the station has tremendous power reserves, making it comparable and putting it on an equal level with unregulated 150 W soldering irons.

The Ersa SENSOTRONIC control with its internally heated soldering tip, where the temperature sensor is mounted directly below the tip, provides for precise temperature control and ensures uniform temperature levels at the soldering joint.

Ersa MULTI-TC, 75 Watt

The long-life ceramic PTC heating element provides up to 290 W heat-up rating which means that the powerful soldering iron is ready for use in only 60 seconds.

The DIGITAL 2000 A is provided with a 2.2 mm wide, chisel-shaped soldering tip. Particularly good results are achieved with the optionally available tip versions 832 VD, 832 GDLF, 832 CDLF and 832 MDLF, which are specifically offered for Tiffany applications.

Ersa DIGITAL 2000 A with POWER TOOL

Ersa tool holders or stick-on rubber supports to safely and ergonomically put down the soldering iron during work stoppages or during heat-up.

Ersa viscose cleaning sponges for moist or special metal wool for dry cleaning of the hot soldering tip prior to the soldering process.

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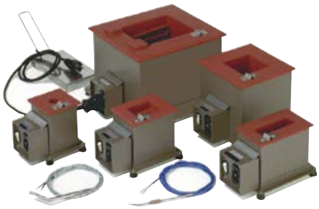

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Ersa SOLDAPULLT desoldering pump

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FLUX-REMOVER

Ersa FLUX-REMOVER

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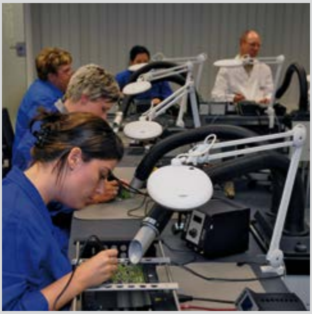

Today more than ever, cost-effective production and highest quality in the electronics manufacturing industry is the basis for profitable competitiveness. A key ingredient for being competitive is a well-qualified staff, which is up-to-date on current technology and process.

Ersa Know-How Seminars are ideal for transmitting this knowledge to those of your staff members with process responsibility in electronic manufacturing. In these seminars, theoretical and practical knowledge is presented in a neutral fashion in workshops and presentations by reputed experts in their field.

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Katalog
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Technical data and further detailed information on our range of hand soldering equipment is available in our "Soldering Tools" catalog. This is available in printed form and as PDF, as are the "Rework & Inspection" catalog.

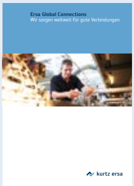

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Aside from the extensive selection of hand soldering tools, rework stations and inspection systems for non-destructive inspection, Ersa, as Europe's largest manufacturer of soldering systems, also offers a complete range of selective, wave and reflow soldering systems, as well as stencil printers for the industrial electronic manufacturing industry.

Please refer to our brochures and our website **www.ersa.com** for further information.

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Soldering Guide

Safety Precautions

- **Never touch the element or tip of the soldering iron.**
  They are very hot (about 400°C) and will give you a nasty burn.
- **Take great care to avoid touching the mains flex with the tip of the iron.**
  The iron should have a heatproof flex for extra protection. Ordinary plastic flex melts immediately if touched by a hot iron and there is a risk of burns and electric shock.
- **Always return the soldering iron to its stand when not in use.**
  Never put it down on your workbench, even for a moment!
- **Allow joints a minute or so to cool down before you touch them.**
- **Work in a well-ventilated area.**
  The smoke formed as you melt solder is mostly from the flux and quite irritating. Avoid breathing it by keeping you head to the side of, not above, your work.
- **Wash your hands after using solder.**
  Solder contains lead.

Treatment for minor burns

Most burns from soldering are likely to be minor and treatment is simple:

- **Immediately cool the affected area under gently running cold water.**
  Keep the burn in the cold water for at least 5 minutes (15 minutes is recommended). If ice is readily available this can be helpful too, but do not delay the initial cooling with cold water.
- **Do not apply any creams or ointments.**
  The burn will heal better without them. A dry dressing, such as a clean handkerchief, may be applied if you wish to protect the area from dirt.
- **Seek medical attention if the burn covers an area bigger than your hand.**

Preparing the soldering iron

- **Place the soldering iron in its stand and plug in.**
  The iron will take a few minutes to reach its operating temperature of about 400°C.
- **Dampen the sponge in the stand.**
  The best way to do this is to lift it out the stand and hold it under a cold tap for a moment, then squeeze to remove excess water. It should be damp, not dripping wet.
- **Wait a few minutes for the soldering iron to warm up.**
  You can check if it is ready by trying to melt a little solder on the tip.
- **Wipe the tip of the iron on the damp sponge.**
  This will clean the tip.
- **Melt a little solder on the tip of the iron.**
  This is called 'tinning' and it will help the heat to flow from the iron's tip to the joint. It only needs to be done when you plug in the iron, and occasionally while soldering if you need to wipe the tip clean on the sponge.
- **You are now ready to start soldering!**
  Please turn the page for further instructions...

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Making soldered joints

- **Hold the soldering iron like a pen, near the base of the handle.**
  Imagine you are going to write your name!
  Remember to never touch the hot element or tip.
- **Touch the soldering iron onto the joint to be made.**
  Make sure it touches both the component lead and the track.
  Hold the tip there for a few seconds and...
- **Feed a little solder onto the joint.**
  It should flow smoothly onto the lead and track to form a volcano shape as shown in the diagram below. Make sure you apply the solder to the joint, not the iron.
- **Remove the solder, then the iron, while keeping the joint still.**
  Allow the joint a few seconds to cool before you move the circuit board.
- **Inspect the joint closely.**
  It should look shiny and have a ‘volcano’ shape. If not, you will need to reheat it and feed in a little more solder. This time ensure that both the lead and track are heated fully before applying solder.

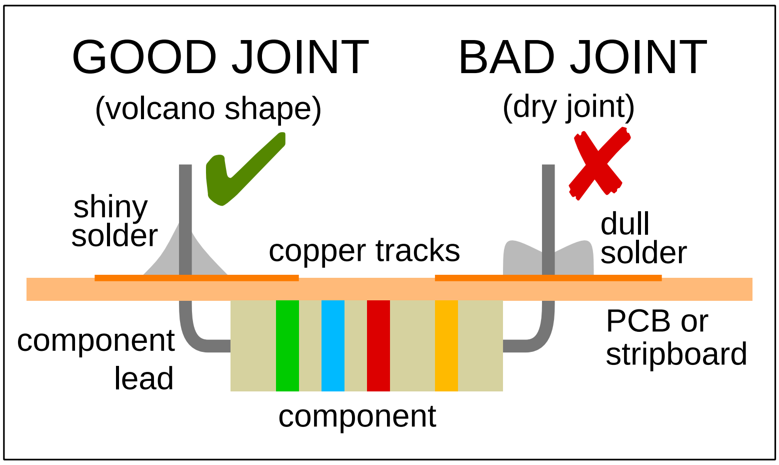

Using a heat sink

Some components, such as transistors, can be damaged by heat when soldering. It is wise to use a heat sink clipped to the lead between the joint and the component body, as shown in the picture. You can buy a special tool, but a standard crocodile clip works just as well and is cheaper!

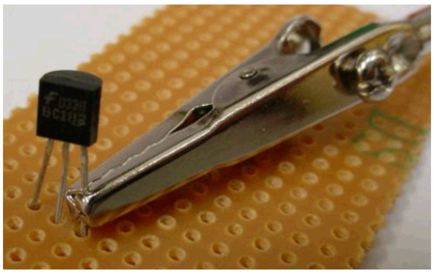

Soldering advice for components

Some components require special care when soldering. Many must be placed the correct way round and a few are easily damaged by the heat from soldering. Appropriate warnings are given in the table on the next page, together with other advice which may be useful when soldering.

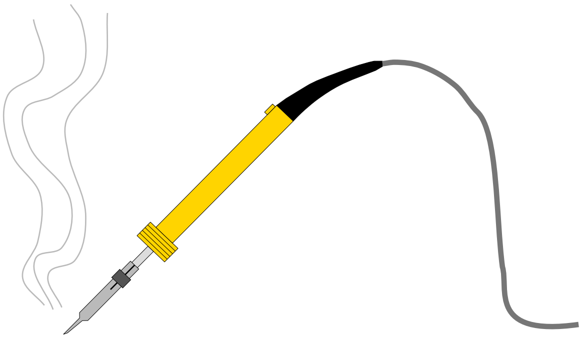

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Components	Pictures	Soldering advice
Resistors	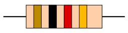	No special precautions are required. Connect either way round.
Diodes	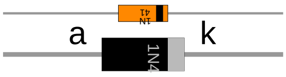	Diodes must be connected the correct way round: a = anode, k = cathode. Use a heat sink with germanium diodes.
IC holders (DIL sockets)	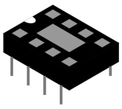	Ensure the notch is at the correct end. Do **not** insert the IC at this stage to prevent it being damaged by heat.
Presets (small variable resistors)		No special precautions are required. On stripboard take care to ensure you insert them the correct way round.
Capacitors, non-polarised (less than 1µF)	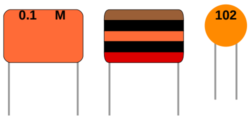	No special precautions are required. Connect either way round. Take care to identify their value.
Capacitors, electrolytic (1µF and greater)	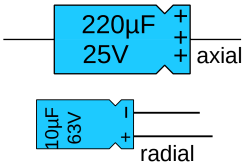 220µF 25V + axial 10µF 63V - + radial	Electrolytic capacitors must be connected the correct way round, they are marked with + or - near one lead.
LEDs (Light Emitting Diodes)	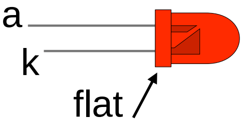	LEDs must be connected the correct way round: a = anode, k = cathode. Use a heat sink with small (3mm) LEDs.
Transistors	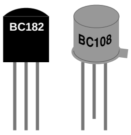	Transistors have three leads and must be connected the correct way round. Use a heat sink clipped to each lead in turn between the joint and the transistor.
Wire links between points on the board		Use tinned copper wire (such as the offcut from a resistor lead) or single-core plastic-coated wire.
Other parts mounted on the board		No special precautions are required for most parts, but make sure they are the correct way round.
Battery clips, buzzers and other parts with wires		Red (+) and black (-) wires must be connected the correct way round.
Wires to parts off the board such as switches		Use plastic-coated stranded wire which is flexible, single-core wire is likely to break at the joint.
Integrated Circuits (ICs or 'chips')	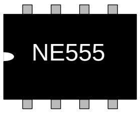	When all soldering is complete, carefully insert ICs the correct way round in their holders. Make sure all the pins are lined up before pushing in firmly.

For further information about electronic components please see: www.kpsec.freeuk.com

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Desoldering

At some stage you will probably need to desolder a joint to remove or re-position a wire or component. There are two ways to remove the solder:

1. With a desoldering pump (solder sucker)

- Set the pump by pushing the spring-loaded plunger down until it locks.
- Apply both the pump nozzle and the tip of your soldering iron to the joint.
- Wait a second or two for the solder to melt.
- Then press the button on the pump to release the plunger and suck the molten solder into the tool.
- Repeat if necessary to remove as much solder as possible.
- The pump will need emptying occasionally by unscrewing the nozzle.

2. With solder remover wick (copper braid)

- Apply both the end of the wick and the tip of your soldering iron to the joint.
- As the solder melts most of it will flow onto the wick, away from the joint.
- Remove the wick first, then the soldering iron.
- Cut off and discard the end of the wick coated with solder.

After removing most of the solder from the joint(s) you may be able to remove the wire or component lead straight away (allow a few seconds for it to cool). If the joint will not come apart easily apply your soldering iron to melt the remaining traces of solder at the same time as pulling the joint apart, taking care to avoid burning yourself.

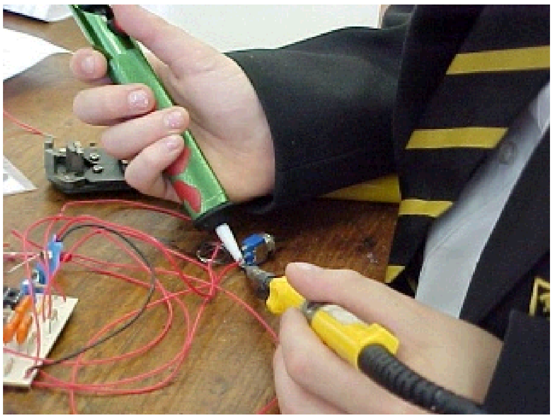

Using a desoldering pump (solder sucker)

What is solder?

Solder is an alloy (mixture) of tin and lead, typically 60% tin and 40% lead. It melts at a temperature of about 200°C. Coating a surface with solder is called ‘tinning’ because of the tin content of solder. Lead is poisonous and you should always wash your hands after using solder.

Solder for electronics use contains tiny cores of flux, like the wires inside a mains flex. The flux is corrosive, like an acid, and it cleans the metal surfaces as the solder melts. This is why you must melt the solder actually on the joint, not on the iron tip. Without flux most joints would fail because metals quickly oxidise and the solder itself will not flow properly onto a dirty, oxidised, metal surface.

The best size of solder for electronic circuit boards is 22swg (swg = standard wire gauge).

For plugs, component holders and other larger joints you may prefer to use 18swg solder.

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Safety Rules for Soldering

Department of Electrical, Computer and Biomedical Engineering, University of Rhode Island

1. Wear goggles for eye protection. When trimming off leads or excess solder dross, be careful of the flyaway that could injury yourself as well as other people nearby.
2. Work in a well-ventilated area and use a fume extractor. Do not inhale fumes from the soldering processes.
3. Always return the soldering iron to its stand when not in use. Never put it down on your workbench. The soldering iron tip is very hot (about 400°C). Avoid touching plastic, wire insulator, or any flammable material in the working area with the soldering iron. Turn the soldering station to standby or off if not used for more than few minutes. Turn unit off or unplug it when done.
4. Use a third hand, a circuit board vice, pliers, tweezers, or clamps for holding components to avoid burns. Legs and arms should be covered to avoid burns from splashed hot solder.
5. Do not have food or drink near the working area. The solder is usually a tin/lead alloy and lead is toxic. The flux is a chemical used to help metal parts soldered together. It is acidic and toxic. Clean up spilled flux immediately. Wash hands after soldering. Flux can cause acid burns to the skin or damage clothing. In case of acid burns, flush immediately with water.
6. Wash hands thoroughly after handling flux and solder containing lead. Use lead-free solder whenever possible.
7. Clean up the area when finished. Discard lead and silver solder and dross in a container with a lid. Label the container: "Lead/Silver Solder Waste for Recycling". Used solder sponges and contaminated rags must be disposed of as hazardous waste.

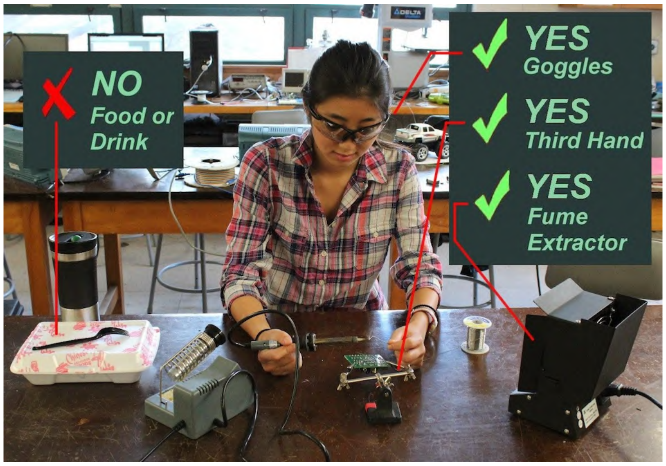

Soldering Techniques

1. Basic tools include an electric soldering station (a temperature-adjustable type preferred), solder, a pair of needle-nose pliers, a wire stripper, a flush cutter, a desoldering bulb, a utility blade, and a third hand or a vice.
2. Workspace should be as uncluttered as possible. Clear the path between the soldering station stand and the project to be soldered.
3. Prepare the soldering iron tip. Scrape off oxides with a utility blade if necessary. Adjust to an appropriate temperature. It won't work if you can't get the solder melt onto the soldering tip. Tinning the soldering tip by coating it with a thin coat of solder. This helps heat transfer between the tip and the components. The cleaning sponge should be soaking wet. Quickly run the soldering tip over the wet sponge to get rid of excess solder.
4. Clean the contact surfaces of the metal parts if necessary. Scrape off oxides with a utility blade. In some cases, it is easier to tin the individual components first before joining them.
5. Position the components using a third hand or a vice. Avoid holding the metal part of a component with your fingers.
6. Timing is important for soldering the components together. The solder needs to be completely melt at the joint to avoid a "cold solder point." However, too much heat could damage a sensitive electronic component or melt the insulator of a wire. The required time depends on the heat transfer, which is affected by the temperature of the soldering tip, the mass of the components, the presence of flux or rosin, and how clean the contact surfaces are.
7. Start over when an attempt fails. Old solder has impurities. Remove old solder completely with a desoldering bulb or pump. Clean up flux/rosin residuals. Try again.

Examples: www.leadsdirect.co.uk/technical/perfectsolderjoint.html

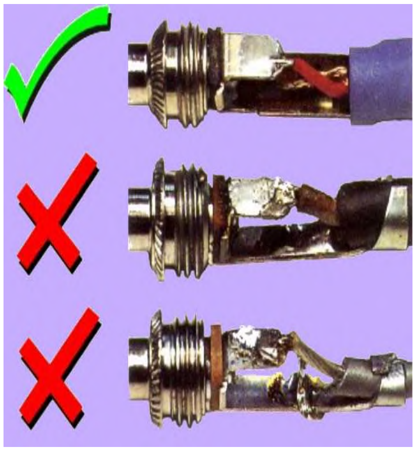

Good – clean, shiny, and just the right amount of solder.

Bad – too much solder which is uneven, has sharp points in places, and was probably overheated.

Worse – uneven texture, and the flux remaining on the joint.

Soldering

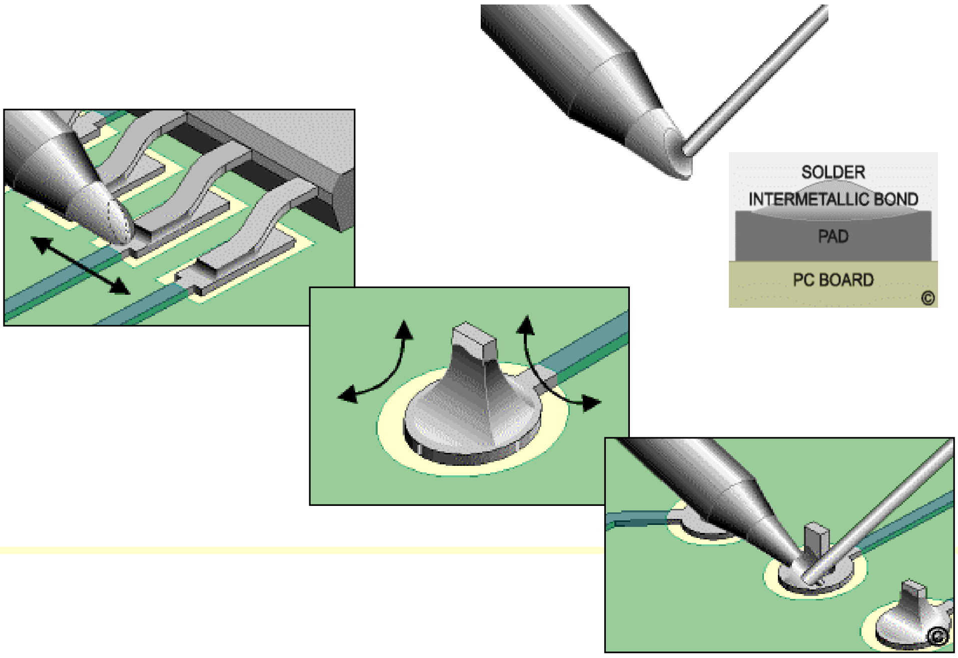
SOLDER
INTERMETALLIC BOND
PAD
PC BOARD
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SOLDERING

Theoretical background for technicians

1. Introduction :

Progress within the electronics industry would not have resulted in the mass production of electronic appliances as we know them today, without a similar progress in the field of soldering technology.

To be able to understand how soldering techniques are used in the electronics industry, we first have to get familiar with the materials used during the soldering process, and we have to learn how a soldering connection is created on a molecular level.

Soldering is an old technique for creating permanent electrical and mechanical connections between metals. In contrast to ordinary glueing, which makes only a physical connection between materials (although electrically conducting glue also exists) soldering causes a chemical reaction with other materials, creating a new alloy.

There are several soldering techniques, which all have a few things in common: basic metals, soldering flux, solder and heating.

2. Basic metals :

When we place electronic components on a PCB, the legs of the components and the soldering lands on the PCB, are the basic metals that will connect with the solder.
Several metals like copper, bronze, silver and some types of steel react with solder and make a strong chemical and physical connection.
Other materials like aluminium, titanium, etc. are difficult or even impossible to solder.
The fact that materials exist which can not be soldered is very important, as these materials can be used for making soldering machines and soldering irons. These materials can also be used for covering components during soldering.

There is a direct relationship between how strongly the surface of the basic metal oxidizes and how the soldering reacts on this: When there is more oxidation present, the soldering connection will be weaker.
The fact that most metals oxidize very quickly when heated, is a specific problem, because if one wants to obtain a chemical soldering reaction, a high temperature is necessary…
Flux is used to counteract this oxidation problem.

3. Soldering flux :

Although the soldering surface looks clean, there is always a thin layer of oxide on the metals. This layer always arises as soon as the metal is exposed to air. Reliable soldering connections can only be made on "clean" surfaces. "Clean" surfaces could be accomplished using cleaning product, but this would be insufficient as metal oxidizes incredibly fast when heated. To prevent the creation of the layer of oxide, the use of soldering flux is necessary.

Using soldering flux on the basic metals before the soldering starts has various reasons and advantages:

The main reason of the use of flux is to stop the oxidation of the basic metals during heating. The flux makes sure that the air can't reach the soldering surface, and therefore prevents the formation of oxidation during warming up.
Most of the different flux types have acid components which are used to remove the oxidation that is already present on the basic metal.
If a very strong acid is active in the flux, theoretically it would be possible to remove all the oxides. This however is in practice not possible, as the acid would also affect the PCB and the components, which of course is not the intention.

Therefore there will always be a search for the balance between a flux that contains strong acids, and as a consequence also removes the oxidates more effectively (but also affects the PCB), and a flux that contains a less strong acid and therefore removes less oxides. (but does not affect the PCB).

Most fluxes though use types of acid. Therefore it generally is necessary to remove the flux residues after soldering.

When solder is applied, the flux needs to flow off so that the solder can make direct contact with the basic metal. During this process it is however impossible to avoid the flux mixing with the solder.
Flux developers make use of this fact to develop a flux that has the property to reduce the surface tension of the solder on contact, as a result of which better "wetting" arises.

Flux consists of natural or synthetic resin and chemical additives, called activators.
In PEM a "no clean" flux of Tamura is used (for the placement of Flat-Package-IC's). Consequently it is not necessary to remove the flux after soldering.
Furthermore it is not necessary to add extra flux when doing easy manual soldering because the soldering wire contains flux (3.3 %), like a resin core.

4. Solder :

There several existing metals and metal alloys that can be used for soldering.
The choice for using a certain metal is based on the properties of the metal:
Is the metal flexible or fragile? How well does it conduct heat?
Does it expand rapidly when heated? What is the electrical resistance of the metal?
How strong is it? Is it toxic? And not unimportant: what does it cost?
Although it is not perfect, an alloy of tin and lead is most often used traditionally.
Pure tin melts at 203°C and pure lead melts at 330°C. A mixture of both metals has a lower melting point.
By using a different mixture the melting temperature of the soldering alloy can be changed.
A alloy of tin and lead (e.g. 60/40) has a relatively low melting point (183°C) and can be produced at a relatively low price, in comparison to other alloys with similar properties.
Lead is a very cheap and can be found in a lot of places. Therefore the cost of the tin-lead alloy is mainly determined by the cost of tin.

When this alloy is warmed up, it goes through several phases:
the alloy goes from a "fixed" condition, to a "paste" condition (semi-liquid), and finally becomes totally liquid. It is difficult to solder with an alloy that is in a "paste" condition: because there is little movement or vibration during this "paste" condition, this can cause bad soldering.
If the alloy is of 50% tin and 50 % lead, it starts to melt at a temperature of 193°C, and will be totally melted at a temperature of 216°C.

To prevent bad soldering during the "paste" condition, "eutectical" solder is used.
An "eutectical" alloy is an alloy that, when heated, goes immediately from a fixed condition to a liquid condition: the "paste" stage is effectively skipped.
An "eutectical" tin-lead alloy contains 63% tin and 37% lead.
Often a tin-lead alloy with 60% tin and 40% lead is used. This alloy can be produced cheaper than the eutectical solder because it contains less tin. But because this alloy is almost "eutectical", it can effectively be used for soldering.
During soldering, be careful to make no sudden movements whilst the solder is cooling.
This can cause "interrupted connections" and therefore unreliable soldering.
An "interrupted" soldering connection has a rough and irregular surface and appears dim instead of clear and shiny.
It is also very important that no impurities get into the solder.
If small metal particles from the components get into the soldering "cup" of the soldering machine.
This can result in a serious change to surface tension, and consequently bad soldering connections.
These metal impurities could even change the melting temperature of the solder.

5. Heat, generation of soldering connection

If the solder gets in contact with a copper surface, the solder dissolves and penetrates the copper layer. The molecules of the solder and the copper get mixed and a new alloy is created, consisting partially of copper and partially of solder. This reaction is called "wetting" and has as a result an "inter-metallic" connection between the components. "Wetting" can only take place if the surface of the copper does not contain oxides. The solder and the surface of the copper also have to be at the right temperature before the "wetting" can take place.

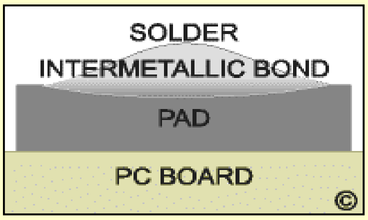

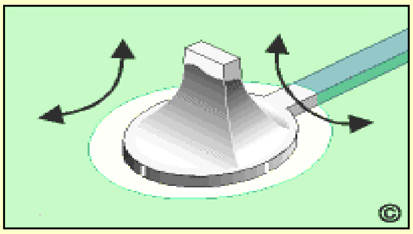

6. Soldering with a soldering iron:

The following 4 factors determine the quality of the soldering connection:

- clean surfaces
- temperature
- time
- quantity of solder

a) Clean surfaces:

"dirt is the enemy of a good soldering connection!"

It is enormously important that there are no impurities on all of the components (including the soldering bit). Soldering on "dirty" components is not possible! Old PCB's or components sometimes can not be soldered due to a large layer of oxide on the islands and the legs of the components. In such cases the solder is rejected and goes to everywhere, except for where we want it to go. In a desperate attempt to solder in such a situation, a common reaction is to raise the soldering temperature. However, this is certainly not a solution. On the contrary! The only correct solution is thorough cleaning. (e.g. with a brush of glass fibre)

Before the soldering iron can be used, the soldering bit first has to be coated with tin. Some solder has to be melted onto the bit. Afterwards the bit has to be cleaned. For cleaning the soldering bit, it is best is to use a slightly moistened sponge (with demineralized water). The use of ordinary tap water is not reccomended, because the silver layer on the bit gets affected by calcium in the tap water, which results in less thermal contact. This diminished thermal contact runs the risk of cold soldering, etc. To improve the thermal contact between the bit and the soldering surface, it is advisable to coat the soldering bit with a little bit of solder before every soldering action.

b) Temperature & time :

The temperature of the soldering bit is not the most determining factor for successful soldering: the heating cycle (combination of temperature of the bit and the time the heating takes) is! How fast the soldering components warm up, how warm they get and how long they stay warm, are the most important factors that have to be controlled to make a reliable soldering connection.

The time soldering takes is very important. A soldering task may only take a couple of seconds: when heated too long, the components and the soldering lands can be damaged.

It is also totally wrong to use the soldering bit to rub melted solder across the soldering surface.

Although the temperature of the bit is not the most determining factor, it is advisable to to do soldering at the lowest possible temperature.

The first that has to be examined before the soldering starts in the 'thermal mass" of the components.

Every soldering task has its own specific "thermal mass" which is determined by the heat absorption of the components. For soldering e.g. the component pins and solder lands.
For components on a heat sink there will be a large thermal mass. In other words: the heat will be "absorbed " by the heat sink, as a result of which more warmth will have to be added than e.g. for soldering the leg of an IC.
Secondly it is very important that the temperature of all the components that will be soldered have more or less the same temperature.
An example: it is necessary that the leg and the soldering land have had at the same time the necessary warming up before the solder is added.
We have to take care that, while warming up, the soldering bit gets in contact with both the leg and the soldering land.
"Thermal contact" is therefore very important.

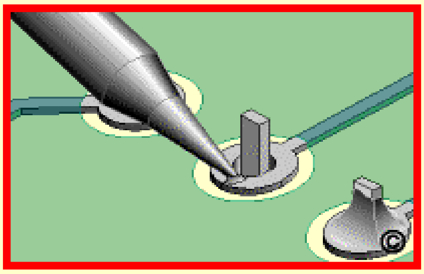

The thermal contact is low
The warmth is transmitted by means of the bit.
to the leg and the soldering land

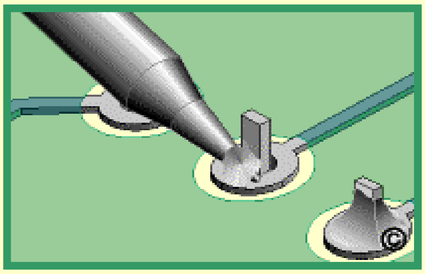

The thermal contact is higher
by adding a bit of solder
to the point of contact

The size and the shape of the soldering bit, as well as the position of the bit, will determine whether or not it makes a good thermal contact. For being able to make a good thermal contact in all circumstances, different types of soldering bits exist (different shapes).
Normally the soldering bit has to be placed on the "largest mass point" of the soldering connection that needs to be made.
This will make fast heating possible.

c) Adding solder & quantity

The last factor necessary for a high quality soldering connection, is adding the correct quantity of solder.
Too much solder is an unnecessary waste and can aid the formation of "bridges" across legs
If not enough solder is added, this can cause an "insufficient soldering" or "dry soldering"
Adding the correct quantity of solder takes a lot of exercise and experience

Melted solder always flows from a "colder" area to a "warmer" area.
Before the solder is added, the surface temperature of the components to be soldered has to be higher than the melting temperature of the solder.
Never let the soldering wire melt by holding it against the soldering bit. This may cause the solder to fall on a surface where the temperature is lower than the melting temperature
This can result in a cold soldering, with almost no or insufficient "wetting".
If the solder is added to a clean, fluxed and sufficiently heated surface, then the solder will melt and flow nicely without direct contact with the heat source. (soldering bit)
Therefore it is advisable to put the soldering wire on the sufficiently heated surface so that the solder melts as a consequence of the contact with the heated surface

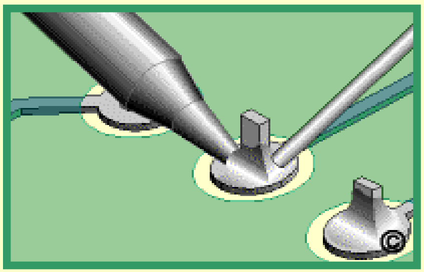

The solder is melted as a consequence of the contact with the heated surface. No contact with the soldering bit is necessary.

d) Soldering : 7 steps

1. Cleaning of the soldering bit:

For soldering to be effective, the soldering bit has to be clean:
no dirt and no oxides are allowed on the soldering bit.
The soldering bit needs to be cleaned before soldering.

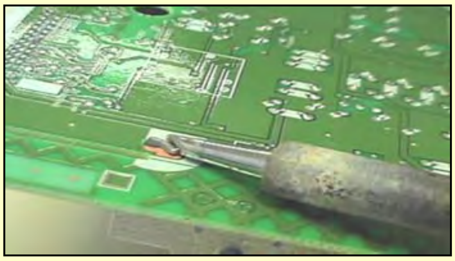

2. Heating of the components that will be soldered.

For soldering to be effective, the components which have to be connected, have to be heated (in this case the pin and the solder lands) to a temperature that at least equals the temperature of the melting point of the soldering alloy. (183 °C)
Bear in mind the "thermal mass", the type of bit and the position of the bit!

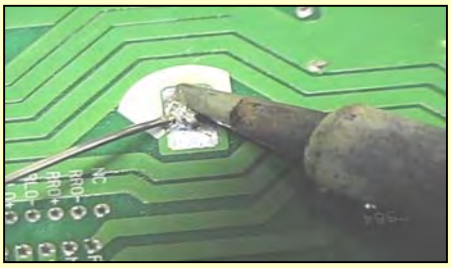

3. Adding the solder:

After both components are heated sufficiently, solder can be added.
Let the solder melt as a consequence of the contact with the heated surface. In other words: don't make any direct contact with the soldering bit.

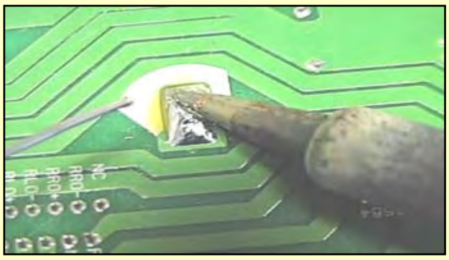

4. Quantity of the solder to be added and letting the solder flow.

Let the solder flow nicely between both components and add solder until the right quantity is reached.

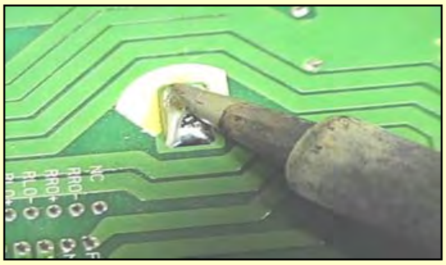

5. Remove the soldering wire

When sufficient solder is added, the soldering wire may be removed.

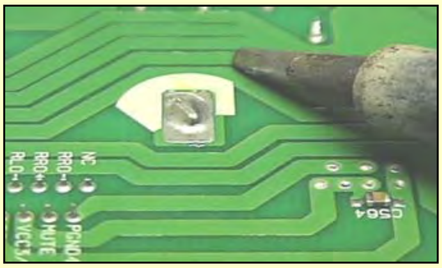

6. Remove the soldering bit.

When the solder has nicely flowed open, and there is "wetting", the soldering bit may be removed so that the solder can solidify.
Pay attention for possible sudden movements during this operation. (risk of "disturbed" soldering)

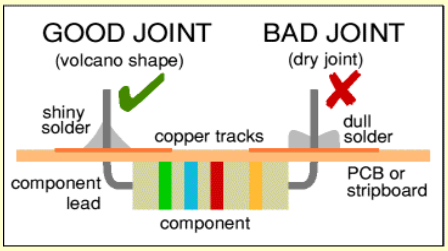

7. Check the soldering connection

Check the soldering connection.
Nicely formed soldering is shining and even. Also pay attention to the shape:
a spherical shape is not good!

e) Soldering of a flatpackage IC

For soldering a "Flat-package IC" (gull wing type) one can use, beside the ordinary point soldering (= leg by leg), a special soldering technique: the DRAGGING TECHNIQUE.
For this technique, one must use a special soldering bit that will, after filling-up, act as a kind of "mini-soldering-wave", and with which one can solder a whole row of legs in one ongoing movement

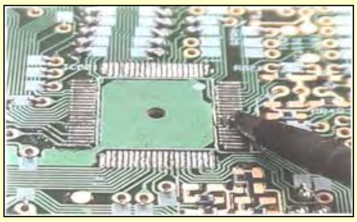

1. Cleaning of the soldering surface:
Remove all possible soldering residues (caused by desoldering) and make all the paths nicely even by going over those paths with the soldering bit. (without adding solder)

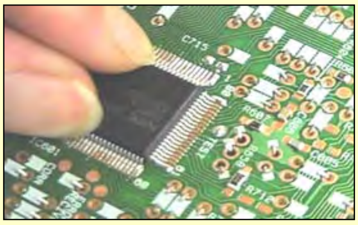

2. Positioning of the IC:
Position the IC on the patterns.
This has to be very precise.
A little movement can cause
serious problems.

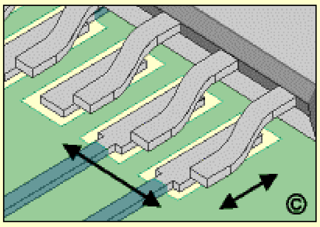

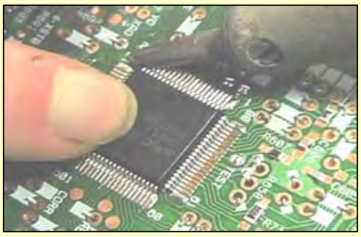

3. Fixing of the IC:
Fix the IC on the PCB, by "temporarily" soldering some legs on both sides.

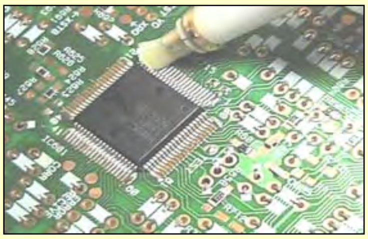

4. Add sufficient flux on all sides.

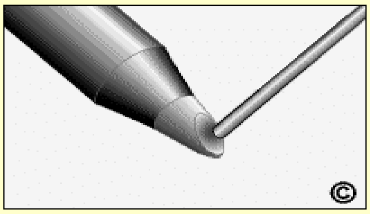

5. Filling of the bit and start of the soldering:
Fill the special (concave) soldering bit with solder.

Now start a slow dragging movement from one leg to another.
Pay attention that the solder nicely moves up on the legs of the IC.

If the PCB is equipped with a "soldering thief" (a soldering land that is positioned next to the last leg), one has to solder in the direction of the soldering thief, so that at the end the possible surplus of solder flows on this soldering thief and no short circuit is created on the last two legs of the row.

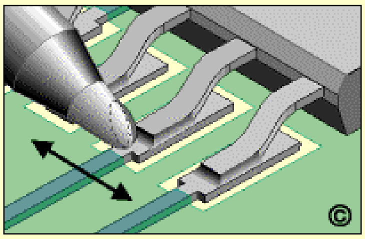

f) Incorrect soldering :

For certain soldering problems or soldering mistakes, specific terms are used:

SOLDER BRIDGE

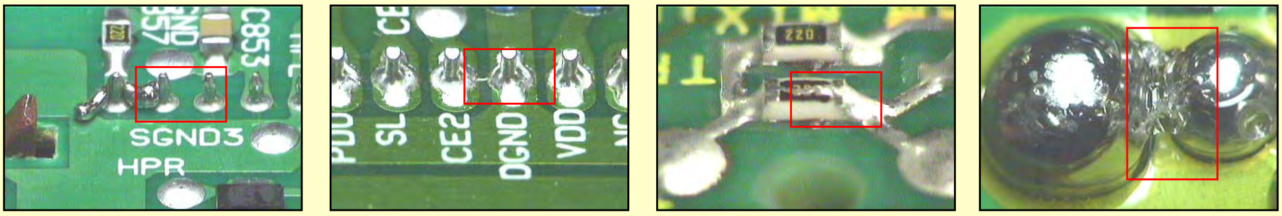

COLD SOLDERING

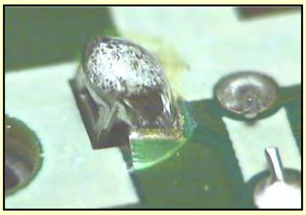

HALF SOLDERING OR DRY SOLDERING

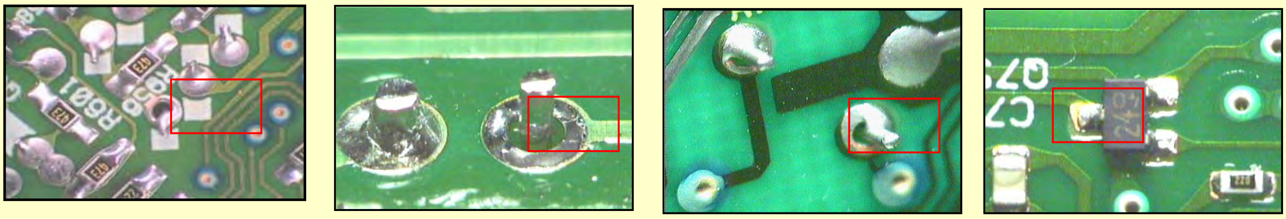

NO SOLDERING

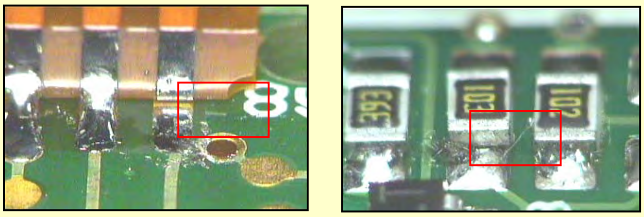

SOLDERING HORN

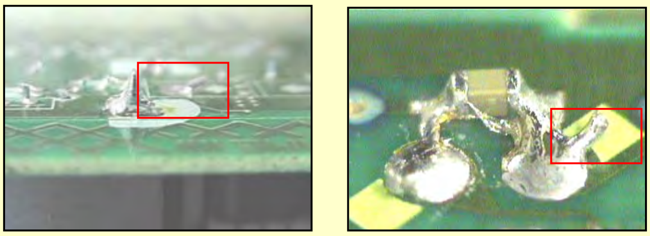

SOLDERING BALL OR SOLDERING SPLASH

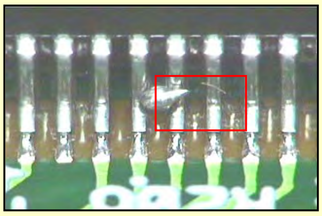

SOLDERING WIRE SHORT CIRCUIT

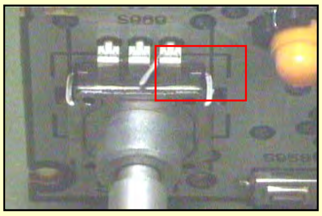

7) (De)soldering with warm air and soldering paste:

In some cases it is impossible to solder or desolder certain components with a classical soldering iron or a normal desoldering station.

This is often the case for SMT components, with contact legs (partly) underneath the component.
In such a case one has to use a (de)soldering appliance that uses warm air or infra-red heat.

SMT component with contact surfaces beneath the component

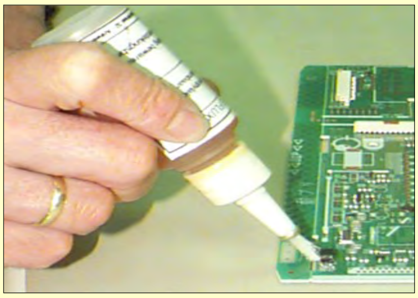

1. Fluxing of the component:

To have a good temperature conductance during warming up, the soldering surfaces need to be moistened with flux.
If these surfaces are parly underneath the component, flux can be put on the borders of the component.

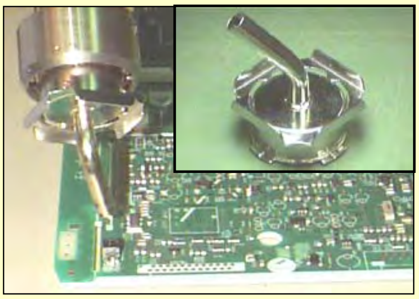

2. Warming-up of the soldered surfaces:

Use a "pointing nozzle" and point it at the component you want to remove. Keep a distance of 1 cm between the nozzle and the surface you want to warm up. Choose the temperature of the warm air e.g. +/- 340°C. (dependant on the temperature profile of the compents.)

Pay attention : if the contact surfaces are partly under the component, it is necessary to warm up the body of the component. Often the component is not useable afterwards.

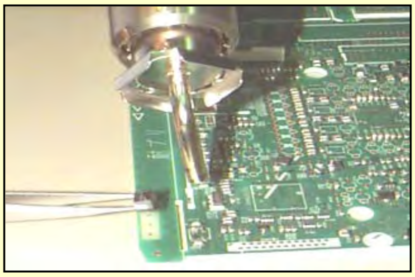

3. Removal of the component

When the solder (paste) has melted, the component can be removed with a pair of tweezers.

4. Cleaning of the soldering surfaces:

Remove all redundant soldering paste with a classical desoldering station.

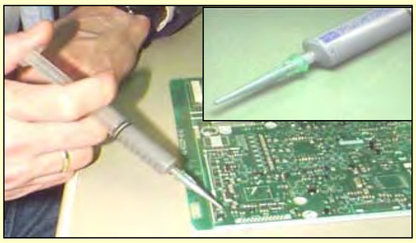

5. Adding soldering paste:

Add with a measured squirt the necessary soldering paste on the soldering lands.

Pay attention: soldering paste needs to be stored in strict circumstances. (see the instructions of the supplier)

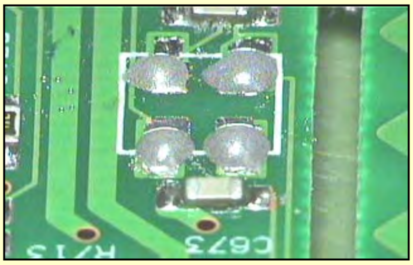

6. Checking the quantity of soldering paste:

Check the quantity of the added soldering paste.
Only the contact surfaces should be covered with soldering paste.
Too much soldering paste can cause a short circuit during "re-flowing".

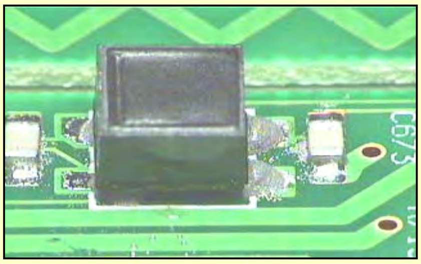

7. Positioning of the component

Position the new component carefully with the contact surfaces in the soldering paste with a pair of tweezers.
Position the component by the guide lines on the PCB.

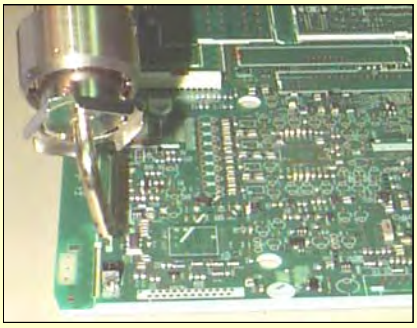

8. Reflowing of the component:

Use a "pointing nozzle" and point it on the component you want to remove. Keep a distance of 1 cm between the nozzle and the surface you want to warm up. Choose the temperature of the warm air e.g. +/- 340°C. (dependant on the temperature profile of the component.) Warm up until one sees that the soldering paste is active or flowing. The result should be a good soldered joint.
Pay attention: For most of the warm air soldering appliances one can choose the air pressure. The speed should be minimum, otherwise there is a possibility of blowing the component away.

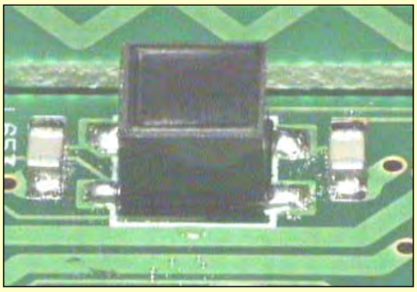

9. Checking of the soldering:

If possible, check the soldered joints.
Good soldering shines and has flowed evenly.

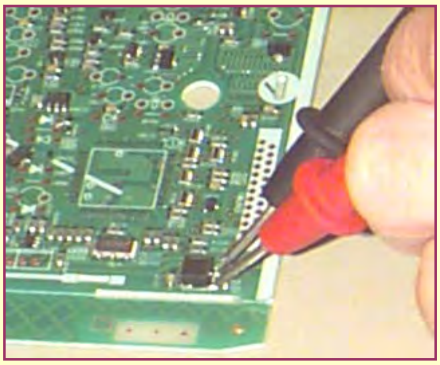

10. Checking of the electrical connection

If possible check the electrical connection with a meter.

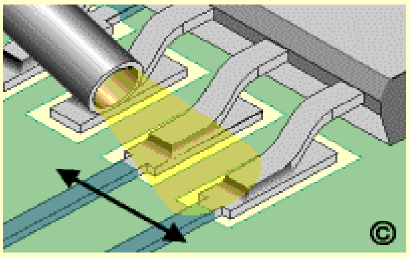

Example of a "warm air soldering appliance": PACE.

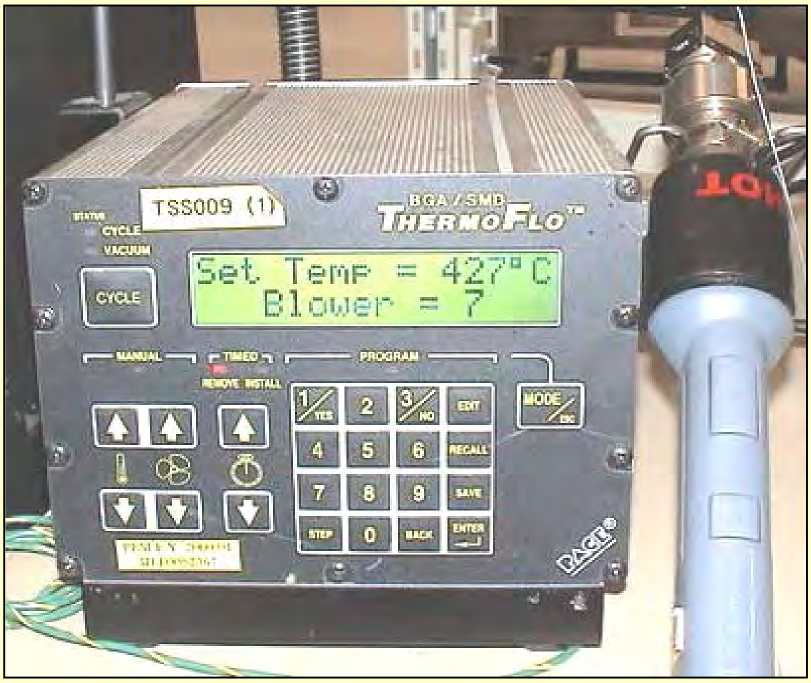
TSS009 (1)
BGA / SMD
THERMOFLO™
STATUS
CYCLE
VACUUM
CYCLE
MANUAL
TIMED
REMOVE INSTALL
PROGRAM
1 YES
2
3 NO
EDIT
MODE ESC
4
5
6
RECALL
7
8
9
SAVE
STEP
0
BACK
ENTER
PACE
HOT

Set Temp = 427°C
Blower = 7

8) Lead free soldering

Introduction.

Normally all solderings (mechanical - and hand soldering) were executed with soldering material that contained lead. (40 % lead / 60 % tin)

But lead is toxic and therefore damaging for humans and for nature.

Hence European directives were made in which companies will be obliged to use soldering techniques without lead after July 2006.

Soldering without lead is relatively new in the world of electronics.

Lead-free solder:

If no lead is present in the soldering wire, this has to be replaced. The soldering wire needs to contain another metal, like SILVER & COPPER. (96,5 % tin / 3% silver / 0,5 % copper)

This new composition has the advantage that it is no longer toxic and that the soldering connections are stronger. (lead is relatively weak). But this new composition also has some negative consequences:

1) The cost is higher (silver and copper alloys are more expensive than lead)
2) The joints look different (more granular instead of shining)
3) The melting temperature is higher

One of the main points of interest is the higher melting temperature. One would think that as a consequence of the higher melting temperature of the solder, also the soldering temperature needs to be raised. This however is not always allowed! Some components are only able to handle a certain maximum temperature for a certain time.

In practice.

- You can use your original soldering station if you can reach the correct temperature at the soldertip
- The soldering bit has to be a bit larger than a soldering bit for soldering with lead.

Pay attention: **Solder with lead and solder without lead can never be mixed.**

9) Temperature specifications of the soldering bit

Solder with lead

Process	**Bit Type**	**Solder**	**Min**	**Center**	**Max**
Pins	ETB / ETCC/ 1121-0519	UOS-014	340°C	**380°C**	400°C
LCD	ETF / ETCC	UOS-005	320°C	**340°C**	360°C
OEL Display	ETCC	UOS-004	280°C	**290°C**	300°C
Connector	ETL / ETF	UOS-005	320°C	**340°C**	360°C
Flexible PCB	ETF	UOS-004	280°C	**300°C**	320°C
IC's & QFP IC's	1121-0490	UOS-005	280°C	**300°C**	320°C
Removal bridge	ETB / ETCC	UOS-005	320°C	**340°C**	360°C
Lights	ETF / ETB /1121-0519	UOS-005	280°C	**300°C**	320°C
SMT/SMD repair	ETL / ETF	UOS-005	280°C	**300°C**	320°C

Temp. specifications Pioneer standard ZES-A015 & ZES-B016

Solder without lead

Process	**Bit Type**	**Solder**	**Min**	**Center**	**Max**
Pins	LTB / LTCC	UOS-026	400°C	**410°C**	420°C
LCD	LTF / LTCC	UOS-027	320°C	**340°C**	360°C
OEL Display	LTCC	UOS-028	280°C	**300°C**	320°C
Connector	LTL / LTF	UOS-027	320°C	**340°C**	360°C
Flexible PCB	LTF	UOS-028	280°C	**300°C**	320°C
IC's & QFP IC's	1121-0490	UOS-027	280°C	**300°C**	320°C
Removal bridge	LTB / LTCC	UOS-027	320°C	**340°C**	360°C
Lights	LTF / LTB	UOS-027	280°C	**300°C**	320°C
SMT/SMD repair	LTL / LTF	UOS-027	280°C	**300°C**	320°C

Temp. specifications Pioneer standard ZES-A043

Types of soldering wire:

With lead	UOS-014 (1 mm) + UOS-005 (0.8 mm) + UOS-004 (0.5mm)
Without lead	UOS-026 (1 mm) + UOS-027 (0.8 mm) + UOS-028 (0.5 mm)

10) Types of soldering bits:

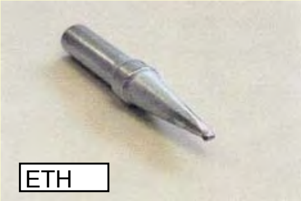
ETH

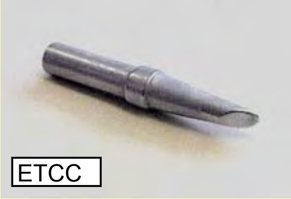
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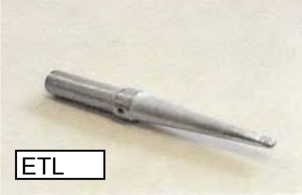
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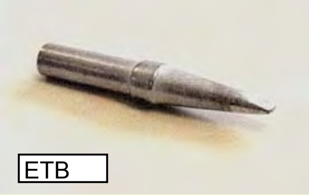
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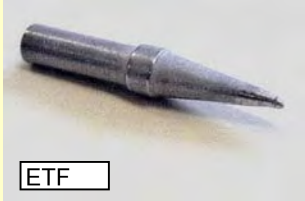
ETF

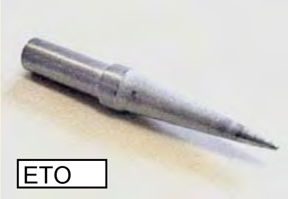
ETO

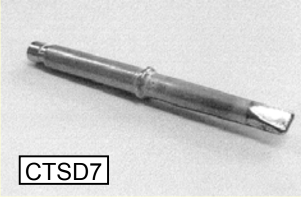
CTSD7

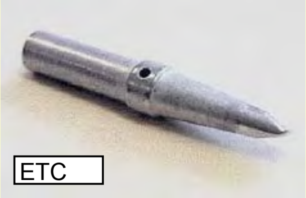
ETC

11) Soldering devices:

"Clean-o-point": for automatic cleaning of the soldering bit with 2 rotating sponges

SOLDERING FLU
Bevat isopropyla
Licht ontvlambaa
gesloten verpakking be
houden van ontsteki
ELECTRONICS Marnixstraat
"Flux dosing bottle": for easy adding of flux (with brush)

"Bit cleaner": for drying and cleaning of the soldering bit

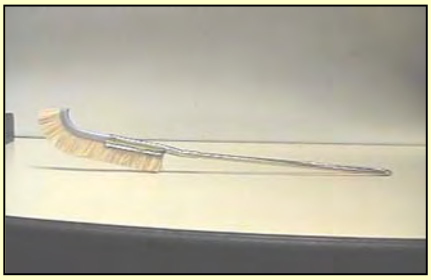
" Brush " : for removal of possible soldering residues after soldering

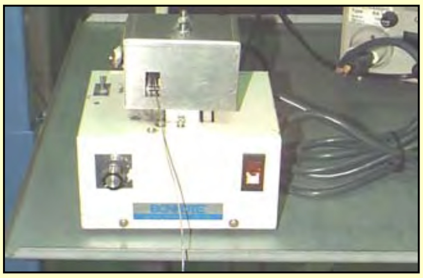
"V-cutter" : for making a cut in the soldering wire, in order to reduce the formation of little soldering balls

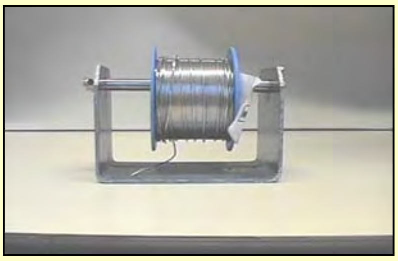
"Solder dispenser" : for a simple supply of soldering wire

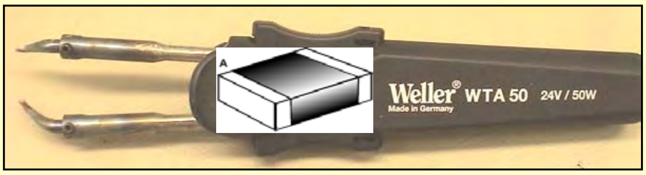
A
Weller® WTA 50 24V / 50W
Made in Germany
"Tweezer-copper bit": handy tool for the removal of SMD/SMT components.

TSS009 (1)
BGA/SMD
THERMOFLO
Set Temp = 427°C
Blower = 7
CYCLE
MODE
PACE
HOT
"Warm air desoldering appliance": for easy desoldering of flat-package IC's

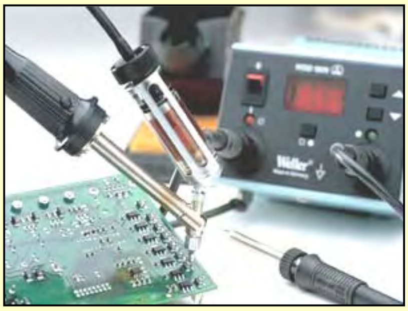

"Desoldering appliance": for easy desoldering of point solderings

"Soldering magnifying glass": for a good view during soldering

The Basic Soldering Guide

http://www.epemag.wimborne.co.uk/solderfaq.htm (for text in this document)

basics for wire (Good intro) : http://www.youtube.com/watch?v=BLfXXRfRIzY
The Happy Soldering Iron: http://www.youtube.com/watch?v=AL-_RGbyf1s
basics: http://www.youtube.com/watch?v=I_NU2ruzyc4
Watt/temp comparison http://www.youtube.com/watch?v=Vh9pWu6K6tc&NR=1
tip sizes: http://www.youtube.com/watch?v=Sfb1Ve52ztY&NR=1
types of solder: http://www.youtube.com/watch?v=COqGkYMOA44
maintenance: http://www.youtube.com/watch?v=krxTfZCFptk&NR=1

Good overview with some odd bits: http://www.youtube.com/watch?v=AOdnGUMi7lQ

Desoldering overview: http://www.youtube.com/watch?v=j-_pnc-Qqm8
2nd good overview: http://www.youtube.com/watch?v=8UN3D2-f64A
Hot air pencil/gun: http://www.youtube.com/watch?v=AxYhF6Ab2CU
Desoldering gun (short): http://www.youtube.com/watch?v=8Z6MvZz_uNc

Crazy Guy from Make Electronics: http://www.youtube.com/watch?v=3N3ApzmyjzE
Not Soldering!! – Bread board: http://www.youtube.com/watch?v=oiqNaSPTI7w

This written guide will help beginners and novices to obtain effective results when soldering **electronic components**. If you have little or no experience of using a soldering iron, then EPE *(Everyday Practical Electronics* magazine) recommends that you practice your soldering technique on some fresh surplus components and clean stripboard (protoboard), before experimenting with a proper constructional project. This will help you to avoid the risk of disappointment when you start to assemble your first prototypes. If you've never soldered before, then read on!

Soldering irons

The most fundamental skill needed to assemble any electronic project is that of ***soldering***. It takes some practice to make the perfect joint, but, like riding a bicycle, once learned is never forgotten! The idea is simple: to join electrical parts together to form an electrical connection, using a molten mixture of lead and tin (solder*) with a soldering iron. A large range of soldering irons is available - which one is suitable for you depends on your budget and how serious your interest in electronics is.

[*Note: the use of lead in solder is now increasingly prohibited in many countries. "Lead free" solder is now statutory instead.]

Electronics catalogues often include a selection of well-known brands of soldering iron. Excellent British-made ones include the universally popular Antex, Adcola and Litesold makes. Other popular brands include those made by Weller and Ungar. A very basic mains electric soldering iron can cost from under £5 (US$ 8), but expect a reasonable model to be approximately £10-£12 (US$ 16 - 20) - though it's possible to spend into three figures on a soldering iron "station" if you're really serious! Check some suppliers' catalogues for some typical types. Certain factors you need to bear in mind include:-

Voltage: most irons run from the mains at 240V. However, low voltage types (e.g. 12V or 24V) generally form part of a "soldering station" and are designed to be used with a special controller made by the same manufacturer.

Wattage: Typically, they may have a power rating of between 15-25 watts or so, which is fine for most work. A higher wattage does ***not*** mean that the iron runs hotter - it simply means that there is more power in reserve for coping with larger joints. This also depends partly on the design of the "bit" (the tip of the iron). Consider a higher wattage iron simply as being more "unstoppable" when it comes to heavier-duty work, because it won't cool down so quickly.

Temperature Control: the simplest and cheapest types don't have any form of temperature regulation. Simply plug them in and switch them on! Thermal regulation is "designed in" (by physics, not electronics!): they may be described as "thermally balanced" so that they have some degree of temperature "matching" but their output will otherwise not be controlled. Unregulated irons form an ideal general purpose iron for most users, and they generally cope well with printed circuit board soldering and general interwiring. Most of these "miniature" types of iron will be of little use when attempting to solder large joints (e.g. very large terminals or very thick wires) because the component being soldered will "sink" heat away from the tip of the iron, cooling it down too much. (This is where a higher wattage comes in useful.)

A proper temperature-controlled iron will be quite a lot more expensive - retailing at say £40 (US$ 60) or more - and will have some form of built-in thermostatic control, to ensure that the temperature of the bit (the tip of the iron) is maintained at a fixed level (within limits). This is desirable especially during more frequent use, since it helps to ensure that the temperature does not "overshoot" in between times, and also guarantees that the output will be relatively stable. Some irons have a bimetallic strip thermostat built into the handle which gives an audible "click" in use: other types use all-electronic controllers, and some may be adjustable using a screwdriver.

Yet more expensive still, ***soldering stations*** cost from £70 (US$ 115) upwards (the iron may be sold separately, so you can pick the type you prefer), and consist of a complete bench-top control unit into which a special *low-voltage* soldering iron is plugged. Some versions might have a built-in digital temperature readout, and will have a control knob to enable you to vary the setting. The temperature could be boosted for soldering larger joints, for example, or for using higher melting-point solders (e.g. silver solder). These are designed for the most discerning users, or for continuous production line/ professional use. The best stations have irons which are well balanced, with comfort-grip handles which remain cool all day. A thermocouple will be built into the tip or shaft, which monitors temperature.

Anti-static protection: if you're interested in soldering a lot of static-sensitive parts (e.g. CMOS chips or MOSFET transistors), more advanced and expensive soldering iron stations use static-dissipative materials in their construction to ensure that static does not build up on the iron itself. You may see these listed as "ESD safe" *(electrostatic discharge proof)*. The cheapest irons won't necessarily be ESD-safe but never the less will still probably perform perfectly well in most hobby or educational applications, if you take the usual anti-static precautions when handling the components. The tip would need to be well earthed (grounded) in these circumstances.

Bits: it's useful to have a small selection of manufacturer's bits (soldering iron tips) available with different diameters or shapes, which can be changed depending on the type of work in hand. You'll probably find that you become accustomed to, and work best with, a particular shape of tip. Often, tips are *iron-coated* to preserve their life, or they may be bright-plated instead. Copper tips are seldom seen these days.

Spare parts: it's nice to know that spare parts may be available, so if the element blows, you don't need to replace the entire iron. This is especially so with expensive irons. Check through some of the larger mail-order catalogues.

A ***solder gun*** is a pistol-shaped iron, typically running at 100W or more, and is completely unsuitable for soldering modern electronic components: they're too hot, heavy and unwieldy for micro-electronics use. Plumbing, maybe..!

Soldering irons are best used along with a heat-resistant ***bench-type holder***, so that the hot iron can be safely parked in between use. Soldering stations already have this feature, otherwise a separate soldering iron stand is essential, preferably one with a holder for tip-cleaning sponges. Now let's look at how to use soldering irons properly, and how to put things right when a joint goes wrong.

The Basic Soldering Guide Photo Gallery

Soldering is a delicate manual skill which only comes with practice. Remember that your ability to solder effectively will determine directly how well the prototype or product functions during its lifespan. Poor soldering can be an expensive business - causing product failure and downtime, engineer's maintenance time and customer dissatisfaction. At hobbyist level, bad soldering technique can be a cause of major disappointment which damages your confidence. It needn't be like that: soldering is really easy to learn, and like learning to ride a bike, once mastered is never forgotten!

These photos illustrate the basic steps in making a perfect solder joint on a p.c.b. If you're a beginner, our advice is that it's best to practice your soldering technique using some clean, new parts with perhaps some new stripboard (protoboard). Be sure to avoid using old, dirty parts; these can be difficult if not impossible to solder.

(Left) Printed circuit board copper tracks must be clean to begin with, especially if they're not previously "tinned" with solder. Clean any raw p.c.b. copper tracks gently with e.g. an abrasive rubber block available from electronics suppliers. **(Right)** Clean the iron "bit" (soldering iron tip) using a damp sponge. The soldering iron featured is an Ungar Concept 2100 Soldering Station. Other popular brands of soldering equipment include Weller and Antex.

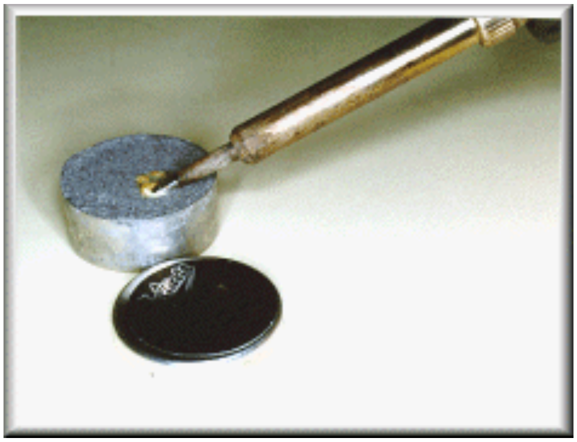

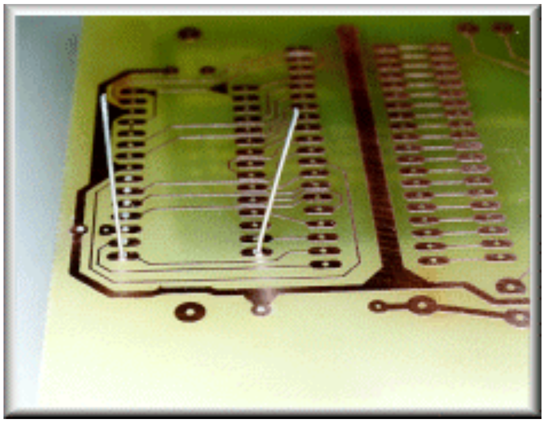

(Left) A useful product is Multicore's Tip Tinner Cleaner (TTC) - a 15 gramme tin of special paste which cleans and "tins" the soldering iron iron, in one go. New tips must be tinned **immediately** when used for the first time. **(Right)** Insert components and splay the leads so that the part is held in place.

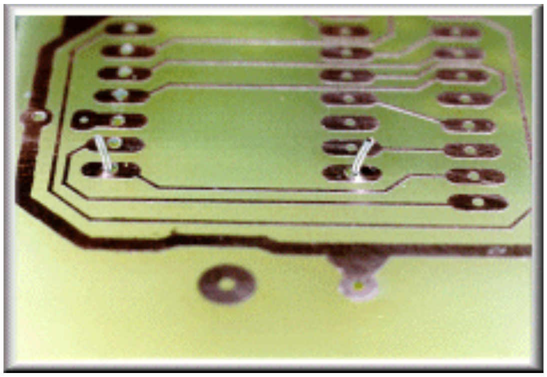

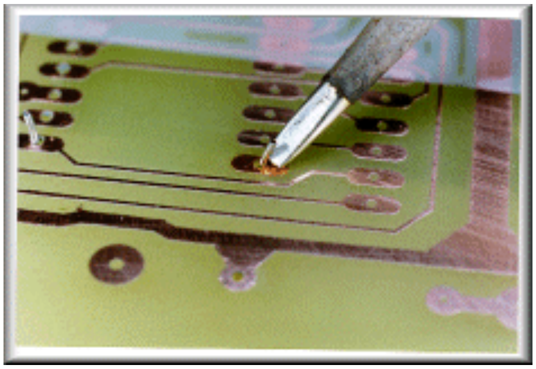

(Left) It's usually best to snip the electronic component wires to length prior to soldering. This helps prevent transmitting mechanical shocks to the copper foil.**(Right)** Apply a clean soldering iron tip to the copper solder pad and the component lead, in order to heat *both* items at the same time.

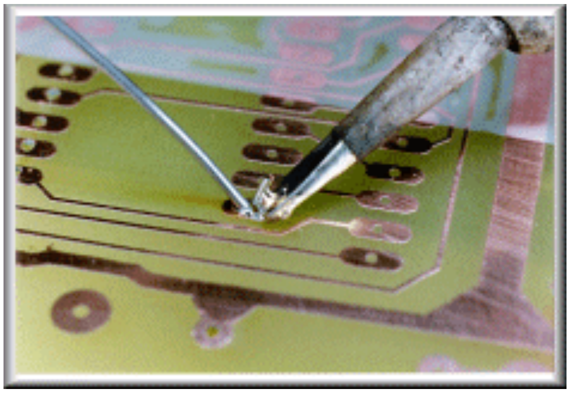

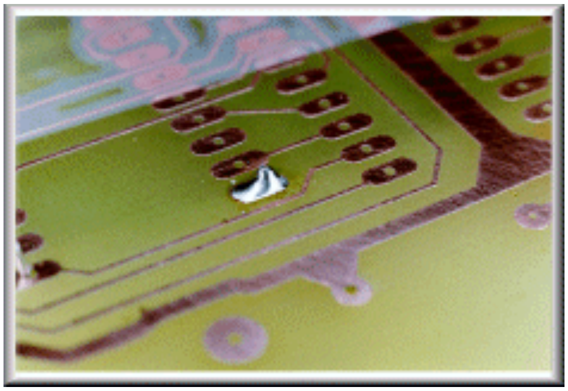

(Left) Continue heating and apply a few millimetres of solder. Remove the iron and allow the solder joint to cool naturally. **(Right)** It only takes a second or two, to make the perfect joint, which should be nice and shiny. Check the Guide for troubleshooting help.

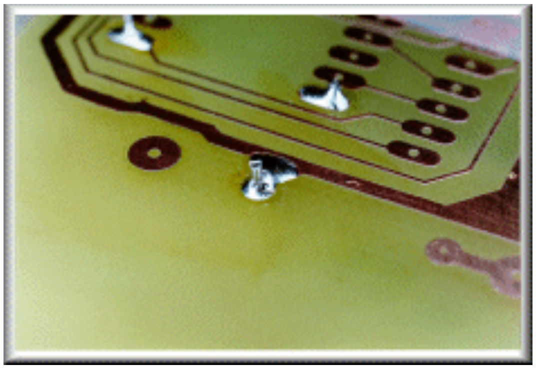

An example of a "dry" or "gray" soller joint - the solder failed to flow, and instead beaded to form globules around the wire.

How to solder

Turning to the actual techniques of soldering, firstly it's best to *secure the work* somehow so that it doesn't move during soldering and affect your accuracy. In the case of a printed circuit board, various holding frames are fairly popular especially with densely populated boards: the idea is to insert all the parts on one side ("stuffing the board"), hold them in place with a special foam pad to prevent them falling out, turn the board over and then snip off the wires with cutters before making the joints. The frame saves an awful lot of turning the board over and over, especially with large boards. Other parts could be held firm in a modeller's small vice, for example.

Solder joints may need to possess some degree of mechanical strength in some cases, especially with wires soldered to, say, potentiometer or switch tags, and this means that the wire should be looped through the tag and secured before solder is applied. The down side is that it is more difficult to *de-solder* the joint (see later) and remove the wire afterwards, if required. Otherwise, in the case of an ordinary circuit board, components' wires are bent to fit through the board, inserted flush against the board's surface, splayed outwards a little so that the part grips the board, and then soldered.

In my view - opinions vary - it's generally better to snip the surplus wires leads off *first*, to make the joint more accessible and avoid applying a mechanical shock to the p.c.b. joint. However, in the case of semiconductors, I often tend to leave the snipping until *after* the joint has been made, since the excess wire will help to sink away some of the heat from the semiconductor junction. Integrated circuits can either be soldered directly into place if you are confident enough, or better, use a dual-in-line socket to prevent heat damage. The chip can then be swapped out if needed.

Parts which become hot in operation (e.g. some resistors), are raised above the board slightly to allow air to circulate. Some components, especially large electrolytic capacitors, may require a mounting clip to be screwed down to the board first, otherwise the part may eventually break off due to vibration.

The perfectly soldered joint will be nice and shiny looking, and will prove reliable in service. I would say that:

- cleanliness
- temperature
- time
- adequate solder coverage

are the key factors affecting the quality of the joint. A little effort spent now in soldering the perfect joint may save you - or somebody else - a considerable amount of time in troubleshooting a defective joint in the future. The basic principles are as follows.

Really Clean

First, and without exception, all parts - including the iron tip itself - must be clean and free from contamination. Solder just will not "take" to dirty parts! Old components or copper board can be notoriously difficult to solder, because of the layer of oxidation which builds up on the surface of the leads. This repels the molten solder and this will soon be evident because the solder will "bead" into globules, going everywhere except where you need it. Dirt is the enemy of a good quality soldered joint!

Hence, it is an absolute necessity to ensure that parts are free from grease, oxidation and other contamination. In the case of old resistors or capacitors, for example, where the leads have started to oxidise, use a small hand-held file or perhaps scrape a knife blade or rub a fine emery cloth over them to reveal fresh metal underneath. Stripboard and copper printed circuit board will generally oxidise after a few months, especially if it has been fingerprinted, and the copper strips can be cleaned using an abrasive rubber block, like an aggressive eraser, to reveal fresh shiny copper underneath.

Also available is a fibre-glass filament brush, which is used propelling-pencil-like to remove any surface contamination. These tend to produce tiny particles which are highly irritating to skin, so avoid accidental contact with any debris. Afterwards, a wipe with a rag soaked in cleaning solvent will remove most grease marks and fingerprints. After preparing the surfaces, avoid touching the parts afterwards if at all possible.

Another side effect of having dirty surfaces is the tendency for people to want to apply *more heat* in an attempt to "force the solder to take". This will often do more harm than good because it may not be possible to burn off any contaminants anyway, and the component may be overheated. In the case of semiconductors, temperature is quite critical and they may be harmed by applying such excessive heat.

Before using the iron to make a joint, it should be "tinned" (coated with solder) by applying a few millimetres of solder, then wiped on a damp sponge preparing it for use: you should always do this immediately with a new bit, anyway. Personally, I always re-apply a very small amount of solder again, mainly to improve the thermal contact between the iron and the joint, so that the solder will flow more quickly and easily. It's sometimes better to tin larger parts as well before making the joint itself, but it isn't generally necessary with p.c.b. work. (All *EPE* printed circuit boards are "roller-tinned" to preserve their quality and to help with soldering.) A worthwhile product is Weller's *Tip Tinner & Cleaner*, a small 15 gram tinlet of paste onto which you dab a hot iron - the product cleans and tins the iron ready for use. An equivalent is Adcola *Tip-Save*.

Normal electronics grade solder is now "lead free" and typically contains Sn 97 Ag 2.5 Cu 0.5 (i.e. 97% tin, 2.5% silver and 0.5% copper). **It already contains cores of "flux"** which helps the molten solder to flow more easily over the joint. Flux removes oxides which arise during heating, and is seen as a brown fluid bubbling away on the joint. The use of separate acid flux paste (e.g. as used by plumbers) should NEVER be necessary in normal electronics applications because electronics-grade solder already contains the correct grade of flux! Other solders are available for specialist work, including aluminium and silver-solder. Different solder diameters are produced, too; 20-22 SWG (19-21 AWG) is 0.91-0.71mm diameter and is fine for most work. Choose 18 SWG (16 AWG) for larger joints requiring more solder.

Temperature

Another step to successful soldering is to ensure that the **temperature** of *all* the parts is raised to roughly the same level before applying solder. Imagine, for instance, trying to solder a resistor into place on a printed circuit board: it's far better to heat *both* the copper p.c.b. *and* the resistor lead at the same time before applying solder, so that the solder will flow much more readily over the joint. Heating one part but not the other is far less satisfactory joint, so strive to ensure that the iron is in contact with *all* the components first, before touching the solder to it. The melting point of most solder is in the region of 188°C (370°F) and the iron tip temperature is typically 330-350°C (626°-662°F). The latest lead-free solders typically require a higher temperature.

Now is the time

Next, the joint should be heated with the bit for just the right amount of time - during which a short length of solder is applied to the joint. Do not use the iron to carry molten solder over to the joint! Excessive time will damage the component and perhaps the circuit board copper foil too! Heat the joint with the tip of the iron, then continue heating whilst applying solder, then remove the iron and allow the joint to cool. This should take only a few seconds, with experience. The heating period depends on the temperature of your iron and size of the joint - and larger parts need more heat than smaller ones - but some parts (semiconductor diodes, transistors and i.c.s), are sensitive to heat and should not be heated for more than a few seconds. Novices sometimes buy a small clip-on heat-shunt, which resembles a pair of aluminium tweezers. In the case of, say, a transistor, the shunt is attached to one of the leads near to the transistor's body. Any excess heat then diverts up the heat shunt instead of into the transistor junction, thereby saving the device from over-heating. Beginners find them reassuring until they've gained more experience.

Solder Coverage

The final key to a successful solder joint is to apply an appropriate amount of solder. Too much solder is an unnecessary waste and may cause short circuits with adjacent joints. Too little and it may not support the component properly, or may not fully form a working joint. How much to apply, only really comes with practice. A few millimetres only, is enough for an "average" p.c.b. joint, (if there is such a thing).

Here's a summary of how to make the perfect solder joint.

1. All parts must be clean and free from dirt and grease.
2. Try to secure the work firmly.
3. "Tin" the iron tip with a small amount of solder. Do this immediately, with new tips being used for the first time.
4. Clean the tip of the hot soldering iron on a damp sponge.
5. Many people then add a tiny amount of fresh solder to the cleansed tip.

6. Heat all parts of the joint with the iron for under a second or so.
7. Continue heating, then apply sufficient solder only, to form an adequate joint.
8. Remove and return the iron safely to its stand.
9. It only takes two or three seconds at most, to solder the average p.c.b. joint.
10. Do not move parts until the solder has cooled.

Troubleshooting Guide

- Solder won't "take" - grease or dirt present - desolder and clean up the parts. Or, material may not be suitable for soldering with lead/tin solder (eg aluminium).
- Joint is crystalline or grainy-looking - has been moved before being allowed to cool, or joint was not heated adequately - too small an iron/ too large a joint.
- Solder joint forms a "spike" - probably overheated, burning away the flux.

Desoldering methods

A soldered joint which is improperly made will be electrically "noisy", unreliable and is likely to get worse in time. It may even not have made any electrical connection at all, or could work initially and then cause the equipment to fail at a later date! It can be hard to judge the quality of a solder joint purely by appearances, because you cannot say how the joint actually formed on the *inside*, but by following the guidelines there is no reason why you should not obtain perfect results.

A joint which is poorly formed is often called a "dry joint". Usually it results from dirt or grease preventing the solder from melting onto the parts properly, and is often noticeable because of the tendency of the solder not to "spread" but to form beads or globules instead, perhaps partially. Alternatively, if it seems to take an inordinately long time for the solder to spread, this is another sign of possible dirt and that the joint may potentially be a dry one.

There will undoubtedly come a time when you need to *remove* the solder from a joint: possibly to replace a faulty component or fix a dry joint. The usual way is to use a ***desoldering pump*** or vacuum pump which works like a small spring-loaded bicycle pump, only in reverse! (More demanding users using CMOS devices might need a pump which is ESD safe.) A spring-loaded plunger is released at the push of a button and the molten solder is then drawn up into the pump. It may take one or two attempts to clean up a joint this way, but a small desoldering pump is an invaluable tool especially for p.c.b. work.

Sometimes, it's effective to actually *add more* solder and then desolder the whole lot with a pump, if the solder is particularly awkward to remove. Care is needed, though, to ensure that the boards and parts are not damaged by excessive heat; the pumps themselves have a P.T.F.E. nozzle which is heat proof but may need replacing occasionally.

An excellent alternative to a pump is to use *desoldering braid*, including the famous American "Soder-Wick" (sic) or Adcola "TISA-Wick" which are packaged in small dispenser reels. This product is a specially treated fine copper braid which draws molten solder up into the braid where it solidifies. The best way is to use the tip of the hot iron to press a short length of braid down onto the joint to be de-soldered. The iron will subsequently melt the solder, which will be drawn up into the braid. Take extreme care to ensure that you don't allow the solder to cool with the braid adhering to the work, or you run the risk of damaging p.c.b. copper tracks when you attempt to pull the braid off the joint. See my photo gallery for more details.

I recommend buying a small reel of de-soldering braid, especially for larger or difficult joints which would take several attempts with a pump. It is surprisingly effective, especially on difficult joints where a desoldering pump may prove a struggle.

The Basic De-soldering Guide Photo Gallery (and Black Museum of Bad Soldering)

De-soldering is required when electronic components need to be removed from a circuit, usually because they are faulty. It may sometimes be necessary during testing or assembly, if a wrong part has been fitted or a modification has to be made. In the field, it's not uncommon for faulty electronic components to be swapped out, or poor joints (perhaps "dry" or gray joints) to need re-making properly, months or years after manufacture. Experienced engineers can often diagnose a particular faulty joint immediately, because they may have seen the same problem on similar electronic equipment before, especially if the equipment has a "reputation". A proper desoldering technique can soon be acquired with practice - all you need to do is buy some scrap boards to have a go with, and desolder to your heart's content!

The next photo sequence illustrates the basic steps for desoldering a printed circuit board, in order to remove a faulty part. Both the technique for using a desoldering suction pump as well as desolder braid are illustrated. Some real-life examples of poor soldering are shown too, in my *Black Museum of Bad Soldering*!

Remember - it costs just as much to get it right as it does to get it wrong! Practice makes perfect.

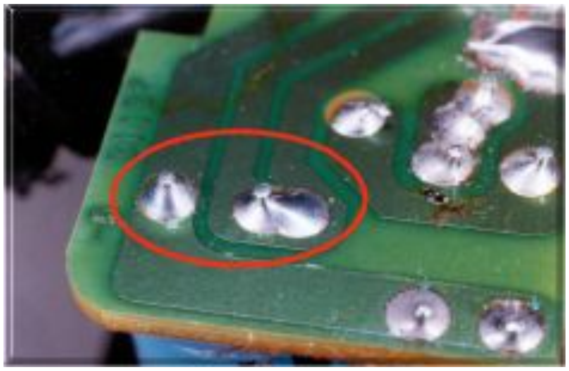

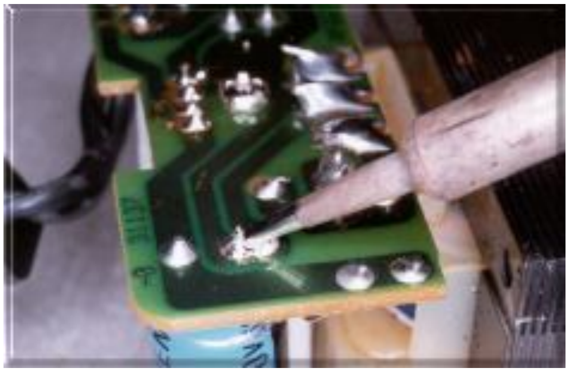

(Left) The two solder joints to be desoldered, to enable a faulty electrolytic capacitor to be removed from the printed circuit board.

(Right) If using a suction-type desoldering pump, apply the soldering iron tip first to melt the solder joint (say for 1-2 seconds). Ensure the spring-loaded desoldering pump is 'primed' and ready to go...

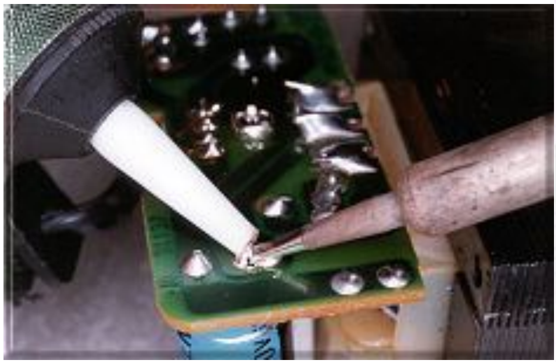

(Left) The PTFE nozzle of the desoldering pump is applied to the molten solder and the spring-loaded plunger is then immediately released, drawing the molten solder up into the pump. Remove the soldering iron tip. Repeat the process if needed. *Handy tip*: sometimes it helps to add some fresh solder and then desolder the whole joint.

(Right) The first p.c.b. joint, now desoldered. The second joint will be desoldered using traditional desoldering braid.

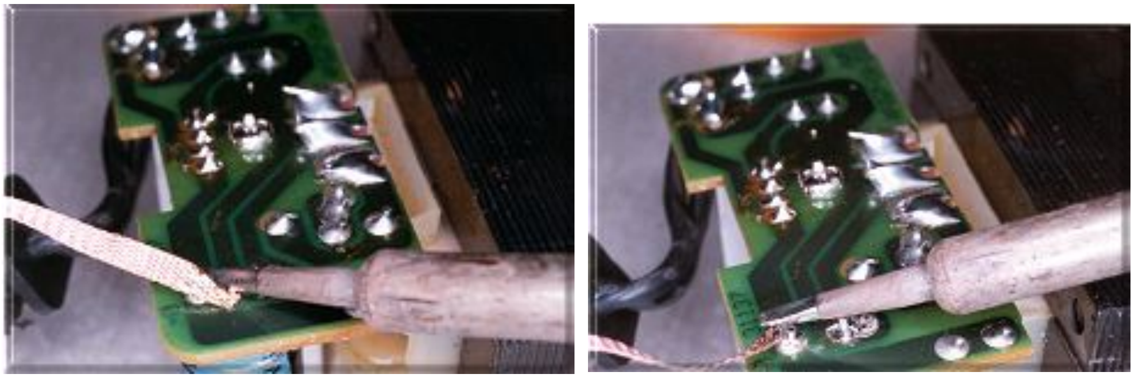

(Left) Select a suitable width of desoldering braid, and **press it down** onto the **COLD** joint using the hot tip of the iron. A flat soldering iron bit is preferable.

(Right) The molten solder is drawn up by capillary action into the desoldering braid. Take care not to overheat the board (the p.c.b. copper track may lift off), nor 'drag whiskers' of solder over the board, nor let the braid solidify onto the joint! Remove the braid while the joint is still molten.

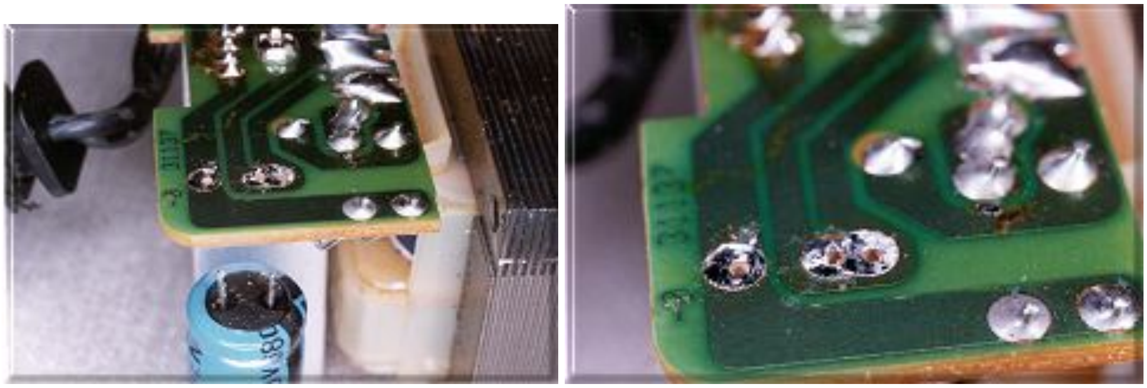

(Left) The faulty electrolytic capacitor dropped out of the board after desoldering. Sometimes, it may need persuading with pliers.... but don't overdo this or you risk damaging the copper tracks on the p.c.b.

(Right) Close-up photograph of both joints, now desoldered and ready for the replacement component to be fitted.

The Black Museum of Bad Soldering

These are all genuine examples which have not been retouched or reworked in any way.

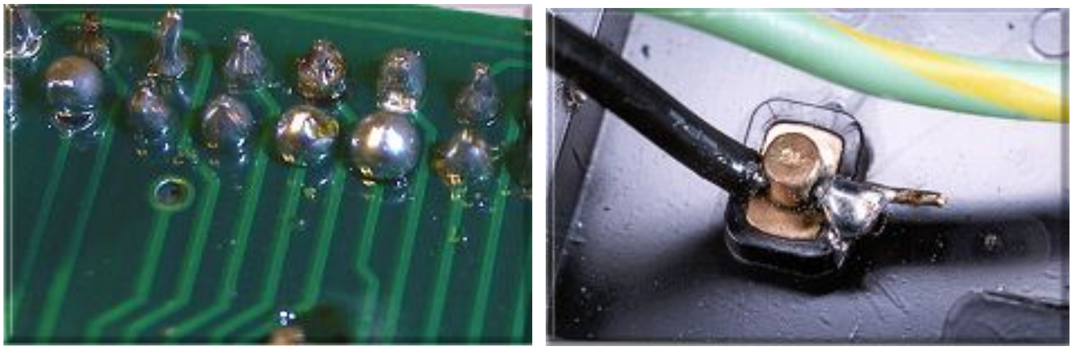

(Left) A tenfold excess of solder on this hand-soldered printed circuit board, and (extreme left) an incomplete solder joint with poor coverage. There is no need to add more solder "for luck".

(Right) An example of a dry (or gray) solder joint found inside a commercial PSU for a computer peripheral. The wire had been fed through the hole in the brass terminal, and merely tacked on with a blob of solder. This is a fire hazard (risk of arcing and overheating).

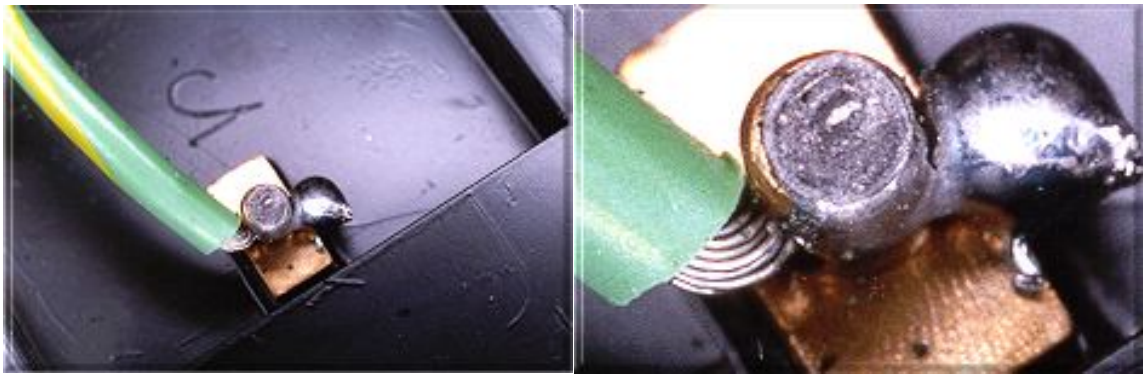

(Left) Hmmmm... this joint looks somewhat suspect as well... it's the earth (ground) wire in the same PSU

(Right) A close-up reveals the terrible standard of soldering (and quality control), with a fracture visible on this ground/ earth joint.

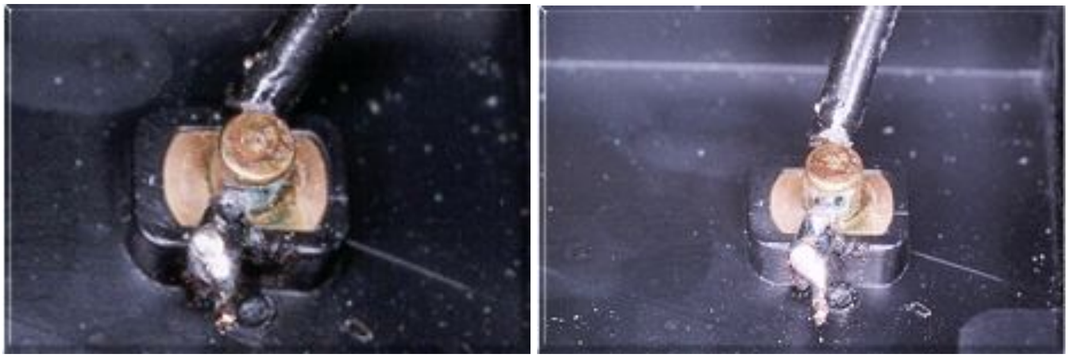

(Left) How **not** to make a mains voltage soldered joint. This solder joint went "dry" and starting arcing, nearly destroying the attached equipment. It is also a fire hazard.

(Right) The same mains connection, the wire merely being 'tacked on' with a blob of solder.

First Aid

If you are unlucky enough to receive burns which require treatment, here's what to do :-

1. Immediately cool the affected area with cold running water for several minutes.
2. Remove any rings etc. before swelling starts.
3. Apply a sterile dressing to protect against infection.
4. Do not apply lotions, ointments etc., nor prick any blisters which form later.
5. Seek professional medical advice where necessary.

A Few Hints about soldering on a Ground Plane

Before starting

- Always remove any grease and water from your hands. This will reduce the extent to which you oxidise and contaminate the board.
- Avoid touching the copper surface with your hands, always hold a board by its edges.
- Ensure all power and signal inputs are turned off (the soldering iron will short anything you touch to ground!!!)

Soldering a component

- Consider the circuit pathway from input to output in order to minimise the distance. This is especially important between ICs.
- Use the cleaning rubbers or solutions to clean away the oxidised surface where you are going to mount the component. This will help improve the electrical characteristic and improve solder flow
- Where you intend to place solder, VERY LIGHTLY scratch a cross-hatch pattern on the copper plate with a sharp tool. This will increase the friction thereby preventing your soldering iron skating across the board surface
- Apply heat to the copper surface first then add the solder so it smoothly flows on to the copper.
- Use pliers to bend the wire/chip legs to form small feet as this will increase the stability and make them much easier to solder. All wire bends should be done with pliers!
- Tin the legs before trying to mount them on the board
- When using wire, devise a colour coding system and stick to it i.e. red +ve rail, black GND rail, yellow –ve rail, blue input etc. This will make debugging so much easier
- If you are soldering an IC, two good techniques are:
    - Bend its legs with pliers so they are all horizontal and the chip can sit flat on the GND plane surface. Then place a bend just after where the pin leg narrows and bend again slightly further down so the leg it touching the ground plane (see image below). This way the IC is firmly held in place.

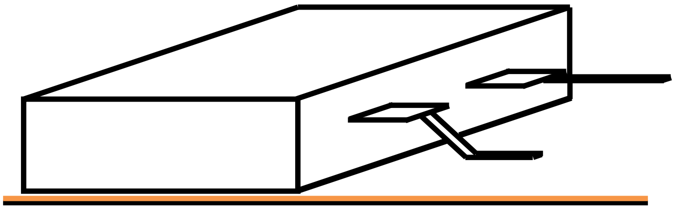

    - Bend legs touching the copper plane at the end to make small feet, then bend all other legs so that they are horizontal. This will result in the chip hovering just off the GND plane reducing the stability, but increasing the space to connect further components.
- Keep component leads as short as possible. This will reduce parasitics, improve mechanical robustness and reduce the chance of accidental shorts

These rules should be followed in conjunction with Dr Clarke's Soldering Guidelines found on the EE2 lab website.

Here is a good copper board layout. Notice the neat leads with none left loose above the circuit, and the way that the layout looks like a schematic. See the web copy (on the AMP handout page) of this picture for more detail.

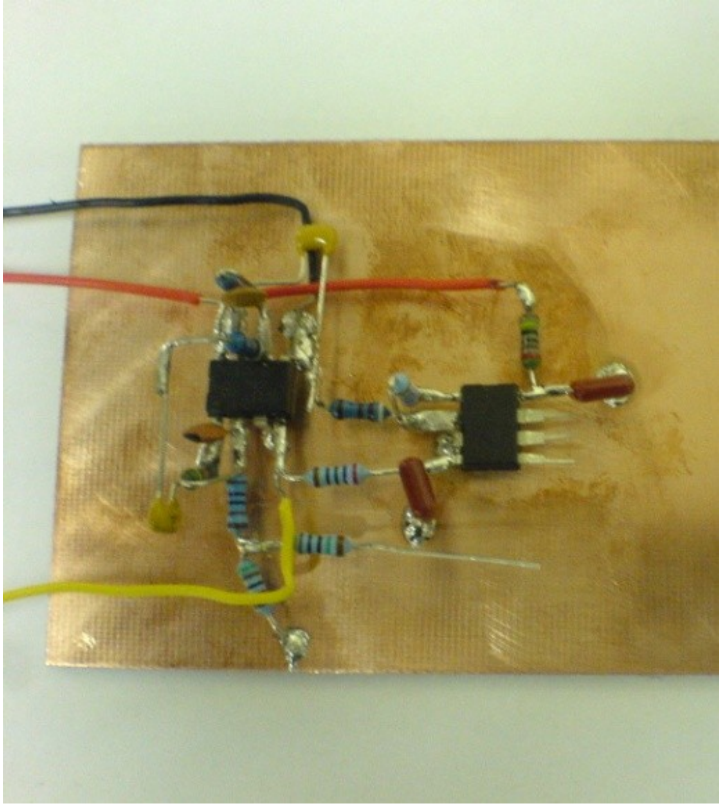

Soldering and Desoldering Instruction

Soldering is defined as "the joining of metals by a fusion of alloys which have relatively low melting points". In other words, you use a metal that has a low melting point to adhere the surfaces to be soldered together. Soldering is more like gluing with molten metal than anything else. Soldering is also a must have skill for all sorts of electrical and electronics work. It is also a skill that must be taught correctly and developed with practice.

Remember that when soldering, the rosin in the solder releases fumes. These fumes are harmful to your eyes and lungs. Therefore, always work in a well-ventilated area. Hot solder is also dangerous. Be sure not to let is splash around because it will burn you almost instantly. Eye protection is also advised.

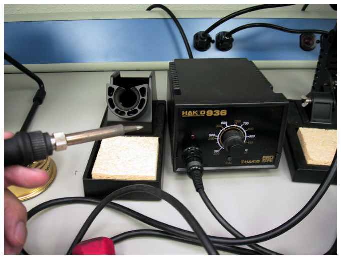

The Tools

Soldering Iron – Even the cheapest of them will do the job. They may not last as long, but they do get hot enough to melt solder and that is the goal. You only need to make sure that the one you buy has a suitable tip on it. The most typical tip is the one that is about the size of a 1/8” stereo mini-plug.

Solder – Get Rosin Core solder. Rosin will help the solder to flow onto the wires. Solder comes in different thickness. Buy what is appropriate for your job.

Desoldering Gun – This tool will make life a lot easier when you need to rework a previous solder job.
Solder Wick – Braided copper with rosin coating used to draw solder off of circuit boards.

SMD Rework station— Basically this is a high temp hair dryer with special nozzle attached. It heats up entire pins of the SMD device so you can remove them.

The Methods

Soldering – There is not art to soldering, it takes patience and practice to get it right. If you are doing it right, it will be easy and very fast. First, make sure that your soldering iron tip is clean. If it is dirtier than just a light gray color, you need to clean it. You can do this with sandpaper or a Scotch Brite pad. Next, turn your iron on and give it plenty of time to heat up. To test the heat, use a piece of solder touched to the tip. If it melts immediately, it is ready.

The most common way to mess up a solder job is to let the soldering iron stay on the parts to be soldered too long. What this does is oxidize the metal, making it too dirty to attract solder. If you are working with a circuit board, too much heat can damage the board, rendering it useless and in need of repair. You should only hold the soldering iron to the parts to be joined for no more than 10-12 seconds. Any longer and you will melt insulation on wire or damage a circuit board.

It has been said that soldering is a two-person job. You need two hands to hold the parts together, one hand to hold the iron, and another to feed the solder. The correct method for applying solder is to hold the joint perfectly still while heating with the soldering iron. After a few seconds, introduce the end of the solder at the point where the iron meets the parts

If the solder does not melt immediately and flow onto the joint, pull the solder away and try again after a couple seconds longer. If you exceed 10 seconds, pull the iron off and try again after it all cools down. You probably didn't have the iron touching enough of the parts to be soldered. Sometimes, the parts to be soldered are so big that they conduct the heat away very quickly and make it difficult to solder. In this case, it is OK to put some solder on each part individually and then put them together later by melting the solder on each one while they are touching.

Joining Two Wires - Strip off about 3/8" of insulation from the two wire ends to be joined. Place a ½" length of heat shrink tubing over one wire and push it back so that the heat from soldering won't shrink it prematurely. Fold each bare wire end back on itself so that the tip of the wire now comes back to the end of the insulation. Link both wires together using the bends like hooks. Now, twist the ends of the wires around themselves tightly. This type of connection is called a Western Union and it is the strongest method of joining two wires together. Now, heat the connection with the iron and allow solder to flow over the entire joint. Wait a few seconds for it to cool off and then slide the heat shrink tubing down over the connection and heat it with a match or heat gun.

Soldering a Wire to a Circuit Board – This is delicate work that you will do while soldering. Too much heat and your board will be damaged. If you are attaching a wire to an existing hole on the board, make sure that the hole is clean and free of any excess solder (see de-soldering for more detail). The best advice when soldering to a circuit board is to angle your soldering iron tip so that it makes good contact with the pad on the circuit board and the wire or part to be soldered at the same time. Heat the parts up and touch the solder at the point where the tip meets the part and the pad. If the solder does not flow immediately, pull everything off and wait for it to cool down and try again later.

Step 1

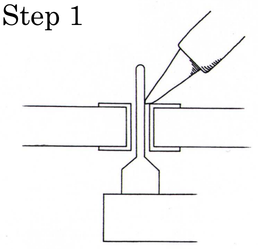

Apply heat to both pin and pad on the circuit board. Make sure tip of the soldering iron is touching both pin and pad.

Step 2

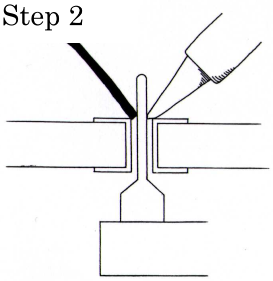

When the both pin and pad are heated enough, apply solder to the pin and pad. Solder should starts to flow.

Step 3

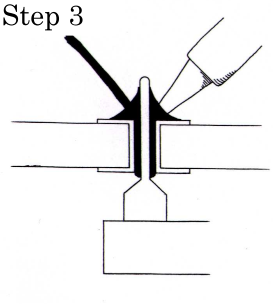

Apply enough but not too much solder. While applying the solder, do not move the tip of iron.

Step 4

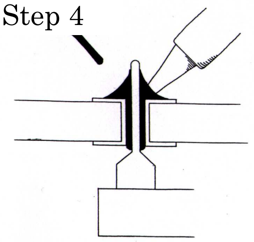

Remove solder away.

Step 5

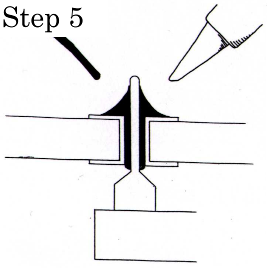

Remove tip of soldering iron also.

Step 6

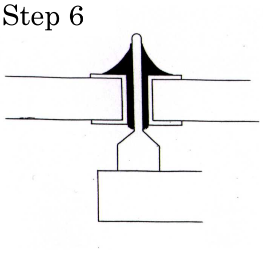

Done! Check the joint to make sure the connection.

Good soldering and Bad soldering Joints

Here are some example of Good soldering and Bad soldering joint.
For Japanese, we often say, “Good soldering joint should look like Mt. Fuji.”

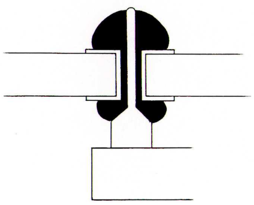

Too much soldering

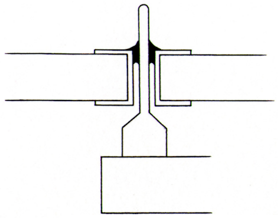

Too little soldering

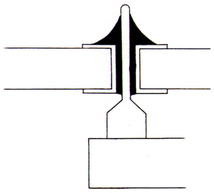

Good soldering

Cold Solder Joints
A cold joint is a joint in which the solder does not make good contact with the component lead or printed circuit board pad. Cold joints occur when the component lead or solder pad moves before the solder is completely cooled. Cold joints make a really bad electrical connection and can prevent your circuit from working.
Cold joints can be recognized by a characteristic grainy, dull gray color, and can be easily fixed. This is done by first removing the old solder with a desoldering tool or simply by heating it up and flicking it off with the iron. Once the old solder is off, you can re-solder the joint, making sure to keep it still as it cools.

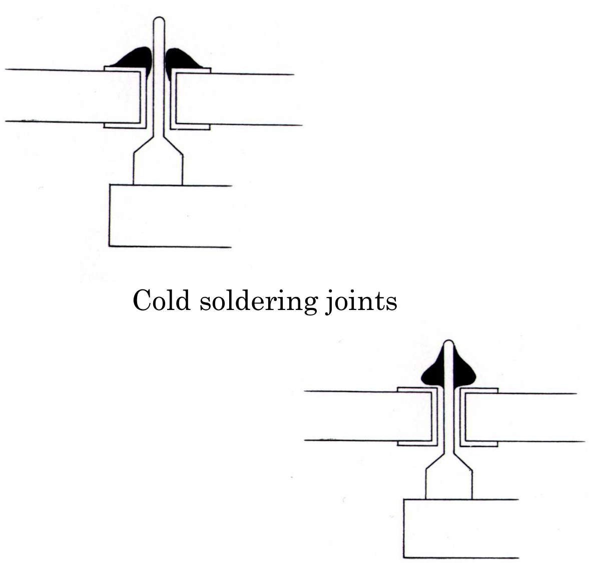

Cold soldering joints

Tips and Tricks

Soldering is something that needs to be practiced. These tips should help you become successful so you can stop practicing and get down to some serious building.

1. Use heat sinks. Heat sinks are a must for the leads of sensitive components such as ICs and transistors. If you don't have a clip on heat sink, then a pair of pliers is a good substitute.

2. Keep the iron tip clean. A clean iron tip means better heat conduction and a better joint. Use a wet sponge to clean the tip between joints.

3. Double-check joints. It is a good idea to check all solder joints with an ohmmeter after they are cooled. If the joint measures any more than a few tenths of an ohm, then it may be a good idea to re-solder it.

4. Use the proper iron or temperature. Remember that bigger joints will take longer to heat up with an 30W iron than with a 150W iron. While 30W is good for printed circuit boards and the like, higher wattages are great when soldering to a heavy metal chassis.

Desoldering

Desoldering is extremely difficult compare to soldering. In the process of RomBoard installation, the parts and circuit board must be in the good shape to re-use them. The tool we use is Desoldering Gun. This device has vacuum pump built in with heater tip. Process of desoldering it self is very simple, but there are some tricks to do clean and safe desoldering job.

Step 1

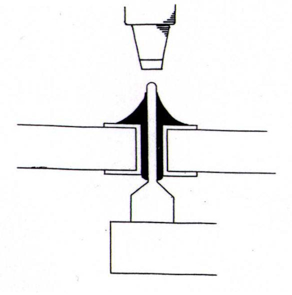

Put the desoldering gun's tip over to the soldering joint. Make sure nozzle is 90° angle from circuit board.

Step 2

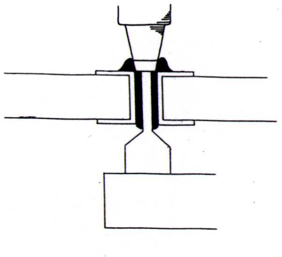

Apply the enough heat to melt entire solder. Multi-layer board or ground pin may take while to transfer heat.

Step 3

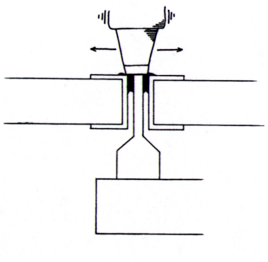

While applying vacuum, move the tip around the pin to get all the solder of around the pin out. At this time, you can also feel pin moves freely, so you know pin is free from circuit board.

Step 4

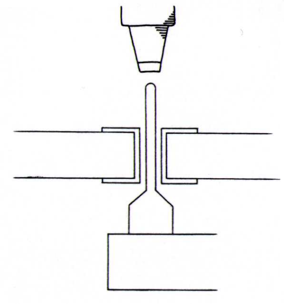

When you can hear air flow sound from hole, you should be done. Stop applying vacuum and remove the gun from the pin. Inspect hole and pin.

When you done with desoldering, the parts that you are trying to remove should move freely. If it doesn't, find which pin is still has solder left, and re-apply fresh solder to it and try desoldering process again. The multi-layer circuit board require more heat to get solder to melt. Make sure pin start to move freely by moving the tip of soldering gun before you apply vacuum to it.

SMD device soldering and removal

In the process of RomBoard installation, chance of handling SMD devices is becoming higher and higher due to ECU configuration change.
Soldering of SMD devices are not much different from regular through hole soldering.
Important thing is positioning of the device is very critical.
Start with applying little solder to two of the each corner of the pads on the circuit board.
Then, place the SMD device and re-heat a one of the solder you just applied to connect a SMD device pin to the pad. Check the position of the device, if position is right re-heat the other end of solder to secure the device completely. If you didn't get position right, re-heat the pin that you just soldered and while heating a pin, move the device to the right position.
Once you positioned the device in the right position, apply Rosin Flux to both pins and pads. This will help your soldering job by keeping solder separate from each pin.
Here is how the joint on SMD device pin should look like.

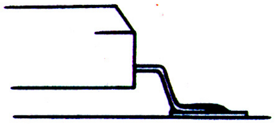

QFP and SOP chip

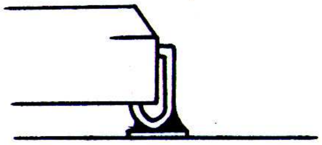

PLCC chip

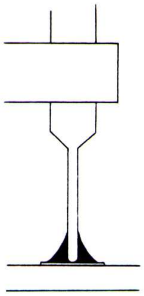

RomBoard adapter socket

Removing SMD device will be the probably the most difficult process. SMD rework station is used to do this. Make sure all the pins are completely heated otherwise you will be removing a pad from the circuit board along with device. Also, you should note, when you are applying heat to the device, some parts around the device is also heated and moves around when you touch. It is good idea to take a note of location of the devices near the target device.

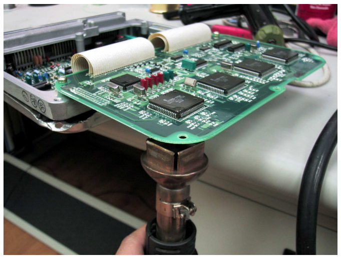

Step 1
Apply pre-heat from back side of the target device. Keep applying heat until you can't touch the chip. By this time, circuit board should have enough heat.

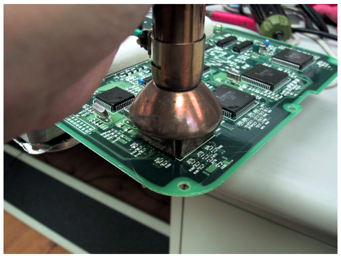

Step 2
Apply heat from top of the target device. Nozzle should cover entire chip. You can check if chip is free from solder by sliding the nozzle left and right. Make sure you don't move other parts. If the chip moves freely, it is ready to be removed.

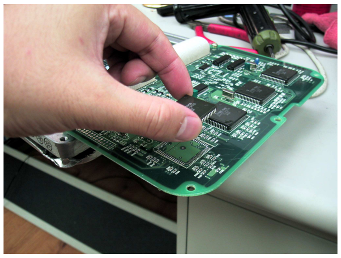

Step 3
Remove the chip straight up to avoid making solder bridge between pins. Chip is extremely hot! Unless you have skin of steel, avoid imitating the picture.

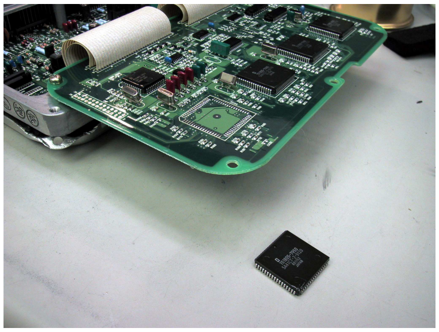

Step 4
After remove the chip, cool down both circuit board and chip.

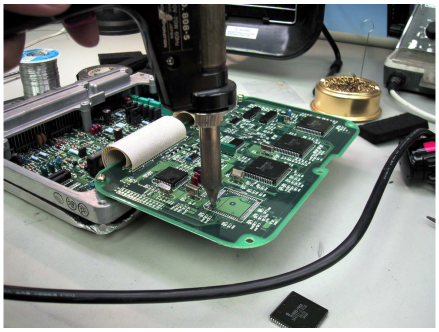

Step 5
Clean the pads on the circuit board with desoldering gun.
Do not apply too much heat to the pad. Pad might peel off from circuit board. Clean the chip by desoldering gun also.
Check for any bridge between pins. If the chip has too much protective coating on it, use solvent to clean it up.

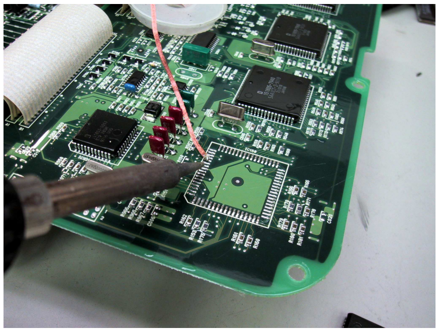

Step 6
If the pads on the circuit board is too small to use desolding gun, try cleaning by solder wick with rosin flux. This may take time but it is much better than peeling pads off.
Once again, do not apply too much heat.

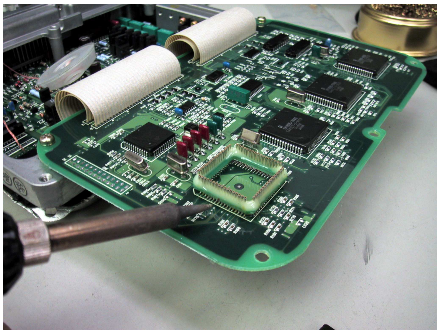

Step 7
Solder the RomBoard adapter where the chip was.
Refer SMD device soldering section for how to solder adapter.

The Final Word

Soldering, desoldering, and working with SMD device will take some effort to learn. You should be relaxed and concentrated when you work.
Keeping every thing clean (tip of iron, gun, work surface, etc) will help you also.
Once you get comfortable to work with soldering you may find your own tips and tricks.
Experience is all bout soldering.

EOF

Strain Gage Soldering Techniques

Introduction

The most common method of making electrical connections in strain gage circuits is by means of soft solders, in wire form. Other methods, such as spot welding, brazing, compression bonding, paste solders, and conductive epoxies, are also available, but find only limited application. Solders have many advantages for strain gage use — they are low in cost, readily available in various alloy compositions to provide a range of melting temperatures, and are easily obtained in the form of either solid wire or wire with a core of flux. They are convenient to use, and offer an excellent combination of electrical and mechanical properties.

Although soldering is basically a simple procedure, it must be done with appropriate tools, supplies, and techniques to assure accurate strain measurement. This is particularly true when test requirements are severe in the sense of approaching the limits of the strain gage circuit capabilities; e.g., long-term stability, high-elongation measurements, fatigue endurance, etc. Use of improper materials or techniques can significantly degrade strain gage performance.

The purpose of this Tech Tip is to outline recommended procedures and materials for attaching leadwires to strain gage solder tabs or to bonded printed-circuit terminals. These reliable, experience-proven methods are based on the use of a professional quality soldering station, in conjunction with Micro-Measurements solders and installation accessories.

Soldering Station and Pencil

For precision soldering of strain gages, it is always necessary to use a temperature- or power-controlled soldering station that provides low voltage and adjustable temperature to the soldering iron tip. An unregulated soldering iron, connected directly to the power line, is not ordinarily suitable for strain gage use because the tip temperature is apt to be far too high. This tends to oxidize the tip, and to instantly vaporize the flux, making soldering much more difficult. In addition, the unnecessarily high temperature may damage the strain gage, the bonding adhesive, or even the test specimen. For these reasons, the soldering station should incorporate provision for adjusting the soldering temperature to suit varying installation conditions and requirements. The temperature must be adjusted, of course, to accommodate the melting points of the different solders commonly used for strain gage connections, but also to allow for environmental conditions such as drafts or outdoor soldering in cold weather. Moreover, the temperature controller should be carefully designed to ensure that it does not generate electrical noise that could adversely affect nearby measuring instruments when both are in use.

Design of the soldering pencil also requires special consideration. It should be light in weight, with a very flexible power cord, and with the gripping area thermally insulated from the heating element. These characteristics contribute to the comfort, ease, and precision of soldering, and minimize operator fatigue during long periods of use. The soldering tip itself should be of the flat, chisel, or screwdriver type. Pointed tips should not be used, because they tend to draw solder away from the work area, and thus make it more difficult to achieve a proper joint. In contrast, flat tips act to confine the solder, while offering greater surface area for better heat transfer and more effective soldering, generally.

Micro-Measurements soldering units incorporate all of the above features and a number of others, designed to help the user easily make consistent, reliable solder joints. These soldering units are widely used by professional strain gage installers everywhere, in both stress analysis laboratories and in transducer manufacture.

Solder Selection

The Micro-Measurements Division stocks a broad range of solder types to meet various installation and test requirements. While solders are sometimes selected to provide specific electrical or mechanical properties, the most common basis for selection is simply the melting-temperature range. Low-melting-point solders, for example, are generally used for strain gage installations on nonmetallic test parts to avoid damaging the gage, bonding adhesive, or test material due to overheating. In contrast, high-temperature solders are normally selected only when necessary to satisfy elevated-temperature testing requirements. These solders are somewhat more difficult to handle because the higher working temperature

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rapidly vaporizes the flux, and oxidizes the soldering tip, both of which tend to impede the soldering process. Specially designed soldering tips are recommended for high-temperature use.

For routine applications, where test conditions do not dictate the use of either a low- or high-temperature solder, an alloy with an intermediate melting temperature is the normal selection. The 63/37 tin-lead alloy (Type 361A-20R) is an excellent choice for general-purpose strain gage soldering. As an eutectic alloy, it has a sharply defined melting temperature — a characteristic that largely eliminates "cold" solder joints. The addition of a trace of antimony provides superior performance when the soldered connections will be exposed to very low (cryogenic) temperatures for long periods of time.

The general-purpose solders are supplied with a core of activated rosin flux. This makes soldering much more convenient, and is particularly useful in field applications where accessory liquid rosin flux (M-Flux AR) may not be available. Solid-wire solder, with externally applied acid flux (M-Flux SS), is recommended for making soldered connections to Micro-Measurements K- and D-alloy (modified Karma and isoelastic) strain gages. Rosin-core solders should not be used in conjunction with acid flux.

Silver solder (Type 1240-FPA) is available for applications where leadwire connections will be exposed to temperatures above about +550°F (*+290°C*). This solder, in paste form, is not suitable for attaching wires directly to strain gage solder tabs or to bondable terminals, but is intended for connecting instrument leads to preattached strain gage leads, as with WK-Series gages using a special resistance soldering unit. Techniques for making leadwire connections with silver solder are described in Micro-Measurements Tech Tip TT-602, *Silver Soldering Technique for Attachment of Leads to Strain Gages.*

Soldering Flux

The function of a soldering flux is to remove oxidation from the members being joined (solder tabs, terminals, leadwires), and to prevent further oxidation during soldering. For making leadwire splices, or soldering directly to constantan foil or copper terminals, the flux contained in a rosin-core solder is usually sufficient. With higher temperature solders, however, it may be necessary to supply additional flux. A liquid activated-rosin flux such as M-Flux AR is recommended for this purpose.

Acid fluxes should never be used on constantan strain gages or copper terminals, or for splicing copper leadwires; and paste fluxes, containing chlorides, should not be used under any circumstances for strain gage soldering. When tinning bare (without soldering options) solder tabs of Micro-Measurements K- and D-alloy strain gages, a liquid acid flux (M-Flux SS) is recommended. After the tinning operation, the residual flux must be completely neutralized within one to two minutes; and then the leadwire joint can be completed using the same solder and M-Flux AR rosin flux or a rosin-cored solder.

Preparation of the Soldering Tip

New soldering tips should always be tinned with solder prior to initial use. This is easily accomplished by wrapping one to two in (*25 to 50 mm*) of solder wire around the working portion of the tip while the soldering iron is cold, before applying power to the soldering station. If rosin-core solder is used, no external flux is required. With solid-wire solder, however, the wrapped tip should be dipped into liquid rosin flux (M-Flux AR) to provide sufficient flux for initial tinning. Set the control on the soldering station to the appropriate temperature range for the solder, and apply power to the unit. Allow the soldering pencil to heat until the solder wrapped around the tip melts completely. Remove excess melted solder from the tip with a dry gauze sponge. Never knock the heated soldering pencil against any object to remove excess solder, since this may result in personal injury or damage to the soldering pencil.

Note: Cross-alloying of solders can change the electrical, chemical, thermal and mechanical properties of the solder being used. To prevent cross-alloying, it is recommended that only one type of solder be used with each soldering tip. Of course, if one type of solder is incorporated in a gage with solder dots and another type is added, a mixture is produced. This mixture cannot be expected to have melting and strength properties any better than those of the lower temperature component.

Oxidation of the soldering tip seriously hinders the soldering operation. The tendency for oxidation can be minimized by ensuring that excess melted solder remains on the tip at all times when it is not actually in use. Negligent maintenance practices, or wiping the hot tip with materials that char on the surface, will produce a buildup of oxide that prevents proper soldering. If the tip does become oxidized, the following procedure is effective for cleaning and re-tinning:

1. Set the soldering station to the appropriate temperature range for the solder in use.
2. Place several drops of M-Flux SS on a glass plate. Re-tin the soldering surface by holding the heated tip in the SS flux while feeding solder onto the tip. A generous amount of solder is essential for proper tinning.

Strain Gage Soldering Techniques

3. Wipe the excess solder from the tinned tip with a dry gauze sponge. For severely oxidized tips, it may be necessary to repeat this operation several times to obtain a properly tinned surface. The soldering tip should never be filed or sanded, since this may remove the plating on the tip, accelerating the oxidation and leading to the early deterioration of the tip. After the cleaning operation, remove excess solder, re-tin and clean the tip several times, using rosin-core solder, or solid-wire solder withM-Flux AR.

Tinning Solder Tabs and Bondable Terminals

All strain gage solder tabs, terminals, and leadwires must be properly tinned before making soldered connections. This helps ensure active surface wetting and good heat transfer during the soldering operation. Tinning stranded leadwires to produce a formable solid conductor will also greatly simplify the leadwire attachment procedure.

Before tinning the solder tabs on open-face (unencapsulated) strain gages, the measuring grid should be protected with PDT drafting tape. The drafting tape is positioned to cover the entire grid and the upper portion of the solder tabs, as shown in Figure 1. This not only shields the grid from soldering flux and inadvertent solder splash, but also restricts the flow of solder on the tabs. The tinned area on the solder tabs should be only large enough to easily accommodate the leadwire size in use. The latter consideration is particularly important when making installations for dynamic applications or large-strain measurement.

The tinning procedure for strain gage tabs and terminals consists of first cleaning and reapplying a small amount of solder to the hot soldering iron tip. Next, apply a drop of M-Flux AR to the tab or terminal (this step can be omitted if a rosin-core solder is used). When soldering directly to bare Karma or isoelastic foil, use M-Flux SS on the gage tabs only. Hold the soldering pencil in a nearly horizontal position (<30°), with the flat surface of the tip parallel to the solder tab or terminal. Place the solder wire flat on the gage tab, and press firmly with the tinned hot soldering tip for about one to two seconds, while adding approximately 1/8 in (*3 mm*) of fresh solder at the edge of the tip. This procedure assures that there is sufficient solder and flux for effective tinning. Simultaneously lift both the soldering pencil and solder wire from the tab area.

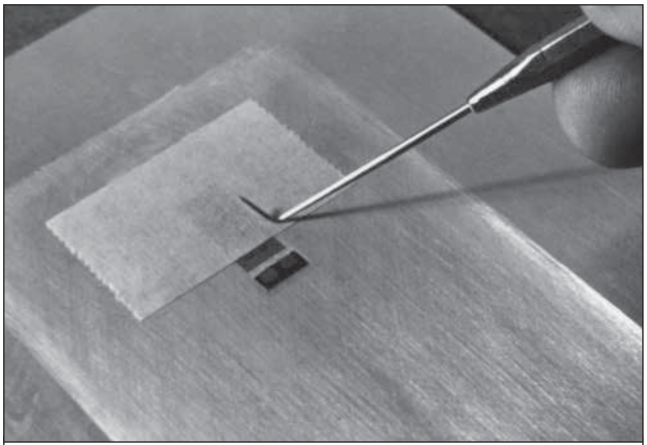

Figure 1 – Gage grid and upper portion of solder tabs masked with drafting tape.

NOTE: Lifting the soldering iron before lifting the solder may result in the end of the solder wire becoming attached to the tab; lifting them in the reverse order can leave a jagged (spike) solder deposit on the tab. When the operation is performed properly, it will produce a small, smoothly tinned area on the tab or terminal.

If M-Flux AR or a rosin-core solder is used in the tinning, it is not necessary to remove the residual soldering flux at this time. However, when M-Flux SS is employed to tin the bare solder tabs of K- or D-alloy gages, the acidic flux residue must be removed immediately following the tinning operation. To remove the residue, apply M-Prep Conditioner A liberally, and wash the area with a soft brush; then blot dry with a clean gauze sponge. Next, wash again with freely applied M-Prep Neutralizer 5A, and blot dry with a clean gauze sponge.

NOTE: Special procedures for tinning and wiring strain gages supplied with preattached solder dots are described in Micro-Measurements Tech Tip TT-606, *Soldering Techniques for Lead Attachment to Strain Gages with Solder Dots.*

Tinning and Attaching Leadwires

Of course, leadwire ends must be stripped of insulation before tinning, and this should be done with a thermal wire stripper to avoid the damage to the wire that often occurs when mechanical wire strippers are used. After the wires are stripped, the ends of stranded conductors should be twisted tightly together before tinning. The bare leadwire ends can then be tinned easily with the following procedure:

1. Remove excess solder from the soldering tip, using a dry gauze sponge. Then melt fresh solder on the hot tip to form a hemisphere of molten solder about twice the diameter of the wire to be tinned.
2. If rosin-core solder is used, slowly draw the bare wire through the molten solder while continuously adding fresh solder to the interface of the wire and soldering tip. With solid-wire solder, apply M-Flux AR to the

Strain Gage Soldering Techniques

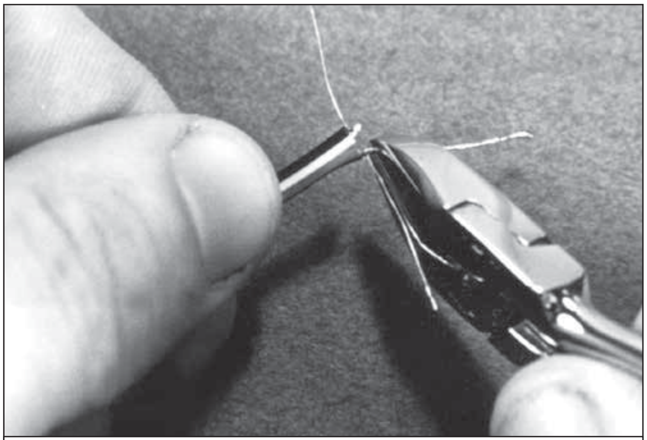

Figure 2 – Trimming leadwire ends before taping in place.

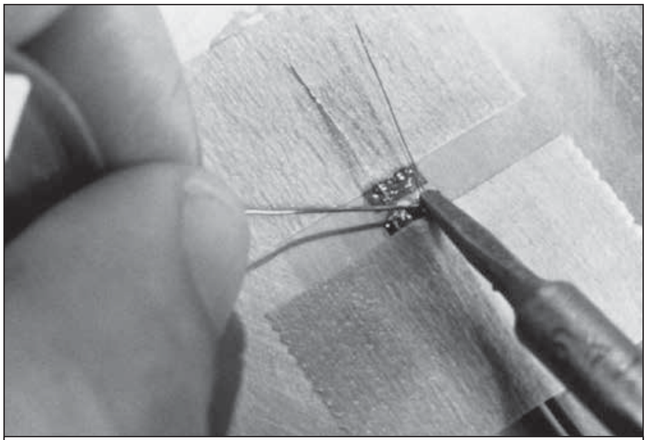

Figure 3 – Leadwire end taped to surface in preparation for soldering.

wire end before starting to tin, and proceed in the same manner. This will produce a smooth, shiny coating of solder over the bare wire.

For applications employing bondable terminal strips and stranded instrumentation wire, it may be convenient to use a single strand of the wire as a jumper between the terminal and the strain gage solder tab. In such cases, the single wire strand should be separated out before twisting and tinning the remaining strands (see Micro-Measurements Tech Tip TT-603, *The Proper Use of Bondable Terminals in Strain Gage Applications*).

Leadwires should be formed and routed to the strain gage or terminal strip, then firmly anchored to the test-part surface with drafting tape before making the soldered connection. Attempting to route the leadwires after completing the solder joint will often result in damage to the gage or terminals. Routing into the connection area should be along a minimum strain direction (such as the "Poisson" direction in a uniaxial stress field) particularly for high elongation or dynamic tests. The tinned leadwire end should be trimmed short enough so that it will not protrude through the connection area, and cannot inadvertently make electrical contact with the test-part surface or adjacent solder connections. Figure 2 illustrates this stage in the procedure. In the final preparatory step, bend the leadwire end slightly to form a spring-like loop, and tape the wire firmly in place over the connection area, using PDT drafting tape. The tape should be within about 1/8 in (*3 mm*) of the connection area, as shown in Figure 3.

Clean and re-tin the soldering iron tip with fresh solder. The temperature of the iron should be adjusted so that the solder is easily melted, without rapidly vaporizing the flux. If the iron temperature is either too low or too high, it may cause poor solder connections, or it may damage the strain gage, terminal, or bonding adhesive. Apply a small amount of M-Flux AR to the joint area and, holding the soldering pencil nearly horizontal, firmly press the flat surface of the tip on the junction for about one second; then lift the tip from the soldered joint. If needed, additional flux can be provided during the joining operation by feeding a little fresh solder into the joint from a spool of rosin-core solder. This procedure should result in a smooth, hemispherical solder joint, without any peaks or jagged areas. If the solder joints are not smooth and uniform in size, repeat the soldering procedure, using additional flux and/or solder as necessary.

Cleanup and Inspection of Soldered Joints

After completing the soldering operation, it is imperative that all traces of residual flux be completely removed with RSK Rosin Solvent. The same solvent is used to soften the mastic of the drafting tape, permitting its easy removal. Do not try to pull away the tape with tweezers or other tools, because this may result in damage to the soldered connections or the strain gage grid. Thoroughly clean the entire installation area with generously applied rosin solvent and a soft-bristled brush. Clean the solder connection area until no visible signs of residual flux remain, and blot the area dry with a clean gauze sponge. Any traces of residual flux can cause gage instability and drift, and will inhibit bonding of the installation's protective coating. Incompletely removed soldering flux is the most common cause of degraded performance in strain gage installations. Residual flux mixed with a protective coating application can completely destroy the coating objective.

Visually inspect the soldered joints for any gritty or jagged joint surfaces, and for traces of flux. Solder connections

Strain Gage Soldering Techniques

should be smooth, shiny, and uniform in appearance. Any soldered joints that look questionable should be re-soldered, and flux removed. Check the resistance-to-ground of the completed gage installation, using the Model 1300 Gage Installation Tester. Low or marginal resistance readings suggest a leakage path between the soldered connections and the test-part surface. This condition usually results from residual soldering flux, or from bare leadwire conductors partially shorting the gage tabs or terminals to the test part. Soldered joints should not be tested by pulling on the leadwire, or by probing at the joint area. These practices frequently cause lifting or tearing of the solder tab from the gage backing material.

Summary

The ability to make consistently good soldered joints is essential for precision strain gage measurements. The techniques described here are straightforward and easily mastered, but they are most effective when used with professional soldering equipment which is specially designed for making soldered connections in strain gage circuits. The soldering pencil should be lightweight, with a flat chisel or screwdriver tip, and it should be connected to the soldering station with a very flexible power cord. Requirements for the soldering station include low-voltage operation of the soldering pencil, and provision for temperature adjustment to suit the type of solder and the application conditions. The equipment should not generate electrical interference that could affect sensitive measuring instrumentation. Solder selection is based primarily on the expected operating temperature range of the strain gage installation; and all solder tabs, bondable terminals, and leadwire ends should be tinned before soldering the joints. Soldered joints should always be smooth and shiny, with no jagged or irregular edges, and all traces of residual flux must be thoroughly removed prior to the application of protective coating. Use of the recommended materials and techniques, with careful attention to detail, will result in consistently proper and reliable soldered connections.

Soldering & De-soldering

Digital Electronics

Soldering & De-soldering

This presentation will…

- Review the tools needed to solder and de-solder electronic components.
- Demonstrate how to *tin* a soldering iron tip.
- Demonstrate the soldering process.
- Show the characteristics of a good solder connection.
- Review classic soldering mistakes.
- Demonstrate the de-soldering process.

Soldering Tools

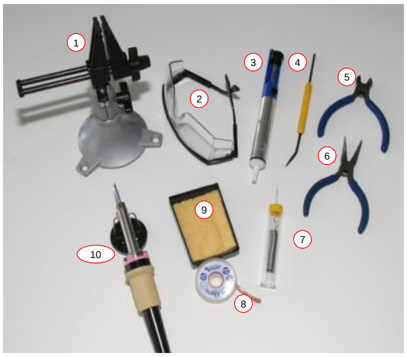

1) Vise
2) Safety glasses
3) Solder sucker
4) Solder tool
5) Diagonal cutters
6) Needle nose pliers
7) Solder
8) Solder wick
9) Damp sponge
10) Soldering iron

Soldering Iron

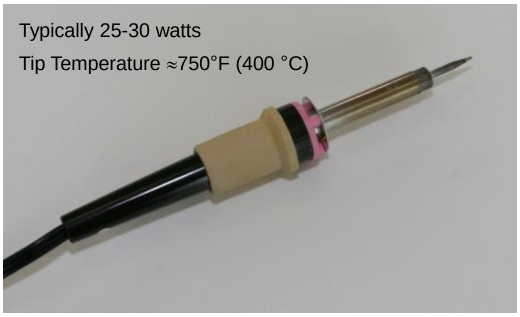

Typically 25-30 watts

Tip Temperature ≈750°F (400 °C)

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Solder

- Solder is an alloy of tin and lead.
- The solder used for electronics is frequently called 60/40 solder because it is made of 63% tin and 37% lead.
- 60/40 solder melts at 361° F.
- Lead-free solder**:** As of July 1st, 2006, European laws mandated that new electronics be entirely lead-free. As of yet, no such laws exist in the United States.

Soldering Iron Care & Maintenance

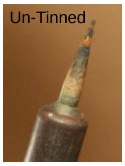

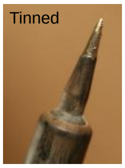

- A soldering iron must be coated with a thin coat of solder. This will allow for the transfer of heat to the work piece.
- This procedure is called tinning.
- The tip must be kept coated with a shiny layer of solder by occasional wiping and applying solder directly to the tip.

Tinning Process

Apply Solder to Soldering Iron Tip

Roll Tip on Damp Sponge

Properly Tinned Soldering Iron Tip

Solder Process

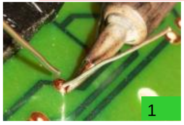

Heat both items at the same time by applying the soldering iron to the copper pad and the component lead.

Continue heating and apply a few millimeters of solder. Remove the iron and allow the solder joint to cool naturally.

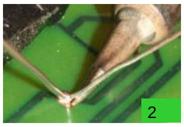

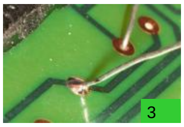

It only takes a second or two to make the perfect joint, which should appear shiny.

A Good Solder Joint

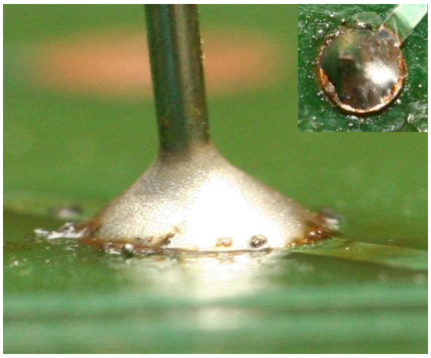

- Smooth
- Bright
- Shiny
- Clean
- Concave fillet

Bad Solder Connections

Too Much Solder

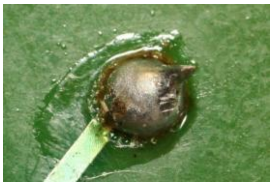

Too Little Solder

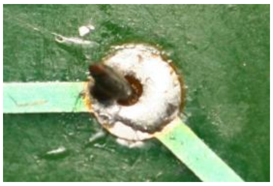

Bad Solder Connections

Cold Solder Joint

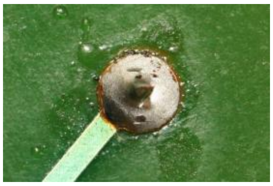

Not Soldered

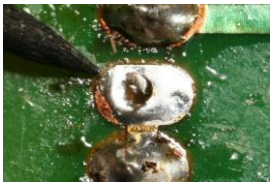

Bad Solder Connections

Solder Bridge

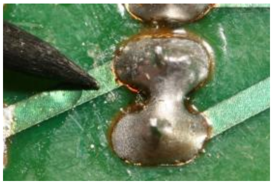

Lifted Trace/Pad

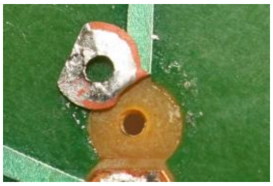

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De-Solder Process: *Solder Sucker*

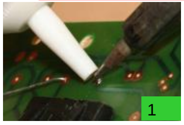

Apply heat to the connection to be de-soldered. When the solder melts, trigger the solder sucker.

Repeat de-soldering as needed until all solder is removed. Remove soldering iron & solder sucker from area.

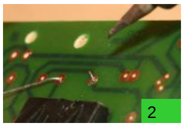

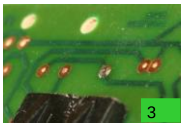

Remove component lead.

De-Solder Process: *Solder Wick*

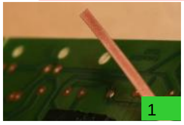

Solder wick is finely braided copper that is used to *wick away* excess solder from a de-soldered connection.

Apply the solder wick and soldering iron to the de-soldered connection. The solder wick will draw the excess solder off of the PCB pad.

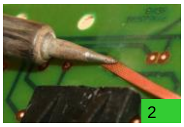

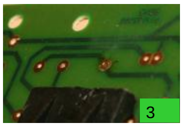

De-soldered PCB pad

Soldering Safety

- Wear safety glasses when soldering. This includes all individuals in the vicinity of someone who is soldering.
- Place soldering iron in an approved holder when not in use. The iron is hot and can cause burns.
- Place the soldering iron so that the cord does not get caught up in your arms or on others.
- Ensure access to proper ventilation.
- Verify that the type of solder is safe to use in your working environment.
- Secure the components to be soldered before beginning the soldering process.

Soldering Safety

- Provide plenty of space to work.
- Use a properly-sized point for the soldering job to be completed.
- Verify that the tip on the soldering iron has a sharp point and has not been damaged in any way.
- Check the power cord for burned or melted sections that show bare wires. Label those cords DO NOT USE and ask the instructor to repair or replace.
- Do not to touch molten solder - it is hot!
- Make sure that the solder strand is long enough to keep fingers away from the hot iron.

Soldering Safety

- Tie back long hair and remove or tuck loose clothing.
- Use heat sinks for heat-sensitive parts. Provide sufficient cooling time before removing parts.
- Do not flick solder off of the iron. Flicking can cause solder to spray and hit skin or eyes.
- Hold the scrap end when cutting excess leads so that the scrap lead is not thrown into the air.
- Cut leads evenly with wire cutters.
- Make sure that leads do not short across other traces or leads.
- Thoroughly wash your hands after handling solder.

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How to Solder Like a Pro

Detailed instruction, helpful hints, safety tips, and a comprehensive troubleshooting guide

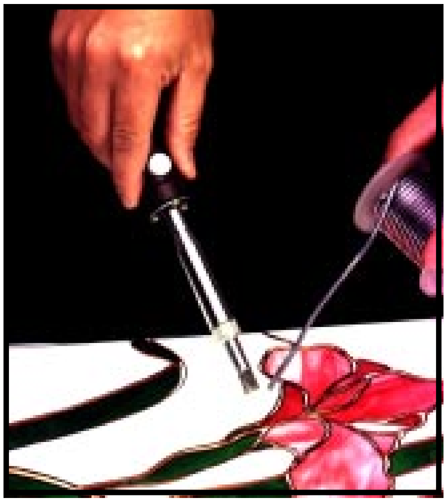

affordable products you can trust!

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Safety

The Importance of Safety

One of the most important aspect of soldering any stained glass project is to take the proper measures to safeguard your health. Soldering involves working with potentially hazardous materials like lead, flux and harmful fumes. By observing specific safety precautions and using informed common sense, working in stained glass can be a safe and enjoyable past time. The following is intended to serve as a general rule of thumb. Since each person and situation is unique, you should use this information as a starting point to help you make informed safety decisions concerning your soldering habits.

Fumes

Solder only in a well ventilated area, and use an exhaust device that moves solder fumes away from your face. It's preferable to exhaust outside (check local/state building codes and restrictions on venting to outside air). If you don't exhaust to the outside, use a bench top fan or intake device with a replaceable smoke/fume absorber made for stained glass artists. It should draw solder fumes into the replaceable filter. The filter should be activated charcoal and designed to remove particles smaller than 1/2 micron from the air. There are also several OSHA approved respirators available for fumes. Consider wearing one in conjunction with a venting system, especially if you plan on soldering for several hours every day.

Lead

Most popular solders used in stained glass are lead based. When you are using them, follow these precautions:

- 👎 Never eat, drink, or smoke in any area where soldering takes place.
- 👍 Always thoroughly wash your hands after soldering.
- 👍 Make sure your soldering equipment and supplies are kept out of the reach of children.
- 👎 Do not discard lead or solder scraps into the trash. Find a means or place to recycle them.
- 👎 Never use lead based solders or cames on items that will come in contact with food or children, or will be frequently handled. If you are making kaleidoscopes, jewelry or napkin holders, use lead free solder.
- 👍 Consider having your blood lead level checked by your physician on a regular basis to help you monitor your handling practices.
- 👍 If you are pregnant, or considering it, you should check with your doctor before using lead or solder.

Heat

Soldering tools operate at high temperatures, so these safeguards are important:

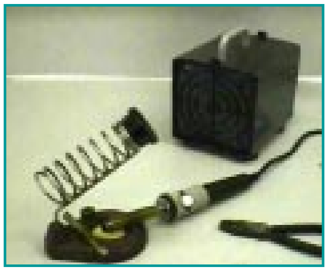

- 👍 Wear safety glasses! Solder and flux can "pop" and "spit."
- 👍 Solder on a fire resistant surface. Homosote, or dry wall are good .
- 👎 Never leave your iron plugged in and unattended.
- 👎 Do not overload a wall outlet with too many electric appliances.
- 👍 Never set your hot iron down on anything other than an iron stand.
- 👍 Replace the cord of your iron if it becomes worn or gets burnt.
- 👍 To prevent burning your fingers, use needle nose pliers or heat resistant gloves to hold small pieces.
- 👎 Never cut off a grounding prong on an iron plug to make it fit an ungrounded receptacle.

Soldering Irons

Choosing a Soldering Iron

There is a lot to consider when you choose an iron for stained glass. The handle should be heat resistant and comfortable for you to hold. You may be holding it for several hours at a time, so consider the weight and balance of the iron. Carefully check the wattage of the iron that you are considering. It must be able to continuously generate enough heat to melt all of the types of solder you plan to work with and be compatible with the type of construction you use (i.e.-copper, foil, lead came, rebar, etc.). You will need an iron that is at least 60 watts, with chisel type tips, and a way to control the temperature.

Types of Temperature Controls

A broad range of soldering irons are available. Most irons, which we will call "conventional irons," are made with wound wire heaters in a barrel with mica insulation. They are often inexpensive, but they do not offer the ability to control operating temperature. A separate temperature controlling device must be used with these irons to achieve the best results. There are three types of soldering irons that are easier to use for stained glass projects, because they allow you to control temperatures more effectively:

Irons with temperature controlled tips.

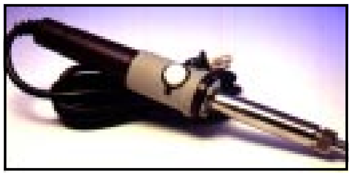

Irons used with temperature controlling devices.

Irons with ceramic heaters.

Irons with Temperature Controlled Tips

These irons are supplied with an internal regulator in the tip that does not allow the iron to exceed a predetermined temperature. An example would be a 600°F tip. The iron heats to that temperature then "shuts off." When heat is required, the iron "turns on" again. Tips are available in predetermined temperatures up to 800°F. These irons are easy for beginners to use, because the temperature is automatically maintained for you, however, as your skills increase, you may prefer to control the amount of heat yourself for different soldering situations. The limited amount of control may become frustrating as your soldering skills increase. With this type of iron you will likely encounter "cold spots" where the iron will not melt your solder. These cold spots occur when heat is being drawn out of the tip faster than it is being replenished. You will need an iron with a minimum of 100 watts.

Ceramic Heating Element Irons

These irons are relatively new to the stained glass trade. They are made with highly efficient ceramic heating elements. Like a ceramic room heater, they produce a consistent temperature using less electrical wattage during operation. When initially heating and when reheating during "recovery" periods, they can draw a "burst" of power exceeding 100 watts and then efficiently reduce electrical consumption, often below 60 watts, during the soldering process. The result is efficiency and economy.

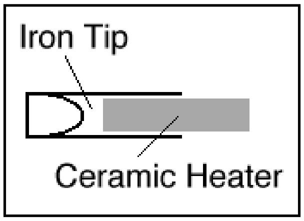

A remarkable feature of ceramic heater irons is they generally reach operating temperature in less than 60 seconds. Of the three types of noncoventional irons, the ceramic heater type best maintains consistent tip temperature over extended periods of time. Problems with slow heat recovery generally don't exist. A ceramic heater iron offers excellent flexibility and can be used with a temperature controller if you like.

Temperature Controlling Devices

A temperature controller is a device that operates similarly to a light dimmer switch. By dialing the control to a higher or lower setting, more or less electricity is fed to the iron. This increases or decreases the iron temperature, allowing the tip temperature to be controlled. You can establish the maximum temperature without changing tips.

A temperature control/iron combination offers you greater control and flexibility than a temperature controlled tip iron when working with different metals and solder mixes. Look for one that is at least 85 watts. Since the flow of electricity to the tip is consistent and never completely stops, encounters with cold spots are nearly eliminated. A temperature control/iron combination is suitable for all types of stained glass construction.

Temperature controllers are generally separate units that the iron plugs into. They are small, easy to use and relatively inexpensive. There are also irons that have controls built into the handle of the iron, which generally cost less than buying an iron and a separate control. Never plug an iron into a temperature control unless the manufacturer specifically states it is suitable for use with it.

Tip Sizes, Styles and Uses

Stained glass irons are generally sold with a "chisel" style tip. There are a variety of tip sizes and styles available for nearly every iron used in the stained glass industry. Different tips can expand the versatility of your soldering iron, so select an iron that offers more than one size replacement tip.

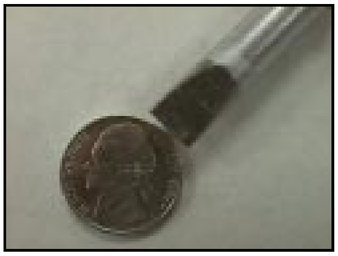

The standard tip size that comes with an iron is usually from 1/4" to 3/8" wide. This size works well for soldering either copper foil or lead came projects.

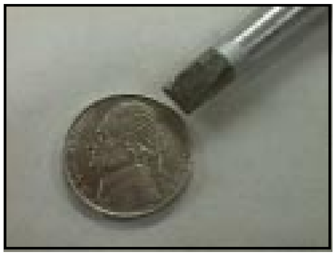

A smaller chisel tip, 3/16" wide, can be useful when soldering small pieces or when soldering in a tight area, such as a narrow inside part of a kaleidoscope. It is also very effective for decorative soldering.

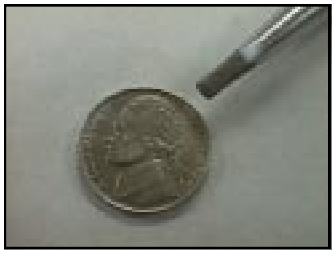

Very small tips, 1/8" or narrower, are usually used for decorative soldering. They allow you to create very fine details and designs with the solder.

Iron and Tip Maintenance

The Importance of Proper Care

Your soldering iron may very well be one of your biggest tool investments, so you will want to do everything possible to ensure that it gives you many years of service. Well maintained soldering irons and tips perform better and make the job of soldering much easier. Always place your soldering iron in a stable iron stand whether it is being used or not.

The Cord

- 👍 Make sure you plug the iron into the correct type of outlet.
- 👍 Try not to use an extension cord. If you must, use a heavy duty one.
- 👎 Don't drop or bang the iron. Ceramic heaters are especially easy to crack or break.
- 👍 Regularly check the cord for burns or cracks and have a professional electrician replace worn cords before using the iron.
- 👍 Make sure that the cord is not hanging in such a way that it can be pulled off of the table.

The Heating Element

- 👍 Do not allow the iron to idle at operating temperatures for extended periods. This could burn out the heater element. Unplug the iron or, if you are using a rheostat, turn it down to a low "idle" setting.
- 👍 Occasionally, remove the tip and **lightly** tap the barrel of wire wound heater irons to remove debris.
- 👍 If you will not be using your iron for an extended period of time, you may want to store it (after it has fully cooled) in a zipper type bag to protect it from corrosion and humidity.

The Tips

- 👍 When you are finished using your iron, remove the tip from the barrel. Removing the tip is essential to preventing "seizing" which can occur if it is left in the iron for extended periods. (If your tip seizes, you can easily damage the heating element trying to remove it. It is best to return you iron to the manufacturer for removal.)
- 👍 When reinserting tips, make sure they are properly seated in the barrel.
- 👎 Never dip your tip into flux in order to clean it. Instead, use a clean damp sponge to wipe all sides of the tip periodically as you solder. Doing this removes impurities the tip has accumulated from the solder and the environment. It will ensure that you are receiving the maximum heat at the tip surface.

- 👍 Properly cleaned tips are bright and shiny. If your tip becomes "blackened," you can usually remove the buildup with a wet sponge, a tinning block or by gently using a brass brush. A “tinning block” (sal-amoniac) is used by placing a small amount of flux on the block and rubbing the tip of your hot iron in it. Wipe the tip on a damp sponge to remove debris. You may need to repeat this several times if your tip is very dirty.)

- 👍 Never use sandpaper or any abrasive material to clean a tip.
- 👍 The best way to minimize your tip maintenance is to find a good quality solder. Use one that has a high tin content and high metal purity.

Solder

Why Do We Use Solder?

Solder is a combination of tin and lead used to create a strong bond between other metals. Since solder won’t stick to glass, we apply a copper foil tape (our metal) to the edges of the glass. This is refered to as the copper foil method of stained glass construction. Solder is melted over the copper foil, creating a structure that holds the pieces of glass together. The other option is to set the glass into channels of lead or metal, and solder the channels together. This is refered to as the lead came method.

The Advantages of Solder

Some of the advantages of soldering versus other bonding methods are:

- Solders are easy to use and relatively inexpensive.
- Low energy is required to solder.
- Properly soldered joints are highly reliable.
- Solder joints are easy to rework or repair.
- Experienced craftpersons can exercise a high degree of control over the soldering process.
- Solder joints age very well. They can last for years, decades and centuries.

Types of Solder

SILVERGLEEM

Stained glass solders are usually a mixture of tin and lead, designated by two numbers representing the percentages of each metal in that specific mix. The first number always refers to the percentage of tin, the second is the percentage of lead. The most commonly used solders in stained glass are 60/40, (60% tin/40% lead) 50/50 and 63/37. "Lead-free" solders have no number designation and are a mixture of tin and small amounts of other metals. Avoid solders containing antimony, a very toxic element. Instead look for lead-free solders containing silver, or copper. They are safer and easy to use. (Note they are, however, more difficult to patina.)

In North America, you will find solder is generally sold in solid core wire form on a spool. The common spool size is one pound. In Europe, you will find solders primarily sold in a bar form. Never use acid-core or rosin-core solders for stained glass work. Look for solders that are sold as "free of impurities" in the component metals. Impurities cause a "scum" on your solder bead, degrade soldering iron tips, and interfere with the proper reaction of patina chemicals resulting in undesired finishes.

An important term for solders is the "working range" or "pasty range." This is the range of temperature between which solder transitions from liquid back to solid.

Characteristics of Solder Types

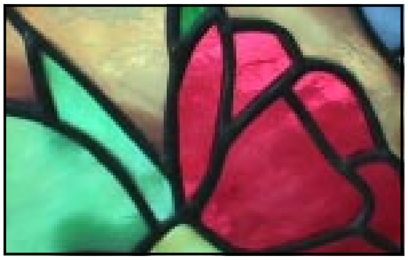

60/40 Solder: Composed of 60% tin and 40% lead, this solder melts at 374°F, but doesn't become completely solid until it cools to 361°F. This means it has a "pasty range" or "working range" of 13 degrees. This solder is your best choice for copper foil work. The liquid temperature and narrow "pasty range" make it easy to form and maintain consistent high, rounded, beaded seams. Because of its relatively low melting point, "60/40" solder is easy to rework to maintain a smooth finish solder bead.

50/50 Solder: This is composed of 50% tin and 50% lead. It is liquid at 421°F, solid at 361°F and has a pasty range of 60 degrees. This solder will produce a much "flatter" bead than 60/40. Because of its higher melting point, 50/50 solder is often used on the back (or inside) of a stained glass project to protect against "melt through" when soldering the front. Because it spreads and flattens out, 50/50 solder is often used when soldering lead came joints.

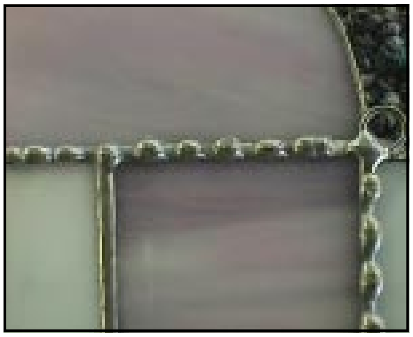

63/37 Solder: This solder is 63% tin and 37% lead. It becomes liquid at 361°F, and solid at 361°F, with a pasty or working range of 0 degrees. This solder is called a eutectic alloy which means at 361°F, you can go instantly from solid to liquid to solid just by applying or removing the heat source. You will often find "63/37" solder referred to as decorative or quick set solder. It is primarily used to create dimensional effects in the solder itself and can be "pulled" and manipulated to produce a variety of textures and designs. 63/37 solder also makes an excellent solder to bead up the outside rim of copper foiled pieces.

Lead-Free Solder: Depending on the specific mix of metals, lead free will produce differing liquid, solid, and pasty range temperatures. Check with the solder manufacturers for these specifics. Lead-free solders will perform similar to a 50/50 mix. Lead-free solders require more practice in order to obtain a smooth bead on copper foiled pieces and should not be used on lead came projects. Lead-free solder is the most expensive solder, but is the solder of choice when constructing pieces that will contact food, that will be handled frequently, or that will be used in a child's play area or room.

Solder Composition Reference Table

Alloy	Tin%	Lead%	Solid to	Liquid at	Pasty Range
50/50	50	50	361^0	421^0	60^0
60/40	60	40	361^0	374^0	13^0
63/37	63	37	361^0	361^0	0^0

Flux

Why Do We Use Flux?

Flux is a chemical compound that is used to promote the bonding of metals by removing the oxide residue simultaneously with the soldering process. Most metals left exposed to the air around us react with the air to form residue on the surface of the metal. The process is oxidization and the residues are oxides. Each mix of metals being joined has a specific flux that best promotes this bonding process. In stained glass, the metals being joined are primarily copper to tin/lead solder and lead, brass or zinc to tin/lead solder.

Types of Flux

Selecting the correct flux for your application is as critical as any other step of the soldering process. The proper flux will assure less soldering problems and a satisfactory solder bond. The best fluxes do three things:

- They remove all the residue that has formed on the surface of the metals you are going to solder.
- They prevent oxides from forming while you are soldering.
- Any post-soldering residue they leave is noncorrosive and easily cleaned off.

Fluxes are available in organic and inorganic forms. If you touch the flux and your skin seems to have a sensitivity to one type of flux, an inorganic type for example, try an organic variety. Often you will find that you are less sensitive to irritation by using the opposite type flux. Organic fluxes are generally some form of oleic (fatty) acids, while inorganic fluxes are most often zinc chloride based.

Characteristics of Fluxes

Liquid flux is the most widely used. It may or may not be water soluble. Water soluble fluxes clean up very easily, but are thinner and some have a tendency to evaporate quickly and require repeat applications. Some liquid fluxes are thinner than others and have a tendency to run or spread out from their point of application.

Gel Flux is generally water soluble and "adheres" well to the surface being soldered. Gels tend not to evaporate as readily as liquid flux, but if you apply too much, they produce more "spitting" and "popping" as you solder.

Paste Flux is very thick, stays where it’s applied, and doesn't evaporate easily. It's effective when soldering 3-D forms such as lamps. Paste fluxes can be difficult to clean. Be very careful not to over apply a paste flux as it will also spit and pop, leaving pits on your solder seams.

Getting the Most From Your Flux

It is important to keep your flux clean and free of impurities. This will ensure the purest possible solder joint. One way to keep your flux clean is to avoid dipping in and out of the original container. Pour out the amount you will need for your current project into a separate, smaller container. Don’t leave the flux bottle sitting around with the cover off. Never pour leftover flux back into the original container. Fluxes often will produce fumes as you solder. Make sure you are aware of and follow the precautions suggested in the health and safety section of this guide.

Soldering Basics for Copper Foil

The quality of the solder job can make or break your project, yet it is the step that takes the most practice to become good at. Soldering is more difficult than the other steps in stained glass because there are so many things that can effect it: the amount of heat, the amount of solder, the type of flux, the rate at which you move, gaps in the project, etc. The following step-by-step instructions will give you the basics of soldering. If you are just starting out, you will learn a lot. If you are experienced, you may just find the trick that makes it all come together. Great soldering takes a little bit of knowledge and a lot of practice.

Before You Start

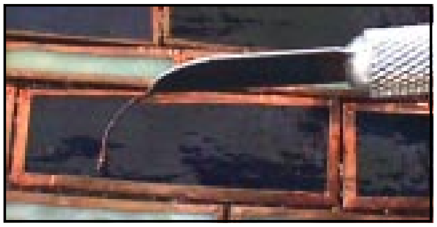

Preparation is the key to producing a good solder bead. Here are some suggestions to help you get of to a great start!

- Make sure that the foil is seated properly over the glass.
- Trim all overlaps in the foil using a sharp craft blade.
- Assemble all the tools you will need so they are at hand.
- Wear safety glasses.
- Have a proper ventilation set up.
- Make sure the foil is well burnished and sealed smoothly to the glass surface.
- Secure the glass pieces using pins, or squaring blocks made for this purpose before soldering.

Set aside enough time to solder your entire project all at once. If you don't, dried flux and solder residues on the unfinished parts will make further soldering difficult. Flux allowed to remain on a project can compromise the strength of the solder joints.

Cleaning Before Soldering

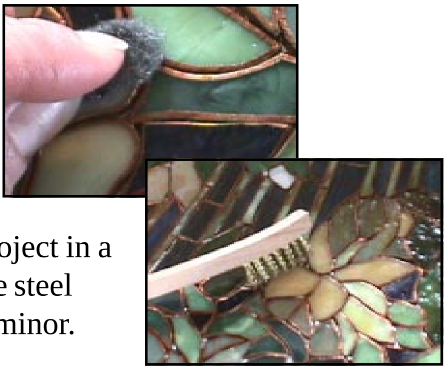

Sometimes the surface you are going to solder needs cleaning to remove visible grime, dirt, residue or oxidization. In this case, use 000 or 0000 steel wool to clean the surface of copper foil. For lead came or excessive oxidation carefully use a soft brass brush. If you won't be able to solder your project immediately after it is copper foiled, store it in a plastic bag to help reduce oxidation. If you partially solder the project and have to stop before it is complete, be sure to clean off all of the flux and store the project in a plastic bag until you are ready to continue. You will probably still need to use steel wool on the joints when you are ready to solder, but the clean up should be minor.

Getting Started

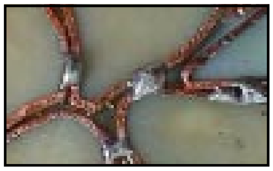

Begin the soldering process by fluxing all intersections of the glass project. Then "flat tack" solder these intersections together by using a very small amount of solder and the flat face of the iron tip. The solder should lay flat on the intersection and you shouldn't have any beads or bumps of solder on the piece. Hence the name "flat-tack" soldering.

Now, fill any gaps between the glass pieces by melting solder into them until the solder is level with the surface of the glass. If you have large gaps, you can ball up some copper foil, with the sticky sides together, and fill the gaps. This will help keep the solder from seeping out the other side.

"Tin" the entire perimeter making sure to work some solder into seams that intersect the perimeter. (Tinning is the process of coating a surface with a thin layer of solder. Apply just enough solder to turn the foil to the silver color of the solder.) This creates a "dam" that prevents solder from spilling over the edge when you solder the interior seams.

Next, flux an area you can comfortably finish soldering before the flux can evaporate. Start at the top of the piece and work down. This prevents you from dragging your sleeves and hands through the flux.

Running The Solder Bead

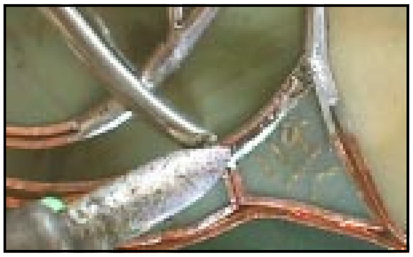

Hold your soldering iron in your writing hand. Position the iron comfortably so the face of the iron tip is perpendicular to the seam. If you hold your iron like a carving knife you will automatically put the tip in the best position for soldering. It will also keep you from "painting" with the iron. You will hold the solder in the opposite hand. Start soldering by placing the iron tip down on the foil seam with the wider face perpendicular to the seam and facing you. Touch the solder to the tip of the iron, just above the point where the iron tip touches the copper foil. Allow the solder to flow down the tip face onto the seam as you move the iron along the seam. Feed the solder at a continuous, even rate to create a consistent, rounded bead of solder over the seam. This takes practice!

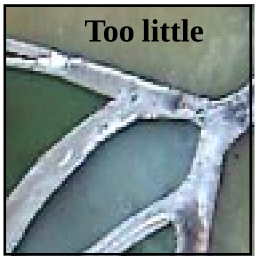

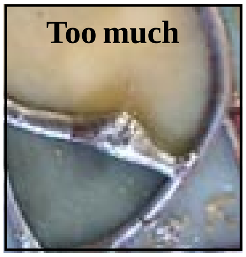

If you apply too little solder or move too quickly, your seam will be flat. To correct this problem, allow the solder to cool, then resolder the joint applying more solder. On the other hand, be careful not to feed the solder too fast or move the iron too slowly, as this will cause the solder seam to bulge and flow out over the glass.

Fixing Imperfections

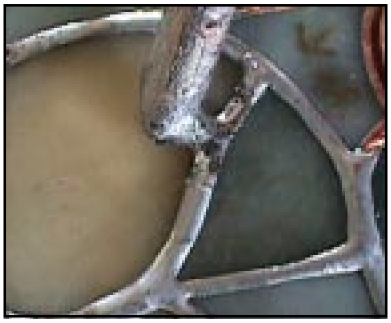

If you have too little solder, just add more, being sure to remelt the previous solder line as you apply another coat. If you applied too much solder the first time, it's easy to remove the excess with the following procedure. Clean your iron tip thoroughly on a sponge. With the iron tip positioned with the flat face down, move it across the seam, "pulling" the excess solder onto the glass. Clean your tip and repeat the process until all excess solder is removed. Another method for removing excess solder is to wait until all the seams have been soldered. Then place your project up on edge and run the tip through the seam allowing the excess to run off. Lay the piece flat, reflux, and rework the seam, adding additional solder as needed.

When you solder, work slowly enough to produce a good bead, but not so slowly that solder melts through seams to the back side of the project. Here's a hint: one way to prevent this is to put damp paper towel under your panel before you start soldering. Moving too slow also increases the likelihood of causing heat fractures on your glass.

Other Things To Consider

Always keep your tip clean by frequently wiping all sides of the tip on your damp sponge. Wait momentarily for the tip to reheat before continuing to solder. A clean tip maintains proper heat and removes impurities.

To achieve a smooth solder line, solder the longest continuous seam possible. Don't start or stop a solder seam at an intersection with another seam. As you meet an intersection, allow the solder to break or "y" out over the intersecting seam about 1/2" and then return to the original path you were soldering in one continuous motion. As you continue to solder seams, you will connect these branches, thus preventing pulling out at intersections of seams (which is a noticeable sign of a beginner). When you encounter a "v" type joint. Solder in a direction that moves up into the "v" point, instead of coming down onto the point. This keeps a nice clean "v" joint without excess solder obscuring it. Do this by soldering up one leg of the "v" and as you approach the apex, drop your iron tip down flatter on the glass, so that it crosses over both seams. Then continue soldering into and out of the point of the "v."

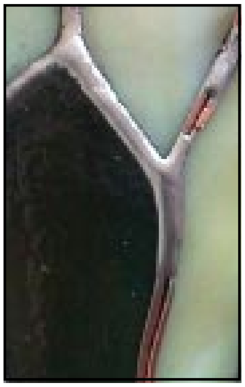

Avoid a "painting" motion when soldering. Visualize your iron as a magnet pulling along a metal strip. Maintain a small puddle of solder at the base of the tip as you solder. When two adjacent pieces of glass vary in thickness, ride the tip on the higher piece of glass as you solder.

Effects of using the iron like a paint brush

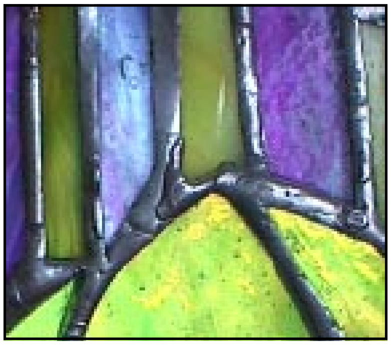

A big advantage of using copper foil is that not-so-perfect solder seams can be reworked. Allow the seam to cool, reflux it, then resolder. Be careful because reworking a seam too many times (more than 2-3) can cause the adhesive on the foil to loosen and bubble.

Solder one side of your project completely, then turn it over and repeat the process on the other side. Some of the flux from the first side you soldered will have seeped to the other side. You may encounter more "spitting," so use flux very sparingly. To achieve a smooth, beaded solder seam: practice! practice!

Ending A Bead

When you are ready to end your seam, pull off across the face of the glass making sure you are in a liquid section of the solder seam and do not lift straight up. This technique leaves a smooth exit point that is virtually unnoticeable. You may notice that this is the same photo used for removing extra solder. It’s not a mistake. The action is very much the same.

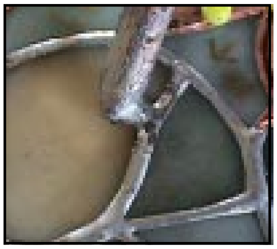

Practice!

Creating perfect solder seams takes practice. One good way is to make a practice board. Make sure to include all types of intersections and lines (curvy and straight). Foil the piece and flat solder it on the front and back. Practice each different soldering technique. When you are finished, you can hold the piece vertical and melt the solder off. Now you are ready to start again. Many people use the practice board before they start soldering each project, just to get the feel of soldering again.

Cleanup After Soldering

After soldering, you will need to remove all flux and solder residues from your solder lines and glass. The best cleaners to use are ones that neutralize the acid property of fluxes. To properly clean your project, you will need a good flux cleaner, very warm water and a soft scrub brush. Thoroughly brush the cleaner into every corner of your project, front and back. Follow this with a long rinse in clean, warm water and then towel the project dry. This step is very important because any flux that remains will continue to react with the solder, causing oxidation. If your project looks good after the initial cleaning, but the solder lines have a white or green growth on them after a few weeks, it generally means that all of the flux was not removed from the project. You can use 000 steel wool to remove the patina and finishing compound and thoroughly clean the project. Then reapply the patina and finishing compound.

A small stiff scrub brush is the best way to clean the entire project. After the initial cleaning, you may find some areas that need additional attention.

You may find small pieces of solder stuck to the glass. You can easily remove these using your fingernail, or 000 steel wool. Be careful not to scratch the glass.

An old toothbrush can be helpful for cleaning in tight intersections and right up against the solder line.

Occasionally you may find that after applying patina, certain types of glass acquire a “rainbow” effect. This is most likely to occur on hot colors, black, white and iridized glass. It is one of those things that is unpredictable and difficult or impossible to remove. You can try to remove it by using a paste made from baking soda, but it doesn’t always work. The only way to prevent this occasional problem is to be very careful not to get patina on your glass. Use a cotton swab to apply the patina only to the solder lines of the project. If you have this problem, it is a good idea to make note of it on any remaining glass, so you can be more careful the next time you use that particular glass.

Finishing

After cleaning your project you should use a finishing wax or compound to keep it looking it’s best. A good quality carnauba wax or pre-mixed wax and cleaner should be applied to all of the solder lines. A nice side effect is that the wax also enhances the color of the patina making it either rich black or shinny copper. You may find it helpful to reapply the wax after a few months. (If you would like to change the color of the solder, see the section about patina on page 16.)

Soldering Basics for Metal Cames

Lead came construction requires a different soldering technique than that used for copper foil. You can use the same iron and flux, but the preparation and actual soldering will differ. You will be soldering only the joints, instead of running an entire bead. With a little knowledge and some practice, you will be able to make perfect solder joints on lead or other metals.

Getting Started

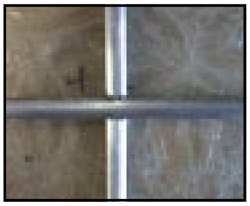

First, make sure that all joints are in line with each other and butt against each other with no gaps. Use a triangle and/or square to check the squareness of the panel and make sure that your lines run true across the panel in all directions. Make any adjustments that are needed. Thoroughly clean surface oxidation from intersections with a soft brass brush.

Soldering

The most desirable solder to use when constructing a lead project is 50/50. It flows out from the point of contact, leaving a nice joint. Do a "lead" test to check the heat of your iron. Allow the iron tip to heat for several minutes. Then, place the flat face of the tip on a scrap of lead. If the lead melts, the iron is too hot. Lower the temperature or change to a lower temperature tip. (This is where a rheostat iron is great.) Now test the tip with 50/50 solder to make sure it can melt it. If it does, your tip temperature is adjusted correctly. If not, raise tip temperature just until you melt the solder. Recheck the tip temperature and test it on the lead again. Now flux all the joints on your panel.

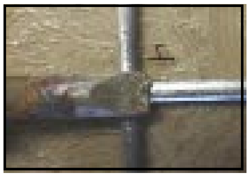

Begin by holding the solder on the joint. Move in to the joint across the glass, not from across the came. The wide face of the tip should be down toward the joint. Coming into the joint over the glass prevents leaving a solder trail on the lead came at one end of the solder joint. Techniques like these are the signature of an accomplished craftsperson.

Melt only a small amount of solder and move the tip in a slight circular motion allowing it to flow out over the joint a distance equal to the width of the came being used. Pull the iron tip straight up off the center of the joint. The desired end result is that intersections of the lead cames are not visible through the solder and the solder on them is smooth, not beaded. You should be able to run a fingernail over the came and into the soldered joint without it catching or clicking. Solder the joints on the front of the project. Then turn the project over and repeat the same process on the back.

Finishing

Lead projects need to be finished by applying a cement. The cement will weatherproof the project and secure the glass in the channels. This step is necessary on any came project to ensure a strong, secure panel. Cement is easily applied to the panel by using a small scrub brush to work the cement under the channels both on the front and back of the project. After the cementing process is complete, whiting sprinkled over the entire surface and allowed to absorb excess moisture for a few minutes. Using a stiff brush, vigerously brush the lead channels, removing excess cement from the glass. The brushing process allows a natural patina to form on the lead, so it is not necessary to apply patina to the project. Allow the project to dry thoroughly, usually for a few days, before installing or hanging the project.

Soldering Basics for Other Metals

Vase Caps

Vase caps are generally made from spun brass. The cap must be very clean of all dirt and oils for the solder to adhere. Use 0000 steel wool to clean the areas that you will be soldering. The cap also needs to be quite hot in order to achieve a good bond between the solder and the brass. An easy way to get the cap hot is to heat it in a hot oven for about 15 minutes. Use pliers to carefully remove the cap from the oven. Center the vase cap on the lamp. Flux all areas you will be soldering. (Paste flux is easy to use for this purpose, because it doesn’t drip.) Get a small amount of solder on your iron and hold it on the vase cap for a minute or so at the area you want to make a connection to the lamp. When the cap is hot enough, the solder will spread out instead of lumping up. Add more solder to make a connection to the lamp. (Some vase caps have a lacquer finish on them. This must be removed at the areas you need to solder. Use a craft knife to gently scrape the lacquer in these areas.

Spiders

Spiders are made from brass as well. You can either cut the legs to fit, or bend them. Like a vase cap, you need to get the brass quite hot in order to create a good bond with the solder. Unlike vase caps, you can get the smaller area of the spider hot enough using just your soldering iron. Simply hold your iron tip on the area that you need to solder for a minute or so. Apply flux and a little solder, and continue to heat the spider with your iron. When it is hot enough, the solder will smooth out around the spider leg and adhere to the lamp. If the solder is globed up, the spider leg isn’t hot enough. Continue in this manner for all of the legs.

Metal Outer Channels

When attaching a zinc, copper or brass edge to a project, use this solder technique: Cut the zinc, copper or brass came vertical members to overlap the horizontal members in a "butt" type joint. A butt joint provides structural stability and distributes weight. Before you solder the butt joints, you can use masking tape to contain the size of the solder joint.

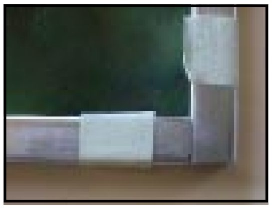

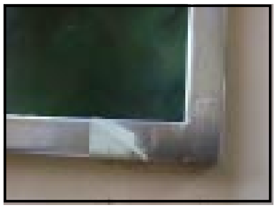

Clean and flux these joints and solder them to each other using the flat tip of the iron on the metal. The metal channel will take a little longer to get hot than copper foil. If the metal is not hot enough the solder will not smooth out. The metal frame should be attached to the panel by soldering it to any lead lines that it touches.

On leaded projects, solder from the outer metal edging onto the lead came, pulling the iron tip straight up over the point of intersection when completing the solder joint. This simple technique will level the solder smoothly over the joint.

For copper foil pieces, stop your solder bead about 1/4-1/2" from the outer edge to allow room for the metal edging to fit onto the perimeter of the project. If you forget to do this initially, flatten the solder bead so the outer edging fits onto the project. After fitting the outer edging material, flux and solder the corners as outlined above. Connect the copper foil beads that intersect with the outer edging metal by continuing the solder bead into the edging making sure that the solder adheres securely to the metal edge.

As you work more with your iron, different solders, lead came, and copper foiled projects, your skills will increase. You will quickly develop the techniques that will make you more confident in tackling increasingly complex projects.

Hanging Hardware

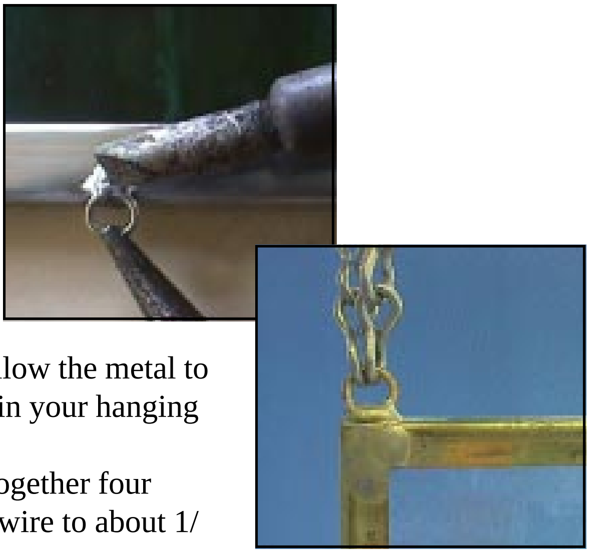

There are many ways to hang your project. You will want to make sure that the method you choose will support the weight of the project. You can purchase pre-made hardware from your stained glass store, or make your own using any type of solderable wire. If you are using wire look for 16 to 18 gauge.

Rings can be added to the metal border of the project if it is not too heavy. A general rule of thumb is about one square foot. Hold the ring with pliers and solder rings to the metal border of the piece wherever they allow it to hang properly. Just like soldering the channel together, if you don't allow the metal to get hot enough, the solder will not adhere well. This will result in your hanging rings failing.

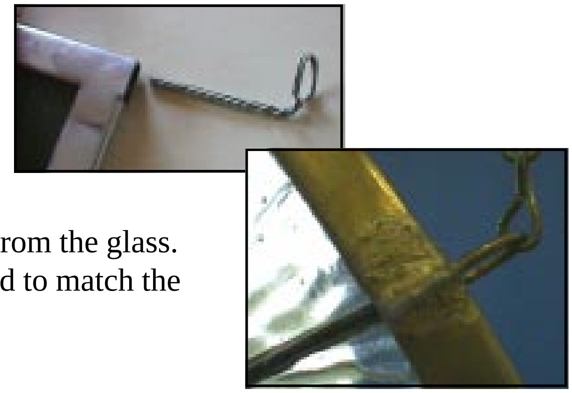

A stronger type of hardware is made using wire. Twist together four strands of 16 -18 gauge wire, leaving a loop at the end. Cut the wire to about 1/2". Insert the wire into the opening of the metal channel, bending the loop the direction you need it to be. Solder the hanger to the channel and fill the opening with solder.

Another option is to make a loop from twisted wire and solder it to the front and back of the metal channel, with the loop extending above the project. Be sure to solder the hanger into an existing solder joint, not just to the channel. This will prevent the weight of the project from pulling the channel away from the glass.

By the way, the joint on the hanger at the right was painted to match the brass channel using a gold paint pen.

Patina

Solder and lead change color naturally over time, but you can change their color instantly by using patinas. There are several different formulas producing a variety of colors. Patinas are easy to use. Make sure that your project is thoroughly clean and free of solder, flux and cutting residues. Use a brush or soft rag to apply the patina to the solder until you reach the desired color. Wash the panel again to remove any patina from the glass.

☞When using antique brass patina, first scrub your solder seams with fine steel wool. Apply the patina sparingly with a clean brush, using only a few strokes. Over use will produce a coppery finish.

☟Never mix patinas and always use proper ventilation and skin protection.

☞To get a nice black finish on brass, add a dash of table salt to a little black patina in a glass or plastic jar. Mix well, apply and allow to dry. Clean and finish a usual.

Trouble Shooting

Problem: The solder won't adhere to the foil or came.

Solutions/Explanations:

1) Did you apply any flux?
2) Did you apply enough flux?
3) Was your iron too cool?
4) Is the foil or lead came too oxidized for flux to activate the surface?
    A) Buff copper foil with 000 or 0000 steel wool.
    B) Clean lead came with brass brush.

Problem: Solder is melting through to the backside of my project.

Solutions/Explanations:

1) Your iron is too hot. Depending on what type of iron you are using, either turn the temperature controller down or change to a lower temperature tip.
2) You may be soldering too long in each area. Move on and let the solder cool. Return to those spots later.
3) The gaps between your glass are too wide. Try to fill the gaps with solder and let it cool. Then go back and solder a bead on top of the filled gaps.
4) Try placing a wet paper towel under the project to provide cooling.

Problem: My solder is "stiff." I am unable to get a smooth bead.

Solutions/Explanations:

1) Your iron is too cool. Depending on what type of iron you are using, either turn the temperature controller up or change to a higher temperature tip.
2) You may not be using enough flux.
3) Is the tip of the iron getting hot? Check to see that the tip is seated correctly down in the barrel of the iron.
4) Are you "painting" with solder, instead of running a long bead with a steady, even, one directional movement? This is one of the most common mistakes that beginners make. In order for the solder to create a bead, it has to get molten. If you are using the iron as a “paint brush”, the solder is not getting hot enough to melt thoroughly.
5) You may be soldering with just a corner of the iron tip. Check for proper positioning of your iron.
6) Try a different solder with a lower melting point.

Problem: My iron seems to be hot, but the solder isn't melting as fast as normal.

Solutions/Explanations:

1) Check your tip. Is it loose?
2) Is your tip too dirty?
    A) Clean it on a wet sponge.
    B) Clean it on a tinning block.
3) Your tip is too corroded or defective. Replace it.
4) Your rheostat may be malfunctioning.
    A) Plug the iron into the outlet you are using without the temperature controller. If the iron works, the controller is malfunctioning. If the iron doesn’t work, the problem may be with the iron itself.
    B) With some types you can check the temperature controller by plugging a lamp into it. Turn on the lamp and see if the controller dims and brightens the lamp.

Problem: My solder seams are flat.

Solutions/Explanations:

1) You are not using enough solder. Reflux your project and add more solder.
2) You are soldering too fast. Move at a speed that lets the solder bead.
3) If the bead was there, but disappeared, you may be working too long in one area causing the solder to melt through to the other side. Allow the area to cool down before trying again. Another option is to place a damp paper towel under the seam you are working on. This will help keep the glass cool, allowing you a little more time to work.
4) Check the type of solder mix you are using. For copper foil work, 60/40 will help produce a higher, more rounded bead. Don't make the mistake of buying 40/60 solder. It has an even longer pasty range than 50/50, and is not recommended for stained glass work.

Problem: My solder seam is too wide.

Solutions/Explanations:

1) Do you have large gaps between the pieces you are soldering?
   A) You may have to recut some pieces.
2) You may be using too much solder causing the seam to bulge over onto the glass. "Pull" or "bleed" the excess solder from the seam.
3) Is the copper foil too wide? This is another common mistake for beginners. Remember that the width of the solder seam is determined by the width of the foil. An attractive solder seam is accomplished by using a foil that shows about 1/16" on both sides of the glass.

Problem: My solder seams are irregular in width.

Solutions/Explanations:

1) You may have poorly fitting pieces that create different size gaps in your project. Recut these pieces.
2) Your foil may be applied unevenly on each side of the glass in some places. You may try to correct this by trimming the foil with a craft knife. If that does not work, remove the foil and start again.

Problem: My glass fractured while I was soldering.

Solutions/Explanations:

1) Your iron is too hot. Depending on what type of iron you are using, either turn the rheostat down or change to a lower temperature tip.
2) You "worked" too long in one location with the iron.
3) There could have been a small chip or crack in the glass which was expanded when it was heated by the iron.

Problem: My solder bead is not bright and shiny. It appears dull and splotchy.

Solutions/Explanations:

1) The solder was applied too cold, so it never fully reached its "liquid state." Turn up the temperature if you are using a rheostat or change to a higher temperature tip if you are using a temperature controlled tip.
2) You may not be using enough flux to "wet" your foil or lead and create a proper solder condition.
3) If you're using 50/50 solder, try 60/40. Because solder crystallizes as it cools through the pasty range, 50/50 is more prone to having a textured look on its surface because of its considerably larger pasty range.
4) The solder you are using may be of inferior quality.

Problem: My solder is "spitting" as I work. What's wrong?

Solutions/Explanations:

1) You are likely using too much flux. It is literally boiling when you apply the solder. Wipe some of the flux off with a paper towel and try soldering again. You may find areas that now need a little more flux, because you removed too much.
2) If the spitting only occurs on the back side of your project (or the second side you are soldering), the problem is still too much flux, but the cure is different. When you use too much flux on the front side of the project, the excess to flows through the panel, so the spitting isn't as bad as it could be. When you use too much flux on the back side of the project, it can't flow through to the front, because the front is already sealed. The obvious cure for this problem is to use less flux the next time. But what about now, when you already have too much and can't remove it from between the glass? The only good solution is to apply your solder, and allow the flux to boil up and out of the seam. (Keep your face as far away from the project as you can.) Once it stops spitting, you can remelt the solder and make it look as good as new.

Problem: I have gooey, glue residue along my solder seams that won't wash away.

Solutions/Explanations:

1) Adhesive from foil may be working up and out onto your glass. This can be caused by poor foiling or burnishing of the copper foil, which allowed flux to seep underneath the foil. To correct this use a cuticle stick or soft toothbrush to clean adhesive away.
2) Your iron is too hot, causing the adhesive on the back of the foil to melt and seep out onto the glass. Depending on what type of iron you are using, either turn the rheostat down or change to a lower temperature tip.
3) If you reworked a seam too often, it may have loosened the foil. Allow the seam to cool to the touch and gently press the foil back down to the glass.

Problem: Attached hooks and rings are pulling away from my project.

Solution/Explanations:

1) Hooks and rings should never be attached to just a foiled edge. Attach hooks/rings to vertical seams in the piece or at a juncture between a vertical seam and the perimeter.
2) If there is no vertical seam or intersection, then attach the ring/hook to a horizontal seam in the piece.

Problem: My solder has a white chalky growth on it. What did I do wrong?

Solution/Explanations:

1) All of the flux was not washed off of the project after it was soldered.
2)The project was not sealed with a finishing compound or wax, or it has worn off. Use 000 steel wool to remove the patina and any remaining wax. Clean the project thoroughly paying special attention to the corners and edges. Reapply the patina and wax.
3) The project has been exposed to the outside elements. Most waxes are intended for indoor use only. Others can be used outside, but must be reapplied regularly. Projects that will be exposed to the elements are better constructed using the lead came method.

Glossary of Soldering Terms

Antimony

An element used in the production of some solders. It should be avoided for use in stained glass.

Ceramic Heater

A type of heating element comprised primarily of ceramic, noted as extremely fast heating and efficient.

Chisel Tip

A soldering iron tip shaped like a chisel tool. This is the most common shape used for soldering stained glass. Chisel tips are made in a variety of sizes, the most common being 1/8”, 1/4” and 3/8”.

Heat Sink

A device used to draw or absorb heat being generated by another source. For example, an object being soldered acts as a heat sink to the soldering iron.

Decorative Soldering

Any decorative effects created in solder. These effects are created with a soldering iron, usually with a very narrow tip. Special solder, like 63/37 or QuickSet, make it easier to create special effects because it has a “zero” pasty range.

Eutectic Point

An exact single temperature point at which an alloy goes from solidus to liquidus with no pasty range. For example, the eutectic point of lead and tin is 361^0 F. This point is obtained only by 63/37 tin/lead alloy.

Flux

A chemical agent used to remove compounds from the surface of metals during the soldering process. (See organic and inorganic flux.)

Idle Temperature

A very low temperature at which the iron is on, maintaining the capability of a more rapid heat up than if the iron was off or “cold”. This is usually between 200^0F and 300^0F.

Inorganic Flux

A flux comprised of one or more inorganic salt such as zinc chloride or ammonium chloride. Inorganic fluxes are more corrosive and conductive than organic fluxes,. They are effective on all common metals.

Leaded Solder

A material used to join metals comprised of tin and lead.

Liquidus

The temperature at which a pure metal becomes completely molten or liquid.

Mica

A mineral based material used as a construction component in wire wound type heaters of soldering irons.

Organic Flux

Organic fluxes are not as corrosive as inorganic fluxes. They are often used when the surface of the glass may be effected by the flux, such as painted glass.

Oxides

Debris on the surface of a metal which is the result of the reaction with chemicals in its environment. Oxides must be removed mechanically (with steel wool or a brass brush) and chemically for proper wetting to occur.

Pasty Range of Solder

The temperature range which is the difference between the solidus and the liquidus temperatures. This is sometimes referred to a the “working range”.

QuickSet™

Another name for 63/37 solder. See decorative solder.

Recovery Time

The time required for a soldering iron to reach soldering temperature after it has hit a “cold spot”.

Rheostat

The term applied to a soldering iron control which is used to vary the temperature of the heater in the iron.

Solder

An alloy of two or more metals with a liquidus temperature of less than 800^0 F.

Solder Bead

The term used to describe the look of solder when it has been properly applied to a copper foil seam.

Solidus

The temperature at which a pure metal or alloy goes from liquid to solid (or “freezes”).

Temperature Control

An electrical or electronic device into which a soldering iron is plugged, or which is within a soldering iron. The device is used to vary the temperature of the soldering iron heater.

Tinning

Applying a thin layer of solder to a metal surface. Most commonly used in reference to the copper foil technique.

Tinning Block

A block of sal-ammoniac on which a soldering tip is cleaned and resurfaced with a layer of solder. It is not actually used for soldering.

Tip Tinning

The process of renewing a soldering iron tip using a sal-ammoniac (tinning) block.

Wetting

The term used to describe the proper flow of liquid solder, promoted by flux, on the surface of another metal. “Wetting” is necessary to form a proper soldering joint.

Wire Wound Heaters

Soldering iron heaters constructed with heating wires wound in a coil around Mica.

Soldering & Desoldering

Soldering/Desoldering Tools & Accessories

Soldering Station with LCD Display, ESD Safe 400 Series

17400

- High-quality sensor and heat exchange system guarantee precise temperature control at the soldering tip
- Soldering iron tool heats rapidly from room temperature to 350C in 30 seconds
- Suitable for general purpose soldering as well as specialized lead-free soldering applications
- Sponge and coiled brass tip cleaner ensure a clean soldering tip free from debris and corrosive material
- Strong, deluxe iron holder provides safe secure place to store heated iron between uses

Product ID	Description
17400	Soldering Station with LCD Display, ESD Safe 400 Series

Soldering Station with LCD Display, ESD Safe 405 Series

17405

- LCD temperature control display with blue backlight
- Long lasting, durable high - quality ceramic heater
- Sponge and recessed area provides a convenient method for cleaning the tip
- Suitable for general purpose soldering as well as specialized lead-free soldering applications
- Safety guard iron holder

Product ID	Description
17405	Soldering Station with LCD Display, ESD Safe 405 Series

Soldering Kit - 6pc

17501

- 40 Watt Soldering Iron heats up to 900° F
- Ideal for use on electrical/electronic components, audio equipment, etc.
- Includes desoldering pump for removing liquid solder
- Provides basic tools needed for many soldering projects
- 6 Pc kit comes complete with replaceable fine tip

Product ID	Description
17501	Soldering Kit - 6pc

Soldering Kit - 7pc

17502

- 40 Watt Soldering Iron heats up to 900° F
- Ideal for use on electrical/electronic components, audio equipment, etc.
- Includes desoldering pump for removing liquid solder
- Provides basic tools needed for many soldering projects
- 6 Pc kit comes complete with replaceable fine tip

Product ID	Description
17502	Soldering Kit - 7pc

Soldering Iron 80W with Fine Tip

17510

- Ideal for general purpose soldering applications including metal board, tube or large components
- Round, soft grip, non-slip handle
- Durable cord with a 5-foot reach
- Fitted with long life replaceable fine tip

Product ID	Description
17521	Soldering Iron 40W with Fine Tip

Soldering Iron 40W with Fine Tip

17521

- Ideal for general purpose soldering
- Round, soft grip, non-slip handle
- Durable cord with a 5-foot reach
- Fitted with long life replaceable fine tip

Product ID	Description
17521	Soldering Iron 40W with Fine Tip

N-Series Soldering Iron Tips

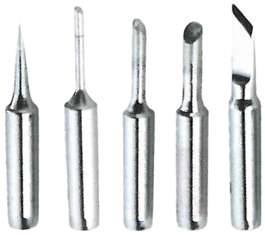

- Long life, lead-free soldering iron tips
- Replacement tips for soldering the different components of PCBs
- Five different sizes
- Includes two tips
- For use with 17400 & 17405 ESD Safe Soldering Stations with LCD Display

Product ID	Description
17400-N9-1	N-Series Soldering Iron Tips (N9-1)
17400-N9-2	N-Series Soldering Iron Tips (N9-2)
17400-N9-3	N-Series Soldering Iron Tips (N9-3)
17400-N9-4	N-Series Soldering Iron Tips (N9-4)
17400-N9-5	N-Series Soldering Iron Tips (N9-5)

C-Series Soldering Iron Tips

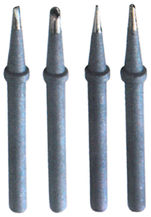

- Long life, lead-free soldering iron tips
- Replacement tips for soldering the different components of PCBs
- Four different sizes
- Includes two tips
- For use with 17521 Soldering Iron 40W

Product ID	Description
17521-C1-1	C-Series Soldering Iron Tips (C1-1)
17521-C1-2	C-Series Soldering Iron Tips (C1-2)
17521-C1-3	C-Series Soldering Iron Tips (C1-3)
17521-C1-4	C-Series Soldering Iron Tips (C1-4)

B-Series Soldering Iron Tips

- Long life, lead-free soldering iron tips
- Includes two tips
- For use with 17510 Soldering Iron 80W

Product ID	Description
17510-B5-1	B-Series Soldering Iron Tips (B5-1)

SMD Soldering

Your reference guide to soldering with surface mount devices

Edited by Lim Siong Boon, last dated 06-May-09.

email: mail@siongboon.com
website: http://www.siongboon.com

Short cut to your reference guides and charts

1. Introduction to SMD soldering
2. SMD soldering (prototyping board)
3. SMD soldering (prototyping PCB socket 2.54mm pitch)

1. Introduction to SMD soldering

SMD IC stands for surface mount device integrated circuit, or commonly known as SMT surface mount technology. Why go into SMD? Small in size, light in weight. This is the advantage of smd. Being small, engineer is able to design small electronics gadget that people can carry around. It is quite obvious that people prefer small mobile phone.

The ultimate advantage will be lower cost to consumer. Being small in size, the printed circuit board (pcb) can be small, meaning low cost. Transportation cost can be reduce because it is now lighter and more products can be packed into the same box. Space required is less, meaning cost saving on the warehouse storage. PCB board is easy to route without the through hole. Better signal integrity. Easily assembled by machine. There is too much advantages. Going SMT is certainly the way forward.

Technology evolution, from big to small.

A phone small enough to carry around.

Smaller mobile phone

Even smaller phone

Mobile phone as thin as biscuit.

I used to build circuits using dual in-line package (DIP or DIL) IC only. I hardly thought of using surface mount device/component (SMD) because I have great doubt that I can solder the fine legs of the IC chip. The pitch for the older DIP IC package are 2.54mm. Pitch is the distance between adjacent pins as illustrated in the picture. Most IC comes with a variety of packages. The IC that I know of, offer both the SMD and DIP packages. I

Through hole packages

	DIP - 8 pins

thought that I will never ever need to use smd packages until one day, I have no more choice. I managed to pick up new circuit designs, and discover more and more new IC chips. Most new IC chips design do not have DIP packages. You can hardly find one. I realised that in order to implement better circuits, I need to learn to use new IC chip. In order to use the new chip, I have to find ways to solder smd components. That's where I venture into the world of smd.

Nowadays people prefer to use smd, because they are small in size, which turns out to be cost efficient fabricating small PCB. With smaller PCB, space & weight is saved, resulting in lower cost for the transportation/distribution and storage.

Research and research, I got to know from other electronics guru that smd is in fact easier to work with than through hole. I try it out and from that day onwards, I am in love with smd components. Small to solder, but it save me the effort to cut the lead for through hole component. I managed to store my component using minimum box and space. There are many many advantage to work with smd.

Many people might think that you need special tools like a rework station or fine tip iron to solder the small smd components with small pitches. With the correct technique, you can use your soldering iron to do the soldering. In fact my 60W goot TQ-95 soldering iron has quite blunt tip. So thick that most people think that it is not possible to solder smd IC with fine pitches. Fine tip iron is easy to reach the fine lead, but I find that it is not as hot as the same iron with blunt tip. If you prefer fine tip, I will recommend hotter soldering iron or those which can allow you to adjust the temperature, they can be hot. I managed to solder smd package TQFP, SSOP QSOP with pitch as small as 0.5mm. Width of the lead of about 0.3mm.

Dealing with SMD components do not necessary requires you to fabricate a professional pcb board. You can also mount smd components on low cost prototyping board. To start off implementing smd components, you might like to try using the soic package. Quite common at this point in time, but may just phase out as what has happened to the dip packaging. SOIC has a pitch of 1.27mm, which is exactly half of DIP packages. This size is great because I can solder the IC to the same old 2.54mm pitch prototyping donut padded board. What I usually do is to cut the donut pad into half. Soldered onto each pad is two pins 1.27mm apart.

You can refer to the following article, for further illustration.

"SMD soldering (prototyping board)"

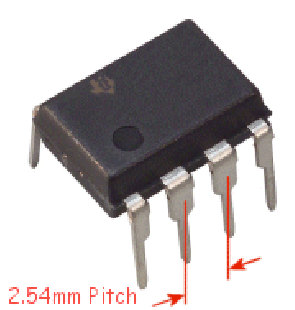	
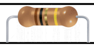	resistor
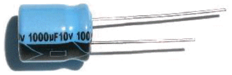	capacitor
	inductor
	diode

SMD packages

1.27mm Pitch	SOIC - 8 pins
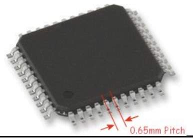	TQFP - 44 pins
	resistor
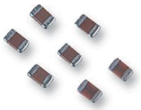	capacitor
	inductor
	diode

With so much advantage there is indeed a disavantage. SMD IC comes with many type of packages with different pitches. Unlike DIP IC, the pitch is typical 2.54mm. I can easy purchase a prototype board with 2.54mm, and almost all the DIP will fit to the board. SOIC package can still be mounted onto the 2.54mm prototype board. The rest of the SMD IC chip has quite a wide range of completely different packaging. This make them difficult to start with, without having to fabricate a PCB.

There are actually solution to this. Most IC company usually introduce their IC chip together with a prototype board for the IC.

Another solution will be to use a pre-fabricated prototyping board that allows mounting of various smd footprint. You can search for the various names such as

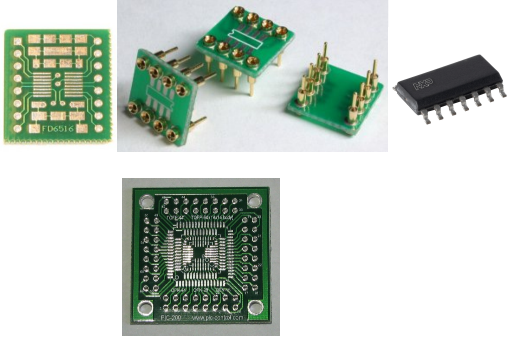

Various distributor for the prototyping adaptor

- prototype adaptor
- chip adaptor
- smd prototyping board
- smd to dip adaptor
- smd socket
- smd adaptor
- smd to 2.54mm converter
- SMD to DIP converter
- chip carrier

You can refer to the following article, for further illustration.

"SMD soldering (prototyping PCB socket 2.54mm pitch)"

In prototyping with DIL IC, pcb mount IC socket is usually used, so that the IC can be removed easily if damaged. Some sockets are designed for programming used where the chip can be inserted and remove easily for programming purpose. To remove the component, you need not have to do de-soldering. Like DIL package, smd also comes with their own IC socket. There are many variety of smd packaging, and getting the socket for your smd components is not going to come cheap & easy compare to DIL. Therefore I usually built prototype without any sockets for smd design. After numerous attempts designing and building of circuits, you will definitely attain a certain level of confident on your design without considering IC socket. Without the socket, cost and space are saved significantly.

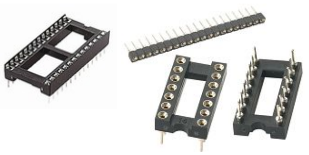

DIL IC sockets/ holder. Turn pins designs is of better quality.

Various distributor for SMD socket

SMD IC sockets:

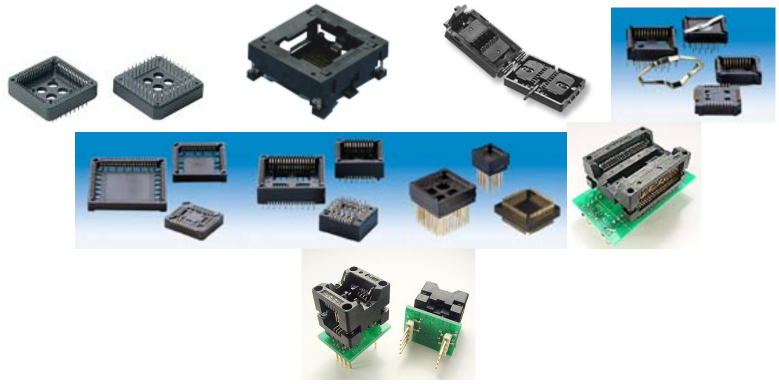

The headache will come when you really need to removed the smd IC. How do you remove the IC from the PCB? For de-soldering of smd component more than 3 leads, you can add in more solder to connect up the IC pins heat pins on all the sides of the IC and eventually pull out the component. It is easier to use the rework station or IR heater to de-solder smd components. The rework station uses hot sir to melt down the solder on the board. You will need to aim the hot air at the solder joint.

Rework Station

If you do not have the lurxy of getting the rework station, another possible method might be to use a special solder that has lower melting point. LowMelt® DeSolder Wire. A lower melting point means that the solder will takes a longer time to cool down to a solid. This allows you more time to remove the IC after heating up the solder. The solder is flooded onto the pins of the IC. The pins are heated up together using a soldering iron and the smd IC can then be removed easily with a tweezer.

Various type of smd packaging

* SOT, SC

* SOIC, ExposedPad™

* SSOP, ExposedPad™

* TQFP, ExposedPad™

* TSOP

* TSSOP, ExposedPad™

Low melt solder wire

* PLCC

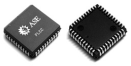

* LQFP, ExposedPad™

* LGA

* PBGA

* PSOP

* Dual Row MicroLeadFrame®

* LQFP PowerQuad®

* MicroLeadFrame® (MLF®)

* MQFP PowerQuad®

* PSvfBGA

* SuperBGA®

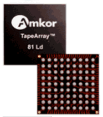

* TapeArray® BGA

* tsCSP

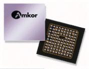

* Ultra CSP™

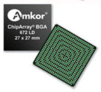

* CABGA, CTBGA, CVBGA

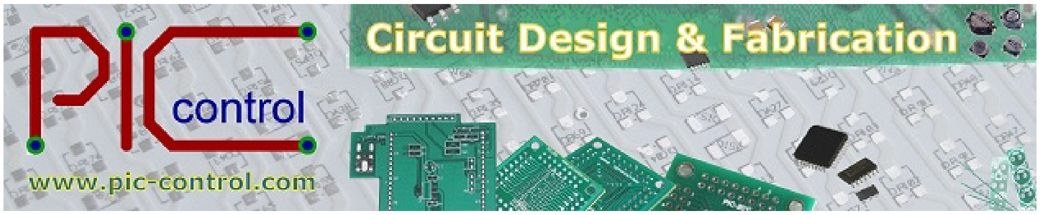
PIC control
Circuit Design & Fabrication
www.pic-control.com

Singapore Customized, custom made Electronics Circuits & Kits

2. SMD soldering (prototyping board)

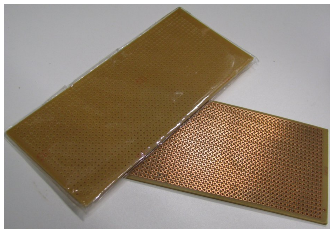

The prototype board above has pad with 2.54mm pitch and is designed for DIL and through hole components. The board is easily available from local store. Dealing with smd components on this 2.54mm pitch board is not difficult as well. I have been using this board to solder quite a number of surface mount components.

- SOIC
- DPAK
- SOT23-6, SOT-3
- TO-263
- PSOP

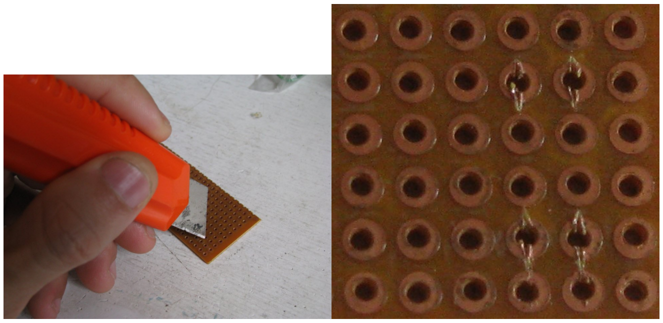

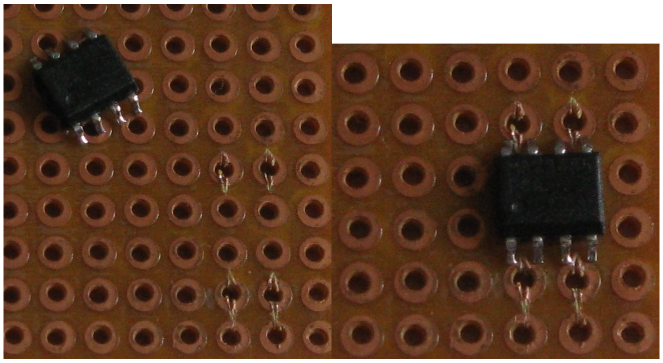

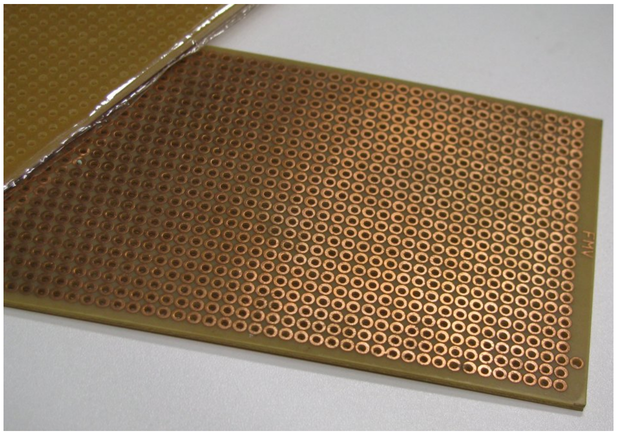

High pin count component with pitch less than 1.27mm will not be suitable to mount onto this board. For passive smd component like resistor, capacitor or inductor which only have 2 pin, mounting is simpler. Size is not an issue soldering onto the board.

Align the SMD IC to the position on the pad. Mark out the pad for the cutting to be done.

Use a penknife to cut the donut pad into half. Ensure that the half pad does not short circuit using your multi-meter. Sometimes the cut may not be deep enough or conductive reside between the gap resulting in a short circuit. Remember to ensure that each is proper cut before you start to solder.

Align the smd with your finger or tweezer and begin soldering one of the pin. Check if the IC is still properly align after soldering the first pin. If not, heat up the soldered pin and realign again. After the ICis align, solder all the rest of the pin. If the solder bridge across to the adjacent pin, use a soldering sucker to remove the excess solder.

The cut between the pad usually make the solder harder to bridge across the adjacent pin. Bridging is still possible, and it is quite easy to have it removed.

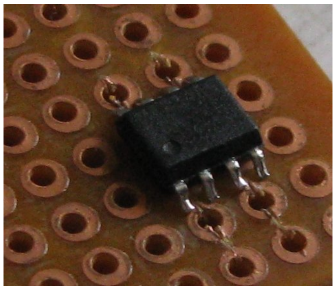

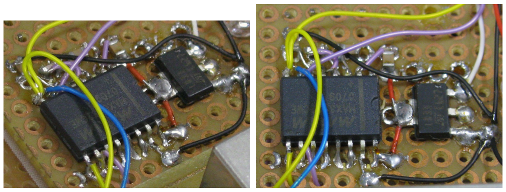

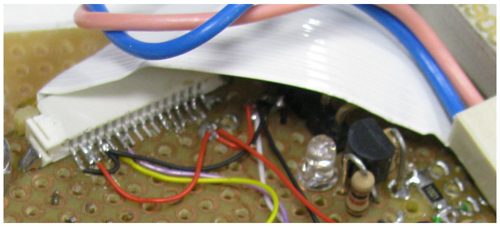

SMD ribbon cable connector being soldered onto the 2.54mm pitch prototype board.

Example of building the circuit using surface mount component on the prototyping board with 2.54mm pitch pads. As shown above, the pins are being wired by fine wire wrapping wire. The single core wire is very flexible and comes in a variety of color, making it easy to identify the type of signal being carried by the wire.

3. SMD soldering (prototyping PCB socket 2.54mm pitch)

What you need...

List of items:
- Surface IC chip (TQFP package)
- Surface mount IC adaptor or converter
- Soldering Iron
- Tweezer or Pincer
- Solder with flux core
- Soldering Flux
- Stick for coating flux
- Wiping paper
- Tinner

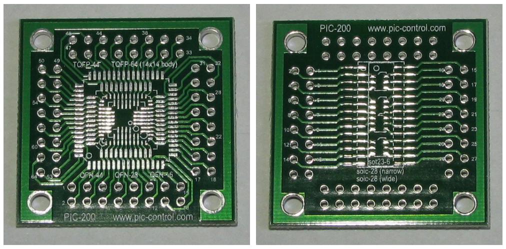

PIC-200 smd to 2.54mm pitch adaptor

from PIC control.

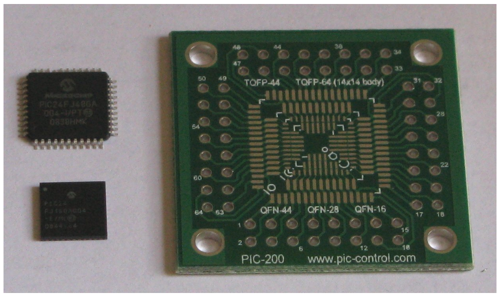

INTRODUCTION

In this setup, I am going to solder a surface mount microcontroller (TQFP 44 pins) onto a smd adaptor. The adaptor will then be used on the commonly available prototyping board, so that I can try out my new design for circuit control.

TQFP, QFN and SOIC are quite some common footprint for prototyping smd microcontroller from 18 to 64pins. This prototyping adaptor pic-200 (on the left) that I have is an ideal adaptor for my microcontroller. Converting the smd device into 2.54mm, I can easily mount the smd unit onto my 2.54mm pitch prototyping board. It is available locally.

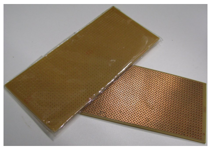

Prototyping board with 2.54mm pitch donut pads.

The pic-200 smd adaptor originate from PIC-CONTROL and is well documented. Commonly used smd footprint can be found on either the top or bottom side of the pcb adaptor. These are some of the smd packages that can be mounted onto pic-200 adaptor.

IC	Front	Back
TQFP-44		

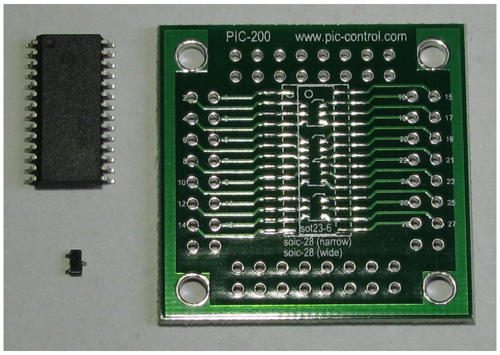

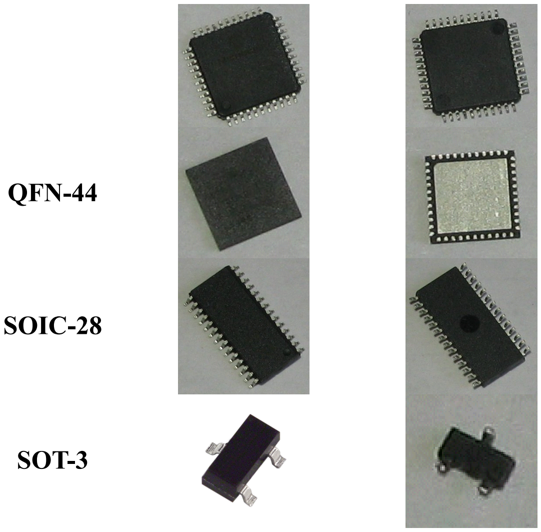

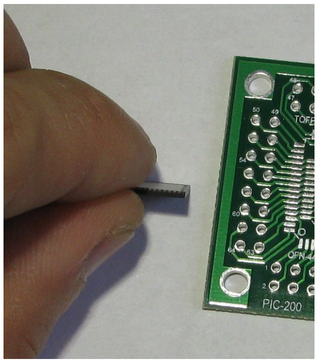

Holding onto the side view of the QFN package IC.

With a wide range of smd components that can be mounted, it is easier to stock up this pcb adaptor for future prototyping use.

The following article is about getting my smd microcontroller PIC24FJ64G004 soldered onto this board. After which I will be on my way to do prototyping for my new control circuit.

This smd adaptor origined from PIC-CONTROL. For other type of adaptors, you can also refer to other manufacturer as mention above.

click here to
Buy this SMD Adaptor Now at the PIC-store
PIC-store

<Step 1>

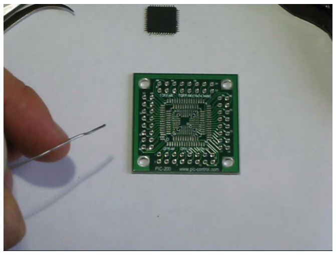

Before soldering, ensure that the soldering pad on the PCB is free of oxidation. PCB is usually tinned to protect the copper surface from oxidation. In cases where the surface is oxidized, you can try cleaning the surface with a contact cleaner. Apply the solution with tissue paper or toothbrush to clean up the contact. This solution make the PCB board rather oily, which I don't quite appreciate.

LPS
LVC
CONTACT CLEANER

Contact cleaner.

Let us start our smd soldering here. Soldering surface mount component. The first important thing to introduce would be the solder.

There are many type of solder. Choosing the correct solder takes a bit of some knowledge too. Leaded or lead free solder? The industries is moving towards Pb free components & PCB, calling for unleaded product. Lead is toxin and not environmental friendly. I would advise ou to wash your hand after soldering or handling pcb board. A soldering fume extractor to vacuum the smoky fume would be quite comfortable for your soldering. The smoke is quite choking and a health hazard if you breath that in.

soldering fume extractor.

Solder also comes with a variety of metal alloy combination. Nowadays it is common in solder core to contain flux. If the solder do not have the flux in the core, the flux have to be manually applied onto the metal surface before the soldering beginning. The flux cleans up the soldering surface, and also make the solder flow rather smooth like liquid. One of the important ingredient to make a good solder joint lays in the soldering flux.

Solder wire also comes in a wide range of diameter to choose from. Generally I use 0.8mm soldering wire roll with flux at the core. Smaller diameter solder wire allows you a better control of the amount of solder to apply. For soldering larger pins or connector component thicker diameter wire will be preferred. Wire too thin is rather troublesome, because you need to feed in a longer length of solder in order to solder the large surface/lead. For general purpose PCB board soldering 0.8mm wire fits somewhere in the middle. Not too thick nor too thin. For smd components, diameter smaller than 0.8mm is preferred. Using 0.8mm for smd soldering is not of any issue.

Solder wire 2mm

1.2mm

1.0mm

0.8mm

0.5mm

<Step 2>

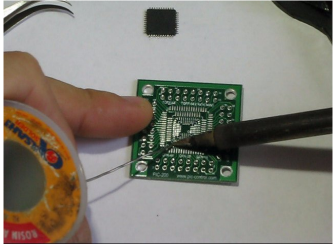

One of the pad being tinned.

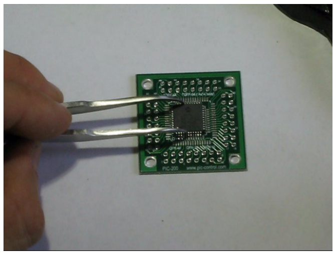

Align smd IC to the respective pad.

My microcontroller TQFP package has 44pins around the square package. To secure the package to the adaptor, I will need to solder one of the pin to the board first. It is important to solder only one pin. In case of mis-alignment, we can correct it easily. If more pins are soldered, it will be more difficult to correct any alignment.

Pin 1 of the adaptor pad is first tinned with a layer of solder. A tweezer is then used to align the IC chip on the pad. The IC is secure to the board with a slight touch from my soldering iron, soldering the IC pin to the pad.

The important factor to consider would be the heat generated by the iron. I prefer to use a 60W iron, which still works well in air-con room. A lower wattage or fine tip iron will not heat up that well in colder environment.

Goot TQ95 60W

If you prefer a fine tip, perhaps the soldering station will be more suitable. The iron temperature can be adjusted to a higher or precise temperature for the component that you want to solder. Component with thick metal contact like connector, heat sink, for thick cables should be solder with a

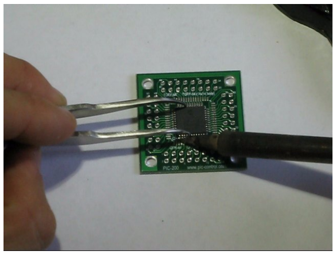

IC being fixed in position

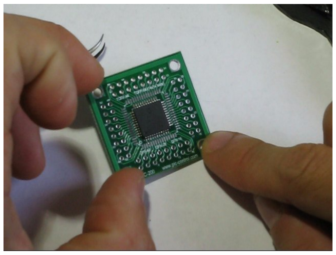

Checking if alignment is correct.

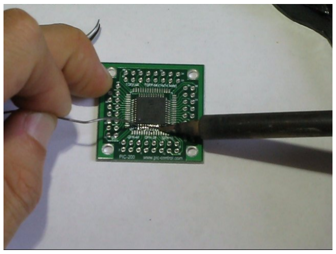

Flooding the pins with the rest of the solder.

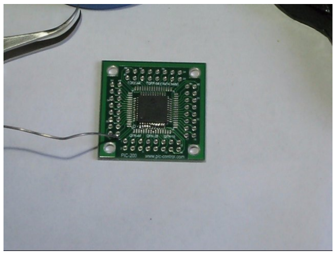

Pins flooded with solder

higher temperature. The iron should be held on longer, in order to have the component fully heated up before any solder is applied.

Solder Station

For soldering the IC pin to the pad, you can start off by heating up the pad. Then while heating up the pad, touch the IC pin and apply the solder wire directly to the pad or IC pin, allowing the solder to flow like liquid. The IC pin is heated last to minimize the chance of over heating the pin. If it doesn't flow very well, you can manually some flux to the joint. The solder wire should not touch the iron directly, because this will vaporize the flux, and solder flow will be restricted.

Heat up the lead and pad longer allows the solder to flow and form a good joint. Not for too long as it can also damaged your IC. You should be able to see the solder flow eventually onto the lead & pad. With a bit of practice, you will see the difference between a quick solder touch and another one with lead & pad heat up a little bit longer. It takes a number of practice to get a good joint with minimum amount of heating time.

The soldering iron that I use has rather thick tip, but that does not matter when I do soldering for the smd microcontroller. All we do is to flood the pins with solder. They can be be suck up later.

There is a technology known as ultrasonic soldering. The soldering iron tip has this micro vibration which helps the solder to flow more easy without much use of flux. It can also solderthose difficult to solder material. The following is one article that I found that describe about it. - Soldering the unsolderable.

<Step 3>

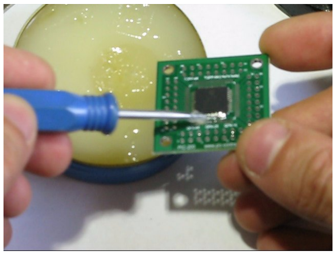

I have applied more flux at this stage. It should have been applied before flooding the pin, but it doesn't matter too much. The flux will make the solder rather liquid so that it is easier to suck up the excess solder.

ACID PASTE FLUX
SP-30

solder flux paste

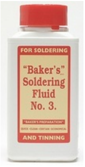

Baker Soldering Fluid

<Step 4>

The flooded solder is being heated up, and the excess solder are being sucked up.

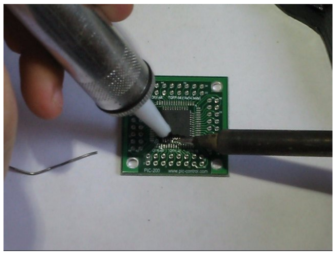

<Step 5>

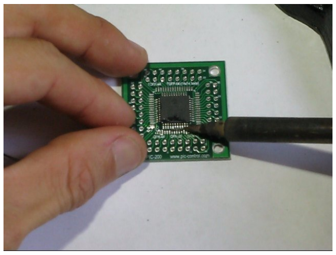

Each pins is being touch up, ensuring that the pin is solder to pad and that they are not bridged across to the adjacent pins.

Now we have got our smd component soldered onto the board.

<Step 6>

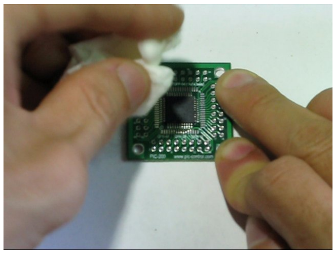

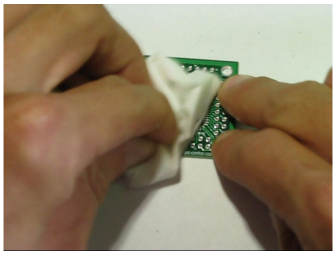

The flux helps a lot in doing a good solder but it often leaves the board with tiny dots of transparent strain, a bit sticky, also known as grease or flux residue. The board looks untidy with these tiny bits of grease.

These are the various recommended cleaning solution for pcb.
- 50% Alcohol + 50% Water
- Thinner
- Flux remover
- Multicore Prozone MCF800
- Solvent-> Bromopropane; propane, 1-bromo-; propyl bromide (Chemical Formula: C3H7Br)

Alcohol MSDS (Material Safety Data Sheet)

Thinner MSDS (Material Safety Data Sheet)

Electrolube, FLU Fluxclene Cleaning Solvent, pdf file

MG Chemicals 413B Heavy Duty Flux Remover

MGC-850 Stainless Steel Cleaning Brush

Brush for the crush

Flux Remover

Multicore Prozone MCF800

Besides using chemical, or after using chemical, there may still be some white blur stain. Those are flux spread dry up on the surface. Using a hot air blower, or heater on the surface can melt the dry up flux, and recover the smooth shiny PCB board surface again. Clean away the melt flux immediate after the heat.

Using alcohol is strongly recommended. Thinner is not suitable for certain plastic/material. Care is required when using thinner for cleaner. Using thinner on the PCB, copper pads and soldering joint isn't a problem. When use on plastic, you are advise to do a trial to ensure that the material is able to with stand thinner solution. Flux remover is commercially ready mixed solution. From what I learn in the manufacturer website, they are non-flammable chemical solution.

Alcohol & thinner has a lower flash point, and catch fire easily. You have to be extremely in handling and storing these flammable chemical. Do not store or work on the chemical near electrical appliances, hot area or things that can cause spark. Keep your windows open to allow air to circulate while working with these chemical. They may cause headache, dizziness and uncomfortable when inhaled.

Chemical comes in different level of grade. A slight different in the chemical concentration or purity can results in a large difference in cost. Alcohol can be expensive. For pcb cleaning purpose, request for technical grade alcohol. Higher grade alcohol is typically used for consumption or lab experiment purpose. Since we are using it for cleaning, there is not much advantage in using high quality chemical which is expensive. Dickson chemical is specialized in high graded chemical for laboratory use. They do sell lower cost technical grade alcohol. They are not suitable for consumption but is ok for cleaning application.

Dickson Chemicals

Dickson Chemical selling Technical grade alcohol

You can easily buy thinner from your local hardware. Typically used for cleaning your brushes after all the wall painting works.

Non-flammable Flux remover

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These are other recommendation in the web. After researching further, I would advise not use them. These chemical are of health hazard. Exposure will have severe adverse health effects.

- 50% isopropanol + 50% water
- Trichloroethylene
- Carbon tetrachloride

Isopropanol (true chemical name) is also known as Isopropyl alcohol or 2-propanol. 2- is refer as Iso. Other chemical may starts with 1- refer as N. These are some jargon used in the chemical industrial. I managed to learn a few of the terms from the vendor.
Trichloroethylene (true chemical name) is typically used for degreasing the metal. It is an extraction solvent for oil. Another name for Trichloroethylene is Trielin. Based on some read up, they can cause cancer.
http://www.answers.com/topic/trichloroethylene

Carbon tetrachloride can harm our environment, producing CFC which deplete the earth's ozone layer. http://en.wikipedia.org/wiki/Carbon_tetrachloride

Initially I tried using contact cleaner to clean the stain off. I use cloth or tissue but the fabric is often tear by the component sharp edges. Most corners are not easy to reach. Later on I tried using a toothbrush, the result is better.

For mass cleaning job, you can try using the ultrasonic pcb cleaner. It is a deep metal container for the solution, using micro vibration to shake off the dirt. I have never tried on it before, and I believe it is the same machine people used for cleaning their jewelry. Basically, you will need to dip the pcb board into the solution, and the ultrasonic will be activated to do it's job. The solution used is the same as manual cleaning, requiring 3-5 minutes of cleaning.

Ultrasonic cleaner

Ultrasonic jewelry cleaner

There is also a flux that does not leave residue on the PCB. I found it on the internet, and have not try it before.

INTERFLUX, IF 2005M No-Residue™ flux, pdf file

Article relating to removing flux residue:

- pcb cleaning - Aqueous Cleaning Process.pdf
- pcb cleaning - Flux Removal, nuxx.pdf
- pcb cleaning - pcb cleaning article.pdf
- pcb cleaning - PCB Cleaning, Printed Circ.pdf
- pcb cleaning - pcb washing chemical composite.txt
- pcb cleaning - remove solder flux.pdf
- pcb cleaning - Solvent washing PCB boards.pdf
- pcb cleaning - washing the board using alcohol.pdf
- pcb cleaning - PCB cleaning article Inventec_S24_03.pdf

<Step 7>

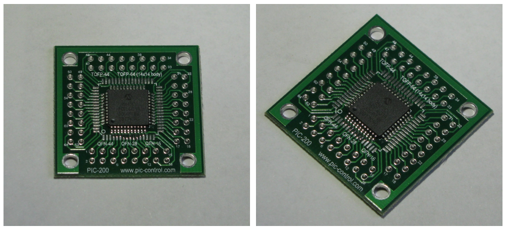

A close up view of the clean and neatly soldered surface mount IC on the prototyping adaptor. Soldering smd components is simple and fast with a bit of practice. Small and easy to clean up. There are too many advantage in working with surface mount, compared to through hole components.

This is the end of the short demonstration on smd soldering. I hope these article can provide you some insight and confident to start experimenting circuits using surface mount components.

Video available. Please click here,

smd soldering.mpg (25MB)

smd cleaning pcb.mpg (5.5MB)

Article on smd soldering.
- 2010-07 How to Solder Surface-Mount Devices.pdf

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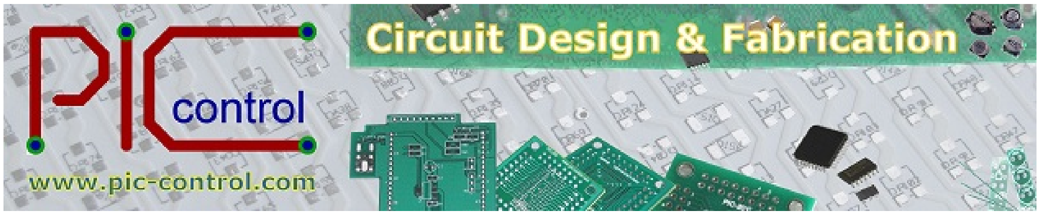

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Various Chemical Reference:

Alcohol 70% + Distill Water 30%
MDX4-4159
7MHFE-71DE

Cyclohexanone
Methylethylketone
ethylacetate,
Silicon Wacker
Wacker M4503, General purpose mould making silicon (Using Two Part Silicon Mold Putty to Make Molds)
http://www.kirkside.com.au/, Mould Material Specialist

Propanol, used to clean PCB. (close to white electric oil)
Acetone, remove away ink printed on PVC stickers
n-Hexane (white electric oil)

smd glue for surface mount component mounting / soldering use
Seal-glo NE series, NE3000S, NE8800T, more Seal-glo

email: mail@siongboon.com
website: http://www.siongboon.com

Keyword: surface mount soldering, smd adaptor, smd to 2.54mm convertor

Surface Mount Soldering Procedure

We believe that the following procedures describe the simplest way to reliably assemble surface mount components without special tools. The only tools required are a pair of fine-tip tweezers, a rosin based flux pen, rosin core solder (.025” dia. preferred), and a soldering iron with a small, clean tip. A spool of fine (0.075”) solderwick will come in handy if you need to rework connections. You will need isopropyl alcohol, cotton balls, and cotton swabs for cleanup. If you have access to hot air rework tools and the skill to use them, feel free to use them instead.

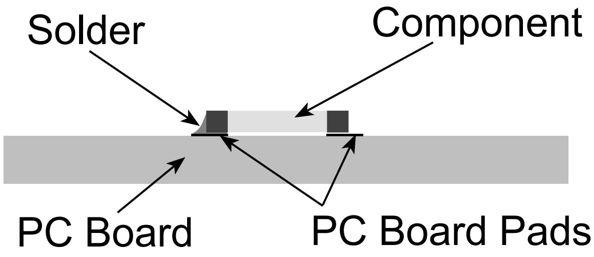

A proper solder joint with fillet

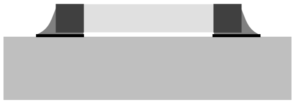

Proper joints

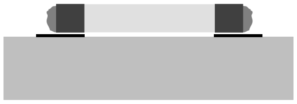

Poor joints

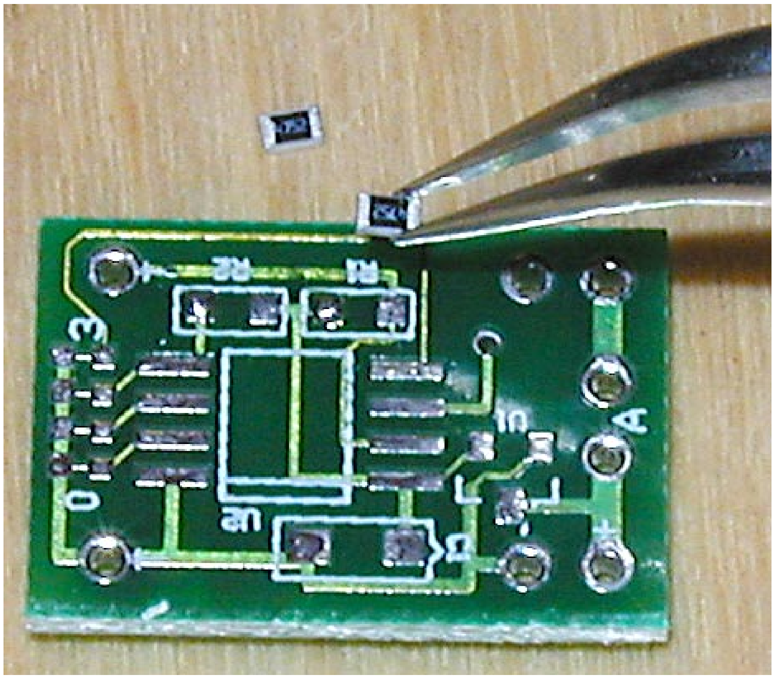

Placing the component

Soldering surface mount components is not difficult, but it does require good eyes, a steady hand, and a soldering iron with a small, clean tip. The illustrations at the left show a proper and a poor solder joint. In the proper joint, the flux has “wetted” both mating surfaces, allowing the molten solder to adhere to both the printed circuit board pad and the component lead. In the illustration of the poor connection, insufficient heat or flux has forced the solder to ball up on the end of the component, without making it to the PCB pad. The component is not attached properly, and the electrical connection will be intermittent at best. This connection can be salvaged by applying flux and heat to the PCB pad to get the solder to flow to the area between the pad and the component.

The most important characteristic of your soldering iron is that it must be equipped with a *small, clean* tip. If the tip is too large or is covered with oxidation, creating a well-flowed solder joint will be nearly impossible. Wipe your tip on a sponge before each joint - it must be shiny and well-tinned in order to transfer its heat properly.

You will find it easiest to work on your board if you clamp it in a moveable vise or stick it to a small block of wood with double-stick tape. This will allow you to rotate the board to whatever angle is most comfortable for access to the component being installed. If you try to hold the tiny parts at awkward angles, you will not have good results!

The first step is to apply a small bead of solder to one of the PCB pads for the component to be installed (the left-hand pads of R1 and R2 in the photo at right). The bead should be approximately 0.020” to 0.030” high (you may want to reevaluate your bead size after you have completed several joints). Apply some liquid *rosin based* flux from a flux pen to the solder bead and to the other pad(s) for the component.

Next, using a pair of tweezers, pick up the component to be installed and place it over the appropriate pads.

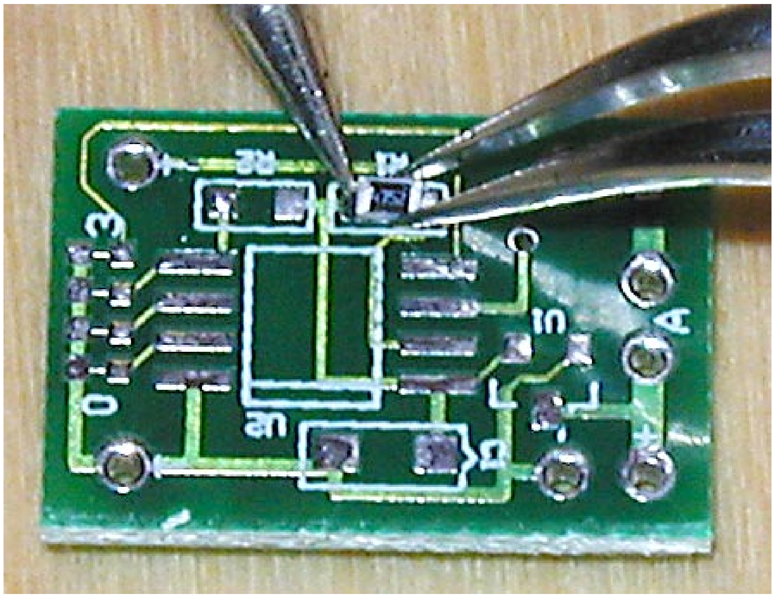

Affix the part by reflowing the first solder bead

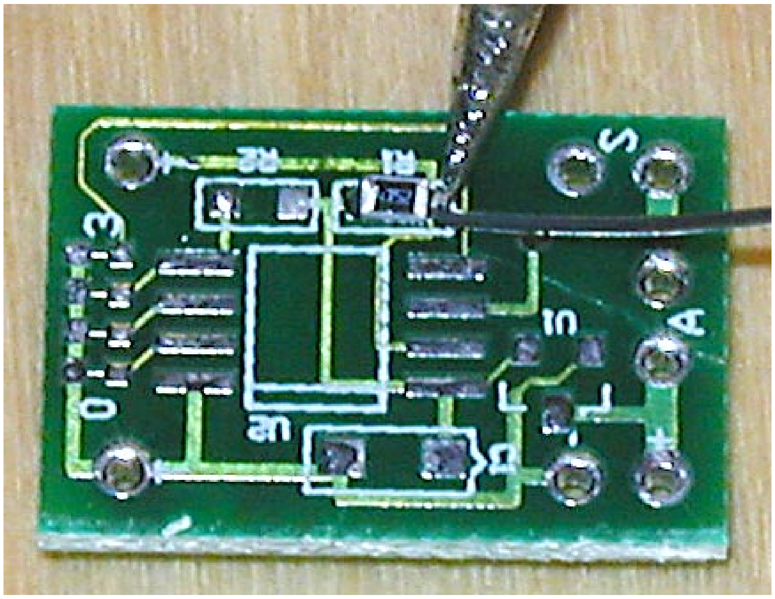

With the part in position, solder the other end

With the part in position, move the soldering iron to the solder bead on the PCB pad. Apply a small amount of heat from the iron to flow the bead, simultaneously lowering the part against the board and correcting for any rotational misalignment. Remove the iron and allow the solder to cool. Inspect the joint -- at this point you are not concerned about the quality of the actual solder joint, just the positioning of the component. The part should be flush against the PCB, with both ends properly contacting the pads. The part should be straight, and centered between the two pads.

Apply a liberal amount of liquid flux (again, a flux pen is the ideal applicator) to both ends of the component. Heat the currently unsoldered end of the component and the adjacent pad with the soldering iron, and carefully wipe on a small amount of solder. You want a small fillet as shown in the earlier illustration, not a large glob of solder. Make sure that the solder has flowed onto the pad as well as the component lead - don’t be fooled by a lump of solder on the end of the component that doesn’t flow under the component and onto the PCB pad.

After the second end is soldered, go back to the original solder joint and reheat the solder. The flux will allow the solder to flow freely, and a good fillet should be observed. If there seems to be insufficient solder, add a little more. If either of the ends appears to have an excessive amount of solder (a large blob sticking up above the part) it can be removed with solder wick. Apply flux to the blob and the wick, position the wick over the blob, and press lightly on the wick with your iron. As the heat is conducted through the wick the solder blob will melt and be drawn off by the wick. You may end up removing too much of the solder, in which case you can reapply a *small* amount of fresh solder to the joint.

After the joints have cooled, inspect them carefully to make sure that they are solid and make contact with the board. If you have any doubt about the quality of the connections, apply more flux and reflow the joints until you are satisfied.

The same procedure is also used for installing components with three or more leads (transistors, ICs, etc.). Start with a bead of solder on one pad, position and “tack” the part, then add more flux and solder the remaining leads. Don’t forget to reflow/improve the first “tacked” connection if necessary.

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Electrical Wire soldering For Beginners

by Randy Glass

DISCLAIMER- First, soldering can be dangerous. This lesson is not meant to be everything you need to know. Your safety is up to you, and you take full responsibility for any damage or injury caused by these instructions, whether as an act of omission or commission on your part or mine. Be aware that an improperly soldered wire can lead to fire, loss of vehicles, injury, and even death. By reading and/or using these instructions you take full responsibility and release me from all liability. Second, I took these photos as I did the work, pressing the remote control for my camera with one finger as I held the soldering pencil in one hand and the solder in the other. I apologize for any images that might be out of focus or poorly composed.

If Yogi Berra ever wrote a book on motorcycles he would probably say, "We seem to spend around forty percent of our time taking things apart, and the other seventy-five percent of the time putting them back together." Some things are easy to put together. We use specialized fasteners like nuts, bolts and screws to hold things together that, some day, we might want to take apart again. But there are some things that, once put together, we would like to know that, to some degree, our fastening system is permanent. One of those places is in electrical wiring. When a wire breaks or needs to be fastened to a connector or another wire in such a way as to be dependable, then the very best way is to solder.

soldering is a method to attach one metal part to another. It is part of a family that uses molten metal to do this job. At the top of the ladder is welding. This is a very high temperature method that actually melts the parts a bit where they are attached, along with some other metal, usually in the form of welding rods. Next is brazing. This melts some hard metal, usually brass, into the gap between two pieces of metal. Normally, the surface of the material being joined is not melted in this process, but it gets very, very hot. Finally there is soldering. soldering flows some molten metal between metal parts at relatively low temperatures.

For our purposes I am going to speak of the type of soldering that attaches two wires together or one wire to a connector- the sort of soldering that any backyard mechanic might need to do when working on any electrical component or the wires that connect them together in almost any type of vehicle.

WHY solder?

Although there are methods that can be used to make these connections without soldering, they are usually inferior. soldering does a lot of things:

1) It Is Strong- You are connecting two metal parts with a liquid metal that becomes solid after it fills the joint and cools. When properly done it leaves no voids so the joint is very strong and the wire is well supported.

2) It Slows or Stops Oxidation - Because solder fills the joint it excludes air and moisture so the metal in the joint will not oxidize. This maximizes electrical flow over time.

3) It Makes An Excellent Electrical Connection- because the solder is a conductor it gives the wire more area from which it can flow electrons to whatever it is connected.

4) Non-permanent - Although soldering is very strong, it can be removed and the joint taken apart in the future if necessary.

5) Connectors do Not Need to be Crimped - Those little metal connectors that are designed to be crimped have a terrible habit of coming loose as well as breaking the little copper wires in the conductor making a weak joint as well as one that does not conduct as well as it should. They easily let air and moisture in which causes corrosion and that leads to poor and broken connections.

MATERIAL LIST

It doesn't take much to set yourself up as a soldering wizard. Here is a list (numbers refer to image to the left):

*1) **soldering Pencil -** Something around 25 to 40 watts would probably be fine for most electrical work. You don't need a huge soldering gun to do electrical work. A little smaller is actually better than too big, as we shall see. Get a brand-named pencil so that down the line you will still be able to

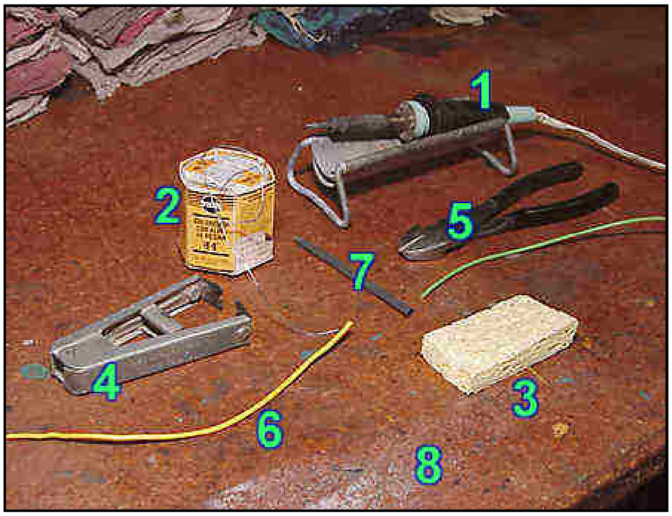

get replacement tips for it. A chisel tip as seen in the pictures that follow is best for most work but you might also need a pointed tip for more delicate work. Those old soldering guns are nice for making battery cables, but are generally too large for what we are doing. it would be like using a sledge hammer to make a picture frame- it would have to be a REALLY big picture frame!

There are also cordless, rechargeable soldering irons available. They generally run about $35-75 or so. Although these cost substantially more than a corded iron, and the replacement tips are more expensive as well, there is no cord to get in the way when working and as they can be carried along on trips. These generally have a built-in light as well making repairs at night easier. I normally loosen the lamp so that it does not light, so the battery lasts longer in use.

There are soldering tools that are actually little, refillable, butane-powered torches with a soldering tip at the end which is heated by the flame. As they are about the size of a fat ball point pen, they are another good way to get a portable soldering tool. These generally are available for less cost than the rechargeable irons mentioned above. I have used electric irons to solder around a gas tank on an automobile- something that I would never consider with one of these.

And a **soldering Pencil Holder** - Most soldering pencils come with a holder or a rest as seen here, but if not, get one. These metal stands are very handy and will help avoid melted parts and burned hands and work surfaces.

*2) **solder** - Resin core solder is what you want. NEVER use acid core solder on electrical components. The acid will stick around and continue to eat into components and wiring well after the soldering job is over.

Resin core solder can be had in various quantities, but I buy the one pound roll for around $12-15 which will be a lifetime supply for most folks. I use Kester brand "44" Resin Core solder in the .031 diameter size. This is about the size of mechanical pencil lead and works quite well for what you will be doing.

It use to be that a standard part of a soldering kit was a little tub of flux. This paste would be spread on the joint ahead of time to help clean the joint chemically as it was heated by the iron. It was necessary as flux-core solder was unavailable. If your wires are clean and you are using a quality, resin core solder, additional flux is not necessary.

*3) A**n Old kitchen sponge** or two

* **Tools** to work on wires such as a (4) wire stripper and a (5) wire cutter, and possibly needle nosed pliers and a small vise (not shown).

* 6) A few bits of **insulated wire** and an old spade connector or two on which to practice. Two or three feet of wire will do.

*7) **Heat Shrink Tubing** - I rarely use electrical tape any more. Heat shrink is really great! I usually buy it in three foot lengths in two or three sizes. This is a sort of memory tubing that, I believe, is made by heating a special tubing and stretching it and allowing it to cool while still stretched. it maintains that size. When heat is applied once again the tubing will shrink back down to its original size.

*8) Protection for the work surface like an old piece of 1/4" plywood about 12" square or such. An old piece of counter-top lamination works also.

* Wicking material (not shown)- You can purchase some special copper wick that is used to unsolder joints. This is usually not necessary, but handy at times, and inexpensive.

* **Eye protection**

* A Ventilated workspace

SOME WARNINGS

HEAT - A soldering pencil as well as molten solder are both really hot. They will burn you and it will hurt. It can hurt a lot. It can make your skin give off smoke and that smells bad. If left unattended a hot soldering pencil can cause fires, melt carpeting, burn workbenches, and make the cat dance like never before. An unsuspecting person can pick up a hot soldering iron and get a nasty burn (trust me on this one!). Never leave a soldering tool warming or hot and unattended.

Additionally, a hot soldering iron can almost instantly melt plastic parts and upholstery in a hurry. Use care when soldering as well as when moving the iron to and from the solder joint. If the cord gets caught when moving the iron it can easily cause you to drop the hot tool onto something expensive or painful. NEVER place a soldering iron on saddles, luggage, body work, painted surfaces, or on or near any heat-sensitive surface.

LEAD and VAPORS- solder contains a good amount of lead and handling it over a long period of time may have negative health consequences. The vapors caused by soldering can, over time, cause health problems as well. Work in a well ventilated area. I usually work out doors and use a fan to blow the vapors away from me. The smoke that is given off by the flux in the solder is also not a good thing to breathe.

MOLTEN METAL - When soldering (and particularly when un-soldering) it is very possible to flick bits of melted solder about. As this stuff is quite hot, even a small drop in the eye can cause permanent damage. Wear eye protection and do not wear your good glasses, or wear them under goggles. The dripped solder can melt plastic parts and permanently damage auto carpeting as well. Be aware of other folks or critters who may be in the area as well.

ELECTRICITY - You will be soldering on wires that, if shorted out, could cause a blown fuse, damaged electrical components, or melting wires and a fire. Always disconnect the battery when soldering wires on a vehicle and remove connectors from heat-sensitive components before soldering on them.

LETS GO

I could spend a lot of time talking about how it all works, but jumping right in is the best way to learn how to solder and I will explain as I go

Begin by creating a safe work area. One free of clutter, with sufficient light, and protected from the soldering iron and melting solder. Set the soldering pencil in its stand and plug it in. be sure that the cord is placed in a way that it will not be accidently pulled or tripped on, upsetting the soldering pencil.

While that is heating up, prepare your sponge. Wet it, squeeze out the excess water, then fold it in

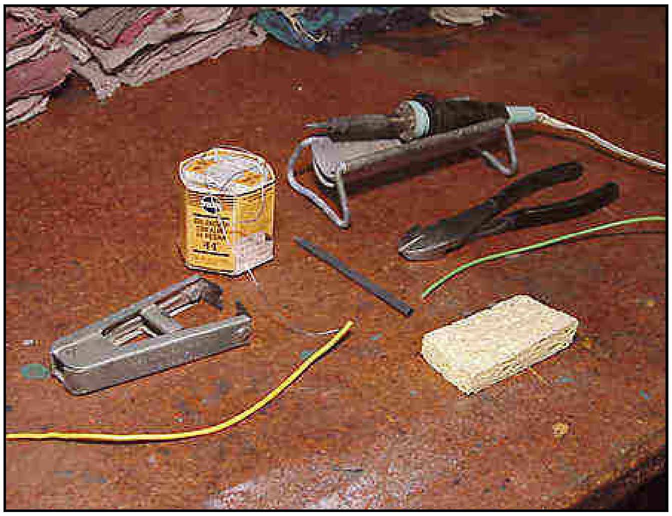

half and rubber band it about half-way down.

Pull out about a foot or two of solder from the roll and touch it to the tip of the soldering iron. Always apply the solder to the flat parts of the tip and not to the sides. When the solder melts fairly easily, melt an amount all over the tip. There will be some smoke from the resin in the solder.

The solder you bought is actually a bit hollow. Inside of the metal there is a channel (or in some cases, channels) that make it sort of like a little garden hose. The channel is filled with a resin. When heated it melts and some of it burns off. The action of the resin when it is heated helps clean the surface to be soldered which helps the solder stick a lot better. Unfortunately, the burned resins can also leave deposits on the soldering pencil, and over time will make it difficult to solder. That's where the sponge comes in. After you have melted some solder onto the tip (about a quarter inch or so of the thin stuff) wipe the soldering pencil's tip off on the damp sponge a few times.

If you examine the tip of the soldering pencil carefully you will see that it is now covered with a thing coat of shiny, silver metal- the solder. You have successfully "tinned" the tip of the pencil. This keeps the metal tip from oxidizing and will assist you in soldering from now on. Always do this before starting a soldering job and occasionally during a larger job.

Place the soldering pencil back into its holder and let's prepare the wires. We are going to solder two wires together, making believe they have broken or need extending.

We start by "stripping" some of the plastic insulation away from where we want to connect the wires. The thicker the wire the more insulation we remove. For most common wires on a motorcycle or in a car, removing about 3/8 to � inch works fine. You will get a

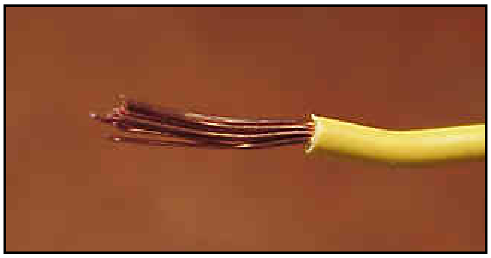

feel for how much in a short period of time. When stripping wire be very careful not to cut the strands of the conductor.

There are special tools available for stripping wire that can save a lot of time. These can be as simple as a carefully wielded razor blade to fancy and somewhat expensive automatic strippers.

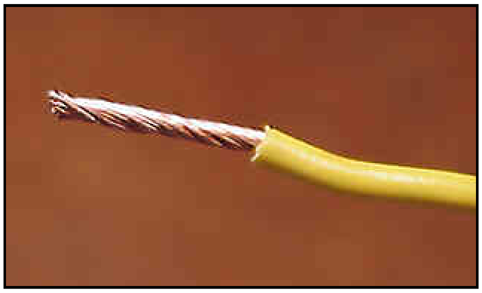

Once stripped, twist the strands together into a neat little bundle.

The exposed wires should look fairly clean and in most cases, shiny, but certainly not green or cruddy. If corroded, then the wires should be cut back and re-stripped until clean wire is found.

Now cut a length of heat shrink tubing off about an inch long. It should be of a large enough diameter that at least two of the wires you are soldering can easily fit into it at the same time. Slide the length of the tubing over one of the stripped wires- it doesn't matter which here, but in real life we would slide it over the lower wire or the one which slopes most downward away from the joint so it will tend to slide out of the way. make sure it is at least three or four inches away from the joint.

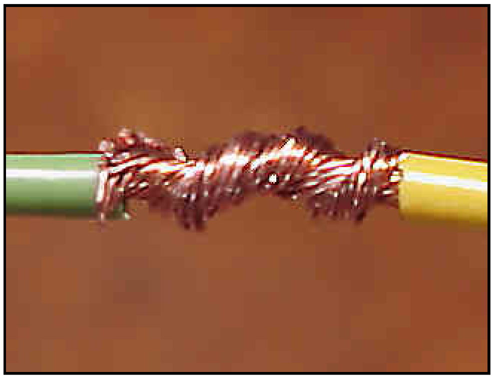

Now, twist the two wires together into a tight, neat pair. This is important because it helps create a good electrical connection. You also do not want any little wires sticking out. Start by crossing the wires about mid-strip, crossing them at about 45 degrees or so, and twisting in opposite directions. When done, the joint should be fairly strong on its own, holding the two wires together tightly. The connected pair of wires should be in line as if they are a single wire and not two joined together.

It's time to solder. Place the roll of solder on your left (if you are right handed) with a good length of solder hanging out of the roll. With the solder in your left hand and the soldering iron in your right hand, check to see that the tip is still tinned and shiny. If not, repeat the process with a bit of solder melted to the tip, then wipe the tip off on the sponge.

Melt a little ball of solder onto the iron....

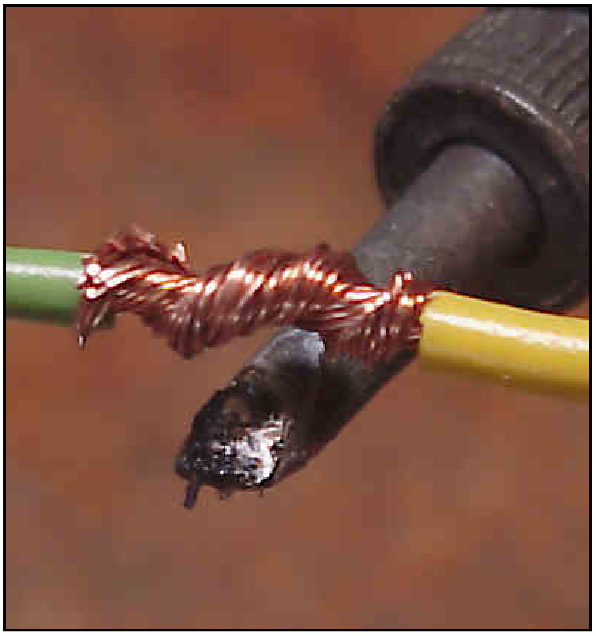

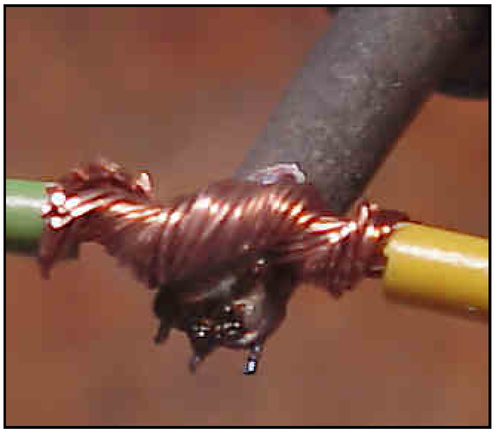

...and immediately place the soldering iron under the twisted wires (if possible) so that the little ball of solder fills much of the gap between the soldering pencil and the wire. Since heat rises, placing the iron under the joint will heat it faster. The little ball of solder works as a heat conductor and will very rapidly conduct the heat from the soldering pencil's tip into the wires. If the ball of solder does not seem like it is contacting the wire very well, without removing the pencil from the joint, melt just a bit more solder in there by feeding the end of the solder wire into the tip. This will not only increase the contact area of the solder to the wire but it will also add a bit of flux that helps the solder adhere to the wire at this time.

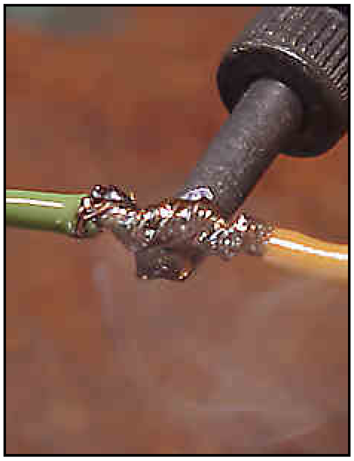

After about two or three seconds, start to feed solder, slowly at first, into the void between the pencil and the wire. You should soon see the solder is flowing into the twisted wires. WHen that happens, increase the feed rate of the solder into the joint, and you can now also feed a little into the top of the joint. Don't move the iron's placement, jut take the end of the solder wire and touch it to the tip of the joint. Continue to feed solder until the individual wires are almost filled with solder and the entire joint has turned silver. When that happens, stop feeding the solder in and immediately but gently remove the soldering iron.

How long do you wait until feeding in solder? One way to test how long to wait is to touch the solder on top of the joint and wait until that area is hot enough to melt the solder. The amount of time it takes varies with the size of the wires to be soldered, the size of the solder, the wattage of the iron, the size of the irons's tip, the ambient air temperature, and other factors. Experience will teach you how long this takes.

The problem comes from waiting too long and putting too much heat into the joint. When you do that it begins to melt the insulation on the wires around the joint (you can see that beginning to happen above at the end of the insulation of the green wire next to the soldered joint). That is why I like tho flow the solder in from where the iron's tip touches the wire. This is the place that will come up to soldering temperature first, and then the flowing solder will more easily flow solder into the joint as it carries heat with it. The larger the wires, the longer it takes and the more important it becomes to feed in some solder from the top of the joint as well. Again, experience will teach you when that is necessary.

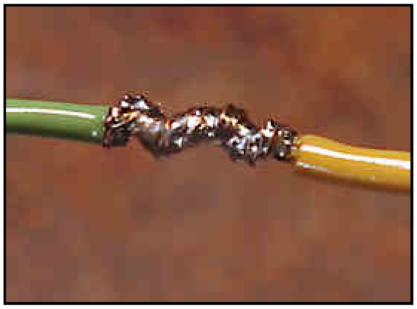

How much solder is enough? Too much? The correct amount of solder is used when the joint is fairly all silver colored but still shows the "outlines" of the individual strands of wire in the joint. If there is very much in the way of copper colored wire showing then you probably didn't use enough solder or the wires weren't clean and would not accept the solder. If there are big blobs and drips of hardened solder on the joint then you probably had either too cool of a joint or used too much solder.

After soldering, let the joint cool for about thirty seconds to a minute or so before handling. If you were successful you should have:

* A pair of wires tightly joined together

* The joint between them is very shiny, looking like polished sterling silver.

* No hardened dribbles or drops of solder hanging off the joint

* No little wires sticking out of the joint.

* A union only slightly larger than each of the wires themselves.

If you were NOT successful you might see:

* Large blobs or possibly a long, pointy finger of hardened solder hanging off the joint. Sometimes, after cleaning the iron, these can be removed by simply heating the joint until the solder melts, then removing the iron which will pull away some of the excess solder with it. This may need to be repeated a few times to remedy the situation.

* Wires that are not soldered together and has movement within it. Re-heat the joint and add some more solder.

* Melted insulation. This can be so bad that the wires are revealed with the insulation dripping off the wires. At this point you will probably need to cut the wires and begin again, or unsolder the joint and add a long piece of heat-shrink tubing to cover the exposed wires.

* Little ends of the copper wires sticking out. These can sometimes be cut off with a wire cutter and/or pressed down with a pair of smooth-jaw pliers, possibly needle nose pliers.

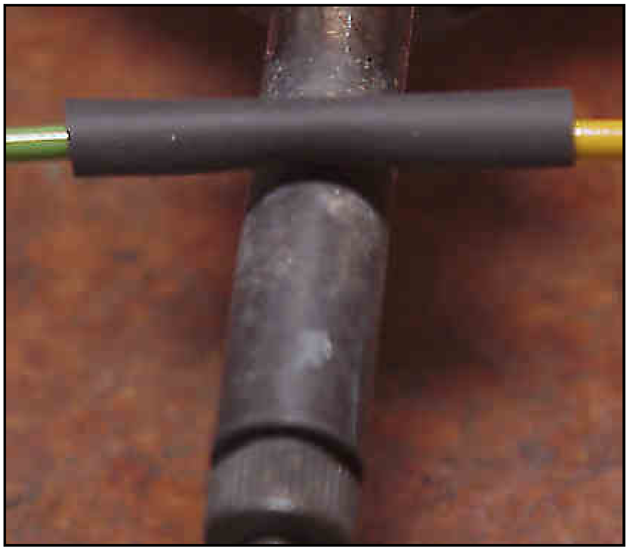

Now it is time to cover the joint with the heat shrink tubing. You DID remember to slide on the heat shrink tubing before beginning, didn't you? Once the joint is cool enough to touch, slide the tubing so it is centered over the joint and gently touch the meaty part of the soldering iron's heating element to the center of the tubing.

Continue this around the center of the tubing until it tightly grips the wire joint, then work outwards until the entire piece of tubing has shrunk tightly around the joint.

Attaching An Electrical Connector

Besides connecting two wires together, soldering is the best way top attach some sort of connector to the end of a wire. The connection is strong as well as fairly well sealed against the elements. It works pretty much the same way as above...

Remember when we "tinned" the tip of the soldering pencil? We did this to apply a film of solder to the tip so it wouldn't oxidize and thus be able to more easily transfer heat. Now I am going to do the same with a piece of wire.

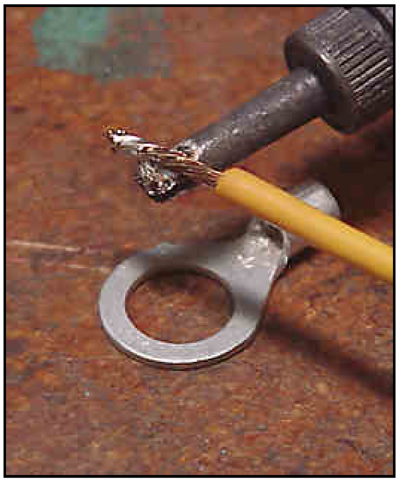

Here I am applying a good amount of solder ahead of time to this wire because I am planning on soldering it to a fairly heavy connector. This way, the wire will be "pre-soldered" and easier to attach, and will have less of a chance of melting the insulation.

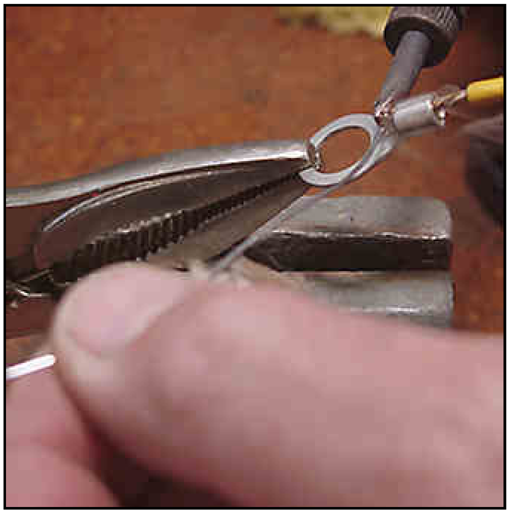

When soldering a connector to the end of a piece of wire it is very helpful to use some sort of vise to hold the connector. A small pair of locking pliers or a pair of needle nose pliers with a rubber band around the handles to hold the jaws shut works well. Here I have locked a pair of locking pliers into a small vise to work as a "hands-free" holder. This not only allows me to use both hands to work but isolates me from the heat of the soldering process.

Remember that the heavy metal pliers will work as a heat sink, pulling heat away from the soldering joint, so it might take longer to achieve the proper heat level in the joint. That is why I have gripped the connector as far away from the area to be soldered as possible,

Be careful as the pliers may get hot near the tips and you might overheat the wire as well. Be sure to slide the heat shrink tubing over then wire BEFORE beginning to solder! If you leave it off and finish soldering, you will be left with the soldering job in one hand, the heat shrink tubing in the other hand, and a stupid look on your face. We call this, "Heat Shrink Tubing Syndrome."

Additionally, if you apply too much solder, particularly with a small connector, it is very possible to fill the connector with solder and thus make it difficult or impossible for the connector to function properly. There are ways to get the solder out, but they are generally more difficult (or dangerous) than just chucking it and starting over. To keep this from happening:

* Never touch the area of the connector where you don't want solder to flow
* Orient the connector with the part where solder shouldn't flow, upwards (or Higher than the end where solder will flow).
* Apply solder sparingly and slowly
* Use a lower wattage soldering pencil
* Use a smaller tip on the soldering pencil

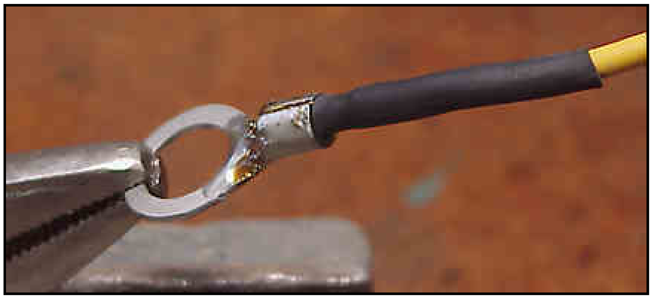

I sometimes use two pieces of heat shrink, one over the other, shrunk one at a time, in areas where extra protection is needed. This is particularly useful when soldering a connector to the end of a wire. I first shrink a small diameter piece about an inch long over the wire up to where it joins the connector as shown here. This acts as a strain relief as well as insulation.

Notice the small amount of flux on the connector ring left over from the soldering process. If you use resin core solder, this stuff is harmless to the electrical device. It can be brushed off with a small wire brush if you wish.

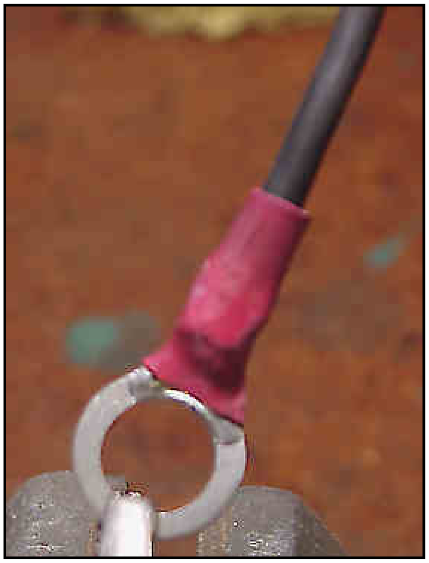

I then shrink another larger diameter piece about � an inch long over the connector to act as an insulating cover. In the case of something like a female spade connector, the entire connector except for the opening can be covered and protected in this way. If the heat shrink interferes with the connection, simply cut the offending part away with a razor blade being careful not to damage anything else including yourself!

In areas where the joint needs to be protected from corrosion, slather the terminal with petroleum jelly, or the special grease for this application.

Following these directions you will become a "master solderer" in a short period of time. It takes some practice to get a feel of how hot for how long with how much solder it takes to create to make a good solder joint, so get some scrap wire and practice before attempting to solder on anything important.

If there are any questions or comments, please feel free to E-mail me at frcn@cncnet.com.

Note by Duane; If you appreciate articles like this, I suggest that you thank Randy at the email address above.

More BMW info

Home page

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Soldering and Desoldering Instruction

Soldering is defined as "the joining of metals by a fusion of alloys which have relatively low melting points". In other words, you use a metal that has a low melting point to adhere the surfaces to be soldered together. Soldering is more like gluing with molten metal than anything else. Soldering is also a must have skill for all sorts of electrical and electronics work. It is also a skill that must be taught correctly and developed with practice.

Remember that when soldering, the rosin in the solder releases fumes. These fumes are harmful to your eyes and lungs. Therefore, always work in a well-ventilated area. Hot solder is also dangerous. Be sure not to let is splash around because it will burn you almost instantly. Eye protection is also advised.

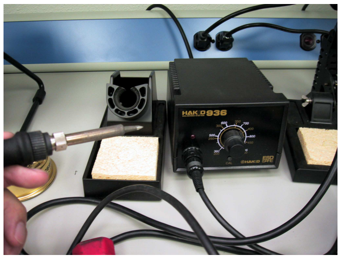

HAKKO 850
HAKKO 850

The Tools

Soldering Iron – Even the cheapest of them will do the job. They may not last as long, but they do get hot enough to melt solder and that is the goal. You only need to make sure that the one you buy has a suitable tip on it. The most typical tip is the one that is about the size of a 1/8” stereo mini-plug.

Solder – Get Rosin Core solder. Rosin will help the solder to flow onto the wires. Solder comes in different thickness. Buy what is appropriate for your job.

Desoldering Gun – This tool will make life a lot easier when you need to rework a previous solder job.
Solder Wick – Braided copper with rosin coating used to draw solder off of circuit boards.

SMD Rework station— Basically this is a high temp hair dryer with special nozzle attached. It heats up entire pins of the SMD device so you can remove them.

The Methods

Soldering – There is not art to soldering, it takes patience and practice to get it right. If you are doing it right, it will be easy and very fast. First, make sure that your soldering iron tip is clean. If it is dirtier than just a light gray color, you need to clean it. You can do this with sandpaper or a Scotch Brite pad. Next, turn your iron on and give it plenty of time to heat up. To test the heat, use a piece of solder touched to the tip. If it melts immediately, it is ready.

The most common way to mess up a solder job is to let the soldering iron stay on the parts to be soldered too long. What this does is oxidize the metal, making it too dirty to attract solder. If you are working with a circuit board, too much heat can damage the board, rendering it useless and in need of repair. You should only hold the soldering iron to the parts to be joined for no more than 10-12 seconds. Any longer and you will melt insulation on wire or damage a circuit board.

It has been said that soldering is a two-person job. You need two hands to hold the parts together, one hand to hold the iron, and another to feed the solder. The correct method for applying solder is to hold the joint perfectly still while heating with the soldering iron. After a few seconds, introduce the end of the solder at the point where the iron meets the parts

If the solder does not melt immediately and flow onto the joint, pull the solder away and try again after a couple seconds longer. If you exceed 10 seconds, pull the iron off and try again after it all cools down. You probably didn't have the iron touching enough of the parts to be soldered. Sometimes, the parts to be soldered are so big that they conduct the heat away very quickly and make it difficult to solder. In this case, it is OK to put some solder on each part individually and then put them together later by melting the solder on each one while they are touching.

Joining Two Wires - Strip off about 3/8" of insulation from the two wire ends to be joined. Place a ½" length of heat shrink tubing over one wire and push it back so that the heat from soldering won't shrink it prematurely. Fold each bare wire end back on itself so that the tip of the wire now comes back to the end of the insulation. Link both wires together using the bends like hooks. Now, twist the ends of the wires around themselves tightly. This type of connection is called a Western Union and it is the strongest method of joining two wires together. Now, heat the connection with the iron and allow solder to flow over the entire joint. Wait a few seconds for it to cool off and then slide the heat shrink tubing down over the connection and heat it with a match or heat gun.

Soldering a Wire to a Circuit Board – This is delicate work that you will do while soldering. Too much heat and your board will be damaged. If you are attaching a wire to an existing hole on the board, make sure that the hole is clean and free of any excess solder (see de-soldering for more detail). The best advice when soldering to a circuit board is to angle your soldering iron tip so that it makes good contact with the pad on the circuit board and the wire or part to be soldered at the same time. Heat the parts up and touch the solder at the point where the tip meets the part and the pad. If the solder does not flow immediately, pull everything off and wait for it to cool down and try again later.

Step 1

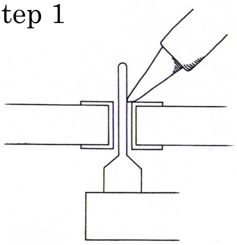

Apply heat to both pin and pad on the circuit board. Make sure tip of the soldering iron is touching both pin and pad.

Step 2

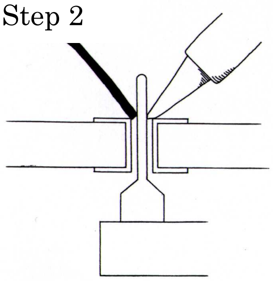

When the both pin and pad are heated enough, apply solder to the pin and pad. Solder should starts to flow.

Step 3

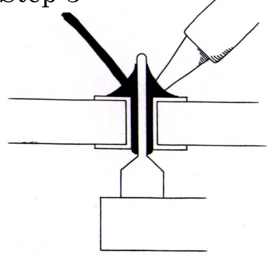

Apply enough but not too much solder. While applying the solder, do not move the tip of iron.

Step 4

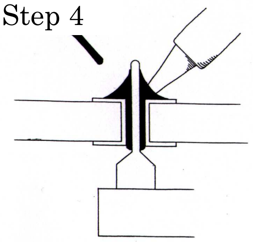

Remove solder away.

Step 5

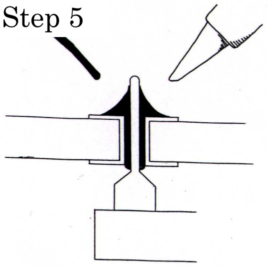

Remove tip of soldering iron also.

Step 6

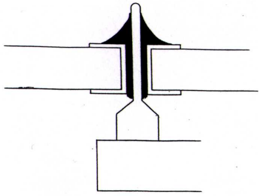

Done! Check the joint to make sure the connection.

Good soldering and Bad soldering Joints

Here are some example of Good soldering and Bad soldering joint.
For Japanese, we often say, “Good soldering joint should look like Mt. Fuji.”

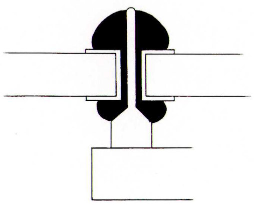
Too much soldering

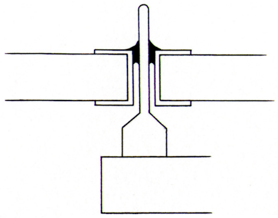
Too little soldering

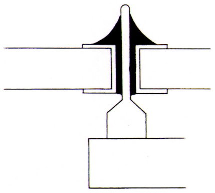
Good soldering

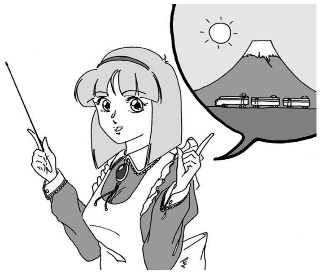

Cold Solder Joints

A cold joint is a joint in which the solder does not make good contact with the component lead or printed circuit board pad. Cold joints occur when the component lead or solder pad moves before the solder is completely cooled. Cold joints make a really bad electrical connection and can prevent your circuit from working.

Cold joints can be recognized by a characteristic grainy, dull gray color, and can be easily fixed. This is done by first removing the old solder with a desoldering tool or simply by heating it up and flicking it off with the iron. Once the old solder is off, you can re-solder the joint, making sure to keep it still as it cools.

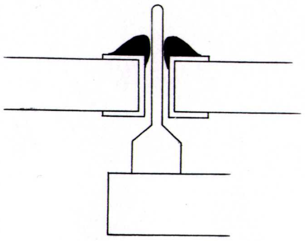
Cold soldering joints

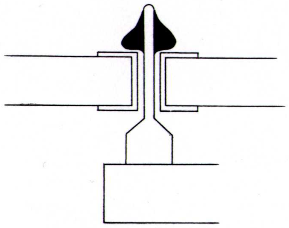

Tips and Tricks

Soldering is something that needs to be practiced. These tips should help you become successful so you can stop practicing and get down to some serious building.

1. Use heat sinks. Heat sinks are a must for the leads of sensitive components such as ICs and transistors. If you don't have a clip on heat sink, then a pair of pliers is a good substitute.

2. Keep the iron tip clean. A clean iron tip means better heat conduction and a better joint. Use a wet sponge to clean the tip between joints.

3. Double-check joints. It is a good idea to check all solder joints with an ohmmeter after they are cooled. If the joint measures any more than a few tenths of an ohm, then it may be a good idea to re-solder it.

4. Use the proper iron or temperature. Remember that bigger joints will take longer to heat up with an 30W iron than with a 150W iron. While 30W is good for printed circuit boards and the like, higher wattages are great when soldering to a heavy metal chassis.

Desoldering

Desoldering is extremely difficult compare to soldering. In the process of RomBoard installation, the parts and circuit board must be in the good shape to re-use them. The tool we use is Desoldering Gun. This device has vacuum pump built in with heater tip. Process of desoldering it self is very simple, but there are some tricks to do clean and safe desoldering job.

Step 1

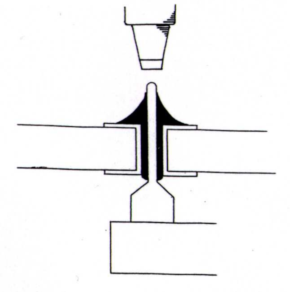

Put the desoldering gun's tip over to the soldering joint. Make sure nozzle is 90° angle from circuit board.

Step 2

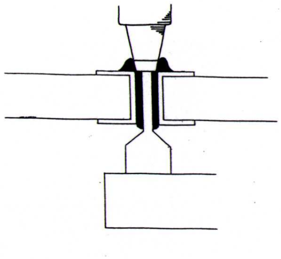

Apply the enough heat to melt entire solder. Multi-layer board or ground pin may take while to transfer heat.

Step 3

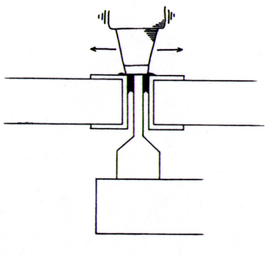

While applying vacuum, move the tip around the pin to get all the solder of around the pin out. At this time, you can also feel pin moves freely, so you know pin is free from circuit board.

Step 4

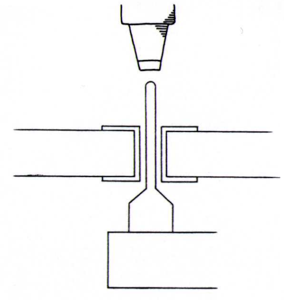

When you can hear air flow sound from hole, you should be done. Stop applying vacuum and remove the gun from the pin. Inspect hole and pin.

When you done with desoldering, the parts that you are trying to remove should move freely. If it doesn't, find which pin is still has solder left, and re-apply fresh solder to it and try desoldering process again. The multi-layer circuit board require more heat to get solder to melt. Make sure pin start to move freely by moving the tip of soldering gun before you apply vacuum to it.

SMD device soldering and removal

In the process of RomBoard installation, chance of handling SMD devices is becoming higher and higher due to ECU configuration change.
Soldering of SMD devices are not much different from regular through hole soldering.
Important thing is positioning of the device is very critical.
Start with applying little solder to two of the each corner of the pads on the circuit board.
Then, place the SMD device and re-heat a one of the solder you just applied to connect a SMD device pin to the pad. Check the position of the device, if position is right re-heat the other end of solder to secure the device completely. If you didn't get position right, re-heat the pin that you just soldered and while heating a pin, move the device to the right position.
Once you positioned the device in the right position, apply Rosin Flux to both pins and pads. This will help your soldering job by keeping solder separate from each pin.
Here is how the joint on SMD device pin should look like.

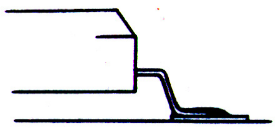

QFP and SOP chip

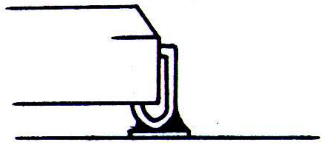

PLCC chip

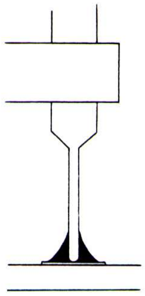

RomBoard adapter socket

Removing SMD device will be the probably the most difficult process. SMD rework station is used to do this. Make sure all the pins are completely heated otherwise you will be removing a pad from the circuit board along with device. Also, you should note, when you are applying heat to the device, some parts around the device is also heated and moves around when you touch. It is good idea to take a note of location of the devices near the target device.

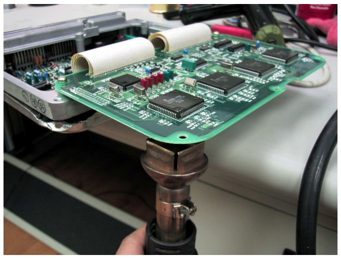

Step 1
Apply pre-heat from back side of the target device. Keep applying heat until you can't touch the chip. By this time, circuit board should have enough heat.

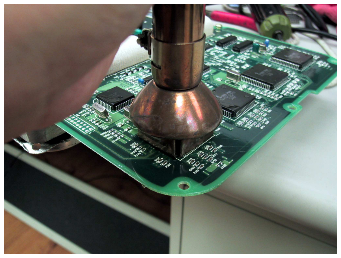

Step 2
Apply heat from top of the target device. Nozzle should cover entire chip. You can check if chip is free from solder by sliding the nozzle left and right. Make sure you don't move other parts. If the chip moves freely, it is ready to be removed.

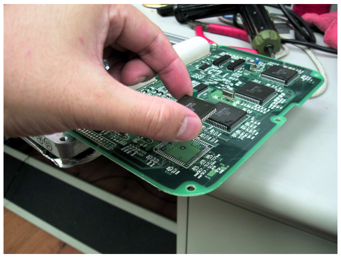

Step 3
Remove the chip straight up to avoid making solder bridge between pins. Chip is extremely hot! Unless you have skin of steel, avoid imitating the picture.

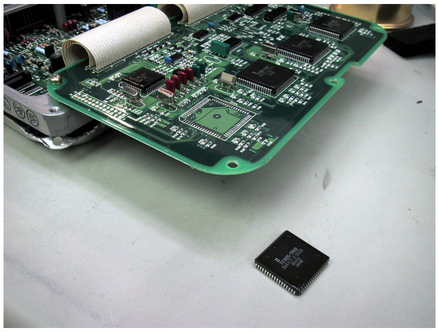

Step 4
After remove the chip, cool down both circuit board and chip.

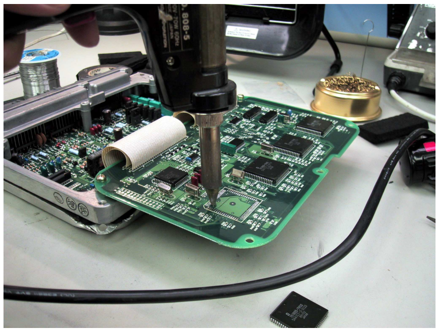

Step 5
Clean the pads on the circuit board with desoldering gun.
Do not apply too much heat to the pad. Pad might peel off from circuit board. Clean the chip by desoldering gun also.
Check for any bridge between pins. If the chip has too much protective coating on it, use solvent to clean it up.

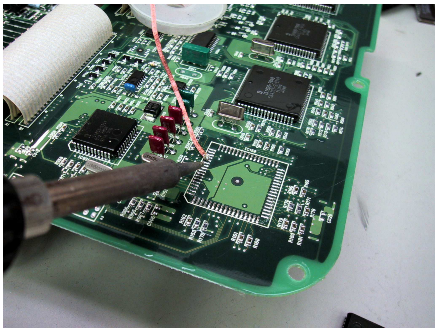

Step 6
If the pads on the circuit board is too small to use desolding gun, try cleaning by solder wick with rosin flux. This may take time but it is much better than peeling pads off.
Once again, do not apply too much heat.

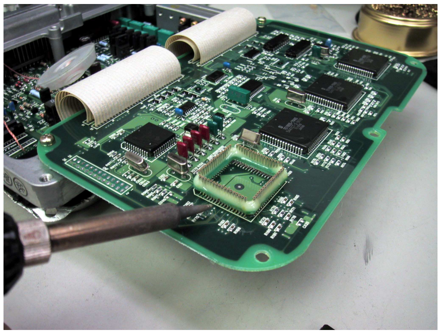

Step 7
Solder the RomBoard adapter where the chip was.
Refer SMD device soldering section for how to solder adapter.

The Final Word

Soldering, desoldering, and working with SMD device will take some effort to learn. You should be relaxed and concentrated when you work.
Keeping every thing clean (tip of iron, gun, work surface, etc) will help you also.
Once you get comfortable to work with soldering you may find your own tips and tricks.
Experience is all bout soldering.

EOF

How To Solder - Soldering Tutorial

Soldering is defined as "the joining of metals by a fusion of alloys which have relatively low melting points". In other words, you use a metal that has a low melting point to adhere the surfaces to be soldered together. Consider that soldering is more like gluing with molten metal, unlike welding where the base metals are actually melted and combined. Soldering is also a must have skill for all sorts of electrical and electronics work. It is also a skill that must be taught correctly and developed with practice. This tutorial will cover the most common types of soldering required for electronics work. This includes soldering components to printed circuit boards and soldering a spliced wire joint. This presentation came from http://www.aaroncake.net/electronics/solder.htm

Soldering Equipment

The Soldering Iron/Gun

The first thing you will need is a soldering iron, which is the heat source used to melt solder. Irons of the 15W to 30W range are good for most electronics/printed circuit board work. Anything higher in wattage and you risk damaging either the component or the board. If you intend to solder heavy components and thick wire, then you will want to invest in an iron of higher wattage (40W and above) or one of the large soldering guns. The main difference between an iron and a gun is that an iron is pencil shaped and designed with a pinpoint heat source for precise work, while a gun is in a familiar gun shape with a large high wattage tip heated by flowing electrical current directly through it.

A 30W Watt Soldering Iron

A 300W Soldering Gun

For **hobbyist electronics** use, a soldering iron is generally the tool of choice as its small tip and low heat capacity is suited for printed circuit board work (such as assembling kits). A soldering gun is generally used in heavy duty soldering such as joining heavy gauge wires, soldering brackets to a chassis or stained glass work.

You should choose a soldering iron with a 3-pronged grounding plug. The ground will help prevent stray voltage from collecting at the soldering tip and potentially damaging sensitive (such as CMOS) components. By their nature, soldering guns are quite "dirty" in this respect as the heat is generated by shorting a current (often AC) through the tip made of formed wire. Guns will have much less use in hobbyist electronics so if you have only one tool choice, an iron is what you want. For a beginner, a 15W to 30W range is the best but be aware that at the 15W end of that range, you may not have enough power to join wires or larger components. As your skill increases, a 40W iron is an excellent choice as it has the capacity for slightly larger jobs and makes joints very quickly. Be aware that it is often best to use a more powerful iron so that you don't need to spend a lot of time heating the joint, which can damage components.

A variation of the basic gun or iron is the soldering station, where the soldering instrument is attached to a variable power supply. A soldering station can precisely control the temperature of the soldering tip unlike a standard gun or iron where the tip temperature will increase when idle and decrease when applying heat to a joint. However, the price of a soldering station is often ten to one hundred times the cost of a basic iron and thus really isn't an option for the hobby market. But if you plan to do very precise work, such as surface mount, or spend 8 hours a day behind a soldering iron, then you should consider a soldering station.

The rest of this document will assume that you are using a soldering iron as that is what the majority of electronics work requires. The techniques for using a soldering gun are basically the same with the only difference being that heat is only generated when the trigger is pressed.

Solder

The choice of solder is also important. There several kinds of solder available but only a few are suitable for electronics work. Most importantly, you will only use *rosin core solder*. *Acid* core solder is common in hardware stores and home improvement stores, but meant for soldering copper plumbing pipes and not **electronic circuits**. If acid core solder is used on electronics, the acid will destroy the traces on the printed circuit board and erode the component leads. It can also form a conductive layer leading to shorts.

For most printed circuit board work, a solder with a diameter of 0.75MM to 1.0MM is desirable. Thicker solder may be used and will allow you to solder larger joints more quickly, but will make soldering small joints difficult and increase the likelihood of creating solder bridges between closely spaced PCB pads. An alloy of 60/40 (60% tin, 40% lead) is used for most electronics work. These days, several lead-free solders are available as well. **Kester "44" Rosin Core** solder has been a staple of electronics for many years and continues to be available. It is available in several diameters and has a non-corrosive flux.

Large joints, such as soldering a bracket to a chassis using a high wattage soldering gun, will require a separate application of brush on flux and a thick diameter solder of several millimeters. Remember that when soldering, the flux in the solder will release fumes as it is heated. These fumes are harmful to your eyes and lungs. Therefore, always work in a well-ventilated area and avoid breathing the smoke created. Hot solder is also dangerous. It is surprisingly easy to splash hot solder onto yourself, which is a thoroughly unpleasant experience. Eye protection is also advised.

Preparing To Solder

Tinning the Soldering Tip

Before use, a new soldering tip, or one that is very dirty, must be tinned. "Tinning" is the process of coating a soldering tip with a thin coat of solder. This aids in heat transfer between the tip and the component you are soldering, and also gives the solder a base from which to flow from.

Step 1: Warm Up the Iron

Warm up the soldering iron or gun thoroughly. Make sure that it has fully come to temperature because you are about to melt a lot of solder on it. This is especially important if the iron is new because it may have been packed with some kind of coating to prevent corrosion.

Step 2: Prepare A Little Space

While the soldering iron is warming up, prepare a little space to work. Moisten a little sponge and place it in the base of your soldering iron stand or in a dish close by. Lay down a piece of cardboard in case you drip solder (you probably will) and make sure you have room to work comfortably.

Step 3: Thoroughly Coat the Tip in Solder

Thoroughly coat the soldering tip in solder. It is very important to cover the entire tip. You will use a considerable amount of solder during this process and it will drip, so be ready. If you leave any part of the tip uncovered it will tend to collect flux residue and will not conduct heat very well, so run the solder up and down the tip and completely around it to totally cover it in molten solder.

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Step 4: Clean the Soldering Tip

After you are certain that the tip is totally coated in solder, wipe the tip off on the wet sponge to remove all the flux residue. Do this immediately so there is no time for the flux to dry out and solidify.

Step 5: You're Done!

You have just tinned your soldering tip. This must be done anytime you replace the tip or clean it so that the iron maintains good heat transfer.

Soldering a Printed Circuit Board (PCB)

Soldering a PCB is probably the most common soldering task an electronics hobbyist will perform. The basic techniques are fairly easy to grasp but it is a skill that will take a little practice to master. The best way to practice is to buy a simple electronics kit or assemble a simple circuit (such as an **LED chaser**) on a perf-board. Don't buy that expensive kit or dive into a huge project after only soldering a few joints.

Soldering components onto a PCB involves preparing the surface, placing the components, and then soldering the joint.

Step 1: Surface Preparation:

A clean surface is very important if you want a strong, low resistance solder joint. All surfaces to be soldered should be cleaned well. **3M Scotch Brite pads** purchased from the home improvement, industrial supply store or automotive body shop are a good choice as they will quickly remove surface tarnish but will not abrade the PCB material. Note that you will want *industrial* pads and not the kitchen cleaning pads impregnated with cleaner/soap. If you have particularly tough deposits on your board, then a fine grade of steel wool is acceptable but be very cautious on boards with tight tolerances as the fine steel shavings can lodge between pads and in holes.

Once you have cleaned the board down to shiny copper you can use a solvent such as acetone to clean any bits of the cleaning pad that may remain and to remove chemical contamination from the surface of the board. Methyl hydrate is another good solvent and a bit less stinky then acetone. Be aware that both these solvents can remove ink, so if your board is silk screened, test the chemicals first before hosing down the entire board.

A few blasts with compressed air will dry out the board and remove any junk that may have built up in the holes.

Step 2: Component Placement

After the component and board have been cleaned, you are ready to place the components onto the board. Unless your circuit is simple and only contains a few components, you will probably not be placing all the components onto the board and soldering them at once. Most likely you will be soldering a few components at a time before turning the board over and placing more. In general it is best to start with the smallest and flattest components (resistors, ICs, signal diodes, etc.) and then work up to the larger components (capacitors, power transistors, transformers) after the small parts are done. This keeps the board relatively flat, making it more stable during soldering. It is also best to save sensitive components (MOSFETs, non-socketed ICs) until the end to lessen the chance of damaging them during assembly of the rest of the circuit.

Bend the leads as necessary and insert the component through the proper holes on the board. To hold the part in place while you are soldering, you may want to bend the leads on the bottom of the board at a 45 degree angle. This works well for parts with long leads such as resistors. Components with short leads such as IC sockets can be held in place with a little masking tape or you can bend the leads down to clamp onto the PC board pads.

In the image below, a resistor is ready to solder and is held in place by slightly bent leads.

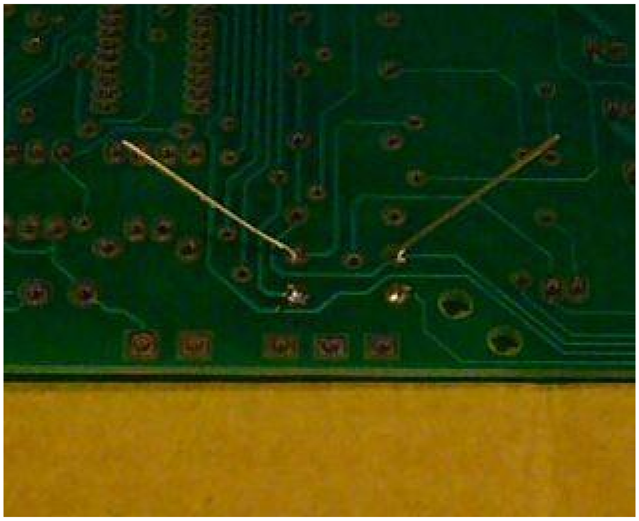

Step 3: Apply Heat

Apply a very small amount of solder to the tip of the iron. This helps conduct the heat to the component and board, but it is **not** the solder that will make up the joint. To heat the joint you will lay the tip of the iron so that it rests against both the *component lead* and the *board*. It is critical that you heat the lead and the board, otherwise the solder will simply pool and refuse to stick to the unheated item. The small amount of solder you applied to the tip before heating the joint will help make contact between the board and the lead. It normally takes a second or two to get the joint hot enough to solder, but larger components and thicker pads/traces will absorb more heat and can increase this time.

If you see the area under the pad starting to bubble, **stop** heating and remove the soldering iron because you are overheating the pad and it is in danger of lifting. Let it cool, then carefully heat it again for much less time.

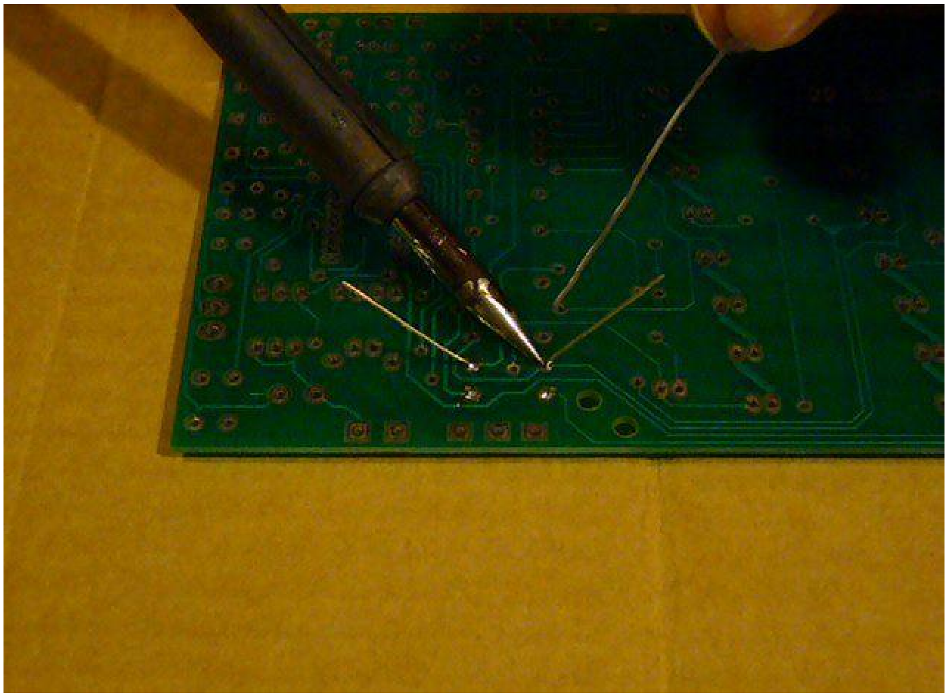

Step 4: Apply Solder to the Joint

Once the component lead and solder pad has heated up, you are ready to apply solder. Touch the tip of the strand of solder to the component lead and solder pad, but **not** the tip of the iron. If everything is hot enough, the solder should flow freely around the lead and pad. You will see the flux melt liquefy as well, bubble around the joint (this is part of its cleaning action), flow out and release smoke. Continue to add solder to the joint until the pad is completely coated and the solder forms a small mound with slightly concave sides. If it starts to ball up, you have used too much solder or the pad on the board is not hot enough.

Once the surface of the pad is completely coated, you can stop adding solder and remove the soldering iron (in that order). Don't move the joint for a few seconds as the solder needs time to cool and solidify. If you do move the joint, you will get what's called a "cold joint". This is recognized by it's characteristic dull and grainy appearance. Many cold joints can be fixed by reheating and applying a small amount of solder, then being allowed to cool without being disturbed.

Step 5: Inspect the Joint and Cleanup

Once the joint is made you should inspect it. Check for cold joints (described a little above and at length below), shorts with adjacent pads or poor flow. If the joint checks out, move on to the next. To trim the lead, use a small set of side cutters and cut at the top of the solder joint.

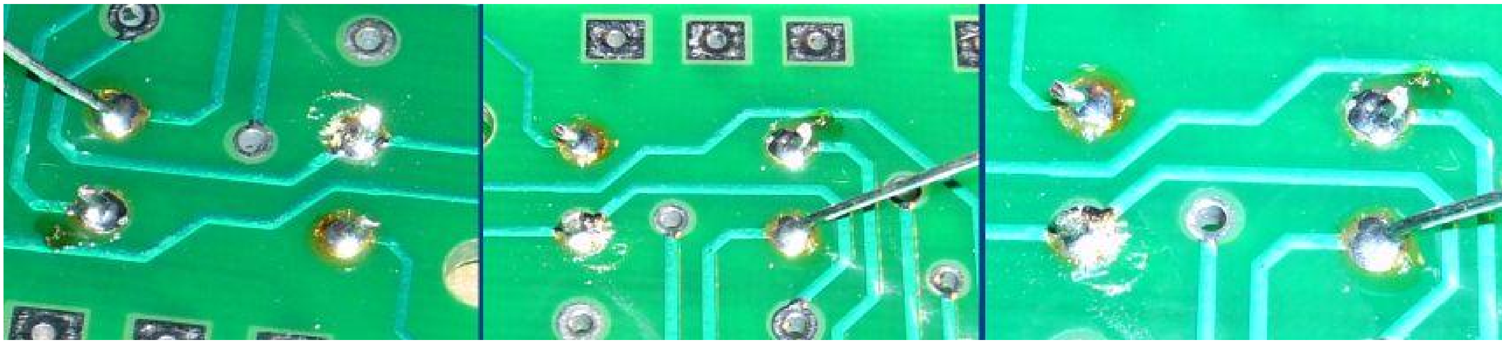

After you have made all the solder joints, it is good practice to clean all the excess flux residue from the board. Some fluxes are hydroscopic (they absorb water) and can slowly absorb enough water to become slightly conductive. This can be a significant issue in a hostile environment such as an automotive application. Most fluxes will clean up easily using methyl hydrate and a rag but some will require a stronger solvent. Use the appropriate solvent to remove the flux, then blow the board dry with compressed air.

Cold Solder Joints

A "cold solder joint" can occur when not enough heat is applied to the component, board, or both. Another common cause is a component moving before the solder has completely cooled and solidified. A cold joint is brittle and prone to physical failure. It is also generally a very high resistance connection which can affect the operation of the circuit or cause it to fail completely.

Cold joints can often be recognized by a characteristic grainy, dull gray color, but this is not always the case. A cold joint can often appear as a ball of solder sitting on the pad and surrounding the component lead. Additionally you may notice cracks in the solder and the joint may even move. Below is the shocking image of every example of a bad solder joint you will ever see. It appears that this **FM transmitter kit** was assembled using the technique of "apply solder to iron then drip onto joint". If your joints are looking like this, then **stop** and practice after rereading this page. Note that not a single of of these joints is acceptable, but amazingly, the circuit worked.

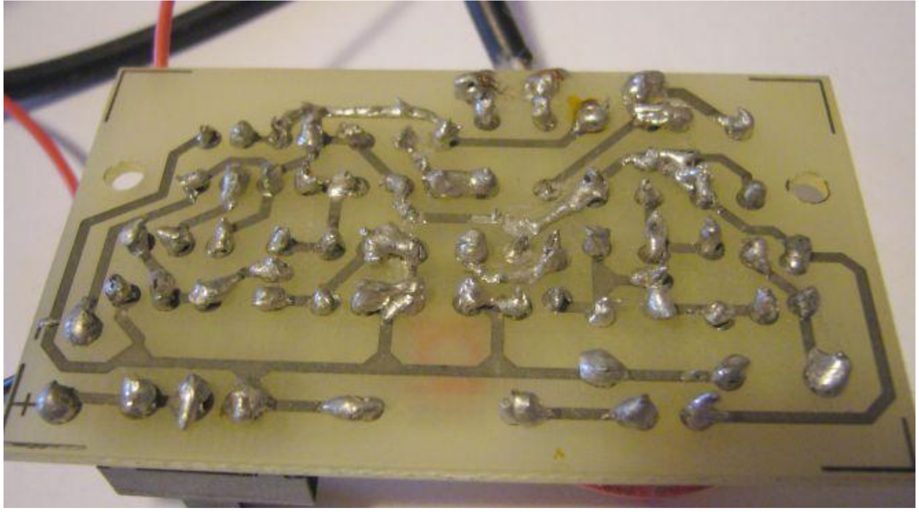

Most cold solder joints can be easily fixed. Generally all that is required is to reheat the joint and apply a little more solder. If there is already too much solder on the joint, then the joint will have to be **desoldered** and then soldered again. This is done by first removing the old solder with a desoldering tool or simply by heating it up and flicking it off with the iron. Once the old solder is off, you can resolder the joint, making sure to heat it thoroughly and keep it still as it cools.

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HOW TO SOLDER - THE QUICK, THOROUGH GUIDE

Technology (/technology/) > Soldering | by IoTalabs (/member/IoTalabs/) Follow

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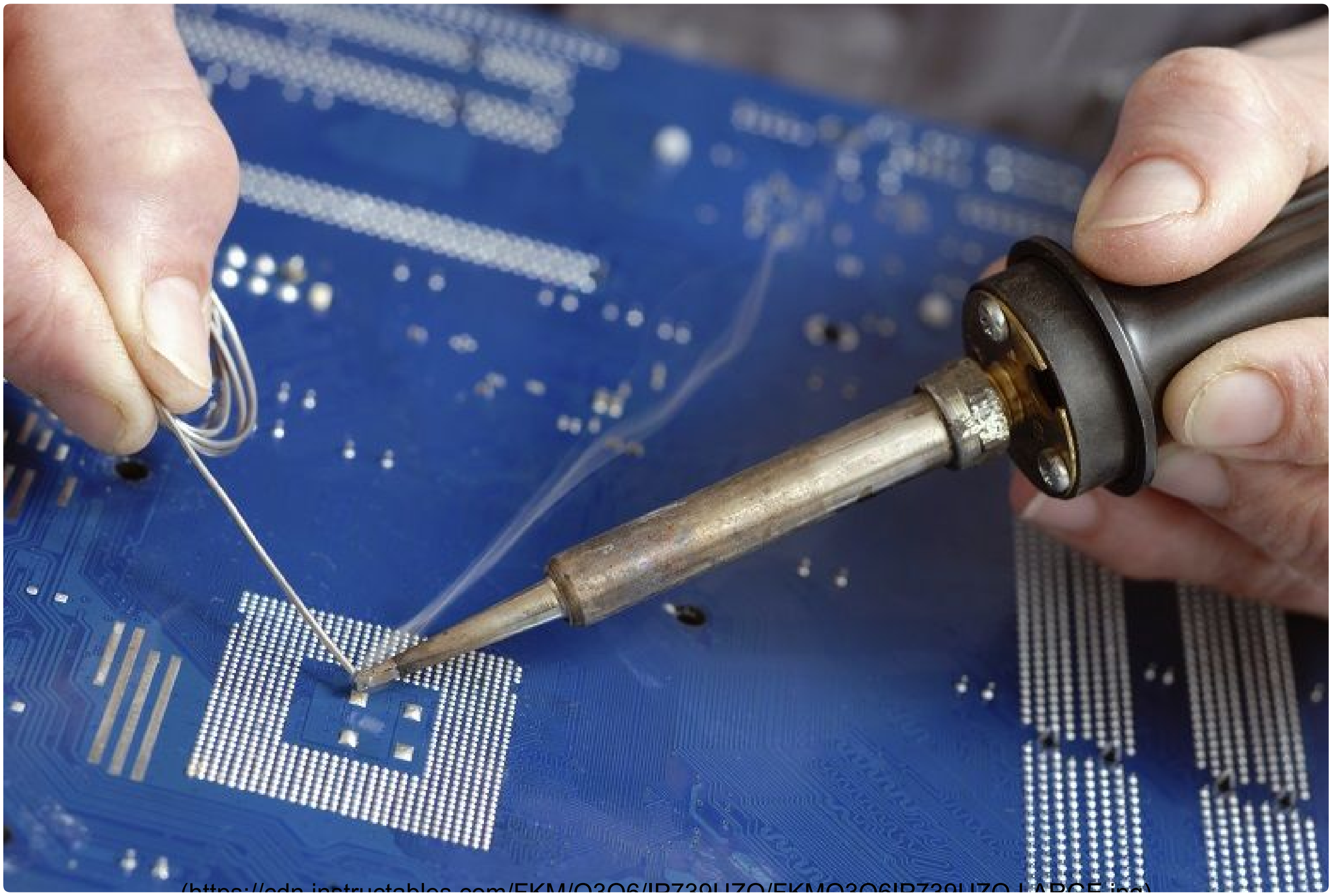

(https://cdn.instructables.com/FKM/O3O6/IP739UZO/FKMO3O6IP739UZO.LARGE.jpg)

We are IoTalabs and we are a group of Internet of Things enthusiasts that love hacking together different devices. Over the past few months we have immersed ourself in the wonderful world of hardware! In our journey, we learned the best soldering practices around.

We've been working on many projects (check out our current project http://doteverything.co/) and we wanted to share our experience on safely and correctly soldering connections!

Add Tip Ask Question

Step 1: What Is Soldering?

Soldering accomplishes a strong bond between two pieces of metal by joining them together. In this procedure, a material called solder, an alloy mixture of tin and lead, flows over two pre-heated pieces of metal and holds them together. The process is similar to welding but differs because when you weld you are fusing and melting two pieces together to make one. When you solder you are essentially ‘gluing’ two parts together with molten metal. Most metals with the exception of aluminum, white metal and porous cast iron can be soldered. Below, you will find instructions and illustrations that show you how to use a soldering iron.

Add Tip Ask Question

Step 2: Materials for Soldering

SOLDERING PASTE FLUX
Ask for ALPHA METALS
RELIABLE
SOLDERING FLUX
ZINC CHLORIDE
SOLDER
ROSIN CORE
UNGAR

(https://cdn.instructables.com/FZC/59XY/IR74OGXI/FZC59XYIR74OGXI.LARGE.jpg)

Soldering Iron

Modeler’s Vise or Frame (optional)

Solder

Damp Sponge

Flux to remove oxides

Add Tip
Ask Question

Step 3: Prepare Your Workspace

Make sure your table or bench top is clear and free of obstructions. You will want as much freedom as possible to move your hand around and make adjustments.

Add Tip Ask Question

Step 4: Turn on the Soldering Iron

The soldering iron needs to be warmed up properly before it can be used to ensure clean application of the solder. Some soldering irons heat up in seconds while others take minutes. Turn it on and leave it in the stand for 2-3 minutes to be safe.

Add Tip Ask Question

Step 5: (Optional) Secure the Items You Are Soldering

Because we only have two hands, it would be nice to stabilize the item we want to solder. This is where a vice or clamp that can hold your item sturdily would come in handy. This is not required, but can greatly increase the ease and quality of your solder joints.

Add Tip Ask Question

Step 6: Cleaning the Soldering Iron

Weller
WESD51
Lockout

(https://cdn.instructables.com/FVM/SZ4M/IR74OGX5/FVMSZ4MIR74OGX5.LARGE.jpg)

Because soldering irons get so hot, they oxidize and become dirty quickly. They key to reliable connections is clean components so make sure that your soldering tip and parts you are joining are clean. To accomplish this, pass the tip of your soldering iron on a wet sponge until it shines.

Add Tip Ask Question

Step 7: Apply Flux

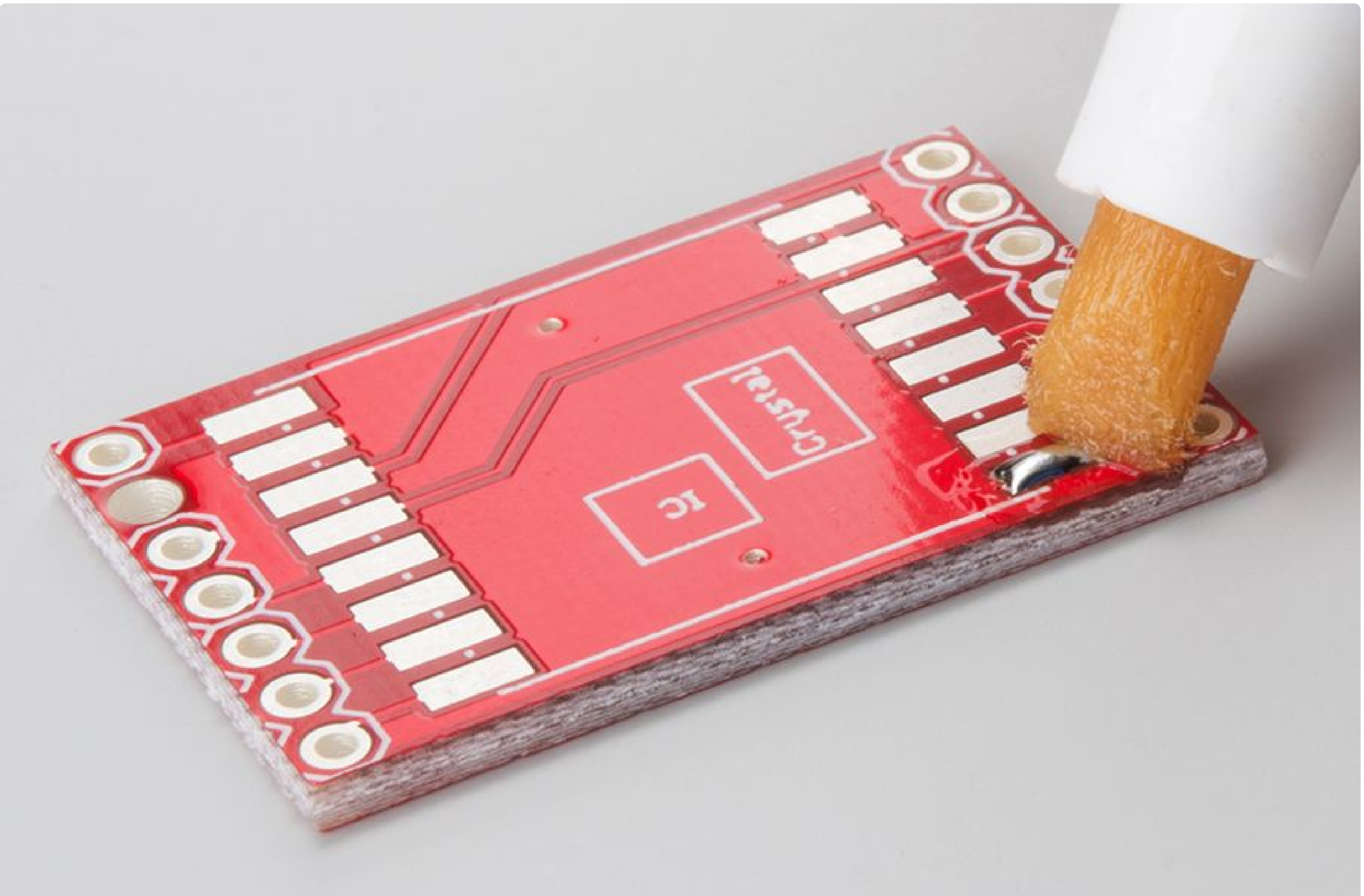

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In soldering it often becomes necessary to use materials called fluxes to help remove oxides and keep them absent while you solder. Flux needs to melt at a temperature lower than solder so that it can do its job prior to the soldering action. There are different methods to apply flux. The method you choose will be dependent on the items you are soldering.

Add Tip Ask Question

Step 8: Tin the Soldering Iron

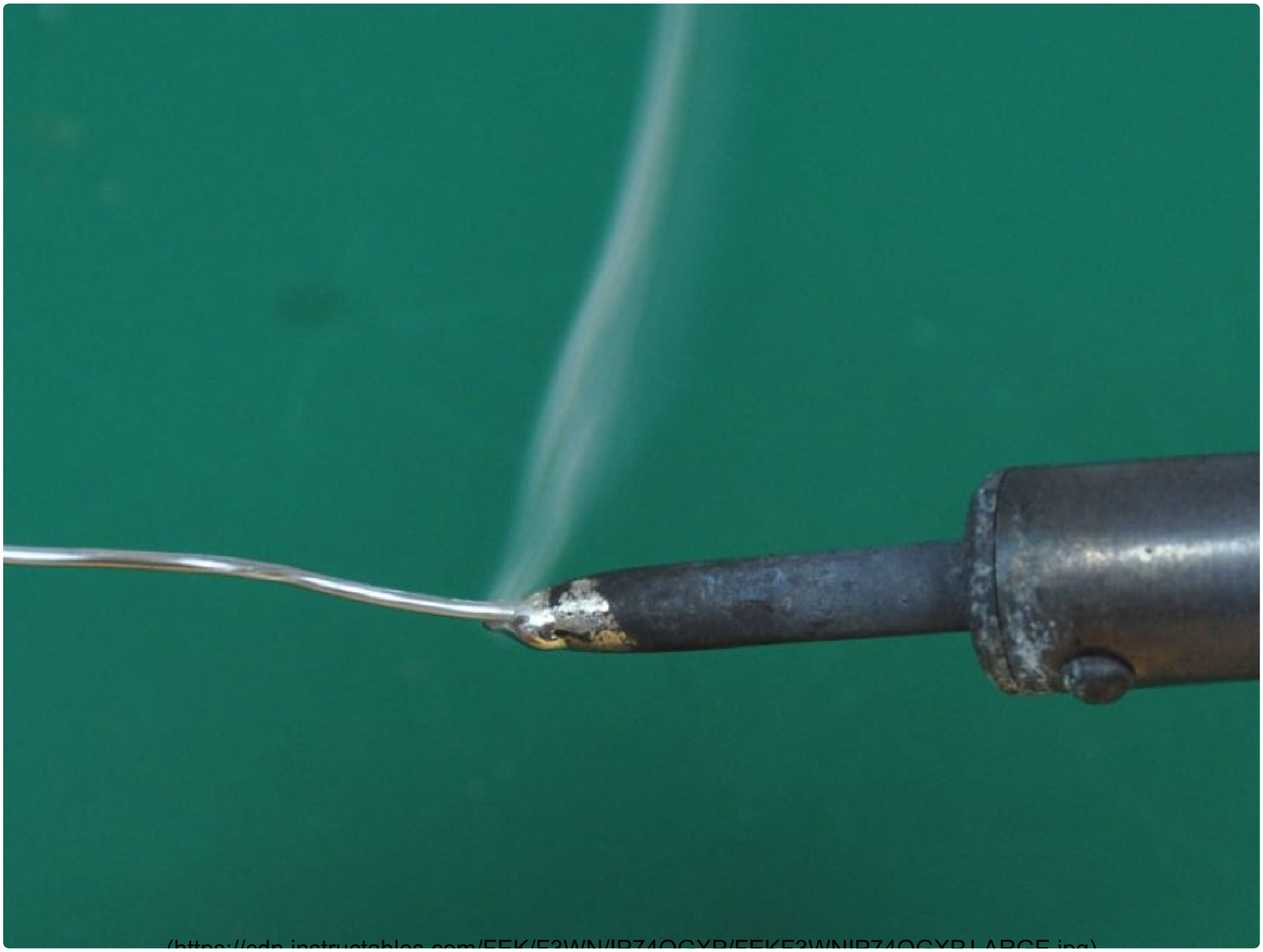

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If you want to know everything there is to know about how to use a soldering iron, you’ll need to know how to tin. Tinning is the process of coating a soldering tip with a thin coat of solder. Melt a thin layer of solder on your iron’s tip. This aids in heat transfer between the tip and the component you are soldering, and also gives the solder a base from which to flow from. This process may need to be repeated as you solder. You will only touch the tip of the soldering iron to the solder when you tin. Do not touch the tip of the iron to the solder while you are actually soldering.

Add Tip Ask Question

Step 9: Start Soldering

Hold the soldering iron like you would a pen in the hand you write with and the solder in the other. Then place the tip of the soldering iron. The tip needs to touch both the wire lead and the surface so they achieve the same temperature.

Add Tip Ask Question

Step 10: Feeding the Solder

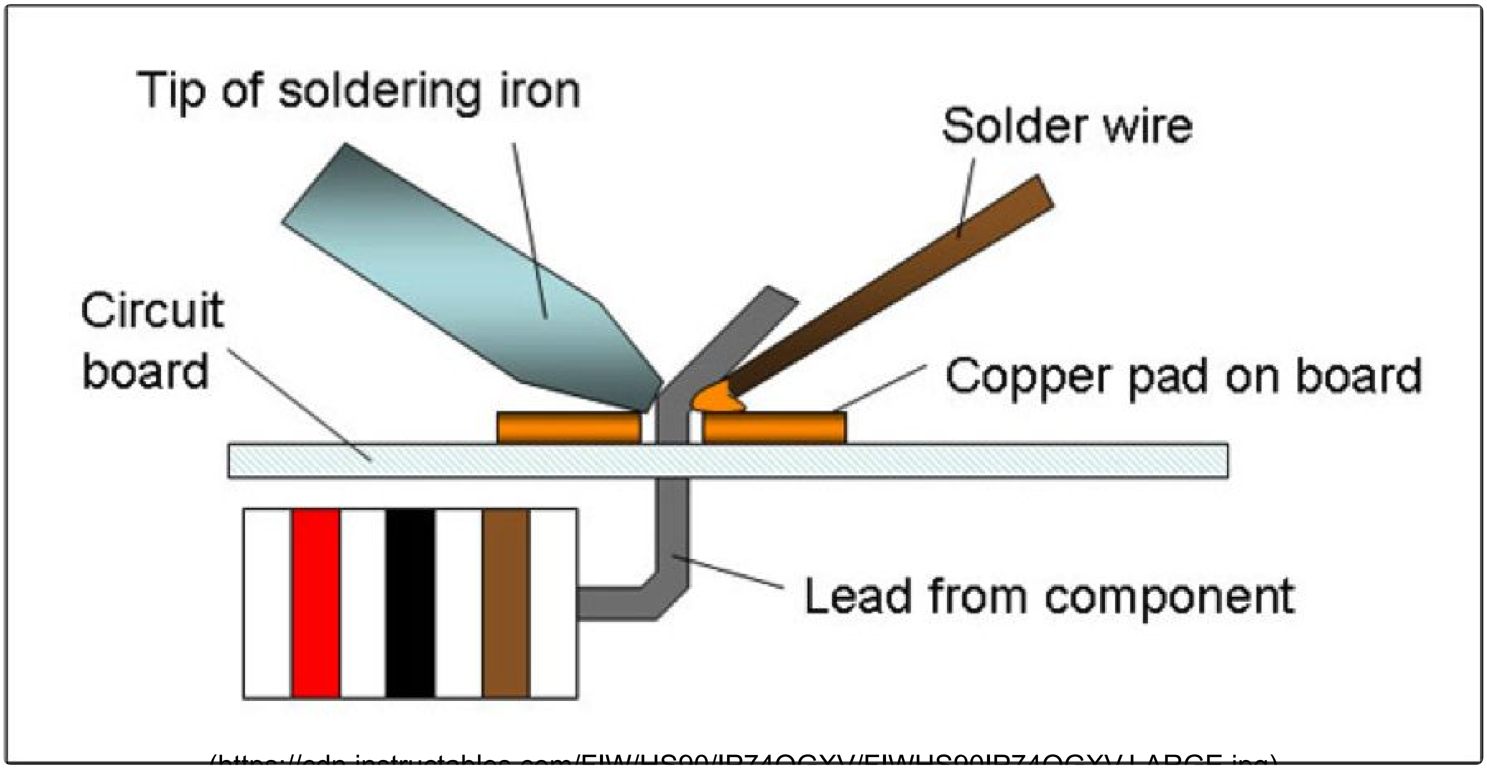
Tip of soldering iron
Solder wire
Circuit board
Copper pad on board
Lead from component

(https://cdn.instructables.com/FIW/HS90/IR74OGXV/FIWHS90IR74OGXV.LARGE.jpg)

Touch the solder to the side of the connection opposite the soldering iron after heating the area for 2-3 seconds. Then, let the solder flow only until the connection is covered.

Add Tip Ask Question

Step 11: Removing the Solder

Remove the solder first, then the iron otherwise your solder will get stuck to your connection point without the appropriate heat. Make sure the joint remains stationary while it cools.

Add Tip Ask Question

Step 12: Check to See If the Connection Is Solid

A smooth, shiny and volcano shaped joint is what you are looking for. If this isn't what you see, you'll need to reheat and feed in more solder.

Add Tip Ask Question

Step 13: Warnings

- DO NOT lay a soldering iron down on any surface. A soldering iron should either be placed on a stand or sealed with a heat resistant cap after every use.
- Soldering should be completed in a well ventilated area.
- Lead is present in most solders. Be sure to wash your hands after your project, or better yet wear gloves.
- Try not to inhale any of the solder smoke that comes off the solder. This is lead and can be dangerous.
- The tip of a soldering iron is very hot. Contact with the tip of a soldering iron would result in a nasty burn.
- Your soldering iron will perform better if kept clean. A damp sponge can be used to clean residue caused by flux material. A very small skim of flux should be applied to the iron after the cleaning.

THE BASICS OF HOW TO SOLDER

Soldering Tutorial for Beginners: Five Easy Steps

Table of Contents:

- Before you begin
- Step 1: Heat your iron to the appropriate temperature
- Step 2: Make your connection mechanically stable
- Step 3: Clean the tip of your iron
- Step 4: Apply heat and solder
- Step 5: Inspect the joint
- Common mistakes

Before you begin

You will need the following equipment:

A temperature-controlled soldering iron of 25W or more
A tip cleaner such as a brass sponge or a wet sponge

Solder (leaded is easier to work with than lead-free)
(Optional) Helping hands
Safety glasses

Note: molten solder is extremely hot! Irons heat up to around twice the boiling point of water, so be extremely careful. Wear safety glasses when soldering.

Step 1: Heat your iron to the appropriate temperature

Weller
WES51
°Fx10

For through-hole components in a circuit board, you will want 600-700 degrees fahrenheit.

If you’re soldering a larger connections, with more copper that’s dissipating heat, then you may want a slightly higher temperature. With a temperature-adjustable iron you can see what works and adjust accordingly.

Step 2: Make your connection mechanically stable

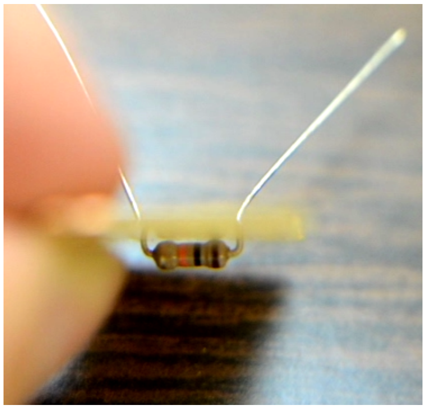

While your iron is heating up, you can work on making your components stay in place without your help. This is where your helping hands may come in handy. Use them to help you arrange your components to be stable without you needing to hold anything. If you’re soldering a through-hole component in a circuit board, you can bend the leads of the component into a V-shape so that it stays in place flush against the board. For components without long leads, you can use a piece of tape to hold them in place.

Step 3: Clean the tip of your iron

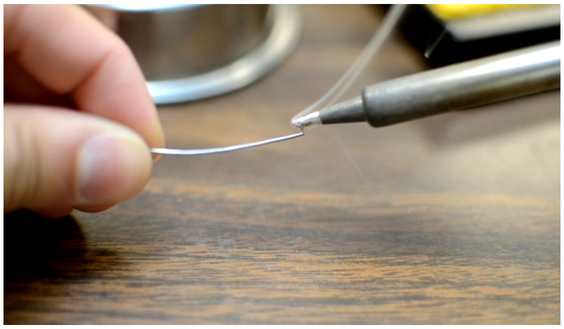

You can check whether your iron is close to its final temperature by touching your solder to the end of the iron and seeing if it melts. When you do this, you'll see some smoke come out. This is not the metal vaporizing, but rather the flux inside of it is burning. Flux is a mild acid that eats away at the oxidation layer that forms on the surface of hot metals. Without flux in the solder to clean your surfaces, you would have a very hard time getting the solder to wet.

Clean your iron using a brass sponge or a wet sponge to remove any oxidation or excess solder from the tip. Remember to always keep your tip clean while you're soldering. A dirty tip is covered in metal oxides that transfer heat badly and can result in poorly soldered joints.

Step 4: Apply heat and solder

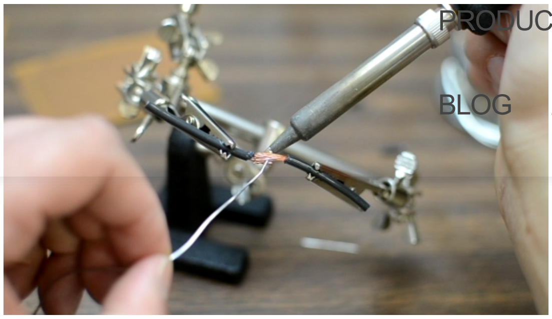

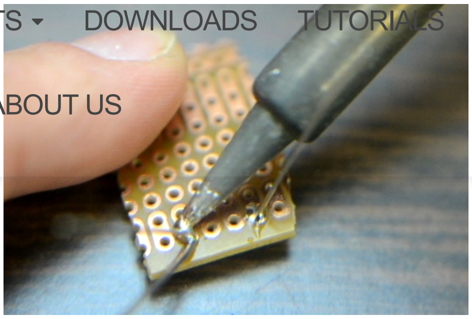

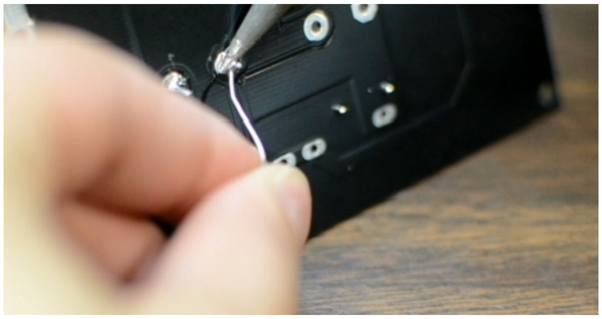

Touch the flat part of your iron's tip to one side of the joint, while feeding solder from the other side of the joint. The idea is to heat up the entire joint to the melting temperature of solder, so when you touch the solder to the surfaces it melts right on. The only way you can ensure a good electrical connection is by letting the solder flow over the components you're joining. Don't apply the solder directly to the tip of the iron. For through-hole components, hold the iron against both the lead and the pad.

Small joints can heat up within a few seconds, but larger joints can take a minute or two. Keep the joint steady for a few seconds after removing the iron, as the solder needs time to cool. Remember that the joint is hot now! don't touch it with your fingers right away.

Step 5: Inspect the joint

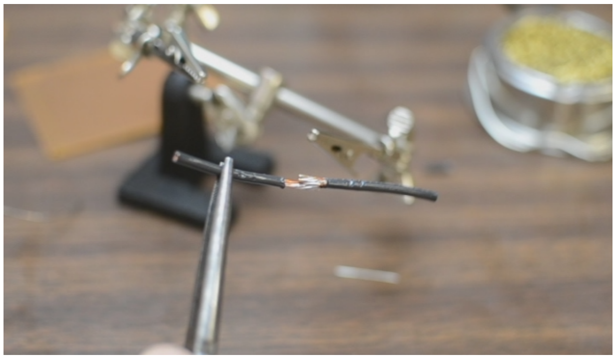
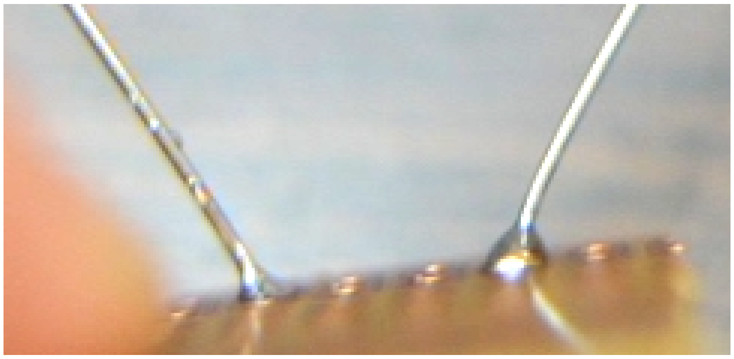
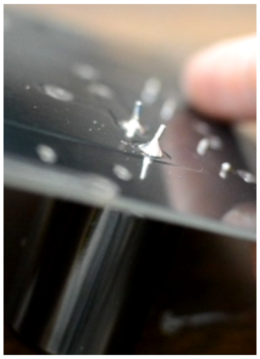

The solder should have wetted to both surfaces. On pads of a printed circuit board, the solder should be covering the entire pad, and it should make a volcano shape between the pad and the lead, indicating good adhesion. Once the joint is perfect, clip the leads of through-hole components.

Common mistakes, or what NOT to do

Now that we’ve gone over what to do, let me tell you what NOT to do.

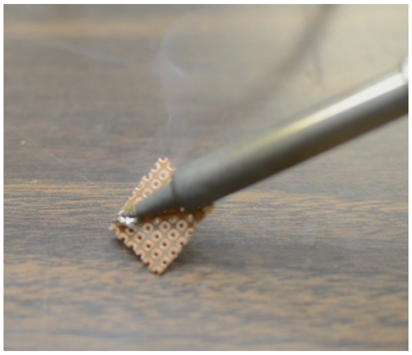

Don’t put a blob of solder on the iron and then try to transfer it to your joint. This burns away all of the flux in the solder, which prevents the flux from cleaning the metal surfaces. Furthermore, it’s easy to transfer the solder blob away from the iron without actually making it wet to the joint. I guarantee you that this will result in an awful electrical connection, so don’t do it.

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Desoldering Tutorial
Tesla Coil FAQ

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Heat Sink Hardware Installation
Main Board's Logic Component Installation
Low Voltage Driver Board Test
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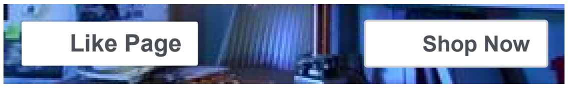
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How To Solder: A Beginner's Guide

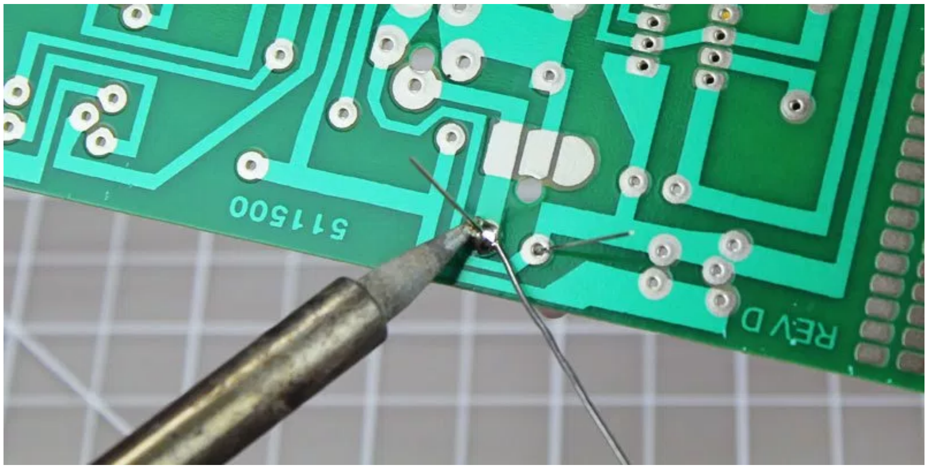

Learning how to solder w/ proper soldering techniques is a fundamental skill every maker should master. In this tutorial, we outline the basics of soldering irons, soldering stations, types of solder, desoldering and safety tips. Whether you're building a robot or working with Arduino, knowing how to solder will come in handy.

FREE EBOOK (PDF) – Learn To Solder Guide (17 pages)

What Is Soldering?

If you were to take apart any electronic device that contains a circuit board, you'll see the components are attached using soldering techniques. Soldering is the process of joining two or more electronic parts together by melting solder around the connection. Solder is a using a desoldering tool as described below.

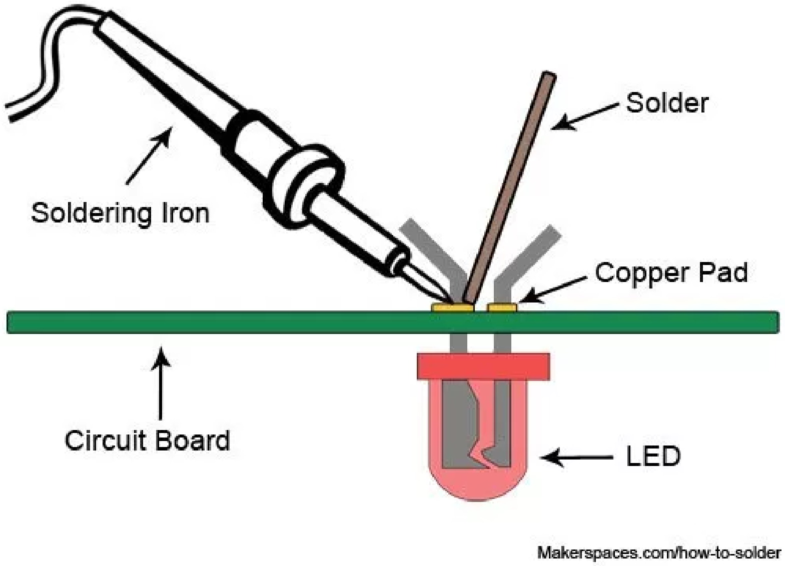
Solder
Soldering Iron
Copper Pad
Circuit Board
LED
Makerspaces.com/how-to-solder

Soldering Tools

The good thing about learning how to solder is the fact that you don't need a lot to get started. Below we'll outline the basic tools and materials you will need for most of your soldering projects.

Soldering Iron

A soldering iron is a hand tool that plugs into a standard 120v AC outlet and heats up in order to melt solder around electrical connections. This is one of the most important tools used in soldering and it can come in a few variations such as pen or gun form. For beginners, it's recommended that you use the pen style soldering iron in type of soldering iron because it can heat up to 896′ F which is extremely hot.

Soldering Station

A soldering station is a more advanced version of the basic standalone soldering pen. If you are going to be doing a lot of soldering, these are great to have as they offer more flexibility and control. The main benefit of a soldering station is the ability to precisely adjust the temperature of the soldering iron which is great for a range of projects. These stations can also create a safer workspace as some include advanced temperature sensors, alert settings and even password protection for safety.

Soldering Iron Tips

At the end of most soldering irons is an interchangeable part known as a soldering tip. There are many variations of this tip and they come in a wide variety of shapes and sizes. Each tip is used for a specific purpose and offers a distinct advantage over another. The most common tips you will use in electronics projects are the conical tip and the chisel tip.

Conical Tip – Used in precision electronics soldering because of the fine tip. Because of its pointed end, it's able to deliver heat to smaller areas without affecting its surroundings.

Chisel Tip – This tip is well-suited to soldering wires or other larger components because of its broad flat tip.

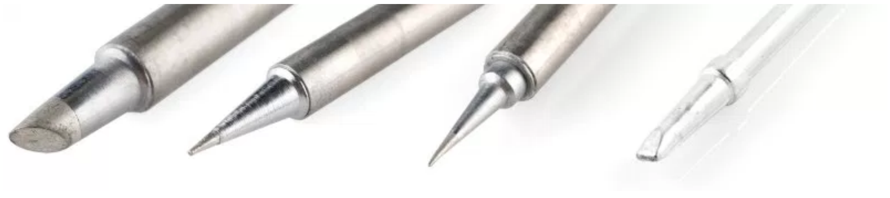

Image Credit – Sparkfun.com

Brass or Conventional Sponge

it did when it was new. You could use a conventional wet sponge but this tends to shorten the lifespan of the tip due to expansion and contraction. Also, a wet sponge will drop the temperature of the tip temporarily when wiped. A better alternative is to use a brass sponge as shown on the left.

Soldering Iron Stand

A soldering iron stand is very basic but very useful and handy to have. This stand helps prevent the hot iron tip from coming in contact with flammable materials or causing accidental injury to your hand. Most soldering stations come with this built in and also include a sponge or brass sponge for cleaning the tip.

Solder

Solder is a metal alloy material that is melted to create a permanent bond between electrical parts. It comes in both lead and lead-free variations with diameters of .032″ and .062″ being the most common. Inside the solder core is a material known as flux which helps improve electrical contact and its mechanical strength.

For electronics soldering, the most commonly used type is lead-free rosin core solder. This type of solder is usually made up of a Tin/Copper alloy. You can also use leaded 60/40 (60% tin, 40% lead) rosin core solder but it’s becoming less popular due to health concerns. If you do use lead solder, make sure you have proper ventilation and that you wash your hands after use.

Net Wt.: 8 oz. (226.7g)
64-009
60/40 ROSIN-CORE SOLDER
LF-99 Lead-Free Solder
99.3% tin 0.7% copper, 4.84g/
5 ft., 0.031" Dia. Rosin Core
WARNING: This product contains or produces a chemical known to the state of

When buying solder, make sure NOT to use acid core solder as this will damage your circuits and components. Acid core solder is sold at home improvement stores and is mainly used for plumbing and metal working.

As mentioned earlier, solder does come in a few different diameters. The thicker diameter solder (.062″) is good for soldering larger joints more quickly but it can make soldering smaller joints difficult. For this reason, it's always a good idea to have both sizes on hand for your different projects.

Helping Hand (Third Hand)

A helping hand is a device that has 2 or more alligator clips and sometimes a magnifying glass/light attached. This clips will assist you by holding the items you are trying to solder while you use the soldering iron and solder. A very helpful tool to have in your makerspace.

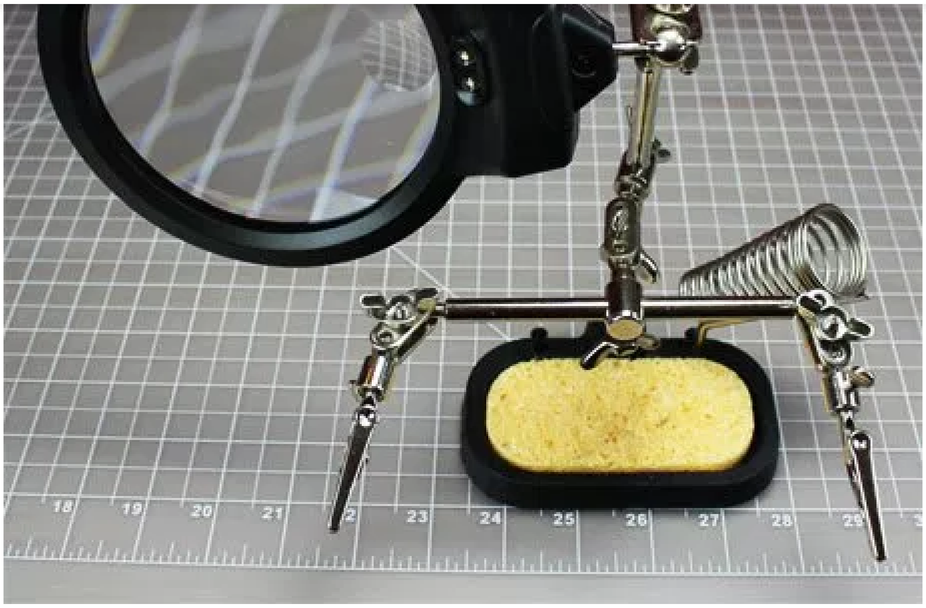

Soldering Safety

Now that you know what tools and materials are required, it’s time to briefly discuss ways of staying safe while soldering.

Soldering irons can reach temperatures of 800′ F so it’s very important to know where your iron is at all times. We always recommend you use a soldering iron stand to help prevent accidental burns or damage.

Make sure you are soldering in a well ventilated area. When solder is heated, there are fumes released that are harmful to your eyes and lungs. It's recommended to use a fume extractor which is a fan with a charcoal filter that absorbs the harmful solder smoke.

It's always a good idea to wear protective eye wear in case of accidental splashes of hot solder. Lastly, make sure to wash your hands when done soldering especially if using lead solder.

Tinning The Tip

Before you can start soldering, you need to prep your soldering iron by tinning the tip with solder. This process will help improve the heat transfer from the iron to the item you're soldering. Tinning will also help to protect the tip and reduce wear.

Step 1: Begin by making sure the tip is attached to the iron and screwed tightly in place.

Step 3: Wipe the tip of the soldering iron on a damp wet sponge to clean it. Wait a few seconds to let the tip heat up again before proceeding to step 4.

Step 4: Hold the soldering iron in one hand and solder in the other. Touch the solder to the tip of the iron and make sure the solder flows evenly around the tip.

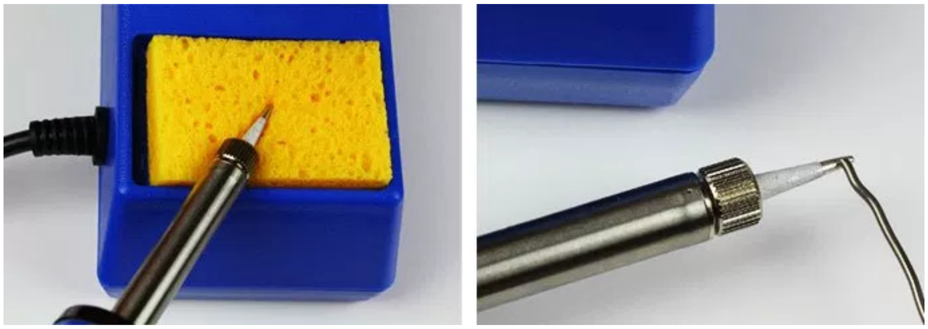

You should tin the tip of your iron before and after each soldering session to extend its life. Eventually, every tip will wear out and will need replacing when it becomes rough or pitted.

How To Solder

To better explain how to solder, we’re going to demonstrate it with a real world application. In this example, we’re going to solder an LED to a circuit board.

Step 1: **Mount The Component** – Begin by inserting the leads of the LED into the holes of the circuit board. Flip the board over and bend the leads outward at a 45′ angle. This will help the component make a better connection with the copper pad and prevent it from falling out while soldering.

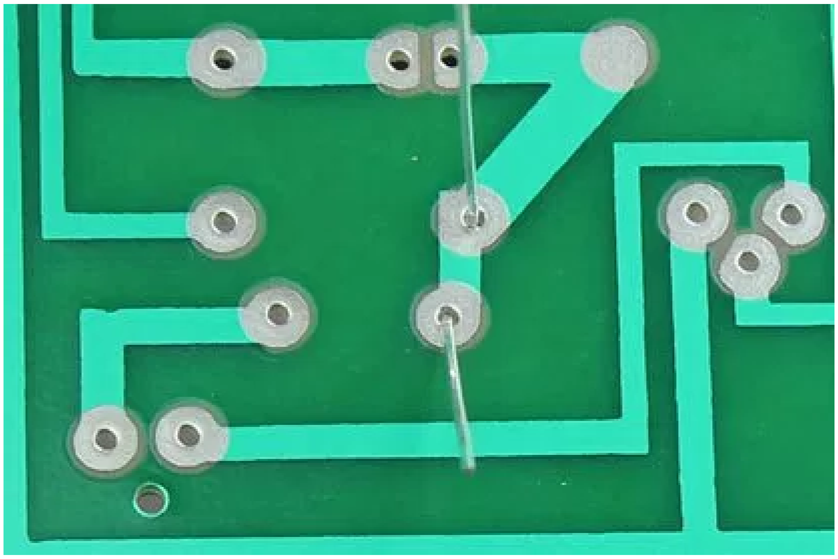

resistor lead at the same time. You need to hold the soldering iron in place for 3-4 seconds in order to heat the pad and the lead.

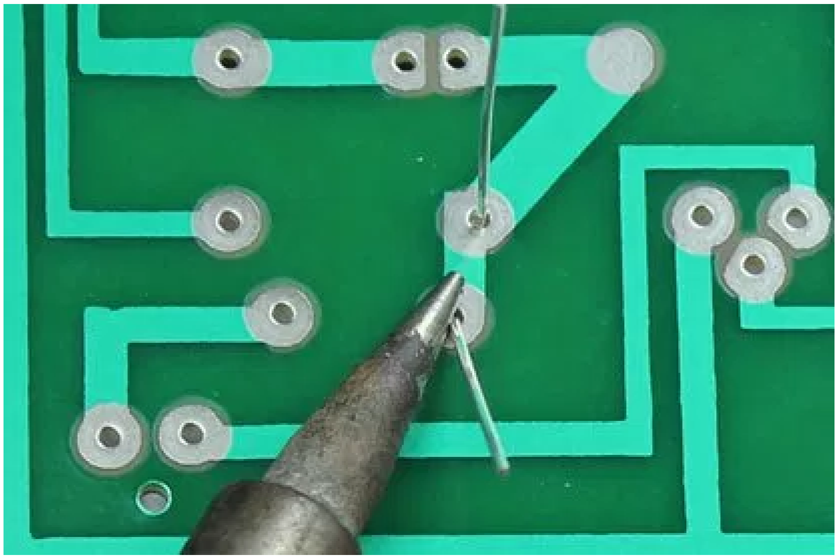

Step 3: **Apply Solder To Joint** – Continue holding the soldering iron on the copper pad and the lead and touch your solder to the joint. **IMPORTANT** – Don't touch the solder directly to the tip of the iron. You want the joint to be hot enough to melt the solder when it's touched. If the joint is too cold, it will form a bad connection.

Step 4: **Snip The Leads** – Remove the soldering iron and let the solder cool down naturally. Don't blow on the solder as this will cause a bad joint. Once cool, you can snip the extra wire from leads.

A proper solder joint is smooth, shiny and looks like a volcano or cone shape. You want just enough solder to cover the entire joint but not too much so it becomes a ball or spills to a nearby lead or joint.

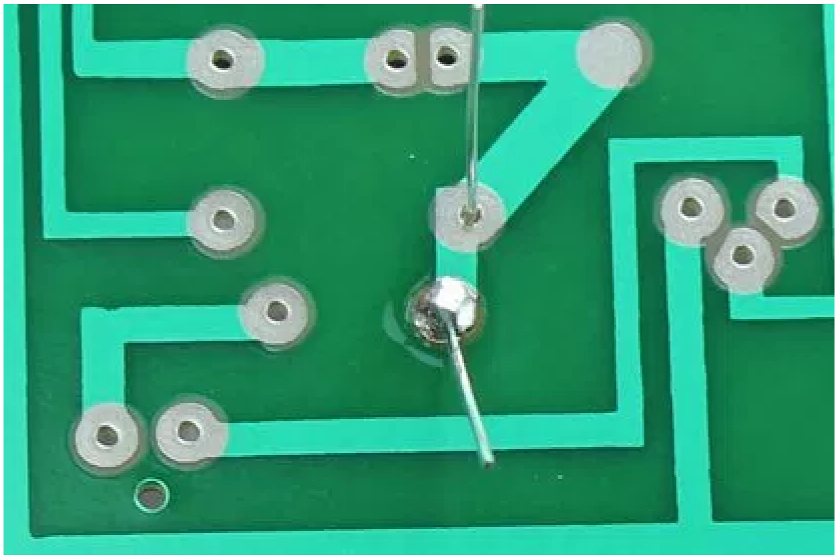

How To Solder Wires

Begin by removing the insulation from the ends of both wires you are soldering together. If the wire is stranded, twist the strands together with your fingers.

Make sure your soldering iron is fully heated and touch the tip to the end of one of the wires. Hold it on the wire for 3-4 seconds.

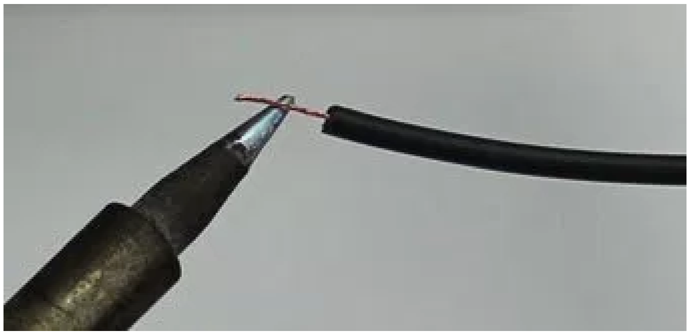

Keep the iron in place and touch the solder to the wire until it’s fully coated. Repeat this process on the other wire.

Hold the two tinned wires on top of each other and touch the soldering iron to both wires. This process should melt the solder and coat both wires evenly.

Remove the soldering iron and wait a few seconds to let the soldered connection cool and harden. Use heat shrink to cover the connection.

Desoldering

The good thing about using solder is the fact that it can be removed easily in a technique known as desoldering.

To desolder a joint, you will need solder wick which is also known as desoldering braid.

Desoldering Braid
Custom Manufactured in China for General Wireless Operations Inc. dba RadioShack, Fort Worth, TX 76102
RadioShack
RoHS
6402090
06F16
SPX13

Step 1 – Place a piece of the desoldering braid on top of the joint/solder you want removed.

Step 2 – Heat your soldering iron and touch the tip to the top of the braid. This will heat the solder below which will then be absorbed into the desoldering braid. You can now remove the braid to see the solder has been extracted and removed. Be careful touching the braid when you are heating it because it will get hot.

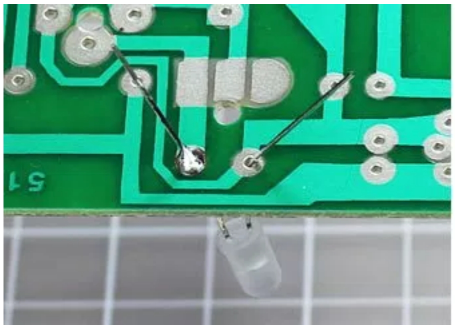

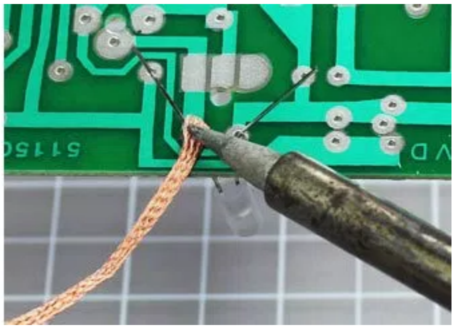

solder with a press of a button.

To use, press the plunger down at the end of the solder sucker. Heat the joint with your soldering iron and place the tip of the solder sucker over the hot solder. Press the release button to suck up the liquid solder. In order to empty the solder sucker, press down on the plunger.

Soldering & Electronics

- Digikey
- Sparkfun
- Adafruit
- Jameco
- Velleman
- Mouser

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adafruit learning system

Adafruit Guide To Excellent Soldering

Created by Bill Earl

Last updated on 2014-06-28 08:30:54 PM EDT

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Tools

Building a Soldering Toolkit

If you are just getting started in Electronics, Ladyada's Electronics Toolkit (http://adafru.it/136) (pictured above) is a great kit full of quality tools - including everything you need to make great solder joints. If you would rather build your toolkit piece-by-piece, read on:

Choosing a Soldering Iron

There are many types of soldering irons. For most Adafruit kits and projects, you will want a pencil-style soldering iron with 25 watts or more.

An under-powered iron is a poor investment. It will end up costing you more in ruined kits and damaged components.

- It will take longer to heat the joint, allowing heat to spread to the component being soldered - potentially overheating and damaging the component.
- Longer heating times will also give more time for oxides to form on the surfaces being soldered. This will prevent the solder from flowing and result in a poor joint.
- Longer recovery times between joints can result in frustration, 'cold joints' or both.

You don't need to spend a fortune to get a good iron. Advanced features such as temperature control and interchangeable tips are nice to have, but not essential for hobbiest-level work.

Basic Irons

There are many basic pencil style irons that are suitable for hobbiest use. But you will need one that is capable of heating the joints quickly enough. Choose an iron with 25 watts at a minimum.

Better Irons

An adjustable temperature iron with a little more power will give you a bit more control and allow you to work faster. The Adjustable 30W 110v Soldering Iron (http://adafru.it/180) in the store is an excellent choice.

This iron is also available as part of Ladyada's Electronics Toolkit (http://adafru.it/136), which contains many other essential soldering tools.

Best Irons

A professional-style temperature-controlled iron with interchangeable tips and 50 watts or more of power is a joy to work with. Feedback control keeps the tip temperature at precisely the level you set. The extra watts speed recovery time so that you can work faster. Interchangeable tips let you select the ideal tip shape for specialized work.

The 65 watt Hakko FX-888 (http://adafru.it/303) is an excellent professional quality soldering iron. The Weller WES51 or WESD51 are also excellent choices for serious electronics work.

Irons to avoid

In addition to underpowered irons, there are several types of irons to avoid for general circuit-board work.

For emergencies only:

These irons are handy for occasions when you have no place to plug in a regular soldering iron. But they are not the best choice for a primary soldering tool:

- **Butane Powered Irons** have plenty of power but are difficult to control.
- **Battery Powered Irons** are generally underpowered for most work.

Not for circuit board use:

These tools are not suitable for circuit board work:

- **Torches** of any kind are not suitable for electronics work and will damage your circuit boards.
- **Soldering Guns** are OK for working with heavy gauge wires, but don't have the precision necessary for soldering delicate electronics components.
- ***Cold-Heat™*** Irons inject current into the joint to heat the tip. This current can be damaging to sensitive electonic components. Avoid these irons for electronics work.

Essential Tools and Supplies:

These tools are the bare-minimum essentials required for soldering:

Stand

If your soldering iron does not have a built-in stand, you will need a safe place to rest the hot iron between uses. A Soldering Iron Stand (http://adafru.it/150) will keep your iron from rolling around and protect both you and your work surface from burns.

Most stand holders come with a sponge and tray for cleaning your soldering iron.

ROSIN CORE
GUARANTEED VIRGIN METALS
GUARANTEED ALLOY
60/40
4 OZ.
.031 DIA

Solder

Standard 60/40 lead/tin Rosin Core Solder (http://adafru.it/145) is the easiest type to work with.

170M Xcelite® U.S.A.

Diagonal Cutters

You will also need a pair of Diagonal Cutters (http://adafru.it/152) for trimming component leads after soldering.

Other Handy Tools and Supplies

These are some other tools and supplies you might find useful when working on soldering projects.

Vise

A vise holds your work steady as you solder. This is important for both safety and sound joints. The Panavise Jr (http://adafru.it/151) is an ideal size for most Adafruit kits and projects.

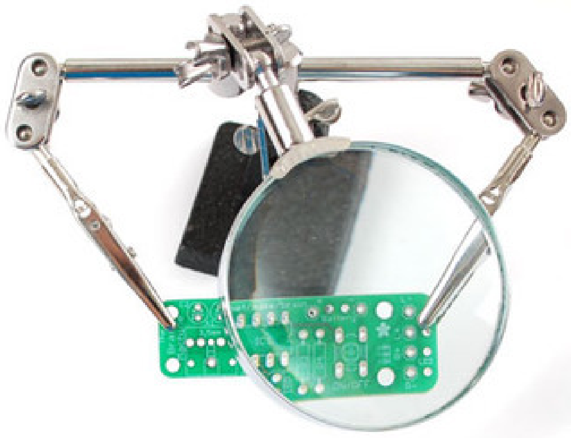

Third Hand

A Helping Third Hand (http://adafru.it/291) Tool is a good for smaller boards, or to hold things in place while terminating or splicing wires.

Solder Sucker

A Solder Sucker (http://adafru.it/148) is a very helpful tools for removing excess solder or when you need to de-solder a joint. As the name implies, this device literally sucks the solder out of the joint.

ROHS
35+YEARS SPIRIG PATENTED VACUUMISATION WICK MANUFACTURE
no clean
size AB (3)
1.5 m / 5 ft
DESOLDERING BRAID
3S-WICK®
part: LS/AB-1.5 m
TRESSE à DESSOUDER
LOTSAUGLITZE®
antistatic
swiss

Solder Wick

Solder Wick (http://adafru.it/149) is another way to clean excess solder from a joint. Unlike the solder sucker, the wick soaks up the molten solder.

Preparation

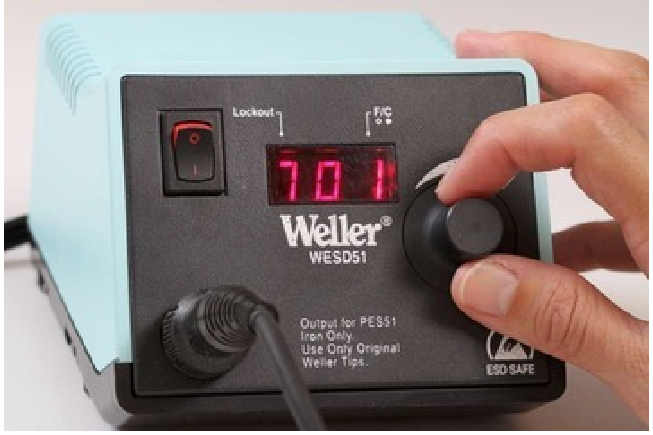
Lockout
F/C
701
Weller®
WESD51
Output for PES51
Iron Only.
Use Only Original
Weller Tips.
ESD SAFE

Heat the Iron

Plug an and/or turn on your soldering iron to warm up. If you are using a temperature controlled iron, set it to 700F/370C for 60/40 or 750F/400C for lead-free solder.

While the iron is heating dampen the sponge with a little bit of water.

Clean the Iron

Wipe the tip of the hot iron on the damp sponge to clean off any oxidation.

Do not use files or abrasives to clean the tip. It will damage the plating and ruin the tip.

Tin the Tip

Apply a small amount of solder to the tip and wipe again to tin the tip. You should have a thin, shiny layer of molten solder on the tip of your iron.

If the tip is badly oxidized and difficult to tin, it can usually be reconditioned with some tip-tinning paste.

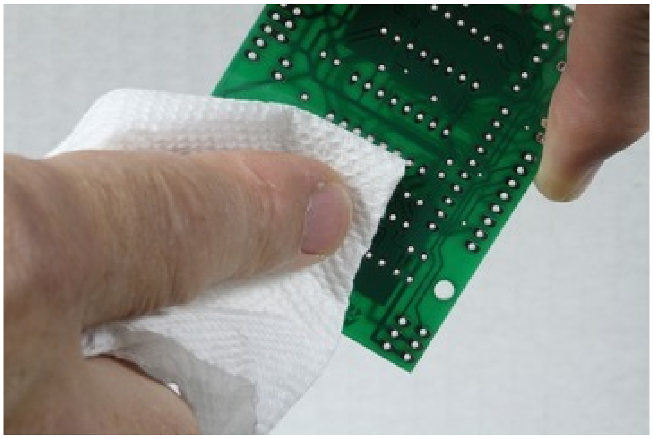

Make sure that the joint is clean

Dirt, oxidation and oily fingerprints can prevent the solder from wetting the solder-pad to create a solid joint. All Adafruit boards are plated to prevent oxidation, but if your board appears dirty from storage or handling, wipe it down with a little isopropyl alcohol.

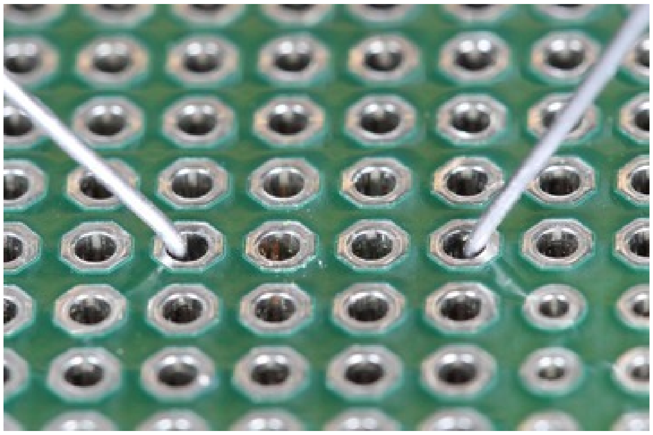

Immobilize the Joint

This is very important! The parts being joined must not move during the soldering process. If there is any movement as the molten solder is solidifying, you will end up with an unreliable 'cold joint'.

Most through-hole components can be immobilized by simply bending the leads on the solder-side of the hole.

Steady the Board

A vise is a good way to keep the board from moving around while you try to solder it.

Once the joint is clean and immobilized, you are ready to apply the solder.

Making a good solder joint

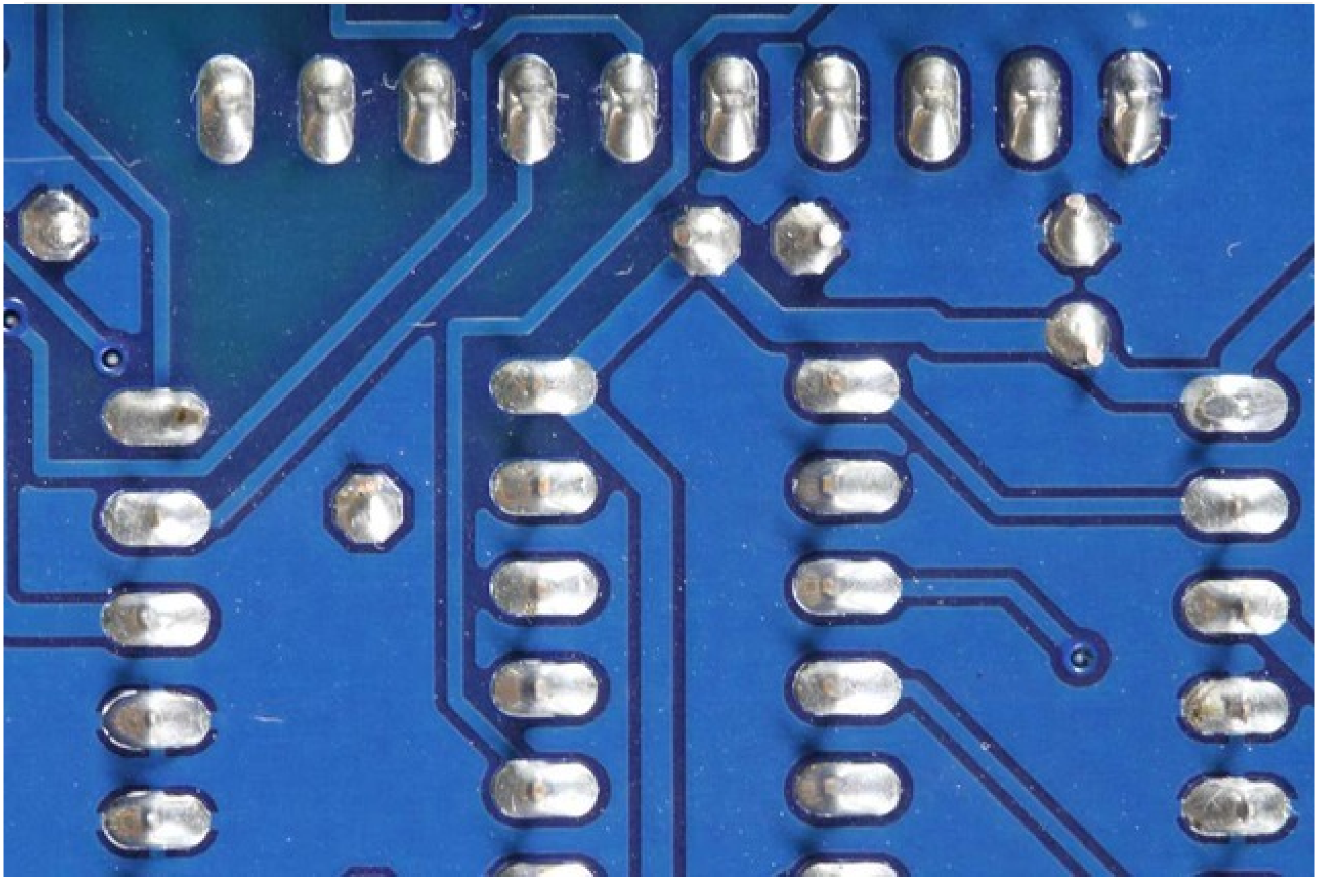

Once you have prepared the your tools and the joint to be soldered, making a good solder joint requires just a few simple steps.

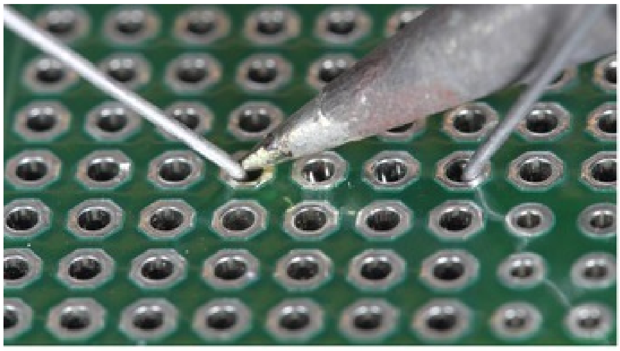

Heat the joint

Heat the joint with the tip of the iron. Be sure to heat both the solder pad and the component lead or pin. A small drop of solder on the tip will help to transfer the heat to the joint quickly.

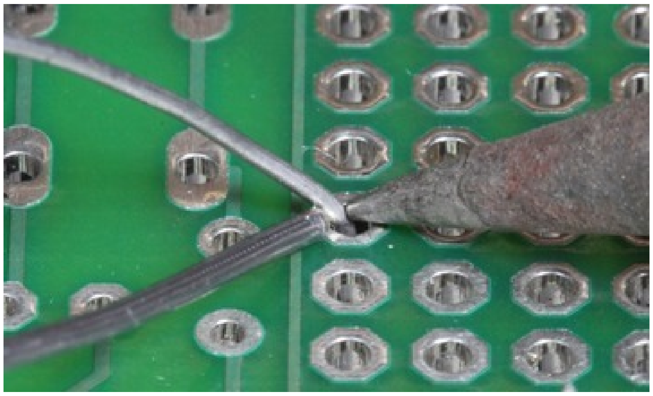

Apply the solder

Touch the end of the solder to the joint so that it contacts both the solder pad and the component lead or pin. It should melt and flow smoothly onto both the pin and the pad.   If the solder does not flow, heat the joint for another second or two and try again.

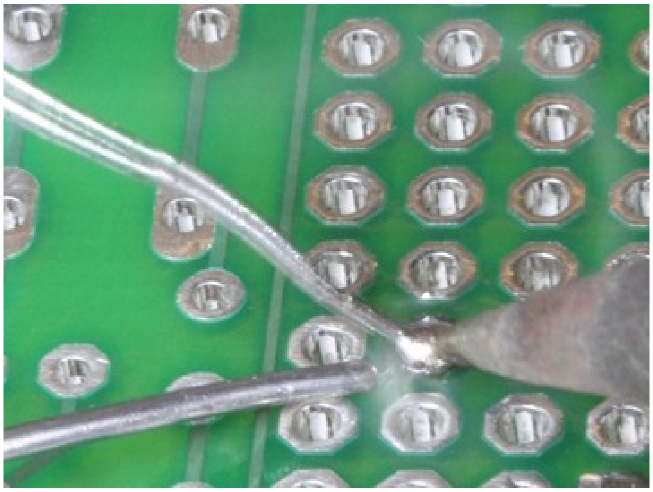

Let It Flow

Keep heating the solder and allow it to flow into the joint. It should fill the hole and flow smoothly onto both the solder pad and the pin or component lead.

Let It Cool

Once enough solder has been added to the joint and it has flowed well onto both the component lead and the solder pad, remove the iron from the joint and allow it to cool undisturbed.

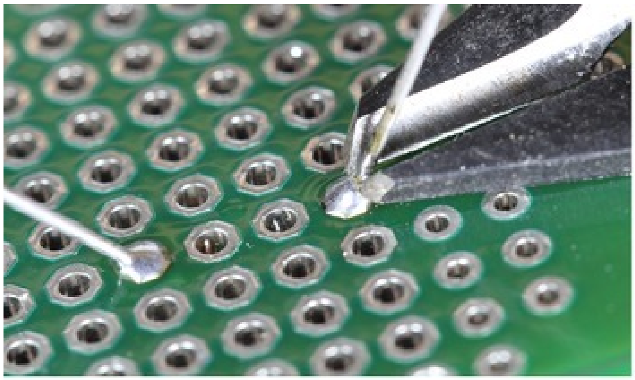

Trim the Lead

Use your diagonal cutters to trim the lead close to the board.

Note: This step applies only to components with wire leads. It is not necessary to trim the pins on Integrated circuit chips or sockets.

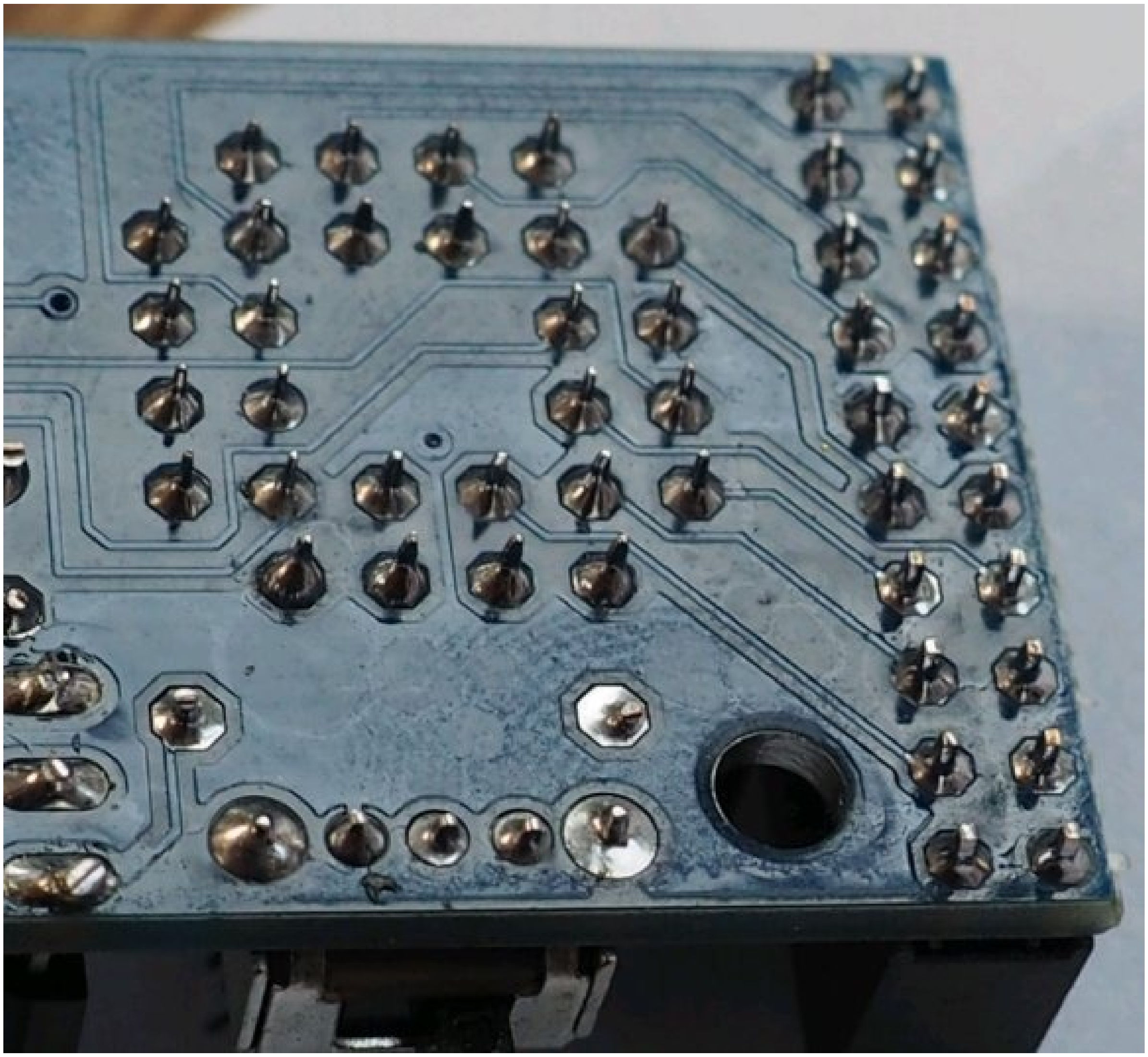

Congratulations!

Reward yourself with a Soldering Badge (http://adafru.it/465).

Problems?

The last page of this guide illustrates a number of common soldering problems with advice on prevention and repair.

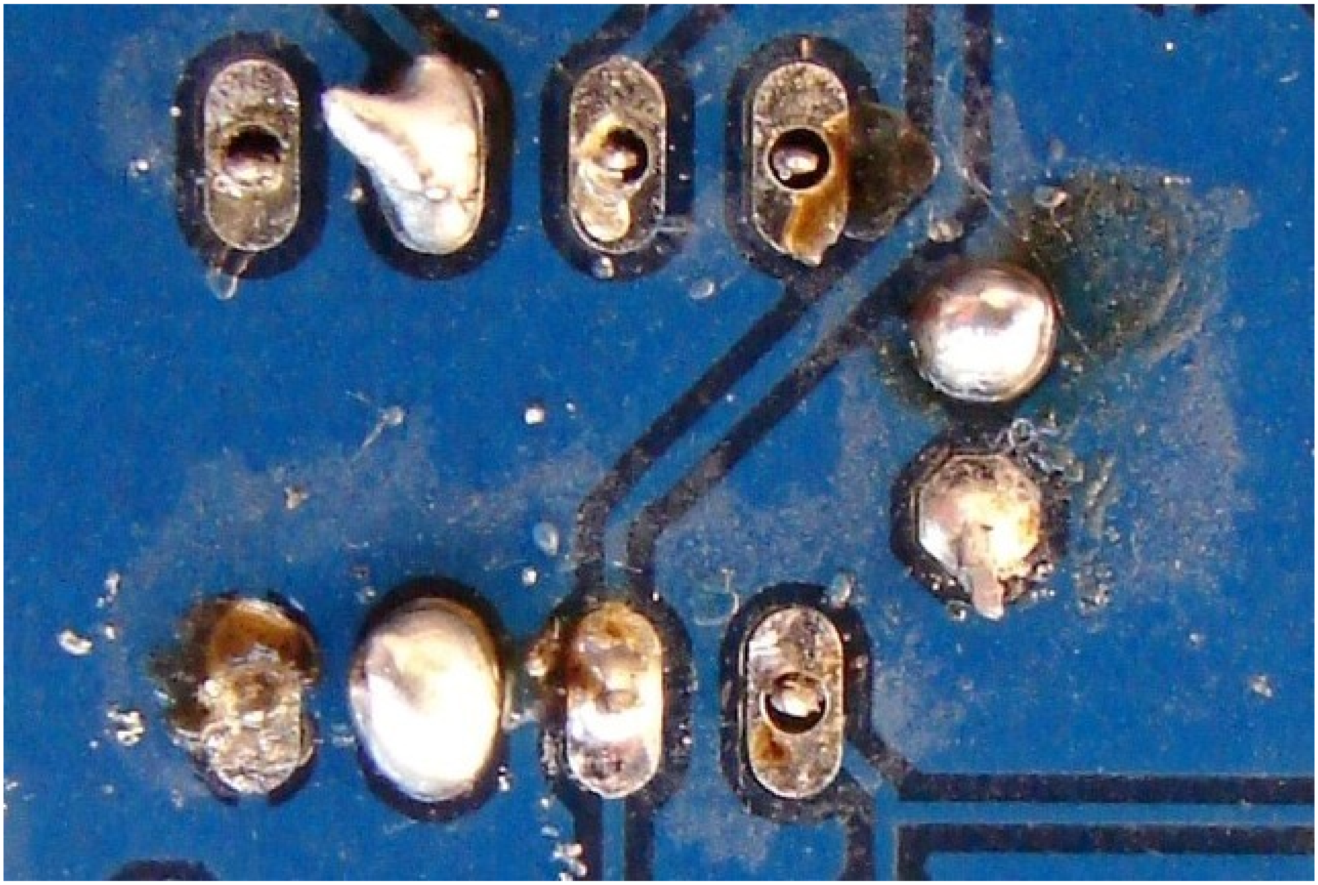

Surface Mount Components

The previous page showed how to make a good through-hole joint. But more and more components are only available in surface mount form these days. Not all surface mount packages are easily worked by hand, but there are plenty that can be managed with the same basic tools used for through-hole soldering.

Let's start with a surface-mount part common to several Adafruit kits: The SD Card Holder:

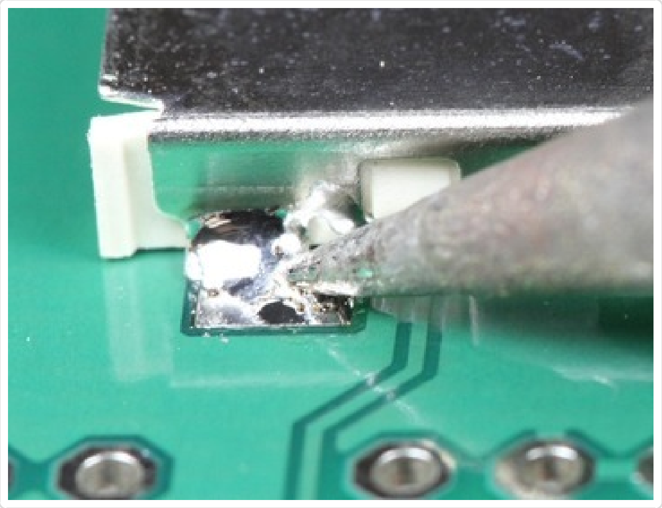

Immobilize the Joint

Unlike many surface mount components, immobilizing the SD card holder is relatively easy. There are small pegs on the back that fit into positioning holes in the board. Once it is in place, solder the four small corner tabs to make it permanent.

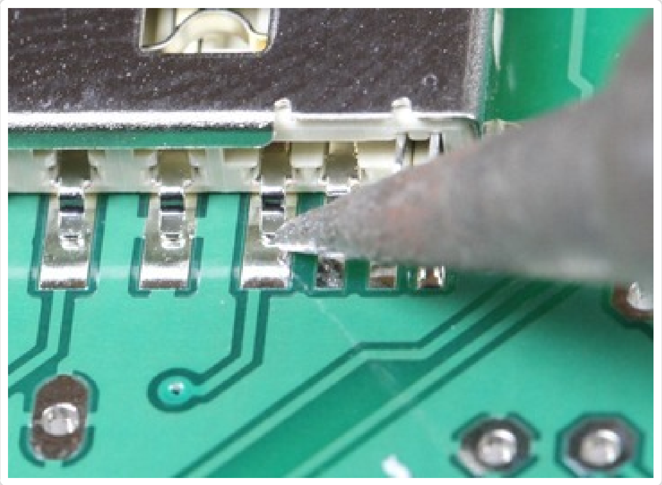

Heat the Joint

Start by putting the tip of the hot iron on the solder pad adjacent to the pin. The pad will take longer to heat, so we apply most of the heat to the pad to start.

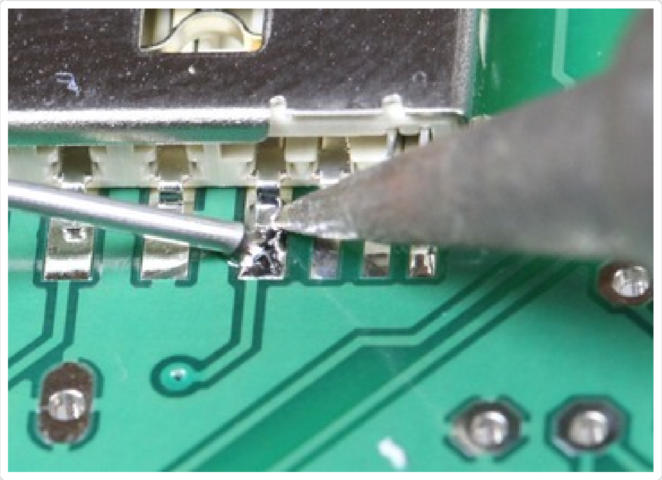

Apply the Solder

When the joint is hot, apply solder to the side opposite the iron. The solder should melt and start to flow into the joint.

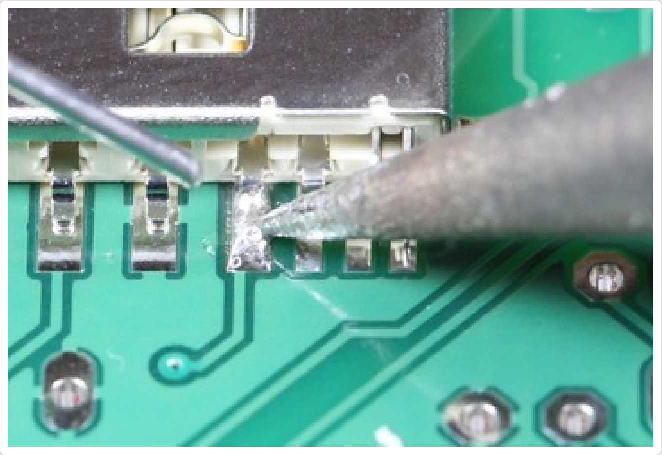

Let it Flow

Apply just enough solder to ensure a good joint, then keep the heat on while the solder wicks up between the pin and the pad to make a good electrical bond.

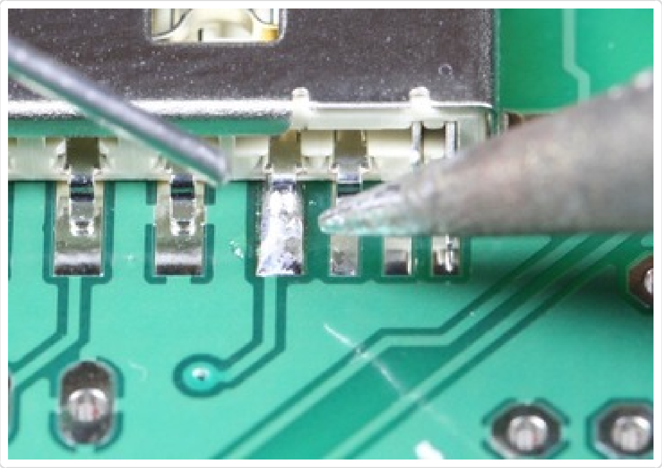

Let it Cool

Remove the iron and allow the joint to cool undisturbed.

Problems?

The last page of this guide illustrates a number of common soldering problems with advice on prevention and repair.

Common Soldering Problems

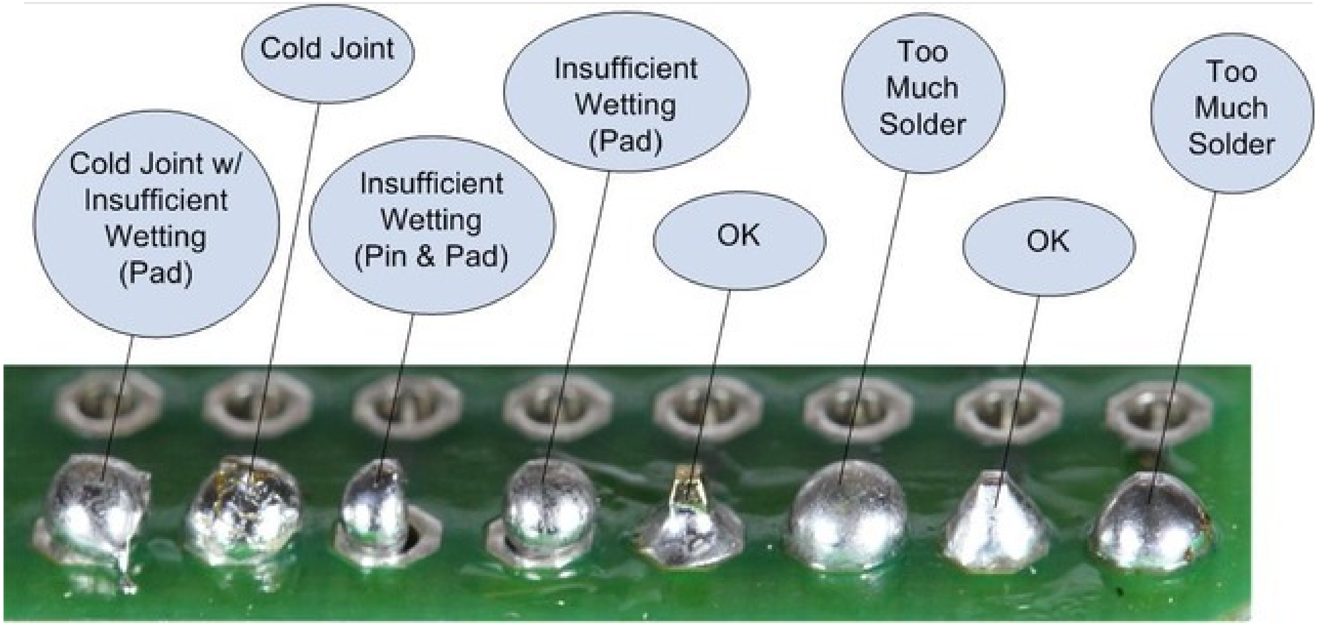
Cold Joint w/ Insufficient Wetting (Pad)
Cold Joint
Insufficient Wetting (Pin & Pad)
Insufficient Wetting (Pad)
OK
Too Much Solder
OK
Too Much Solder

The Ideal Solder Joint

The ideal solder joint for through-hole components should resemble the diagram below.

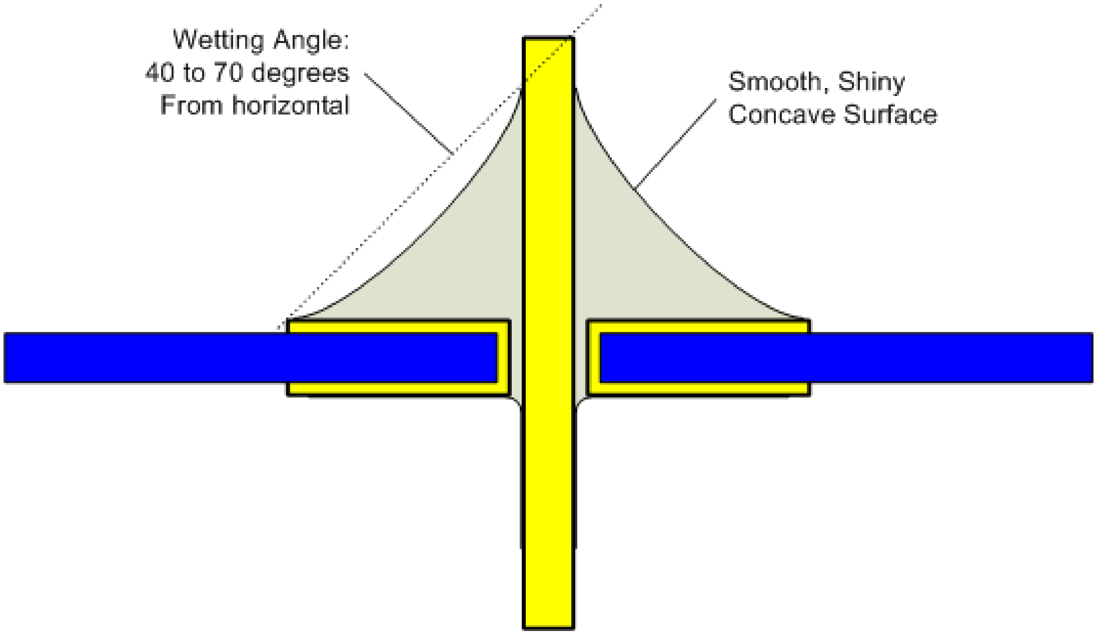
Wetting Angle: 40 to 70 degrees From horizontal
Smooth, Shiny Concave Surface

The photos that follow show some common soldering problems, with suggestions for repair and prevention:

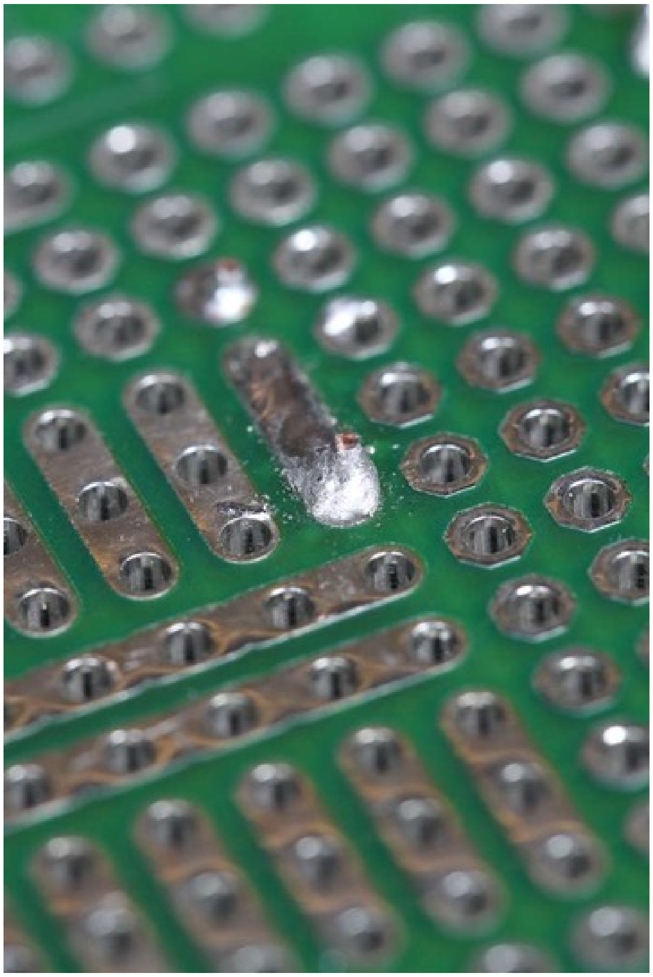

Disturbed Joint

A Disturbed joint is one that has been subjected to movement as the solder was solidifying. The surface of the joint may appear frosted, crystalline or rough.

Often called a 'Cold Joint'. They can look similar to a true cold joint, but the cause is different.

Repair: This joint can be repaired by reheating and allowing it to cool undisturbed.

Prevention: Proper preparation, including immobilizing the joint and stabilizing the work in a vise can prevent disturbed joints.

Cold Joint

A 'Cold Joint' is one where the solder did not melt completely. It is often characterized by a rough or lumpy surface. Cold joints are unreliable. The solder bond will be poor and the cracks may develop in the joint over time.

Repair: Cold joints can usually be repaired by simply re-heating the joint with a hot iron until the solder flows. Many cold joints (such as the one pictured) also suffer from too much solder. The excess solder can usually be drawn-off with the tip of the iron.

Prevention: A properly pre-heated soldering iron with sufficient power will help prevent cold joints.

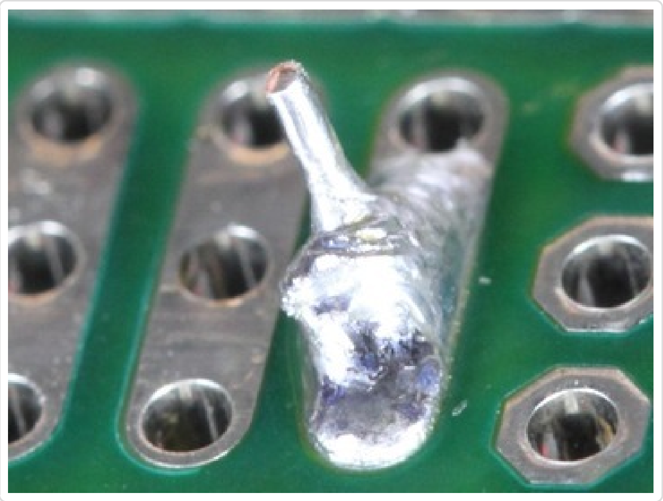

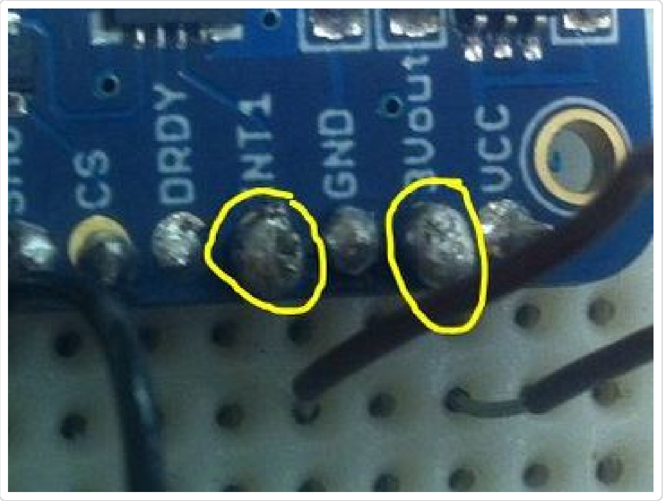

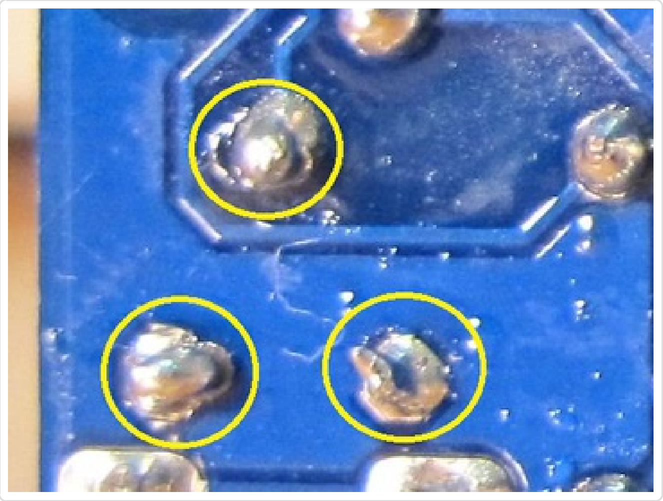

CE1
CE0
#2
SCLK

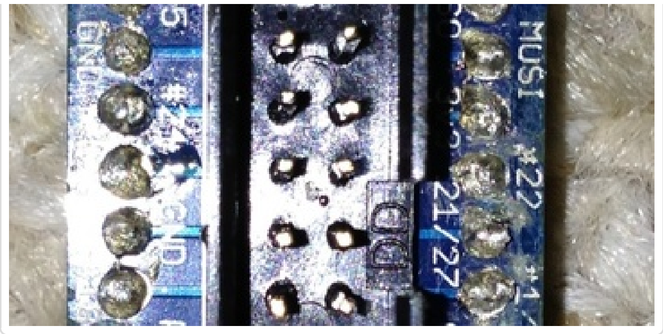
GND
GND
MOSI
#22
21/27

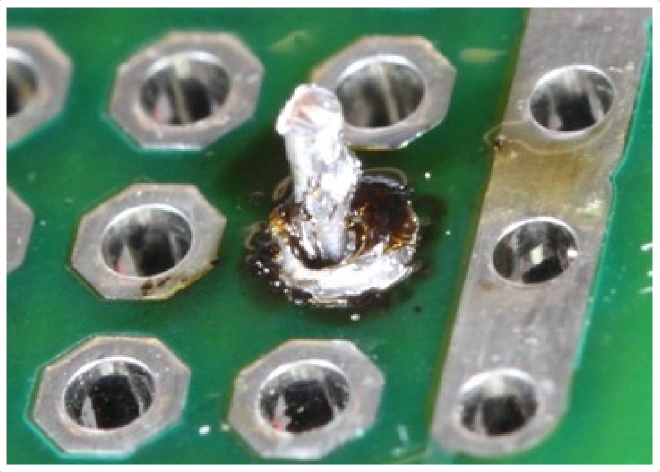

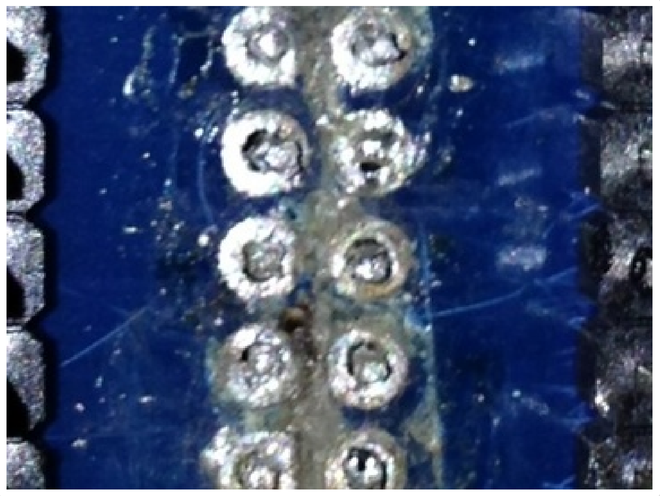

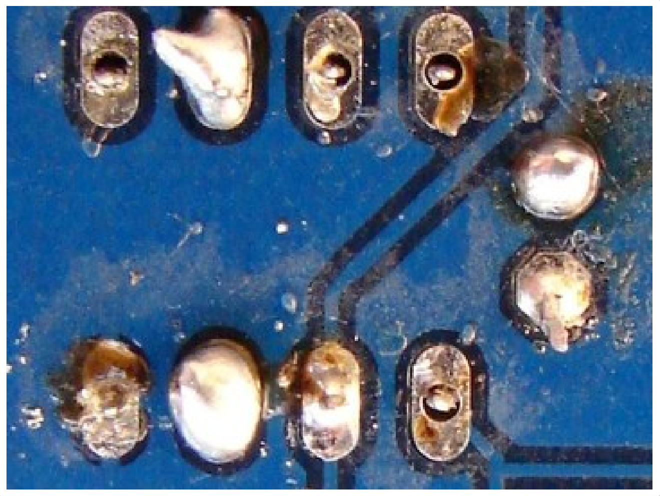

Overheated Joint

At the other extreme, we have the overheated joint. The solder has not yet flowed well and the residue of burnt flux will make fixing this joint difficult.

Repair: An overheated joint can usually be repaired after cleaning. Careful scraping with the tip of a knife, or little isopropyl alcohol & a toothbrush will remove the burnt flux.

Prevention: A clean, hot soldering iron, proper preparation and cleaning of the joint will help prevent overheated joints.

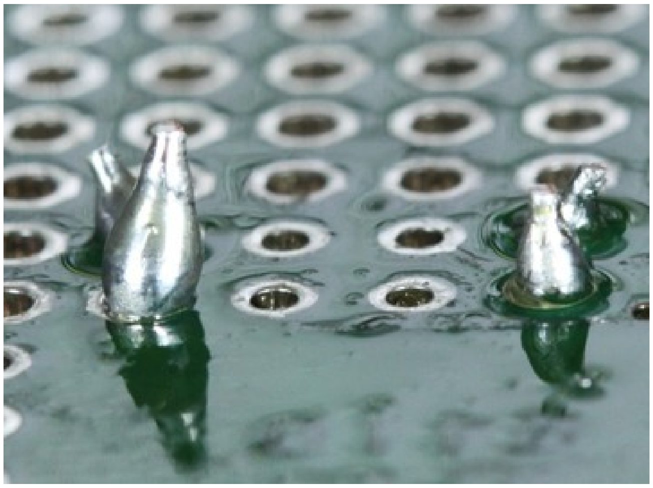

Insufficient Wetting (Pad)

These two joints both show signs of insufficient wetting of the solder pad. The solder has wetted the leads nicely, but it has not formed a good bond with the pad. This can be caused by a dirty circuit board, or by failing to apply heat to the pad as well as the pin.

Repair: This condition can usually be repaired by placing the tip of the hot iron at the base of the joint until the solder flows to cover the pad.

Prevention: Cleaning the board and even heating of both the pad and the pin will prevent this problem.

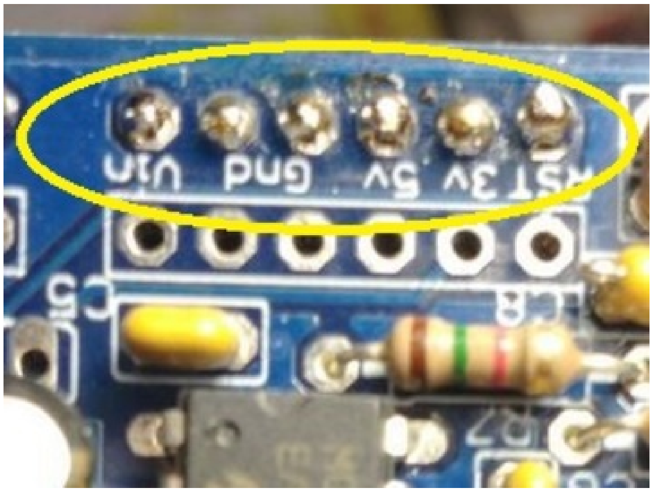

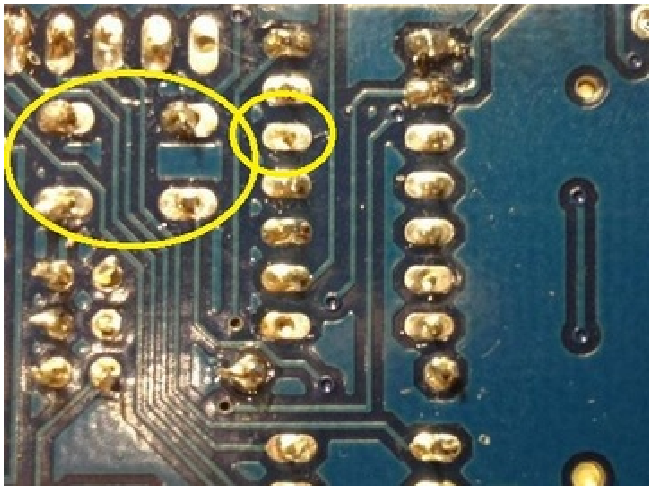

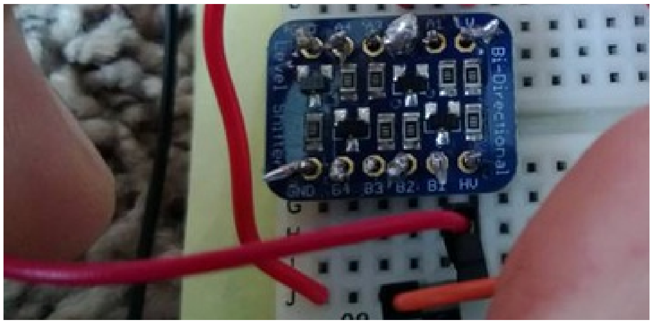
Bi-Directional
Level Shifter
GND B4 B3 B2 B1 HV

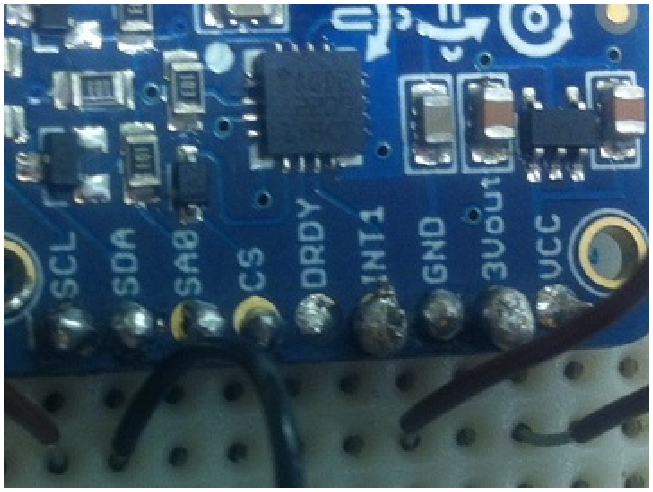
SCL
SDA
SA0
CS
DRDY
INT1
GND
3Vout
VCC

Insufficient Wetting (Pin)

This solder in this joint has not wetted the pin at all and has only partially wetted the pad. In this case, heat was not applied to the pin and the solder was not given adequate time to flow.

Repair: This joint can be repaired by re-heating and applying more solder. Be sure that the tip of the hot iron is touching both the pin and the pad.

Prevention: Even heating of both the pin and the pad will prevent this problem.

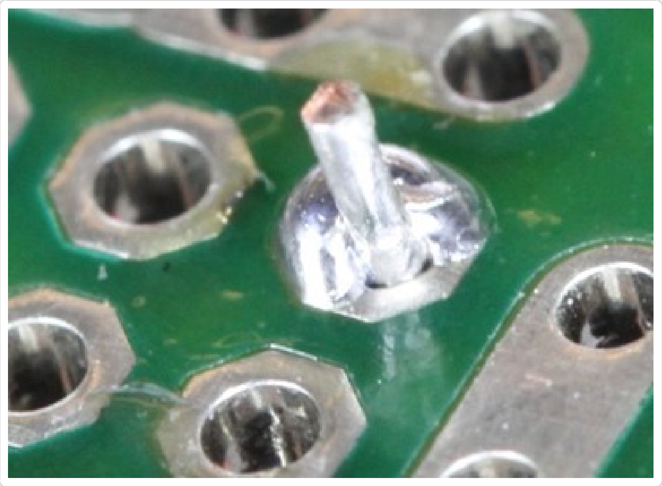

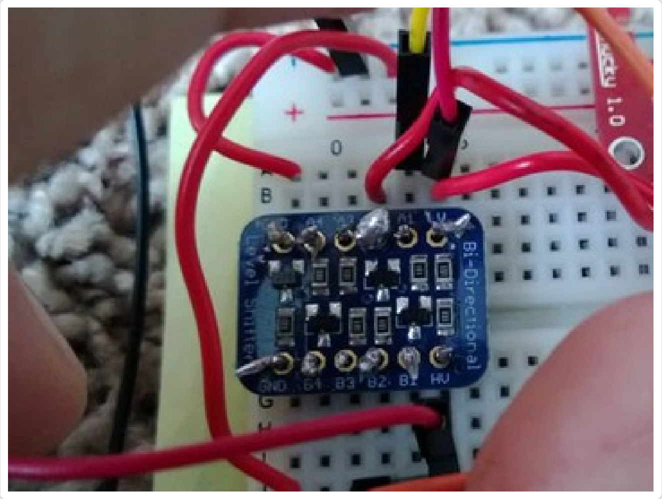

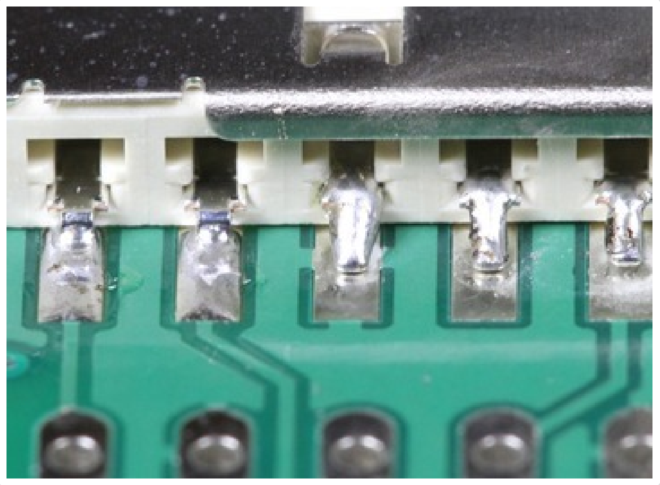

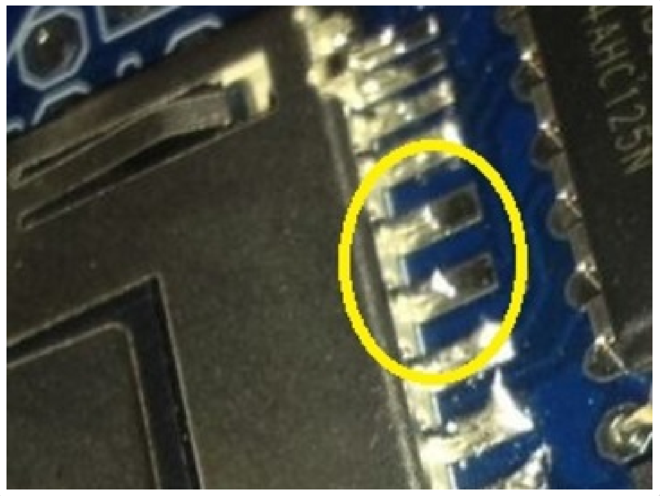

Insufficient Wetting (Surface Mount)

Here we have three pins of a surface mount component where the solder has not flowed onto the solder pad. This is caused by heating the pin instead of the pad.

Repair: This is easily repaired by heating the solder pad with the tip of the iron, then applying solder until it flows and melts together with the solder already on the pin.

Prevention: Heat the pad first.

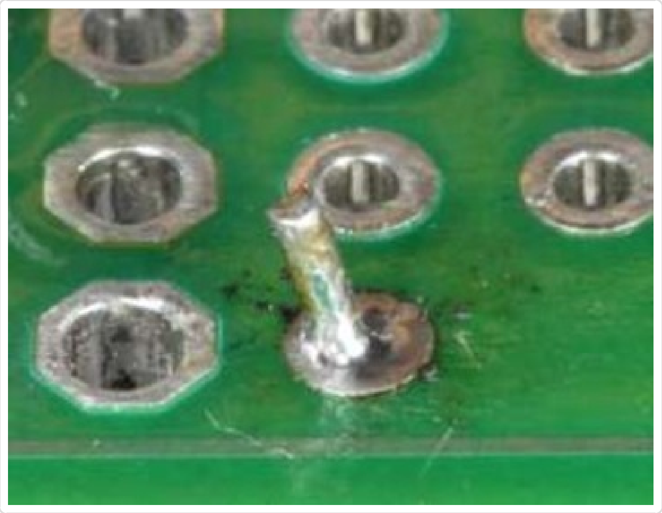

Solder Starved

A solder starved joint simply does not have enough solder. It may make good electrical contact, but it is hard to verify by inspection. In any case, it is not a strong joint and may develop stress cracks and fail over time.

Repair: Re-heat the joint and add more solder to make a good strong joint.

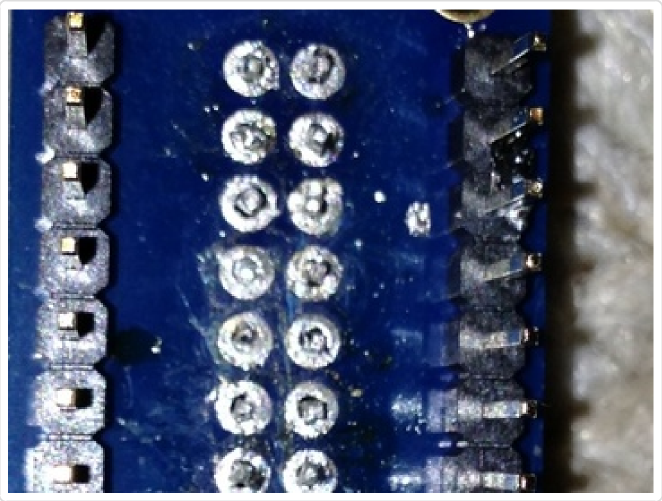

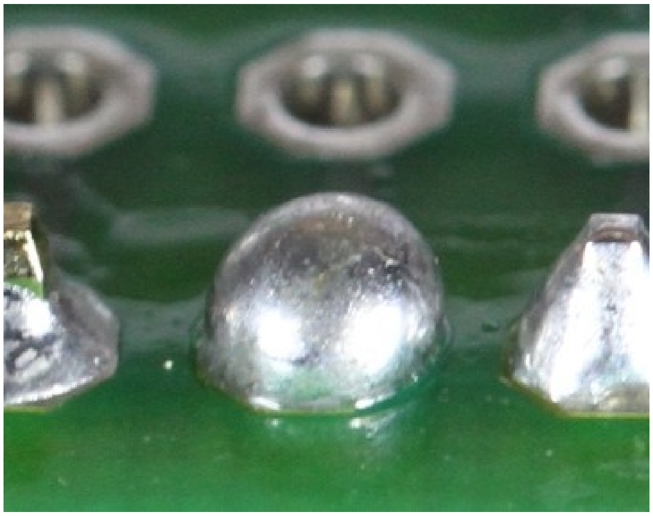

Too Much Solder

This might be a perfectly good joint, but we can't tell for sure. It is entirely possible that this blob of solder wets neither the pin nor the pad and is not a reliable electrical connection. The best evidence of proper wetting (and good electrical contact) is a nice concave surface as on the joint on the far left.

Repair: It is usually possible to draw off some of the excess solder with the tip of a hot iron. In extreme cases, a solder-sucker or some solder wick can be helpful as well.

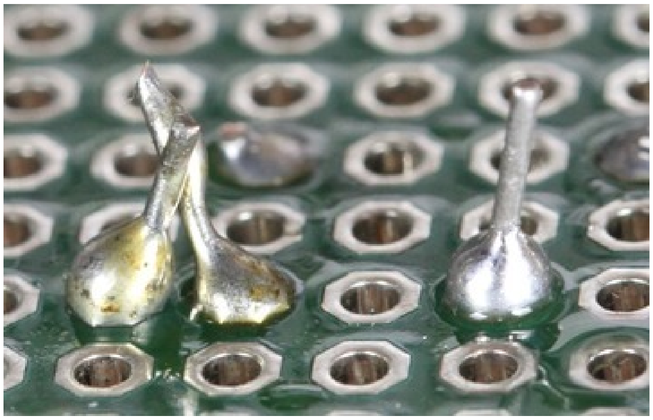

Untrimmed Leads

Leads that are too long are potential short circuits. The two joints on the left are an obvious danger of touching. But the one on the right is long enough to be dangerous as well. It would not take much force to bend that lead over to touch an adjacent trace.

Repair: Trim all leads just at the top of the solder joint.

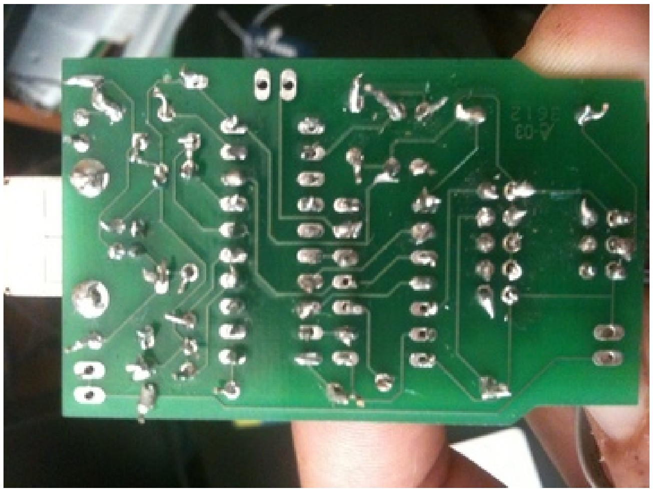

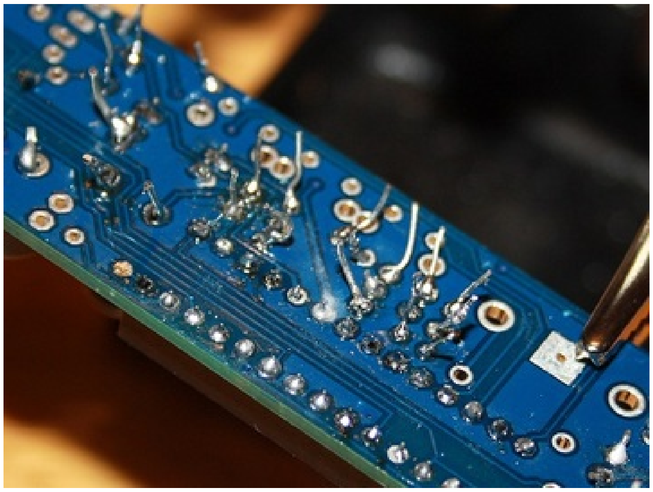

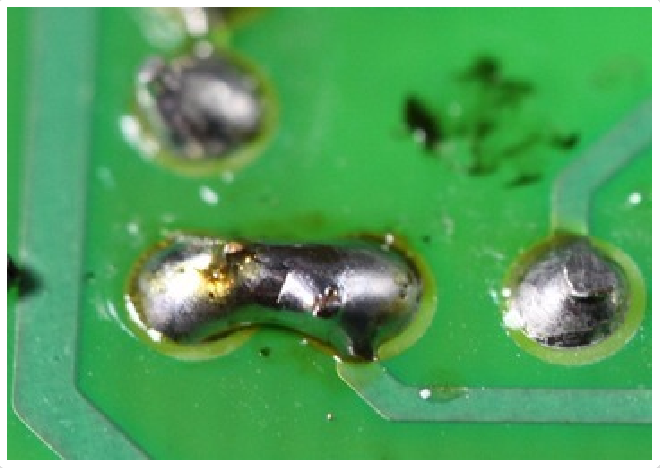

Solder Bridge

The left two solder joints have melted together, forming an unintended connection between the two.

Repair: Sometimes the excess solder can be drawn off by dragging the tip of a hot iron between the two solder joints. If there is too much solder, a solder sucker or solder wick can help get rid of the excess.

Prevention: Solder bridges most often happen between joints with too much solder to begin with. Use only enough solder to make a good joint.

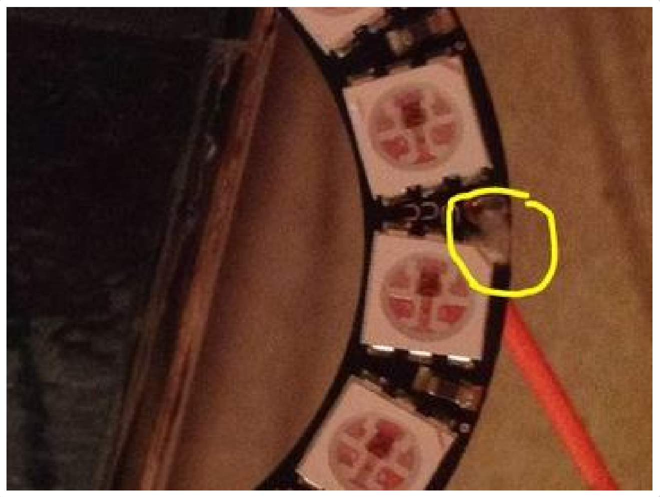

Adafruit i2c 16

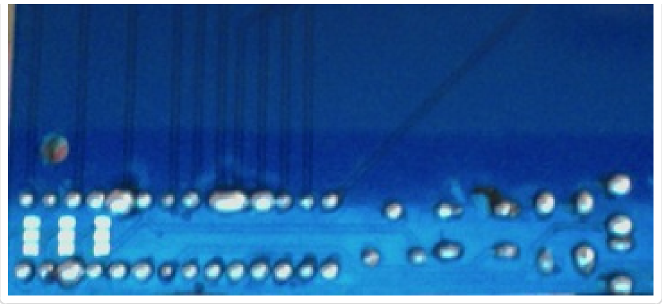

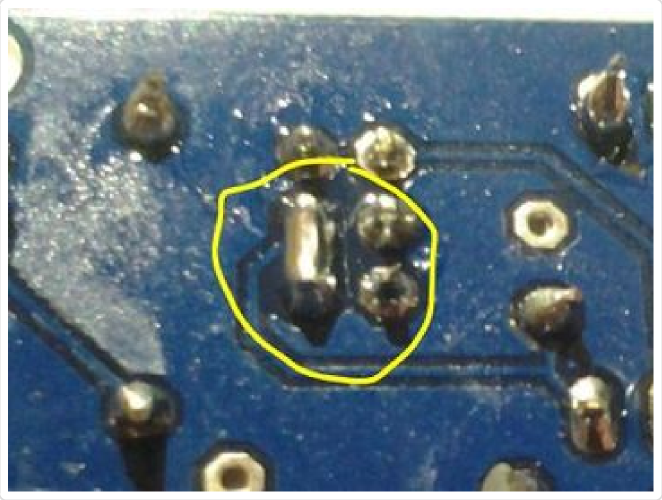

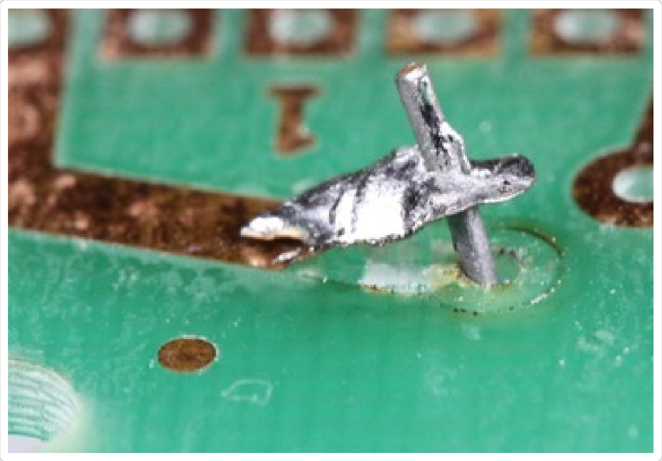

Lifted Pad

This photo shows a solder pad that has become detached from the surface of the circuit board. This most often occurs when trying to de-solder components from the board. But it can result simply from overworking the joint to the point where the adhesive bond between copper and the board is destroyed.

Lifted pads are especially common on boards with thin copper layers and/or no through-plating on the holes.

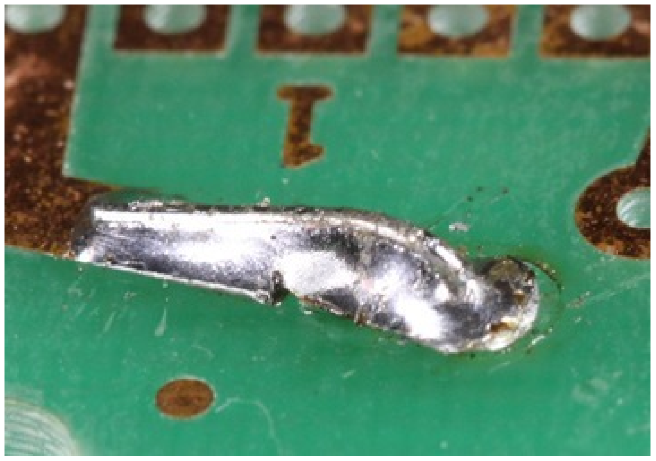

Repairing a Lifted Pad

It may not be pretty, but a lifted pad can usually be repaired. The simplest repair is to fold the lead over to a still-attached copper trace and solder it as shown to the left. If your board has a solder-mask, you will need to carefully scrape off enough to expose the bare copper.

Other alternatives are to follow the trace to the next via and run a jumper to there. Or, in the worst case, follow the trace to the nearest component and solder your jumper to the leg of that. Not exactly pretty, but functional.

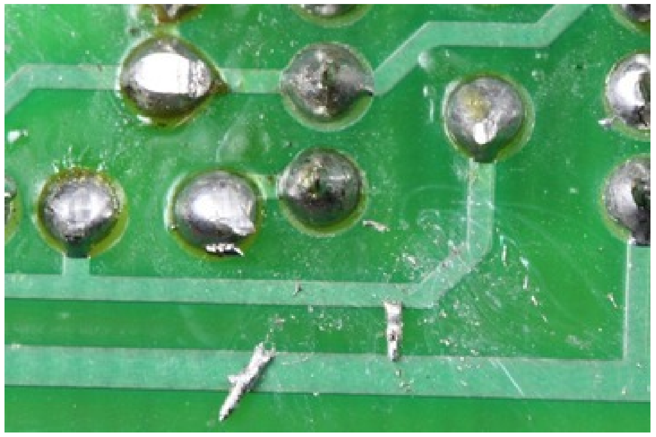

Stray Solder Spatters

These bits of solder are held to the board only by sticky flux residue. If they work loose, they can easily cause a short circuit on the board.

Repair: These are easy to remove with the tip of a knife or tweezers.

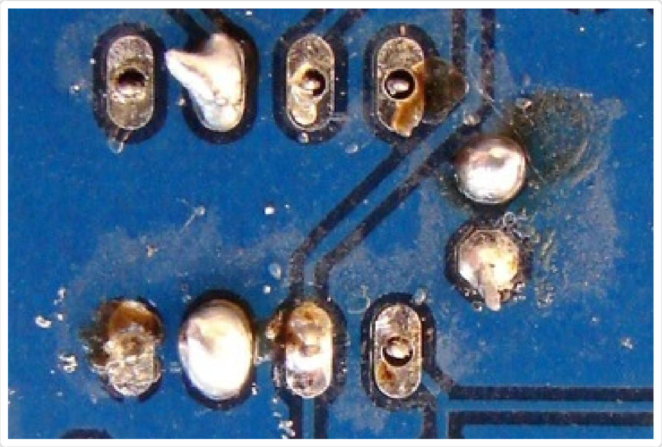

All of the Above!

Don't panic. Take your time. Most joints can be repaired with patience. If the solder refuses to flow the way you want it to:

1. Stop and let the joint cool.
2. Clean and tin your iron.
3. Clean off any burnt flux from the joint.
4. Let the iron come back up to temperature.
5. Then reheat the joint and try again.

HAND SOLDERING TUTORIAL FOR FINE PITCH QFP DEVICES

Scope

This document is intended to help designers create their initial prototype systems using Silicon Lab's TQFP and LQFP devices where surface mount assembly equipment is not readily available. This application note assumes that the reader has at least basic hand soldering skills for through-hole soldering. The example presented will be the removal, cleanup and replacement of a TQFP with 48 leads and 0.5 mm lead pitch.

Safety

Work should be done in a well-ventilated area. Prolonged exposure to solder fumes and solvents can be hazardous. There should be no presence of sparks or flames when solvents are in use.

Materials

The right materials are key to a good solder job. The list below are the recommendations from Silicon Labs. Other materials may work, so the user should feel free to substitute and experiment. The use of organic solder is highly recommended.

Required

1. Wire wrap wire (30 gauge) *
2. Wire strippers for wire wrap wire *
3. Soldering station - variable temperature, ESD-safe. Should support temperatures 800°F (425°C). This example uses a Weller model EC1201A. The soldering wand should have a fine tip no more than 1 mm wide.
4. Solder - 10/18 organic core; 0.2" (0.5 mm) diameter
5. Solder flux - liquid type in dispenser
6. Solder wick - size C 0.075" (1.9 mm)
7. Magnifier - 4X minimum. An inexpensive headset OptiVISOR by Donegan Optical Co. is used for this example.
8. ESD mat or tabletop and ESD wrist strap - both grounded
9. Tweezers with pointed (not flat) tips
10. Isopropyl Alcohol
11. Small stiff bristle brush for cleaning (nylon or other non-metallic material). Cut off hair to approximately 0.25" (6 mm)

* Required for device removal only.

Optional

1. Board vise to hold printed circuit board
2. Dental pick (90 degree bend)
3. Compressed dry air or nitrogen to dry boards

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4. Optical inspection stereo microscope 30-40X

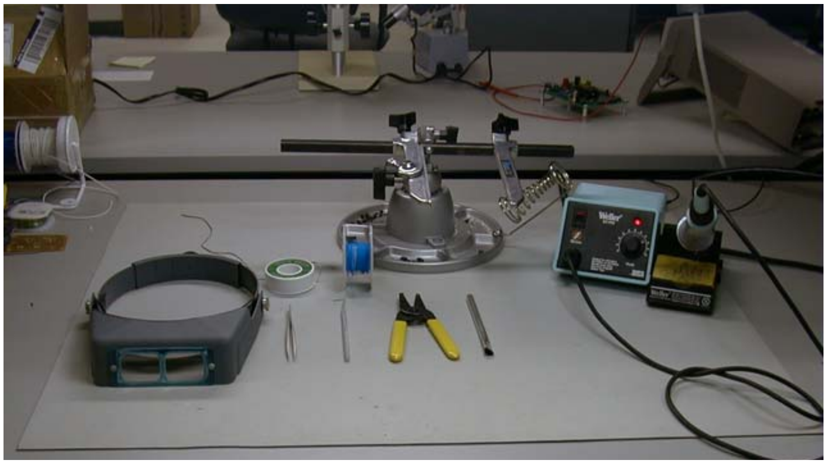

Figure 1. Some of the materials to get started...

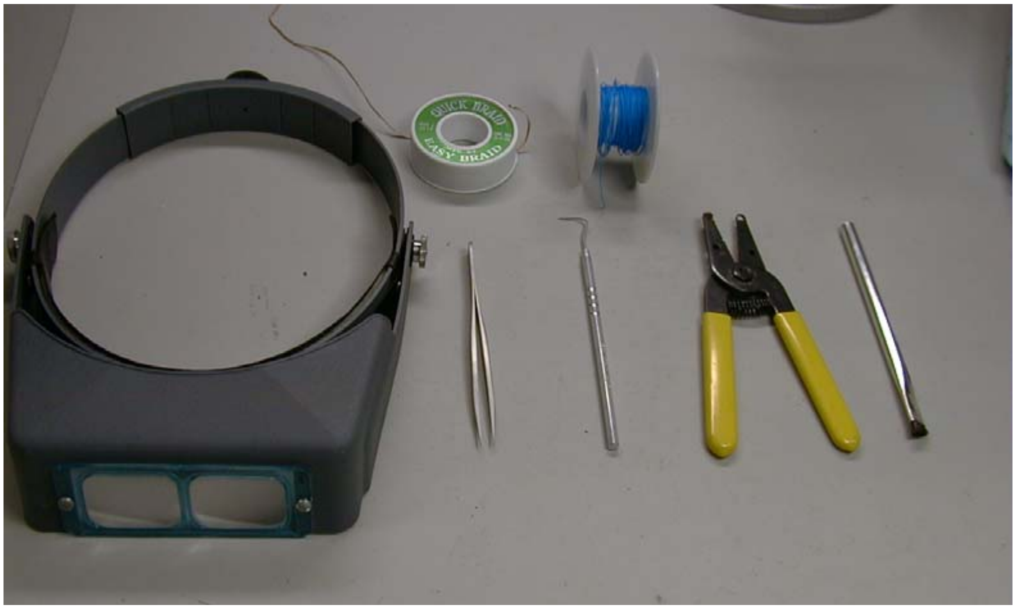

Figure 2. clock-wise from left: 4X magnifying headset, solder wick, wire wrap wire, stiff cleaning brush, wire strippers, and pointed tweezers

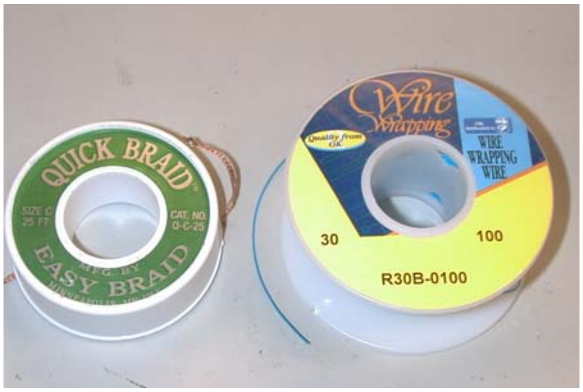
QUICK BRAID
EASY BRAID
Wire Wrapping
WIRE WRAPPING WIRE
30
100
R30B-0100

Figure 3. Solder wick and wire wrap wire

HEALTH ★ CARE
AMERICA
ISOPROPYL
RUBBING ALCOHOL
91% BY VOLUME

Figure 3. Isopropyl Alcohol

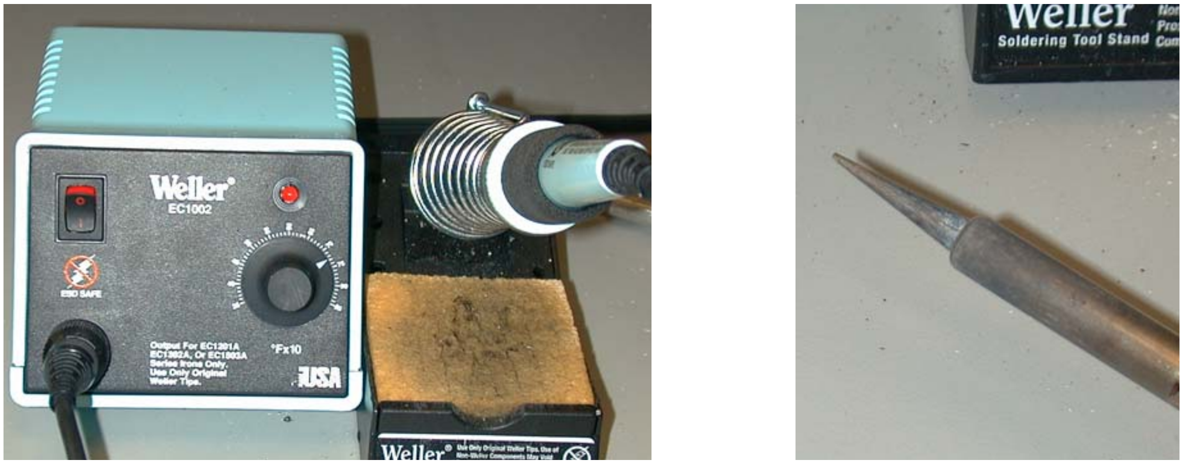
Weller
EC1002
ESD SAFE
°Fx10
Weller
Soldering Tool Stand

Figure 4. ESD safe soldering station with fine tip wand. This one is Weller model EC1201A

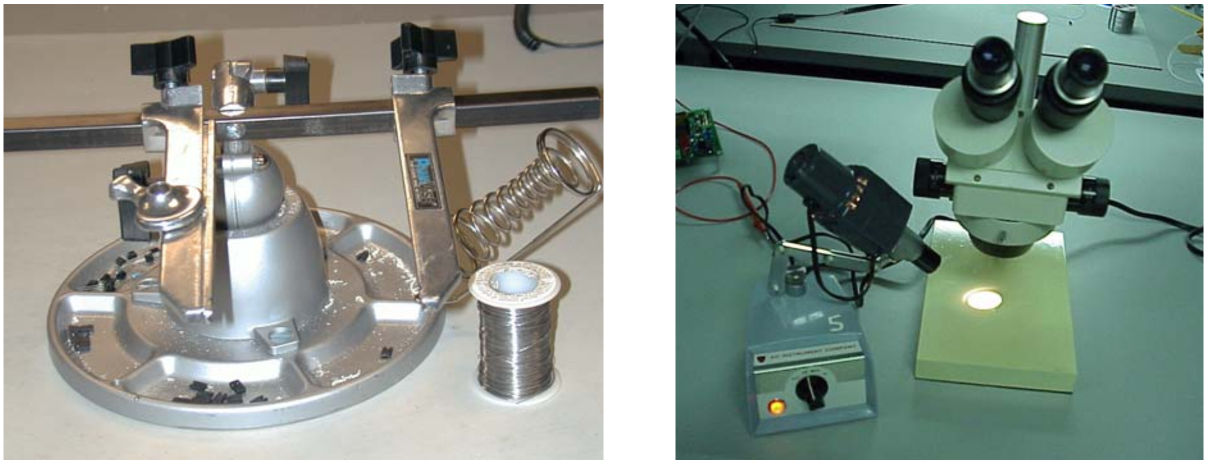

Figure 5. Optional equipment includes a PCB vise and an inspection microscope 7-40X

Procedure

The following procedures cover the replacement of a TQFP 48 pin device with 0.5 mm lead pitch. The lead shape is the standard gullwing associated with JEDEC standard QFPs. This procedure section is divided into three parts:

A. Part Removal

B. Board Cleanup

C. Soldering a new device.

If you are soldering parts to a new printed circuit board, skip part A and refer to the new board cleanup section in part B.

A. Part Removal

Preparation:

- Board with IC to be removed is mounted in a holder or vise. A PCB holder/vise is optional but it is required that the PCB is held steady for the part removal.
- The soldering station is warmed up to 800°F (422°C) and the solder tip is clean.
- ESD precautions have been taken.

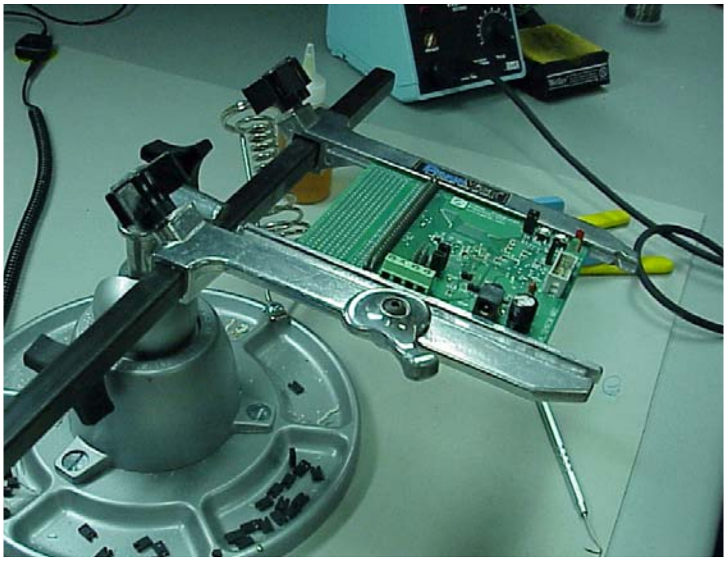

Figure 6. Ready to get started

Begin by wetting all the leads with flux to enhance the initial solder wicking cleanup. Wick up solder as much as possible from the QFP leads. Be careful not to scorch the PCB board with prolonged solder heat.

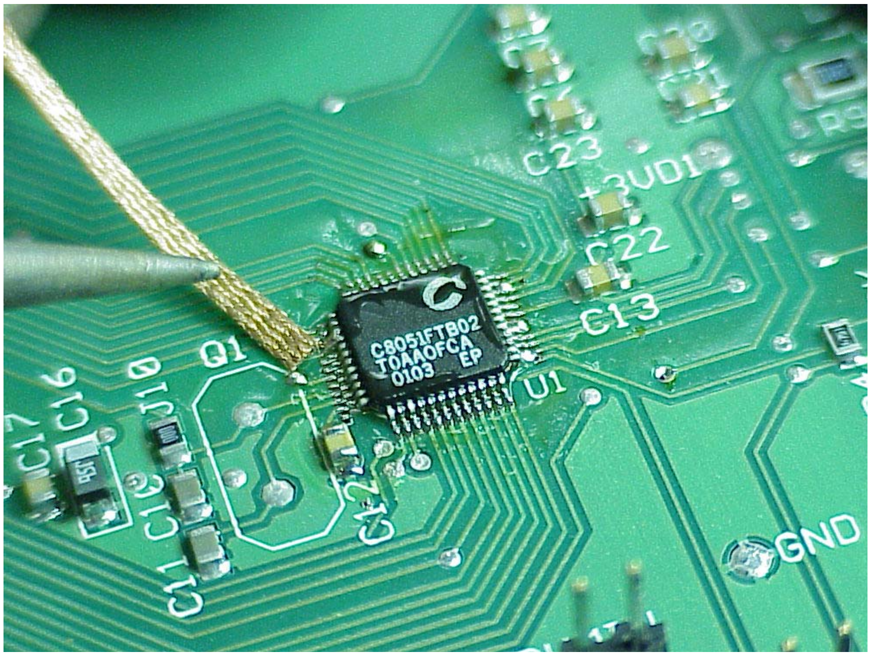
C8051FTB02
T0AA0FCA
0103 EP
C23
C22
C13
Q1
U1
GND
C16
C17
J10
C12
C11

Figure 7. Apply flux; wick excess solder from pins

Next, strip off approximately 3 inches of insulation from a piece of the 30 gauge wire wrap wire. Cut the wire at a comfortable 12 inch length or so.

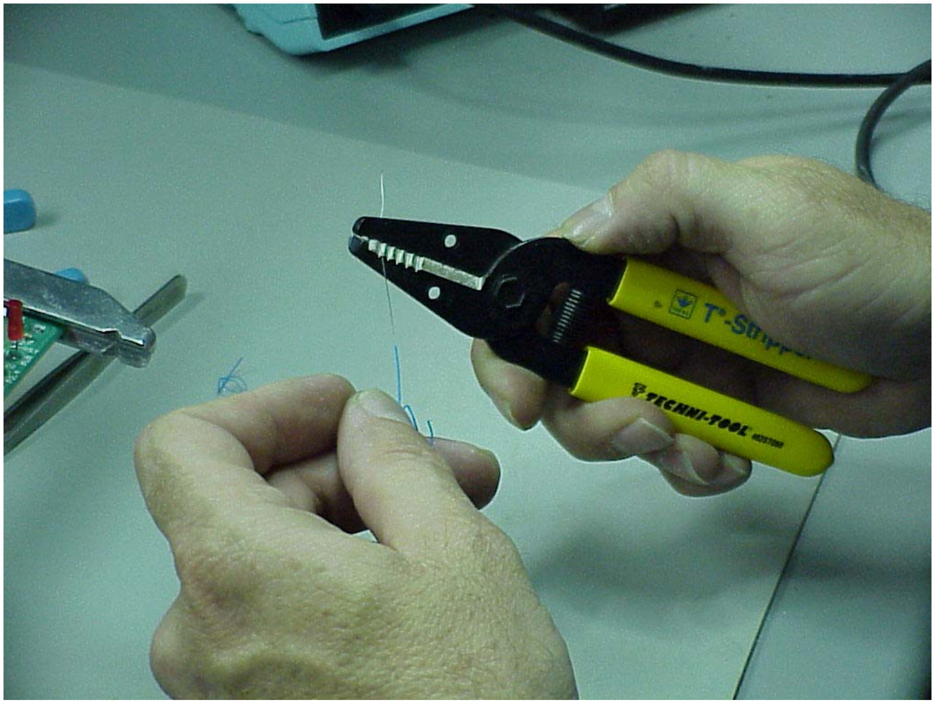
T-Stripper
TECHNI-TOOL

Figure 8. Wire stripping

Feed the wire behind and under the leads on one side of the IC as shown in Figure 9.

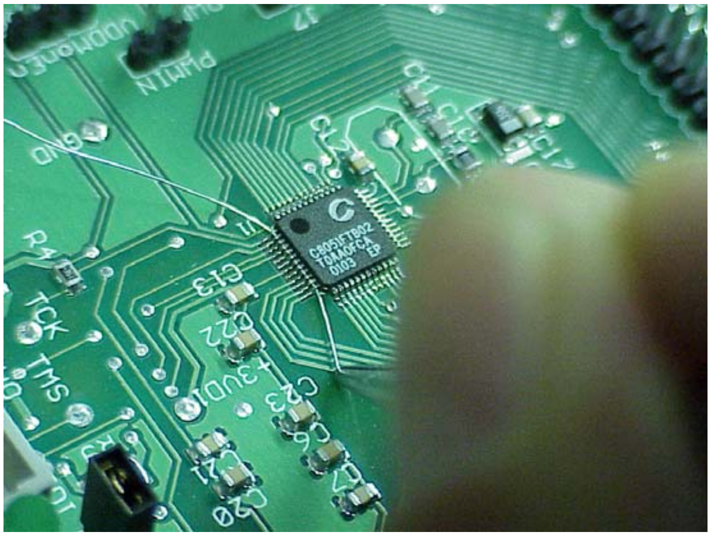

Figure 9. Feeding wire under QFP leads

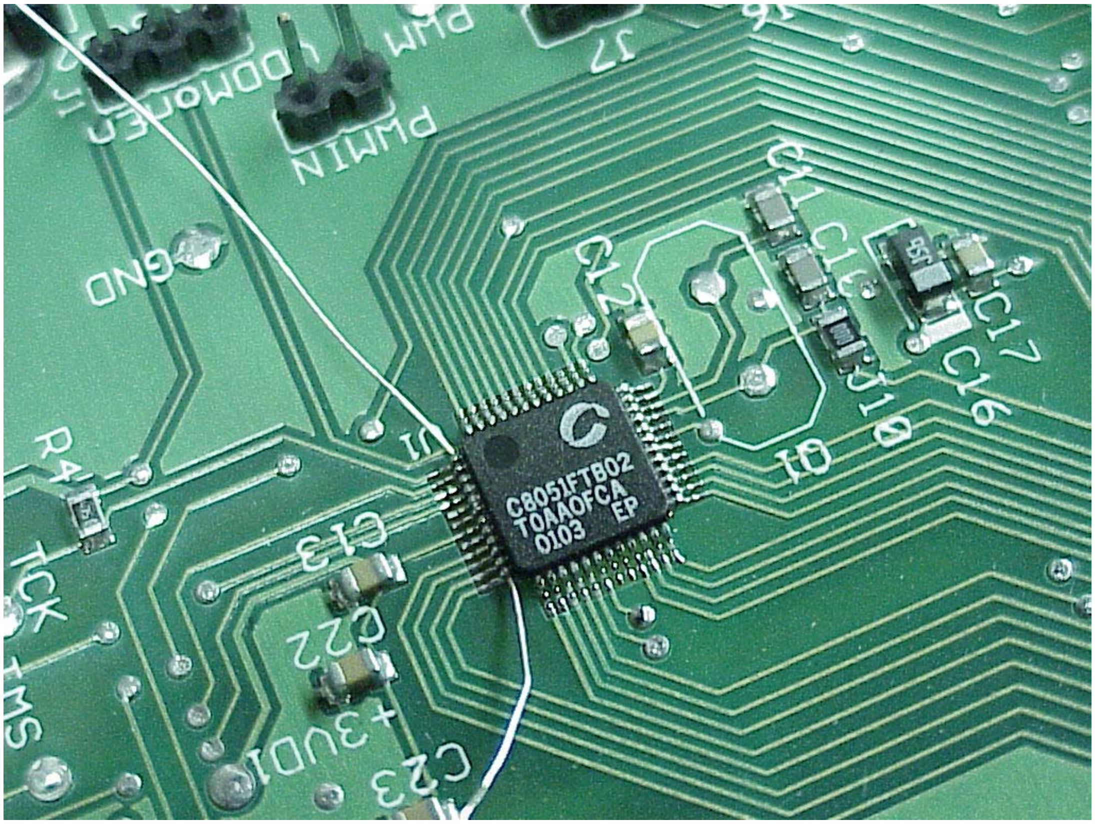

Figure 9. Wire with one side anchored to nearby component

Solder tack (anchor) one end of the 3 inch wire to a nearby via or component on the PCB. The anchor point should be in a location similar to that should in Figure 10.

Dispense a small amount of liquid flux across the leads.

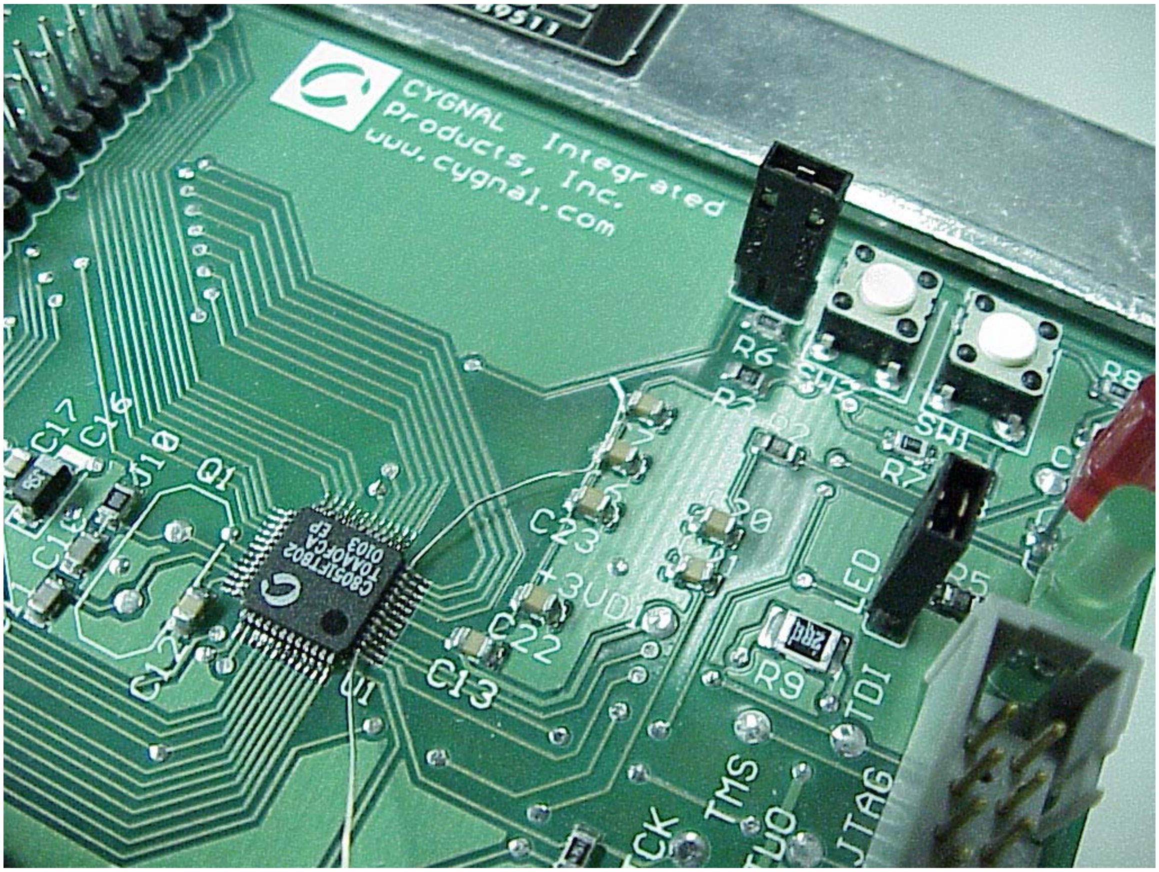

Figure 10. Bus wire is anchored on C6

Hold the loose (non-anchored) end of the wire with tweezers in close proximity to the device as shown in Figure 11.

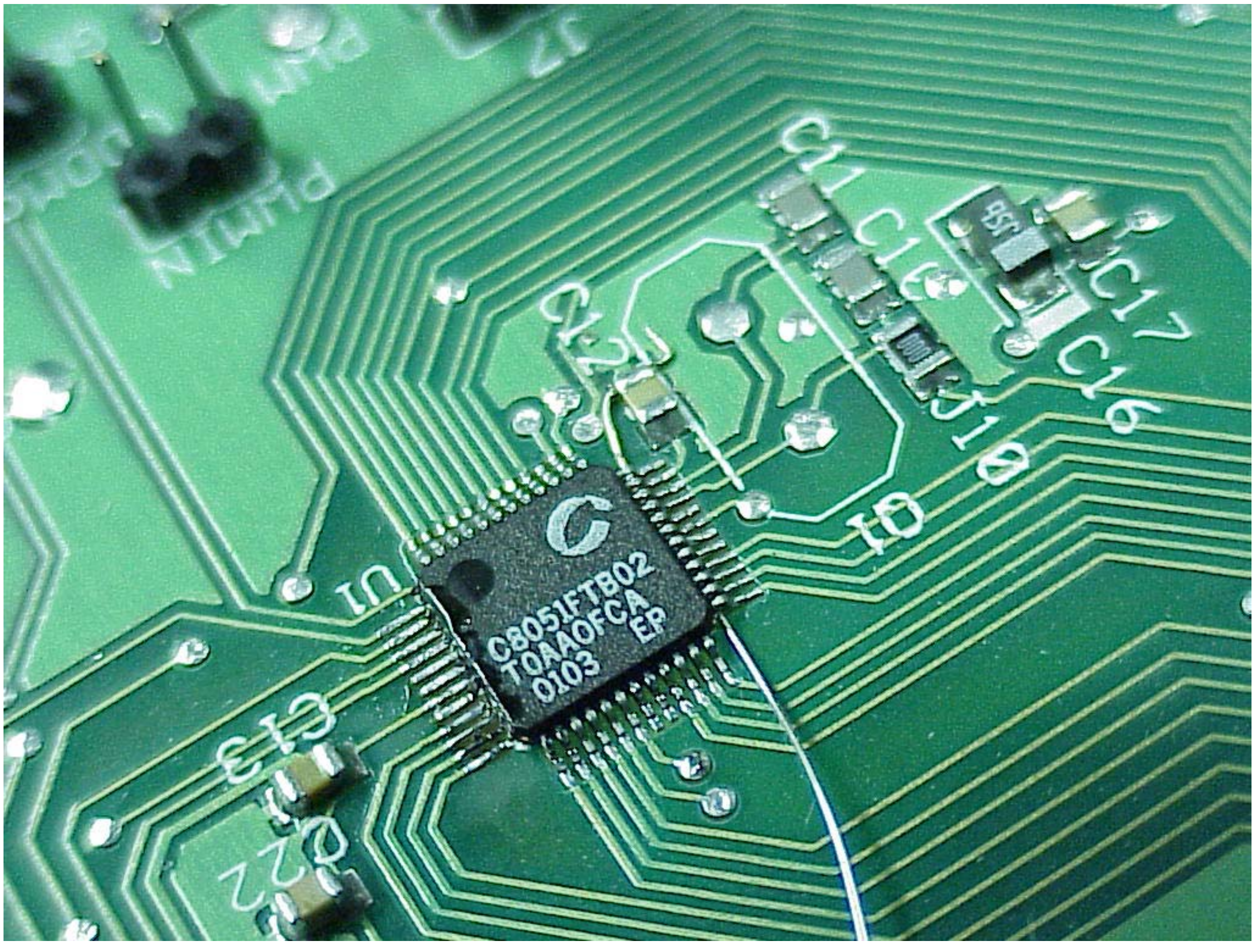

Figure 11. Side 2 anchored and ready for solder heat

You will now need to simultaneously apply solder heat and pull the wire away from the QFP, pulling at a slight upward angle from the board surface. Apply solder heat beginning at the lead closest to your tweezers. As the solder melts, gently pull the wire away from the QFP while continuing to move the solder heat from pin to pin to the right. You should not pull very hard. Pull as the solder melts. Do not leave the solder heat on any lead for more than necessary. The first lead will take the longest to heat, and after the wire gets hot, solder on the other leads will melt quickly. Excessive heat will damage the IC device and the PCB pad. The removal of 12 pins from a 48TQFP should take about 5 seconds total. Signs of excessive heat are:

- Melted plastic on the IC device
- PCB pads that lift off
- Brown scorch marks on the PCB

With one side of the QFP completed, repeat the same procedure on the other three sides of the QFP. Cut off the dirty part of the wire wrap wire or use a new piece for each side. Dispense flux again for each side.

Note that in the following pictures, the old IC device is not being saved. There is slightly more heat being applied here than necessary to speed up the process. This result is some melted plastic and missing gull-wing leads. These are visible in the pictures that follow. If you are trying to save the IC being removed, then you must be very careful to apply as little heat as possible during the removal process such that the QFP leads remain intact in the plastic QFP body. This will require some experimentation with solder heat settings and timing.

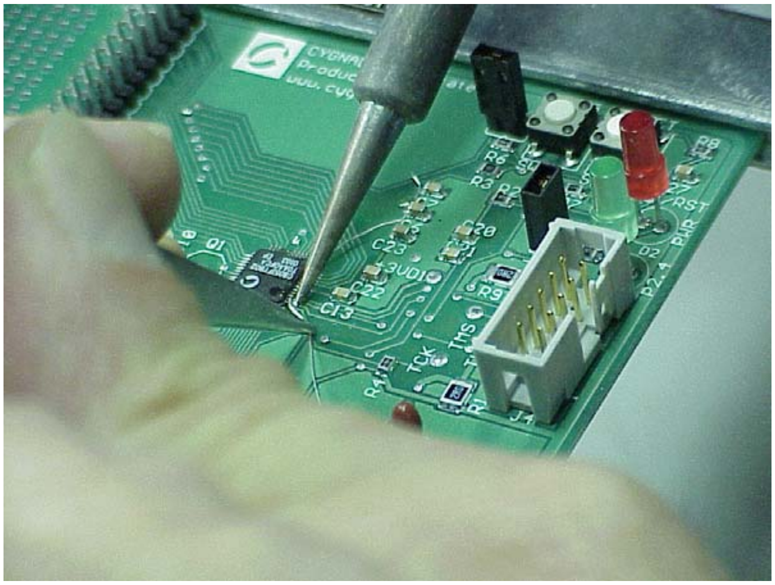

Figure 12. Hold tweezers close to device

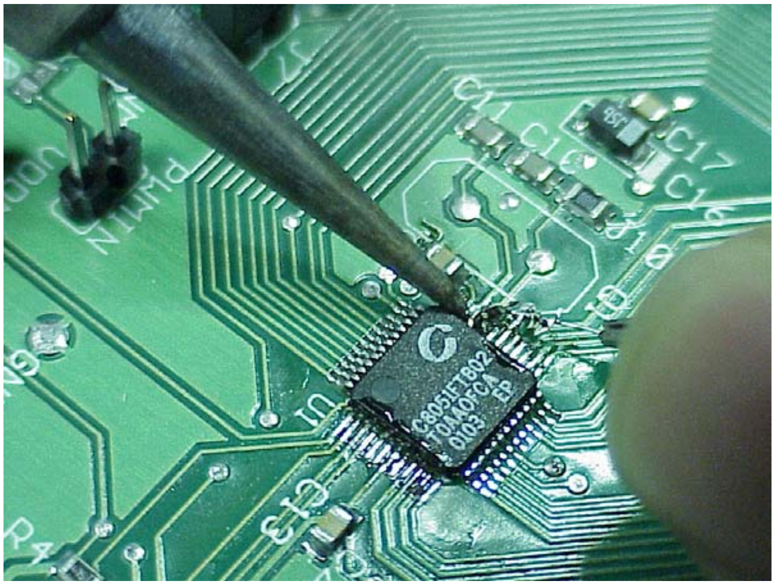

Figure 14. Side 2 almost complete

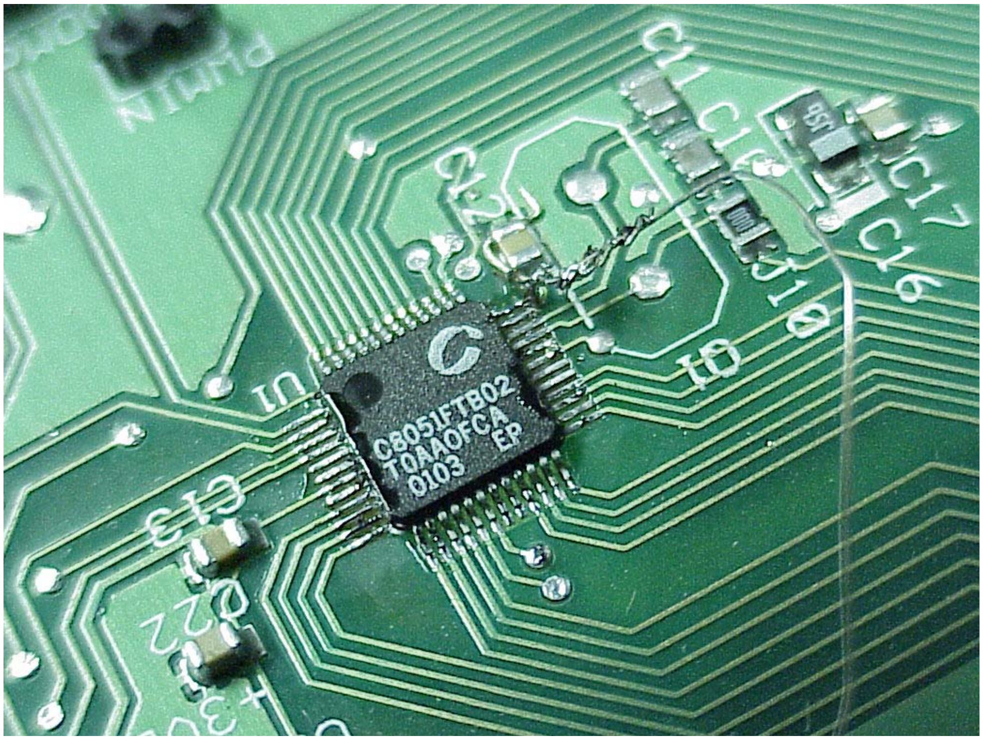
C8051FTB02
TOAAOFCA EP
0103
C13
C22
C12
C16
C17
J10
U1
C1

Figure 15. Side 2 is done

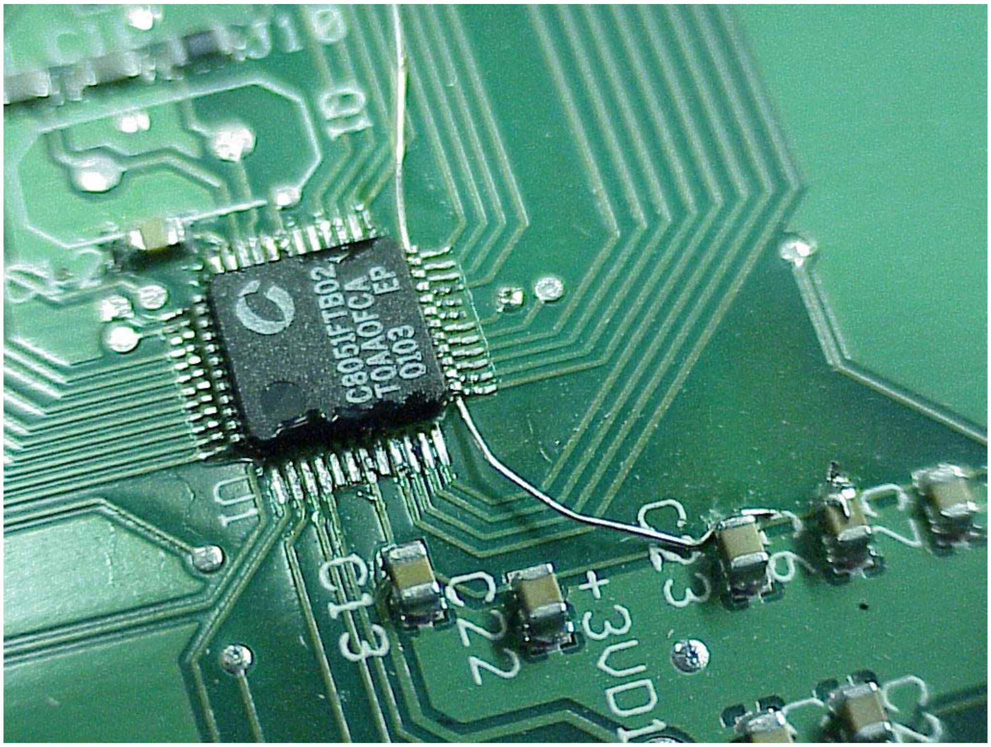
C8051FTB02
TOAAOFCA EP
0103
J10
U1
C13
C22
C23
+3VD

Figure 16. Side 3 anchored and ready

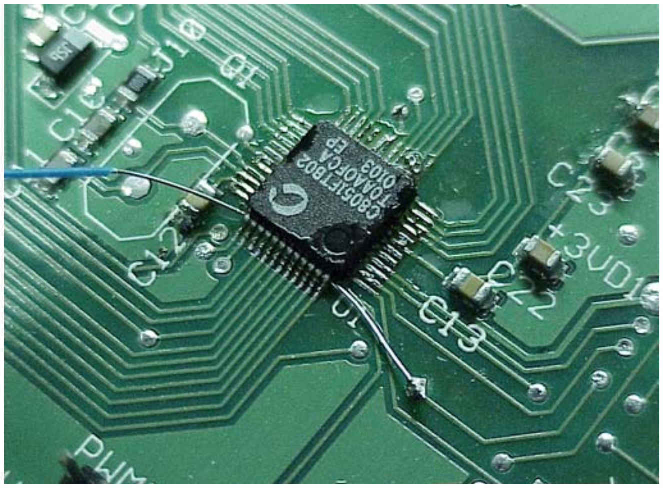

Figure 17. Side 4 anchored to a via

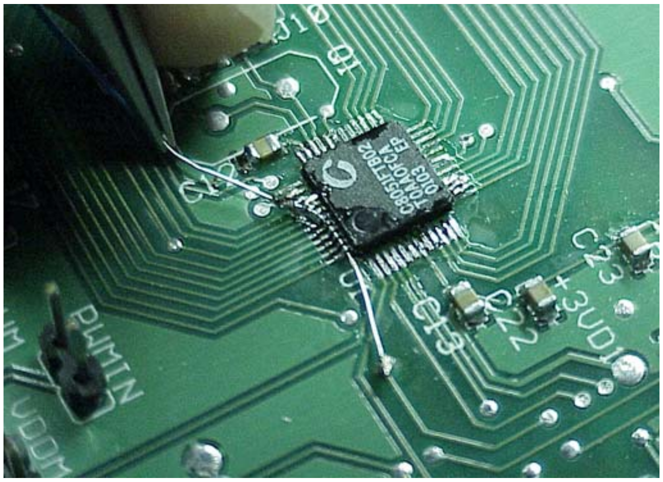

Figure 18. Side 4 removal started

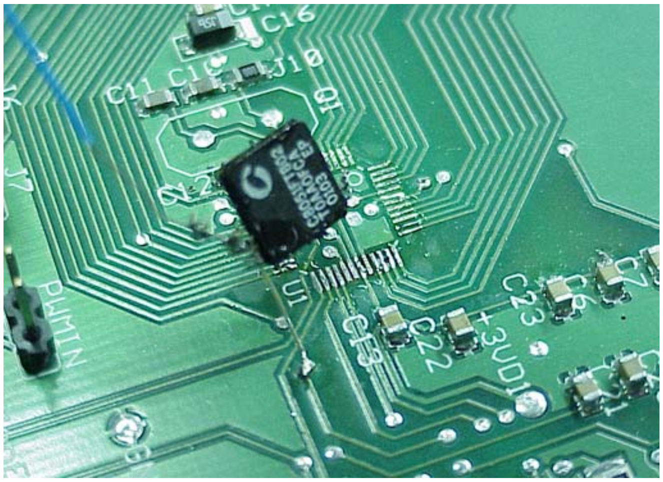

Figure 19. QFP removal a second before completion

B. Board Cleanup

New PCBs

For mounting a device to a new PCB, the amount of cleanup should be minimal. On a new PCB, there should be no solder on the pads. Brushing the pads with isopropyl alcohol (Figure 33) and drying the board should be enough preparation to begin the mounting procedure.

Reworked PCBs

The following section is the cleanup sequence that follows the QFP removal in the previous section. After removing the device, the solder pads will need cleanup. The idea is to clean the pads so that they are flat and free or solder and flux. Solder wick the pads until they are flat and dull. A clean pad appearance should be a dull silver color.

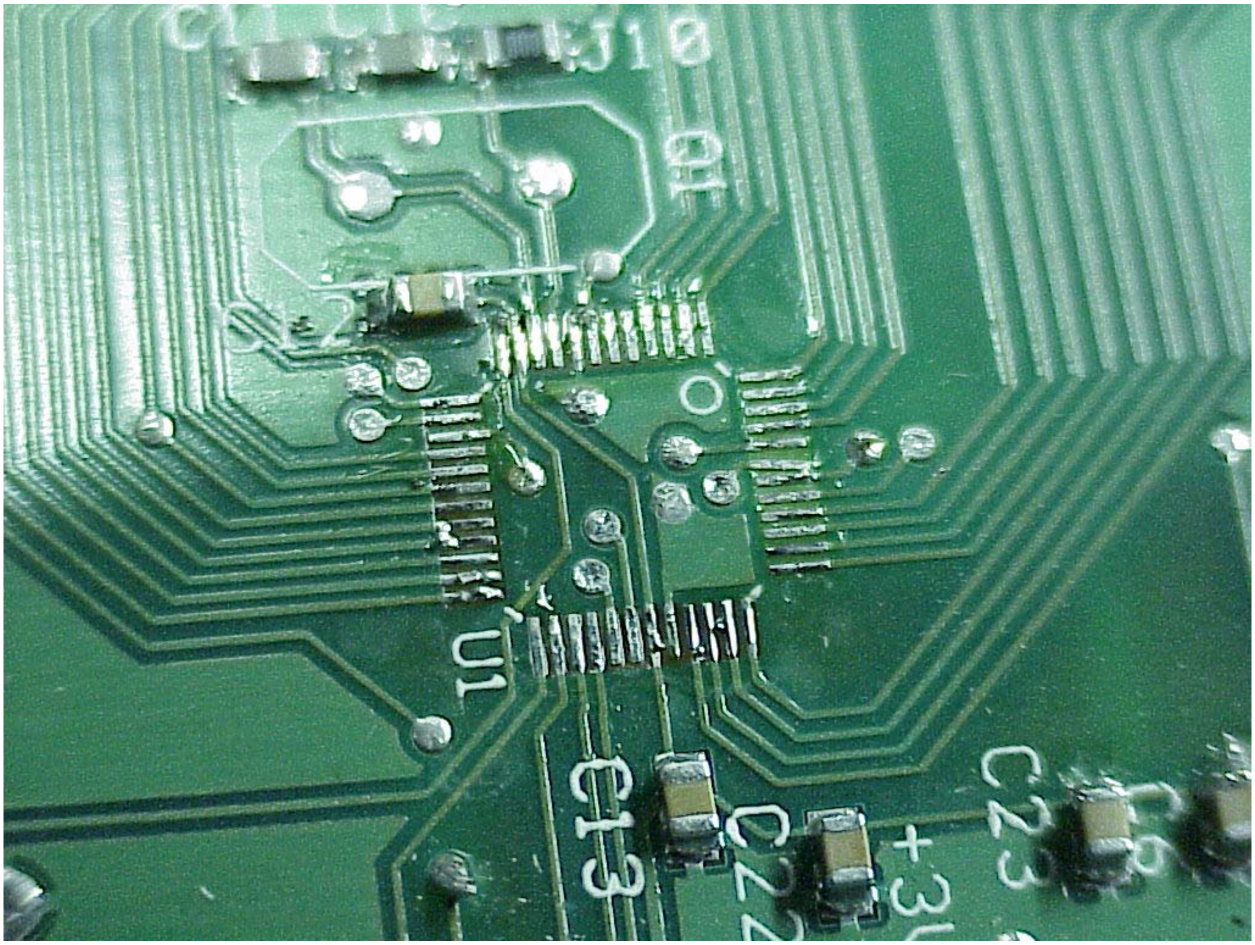

Figure 20. Pads after QFP removal procedure

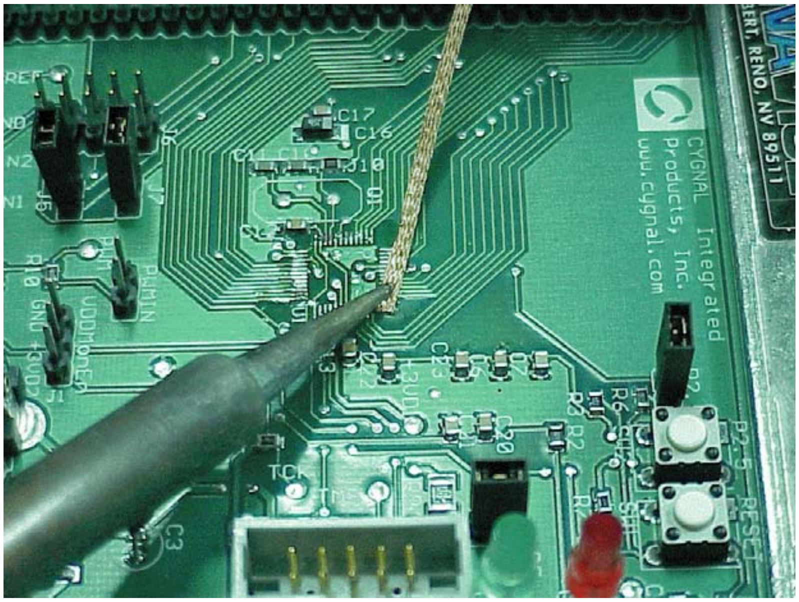

Figure 21. Solder wick to remove solder on the pads

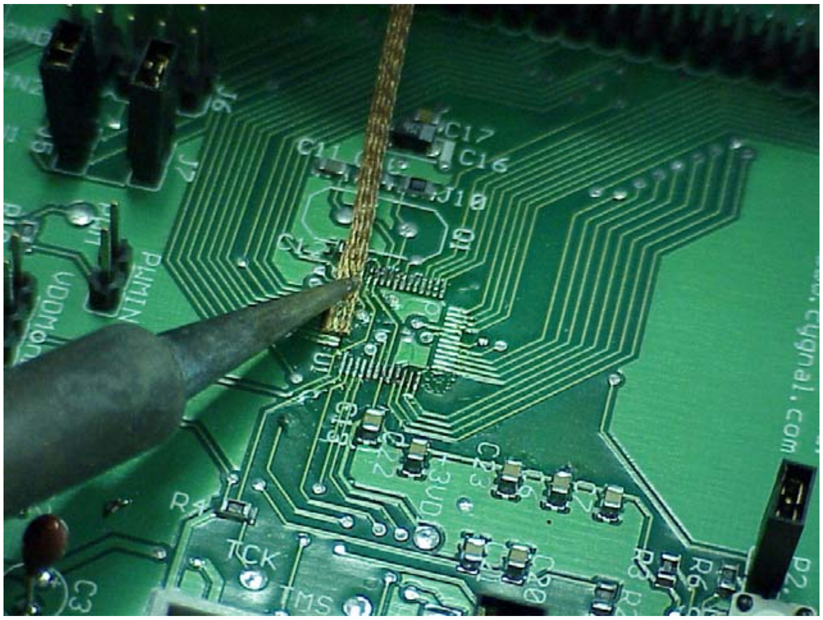

Figure 22. Repeat for all pads

If any pads become loose from the PCB, use a dental pick or other pointed object to re-align the pad (Figure 23 and Figure 24).

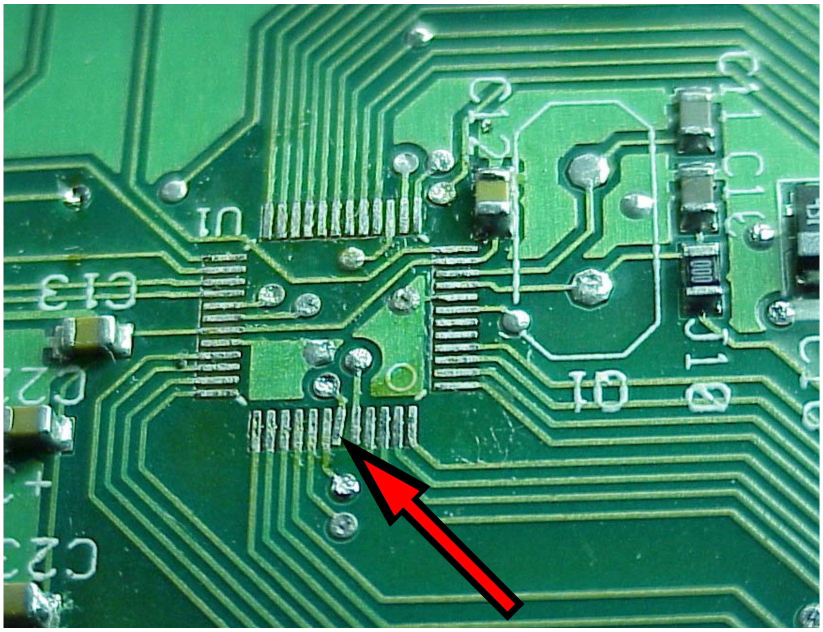
C11
C12
C16
U1
C13
C22
C23
Q1
J10

Figure 23. Clean pads but one pad is slightly crooked

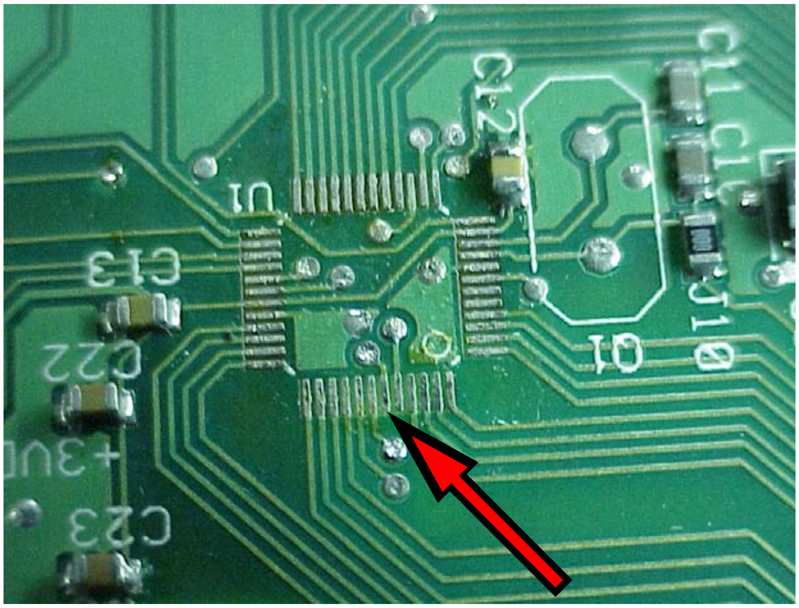
C11
C12
C16
U1
C13
C22
+3VD
C23
Q1
J10

Figure 24. Pad straightened out

B. Soldering a new QFP

The pads on the PCB should be clean and free of any solder.

Carefully place the new QFP device on the PCB using tweezers or another safe method. Make sure the part is not dropped as the leads can be easily damaged.

Align the part over the pads using a small pick or similar tool to push the part. Get the alignment as accurate as you can. Also, make sure that the part is oriented correctly (pin 1 orientation).

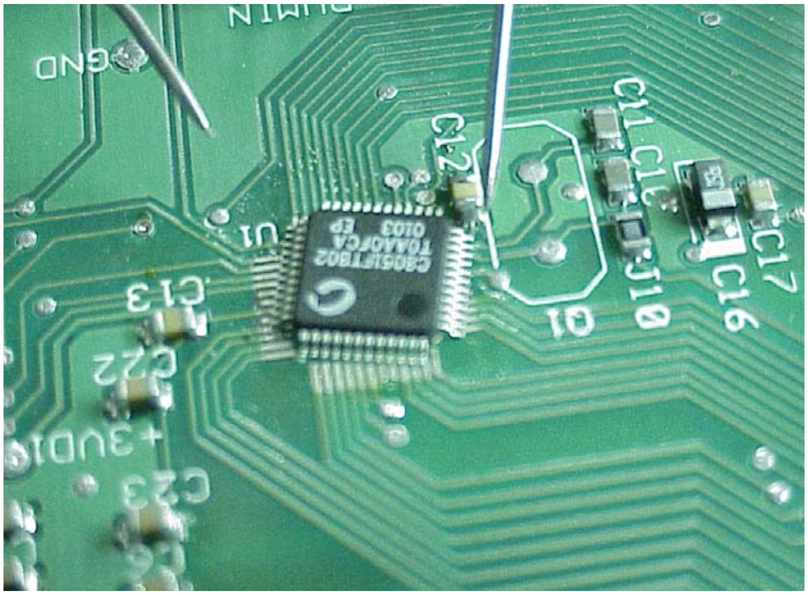

Figure 25. New QFP near pads, ready for alignment

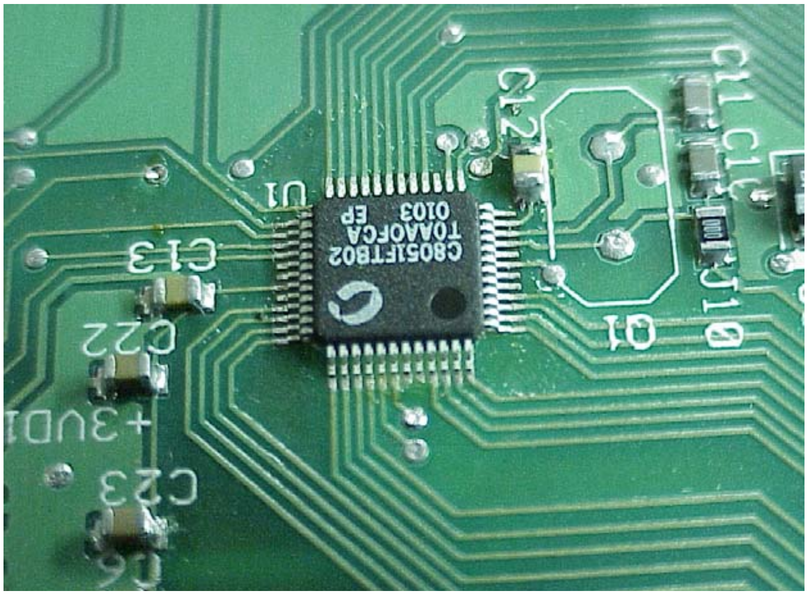

Figure 26. QFP aligned

Adjust the soldering station temperature to 725°F (385°C). Put a small amount of solder on the tip of the solder iron. While holding down the aligned QFP with a pick or other pointed tool, add a small amount of solder flux to the corner leads in two opposite corners. While still holding the part down with the pick, solder down two opposite corner leads on the QFP. Do not worry about excess solder or shorts between adjacent leads at this time. The idea is to anchor down the aligned QFP with solder so it does not move.

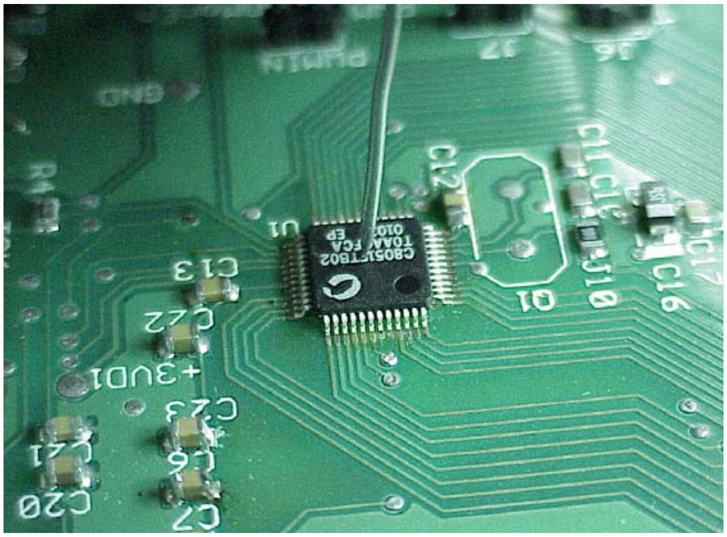

Figure 27. Aligned QFP ready for solder anchoring

Re-check the QFP alignment after soldering the corners. If necessary, make adjustments or remove and start over to get good QFP to PCB alignment.

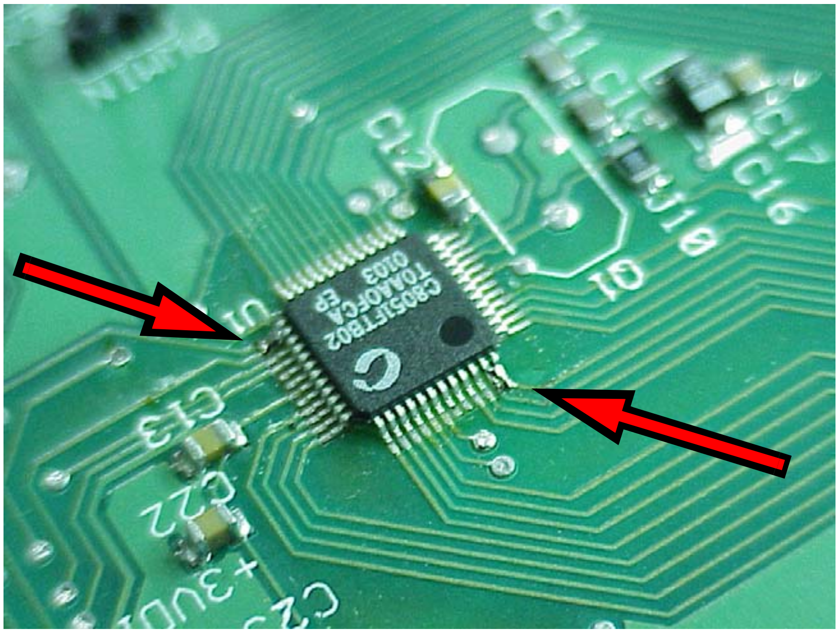

Figure 28. Aligned QFP with corners soldered down

Now you are ready to solder all the leads. Add solder to the tip of the soldering iron. Dispense flux over all the leads to keep them wet.

Touch the solder iron tip to the end of each QFP lead until the solder is seen running up the lead. Repeat for all the leads. Add small amounts of solder as needed to the soldering iron tip. Again, do not worry if you see some solder bridging as you will clean that up in the next step.

When soldering, keep the soldering iron tip parallel with the pins being soldered to prevent excessive solder shorts.

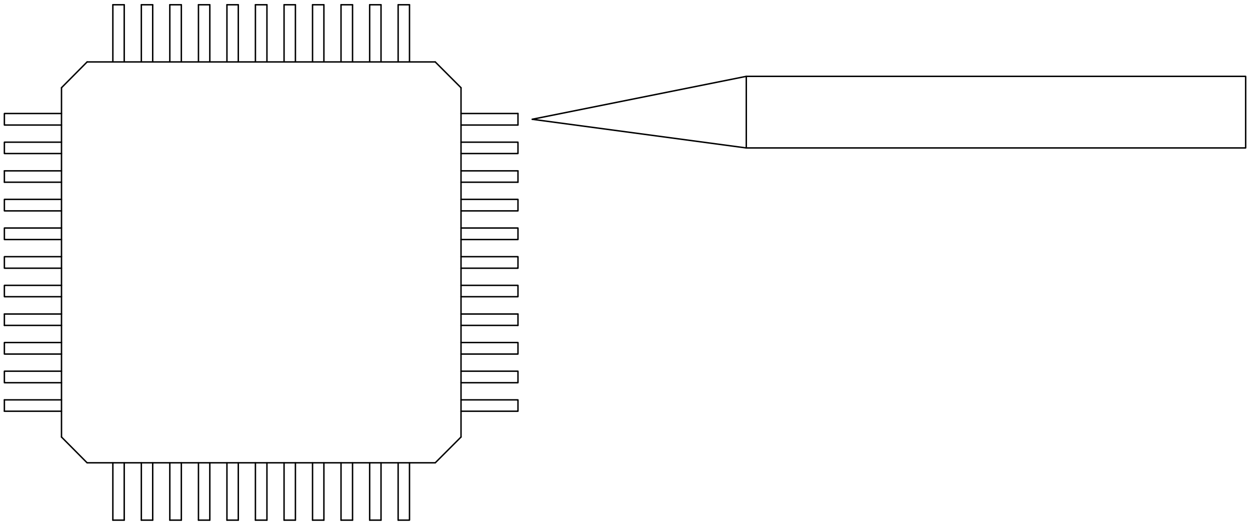

Figure 29. Keep iron tip parallel to pins being soldered

After soldering all the leads, wet all the leads with flux to enhance the solder wicking cleanup. Wick up solder where needed to eliminate any shorts/bridging.

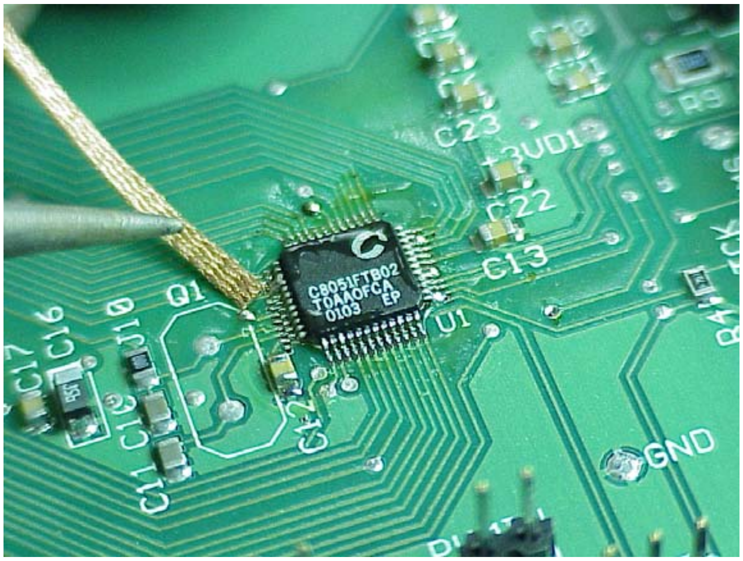

Figure 30. Wicking Solder #1

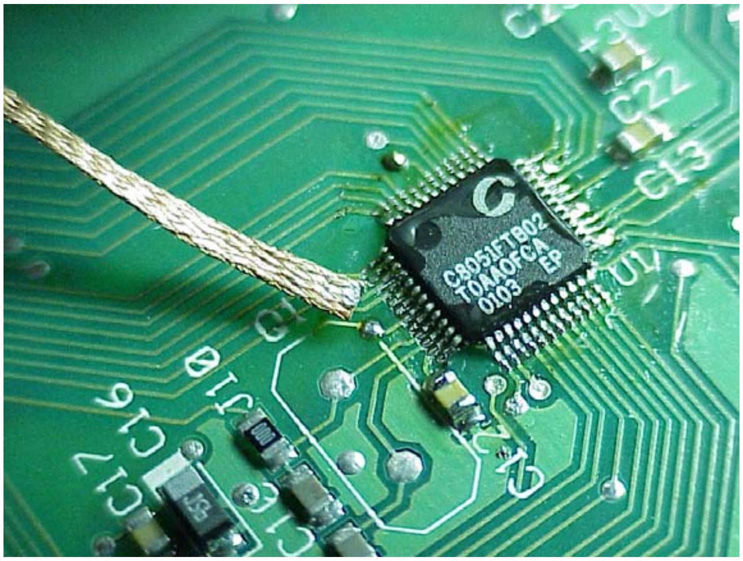

Figure 31. Wicking Solder #2

Hand inspect the board using 4X magnification (or higher) for shorts or marginal solder joints. Solder joints should have a smooth melt transition between each device pin and the PCB. Rework any pins as needed

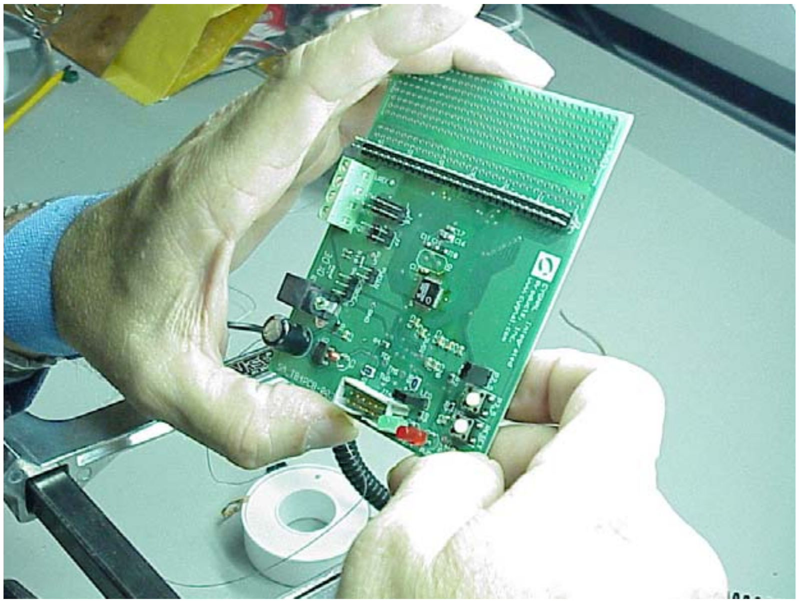

Figure 32. Visual Inspection

After the inspection passes, it is time to clean the flux off the board. Dip the stiff bristle brush into alcohol and wipe in the direction of the leads. Use moderate, but not excessive pressure. Use liberal amounts of alcohol and brush well between the QFP leads until the flux disappears.

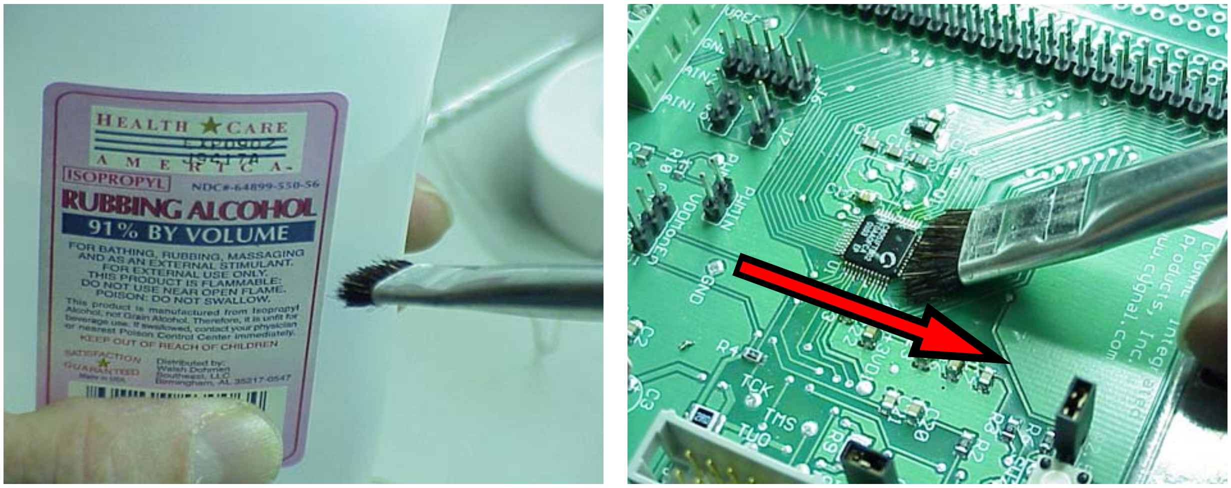

**Figure 33. Isopropyl Alcohol and stiff brush used for cleanup.
Brush only in direction of leads**

Dry the board with compressed dry air or nitrogen. If this is not available, let the board dry for 30 minutes or more to let the alcohol evaporate under the QFP. The QFP leads should look bright and there should be no flux residue.

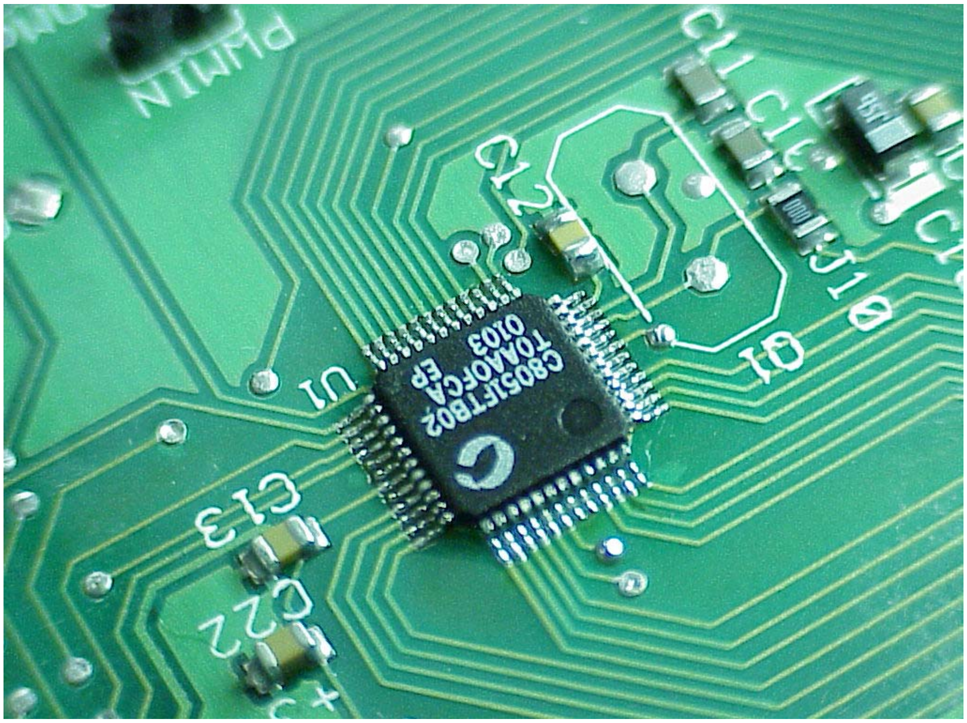
PWMIN
C11
C12
C1
J10
Q1
U1
C8051F0B02
TOAAOFCA
EP
0103
C13
C22

Figure 34. Clean and Pristine

Re-inspect the board for workmanship. Rework any leads if needed.

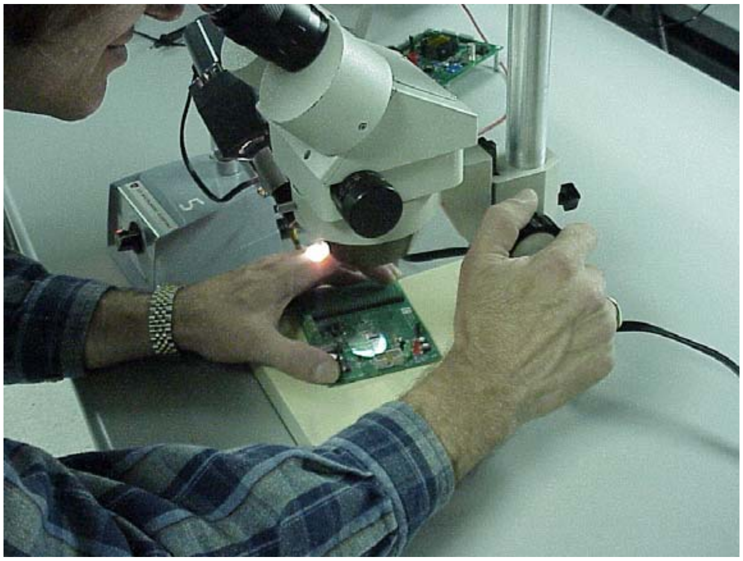

Figure 35. Stereo zoom inspection station (7X to 40X magnification) helps to inspect solder joint workmanship

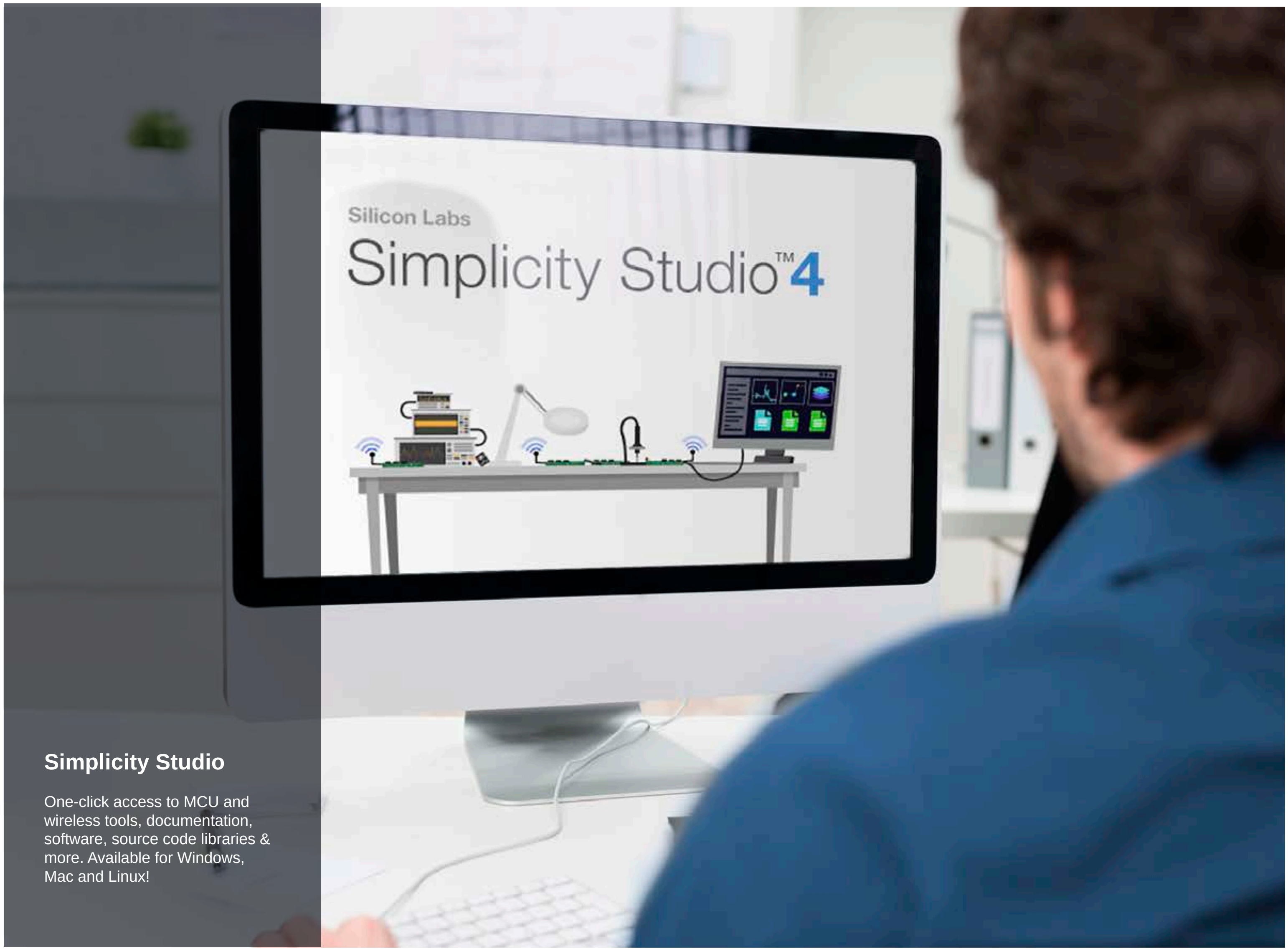

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Soldering Guidelines

Solder0 R0.1

EE400/1
Design

Revision History

Rev.	**Date**	**Contributor**	
0.1	September 2005	L. Wyard-Scott	Updates to reflect changed Capstone Design Course format and new de/soldering equipment.
0.0	January 2004	V.J. Sieben, L. Wyard-Scott, E. Tiong	Creation.

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Chapter 1

Soldering Technique

This guide is intended to give an introduction to basic soldering technique. If the reader desires to pursue advanced soldering techniques, there are several books as well as technical institutions that offer detailed courses in the area of soldering.

1.1 Required Tools

Before discussing soldering techniques, one should must set up a "soldering work station". The following is a list of tools for a typical soldering station. See Appendix A for pictures of the various parts listed below.

1. **Variable temperature soldering iron:** used for applying heat to joints during the soldering process.
2. **Damp sponge:** for cleaning soldering iron tip.
3. **Rosin-core solder:** to electrically and mechanically bond a component to the PCB.
4. **Wire cutters or side cutter:** for trimming component leads and stripping insulation from wires.
5. **Needle nose pliers:** for holding, placing and shaping components.
6. **Desoldering pump and/or desoldering braid:** for removing solder.
7. **Scotch tape and/or a "Third Hand":** for securing components.

8. **Safety glasses:** for eye protection. These are mandatory in the lab.
9. **Magnifier:** to provide more detail during intricate work. A magnifying glass is convenient, but an illuminated magnifier is better.
10. **Light source:** to prevent eye-strain.
11. **Ventilation:** to extract and dispel fumes generated during the soldering process.
12. **Flux:** to clean components and PCB pads.
13. **Acid brush:** to assist in the removal of flux residue.

Prior to soldering it is a good idea to have all components organized as it will make populating the PCB more efficient. Make a BOM (bill of materials) for the PCB, and ensure before soldering that the components have been collected. The schematic and PCB layout will also be referred to when populating the board.

1.2 Important Soldering Tips

The following tips provide a quick guideline on how to make proper joints.

Cleanliness: All parts, including the soldering iron tip, must be clean and free from grease, oxidation and contamination. Solder does not flow over contaminated areas; moreover, solder is repelled by dirt. Severe contamination is evident when solder begins to “bead”. A common source of contamination is oxidation. Old components and copper boards will often have an oxide layer that prevents a good solder joint. Ensure all components have shiny leads and the PCB has clean traces. An abrasive such as a blue or pink eraser, emery paper, or stell wool can be used to remove the oxidized layer from the PCB board and components.

Tinning: In addition to being clean, the soldering iron tip must also be tinned (coated with solder). Tinning the tip allows solder to flow on the components more quickly rather than the soldering iron tip itself. Tinning involves adding a few millimetres of solder to the tip and then wiping and rotating the tip on the damp sponge to reveal a shiny surface on the tip of the soldering iron: a thin layer of solder will coat or “tin” the tip of the soldering iron. **When done soldering,**

tinning the iron is required to protect the tip from oxidation thereby dramatically increasing its life.

Temperature: Ensure that both the component leads and the PCB's copper layer are heated at the same time. The soldering iron tip should contact both the component and the PCB pad. This will ensure that each surface is relatively close in temperature resulting in a good joint. If there is a temperature difference between the two surfaces, the solder will form a "dry" joint. Soldering irons are typically set around 650 Fahrenheit, depending on the lead-tin ratio of the solder being used. Too much heat causes excessive "sputtering" of flux, and too little doesn't melt the solder in a timely manner.

Duration: The duration that the iron is in contact with the component and PCB is dependent on the size of the joint and your soldering iron temperature. For the typical PCB through-hole joint, it should take a few seconds to heat the joint and apply the solder. This will require practice, so don't expect to be fast if you are a beginner. Excessive heat (several seconds in duration) will damage sensitive semiconductors. If this is a concern, use a heat sink attached to the component leads: sometimes as simple as an alligator clip. These concerns can sometimes be avoided by soldering sockets instead of the semiconductor itself.

Adequate solder coverage: If too little solder is applied, the joint will not make a secure connection and will cause erratic behaviour. However, if too much solder is applied, the joint may bridge with adjacent joints resulting in electrical shorts. How much solder to apply comes with experience. Figs. 1.4 through 1.7 show good and bad solder joints.

Handling: Most modern electronics systems contain static-sensitive devices. Use proper handling procedures to minimize the likelihood of damage: grounding wrist-straps, grounded soldering irons, grounding mats, etc.

1.3 Precautions

Soldering Irons get very hot (600-800^{0}F, 315-425^{0}C), please ensure you follow precautions during use. Basic safety precautions are listed below.

- Never leave your iron turned on while unattended.

- Turn the soldering iron off when it is not being used. If the iron is left on for long periods of idle time, the soldering iron tip will be destroyed through oxidation.
- Eye protection must always be worn when soldering. Hot flux can spit up and into an unprotected eye. **In the Capstone Design Lab, use of eye protection is mandatory.**
- If the cord of the soldering iron is damaged, inform the lab staff who will ensure it is replaced.
- Never set the soldering iron down on anything other than an iron stand.
- To prevent burning your fingers, use needle nose pliers, heat resistant gloves, or a third hand tool to hold small pieces.
- Familiarize yourself with the safe handling of all materials used during the soldering process. This includes solder, flux, alcohol, and desoldering braid. Each has a Material Safety Data Sheet (MSDS) and can be found in the lab or online. "Safe Operating Procedures" are found posted on the wall close to the soldering facilities.

1.4 How to Solder Through-Hole Components

Most of the soldering done in the Capstone Design Lab is through-hole. A through-hole joint is a type of soldering joint in which the component joins with the PCB pad through a physical hole in the board. The following steps will illustrate how to make a proper through hole solder joint on a PCB.

1. Ensure that the printed circuit board and all components are clean. Cleaning can be achieved with a mild abrasive and/or the application of flux.
2. Plug in the soldering iron, turn it on, and let it warm up for 2–3 minutes.
3. Wet the soldering station sponge with the water provided in the lab. Do not wet the sponge in the bathroom or the water fountain.
4. Clean the tip of the soldering iron and tin it with solder.

5. Insert the component into the holes. Ensure that the component is secure by taping the component or by using a third hand. Optionally, the component leads can be clinched as shown in Fig. 1.1. This technique, however, is not recommended for two-sided boards as the flow of solder to the component side is restricted.

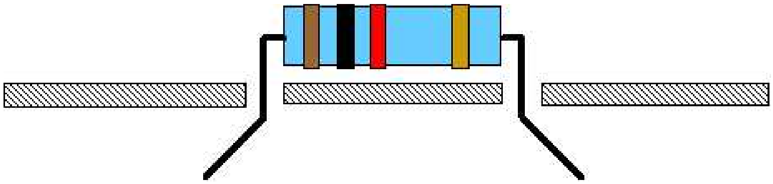

Figure 1.1: Clinched Component Leads

6. Apply the soldering iron tip to one side of joint making contact with the component lead and the board copper foil, ensuring that both are heated up to the same temperature as shown in Fig. 1.2 and Fig 1.3. Notice the tinned tip in Fig. 1.3.

7. Slowly add a few millimetres of solder to the other side of the joint. DO NOT apply solder to the soldering iron tip. If enough heat was applied to the PCB pad and component wire, the solder will flow freely onto the joint.

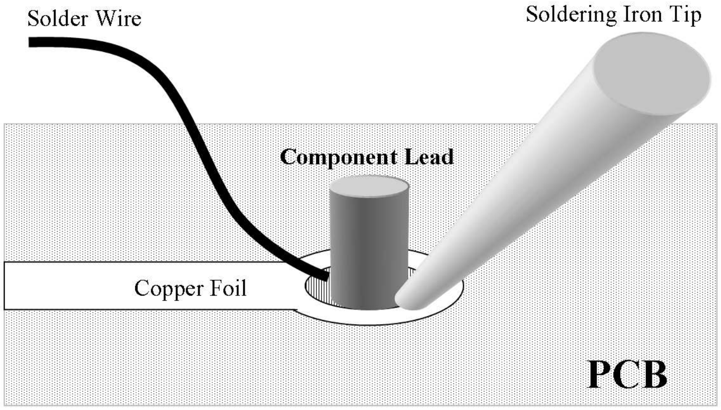

Figure 1.2: Method of Soldering Through Hole Joints

8. Remove the solder when the joint is suitably covered as shown in

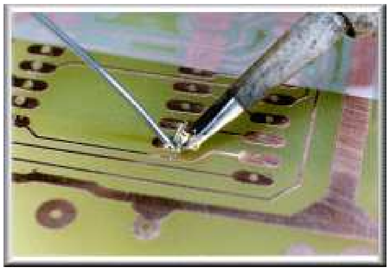

Figure 1.3: Method of Soldering Through Hole Joints, [8]

Fig. 1.4. The goal is to get the joint to be a “fillet”: a curve as shown in Fig. 1.4.

9. If the PCB is double-sided, the solder should flow through the hole around the component lead and make a bond on the component side of the board (opposite to the side that the solder was applied). If this “wicking” does not occur, the hole may be undersized, clinching could be blocking the solder’s path, or the component lead is not clean.

10. Remove the soldering iron and allow the joint to cool naturally.

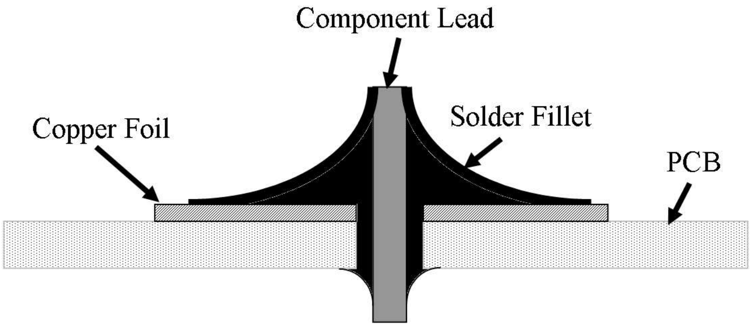

Figure 1.4: Good Solder Joint - Solder Fillet

11. Cut the lead of the component, if necessary.

Fig. 1.6 and Fig. 1.7 below are pictures showing good and bad solder joints.

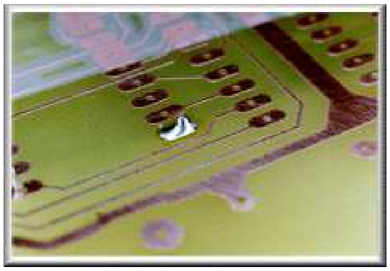

Figure 1.5: Good Solder Joint, [8]

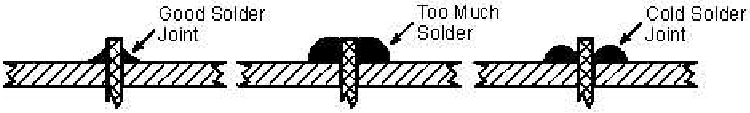
Good Solder Joint
Too Much Solder
Cold Solder Joint

Figure 1.6: Joint Examples, [3]

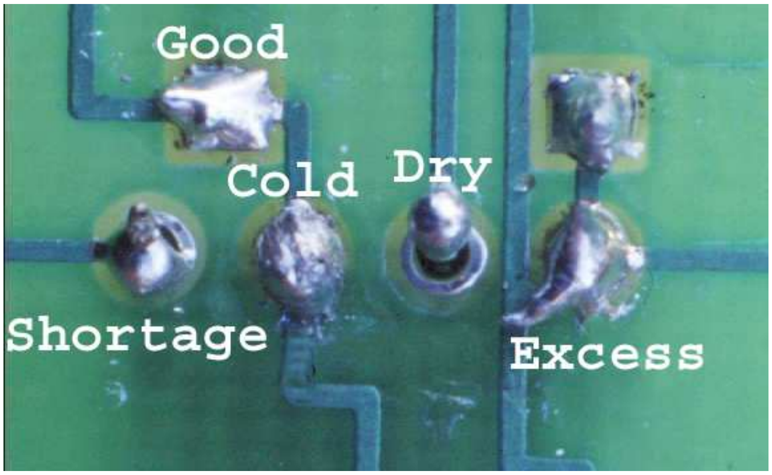
Good
Cold
Dry
Shortage
Excess

Figure 1.7: Joint Examples, [2]

1.5 How to Solder Surface-Mount Components

Surface mount soldering requires more experience and skill than through hole. It is recommended that one practices with through-hole prior to attempting any surface mount soldering. As the name suggests, surface mount involves soldering a component to either the top or bottom surface of a PCB. Depending on the footprint, the pads are usually a spaced closer together (finer pitch), making the soldering more susceptible to solder bridges, etc.

Figs. 1.8 and 1.9 show examples of good surface-mount solder joints.

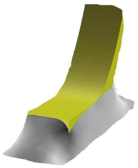

Figure 1.8: Surface Mount Good Solder Joint, [6]

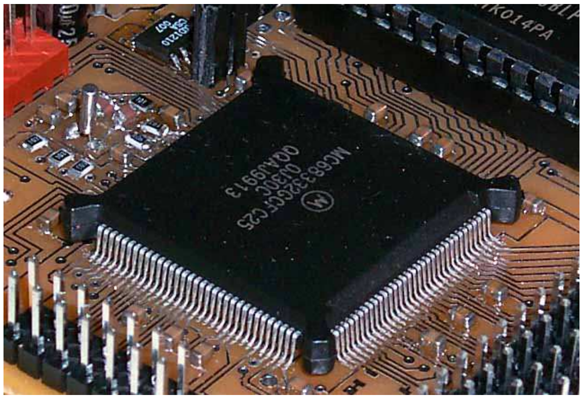

Figure 1.9: Surface Mount IC with Good Solder Joints, [5]

The actual soldering of the joints is similiar to the through-hole method. One difficulty, however, is maintaining the part's alignment on the PCB pads. A good technique is outlined here:

1. Align the component on the PCB pads. This can be aided with the use of tweezers and dental picks.
2. Secure the component to the PCB by applying a small amount of pressure onto the top of the component using a small slot screwdriver.

An index finger resting on the end of the screwdriver provides enough force to secure the device.

3. Solder one of the corner component leads to the PCB pad.
4. Align the remaining pads and solder the opposite corner PCB pad.
5. Solder the remaining pads in a pattern that does not build-up too much heat in the device.

1.6 Wire Connectors and Headers

When PCBs are manufactured they often have connectors to peripheral devices. These connectors are like other components in how they are soldered onto the PCB. However, the plug that matches the connector usually also requires some soldering. **Please note that with very few exceptions, the wire used for cabling is stranded (rather than solid-core) due to its higher strength and flexibility.** Below are procedures for a few of the more common plug types.

1.6.1 Crimp Connectors and Pins

1. Strip off about 1cm of the wire insulation.
2. Place the exposed wire into the crimp-style connector or pin. The wire should just barely show coming out the other side. Some crimp pins have two crimping areas – one for the stripped wire, and the other for the wire *with* the insulation.
3. Crimp the connector with the appropriate crimping tool. Note that the connectors are colour coded to settings on the crimping tool, try and match the correct colour.
4. As added insurance, apply solder to the joint to solidify the connection.

Before crimping all pins destined for a connector housing, start with one and ensure that it fits successfully into the housing. If the crimp is made too tightly, or otherwise mis-shaped, the pin may no longer fit.

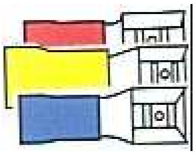

Figure 1.10: Colour Coded Crimp Connectors

Figure 1.11: Crimp connector without shrink wrap, [1]

1.6.2 DB Connectors (Solder Cup Type)

1. Strip off about 5mm of the wire insulation.
2. Tin the wire.
3. Slide shrink wrap on the wire.
4. Place the wire into the DB - connector solder end.
5. Apply the soldering iron tip to the connector and wire.
6. Apply a few millimetres of solder until the joint is adequately covered.
7. Let the joint cool.
8. Slide the shrink wrap over the joint and heat the shrink wrap with a heat gun (or other heat source) until the wrap shrinks around the joint.

1.6.3 Joining Two Wires

1. Slide shrink wrap on one of the wires.
2. Tin or coat each wire with some solder.
3. Join the wires in a way that provides a good mechanical connection (such as twisting together) and apply the soldering iron tip and some solder.

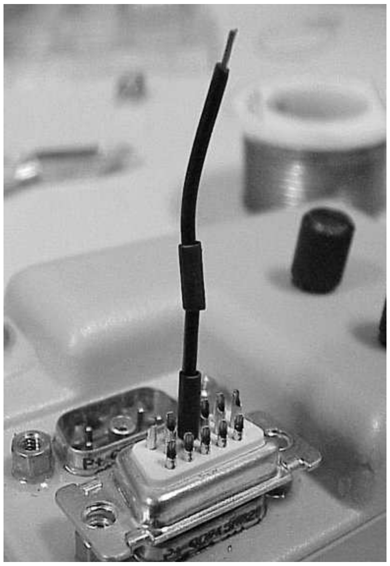

Figure 1.12: DB Connector with shrink wrap, [7]

4. Let the joint cool.
5. Slide shrink wrap over the joint and heat the shrink wrap with a heating gun or a heat source until it the the wrap shrinks around the joint.

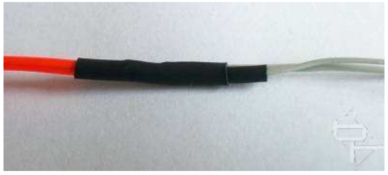

Figure 1.13: Two wire joint insulated by shrink wrap, [4]

1.7 Testing Connections

After completely soldering a component to a PCB, it is good practice to ensure connectivity between the component wire leads and the PCB pads they are soldered to. A DMM (Digital Multi-Meter) is sufficient to determine connectivity; many DMMs include an audible connectivity setting, but failing this, measure the joint resistance.

1.8 Milled Board Soldering

In-lab manufacture of PCBs uses a technique known as “milling”. The milling technique involves cutting out the PCB tracks and pads from the copper-clad board.

Due to its construction, a milled PCB is susceptible to solder-bridging across the milled grooves, particularly when an excess of solder is used. Finding a short caused by a bridge is a difficult task, particularly when many solder joints exist. To this end, make a limited number of solder connections and then test for bridges using a multimeter.

1.9 Post-Soldering Cleanup

1.9.1 PCB Cleanup

The flux left behind by rosin-core solders, or perhaps as part of the cleaning process, needs to be removed from the PCB. Due to the flux’s sticky nature, dirt gathers and contributes to short-circuiting problems. The most frustrating part of this situation is that a short does not necessarily occur immediately. Weeks, or even years later, a short can develop.

To remove flux, alcohol is used. Apply the alcohol liberally and then brush away with an acid brush, starting at the center of the PCB and working out toward the edges. This is a time-consuming task, but a clean board is well-worth the effort.

1.9.2 Work Area Cleanup

The importance of keeping your work area clean cannot be emphasized enough. When clear of obstructions and garbage, handling a hot soldering iron is safer. The soldering process itself involves chemicals and substances which are known to have ill-effects in humans. Wiping-down the work-area surfaces with a moist paper towel will help reduce some contamination. When you are done soldering, **wash your hands with soap and water** to get rid of contamination. The primary concern here is accidental ingestion of the chemicals. For more information, please refer to the Safe Operating Procedures, posted in the lab’s soldering area.

Chapter 2

Desoldering Technique

Desoldering may be required for several reasons:

- a component may have failed
- a wrong part was installed;
- a design modification necessitates a change; or
- if a board contains expensive components that can be salvaged.

Whatever the reason, there are three common techniques to remove solder from a joint: using a desoldering pump, a desoldering wick, or desoldering iron.

Regardless of the method used, if it is permissible to destroy the part during removal, then a lot of time and effort can be saved. For instance, using wire cutters to trim off all the pins of a through-hole IC so they can be removed individually makes the removal process much easier. In most cases, avoiding damage to the PCB is of paramount importance.

2.1 Solder Pump/Sucker

A desoldering pump is exactly what it sounds like: a pump that sucks up solder. Usually the pump is spring-loaded and provides a recoil when released. The four steps below outline how to desolder a joint using a desoldering pump.

1. Prime the desoldering pump. This involves depressing the desoldering pump spring. The pump will click when correctly depressed.

2. Heat the joint from one side with the soldering iron tip. Wait 1-2 seconds until the solder begins to melt from the soldering iron heat.
3. Put the pump tip on the other side of the joint. Don't be afraid to actually touch the joint.

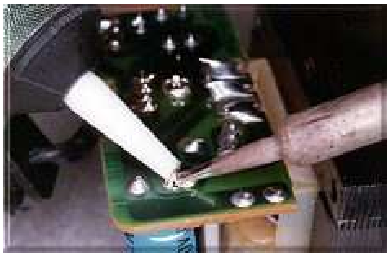

Figure 2.1: Desoldering with a Solder Pump, [8]

4. Press the desoldering pump spring-release button to suck up the solder.

This procedure should be repeated if the joint has a significant amount of solder. If done correctly the joint should eventually look as shown in Fig. 2.2 shown below.

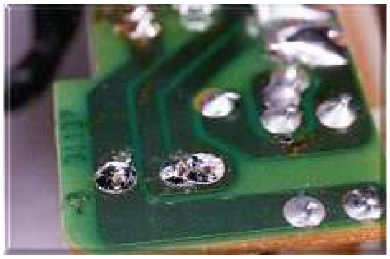

Figure 2.2: Clean Joint from Desoldering with a Solder Pump, [8]

2.2 Desoldering Braid/Wick

A desoldering braid removes solder from a joint using a technique known as "wicking". Desolder braid is a piece of material that sponges up molten solder by capillary action that draws solder away from the joint the braid. The following procedure outlines the basic steps involved in desoldering a joint using desoldering braid.

1. Place the desoldering braid over the joint.
2. Press the desoldering braid onto the joint with the soldering iron tip. This will apply heat to the desoldering braid and the joint allowing the molten solder to flow.
3. Wait for the solder to melt. The solder should flow onto the braid and away from the joint.

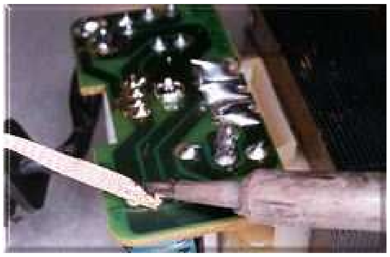

Figure 2.3: Desoldering with a Solder Wick, [8]

4. Cut off the solder coated portion of the desoldering braid. **There should be no copper visible in the portion that is removed: braid is very expensive.**

2.3 Desoldering Iron

Using a desoldering iron, available with higher-end soldering stations, is similar to using a solder sucker. The desoldering iron is essentially a soldering iron with a built-in vacuum.

1. Make contact between the iron and the joint to be desoldered, ensuring the vacuum opening is not blocked.
2. Once the solder on the joint has become molten, depress the button on the iron to activate the vacuum.

It is very important for the life of the desoldering iron that the vacuum assembly be cleaned after every session of use. Please ask the lab personnel for a description of the cleaning procedure.

As with a normal soldering iron, the desoldering iron tip should be tinned before and after every use.

2.4 Removing Components Effectively

To remove a component with little or no damage to the PCB or component takes practice and **patience**. Often when removing a component, PCB pads and tracks may be damaged by “lifting” off the board. Below are some tips that may be useful when removing components from a PCB.

- Desolder all joints pertaining to a component prior to removal. It may be necessary to go over the joints several times before all the solder is removed. Practice patience.
- Use pliers and *gently* pull on components while applying heat to the joints. The assistance of a friend can help with this.
- Do not pull with force, because the PCB pads and tracks will be damaged.
- Do not try and remove components by prying them.
- Do not try to push the component out of the holes with the soldering tip. This will certainly lift the copper pad off of the PCB and ruin the iron tip.
- In order to get better thermal conductivity between the iron and the solder joint, it is sometimes effective to *add* a small amount of solder.

Chapter 3

Glossary

BOM: Bill of Materials, which contains a list of all components and values contained on a particular PCB. Used as a “shopping list”.

Desoldering Braid: A material used to remove solder with capillary action.

Desoldering Pump: A device used to remove solder with a swift vacuum action.

Flux: Cleans the surfaces that are being heated by bringing contaminants to the surface. Most solders include flux in their core. For excessive contamination use a flux pen.

Footprint: The spacing pattern or layout of pads for a particular component or integrated chip, as used on a PCB.

PCB (Printed Circuit Board): A fibreglass board upon which copper traces are laminated to make connections between various components. The copper traces serve as flat wires connecting various components.

Shrink Wrap: A tube that fits over a wire, that when heated shrinks to provide insulation and support for the joints.

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[8] A. Winstanley. The basic electronics soldering and desoldering guide. Technical report, Feb 1999. http://www.epemag.wimborne.co.uk/solderfaq.htm.

Appendix A

Pictures of Tools

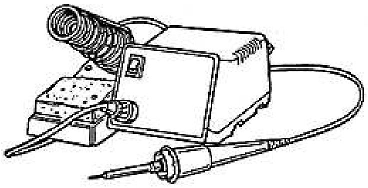

Figure A.1: Soldering Iron

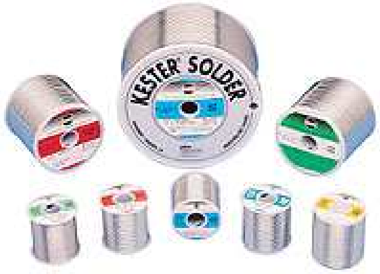
KESTER SOLDER

Figure A.2: Solder Wire

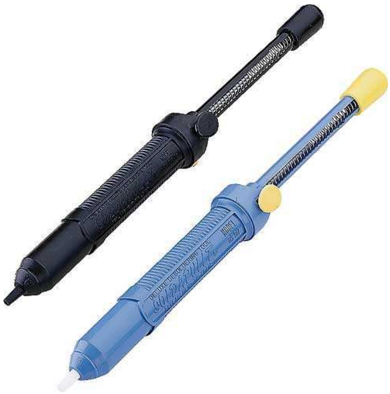

Figure A.3: Desolder Pump

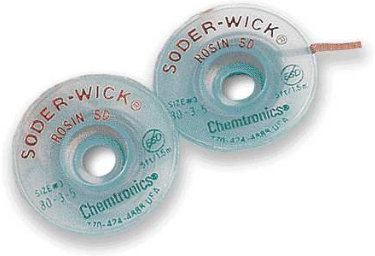

SODER-WICK®
ROSIN SD
SIZE#3
80-3-5
Chemtronics®
5ft/1.5m
SODER-WICK®
ROSIN SD
SIZE#3
80-3-5
Chemtronics®
5ft/1.5m

Figure A.4: Desolder Braid

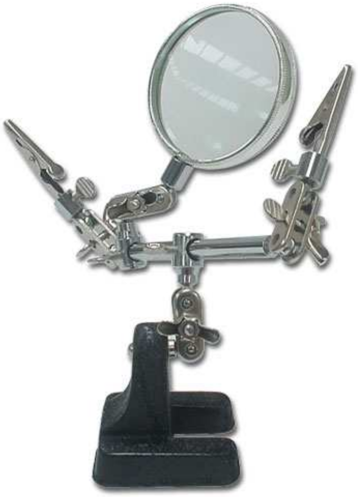

Figure A.5: Third Man

1

Soldering

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2

Introduction

Soldering is a process used for joining metal parts to form a mechanical or electrical bond. It typically uses a low melting point metal alloy (solder) which is melted and applied to the metal parts to be joined and this bonds to the metal parts and forms a connection when the solder solidifies. It is different to welding in that the parts being joined are not melted and are usually not the same material as the solder.

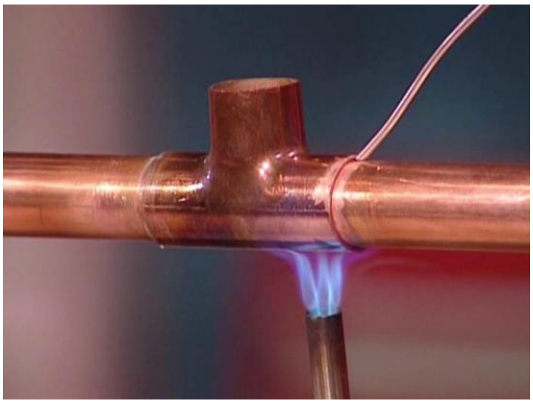	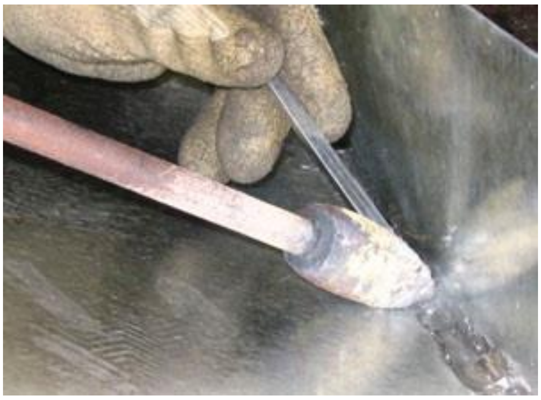
Soldering copper pipe	Sheet metal fabrication

Figure 1 – Different Types of Soldering

Soldering is a common practice for assembling electrical components and wiring. Although it can be used for plumbing, sheet metal fabrication or automotive radiator repair the techniques and materials used are different to those used for electrical work. This document is intended to provide guidance on the safe working methods and proper tools and techniques for soldering of electrical components.

1 Soldering Printed Circuit Boards

Soldering may be used to join wires or attached components to a printed circuit board (PCB). Wires, component leads and tracks on circuit boards are mostly made of copper. The copper is usually covered with a thin layer of tin to prevent oxidization and to promote better bonding to other parts with solder. When soldering bare copper wires they are often “tinned” by applying molten solder before making a joint.

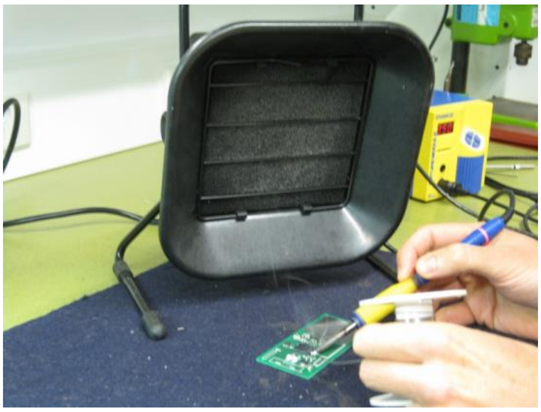	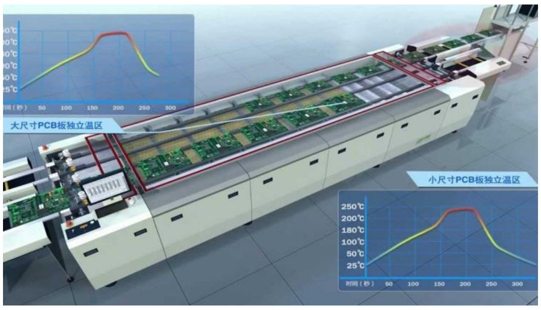
Hand soldering components on PCB	Industrial oven for surface mount

大尺寸PCB板独立温区
小尺寸PCB板独立温区
250℃
200℃
180℃
100℃
50℃
25℃
时间（秒）
50
100
150
200
250
300

Figure 2 – Different Types of PCB Soldering

2 Types of Solder

There are different types of solder used for electrical work. They are broadly classified as tin/lead solders or lead free solders. Tin/lead solders have been used for many years because of their ease of use however they have been phased out of commercial use due to the harmful effects on humans and the environment. Tin/lead solder is still available and is used by “hobbyists” and other non-commercial users as it is still easier to use than lead free types. When using tin/lead (or leaded) solder there are additional safety precautions that must be observed.

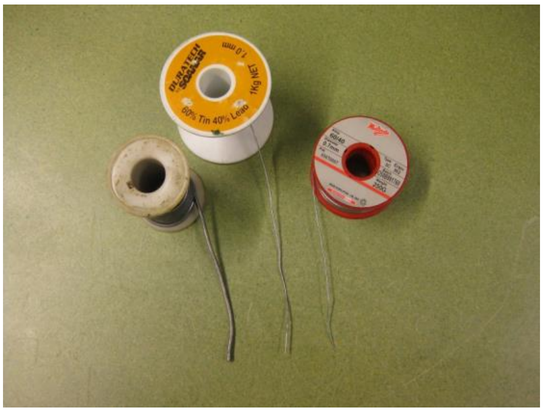	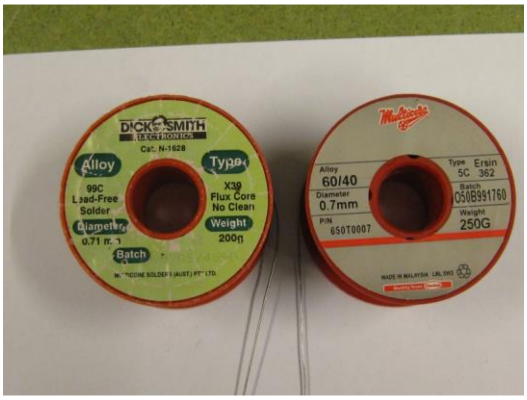
Different gauges of solder wire	Solder composition is labelled (Lead free on left)

Figure 3 – Different Types of Solder

3 Types of PCB

Printed circuit boards (PCBs) are populated by electronic components and these may be “surface mount” or “through-hole” types.

3.1 Through-Hole Components

As the description “through-hole” suggests, the leads of the component are passed through holes in the PCB and then soldered to a “pad” on the reverse side of the PCB. Soldering is accomplished by heating the component lead and PCB pad with a soldering iron and melting solder wire into the joint. This type of construction was common from the 1960’s until early 2000’s and is still used by hobbyists and in small scale production where manual assembly is preferred.

3.2 Surface Mount Components

Commercial circuits are mostly of the surface mount type as these are cheaper to make, more compact and easier to automate assembly. For surface mount construction the component’s pads are on the same side of the PCB as the component and the component connections sit onto these pads. Soldering is accomplished by applying solder paste onto component pads on the PCB, placing the component onto the paste and then heating the entire assembly to melt the solder. Commercial assembly uses ovens to heat the boards. Hobbyists can also use surface mount components and soldering can be accomplished by applying solder paste and melting with a hot plate, small oven or soldering iron. Some surface mount joints can be soldered using a soldering iron and solder wire.

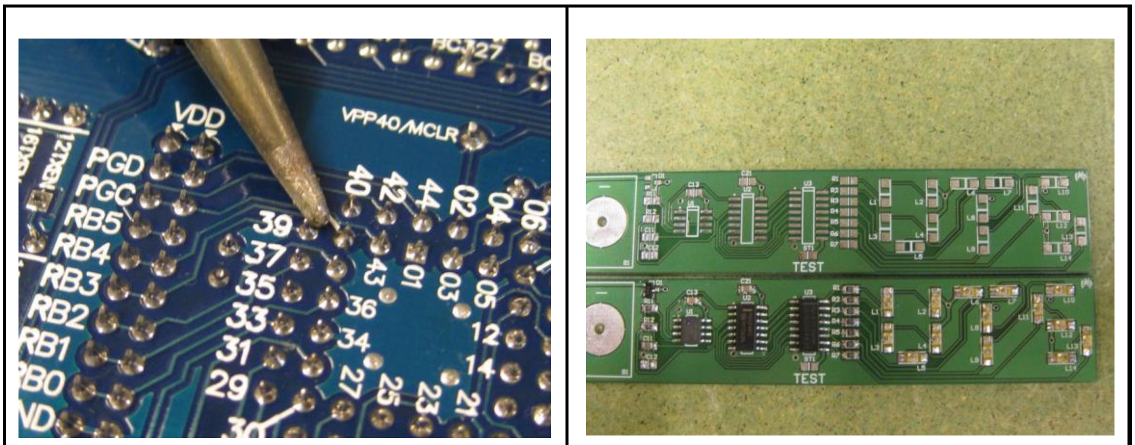

Through-hole PCB (non-component side)	Surface mount PCB (component side)

Figure 4 – Different Types of PCB

4 Flux

For electrical soldering both solder wire and solder paste contain flux. This helps to clean the surfaces being soldered and prevent oxidization of the hot solder. The composition of the flux will vary depending on whether it is in a paste or wire, leaded or unleaded solder. Solder wire usually contains a flux called “rosin”. Most fluxes will produce fumes when the solder is heated and these fumes are likely harmful to your health. For occasional soldering it may be sufficient to have a well-ventilated workspace but for longer or repeated exposure a fume extractor should be used. Solder flux can also cause solder to spatter and eye protection should be worn when soldering.

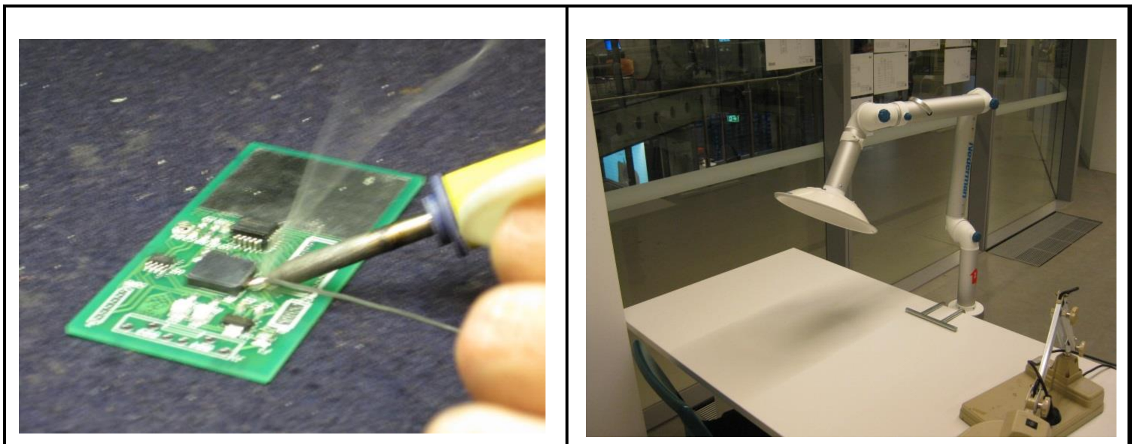

Fumes produced when soldering

Workstation with fume extraction system

Figure 5 – Fumes and Fume Extraction Systems

5 Soldering Irons

Soldering irons come in many varieties and sizes. Soldering irons may be electric, gas powered or externally heated. Most common types are electric. Simple electric soldering irons have no controls and you simply plug them in and wait for them to heat up. Their temperature is regulated by the power of the heating element and heat loss to the environment. Some soldering irons have temperature controls which allow the user to set a desired operating temperature for the soldering iron. This is useful if the soldering iron is being used for different types of solders which have different melting points or if the soldering iron is being used for other purposes such as heating heatshrink. It also introduces a problem if the user does not set an appropriate temperature for the work, solder can be overheated and decompose. Hotter is not better! A temperature of around 320 °C works well for 60/40 leaded solder. Some temperature controlled soldering irons use interchangeable tips to change the temperature at which they operate.

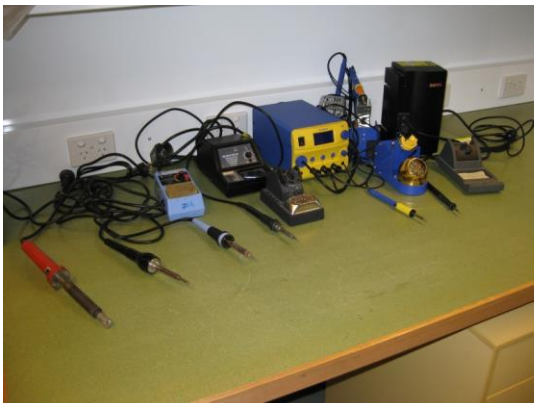	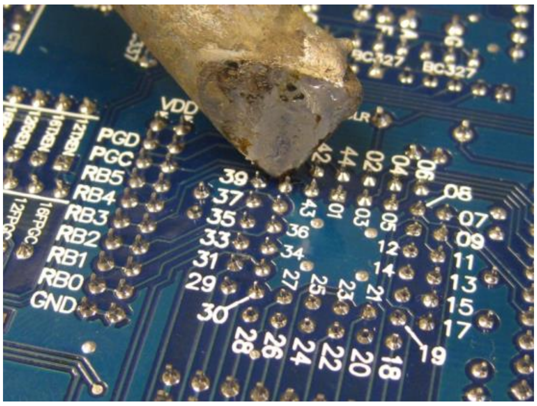 VDD PGD PGC RB5 RB4 RB3 RB2 RB1 RB0 GND
A range of electric soldering irons	Choose an iron appropriate for your task!

Figure 6 – Types of soldering irons

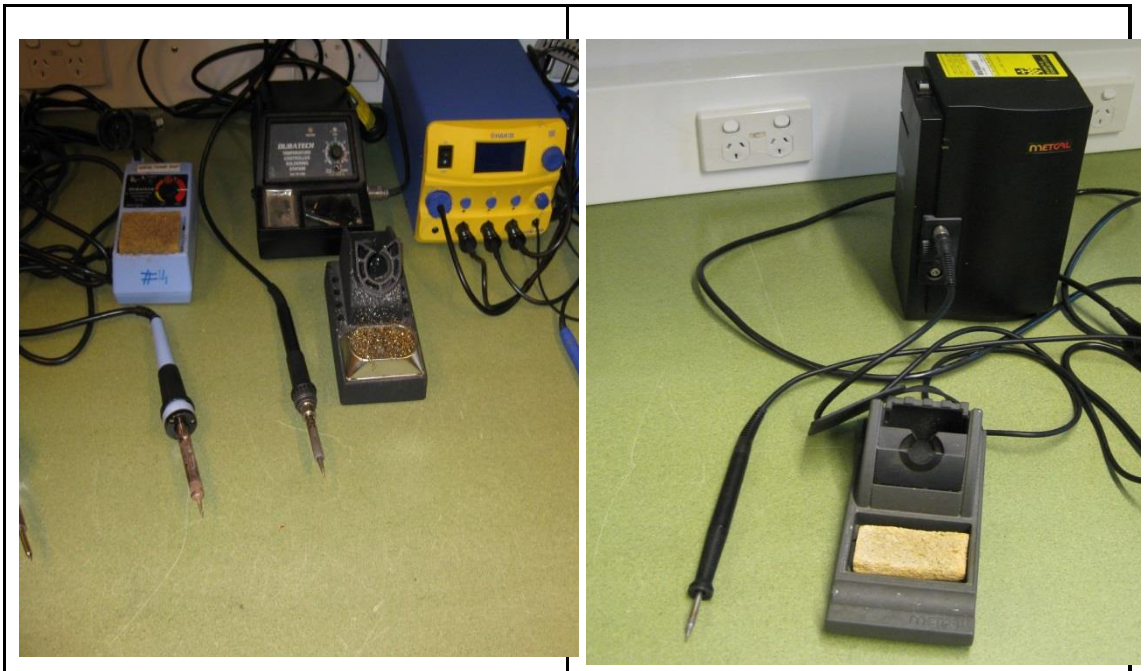

Adjustable temperature soldering stations

Different tips set the temperature for this station

Figure 7 – Types of soldering stations

5.1 Tips

Heat is transferred from the tip of the soldering iron to the joint by thermal conduction enabled by metal to metal contact between the tip and joint. The tips of soldering irons come in various shapes and sizes to enable the best contact to be made. Most tips are either conical or chisel shapes. The shape is largely a personal preference and you can use whichever type works best for you. The size of the tip should be selected to allow the tip to be placed against the joint being soldered without interfering with adjacent parts. The tip should be large enough to conduct sufficient heat into the joint to allow the solder to melt and flow properly. The choice of tip size is not a precise calculation and a “normal” size tip will work for most joints on a PCB.

5.2 Tip Contamination and Cleaning

The thermal conduction from the tip to the joint may be inhibited by contamination on the tip. This contamination can be formed by burnt solder flux or oxidized solder. To make best thermal contact the tip should be cleaned using a tip cleaner(!). Two types are a wet sponge or a brass wire wool. The wet sponge removes the contaminated material when the tip is wiped across it, the water in the sponge cools the solder and the mechanical abrasion removes the contamination leaving a thin coating of clean solder on the tip. This method can cause the tip temperature to dip momentarily. The brass wire wool type removes the contamination by mechanical abrasion and bonding contaminated solder to the brass. The tip is pushed into the brass wool and when it is withdrawn the tip is clean with a thin coating of solder. You must not “wipe” the tip on the brass wool type because the springiness of the brass wool may flick molten solder which may cause burns to people or objects. You should never “flick” excess solder from the soldering iron as this may also cause burns or damage.

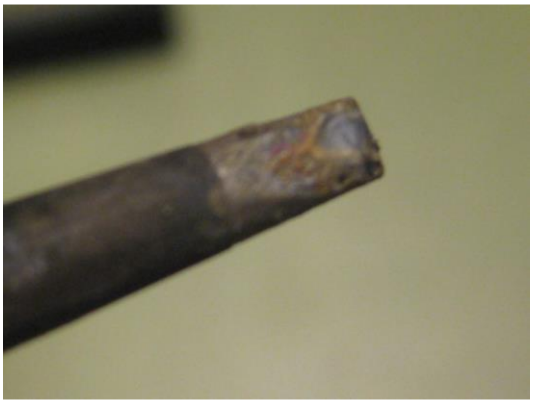	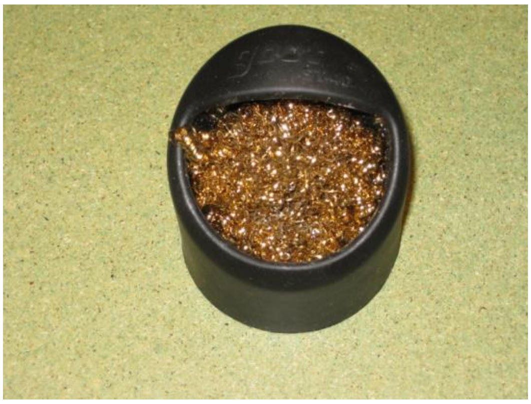
Tip contaminated with old solder and burnt flux	Brass wool type tip cleaner

Figure 8 – Dirty tip and brass wool cleaner

6 Ovens and Hot Plates

For surface mount soldering the heat is usually applied to the whole PCB and all components soldered at the same time. For commercial work this is done in large ovens, often with conveyors to move the boards through the oven. For small scale work simple infrared ovens are available. Another technique uses a hotplate. The same considerations for temperature apply, although because the heat source does not come into contact with the solder or flux, contamination is less likely. Time and temperature are considerations with these methods as the components are exposed to the high temperature for the period required for the solder paste to melt and flow.

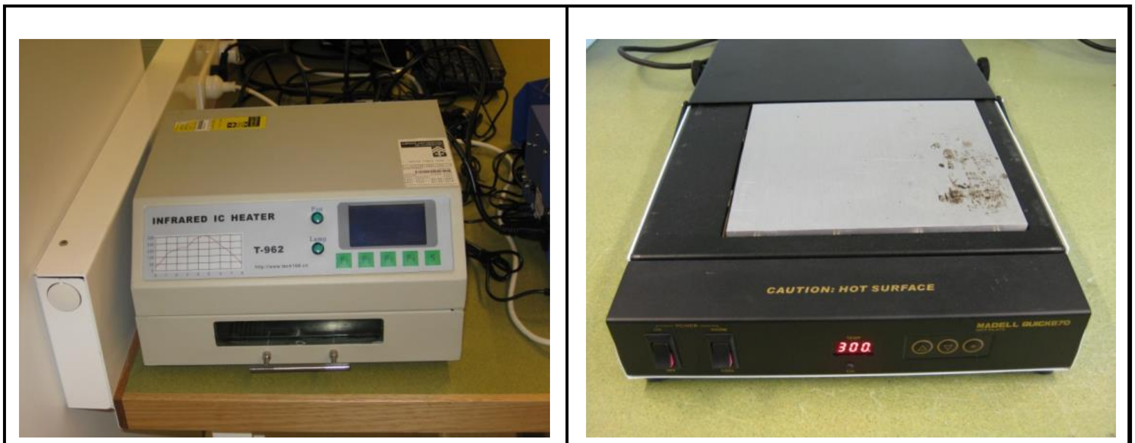

Infrared oven for surface mount soldering

Hotplate for surface mount soldering

Figure 9 – Oven and hot plate used for surface mount soldering

7 Desoldering

If a part that has been soldered needs to be replaced it needs to be “de-soldered”. Depending on the part and type of joint it may be possible to simply re-melt the solder and remove the part, or it may be necessary to remove the solder from the joint so the part can be freed. Some methods for removing solder are solder wick, solder sucker or de-soldering tool. Solder wick is a copper braid which is applied to the joint and heated with a soldering iron. As the solder in the joint is melted it is drawn into the solder wick like a sponge and is removed from the joint. A solder sucker is a spring loaded syringe or rubber bulb. The tip of the solder sucker is placed near the joint as the joint is melted by a soldering iron. When the sucker is operated a vacuum is created which draws the molten solder from the joint into the body of the sucker. A de-soldering tool is a type of soldering iron with a hollow tip and is connected to a pump or vacuum source. The tip of the de-soldering tool is placed onto the joint, typically over a component lead, and once the solder has melted the pump is operated to draw the molten solder away.

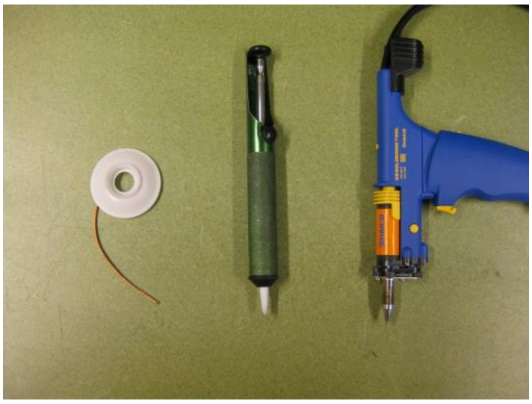	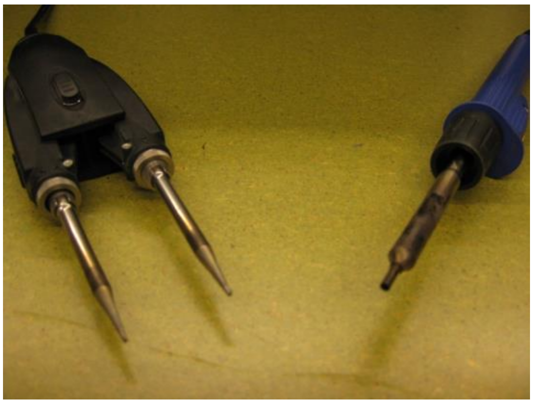
Solder wick, syringe type sucker, vacuum de-soldering tool	Hot tweezers or Hot air nozzle are options for SMDs

Figure 10 – Desoldering tools and tweezers for surface mount devices

8 Hazards involved in soldering

8.1 Heat

Although solder has a relatively low melting point this temperature is more than high enough to cause serious burns to people or objects. It is important to hold the soldering iron only by the insulated handle, never touch the heating element or tip when the soldering iron is on. The soldering iron will remain hot for some time after it is turned off so always check that it has cooled down before touching it, e.g. if changing the tip. When you are not soldering always keep the soldering iron in a proper holder so that you don’t touch it accidently and it doesn’t heat or burn other objects such as the benchtop. Don’t hold parts being soldered with your hands as these will also be heated when being soldered. Don’t flick molten solder from the soldering iron or wipe the tip on brass wool type tip cleaners.

If using a hot plate for surface mount soldering do not touch the hot plate. Use utensils such as pliers to place and remove PCB’s from the hotplate. If using hot air tools for soldering, de-soldering or rework, do not direct the hot air stream onto yourself or other people. If using an oven allow the PCB to cool before handling or use utensils. Don’t place hot PCB’s on temperature sensitive surfaces.

If burns occur they should be treated by holding under cold running water for several minutes and assistance sought if burns are severe. Incidents should be reported.

8.2 Toxic materials

Leaded solder contains lead which is a harmful material. Use of this type of solder will probably involve handling it and your skin may become contaminated by it. Although it is unlikely that the lead can be absorbed directly through your skin it may be ingested indirectly if it is transferred by handling food whilst your skin is contaminated. Always wash your hands thoroughly before eating or handling food.

Solder flux creates fumes when heated during soldering which may be harmful if inhaled. Use a fume extractor to avoid inhaling fumes.

8.3 Spattering

Solder and flux can spit or spatter when heated. Always wear eye protection (safety glasses) when soldering.

8.4 Electrical Safety

Electric soldering irons are plugin appliances and must have a current safety test tag. The test will confirm that the soldering iron conforms to electrical safety standards and has not been damaged at the time of the test. Before use you should visually check that the soldering iron does not have damage such as melted insulation on the lead, broken or cracked handle or exposed conductors. Don’t use damaged equipment and report the damage.

For electrical safety the exposed metal parts such as the tip and heating element are earthed. Don’t solder on any live equipment as contact with the earthed tip may cause damage to the equipment or soldering iron.

SMD Soldering

Information & Instructions

This is a walkthrough of a SMD Soldering Workshop. The following information and instructions can be used as a simple method for soldering SMD components. The recipient of this information should acknowledge the danger of soldering *(written on the back page of this pamphlet)* before attempting to solder.

Recommended Tools:

- Soldering Iron
- Solder
- Tweezers
- Solder Wick
- Flux Pen

① Add solder to one pad.

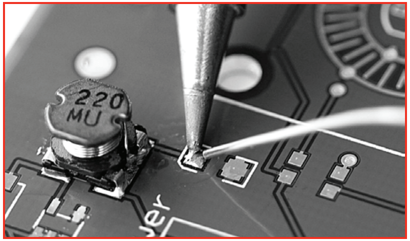

② While that pad is molten, slide the component into place. Do not push down from the top - slide the component into the blob of solder horizontally.

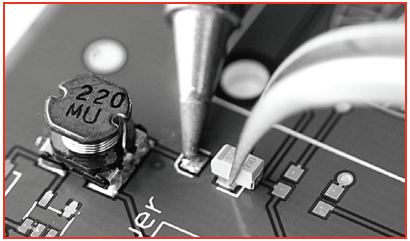

③ Align the component while connection is still molten.

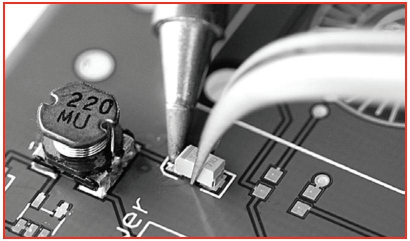

④ Once you have good alignment, continue to hold the component in place, and remove your iron. Continue to hold component for 1-2 seconds while the solder joint solidifies.

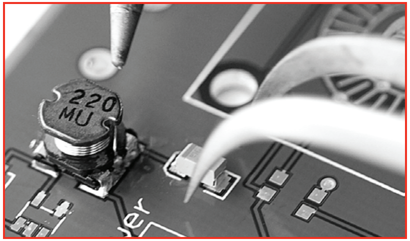

⑤ From above, the alignment looked good. From the side, you can see the rear pad is hovering slightly above the PCB. This can lead to problems on multi-pin components (open connections). Be sure the component is flush up against the PCB before soldering more connections. Re-grip the component, re-heat pad 1 and push the component flush against the PCB.

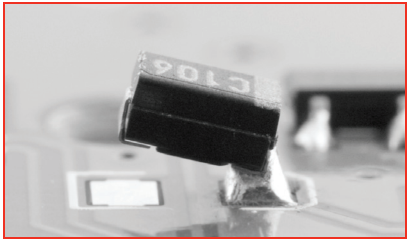

⑥ This is how a tantalum capacitor should look after making both solder connections.

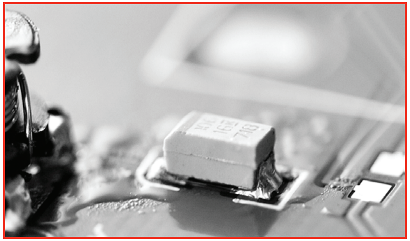

⑦ If alignment is not good, do not solder more than 1 pad! Re-heat the joint, re-adjust component until aligned correctly, then move on to soldering other connections.

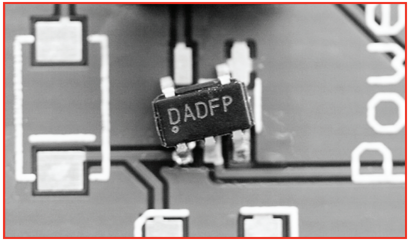

⑧ This is bad. It would be nearly impossible to finish the connections on this part. Make sure you have the component flush against the PCB.

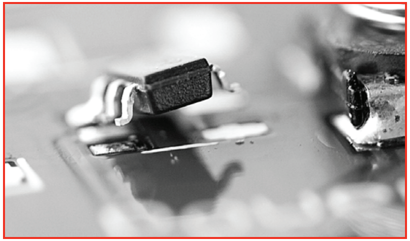

⑨ If you solder multiple pins together, don't worry about it! It can be easily fixed. Do not worry about jumpers! There are actually three pins under that blob.

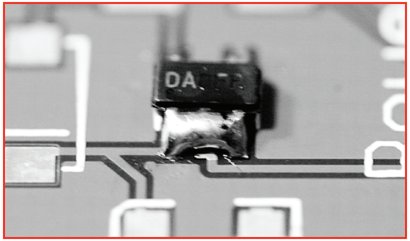

⑩ Pull out some solder wick. Put a small amount of solder on the end of your iron (this will transfer heat from iron to wick to the jumper). Sandwich the wick in between the iron and the solder jumper.

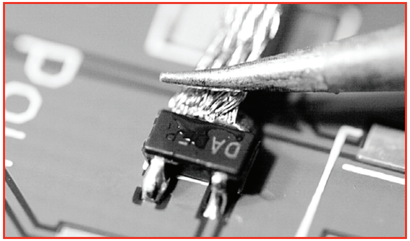

⑪ Hold still for 2-3 seconds. You will see solder start to flow up the wick. Once the excess solder has flowed into the wick, carefully lift up the wick and your iron in one fluid motion.

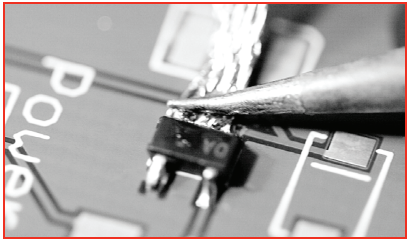

⑫ Nice and clean!

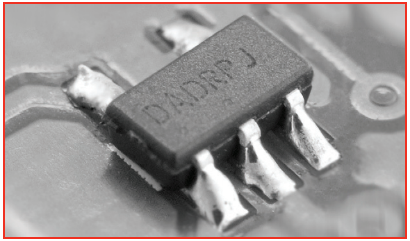

⑬ Bad bad bad. There was not enough solder for the connection on the left. Middle pin is lacking solder and should have been heated for longer. Right pin has had solder applied by an iron rather than applied to two metal contacts (the board and the pin).

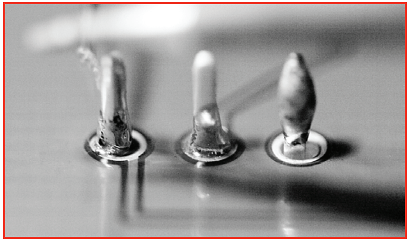

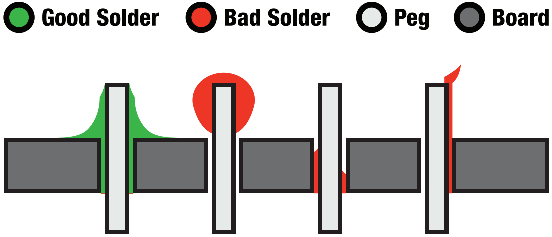

TIPS & TRICKS

	A	Solder flows smooth all the way to the bottom.
	B	Error: Solder balls up on top of pad, not connecting pin to pad. Solution: Flux then wick. If you wick too much add solder.
	C	Error: Too little solder makes for weak connection. Solution: Flux then add solder.
	D	Error: Bad Connection... and ugly... oh so ugly. Solution: Flux then add solder.

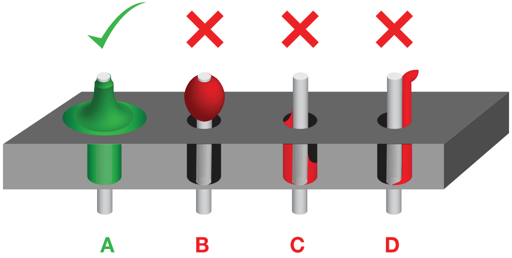

Safety Issues

Soldering

The tip of the iron is normally 700 °F, hot enough to melt metal. It is normal for the handle of the soldering iron to heat up a bit. Hold it like a pencil and move your hand further away from the tip if the heat is uncomfortable. The solder smokes because the rosin inside the solder is burning off - it's not harmful.

sparkfun.com

RoHS COMPLIANT PB

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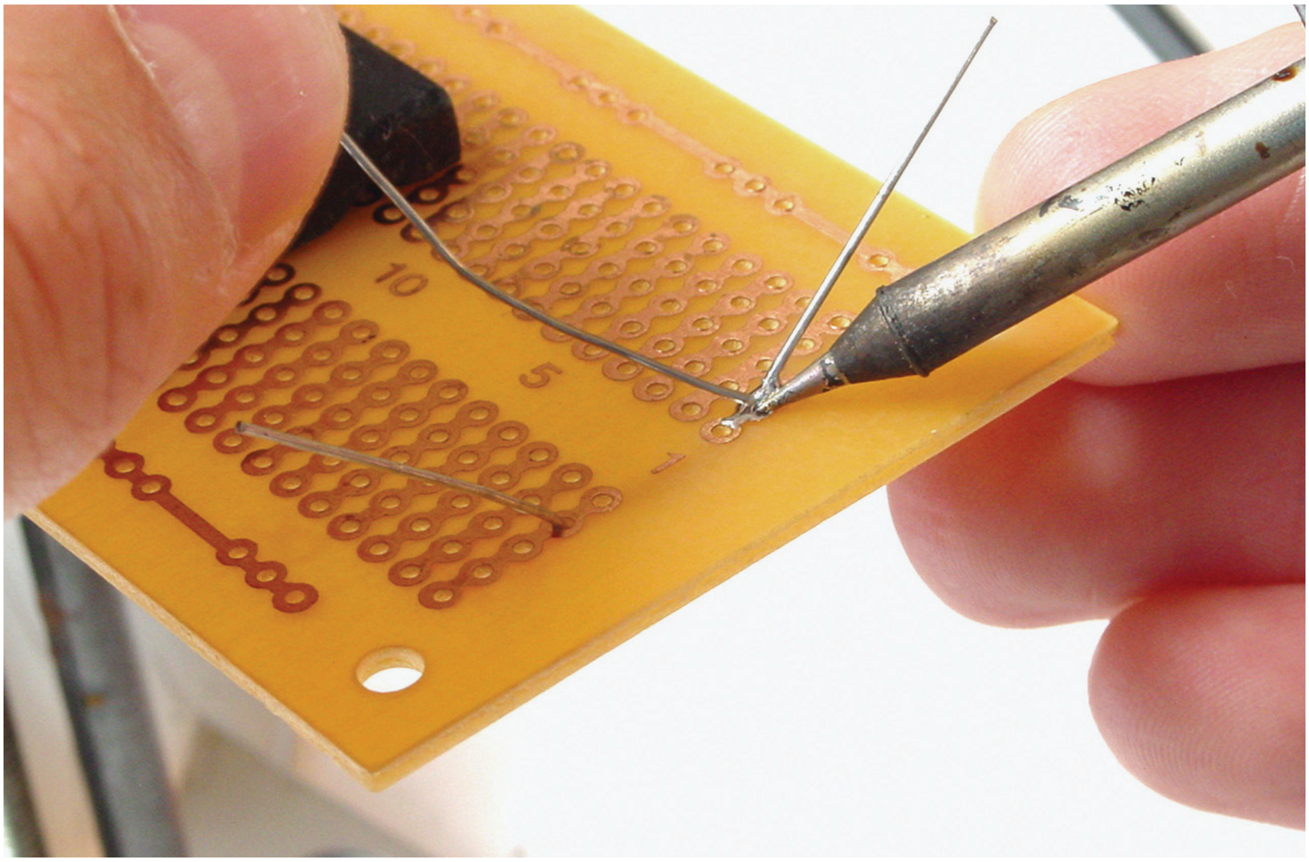

Soldering and Desoldering

Step-by-step instructions for making (and unmaking) the perfect solder joint.

By Joe Grand

The two key parts of soldering are good heat distribution and cleanliness of the soldering surface and component. With practice, you'll become comfortable and experienced with the process.

In this primer, I'll explain how to solder a component onto a printed circuit board (PCB). I'll also provide desoldering tips and show you how to remove a surface-mount component from a printed circuit board using a Chip Quik kit. And I'll show you how to remove a component by removing the solder in a way that won't damage the components or the circuit board.

Photography by Joe Grand

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OVERVIEW

TOOLS AND TIPS

Tools of the Trade

Soldering iron You could pay as little as $10 or as much as $1,000 for a soldering iron. I recommend a fine-tip, 700°F, 50W soldering stick iron. A good general-purpose iron for hardware hacking is the Weller W60P Controlled-Output Soldering Iron, which sells for under $70.

Solder Should be thin gauge (0.032" or 0.025" diameter) 60/40 rosin core.

Desoldering tool (aka solder sucker) A manual vacuum device that pulls up hot solder, useful for removing components from circuit boards. I like the one RadioShack sells (#64-2098, $10).

IC extraction tool Helps lift integrated circuits from the board during removal/desoldering.

Chip Quik SMD Removal Kit Allows you to remove surface mount components quickly and easily. Chipquik.com offers the kit for $16.

Sandpaper A very fine-grit sandpaper is useful for removing oxidation from component and circuit board surfaces.

Desoldering braid Woven metal material used to wick up melted solder.

Small, flat-tip screwdriver Comes in handy for removing some types of components.

Needlenose pliers, wire cutters, and vise These common tools will make your job easier.

The Chip Quik SMD Removal Kit

The Chip Quik SMD Removal Kit allows you to quickly and easily remove surface-mount components such as PLCC, SOIC, TSOP, QFP, and discrete packages. The main component of the kit is a low-melting-temperature solder (requiring less than 300°F) that reduces the overall melting temperature of the solder on the SMD pads. Essentially, this enables you to just lift the part right off the PCB.

INCLUDES
- Alcohol pads for cleaning the circuit board after device removal
- A special low-melting-temperature alloy
- Standard no-clean flux
- Application syringe

CHIPQUIK
CURITY
Alcohol Prep
2 Ply - Medium
CHIPQUIK
No-Clean Paste Flux

Desoldering Tips

FOR STANDARD THROUGH-HOLE COMPONENTS
- First grasp the component with a pair of needlenose pliers. Heat the pad beneath the lead you intend to extract and pull gently. The lead should come out. Repeat for the other lead.
- If solder fills in behind the lead as you extract it, use a spring-loaded solder sucker to remove the excess solder.

FOR THROUGH-HOLE ICs OR MULTI-PIN PARTS
- Use a solder sucker or desoldering braid to remove excess from the hole before attempting to extract the part.
- You can use a small, flat-tip screwdriver or IC extraction tool to help loosen the device from the holes.
- Be careful to not overheat components, since they can become damaged and may fail during operation.

BEFORE YOU START

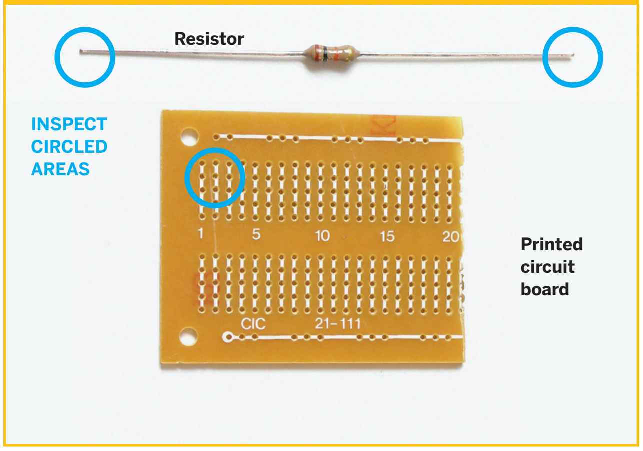

Joe Grand is the president of Grand Idea Studio, Inc. (joe@grandideastudio.com), a product-development and intellectual-property licensing firm. He specializes in embedded system design, computer security research, and inventing new concepts and technologies. He is also a host on The Discovery Channel's *Prototype This*.

SOLDERING

SOLDERING A RESISTOR TO A CIRCUIT BOARD

BEFORE YOU START

Inspect the leads or pins for oxidation. If the metal surface is dull, sand with fine sandpaper until shiny. In addition, use the sandpaper to clean the oxidation and excess solder from the soldering iron tip to ensure maximum heat transfer.

This simple example shows the step-by-step process to solder a through-hole component to a printed circuit board (PCB). I used a piece of prototype PCB and a single resistor.

⚠ DANGER: It's important to consider safety precautions. Improper handling of the soldering iron can lead to burns or other physical injuries. Wear safety goggles and other protective clothing when working with solder tools. With temperatures hovering around 700°F, the tip of the soldering iron, molten solder, and flux can quickly sear through clothing and skin. Keep all soldering equipment away from flammable materials and objects. Be sure to turn off the iron when it's not in use and store it properly in its stand.

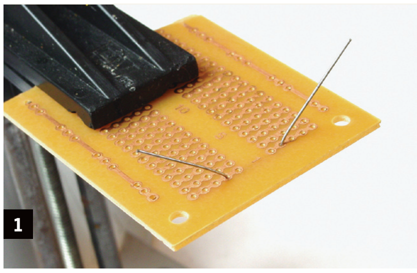
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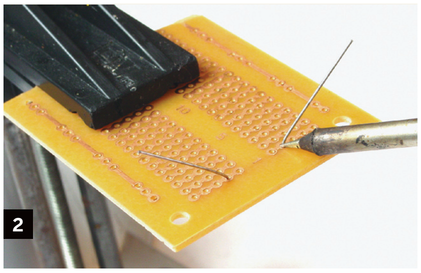
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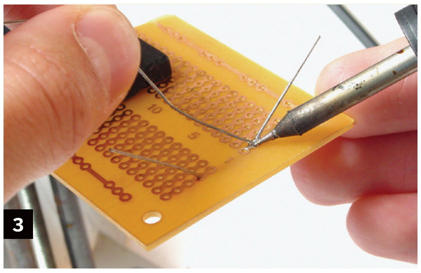
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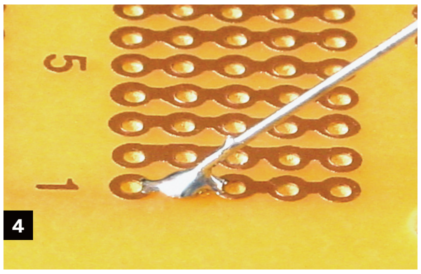
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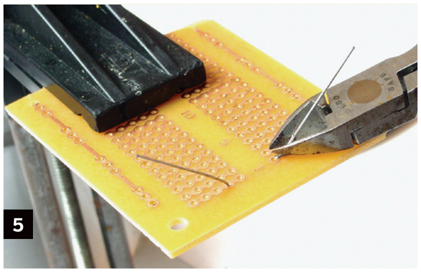
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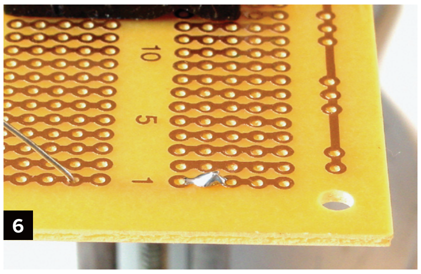
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1. Bend and insert the component leads into the desired holes on the PCB. Flip the board to the other side. Slightly bend the lead you'll be soldering to prevent the component from falling out when the board is turned upside down.

2. To begin the actual soldering process, allow the tip of your iron to contact both the component lead and the pad on the circuit board for about 1 second before feeding solder to the connection. This will allow the surface to become hot enough for solder to flow smoothly.

3. Next, apply solder sparingly and hold the iron in place until solder has evenly coated the surface. Ensure that the solder flows all around the 2 pieces (component lead and PCB pad) that you're fastening together.

Don't put solder directly onto the hot iron tip before it has made contact with the lead or pad; doing so can cause a cold-solder joint (a common mistake that can prevent your hack from working properly). Soldering is a function of heat, and if the pieces aren't heated uniformly, solder may not spread as desired. A cold-solder joint will loosen over time and can build up corrosion.

4. When it appears that the solder has flowed properly, remove the iron from the area and wait a few seconds for the solder to cool and harden. Do not attempt to move the component during this time.

The solder joint should appear smooth and shiny, resembling the image above. If your solder joint has a dull finish, reheat the connection and add more solder.

5. Once the solder joint is in place, snip the lead to the desired length. Usually, you'll simply cut the remaining portion of the lead that isn't part of the actual solder joint. This prevents any risk of short circuits between leftover component leads on the board.

6. Here's a completed soldering example.

DESOLDERING

SMD REMOVAL WITH CHIP QUIK

BEFORE YOU START

Use a rubbing alcohol pad to remove any residue from the solder pads. Verify that the solder pads are clean and free of cuts or solder jumps before proceeding. Desoldering, or removing a soldered component from a circuit board, is typically trickier than soldering because you can easily damage the device, the circuit board, or surrounding components. For surface mount devices (SMDs) with more than a few pins, the easiest method to remove the part is the Chip Quik SMD Removal Kit, as shown in the following step-by-step example.

PLEASE READ through this example completely before attempting SMD removal on an actual device. When removing the device, be careful not to scratch or damage any of the surrounding components or pull up any PCB traces.

THREE PRIMARY FUNCTIONS OF FLUX

- **Cleans metal surfaces to assist the flow of *filler metals* (solder) over *base metals* (device pins).**
- **Assists with heat transfer from heat source (soldering iron) to metal surface (device pins).**
- **Helps in the removal of *surface metal oxides* (created by oxygen in the air when the metal reaches high temperatures).**

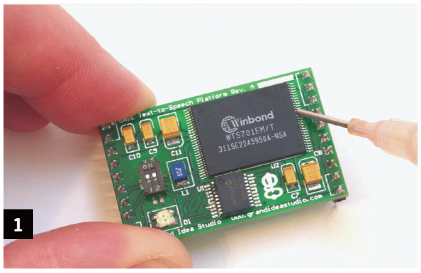
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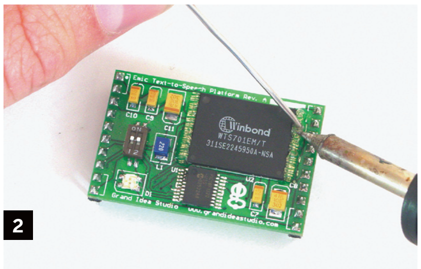
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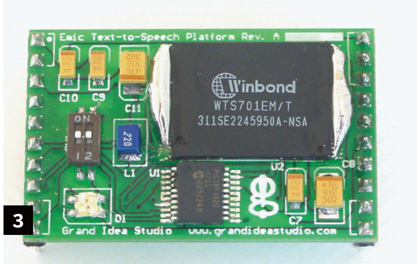
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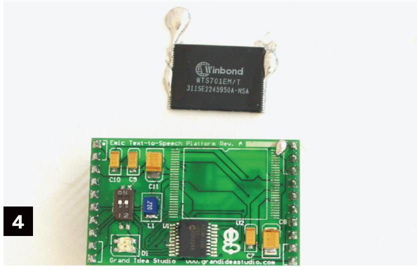
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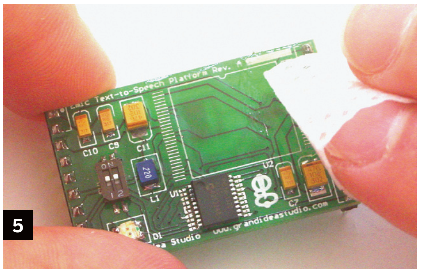
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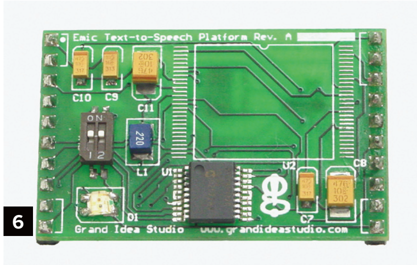
6

1. The first step is to assemble the syringe, which contains the no-clean flux. Simply insert the plunger into the syringe and push down to dispense the compound. The flux should be applied evenly across all the pins on the package you'll be removing. (Flux is a chemical compound used to assist in the soldering or removal of electronic components or other metals.)

2. Once the flux is evenly spread over the pins of the target device, the next step is to apply the special Chip Quik alloy to the device. This step is just like soldering: apply heat to the pins of the device and the alloy at the same time. The alloy has a melting point of approximately 300°F, which is quite low. You shouldn't have to heat the alloy with the soldering iron for very long before it begins to melt. The molten alloy should flow around and under the device pins. Starting at one end of the device, simply heat and apply the alloy. Repeat for the other side(s) of the device.

3. Flux will help ensure a nice flow of the alloy onto the device pins. Make sure the alloy has come in contact with every single pin by gently moving the soldering iron around the edges of the device. Avoid touching nearby components on the PCB with the soldering iron.

4. Now that the alloy has been properly applied to all pins of the device, it's time to remove the device from the board. After making sure that the alloy is still molten by reheating all of it with the soldering iron, gently slide the component off the board. You can use a small, jeweler's flat-tip screwdriver to help with the task. If the device is stuck, reheat the alloy and wiggle the part back and forth to help the alloy flow underneath the pads of the device and loosen the connections.

5. The final step in the desoldering process is to clean the circuit board. This step is important because it will remove any impurities left behind from the Chip Quik kit and get you ready for the next step.

First, use the soldering iron to remove any stray alloy left on the device pads or anywhere else on the circuit board. Next, apply a thin, even layer of flux to all of the pads that the device was just soldered to. Use the included alcohol swab or a flux-remover spray to remove the flux and clean the area.

6. The desoldering process is now complete. The surface-mount device has been removed and the circuit board cleaned.

TECHNOLOGY IN ACTION™

Building Your Own Electronics Lab

A Guide to Setting Up Your Own Gadget Workshop

Dale Wheat

For your convenience Apress has placed some of the front matter material after the index. Please use the Bookmarks and Contents at a Glance links to access them.

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Introduction

We're surrounded by electronics these days. Did you ever wonder how it all worked? Do you know just enough about electricity to be dangerous? Would you like to learn more? Then this book is for you.

There are many excellent textbooks on how electricity works. This is not one of them. This book helps you get started learning about electricity and electronics by showing you how to set up your own electronics laboratory. You might have guessed that from the title.

Along the way, several simple exercises are presented to show you some basic concepts about how electricity works in the real world—not just in a lecture hall. By the time you get done reading this short book, you'll have a good idea of where to begin and what kinds of tools and components you might need, and you'll have some excellent advice about how to keep it all organized.

Once you've got your own space set up to perform your electronic experiments, the sky is the limit.

Here's what you have to look forward to in this book, one chapter at a time.

Chapter 1: Planning Your Electronics Workshop

Your very own electronics laboratory is a great place to build, repair, invent, and learn more about electronics. We seem to be surrounded by electronics more and more every day. We can easily become dependent upon them, without even understanding how they work. Having your own electronics lab can help you gain some control over your electronic minions. Here you can learn about their inner mysteries, including how to repair them when possible or, better yet, improve them with your own custom modifications. You can also turn your own ideas into reality by building electronic circuits from scratch.

What will you need to plan your lab? What if you already have a basic understanding of electronics and the beginnings of a workshop at your disposal? This chapter helps get you going in the right direction.

Chapter 2: Building Your Tool Chest

You're going to need some tools in your lab, as well as the skills to use them effectively. This chapter will get you started.

If you're starting from scratch, don't worry. There's not a whole lot you absolutely *must* have to get started. Some basic hand tools and a place to keep them organized is all you will need. You don't even have to spend a lot of money at first. As you progress in your hobby, you will most likely want to add to your tool chest and upgrade some of those tools. Electronics can be the perfect hobby because it can take up (1) all your spare time and (2) all your discretionary income. What more could you ask for?

Chapter 3: Components

You're going to need some components to play with, as well as the knowledge to use them effectively. This chapter will introduce you to some of the bits and pieces that make up modern electric and electronic circuits. You'll also learn a little bit about how to identify components from their appearance and markings, when available.

Once you've got an idea about what these parts do in a circuit, you'll learn a little more about how to measure their electrical properties and put them to use. You'll also be shown what *not* to do, in some select examples.

Chapter 4: A Portable Mini-Lab

Having a portable (or at least (*trans*portable) electronics lab comes in handy in several circumstances. Maybe you don't have a place (yet) for a permanent home for all that equipment. Maybe you need to bounce at a moment's notice, heading off on electronic adventures at the drop of a hat. Or maybe you like to keep everything where you can find it in a hurry, without having to rummage through shelves and boxes, looking for just the right tool or component.

Whatever your motivation for wanting a portable lab at your disposal, this chapter should help you get started.

Chapter 5: The Cozy Corner Lab

You don't need an entire garage or extra office for a functional laboratory for your electronic endeavors. It's certainly nice if these areas are available to you, but you might be surprised at how much you can do in just a small space, if you set it up properly and maintain it with determination.

Chapter 6: The Small Group Lab and Classroom

The first part of this book deals with how to get along with electrons and make them do your bidding. In this chapter, you'll explore a completely different topic: other people, and how to get along with them.

You might not ever figure out how to get *them* to do your bidding, but at least you can keep them from stealing your tools. Maybe.

Appendix A: Getting Started with Tool Building

Once you've become comfortable in your lab and had time to play with a few circuits, you might start to notice that some of the "tools" you've been using are just simple electronic circuits themselves. Good examples are power supplies and meters. These are great tool-building projects because you can see useful results early.

This appendix takes a look at building a couple of simple electronic tools that might be of use in your lab. Hopefully you will develop a better understanding of how these tools work. Ideally, you will progress from the basic question of "Does it work?" to the more involved questions of "How well does it work and what can I do to improve it?"

CHAPTER 1

Planning Your Electronics Workshop

Are you interested in electronics? Would you like to set up your own “electro lab” to conduct amazing experiments, build crazy gizmos, and repair or modify your existing electronics? Then this book is for you!

Your very own electronics laboratory is a great place to build, repair, invent, and learn more about electronics. We seem to be surrounded by electronics more and more every day. We can easily become dependent upon them, without even understanding how they work. Having your own electronics lab can help you gain some control over your electronic minions. Here you can learn about their inner mysteries, including how to repair them when possible or, better yet, improve them with your own custom modifications. You can also turn your own ideas into reality by building electronic circuits from scratch.

What will you need to plan your lab? What if you already have a basic understanding of electronics and the beginnings of a workshop at your disposal? This chapter helps get you going in the right direction.

What to Expect

This book can’t teach you everything about electronics, and it doesn’t try. That would take several lifetimes. What it can do is introduce you to the tools and the skills you will need to set up your own electronics lab. This will include a very basic introduction to electricity, a little bit of theory, some safety tips, and a whole lot of example projects. It’s a great starting place. Where it will lead you is mostly determined by you and what you’re wanting to do with electronics.

If you’re already familiar with electricity and electronic concepts, there is still plenty of fun and interesting stuff waiting for you to explore. The field of electronics itself is constantly expanding. From the time this book was written to the time that you’ve finished reading this sentence, many advances will have occurred in both our understanding of electronics as well as the development of new applications and electronic devices. This is one of the many things that makes the study of electronics so interesting and exciting.

Every lab is different. Your lab will reflect not only your immediate electronics goals but also your personality. Feel free to pick and choose from all the ideas presented in this book and add in some of your own. The repair shop and the design studio are necessarily going to be arranged differently. There really is no right or wrong way to go.

Even the best laid plans, so the saying goes, end up somewhere unexpected. When planning your electronics lab for the first time, or for the tenth time, keep in mind that your interests, resources, and reasons for wanting to work on electronics are going to change over time. Please feel free to reinvent yourself and your lab as conditions permit. You might also be forced to reconsider your priorities when other factors in your life exert themselves. That being said, stay tuned for “A Cautionary Tale” at the end of this chapter.

Some configurations are more appropriate for certain endeavors, and nothing replaces the right tool for the job. This book should at least give you an idea of what is involved and get you pointed down the right road.

It Starts with a Plan

Most of the decisions you’ll make when planning your laboratory will depend on what *you’re* interested in doing there. Having a good plan at the beginning is like having a clear map when taking a long journey. It helps you from getting lost and also is handy for figuring out when you’ve arrived.

■ **Note** If you fail to plan, you plan to fail.

Remember, at this point in the game, you don’t have to make any final decisions about what you want to be able to do in your lab. This book is all about illustrating possibilities and giving you the information and advice necessary to branch out into the areas that hold the most interest for *you*.

A Broad Outline

Here’s what you need to get started: a little time, a small amount of space, some basic tools, and a few components. Those are the boring parts. The fun stuff includes your ideas, goals, and inspiration. Combine all that with some fundamental information about how electricity and electronics work, and you’re in business.

A Little Time

Like any good hobby, setting up your electronics lab and conducting experiments there is going to take up some of your time. For some, this is the *main reason* for getting started in electronics and building a lab: a place to escape, unwind, and tinker with ideas, prototypes, and complex systems. Maybe it’s your job. Maybe it’s your passion. Perhaps it’s a bit of both.

You’re going to need time to plan and build your lab. This book will spell out several specific arrangements for various-sized labs, but they are just examples and not hard-and-fast rules. More time will be required for obtaining the proper tools and materials that you will use there. Time will be spent not only *doing* things in your lab, but also in just *thinking* about doing things in your lab. For example, you might build a clever little gizmo that ought to do a simple task, only to find out that it refuses to work. You might need to spend a little bit of time thinking of ways of testing it to find out where the problem lies. This is sometimes called *troubleshooting* or *debugging*.

This is the basis of the scientific method. To help understand how something works, you first form a theory that would explain its behavior. Next you prepare one or more experiments that will demonstrate the accuracy of your theory. The experiments are conducted and their results are analyzed. If the results are in agreement with your theory’s predictions, then your theory is more than likely correct. If not, you may need to modify or extend your theory to accommodate the behavior observed. All of these things take time, which helps explain why we don’t have jet packs or time machines yet.

A Little Space

You don't have to start out with a cavernous underground bunker for your electronics lab. If you already have one, that's great. You might have an extra classroom available, some unused warehouse space, or an empty bench in a garage.

Then again, you might only have a corner of the dining-room table, and then only between mealtimes. That's plenty of room when you're just getting started! Once you learn more about electronics, and especially when you learn more about what it is that *you* want to do with electronics, then you can start looking for a more permanent home for your toys, tools, and spare parts.

The main points that will be stressed throughout this book when planning and working in your space are safety, good lighting, and organization, in that order.

- Your lab needs to be relatively safe for you, and *very* safe for your visitors and neighbors. The "Go Away!" sign on the door does not guarantee that you will be free from curious visitors, pesky and otherwise. People are naturally attracted to the creative and mysterious activities going on in your lab.
- Be prepared to buy, build, or borrow more lighting, because you're going to need it. Proper lighting improves the quality of your doodlings and tinkering enormously. You might think you already have enough light, and unless you were a photographer in a previous life, you don't. (Photographers understand that you can never have too much light.)
- An organized lab is a productive lab. Don't waste time looking for parts or tools when it would have only taken mere moments to put them in their proper places in the first place. A place for everything, and everything in its place. You get to decide where all these tools and bits get to live, so spend some time and do it wisely.

These three tenets will be repeated throughout the book, so you might as well get used to hearing about them.

Basic Tools

You really don't need a lot of tools to get started. There is a tendency to want to be a bit overprepared before tackling any new project, but it really isn't necessary when it comes to planning and building a new electronics lab. This is also true when sorting out a lab that's gone badly out of control.

You're going to be working with wire quite often. Claude Debussy has been quoted as saying that music is the space between the notes. It's the connections between the various electronic components that make the magic happen in an electronic circuit, in the same way that it's the relationships between people that make their lives so interesting.

The connections between all the various imaginable electronic components almost always start out as bits of wire. These connections can then be optimized into copper traces etched on a printed circuit board or even as metallization links in an integrated circuit. You're going to be working with a lot of wires in this hobby, and that usually boils down to two basic hand tools: *wire cutters* and *wire strippers*.

A wire cutter does what it says and says what it does: it cuts wire. A wire stripper is a more specialized tool that helps remove the outer layer of insulation from a wire. Ever more specialized versions of both tools abound. Some tools aim to perform both tasks at once, while never perfecting the art of either.

Resist the temptation to use your teeth for cutting and stripping wire. If you're caught in a situation without proper tools, use your fingernails. They grow back faster than teeth.

■ **Tip** Use the right tool for the job. Knowing which tool is the right tool is half the battle.

If you're performing detailed work on smaller circuits, you might benefit from having some small needle-nosed pliers, a small vise, clip, or helping-hands jig, and possibly a magnifying glass.

A popular and handy skill in the electronic arena is *soldering*. Soldering is the process of making electrical and mechanical connections. This is done by heating the items to be joined together and adding solder. The solder melts and fills in all the gaps between the items being joined. Once cooled, the solder forms a solid, conductive link.

■ **Note** Soldering is similar to welding, with the exception that welding actually melts the parts being joined.

A suitably sized soldering iron and the right kind of solder are indispensible for many projects, including repair, prototyping, and production. Picking up the skill to make quality connections is obtained in the same way as all worthwhile skills: with lots of practice.

Besides these basic fabrication tools, you will also want some *test and measurement equipment*. These are devices used to measure various aspects of electrical circuit behavior. These range from the very simple, such as voltage meters, current meters, and continuity testers, to the very exotic (and sometimes expensive), which include oscilloscopes and various logic, network, and signal analyzers. See the Appendix for information about building your own simple test equipment for your lab.

This is just a quick summary of the kinds of tools you might want in your electronics lab. Chapter 2 goes into much more detail about the tools you will probably need or want in your lab, as well as the skills needed to operate them safely and effectively.

Fundamental Components

As mentioned in the previous section, you're more than likely going to be wiring up various contraptions and rewiring others. This is probably going to involve a lot of wire.

For small voltages and currents, small-gauge insulated copper wire is often used. It's easy to handle, cut, and splice. This can be done with mechanical connectors such as wire-nuts or screw terminals, as well as with soldering.

Back in the day when computers were all connected using fat cables, lots of tiny wires were bundled up into cables and snaked all over a typical desktop computer installation. With the increasing popularity of wireless devices, those fat, juicy cables are lying around, discarded, unwanted, and just waiting to be harvested for their valuable conductors. You can also buy various kinds of wire in all colors and sizes from most hardware stores and from online suppliers.

Now consider the types of projects you'll be working on:

- If you're most interested in building your own lighting, you're going to want some lightbulbs, sockets, and LEDs, or whatever lighting technology appeals most to you. Don't forget that you're also going to need switches, knobs, dimmers, housings, plugs, and *more wire*.

- If you like to work with things that move, you're going to need motors, relays, solenoids, servos, and fans. You'll probably be needing some gears, pulleys, chains, belts, shafts, and couplings, along with connectors, switches, controllers, position sensors, and *more wire*.
- If you're into making lots and lots of sound, you'll be needing speakers, headphones, microphones, pickups, transducers, transformers, amplifiers, connectors, jacks, plugs, and, you guessed it, *more wire*.
- Are computers and digital devices more to your liking? Be thinking about getting yourself a wide variety of chips, microcontrollers, software, cables, sockets, connectors, and still *more wire*.

Now you've got an idea of some of the different components you might want to have on hand, depending on what kind of inspiration happens to strike. You're going to need a place to keep all these different parts sorted. This will play a big part in the overall planning phase of your lab. Maybe your old fishing tackle box has enough room for your basic hand tools and enough secret compartments to hold an interesting variety of components. On the other end of the spectrum, maybe you need to start thinking about some industrial-grade shelving units or pallet racks. Now is the time to think about all these factors and start making the right kind of plans to help make your lab a successful one.

Again, this is just a quick summary of some of the types of components you might want to work on in your lab. Chapter 3 is going to take you much farther into understanding many of the more common electrical and electronic components that you are likely to encounter in your lab.

Ideas

Admit it: you've already got some ideas for cool projects that you'd like to be working on in your own electronics lab. That's great! You're well on your way to making those dreams a reality.

The best possible thing you could do with your ideas is to write them down somewhere. It can be as simple as a sketch on a piece of scrap paper or as formal as a complete set of project documentation. The important thing is that you actually get the idea across using either words or pictures in a form that you will be able to revisit in the future. This will be of immense benefit to you, as well as anyone else that might be interested in your ideas.

It's also a great idea to keep a log as you work on your projects. That's the perfect place to jot down those ideas as they come popping out of your brain. Be as detailed as you can be. You will thank yourself later.

Even if you don't already have a backlog of ideas jostling for your attention in the lab, it's still a good idea to keep a log and explore the things that interest you. Leonardo da Vinci kept detailed notebooks on almost every possible subject. Anything that interested him got written down, sketched, or diagrammed in his notes. Even today, people are still getting inspiration from his doodles (see Figure 1-1).

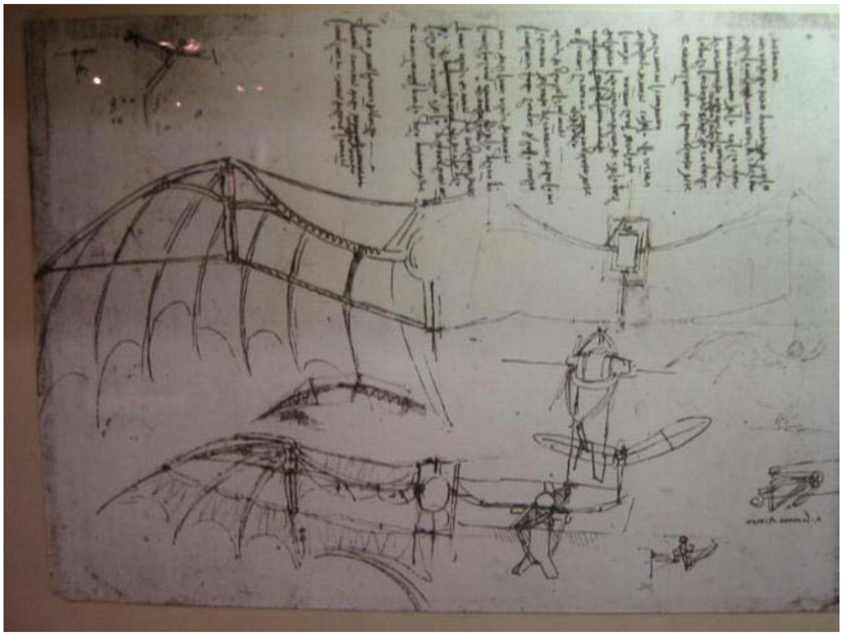

Figure 1-1. *Sketches and notes for a "flying machine" by Leonardo da Vinci. Photograph by Arnaud 25 (public domain), via Wikimedia Commons.*

Writing down your ideas also helps you pick which projects you want to work on first. It just isn't possible to work on all of them at the same time! Narrowing down the list helps get you focused and lets you concentrate all of your talents and energies on the most important projects.

When you're just beginning, the "most important projects" are the ones that provide the most positive reinforcement in the shortest amount of time. Plan a few simple, straightforward projects with a high probability of success at first. You can become more ambitious and take greater risks when you've built up a good reserve of self-confidence and techniques. Remember, the only experiments that fail are the ones from which you don't learn anything. Sometimes learning how *not* to do something is just as important as learning how to do it correctly.

Goals

The best way to turn great ideas into spectacular projects is to have a plan. Set some achievable goals for yourself. When you're first starting, don't be afraid to take those baby steps. You have to crawl before you can teleport.

Project planning is its own art form, and a dark and mysterious art it can be sometimes. It really helps to have clearly defined goals and expectations early in a project. Otherwise, how will you know when you're finished?

Any large, complex problem or project can be broken down into smaller, more manageable subprojects. Unfortunately, this can be carried too far. You don't need to reinvent the wheel every time you start a new project. There's a saying that suggests, "Don't build anything you can buy." The counterpoint to this wisdom is the equally ancient saying, "Don't buy what you can build." You'll have to be the judge as to which one applies best to you and your situation.

Do you have lots of time and very little money? This is good news! This helps simplify the decision-making process enormously. Design and build everything yourself, from scratch. This can include your own tools as well as custom-made components. The trick to this approach is not get lost in all the inevitable details that will arise.

No time to spare, but there's a bit of a budget available? This is likewise good news. With few exceptions, there's someone out there that's willing to part with just what you need for a reasonable price. The trick here is to find them and make that connection.

Inspiration!

Remind yourself what your inspiration is. What initially prompted you to start thinking about building your own electronics lab? Why did you want to get into electronics as a hobby or a career in the first place? Do you even remember?

It really helps to have a firm grasp on what your underlying motives are (or were) when faced with the challenges that regularly present themselves along the way. While it's true that some things just need doing, does it really have to be *you* that does them? Could you farm out some of the work and still feel a sense of satisfaction in the completion of the project? Or do you feel the need to take the do-it-yourself mind frame to its utmost limit?

Whatever your inspiration is, or wherever it came from, do your best to keep it in your sights while pursuing your dreams and goals. It makes it that much more satisfying when you eventually attain them.

How Electricity Works

There are two ways to go about learning how electricity actually works. The first involves just a whole bunch of *fascinating* theoretical information about atoms, electrons, fairies, and dragons. The second way is to just assume that it does indeed work, and spend some time actually putting it to work.

You don't need to know everything about electricity to have fun with it. A passing understanding is sufficient to get you started. As your technical requirements grow more elaborate, you will find yourself going back to revisit some of the basic concepts, until your comprehension is sufficient to carry you forward.

The Theoretical Approach

The prevailing theories about how electricity works center around the orbits of negatively charged subatomic particles called *electrons*. Electrons are quite small, even when compared to individual atoms. Electrons normally whiz around the *nucleus* of the atom, which is usually made up of other subatomic particles called *protons* and *neutrons*. The exception is hydrogen, whose most common isotope has only a single proton and no neutrons. Protons have a positive electrical charge and neutrons have no electrical charge.

When an atom has a balance of protons and electrons, it is said to be electrically neutral. If an atom has more electrons than protons, it has a negative electrical charge. Conversely, if there are more protons than electrons, the atom has a positive charge. An atom that has either a positive or negative electrical charge is called an *ion*.

While flying round and round the nucleus, electrons tend to cluster into well-defined orbits, or *shells*. The innermost shell of an atom can hold as many as 2 electrons. Once this orbit is "full," up to 8 more electrons can be accommodated in the next larger shell. The next shell holds up to 18 electrons, and the one after that can contain up to 32 electrons. After that, the shells get smaller again, stepping back down symmetrically from 18 to 8 to 2.

Each unique combination of electrons and protons represents one of the chemically distinct *elements*. Each element has its own particular chemical characteristics, and cannot be further subdivided by conventional chemical or mechanical means. Toward the end of the *periodic table*, which arranges all the known elements into meaningful rows and columns, you'll start to find some exceptions to the shell symmetry. These heavier elements, however, don't usually turn up in most electronics labs, so we'll not be spending a lot of time there.

Individual atoms can combine into more complex structures called *molecules*. One popular molecule is water, which is made up of two hydrogen atoms and one oxygen atom. Each of the hydrogen atoms has a single electron. The oxygen atom has eight electrons. The first two electrons in the oxygen atom occupy the first shell, leaving six electrons in the next outer shell. That leaves two "open" places in the second shell, which is where the two electrons from the two hydrogen atoms come into play. The electrons are shared by the three atoms, linking them all together and forming a *covalent bond*. Water has vastly different physical properties than either hydrogen or oxygen.

It's also possible to bump an electron out of orbit around a nucleus. When this happens, the atom becomes an ion and is electrically positive. This makes it especially attractive to any loose electrons that happen to be in the vicinity. This is because electrons are negatively charged, and in the case of electrical charges, opposites attract. This movement of electrons is how an electric charge flows through a substance.

Some materials are very good at slinging those electrons around, and as such are called good *conductors* of electrical energy. Examples of good conductors are copper and silver. Some materials resist the flow of electrical charge, and can be used as *insulators*.

An important concept to understand about the flow of electricity is that it is based on the movements of tiny, *negatively charged particles*. This is referred to as the flow of *electron current*, but this term is rarely used. For some reason, the more popular, or conventional, idea of electric current flow is from the more positive point to the more negative point in a circuit. This is referred to as *conventional current* and is the standard used throughout this book.

The fairies and the dragons come into the picture when you start to look any deeper into how the building blocks of matter are actually (or allegedly) constituted. The previous quick summary of how electricity works covers less than 1 percent of the physics needed to understand even how basic atomic principles operate. Even then there are various schools of thought as to how, *exactly*, all that tiny stuff works together to produce rainbows and cousins and moon rocks. A proton, once thought to be an indivisible *elementary particle*, is now thought to be built out of a "down" quark and two "up" quarks. There are also "strange" and "charmed" quarks flitting about, along with an entire pantheon of mythological particles. Go figure.

Now all of that *fascinating* information only scratched the surface of how *electricity* works. Electricity does a lot of work for us. We use it for lighting, heating, motion; just all kinds of things. *Electronics* is where we start to get into some really bizarre physics involving semiconductors, transistors, computer chips, and other miracles of the modern age. Explaining even the basic ideas about how *electronics* works is way beyond the scope of this little book. It's certainly possible to learn and understand it, but for the purposes of setting up a lab and building some example projects, we can just assume that it does indeed work. We can start from there and have some fun with it.

If your curious mind just can't stand *not knowing* how electronics works, the interwebs are your friends, and so are the helpful folks at your local library.

A Practical Approach

An easier way to think about electricity is to skip over *why* it flows and concentrate on *how* it flows. That's what we'll be doing in the remainder of this book, for the most part.

■ **Note** Electricity flows in a circle.

Any continuous flow of electrical current travels in a circle. There are exceptions to this broad generalization, but most of the example circuits encountered in this book will have a definite circular arrangement, if you know how to look for it.

Here are some technical terms that will be used throughout this book. You don't have to memorize any of them right now (there will *not* be a test), but you should at least take a glance at them so you know where to come back when you want to know more.

> *Circuit*: A circuit is anything that forms a continuous loop or circle. The term *circuit* is formed from the same Latin word that means *circle* or *wheel*.
>
> *Amps*: The *intensity* of an electrical current is measured in units called *amperes*, named after André-Marie Ampère. This is usually shortened to *amp* in popular usage. The symbol for amperage in a circuit is *I* (for intensity), while the unit is abbreviated *A*. For example, you could say that the intensity of the electrical current (I) in a circuit was measured to be 3.75A (amperes). Electrical current is measured with an *ammeter*.
>
> *Volts*: The voltage in a circuit is the measure of the difference in electrical *potential*, or how much work it *could* do. The unit of voltage is the volt (V), named after Alessandro Volta. This is sometimes referred to as pressure or tension. For example, a "high-tension wire" means a high-voltage line, not necessarily one that has been pulled really, really tight. Voltage is, not surprisingly, measured with a *voltmeter*.
>
> *Watts*: Electrical power is measured in watts (W), named after James Watt. The easy way to calculate watts, or the amount of energy that is converted into work (either useful or not) is to multiply the voltage across the circuit by the current flowing through the circuit. For example, if a 12V battery is connected to a lightbulb that draws 2A, the bulb converts the electrical energy into both light and heat (mostly heat) to the tune of 24W (12V × 2A = 24W).
>
> *Ohms*: The resistance to the flow of electrical current is measured in *ohms*, named after Georg Ohm. A *resistor* is a simple electronic component that exhibits a fixed resistance to the flow of electrical current. The symbol for resistance is *R* and the unit of measure is the capital Greek letter omega, Ω.

Safety

Make no mistake: electricity can kill you. It bears repeating, as well as emphasis.

■ **Warning** Electricity can kill you.

Working safely with electricity is like working safely with a sharp knife, for example. A good knife is a useful tool. Life would be cumbersome and crude (not to mention short) without good tools. However, when using *any* tools it's important to understand their proper use and operation. The same goes for electricity.

The point here is not to be overdramatic about the dangers of electricity. Billions of people are safely and peacefully coexisting with electricity, largely due to wise safety rules and well-designed electrical appliances. However, there are three major ways that you can be harmed when working around electricity, and it is important that you be aware of them:

- Your body uses tiny amounts of electricity to send nerve impulses to and from your brain. Sending relatively giant shocks of electricity through your body is a good way to stop your heart from beating or your lungs from breathing. You need to keep doing both of those things, so be careful.
- Since your body is not a very good conductor of electricity, it converts the electrical current into heat, which can produce very damaging burns, both on the inside and the outside of your body.
- Additionally, many electrically related injuries are sustained while trying to *get away* (i.e., your body's involuntary reflex when exposed to dangerous voltages).

Yet working safely with electricity is easy. Observe the following rules and you'll be relatively safe, both in your lab and outside of it:

- Always assume a circuit is "live." Electrical devices can retain lethal voltages even when completely disconnected from power.
- Don't work with high voltage (more than 36 volts) unless you're specifically trained. Reading this book does *not* mean you're "specifically trained," even if you read it *twice*.
- Don't short-circuit batteries (i.e., deliberately connect the positive and negative terminals together). Even very small batteries can hold dangerous amounts of power and can produce enough heat to burn you. Even worse, it can start a fire, which is yet another unpleasant way to die.
- Be careful when using metal (conductive) tools around battery terminals so that you don't accidentally short the terminals together or to other circuitry.
- Don't assume other people are aware of these dangers.

Lighten Up!

Now it's time to have a little fun with electricity, don't you think? While it's important to keep safety in mind, it's just as important to be curious and willing to try new things. Don't let the (important) safety rules immobilize your creativity. Use these rules, like any tool, to leverage your enjoyment of this fun and exciting hobby.

Let's start with a simple circuit that is almost guaranteed to lighten things up. Let's take apart a flashlight (or *torch* for you metric types) and see how it works.

First, find a typical household flashlight. The flashlight in Figure 1-2 was purchased for $3, and it included two new D-cell batteries. Put the batteries in the flashlight and make sure it lights up when you turn on the switch. If the bulb is burned out or the batteries are dead, then this experiment is not going to be much fun at all.

DORCY
Frost Brite
ClearView Design
TrueSpot Reflector
Modèle transparent
Réflecteur TrueSpot
DORCY
HEAVY DUTY

Figure 1-2. *A typical household flashlight will be the ~~victim~~ subject of our first electrical experiment.*

Once we've established that the flashlight works as intended, we can begin the experiment.

DISSECTING A FLASHLIGHT

We don't need most of the pieces of the flashlight body. Let's take it apart and have a look inside.

1. Open the flashlight be unscrewing the end with the lightbulb in it.
2. Remove the batteries. Set them aside for the moment. We'll use them in a bit.
3. Remove the plastic retainer that holds the bulb in the reflector.
4. Take out the bulb.
5. We'll need to replace the wiring that was contained within the flashlight's body. Find a short piece of wire 8" to 12" long. A specialized jumper wire with alligator clips on the end was used in the photos for this exercise, but almost any kind of wire will do. See Figure 1-3.

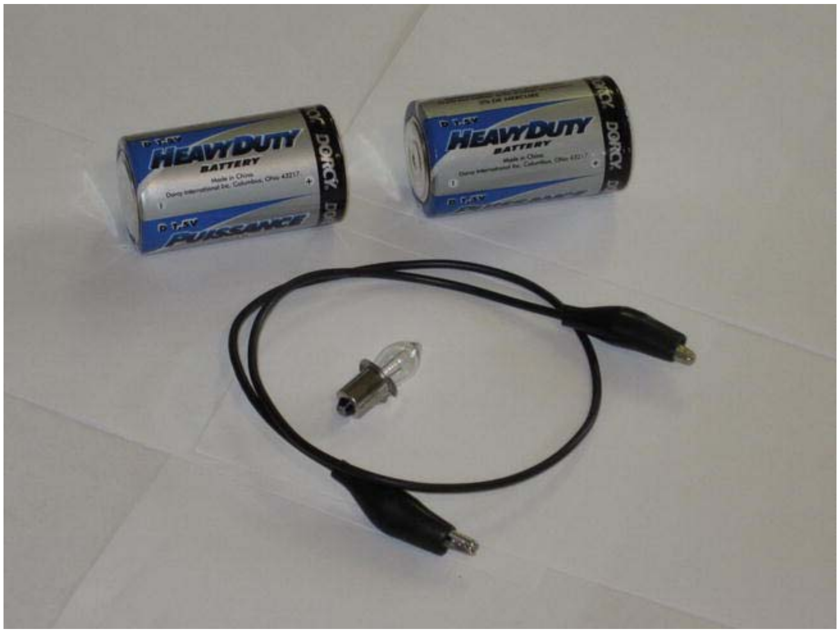

Figure 1-3. *All the pieces you'll need to light up the bulb.*

6. If you're using plain, insulated wire, you'll need to remove a small bit of it from both ends of the wire to expose the *conductor*, or metal wire part inside.
7. This step can be tricky. Try to hold both batteries in one hand, along with the bulb. The batteries need to be pointed in the same direction. If this is too hard to do, try it with just one battery.

8. The positive end of the battery has a small cap on it. Touch the bottom point of the bulb to the top of the battery.
9. Now, using your other hand, connect the wire from the bottom of the battery to the metal base of the bulb.
10. The lightbulb should start to glow. See Figure 1-4.

■ **Caution** If you have a super-bright bulb, it can get hot. Don't burn yourself!

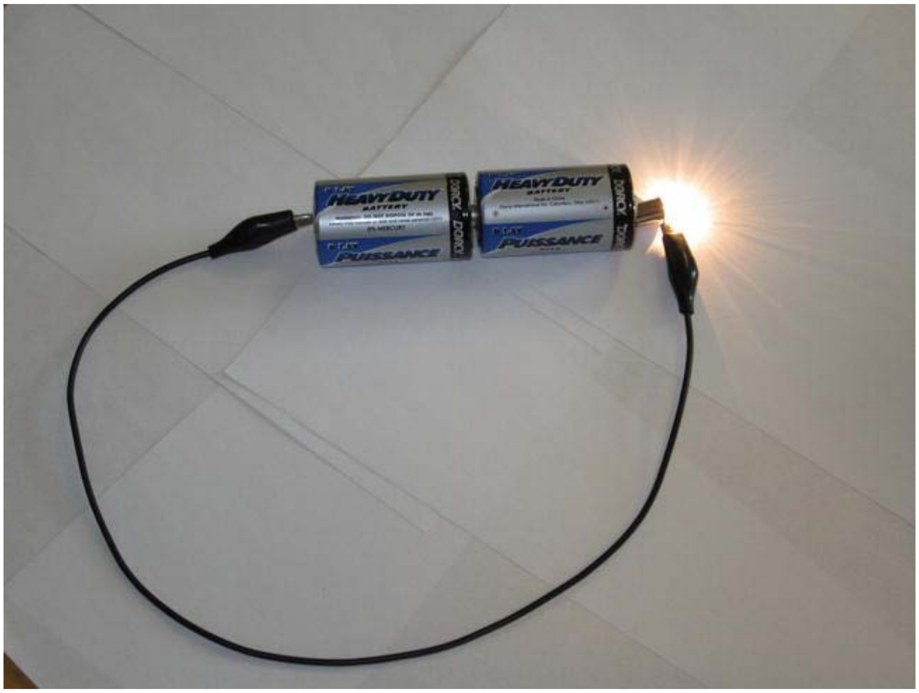

Figure 1-4. The completed circuit, showing the glowing bulb. Electricity is flowing!

Several important things are going on in this very simple circuit. Electrical current is flowing, producing useful work (in this case, light). Can you see the "circle"? When you *break* the circuit, the bulb stops glowing. This is exactly how the switch in the flashlight body works. Peek inside the flashlight and see if you can tell how it works. By connecting and disconnecting the wire, you can make the bulb flash. If you only use one battery, the bulb turns on, but is not as bright. Why do you think that happens?

Environmental Impact

You affect your environment every day, and your environment affects you, as well. As you learn more about electronics and all the interesting and wonderful things it can teach you, be mindful of what kind of trail you're leaving behind for others to clean up.

A good way to get a feel for your environmental impact is to take a look at your garbage. It doesn't sound that interesting or fun, but it *will* teach you a lot about yourself and your habits. What are you throwing away? Could you have found either another use for it, or perhaps another home? Is it going to be a nuisance to someone else, or even worse, a hazard?

A good example is the use of "disposable" batteries. We used batteries (technically *cells*, but that distinction will be spelled out in more detail in Chapter 3) in our very first experiment. We buy new batteries and plug them into our devices, and when they run out of power we take them out and throw them away. Where do they go? How do they then interact with the environment? They don't just "go away."

Disposable batteries are very convenient. They are generally inexpensive, compact, self-contained, and reliable. This *convenience*, however, comes with a price all its own. Consider using *rechargeable* batteries whenever possible in your lab. They cost a little more than their disposable counterparts, but can easily and cheaply be refilled with electrical goodness over and over again.

You should also be aware of any hazardous materials that you use or store in your lab. For example, lead is a very common material used in many electrical devices, even though its use is being reduced worldwide. It is found in older-technology rechargeable batteries, solder, and printed circuit boards.

Some of the chemicals used to etch printed circuit boards can be dangerous if not used, stored, and disposed of properly. Take the time to understand what, exactly, you're working with when you're conducting your experiments in your laboratory.

Just like the captain of a seagoing vessel, you're in charge of what happens in *your* lab. With this authority come important responsibilities that rest squarely upon your shoulders. Please take these responsibilities seriously.

Budgeting

How much is all this stuff going to cost? A lot of it depends on how creative you want to be in stocking your lab with tools and parts.

If your budget is small, then start small. If your budget is nonexistent, then you'll just have to start even smaller. You should generally approach acquisitions for your lab under one of these three headings:

- Buying new
- Finding used
- Harvesting or recycling

Buying New

Buying everything new is obviously the most expensive approach, at least from the *money* side of it. What a lot of people fail to take into account is that their *time* is also a very valuable commodity. Try to balance the one with the other, as befits your particular situation.

Except for the folks in the most *dreadful* of hurries, it always makes sense to shop around for the tools, equipment, and components that you are going to need in your lab. You'll find that a lot of "professional-grade" equipment carries an enormous price premium compared with "consumer-" or "hobby-grade" alternatives. This is generally to be blamed on the fact that there is a correspondingly enormous amount of money to be made in the field of electronics.

New components are almost always more desirable to use, especially when you're looking at a production environment and you need to make sure everything produced is of the highest possible quality and reliability. New, unused components are also more appropriate when conducting complex experiments, as this helps to reduce, if not eliminate, many variables in the testing and analysis phases. You don't have to worry that someone (probably you) might have "borrowed" some parts for a quick fix or some other temporary usage and then surreptitiously replaced them back in inventory, having possibly compromised them in some unseen way.

Finding Used

A prudent way to fill up a new lab, especially when first starting out, is to look for bargains on used tools and components. This is especially true of the fixtures, shelves, cabinets, benches, and other furniture that belongs in a lab.

Tools wear out. Tools are replaced. This is a fact of life when you're in the business of working with tools. The good news is that "one man's trash is another man's treasure." If we consider the possibility of women participating, we get three more potential combinations, all of which can end up in a win-win situation.

Many used tools can be retrofitted and placed back into service in your lab. On the other hand, there are a lot of tools that are simply used up and can not feasibly be brought back into useful service. Either their repair is cost prohibitive or they are no longer supported by their original manufacturers.

Another factor working in favor of the patient and observant collector of discarded tools is the inevitable march of progress. What was shiny and top-of-the-line a year ago might be intolerable or insufficient next year, from the standpoint of the original purchaser. Many bargain opportunities arise from this simple understanding.

This can sometimes be applied to the purchase of components that have never been used, but have been sitting somewhere waiting for their chance. A commonly used phrase to describe these parts, which are often sold at a discount, is *new old stock (NOS)*. Sometimes these parts are sold this way because of overstock or because a manufacturing run was cancelled or cut short.

Harvesting or Recycling

There's an absurdly large amount of perfectly good equipment, tooling, fixtures, and components sitting out there, looking for a new home. A lot of companies, as well as individuals, either outgrow their present fittings or turn toward other interests and endeavors. This can be an excellent opportunity to acquire the furnishings you need to populate your lab.

On the other hand, please don't go crazy. You don't have to pick up every discarded appliance or chair you see sitting by the roadside. Why pay rent for something you can easily and cheaply obtain when you actually need it? Are you really wanting to pay the heating and air-conditioning bill for that box full of odd-sized capacitors that are probably past their prime? Don't fall into the trap of the *false economy* when it comes to bargain-hunting for your lab. The most important ingredient in your lab is *you*. Leave a little room to move around a bit.

Another factor to keep in mind is *shelf life*. Not all parts (or tools) last forever, especially when not being used. Batteries are the worst. You can prolong the shelf life of nonrechargeable batteries by storing them in your refrigerator, as this slows down the electrochemical processes within them that produce the electricity. Even solar panels will wear out with either constant use or constant disuse, although this can take years to happen.

Some Example Workshops

Here's a little peek into some actual electronic laboratories, each with its own personality and history. Each one grew from something small into something, well, not so small.

A Fresh Start

Harold Timmis is an electronic engineer, software developer, and author. His curiosity about how things worked started as a small child, which led him from taking apart everything in his parents' house to studying engineering at the Florida Institute of Technology.

Harold keeps a lab in his home where he can work on gadgets in his spare time. Harold recently moved, and used the opportunity to "clean house" and set up everything in his lab exactly the way he wanted things.

He took this photo of his new lab after working on a couple of projects (see Figure 1-5). Note that everything is within easy reach when sitting at the desk. It's still quite tidy, as you can see.

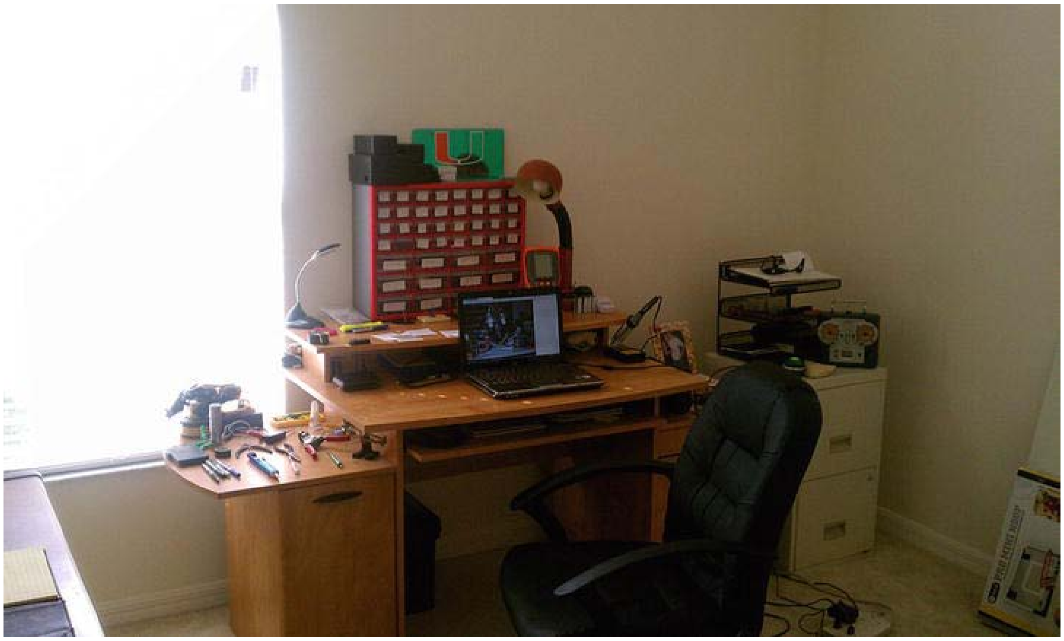

Figure 1-5. *The reorganized home lab of Harold Timmis (photo by Harold Timmis)*

The Robot Clubhouse

The Dallas Personal Robotics Group (`http://dprg.org`) is the world's oldest personal robotics group known to man. From 2002 to 2009, Mike Dodson of Modern Assemblies donated the use of a portion of one of his warehouses to DPRG. This gave DPRG a permanent home for meetings, contests, and social gatherings.

Robot builders enjoyed a spacious and comfortable area for working on robot projects, among other pursuits. Over the years, members contributed time, equipment, and lots of hard work to improving the space. The photo in Figure 1-6 shows one end of the available space, after an extensive remodeling. Several workstations along the wall are in the process of being set up. That good-looking fellow seated at the table is the author.

When Mike retired in 2009, DPRG began a search for another home.

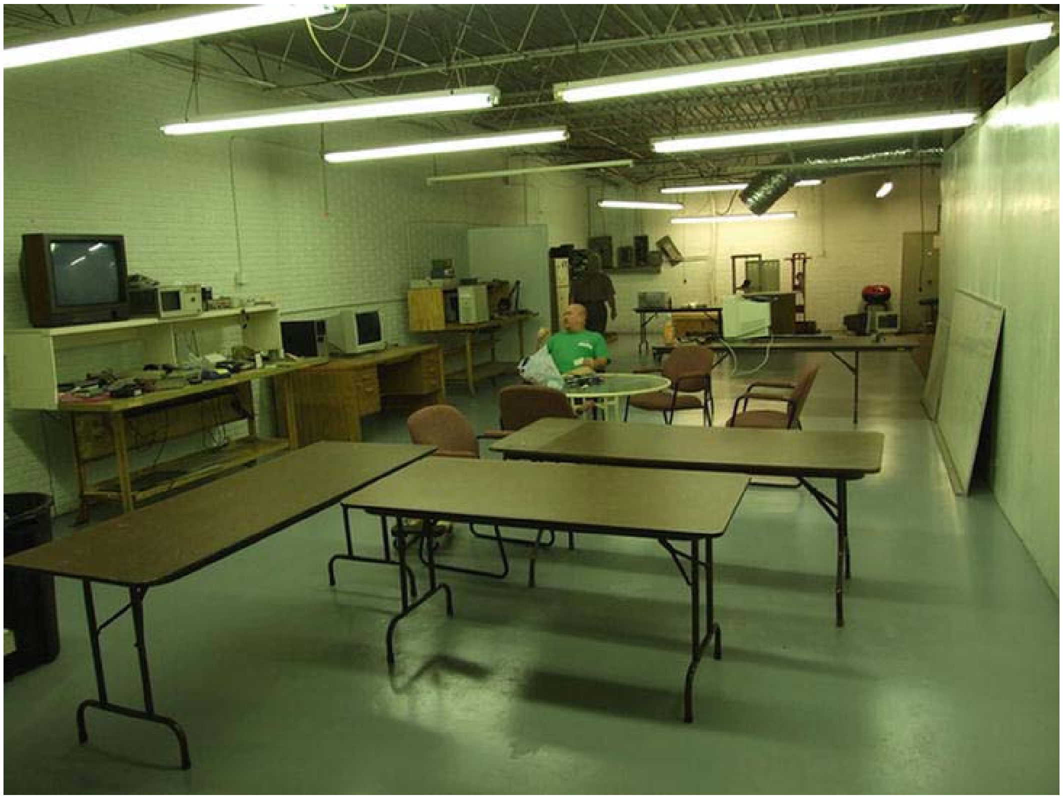

Figure 1-6. *DPRG's world headquarters from 2002 to 2009 (photo by R. Steve Rainwater)*

A Cautionary Tale

It's relatively easy to go from a well-designed and effective lab to something, let's say, less desirable. This doesn't happen overnight, but it can happen. Let this be a warning to you about how even the best of intentions can still produce embarrassing and unproductive confusion (see Figure 1-7).

Unfinished projects and leftover parts and tools compete for the limited space available in this photo. Not only is a lot of time wasted in searching for both components and tools, but the limited space restricts the scale of projects that can be entertained.

Don't let this happen to you.

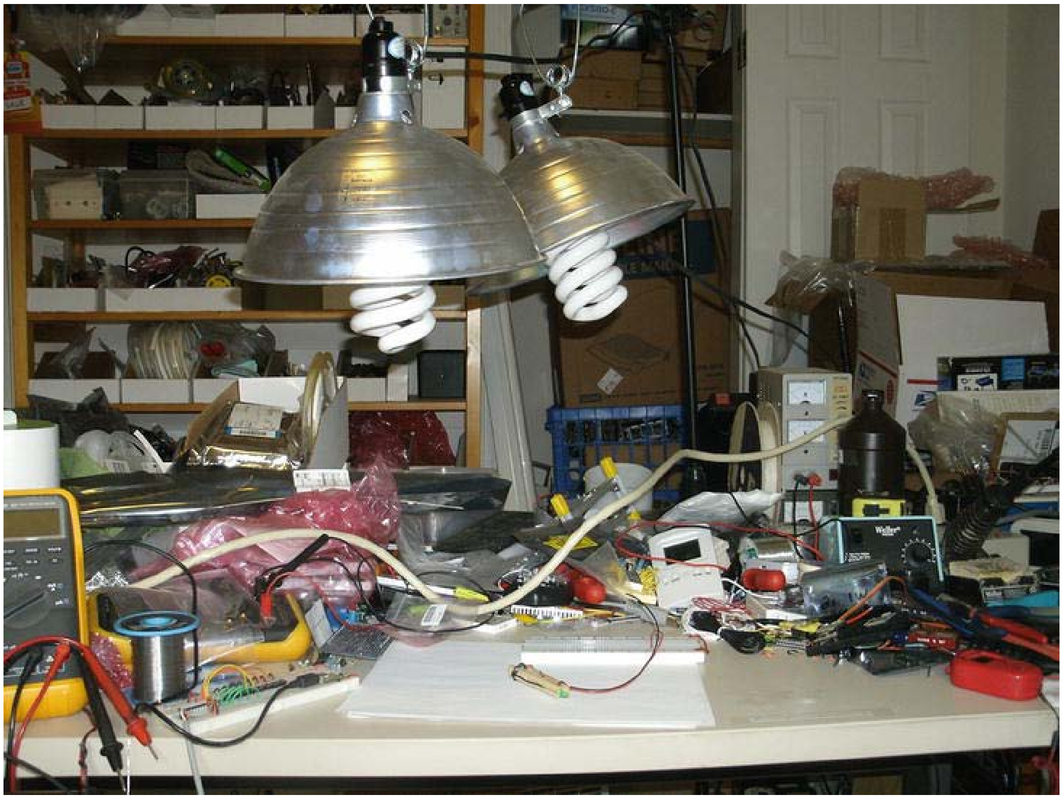

Figure 1-7. *It's not safe. It's not pretty. It's not even properly "eccentric." You have been warned.*

Summary

So now you know a little something about electricity and electronics. Hopefully this chapter has covered your very basic questions about how all this magic stuff actually works.

Now you're ready to start poking around some circuits. You're going to need the right tools for the job. Chapter 2 will get you started. You'll learn about some basic hand tools that are very useful in the lab, as well as some fairly high-tech machines that you might require in the future.

CHAPTER 2

Building Your Tool Chest

You're going to need some tools in your lab, as well as the skills to use them effectively. This chapter will get you started. If you're starting from scratch, don't worry. There's not a whole lot you absolutely *must* have to get started. Some basic hand tools and a place to keep them organized is all you will need. You don't even have to spend a lot of money at first. As you progress in your hobby, you will most likely want to add to your tool chest and upgrade some of those tools. Electronics can be the perfect hobby because it can take up (1) all your spare time and (2) all of your discretionary income. What more could you ask?

The very basic hand tools, such as screwdrivers and tweezers, are mostly self-evident in their usage. Try not to poke yourself in the eye. Where some helpful advice is appropriate, it will be given.

Here's an excellent example of a simple safety rule that will absolutely improve and extend your life: when using any kind of cutting tool, always direct the cutting motion away from yourself. For example, you might receive a package in the mail, and get all excited about opening it. You then discover it's sealed up with indestructible packing tape and can't simply be ripped open with your bare hands. Use a small knife or box cutter and make a single cut at a time, starting from the point closest to you on the package and cutting outward. Using this method, should the knife slip for any reason, the blade will travel away from you. This allows your blood and other bits to stay inside you, where they can do the most good. Never cut toward yourself.

If you've already got some tools (or even a *lot* of tools), it never hurts to review their proper usage. Also, if you're suffering from an *overabundance* of tools, to the point where you can no longer keep them organized, this chapter might help you to prioritize them, at least as far as permanent residency in your lab is concerned.

■ **Tip** Every tool in your shop must *earn* its place there. It must *deserve* to be there. *No exceptions*.

The Most Important Tool Ever

The most important tool you'll ever use is your mind. Every other tool you will ever work with depends on the correct and proper functioning of your mind. If you're careful with it, you won't misplace it, neglect it, damage it, or use it for the wrong job. Your mind is a wonderful asset when cared for properly, and a terrible liability when ill-treated.

Your mind is in many ways like a muscle. The more you use it, the stronger it gets. Learning new things does not "push out" the old things you've already learned. Your brain is capable of forging new neural pathways when challenged, and there's plenty of extra capacity in that old noggin of yours to handle whatever may arise.

■ **Tip** Try to learn something new every day.

Take care of that brain of yours. Just like you wouldn't use a dull drill bit or a rusty saw, don't try to work on electrical or electronic projects when your mind is not in the right place. Ideally, you should never try to get any work done in your lab when you are sleepy, distracted, angry, upset, medicated, or overly tired. Deal with whatever problems you're facing in a responsible manner and then get back to work in the lab.

- Are you sleepy? Take a nap or head off to bed for the night. Really bad mistakes are made when the brain does not get enough sleep. Sleep deprivation is notorious for being obvious (and obnoxious!) to everyone else except you. "Really bad mistakes" made while working with electrical or electronic projects can produce very hazardous conditions for you and everyone around you, such as fire, damaged equipment, injuries, and even death.

- Are you angry or upset? Then your mind is not going to be adequately focused on what you need to do in the lab. "Fools! I'll destroy them all!" are famous last words *for a reason*. Give yourself some time to calm down from whatever has angered or upset you. Also, it's OK for you to give yourself permission to admit that you are angry or upset about something in the first place. Ignoring it probably won't make it go away, and probably won't make your feelings about it go away, either. Walk away, count to ten, or whatever works for you.

- Feeling distracted? Then now is *not* the time to be conducting electronic experiments in the lab. You need to be *present* in the lab, both bodily and mentally. There are just too many ways to make simple blunders that have far-reaching and sometimes overly expensive consequences.

- Have your cognitive functions been compromised? This can happen from taking certain medicines or even recreational intoxicants. If the little bottle says, "Don't operate machinery or drive an automobile," then you probably shouldn't be making important decisions or working with dangerous circuits in your lab, either. Wait until you're clear-headed enough to proceed with your plan for world domination, adding blinking eyes to a plush doll, or what have you.

The worst thing about cognitive impairment is that the first thing that gets impaired is the ability to judge the level of your cognitive impairment!

Care and Feeding of Your Brain

Here are a few tips to keep your brain (and the rest of you) in good working order:

- Stay hydrated. Drink more water than you think you need. This might result in more trips to the bathroom, but this is much more desirable than the alternative. A good flow of water through your systems helps your body feed and repair itself, as well as aiding in the elimination of toxins. Drink more water.
- Avoid excess consumption of coffee, tea, sodas, and especially "energy" drinks. These contain ingredients that stress both your body and your mental capacity. They do not contain energy, but trick your body into going into overdrive by triggering a stress reaction.
- Take frequent breaks. Get up and walk around, if possible. Raise your arms over your head and hold them there as you count to ten. This redirects blood flow and helps restore a balance within your peripherals.

All Those Other Bits, Too

Just as your mind is the most important tool you'll ever use, the rest of your bodily bits and personal pieces are vital and important in your work in the lab. For the most part, there are no spare parts laying around for things like your eyes, your ears, your hands, or your skin.

Should you wear eye protection in the lab? Yes, you should. Are you always going to do so? Probably not. It's true, it can be inconvenient or perhaps a tad uncomfortable. Consider the cost, however. Even the tiniest scratch on your eyeball can take weeks to heal and leave you susceptible to infection or vision loss. It's just not worth it to be lazy. Ask the next one-eyed person you see. If you're a bit uncomfortable asking one-eyed people, "Hey, what's with the one eye?" then perhaps you can just try to imagine them advocating or encouraging you along the same path they took, whether intentionally or accidentally. They won't do it.

Invest in quality eye protection that is comfortable and properly sized for you. Provide eye protection for visitors to your lab as well, if they will be present when soldering, welding, machine tooling, or wire clipping is being performed. Then invest in the habit of wearing your eye protection whenever it is appropriate.

■ **Note** Don't pretend that your prescription glasses with polycarbonate lenses are "safety glasses." They aren't. They do not protect either your eyes or your face from impact or objects entering from the side, as proper safety glasses should. If you usually wear glasses, use safety glasses that comfortably accommodate your glasses when worn.

Will you be working with really loud noises? These could be from powerful audio amplifiers ("it goes to 11") or power tools. Hearing loss from exposure to excessively loud noises is cumulative. This means it slowly (or suddenly) chips away at your hearing, bit by bit. Why do you think old people turn up the TV so loud?

Hearing protection is both affordable and comfortable. For temporary protection, you can use disposable earplugs. If you need protection all day, consider earmuffs designed for hearing protection. Don't let "Hey, y'all, check this out" be the last thing you ever hear.

It's hard to work with hand tools with no hands. It's possible; just really hard. Take care of your hands. There are a hundred ways to burn, tear, cut, or otherwise mangle those mitten-fittings of yours. Have a variety of work gloves on hand to handle the different needs of your lab. The choice will be ultimately determined by the particular hazards present in your lab. Are you working with chemicals as well as electronics? How about sharp edges or glassware? Normally, you won't need to wear gloves for soldering small electronics, but if you start working with really large-scale projects, such as sculptures or plumbing, you might.

Make sure you are still "handy" when wearing the proper gloves for the job. Make sure the gloves fit you properly and allow you the adequate dexterity you need.

■ **Tip** Be safe. Don't be lazy.

Basic Hand Tools

Assuming that you're going to start small and build toward bigger things, you should also start small with some small hand tools. These tools will make it much easier to work on small parts and wires.

Good hand tools increase your effective strength and improve the accuracy and precision of your motions. They allow you to focus a great deal of your strength on exactly the part that needs it, without wasting a lot of effort. Good hand tools also insulate you from sharp, hot, or otherwise unpleasant objects when you work on them.

Take care of your hand tools. Put them up when you're done with them. Make sure they are clean and ready to be used again the next time you need them. Few things are more frustrating than attempting to start a quick repair job and finding out that you need to spend twice as much time preparing your tools for use.

Have some sort of methodical plan or reasoning involved with the storage of your tools. They need a safe and comfortable home, just like you do. You need to be able to find them quickly when you want them. Try out different organizational strategies until you find one that works for you and your lab. This is an easy task when you have just a few tools to organize. Once you've accumulated a large collection of hand tools, this is no longer optional. You *must* know what tools are available and where they are located.

Frequently used tools should be within easy reach of your primary workstation. If your tools need any sort of adjustment or setup before use, make sure you've got all the proper bits handy. For example, a drill press will often have a chuck key used to tighten and loosen the chuck that holds a drill bit in place. That key needs to be in the immediate vicinity of the drill press, as well as easy to locate. Don't spend a lot of time needlessly hunting for tools. Decide for yourself on some safe and practical policies for where you keep your tools.

■ **Tip** Don't waste time guessing where your tools are located. *Decide* where they are located.

Just like everything else, hand tools have a limited useful lifetime. While some tools can easily outlast you, it's up to you to keep track of exactly how much utility you can continue to expect from your tools. This doesn't mean that you have to trash your hand tools once they develop some tiny flaw. If it's beyond your capabilities to repair the tool, then consider replacing it and reassigning it to the second string or backup tool chest. Having a spare tool, even a slightly imperfect one, on hand when you need it can make the difference between success and failure in a project.

Bear in mind, however, that some tools are simply too dangerous to keep around once they've outlived their useful life span. A dull cutting tool that cannot be reasonably resharpened is a good example of a tool that has lost its honored place among your other tools. Thank it for its service, wipe away that little tear, and then figure out a good way to recycle any of its bits that are still functional.

Wire Cutters and Wire Strippers

As you might have picked up from Chapter 1, you can spend a lot of time working with wire in this hobby. Understanding a little bit about how wire is made and how it functions in a circuit will aid you in your experiments.

How Wire is Made—The Very Short Version

Most wire is made of copper or a copper alloy. Some wire used for electrical wiring in houses is made of aluminum. The wire itself starts out as a fairly thick strand and is stretched and pulled—a process called *drawing*—until the desired diameter is obtained. This strand is then wrapped up on spools or bobbins.

- Some wire is made of a single strand of copper (or aluminum). This is called *solid-core* or *single-strand* wire. It is a single strand of wire, usually circular in cross-section.
- Multiple, thinner strands of wire are often bundled or twisted together to make larger-diameter wire. Stranded wire is much more flexible than solid-core wire, but is more expensive to produce because of the extra manufacturing steps required. Because stranded wire has a larger surface area per unit of length, it is more susceptible to environmental hazards such as corrosion.

Most electrical wire is covered with an insulating jacket, usually made of plastic or rubber. This sheathing must be removed to make electrical connections. There is sometimes more than one layer of insulation on a wire, depending on what its final application is destined to be.

More information about wire as a *component* will be presented in Chapter 3. For now, the emphasis is on the characteristics of wire that help determine the best tools to use when working with wire.

Selecting the Correct Tool

Both copper and the aluminum alloys used for electrical wiring are fairly soft metals and can be easily cut or formed with simple hand tools. Wire *cutters* are specialized tools made to make a clean cut through the wire's strand or stands. Wire *strippers* are another kind of specialized tool used to remove the insulation from a wire.

Figure 2-1 shows two rows of commonly available wire cutters.

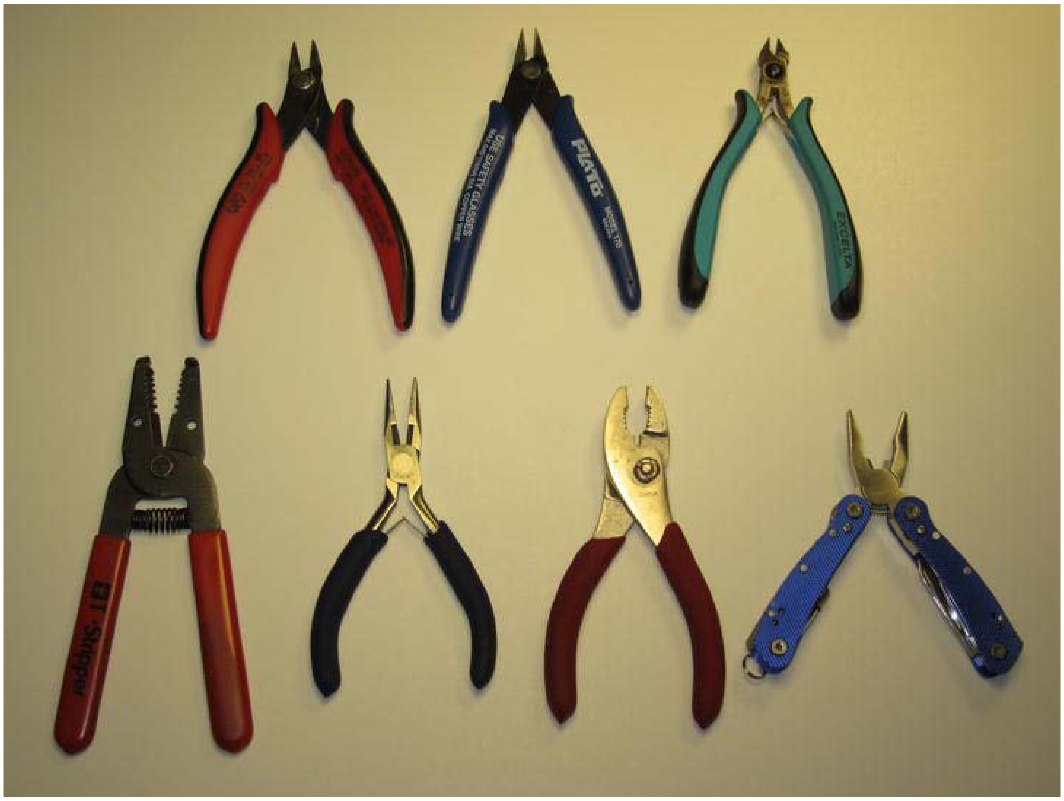

Figure 2-1. *Commonly available wire-cutting tools. The top row shows three styles of diagonal cutters, which are the preferred tools for cutting small-gauge copper wire. The bottom row shows some tools that offer wire cutting as a secondary facility, and should only be used when proper wire cutters are not available.*

The top row of cutting implements in Figure 2-1 are various forms of what are known as diagonal cutters, side cutters, or flush cutters. These cutters have beveled cutting edges that meet in the middle of the wire being cut. One side of the cutters is flat, or *flush*, allowing wires to be cut with some precision. These are the preferred cutters for small-gauge copper wire, as well as for clipping excess component leads from a printed circuit board (PCB). See Figure 2-2.

Compare the cutting action of the side cutters to the other, less optimized wire cutters in the second row of cutters in Figure 2-1. These cutters either use a shearing action to cut the wire or include a flush-cutting area as a secondary feature.

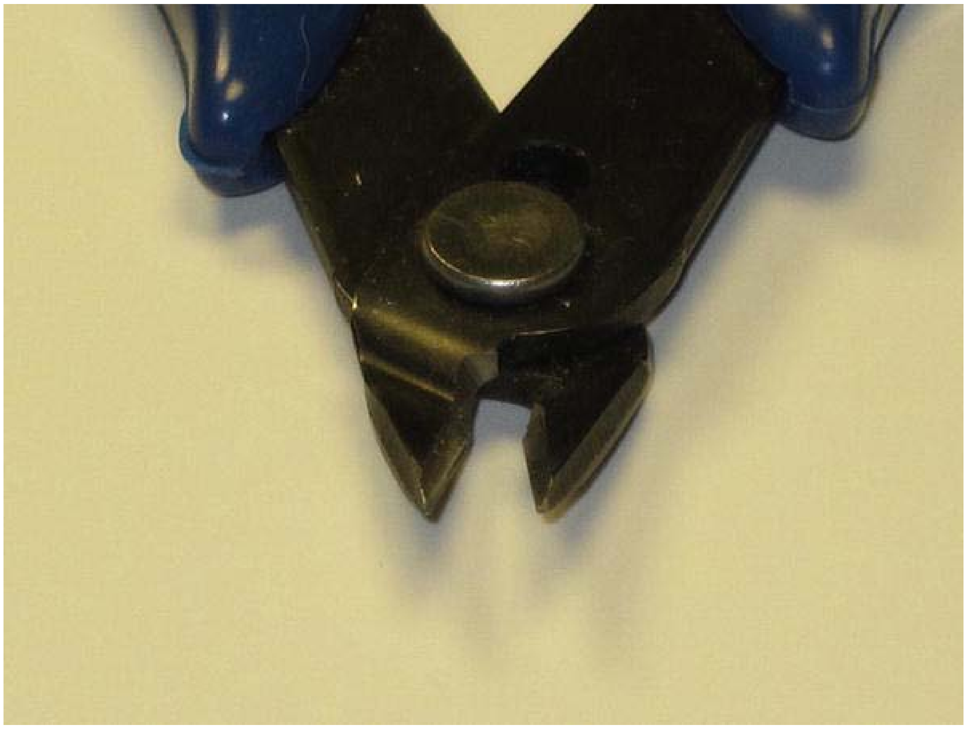

Figure 2-2. *A close-up look at the business end of a pair of side cutters. When the two cutting edges meet in the middle, the bottom side is flat, or flush, allowing the user to get quite close to where a wire or component lead emerges from a solder joint.*

Use caution when clipping component leads or small wires with any wire cutters. The cut lead can easily fly away at sufficient velocity to poke you right in the eye or other sensitive area. If possible, hold *both* ends of a wire being cut or direct the cut leads *away* from your face.

■ **Caution** Use eye protection when clipping leads. Don't say you weren't warned about this hazard.

Wire Strippers

Wire strippers are tools that allow you to easily strip the nonconductive insulation from wires. You can try chewing it off with your remaining teeth, but this is not recommended.

Wire strippers usually consist of a pair of hinged blades with some sort of machined notch. The notch allows the blades to cut the insulation around the wire without cutting or nicking the underlying conductor. A good example is shown in Figure 2-3.

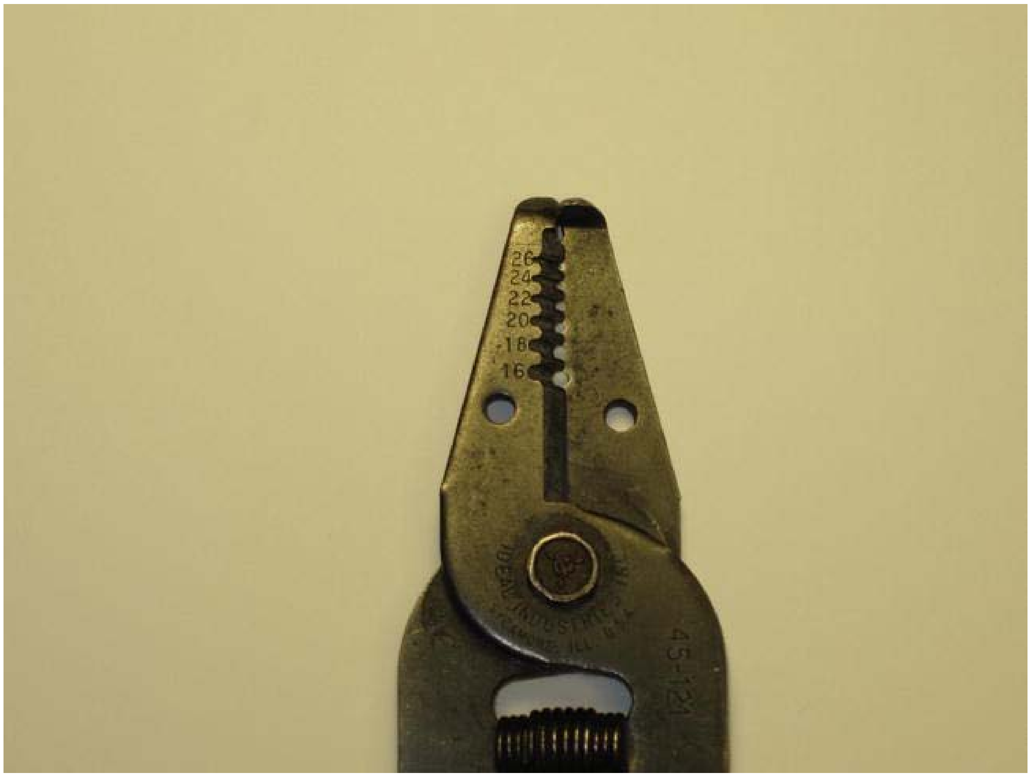

Figure 2-3. *The popular T-Stripper combination wire cutter and stripper tool from Ideal Industries has been around for over half a century. Note the wire gauge sizes stamped into the face of the cutter blade. New models feature laser-engraved text.*

The wire strippers in Figure 2-3 can easily strip the insulation from wires with a conductor diameter, or *gauge*, between 16 (0.0508" or 1.291 mm) and 26 (0.0159" or 0.405 mm). The higher-numbered wire gauges represent *smaller*-diameter wires. Once upon a time, the gauge number represented the number of *drawing* operations that were performed on a wire when being manufactured. The more times it was drawn through the processing equipment, the thinner the wire became. Today, the wire-manufacturing industry in the United States and Canada has adopted the American Wire Gauge standard (AWG). See Table 2-1.

Table 2-1. *The AWG. A more complete listing is available at http://en.wikipedia.org/wiki/American_wire_gauge, from which this partial list was obtained.*

AWG	Diameter Area			Copper Resistance	
	Inch mm		mm^2	Ω/km mΩ/m	Ω/1000 ft mΩ/ft
0000 (4/0) 0.46	00	11.684 107		0.1608	0.04901
000 (3/0)	0.4096	10.404	85.0 0.20	28	0.06180
00 (2/0)	0.3648	9.266	67.4 0.25	57	0.07793
0 (1/0)	0.3249	8.252	53.5 0.32	24	0.09827
1 0.28	93	7.348	42.4 0.40	66	0.1239
2 0.25	76	6.544	33.6 0.51	27	0.1563
3 0.22	94	5.827	26.7 0.64	65	0.1970
4 0.20	43	5.189	21.2 0.81	52	0.2485
5 0.18	19	4.621	16.8 1.02	8	0.3133
6 0.16	20	4.115	13.3 1.29	6	0.3951
7 0.14	43	3.665	10.5 1.63	4	0.4982
8 0.12	85	3.264	8.37 2.06	1	0.6282
10 0.10	19	2.588	5.26 3.27	7	0.9989
12 0.08	08	2.053	3.31 5.21	1	1.588
14 0.06	41	1.628	2.08 8.28	6	2.525
16 0.05	08	1.291	1.31 13.1	7	4.016
18 0.04	03	1.024	0.823 20.9	5	6.385
20 0.03	20	0.812	0.518 33.3	1	10.15

22 0.02	53	0.644	0.326 52	.9 6	16.14
24 0.02	01	0.511	0.205 84	.2 2	25.67
26 0.01	59	0.405	0.129	133.9	40.81
28	0.0126 0	.32 1	0.0810 2	12. 9	64.90
30	0.0100 0	.25 5	0.0509 3	38. 6	103.2

We'll return to this table again in Chapter 3 when the electrical properties of wire are discussed. For now, note that as the wire gauge number goes *up*, the wire's physical diameter goes *down*. Similarly, as a conductor's physical size goes down, its ability to carry current also goes down, and its electrical *resistance* goes up.

■ **Note** Other standards exist throughout the world. Steel-wire manufacturers use a different scale, as their interest is more on the tensile strength of the wire, not its electrical properties.

Note that the AWG is for single-strand copper wire. Equivalent gauges in stranded wire are physically a bit larger, although they have the same effective cross-sectional area and can carry the same amount of current.

When using wire strippers, keep in mind that your goal is to cut and remove only the nonconductive insulation from the wire, leaving the internal conductor intact. Even a small nick can result in a weak point in the wire, both electrically and mechanically.

Practice Makes Perfect

The best way to attain proficiency with a new tool is with practice—lots and lots of practice. This is true for working with your hands as well as with that big brain of yours. Ideally, any task worth doing will involve at least a little bit of both manual dexterity and focused brain power.

Cutting and stripping wires is an excellent example. For your first practice assignment, spend some time turning long, beautiful lengths of wire into little bits of wire with stripped ends.

CUTTING AND STRIPPING WIRE

For this exercise, you're going to need the following:

- Wire cutters
- Wire strippers
- Much wire
- A comfortable, well-lit location

Cut the Wire into Segments

Don't watch TV or be otherwise distracted. Pay attention to what you are doing.

Begin by cutting the wire into various-sized segments from 2" to 6" in length. Accuracy in length is not critical at this point. You need to get a good feel for your wire cutters and how much force is needed to cut the wire, without cutting yourself or others.

Collect the cut wire segments into a bowl or small container for the next step.

Strip the Wire Segments

Using your wire strippers, remove about 1/4" (6 mm) of insulation from both ends of each wire. Try not to cut or nick the wire core. The insulation that you remove can either be discarded or collected for use in some sort of art or craft project.

Once you've completed the cutting and stripping portion of this exercise, sort the wires according to their length, or their color if you used different colors of wire. Compare the quality and consistency of your work by looking at the first few wires and the last ones you did. Do you see any improvements in your work?

If you spend about an hour working on your wire-cutting and wire-stripping technique, you will perhaps master a skill that will prove useful for the rest of your life, as well as prepare a big pile of wires that you can use in many of the sample projects illustrated in this book.

Pliers and Tweezers

Every day, the size of the "typical" electronic component gets smaller and smaller. This miniaturization process has brought about a world where you can carry a phenomenally powerful computer in your pocket, and sometimes even make phone calls with it. The individual transistors, resistors, capacitors, and other components inside such modern marvels are literally microscopic in size. You need a fairly powerful microscope to be able to see them at all.

In your typical home electronics lab, and even in many professional labs, you will not be dealing with these tiny things, except as large clumps all tied together inside a chip or other framework. Still, the typical components you will use are often a bit too small for all but the tiniest of fingers. That's where pliers and tweezers come into play. They are an extension of your own hands and fingers, increasing your precision and allowing you to perform delicate tasks with tiny parts.

There are several types of pliers and tweezers that you may use on a daily basis in your lab. See Figure 2-4.

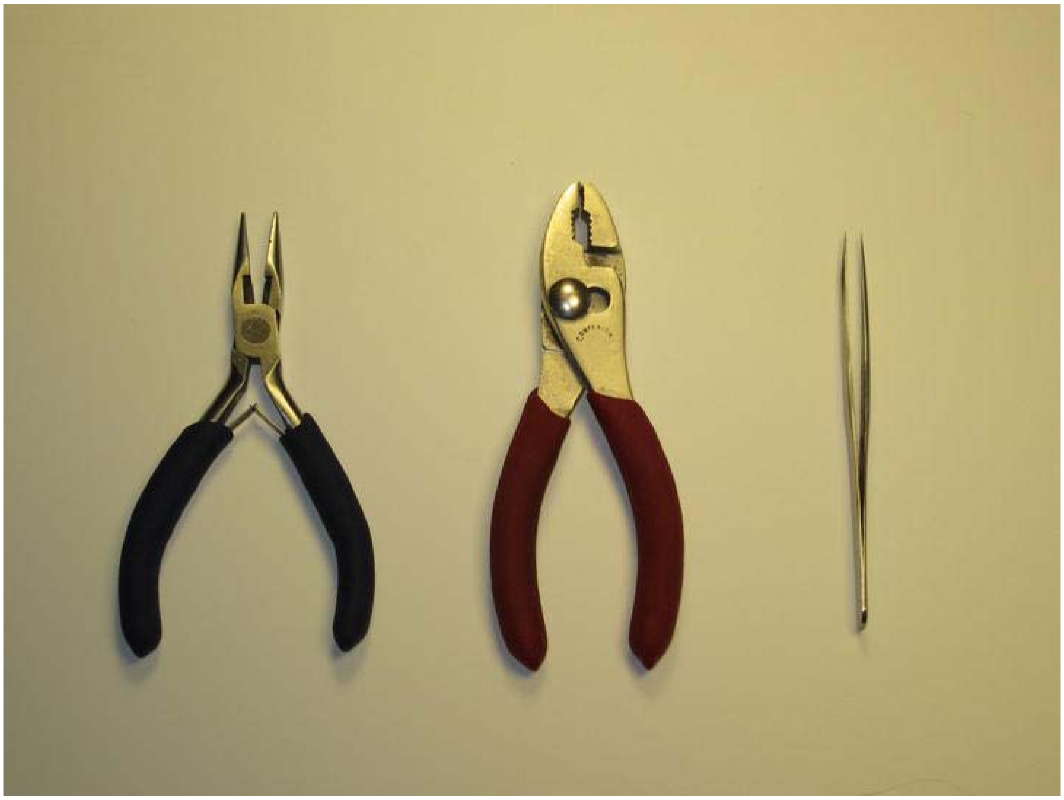

Figure 2-4. *Pliers and tweezers aid in working with small parts. On the left is a pair of needle-nosed pliers with cushioned grips and leaf springs. In the center is a pair of slip-joint pliers that can be adjusted to accommodate two different ranges of gripping action. On the right is a pair of needle-sharp tweezers, which can be used to pick up and place even the tiniest of electronic components—if your hand is steady enough!*

Screwdrivers, Nut Drivers, Wrenches, and Ratchets

A lot of electrical connections can be made using only a screwdriver. Figure 2-5 shows an electrical connection using a *barrier strip*. A specialized connector is crimped onto the end of the wire and held in place with a screw. A variety of crimp-on connectors are available and should be installed using the appropriate tool, as indicated by the connector's manufacturer. Just smashing the connector onto the wire with some pliers is not recommended.

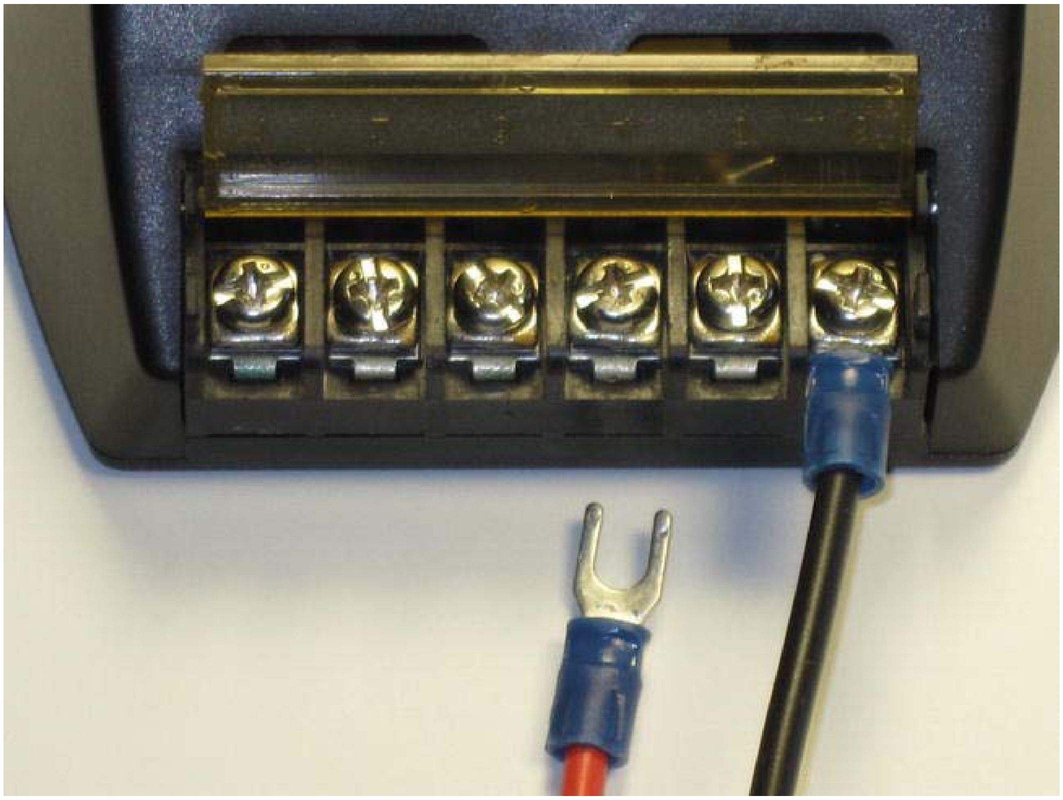

Figure 2-5. *A barrier strip on a low-cost solar-charge controller. No soldering required! The specialized connector is held in place with a screw. The connector is affixed to the end of the wire by deformation using a specially designed crimping tool. You can see the indentations in the insulating collar around the connector.*

Another type of connector that is tightened with a screw is called a *terminal block*. Unlike a barrier strip, no specialized connector is required on the wire. You can simply insert a stripped wire into the terminal block and tighten the connector using a screwdriver. Try to strip the wire only enough to allow the bare conductor to enter the terminal block, without leaving any noninsulated wire exposed that could accidentally short out against another wire. See Figure 2-6.

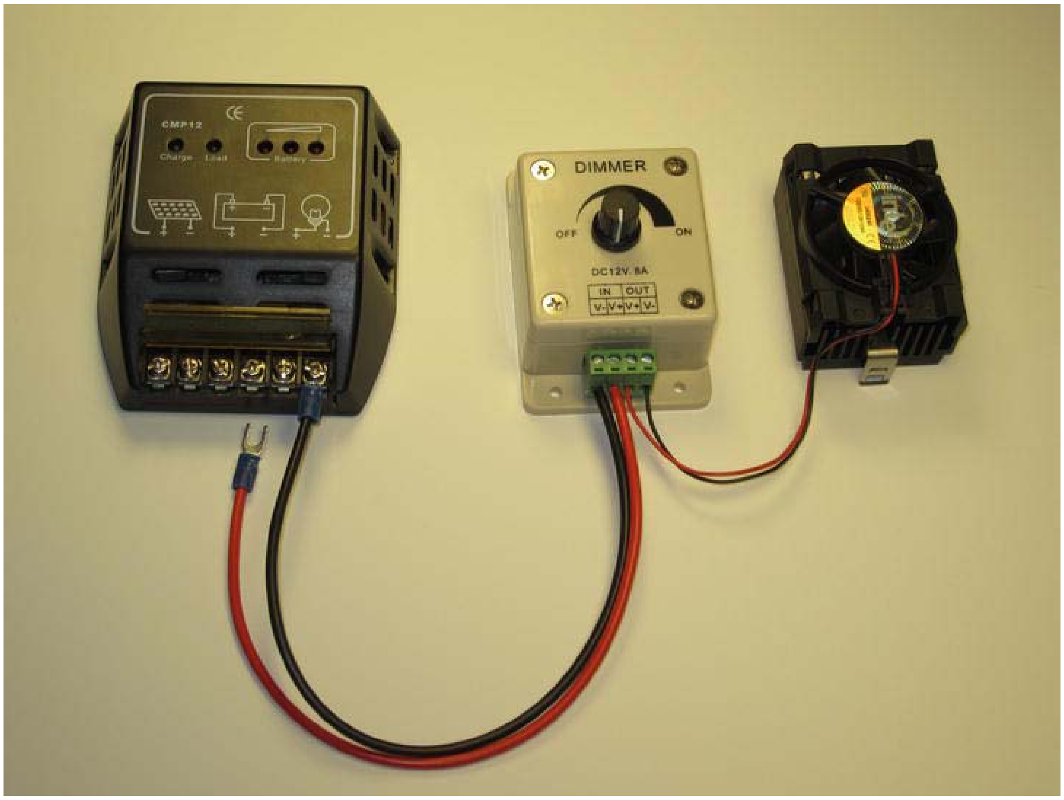
CMP12
Charge
Load
Battery
DIMMER
OFF
ON
DC12V. 8A
IN
OUT
V-
V+
V+
V-

Figure 2-6. *A terminal block uses a screw for tightening the connection with a bare wire.*

Besides being useful for making electrical connections using barrier strips and terminal blocks, screwdrivers are also quite handy in their original function, which is to tighten and loosen mechanical fastening devices such as screws and bolts. See Figure 2-7.

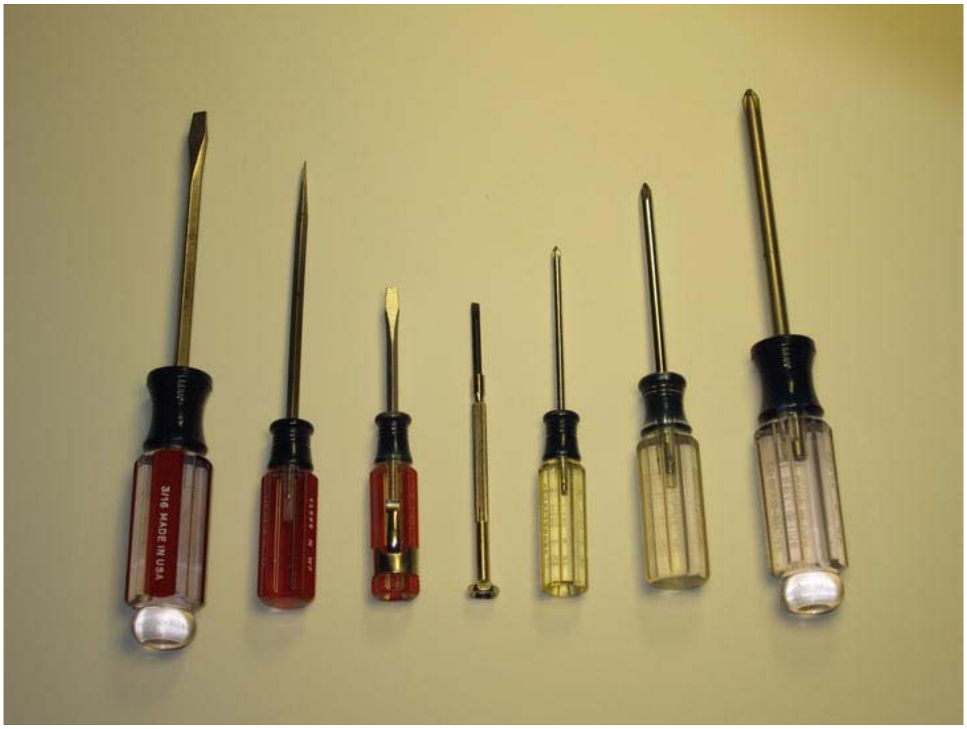

Figure 2-7. *A variety of screwdrivers. The four on the left are standard, or straight-bladed, screwdrivers. The three on the right are Phillips-style screwdrivers. Other specialty bits are also available.*

You should only use screwdrivers to drive screws and bolts. Don't try to use them as levers, pry bars, chisels, punches, or other tools. When you need a chisel, use a chisel. Keep your screwdrivers clean and dry. Put them back where they belong when you're done with them. You get to decide where they belong.

Screws, Bolts, and Nuts

There are a *very* large number of different kinds of screws and bolts. Some screws, such as wood screws, are made to be driven directly into wood and create their own threads in the material as they are installed. Other screws, largely referred to as machine screws, mate with a premachined or tapped hole, or a machine nut.

Nuts are often shaped with four or six sides that allow them to be held in place while the screw is turned. Alternately, the nuts themselves are turned while the screw is held in place. Some screws and bolts have a similarly shaped head that allows them to be turned with a wrench or nut driver instead of a traditional screwdriver.

Please resist the urge to overtighten screws and bolts. The mechanical advantage gained by the inclined plane of the screw thread multiplies the force used to turn the screw into a terrific amount of pressure on the screw itself. You can easily damage either the screw or the threads in the material to be fastened by overtightening a screw.

More Specialized Hand Tools

A good set of wire tools, pliers, and screwdrivers will go a long way when working with electronics. However, sometimes you need a more specialized tool for more specialized work.

Here are some of the more common tools that are a little more focused on a particular task than they are for general-purpose usage.

Wire Crimpers

As mentioned previously in this chapter, you can make solid electrical and mechanical connections using barrier strips and specially terminated wires. The optimized connectors used for this purpose require optimized tools for best performance.

Figure 2-8 depicts some examples of specialized crimp tools for electrical connections.

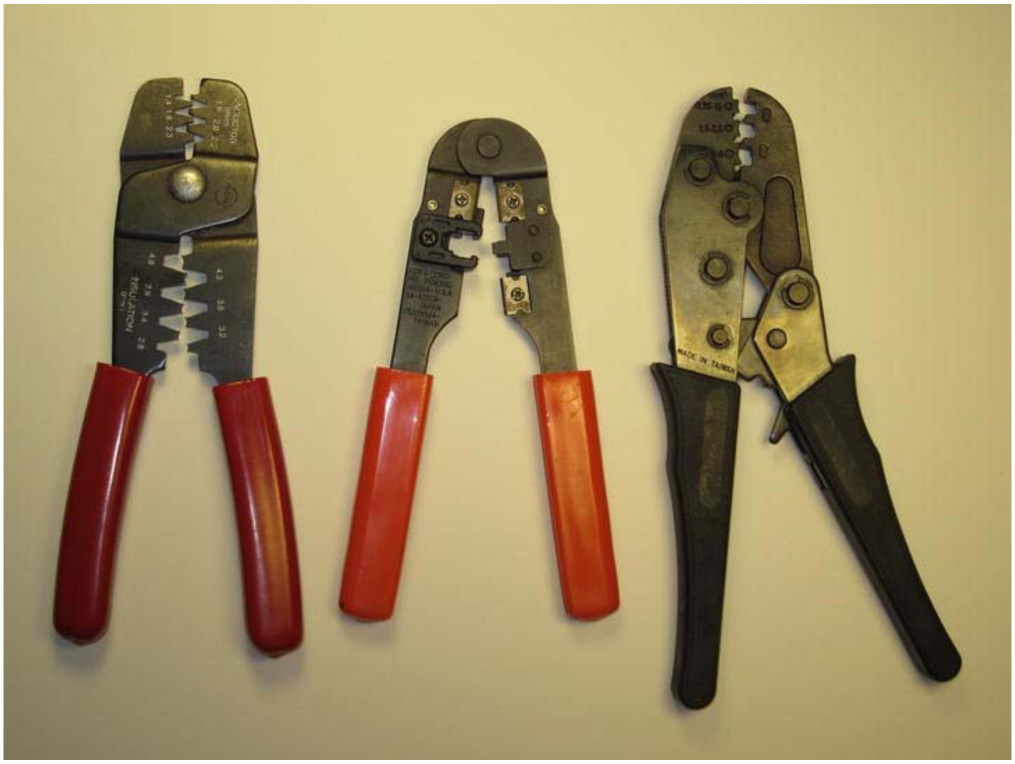

Figure 2-8. *Some common crimping tools for affixing electrical connectors to wire*

Referring again to Figure 2-8, the crimpers on the left are for crimping tiny pins to the ends of tiny wires that are then inserted into plastic connector bodies. The center crimp tool is for crimping modular jacks onto telephone cables. It also includes a wire-cutter blade (bottom) and a pair of controlled-depth stripper blades for removing only the outside layer of insulation from silver-satin flat telephone cord, without disturbing the individually insulated wires contained within. The crimp tool on the right features a ratcheting action that increases the crimping force applied to the connectors. This is the tool used to crimp the connectors show previously in Figure 2-5.

Computers

You might not think about computers as being "power tools" in your toolbox. As the size of computers, laptops, tablets, and smart phones decreases, and their computing power, networking ability, and storage capacities increase, they become much better candidates for use in the lab.

Traditional "desktop" personal computers (PCs), laptops, netbooks, and tablets can perform multiple roles in your laboratory setting. If you are lucky enough to have Internet access on your computer, it can become a conduit for all types of useful electronics information, in addition to its more accepted role as a source of funny cat videos. See Figure 2-9.

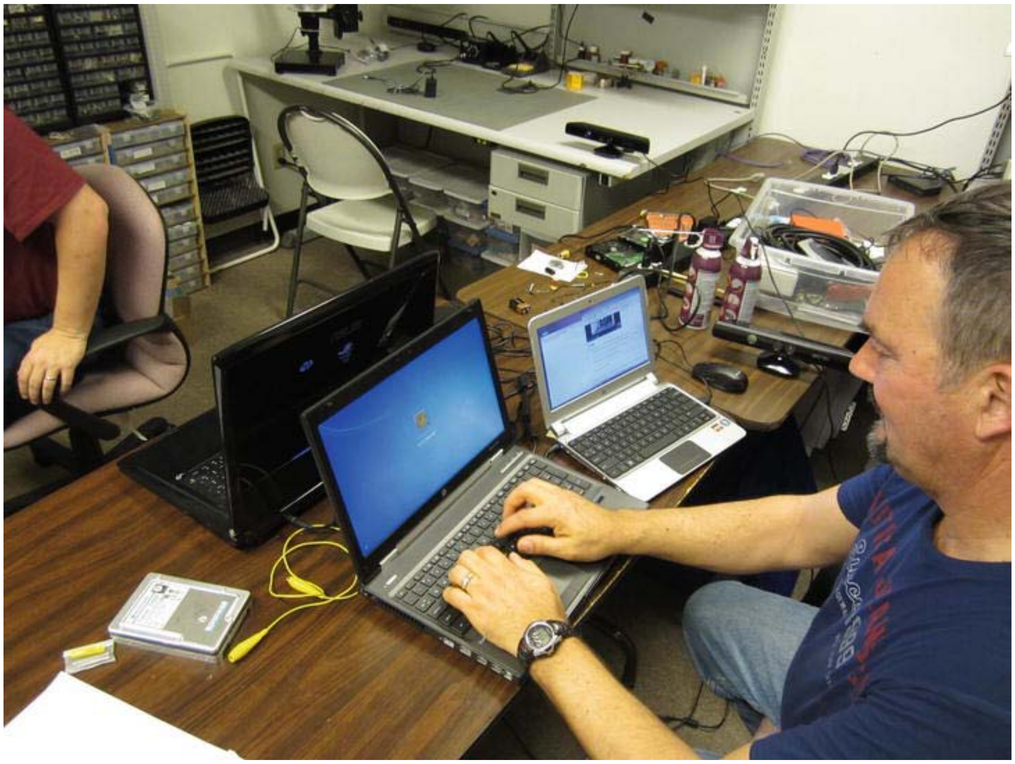

Figure 2-9. *Computers being used in the lab. Paul Bouchier of DPRG uses two laptops at once when testing new robot software with the Microsoft Kinect (just to the right of his mouse).*

Here are just a few of the many possible areas of practical knowledge, learning opportunities, and bits of interesting information that you can access using your computer:

> *Data sheets*: Almost all electronics manufacturers provide online access to a library of technical data sheets and application notes for their products. These should be your first choice for information about how and when to use their products. These sources also contain important product *errata*, which contains corrections and updates for products that have been made since their first publication.
>
> *Online tutorials*: The Web abounds with detailed and thought-provoking tutorials and background information on every topic imaginable, including, not surprisingly, mountains of information on computers and electronics.
>
> *User forums*: People tend to cluster around others with similar interests. Once upon a time when people where geographically limited and unable to communicate or interact with folks around the world, this severely restricted a lot of the more specialized areas of knowledge. Today, you can find user groups centered on every conceivable human endeavor (and some inconceivable ones, too) that are filled with helpful, knowledgeable members that are more than happy to answer questions and share experiences with you. Do try to be courteous, respectful, and fair when asking for help with your projects, and always try to repay in kind by helping those with similar questions that you've had to master.
>
> *Sharing/collaboration web sites*: As the cost and complexity of publishing your work on the Internet becomes more manageable, it becomes faster and easier to let others know about your progress, as well as your problems. You can easily set up your own web page for little or no cash, or join many of the available user groups that allow their members to post, browse, and otherwise benefit from the works of other similarly minded individuals.
>
> *Design tools*: You can find many free or reasonably priced electronic design and simulation tools online. Some manufacturers also provide free tools specifically for optimizing designs for their products.
>
> *Online suppliers*: Where you once had to walk (or drive) down to the store and see what was available in your area as far as electronic components and tools went, now you can browse through the catalogs of suppliers from all over the world, from the comfort of your own lab. Not only does this provide a much larger field from which to choose, it also levels the playing field, so to speak, forcing worldwide competition for your hard-earned cash. Bonus: Some manufacturers offer a limited numbers of free samples. Yip!

This list only scratches the surface of the kinds of information you can access using a computer. You can also use a computer as part of your electronic projects, and several examples of doing this are included later in the book.

Tools for Soldering

You don't have to learn how to solder to work with electronics, but it helps. It really does. It opens a whole new world of possible projects, repairs, and custom modifications to existing equipment. Just remember, as always, to keep your work area clean and safe. See Figure 2-10.

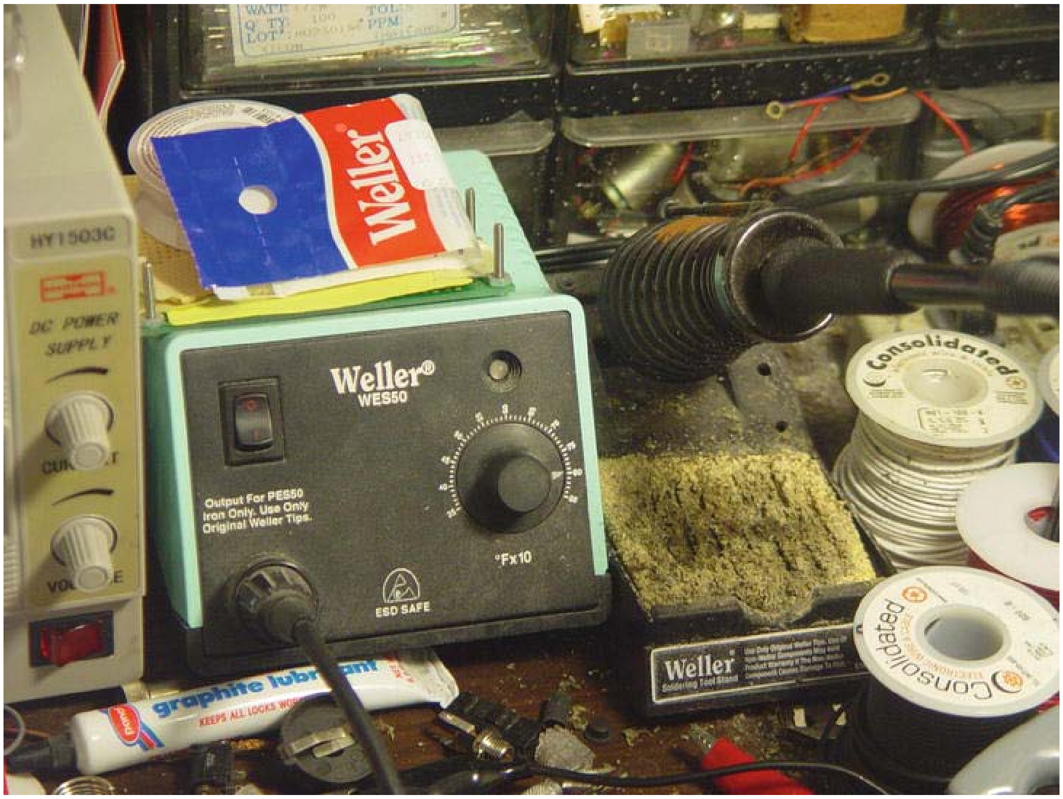
Weller
Weller
WES50
Output For PES50
Iron Only. Use Only
Original Weller Tips.
°Fx10
ESD SAFE
Weller
Soldering Tool Stand
HY1503C
DC POWER
SUPPLY
graphite lubricant
KEEPS ALL LOCKS WORKING
Consolidated
Consolidated

Figure 2-10. *A Weller controlled-temperature soldering station. What a mess!*

Like any worthwhile skill, soldering is best mastered with lots and lots of practice. The best way to learn this useful skill is to have someone show you how it's done. It's difficult, but not impossible, to learn proper soldering techniques from a book. That being said, have a look at Figure 2-11.

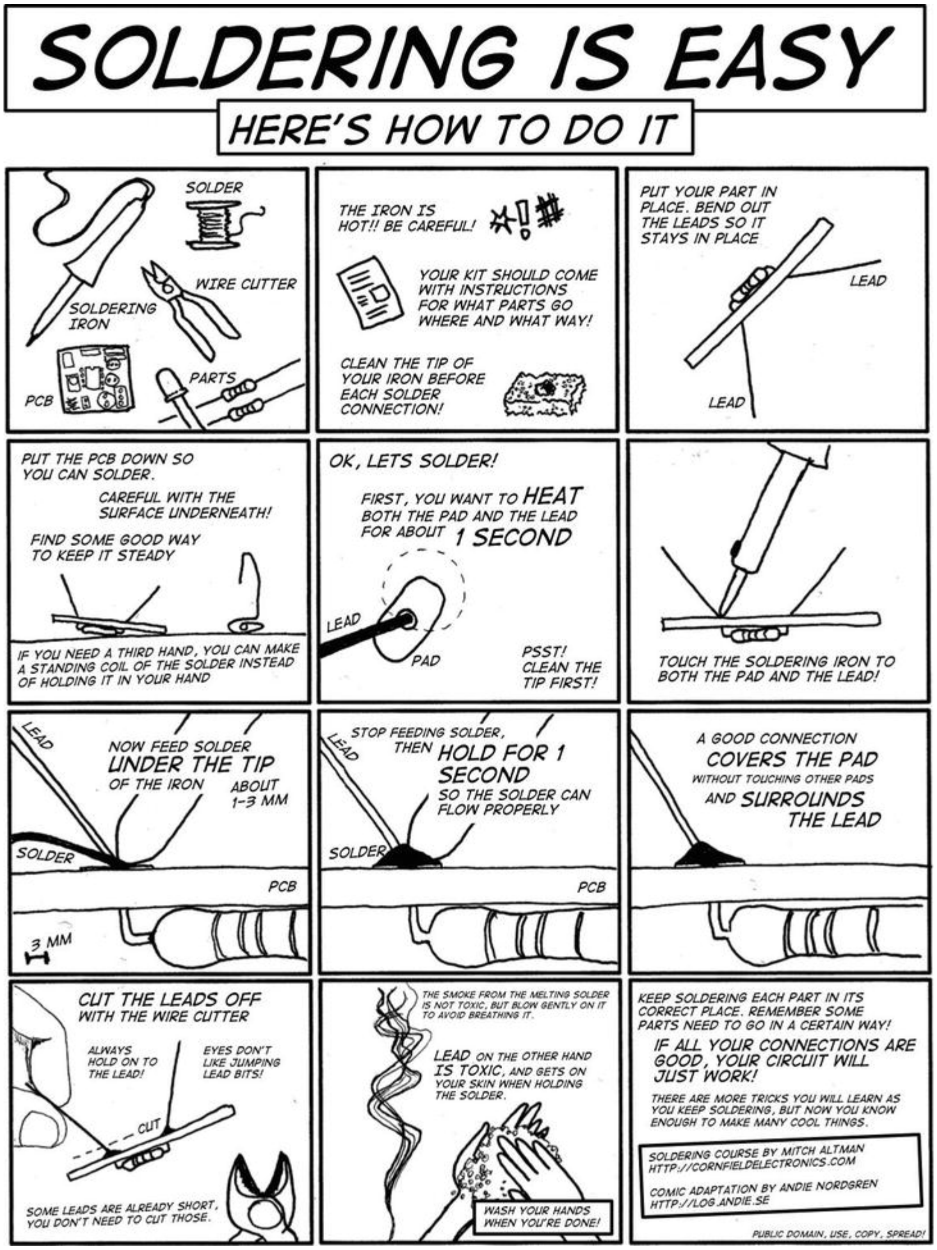
SOLDERING IS EASY
HERE'S HOW TO DO IT
SOLDER
WIRE CUTTER
SOLDERING IRON
PCB
PARTS
THE IRON IS HOT!! BE CAREFUL!
YOUR KIT SHOULD COME WITH INSTRUCTIONS FOR WHAT PARTS GO WHERE AND WHAT WAY!
CLEAN THE TIP OF YOUR IRON BEFORE EACH SOLDER CONNECTION!
PUT YOUR PART IN PLACE. BEND OUT THE LEADS SO IT STAYS IN PLACE
LEAD
LEAD
PUT THE PCB DOWN SO YOU CAN SOLDER.
CAREFUL WITH THE SURFACE UNDERNEATH!
FIND SOME GOOD WAY TO KEEP IT STEADY
IF YOU NEED A THIRD HAND, YOU CAN MAKE A STANDING COIL OF THE SOLDER INSTEAD OF HOLDING IT IN YOUR HAND
OK, LETS SOLDER!
FIRST, YOU WANT TO HEAT BOTH THE PAD AND THE LEAD FOR ABOUT 1 SECOND
LEAD
PAD
PSST! CLEAN THE TIP FIRST!
TOUCH THE SOLDERING IRON TO BOTH THE PAD AND THE LEAD!
LEAD
NOW FEED SOLDER UNDER THE TIP OF THE IRON
ABOUT 1-3 MM
SOLDER
PCB
3 MM
LEAD
STOP FEEDING SOLDER, THEN HOLD FOR 1 SECOND SO THE SOLDER CAN FLOW PROPERLY
SOLDER
PCB
A GOOD CONNECTION COVERS THE PAD WITHOUT TOUCHING OTHER PADS AND SURROUNDS THE LEAD
CUT THE LEADS OFF WITH THE WIRE CUTTER
ALWAYS HOLD ON TO THE LEAD!
EYES DON'T LIKE JUMPING LEAD BITS!
CUT
SOME LEADS ARE ALREADY SHORT, YOU DON'T NEED TO CUT THOSE.
THE SMOKE FROM THE MELTING SOLDER IS NOT TOXIC, BUT BLOW GENTLY ON IT TO AVOID BREATHING IT.
LEAD ON THE OTHER HAND IS TOXIC, AND GETS ON YOUR SKIN WHEN HOLDING THE SOLDER.
WASH YOUR HANDS WHEN YOU'RE DONE!
KEEP SOLDERING EACH PART IN ITS CORRECT PLACE. REMEMBER SOME PARTS NEED TO GO IN A CERTAIN WAY!
IF ALL YOUR CONNECTIONS ARE GOOD, YOUR CIRCUIT WILL JUST WORK!
THERE ARE MORE TRICKS YOU WILL LEARN AS YOU KEEP SOLDERING, BUT NOW YOU KNOW ENOUGH TO MAKE MANY COOL THINGS.
SOLDERING COURSE BY MITCH ALTMAN HTTP://CORNFIELDELECTRONICS.COM
COMIC ADAPTATION BY ANDIE NORDGREN HTTP://LOG.ANDIE.SE
PUBLIC DOMAIN, USE, COPY, SPREAD!

Figure 2-11. *Instructions for soldering. This delightful illustration by Andie Nordgren captures the basics of soldering as taught by soldering guru Mitch Altman (http://log.andie.se/post/397677855/soldering-is-easy).*

To solder, you will need a soldering iron. You will also need some solder and probably some wire cutters. That's just the tip of the iceberg, however. Like any good tool, your soldering station will soon accumulate many *accessories* to enhance your soldering prowess.

To begin your soldering adventure, you will need a *small* soldering iron, some solder, and a damp sponge. The big, pistol-grip style of soldering irons are for much larger projects, such as plumbing. Ideally you want something in the 15W to 50W range. See Figure 2-12.

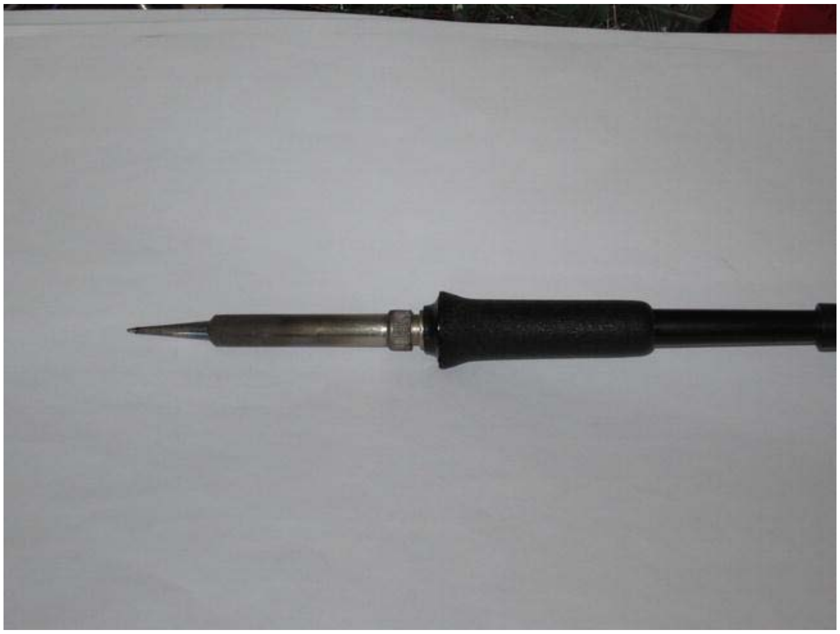

Figure 2-12. *The pencil-grip style of soldering irons is better suited for working on small electronics projects.*

The soldering iron in Figure 2-12 has a replaceable, conical tip. These tips are generally interchangeable for a particular model of soldering iron, but unfortunately not interchangeable between different models or manufacturers. Different tip shapes are also available, depending on what types of things you're wanting to solder.

The tip is usually made of copper, which is an excellent conductor of heat. Since copper really likes to combine with other metals at high temperatures (which is exactly what happens when soldering), most tips are coated in a thin layer of steel to give them much longer useful lifetimes. Tips still wear out, however, and should be replaced.

In this particular soldering iron, the next part of the iron is the removable barrel that holds the tip in place. This barrel is where the heating element is housed, so remember that it is just as hot as the tip! Try not to touch it. You will probably not want to make that mistake more than once.

The next section is the padded and insulated handle of the soldering iron, which is made of dense plastic foam. A quality soldering iron will be comfortable in your hand and won't produce excessive fatigue, even after hours of use. Lower-quality and lower-priced models will more rapidly take their toll on your hands.

Not shown in Figure 2-12 is the flexible power cord running back to the soldering iron's base. This cord supplies the electrical power that is converted to heat in the barrel, as well as some wires for a temperature sensor. This allows the unit to control the temperature of the tip with great accuracy. Note the temperature dial in Figure 2-10. Lower-cost units omit the temperature control features and run at a constant power output.

It will take some amount of time for the soldering iron tip to reach a working temperature. Likewise, it will also take some time to cool off once you've turned off the soldering iron.

■ **Caution** Soldering irons are very hot in use and can cause painful burns. Always treat them with respect!

The solder you use will be determined by what kind of soldering you want to do. For most small, electronics-related soldering projects, a small-gauge tin-lead or lead-free solder can be used. Bear in mind that lead is a poisonous material that slowly accumulates in your system, should you come into contact with it, as your body has no good way of eliminating it. Wash your hands before and after soldering, just to be safe.

Soldering works best when everything being soldered is sparklingly clean. To help facilitate this cleanliness, chemical compounds known as soldering rosin are used. These compounds chemically clean the surfaces being soldered when exposed to high levels of heat. Some types of solder have rosin incorporated into them. You can also obtain rosin as a paste into which you can dip wires and component leads before soldering. Other types can be applied with a dispensing pen.

■ **Caution** Don't breathe the smoke emitted during the soldering process. If possible, use a fan or fume extractor to redirect the soldering fumes away from you.

Once your soldering iron is up to its proper operating temperature, clean the tip by wiping it gently on a damp sponge. Your tips will last longer if you resist the urge to clean them before replacing the soldering iron in its holder. Even though it seems counterintuitive to "put it up dirty," this will more than double the life of your soldering iron tips. Just be sure to clean the tip *before* you solder anything.

Power Tools

Everybody loves power tools, don't they? Sometimes it's enough to just *imagine* that you might need one to justify a trip to the store and subsequent purchase. While this may be human nature (or perhaps only the nature of one particular gender), it doesn't fully justify having one of each in the lab, *just in case*.

Drills and Drill Bits

You will, however, find a few particular tools to be especially useful in your lab. A good hand drill or drill press is one of those tools. There seems to be no end of things electronical that need a few more holes drilled into them. Electronic enclosures and control panels need good, clean holes drilled into them. If you make your own PCBs at home, you will find that they need *lots* of holes drilled into them.

Like any power tool, an electric drill needs and deserves your respect. You'd be surprised how much unintentional damage you can cause with such a simple device. Observe these simple safety rules when operating a power drill:

- Keep your work area clean and well illuminated.
- Remove any watches or jewelry you might be wearing.
- If you have long hair, keep it pulled back and tied out of the way.
- Always clamp down any work to be drilled on a drill press.
- Always remove drill bits from the drill chuck after use.
- Discard dull or rusted drill bits that cannot be resharpened.
- Always wear safety glasses when operating power tools.

Hand drills come in all shapes, sizes, and price ranges. Some are powered by hand cranks and some are electric. Rechargeable batteries make for very portable drills that you can carry almost anywhere. See Figure 2-13. The only drawback is their limited charge time. That's why you should always have at least one spare battery charged up and ready to go. Electric drills with wires attached don't have this problem. Just don't trip over the cord!

RYOBI
15
20
ONE+
18v

Figure 2-13. *A rechargeable hand drill. This model is both variable speed and reversible, which are two very desirable features in a hand drill.*

■ **Note** Power drills are also very handy when used with screwdriver bits. They can save you time and many blisters!

Drill bits likewise come in all sizes and shapes. You can buy sets with a variety of sizes, and these will usually come with a handy storage container that conveniently labels all the sizes for you. This only works, however, if you take the time to return the drill bits to their proper location once you've finished working with them.

A drill press has a large frame that facilitates drilling a precisely aligned hole, over and over again. You can make spindle-speed adjustments to drill presses (even small ones, such as the one pictured in Figure 2-14) either through an electronic speed control or by changing up the belts and pulleys that drive the spindle. There are even small frames for mounting handheld drills or rotary tools, such as the Dremel brand of tools. You can often, however, find actual, dedicated drill presses on sale for about the same price as the daintier Dremel tools.

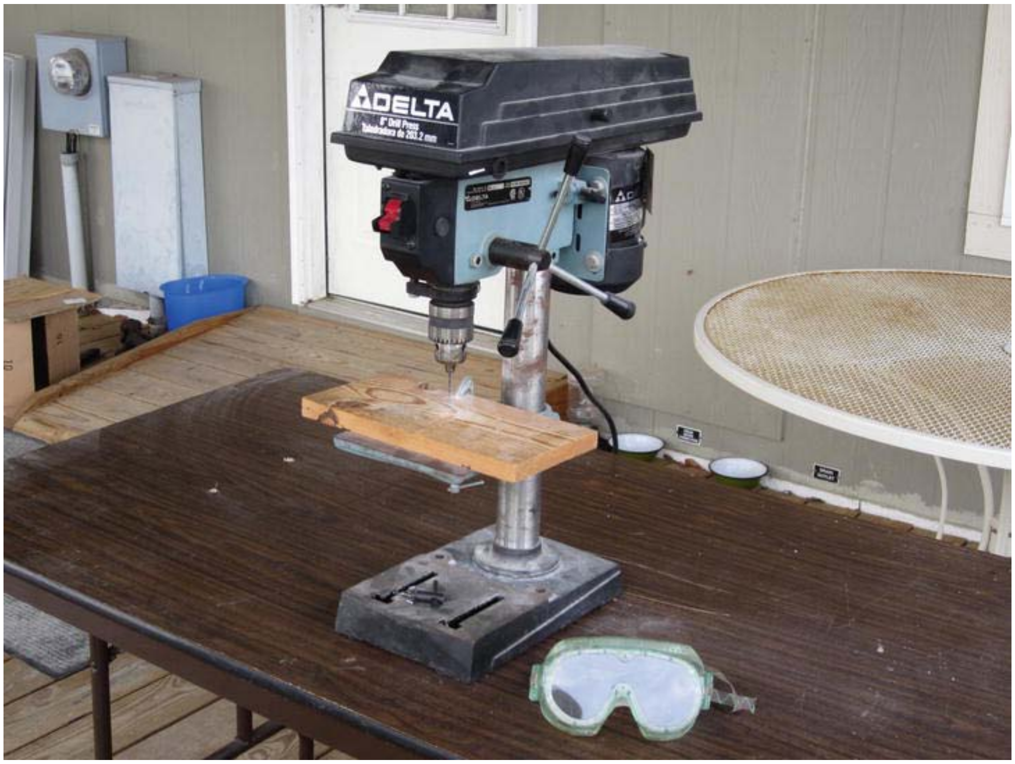

Figure 2-14. *A small tabletop drill press*

■ **Caution** When working with drills and presses, always keep your work area clear. Always wear safety glasses when using power tools. Try to keep the chuck key handy. Don't leave drill bits mounted in the chuck when not in use. Many chuck keys have built-in springs that prevent them from remaining in the chuck. Those that don't risk being accidentally left in the chuck when the drill its turned on, which can either fling the chuck across the workshop or make a big mess of your favorite hands.

Laser Cutters and 3D Printers

While not everyone can afford some of the more expensive and esoteric tools that are available, some of these tools are getting more popular than others; excellent examples are laser cutters and 3D printers. See Figures 2-15 and 2-16.

Laser cutters and engravers use a powerful carbon-dioxide laser to cut through wood and non-chlorine-based plastics. The laser beam is focused onto the work surface using mirrors that are mounted in an XY gantry, allowing the cutting area to be controlled by a computer. Typical installations require venting to the outside because of the various aromas produced in the process, as well as a water-cooling system for the laser tube itself.

There are also some newer laser cutters being built by hobbyists from scratch.

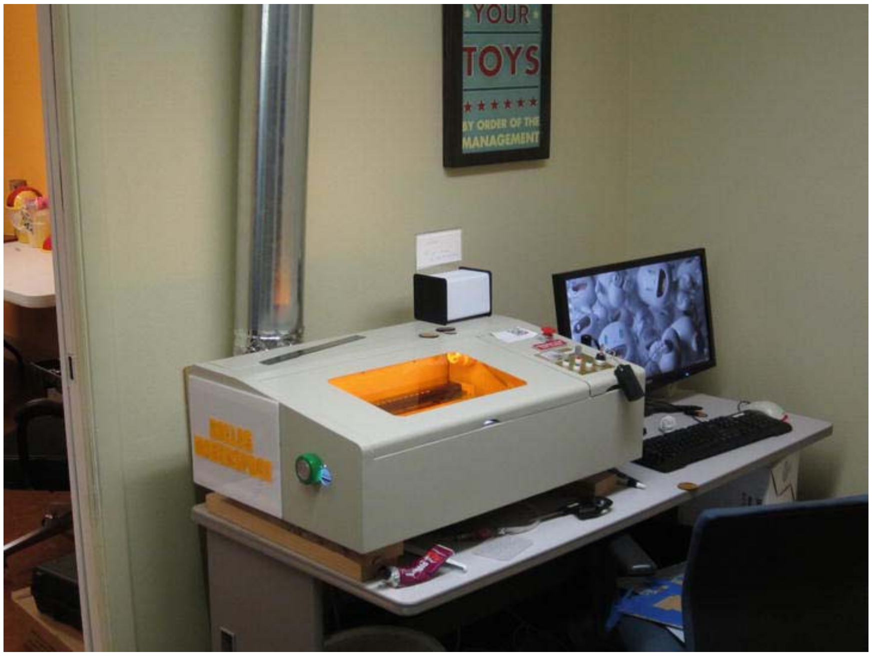

Figure 2-15. *A laser cutter. A powerful 40W carbon-dioxide laser is used to cut through wood and non-chlorine-based plastic, all under computer control. It can also be used as an engraver. This model is manufactured by Full Spectrum Engineering.*

3D printers seem to be all the rage these days. We're all pretty accustomed to the idea of printing on paper with a computer, although it's still a pretty recent innovation, as far as the history of printing goes. The idea of printing a solid object, on the other hand, is considered to be something of a game-changer.

The simplest 3D printers use a plastic extrusion and a motorized gantry to operate as a kind of a robotic glue gun. A plastic filament is fed into a heated fixture that is moved around a print bed, leaving a trail of cooling, gooey plastic. Either the extruder or the print bed is moved using motors under computer control to build up a layer at a time of the desired object.

Higher-technology 3D printers use this and other techniques to produce tangible, solid objects. Some use layers of fine powder that is glued together with a binder dispensed from a print head, similar to an inkjet printer. As each layer is printed, the object is lowered and another layer is deposited. This can even be done with sugar, as in the case of the CandyFab 4000, designed by the clever folks at Evil Mad Scientist Laboratories (`www.evilmadscientist.com/article.php/candyfab`). A stream of heated air is used to fuse a layer of sugar into a single solid structure, and an object is built up of successive layers.

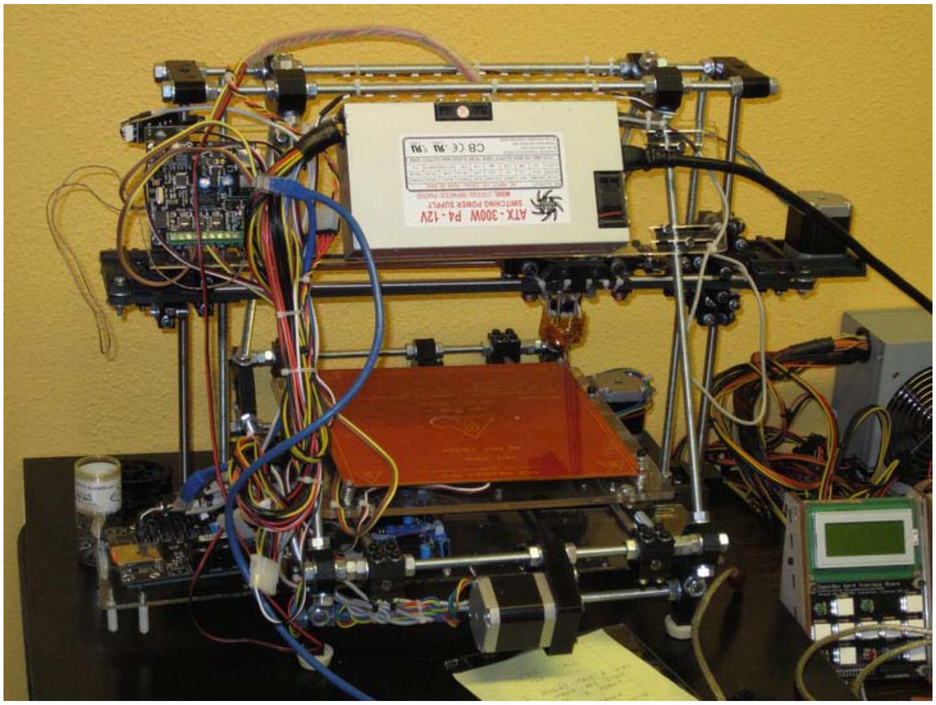

Figure 2-16. *A 3D printer at Dallas Makerspace. This machine uses a heated extruder to build 3D objects out of plastic.*

Basic Test and Measurement Equipment

When it is behaving itself, electricity is generally invisible. To "see" what it is doing, or not doing, you will need some specialized tools. These fall into the two general categories of *test* and *measurement* equipment.

The line between testing and measuring is sometimes blurry. One possible distinction might be that testing verifies proper operation within acceptable parameters, while measurement actually assigns values to those parameters. An example of testing is, Does that flashlight work? The answer is yes or no, arrived at by the simple expedient of turning it on and observing the results. An example of measurement is, How much current does that flashlight draw? The answer might be 0.78A, and this would be determined using the appropriate measurement device, which in this case could be an ammeter.

Inspection Equipment

Sometimes, however, measuring things isn't hard at all, especially when the things being measured are actual, tangible items that you can hold in your hand. What you will need are some basic tools, primarily to be able to *see* what it is that you are measuring, and secondarily to take accurate measurements of them, at least in regard to their physical dimension. This comes in very handy when trying to identify components during repair or equipment upgrades, when the original technical documentation is not at hand.

Even the youngest and finest of eyeballs will need help with the teeny-tiny components that are available nowadays. You should try to find at least a small magnifying glass to examine fine details. If your budget allows, you might want to consider a microscope of modest power to look at your handiwork. Careful shopping will result in finding some older microscopes at bargain prices. Expect to pay a premium price for the shiny, new stuff. See Figure 2-17.

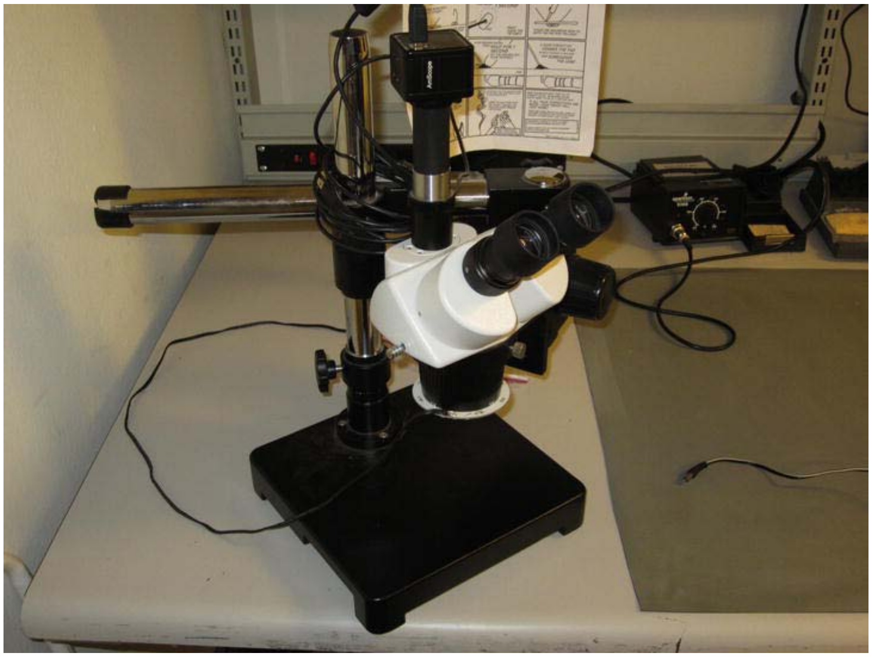

Figure 2-17. *A very nice stereo microscope. The power cord running to the white ring (partially hidden) supplies power to a ring of white LEDs that help illuminate the field of view. The base is very heavy to help stabilize the microscope.*

Even a humble magnifying lens can be very helpful in the lab, especially if it has a built-in light. See Figure 2-18.

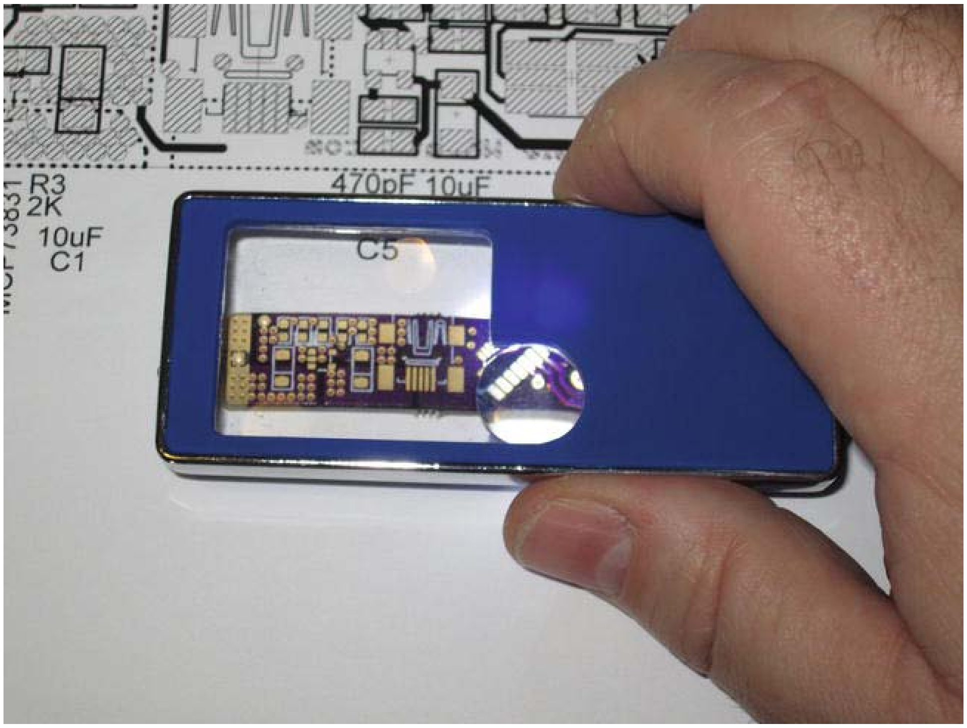

Figure 2-18. *A small, handheld magnifier with a built-in LED light is very handy for examining small features and details, such as are found on many PCBs.*

Physical Measurement Devices

Once you know what something looks like, at extreme close-ups, can you describe in absolute terms how big it is?

Take a look at Figure 2-19. Here we have, from the top to the bottom, a traditional tape measure, marked in both English and metric units (fractional inches and decimal centimeters), a digital caliper that can render measurements in either system at the touch of a button, and an architect's scale. While it may not be evident in the top-down view, the architect's scale is triangular in cross-section, resulting in not two but *six* different measurement options. This is mostly due to architects liking to draw things to scale, instead of full-sized.

The digital caliper is interesting in that it also provides a computer interface so that its readings can be pulled in by a computing device of some sort. These devices used to be quite expensive, but mass production has brought their prices down significantly.

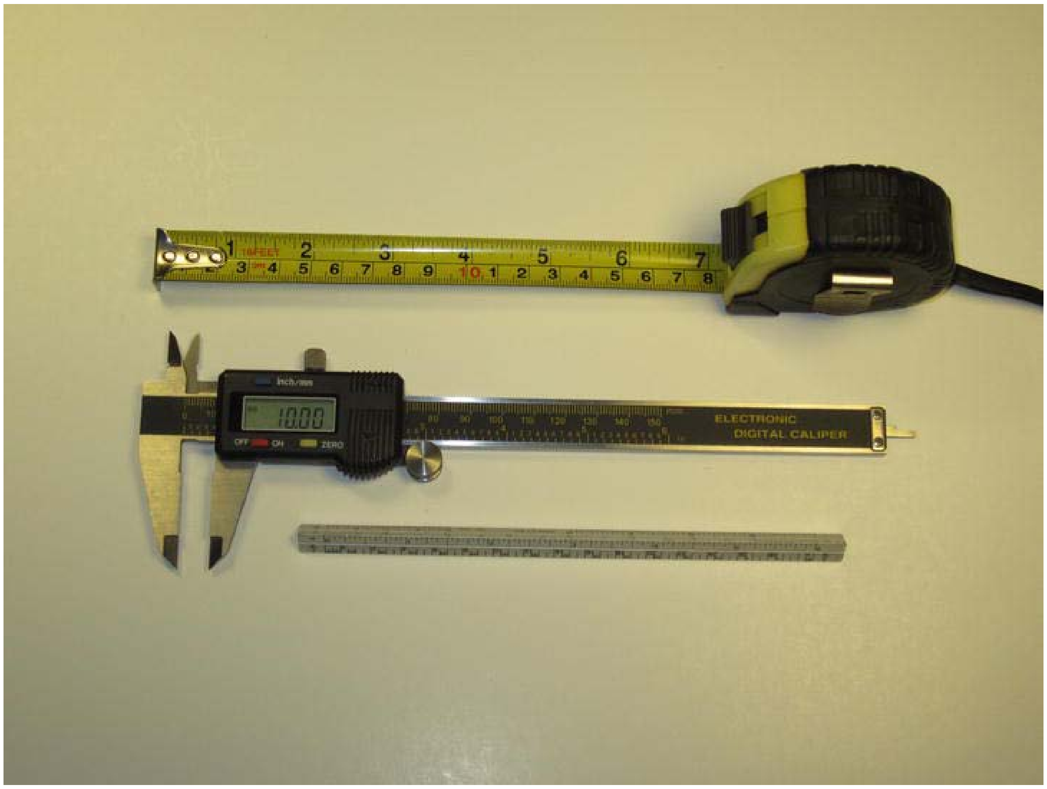

Figure 2-19. *From top to bottom, a tape measure, a set of digital calipers, and an architect's scale.*

Simple Electronic Measurement Tools

Now that you've got the tools to examine what these things look like and how big or small they are, let's move on to the more mysterious art of measuring their electrical properties.

Voltmeters

Voltage is a measure of electromotive force, and the standard unit of measure is the *volt*, named after Alessandro Volta, an Italian physicist. Voltage is sometimes compared to the pressure of water flowing through a garden hose, while amperage is compared to the amount of water flowing through the hose at any given time. It's not particularly useful to push this water analogy too far, but it's helpful in the beginning.

Voltage can be accurately measured with, you guessed it, a voltmeter. See Figure 2-20.

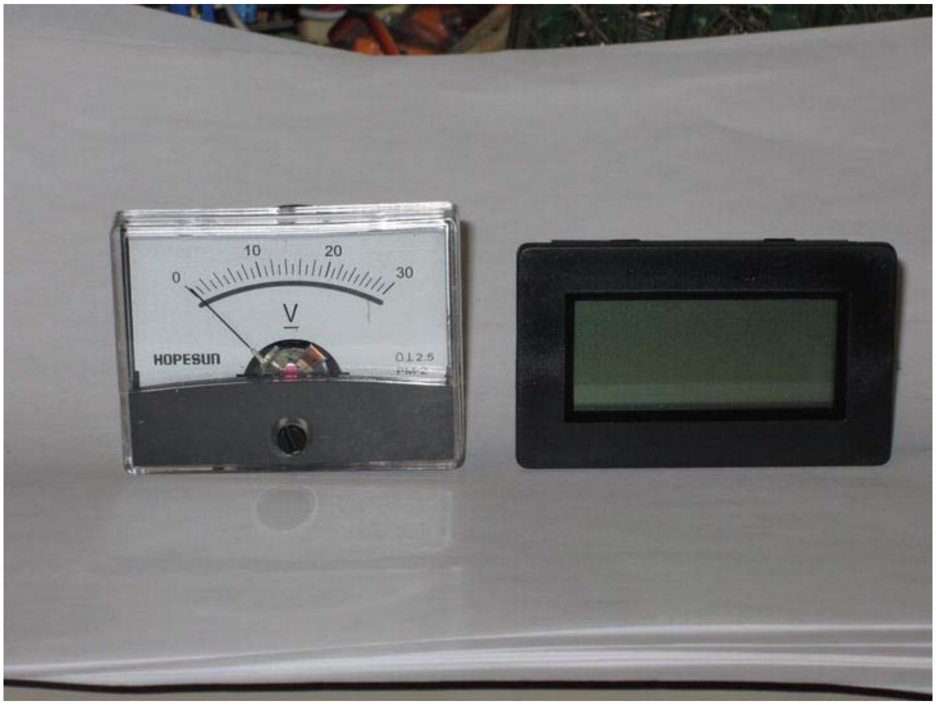

Figure 2-20. *A panel-mount analog voltmeter (left) and a digital version (right)*

A voltmeter measures the voltage, or *potential difference*, in a circuit across two points. Sometimes one of the points is a fixed reference point, such as the electrical *ground* mentioned in many circuits. This is often just a convenience for the purpose of measuring things, as the ground in an electrical circuit may or may not be connected to the ground under your feet.

A voltmeter will have two terminals, labeled positive (+) and negative (–). Looking at the analog voltmeter in Figure 2-20 (the one on the left), we see a needle that can swing from 0 on the left to 30 on the right. The prominent capital *V* on the dial indicates that the unit of measure is the volt. This indicates that you can use this meter to directly read from 0 to 30 volts, just by placing its terminals across a voltage. The meter itself is electromechanical in design, and creates a magnetic field that works against a spring and a fixed magnet. This action causes the needle to move to a point generally corresponding to the labeled voltage on the dial. These needles are not especially accurate, but can be corrected using the screwdriver adjustment at the bottom of the meter.

An analog panel meter such as this one does not require a separate power supply for proper operation. It draws all the power it needs from the signal being measured. This makes it unsuitable for measuring low-power circuits, where the current draw from the meter would unduly influence the reading.

The panel meter on the right is a digital circuit that measures the voltage and displays it on the built-in liquid crystal display (LCD). It requires a separate power supply for normal operation.

Ammeters

An *ammeter* looks and operates just like a voltmeter, except that it measures electrical current flow instead of voltage. The flow of electrical current is measured in units called *amperes* (A). The basic mechanism is almost identical to a voltmeter. To convert a current flow into a voltage, an electrical device known as a *shunt* is used. The shunt is simply a fixed-value resistor that produces a voltage across its terminals in relation to the amount of current that is flowing through it and its inherent resistance to the flow of current.

This relationship between voltage, current, and resistance is elegantly expressed in *Ohm's Law*. If you know two of the measurements in a circuit, you can calculate the third, based on their fixed and proportional relationship to each other. You will find this law to be exceedingly helpful to you when designing, repairing, and upgrading electronics.

To avoid using fractions, which seem to terrify so many people for no good reason, you can use Ohm's Law thusly:

- Voltage (volts) = current (amps) × resistance (ohms)
- Current (amps) = voltage (volts) ÷ resistance (ohms)
- Resistance (ohms) = voltage (volts) ÷ current (amps)

That's all there is to it, if you're just working with volts, amps, and ohms. Things can get weird, however, when you start to work with alternating current (AC), which is the kind of electricity you find in wall outlets and audio circuits.

Ohmmeters

An excellent application of Ohm's Law is found in building a resistance meter, also called an ohmmeter, because it measures resistance. Resistance is measured in units called ohms, often abbreviated with the capital Greek letter omega (Ω).

There are two ways to do measure resistance. One is to pass a known voltage though the unknown resistance and measure the current that is flowing in the circuit. The other is to pass a fixed current though an unknown resistance and measure the voltage across it. This second method is the one most commonly used.

You're most likely going to use a multimeter to measure resistance, as this is one of the more common functions of these handy devices. Mutlimeters are covered in the very next section.

Advanced Test and Measurement Equipment

It would seem that for simple circuits, having just a voltmeter, an ammeter, and an ohmmeter would be all you need. For the most part, this is correct. However, have you considered what would happen if you applied 100V to the 30V meter shown in Figure 2-20? What if you simply reversed the polarity of the signal by accident? Something bad for the meter, that's for sure. It might not actually catch on fire *right away*, but it would certainly damage the delicate, spring-loaded mechanism, possibly rendering it useless as a reliable measuring instrument.

The same can be said for an unprotected ammeter or ohmmeter. Luckily, the nice people that make good test equipment stay up late at night, thinking of the stupid things we might do with their products, and protect them accordingly. Let's look at some meters that measure multiple electrical characteristics, which strangely enough are called *multimeters*.

Multimeters

Multimeters will almost always allow you to measure various ranges of DC (direct current) volts, AC volts, current, and resistance. More advanced meters also measure things like frequency and duty cycle or even temperature. Some meters will even directly measure capacitors, inductors, and transistors using specialized connectors.

As with most tools, you generally get what you pay for with multimeters. The meter on the left in Figure 2-21 was purchased for under $3, including shipping from China. It arrived DOA (dead on arrival) and was not deemed important enough to return. It will make an interesting clock or fake lie detector someday. The unit on the right was purchased new for nearly $400 and has provided over a decade of useful service. The unit in the center is modeled after the unit on the right, it would seem, but can be bought new for between $10 and $20. The unit in the photo was bought wholesale for $4, because sometimes you get lucky. It's often handy to have a second meter in the lab—for example, when you need to measure the voltage *and* the current flowing in a circuit simultaneously, which you just can't do with a single meter.

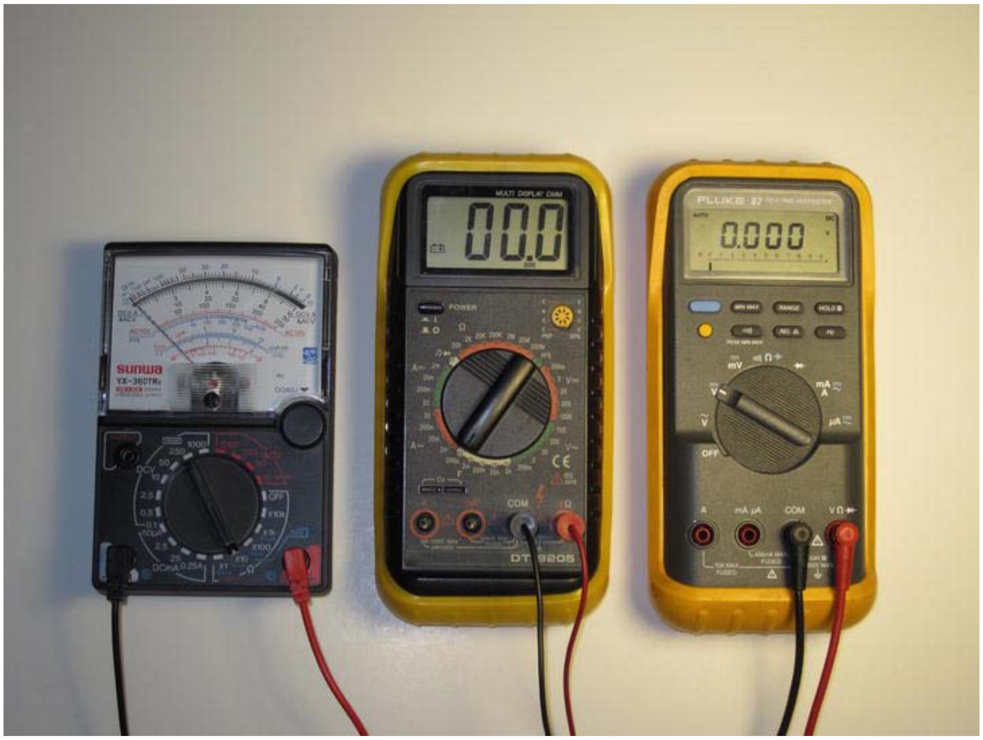

Figure 2-21. *Examples of some multimeters. The meter on the left features an analog display that is easy to read and acommodates several readout scales simultaneously. The remaining two meters have digital readouts and offer more accuracy. All the meters use a large rotary knob for selecting the proper function. The higher-cost unit on the right features auto-ranging, intellignetly deciding what range to use. The right two units also have high-impact boots to help protect them in the event of a fall.*

Your present budget will help determine what level of multimeter you might want to obtain. If you're wanting to sink less cash into a multimeter right now, consider looking for used equipment in good shape. As with any good tool, you can spend as much as you like on these. The sky really is the limit here.

Most all-in-one meters protect their inputs using fuses. You will have to disassemble your meter to replace these fuses, so think twice and measure once (to paraphrase the old carpenter's saying, "Measure twice and cut once").

■ **Tip** Be sure to set up your meter for the proper function and range *before* taking measurements.

Oscilloscopes

Once you've gone beyond measuring simple DC and AC voltages and move on to more complex signals and waveforms, you'll have to lay aside your trusty meter and fire up your favorite oscilloscope. This instrument is more complex than your traditional multimeter, and offers a different perspective on what's going on in your circuit.

While many modern oscilloscopes have many modes of operation, their basic function is to draw a picture of your signal on a small screen. In the olden days, this was done with a moving dot that was swept across a phosphorescent screen, leaving a residual, fading line of light. If this pattern was repeated over time, a visual representation of the signal could be seen on the screen. See Figure 2-22.

Modern oscilloscopes use a computer monitor or built-in screen display to draw the signal. This saves space, weight, and power requirements.

When purchasing an oscilloscope, the features you pay most for are the number of available channels and the bandwidth. The least expensive oscilloscopes will have a single channel. Having multiple channels allows you to "see" multiple signals simultaneously, which is often helpful in understanding what is going on in a circuit.

Bandwidth refers to the range of frequencies that can accurately be measured by the oscilloscope. Lower bandwidth scopes require much simpler electronics, and are thus cheaper to produce.

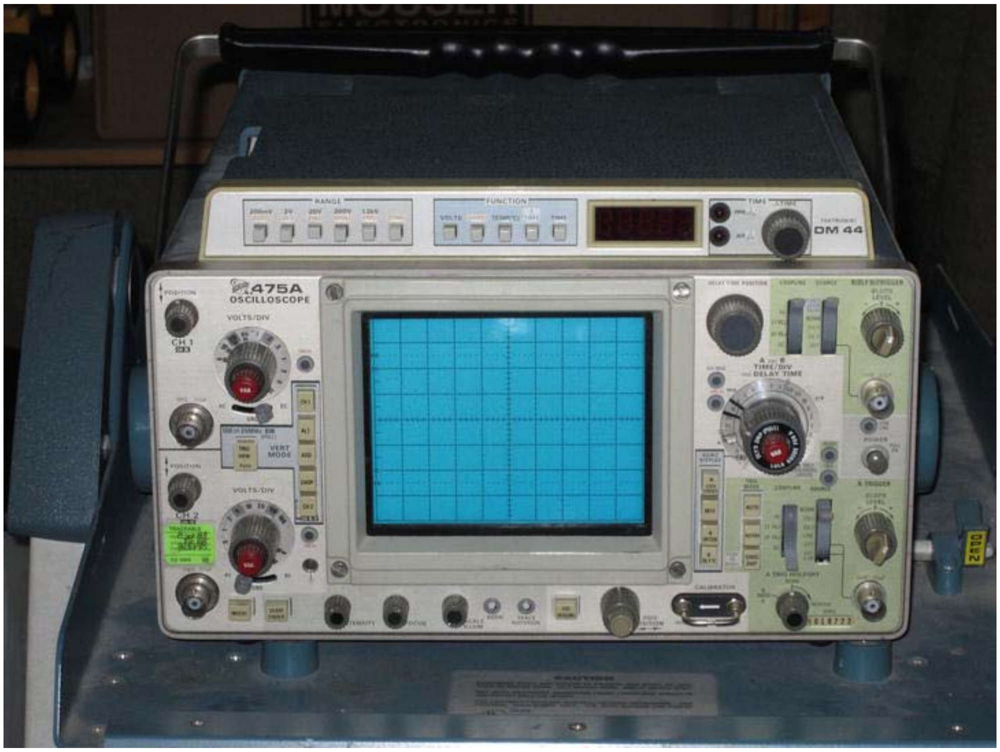

Figure 2-22. *A Tektronix 475A oscilloscope. This piece of vintage test equipment is considered by some to be the best analog oscilloscope ever made. It also has a digital multimeter built in along the top edge.*

The Golden Age

Once upon a time, not so long ago, a quality oscilloscope weighed 40 pounds and had a folding handle to make it, if not portable, at least *transportable*. It also had its own line of furniture to place it on, so that you could wheel it around the lab as you needed. Oh, and it also cost about three months' salary, and that's if you had a *good* job.

The good news? That same scope still works today. It can be repaired or calibrated to the exact same standards as when it was brand new, *plus* you can buy it on eBay for a few hundred dollars, sometimes less. That's because when these devices were designed back in the 1970s, they were made to be the best in the world, and cost was not a factor.

Modern Oscilloscopes

Today you can buy a quality oscilloscope for a few hundred to a few thousand dollars. These scopes not only display your signal on a large, colorful screen, but they can also analyze the signal and tell you all kinds of interesting things about it. For an example of such an oscilloscope, see Figure 2-23.

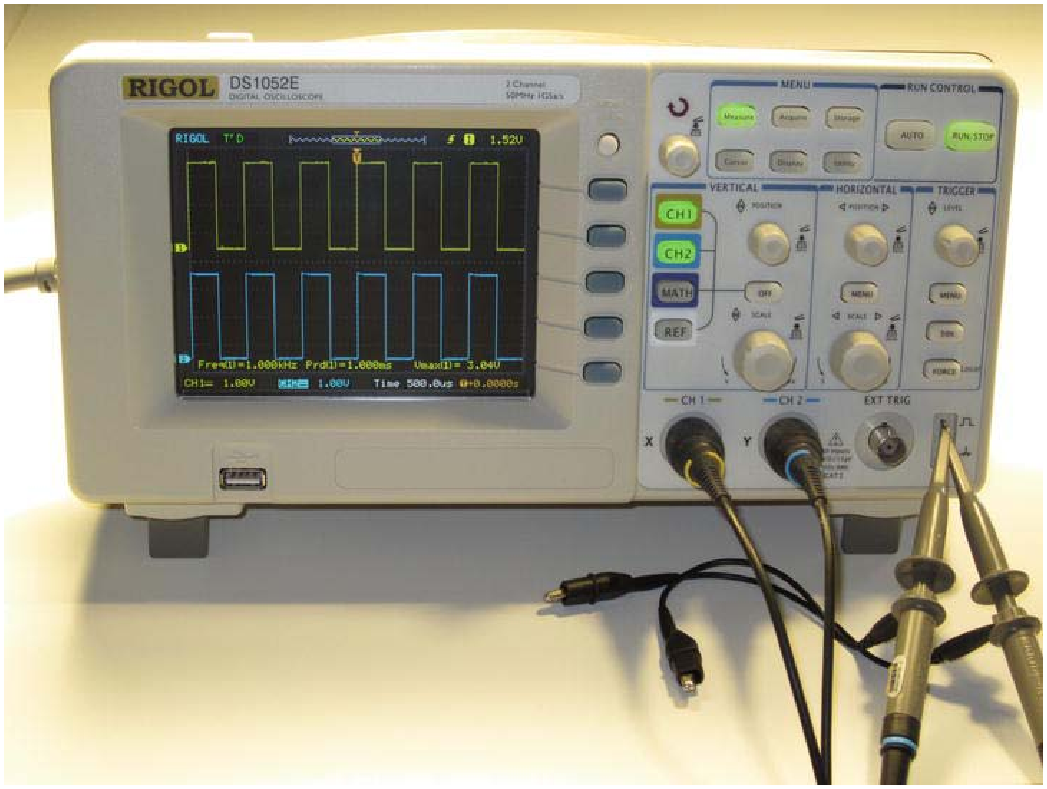

Figure 2-23. *A modern digital storage oscilloscope. The RIGOL DS1052E is an affordable scope that will handle most troubleshooting and design challenges that you might encounter in your lab.*

This new breed of digital storage oscilloscope (DSO) can even connect to your PC to be remotely operated and allow you to capture screen shots that can then be pasted into books about how to build your own electronics lab. It's true. See Figure 2-24.

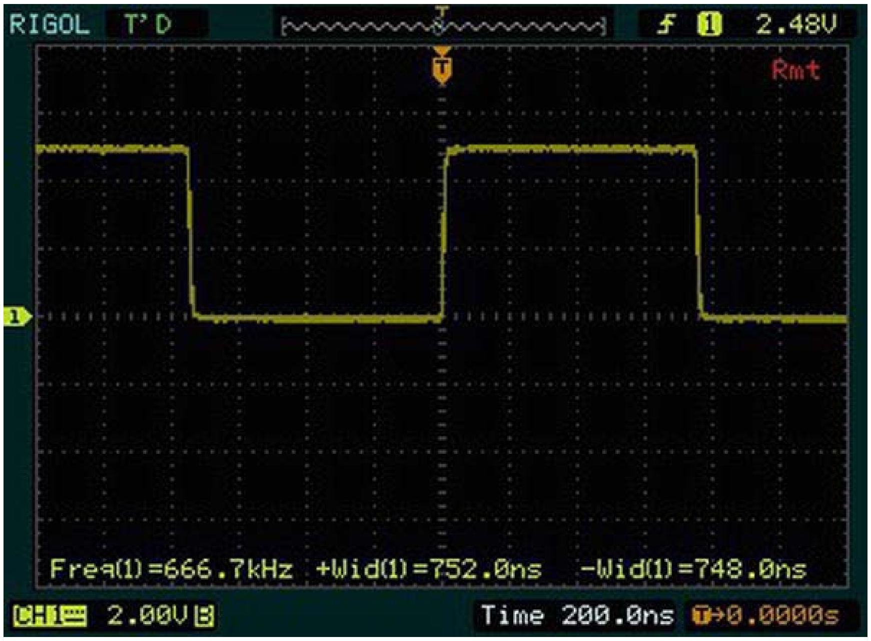

Figure 2-24. *A screen capture made with the RIGOL DS1052E oscilloscope.*

Tiny Oscilloscopes

The march of electronic miniaturization never stops, and so it is with oscilloscopes. If both your needs and your budget are modest enough, perhaps you can get by with something like the pocket-sized wonder shown in Figure 2-25.

While little scopes like this lack the accuracy and bandwidth of their larger relatives, they are definitely handy to have when you need to look at a signal. If you can keep your expectations in check when it comes to the user interface, you can get a lot of utility from such a small package.

Additionally, one of the benefits of a device such as this is that the hardware and internal software (yes, there's a little computer in there, somewhere) is all open source. This means that you have access to all the schematics and source code. And what does that mean? It means that if you have the skills and the right equipment, you can redesign the entire apparatus to fit your own requirements, assuming that you understand the basic limitations of the electronics. The sky is the limit. You are empowered.

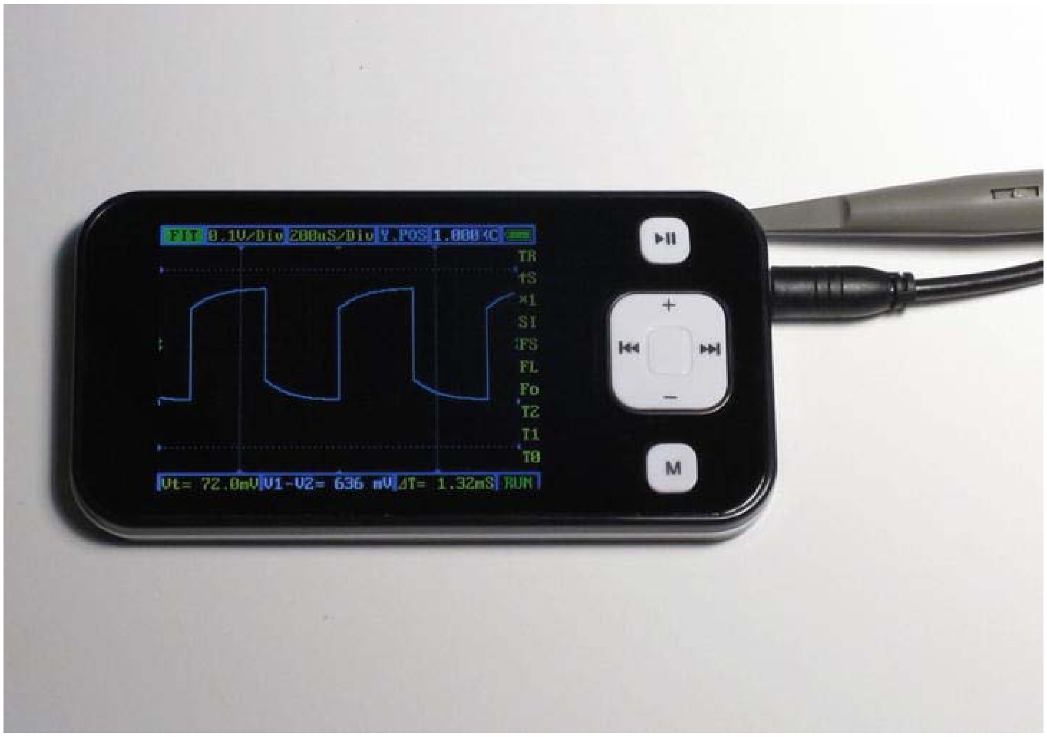

Figure 2-25. *A handheld oscilloscope, which can also fit in your pocket. This is the DSO201, which has been discontinued by the manufacturer, but can still be snapped up for a song from various online distributors, as well as eBay. This unit was purchased new for $60 and features a single channel with a bandwidth of 1 MHz.*

Power Supplies

One of the most important pieces of test equipment in your lab is a reliable power supply. Building a good bench power supply is an excellent first or second electronics project (see Chapter 5 for more on adding power supply to your lab and Appendix A for more on building your own). This is because the basic design is very simple and easy to build, yet allows you to add any number of additional features later.

Once you get tired of throwing away spent 9V batteries and grow weary of waiting for the red light on the battery charger to go out, it’s time to invest (either time or money or both) in a decent bench power supply.

It doesn’t have to be fancy. In fact, the simpler the better at first. What you’re aiming for primarily at this point is reliability. You want to know that when you turn on your 5V supply, it’s putting out 5 volts, not 2 or 11, no matter what you do to it. If it’s overloaded, it needs to deal with it and not be catching on fire. If it’s underloaded, or not loaded at all, it still needs to maintain a nice, clean output.

Want a cheap or free power supply? Do you have any dead or discarded electrical gizmos that came with a charger? These make excellent starter supplies for the new lab. Do you have any extra USB chargers? These are even better, because they supply up to 2.5W (and sometimes more) of *regulated* 5V. We'll use some of these in experiments in Chapter 3.

Organizing Your Tools

So now you have an idea about some of the tools you want (or already have) for your lab. Where are they all going to live? This is a big question, and deserves a big answer.

One way to look at this book is that the entire latter half is dedicated to answering this question. There are, obviously, many possible arrangements that will work for most people. But we're talking about *your* lab, with *your* tools, arranged and ordered to meet, specifically, *your* needs.

As you progress through Chapter 3 (the very next chapter in this book), you'll get a chance to play with both your tools and some interesting electronic components, all in the interest of getting you familiar with some basic concepts. These concepts and ideas are not new, but they may be new to you. The good news is that time invested today and in the very near future should pay off big dividends to you later in life. Who knows what you'll devise in that electronics lab of yours?

Summary

Starting with your brain and working outward, this chapter has covered some of the tools and devices you might use in your electronics lab. These include basic hand tools, computers, tools for soldering, some common power tools you might find handy, as well as some fancy-schmancy tools you might only find in a hackerspace, school, or electronics clubs, such as laser cutters and 3D printers.

You also learned about some of the basic test and measurement tools you'll be needing when working on electronic circuits in your lab. These include magnifying glasses, measuring tapes, and meters (oh my!), as well as oscilloscopes and power supplies.

Additionally, *lots* of advice on safety was presented. These topics were learned the hard way. Do try to learn from the mistakes of others, won't you?

Just a hint was given about how you might want to organize your tools within your lab. Take care of your tools and they will most certainly take care of you. The details about possible organizational scenarios is left for the second half of the book, where you will learn about setting up labs big and small, as befits your needs, budget, and interests.

Chapter 3 ties in much that you have learned here in Chapter 2 by introducing you to not only some of the basic electronics components and their uses and characteristics, but also how to use a good number of the tools described in this chapter. Hopefully this chapter has whetted your appetite and readied you to dive into some circuits and see what kind of mischief you can wreak on the world.

CHAPTER 3

Components

You're going to need some components to play with, as well as the knowledge to use them effectively. This chapter will introduce you to some of the bits and pieces that make up modern electric and electronic circuits. It will also teach you a little bit about how to identify components from their appearance and markings, when available.

Once you've got an idea about what these parts do in a circuit, you'll learn a little more about how to measure their electrical properties and put them to use. You'll also be shown what *not* to do, in some select examples.

There are an enormous number of both manufacturers and vendors of electronic components these days. Trying to list even a few of them here in print doesn't really make much sense, as a good percentage of that information will be incorrect or obsolete as soon as the ink dries on the page.

Having a variety of basic components readily available is convenient, until your collection grows beyond your ability to house or organize it. This happens far too often, in reality. Most common electronic parts can be obtained within a day or two from local sources, unless you live in a really secluded part of the planet. Also, most of the more common parts will typically cost only a few pennies apiece, so there aren't a lot of reasons to stockpile random parts. Keep a few of each on hand for experimentation, but hold off on pointless hoarding . . . if you can.

Conductors and Interconnects

In any electrical or electronic circuit, there are just as many connections between components as there are components. These include wires, cables, connectors, plugs, sockets, and all those other pieces that help the little electrons zip around the circuit.

First, let's take a look at wires and interconnects in a very abstract way. We can think of wires as connections between other components, without having to get into a lot of detail about the wire itself. We just want a way to indicate that there is an electrical connection among all the bits, and using an electrical schematic diagram is an easy and effective way to do this.

Electrical Schematics

A *schematic* diagram is any kind of stylized drawing that represents a simplified view of something. Usually some sorts of symbols are used to represent the parts that make up the whole, as well as the connections or relationships that exist between them and possibly the outside world. You can have schematics for plumbing, hiking trails, or tribbles, a well as electrical and electronic circuits. Let's talk about electronic schematics for a little bit.

The electrical symbol for a wire is almost always just a plain, solid line. If there's something really special about the wire that needs to be used, it is usually indicated in a note somewhere on the schematic. This can be used to indicate what color the wire needs to be, what size is appropriate, whether there are any special requirements for the insulation, and so forth. Most of the time it's just a plain, solid line. For an example of just how simple it can be to draw a wire in a schematic, see Figure 3-1.

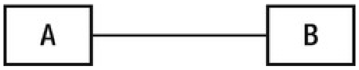

Figure 3-1. *A very simple electrical schematic diagram, showing how to get from point A to point B with a single wire. Drawing wires in schematics is easy!*

If a wire starts in just one place and ends in just one place, everything stays nice and easy. If multiple wires need to converge on a single point, or one signal wire needs to split up to go to more than one destination, it gets just a little more complicated, but not too much. See Figure 3-2.

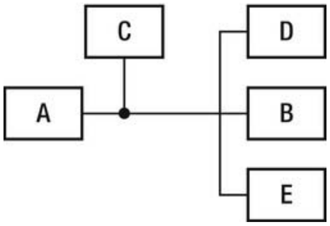

Figure 3-2. *Wires that are connected to each other usually have a dot at their intersection. If there is no dot, there is no connection between overlapping wires.*

In the figure, points A, B, and C are connected together. Points D and E are connected together, but are not connected to points A, B or C, even though the wires look like they are crossing. In a professional schematic, a careful draftsperson would route the wire from point D to point E on the right side of the components to avoid any possible confusion.

Some folks like to draw a little bump, or bridge, when two unconnected wires cross in a schematic, just to make sure that everyone knows that the wires aren't connected. This gets to be a bit tedious once you've got more than two or three components in your schematic, and it can look a bit unsightly. Feel free, however, to draw your schematics however you see fit. Just remember that others might not share your particular drafting sensibilities.

Wire and Cables

Chapter 2 took a quick look at wire and how it is made to help you pick out the best wire-cutting and wire-stripping tools. Now it is time to consider wire as an electrical component within your circuits. Knowing what a wire can and cannot do will help you pick the right kind of wire to use. Yes, wire has limits! This is important both for building new circuits from scratch as well as repairing, replacing, or upgrading wiring in existing circuits.

Wire can be used for all sorts of artsy and craftsy purposes. Copper wire is the most common wire used in electronics. Sometimes the copper conductor is *tinned* with another conductive metal with a low melting point to make it easier to solder. When you cut this wire, you can see the copper on the inside.

Pure copper wire is getting very expensive these days. Unscrupulous people try to pass off copper alloy with inferior electrical properties as the real deal. A quick way to test is with a magnet. Copper is not attracted to magnets.

As mentioned in Chapter 2, wire comes in two major categories: solid core and stranded. Solid core wire is just a single piece of copper wire, while stranded wire is made up of many smaller strands of copper wire, usually twisted together. Stranded wire is generally more flexible than solid core wire.

Copper wire is measured using a gauge system. Different systems exist around the world. A common system used in the United States and Canada is the American Wire Gauge (AWG) standard. It uses a series of single numbers to denote the relative size of the wire, with larger numbers representing smaller-diameter wires. These numbers go all the way down to zero (0 gauge), but they don't stop there. Larger wires than 0 gauge are called 00 gauge, double-ought, or sometimes 2/0. There are also three- and four-digit versions, but after that, those giant wires are specified with their actual cross-sectional diameter.

Using Wire: The Very Short Version

Fatter wires carry more current with less heat being generated due to resistance. The wire's insulation is rated for a maximum voltage and temperature. If this temperature is exceeded, the insulation will soften, melt, or catch on fire. Avoid this by using the right sized wire for the job. Exceeding the maximum voltage can cause more problems if the current arcs through the insulation. This can cause a short circuit and may even cause a fire. It is also likely to give off noxious fumes. Choose wisely!

For low voltages (under 36V) and small current loads (under 1A), you can use whatever you want. It doesn't matter. Pick something pretty. A thing of beauty is a joy forever.

For higher-voltage applications, make sure the wire's insulation is rated *far in excess* of what you anticipate. The rating should be visibly printed on the insulation itself. See Figure 3-3.

Figure 3-3. *The wire's insulation only works up to a point. That point is usually printed on the insulation itself, but you may need to put on your good reading glasses to see it. This wire states, "LL33911 CSA TEW 105°C 600V FTT 14AWG," which translates to the manufacturer's part number, Canadian Standards Association certified thermoplastic equipment wire, maximum temperature of 105°C, 600V insulation dialectric strength, 14 gauge.*

For higher-current applications, you really need to use the highest-gauge wire that is necessary to carry the required current. Hot wires cause fires.

Using Wire: The Longer Version

If you will spend some time learning about the properties of wire, you will be able to make *much* better decisions regarding its use and application. Assuming that the overall shape of the cross section of the wire is round, the gauge of the wire determines how much resistance to the flow of electrical current the wire will exhibit over a given distance. This resistance, in turn, helps determine the amount of electrical current that the wire can safely carry.

When electric current meets resistance, the electrical power is converted into some other form of energy. Usually this energy is given off as heat, or thermal energy. It can also produce magnetic fields, sound, light, and radio waves.

A good example of this is demonstrated by the heater coils on an electric stovetop. When the stove's switch is turned on, current flows through the coil. Most of the current is converted directly into heat. Electric heaters are very efficient this way. A small amount of the electrical power is converted into light. You can see this as a red glow coming from the heater coil when it is hot. The coil also creates a magnetic field.

If you know the gauge of a wire, you can look up the wire's characteristic resistance. These numbers will be close but perhaps not exact, as there will always be small variations in wire diameter, conductor purity, and other factors. Generally, however, the numbers are pretty close.

Let's take another look at the AWG table (see Table 3-1), and look at a few simple examples to help understand what these wires can do for us. (A more complete listing is available at `http://en.wikipedia.org/wiki/American wire` gauge, from which this partial list was obtained.)

Table 3-1. *The AWG*

AWG	Diameter		Area	Copper Resistance	
	Inch	mm	mm^2	Ω/km mΩ/m	Ω/1000 ft mΩ/ft
0000 (4/0)	0.4600	11.684	107	0.1608	0.04901
000 (3/0)	0.4096	10.404	85.0	0.2028	0.06180
00 (2/0)	0.3648	9.266	67.4	0.2557	0.07793
0 (1/0)	0.3249	8.252	53.5	0.3224	0.09827
1	0.2893	7.348	42.4	0.4066	0.1239
2	0.2576	6.544	33.6	0.5127	0.1563
3	0.2294	5.827	26.7	0.6465	0.1970
4	0.2043	5.189	21.2	0.8152	0.2485
5	0.1819	4.621	16.8	1.028	0.3133
6	0.1620	4.115	13.3	1.296	0.3951
7	0.1443	3.665	10.5	1.634	0.4982

8 0.12	85	3.264	8.37 2.	06 1	0.6282
10 0.10	19	2.588	5.26 3.	27 7	0.9989
12 0.08	08	2.053	3.31 5.	21 1	1.588
14 0.06	41	1.628	2.08 8.	28 6	2.525
16 0.05	08	1.291	1.31 1	3.1 7	4.016
18 0.04	03	1.024	0.823 2	0.9 5	6.385
20 0.03	20	0.812	0.518 3	3.3 1	10.15
22 0.02	53	0.644	0.326 5	2.9 6	16.14
24 0.02	01	0.511	0.205 8	4.2 2	25.67
26 0.01	59	0.405	0.129	133.9	40.81
28	0.0126 0	.32 1 0	08 10	212.9	64.90
30	0.0100 0	.25 5 0	05 09	338.6	103.2

Conductivity

The first thing you need to know is that copper wire really, really wants to conduct electricity. It wants to conduct electricity more than it wants to *resist* the flow of electrical current. Even so, copper is not a perfect conductor, and it has a certain amount of inherent resistance. This resistance causes the energy carried by the electrical current to be sidetracked, or converted into heat and other forms of energy. The higher the resistance in the wire, the more heat will be produced.

Normally this heat is a very small thing and is easily dissipated into the surrounding air. You usually can't even tell by touching that a wire is a fraction of a degree warmer than its surroundings—but this is only true when the amount of energy is relatively small, like in our rewired flashlight example. When you start to push a *lot* of power through a wire, the heat buildup can outpace the cooling-off provided by the surrounding air, and the temperature of the wire increases.

Again, this is no big deal as long as that temperature stays within a comfortable range. But what happens when the temperature gets really high?

First, the insulation will get soft, melt, or even catch on fire. After the insulation, if any, has burned off, the wire will glow red hot and eventually melt. This is known as *catastrophic wire failure*, which can result in what electrical engineers refer to as an unauthorized thermal event, which we call a fire. Yikes!

But look around you. You're probably sitting right next to some wires right now, very few of which (hopefully) are on fire, even though they are carrying variously large loads. How do they keep from burning up? The answer is in the proper selection of the right *size* of wire for the job. Bigger wires have less resistance to the flow of electricity, so they are able to carry more power with less heat being produced.

Now, you don't want to have to wire up all of your electronic circuits using jumper cables from your car's trunk, as that gets to be cumbersome after a while. Let's look at some good guidelines for what size wire to use for your projects.

In Chapter 2 you learned about (or were reminded of) Ohm's Law, which illustrates the relationships between voltage, current, and resistance in any electrical circuit. In summary, $V = I \times R$, where V is volts, I is current in amps, and R is resistance in ohms. It's not just a good idea, it's the law!

So how much electricity will we lose going through a foot or so of 16-gauge wire? If we know that one foot of 16-gauge wire has a resistance of 4mΩ (and we know this from looking it up in the chart), and we build a circuit that pushes 1A of current through this wire, we can figure out a couple of interesting things using Ohm's Law and a calculator.

Applying Ohm's Law

If you know two of the three variables used in Ohm's Law, you can calculate the third variable. Since we know R and I, we can calculate V. Since V = I × R, we can substitute our values of 1A and 4mΩ (0.004Ω) into the equation, and get 0.004V, or 4 millivolts.

That's not very many volts at all! In this case, that's a good thing. The voltage we just calculated is the *voltage drop* across the length of the wire. Those millivolts never make it from one end of the wire to the other—they're lost. Poor millivolts, they never had a chance.

OK, let's not let their heroic sacrifice be in vain. If we know volts, and we know amps, we can also calculate power, which is the rate at which energy is converted to work. The unit of measure for electrical power is *watts*, and is also the same as Joules per second (J/s), but that's another story. We usually use the capital letter *W* to abbreviate wattage, but we use the capital letter *P* to represent the *value* in equations.

Calculating power is simple if you know the volts and the amps. Just multiply them together: P = V × I. Easy.

So in our example so far, we have 4mV, 1A, and 4mΩ. How much power is being dissipated (wasted) in this circuit? P = 0.004V × 1A = 0.004W, or 4 milliwatts, which is just four-thousandths of a watt. That's just about enough power to light up a dim LED, and not much else. So you're not going to be starting any fires with these numbers. You most likely would not even be able to measure the rise in temperature that is occurring in the wire (oh yes, it's occurring, but it's very, very small).

Let's put 10A through a foot of 30-gauge wire. On second thought, let's not, and just do the math instead. The voltage drop will be V = I × R, or 10A × 0.1032Ω = 1.032V. The power dissipated would be P = V × I, or 1.032V × 10A = 10.32W. That wire would be a crispy critter in no time. Ten watts doesn't sound like much when you're talking about a home stereo or a lightbulb or a hair dryer, but that skinny little wire has almost no surface area with which to dissipate the generated heat. This means that the temperature goes up, quickly. Bye-bye, little piece of wire.

As a side note, you just learned how most current-limiting fuses operate. The conductor within the fuse literally *fuses*, or evaporates, when the internally generated heat produced from an "overcurrent" situation rises beyond its melting point. Poof, the circuit is opened, and property and lives are saved.

■ **Warning** Never circumvent the protection afforded by a fuse.

Ideally what you want is the smallest wire that will carry the required amount of current with an acceptable rise in temperature. Remember that any rise in temperature is in addition to the *ambient* temperature. If you're sitting in a room that is "room temperature," which is assumed to be 25°C or 77°F (the same thing, if you want to check it), and you're expecting a 50°C rise in temperature due to waste heat, your wire is going to be 75°C, which is far too hot to touch. Remember that 100°C is the boiling point of (pure) water (at sea level). Hot!

One more thing that complicates the thermal calculations is that copper, as a conductor, has a *positive thermal coefficient*, meaning that the characteristic resistance of a piece of wire (which we can look up in the AWG table) goes *up* by a known amount as the temperature increases. You need to consider this when you build circuits that are *supposed* to get hot, such as electric heaters. In most other cases, it's best to keep the heat to a minimum, as it represents wasted power, plain and simple.

Testing Your Wires

Can something as simple as a wire go bad? Yes, it most certainly can. How can you tell? Usually, it's because something doesn't work the way you think it should, or *worse*, it works sometimes and not others. A great deal of time, the problem is right at the end of the wire, where it is trying to make a connection with something else. However, it's possible for a wire to develop a problem right in the middle. This can be caused by a tiny nick in the insulation that lets in nasty elements such as rain and dirt, allowing the inner conductor to corrode. This type of problem takes time to make itself apparent, but it can certainly happen, especially in equipment that is exposed to the outside world for any length of time.

A quick way to test a wire is with a piece of test equipment called a *continuity tester*. This simple device usually is battery powered and has two probes. When you connect the probes together, the tester makes a noise, lights up a light, or maybe does both. Make sure your continuity tester's batteries are fresh and that the probes, if they are removable, are firmly seated in their sockets. Even test equipment needs testing from time to time.

■ **Note** A continuity tester is one of the easiest pieces of test equipment to cobble together yourself. See Appendix A for more information about building your own tools.

As mentioned previously, the problem is almost always at the very end of the wire. This is a good thing to know, so you can start looking in the most likely places first, saving valuable troubleshooting time.

A much better way to test a wire is with an ohmmeter. Using an ohmmeter, you can determine the *exact* amount of resistance in a wire, which under ideal circumstances should be very low. One ohm or less is typical for most normal-sized wires that you are likely to encounter. Super-long wires can have higher resistance, and that's where you can consult the handy AWG table to find out what the resistance is *supposed* to be.

When testing wires, especially wires with attached connectors, it's a good idea to wiggle the wire about vigorously, as this will reveal some intermittent connections for you.

Storing Your Wire

If you're buying new wire, it will probably come on a reel. It's often handy to keep common sizes and colors on your bench, if you have room. A paper towel–holder makes an excellent wire dispenser rack, although you can also spend more time or money buying a prebuilt one or designing and fabricating your own.

A custom red-and-black wire dispenser is shown in Figure 3-4. You might use a fixture like this if many pairs of identical-length wires are needed for a project. Not having to chase the wire spools all over the bench really saves a lot of time. This structure was built using a MicroRax miniature slotted aluminum extrusion (*http://www.microrax.com*), which is perhaps a bit of overkill, but was a lot of fun to plan and build. A coat hanger, artfully bent, would have also done the trick.

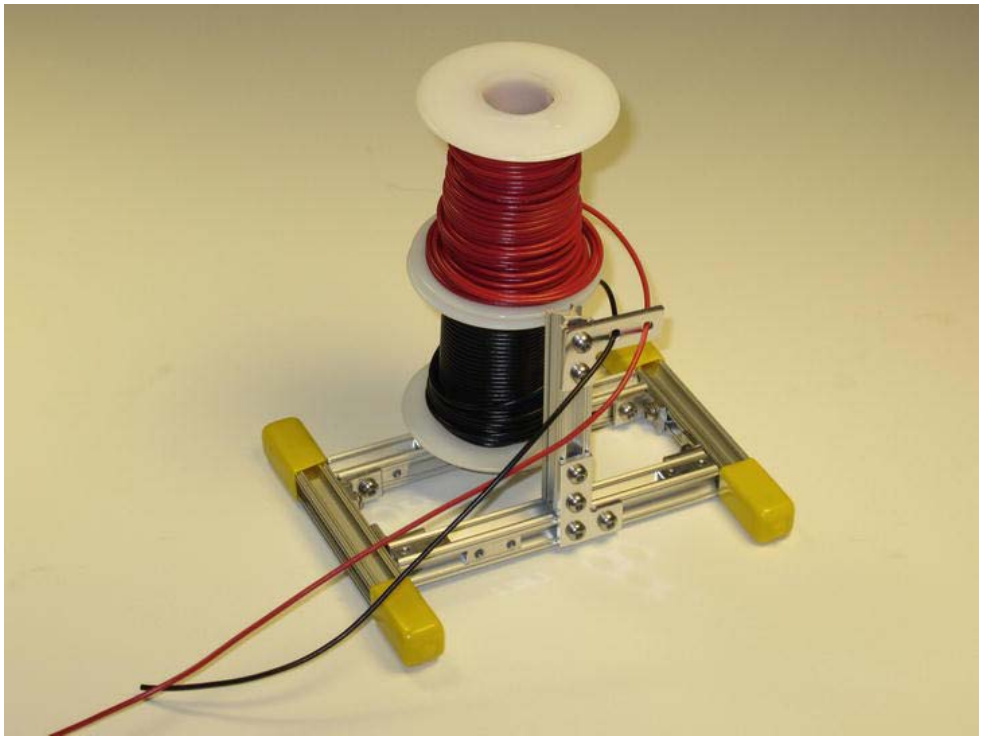

Figure 3-4. *A custom wire-dispensing frame made from modular aluminum extrusion. This kind of fixture makes it easier to cut both a red and a black wire to almost exactly the same length, which happens a lot when you use red and black wire for positive and negative power connections, respectively.*

Connectors

Connectors make life easier for the casual wiring enthusiast. The hardcore types solder everything together, but that is not always practical or even the right thing to do in every circumstance.

Keep in mind that every connector, just like every wire, has some sort of electrical limits. These limits must be respected.

Clip Leads

Also called *alligator clips* or *test leads*, you can buy ready-made wires or build your own from individual connectors. The flexible rubber or plastic boot extends the insulation of the wire. A spring-loaded jaw, often with serrated teeth, is used to clamp down on the wire, lead, or electrical terminal desired (see Figure 3-5).

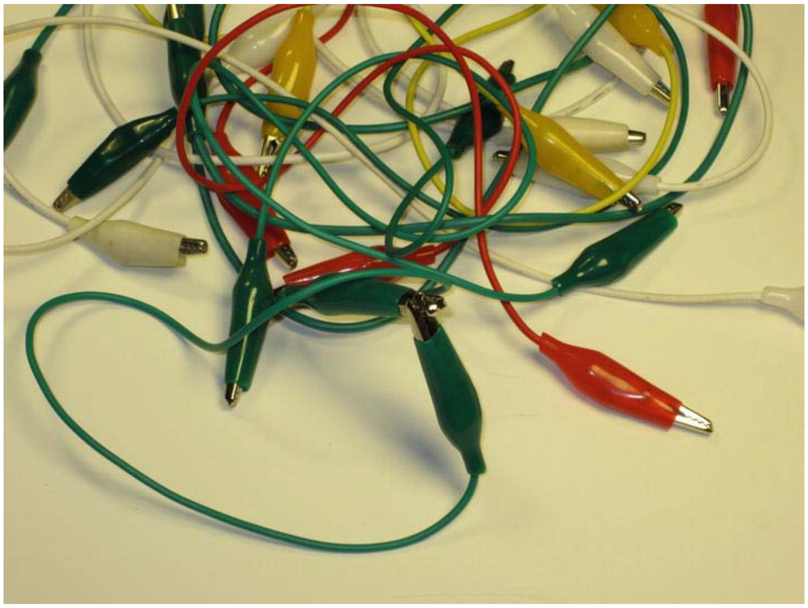

Figure 3-5. *Clip leads come in all sizes, gauges, colors, and terminal types. They are handy for making quick electrical connections.*

Clip leads are quite handy to have around your bench, if you've got the room for them. They tend to get tangled up, so some people hang them from a specially slotted rack, making them easier to pluck at a moment's notice.

Keep in mind that clip leads are generally for *temporary* electrical connections, such as when you're testing something or trying out a prototype circuit. They don't make very good long-term solutions to your electrical connection needs for a variety of reasons.

The first problem is that even when the spring-loaded jaws make a solid, low-impedance connection when first attached, this electrical connection will deteriorate over time as oxidation inevitably forms on the contacts.

Another problem is that many mass-produced clip leads are inexpertly smashed onto the ends of wires, without taking advantage of the alligator clips' built-in features, such as strain reliefs and soldering points. This leads to additional resistance in your circuit at both ends of the clip lead, where you would probably never think to look. The next time you buy some brand-new clip leads, hook them up to your ohmmeter and see just how conductive they really are. A good practice is to carefully remove the insulating boot and make a proper electrical connection yourself, so that you've got one less thing to worry about.

Solderless Breadboards

A very versatile prototyping platform is the solderless breadboard. Once upon a time, people would tack together simple electrical circuits using wires, small nails, and a hammer, utilizing a wooden plank or small board as the substrate. The kitchen breadboard was often just right in size and weight and would mysteriously disappear into the workshop. You can still cobble together simple circuits using this technique.

The solderless breadboard is a miracle of modern manufacturing techniques. A body made of precision-molded plastic has an array of small openings built in, and within each opening is a row of small spring clips that are just the right size to grasp and hold a small-gauge (22–26 AWG) wire. Adjacent points within the array are electrically connected together, which lets you easily connect small components into a circuit using your bare hands, with no soldering required. About all you would normally need would be some solid-core wire (preferably), some wire cutters, and some wire strippers. You can even buy precut jumper wires specifically made for use with solderless breadboards. They're terrifically handy! See Figure 3-6.

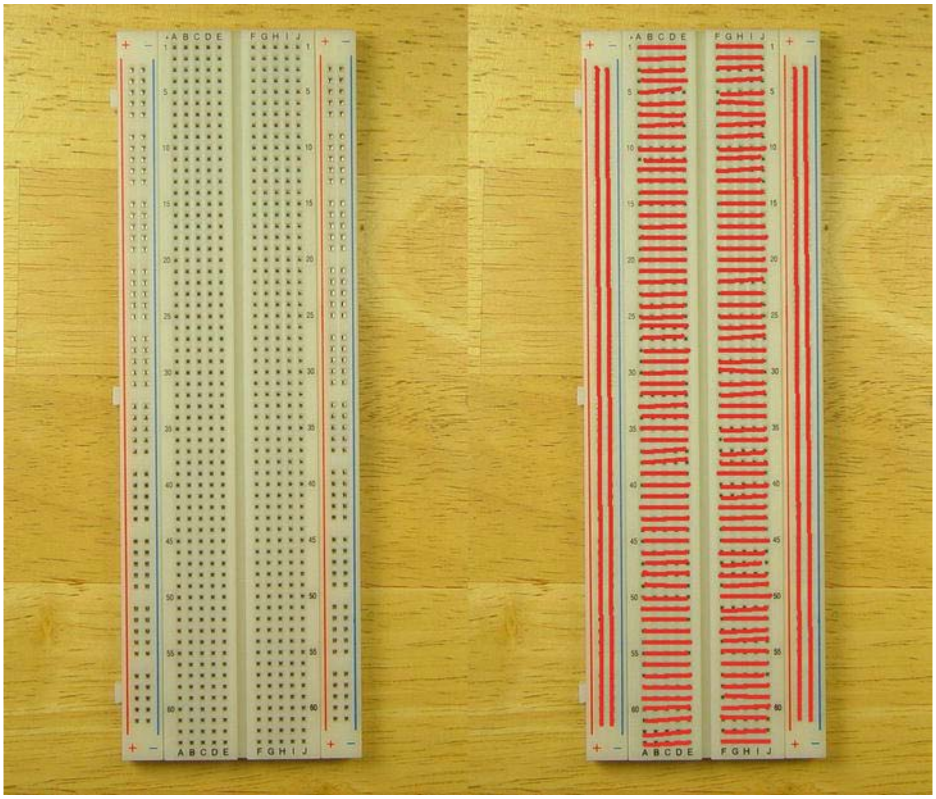

Figure 3-6. *On the left is a solderless breadboard with 830 tie points. Each hole has a spring clip inside that can hold a small wire or component lead. On the right, the underlying electrical connections between the tie points are illustrated.*

The spacing between adjacent tie points is exactly 0.1", which corresponds to many common "footprints" for electronic components. You can easily build simple circuits in just a few minutes. You can even build fairly complex circuits using integrated circuits and other components. Figure 3-7 shows a complete Arduino-compatible microcomputer that you can build with your bare hands and then program using your PC and the free Arduino software.

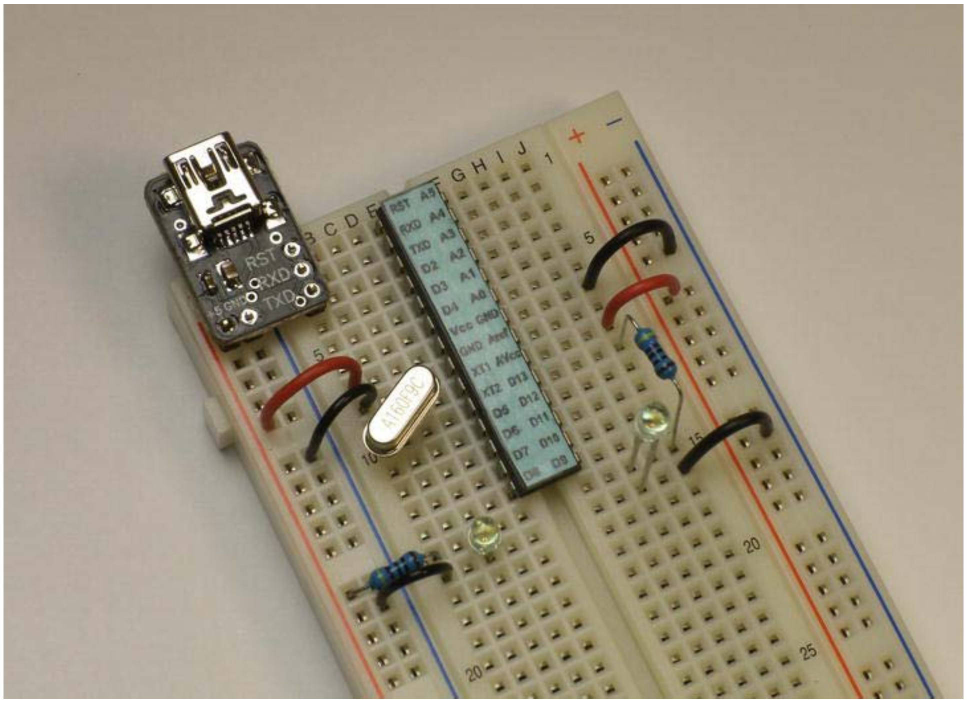
RST
RXD
TXD
5 GND
B C D E
F G H I J
1
5
10
15
20
25
+
−
RST A5
RXD A4
TXD A3
D2 A2
D3 A1
D4 A0
Vcc GND
GND Aref
XT1 AVcc
XT2 D13
D5 D12
D6 D11
D7 D10
D8 D9
A160F9C

Figure 3-7. *A breadboard Arduino, which is compatible with the popular Arduino Duemilanove microcontroller, can be built using just a handful of components on a solderless breadboard, leaving plenty of room for more experimentation. The black, rectangular component in the upper-left corner is a miniature USB adapter that supplies power, and provides communication and control signals for the microcontroller.*

You'll find that projects tend to expand to fill the available area (and budget). See Figure 3-8.

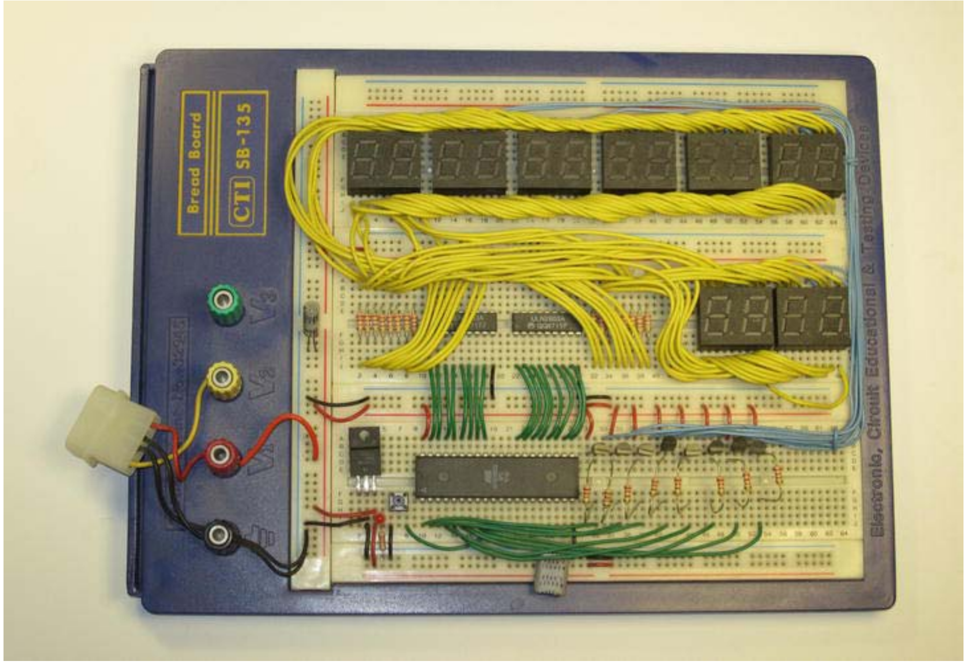

Figure 3-8. *A prototype LED display with computer control, built on a solderless breadboard. That's a lot of wires!*

Passive Components

Most electronic components fall into one of two different categories: *passive* and *active*. There are a few different ideas floating around as to what, exactly, is the difference between passive and active components. For the purposes of this book, we will use the simple definition that an *active* component requires a power source to work properly, while a *passive* component does not.

Resistors

A good example of a passive component is a *resistor*. You've already learned a lot about resistance in an electronic circuit. Resistance is measured in ohms, and it converts electricity into heat. When you're working with wires, cables, and other conductors, resistance is usually a *bad thing*. You want the least amount of resistance possible. However, there are times when you both want and need resistance in a circuit.

One example of when you would want resistance in a circuit is when you want to light up an LED. Unlike an incandescent lightbulb, an LED has no built-in current-limiting ability. Without a fixed amount of external resistance added to the circuit, an LED would self-destruct in a very short time, because it would overheat from excessive current flowing through it. A resistor would limit the amount of current flowing and control the brightness of the LED.

The exception to this dire prediction is when the power source that is lighting up the LED has insufficient gumption to blow up anything, such as with a small coin-cell battery. Anything bigger than that normally has no trouble convincing the LED to release its magic smoke, without which it can no longer function.

A typical resistor has a fixed resistance and a maximum power rating. The resistance is determined by the material from which the resistor is made. The value of a resistor, as you already know, is measured in ohms, and can range from just a fraction of an ohm (often expressed as milliohms) up to millions of ohms.

Through-Hole and Surface-Mount Resistors

Resistors come in all shapes and sizes. Generally speaking, the larger the surface area of the resistor, the more power it can safely dissipate. A typical resistor that you might work with on a solderless breadboard or on an older PCB is shown in Figure 3-9. These are called *through-hole* components because their extended leads are meant to be formed and threaded through holes that are drilled into PCBs. Also in Figure 3-9, for comparison, are some teensy-weensy *surface-mount* resistors. Surface-mount resistors have no leads and are meant to be soldered directly to pads laid out on the surface of the PCB.

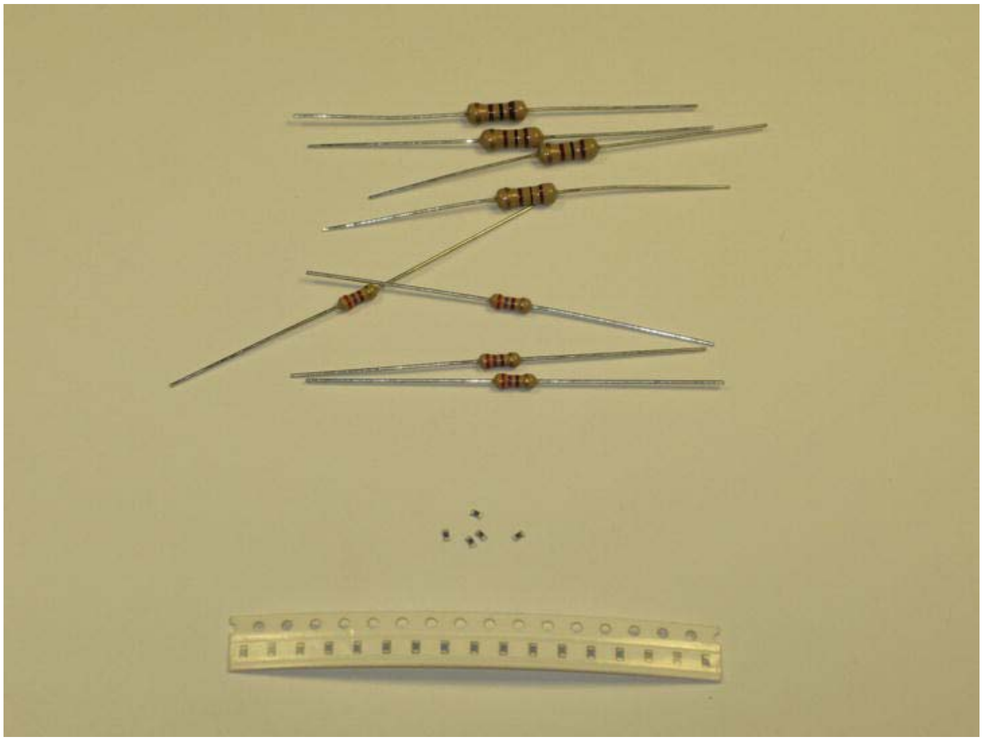

Figure 3-9. *Some through-hole resistors (top) and surface mount resistors (bottom). The surface mount resistors are so small that they are shipped packaged in tape, which is usually wound on reels for automated placement in PCB assembly.*

You can easily form the leads of through-hole resistors by hand or by using a *lead-bending jig*, a small tool with accurately spaced notches. Traditionally, these resistors have their leads formed so as to be threaded through holes in a PCB, and then soldered to the PCB. The extra lead length on the bottom of the PCB is then clipped off. See Figure 3-10.

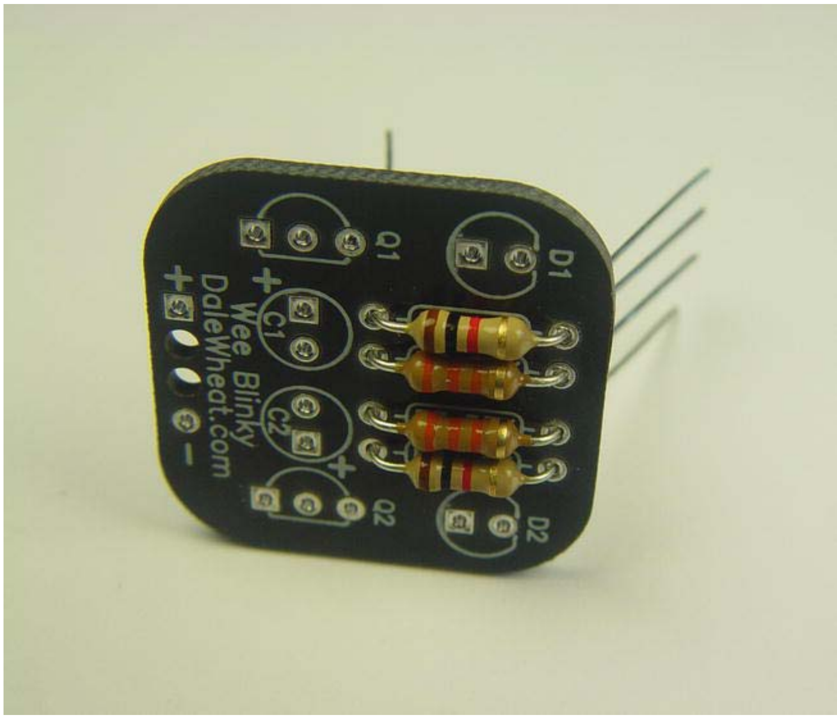

Figure 3-10. *Resistor leads are bent at right angles and inserted into holes in the PCB to be soldered.*

Schematic Symbols and Reference Designators

The schematic symbol for a fixed-value resistor is a zigzag line. See Figure 3-11. Every component in your circuit should have a name, which is also called a *reference designator*. Typically, most reference designators will have a short letter abbreviation to describe what kind of part it is (*R* is for *resistor*) and a sequential number assigned as more parts are added to the schematic. R1 would be the first resistor, R2 would be the second resistor, and so on.

If there is only one resistor in your circuit, then you don't have to number them, do you? You can just called it *R*, or *Galactic Emperor R the Mighty*, or whatever strikes your fancy. Most people stick to simple numbers.

Your numbering scheme depends a lot on the complexity of your schematic. If you only have a few resistors in your circuit, you can start at one and go up as needed. If you have a complex circuit with many subcircuits, you might allocate R101, R102, R103, and so on, to the first subcircuit (e.g., a power supply), and then assigned R201, R202, and so on, to a different section, such as a display. It's entirely up to you. Use a system that helps *you* keep track of things.

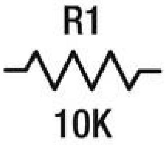

Figure 3-11. *The schematic symbol for a fixed-value resistor is a zigzag. The reference designator for this resistor is R1 and its value is 10,000 ohms, or 10KΩ. A simple rectangle symbol is also used to represent resistors, although many components are available in this physical form factor. Use the symbol you like best.*

Standard Resistor Values and Tolerances

Remember how wires have their own peculiar numbering scheme to describe their basic characteristics (i.e., the AWG, which uses *smaller* numbers to represent *larger* wires)? Well, resistors have their own peculiar numbering system as well to describe their electrical properties, or *value*. Even though the *value* of a resistor is measured in ohms and succinctly describes its characteristic resistance, not every possible value is readily available.

Some smart cookies at the Electronics Industries Alliance (EIA; see `http://www.ecaus.org/eia/site/index.html#`) have come up with some standard values that fill in most of the commonly used values for resistors and other components. Their scale is not linear but logarithmic, meaning that it takes larger steps as the values go up. This makes a little more sense once you understand how component value *tolerances* work.

You can buy, for example, a 1Ω resistor and expect it to be pretty close to being 1Ω at room temperature, but it's not going to be *exactly* 1Ω. It's going to be pretty close. How close? Well, that mostly depends on how much money you're willing to spend on this single resistor. If the answer is "not that much," then "pretty close" is going to mean within 5 percent of the stated value. That means your 1Ω resistor could actually measure as little as 0.95Ω or as much as 1.05Ω and still be "within tolerance." Five-percent resistors cost only a few cents even in small quantities.

Given that there's a little wiggle room for each resistor value, people who can tolerate their resistor values being off by as much as 5 percent don't need to be ordering 50 resistors of 0.99Ω and another 50 of 1.01Ω when they could just as easily (and certainly less expensively) order 100 resistors of 1Ω with a 5 percent tolerance.

This overlap in the values of the resistors allows us to skip from 1.0Ω to 1.1Ω without having to keep track of all the little resistors in between. This is because a 1.1Ω resistor could measure as little as 1.05Ω or as much as 1.15Ω and still be in tolerance.

With a standard resistor tolerance of 5 percent, we can use just 24 values to cover the range between 1Ω and 10Ω. The same multiples can then be used to cover the range between 10Ω and 100Ω, and so on. Aren't logarithms fun? See Table 3-2.

Table 3-2. *The E24 Standard Values for 5 Percent Resistor Value Tolerances (Higher and Lower Decades Are Also Available)*

1.0 10		100	1.0K	10K	100K	1.0M
1.1 11		110	1.1K	11K	110K	1.1M
1.2 12		120	1.2K	12K	120K	1.2M
1.3 13		130	1.3K	13K	130K	1.3M
1.5 15		150	1.5K	15K	150K	1.5M

1.6 16		160	1.6K	16K	160K	1.6M
1.8 18		180	1.8K	18K	180K	1.8M
2.0 20		200	2.0K	20K	200K	2.0M
2.2 22		220	2.2K	22K	220K	2.2M
2.4 24		240	2.4K	24K	240K	2.4M
2.7 27		270	2.7K	27K	270K	2.7M
3.0 30		300	3.0K	30K	300K	3.0M
3.3 33		330	3.3K	33K	330K	3.3M
3.6 36		360	3.6K	36K	360K	3.6M
3.9 39		390	3.9K	39K	390K	3.9M
4.3 43		430	4.3K	43K	430K	4.3M
4.7 47		470	4.7K	47K	470K	4.7M
5.1 51		510	5.1K	51K	510K	5.1M
5.6 56		560	5.6K	56K	560K	5.6M
6.2 62		620	6.2K	62K	620K	6.2M
6.8 68		680	6.8K	68K	680K	6.8M
7.5 75		750	7.5K	75K	750K	7.5M
8.2 82		820	8.2K	82K	820K	8.2M
9.1 91		910	9.1K	91K	910K	9.1M

Color Codes

Even the old-fashioned through-hole parts are a bit too small to legibly label with a numeric value and tolerance factor. A system of color codes was developed to designate resistor values, using colors to represent both single digits, a power-of-ten multiple, and the resistor's tolerance. These colors are painted on the resistors in bands. A little memorization and careful practice will have you reading resistor color codes in no time.

For 5 percent tolerance resistors, only four bands are needed to completely specify the resistor's value and tolerance. The first two bands represent the first two significant digits of the value. The next value is the multiplier. The final value is a special case to tell the resistor's tolerance.

The first two bands, as well as the multiplier value, use the color codes shown in Table 3-3 to represent the digits 0 through 9. (Unfortunately, these colors were chosen before the subtleties of colorblindness were widely understood.)

Table 3-3. *The Resistor Color Codes for the Significant Digits and Multiplier Digit of the Resistor's Value*

Digit	Color
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Gray
9	White

The last band indicates the tolerance of the resistor using a different set of colors, as shown in Table 3-4. The most common are 5 percent (gold) and 1 percent (brown). There is supposed to be a slightly larger gap between the digits and the tolerance bands, but this is sometimes hard to see.

Table 3-4. *Resistor Color Codes for the Final Color Band*

Tolerance	Color
0.05%	Orange
0.25%	Blue
0.5%	Green
1%	Brown
2%	Red
5%	Gold
10%	Silver
20%	None

The multiplier digit can be thought of as either the number of 0s after the specified digits or as the exponent to which the number 10 is raised, as in scientific notation. Some examples make this easy to understand and remember.

A resistor marked with brown, black, red, and gold stripes has a resistance of 1KΩ with a tolerance of 5 percent. An easy way to decipher this code is to do a simple substitution for the first two digits (brown is 1 and black is 0, so we have 10 so far). Next decipher the multiplier band and write down that many 0s after the first two digits. Red is 2, so write down two 0s. That gives us 1000 so far. The final band is gold, and that means a 5 percent tolerance; 1,000 ohms is usually abbreviated as 1.0KΩ or simply 1KΩ.

■ **Note** *K* stands for *kilo*, the Greek prefix for 1,000. Likewise, *M* stands for *mega*, the prefix for 1 million.

This method works for most values from 10Ω to 10MΩ. A problem occurs, however, when we need to specify a value less than 10, as a negative multiplier value must be used to get an exponent of less than 0. For the value 1 and those less than 10Ω, a gold band is used for the multiplier. For values less than 1Ω, a silver band is used.

To save even more precious space on our schematics, another convention is to replace the decimal point with the multiplier. For example, 4.7KΩ would be written as just 4K7. 1.8MΩ would become 1M8 and 1.5Ω would be 1E5. 10KΩ would still be 10K using this method. If it is clearly understood that the unit of measure is the ohm, then even the Ω can be omitted.

Resistor Power Ratings

Any resistor has a maximum power-handling capability. This rating is usually expressed in watts or fractions of a watt. The larger through-hole resistors shown previously in Figure 3-9, for example, have a power rating of 1/2W (or 0.5W, if you prefer). This means that if you attempt to dissipate more than half a watt of power through the resistor, it is most likely going to quickly overheat and fail.

Thermal failure in a resistor starts with a thin curl of smoke, and then results in the discoloration of the resistor itself and sometimes actual flames. In any case, it gets dangerously hot, so do try to avoid this situation.

If you know the voltage across the resistor, as well as the current, you can easily calculate the power being dissipated using the simple formula P = V × I. Remember that P is the power value in watts, V is the voltage in volts, and I is the current in amps. One volt at one amp is one watt, which is way more than enough to smoke our little resistors. Be careful! Any time you calculate the correct value for a resistor in ohms, be sure to also calculate the required power-handling capability.

Variable Resistors

So far we've only looked at *fixed*-value resistors. They usually exhibit the same resistance day in and day out. That's what we love about them. But what if you need to vary the resistance in a circuit? We have resistors for that, too! A good example is a volume control on an amplifier. Turn it to the left (down), and the volume goes down. Turn it to the right (up), and the volume goes up. How does that work?

One kind of variable resistor is called a *potentiometer*. Potentiometers are sometimes abbreviated as *pots*. Pots usually have three terminals instead of two. Two of the terminals connect to the fixed resistor that is inside the potentiometer. Instead of being all sealed up like the fixed resistors you've been studying, the internal, resistive conductor is exposed along a track or groove. The third terminal, which is often physically in the center, between the two other terminals, is called the *wiper*, and can be moved from one end of the fixed resistor to the other end, making electrical connection to the inner part of the fixed resistor as it goes. As the wiper moves along the length of the resistive element, it taps into the resistor at a different point, varying the resistance. This is how a potentiometer can be used as a variable resistor.

Figure 3-12 shows a typical three-terminal potentiometer with a round body. The shaft can be turned to adjust the resistance. There are many variations on this basic design.

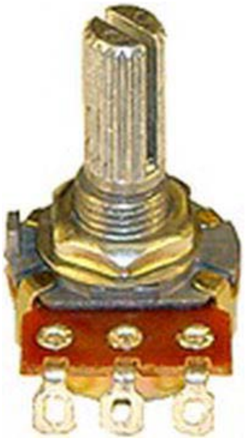

Figure 3-12. *A typical potentiometer, or variable resistor. Image by BG Micro (http://bgmicro.com).*

The schematic symbol for a potentiometer looks suspiciously like a resistor with an extra terminal, which happens to be exactly what it is. The extra terminal is the wiper, shown as the upward-pointing arrow. See Figure 3-13.

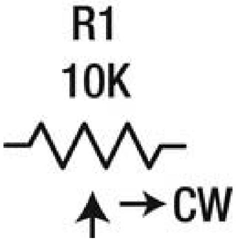

Figure 3-13. *The schematic symbol for a potentiometer is a fixed resistor with a wiper terminal. The "CW" arrow indicates which way the wiper goes when the shaft is rotated clockwise.*

Potentiometers generally come with two distinctive *response curves*, or *tapers*:

- A *linear* curve means that every equal step of rotation about the axis changes the resistance by the same amount. For example, if you were to center the shaft in the middle of its rotation, the resistance from the wiper contact to either of the end contacts would be nearly exactly half of the total resistance between the two end contacts. This is quite useful for when you need to adjust a voltage up or down in a relatively straight line. This is sometimes indicated by adding a capital *B* to the end of the resistance value (e.g., 10KΩB).
- In many audio circuits, however, it has been discovered that the human ear is anything *but* linear. A special response curve that more accurately describes this sensitivity is called an *audio* curve or taper. An *A* is used as a suffix to indicate that an audio taper is used for a potentiometer.

Note that linear and audio tapers are *not* interchangeable. If you find some random potentiometers in a parts bin, you can get a quick idea of what you've got by centering the shafts and seeing if the resistance is "symmetrical" or not, using an ohmmeter. Equal resistance to either end terminal indicates a linear taper, and anything else is mostly probably an audio taper.

Just like any other resistor, a potentiometer has a maximum power rating as well as a tolerance. These are usually either printed on the body of the potentiometer, if there is room, or hidden away in a product data sheet somewhere.

Specialty Resistors

There are many different kinds of resistors made for many special kinds of applications. High-power resistors are built out of sturdier materials that can take the thermal stress required to dissipate large amounts of heat. See Figure 13-14.

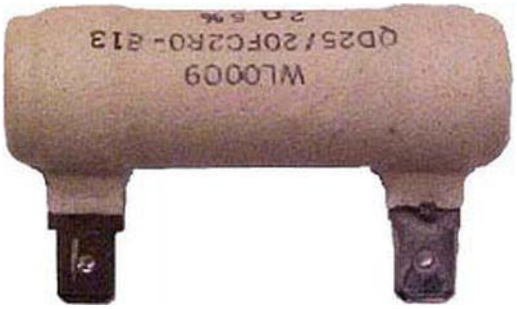

Figure 13-14. *A power resistor can handle much more heat dissipation than the smaller though-hole or surface-mount varieties. They are often so big that they need special mounting hardware. Image by BG Micro (http://bgmicro.com).*

Another popular option is the *multiturn* potentiometer. These potentiometers have an internal gear system that allows their shafts or wipers to be moved slowly across their internal resistive tracks by multiple turns of the control element. Increasing the number of turns allows the user much finer control of the resistance adjustment. It also takes the user longer to get from one point to another along the scale.

Capacitors

The basic definition of a *capacitor* is two conductors separated by an insulator. By itself, it doesn't sound like that would be a very interesting configuration at all. It turns out, however, that there's a lot more to it.

When a voltage is applied across a capacitor, no steady current flows through it. Remember, there is an *insulator* in the middle of that capacitor. Any insulator, just like the insulation on a piece of wire, *does not conduct electricity*.

What happens is that an *electric field* is created between the two conductors, or *plates*, as they are called when they are part of a capacitor. Now we get back to the fairies and dragons and molecules and so forth, way down deep at the heart of the problem. This electric field is a form of energy. Once it is built up by the difference in voltage, or *potential*, between the two conductors, it has nowhere to go, so there it stays . . . at least until something else in the circuit changes.

For this reason, capacitors are sometimes used as *reservoirs* of electrical energy in a circuit, holding a bit of spark here and there as needed. Just as it takes electrical energy to build up this electric field, a certain amount of electrical energy will be released when the field collapses. This will happen when the voltage between the two conductors drops.

Using capacitors as tiny electric batteries in a circuit is only one of many applications for this versatile part. While a capacitor will not conduct a *steady* flow of electric current between its terminals, it will often *appear* to conduct *alternating current* (as opposed to *direct current*), which is why you see them so often in audio circuits. As a charge builds up on one plate within the capacitor, it then attracts electrons from the other side, pulling them in from the other side. Even though they don't "jump the gap" of the central insulator, it looks like a tug-of-war is going on from both sides.

This behavior can also be used to send the higher-frequency components of a signal one way in a circuit and the lower-frequency components of a signal in another direction. This is one way that analog filters are built, and it has all kinds of useful and interesting applications.

Capacitors come in all shapes and sizes. They are made of many different materials, depending on what particular characteristics are needed. See Figure 3-15.

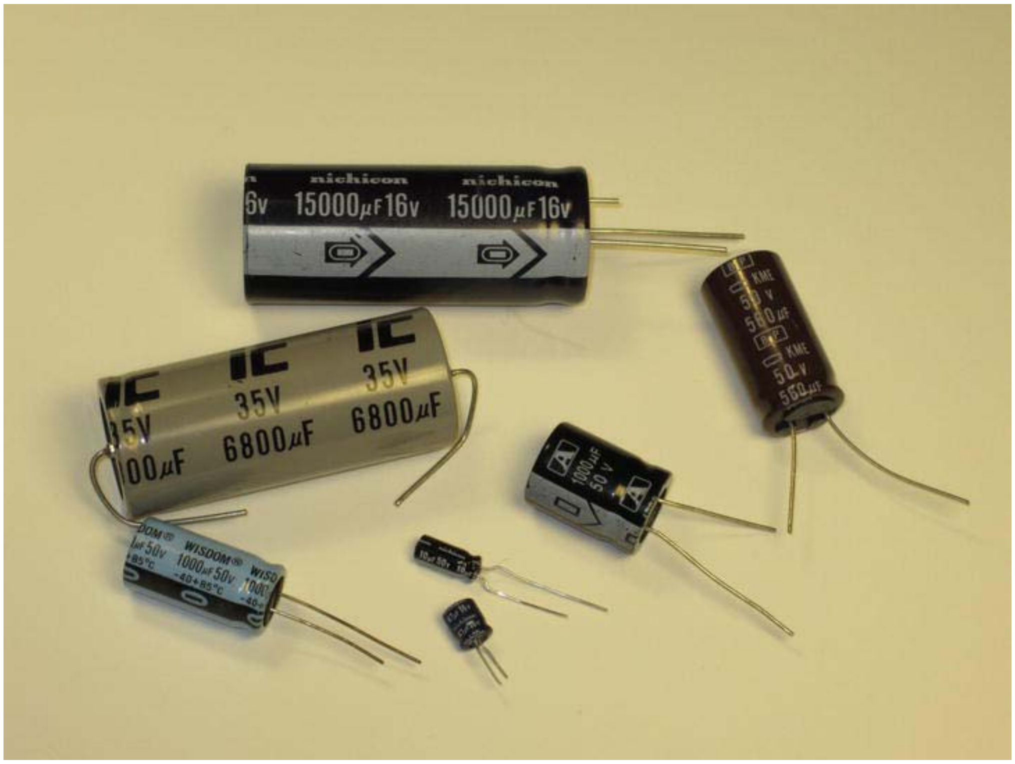
nichicon
15000µF 16v
35V
6800µF
50 V
560µF
KME
1000µF
WISDOM
1000µF 50v
-40+85°C

Figure 3-15. *Some electrolytic capacitors of various sizes and capacities. Both much larger and much smaller capacitors exist and are very common in electronics.*

Schematic Symbols

While there are a large number of special-purpose capacitors that are custom made for certain applications, a very large number of capacitors fall into two broad categories: polarized and nonpolarized. The schematic symbols for both types of capacitors display the fundamental construction of two conducting plates separated by an insulator. See Figure 3-16.

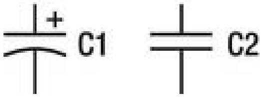

Figure 3-16. *The schematic symbols for polarized capacitors (left) and nonpolarized capacitors (right)*

C1 is a *polarized* capacitor, meaning one terminal is more positive than the other. In practice, this is indicated on the part itself in a variety of ways. One convention is that the *anode*, or more positive lead, is physically a little bit longer than the *cathode*, or negative lead. There is generally some sort of mark made on the capacitor body itself. Usually this is a stripe on the *negative* side of the capacitor.

What's really odd and potentially confusing is that one type of capacitor, specifically that made primarily of tantalum, has a stripe that indicates the *positive* lead of the polarized capacitor. Know your capacitors!

A polarized capacitor that is installed backward will experience terrible physical and thermal stresses and can sometimes explode, sending bits of itself all over the place.

C2 in Figure 3-16 illustrates a *nonpolarized* capacitor. It doesn't matter which way it is installed in a circuit. It is electrically symmetrical and works just as well in either orientation.

Inductors

An inductor is almost always made out of coils of wire. Sometimes inductors are quite large, as with transformers, while other times they are as small as a speck. An inductor would appear, electrically, as a simple short-circuit if it weren't configured to take advantage of certain principles of *electromagnetism*, or the tendency for the flow of electric current in a conductor to form a *magnetic field* around the conductor. The shape and orientation of the loops of wire that compose the inductor determine its electrical characteristics.

In many ways, an inductor is the opposite or complement of the capacitor. While a capacitor does not conduct direct current from one terminal to another, an inductor will happily do so, at least for a time. While a capacitor will resist a change in voltage across its terminal as it builds up its electric field, an inductor will resist a change in current flow across its terminal once it has established a magnetic field.

Because of their complementary natures, the two components can be used together to form a *tuned circuit*—one that resonates at a particular frequency, or allows the passage of only a certain range of frequencies, with the capacitor shuffling the high-frequency portions and blocking the low-frequency portions, while the inductor does the opposite, blocking the high-frequency components and passing the low-frequency ones. This is how many older radios and televisions worked before the advent of low-cost solid-state electronics.

Once an inductor has built up a magnetic field, any drop in the current flow across its terminals will result in the collapse of the field and the generation of a very-high-voltage spike. This is the basic electrical circuit that was used in automobile engines to create the high-voltage spark needed to ignite the fuel-and-air mixture in the combustion chamber.

Inductors can also be used to efficiently pass alternating current via a magnetic field from one inductor to another. This is how the primary windings of a power transformer *induce* a current in the neighboring secondary coil, which, depending on the ratio of windings and a few other factors, determines if the transformer *steps up* the voltage or *steps down* the voltage. It can even keep the voltage the same, for when electrical isolation is needed between two different systems.

Most electric motors employ some sort of inductor that alternately attracts and repels another electromagnet or permanent magnet. The most basic direct-current (DC) motors require a fairly complex mechanical arrangement to perform the necessary switch-swap to alternate the fields. This process is called *commutation*. In other types of electric motors, such as brushless motors and stepper motors, this commutation process is done electronically, externally to the motor itself, and requires more complex circuitry to control the speed and direction of the motors. See Figure 3-17.

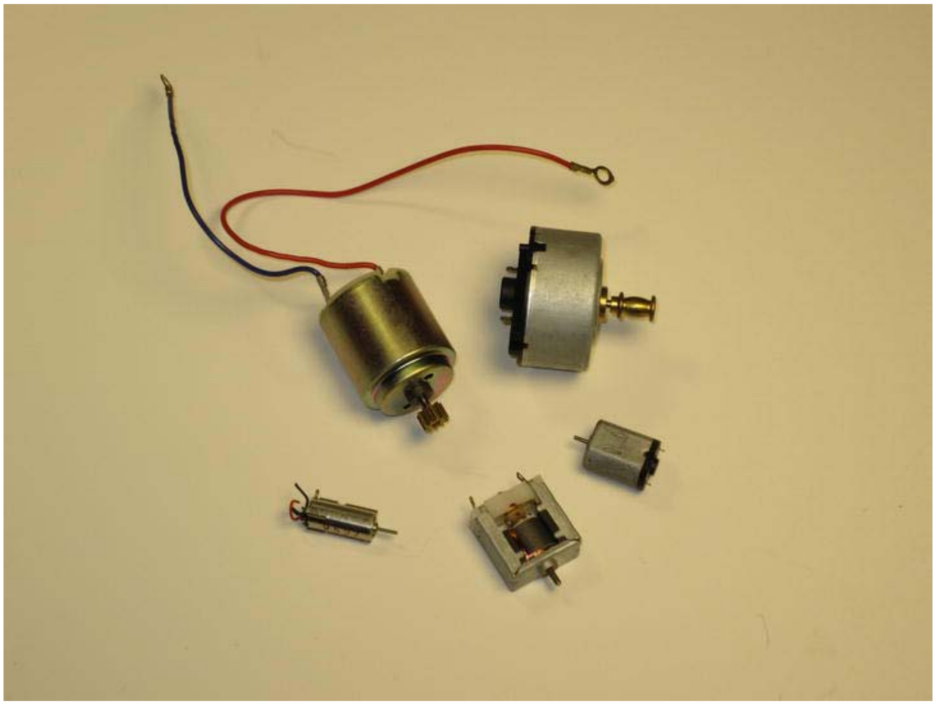

Figure 3-17. *Some simple DC motors. When direct current is applied to their terminals, they spin. The magic happens with an electrical and mechanical arrangement inside that performs the necessary commutation of the magnetic fields.*

Switches

The most basic way to control the flow of electric current in a circuit it to literally *break* the circuit. This means that instead of forming a conductive loop from power source to components and back again, a gap is introduced somewhere in the loop.

This gap can come anywhere in the loop. It can be right next to the battery, for example, or somewhere off in the middle—as long as the circle is broken, no current will flow.

If you perform the lightbulb experiment in Chapter 1, you can see how this works. When everything is lined up properly and the final connection is made, the lightbulb lights up. When any of the connections are broken, the light goes out. It's really as simple as that.

Most of the electrical switches that you operate every day are really mechanical in nature. Their main function is to physically move two conductors either together or apart.

In the lightbulb experiment, you could use the wire as a switch, by physically touching either the battery terminal or the lightbulb (depending on how you were holding everything together). With a little practice, you could probably send Morse code, or at least a variation on "one if by land, two if by sea."

There are many kinds of switches for many kinds of switching tasks. The most basic are *momentary action* switches. These are usually push buttons, and only conduct electricity when pressed. Alternately, they can be built so that they conduct electricity all the time, *except* when pressed:

- The first option is called *normally open*. When a circuit is open, it is not conducting electricity. When you *close* the circuit, by completing the loop, electricity can flow. A normally open switch would be welcome in a doorbell circuit. When no one is pressing the button, no bells are ringing. It would be annoying the other way around.
- A *normally closed* switch acts like a solid piece of wire (being a conductor of electricity) until it is activated, when it ceases to provide a path for the electricity to follow. This type of switch can be used as a *kill switch* on a gasoline-powered engine, such as a lawn mower, for example. By interrupting the flow of electricity generated by the magneto and powering the spark plug, you interrupt the internal combustion cycle, which will eventually cause the engine to slow down and then stop.

This type of switch is called a *single-throw* switch. It's either on or it's off—conducting electricity or not conducting electricity.

■ **Note** For almost every possible configuration of switches, there is a corresponding *opposite* configuration that is almost as popular.

Another useful configuration for a switch is to switch from one circuit to another circuit, and not just on and off. This is referred to as a *double-throw* circuit. A switch like this normally has three terminals. A *common* terminal is usually, but not always, in the center. At any rate, the common terminal is electrically connected to the moving part of the switch that is going to make contact with one or the other two remaining contacts. The *normally closed* contact is the one that will be making contact with the common terminal when the switch is not activated, or at rest. The *normally open* contact is simply the other terminal. This assumes that the switch has some sort of bias or mechanical spring action that returns it to a certain orientation when no one is activating it.

Some double-throw switches can remain in either state indefinitely. A typical light switch used in indoor lighting is a good example. It's just as happy to stay on as off.

Switches can have more than one circuit built into them. These switches are called *double pole*, *triple pole*, and so forth. They're like two or more single-pole switches physically taped together, so that when one is switched, they all are switched. Usually these poles are electrically isolated from each other.

We'll play with switches again in Chapter 5, where you'll learn some interesting ways to wire them up.

Active Components

While it could truthfully be said that *all* electronic components require some electricity to do anything, the distinction made in this book between *passive* and *active* components is that *active* components need a little more power to be really interesting.

First we'll look at sources of this magical electricity, and then we'll move on to some of the fascinating and complex components that will happily use it all up for you.

Power Supplies

You're going to need some sort of power source for any electric or electronic circuit you run across. If it doesn't use electricity in some structured form, it's not really electronics, now is it?

Batteries

You can use regular batteries to power a lot of your circuits, but they eventually wear out, and then you have no real recourse other than to throw them away or recycle them, if possible. If you're going to be using batteries, at least get some good ones. Many of the bargain brands are terribly inferior in their manufacture and are only providing you with a false economy. Spend a little more and get higher-quality parts, and you will be rewarded with longer life and more reliable operation.

A great way to work with batteries is to use the appropriate battery connectors or battery holders. Sometimes you can remove these from obsolete electronic devices that have outlived their useful lifetime. Always observe the proper orientation and polarity of batteries. Even smaller batteries contain an annoying amount of power, especially when it all decides to come out at once, such as when you accidentally plug something in backward or short something out. This can result in damaged parts, burns, or even fires. Be careful with batteries.

Having a fuse holder wired inline with your battery-powered supply is an excellent and cheap way to prevent such "unauthorized thermal events." Keep several spare fuses on hand as well. Fuses cost little and save much.

Rechargeable batteries are becoming more common, and they keep coming down in price while improving in longevity and power capacity, and decreasing in size and weight. Any rechargeable battery technology beats any kind of primary, or nonrechargeable, battery in the long run.

■ **Caution** The same warnings about battery polarity and fuses apply to rechargeable batteries as well.

Since there's no easy way to "turn off" a battery, it would be a good idea to include a power switch in your supply, if possible. Just make sure that whatever switch you select can stand up to the maximum current you will want to be extracting from your power supply. You should also make your switch large and easy to see, so that you can find it quickly when you need it. An obvious power-on indicator is also a great plus for a homemade power supply. This can be as simple as a green LED (with appropriate current-limiting resistor—see below) or as complex as a voltage meter indicating how much juice is left.

Transformers

Another great power supply that you probably already own is a power adapter or transformer from another electronic appliance. You should use caution, of course, with anything that plugs into the wall for power, especially if you're planning on monkeying around with the other end of it.

Almost all commercially produced power adapters have a slew of certifications plastered on them. Somewhere in there should be the basic data concerning what type of power input it expects, what it is going to try to produce, and what the maximum limits are on the output. Make sure that whatever it is that you're going to plug into your wall is specifically designed to plug into *your* wall, as electrical power standards vary from one location to another.

Make sure that any repurposed power supply you use does not get overly warm when in use. This is an indication that it is presently or has been overloaded in the past. Such a device is a fire-starter waiting for its magic moment.

You need to know how much voltage is coming out of your power supply. Even if it is clearly printed on the device itself, if you have access to a voltmeter, you need to verify the output voltage before connecting it to anything. Many lower-cost power adapters are *unregulated* and will produce an output voltage that will vary wildly depending on the load applied to it. A *regulated* voltage output, on the other hand, will provide consistent voltage levels on the output, even with varying loads.

USB adapters and chargers are becoming quite common and can provide *regulated* +5V at up to 1/2A and sometimes more. These are great devices to use for small electronic experiments. They are generally small, lightweight, and reliable.

A dedicated bench power supply is a very handy piece of test and measurement gear to have available in your lab. A good supply will have a variable voltage and a readout to show you what's going on (or coming out). A step up and you get to set the maximum current that it will supply (to keep things from getting out of control too fast). Additional desirable features include multiple outputs and remote control from your PC.

No matter what kind of power supply you use, use it responsibly. Don't leave equipment powered up if you're not using it. Don't attempt to bypass safety measures that are in place for *your* protection.

Diodes

A diode is a semiconductor device that will conduct current in one direction only. That's the simple story. Of course, the reality is much more complex. A typical diode is composed of two pieces of a semiconductor material, usually silicon, but sometimes germanium or some other exotic substance. The diode action occurs in the *junction* between the two types of semiconductors, which have been specially manufactured to contain the exact right balance of impurities required. This is generally not the kind of thing you can build in your lab, unless you're Jeri Ellsworth.

These two bits of semiconductor, called the *N region* and the *P region* (for negative and positive, respectively), are sealed up in either a glass or plastic enclosure. A standard diode has two terminals—an *anode* and a *cathode*—which represent the positive and negative leads, again respectively. Conventional current (i.e., current flowing from the more positive voltage to the more negative voltage) can flow through the diode from the anode to the cathode, but not the other way around. It's magic! Well, technically it's semiconductor physics, but either answer will serve for our purposes.

Diodes come in all sizes. Generally speaking, the more power a diode is expected to handle, the larger it is going to be. *Small-signal* diodes are the same size or smaller than typical resistors. Power diodes, often called *rectifiers,* depending on their application, can be so large they have to be mounted with large bolts.

The two most important electrical characteristics for the happy care and feeding of diodes are their maximum reverse voltage and forward current capability. You don't want to exceed either one.

Since a diode is, at best, only ever going to have a cryptic part number written on it, you'll need to consult the manufacturer's data sheet to find out all the necessary information. Many semiconductor producers offer "commodity" parts that conform to standard part numbering schemes. That way, you know that a 2N4148 diode from one manufacturer is going to be pretty close to a 2N4148 diode from any other manufacturer, but you should always check to make sure.

Diodes typically have a *forward voltage* that must be exceeded before current will flow. This voltage is essentially lost and is dissipated as waste heat from the device. Silicon diodes will have an average forward voltage around 0.7V and up. Germanium diodes will have a smaller forward voltage, in the area of 0.3V. Schottky diodes use a metal-to-semiconductor interface region and achieve substantially lower voltage drops, making them much more suitable for higher-power applications.

LEDs

One special kind of diode is the popular *light-emitting diode*. You see these little guys everywhere these days. In fact, some folks go around with black tape, just trying to cover them all up so they can get their darkness back at night.

The reason that they are everywhere is that they are cheap, reliable, and easy to use. They don't take up much room, don't take up much power, and don't generate that much heat. The exceptions to these admirable qualities, of course, are in the newer generation of LED lighting products that emit tremendous amounts of light and produce tremendous amounts of heat. Every month it seems that a new record is set for efficiency. Let's hope that trend continues.

Being essentially diodes, LEDs have both an anode and a cathode. LEDs only conduct current in a single direction. You'll need to make sure you limit the amount of current flowing through your LEDs, because the LEDs themselves sure aren't going to do it.

LEDs designed to be indicator lights can be powered with as little as 1mA. High-efficiency LEDs can be used for illumination purposes and still only draw 20–30mA each. These very modest power requirements make LEDs a favorite for microcontroller projects, as these output power levels are easily handled by most popular chips.

The forward voltage drop across LEDs is typically much higher than for a rectifier or signal diode. In fact, the voltage goes up as the emitted color of the LED goes from the infrared and red end of the spectrum (1.2–2V) up to the blue and ultraviolet end of the spectrum (3–3.6V).

Transistors

A true modern miracle, the semiconductor transistor ushered in the age of solid-state electronics. More than a million individual transistors can be used to build modern computer processors, all on a single chip.

The first types of transistors to be built and used were called *bipolar junction transistors (BJTs)*. This type of transistor is similar in construction to the diode, except that there are two semiconductor junction areas inside.

This arrangement of magic beans allows a small amount of electrical current to be applied to one of the three terminals of the transistor, called the *base*, which in turn allows a much greater amount of electrical current to flow between the remaining two terminals, known as the *collector* and *emitter*.

Two complementary types of BJTs are made, depending on the way that the positive and negative semiconductors are sandwiched together. NPN transistors will conduct conventional current from the collector to the emitter when current flows from the base to the emitter. The opposite variety, called the PNP transistor, does precisely the opposite, conducting conventional current from the emitter to the collector when the base is negatively biased.

Transistors can be used to make amplifiers, switches, current limiters, voltage regulators, oscillators, and any number of other useful circuits. They are generally very low cost, lightweight, and reliable.

As with any other electrical components, you need to be aware of the electrical limitations of your transistors. Even when a transistor is fully saturated and conducting very efficiently, it's still dissipating a certain amount of its energy as heat. Too much heat and say goodbye to your transistor.

A newer type of transistor is becoming quite popular in power circuit applications, and uses a different type of semiconductor property to accomplish its mission. The *MOSFET (metal-oxide–semiconductor field-effect transistor)* has three terminals, just like the BJT. Each terminal performs a similar job, but does it in a different way. The *gate* of a MOSFET is electrically isolated from the conduction *channel* between the *drain* and *source* terminals. However, when a proper voltage is applied to the gate, it creates an electrical field that influences the conductivity of the channel between the drain and the source.

The important differences between BJTs and MOSFETs lie in the type of signal needed to drive each of the transistors and how much power is wasted by being converted to heat. A BJT is a current-controlled device, where more current into (or out of) the base results in more current flow through the device. The MOSFET is a voltage-controlled device, where more voltage applied to the gate increases the current flowing through the channel.

Additionally, MOSFETs typically have much lower on-state resistance than BJTs, meaning they can more efficiently switch higher currents. Finally, MOSFETs have a *positive temperature coefficient*, meaning that they conduct less power as they heat up—which is a good thing. BJTs are subject to *thermal runaway*—conducting more current as they heat up, which in turn generates more heat, and so on, until something snaps, crackles, or pops.

Integrated Circuits

As parts get more specialized, they become less fun. There are a hundred ways to wire up some transistors, resistors, and capacitors, but there's generally only one way to hook up a thermocouple interface chip.

The good news is that it has become much easier for companies to design and build vastly complex chips that can do things for us that, honestly, most people cannot comprehend. And that's OK. We need airplanes that can, mostly, fly themselves. If we had to depend on humans to get everything done, you can imagine what kind of world we'd live in. Humans are notoriously sleepy, hungry, distracted, and forgetful. A voltage comparator chip does nothing but compare two voltages, all day, every day, perfectly, all the time.

Integrated circuits come in an unbelievably wide range of functions, packages, and capabilities. The first integrated circuits were amplifiers. Integrated circuits allowed manufacturers to make chips that have dozens or hundreds of transistors and other parts *all at once*. Just plop that little silicon chip into a plastic package with legs on it, and you're done.

What kind of chips do you need in your lab? Well, that's going to depend heavily on what kind of circuits you're wanting to design, build, or repair.

Many older chips had a standard 0.1" pin spacing that made them easy to plug into a solderless breadboard for prototyping purposes. Most newer chips have been considerably shrunk, because phones and tablet computers are all the rage these days. It's still possible to work with these newer chips, but it almost always requires mounting them to some sort of breakout board or expander that brings out their tiny leads to a more reasonable, and reachable, size.

Acquiring Components

Where do components come from? The same place as everything else—the store—just like food, just like money.

The electronic component manufacturing industry spans the globe. If someone's not putting something electronic together, they're taking something electronic apart.

Once upon a time it took some hunting to find sources for electronic parts. Swap meets and "ham fests" were great places to find components, assemblies, and entire appliances just ready to be hacked, studied, improved, or rebuilt. Now you have to spend time looking for places to *get away* from all the electronic hustle and bustle.

One of the great things about today's Internet is that it takes almost no effort to find both electronic parts and the information needed to use them. The real trick these days is finding the best deal.

If you're strictly a hobbyist, looking to spend some quality time alone or with your kids, learning about electronics and building fun projects, then it just about doesn't matter if you get the absolute, rock-bottom price on every component and tool. Even if you're a budding entrepreneur, you're still in a much better position today to leverage those brilliant ideas floating around in that noggin of yours than you would have been even ten years ago, all because of the ubiquitous nature of electronics and technology saturating our lives. Not only can you get the right tools and the best parts shipped right to your door for a song, you can easily network with knowledgeable folk from all over the globe, contributing ideas and brainstorming across time zones and borders.

Buying New Components

It would be more than a full-time job just keeping up with all of the new tools, parts, software, and hardware that are available today. Even if you could, it would take many lifetimes to make and grow the connections and relationships you need to successfully compete in the global economy.

That being said, a good place to start is in your own backyard. If at all possible, you should deal locally for the things you need. When what you want or need cannot be obtained locally, expand outward until you find it.

While it's certainly nice to be able to find all your needs met close to home, it's also good to know that the world is shrinking every day. The sort of deals and relationships that couldn't possibly have existed in your parents' time are happening right now.

If you are in a position to spend some money on quality tools and components, then by all means do so. You will not regret it. Buying questionable items is like buying your groceries out of some guy's van in a parking lot. Maybe he'll be there next week and maybe he won't.

Even the small fry can get treated like an honored guest when dealing with the right people. The trick is finding the right people. The best way to find them is to ask your friends and others with similar interest where they trade. Ask them how they feel about their relationships with their vendors. Are they just a number? Or are they a partner?

Recycling Used Components

It's really a bad idea to waste anything. In a more perfect world, there'd be no "other" category at the recyclers. Everything would have an exit strategy, especially the complex and fragile toys we're so addicted to these days.

Until that day, try to look at your trash with new eyes. Is it conceivable that someone else might be able to use this equipment, or is it truly past its useful life? Or are you just being lazy?

You can do your part, and you should believe that others are doing their part as well. Take the time to find them, find out what they can offer you, and find out what you have that they might be able to use. You won't know until you ask.

Be careful when harvesting components with which you are unfamiliar. Novice recyclers should give yesterday's cathode ray tube (CRT) TVs and monitors a wide berth. They can retain *lethal* voltages for considerable periods of time after being retired from service. Just leave them on the side of the road. The same goes for microwave ovens, or any equipment that has refrigerant in it. The stuff they use nowadays is quite toxic.

There is a growing surplus of both components and “last year’s models” available to the student of electronics these days. Sometimes it’s worth your time and money just to take something apart to see how it works. Then sometimes you find some useful parts inside that you can use in projects of your own.

Component Data Sheets

Every component ever manufactured has a data sheet. This data sheet contains everything you ever wanted or needed to know about this particular component. It’s probably available right now on the manufacturer’s web site, along with a dozen application notes. If not, then it’s probably available on a university’s computer system in a project folder.

This isn’t always the case, sadly. Past a certain point, it doesn’t make sense to allocate resources to information that no one wants or needs anymore. That point varies with each company, with some diligently archiving their information and others tossing it out the window at the end of the quarter.

When possible, collect and maintain your own private set of data sheets. When you acquire a new piece of equipment, get everything you can find in electronic form and stash it away somewhere where you can find it when you need it. If you’re experimenting with some new components, squirrel away those data sheets, just in case you strike gold.

Have you built something cool? Write up your own data sheet for it! Pretend that you’re still going to be interested in this project next year. Better yet, imagine that *someone else* could take an interest in your work. You’ll be pleasantly surprised at how useful you’ll find this information in the future, after you’ve slept a bit.

Summary

This chapter has covered a lot of different types of electronic components, but it has only scratched the surface of what is presently available.

It’s perfectly possible to spend a lifetime pleasantly tinkering with electronics and never have a clue how any of the underlying principles work. Sometimes all you need is a *practical* understanding of what the different components do in a circuit. Hopefully this chapter has given you a rough outline of what is involved. Ideally, your interest has been sparked enough to pursue more detailed study elsewhere. Good luck and happy discovering!

Now that you’re armed with some basic tools and some ideas about some of the available components, it’s time to get busy building your own lab, one experiment at a time.

The remainder of this book will take you on a journey of trial, error, and experimentation that will help you build the best possible lab for your needs, both for now and in the future.

CHAPTER 4

A Portable Mini-Lab

Having a portable (or at least (*trans*portable) electronics lab comes in handy in several circumstances. Maybe you don't have a place (yet) for a permanent home for all that equipment. Maybe you need to bounce at a moment's notice, heading off on electronic adventures at the drop of a hat. Or maybe you like to keep everything where you can find it in a hurry, without having to rummage through shelves and boxes, looking for just the right tool or component.

Whatever your motivation for wanting a portable lab at your disposal, this chapter should help you get started.

Have Lab, Will Travel

First, a note or two is in order concerning *travelling* with your electronics lab. Nothing makes security screeners at an airport or customs inspectors at border crossings more nervous than a bunch of mysterious devices, especially devices that are tangled up in a rat's nest of wires.

Do what you can to keep your collection of tools and components tidy and in working order. You will most likely be asked to at least turn on any questionable items and demonstrate that they are not hollowed-out shells for transporting questionable items. It also doesn't hurt to clearly label equipment as to its function and ownership, which makes sense in any case, not just travel scenarios.

The Compact Executive Model

"A full mongoose is a slow mongoose." This is an important lesson learned from Rudyard Kipling's *Rikki-Tikki-Tavi*. Rikki, a mongoose, has to stay fast on his feet to be able to combat Nag the cobra and hope to win. Therefore, Rikki learns to only take a few bites at a time when eating and never gorge himself.

Although hopefully not in a life-or-death situation like Rikki's, you can learn a thing or two from this simple philosophy. Only take what you absolutely need when travelling, and never take something you can obtain at your destination. These things will only slow you down. Don't be a slow mongoose.

■ **Tip** Travel light.

A slim and lightweight briefcase or attaché can hold many of the tools and components you might need for your mobile electronic experimentations. The main advantage is that you will only need one hand to carry it (leaving one hand free to open doors, bribe guards, or fend off ninja—assuming you have two hands to begin with). See Figure 4-1.

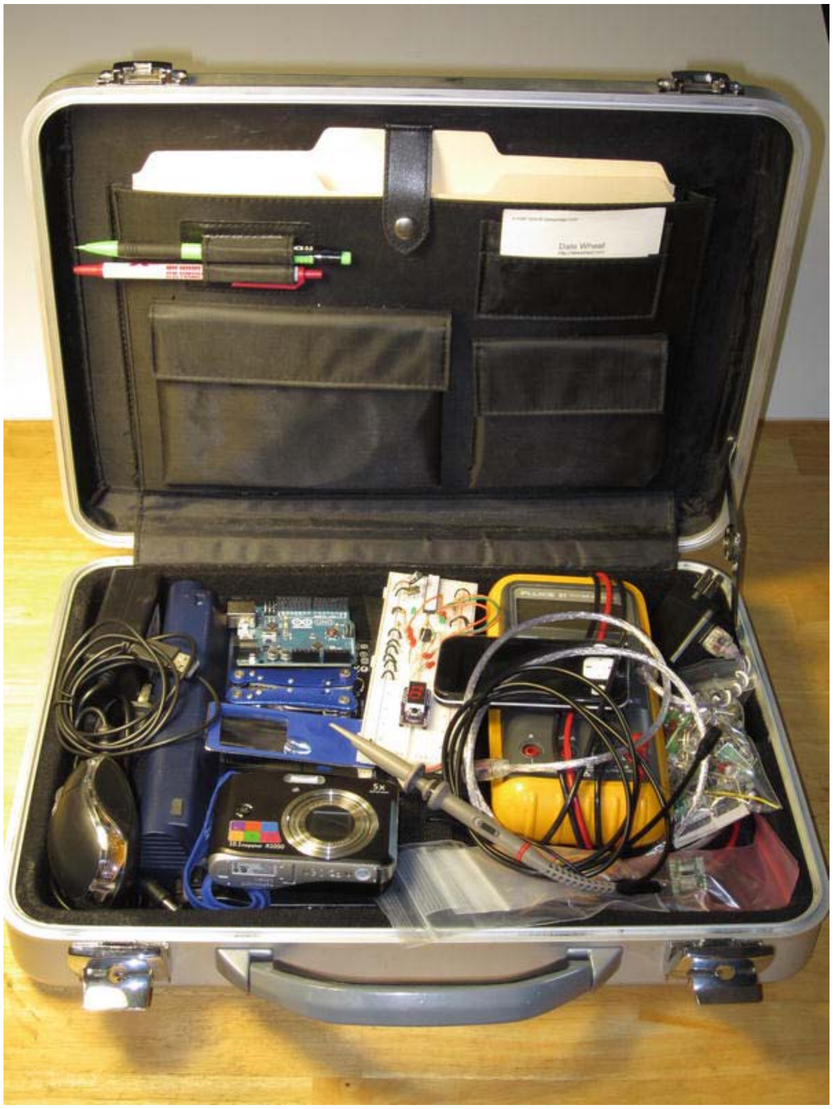

Figure 4-1. *The compact executive mobile electronics laboratory. There's plenty of room for lots of tiny things, but not much else. Also handy for transporting big stacks of cash, should the situation arise.*

Let's take a look at what all you can take with you without a lot of heavy lifting. Starting on the left and moving to the right, we have

- Netbook PC with AC charger and USB mouse (it might be hard to see in Figure 4-1 because it's upside down and covered by other stuff)
- Arduino Uno programmable microcontroller (or *physical computing platform*)
- Folding multitool
- Lighted magnifier
- Digital camera
- Solderless breadboard with lots of precut jumper wires
- Digital multimeter and probes
- Compact single-channel oscilloscope with probe
- AC-powered USB charger—can also be used as a stand-alone regulated 5V power supply
- USB cable
- A variety of LEDs in all shapes and sizes
- Additional passive components
- A variety of batteries, both rechargeable and otherwise, and various battery holders (not shown)
- Static-sensitive integrated circuits and modules stored in antistatic bags
- Notebooks, writing implements, blank media, and documentation
- Your contact information in case of loss

One of the interesting features of this lab is that it is completely self-contained, power-wise. While it's nice to have access to AC power, it's not strictly required, at least for a while. The Arduino and the attached breadboard are powered by the battery in the netbook, via the USB cable. The multimeter has its own 9V battery, while the mini-oscilloscope can be recharged from a spare USB connector. With an extended-life battery, you can expect four to five hours of on-location electronic experimentation.

If your netbook or PC has Wi-Fi or other connectivity to the Internet, you can browse tutorials, data sheets, user forums, and even this book, unless you've already downloaded these items to the internal hard drive.

Have a look at this particular lab deployed and ready for action in Figure 4-2.

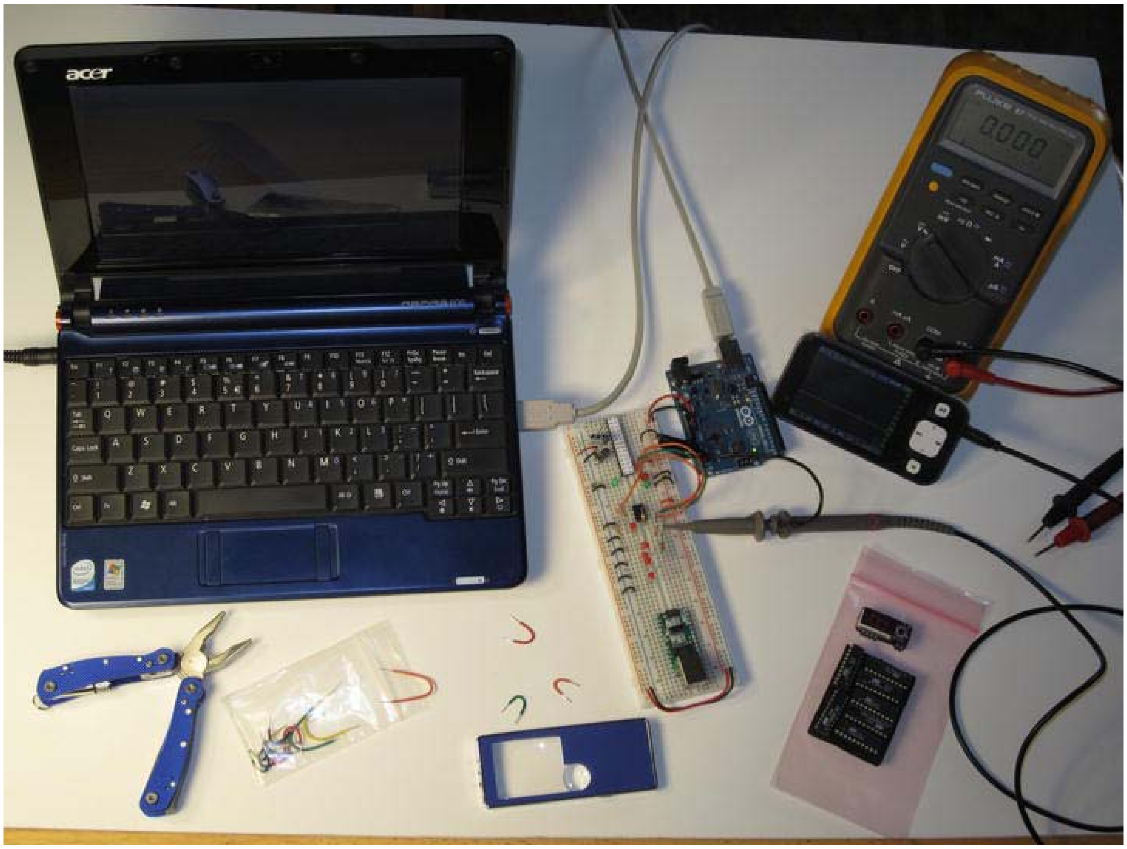

Figure 4-2. *The compact executive lab is deployed on a desktop. You have access to lots of electronic building and debugging capabilities in a small area. Using a solderless breadboard helps reduce the number of fabrication tools that you need to carry with you on your adventures.*

The Arduino was included for its small size, popularity, and ease of use. There's a whole world waiting for you inside that little board, waiting to be explored, but that's a story for another day.

You can use the USB cable to extract a regulated +5V supply from your PC for your low-voltage-experimenting pleasure. You can also use an inexpensive USB charger to do the same thing, if you don't feel like hauling a whole PC around with you. Just don't try to draw more than half an amp of current, which is the "official" USB limit for supplying power to USB devices. Technically, *unenumerated* devices (i.e., just a USB cable with nothing intelligent enough to identify itself to your computer) can only draw up to 100 mA (0.1A) of current. A USB charger, on the other hand, is not so picky.

No Soldering Required

One notable omission from this particular configuration is any sort of soldering tool. You could certainly add a small soldering iron, some solder, and a few more hand tools. You'll either need to boot out some of the bulkier items, such as the PC or the full-sized multimeter, or get a slightly bigger carrying case.

The Ever-Shrinking Computing Device

One option that will be gaining momentum in the very near future is the use of tablet computers or smart phones instead of the physically larger laptops or netbooks. They already have a lot of the computing capabilities of reasonably powered portable computers. Also, you can look forward to innovative hardware and software interfaces that will make them more useful in the lab as programmable test and measurement devices. While name-brand products still command a premium price, many no-name or OEM (original equipment manufacturer) products are being sold for a fraction of the cost.

Electrical Experiments You Can Perform

Here are some simple electronic experiments that you can perform using only the tools and components found in the compact executive mobile electronics lab. Start out with something simple and incrementally build on your success. Don't try the most complex problems first. What you want is to build up both your knowledge *and* your confidence at the same time.

Lighten Up, 20th Century Style

Here's an easy experiment that will teach you several interesting things about electronics, believe it or not. You can light up a typical LED using only a lithium coin cell. It needs to be a lithium coin cell that produces at least three volts (marked "3V"), not one of the smaller batteries that only supplies 1.5V, such as a watch or hearing-aid battery, as these will not produce enough voltage to light up a typical LED.

Slide the coin cell between the leads of your LED. There are four possible outcomes, three of which are "nothing interesting happens." Let's start with the least likely possibility, in which the LED lights up. Sometimes you just get lucky.

First Possible Outcome: The LED Lights Up When Attached to the Coin Cell

Figure 4-3 shows the results of this outcome. Notice that the longer lead of the sLED (the positive, or anode, lead) is touching the side of the coin cell marked with a +. No current-limiting resistor is required in this circuit because the battery's internal resistance is sufficient to keep from blowing up the LED. It just happens to work out that way, this time. Most other times, you will need to add a current-limiting resistor to the circuit.

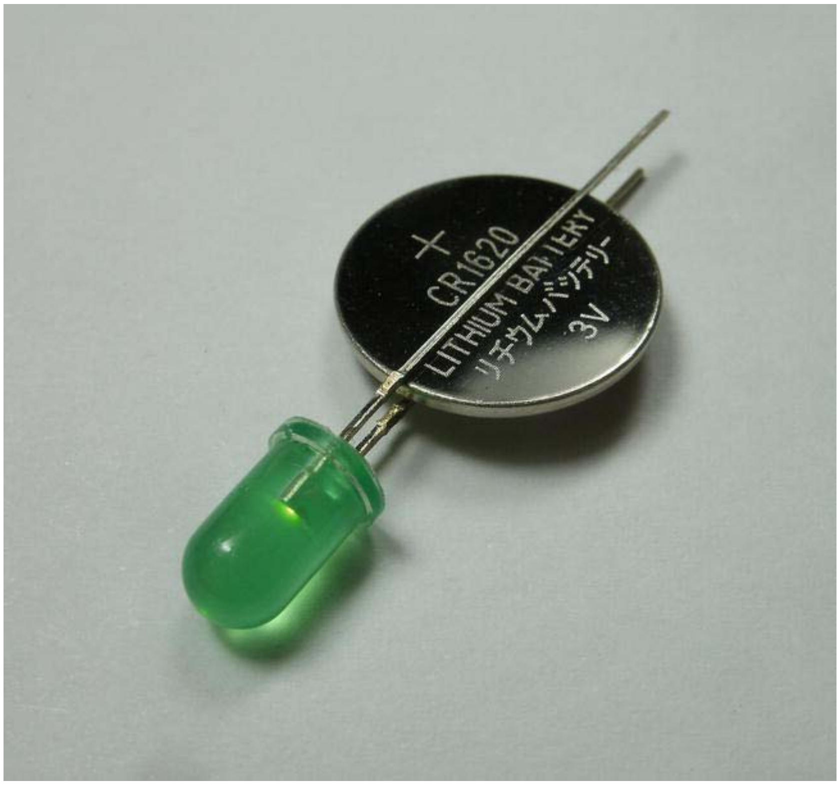

Figure 4-3. *A typical LED lights up when attached to a lithium coin cell. No extra wires needed!*

The other three scenarios? Let's look at them one at a time.

Second Possible Outcome: Nothing Interesting Happens

Why? Because the LED has been installed backward. Alternatively, the coin cell has been installed backward. Remember from Chapter 2 that LEDs are light-emitting diodes, and diodes only carry current in one direction. Therefore, when connected backward, they block the flow of electric current, preventing anything interesting from happening in the rest of the circuit.

Typical lithium coin cells have one broad, flat side that usually has something printed or etched on it, almost always with a + to indicate the positive polarity of the cell. The other side is often textured or rippled in some way to help make better electrical contact when installed in a device. This other side is the negative terminal of the battery.

The LED, being a diode, is *polarized.* It will only work when installed in the proper orientation inside the circuit. Most LEDs will offer one or more ways of easily identifying which lead is which (see Figure 4-4).

- Brand-new LEDs will have extended leads about an inch or so long. One lead will be slightly longer than the other one. The longer lead is the *anode*, or positive lead. The shorter lead is the *cathode*, or negative lead. This information is lost when the leads of the LED are trimmed—for example, after being installed in a PCB.
- Another industry standard for identifying the polarity of an LED is to look at the small ridge or shoulder at the base of the LED body. There will be a flat portion molded into the otherwise circular outline. This flat spot marks the cathode, or negative terminal of the LED.

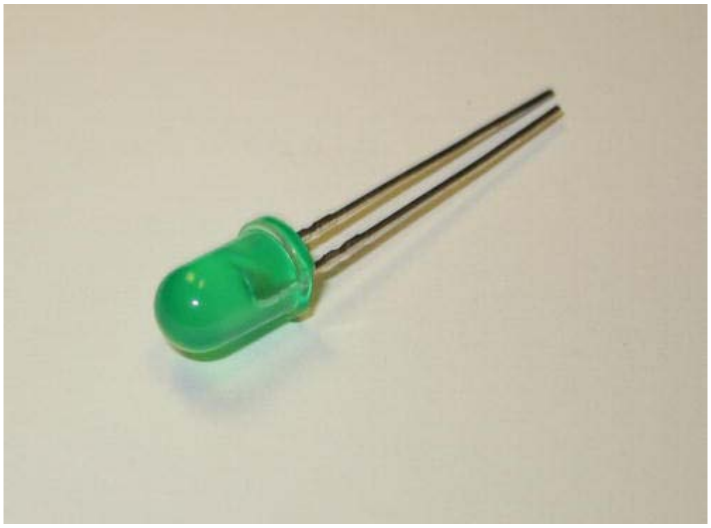

Figure 4-4. *Typical LEDs in the 3mm, 5mm, 8mm, and 10mm sizes almost always have two polarity indicators. The first is that the longer lead is the positive lead, or anode (top). The second is that the flat side on the base indicates the negative lead, or cathode (bottom).*

On really tiny LEDs, there may be an even tinier mark printed or etched onto the LED to indicate the cathode. You will sometimes need a magnifying glass just to see it!

The quick and easy fix for this problem is to swap the direction of either the LED or the battery. If this still produces no good results, we have to consider some more possibilities.

Third Possible Outcome: Nothing Interesting Happens

This time, after establishing that the LED has been properly oriented with respect to the polarity of the battery, we must entertain the possibility that the battery has been previously depleted. Coin cells have a limited amount of energy stored within them, and this can be easily drained in normal use over time.

A quick way to measure a battery's electrical goodness is to use a voltmeter. See Figure 4-5.

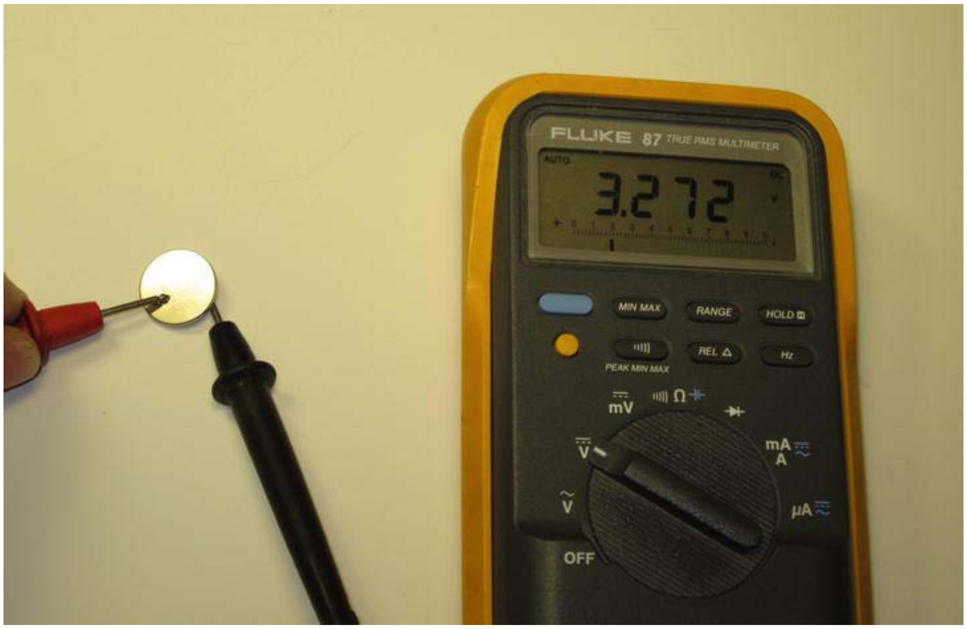

Figure 4-5. *Measuring a coin cell's electrical goodness using a digital multimeter. This one is chock-full of goodness!*

If you have a multimeter, be sure to set it to read DC voltage, in the appropriate voltage range (unless you have a fancy "autoranging" meter). Touch one of the meter's probes to one side of the battery and the other probe to the other side of the battery, and see how much voltage is measured. Anything below 3V should be considered depleted and of no further use, as far as electronic-type projects are concerned. The batteries are shiny and round, so they may have a second career in some sort of art project, but otherwise they should be disposed of in a responsible manner.

Also, perhaps because of their very shininess and roundness, they like to be eaten by small children. Don't let this happen! Take whatever steps are necessary to prevent small children from handling or even touching your electronic tools and components. Use extra care when your lab is mobilized.

■ **Caution** No unsupervised children, no matter how adorable, are allowed in the lab!

Fourth Possible Outcome: Nothing Interesting Happens Because the LED Is Defective

This can happen when an LED is subjected to too much current and the tiny, tiny wires within the plastic body overheat and fail. It can also occur when the LED has been exposed to the elements and moisture has penetrated the casing, allowing the internal connections to oxidize. This scenario, while within the realm of possibility, is certainly the least likely of the four, unless you are habitually cruel to your LEDs. It's also easy to test, if you have a known-good lithium coin cell handy.

Where's the Resistor?

You might be wondering where the current-limiting resistor can be found in this circuit. It's in there, all right, but it's hidden within the battery, so to speak. Coin cells are designed to provide tiny amounts of current over a long period of time. You're not going to arc-weld or start your car with one. As such, they have a much higher *internal resistance* than most any other kind of battery. We use this "feature" to our advantage when testing LEDs using just a coin cell, as the maximum amount of current that will normally flow out of the battery is below that necessary to destroy the LED.

A Slightly More Permanent Circuit

You can build a more permanent circuit for the coin cell and LED using a solderless breadboard. If you recall from the "Solderless Breadboards" section of Chapter 3 (see Figure 3-6), a solderless breadboard is an array of spring-loaded tie points, which serve to both physically hold electronic components and provide electrical connections between certain points. Let's build an LED circuit on a solderless breadboard using an LED, a coin cell, a resistor, a jumper wire, and a custom battery holder (see Figure 4-6). Later on, in Figure 4-7, you can see details of the custom battery holder.

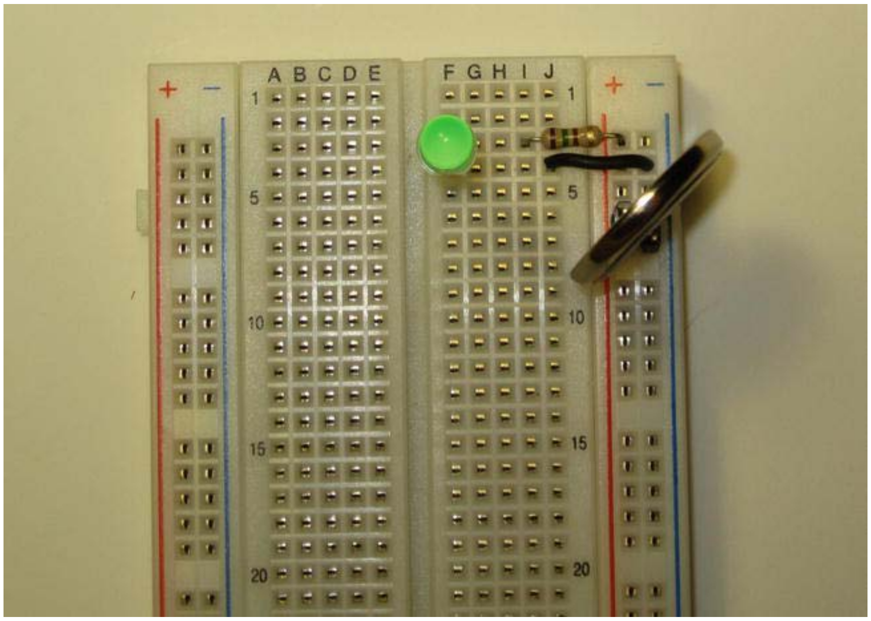

Figure 4-6. *A slightly more permanent LED circuit, built on a solderless breadboard. The tie points on the breadboard are labeled left to right with the letters A–E and F–J for the columns. The rows are numbered starting at 1 at the top. The LED's anode, for example, is installed in tie point F3. The power rails on either side are simply marked with + for positive and – for negative.*

Referring again to Figure 4-6, you can see the overall layout of the LEDcircuit. The power rails along both sides of the breadboard are just longer versions of the electrical connections that connect each of the groups of five tie points together. In this example, the right-hand power rails are used, but the left-hand side is not.

The schematic diagram of this circuit shows how simple it is, at least in principle (see Figure 4-7). Can you see the circle?

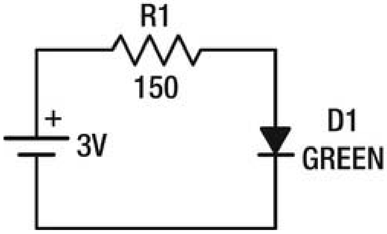

Figure 4-7. *The schematic diagram of the LED circuit as built on the solderless breadboard. Schematics are intentionally simpler than reality (most of the time) in order to help convey the very basic idea of how things are to be wired and the relationships between the components, without bogging you down in all the inevitable details that are involved.*

The Battery

The symbol for the battery actually looks like the battery in this case. The same symbol is used for most single-cell batteries, even when they are of completely different shapes or proportions. Multicell batteries are usually represented with repeated stacks of long and short lines.

The battery symbol's long line represents the positive terminal of the battery, and the short line represents the negative terminal. Again, it's just a coincidence that the wide side of the lithium coin cell is the positive terminal. The addition of the + sign in the schematic is redundant, but you'd be surprised how many people accidentally reverse this symbol. Better safe than sorry when it comes to electricity!

The Resistor

The battery's positive terminal is connected via a wire (drawn as a simple, solid line) to one side of the resistor. The schematic symbol for the resistor is a zigzag line.

The resistor is labeled "R1" (resistor 1) in this schematic, even though it's the only resistor and could just as well have been labeled "RESISTOR #1," or just plain "resistor." The numeric value underneath the resistor is the component's primary electrical characteristic, at least as far as we're concerned when looking at the schematic. In this case, it indicates a resistor whose *value* is 150Ω. In this simple example, the value of the resistor is quite flexible. A larger value, such as 1KΩ (1,000 ohms) or more, would also work, except that the LED would not shine as brightly. This is because *more* resistance results in *less* current flow, and it's the current flow that makes the LED shine. More current, more shiny.

We haven't specified any of the other important characteristics of the resistor, such as the tolerance or the power-handling capacity. Because this is such a low-power circuit, almost anything will do. When you start to work with really big LEDs that require correspondingly really big power supplies, this becomes a much more critical issue. For now, we start simply.

The LED

The other side of the resistor is connected, again, with a simple, solid line, to the anode of the LED, whose *reference designator* in this schematic is D1 (for diode 1). You could have called it "LED," and future generations would probably have understood your intentions, which should be your overriding goal. Its characteristic "value" in this case is "green." Of course, any color will do, as long as you have the eyes to see it.

The LED's schematic diagram effectively communicates its polarized nature. The arrow indicates the flow of *conventional current*. The flat bar indicates the cathode, or negative terminal of the LED. This corresponds to the flat side of the LED body in this example. The cathode is connected via a wire back to the negative terminal of the battery, completing the circuit.

Can you see the circle yet? Hint: It's disguised as a rectangle. The important point is that it forms a complete loop.

Building the Actual Circuit

Comparing the schematic to the photograph of the completed circuit might not immediately click in your head. Take a look at Figure 4-8 for a slightly different angle, where you can see some more details, such as how the battery is being mounted.

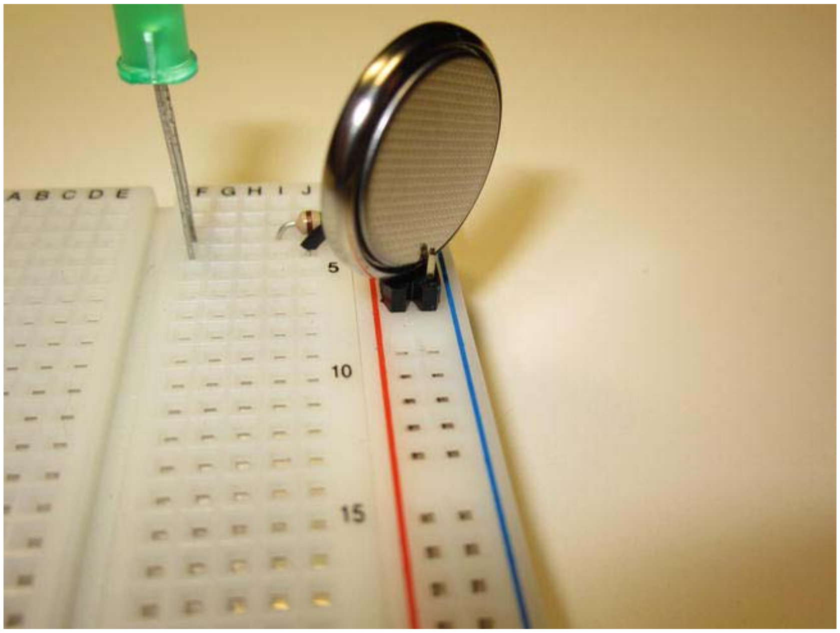

Figure 4-8. *Another view of the LED circuit as built on a solderless breadboard. The battery holder is a modified pin block that has had a couple of its pins removed, allowing the coin cell to fit in on the diagonal. A thinner coin cell could have fit without your having to remove the corner pins. A proper coin cell holder is inexpensive and would provide a much more robust solution to the problem.*

Looking at Figure 4-8, you can see how the positive side of the battery is making physical and electrical contact with the gold-plated pin of the pin block. The remainder of the pin emerges underneath the black plastic molding to make contact with the spring-loaded tie point within the body of the solderless breadboard, which in this case is the negative power rail. The positive terminal, in a similar fashion, makes contact with the positive power rail.

By attaching the battery directly to the right-side power rails, you ensure that your circuits are only a short jumper away from power, no matter where along the breadboard you decide to build them. Handy!

Note that the left-side and right-side power rails are not connected at this time. If you would like them to be, you can easily attach them using jumper wires. See Figure 4-9.

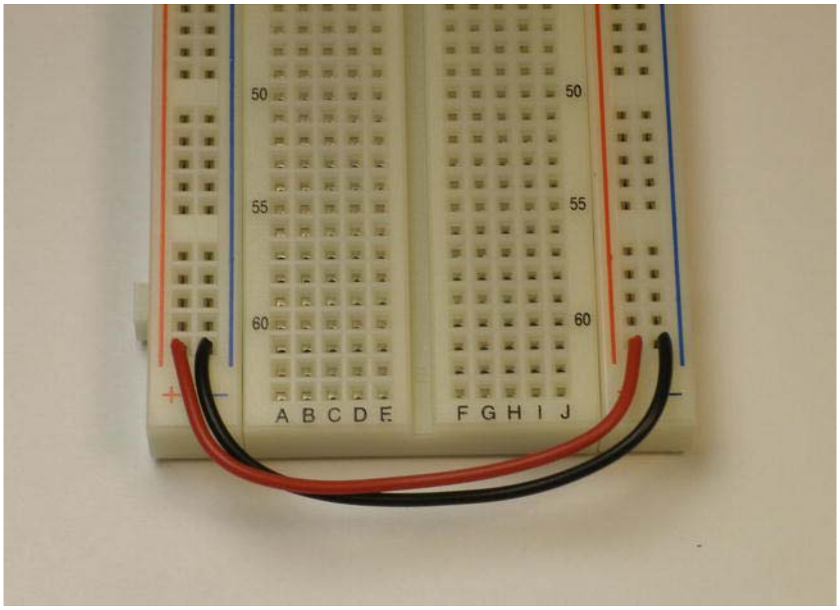

Figure 4-9. *Attaching the left- and right-side power rails using jumpers. By default, the power rails are not connected. There are some situations where you need them to not be connected, such as when using multiple supply voltages within a single circuit. These things happen.*

Now, referring *all the way back* to Figure 4-6 (sorry about that), you should be able to see how the positive terminal of the battery is indeed connected to one side of the resistor. The other side of the resistor, then, makes an electrical connection with the anode of the LED (the non-flat side, when seen from above). The cathode is connected to the negative power rail using a short jumper wire. The negative power rail then completes the circuit back to the battery. The circle is complete.

Note that the resistor could have been placed either before the LED in the circuit (as shown in the photographs) or after the LED. The only important points are that it is in the same circuit, or circle, and that the current must flow through *both* the LED and the resistor. It really doesn't matter which one comes first, especially in this simple circuit. It will only make a difference when you start to do fancy stuff, like adding switches and such to complicate things.

If you're using a different kind of solderless breadboard (and there are a few distinct varieties), you may or may not have power rails available. If so, fret not. You can still make point-to-point connections using more jumper wires. Now you're starting to understand why you were assigned to cut and strip so many jumper wires back in Chapter 2! They should start to be coming in handy just about now.

Multiple Uses for the LED

Now we've moved from the 19th century incandescent bulb to the 20th century LED. What kind of lighting devices will we encounter in the centuries ahead?

One of the nice features of LEDs is that they don't typically require a great deal of power to operate. This is certainly true of indicator-style LEDs, whose only purpose is to be seen as either on or off. We can leave this LED installed right where it is and use it as a handy power-on indicator for future projects. You might be surprised how many heads get scratched in puzzlement, wondering why a newly wired prototype isn't working, only to find out after exhaustive investigation that the power wasn't turned on! Then again, you might not be surprised by this.

Now let's take this perfectly working circuit and break it—on purpose. If we interrupt the circuit, for example, by removing any of the components or their connections, the circuit stops working. To that end, remove the short jumper wire and replace it with two longer jumper wires. Plug in each of the new, longer jumper wires where the two ends of the short jumper were installed. See Figure 4-10.

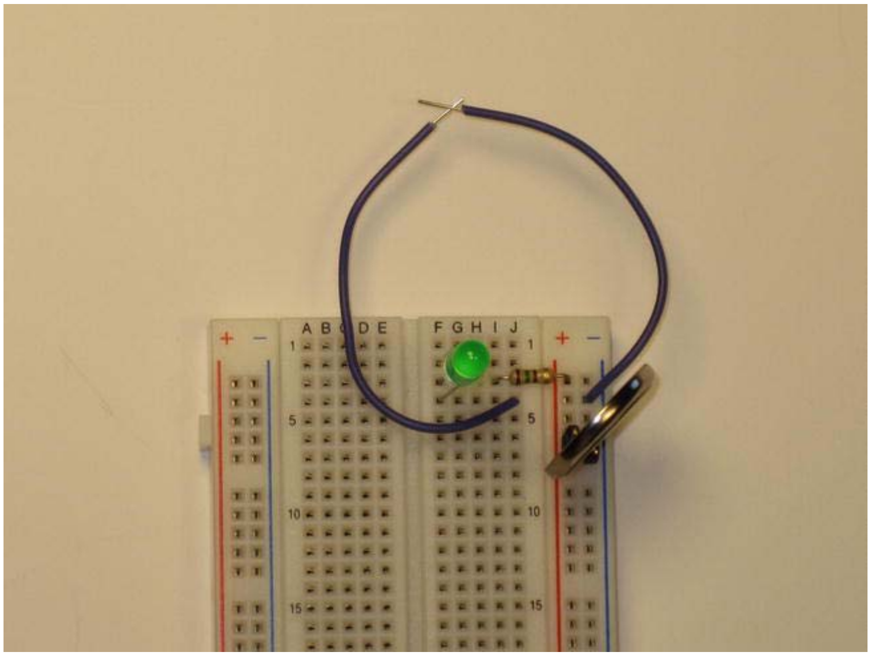

Figure 4-10. *By intentionally breaking the circuit, we stop the flow of electricity through the components, extinguishing the LED. By reconnecting the longer jumpers (or just touching them together), we reestablish the circuit, and the LED should light back up again. We can use this mechanism to test whether there is continuity in another circuit.*

Now, by touching the two probe wires together, you recomplete the circuit, and the LED should glow in happiness. This is exactly how a switch works. You can use this basic idea to build a continuity tester that lights up the LED when the current flows in the circuit. This is very handy for testing cables and wiring in a more complex assembly.

More electronic experiments, including how to both calculate and measure what's happening in a circuit, can be found in Chapter 5.

The Special Project Portable Laboratory

When you move past the simple joys of lighting LEDs and wiring up tutorial circuits, where do you go and what do you build? How about a robot?

Doug Paradis is an award-winning writer and robot builder. When Doug wants to work on one of his robots, he packs up a small kit of tools and heads over the local robot club, which in Doug's case is the Dallas Personal Robotics Group (DPRG). They meet every Tuesday at the Dallas Makerspace for an informal evening of robot building and socializing. See Figure 4-11.

Figure 4-11. *Doug Paradis of DPRG, arriving at the Dallas Makerspace for an evening of robot building. Doug uses the club's laser cutter and other specialized tools to give his robots that winning edge. He brings his own set of hand-picked tools along with him.*

Figure 4-12 shows what Doug brings with him to work on his robots.

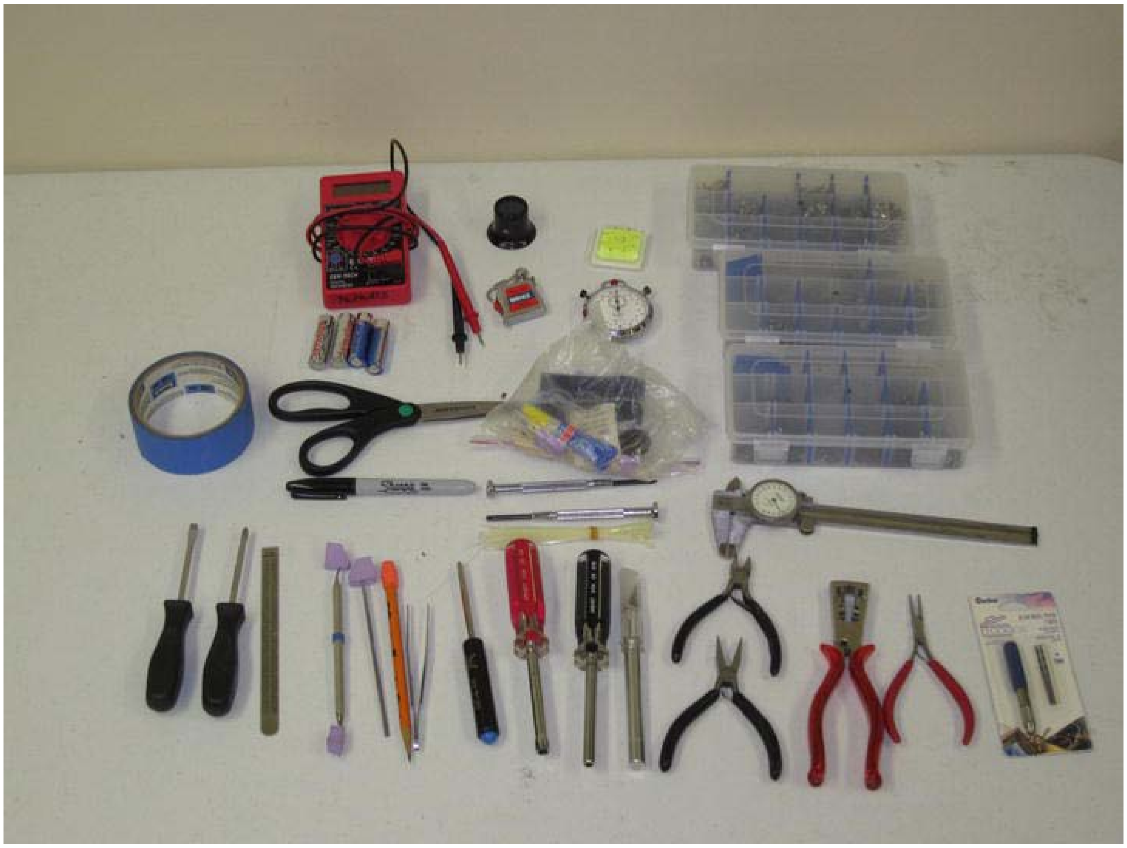

Figure 4-12. *The contents of Doug's portable workshop. A variety of hand tools, precison measurement devices, and fasteners (including tape, tie wraps, and super glue) are easily stored in a small tool bag for easy transport. The comparmentalized storage containers at the upper right contain a large assortment of screws, washers, and nuts.*

Doug has learned the lesson of travelling light. The electronic portions of his robotic creations evolve slowly over time, but the mechanical aspects get a lot of tweaking along the way.

Not everyone has perfected the art of light travelling. See Figure 4-13.

DRAIN OUTLET

Figure 4-13. *A sort-of-portable robotics lab, with lots of tools and spare parts. One way of looking at this bounteous splendor is "three trips to the car."*

This caravan of tools, parts, and miscellaneous supplies forms the entourage of Kyle the Robot. Kyle is very much a work-in-progress. The basic framework is made of hand-tooled aluminum. The large wheels use O-rings for tires and are driven by 24V gear motors. The 24V supply is made up of two 12V, 5Ah rechargeable lead-acid batteries. Ah stands for amp hours, and represents the capacity of the battery. In this case, it can deliver an amp of current for five hours, or five amps for one hour. The custom PCB holds the electronics for the drive motors and will be controlled by a separate microcontroller that has yet to be added. See Figure 4-14.

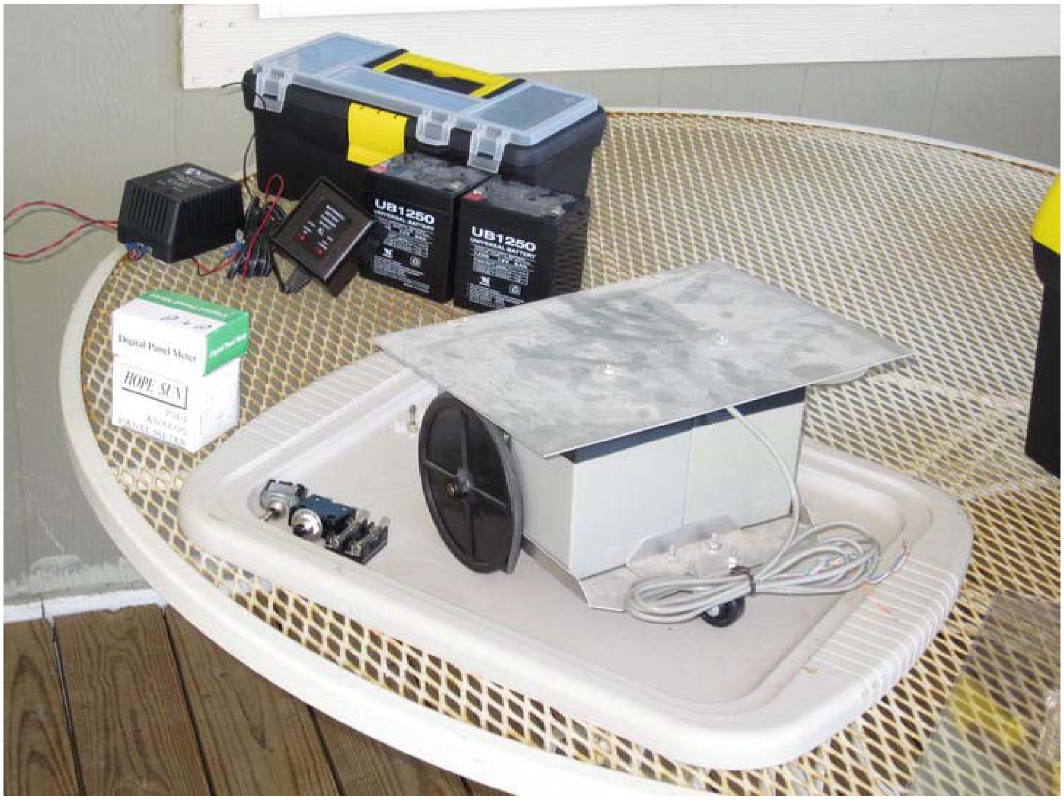

***Figure 4-14.** Kyle the Robot is a work-in-progress who requires a wide range of specialized tools and components. Some new components are being fitted, including dedicated battery voltmeters, fuses, a circuit breaker, and a master power switch. Once the sharp corners are filed off, Kyle will be able to roll around the house, looking for chores to do.*

Summary

As we come to the end of this chapter, you should have some good ideas bouncing around in your head about how you want to pack your mobile electronics lab, what tools and components you *absolutely* must have with you, and how you want them organized. The best way to find out for sure what works for you is to make a few field trips, paying careful attention to what was actually used compared to what you anticipated needing. This will help you whittle down your cargo to the bare essentials, which is what you want. Remember, travel light. Excess baggage is a purely optional curse.

In the next chapter, we'll look at some suggestions for organizing and working in a more permanent setting. This could be a domain as small as the corner of a desk or as large as a warehouse. You will soon discover, if you haven't already, that this hobby, like many other projects, will quickly expand to fill the space available. Try to keep in mind that *you* are the one that ultimately makes the decisions. Effort spent planning ahead of time will help keep the sprawl to a minimum, while helping you stay focused on what you wanted to be able to do in the first place.

CHAPTER 5

The Cozy Corner Lab

Chapter 4 focused on the needs of the travelling electronic adept. Here in Chapter 5 you can come home to a lab that is always ready and waiting for some electrical fun and doodling. Nice!

You don't need an entire garage or extra office for a functional laboratory for your electronic endeavors. It's certainly nice if these areas are available to you, but you might be surprised at how much you can do in just a small space, if you set it up properly and maintain it with determination.

The first part of this chapter will deal with the task of rehabilitating a small, dedicated work area that has succumbed to years of poor organizational habits. These things happen. The second half of the chapter explores the possibilities of starting afresh with a nice, clean space—either something brand new or just newly cleaned. Some more projects help break in your new work area, as well as familiarize you with more interesting information about some of the basic electronic components reviewed in Chapter 3.

The Rehabilitation of a Small but Useful Area

Let's perform a little magic, in the form of a complete makeover for a small workstation. Have a look at Figure 5-1. Don't let this happen to you!

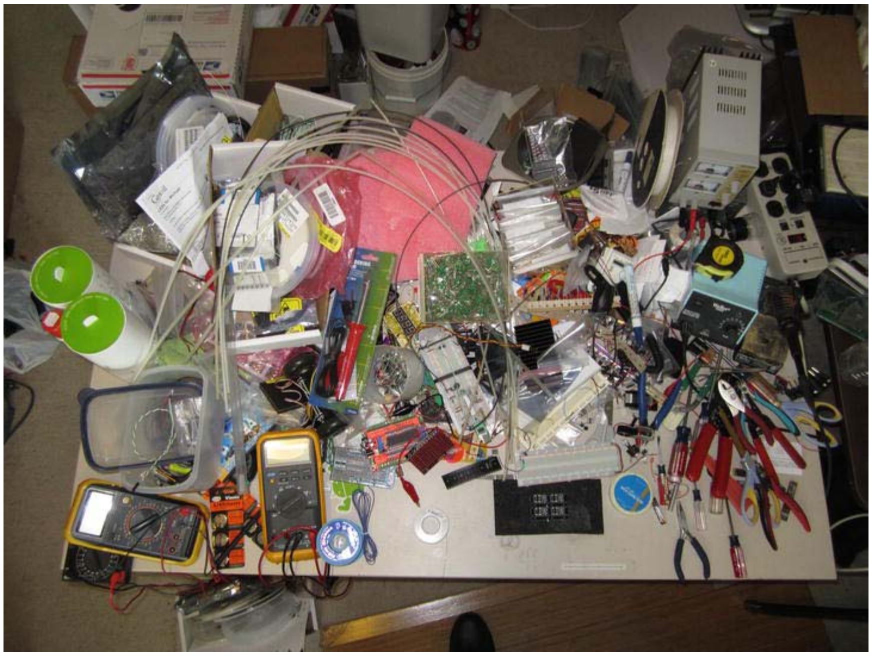

***Figure 5-1.** A workstation that has been in continuous use for several years. Not much planning went into the original organization of this work area. Such a space can often accumulate flotsam and jetsam that might have at one time seemed appropriate, but now just competes for precious space. The effective work area is down to only a few dozen square inches! This limits the scope of projects that can be comfortably undertaken. It also causes unnecessary delays in rooting around for tools and parts. It's not pretty and it's not safe.*

Where to begin? Like any other project, this big project is made up of many smaller projects, none of which are especially difficult, if approached in the right order and with the right attitude.

If you're starting from scratch with your electronics lab and don't want to wade through this mess, jump on over to the "Adding a Power Source" section of this chapter.

Science to the Rescue!

Let's use the science of *taxonomy* to help break down this task into smaller, more manageable jobs. Taxonomy comes from the Greek words for "arrangement" (*taxis*) and "method" (*nomia*). That sound like *exactly* what is needed here! An "arrangement method" would assist in building up a plan for attacking this project.

■ **Tip** Method plus rigor equals success! Have a plan, pursue it with determination, and you will succeed.

Let's break down the overall category of "big mess on table" into two major *taxa* (singular: *taxon*), or categories. Ideally, what we will find here are *tools* and *components*. There will be other bits and pieces that don't easily fit into one category or the other (or will maybe fit into both), but it gives us a place to start.

Organization

Divide and *conquer*! These are the two words that will help us through the ordeal of rehabilitating this workspace. We'll get to do a lot of dividing here, and end up as conquerors. The spoils will be a useful (and tidy!) work area that will encourage you to begin new electronic adventures, instead of scaring small children.

The Great Divide

It would be possible to reorganize this workspace *in situ* (i.e., in place), but it would require a great deal of inner peace and lots of patience. Lacking these, a complete reboot is in order. Let's clear off the entire table and start afresh. This will provide the excellent opportunity to arrange things in exactly the best possible order.

First, get two big containers. These can be cardboard boxes or plastic storage bins—it really doesn't matter. We'll just be using them as temporary staging areas as we make like an embryo (and divide and divide again). See Figure 5-2.

Figure 5-2. *Two large cardboard boxes are enlisted to help with the initial organization of the contents of the tabletop. One will be for tools and the other one for components. Further subdivisions will be made later.*

Now, the first thing you will want to do is remove any items that really don't belong in the lab at all, such as coffee cups, personal effects, and any obvious trash. Everything that is about to go into one of the two boxes should eventually find its way back to the work area, so now is the time to omit the things just don't belong here.

Is it a tool? Is it a component? How do we tell? Ask five people and you will get five different answers. For the purposes of this little endeavor, a *component* is something that will become a part of a project, while a *tool* is something that is used to modify or manipulate a component. Another way of looking at it is that components get used up quickly, while tools get used up slowly. If you build enough projects, you will be lucky enough to see exceptions to these guidelines.

Here are some examples. Wire is a component. Wire cutters are tools. That was easy. A flashlight is a "visual inspection aid," so it goes under the category of tools. Batteries for the flashlight are consumable, so they are components. There's no real need to be ultra-precise at this point. Use your best judgment and make up policies that make sense to *you*.

It might help, from a physical logistics standpoint, to use smaller subcontainers to hold the really small bits as you're lumping them into the two broad categories. Folding cardboard bin boxes are handy both on the tabletop as well as on shelves, if you have them. The cardboard bin boxes shown in Figure 5-3 are from Uline (`http://uline.com`), part numbers S-16268 (4" wide) and S-16269 (6" wide).

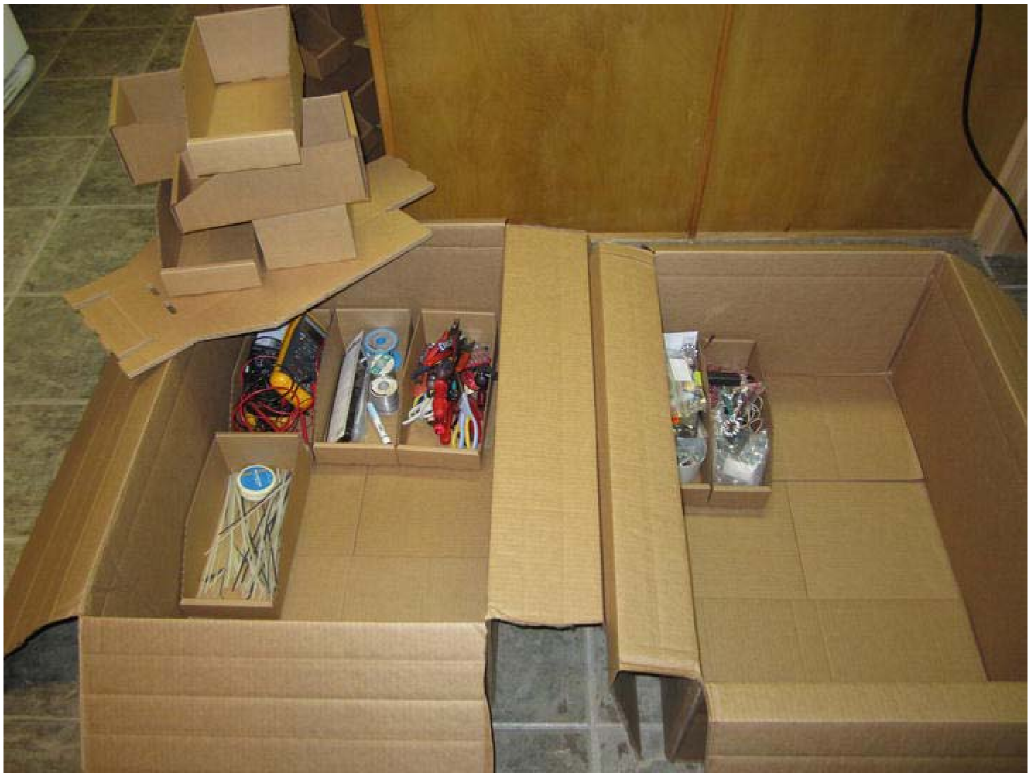

Figure 5-3. *Folding cardboard bin boxes help contain some of the smaller bits and pieces during the Big Sort. You can use whatever happens to be available. Some preliminary subsubdivision is going on here. For the most part, the tools are on the left and the components are on the right.*

After everything is removed from the table and the cardboard boxes are nearly full, the table itself should get a good washing. Behold the *tabula rasa* (blank slate) depicted in Figure 5-4.

Figure 5-4. *The tabletop has been cleared of tools, components, and various bits of debris. A good washing with soap and water completes the cleansing. A burned spot (the result of a poorly supervised thermal test) is covered with a small sticker (see inset).*

Adding a Power Source

Here's where a bit of planning will save you a lot of headaches in the future. What you never seem to have enough of in any laboratory, especially electronics labs, are lots of conveniently located power outlets. Let's take care of that issue right away, before building anything else onto the tabletop. See Figure 5-5.

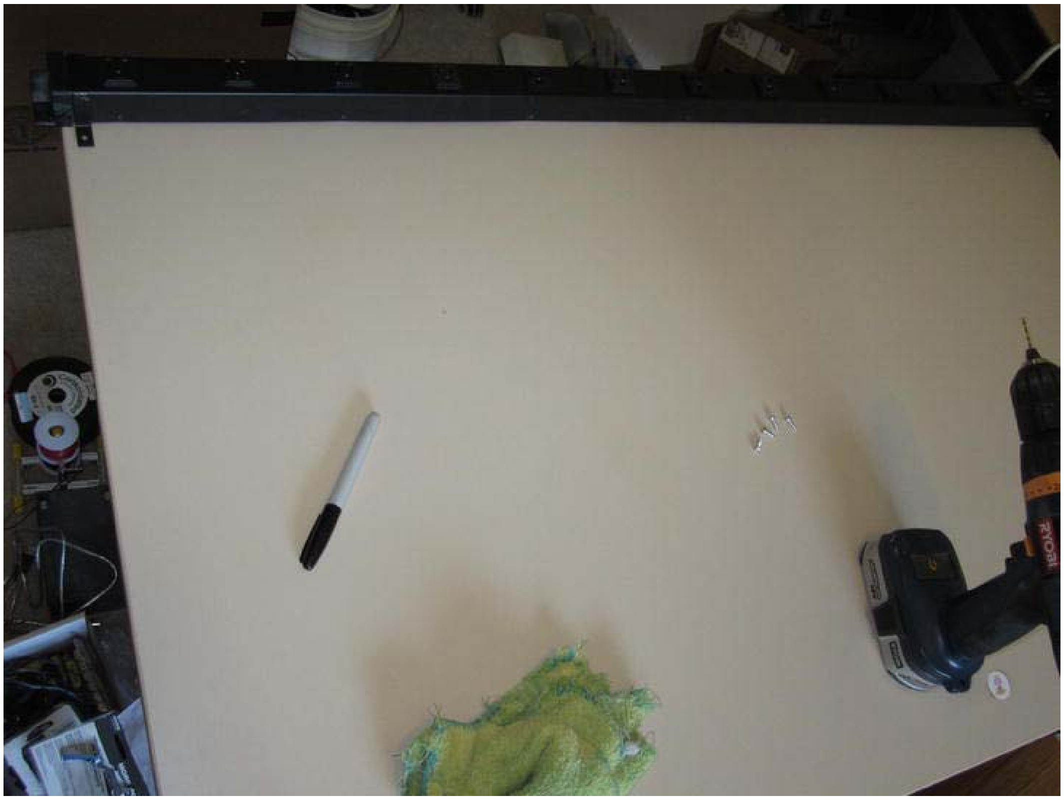

Figure 5-5. *A 12-outlet power strip is attached to the back edge of the tabletop. This will provide a safe and convenient source of power for all those gadgets you'll eventually want on your bench. Tools needed for the job include a drill motor to drill out some small pilot holes for the brackets, a small drill bit, and a felt-tipped marker. Before drilling the pilot holes, align the brackets where you want them to go and use the marker to put a dot where the pilot hole should be drilled. Make sure the power strip is not plugged in when you're drilling right next to it!*

Having lots of extra power outlets is a nice bonus, but is not absolutely required. What you want to avoid, however, is excessive daisy-chaining of power strips and extension cords. This is a fire hazard. Remember from Chapter 3 that every conductor has a certain amount of resistance. This resistance turns electricity into heat. Enough heat makes things catch on fire.

If you do have the luxury of being able to mount a permanent power strip (which, technically, remains a temporary power tap as far as the manufacturer is concerned), then be sure to install it securely using the hardware provided. See Figure 5-6.

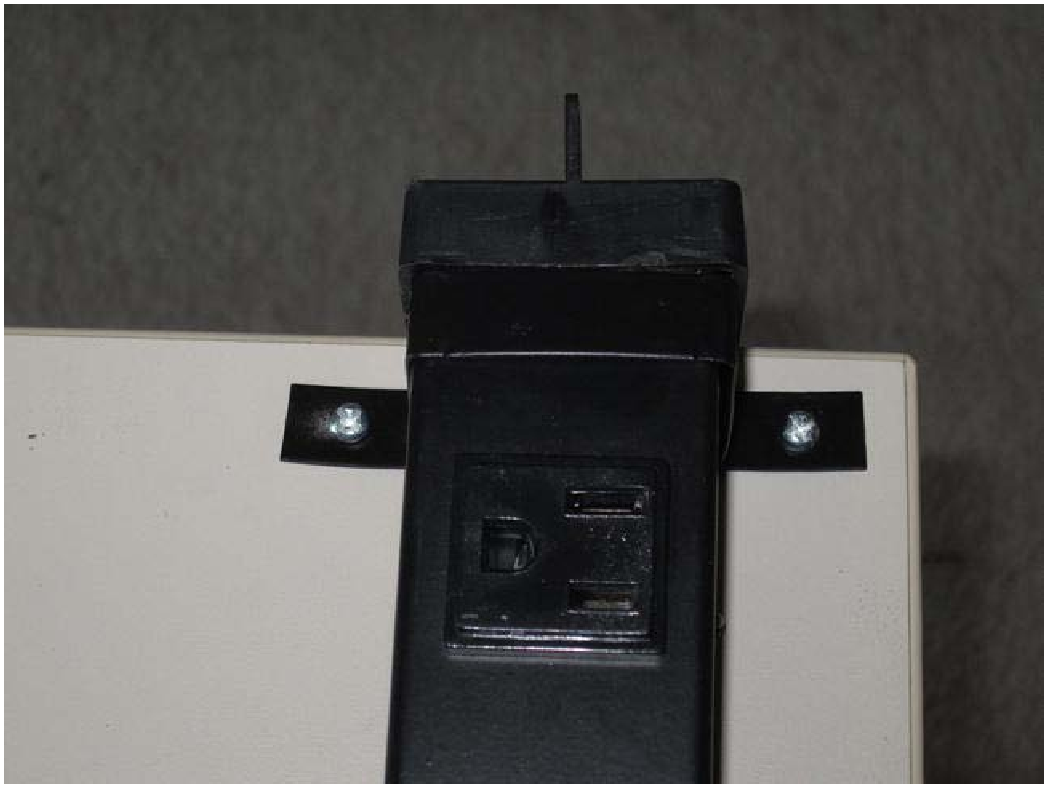

Figure 5-6. *The power strip is fastened securely to the table using the provided hardware. You do not want your power strip wiggling around, or worse yet, falling off the table, dragging all of your power tools with it!*

■ **Tip** Test every outlet of your power strip before permanently mounting it to your workbench.

A Clean, Well-Lighted Space

You can never have enough light, it seems. What passes for normal room illumination might be sufficient for such adventurous undertakings as finding your way to the door or looking for the remote control for the television. For anything more demanding, you're going to have to add some more lighting, and probably lots of it.

At a minimum, you are going to want some *task lighting*, which helps illuminate the immediate area of your focus. In this case, where a small table is being used as a workbench, an articulated fluorescent lamp with a built-in magnifier will do a great job, at least until more lighting can be strung up. See Figure 5-7.

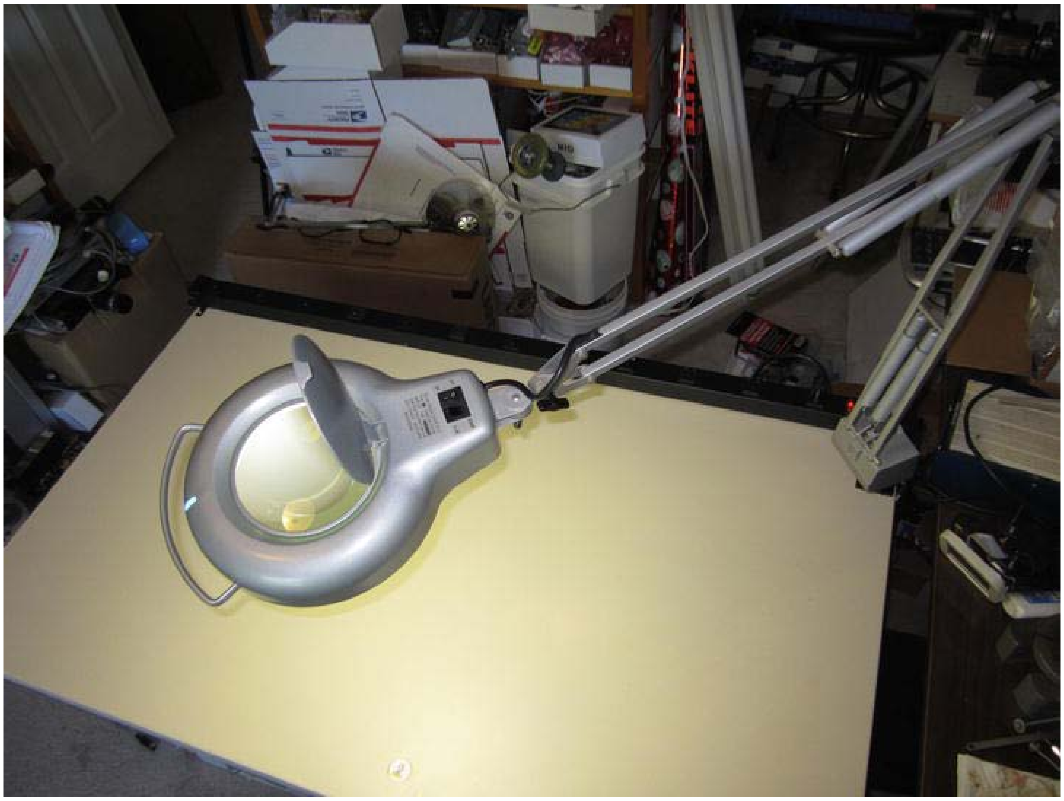

Figure 5-7. *You will need some task lighting for your bench. This desk lamp also includes a handy magnifier for really close work.*

Tools

Now we're ready to bring some of the tools back in to the lab. Here's where you get to decide which tools get a *permanent* home on the bench and which ones get put up and stored when not in use.

The permanently deployed tools on your workbench should be the ones that you find that you are using the most. The ones that get put up after every use are the ones that either only get used infrequently or pose some sort of hazard, such as sharp edges or hot surfaces. Again, you get to decide. It's your lab.

Tools for Soldering

An activity that is practiced frequently in many electronics labs is soldering. If you haven't learned how to solder yet, you are strongly encouraged to do so. Here's a handy setup for soldering, sitting in one corner of the newly refurbished workbench. See Figure 5-8.

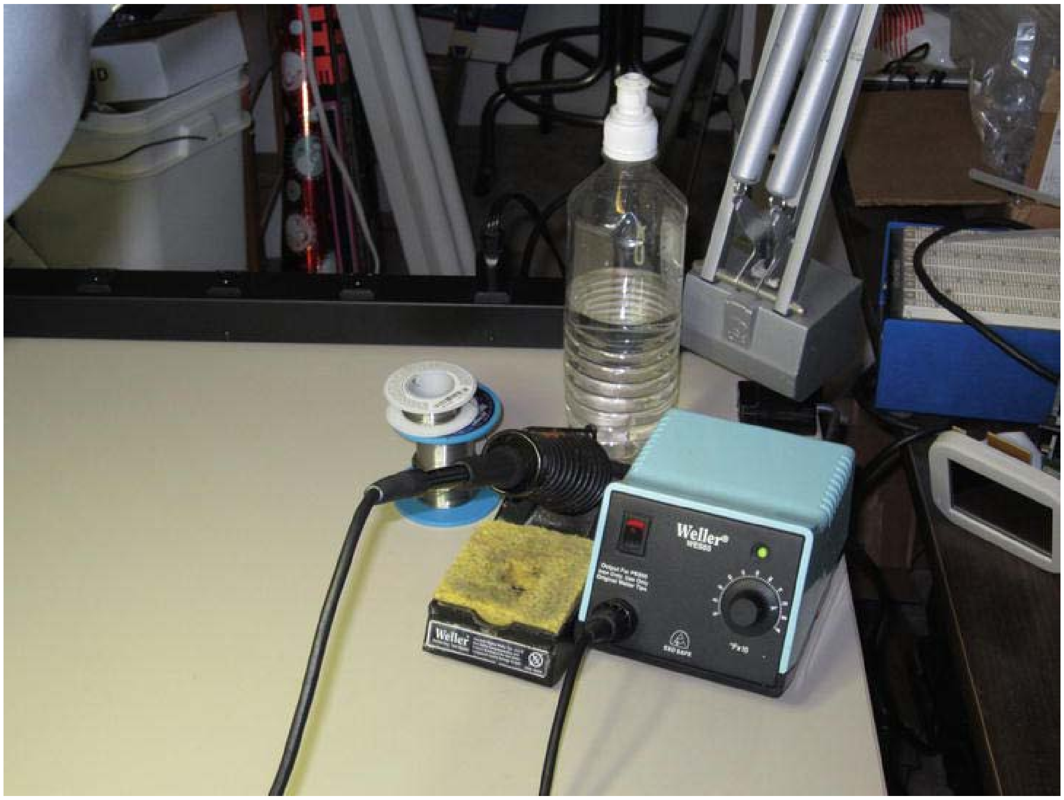

Figure 5-8. *A temperature-controlled soldering station with a stand for the soldering iron, a water bottle to wet the tip-wiping sponge, and some different kinds of solder. Some people prefer to have the soldering station nearer to the front edge of the table. Use whatever configuation makes the most sense in your lab.*

■ **Caution** Soldering irons are hot and can cause serious burns. Do not place a soldering iron where you might accidentally knock it off the work table or brush against it.

Hand Tools and Some Test Equipment

No matter what you work on at the bench, you will most likely discover the need for some common hand tools. When working with electronics, especially, you will often need wire cutters, wire strippers, and small pliers. These tools have been laid out conveniently (for a right-handed person) at the lower-right-hand side of the bench, while the less-often-used hand tools can reside in a box.

A regulated, adjustable bench power supply is also very handy when working with electronics of all kinds. A good, reliable multimeter can also claim a permanent home on the bench, as these will get a lot of use. See Figure 5-9.

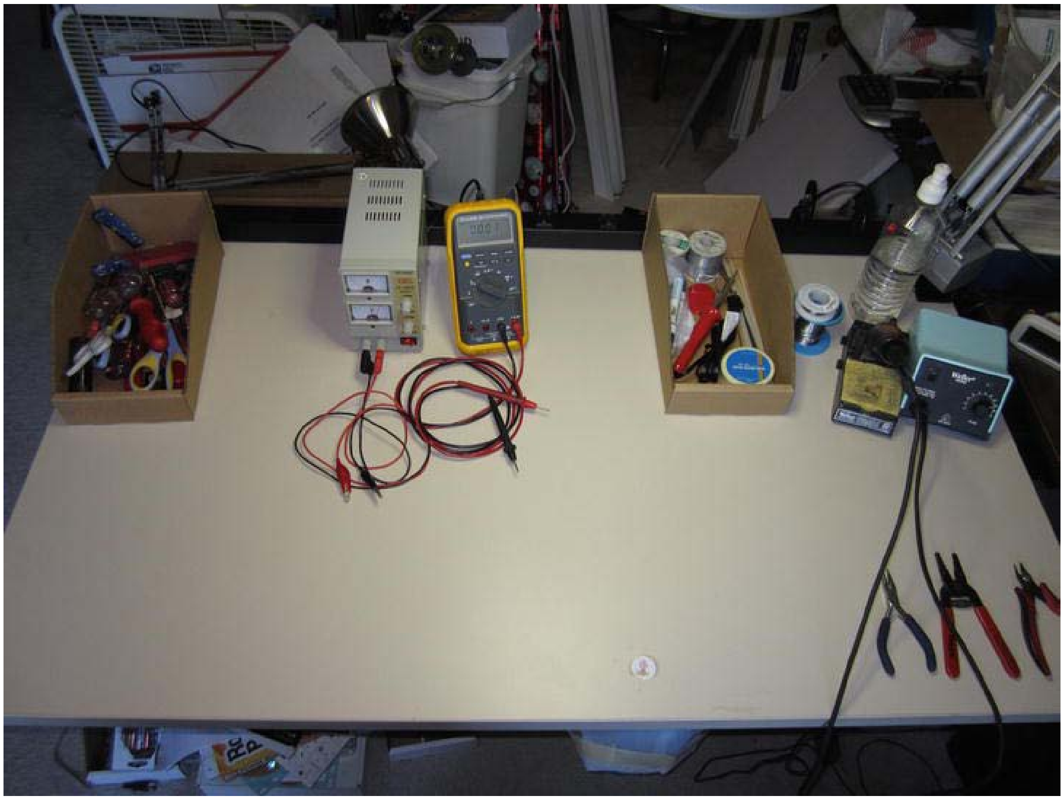

Figure 5-9. *A clean bench with just enough tools to have some fun. Extra soldering supplies, including more kinds of solder , extra soldering iron tips, soldering flux, and an emergency backup soldering iron, sit in a box adjacent to the soldering station. Hand tools and basic test-and-measurement equipment complete the set of "most-useful tools." There's still room for a few more, when you need them.*

Under the Desk

If your workbench has the luxury of drawers, by all means use them! Try to keep your under-desk environment as free of clutter as possible. It's not really a very convenient place to store unused tools or components. You're going to drop the occasional item from time to time, so having to dig out a bunch of junk just to find it is just going to be more frustrating for you. Keep it clean!

You *should* keep a medium-sized trash can under or near your work area, as you will inevitably generate some waste products in this hobby. By minimizing the amount of food-related garbage deposited in your laboratory trash receptacle, you can postpone the invasion of little critters looking for a free meal. Also, bits of wire and old components don't tend to stink after a few days, but a half-eaten sandwich might.

■ **Tip** Copper easily recycles at a premium price. Collect your copper wire snippings and cash them in someday.

A nice addition to the under-the-table accessories you might consider is some low-wattage strip lighting. LEDs are especially good for this. You will appreciate this more once you conduct your first search-and-rescue mission for that teensy-tiny component that dropped off the edge of your table and into the carpet.

Components

Most of our tools are now ready to go. The most frequently used tools are permanently set up, ready for action. The less frequently used tools are carefully stored where we can get to them when we need them, but are not in the way the rest of the time. This is a big improvement over the situation you saw back in Figure 5-1.

Now we need some components with which to work, using our scientifically arrayed tools. Have a look at Figure 5-10 to see one example of how to keep your parts organized yet within easy reach.

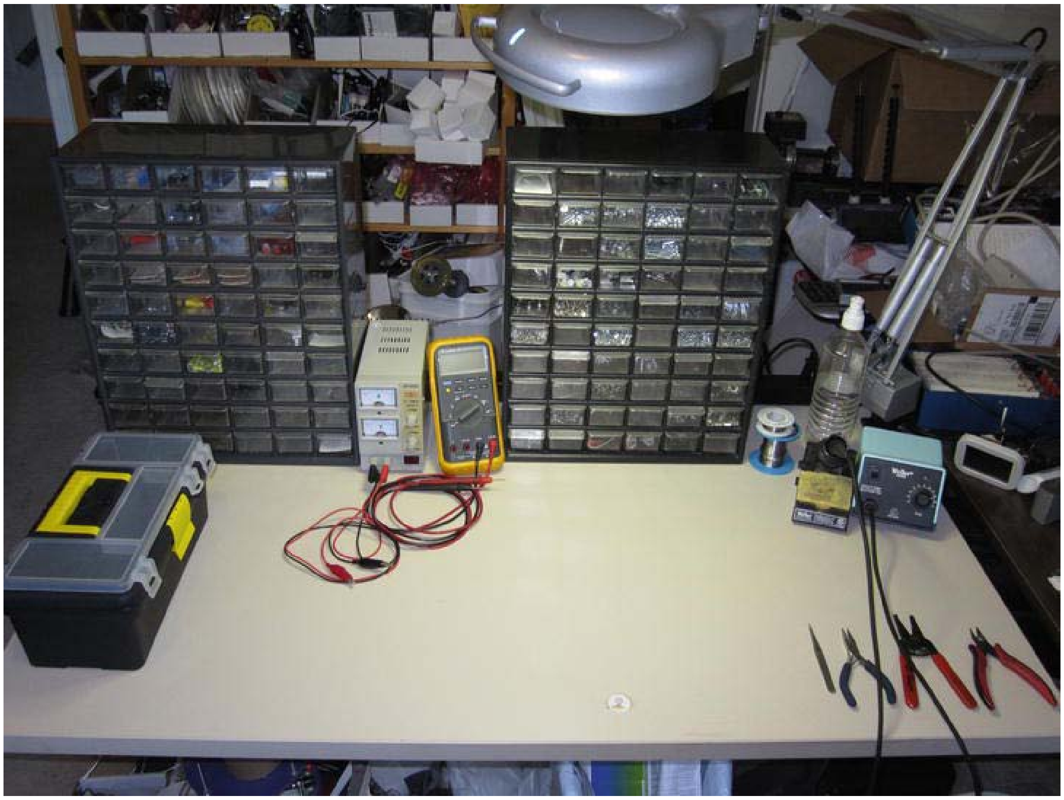

Figure 5-10. *Parts bins are used to organize components. This style of container is available in many sizes with different numbers and sizes of drawers. Even more parts are stored on a shelf behind the work area. The most commonly used hand tools are laid out on the right. The other hand tools are collected in a small toolbox on the left.*

Where to Go from Here

This work space could be further augmented with shelving, both above the work surface and underneath. More lighting wouldn't hurt, either. However, this is plenty to get started. Let's build some electronics projects on this squeaky-clean table and see if we can dirty it up a bit.

Projects

Let's look at a few smaller circuits you can easily build on your tidy, new work area using a solderless breadboard. Expanding on the LED-and-coin-cell experiments in Chapter 4, we'll add a few more components and hopefully start to see how they all interact.

There are any number of different types of solderless breadboards available today. A range of them is shown in Figure 5-11.

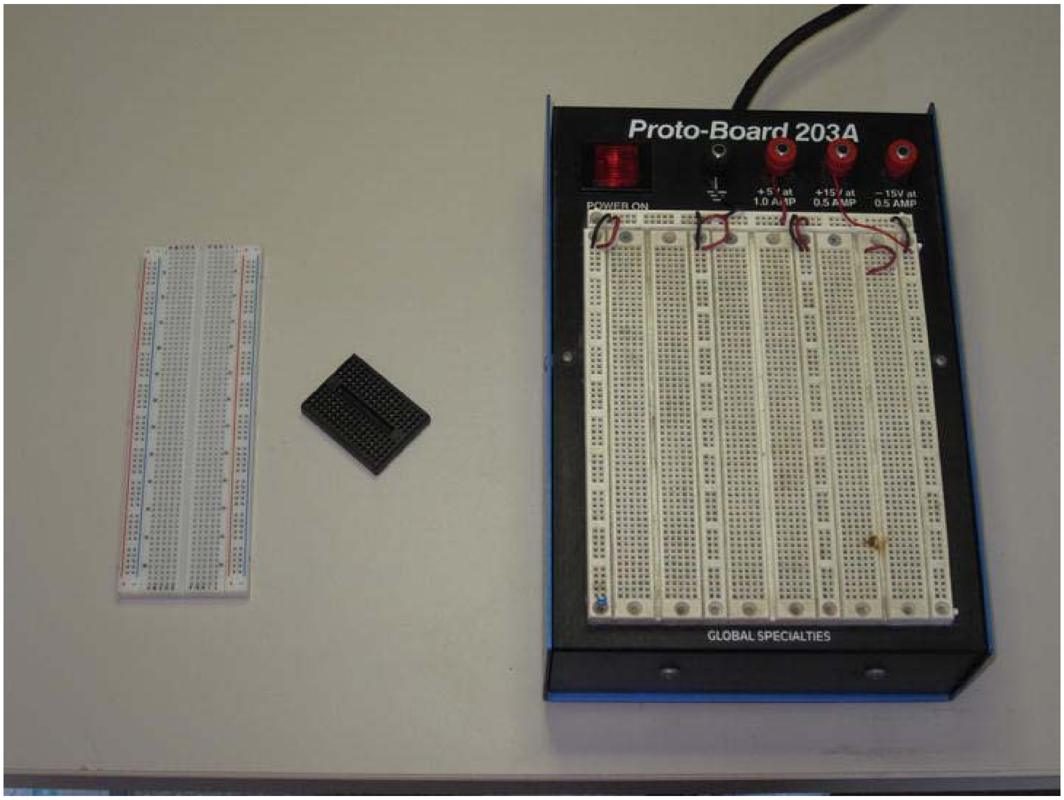

Figure 5-11. *Different sizes of solderless breadboards, all with the same lead pitch and internal connections. The small black unit in the center is perfect for little circuits with only a few small components. The white unit on the left has more tie points and offers power rails along each side. The deluxe, powered unit on the right adds even more space, as well as multiple regulated power supplies for all your tinkering requirements.*

Parallel and Series Circuits

The circuits presented so far have all illustrated the "loop" characteristic of electrical circuits. Electricity generally flows in a circle. It's possible to have more than one path through a circuit, however. What happens then?

Like most good questions, the answer is, "It depends." Let's hook up *two* LEDs at once and try to figure out exactly what's going on. Figure 5-12 shows how it's put together. See Figure 5-13 for the schematic diagram.

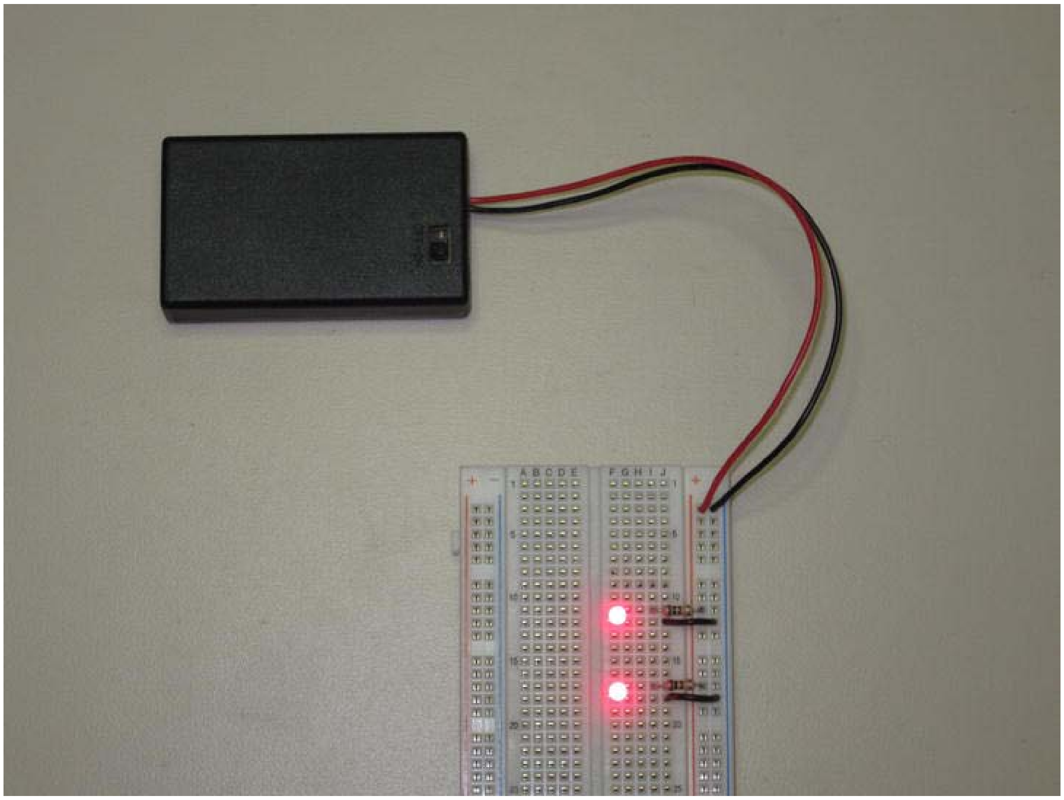

Figure 5-12. *Two LEDs are illuminated at the same time. This simple circuit demonstrates both parallel and series electrical circuits. A 3×AAA battery holder with an integrated power switch is used to provide power to the circuit.*

To build this circuit as shown, you will need the following components:

- A solderless breadboard with power rails
- A 3×AAA battery holder (which holds three AAA cells) and three fresh AAA cells—rechargeable cells are better
- Two LEDs (any visible color will do
- Two 100Ω 1/4W resistors
- Two short jumper wires

Using the letters printed on the breadboard to find the columns across the top and the numbers to find the rows, we can describe each of the tie points using a single letter and a number, such as A-1 or B-2. The following exercise shows how to put it all together.

ASSEMBLY INSTRUCTIONS

1. Install the top LED with its anode (longer lead) in tie point F-11 and the cathode in tie point F-12.
2. Insert one of the resistors from the red power rail on the right at row 11 across to tie point I-11.
3. Connect the right-hand blue power rail at row 12 to tie point J-12 using a short jumper wire.
4. Install another LED just below the top LED, with its anode in tie point F-17 and the cathode in F-18.
5. Install the other resistor from the right-hand power rail at row 17 across to tie point I-17.
6. Use another short jumper wire to connect the blue power rail on the right at row 18 to tie point J-18.
7. Install three fresh AAA cells into the battery holder.
8. Insert the red wire (positive) coming from the battery holder to the red power rail on the right at row 3 (the top).
9. Insert the black wire (negative) from the battery holder to the blue power rail on the right at row 3.
10. If your battery holder has a power switch, turn it on now.

The circuit is now complete. Please verify that both LEDs are illuminated, as shown in Figure 5-12.

Troubleshooting

If both LEDs are not shining at this point, you're going to have to do some troubleshooting.

- The first thing to do is double-check your wiring. Does your breadboard look like the one in Figure 5-12?
- Next, make sure you're using good batteries. If you have a voltmeter, you can test the batteries by measuring their voltage. New alkaline or carbon zinc cells should read 1.5V or more. Rechargeable nickel-cadmium (NiCd) or nickel–metal hydride (NiMH) batteries should read around 1.2V each when completely charged.
- Are the cells properly installed in the holder? Are they in the proper orientation and firmly seated?

- Is the power switch (if available) not in the On position? This happens more frequently than anyone would like to admit. Wiggle the switch back and forth and see if it's only making intermittent connection.
- Check the orientation of the LEDs. They will only work if installed in the correct orientation. It only takes a second to unplug them, swap them around, and try them the other way. At these low voltages, it won't hurt them to be installed backward.
- Are your resistors the right value? The 100Ω value is not critical. Anything from 100Ω to 1KΩ will do nicely. Don't use smaller values, as this will allow too much current to flow through the circuit, perhaps damaging the LEDs. How much current? We'll figure that out in just a bit. Larger-value resistors will decrease the amount of light emitted by the LEDs, down to the point where you can't see them anymore.
- Are you sure your LEDs emit visible light? Millions of infrared LEDs are manufactured every month for use in remote controls and night-vision gear. This light is not visible with the human eye, although some digital cameras can see it. Just because it looks like an LED doesn't mean it *is* an LED.

A Different View of the Same Thing

Your version of the circuit in Figure 5-12 might look a little different, and that's just fine. The important point is that both LEDs are lit up at the same time when you apply power.

Let's look at the traditional schematic for this circuit to get an idea of what's going on here. See Figure 5-13.

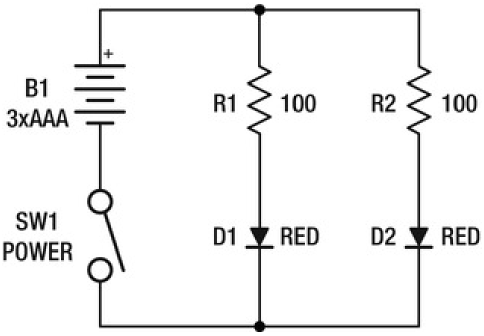

Figure 5-13. *The traditional schematic diagram of the two-LED circuit. This diagram should convey the very basic information needed to build the circuit, as well as understand the important aspects of how the circuit is supposed to work, without going into much detail at all about the actual implementation or assembly of the components.*

By now you should be able to look at the schematic and see the loop formed by the circuit. The only new twist is that there are *two* paths along which the electricity can flow, either through R1 and D1 (the top LED on the breadboard) or through R2 and D2 (the bottom LED, or the initials of a certain adorable robot from the movies).

The three AAA cells in the battery holder are shown as B1 in the diagram. The power switch, labeled SW1, is shown as a separate component to remind us that the circuit can easily be broken, halting the flow of electricity, which is something we want to happen from time to time. The connections between the two resistors and the two LEDs should be somewhat obvious. I'll discuss the details for the parallel and series connections momentarily.

Remember that an electronic schematic diagram is an abstract representation, boiled down to only the essential items involved and the relationships among them. As such, it doesn't need to resemble the final product, but it could. See Figure 5-14.

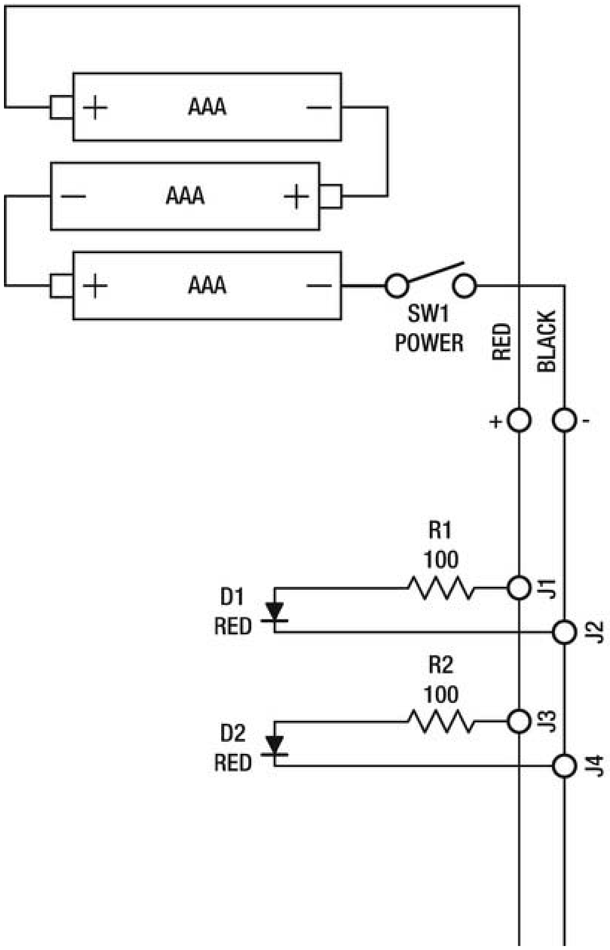

Figure 5-14. *Another schematic diagram of the two-LED circuit, showing the approximate physical layout of the components on the solderless breadboard. This style of schematic is often used when describing how to actually build a circuit, showing the constraints of the actual, physical components and the connections between them. It conveys more specific information than the previous example in Figure 5-13.*

Batteries in Series and Parallel

Let's look at the batteries first. Technically, as mentioned in Chapter 1, there is one *battery* in this circuit, and it happens to be composed of three *cells*. The term *battery* is very often used interchangeably with *cells*, and the distinction is minor. It's better to avoid confusion than it is to be exactly, precisely *correct*—usually.

We see three cells sitting side by side in both the schematic in Figure 5-14 and the actual battery holder shown in Figure 5-12. The cells are connected *in series*, meaning that one connects to another that connects to another, and so forth. They are like beads on a single wire. You should be able to trace the wiring (the solid lines) that connects the individual cells in the schematic.

Note the polarity of each of the cells within the battery. The positive terminal of the bottom-most cell is wired to the negative terminal of the center cell. The positive terminal of the center cell is connected to the negative terminal of the topmost cell.

The negative terminal of the bottom-most cell is connected to one side of an *SPST (single-pole, single-throw)* switch. The other side of the switch emerges from the battery holder's body as the black, or negative, lead from the battery pack. The positive terminal of the topmost cell connects directly to the red, or positive, lead coming out of the battery pack.

The switch could have just as easily been installed in the positive lead, and it would have worked exactly the same. The battery holder used in the photograph happens to switch the negative lead, as was revealed by examining the internal wiring using a multimeter as a continuity tester.

When the switch is *open* (i.e., in the Off position), the circle is broken and no electricity is going to flow. When the switch is *closed*, the circuit is complete and power is made available to the remainder of the LED circuit, assuming that it is wired up correctly.

The amount of *voltage* being supplied by the battery holder depends on the electrical characteristics of the individual cells. If alkaline batteries are used, each cell will provide 1.5V, assuming that the cells are relatively fresh. Rechargeable NiCd or NiMH cells will provide around 1.2V when fully charged.

When batteries like these are connected in series, the total voltage available is the sum of each of the cells. Just add all the voltages together. For example, using fresh alkaline batteries, the total voltage would be 3 × 1.5V = 4.5V. Rechargeable cells would provide 3 × 1.2V = 3.6V when fully charged.

If the cells were wired *in parallel*, with all of the positive terminals being connected together and all of the negative terminals wired together, the total output voltage would only be 1.5V for alkaline cells. The total output *current*, however, would be triple the capacity of each individual cell. See Figure 5-15 for a comparison of series, parallel, and combination circuits using batteries.

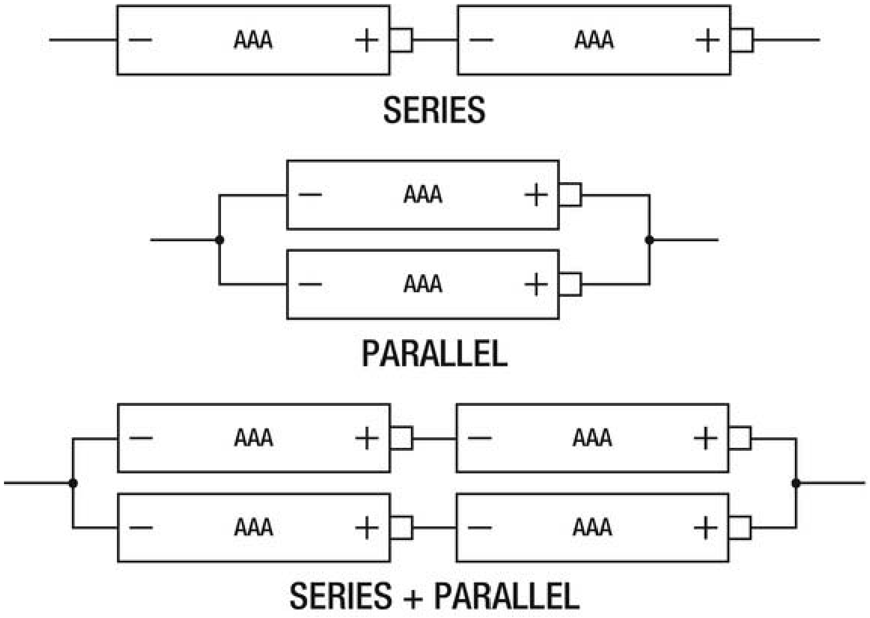

Figure 5-15. *Different arrangements of the wiring of the batteries produce different results. The top two cells are arranged in series. Their respective voltages are added together. The center circuit consists of two cells arranged in parallel. This configuration doubles the current that can be delivered. The bottom drawing shows a combination of both series and parallel circuits, doubling both the voltage and the current.*

When connected in series, the total current output is the same as the current capacity of each individual cell.

In summary, if you need more voltage, stack the cells end to end. If you need more current, stack them side by side. Even more complex arrangements are possible, using both parallel and series circuits to achieve the desired power output characteristics. This practice is very common in hobby model aircraft and battery-powered vehicles. A designation such as 3S2P means that there are two parallel circuits (2P) of three cells in series (3S).

Looking back at the circuit in Figures 5-13 and 5-14, we see that the "battery" used in this circuit consists of three cells in series. This means that if alkaline batteries of 1.5V each are used, the total voltage available to the circuit is 4.5V. If typical rechargeable cells (NiCd or NiMH) are used, we can expect 3.6V to flow through the circuit.

Switches in Series

The power switch, labeled SW1 in the schematic, is *in series* with the rest of the circuit. As mentioned in the previous section, when this switch is open, no current flows through the circuit at all. The switch is intentionally placed at this location in this circuit to act as a bottleneck. When the power switch is turned off, no power flows through the circuit. That seems like a good idea, considering the desired operational goal.

The schematic symbol for SW1 shows a pretty good likeness to the internal wiring of any simple SPST switch. There are two terminals, and a conductor that can be moved to either electrically connect them or electrically isolate them. As drawn, the switch is in the open position.

If we added another identical switch in series with the existing switch, what would happen? Take a look at Figure 5-16.

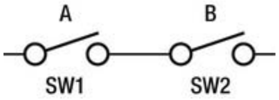

Figure 5-16. *Two switches in series. Both switches must be closed for electricity to flow through this part of the circuit. If either switch is open, the circuit is broken and no current will flow.*

Both switch A (SW1) and switch B (SW2) must be moved to the closed position for any electricity to flow through the circuit. If either switch is opened, then no current will flow. This is sometimes referred to as an *AND* circuit. Both A *and* B must be on for the circuit to operate.

A circuit just like this is often used in security systems. Switches are attached to doors and windows. All of the switches are wired in series, forming a large loop. The switches are all configured to be closed when the doors and windows are closed, and to open when doors or windows are opened.

If all the doors and windows are closed, then the loop of switches will allow the flow of electricity. Although it sounds exactly *backward*, when electricity is flowing in the circuit, this keeps the security alarm *turned off*. When any one of the switches is opened, the circuit is broken. The alarm then sounds.

Most real security systems are more complex than this, of course. The main advantage of this particular configuration is that it is easy to install and requires the least amount of wiring. The chief disadvantage is that when the alarm is triggered, you have no idea exactly *which switch* caused it.

Switches in Parallel

Just like with batteries, switches behave differently when configured in a different manner. Let's connect two switches *in parallel* this time and see what happens. See Figure 5-17.

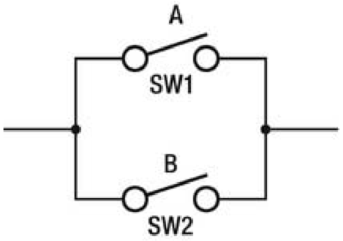

Figure 5-17. *Two SPST switches in parallel. If either one of the switches is closed, then power can flow through this part of the circuit. Both switches must be opened to stop the flow of current.*

The circuit in Figure 5-17 will conduct electricity if switch A (SW1) *or* switch B (SW2) are closed. To stop the flow of current, you have to open both switches. This can be used as a simple *OR* circuit. If switch A *or* switch B is closed, then power can flow through the circuit.

Looking back at the schematics in Figures 5-13 and 5-14, we see that SW1 is in series with the rest of the circuit. This makes it a very effective way to turn power on and off from a single location. Handy!

The Three-Way Switch

You might think that the circuit shown in Figure 5-17 could be used to turn lights on and off from two different locations. You would be partly correct. You could turn lights *on* from either switch location, since flipping either switch to On will cause current to flow and lights (or other appliances) to operate.

Unfortunately, you would not be able to turn *off* the light from either switch if the other switch were on. So this configuration is good for turning lights on but not off. A slightly more complex arrangement is required to do both.

We will need two switches, as before, but they will need to have a little more functionality to accomplish what we've set out to do. Instead of a switch that's either open or closed, we need a switch that alternates between two different routes, depending on how it is positioned. This type of switch is called a *double-throw* switch, as it connects a *common* terminal to either one of two different terminals. It can be *thrown* in two different directions. This should be much easier to understand when looking at a schematic symbol. See Figure 5-18.

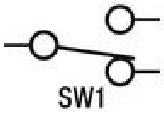

Figure 5-18. *A single-pole, double-throw (SPDT) switch. The common terminal on the left side is connected to either the top or bottom terminal on the right. Variations of this type of switch have a neutral position in the middle. Push-button (i.e., momentary contact) versions of this switch will label the two right-side terminals as either "normally open" or "normally closed," depending on the physical configuration of the switch.*

Now comes the clever bit. We'll connect a pair of these switches together by tying the two non-common terminals on one switch to their counterparts on the other switch. This results in four possible combinations of switch positions (both down, one up, the other up, and both up). Two possibilities turn the light on, and the other two turn the light off. The important point is that the "on" or "off" state of the entire circuit can be changed from either location, independently of the state of the other switch. Problem solved! Again, this should be easier to see when presented as a diagram. See Figure 5-19.

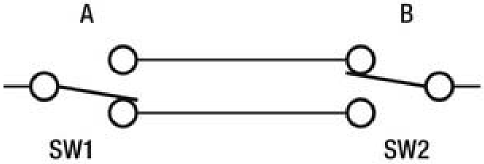

Figure 5-19. *A three-way switch circuit built using two SPDT switches. Power is either carried by the upper wire or the lower wire, as long as both switches are in the same position. If not, then no power flows across this part of the circuit. As shown, the three-way switch is effectively off. Flip either switch to turn it on.*

If you ask a real electrician how to wire a three-way switch, you'll get several answers, or more likely, you'll get, "It depends." That's because *it really does* depend on the actual wiring situation. Sometimes the power is routed through one or the other of the two switches, and sometimes the power is routed through the load. Each of these scenarios requires a different routing of wires and connections.

You are strongly advised to consult a real electrician concerning wiring in your house, where your family, pets, and all your stuff live. Less-than-perfect wiring causes fires or electrocution, which are both very unpleasant ways to die.

■ **Caution** This book does *not* teach you how to wire electricity in your home. Consult a professional.

Resistors in Series

Just like batteries and switches, resistors perform different functions in a circuit depending on their configuration. Let's look at using resistors *in series* first, and then consider using them in parallel later. Both combinations have their uses, as you will see.

Let's look at just a small part of the schematic that we've been working with so far in this chapter. See Figure 5-20.

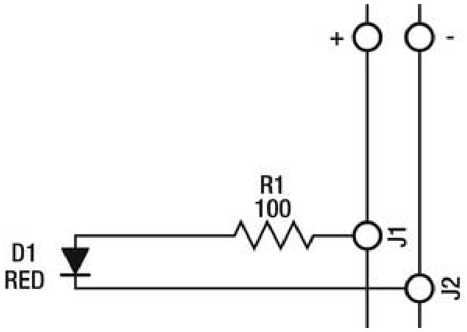

Figure 5-20. *One part of the circuit showing an LED, a resistor, and the power rails from our solderless breadboard. The resistor and LED are connected in series. The battery and power switch are not shown.*

LED Curiosities

D1 is an LED. It is a polarized component and will only work when installed in the proper orientation. The schematic indicates a red LED should be used, but feel free to use whatever color LED you like or happen to have available. The triangle shape of the schematic symbol helps remind us of the direction of *conventional current* through the device. The actual flow of electrons is the other way, but that's only because electrons are negatively charged particles and do everything backward. Apparently this was not well understood when electricity was first being tamed for our use.

LEDs are fascinating devices, emitting light in a wide range of colors, coming in an astounding array of shapes and sizes, and generally requiring very little power to operate. They are almost as easy to use as incandescent bulbs and are certainly more power efficient.

Being semiconductors, however (which leads to their being semimagical in their inner workings), LEDs generally only operate correctly within tightly bounded parameters. For example, a typical LED will only need between 2 and 3V to shine quite brightly. Incandescent lightbulbs, on the other hand, can operate from less than 1V to many hundreds of volts, depending on their construction and intended purpose.

While LEDs have a minimum *forward voltage* requirement that must be met for them to work at all, the brightness of an LED is determined solely by the amount of current flowing through it.

LEDs Have No Self-Control

In addition, LEDs have no internal, inherent mechanism to limit the amount of current flowing through them. Incandescent bulbs, when cold, have a low internal resistance, allowing much current to flow through them when connected to the right power supply. Remember that less resistance means more current can flow, and vice versa. This resistance almost instantly goes way up as the filament of the bulb glows white hot. The filament itself then becomes the limiting factor in how much current flows through the bulb, usually stabilizing at the proper power level.

LEDs have no such sense of self-control. They will conduct as much current though themselves as you are willing to provide, up to and beyond the point where the internal heat generated by the small amount of resistance they do possess causes them to literally burn up. In general, it's usually the tiny, almost microscopic internal bond wires that fizzle out, not the actual LED chip itself. However, dead is dead, and LEDs are generally considered to be "unrepairable" subassemblies. (Believe it or not, that's the correct technical term, even though it's not the correct English word—*irreparable* is the correct term when speaking of non-electrical things).

Care and Feeding of LEDs

The simplest possible solution to this ~~problem~~ opportunity for excellence is the use of a *current-limiting resistor* in series with the LED. Recall that a resistor will resist the flow of current in a circuit. The resistor used in this circuit, R1, is indicated to exhibit a resistance of 100Ω.

Let's say that D1, the red LED in our circuit, requires 2V in normal operation. This is pretty common for red LEDs. Generally speaking, the forward voltage requirement for LEDs goes up as you get farther up the color spectrum. Blue LEDs, for example, often require 3.0V to 3.6V to operate.

If we're using rechargeable cells in our prototype (and we really should be, you know), we can expect 3.6V to be made available to the resistor-plus-LED loop within our circuit. If 2V is needed for the LED, where are the rest of those volts going?

The answer is that they are being used to heat up the current-limiting resistor R1. Resistors turn current into heat. That's what they do. They do it, however, in a very precise and predictable way, which makes it easy for us to calculate how much current, voltage, and heat will be churning around in our circuits.

■ **Caution** Third-grade arithmetic ahead: Addition, subtraction, multiplication, and (shudder) division. You have been warned.

If we started with 3.6V, and two of those volts are being used by the LED, then our good friend Subtraction tells us that we've got 1.6V flowing through R1. For a thorough explanation of why this happens the way it does, feel free to look up Kirchhoff's Voltage Law. It basically says that all the voltages in a circuit end up being equal. The voltage across the resistor and LED will equal the battery voltage. The voltages within the LED-in-series-with-resistor circuit add up, just like battery voltages add up in series.

If we know the voltage across R1 (1.6V) and the resistance of R1 (100Ω), then we can use Ohm's Law to calculate the current flowing through R1. Reviewing what you learned in Chapter 3 about the predictable and inviolable relationships between voltage, resistance, and current, you can see that I = E / R (i.e., current equals voltage divided by resistance), where I is the current in amps, E is the voltage in volts. and R is the resistance in ohms.

It's not that hard! It sounds much worse than it actually is. The answer is 0.016A, or 16mA (1.6V/100Ω). That's the teeny-tiny amount of current needed to light up a typical red LED. Most small LEDs can handle up to 25mA safely, and some can handle much more than that, especially if they are intended for illumination purposes.

One quick side trip to multiplication land and we'll know everything we need to know about R1 in this circuit. While the schematic specified the resistance of R1 as 100Ω (the primary characteristic or component *value*), nothing was said about the power-handling capability of this component.

Power is calculated as voltage multiplied by current. That's all there is to it. We know the voltage: 1.6V. We know the current: 16mA. We multiply them together to get 0.0256W (watts), or almost 26mW. Remember that you have to enter the current as 0.016 because the formula calls for the number of *amps*, not milliamps.

Not quite 26mA is not quite much of anything. You will not be able to tell that the resistor is shedding all those extra volts as heat with your fingertip. It might not even register with a sensitive thermometer. It's just a really tiny amount of power. A typical small resistor (a 1/4W resistor) will handle 250mW of power, which is almost ten times what is needed in this application.

■ **Tip** It's always a good idea to calculate the power requirements of your components, just so you're not *too* surprised when the magic smoke leaves the circuit, rendering it crispy and nonfunctional.

OK, we're back from the frightening land of multiplication. It wasn't *that* bad was it? The remainder of understanding resistors in series depends only upon the science of addition. Counting on your fingers will be good enough.

We can change the brightness of the LED by changing the amount of current flowing through it. We can change the amount of current flowing through the LED by either raising the supply voltage or by changing the resistance of R1. Since we can easily substitute any other value of resistor for the 100Ω resistor with which we began, this is easy to do. Just don't go *too low* in resistor value, as this will allow *too much* current to flow through the LED, possibly damaging it permanently.

Adding resistors in series adds their resistances together. For example, if you placed two 100Ω resistors end to end, the total resistance across them would be 200Ω. That's really all there is to it: 100Ω + 100Ω = 200Ω.

If you perform this experiment with the LED circuit we built on the breadboard, you can see that the LED will not shine as brightly as it did before. This is because the resistance has doubled, which means, all other factors remaining the same, that the current through the LED has been cut in half. Half the current results in half the brightness, since LEDs are controlled by the amount of current flowing through them.

What's interesting about this arrangement is that the power-handling capacity of the two resistors is *also* double what it was when only one resistor was in the circuit. This is because each resistor is now dissipating half the power when compared with the previous scenario. If two 1/4W resistors are used in series, they can together safely dissipate up to 1/2W of power, although pushing any component to 100 percent of its capacity is just asking for trouble, especially when heat is concerned.

By connecting resistors end to end, you add their resistances together, as well as their power-handling capabilities. By keeping a small variety of basic values on hand (e.g., 1Ω, 10Ω, 100Ω, 1KΩ, 10KΩ, etc.), you can easily stack up the right combination needed for almost any electronic application. This is the method used in the very handy device known as a *decade resistor* or *decade box*, which has dials for each digit in the desired resistance, allowing you to dial up any value of resistor needed.

Extra credit: If you've followed along this far, consider researching voltage dividers built using only resistors.

Resistors in Parallel

What happens when resistors are connected side by side instead of end to end? That's where things get interesting, at least from a mathematical point of view.

An easy way to look at parallel resistors is to think about the amount of current flowing through each one, and then add them all up. See Figure 5-21.

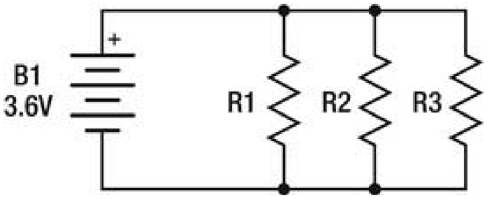

Figure 5-21. *Parallel resistors each conduct a portion of the total current flow through the circuit. Each resistor allows a certain amount of current to flow. The sum of their currents can be calculated if their individual resistances are known.*

Let's assume that R1, R2, and R3 have resistances of 100Ω, 200Ω, and 300Ω, respectively. The total resistance of the circuit across the battery terminals is *not* 600Ω, as would be the case if they were in series instead of parallel. The total resistance is less than 100Ω, which is the least of the resistors. How can this be?

First, let's think in terms of how much current is flowing in each of the three parallel pathways within this circuit. If B1 is putting out 3.6V, and R1 is 100Ω, then we know to use Ohm's Law to calculate the current, with I = E / R. In this case, I = 3.6V / 100Ω = 0.036A, or 36mA. *In addition*, the path through R2 is drawing half that (because R2 is double the value of R1—get it?), or 18 mA. *In addition*, the final pathway is drawing one-third as much current as the first one, or 12 mA. Just to verify: I = 3.6 / 300Ω = 0.012A, or 12mA. Everything checks out.

Now add all those currents together: 36mA + 18mA + 12mA = 66mA. That's the total current, using this method. Again, since we know both the voltage and the current, we can find the *effective* or *equivalent resistance* of all three resistors in parallel, as if they were one single resistor. Rearranging the formula for Ohm's Law, we find that R = E / I. In our case, R = 3.6 / 0.066A = ~54.55Ω. See? Smaller than 100Ω, somehow.

Thinking about the individual *currents* flowing through each resistor is the same as adding the current-supplying capacity of battery cells together when arrayed in parallel. Just add them together. However, we had to calculate each current separately and then add them together. There is a more direct way, depending upon how you look at things, but beware: it involves not only *fractions*, but *fractions upon fractions*. Oh, the horror.

■ **Note** Some people don't dig math. Weird, but true.

Here is the equation for calculating the total resistance (R_T) of three resistors in parallel (R_1, R_2, R_3):

$$R_T = \frac{1}{\left(\frac{1}{R_1}\right) + \left(\frac{1}{R_2}\right) + \left(\frac{1}{R_3}\right)}$$

The good thing about this equation is that you don't need to know what the supply voltage is to get the correct answer. All you need to know are the values of the resistors. If you need to use more resistors, just add more terms to the equation.

Calculating the value of parallel resistors occurs quite frequently when designing electronics. Some special cases are simple enough to do in your head. For example, if two identical-value resistors are placed in parallel, their combined resistance is half the value of each individual resistor. That is, if you placed two 100Ω ohm resistors in parallel, their effective resistance would be 50Ω. Similarly, if you have three identical resistors, the net resistance is one-third the value of each constituent resistor. Make sense? These are special cases of the general equation just shown.

This happens so much that an alternate notation method has been developed: $R_T = R_1|R_2|R_3$. This is not often used for hobby electronics, however.

The power-handling ratings of resistors are added together, so if you have two 10W resistors in parallel, the net power-handling capacity is now 20W. At least that part was easy.

Capacitors in Series and Parallel

Capacitors are completely different from resistors. When calculating their values in series and in parallel, you have to use *exactly the opposite* methods. Isn't electronics interesting?

The values of capacitors *in parallel* are added together. This makes them much more like batteries in parallel than resistors. However, you still have to use the fractions-upon-fractions method to calculate the value of capacitors in series.

Again, some shortcuts are available. Two identical capacitors in series have *half* the capacitance of each individual capacitor, but *double* the working voltage, which is the maximum voltage they were designed to withstand before failing.

Inductors in Series and Parallel

It gets more interesting, believe it or not. Inductors act like resistors as far as adding their values together in series and taking the reciprocal of the sum of the reciprocals of their values in parallel, but *only* when the magnetic fields of all of the inductors involved do not interfere with each other. If the magnetic fields generated when current flows though the inductors overlap, then you have to factor in their *mutual inductance*, which starts to get complicated.

Extra credit: Figure out how all that works and let me know.

LEDs in Series and Parallel

You learned (or were reminded of) a few of the basic characteristics of LEDs in the previous section, although it was really to help illustrate the operation of resistors in series and parallel. A couple of major oversimplifications were introduced to help concentrate on the resistor. We'll address a couple of these issues here.

Lighting up a single LED using a battery and a fixed current-limiting resistor is fun, but it's pretty basic stuff. Lighting up a *lot* of LEDs is where it gets to be a *lot* of fun. To do so, you need to learn a little more about the weirdness that is *semiconductor*.

LEDs are diodes (*LED* stands for *light-emitting diode*, after all). Diodes are semiconductors and are made by elves in a hollow tree. Semiconductors do not have nice linear voltage-to-current curves.

For the purposes of simplicity, in the previous section, it was suggested that LEDs have a certain minimum voltage that they need to operate. This is called their *forward voltage*, and is sometimes referred to as their *voltage drop* within a circuit. So far, this is all true. You can find an LED's forward voltage specification in the data sheet published by the manufacturer.

What you'll find, when you look, is that every manufacturer only publishes a *range* of voltages, such as 1.8V–2.2V, giving a minimum and a maximum voltage. This is what they are contractually obligated to deliver in their product. Anything outside of this range is considered *defective*, or at least out of tolerance. You might get a good deal on "rejects" that fall outside these parameters but still light up quite nicely. Such is the provenance of many of the penny LEDs available from overseas. Yes, they exist. And yes, you get what you pay for.

There are two reasons why LED manufacturers are being so deliberately vague in their specifications. The first is that process variations are going to produce a certain randomness to these values. One batch might be identical to the next batch, but then the third batch might be all over the place. Such things happen.

The second reason is where the real weirdness begins. Forward voltage is not a fixed value in any given device, but instead increases as the current increases. Again, this increase is *nonlinear* and cannot be calculated with a simple formula.

The best way to demonstrate this to yourself is to connect an LED to a power source via a variable resistor, such as a potentiometer. For the protection of your LED, add a fixed resistor in series with the potentiometer so that you establish a maximum current level, even when the potentiometer is turned all the way up (i.e., has almost zero resistance).

Now apply power and adjust the potentiometer until the LED just barely lights up. Now measure the voltage across the terminals of the LED, using a voltmeter. It should be in the neighborhood of 2V–3V. For extra credit, measure the current flowing *through* the LED, using an ammeter. This measurement will most likely be less than 1mA.

Compare these readings to what you find when the LED is at full brightness. The forward voltage across the LED goes up as the current goes up. To map the nonlinearity of this function, you would need to record many readings of both voltage and current, and then plot them in a graph.

Just as you can wire resistors, capacitors, and inductors in series and in parallel, you can do the same with LEDs. As with resistors, the forward voltage of the LEDs are added together when arranged in a series circuit. This raises the minimum voltage required to light up a string of LEDs in series. This means that you can't light up ten LEDs in a single string using a 9V battery. You have to first overcome the minimum forward voltage just to get any current at all flowing. Then you have to up the current to get the desired brightness, which simultaneously raises the total forward voltage through the circuit. You still need a current-limiting resistor in this circuit—but only one is needed. You don't have to have one for each LED.

The amount of current flowing through the string of LEDs is determined by the supply voltage, the cumulative forward voltage of all the LEDs, and the resistance of the current-limiting resistor. The same amount of current is flowing in every part of the circuit. If 25mA is being drawn from the power supply to light up your single string of LEDs, that means that each and every LED has 25mA of juice flowing through it—more than enough to light them up quite nicely.

If you have a 12V power supply (or a car battery), you could string up to five or maybe six red LEDs in series, with a small current-limiting resistor. That's because each red LED will typically have a forward voltage between 1.8V and 2.2V. Other colors higher up the rainbow might need more voltage per LED, meaning fewer can be lit at once using a single string of LEDs in series.

But don't fret. You can light up as many LEDs as you want by placing multiple strings of LEDs in parallel with each other. Each additional string of LEDs adds to the total current draw, so you will eventually find a limit along that dimension as well. For an example of a small LED array using both parallel and series circuits, see Figure 5-22. The schematic is shown in Figure 5-23.

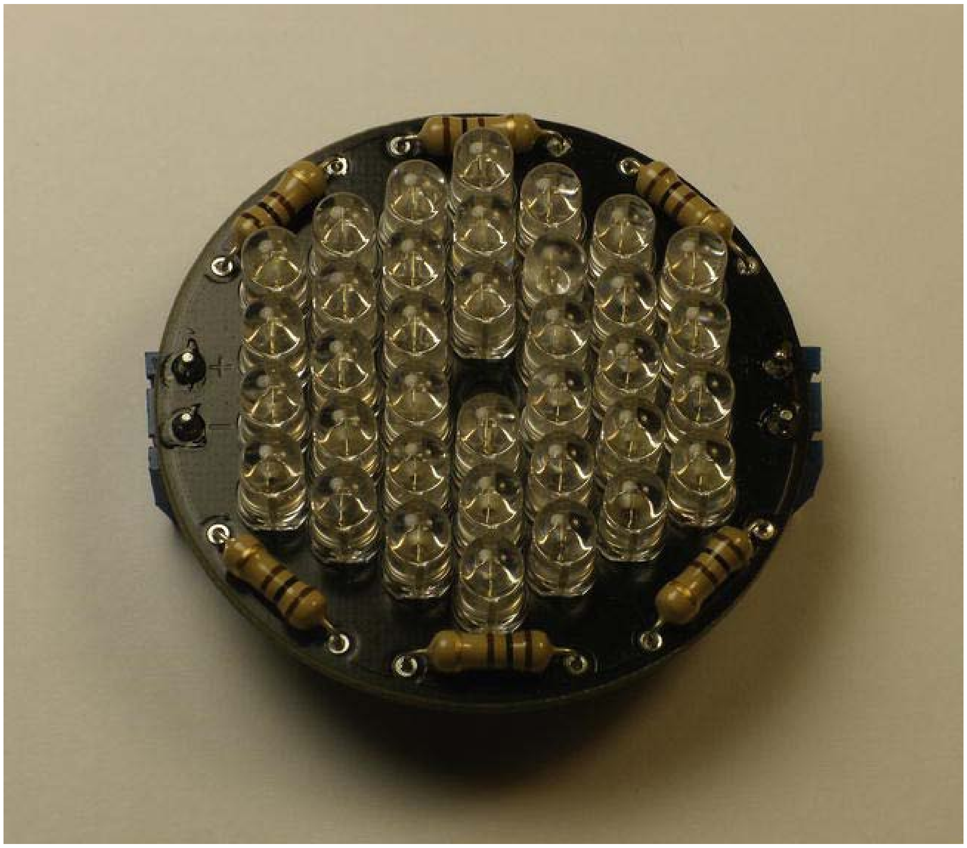

Figure 5-22. *An array of six parallel strings of six infrared LEDs in series. These infrared spotlights are used for covert surveillance and security applications.*

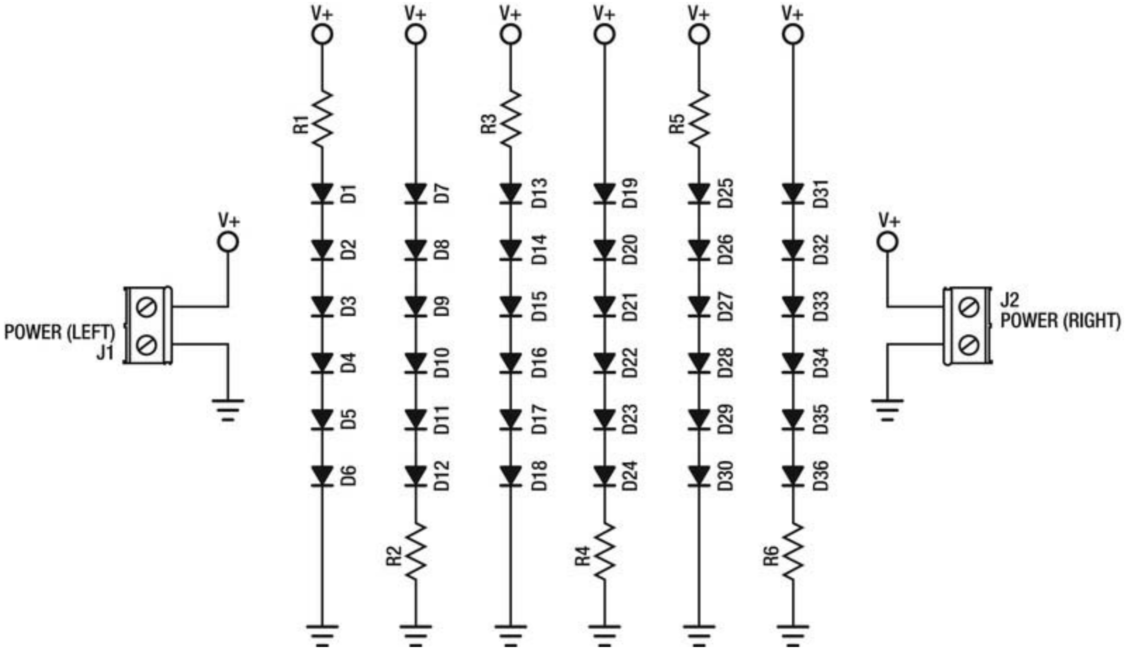

Figure 5-23. *The schematic of the LED array, showing both parallel and series circuits. The circuit offers two power connectors to make it easy to wire multiple LED arrays using the same power supply.*

Summary

Even if your workbench doesn't look as bad as the one presented at the beginning of this chapter (or even if it looks *worse*), hopefully you've learned a thing or two about the importance of they saying, "A place for everything and everything in its place." Since *you* get to decide where everything goes, you can either make it easy or hard on yourself as the years go by.

The workspace in this chapter extended to a total of 10 square feet. If this is what you have to work with, you can certainly set up a comfortable, safe, and productive area for your electronic projects. If you have even more space available (adding a shelf either above or below the desk is a great way to do this), then even better.

Hopefully some of the more detailed descriptions of how electronic components can be wired up have given you some ideas for projects of your own. The very best possible way to learn more about electronics is to think up some simple experiments and try to build them in your lab. Have a goal, take lots of notes, and have some fun—even your failures can be used as stepping stones to more ambitious and creative projects in the future.

Have a *lot* more room? Then perhaps you should be thinking about setting up a group lab or classroom. Chapter 6 will give you some helpful advice about what you are going to need to get started. See you there!

CHAPTER 6

The Small Group Lab and Classroom

The first part of this book covered what you need to know to build your own personal electronics lab. Now it's time to share the love with your fellow electronics enthusiasts. Where to begin?

Like most important questions, the answer remains, "It depends." What resources are available to you and your group? How many folks will likely want to be working together, and for how long? How well do you really know these people? And these are just a few of the questions you're going to encounter along the way.

Take the time to understand exactly who "you" (plural; in Texas, *y'all*) are and what your requirements and goals could be. By doing so, you map out the future of your successful facility. Likewise, *not* planning ahead or making reasonable assumptions about your needs is simply an invitation to problems, problems, and more problems. Who wants *more* problems?

■ **Tip** If you fail to plan, you plan to fail.

Know Yourself

The ancient Greek maxim "know thyself" has as many definitions as it has authors, it seems. Plato indicated in several of his dialogues that Socrates would use this phrase to admonish his students to learn more about themselves and their own characters and capabilities before attempting to figure out the rest of the universe. Wise advice then and now.

As far as knowing yourself in relation to setting up a shared electronics lab, you should first think about what role *you* are going to play in this endeavor. Yes, *you*. Here are some of the major ones, and you might end up being all of them at some point.

Facilitator or Coordinator

In the role of the facilitator, you plan on providing an environment for others to use for their projects and explorations in electronics. You may or may not partake in these activities yourself, but have been tasked with (or volunteered for) the organization and coordination of the lab.

It's critically important to understand the needs of your intended ~~lab monkeys~~ users. See the "Know Your Group" section later in the chapter for more information on this topic.

As the lab facilitator, lab workers will come to you with questions, requests, comments, and complaints. Be prepared to address their needs in a responsive and professional manner—even if they're just your cousin.

Your responsibilities will include

- Communicating the scope of the lab (i.e., deciding what *is* and what *is not* acceptable or expected)
- Publishing any important information or updates regarding location, available times, features, rules, and possibly ongoing projects
- Crafting policies involving safety, proper tool usage and training, and participant conduct
- Maintaining supplies of commonly used materials
- Inspecting and repairing tools as the need arises

To balance out your responsibilities, you should be granted adequate authority in the following areas:

- Characterizing the scope of the lab, based on present and anticipated future needs
- Enforcing the policies of the lab
- Budgetary discretion in acquiring, provisioning, and maintaining lab assets
- Granting or revoking access to the lab based on established parameters

If you're going to be the Keeper of the Lab, then you should have both a personal interest in keeping it in good shape as well as the wherewithal to decide how things should be done.

Good luck finding the right balance there.

Teacher or Presenter

Let's assume that your lab has already been set up (or can be set up in a jiffy), and your main goal is to present information or teach classes there. Again, it should be apparent that a good knowledge of your intended audience will play a vital part in your success. See the "Know Your Group" section for more information.

Once you understand the needs of your class and the goals of your presentation, the next step is to leverage the existing facilities to your best advantage. Will you need specialized presentation equipment or materials? If so, see what is already available, and then make a shopping list of everything else you will need. Examples include lighting, a projector, specialized power distribution, and test equipment.

Are you making an interactive presentation? If so, what materials will you need to provide for your students to be able to fully participate in your presentation?

What will be your optimum teacher-to-student ratio? If you have a simple message that's easily communicated and reinforced, a single speaker can effectively address a rather large crowd. Once you start adding layers of complexity to the subject matter, you're going to have to be prepared to backtrack and explain things in more detail from time to time. If you're leading a group through a technical exercise, it's often profitable to have assistants available to help just those individuals that need a little more help, without having to stop the class in its tracks. These assistants need to be up to speed on the subject matter as well as have good communication and troubleshooting skills.

Remember that students look to the teacher for leadership, not only as a subject-matter expert. Take the lead, set a good example, and share your enthusiasm for your topic with your students.

A successful teacher leads a class on a journey of discovery. Make sure you don't lose too many along the way.

Participant

Your goal as primarily a group lab participant is to make effective use of the facilities at hand, making the most of your time and energy. Having access to a well-stocked lab with a good array of tools can be a decided advantage for both your immediate project goals, and it can be an excellent opportunity to accelerate your knowledge of electronics and other mysterious arts.

Imagining yourself as an active participant is the best perspective when laying out the flow of your lab. Set up workstations that have almost everything you need, leaving room for the complex or specialized stuff elsewhere. There are more suggestions about specific workstation configurations in the "Workstations" section of this chapter.

While the active-participant model helps you squeeze out the maximum utilization of your lab, be sure to consider the sort-of-working-but-also-sort-of-goofing-off model. Not everyone wants to be working full-tilt all of the time. Leave room for a certain amount of idleness, contemplation, and whimsy. You might be surprised at the results.

Observer

You want to be in on the action, but not necessarily working on anything in particular. That's great! Don't underestimate the importance of the purely social aspects of technical gatherings.

Some people just like to hang out with other like-minded individuals. This is a good thing—when resources and circumstances allow it. Watching creative, talented, and driven folks working on projects with passion is very often the best kind of inspiration. Let your kids see you having fun and making cool stuff in your lab, and the next thing you know, they are going to want to be there whenever you are. Pretty soon, they are going to want to start working on projects of their own—and that is its own special reward.

Know Your Group

Now you know a little bit about who you are and what your expectations of your lab may be. Now it's time to get to know the group of people who will most benefit from access to the lab.

Identify the needs and requirements of your group by first identifying *precisely* who your intended audience is going to be. Knowing this one item, up front, before any big plans are laid, is the best way to ensure success down the road.

There are several broad categories for which you might need to prepare. The more you know about your particular group, the better. Let's start fairly close to home and expand outward.

Your Family

Once you've established your own electronics lab at home, it's great to be able to share some of the fun with those that are closest to you. This might be your children, parents, siblings, or extended family. A well-planned and well-maintained electronics lab is going to generate some interest, or at least some curiosity. Here's how you can carve out some room for them, while still being able to get things done yourself.

It's very natural to want to share your hobbies and interest with others, and a safe and well-stocked electronics lab is a great place to do so. This is an especially ripe opportunity for parents to pass on their knowledge, skills, values, and work ethic to the next generation.

The family lab can be a logical extension of the family home. Everything is shared, including responsibilities and privileges. In more agrarian societies, this is already well understood at an early age, where chores around the farm and in the fields and a respect for the tools being used help enhance a sense of group belonging and worth. Everyone has a stake in the prosperity of the family endeavor.

Do you want your kids to appreciate what you give them? Then give them chores before you give them presents. Let them clean up the lab, put away tools, inventory parts, and take out the trash before spoiling them with all the fun stuff you get to do in the lab. This will help foster a sense of ownership in the long-term success of the lab, whether you're there to supervise or not.

It bears repeating (from Chapter 4) that no unsupervised children, no matter how adorable, should be allowed in the lab. Would you allow unsupervised cooking in the kitchen? It's the same basic scenario. When everything goes well, everyone has a good time. It only takes a split-second distraction to go from a good time to a trip to the emergency room in either case. Have rules and enforce them, even if it's your elders that you are protecting by doing so.

Sometimes having a resource like a shared electronic laboratory is the first opportunity people have to assert some sort of control over their relationships. Use the opportunity to make friends with your relatives, while you still can.

Your Friends

Unlike your family, as the saying goes, you get to *pick* your friends. Now you have the opportunity to provide a cool place to hang out as well as build all manner of awesome gizmos. It's only natural to want to share some of the fun with your like-minded friends.

The basic framework of rules and accountability apply to the friendly lab as well as any other group endeavor. Let your friends know up front what your expectations of them are in regard to use of the lab. Can they use your tools? Can they store artwork-in-progress at your place? When is it cool to come over to tinker, and when is it not? These kinds of questions should be dealt with early in the game; otherwise, these issues can flare up and become trouble spots. There's no substitute for good communication.

Once you extend your laboratory's hospitality to those outside your immediate family, it's a good idea to clearly designate what is your personal property and what belongs to the lab and all its participants. This can be as simple as putting name tags on all your tools and marking shared resources appropriately.

This is where *trust* really factors into the success or failure of a group lab. Just like in math, you want to eliminate as many variables as possible to ensure that a good time is had by all, and to ensure the long-term safety and viability of the facility itself. Which of your friends do you *trust* in your lab? Think about these things at length before opening the doors to just anybody.

Coworkers and Fellow Students

So you've been tasked with organizing or supervising a lab for a school class or university department. You may or may not have any choice in who will be granted access, or even when they can avail themselves to the facilities.

The balance of responsibility and authority is crucial in this scenario, just like in most other situations in life. Hopefully you will be in a position to enforce whatever rules are already in place. Ideally, you will have some say in crafting new rules as they become necessary, or adjust existing rules when they need it. In either case, it's just not fair for someone to expect you to do a good job, yet not provide you the tools to get it done.

Positions like this become available from time to time in most schools. Sometimes there's an opportunity for a small paycheck, and other times all you are going to get are points with the administration. Hopefully, at least you will also enjoy lab privileges. That's got to be worth something, yes?

If you are helping to run an existing lab, there are probably others you can consult who have had this particular honor in the past. Try to find out who these folks might be and see if you can get any helpful advice from them about your lab and its care and feeding.

If you're starting from scratch, you will enjoy the double-edged sword of setting things up the way you want, as well as setting things up the way everyone else wants it. You *get* to establish whatever level of functionality you want, with the caveat that you then must maintain that level. It's a freedom, like most freedoms, that comes with a price.

Special-Interest Groups

Are you a member of club that has a special interest in electronics? Several popular interests, such as ham radio operators, remote-control model flyers or drivers, robot builders, and computer users, have a love-hate relationship with electronics. Having a dedicated electronics lab available to the membership is a great way to build up the love as well as work out the hate.

Given a highly specialized crowd, such as the members of a university or trade school, you might even find people organized into an electronics club, especially these days when almost every aspect of our lives is touched by this technology in one way or another.

The specialized nature of your group helps focus what areas of electronics are of most practical interest, at least from a lab point of view. This cascades into easier choices when it comes to stocking the lab with workstations, tools, and components.

The Dallas Personal Robotics Group (DPRG; see `http://dprg.org`), for example, had the use of an 1,800-square-foot warehouse for over six years, rent free, due to the generosity of one of the members, Mike Dodson of Modern Assemblies. Having access to an excellent industrial setting allowed the club members to dream of and then realize much more ambitious robot projects than could be attempted at home. After Mike's retirement, the DPRG went into a nomadic phase and finally spun off a dedicated workshop and meeting area, now called the Dallas Makerspace.

The General Public

A lot of people see the popularity of do-it-yourself (DIY) and *maker-movement* projects and envision themselves as entrepreneurs, seeing a need and being able to meet it. Unfortunately, most of these people are wrong.

Building a lab dedicated to public use sounds like a great and noble aim. The realities of such an undertaking, including the financial, logistical, and business related, are not to be underestimated. While it seems to work well in certain areas and at certain times, it's almost always the result of the right combination of people coming together at the right time.

Hackerspaces (a terribly unfortunately chosen label) are springing up all over the world. The term *hacker*, while understood within some technical communities to mean a person of respectable skills, has a decidedly *unrespectable* taint to it when viewed from the outside. To the vast majority of the English-speaking world, a hacker is a rogue computer jockey, a criminal intent on breaking and entering into computer systems for nefarious purposes.

The term *maker*, on the other hand, leaves a more positive first impression. The Dallas Makerspace members deliberately made this decision when naming themselves, while they were still just a subcommittee within the board of directors of the nomadic DPRG, looking for a new home. It was important to them to maintain the very positive image that the DPRG had established and built over its long history, while still looking to the future.

If you're going to set up a lab for use by the general public, whether you decide to call it a hackerspace, a makerspace, or something entirely different, you get to make almost *no* assumptions about the good intentions of your membership. It's a sad state of affairs, to be sure, but it seems to be the prevailing wisdom of the day.

Some popular and successful organizations—such as Noisebridge (`www.noisebridge.net`), in San Francisco, California, which was incorporated in the state as a "non-profit educational corporation for public benefit"—operate almost entirely on a "consensus basis," sometimes known as "anarchic chaos." Noisebridge's overriding motto is "Be excellent to each other," very often shortened to just "Be excellent." Its very real success and sense of community among members is based on what seems to be a very local tolerance that is not to be found in many parts of the globe. If you ever get a chance, do stop by and prepare to be impressed. It's an amazing place.

A good parallel would be to visit your local public library. In the areas that still maintain libraries (shockingly, they are on the decline), you will find a finely tuned machine that meshes well with the surrounding locality. Are there bars on the windows? If so, you're going to need some bars on your windows. Are there metal detectors at the entrance? Oh, dear. Do you see any uniformed security forces present? These are not good signs.

Don't be completely discouraged, however. Sometimes a community in decline needs a little boost of energy and an injection of esprit de corps. This can often be accomplished by introducing some new alternatives for people's spare time. An ancient Muslim saying reads, "Trust in Allah, but tie your camel."

A Shared Resource

Do you have a dedicated space available? If so, you are way ahead of the game. Finding a good location is half the battle. If your space is truly dedicated to your pursuits and activities (i.e., a private home, club, or makerspace), you have the advantage of being able to leave tools, components, and projects in place, returning to them (and finding them still there!) when the opportunity arises. "Truly dedicated" in this sense can be equated with having your own key to the door and reasonably free access. While a 24-hour facility sounds like a great idea, there are a lot of logistical problems associated, such as security, utility costs, scheduling, and parking, just to name a few.

If your space is not-so-dedicated, such as a school lab or friend's garage, you can still make it a home away from home if you are able to arrange for secure storage of all your shiny toys. This could take the form of individual lockers or a storage closet.

No matter what the logistical arrangements, the main challenge to providing a versatile and effective setting for electronic and other kinds of tinkers is basically a social one. Once it's more than just you, it can start to get complicated.

Luckily, there are some time-tested methods for making these types of things run smoothly.

Be a Hospitable Host

If you are taking the lead in arranging a shared work space, please remember that you are responsible for extending the appropriate hospitality to your present and future guests. This single factor will greatly determine the vibe, feeling, or ambiance of the facility, even more than having the latest and greatest tools and gizmos on hand.

This task may or may not fall entirely on your shoulders. Many hands make light work. If you are able to delegate some of the duties of a hospitable host to other members of your group, consider doing so.

Think of your task in the same light as planning a successful party, even if it's one that you anticipate will last for days on end. These basic ideas are as old as civilized living. Think about fabulous parties or memorable events that you have been privileged to attend in the past, and then plan on taking it up a notch.

Try to anticipate the human needs of your attendees as well as their technological expectations. People have what seems like an endless list of requirements, some of which you can address, some not.

Make your location known. Make this information easy to find to those interested, and easy to update when the venue changes. A web site is trivial to set up these days, and even a post to a popular forum will tend to be accessible via Internet search engines, in time. There's a new social media outlet popping up every third Tuesday, so avail yourself to what makes sense for your audience. Word of mouth only goes so far these days.

Once you've gone to the trouble of publishing your location, go the extra mile and put out some sort of actual sign or indicator that your arriving guests have found the right spot. If you have an identifiable logo or symbol associated with your group, be sure to proudly wave that flag. People don't like feeling lost, or unsure whether they're entering a welcoming space or about to trespass on private property.

Let everyone know when they are expected as well as when they are *not* expected. Post your regular meeting times, if you have them. Alternatively, make known the appropriate hours of operation. It's disappointing to be turned away at the door just because it's 1:00 a.m. on a school night.

When possible, welcome your guests. This makes a big impression on both newcomers as well as the regulars. Being part of a group is supposed to *enhance* a feeling of inclusiveness and belonging. We are social animals at heart, and even a simple hello is often the prelude to an interesting and productive time together.

Have rules. Make these rules known. A sign on the front door is not out of place, as long as it's not too negative or off-putting. Rules should *prevent* problems from occurring, and not be enacted as a spontaneous reaction when problems inevitably occur.

Ensure your guests' comfort when attending. Is there enough room for the largest (and the smallest) participant to safely enter and exit the facilities? Is there adequate lighting in the common areas, if they exist? Is there a place for everyone to sit? Who has dominion over the thermostat?

Do you plan on making refreshments available? Will this duty rotate among the membership? Keep track of such things, if only to keep from overextending yourself in all the myriad details of hosting a successful meeting. While massive banqueting and consumption of yummies make for a festive and enjoyable association, these activities are not always aligned with maintaining an effective laboratory. Separate the feeding trough from the work areas. Stay focused on what you're trying to accomplish here.

Will everyone have access to restrooms, and whose job is it to keep these areas tidy?

And the most important question of all: Who takes out the trash?

Be a Courteous Guest

Just as it's important to play the role of the hospitable host, it is likewise critical to be a courteous guest when visiting a facility, whether you are a paid-up member in good standing or an invited guest. Again, these guidelines will vary according to the intents and purposes of your lab, but the basics will always remain the same.

If possible, and when appropriate, let your host know if you are planning on attending. This won't apply in a causal, drop-in type of laboratory. Even so, by making your intentions of attending known ahead of time, you might influence (one way or the other) the attendance of other potential participants. Nothing succeeds like success. A well-attended party has a better potential for awesomeness than a sparsely peopled event.

Arrive on time or within the established time frames set forth by your host. Similarly, unless you have been granted special access, plan on leaving at a reasonable time as well. Benjamin Franklin wrote in his *Poor Richard's Almanack* (1736) that "Fish & Visitors stink in 3 days." Don't be a stinker.

Try to contribute something. Don't show up empty-handed, expecting to be fed, entertained, and enlightened.

Workstations

Now it's time to talk about your workstations. Even if it's just you in the lab, having a separate workstation for each type of activity is a great idea. For example, you might have one workstation set up for programming a computer, another for soldering electronics, and another for working with power tools, such as a drill press or a saw.

Workstations dedicated to a particular task should have everything within easy reach, including tooling, supplies, power, and lighting. Don't waste time by forcing people to wander around the lab looking for the right drill bit or magnifying glass. Keep everything close so you can find what you need, when you need it.

Having a place for everything ahead of time is the best way to follow the wise adage, "A place for everything and everything in its place." You get to decide where everything lives. It doesn't hurt to go ahead and label everything conspicuously so that others can find their way around the lab.

If you have several people wanting to work on the same kinds of projects at the same time, you're going to need multiple, nearly identical workstations. The exact number depends on your available space and the number of people you expect to want to participate simultaneously, as well as your budget.

Most indoor-oriented work can often be performed at a work table. Exceptions include giant-scale mechatronics, pyrotechnics, and underwater robotics. Some of their constituent bits and pieces, however, can be crafted on an adequately prepared work table.

Make sure each work area has plenty of power outlets available. You're almost guaranteed to run short at some point. Take care not to overload your circuits, however. If you anticipate needing a lot more power than is presently provisioned, you're going to have to consider the real possibility of having your facility expanded by qualified, *licensed* professionals. These requirements will vary from one location to the next. Check with your local building codes to be sure.

As repeated often in previous chapters, you can never have *too much* lighting available, especially for the more detail-oriented chores. Typical indoor room lighting is just about adequate for finding your way out of the room, and that's about all. You'll need area lighting for each workstation, and possible additional task lighting, depending on your particular requirements.

Providing network access to each workstation can be challenging. Wireless networking is a good way to accommodate a relatively small number of users at once. More than a handful of computers trying to access the Internet at the same time can bring many wireless routers to a slow crawl. Dedicated high-speed Ethernet connectivity is more expensive and takes more effort to deploy, but offers much greater bandwidth to your lab-folk.

If you're especially cramped (or *dimensionally constrained*) in your lab, you'll need to get inventive. For example, a table placed in the center of the room can be approached from multiple sides. There's no reason all the workbenches have to be pushed up against a wall, allowing access from only a single side. Get creative!

Safety Planning

While it's tempting to fill up all the available space in a lab with workstations, especially when the budget permits it, do try to leave a bit of common area here and there. You always want to be able to walk *away* from a workstation with the same (or sometimes even more) rapidity you approached it with. Fire is an excellent example of such a motivator.

■ **Tip** Keep a properly selected and maintained fire extinguisher at each workstation, if possible.

Post emergency procedures prominently, where everyone, including visitors, can see. Have an evacuation plan, complete with map and "You are here" indicator posted at each workstation. Hopefully you will never need it.

Presentations

Are you excited about your latest project? Have you just learned a great new skill? Setting up your lab for group presentations is an excellent way to communicate these ideas to your friends, family, and coworkers.

Make your ~~victims~~ guests comfortable. Have adequate seating for everyone, with plenty of room between the rows (if you have more than one row of chairs). Ensure that everyone has a good view of what you intend to present.

Will the attendees be expected to take notes? Then perhaps you should set up tables where they can comfortably jot down some of the more spectacular aspects of your presentation. If you will be providing a handout or other documentation packages, make sure you have enough for the anticipated demand. Will you be entertaining questions or comments either during the presentation or afterward? Then make sure that not only can your audience see *you*, but that *you* can see *them*.

If you're going to be using some sort of projector for your presentation, by all means set aside some time to get to know the equipment ahead of time. Nothing ever seems to work just exactly as you imagined that it should. This seems to be an invariant law of presentation physics. No one is really sure why.

Your audience's time is just as valuable as your own. In fact, if there are only two people attending, then their collective time is worth approximately *twice* as much as yours. Think about it. Have all your ducks in a row, so to speak. Wasting time figuring out which cable goes where is not a good use of your time together.

Summary

Wow! You can really go crazy setting up a shared electronics lab, can't you?

Before you even flip on the light in your shiny new group lab, you should already have an insightful idea of who is going to be using it and why. You should also have some honest expectations of what your own expectations are going to be, and how you would like to interact with both the lab itself and its population.

The details, of course, are always going to be specific to your particular situation. Be on guard, however, for the future. It's going to sneak up on you, someday. Not too long ago, for example, it took a fairly hefty desk to keep a modern personal computer up off the floor. That kind of computing power now fits in a pocket. Think of what better uses you could dream up for that space these days!

That kind of forward thinking is exactly what turns the dreams of today into the reality of tomorrow. It's forward-thinking people like you, dear reader, that help map out those realities. Take the opportunity you have right now to spend some quality time daydreaming about how things *could* be. Then take those steps necessary to make it happen. Your family, your society, and your world expect great things from you. You can do it!

APPENDIX A

Getting Started with Tool Building

Once you've become comfortable in your lab and have had time to play with a few circuits, you might start to notice that some of the "tools" you've been using are just simple electronic circuits themselves. Good examples are power supplies and meters. These are great tool-building projects because you can see useful results early.

Let's take a look at building a couple of simple electronic tools that might be of use in your lab. Hopefully you will develop a better understanding of how these tools work. Ideally, you will progress from the basic question of "Does it work?" to the more involved questions of "How well does it work and what can I do to improve it?"

Please bear in mind that these exercises, while hopefully useful, are to illustrate what needs to go into the building of practical, reliable tools. At every stage you should be thinking about what design choices you have and which choices will enhance the usefulness of your tool-building process.

A Very Simple Power Supply

Almost all electronic projects need electricity to work. Having a good, dependable power supply at your disposal on your bench will get you started faster on new projects. You won't have to worry about dead batteries and flaky power adapters. See Figure A-1.

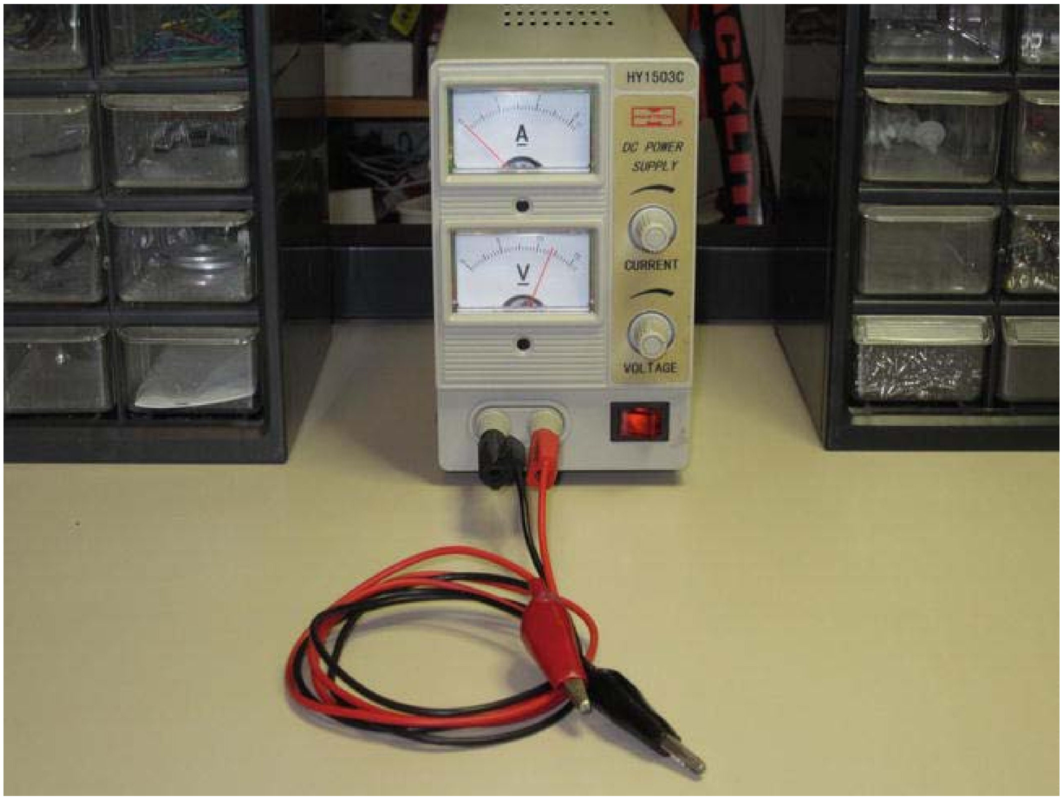

Figure A-1. *A professional bench power supply. This device allows both the voltage and the maximum current to be adjusted. It provides two dedicated meters to show how much power is flowing: one for voltage and the other for current. It also provides a modular set of plugs (banana plugs) for easily connecting and disconnecting power leads.*

A bench power supply such as the one shown in Figure A-1 has many features and includes extra circuitry to make it safe and easy to use. It will also set you back a good chunk of change (i.e., cost money). We're going to build something a bit simpler to start. Feel free to add more bells and whistles as your needs arise.

■ **Caution** Anything plugged into the wall has the potential to shock, burn, or kill you. Do not defeat their safety features!

An Easy 2.5 Watts

You probably have a spare USB charger lying around somewhere. If you don't already, you more than likely will at some point in the near future, as these are becoming more common with smaller electronic devices. If not, you can obtain one relatively cheaply if you do some smart shopping. The USB charger shown in Figure A-2 was obtained from overseas via eBay for less than $1. You will also need a USB cable about 3 or 4 feet long. Again, don't spend a lot of money on a new cable. If you don't already have one floating around in a drawer somewhere, you probably know someone that does.

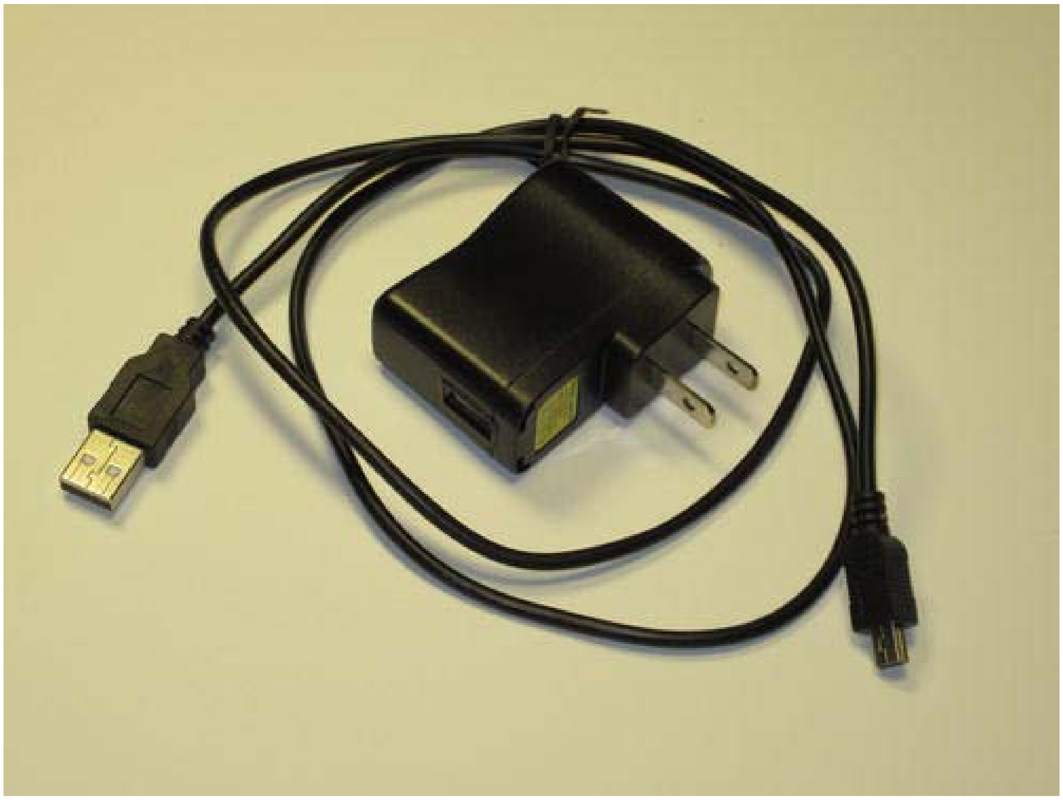

Figure A-2. *A USB charger that plugs into the wall and provides a regulated +5V supply. This plug is intended for US wiring, but will operate from 110AC to 240VAC at 50 or 60Hz, which pretty much covers the whole world, if you have the right adapter plug.*

It doesn't matter what type of USB cable you find, because we're going to cut off the smaller end and use the bare wires inside the cable. It just has to have the USB A–style plug shown on the left side of Figure A-2. The plug will fit into the socket of the charger. You do not need to open or modify the USB charger at all, and you are seriously advised not to do so for any reason.

Let's take a closer look at the label on the charger to find out exactly what it's supposed to be doing for us. See Figure A-3.

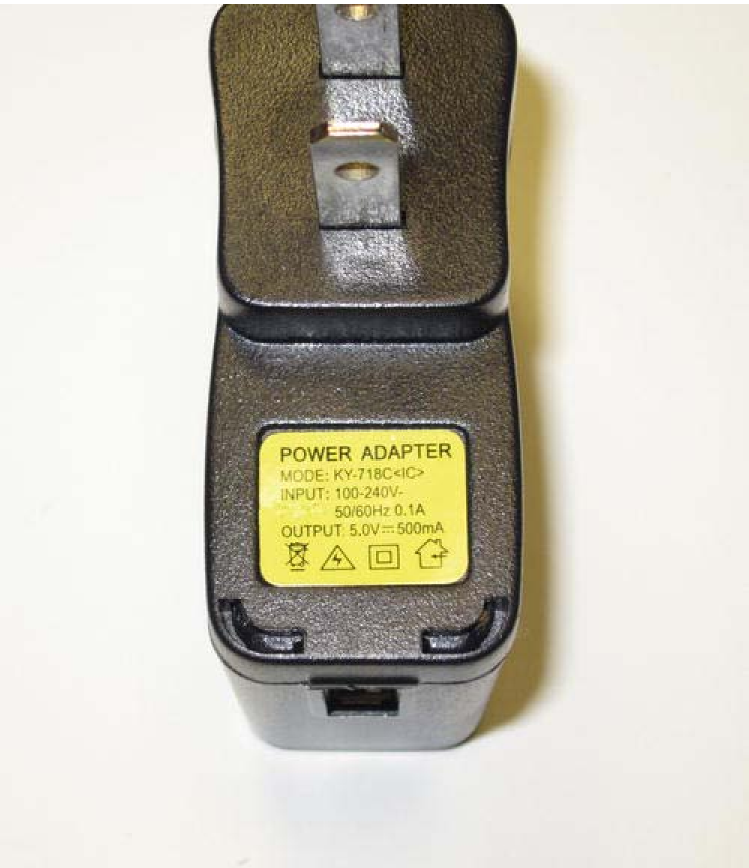

Figure A-3. *The label of the USB charger tells us that it accepts anything from 110VAC to 240VAC at either 50Hz or 60Hz. This wide range of input power allows the same internal electronic design to be used worldwide. Only the prongs that plug into the wall vary from location to location. The label also tells us that the USB charger will output +5V at up to 500mA. That's 2.5W!*

The "OUTPUT: 5.0V ⎓ 500mA" marking tells us what we need to know about the flavor of the power coming out of the adapter. The "5.0V" is the measure of the voltage. This is a very useful voltage level for small projects. Many digital chips require a 5V supply, although 3.3V is also becoming quite popular.

The ⎓ symbol represents *direct current (DC)* voltage. The symbol for *AC (alternating current)* voltage is the tilde, or wavy line symbol ~. The "500mA" is the maximum current that can be supplied by this charger (500 milliamps, or 0.5A), although you are cautioned not to expect a low-cost item such as this one to produce 100 percent of its rated power 100 percent of the time.

While this USB charger will most likely work for our intended purposes, it's best to keep those expectations in check. Note that "Model:" is misspelled ("Mode:"); and also note the absence of the magic letters *USB* or the USB logo. Also, there is a complete lack of any safety certifications present on this humble device, as befits its ~~cheap~~ economically optimized provenance. Compare this with the veritable constellation of safety certifications on the name-brand laptop charger shown in Figure A-4.

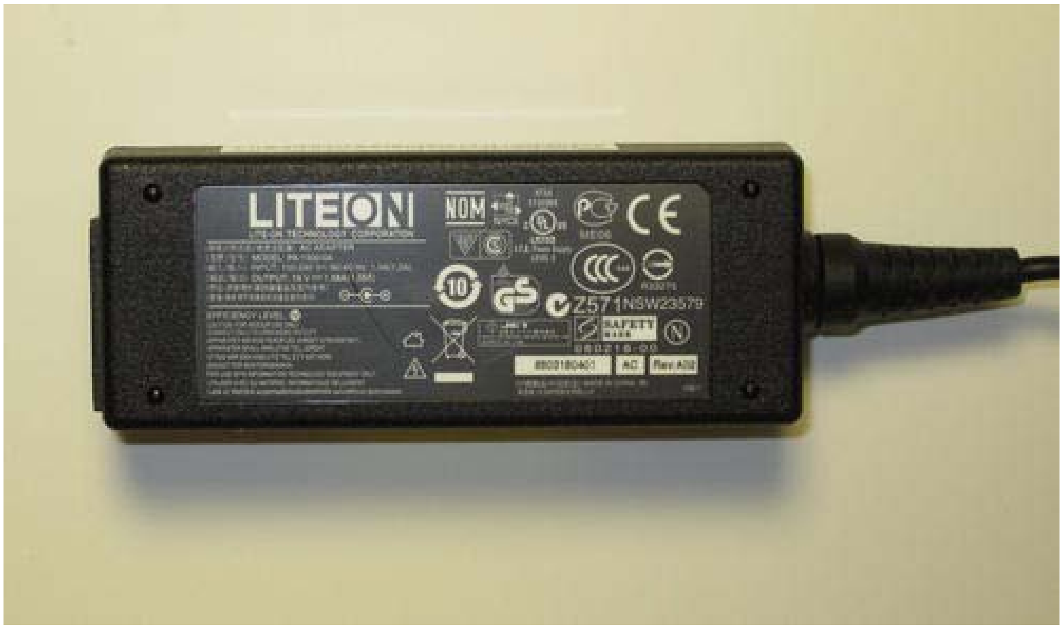

Figure A-4. *A name-brand laptop charger with several international safety certifications. Every one of these certifications costs money to obtain, and shows that the device was demonstrated to be safe for use in a typical home or business application.*

Next we adapt the USB cable to our needs. In the words of the Red Queen, “Off with his head!”

■ **Caution** Make sure the USB charger is not plugged into the wall or a power strip when making modifications to the cable.

First, plug the USB cable into the USB charger. Now cut off the *other* end of the cable. See Figure A-5.

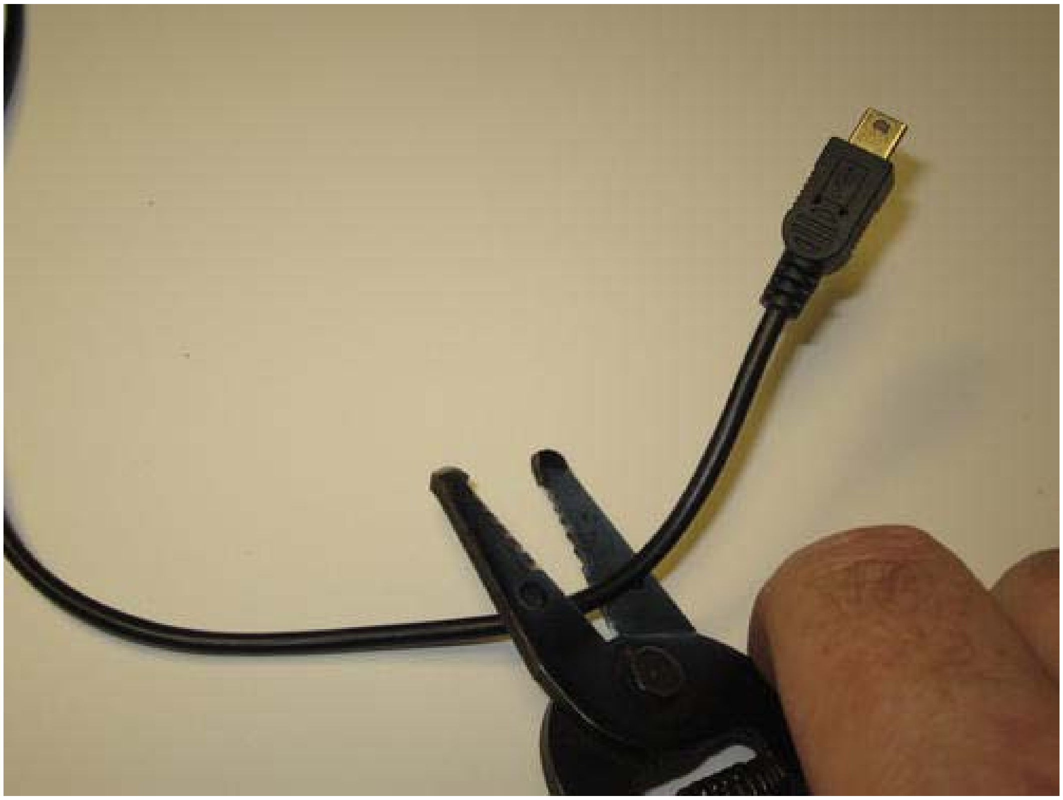

Figure A-5. *Cut off the device end of the USB cable. If you cut off the wrong end, you're not going to be able to plug it back into the charger, at least not without a considerable amount of effort. To ensure you cut the correct end, plug the host end of the cable into the USB charger before snipping, and then cut off the other end.*

Now carefully strip off about an inch of the cable's insulating jacket. Do your best to not nick the insulation on the wires inside. Within the jacket you should find four wires. Two of these wires carry the +5V and ground from the power supply. The other two wires carry the data on the USB connection. Since we're only interested in the power, we can ignore the other two wires for now. See Figure A-6.

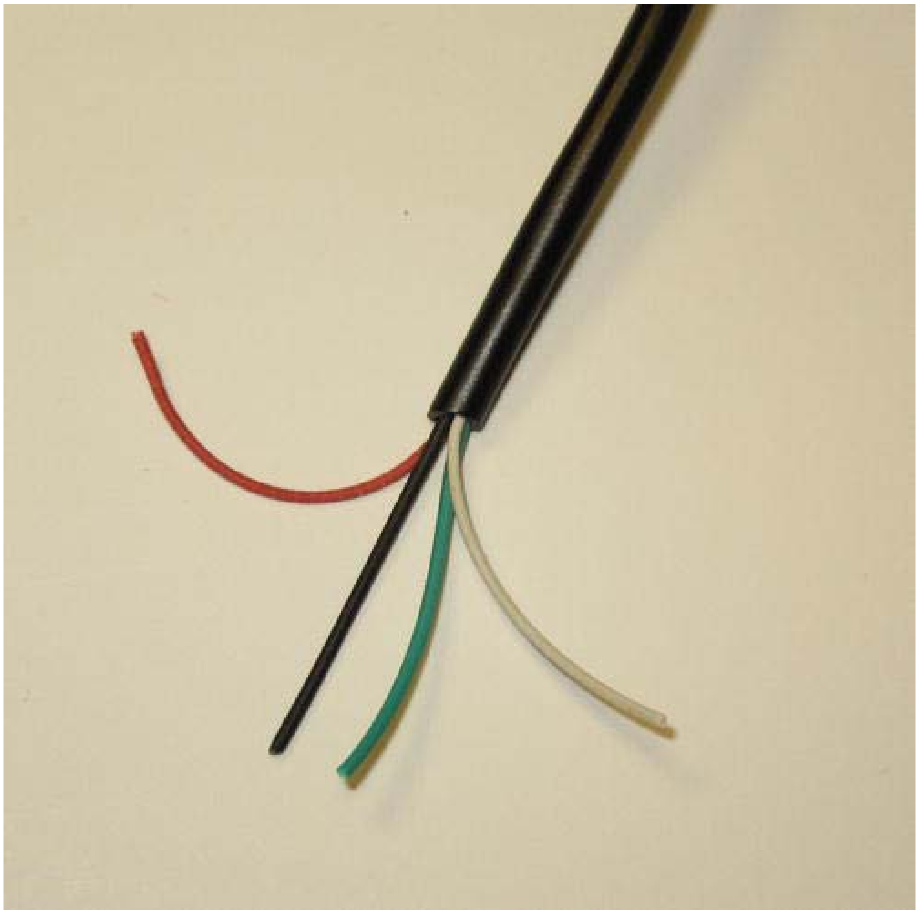

***Figure A-6.** The four internal wires within the USB cable. From left to right they are red (VBUS or +5V), black (ground), green (USB D+), and white (USB D–). Use the red and black wires to pull a regulated +5V from the charger.*

The USB standard specifies every little detail about how to build and mark USB cables, even down to the colors of the internal wires in the cable that you're not ever supposed to see! That's dedication.

■ **Note** Apple violates the USB standard by not having a raised USB symbol molded into its cables.

However, sometimes cable manufacturers fudge a bit and use whatever four-conductor cable they happen to have lying around. A very common substitute cable uses red, blue, yellow, and brown wires internally. See Table A-1 for a list of which wires go where.

Table A-1. *Standard USB Wire Colors and Their Functions, Along with Popular Alternate Colors*

Function	Pin Number	Standard USB Color	Alternate Color
VBUS (+5V)	1	Red	Red
D– 2		White	Blue
D+ 3		Green	Yellow
GND 4		Black	Brown

Now is the time to verify the wiring before we get much further. Even if your cable has the official wire colors within the insulating jacket, you are strongly advised to double-check both the voltage and the polarity coming out of the charger before connecting it to your tender, sensitive circuits. Minimize your assumptions about the compliance of others. Testing proves testing works!

Strip about 1/4 inch of the insulation from the ends of the red and black wires. Get out your meter and set it up to read voltage at or above the 5V range. If your fancy meter has autoranging, then just set it to read DC voltage. Plug the USB cable into the charger, if it's not already installed. Make sure the red and black wires are not touching, and then plug the charger into the wall or a convenient power strip.

Now measure the voltage between the red and black wires. Hopefully you should see a reading at or near 5.0V. The USB standard specifies a tolerance of ±10 percent, so anything between 4.5V and 5.5V is considered OK. See Figure A-7.

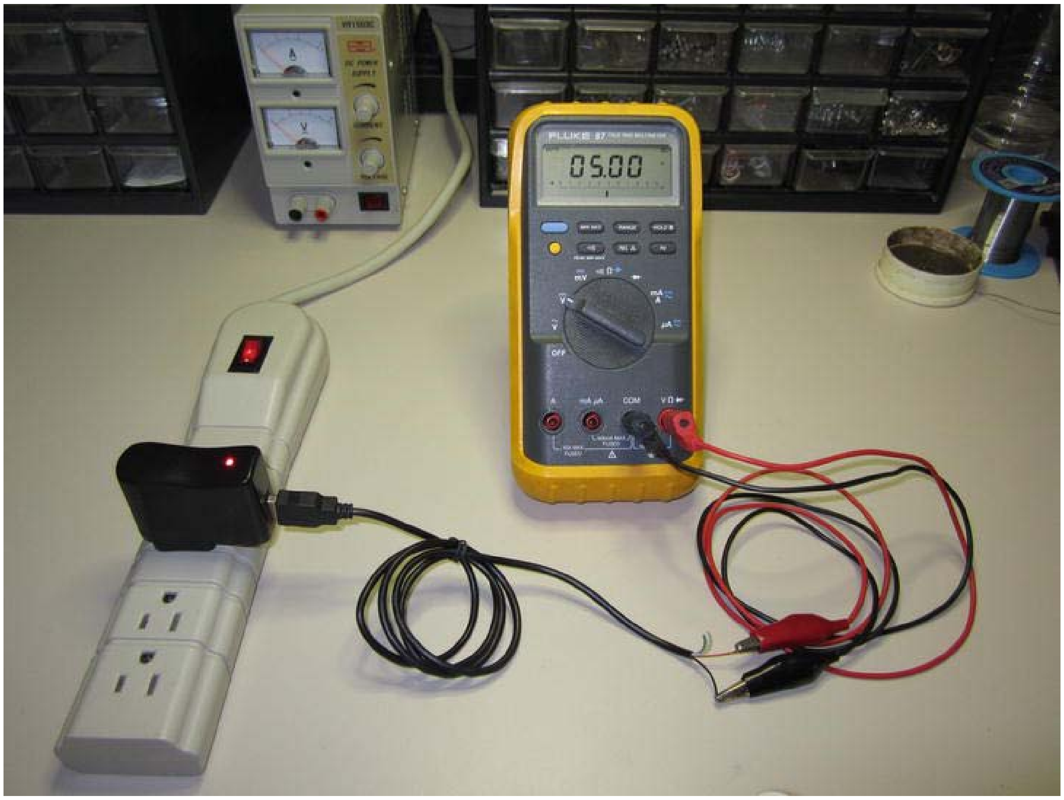

Figure A-7. *Measure the voltage coming from the USB charger before connecting it to any of your circuits. This one reads 5V on the dot! This is a much safer method than trial by fire (i.e., plugging it into your circuit and looking for a fire).*

Now that you've confirmed that the red and black wires do indeed carry the regulated +5V from the USB charger, you can clip off the unused green and white wires. At this point you can either use the bare, stripped wires of the USB cable or solder on a more robust connector. Since this power supply is destined to be used with a solderless breadboard, a small, two-pin connector with the appropriate spacing will be attached. See Figure A-8.

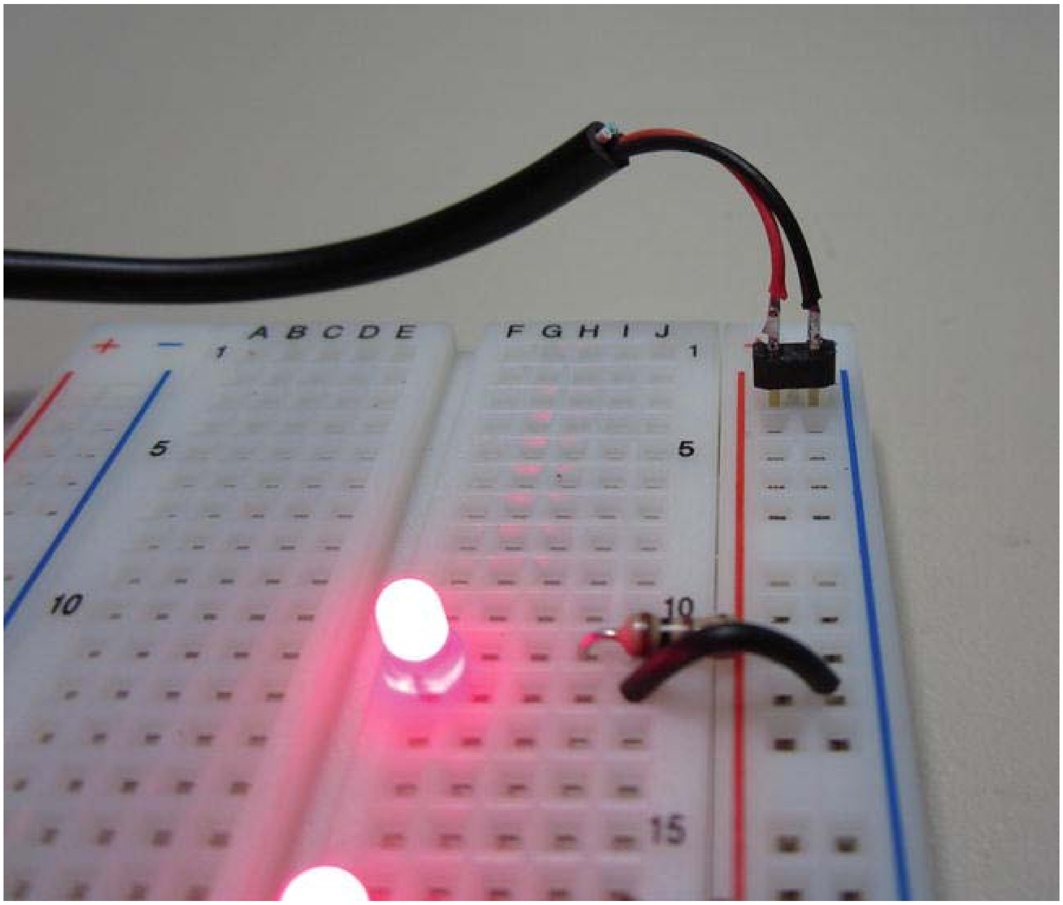

Figure A-8. *A gold-plated pin connector is soldered to the modified USB cable. The red and black insulation is left visible to be a polarity indicator when installing the cable to the solderless breadboard. Another happy LED!*

Adding Features

This power supply works just fine for most projects. If your requirements are, “Translate AC power from the wall into regulated DC power I can use for small projects, without spending a lot of money,” then this contraption fits the bill precisely.

You can see for yourself in Figure A-8 that it does indeed work as advertised. Looking back at Figure A-7, you can see that the charger itself has a power-on indicator LED built into the housing. What it doesn’t have is a power control or a switch. The power to the circuit is controlled by the switch on the power strip. This works just fine as long as you don’t mind turning on and off everything else that happens to be plugged into the same power strip.

Various Indicators

Not all USB chargers have a power indicator, however. Some have both a power indicator LED as well as a *charge status indicator*, which can tell you at a glance if your USB device is fully charged or still charging. A charge status indicator is usually implemented by measuring the amount of current being drawn from the supply. If more than a preset current is flowing, the power supply assumes a battery is still being charged. When that current drops below a certain level, it assumes that the battery has been completely (or maybe just mostly) charged. Some chargers use a red or orange LED to indicate charging, and a green or blue LED to show that the battery is finished charging. Again, this type of charge status display is provided to give the user a quick status update with a single glance. You don't need to consult the product manual to interpret the status code, if you can remember that red means "charging" and green means "charged."

Let's rearrange some of the parts on the solderless breadboard to make room for some new features. See Figure A-9.

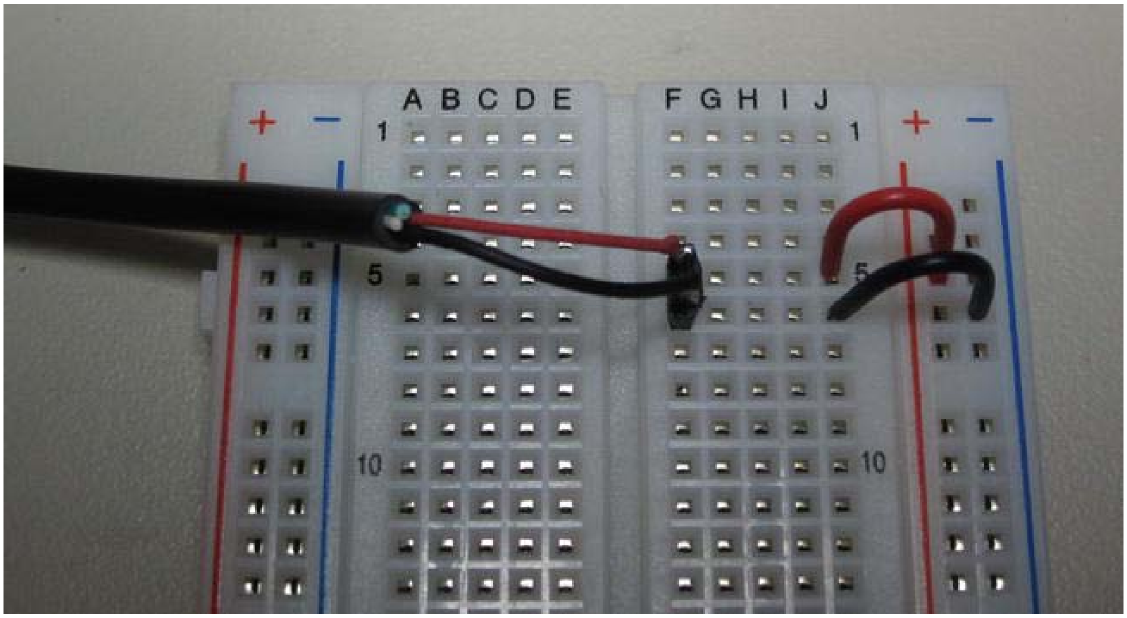

Figure A-9. *The regulated power coming from the USB charger is no longer directly connected to the breadboard's power rails. Instead, it is routed to some internal tie points and then connected to the power rails via two short jumpers.*

Power-On Indicator

First, we add a local power-on indicator by reinstalling the LED and current-limiting resistor used in the previous experiments. While this duplicates the function of any LEDs that might be present on the USB charger itself, it brings the indicator closer to the area of interest, which in this case is the circuitry onboard the solderless breadboard.

The anode of the LED goes into tie point F-3, with the cathode being installed at tie point F-4. The current-limiting resistor spans the gap between tie point I-3 and the right-hand positive (red) power rail. A short jumper connects tie point J-4 and the right-hand negative power rail. See Figure A-10.

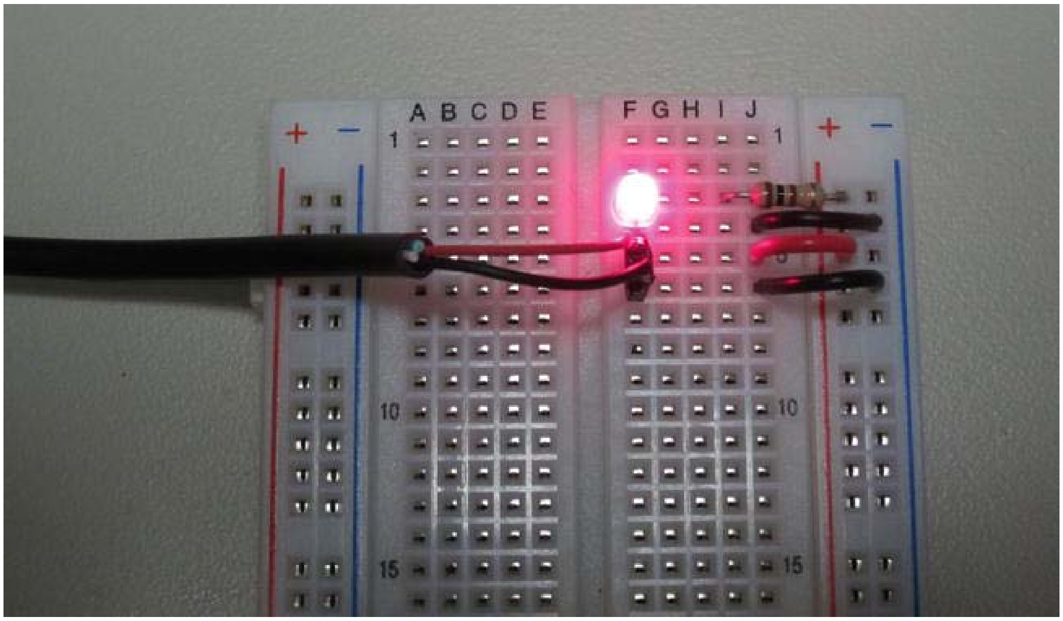

Figure A-10. *Add an LED and a current-limiting resistor across the power rails of the solderless breadboard to give an at-a-glance power indicator, right where the action is taking place.*

Now we have a good power-on indicator, right where we need it. It may or may not be redundant, depending on the features of your USB charger. This type of indicator is digital in the sense that it tells us that the circuit is either on or off, without giving us a lot of precise information about anything in between. For a lot of applications, however, this is more than enough information.

Power Supply Voltage

What if you *did* either want or need more precise information about the power supply? One method would be to permanently connect your multimeter to the circuit so that you can see how many volts are being delivered. That method assumes that you're not going to need your multimeter for anything else, ever.

A practical variation of that method, however, it to provide convenient *test points* in your circuit so that you can quickly and easily take a voltage reading when the need arises. Be sure to position the test points so that they are easy to access. Having a nice, big, readable label wouldn't hurt, either. Also, try to arrange things so that it's not likely that contact with a metal object, such as a tool or your wristwatch, will accidentally short out the power supply by touching both test points at the same time. Even simple "features" get complicated quickly, it seems!

If you want an accurate (and permanent) voltage reading on your circuit, consider adding a voltmeter. Small panel meters are relatively inexpensive and reasonably accurate. A DC voltmeter has two leads, positive and negative, that are attached across the voltage to be measured. See Figure A-11.

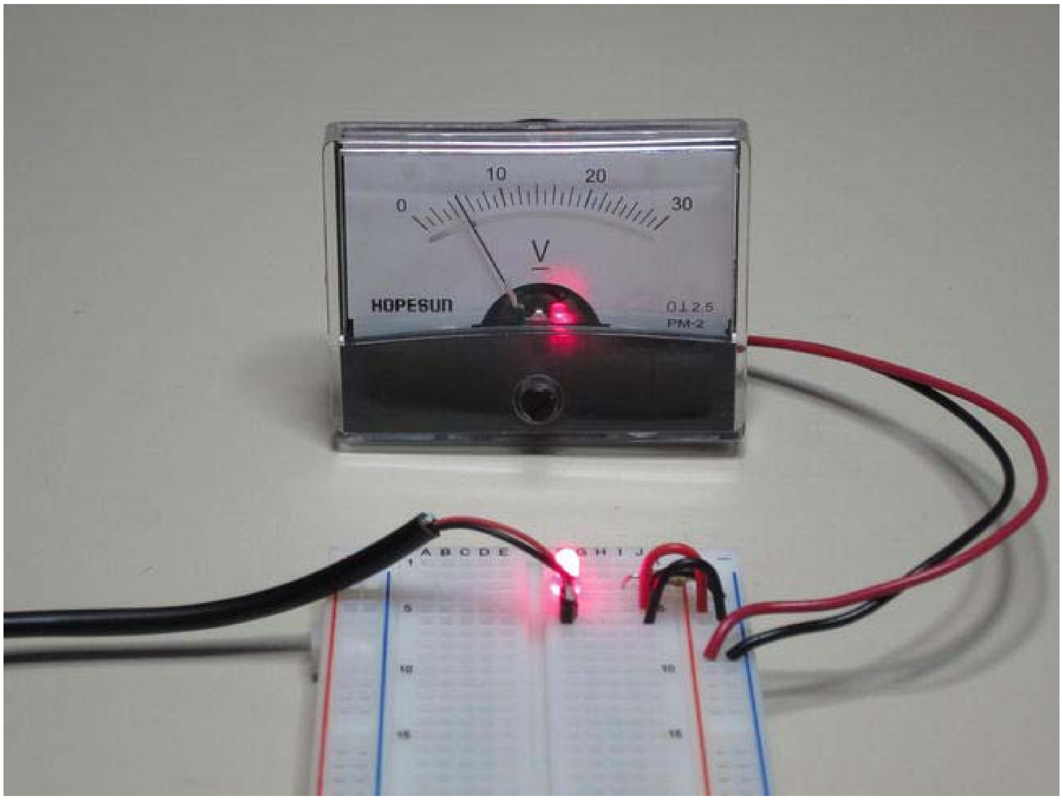

Figure A-11. *A DC voltmeter is attached to the circuit to accurately measure the supply voltage. The V on the meter's legend stands for voltage. The underline beneath the V indicates that it is designed to measure DC voltages, as opposed to AC voltages.*

The panel meter shown in Figure A-11 has a range of 0–30VDC. That's a bit more than we need, since our little power supply is only supposed to produce 5.0VDC ±10 percent. Since the meter's range does not accurately match the expected range of supply voltages, we lose a bit of precision when attempting to read the display. All the action is crowded together on the left side of the meter.

It might seem that a 0–5VDC meter would be preferable, but that would not allow for any overvoltage conditions at all. Remember, the USB standard allows for up to 5.5VDC to be delivered over the cable. A 0–6VDC meter, if available, would be more suitable. The meter introduced in Figure A-11, however, would be perfect when used with the laptop supply shown in Figure A-4, because its output voltage is 19.0V. That leaves a bit of room for overvoltage conditions and gives a wide enough swing of the needle to produce fine detail.

Power Supply Current

Measuring the *voltage* at any point in a circuit is easy. Just put a voltmeter between two points and voilà! In our previous example, we measured the VBUS power supply voltage with reference to GND, the ground potential of the circuit. Many voltage measurements are made with respect to ground.

To measure the current flowing through a circuit, we have two options. The first option is the most direct route. Install an ammeter (a meter that measures *amps* of current) inline with the circuit you want to measure. This requires that you *break* the circuit to make room for the meter. Once installed, the current flowing in the circuit actually flows through the ammeter as well.

The second option involves using a bit of trickery and some math. Instead of installing an ammeter directly inline with the current flow to be measured, we install a resistor of known resistance and measure the *voltage* that develops across the resistor.

Since we know that the values of volts, ohms, and amps are always related in any circuit, we can use Ohm's Law to determine how much current is flowing through a circuit by measuring the voltage across a known resistance.

To make things very easy, let's use a 1Ω resistor in series with the power supply, inserted in the circuit between where the positive lead of the power supply arrives at the circuit and where it is connected to the rest of the circuitry.

Unlike our previous use of Ohm's Law to calculate the missing value based on two known values, we only use *one* known value (the value of the resistor, called a *shunt resistor* when used in this manner). This one known value (resistance) then establishes the relationship between the two other values, voltage and current. As the current increases in the circuit, so does the voltage across the resistor. The two values will mirror each other—as one increases or decreases, the other will follow.

Since we used a 1Ω resistor in the circuit, this sets the relationship between current through the circuit and voltage across the resistor at a 1:1 ratio. For every ampere of current through the circuit, for example, 1V will be measured across the resistor.

Our power supply is only supposed to be able to deliver 0.5A of current, maximum, so we'll be dealing with voltages of less than 0.5V, unless something terribly unexpected happens.

Again, we could permanently attach a multimeter across the leads of a 1Ω resistor inserted into the circuit, or we could attach a voltmeter that is sensitive enough to give accurately readable information in the range we need. The 0–30VDC meter used before is much too large in range to do us any good here. We might see a tiny wiggle in the needle, but that's all.

Instead, we'll use a different kind of meter entirely. A digital voltmeter contains its own dedicated measurement circuitry and a numeric display to indicate the voltage reading. It also requires its own separate power supply. See Figure A-12.

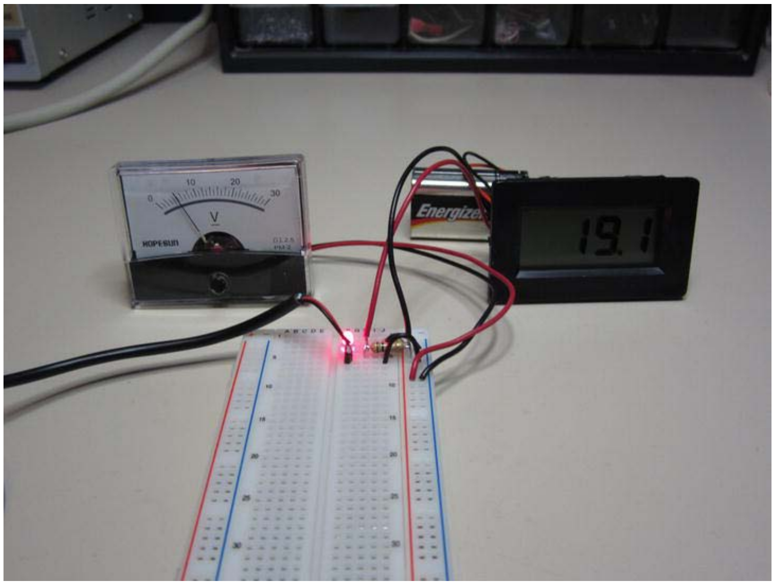

Figure A-12. *A digital voltage meter is used to read the voltage across the shunt resistor installed in the circuit. Because the shunt resistor has a 1.0Ω value, Ohm's Law dictates that the reading in millivolts on the digital meter correspond exactly to the number of milliamps flowing through the circuit. Math is useful, sometimes.*

The jumper wire connecting the incoming power supply directly to the power rail has been replaced with a 1Ω resistor. Leads from both ends of the resistor have been connected to the input terminals of the digital voltage meter on the right. The digital meter, unlike the analog meter on the left, requires an independent power supply to operate, in this case a 9V battery.

So now we've added some features to our simple power supply, including a power-on indicator, a supply voltage reading, and a supply current reading.

These are very useful features to have on any power supply. However, at this point in the prototyping stage, we've just barely covered what the added circuitry is supposed to do. Packaging all this up into an easy-to-use and reliable device takes as much if not more thought and effort.

First, you have to rebuild this entire circuit in a more permanent fashion. Next, you will have to wedge all that clever gadgetry into some sort of enclosure to protect the delicate bits while still permitting access to the inputs, outputs, and controls, if any. Then you get to label everything so that you can remember how to use it in the future.

Summary

So now you just might be developing a certain respect for how much work goes into building even the simplest tools—tools that are useful, accurate, reliable, and an asset to your toolbox. Remember, every tool on your workbench has to earn its place there. This applies to tools you design and build yourself, as well.

Good luck with your tool-building projects. Sometimes it's just as much fun to work on your tools as it is to work *with* your tools.

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■ ■ ■

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To my father, John H. Wheat, who patiently taught me about electricity and electronics over 40 years ago. To this day, I remain fascinated by it. My life has been enriched in so many ways by the many things that I learned from my father.

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VOL. 1

Charles Platt

Encyclopedia of Electronic Components

Power Sources & Conversion

Resistors ▪ Capacitors ▪ Inductors
Switches ▪ Encoders ▪ Relays ▪ Transistors

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Encyclopedia of Electronic Components

Volume 1

Charles Platt

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Encyclopedia of Electronic Components Volume 1

by Charles Platt

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[TI]

To Mark Frauenfelder, who reacquainted me with the pleasures of Making.

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Preface

At a time when information is widely and freely available in greater quantities than ever before, the reader may wonder whether *The Encyclopedia of Electronic Components* is really necessary. Surely, anything you want to know can be found online?

Well, yes and no. Let's consider the available resources.

1. Datasheets

Datasheets are indispensable, but they have limitations. Some are detailed; others are skimpy. Some show you sample schematics as a guide to using a component; many don't. None of them tells you much about how a component works, because that's not their purpose. Often they don't mention other components that must be added. Some datasheets for DC-DC converters, for instance, say nothing at all about bypass capacitors, even though the capacitors may be essential. A datasheet for an optocoupler says nothing about the pullup resistor required by the open-collector output.

Datasheets don't facilitate comparison shopping. A datasheet from one manufacturer will not compare its products with those from another manufacturer, and may not even provide much guidance about alternatives that are available from the same manufacturer. For example, a datasheet for a linear voltage regulator won't suggest that you might do better to use a DC-DC converter in an application where high efficiency is important.

Most of all, datasheets don't tell you how to avoid common mistakes. What actually happens if you connect that tantalum capacitor the wrong way around? A datasheet gives you the customary list of absolute maximum values, and after that, you are on your own, burning things out, encountering mysterious electronic behavior, and discovering limitations that are so well known, the datasheet didn't bother to mention them. In my experience, relying on datasheets creates a significant risk of reinventing the wheel.

2. Wikipedia

Wikipedia's coverage of electronics is impressive but inconsistent. Some entries are elementary, while others are extremely technical. Some are shallow, while others are deep. Some are well organized, while others run off into obscure topics that may have interested one of the contributors but are of little practical value to most readers. Many topics are distributed over multiple entries, forcing you to hunt through several URLs. Overall, Wikipedia tends to be good if you want theory, but not-so-good if you want hands-on practicality.

3. Manufacturers' Tutorials

A few helpful and enlightened manufacturers have compiled highly authoritative, instructional overviews of the components that they sell. Littelfuse, for instance, publishes an excellent series of documents telling you everything you could possibly want to know about fuses. But now you encounter a different problem: There is so much information, you'll need a couple of hours to dig through it all. Also, because the tutorials tend not to receive high page rankings on Google, they can be hard to find. And if a manufacturer has gaps in its product line, its tutorial is unlikely to mention them. Consequently, you won't know what's missing.

4. Personal Guides

It is a well-known attribute of the Web that many individuals feel the impulse to share everything they know (or think they know) about a particular topic. These personal guides can present surprisingly thorough online coverage of relatively obscure issues, such as the types of capacitors most suitable for loudspeaker crossover circuits, or the correct derivation of amp-hour numbers for lead-acid batteries. Unfortunately, on some sites you can also find errors, unsubstantiated opinions, plagiarism, and eccentricity. My general rule is that three or more guides generally have to agree with each other before their statements can be trusted—and even then, I have a small residue of doubt. The search-inspect-and-verify process can take a while.

So—yes, the information that you want usually does exist somewhere online, but no, it may not be easy to find. The vastness of the Web is not organized like an encyclopedia.

What about books? Generally speaking, they tend to be entry-level, or they specialize in narrow areas. A few broad-ranging books are truly excellent, but they are primarily educational, organized in an instructional sequence. They are not reference books.

The Encyclopedic Solution

Scarcity or inaccessibility of information ceased to be a problem many years ago. Its vast quantity, inconsistency, and dispersal have become the new barriers to acquiring knowledge. If you have to go hunting among datasheets, Wikipedia, manufacturers' tutorials (which may or may not exist), personal guides (which may have unrevealed bias), and multiple educational books, the process will be inconvenient and time-consuming. If you plan to revisit the topic in the future, you'll have to remember which URLs were useful and which ones weren't—and you may find that many of them are not even there anymore.

When I considered these issues during my own work as an electronics columnist for *Make* magazine, I saw a real need for a fact-checked, cross-referenced encyclopedia that would compile the basic information about components concisely, in an organized, consistent format, with informative photographs, schematics, and diagrams. It might save many people a lot of search time if it could summarize how components work, how to use them, what the alternatives are, and what the common errors and problems may be.

That is the modest ambition of *The Encyclopedia of Electronic Components*.

The Audience

Like any reference work, this one hopes to serve two categories of readers: The informed and the not-yet-informed.

Perhaps you are learning electronics, and you see a part listed in a catalog. It looks interesting, but the catalog doesn't tell you exactly what the part does or how it is commonly used. You need to look it up either by function or by name, but you're not sure where to start. An encyclopedic reference can simplify the fact-finding process, can save you from ordering a part that may be inappropriate, and can tell you how it should be used.

Perhaps, instead, you are an electronics engineer or hobbyist, thinking about a new circuit. You remember using a component three or four years ago, but your recollection may not be reliable. You need to refresh your memory with a quick summary—and so, you open the encyclopedia, just to make sure.

Completeness

Obviously, this book cannot include every component that exists. Mouser Electronics claims to have more than 2 million products listed in its online database. *The Encyclopedia of Electronic Components* only has room for a fraction of that number—but still, it can refer you to the primary types. The electronic edition of this book should allow easy insertions and updates. My hope is that it can become an ever-expanding resource.

Acknowledgments

Any reference work draws inspiration from many sources, and this one is no exception. Three were of special importance:

Practical Electronics for Inventors by Paul Scherz (second edition) McGraw-Hill, 2007

Electronic Devices and Circuit Theory by Robert L. Boylestad and Louis Nashelsky (ninth edition) Pearson Education Inc., 2006

The Art of Electronics by Paul Horowitz and Winfield Hill (second edition) Cambridge University Press, 2006

I also made extensive use of information gleaned through Mouser Electronics and Jameco Electronics. And where would any of us be without *Getting Started in Electronics* by Forrest M. Mims III, or *The TTL Cookbook* by Don Lancaster?

In addition, there were individuals who provided special assistance. My editor, Brian Jepson, was immensely helpful in the development of the project. Michael Butler contributed greatly to the early concept and its structure. Josh Gates did resourceful research. My publishers, O'Reilly Media, demonstrated their faith in my work. Kevin Kelly unwittingly influenced me with his legendary interest in "access to tools."

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Lastly I should mention my school friends from decades ago: Hugh Levinson, Patrick Fagg, Graham Rogers, William Edmondson, and John Witty, who helped me to feel that it was okay to be a nerdy kid building my own audio equipment, long before the word "nerd" existed.

—Charles Platt, 2012

How to Use This Book

1

To avoid misunderstandings regarding the purpose and method of this book, here is a quick guide regarding the way in which it has been conceived and organized.

Reference vs. Tutorial

As its title suggests, this is a reference book, not a tutorial. In other words, it does not begin with elementary concepts and build sequentially toward concepts that are more advanced.

You should be able to dip into the text at any point, locate the topic that interests you, learn what you need to know, and then put the book aside. If you choose to read it straight through from beginning to end, you will not find concepts being introduced in a sequential, cumulative manner.

My book *Make:Electronics* follows the tutorial approach. Its range, however, is more circumscribed than that of this encyclopedia, because a tutorial inevitably allocates a lot of space to step-by-step explanations and instructions.

Theory and Practice

This book is oriented toward practicality rather than theory. I am assuming that the reader mostly wants to know how to use electronic components, rather than why they work the way they do. Consequently I have not included any proofs of formulae, any definitions rooted in electrical theory, or any historical background. Units are defined only to the extent that is necessary to avoid confusion.

Many books on electronics theory already exist, if theory is of interest to you.

Organization

The encyclopedia is divided into entries, each entry being devoted to one broad type of component. Two rules determine whether a component has an entry all to itself, or is subsumed into another entry:

1. A component merits its own entry if it is (a) widely used or (b) not-so-widely used but has a unique identity and maybe some historical status. A widely used component would be a **bipolar transistor**, while a not-so-widely-used component with a unique identity would be a **unijunction transistor**.
2. A component does not merit its own entry if it is (a) seldom used or (b) very similar in function to another component that is more widely used. For example, the *rheostat* is sub-

sumed into the **potentiometer** section, while *silicon diode*, *Zener diode*, and *germanium diode* are combined together in the **diode** entry.

Inevitably, these guidelines required judgment calls that in some cases may seem arbitrary. My ultimate decision was based on where I would expect to find a component if I was looking for it myself.

Subject Paths

Entries are not organized alphabetically. Instead they are grouped by subject, in much the same way that books in the nonfiction section of a library are organized by the Dewey Decimal System. This is convenient if you don't know exactly what you are looking for, or if you don't know all the options that may be available to perform a task that you have in mind.

Each primary category is divided into subcategories, and the subcategories are divided into component types. This hierarchy is shown in Figure 1-1. It is also apparent when you look at the top of the first page of each entry, where you will find the path that leads to it. The **capacitor** entry, for instance, is headed with this path:

power > moderation > capacitor

Any classification scheme tends to run into exceptions. You can buy a chip containing a *resistor array*, for instance. Technically, this is an *analog integrated circuit*, but should it really be included with solid-state relays and comparators? A decision was made to put it in the **resistor** section, because this seemed more useful.

Some components have hybrid functions. In Volume 2, in the *integrated circuit* subcategory, we will distinguish between those that are *analog* and those that are *digital*. So where should an **analog-digital converter** be listed? It will be found under *analog*, because that category seems better associated with its primary function, and people may be more likely to look for it there.

Primary Category	Secondary Category	Component Type
power	source	battery
	connection	jumper
		fuse
		pushbutton
		switch
		rotary switch
		rotational encoder
	moderation	relay
		resistor
		potentiometer
		capacitor
		variable capacitor
	conversion	inductor
		AC-AC transformer
		AC-DC power supply
		DC-DC converter
		DC-AC inverter
	regulation	voltage regulator
electro-magnetism	linear output	electromagnet
		solenoid
	rotational output	DC motor
		AC motor
		servo motor
		stepper motor
discrete semi-conductor	single junction	diode
		unijunction transistor
	multi-junction	bipolar transistor
		field-effect transistor

Figure 1-1. *The subject-oriented organization of categories and entries in this encyclopedia.*

Inclusions and Exclusions

There is also the question of what is, and what is not, a component. Is wire a component? Not for the purposes of this encyclopedia. How about a **DC-DC converter**? Because converters are now sold in small packages by component suppliers, they have been included as components.

Many similar decisions had to be made on a case-by-case basis. Undoubtedly, some readers will disagree with the outcome, but reconciling all the disagreements would have been impossible. Speaking personally, the best I could do was create a book that is organized in the way that would suit me best if I were using it myself.

Typographical Conventions

Throughout this encyclopedia, the names of components that have their own entries are presented in **bold type.** Other important electronics terms or component names are presented in *italics* where they first appear in any one section.

The names of components, and the categories to which they belong, are all set in lower-case type, except where a term is normally capitalized because it is an acronym or a trademark. *Trimpot*, for instance, is trademarked by Bourns, but *trimmer* is not. **LED** is an acronym, but *cap* (abbreviation for **capacitor**) is not.

Where formulae are used, they are expressed in a format that will be familiar to computer programmers but may be unfamiliar to others. The * (asterisk) symbol is used in place of a multiplication sign, while the / (slash symbol) is used to indicate division. Where pairs of parentheses are nested, the most deeply nested pair identifies the operations that should be performed first.

Volume Contents

Practical considerations relating to book length influenced the decision to divide *The Encyclopedia of Electronic Components* into three volumes. Each volume deals with broad subject areas as follows.

Volume 1

Power, electromagnetism, and discrete semiconductors.

The *power* category includes sources of power and methods to distribute, store, interrupt, and modify power. The *electromagnetism* category includes devices that exert force linearly, and others that create a turning force. *Discrete semiconductors* include the main types of diodes and transistors.

Volume 2

Integrated circuits, light sources, sound sources, heat sources, and high-frequency sources.

Integrated circuits are divided into analog and digital components. *Light sources* range from incandescent bulbs to LEDs and small display screens; some reflective components, such as liquid-crystal displays and e-ink, are also included. *Sound sources* are primarily electromagnetic.

Volume 3

Sensing devices.

The field of sensors has become so extensive, they easily merit a volume to themselves. *Sensing devices* include those that detect light, sound, heat, motion, pressure, gas, humidity, orientation, electricity, proximity, force, and radiation.

At the time of writing, volumes 2 and 3 are still in preparation, but their contents are expected to be as described above.

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battery

2

This entry covers electrochemical power sources. Electricity is most often generated electromagnetically, but since these sources cannot be classified as components, they are outside the scope of the encyclopedia. Electrostatic sources are excluded for similar reasons.

A battery is sometimes referred to as a *cell* or *power cell*, but can actually contain multiple cells, as defined in this entry. It used to be called an *accumulator* or a *pile*, but those terms are now archaic.

OTHER RELATED COMPONENTS

- **capacitor** (see Chapter 12)

What It Does

A battery contains one or more *electrochemical cells* in which chemical reactions create an electrical potential between two immersed terminals. This potential can be discharged as *current* passing through a *load*.

An electrochemical cell should not be confused with an *electrolytic cell*, which is powered by an external source of electricity to promote *electrolysis*, whereby chemical compounds are broken down to their constituent elements. An electrolytic cell thus consumes electricity, while an electrochemical cell produces electricity.

Batteries range in size from *button cells* to large *lead-acid* units that store power generated by solar panels or windmills in locations that can be off the grid. Arrays of large batteries can provide bridging power for businesses or even small communities where conventional power is unreliable. Figure 2-1 shows a 60KW, 480VDC self-watering battery array installed in a corporate data center, supplementing wind and solar sources and providing time-of-day peak shaving of energy usage. Each lead-acid battery in this array measures approximately 28″ × 24″ × 12″ and weighs about 1,000 lb.

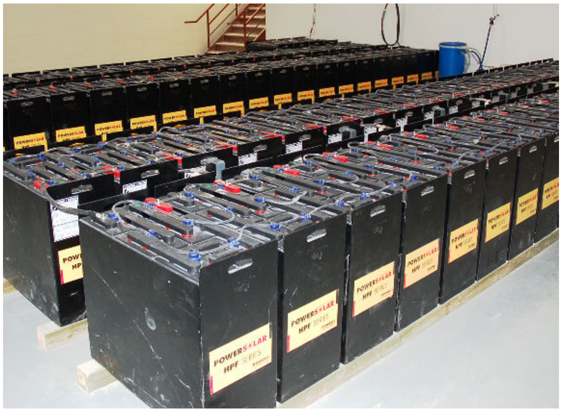

Figure 2-1. *A battery array providing 60KW at 480VDC as backup for a corporate data center. (Photo by permission of Hybridyne Power Systems, Canada, Inc., and the Hybridyne group of companies. Copyright by Hybridyne, an internationally registered trademark of Hybridyne Power Systems Canada Inc. No right of further reproduction unless specifically granted by Hybridyne.)*

Schematic symbols for a battery are shown in Figure 2-2. The longer of the two lines represents the positive side of the battery, in each case. One way to remember this is by imagining that the longer line can be snipped in half so that the two segments can combine to form a + sign. Traditionally, multiple connected battery symbols indicate multiple cells inside a battery; thus the center symbols in the figure could indicate a 3V battery, while those on the right would indicate a voltage greater than 3V. In practice, this convention is not followed conscientiously.

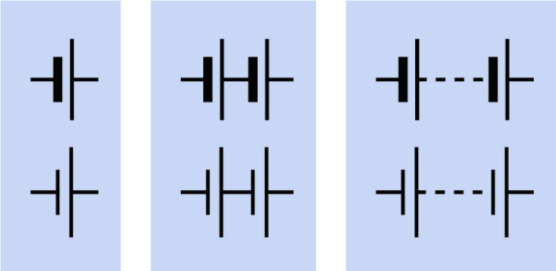

Figure 2-2. *Schematic symbols for a battery. Each pair of symbols within a blue rectangle is functionally identical.*

How It Works

In a basic battery design often used for demonstration purposes, a piece of copper serves as an *electrode*, partially immersed in a solution of copper sulfate, while a piece of zinc forms a second electrode, partially immersed in a solution of zinc sulfate. Each sulfate solution is known as an *electrolyte*, the complete battery may be referred to as a *cell*, and each half of it may be termed a *half-cell*.

A simplified cross-section view is shown in Figure 2-3. Blue arrows show the movement of electrons from the zinc terminal (the *anode*), through an external load, and into a copper terminal (the *cathode*). A *membrane separator* allows the electrons to circulate back through the battery, while preventing electrolyte mixing.

Orange arrows represent positive copper *ions*. White arrows represent positive zinc ions. (An ion is an atom with an excess or deficit of electrons.) The zinc ions are attracted into the zinc sulfate electrolyte, resulting in a net loss of mass from the zinc electrode.

Meanwhile, electrons passing into the copper electrode tend to attract positive copper ions, shown as orange arrows in the diagram. The copper ions are drawn out of the copper sulfate electrolyte, and result in a net accumulation of copper atoms on the copper electrode.

This process is energized partially by the fact that zinc tends to lose electrons more easily than copper.

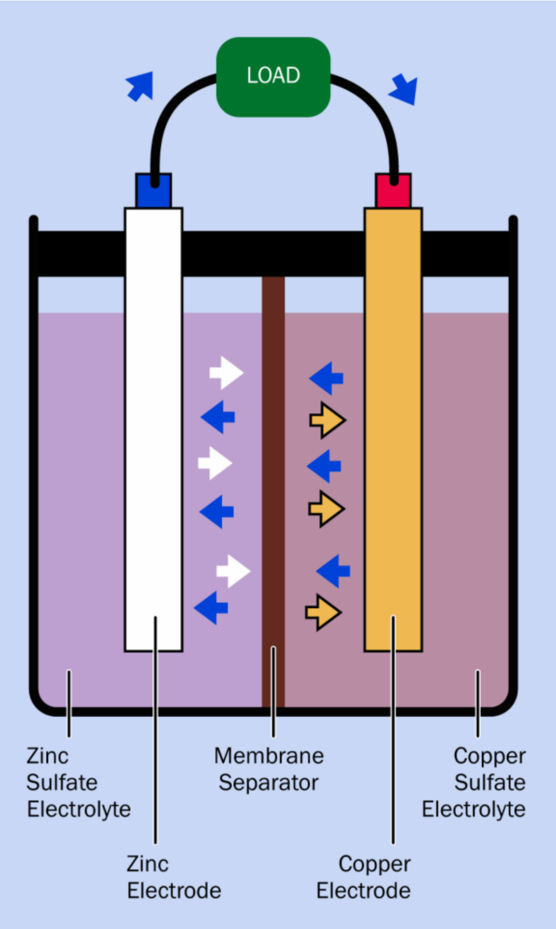

Figure 2-3. *A classically simple electrochemical cell. See text for additional details.*

Batteries for use in consumer electronics typically use a paste instead of a liquid as an electrolyte, and have been referred to as *dry cells*, although this term is becoming obsolete. The two half-cells may be combined concentrically, as in a typical 1.5-volt C, D, AA, or AAA alkaline battery (see Figure 2-4).

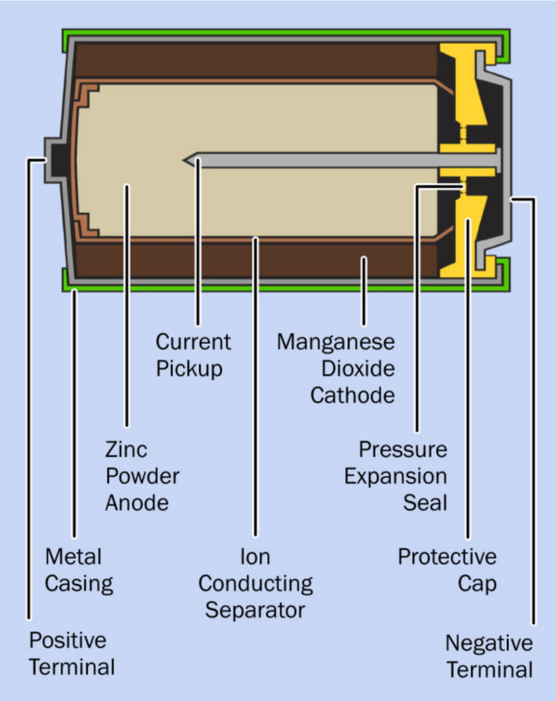

Figure 2-4. *Cross-section view of a typical 1.5-volt alkaline battery.*

A 1.5V battery contains one cell, while a 6V or 9V battery will contain multiple cells connected in series. The total voltage of the battery is the sum of the voltages of its cells.

Electrode Terminology

The electrodes of a cell are often referred to as the *anode* and the *cathode*. These terms are confusing because the electrons enter the anode inside the cell and leave it outside the cell, while electrons enter the cathode from outside the cell and leave it inside the cell. Thus, the anode is an electron emitter if you look at it externally, but the cathode is an electron emitter if you look at it internally.

Conventional current is imagined to flow in the opposite direction to electrons, and therefore, outside the cell, this current flows from the cathode to the anode, and from this perspective, the cathode can be thought of as being "more positive" than the anode. To remember this, think of the letter t in "cathode" as being a + sign, thus: ca+hode. In larger batteries, the cathode is often painted or tagged red, while the anode may be painted or tagged black or blue.

When a reusable battery is recharged, the flow of electrons reverses and the anode and the cathode effectively trade places. Recognizing this, the manufacturers of rechargeable batteries may refer to the more-positive terminal as the anode. This creates additional confusion, exacerbated further still by electronics manufacturers using the term "cathode" to identify the end of a **diode** which must be "more negative"(i.e., at a lower potential) than the opposite end.

To minimize the risk of errors, it is easiest to avoid the terms "anode" and "cathode" when referring to batteries, and speak instead of the negative and positive terminals. This encyclopedia uses the common convention of reserving the term "cathode" to identify the "more negative" end of any type of diode.

Variants

Three types of batteries exist.

1. *Disposable batteries*, properly (but infrequently) referred to as *primary cells*. They are not reliably rechargeable because their chemical reactions are not easily reversible.
2. *Rechargeable batteries*, properly (but infrequently) known as *secondary cells*. They can be recharged by applying a voltage between

the terminals from an external source such as a *battery charger*. The materials used in the battery, and the care with which the battery is maintained, will affect the rate at which chemical degradation of the electrodes gradually occurs as it is recharged repeatedly. Either way, the number of charge/ discharge cycles is limited.

3. *Fuel Cells* require an inflow of a reactive gas such as hydrogen to maintain an electrochemical reaction over a long period. They are beyond the scope of this encyclopedia.

A large **capacitor** may be substituted for a battery for some applications, although it has a lower energy density and will be more expensive to manufacture than a battery of equivalent power storage. A capacitor charges and discharges much more rapidly than a battery because no chemical reactions are involved, but a battery sustains its voltage much more successfully during the discharge cycle. See Figure 2-5.

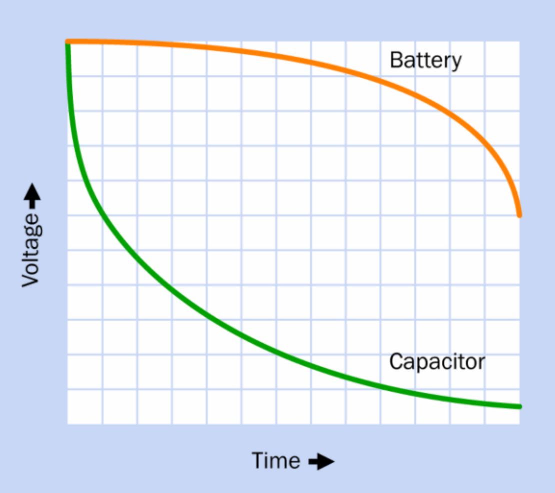

Figure 2-5. *The voltage drop of a discharging capacitor is much steeper initially than that of a battery, making capacitors unsuitable as a battery substitute in many applications. However, the ability of a capacitor to discharge very rapidly at high amperage can sometimes be a significant advantage.*

Capacitors that can store a very large amount of energy are often referred to as *supercapacitors.*

Disposable Batteries

The energy density of any disposable battery is higher than that of any type of rechargeable battery, and it will have a much longer shelf life because it loses its charge more slowly during storage (this is known as the *self-discharge rate*). Disposable batteries may have a useful life of five years or more, making them ideal for applications such as smoke detectors, handheld remotes for consumer electronics, or emergency flashlights.

Disposable batteries are not well suited to delivering high currents through loads below 75Ω. Rechargeable batteries are preferable for higher-current applications. The bar chart in Figure 2-6 shows the rated and actual capabilities of an alkaline battery relative to the three most commonly used rechargeable types, when the battery is connected with a resistance that is low enough to assure complete discharge in 1 hour.

The manufacturer's rating of watt hours per kilo is typically established by testing a battery with a relatively high-resistance load and slow rate of discharge. This rating will not apply in practice if a battery is discharged with a C-rate of 1, meaning complete discharge during 1 hour.

Common types of disposable batteries are *zinc-carbon cells* and *alkaline cells*. In a zinc-carbon cell, the negative electrode is made of zinc while the positive electrode is made of carbon. The limited power capacity of this type of battery has reduced its popularity, but because it is the cheapest to manufacture, it may still be found where a company sells a product with "batteries included." The electrolyte is usually ammonium chloride or zinc chloride. The 9V battery in Figure 2-7 is actually a zinc-carbon battery according to its supplier, while the smaller one beside it is a 12V alkaline battery designed for use in burglar alarms. These examples show that batteries cannot always be identified correctly by a casual assessment of their appearance.

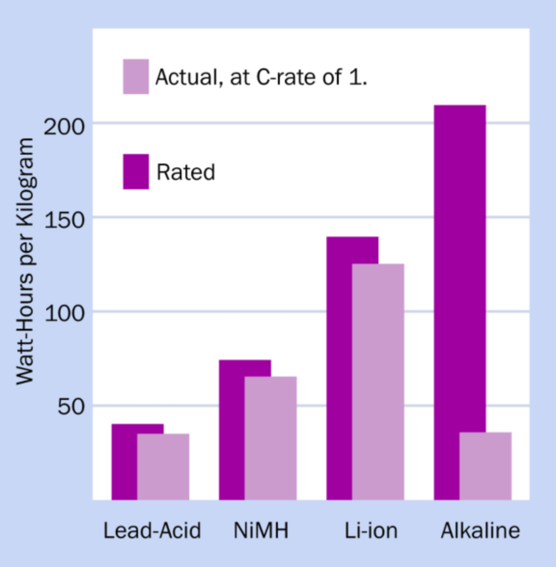

Figure 2-6. *Because of their relatively high internal resistance, alkaline batteries are especially unsuited to high discharge rates, and should be reserved for applications where a small current is required over a long period. (Chart derived from http://batteryuniversity.com.)*

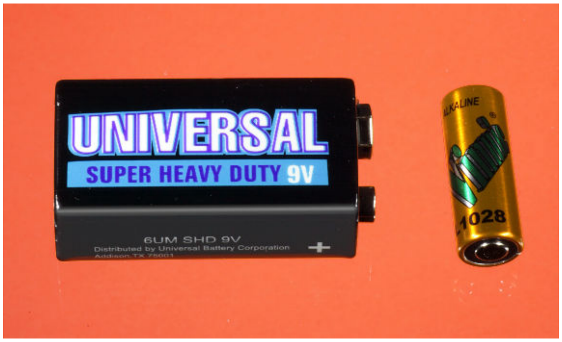

Figure 2-7. *At left, a cheap carbon-zinc battery; at right, a 12V alkaline burglar-alarm battery. See text for additional details.*

In an alkaline cell, the negative electrode is made of zinc powder, the positive electrode is manganese dioxide, and the electrolyte is potassium hydroxide. An alkaline cell may provide between three to five times the power capacity of an equal size of zinc-carbon cell and is less susceptible to voltage drop during the discharge cycle.

Extremely long shelf life is necessary in some military applications. This may be achieved by using a *reserve battery*, in which the internal chemical compounds are separated from each other but can be recombined prior to use.

Rechargeable Batteries

Commonly used types are *lead-acid*, *nickel cadmium* (abbreviated *NiCad* or *NiCd*), *nickel-metal hydride* (abbreviated *NiMH*), *lithium-ion* (abbreviated *Li-ion*), and *lithium-ion polymer*.

Lead-acid batteries have existed for more than a century and are still widely used in vehicles, burglar alarms, emergency lighting, and large power backup systems. The early design was described as *flooded*; it used a solution of sulfuric acid (generically referred to as *battery acid*) as its electrolyte, required the addition of distilled water periodically, and was vented to allow gas to escape. The venting also allowed acid to spill if the battery was tipped over.

The *valve-regulated lead-acid* battery (*VRLA*) has become widely used, requiring no addition of water to the cells. A pressure relief valve is included, but will not leak electrolyte, regardless of the position of the battery. VRLA batteries are preferred for *uninterruptible power supplies* for data-processing equipment, and are found in automobiles and in electric wheelchairs, as their low gas output and security from spillage increases their safety factor.

VRLA batteries can be divided into two types: absorbed glass mat (AGM) and gel batteries. The electrolyte in an AGM is absorbed in a fiber-glass mat separator. In a gel cell, the electrolyte is mixed with silica dust to form an immobilized gel.

The term *deep cycle battery* may be applied to a lead-acid battery and indicates that it should be more tolerant of discharge to a low level—perhaps 20 percent of its full charge (although manufacturers may claim a lower number). The plates in a standard lead-acid battery are composed of a lead *sponge*, which maximizes the surface area available to acid in the battery but can be physically abraded by deep discharge. In a deep cycle battery, the plates are solid. This means they are more robust, but are less able to supply high amperage. If a deep-discharge battery is used to start an internal combustion engine, the battery should be larger than a regular lead-acid battery used for this purpose.

A sealed lead-acid battery intended to power an external light activated by a motion detector is shown in Figure 2-8. This unit weighs several pounds and is trickle-charged during the daytime by a 6″ × 6″ solar panel.

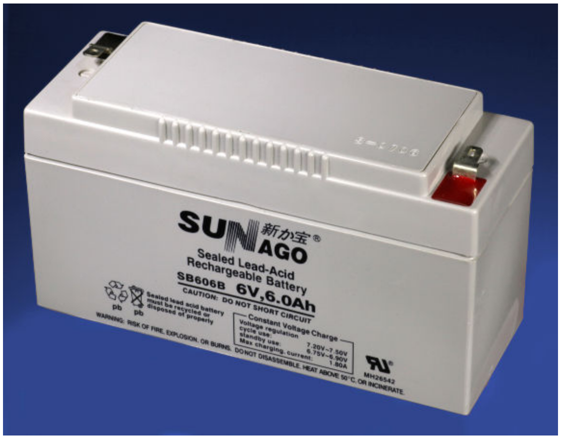

Figure 2-8. *A lead-acid battery from an external light activated by a motion sensor.*

Nickel-cadmium (*NiCad*) batteries can withstand extremely high currents, but have been banned in Europe because of the toxicity of metallic cadmium. They are being replaced in the United States by *nickel-metal hydride* (*NiMH*) types, which are free from the *memory effect* that can prevent a NiCad cell from fully recharging if it has been left for weeks or months in a partially discharged state.

Lithium-ion and lithium-ion polymer batteries have a better energy-to-mass ratio than NiMH batteries, and are widely used with electronic devices such as laptop computers, media players, digital cameras, and cellular phones. Large arrays of lithium batteries have also been used in some electric vehicles.

Various small rechargeable batteries are shown in Figure 2-9. The NiCad pack at top-left was manufactured for a cordless phone and is rapidly becoming obsolete. The 3V lithium battery at top-right was intended for a digital camera. The three batteries in the lower half of the photograph are all rechargeable NiMH substitutes for 9V, AA, and AAA batteries. The NiMH chemistry results in the AA and AAA single-cell batteries being rated for 1.2V rather than 1.5V, but the manufacturer claims they can be substituted for 1.5V alkaline cells because NiMH units sustain their rated voltage more consistently over time. Thus, the output from a fresh NiMH battery may be comparable to that of an alkaline battery that is part-way through its discharge cycle.

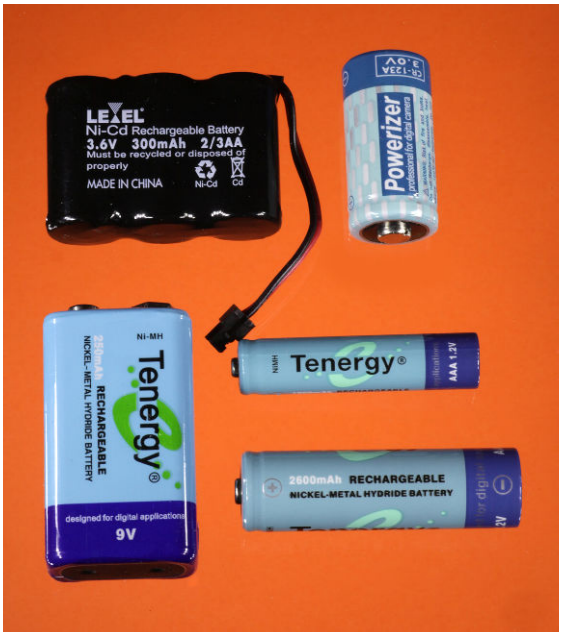

Figure 2-9. *Top left: NiCad battery pack for a cordless phone. Top right: Lithium battery for a digital camera. The other batteries are rechargeable NiMH substitutes for everyday alkaline cells.*

NiMH battery packs are available to deliver substantial power while being smaller and lighter than lead-acid equivalents. The NiMH package in Figure 2-10 is rated for 10Ah, and consists of ten

D-size NiMH batteries wired in series to deliver 12VDC. This type of battery pack is useful in robotics and other applications where a small motor-driven device must have free mobility.

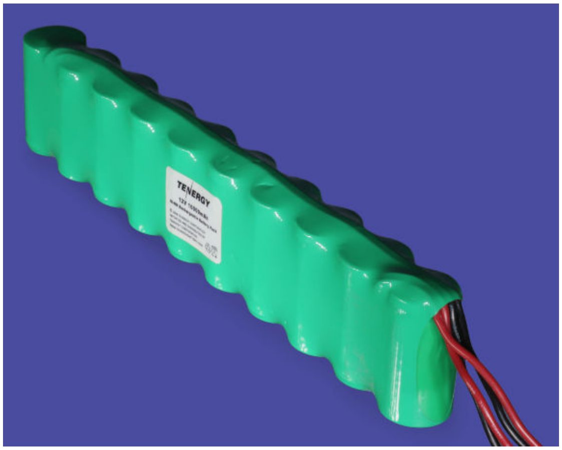

Figure 2-10. *This NiMH battery pack is rated at 10Ah and delivers 12 volts from ten D-size cells wired in series.*

Values

Amperage

The current delivered by a battery will be largely determined by the resistance of the external load placed between its terminals. However, because ion transfer must occur inside the battery to complete the circuit, the current will also be limited by the *internal resistance* of the battery. This should be thought of as an active part of the circuit.

Since a battery will deliver no current if there is no load, current must be measured while a load is attached, and cannot be measured by a meter alone. The meter will be immediately overloaded, with destructive results, if it is connected directly between the terminals of a battery, or in parallel with the load. Current must always be measured with the meter in series with the load, and the polarity of the meter must correspond with the polarity of the battery. See Figure 2-11.

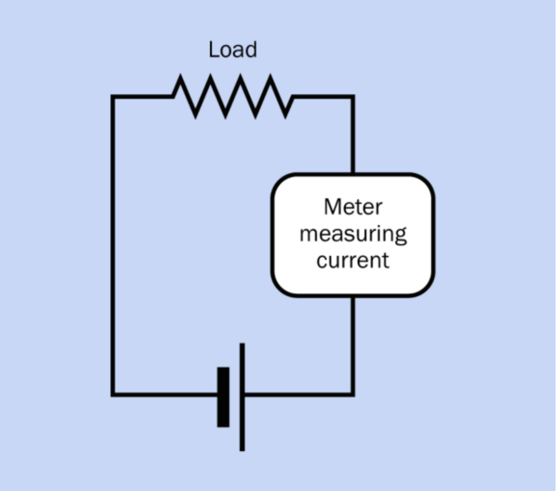

Figure 2-11. *When measuring current using an ammeter (or a multimeter configured to measure amps), the meter must be placed in series with the battery and a load. To avoid damaging the meter, it must never be applied directly across the terminals of the battery, or in parallel with a load. Be careful to observe the polarity of the meter.*

Capacity

The *electrical capacity* of a battery is measured in *amp-hours*, abbreviated *Ah*, *AH*, or (rarely) *A/H*. Smaller values are measured in *milliamp-hours*, usually abbreviated *mAh*. If I is the current being drawn from a battery (in amps) and T is the time for which the battery can deliver that current (in hours), the amp-hour capacity is given by the formula:

```
Ah = I * T
```

By turning the formula around, if we know the amp-hour rating that a manufacturer has determined for a battery, we can calculate the time in hours for which a battery can deliver a particular current:

```
T = Ah / I
```

Theoretically, Ah is a constant value for any given battery. Thus a battery rated for 4Ah should provide 1 amp for 4 hours, 4 amps for 1 hour, 5 amps for 0.8 hours (48 minutes), and so on.

In reality, this conveniently linear relationship does not exist. It quickly breaks down as the current rises, especially when using lead-acid batteries, which do not perform well when required to deliver high current. Some of the current is lost as heat, and the battery may be electrochemically incapable of keeping up with demand.

The *Peukert number* (named after its German originator in 1897) is a fudge factor to obtain a more realistic value for T at higher currents. If n is the Peukert number for a particular battery, then the previous formula can be modified thus:

$$\mathtt{T = Ah / I^{n}}$$

Manufacturers usually (but not always) supply Peukert's number in their specification for a battery. So, if a battery has been rated at 4Ah, and its Peukert number is 1.2 (which is typical for lead-acid batteries), and I=5 (in other words, we want to know for how long a time, T, the battery can deliver 5 amps):

$$\mathtt{T = 4 / 5^{1.2} = approximately\ 4 / 6.9}$$

This is about 0.58 hours, or 35 minutes—much less than the 48 minutes that the original formula suggested.

Unfortunately, there is a major problem with this calculation. In Peukert's era, the amp-hour rating for a battery was established by a manufacturer by drawing 1A and measuring the time during which the battery was capable of delivering that current. If it took 4 hours, the battery was rated at 4Ah.

Today, this measurement process is reversed. Instead of specifying the current to be drawn from the battery, a manufacturer specifies the time for which the test will run, then finds the maximum current the battery can deliver for that time. Often, the time period is 20 hours. Therefore, if a battery has a modern 4Ah rating, testing has probably determined that it delivered 0.2A for 20 hours, not 1A for 4 hours, which would have been the case in Peukert's era.

This is a significant distinction, because the same battery that can deliver 0.2A for 20 hours will not be able to satisfy the greater demand of 1A for 4 hours. Therefore the old amp-hour rating and the modern amp-hour rating mean different things and are incompatible. If the modern Ah rating is inserted into the old Peukert formula (as it was above), the answer will be misleadingly optimistic. Unfortunately, this fact is widely disregarded. Peukert's formula is still being used, and the performance of many batteries is being evaluated incorrectly.

The formula has been revised (initially by Chris Gibson of SmartGauge Electronics) to take into account the way in which Ah ratings are established today. Suppose that AhM is the modern rating for the battery's capacity in amp-hours, H is the duration in hours for which the battery was tested when the manufacturer calibrated it, n is Peukert's number (supplied by the manufacturer) as before, and I is the current you hope to draw from the battery. This is the revised formula to determine T:

$$\mathtt{T = H * (AhM / (I * H)^{n}\ )}$$

How do we know the value for H? Most (not all) manufacturers will supply this number in their battery specification. Alternatively, and confusingly, they may use the term *C-rate*, which can be defined as 1/H. This means you can easily get the value for H if you know the C-rate:

$$\mathtt{H = 1 / C\text{-}rate}$$

We can now use the revised formula to rework the original calculation. Going back to the example, if the battery was rated for 4Ah using the modern system, in a discharge test that lasted 20 hours (which is the same as a C-rate of 0.05), and the manufacturer still states that it has a Peukert number of 1.2, and we want to know for how long we can draw 5A from it:

$$\mathtt{T = 20 * (4/(5 * 20)^{1.2}) = approximately\ 20 * 0.021}$$

This is about 0.42 hours, or 25 minutes—quite different from the 35 minutes obtained with the old version of the formula, which should never be used when calculating the probable discharge time based on a modern Ah rating. These issues may seem arcane, but they are of great importance when assessing the likely performance of battery-powered equipment such as electric vehicles.

Figure 2-12 shows the probable actual performance of batteries with Peukert numbers of 1.1, 1.2, and 1.3. The curves were derived from the revised version of Peukert's formula and show how the number of amp-hours that you can expect diminishes for each battery as the current increases. For example, if a battery that the manufacturer has assigned a Peukert number of 1.2 is rated at 100Ah using the modern 20-hour test, but we draw 30A from it, the battery can actually deliver only 70Ah.

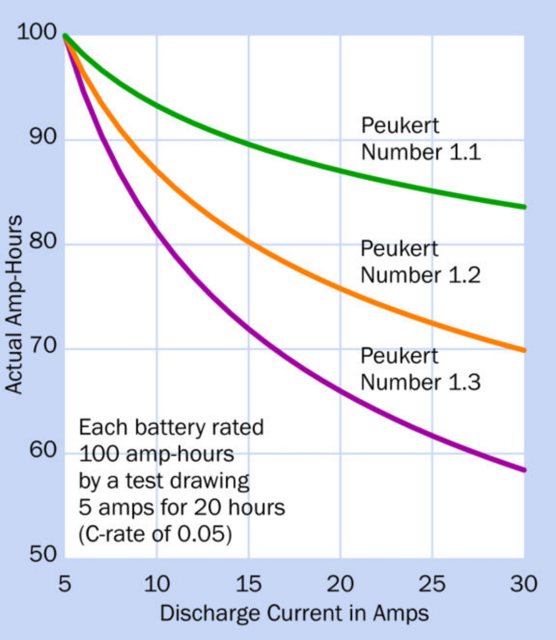

Figure 2-12. *Actual amp-hour performance that should be expected from three batteries of Peukert numbers 1.1, 1.2, and 1.3 when they discharge currents ranging from 5 to 30 amps, assuming that the manufacturer has rated each battery at 100Ah using the modern system, which usually entails a 20-hour test (a C-rate of 0.05).*

One additional factor: For any rechargeable battery, the Peukert number gradually increases with age, as the battery deteriorates chemically.

Voltage

The rated voltage of a fully charged battery is known as the *open circuit voltage* (abbreviated *OCV* or V_{oc}), defined as the potential that exists when no load is imposed between the terminals. Because the internal resistance of a volt meter (or a multimeter, when it is used to measure DC volts) is very high, it can be connected directly between the battery terminals with no other load present, and will show the OCV quite accurately, without risk of damage to the meter. A fully charged 12-volt car battery may have an OCV of about 12.6 volts, while a fresh 9-volt alkaline battery typically has an OCV of about 9.5 volts. Be extremely careful to set a multimeter to measure DC volts before connecting it across the battery. Usually this entails plugging the wire from the red probe into a socket separately reserved for measuring voltage, not amperage.

The voltage delivered by a battery will be pulled down significantly when a load is applied to it, and will decrease further as time passes during a discharge cycle. For these reasons, a **voltage regulator** is required when a battery powers components such as digital integrated circuit chips, which do not tolerate a wide variation in voltage.

To measure voltage while a load is applied to the battery, the meter must be connected in parallel with the load. See Figure 2-13. This type of measurement will give a reasonably accurate reading for the potential applied to the load, so long as the resistance of the load is relatively low compared with the internal resistance of the meter.

Figure 2-14 shows the performance of five commonly used sizes of alkaline batteries. The ratings in this chart were derived for alkaline batteries under favorable conditions, passing a small current through a relatively high-ohm load for long periods (40 to 400 hours, depending on battery type). The test continued until the final voltage for each 1.5V battery was 0.8V, and the final voltage for the 9V battery was a mere 4.8V. These voltages were considered acceptable when the

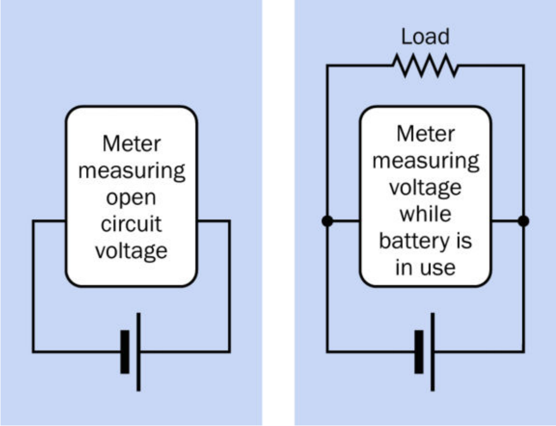

Figure 2-13. *When using a volt meter (or a multimeter configured to measure voltage), the meter can be applied directly between the battery terminals to determine the open-circuit voltage (OCV), or in parallel with a load to determine the voltage actually supplied during use. A multimeter must be set to measure DC volts before connecting it across a battery. Any other setting may damage the meter.*

Ah ratings for the batteries were calculated by the manufacturer, but in real-world situations, a final voltage of 4.8V from a 9V battery is likely to be unacceptable in many electronics applications.

Battery type	Rating (Ah)	Final voltage	Load (ohms)	Current (mA)
AAA	1.15	0.8	75	20
AA	2.87	0.8	75	20
C	7.8	0.8	39	40
D	17	0.8	39	40
9V	0.57	4.8	620	14

Figure 2-14. *The voltage delivered by a battery may drop to a low level while a manufacturer is establishing an amp-hour rating. Values for current, shown in the chart, were calculated subsequently as estimated averages, and should be considered approximate. (Derived from a chart published by Panasonic.)*

As a general rule of thumb, if an application does not tolerate a significant voltage drop, the manufacturer's amp-hour rating for a small battery may be divided by 2 to obtain a realistic number.

How to Use it

When choosing a battery to power a circuit, considerations will include the intended shelf life, maximum and typical current drain, and battery weight. The amp-hour rating of a battery can be used as a very approximate guide to determine its suitability. For 5V circuits that impose a drain of 100mA or less, it is common to use a 9V battery, or six 1.5V batteries in series, passing current through a **voltage regulator** such as the LM7805. Note that the voltage regulator requires energy to function, and thus it imposes a voltage drop that will be dissipated as heat. The minimum drop will vary depending on the type of regulator used.

Batteries or cells may be used in series or in parallel. In series, the total voltage of the chain of cells is found by summing their individual voltages, while their amp-hour rating remains the same as for a single cell, assuming that all the cells are identical. Wired in parallel, the total voltage of the cells remains the same as for a single cell, while the combined amp-hour value is found by summing their individual amp-hour ratings, assuming that all the batteries are identical. See Figure 2-15.

In addition to their obvious advantage of portability, batteries have an additional advantage of being generally free from power spikes and noise that can cause sensitive components to misbehave. Consequently, the need for smoothing will depend only on possible noise created by other components in the circuit.

Motors or other inductive loads draw an initial surge that can be many times the current that they use after they start running. A battery must be chosen that will tolerate this surge without damage.

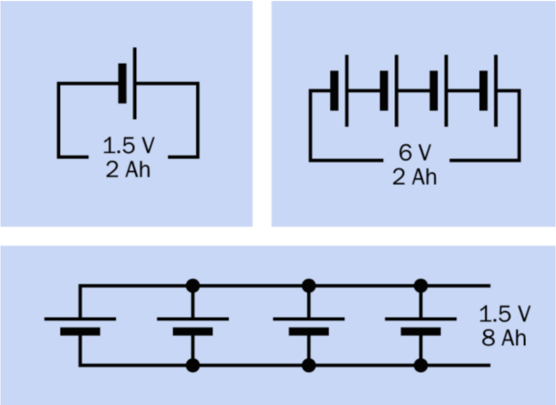

Figure 2-15. *Theoretical results of using 1.5V cells in series or in parallel, assuming a 2Ah rating for one cell.*

Because of the risk of fire, United States airline regulations limit the amp-hour capacity of lithium-ion batteries in any electronic device in carry-on or checked passenger baggage. If a device may be carried frequently as passenger baggage (for example, emergency medical equipment), NiMH batteries are preferred.

What Can Go Wrong

Short Circuits: Overheating and Fire

A battery capable of delivering significant current can overheat, catch fire, or even explode if it is short-circuited. Dropping a wrench across the terminals of a car battery will result in a bright flash, a loud noise, and some molten metal. Even a 1.5-volt alkaline AA battery can become too hot to touch if its terminals are shorted together. (Never try this with a rechargeable battery, which has a much lower internal resistance, allowing much higher flow of current.) Lithium-ion batteries are particularly dangerous, and almost always are packaged with a current-limiting component that should not be disabled. A short-circuited lithium battery can explode.

If a battery pack is used as a cheap and simple workbench DC power supply, a **fuse** or circuit breaker should be included. Any device that uses significant battery power should be fused.

Diminished Performance Caused by Improper Recharging

Many types of batteries require a precisely measured charging voltage and a cycle that ends automatically when the battery is fully charged. Failure to observe this protocol can result in chemical damage that may not be reversible. A charger should be used that is specifically intended for the type of battery. A detailed comparison of chargers and batteries is outside the scope of this encyclopedia.

Complete Discharge of Lead-Acid Battery

Complete or near-complete discharge of a lead-acid battery will significantly shorten its life (unless it is specifically designed for deep-cycle use —although even then, more than an 80% discharge is not generally recommended).

Inadequate Current

Chemical reactions inside a battery occur more slowly at low temperatures. Consequently, a cold battery cannot deliver as much current as a warm battery. For this reason, in winter weather, a car battery is less able to deliver high current. At the same time, because engine oil becomes more viscous as the temperature falls, the starter motor will demand more current to turn the engine. This combination of factors explains the tendency of car batteries to fail on cold winter mornings.

Incorrect Polarity

If a battery charger or generator is connected with a battery with incorrect polarity, the battery may experience permanent damage. The **fuse** or *circuit breaker* in a charger may prevent this from occurring and may also prevent damage to the charger, but this cannot be guaranteed.

If two high-capacity batteries are connected with opposite polarity (as may happen when a clumsy attempt is made to start a stalled car with jumper cables), the results may be explosive. Never lean over a car battery when attaching cables to it, and ideally, wear eye protection.

Reverse Charging

Reverse charging can occur when a battery becomes completely discharged while it is wired (correctly) in series with other batteries that are still delivering current. In the upper section of the schematic at Figure 2-16 two healthy 6V batteries, in series, are powering a resistive load. The battery on the left applies a potential of 6 volts to the battery on the right, which adds its own 6 volts to create a full 12 volts across the load. The red and blue lines indicate volt meter leads, and the numbers show the reading that should be observed on the meter.

In the second schematic, the battery on the left has become exhausted and is now a “dead weight” in the circuit, indicated by its gray color. The battery on the right still sustains a 6-volt potential. If the internal resistance of the dead battery is approximately 1 ohm and the resistance of the load is approximately 20 ohms, the potential across the dead battery will be about 0.3 volts, in the opposite direction to its normal charged voltage. Reverse charging will result and can damage the battery. To avoid this problem, a battery pack containing multiple cells should never be fully discharged.

Sulfurization

When a lead-acid battery is partially or completely discharged and is allowed to remain in that state, sulfur tends to build up on its metal plates. The sulfur gradually tends to harden, forming a barrier against the electrochemical reactions that are necessary to recharge the battery. For this reason, lead-acid batteries should not be allowed to sit for long periods in a discharged condition. Anecdotal evidence suggests that even a very small trickle-charging current can prevent sulfurization, which is why some people recommend attaching a small solar panel to a battery that is seldom used—for example, on a sail boat, where the sole function of the battery is to start an auxiliary engine when there is insufficient wind.

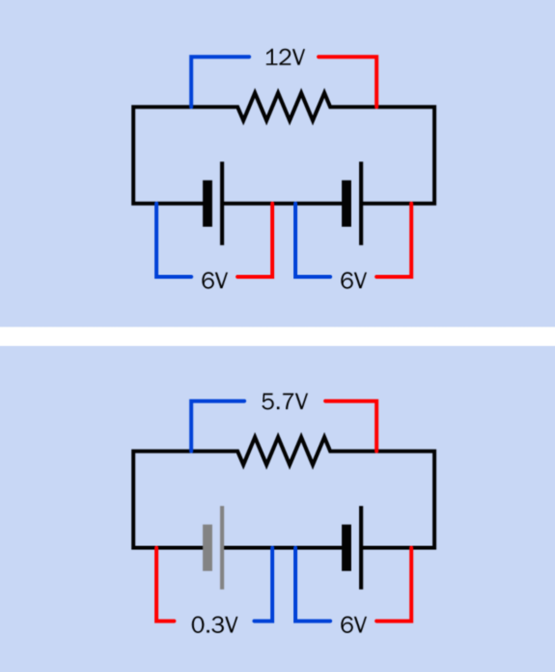

Figure 2-16. *When a pair of 6V batteries is placed in series to power a resistive load, if one of the batteries discharges completely, it becomes a load instead of a power source, and will be subjected to reverse charging, which may cause permanent damage.*

High Current Flow Between Parallel Batteries

If two batteries are connected in parallel, with correct polarity, but one of them is fully charged while the other is not, the charged battery will attempt to recharge its neighbor. Because the batteries are wired directly together, the current will be limited only by their internal resistance and the resistance of the cables connecting them. This may lead to overheating and possible damage. The risk becomes more significant when linking batteries that have high Ah ratings. Ideally they should be protected from one another by high-current **fuses.**

jumper

3

A jumper may also be referred to as a *jumper socket* or a *shunt*. A jumper should not be confused with *jumper wires*, which are not considered components for the purposes of this encyclopedia.

OTHER RELATED COMPONENTS

- **switch** (See Chapter 6)

What It Does

A jumper is a low-cost substitute for a **switch,** where a connection has to be made (or unmade) only a few times during the lifetime of a product. Typically it allows a function or feature on a circuit board to be set on a semipermanent basis, often at the time of manufacture. A *DIP switch* performs the same function more conveniently. See "DIP" (page 43).

There is no standardized schematic symbol to represent a jumper.

How It Works

A jumper is a very small rectangular plastic tab containing two (or sometimes more) metal sockets usually spaced either 0.1" or 2mm apart. The sockets are connected electrically inside the tab, so that when they are pushed over two (or more) pins that have been installed on a circuit board for this purpose, the jumper shorts the pins together. The pins are usually 0.025" square and are often part of a *header* that is soldered into the board. In a parts catalogue, jumpers may be found in a section titled "Headers and Wire Housings" or similar.

Three jumpers are shown in Figure 3-1. The blue one contains two sockets spaced 0.1" and is deep enough to enclose the pins completely. The red one contains two sockets spaced 2mm and may allow the tips of the pins to emerge from its opposite end. The black one contains four sockets, each pair spaced 0.1" apart.

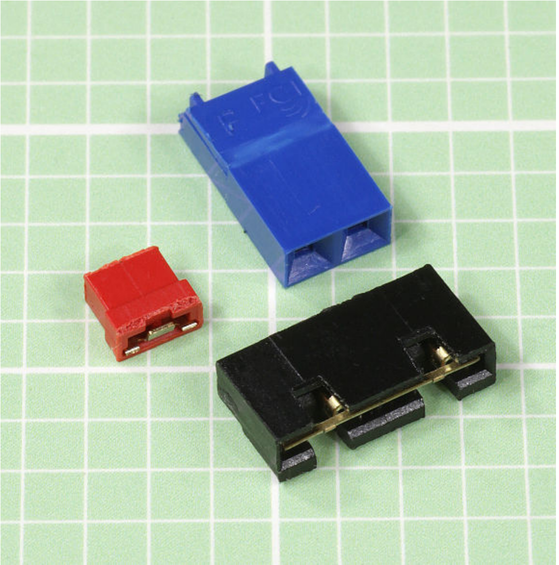

Figure 3-1. *Three jumpers containing two sockets spaced 2mm (left), two sockets spaced 0.1" (top right), and four sockets, each pair spaced 0.1" (bottom right).*

The set of pins with which a jumper is used is often referred to as a *header*. Headers are available with pins in single or dual rows. Some headers are designed to be snapped off to provide the desired number of pins. A dual 28-pin header is shown in Figure 3-2 with a black jumper pushed onto a pair of pins near the midpoint.

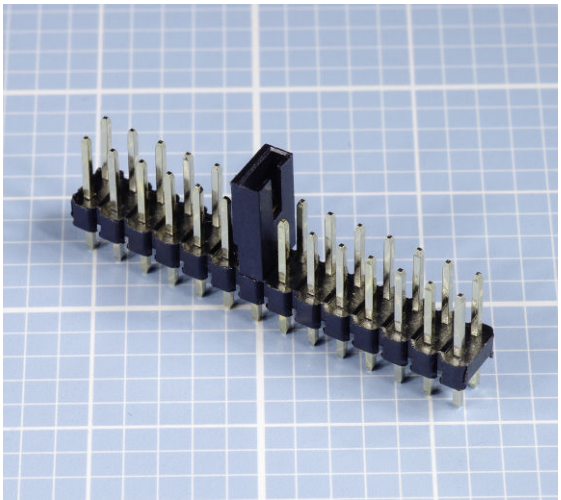

Figure 3-2. *A jumper pushed onto a pair of pins midway along a dual 28-pin header.*

Variants

A *jumper assembly* may be a kit containing not only the jumper but also the array of pins with which it is intended to be used. Check the manufacturer's datasheet to find out exactly what is included.

The most common types of jumpers have two sockets only, but variants are available with as many as 12 sockets, which may be arranged in one or two rows. *Header sockets* may be used as a substitute for purpose-made jumpers, with the advantage that they are often sold in long strips that can be snapped off to provide as many sockets as needed. However, the pins attached to header sockets must be manually connected by soldering small lengths of wire between them.

In some jumpers, the plastic tab extends upward for about half an inch and functions as a finger grip, making the jumper much easier to hold during insertion and removal. This is a desirable feature if there is room to accommodate it.

The sockets inside a jumper are often made from phosphor-bronze, copper-nickel alloy, tin alloy, or brass alloy. They are usually gold-plated, but in some instances are tin-plated.

Rarely, a jumper may consist of a metal strip with U-shaped connections suitable for being used in conjunction with screw terminals. Two jumpers of this type are shown in Figure 3-3. They should not be confused with high-amperage fuses that look superficially similar.

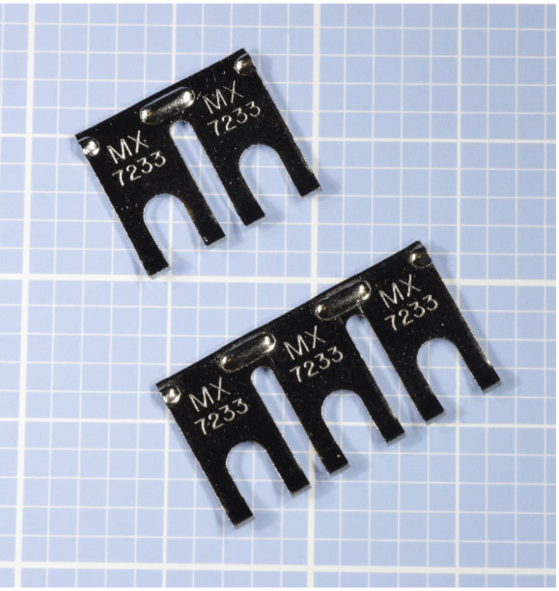

Figure 3-3. *These jumpers are designed to short together two or three screw terminals.*

Values

The spacing between the sockets in a jumper is referred to as its *pitch*. As previously noted, 0.1" and 2mm are the most popular values.

A typical maximum rating for a jumper of 0.1" pitch is 2A or 2.5A at 250V.

How to Use it

A jumper may activate a “set it and forget it” circuit function. An example would be the factory configuration of a product to work with 115VAC or 230VAC power input. End users were expected to set jumpers in some computer equipment sold during the 1980s, but this is no longer the case.

What Can Go Wrong

Jumpers are easily dropped, easily lost, and easily placed incorrectly. When purchasing jumpers, buy extras to compensate for their fragility and the ease of losing them.

Any location where a jumper may be used should be clearly labelled to define the function of each setting.

Cheap, poorly made jumpers may self-destruct from mechanical stresses when removed from their pins. The plastic casing can come away, leaving the sockets clinging naked to the pins protruding from the circuit board. This is another reason why it is a good idea to have a small stock of spare jumpers for emergencies.

Oxidation in jumpers where the contacts are not gold- or silver-plated can create electrical resistance or unreliable connections.

fuse

4

The alternate spelling *fuze* is seldom used.

OTHER RELATED COMPONENTS

- None

What It Does

A fuse protects an electrical circuit or device from excessive current when a metal element inside it melts to create an open circuit. With the exception of *resettable fuses* (discussed separately in "Resettable Fuses" (page 24)), a fuse must be discarded and replaced after it has fulfilled its function.

When high current melts a fuse, it is said to *blow* or *trip* the fuse. (In the case of a resettable fuse, only the word *trip* is used.)

A fuse can work with either AC or DC voltage, and can be designed for almost any current. In residential and commercial buildings, *circuit breakers* have become common, but a large cartridge fuse may still be used to protect the whole system from short-circuits or from overcurrent caused by lightning strikes on exposed power lines.

In electronic devices, the **power supply** is almost always fused.

Schematic symbols for a fuse are shown in Figure 4-1. Those at the right and second from right are most frequently used. The one in the center is approved by ANSI, IEC, and IEEE but is seldom seen. To the left of that is the fuse symbol understood by electrical contractors in architectural plans. The symbol at far left used to be common but has fallen into disuse.

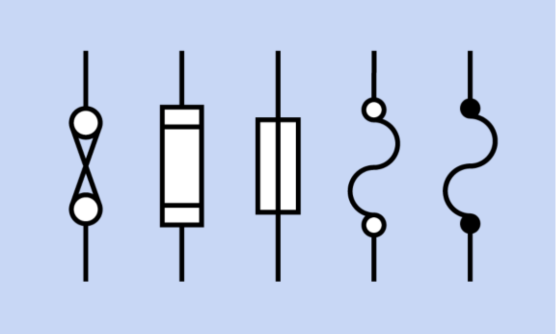

Figure 4-1. *Alternate schematic symbols for a fuse. See text for explanation.*

How It Works

The *element* in a fuse is usually a wire or thin metal strip mounted between two terminals. In a cartridge fuse, it is enclosed in a glass or ceramic cylinder with a contact at each end, or in a small metallic can. (Old-style, large, high-amperage fuses may be packaged in a paper or cardboard tube.) The traditional glass cartridge allows visual inspection to confirm that the fuse has blown.

A fuse responds only to current, not to voltage. When choosing a fuse that will be reliable in conditions of steady current consumption, a safe rule is to figure the maximum amperage when all components are functioning and add 50%. However, if current surges or spikes are likely, their duration will be relevant. If I is the current surge in amps and t is its duration in seconds, the surge sensitivity of a fuse—which is often referred to verbally or in printed format as I2t—is given by the formula:

```
I2t = I² * t
```

Some semiconductors also have an I2t rating, and should be protected with a similarly rated fuse.

Any fuse will present some resistance to the current flowing through it. Otherwise, the current would not generate the heat that blows the fuse. Manufacturer datasheets list the voltage drop that the internal resistance of a fuse is likely to introduce into a circuit.

Values

The *current rating* or *rated current* of a fuse is usually printed or stamped on its casing, and is the maximum flow that it should withstand on a continuous basis, at the ambient temperature specified by the manufacturer (usually 25 degrees Centigrade). The ambient temperature refers to the immediate environment of the fuse, not the larger area in which it may be located. Note that in an enclosure containing other components, the temperature is usually significantly higher than outside the enclosure.

Ideally a fuse should function reliably and indefinitely at its rated maximum amperage, but should blow just as reliably if the current rises by approximately 20% beyond the maximum. In reality, manufacturers recommend that continuous loading of a fuse should not exceed 75% of its rating at 25 degrees Centigrade.

The *voltage rating* or *rated voltage* of a fuse is the maximum voltage at which its element can be counted on to melt in a safe and predictable manner when it is overloaded by excess current. This is sometimes known as the *breaking capacity*. Above that rating, the remaining pieces of the fuse element may form an arc that sustains some electrical conduction.

A fuse can always be used at a lower voltage than its rating. If it has a breaking capacity of 250V, it will still provide the same protection if it is used at 5V.

Four differently rated glass cartridge fuses are shown in Figure 4-2. The one at the top is a slow-blowing type, rated at 15A. Its element is designed to absorb heat before melting. Below it is a 0.5A fuse with a correspondingly thinner element. The two smaller fuses are rated at 5A each. The center two fuses have a maximum voltage rating of 250V, while the one at the top is rated at 32V and the one at the bottom is rated at 350V. Clearly, the size of a fuse should never be used as a guide to its ratings.

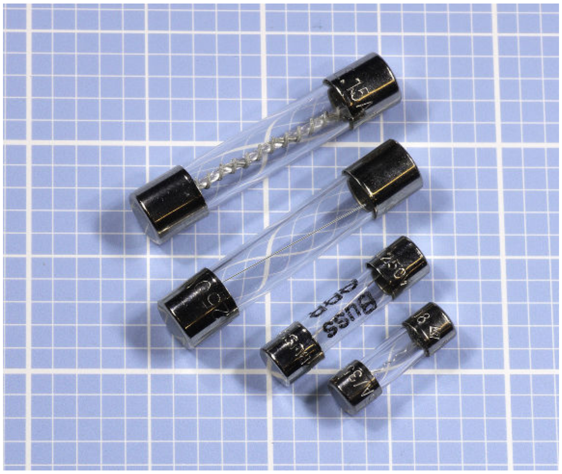

Figure 4-2. *Four glass cartridge fuses. See text for details.*

Variants

Early power fuses in residential buildings consisted of bare nichrome wire wrapped around a porcelain holder. In the 1890s, Edison developed *plug fuses* in which the fuse was contained in a porcelain module with a screw thread, compatible with the base of an incandescent bulb. This design persisted in some U.S. urban areas for more than 70 years, is still found in old buildings, and is still being manufactured.

Small Cartridge Fuses

Small cartridge fuses for appliances and electronics equipment—such as those shown in Figure 4-2--are available in sizes tabulated in Figure 4-3. With the exception of the 4.5mm diameter fuse (a European addition), these sizes were originally measured in inches; today, they are often described only with the equivalent metric measurement. Any cartridge fuse is usually available with the option of a lead attached to it at each end, so that it can be used as a through-hole component.

Fuse type	Diameter (inches)	Diameter (metric)	Length (inches)	Length (metric)
1AG	1/4"	6mm	5/8"	16mm
2AG	0.177"	4.5mm	0.588"	15mm
3AG	1/4"	6mm	1-1/4"	32mm
4AG	9/32"	7mm	1-1/4"	32mm
5AG	13/32"	10mm	1-1/2"	38mm
7AG	1/4"	6mm	7/8"	22mm
8AG	1/4"	6mm	1"	25mm

Figure 4-3. *The approximate physical sizes of commonly used small glass or ceramic cartridge fuses are shown here with the codes that are often used to identify them.*

Fuses may be fast acting, medium acting, or slow-blowing, the last of which may alternatively be referred to as *delay fuses*. Extra-fast–acting fuses are available from some manufacturers. The term *Slo-Blo* is often used but is actually a trademark of Littelfuse. None of the terms describing the speed of action of a fuse has been standardized with a specific time or time range.

Some cartridge fuses are available in a ceramic format as an alternative to the more common glass cylinder. If accidental application of extremely high current is possible (for example, in a multimeter that can be set to measure amps, and may be accidentally connected across a powerful battery), a ceramic cartridge is preferable because it contains a filler that will help to stop an arc from forming. Also, if a fuse is physically destroyed by application of very high current, ceramic fragments may be preferable to glass fragments.

Automotive Fuses

Automotive fuses are identifiable by their use of blades designed for insertion in flat sockets where the fuse is unlikely to loosen as a result of vibration or temperature changes. The fuses come in various sizes, and are uniformly color-coded for easy identification.

A selection of automotive fuses is shown in Figure 4-4. The type at the top is typically described as a "maxi-fuse" while the type at bottom-left is a "mini-fuse." Here again, size is irrelevant to function, as all three of those pictured are rated 30A at 32V.

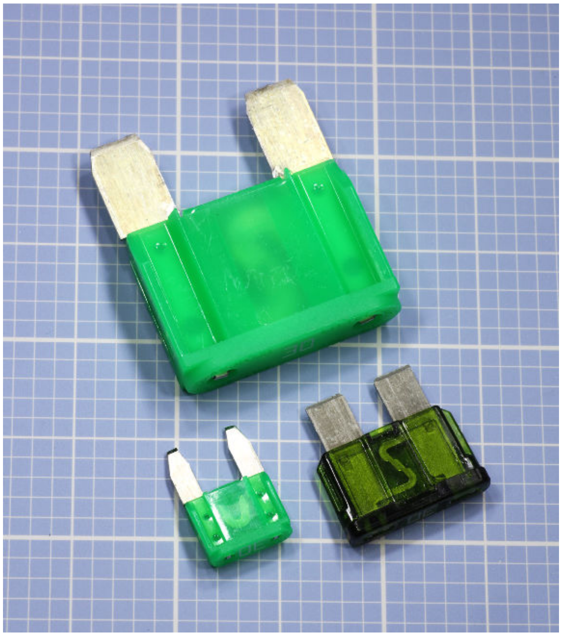

Figure 4-4. *Three automotive fuses. All have the same rating: 30A at 32V.*

In Figure 4-5, the largest of the fuses from Figure 4-4 has been cut open to reveal its element.

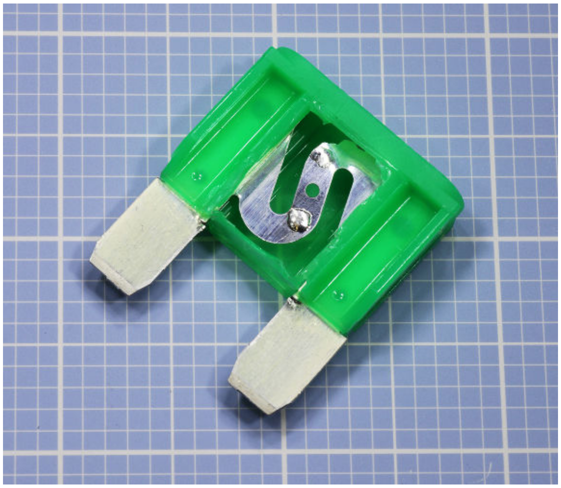

Figure 4-5. *The largest fuse from the previous figure, cut open to reveal its element.*

Usually automotive fuses are mounted together in a block, but if aftermarket accessory equipment is added, it may be protected by an inline fuse in a holder that terminates in two wires. This is shown with two sample fuses in Figure 4-6. Similar inline fuse holders are manufactured for other types of fuses.

Strip Fuses

High-amperage fuses for vehicles may be sold in "strip fuse" format, also known as a *fusible link*, designed to be clamped between two screw-down terminals. Since some **jumpers** may look very similar, it is important to keep them separate. A strip fuse is shown in Figure 4-7.

Through-Hole Fuses

Small fuses with radial leads, which seem appropriate for through-hole insertion in printed circuit boards, are actually often used in conjunction with appropriate sockets, so that they can be easily replaced. They are described in catalogues as "subminiature fuses" and are typically found in laptop computers and their power supplies, also televisions, battery chargers, and air conditioners. Three examples are shown in Figure 4-8. All have slow-blowing characteristics.

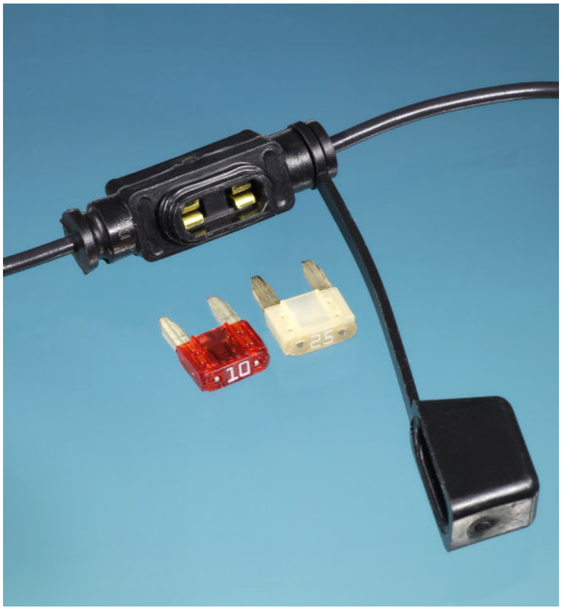

Figure 4-6. *Two blade-type fuses, commonly used for automotive applications, shown with an inline fuse holder. The plastic cap, at right, is closed over the holder when a fuse has been installed.*

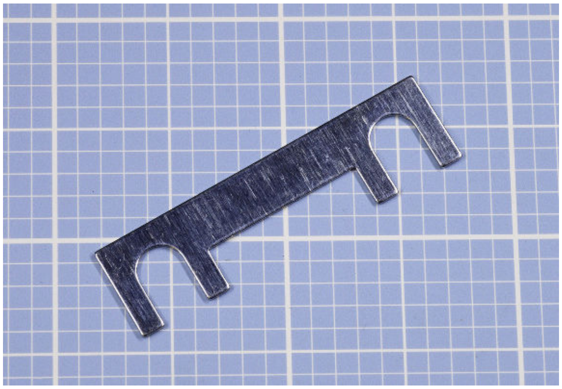

Figure 4-7. *This strip fuse is intended for use in diesel vehicles. The example shown is rated 100A at 36V.*

Resettable Fuses

Properly known as a *polymeric positive temperature coefficient* fuse (often abbreviated *PTC* or *PPTC*), a *resettable fuse* is a solid-state, encapsulated component that greatly increases its resistance in response to a current overload, but gradually returns to its original condition when the flow of current is discontinued. It can be thought

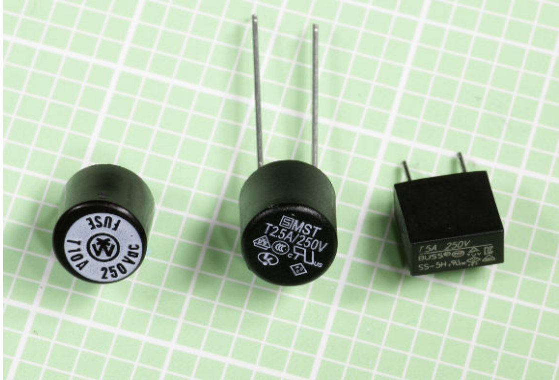

Figure 4-8. *Three subminiature fuses terminating in wire leads. From left to right: 10A at 250V, 2.5A at 250V, and 5A at 250V.*

of as a **thermistor** that has a nonlinear response. Three through-hole examples are shown in Figure 4-9. While different sizes of cartridge fuse may share the same ratings, differently rated resettable fuses may be identical in size. The one on the left is rated 40A at 30V, while the one on the right is rated 2.5A at 30V. (Note that the codes printed on the fuses are not the same as their manufacturer part numbers.) The fuse at the top is rated 1A at 135V.

When more than the maximum current passes through the fuse, its internal resistance increases suddenly from a few ohms to hundreds of thousands of ohms. This is known as *tripping* the fuse. This inevitably entails a small delay, but is comparable to the time taken for a slow-blowing fuse to respond.

A resettable fuse contains a polymer whose crystalline structure is loaded with graphite particles that conduct electricity. As current flowing through the fuse induces heat, the polymer transitions to an amorphous state, separating the graphite particles and interrupting the conductive pathways. A small current still passes through the component, sufficient to maintain its amorphous state until power is disconnected.

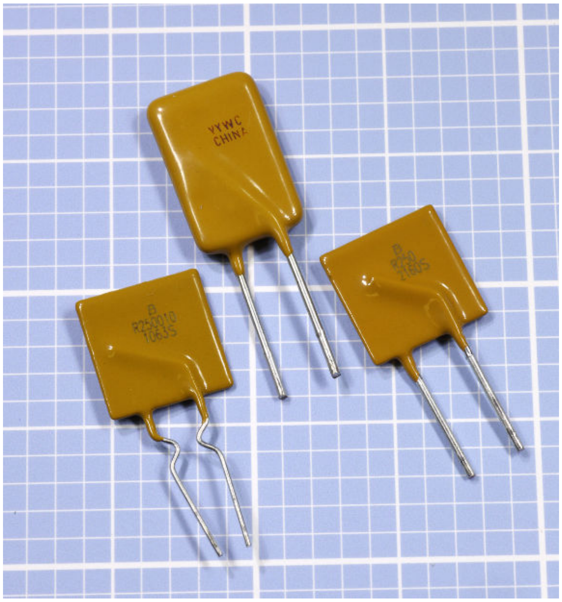

Figure 4-9. *Some through-hole resettable fuses. See text for details.*

After the resettable fuse cools, it gradually recrystallizes, although its resistance does not fall back completely to its original value for more than an hour.

The maximum safe level of current for a resettable fuse is known as the *hold current*, while the current that triggers its response is termed the *trip current*. Resettable fuses are available with trip-current ratings from 20mA to 100A. While conventional appliance and electronics fuses may be rated as high as 600V, resettable fuses are seldom rated above 100V.

Typical cartridge fuses are affected only to a minor extent by temperature, but the current rating of a resettable fuse may diminish to 75% of its normal value at 50 degrees Centigrade and may drop to 50% of its normal value at 80 degrees Centigrade. In other words, a fuse that is rated for 4A at 25 degrees may tolerate a maximum of only 3A when it operates at twice that temperature. See Figure 4-10.

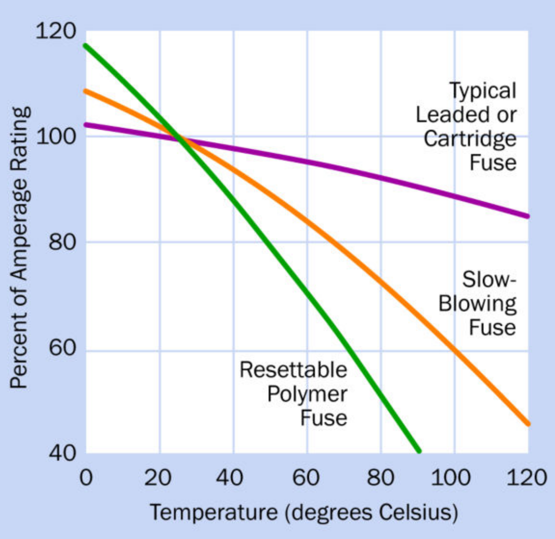

Figure 4-10. *The three curves give a very approximate idea of the temperature sensitivity of three types of fuses commonly used to protect electronic equipment. The left-hand scale provides an approximate value for the amperage which will trip the fuse.*

Conventional slow-blowing fuses are temperature-sensitive, but to a lesser degree than resettable fuses.

Resettable fuses are used in computer power supplies, USB power sources, and loudspeaker enclosures, where they protect the speaker coils from being overdriven. They are appropriate in situations where a fuse may be tripped relatively often, or where technically unsophisticated users may feel unable to replace a fuse or reset a circuit breaker.

Brand names for resettable fuses include PolySwitch, OptiReset, Everfuse, Polyfuse, and Multifuse. They are available in *surface-mount* (SMT) packages or as *through-hole* components, but not in cartridge format.

Surface Mount Fuses

Because surface-mount fuses are difficult or impossible to replace after they have been soldered onto the board, they are often resettable.

A surface-mount resettable fuse approximately 0.3″ square is shown in Figure 4-11. It is rated for 230V and has an internal resistance of 50 ohms. Its hold current is 0.09A and its trip current is 0.19A.

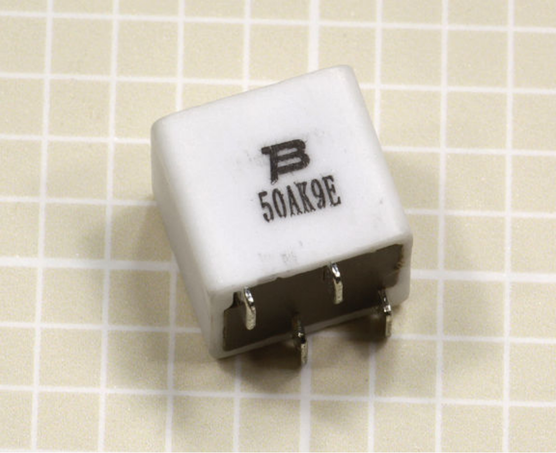

Figure 4-11. *A surface-mount resettable fuse. See text for details.*

How to Use it

Any equipment that may be plugged into a wall outlet should be fused, not only to protect its components but also to protect users who may open the box and start investigating with a screwdriver.

Equipment that contains powerful motors, pumps, or other inductive loads should be protected with slow-blowing fuses, as the initial surge of current when the equipment is switched on is likely to rise well above the rating of the fuse. A slow-blowing fuse will tolerate a surge for a couple of seconds. Other fuses will not.

Conversely, fast-acting fuses should be used with electronic equipment, especially integrated circuits that are quickly and easily damaged.

Any device using substantial **battery** power should be fused because of the unpredictable and generally bad behavior of batteries when they are short-circuited. Parallel connections between multiple large batteries should be fused to avoid the possibility that a highly charged battery may attempt to recharge its neighbor(s). Large "J size" fuses rated from 125A to 450A have become common in the solar power community, where banks of lead-acid batteries are often used. These fuses have a thick brass tab at each end, drilled so that they can be bolted into place. Alternatively, they will push-fit into an appropriate *fuseholder*.

For cartridge fuses up to 1/4" in diameter that don't have leads attached, appropriately sized fuseholders are available in several formats:

Panel mounted fuse enclosure is probably the most common, consisting of a plastic tube with a spring-contact at the bottom, and a plastic cap with a second contact inside. The cap either screws onto the tube of the fuse, or is pushed down and turned to hold it in place. A nut is provided to secure the fuseholder after it has been inserted into a hole drilled in the panel. The fuse is dropped into the tube, and the cap is applied. This type of holder is available in full-length or shorter, "low profile" formats. A low-profile holder is shown in Figure 4-12. It is shown assembled at right, with its component parts disassembled alongside.

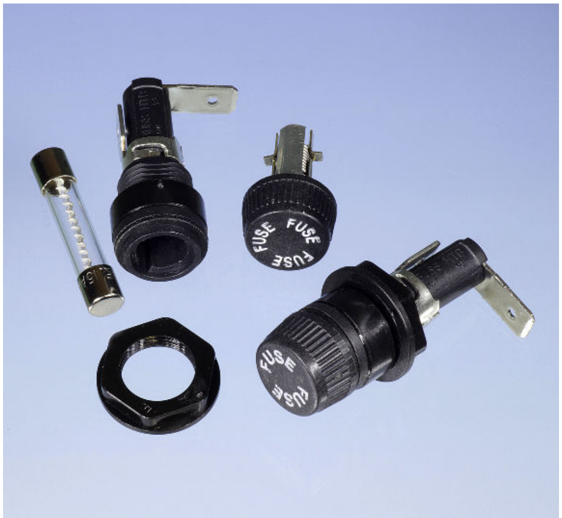

Figure 4-12. *A low-profile panel-mounted fuse holder shown disassembled (left) and assembled (right).*

Circuit board mounted fuse enclosure is basically the same as the panel-mounted version, but with through-hole solder pins attached.

Fuse block is a small plastic block with two clips on its upper surface for insertion of a cartridge fuse.

Fuse clips can be bought individually, with solder pins for through-hole mounting.

Inline fuse holder is designed to be inserted in a length of wire. Usually made of plastic, it will either terminate it, wires or will have metal contacts to crimp or solder at each end. See Figure 4-6.

Through-hole fuse holders are available for subminiature fuses.

What Can Go Wrong

Repeated Failure

When a fuse in a circuit blows frequently, this is known as *nuisance opening*. Often it can result from failure to take into account all the aspects of the circuit, such as a large filtering capacitor in a power supply that draws a major surge of current when the power supply is switched on. The formally correct procedure to address this problem is to measure the power surge, properly known as *peak inrush current*, with an oscilloscope, calculate the $I^2 * t$ of the wave form, and select a fuse with a rating at least 5 times that value.

A fuse should never be replaced with an equivalent length of wire or any other conductor.

Soldering Damage

When a through-hole or surface-mount fuse is soldered into place, heat from the soldering process can cause the soft metal element inside the fuse to melt partially and reflow. This is likely to change the rating of the fuse. Generally, fuses should be treated with the same caution as semiconductors when they are fixed in place with solder.

Placement

A fuse should be placed close to the power source or power input point in a circuit, so that it protects as much of the circuit as possible.

pushbutton

5

Often referred to as a *pushbutton switch* and sometimes as a *momentary switch*. In this encyclopedia, a pushbutton is considered separately from a **switch**, which generally uses a lever-shaped actuator rather than a button, and has at least one *pole* contact where a pushbutton generally has contacts that are not distinguishable from each other.

OTHER RELATED COMPONENTS

- **switch** (See Chapter 6)
- **rotary switch** (See Chapter 7)

What It Does

A pushbutton contains at least two contacts, which close or open when the button is pressed. Usually a spring restores the button to its original position when external pressure is released. Figure 5-1 shows schematic symbols for pushbuttons. The symbols that share each blue rectangle are functionally identical. At top is a normally-open single-throw pushbutton. At center is a normally-closed single-throw pushbutton. At bottom is a double-throw pushbutton.

Unlike a **switch**, a basic pushbutton does not have a primary contact that can be identified as the *pole*. However, a single pushbutton may close or open two separate pairs of contacts, in which case it can be referred to, a little misleadingly, as a double-pole pushbutton. See Figure 5-2. Different symbols are used for slider pushbuttons with multiple contact pairs; see "Slider" (page 31).

A generic full-size, two-contact pushbutton is shown in Figure 5-3.

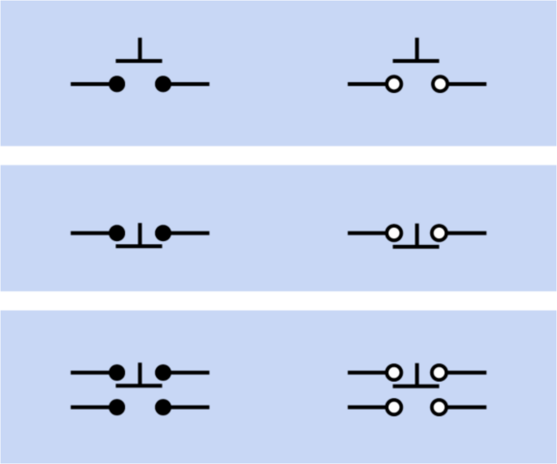

Figure 5-1. *Commonly used schematic symbols to represent a simple pushbutton. See text for details.*

How It Works

Figure 5-4 shows a cross-section of a pushbutton that has a single steel return spring, to create resistance to downward force on the button, and a pair of springs above a pair of contacts, to hold each contact in place and make a firm connection when the button is pressed. The two upper contacts are electrically linked, although this feature is not shown.

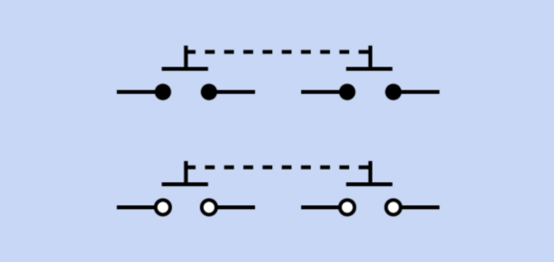

Figure 5-2. *Commonly used schematic symbols to represent a double-pole pushbutton.*

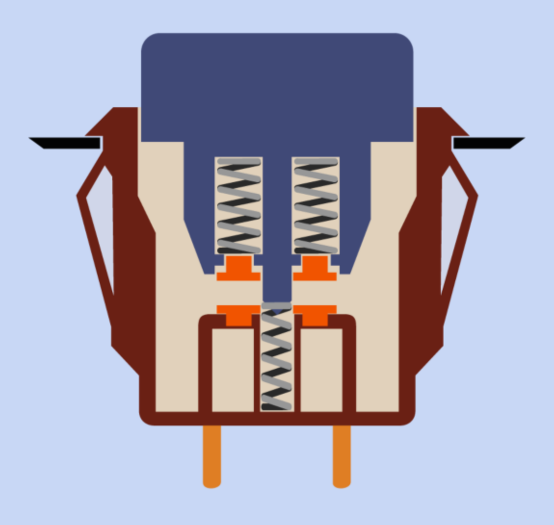

Figure 5-4. *Cross-section of a pushbutton showing two spring-loaded contacts and a single return spring.*

Variants

Poles and Throws

Abbreviations that identify the number of poles and contacts inside a pushbutton are the same as the abbreviations that identify those attributes in a **switch**. A few examples will make this clear:

SPST, also known as 1P1T
Single pole, single throw

DPST also known as 2P1T
Double pole, single throw

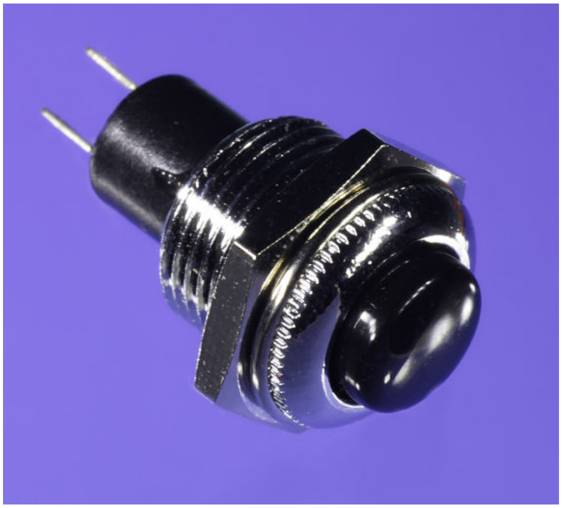

Figure 5-3. *The simplest, traditional form of pushbutton, in which pressing the button creates a connection between two contacts.*

SPDT also known as 1P2T
Single pole, double throw

3PST also known as 3P1T
Three pole, single throw

While a switch may have an additional center position, pushbuttons generally do not.

On-Off Behavior

Parentheses are used to indicate the momentary state of the pushbutton while it is pressed. It will return to the other state by default.

OFF-(ON) or (ON)-OFF
Contacts are normally open by default, and are closed only while the button is pressed. This is sometimes described as a *make-to-make* connection, or as a *Form A* pushbutton.

ON-(OFF) or (OFF)-ON
Contacts are normally closed by default, and are open only while the button is pressed. This is sometimes described as a *make-to-break* connection, or as a *Form B* pushbutton.

ON-(ON) or (ON)-ON
This is a double-throw pushbutton in which one set of contacts is normally closed. When the button is pressed, the first set of contacts

is opened and the other set of contacts is closed, until the button is released. This is sometimes described as a *Form C* pushbutton.

For a single-throw pushbutton, the terms NC or NO may be used to describe it as *normally closed* or *normally open*.

Slider

This type, also known as a *slide* pushbutton, contains a thin bar or rod that slides in and out of a long, narrow enclosure. Contacts on the rod rub across secondary contacts inside the enclosure. Closely resembling a slider switch, it is cheap, compact, and well adapted for multiple connections (up to 8 separate poles in some models). However, it can only tolerate low currents, has limited durability, and is vulnerable to contamination.

A four-pole, double-throw pushbutton is shown in Figure 5-5. A variety of plastic caps can be obtained to press-fit onto the end of the white nylon actuator.

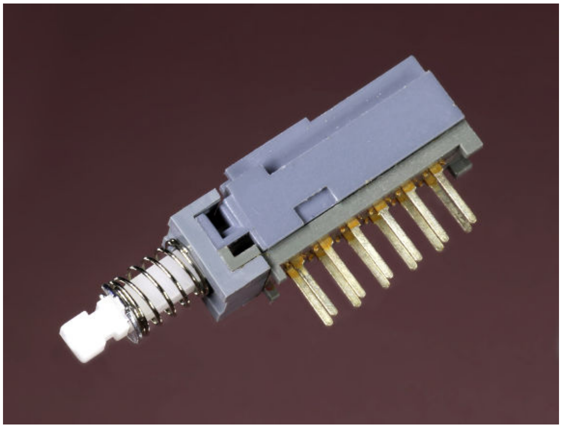

Figure 5-5. *A 4PDT slider pushbutton, shown without the cap that can be snapped onto the end of the actuator.*

Figure 5-6 shows schematic symbols for two possible slide pushbuttons, with a black rectangle indicating each sliding contact. The lead that functions as a pole is marked with a P in each case. Standardization for slide pushbutton schematic symbols does not really exist, but these examples are fairly typical. An insulating section that connects the sliding contacts internally is shown here as a gray rectangle, but in some datasheets may appear as a line or an open rectangle.

Since the symbols for a slide pushbutton may be identical to the symbols for a slide switch, care must be taken when examining a schematic, to determine which type of component is intended.

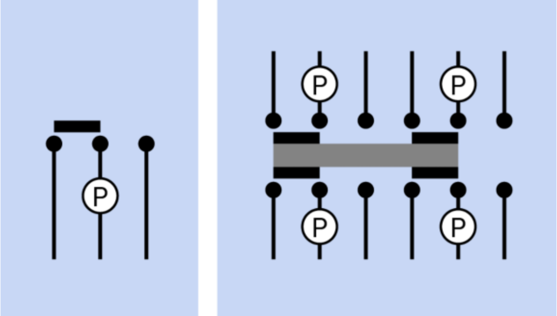

Figure 5-6. *Left: schematic symbol for a simple SPDT slide pushbutton, where a movable contact shorts together either the left pair or right pair of fixed contacts. Right: A 4PDT pushbutton in which the same principle has been extended. The movable contacts are attached to each other mechanically by an insulator. Each pole terminal is marked with a P.*

Styles

Many pushbutton switches are sold without caps attached. This allows the user to choose from a selection of styles and colors. Typically the cap is a push-fit onto the end of the rod or bar that activates the internal contacts. Some sample caps are shown in Figure 5-7, alongside a DPDT pushbutton. Any of the caps will snap-fit onto its actuator.

An *illuminated* pushbutton contains a small *incandescent bulb*, *neon bulb*, or **LED** (*light-emitting diode*). The light source almost always has its own two terminals, which are isolated from the other terminals on the button housing and can be wired to activate the light when the button is pressed, when it is released, or on some other basis. Pushbuttons containing LEDs usually

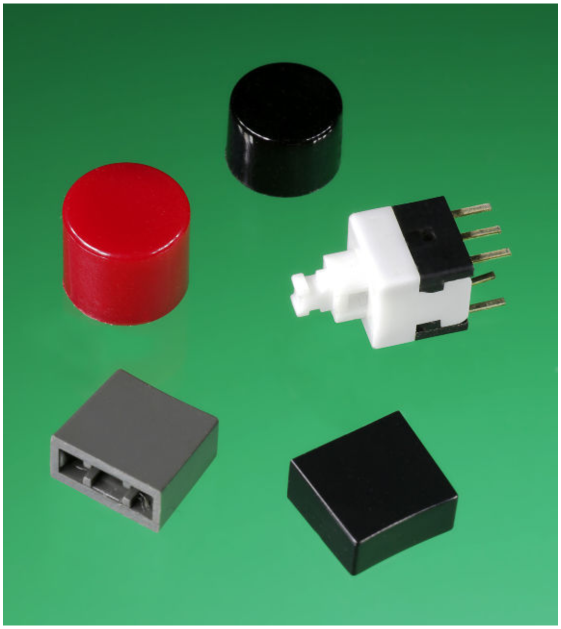

Figure 5-7. *Caps (buttons or knobs) that may be sold as separate accessories for some pushbuttons, shown here alongside a compatible pushbutton switch.*

require external series resistors, which should be chosen according to the voltage that will be used. See the **LED** entry in Volume 2 for additional commentary on appropriate series resistors. An example of an illuminated pushbutton is shown in Figure 5-8. This is a DPDT component, designed to be mounted on a printed circuit board, with an additional lead at each end connecting with an internal LED underneath the translucent white button.

Termination and Contact Plating

These options are the same as for a **switch** and are described in that entry.

Mounting Style

The traditional panel-mounted button is usually secured through a hole in the panel by tightening a nut that engages with a thread on the bushing of the pushbutton. Alternatively, a pushbutton housing can have flexible plastic protrusions on either side, allowing it to be snapped into place in an appropriate-sized panel cutout. This style is shown in Figure 5-4.

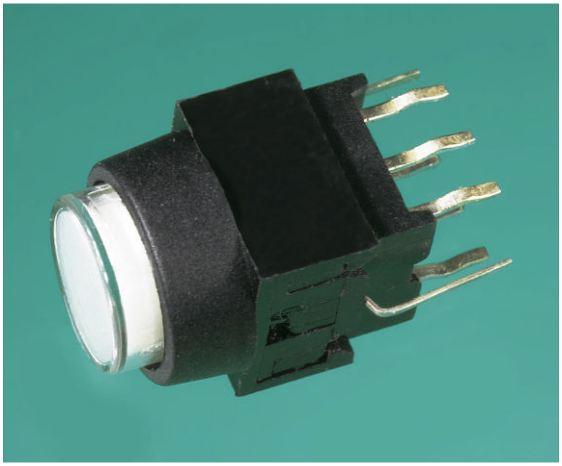

Figure 5-8. *This pushbutton contains an LED underneath the white translucent button.*

PC pushbuttons (pushbuttons mounted in a printed circuit board, or PCB) are a common variant. After the component has been installed in the circuit board, either the button must align with a cutout in the front panel and poke through it when the device is assembled, or an external (non-electrical) button that is part of the product enclosure must press on the actuator of the pushbutton after assembly.

Surface-mount pushbuttons that allow direct fingertip access are uncommon. However, about one-quarter of tactile switches are designed for surface mount at the time of writing. They are typically found beneath membranes that the user presses to activate the switch beneath—for example, in remotes that are used to operate electronic devices.

Sealed or Unsealed

A sealed pushbutton will include protection against water, dust, dirt, and other environmental hazards, at some additional cost.

Latching

This variant, also known as a *press-twice* pushbutton, contains a mechanical ratchet, which is rotated each time the button is pressed. The first press causes contacts to latch in the closed state. The second press returns the contacts to the open state, after which, the process repeats. This press-twice design is typically found on flashlights, audio equipment, and in automotive applications. While *latching* is the most commonly used term, it is also known as *push-push*, *locking*, *push-lock push-release*, *push-on push-off*, and *alternate*.

In a latching pushbutton with *lockdown*, the button is visibly lower in the latched state than in the unlatched state. However, buttons that behave this way are not always identified as doing so on their datasheets.

A six-pole double-throw pushbutton that latches and then unlatches each time it is pressed is shown in Figure 5-9.

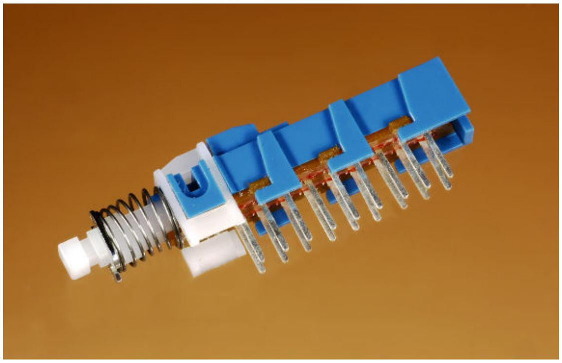

Figure 5-9. *This 6PDT pushbutton latches and then unlatches, each time it is pressed.*

Two more variants are shown in Figure 5-10. On the right is a simple DPDT latching pushbutton with lockdown. On the left is a latching pushbutton that cycles through four states, beginning with one "off" state, the remaining three connecting a different pair of its wires in turn.

A simple OFF-(ON) button may appear to have a latching output if it sends a pulse to a **microcontroller** in which software inside the microcontroller toggles an output between two states. The microcontroller can step through an unlimited number of options in response to each button press. Examples are found on cellular phones or portable media players.

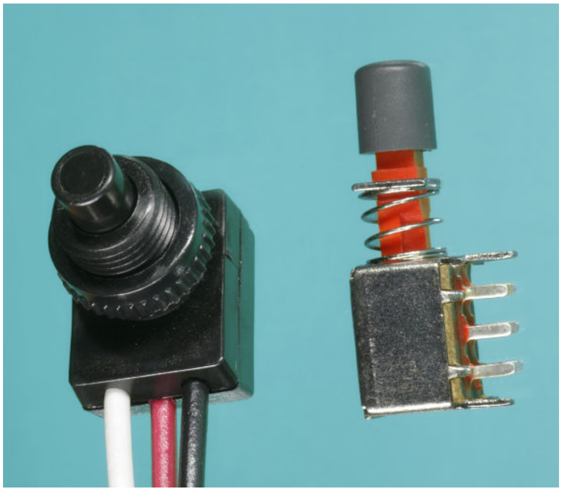

Figure 5-10. *At right, a simple DPDT latching pushbutton with lockdown. At left, this pushbutton cycles through four states, one of them an "off" state, the others connecting a different pair of its wires in turn.*

A mechanically latching pushbutton has a higher failure rate than a simple OFF-(ON) button, as a result of its internal mechanism, but has the advantage of requiring no additional microcontroller to create its output. Microcontrollers are discussed in Volume 2.

Foot Pedal

Foot pedal pushbuttons generally require more actuation force than those intended for manual use. They are ruggedly built and are commonly found in vacuum cleaners, audio-transcription foot pedals, and "stomp boxes" used by musicians.

Keypad

A keypad is a rectangular array of usually 12 or 16 OFF-(ON) buttons. Their contacts are accessed via a *header* suitable for connection with a ribbon cable or insertion into a printed circuit board. In some keypads, each button connects with a separate contact in the header, while all the buttons share a common ground. More often, the buttons are *matrix encoded*, meaning that each of them bridges a unique pair of conductors in a matrix. A 16-button matrix is shown in Figure 5-11. This configuration is suitable for polling by a **microcontroller**, which can be programmed to send an output pulse to each of the four horizontal wires in turn. During each pulse, it checks the remaining four vertical wires in sequence, to determine which one, if any, is carrying a signal. Pullup or pulldown resistors should be added to the input wires to prevent the inputs of the microcontroller from behaving unpredictably when no signal is present. The external appearance of two keypads is shown in Figure 5-12.

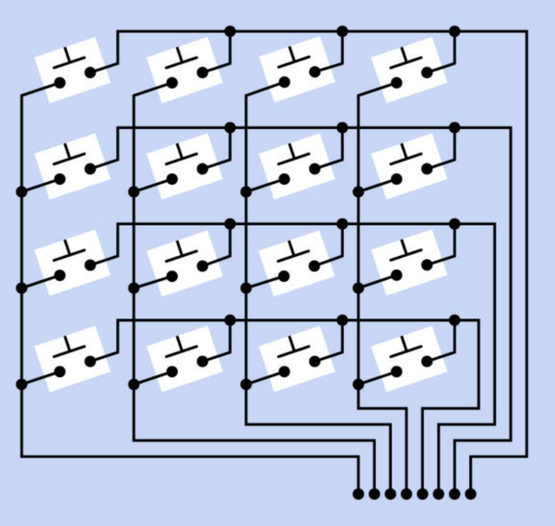

Figure 5-11. *Buttons in a numeric keypad are usually wired as a matrix, where each button makes a connection between a unique pair of wires. This system is suitable for being polled by a microcontroller.*

Tactile Switch

Despite being called a switch, this is a miniature pushbutton, less than 0.4″ square, designed for insertion in a printed-circuit board or in a solderless breadboard. It is almost always a SPST device but may have four pins, one pair connected to each contact. Tactile switches may be PC-mounted behind membrane pads. An example is shown in Figure 5-13.

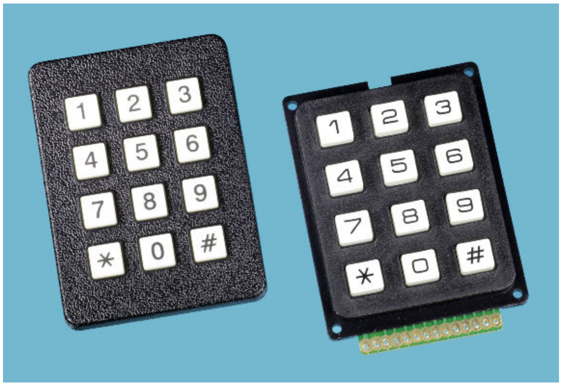

Figure 5-12. *The keypad on the left is matrix-encoded, and is polled via seven through-hole pins that protrude behind it. The keypad on the right assigns each button to a separate contact in its header. See the text for details about matrix encoding.*

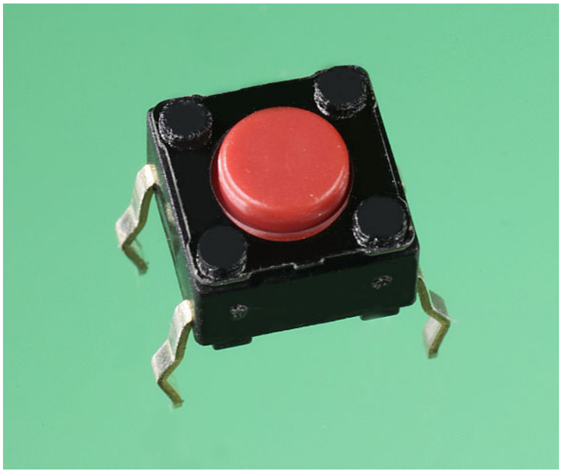

Figure 5-13. *A typical tactile switch.*

Membrane Pad

Typically found on devices such as microwave ovens where contacts must be sealed against particles and liquids. Finger pressure on a membrane pad closes hidden or internal pushbuttons. They are usually custom-designed for specific product applications and are not generally available as generic off-the-shelf components. Some surplus pads may be found for sale on auction websites.

Radio Buttons

The term *radio buttons* is sometimes used to identify a set of pushbuttons that are mechanically interlinked so that only one of them can make an electrical connection at a time. If one button is pressed, it latches. If a second button is pressed, it latches while unlatching the first button. The buttons can be pressed in any sequence. This system is useful for applications such as component selection in a stereo system, where only one input can be permitted at a time. However, its use is becoming less common.

Snap-Action Switches

A snap-action switch (described in detail in the **switch** section of this encyclopedia) can be fitted with a pushbutton, as shown in Figure 5-14. This provides a pleasingly precise action, high reliability, and capability of switching currents of around 5A. However, snap-action switches are almost always single-pole devices.

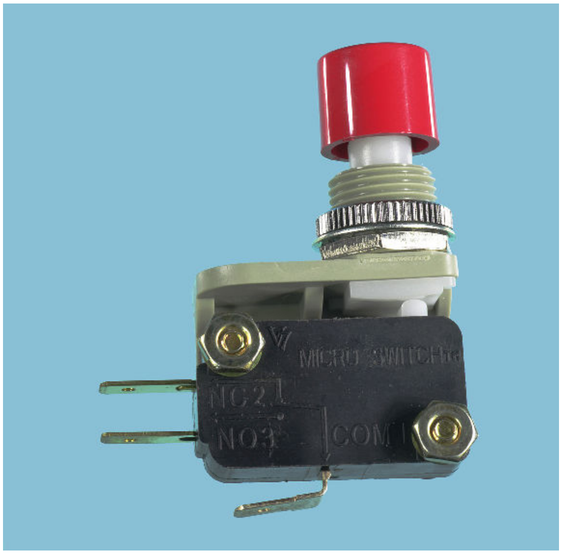

Figure 5-14. *A pushbutton mounted on top of a SPDT snap-action switch.*

Emergency Switch

An emergency switch is a normally-closed device, usually consisting of a large pushbutton that clicks firmly into its "off" position when pressed, and does not spring back. A flange around the button allows it to be grasped and pulled outward to restore it to its "on" position.

Values

Pushbutton current ratings range from a few mA to 20A or more. Many pushbuttons have their current ratings printed on them but some do not. Current ratings are usually specified for a particular voltage, and may differ for AC versus DC.

How to Use it

Issues such as appearance, tactile feel, physical size, and ease of product assembly tend to dictate the choice of a pushbutton, after the fundamental requirements of voltage, current, and durability have been satisfied. Like any electromechanical component, a pushbutton is vulnerable to dirt and moisture. The ways in which a device may be used or abused should be taken into account when deciding whether the extra expense of a sealed component is justified.

When a pushbutton controls a device that has a high inductive load, a *snubber* can be added to minimize arcing. See "Arcing" (page 47) in the **switch** entry of this encyclopedia, for additional information.

What Can Go Wrong

No Button

When ordering a pushbutton switch, read datasheets carefully to determine whether a cap is included. Caps are often sold separately and may not be interchangeable between switches from different manufacturers.

Mounting Problems

In a panel-mount pushbutton that is secured by turning a nut, the nut may loosen with use, allowing the component to fall inside its enclosure when the button is pressed. Conversely, overtightening the nut may strip the threads on the pushbutton bushing, especially in cheaper components where the threads are molded into plastic. Consider applying a drop of Loc-Tite or similar adhesive before completely tightening the nut. Nut sizes vary widely, and finding a replacement may be time-consuming.

LED Issues

When using a pushbutton containing an LED, be careful to distinguish the LED power terminals from the switched terminals. The manufacturer's datasheet should clarify this distinction, but the polarity of the LED terminals may not be clearly indicated. If a diode-testing meter function is unavailable, a sample of the switch should be tested with a source of 3 to 5VDC and a 2K series resistor. Briefly touching the power to the LED terminals, through the resistor, should cause the LED to flash dimly if the polarity is correct, but should not be sufficient to burn out the LED if the polarity is incorrect.

Other Problems

Problems such as arcing, overload, short circuits, wrong terminal type, and contact bounce are generally the same as those associated with a **switch**, and are summarized in that entry in this encyclopedia.

switch

The term **switch** refers here to a physically operated mechanical switch, controlled by flipping a lever or sliding a knob. Although there is some overlap of function, **rotary switches** and **pushbuttons** have their own separate entries. Solid-state switching components are described in entries for **bipolar transistor**, **unijunction transistor**, and **field-effect transistor**. Integrated-circuit switching devices will be found in Volume 2. *Coaxial switches* are used for high-frequency signals, and are not included in this encyclopedia. *Multidirectional switches* differentiate up, down, left, right, diagonal, rotational, and other finger inputs, and are not included in this encyclopedia.

OTHER RELATED COMPONENTS

- **pushbutton** (See Chapter 5)
- **rotary switch** (See Chapter 7)

What It Does

A switch contains at least two contacts, which close or open when an external lever or knob is flipped or moved. Schematic symbols for the most basic type of on-off switch are shown in Figure 6-1.

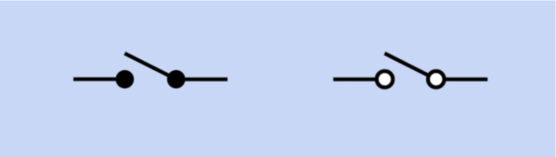

Figure 6-1. *The two most common schematic symbols for a SPST switch, also known as an on-off switch. The symbols are functionally identical.*

The most fundamental type of switch is a *knife switch*, illustrated in Figure 6-2. Although it was common in the earliest days of electrical discovery, today it is restricted to educational purposes in schools, and (in a more robust format) to AC electrical supply panels, where the large contact area makes it appropriate for conducting high amperages, and it can be used for "hot switching" a substantial load.

How It Works

The *pole* of a switch is generally connected with a movable contact that makes or breaks a connection with a secondary contact. If there is only one pole, this is a *single-pole* switch. If there is an additional pole, electrically isolated from the first, with its own contact or set of contacts, this is a *two-pole* switch, also known as a *double-pole* switch. Switches with more than 4 poles are uncommon.

If there is only one secondary contact per pole, this is a *single-throw* or *ST* switch, which may also be described as an *on-off* or *off-on* switch. If there is an additional secondary contact per pole, and the pole of the switch connects with the second contact while disconnecting from the first, this is a *double-throw* or *DT* switch, also known as a *two-way* switch.

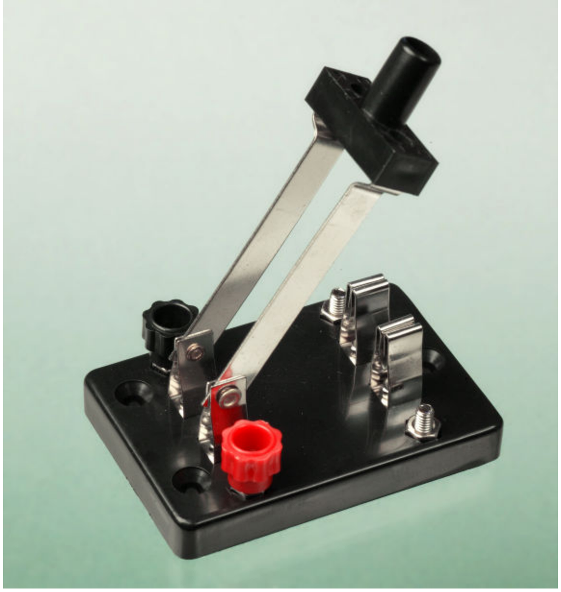

Figure 6-2. *A DPST knife switch intended for the educational environment.*

A double-throw switch may have an additional center position. This position may have no connection (it is an "off" position) or in some cases it connects with a third contact.

Where a switch is spring-loaded to return to one of its positions when manual pressure is released, it functions like a **pushbutton** even though its physical appearance may be indistinguishable from a switch.

Variants

Float switch, *mercury switch*, *reed switch*, *pressure switch*, and *Hall-effect switch* are considered as sensing devices, and will be found in Volume 3.

Terminology

Many different types of switches contain parts that serve the same common functions. The *actuator* is the lever, knob, or toggle that the user turns or pushes. A *bushing* surrounds the actuator on a toggle-type switch. The *common contact* inside a switch is connected with the *pole* of the switch. Usually a *movable contact* is attached to it internally, to touch the secondary contact, also known as a *stationary contact* when the movable contact is flipped to and fro.

Poles and Throws

Abbreviations identify the number of poles and contacts inside a switch. A few examples will make this clear:

SPST also known as 1P1T
Single pole, single throw

DPST also known as 2P1T
Double pole, single throw

SPDT also known as 1P2T
Single pole, double throw

3PST also known as 3P1T
Three pole, single throw

Other combinations are possible.

In Figure 6-3, schematic symbols are shown for double-throw switches with 1, 2, and 3 poles. The dashed lines indicate a mechanical connection, so that all sections of the switch move together when the switch is turned. No electrical connection exists between the poles.

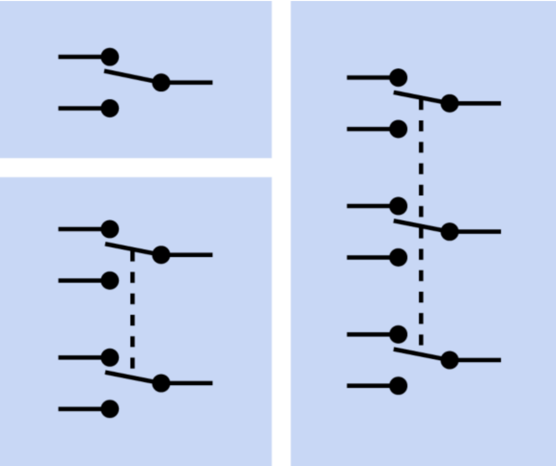

Figure 6-3. *Schematic symbols to represent three types of double-throw switch. Top left: Single-pole. Bottom left: Double-pole. Right: Triple-pole, more commonly known as 3-pole.*

On-Off Behavior

The words ON and OFF are used to indicate the possible states of a switch. The additional word NONE is used by some manufacturers to indicate that a switch does not have a center position. Some manufacturers don't bother with the word NONE, assuming that if the word is omitted, a center position does not exist.

ON-OFF or ON-NONE-OFF

A basic on-off SPST switch with no center position.

ON-ON or ON-NONE-ON

A basic SPDT switch with no center position.

ON-OFF-ON

A double-throw switch with center-off position (no connection when the switch is centered).

ON-ON-ON

A triple-throw switch where the center position connects with its own set of terminals.

Parentheses are used in descriptions of spring-loaded switches to indicate a momentary state that lasts only as long as pressure is applied to the actuator.

(ON)-OFF or OFF-(ON)

A spring-loaded switch that is normally off and returns to that position when pressure is released. Also known as *NO* (normally open), and sometimes described as *FORM A*. Its performance is similar to that of a push-button and is sometimes described as a *make-to-make* connection.

ON-(OFF) or (OFF)-ON

A spring-loaded switch that is normally on and returns to that position when pressure is released. This is sometimes described as a *make-to-break* connection. Also known as *NC* (normally closed), and sometimes described as *FORM B*.

(ON)-OFF-(ON)

A spring-loaded double-throw switch with a no-connection center position to which it returns when pressure on its actuator is released.

Other combinations of these terms are possible.

Most double-throw switches break the connection with one contact (or set of contacts) before making the connection with the second contact (or set of contacts). This is known as a *break before make* switch. Much less common is a *make before break* switch, also known as a *shorting switch*, which establishes the second connection a moment before the first connection is broken. Use of a shorting switch may cause unforeseen consequences in electronic components attached to it, as both sides of the switch will be briefly connected when the switch is turned.

Snap-Action

Also known as a *limit switch* and sometimes as a *microswitch* or *basic switch*. This utilitarian design is often intended to be triggered mechanically rather than with finger pressure, for example in 3D printers. It is generally cheap but reliable.

Two snap-action switches are shown in Figure 6-4. A sectional view of a snap-action ON-(ON) limit switch is shown in Figure 6-5. The pole contacts are mounted on a flexible strip which can move up and down in the center of the switch. The strip has a cutout which allows an inverted U-shaped spring to flip to and fro. It keeps the contacts pressed together in either of the switch states.

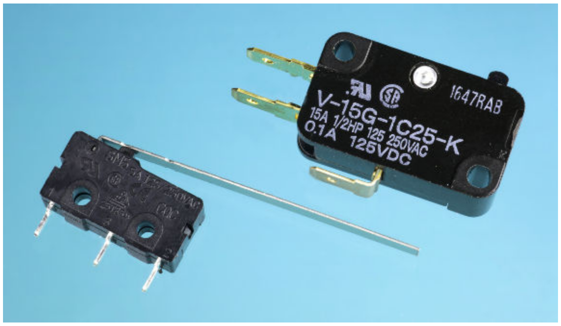

Figure 6-4. *Two SPDT snap-action switches, also known as limit switches. The one on the right is full-size. The one on the left is miniature, with an actuator arm to provide additional leverage. The arm may be trimmed to the required length.*

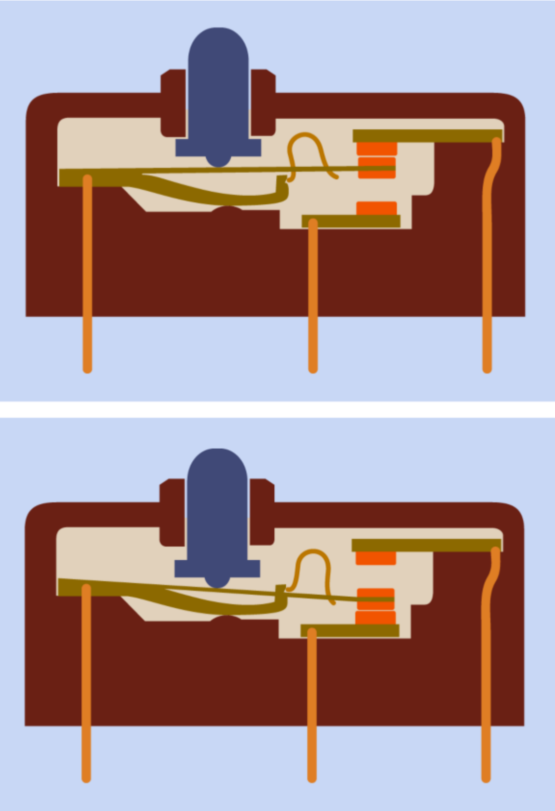

Figure 6-5. *Top: Two contacts inside this limit switch are touching by default. Bottom: When the external button is pressed, it pushes a flexible metal strip downward until it connects with the lower contact. The inverted-U–shaped component is a spring that rests inside a cutout in the flexible strip and resists motion through the central part of its travel.*

The term *snap action* refers to a spring-loaded internal mechanism which snaps to and fro between its two positions. This type of switch is usually SPDT and has a momentary action; in other words, it functions in ON-(ON) mode, although OFF-(ON) and (less often) ON-(OFF) versions are available. The body of the switch is sealed, with a small button protruding through a hole. A thin metal arm may provide additional leverage to press the button. A roller may be mounted at the end of the arm so that the switch can be activated as it slides against a moving mechanical component such as a cam or a wheel. The switch is commonly used to limit the travel or rotation of such a component. Literally thousands of variants are available, in different sizes, requiring different amounts of force for activation. Subminiature snap-action switches can often be actuated by a pressure of only a few grams.

Rocker

Three rocker switches are shown in Figure 6-6. A sectional view of a rocker switch is shown in Figure 6-7. In this design, a spring-loaded ball bearing rolls to either end of a central rocker arm when the switch is turned. Rocker switches are often used as power on-off switches.

Slider

Many types of slider switch (also known as *slide switch*) are widely used as a low-cost but versatile way to control small electronic devices, from clock-radios to stereos. The switch is usually mounted on a circuit board, and its knob or cap protrudes through a slot in the panel. This design is more vulnerable to dirt and moisture than other types of switch. It is usually cheaper than a toggle switch but is seldom designed for use with a high current.

Most slide switches have two positions, and function as SPDT or DPDT switches, but other configurations are less commonly available with more poles and/or positions. A subminiature slide switch is shown in Figure 6-8, while some schematic representations are shown in Figure 6-9,

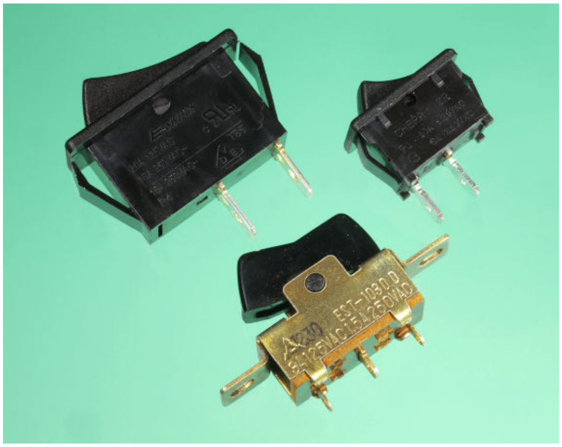

Figure 6-6. *Three rocker switches, the upper two designed for push-insertion into a suitably sized rectangular hole in a panel. The switch at front-center is intended to be screwed in place, and is more than 20 years old, showing that while the choice of materials has changed, the basic design has not.*

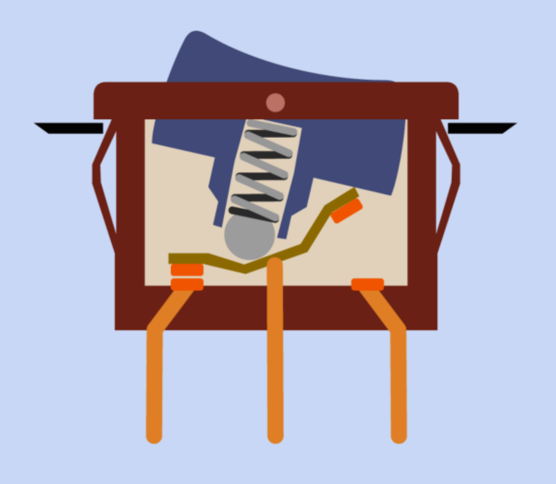

Figure 6-7. *This sectional view of a rocker switch shows a spring-loaded ball-bearing that rolls to and fro along a rocker arm, connecting either pair of contacts when the switch is turned.*

where a black rectangle indicates a sliding internal contact, and a terminal that functions as a pole is identified with letter P in each case. Top left: A SPDT switch using a two-position slider. Top right: A 4PDT slide switch. Bottom left: There are no poles in this switch, as such. The slider can short together any of four pairs of contacts. Bottom right: The slider shorts together three possible pairs of contacts out of four. Here again, there is no pole.

Note that the schematic representation of a slide switch may be identical to that of a slide **pushbutton**. A schematic should be inspected carefully to determine which type is intended.

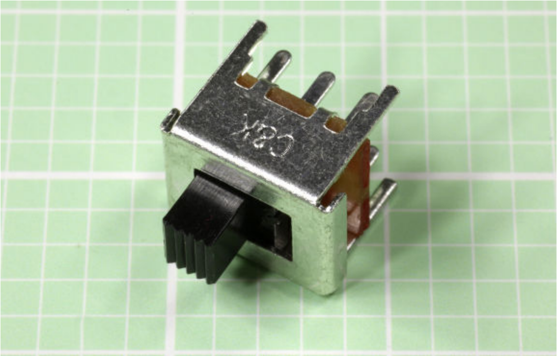

Figure 6-8. *This subminiature slide switch is less than half an inch long, rated 0.3A at 30VDC. Larger versions look almost identical, but can handle only slightly more current.*

The representation of sliders in schematics has not been standardized, but the samples shown are common.

Toggle

A *toggle switch* provides a firm and precise action via a lever (the *toggle*) that is usually tear-drop shaped and nickel plated, although plastic toggles are common in cheaper variants. Formerly used to control almost all electronic components (including early computers), the toggle has declined in popularity but is still used in applications such as automobile accessory kits, motorboat instrument panels, and industrial controls.

Three miniature DPDT toggle switches are shown in Figure 6-10. Two full-size, heavy-duty toggle switches are shown in Figure 6-11. A full-size, four-pole, double-throw heavy-duty toggle switch is shown in Figure 6-12. Toggle switches with more poles are extremely rare.

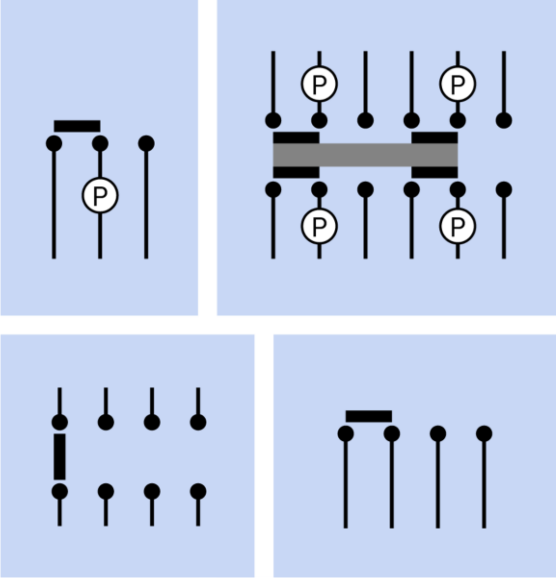

Figure 6-9. *Slide switch schematics. Each black rectangle represents a movable contact that connects two pairs of fixed contacts at a time. Detailed commentary on these variants will be found in the body of the text. Manufacturers may use variants of these symbols in their datasheets (for example, the gray rectangle indicating an insulating contact carrier, at top right, may be represented as a single line, or a black outline with a white center).*

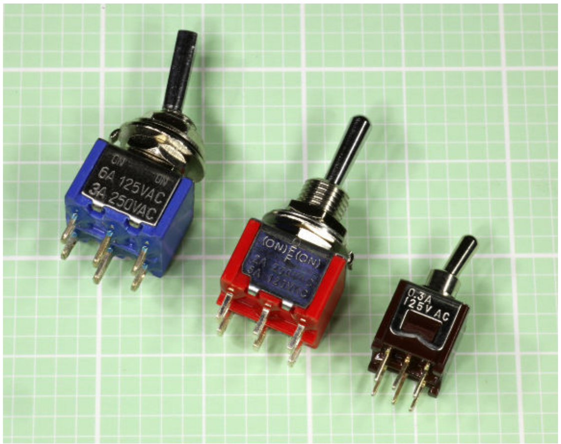

Figure 6-10. *Three miniature toggle switches with current ratings ranging from 0.3A to 6A at 125VAC. Each small square in the background grid measures 0.1" x 0.1".*

An automotive toggle switch is shown in Figure 6-13. Its plastic toggle is extended to minimize operating error.

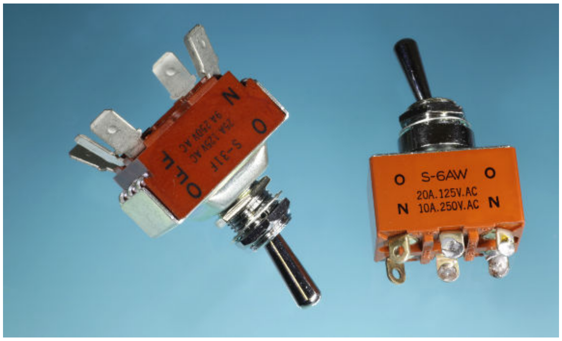

Figure 6-11. *Two full-size toggle switches capable of handling significant current. At left, the switch terminates in quick-connect terminals. At right, the switch has solder terminals (some of them containing residual traces of solder).*

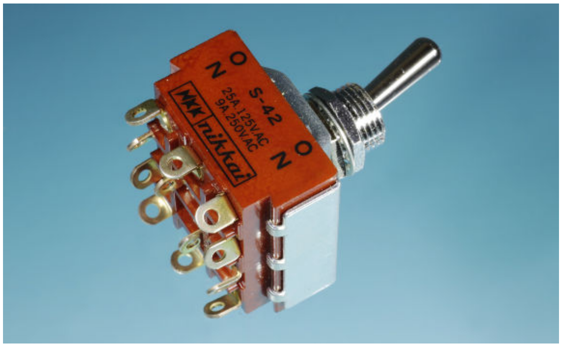

Figure 6-12. *A 4PDT full-size toggle switch with solder terminals, capable of switching 25A at 125VAC. Four-pole switches are relatively unusual.*

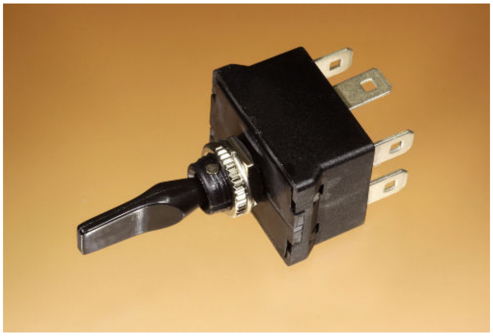

Figure 6-13. *A toggle switch intended for control of automotive accessories.*

High-end toggle switches are extremely durable and can be sealed from environmental contamination with a thin *boot* made from molded rubber or vinyl, which screws in place over the toggle, using the thread on the switch bushing. See Figure 6-14.

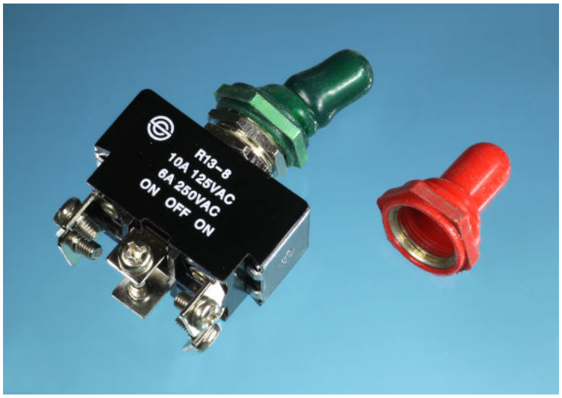

Figure 6-14. *A rubber or vinyl boot can be used to protect a toggle switch from contamination with dirt or water. Each boot contains a nut that screws onto the threads of a toggle switch, as shown at left.*

A *locking toggle switch* has a toggle that must be pulled out against the force of a retaining spring, before the toggle can be moved from one position to another. The toggle then snaps back into place, usually engaging in a small slot in the bushing of the switch.

DIP

A DIP switch is an array of very small, separate switches, designed for mounting directly on a circuit board, either in through-hole or surface-mount format. Through-hole DIP switches have two rows of pins with a 0.1″ pitch, the rows being spaced 0.3″ apart to fit a standard DIP (dual-inline package) socket or comparable configuration of holes in the board. Surface-mount DIP switches may have 0.1″ or 0.05″ pitch.

Most DIP arrays consist of SPST switches, each of which can close or open a connection between two pins on opposite sides of the switch body. The switch positions are usually labelled ON and OFF. Figure 6-15 shows a selection of DIP switches. Figure 6-16 shows the internal connections in a DIP switch.

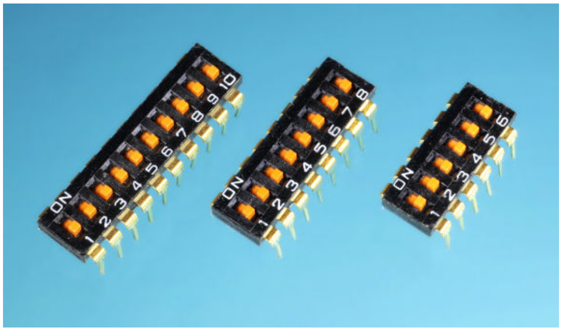

Figure 6-15. *As shown here, DIP switches are available with a variety of "positions," meaning the number of switches, not the number of switch states.*

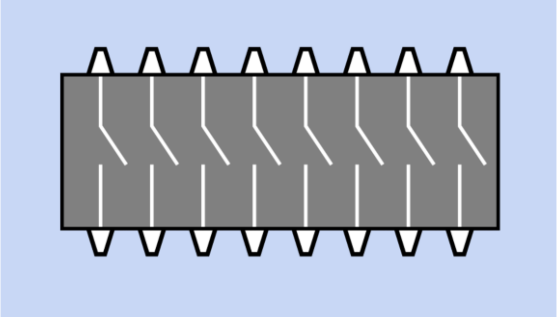

Figure 6-16. *The interior connections of a 16-pin DIP switch.*

The number of switches in a DIP array is usually referred to as its number of "positions." This should not be confused with the two positions of each physical switch lever. SPST DIP switches are made with 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, and 16 positions.

Early IBM-compatible desktop computers often required the user to set the position of an internal DIP switch when making routine upgrades such as installing an additional disk drive. While this feature is now obsolete, DIP switches are still used in scientific equipment where the user is expected to be sufficiently competent to open a cabinet and poke around inside it. Because of the 0.1″ spacing, a small screwdriver or the tip of a pen is more appropriate than a finger to flip individual levers to and fro.

DIP switches may also be used during prototype development, as they allow a convenient way to test a circuit in numerous different modes of operation.

Most DIP switches have wire terminals which are just long enough for insertion into a standard breaboard.

DIP switch package options include standard, low-profile, right-angle (standing at 90 degrees relative to the circuit board), and piano (with switch levers designed to be pressed, like tiny rocker switches, instead of being flipped to and fro).

Some SPDT, DPST, DPDT, 3PST, and 4PST variants exist, but are uncommon. Multiple external pins connect with the additional internal switch contacts, and a manufacturer's datasheet should be consulted to confirm the pattern of internal connections. A surface-mount, 0.1" pitch, DPST DIP switch is shown in Figure 6-17, with a plastic cover to protect the switches from contamination during wave soldering (at left), and with the cover peeled off (at right).

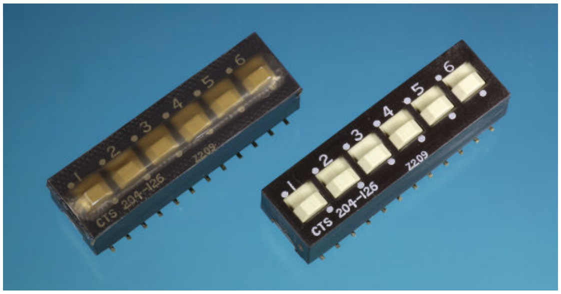

Figure 6-17. *A SPDT surface-mount double-throw DIP switch, sold with a plastic cover (shown at left) to protect it during wave soldering. The cover has been removed at right.*

SIP

A SIP switch is an array of small, separate switches, identical in concept to a DIP switch, but using only one row of pins instead of a double row. The applications for SIP switches are the same as DIP switches; the primary difference is simply that the SIP switch occupies a little less space, while being perhaps slightly less convenient to use.

One terminal of each switch usually shares a common bus. The internal connections in a typical 8-pin SIP array are shown in Figure 6-18. Pin spacing is 0.1", as in a typical DIP switch.

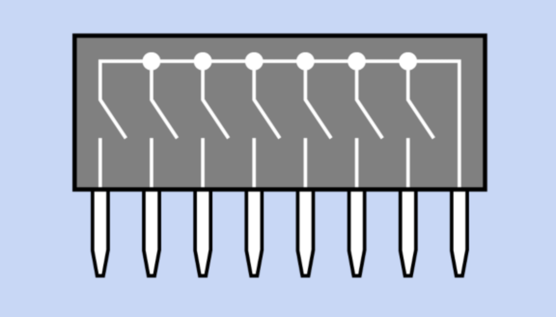

Figure 6-18. *The interior connections of an 8-pin SIP switch incorporating a common bus.*

Paddle

A paddle switch has a flat-sided tab-shaped plastic actuator, relatively large to allow a firm, error-free grip. Internally it is often comparable with a rocker switch, and is generally used with AC power. Some toggle-switch bodies are also sold with paddle-shaped actuators. A subminiature paddle switch is shown in Figure 6-19.

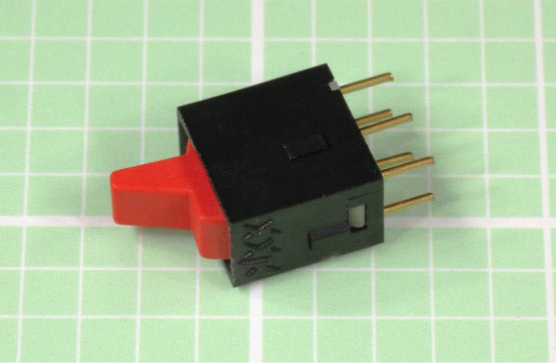

Figure 6-19. *A subminiature paddle switch. Full-size versions are often used as power switches.*

Vandal Resistant Switch

Typically fabricated from stainless steel, this is designed to withstand most types of abuse and is also weather-proof. The pushbuttons that allow pedestrians to trigger a traffic signal are a form of vandal-resistant switch.

Tactile Switch

This is considered to be a **pushbutton**, and is described in that entry. See "Tactile Switch" (page 34).

Mounting Options

A *panel mount* switch generally has a threaded bushing that is inserted from behind the front panel of a product, through a hole of appropriate size. It is supplied with a lockwasher and a nut (often, two nuts) that fit the thread on the switch bushing.

Front panel mount usually means that screws visible from the front of the panel are attached to a bracket on the switch behind the panel. The actuator of the switch is accessible through a cutout in the panel. This mounting style is mostly used for rocker switches and sometimes for slide switches.

Subpanel mount means that the switch is attached to a separate plate or chassis behind the control panel. The actuator of the switch is accessible through a cutout.

Snap-in mount requires a switch with flexible plastic or metal tabs each side, designed to push through a cutout in the panel, at which point the tabs spring out and retain the switch.

PC mount switches have pins that are soldered into a printed circuit board. They may have additional solderable lugs to provide mechanical support.

Surface mount switches are attached to a board in the same manner as other surface-mount components.

Termination

Switches (and pushbuttons) are available with a variety of terminals.

Solder lugs are small tabs, each usually perforated with a hole through which the end of a wire can be inserted prior to soldering.

PC terminals are pins that protrude from the bottom of the switch, suitable for insertion in a printed circuit board. This style is also known as a *through-hole*. The terminals may have a right-angle bend to allow the component to be mounted flat against the board, with the switch actuator sticking out at the side. This termination style is known as *right-angle PC.* Many manufacturers offer a choice of straight or bent pin terminals, but the component may be listed in a catalog under either of those options, with no indication that other options exist. Check manufacturer datasheets carefully.

Quick connect terminals are spade-shaped to accept push-on connectors, commonly used in automotive applications. Hybrid quick-connect terminals that can also function as solder lugs are sometimes offered as an option.

Screw terminals have screws premounted in flat terminals, for solderless attachment of wires.

Wire leads are flexible insulated wires, often with stripped and tinned ends, protruding at least an inch from the body of the component. This option is becoming uncommon.

Contact Plating Options

The internal electrical contacts of a switch are usually plated with silver or gold. Nickel, tin, and silver alloys are cheaper but less common. Other types are relatively rare.

Values

Switches designed for electronic devices vary widely in power capability, depending on their purpose. Rocker switches, paddle switches, and toggle switches are often used to turn power on and off, and are typically rated for 10A at 125VAC, although some toggle switches go as high as 30A. Snap-action or limit switches may be similarly rated, although miniature versions will have reduced capability. Slide switches cannot handle significant power, and are often rated around 0.5A (or less) at 30VDC. DIP and SIP switches have a typical maximum rating of 100mA at 50V and are not designed for frequent use. Generally they are used only when the power to the device is off.

How to Use it

Power Switches

When a simple SPST switch is used to turn DC power on and off, it conventionally switches the positive side of the power supply, also sometimes known as the *high side*. The primary reason for following this convention is that it is widely used; thus, following it will reduce confusion.

More importantly, an on-off switch that controls AC power must be used on the "live" side of the supply, not the "neutral" side. If you have any doubts about these concepts (which go beyond the scope of this book), consult a reference guide on this subject. Using a DPST component to switch both sides of an AC supply may be a worthwhile additional precaution in some applications. The ground wire of an AC supply should never be switched, because the device should always be grounded when it is plugged into an electric outlet.

Limit Switches

An application for two limit switches with a DC motor and two rectifier **diodes** is shown in Figure 6-20. This diagram assumes that the motor turns clockwise when its lower terminal is positive, and counter-clockwise when its upper terminal is positive. Only two terminals are used (and shown) in each limit switch; they are chosen to be normally-closed. Other terminals inside a switch may exist, may be normally-open, and can be ignored.

The motor is driven through a dual-coil, DPDT latching **relay**, which will remain in either position indefinitely without drawing power. When the upper coil of the relay receives a pulse from a pushbutton or some other source, the relay flips to its upper position, which conducts positive current through the lower limit switch, to the lower terminal of the motor. The motor turns clockwise until the arm attached to its shaft hits the lower limit switch and opens it. Positive current is blocked by the lower diode, so the motor stops.

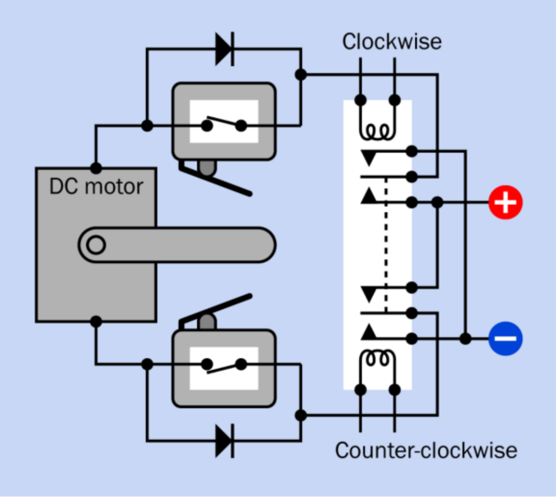

Figure 6-20. *In this schematic, normally-closed limit switches are opened by pressure from an arm attached to a motor, thus switching off its power at each end of its permitted travel and preventing overload and burnout. A two-coil latching relay activates the motor. Rectifier diodes allow power to reach the motor to reverse its rotation when a limit switch is open.*

When the lower coil of the relay is activated, the relay flips to its lower position. Positive current can now reach the upper side of the motor through the upper limit switch. The motor runs counter-clockwise until its arm opens the upper limit switch, at which point the motor stops again. This simple system allows a DC motor to be run in either direction by a button-press of any duration, without risk of burnout when the motor reaches the end of its travel. It has been used for applications such as raising and lowering powered windows in an automobile.

A DPDT pushbutton could be substituted for the latching relay if manual control, only, is acceptable. However, in this scenario, sustained pressure on the pushbutton would be necessary to move the motor arm all the way to the opposite end of its travel. A DPDT switch might be more appropriate than a pushbutton.

Logic Circuits

Logic circuits that depend purely on switches can be constructed (for example, to add binary numbers) but are rare and have no practical applications. The most familiar and simplest example of manually switched logic is a pair of SPDT switches in house wiring, one positioned at the top of a flight of stairs and the other at the bottom, as shown in Figure 6-21. Either switch will turn the light on if it is currently off, or off if it is currently on. To extend this circuit by incorporating a third switch that has the same function as the other two, a DPDT switch must be inserted. See Figure 6-22.

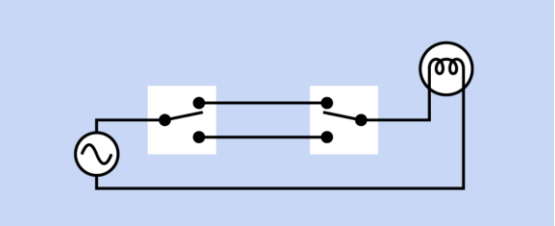

Figure 6-21. *SPDT switches are commonly used in house wiring so that either of them will turn a shared light on if it is off, or off it is on.*

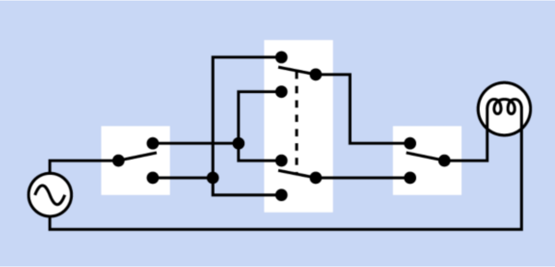

Figure 6-22. *A DPDT switch must be inserted if three switches must have identical function to control the on-off state of a single light bulb.*

Alternatives

As **microcontrollers** have become cheaper and more ubiquitous, they have taken over many functions in electronic products that used to be served by switches. A menuing system driven by a microcontroller can use one **rotational encoder** with a SPST pushbutton built into it to select and adjust numerous parameters in a device such as a car stereo, where functions were once selected and adjusted by individual switches and potentiometers. The rotational-encoder option takes up less space, is cheaper to build (assuming a microcontroller is going to be used in the device for other purposes anyway), and can be more reliable, as it reduces the number of electromechanical parts. Whether it is easier to use is a matter of taste. Cost and ergonomics may be the primary factors to consider when choosing where and how to use switches.

What Can Go Wrong

Arcing

The contacts inside a switch will be rapidly eroded if *arcing* (pronounced "arking") occurs. An electric arc is a spark that tends to form when a switch is opened while conducting a high current or high voltage (typically 10A or more and 100V or more). The most common cause is an inductive load that generates back-EMF when it is switched on and forward-EMF when it is switched off. The surge can be many times the amperage that the load draws during continuous operation. In DC circuits, arcing can be reduced by using a rectifier **diode** in parallel with the load (with its polarity blocking normal current flow). This is often referred to as a *flyback diode* or *freewheeling diode*. In AC circuits, where a diode cannot be used in this way, a *snubber* (a simple combination of capacitor and resistor) may be placed around the load. A snubber can also be used around the switch itself, in DC circuits. See "Snubber" (page 108).

When switching an inductive load, it is generally prudent to use switches rated for twice as much current as the circuit will normally draw.

Dry Joints

Switches that control significant current will have substantial terminals, and these terminals will be attached to heavy-gauge wire. When using solder to make this type of connection, the combined heat capacity of the wire and the terminal will sink a lot more heat than a small component on a circuit board. At least a 30W soldering iron should be used. Lower-wattage irons may be incapable of melting the solder completely (even though they seem to), and a "dry joint" will result, which can have a relatively high electrical resistance and will be mechanically weak, liable to break later. Any good solder joint should withstand flexing of the wire attached to it.

Short Circuits

Because many switches are still wired in with solder tabs, screw terminals, or quick-connect terminals, wires that become accidentally detached can be a significant hazard. Heat-shrink tubing should be applied to enclose wires and terminals at the rear of a power switch, as an additional precaution. Power switches should always be used in conjunction with appropriate **fuses**.

Contact Contamination

Sealed switches should be used in any environment where dirt or water may be present. Slide switches are especially vulnerable to contamination, and are difficult to seal. Switches used in audio components will create "scratchy" sounds if their contacts deteriorate.

Wrong Terminal Type

Because switches are available with a wide variety of terminal types, it's easy to order the wrong type. Switches may be supplied with pins for through-hole insertion in circuit boards; screw terminals; quick-disconnect terminals; or solder lugs. Variants may also be available for surface mount. If a project requires, for example, the insertion of pins in a printed circuit board, and a switch is supplied with solder lugs, it will be unusable.

Part numbers generally include codes to identify each terminal variant, and should be studied carefully.

Contact Bounce

Also known as *switch bounce*. When two contacts snap together, extremely rapid, microscopic vibrations occur that cause brief interruptions before the contacts settle. While this phenomenon is not perceptible to human senses, it can be perceived as a series of multiple pulses by a **logic chip**. For this reason, various strategies are used to *debounce* a switch that drives a logic input. This issue is explored in detail in the entry on logic chips in Volume 2 of the encyclopedia.

Mechanical Wear

Any toggle or rocker switch contains a mechanical pivot, which tend to deteriorate in harsh environments. Friction is also an issue inside these switches, as the design often entails the rounded tip of a lever rubbing to and fro across the center of a movable contact.

The spring inside a snap switch or limit switch may fail as a result of metal fatigue, although this is rare. A slide switch is far less durable, as its contacts rub across each other every time the switch changes position.

In any application that entails frequent switching, or where switch failure is a critical issue, the most sensible practice is to avoid using cheap switches.

Mounting Problems

In a panel-mount switch that is secured by turning a nut, the nut may loosen with use, allowing the component to fall inside its enclosure. Conversely, overtightening the nut may strip the threads on the switch body, especially in cheaper components where the threads are molded into plastic. Consider applying a drop of Loc-Tite or similar adhesive after moderately tightening the nut. Note that nut sizes vary widely, and finding a replacement may be time-consuming.

Cryptic Schematics

In some circuit schematics, the poles of a multi-pole switch may be visually separated from each other, even at opposite sides of the page, for convenience in drawing the schematic. Dotted lines usually, but not always, link the poles. In the absence of dotted lines, switch segments are often coded to indicate their commonality. For example, SW1(a) and SW1(b) are almost certainly different parts of the same switch, with linked poles.

rotary switch

7

Not to be confused with **rotational encoder**, which has its own entry in this encyclopedia.

OTHER RELATED COMPONENTS

- **switch** (See Chapter 6)
- **rotational encoder** (See Chapter 8)

What It Does

A rotary switch makes an electrical connection between a *rotor*, mounted on a shaft that is turned by a knob, and one of two or more stationary contacts. Traditionally, it was the component of choice to select wavebands on a radio receiver, broadcast channels on a television or inputs on a stereo preamplifier. Since the 1990s, it has been substantially superceded by the **rotational encoder**. However it still has applications in military equipment, field equipment, industrial control systems, and other applications requiring a rugged component that will withstand heavy use and a possibly harsh environment. Also, while the output from a rotational encoder must be decoded and interpreted by a device such as a microcontroller, a rotary switch is an entirely passive component that does not require any additional electronics for its functionality.

Two typical schematic symbols for a rotary switch are shown in Figure 7-1. They are functionally identical. A simplified rendering of the interior of a traditional-style rotary switch is shown in Figure 7-2. A separate contact (not shown) connects with the rotor, which connects with each of the stationary contacts in turn. The colors were chosen to differentiate the parts more clearly, and do not correspond with colors in an actual switch.

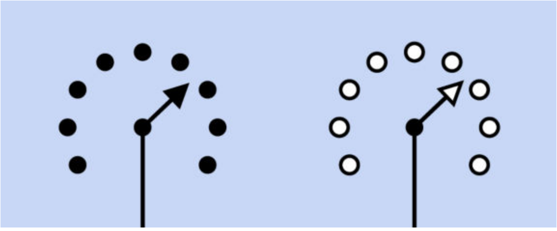

Figure 7-1. *Typical schematic symbols for a rotary switch. The two symbols are functionally identical. The number of contacts will vary depending on the switch.*

A selection of rotary switches is shown in Figure 7-3. At top-left is an *open frame* switch, providing no protection to its contacts from contaminants. This type of component is now rare. At top-right is a twelve-position, single-pole switch rated 2.5A at 125VAC. At front-left is a four-position, single-pole switch rated 0.3A at 16VDC or 100VAC. At front right is a two-position, two-pole switch with the same rating as the one beside it. All the sealed switches allow a choice of panel mounting or through-hole printed circuit board mounting.

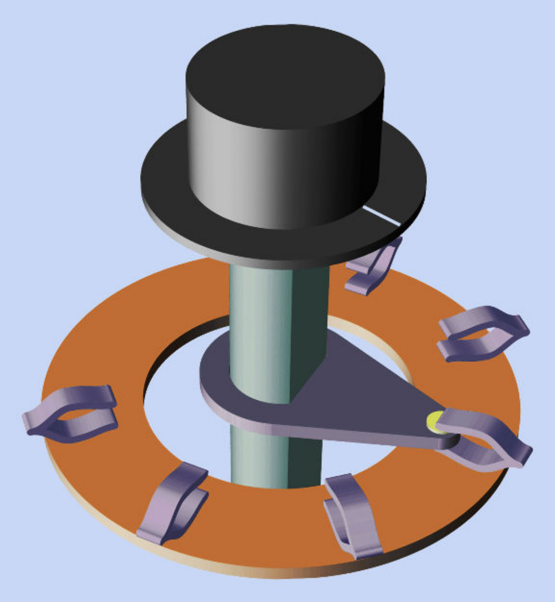

Figure 7-2. *A simplified rendering of interior parts in a basic SP6T rotary switch. Arbitrary colors have been added for clarity.*

How It Works

A switch may have multiple poles, each connecting with its own rotor. The rotors are likely to be on separate *decks* of the switch, but two, three, or four rotors, pointing in different directions, may be combined on a single deck if the switch has only a small number of positions.

Rotary switches are usually made with a maximum of twelve positions, but include provision for limiting the number of positions with a *stop*. This is typically a pin, which may be attached to a washer that fits around the bushing of the switch. The pin is inserted into a choice of holes to prevent the switch from turning past that point. For example, an eight-position rotary switch can be configured so that it has only seven (or as few as two) available positions.

A specification for a rotary switch usually includes the angle through which the switch turns between one position and the next. A twelve-position switch usually has a 30-degree turn angle.

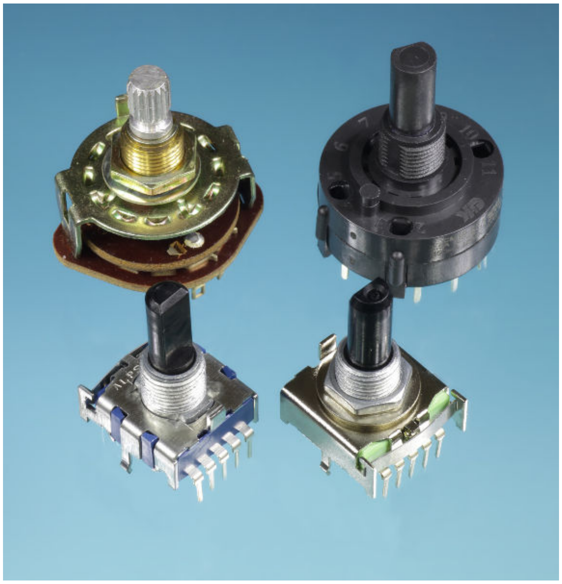

Figure 7-3. *A selection of rotary switches. See text for details.*

Variants

Conventional

The traditional style of rotary switch is designed to be panel-mounted, with a body that ranges from 1″ to 1.5″ in diameter. If there is more than one deck, they are spaced from each other by about 0.5″. The switch makes an audible and tactile “click” as it is turned from one position to the next.

A rugged sealed five-deck rotary switch is shown in Figure 7-4. It has five poles (one per deck), and a maximum of 12 positions. The contacts are rated 0.5A at 28VDC. This type of heavy-duty component is becoming relatively rare.

If the rotor in a switch establishes a connection with the next contact a moment before breaking the connection with the previous contact, this is known as a *shorting* switch, which may also be described as a *make-before-break* switch. In a *nonshorting* or *break-before-make* switch, a tiny

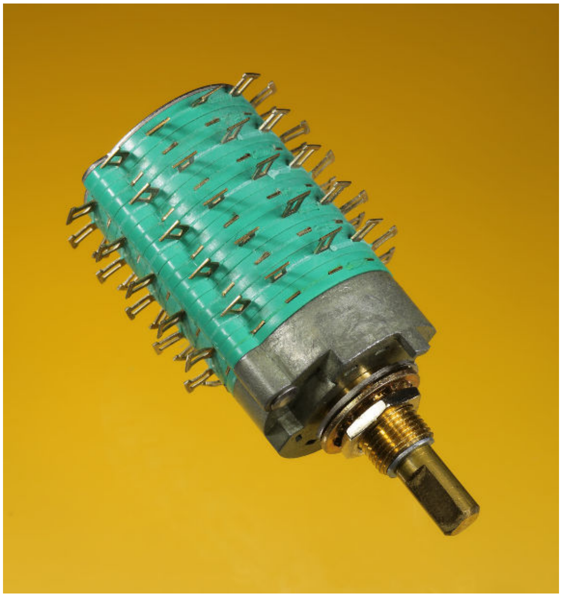

Figure 7-4. *A five-pole, twelve-position rotary switch.*

interval separates one connection from the next. This can be of significant importance, depending on the components that are connected with the switch.

The shaft may be round, splined, or D-shaped in section. A knob is seldom supplied with a switch and must be chosen to match the shaft. Some shaft dimensions are metric, while others are measured in inches, with 1/4" diameter being the oldest standard. Some switches with a splined shaft are supplied with an adapter for a knob of D-shaped internal section; the adapter can be slipped onto the shaft in any of 12 or more positions, to minimize the inconvenience of positioning the body of the switch itself so that the knob is correctly oriented in relation to positions printed on the face of the panel.

Miniature rotary switches may be as small as 0.5" diameter, and usually terminate in pins for through-hole mounting on a PC board. Miniature switches usually have lower current ratings than full-size switches.

Rotary switches must be securely anchored to resist the high turning forces that can be inflicted upon them by users. In a panel-mount design, a nut is tightened around a thread on the bushing of the switch. Through-hole versions can be secured to the PC board with the shaft protruding loosely through a cutout in the panel. To minimize mechanical stress on the circuit board, the detents in a PC-board switch are usually weaker than in a full-size switch, and the knob is usually smaller, allowing less leverage.

Rotary DIP

A conventional *DIP switch* is a linear array of miniature SPST switches designed to fit a standard DIP (dual-inline package) layout of holes in a circuit board. It is described in the **switch** entry of this encyclopedia. A *rotary DIP* switch (also known as an *encoded output rotary switch* or a *coded rotary switch*) does not conform with a DIP layout, despite its name. It is approximately 0.4" square and usually has five pins, one of which can be considered the input or common pin while the other four can function as outputs. The pins are spaced at 0.1" pitch from one another. Pin function and layout are not standardized.

A dial on top of the switch has either 10 positions (numbered 0 through 9) or 16 positions (0 through 9 followed by letters A through F). One switch of each type is shown in Figure 7-5.

Each position of the dial closes pairs of contacts inside the component to create a unique binary-coded decimal pattern (in a 10-position switch) or binary-coded hexadecimal pattern (in the 16-position switch) on the four output pins. The pin states are shown in Figure 7-6. A rotary DIP switch is a relatively flimsy device, and is not designed for frequent or heavy use. It is more likely to be a "set it and forget it" device whose state is established when it is installed in a circuit board.

Because each position of the switch is identified with a unique binary pattern, this is an example of *absolute encoding*. By contrast, a typical **rotational encoder** uses *relative encoding*, as it merely generates a series of undifferentiated pulses when the shaft is turned.

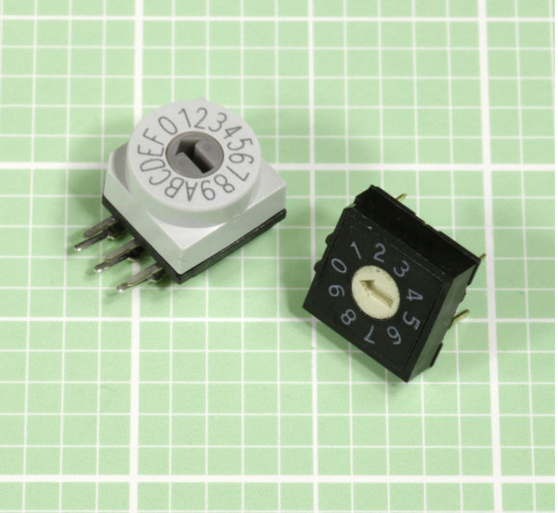

Figure 7-5. *A rotary DIP switch, also known as an encoded output rotary switch, may be used as a substitute for a DIP switch in some applications.*

A *real-coded* rotary DIP makes a connection between input and output pins wherever a binary 1 would exist. In the *complement-coded* version, the output is inverted. The switch is primarily intended for use with a **microcontroller**, enabling only four binary input pins on the microcontroller to sense up to sixteen different switch positions.

A six-pin rotary DIP variant is available from some manufacturers, with two rows of three pins, the two center pins in each row being tied together internally, and serving as the pole of the switch.

Rotary DIPs are available with a screw slot, small knurled knob, or larger knob. The screw-slot version minimizes the height of the component, which can be relevant where circuit boards will be stacked close together. A *right-angle PC* variant stands at 90 degrees to the circuit board, with pins occupying a narrower footprint. The switch on the left in Figure 7-5 is of this type.

While most rotary DIPs are through-hole components, surface-mount versions are available.

Most rotary DIPs are sealed to protect their internal components during wave-soldering of circuit boards.

Switch Position	Pin 1	Pin 2	Pin 3	Pin 4
0	⚫	⚫	⚫	⚫
1	🔴	⚫	⚫	⚫
2	⚫	🔴	⚫	⚫
3	🔴	🔴	⚫	⚫
4	⚫	⚫	🔴	⚫
5	🔴	⚫	🔴	⚫
6	⚫	🔴	🔴	⚫
7	🔴	🔴	🔴	⚫
8	⚫	⚫	⚫	🔴
9	🔴	⚫	⚫	🔴
A	⚫	🔴	⚫	🔴
B	🔴	🔴	⚫	🔴
C	⚫	⚫	🔴	🔴
D	🔴	⚫	🔴	🔴
E	⚫	🔴	🔴	🔴
F	🔴	🔴	🔴	🔴

Figure 7-6. *Positive and negative states of the four output pins of a real-coded 16-position rotary DIP switch, assuming that the common pin of the switch is connected with a positive supply voltage. A ten-position rotary DIP switch would use only the states from 0 through 9. In a complement-coded switch, the positive and negative states would be reversed.*

Gray Code

A Gray code (named after its originator, Frank Gray) is a system of absolute encoding of a switch output, using a series of nonsequential binary numbers that are chosen in such a way that each number differs by only one digit from the preceding number. Such a series is useful because it eliminates the risk that when a switch turns, some bits in the output will change before others, creating the risk of erroneous interpretation. A minority of rotary switches or rotational encoders are available with Gray-coded outputs. Typically, a microcontroller must use a lookup table to convert each binary output to an angular switch position.

PC Board Rotary Switch

Miniature switches with a conventional, non-encoded output are available for printed-circuit board mounting, sometimes requiring a screwdriver or hex wrench to select a position. A single-pole eight-position switch of this type is shown in Figure 7-7. Its contacts are rated to carry 0.5A at 30VDC, but it is not designed to switch this current actively.

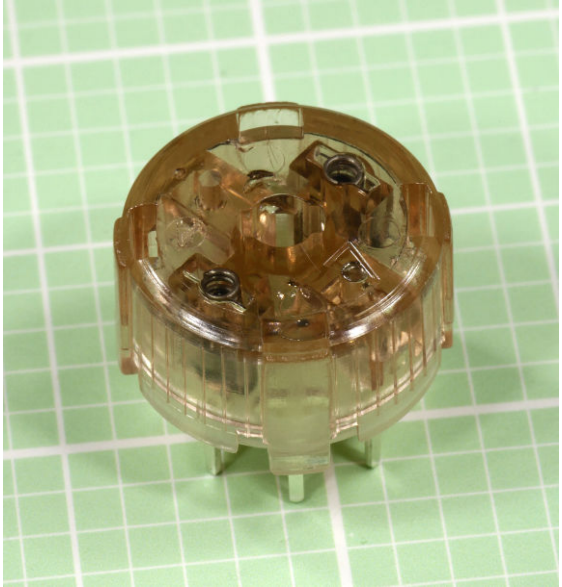

Figure 7-7. *This miniature switch is designed for insertion on a printed circuit board. It can be used to make a setting before a device is shipped to the end user.*

Mechanical Encoder

A *mechanical encoder* functions similarly to a rotary DIP switch but is intended for much heavier use. It outputs a binary-coded-decimal value corresponding with its shaft position, is typically the size of a miniature rotary switch, and is designed for panel mounting. The Grayhill Series 51 allows 12 positions, each generating a code among four terminals. The Bourns EAW provides 128 positions, each generating a code among 8 terminals.

Pushwheel and Thumbwheel

A *pushwheel switch* is a simple electromechanical device that enables an operator to provide a code number as input to data processing equipment, often in industrial process control. The decimal version contains a wheel on which numbers are printed, usually in white on black, from 0 through 9, visible one at a time through a window in the face of the switch. A button above the wheel, marked with a minus sign, rotates it to the next lower number, while a button below the wheel, marked with a plus sign, rotates it to the next higher number. A connector at the rear of the unit includes a common (input) pin and four output pins with values 1, 2, 4, and 8. An additional set of pins with values 1, 2, 3, and 4 is often provided. The states of the output pins sum to the value that is currently being displayed by the wheel. Often two, three, or four pushwheels (each with an independent set of connector pins) are combined in one unit, although individual pushwheels are available and can be stacked in a row.

A *thumbwheel switch* operates like a pushwheel switch, except that it uses a thumbwheel instead of two buttons. Miniaturized thumbwheel switches are available for through-hole mounting on PC boards.

Hexadecimal versions are also available, with numbers from 0 through 9 followed by letters A through F, although they are less common than decimal versions.

Keylock

A *keylock switch* is generally a two-position rotary switch that can be turned only after insertion of a key in a lock attached to the top of the shaft. This type of switch almost always has an OFF-(ON) configuration and is used to control power.

Keylock switches are found in locations such as elevators, for fire-department access; in cash registers; or on data-processing equipment where switching power on or off is reserved for a system administrator.

Values

A full-size rotary switch may be rated from 0.5A at 30VDC to 5A at 125VAC, depending on its purpose. A very few switches are rated 30A at 125VAC; these are high-quality, durable, expensive items.

A typical rotary DIP switch is rated 30mA at 30VDC and has a carrying current rating (continuous current when no switching occurs) of no more than 100mA at 50VDC.

How to Use it

In addition to its traditional purpose as a mode or option selector, a rotary switch provides a user-friendly way to input data values. Three ten-position switches, for instance, can allow user input of a decimal number ranging from 000 to 999.

When used with a **microcontroller**, a rotary switch can have a *resistor ladder* mounted around its contacts, like a multi-point *voltage divider*, so that each position of the rotor provides a unique potential ranging between the positive supply voltage and negative ground. This concept is illustrated in Figure 7-8, where all the resistors have the same value. The voltage can be used as an input to the microcontroller, so long as the microcontroller shares a common ground with the switch. An analog-digital converter inside the microcontroller translates the voltage into a digital value. The advantage of this scheme is that it allows very rapid control by the user, while requiring only one pin on the microcontroller to sense as many as twelve input states.

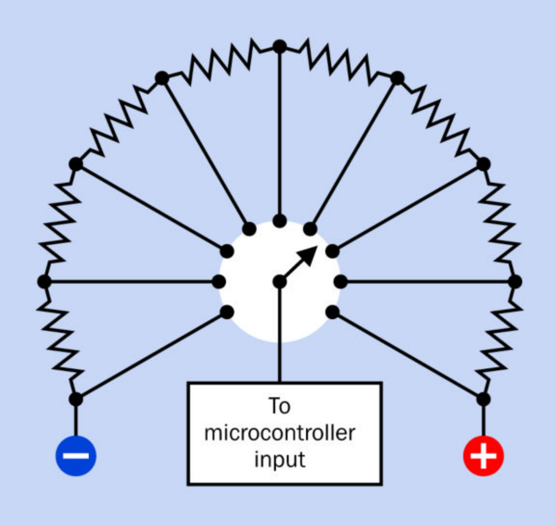

Figure 7-8. *A resistor ladder can be formed around the contacts of a rotary switch, with the pole of the switch connected to a microcontroller that has an analog-digital converter built in. The microcontroller converts the voltage input to an internal digital value. Thus, one pin can sense as many as twelve input states.*

For a ladder consisting of 8 resistors, as shown, each resistor could have a value of 250Ω. (The specifications for a particular microcontroller might require other values.) To avoid ambiguous inputs, a nonshorting rotary switch should be used in this scheme. A *pullup resistor* of perhaps 10K should be added to the microcontroller input, so that there is no risk of it “floating” when the switch rotor is moving from one contact to the next. The code that controls the microcontroller can also include a blanking interval during which the microcontroller is instructed to ignore the switch.

Because the rotary switch is an electromechanical device, it has typical vulnerabilities to dirt and moisture, in addition to being bulkier, heavier, and more expensive than a **rotational encoder**. Rotary switches have also been partially replaced by pushbuttons wired to a microcontroller. This option is found on devices ranging from digital alarm clocks to cellular phones. In addition to being cheaper, the pushbutton alternative is preferable where space on a control panel, and behind it, is limited.

What Can Go Wrong

Vulnerable Contacts

Most modern rotary switches are sealed, but some are not. Any switch with exposed contacts will be especially vulnerable to dirt and moisture, leading to unreliable connections. This was an issue in old-fashioned TV sets, where periodic contact cleaning of the channel selector switch was needed.

Exposed contacts are also more vulnerable to side-effects from temperature cycling (when a device warms up and then cools down).

Contact Overload

The contacts on a cheap rotary switch are especially vulnerable to arcing, as the user may turn the switch slowly, causing gradual engagement and disengagement of contacts instead of the snap-action that is characteristic of a well-made toggle switch. If a rotary switch may control significant currents or current surges, it must be appropriately rated, regardless of the extra expense. For more information on arc suppression in switches, see "Arcing" (page 47).

Misalignment

Most knobs for rotary switches consist of a pointer, or have a white line engraved to provide clear visual indication of the position of the switch. If this does not align precisely with indications printed on the panel, confusion will result. For hand-built equipment, the switch can be installed first, after which the control-panel indications can be glued or riveted in place on a separate piece of laminated card, plastic, or metal for precise alignment. If the switch is not secured tightly, its body may turn slightly under repeated stress, leading to erroneous interpretation of the knob position.

Misidentified Shorting Switch

If a shorting switch is used where a nonshorting switch was intended, the results can be disconcerting or even destructive, as one terminal will be briefly connected with the adjacent terminal while the switch is being turned. Multiple functions of a circuit may be activated simultaneously, and in a worst case scenario, adjacent terminals may be connected to opposite sides of the same power supply.

User Abuse

The turning force that must be applied to a full-size conventional rotary switch is significantly greater than the force that is applied to most other types of panel-mounted switches. This encourages aggressive treatment, and the turning motion is especially likely to loosen a nut holding the switch in place. The lighter action characteristic of miniature rotary switches does not necessarily solve this problem, as users who are accustomed to older-style switches may still apply the same force anyway.

Rotary switches should be mounted in expectation of rough use. It is prudent to use Loc-Tite or a similar compound to prevent nuts from loosening, and a switch should not be mounted in a thin or flimsy panel. When using a miniature rotary switch that has through-hole mounting in a circuit board, the board must be sufficiently robust and properly secured.

Wrong Shaft, Wrong Knobs, Nuts That Get Lost, Too Big to Fit

These problems are identical to those that can be encountered with a **potentiometer**, which are discussed in that entry in this encyclopedia.

rotational encoder

8

The term *rotational encoder* used to be reserved for high-quality components, often using optical methods to measure rotation with precision (more than 100 intervals in 360 degrees). Cheaper, simpler, electromechanical devices were properly referred to as *control shaft encoders*. However, the term *rotational encoder* is now applied to almost any device capable of converting rotational position to a digital output via opening and closing internal mechanical contacts; this is the sense in which the term is used here. It is sometimes distinguished from other types of encoder with the term *mechanical rotary encoder*. Magnetic and optical rotary encoders do not contain mechanical switches, are classified as *sensors* by this encyclopedia, and will appear in Volume 3. They are found in a device such as an *optical mouse*.

OTHER RELATED COMPONENTS

- **rotary switch** (See Chapter 7)

What It Does

A rotational encoder has a knob that a user can turn to display a series of prompts on an LCD screen, or to adjust the input or output on a product such as a stereo receiver. The component is almost always connected to inputs on a **microcontroller** and is usually fitted with *detents* that provide tactile feedback suggesting many closely spaced positions. The encoder often allows the user to make a selection by pushing the knob in, which closes an internal momentary switch. Thus, this type of encoder functions as a pushbutton as well as a switch.

A rotational encoder is an *incremental* or *relative* device, meaning that it merely creates and breaks internal switch connections when rotation occurs, without providing a unique code to identify each absolute rotational position. An *absolute* encoder is discussed in the **rotary switch** entry of this encyclopedia.

No schematic symbol exists to represent a rotational encoder.

How It Works

An encoder contains two pairs of contacts, which open and close out of phase with each other when the shaft rotates. In a clockwise direction, the A pair of contacts may be activated momentarily before the B pair; in a counter-clockwise direction, the B pair may be activated before the A pair. (Some encoders reverse this phase difference.) Thus if one contact from each pair is connected with two inputs of an appropriately programmed microcontroller, and if the other contact of each pair is connected with negative ground, the microcontroller can deduce which way the knob is turning by sensing which pair of contacts closes first. The microcontroller can then count the number of pulses from the contacts and interpret this to adjust an output or update a display.

A simplified schematic is shown in Figure 8-1. The two buttons inside the dashed line represent the two pairs of contacts inside the encoder, while the chip is a microcontroller. The knob and shaft that activate the internal switches are not shown. The schematic assumes that when a contact closes, it pulls the chip input to a low state. A pullup resistor is added to each input of the chip to prevent the pins from "floating" when either pair of contacts is open.

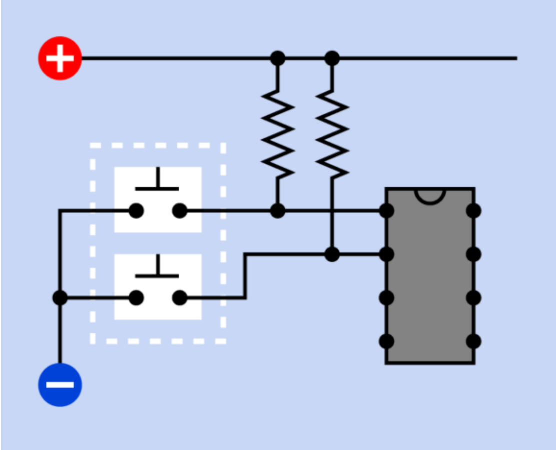

Figure 8-1. *Simplified schematic showing the typical setup for a rotational encoder. The pushbuttons inside the dashed line represent the contacts inside the encoder. The chip is a microcontroller.*

Figure 8-2 gives a conceptual view of the outputs of an encoder that is turned clockwise (top) and then counter-clockwise (bottom). Some encoders may reverse this phase sequence. Red and black colors have been assigned to the pin states on the assumption that the terminals that are common to both pairs of contacts are connected with negative ground. Thus a "high" pulse in the graphical representation actually indicates that the encoder is grounding its output.

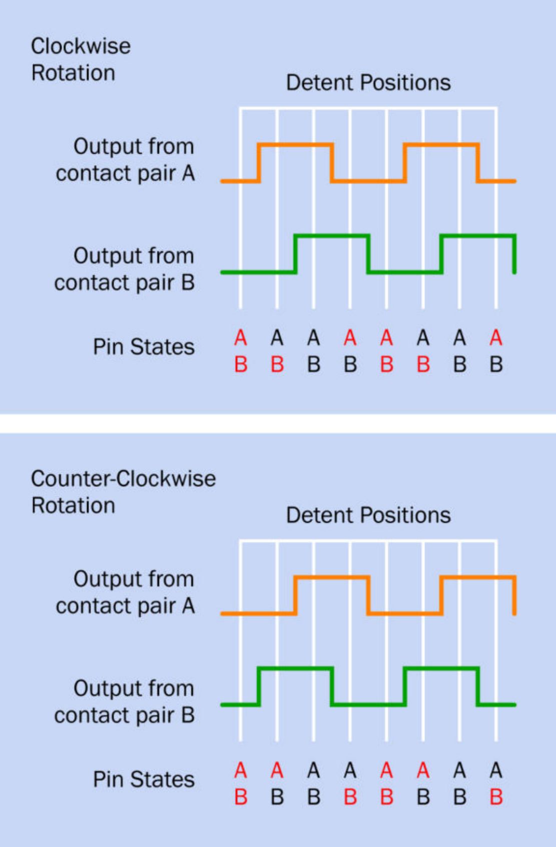
Clockwise Rotation
Detent Positions
Output from contact pair A
Output from contact pair B
Pin States
A A A A A A A A
B B B B B B B B
Counter-Clockwise Rotation
Detent Positions
Output from contact pair A
Output from contact pair B
Pin States
A A A A A A A A
B B B B B B B B

Figure 8-2. *Hypothetical outputs from a rotational encoder, assuming that the common terminals of the contact pairs are connected to negative ground. A high pulse in the graphical representation therefore indicates that the contact pair is grounded. The number of detents relative to the number of pulses per rotation varies from one type of encoder to another.*

Microcontrollers have become so ubiquitous, and rotational encoders are so cheap, they have displaced rotary switches in many applications where a low current is being switched. The combination of a rotational encoder and a microcontroller is very versatile, allowing display and control of an almost unlimited number of menus and options.

Variants

There are two types of rotational encoders containing mechanical contacts: absolute and relative. An absolute encoder generates a code corresponding with each specific rotational position. The code is usually a binary output among four or more pins. It is discussed under *mechanical encoder* in the **rotary switch** section of this encyclopedia. The variants listed here are all relative encoders.

Pulses and Detents

Rotational encoders from different manufacturers may have as few as 4 or as many as 24 pulses per rotation (PPR), with 12 to 36 detents (or no detents at all, in a few models.) The relationship between pulses and detents shown in Figure 8-2 is typical but is far from being universal. The number of detents may be equal to, greater than, or less than the number of pulses per rotation.

Format

Rotational encoders are generally panel-mounted or through-hole devices. In the latter category, most are horizontally mounted, with a minority being at 90 degrees to the board.

Output

In an encoder containing two switches, four switch-state combinations are possible: OFF-OFF, ON-OFF, OFF-ON, and ON-ON. This is known as a *quadrature* output. All of the rotational encoders discussed here conform with that system.

Rotational Resistance

Rotational encoders vary widely in the resistance that they offer when the user turns the knob. This is largely a function of the detents, if they are included. Still, all rotational encoders generally offer less rotational resistance than a rotary switch, and do not have the kind of heavy-duty knobs that are typically used with rotary switches. Since an encoder creates only a stream of pulses without any absolute positional information, a knob with any kind of pointer on it is inappropriate.

Values

Virtually all rotational encoders are designed to work with a low-voltage supply, 12VDC or less. All of them are intended for low currents, reflecting their purpose to drive microcontroller inputs. Some sample rotational encoders are pictured in Figure 8-3. At rear: nine pulses per rotation (PPR), 36 detents, 10mA at 10VDC. Far left: 20PPR, 20 detents, with switch. Far right: 24PPR, no detents, 1mA at 5VDC. Center (blue): 16PPR, no detents, 1mA at 5VDC. Front: 12PPR, 24 detents, 1mA at 10VDC, requires Allen wrench or similar hexagonal shaft to engage with the rotor.

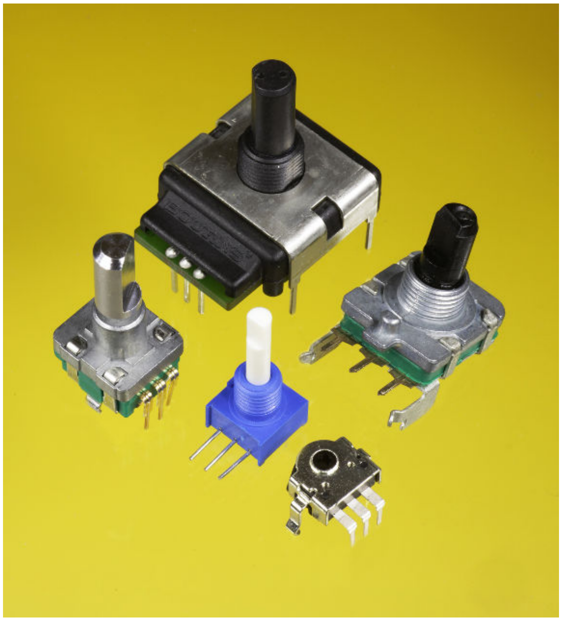

Figure 8-3. *Rotational encoders with a variety of specifications. See text for details.*

Contact Bounce

Any mechanical switch will suffer some degree of *contact bounce* when its contacts close. Datasheets for rotational encoders may include a specification for bounce duration ranging from around 2ms to 5ms, which is sometimes known as the *settling time*. Naturally, a lower value is preferred. The microcontroller that interprets the positional information from the encoder can include a debouncing routine that simply disregards any signals during the bounce period following switch closure.

Sliding Noise

Sliding noise is the opposite of contact bounce. When two contacts have made a connection and then rub across each other (as occurs inside a rotational encoder while the knob is being turned), the connection may suffer momentary lapses. Datasheets for rotational encoders generally do not supply ratings for this.

How to Use it

As noted above, a rotational encoder can only be used in conjunction with a microcontroller or similar device that is capable of interpreting the phase difference between the pairs of contacts, and is capable of counting the number of opening/closing events while the knob is being turned. (Some dedicated chips are designed for this specific purpose.)

It can be adapted to be driven by a **stepper motor**, to provide feedback regarding the rotation of the motor shaft, and its output can also be interpreted to calculate angular acceleration.

Programming the microcontroller is the most significant obstacle. Generally the program should follow a sequence suggested by this pseudocode:

Check:

- If the encoder contains a pushbutton switch, check it. If the pushbutton is being pressed, go to an appropriate subroutine.
- The status of contacts A.
- The status of contacts B.

Compare their status with previously saved states for A and B. If the status has not changed, repeat from Check.

Debounce:

- Recheck the contacts status rapidly and repeatedly for 50ms, and count the states for contacts A and B. (The 50ms duration may be adjusted for different encoders, as an encoder with a higher number of pulses per rotation will tend to create shorter pulses.)
- Compare the total number of changed states with unchanged states.

If the changed states are in a small minority, probably the signal was erroneous, caused by bounce or sliding noise. Go back to Check and start over.

Interpret:

- Deduce the rotational direction from these four possibilities:
  - — Contacts A were open and have closed.
  - — Contacts A were closed and have opened.
  - — Contacts B were open and have closed.
  - — Contacts B were closed and have opened. (The specific type of encoder will determine how these transitions are interpreted.)
- Revise the variable storing the direction of rotation if necessary.
- Depending on the direction of rotation, increment or decrement a variable that counts pulses.
- Take action that is appropriate to the direction of rotation and the cumulative number of pulses.
- Go back to Check again.

What Can Go Wrong

Switch Bounce

In addition to a debouncing algorithm in the microcontroller, a 0.1µF bypass capacitor can be used with each of the output terminals from the encoder, to help reduce the problem of switch bounce.

Contact Burnout

Rotational encoders are TTL-compatible. They are not generally designed to drive even a small output device, such as an LED. The contacts are extremely delicate and will be easily damaged by any attempt to switch a significant current.

relay

9

Properly known as an *electromagnetic armature relay* to distinguish it from a *solid-state relay*. However, the full term is very rarely used. It may also be described as an *electromechanical relay*, but the term **relay** is normally understood to mean a device that is not solid state.

OTHER RELATED COMPONENTS

- **solid state relay** (Volume 2)
- **switch** (See Chapter 6)

What It Does

A relay enables a signal or pulse of electricity to switch on (or switch off) a separate flow of electricity. Often, a relay uses a low voltage or low current to control a higher voltage and/or higher current. The low voltage/low current signal can be initiated by a relatively small, economical switch, and can be carried to the relay by relatively cheap, small-gauge wire, at which point the relay controls a larger current near to the load. In a car, for example, turning the ignition switch sends a signal to a relay positioned close to the starter motor.

While solid-state switching devices are faster and more reliable, relays retain some advantages. They can handle double-throw and/or multiple-pole switching and can be cheaper when high voltages or currents are involved. A comparison of their advantages relative to **solid state relays** and **transistors** is tabulated in the entry on **bipolar transistor** in Figure 28-15.

Common schematic symbols for single-throw relays are shown in Figure 9-1 and for double-throw relays in Figure 9-2. The appearance and orientation of the coil and contacts in the symbols may vary significantly, but the functionality remains the same.

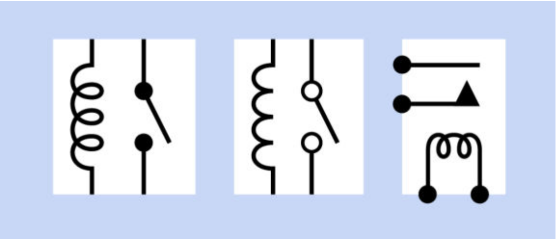

Figure 9-1. *Commonly used schematic symbols for a SPST relay. The symbols are functionally identical.*

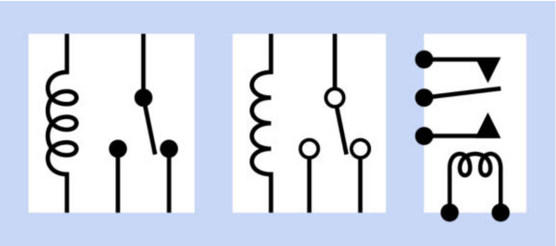

Figure 9-2. *Commonly used schematic symbols for a SPDT relay. The symbols are functionally identical.*

How It Works

A relay contains a *coil*, an *armature*, and at least one pair of *contacts*. Current flows through the coil, which functions as an **electromagnet** and generates a magnetic field. This pulls the armature, which is often shaped as a pivoting bracket that closes (or opens) the contacts. These parts are visible in the simplified rendering of a DPST relay in Figure 9-3. For purposes of identification, the armature is colored green, while the coil is red and the contacts are orange. The two blue blocks are made of an insulating material, the one on the left supporting the contact strips, the one on the right pressing the contacts together when the armature pivots in response to a magnetic field from the coil. Electrical connections to the contacts and the coil have been omitted for simplicity.

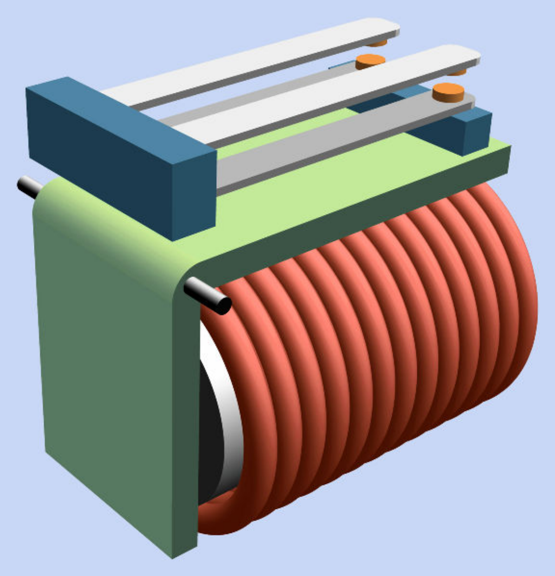

Figure 9-3. *This simplified rendering shows the primary parts of a DPST relay. See text for details.*

Various small relays, capable of handling a variety of voltages and currents, are pictured in Figure 9-4. At top-left is a 12VDC automotive relay, which plugs into a suitable socket shown immediately below it. At top-right is a 24VDC SPDT relay with exposed coil and contacts, making it suitable only for use in a very clean, dry environment. Continuing downward, the four sealed relays in colored plastic cases are designed to switch currents of 5A at 250VAC, 10A at 120VAC, 0.6A at 125VAC, and 2A at 30VDC, respectively. The two blue relays have 12VDC coils, while the red and yellow relays have 5V coils. All are nonlatching, except for the yellow relay, which is a latching type with two coils. At bottom-left is a 12VDC relay in a transparent case, rated to switch up to 5A at 240VAC or 30VDC.

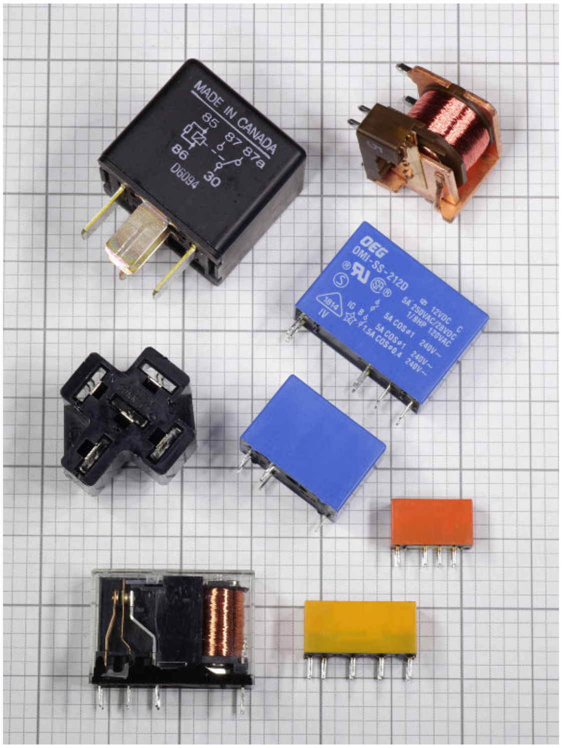

Figure 9-4. *An assortment of small DC-powered relays. See text for details.*

The configuration of a relay is specified using the same abbreviations that apply to a **switch**. SP, DP, 3P, and 4P indicate 1, 2, 3, or 4 poles (relays with more than 4 poles are rare). ST and DT indicate single-throw or double-throw switching. These abbreviations are usually concatenated, as in 3PST or SPDT. In addition, the terminology Form

A (meaning normally open), Form B (normally closed), and Form C (double-throw) may be used, preceded by a number that indicates the number of poles. Thus "2 Form C" means a DPDT relay.

Variants

Latching

There are two basic types of relay: *latching* and *nonlatching*. A nonlatching relay, also known as a *single side stable* type, is the most common, and resembles a *momentary switch* or **pushbutton** in that its contacts spring back to their default state when power to the relay is interrupted. This can be important in an application where the relay should return to a known state if power is lost. By contrast, a latching relay has no default state. Latching relays almost always have double-throw contacts, which remain in either position without drawing power. The relay only requires a short pulse to change its status. In semiconductor terms, its behavior is similar to that of a *flip-flop*.

In a *single-coil* latching relay, the polarity of voltage applied to the coil determines which pair of contacts will close. In a *dual-coil* latching relay, a second coil moves the armature between each of its two states.

Schematic symbols for a dual-coil latching relay are shown in Figure 9-5. Some symbol styles do not make it clear which switch position each coil induces. It may be necessary to read the manufacturer's datasheet or test the relay by applying its rated voltage to randomly selected terminal pairs while testing for continuity between other terminal pairs.

Polarity

There are three types of DC relay. In a *neutral relay*, polarity of DC current through the coil is irrelevant. The relay functions equally well either way. A *polarized relay* contains a diode in series with the coil to block current in one direction. A *biased relay* contains a permanent magnet near the armature, which boosts performance when current flows through the coil in one direction, but blocks a response when the current flows through the coil in the opposite direction. Manufacturers' datasheets may not use this terminology, but will state whether the relay coil is sensitive to the polarity of a DC voltage.

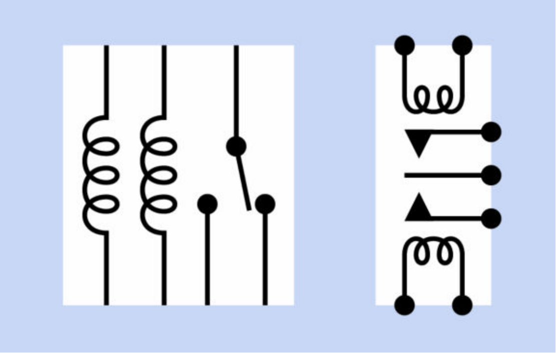

Figure 9-5. *Schematic symbols for a two-coil latching relay. The symbols are functionally identical.*

All relays can switch AC current, but only an *AC relay* is designed to use AC as its coil current.

Pinout Variations

The layout and function of relay pins or quick connects is not standardized among manufacturers. Often the component will have some indication of pin functions printed on it, but should always be checked against the manufacturer's datasheet and/or tested for continuity with a meter.

Figure 9-6 shows four sample pin configurations, adapted from a manufacturer's datasheet. These configurations are functionally quite different, although all of them happen to be for DPDT relays. In each schematic, the coil of the relay is shown as a rectangle, while the pins are circles, black indicating an energized state and white indicating a non-energized state. The bent lines show the possible connections between the poles and other contacts inside the relay. The contacts are shown as arrows. Thus, pole 4 can connect with either contact 3 or contact 5, while pole 9 can connect with either contact 8 or contact 10.

Top-left: Polarized nonlatching relay in its resting condition, with no power applied. Top right: Single-coil latching relay showing energized contacts (black circles) when the coil is powered with the polarity indicated. If the polarity is reversed, the relay flips to its opposite state. Some manufacturers indicate the option to reverse polarity by placing a minus sign alongside a plus sign, and a plus sign alongside a minus sign. Bottom-left and bottom-right: Polarized latching relays with two coils, with different pinouts.

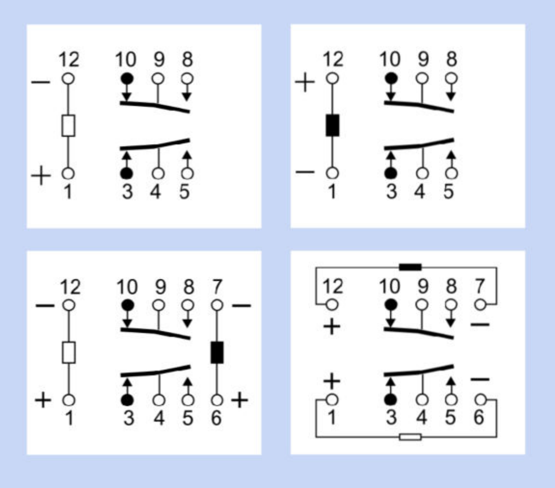

Figure 9-6. *Relay pinouts depicted in the style commonly found in manufacturers' datasheets, showing different relay types. Top-left: Single coil, nonlatching. Top-right: Single coil, latching. Bottom left: Two-coil, latching. Bottom right: Two-coil, latching, alternate pinouts. (Adapted from a Panasonic datasheet.)*

In these diagrams, the relay is seen from above. Some datasheets show the relay seen from below, and some show both views. Some manufacturers use slightly different symbols to indicate interior functions and features. When in doubt, use a meter for verification.

Reed Relay

A *reed relay* is the smallest type of electromechanical relay with applications primarily in test equipment and telecommunications. With a coil resistance ranging from 500 to 2000 ohms, these relays consume very little power. The design consists of a *reed switch* with a coil wrapped around it. Figure 9-7 shows a simplified rendering. The two black contacts are enclosed in a glass or plastic envelope and magnetized in such a way that a magnetic field from the surrounding coil bends them together, creating a connection. When power to the coil is disconnected, the magnetic field collapses and the contacts spring apart.

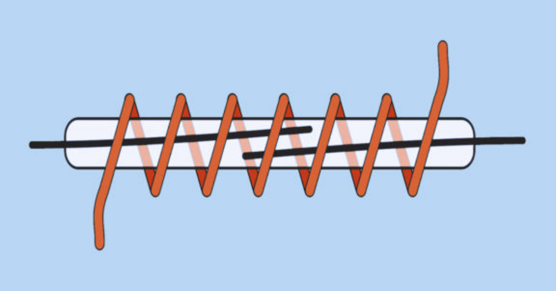

Figure 9-7. *This simplified rendering shows a reed relay, consisting of a magnetized reed switch inside a glass or plastic pod, activated by a coil wrapped around it.*

In Figure 9-8, two reed relays are shown, at top-left and center-right. At bottom-left, the type of relay on the right has been opened by a belt sander to reveal its copper coil and inside that, a capsule in which the relay contacts are visible.

Surface-mount reed relays can be smaller than 0.5″ × 0.2″. Through-hole versions are often around 0.7″ × 0.3″ with pins in two rows, though some are available in SIP packages.

Reed relays have limited current switching capacity and are not suitable to switch inductive loads.

Small Signal Relay

A *small signal relay* is also known as a *low signal relay*. This type may have a footprint as small as a reed relay but generally stands slightly taller, requires slightly more coil current, and is available in versions that can switch slightly higher

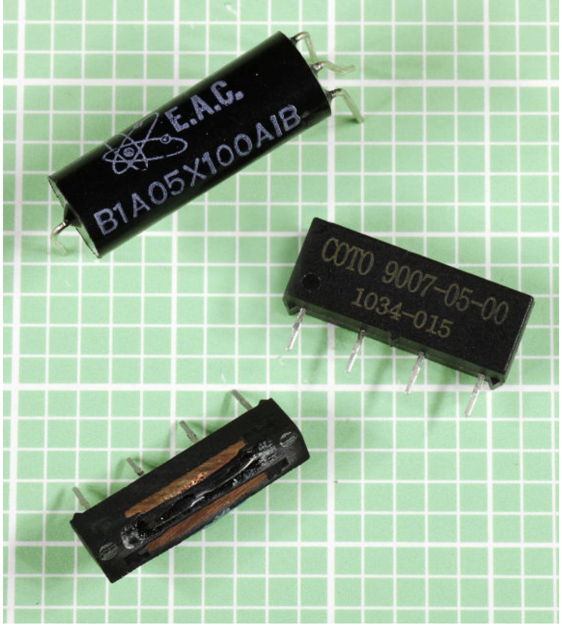

Figure 9-8. *Three reed relays, one of which has had its packaging partially removed by a belt sander to reveal its copper coil and internal contacts.*

voltages and currents. There are usually two rows of pins, spaced either 0.2″ or 0.3″ apart. The red and orange relays in Figure 9-4 are small signal relays.

Automotive Relays

An *automotive relay* is typically packaged in a cube-shaped black plastic case with quick-connect terminals at the bottom, typically plugged into a socket. Naturally they are designed to switch, and be switched by, a 12VDC supply.

General Purpose/Industrial

These relays cover a very wide range and are usually built without significant concern for size. They may be capable of switching high currents at high voltages. Typically they are designed to plug into a socket such as an *octal base* of the type that was once used for **vacuum tubes**. The base, in turn, terminates in solder tabs, screws, or quick connects and is designed to be screwed to a chassis. It allows the relay to be unplugged and swapped without resoldering.

Two industrial relays are shown in Figure 9-9. Both are DPDT type with 12VDC coils and rated to switch up to 10A at 240VAC. The one on the left has an octal base. An octal socket that fits an octal base is shown in Figure 9-10.

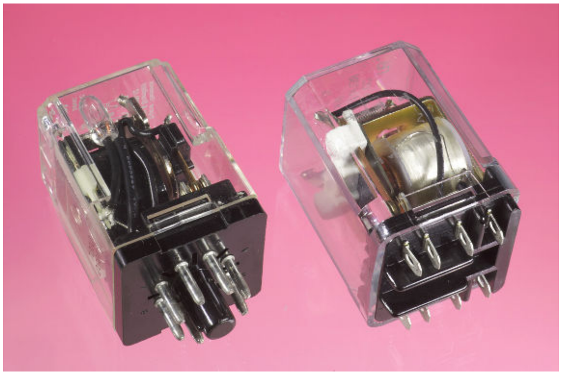

Figure 9-9. *Two relays powered by 12VDC, capable of switching up to 10A at 240VAC.*

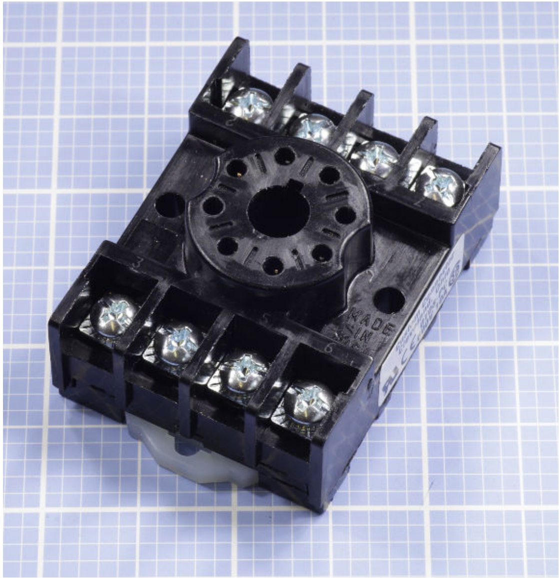

Figure 9-10. *An octal socket with screw terminals, designed to accept a relay with an octal base.*

Time Delay Relay

Generally used to control industrial processes, a *time delay relay* switches an output on and off at preset time intervals that can be programmed to repeat. The example in Figure 9-11 has a 12VDC coil and is rated to switch up at 10A at 240VAC. It has an octal base.

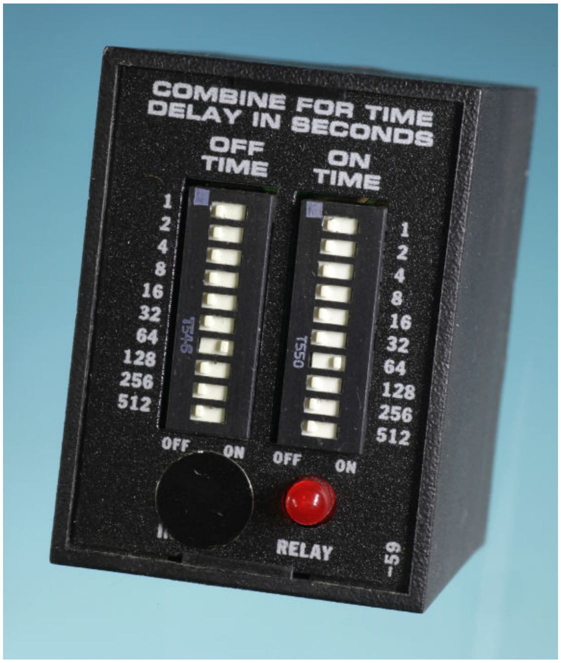

Figure 9-11. *The control switches on a time-delay relay, allowing separately configured "on" and "off" intervals.*

Contactor

A contactor functions just like a relay but is designed to switch higher currents (up to thousands of amperes) at higher voltages (up to many kilovolts). It may range from being palm-sized to measuring more than one foot in diameter, and may be used to control heavy loads such as very large motors, banks of high-wattage lights, and heavy-duty power supplies.

Values

Datasheets usually specify maximum voltage and current for the contacts, and nominal voltage and current for the coil, although in some cases the coil resistance is stated instead of nominal coil current. The approximate current consumption can be estimated, if necessary, by using Ohm's Law. The minimum voltage that the relay needs for activation is sometimes described as the *Must Operate By* voltage, while the *Must Release By* voltage is the maximum coil voltage that the relay will ignore. Relays are rated on the assumption that the coil may remain energized for long periods, unless otherwise stated.

While the contact rating may suggest that a relay can switch a large load, this is not necessarily true if the load has significant inductance.

Reed relays

Usually use a coil voltage of 5VDC and have a contact rating of up to 0.25A at 100V. Through-hole (PCB) versions may have a coil voltage of 5VDC, 6VDC, 12VDC, or 24VDC and in some cases claim to switch 0.5A to 1A at up to 100V, although this rating is strictly for a noninductive load.

Small signal/low signal relays

Usually use a coil voltage ranging from 5VDC to 24VDC, drawing about 20mA. Maximum switching current for noninductive loads ranges from 1A to 3A.

Industrial/general purpose relays

A very wide range of possible values, with coil voltages ranging up to 48VDC or 125VAC to 250VAC. Contact rating is typically 5A to 30A.

Automotive relays

Coil voltage of 12VDC, and contact rating often 5A at up to 24VDC.

Timer relays

Usually these specify a coil voltage of 12VDC, 24VDC, 24VAC, 125VAC, or 230VAC. The timed interval can range from 0.1 sec to 9999 hours in some cases. Common values for contact ratings are 5A up to 20A, with a voltage of 125V to 250V, AC or DC.

How to Use it

Relays are found in home appliances such as dishwashers, washing machines, refrigerators, air conditioners, photocopy machines, and other products where a substantial load (such as a motor or compressor) has to be switched on and off by a control switch, a thermostat, or an electronic circuit.

Figure 9-12 shows a common small-scale application in which a signal from a microcontroller (a few mA at 5VDC) is applied to the base of a transistor, which controls the relay. In this way, a logic output can switch 10A at 125VAC. Note the rectifier diode wired in parallel with the relay coil.

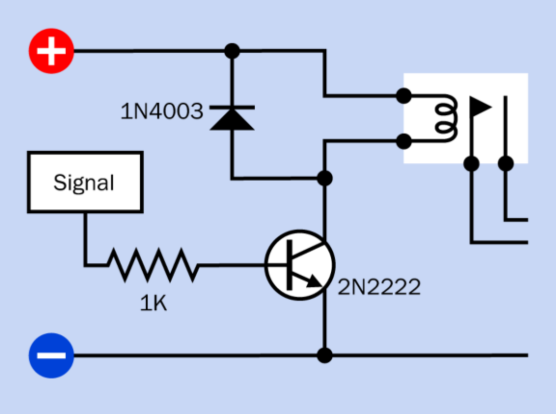

Figure 9-12. *A signal from a digital source such as a microcontroller can switch substantial voltage and current if it is applied to the base of a transistor that activates a relay.*

A latching relay is useful wherever a connection should persist when power is switched off or interrupted, or if power consumption must be minimized. Security devices are one common application. However, the circuit may require a "power reset" function to restore known default settings of latched relays.

A circuit including every possible protection against voltage spikes is shown in Figure 9-13, including a snubber to protect the relay contacts, a rectifier diode to suppress back-EMF generated by the relay coil, and another rectifier diode to protect the relay from EMF generated by a motor when the relay switches it on and off. The snubber can be omitted if the motor draws a relatively low current (below 5A) or if the relay is switching a noninductive load. The diode around the relay coil can be omitted if there are no semiconductors or other components in the circuit that are vulnerable to voltage spikes. However, a spike can affect components in adjacent circuits that appear to be electrically isolated. A severe spike can even be transmitted back into 125VAC house wiring. For information on using a resistor-capacitor combination to form a snubber, see "Snubber" (page 108).

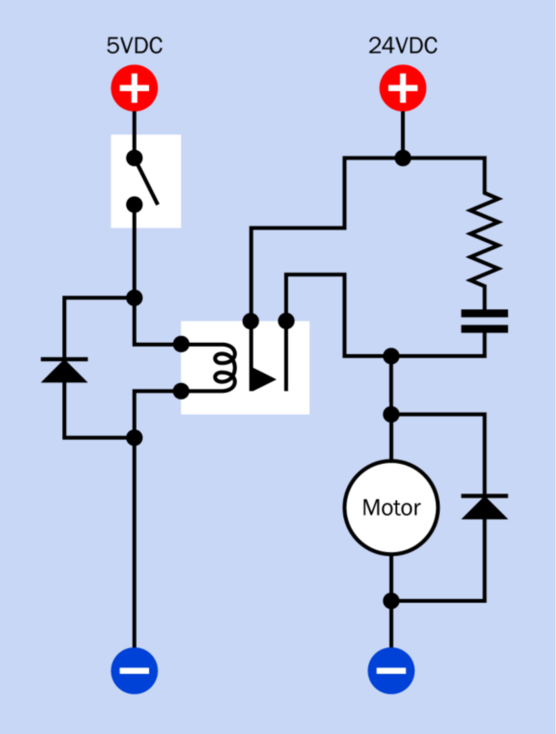

Figure 9-13. *This hypothetical schematic shows three types of protection against voltage spikes induced by an inductive load (a motor, in this instance) and the coil of the relay.*

What Can Go Wrong

Wrong Pinouts

The lack of standardization of relay pinouts can cause errors if one relay is replaced with another that appears to be the same, but isn't. In particular, the pins that connect with normally-closed contacts may trade places with pins connected with normally-open contacts, in relays from different manufacturers.

Pinouts are also confusing in that some datasheets depict them from above, some from below, and some from both perspectives.

Wrong Orientation

Small relays of through-hole type usually have pins spaced in multiples of 0.1". This allows them to be inserted the wrong way around in a perforated board. Almost all relays have an identification mark molded into one end or one corner of the plastic shell. Manufacturers do not standardize the position and meaning of these marks, but they are usually replicated in datasheets. When using a relay of a type that you have not used before, it is a sensible precaution to test it with a meter to verify the functions of its terminals before installing it.

Wrong Type

A latching relay may have exactly the same appearance as a nonlatching relay from the same manufacturer, and the same two pins may energize the coil. However, in a latching relay, the contacts won't spring back to their non-energized position, causing functional errors that may be difficult to diagnose. The part numbers printed on latching and nonlatching versions of the same relay may differ by only one letter or numeral and should be checked carefully.

Wrong Polarity

A relay with a DC-energized coil may require power to be applied with correct polarity and may malfunction otherwise.

AC and DC

A relay coil designed to be powered by DC will not work from AC and vice-versa. The contact rating of a relay is likely to be different depending whether it is switching AC or DC.

Chatter

This is the noise created by relay contacts when they make rapid intermittent connection. Chatter is potentially damaging to relay contacts and should be avoided. It can also create electrical noise that interferes with other components. Likely correctible causes of chatter include insufficient voltage or power fluctuations.

Relay Coil Voltage Spike

A relay coil is an inductive device. Merely switching a large relay on and off can create voltage spikes. To address this problem, a rectifier diode should be placed across the coil terminals with polarity opposing the energizing voltage.

Arcing

This problem is discussed in the **switch** entry of this encyclopedia. See "Arcing" (page 47). Note that because the contacts inside a *reed relay* are so tiny, they are especially susceptible to arcing and may actually melt and weld themselves together if they are used to control excessive current or an inductive load.

Magnetic Fields

Relays generate magnetic fields during operation and should not be placed near components that are susceptible.

The reed switch inside a reed relay can be unexpectedly activated by an external magnetic field. This type of relay may be enclosed in a metal shell to provide some protection. The adequacy of this protection should be verified by testing the relay under real-world conditions.

Environmental Hazards

Dirt, oxidation, or moisture on relay contacts is a significant problem. Most relays are sealed and should remain sealed.

Relays are susceptible to vibration, which can affect the contacts and can accelerate wear on moving parts. Severe vibration can even damage a relay permanently. **Solid-state relays** (discussed in Volume 2) should be used in harsh environments.

resistor

10

OTHER RELATED COMPONENTS

- **potentiometer** (See Chapter 11)

What It Does

A resistor is one of the most fundamental components in electronics. Its purpose is to impede a flow of current and impose a voltage reduction. It consists of two wires or conductors attached at opposite ends or sides of a relatively poor electrical conductor, the resistance of which is measured in ohms, universally represented by the Greek omega symbol, Ω.

Schematic symbols that represent a resistor are shown in Figure 10-1 (Left: The traditional schematic symbol. Right: The more recent European equivalent). The US symbol is still sometimes used in European schematics, and the European symbol is sometimes used in US schematics. Letters K or M indicate that the value shown for the resistor is in thousands of ohms or millions of ohms, respectively. Where these letters are used in Europe, and sometimes in the US, they are substituted for a decimal point. Thus, a 4.7K resistor may be identified as 4K7, a 3.3M resistor may be identified as 3M3, and so on. (The numeric value in Figure 10-1 was chosen arbitrarily.)

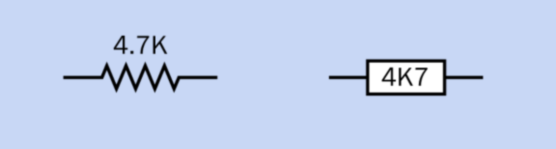

Figure 10-1. *Resistor symbols. The left one is more common in the United States, while the right one is widely used in Europe. The 4.7K value was chosen arbitrarily.*

A resistor is commonly used for purposes such as limiting the charging rate of a **capacitor**; providing appropriate control voltage to semiconductors such as **bipolar transistors**; protecting **LED**s or other semiconductors from excessive current; adjusting or limiting the frequency response in an audio circuit (in conjunction with other components); pulling up or pulling down the voltage at the input pin of a digital logic chip; or controlling a voltage at a point in a circuit. In this last application, two resistors may be placed in series to create a *voltage divider*.

A **potentiometer** may be used instead of a resistor where variable resistance is required.

Sample resistors of various values are shown in Figure 10-2. From top to bottom, their power dissipation ratings are 3W, 1W, 1/2W, 1/4W, 1/4W, 1/4W, and 1/8W. The accuracy (tolerance) of each resistor, from top to bottom, is plus-or-minus 5%, 5%, 5%, 1%, 1%, 5%, and 1%. The beige-colored body of a resistor is often an indication that its tolerance is 5%, while a blue-colored body often indicates a tolerance of 1% or 2%. The blue-bodied resistors and the dark brown resistor contain metal-oxide film elements, while the beige-bodied resistors and the green resistor contain carbon film. For more information on resistor values, see the upcoming *Values* section.

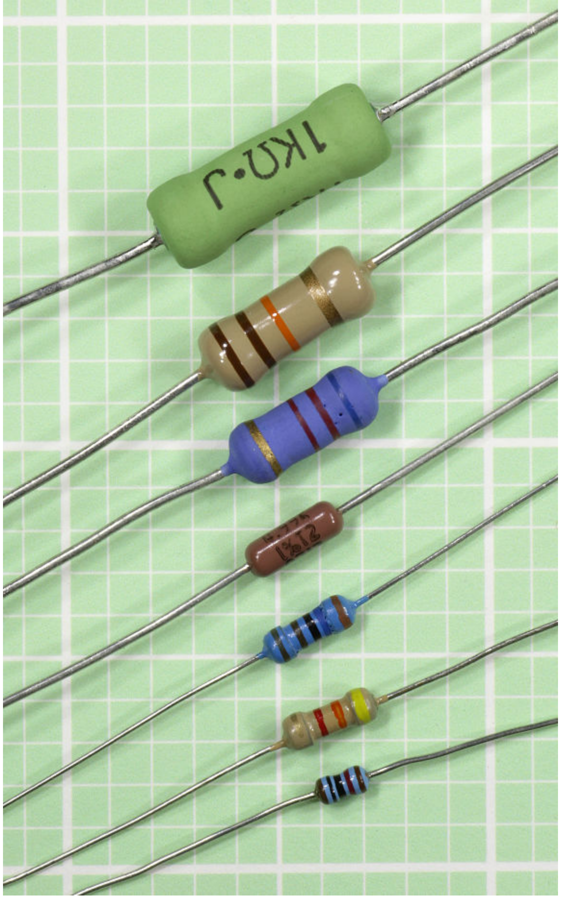

Figure 10-2. *A range of typical resistors. See text for details.*

How It Works

In the process of impeding the flow of current and reducing voltage, a resistor absorbs electrical energy, which it must dissipate as heat. In most modern electronic circuits, the heat dissipation is typically a fraction of a watt.

If R is the resistance in ohms, I is the current flowing through the resistor in amperes, and V is the voltage drop imposed by the resistor (the difference in electrical potential between the two contacts that are attached to it), Ohm's law states:

```
V = I / R
```

This is another way of saying that a resistor of 1Ω will allow a current of 1 amp when the potential difference between the ends of the resistor is 1 volt.

If W is the power in watts dissipated by the resistor, in a DC circuit:

```
W = V * I
```

By substitution in Ohm's law, we can express watts in terms of current and resistance:

$$W = I^2 / R$$

We can also express watts in terms of voltage and resistance:

$$W = V^2 * R$$

These alternates may be useful in situations where you do not know the voltage drop or the current, respectively.

Approximately similar relationships exist when using alternating current, although the power will be a more complex function.

Variants

Axial resistors have two leads that emerge from opposite ends of a usually cylindrical body. *Radial resistors* have parallel leads emerging from one side of the body and are unusual.

Precision resistors are generally defined as having a tolerance of no more than plus-or-minus 1%.

General-purpose resistors are less stable, and their value is less precise.

Power resistors are generally defined as dissipating 1 or 2 watts or more, particularly in power supplies or power amplifiers. They are physically larger and may require *heat sinks* or fan cooling.

Wire-wound resistors are used where the component must withstand substantial heat. A wire-wound resistor often consists of an insulating tube or core that is flat or cylindrical, with multiple turns of resistive wire wrapped around it. The wire is usually a nickel-chromium alloy known as *nichrome* (sometimes written as *Ni-chrome*) and is dipped in a protecting coating.

The heat created by current passing through resistive wire is a potential problem in electronic circuits where temperature must be limited. However, in household appliances such as hair dryers, toaster ovens, and fan heaters, a nichrome element is used specifically to generate heat. Wire-wound resistors are also used in 3D printers to melt plastic (or some other compound) that forms the solid output of the device.

Thick film resistors are sometimes manufactured in a flat, square format. A sample is shown in Figure 10-3, rated to dissipate 10W from its flat surface. The resistance of this component is 1K.

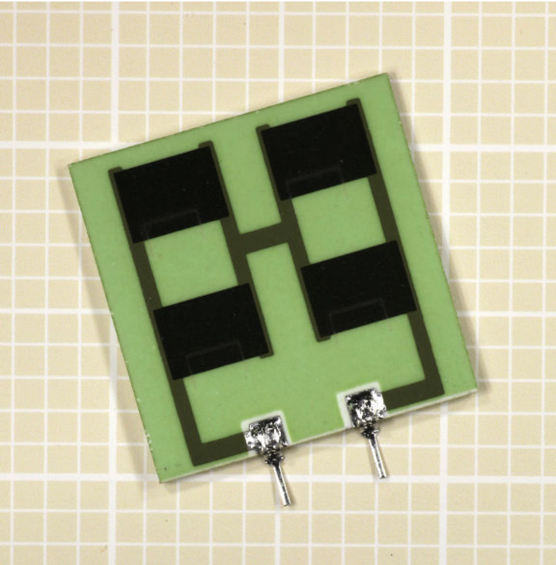

Figure 10-3. *A thick-film resistor measuring about 1" square and 0.03" thick.*

Surface-mount resistors generally consist of a resistive ink film printed on top of a tablet of aluminum oxide ceramic compound, often approximately 6mm long, known as a 2512 form factor. Each surface-mount resistor has two nickel-plated terminations coated in solder, which melts when the resistor is attached to the circuit board. The upper surface is coated, usually with black epoxy, to protect the resistive element.

Resistor Array

This is also known as a *resistor network* or *resistor ladder*, and consists of a chip containing multiple equal-valued resistors.

A resistor array in a *single-inline package* (or *SIP*) may have three possible internal configurations: isolated, common bus, and dual terminator. These options are shown at top, center, and bottom, respectively, in Figure 10-4. The isolated variant is commonly available in SIPs with 6, 8, or 10 pins. The common-bus and dual-terminator configurations generally have 8, 9, 10, or 11 pins.

In the isolated configuration, each resistor is electrically independent of the others and is accessed via its own pair of pins. On a common bus, one end of each resistor shares a bus accessed by a single pin, while the other ends of the resistors are accessed by their own separate pins. A dual-terminator configuration is more complex, consisting of pairs of resistors connected between ground and an internal bus, with the midpoint of each resistor pair accessible via a separate pin. The resistor pairs this function as voltage dividers and are commonly used in emitter-coupled logic circuits that require termination with -2 volts.

A *dual-inline package* (*DIP*) allows a similar range of internal configurations, as shown in Figure 10-5. At top, isolated resistors are commonly available in DIPs with 4, 7, 8, 9, or 10 pins. At center, the common bus configuration is available in DIPs with 8, 14, 16, 18, or 20 pins. At bottom, the dual-terminator configuration usually has 8, 14, 16, 18, or 20 pins.

The external appearance of SIP and DIP resistor arrays is shown in Figure 10-6. From left to right, the packages contain seven 120Ω resistors in

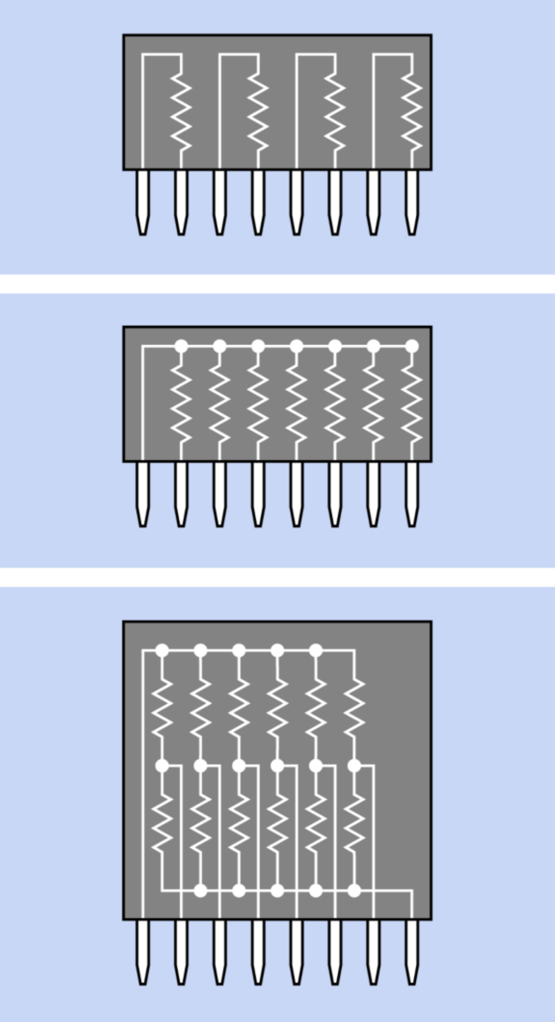

Figure 10-4. *Multiple resistors can be embedded in a single-inline package (SIP) in a variety of formats. See text for additional details.*

isolated configuration; thirteen 120Ω resistors in bussed configuration; seven 5.6K resistors in bussed configuration; and six 1K resistors in bussed configuration.

Resistor arrays with isolated or common-bus configurations are a convenient way to reduce the component count in circuits where pullup, pulldown, or terminating resistors are required for multiple chips. The common-bus configuration is also useful in conjunction with a 7-segment **LED display**, where each segment must be terminated by a series resistor and all the resistors share a common ground or common voltage source.

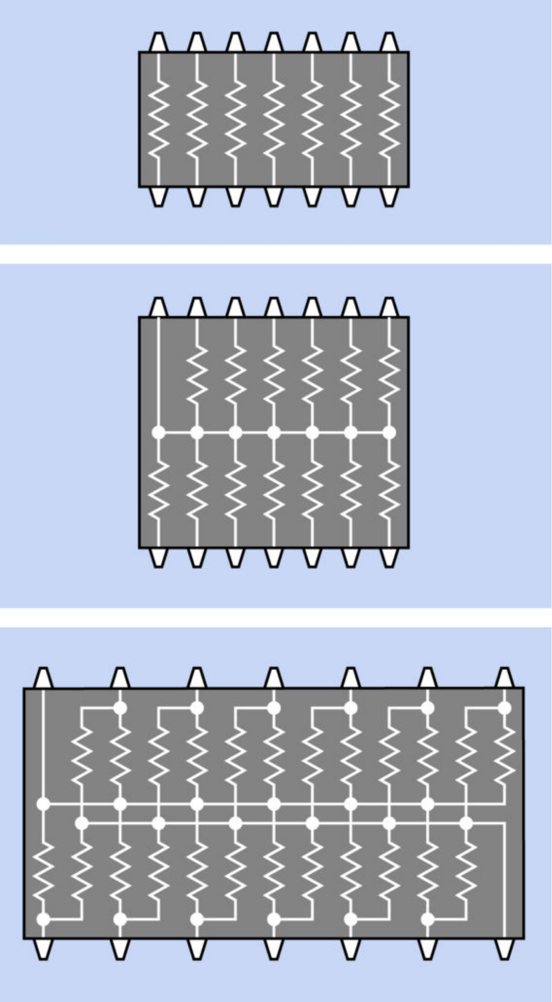

Figure 10-5. *Multiple resistors can be obtained embedded in a dual-inline package (DIP). See text for additional details.*

Surface-mount chips are available containing a pair of resistors configured as a single voltage divider.

Chips containing multiple *RC circuits* (each consisting of a capacitor and a resistor in series) are available, although uncommon. A package containing a single RC circuit may be sold as a

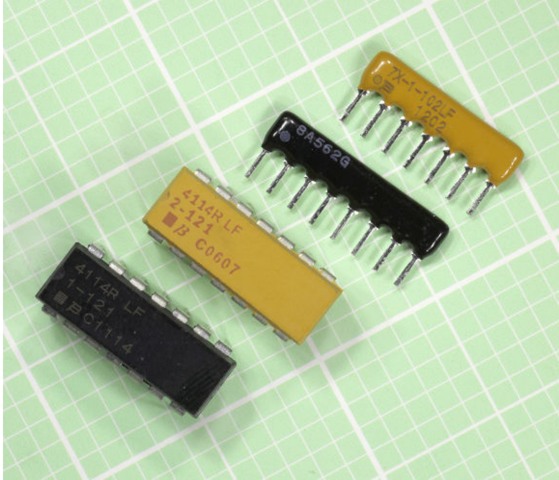

Figure 10-6. *Resistor arrays in DIP and SIP packages. See text for values.*

snubber to protect contacts in a **switch** or **relay** that switches a large inductive load. More information on snubber circuits is in the **capacitor** entry of this encyclopedia; see "Snubber" (page 108).

Values

1 *kilohm,* usually written as 1K, is 1,000Ω. 1 *megohm,* usually written as 1M or 1 meg, is 1,000K. 1 *gigaohm* is 1,000 megs, although the unit is rarely used. Resistances of less than 1Ω are uncommon and are usually expressed as a decimal number followed by the Ω symbol. The term *milliohms* (thousandths of an ohm) is used in special applications. Equivalent resistor values are shown in Figure 10-7.

A resistance value remains unchanged in DC and AC circuits, except where the AC reaches an extremely high frequency.

In common electronics applications, resistances usually range from 100Ω to 10M. Power ratings may vary from 1/16 watt to 1000 watts, but usually range from 1/8 watt to 1/2 watt in most electronic circuits (less in surface-mount applications).

Ohms	Kilohms	Megohms
1	0.001	0.000001
10	0.01	0.00001
100	0.1	0.0001
1,000	1	0.001
10,000	10	0.01
100,000	100	0.1
1,000,000	1,000	1

Figure 10-7. *Equivalent values in ohms, kilohms, and megohms.*

Tolerance

The tolerance, or precision, of a resistor may range from plus-or-minus 0.001% up to plus-or-minus 20%, but is most commonly plus-or-minus 1%, 2%, 5%, or 10%.

The traditional range of resistor values was established when a tolerance of 20% was the norm. The values were spaced to allow minimum risk of a resistor at one end of its tolerance range having the same value as another resistor at the opposite end of its tolerance range. The values were rounded to 10, 15, 22, 33, 47, 68, and 100, as illustrated in Figure 10-8 where each blue diamond represents the possible range of actual values of a 20% resistor with a theoretical value shown by the white horizontal line at the center of the diamond.

Resistor factors repeat themselves in multiples of 10. Thus, for example, beginning with a resistor of 100Ω, subsequent increasing values will be 150, 220, 330, 470, 680, and 1K, whereas the range of resistors beginning with 1Ω will be 1.5, 2.2, 3.3, 4.7, 6.8, and 10Ω.

Resistance multiplication factors are now expressed as a list of preferred values by the International Electrotechnical Commission (IEC) in their 60063 standard. Intermediate factors have been added to the basic sequence to

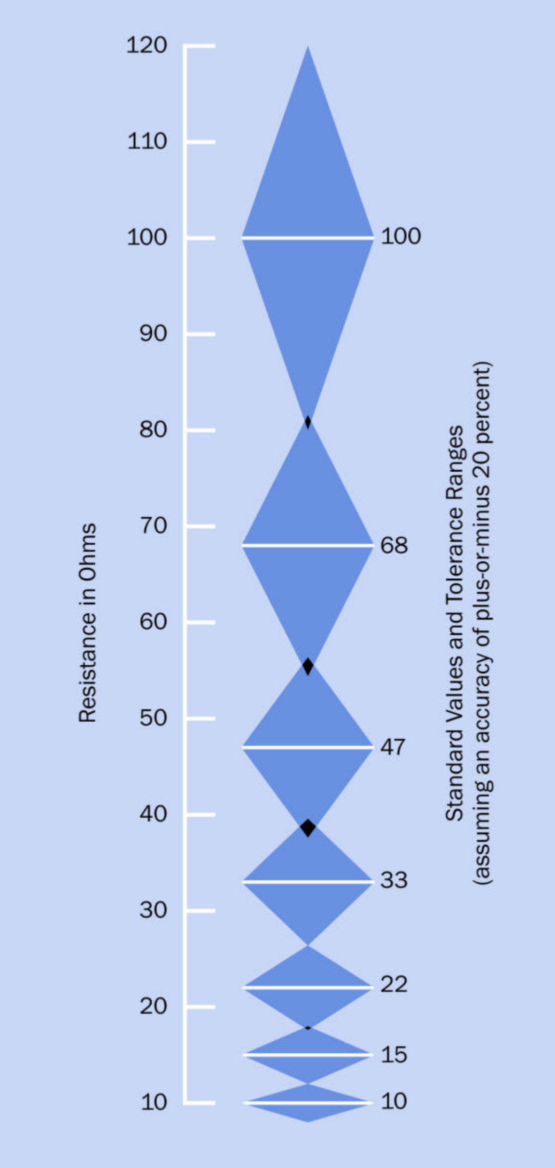

Figure 10-8. *Graphical representation of standard resistor values (white lines) established by the International Electrotechnical Commission, showing the acceptable range of actual values (dark blue areas) assuming precision of plus-or-minus 20%. The overlap, if any, between each range and the next is shown in black.*

accommodate better tolerances. A table showing resistor values for tolerances of plus-or-minus 20%, 10%, and 5% appears in Figure 10-9. Resistors with a tolerance of 5% have become increasingly common.

	Resistor Tolerances (plus or minus)		
	20%	10%	5%
Standard Resistor Values	100	100	100
			91
		82	82
			75
	68	68	68
			62
		56	56
			51
	47	47	47
			43
		39	39
			36
	33	33	33
			30
		27	27
			24
	22	22	22
			20
		18	18
			16
	15	15	15
			13
		12	12
			11
	10	10	10

Figure 10-9. *Standard values for resistors of different precisions. For resistors outside the range shown, values can be found by multiplying or dividing (repeatedly, if necessary) by a factor of 10.*

The IEC has established 3-digit preferred values for resistors with values accurate to plus-or-minus 0.5%.

Because many capacitors still have a tolerance no better than 20%, their values also conform with the old original set of resistance values, although the units are expressed in farads or fractions of a farad. See the **capacitors** entry in this encyclopedia for additional information.

Value Coding

Through-hole axial resistors are traditionally printed with a sequence of three colored bands to express the value of the component, each of the first two bands representing a digit from 0 through 9, while the third band indicates the decimal multiplier (the number of zeroes, from 0 to 9, which should be appended to the digits). A fourth band of silver or gold indicates 10% or 5% tolerance respectively. No fourth band would indicate 20% tolerance, although this has become very rare.

Many resistors now have five color bands, to enable the representation of intermediate or fractional values. In this scheme, the first three bands have numeric values (using the same color system as before) while the fourth band is the multiplier. A fifth band, at the opposite end of the resistor, indicates its tolerance.

In Figure 10-10 the numeric or multiplier value of each color is shown as a "spectrum" at the top of the figure. The tolerance, or precision of a resistor, expressed as a plus-or-minus percentage, is shown using silver, gold, and various colors, at the bottom of the figure.

Two sample resistors are shown. The upper one has a value of 1K, indicated by the brown and black bands on the left (representing numeral 1 followed by a numeral 0) and the third red band (indicating two additional zeroes). The gold band at right indicates a precision of 5%. The lower one has a value of 1.05K, indicated by the brown, black, and green bands on the left (representing numeral 1 followed by numeral 0 followed by a numeral 5) and the fourth band brown (indicating one additional zero). The brown band at right indicates a precision of 1%.

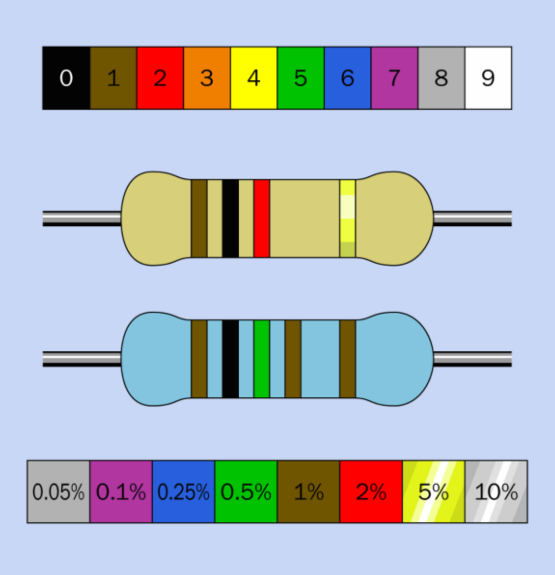

Figure 10-10. *Color coding of through-hole resistors. See text for details.*

In extremely old equipment, resistors may be coded with the body-tip-dot scheme, in which the body color represents the initial digit, the end color represents the second digit, and a dot represents the multiplier. The numeric identities of the colors is the same as in the current color scheme.

In all modern schemes, the three or four bands that show the resistance value are spaced close together, while a larger gap separates them from the band that shows the tolerance. The resistor value should be read while holding the resistor so that the group of closely-spaced numeric bands is on the left.

Confusingly, some resistors may be found where the first three bands define the value, using the old three-band convention; the fourth band indicates tolerance; and a fifth band at the opposite end of the component indicates reliability. However, this color scheme is uncommon.

Other color-coding conventions may be found in special applications, such as military equipment.

It is common for through-hole carbon-film resistors to have a beige body color, while through-hole metal-film resistors often have a blue body color. However, in relatively rare instances, a blue body color may also indicate a *fusible* resistor (designed to burn out harmlessly like a fuse, if it is overloaded) while a white body may indicate a *non-flammable* resistor. Use caution when replacing these special types.

Some modern resistors may have their values printed on them numerically. Surface-mount resistors also have digits printed on them, but they are a code, not a direct representation of resistance. The last digit indicates the number of zeroes in the resistor value, while the preceding two or three numbers define the value itself. Letter R is used to indicate a decimal point. Thus a 3R3 surface-mount resistor has a value of 3.3Ω, while 330 would indicate 33Ω, and 332 indicates 3,300Ω. A 2152 surface-mount resistor would have a value of 21,500Ω.

A surface-mount resistor with a single zero printed on it is a *zero ohm* component that has the same function as a **jumper** wire. It is used for convenience, as it is easily inserted by automated production-line equipment. It functions merely as a bridge between traces on the circuit board.

When resistor values are printed on paper in schematics, poor reproduction may result in omission of decimal points or introduction of specks that look like decimal points. Europeans have addressed this issue by using the letter as a substitute for a decimal point so that a 5.6K resistor will be shown as 5K6, or a 3.3M resistor will be shown as 3M3. This practice is followed infrequently in the United States.

Stability

This term describes the ability of a resistor to maintain an accurate value despite factors such as temperature, humidity, vibration, load cycling, current, and voltage. The *temperature coefficient* of a resistor (often referred to as T_{cr} or T_c, not to be confused with the time constant of a charging capacitor) is expressed in parts per million change in resistance for each degree centigrade deviation from room temperature (usually assumed to be 25 degrees Centigrade). T_c may be a positive or a negative value.

The *voltage coefficient* of resistance—often expressed as V_c—describes the change of a resistor's value that may occur as a function of changes in voltage. This is usually significant only where the resistive element is carbon-based. If V1 is the rated voltage of the resistor, R1 is its rated resistance at that voltage, V2 is 10% of the rated voltage, and R2 is the actual resistance at that voltage, the voltage coefficient, V_c, is given by this formula:

$$V_c = (100 * (R1 - R2)) / (R2 * (V1 - V2))$$

Materials

Resistors are formed from a variety of materials.

Carbon composite. Particles of carbon are mixed with a binder. The density of the carbon determines the end-to-end resistance, which typically ranges from 5Ω to 10M. The disadvantages of this system are low precision (a 10% tolerance is common), relatively high voltage coefficient of resistance, and introduction of noise in sensitive circuits. However, carbon-composite resistors have low inductance and are relatively tolerant of overload conditions.

Carbon film. A cheap and popular type, made by coating a ceramic substrate with a film of carbon compound. They are available in both through-hole and surface-mount formats. The range of resistor values is comparable with carbon-composite types, but the precision is increased, typically to 5%, by cutting a spiral groove in the carbon-compound coating during the manufacturing process. The carbon film suffers the same disadvantages of carbon composite resistors, but to a lesser extent. Carbon film resistors generally should not be substituted for metal film resistors in applications where accuracy is important.

Metal film. A metallic film is deposited on a ceramic substrate, and has generally superior characteristics to carbon-film resistors. During manufacture, a groove may be cut in the metal film to adjust the end-to-end resistance. This may cause the resistor to have higher inductance than carbon-composite types, though it has lower noise. Tolerances of 5%, 2%, and 1% are available. This type of resistor was originally more expensive than carbon-film equivalents, but the difference is now fractional. They are available in both through-hole and surface-mount formats. They are available in lower-wattage variants (1/8 watt is common).

Thick-film resistors are spray-coated, whereas thin-film resistors are sputtered nichrome. Thin-films enjoy a flatter temperature coefficient and are typically used in environments that have a huge operational temperature range, such as satellites.

Bulk metal foil. The type of foil used in metal film resistors is applied to a ceramic wafer and etched to achieve the desired overall resistance. Typically these resistors have axial leads. They can be extremely accurate and stable, but have a limited maximum resistance.

Precision wire-wound. Formerly used in applications requiring great accuracy, but now largely replaced by precision metal foil.

Power wire-wound. Generally used when 1 or 2 watts or more power dissipation is required. Resistive wire is wrapped around a core that is often ceramic. This can cause the resistor to be referred to, inaccurately, as "ceramic." The core may alternatively be fiberglass or some other electrically insulating compound that actively sinks heat. The component is either dipped (typically in vitreous enamel or cement) or is mounted in an aluminum shell that can be clamped to a heat sink. It almost always has the ohm value printed on it in plain numerals (not codes).

Two typical wire-wound resistors are shown in Figure 10-11. The upper resistor is rated at 12W and 180Ω while the lower resistor is rated at 13W and 15K.

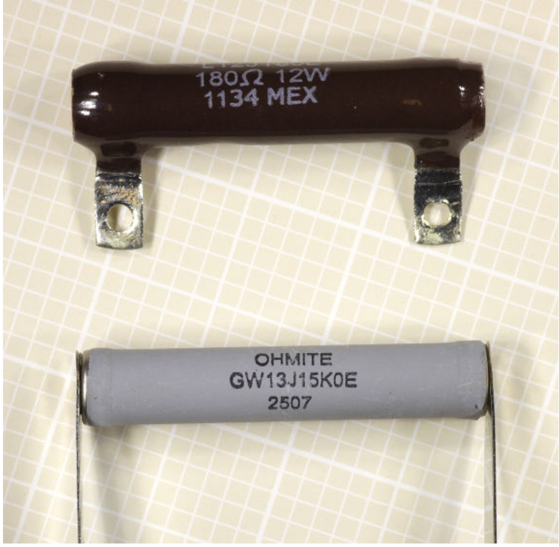

Figure 10-11. *Two wire-wound resistors of greatly differing resistance but similar power dissipation capability.*

A larger wire-wound resistor is shown in Figure 10-12, rated for 25W and 10Ω.

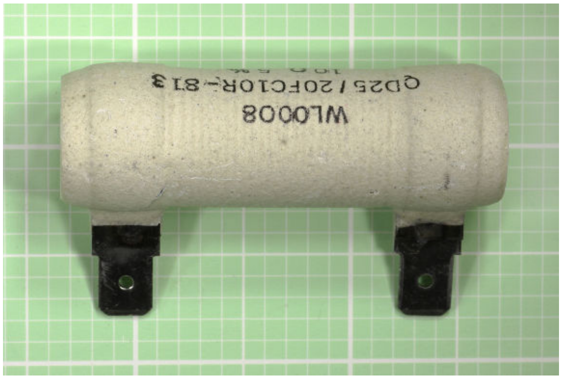

Figure 10-12. *A large wirewound resistor rated to dissipate 25W.*

In Figure 10-13, two resistors encapsulated in cement coatings are shown with the coatings removed to expose the elements. At left is a 1.5Ω 5W resistor, which uses a wire-wound element. At right is a very low-value 0.03Ω 10W resistor.

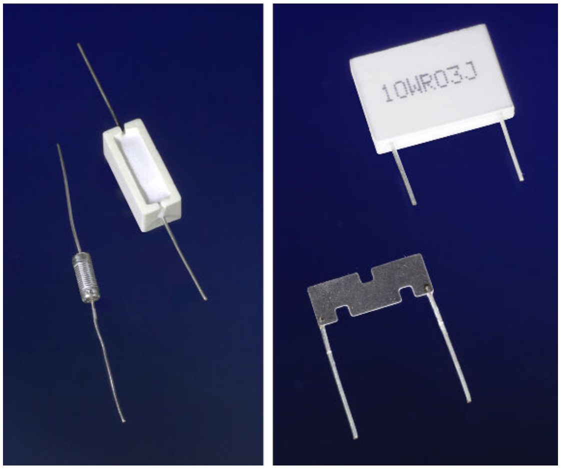

Figure 10-13. *Two low-value resistors with their cement coatings removed to show the resistive elements.*

In Figure 10-14, the resistor at right has an exposed 30Ω element while the resistor at left is rated 10W and 6.5Ω, enclosed in an anodized aluminum shell to promote heat dissipation.

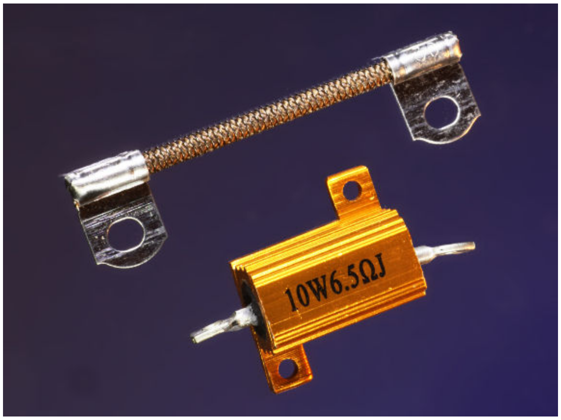

Figure 10-14. *A 30Ω resistor (right) and 6.5Ω resistor (left).*

In power resistors, heat dissipation becomes an important consideration. If other factors (such as voltage) remain the same, a lower-value resistor will tend to pass more current than a higher-value resistor, and heat dissipation is proportional to the square of the current. Therefore power wire-wound resistors are more likely to be needed where low resistance values are required. Their coiled-wire format creates significant inductance, making them unsuitable to pass high frequencies or pulses.

How to Use it

Some of the most common applications for a resistor are listed here.

In Series with LED

To protect an LED from damage caused by excessive current, a *series resistor* is chosen to allow a current that does not exceed the manufacturer's specification. In the case of a single through-hole LED (often referred to as an *indicator*), the forward current is often limited to around 20mA, and the value of the resistor will depend on the voltage being used. (See Figure 10-15.)

When using high-output LEDs (which may contain multiple elements in a single 5mm or 10mm package), or LED arrays that are now being used for domestic lighting, the acceptable current may be much greater, and the LED unit may contain its own current-limiting electronics. A datasheet should be consulted for details.

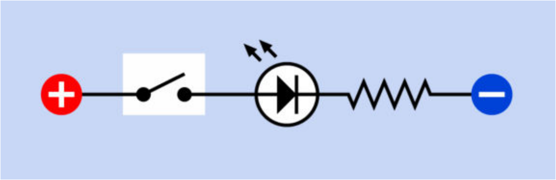

Figure 10-15. *A series resistor is necessary to limit the current that passes through an LED.*

Current Limiting with a Transistor

In Figure 10-16, a transistor is switching or amplifying current flowing from B to C. A resistor is used to protect the base of the transistor from excessive current flowing from point A. Resistors are also commonly used to prevent excessive current from flowing between B and C.

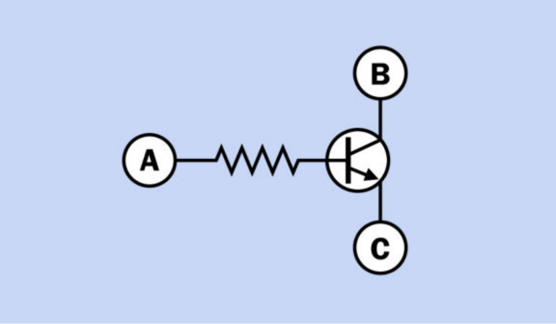

Figure 10-16. *A resistor is typically necessary to protect the base of a transistor from excessive current.*

Pullup and Pulldown Resistors

When a mechanical switch or pushbutton is attached to the input of a logic chip or **microcontroller**, a *pullup* or *pulldown* resistor is used, applying positive voltage or grounding the pin, respectively, to prevent it from "floating" in an indeterminate state when the switch is open. In Figure 10-17, the upper schematic shows a pulldown resistor, whereas the lower schematic shows a pullup resistor. A common value for either of them is 10K. When the pushbutton is pressed, its direct connection to positive voltage or to ground easily overwhelms the effect of the resistor. The choice of pullup or pulldown resistor may depend on the type of chip being used.

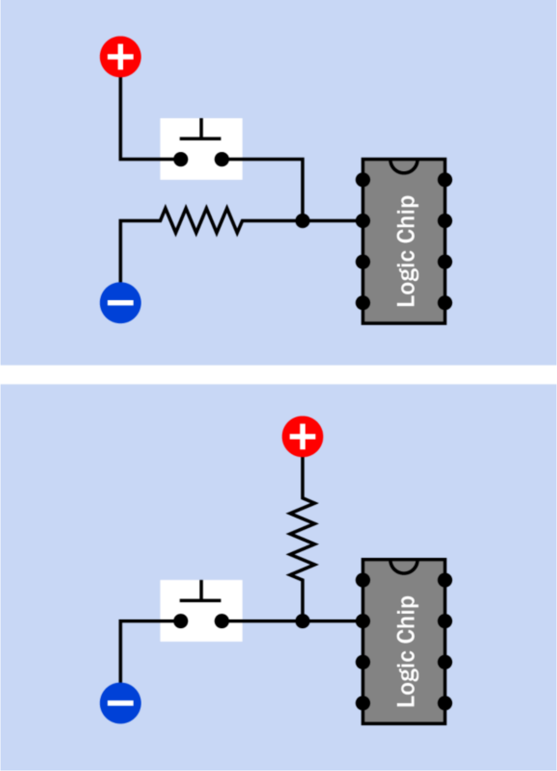

Figure 10-17. *A pulldown resistor (top) or pullup resistor (bottom) prevents an input pin on a logic chip or microcontroller from "floating" in an indeterminate state when the button is not being pressed.*

Audio Tone Control

A resistor-capacitor combination can limit the high-frequency in a simple audio tone-control circuit, as shown in Figure 10-18. Beneath a signal travelling from A to B, a resistor is placed in series with a capacitor that passes high frequencies to ground. This is known as a low-pass filter.

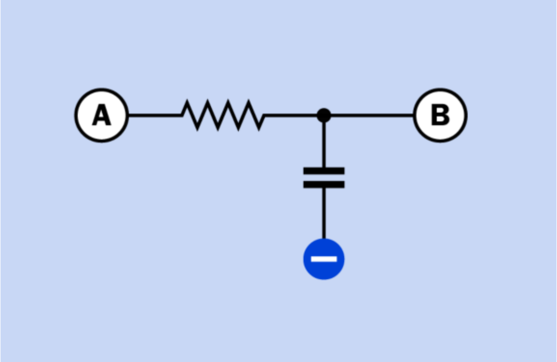

Figure 10-18. *This configuration may be used to remove high frequencies from an audio signal. It is known as a low-pass filter because low frequencies are passed from A to B.*

RC Network

A resistor will adjust the charge/discharge time when placed in series with a capacitor, as in Figure 10-19. When the switch closes, the resistor limits the rate at which the capacitor will charge itself from the power supply. Because a capacitor has an ideally infinite resistance to DC current, the voltage measured at point A will rise until it is close to the supply voltage. This is often referred to as an *RC* (*resistor-capacitor*) network and is discussed in greater detail in the **capacitor** section of this encyclopedia.

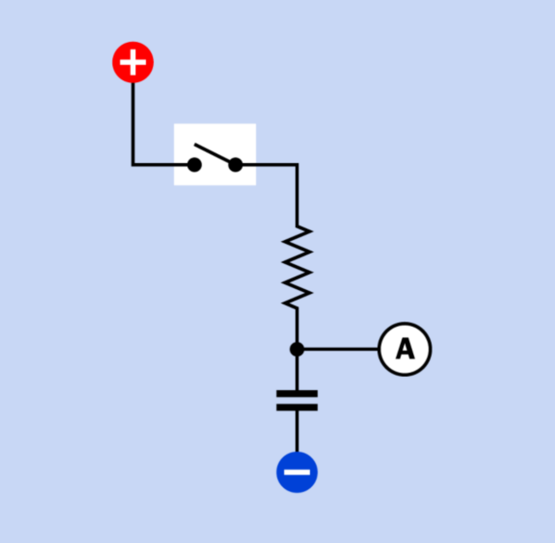

Figure 10-19. *In an RC (resistor-capacitor) network, a resistor limits the rate of increase in potential of the capacitor, measured at A, when the switch is closed.*

Voltage Divider

Two resistors may be used to create a voltage divider (see Figure 10-20). If V_{in} is the supply voltage, the output voltage, V_{out}, measured at point A, is found by the formula:

$$V_{out} = V_{in} * (R2 / (R1 + R2))$$

In reality, the actual value of V_{out} is likely to be affected by how heavily the output is loaded.

If the output node has a high impedance, such as the input to a logic chip or comparator, it will be more susceptible to electrical noise, and lower-value resistors may be needed in the voltage divider to maintain a higher current flow and maintain stability in the attached device.

Resistors in Series

If resistors in series have values R1, R2, R3 . . . the total resistance, R, is found by summing the individual resistances:

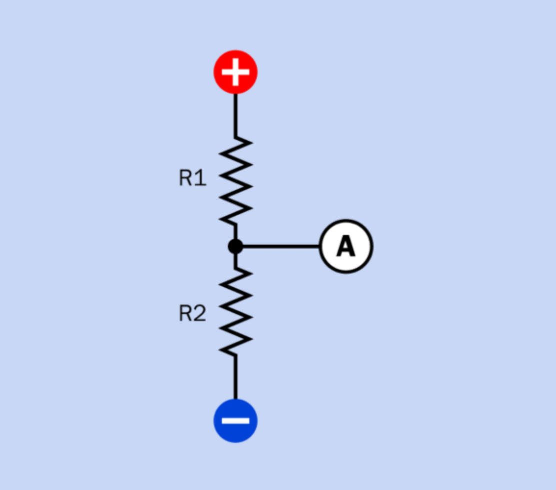

Figure 10-20. *In a DC circuit, a pair of resistors may be placed in series to function as a voltage divider. The voltage measured at A will be lower than the supply voltage, but above ground potential.*

```
R = R1 + R2 + R3. . .
```

The current through each of the resistors will be the same, whereas the voltage across each of them will vary proportionately with its resistance. If the supply voltage across the series of resistors is VS, and the total of all the resistor values is RT, and the resistance of one resistor is R1, the voltage across that resistor, V1, will be given by the formula:

```
V1 = VS * (R1 / RT)
```

Resistors in Parallel

Where two or more resistors (R1, R2, R3 . . .) are wired in parallel, their total resistance, R, is found from the formula:

```
1/R = ( 1/R1 ) + ( 1/R2 ) + ( 1/R3 ). . .
```

Suppose that R1, R2, R3 . . . all have the same individual resistance, represented by RI, and the number of resistors is N. Their total resistance, RT, when wired in parallel, will be:

```
RT = RI / N
```

If each resistor has an equal resistance and also has an equal individual rating in watts (represented by WI), the total wattage (WT) that they can handle when wired in parallel to share the power will be:

```
WT = WI * N
```

Therefore, if an application requires high-wattage resistors, multiple lower-wattage, higher-value resistors may be substituted if they are wired in parallel—and may even be cheaper than a single high-wattage wire-wound resistor. For example, if a 5W, 50Ω resistor is specified, 10 resistors can be substituted, each rated at 0.5W and 500Ω. Bear in mind that if they are tightly bundled, this will interfere with heat dissipation.

What Can Go Wrong

Heat

Resistors are probably the most robust of all electronic components, with high reliability and a long life. It is difficult to damage a resistor by overheating it with a soldering iron.

The wattage rating of a resistor does not necessarily mean that it should be used to dissipate that amount of power on a constant basis. Small resistors (1/4 watt or less) can overheat just as easily as big ones. Generally speaking, it is safe practice not to exceed 75% of a resistor's power rating on a constant basis.

Overheating is predictably more of a problem for power resistors, where provision must be made for heat dissipation. Issues such as component crowding should be considered when deciding how big a heat sink to use and how much ventilation. Some power resistors may function reliably at temperatures as high as 250 degrees Centigrade, but components near them are likely to be less tolerant and plastic enclosures may soften or melt.

Noise

The electrical *noise* introduced by a resistor in a circuit will vary according to the composition of the resistor, but for any given component, it will be proportional to voltage and current. Low-noise circuits (such as those at the input stage of a high-gain amplifier) should use low-wattage resistors at a low voltage where possible.

Inductance

The coiled wire of a wire-wound resistor will be significantly inductive at low frequencies. This is known as *parasitic inductance*. It will also have a resonant frequency. This type of resistor is unsuitable for applications where frequency exceeds 50KHz.

Inaccuracy

When using resistors with 10% tolerance, imprecise values may cause greater problems in some applications than in others. In a voltage divider, for instance, if one resistor happens to be at the high end of its tolerance range while the other happens to be at the low end, the voltage obtained at the intersection of the resistors will vary from its expected value. Using the schematic shown in Figure 10-20, if R1 is rated for 1K and R2 is rated for 5K, and the power supply is rated at 12VDC, the voltage at point A should be:

```
V = 12 * (( 5 / (5 + 1)) = 10
```

However, if R1 has an actual value of 1.1K and R2 has an actual value of 4.5K, the actual voltage obtained at point A will be:

```
V = 12 * (( 4.5 / (4.5 + 1.1)) = 9.6
```

If the resistors are at opposite ends of their respective tolerance ranges, so that R1 has an actual value of 900Ω while the lower resistor has an actual value of 5.5K, the actual voltage obtained will be:

```
V = 12 * (( 5.5 / (5.5 + 0.9)) = 10.3
```

The situation becomes worse if the two resistors are chosen to be of equal value, to provide half of the supply voltage (6 volts, in this example) at their intersection. If two 5K resistors are used, and the upper one is actually 4.5K while the lower one is 5.5K, the actual voltage will be:

```
V = 12 * (( 5.5 / (4.5 + 5.5)) = 6.6
```

Whether this variation is significant will depend on the particular circuit in which the voltage divider is being used.

Common through-hole resistors may occasionally turn out to have values that are outside their specified tolerance range, as a result of poor manufacturing processes. Checking each resistor with a meter before placing it in a circuit should be a standard procedure.

When measuring the voltage drop introduced by a resistor in an active circuit, the meter has its own internal resistance that will take a proportion of the current. This is known as *meter loading* and will result in an artificially low reading for the potential difference between the ends of a resistor. This problem becomes significant only when dealing with resistors that have a high value (such as 1M), comparable with the internal resistance of the meter (likely to be 10M or more).

Wrong Values

When resistors are sorted into small bins by the user, errors may be made, and different values may be mixed together. This is another reason for checking the values of components before using them. Identification errors may be nontrivial and easily overlooked: the visible difference between a 1 megohm resistor and a 100Ω resistor is just one thin color band.

potentiometer

11

Also known as a *variable resistor*; may be substituted for a *rheostat*.

OTHER RELATED COMPONENTS

- **rotational encoder** (see Chapter 8)
- **resistor** (see Chapter 10)

What It Does

When a voltage is applied across a potentiometer, it can deliver a variable fraction of that voltage. It is often used to adjust sensitivity, balance, input, or output, especially in audio equipment and sensors such as motion detectors.

A potentiometer can also be used to insert a variable resistance in a circuit, in which case it should really be referred to as a *variable resistor*, although most people will still call it a potentiometer.

It can be used to adjust the power supplied to a circuit, in which case it is properly known as a *rheostat*, although this term is becoming obsolete. Massive rheostats were once used for purposes such as dimming theatrical lighting, but solid-state components have taken their place in most high-wattage applications.

A full-size, classic-style potentiometer is shown in Figure 11-1.

Schematic symbols for a potentiometer and other associated components are shown in Figure 11-2, with American versions on the left and European versions on the right in each case. The symbols for a potentiometer are at the top. The correct symbols for a variable resistor or rheostat are shown at center, although a potentiometer symbol may often be used instead. A preset variable resistor is shown at the bottom, often referred to as a *trimmer* or *Trimpot*. In these examples, each has an arbitrary rated resistance of 4,700Ω. Note the European substitution of K for a decimal point.

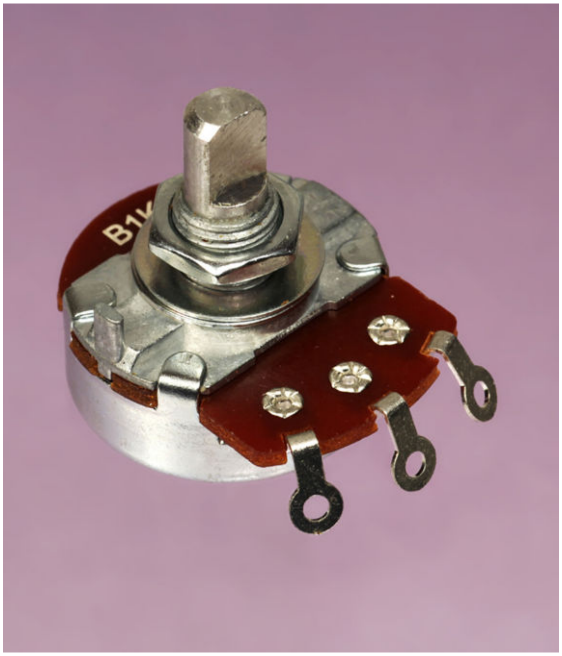

Figure 11-1. *A generic or classic-style potentiometer, approximately one inch in diameter.*

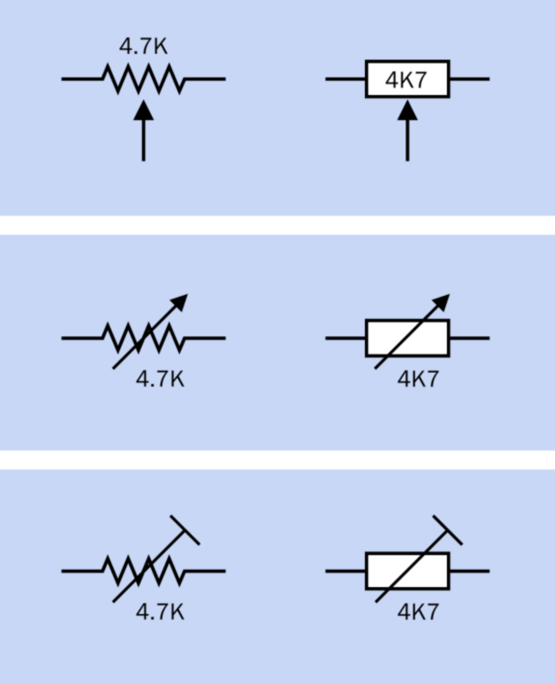

Figure 11-2. *American (left) and European (right) symbols for a potentiometer, a rheostat, and a trimmer potentiometer, reading from top to bottom. The 4.7K value was chosen arbitrarily.*

How It Works

A potentiometer has three terminals. The outer pair connect with the opposite ends of an internal resistive element, such as a strip of conductive plastic, sometimes known as the *track*. The third center terminal connects internally with a contact known as the *wiper* (or rarely, the *pick-off*), which touches the strip and can be moved from one end of it to the other by turning a shaft or screw, or by moving a slider.

If an electrical potential is applied between opposite ends of the resistive element, the voltage "picked off" by the wiper will vary as it moves. In this mode, the potentiometer works as a resistive voltage divider. For example, in a potentiometer with a linear taper (see "Variants," coming up), if you attach the negative side of a 12V battery to the right-hand end terminal and the positive side to the left-hand end terminal, you will find an 8V potential at the center terminal when the potentiometer has rotated clockwise through one-third of its range. In Figure 11-3, the base of the shaft (shown in black) is attached to an arm (shown in green) that moves a wiper (orange) along a resistive element (brown). The voltages shown assume that the resistive element has a linear taper and will vary slightly depending on wire resistance and other factors.

Because a potentiometer imposes a voltage reduction, it also reduces current flowing through it, and therefore creates waste heat which must be dissipated. In an application such as an audio circuit, small currents and low voltages generate negligible heat. If a potentiometer is used for heavier applications, it must be appropriately rated to handle the wattage and must be vented to allow heat to disperse.

To use a potentiometer as a *variable resistor* or *rheostat*, one of its end terminals may be tied to the center terminal. If the unused end terminal is left unconnected, this raises the risk of picking up stray voltages or "noise" in sensitive circuits. In Figure 11-4, a potentiometer is shown adjusting a series resistance for an *LED* for demonstration purposes. More typically, a trimmer would be used in this kind of application, since a user is unlikely to need to reset it.

Variants

Linear and Log Taper

If the resistive element in a potentiometer is of constant width and thickness, the electrical potential at the wiper will change in ratio with the rotation of the wiper and shaft (or with movement of a slider). This type of potentiometer is said to have a linear taper even though its element does not actually taper.

For audio applications, because human hearing responds nonlinearly to sound pressure, a potentiometer that has a linear taper may seem to have a very slow action at one end of its scale and an abrupt effect at the other. This problem used to be solved with a non-uniform or tapered re-

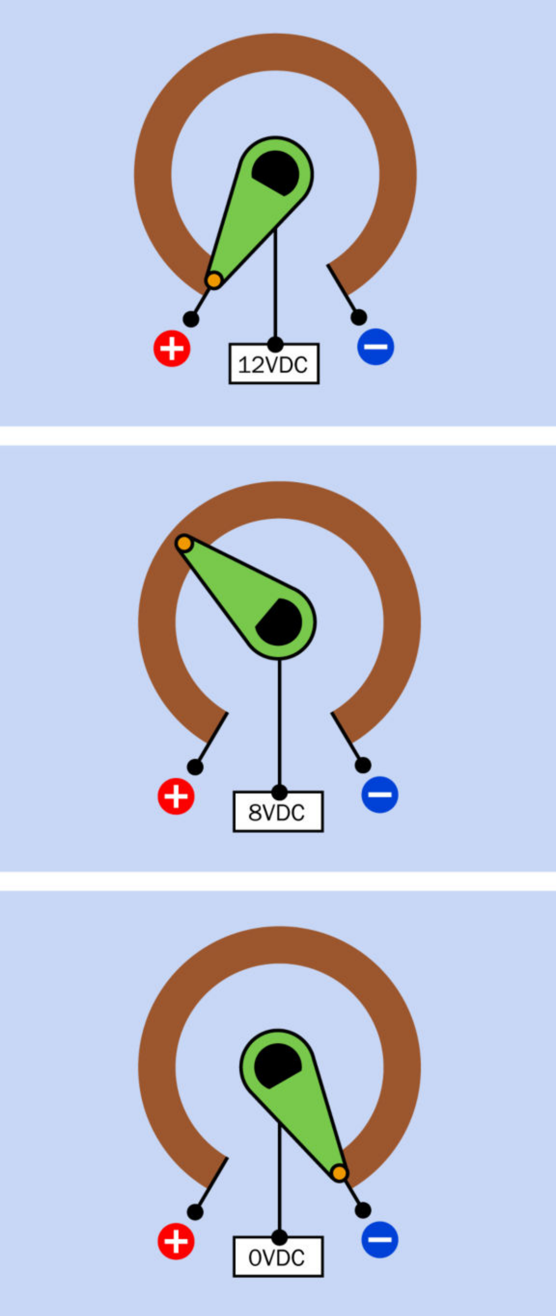

Figure 11-3. *Inside a potentiometer. See text for details.*

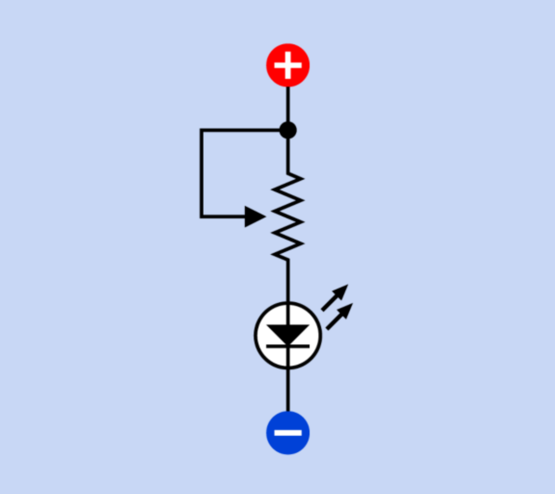

Figure 11-4. *A potentiometer can be used to adjust a series resistance, as shown in this schematic. Tying the wiper to one of the end terminals reduces the risk of picking up electrical noise.*

sistive element. More recently, a combination of resistive elements has been used as a cheaper option. Such a potentiometer is said to have an audio taper or a log taper (since the resistance may vary as a logarithm of the angle of rotation). A reverse audio taper or antilog taper varies in the opposite direction, but this type has become very uncommon.

Classic-style Potentiometer

This consists of a sealed circular can, usually between 0.5″ and 1″ in diameter, containing a resistive strip that is shaped as a segment of a circle. A typical example is shown in Figure 11-1, although miniaturized versions have become more common. A shaft mounted on the can turns the internal wiper that presses against the strip. For panel-mount applications, a threaded bushing at the base of the shaft is inserted through a hole in the front panel of the electronics enclosure, and a nut is tightened on the bushing to hold the potentiometer in place. Often there is also a small offset index pin that, when paired with a corresponding front panel hole, will keep the pot from spinning freely.

Many modern potentiometers are miniaturized, and may be packaged in a box-shaped plastic enclosure rather than a circular can. Their power ratings are likely to be lower, but their principle of operation is unchanged. Two variants are shown in Figure 11-5.

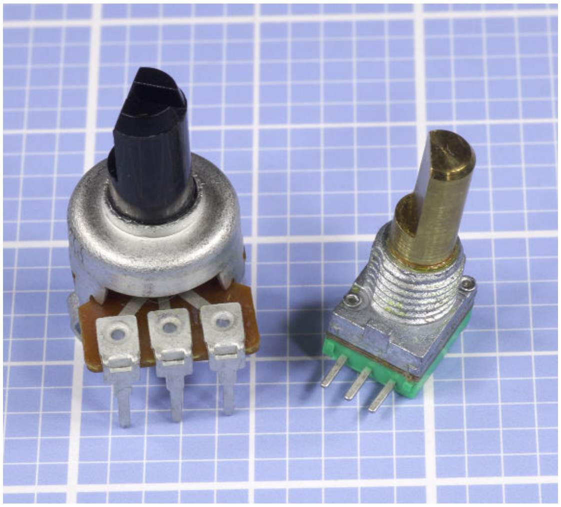

Figure 11-5. *Two modern miniaturized potentiometers. At left: 5K. At right: 10K. Both are rated to dissipate up to 50mW.*

The three terminals on the outside of a potentiometer may be solder lugs, screw terminals, or pins for direct mounting on a circuit board. The pins may be straight or angled at 90 degrees.

The resistive element may use carbon film, plastic, cermet (a ceramic-metal mixture), or resistive wire wound around an insulator. Carbon-film potentiometers are generally the cheapest, whereas wire-wound potentiometers are generally the most expensive.

Wire-wound potentiometers may handle more power than the other variants, but as the wiper makes a transition from one turn of the internal wire element to the next, the output will tend to change in discrete steps instead of varying more smoothly.

In a potentiometer with detents, typically a spring-loaded lever in contact with notched internal wheel causes the shaft to turn in discrete steps that create a stepped output even if the resistive element is continuous.

The shaft may be made of metal or plastic, with its length and width varying from one component to another. A control knob can be fitted to the end of the shaft. Some control knobs are push-on, others have a set screw to secure them. Shafts may be splined and split, or round and smooth, or round with a flat surface that matches the shape of a socket in a control knob and reduces the risk of a knob becoming loose and turning freely. Some shafts have a slotted tip to enable screwdriver adjustment.

Some shaft options for full-size potentiometers are shown in Figure 11-6.

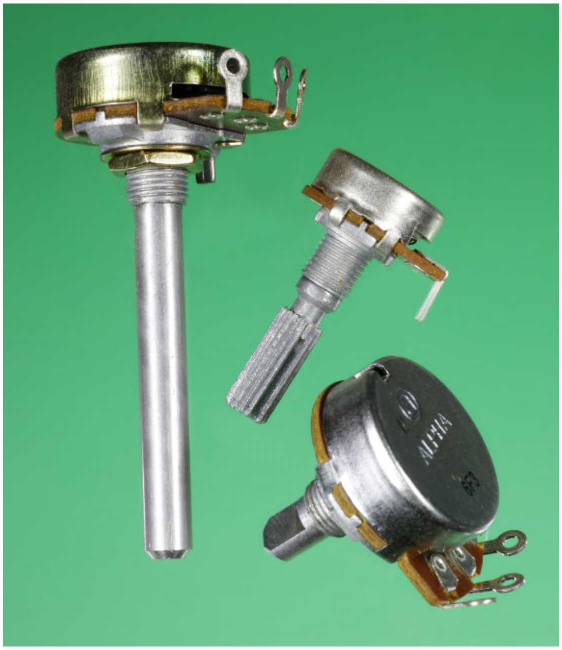

Figure 11-6. *Three shaft options for potentiometers.*

Multiple-Turn Potentiometer

To achieve greater precision, a track inside a potentiometer may be manufactured in the form of a helix, allowing the wiper to make multiple turns on its journey from one end of the track to the other. Such multiple-turn potentiometers typically allow 3, 5, or 10 turns to move the wiper from end to end. Other multiple-turn potentiometers may use a screw thread that advances a wiper along a linear or circular track. The latter is comparable with a trimmer where multiple turns of a screwdriver are used to rotate a worm gear that rotates a wiper between opposite ends of a circular track.

Ganged Potentiometer

Two (or rarely, more) potentiometers can be stacked or combined so that their resistive elements and wipers share the same shaft but can use different voltages or have different taper. Each resistance-wiper assembly is known as a *cup*, and the potentiometers are said to be *ganged*.

Flat ganged potentiometers combine two resistive elements in one enclosure. Some *dual ganged* potentiometers are concentric, meaning that the pots are controlled separately by two shafts, one inside the other. Suitable concentric knobs must be used. You are unlikely to find these potentiometers sold as components in limited quantities.

Switched Potentiometer

In this variant, when the shaft is turned clockwise from an initial position that is fully counterclockwise, it flips an internal switch connected to external terminals. This can be used to power-up associated components (for example, an audio amplifier). Alternatively, a switch inside a potentiometer may be configured so that it is activated by pulling or pushing the shaft.

Slider Potentiometer

Also known as a *slide potentiometer*. This uses a straight resistive strip and a wiper that is moved to and fro linearly by a tab or lug fitted with a plastic knob or finger-grip. Sliders are still found on some audio equipment. The principle of operation, and the number of terminals, are identical to the classic-style potentiometer. Sliders typically have solder tabs or PC pins. In Figure 11-7, the large one is about 3.5” long, designed for mounting behind a panel that has a slot to allow the sliding lug to poke through. Threaded holes at either end will accept screws to fix the slider behind the panel. A removable plastic finger-grip (sold separately, in a variety of styles) has been pushed into place. Solder tabs underneath the slider are hidden in this photo. The smaller slider is designed for through-hole mounting on a circuit board.

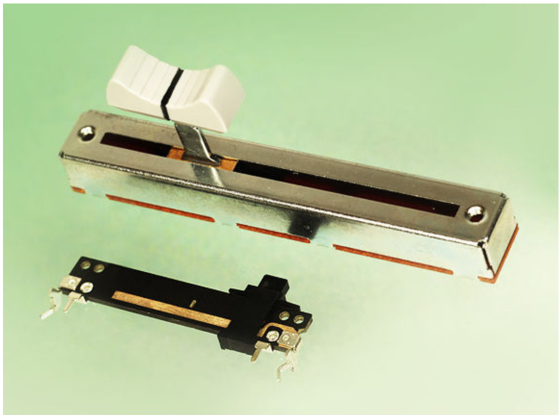

Figure 11-7. *Slider potentiometers.*

Trimmer Potentiometer

Often referred to as Trimpots, this is actually a proprietary brand name of Bourns. They are usually mounted directly on circuit boards to allow fine adjustment or trimming during manufacturing and testing to compensate for variations in other components. Trimmers may be single-turn or multi-turn, the latter containing a worm gear that engages with another gear to which the wiper is attached. Trimmers always have linear taper. They may be designed for screwdriver adjustment or may have a small knurled shaft, a thumb wheel, or a knob. They are not usually accessible by the end user of the equipment, and their setting may be sealed or fixed when the equipment is assembled. In Figure 11-8, the beige Spectrol trimmer is a single-turn design, whereas the blue trimmer is multi-turn. A worm gear inside the package, beneath the screw head, engages with an interior gear wheel that rotates the wiper.

In Figure 11-9, a 2K trimmer potentiometer has a knurled dial attached to allow easy finger adjustment, although the dial also contains a slot for a flat-blade screwdriver.

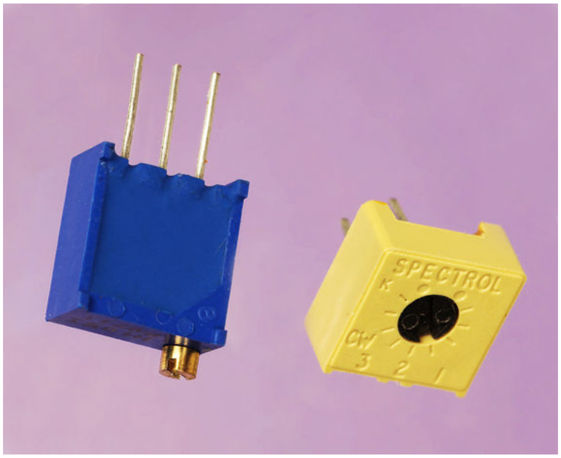

Figure 11-8. *Like most trimmers, these are designed for through-hole mounting on a circuit board.*

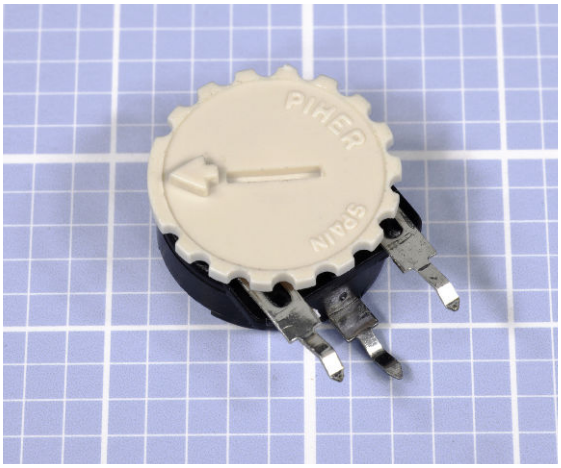

Figure 11-9. *A trimmer potentiometer with a knurled dial to facilitate finger adjustment.*

How to Use it

The classic-style potentiometer was once used universally to control volume, bass, and treble on audio equipment but has been replaced increasingly by digital input devices such as **tactile switches** (see "Tactile Switch" (page 34)) or **rotational encoders** (see Chapter 8), which are more reliable and may be cheaper, especially when assembly costs are considered.

Potentiometers are widely used in lamp dimmers and on cooking stoves (see Figure 11-10). In these applications, a solid-state switching device such as a **triac** (described in Volume 2) does the actual work of moderating the power to the lamp or the stove by interrupting it very rapidly. The potentiometer adjusts the duty cycle of the power interruptions. This system wastes far less power than if the potentiometer controlled the lighting or heating element directly as a rheostat. Since less power is involved, the potentiometer can be small and cheap, and will not generate significant heat.

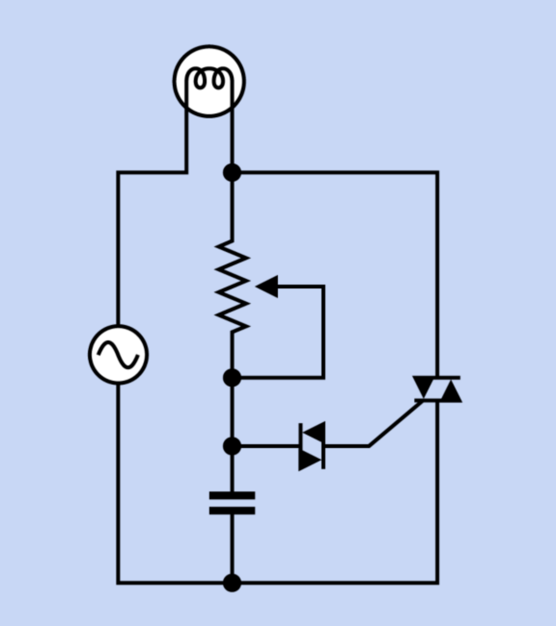

Figure 11-10. *Typical usage of a potentiometer in conjunction with a diac, triac, and capacitor to control the brightness of an incandescent bulb, using an AC power supply. Diacs and triacs are discussed in Volume 2.*

Because true logarithmic potentiometers have become decreasingly common, a linear potentiometer in conjunction with a fixed resistor can be used as a substitute, to control audio input. See Figure 11-11.

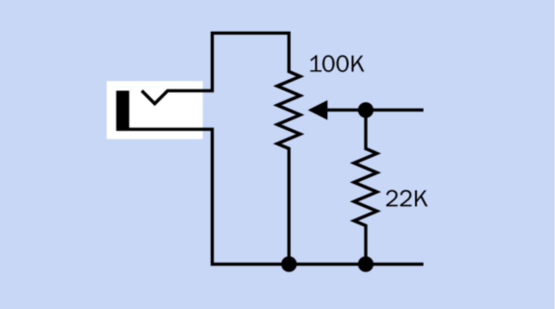

Figure 11-11. *In this circuit, a 100K linear potentiometer is used in conjunction with a 22K resistor to create an approximately logarithmic volume control for an audio system with input coming from a mono jack socket at left.*

A potentiometer may be used to match a sensor or analog input device to an analog-digital converter, or it can calibrate a device such as a temperature or motion sensor.

What Can Go Wrong

Wear and Tear

Since classic-style potentiometers are electromechanical devices, their performance will deteriorate as one part rubs against another. The long open slot of a slider potentiometer makes it especially vulnerable to contamination with dirt, water, or grease. Contact-cleaner solvent, lubricant-carrying sprays, or pressurized "duster" gas may be squirted into a potentiometer to try to extend its life. Carbon-film potentiometers are the least durable and in audio applications will eventually create a "scratchy" sound when they are turned, as the resistive element deteriorates.

If the wiper deteriorates to the point where it no longer makes electrical contact with the track, and if the potentiometer is being used as a variable resistor, two failure modes are possible, shown in Figure 11-12. Clearly the right-hand schematic is a better outcome. This is an argument for always tying the wiper to the "unused" end of the track.

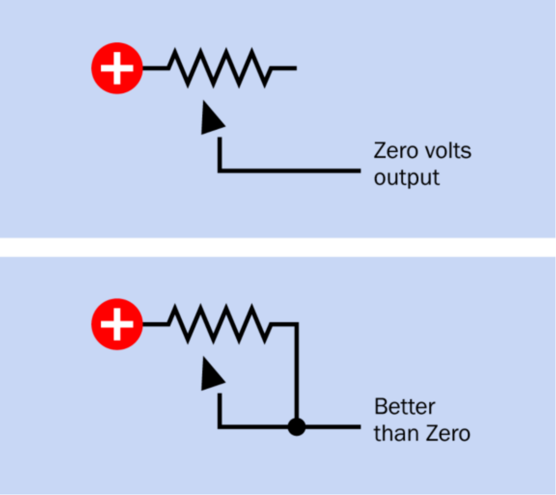

Figure 11-12. *If the wiper of a potentiometer breaks (indicated by the loose arrow head) as a result of wear and tear, and the potentiometer is being used as a variable resistor, the voltage from it will drop to zero (top schematic) unless the wiper has been tied to one end of the track (bottom schematic).*

If you are designing a circuit board that will go through a production process, temperature variations during wave soldering, and subsequent washing to remove flux residues, create hostile conditions for potentiometers, especially sliders where the internal parts are easily contaminated. It will be safer to hand-mount potentiometers after the automated process.

Knobs that Don't Fit

Control knobs are almost always sold separately from potentiometers. Make sure the shaft of the potentiometer (which may be round, round-with-flat, or knurled) matches the knob of your choice. Note that some shaft diameters are expressed in inches, while others are metric.

Nuts that Get Lost

For panel-mounted potentiometers, a nut that fits the thread on the bushing is almost always included with the potentiometer; an additional nut and lock washer may also be supplied. Because there is no standardization of threads on potentiometers, if you lose a nut, you may have some difficulty finding an exact replacement.

A Shaft that Isn't Long Enough

When choosing a shaft length, if in doubt, buy a potentiometer with a long shaft that you can cut to the desired length.

Sliders with No Finger Grip

Slider potentiometers are often sold without a knob or plastic finger-grip, which must be ordered separately and may be available in different styles. The finger-grip usually push-fits onto the metal or plastic tab or lug that moves the slider to and fro.

Too Big to Fit

Check the manufacturer's datasheet if you need to know the physical size of the potentiometer. Photographs may be misleading, as a traditional-style potentiometer that is 0.5" in diameter looks much the same as one that is 1" in diameter. High-wattage potentiometers will be more costly and physically large (2 to 3 inches in diameter). See Figure 11-13.

Overheating

Be sure to leave sufficient air space around a high-wattage potentiometer. Carefully calculate the maximum voltage drop and current that you may be using, and choose a component that is appropriately rated. Note that if you use the potentiometer as a rheostat, it will have to handle more current when its wiper moves to reduce its resistance. For example, if 12VDC are applied through a 10-ohm rheostat to a component that has a resistance of 20 ohms, current in the circuit will vary from 0.4 amps to 0.6 amps depending on the position of the rheostat. At its maximum setting, the rheostat will impose a 4V voltage drop and will therefore dissipate 1.6 watts from the full length of its resistive element. If the rheostat is reset to impose only a 4-ohm resistance, the voltage drop that it imposes will be 2V, the current in the circuit will be 0.5 amps, and the rheostat will therefore dissipate 1 watt from 4/10ths of the length of its resistive element. A wire-wound potentiometer will be better able to handle high dissipation from a short segment of its element than other types of rheostat. Add a fixed resistor in series with a rheostat if necessary to impose a limit on the current.

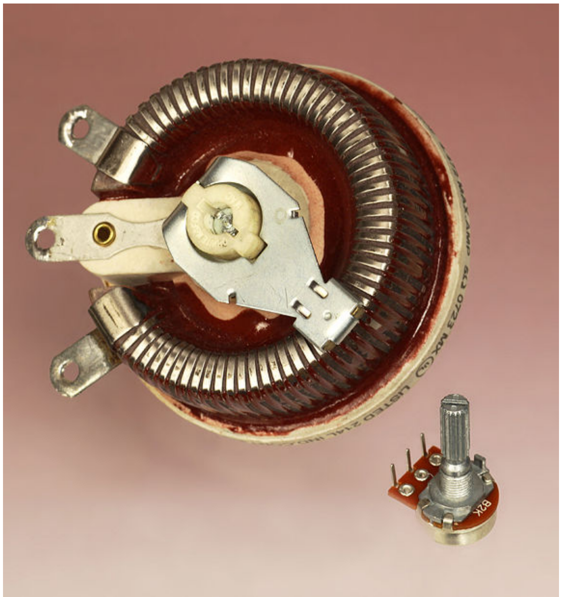

Figure 11-13. *The large potentiometer is approximately 3" in diameter, rated at 5 ohms, and able to handle more than 4 amps. The small potentiometer is 5/8" diameter, rated at 2K and 1/4 watt, with pins designed for through-hole insertion in a circuit board, and a grooved shaft that accepts a push-on knob. Despite the disparity in size, the principle of operation and the basic features are identical.*

When using a trimmer potentiometer, limit the current through the wiper to 100mA as an absolute maximum value.

The Wrong Taper

When buying a potentiometer, remember to check the specification to find out whether it has linear or audio/log taper. If necessary, attach a meter, with the potentiometer set to its center position, to verify which kind of taper you have. While holding the meter probes in place, rotate the potentiometer shaft to determine which way an audio/log taper is oriented.

capacitor

12

Quite often referred to as a *cap*. Formerly known (primarily in the United Kingdom) as a *condenser*, but that term has become obsolete.

OTHER RELATED COMPONENTS

- **variable capacitor** (See Chapter 13)
- **battery** (See Chapter 2)

What It Does

A capacitor connected across a DC power source will accumulate a charge, which then persists after the source is disconnected. In this way, the capacitor stores (and can then discharge) energy like a small rechargeable battery. The charge/discharge rate is extremely fast but can be limited by a series resistor, which enables the capacitor to be used as a timing component in many electronic circuits.

A capacitor can also be used to block DC current while it passes pulses, or electrical "noise," or alternating current, or audio signals, or other wave forms. This capability enables it to smooth the output voltage provided by **power supplies**; to remove spikes from signals that would otherwise tend to cause spurious triggering of components in digital circuits; to adjust the frequency response of an audio circuit; or to couple separate components or circuit elements that must be protected from transmission of DC current.

Schematic symbols for capacitors are shown in Figure 12-1. At top-left is a nonpolarized capacitor, while the other two indicate that a polarized capacitor must be used, and must be oriented as shown. The variant at the bottom is most commonly used in Europe. Confusingly, the nonpolarized symbol may also be used to identify a polarized capacitor, if a + sign is added. The polarized symbols are sometimes printed without + signs, but the symbols still indicate that polarity must be observed.

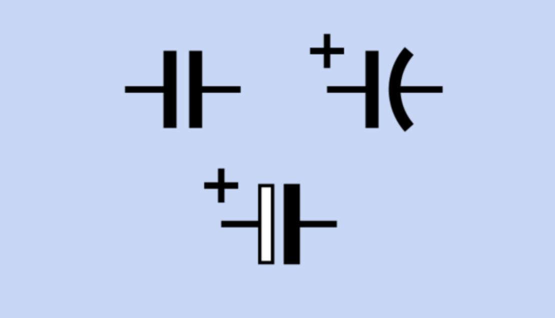

Figure 12-1. *Schematic symbols for polarized and nonpolarized capacitors. See text for details.*

How It Works

In its simplest form, a capacitor consists of two plates, each with a lead attached to it for connection with a DC power source. The plates are separated by a thin, insulating layer known as the *dielectric*, which is usually a solid or a paste but may be liquid, gel, gaseous, or vacuum.

The plates in most capacitors are made from thin metal film or metallized plastic film. To minimize the size of the component, the film may be rolled up to form a compact cylindrical package, or multiple flat sections may be interleaved.

Electrons from the power source will migrate onto the plate attached to the negative side of the source, and will tend to repel electrons from the other plate. This may be thought of as creating *electron holes* in the other plate or as attracting *positive charges*, as shown in Figure 12-2. When the capacitor is disconnected from the power source, the opposite charges on its plates will persist in equilibrium as a result of their mutual attraction, although the voltage will gradually dissipate as a result of *leakage,* either through the dielectric or via other pathways.

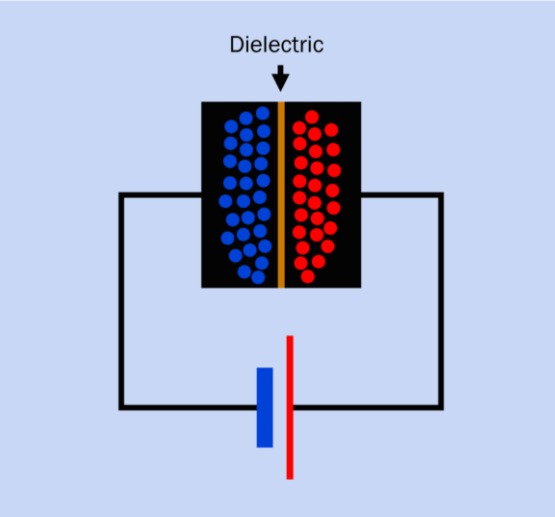

Figure 12-2. *Because the plates of a capacitor are electrically conductive, they will become populated with positive and negative charges when connected with a DC power source. As opposite charges attract each other, they will tend to congregate on either side of the dielectric, which is an insulating layer. The battery symbol is shown here colored for clarity.*

When a **resistor** is placed across the leads of a charged capacitor, the capacitor will discharge itself through the resistor at a rate limited by the resistance. Conversely, if a capacitor is charged through a resistor, the resistor will limit the charging rate.

A resistor in series with a capacitor is known as an *RC network* (Resistor-Capacitor network). In Figure 12-3, an RC circuit is shown with a SPDT switch that charges or discharges the capacitor via a series resistor. The voltage at point A increases nonlinearly (relative to the negative side of the power supply) while the capacitor is charging, and decreases nonlinearly while the capacitor is discharging, as suggested by the graphs. At any moment, the time that the capacitor takes to acquire 63% of the difference between its current charge and the voltage being supplied to it is known as the *time constant* for the circuit. See "The Time Constant" (page 105) for additional information.

When a capacitor is connected across an AC voltage source, each surge of electrons to one plate induces an equal and opposite positive surge to the other plate, and when polarity of the power supply reverses, the charges on the plates switch places. These surges may make it seem that the capacitor is conducting AC current, even though the dielectric that separates the plates is an insulator. See Figure 12-4. Often a capacitor is said to "pass" AC, even though this is not really happening. For convenience, and because the concept is widely established, this encyclopedia refers to capacitors as "passing" AC.

Depending on the size of the capacitor, it will block some AC frequencies while passing others. Generally speaking, a smaller capacitor will pass high frequencies relatively efficiently, as each little surge of current fills each plate. However, the situation is complicated by the *inductive reactance* (which creates the *effective series resistance*) of a capacitor, as discussed below. See "Alternating Current and Capacitive Reactance" (page 106).

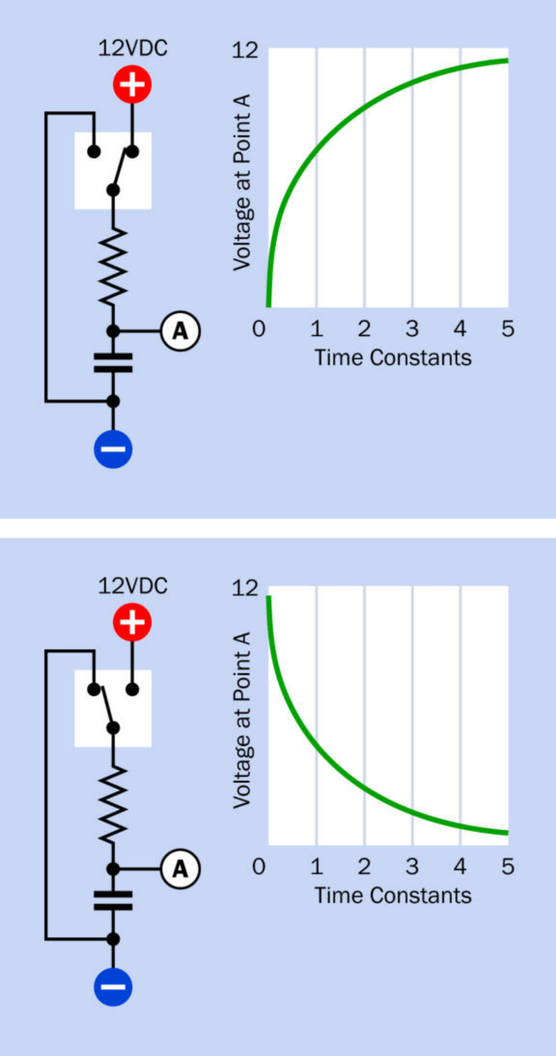

Figure 12-3. *An RC (Resistor-Capacitor) network with a switch to control charge and discharge of a capacitor. At top, the curve gives an approximate idea of the charging behavior of the capacitor. At bottom, the curve illustrates its discharging behavior.*

Variants

Format

The three most common packages for capacitors are cylindrical, disc, and rectangular tablet.

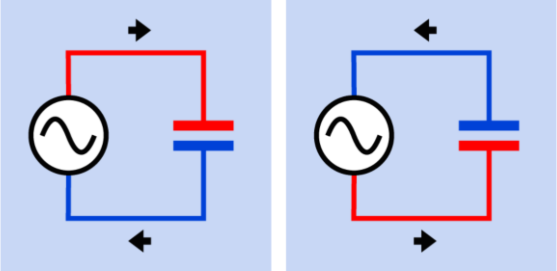

Figure 12-4. *In the left diagram, a source of alternating current charges the upper plate of a capacitor positively and the lower plate negatively. This process entails a flow of conventional current shown by the arrows. A moment later, when the AC current flow reverses, the flow also reverses, creating the impression that the capacitor "passes" AC current.*

A *cylindrical capacitor* may have *axial leads* (a wire attached to each end) or *radial leads* (both wires emerging from one end). Radial capacitors are more widely used as they allow easy insertion into a circuit board. The capacitor is usually packaged in a small aluminum can, closed at one end, capped with an insulating disc at the other end, and wrapped in a thin layer of insulating plastic. Some samples are shown in Figure 12-5 and Figure 12-6.

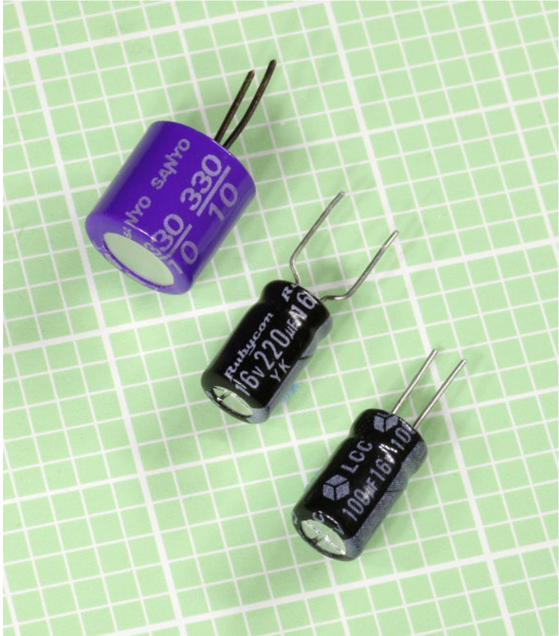

Figure 12-5. *Cylindrical capacitors with radial leads. All are electrolytic.*

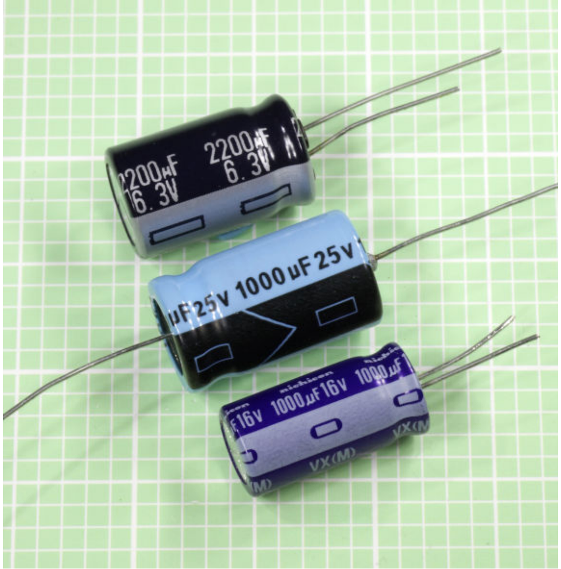

Figure 12-6. *Cylindrical capacitors with radial leads (top and bottom) and axial leads (center). All are electrolytic.*

A *disc capacitor* (sometimes referred to as a *button capacitor*) is usually encased in an insulating ceramic compound, and has radial leads. Modern small-value ceramic capacitors are more likely to be dipped in epoxy, or to be square tablets. Some samples are shown in Figure 12-7.

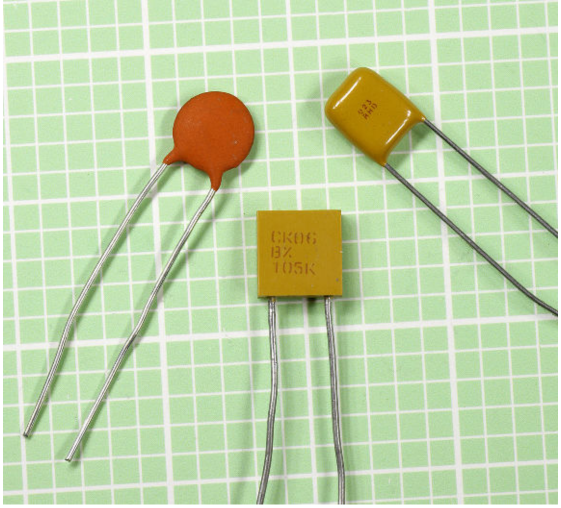

Figure 12-7. *Generic ceramic capacitors. Left: rated for 0.1µF at 50V. Center: 1µF at 50V. Right: 1µF at 50V.*

A *surface-mount capacitor* is square or rectangular, usually a few millimeters in each dimension, with two conductive pads or contacts at opposite ends. It appears almost identical to a surface-mount resistor. Larger-value capacitors are inevitably bigger but can still be designed for surface-mount applications. See Figure 12-8.

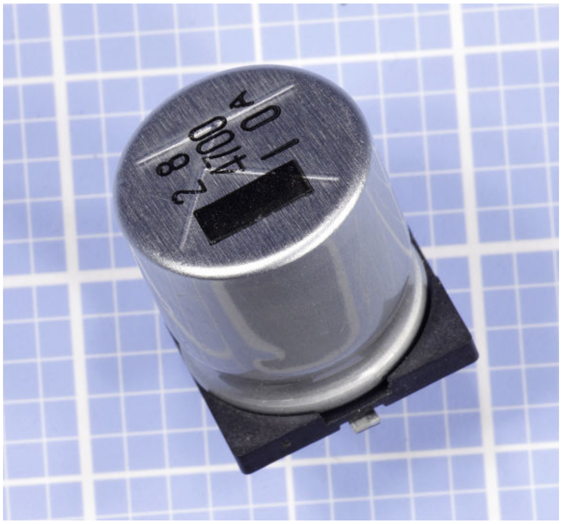

Figure 12-8. *Most surface-mount capacitors are as tiny as other surface-mount components, but this 4,700µF electrolytic (at 10V) has a base approximately 0.6" square. A solder tab is visible at the center of the nearest edge.*

Many capacitors are nonpolarized, meaning that they are insensitive to polarity. However, electrolytic and tantalum capacitors must be connected "the right way around" to any DC voltage source. If one lead is longer than the other, it must be the "more positive" lead. A mark or band at one end of the capacitor indicates the "more negative" end. Tantalum capacitors are likely to indicate the positive lead by using a + sign on the body of the component.

An arrow printed on the side of a capacitor usually points to the "more negative" terminal. In an aluminum can with axial leads, the lead at one end will have an insulating disc around it while the other lead will be integral with the rounded end of the can. The wire at the insulated end must be "more positive" than the wire at the other end.

A *capacitor array* contains two or more capacitors that are isolated from each other internally and accessed by external contacts. They are sold in surface-mount format and also in *through-hole* chips of DIP (dual-inline package) or SIP (single-inline package) format. The internal components may be connected in one of three configurations: isolated, common-bus, or dual-ended common bus. Technically the isolated configuration should be referred to as a capacitor array, but in practice, all three configurations are usually referred to as *capacitor networks*. See Figure 12-9 and Figure 12-10.

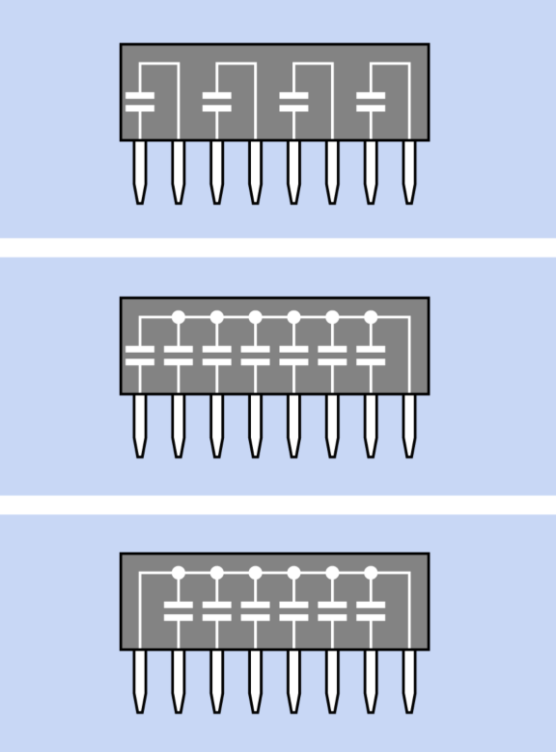

Figure 12-9. *A capacitor network most often consists of a single-inline package (SIP) chip containing multiple capacitors in one of three configurations shown here. Top: Isolated. Center: Common bus. Bottom: Dual-ended common bus. Individual capacitor values ranging from 0.001μF to 0.1μF are common.*

Capacitor networks can reduce the component count in circuits where digital logic chips require bypass capacitors. They are comparable in concept to *resistor arrays*.

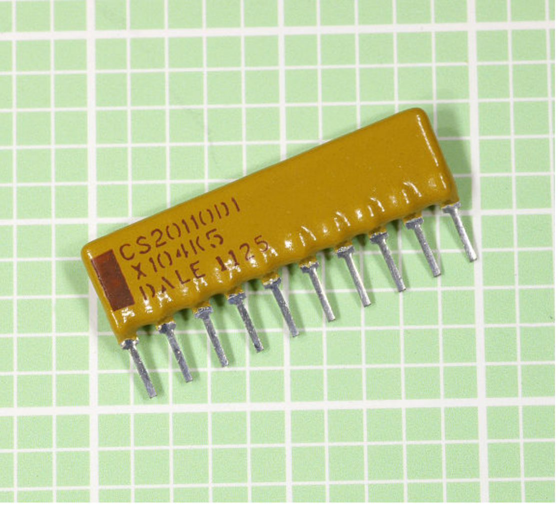

Figure 12-10. *A capacitor array in through-hole, SIP format.*

Chips containing *RC circuits* (multiple resistor-capacitor pairs) are available, although uncommon.

Principal Types

Electrolytic capacitors are relatively cheap, compact, and available in large values. These attributes have made them a popular choice in consumer electronics, especially for power supplies. The capacitive capability of an electrolytic is refreshed by periodic application of voltage. A moist paste inside the capacitor is intended to improve the dielectric performance when voltage is applied, but can dry out during a period of years. If an electrolytic is stored for 10 years or so, it may allow a short circuit between its leads when power is applied to it. The capacitors in Figure 12-5 and Figure 12-6 are all electrolytic. The capacitor in Figure 12-11 is at the high end of the scale.

A *bipolar electrolytic* is a single package containing two electrolytic capacitors in series, end-to-end, with opposed polarities, so that the combination can be used where the voltage of a signal fluctuates above and below 0VDC. See Figure 12-12 and Figure 12-13. This type of component is likely to have “BP” (bipolar) or “NP”

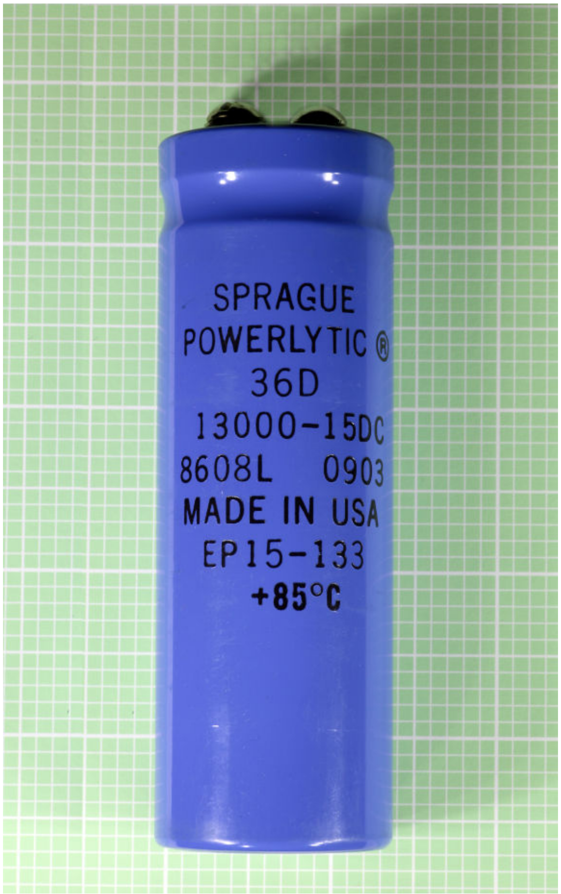

Figure 12-11. *This 13,000µF electrolytic capacitor is larger than would be required in most everyday applications.*

(nonpolarized) printed on its shell. It may be used in audio circuits where polarized capacitors are normally unsuitable, and is likely to be cheaper than non-electrolytic alternatives. However, it suffers from the same weaknesses as all electrolytics.

Tantalum capacitors are compact but relatively expensive, and can be vulnerable to voltage spikes. They are sensitive to application of the wrong polarity. Typically they are epoxy-dipped rather than mounted inside a small aluminum can like electrolytics, and consequently the electrolyte may be less likely to evaporate and dry out. In Figure 12-14, two tantalum capacitors (rated 330µF at 6.3V, left, and 100µF at 20V, right) are shown above a polyester film capacitor (rated 10µF at 100V). Surface-mount tantalum capacitors are decreasing in popularity as large-value ceramic capacitors are becoming available, with smaller dimensions and lower equivalent series resistance.

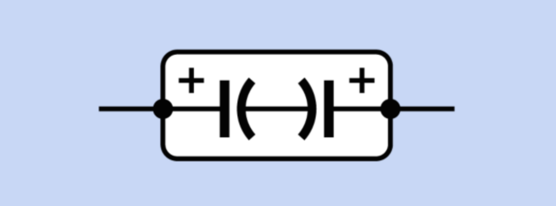

Figure 12-12. *Schematic view of the internal configuration of a bipolar electrolytic capacitor, also known as nonpolarized electrolytic capacitor. It consists of two electrolytics in series, with opposing polarities.*

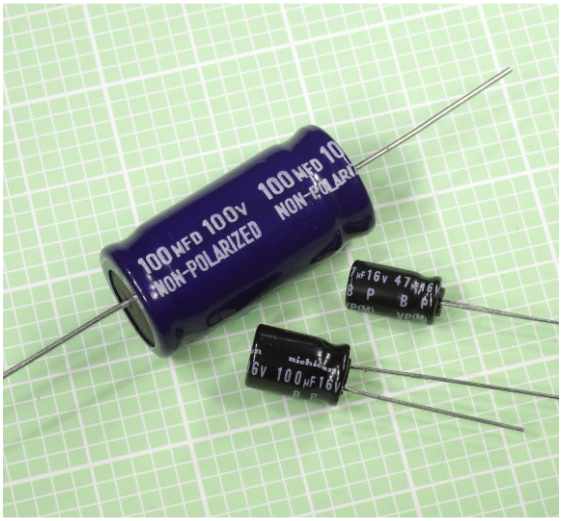

Figure 12-13. *Bipolar electrolytic capacitors. The larger size of the one at top-left is a consequence of its higher voltage rating. "BP" on the other two capacitors is an acronym for "bipolar," meaning that they have no polarity, even though one lead may be shorter than the other.*

Plastic-film capacitors are discussed in the following section.

Single-layer *ceramic* capacitors are often used for bypass, and are suitable for high-frequency or audio applications. Their value is not very stable with temperature, although the "NPO" variants are more stable. Multilayer ceramic capacitors are more compact than single-layer ceramic, and

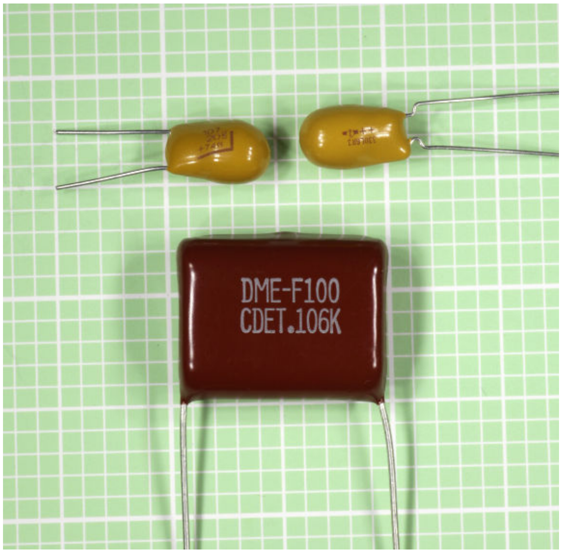

Figure 12-14. *Two tantalum capacitors are shown above a polyester film capacitor. The polarity of the tantalum capacitors is indicated by the plus signs adjacent to the longer lead, in each case. The polyester capacitor is nonpolarized.*

consequently are becoming increasingly popular. Three multilayer ceramic capacitors are shown in Figure 12-15. At bottom-right, even the largest (rated at 47µF at 16V) is only 0.2″ square.

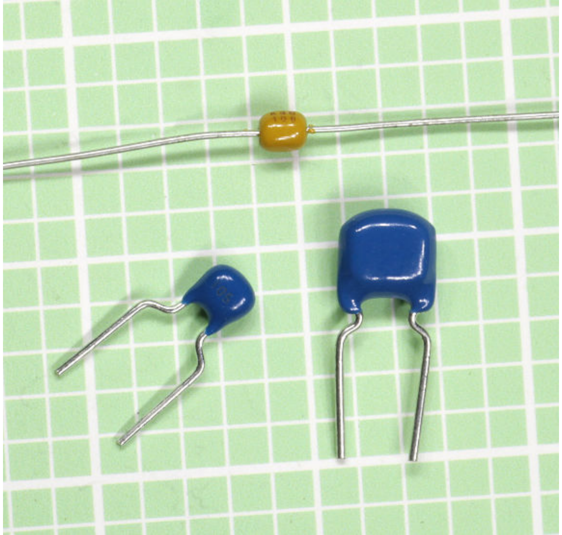

Figure 12-15. *Multilayer ceramic capacitors are extremely compact, and are nonpolarized. Top: 1,000pF (i.e. 1nF) at 100V. Bottom left: 1µF at 25V. Bottom right: 47µF at 16V.*

Dielectrics

The dielectric used in a capacitor most often consists of an electrolytic layer, a ceramic compound, a plastic film (polycarbonate, polypropylene, or polystyrene), or paper.

An *electrolytic layer* in an electrolytic capacitor traditionally consists of paper soaked in an electrolyte. It is interleaved with a thin film of aluminum on which is deposited a layer of aluminum oxide. The layers are rolled up to create a cylindrical component. The functioning dielectric is created when voltage is applied.

Polyester

This is the most common type of plastic film, with the highest dielectric constant, enabling highest capacitance per unit volume. Widely used in DC applications, but the rolled layers create parasitic inductance. Often used in decoupling, coupling, and bypass, but not so suitable for situations requiring stability and low leakage. May not be suitable for high current.

Polycarbonate

Thermally very stable, often specified for filters and timing circuits that require a fixed frequency. An excellent type of capacitor, compatible for mil-spec applications, but expensive.

Mylar, Polyester, and other plastic-film types are often used in audio circuits, where their voltage limitation (typically less than 100VDC) is not a problem, and their nonpolarized attribute is an advantage.

Polypropylene

Vulnerable to heat (a maximum of 85 degrees Centigrade is common), and less thermally stable than polycarbonate. A very low power dissipation factor allows it to handle higher power at higher frequencies. Available with tolerances down to 1%. These capacitors are a popular choice in crossover networks for loudspeaker combinations, and are used in switching power supplies. They tend to be physically larger than other capacitors using film dielectric.

Values

Farads

The electrical storage capacity of a capacitor is measured in *farads,* universally represented by the letter F. A capacitor that can be charged with a potential difference between its plates of 1 volt, in a time of 1 second, during which it draws 1 amp, has a capacitance of 1 farad.

Because the farad is a large unit, capacitors in electronic circuits almost always have fractional values: *microfarads* (μF), *nanofarads* (nF), and *picofarads* (pF). The Greek letter μ (mu) should be used in the μF abbreviation, but a lowercase letter u is often substituted. Thus, for example, 10uF means the same as 10μF.

1F = 1,000,000μF, and 1μF = 1,000,000pF. Therefore, 1 farad is equivalent to 1 trillion picofarads —a very wide range of possible values. See Figure 12-16 and Figure 12-17 for charts showing equivalent values in different units.

pF	nF	μF
1	0.001	0.000001
10	0.01	0.00001
100	0.1	0.0001
1,000	1	0.001
10,000	10	0.01
100,000	100	0.1
1,000,000	1,000	1

Figure 12-16. *Equivalent values for picofards, nanofarads, and microfarads. The nF unit is used primarily in Europe.*

μF	F
1	0.000001
10	0.00001
100	0.0001
1,000	0.001
10,000	0.01
100,000	0.1
1,000,000	1

Figure 12-17. *Equivalent values for microfarads and farads. Because the farad is such a large unit, electronic circuits almost always use fractional values.*

The nF unit is more common in Europe than in the United States. A 1nF capacitance is often expressed in the US as 0.001μF or 1,000pF. Similarly, a 10nF capacitance is almost always expressed as a 0.01μF, and a 0.1nF capacitance is more likely to be expressed as 100pF.

European schematics may use value-symbols as a substitute for decimal points. For example, a 4.7pF capacitor may be shown as 4p7, a 6.8nF capacitor may be shown as 6n8, and a 3.3μF capacitor may be shown as 3μ3.

Commonly Used Values

The traditional range of capacitor values was established on the same basis as the traditional range of resistor values, by assuming an accuracy of plus-or-minus 20% and choosing factors that would minimize the possible overlap between adjacent tolerance ranges. The factors 1.0, 1.5, 2.2, 3.3, 4.7, 6.8, and 10 satisfy this requirement. See Chapter 10 for a more detailed explanation, including a graphical representation of values and overlaps in Figure 10-8. While many resistors are now manufactured with high precision, 20%

tolerance is still common for electrolytic capacitors. Other types of capacitors are available with an accuracy of 10% or 5%, but are more expensive.

While large-value capacitors are likely to have their actual value printed on them, smaller capacitors are identified by a variety of different codes. These codes are not standardized among manufacturers, and exist in various colors and abbreviations. A multimeter that can measure capacitance is a quicker, easier, and more reliable method of determining the value of a component than trying to interpret the codes.

In addition to capacitance, a large capacitor is likely to have its working voltage printed on it. Exceeding this value increases the risk of damaging the dielectric. In the case of electrolytic capacitors, a voltage that is much lower than the rated value should also be avoided, because these capacitors require an electrical potential to maintain their performance.

In common electronics applications, values larger than 4,700µF or smaller than 10pF are unusual.

Electrolytics are available at a moderate price in a wider range of values than other commonly used capacitors. They range from 1µF to 4,700µF and sometimes beyond. Working voltages typically range from 6.3VDC to 100VDC, but can be as high as 450VDC.

Tantalum capacitors are usually unavailable in sizes above 150µF or for voltages above 35VDC.

Single-layer ceramic capacitors have small values ranging from 0.01µF to 0.22µF, with working voltages usually not exceeding 50VDC, although very small-value capacitors may be rated much higher for special applications. Poor tolerances of +80% to -20% are common.

Some variants of multi-layer ceramic capacitors are capable of storing up to 47µF, although 10µF is a more common upper limit. They are seldom rated above 100VDC. Some are accurate to plus-or-minus 5%.

Dielectric Constant

If A is the area of each plate in a capacitor (measured in square centimeters), and T is the thickness of the dielectric (measured in centimeters), and K is the *dielectric constant* of the capacitor, the capacitance, C (measured in farads) will be obtained from the formula:

```
C = (0.0885 * K * A) / T
```

The dielectric constant of air is 1. Other dielectrics have different standard values. Polyethylene, for instance, has a constant of approximately 2.3. Thus a capacitor of 1 square centimeter plate area and polyethylene dielectric 0.01 centimeters thick would have a capacitance of about 20pF. A tantalum capacitor of equal plate area and dielectric thickness would have capacitance closer to 100pF, since the dielectric constant of tantalum oxide is much higher than that of polyethylene.

The Time Constant

When a capacitor is charged in series through a resistor (it is used in an RC network), and it begins with no charge on its plates, the *time constant* is the time, in seconds, required to charge the capacitor to 63% of the supply voltage. After an additional, identical interval of time, the capacitor will acquire 63% of the remaining difference between itself and the power supply. In theory the capacitor gets closer and closer to a full charge, but never quite reaches 100%. However, five time constants are sufficient for the capacitor to reach 99%, which is regarded as close enough to being fully charged for all practical purposes.

Refer to Figure 12-3 for a schematic of an RC network.

The time constant is a simple function of the resistance and the capacitance. If R is the value of the resistor (in ohms), and C is the value of the capacitor (in farads), the time constant, TC, will be obtained by the formula:

```
TC = R * C
```

If we multiply the R value by 1,000 while dividing the C value by 1,000, the time constant remains the same, and we can use the more convenient values of kilohms for the resistance and µF for the capacitance. In other words, the formula tells us that a 1K resistor in series with a 1,000µF capacitor has a time constant of 1 second.

The formula suggests that if the value of R diminishes to zero, the capacitor will charge instantly. In reality, the charging time will be rapid but finite, limited by factors such as the electrical resistance of the materials used.

Multiple Capacitors

When two or more capacitors are wired in parallel, their total capacitance is the sum of their separate capacitances. When two or more capacitors are wired in series, the relationship between their total capacitance © and their individual capacitances (C1, C2, C3 . . .) is given by this formula:

```
1 / C = (1/C1) + (1/C2) + (1/C3). . .
```

The formula to calculate the total capacitance of capacitors connected in series resembles the one used to calculate the total resistance of resistors connected in parallel. See Chapter 10.

Alternating Current and Capacitive Reactance

The apparent resistance of a capacitor to AC is properly known as *capacitive reactance*. In the following formula, capacitive reactance (X_C, in ohms) is derived as a function of capacitance (C, in farads) and AC frequency (f, measured in hertz):

$$X_C = 1 / (2 * \pi * f * C)$$

The formula shows that when frequency becomes zero, capacitive reactance becomes infinite; in other words, a capacitor has theoretically infinite resistance when DC current tries to flow through it. In reality, a dielectric has a finite resistance, and thus always allows some leakage.

The formula also shows that capacitive reactance diminishes when the size of the capacitor increases and/or the frequency being applied to it increases. From this it appears that an AC signal will be attenuated less at higher frequencies, especially if we use a small capacitor. However, a real-world capacitor also exhibits some degree of *inductive reactance*. This value will depend on its configuration (cylindrical vs. multiple flat plates), its physical length, the materials from which it is fabricated, the lengths of its leads, and other factors. Inductive reactance tends to *increase* with frequency, and since capacitive reactance tends to *decrease* with frequency, at some point the curves for the two functions intersect. This point represents the capacitor's *self-resonant frequency*, which is often referred to simply as its *resonant frequency*. See Figure 12-18.

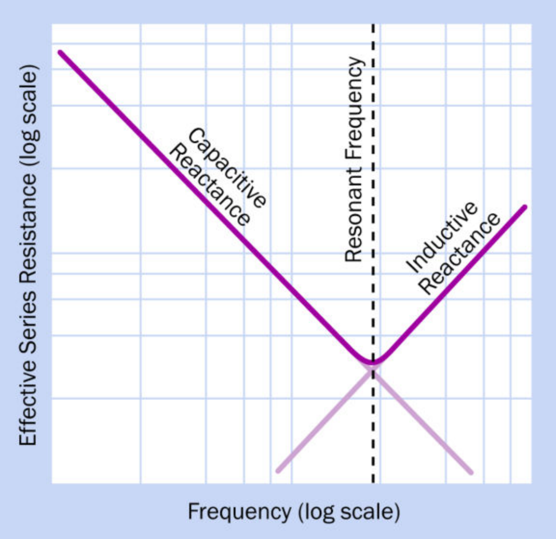

Figure 12-18. *As an AC current applied to a capacitor increases in frequency, the capacitive reactance of the component decreases, while its inductive reactance increases. The resonant frequency of the capacitor is found where the two functions intersect.*

Equivalent Series Resistance

A theoretically ideal capacitor would be purely reactive, without any resistance. In reality, capacitors are not ideal, and they have *equivalent series resistance,* or *ESR*. This is defined as the resistor that you would have to place in series with an ideal version of the capacitor, so that the combination would behave like the real version of the capacitor on its own.

If X_c is the reactance of the capacitor, then its Q factor (which means its *quality factor*) is given by the simple formula:

```
Q = Xc / ESR
```

Thus, the quality factor is higher if the ESR is relatively low. However, the reactance of the capacitor will vary significantly with frequency, and this simple formula is only an approximate guide.

The Q-factor for capacitors should not be confused with the Q-factor for inductors, which is calculated quite differently.

How to Use it

The figures illustrate some simplified schematics for common applications.

Bypass Capacitor

In Figure 12-19, a low-value capacitor (often 0.1μF) is placed near the power input pin of a sensitive digital chip to divert high-frequency spikes or noise to negative ground. This *bypass capacitor* may also be described as a *decoupling capacitor*.

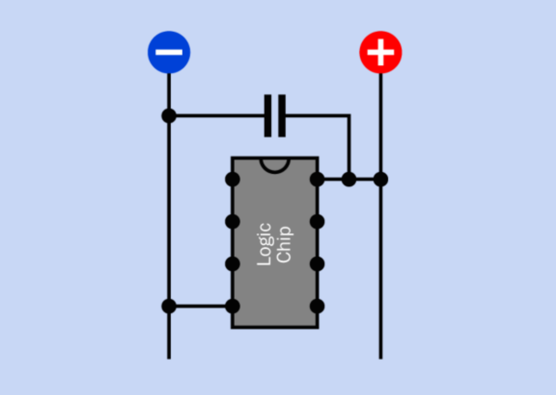

Figure 12-19. *A bypass capacitor (typically 0.1μF) configured to protect an integrated circuit logic chip from voltage spikes and noise in the power supply.*

Coupling Capacitor

In Figure 12-20, a 1μF *coupling capacitor* transmits a pulse from one section of a circuit to another, while blocking the DC voltage. Some reshaping of the waveform may occur.

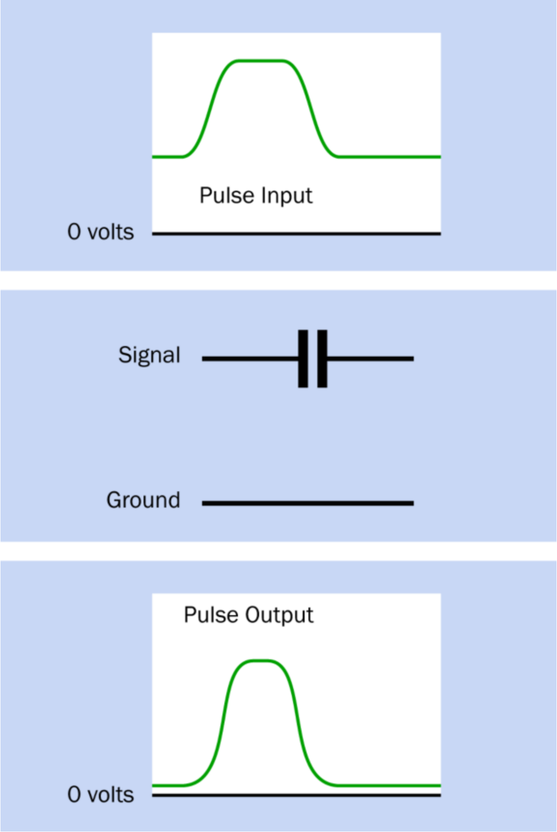

Figure 12-20. *A coupling capacitor (typically around 1μF) preserves DC isolation of one section of a circuit from another, while allowing a pulse to be transmitted.*

High-Pass Filter

In Figure 12-21, a 0.1μF capacitor blocks the low-frequency component of a complex waveform and transmits only the higher frequency that was superimposed on the low frequency.

Low-Pass Filter

In Figure 12-22, a 0.1μF decoupling capacitor diverts the higher frequency component of a complex waveform to negative ground, allowing only

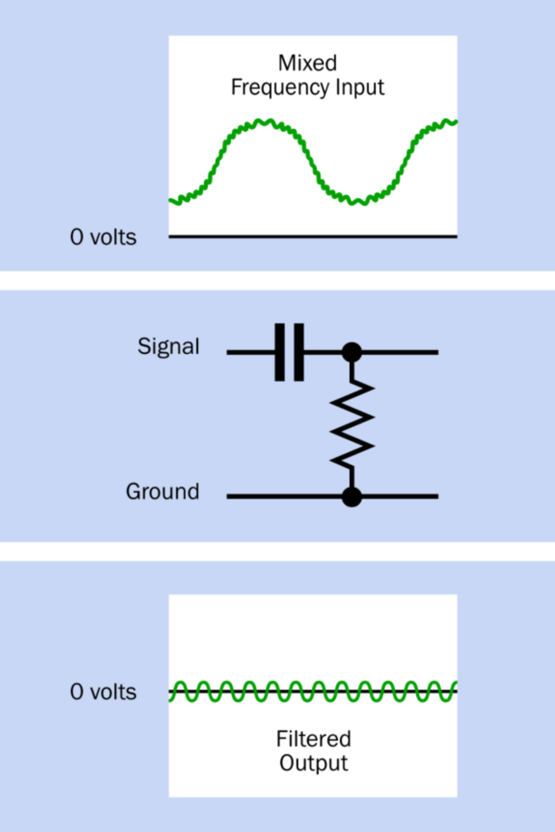

Figure 12-21. *A small capacitor (typically 0.1µF) can be used to create a high-pass filter, passing high frequencies while blocking low frequencies.*

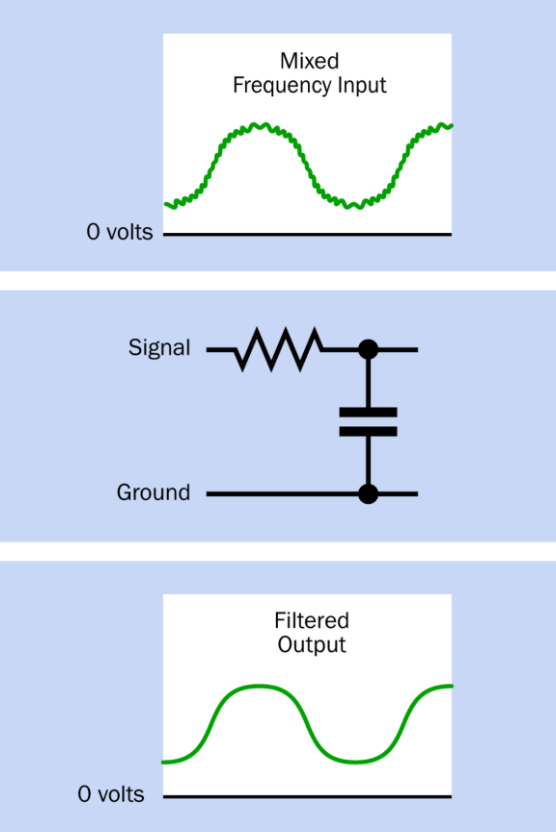

Figure 12-22. *A small capacitor (typically 0.1µF) in this configuration routes high frequencies to negative ground, filtering them out of an analog signal.*

the lower frequency to be preserved. A lower-value capacitor (such as 0.001µF) will bleed away high-frequency noise from an AM radio source without affecting audio frequencies.

Smoothing Capacitor

In Figure 12-23, a 100µF capacitor charges and discharges to smooth an AC signal after a diode has removed the negative portion.

Snubber

In Figure 12-24, an RC network (inside a white dashed line) is known as a *snubber* when used to protect a switch from the problem of *arcing* (pronounced “arking”)—that is, a sustained spark that can quickly erode the switch contacts. Arcing may occur in switches, pushbuttons, or relays that control an inductive load, such as a large motor. This problem can become significant at high DC currents (10A or more) or relatively high AC or DC voltages (100V or more).

When the switch is opened, the magnetic field that has been sustained by the inductive load collapses, causing a surge of current, or *forward EMF*. The capacitor in the snubber absorbs this surge, thus protecting the switch contacts. When the switch is closed again, the capacitor discharges itself, but the resistor limits the outrush of current—again, protecting the switch.

A snubber placed around the switch in a DC circuit could typically use a 0.1µF capacitor (polypropylene or polyester) rated for 125VAC/200VDC, and a 100-ohm carbon resistor rated 0.5

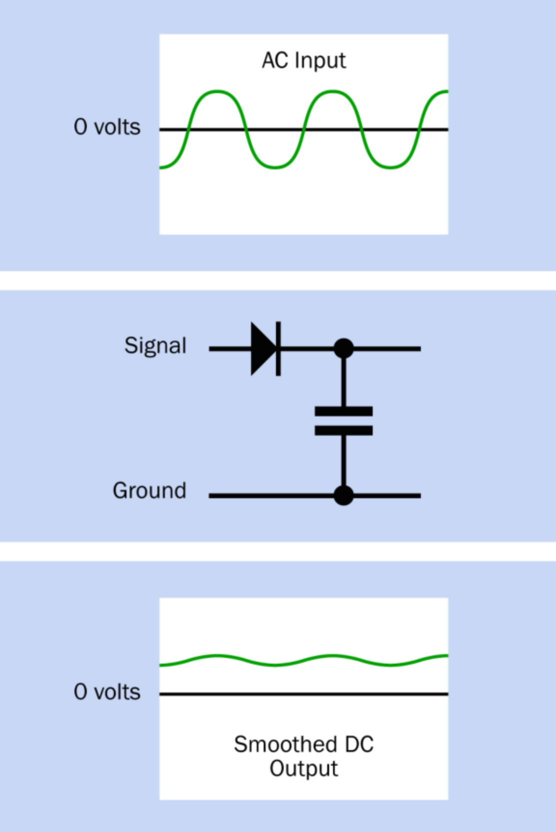

Figure 12-23. *A capacitor of 100µF or more smooths the upper half of an AC signal that has passed through a diode. The capacitor charges during each positive pulse and discharges to “fill the gaps” between them.*

watt or higher. Prepackaged snubbers containing appropriate capacitor-resistor pairs are available from some parts suppliers, primarily for industrial use.

In an AC circuit, a snubber can be placed around the inductive load itself. Although a **diode** is often used this way in a DC circuit, it cannot be used with AC.

Although solid-state switching devices such as a **solid state relay** contain no mechanical contacts, they may still be damaged by substantial pulses of back-EMF, and can be protected by a snubber where they are controlling inductive loads that take 10A or more at 100V or more.

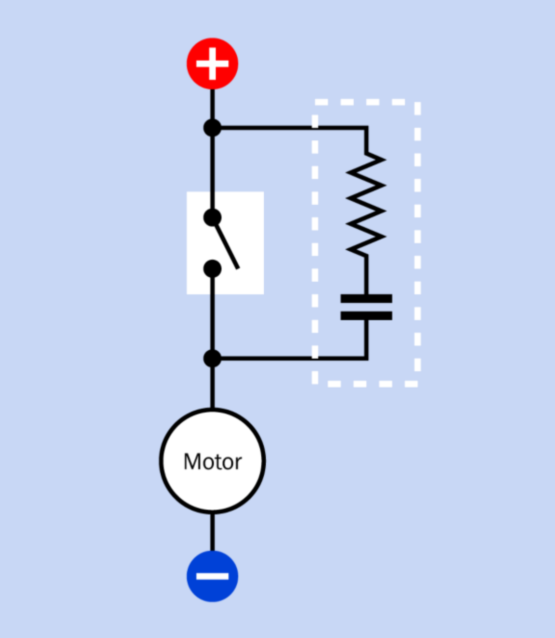

Figure 12-24. *An RC network (outlined with a white dashed line) protects a switch that controls a high inductive load. Used in this way, the RC network is known as a snubber.*

Capacitor as a Battery Substitute

A capacitor may be substituted for a battery for some applications, although it has a lower energy density and will be more expensive to manufacture. A capacitor charges and discharges much more rapidly than a battery because no chemical reactions are involved, but a battery sustains its voltage much more successfully during the discharge cycle.

Capacitors that can store a very large amount of energy are often referred to as *supercapacitors.*

What Can Go Wrong

Common problems associated with capacitors are age-related deterioration (especially in electrolytics), inductive reactance (especially in cylindrical formats), nonlinear response, resistivity, excessive current leakage, and dielectric memory. Some of these problems are discussed below. A manufacturer’s datasheet should be consulted carefully in conjunction with the notes regarding compositions in the preceding Variants section before making a commitment to a particular type of capacitor.

Wrong Polarity

A polarized capacitor may offer virtually no resistance if it is connected the wrong way around to a DC power source. A very high current can result, damaging the capacitor and probably other components in the circuit. Failing to observe the polarity of a tantalum capacitor can have destructive or even explosive consequences, depending on the amperage.

Voltage Overload

If the DC working voltage of a capacitor is exceeded, there is a risk of breaking down the dielectric and allowing a spark, or arc, that will form a short circuit. Note that the DC rating of a capacitor does not mean that it can be used safely with an equivalent AC voltage. The maximum AC voltage should be no greater than approximately 0.7 times the DC rated voltage. If a DC-rated capacitor is used directly across an AC power line, it will create an effective short circuit.

If capacitors are connected in series or in parallel, ideally the voltage rating for each capacitor should be the same, and certainly no less than the supply voltage.

Tantalum capacitors are easily damaged by current spikes that exceed their maximum working voltage, and are unsuitable for high-frequency coupling because of their inductance.

Leakage

Charge leakage is a problem especially associated with electrolytic capacitors, which are not suitable for storing a charge over a significant interval. Polypropalene or polystyrene film capacitors are a better choice.

Dielectric Memory

Also known as *dielectric absorption*, this is a phenomenon in which a capacitor's electrolyte displays some percentage of its former voltage after the capacitor has been discharged and then disconnected from the circuit. Single-layer ceramic capacitors especially tend to suffer from this problem.

Specific Electrolytic Issues

Electrolytic capacitors have high inductive reactance, are not manufactured to close tolerances, and deteriorate significantly with age. While other components may be stockpiled and used over a period of years, this is not a sensible policy with electrolytics.

The “capacitor plague” affecting many of these capacitors manufactured from 1999 onward provided a salutary lesson regarding their potential weaknesses. Faulty composition of the dielectric allowed it to deteriorate, liberating hydrogen gas, which eventually caused the aluminum shells of the capacitors to bulge and burst. Circuit boards from major manufacturers were affected. Because the problem took two years to become apparent, literally millions of boards with faulty capacitors had been sold before the fault was diagnosed and eventually corrected.

Unfortunately electrolytics cannot be easily replaced with other types of capacitors in applications such as power supplies, because substitutes will be considerably larger and more expensive.

Heat

The equivalent series resistance (ESR) of a large capacitor inevitably means that it must dissipate some power as heat during use. Ripple current can also create heat. Capacitor performance will change as the temperature increases. A common maximum component temperature for electrolytic capacitors is 85 degrees Centigrade.

Vibration

In a high-vibration environment, electrolytics should be protected by clamping them mechanically in place, using a *capacitor clamp*, also known as a *c-clamp*.

Misleading Nomenclature

Rarely, in the United States, the term “mF” may be used as a probable alternative to μF. This can be a source of confusion and risk because mF is properly (but very rarely) used to mean “millifarads.” The term should always be avoided.

variable capacitor

13

Formerly known (primarily in the United Kingdom) as a *variable condenser*. The term is now obsolete.

OTHER RELATED COMPONENTS

- **capacitor** (See Chapter 12)

What It Does

A variable capacitor allows adjustment of capacitance in much the same way that a **potentiometer** allows adjustment of resistance.

Large variable capacitors were developed primarily to tune radio receivers, in which they were known as *tuning capacitors*. Cheaper, simpler, and more reliable substitutes gradually displaced them, beginning in the 1970s. Today, they are still used in semiconductor fabrication, in RF plastic welding equipment, in surgical and dental tools, and in ham radio equipment.

Small *trimmer capacitors* are widely available and are mostly used to adjust high-frequency circuits. Many of them look almost indistinguishable from *trimmer potentiometers*.

The schematic symbols commonly used to represent a variable capacitor and a trimmer capacitor are shown in Figure 13-1.

A *varactor* is a form of diode with variable capacitance, controlled by reverse voltage. See "Varactor Diode" (page 225) for this component.

How It Works

The traditional form of variable capacitor consists of two rigid semicircular plates separated by an air gap of 1mm to 2mm. To create more capacitance, additional interleaved plates are added to form a stack. One set of plates is known as the *rotor*, and is mounted on a shaft that can be turned, usually by an externally accessible knob. The other set of plates, known as the *stator*, is mounted on the frame of the unit with ceramic insulators. When the sets of plates completely overlap, the capacitance between them is maximized. As the rotor is turned, the sets of plates gradually disengage, and the capacitance diminishes to near zero. See Figure 13-2.

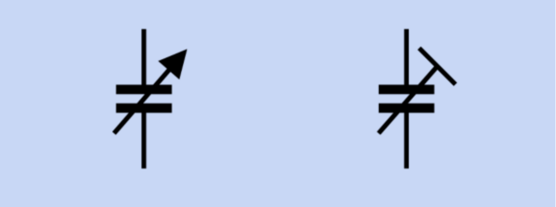

Figure 13-1. *Typical schematic symbols for variable capacitor (left) and trimmer capacitor (right).*

The air gaps between the sets of plates are the *dielectric*. Air has a dielectric constant of approximately 1, which does not vary significantly with temperature.

The most common shape of plate is a semicircle, which provides a linear relationship between capacitance and the angle of rotation. Other shapes have been used to create a nonlinear response.

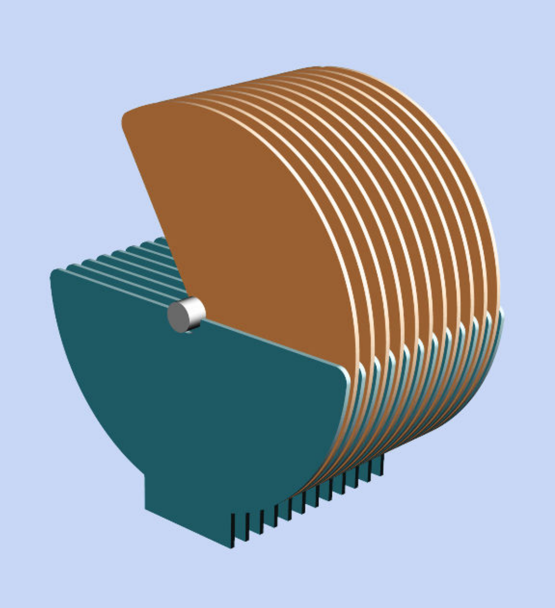

Figure 13-2. *In this simplified view of a variable capacitor, the brown plates constitute the rotor, attached to a central shaft, while the blue plates are the stator. The colors have no electrical significance and are added merely for clarity. The area of overlap between rotor and stator determines the capacitance.*

Reduction gears may be used to enable fine tuning of a variable capacitor, which means multiple turns of a knob can produce very small adjustments of the capacitor. At the peak of variable capacitor design, units were manufactured with high mechanical precision and included *anti-backlash gears*. These consisted of a pair of equal-sized gears mounted flat against each other with a spring between them that attempted to turn the gears in opposite directions from each other. The pair of gears meshed with a single pinion, eliminating the looseness, or backlash, that normally exists when gear teeth interlock. A vintage capacitor with a spring creating anti-backlash gearing (circled) is shown in Figure 13-3. This is a two-gang capacitor—it is divided into two sections, one rated 0 to 35pF, the other rated 0 to 160pF.

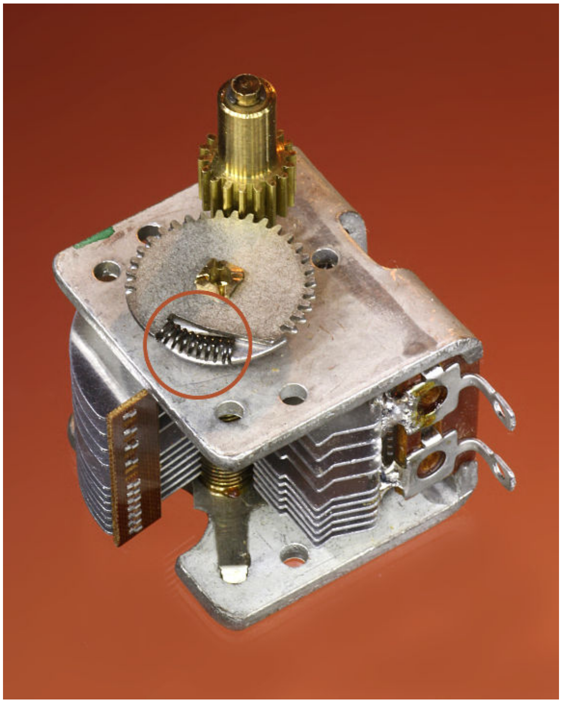

Figure 13-3. *A "traditional style" variable capacitor of the type designed to tune radio frequencies. The spring, circled, enables anti-backlash gearing.*

Variants

The traditional variable capacitor, with exposed, air-spaced, rigid, rotating vanes, is becoming hard to find. Small, modern variable capacitors are entirely enclosed, and their plates, or vanes, are not visible. Some capacitors use a pair of concentric cylinders instead of plates or vanes, with an external thumb screw that moves one cylinder up or down to adjust its overlap with the other. The overlap determines the capacitance.

Trimmer capacitors are available with a variety of dielectrics such as mica, thin slices of ceramic, or plastic.

Values

A large traditional capacitor can be adjusted down to a near-zero value; its maximum will be no greater than 500pF, limited by mechanical factors. (See Chapter 12 for an explanation of capacitance units.)

A maximum value for a trimmer capacitor is seldom greater than 150pF. Trimmers may have their values printed on them or may be color-coded, but there is no universal set of codes. Brown, for example, may indicate either a maximum value around 2pF or 40pF, depending on the manufacturer. Check datasheets for details.

The upper limit of a trimmer's rated capacitance is usually no less than the rated value, but can often be 50% higher.

Formats

All trimmer capacitors are designed for mounting on circuit boards. Many are surface-mount, with a minority being through-hole. Surface-mount units may be 4mm × 4mm or smaller. Through-hole are typically 5mm × 5mm or larger. Superficially, trimmer capacitors resemble single-turn trimmer potentiometers with a screw head in the center of a square package. A through-hole example is shown in Figure 13-4.

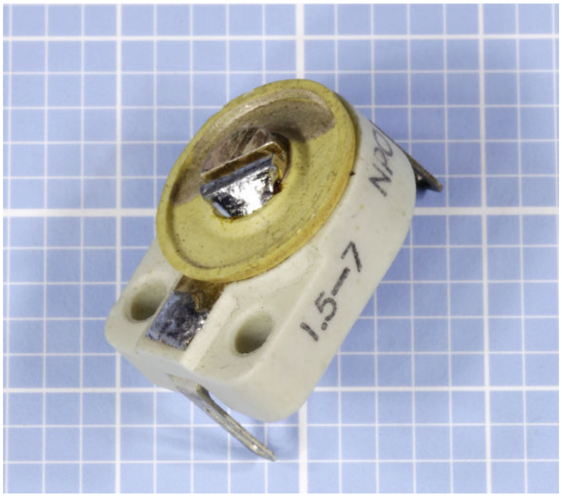

Figure 13-4. *A trimmer capacitor rated 1.5pF to 7.0pF.*

How to Use it

A variable capacitor is often used to tune an *LC circuit,* so called because a coil (with reactance customarily represented by letter L) is wired in parallel with a variable capacitor (represented by letter C). The schematic in Figure 13-5 shows an imaginary circuit to illustrate the principle. When the switch is flipped upward, it causes a large fixed-value capacitor to be charged from a DC power source. When the switch is flipped down, the capacitor tries to pass current through the coil—but the coil's *reactance* blocks the current and converts the energy into a magnetic field. After the capacitor discharges, the magnetic field collapses and converts its energy back into electricity. This flows back to the capacitor, but with inverted polarity. The cycle now repeats with current flowing in the opposite direction. A low-current **LED** across the circuit would flash as the voltage oscillates, until the energy is exhausted.

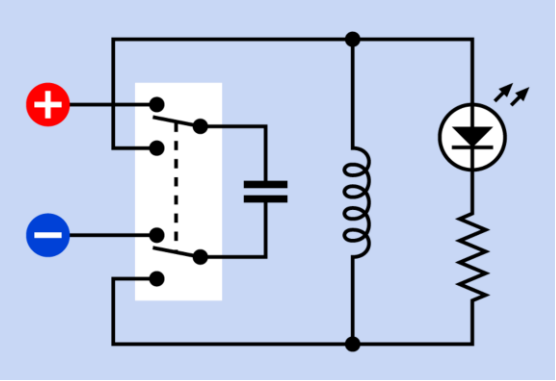

Figure 13-5. *In this imaginary circuit, the capacitor is charged through the double-pole switch in its upper position. When the switch is turned, the capacitor forms an LC (inductance-capacitance) circuit with the coil, and resonates at a frequency determined by their values. In reality, extremely high values would be needed to obtain a visible result from the LED.*

Because the oscillation resembles water sloshing from side to side in a tank, an LC circuit is sometimes referred to as a *tank circuit.*

In reality, unrealistically large values would be required to make the circuit function as described. This can be deduced from the following formula, where f is the frequency in Hz, L is inductance in Henrys, and C is capacitance in Farads:

```
f = 1 / (2π * √(L * C) )
```

For a frequency of 1Hz, a massive coil opposite a very large capacitor of at least 0.1F would be needed.

However, an LC circuit is well-suited to very high frequencies (up to 1,000MHz) by using a very small coil and variable capacitor. The schematic in Figure 13-6 shows a high-impedance earphone and a diode (right) substituted for the LED and the resistor in the imaginary circuit, while a variable capacitor takes the place of the fixed capacitor. With the addition of an antenna at the top and a ground wire at the bottom, this LC circuit is now capable of receiving a radio signal, using the signal itself as the source of power. The resonant frequency of the circuit is tuned by the variable capacitor. The impedance peaks at the resonant frequency, causing other frequences to be rejected by passing them to ground. With suitable refinement and amplification, the basic principle of an LC circuit is used in AM radios and transmitters.

Because variable capacitors are so limited in size, they are unsuitable for most timing circuits.

Trimmer capacitors are typically found in high-power transmitters, cable-TV transponders, cellular base stations, and similar industrial applications.

They can be used to fine-tune the resonant frequency of an oscillator circuit, as shown in Figure 13-7.

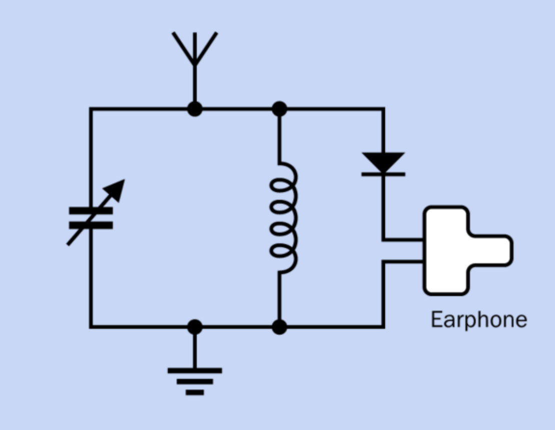

Figure 13-6. *The principle of an LC circuit is used here in a basic circuit that can tune in to a radio station and create barely audible sound through the earphone at right, using only the broadcast signal for power. The variable capacitor adjusts the frequency of the circuit to resonate with the carrier wave of the radio signal.*

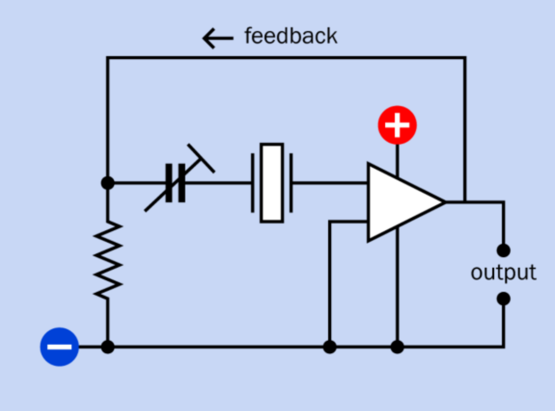

Figure 13-7. *A trimmer capacitor in series with a crystal fine-tunes the frequency of this basic circuit using an op-amp.*

In addition to tuning a circuit frequency, a trimmer capacitor can be used to compensate for changes in capacitance or inductance in a circuit that are caused by the relocation of wires or rerouting of traces during the development process. Readjusting a trimmer is easier than swapping fixed-value capacitors. A trimmer may also be used to compensate for capacitance in a circuit that gradually drifts with age.

What Can Go Wrong

Failure to Ground Trimmer Capacitor While Adjusting it

Although trimmer capacitors are not polarized, the manufacturer may mark one terminal with a plus sign and/or the other with a minus sign. If the capacitor is adjusted while its negative terminal is floating or ungrounded, a metal screwdriver blade will create erroneous readings. Always ground the appropriate side of a trimmer capacitor before fine-tuning it, and preferably use a plastic-bladed screwdriver.

Application of Overcoat Material or "Lock Paint"

Overcoat material is a rubbery adhesive that may be spread over assembled components to immunize them against moisture or vibration. *Lock paint* is a dab of paint that prevents a screw adjustment from turning after it has been set. Most manufacturers advise against applying these materials to a trimmer capacitor, because if penetration occurs, the capacitor can fail.

Lack of Shielding

Variable capacitors should be shielded during use, to protect them from external capacitive effects. Merely holding one's hand close to a variable capacitor will change its value.

inductor

14

The term **inductor** is used here to describe a coil that has the purpose of creating *self-inductance* in an electronic circuit, often while passing alternating current in combination with resistors and/or capacitors. A *choke* is a form of inductor. By comparison, the **electromagnet** entry in this encyclopedia describes a coil containing a center component of ferromagnetic material that does not move relative to the coil, and has the purpose of attracting or repelling other parts that respond to a magnetic field. A coil containing a center component of ferromagnetic material that moves as a result of current passing through the coil is considered to be a **solenoid** in this encyclopedia, even though that term is sometimes more broadly applied.

OTHER RELATED COMPONENTS

- **solenoid** (See Chapter 21)
- **electromagnet** (See Chapter 20)

What It Does

An inductor is a coil that induces a magnetic field in itself or in a *core* as a result of current passing through the coil. It may be used in circuits to block or reshape AC current or a range of AC frequencies, and in this role can "tune" a simple radio receiver or various types of oscillators. It can also protect sensitive equipment from destructive voltage spikes.

The schematic symbol for an inductor includes a coil that can be drawn in two basic styles, shown at the top and at the bottom of Figure 14-1. The style at the bottom has become more common. In each vertical section of the diagram, the functionality of the symbols is identical.

One or two parallel lines alongside the coil indicate that it is wound around a solid core of material that can be magnetized, while one or two dotted lines indicate that it is wound around a core containing metal particles, such as iron filings. Where no core is shown, this indicates an air core.

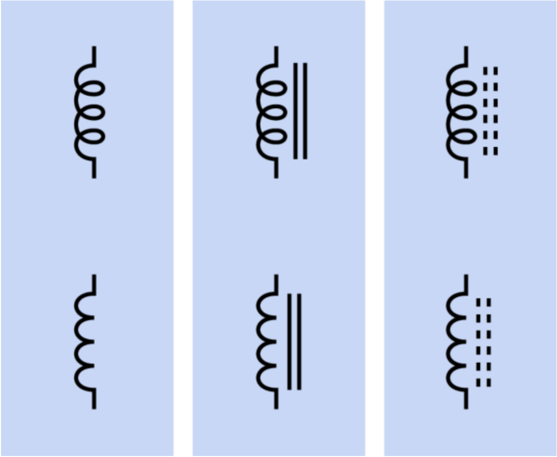

Figure 14-1. *The coil symbol for an inductor may be drawn in two styles which are functionally identical. Line(s) beside the coil indicate a solid core. Dotted line(s) indicate a core containing metal particles.*

A selection of inductors designed for through-hole mounting is shown in Figure 14-2.

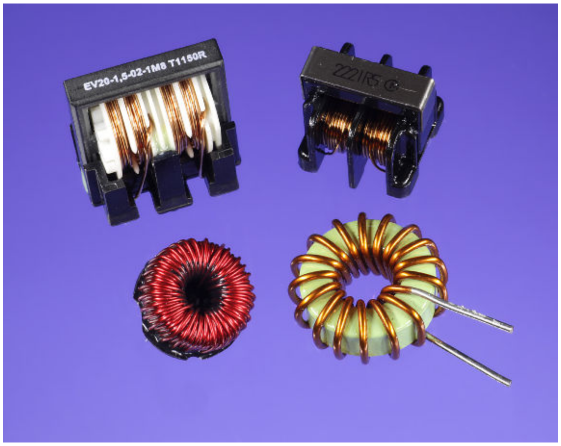

Figure 14-2. *Four inductors designed for through-hole insertion into printed circuit boards.*

How It Works

Direct current passing through an electrical conductor, such as a wire, creates a magnetic field around the conductor. In Figure 14-3, *conventional current* (flowing from positive to negative) is passing through a straight wire from left to right, as indicated by the red/blue arrow. The resulting magnetic field is indicated by the green arrows. If the wire is now bent into a curve, as shown in Figure 14-4, the magnetic field exerts an aggregate force downward through the curve. This magnetic force is conventionally said to flow from *south* to *north*.

If direct current could be induced to circulate through an unbroken circle of wire, the resulting magnetic field could exert a force through the circle as shown in Figure 14-5, assuming clockwise circulation of conventional current as suggested by the red/blue arrows.

Conversely, if a magnet was pushed through the center of the circle, it would induce a pulse of electric current in the circle. Thus, electricity passing through a wire can induce a magnetic field around the wire, and conversely, a magnet moving near a wire can induce an electric current in the wire. This principle is used in an electrical *generator*, and also in a **transformer**, where alternating current in the primary coil induces a fluctuating magnetic field in the core, and the field in the core is turned back into alternating current in the secondary coil.

Note that a static or unchanging magnetic field will not induce a flow of electricity.

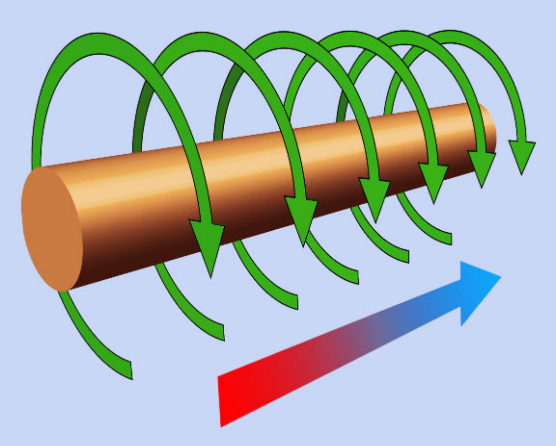

Figure 14-3. *Conventional current passing through a wire from left to right (as indicated by the red/blue arrow) induces a magnetic field around the wire (shown by the green arrows).*

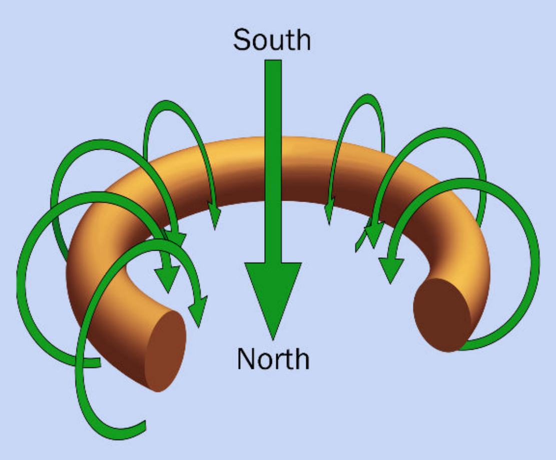

Figure 14-4. *If the wire is bent into a curve, the magnetic fields can create a net force shown by the large green arrow.*

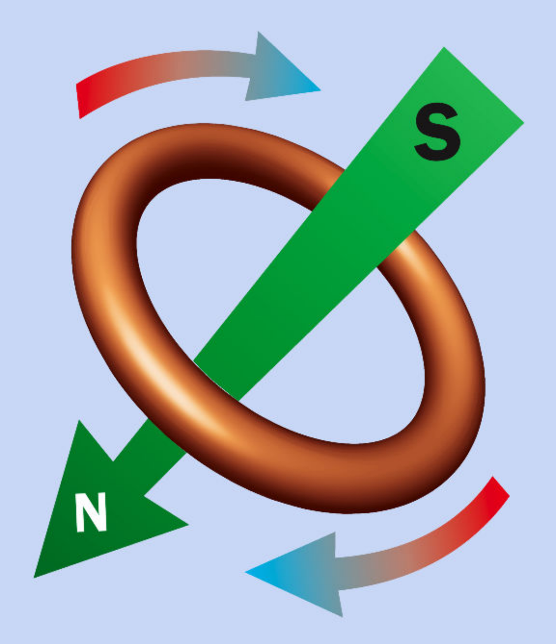

Figure 14-5. *Hypothetically, if conventional current flows around a circular conductor (as suggested by the red/blue arrows), it will create a magnetic field that can create a force as shown by the green arrow.*

DC Through a Coil

If the wire is formed into a helix (a series of approximate circles) as shown in Figure 14-6, and if DC current is passed through the wire, the aggregate of the magnetic fields can create a force in the direction of the green arrow in each example, depending whether the wire is wound clockwise or counter-clockwise, and depending on the direction of the current. The helix is usually referred to as a *coil* or a *winding*.

In actuality, a magnetic field is not open-ended, and its lines of force are completed by circling around outside the inductor, to complete a *magnetic circuit*. This completion of the field can be demonstrated by the traditional high-school experiment of positioning a compass or scattering iron filings on a sheet of paper above a magnet. A simplified depiction of lines of force completing a magnetic circuit is shown in Figure 14-7, where a coil is inducing the magnetic field. Note that throughout this encyclopedia, the color green is used to indicate the presence of magnetic force.

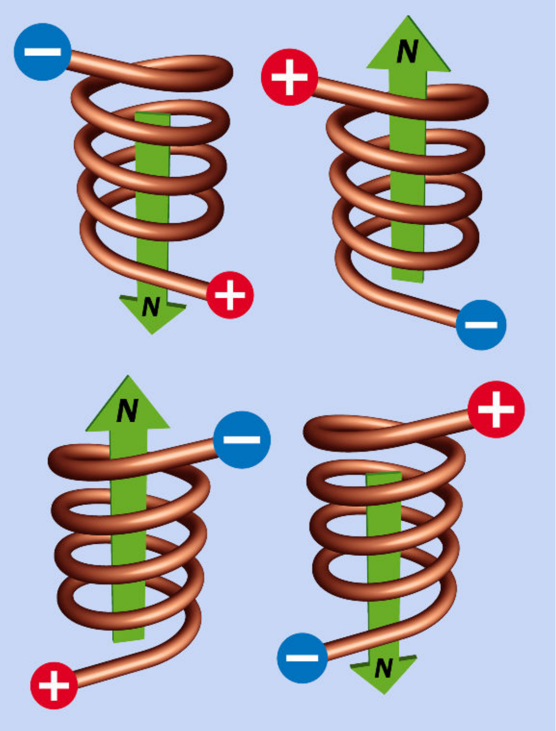

Figure 14-6. *When DC current flows through a coil, it creates magnetic fields that will exert a force whose direction depends on the direction of the current and on whether the coil is wound clockwise or counterclockwise. The force is shown by the green arrow in each case.*

The completion of a magnetic field is not relevant to the primary function of the inductor. In fact the external part of the magnetic field is mostly a source of trouble in electronics applications, since it can interact with other components, and may necessitate the use of magnetic shielding. In addition, the field is weakened by completing itself through air, as air presents much greater *reluctance* (the magnetic equivalent of resistance) than the core of an electromagnet.

The polarity of a magnetic field created by a coil can be demonstrated by moving a small permanent magnet toward the coil, as shown in

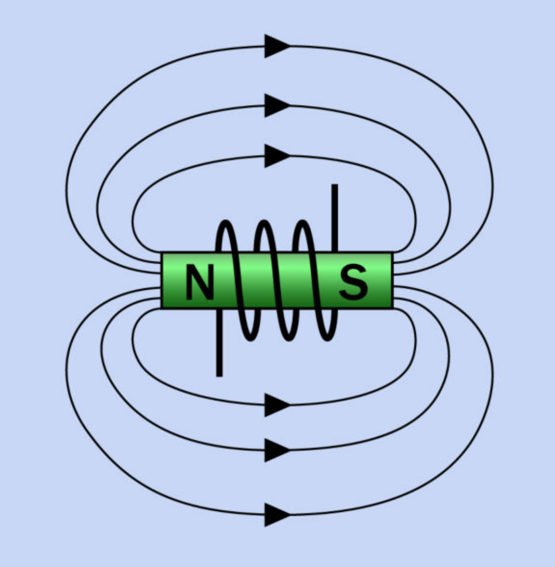

Figure 14-7. *A magnetic field in reality is not open-ended, and each line of force traveling through a rod-shaped magnet or electromagnet is completed outside of the magnet. The completion of magnetic fields has been omitted from other diagrams here for clarity.*

Figure 14-8. If the magnet has opposite polarity to the coil, it will tend to be repelled, as like poles repel. If it has the same polarity, it will tend to be attracted, because opposite poles attract. This principle may be used in **solenoids**.

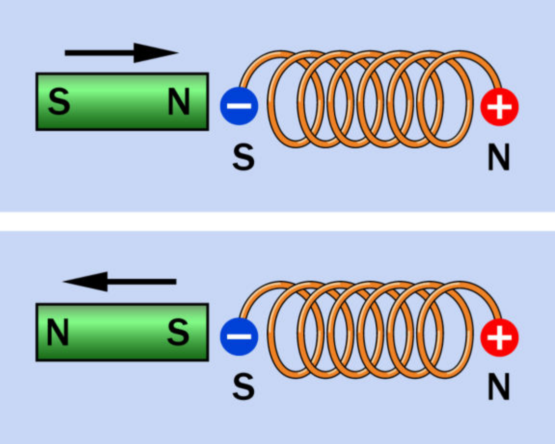

Figure 14-8. *A permanent magnet (left) will either be drawn toward a DC-energized coil or repelled from it, depending on the polarity of the two magnetic fields.*

Magnetic Core

The inductive power of a coil will be enhanced, and the saturation point will be reduced, by using a *magnetic core*. The term "magnetic" in this context does not mean that the core is a permanent magnet; it means that the core can be magnetized briefly by a transient pulse of electricity through the surrounding coil.

A core enhances the effectiveness of an inductor because it has a lower reluctance than that of air. In other words, magnetic flux will flow much more readily through the core than through air.

Roughly speaking, the *permeability* of a magnetic circuit is the opposite of reluctance; it is a measure of how easily a magnetic field can be induced, and is usually expressed relative to the permeability of air, which is approximately 1. The permeability of different core types is discussed in the following "Values" section.

The core of the coil contains *magnetic domains* that behave as tiny magnets, with north and south poles. In the absence of a polarizing magnetic field, the domains are randomly aligned. As a magnetic field is introduced around them and grows stronger, the domains align themselves with it, increasing the total magnetic force. When the domains are almost all uniformly aligned, the core approaches *magnetic saturation* and ceases adding to the net magnetic field. At this point the current in the inductor is said to be *continuous*.

When power to the coil is disconnected, the domains revert partially to their previous random orientation. Thus the core remains a weak permanent magnet. This effect is known as *hysteresis*, while the weak residual field is known as *remanent magnetism*.

EMF and Back-EMF

When DC current is connected through an inductor, the creation of a magnetic field takes a brief but measurable period of time. The field induces an *EMF* (*electro-motive force*) in the wire. Since this force opposes the supplied current, it is referred to as *back-EMF*. It lasts only so long as the field is increasing to its full strength. After the field reaches a steady state, current flows through the coil normally.

This transient resistive effect is caused by the *self-inductance* of the coil, and is opposite to the behavior of a capacitor, which encourages an initial inrush of direct current until it is fully charged, at which point it blocks subsequent current flow.

When high-frequency alternating current attempts to flow through an inductor, if each pulse is too brief to overcome the back-EMF, the coil will block the current. A coil can thus be designed to block some frequencies but not others.

Even a simple electrical circuit that does not contain a coil will still have some self-inductance, simply because the circuit consists of wires, and even a straight length of wire induces a magnetic field when the power is switched on. However, these inductive effects are so small, they can generally be ignored in practical applications.

The transient electrical resistance to alternating current caused by either an inductor or a capacitor is known as *reactance*, although it occurs under opposite electrical conditions, as the coil impedes an initial pulse of DC current and then gradually allows it to pass, while a capacitor allows an initial pulse of DC current and then impedes it.

When a flow of DC current through a coil is switched off, the magnetic field that was created by the coil collapses and releases its stored energy. This can cause a pulse of forward EMF, and like back-EMF, it can interfere with other components in a circuit. Devices such as motors and large relays that contain substantial coils can create problematic spikes of back-EMF and forward-EMF. The forward-EMF that occurs when power to the coil is interrupted is typically dealt with by putting a diode in parallel with the coil, allowing current to circulate through it. This is known as *clamping* the voltage transient. A diode-capacitor combination known as a *snubber* is also commonly used. For a schematic and additional information on this topic, see "Snubber" (page 108).

A schematic to demonstrate EMF and back-EMF is shown in Figure 14-9. The coil can be a 100-foot spool of 26-gauge (or smaller) hookup wire, or magnet wire. It will function more effectively if a piece of iron or steel, such as half-inch galvanized pipe, is inserted through its center. When the button is pressed, current is briefly impeded by the back-EMF created by the coil, and is diverted through D1, making it flash briefly. Then the coil's reactance diminishes, allowing the current to flow through the coil and bypass the LED. When the pushbutton is released, the coil's magnetic field collapses, and the consequent forward-EMF circulates through D2, causing it to flash briefly. Note that the polarity of back-EMF and forward-EMF are opposite, which is why the LEDs in the circuit are oriented with opposite polarities.

The 220Ω resistor should be rated at 1/4 watt minimum, and the button should not be held down for long, as the electrical resistance of the coil is relatively low. The LEDs ideally should be rated for a minimal forward current of no more than 5mA.

Electrical and Magnetic Polarity

Various mnemonics and images have been created to assist in memorizing the polarity or direction of the magnetic field that will be created by a flow of electricity. The *right-hand rule* suggests that if the fingers of the right hand are curled around a coil in the same direction in which the turns of the coil were wound, and if conventional DC current also flows in this direction, the extended thumb will point in the direction of the principal force that can be created by the magnetic field.

By convention, the magnetic field is oriented from *south* to *north*, which can be remembered since the north end of the magnetic field will be

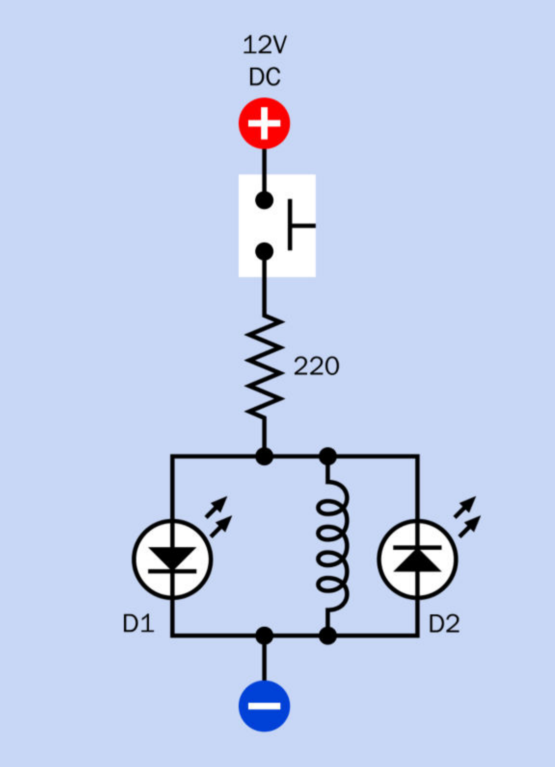

Figure 14-9. *A test circuit to demonstrate the EMF and back-EMF created when DC current starts and stops passing through a coil. See text for details.*

the negative end of the coil (north and negative both beginning with letter N). This mnemonic only works if conventional (positive) current flows through a coil that is wound clockwise.

Another model is the "corkscrew rule" in which we imagine conventional DC current flowing from the handle of a corkscrew, down through its metal section, toward the pointed end. If the corkscrew is turned clockwise, in the same direction as the electricity, the corkscrew will sink into the cork in the same as the direction as the resulting magnetic force.

Variants

Variants include core materials, core shapes, termination style (for through-hole mounting in perforated board, or for surface-mount), and external finish (some inductors are dipped in insulating material, while others allow their copper magnet wire to be exposed).

In addition there are two functional variants: variable inductors and ferrite beads. Their schematic symbols are shown in Figure 14-10.

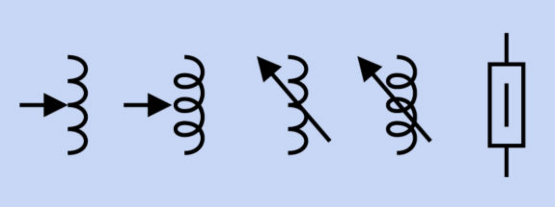

Figure 14-10. *Schematic symbols for a ferrite bead (farthest right) and variable inductors (all other symbols, which are functionally identical).*

Magnetic Cores

A magnetic core may be made from solid iron, plates of iron or steel separated by thin insulating material, powdered iron mixed with a binder, or a ferrite compound derived from nickel, zinc, manganese, or a combination. An iron core has at least 1,000 times the permeability of air, while some ferrites are 10,000 times as permeable.

One major disadvantage of a magnetic core is *hysteresis*, which in this context refers to the tendency of the core to retain some magnetic "memory" as a cycle of alternating current changes from positive to negative. This residual magnetism must be overcome by the next positive pulse of AC. The tendency of the core to retain magnetic polarity is known as its *retentivity*. Iron cores are especially retentive.

Another disadvantage of some magnetic cores is that they may host eddy currents induced by the magnetic field of the coil. These electrical currents tend to circulate through the core, reducing efficiency by generating waste heat, especially if coil currents are high. Forming a core from iron or steel plates, separated by thin layers of insulation, will inhibit these currents. Powdered iron inhibits eddy currents because the particles have limited contact. Ferrites are nonconductive, and are therefore immune to eddy currents. They are widely used.

Hysteresis and eddy currents both incur energy losses with each AC cycle. Therefore, the losses increase linearly as the AC frequency increases. Consequently, inductor cores that suffer either of these problems are not well-suited to high frequencies.

Nonmagnetic Cores

The problems associated with magnetic cores may be avoided by winding the coil around a nonmagnetic core that may be hollow, ceramic, or plastic. A hollow core is referred to as an *air core*. The permeability of ceramic and plastic cores is close to that of air.

An inductor with a nonmagnetic core will be immune to eddy currents and retentivity, but will have to be significantly larger than a magnetic-cored coil with comparable inductance. In the case of a very primitive radio receiver, such as a crystal set, the air-cored coil that selects a radio frequency may be several inches in diameter. A basic circuit diagram for a crystal set (so-called because it uses a diode containing a germanium crystal) is shown in Figure 14-11. The antenna, at top, receives signals broadcast from radio stations. The coil can be tapped (as indicated by the black dots) as a simple way to select different inductance values, blocking all but a narrow range of frequencies. The T-shaped white component at right is a high-impedance earphone. The diode blocks the lower half of the alternating current in a radio signal, and since the signal is *amplitude-modulated*, the earphone responds to variations in intensity in the signal and reproduces the sound encoded in it.

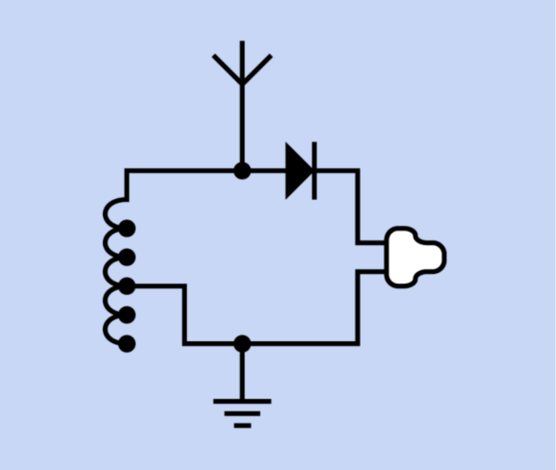

Figure 14-11. *An early and basic application for an inductor is to select radio-station frequencies, as in this schematic for a crystal set. See text for details.*

Variable Inductors

A *variable inductor*, also known as an *adjustable inductor*, is relatively uncommon but can be fabricated by using a magnetic core that penetrates the center of the inductor on an adjustable screw thread. The inductance of the assembly will increase as a larger proportion of the magnetic core penetrates into the open center of the coil. A photograph of a variable inductor is at Figure 14-12.

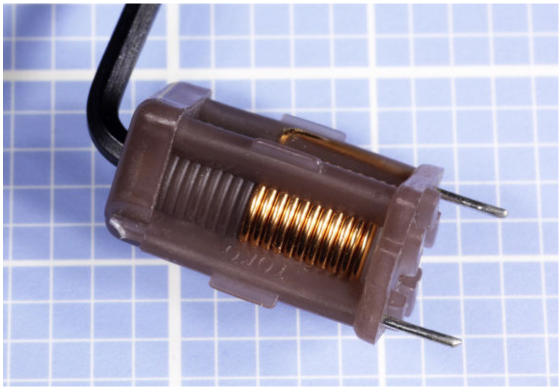

Figure 14-12. *A variable inductor. Its inductance is adjusted via a screw thread that varies the insertion of the core in the coil. In this component the core is turned by inserting a hex wrench, as shown. It is rated from 0.09μH to 0.12μH.*

Ferrite Beads

A *ferrite bead* inverts the design of a typical inductor by running a wire through a hole in the center of the bead, instead of coiling the wire around the core. Two ferrite beads are shown in Figure 14-13. At top, the bead is divided into two sections, each mounted in one-half of a plastic clam shell, which can be closed around a wire. At bottom, the bead must be threaded onto a wire. The purpose is either to limit radio-frequency radiation from a wire by absorbing it into the bead (where it is transformed into heat), or to protect a wire from external sources of radio-frequency radiation. Computer cabling to external devices; lamp dimmers; and some types of motors can be sources of radio frequency.

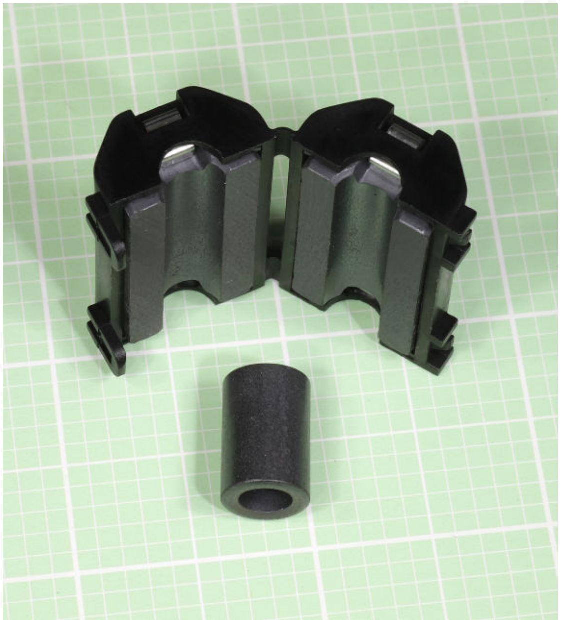

Figure 14-13. *Two examples of ferrite beads. They can inhibit radio-frequency radiation from a wire, or protect the wire from interference.*

Toroidal Cores

The magnetic circuit created by a rod-shaped core must be completed by the lines of force traveling back around from one end of the rod to the other, through the surrounding air. Since air has low permeability, this is a major source of inefficiency. By comparison, a torus (a geometrical shape resembling a donut) completes the entire magnetic circuit inside its core. This significantly increases its efficiency. Also, because its field is better contained, a toroidal inductor needs little or no shielding to protect other components from stray magnetic effects.

Two through-hole toroidal inductors are shown in Figure 14-2. Bottom left: Rated at 345µH. Bottom right: Rated at 15µH. The one at bottom-left has pins beneath it for insertion into a printed circuit board.

Surface-mount inductors often are toroidal to maximize the efficiency of a component that has to function on a very small scale. Examples are shown in Figure 14-14, Figure 14-15, and Figure 14-16.

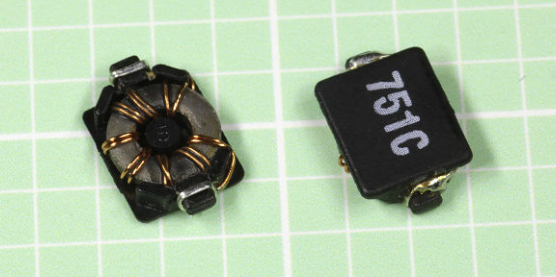

Figure 14-14. *In a typical toroidal inductor, the coil is wrapped around a magnetic core shaped as a torus. This surface-mount component (viewed from the bottom, at left, and from the top, at right) is at the low end of the range of component sizes. It is rated at 750nH.*

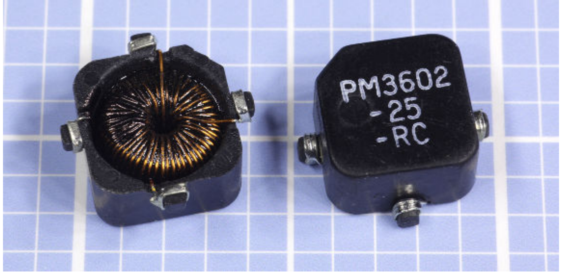

Figure 14-15. *A medium-sized surface-mount toroidal inductor (viewed from the bottom, at left, and from the top, at right). It is rated at 25µH.*

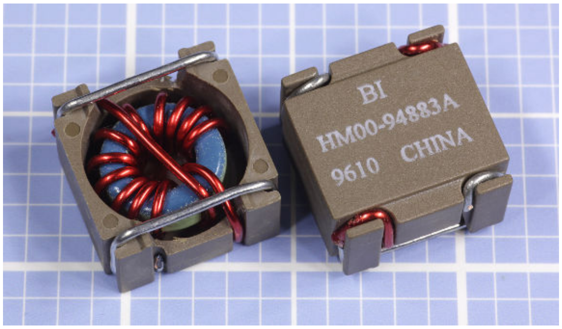

Figure 14-16. *A larger-sized surface-mount toroidal inductor (viewed from the bottom, at left, and from the top, at right). It is rated at 3.8µH.*

A chart showing some types of inductor cores, their commonly available inductances, and their maximum frequencies is shown in Figure 14-17.

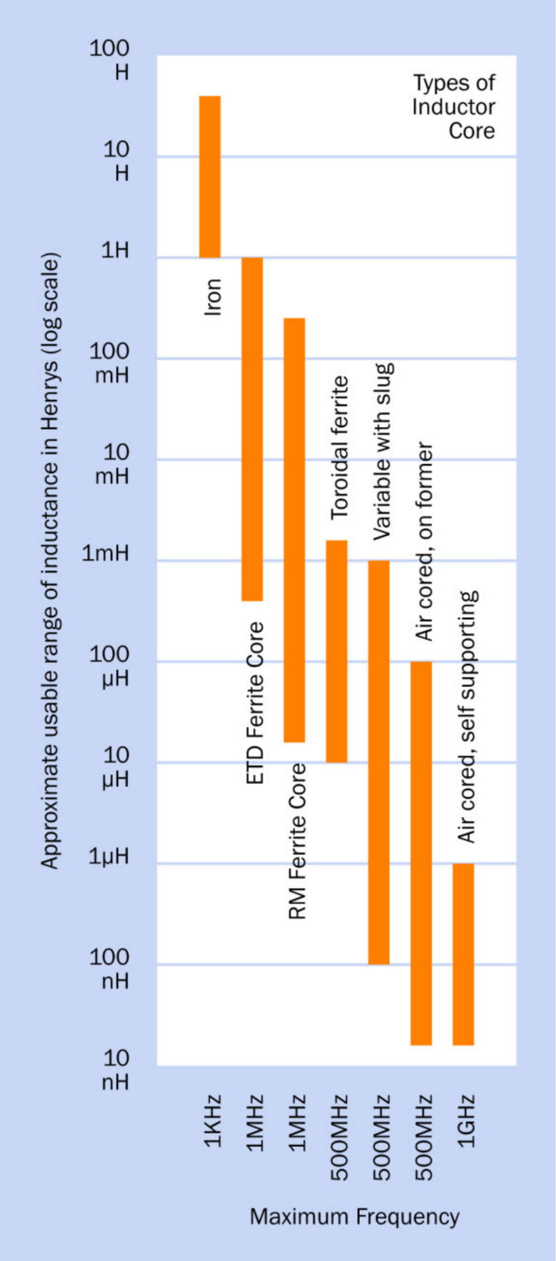

Figure 14-17. *Some commonly used inductor cores and their characteristics. Adapted from "Producing wound components" by R.Clark@surrey.ac.uk.*

Gyrator

A *gyrator* is a small network, sometimes encapsulated in a silicon chip, using **resistors**, a semiconductor, and a **capacitor** to simulate some but not all of the behavior of a coil-based inductor. The semiconductor may be a transistor or a capacitor, depending on the specific circuit. A sample schematic is shown in Figure 14-18. Because no magnetic effects are induced, the gyrator is completely free from the problems of saturation and hysteresis, which affect coils with cores, and also produces no back-EMF. It simply attenuates a signal initially, and then gradually lowers its reactance, thus imitating this aspect of an inductor.

A gyrator may be used where a coil may be unacceptably large (as in a cellular phone) or where signal quality is of paramount importance—for example, in a graphic equalizer or other audio components that perform signal processing at input stages, such as preamplifiers.

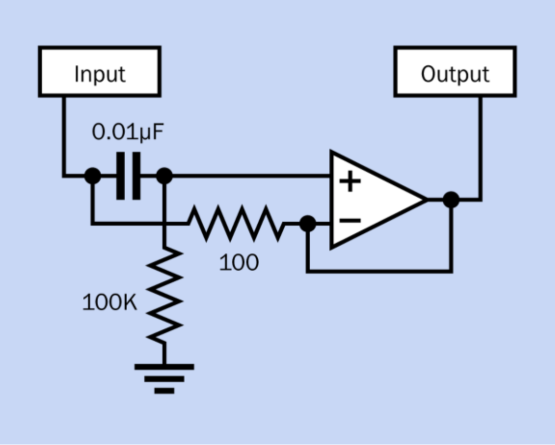

Figure 14-18. *A possible schematic for a coil substitute known as a gyrator, which may be used where a conventional coil would be unacceptably bulky.*

A gyrator does impose some limits on circuit design. While neither side of a real inductor needs to be at ground potential, a gyrator does require a ground connection. However, the performance advantages of gyrators are significant, as they can emulate high inductance without parasitic effects, can be more accurately calibrated (leading to more predictable performance), and do not create magnetic fields that can interfere with other components.

Values

Calculating Inductance

The magnetic inductance of a coil is measured with a unit known as the Henry, named after Joseph Henry, a pioneer in electromagnetism. It is defined by imagining a coil in which current is fluctuating, causing the creation of EMF. If the rate of fluctuation is 1 amp per second and the induced EMF is 1 volt, the inductance of the coil is 1 Henry.

The letter L is commonly used to represent inductance. To derive a useful formula, L will be expressed in microhenrys. If D is the diameter of a coil, N is the number of turns of wire, and W is the width of coil (when the windings are viewed from the side, as shown in Figure 14-19), the precise relationship of the variables is complex but can be reduced to an approximate formula:

$$L = \text{approx } (D^2 * N^2) / 18 * D) + (40 * W$$

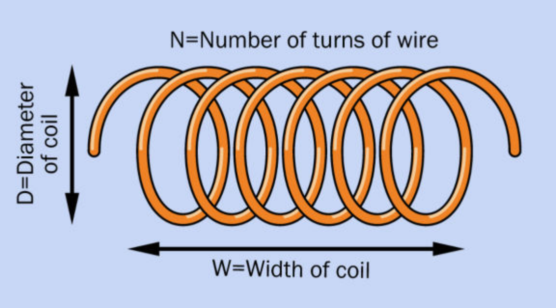

Figure 14-19. *Dimensions of a coil, referenced by a formula to calculate its approximate inductance. See text for details.*

From this, it is clear that inductance tends to increase with coil diameter, and also increases (more significantly) with the square of the number of turns. If the number of turns remains constant, inductance will be higher for a coil that is short and fat than for a coil that is narrow and long.

Because the Henry is a large unit, inductors in electronics circuits typically have their inductances measured in millihenrys (mH), microhenrys (µH), and nanohenrys (nH), where 1H = 1,000mH, 1 mH = 1,000µH, and 1µH = 1,000 nH. This relationship is shown in Figure 14-20.

Calculating Reactance

The reactance of an inductor (that is, its dynamic resistance to alternating current) varies with the frequency of the current. If f is the AC frequency (in Hertz), and L is the inductance (in Henrys), the reactance, X_L in ohms, is given by the formula:

$$X_L = 2 * \pi * f * L$$

From this equation, it's apparent that as the frequency tends toward zero (DC current), or if the inductance tends toward zero (a short piece of

nH	µH	mH
1	0.001	0.000001
10	0.01	0.00001
100	0.1	0.0001
1,000	1	0.001
10,000	10	0.01
100,000	100	0.1
1,000,000	1,000	1

Figure 14-20. *Inductance is typically measured in nanohenrys (nH), microhenrys (µH), and millihenrys (mH). Equivalent values in these units are shown here.*

straight wire), the reactance will tend toward zero. Conversely, the inductor will impede current increasingly as the frequency and/or the inductance increases.

Calculating Reluctance

The letter S is often used to represent reluctance, while Greek letter µ customarily represents permeability (not to be confused with the use of µ as a multiplication factor of 1/1,000,000, as in µF, meaning "microfarad"). If A is the area of cross-section of the magnetic circuit and L is its length:

```
S = L / µ * A
```

Datasheet Terminology

A typical manufacturer's datasheet should include an *inductance index* for an inductor, expressed in µH per 100 turns of wire (assuming the wire is in a single layer) for inductors with a powdered iron core, and mH per 1,000 turns of wire for inductors with ferrite cores.

The *DCR* is the DC resistance of an inductor, derived purely from the wire diameter and its length.

The *SRF* is the *self-resonant frequency*. An inductor should be chosen so that AC current passing through it will never get close to that frequency.

ISAT (or I_{sat}) is the saturation current, which results in a magnetic core losing its function as a result of magnetic saturation. When this occurs, inductance drops and the charge current rate increases drastically.

Series and Parallel Configurations

Because the inductance of a coil conducting DC current is proportional to the current, the calculations to derive the total inductance of coils in series or in parallel are identical to the calculations used for resistors.

In series, all the coils inevitably pass the same current, and the total inductance is therefore found by summing the individual inductances. When coils are wired in parallel, the current distributes itself according to the inductances; therefore, if L1 is the reluctance of the first coil, L2 is the reluctance of the second coil, and so on, the total reluctance L of the network is found from the formula:

```
1/L = 1/L1 + 1/L2 + 1/L3. . .
```

This is shown in Figure 14-21. In reality, differences between the coils (such as their electrical resistance), and magnetic interaction between the coils, will complicate this simple relationship.

Time Constant

Just as the *time constant* of a capacitor defines the rate at which it accumulates voltage when power is applied through a resistor, the time constant of an inductor defines the rate at which it gradually allows amperage to pass through it, overcoming the EMF generated by the coil. In both cases, the time constant is the number of seconds that the component requires to acquire approximately 63% of the difference between its current value and its maximum value. In the case of an inductor, suppose we assume zero internal resistance in the power source, zero resistance in

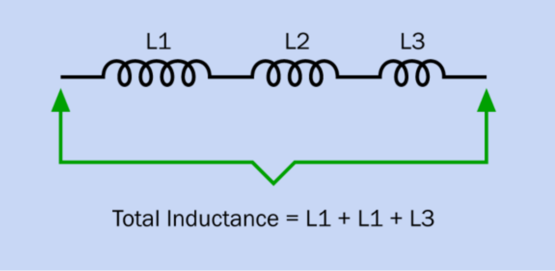

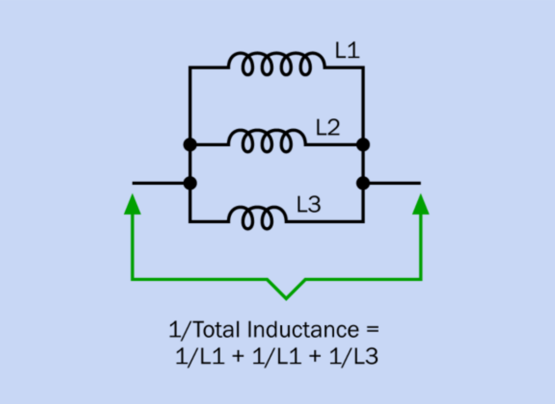

Figure 14-21. *Calculating the total inductance of inductors in parallel (top) and series (bottom).*

the coil windings, and an initial current of zero. If L is the inductance of the coil and R is the value of the series resistor, then the time constant—TC—is given in seconds by the formula

```
TC = L / R
```

Therefore a coil of 10 millihenrys (0.01 Henry) in series with a 100-ohm resistor will pass 63% of the full current in 0.0001 seconds, or 1/10 of a millisecond; it will take an equal additional amount of time for the current to rise by another 63% of the remaining difference between its charge and the maximum amperage of the circuit. In theory, the reactance of a coil can never diminish to zero, but in practice, five time constants are considered adequate to allow maximum current flow.

How to Use it

Because the inductance of an inductor peaks as current increases, and then gradually diminishes, an inductor can be used to block or attenuate high frequencies. A circuit that does this is often referred to as a *low-pass filter*. The schematic and a graph suggesting its performance are shown in Figure 14-22. A basic application could be the *crossover network* in a loudspeaker system, where high-frequency signals are blocked from a low-frequency driver and are diverted to a high-frequency driver.

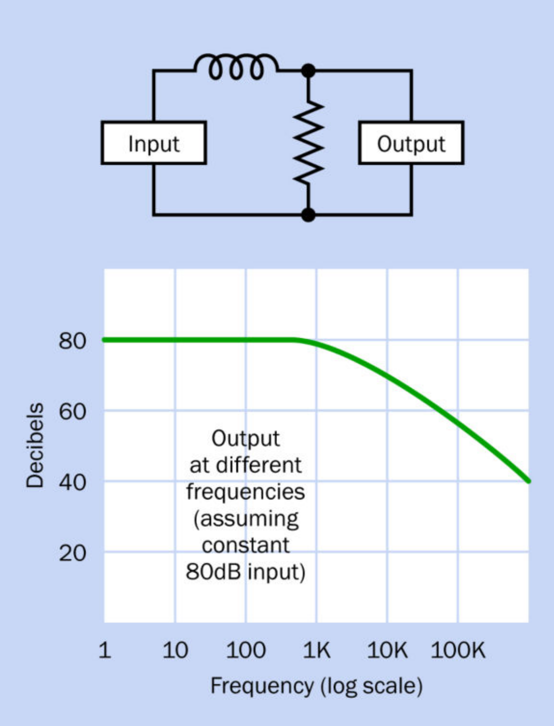

Figure 14-22. *By using the ability of an inductor to block a range of frequencies, a low-pass filter blocks higher frequencies.*

If the location of the inductor is shifted so that it shunts the signal away from the output, the results are reversed, and the circuit becomes a *high-pass filter*. The schematic and a graph suggesting its performance are shown in Figure 14-23.

Note that **capacitors** may also be used to create frequency filters, but because their function is roughly inverse to that of inductors, the place-

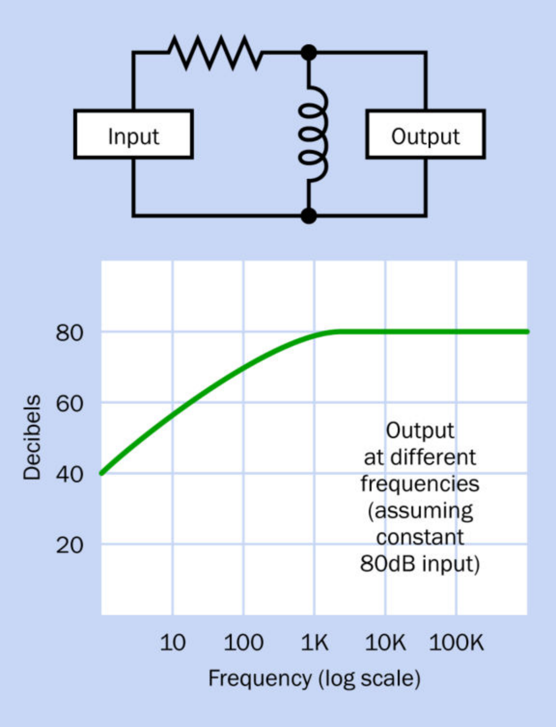
Input
Output
Decibels
80
60
40
20
Output
at different
frequencies
(assuming
constant
80dB input)
10
100
1K
10K
100K
Frequency (log scale)

Figure 14-23. *Here the inductor diverts low frequencies away from the output, allowing high frequencies to pass through.*

ment of a capacitor in a circuit would be opposite to the placement of the inductor. Examples of filter circuits using capacitors are found in the entry for that component in this encyclopedia.

An inductor can be combined with a capacitor to form a *bandpass filter*, as shown in Figure 14-24. In this configuration, the inductor blocks the high frequencies while the capacitor blocks the low frequencies, allowing only a limited band of frequencies to get through.

Once again if the location of the components is shifted to shunt the signal away from the output, the results are reversed, as shown in Figure 14-25. This is known as a *notch filter*.

The performance of these filters will depend on the component values, and in most applications, additional components will be necessary. Sophisticated filter circuits are outside the scope of this encyclopedia.

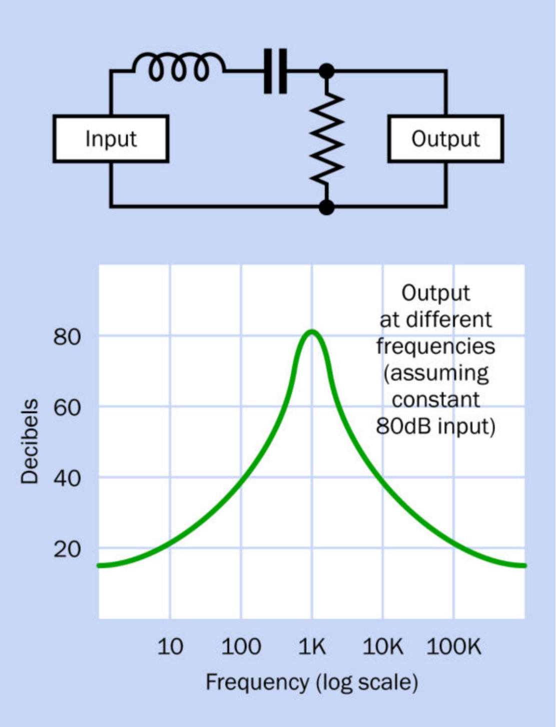
Input
Output
Decibels
80
60
40
20
Output
at different
frequencies
(assuming
constant
80dB input)
10
100
1K
10K
100K
Frequency (log scale)

Figure 14-24. *If the values of a capacitor and an inductor are correctly chosen, and the components are placed in series, the inductor blocks high frequencies while the capacitor blocks low frequencies, creating a bandpass filter, in which only a narrow band of frequencies can get through.*

Inductors are of great importance in **DC-DC converters** and **AC-DC power supplies** where voltage changes are enabled by rapid switching. See the relevant entries of this encyclopedia for additional details.

Generally, as electronic equipment has become increasingly miniaturized, the unavoidable bulk of inductors has limited their application. However they may still be used to tune oscillators, to block sudden spikes in power supplies, and to protect equipment from sudden voltage spikes (they are used, for example, in surge suppressors for computing equipment).

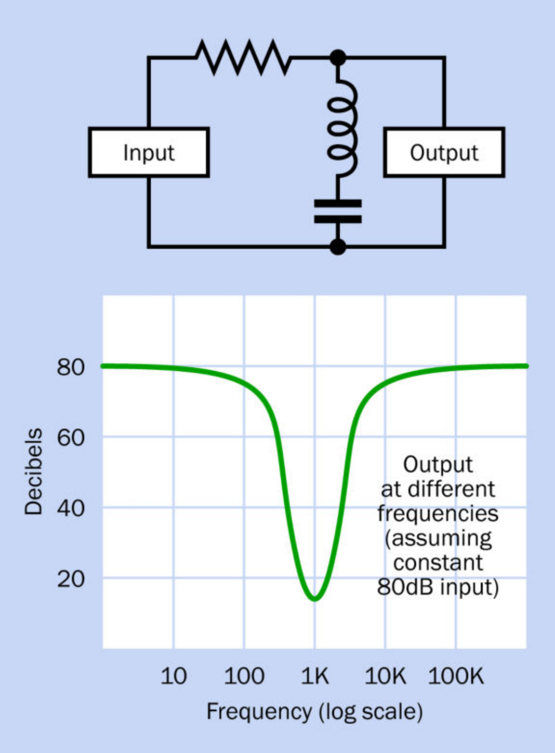

Figure 14-25. *Here the capacitor and inductor block all frequencies except a narrow band, which they divert from the output. The result is a notch filter.*

Core Choices

Air-cored inductors have relatively low inductance, because of their low permeability. However, they can be operated at very high frequencies up to the gigahertz range, and can tolerate higher peak currents.

Inductors with an iron core suffer increasing power losses due to hysteresis and eddy currents as the AC frequency passing through the inductor increases. Consequently, iron-cored inductors are not suitable for frequencies much above 10KHz.

Miniaturization

A low-value inductor can be formed by etching a spiral onto a circuit board, in applications where size must be minimized. They may also be incorporated in integrated circuit chips. However, in small devices such as cellular phones, it is more common to use a coil substitute such as a *gyrator*, as described previously.

What Can Go Wrong

Real-World Defects

The theoretically ideal inductor has no resistance or capacitance and suffers no energy losses. In reality, an inductor possesses both resistance and capacitance, also creates electrical noise, and may pick up electrical noise. It tends to create stray magnetic fields, and generally is more troublesome to deal with than its two cousins, the **resistor** and the **capacitor**.

Parasitic capacitance occurs between adjacent turns of wire. This capacitance becomes more significant at higher frequencies, leading ultimately to a situation where the coil becomes *self resonant*.

The workarounds for these problems involve coil geometries and choices of core material that go beyond the scope of this encyclopedia.

A *gyrator* should be considered as a possible substitute where inductors are troublesome or excessively expensive.

Saturation

Inductance increases as the current passing through a coil increases, but if a magnetic core is used, its contribution to inductance will stop abruptly when the core becomes magnetically *saturated*. In other words, when all of the randomly distributed *magnetic domains* in the core have been induced to align themselves with the pervasive magnetic field, the core cannot become more highly magnetized, and ceases to contribute to the inductance. Note that as a core approaches saturation levels, its hysteresis increases because reversing its magnetization requires greater energy. Antidotes to saturation would include a larger core, a lower current, a smaller number of turns in the coil, and using a core with lower permeability (such as air).

RF Problems

Radio frequencies (*RF*) introduce various problems affecting the efficiency of inductors. The *skin effect* is the tendency of high-frequency AC current to flow primarily on the surface of a strand of wire. The *proximity effect* refers to the tendency of the magnetic fields caused by adjacent wires to introduce eddy currents in the coil. Both of these effects increase the effective resistance of the coil. Various coil geometries have been developed to minimize these effects, but are outside the scope of this encyclopedia. The fundamental lesson is that coils specifically designed for RF are the only ones that should be used with RF.

AC-AC transformer

15

OTHER RELATED COMPONENTS

- **AC-DC power supply** (See Chapter 16)
- **DC-DC converter** (See Chapter 17)
- **DC-AC inverter** (See Chapter 18)

What It Does

A transformer requires an input of *alternating current* (AC). It transforms the input voltage to one or more output voltages that can be higher or lower.

Transformers range in size from tiny impedance-matching units in audio equipment such as microphones, to multi-ton behemoths that supply high voltage through the national power grids. Almost all electronic equipment that is designed to be powered by municipal AC in homes or businesses requires the inclusion of a transformer.

Two small power transformers are shown in Figure 15-1. The one at the rear is rated to provide 36VAC at 0.8A when connected with a source of 125VAC. At front, the miniature transformer is a Radio Shack product designed to provide approximately 12VAC at 300mA, although its voltage will be more than 16VAC when it is not passing current through a load.

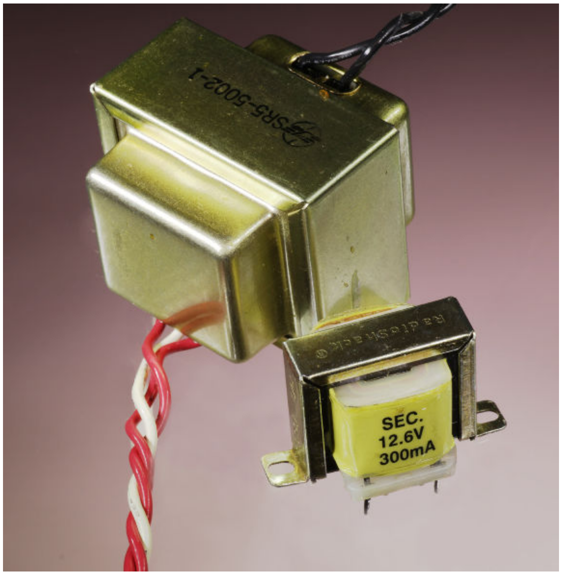

Figure 15-1. *Two small power transformers. The one at the rear measures approximately 1" × 2" × 2" and is rated to provide 36VAC at 0.8A. The term "sec" on the smaller unit is an abbreviation for "secondary," referring to the rating for its secondary winding.*

Transformer schematic symbols are shown in Figure 15-2. The different coil styles at left and right are functionally identical. Top: A transformer with a magnetic core—a core that can be magnetized. Bottom: A transformer with an air core. (This type of transformer is rare, as it tends to be less efficient.) The input for the transformer is almost always assumed to be on the left, through the *primary* coil, while the output is on the right, through the *secondary* coil. Often the two coils will show differing numbers of turns to indicate whether the transformer is delivering a reduced voltage (in which case there will be fewer turns in the secondary coil) or an increased voltage (in which case there will be fewer turns in the primary coil).

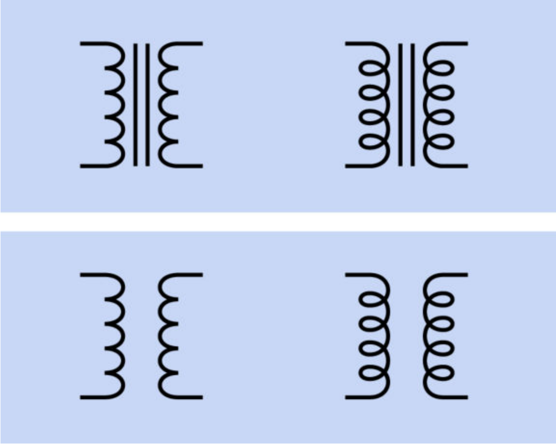

Figure 15-2. *Alternate symbols for a transformer with a ferromagnetic core (top) and air core (bottom). The differing coil symbols at left and right are functionally identical.*

How It Works

A simplified view of a transformer is shown in Figure 15-3. Alternating current flowing through the primary winding (orange) induces magnetic flux in a laminated core formed from multiple steel plates. The changing flux induces current in the secondary winding (green), which provides the output from the transformer. (In reality, the windings usually consist of thousands of turns of thin magnet wire, also known as enameled wire; and various different core configurations are used.)

The process is known as *mutual induction*. If a load is applied across the secondary winding, it will draw current from the primary winding, even though there is no electrical connection between them.

In an ideal, lossless transformer, the ratio of turns between the two windings determines whether the output voltage is higher, lower, or the same as the input voltage. If V_p and V_s are the voltages across the primary and secondary windings respectively, and N_p and N_s are the number of turns of wire in the primary and secondary windings, their relationship is given by this formula:

$$V_p \ / \ V_s = N_p \ / \ N_s$$

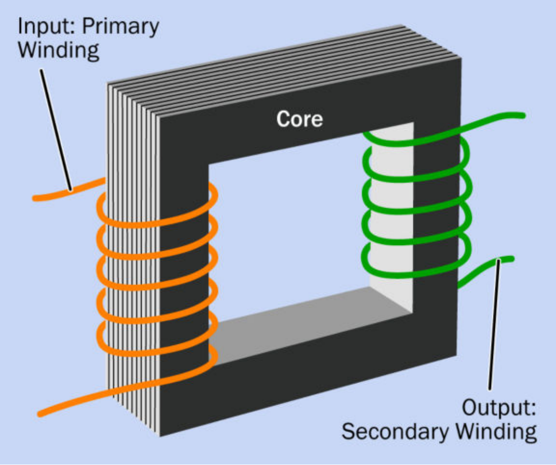

Figure 15-3. *Three basic parts of a transformer, shown in simplified form.*

A simple rule to remember is that fewer turns = lower voltage while more turns = higher voltage.

A *step-up transformer* has a higher voltage at its output than at its input, while a *step-down transformer* has a higher voltage at its input than at its output. See Figure 15-4.

In an ideal, lossless transformer, the power input would be equal to the power output. If V_{in} and V_{out} are the input and output voltages, and I_{in} and I_{out} are the input and output currents, their relationship is given by this formula:

$$V_{in} * I_{in} = V_{out} * I_{out}$$

Therefore, if the transformer doubles the voltage, it allows only half as much current to be drawn from the secondary winding; and if the voltage is cut in half, the available current will double.

Transformers are not 100% efficient, but they can be more than 98% efficient, and relationships between voltage, current, and the number of turns in the windings are reasonably realistic.

When the transformer is not loaded, the primary winding behaves like a simple inductor with reactance that inhibits the flow of current. Therefore a power transformer will consume relatively

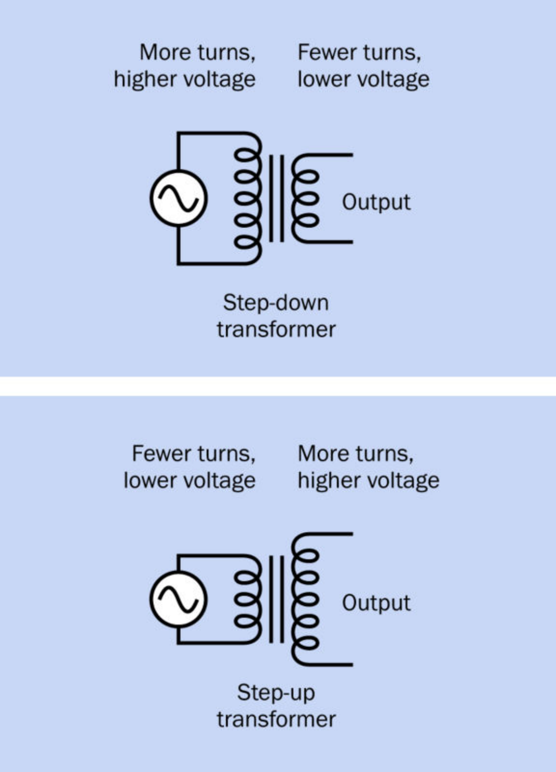

Figure 15-4. *The ratio of input voltage to output voltage is equal to the ratio of primary turns to secondary turns in the transformer windings, assuming a transformer of 100% efficiency.*

little electricity if it is left plugged in to an electrical outlet without any load connected to its output side. The power that it does consume will be wasted as heat.

The Core

The ferromagnetic core is often described as being made of iron, but in reality is more often fabricated from high permeability silicon steel. To reduce losses caused by eddy currents, the core is usually laminated—assembled from a stack of plates separated from each other by thin layers of varnish or a similar insulator. Eddy currents tend to be constrained within the thickness of each plate.

Because a DC voltage would cause magnetic saturation of the core, all transformers must operate with alternating current or pulses of current. The windings and geometry of a transformer are optimized for the frequency range, voltage, and current at which it is designed to operate. Deviating significantly from these values can damage the transformer.

Taps

A *tap* on a transformer is a connection part-way through the primary or (more often) the secondary coil. On the primary side, applying an input between the start of a coil and a tap part-way through the coil will reduce the number of turns to which the voltage is applied, therefore increasing the ratio of output turns to input turns, and increasing the output voltage. On the secondary side, taking an output between the start of a coil and a tap part-way through the coil will reduce the number of turns from which the voltage is taken, therefore decreasing the ratio of output turns to input turns, and decreasing the output voltage. This can be summarized:

- A tap on the primary side can increase output voltage.
- A tap on the secondary side can provide a decreased output voltage.

In international power adapters, a choice of input voltages may be allowed by using a double-throw switch to select either the whole primary winding, or a tapped subsection of the winding. See Figure 15-5. Modern electronics equipment often does not require a voltage adapter, because a **voltage regulator** or **DC-DC converter** inside the equipment will tolerate a wide range of input voltages while providing a relatively constant output voltage.

A transformer's secondary winding is often tapped to provide a choice of output voltages. In fact, most power transformers have at least two outputs, since the cost of adding taps to the secondary winding is relatively small. As an

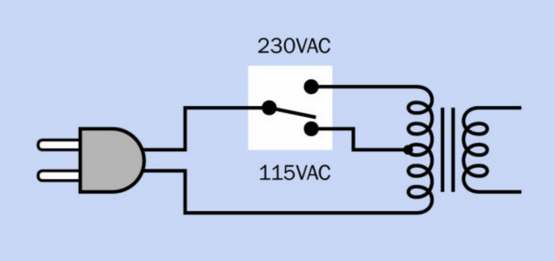

Figure 15-5. *An international power adapter can provide a fixed output voltage by using a double-throw switch to apply 230VAC voltage across a transformer's primary winding, or 115VAC to a tapped midpoint of the primary winding.*

alternative to tapped outputs, two or more separate secondary windings may be used, allowing the outputs to be electrically isolated from each other. See Figure 15-6.

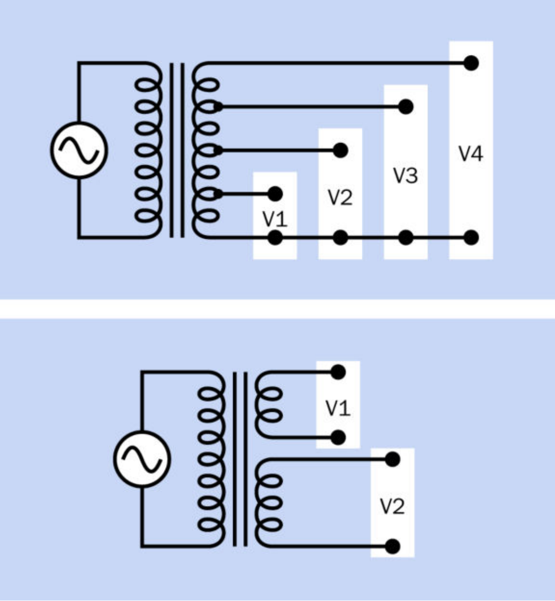

Figure 15-6. *Multiple output voltages may be obtained from a transformer by tapping into the secondary winding (top) or using two or more separate secondary windings (bottom), in which case the outputs will be electrically isolated from each other.*

If the winding on the primary side of a transformer is coiled in the same direction as the winding on the secondary side, the output voltage will be 180 degrees out of phase with the input voltage. In schematics, a dot is often placed at one end of a transformer coil to indicate where the coil begins. If the dots on the primary and secondary sides are at the same ends of the coils, there will be a 180 degree phase difference between input and output. For many applications (especially where the output from a power transformer is going to be converted to DC), this is immaterial.

If there is a center tap on the secondary winding, and it will be referenced as ground, the voltages relative to it, at opposite ends of the secondary winding, will be out of phase. See Figure 15-7.

Variants

Core Shapes

The *shell core* is a closed rectangle, as shown in Figure 15-3. This is the most efficient but most costly to manufacture. A C-shaped core is another option (three sides of the rectangle) and an E-I core is popular, consisting of a stack of E-shaped plates with two coils wound around the top and bottom legs of the E, or wound concentrically around the center leg of the E. An additional stack of straight plates is added to close the gaps in the E and form a magnetic circuit.

In Figure 15-8, the small transformer from Figure 15-1 has been sliced open with a band saw and a belt sander to reveal a cross-section of its windings. This clearly shows that its primary and secondary windings are concentric. It also reveals the configuration of its core, which is in the E-I format. In Figure 15-9, the E-I configuration is highlighted to show it more clearly.

Power Transformer

Typically designed to be bolted onto a chassis or secured inside the case or cabinet housing a piece of electrical equipment with solder tabs or connectors allowing wires to connect the transformer to the power cord, on one side, and a cir-

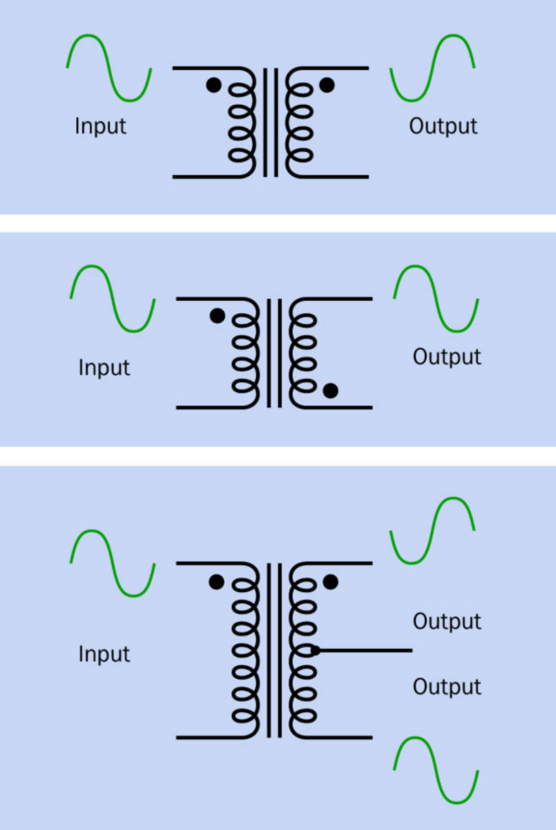

Figure 15-7. *A dot indicates the start of each winding. Where primary and secondary windings are in the same direction, the voltage output will be 180 degrees out of phase with the input. Where the dots indicate windings in opposite directions, the voltage output will have the same phase as the input. Where a center tap on the secondary winding serves as a common ground, the voltages at opposite ends of the secondary winding will be opposite to each other in phase.*

cuit board, on the other side. Smaller power transformers such as the one in Figure 15-1 have "through-hole" design with pins allowing them to be inserted directly onto circuit boards.

Plug-in Transformer

Usually sealed in a plastic housing that can be plugged directly into a wall power outlet. They are visually identical to **AC adapters** but have an AC output instead of a DC output.

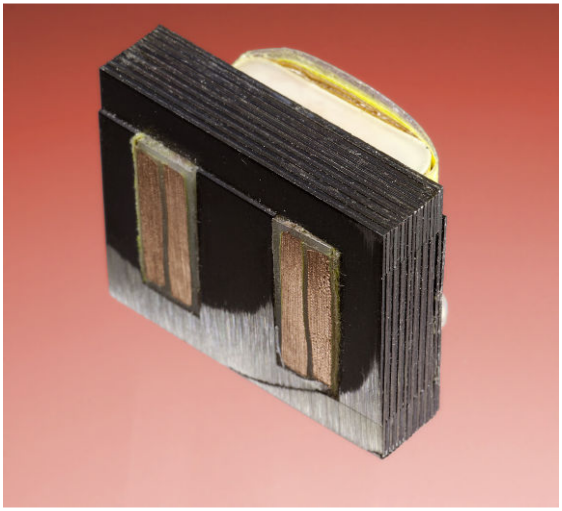

Figure 15-8. *The small transformer from the first figure in this entry is shown sliced open to reveal its internal configuration.*

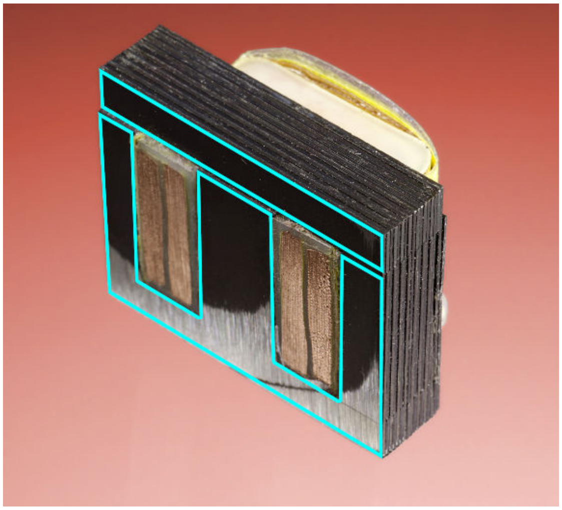

Figure 15-9. *The "EI" shaped plates that form the core of the transformer are outlined to show their edges.*

Isolation Transformer

Also known as a *1:1 transformer* because it has a 1:1 ratio between primary and secondary windings, so that the output voltage will be the same as the input voltage. When electrical equipment is plugged into the isolation transformer, it is separated from the electrical ground of AC power wiring. This reduces risk when working on "live" equipment, as there will be negligible electrical potential between itself and ground. Consequently, touching a grounded object while also touching a live wire in the equipment should not result in potentially lethal current passing through the body.

Autotransformer

This variant uses only one coil that is tapped to provide output voltage. Mutual induction occurs between the sections of the coil. An autotransformer entails a common connection between its input and output, unlike a two-coil transformer, which allows the output to be electrically isolated from the input. See Figure 15-10. Autotransformers are often used for impedance matching in audio circuits, and to provide output voltages that differ only slightly from input voltages.

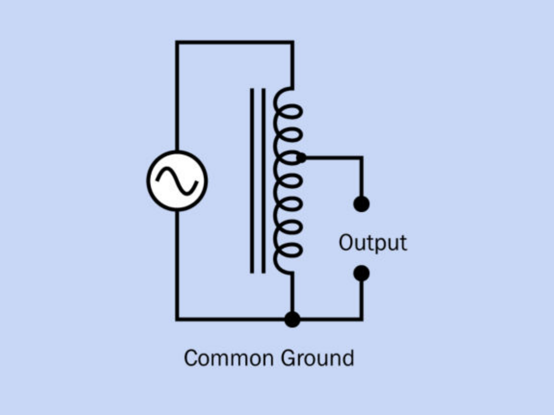

Figure 15-10. *An autotransformer contains only one coil and core. A reduced output voltage can be obtained by tapping into the coil. A common connection prevents the output from being electrically isolated from the input.*

Variable Transformer

A variable transformer, also known as a *variac*, resembles a wire-wound **potentiometer**. Only one winding is used. A *wiper* can be turned to contact the winding at any point, and serves as a movable tap. Like an autotransformer, a variable transformer entails a common connection between input and output.

Audio Transformer

When a signal is transmitted between two stages of a circuit that have different impedance, the signal may be partially reflected or attenuated. (Impedance is measured in ohms but is different from DC electrical resistance because it takes into account reactance and capacitance. It therefore varies with frequency.)

A device of low input impedance will try to draw significant current from a source, and if the source has high output impedance, its voltage will drop significantly as a result. Generally, the input impedance of a device should be at least 10 times the output impedance of the device that is trying to drive it. Passive components (resistors, and/or capacitors, and/or coils) can be used for impedance matching, but in some situations a small transformer is preferable.

If N_p and N_s are the number of turns of wire in the transformer primary and secondary windings, and Z_p is the impedance of a device (such as an audio amplifier) driving the transformer on its primary side, and Z_s is the impedance of a device (such as a loudspeaker) receiving power from the secondary side:

$$N_p / N_s = \sqrt{(Z_p / Z_s)}$$

Suppose that an audio amplifier with rated output impedance of 640Ω is driving a loudspeaker with 8Ω impedance. A matching transformer would be chosen with a ratio of primary turns to secondary turns give by:

```
√(640/8) = √80 = approximately 9:1
```

The two transformers in Figure 15-11 are through-hole components designed for telecommunications purposes, but are capable of passing audio frequencies and can be used for impedance matching in applications such as a preamplifier.

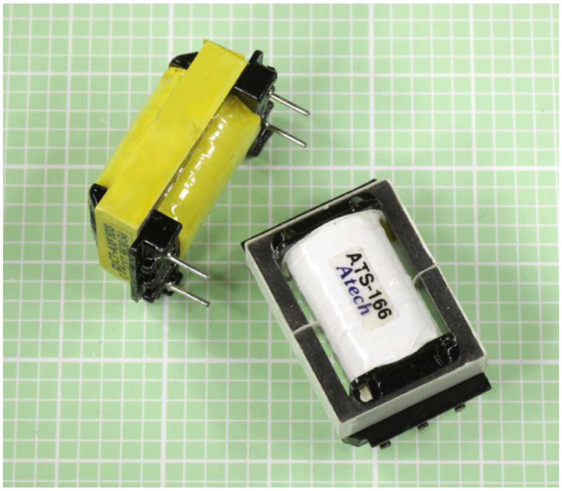

Figure 15-11. *Through-hole transformers. See text for details.*

In Figure 15-12, the transformers are designed for audio coupling. The one on the right has impedances of 500 ohms (primary) and 8 ohms (secondary). On the left is a fully encapsulated line matching transformer with a 1:1 turns ratio.

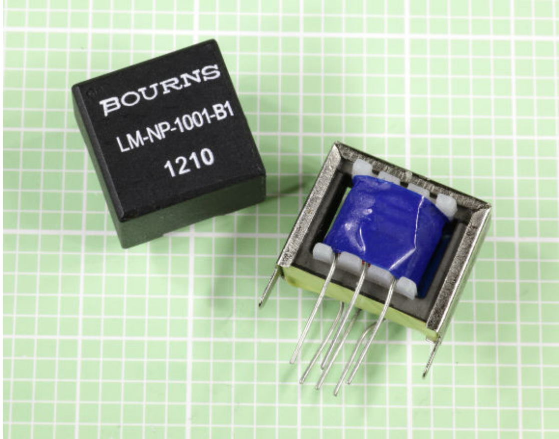

Figure 15-12. *Through-hole transformers. See text for details.*

Split-Bobbin Transformer

This variant has primary and secondary coils mounted side by side to minimize capacitive coupling.

Surface-Mount Transformer

May be less than 0.2" square and is used for impedance matching, line coupling, and filtering. Two surface-mount transformers are shown in Figure 15-13.

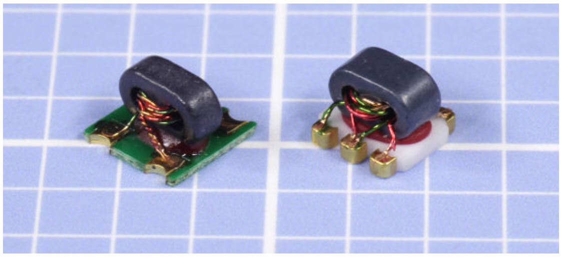

Figure 15-13. *Two surface-mount transformers, each measuring less than 0.2" square, typically used in communications equipment and suited for frequencies higher than 5 MHz.*

Values

When selecting a power transformer, its power handling capability is the value of primary interest. It is properly expressed by the term VA, derived from "volts times amps." VA should not be confused with watts because watts are measured instantaneously in a DC circuit, whereas in an AC circuit, voltage and current are fluctuating constantly. VA is actually the *apparent power*, taking reactance into account.

The relationship between VA and watts will vary depending on the device under consideration. In a worst-case scenario:

```
W = 0.65 VA (approximately)
```

In other words, the averaged power you can draw from a transformer should be no less than two-thirds of its VA value.

Transformer specifications often include input voltage, output voltage, and weight of the component, all of which are self-explanatory. Coupling transformers may also specify input and output impedances.

How to Use it

For most electronic circuits, a power transformer will be followed by a *rectifier* to convert AC to DC, and **capacitors** to smooth fluctuations in the supply. Using a prepackaged **power supply** or *AC adapter* that already contains all the necessary components will be more time-effective and probably more cost-effective than building a power supply from the ground up. See Chapter 16.

What Can Go Wrong

Reversal of Input and Output

Suppose a transformer is designed to provide an output voltage of 10 volts from domestic AC power of 115 volts. If the wrong side of the transformer is connected with 115VAC by mistake, the output will now be more than 1,000 volts—easily enough to cause death, quite apart from destroying components that are connected with it. Reversing the transformer in this way may also destroy it. Extreme caution is advisable when making connections with power transformers. A meter should be used to check output voltage. All devices containing transformers should be fused on the live side and grounded.

Shock Hazard from Common Ground

When working on equipment that uses an autotransformer, the chassis will be connected through the transformer to one side of 115VAC power. So long as a plug is used that prevents reversed polarity, the chassis should be "neutral." However, if an inappropriate power cord is used, or if the power outlet has been wired incorrectly, the chassis can become live. For protection, before working on any device that uses 115VAC power with an autotransformer, plug the device into an isolation transformer, and plug the isolation transformer into the wall outlet.

Accidental DC Input

If DC current is applied to the input side of a transformer, the relatively low resistance of the primary coil will allow high current that can destroy the component. Transformers should only be used with alternating current.

Overload

If a transformer is overloaded, heat will be generated that may be sufficient to destroy the thin layers of insulation between coil windings. Consequently, input voltage can appear unexpectedly on the output side. Transformers with a toroidal (circular) core are especially hazardous in this respect, as their primary and secondary windings usually overlap.

Some (not all) power transformers contain a thermal fuse that melts when it exceeds a temperature threshold. If the fuse is destroyed, the transformer must be discarded.

The consequences of moderate overloading may not be obvious, and can be cumulative over time. Ventilation or heat sinkage should be taken into account when designing equipment around a power transformer.

Incorrect AC Frequency

Single-phase AC power in the United States fluctuates at 60Hz, but Great Britain and some other countries use AC power at 50Hz. Many power transformers are rated to be compatible with either frequency, but if a transformer is specifically designed for 60Hz, it may eventually fail by overheating if it is used with a 50Hz supply. (A 50Hz transformer can be used safely with 60Hz AC.)

AC-DC power supply

16

Also known as an *AC adapter*. When packaged as a palm-sized plastic package that plugs directly into a power outlet, it is occasionally known colloquially as a *wall-wart*.

OTHER RELATED COMPONENTS

- **transformer** (See Chapter 15)
- **DC-DC converter** (See Chapter 17)
- **DC-AC inverter** (See Chapter 18)

What It Does

An AC-DC power supply converts *alternating current* (*AC*) into the *direct current* (*DC*) that most electronic devices require, usually at a lower voltage. Thus, despite its name, a power supply actually requires an external supply of power to operate.

Larger products, such as computers or stereo equipment, generally have a power supply contained within the device, enabling it to plug directly into a wall outlet. Smaller battery-powered devices, such as cellular phones or media players, generally use an external power supply in the form of a small plastic pod or box that plugs into a wall outlet and delivers DC via a wire terminating in a miniature connector. The external type of power supply is often, but not always, referred to as an *AC adapter*.

Although an AC-DC power supply is not a single component, it is often sold as a preassembled modular unit from component suppliers.

Variants

The two primary variants are a *linear regulated power supply* and *switching power supply*.

Linear Regulated Power Supply

A linear regulated power supply converts AC to DC in three stages:

1. A power **transformer** reduces the AC input to lower-voltage AC.
2. A *rectifier* converts the AC to unsmoothed DC. Rectifiers are discussed in the entry on **diodes** in this encyclopedia.
3. A **voltage regulator**, in conjunction with one or more **capacitors**, controls the DC voltage, smooths it, and removes *transients*. The regulator is properly known as a *linear voltage regulator* because it contains one or more **transistors**, which are functioning in linear mode—that is, responding linearly to fluctuations in base current, at less than their saturation level. The linear voltage regulator gives the linear regulated power supply its name.

A simplified schematic of a linear regulated power supply is shown in Figure 16-1.

This type of power supply may be described as *transformer-based*, since its first stage consists of a transformer to drop the AC input voltage before it is rectified.

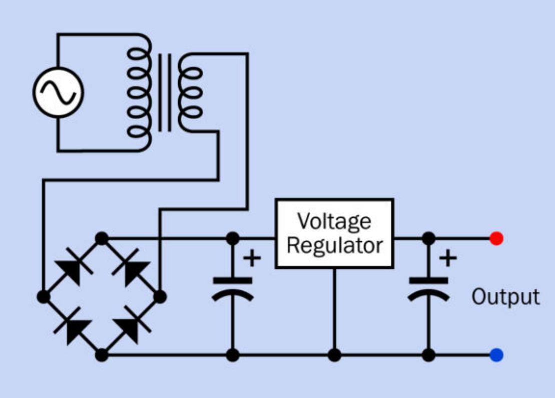

Figure 16-1. *A basic linear regulated power supply.*

Because the rectifier in a power supply generally passes each pulse of AC through a pair of silicon diodes, it will impose a voltage drop of about 1.2V at peak current. A smoothing capacitor will drop the voltage by about 3V as it removes ripple from the current, whereas a voltage regulator typically requires a difference of at least 2V between its input and its output. Bearing in mind also that the AC input voltage may fluctuate below its rated level, the output from the power transformer should be at least 8VAC higher than the ultimate desired DC output. This excess power will be dissipated as heat.

The basic principle of the linear regulated power supply originated in the early days of electronic devices such as radio receivers. A transistorized version of this type of power supply remained in widespread use through the 1990s. Switching power supplies then became an increasingly attractive option as the cost of semiconductors and their assembly decreased, and high-voltage transistors became available, allowing the circuit to run directly from rectified line voltage with no step-down power transformer required.

Some external AC adapters are still transformer-based, but are becoming a minority, easily identified by their relatively greater bulk and weight. An example is shown in Figure 16-2.

Figure 16-2. *A simple transformer-based power supply can be encapsulated in a plastic shell, ready to plug into a power outlet. However, today this format more typically contains a switching power supply, which is usually lighter, smaller, and cheaper.*

Figure 16-3 shows the handful of components inside a cheap, relatively old AC adapter. The output from a power transformer is connected directly to four diodes (the small black cylinders), which are wired as a full-wave rectifier. A single electrolytic capacitor provides some smoothing, but because there is no voltage regulator, the output will vary widely depending on the load. This type of AC adapter is not suitable for powering any sensitive electronic equipment.

Switching Power Supply

Also known as a *switched-mode power supply*, an *SMPS,* or *switcher*, it converts AC to DC in two stages.

1. A *rectifier* changes the AC input to unsmoothed DC, without a power transformer.
2. A DC-DC **converter** switches the DC on and off at a very high frequency using *pulse-width modulation* to reduce its average effective voltage. Often the converter will be the *flyback* type, containing a transformer, but the high-frequency switching allows the transformer to be much smaller than the power transformer required in a linear regulated power supply. See the DC-DC **converter** entry in this encyclopedia for an explanation of the working principles.

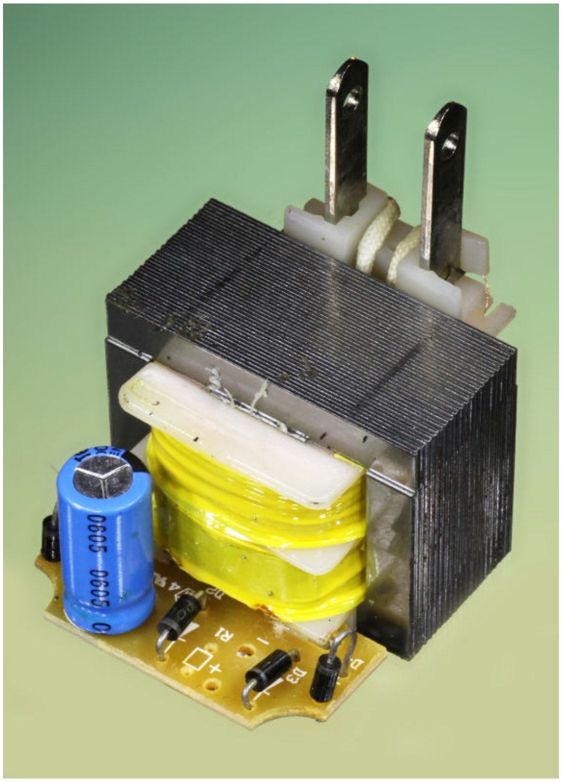

Figure 16-3. *A relatively old, cheap AC adapter contains only the most rudimentary set of components, and does not supply the kind of properly regulated DC power required by electronic equipment.*

A simplified schematic of a switching power supply is shown in Figure 16-4.

The interior of a relatively early switching power supply designed to deliver 12VDC at up to 4A is shown in Figure 16-5. This supply generated considerable waste heat, necessitating well-spaced components and a ventilated enclosure.

The type of small switching power supply that is now almost universally used to power laptop computers is shown in Figure 16-6. Note the smaller enclosure and the higher component count than in the older power supply shown in Figure 16-5. The modern unit also delivers considerably more power, and generates less waste heat. Although this example is rated at 5A, the transformer (hidden under the yellow wrapper at the center of the unit) is smaller than the power transformer that would have been found in an old-style AC adapter delivering just 500mA.

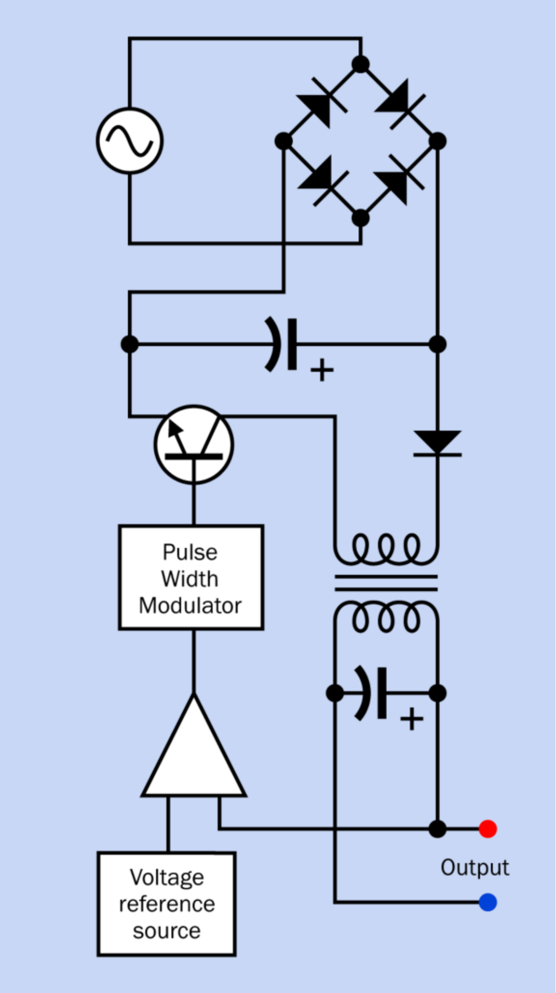

Figure 16-4. *Greatly simplified schematic showing the principal components of a switching power supply. Note the absence of a 115VAC power transformer. The transformer that is inserted subsequently in the circuit functions in conjunction with the high switching frequency, which allows it to be very much smaller, cheaper, and lighter.*

The modern power supply is completely sealed, where earlier versions required ventilation. On

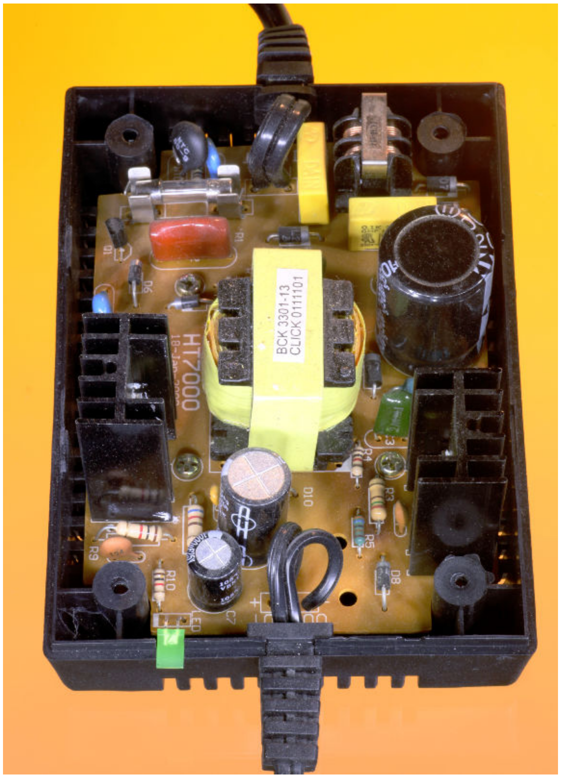

Figure 16-5. *The interior of an early switching power supply.*

the downside, the plastic case of the switching supply requires a metal liner (removed for this photograph) to contain high-frequency electromagnetic radiation.

Unregulated Power Supply

Typically this consists of a transformer and rectifying diodes with little or no smoothing or voltage control of the output.

Adjustable Power Supply

This is usually a linear power supply incorporating an adjustable **voltage regulator**. This type of supply has laboratory applications and is found as a benchtop item to power electronics design projects during their development.

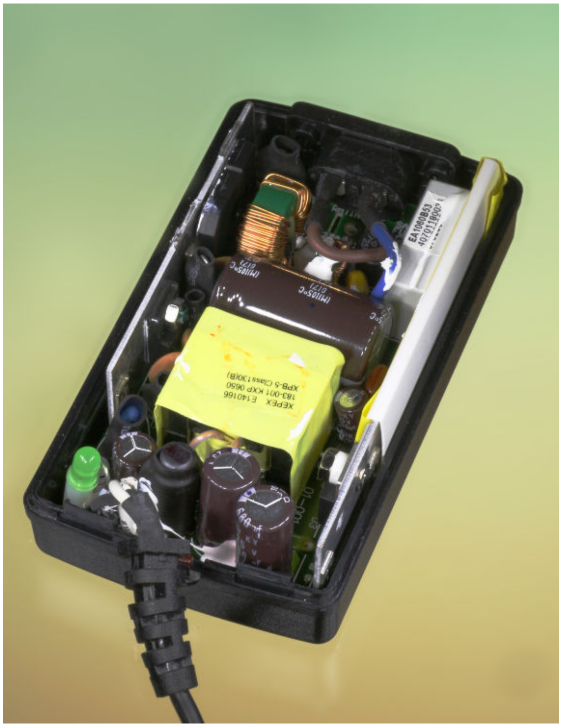

Figure 16-6. *The interior of the type of switching power supply that powers a laptop computer.*

Voltage Multiplier

Devices such as photocopiers and laser printers, televisions, cathode-ray tubes, and microwave ovens require voltages significantly higher than those supplied by domestic AC power outlets. A voltage multiplier usually contains a step-up transformer followed by DC conversion components, but detailed consideration is outside the scope of this encyclopedia.

Formats

An *open frame* power supply consists of components on a circuit board, usually mounted on a metal chassis, with no enclosure or fan cooling.

A *covered* power supply is enclosed in a protective perforated metal box with a cooling fan if needed. Power supplies sold for desktop computers are usually in this format.

Power supplies are also available in rack-mount and DIN-rail formats.

How to Use it

Because a switching power supply contains no power transformer, it is lighter and smaller, and may be cheaper than a linear power supply. It is also more efficient and generates less waste heat. These advantages have made switching power supplies the most popular option to provide DC power for electronics devices. However, the high-frequency switching tends to create *electromagnetic interference* (*EMI*), which must be filtered to protect the output of the device and also to minimize the risk of this interference feeding back into AC power wiring. The high-frequency switched power may also generate harmonics, which must be suppressed.

High-quality linear regulated power supplies still find application in laboratory equipment, low-noise signal processing, and other niches where excellent regulation and low-ripple output are necessary. They are relatively heavy, bulky, and inefficient.

See Figure 16-7 for a chart comparing the advantages and disadvantages of linear and switching power supplies.

What Can Go Wrong

High Voltage Shock

One or more capacitors in a power supply may retain a relatively high voltage for some time after the unit has been unplugged. If the power supply is opened for inspection or repairs, caution is necessary when touching components.

Capacitor Failure

If *electrolytic capacitors* fail in a switching power supply (as a result of manufacturing defects, disuse, or age), allowing straight-through conduction of alternating current, the high-frequency switching semiconductor can also fail, allowing input voltage to be coupled unexpectedly to the output. Capacitor failure is also a potential problem in linear power supplies. For additional information on capacitor failure modes, see Chapter 12.

	Switching power supply	Linear power supply
Component count	High	Medium
Load regulation	0.05% to 0.5%	0.005% to 0.2%
Line regulation	0.05% to 0.2%	0.005% to 0.05%
Ripple (RMS)	10mV to 25mV	0.25mV to 1.5mV
Efficiency	70% to 85%	40% to 60%
EMI	High	Very low
Leakage	High	Low
Physical size	Small	Large
Weight	Light	Heavy
Heat management	Usually fan-cooled	Usually cooled by convection

Figure 16-7. *Comparison of attributes of linear regulated power supplies and switching power supplies. (Adapted from Acopian Technical Company.)*

Electrical Noise

If *electrolytic capacitors* are used, their gradual deterioration over time will permit more electrical noise associated with high-frequency switching in a switching power supply.

Peak Inrush

A switching power supply allows an initial inrush or surge of current as its capacitors accumulate their charge. This can affect other components in the circuit, and requires fusing that tolerates brief but large deviations from normal power consumption.

DC-DC converter

17

Often referred to as a *switching regulator*, and sometimes as a *switcher*, not to be confused with a *switching power supply*.

OTHER RELATED COMPONENTS

- **AC-DC power supply** (See Chapter 16)
- **voltage regulator** (See Chapter 19)
- **DC-AC inverter** (See Chapter 18)

What It Does

A DC-DC converter, often referred to simply as a *converter*, receives a DC voltage as its input and converts it to a regulated DC voltage as its output. The output voltage may be higher or lower than the input voltage, may be user-adjustable by adding an external resistor, and may be completely electrically isolated from the input, depending on the type of converter that is used. The overall efficiency is not greatly affected by the difference between input and output voltage, and can exceed 90%, minimizing waste heat and enabling the unit to be extremely compact.

A DC-DC converter is an integrated circuit package that includes a high-speed switching device (almost always, a *MOSFET*) in conjunction with an oscillator circuit, an inductor, and a diode. By comparison, a **linear regulator** is usually based around bipolar transistors. Its input must always be at a higher voltage than its output, and its efficiency will be inversely proportional with the voltage drop that it imposes. See the **voltage regulator** entry in this encyclopedia for additional information.

There is no single symbol to represent a DC-DC converter. Some simplified schematics showing the principles of operation of commonly used converters are referenced under the following Variants section.

A DC-DC converter is also typically found in the output stage of a switching **AC-DC power supply**.

How It Works

An internal oscillator controls a *MOSFET* semiconductor that switches the DC input on and off at a high frequency, usually from 50KHz to 1MHz. Output voltage is adjusted by varying the *duty cycle* of the oscillator—the length of each "on" pulse relative to each "off" interval. This is known as *pulse-width modulation*, or *PWM*. The duty cycle is controlled by sampling the output of the converter and using a comparator to subtract the output voltage from a reference voltage, to establish an error value. This is passed to another comparator, which subtracts the error voltage from an oscillator ramp signal. If the error increases, the oscillator signal is more heavily clipped, thus changing the effective ratio of on/off pulse lengths. A simplified schematic of the PWM circuit is shown in Figure 17-1, which omits other components for clarity. The system of subtracting an error voltage from a ramp oscillator voltage to obtain a pulse-width modulated signal is illustrated in Figure 17-2.

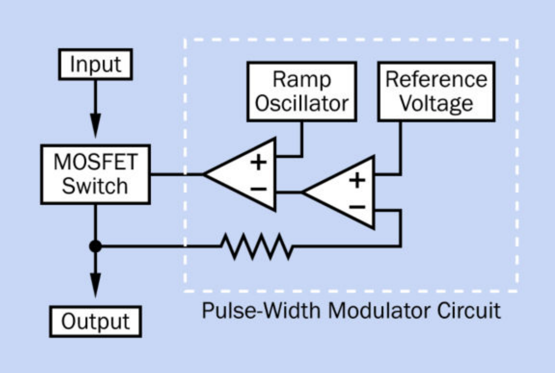

Figure 17-1. *The heart of a DC-DC converter is a MOSFET switch, which operates at a high frequency with pulse-width modulation used to create an adjustable DC output.*

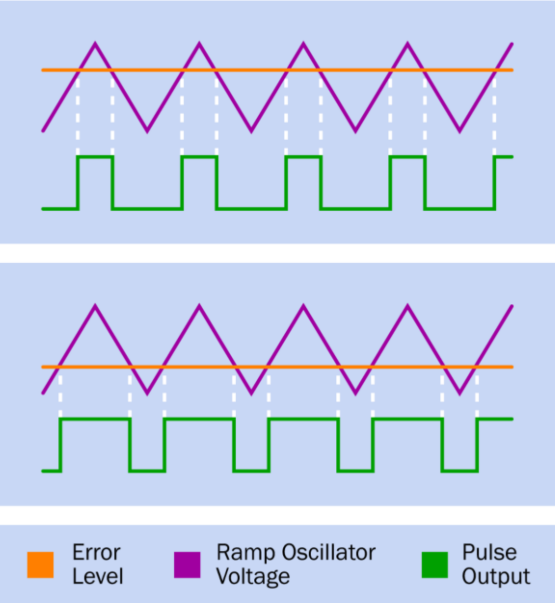

Figure 17-2. *To achieve pulse-width modulation, an error-level voltage is established by comparing the output from the converter with a reference voltage. The error level, shown as an orange line, is then subtracted from the output from a ramp oscillator. The pulse width varies accordingly.*

The key to the efficiency of a DC-DC converter is an inductor, which stores energy in its magnetic field during "on" pulse and releases it in the discharge phase. Thus, the inductor is used as a temporary reservoir and minimizes the ripple current. All converter variants use a coil for this purpose, although its placement varies in relation to the diode and capacitor that complete the basic circuit.

Variants

Four basic switching circuits are used in DC-DC converters and are defined in the coming sections, with a formula to determine the ratio between input voltage (V_{in}) and output voltage (V_{out}) in each case. In these formulae, variable D is the duty cycle in the pulse train generated through an internal MOSFET switch. The duty cycle is the fraction of the total on-off cycle that is occupied by each "on" pulse. In other words, if T_{on} is the duration of an "on" pulse and T_{off} is the "off" time:

$$D = T_{on} / (T_{on} + T_{off})$$

Buck Converter

See Figure 17-3. The output voltage is lower than the input voltage. The input and output share a common ground. For this circuit:

$$V_{out} = V_{in} * D$$

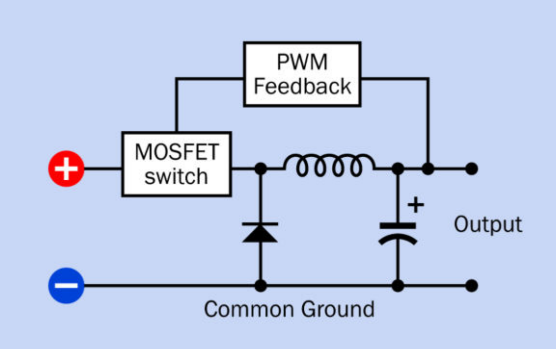

Figure 17-3. *Basic topology of a buck-type DC-DC converter.*

Boost Converter

See Figure 17-4. The output voltage is greater than the input voltage. The input and output share a common ground. For this circuit:

$$V_{out} = V_{in} / (1-D)$$

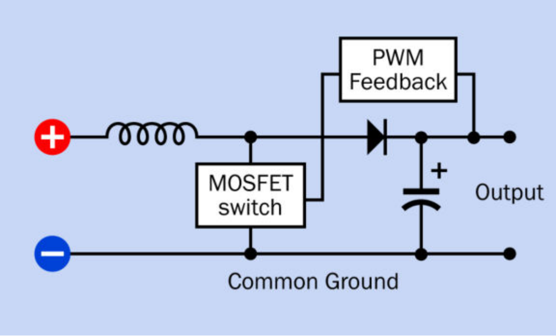

Figure 17-4. *Basic topology of a boost-type DC-DC converter.*

Flyback Converter with Inductor

Commonly known as a *buck-boost converter*. See Figure 17-5. The output voltage can be less than or greater than the input voltage. The input and output share a common ground. For this circuit:

$$V_{out} = V_{in} * (D / (1-D))$$

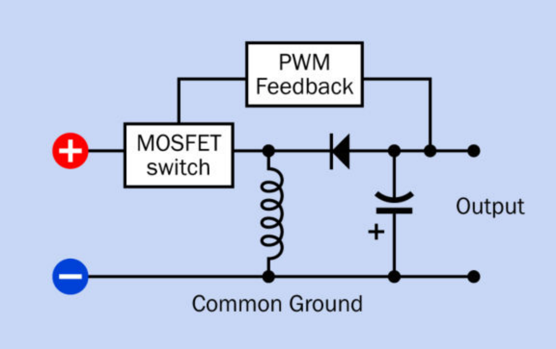

Figure 17-5. *Basic topology of a flyback-type DC-DC converter.*

Flyback Converter with Transformer

See Figure 17-6. The output voltage can be less than or greater than the input voltage. The input and output are isolated from one another. For this circuit:

$$V_{out} = V_{in} * (D / (1-D))$$

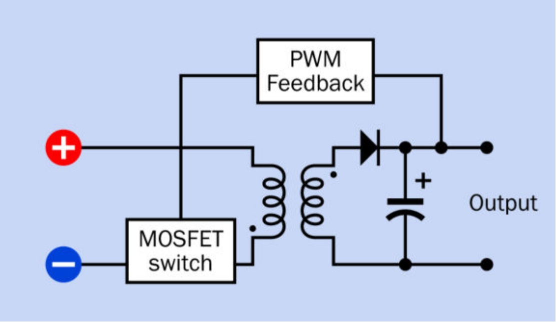

Figure 17-6. *Basic topology of a flyback-type DC-DC converter. (Buck, boost, and flyback topologies adapted from Maxim Integrated Products.)*

Using a transformer in the converter allows multiple outputs with different voltages, supplied through multiple transformer windings.

Formats

A converter may be packaged in a flat rectangular box that requires no additional heat sink and has pins for through-hole insertion into a PC board. Sizes usually range up to to 2″ × 2″. Power handling can range from 5 to 30 watts. Converters of this type are shown in Figure 17-7. (Top: Input range of 9 to 18VDC, fixed output of 5VDC at 3A completely isolated from the input. Typical efficiency of approximately 80%. The case is made of copper, providing good heat dissipation with electrical shielding. Center: Input range of 9 to 18VDC, fixed output of 5VDC at 500mA completely isolated from the input. Typical efficiency of approximately 75%. The manufacturer claims that external capacitors are only needed in critical applications. Bottom: SIP format, fixed input of 12VDC, fixed output of 5VDC at 600mA completely isolated from the input. Typical efficiency of approximately 75%. Requires external capacitors for ripple rejection.)

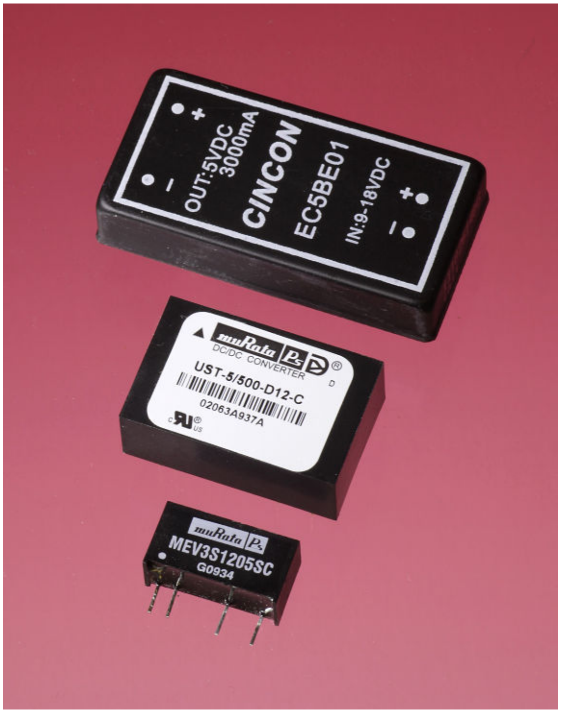

Figure 17-7. *A selection of sealed DC-DC converters.*

Lower-power converters are also available as surface-mount devices.

Some adjustable-output converters are supplied as multiple surface-mounted components preinstalled on a mini-board that has pins for through-hole insertion in a printed circuit board. Their high efficiency enables them to handle a lot of power for their size. In Figure 17-8, the converter accepts a 4.5 to 14VDC input range and has an adjustable output of 0.6 to 6VDC. It is rated at a surprising 10A or 50W and is more than 90% efficient. However, it draws 80mA in a no-load state, causing it to become quite hot. A thermal cutout or automatic shutdown may be used if the converter will not be driving a consistent load.

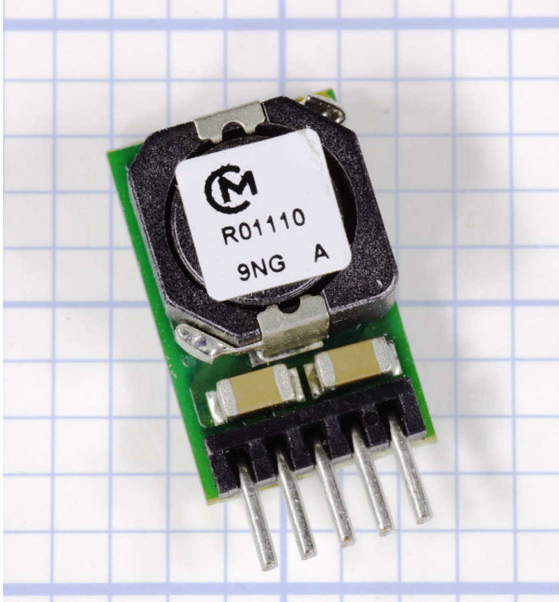

Figure 17-8. *An adjustable DC-DC converter rated for 10A or 50W. The output voltage is determined by adding an external resistor or trimmer potentiometer. External smoothing capacitors are required, as shown in the component's datasheet.*

The miniboard in Figure 17-9 accepts an input voltage from 7 to 36VDC and has an adjustable output ranging from 2.5 to 12.6VDC, at up to 6A. It is non-isolated (has a common negative bus) and claims to be more than 95% efficient at full load.

The miniboard in Figure 17-10 accepts an input voltage from 4.5 to 14VDC and has an adjustable output ranging from 0.6 to 6VDC at up to 20A. It is non-isolated (has a common negative bus) and claims to be more than 90% efficient at full load.

Values

Relevant values include:

Nominal Input Voltage and Frequency

A wide range of input voltages is often acceptable, as the PWM can vary accordingly. Converters

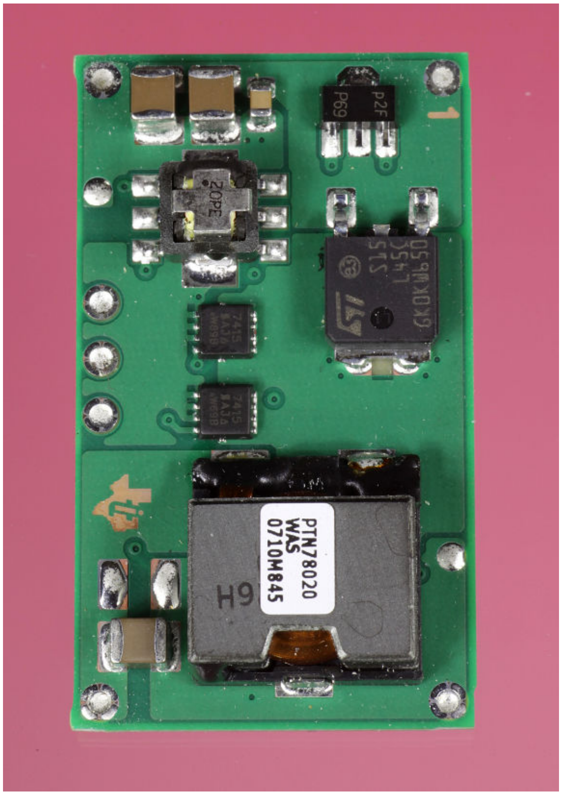

Figure 17-9. *Another adjustable DC-DC converter. The output voltage is determined by adding an external resistor or trimmer potentiometer. External smoothing capacitors are required, as shown in the component's datasheet.*

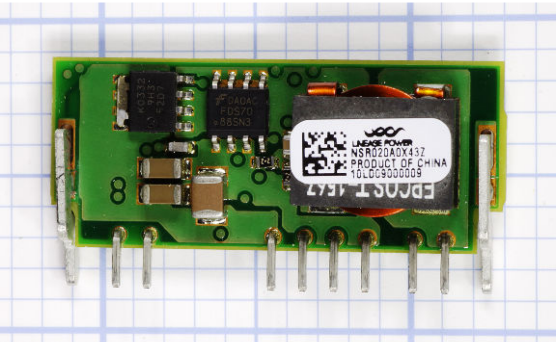

Figure 17-10. *Another adjustable DC-DC converter. The output voltage is determined by adding an external resistor or trimmer potentiometer. External smoothing capacitors are required, as shown in the component's datasheet.*

often allow equipment to be usable internationally, on any voltage ranging from 100VAC to 250VAC, at a fequency of 50Hz or 60Hz, without any adaptation.

Output Voltage

As previously noted, many converters allow the output voltage to be adjusted by adding an external resistor or potentiometer. Alternatively, there may be multiple fixed output voltages, accessible via different pins on the package. They may also provide a positive voltage and equally opposite negative voltage relative to a ground pin.

Input Current and Output Current

Because input voltage and output voltage are likely to be different, the current alone is not a reliable guide to power handling.

A datasheet should specify input current with no load (open circuit on the output side). This current will have to be entirely dissipated as heat.

Load Regulation

This is usually expressed as a percentage and suggests the extent to which output voltage may be pulled down when the load on a DC-DC converter increases. If V_{nil} is the measured output voltage with no load, and V_{max} is the measured output voltage with the maximum rated load:

$$\text{Load regulation} = 100 * (V_{nil} - V_{max})/V_{max}$$

However, note that some converters are designed with the expectation that they will never be used with zero load across the output. In these cases, V_{nil} will be the voltage at minimum rated load.

Efficiency

This is a measure of how much input current must be dissipated as heat. A converter with a 12-volt input, drawing a maximum 300mA input current, will consume 3.6 watts (3,600mW). If it is 80% efficient, it will have to dissipate roughly 20% of its power as heat, or 720mW.

Ripple and Noise

Sometimes abbreviated R/N, this may be measured in mV or as a percentage. Check the specification carefully to determine whether the ripple-and-noise values require use of external smoothing capacitors. Often, this is the case.

Isolated or Non-Isolated

This crucial piece of information is often found near the top of a datasheet, not in the detailed specifications.

How to Use it

Because a converter creates electrical noise, it should be prevented from affecting other components by adding substantial *bypass capacitors* as close as possible to its input and output pins. For most converters, external capacitors are mandatory, and their *effective series resistance* (ESR) should be as low as possible (see the **capacitor** entry in this encyclopedia for an explanation of ESR). Tantalum capacitors are preferable to electrolytics for this reason, and are also more durable. Some manufacturers recommend placing a tantalum capacitor in parallel with an electrolytic. A small ceramic capacitor, typically 0.1µF, is often recommended in an addition to larger-value capacitors on the output side.

The voltage rating of each capacitor should be twice the voltage at the point in the circuit where it is used. The capacitance value will usually be higher for higher-current converters. Values of 100µF are common, but for high amperage, a value may be as high as 1,000µF.

While datasheets are often inadequate for some types of components, datasheets for DC-DC converters usually include detailed instructions regarding bypass capacitors. Following these instructions is essential. In the relatively rare instances that a datasheet makes no mention of bypass capacitors for a converter, this does not necessarily mean that the capacitors are unnecessary. The manufacturer may assume that they will be used as a matter of course.

Converters are used in a very wide range of devices, supplying power ranging from a few milliamps to tens of amps. At the lower end of the scale, devices such as cellular telephones, portable computers, and tablets contain subcircuits that require different voltages, some of which may be higher than the voltage of a single battery or battery pack that powers the device. A converter can satisfy this requirement. Because a converter can be designed to maintain a fixed output in response to a range of input voltages, it can also compensate for the gradual decline in voltage that occurs during battery usage.

A boost-type converter can be used to double the voltage from a single 1.5V battery in an LED flashlight where 3 volts are required to power the LED. Similarly, a boost-type converter can provide the necessary voltage to run a cold-cathode fluorescent tube that provides backlighting in an LCD computer display.

On a circuit board that is primarily populated with 5VDC components and is fed by a single 5VDC power supply, a converter can be used to supply 12VDC for one special purpose, such as an analog-digital converter or a serial data connection.

If electromechanical **relays** or other inductive loads share a common ground with components ,such as *logic chips* or **microcontrollers**, it may be difficult to protect the sensitive components from voltage spikes. A A flyback converter with a transformer separating the output from the input can allow the "noisy" section of the circuit to be segregated, so long as the converter itself does not introduce noise. Since the electromagnetic interference (EMI) introduced by converters varies widely from one model to another, specifications should be checked carefully.

Very low-power components can pick up EMI from the wires or traces leading into and out of a converter. In this type of circuit, adequate noise suppression may be impossible, and a converter may not be appropriate.

What Can Go Wrong

Electrical Noise in Output

Electrolytic capacitors may be inadequate to smooth the high frequencies used. Multilayer ceramic capacitors or tantalum capacitors may be necessary. Check the manufacturer's datasheet for minimum and maximum values. Also check the datasheet for advice regarding placement of capacitors on the input side as well as across the output.

Excess Heat with No Load

Some converters generate substantial heat while they are powered without a load. The manufacturer's datasheet may not discuss this potential problem very prominently or in any detail. Check the input rating, usually expressed in mA, specified for a no-load condition. All of this current will have to be dissipated as heat, and the very small size of many converters can result in high localized temperatures, especially since many of them allow no provision for a heat sink.

Inaccurate Voltage Output with Low Load

Some converters are designed to operate with at least 10% of full rated load across their output at all times. Below this threshold, output voltage can be grossly inaccurate. Read datasheets carefully for statements such as this: "Lower than 10% loading will result in an increase in output voltage, which may rise to typically double the specified output voltage if the output load falls to less than 5%." Always use a meter to verify the output voltage from a converter at a variety of different loads, and perform this test before installing the converter in a circuit.

DC-AC inverter

18

A power inverter must not be confused with a *logic inverter*, which functions as a digital component in *logic circuits* to invert the state of a low-voltage DC input from high to low or low to high. Logic inverters are discussed in Volume 2.

OTHER RELATED COMPONENTS

- **AC-DC power supply** (See Chapter 16)
- **DC-DC converter** (See Chapter 17)

What It Does

A power inverter is included here as counterpoint to a **power supply** or *AC adapter*, since it has the opposite function. The inverter receives an input of *direct current* (typically 12VDC from a car battery) and delivers an output of *alternating current* (AC) in the range 110VAC-120VAC or 220VAC-240VAC, suitable to power many low-wattage appliances and devices. The interior of a low-cost inverter is shown in Figure 18-1.

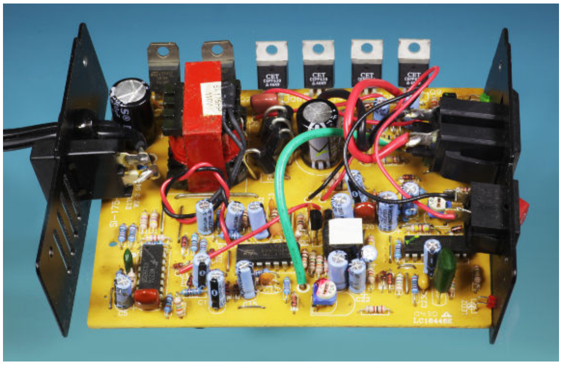

Figure 18-1. *The interior components in a 175-watt inverter.*

How It Works

The first stage of an inverter typically raises a 12VDC input to a higher DC voltage via an internal **DC-DC converter**, then uses a switching circuit to create an approximation of the sinusoidal profile that is characteristic of AC voltage.

Digital switching components naturally tend to create square waves, whose simple appearance conceals the presence of higher frequencies, or *harmonics*, that are ignored by some devices (especially those that convert electricity into heat) but can be troublesome in consumer electronics equipment. A primary objective of inverter design is to adapt or combine square waves to emulate a classic AC sine wave with reasonable fidelity. Generally speaking, the more accurately an inverter emulates a sine wave, the more expensive it tends to be.

The most primitive inverter would create a plain square wave such as that shown in red in Figure 18-2, superimposed on a comparable sine wave (in green). Note that alternating current rated at 115 volts actually peaks at around 163 volts because the number 115 is the approximate *root mean square* (*RMS*) of all the voltage values during a single positive cycle. In other words, if the voltage is sampled x times during a cycle, an

RMS value can be derived by squaring each sample, adding all the samples, dividing by x, and then taking the square root of the result. The RMS value is important as a means to calculate actual power delivered because it can be multiplied by the current to obtain an approximate value in watts.

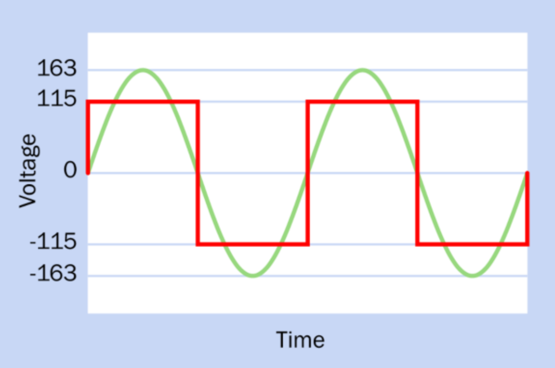

Figure 18-2. *Comparison of an AC voltage sine wave (green) and a square wave of the same frequency (red), both delivering a roughly similar amount of power.*

Variants

As a first step toward a better approximation of a sine wave, gaps of zero voltage can be inserted between square-wave pulses. This "gapped" square wave is shown in Figure 18-3.

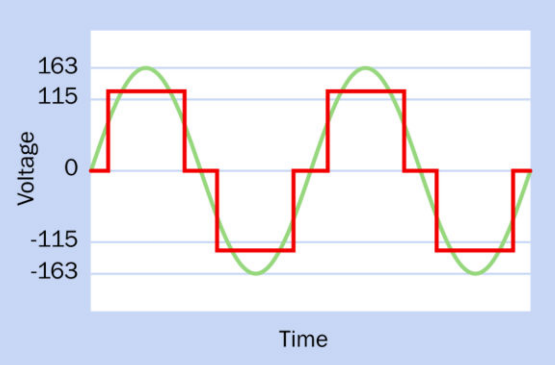

Figure 18-3. *Introducing pauses or gaps of zero voltage between square-wave pulses can produce slightly improved resemblance to a sine wave.*

A further improvement can be achieved if an additional, shorter pulse of higher voltage is added to each primary pulse, as shown in Figure 18-4. Outputs of this kind are referred to as *modified sine wave*, although they are actually square waves modified to emulate a sine wave. Their inaccuracy is expressed as *total harmonic distortion* (*THD*). Some authorities estimate that the THD of gapped square-wave output is around 25%, whereas the addition of shorter square waves reduces this to around 6.5%. This is a topic on which few people agree, but there is no doubt that a "stacked" sequence of square waves provides a closer emulation of a sine wave.

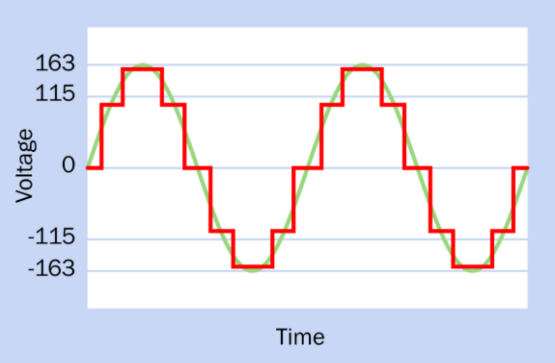

Figure 18-4. *A secondary stream of narrower square-wave pulses can improve the fidelity of an inverter's output.*

A *true sinewave inverter* typically uses *pulse-width modulation* (*PWM*) to achieve THD of less than 1%. It generates a stream of pulses much higher in frequency than that of the AC output, and varies their widths in such a way that their averaged voltage closely approximates the voltage variations in a sine wave. A simplified representation of this principle is shown in Figure 18-5.

Values

Small inverters are typically rated to deliver up to 100 watts and may be fitted with a 12VDC plug for insertion in a vehicle's cigarette lighter. Since a cheap inverter may be only 80% efficient, 100 watts at 135VAC will entail drawing as much as

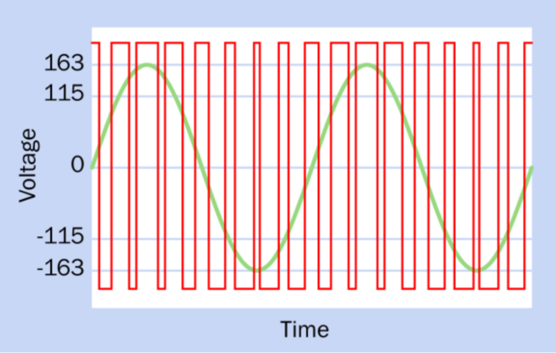

Figure 18-5. *Pulse-width modulation adjusts the widths of pulses delivered at a high frequency. The pulse widths can be averaged to generate voltage that follows a close approximation of a sine wave.*

10 amps at 12VDC. Cigarette lighters are usually fused at 15 or 20 amps, so 100 watts is a reasonable value. Inverters that are rated above 150 watts usually have cables terminating in oversize alligator clips for direct connection to the terminals of a 12V battery.

While the *cold cranking* rating of a car battery may be 100 amps or more, the battery is only designed to deliver that power for up to 30 seconds at a time. Inverters rated for as much as 500 watts will exceed the normal capacity of a single car battery, although if the battery is mounted in a vehicle, it can be supplemented by running the engine so that the alternator shares some of the load. A 500-watt inverter is better supplied by two or more 12-volt car batteries wired in parallel.

How to Use it

Small inverters are typically used in vehicles to run cellphone chargers, music players, or laptop computers. Large inverters are an integral part of off-the-grid solar and wind-powered systems, where battery power must be converted to AC house current. Uninterruptible power supplies contain batteries and inverters capable of running computer equipment for a brief period. Battery-driven electric vehicles with AC motors use inverters with an exceptionally high current rating.

There is a lack of consensus regarding possible harmful effects of powering electronics equipment with a low-cost modified sine wave inverter. Anecdotal evidence suggests that where the equipment uses its own *switching power supply* or uses an *AC adapter* (either mounted internally or as an external plug-in package), the filtering built into the power supply will block harmonics from the inverter.

Other evidence suggests that cheap inverters may have adverse effects on devices containing synchronous motors that run direct from AC. There are reports that fluorescent lighting and photographic electronic flash systems may be unsuitable for use even with modified sine wave inverters. However, differences in product design and component quality make it impossible to generalize. A cheaply made inverter may generate a wave form that is not even a close approximation of a square wave. See Figure 18-6.

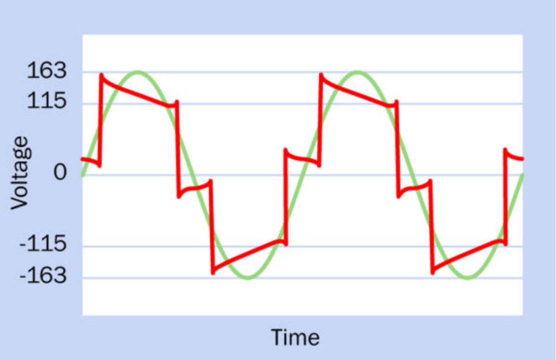

Figure 18-6. *A cheaply made inverter can generate a distorted wave form that is even higher in noise than a pure square wave. This sample is adapted from an actual oscilloscope trace.*

What Can Go Wrong

If multiple batteries are connected in parallel, using suitably heavy-gauge wire to power a large inverter, the batteries must be identical in specification and age, and must all be equally charged to prevent high and potentially dangerous flows of current among the batteries as they attempt to reach an equilibrium among themselves. Interconnections must be firmly clamped to clean battery terminals. For additional information, see the **battery** entry in this encyclopedia.

Problems associated with inverters are likely to be mundane. A 12V wiring to the inverter can overheat if items such as clothes or bedding are left on top of it; a high-wattage fan-cooled inverter can overheat if the fan is obstructed by poor placement or impaired by accumulated dirt; alligator clips may become dislodged from battery terminals; and power surges drawn by inductive loads such as motors may trigger the inverter's *breaker*, especially if they are used in conjunction with other equipment.

As always, high amperage should be treated with caution and respect, regardless of it being delivered at "only 12 volts."

voltage regulator

19

Correctly known as a *linear voltage regulator* to distinguish it from a *switching regulator* or **DC-DC converter**. However, the full term is not generally used, and "voltage regulator" is normally understood to mean a linear voltage regulator.

OTHER RELATED COMPONENTS

- **DC-DC converter** (See Chapter 17)
- **AC-DC power supply** (See Chapter 16)

What It Does

A linear voltage regulator provides a tightly controlled DC output, which it derives from an unregulated or poorly regulated DC input. The DC output remains constant regardless of the load on the regulator (within specified limits). It is a cheap, simple, and extremely robust component.

There is no single schematic symbol for a linear voltage regulator.

The general physical appearance of a commonly used type of regulator, rated for an output of around 1A DC, is shown at Figure 19-1. The LM7805, LM7806, LM7812, and similar regulators in the LM78xx series are encapsulated in this type of package, with pins that are spaced at 0.1" and have functions as shown. Other types of regulator may differ in appearance, or may look identical to this one but have different pin functions. Always check datasheets to be sure.

How It Works

All linear regulators function by taking some feedback from the output, deriving an error value by comparing the output with a reference voltage (most simply provided by a zener diode), and using the error value to control the base of a *pass transistor* that is placed between the input and the output of the regulator. Because the transistor operates below saturation level, its output current varies linearly with the current applied to its base, and this behavior gives the linear regulator is name. Figure 19-2 shows the relationship of these functions in simplified form; Figure 19-3 shows a little more detail, with a *Darlington pair* being used as the pass transistor. The base of the pair is controlled by two other transistors and a comparator that delivers the error voltage. This version of a voltage regulator is known as the *standard type*.

The voltage difference required between the base and emitter of an NPN transistor is a minimum of 0.6V. Because multiple transistors are used inside a standard-type voltage regulator, it requires a minimum total voltage difference, between its input and its output, of 2VDC. This voltage difference is known as the *dropout voltage*. If the voltage difference falls below this minimum, the regulator ceases to deliver a reliable output voltage until the input voltage rises again. *Low dropout regulators* allow a lower voltage difference, but are more expensive and less commonly used. They are described under the following Variants section.

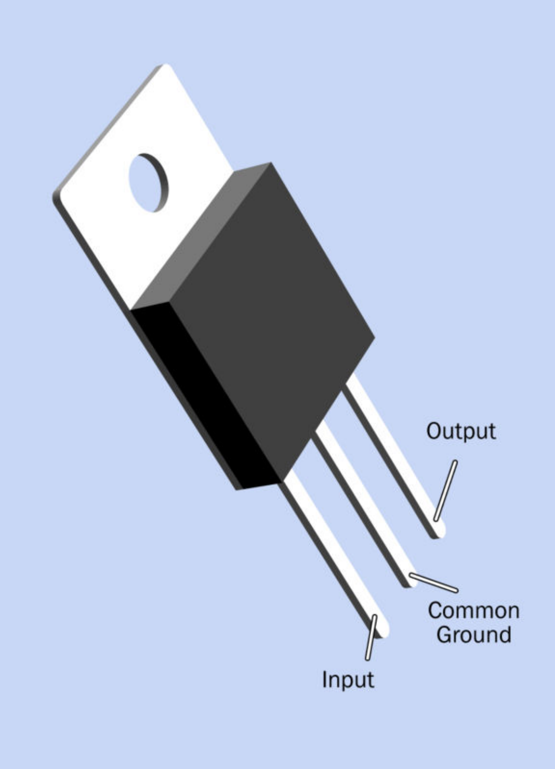

Figure 19-1. *The package design of a commonly used voltage regulator. Others may be significantly different, and the pin functions may vary. Check manufacturer datasheets for details.*

Discrete components could in theory be used to build a voltage regulator, but this ceased to be cost-effective several decades ago. The term is now understood to mean one small integrated package containing the basic circuit augmented with additional, desirable features, such as automatic protection against overload and excessive heat. Instead of burning out if it is overloaded, the component simply shuts down. Most voltage regulators also tolerate accidentally reversed power connection (as when batteries are inserted the wrong way around) and accidentally reversed insertion of the regulator in a circuit board.

Other components can satisfy the requirement to deliver power at a reduced voltage. Most simply, if two resistors in series are placed across a

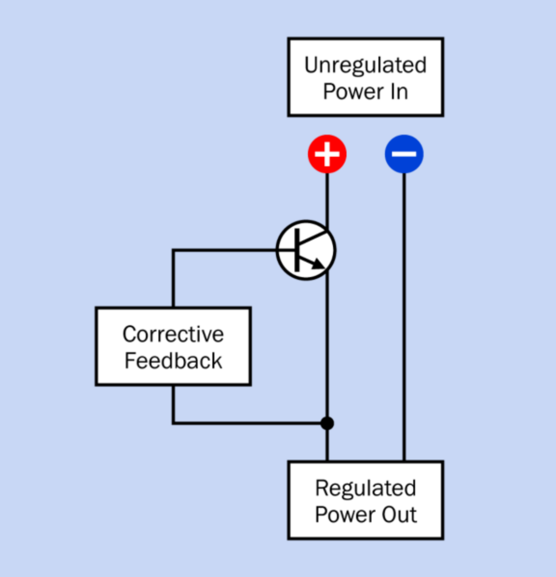

Figure 19-2. *A linear voltage regulator basically consists of a transistor whose base is controlled by corrective feedback derived from the output.*

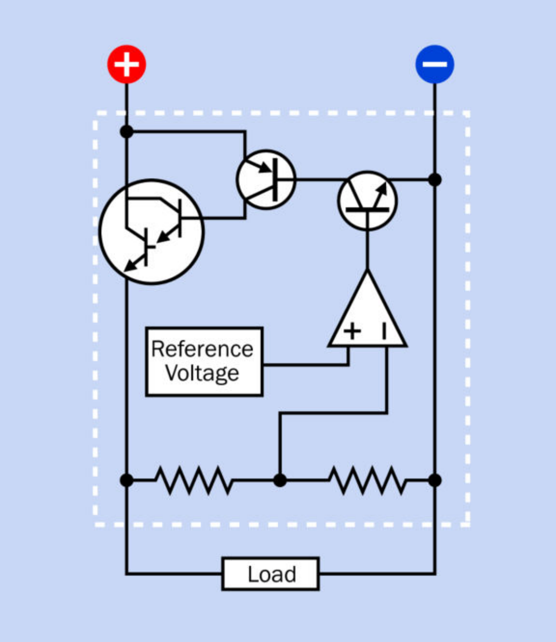

Figure 19-3. *The fundamental internal features of a standard-type voltage regulator, including a Darlington pair, two transistors, a voltage divider, comparator, and reference voltage source, shown inside the dashed white line.*

power source, they form a *voltage divider*, which provides an intermediate voltage at the connection between them. However, this voltage will vary depending on fluctuations in the input voltage and/or load impedance. A voltage regulator is the simplest way to supply a voltage that remains stable regardless of excursions in the input or fluctuations in power consumed by the load.

The disadvantage of a standard-type voltage regulator is that it is inefficient, especially when a relatively high input voltage is used to deliver a relatively low output voltage. If V_{in} is the input voltage, V_{out} is the output voltage, and I_{out} is the output current, the average power loss, P, is given by the formula:

$$P = I_{out} * (V_{in} - V_{out})$$

For example, if the output current is 1A, the input voltage is 9VDC, and the output is 5VDC, 44% of the input power will be wasted, and the component will be only 56% efficient. The wasted power (about 4 watts, in this case) will be dissipated as heat. Even when a standard-type regulator runs at its minimum 2VDC dropout voltage, it must dissipate 1W when delivering 0.5A.

Variants

Packaging

The package for the LM78xx series of regulators, shown in Figure 19-1, incorporates an aluminum plate drilled with a hole so that it can be bolted to a heat sink. Voltage regulators with a lower rated maximum output current (typically, 100mA) do not have the same need for a heat sink, and are available in a package that resembles a small transistor.

Some integrated circuits are available containing two voltage regulators, electrically isolated from each other.

Popular Varieties

In the LM78xx series, the last two digits in the part number specify the output voltage, which is fixed. Thus the LM7805 delivers 5VDC, the LM7806 delivers 6VDC, and so on. For regulators with a fractional voltage output (3.3VDC being common), an additional letter may be inserted in the part number, as in the 78M33.

Many copies of the LM78xx series are made by different manufacturers, the copies being functionally identical, regardless of additional letters that are added to the part number to identify its source or other attributes.

The LM78xx regulators are mostly rated to be accurate within 4%, although actual samples almost always deliver voltages that are more precise than this range suggests.

Adjustable Regulators

While the majority of regulators have a fixed output, some allow the user to set the output by adding one or more resistors. The LM317 is a popular example. Its output voltage can range from 1.25VDC to 37VDC and is set via a resistor and a trimmer potentiometer, as illustrated in Figure 19-4. If R1 is the fixed-value resistor and R2 is the trimmer, as shown in the schematic, the output voltage, V_{out}, is given by the formula

$$V_{out} = 1.25 * (1 + (R2 / R1))$$

Typical values for R1 and R2 would be 240Ω and 5K, respectively. With the trimmer at the middle of its range, V_{out} would be 1.25 * (1 + (2500 / 240)) = approximately 15VDC, requiring an input of at least 17VDC. However, if the trimmer is reduced to 720Ω, the output would be 5VDC. In practice, the value of a trimmer should be chosen so that a mid-range setting provides approximately the desired output. This will enable fine adjustment of the output voltage.

While the versatility of an adjustable regulator is desirable, its overall power dissipation is still proportional to the difference between the input voltage and the output voltage. To minimize heat loss, this difference should not exceed the dropout voltage by a larger amount than is absolutely necessary.

An adjustable regulator may require larger bypass capacitors than a regulator with a fixed output. A manufacturer's recommendations for the LM317 are shown in Figure 19-4.

Negative and Positive Regulators

While most linear voltage regulators are designed for "positive input" (conventional current flow from input to output), some are intended for "negative input." In this variant, the common terminal is positive, and the input and output are negative in relation to it.

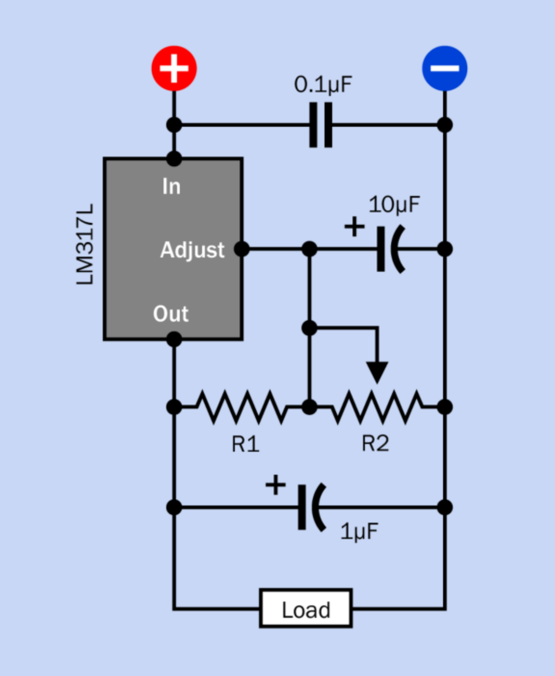

Figure 19-4. *Schematic for the LM317L adjustable voltage regulator, based on a circuit recommended by National Semiconductor, with bypass capacitors added for ripple rejection.*

Low-Dropout Linear Regulators

Low-dropout regulators (sometimes referred to as *LDO* regulators) allow a much lower dropout voltage by using a single PNP or MOSFET transistor. LDO regulators are popularly used in battery-powered devices where efficiency should be maximized and heat dissipation should be minimized. For example, the LM330 is a regulator with a 5VDC output, tolerating a dropout voltage of 0.6V, allowing it to be used with four AAA cells. In an LDO regulator the dropout voltage actually varies with load current and may diminish to as little as one-tenth of its rated value when the output current is minimal.

The majority of low-dropout regulators are sold in surface-mount packages, and are designed for maximum output of 100mA to 500mA. Only a few exceptions exist. They tend to be slightly more expensive than regulators with the typical 2V dropout rating.

Three voltage regulators are shown in Figure 19-5. From left to right, they are rated 5VDC at 1A, 12VDC at 1A, and 5VDC at 7.5A. The two smaller regulators are of the LM78xx series. The larger regulator claims a low maximum dropout voltage of 1.5VDC, and its output voltage can be adjusted with an external potentiometer and resistor.

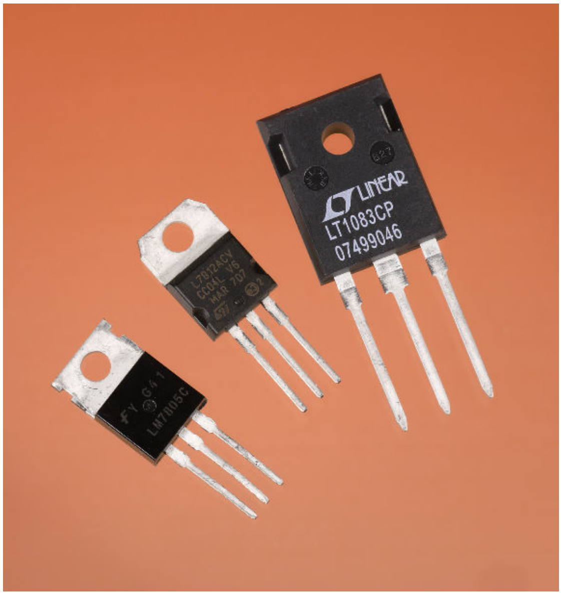

Figure 19-5. *Two voltage regulators from the LM78xx series, and a third high-current, low-dropout, adjustable regulator rated 5VDC (adjustable upward) at 7.5A.*

Quasi-Low-Dropout Linear Regulators

Where a standard regulator uses a Darlington pair as the pass transistor and an LDO uses a single PNP transistor, the so-called Quasi-LDO uses a combination of NPN and PNP transistors and has an intermediate dropout voltage, typically a maximum of 1.5VDC. However, the terms LDO and Quasi-LDO are not used uniformly in the industry. One manufacturer markets Quasi-LDO regulators as LDO regulators, and describes its LDO regulators as *Very Low Dropout* regulators. Consult datasheets to determine the actual specification of the product, regardless of its classification.

Additional Pin Functions

Some voltage regulators include an extra pin, typically known as an *enable pin*, which switches off the device in response to a signal from a microcontroller or logic gate.

Some regulators offer another option, an additional *status pin* that can signal a microcontroller that an error mode exists if the regulator output falls significantly below its rated value.

In battery-powered devices, a low-battery sensor is a desirable feature, since a regulator may simply shut down without warning if the input voltage is insufficient. A few regulators, such as the LP2953, provide a low-battery warning output via an extra pin.

Values

Linear voltage regulators with a single, fixed output are commonly available to supply DC outputs of 3.3, 5, 6, 8, 9, 10, 12, 15, 18, and 24 volts, with a few variants offering fractional values in between. The most commonly used values are 5, 6, 9, 12, and 15 volts. The input voltage may be as high as 35VDC.

Maximum output current is typically 1A or 1.5A, in the traditional three-pin, through-hole, TO-220 format. A surface-mount version is available. Other surface-mount formats have lower power limits.

Accuracy may be expressed as a percentage or as a figure for load regulation in mV. A typical load regulation value would be 50mV, while voltage regulation accuracy ranges from 1% to 4%, depending on the manufacturer and the component. While low-dropout regulators are generally more efficient, they do require more ground-pin current. This is not usually a significant factor.

How to Use it

Some components, such as many old-design CMOS chips or the traditional TTL version of the 555 timer, allow a wide range of acceptable input voltages, but most modern logic chips and microcontrollers must have a properly controlled power supply. Regulators such as the LM7805 are traditionally used to provide this, especially in small and relatively simple devices that draw a moderate amount of current, have a low component count, and are powered via a battery or an **AC adapter**. A fully fledged switching power supply is overkill in this kind of application.

A linear voltage regulator cannot respond instantly to changes in input voltage. Therefore, if the input supply contains voltage spikes, these spikes may pass through the regulator. Bypass capacitors should be applied preventively. A sample schematic showing an LM7805 regulator with bypass capacitors recommended by a manufacturer is shown in Figure 19-6.

In a battery-powered device where standby power is required for long periods and full power is only needed intermittently, the *quiescent current* drawn by a minimally loaded voltage regulator is important. Modern LDO regulators may draw as little as 100µA when they are very lightly loaded. Other types may consume significantly more. Check datasheets to find the most appropriate component for a particular application.

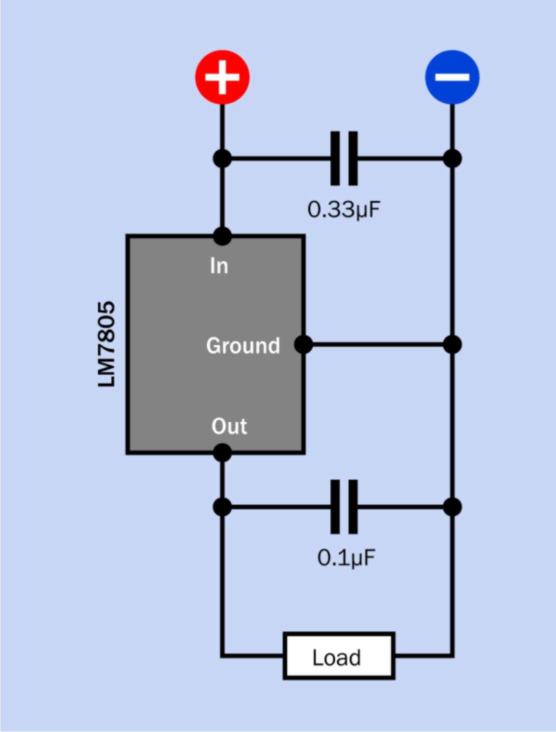

Figure 19-6. *Typical schematic for use of an LM7805 regulator, with capacitor values based on recommendations from Fairchild Semiconductor.*

Note that DC-DC power **converters** may draw a lot of current when they are lightly loaded, and will dissipate large amounts of heat as a result. An LDO is therefore preferable in this situation.

What Can Go Wrong

Inadequate Heat Management

The ability to “dial up” a wide range of voltages from an adjustable regulator such as the LM317 can be a temptation to use it on a “one size fits all” basis, to deliver any output ranging from 5VDC to 18VDC from a uniform 24VDC input. Assuming 1A output current, the worst-case power dissipation in this scenario would be almost 20W. To achieve reasonable efficiency and maintain waste heat at a manageable level, the input voltage should not exceed the output voltage by much more than the dropout voltage.

Even when a voltage regulator is used correctly, it can generate more heat than was expected if the requirements of a circuit are altered during development. An initial handful of components may draw only 100mA, but as more capabilities are requested and more parts are added (especially relays or LED displays) the power consumption can quickly add up, generating an unexpected amount of waste heat and raising the possibility of a sudden (and mysterious) shutdown if the regulator does not have an adequate heat sink.

Transient Response

When there is a major fluctuation in the demand by the load (for example, if an inductive device is switched on elsewhere in the circuit), the voltage regulator requires a finite time to adjust itself and maintain its specified output voltage. This time lag is known as its *transient response*. If a momentary fluctuation is likely, and other components may be sensitive to it, a larger capacitor should be used between the output of the voltage regulator and ground.

The transient response time may also be insufficient to block sudden, brief spikes in input voltage. This may occur, for example, when a low-cost AC adapter that does not have a properly smoothed output is used as the power source. Additional 1µF bypass capacitors may be added at the input and output of a regulator to provide better protection from power fluctuations.

Misidentified Parts

Many types of linear voltage regulators appear physically identical. Care is needed to distinguish those which have fixed output from those that allow a variable output. When using the LM78xx series, double-check the last pair of digits in the part number, which provide the only guide regarding the output. Using an LM7808 instead of an LM7805 may be sufficient to destroy all the 5VDC chips in a logic circuit. It is advisable to use a meter to check the output of any power supply before connecting it with a circuit.

Misidentified Pins

The LM78xx series of voltage regulators uses a very intuitively obvious and consistent scheme for the functions of its pins: input on the left, ground in the center, and output on the right, when looking at the regulator from the front, with its pins facing downward. Unfortunately the consistency of this scheme can encourage an unthinking habit for making connections. The LM79xx series of negative voltage regulators swaps the identity of the input and ground pins, whereas adjustable regulators use yet another different scheme. Good practice suggests checking a component against the manufacturer's datasheet before connecting it.

Dropout Caused by Low Battery

If a regulator rated to deliver 6VDC has a 2VDC dropout voltage and is powered from a 9V battery, the battery can easily drop below the minimum acceptable 8VDC if it becomes old or depleted. When this happens, the output from the regulator will tend to fall, or may oscillate.

Inaccurate Delivered Voltage

A voltage regulator maintains its output voltage between its output pin and ground pin. Thin traces on a circuit board, or a long run of very small-gauge wiring, can impose some electrical resistance, reducing the actual voltage delivered to a component. Ohm's Law tells us that the voltage drop imposed by a trace (or thin wire) will be proportional to the current flowing through it. For example, if the resistance between the output pin of a voltage regulator and a component is 0.5Ω and the current is 0.1A, the voltage drop will be only 0.05V. But if the current increases to 1A, the voltage drop is now 0.5V. Bearing this in mind, a linear voltage regulator should be positioned close to voltage-sensitive components. In printed circuit designs, the traces that deliver power should not have significant resistance.

When using linear voltage regulators with adjustable output, there may be a temptation to connect adjustment resistor R1 to the positive end of the load, to obtain a "more accurate" delivered voltage. This configuration will not produce the desired result. R1 should always be connected as closely as possible between the output pin and the adjustment pin of the voltage regulator, while R2 should connect between the adjustment pin and the negative end of the load. This is illustrated in Figure 19-7, where the gray wire in each schematic indicates that it possesses significant resistance.

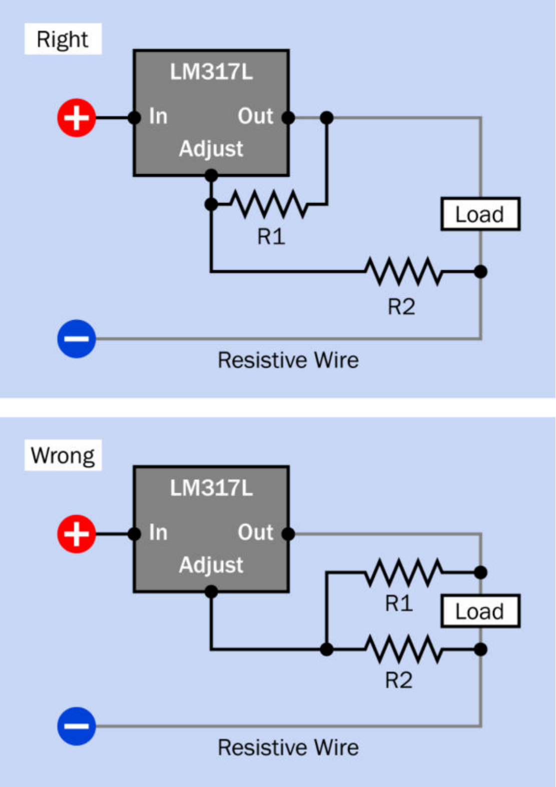

Figure 19-7. *When the connection between an adjustable-output voltage regulator and load components has a significant resistance (shown here as a gray "resistive wire"), R1 should always be connected as closely as possible to the pins of the regulator, as shown in the upper schematic. (Derived from schematics prepared by National Semiconductor.)*

electromagnet

20

The term **electromagnet** is used here to mean a coil containing a core of ferromagnetic material that does not move relative to the coil. The core is used solely to create a magnetic field that attracts or repels other parts that have appropriate inherent magnetic properties. Where a center component moves in response to the magnetic force created by current through a coil, this is discussed in the **solenoid** entry. By comparison, the **inductor** entry describes a coil that may or may not have a ferromagnetic core, and is used for the specific purpose of creating reactance, or self-inductance, in an electronic circuit, often in association with alternating current and in combination with resistors and/or capacitors. The **inductor** entry contains a basic discussion and explanation of magnetic force created by electricity.

OTHER RELATED COMPONENTS

- **solenoid** (See Chapter 21)
- **electromagnet** (See Chapter 20)
- **DC motor** (See Chapter 22)
- **AC motor** (See Chapter 23)

What It Does

An electromagnet consists of a coil that creates a magnetic field in response to an electric current. The field is channeled and reinforced by a core of magnetic material (that is, material that can be magnetized). Electromagnets are incorporated in motors, generators, loudspeakers, microphones, and industrial-sized applications such as mag-lev trains. On their own, they provide a means for electric current to hold, lift, or move objects in which a magnetic field can be induced.

A very small, basic electromagnet about 1 inch in diameter is shown in Figure 20-1. No specific schematic symbol for an electromagnet exists, and the symbol for an induction coil with a solid core is often used instead, as shown in Figure 14-1 (the center variant of each of the three) in the **inductor** entry of this encyclopedia.

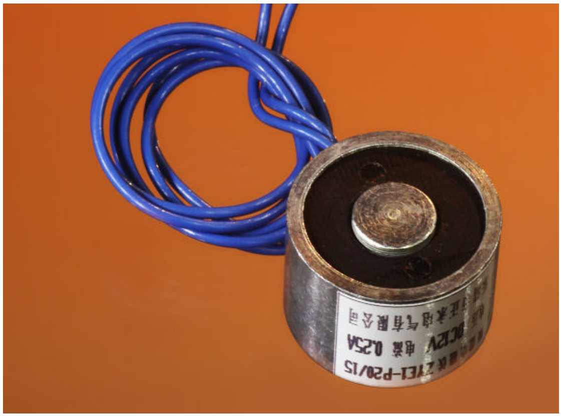

Figure 20-1. *An electromagnet approximately 1 inch in diameter, rated to draw 0.25A at 12VDC.*

How It Works

Electric current flowing through a circle of wire (or a series of connected loops that form a helix or *coil*) will induce a magnetic field through the center. This is illustrated in the **inductor** entry of this encyclopedia, specifically in diagrams Figure 14-3, Figure 14-4, Figure 14-5, and Figure 14-6.

If a stationary piece of ferromagnetic material is placed in the center of the circle or coil, it enhances the magnetic force because the *reluctance* (magnetic resistance) of the material is much lower than the reluctance of air. The combination of the coil and the core is an electromagnet. This is illustrated in Figure 20-2. For a lengthier discussion of this effect, see "Magnetic Core" (page 122).

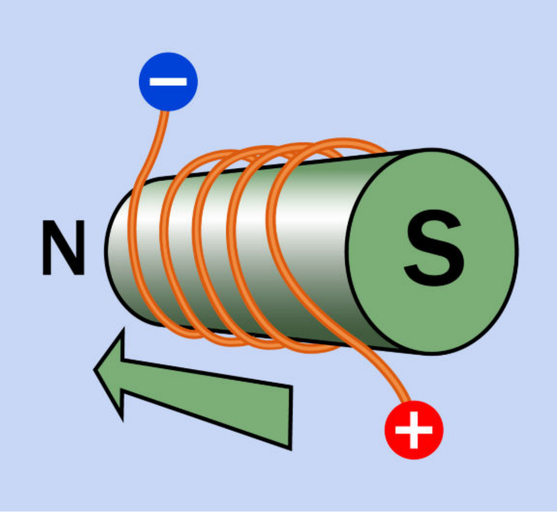

Figure 20-2. *Direct conventional current flowing through a wire coiled around a ferromagnetic rod induces a magnetic force in the rod, conventionally considered to flow from south to north.*

The magnitude of the electromagnetic *flux density* will be proportional to the current flowing through the coil, assuming a DC power source.

Variants

Electromagnet designs vary according to their application. The simplest design consists of a single coil wound around a rod which may terminate in a plate for applications such as lifting scrap metal. This design is relatively inefficient because the magnetic circuit is completed through air surrounding the electromagnet.

A more efficient, traditional design consists of a U-shaped core around which are wound one or two coils. If the U-shaped core is smoothly curved, it resembles a *horse-shoe magnet*, as shown in Figure 20-3. This design has become relatively uncommon, as it is cheaper to make windings across two separate, straight vertical cores and bridge them. However, the horseshoe configuration is extremely efficient, as the coils induce north and south magnetic polarities in the open ends of the U-shaped core, and the magnetic circuit is completed through any object that is attracted toward the open ends and links them. The attracted object is shown as a rectangular plate in Figure 20-3. Because a magnetic circuit will naturally attempt to limit its extent, and because this goal will be achieved when the circuit is completed, the attractive force of the U-shaped magnet is maximized.

An electromagnet powered by direct current naturally produces a consistently polarized, stable magnetic field. When AC current is applied, an electromagnet may still be used to exert an attractive force on a passive object that is not magnetized but is capable of being magnetized. The electromagnet will change its polarity at almost the same frequency as the AC, and will induce equal and opposite fluctuating polarity in the target, causing mutual attraction. The core of the magnet will be composed of plates separated by thin layers of insulation to inhibit the eddy currents induced by the AC, but still an AC-powered electromagnet will be less efficient than a comparable DC-powered electromagnet because it will also suffer from *hysteresis* as power is consumed by repeatedly reversing the polarity of the *magnetic domains* in the core.

Some electromagnets that are described as suitable for AC power actually contain *rectifiers* that convert the AC to DC.

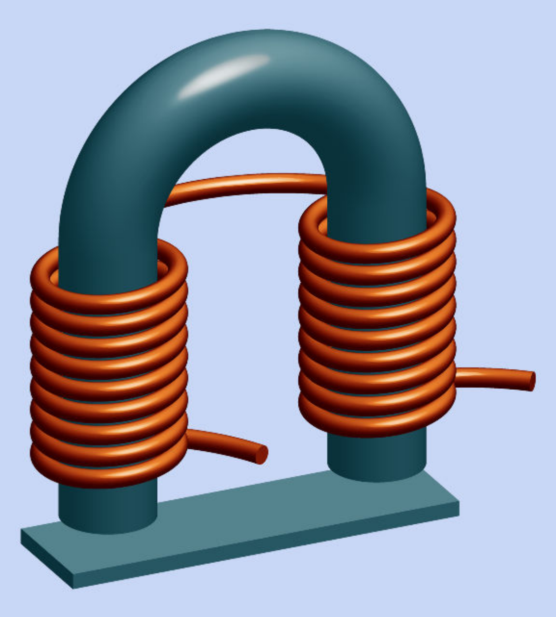

Figure 20-3. *This traditional design for an electromagnet has a pedigree stretching back for more than a century. It maximizes efficiency by completing a magnetic circuit through any object that the magnet attracts.*

Values

Electromagnets are typically calibrated in terms of their power consumption and retaining force (the weight of an iron target that they can support). The retaining force is usually measured in grams or kilograms.

How to Use it

Electromagnets are used mostly as subassemblies in other components, such as motors and generators, relays, loudspeakers, and disk drives. They have also been used in audio (and video) tape recorders to magnetize ferric oxide on tape, using a magnetic field of varying strength to record an audio signal. In this application, a form of horseshoe magnet with an extremely narrow gap is used, the width of the gap determining the highest frequency that the electromagnet can record, in conjunction with the speed of the tape moving past the head.

The tape recording process can be reversed when the electromagnet "reads" the tape and turns the signal back into a weak alternating current that can be amplified and reproduced through a loudspeaker.

A simple application for an electromagnet is in a traditional-style doorbell, where one or two coils attract a spring-loaded lever, at the top of which is a knob that hits a bell. When the lever is pulled toward the bell, it breaks a contact that supplies power to the electromagnet. This allows the lever to spring back to its original position, which re-establishes the circuit, repeating the process for as long as power is applied to the bell. The bulk and weight of the component parts in this type of doorbell are making it obsolete, as electronic versions containing small loudspeakers become relatively cheaper. However, a **solenoid** may still be used in the type of bell that creates a single chime or pair of chimes.

In any device using a *cathode-ray tube*, electromagnetic coils are used to form a *yoke* around the neck of the tube, to deflect the beam of electrons on its way to the screen. A similar principle is used in electron microscopes. In some cases, electrostatically charged plates are used to achieve the same purpose.

An electromagnet may be used to activate a *reed switch* (the diagram in Figure 9-7 shows such a switch). In this application, the combination of the electromagnet and the switch are functioning as a **relay**.

When an electromagnet is energized by alternating current, it can be used to *degauss* (in other words, to demagnetize) other objects. The AC is either applied with diminishing current, so that the alternating magnetic polarities gradually subside to zero, or the electromagnet is gradually moved away from the target, again reducing the magnetic influence to (virtually) zero. This latter procedure may be used periodically to demagnetize record and replay heads on tape recorders, which otherwise tend to acquire residual magnetism, inducing background hiss on the tape.

Traditional large-scale applications for electromagnets tend to involve lifting and moving heavy objects or scrap metal, such as junked cars. A more modern application is in magnetic resonance imaging (MRI), which has revolutionized some areas of medicine.

Very large-scale applications for electromagnets include particle accelerators, in which multiple magnetic coils are energized sequentially, and fusion-power generators, where high-temperature plasma is contained by a magnetic field.

What Can Go Wrong

Because an electromagnet requires constant power to maintain its magnetic force, yet it is not doing any actual work so long as its target remains stationary (in contact with the core of the magnet), the current running through the coil of the magnet must be dissipated entirely as heat. Further discussion of this issue will be found at "Heat" (page 177) in the **solenoid** section of this encyclopedia.

solenoid

21

The term **solenoid** was historically used to describe any coil without a magnetic core. More recently and more commonly it describes a coil inside of which a cylindrical plunger moves in response to the magnetic field generated by the coil. In this encyclopedia, the term **electromagnet** has its own entry, and describes a coil with a center component of ferromagnetic material that does not move relative to the coil. It is used solely to attract or repel other parts that have inherent magnetic properties. By comparison, the **inductor** entry describes a coil that is used for the specific purpose of creating reactance, or self-inductance, in an electronic circuit, often in association with alternating current and in combination with resistors and/or capacitors. The **inductor** entry contains a basic discussion and explanation of magnetic force created by electricity.

OTHER RELATED COMPONENTS

- **inductor** (See Chapter 14)
- **solenoid** (See Chapter 21)

What It Does

A typical solenoid consists of a hollow coil inside a *frame*, which may be a sealed cylinder or box-shaped with open sides. In the case of a cylinder, its opposite ends may be referred to as *pole faces*.

At least one of the pole faces has a hole through which a *plunger* (also known as an *armature*) is pulled or pushed by the solenoid. Thus, the solenoid is a device for applying a linear mechanical force in response to current passing through it. In most solenoids, current must be maintained in order to maintain the mechanical force.

A small open-frame solenoid is pictured in Figure 21-1. The upper section of the figure shows the three basic parts: frame, compression spring, and plunger. The lower part of the figure shows the parts assembled.

A larger, closed, cynlindrical solenoid is shown in Figure 21-2, with the plunger and spring removed.

A 3D rendering showing a simplified, imaginary, cylindrical solenoid cut in half appears in Figure 21-3. The diagram includes a gray cylindrical shell, often described as the frame; the coil, shown in orange; the plunger, which is pulled into the coil by its magnetic field; and the triangular stop, which limits the plunger's upward travel. The frame of the solenoid exists not merely to protect the coil, but to provide a magnetic circuit, which is completed through the plunger.

The lower end of the plunger is often fitted with a nonmagnetic yoke or perforated plate for connection with other components. Stainless steel can be used for this purpose. The stop may be fitted with a thrust rod (also fabricated from stainless steel) if the solenoid is intended to "push" as well as "pull." Springs to adjust the force of the plunger, or to return it to its initial position when the current through the coil is interrupted, are not shown in the rendering.

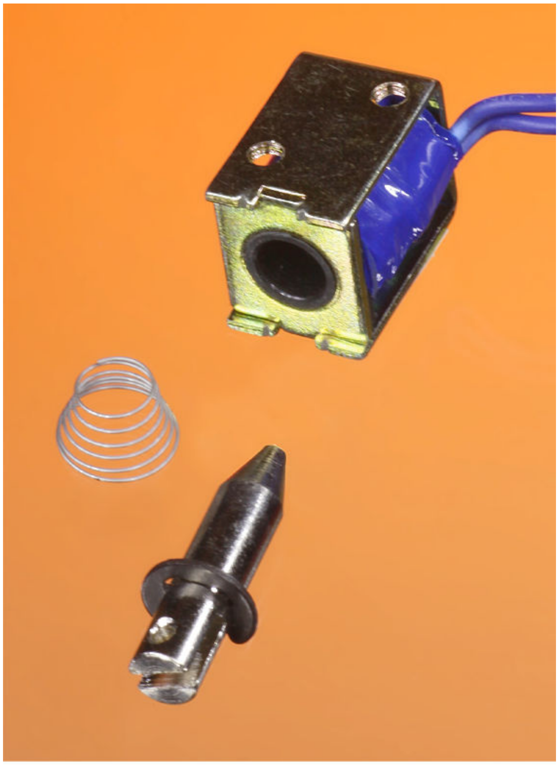

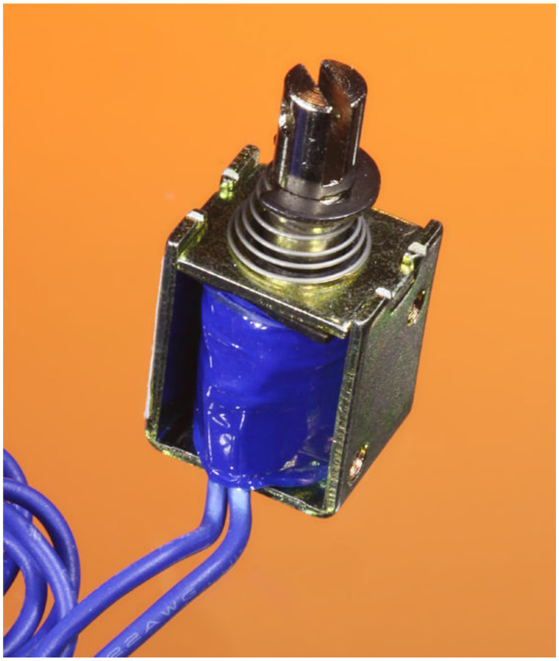

Figure 21-1. *A small 12VDC solenoid.*

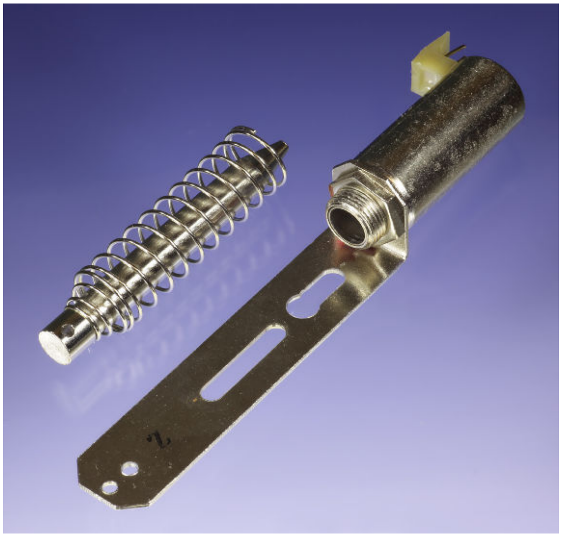

Figure 21-2. *A larger solenoid rated for 24VDC.*

Because there is no standardized schematic symbol for a solenoid, and because this type of component is so widely used in conjunction with valves, any diagram involving solenoids is more likely to emphasize fluid or gas flow with symbols that have been developed for that purpose. In such circuits, a solenoid may be represented simply by a rectangle. However, the symbols shown in Figure 21-4 may occasionally be found.

How It Works

Current flowing through the coil creates a magnetic force. This is explained in the **inductor** entry of this encyclopedia, using diagrams in Figure 14-3, Figure 14-4, Figure 14-5, and Figure 14-6.

If the plunger is fabricated from a material such as soft iron, the coil will induce an equal and opposite magnetic polarity in the plunger. Consequently the plunger will attempt to occupy a position inside the coil where the ends of the plunger are equal distances from the ends of the coil. If a collar is added to the free end of the plunger, this can increase the pulling force on the plunger when it is near the end of its throw because of the additional magnetic pull distributed between the collar and the frame of the solenoid.

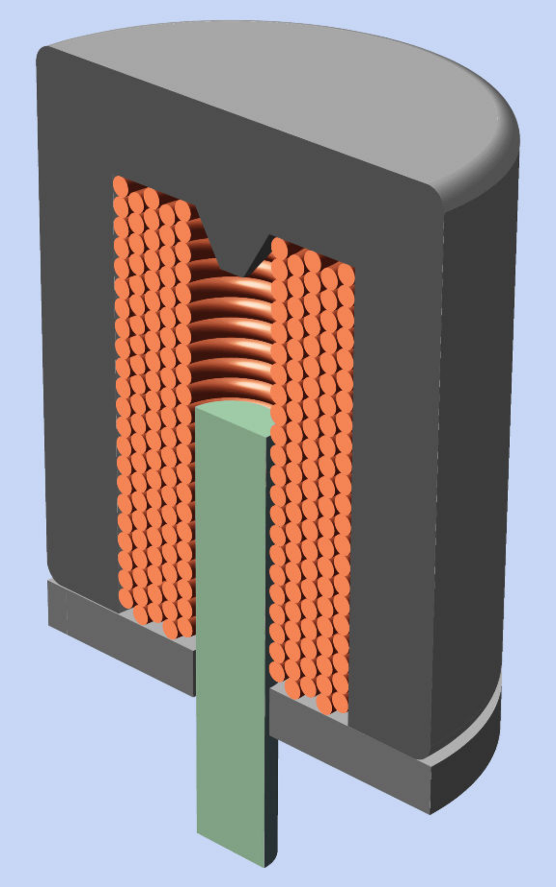

Figure 21-3. *A simplified view of a solenoid cut in half, showing the primary parts.*

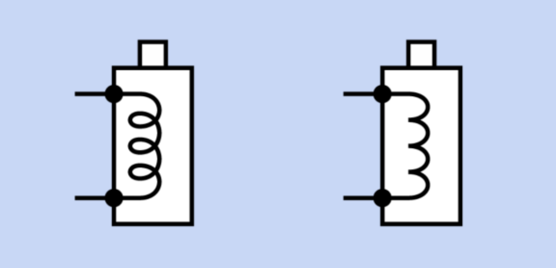

Figure 21-4. *Although no standard schematic symbol for a solenoid exists, these symbols may sometimes be found.*

A spring can be inserted to apply some resistive force to compensate for the increase in pulling force that occurs as a larger proportion of the plunger enters the coil. A spring may also be used to eject the plunger, partially at least, when current to the coil is interrupted.

If the plunger is a permanent magnet, reversing DC current to the coil will reverse the action of the plunger.

A solenoid with a nonmagnetized plunger may be energized by AC current, since polarity reversals in the magnetic field generated by the coil will induce equal and opposite reversals in the polarity of the plunger. However, the force curve of an AC-powered solenoid will be different from the force curve of a DC-powered solenoid. See Figure 21-5. The alternating current is likely to induce humming, buzzing, and vibration.

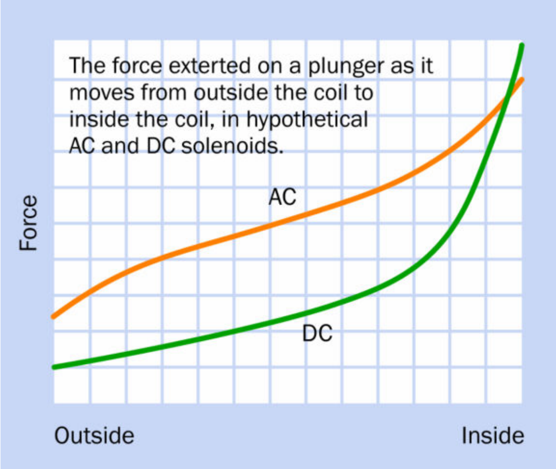

Figure 21-5. *A comparison of the force exerted on a plunger, relative to its position as it enters the coil, in hypothetical AC and DC solenoids.*

The frame of the solenoid increases the magnetic power that the coil can exert by providing a magnetic circuit of much lower *reluctance* than that of air (reluctance being the magnetic equivalent of electrical resistance). For a lengthier discussion of this effect, see "Magnetic Core" (page 122) in the **inductor** entry of this encyclopedia. If current flowing through the coil increases to the point where the frame becomes magnetically *saturated*, the pulling power of the solenoid will level off abruptly.

The heat generated by a solenoid when it is maintained in its energized state may be reduced if the manufacturer includes a series resistor and a switch that functions as a *bypass switch*. The switch is normally closed, but is opened mechanically when the plunger reaches the end of its throw, thus diverting electricity through the series resistor. This itself will generate some heat as a result of the current flowing through it, but by increasing the total resistance of the system, the total heat output will be reduced. The resistor value is chosen to provide the minimum power needed to retain the plunger at the end of its throw.

Variants

The most common variant is tubular, with open-frame as a secondary option. A tubular solenoid has been shown in Figure 21-2.

Additional variants include:

Low Profile

A shorter, fatter solenoid which may be used if a short throw is acceptable.

Latching

A permanent magnet holds the plunger when it reaches the end of its travel, and continues to hold it after power to the solenoid is disconnected. The plunger itself is also a permanent magnet, and is released by running current of reverse polarity through the coil.

Rotary

This variant is similar in principle to a brushless DC motor and causes the armature to rotate through a fixed angle (typically ranging from 25 to 90 degrees) instead of moving linearly. It is used as a mechanical indicator in control panels, although it is being displaced by purely electronic indicators.

Hinged Clapper

Instead of a plunger, a small hinged panel (the “clapper”) moves in when the solenoid is active, and springs back when the power is interrupted.

Values

The stroke length, duty cycle, and holding force are the most significant values found in solenoid datasheets.

Holding forces for DC solenoids can range from a few grams to hundreds of kilograms. The holding force will be inversely proportional to the length of the solenoid, if all other variables are equal. The force that the solenoid can exert on its plunger also varies depending on the position of the plunger in the length of its throw.

Duty cycle is of special importance because the solenoid continues to draw power and create heat so long as it is holding the plunger at the end of its throw (assuming the solenoid is not the latching type). The initial current surge in an AC solenoid generates additional heat.

The duty cycle is simply calculated. If T1 is the time for which the solenoid is on and T2 is the time for which the solenoid is off, the duty cycle, D, is derived as a percentage from the formula

```
D = 100 * (T1 / (T1 + T2))
```

Some solenoids are designed to withstand a 100% duty cycle, but many are not, and in those cases, there is a maximum value not only for D but for the peak “on” time, regardless of the duty cycle. Suppose a solenoid is rated for a 25% duty cycle. If the solenoid is appropriately switched on for one second and off for three seconds, the heat will be allowed to dissipate before it has time to reach overload levels. If the solenoid is switched on for one minute and off for three minutes, the duty cycle is still 25%, but the heat that may accumulate during a one-minute "on" cycle may overload the component before the "off" cycle can allow it to dissipate.

Coil Size vs. Power

Because additional windings in a coil will induce a greater magnetic force, a larger solenoid tends to be more powerful than a smaller solenoid. However this means that if a larger and a smaller solenoid are both designed to generate the same force over the same distance, the smaller solenoid will probably draw more current (and will therefore generate more heat) because of its fewer coil windings.

How to Use it

Solenoids are primarily used to operate valves in fluid and gas circuits. Such circuits are found in laboratory and industrial process control, fuel injectors, aircraft systems, military applications, medical devices, and space vehicles. Solenoids may also be used in some electronic locks, in pinball machines, and in robotics.

What Can Go Wrong

Heat

Overheating is the principal concern when using solenoids, especially if the maximum "on" time is exceeded, or the duty cycle is exceeded. If the plunger is prevented from reaching the end of its throw, this can be another cause of overheating.

Because coil resistance increases with heat, a hot solenoid passes less current and therefore develops less power. This effect is more pronounced in a DC solenoid than an AC solenoid. A manufacturer's force curve should show the solenoid performance at its maximum rated temperature, which is typically around 75 degrees Centigrade, in a hypothetical ambient temperature of 25 degrees Centigrade. Exceeding these values may result in the solenoid failing to perform. As in all coils using magnet wire, there is the risk of excessive heat melting the insulation separating the coil windings, effectively shortening the coil, which will then pass more current, generating more heat.

AC Inrush

When an AC solenoid reaches the end of its travel, the sudden stop of the plunger results in forward *EMF* that generates additional heat. Generally speaking, a longer stroke creates a greater surge. Rapid cycling will therefore exacerbate coil heating.

Unwanted EMF

Like any device containing a coil, a solenoid creates back EMF when power is connected, and forward EMF when the power is disconnected. A protection diode may be necessary to suppress power spikes that can affect other components.

Loose Plunger

The plunger in many solenoids is not anchored or retained inside the frame and may fall out if the solenoid is tilted or subjected to extreme vibration.

22

DC motor

In this section, the term "traditional DC motor" is used to describe the oldest and simplest design, which consists of two *brushes* delivering power via a rotating, sectioned *commutator* to two or more electromagnetic coils mounted on the motor shaft. *Brushless* DC motors (in which DC is actually converted to a pulse train) are also described here because "brushless DC" has become a commonly used phrase, and the motor is powered by direct current, even though this is modified internally via *pulse-width modulation*.

OTHER RELATED COMPONENTS

- **AC motor** (See Chapter 23)
- **stepper motor** (See Chapter 25)
- **servo motor** (See Chapter 24)

What It Does

A traditional DC motor uses direct current to create magnetic force, which turns an output shaft. When the polarity of the DC voltage is reversed, the motor reverses its direction of rotation. Usually, the force created by the motor is equal in either direction.

How It Works

Current passes through two or more coils that are mounted on the motor shaft and rotate with it. This assembly is referred to as the *rotor*. The magnetic force produced by the current is concentrated via cores or poles of soft iron or high-silicon steel, and interacts with fields created by permanent magnets arrayed around the rotor in a fixed assembly known as the *stator*.

Power to the coils is delivered through a pair of *brushes*, often made from a graphite compound. Springs press the brushes against a sleeve that rotates with the shaft and is divided into sections, connected with the coils. The sleeve assembly is known as the *commutator*. As the commutator rotates, its sections apply power from the brushes to the motor coils sequentially, in a simple mechanical switching action.

The most elementary configuration for a traditional DC motor is shown in Figure 22-1.

In reality, small DC motors typically have three or more coils in the rotor, to provide smoother operation. The operation of a three-coil motor is shown in Figure 22-2. The three panels in this figure should be seen as successive snapshots of one motor in which the rotor turns progressively counter-clockwise. The brushes are colored red and blue to indicate positive and negative voltage supply, respectively. The coils are wired in series, with power being applied through the commutator to points between each pair of coils. The direction of current through each coil determines its magnetic polarity, shown as N for north or S for south. When two coils are energized in series without any power applied to their midpoint, each develops a smaller magnetic field than an individually energized coil. This is

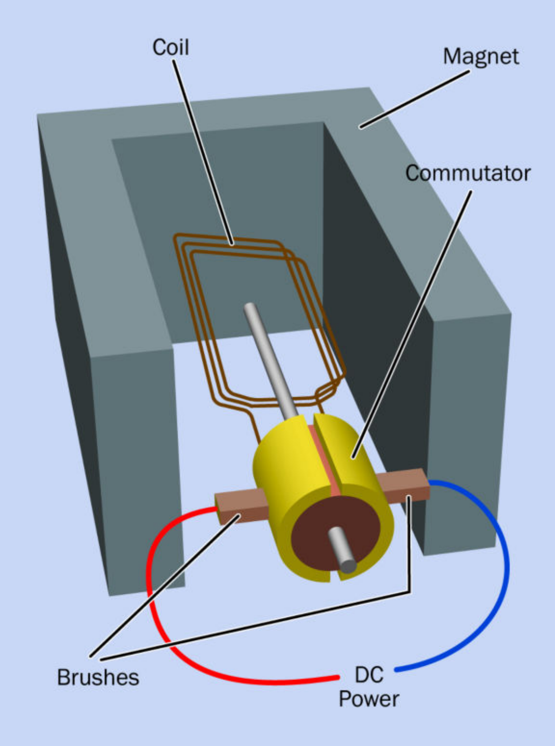

Figure 22-1. *The simplest traditional DC motor contains these parts. The combination of coil, shaft, and commutator is the rotor. The fixed magnetic structure in which it rotates is the stator.*

indicated in the diagram with a smaller white lowercase n and s. When two ends of a coil are at equal potential, the coil produces no magnetic field at all.

The stator consists of a cylindrical permanent magnet, which has two poles—shown in the figure as two black semicircles separated by a vertical gap for clarity—although in practice the magnet may be made in one piece. Opposite magnetic poles on the rotor and stator attract each other, whereas the same magnetic poles repel each other.

DC motors may be quite compact, as shown in Figure 22-3, where the frame of the motor measures about 0.7" square. They can also be very powerful for their size; the motor that is shown disassembled in Figure 22-4 is from a 12VDC bilge pump rated at 500 gallons per hour. Its output was delivered by the small impeller attached to the rotor at right, and was achieved by using

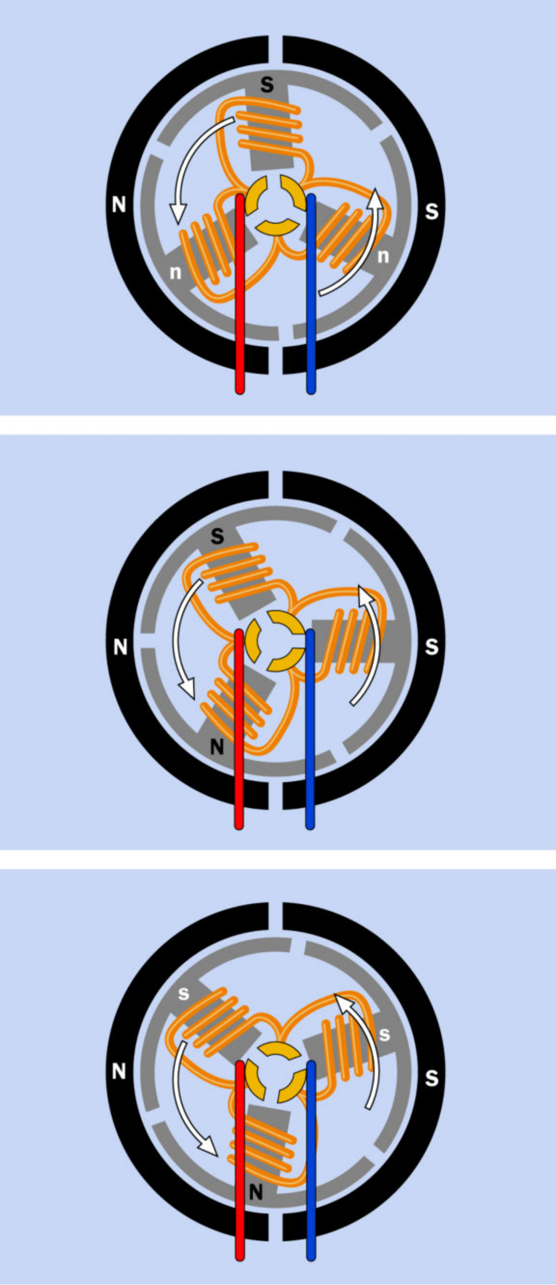

Figure 22-2. *Three sequential views of a typical three-coil DC motor viewed from the end of its shaft (the shaft itself is not shown). Magnetic effects cause the rotor to turn, which switches the current to the coils via the commutator at the center.*

two extremely powerful neodymium magnets, just visible on the inside of the motor's casing (at top-left) in conjunction with five coils on the rotor.

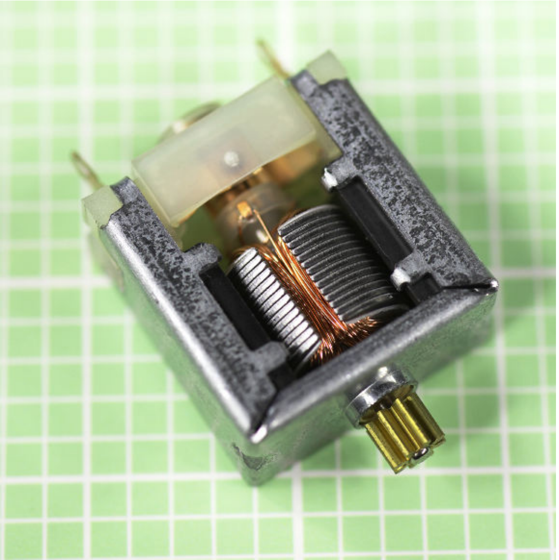

Figure 22-3. *A miniature 1.5VDC motor measuring about 0.7" square.*

Variants

Coil Configurations

The series connection of coils used in Figure 22-2 is known as the *delta configuration*. The alternative is the *wye configuration* (or *Y configuration*, or *star configuration*). Simplified schematics are shown in Figure 22-5. Generally speaking, the delta configuration is best suited to high-speed applications, but provides relatively low torque at low speed. The wye configuration provides higher torque at low speed, but its top speed is limited.

Gearhead Motor

A *gearhead motor* (also often known as a *gear motor*) incorporates a set of reduction gears that increase the torque available from the output shaft while reducing its speed of rotation. This is often desirable as an efficient speed for a traditional DC motor may range from 3,000 to 8,000 RPM, which is too fast for most applications. The gears and the motor are often contained in a single sealed cylindrical package. Two examples are shown in Figure 22-6. A disassembled motor, revealing half of its gear train under the cap and the other half still attached to a separate circular plate, appears in Figure 22-7. When the motor is assembled, the gears engage. As in the case of the bilge-pump motor, the stator magnets are mounted inside the cylindrical casing. Note that the brushes, inside the circular plate of white plastic, have a resistor and capacitor wired to suppress voltage spikes.

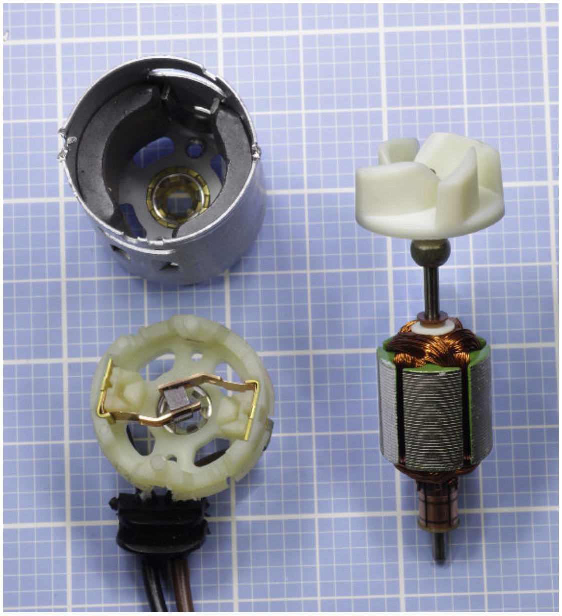

Figure 22-4. *A traditional DC motor removed from its cylindrical casing. The brushes of the motor are attached to the white plastic end piece at bottom-left. Large squares on the graph paper in the background are 1" × 1", divided in 0.1" increments. The motor was used in a small bilge pump.*

Spur gears are widely used for speed reduction. *Planetary gears* (also known as *epicyclic gears*) are a slightly more expensive option. Spur gears such as those in Figure 22-8 may require three or more pairs in series. The total speed reduction is

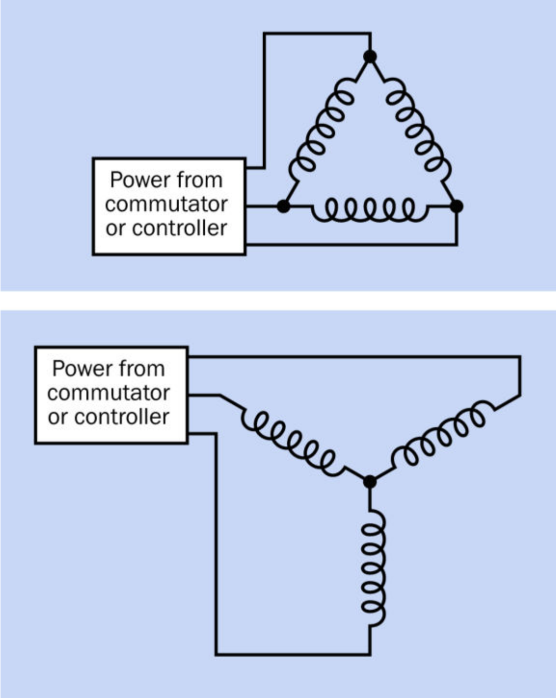

Figure 22-5. *Coils on the rotor of a traditional DC motor may be connected in delta configuration (top) or wye configuration (bottom).*

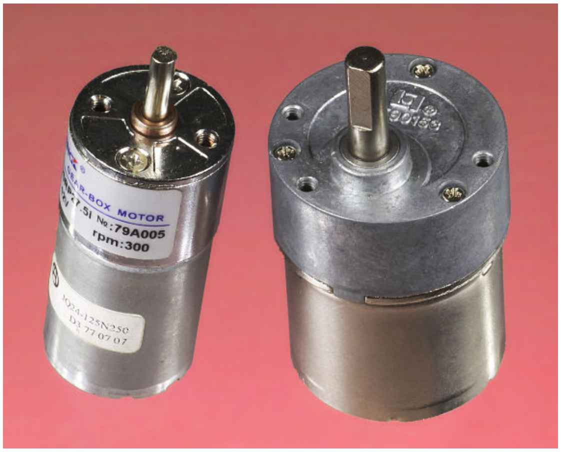

Figure 22-6. *Two typical small gearhead motors.*

found by multiplying the individual ratios. Thus, if three pairs of gears have ratios of 37 : 13, 31 : 15, and 39 : 17, the total speed reduction ® is obtained by:

```
R = ( 37 * 31 * 39 ) / ( 13 * 15 * 17 )
```

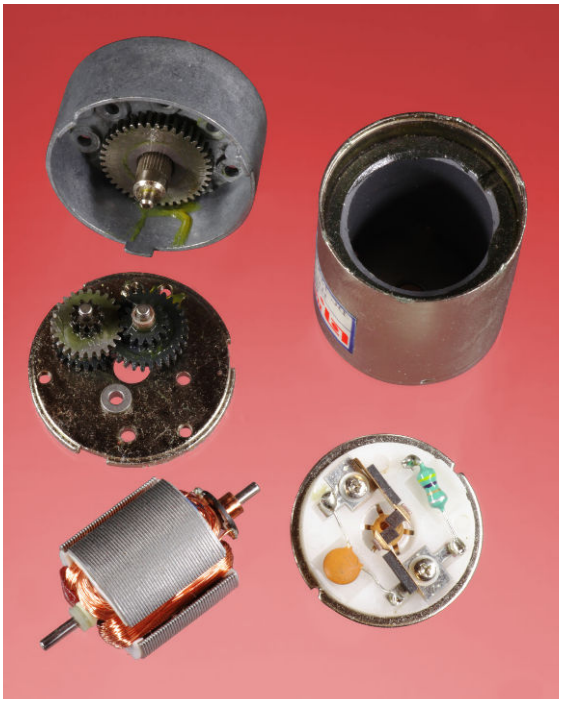

Figure 22-7. *Spur gears from a gearhead motor provide speed reduction and increased torque.*

Therefore:

```
R = 44733 / 3315 = about 13.5 : 1
```

Datasheets almost always express R as an integer. For example, the gear train shown in Figure 22-7 is rated by the manufacturer as having an overall reduction of 50:1. In reality, the reduction can be expected to have a fractional component. This is because if two gears have an integer ratio, their operating life will be shortened, as a manufacturing defect in a tooth in the smaller gear will hit the same spots in the larger gear each time it rotates. For this reason, the numbers of teeth in two spur gears usually do not have any common factors (as in the example above), and if a motor rotates at 500 RPM, a gear ratio stated as 50:1 is very unlikely to produce an output of exactly 10

RPM. Since traditional DC motors are seldom used for applications requiring high precision, this is not usually a significant issue, but it should be kept in mind.

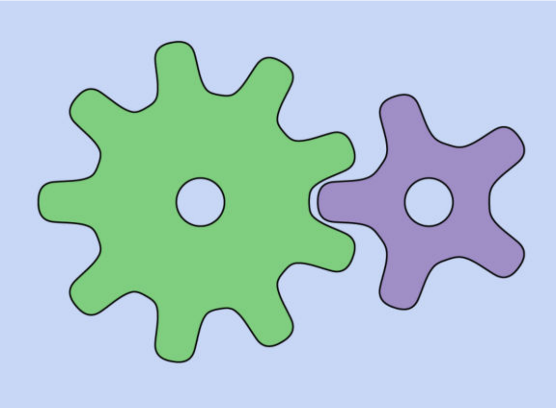

Figure 22-8. *A pair of spur gears.*

Figure 22-9 shows *planetary gears*, also known as *epicyclic gears*. The outer ring gear is properly referred to as the *annulus*, while the *sun gear* is at the center, and the intermediate *planet gears* may be mounted on a *carrier*. The greatest speed reduction will be achieved by driving the sun gear while the annulus is kept in a stationary position and the output is taken from the carrier of the planet gears. If A is the number of teeth in the annulus and S is the number of teeth in the sun gear, the total speed reduction, R, is given by the following formula:

```
R = (S + A) / S
```

Note that in this drive configuration, the number of teeth in each planet gear is irrelevant to the speed reduction. In Figure 22-9, the sun gear has 27 teeth whereas the annulus has 45 teeth. Therefore, the reduction is found by:

```
R = (27 + 45) / 27 = about 2.7 : 1
```

Successive reductions can be achieved by stacking planetary gear sets, using the carrier of one set to drive the sun gear in the next set.

Planetary gears are used primarily if a motor drives a heavy load, as the force is divided among

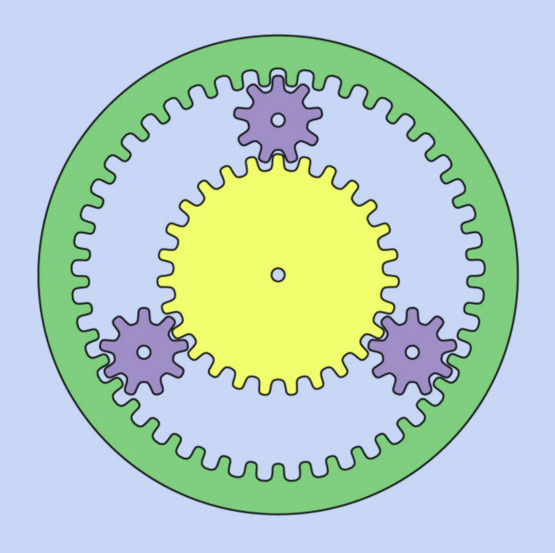

Figure 22-9. *Planetary gears, also known as epicyclic gears, share the torque from a motor among more teeth than simple spur gears.*

more gear pairs, reducing wear and tear on gear teeth and minimizing the breakdown of lubrication. A planetary gear train may also be more compact than a train of spur gears. These advantages must be evaluated against the higher price and slightly increased friction resulting from the larger number of gears interacting with each other.

Brushless DC Motor

In a *brushless* DC motor, sometimes referred to as a *BLDC motor*, the coils are located in the stator and the permanent magnets are relocated in the rotor. The great advantage of this design is that power can be applied directly to the coils, eliminating the need for brushes, which are the primary source of failure in DC motors as a result of wear and tear. However, since there is no rotating commutator to switch the DC current to the coils, the current must be switched by electronic components, which add to the cost of the motor.

In the *inrunner* configuration the stator surrounds the rotor, whereas in the *outrunner* configuration the stator is located in the center of the motor while the rotor takes the form of a ring or cup that spins around the stator. This is a common design for small cooling fans, where the blades are attached to the outer circumference of a cup that is lined with permanent magnets. An example is shown in Figure 22-10. In this picture, the stator coils are normally hidden from view, being fixed to the fan housing (shown at the top of the picture). Power is controlled by the surface-mount components on the green circular circuit board. The cup attached to the fan blades contains permanent magnets.

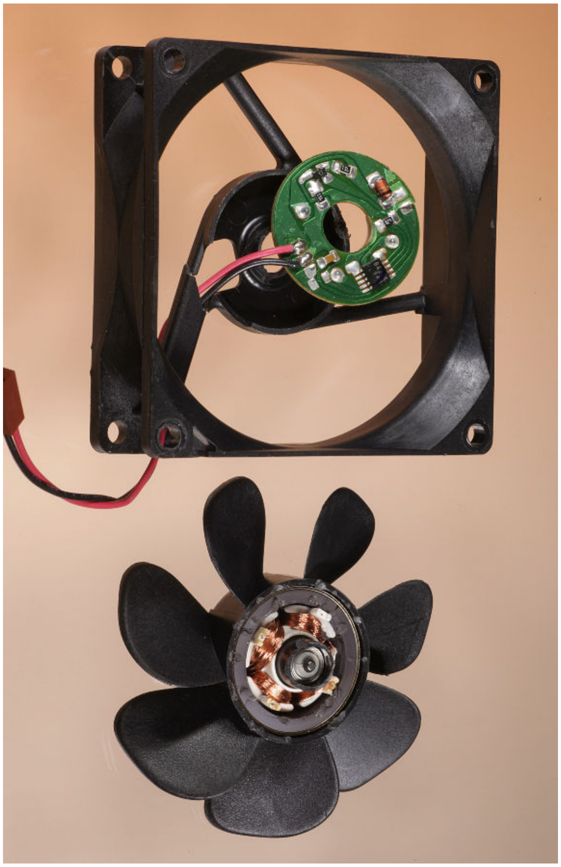

Figure 22-10. *A typical brushless DC cooling fan uses stationary coils, with permanent magnets rotating around them.*

The use of a solid-state switching system to energize the coils sequentially is known as *electronic commutation*. *Hall effect* sensors may be used to detect the position of the rotor and feed this information back to the frequency control circuit, so that it stays “one step ahead” of the rotor (when bringing it up to speed) or is synchronized with the rotor (for a constant running speed). The system is comparable to a *reluctance motor* or *synchronous motor.* These variants are described in the **AC motor** section of this encyclopedia.

While traditional DC motors have been commercially available since the late 1800s, brushless DC motors were not introduced until the 1960s, when the availability of solid-state control electronics began to make the motor design economically viable.

Linear Actuator

Linear actuator is a generic term for any device that can exert a pushing or pulling force in a straight line. In industrial applications, actuators may be powered pneumatically or hydraulically, but smaller-scale units are usually driven by a traditional DC motor. These are more properly (but not often) referred to as *electromechanical linear actuators*.

The rotational force of the motor is typically converted to linear motion by using a threaded motor shaft in conjunction with a nut or collar. The unit is often mounted in an enclosure containing *limit switches* that stop the motor automatically at the limits of travel. For an explanation of limit switches, see “Limit Switches” (page 46) in the **switch** entry in this encyclopedia.

Values

A manufacturer’s datasheet should list the maximum operating voltage and typical current consumption when a motor is moderately loaded, along with the *stall current* that a motor draws when it is so heavily loaded that it stops turning. If stall current is not listed, it can be determined empirically by inserting an ammeter (or multimeter set to measure amperes) in series with the motor and applying a braking force until the motor stops. Motors should generally be protected with slow-blowing **fuses** to allow for the power fluctuations that occur when the motor starts running or experiences a change in load.

In addition, the *torque* that a motor can deliver should be specified. In the United States, torque is often expressed in *pound-feet* (or *ounce-inches* for smaller motors). Torque can be visualized by imagining an arm pivoted at one end with a weight hung on the other end. The torque exerted at the pivot is found by multiplying the weight by the length of the arm.

In the metric system, torque can be expressed as gram-centimeters, Newton-meters, or dyne-meters. A Newton is 100,000 dynes. A dyne is defined as the force required to accelerate a mass of 1 gram, increasing its velocity by 1 centimeter per second each second. 1 Newton-meter is equivalent to approximately 0.738 pound-feet.

The speed of a traditional DC motor can be adjusted by varying the voltage to it. However, if the voltage drops below 50% of the rated value, the motor may simply stop.

The power delivered by a motor is defined as its speed multiplied by its torque at that speed. The greatest power will be delivered when the motor is running at half its *unloaded speed* while delivering half the *stall torque*. However, running a motor under these conditions will usually create unacceptable amounts of heat, and will shorten its life.

Small DC motors should be run at 70% to 90% of their unloaded speed, and at 10% to 30% of the stall torque. This is also the range at which the motor is most efficient.

Ideally, DC motors that are used with reduction gearing should be driven with less than their rated voltage. This will prolong the life of the motor.

When choosing a motor, it is also important to consider the *axial loading* (the weight or force that will be imposed along the axis or shaft of the motor) and *radial loading* (the weight or force that will be imposed perpendicularly to the axis). Maximum values should be found in motor datasheets.

In the hobby field, motors for model aircraft are typically rated in watts-per-pound of motor weight (abbreviated w/lb). Values range from 50 to 250 w/lb, with higher values enabling better performance.

Relationships between torque, speed, voltage, and amperage in a traditional DC motor can be described easily, assuming a hypothetical motor that is 100% efficient:

If the amperage is constant, the torque will also be constant, regardless of the motor speed.

If the load applied to the motor remains constant (thus forcing the motor to apply a constant torque), the speed of the motor will be determined by the voltage applied to it.

If the voltage to the motor remains constant, the torque will be inversely proportional with the speed.

How to Use it

A traditional DC motor has the advantages of cheapness and simplicity, but is only suitable for intermittent use, as its brushes and commutator will tend to limit its lifetime. Its running speed will be approximate, making it unsuitable for precise applications.

As the cost of control electronics has diminished, brushless DC motors have replaced traditional DC motors. Their longevity and controllability provide obvious advantages in applications such as hard disk drives, variable-speed computer fans, CD players, and some workshop tools. Their wide variety of available sizes, and good power-to-weight ratio, have encouraged their adoption in toys and small vehicles, ranging from remote-controlled model cars, airplanes, and helicopters to personal transportation devices such as the Segway. They are also used in direct-drive audio turntables.

Where an application requires the rotation of a motor shaft to be converted to linear motion, a prepackaged *linear actuator* is usually more reliable and simpler than building a crank and connecting rod, or cam follower, from scratch. Large linear actuators are used in industrial automation, while smaller units are popular with robotics hobbyists and can also be used to control small systems in the home, such as a remote-controlled access door to a home entertainment center.

Speed Control

A *rheostat* or **potentiometer** may be placed in series with a traditional DC motor to adjust its speed, but will be inefficient, as it will achieve a voltage drop by generating heat. Any rheostat must be rated appropriately, and should probably be wire-wound. The voltage drop between the wiper and the input terminal of the rheostat should be measured under a variety of operating conditions, along with the amperage in the circuit, to verify that the wattage rating is appropriate.

Pulse-width modulation (*PWM*) is preferable as a means of speed control for a traditional DC motor. A circuit that serves this purpose is sometimes referred to as a *chopper*, as it chops a steady flow of current into discrete pulses. Usually the pulses have constant frequency while varying in duration. The pulse width determines the average delivered power, and the frequency is sufficiently high that it does not affect smoothness of operation of the motor.

A **programmable unijunction transistor** or PUT can be used to generate a train of pulses, adjustable with a potentiometer attached to its emitter. Output from the transistor goes to a *silicon-controlled rectifier* (*SCR*), which is placed in series with the motor, or can be connected directly to the motor if the motor is small. See Figure 27-7.

Alternatively, a *555 timer* can be used to create the pulse train, controlling a *MOSFET* in series with the motor.

A **microcontroller** can also be used as a pulse source. Many microcontrollers have PWM capability built in. The microcontroller will require its own regulated power supply (typically 5VDC, 3.3VDC, or sometimes less) and a switching component such as an *insulated-gate bipolar transistor* (*IGBT*) to deliver sufficient power to the motor and to handle the flyback voltage. These components will all add to the cost of the system, but many modern devices incorporate microcontrollers anyway, merely to process user input. Another advantage of using a microcontroller is that its output can be varied by rewriting software, for example if a motor is replaced with a new version that has different characteristics, or if requirements change for other reasons. Additionally, a microcontroller enables sophisticated features such as pre-programmed speed sequences, stored memory of user preferences, and/or responses to conditions such as excessive current consumption or heat in the motor.

A PWM schematic using a microcontroller and IGBT is shown in Figure 22-11.

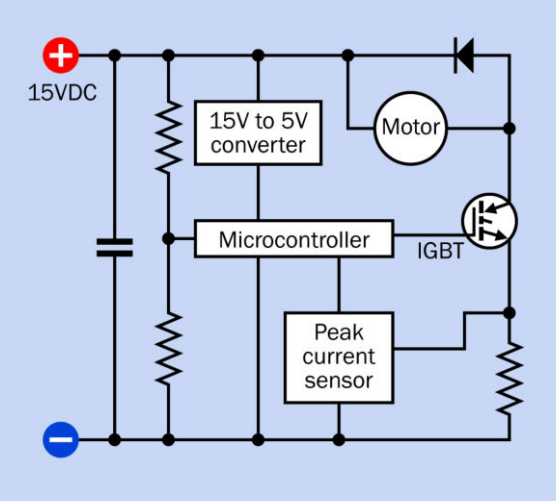

Figure 22-11. *A sample schematic for control of a DC motor via pulse-width modulation, using a microcontroller and an insulated-gate bipolar transistor.*

Direction Control

The *H bridge* is a very early system for reversing the direction of a DC motor simply by swapping the polarity of its power supply. This is shown in Figure 22-12. The switches diagonally opposite each other are closed, leaving the other two switches open; and then to reverse the motor, the switch states are reversed. This is obviously a primitive scheme, but the term "H bridge" is still used when prepackaged in a single chip such as the LMD18200 H bridge motor controller from National Semiconductor.

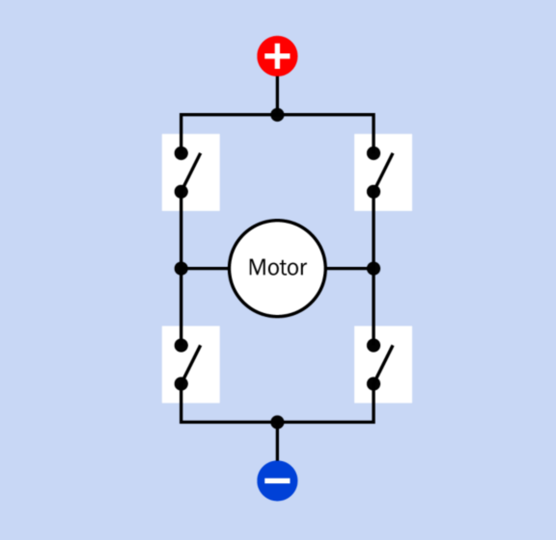

Figure 22-12. *A DC motor can be reversed by this very basic circuit, known as an H bridge, by opening and closing pairs of switches that are diagonally opposite each other.*

A double-throw, double-pole **switch** or **relay** can achieve the same purpose, as shown in Figure 22-13.

Limit Switches

When a traditional DC motor is used reversibly within a restricted range of motion, it can be fitted with *limit switches* to prevent the motor from stalling and burning out at either end of its permitted travel. Limit switches are explained in "Limit Switches" (page 46) in the **switch** entry in this encyclopedia.

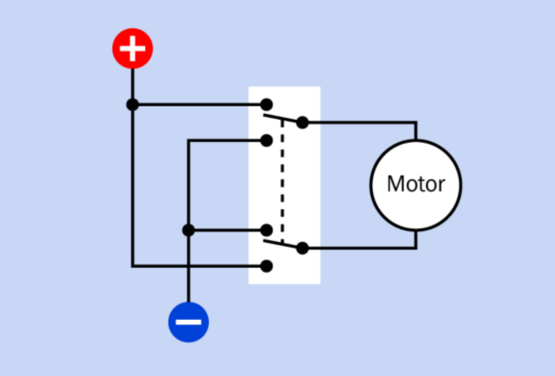

Figure 22-13. *A DPDT switch or relay can reverse the direction of a traditional DC motor simply by swapping the polarity of the power supply.*

What Can Go Wrong

Brushes and Commutator

The primary cause of failure in DC motors is abrasion of the brushes and wear and tear, oxidation, and/or accumulation of dirt on the commutator. Some motors are designed to allow replacement of the brushes; sealed motors and gearhead motors generally are not. High current and high speed will both tend to accelerate wear in the areas where the brushes meet the commutator.

Electrical Noise

The intermittent contact between the brushes and sections of the commutator of a traditional DC motor can induce voltage spikes that may travel back into the power supply for the motor and cause seemingly random effects in other components. Sparking in the commutator can be a significant source of *electromagnetic interference* (*EMI*), especially where cheap or poorly fitted brushes are used. Even if the commutator is running cleanly, the rapid creation of a magnetic field in a motor winding, following by collapse of the field, can create spikes that feed back into the power supply.

Wires that power a motor should be in twisted-pair configuration, so that their radiated EMI tends to cancel itself out. They should be routed away from data lines or encoder outputs, and may be shielded if necessary. Data lines from sensors in brushless motors may also be shielded.

Installing a capacitor across the motor terminals can significantly reduce EMI. Some motors have capacitors preinstalled. If the motor is in a sealed casing, it may have to be disassembled to reveal whether a capacitor is present.

Heat effects

Since all motors in the real world are less than 100% efficient, some power is lost by the motor during normal operation, and will be dissipated as heat. The resistance of motor windings, and consequently the magnetic force that they generate, will decrease as the temperature rises. The motor becomes less efficient, and will try to draw more current, worsening the situation. A manufacturer's rating for maximum temperature should be taken seriously.

The insulation of the coil windings is usually the most vulnerable part of a motor if excess heat persists. Short circuits between adjacent coils as a result of insulation breakdown will degrade the performance of the motor while increasing its power consumption, which will create even more heat.

Where motor casings have protruding ridges, these cooling fins should be exposed to ambient air.

Frequent starting, stopping, and reversing will tend to generate heat as a result of power surges, and will reduce the lifetime of the motor.

Ambient Conditions

A warm, dry environment will tend to dry out bearing lubricants and graphite brushes. Conversely, a very cold environment will tend to thicken the bearing lubricants. If a motor will be used in unusual environmental conditions, the manufacturer should be consulted.

Wrong Shaft Type or Diameter

Motors have a variety of possible output shaft diameters, some measured in inches and others in millimeters, and shafts may be long or short, or may have a D-shaped cross section or splines to mate with appropriate accessories such as gears, pulleys, or couplings. Careful examination of datasheets and part numbers is necessary to determine compatibility. In the hobby-electronics world, retailers may offer purpose-built discs or arms for specific motor shafts.

Incompatible Motor Mounts

Mounting lugs or flanges may or may not be provided, and may be incompatible with the application for which the motor is intended. The same motor may be available with a variety of mount options, differentiated only by one letter or digit in the motor's part number. A mount option that was available in the past may become obsolete or may simply be out of stock. Again, examination of datasheets is necessary.

Backlash

Backlash is the looseness or "slack" in a gear train that results from small gaps between meshing gear teeth. Because backlash is cumulative when gears are assembled in series, it can become significant in a slow-output gearhead motor. When measured at the output shaft, it is generally in the range of 1 to 7 degrees, tending to increase as the load increases. If a geared motor is used as a positioning device, and is fitted with an encoder to count rotations of the motor shaft, control electronics may cause the motor to hunt to and fro in an attempt to overcome the hysteresis allowed by the backlash. A **stepper motor** or **servo motor** is probably better suited to this kind of application.

Bearings

When using a motor that is not rated for significant axial loading, the bearings may be damaged by applying excessive force to push-fit an output gear or pulley onto the motor shaft. Even minor damage to bearings can cause significant noise (see the following section) and a reduced lifetime for the component.

In brushless DC motors, the most common cause of failure is the deterioration of bearings. Attempting to revive the bearings by unsealing them and adding lubricant is usually not worth the trouble.

Audible Noise

While electric motors are not generally thought of as being noisy devices, an enclosure can act as a sounding board, and bearing noise is likely to increase over time. Ball bearings become noisy over time, and gears are inherently noisy.

If a device will contain multiple motors, or will be used in close proximity to people who are likely to be sensitive to noise (for example, in a medical environment), care should be taken to insure that motor shafts are properly balanced, while the motors may be mounted on rubber bushings or in sleeves that will absorb vibration.

AC motor

23

The distinction between AC and DC motors has become blurred as controllers for DC motors make increasing use of *pulse-width modulation*, which can be viewed as a form of alternating current. All motors that consume DC power are referenced in the **DC motor** section of this encyclopedia, regardless of whether they modulate the power internally. **Stepper motors** and **servo motors** are considered as special cases, each with its own entry. AC motors, described here, are those that consume alternating current, usually in the form of a sine wave with a fixed frequency.

OTHER RELATED COMPONENTS

- **DC motor** (see Chapter 22)
- **stepper motor** (see Chapter 25)
- **servo motor** (see Chapter 24)

What It Does

An AC motor uses a power supply of alternating current to generate a fluctuating magnetic field that turns a shaft.

How It Works

The motor consists primarily of two parts: the *stator*, which remains stationary, and the *rotor*, which rotates inside the stator. Alternating current energizes one or more coils in the stator, creating fluctuating magnetic fields that interact with the rotor. A simplified representation is shown in Figure 23-1, where the coils create magnetic forces indicated by the green arrows, N representing North and S representing South.

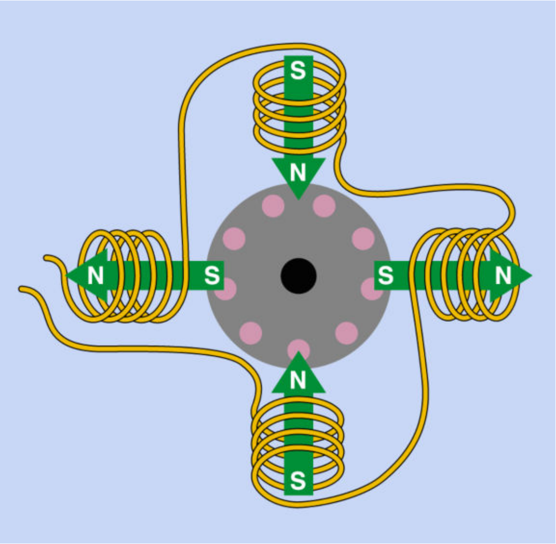

Figure 23-1. *A simplified representation of a basic AC motor. The green arrows indicate magnetic force.*

Stator Design

Plug-in electric fans typically use AC motors. The stator from a large electric fan is shown in Figure 23-2, where the large diameter of each coil maximizes its magnetic effect. The stator from a smaller electric fan is shown in Figure 23-3, in which only one coil is used. (The coil is wrapped in black electrical tape.)

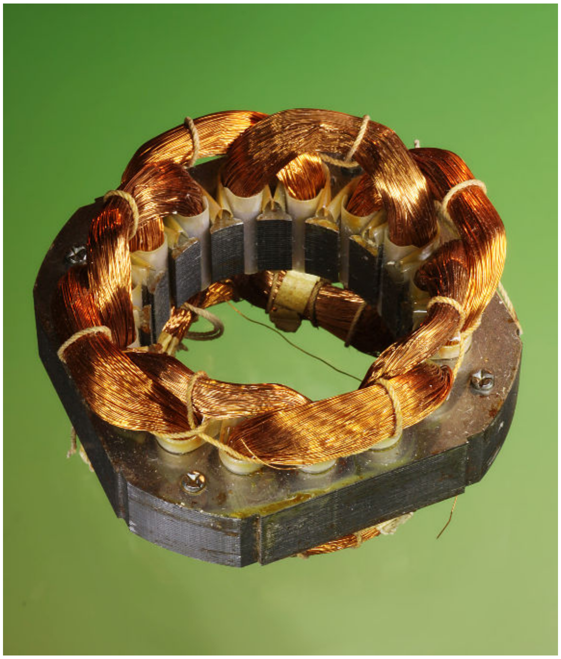

Figure 23-2. *The stator from a large electric fan. Each coil of copper wire is centered on a lug pointing inward to the hole at the center, where the rotor would normally be mounted. The coils overlap because their diameter is maximized to increase their magnetic effect. Each coil is tapped to allow speed selection in steps via an external rotary switch.*

The core of a stator resembles the core of a **transformer** in that it usually consists of a stack of wafers of high-silicon steel (or sometimes aluminum or cast iron). The layers are insulated from one another by thin layers of shellac (or a similar compound) to prevent eddy currents that would otherwise circulate through the entire thickness of the stator, reducing its efficiency.

The coil(s) wound around the stator are often referred to as *field windings*, as they create the magnetic field that runs the motor.

Rotor Design

In most AC motors, the rotor does not contain any coils and does not make any electrical connection with the rest of the motor. It is powered entirely by induced magnetic effects, causing this type of motor to be known generally as an *induction motor*.

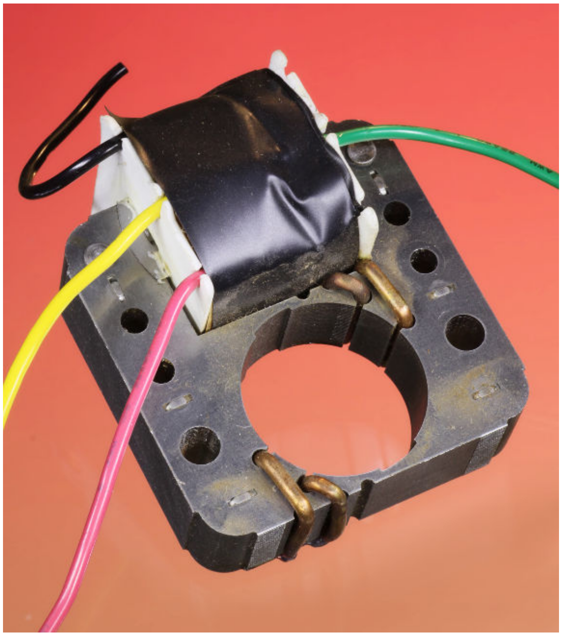

Figure 23-3. *This stator from a smaller electric fan uses only a single coil, wrapped in black tape. It is sufficient to induce a magnetic field but is generally less efficient than a motor using multiple coils.*

As the AC voltage changes from positive to negative, the magnetic force induced in the stator collapses and a new field of opposite polarity is created. Because the stator is designed to create an asymmetrical field, it induces a rotating magnetic field in the rotor. The concept of a rotating magnetic field is fundamental in AC motors.

Like the stator, the rotor is fabricated from wafers of high-silicon steel; embedded in the wafers are nonmagnetic rods, usually fabricated from aluminum but sometimes from copper, oriented approximately parallel to the axis of rotation. The rods are shorted together by a ring at each end of the rotor, forming a conductive "cage," which explains why this device is often referred to colloquially as a *squirrel cage* motor.

Figure 23-4 shows the configuration of a rotor cage with the surrounding steel wafers removed for clarity. In reality, the rods in the cage are almost always angled slightly, as shown in Figure 23-5, to promote smooth running and reduce *cogging*, or fluctuations in torque, which would otherwise occur.

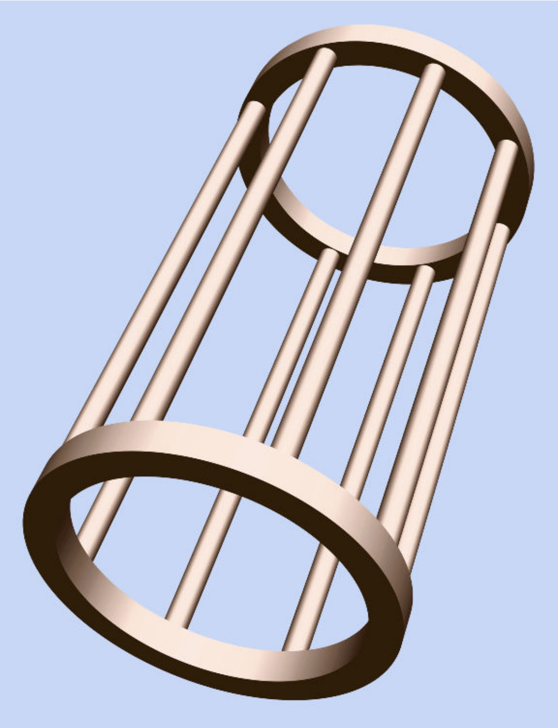

Figure 23-4. *The rotor of a typical AC motor contains a cage of aluminum (or sometimes copper) in which eddy currents occur, as a result of the rotating magnetic field inside the steel body of the rotor (which is omitted here for clarity). These currents cause their own magnetic fields, which interact with the fields generated by coils in the stator.*

In Figure 23-6, the steel wafers of a rotor are shown, with channels to accommodate an angled aluminum cage. Figure 23-7 shows a cross-section of a rotor with the cage elements in pale red and the steel wafer in gray.

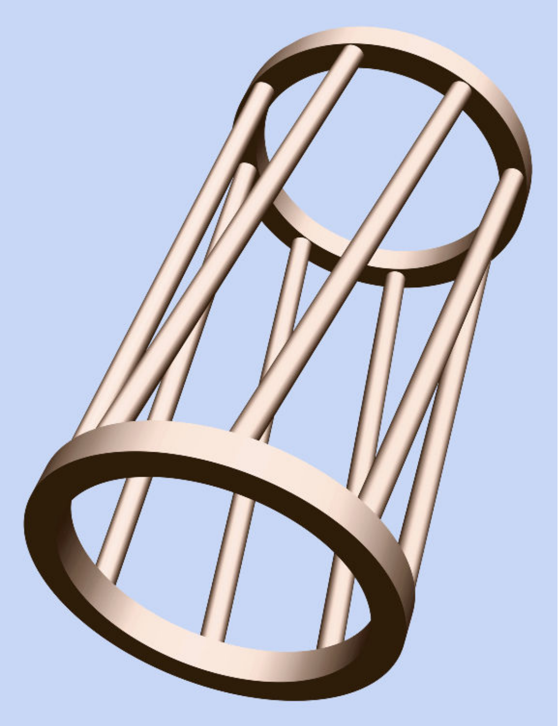

Figure 23-5. *To promote smooth running of the motor, the longitudinal elements of the cage are typically angled, as suggested in this rendering.*

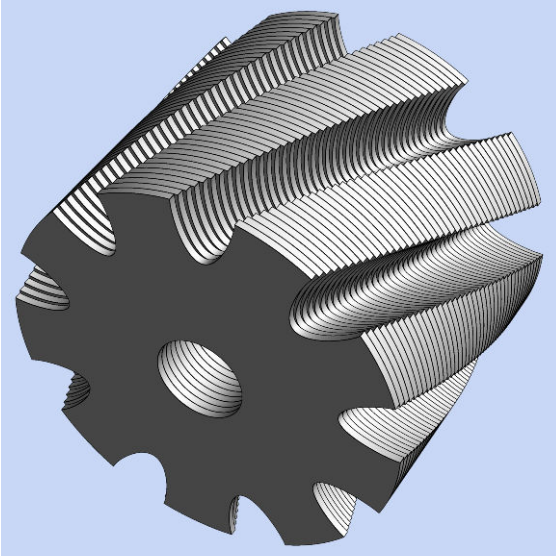

Figure 23-6. *The steel wafers in the rotor of an AC motor are typically offset as shown here. The channels are to accommodate a cage of aluminum or copper conductors.*

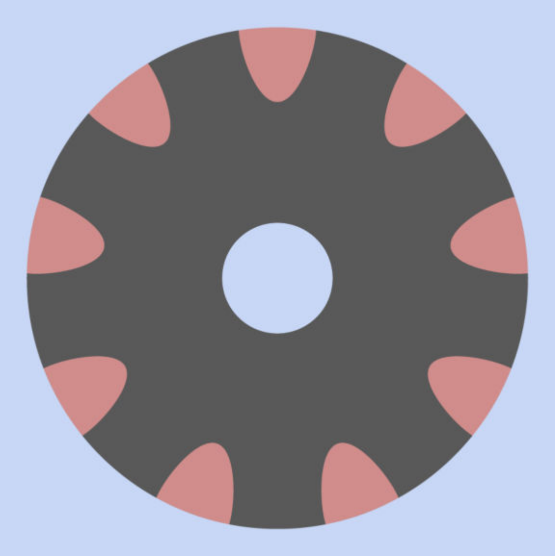

Figure 23-7. *Cross-section of a rotor with steel shown in gray and embedded elements of an aluminum cage shown in pale red.*

The actual rotor from an induction motor is shown in Figure 23-8. This rotor was removed from the stator shown in Figure 23-3. The bearings at either end of the rotor were bolted to the stator until disassembly.

Although the cage is nonmagnetic, it is electrically conductive. Therefore the rotating magnetic field that is induced in the steel part of the rotor generates substantial secondary electric current in the cage, so long as the magnetic field inside the rotor is turning faster than the rotor itself. The current in the longitudinal elements of the cage creates its own magnetic field, which interacts with the fields created by coils in the stator. Attraction and repulsion between these fields causes the rotor to turn.

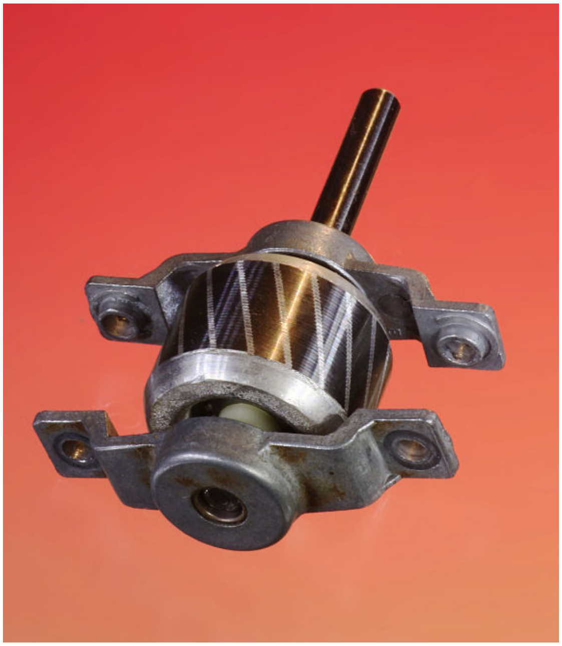

Figure 23-8. *The rotor from a small fan motor. The aluminum cage and its end pieces are the pale gray sections, steel plates are the darker sections.*

Note that if the turning speed of the rotor rises to match the frequency of the alternating current powering the coils in the stator, the cage in the rotor is no longer turning through magnetic lines of force, and ceases to derive any power from them. In an ideal, frictionless motor, its unloaded operating speed would be in equilibrium with the AC frequency. In reality, an induction motor never quite attains that speed.

When power is applied while the rotor is at rest, the induction motor draws a heavy surge of current, much like a short-circuited **transformer**. Electrically, the coils in the stator are comparable to the primary winding of a transformer, while the cage in the rotor resembles the secondary winding. The turning force induced in the stationary rotor is known as *locked-rotor torque*. As the motor picks up speed, its power consumption diminishes. See Figure 23-9.

When the motor is running and a mechanical load is applied to it, the motor speed will drop. As the speed diminishes, the cage of conductors embedded in the rotor will derive more power, as they are turning more slowly than the rotating magnetic field. The speed of rotation of the field is determined by the frequency of the AC power, and is therefore constant. The difference in rota-

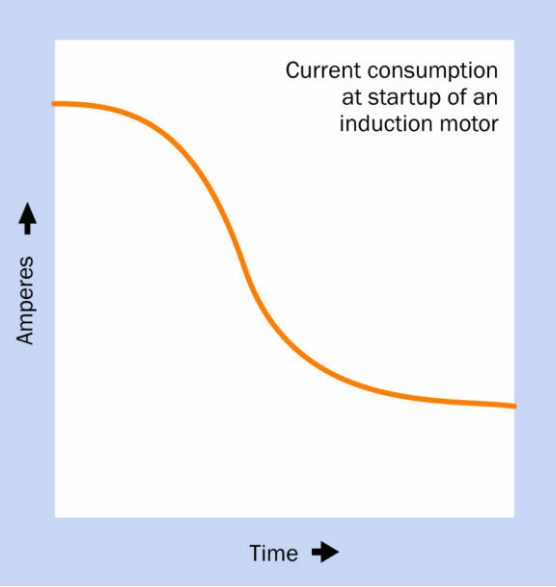

Figure 23-9. *An approximated graph showing the typical current consumption of an AC induction motor as it starts from rest and gains speed over a period of time.*

tional speed between the magnetic field and the rotor is known as *slip*. Higher levels of slip induce greater power, and therefore the induction motor will automatically find an equilibrium for any load within its designed range.

When running under full load, a small induction motor may have a slip value from 4 to 6 percent. In larger motors, this value will be lower.

Variants

Variants of the generic induction motor described above are generally designed to take advantage of either *single-phase* or *three-phase* alternating current.

A *synchronous motor* is a variant in which the rotor maintains a constant speed of rotation regardless of small fluctuations in load.

Some AC motors incorporate a *commutator*, which allows an external connection to coils mounted on the rotor, and can enable variable speed control.

A *linear motor* may consist of two rows of coils, energized by a sequence of pulses that can move a permanent magnet or electromagnet between the coils. Alternatively, the linear motor's coils may move as a result of magnetic interaction with a segmented fixed rail. Detailed description of linear motors is outside the scope of this encyclopedia.

Single-Phase Induction Motor

The majority of induction motors run on single-phase alternating current (typically, from domestic wall outlets). This type of motor is not innately self-starting because the stator coils and rotor are symmetrical. This tends to result in vibration rather than rotation.

To initiate rotation, the stator design is modified so that it induces an asymmetrical magnetic field, which is more powerful in one direction than the other. The simplest way to achieve this is by adding one or more *shorting coils* to the stator. Each shorting coil is often just a circle of heavy-gauge copper wire. This ploy reduces the efficiency of the motor and impairs its starting torque, and is generally used in small devices such as electric fans, where low-end torque is unimportant. Because the shorting coil obstructs some of the magnetic field, this configuration is often known as a *shaded pole* motor.

Copper shorting coils are visible in the fan motor shown in Figure 23-3.

A **capacitor** is a higher-cost but more efficient alternative to a shorting coil. If power is supplied to one or more of the stator coils through a capacitor, it will create a phase difference between these coils and the others in the motor, inducing an asymmetrical magnetic field. When the motor reaches approximately 80% of its designed running speed, a centrifugal switch may be included to take the capacitor out of the circuit, since it is no longer necessary. Switching out the capacitor and substituting a direct connection to the stator coils will improve the efficiency of the motor.

A third option to initiate rotation is to add a second winding in the stator, using fewer turns of smaller-gauge wire, which have a higher resistance than the main winding. Consequently the magnetic field will be angled to encourage the motor to start turning. This configuration is known as a *split-phase* induction motor, in which the starter winding is often referred to as the *auxilliary winding* and consists of about 30% of the total stator windings in the motor. Here again, a centrifugal switch can be incorporated, to eliminate the secondary winding from the circuit when the motor has reached 75 to 80 percent of its designed running speed.

The relationship between motor speed and torque of the three types of motors described above is shown in Figure 23-10. These curves are simplified and do not show the effect that would be produced by introducing a centrifugal switch.

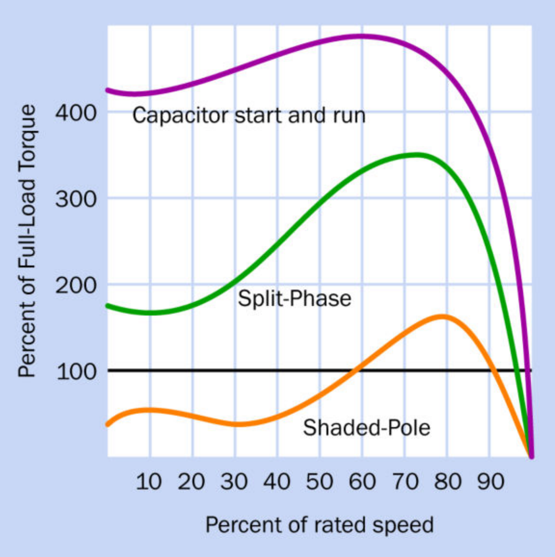

Figure 23-10. *Approximate curves showing the relationship between speed and torque for three types of single-phase induction motor. (Graph derived from AC Induction Motor Fundamentals published by Microchip Technology Inc.)*

Three-Phase Induction Motor

Larger induction motors are often *three-phase* devices. Three-phase AC (which is by far the most common form of *polyphase* AC) is delivered by a power utility company or generator via three wires, each of which carries alternating current with a phase difference of 120 degrees relative to the other two, usually for industrial applications. A common configuration of stator coils for a three-phase motor is shown in Figure 23-11. Since the three wires take it in turns to deliver their peak voltage, they are ideally suited to turn the stator of a motor via induction, and no shorting coil or capacitor is needed for startup. Heavy-duty 3-phase induction motors are extremely reliable, being brushless and generally maintenance-free.

Synchronous Motor

A synchronous motor is a form of induction motor that is designed to reach and maintain equilibrium when the rotor is turning in perfect synchronization with the AC power supply. The speed of the motor will depend on the number of poles (magnetic coils) in the stator, and the number of phases in the power supply. If R is the RPM of a synchronous motor, f is the frequency of the AC current in Hz, and p is the number of poles per phase:

```
R = (120 * f) / p
```

This formula assumes 60Hz AC current. In nations where 50Hz AC is used, the number 120 should be replaced with the number 100.

Two basic types of synchronous motors exist: *direct current excited*, which require external power to start turning, and *non-excited*, which are self-starting. Since non-excited synchronous motors are more common in electronic applications, this encyclopedia will not deal with direct current excited variants.

A *hysteresis motor* is a synchronous motor containing a solid rotor cast from cobalt steel, which has high coercivity, meaning that once it is magnetized, a substantial field is required to reverse the magnetic polarity. Consequently the polarity of the rotor lags behind the constantly changing

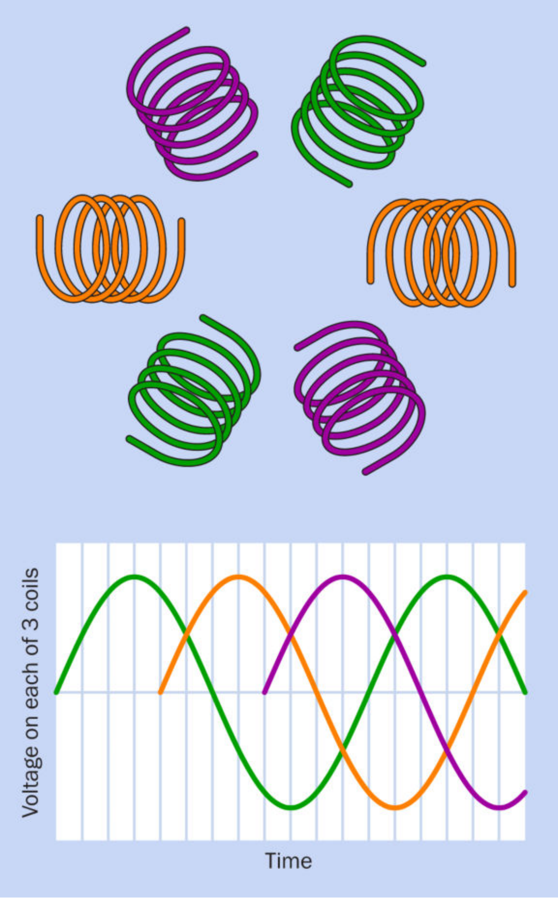

Figure 23-11. *The graph shows voltage delivered via three wires constituting a three-phase power supply. (The curve colors are arbitrary.) A three-phase motor contains a multiple of three coils—often six, as shown here diagrammatically. The three wires of the power supply are connected directly to the coils, which induce a rotating magnetic field.*

polarity of the stator, creating an attracting force that turns the rotor. Because the lag angle is independent of motor speed, this motor delivers constant torque from startup.

Reluctance Motor

Reluctance is the magnetic equivalent to electrical resistance. If a piece of iron is free to move in a magnetic field, it will tend to align itself with the field to reduce the reluctance of the magnetic circuit. This principle was used in very early reluctance motors designed to work from AC and has been revived as electronics to control variable frequency drives have become cheaper.

The simplest reluctance motor consists of a soft iron rotor with projecting lugs, rotating within a stator that is magnetically energized with its own set of inwardly projecting poles. The rotor tends to turn until its lugs are aligned with the poles of the stator, thus minimizing the reluctance.

A basic reluctance motor design is shown in Figure 25-2. It is located in the **stepper motor** section of this encyclopedia, as stepper motors are a primary application of the reluctance principle.

Although a reluctance motor can be used with polyphase fixed-frequency AC power, a variable frequency drive greatly enhances its usefulness. The timing of the frequency is adjusted by the speed of the motor, which is detected by a sensor. Thus the energizing pulses can remain “one step ahead” of the rotor. Since the rotor is not a magnet, it generates no back-EMF, allowing it to reach very high speeds.

The simplicity of the motor itself is a compensating factor for the cost of the electronics, as it requires no commutator, brushes, permanent magnets, or rotor windings. Characteristics of reluctance motors include:

- Cheap parts, easily manufactured, and high reliability.
- Compact size and low weight.
- Efficiencies greater than 90% possible.
- Capable of high start-up torque and high speed operation.

Disadvantages include noise, cogging, and tight manufacturing tolerances, as the air gap between the rotor and stator must be minimized.

A reluctance motor can function synchronously, if it is designed for that purpose.

Variable Frequency Drive

A basic induction motor suffers from significant problems. The surge of power that it draws when starting from rest can pull down the supply voltage enough to affect other devices that share the AC power supply. (Hence, the brief dimming of lights that may occur when the compressor in an air conditioner or refrigerator starts running.) While the motor is turning, it can introduce electrical noise, which feeds back into the power supply, once again causing potential problems for other devices. In addition, the narrow range of speed of an AC induction motor is a great disadvantage.

The advent of cheap solid-state technology encouraged the development of *variable-frequency power supplies* for induction motors. Because the impedance of the motor will diminish as the frequency diminishes, the current drawn by the motor will tend to increase. To prevent this, a variable frequency supply also varies the voltage that it delivers.

Wound-Rotor AC Induction Motor

The stator of this variant is basically the same as that of a single-phase induction motor, but the rotor contains its own set of coils. These are electrically accessible via a *commutator* and *brushes*, as in a **DC motor**. Because the maximum torque (also known as *pull-out* torque) will be proportional to the electrical resistance of the coils in the rotor, the characteristics of the motor can be adjusted by adding or removing resistance externally, via the commutator. A higher resistance will enable greater torque at low speed when the slip between the rotor speed and rotation of the magnetic field induced by the stator is greatest. This is especially useful in corded power tools such as electric drills, where high torque at low speed is desirable, yet the motor can accelerate to full speed quickly when the external resistance is reduced. Typically, the resistance is adjusted via the trigger of the drill.

Figure 23-12 shows a wound-rotor AC induction motor. The disadvantage of this configuration is the brushes that supply power to the rotor will eventually require maintenance. Much larger wound-rotor motors are also used in industrial applications such as printing presses and elevators, where the need for variable speed makes a simple three-phase motor unsuitable.

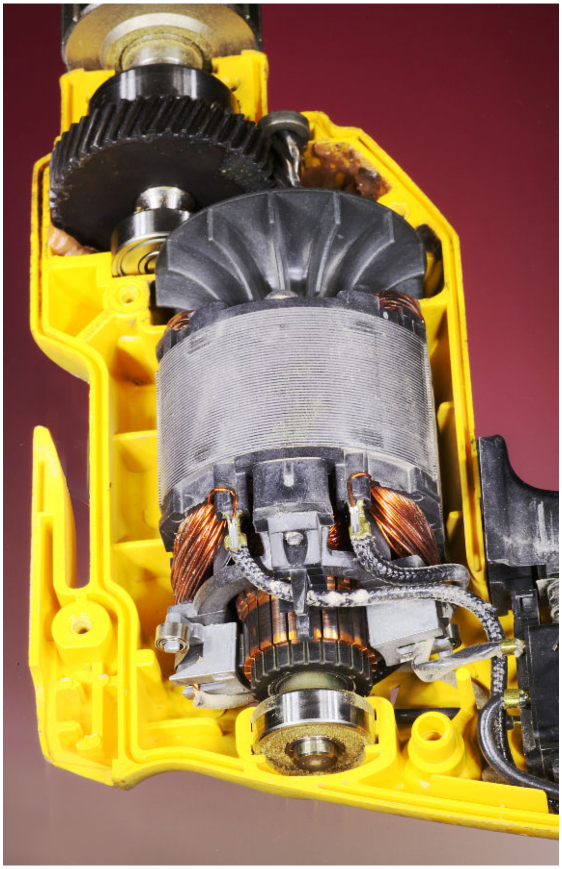

Figure 23-12. *A motor in a corded electric drill uses coils in a brushed rotor to enable variable speed output. In most AC motors, the speed is not adjustable and the rotor does not make any electrical connection with the rest of the motor.*

Universal Motor

A wound-rotor motor may also be described as a *universal motor* if its rotor and stator coils are connected in series. This configuration allows it to be powered by either AC or DC.

DC supplied to the rotor and the stator will cause mutual magnetic repulsion. When the rotor turns, the brushes touching the split commutator reverse the polarity of voltage in the rotor coils, and the process repeats. This configuration is very similar to that of a conventional DC motor, except that the stator in a universal motor uses electromagnets instead of the permanent magnets that are characteristic of a **DC motor**.

When powered by AC, the series connection between stator and rotor coils insures that each pulse to the stator will be duplicated in the rotor, causing mutual repulsion. The addition of a shorting coil in the stator provides the necessary asymmetry in the magnetic field to make the motor start turning.

Universal motors are not limited by AC frequency, and are capable of extremely high-speed operation. They have high starting torque, are compact, and are cheap to manufacture. Applications include food blenders, vacuum cleaners, and hair dryers. In a workshop, they are found in routers and miniature power tools such as the Dremel series.

Because a universal motor requires commutator and brushes, it is only suitable for intermittent use.

Inverted AC Motors

Some modern domestic appliances may seem to contain an AC motor, but in fact the AC current is *rectified* to DC and is then processed with pulse-width modulation to allow variable speed control. The motor is really a **DC motor**; see the entry on this type of motor for additional information.

Values

Because a basic AC induction motor is governed by the frequency of the power supply, the speed of a typical four-pole motor is limited to less than 1,800 RPM (1,500 RPM in nations where 50Hz AC is the norm).

Variable-frequency, universal, and wound-rotor motors overcome this limitation, and can reach speeds of 10,000 to 30,000 RPM. Synchronous motors typically run at 1,800 or 1,200 RPM, depending on the number of poles in the motor. (They run at 1,500 or 1,000 RPM in locations where the frequency of AC is 50Hz rather than 60Hz).

For a discussion of the torque that can be created by a motor, see "Values" (page 184) in the **DC motor** entry in this encyclopedia.

How to Use It

Old-fashioned record players (where a turntable supports a vinyl disc that must rotate at a fixed speed) and electric clocks (of the analogue type) were major applications for synchronous motors, which used the frequency of the AC power supply to control motor speed. These applications have been superceded by CD players (usually powered by brushless DC motors) and digital clocks (which use crystal oscillators).

Many home appliances continue to use AC-powered induction motors. Small cooling fans for use in electronic equipment are sometimes AC-powered, reducing the current that must be provided by the DC power supply. An induction motor generally tends to be heavier and less efficient than other types, and its speed limit imposed by the frequency of the AC power supply is a significant disadvantage.

A simple induction motor cannot provide the sophisticated control that is necessary in modern devices such as CD or DVD players, ink-jet printers, and scanners. A **stepper motor**, **servo motor**, and **DC motors** controlled with *pulse-width modulation* are preferable in these applications.

A *reluctance motor* may find applications in high-speed, high-end equipment including vacuum cleaners, fans, and pumps. Large variable reluctance motors, with high amperage ratings, may be used to power vehicles. Smaller variants are being used for power steering systems and windshield wipers in some automobiles.

What Can Go Wrong

Compared with other devices that have moving parts, the brushless induction motor is one of the most reliable and efficient devices ever invented. However, there are many ways it can be damaged. General problems affecting all types of motors are listed at "Heat effects" (page 188). Issues relating specifically to AC motors are listed below.

Premature Restart

Large industrial three-phase induction motors can be damaged if power is reapplied before the motor has stopped rotating.

Frequent Restart

If a motor is stopped and started repeatedly, the heat that is generated during the initial surge of current is likely to be cumulative.

Undervoltage or Voltage Imbalance

A voltage drop can cause the motor to draw more current than it is rated to handle. If this situation persists, overheating will result. Problems also are caused in a three-phase motor where one phase is not voltage-balanced with the others. The most common cause of this problem is an open circuit-breaker, wiring fault, or blown fuse affecting just one of the three conductors. The motor will try to run using the two conductors that are still providing power, but the result is likely to be destructive.

Stalled Motor

When power is applied to an induction motor, if the motor is prevented from turning, the conductors in the rotor will carry a large current that is entirely dissipated as heat. This current surge will either burn out the motor or blow a fuse or circuit breaker. Care should be taken, in equipment design, to minimize the risk that an induction motor may stall or jam.

Protective Relays

Sophisticated protective relays are available for industrial 3-phase motors, and can guard against all of the faults itemized above. Their details are outside the scope of this encyclopedia.

Excess Torque

As has been previously noted, the torque of an induction motor increases with the slip (speed difference) between the rotation of the magnetic field and the rotation of the rotor. Consequently, if the motor is overloaded and forced to run more slowly, it can deliver more rotational force. This can destroy other parts attached to the motor, such as drive belts.

Internal Breakage

An overloaded induction motor may suffer some cracking or breakage of its rotor. This may be obvious because of reduced power output or vibration, but can also be detected if the motor's power consumption changes significantly.

servo motor

24

Should be referred to as an *RC servo* if it is intended for use in small devices that are remote-controlled and battery powered. However, in practice, the RC acronym is often omitted.

OTHER RELATED COMPONENTS

- **AC motor** (See Chapter 23)
- **DC motor** (See Chapter 22)
- **stepper motor** (See Chapter 25)

What It Does

A servo motor is actually a combination of a motor, reduction gearing, and miniaturized control electronics, usually packaged together inside a very compact sealed plastic case. The motor itself may be AC or DC, and if DC, it may be brushed or brushless. What distinguishes a servo from other types of motor is that it is not designed for continuous rotation. It is a position-seeking device. Its rotational range may be more than 180 degrees but will be significantly less than 360 degrees. Two typical RC servos are shown in Figure 24-1. A side view of a motor is shown in Figure 24-2.

The electronics inside the motor enclosure interpret commands from an external controller. The command code specifies the desired turn angle measured as an offset either side of the center position of the motor's range. The motor turns quickly to the specified position and stops there. So long as the command signal continues and power to the motor is sustained, the motor will hold its position and "push back" against any external turning force. In the absence of such a force, while the motor is stationary, it will use very little current.

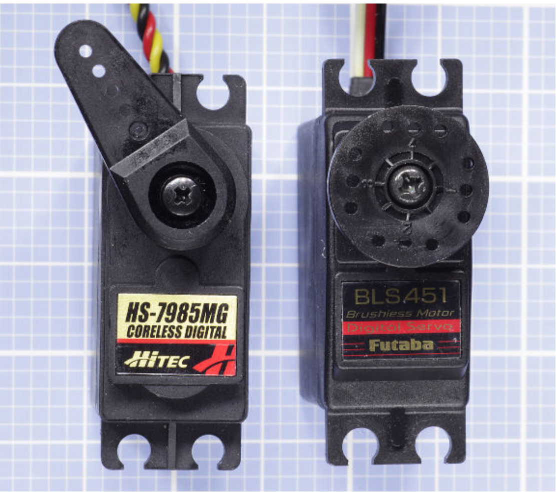

Figure 24-1. *A typical RC servo motor is capable of more than 50 inch-ounces of torque yet can be driven by three or four AA alkaline cells in series, and weighs under 2 ounces.*

The electronics inside a typical RC servo motor are shown in Figure 24-3.

How It Works

Servo motors are generally controlled via *pulse-width modulation* (*PWM*).

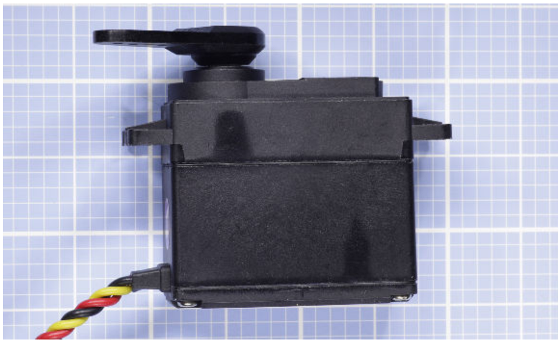

Figure 24-2. *RC servo motors are mostly similar in size. This is a typical side view.*

An industrial servo typically requires a controller that is an off-the-shelf item sold by the manufacturer of the motor. The encoding scheme of the control signals may be proprietary. A heavy-duty servo may be designed to run from three-phase power at a relatively high voltage, and may be used in applications such as production-line automation.

The remainder of this encyclopedia entry will focus primarily on small RC servos rather than industrial servos.

For small RC servos, the stream of control pulses is at a constant frequency of 20ms, with the positive durations of each pulse being interpreted as a positioning command to the motor, and the gaps between the pulses being disregarded. A typical range of pulse widths for a small motor is 1ms to 2ms, specifying a range of -90 to +90 degrees either side of a center location. Many modern motors are capable of excursions beyond these limits, and can be calibrated to establish the precise relationship between pulse width and turn angle. The motor can then be controlled by a lookup table in microcontroller software, or by using a conversion factor between degree-angle and pulse width.

Figure 24-4 shows the typical range of pulse widths within the fixed 20ms period (a frequency of 50Hz) between the start of one pulse and the start of the next, and the meaning of each pulse width to the servo motor. Intermediate pulse widths are interpreted as instructions to rotate to intermediate positions.

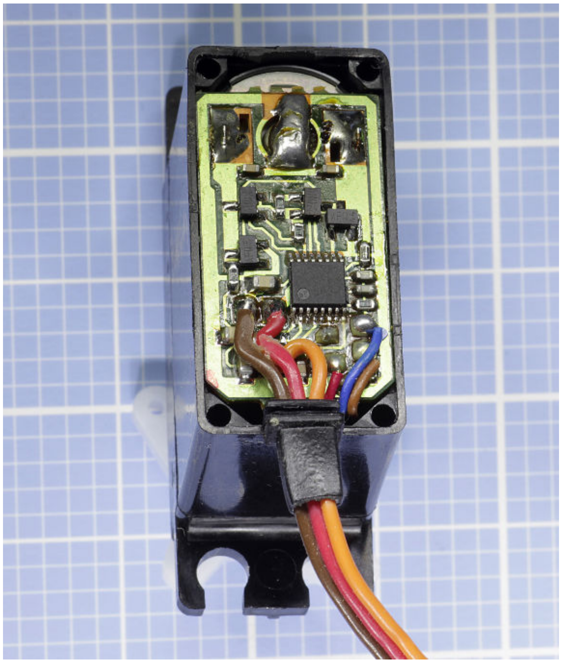

Figure 24-3. *The electronics inside a servo motor decode a stream of pulses that specify the turn angle of the motor.*

Small servo motors require the user to provide a controller that will conform with the above specification. This is often achieved by programming a *microcontroller*, and some microcontroller chips make this especially easy by providing a PWM output specifically tailored to the requirements of an RC servo. Either way, the microcontroller can be directly connected to the servo, enabling an extremely simple and flexible way to manage a positioning device.

Alternatively, a simple pulse generator such as a *555 timer chip* can be used, or controller boards are available from hobbyist supply sources. Some controller boards have USB connections enabling a servo to be governed by computer software.

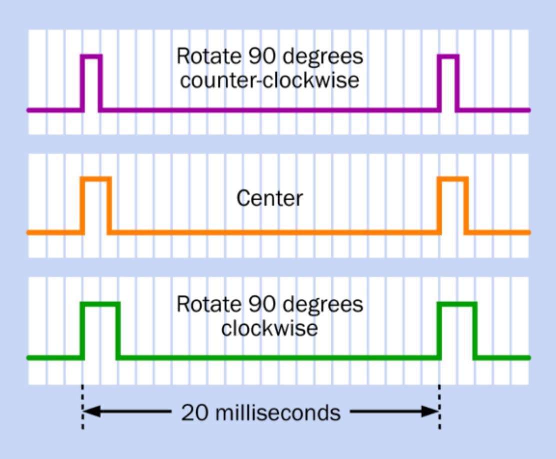

Figure 24-4. *The turn angle of a small RC servo motor is determined by a pulse width from a controller ranging from 1ms to 2ms in duration. The frequency of the pulses is constant at 50Hz.*

In Figure 24-5, a schematic illustrates the connection of a 555 timer with an RC servo, with component values to create a constant frequency of about 48Hz (slightly more than 20ms from peak to peak). The 1μF capacitor in the circuit charges through the 2.2K resistor in series with the diode, which bypasses the 28K resistor. This charging time represents the "on" cycle of the timer chip. The capacitor discharges through the 28K resistor, representing the "off" cycle. The 1K potentiometer, in series with the 5K resistors, acts as a voltage divider applied to the control pin of the timer, adjusting the timer's charge and discharge thresholds. Turning the potentiometer will lengthen or shorten the "on" time of each cycle, without changing the frequency. In practice, because capacitors are manufactured with wide tolerances, the frequency of the timer output cannot be guaranteed. Fortunately most servos will tolerate some inaccuracy.

Since the motor shares the power supply of the timer in this circuit, a protection diode and capacitor have been added between the power supply to the motor and negative ground, to suppress noise and back-EMF.

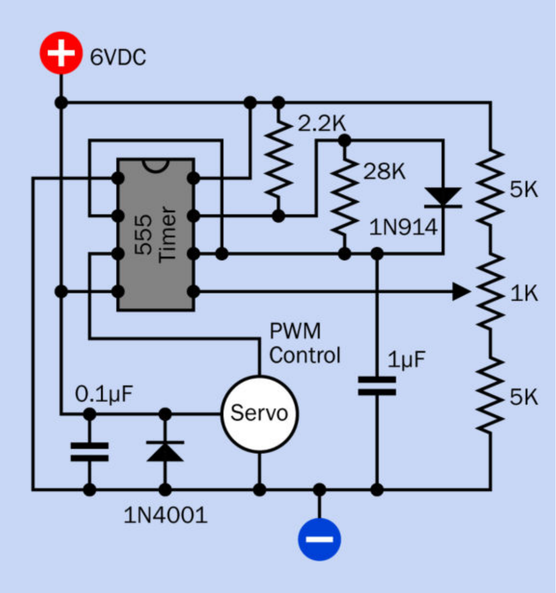

Figure 24-5. *An RC servo can be controlled via a 555 timer with appropriate component values. The potentiometer determines the angular position of the servo.*

Inside a servo motor's casing, the electronics include a **potentiometer** that turns with the output shaft, to provide feedback confirming the motor's position. The limited turning range of the potentiometer determines the turn limits of the motor output shaft.

Variants

Small servos may contain brushed or brushless DC motors. Naturally the brushless motors have greater longevity and create less electrical noise. See the **DC motor** entry in this encyclopedia for a discussion of brushed versus brushless motors.

Servos may use nylon, "Karbonite," or metal reduction gearing. The nylon gears inside a cheaper RC servo are shown in Figure 24-6.

Brushless motors and metal gears add slightly to the price of the motor. Metal gears are stronger than nylon (which can crack under load) but may wear faster, leading to *backlash* and inaccuracy in the gear train. The friction between nylon-to-nylon surfaces is very low, and nylon is certainly

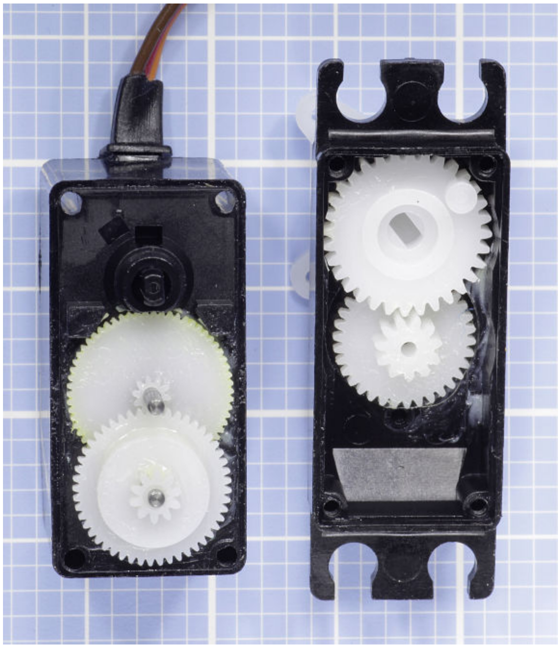

Figure 24-6. *Nylon gearing inside a servo motor.*

adequate and may be preferable if a servo will not be heavily loaded. "Karbonite" is claimed to be five times stronger than nylon and may be a satisfactory compromise. If a gear set experiences a failure (for example, teeth can be stripped as a result of excessive load), manufacturers usually will sell a replacement set to be installed by the user. Installation requires manual dexterity and patience, and some skill.

Servos may have roller bearings or plain sintered bearings, the latter being cheaper but much less durable under side loading.

So-called *digital servos* use faster internal electronics than the older, so-called *analog servos*, and because they sample the incoming pulse stream at a higher frequency, they are more responsive to small, rapid commands from the controller. For this reason they are preferred by hobbyists using servos to control the flight of model airplanes. Externally, the control protocol for digital and analog servos is the same, although a digital servo can be reprogrammed with new code values establishing the limits to its range. A standalone programming unit must be purchased to achieve this.

The most popular manufacturers of small servo motors are Futaba and Hitec. While their control protocols are virtually identical, the motor output shafts differ. The shaft is typically known as the *spline*, and is grooved to fit push-on attachments. The spline of a Futaba motor has 25 grooves, while Hitec uses 24 grooves. Attachments must be appropriate for the brand of motor that has been chosen.

Values

A small servo typically weighs 1 to 2 ounces, has a rotation time of 1 to 2 seconds from one end of its travel to the other, and can exert a surprisingly robust torque of 50 ounce-inches or greater.

Voltage

Small servos were originally designed to run from 4.8V rechargeable batteries in model aircraft. They can be driven with 5VDC to 6VDC on a routine basis. A few servos are designed for higher voltages.

Amperage

The datasheets provided by most manufacturers often fail to specify the power that a servo will draw when it is exerting maximum torque (or indeed, any torque at all). Since small servos are often driven by three or four AA alkaline batteries in series, the maximum current draw is unlikely to be much greater than 1 amp. When the motor is energized but not turning, and is not resisting a turning force, its power consumption is negligible. This feature makes servos especially desirable for remote-controlled battery-powered devices.

Some motors that have a turning range exceeding 180 degrees will respond to pulses of less than 1ms or greater than 2ms. A newly acquired motor should be tested with a microcontroller that steps through a wide range of pulse durations, to determine the limits empirically. Pulses that are outside the motor's designed range will generally be ignored and will not cause damage.

The *turn rate* or *transit time* specified in a datasheet is the time a servo takes to rotate through 60 degrees, with no load on the output shaft. A high-torque servo generally achieves its greater turning force by using a higher reduction gear ratio, which tends to result in a longer transit time.

How to Use it

Typical applications for a small servo include rotating the flaps or rudder of a model aircraft, steering a model boat, model car, or wheeled robot, and turning robotic arms.

A servo generally has three wires, colored red (power supply), black or brown (ground), and orange, yellow, or white (for the pulse train from the controller). The ground wire to the motor must be common with the ground of the controller, and consequently a ceramic bypass **capacitor** of 0.1µF or 0.01µF should be placed between the (red) power wire to the motor and ground. A protection **diode** should also be used. Neither a diode nor a capacitor should be attached to the wire carrying control signals, as it will interfere with the pulse train.

When powering the motor, an AC adapter should only be used with some caution, as its power output may be inadequately smoothed. A voltage regulator is not necessary, but bypass **capacitors** are mandatory. Figure 24-7 shows two hypothetical schematics. The upper section of the figure shows a battery-driven system, possibly using four 1.2V NiMH rechargeable batteries. Since batteries do not generally create voltage spikes, no capacitors are used, but a diode is included to protect the microcontroller from EMF when the servo stops and starts. The lower section of the figure shows the additional precautions that may be necessary when using DC power from an **AC adapter**. The DC-DC **converter**, which derives 6VDC for the motor requires smoothing capacitors (this should be specified in its datasheet), and so does the **voltage regulator**, which delivers regulated 5VDC power to the microcontroller. Once again, the protection diode is included. In both diagrams, the orange wire represents the control wire transmitting pulses to the servo motor.

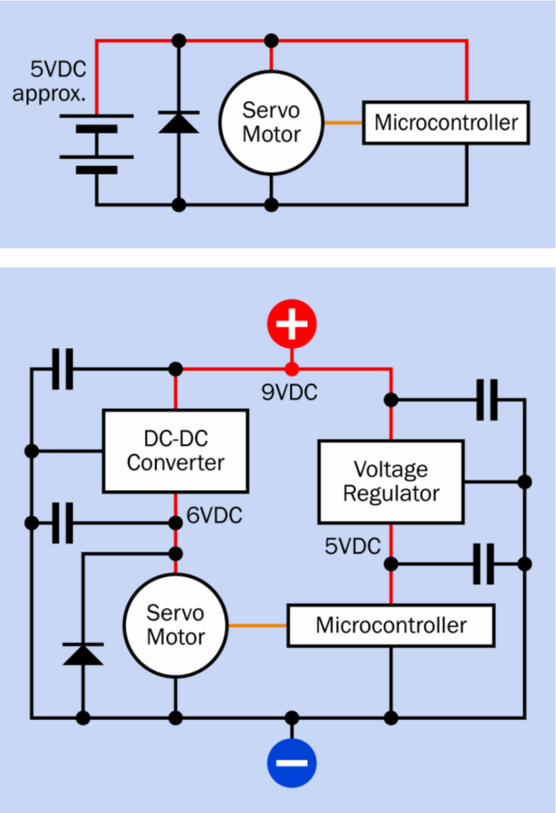

Figure 24-7. *Two possible schematics to run a small servo motor, the upper example using battery power (for example, from four 1.2V NiMH cells) and the lower example using a 9VDC AC adapter. See text for additional explanation.*

Various shaft attachments are available from the same online hobby-electronics suppliers that sell servos. The attachments include discs, single arms, double arms, and four arms in a cross-shaped configuration. A single-arm attachment is often known as a *horn*, and this term may be applied loosely to any kind of attachment. The horn is usually perforated so that other components can be fixed to it by using small screws or nuts and bolts. Figure 24-8 shows a variety of horns.

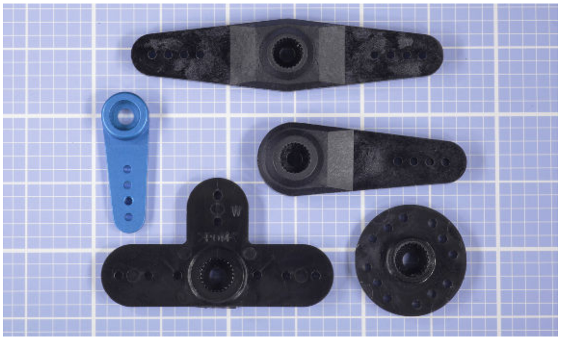

Figure 24-8. *Various shaft attachments, known as horns, are available from motor manufacturers. The blue one is metallic; the others are plastic.*

After the horn is pushed onto the spline (the motor shaft), it is held in place with one central screw. As previously noted, the two major manufacturers of small servos, Futaba and Hitec, have incompatible splines.

Modification for Continuous Rotation

It is possible to modify a small servo motor so that it will rotate continuously.

First the motor case must be opened, and the potentiometer must be centered by using a controller to send some 1.5ms pulses. The potentiometer must then be glued or otherwise secured with its wiper in this precise center position, after which the potentiometer is disconnected from the drive train.

Mechanical stops that would limit the rotation of the motor shaft must be cut away, after which the motor is reassembled. Because the potentiometer has been immobilized, the motor's internal electronics will now "see" the shaft as being in its center position at all times. If the controller sends a pulse instructing the motor to seek a position clockwise or counter-clockwise from center, the motor will rotate in an effort to reach that position. Because the potentiometer will not provide feedback to signal that the motor has achieved its goal, the shaft will continue to rotate indefinitely.

In this mode, the primary distinguishing characteristic of the servo has been disabled, in that it can no longer turn to a specific angle. Also, stopping the servo may be problematic, as it must receive a command that precisely matches the fixed position of the potentiometer. Since the potentiometer may have moved fractionally during the process in which it was immobilized, some trial and error may be needed to determine the pulse width that corresponds with the potentiometer position.

The purpose of modifying a servo for continuous rotation is to take advantage of its high torque, small size, light weight, and the ease of controlling it with a microcontroller.

In response to the interest shown by hobbyists in modifying servos for continuous rotation, some manufacturers now market servos with continuous rotation as a built-in feature. Typically they include a trimmer potentiometer to calibrate the motor, to establish its center-off position.

What Can Go Wrong

Incorrect Wiring

The manufacturer's datasheet should be checked to confirm the color coding of the wires. While a simple DC motor can be reversed by inverting the polarity of its power supply, this is totally inappropriate for a servo motor.

Shaft/Horn Mismatch

Attachments for the spline of one brand of motor may not fit the spline of another brand, and cannot be forced to fit.

Unrealistically Rapid Software Commands

Microcontroller software that positions a servo must allow sufficient time for the servo to respond before the software specifies a new position. It may be necessary to insert delay loops or other wait times in the software.

Jitter

A servo arm that twitches unpredictably usually indicates that the pulse train is being corrupted by external electrical noise. The control wire to the servo should be as short as possible, and should not run closely adjacent to conductors carrying AC or high frequency current switching, or control wires for other servo motors.

Motor Overload

A servo capable of delivering 2 lbs of force 1 inch from its shaft can easily generate enough torque, when it stalls, to break itself free from its mounts, or bend or break any arm or linkage attached to its shaft. Ideally, a relatively "weak link" should be included so that if breakage occurs, it will be predictable and will be relatively easy and cheap to repair.

Unrealistic Duty Cycle

Small servos are designed for intermittent use. Constant cycling will cause wear and tear, especially if the motor has a brushed commutator or metal reduction gears.

Electrical Noise

Brushed motors are always a source of electrical interference, and any servo will also tend to create a voltage dip or surge when it starts and stops. A protection diode may be insufficient to isolate sensitive microcontrollers and other integrated circuit chips. To minimize problems, the servo can be driven by a source of positive voltage that is separate from the regulated power supply used by the chips, and larger filter capacitors may be added to the voltage supply of the microcontroller. A common ground between the motor and the chips is unfortunately unavoidable.

25

stepper motor

Also often referred to as a *stepping motor*, and sometimes known as a *step motor*. It is a type of *induction motor* but merits its own entry in this encyclopedia as it has acquired significant and unique importance in electronics equipment where precise positioning of a moving part is needed and digital control is available.

OTHER RELATED COMPONENTS

- **DC motor** (See Chapter 22)
- **AC motor** (See Chapter 23)
- **servo motor** (See Chapter 24)

What It Does

A stepper motor rotates its drive shaft in precise steps in response to a timed sequence of pulses (usually one step per pulse). The pulses are delivered to a series of coils or *windings* in the *stator*, which is the stationary section of the motor, usually forming a ring around the *rotor*, which is the part of the motor that rotates. Steps may also be referred to as *phases*, and a motor that rotates in small steps may be referred to as having a high *phase count*.

A stepper motor theoretically draws power for its stator coils at a constant level that does not vary with speed. Consequently the torque tends to decrease as the speed increases, and conversely, it is greatest when the motor is stationary or locked.

The motor requires a suitable control system to provide the sequence of pulses. The control system may consist of a small dedicated circuit, or a microcontroller or computer with the addition of suitable driver transistors capable of handling the necessary current. The torque curve of a motor can be extended by using a controller that increases the voltage as the speed of the control pulses increases.

Because the behavior of the motor is controlled by external electronics, and its interior is usually symmetrical, a stepper motor can be driven backward and forward with equal torque, and can also be held in a stationary position, although the stator coils will continue to consume power in this mode.

How It Works

The stator has multiple poles made from soft iron or other magnetic material. Each pole is either energized by its own coil, or more commonly, several poles share a single, large coil. In all types of stepper motor, sets of stator poles are magnetized sequentially to turn the rotor and can remain energized in one configuration to hold the rotor stationary.

The rotor may contain one or more permanent magnets, which interact with the magnetic fields generated in the stator. Note that this is different from a *squirrel-cage* **AC motor** in which a "cage" is embedded in the rotor and interacts with a rotating magnetic field, but does not consist of permanent magnets.

Three small stepper motors are shown in Figure 25-1. Clockwise from the top-left, they are four-wire, five-wire, and six-wire types (this distinction is explained in the following section). The motor at top-left has a threaded shaft that can engage with a collar, so that as the motor shaft rotates counter-clockwise and clockwise, the collar will be moved down and up.

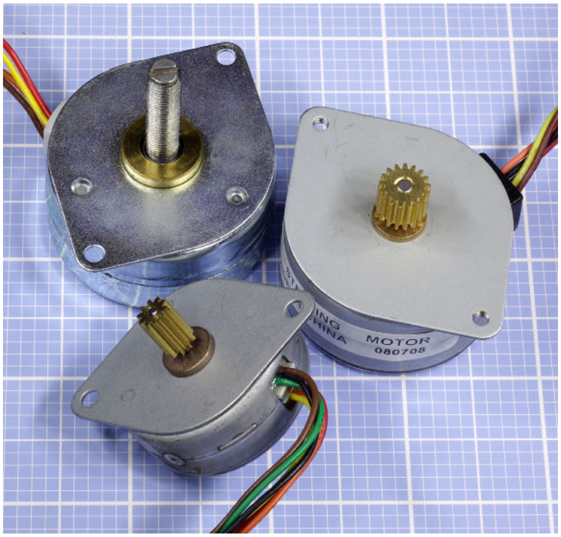

Figure 25-1. *Three small stepper motors.*

Reluctance Stepper Motors

The simplest form of stepper motor uses a rotor that does not contain permanent magnets. It relies on the principle of *variable reluctance*, reluctance being the magnetic equivalent of electrical *resistance*. The rotor will tend to align its protruding parts with the exterior source(s) of the magnetic field, as this will reduce the reluctance in the system. Additional information about variable reluctance is included in "Reluctance Motor" (page 197) in the section of this encyclopedia dealing with the **AC motor**.

A variable reluctance motor requires an external controller that simply energizes the stator coils sequentially. This is shown in Figure 25-2, where six poles (energized in pairs) are arrayed symmetrically around a rotor with four protrusions, usually referred to as *teeth*. Six stator poles and four teeth are the minimum numbers for reliable performance of a reluctance stepper motor.

In the diagram, the core of each pole is tinted green when it is magnetized, and is gray when it is not magnetized. In each section of this diagram, the stator coils are shown when they have just been energized, and the rotor has not yet had time to respond. External switching to energize the coils has been omitted for simplicity. In a real motor, the rotor would have numerous ridges, and the clearance between them and the stator would be extremely narrow to maximize the magnetic effect.

In a 6-pole reluctance motor where the rotor has four teeth, each time the controller energizes a new pair of poles, the rotor turns by 30 degrees counter-clockwise. This is known as the *step angle*, and means that the motor makes 12 steps in each full 360-degree rotation of its shaft. This configuration is very similar to that of a 3-phase AC *induction motor*, as shown in Figure 23-11 in the **AC motor** section of this encyclopedia. However, the AC motor is designed to be plugged into a power source with a constant frequency, and is intended to run smoothly and continuously, not in discrete steps.

Generally, reluctance motors tend to be larger than those with magnetized rotors, and often require feedback from a sensor that monitors shaft angle and provides this information to control electronics. This is known as a *closed loop* system. Most smaller stepper motors operate in an *open loop* system, where positional feedback is considered unnecessary if the number of pulses to the motor is counted as a means of tracking its position.

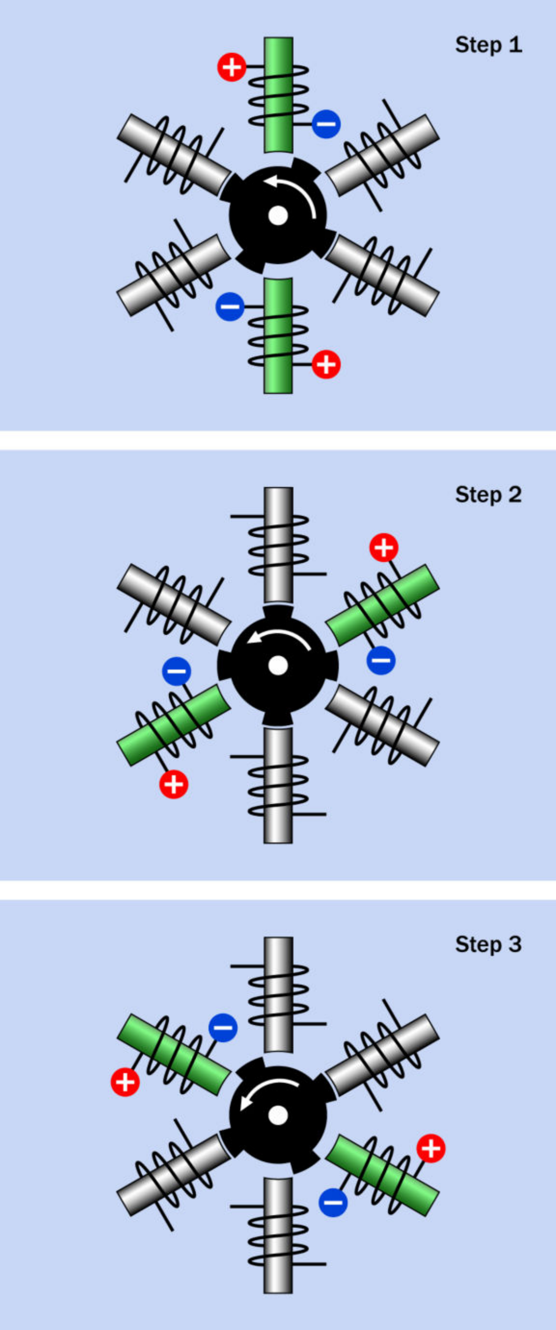

Figure 25-2. *In a variable reluctance stepper motor, the rotor moves to minimize magnetic reluctance each time the next pair of coils is energized. At each step, the coils have been energized a moment before the rotor has had time to respond.*

Permanent Magnet Stepper Motors

More commonly, the rotor of a stepper motor contains permanent magnets, which require the controller to be capable of reversing the magnetic field created by each of the stator coils, so that they alternately attract and repel the rotor magnets.

In a *bipolar* motor, the magnetic field generated by a coil is reversed simply by reversing the current through it. This is shown diagrammatically in Figure 25-3. In a *unipolar* motor, the magnetic field is reversed by applying positive voltage to the center tap of a coil, and grounding one end or the other. This is shown diagrammatically in Figure 25-4.

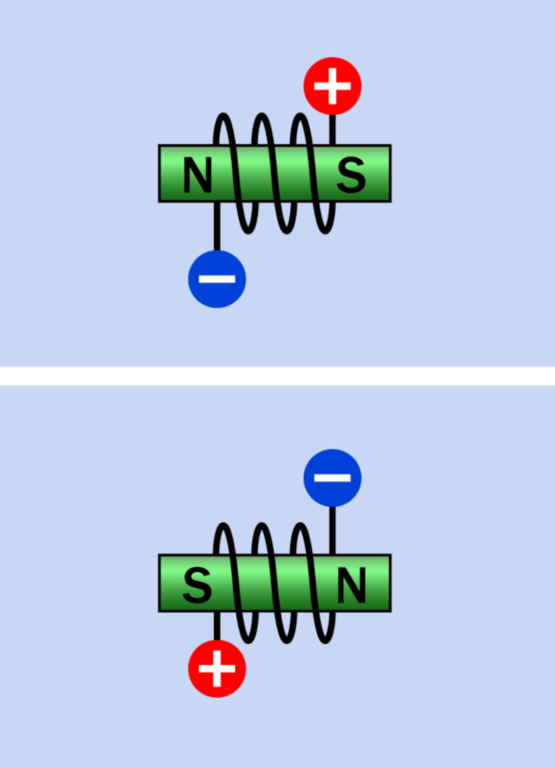

Figure 25-3. *In a bipolar motor, the magnetic field generated by each stator coil is reversed simply by reversing the current through the coil.*

Either type of motor is often designed with an upper and lower deck surrounding a single rotor,

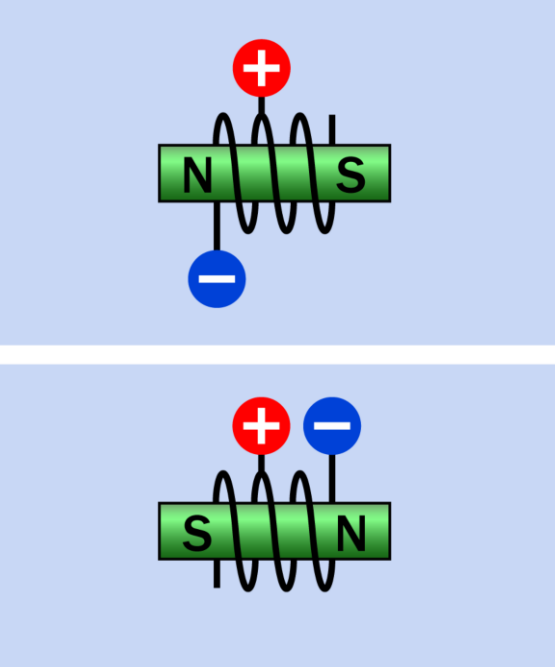

Figure 25-4. *The magnetic field of this coil is reversed by applying positive voltage constantly to a center tap and grounding one end of the coil or the other.*

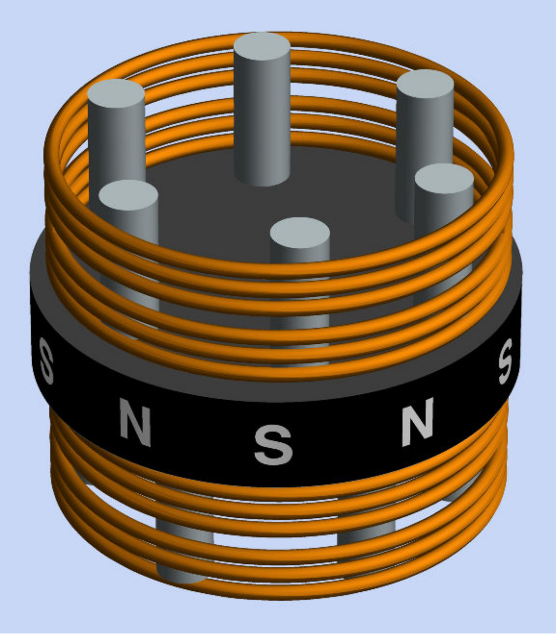

Figure 25-5. *A simplified rendering of the common "two deck" type of motor. See text for details.*

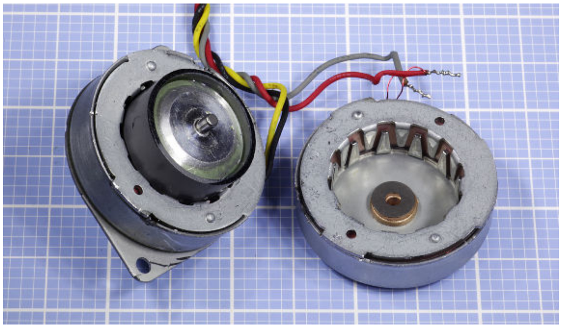

Figure 25-6. *A two-deck stepper motor split open to reveal its rotor (left) and one of the stators (right) encircled by a coil.*

as suggested in Figure 25-5. A large single coil, or center-tapped coil, induces a magnetic field in multiple poles in the top deck, out of phase by one step with a second set of poles, energized by their own coil, in the bottom deck. (All three motors shown in Figure 25-1 are of this type.) The rotor of the motor is tall enough to span both decks, and is rotated by each of them in turn.

In Figure 25-6, the decks of a two-deck four-wire motor have been split apart. The rotor remains in the left-hand section. It is enclosed within a black cylinder that is a permanent magnet divided into multiple poles. In the right-hand section, a coil is visible surrounding metal "teeth" that function as stator poles when the coil is energized.

In Figure 25-7, the same motor has been further disassembled. The coil was secured with a length of tape around its periphery, which has been removed to make the coil visible. The remaining half of the motor, at top-right, contains a second, concealed but identical coil with its own set of poles, one step out of phase with those in the first deck.

Because the field effects in a two-deck stepper motor are difficult to visualize, the remaining diagrams show simplified configurations with a minimum number of stator poles, each with its own coil.

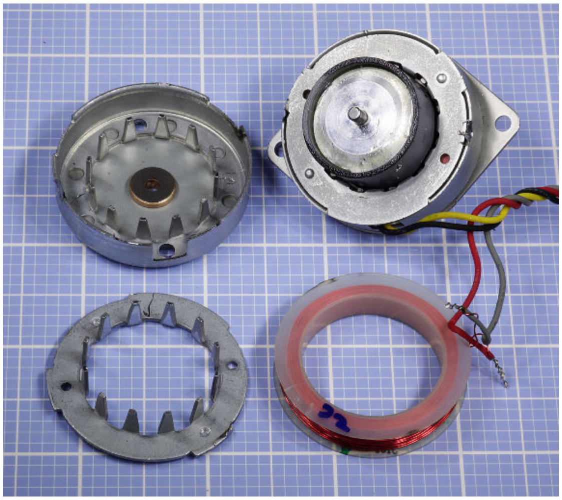

Figure 25-7. *The stepper motor from the previous figure, further disassembled.*

Bipolar Stepper Motors

The most basic way to reverse the current in a coil is by using an *H-bridge* configuration of switches, as shown in Figure 25-8, where the green arrow indicates the direction of the magnetic field. In actual applications, the switches are solid-state. Integrated circuits are available containing all the necessary components to control a bipolar stepper motor.

Four sequential steps of a bipolar motor are shown in Figure 25-9, Figure 25-10, Figure 25-11, and Figure 25-12. The H-bridge control electronics for each coil are omitted for clarity. As before, energized coils are shown with the pole inside the coil tinted green, while non-energized coils are gray, and the rotor is shown before it has had time to respond to the magnetic field in each step.

Unipolar Motors

The control electronics for a unipolar motor can be simpler than those for a bipolar motor, as off-the-shelf switching transistors can ground one end of the coil or the other. The classic five-wire unipolar stepper motor, often sold to hobbyists and used in robotics projects and similar applications, can be driven by nothing more elaborate

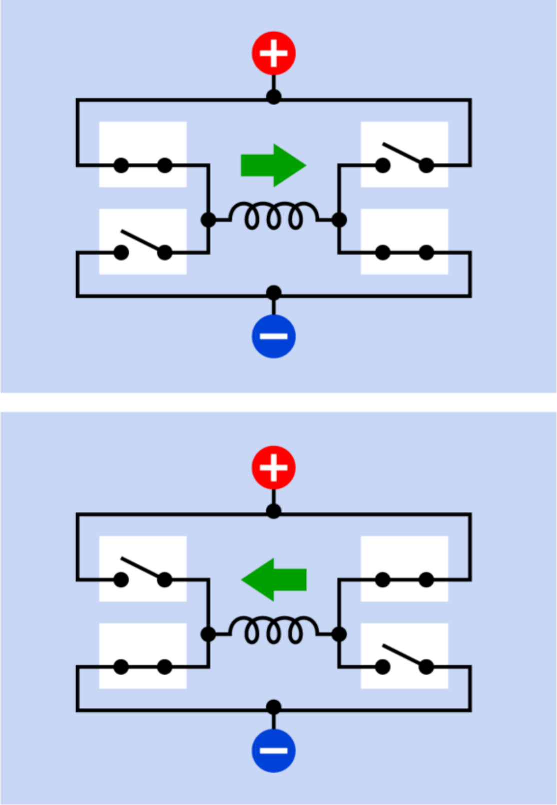

Figure 25-8. *The simplest and most basic way to reverse the current through a coil is via an H-bridge circuit. In practice, the switches are replaced by solid-state components.*

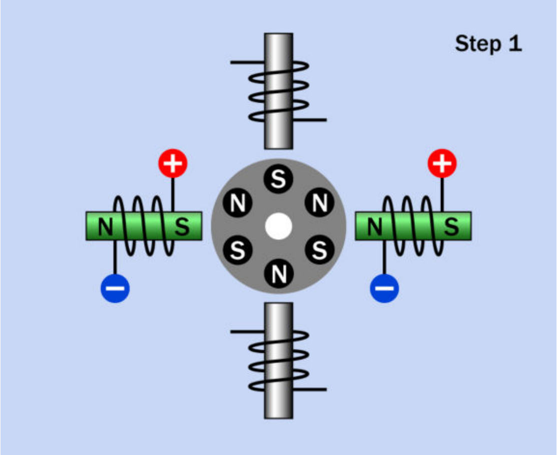

Figure 25-9. *A bipolar stepper motor depicted a moment before the rotor has had time to make its first step in response to magnetic fields created by the stator coils.*

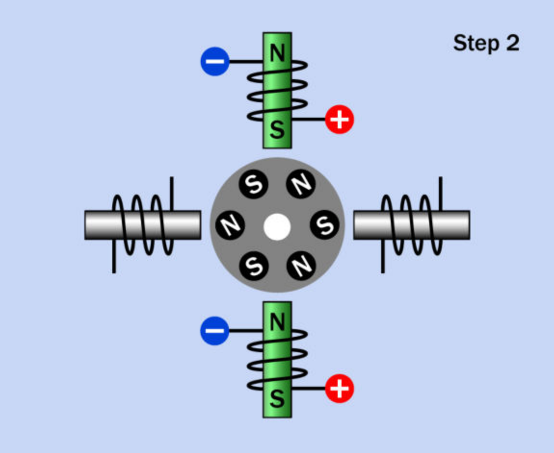

Figure 25-10. *The bipolar stepper motor from the previous figure is shown with its rotor having advanced by one step, and coil polarity changed to induce it to make a second step.*

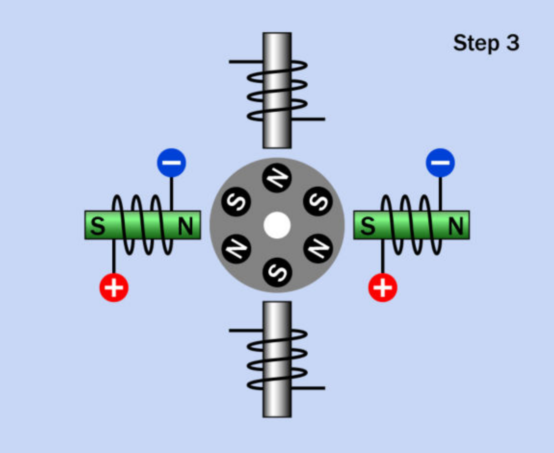

Figure 25-11. *The bipolar stepper motor after taking its second step, immediately before making its third step.*

than a set of *555 timer* chips. However, this type of motor is less powerful for its size and weight because only half of each coil is energized at a time.

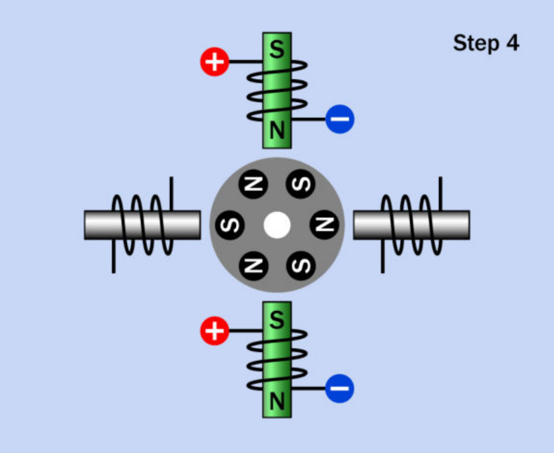

Figure 25-12. *The bipolar stepper motor after taking its third step. When the rotor responds to the new pattern of magnetic fields, its orientation will be functionally identical with that shown in the first step.*

In Figure 25-13, Figure 25-14, Figure 25-15, and Figure 25-16, the simplest configuration of a unipolar system is shown in diagrammatic form using four stator coils and a rotor containing six magnetic poles. Each figure shows the stator coils when they have just been energized, a moment before the rotor has had time to move in response to them. Coils that are energized are shown with the metal cores tinted green. Wires that are not conducting current are shown in gray. The open and closed positions of switches a, b, c, and d suggest the path that current is taking along the wires that are colored black.

Note that coils on opposite sides of the motor are energized simultaneously, while the other pair of coils is de-energized. Adjusting the controller so that it overlaps the "on" cycles of the coils can generate more torque, while consuming more power.

A motor containing more stator poles can advance in smaller steps, if the poles are separately energized. However, if the coils have individual windings, this will increase the cost of the motor.

Variants

In addition to bipolar and unipolar variants, previously described, three others are available.

High Phase Count

This term describes any type of stepper motor in which additional poles reduce the step size. The advantages of a high phase count include

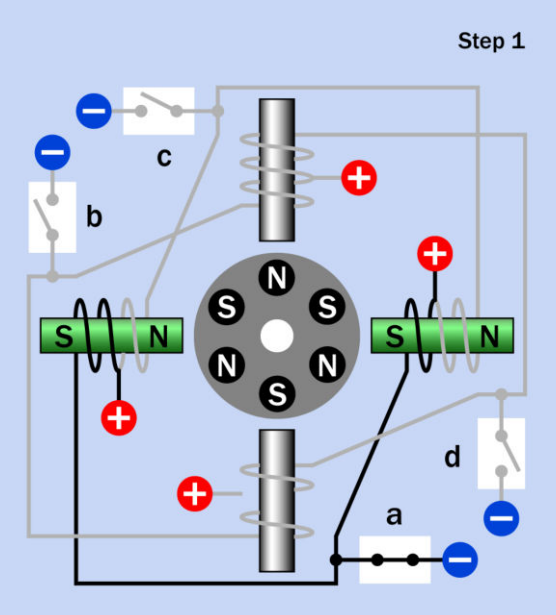

Figure 25-13. *The coils of this unipolar stepper motor are shown an instant after they have been energized, before the rotor has had time to respond by making its first step.*

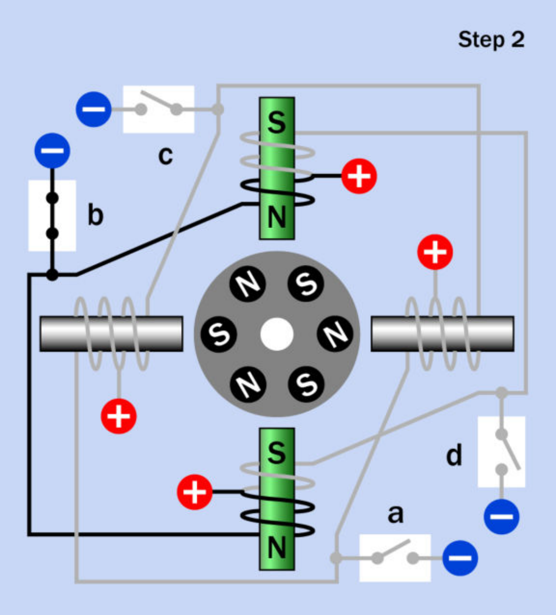

Figure 25-14. *The same motor from the previous figure is shown with coils energized to induce the rotor to make its second step.*

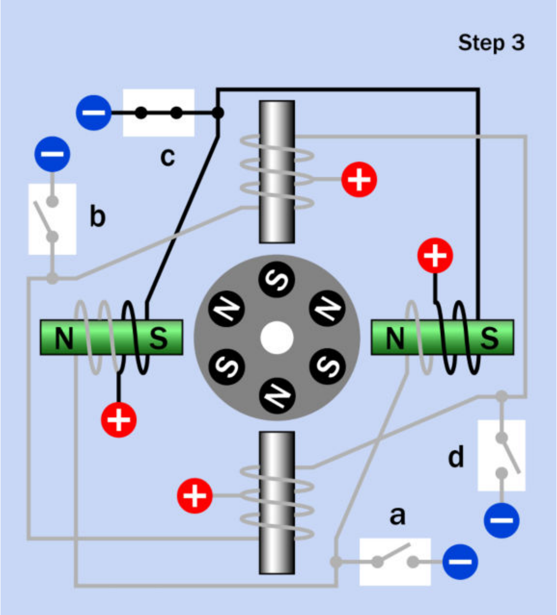

Figure 25-15. *The same motor from the previous figure is shown with coils energized to induce the rotor to make its third step.*

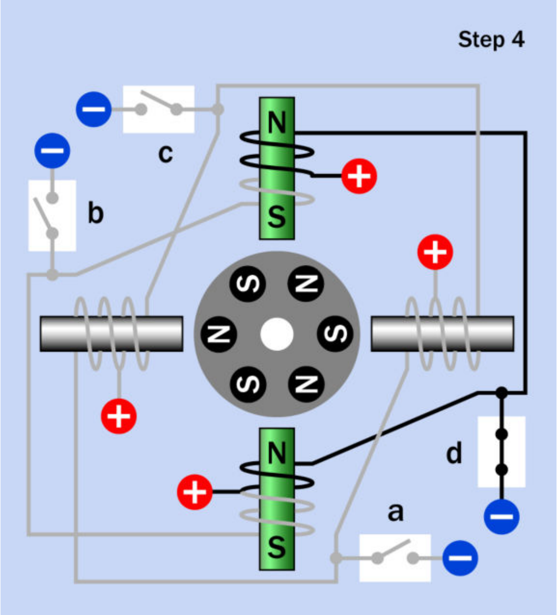

Figure 25-16. *When the rotor makes its fourth step, it will be back in an orientation that is functionally identical with the first figure in this series.*

smoother running at high speed and greater precision when selecting a desired motor position. The additional coils also enable higher power density, but naturally tend to add to the cost of the motor.

Hybrid

This type of motor uses a toothed rotor that provides variable reluctance while also containing permanent magnets. It has become relatively common, as the addition of teeth to the rotor enables greater precision and efficiency. From a control point of view, the motor behaves like a regular permanent-magnet stepper motor.

Bifilar

In this type of motor, also sometimes known as a *universal* stepper motor, two coils are wound in parallel for each stator pole. If there are two poles or sets of poles, and both ends of each winding are accessible via wires that are run out of the motor, there will be eight wires in total. Consequently this type is often referred to as an *8-wire motor*.

The advantage of this scheme is that it allows three possible configurations for the internal coils. By shorting together the wires selectively, the motor can be made to function either in unipolar or bipolar mode.

In Figure 25-17, the upper pair of simplified diagrams depicts one end of one coil connected to the beginning of the other, while positive voltage is applied at the midpoint, as in a unipolar motor. The magnetic polarity of the coil is determined by grounding either end of the coil. The section of each coil that is not conducting current is shown in gray.

The center pair of diagrams shows the adjacent ends of the coils tied together, so that they are now energized in parallel, with the magnetic polarity being determined by the polarity of the voltage, as in a bipolar motor.

The coils may also be connected in series, as shown in the lower pair of diagrams. This will provide greater torque at low speed and lower torque at high speed, while enabling higher-voltage, lower-current operation.

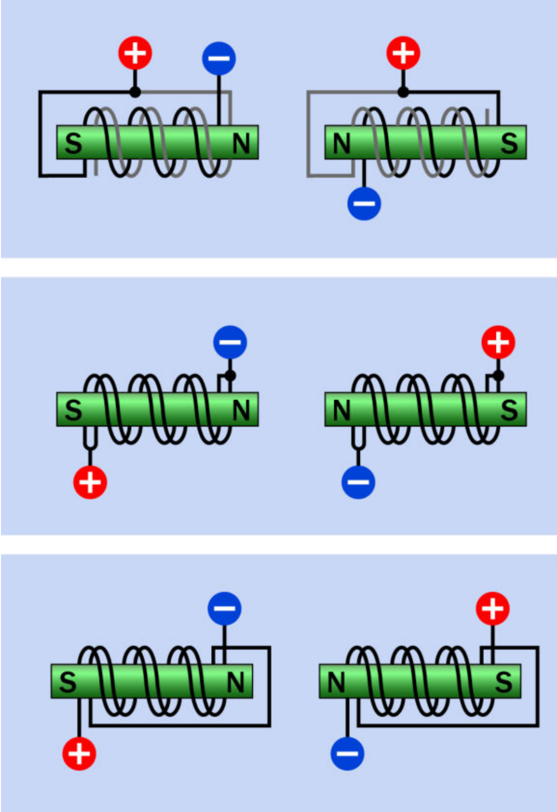

Figure 25-17. *In a bifilar motor, two coils are wound in parallel around each stator pole and can be connected with a center tap to emulate a unipolar motor (upper diagrams), or can be energized in parallel (middle diagrams) or series (lower diagrams) to emulate a bipolar motor.*

Multiphase

In a multiphase motor, multiple stator coils are usually connected in series, with a center tap applied between each pair. A possible configuration is shown in Figure 25-18, where the two diagrams show two consecutive steps in rotation, although the step angle could be halved by changing the voltage polarity in only one location at a time. The way in which the motor is wired enables only one stator coil to be unpowered during any step, because its two ends are at equal potential. Therefore this type of motor is capable of high torque in a relatively small format.

In some multiphase motors, additional wires allow access to both ends of each coil, and the coils are not connected internally. This allows control of the motor to be customized.

Microstepping

An appropriately designed stepper motor can be induced to make very small, intermediate steps if the control voltage is modulated to intermediate levels. Step angles as low as 0.007 degrees are claimed by some manufacturers. However, a motor running in this mode is less able to generate torque.

The simplest form of microstepping is half-stepping. To achieve this in a unipolar motor, each coil passes through an "off" state before its magnetic polarity is reversed.

Sensing and Feedback

So long as the series of pulses to the motor allows the rotor ample time to respond, no feedback mechanism from the rotor is necessary to confirm its position, and an open-loop system is sufficient. If sudden acceleration, deceleration, load fluctuations, and/or rotation reversal will occur, or if high speeds are involved, a *closed loop system*, in which a sensor provides positional feedback, may be necessary.

Voltage Control

Rapid stepping of a motor requires rapid creation and collapse of magnetic fields in the stator windings. Therefore, self-inductance of the windings can limit the motor speed. One way to overcome this is to use a higher voltage. A more sophisticated solution is to use a controller that provides a high initial voltage, which is reduced or briefly interrupted when a sensor indicates that coil current has increased sufficiently to overcome the self-inductance of the windings and has reached its imposed limit. This type of controller may be referred to as a *chopper drive* as the voltage is "chopped," usually by power transistors. It is a form of *pulse width modulation*.

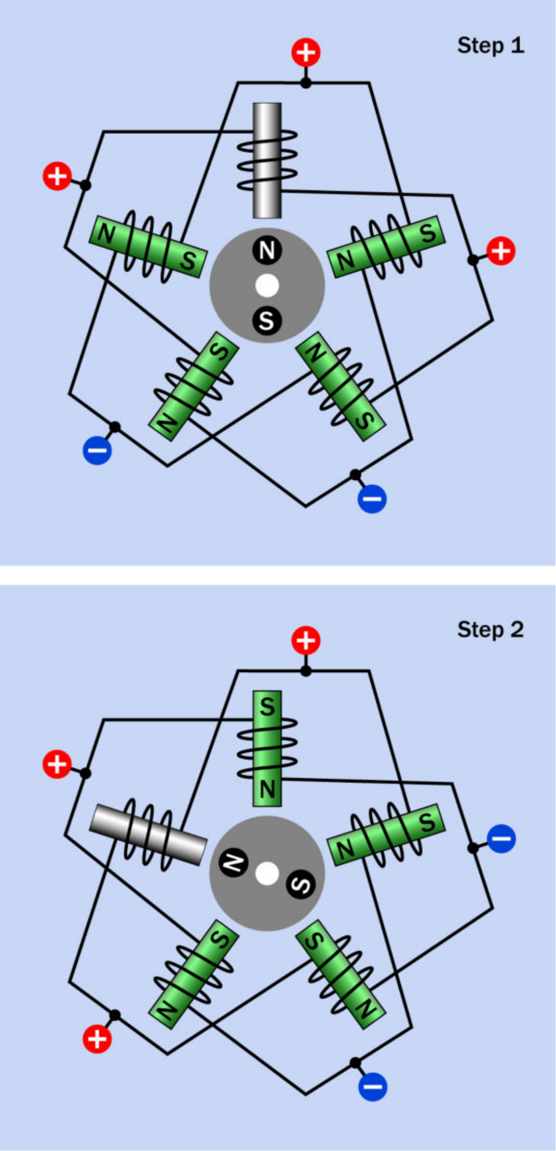

Figure 25-18. *A multiphase stepper motor. By applying voltage in the pattern shown, only one coil is not energized during each step. This enables high torque compared with the size of the motor.*

Values

The *step angle* of a stepper motor is the angular rotation of its shaft, in degrees, for each full step. This will be determined by the physical construction of the motor. The coarsest step angle is 90 degrees, while sophisticated motors may be capable of 1.8 degrees (without microstepping).

The maximum torque that a motor can deliver is discussed in "Values" (page 184) in the **DC motor** entry of this encyclopedia.

Motor weight and size, shaft length, and shaft diameter are the principal passive values of a stepper motor, which should be checked before it is selected for use.

How to Use it

Stepper motors are used to control the seek action in disk drives, the print-head movement and paper advance in computer printers, and the scanning motion in document scanners and copiers.

Industrial and laboratory applications include the adjustment of optical devices (modern telescopes are often oriented with stepper motors), and valve control in fluid systems.

A stepper motor may be used to power a *linear actuator*, usually via a screw thread (properly known as a lead screw) or worm gear. For more on linear actuators, see "Linear Actuator" (page 184). While the stepper motor will enable greater accuracy than a traditional DC motor, the gearing inevitably will introduce some imprecision.

Advantages of stepper motors include:

- Precise positioning, typically within 3 percent to 5 percent per step. The percentage step error does not accumulate as the motor rotates
- Able to run at a wide range of speeds, including very slow speeds without reduction gearing
- Trouble-free start, stop, and reverse action
- Cheap controller hardware where open-loop applications are acceptable
- High reliability, since no brushes or commutator are involved

Disadvantages include:

- Noise and vibration
- Resonance at low speeds
- Progressive loss of torque at high speeds

Protection Diodes

While a small stepper motor may be driven directly from power transistors, *darlington pairs*, or even *555 timers*, larger motors will create *back-EMF* when the magnetic field of each stator coil is induced or forward EMF when the field is allowed to collapse, and bipolar motors will also induce voltage spikes when the current reverses. In a unipolar motor, while only one-half of the coil is actually energized via its center tap, the other half will have an induced voltage, as the coil acts like a *linear transformer*.

A simplified schematic illustrating diode placement for a bipolar motor is shown in Figure 25-19.

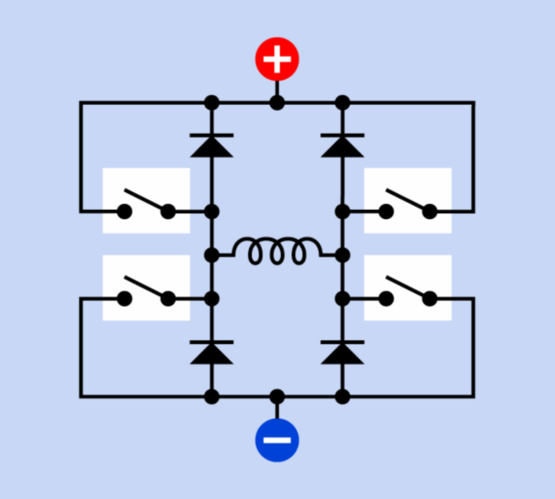

Figure 25-19. *The H-bridge circuit must be augmented with protection diodes to guard against back-EMF created by fluctuating current in the stator coil.*

Integrated circuit chips are available taht incorporate protection diodes, in addition to the necessary power transistors. Stepper motors may also have protection diodes built in. Consult the manufacturer's datasheet for details before attaching a motor to a power source.

Positional Control

The built-in control electronics of a **servo motor** typically turn the shaft to a precisely known position in response to pulse-width modulation from an exterior source such as a **microcontroller**, whereas the angle of rotation of a stepper motor in an open-loop system must be calculated by counting the number of steps from an initial, home position. This limitation of a stepper motor can be overcome by using a closed-loop system, but that will require monitoring the motor, adding complexity to the external controller. The choice between stepper and servo motors should be evaluated on a case-by-case basis.

What Can Go Wrong

General problems affecting all types of motors are listed in "Heat effects" (page 188). Issues relating more specifically to stepper motors are listed in the following sections.

Incorrect Wiring

Because a stepper motor is driven via multiple conductors, there is a significant risk of wiring errors, especially since many motors are not identified with part numbers. The first challenge, then, may be to determine what type of motor it is. When the motor is disconnected from any power, and the shaft is rotated with finger and thumb, a magnetized-rotor motor will not spin as freely as a reluctance motor, because the magnets in the rotor will provide intermittent turning resistance.

If a unipolar motor is relatively small and is fitted with five wires, almost certainly the motor contains two coils, each with a center tap, and their function can be determined by applying positive voltage to the red wire and grounding each of the other wires in turn. Attaching a small piece of tape to the motor shaft will assist in viewing its orientation.

A multimeter set to measure ohms can also be useful in deducing the internal coil connections of the motor, since the end-to-end resistance of a coil should be approximately twice the resistance between the center tap and either end of the coil.

A multiphase motor may have five wires, but in this case, the resistance between any two nonadjacent wires will be 1.5 times the resistance between any two adjacent wires.

Step Loss

In an open-loop system, if the motor skips or misses pulses from the controller, the controller no longer has an accurate assessment of the shaft angle. This is known as *step loss*. Since this can be caused by sudden changes in control frequency, the frequency should be increased (or decreased) gradually. This is known as *ramping* the motor speed. Stepper motors cannot respond instantly to changes in speed, because of inertia in the rotor or in the device that the motor is driving.

Where the motor turns one or more steps beyond its commanded stopping point, this is known as *overshoot*.

Step loss may also occur if the motor continues turning after power has been interrupted (either intentionally or because of an external fault). In an open-loop system, the controller should be designed to reset the motor position when power is initiated.

Excessive Torque

When the motor is stationary and not powered, *detent torque* is the maximum turning force that can be applied without causing the shaft to turn. When the motor is stationary and the controller does deliver power to it, *holding torque* is the maximum turning force that can be applied without causing the shaft to turn, and *pull-in torque* is the maximum torque which the motor can apply to overcome resistance and reach full speed. When the motor is running, *pull-out torque* is the maximum torque the motor can deliver without suffering step loss (pulling it out of sync with its controller). Some or all of these values should be specified on the motor's datasheet. Exceeding any of them will result in step loss.

Hysteresis

When a controller directs a stepper motor to seek a specified position, the term *hysteresis* is often used to mean the total error between the actual position it reaches when turning clockwise, and the actual position it reaches when turning counter-clockwise. This difference may occur because a stepper motor tends to stop a fraction short of its intended position, especially under significant load. Any design that requires precision should be tested under real-world conditions to assess the hysteresis of the motor.

Resonance

A motor has a natural resonant frequency. If it is stepped near that frequency, vibration will tend to be amplified, which can cause positional errors, gear wear (if gears are attached), bearing wear, noise, and other issues. A good datasheet should specify the resonant frequency of the motor, and the motor should run above that frequency if possible. The problem can be addressed by rubber motor mounts or by using a resilient component, such as a drive belt, in conjunction with the drive shaft. *Damping* the vibration may be attempted by adding weight to the motor mount.

Note that if the motor has any significant weight attached directly to its shaft, this will lower its resonant frequency, and should be taken into account.

Resonance may also cause *step loss* (see preceding sections).

Hunting

In a closed-loop system, a sensor on the motor reports its rotational position to the controller, and if necessary, the controller responds by adjusting the position of the motor. Like any feedback system, this entails some lag time, and at certain speeds the motor may start *hunting* or *oscillating* as the controller over-corrects and must then correct its correction. Some closed-loop controllers avoid this issue by running mostly in open-loop mode, using correction only when the motor experiences conditions (such as sudden speed changes), which are likely to cause step loss.

Saturation

While it may be tempting to increase the torque from a stepper motor by upping the voltage (which will increase the current through the stator coils), in practice motors are usually designed so that the cores of the coils will be close to saturation at the rated voltage. Therefore, increasing the voltage may achieve very little increase in power, while causing a significant increase in heat.

Rotor Demagnetization

The permanent magnets in a rotor can be partially demagnetized by excessive heat. Demagnetization can also occur if the magnets are exposed to high-frequency alternating current when the rotor is stationary. Therefore, attempting to run a stepper motor at high speed when the rotor is stalled can cause irrevocable loss of performance.

diode

26

The term **diode** almost always means a semiconductor device, properly known as a *PN junction diode*, although the full term is not often used. It was formerly known as a *crystal diode*. Before that, **diode** usually meant a type of *vacuum tube*, which is now rarely used outside of high-wattage RF transmitters and some high-end audio equipment.

OTHER RELATED COMPONENTS

- **rectifier** (See "Rectification" (page 227))
- **unijunction transistor** (See Chapter 27)
- **LED** (light-emitting diode) (Volume 2)

What It Does

A diode is a two-terminal device that allows current to flow in one direction, known as the *forward direction,* when the *anode* of the diode has a higher positive potential than the *cathode*. In this state, the diode is said to be *forward biased*. If the polarity of the voltage is reversed, the diode is now *reverse biased*, and it will attempt to block current flow, within its rated limits.

Diodes are often used as *rectifiers* to convert alternating current into direct current. They may also be used to suppress voltage spikes or protect components that would be vulnerable to reversed voltage, and they have specialized applications in high-frequency circuits.

A *Zener diode* can regulate voltage, a *varactor diode* can control a high-frequency oscillator, and *tunnel diodes*, *Gunn diodes*, and *PIN diodes* have high-frequency applications appropriate to their rapid switching capability. An **LED** (*light-emitting diode*) is a highly efficient light source, which is discussed in Volume 2 of this encyclopedia. A **photosensitive diode** will adjust its ability to pass current depending on the light that falls upon it, and is included as a *sensor* in Volume 3.

See Figure 26-1 for schematic symbols representing a generic diode.

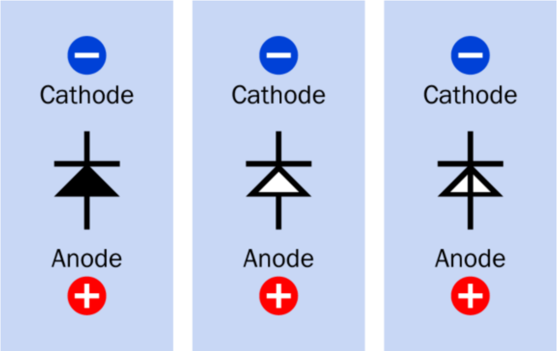

Figure 26-1. *Commonly used schematic symbols for a generic diode. All the symbols are functionally identical. The direction of the arrow formed by the triangle indicates the direction of conventional current (from positive to negative) when the diode is forward-biased.*

The basic diode symbol is modified in various ways to represent variants, as shown in Figure 26-2.

At top
    Each symbol in the group of six indicates a Zener diode. All are functionally identical.

Bottom-left
Tunnel diode.

Bottom-center
Schottky diode.

Bottom-right
Varactor.

A triangle with an open center does not indicate any different function from a triangle with a solid center. The direction of the arrow always indicates the direction of conventional current, from positive to negative, when the diode is forward-biased, although the functionality of Zener diodes and varactors depends on them being reverse-biased, and thus they are used with current flowing opposite to the arrow symbol. The bent line used in the Zener symbol can be thought of as an opened letter Z, while the curled line used in the Schottky diode symbol can be thought of as a letter S, although these lines are sometimes drawn flipped left-to-right.

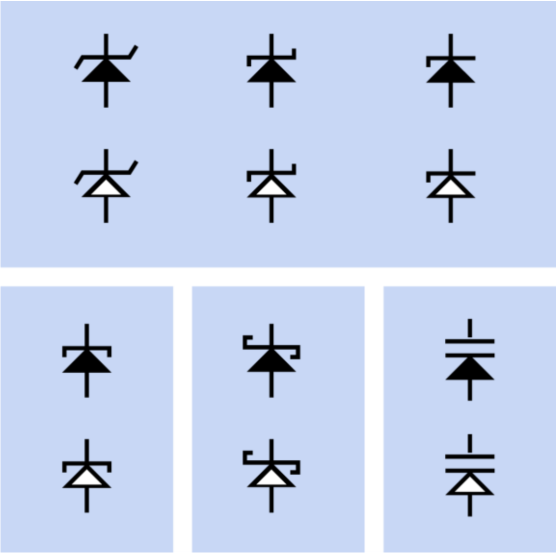

Figure 26-2. *Commonly used schematic symbols for specialized types of diodes. See text for details.*

A range of rectifier and signal diodes is shown in Figure 26-3. (Top: Rectifier diode rated 7.5A at 35VDC. Second from top: Rectifier diode rated 5A at 35VDC. Center: Rectifier diode rated 3A at 35VDC. Second from bottom: 1N4001 Rectifier diode rated 1A at 35VDC. Bottom: 1N4148 signal switching diode rated at 300mA.) All values are for forward continuous current and RMS voltage. Each cylindrical diode is marked with a silver stripe (a black stripe on the 1N4148) to identify its *cathode*, or the end of the diode that should be "more negative" when the component is forward biased. Peak current can greatly exceed continuous current without damaging the component. Datasheets will provide additional information.

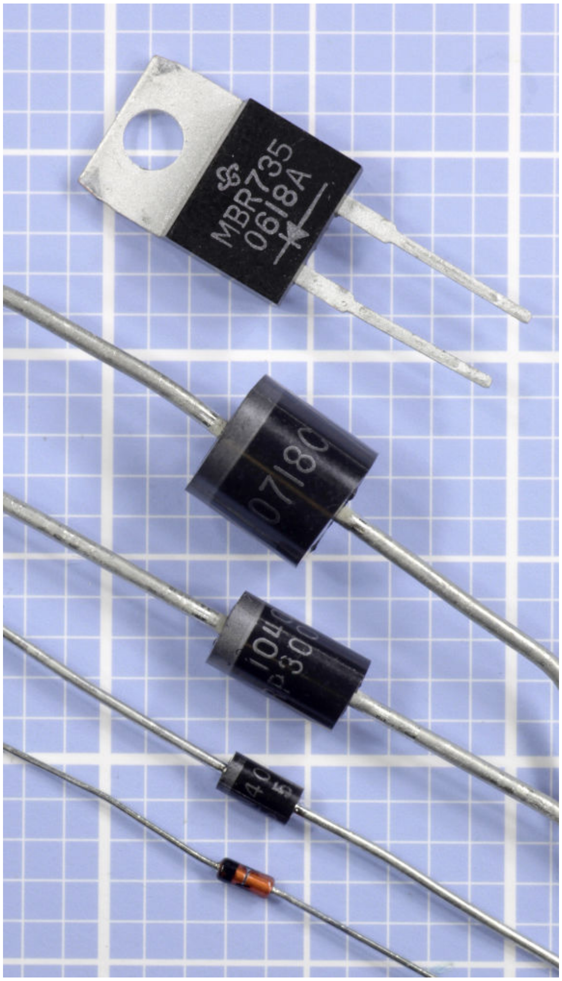

Figure 26-3. *Diodes ranging in continuous forward-current capability from 7.5A (top) to 300mA (bottom). See text for additional details.*

How It Works

A PN diode is a two-layer *semiconductor*, usually fabricated from silicon, sometimes from germanium, and rarely from other materials. The layers are doped with impurities to adjust their electrical characteristics (this concept is explained in more detail in Chapter 28). The *N layer* (on the negative, cathode side) has a surplus of electrons, creating a net negative charge. The *P layer* (on the positive, anode side) has a deficit of electrons, creating a net positive charge. The deficit of electrons can also be thought of as a surplus of "positive charges," or more accurately, a surplus of *electron holes*, which can be considered as spaces that electrons can fill.

When the negative side of an external voltage source is connected with the cathode of a diode, and the positive side is connected with the anode, the diode is forward-biased, and electrons and electron holes are forced by mutual repulsion toward the junction between the n and p layers (see Figure 26-4). In a silicon diode, if the potential difference is greater than approximately 0.6 volts, this is known as the *junction threshold voltage*, and the charges start to pass through the junction. The threshold is only about 0.2 volts in a germanium diode, while in a Schottky diode it is about 0.4 volts.

If the negative side of an external voltage source is connected with the anode of a diode and positive side is connected with the cathode, the diode is now reverse-biased, and electrons and electron holes are attracted away from the junction between the n and p layers. The junction is now a *depletion region*, which blocks current.

Like any electronic component, a diode is not 100% efficient. When it is forward-biased and is passing current, it imposes a small voltage drop of around 0.7V for a silicon-based diode (Schottky diodes can impose a drop of as little as 0.2V, germanium diodes 0.3V, and some LEDs between 1.4V and 4V). This energy is dissipated as heat. When the diode is reverse-biased, it is still not 100% efficient, this time in its task of blocking current. The very small amount of current that manages to get through is known as *leakage*. This is almost always less than 1mA and may be just a few µA, depending on the type of diode.

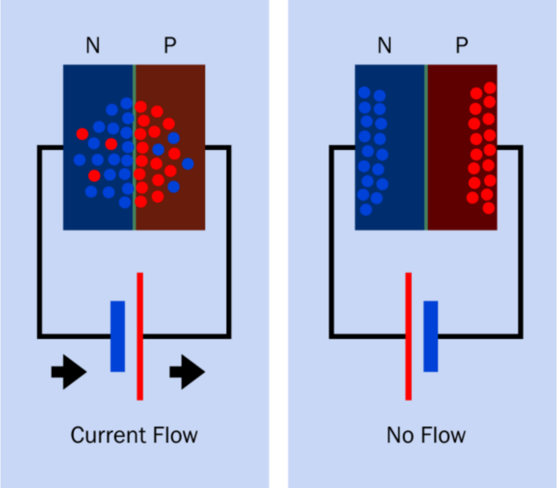

Figure 26-4. *Inside a PN junction diode. Left: in forward-biased mode, voltage from a battery (bottom, with plates colored for clarity) forces charges in the N and P layers toward the central junction of the diode. Current begins to flow. Right: in reverse-biased mode, charges in the N and P layers are attracted away from the central junction, which becomes a depletion region, unable to pass significant current.*

The performance of a theoretical generic PN diode is illustrated in Figure 26-5. The right-hand side of the graph shows that if a diode is forward-biased with a gradually increasing potential, no current passes until the diode reaches its junction threshold voltage, after which the current rises very steeply, as the *dynamic resistance* of the diode diminishes to near zero. The left-hand side of the graph shows that when the diode is reverse-biased with a gradually increasing potential, initially a very small amount of current passes as leakage (the graph exaggerates this for clarity). Eventually, if the potential is high enough, the diode reaches its intrinsic *breakdown voltage*, and once again its effective resistance diminishes to near zero. At either end of the curve, the diode will be easily and permanently damaged by excessive current. With the exception of Zener diodes and varactors, reverse bias on a diode should not be allowed to reach the breakdown voltage level.

The graph in Figure 26-5 does not have a consistent scale on its Y axis, and in many diodes the magnitude of the (reverse-biased) breakdown voltage will be as much as 100 times the magnitude of the (forward-biased) threshold voltage. The graph has been simplified for clarity.

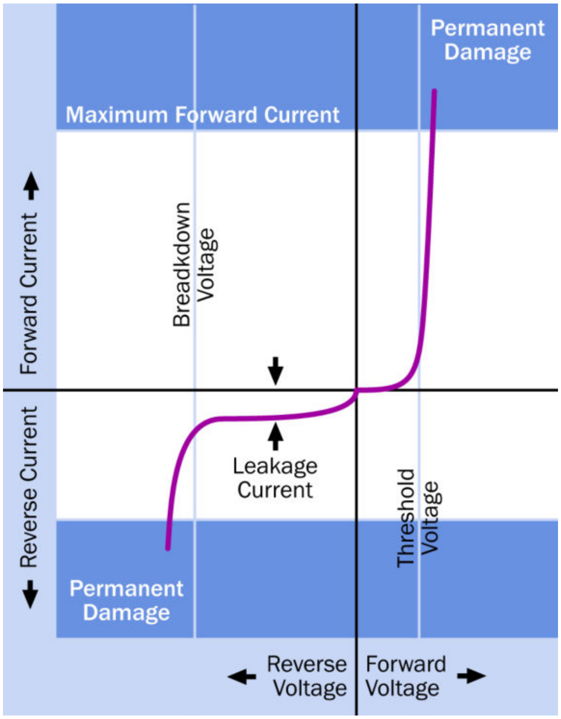

Figure 26-5. *As the forward voltage across a diode reaches the junction threshold, the diode begins passing current. If the voltage across the diode is reversed, initially a small amount of current leakeage occurs. Excessive forward or reverse voltage will create sufficient current to destroy the component.*

Variants

Packaging

Some diodes have no information at all printed on them, while others may have a part number. Any additional information is rare. No convention exists for indicating the electrical characteristics of the component by colors or abbreviations. If one terminal is marked in any way, almost certainly it is the cathode. One way to remember the meaning of a stripe on the cathode end of a rectifier diode or signal diode is by thinking of it as resembling the line in the diode schematic symbol.

Signal Diodes

Also known as *switching diodes* and *high-speed diodes*, their small size provides a low junction capacitance, enabling fast response times. They are not designed to withstand high currents. Signal diodes traditionally were packaged with axial leads for through-hole installation (like traditional-style resistors). Although this format still exists, signal diodes are now more commonly available in surface-mount formats.

Rectifier Diodes

Physically larger than signal diodes, and capable of handling higher currents. Their higher junction capacitance makes them unsuitable for fast switching. Rectifier diodes often have axial leads, although different package formats are used where higher currents are involved, and may include a heat sink, or may have provision for being attached to a heat sink.

There are no generally agreed maximum or minimum ratings to distinguish signal diodes from rectifier diodes.

Zener Diode

A Zener diode generally behaves very similarly to a signal or rectifier diode, except that its breakdown voltage is lower.

The Zener is intended to be reverse-biased; that is, conventional current is applied through it “in the wrong direction” compared with conventional diodes. As the current increases, the *dynamic resistance* of the Zener diode decreases. This relationship is shown in Figure 26-6, where the two colored curves represent the performance of different possible Zener diodes. (The curves are adapted from a manufacturer’s datasheet.) This behavior allows the Zener to be used in simple voltage-regulator circuits, as it can allow a reverse current to flow at a voltage limited by the diode's breakdown voltage. Other applications for Zener diodes are described in "DC Voltage Regulation and Noise Suppression" (page 230). A typical Zener diode is shown in Figure 26-7.

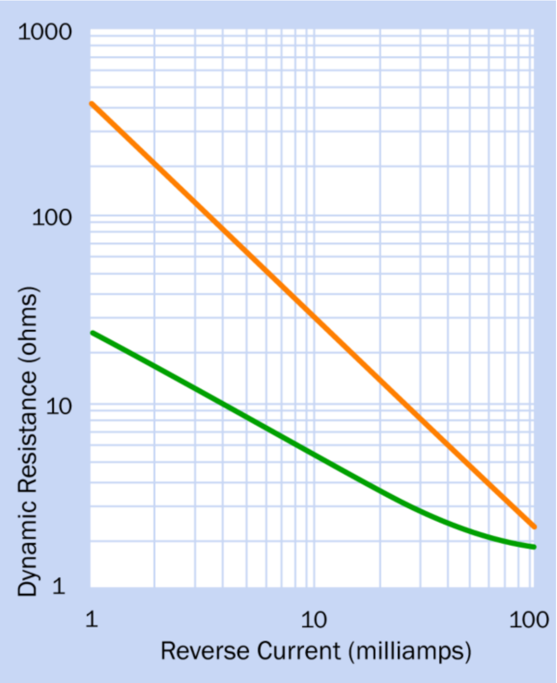

Figure 26-6. *A manufacturer's datasheet may include graphs of this kind, showing the variation in dynamic resistance of two reverse-biased Zener diodes in response to changes in current.*

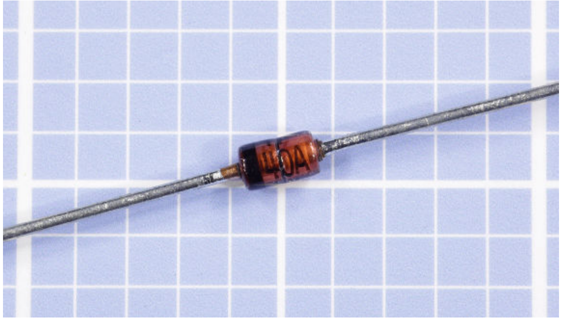

Figure 26-7. *A 1N4740 Zener diode.*

Transient Voltage Suppressor (TVS)

A form of Zener diode designed to protect sensitive devices from transient voltage spikes by clamping them—in other words, diverting the energy to ground. A TVS can absorb as much as 30,000 volts from a lightning strike or static discharge. Typically the Zener diode is incorporated in a network of other diodes in a surface-mount integrated circuit chip.

Zener diodes can also be used in circuits to handle electrostatic discharge (ESD), which can occur when a person unknowingly accumulates an electrostatic potential and then grounds it by touching an electronic device.

Schottky Diode

This type has a low junction capacitance, enabling faster switching than comparable generic silicon diodes. It also imposes a lower forward voltage drop, which can be desirable in low-voltage applications, and allows less power dissipation when a diode is necessary to control current flow. The Schottky diode is fabricated with a semiconductor-to-metal junction, and tends to be slightly more expensive than generic silicon diodes with similar voltage and current specifications.

Varactor Diode

Also known as a *varicap*, this type of diode has variable capacitance controlled by reverse voltage. While other diodes may exhibit this same phenomenon, the varactor is specifically designed to exploit it at very high frequencies. The voltage expands or contracts the depletion region in the junction between the P and N regions, which can be thought of as analogous to moving the plates of a capacitor nearer together or farther apart.

Because the capacitance of a varactor has a low maximum of about 100pF, its uses are limited. It is used extensively in RF applications where its voltage-controlled variable capacitance provides a uniquely useful way to control the frequency of an oscillator circuit. In almost all radio, cellular, and wireless receivers, a varactor controls a phase-locked loop oscillator. In ham radio receivers, it can be used to adjust the tuning of a filter that tracks an incoming radio frequency.

A varactor is always reverse-biased below its breakdown voltage, so that there is no direct conduction. The voltage that controls a varactor must be absolutely free from random fluctuations that would affect its resonant frequency.

Tunnel Diode, Gunn Diode, PIN Diode

Mostly used in very high frequency or microwave applications, where ordinary diodes are unacceptable because they have insufficiently high switching speeds.

Diode Array

Two or more diodes may be encapsulated in a single DIP or (more commonly) surface-mount integrated circuit chip. The internal configuration and the pinouts of the chip will vary from one device to another. Diode arrays may be used for termination of data lines to reduce reflection noise.

Bridge Rectifier

Although this is a diode array, it is commonly indexed in parts catalogues under the term *bridge rectifier*. Numerous through-hole versions are available with ratings as high as 25A, some designed for single-phase input while others process three-phase AC. Screw-terminal components can rectify more than 1,000 volts at 1,000 amps. The package does not usually include any provision for smoothing or filtering the output. See "Rectification" (page 227) for more information on the behavior of a bridge rectifier.

Values

A manufacturer's datasheet for a typical generic diode should define the following values, using abbreviations that may include those in the following list.

- Maximum sustained forward current: I_f or I_o or I_{Omax}
- Forward voltage (the voltage drop imposed by the diode): V_f
- Peak inverse DC voltage (may be referred to as maximum blocking voltage or breakdown voltage): P_{iv} or V_{dc} or V_{br}
- Maximum reverse current (also referred to as leakage): I_r

Datasheets may include additional values when the diode is used with alternating current, and will also include information on peak forward surge current and acceptable operating temperatures.

A typical signal diode is the 1N4148 (included at the bottom of Figure 26-3), which is limited to about 300mA forward current while imposing a voltage drop of about 1V. The component can tolerate a 75V peak inverse voltage. These values may vary slightly among different manufacturers.

Rectifier diodes in the 1N4001/1N4002/1N4003 series have a maximum forward current of 1A and will impose a voltage drop of slightly more than 1V. They can withstand 50V to 1,000V of inverse voltage, depending on the component. Here again, the values may vary slightly among different manufacturers.

Zener diodes have a different specification, as they are used with reverse bias as voltage-regulating devices rather than rectification devices. Manufacturers' data sheets are likely to contain the following terminology:

- Zener voltage (the potential at which the diode begins to allow reverse current flow when it is reverse-biased, similar to breakdown voltage): V_z
- Zener impedance or dynamic resistance (the effective resistance of the diode, specified when it is reverse-biased at the Zener voltage): Z_z

- Maximum or admissible Zener current (or reverse current): I_z or I_{zm}
- Maximum or total power dissipation: P_d or P_{tot}

Zener voltage may be defined within a minimum and maximum range, or as a simple maximum value.

Limits on forward current are often not specified, as the component is not intended to be forward-biased.

How to Use it

Rectification

A *rectifier diode*, as its name implies, is commonly used to rectify alternating current—that is, to turn AC into DC. A half-wave rectifier uses a single diode to block one-half of the AC sinewave. The basic circuit for a half-wave rectifier is shown in Figure 26-8. At top, the diode allows current to circulate counter-clockwise through the load. At bottom, the diode blocks current that attempts to circulate clockwise. Although the output has "gaps" between the pulses, it is usable for simple tasks such as lighting an LED, and with the addition of a smoothing capacitor, can power the coil of a DC relay.

A full-wave bridge rectifier employs four diodes to provide a more efficient output, usually filtered and smoothed with appropriate **capacitors**. The basic circuit is shown in Figure 26-9. A comparison of input and output waveforms for half-wave and full-wave rectifiers appears in Figure 26-10.

Discrete components are seldom used for this purpose, as off-the-shelf bridge rectifiers are available in a single integrated package. Rectifier diodes as discrete components are more likely to be used to suppress *back-EMF* pulses, as described below.

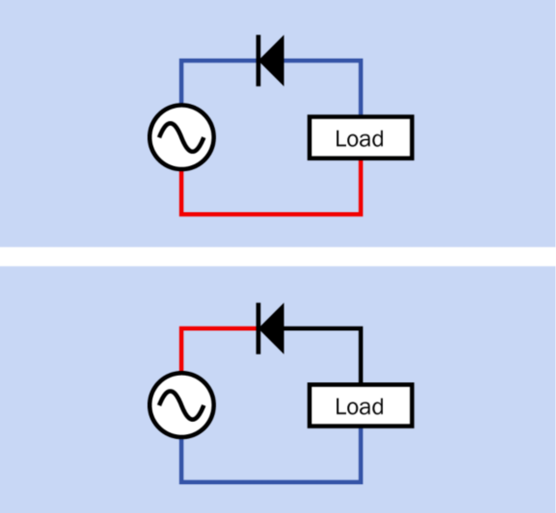

Figure 26-8. *A half-wave rectifier. In this configuration the diode allows AC current to circulate counter-clockwise but blocks it clockwise.*

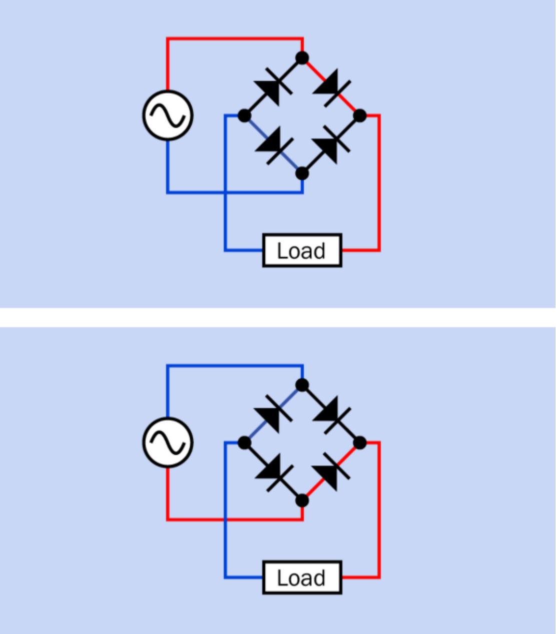

Figure 26-9. *The basic circuit commonly used to form a bridge rectifier, with color added to indicate polarity. Wires shown in black are not passing current because diodes are blocking it. Note that the polarity at the load remains constant.*

An old but widely used design for a full-wave bridge rectifier is shown in Figure 26-11. This unit measured approximately 2" × 2" × 1.5" and was divided into four sections (as indicated by the solder terminals on the right-hand side), each

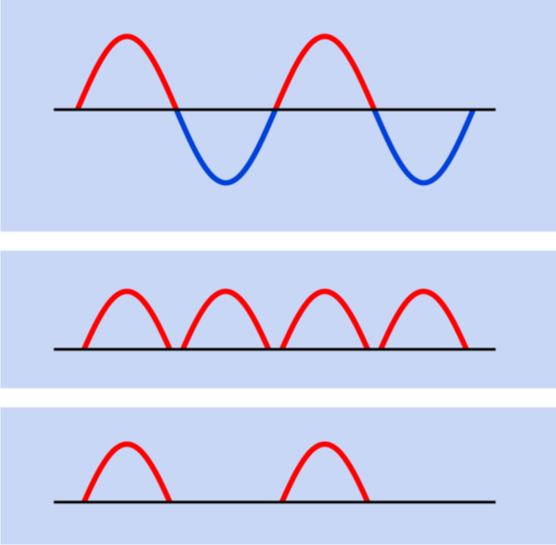

Figure 26-10. *Top: The voltage-amplitude sinewave of an alternating current source that fluctuates between positive voltage (shown red) and negative voltage (shown blue) relative to a neutral (black) baseline. Center: AC current converted by a full-wave rectifier. Because the diodes do not conduct below their threshold voltage, small gaps appear between pulses. Bottom: Output from a half-wave rectifier.*

section corresponding with the functionality of one modern diode. Figure 26-12 shows relatively modern rectifier packages, the one on the left rated at 20A continuous at 800V RMS, the one on the right rated 4A continuous at 200V RMS. In Figure 26-13, the one on the left is rated 4A continuous at 50V RMS, whereas the one on the right is rated 1.5A at 200V RMS.

DC output from rectifier packages is usually supplied via the outermost pins, while the two pins near the center receive AC current. The positive DC pin may be longer than the other three, and is usually marked with a + symbol.

Full-wave bridge rectifiers are also available in surface-mount format. The one in Figure 26-14 is rated for half an amp continuous current.

Back-EMF Suppression

A relay coil, motor, or other device with significant inductance will typically create a spike of voltage when it is turned on or off. This *EMF* can be shunted through a rectifier diode to safeguard other components in the circuit. A diode in this configuration may be referred to as a *protection diode*, a *clamp diode*, or *transient suppressor*. See Figure 26-15.

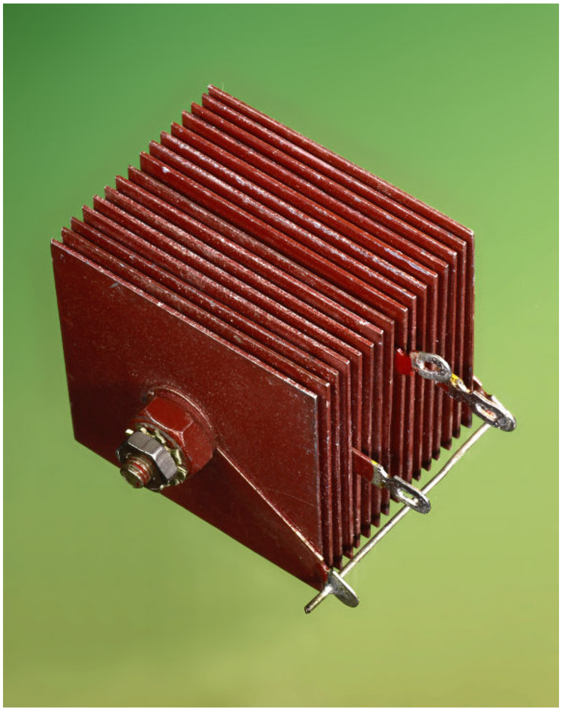

Figure 26-11. *Prior to the perfection of chip fabrication in the late 1960s, it was common to find silicon rectifiers of this type, measuring about 2" square.*

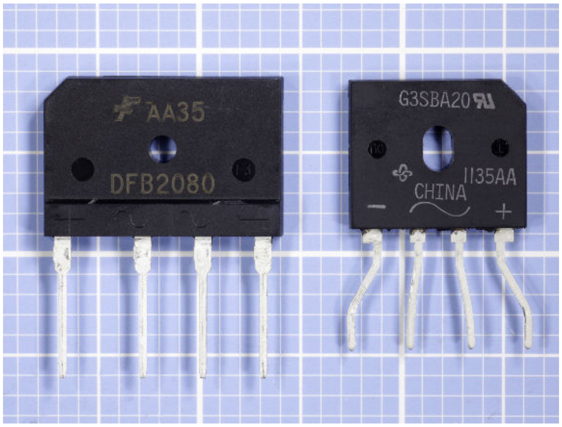

Figure 26-12. *Full-wave bridge rectifies are commonly available in packages such as these. See text for details.*

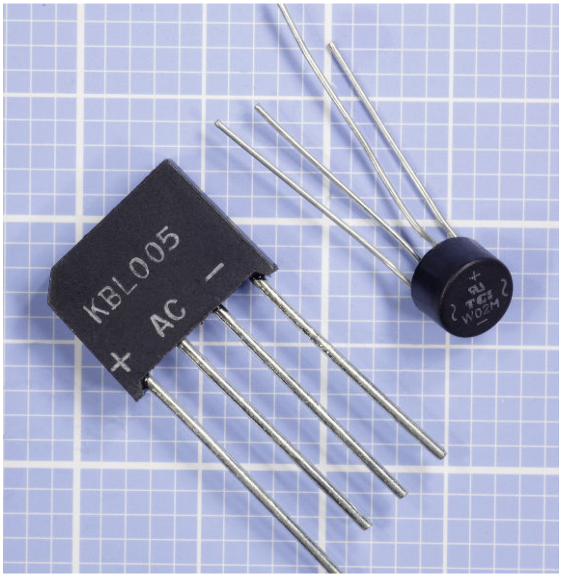

Figure 26-13. *Smaller full-wave bridge rectifiers capable of 1.5A to 4A continuous current.*

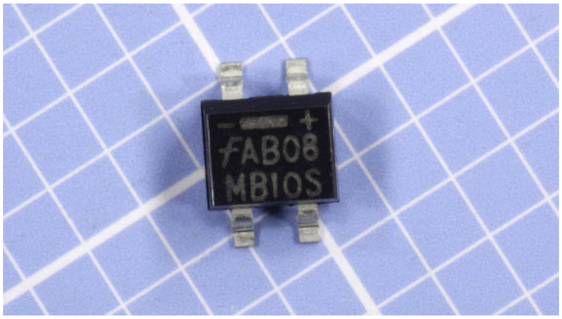

Figure 26-14. *This surface-mount component contains four diodes forming a full-wave bridge rectifier circuit, and can pass 0.5A continuous current. It measures approximately 0.2" square.*

Voltage Selection

A diode is sensitive to the relative voltage between its anode and cathode terminals. In other words, if the cathode is at 9V relative to the ground in the circuit, and the anode is at 12V, the 3V difference will easily exceed the threshold voltage, and the diode will pass current. (Actual tolerable values will depend on the forward voltage capability of the diode.) If the voltages are reversed, the diode will block the current.

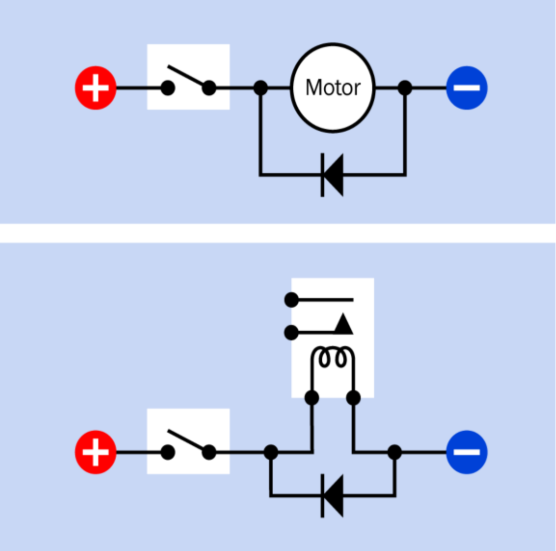

Figure 26-15. *A rectifier diode is very often placed across a motor (top), relay (bottom), or other device with significant inductance that creates a spike of reverse voltage when switched on or off. The surge is shunted through the diode, protecting other components in the circuit.*

This attribute can be used to make a device choose automatically between an AC adapter and a 9V battery. The schematic is shown in Figure 26-16. When an AC adapter that delivers 12VDC is plugged into a wall outlet, the adapter competes with the battery to provide power to a voltage regulator. The battery delivers 9VDC through the lower diode to the cathode side of the upper diode, but the AC adapter trumps it with 12VDC through the upper diode. Consequently, the battery ceases to power the circuit until the AC adapter is unplugged, at which point the battery takes over, and the upper diode now prevents the battery from trying to pass any current back through the AC adapter.

The voltage regulator in this schematic accepts either 12VDC or 9VDC and converts it to 5VDC. (In the case of 12VDC, the regulator will waste more power, which will be dissipated as waste heat.)

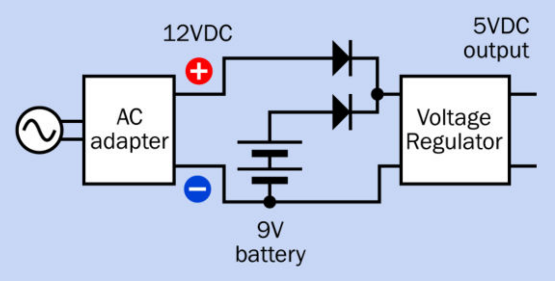

Figure 26-16. *Two diodes with their cathodes tied together will choose automatically between an AC adapter that delivers 12VDC and an internal 9V battery.*

Voltage Clamping

A diode can be used to *clamp* a voltage to a desired value. If an input to a 5V CMOS semiconductor or similarly sensitive device must be prevented from rising out of range, the anode of a diode can be connected to the input and the cathode to a 5V voltage source. If the input rises much above 5.6V, the potential difference exceeds the diode's junction threshold, and the diode diverts the excess energy. See Figure 26-17.

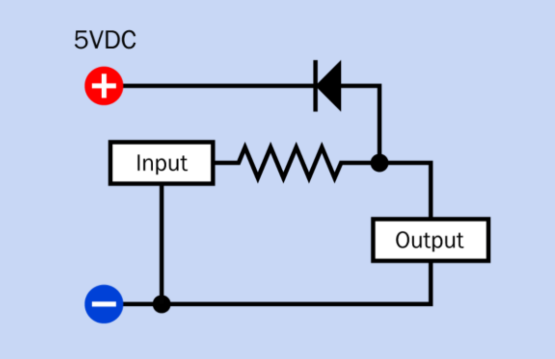

Figure 26-17. *A clamping diode can limit output voltage—in this example, to about 5.6V. If the input rises above that value relative to the common ground, the potential difference across the diode feeds the excess voltage back through it to the 5V source.*

Logic Gate

A signal diode is less than ideal as a logic gate, because it imposes a typical 0.6V voltage reduction, which can be significant in a 5V circuit and is probably unacceptable in a 3.3V circuit. Still, it can be useful on the output side—for example, if two or more outputs from a logic chip or microcontroller are intended to drive, or share, another device such as a single **LED**, as shown in Figure 26-18. In this role, the diodes wired in parallel behave similarly to an OR gate, while preventing either output from the chip from feeding current back into the other output.

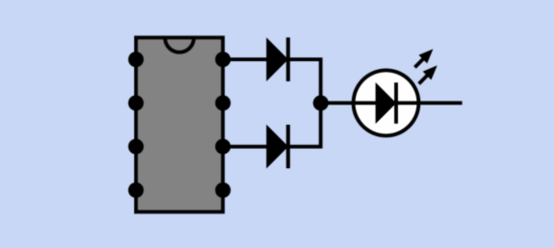

Figure 26-18. *Two or more outputs from a logic chip or microcontroller may be coupled with diodes to power another device, such as an LED, while protecting the chip from backflow of current. The diodes form a logical OR gate.*

DC Voltage Regulation and Noise Suppression

As previously noted, the dynamic resistance of a reverse-biased Zener diode will diminish as the current increases. This relationship begins at the point where breakdown in the diode begins—at its *Zener voltage*--and is approximately linear over a limited range.

The unique behavior of the Zener makes it usable as a very simple voltage controller when placed in series with a resistor as shown in Figure 26-19. It is helpful to imagine the diode and the resistor as forming a kind of voltage divider, with power being taken out at point A in the schematic. If a supply fluctuation increases the input voltage, this will tend to increase the current flowing through the Zener, and its dynamic resistance will diminish accordingly. A lower resistance in its position in the voltage divider will reduce the output voltage at point A, thus tending to compensate for the surge in input voltage.

Conversely, if the load in the circuit increases, and tends to pull down the input voltage, the current

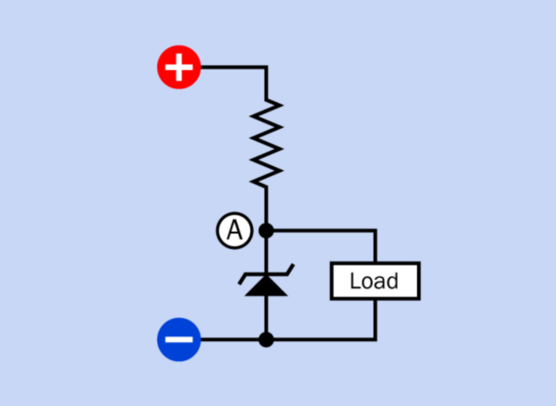

Figure 26-19. *A simplified, basic circuit illustrating the ability of a Zener diode to compensate for variations in the power supply or load in a circuit, creating an approximately constant voltage at point A.*

flowing through the Zener will diminish, and the voltage at point A will tend to increase, once again compensating for the fluctuation in the circuit.

As the series resistor would be a source of heat, a transistor could be added to drive the load, as shown in Figure 26-20.

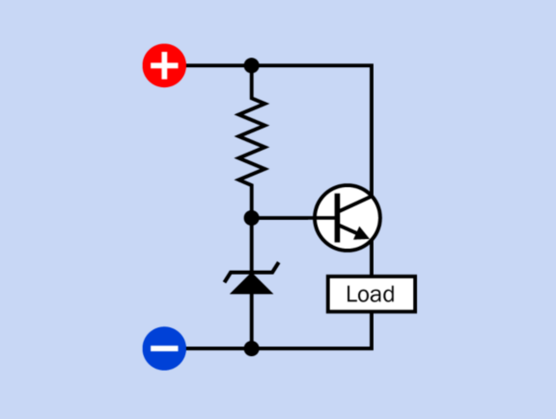

Figure 26-20. *A transistor could be added to the circuit in the previous figure to reduce power waste through the resistor.*

A manufacturer's datasheet may provide guidance regarding the dynamic resistance of a Zener diode in response to current, as previously shown in Figure 26-6. In practice, a packaged **voltage regulator** such as the LM7805 would most likely be used instead of discrete components, since it includes self-calibrating features, requires no series resistor, and is relatively unaffected by temperature. However, the LM7805 contains its own Zener diode, and the principle of operation is still the same.

AC Voltage Control and Signal Clipping

A more practical Zener application would be to limit AC voltage and/or impose clipping on an AC sinewave, using two diodes wired in series with opposed polarities. The basic schematic is shown in Figure 26-21, while clipping of the AC sinewave is illustrated in Figure 26-22. In this application, when one diode is reverse-biased, the other is forward-biased. A forward-biased Zener diode works like any other diode: it allows current to pass relatively freely, so long as the voltage exceeds its threshold. When the AC current reverses, the Zeners trade their functions, so that the first one merely passes current while the second one limits the voltage. Thus, the diodes divert peak voltage away from the load. The Zener voltage of each diode would be chosen to be a small margin above the AC voltage for voltage control, and below the AC voltage for signal clipping.

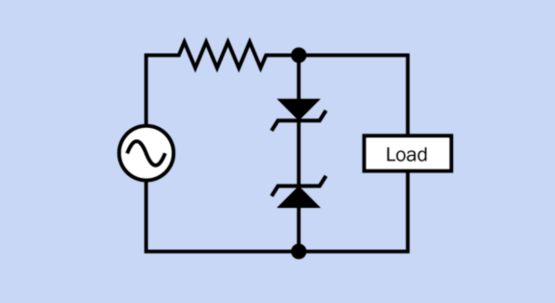

Figure 26-21. *Two Zener diodes placed in series, with opposite polarities, can clip or limit the voltage sinewave of an AC signal.*

Voltage Sensing

A Zener diode can be used to sense a small shift in voltage and provide a switched output in response.

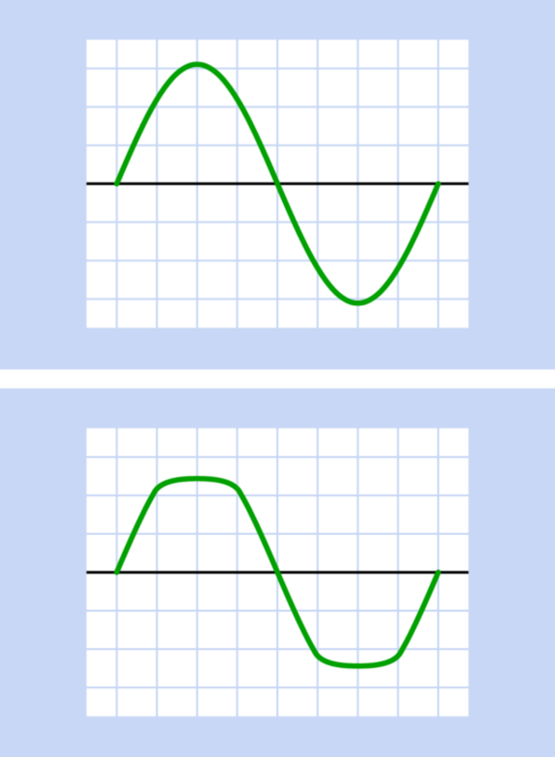

Figure 26-22. *AC input showing a pure sinewave (left) and a clipped version (right) created by Zener diodes wired in series, as in the previous figure.*

In Figure 26-23, the upper schematic shows a Zener diode preventing voltage from reaching the emitter of a PNP transistor while the divided input signal is below the Zener (breakdown) voltage of the diode. In this mode, the transistor is relatively non-conductive, very little current flows through it, and the output is now at near-zero voltage. As soon as the input signal rises above the Zener voltage, the transistor switches on and power is supplied to the output. The input is thus replicated in the output, as shown in the upper portion of Figure 26-24.

In Figure 26-23, the lower schematic shows a Zener diode preventing voltage from reaching the base of an NPN transistor while the input signal is below the Zener (breakdown) voltage of the diode. In this mode, the transistor is relatively non-conductive, and power is supplied to the output. As soon as the input signal rises above the Zener voltage, the transistor is activated, diverting the current to ground and bypassing the output, which is now at near-zero voltage. The input is thus inverted, as shown in the lower portion of Figure 26-24 (provided there is enough current to drive the transistor into saturation).

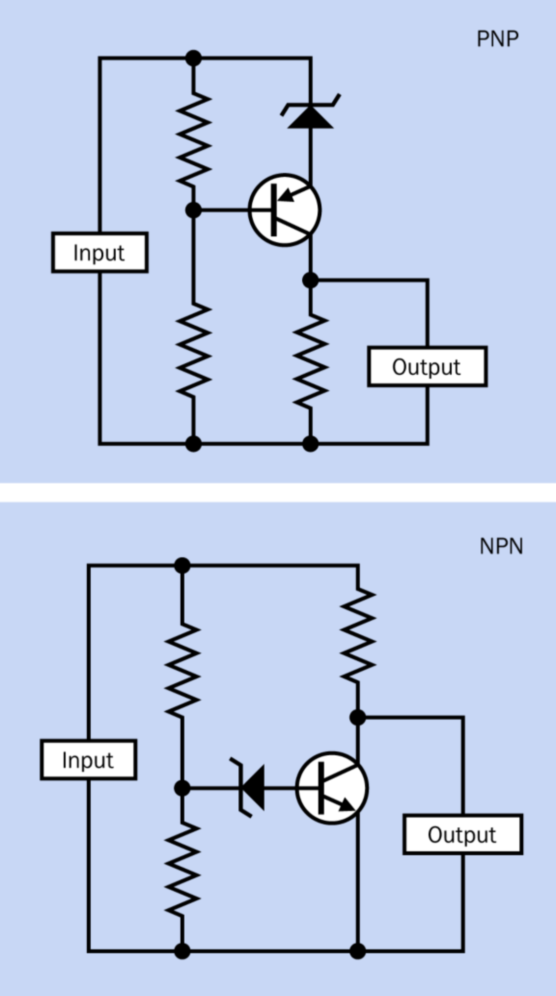

Figure 26-23. *A Zener diode can be used in conjunction with a PNP transistor. See text for details.*

What Can Go Wrong

Overload

If maximum forward current is exceeded, the heat generated is likely to destroy the diode. If the diode is reverse-biased beyond its peak in-

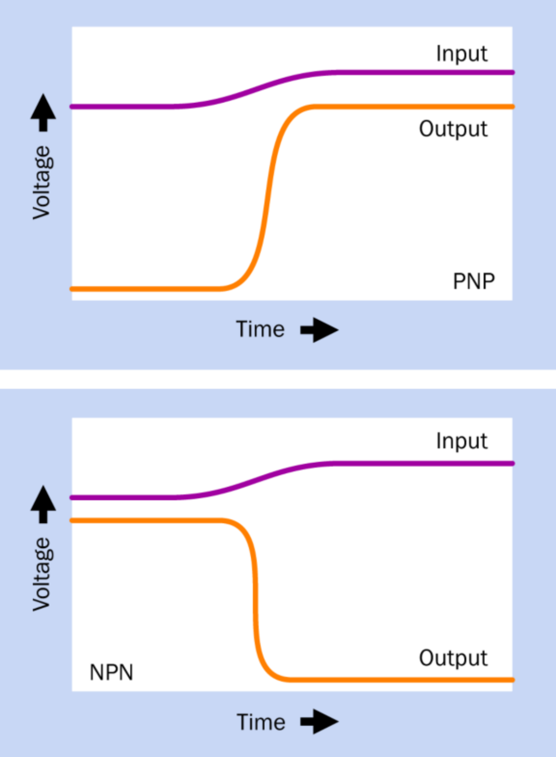

Figure 26-24. *Theoretical output from the transistors in the two previous schematics.*

verse voltage limit, the current will overwhelm the diode's ability to block it, and an *avalanche breakdown* will occur, once again probably destroying the component. The graph in Figure 26-5 illustrates the performance range of a hypothetical generic diode.

Reversed Polarity

Zener diodes look almost identical to other types, and all diodes share the same convention of marking the cathode for identification. Yet Zeners must be reverse-biased while others are forward-biased. This creates a significant risk of installing a diode "the wrong way around," with potentially destructive or at least confusing results, especially when used in a power supply. The very low resistance of a diode to forward current makes it especially vulnerable to burnout if installed incorrectly.

Wrong Type of Diode

If a Zener diode is used accidentally where a signal or rectifier diode is appropriate, the circuit will malfunction, as the Zener will probably have a much lower breakdown voltage, and therefore will not block reverse current. Conversely, if a signal or rectifier diode is used where the circuit calls for a Zener diode, reverse voltage will be clamped (or regulated at the diode's forward voltage value). Since diodes are often poorly marked, a sensible precaution is to store Zener diodes separately from all other types.

unijunction transistor

27

The unijunction transistor (UJT) and programmable unijunction transistor (PUT) are different internally, but are sufficiently similar in function to be combined in this entry.

OTHER RELATED COMPONENTS

- **diode** (See Chapter 26)
- **bipolar transistor** (See Chapter 28)
- **field-effect transistor** (See Chapter 29)

What It Does

Despite their names, the unijunction transistor (UJT) and programmable unijunction transistor (PUT) are not current-amplification devices like bipolar transistors. They are switching components that are more similar to diodes than to transistors.

The UJT can be used to build low- to mid-frequency oscillator circuits, while the PUT provides similar capability with the addition of more sophisticated control, and is capable of functioning at lower currents. The UJT declined in popularity during the 1980s after introduction of components such as the *555 timer*, which offered more flexibility and a more stable output frequency, eventually at a competitive price. UJTs are now uncommon, but PUTs are still available in quantity as through-hole discrete components. Whereas an integrated circuit such as a 555 timer generates a square wave, unijunction transistors in oscillator circuits generate a series of voltage spikes.

The PUT is often used to trigger a **thyristor** (described in Volume 2) and has applications in low-power circuits, where it can draw as little as a few microamps.

Schematic symbols for the two components are shown in Figure 27-1 and Figure 27-2. Although the symbol for the UJT is very similar to the symbol for a field-effect transistor (FET), its behavior is quite different. The bent arrow identifies the UJT, while a straight arrow identifies the FET. This difference is of significant importance.

The schematic symbol for a PUT indicates its function, as it resembles a diode with the addition of a gate connection.

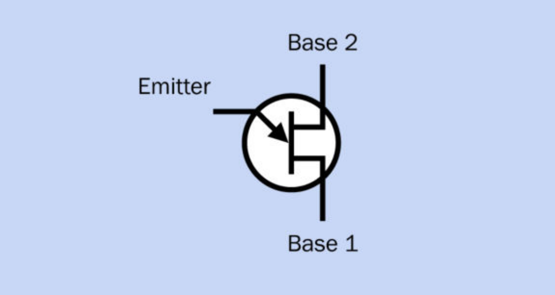

Figure 27-1. *Schematic symbol for a unijunction transistor (UJT). Note the bent arrow. The symbol for a field-effect transistor looks similar, but has a straight arrow. The functionality of the two components is very different.*

In Figure 27-3, the transistors at left and center are old-original unijunction transistors, while the one at right is a programmable unijunction transistor. (Left: Maximum 300mW, 35V interbase voltage. Center: 450mW, 35V interbase voltage. Right: 300mW, 40V gate-cathode forward voltage, 40V anode-cathode voltage.)

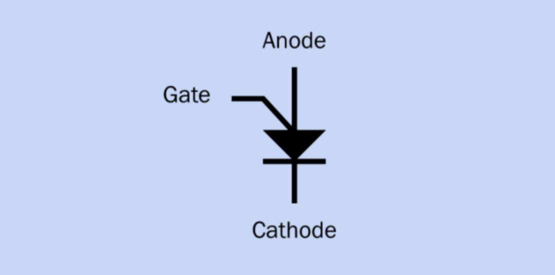

Figure 27-2. *Schematic symbol for a programmable unijunction transistor (PUT). The symbol accurately suggests the similarity in function to a diode, with the addition of a gate to adjust the threshold voltage.*

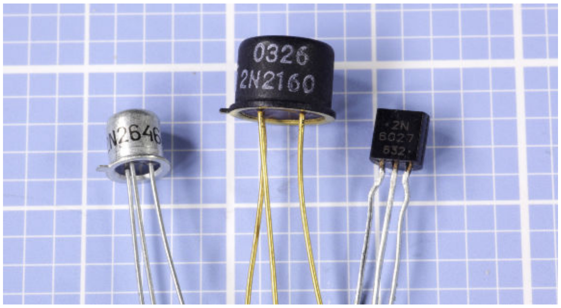

Figure 27-3. *The unijunction transistors at left and center are becoming obsolete; the one at the right is a programmable unijunction transistor (PUT), still readily available and widely used as a thyristor trigger.*

How It Works

The UJT is a three-terminal semiconductor device, but contains only two sections sharing a single junction—hence its name. Leads attached to opposite ends of a single channel of N-type semiconductor are referred to as base 1 and base 2, with base 2 requiring a slightly higher potential than base 1. A smaller P-type insert, midway between base 1 and base 2, is known as the emitter.

The diagram in Figure 27-4 gives an approximate idea of internal function.

When no voltage is applied to the emitter, a relatively high resistance (usually more than 5K) prevents significant current flow from base 2 to base 1. When the positive potential at the emitter increases to a *triggering voltage* (similar to the *junction threshold voltage* of a forward-biased diode), the internal resistance of the UJT drops very rapidly, allowing current to enter the component via both the emitter and base 2, exiting at base 1. (The term "current" refers, here, to conventional current; electron flow is opposite.) Current flowing from base 2 to base 1 is significantly greater than current flowing from the emitter to base 1.

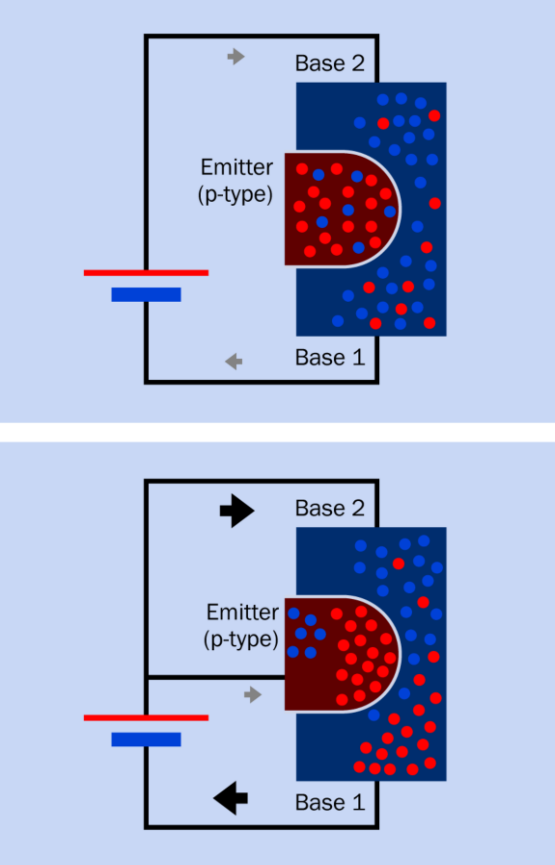

Figure 27-4. *Internal workings of a unijunction transistor.*

The graph in Figure 27-5 outlines the behavior of a UJT. As the voltage applied to the emitter increases, current flowing into the component from the emitter increases slightly, until the triggering voltage is reached. The component's internal resistance now drops rapidly. This pulls down the voltage at the emitter, while the current continues to increase significantly. Because of the drop in resistance, this is referred to as a *negative resistance* region. The resistance actually cannot fall below zero, but its change is negative. After emitter voltage drops to a minimum known as the *valley voltage*, the current continues to increase with a small increase in voltage. On datasheets, the peak current is often referred to as I_p while valley current is I_v.

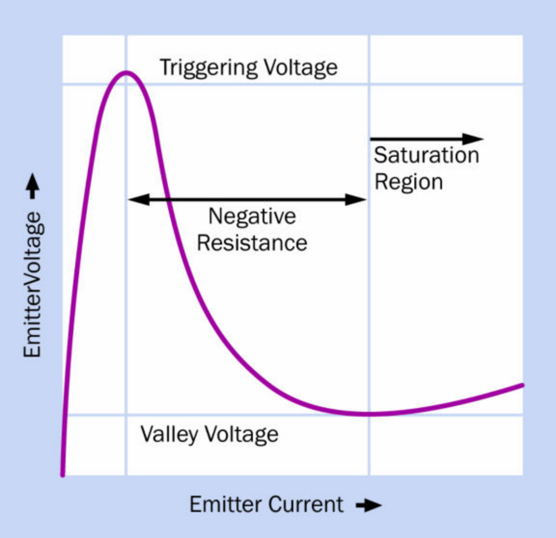

Figure 27-5. *Response curve of a unijunction transistor (UJT). When positive potential at the emitter reaches the triggering voltage, internal resistance drops radically and the component goes through a phase known as "negative resistance" as current increases.*

Figure 27-6 shows a test circuit to demonstrate the function of a UJT, with a volt meter indicating its status. A typical supply voltage would range from 9VDC to 20VDC.

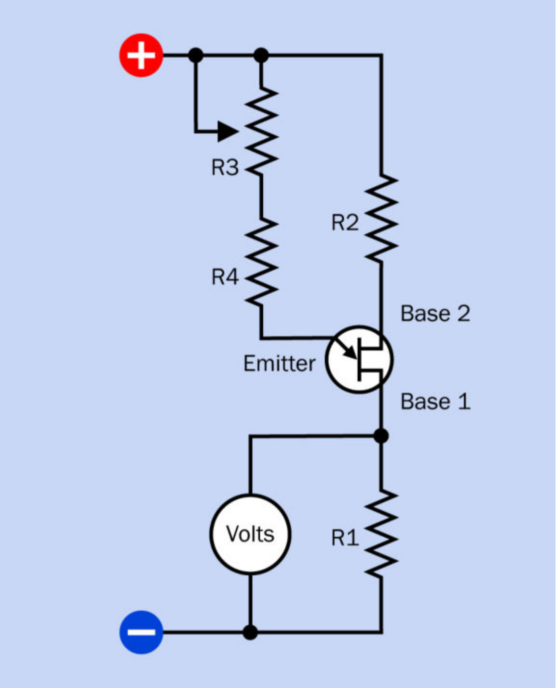

Figure 27-6. *A test circuit for a unijunction transistor (UJT) using a volt meter to show its response as a potentiometer increases the voltage applied to its emitter.*

A PUT behaves similarly in many ways to a UJT but is internally quite different, consisting of four semiconducting layers and functioning similarly to a thyristor.

The PUT is triggered by increasing the voltage on the anode. Figure 27-7 shows a test circuit for a PUT. This component is triggered when the voltage at its anode exceeds a threshold level, while the gate sets the threshold where this occurs. When the PUT is triggered, its internal resistance drops, and current flows from anode to cathode, with a smaller amount of current entering through the gate. This behavior is almost identical to that of a forward-biased diode, except that the threshold level can be controlled, or "programmed," according to the value of the positive potential applied at the gate, with R1 and R2 establishing that potential by functioning as a voltage divider.

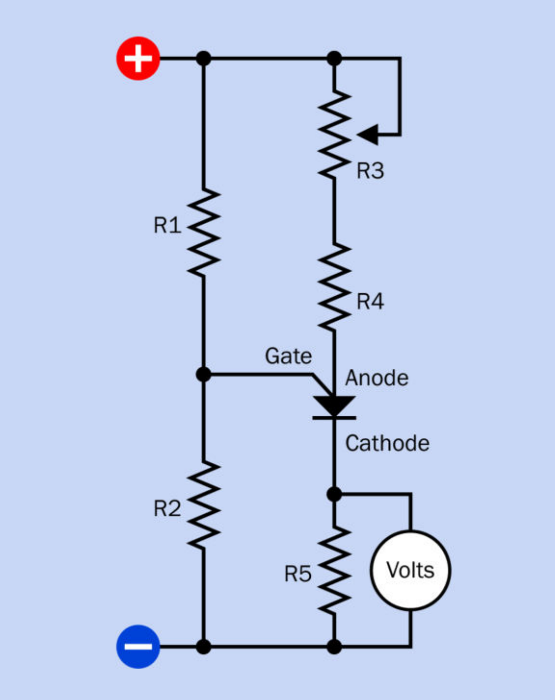

Figure 27-7. *A test circuit for a programmable unijunction transistor (PUT) using a volt meter to show its response as a potentiometer increases the voltage applied to its anode.*

The voltage output of a PUT follows a curve that is very similar to that shown in Figure 27-5, although current and voltage would be measured at the cathode.

Variants

PUTs and UJTs are not made as surface-mount components.

UJTs are usually packaged in black plastic, although older variants were manufactured in cans. PUTs are almost all packaged in black plastic. With the leads pointing downward and the flat side facing toward the viewer, the lead functions of a PUT are usually anode, gate, and cathode, reading from left to right.

Values

The triggering voltage of a UJT can be calculated from the values of R1 and R2 in Figure 27-7 and the voltage at base 1. The term R_{bb} is often used to represent the sum of R1 + R2, with V_{bb} representing the total voltage across the two resistors (this is the same as the supply voltage in Figure 27-6). V_t, the triggering voltage, is given by:

$$V_t = V_{bb} * (R1 / R_{bb})$$

The term ($R1/R_{bb}$) is known as the *standoff ratio*, often represented by the Greek letter ϱ.

Typically the standoff ratio in a UJT is at least 0.7, as R1 is chosen to be larger than R2. Typical values for R1 and R2 could be 180Ω and 100Ω, respectively. If R4 is 50K and a 100K linear potentiometer is used for R3, the PUT should be triggered when the potentiometer is near the center of its range. The emitter saturation voltage is typically from 2V to 4V.

If using a PUT, typical values in the test circuit could be supply voltage ranging from 9VDC to 20VDC, with resistances 28K for R1 and 16K for R2, 20Ω for R5, 280K for R4, and a 500K linear potentiometer for R3. The PUT should be triggered when the potentiometer is near the center of its range.

Sustained forward current from anode to cathode is usually a maximum of 150mA, while from gate to cathode the maximum is usually 50mA. Power dissipation should not exceed 300mW. These values should be lower at temperatures above 25 degrees Centigrade.

Depending on the PUT being used, power consumption can be radically decreased by upping the resistor values by a multiple of 100, while supply voltage can be decreased to 5V. The cathode output from the PUT would then be connected with the base of an NPN transistor for amplification.

How to Use it

Figure 27-8 shows a simple oscillator circuit built around a UJT, Figure 27-9 shows a comparable circuit for a PUT. Initially the supply voltage charges the capacitor, until the potential at the emitter of the UJT or the gate of the PUT reaches the threshold voltage, at which point the capacitor discharges through the emitter and the cycle repeats. Resistor values would be similar to those used in the test circuits previously described, while a capacitor value of 2.2μF would provide a visible pulse of the LED. Smaller capacitor values would enable faster oscillation. In the PUT circuit, adjusting the values of R1 and R2 would allow fine control of triggering the semiconductor.

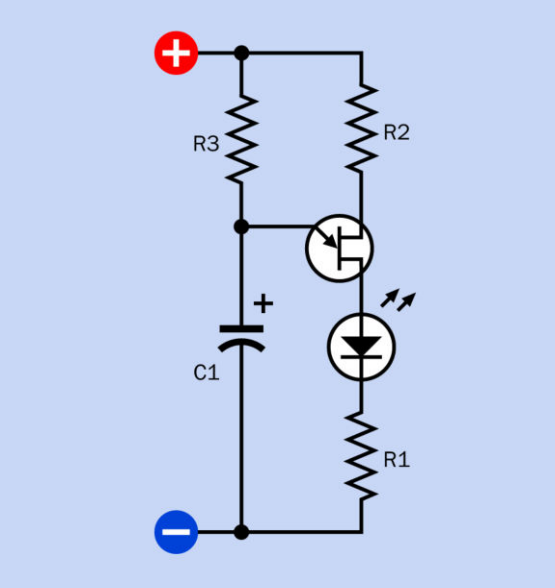

Figure 27-8. *A basic oscillator circuit using a unijunction transistor (UJT). As the capacitor accumulates charge, the voltage on the emitter increases until it triggers the UJT, at which point the capacitor discharges through the emitter.*

Probably the most common use for a PUT at this time is to trigger a **thyristor**.

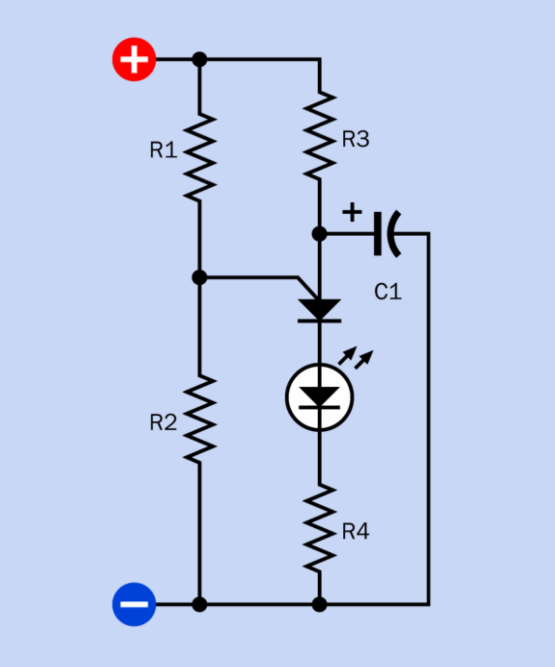

Figure 27-9. *A basic oscillator circuit using a programmable unijunction transistor (PUT). As the capacitor accumulates charge, the voltage on the anode increases until it triggers the PUT, at which point the capacitor discharges through the anode. The gate voltage is preset by R1 and R2 to adjust the triggering voltage.*

What Can Go Wrong

Name Confusion

A programmable unijunction transistor (PUT) is sometimes referred to simply as a "unijunction transistor" (UJT). Bearing in mind the totally different modes of operation of UJT and PUT, the PUT should always be identified by its acronym or by its full name. A circuit will not function if a UJT is substituted for a PUT, or a PUT is substituted for a UJT.

Incorrect Bias

Neither the UJT nor the PUT is designed to operate with reverse bias. In the UJT, a small forward bias should be applied from base 2 to base 1 (that is, base 2 should be at a higher potential relative to base 1) regardless of the voltage on the emitter. The emitter voltage may vary from 0 volts upward. The PUT must be forward biased between its anode and cathode (the anode must have a higher potential relative to the cathode), with an intermediate positive voltage at the gate established by resistors R1 and R2 functioning as a voltage divider (see Figure 27-7). Failure to observe correct biasing will result in unpredictable behavior and possible damage to the component.

Overload

Like any semiconductor, the UJT and the PUT must be protected from excessive current, which can burn out the component. Never connect either of these components directly across a power source without appropriate resistances to limit current flow. Maximum continuous power dissipation for UJTs and PUTs is usually 300mW.

bipolar transistor

28

The word *transistor*, on its own, is often used to mean *bipolar transistor*, as this was the type that became most widely used in the field of discrete semiconductors. However, *bipolar transistor* is the correct term. It is sometimes referred to as a *bipolar junction transistor* or *BJT*.

OTHER RELATED COMPONENTS

- **unijunction transistor** (See Chapter 27)
- **field-effect transistor** (See Chapter 29)
- **diac** (Volume 2)
- **triac** (Volume 2)
- **relay** (Volume 2)
- **solid-state relay** (Volume 2)

What It Does

A bipolar transistor amplifies fluctuations in current or can be used to switch current on and off. In its amplifying mode, it replaced the *vacuum tubes* that were formerly used in the amplification of audio signals and many other applications. In its switching mode it resembles a **relay**, although in its "off" state the transistor still allows a very small amount of current flow, known as *leakage*.

A bipolar transistor is described as a *discrete* semiconductor device when it is individually packaged, with three leads or contacts. A package containing multiple transistors is an *integrated circuit*. A Darlington pair actually contains two transistors, but is included here as a discrete component because it is packaged similarly and functions like a single transistor. Most integrated circuits will be found in Volume 2 of this encyclopedia.

How It Works

Although the earliest transistors were fabricated from germanium, silicon has become the most commonly used material. Silicon behaves like an insulator, in its pure state at room temperature, but can be "doped" (carefully contaminated) with impurities that introduce a surplus of electrons unbonded from individual atoms. The result is an *N-type semiconductor* that can be induced to allow the movement of electrons through it, if it is *biased* with an external voltage. *Forward bias* means the application of a positive voltage, while *reverse bias* means reversing that voltage.

Other dopants can create a deficit of electrons, which can be thought of as a surplus of "holes" that can be filled by electrons. The result is a *P-type semiconductor*.

A bipolar NPN transistor consists of a thin central P-type layer sandwiched between two thicker N-type layers. The three layers are referred to as *collector*, *base*, and *emitter*, with a wire or contact attached to each of them. When a negative charge is applied to the emitter, electrons are forced by mutual repulsion toward the central base layer. If a forward bias (positive potential) is applied to the base, electrons will tend to be attracted out through the base. However, because the base layer is so thin, the electrons are now close to the collector. If the base voltage increases, the additional energy encourages the electrons to jump into the collector, from which they will make their way to the positive current source, which can be thought of as having an even greater deficit of electrons.

Thus, the emitter of an NPN bipolar transistor emits electrons into the transistor, while the collector collects them from the base and moves them out of the transistor. It is important to remember that since electrons carry a negative charge, the flow of electrons moves from negative to positive. The concept of positive-to-negative current is a fiction that exists only for historical reasons. Nevertheless, the arrow in a transistor schematic symbol points in the direction of conventional (positive-to-negative) current.

In a PNP transistor, a thin N-type layer is sandwiched between two thicker P-type layers, the base is negatively biased relative to the emitter, and the function of an NPN transistor is reversed, as the terms “emitter” and “collector” now refer to the movement of electron-holes rather than electrons. The collector is negative relative to the base, and the resulting positive-to-negative current flow moves from emitter to base to collector. The arrow in the schematic symbol for a PNP transistor still indicates the direction of positive current flow.

Symbols for NPN and PNP transistors are shown in Figure 28-1. The most common symbol for an NPN transistor is shown at top-left, with letters C, B, and E identifying collector, base, and emitter. In some schematics the circle in the symbols is omitted, as at top-right.

A PNP transistor is shown in the center. This is the most common orientation of the symbol, since its collector must be at a lower potential than its emitter, and ground (negative) is usually at the bottom of a schematic. At bottom, the PNP symbol is inverted, allowing the positions of emitter and collector to remain the same as in the symbol for the NPN transistor at the top. Other orientations of transistor symbols are often found, merely to facilitate simpler schematics with fewer conductor crossovers. The direction of the arrow in the symbol (pointing out or pointing in) always differentiates NPN from PNP transistors, respectively, and indicates current flowing from positive to negative.

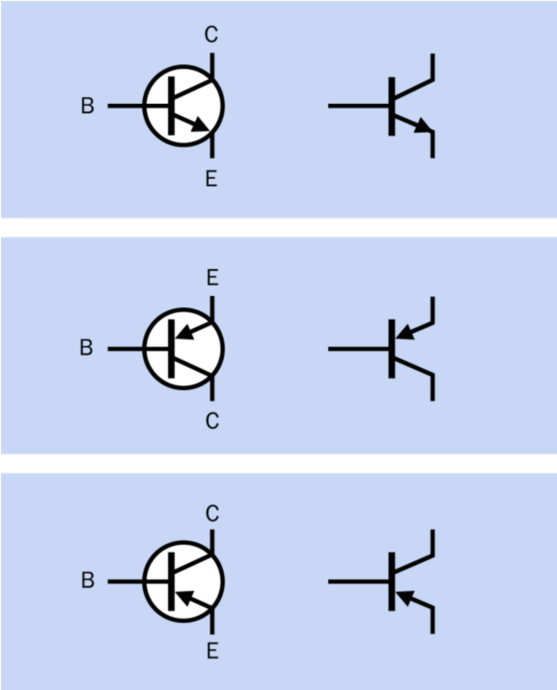

Figure 28-1. *Symbols for an NPN transistor (top) and a PNP transistor (center and bottom). Depending on the schematic in which the symbol appears, it may be rotated or inverted. The circle may be omitted, but the function of the component remains the same.*

NPN transistors are much more commonly used than PNP transistors. The PNP type was more difficult and expensive to manufacture initially, and circuit design evolved around the NPN type. In addition, NPN transistors enable faster switching, because electrons have greater mobility than electron-holes.

To remember the functions of the collector and the emitter in an NPN transistor, you may prefer to think in terms of the collector collecting positive current *into* the transistor, and the emitter emitting positive current *out of* the transistor. To remember that the emitter is always the terminal with an arrow attached to it (both in NPN and PNP schematic symbols), consider that "emitter" and "arrow" both begin with a vowel, while "base" and "collector" begin with consonants. To remember that an NPN transistor symbol has its arrow pointing outward, you can use the mnemonic "N/ever P/ointing i/N."

Current flow for NPN and PNP transistors is illustrated in Figure 28-2. At top-left, an NPN transistor passes no current (other than a small amount of leakage) from its collector to its emitter so long as its base is held at, or near, the potential of its emitter, which in this case is tied to negative or ground. At bottom-left, the purple positive symbol indicates that the base is now being held at a *relatively* positive voltage, at least 0.6 volts higher than the emitter (for a silicon-based transistor). This enables electrons to move from the emitter to the collector, in the direction of the blue arrows, while the red arrows indicate the conventional concept of current flowing from positive to negative. The smaller arrows indicate a smaller flow of current. A resistor is included to protect the transistor from excessive current, and can be thought of as the load in these circuits.

At top-right, a PNP transistor passes no current (other than a small amount of leakage) from its emitter to its collector so long as its base is held at, or near, the potential of the emitter, which in this case is tied to the positive power supply. At bottom-right, the purple negative symbol indicates that the base is now being held at a *relatively* negative voltage, at least 0.6 volts lower than the emitter. This enables electrons and current to flow as shown. Note that current flows into the base in the NPN transistor, but out from the base in the PNP transistor, to enable conductivity. In both diagrams, the resistor that would normally be included to protect the base has been omitted for the sake of simplicity.

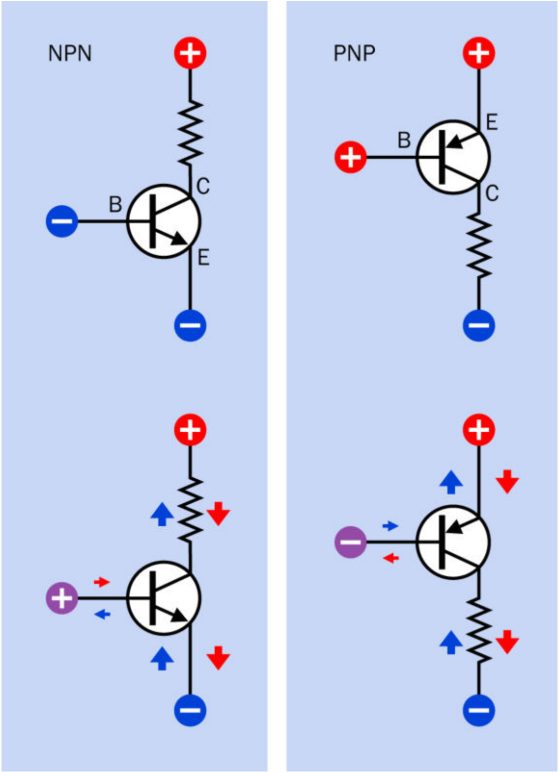

Figure 28-2. *Current flow through NPN and PNP transistors. See text for details.*

An NPN transistor amplifies its base current only so long as the positive potential applied to the collector is greater than the potential applied to the base, and the potential at the base must be greater than the potential at the emitter by at least 0.6 volts. So long as the transistor is biased in this way, and so long as the current values remain within the manufacturer's specified limits, a small fluctuation in current applied to the base will induce a much larger fluctuation in current between the collector and the emitter. This is why a transistor may be described as a *current amplifier*.

A *voltage divider* is often used to control the base potential and ensure that it remains less than the potential on the collector and greater than the potential at the emitter (in an NPN transistor). See Figure 28-3.

See Chapter 10 for additional information about the function of a voltage divider.

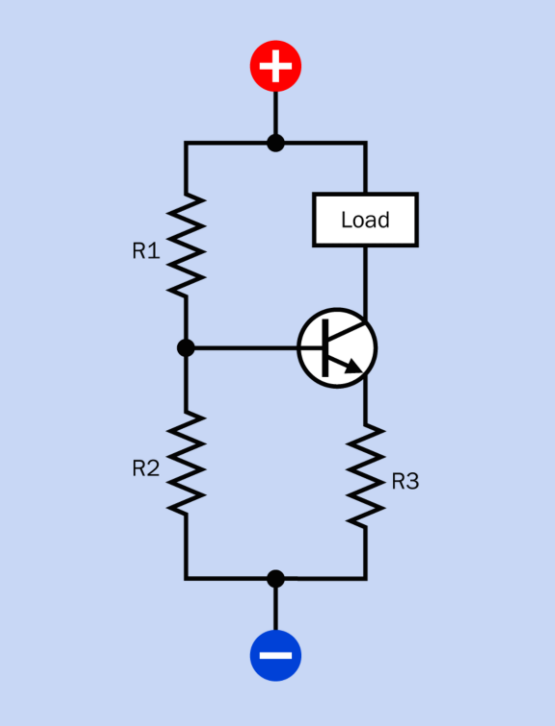

Figure 28-3. *Resistors R1 and R2 establish a voltage divider to apply acceptable bias to the base of an NPN transistor.*

Current Gain

The amplification of current by a transistor is known as its *current gain* or *beta value*, which can be expressed as the ratio of an increase in collector current divided by the increase in base current that enables it. Greek letter β is customarily used to represent this ratio. The formula looks like this:

$$\beta = \Delta I_c \ / \ \Delta I_b$$

where I_c is the collector current and I_b is the base current, and the Δ symbol represents a small change in the value of the variable that follows it.

Current gain is also represented by the term h_{FE}, where E is for the common Emitter, F is for Forward current, and lowercase letter h refers to the transistor as a “hybrid” device.

The beta value will always be greater than 1 and is often around 100, although it will vary from one type of transistor to another. It will also be affected by temperature, voltage applied to the transistor, collector current, and manufacturing inaccuracies. When the transistor is used outside of its design parameters, the formula to determine the beta value no longer directly applies.

There are only two connections at which current can enter an NPN transistor and one connection where it can leave. Therefore, if I_e is the current from the emitter, I_c is the current entering the collector, and I_b is the current entering the base:

$$I_e = I_c + I_b$$

If the potential applied to the base of an NPN transistor diminishes to the point where it is less than 0.6V above the potential at the emitter, the transistor will not conduct, and is in an “off” state, although a very small amount of leakage from collector to emitter will still occur.

When the current flowing into the base of the transistor rises to the point where the transistor cannot amplify the current any further, it becomes *saturated*, at which point its internal impedance has fallen to a minimal value. Theoretically this will allow a large flow of current; in practice, the transistor should be protected by resistors from being damaged by high current resulting from saturation.

Any transistor has maximum values for the collector current, base current, and the potential difference between collector and emitter. These values should be provided in a datasheet. Exceeding them is likely to damage the component.

Terminology

In its *saturated mode*, a transistor's base is saturated with electrons (with no room for more) and the internal impedance between collector and emitter drops as low as it can go.

The *cutoff mode* of an NPN transistor is the state where a low base voltage eliminates all current flow from collector to emitter other than a small amount of leakage.

The *active mode*, or *linear mode*, is the intermediate condition between cutoff and saturated, where the beta value or h_{FE} (ratio of collector current to base current) remains approximately constant. That is, the collector current is almost linearly proportional to the base current. This linear relationship breaks down when the transistor nears its saturation point.

Variants

Small signal transistors are defined as having a maximum collector current of 500 mA and maximum collector power dissipation of 1 watt. They can be used for audio amplification of low-level inputs and for switching of small currents. When determining whether a small-signal transistor can control an inductive load such as a motor or relay coil, bear in mind that the initial current surge will be greater than the rated current draw during sustained operation.

Small switching transistors have some overlap in specification with small signal transistors, but generally have a faster response time, lower beta value, and may be more limited in their tolerance for collector current. Check the manufacturer's datasheet for details.

High frequency transistors are primarily used in video amplifiers and oscillators, are physically small, and have a maximum frequency rating as high as 2,000 MHz.

Power transistors are defined as being capable of handling at least 1 watt, with upper limits that can be as high as 500 watts and 150 amps. They are physically larger than the other types, and may be used in the output stages of audio amplifiers, and in switching **power supplies** (see Chapter 16). Typically they have a much lower current gain than smaller transistors (20 or 30 as opposed to 100 or more).

Sample transistors are shown in Figure 28-4. Top: A 2N3055 NPN power transistor. This type was originally introduced in the late 1960s, and versions are still being manufactured. It is often found in power supplies and in push-pull power amplifiers, and has a total power dissipation rating of 115W. Second row, far left: general purpose switching-amplification PNP power transistor rated for up to 50W power dissipation. Second row, far right: A high-frequency switching transistor for use in lighting ballast, converters, inverters, switching regulators, and motor control systems. It tolerates relatively high voltages (up to 700V collector-emitter peak) and is rated for up to 80W total power dissipation. Second row, center-left and center-right: Two variants of the 2N2222 NPN small signal switching transistor, first introduced in the 1960s, and still very widely used. The metal can is the TO-19 package, capable of slightly higher power dissipation than the cheaper plastic TO-92 package (1.8W vs. 1.5W with a collector temperature no greater than 25 degrees Centigrade).

Packaging

Traditionally, small-signal transistors were packaged in small aluminum "cans" about 1/4" in diameter, and are still sometimes found in this form. More commonly they are embedded in buds of black plastic. Power transistors are packaged either in a rectangular module of black

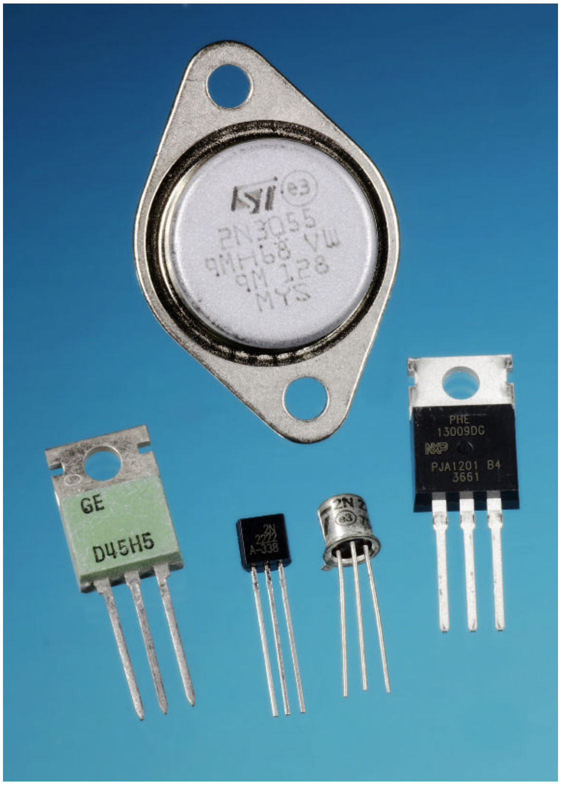

Figure 28-4. *Samples of commonly used transistors. See text for details.*

plastic with a metal back, or in a round metal "button." Both of these forms are designed to dissipate heat by being screw-clamped to a *heat sink*.

Connections

Often a transistor package provides no clue as to which lead is the emitter, which lead is the base, and which lead is the collector. Old can-style packaging includes a protruding tab that usually points toward the emitter, but not always. Where power transistors are packaged in a metal enclosure, it is typically connected internally with the collector. In the case of surface-mount transistors, look for a dot or marker that should identify the base of a bipolar transistor or the gate of a field-effect transistor.

A through-hole transistor usually has its part number printed or engraved on its package, although a magnifying glass may be necessary to see this. The component's datasheet may then be checked online. If a datasheet is unavailable, meter-testing will be necessary to confirm the functions of the three transistor leads. Some multimeters include a transistor-test function, which may validate the functionality of a transistor while also displaying its beta value. Otherwise, a meter can be put in diode-testing mode, and an unpowered NPN transistor should behave as if diodes are connected between its leads as shown in Figure 28-5. Where the identities of the transistor's leads are unknown, this test will be sufficient to identify the base, after which the collector and emitter may be determined empirically by testing the transistor in a simple low-voltage circuit such as that shown in Figure 28-6.

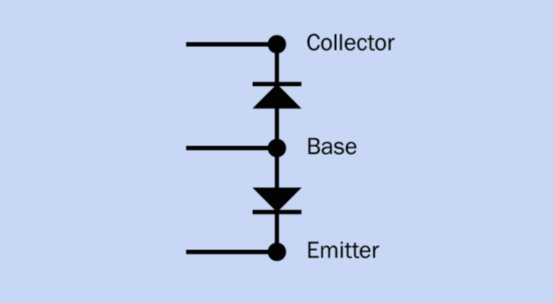

Figure 28-5. *An NPN transistor can behave as if it contains two diodes connected as shown. Where the functions of the leads of the transistor are unknown, the base can be identified by testing for conductivity.*

How to Use it

The following abbreviations and acronyms are common in transistor datasheets. Some or all of the letters following the initial letter are usually, but not always, formatted as subscripts:

h_{FE}
Forward current gain

β
Same as hFE

V_{CEO}
Voltage between collector and emitter (no connection at base)

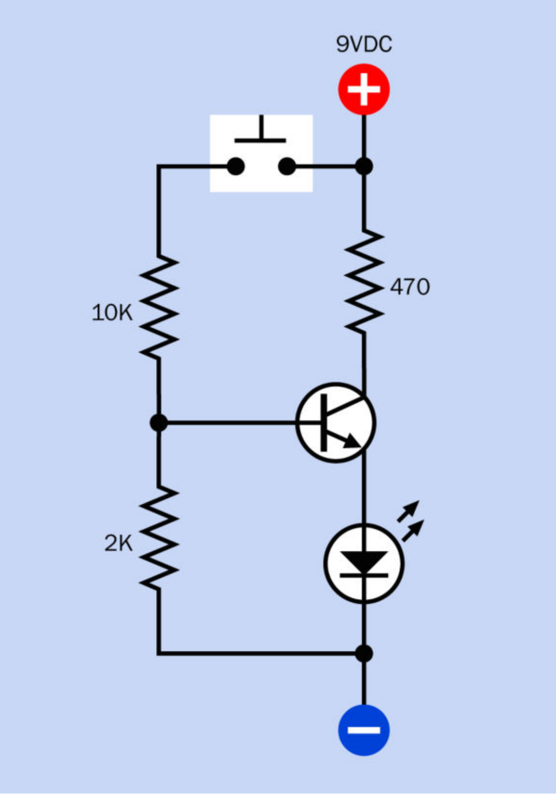

Figure 28-6. *This simple schematic can be used to breadboard-test a transistor empirically, determining its functionality and the identities of its collector and emitter leads.*

V_{CBO}

Voltage between collector and base (no connection at emitter)

V_{EBO}

Voltage between emitter and base (no connection at collector)

V_{CEsat}

Saturation voltage between collector and emitter

V_{BEsat}

Saturation voltage between base and emitter

I_c

Current measured at collector

I_{CM}

Maximum peak current at collector

I_{BM}

Maximum peak current at base

P_{TOT}

Total maximum power dissipation at room temperature

T_J

Maximum junction temperature to avoid damage

Often these terms are used to define “absolute maximum values” for a component. If these maximums are exceeded, damage may occur.

A manufacturer’s datasheet may include a graph showing the *safe operating area* (SOA) for a transistor. This is more common where power transistors are involved, as heat becomes more of an issue. The graph in Figure 28-7 has been adapted from a datasheet for a silicon diffused power transistor manufactured by Philips. The safe operating area is bounded at the top by a horizontal segment representing the maximum safe current, and at the right by a vertical segment representing the maximum safe voltage. However, the rectangular area enclosed by these lines is reduced by two diagonal segments representing the *total power limit* and the *second breakdown limit*. The latter refers to the tendency of a transistor to develop internal localized “hot spots” that tend to conduct more current, which makes them hotter, and able to conduct better—ultimately melting the silicon and causing a short circuit. The total power limit and the second breakdown limit reduce the safe operating area, which would otherwise be defined purely by maximum safe current and maximum safe voltage.

Uses for discrete transistors began to diminish when integrated circuits became cheaper and started to subsume multi-transistor circuits. For instance, an entire 5-watt audio amplifier, which used to be constructed from multiple components can now be bought on a chip, requiring just

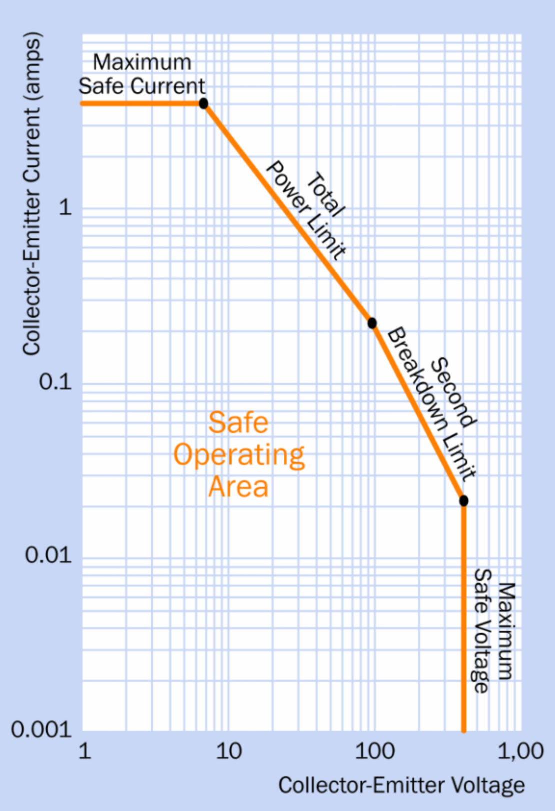

Figure 28-7. *Adapted from a Philips datasheet for a power transistor, this graph defines a* safe operating area *(SOA) for the component. See text for details.*

a few external capacitors. More powerful audio equipment typically uses integrated circuits to process inputs, but will use individual power transistors to handle high-wattage output.

Darlington Pairs

Discrete transistors are useful in situations where current amplification or switching is required at just one location in a circuit. An example would be where one output pin from a **microcontroller** must switch a small motor on and off. The motor may run on the same voltage as the microcontroller, but requires considerably more current than the typical 20mA maximum available from a microcontroller output. A *Darlington pair* of transistors may be used in this application. The overall gain of the pair can be 100,000 or more. See Figure 28-8. If a power source feeding through a potentiometer is substituted for the microcontroller chip, the circuit can function as a motor speed control (assuming that a generic DC motor is being used).

In the application shown here, the microcontroller chip must share a common ground (not shown) with the transistors. The optional resistor may be necessary to prevent leakage from the first transistor (when in its "off" state) from triggering the second. The diode protects the transistors from voltage transients that are likely when the motor stops and starts.

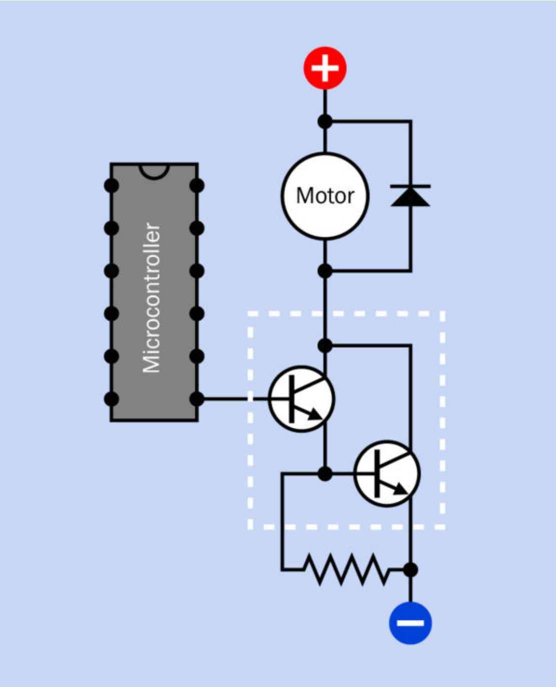

Figure 28-8. *Where the emitter of one NPN transistor is coupled to the base of another, they form a Darlington pair (identified by the dashed rectangle in this schematic). Multiplying the gain of the first transistor by the gain of the second gives the total gain of the pair.*

A Darlington pair can be obtained in a single transistor-like package, and may be represented by the schematic symbol shown in Figure 28-9.

Various through-hole Darlington packages are shown in Figure 28-10.

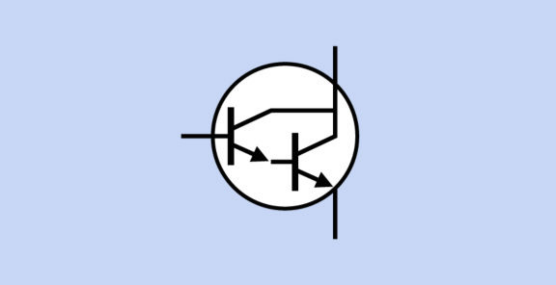

Figure 28-9. *When a Darlington pair is embedded in a single transistor-like package, it may be represented by this schematic symbol. The leads attached to the package can be used as if they are the emitter, base, and collector of a single NPN transistor.*

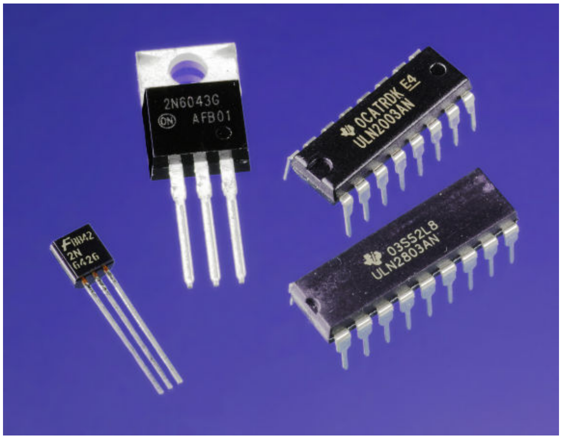

Figure 28-10. *Various packaging options for Darlington pairs. From left to right: The 2N6426 contains a Darlington pair rated to pass up to 500mA continuous collector current. The 2N6043 is rated for 8A continuous. The ULN2003 and ULN2083 chips contain seven and eight Darlington pairs, respectively.*

Seven or eight Darlington pairs can be obtained in a single integrated chip. Each transistor pair in these chips is typically rated at 500mA, but they can be connected in parallel to allow higher currents. The chip usually includes protection diodes to allow it to drive inductive loads directly.

A typical schematic is shown in Figure 28-11. In this figure, the microcontroller connections are hypothetical and do not correspond with any actual chip. The Darlington chip is a ULN2003 or similar, containing seven transistor pairs, each with an "input" pin on the left and an "output" pin opposite it on the right. Any of pins 1 through 7 down the left side of the chip can be used to control a device connected to a pin on the opposite side.

A high input can be thought of as creating a negative output, although in reality the transistors inside the chip are sinking current via an external device—a motor, in this example. The device can have its own positive supply voltage, shown here as 12VDC, but must share a common ground with the microcontroller, or with any other component which is being used on the input side. The lower-right pin of the chip shares the 12VDC supply because this pin is attached internally to clamp diodes (one for each Darlington pair), which protect against surges caused by inductive loads. For this reason, the motor does not have a clamp diode around it in the schematic.

The Darlington chip does not have a separate pin for connection with positive supply voltage, because the transistors inside it are sinking power from the devices attached to it.

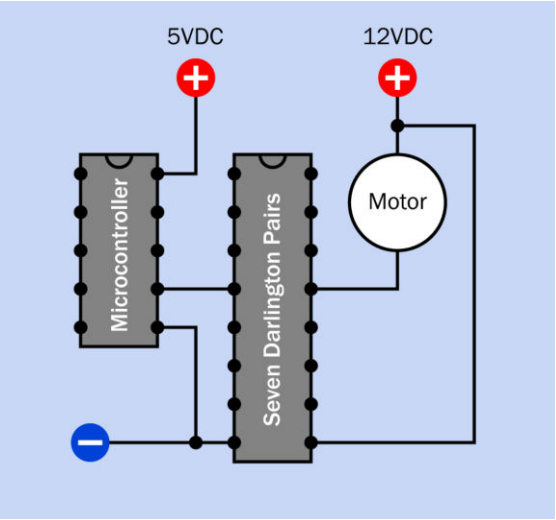

Figure 28-11. *A chip such as the ULN2003 contains seven Darlington pairs. It will sink current from the device it is driving. See text for details.*

A surface-mount Darlington pair is shown in Figure 28-12. This measures just slightly more than 0.1" long but is still rated for up to 500mA collector current or 250mW total power dissipation (at a component temperature no higher than 25 degrees Centigrade).

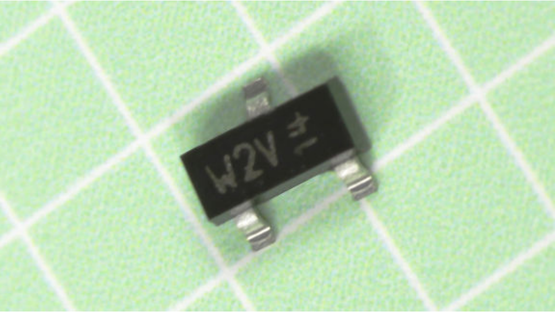

Figure 28-12. *A surface-mount package for a Darlington pair. Each square in the background grid measures 0.1". See text for additional details.*

Amplifiers

Two basic types of transistor amplifiers are shown in Figure 28-13 and Figure 28-14. The *common-collector* configuration has current gain but no voltage gain. The capacitor on the input side blocks DC current from entering the amplifier circuit, and the two resistors forming a voltage divider on the base of the transistor establish a voltage midpoint (known as the *quiescent point* or *operating point*) from which the signal to be amplified may deviate above and below.

The *common-emitter* amplifier provides voltage gain instead of current gain, but inverts the phase of the input signal. Additional discussion of amplifier design is outside the scope of this encyclopedia.

In switching applications, modern transistors have been developed to handle a lot of current compared with earlier versions, but still have some limitations. Few power transistors can handle more than 50A flowing from collector to emitter, and 1,000V is typically a maximum value. Electromechanical relays continue to exist because they retain some advantages, as shown in the table in Figure 28-15, which compares switching capabilities of transistors, **solid-state relays**, and electromechanical **relays**.

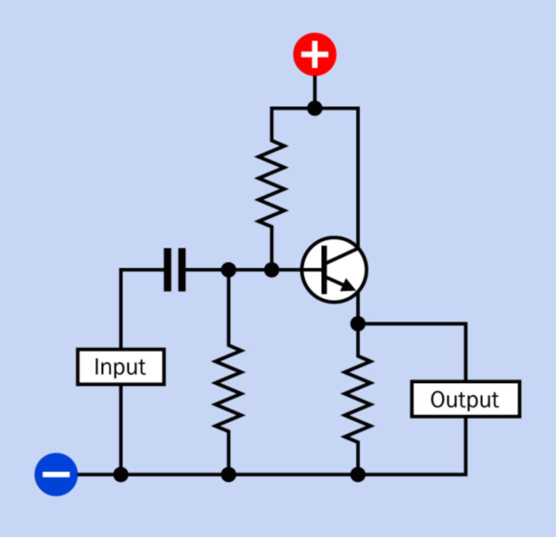

Figure 28-13. *The basic schematic for a common-collector amplifier. See text for details.*

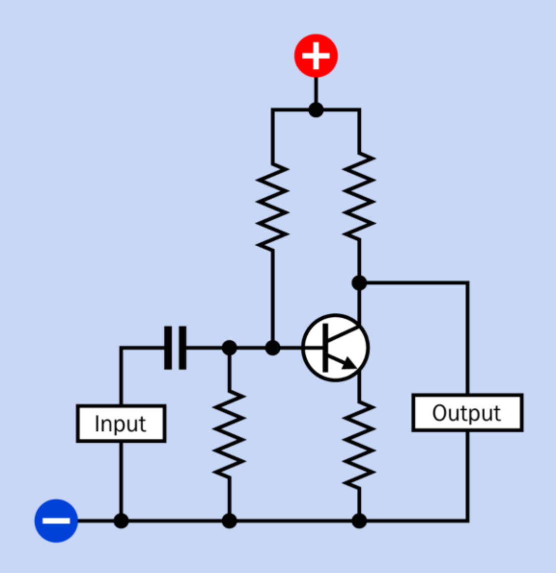

Figure 28-14. *The basic schematic for a common-emitter amplifier. See text for details.*

	Transistor	Solid-State Relay	Electro-Mechanical Relay
Long-term reliability	Excellent	Excellent	Limited
NC contacts?	No	Yes	Yes
DT contacts?	No	No	Yes
Ability to switch large current	Limited	Some	Good
Ability to switch AC	No	Yes	Yes
Can be triggered by AC voltage?	No	Yes	Yes
Suitability for miniaturization	Excellent	Poor	Poor
Vulnerable to heat	Yes	Yes	Not very
Vulnerable to corrosion	No	No	Yes
OK at high speed	Excellent	Good	Poor
Price advantage for low-voltage low-current	Yes	No	No
Price advantage for high-voltage high-current	No	No	Yes
Current leakage when "off"	Yes	Yes	No
Trigger circuit isolated from switched circuit	No	Yes	Yes

Figure 28-15. *A comparison of characteristics of switching devices.*

What Can Go Wrong

Wrong Connections on a Bipolar Transistor

Failing to identify a transistor's leads or contacts correctly can obviously be a potential source of damage, but swapping the collector and emitter accidentally will not necessarily destroy the transistor. Because of the inherent symmetry of the device, it will in fact function with collector and emitter connections reversed. Rohm, a large semiconductor manufacturer, has included this scenario in its general information pages and concludes that the primary indicator of transposed connections is that the β value, or h_{FE} , drops to about 1/10th of specification. If you are using a transistor that works but provides much less amplification than you expect, check that the emitter and collector leads are not transposed.

Wrong Connections on a Darlington Pair Chip

While a single-component package for a Darlington pair functions almost indistinguishably from a single transistor, multiple Darlington pairs in a DIP package may create confusion because the component behaves differently from most other chips, such as logic chips.

A frequent error is to ground the output device instead of applying positive power to it. See Figure 28-11 and imagine an erroneous connection of negative power instead of the 12VDC positive power.

Additional confusion may be caused by reading a manufacturer's datasheet for a Darlington pair chip such as the ULN2003. The datasheet depicts the internal function of the chip as if it contains logic inverters. While the chip can be imagined as behaving this way, in fact it contains bipolar transistors that amplify the current applied to the base of each pair. The datasheet also typically will not show the positive connection that should be made to the common-diode pin (usually at bottom-right), to provide protection from surges caused by inductive loads. This pin must be distinguished carefully from the common-ground pin (usually at bottom-left). The positive connection to the common-diode pin is optional; the common-ground connection is mandatory.

Soldering Damage

Like any semiconductor, transistors are vulnerable to heat and can be damaged while soldering, although this seldom happens if a low-wattage iron is used. A copper alligator clip can be applied as a heat sink to each lead before it is soldered.

Excessive Current or Voltage

During use, a transistor will be damaged if it is subjected to current or voltage outside of its rated range. Passing current through a transistor without any series resistance to protect it will almost certainly burn it out, and the same thing can happen if incorrect resistor values are used.

The maximum wattage that a transistor can dissipate will be shown in its datasheet. Suppose, for example, this figure is 200mW, and you are using a 12VDC supply. Ignoring the base current, the maximum collector current will be 200 / 12 = approximately 15mA. If the transistor's emitter is connected to ground, and the load applied to the transistor output has a high impedance, and if we ignore the transresistance, Ohm's Law suggests that a resistor that you place between the collector and the supply voltage should have a resistance of at least 12 / 0.015 = 800 ohms.

When transistors are used in switching applications, it is customary for the base current to be 1/5th of the collector current. In the example discussed here, a 4.7K resistor might be appropriate. A meter should be used to verify actual current and voltage values.

Excessive Leakage

In a Darlington pair, or any other configuration where the output from one transistor is connected with the base of another, leakage from the first transistor while in its "off" state can be amplified by the second transistor. If this is unacceptable, a bypass resistor can be used to divert some of the leakage from the base of the second transistor to ground. Of course the resistor will also steal some of the base current when the first transistor is active, but the resistor value is typically chosen so that it takes no more than 10% of the active current. See Figure 28-8 for an example of a bypass resistor added to a Darlington pair.

field effect transistor

28

The term **field-effect transistor** encompasses a family primarily consisting of the *junction field-effect transistor* (or *JFET*, which is the simplest generic type) and the *metal-oxide semiconductor field-effect transistor* (or *MOSFET*, also sometimes known as an *insulated-gate field-effect transistor*, or *IGFET*). Because the principles of operation overlap considerably, the entire -FET family is grouped in this entry.

OTHER RELATED COMPONENTS

- **bipolar transitor** (See Chapter 28)
- **unijunction transistor** (See Chapter 27)
- **diode** (See Chapter 26)

What It Does

A field-effect transistor creates an electric field to control current flowing through a channel in a semiconductor. MOSFETs of microscopic size form the basis of complementary metal oxide semiconductor (CMOS) *integrated circuit chips*, while large discrete MOSFETs are capable of switching substantial currents, in lamp dimmers, audio amplifiers, and motor controllers. FETs have become indispensable in computer electronics.

A **bipolar transistor** is generally thought of as a *current amplifier* because the current passing through it is controlled by a smaller amount of current passing through the base. By contrast, all FETs are considered to be *voltage amplifiers*, as the control voltage establishes field intensity, which requires little or no current. The negligible leakage through the gate of an FET makes it ideal for use in low-power applications such as portable hand-held devices.

How It Works

This section is divided into two subsections, describing the most widely used FETs: JFETs and MOSFETs.

JFETs

A *junction field-effect transistor* (or *JFET*) is the simplest form of FET. Just as a bipolar transistor can be of NPN or PNP type, a JFET can have an *N-channel* or *P-channel*, depending whether the channel that transmits current through the device is negatively or positively *doped*. A detailed explanation of semiconductor doping will be found in the **bipolar transistor** entry.

Because negative charges have greater mobility, the N-channel type allows faster switching and is more commonly used than the P-channel type. A schematic symbol for it is shown in Figure 29-1 alongside the schematic for an NPN transistor. These symbols suggest the similarity of the devices as amplifiers or switches, but it is important to remember that the FET is a primarily a voltage amplifier while the bipolar transistor is a current amplifier.

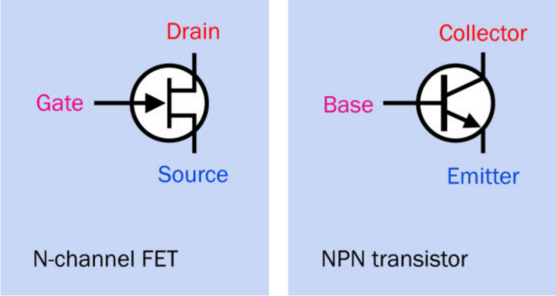

Figure 29-1. *A comparison between schematic symbols for N-channel JFET (left) and NPN bipolar transistor (right) suggests their functional similarity as switches or amplifiers, although their behavior is markedly different.*

Three JFETs are shown in Figure 29-2. The N-channel J112 type is supplied by several manufacturers, the figure showing two samples, one from Fairchild Semiconductor (left) and the other from On Semiconductor (right). Although the full part numbers are different, the specifications are almost identical, including a drain-gate voltage of 35V, a drain-source voltage of 35V, and a gate current of 50mA. The metal-clad 2N4392 in the center has similar values but is three times the price, with a much higher power dissipation of 1.8W, compared with 300mW and 350mW for the other two transistors respectively.

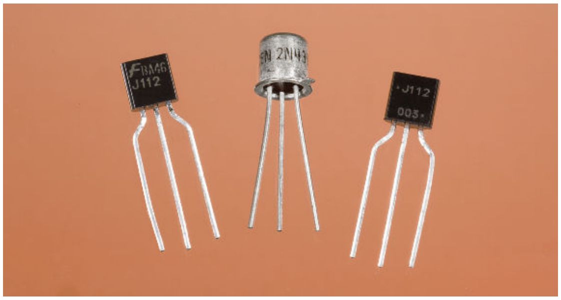

Figure 29-2. *Junction Field Effect Transistors (JFETs). See text for details.*

Schematic symbols for N-channel and P-channel JFETs are shown in Figure 29-3, N-channel being on the left while P-channel is on the right. The upper-left and lower-left symbol variants are both widely used and are functionally identical. The upper-right and lower-right variants likewise mean the same thing. Because the upper variants are symmetrical, an S should be added to clarify which terminal is the source. In practice, the S is often omitted, allowing some ambiguity. While the source and drain of some JFETs are in fact interchangeable, this does not apply to all types.

The circle around each symbol is occasionally omitted when representing discrete components, and is almost always omitted when multiple FETs are shown connected to form an integrated circuit.

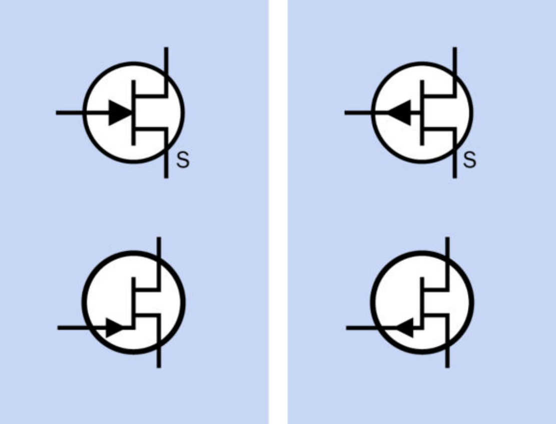

Figure 29-3. *Schematic symbols for junction field-effect transistors (JFETs). Left: N-channel. Right: P-channel. The symbols at top and bottom on each side are functionally identical. Circles may be omitted. Letter S may be omitted from the symmetrical symbol variants, even though this creates some ambiguity.*

The internal function of an N-channel JFET is shown diagrammatically in Figure 29-4. In this component, the source terminal is a source of electrons, flowing relatively freely through the N-doped channel and emerging through the drain. Thus, conventional current flows nonintuitively from the drain terminal, to the source terminal, which will be of lower potential.

The JFET is like a normally-closed switch. It has a low resistance so long as the gate is at the same potential as the source. However, if the potential of the gate is reduced below the potential of the source—that is, the gate acquires a more relatively negative voltage than the source—the current flow is *pinched off* as a result of the field created by the gate. This is suggested by the lower diagram in Figure 29-4.

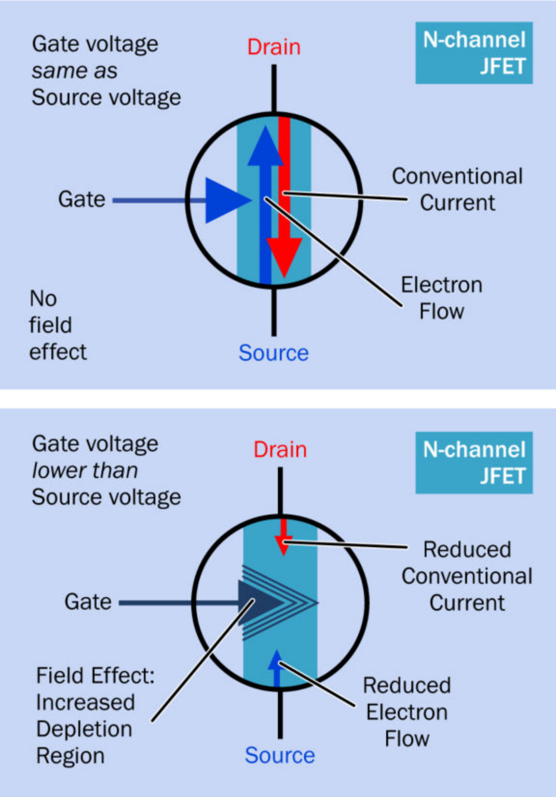
Gate voltage
same as
Source voltage
Drain
N-channel
JFET
Gate
Conventional
Current
Electron
Flow
No
field
effect
Source
Gate voltage
lower than
Source voltage
Drain
N-channel
JFET
Reduced
Conventional
Current
Gate
Field Effect:
Increased
Depletion
Region
Reduced
Electron
Flow
Source

Figure 29-4. *At top, conventional current flows freely from drain to source through the channel of an N-doped JFET. At bottom, the lowered voltage of the gate relative to the source creates a field effect that pinches off the flow of current.*

The situation for a P-channel JFET is reversed, as shown in Figure 29-5. The source is now positive (but is still referred to as the source), while the drain can be grounded. Conventional current now flows freely from source to drain, so long as the gate is at the same positive potential as the source. If the gate voltage rises above the source voltage, the flow is pinched off.

A bipolar transistor tends to block current flow by default, but becomes less resistive when its base is forward-biased. Therefore it can be referred to as an *enhancement device*. By contrast, an N-channel JFET allows current to flow by default, and becomes more resistive when its base is reverse-biased, which widens the *depletion layer* at the base junction. Consequently it can be referred to as a *depletion device*.

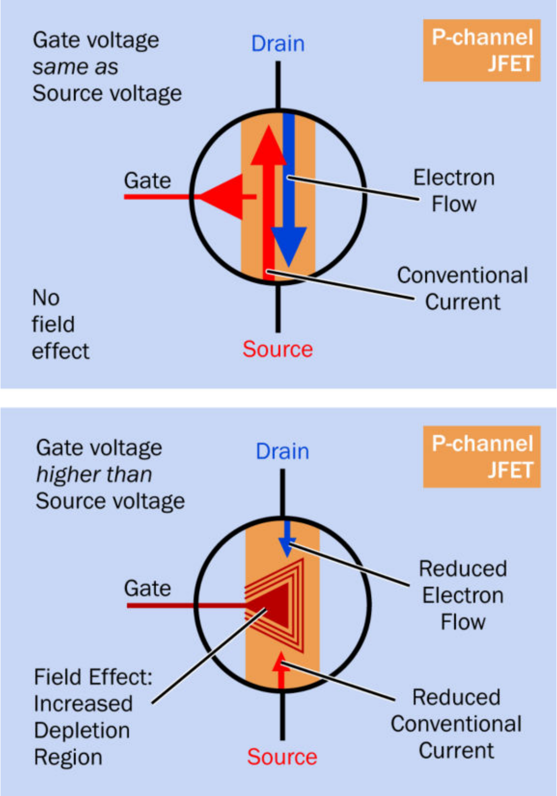
Gate voltage
same as
Source voltage
Drain
P-channel
JFET
Gate
Electron
Flow
Conventional
Current
No
field
effect
Source
Gate voltage
higher than
Source voltage
Drain
P-channel
JFET
Gate
Reduced
Electron
Flow
Field Effect:
Increased
Depletion
Region
Reduced
Conventional
Current
Source

Figure 29-5. *At top, conventional current flows freely from source to drain through the channel of a P-doped JFET. At bottom, the higher voltage of the gate relative to the source creates a field effect that pinches off the flow of current.*

The primary characteristics of a junction field-effect transistor relative to an NPN bipolar transistor are summarized in the table in Figure 29-6.

JFET Behavior

The voltage difference between gate and source of a JFET is usually referred to as V_{gs} while the voltage difference between drain and source is referred to as V_{ds}.

	NPN Bipolar Transistor	N-Channel JFET
Type of amplifier	Current	Voltage
Active bias	Positive	Negative
Unbiased state	Nonconductive	Conductive
Biased state	More conductive	Less conductive

Figure 29-6. *This table contrasts the characteristics of an N-channel JFET with those of an NPN bipolar transistor.*

Suppose the gate of an N-channel JFET is connected with the source, so that $V_{gs}=0$. Now if V_{ds} increases, the current flowing through the channel of the JFET also increases, approximately linearly with V_{ds}. In other words, initially the JFET behaves like a low-value resistor in which the voltage across it, divided by the amperage flowing through it, is approximately constant. This phase of the JFET's behavior is known as its *ohmic region*. While the unbiased resistance of the channel in a JFET depends on the component type, it is generally somewhere between 10Ω and 1K.

If V_{ds} increases still further, eventually no additional flow of current occurs. At this point the channel has become *saturated*, and this plateau zone is referred to as the *saturation region*, often abbreviated I_{dss}, meaning "the saturated drain current at zero bias." Although this is a nearly constant value for any particular JFET, it may vary somewhat from one sample of a component to another, as a result of manufacturing variations.

If V_{ds} continues to increase, the component finally enters a *breakdown* state, sometimes referred to by its full formal terminology as *drain-source breakdown*. The current passing through the JFET will now be limited only by capabilities of the external power source. This breakdown state can be destructive to the component, and is comparable to the breakdown state of a typical **diode**.

What if the voltage at the gate is reduced below the voltage at the source—such as V_{gs} becomes negative? In its ohmic region, the component now behaves as if it has a higher resistance, and it will reach its saturation region at a lower current value (although around the same value for V_{ds}). Therefore, by reducing the voltage on the gate relative to the voltage at the source, the effective resistance of the component increases, and in fact it can behave as a *voltage-controlled resistor*.

The upper diagram in Figure 29-7 shows this graphically. Below it, the corresponding graph for a P-channel JFET looks almost identical, except that the current flow is reversed and is pinched off as the gate voltage rises above the source voltage. Also, the breakdown region is reached more quickly with a P-channel JFET than with an N-channel JFET.

MOSFETs

MOSFETs have become one of the most widely used components in electronics, everywhere from computer memory to high-amperage switching power supplies. The name is an acronym for *metal-oxide semiconductor field-effect transistor*. A simplified cross-section of an N-channel MOSFET is shown in Figure 29-8.

Two MOSFETs are shown in Figure 29-9.

Like a JFET, a MOSFET has three terminals, identified as drain, gate, and source, and it functions by creating a field effect that controls current flowing through a channel. (Some MOSFETS have a fourth terminal, described later). However, it has a metal source and drain making contact with each end of the channel (hence the term "metal" in its acronym) and also has a thin layer of silicon dioxide (hence the term "oxide" in its acronym) separating the gate from the channel, thus raising the impedance at the gate to at least

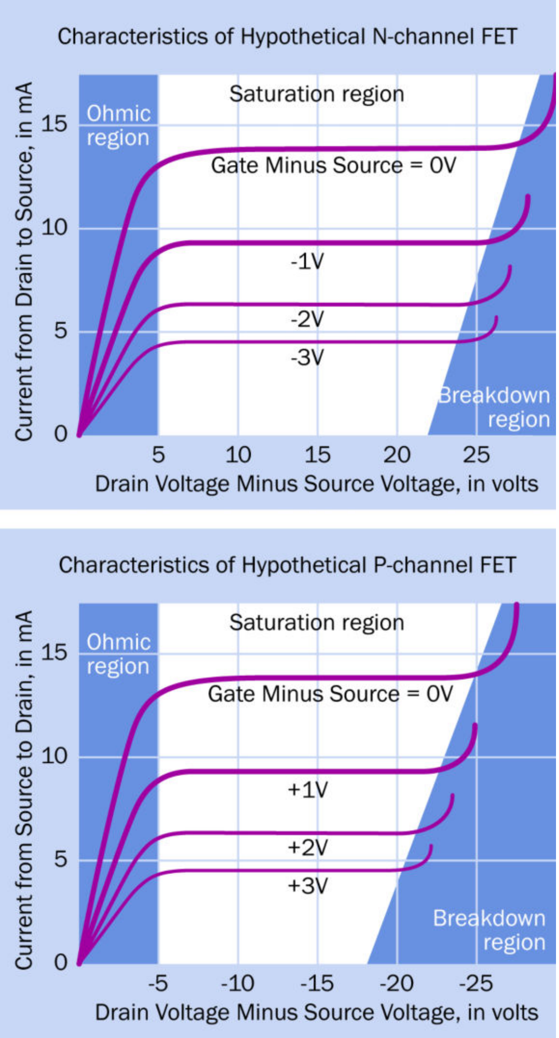

Figure 29-7. *The top graph shows current passing through the channel of an N-channel JFET, depending on gate voltage and source voltage. The lower graph is for a P-channel JFET.*

100,000 gigaohms and reducing gate current essentially to zero. The high gate impedance of a MOSFET allows it to be connected directly to the output of a digital integrated circuit. The layer of silicon dioxide is a *dielectric*, meaning that a field applied to one side creates an opposite field on the other side. The gate attached to the surface of the layer functions in the same way as one plate of a capacitor.

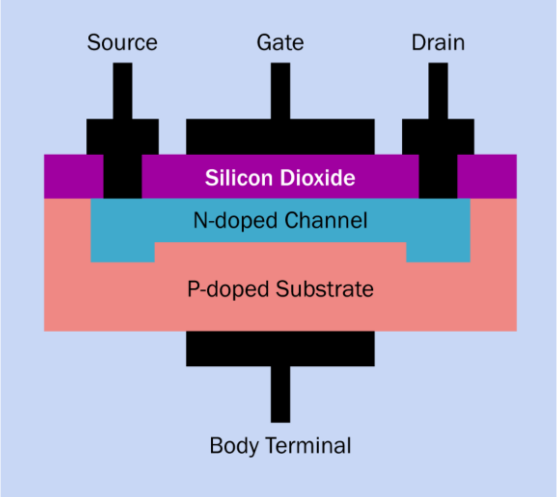

Figure 29-8. *Simplified diagram of an N-channel MOSFET. The thickness of the silicon dioxide layer has been greatly exaggerated for clarity. The black terminals are metallic.*

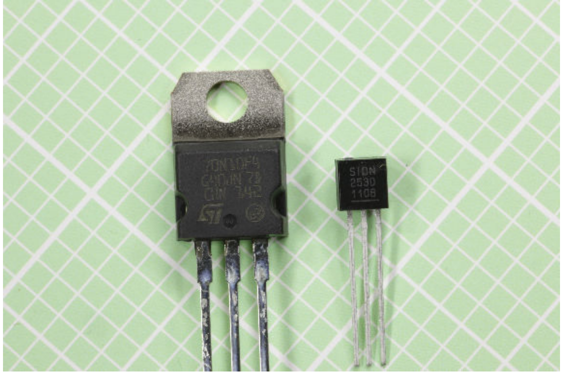

Figure 29-9. *Two MOSFETs. At left, the TO-220 package claims a drain current of up to 65A continuous, and a drain-to-source breakdown voltage 100V. At right, the smaller package offers a drain current of 175mA continuous, and a drain-to-source breakdown voltage of 300V.*

The silicon dioxide also has the highly desirable property of insulating the gate from the channel, thus preventing unwanted reverse current. In a JFET, which lacks a dielectric layer, if source voltage is allowed to rise more than about 0.6V higher than gate voltage, the direct internal connection between gate and channel allows negative charges to flow freely from source to gate, and as the internal resistance will be very low, the resulting current can be destructive. This is why the JFET must always be reverse-biased.

A MOSFET is freed from these restrictions, and the gate voltage can be higher or lower than the source voltage. This property enables an N-channel MOSFET to be designed not only as a depletion device, but alternatively as an *enhancement device*, which is “normally off” and can be switched on by being forward-biased. The primary difference is the extent to which the channel in the MOSFET is N-doped with charge carriers, and therefore will or will not conduct without some help from the gate bias.

In a depletion device, the channel conducts, but applying negative voltage to the gate can pinch off the current.

In an enhancement device, the channel does not conduct, but applying positive voltage to the gate can make it start to do so.

In either case, a shift of bias from negative to positive encourages channel conduction; the depletion and enhancement versions simply start from different points.

This is clarified in Figure 29-10. The vertical (logarithmic) scale suggests the current being conducted through the channel of the MOSFET, while the green curve describes the behavior of a depletion version of the device. Where this curve crosses the center line representing 0 volts bias, the channel is naturally conductive, like a JFET. Moving left down the curve, as reverse bias is applied (shown on the horizontal axis), the component becomes less conductive until finally its conductivity reaches zero.

Meanwhile on the same graph, the orange curve represents an enhancement MOSFET, which is nonconductive at 0 volts bias. As forward bias increases, the current also increases—similar to a bipolar transistor.

To make things more confusing, a MOSFET, like a JFET, can have a P-doped channel; and once again it can function in depletion or enhancement mode. The behavior of this variant is shown in Figure 29-11. As before, the green curve shows the behavior of a depletion MOSFET, while the orange curve refers to the enhancement version. The horizontal axis now shows the voltage difference between the gate and the drain terminal. The depletion component is naturally conductive at zero bias, until the gate voltage increases above the drain voltage, pinching off the current flow. The enhancement component is not conductive until reverse bias is applied.

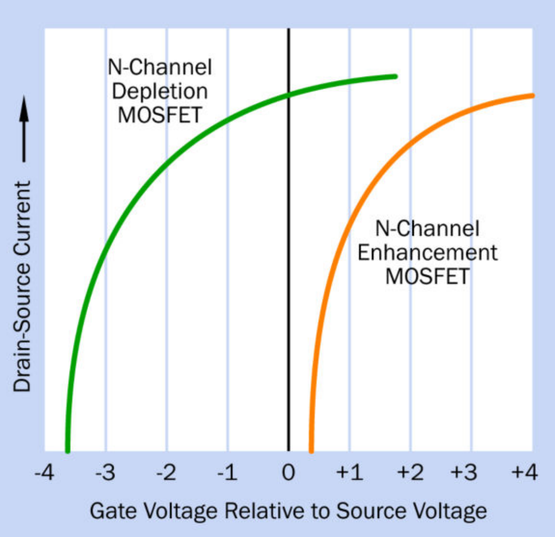

Figure 29-10. *The current conduction of depletion and enhancement N-channel MOSFETs. See text for details. (Influenced by The Art of Electronics by Horowitz and Hill.)*

Figure 29-12 shows schematic symbols that represent depletion MOSFETs. The two symbols on the left are functionally identical, representing N-channel versions, while the two symbols on the right represent P-channel versions. As in the case of JFETs, the letter “S” should be (but often is not) added to the symmetrical versions of the symbols, to clarify which is the source terminal. The left-pointing arrow identifies the components as N-channel, while in the symbols on the right, the right-pointing arrows indicate P-channel MOS-

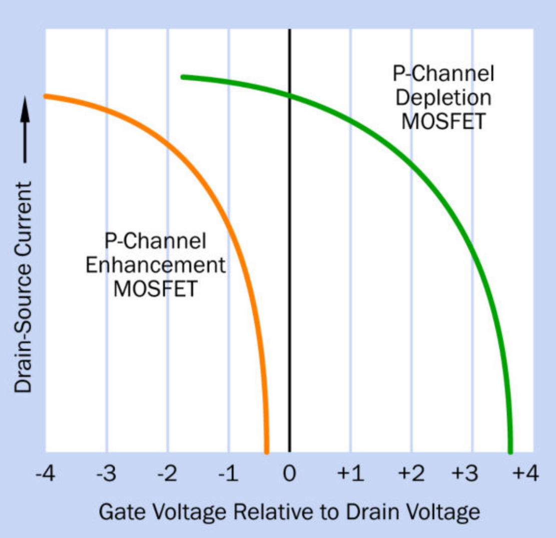

Figure 29-11. *The current conduction of depletion and enhancement P-channel MOSFETs. See text for details.*

FETs. The gap between the two vertical lines in each symbol suggests the silicon dioxide dielectric. The right-hand vertical line represents the channel.

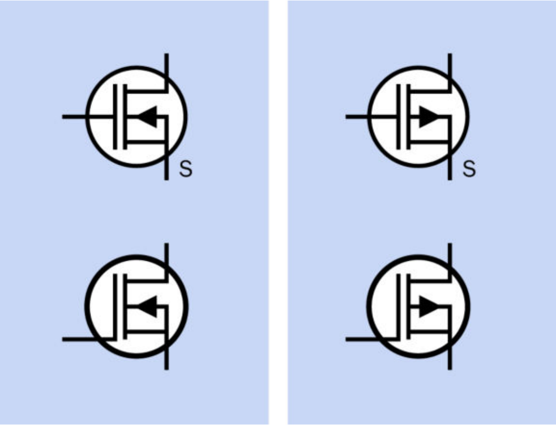

Figure 29-12. *Schematic symbols for depletion MOSFETs. These function similarly to JFETs. The two symbols on the left are functionally identical, and represent N-channel depletion MOSFETs. The two symbols on the right are both widely used to represent P-channel depletion MOSFETs.*

For enhancement MOSFETs, a slightly different symbol uses a broken line between the source and drain (as shown in Figure 29-13) to remind us that these components are "normally off" when zero-biased, instead of "normally on." Here again a left-pointing arrow represents an N-channel MOSFET, while a right-pointing arrow represents a P-channel MOSFET.

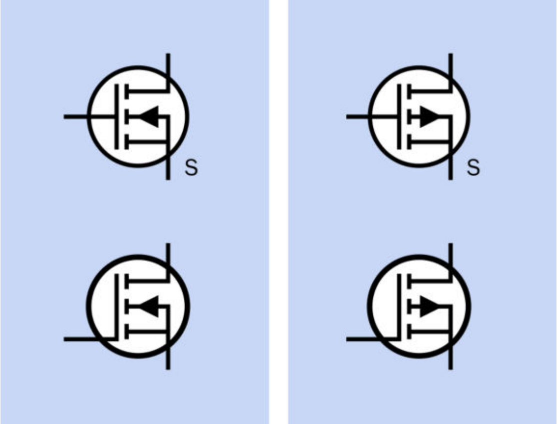

Figure 29-13. *Schematic symbols for enhancement MOSFETs. The two on the left are functionally identical, and represent N-channel enhancement MOSFETs. The two on the right represent P-channel enhancement MOSFETs.*

Because there is so much room for confusion regarding MOSFETs, a summary is presented in Figure 29-14 and Figure 29-15. In these figures, the relevant parts of each schematic symbol are shown disassembled alongside text explaining their meaning. Either of the symbols in Figure 29-14 can be superimposed on either of the symbols in Figure 29-15, to combine their functions. So, for instance, if the upper symbol in Figure 29-14 is superimposed on the lower symbol in Figure 29-15, we get an N-channel MOSFET of the enhancement type.

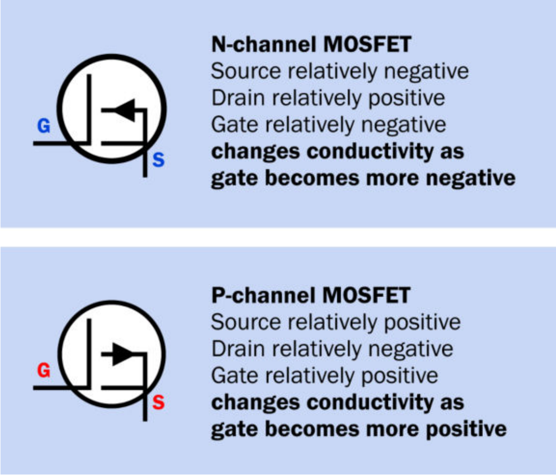
G
S
N-channel MOSFET
Source relatively negative
Drain relatively positive
Gate relatively negative
changes conductivity as
gate becomes more negative
G
S
P-channel MOSFET
Source relatively positive
Drain relatively negative
Gate relatively positive
changes conductivity as
gate becomes more positive

Figure 29-14. *Either of the two symbols can be combined with either of the two symbols in the next figure, to create one of the four symbols for a MOSFET. See text for details.*

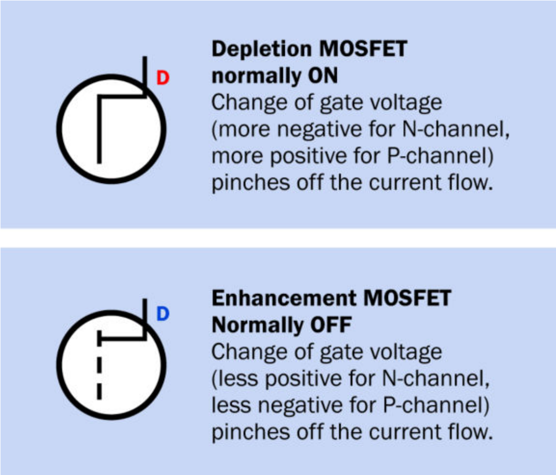
D
Depletion MOSFET
normally ON
Change of gate voltage
(more negative for N-channel,
more positive for P-channel)
pinches off the current flow.
D
Enhancement MOSFET
Normally OFF
Change of gate voltage
(less positive for N-channel,
less negative for P-channel)
pinches off the current flow.

Figure 29-15. *Either of the two symbols can be combined with either of the two symbols from the previous figure, to create one of the four symbols for a MOSFET. See text for details.*

In an additional attempt to clarify MOSFET behavior, four graphs are provided in Figure 29-16, Figure 29-17, Figure 29-18, and Figure 29-19. Like JFETs, MOSFETs have an initial ohmic region, followed by a saturation region where current flows relatively freely through the device. The gate-to-source voltage will determine how much flow is permitted. However, it is important to pay close attention to the graph scales, which differ for each of the four types of MOSFET.

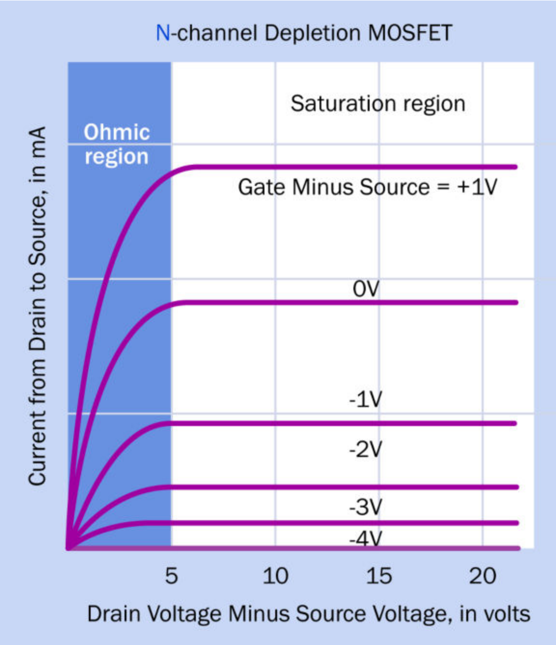

Figure 29-16. *Current flow through a depletion-type, N-channel MOSFET.*

In all of these graphs, a bias voltage exists, which allows zero current to flow (represented by the graph line superimposed on the horizontal axis). In other words, the MOSFET can operate as a switch. The actual voltages where this occurs will vary with the particular component under consideration.

The N-channel, enhancement-type MOSFET is especially useful as a switch because in its normally-off state (with zero bias) it presents a very high resistance to current flow. It requires a relatively low positive voltage at the gate, and effectively no gate current, to begin conducting conventional current from its drain terminal to its source terminal. Thus it can be driven directly by typical 5-volt logic chips.

Depletion-type MOSFETs are now less commonly used than the enhancement-type.

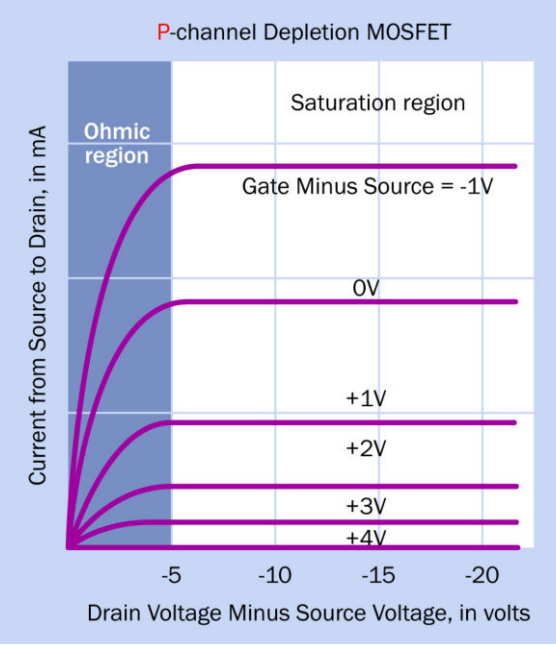

Figure 29-17. *Current flow through a depletion-type, P-channel MOSFET.*

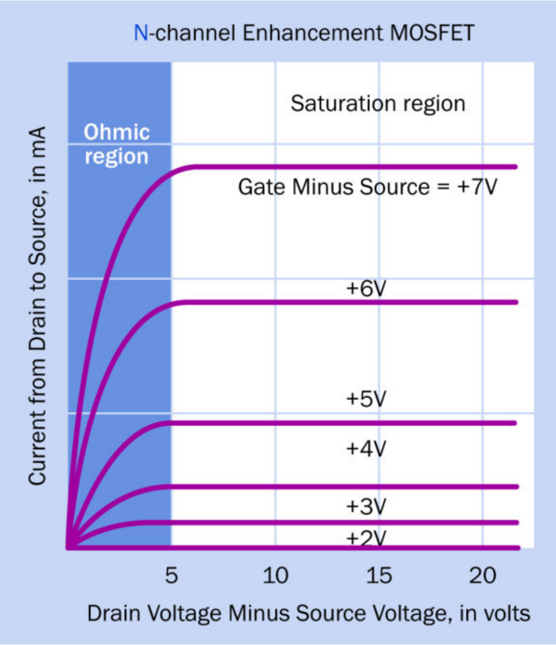

Figure 29-18. *Current flow through an enhancement-type, N-channel MOSFET.*

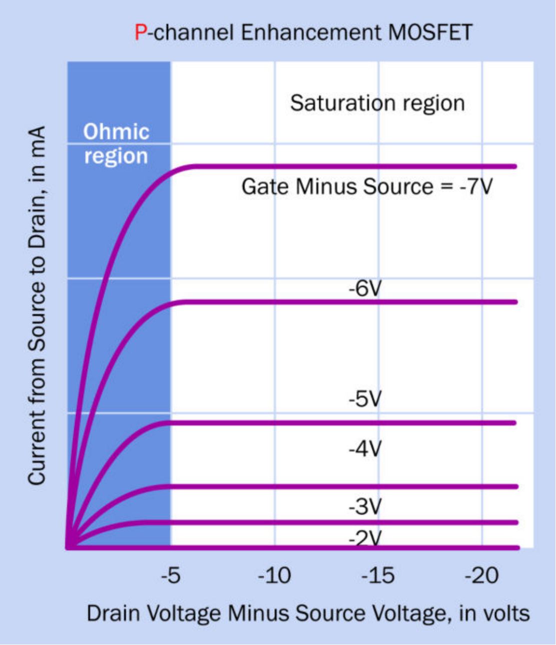

Figure 29-19. *Current flow through an enhancement-type, P-channel MOSFET.*

The Substrate Connection

Up to this point, nothing has been said about a fourth connection available on many MOSFETs, known as the *body terminal*. This is connected to the substrate on which the rest of the component is mounted, and acts as a diode junction with the channel. It is typically shorted to the source terminal, and in fact this is indicated by the schematic symbols that have been used so far. It is possible, however, to use the body terminal to shift the threshold gate voltage of the MOSFET, either by making the body terminal more negative than the source terminal (in an N-channel MOSFET) or more positive (in a P-channel MOSFET). Variants of the MOSFET schematic symbols showing the body terminal are shown in Figure 29-20 (for depletion MOSFETS) and Figure 29-21 (for enhancement MOSFETS).

A detailed discussion of the use of the body terminal to adjust characteristics of the gate is beyond the scope of this encyclopedia.

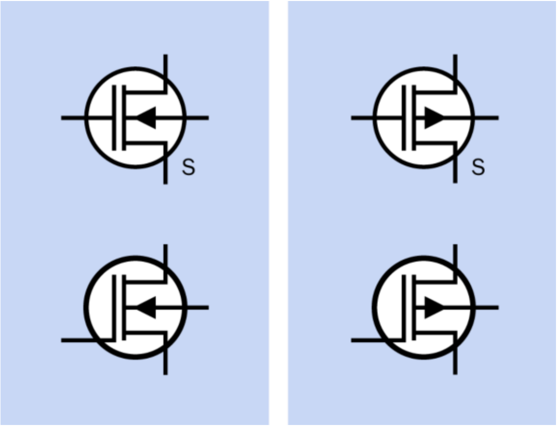

Figure 29-20. *Schematic symbol variants for depletion MOSFETs, showing the body terminal separately accessible instead of being tied to the source terminal.*

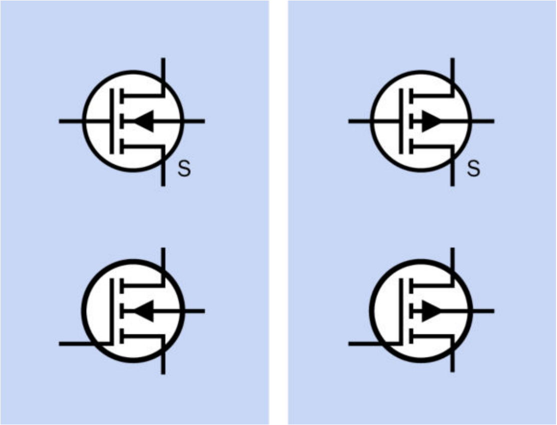

Figure 29-21. *Schematic symbol variants for enhancement MOSFETs, showing the body terminal separately accessible instead of being tied to the source terminal.*

Variants

A few FET variants exist in addition to the two previously discussed.

MESFET

The acronym stands for *MEtal-Semiconductor Field Effect Transistor*. This FET variant is fabricated from gallium arsenide and is used primarily in radio frequency amplification, which is outside the scope of this encyclopedia.

V-Channel MOSFET

Whereas most FET devices are capable of handling only small currents, the *V-channel MOSFET* (which is often abbreviated as a *VMOS FET* and has a V-shaped channel as its name implies) is capable of sustained currents of at least 50A and voltages as high as 1,000V. It is able to pass the high current because its channel resistance is well under 1Ω. These devices, commonly referred to as *power MOSFETs*, are available from all primary semiconductor manufacturers and are commonly used in switching power supplies.

Trench MOS

The TrenchMOS or Trenchgate MOS is a MOSFET variant that encourages current to flow vertically rather than horizontally, and includes other innovations that enable an even lower channel resistance, allowing high currents with minimal heat generation. This device is finding applications in the automobile industry as a replacement for electromechanical **relays**.

Values

The maximum values for JFETs, commonly found listed in datasheets, will specify V_{ds} (the drain-source voltage, meaning the potential difference between drain and source); V_{dg} (the drain-gate voltage, meaning the potential difference between drain and gate); V_{gsr} (the reverse gate-source voltage); gate current; and total device dissipation in mW. Note that the voltage differences are relative, not absolute. Thus a voltage of 50V on the drain and 25V on the source might be acceptable in a component with a V_{ds} of 25V. Similarly, while a JFET's "pinch-off" effect begins as the gate becomes "more negative" than the source, this can be achieved if, for example, the source has a potential of 6V and the gate has a potential of 3V.

JFETs and MOSFETs designed for low-current switching applications have a typical channel resistance of just a few ohms, and a maximum switching speed around 10Mhz.

The datasheet for a MOSFET will typically include values such as gate threshold voltage, which may be abbreviated V_{gs} (or V_{th}) and establishes the relative voltage at which the gate starts to play an active role; and the maximum on-state drain current, which may be abbreviated $I_{d(on)}$ and establishes the maximum limiting current (usually at 25 degree Centigrade) between source and gate.

How to Use it

The combination of a very high gate impedance, very low noise, very low quiescent power consumption in its off state, and very fast switching capability makes the MOSFET suitable for many applications.

P-Channel Disadvantage

P-channel MOSFETs are generally less popular than N-channel MOSFETS because of the higher resistivity of P-type silicon, resulting from its lower carrier mobility, putting it at a relative disadvantage.

Bipolar Substitution

In many instances, an appropriate enhancement-type MOSFET can be substituted for a bipolar transistor with better results (lower noise, faster action, much higher impedance, and probably less power dissipation).

Amplifier Front Ends

While MOSFETs are well-suited for use in the front end of an audio amplifier, chips containing MOSFETs are now available for this specific purpose.

Voltage-Controlled Resistor

A simple voltage-controlled resistor can be built around a JFET or MOSFET, so long as its performance remains limited to the linear or ohmic region.

Compatibility with Digital Devices

A JFET may commonly use power supplies in the range of 25VDC. However, it can accept the high/low output from a 5V digital device to control its gate. A 4.7K pullup resistor is an appropriate value to be used if the FET is to be used in conjunction with a TTL digital chip that may have a voltage swing of only approximately 2.5V between its low and high thresholds.

What Can Go Wrong

Static Electricity

Because the gate of a MOSFET is insulated from the rest of the component, and functions much like a plate of a capacitor, it is especially likely to accumulate static electricity. This static charge may then discharge itself into the body of the component, destroying it. A MOSFET is particularly vulnerable to electrostatic discharge because its oxide layer is so thin. Special care should be taken either when handling the component, or when it is in use. Always touch a grounded object or wear a grounded wrist band when handling MOSFETs, and be sure that any circuit using MOSFETs includes appropriate protection from static and voltage spikes.

A MOSFET should not be inserted or removed while the circuit in which it performs is switched on or contains residual voltage from undischarged capacitors.

Heat

Failure because of overheating is of special concern when using power MOSFETs. A Vishay Application Note ("Current Power Rating of Power Semiconductors") suggests that this kind of component is unlikely to operate at less than 90 degrees Centigrade in real-world conditions, yet the power handling capability listed in a datasheet usually assumes an industry standard of 25 degrees Centigrade.

On the other hand, ratings for continuous power are of little relevance to switching devices that have duty cycles well below 100%. Other factors also play a part, such as the possibility of power surges, the switching frequency, and the integrity of the connection between the component and its heat sink. The heat sink itself creates uncertainty by tending to average the temperature of the component, and of course there is no simple way to know the actual junction temperature, moment by moment, inside a MOSFET.

Bearing in mind the accumulation of unknown factors, power MOSFETs should be chosen on an extremely conservative basis. According to a tutorial in the *EE Times*, actual current switched by a MOSFET should be less than half of its rated current at 25 degrees, while one-fourth to one-third are common. Figure 29-22 shows the real-world recommended maximum drain current at various temperatures. Exceeding this recommendation can create additional heat, which cannot be dissipated, leading to further accumulation of heat, and a thermal runaway condition, causing eventual failure of the component.

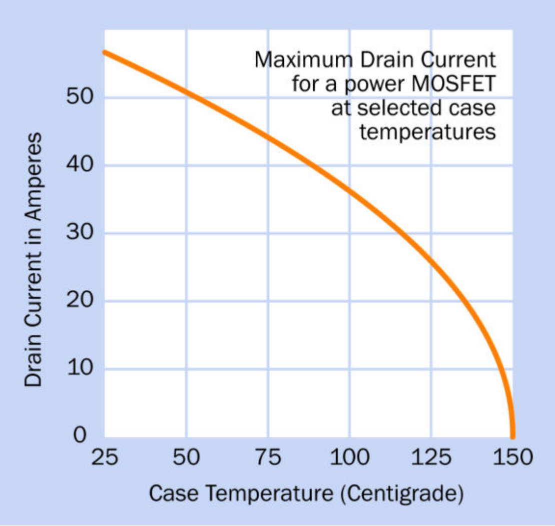

Figure 29-22. *Maximum advised drain current through a power MOSFET, related to case temperature of the component. Derived from EE Times Power MOSFET Tutorial.*

Wrong Bias

As previously noted, applying forward bias to a JFET can result in the junction between the gate and the source starting to behave like a forward-biased diode, when the voltage at the gate is greater than the voltage at the source by approximately 0.6V or more (in an N-channel JFET). The junction will present relatively little resistance, encouraging excessive current and destructive consequences. It is important to design devices that allow user input in such a way that user error can never result in this eventuality.

Schematic Symbols

A

This section contains a compilation of schematic symbols for components that have been described in this volume. They are sequenced primarily in alphabetical order, as this section is intended for use as an index. However, symbols that have a strong similarity are grouped together; thus **potentiometer** is found adjacent to **resistor**, and all types of transistors are in the same group.

The symbol variants shown in each blue rectangle are functionally identical.

Where a component has mandatory polarity or is commonly used with a certain polarity, a red plus sign (+) has been added for guidance. This sign is not part of the symbol. In the case of polarized capacitors, where a plus sign is normally shown (or should be shown) with the symbol, the plus sign is a part of the symbol and appears in black.

This is not intended to be an exhaustive compilation of symbol variants. Some uncommon ones may not be here. However, the list should be sufficient to enable identification of components in this volume.

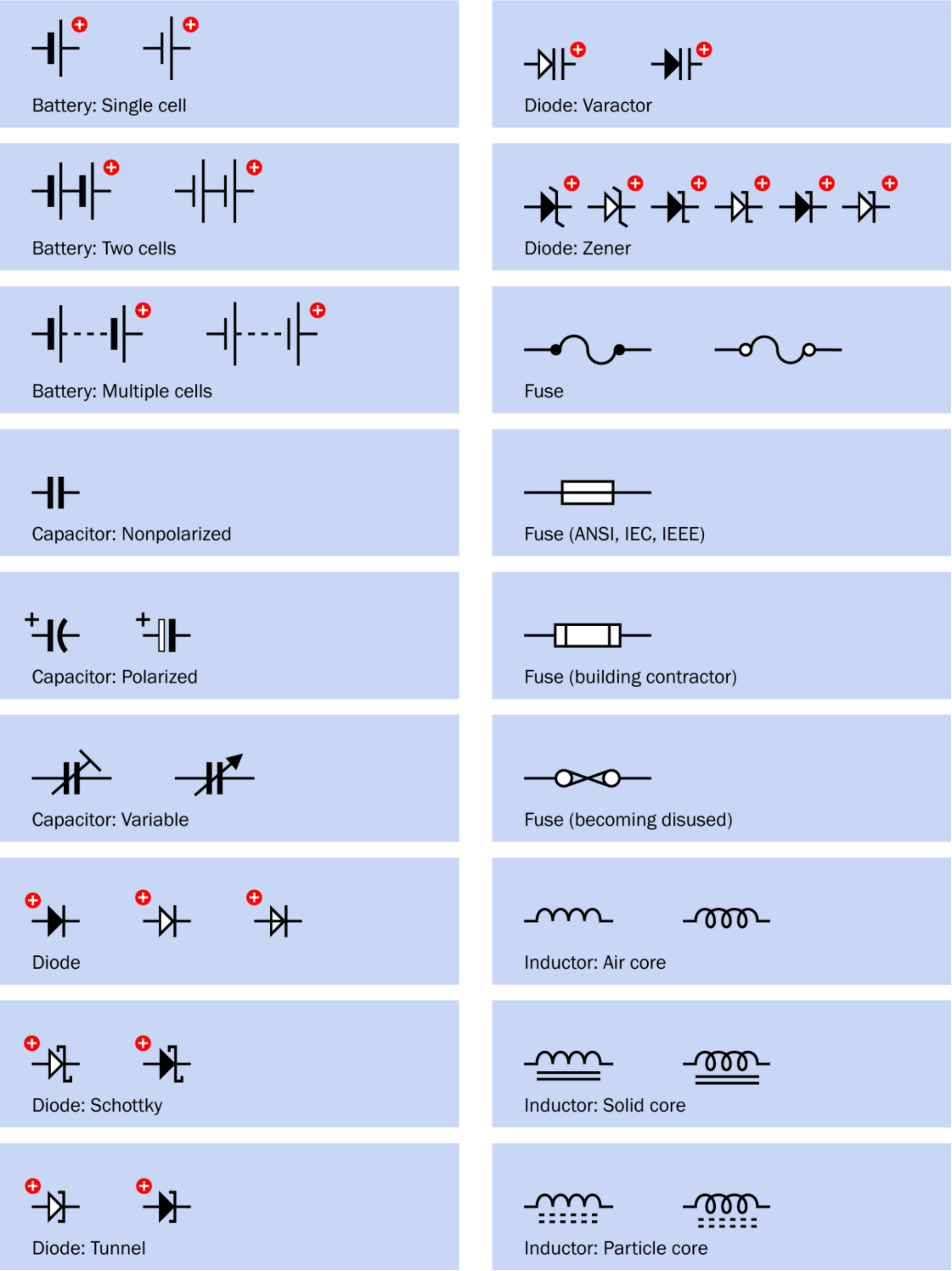
Battery: Single cell
Battery: Two cells
Battery: Multiple cells
Capacitor: Nonpolarized
Capacitor: Polarized
Capacitor: Variable
Diode
Diode: Schottky
Diode: Tunnel
Diode: Varactor
Diode: Zener
Fuse
Fuse (ANSI, IEC, IEEE)
Fuse (building contractor)
Fuse (becoming disused)
Inductor: Air core
Inductor: Solid core
Inductor: Particle core

Figure A-1. *Schematic symbols*

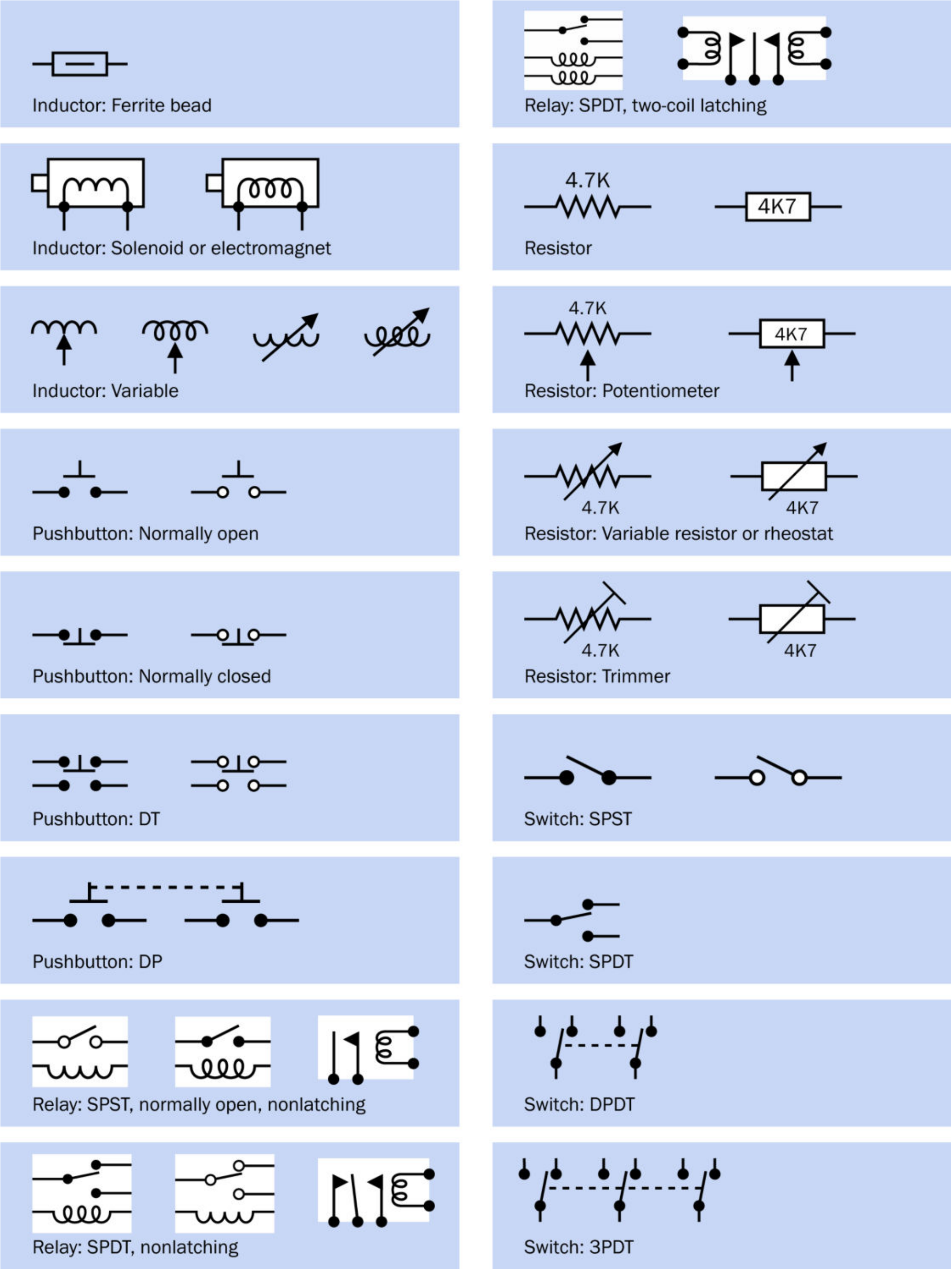
Inductor: Ferrite bead

Relay: SPDT, two-coil latching

Inductor: Solenoid or electromagnet

Resistor

Inductor: Variable

Resistor: Potentiometer

Pushbutton: Normally open

Resistor: Variable resistor or rheostat

Pushbutton: Normally closed

Resistor: Trimmer

Pushbutton: DT

Switch: SPST

Pushbutton: DP

Switch: SPDT

Relay: SPST, normally open, nonlatching

Switch: DPDT

Relay: SPDT, nonlatching

Switch: 3PDT

Figure A-2. *Schematic symbols, continued*

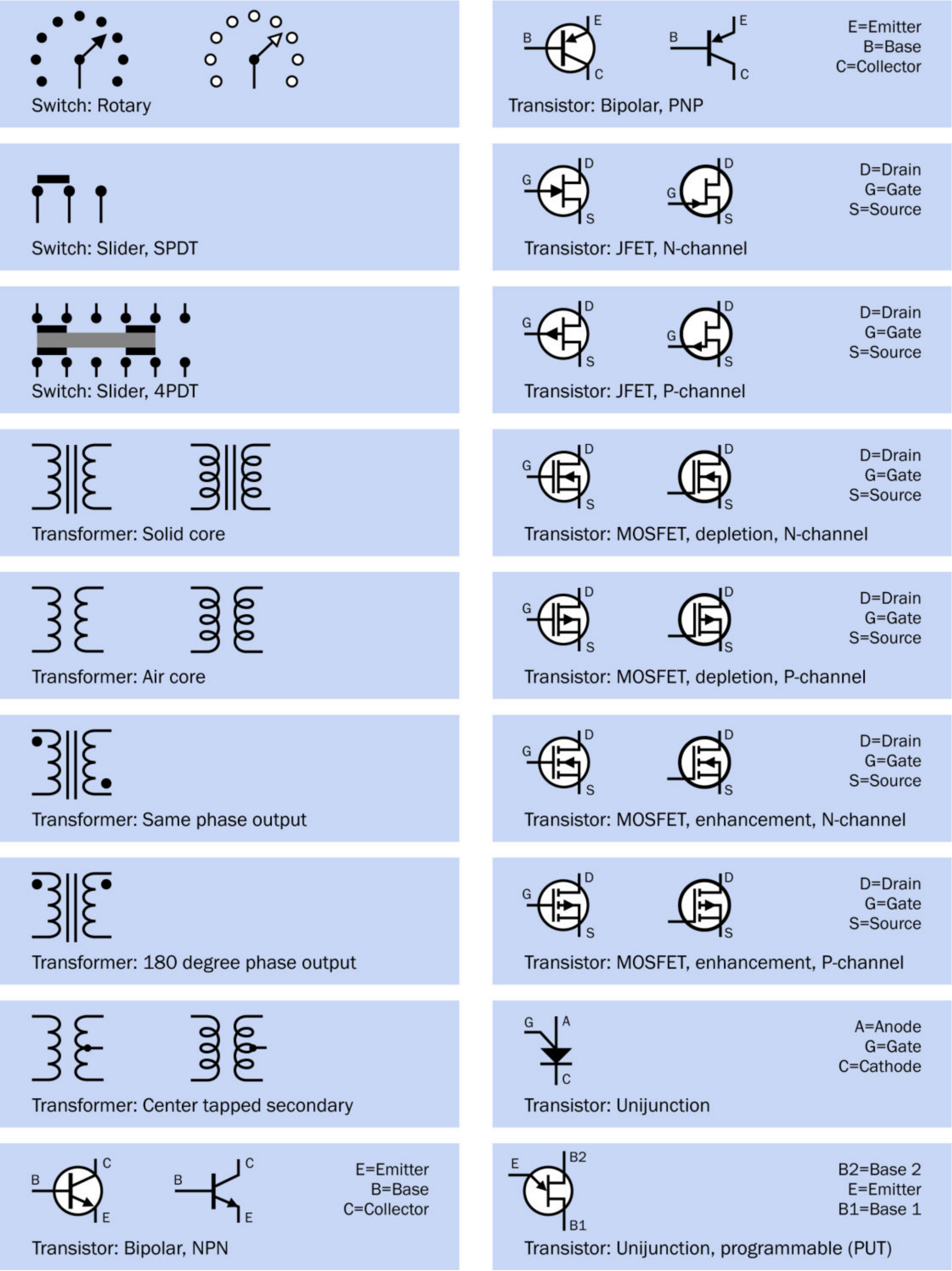

Switch: Rotary

Switch: Slider, SPDT

Switch: Slider, 4PDT

Transformer: Solid core

Transformer: Air core

Transformer: Same phase output

Transformer: 180 degree phase output

Transformer: Center tapped secondary

Transistor: Bipolar, NPN

Transistor: Bipolar, PNP

Transistor: JFET, N-channel

Transistor: JFET, P-channel

Transistor: MOSFET, depletion, N-channel

Transistor: MOSFET, depletion, P-channel

Transistor: MOSFET, enhancement, N-channel

Transistor: MOSFET, enhancement, P-channel

Transistor: Unijunction

Transistor: Unijunction, programmable (PUT)

B
C
E
E=Emitter
B=Base
C=Collector
G
D
S
D=Drain
G=Gate
S=Source
A
A=Anode
G=Gate
C=Cathode
B2
B1
B2=Base 2
E=Emitter
B1=Base 1

Figure A-3. *Schematic symbols, continued*

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Science / Electronics

VOL. 2

Encyclopedia of Electronic Components

Signal Processing

Want to know how to use an electronic component? This second book of a three-volume set includes key information on electronics parts for your projects—complete with photographs, schematics, and diagrams. You'll learn what each one does, how it works, why it's useful, and what variants exist. No matter how much you know about electronics, you'll find fascinating details you've never come across before.

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Charles Platt

Charles Platt's lifelong love of electronics began when he built a telephone answering machine at age 15. A contributing editor to *Make Magazine*, he wrote the widely acclaimed *Make: Electronics*. He's also a science-fiction writer (author of *The Silicon Man*), and a former senior writer at *Wired* magazine.

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Charles Platt
with Fredrik Jansson

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SEBASTOPOL, CA

Encyclopedia of Electronic Components Volume 2
by Charles Platt
with Fredrik Jansson

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[TI]

In fond memory of my father, Maurice Platt

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How to Use This Book

This is the second of three volumes. Its purpose is to provide an overview of the most commonly used electronic components, for reference by students, engineers, hobbyists, and instructors. While you can find much of this information dispersed among datasheets, introductory books, websites, and technical resources maintained by manufacturers, the *Encyclopedia of Electronic Components* gathers all the relevant facts in one place, properly organized and verified, including details that may be hard to find elsewhere. Each entry includes typical applications, possible substitutions, cross-references to similar devices, sample schematics, and a list of common problems and errors.

You can find a more detailed rationale for this encyclopedia in the Preface to Volume 1.

Volume Contents

Practical considerations influenced the decision to divide this encyclopedia into three volumes. Each deals with broad subject areas as follows.

Volume 1

Power; electromagnetic devices; discrete semiconductors

The *power* category includes sources of electricity and methods to distribute, store, interrupt, convert, and regulate power. The *electromagnetic devices* category includes devices that exert force linearly, and others that create a turning force. *Discrete semiconductors* include the primary types of diodes and transistors. A contents listing for Volume 1 appears in Figure P-1.

Volume 2

Thyristors (SCRs, diacs, and triacs); integrated circuits; light sources, indicators, and displays; and sound sources

Integrated circuits are divided into analog and digital components. *Light sources, indicators, and displays* are divided into reflective displays, single sources of light, and displays that emit light. *Sound sources* are divided into those that create sound, and those that reproduce sound. A contents listing for Volume 2 appears in Figure P-2.

Volume 3

Sensing devices

The field of sensors has become so extensive, they easily merit a volume to themselves. *Sensing devices* include those that detect light, sound, heat, motion, pressure, gas, humidity, orientation, electricity, proximity, force, and radiation.

At the time of writing, Volume 3 is still in preparation, while Volume 1 is complete and is available in a variety of formats.

Primary Category	Secondary Category	Component Type
power	source	battery
	connection	jumper
		fuse
		pushbutton
		switch
		rotary switch
		rotational encoder
	moderation	relay
		resistor
		potentiometer
		capacitor
		variable capacitor
	conversion	inductor
		AC-AC transformer
		AC-DC power supply
		DC-DC converter
		DC-AC inverter
	regulation	voltage regulator
electromagnetism	linear output	electromagnet
		solenoid
	rotational output	DC motor
		AC motor
		servo motor
		stepper motor
discrete semiconductor	single junction	diode
		unijunction transistor
	multijunction	bipolar transistor
		field-effect transistor

Figure P-1. *The subject-oriented organization of categories and entries in Volume 1.*

Primary Category	Secondary Category	Component Type
discrete semiconductor	thyristor	SCR
		diac
		triac
integrated circuit	analog	solid-state relay
		optocoupler
		comparator
		op-amp
		digital potentiometer
		timer
	digital	logic gate
		flip-flop
		shift register
		counter
		encoder
		decoder
		multiplexer
light source, indicator or display	reflective	LCD
	single source	incandescent lamp
		neon bulb
		fluorescent light
		laser
		LED indicator
		LED area lighting
	multi-source or panel	LED display
		vacuum-fluorescent
		electroluminescence
sound source	audio alert	transducer
		audio indicator
	reproducer	headphone
		speaker

Figure P-2. *The subject-oriented organization of categories and entries in Volume 2.*

Organization

Reference versus Tutorial

As its title suggests, this is a reference book, not a tutorial. A tutorial begins with elementary concepts and builds sequentially toward concepts that are more advanced. A reference book assumes that you may dip into the text at any point, learn what you need to know, and then put the book aside. If you choose to read it straight through from beginning to end, you will find some repetition, as each entry is intended to be self-sufficient, requiring minimal reference to other entries.

My books *Make: Electronics* and *Make: More Electronics* follow a tutorial approach. They don't go into as much depth as this Encyclopedia, because a tutorial inevitably allocates a lot of space to step-by-step explanations and instructions.

Theory and Practice

This book is oriented toward practicality rather than theory. I assume that the reader mostly wants to know how to use electronic components, rather than why they work the way they do. Consequently, I have not included proofs of formulae or definitions rooted in electrical theory. Units are defined only to the extent necessary to avoid confusion.

Many books on electronics theory already exist, if theory is of interest to you.

Entries

This encyclopedia is divided into entries, each entry being devoted to one broad type of component. Two rules determine whether a component has an entry all to itself, or is subsumed into another entry:

Rule 1

> A component merits its own entry if it is (a) widely used, or (b) not so widely used but has a unique identity and maybe some historical status. The **bipolar transistor** entry is an example of a widely used component, whereas the **unijunction transistor** entry is an example of a not so widely used component with a unique identity.

Rule 2

> A component does not merit its own entry if it is (a) seldom used, or (b) very similar in function to another component that is more widely used. For example, a *rheostat* is subsumed into the **potentiometer** section, while *silicon diode*, *Zener diode*, and *germanium diode* are combined together in the **diode** entry.

Inevitably, these guidelines required judgment calls which in some cases may seem arbitrary. My ultimate decision was based on where I would expect to find a component if I was looking for it myself.

Subject Paths

Entries are not organized alphabetically. They are grouped by subject, in much the same way that books in the nonfiction section of some libraries are organized by the Dewey Decimal System. This is convenient if you don't know exactly what you are looking for, or if you don't know all the options that may be available to perform a task that you have in mind.

Each primary category is divided into subcategories, and the subcategories are divided into component types. This hierarchy is shown in Figure P-2. It is also apparent when you look at the top of the first page of each entry, where you will find the path that leads to it. The **diac** entry, for instance, is headed with this path:

discrete semiconductor > thyristor > diac

Any classification scheme will run into exceptions. You can buy a chip containing a *resistor array*, for instance. Technically, this is an *analog integrated circuit*, but a decision was made to put it in the **resistor** section of Volume 1, because it can be directly substituted for a group of resistors.

Some components have hybrid functions. A **multiplexer**, for instance, may pass analog signals and may have "analog" in its name. However, it is digitally controlled and is mostly used in conjunction with other digital integrated circuits. This seemed to justify placing it in the digital category.

Inclusions and Exclusions

There is also the question of what is, and is not, a component. Is wire a component? Not for the purposes of this encyclopedia. How about a **DC-DC converter**? Because converters are now sold in small packages by component suppliers, they are included in Volume 1 as components.

Many similar decisions had to be made on a case-by-case basis. Some readers will disagree with the outcome, but reconciling all the disagreements would have been impossible. The best I could do was to create a book which is organized in the way that would suit me best if I were using it myself.

Typographical Conventions

Within each entry, **bold type** is used for the first occurrence of the name of a component that has its own entry elsewhere. Other important electronics terms or component names may be presented in *italics*.

The names of components, and the categories to which they belong, are all set in lowercase type, except where a term is normally capitalized because it is an acronym or a trademark. The term *Trimpot*, for instance, is trademarked by Bourns, but *trimmer* is not. **LED** is an acronym, but *cap* (abbreviation for **capacitor**) is not.

The European convention for representing fractional component values eliminates decimal points. Thus, values such as 3.3K and 4.7K are expressed as 3K3 and 4K7. This style has not been adopted to a significant degree in the United States, and is not used in this encyclopedia.

In mathematical formulae, I have used the style that is common in programming languages. The * (asterisk) is used as a multiplication symbol, while the / (forward slash) is used as a division symbol. Where some terms are in parentheses, they must be dealt with first. Where parentheses are inside parentheses, the innermost ones must be dealt with first. So, in this example:

```
A = 30 / (7 + (4 * 2) )
```

You would begin by multiplying 4 times 2, to get 8; then add 7, to get 15; then divide that into 30, to get the value for A, which is 2.

Visual Conventions

Figure P-3 shows the conventions that are used in the schematics in this book. A black dot always indicates a connection, except that to minimize ambiguity, the configuration at top right is avoided, and the configuration at top center is used instead. Conductors that cross each other without a black dot do not make a connection. The styles at bottom right are sometimes seen elsewhere, but are not used here.

All the schematics are formatted with pale blue backgrounds. This enables components such as switches, transistors, and LEDs to be highlighted in white, drawing attention to them and clarifying the boundary of the component. The white areas have no other meaning.

Photographic Backgrounds

All photographs of components include a background grid that is divided into squares measuring 0.1". Although the grid is virtual, it is equivalent in scale to physical graph paper placed immediately behind the component. If the component is photographed at an angle, the grid may be reproduced at a similar angle, creating perspective on the squares.

Background colors in photographs were chosen for contrast with the colors of the components, or for visual variety. They have no other significance.

Component Availability

Because there is no way of knowing if a component may have a long production run, this encyclopedia is cautious about listing specific part numbers. To find a specific part that has a narrow function, searching the websites maintained by suppliers will be necessary. The following suppliers were checked frequently during the preparation of the book:

- Mouser Electronics
- Jameco Electronics

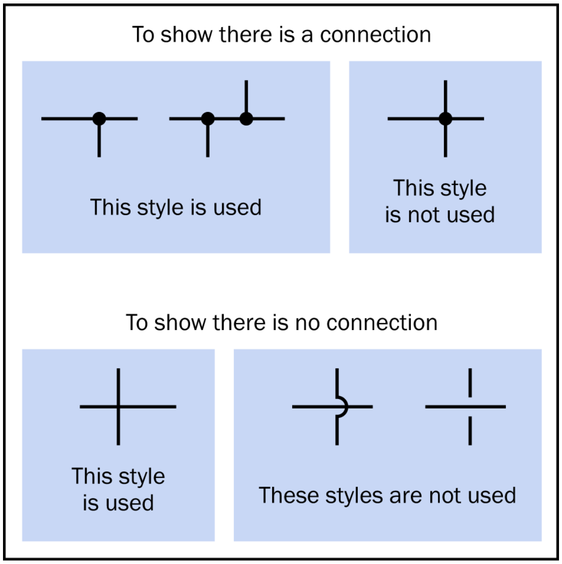
To show there is a connection
This style is used
This style is not used
To show there is no connection
This style is used
These styles are not used

Figure P-3. *Visual conventions that are used in the schematics in this book.*

When seeking obsolete parts, or those that are nearing the end of their commercial life, eBay can be very useful.

Issues and Errata

If you believe you have found an error in this book, you will find guidance on how to report it here: *http://bit.ly/eec_v2_errata*.

Before posting your own erratum, please check those that have been submitted previously, to see if someone else already reported it.

I value and encourage reader feedback. However, before you post feedback publicly to a site such as Amazon, I have a request. Please be aware of the power that you have as a reader, and use it fairly. A single negative review can create a bigger effect than you may realize. It can certainly outweigh half-a-dozen positive reviews. If you feel you have not received a prompt or adequate response from the O'Reilly errata site mentioned here, you can email me personally at:

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I check that address irregularly—sometimes only once in a couple of weeks. But I do answer all messages.

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Maker Shed: *http://makershed.com/*

We have a web page for this book, where we list errata, examples, and any additional information. You can access this page at: *http://bit.ly/encyclopedia_of_electronic_components_v2*.

Acknowledgments

Any reference work draws inspiration from many sources. Datasheets and tutorials maintained by component manufacturers were considered the most trustworthy sources of information online. In addition, component retailers, college texts, crowd-sourced reference works, and hobbyist sites were used. The following books provided useful information:

Boylestad, Robert L. and Nashelsky, Louis: *Electronic Devices and Circuit Theory*, 9th edition. Pearson Education, 2006.

Braga, Newton C.: *CMOS Sourcebook*. Sams Technical Publishing, 2001.

Hoenig, Stuart A.: *How to Build and Use Electronic Devices Without Frustration, Panic, Mountains of Money, or an Engineering Degree*, 2nd edition. Little, Brown, 1980.

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Mims III, Forrest M.: *Timer, Op Amp, & Optelectronic Circuits and Projects*. Master Publishing, 2007.

Predko, Mike: *123 Robotics Experiments for the Evil Genius*. McGraw-Hill, 2004.

Scherz, Paul: *Practical Electronics for Inventors*, 2nd edition. McGraw-Hill, 2007.

Williams, Tim: *The Circuit Designer's Companion*, 2nd edition. Newnes, 2005.

I also made extensive use of information on vendor sites, especially:

- Mouser Electronics
- Jameco Electronics
- All Electronics
- sparkfun
- Electronic Goldmine
- Adafruit
- Parallax, Inc.

In addition, some individuals provided special assistance. My editor, Brian Jepson, was immensely helpful in the development of this book. Philipp Marek and Steve Conklin reviewed the text for errors. My publisher demonstrated faith in my work. Kevin Kelly unwittingly influenced me with his legendary interest in "access to tools." It was Mark Frauenfelder who originally brought me back to the pleasures of building things, and Gareth Branwyn who revived my interest in electronics.

Lastly, I should mention my school friends from decades ago: Patrick Fagg, Hugh Levinson, Graham Rogers, William Edmondson, and John Witty, who helped me to feel that it was OK to be a nerd building my own audio equipment, long before the word "nerd" actually existed.

—Charles Platt, 2014

SCR

1

The acronym **SCR** is derived from *silicon-controlled rectifier*, which is a gate-triggered type of *thyristor*. A thyristor is defined here as a semiconductor having four or more alternating layers of p-type and n-type silicon. Because it predated integrated circuits, and in its basic form consists of a single multilayer semiconductor, a thyristor is considered to be a discrete component in this encyclopedia. When a thyristor is combined with other components in one package (as in a **solid-state relay**), it is considered to be an integrated circuit.

Other types of thyristor are the **diac** and **triac**, each of which has its own entry.

Thyristor variants that are not so widely used, such as the *gate turn-off thyristor (GTO)* and *silicon-controlled switch (SCS)*, do not have entries here.

OTHER RELATED COMPONENTS

- **diac** (see Chapter 2)
- **triac** (see Chapter 3)

What It Does

In the 1920s, the *thyratron* was a gas-filled tube that functioned as a switch and a rectifier. In 1956, General Electric introduced a solid-state version of it under the name *thyristor*. In both cases, the names were derived from the thyroid gland in the human body, which controls the rate of consumption of energy. The thyratron and, subsequently, the thyristor enabled control of large flows of current.

The **SCR** (silicon-controlled rectifier) is a type of thyristor, although the two terms are often used as if they are synonymous. Text that refers loosely to a thyristor may actually be discussing an SCR, and vice versa. In this encyclopedia, the **SCR**, **diac**, and **triac** are all considered to be variant types of thyristor.

An SCR is a solid-state switch that in many instances can pass high currents at high voltages. Like a **bipolar transistor**, it is triggered by voltage applied to a gate. Unlike the transistor, it allows the flow of current to continue even when the gate voltage diminishes to zero.

How It Works

This component is designed to pass current in one direction only. It can be forced to conduct in the opposite direction if the reversed potential exceeds its *breakdown voltage*, but this mistreatment is likely to cause damage.

By comparison, the diac and triac are designed to be bidirectional.

The SCR has three leads, identified as anode, cathode, and gate. Two functionally identical versions of the schematic symbol are shown in Figure 1-1. Early versions sometimes included a circle drawn around them, but this style has become obsolete. Care must be taken to distinguish between the SCR symbol and the symbol that represents a **programmable unijunction transistor** (PUT), shown in Figure 1-2.

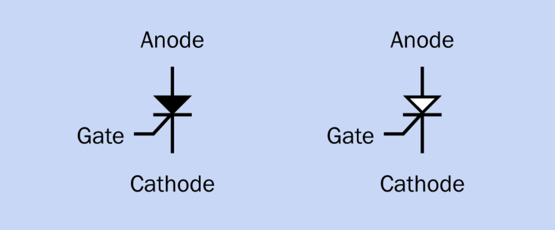

Figure 1-1. *Two functionally identical schematic symbols for an SCR (silicon-controlled rectifier). The symbol on the left is more common.*

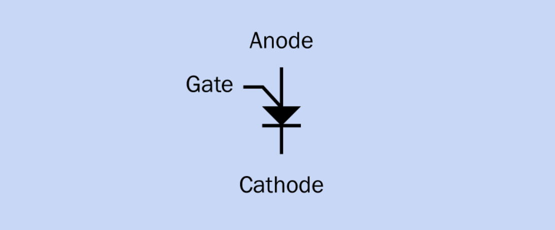

Figure 1-2. *The symbol shown here is for a programmable unijunction transistor (PUT). Care must be taken to distinguish it from the symbol for an SCR.*

Switching Behavior

When the SCR is in its passive or nonconductive state, it will block current in either direction between anode and cathode, although a very small amount of *leakage* typically occurs. When the SCR is activated by a positive voltage at the gate, current can now flow from anode to cathode, although it is still blocked from cathode to anode. When the flow reaches a level known as the *latching current*, the flow will continue even after the triggering voltage drops to zero. This behavior causes it to be known as a *regenerative* device.

If the current between anode and cathode starts to diminish while the gate voltage remains zero, the current flow will continue below the latching level until it falls below the value known as the *holding current*. The flow now ceases. Thus, the only way to end a flow of current that has been initiated through an SCR is by reducing the flow or attempting to reverse it.

Note that the self-sustaining flow is a function of current rather than voltage.

Unlike a transistor, an SCR is either “on” or “off” and does not function as a *current amplifier*. Like a diode, it is designed to conduct current in one direction; hence the term *rectifier* in its full name. When it has been triggered, the impedance between its anode and cathode is sufficiently low that heat dissipation can be managed even at high power levels.

The ability of SCRs to pass relatively large amounts of current makes them suitable for controlling the power supplied to motors and resistive heating elements. The fast switching response also enables an SCR to interrupt and abbreviate each positive phase of an AC waveform, to reduce the average power supplied. This is known as *phase control*.

SCRs are also used to provide *overvoltage protection*.

SCR packages reflect their design for a wide range of voltages and currents. Figure 1-3 shows an SCR designed for on-state current of 4A RMS (i.e., measured as the root mean square of the alternating current). Among its applications are small-engine ignition and *crowbar* overvoltage protection, so named because it shorts a power supply directly to ground, much like a crowbar being dropped across the terminals of a car battery (but hopefully with a less dramatic outcome). See Figure 1-15.

In Figure 1-4, the SCR can handle up to 800V repetitive peak off-state voltage and 55A RMS. Possible applications include AC rectification, crowbar protection, welding, and battery charging. The component in Figure 1-5 is rated for 25A and 50V repetitive peak off-state voltage. To assess the component sizes, bear in mind that the graph line spacing is 0.1″.

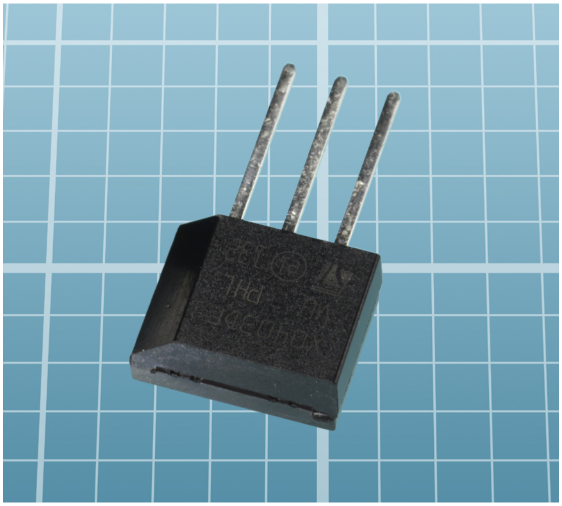

Figure 1-3. *SCR rated for 400V repetitive off-state voltage, no greater than 4A RMS.*

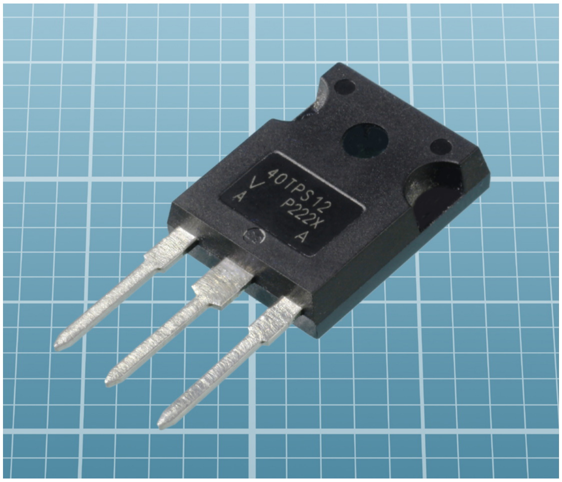

Figure 1-4. *SCR rated for 800V repetitive off-state voltage, no greater than 55A RMS.*

Internal Configuration

The function of an SCR can be imagined as being similar to that of a PNP transistor paired with an NPN transistor, as shown in Figure 1-6. In this simplified schematic, so long as zero voltage is applied to the "gate" wire, the lower (NPN) transistor remains nonconductive. Consequently, the upper (PNP) transistor cannot sink current, and this transistor also remains nonconductive.

When voltage is applied to the "gate," the lower transistor starts to sink current from the upper transistor. This switches it on. The two transistors now continue to conduct even if power to the "gate" is disconnected, because they have created a positive feedback loop.

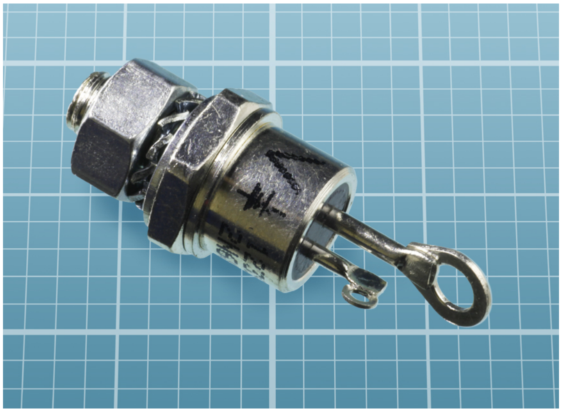

Figure 1-5. *Stud-packaged SCR rated for 50V repetitive off-state voltage, no greater than 25A RMS.*

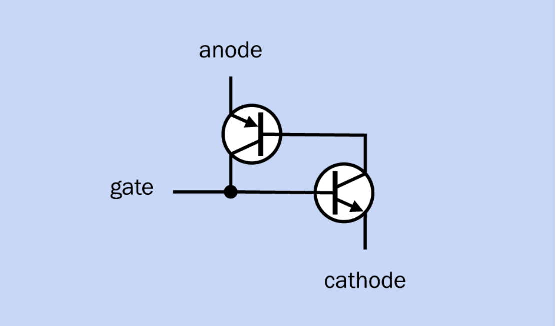

Figure 1-6. *An SCR behaves similarly to an NPN and a PNP transistor coupled together.*

Figure 1-7 shows the same two transistors in simplified form as sandwiches of p-type and n-type silicon layers (on the left), and their combination in an SCR (on the right). Although the actual configuration of silicon segments is not as simple or as linear as this diagram suggests, the SCR can be described correctly as a *PNPN device*.

An SCR is comparable with an electromagnetic **latching relay**, except that it works much faster and more reliably.

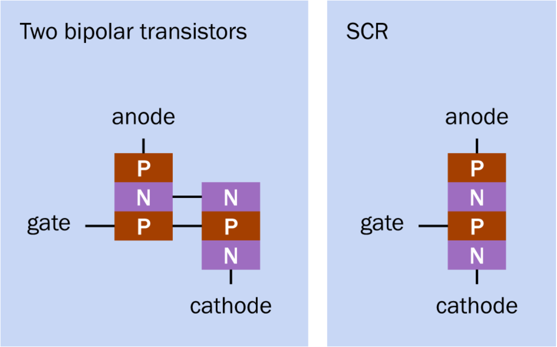

Figure 1-7. *The two transistors from the previous figure are shown here in simplified form as two stacks of p-type and n-type silicon layers. These layers are combined in an SCR, on the right.*

Breakdown and Breakover Voltage

The curves in Figure 1-8 illustrate the behavior of a hypothetical SCR, and can be compared with the curves shown for a diac in Figure 2-5 and a triac in Figure 3-10. Beginning with zero voltage applied between anode and cathode, and zero current flowing (i.e., at the center origin of the graph), if we apply a voltage at the anode that is increasingly negative relative to the cathode (i.e., we attempt to force the SCR to allow negative current flow), we see a small amount of leakage, indicated by the darker blue area (which is not drawn to scale). Finally the *breakdown voltage* is reached, at which point the negative potential overcomes the SCR and its impedance drops rapidly, allowing a surge of current to flow, probably damaging it.

Alternatively, starting once again from the center, if we apply a voltage at the anode that is increasingly positive relative to the cathode, two consequences are possible. The dashed curve assumes that there is zero voltage at the gate, and shows that some leakage occurs until the applied potential at the anode reaches the *breakover voltage*, at which point the SCR allows a large current flow, which continues even when the voltage decreases.

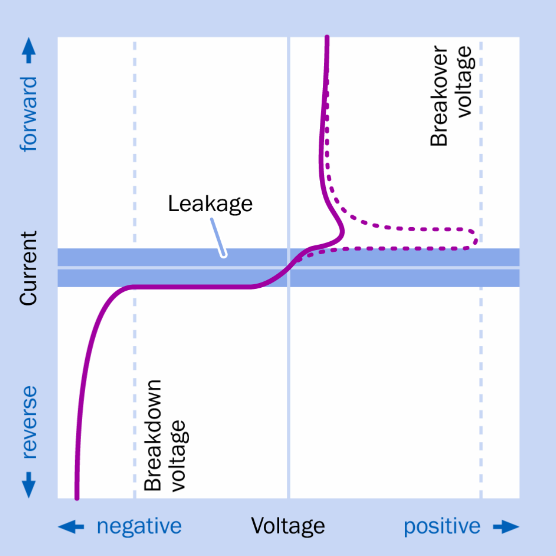

Figure 1-8. *The solid curve shows current passing between the anode and cathode of a hypothetical SCR for varying voltages, while a triggering voltage is applied to the gate. The dashed curve assumes that no triggering voltage is applied to the gate.*

In practice, the SCR is intended to respond to a positive gate voltage. Under these circumstances, its behavior is shown by the solid curve in the top-right quadrant in Figure 1-8. The SCR begins to conduct current without having to reach the breakover voltage at the anode.

- When used as it is intended, the SCR should not reach breakdown or breakover voltage levels.

SCR Concept Demo

In Figure 1-9, pushbutton S1 applies voltage to the gate of the SCR, which puts the SCR in self-sustaining conductive mode. When S1 is released, the meter will show that current continues to pass between the anode and the cathode. The X0403DF SCR suggested for this circuit has a holding current of 5mA, which a 5VDC supply should be able to provide with the 1K resistor in the circuit. If necessary, this resistor can be reduced to 680Ω.

Now if pushbutton S2 is pressed, the flow is interrupted. When S2 is released, the flow will not resume. Alternatively, if pushbutton S3 is pressed while the SCR is conducting current, the flow is diverted around the SCR, and when the pushbutton is released, the flow through the SCR will not resume. Thus, the SCR can be shut down either by a normally closed pushbutton in series with it (which will interrupt the current), or a normally open pushbutton in parallel with it (which will divert the current).

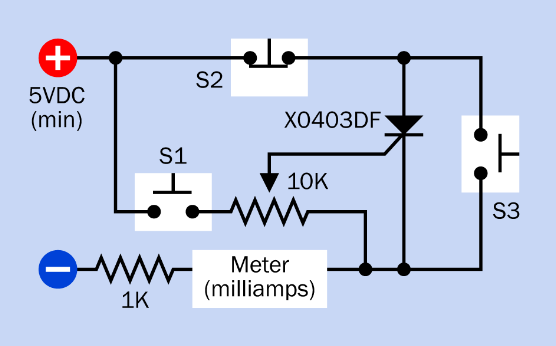

Figure 1-9. *In this test circuit, S1 triggers the SCR, while S2 or S3 will stop it. See text for additional details.*

The test circuit is shown installed on a breadboard in Figure 1-10. In this photograph, the red and blue wires supply a minimum of 5VDC. The two red buttons are tactile switches, the one at top left being S1 in the schematic while the one at bottom right is S3. The large switch with a rectangular button is S2; this is normally closed, and opens when pressed. The X0403DF SCR is just below it and to the right. The square blue trimmer is set to the midpoint of its range.

AC Current Applications

If the SCR is used with alternating current, it stops conducting during each negative cycle, and is retriggered in each positive cycle. This suggests one of its primary applications, as a controllable rectifier that can switch rapidly enough to limit the amount of current that passes through it during each cycle.

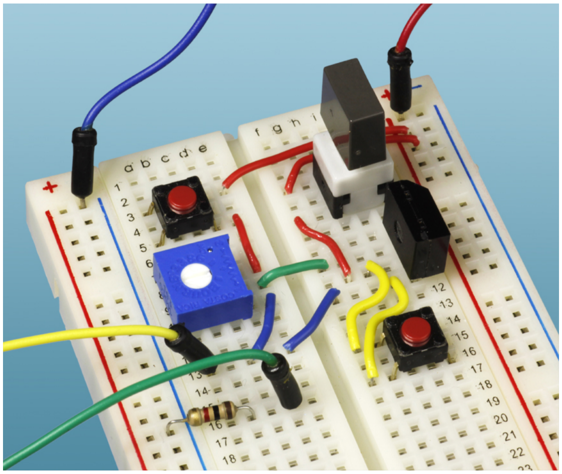

Figure 1-10. *A breadboarded version of the SCR test circuit. The two red buttons correspond with S1 and S3 in the schematic, while the large rectangular button at top right opens S2. See text for details.*

Variants

SCRs are available in surface-mount, through-hole, and stud packages, to handle increasing currents and voltages. Some special-purpose SCRs can control currents of hundreds of amps, while high-power SCRs are used to switch thousands of amps at more than 10,000V in power distribution systems. They are too specialized for inclusion in this encyclopedia.

Typical power ratings for SCRs in general use are summarized in the next section.

Values

Any SCR will impose a forward voltage drop, which typically ranges from around 1V to 2V, depending on the component.

Because SCRs are often used to modify AC waveforms, the current that the component can pass is usually expressed as the root mean square (RMS) of its peak value.

Commonly Used Abbreviations

- V_{DRM} Maximum repetitive forward voltage that may be applied to the anode while no voltage is applied to the gate (i.e., when the SCR is not in conductive mode).
- V_{RRM} Maximum repetitive reverse voltage that may be applied to the anode while no voltage is applied to the gate (i.e., when the SCR is not in conductive mode).
- V_{TM} Maximum on-state voltage while the SCR is in conductive mode. T indicates that this value changes with temperature.
- V_{GM} Forward maximum gate voltage.
- V_{GT} Minimum gate voltage required to trigger.
- V_{GD} Maximum gate voltage that will not trigger.
- I_{DRM} Peak repetitive forward blocking current (i.e., maximum leakage).
- I_{RRM} Peak repetitive reverse blocking current (i.e., leakage in the off state).
- I_{GM} Maximum forward gate current.
- $I_{T(RMS)}$ Maximum RMS current between anode and cathode while the SCR is in conductive mode. T indicates that this value changes with temperature.
- $I_{T(AV)}$ Maximum average current between anode and cathode while the SCR is in conductive mode. T indicates that this value changes with temperature.
- I_{GT} Maximum gate current required to trigger.
- I_H Typical holding current.
- I_L Maximum latching current.
- T_C Case temperature, usually expressed as an acceptable range.
- T_J Operating junction temperature, usually expressed as an acceptable range.

Surface-mount variants may tolerate maximum anode-cathode currents that typically range from 1A to 10A. Maximum voltages as high as 500V are allowed in some cases. Leakage in the “off” state may be as high as 0.5mA or as low as 5μA. Gate trigger voltage is likely to range from 0.8V to 1.5V, and trigger current of 0.2mA to 15mA is typical.

Through-hole variants may be packaged in TO-92 format (like discrete transistors) or, more commonly, in TO-220 format (like a typical 1A voltage regulator). They may be rated for a maximum of 5A up to 50A, depending on the component, with maximum voltages ranging from 50V to 500V. Leakage is similar to surface-mount variants. The gate trigger voltage is typically around 1.5V, and trigger current ranges from 25–50mA.

A stud-type SCR may have a maximum 50A to 500A current rating, although some components are capable of tolerating even higher values. Maximum voltages of 50V to 500V are possible. Leakage is likely to be higher than in other formats, with 5mA to 30mA being common. The gate trigger voltage is typically 1.5 to 3V, and trigger current may range from around 50mA to 200mA.

How to Use It

Although other applications are possible, in practice SCRs have two main applications:

- Phase control, which interrupts each positive phase of an AC power supply. It can moderate the speed of a motor or the heat generated by a resistive load.
- Overvoltage protection. This can safeguard sensitive components in a circuit where there is a DC power supply.

SCRs are often incorporated in ground-fault circuit interruptors (although not usually as discrete components) and in automotive ignition systems.

Phase Control

Phase control is a convenient way to control or limit the AC power delivered to a load by abbreviating each pulse in the AC waveform. This is done by adjusting the gate voltage so that the SCR blocks the first part of each positive phase, then conducts the remainder, and then stops conducting below its holding level. The SCR will then block the reversed flow in the negative phase of the AC waveform, but an additional SCR with opposite polarity can be added.

This is a form of *pulse-width modulation*. It is highly efficient, as the effective internal resistance of the SCR is either very high or very low, and the component does not waste significant energy in the form of heat.

On a graph showing the fluctuating voltage of an AC waveform, a single cycle is customarily divided into four stages: (1) zero voltage, (2) maximum positive voltage, (3) zero voltage, (4) minimum negative voltage, all measurements being made between the live side of the supply and the neutral side of the supply.

The cycle then repeats. Its transitions are often referred to as *phase angles* of 0 degrees, 90 degrees, 180 degrees, and 270 degrees, as shown in Figure 1-11.

The fluctuating voltage in an AC power supply is proportional with the sine of the phase angle. This concept is illustrated in Figure 1-12. If an imaginary point (shown as a purple dot) is moving in a circular path counterclockwise at a constant speed, its vertical distance (shown in green) above or below the X axis (horizontal centerline) can represent an AC voltage corresponding with the angle (shown as purple arcs) of the circle radius to the point, each angle being measured from at the center relative to a start position at right on the X axis.

When an SCR is used for phase control, the point at which it starts to conduct may be anywhere from 0 to almost 180 degrees. This is achieved by diverting a small amount of the AC power into an RC network attached to the gate of the SCR, as shown in Figure 1-13. The capacitor in this schematic introduces a delay that can be varied by the potentiometer. This enables the SCR to be triggered even after the peak of the AC power signal. In Figure 1-14, the AC power is shown by the center (green) curve, and the slightly delayed, reduced voltage at the gate is shown by the upper, purple curve. When the gate voltage rises to the trigger level, it causes the SCR to begin conducting current, creating an abbreviated output shown in the bottom curve. In this way, triggering from an AC phase angle of 0 degrees to almost 180 degrees is possible. The phase angle where the SCR begins to allow conduction is known as the *conduction angle*.

If two SCRs with opposite polarity are placed in parallel with each other, they can be used to provide phase control on both the positive-going and negative-going sections of an AC cycle. This configuration is used in high-powered devices. A **triac** is used for the same purpose with lower current.

Six SCRs may be used to control three-phase power.

Overvoltage Protection

The tolerance of an SCR for high current makes it suitable for use in a crowbar voltage limiting circuit.

In Figure 1-15, the SCR does not conduct current (other than a small amount of leakage) until the Zener diode senses a voltage above the maximum level considered safe. The diode then allows power to reach the gate of the SCR. Its impedance drops immediately, and the resulting surge of current trips the fuse. After the cause of the overvoltage condition is corrected, the fuse can be replaced and the circuit may resume functioning.

A capacitor is included so brief spikes in the power supply will be passed to ground without triggering the SCR. A resistor of around 100Ω ensures that the gate voltage of the SCR remains near zero during normal operation. When the Zener diode starts to conduct current, the resistor acts as a voltage divider with the diode, so that sufficient voltage reaches the SCR to activate it.

This circuit may be unsuitable for low-voltage power supplies, because the Zener diode has to be chosen with a high enough rating to prevent small power fluctuations from tripping it. Bearing in mind that the real triggering voltage of the diode may be at least plus-or-minus 5% of its rated voltage, the diode may have to be chosen with at least a 6V rating in a 5V circuit, and it may not be activated until the voltage is actually 6.5V. This may be insufficient to protect the components being used with the power supply.

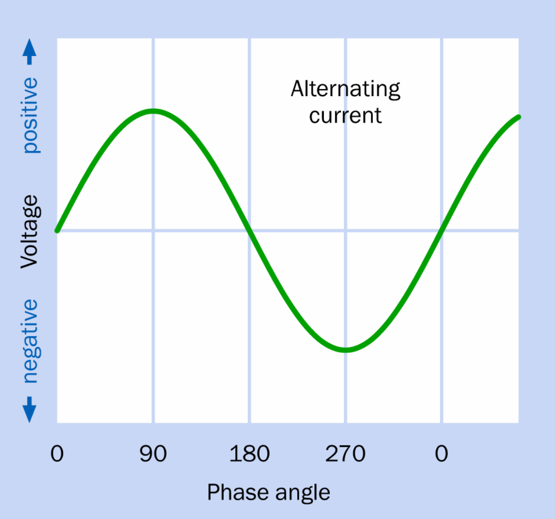

Figure 1-11. *An AC waveform is customarily measured in degrees of phase angle.*

What Can Go Wrong

Like other semiconductors, an SCR can be adversely affected by excessive heat. Usual precautions should be taken to allow sufficient ventilation and heat sinking, especially when components are moved from an open prototyping board to an enclosure in which crowding is likely.

Unexpected Triggering Caused by Heat

On a datasheet, the values for triggering current and holding current are valid only within a recommended temperature range. A buildup of heat can provoke unexpected triggering.

Unexpected Triggering Caused by Voltage

A very rapid increase in forward voltage at the anode can induce a triggering voltage in the gate by capacitive coupling. As a result, the SCR can trigger itself without any external application of gate voltage. This is sometimes known as *dv/dt triggering*. If necessary, a snubber circuit can be added across the anode input to prevent sudden voltage transitions.

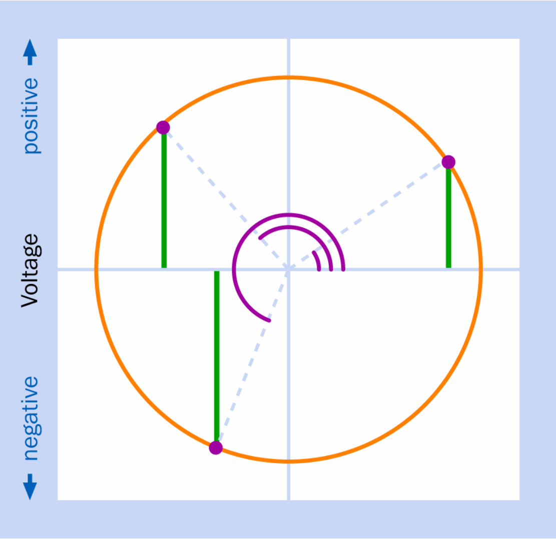

Figure 1-12. *The fluctuating voltage of an AC power supply (shown as vertical green lines) is proportional with the sines of the angles (purple arcs) in this diagram. The angles are referred to as phase angles.*

Confusion of AC and DC Ratings

The on-state current for an SCR is averaged only over the width of each pulse that the SCR actually conducts. It is not time-averaged over an entire AC cycle, and it will be different again from a DC rating. Care must be taken to match the current rating with the way in which the component will actually be used.

Maximum Current versus Conduction Angle

Current-carrying capability will be very significantly affected by the length of the duty cycle when the SCR is being used to abbreviate each positive AC pulse. When the SCR imposes a 120-degree conduction angle, it may be able to handle twice the average on-state current as when it is imposing a 30-degree conduction angle. The manufacturer's datasheet should include a graphical illustration of this relationship. If an SCR is chosen for a high conduction angle, and the angle is later reduced, overheating will result, and damage is likely.

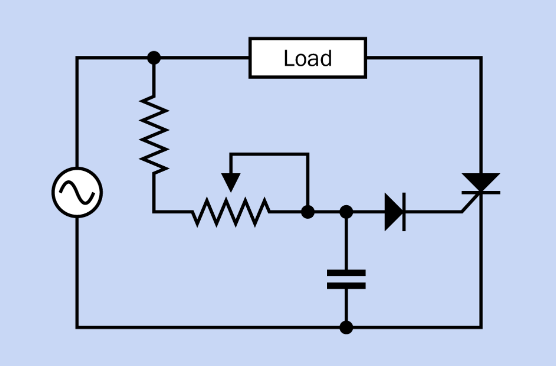

Figure 1-13. *In this schematic, an SCR is used to apply phase control, adjusting the power that passes through a load.*

Confusing Symbols

When reading a schematic, unfortunate errors can result from failure to distinguish between the symbol for a **programmable unijunction transistor (PUT)** and the symbol for an SCR. The characteristics of a PUT are described in Volume 1 of this encyclopedia.

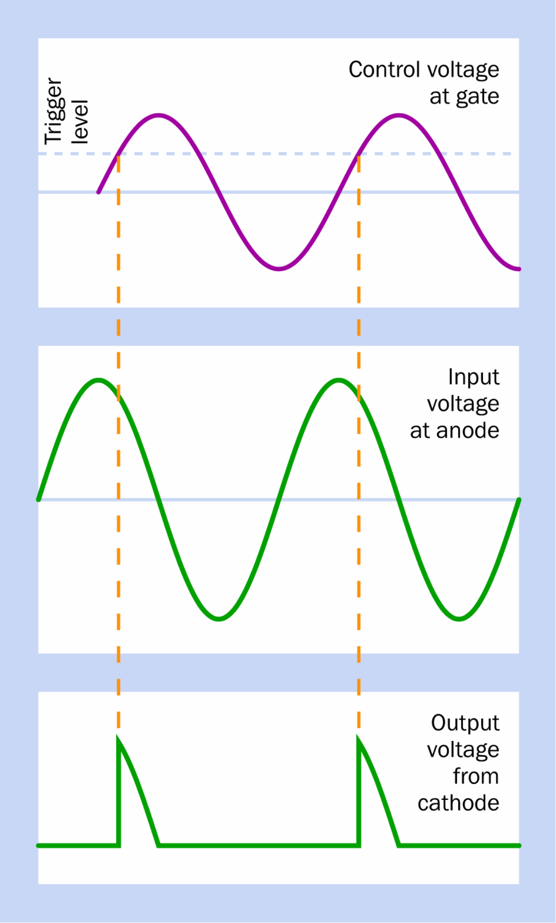

Figure 1-14. *If the AC power applied to the anode of an SCR (center) is reduced in voltage and delayed slightly by an RC network, it can trigger the SCR (top), causing it to pass only an abbreviated segment of each positive AC pulse (bottom).*

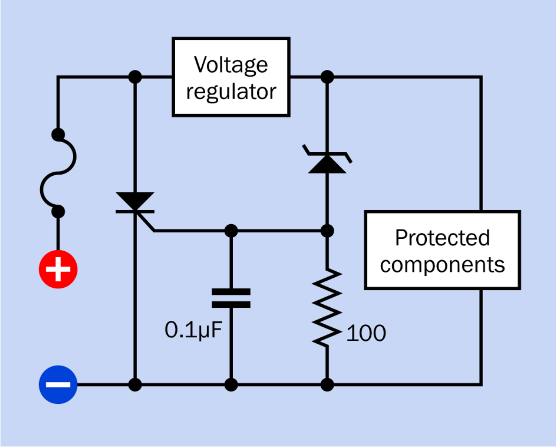
Voltage regulator
Protected components
0.1µF
100

Figure 1-15. *In this schematic, an SCR is used to provide crowbar overvoltage protection for sensitive components.*

diac

2

A **diac** is a self-triggering type of *thyristor*. Its name is said to be derived from the phrase "diode for AC," and because it is not an acronym, it is not usually capitalized.

A thyristor is defined here as a semiconductor having four or more layers of p-type and n-type silicon. Because the thyristor predated integrated circuits, and in its basic form consists of a single multilayer semiconductor, it is categorized as a discrete component in this encyclopedia. When a thyristor is combined with other components in one package (as in a **solid-state relay**) it is considered to be an integrated circuit.

Other types of thyristor are the **SCR** (silicon-controlled rectifier) and the **triac**, each of which has its own entry in this encyclopedia.

Thyristor variants that are not so widely used, such as the *gate turn-off thyristor (GTO)* and *silicon-controlled switch (SCS)*, do not have entries here.

OTHER RELATED COMPONENTS

- **SCR** (see Chapter 1)
- **triac** (see Chapter 3)

What It Does

The **diac** is a bidirectional thyristor with only two terminals. It blocks current until it is subjected to sufficient voltage, at which point its impedance drops very rapidly. It is primarily used to trigger a **triac** for purposes of moderating AC power to an **incandescent lamp**, a resistive heating element, or an AC **motor**. The two leads on a diac have identical function and are interchangeable.

By comparison, a **triac** and an **SCR** are thyristors with three leads, one of them being referred to as the gate, which determines whether the component becomes conductive. A triac and a diac allow current to flow in either direction, while an SCR always blocks current in one direction.

Symbol Variants

The schematic symbol for a diac, shown in Figure 2-1, resembles two diodes joined together, one of them inverted relative to the other. Functionally, the diac is comparable with a pair of Zener diodes, as it is intended to be driven beyond the point where it becomes saturated. Because its two leads are functionally identical, they do not require names to differentiate them. They are sometimes referred to as A1 and A2, in recognition that either of them may function as an anode; or they may be identified as MT1 and MT2, MT being an acronym for "main terminal."

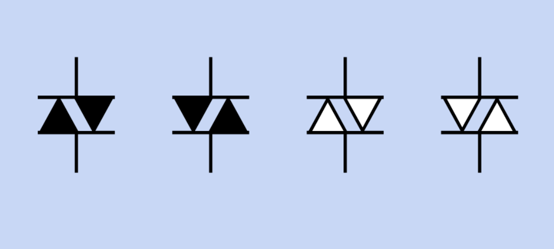

Figure 2-1. *Symbol variants to represent a diac. All four are functionally identical.*

The symbol may be reflected left to right, and the black triangles may have open centers. All of these variants mean the same thing. Occasionally the symbol has a circle around it, but this style is now rare.

When only a moderate voltage is applied (usually less than 30V) the diac remains in a passive state and will block current in either direction, although a very small amount of *leakage* typically occurs. When the voltage exceeds a threshold known as its *breakover level*, current can flow, and the diac will continue to conduct until the current falls below its *holding level*.

A sample diac is shown in Figure 2-2.

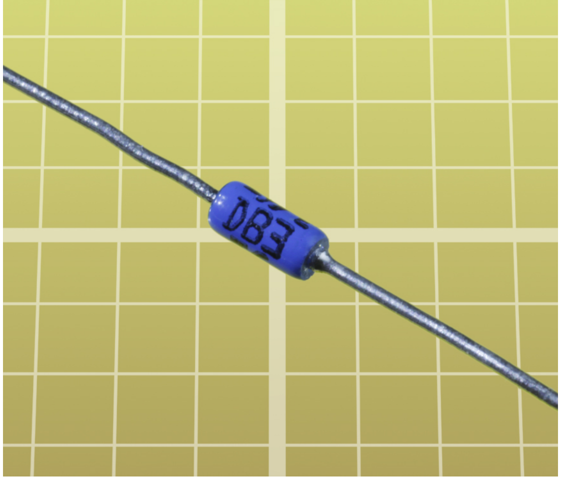

Figure 2-2. *Because a diac is not intended to pass significant current, it is typically packaged in a small format. The graph squares in the photograph each measure 0.1".*

How It Works

Figure 2-3 shows a circuit that demonstrates the conductive behavior of a diac.

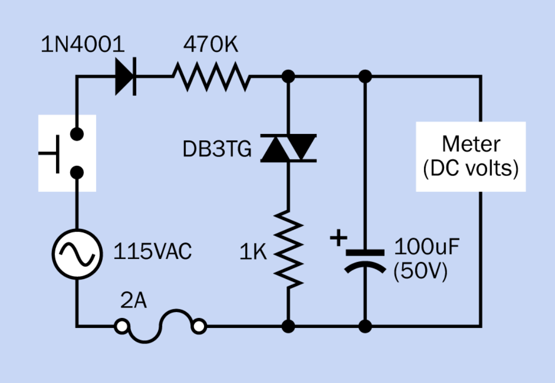

Figure 2-3. *A test circuit to demonstrate the behavior of a diac. See text for details.*

When the pushbutton is held down, current from the positive side of the AC supply flows through the diode and the 470K resistor to the capacitor. The diac is not yet conductive, so the capacitor accumulates a potential that can be monitored with the volt meter. After about 30 seconds, the charge on the capacitor reaches 32V. This is the breakover voltage for this particular diac, so it becomes conductive. The positive side of the capacitor can now discharge through the diac and the 1K series resistor to ground.

If the pushbutton is released at this moment, the meter will show that the capacitor discharges to a potential below the holding level of the diac. The capacitor now stops discharging because the diac has ceased being conductive.

If the pushbutton is held down constantly, the meter will show the capacitor charging and then discharging through the diac repeatedly, so that the circuit behaves as a *relaxation oscillator*. The 1K series resistor is included to protect the diac from excessive current. If a standard quarter-watt resistor is used, it should not become unduly warm because current passes through it only intermittently.

- Because this circuit uses 115VAC, basic precautions should be taken. The fuse should not be omitted, the capacitor should be rated for at least 50V, and the circuit should not be touched while it is connected to the power source. Breadboarding a circuit using this voltage requires caution and experience, as wires can easily come loose, and components can be touched accidentally while they are live.

Figure 2-4 shows the test circuit on a breadboard. The red and blue leads at the top of the photograph are from a fused 115VAC power supply. The live side of the supply passes through a diode to a pushbutton switch that has a rectangular black cap. A 470K resistor connects the other side of the switch to the positive side of a 100µF electrolytic capacitor, and also to the diac (small blue component). A 1K resistor connects the other end of the diac back to the negative side of the capacitor, which is grounded. The yellow and blue wires leaving the photograph at the left are connected with a volt meter, which is not shown.

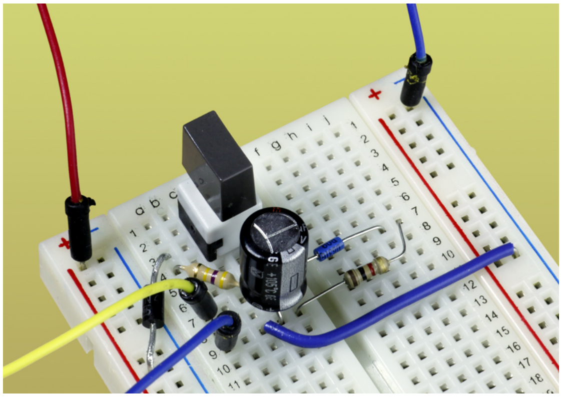

Figure 2-4. *A breadboarded version of the diac test circuit. See text for details.*

The behavior of a diac is also illustrated in Figure 2-5, which can be compared with the curves in Figures 3-10 and 1-8, depicting the behavior of a triac and an SCR respectively.

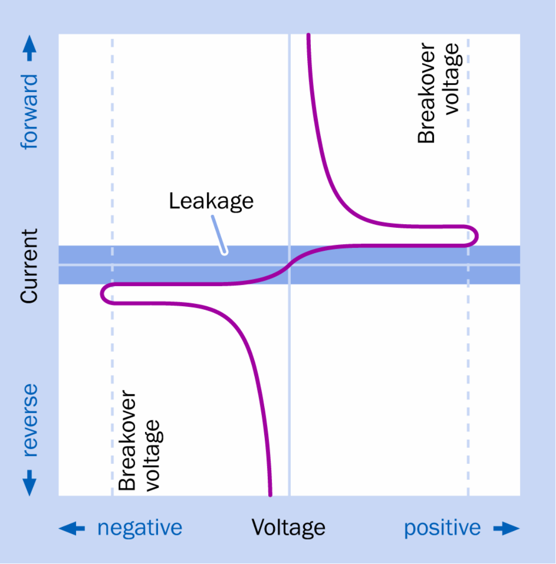

Figure 2-5. *The curve shows current passing through a diac when various voltages are applied.*

Switching AC

The diac cannot function as a switch, because it lacks the third terminal which is found in a triac, an SCR, or a bipolar transistor. However, it is well suited to drive the gate of a triac, because the behavior of a diac is symmetrical in response to opposite voltages, while the triac is not. If an AC voltage applied to a diac is adjusted with a potentiometer in an RC circuit, the diac will pass along a portion of each positive or negative pulse, and will delay it by a brief amount of time determined by the value of the capacitor in the RC circuit and the setting of the potentiometer. This is known as *phase control*, as it controls the *phase angle* at which the diac allows current to flow.

See Figure 3-13 for a schematic showing a diac driving a triac. See Figures 1-14 and 3-11 for graphs illustrating phase control. See "Phase Control" for a discussion of phase in AC waveforms.

Variants

Diacs are available in through-hole and surface-mount formats. Because they are not intended to handle significant current, no heat sink is included.

A *sidac* behaves very similarly to a diac, its name being derived from “silicon diode for alternating current.” Its primary difference from generic diacs is that it is designed to reach its breakover voltage at a higher value, typically 120VAC or 240VAC.

Values

When performing its function to trigger a triac, a diac is unlikely to pass more than 100mA.

The breakover voltage of a diac is usually between 30V and 40V, with a few versions designed for up to 70V. When the diac starts to conduct, its on-state impedance is sufficient to reduce the voltage significantly, with 5V being a typical minimum output voltage.

Although the rise time when a diac responds is very brief (around 1µs), the component is not expected to run at a high frequency. It will normally be used with 50Hz or 60Hz AC to trigger a triac. For this reason, its repetitive peak on-state current is usually specified at no more than 120Hz.

Abbreviations in datasheets are likely to include:

- V_{BO} Breakover voltage (sometimes may be specified as latching voltage, which for a diac is the same thing).
- V_{BO1} - V_{BO2} Breakover voltage symmetry. The hyphen is intended as a minus sign, so that this value is the maximum difference between breakover voltage in each direction.
- V_O Minimum output voltage.
- I_{TRM} Repetitive peak on-state current.
- I_{BO} Breakover current, usually the maximum required, and less than 20µA.
- I_R Maximum leakage current, usually less than 20µA.
- T_J Operating junction temperature, usually expressed as an acceptable range.

What Can Go Wrong

Like other semiconductors, a diac is heat sensitive. Usual precautions should be taken to allow sufficient ventilation and heat sinking, especially when components are moved from an open prototyping board to an enclosure in which crowding is likely.

Unexpected Triggering Caused by Heat

On a datasheet, a value for breakover current is valid only within a recommended temperature range. A buildup of heat can provoke unexpected triggering.

Low-Temperature Effects

A higher breakover voltage will be required by a diac operating at low temperatures, although the variation is unlikely to be greater than plus-or-minus 2% within a normal operating range. Temperature has a much more significant effect on a triac.

Manufacturing Tolerances

The breakover voltage for a diac is not adjustable, and may vary significantly between samples of the component that are supposed to be identical. The diac is not intended to be used as a precision component. In addition, while its breakover voltage should be the same in either direction, a difference of plus-or-minus 2% is possible (1% in some components).

triac

3

A **triac** is a gate-triggered type of *thyristor*. Its name was probably derived from the phrase "triode for AC," and because it is not an acronym, it is not usually capitalized.

A thyristor is defined here as a semiconductor having four or more layers of p-type and n-type silicon. Because the thyristor predated integrated circuits, and in its basic form consists of a single multilayer semiconductor, it is categorized as a discrete component in this encyclopedia. When a thyristor is combined with other components in one package (as in a **solid-state relay**) it is considered to be an integrated circuit.

Other types of thyristor are the **SCR** (silicon-controlled rectifier) and the **diac**, each of which has its own entry in this encyclopedia.

Thyristor variants that are not so widely used, such as the *gate turn-off thyristor (GTO)* and *silicon-controlled switch (SCS)*, do not have entries here.

OTHER RELATED COMPONENTS

- **SCR** (see Chapter 1)
- **diac** (see Chapter 2)

What It Does

The **triac** is ubiquitous in AC dimmers for **incandescent lamps**. It is also used to control the speed of AC motors and the output of resistive heating elements. It is a type of *thyristor* which contains five segments of p-type and n-type silicon and has three leads, one of them attached to a gate that can switch a bidirectional flow of current between the other two. Its name was originally a trademark, generally thought to be derived from the phrase "triode for AC." A triode was a common type of vacuum tube when thyristors were first introduced in the 1950s.

By comparison, a **diac** is a thyristor with only two leads, allowing current to flow in either direction when the component reaches a *breakover voltage*. Its name was probably derived from the phrase "diode for AC." It is often used in conjunction with a triac.

An **SCR** (silicon-controlled rectifier) is a thyristor that resembles a triac, as it has three leads, one of them a gate. However, it only allows current to flow in one direction.

Symbol Variants

The schematic symbol for a triac, shown in Figure 3-1, resembles two diodes joined together, one of them inverted relative to the other. While a triac does not actually consist of two diodes, it is functionally similar, and can pass current in either direction.

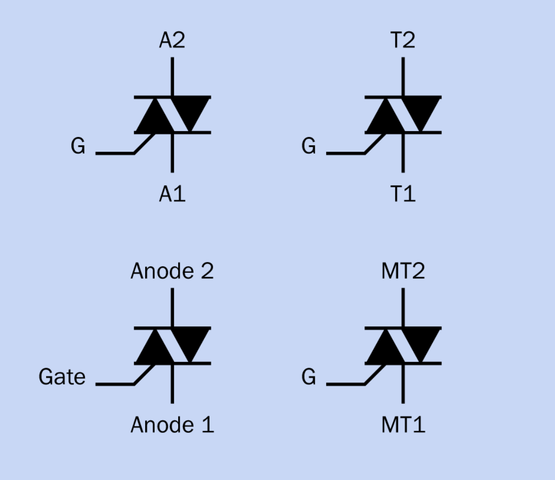

Figure 3-1. *The schematic symbol for a triac, with four naming conventions that are used for its leads. The different conventions do not indicate any functional difference.*

An appended bent line represents the gate. The labels for the other two leads are not standardized, and can be referred to as A1 and A2 (for Anode 1 and Anode 2), or T1 and T2 (for Terminal 1 and Terminal 2), or MT1 and MT2 (for Main Terminal 1 and Main Terminal 2). The choice of terms does not indicate any functional difference. In this encyclopedia entry, A1 and A2 are used.

The A1 terminal (or T1, or MT1) is always shown closer to the gate than A2 (or T2, or MT2). This distinction is important because although the triac can pass current in either direction, its behavior is somewhat asymmetrical.

- Voltages are expressed relative to terminal A1 (or T1, or MT1, if those terms are used).

The schematic symbol may be reflected or rotated, the black triangles may have open centers, and the placement of the bent line representing the gate may vary. However, terminal A1 is always nearer to the gate than terminal A2.

Figure 3-2 shows 12 of the 16 theoretical possibilities. All of these variants are functionally identical. Occasionally the symbol has a circle around it, but this style is now rare.

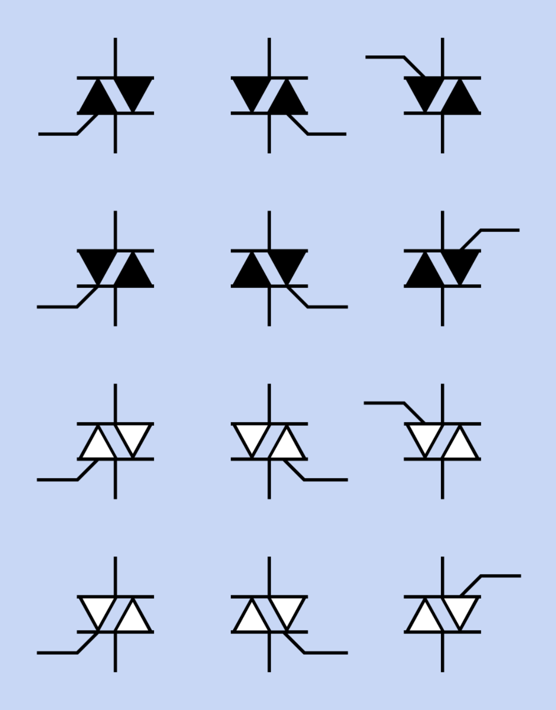

Figure 3-2. *Interchangeable variants of the schematic symbol for a triac.*

Triacs with various characteristics are shown in Figures 3-3, 3-4, and 3-5.

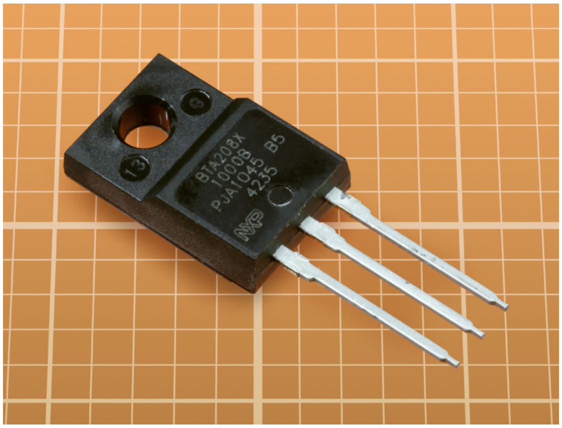

Figure 3-3. *The BTA208X-1000B triac can conduct 8A continuous on-state current RMS, and withstands peak off-state voltage of up to 1,000V. This is a "snubberless" triac.*

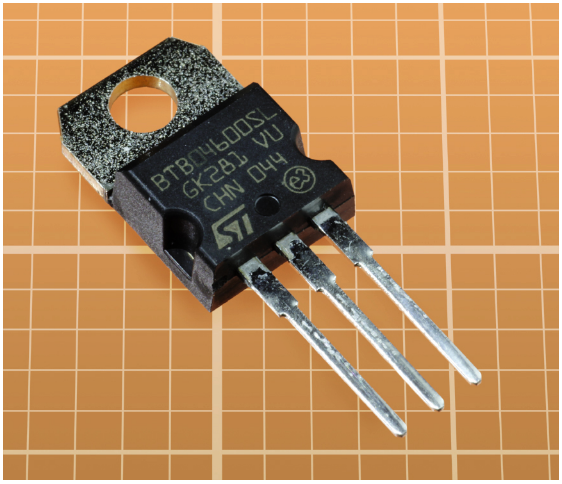

Figure 3-4. *The BTB04-600SL triac can conduct 4A continuous on-state current RMS, and withstands peak off-state voltage of up to 600V.*

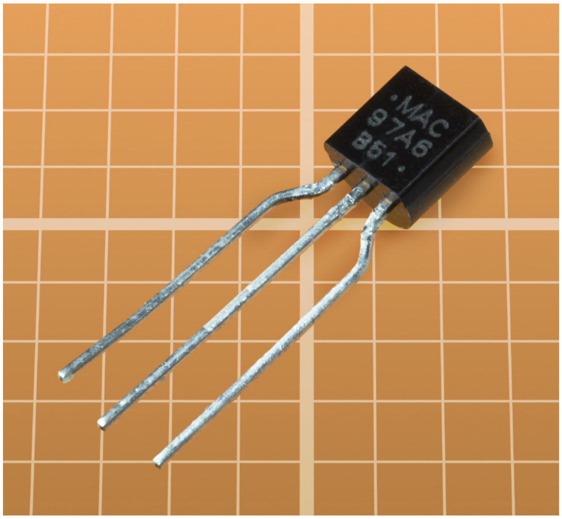

Figure 3-5. *The MAC97A6 triac can conduct 0.8A continuous on-state current RMS, and withstands peak off-state voltage of up to 400V.*

How It Works

When no gate voltage is applied, the triac remains in a passive state and will block current in either direction between A1 and A2, although a very small amount of *leakage* typically occurs. If the gate potential becomes sufficiently positive *or* negative relative to terminal A1, current can begin to flow between A1 and A2 in *either* direction. This makes the triac ideal for controlling AC.

Quadrants

While a gate voltage is applied, four operating modes are possible. In each case, A1 is the reference (which can be thought of as being held at a neutral ground value). Because the triac is conducting AC, voltages above and below ground will occur. The four modes of operation are often referred to as four *quadrants*, and are typically arranged as shown in Figure 3-6.

In some reference sources (especially educational text books), current is shown with an arrow indicating a flow of electrons moving from negative to positive. Because the type of current flow is often undefined, diagrams should be interpreted carefully. In this encyclopedia, current is always shown flowing from a more-positive location to a more-negative location.

Quadrant 1 (upper right)

A2 is more positive than A1, and the gate is more positive than A1. Conventional current (positive to negative) will flow from A2 to A1. (This behavior is very similar to that of an **SCR**.)

Quadrant 2 (upper left)

A2 is more positive than A1, and the gate is more negative than A1. Once again, conventional current (positive to negative) will flow from A2 to A1.

Quadrant 3 (lower left)

A2 is more negative than A1, and the gate is more negative than A1. Conventional current is reversed from A1 to A2.

Quadrant 4 (lower right)

A2 is more negative than A1, but the gate is more positive than A1. Conventional current is reversed from A1 to A2.

- Note that two positive symbols or two negative symbols in Figure 3-6 do not mean that both locations are of equal voltage. They simply mean that these locations are at potentials that are significantly different from A1.

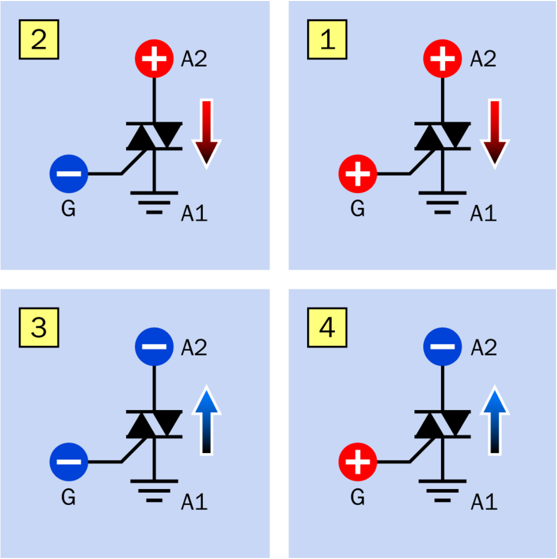

Figure 3-6. *The "quadrants" of triac behavior. Positive and negative symbols indicate which terminal is "more positive" or "more negative" than A1. The ground symbol represents a potential midway between positive and negative. See text for details.*

Suppose that gate current increases gradually. When it reaches the *gate threshold current* of the triac, the component starts conducting between A1 and A2. If the current between A1 and A2 rises above the value known as the *latching current*, it will continue to flow, even if gate current disappears completely.

If the self-sustaining current through the triac gradually diminishes, while there is no voltage applied to the gate, conduction between the main terminals will stop spontaneously when it falls below a level known as the *holding current*. This behavior is similar to that of an SCR. The triac now returns to its original state, blocking current until the gate triggers it again.

The triac is sufficiently sensitive to respond to rapid fluctuations, as in 50Hz or 60Hz AC.

Threshold, Latching, and Holding Current

Figure 3-7 shows the relationship between the gate threshold current, the latching current, and holding current. In the upper half of the figure, gate current is shown fluctuating until it crosses the threshold level. This establishes current flow between the main terminals, shown in the lower half of the figure. Prior to this moment, a very small amount of leakage current occurred (shown in the figure, but not to scale).

In this hypothetical scenario, the triac starts passing current between external components—and the current exceeds the latching level. Consequently, gate current can diminish to zero, and the triac remains conductive. However, when external factors cause the current between the main terminals to diminish below the holding level, the triac abruptly ceases to be conductive, and current falls back to the leakage level.

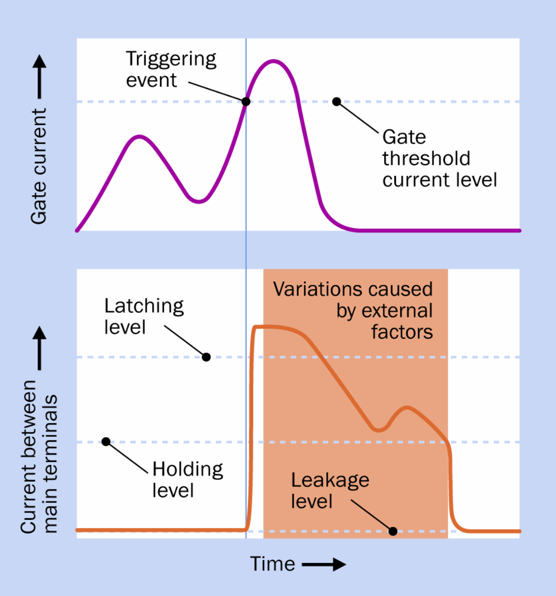

Figure 3-7. *The relationship between gate current of a triac and the current between its main terminals. See text for details.*

Unlike a **bipolar transistor**, a triac is either "on" or "off" and does not function as a *current ampli-*

fier. When it has been triggered, the impedance between A1 and A2 is low enough for heat dissipation to be manageable even at relatively high power levels.

Triac Testing

Figure 3-8 shows a circuit which can demonstrate the conductive behavior of a triac. For simplicity, this circuit is DC powered. In a real application, the triac is almost always used with AC.

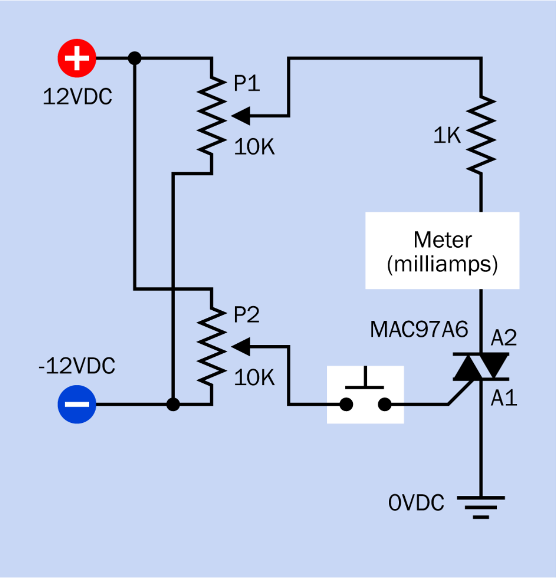

Figure 3-8. *A test circuit to show the behavior of a triac when varying positive and negative potentials are applied to the gate and to the A2 terminal, relative to A1.*

Note that this circuit requires at least a +12VDC and -12VDC power supply (higher values may also be used). The ground symbol represents a midpoint voltage of 0VDC, applied to terminal A1 of the triac, which is an MAC97A6 or similar. If a dual-voltage power supply is unavailable, the gate of the triac can be connected directly to +12VDC, omitting potentiometer P2; but in this case, only two operating modes of the triac can be demonstrated by turning potentiometer P1.

Each potentiometer functions as a voltage divider between the positive and negative sides of the power supply. P1 applies a positive or negative voltage to A2, relative to A1. P2 applies a positive or negative voltage to the gate, relative to A1.

If the test begins with both potentiometers at the top ends of their range, A1 and G both have a positive potential relative to A1, so that the triac is now in quadrant 1 of its operating modes. Pressing the pushbutton should cause it to start conducting current limited by the 1K resistor, and the meter should change from measuring 0mA to around 12mA. If the pushbutton is released, the triac should continue to conduct current, because 12mA is above this triac's latching level. If P1 is slowly moved toward the center of its range, the current diminishes, ceasing when it falls below the holding level. If P1 is now moved back to the top of its range, the current will not resume until the triac is retriggered with the pushbutton.

The test can be repeated with P1 at the top of its range and P2 at the bottom of its range, to operate the triac in quadrant 2; P1 at the bottom of its range and P2 at the bottom of its range, to operate the triac in quadrant 3; and P1 at the bottom of its range and P2 at the top of its range, to operate the triac in quadrant 4. The functionality should be the same in each case. The pushbutton will initiate a flow of current, which will diminish when P1 is turned toward the center of its range.

In any of these quadrants, P2 can be turned slowly toward the center of its range while the pushbutton is pressed repeatedly. This will allow empirical determination of the gate threshold current for this triac. The meter, measuring milliamps, will measure the current if it is inserted between the wiper of the potentiometer and the gate of the triac.

The test circuit is shown installed on a breadboard in Figure 3-9. In this photograph, the red and blue wires at left supply +12VDC and -12VDC relative to the black ground wire at top right. The yellow and green wires connect with a meter set to measure milliamps. The red button is a tactile switch, while the MAC97A6 triac is just above it and to the left. The square blue 10K trimmers are set to opposite ends of their scales, so that the meter will show current flowing when the tactile switch is pressed.

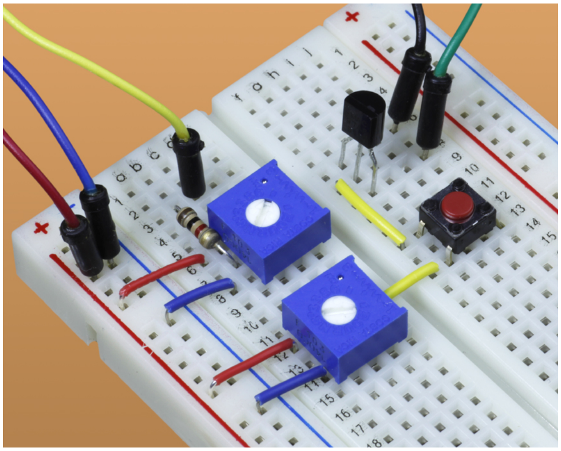

Figure 3-9. *A breadboarded triac test circuit.*

Breakover Voltage

If a much higher voltage is applied to A2, the triac can be forced to conduct current without any triggering voltage being applied to the gate. This occurs when the potential between A1 and A2 reaches the triac's *breakover voltage*, although the component is not designed to be used this way. The concept is illustrated in Figure 3-10, which can be compared with the behavior of an SCR illustrated in Figure 1-8 and the behavior of a diac shown in Figure 2-5. While the term *breakdown voltage* defines the minimum reverse voltage required to force a diode to conduct, *breakover voltage* refers to the minimum forward voltage that has this effect. Because a triac is designed to conduct in both directions, it can be thought of as having a breakover voltage in both directions.

In Figure 3-10, the numbers in yellow squares are the quadrants referred to in Figure 3-6. The solid curve represents current flow if a triggering voltage is applied to the gate while a positive or negative potential is applied to A2, relative to A1. If the gate is not triggered while the voltage between A1 and A2 gradually increases, the dashed section of the curve illustrates the outcome when the component reaches breakover voltage. Although this may not damage the triac, the component becomes uncontrollable.

- In normal usage, the voltage between A1 and A2 should not be allowed to reach breakover level.

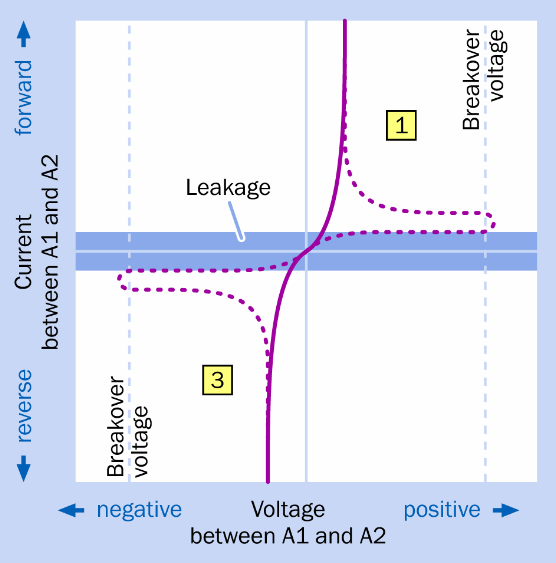

Figure 3-10. *The solid curve shows current passing between A1 and A2 in a hypothetical triac, for varying voltages, while triggering voltage is applied to the gate. The dashed curve assumes that no triggering voltage is applied to the gate. The numbers in yellow squares are the quadrants of triac operation.*

Switching AC

"Switching" AC with a triac means interrupting each pulse of current so that only a portion of it is conducted through to the load. Usually this is done with the triac functioning in quadrants 1 and 3. In quadrant 3, the polarity of the flow between A1 and A2 is opposite to that in quadrant 1, and the gate voltage is also reversed. This enables a relatively simple circuit to control the duration of each half-cycle passing through the triac. The theory of this circuit is shown in Figure 3-11.

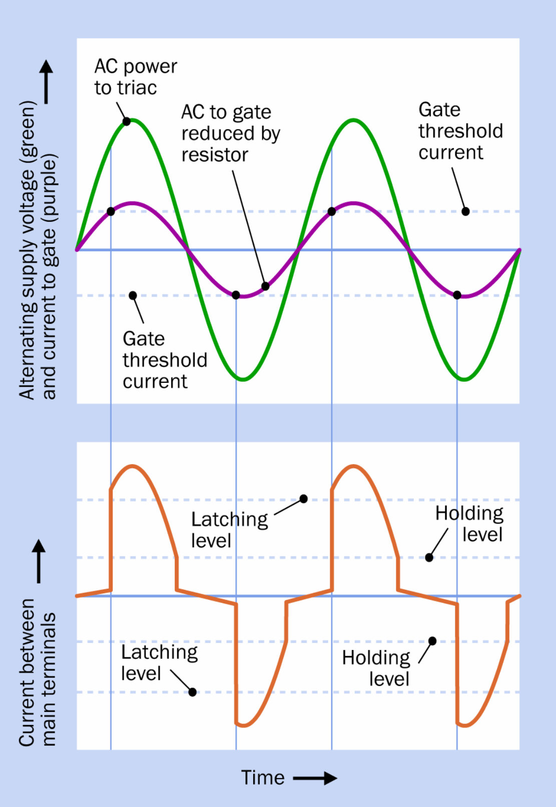

Figure 3-11. *To moderate the power of AC current, a triac can block a section of each AC pulse.*

The upper section of Figure 3-11 shows alternating voltage to the triac in green. The purple curve represents the gate current of the triac, reduced by a variable resistor. (The figure is for conceptual purposes only; the alternating power supply voltage and the fluctuating gate current cannot actually share the same vertical scale of a graph.)

Figure 3-11 can be compared with Figure 3-7, except that the negative threshold level for the gate is now shown as well as the positive threshold level. Remember, either a positive or negative voltage can activate the gate.

In Figure 3-11, initially the triac is nonconductive. As time passes, the gate current reaches the threshold level, and this triggering event enables current to flow between the main terminals of the triac, as shown in the lower part of the figure.

This current exceeds the latching level, so it continues to flow, even though the gate current diminishes below its threshold level. Finally the current between the main terminals falls below the holding level, at which point the triac stops conducting. It waits for the next triggering event, which occurs as the power supply swings to negative.

This simple system blocks a section of each AC pulse, which will vary in length depending how much current is allowed to flow through the gate. Because the blocking process occurs rapidly, we notice only the reduced overall power passing through the triac (in terms of the brightness of a light, the heat emitted by a resistive element, or the speed of a motor).

Unfortunately, there is a problem in this scenario: the triac does not quite behave symmetrically. Its gate threshold level for positive current is not exactly equal and opposite to its gate threshold level for negative current. The upper part of Figure 3-11 shows this flaw in the differing vertical offsets of the positive and negative thresholds from the central zero line.

The result is that negative AC pulses through the triac are shorter than positive pulses. This asymmetry produces harmonics and noise that can feed back into power supply wiring, interfering with other electronic equipment. The actual disparities in gate response, in each quadrant of operation for two triacs, are shown in Figure 3-12.

Current capacity of triac	Ratio of gate current required to conduct, relative to quadrant 1		
	Quadrant 2	Quadrant 3	Quadrant 4
4 amp	1.6	2.5	2.7
10 amp	1.5	1.4	3.1

Figure 3-12. *Because the internal structure of a triac is asymmetrical, it requires a different trigger current in each of its operating quadrants. This table, derived from a Littelfuse technical briefing document, shows the ratio of the minimum trigger current in quadrants 2, 3, and 4 relative to quadrant 1.*

See Figure 1-14 for a graph illustrating phase control in the SCR. See "Phase Control" for a discussion of phase in AC waveforms generally.

Triac Triggered by a Diac

The problem of asymmetrical triggering can be overcome if the triac is triggered with a voltage pulse generated by another component that does behave symmetrically. The other component is almost always a diac, which is another type of thyristor. Unlike an SCR or a triac, it has no gate. It is designed to be pushed beyond its breakover voltage, at which point it latches and will continue to conduct until current flowing through it diminishes below its holding level. See Chapter 2 for more information about the diac.

In Figure 3-13, the diac is shown to the right of the triac, and is driven by a simple RC network consisting of a fixed resistor, a potentiometer, and a capacitor. (In an actual application, the RC network may be slightly more complex.) The capacitor takes a small amount of time to charge during each half-cycle of AC. The length of this delay is adjusted by the potentiometer, and determines the point in each AC half-cycle when the voltage to the diac reaches breakover level. Because the delay affects the phase of the AC, this adjustment is known as *phase control*.

As the voltage exceeds breakover level, the diac starts to pass current through to the gate of the triac, and triggers it. The holding level of the diac is lower than its latching level, so it continues to pass current while the capacitor discharges and the voltage diminishes. When the current falls below the holding level, the diac stops conducting, ready for the next cycle. Meanwhile, the triac continues to pass current until the AC voltage dips below its holding level. At this point, the triac becomes nonconductive until it is triggered again.

This chopped waveform will still create some harmonics, which are suppressed by the coil and capacitor at the left side of the circuit in Figure 3-13.

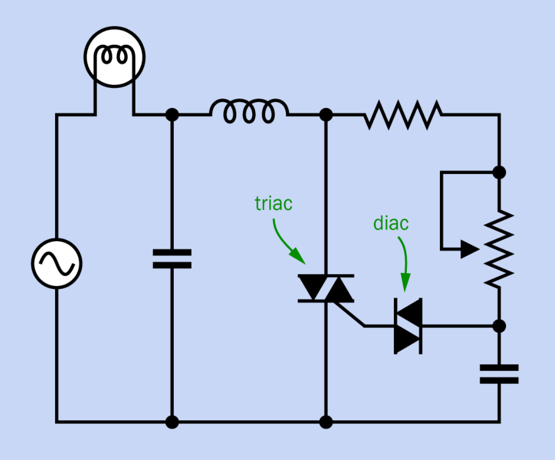

Figure 3-13. *A minimal schematic showing typical operation of a triac, with a diac supplying pulses to the triac gate. The potentiometer adjusts the delay created by the capacitor.*

Other Triac Drivers

It is possible, although unusual, to drive a triac from a source other than a diac.

Simple on-off control can be achieved by using a special optocoupler such as the MOC3162 by Fairchild Semiconductor. This emits a switching signal to a triac only when the AC voltage passes through zero. A *zero cross* circuit is desirable because it creates much less interference. The use of an optocoupler helps to isolate the triac from other components.((("zero cross circuit"))

Phase control can be achieved using an optocoupler such as the H11L1, which can be driven by rectified but unsmoothed AC after it passes through a Zener diode to limit the voltage. The output from the optocoupler is logic-compatible and can be connected with the input to a timer such as the 555, set to one-shot mode. Each pulse from the timer passes through another optocoupler such as the MOC3023, which uses an internal LED to trigger the gate of a triac.

Yet another possibility is to use the programmed output from a microcontroller, through an optocoupler, to control the gate of a triac. An online search for the terms "microcontroller" and "triac" will provide some additional suggestions.

Charge Storage

While switching AC, the internal charge between A1 and A2 inside the triac requires time to dissipate before the reverse voltage is applied; otherwise, *charge storage* occurs, and the component may start to conduct continuously. For this reason, the triac is normally restricted to relatively low frequencies such as domestic 60Hz AC power.

When a triac controls a motor, the phase lag between voltage and current associated with an inductive load can interfere with the triac's need for a transitional moment between a positive and negative voltage cycle. In a datasheet, the term *commutating dv/dt* defines the rate of rise of opposite polarity voltage that the triac can withstand without locking into a continuous-on state.

An RC *snubber network* is often wired in parallel with A1 and A2 to control the rise time of voltage to the triac, as shown within the darker blue rectangle in Figure 3-14, where a resistor and capacitor have been added just to the left of the triac. The highest resistance and lowest capacitance, consistent with trouble-free operation, should be chosen. Typical values are 47Ω to 100Ω for the resistor, and 0.01µF to 0.1µF for the capacitor.

Variants

Triacs are available in through-hole and surface-mount packages.

Some components that are referred to as triacs actually contain two SCR components of opposite polarity. The "alternistor" range from Littelfuse is an example. The SCR will tolerate faster voltage rise times than a conventional triac, and is more suitable for driving inductive loads such as large motors.

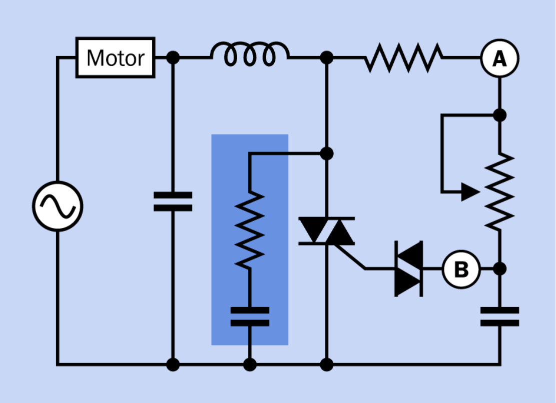

Figure 3-14. *To prevent a triac from locking itself into a continuous-on state while driving an inductive load such as a motor, a snubber circuit can be added (shown here as a resistor and capacitor in the darker blue rectangle to the left of the triac).*

A *snubberless triac*, as its name implies, is designed to drive an inductive load without need for a snubber circuit. An example is the STMicroelectronics BTA24. Datasheets for this type of component impose some limits that may be stricter than for a generic triac.

Values

Surface-mount triacs are typically rated between 2A to 25A of switched AC current (RMS), the higher-current versions being as large as 10mm square. The necessary gate trigger voltage may range from 0.7V to 1.5V. Through-hole packages may be capable of slightly higher currents (up to 40A), with gate trigger voltages of 1V to 2.5V being common.

As noted previously, the majority of triacs are restricted to relatively low frequency switching, 60Hz being very common.

Abbreviations in datasheets are likely to include:

- V_{DRM} or V_{RRM} Peak repetitive reverse off-state voltage. The maximum reverse voltage that the component will withstand in its "off" state without experiencing damage or allowing current to pass.

- V_{TM} The maximum voltage difference between A1 and A2, measured with a short pulse width and low duty cycle.
- V_{GT} Gate trigger voltage necessary to produce the gate trigger current.
- I_{DRM} Peak repetitive blocking current (i.e., maximum leakage).
- I_{GM} Maximum gate current.
- I_{GT} Minimum gate trigger current.
- I_H Holding current.
- I_L Latching current.
- $I_{T(RMS)}$ On-state RMS current. The maximum value passing through the component on a continuous basis.
- I_{TSM} Maximum non-repetitive surge current. Specified at a stated pulse width, usually 60 Hz.
- T_C Case temperature, usually expressed as an acceptable range.
- T_J Operating junction temperature, usually expressed as an acceptable range.

What Can Go Wrong

Like other semiconductors, a triac is heat sensitive. Usual precautions should be taken to allow sufficient ventilation and heat sinking, especially when components are moved from an open prototyping board to an enclosure in which crowding is likely.

Unexpected Triggering Caused by Heat

On a datasheet, a value for triggering current is valid only within a recommended temperature range. A buildup of heat can provoke unexpected triggering.

Low-Temperature Effects

Significantly higher gate current will be required by a triac operating at low temperatures. It is quite possible that the component will need twice as much current at 25° C compared with 100° C, junction temperature. If the triac receives insufficient current, it will not turn on.

Wrong Type of Load

If an **incandescent lamp** is replaced with a **fluorescent light** or **LED area lighting**, a preexisting triac may no longer work as a dimmer. Fluorescent lamps will have some inductance, and may also provide a capacitive load, either of which will interfere with the normal behavior of a triac.

The light output of an LED varies very differently compared with the light output of an incandescent bulb, in response to reduction in power. Therefore an LED should be dimmed using pulse-width modulation that is appropriate for its output characteristics. A triac is generally not suitable.

Wrongly Identified Terminals

A triac is often thought of as a symmetrical device, because it is designed to switch AC current using either positive or negative voltage at the gate. In reality, its behavior is asymmetrical, and if it is installed “the wrong way around” it may function erratically or not at all.

Failure to Switch Off

As already noted (see “Charge Storage” on page 23), a triac will tend to suffer from *charge storage* if there is insufficient time between the end of one half-cycle and the beginning of the next. A component that works with a resistive load may cease to function if it is used, instead, to power an inductive load.

4

solid-state relay

A **solid-state relay** is less-commonly referred to by its acronym, *SSR*. It is sometimes regarded as an **optocoupler**, but in this encyclopedia the two components have separate entries. An optocoupler is a relatively simple device consisting of a light source (usually an **LED**) and a light sensor, in one package. It is used primarily for isolation rather than to switch a high current. A solid-state relay can be thought of as a substitute for an electromagnetic **relay**, usually has additional components in its package, and is intended to switch currents of at least 1A.

A component that works like a solid-state relay but only switches a 5V (or lower) logic signal may be referred to as a *switch*, even though it is entirely solid-state. This type of component is included in this entry because it functions so similarly to a solid-state relay.

OTHER RELATED COMPONENTS

- **electromagnetic relay** (see Volume 1)
- **optocoupler** (see Chapter 5)

What It Does

A **solid-state relay** (SSR) is a semiconductor package that emulates an electromagnetic **relay** (see Volume 1). It switches power on or off between its output terminals in response to a smaller current and voltage between its input terminals. Variants can switch AC or DC and may be controlled by AC or DC. An SSR functions as a *SPST switch*, and is available in normally open or normally closed versions. SSRs that function as an SPDT switch are relatively unusual and actually contain more than one SSR.

No single schematic symbol has been adopted to represent a solid-state relay, but some alternatives are shown in Figure 4-1:

Top

An unusually detailed depiction of an SSR that switches DC current using MOSFETS. Symbols for this device often omit the diodes on the output side and may simplify the MOSFET symbols.

Bottom left

An SSR that uses an internal **triac** to switch AC. The box labeled 0x indicates that this is a *zero-crossing* relay, meaning that it switches when alternating voltage crosses the 0V level from positive to negative or negative to positive.

Bottom right

A generic SSR, showing a symbol for a normally open relay, although whether it is designed for AC or DC is unclear.

Advantages

- Great reliability and long life.
- No physical contacts that are vulnerable to arcing and erosion or (under extreme conditions) that could weld themselves together.

- Very fast response, typically 1µs on and 0.5µs off.
- Very low power consumption on the input side, as low as 5mA at 5VDC. Many solid-state relays can be driven directly from logic chips.
- Lack of mechanical noise.
- No contact bounce; a clean output signal.
- No coil that would introduce back EMF into the circuit.
- Safe with flammable vapors, as there is no sparking of contacts.
- Often smaller than a comparable electromagnetic relay.
- Insensitive to vibration.
- Safer for switching high voltages, as there is complete internal separation between input and output.
- Some variants work with input control voltages as low as 1.5VDC. Electromagnetic relays typically require at least 3VDC (or more, where larger relays are required to switch higher currents).

Disadvantages

- Less efficient; its internal impedance introduces a fixed-value voltage drop on the output side (although this may be negligible when switching higher voltages).
- Generates waste heat in its "on" mode, in accordance with the voltage drop.
- Passes some *leakage* current (usually measured in microamps) on the output side when the relay is supposed to be "off."
- A DC solid-state relay usually requires observation of polarity on the output side. An electromagnetic relay does not.
- Brief voltage spikes on the input side, which would be ignored by a slower electromagnetic relay, may trigger a solid-state relay.
- More vulnerable than an electromagnetic relay to surges and spikes in the current that is switched on the output side.

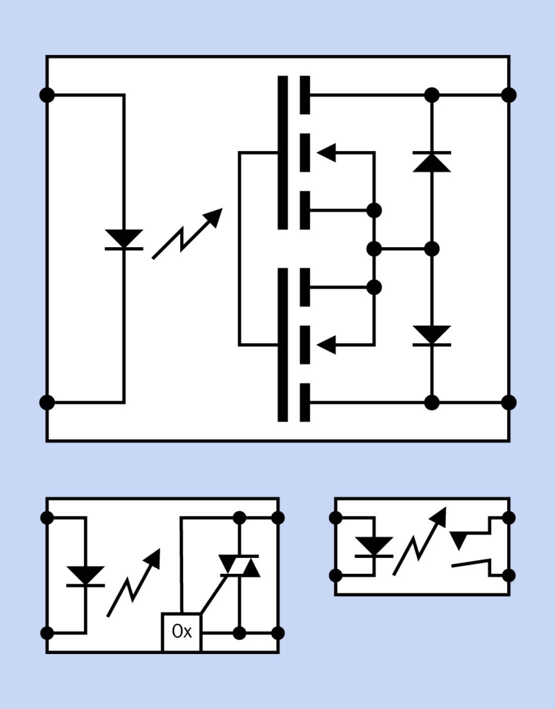

Figure 4-1. *Schematic symbols for solid-state relays have not been standardized. See text for details.*

How It Works

Almost all modern SSRs contain an internal **LED** (light-emitting diode, see Chapter 22) which is switched on by the control input. Infrared light from the LED is detected by a sensor consisting of one or more **phototransistors** or **photodiodes**. In a relay that controls DC current, the sensor usually switches a **MOSFET** (see Volume 1) or an **SCR** (silicon-controlled rectifier—see Chapter 1). In relays that control AC current, a **triac** (see Chapter 3) controls the output. Because the input side and the output side of the SSR are linked only by a light signal, they are electrically isolated from each other.

The MOSFETs require so little power, it can be provided entirely by light falling on an array of 20 or more photodiodes inside the SSR package.

Typical solid-state relays are shown in Figures 4-2 and 4-3.

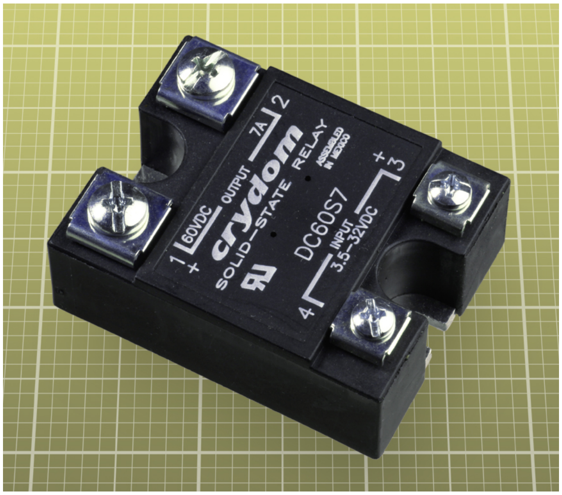

Figure 4-2. *A solid-state relay capable of switching up to 7A DC. See text for a detailed description.*

The Crydom DC60S7 accepts a control voltage ranging from 3.5VDC to 32VDC, with a typical input current of less than 3mA. Maximum turn-on time is 0.1ms and maximum turn-off time is 0.3ms. This relay can switch up to 7A and tolerates a surge of up to twice that current. It imposes a voltage drop of as much as 1.7VDC, which can become a drawback when switching voltages that are significantly lower than its maximum 60VDC. The electronics are sealed in thermally conductive epoxy, mounted on a metal plate approximately 1/8" thick which can be screwed down onto an additional heat sink.

The Crydom CMX60D10 tolerates a more limited range of control voltages (3VDC to 10VDC) and requires a higher input current of 15mA at 5VDC. However, its very low maximum on-state resistance of 0.018Ω imposes a much smaller voltage drop of less than 0.2 volts when passing 10A. This results in less waste heat and enables a *single-inline package* (SIP) without a heat sink. The CMX60D10 weighs 0.4 ounces, as opposed to the 3 ounces of the DC60S7. Relays from other manufacturers use similar packaging and have similar specifications.

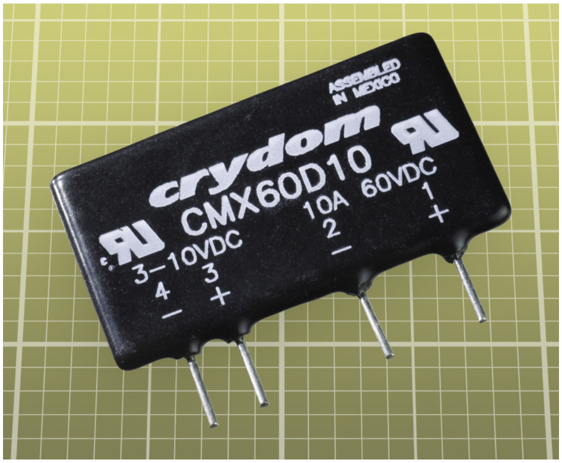

Figure 4-3. *A solid-state relay capable of switching up to 10A. Its lower internal resistance results in less waste heat and enables a smaller package. See text for a detailed description.*

Variants

Many solid-state relays have protective components built into the package, such as a varistor on the output side to absorb transients. Check datasheets carefully to determine how much protection from external components may be necessary when switching an inductive load.

Instantaneous versus Zero Crossing

A *zero crossing* SSR is one that (a) switches AC current and (b) will not switch "on" until the instant when the AC voltage crosses through 0V. The advantages of this type are that it does not have to be built to switch such a high current, and creates minimal voltage spike when the switching occurs.

All SSRs that are designed to switch AC will wait for the next voltage zero crossing before switching to their "off" state.

NC and NO Modes

Solid-state relays are SPST devices, but different models may have a normally closed or normally open output. If you require double-throw operation, two relays can be combined, one normally closed, the other normally open. See Figure 4-4. A few manufacturers combine a normally closed relay and a normally open relay in one package, to emulate a SPDT relay.

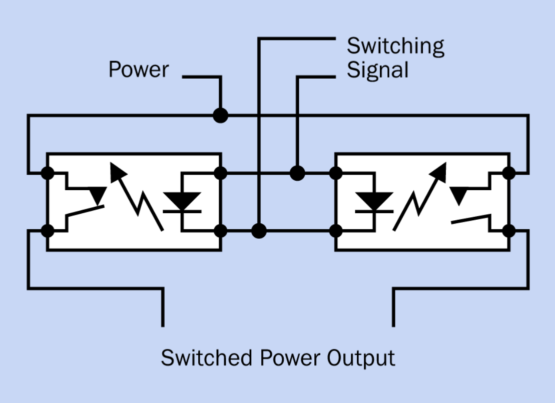

Figure 4-4. *A normally closed solid-state relay can be paired with a normally open solid-state relay to emulate a SPDT switch. This combination is available in a single package from some manufacturers.*

Packaging

High-current solid-state relays are often packaged with screw terminals and a metal base that is appropriate for mating with a *heat sink*. Some are sold with heat sinks integrated. Spade terminals and crimp terminals may be optional. The Crydom DC60S7 shown in Figure 4-2 is an example. This type of package may be referred to as *industrial mount.*

Lower-current solid-state relays (5A or less), and those with a very low output resistance, may be packaged with single-inline pins for through-hole mounting in circuit boards.

Solid-State Analog Switch

DIP packaging may be used for solid-state relays that are designed for compatibility with the low voltages and currents of logic chips. This type of component may be referred to simply as a *switch*. The 74HC4316 is an example, pictured in Figure 4-5.

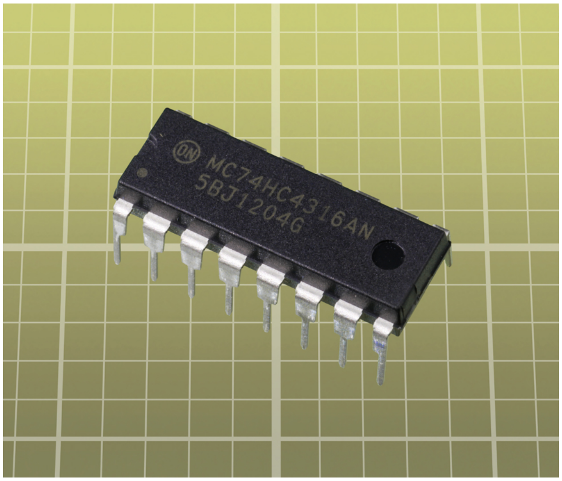

Figure 4-5. *This DIP package contains four "switches" that function as solid-state relays but are restricted to low voltages and currents, compatible with logic chips. See text for details.*

Typically the control voltage and the switched voltage are limited between +7V and −7V, with a maximum output current of 25mA. Each internal switch has its own Control pin, while an additional Enable pin forces all switches into an "off" state if its logic state is high. The simplified functionality of this component is illustrated in Figure 4-6, without showing internal optical isolation.

The "on" resistance of each internal pathway will be approximately 200Ω when the component is powered with +5VDC on the positive side and 0VDC on the negative side. This resistance drops to 100Ω if the negative power supply is -5VDC.

If all of the outputs from the chip are shorted together, it functions as a **multiplexer** (see Chapter 16). In fact, this type of switch component is often listed in catalogs as a multiplexer, even though it has other applications.

Because the component tolerates equal and opposite input voltages, it is capable of switching AC.

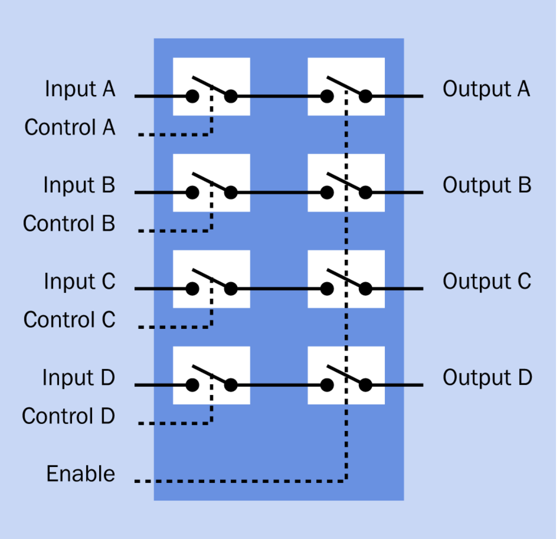

Figure 4-6. *The functionality of a chip containing four solid-state analog switches. A high state on a Control pin closes its associated switch. The Enable pin must be held low for normal operation; a high Enable state forces all the switches into the "off" position. If the outputs are tied together, this component can function as a multiplexer.*

Values

Industrial-mount solid-state relays typically can switch currents ranging from 5A to 500A, with 50A being very common. The higher-current relays mostly require DC control voltage; 4V to 32V are typical, although some versions can go much higher. They contain an SCR or triac to switch AC.

Smaller solid-state relays in SIP, DIP, or surface-mount packages often use MOSFETs on the output side, and are often capable of switching up to 2A or 3A. Some can switch either AC or DC, depending on the way the output is wired. The LED on the input side may require as little as 3mA to 5mA for triggering.

How to Use It

Solid-state relays find their primary uses in telecommunications equipment, industrial control systems and signalling, and security systems.

The component is very simple externally. Power on the input side can come from any source capable of delivering the voltage and current specified by the manufacturer, and any device that doesn't exceed maximum current rating can be connected to the output side, so long as provision is made for suppressing back-EMF from an inductive load, as shown in Figure 4-7. Often a solid-state relay can be substituted directly for an electromagnetic relay, without modifying the circuit.

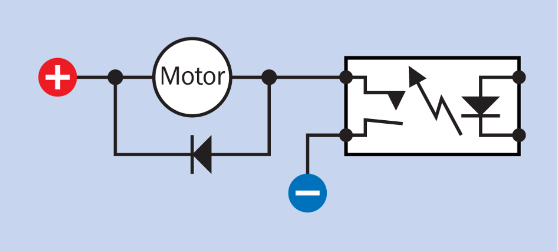

Figure 4-7. *Use of a diode around an inductive load, to protect a solid-state relay from back-EMF.*

Solid-state relays are heat sensitive, and their rating for switching current will diminish as their temperature increases. Manufacturer datasheets will provide specific guidance. Using a heat sink will greatly improve the performance. Bear in mind that the relay generates heat continuously while it is in its "on" mode—about 1 watt per ampere.

Because it requires so little current on the input side (typically no more than 15mA), a solid-state relay can usually be driven directly by chips such as *microcontrollers* that would not be able to activate an equivalent electromagnetic relay.

Applications may take advantage of the solid-state relay's reliability, immunity to vibration, lack of contact sparking, freedom from coil-induced surges on the input side, and lack of contact bounce on the output side. A solid-state relay is ideal within digital equipment that is sensitive to power spikes. It may switch a fuel pump that handles volatile, flammable liquids, or a wastewater pump in a basement subject to flooding (where long-term zero-maintenance reliability is necessary, and contact corrosion could be a risk in electromagnetic relays). Small solid-state relays can switch motors in robots or appliances where vibration is common, and are often used in arcade games.

What Can Go Wrong

Overheating Caused by Overloading

Relays must be *derated* when used at operating temperatures above the typical 20 or 25° C for which their specification applies. In other words, the sustained operating current must be reduced, usually by an amount such as 20% to 30% for each 10-degree increase in ambient temperature. Failure to observe this rule may result in failure of the component. Burnout may also occur if a high-current solid-state relay is used without a heat sink, or the heat sink isn't big enough, or *thermal compound* is not applied between the solid-state relay and the heat sink.

Overheating Caused by Bad Terminal Contact

If the screw terminals on the output side of a high-current solid-state relay are not tightened sufficiently, or if there is a loose spade terminal, or if a crimped connection isn't crimped tightly enough, the poor contact will create electrical resistance, and at high currents, the resistance will create heat, which can cause the solid-state relay to overheat and burn out.

Overheating Caused by Changing Duty Cycle

If a high-current solid-state relay is chosen for an application where it is in its "on" state only half the time, but the application changes during product development so that the solid-state relay is in its "on" state almost all the time, it will have to dissippate almost twice as much heat. Any time the duty cycle is changed, heat should be considered. The possibility of the relay being used in an unconventional or unexpected manner should also be considered.

Overheating Caused by Component Crowding

Overheating increases dramatically when components are tightly crowded. At least 2cm (3/4") should be allowed between components.

Overheating in Dual Packaging

When a package contains two solid-state relays, the additive effects of the heat created by each of them must be considered.

Reverse-Voltage Burnout

Because a solid-state relay is more sensitive to *back-EMF* than an electromagnetic relay, greater care should be used to protect it from reverse voltage when switching inductive loads. A *protection diode* should be used, and a *snubber* can be added between its output terminals, if it is not included inside the relay package.

Low Voltage Output Current May Not Work

Unlike electromagnetic relays, solid-state relays require some voltage on the output side to enable their internal operation. If there is no voltage, or only a very low voltage, the SSR may not respond to an input. The minimum voltage required on the output side is usually specified in a datasheet.

To test a solid-state relay, apply actual voltages on input and output sides and use a load such as an incandescent light bulb. Merely applying a meter on the output side, set to measure continuity, may not provide sufficient voltage to enable the relay to function, creating the erroneous impression that it has failed.

Inability to Measure AC Output

When a multimeter is used to test continuity across the output of an AC-switching solid-state relay of zero-crossing specification, the meter will generate enough voltage to prevent the solid-state relay from finding zero voltage across its output terminals, and consequently the solid-state relay won't switch its output.

Relay Turns On but Won't Turn Off

When a solid-state relay controls a relatively high-impedance load such as a small **solenoid** (see Volume 1) or a **neon bulb** (see Chapter 19), the relay may switch the device on but will seem unable to switch it off. This is because the leakage current of the solid-state relay, in its "off" state, may be just enough to maintain the load in its "on" state.

If an SSR containing a triac is used erroneously to switch DC, it will not be able to switch off the current.

Relays in Parallel Won't Work

Two solid-state relays usually cannot be used in parallel to switch twice as much current. Because of small manufacturing variances, one relay will switch on a moment before the other. When the first relay is on, it will divert the load current away from the second relay. The second relay needs a small amount of current on its output side, to function. Without any current, it will not switch on. This means the first relay will pass the total current without any help from the second relay, and will probably burn out, while the second relay does nothing.

Output Device Doesn't Run at Full Power

A solid-state relay imposes a voltage reduction on its output side. This will be a fixed amount, not a percentage. When switching 110V, this difference may be negligible; when switching 12V, it may deliver only 10.5V, which represents enough of a drop to cause a motor or a pump to run noticeably more slowly. The internal switching device inside the relay (MOSFET, triac, SSR, or bipolar transistor) will largely determine the voltage drop. Check the manufacturer's datasheet before using the relay.

Solid-State Relays and Safety Disconnects

Because a solid-state relay always allows some leakage in its "off" state, it can still deliver a shock when used to switch high voltages. For this reason, it may not be suitable in a safety disconnect.

optocoupler

5

Sometimes known as an *optoelectronic coupler*, *opto-isolator*, *photocoupler*, or *optical isolator*.

A **solid-state relay** is sometimes referred to as an **optocoupler**, but in this encyclopedia it has a separate entry. An optocoupler is a relatively simple device consisting of a light source (usually an LED) and a light sensor, both embedded in one package. It is used primarily for isolation rather than to switch a high current. A solid-state relay can be thought of as a substitute for an electromagnetic **relay**, usually has additional components in its package, and is intended to switch currents of at least 1A.

OTHER RELATED COMPONENTS

- **electromagnetic relay** (see Volume 1)
- **solid-state relay** (see Chapter 4)

What It Does

An optocoupler allows one section of a circuit to be electrically isolated from another. It protects sensitive components, such as logic chips or a microcontroller, from voltage spikes or incompatible voltages in other sections of a circuit. Optocouplers are also used in medical devices where a patient has to be protected from any risk of electric shock, and are used in devices which conform with the MIDI standard for digital control of music components.

In Figure 5-1, three possible applications for an optocoupler are suggested:

Top
: The output from a logic chip passes through an optocoupler to an inductive load such as a relay coil, which may create voltage spikes that would be hazardous to the chip.

Center
: The noisy signal from an electromagnetic switch passes through an optocoupler to the input of a logic chip.

Bottom
: The low-voltage output from a sensing device on a human patient passes through an optocoupler to some medical equipment, such as an EEG machine, where higher voltages are used.

Internally, an optocoupler works on the same principle as a **solid-state relay**. An LED is embedded on the input side, shining light through an interior channel or transparent window to a sensing component that is embedded on the output side. Because the only internal connection is a light beam, the input and output of the optocoupler are isolated from each other.

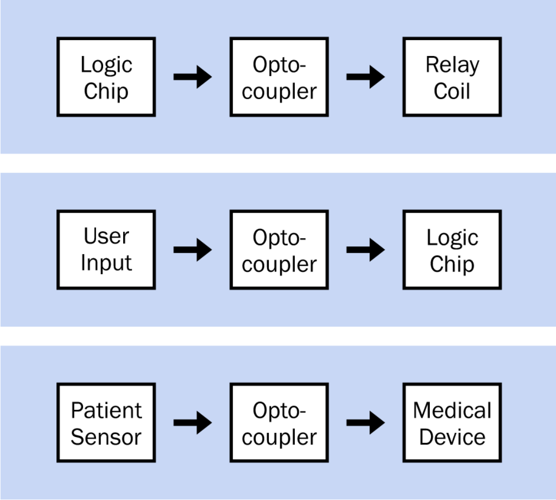

Figure 5-1. *Possible applications for a photocoupler. See text for details.*

Isolation transformers were traditionally used for this purpose prior to the 1970s, when optocouplers became competitive. In addition to being smaller and cheaper, an optocoupler can also pass slow-changing signals or on-off DC states which a transformer would ignore.

More recently, inductive and capacitive coupling components have become available in surface-mount packages that are competitive with optocouplers for high-speed data transfer. They also claim to be more durable. Because of the gradual reduction in output from an LED, the performance of an optocoupler degrades over time, and is typically rated for up to 10 years.

How It Works

The LED in an optocoupler almost always emits light in the near-infrared part of the spectrum, and is matched to the sensitivity of a **phototransistor**, or a **photodiode**, or (less often) a **photoresistor** that provides the output. Photosensitive **triacs** and **SCRs** are also sometimes used.

The most common type of optocoupler uses a bipolar phototransistor with an open-collector output. Schematic symbols for this type are shown in Figure 5-2:

Top left

The most common generic form.

Top right

Two diodes on the input side allow the use of alternating current.

Center left

An additional terminal allows addition of bias to the photosensitive base of the output transistor, to reduce its sensitivity.

Center right

An Enable signal can be used as the input to the NAND, suppressing or enabling the output.

Bottom left

A *photodarlington* allows higher emitter current.

Bottom right

Relatively uncommon, and is also used for a **solid-state relay**.

In each symbol, the diode is an LED, and the zig-zag arrow indicates light that is emitted from it. A pair of straight arrows, or wavy arrows, may alternatively be used.

An optocoupler in through-hole DIP format is shown in Figure 5-3.

An *optical switch* can be thought of as a form of optocoupler, as it contains an LED opposite a sensor. However, the LED and the sensor are separated by an open slot, to allow a thin moving object to pass through, interrupting the light beam as a means of detecting the event. It is categorized as a *sensor* in this encyclopedia, and will be found in Volume 3.

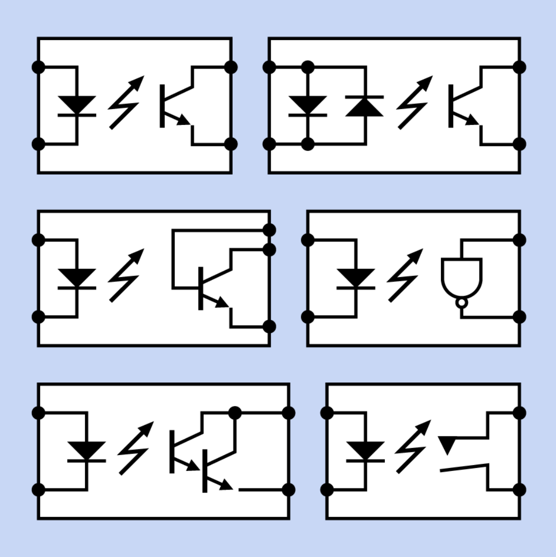

Figure 5-2. *Six variants of schematic symbols that may be used to represent an optocoupler. See text for details.*

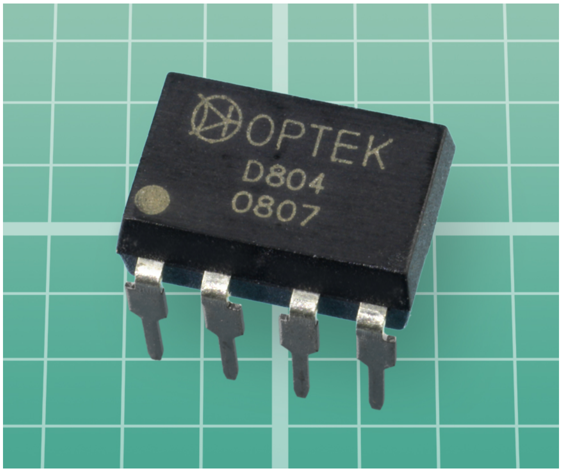

Figure 5-3. *An optocoupler in through-hole 8-pin DIP format.*

Variants

Internal Sensors

Historically, a photoresistor (often referred to as a *photocell*) was the first type of sensor to be used. It has a more linear response than other sensor types, but its response is much slower. It is still found in audio applications. "Stomp box" pedals used by guitarists typically contain an optocoupler that employs a photoresistor, and are valued for their linearity and their immunity from the mechanical wear, contamination, and "scratchiness" that builds up over time in a **potentiometer**. Optocouplers also eliminate *ground loops*, which tend to be induced by small differences in ground potential, introducing hum or buzz in audio applications when two or more power supplies are tied together.

The type of optocoupler that contains a photoresistor and is commonly used by musicians was initially trademarked as a *Vactrol*, and that term is still used generically. Vactrols have also been used to provide audio compression in telephone voice networks, and were used in photocopiers and photographic exposure meters, but these applications are now obsolete.

Photoresistors are becoming uncommon because of their cadmium content, which is unlawful in many countries (especially in Europe) because of its environmental toxicity.

A photodiode provides the fastest response time in an optocoupler, limited primarily by the characteristics of the LED that shines light upon it. A *PIN diode* can respond in less than a nanosecond; its acronym is derived from its fabrication from p-type and n-type semiconductor layers with an *intrinsic* layer connecting them. This additional layer can be responsive to light. When the diode is slightly reverse-biased, a photon entering the intrinsic layer can dislodge an electron, enabling current to flow. The reverse bias enlarges the active area and enhances the effect. In this mode, the PIN acts like a photoresistor, appearing to reduce its resistance in response to light.

When the PIN is used in *photovoltaic* mode, no bias is applied, and the component actually generates a small voltage (less than 1VDC), like a solar cell, in response to incoming light. Where an optocoupler uses a MOSFET on its output side, as many as 30 photodiodes may be connected in series to develop the necessary threshold voltage to trigger the transistor. This arrangement is common in **solid-state relays**.

A bipolar phototransistor is a slower-speed device but is still usually capable of a 5μs response time or better. Its open collector requires external voltage and a *pull-up resistor* to deliver a positive output so long as the phototransistor is nonconductive. When the LED turns on, the phototransistor sinks current, effectively creating a low output. In this way, the optocoupler functions like an *inverter*, although some variants include a noninverting output.

Basic Optocoupler Types

An optocoupler with *high linearity* will respond more proportionally to variations in current to its LED. *High Speed* optocouplers are used for high-frequency data transfer. *Logic-output* optocouplers have a clean high/low output transition, rather than an *analog output*, which varies with fluctuations in the input. Linearity is of importance only where an optocoupler is being used to transmit an analog signal with some fidelity. Some logic-output optocouplers provide the function of a Schmitt trigger on their output side.

While optocouplers are available in various package formats, the DIP style with six or eight pins remains popular, providing sufficient physical space for the LED, the sensor, and a light channel, while providing good electrical isolation.

Variants may have two or four optocouplers combined in one package. A *bidirectional* optocoupler may consist of two optocouplers in parallel, inverted with respect to each other.

Values

In a datasheet, the characteristics of primary importance in an optocoupler are:

- CTR is the Current Transfer Ratio, the ratio of maximum output current to input current, expressed as a percentage. With a bipolar phototransistor output, 20% is a typical minimum CTR. With a photodarlington output, the CTR may be 1,000% but the bandwidth is much lower—the response time may be measured in microseconds rather than nanoseconds. Optocouplers with a photodiode output have a very low CTR, and their output is in microamps. However, they provide the most linear response.
- $V_{CE(MAX)}$ is the maximum collector-emitter voltage difference (in an optocoupler with a bipolar phototransistor output). Values from 20 to 80 volts are common.
- V_{ISO} is the maximum potential difference, in VDC, between the two sides of the optocoupler.
- I_{MAX} is the maximum current the transistor can handle, generally in mA.
- Bandwidth is the maximum transmittable signal frequency, often in the range of 20kHz to 500kHz.

The LED in an optocoupler typically requires 5mA at a forward voltage of 1.5V to 1.6V.

The maximum collector current on the output side of an optocoupler is unlikely to be higher than 200mA. For higher output currents, a solid-state relay should be considered. It provides photo-isolation on the same basis as an optocoupler, but high-current versions tend to be considerably more expensive.

How to Use It

The primary purpose of an optocoupler is to provide protection against excessive voltage—from transients, incompatible power supplies, or equipment with unknown characteristics. If a device is designed to be plugged into a USB port on a computer, for instance, the computer may be isolated via an optocoupler.

A series resistor for the LED is not built into most optocouplers, because the value of the resistor will depend on the input voltage that is used. Care must be taken to determine what the maximum voltage on the input side will be, and a series resistor should be chosen to reduce current appropriately. Allowance should be made for some degradation in the performance of the LED over time.

For an optocoupler with an open-collector output, a pull-up resistor is necessary in most applications. The voltage from the optocoupler must be matched to the input requirements of other components, and the collector current must remain within the specified limits. Some trial and error in resistor selection may be necessary.

In Figure 5-4, a schematic shows typical component values in a test circuit using a pushbutton as input. The separation of the two power supplies is emphasized by the different color shades used for the positive and negative symbols. Although the input side and the output side of an optocoupler may be used with a common ground, this defeats its purpose in providing complete isolation between the sections of the circuit.

The pinouts for an optocoupler must be checked carefully in the manufacturer's datasheet. While the input for an 8-pin DIP chip is usually applied to pins 2 and 3, the output pin functions are not standardized and will vary depending on the internal configuration of the chip. An optocoupler such as the Optek D804, with an enable function using an internal NAND gate, requires its own power supply.

Where an optocoupler allows an external connection to the base of its internal bipolar output phototransistor, reverse bias applied to this pin will decrease the sensitivity of the optocoupler but can increase its immunity to noise on the input side.

What Can Go Wrong

Overload conditions on the input or the output side of an optocoupler will be the most likely cause of failure.

Age

Because optocouplers are typically rated for only 10 years of average use, the age of a component may cause it to fail.

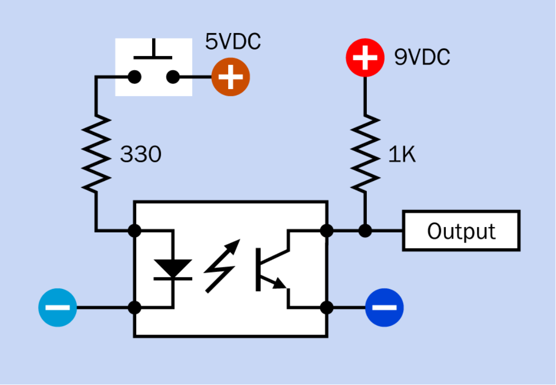

Figure 5-4. *Typical values for a series resistor (to protect the LED) and pull-up resistor (to control current and voltage on the output side) in an optocoupler test circuit.*

LED Burnout

Because the LED is hidden inside the component, there is no immediate indication of its performance. A meter can be inserted into the circuit on the input side to determine if current is passing through the LED. A meter set to measure volts can be used to discover whether the LED is imposing a normal voltage drop. While significant overload will cause immediate burnout, slightly exceeding the current rating of the LED may have more pernicious consequences, as the LED may not fail until days or weeks have passed without any sign of trouble. The failure of the optocoupler will be unexpected and difficult to determine.

Transistor Burnout

Here again the damage caused by excessive current may be progressive, occurring over a prolonged period. The easiest way to test an optocoupler that may have failed is by removing it from the circuit. A socketed DIP package is preferable for this purpose.

6

comparator

Although a **comparator** has the same schematic symbol as an **op-amp**, their applications differ and they are described in separate sections of this encyclopedia.

This entry describes an analog comparator. A *digital comparator* is very different, being a logic chip that compares two binary numbers that can be referred to as A and B. Outputs from the chip indicate whether A>B or A<B or A=B. The digital comparator does not have an entry in this encyclopedia.

OTHER RELATED COMPONENTS

- **op-amp** (see Chapter 7)

What It Does

A **comparator** is an integrated circuit chip that compares a variable voltage on one input pin with a fixed, reference voltage on a second input pin. Depending which voltage is higher, the output from the comparator will be high or low.

The output will make a clean transition between two fixed values, even if the input is infinitely variable. Thus the comparator can function as an *analog-digital converter*, as shown in Figure 6-1.

Because the output voltage range can be adjusted up or down independently of the input range, a comparator can also function as a *voltage converter*.

Hysteresis

If positive feedback is added through external resistors, *hysteresis* can be introduced. We may imagine a *hysteresis zone* extending above and below the reference voltage level. Small input variations that occur within the zone will be ignored. The comparator only reacts when the input signal emerges above or below the hysteresis zone. When the input signal returns into the hysteresis zone, this event also will be ignored. The concept is illustrated graphically in Figure 6-2. A circuit to create hysteresis is shown in Figure 6-10.

How It Works

The schematic symbol for a comparator is shown in Figure 6-3. This seems identical to the symbol for an op-amp, described in Chapter 7, but an op-amp is traditionally a *dual-voltage* device using positive and negative power sources that are equal and opposite, in addition to a zero value midway between the two. Modern comparators mostly use a conventional single voltage, and therefore the negative symbol used in comparator schematics throughout this section of the encyclopedia represents 0 volts. It has the same meaning as the ground symbol found in many schematics elsewhere.

The two inputs to a comparator are described as *inverting* and *noninverting* (for reasons explained later). Confusingly, these are identified with plus and minus symbols inside the triangle that represents the component. These plain black-and-white symbols have nothing to do with the power supply.

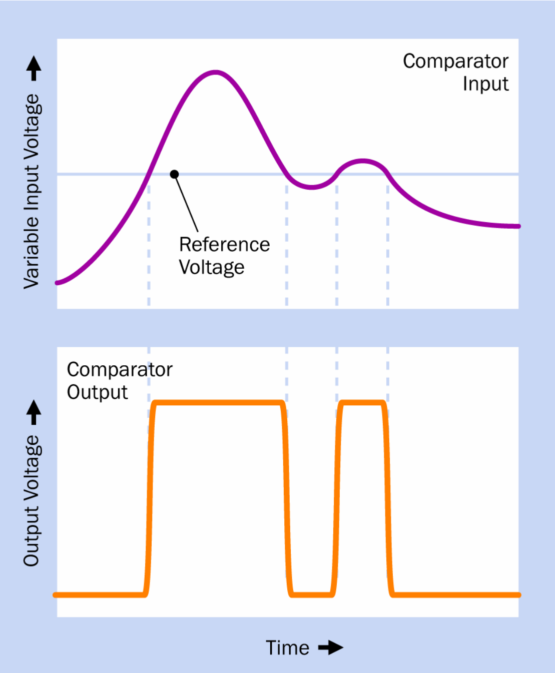

Figure 6-1. *The basic behavior of a simple comparator is shown here.*

Often, in schematics, the power supply is not shown, because it is assumed to be present. However, all comparators require a power supply in order to function.

The basic internal and external connections used in conjunction with a typical comparator are shown in Figure 6-4.

The potentiometer at top left is often a *trimmer*, to fine-tune a reference voltage. The variable input can come from a sensor or any other device capable of delivering a voltage up to the limit set by V1.

The output is often an *open collector* from an internal bipolar transistor, as shown in the figure.

Note that as many as three different voltages can be used, as indicated by the different colors associated with V1, V2, and V3. However, they must share a common ground to enable the comparator to make valid comparisons.

When the noninverting input exceeds the voltage of the inverting input, the output transistor goes into its "off" state, and blocks current from an external *pullup resistor*. Because the current from the resistor now has nowhere else to go, it is available to drive other devices attached to the comparator output, and the output appears to be high.

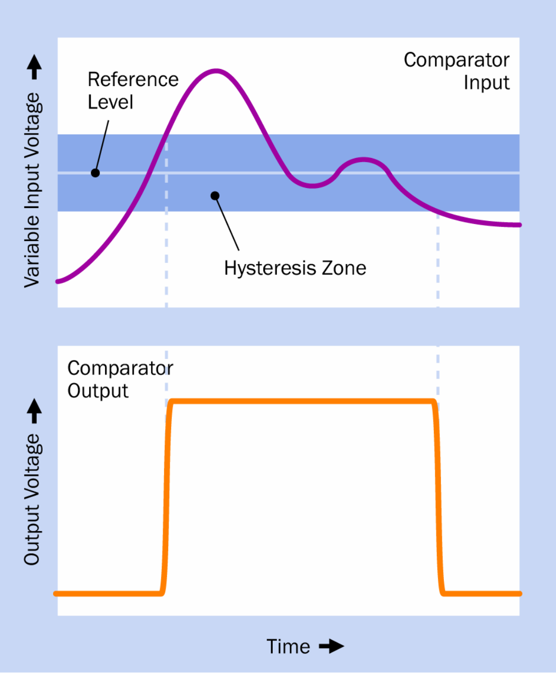

Figure 6-2. *The performance of a comparator shown in the previous figure can be modified by the addition of hysteresis. Small variations that occur within the hysteresis zone are ignored.*

When the noninverting input falls below the voltage of the inverting input, the transistor becomes conductive, and sinks almost all the current from the pullup resistor, assuming other devices attached to the output have a relatively high impedance. The output from the comparator now appears to be low.

This can be summed up as follows:

- When a variable voltage is applied to the noninverting input, and it rises *above* the reference voltage applied to the *inverting input*, the output transistor turns off, and the comparator delivers a *high* output.
- When a variable voltage is applied to the noninverting input, and it falls *below* the reference voltage applied to the *inverting input*, the output transistor turns on, and the comparator delivers a *low* output.

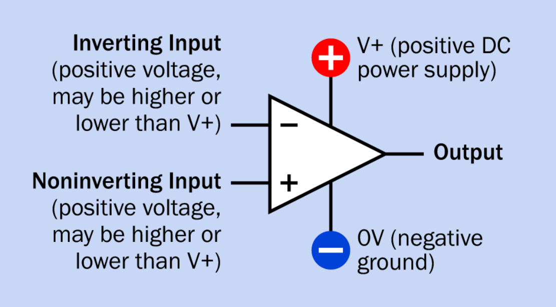
Inverting Input
(positive voltage, may be higher or lower than V+)
Noninverting Input
(positive voltage, may be higher or lower than V+)
V+ (positive DC power supply)
Output
0V (negative ground)
−
+

Figure 6-3. *The symbol for a comparator is the same as the symbol for an op-amp, even though they often require different types of power supply and their functions are significantly different.*

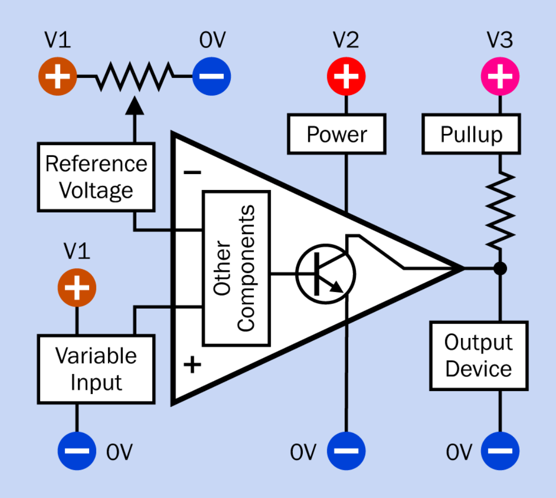
V1
0V
V2
V3
Reference Voltage
Power
Pullup
V1
Other Components
Variable Input
Output Device
0V
0V
0V
−
+

Figure 6-4. *Connections to a comparator, and their functions.*

If the reference voltage and the variable voltage are swapped between the input pins, the behavior of the comparator is reversed. This relationship is illustrated in Figure 6-5. When a voltage transition is applied to the *inverting* input, the transition is *inverted* at the output.

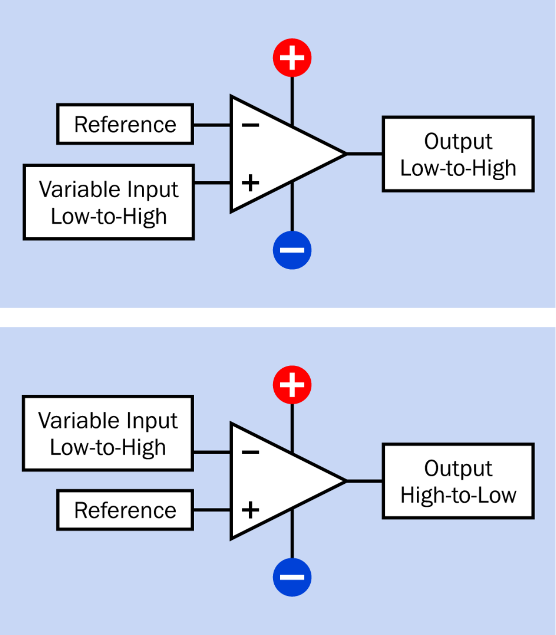
Reference
Variable Input Low-to-High
Output Low-to-High
Variable Input Low-to-High
Reference
Output High-to-Low

Figure 6-5. *Depending which input pin is used for the reference voltage, and which input carries a variable voltage, the comparator output either follows the variable voltage or inverts it.*

Placement of the plus and minus signs inside the comparator symbol may vary. Most often, the minus sign is above the plus sign, as shown in all the schematics here. Sometimes, however, for convenience in drawing a schematic, the plus sign may be shown above the minus sign. Regardless of their placement, the plus sign always identifies the noninverting input, and the minus sign always identifies the inverting input. To avoid misinterpretations, schematics should be inspected carefully.

Where a power supply for the comparator is shown, the positive side is always attached to the upper edge of the symbol, while 0V ground is always attached to the lower edge.

Differences from an Op-Amp

Saturation versus linearity

The output of a comparator is optimized for saturation (high or low, without intermediate levels, using positive feedback). The output of an op-amp is optimized for linearity (faithful reproduction of nuances in the input, using negative feedback).

Output mode

The majority of comparators have open-collector outputs (or open-drain outputs in CMOS devices) where the voltage is established by a pullup resistor. This can be adjusted for compatibility with other components, especially 5VDC logic. Only a minority have push-pull amplifier outputs that require no pullup resistor. By comparison, among op-amps, a push-pull output that functions as a voltage source is the traditional default.

Faster response

A comparator responds more quickly than an op-amp to changes in input voltage, if the op-amp is used in the role of a comparator. The comparator is primarily a switching device, not an amplifier.

Hysteresis

This is generally desirable in a comparator, for reasons already explained, and some components are designed with hysteresis built in. This feature is undesirable in an op-amp, as it degrades sensitivity.

Open-loop operation

(i.e., without feedback) this can be used with a comparator. An op-amp is intended for use in closed-loop circuits (i.e., with feedback), and manufacturers will not specify its performance in an open loop.

As previously noted, a comparator usually requires a single-voltage power supply, while an op-amp often requires a dual-voltage power supply.

Variants

Where a comparator uses a MOSFET output transistor, it may have an open-drain output, which requires a pullup resistor, as with an open-collector output.

Some comparators have a *push-pull* output, capable of supplying output current (usually a small amount). In these instances, no pullup resistor is necessary or desirable. The output voltage range will be closest to *rail-to-rail* values (i.e., the range of the power supply) where MOSFETs are used for the output, as MOSFETs impose a smaller voltage drop than bipolar transistors.

The advantage of an open collector (or open drain) relative to a push-pull output is that it allows the output voltage to be set independently of the power supply voltage. Another advantage is that multiple outputs can be connected in parallel, as in a *window comparator* circuit (described below).

Some comparators incorporate a reference voltage on the chip, based on the power supply to the chip. In this case, a separate reference voltage does not have to be supplied, and the component will draw less current.

Many chips are available containing two or more comparators. This is often expressed as the number of *channels* in the component. A *dual comparator* typically allows two different voltage sources for the outputs of the comparators. They will share the same 0V ground, however. Chips such as the LM139 and LM339 contain four comparators, and are available in through-hole or surface-mount formats. They have become a generic choice, costing less than $1 apiece.

An LM339 comparator chip is shown in Figure 6-6. This is a quad chip, meaning that it contains four comparators. They share a common power supply. The chip is TTL and CMOS compatible, is typically powered by 5VDC, but can be driven by up to 36VDC. The input differential voltage range also extends up to 36V.

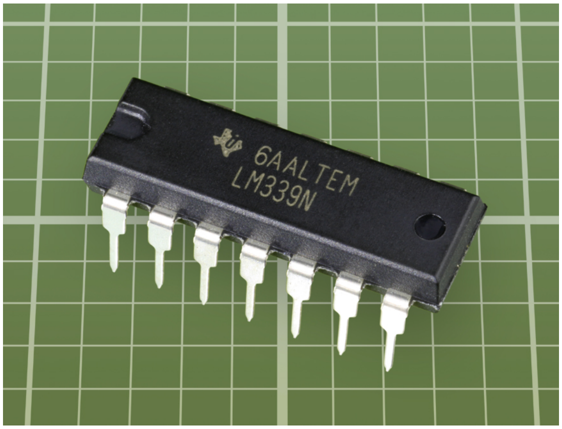

Figure 6-6. *The LM339 quad comparator chip, shown here, was introduced long ago but remains widely used.*

Some comparators have an internal *latch* function that is accessed by a dedicated pin. The latch-enable signal forces the comparator to assess its inputs and hold an appropriate output which can then be checked by other components.

Values

In a datasheet, V_{IO} (also referred to as V_{OS}) is the *input offset voltage*. This is a small voltage, in addition to the reference voltage, which the comparator will require to *toggle* its output in either direction, up or down. Figure 6-7 shows this graphically. V_{IO} sets the limit of *resolution* of the comparator, which will not respond unless the input voltage exceeds the reference voltage by this amount. A smaller value for V_{IO} is better than a larger value. Common values for V_{IO} range from 1mV to 15mV. The actual offset voltage tends to vary between one sample of a component and another. V_{IO} is the maximum allowed value for a component.

Because the comparator will not respond until the reference voltage is exceeded by V_{IO}, the output pulse width will be narrower than if the comparator reacted at the point where the variable voltage input was precisely the same as the reference voltage.

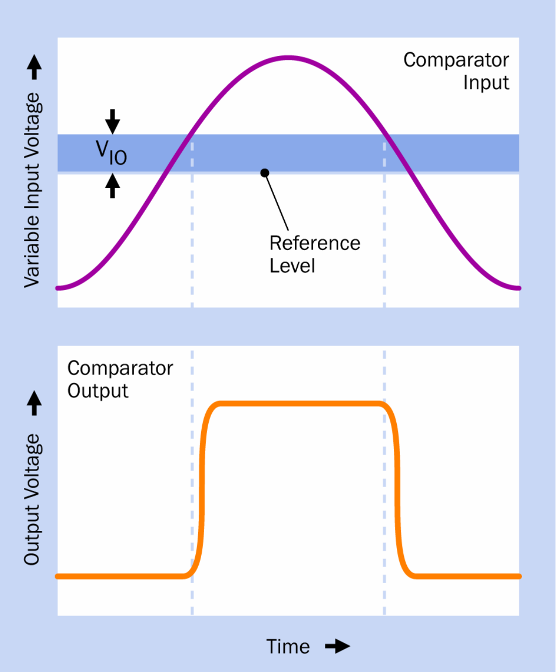

Figure 6-7. *The input offset voltage is the very small voltage that a comparator requires, additional to the reference input voltage, before it will toggle its output from low to high or high to low.*

V_{TRIP+} and V_{TRIP-} are the *rising* and *falling voltages*, respectively, that will trip the comparator output where the comparator exhibits some innate hysteresis without an external feedback loop. They are also referred to as *Lower State Transition Voltage* (LSTV) and *Upper State Transition Voltage* (USTV).

V_{HYST} is the *hysteresis range* defined as V_{TRIP+} minus V_{TRIP-}. The relationship is shown graphically in Figure 6-8.

A_{VD} is the *voltage gain* of a comparator, in which the letter "A" can be thought of as meaning "amplification." The gain is measured as a maximum ratio of output voltage to input voltage. Typically it ranges from 40 to 200.

Supply voltage for modern comparators is often low, as the components are used in surface-mount format for battery-powered devices where low power consumption is a primary concern. Thus, 3VDC is common as a power requirement, and 1.5VDC comparators are available. Still, older chips can use as much as 35VDC.

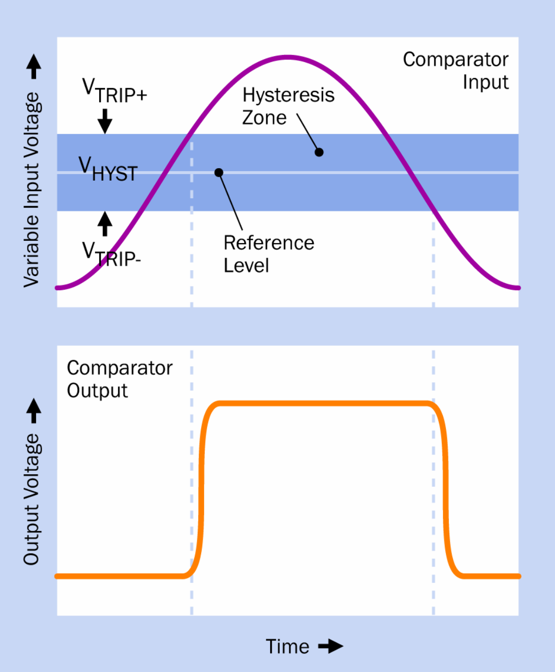

Figure 6-8. *The value of V_{TRIP} shows the hysteresis in a comparator—the range of input voltages, relative to the reference voltage, in which it will not respond.*

Supply current can range from 7mA down to below 1μA.

I_{SINK} is the recommended typical or maximum *sink current* that the component will tolerate, if it has an open-collector output. This value should be considered in relation to the power dissipation, P_D.

The *propagation delay* in a comparator is measured from the moment when an input (usually a square wave) reaches the triggering value, to the time when the consequent output reaches 50% of its final value.

When a comparator is driving CMOS logic using a 5VDC power supply, a typical value for a pullup resistor is 100K. It does not have to be lower, because CMOS has such a high input impedance.

How to Use It

In Figure 6-1, a hypothetical comparator responds immediately when the input voltage equals the reference voltage value. However, this is an idealized scenario. A magnified view, in Figure 6-9, suggests that the comparator is likely to respond with *jitter* when the input signal is very close to the reference voltage, because of tiny variations in heat, current, and other variables. This jitter will cause significant problems if the comparator is driving a device such as a relay, directly or indirectly.

Hysteresis eliminates this uncertainty around the transition level of the input, by telling the comparator to ignore small irregularities in the input voltage. Hysteresis is also useful in many situations where larger variations in a sensor input should be ignored. In Figure 6-2, for instance, suppose that the input voltage comes from a temperature sensor. The small bump in the right-hand section of the curve is probably unimportant; it could be caused by someone opening a door, or a person's body heat in brief proximity to the sensor. There's no point in responding to every little event of this type. In this application, the larger, longer-term temperature trend is what matters, and significant hysteresis is appropriate.

Also, if a comparator is being used as a thermostat, to switch a heating system on and off, we do not want the comparator to respond as soon as the temperature rises just a small amount. The heating system should run for a while before it elevates the temperature beyond the hysteresis zone.

The usual way to create hysteresis is with *positive feedback*. In Figure 6-10, a connection from the output of the comparator runs back through a 1M potentiometer to the variable (noninverting) input. The effect that this has is to reinforce the input voltage with the output voltage, as soon as the comparator input goes high. Now the input can diminish slightly without switching off the comparator. But if the input declines significantly, even the feedback from the output voltage won't be sufficient to maintain the variable input at a higher level than the reference voltage. (Remember, the "high" output voltage from the comparator is a fixed value; it does not change in proportion with the input voltage.) Consequently, the output toggles to low. Now the variable input is deprived of help from the comparator output, so it will be low enough that it has to rise considerably to toggle the comparator back on again. During that period, once again, small variations will be ignored.

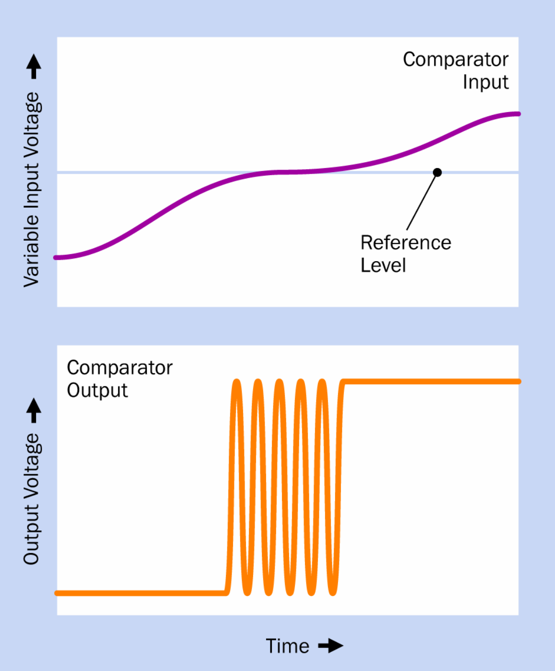

Figure 6-9. *In real-world applications, tiny variations where the variable input voltage crosses the reference voltage can induce jitter in the output from a comparator that has no hysteresis.*

In the schematic, a **phototransistor** (PT1, at left) is in series with a 3.3K resistor to adjust its voltage output to a suitable range. A 1M potentiometer at upper-left is wired as a voltage divider, so that it can establish a reference level that matches the light level that we wish to detect with the phototransistor.

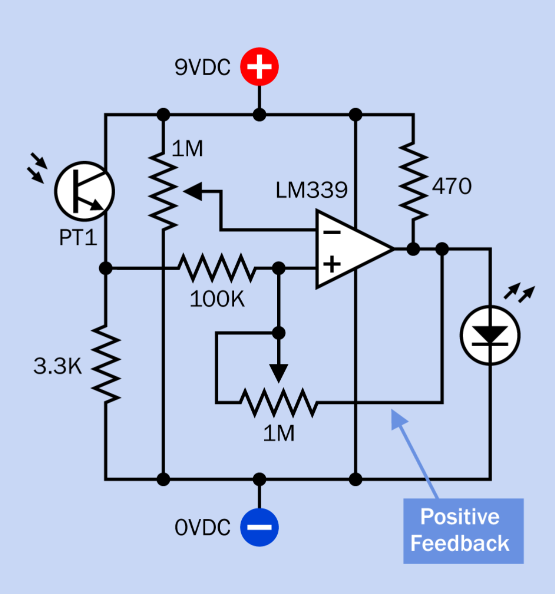

Figure 6-10. *A simple circuit to achieve hysteresis with positive feedback to the variable input of a comparator.*

The 470Ω resistor is the pullup resistor, which protects the LED from excessive current. The lower 1M resistor adjusts the amount of positive feedback, which determines the width of the hysteresis zone.

Values for components may have to be adjusted depending on the supply voltage, the variable input voltage, and other factors. But the principle will remain the same. Note that in the example shown, all the positive voltage sources are identical. In practice, different voltages could be used, so long as they share a common ground.

AND gate

A set of open-collector comparators can function jointly as an AND gate, when their outputs are tied together with one pullup resistor. So long as all the output transistors are nonconductive, the output will be high. If just one comparator toggles into conductive mode, the output will be low. See Figure 6-11.

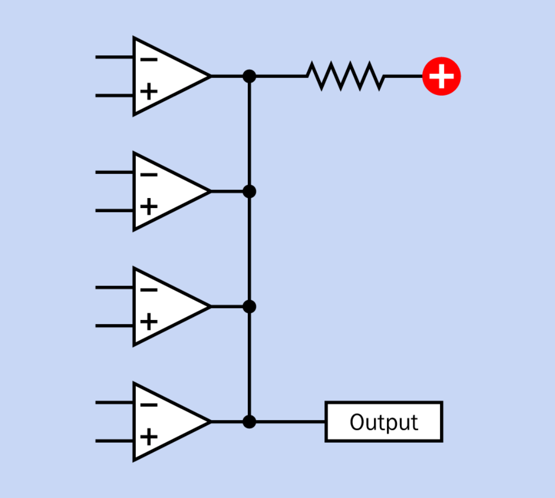

Figure 6-11. *If the outputs of multiple open-collector comparators are tied together with a suitable pullup resistor, they will function as an AND gate.*

Bistable Multivibrator

If positive feedback to the noninverting input of the comparator is sufficiently high, a voltage almost at 0V ground will be required to counter the high output from the comparator—after which, a voltage almost equal to the supply voltage will be needed to turn it back on. In other words, the comparator is behaving like a *bistable multivibrator*, or **flip-flop**.

Relaxation Oscillator

A *relaxation oscillator*, which is a form of *astable multivibrator,* can be created using direct positive feedback in combination with delayed negative feedback. In Figure 6-12, positive feedback goes to the noninverting input, as before, but negative feedback also passes through a 220K resistor to the inverting input of the comparator. A 0.47μF capacitor initially holds the inverting input low, while the capacitor charges. Gradually the capacitor reaches and exceeds the charge on the noninverting input, so the output from the comparator toggles to its low state. This means that its internal transistor is now sinking current, and it discharges the capacitor. Because the noninverting input is being held at a voltage midway between supply and ground by the two 100K resistors forming a voltage divider, eventually the voltage on the inverting input controlled by the capacitor falls below the noninverting voltage, so the cycle begins again.

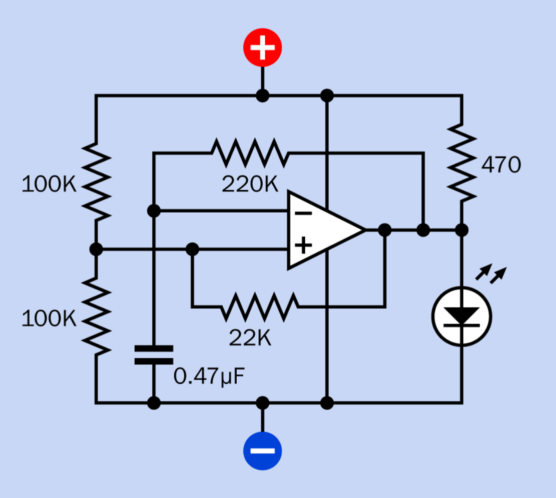

Figure 6-12. *A comparator can be used to create a relaxation oscillator.*

Level Shifter

Where a comparator is used simply to change the level of an input voltage, it can be referred to as a *level shifter*. An example of a level shifter is shown in Figure 6-13, in which a high/low 3VDC logic input is converted to a high/low logic output at 5VDC.

Window Comparator

A *window comparator* is a circuit (not a single component) that will respond to input voltages that deviate outside an acceptable "window" of values. In other words, the circuit responds anytime the variable input is either unacceptably low or unacceptably high.

An example could be an alarm that will sound if a temperature is either too low or too high. In Figure 6-14, two comparators are used to create a window comparator circuit, both sharing a variable voltage input from a sensor. A voltage divider is necessary to establish a higher voltage limit at the noninverting input of the upper comparator, while a separate voltage divider would establish a lower limit at the inverting input of the lower comparator. If an alarm has an appropriate resistance, it can be used instead of a pullup resistor. The alarm will sound when the output from either comparator is low, which happens if the inverting input has a higher voltage than the non-inverting input.

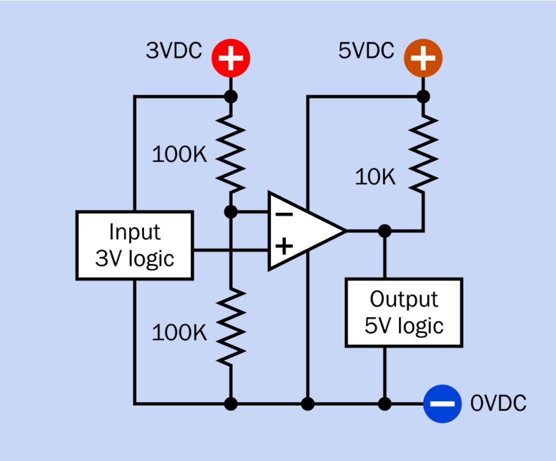

Figure 6-13. *A comparator can be used to convert high and low 3V logic inputs into high and low 5V logic outputs.*

Other Applications

As previously noted, a comparator can be used as a simple *analog-digital converter*. It has "one bit" accuracy (i.e., its output is either high or low).

A comparator can be used as a *zero point finder* when its variable voltage input is attached to an AC signal. The output from the comparator will be toggled whenever the AC signal passes through zero volts. The output will be a square wave (approximately) instead of a sine wave.

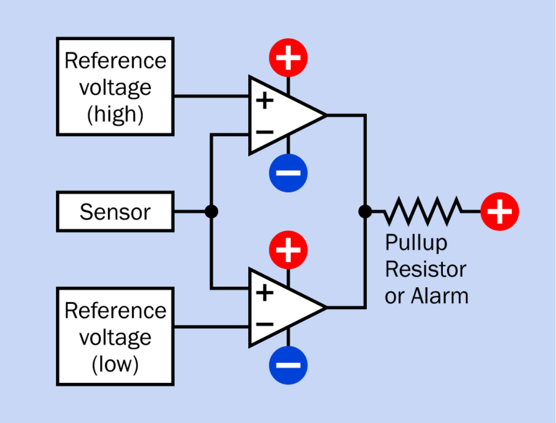

Figure 6-14. *A basic, simplified circuit for a window comparator. See text for details.*

A *continuous converter* changes its output promptly in response to a change in input. This requires continuous current consumption. Because many applications only need to check the output from a comparator at intervals, power can be saved by using a *clocked* or *latched* comparator.

What Can Go Wrong

Oscillating Output

The high input impedance of a comparator is vulnerable to stray electromagnetic fields. If the conductors leading to and from the comparator are relatively long, the output can couple capacitively with the input during voltage transitions, causing unwanted oscillations.

The commonly recommended solution to this problem is to add 1µF bypass capacitors to the power supply on either side of the comparator. However, some manufacturers recommend alternatives such as introducing just a small amount of hysteresis, or reducing the value of input resistors to below 10K.

If a chip contains multiple comparators, and one of them is unused, one of its input pins should be tied to the positive side of the voltage supply while the other should be tied to 0V ground, to eliminate the possibility of an oscillating output.

Confused Inputs

A comparator will function if its two inputs are swapped accidentally, but its high and low output states will be the inverse of what is expected. Also, if positive feedback is used, transposed inputs can create oscillations. Because the comparator symbol may appear in a schematic with the noninverting input either below or above the inverting input, the inputs are easily transposed by accident.

One way to remember which way the inputs should be connected is to use the mnemonic: "plus, high, positive." The *plus* input creates a *high* output when the input becomes *more positive* than the reference voltage on the other input. The opposite is less intuitively obvious: the *minus* input creates a *high* output when the input becomes *more negative* than the reference voltage on the other input.

Wrong Chip Type

Different comparators offer different outputs: open collector, open drain, and push-pull. While open collector and open drain function similarly, the pullup resistor value is likely to be different in each case. If a push-pull output is mistakenly connected as if it is open collector or open drain, it will not work correctly, if at all. Different types of comparators must be sorted and stored in clearly labeled bins.

Omitted Pullup Resistor

It is relatively easy to forget to include the pullup resistor on an open-collector output. In this case, when the transistor inside the comparator is in its nonconductive state, the output pin will be floating, with an indeterminate voltage that will create confusing or random results.

CMOS Issues

As usual when using CMOS chips, it is bad practice to allow unconnected, floating inputs. This is an issue where a chip contains multiple comparators, some of which are not being used. The solution recommended by some manufacturers is to tie one input of an unused comparator to the supply voltage, and the other input of the same comparator to ground.

Erratic Output

If positive feedback is insufficient, the comparator output may show signs of *jitter*. Conversely, if the positive feedback is excessive, the comparator may get stuck in an on state or an off state. Feedback must be chosen carefully.

Swapped Voltages

A comparator is often capable of controlling an output voltage that is much higher than that of its power supply. Because both voltages are applied to different pins on the same chip, mistakes can be made quite easily. The chip is likely to be damaged if the voltages are swapped accidentally between the relevant pins.

Heat-Dependent Hysteresis

Remember that the voltages at which the comparator turns on and off will vary slightly with the temperature of the component. This *drift* should be tested by running the comparator at higher temperatures.

op-amp

7

Although a comparator has the same schematic symbol as an **op-amp**, their applications differ and they are described in separate sections of this encyclopedia.

The unabbreviated name for an op-amp is an *operational amplifier*, but this term is seldom used.

OTHER RELATED COMPONENTS

- **comparator** (see Chapter 6)

What It Does

An op-amp is an *operational amplifier* consisting of multiple transistors packaged in an integrated circuit chip. It senses the fluctuating voltage difference between two inputs, uses power from an external supply to amplify that difference, and uses *negative feedback* to ensure that the output is an accurate replica of the input. Its amplification can be adjusted by changing the values of two external resistors.

Op-amps were developed originally using vacuum tubes, for use in analog computers, before the era of digital computing. Their implementation in integrated circuits dates from the late 1960s, when chips such as the LM741 were introduced (lower-noise versions of it still being widely used today). Multiple op-amps in a single package were introduced in the 1970s.

An LM741 is shown in Figure 7-1. Inside the 8-pin, DIP package is a single op-amp.

How It Works

In alternating current, voltages deviate above and below a zero value, which is sometimes referred to as the *neutral* value. This occurs in domestic power supplies and in audio signals, to name two very common examples. A *voltage amplifier* multiplies the positive and negative voltage excursions, using an external power source to achieve this. Most op-amps are voltage amplifiers.

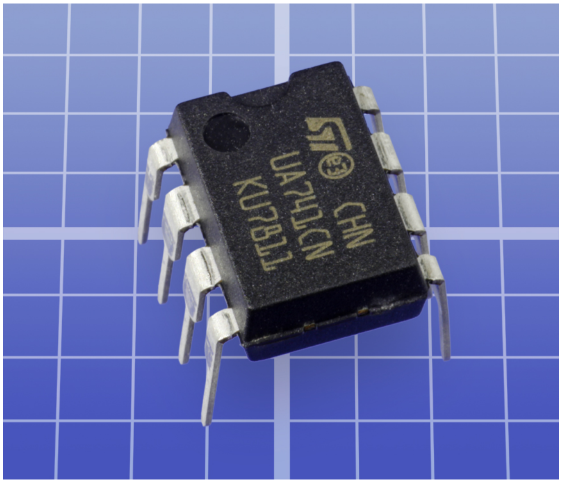

Figure 7-1. *The LM741, shown here, is still one of the most widely used op-amps.*

An ideal amplifier maintains a *linear relationship* between its input and its output, meaning that the output voltage values are a constant multiple of the input voltages over a wide range. This is illustrated in Figure 7-2, where the lower curve is a duplicate of the upper curve, the only difference being that its amplitude is multiplied by a fixed amount (usually much greater than shown here). The ratio is properly known as the *gain* of the amplifier, usually represented with letter A (for amplification).

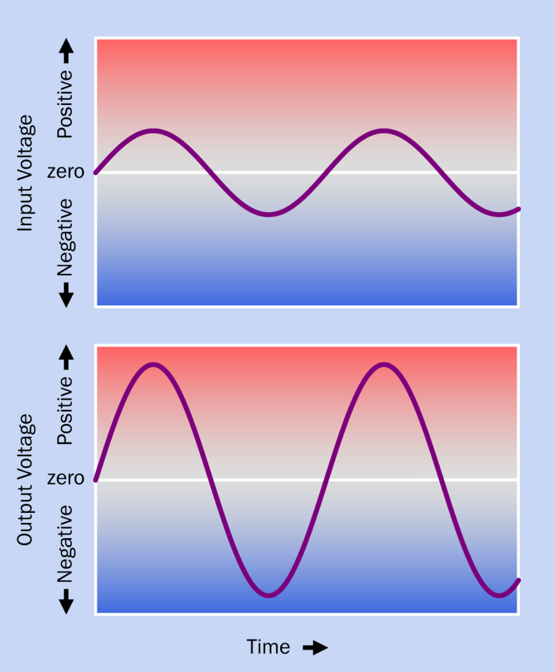

Figure 7-2. *In an ideal voltage amplifier, the output voltage will be a duplicate of the fluctuating input voltage, the only difference being that the amplitude of the output is multiplied by a fixed amount. This ratio is known as the gain of the amplifier.*

Figure 7-3 shows the triangular symbol for a generic single-input amplifier (not an op-amp). It may contain any number of components. The triangle almost always points from left to right, with its input on the left and its output on the right, and power attached above and below. This is often a *dual voltage* power supply, which is convenient for amplifying a signal that fluctuates above and below 0V. In some schematics, the power supply connections may not be shown, as they are assumed to exist.

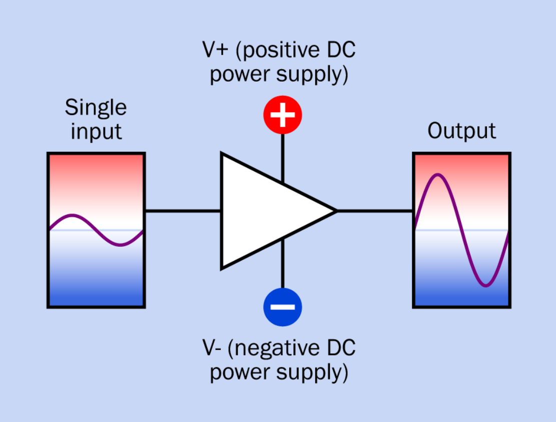

Figure 7-3. *The generic symbol for a single-input amplifier (not an op-amp), with the positive side of its power supply being equal and opposite in value to the negative side, and 0V being at the midpoint between them.*

- While the blue negative symbol is generally used throughout this encyclopedia to indicate 0V ground, it represents a voltage identified as V– in a dual voltage power supply, being equal in value but opposite in polarity to the positive side of the supply, V+. (Sometimes these voltages are indicated as V– and V+.)

The output from this imaginary generic amplifier is shown in the figure as a linear amplification of the input.

Dual Inputs

An op-amp has two inputs instead of one, and amplifies the voltage difference between them. Its symbol is shown in Figure 7-4. The upper input in this figure is held at 0V, midway between V+ and V–. Because the op-amp has so much gain, an accurate reproduction of its input would create an output exceeding the voltage of the power supply. Because this is not possible, the output tends to become saturated and consequently is *clipped* when it reaches its maximum value, as shown in the figure. The thumbnail graphs give only an approximate impression, as they are not drawn to the same scale.

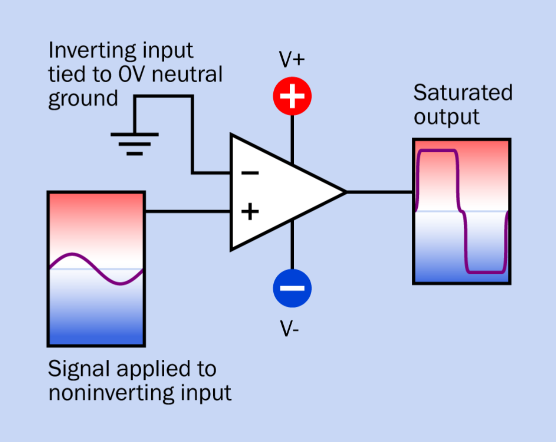
Inverting input tied to 0V neutral ground
V+
Saturated output
V-
Signal applied to noninverting input

Figure 7-4. *An op-amp has so much gain, its output will tend to saturate, producing a square wave regardless of the shape of the input.*

The small black plus and minus signs alongside the two inputs to the op-amp have nothing to do with the voltage supplied to the component. The "minus" input is properly referred to as the *inverting input* while the "plus" input is the *noninverting input*, in recognition of their functions.

The inputs are sometimes arranged with the minus above the plus, and sometimes with the plus above the minus. Schematics should be inspected carefully to note which arrangement is being used.

The positive and negative power connections to the op-amp may be omitted, but if shown, they always place V+ at the top, regardless of which way around the inputs are presented.

If a signal is applied to the noninverting input, while the inverting input is held at 0V ground, the op-amp provides an output in which the voltage is not inverted relative to the input.

If the input connections are swapped, so that the inverting input receives the incoming signal while the noninverting input is tied to 0V ground, the output from the op-amp is inverted (the gain remains the same). See Figure 7-5.

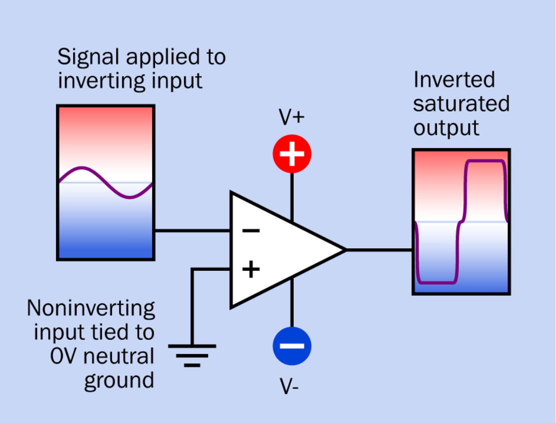
Signal applied to inverting input
V+
Inverted saturated output
Noninverting input tied to 0V neutral ground
V-

Figure 7-5. *When the incoming signal is applied to the inverting input of an op-amp while its noninverting input is held at 0V ground, the output is inverted.*

- An op-amp that is being used without any other components to moderate its output is functioning in *open loop* mode.

Negative Feedback

To create an output that is an accurate replica of the input, the op-amp must be brought under control with *negative feedback* to the input signal. This is illustrated in Figure 7-6. A resistor connects the output back to the inverting input, so that the input is automatically reduced to the point where the output is no longer saturated. The values of R1 and R2 will determine the gain of the op-amp, as explained in "How to Use It" on page 53. The op-amp is now functioning in its intended *closed loop* mode, meaning that the output is being tapped for feedback.

To obtain a linear output that is noninverted, connections are made as shown in Figure 7-7. The resistors form a voltage divider between the output and 0V ground, effectively increasing the comparison value on the inverting input.

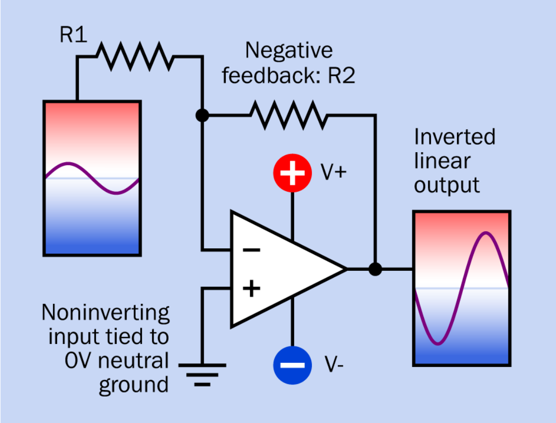

Figure 7-6. *A resistor applies negative feedback to the inverting input of an op-amp, and creates a linear output.*

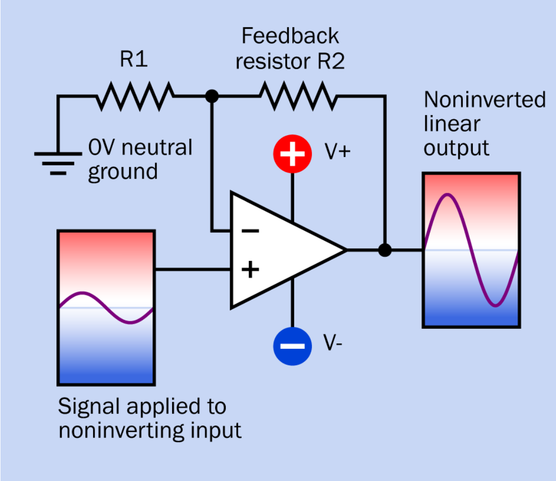
R1
Feedback resistor R2
Noninverted linear output
0V neutral ground
V+
V-
Signal applied to noninverting input

Figure 7-7. *Where the incoming signal is applied to the noninverting input, negative feedback is created by using a pair of resistors forming a voltage divider between the output and 0V ground.*

- Note that the gain of an op-amp is specific to a particular frequency range of AC signal. This is discussed in "How to Use It" on page 53.

Op-Amps and Comparators

A **comparator** can be regarded as a type of op-amp, and in fact an op-amp can be used as a comparator, comparing a variable DC voltage on one input with a reference voltage on another input. However, the two types of components have diverged in design to the point where they should be considered separately. The distinction is sufficiently important to have prompted Texas Instruments to issue an Application Report in 2001 titled "Op Amp and Comparators—Don't Confuse Them!".

Differences in function are summarized in the previous entry discussing comparators (see "Differences from an Op-Amp" on page 42).

Variants

Because op-amps are mostly low-current devices, they are widely available in very small surface-mount formats, in addition to the through-hole DIP packages which used to be more common.

Many chips are available containing two or more op-amps. This is often expressed as the number of *channels* in the component. A dual chip contains two op-amps, while a quad chip contains four op-amps. Usually all the op-amps in a chip share the same power supply. Bipolar or CMOS transistors may be used.

Because op-amps are widely available in dual and quad packages, it's quite common for a circuit designer to have one op-amp in a chip "left over." The designer may be tempted to use that spare unit as a comparator instead of installing an additional chip. To address this situation, some manufacturers offer hybrid op-amp chips containing an additional comparator. The Texas Instruments TLV2303 and TLV2304 are examples.

Values

The op-amps derived from 1970s designs often tolerate a wide range of power-supply voltages. Plus-or-minus 5VDC to plus-or-minus 15VDC is a common range. Modern op-amps are available that run from as little as 1VDC to as much as 1,000VDC.

Op-amps are available for frequencies ranging from 5KHz all the way up to 1GHz.

A “classic” op-amp such as the LM741, which is still widely used, will operate with a power supply ranging from plus-or-minus 5VDC to plus-or-minus 22VDC. Its output is rated for up to 25mA, and its input impedance is at least 2MΩ. The most current it will draw from an input is around 0.5μA.

V_{IO} is the *input offset voltage*. In an ideal component, the output from an op-amp should be 0V when its inputs have a voltage difference of 0V. In practice, the output will be 0V when the inputs differ by the offset voltage. V_{IO} is likely to be no greater than a couple of mV, and negative feedback can compensate for the offset.

V_{ICR} is the *common mode voltage range*. This is the range of input voltages that the op-amp will tolerate. This can never be more than the positive power supply voltage and will often be less, depending on the types of transistors that are used on the input side. If an input voltage goes outside the common mode voltage range, the op-amp will stop functioning.

V_{IDR} is the *input differential voltage range*—the maximum permissible difference between peak positive and peak negative input voltages. This is often expressed as plus-or-minus the power supply voltage, or slightly less. Exceeding the range can have destructive consequences.

I_B is the *input bias current*, averaged over the two inputs. Most op-amps have extremely high input impedance and consequently use very low input currents.

Slew rate at unity gain is the rate of change of the output voltage caused by an instantaneous change on the input side, when the output of the op-amp is connected directly back to the inverting input (during operation in noninverting mode).

How to Use It

In addition to being an amplifier for AC signals, an op-amp can serve as an oscillator, filter, signal conditioner, actuator driver, current source, and voltage source. Many applications require some understanding of the complexities of mathematics describing alternating current, which are not included this encyclopedia. Almost all the applications have a common starting point, however, which is to establish and control the gain of the feedback circuit.

Controlling the Gain

"A_{VOL} is the *open-loop voltage gain*, defined as the maximum voltage amplification that can be achieved when no feedback is applied from the output to an input. This remains constant until the AC frequency rises to a point known as the *breakover frequency*. If the frequency continues to rise, the maximum gain diminishes quite rapidly, until finally it terminates in 1:1 amplification at the *unity gain frequency*. This transition is shown by the orange line in Figure 7-8. The length of each purple line shows the frequencies which can be tolerated when the op-amp is used in closed-loop mode, and a negative feedback loop limits the gain. For example, where the gain is just 10:1, it can remain constant to just above 10KHz.

Note that both of the scales in this graph are logarithmic.

Calculating Amplification

So long as an op-amp is used within the boundaries of the graph, its voltage amplification can be controlled by choosing appropriate feedback and input resistors. If the op-amp is being used in noninverting mode, and R1 and R2 are placed as shown in Figure 7-7, the amplification ratio, A, is found approximately by the formula:

```
A = (approximately) 1 + (R2 / R1)
```

From this it can be seen that when R1 is very large compared with R2, the gain diminishes to near unity. If R1 becomes infinite and R2 is zero, the gain is exactly 1:1. This can be achieved by replacing R2 with a section of wire (theoretically of zero resistance) and omitting R1 entirely, as in Figure 7-9. In this configuration, the output from the op-amp should be identical with its input.

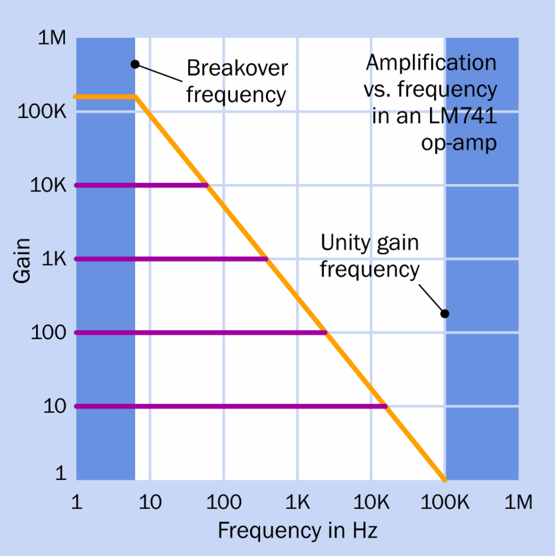

Figure 7-8. *Where each horizontal purple line meets the diagonal orange line, this is the maximum frequency that can be used without reduction in the maximum gain of an op-amp.*

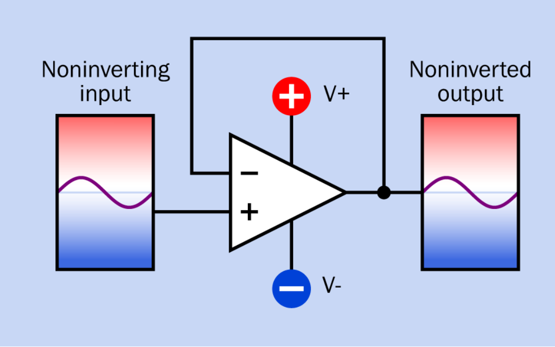

Figure 7-9. *While an op-amp is in noninverting mode, if the feedback resistor is replaced with a section of wire and the 0V ground connection is omitted entirely, the gain of the op-amp diminishes theoretically to 1:1.*

If the op-amp is being used in inverting mode, and R1 and R2 are placed as shown in Figure 7-6, then the voltage amplification ratio, A, is found approximately by the formula:

```
A = (approximately) −(R2 / R1)
```

- Note the minus sign. In inverting mode, gain is expressed as a negative number.
- In a practical circuit, at the expected frequency, the amplification factor established by choice of resistors should be no more than 20.
- An inverting circuit has a relatively low input impedance. For this reason, in most applications, a noninverting circuit is preferred.

Unintentional DC Voltage Amplification

Although the op-amp is intended primarily as an AC signal voltage amplifier, it will also amplify a DC difference between the voltages on its inputs. In the upper section of Figure 7-10, a positive DC offset is inverted and amplified to the point where the output is forced to its negative limit, and the signal is lost, because its fluctuations have been overwhelmed by the positive offset. A coupling capacitor (shown in the lower section of the figure) removes the DC voltage while passing the AC signal. The appropriate capacitor value will depend on the frequency of the signal.

Low-Pass Filter

An op-amp can facilitate a very simple low-pass audio filter, just by adding a capacitor to the basic inverting circuit previously shown in Figure 7-6. The filter schematic is shown in Figure 7-11. Capacitor C1 is chosen with a value that passes higher audio frequencies and blocks lower audio frequencies. Because the gain of the basic inverting circuit is approximately −(R2 / R1), the op-amp functions normally when the impedance of C1 is blocking the low frequencies, forcing them to pass through R2. Higher frequencies, however, are able to bypass R2 through C1, lowering the effective resistance of the feedback section of the circuit, thus reducing its gain. This way, the power of the op-amp is greatly reduced for higher frequencies compared with lower frequencies. A passive RC circuit could achieve the same effect, but would attenuate the signal, while the op-amp circuit boosts part of it.

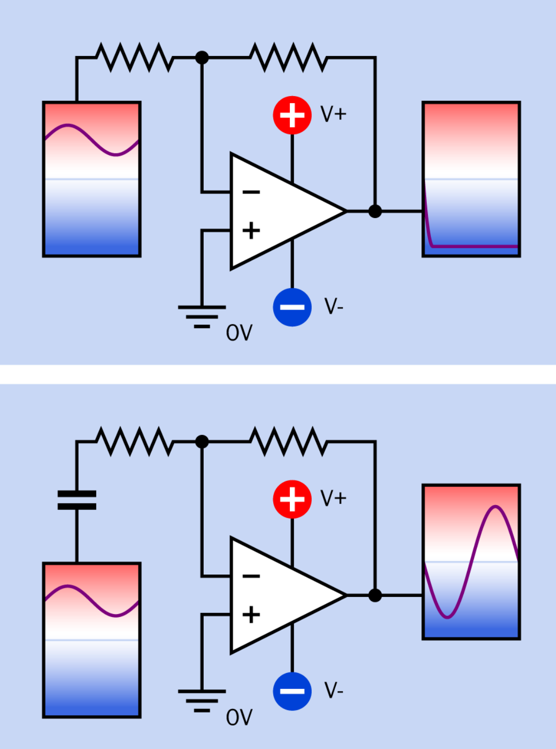

Figure 7-10. *The addition of a capacitor at the input of an op-amp is often necessary to prevent any DC voltage offset being amplified. In the upper section of this figure, a DC offset is large enough to force the inverted output to its negative limit, and the signal is completely lost.*

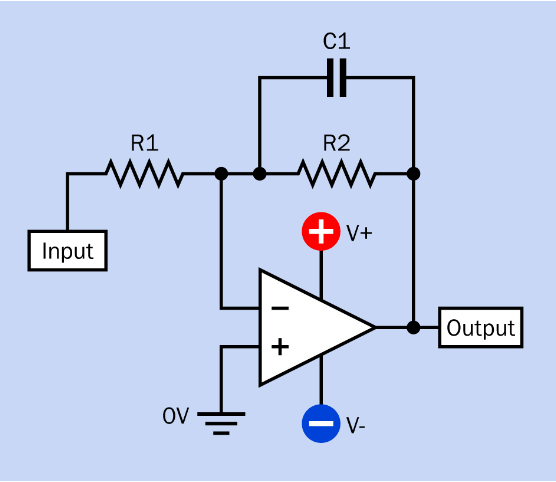

Figure 7-11. *A very basic low-pass filter, which works by allowing capacitor C1 to bypass resistor R2 at higher audio frequencies.*

High-Pass Filter

A simple high-pass filter can be created by adding a capacitor to the basic noninverting circuit previously shown in Figure 7-7. The filter schematic is shown in Figure 7-12. Once again capacitor C1 is chosen with a value that passes higher audio frequencies and blocks lower audio frequencies. Because the gain of the basic noninverting circuit is approximately 1 + (R2 / R1), the op-amp functions normally when the impedance of C1 is blocking the low frequencies, forcing them to pass through R1. Higher frequencies, however, are able to bypass R1 through C1, lowering the effective resistance of that section of the circuit, thus reducing the negative feedback and increasing the gain. This way, the power of the op-amp is increased for higher frequencies compared with lower frequencies. A passive RC circuit could achieve the same effect, but would attenuate the signal, while the op-amp circuit boosts part of it.

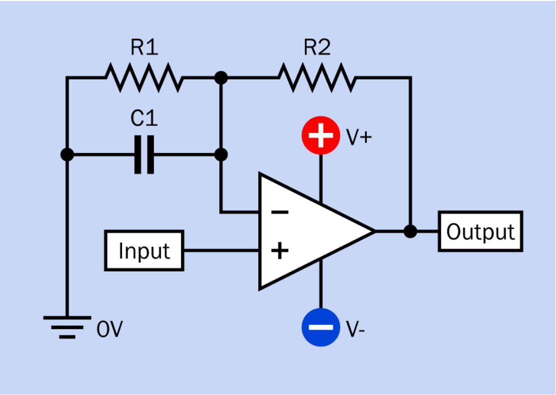

Figure 7-12. *A very basic high-pass filter, which works by allowing capacitor C1 to bypass resistor R1 at higher audio frequencies.*

Relaxation Oscillator

The schematic in Figure 7-13 is similar to the circuit shown in Figure 6-12 using a comparator. It functions as a *relaxation oscillator*, which is a form of *astable multivibrator*. The lower half of the circuit is a positive feedback loop that reinforces the output while the upper half of the circuit is charging the capacitor. Eventually the charge on the capacitor exceeds the voltage on the noninverting input of the op-amp, creating negative feedback that exceeds the positive feedback. The capacitor discharges and the cycle repeats. The component values in the figure should generate an output that runs at around 2Hz. Reducing the value of the capacitor will increase the frequency.

Single Power Source

A few op-amps are designed to work from single voltages, but they are a relatively small minority, and will clip the output signal if the input goes negative. Power supplies are readily available that provide multiple voltages such as +15VDC, 0V, and -15VDC. They are ideal for driving an op-amp—but may not be useful for any other components in the circuit. Can an op-amp that is designed for dual voltages be made to run from a single supply, such as 30VDC?

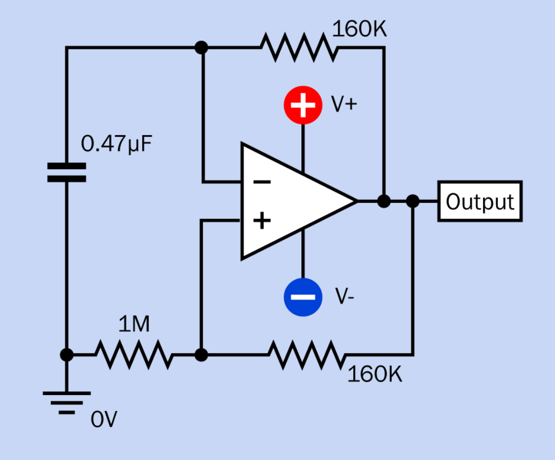

Figure 7-13. *A relaxation oscillator.*

This is relatively easy to do. The op-amp simply needs a potential difference to power its internal transistors, and 30VDC on the V+ pin with 0VDC on the V– pin will work just as well as +15VDC and -15VDC. However, referring back to Figure 7-6, if the op-amp is used in inverting mode, an intermediate voltage must be supplied to the noninverting input. Likewise, in noninverting mode, an intermediate voltage is necessary for one of the inputs, and must be half-way between the extremes of the power supply. If the supply is +15VDC and -15VDC, the midpoint is 0V. If the supply is 30VDC and 0V, the midpoint is 15VDC.

Because the inputs of an op-amp have a very high impedance and draw negligible current, the intermediate voltage can be provided with a simple voltage divider, as shown in Figure 7-14, where R3 and R4 should be no greater than 100K each. Their exact values are not important, so long as they are equal.

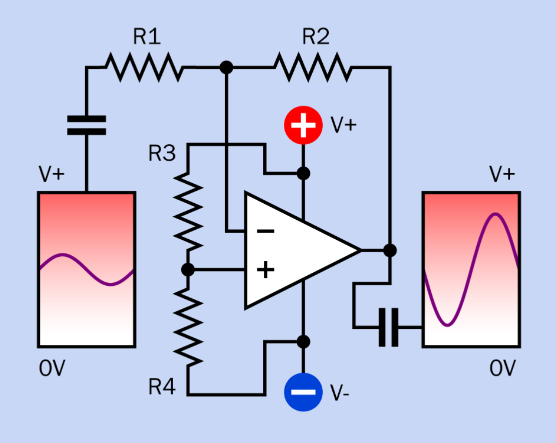

Figure 7-14. *A voltage divider, comprised of R3 and R4 in this schematic, can provide a voltage halfway between V+ and negative ground, enabling the op-amp to use just one power supply instead of two.*

A coupling capacitor should still be used on the input side, as shown, because there is no guarantee that the input signal will be centered precisely on 15V, and any offset will be amplified, potentially causing clipping of the signal. For similar reasons, a coupling capacitor is also added on the output side.

Offset Null Adjustment

Some op-amps provide two pins for *offset null adjustment*, which is a setup process to ensure that identical voltage on the two inputs will produce a null output. This is a way of compensating for any internal inconsistencies introduced during the manufacturing process.

To perform offset null adjustment, both input pins are connected directly to 0V ground, and the ends of a trimmer potentiometer (typically, 10K) are connected with the offset null pins, while the wiper of the potentiometer is centered and then connected with the negative power supply. The probes of a meter that is set to measure DC volts are placed between the output of the op-amp and 0V ground. The potentiometer is then adjusted until the meter shows a reading of 0VDC. A schematic is shown in Figure 7-15.

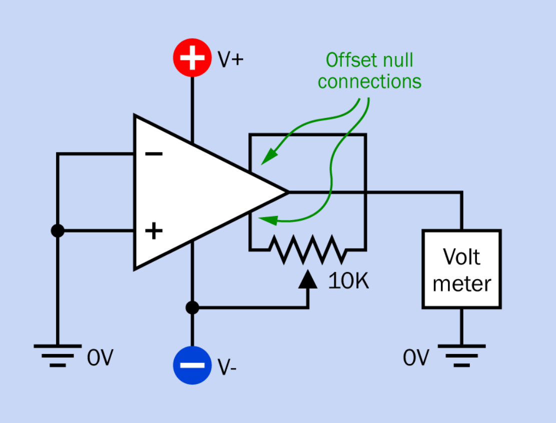

Figure 7-15. *Connections for making an offset null adjustment to an op-amp that allows this procedure.*

What Can Go Wrong

Power Supply Problems

Op-amps are especially vulnerable to reversed polarity in a power supply. If there is even a remote possibility of this occurring, a diode in series with one side of the supply can provide protection.

A more realistic concern is the destructive consequence of an input signal that exceeds the power supply voltage(s) of the op-amp. Even if the input is within the acceptable range, it can still cause permanent damage if it is applied before the op-amp powers up.

Bad Connection of Unused Sections

Multiple op-amps are often combined in a single package. If some of these "sections" remain unused, they will still receive power from the shared supply, and will attempt to function. If the inputs are left unconnected, they will pick up small stray voltages by capacitance or induction, and in the absence of negative feedback, the op-amp will create unpredictable outputs, consuming power and possibly interacting with other sections of the same chip. Figure 7-16 shows three incorrect options for addressing this problem, and one recommended option (derived from Texas Instruments Application Report SLOA067).

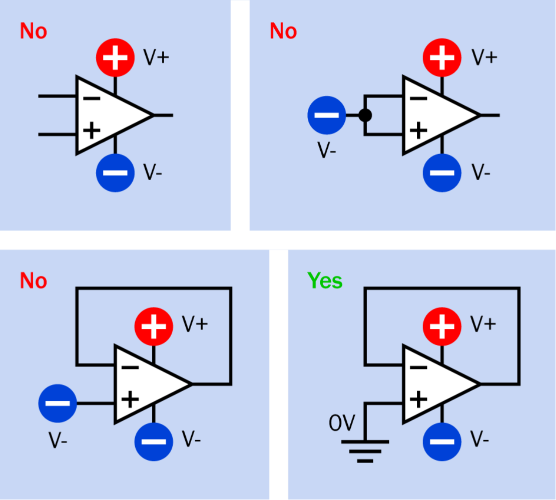

Figure 7-16. *When multiple op-amps share a chip, one that is unused will still receive power from the shared supply. Its inputs must not be allowed to float, and must be connected to minimize activity and power consumption. Three common errors are shown here, with one recommended option. Note the distinction between 0V ground (0V) and negative power (V−).*

Oscillating Output

The inputs of an op-amp are vulnerable to stray electromagnetic fields. If the conductors leading to and from the op-amp are relatively long, the output can couple capacitively with the input during voltage transitions, causing unwanted oscillations.

The commonly recommended solution to this problem is to add a 1µF bypass capacitor between the power supply and 0V ground. However, some manufacturers recommend alternatives such as introducing a very small amount of hysteresis, or reducing the value of input resistors to below 10K.

Confused Inputs

A schematic may show an op-amp with the noninverting input above the inverting input, or vice versa. The only indication of this will be the plus and minus signs inside the chip, which can be extremely small and easily overlooked. For convenience in drawing a diagram, two op-amps in the same circuit may have their inputs shown in opposite configurations. Special care must be taken to verify that the inverting and noninverting input pins on a chip are correctly assigned.

digital potentiometer

8

A **digital potentiometer** is also known as a *digitally adjustable potentiometer*, a *digitally controlled potentiometer*, a *digitally programmed potentiometer* (with acronym *DPP*), a *digpot*, or a *digipot*. The terms are functionally interchangeable. Because the abbreviation *pot* is often used to describe an analog potentiometer, some people refer to digital potentiometers colloquially as *digital pots*. In printed documentation, the letters in *pot* may be capitalized. Because it is an abbreviation, not an acronym, it is not capitalized here.

Because this component enables digital control of a variable voltage, it is a *mixed signal device*. It is classified here as an analog chip because it primarily emulates the function of an analog device. It may be thought of as a form of *digital-analog converter*, although this encyclopedia does not have a section devoted to that type of component or to *analog-digital converters*, as their application is relatively specialized.

OTHER RELATED COMPONENTS

- **potentiometer** (see Volume 1)

What It Does

This component is an integrated circuit chip that emulates the function of an analog **potentiometer**. It is often described as being *programmable*, meaning that its internal resistance can be changed via a control input.

Digital potentiometers are particularly suited for use in conjunction with a *microcontroller*, which can control the internal resistance of the component. Possible applications include adjustment of the pulse width of an oscillator or multistable multivibrator (e.g., using the Control pin of a 555 **timer** chip); adjustment of the gain in an **op-amp**; specification of voltage delivered by a *voltage regulator*; and adjustment of a *bandpass filter*.

A digital potentiometer in combination with a microcontroller may also be used in conjunction with a pair of external buttons or a rotational encoder, to adjust the gain of an audio amplifier and for similar applications.

Advantages

A digital potentiometer offers significant advantages over an analog potentiometer:

- Reliability. The digital component may be rated for as many as a million cycles (each storing the wiper position in an internal memory location). An analog component may be capable of just a few thousand adjustment cycles.
- Digital interface.
- Elimination of long signal paths or cable runs. The digital potentiometer can be placed close to other chips, whereas an analog potentiometer often has to be some distance away to enable control by the end user. Reduction in the length of signal paths can reduce capacitive effects, while elimina-

tion of cable runs will reduce manufacturing costs.

- Reduction in size and weight compared with a manual potentiometer.

A digital potentiometer also has some disadvantages:

- Its internal resistance is somewhat affected by temperature.
- It is not usually capable of passing significant current. Few chips can sink or source more than 20mA at the output, and 1mA is common. The output is primarily intended for connection with other solid-state components that have high impedance.
- Users may prefer the immediacy and tactile feel of a knob attached to an analog potentiometer, rather than a pair of buttons or a rotational encoder.

How It Works

A digital potentiometer changes the point at which a connection is made along a *ladder* of many fixed resistors connected in series inside the chip. Each end of the ladder, and each intersection between two adjacent resistors, is known as a *tap*. The pin that can connect with any of the taps is referred to as the *wiper*, because it emulates the function of a wiper in an analog potentiometer. In reality, a digital potentiometer does not contain a wiper or any other moving parts.

A fully featured digital potentiometer allows access to each end of the ladder through two pins that are often labeled “high” and “low,” even though they are functionally interchangeable (except in the case of a component that simulates a logarithmic taper, as described later). The “low” end of the ladder is sometimes numbered 0. In this case, if there are *n* resistors, the “high” end of the ladder will be numbered *n*. Alternatively, if the “low” end of the ladder is numbered 1, and there are *n* resistors, the “high” end will be numbered *n+1*. This principle is illustrated in Figure 8-1.

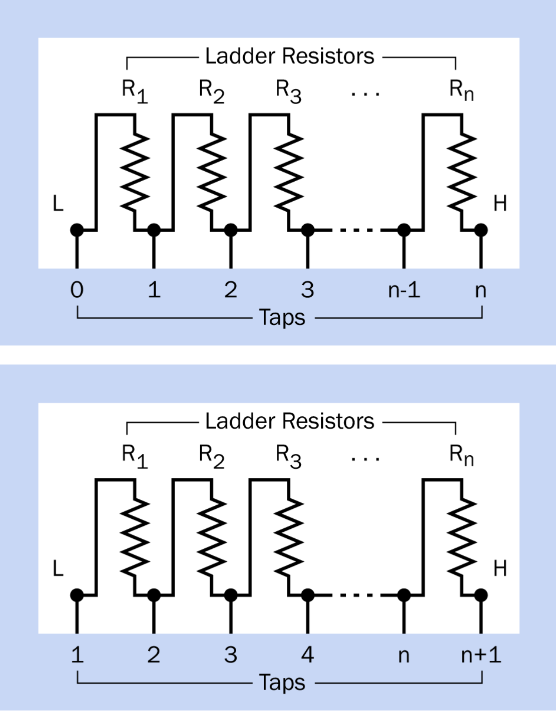

Figure 8-1. *Available wiper connections to a resistor ladder inside a digital potentiometer, showing two numbering systems that may be used.*

The “low” pin on a digital potentiometer may be identified as L, or A, or R_L, or P_A in a datasheet, while the “high” pin may be identified as H, or B, or R_H, or P_B and the pin that accesses the wiper is typically identified as W, or R_W, or P_W. Letters L, H, and W are used below. Although the L and H pins are functionally interchangeable, their labels are useful to identify which direction the W connection will move in response to an external signal.

Digital potentiometers are available with as few as 4 or as many as 1,024 taps, but common values are 32, 64, 128, or 256 taps, with 256 being the most common.

No specific schematic symbol represents a digital potentiometer. Often the component is shown as an analog potentiometer symbol inside a box that has a part number, as suggested in

Figure 8-2. Control pins and the power supply may be omitted if the schematic is just intended to show logical connections. Alternatively, if the digital potentiometer is depicted in a schematic where it is connected with other components such as a microcontroller, multiple pins and functions may be included, as shown in Figure 8-3. The pins additional to L, H, and W are explained below.

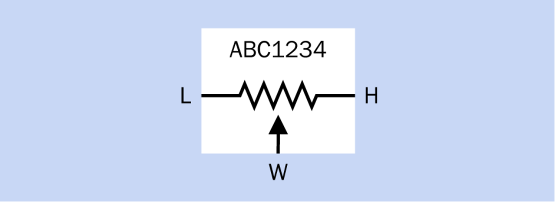

Figure 8-2. *There is no single specific symbol to represent a digital potentiometer. It may be shown using an analog potentiometer symbol in a box with a part number, as suggested here, where power connections and additional pins are omitted for clarity.*

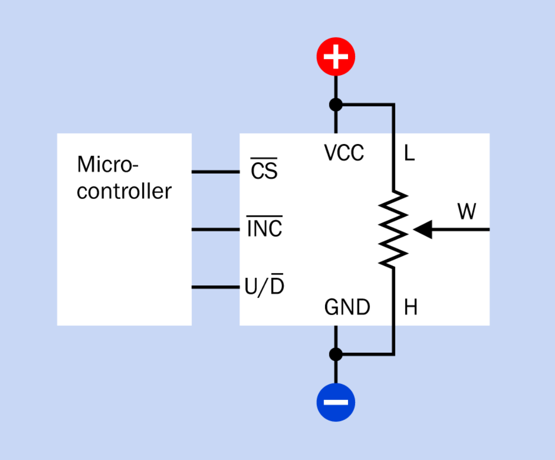

Figure 8-3. *If a digital potentiometer appears in a schematic where it is connected with other components such as a microcontroller, additional pins and functions may be indicated. This generic representation of a digital potentiometer shows some of the functions that can be included.*

Variants

A *dual* digital potentiometer contains two complete units, while a *quad* contains four. Triples exist but are relatively uncommon. A few chips contain six potentiometers. Multiple digital potentiometers in a chip can be used as the digital equivalent of *ganged* analog potentiometers, for simultaneous synchronized adjustment of multiple inputs in an audio system (two channels in a stereo amplifier, or more in a surround-sound system).

The pinouts of a sophisticated quad digital potentiometer chip are shown in Figure 8-4. Other quad chips have different pinouts and capabilities; there is no standardized format as there is with digital logic chips. In this example, the high/low states of Address 0 and Address 1 select one of the four internal resistor ladders, numbered 0 through 3. The Chip Select pin makes the whole chip either active or inactive. The Write Protect pin disables writing to the internal wiper memory. The Serial Clock pin inputs a reference pulse stream to which the serial input data must be synchronized. The Hold pin pauses the chip while data is being transmitted, allowing the data transmission to be resumed subsequently. The NC pins have no connection.

Volatile and Nonvolatile Memory

Any type of digital potentiometer requires memory to store its current wiper position, and this memory may be volatile or nonvolatile. Nonvolatile memory may be indicated in a datasheet by the term *NV*.

A digital potentiometer with volatile memory will typically reset its wiper to a center-tap position if power is disconnected and then restored. A digital potentiometer with nonvolatile memory will usually restore the most recently used wiper position, provided the chip is fully powered down and then fully powered up without glitches in the supply. If a microcontroller is being used to control the digital potentiometer, it can store the most recent resistance value in its own nonvolatile memory, in which case the type of memory in the potentiometer becomes irrelevant.

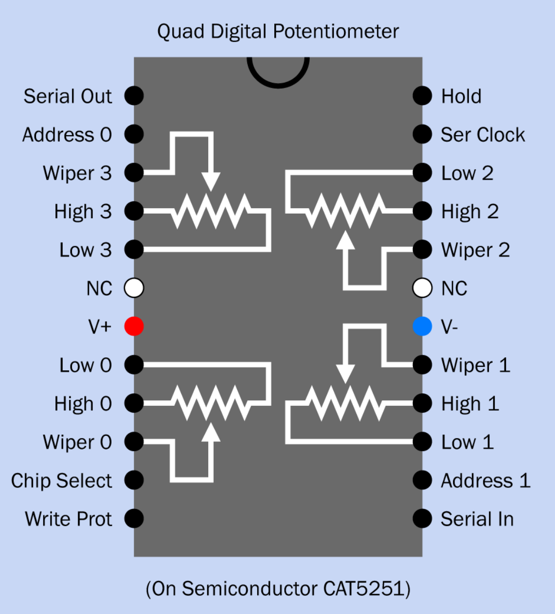

Figure 8-4. *Pinouts of a sophisticated quad digital potentiometer chip. Other chips will have different pinouts and capabilities. This example is available in surface-mount formats only. See text for details.*

Taper

Digital potentiometers are available with *linear taper* or *logarithmic taper*. In the former, each resistor in the ladder has the same value. In the latter, values are chosen so that the cumulative resistance between the wiper and the L end of the ladder increases geometrically as the wiper steps toward the H end of the ladder. This is useful in audio applications where sound intensity that increases exponentially may seem to increase linearly when perceived by the human ear.

A microcontroller can emulate logarithmic steps by skipping some taps in the ladder in a digital potentiometer, but this will result in fewer increments and lower precision.

Data Transfer

Digital potentiometers are mostly designed to use one of three serial protocols:

- *SPI*. This acronym is derived from *serial peripheral interface*, a term trademarked by Motorola but now used generically. The standard is adapted in various radically different ways among digital potentiometers.
- *I2C*. More correctly printed as *I^2C* and properly pronounced "I squared C," this acronym is derived from the term *inter-integrated circuit*. Developed by Philips in the 1990s, it is a relatively slow-speed bus-communication protocol (up to 400kbps or 1Mbps in its basic form). It is built into some microcontrollers. The standard is more uniformly and rigorously defined than SPI.
- *Up/down*, also sometimes known as *pushbutton* or *increment/decrement* protocol.

Both SPI and I2C are supported by many microcontrollers, including the Atmel AVR at the heart of the Arduino.

These three systems for controlling a digital potentiometer are described in more detail in the following sections.

SPI

This is the most widely used protocol, but when reading datasheets, a lot of care must be taken to determine how it varies in each case.

The Microchip 4131-503, shown in Figure 8-5, uses SPI protocol. It contains 128 resistors and can be powered by 1.8VDC to 5.5VDC.

The one feature that all versions of SPI have in common is that a series of high/low pulses is interpreted by the chip as a set of bits whose value defines a tap point in the resistor ladder. In computer terminology, every tap point has an *address*. The incoming bits define the address, after which the status of an additional input pin can tell the chip to move the wiper to that location.

Typically, there will be a chip select pin, identified as CS; a serial data input pin, identified as SDA, SI, DIN, or a similar acronym; and a serial clock pin, identified as SCL, SCLK, or SCK, which must receive a stream of pulses to which the high/low data input pulses must be synchronized. In addition, the SPI protocol allows bidirectional (duplex) serial communication. Only a minority of digital potentiometers make use of this capability, but where it exists, a serial data output pin may be labeled SDO. Alternatively, one pin may be multiplexed to enable both input and output, in which case it may be labeled SDI/SDO.

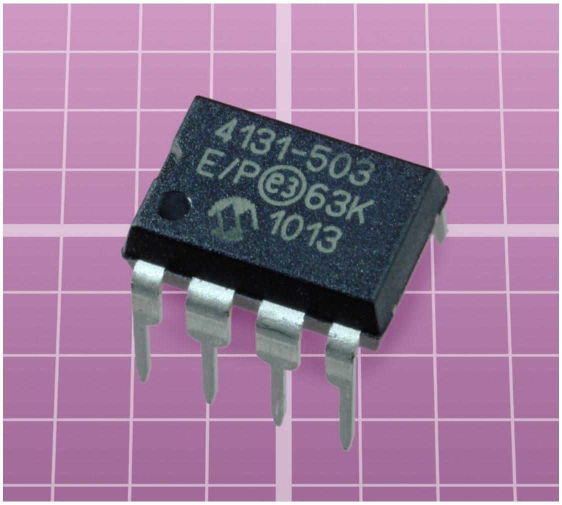

Figure 8-5. *This digital potentiometer uses SPI protocol. See text for details.*

If a pin is active-low, a bar (a horizontal line) will be printed above its acronym.

The most common type of digital potentiometer has 255 resistors and therefore 256 tap points, which have addresses numbered 0 through 255, each of which can be specified by a sequence of eight data bits constituting one byte. However, a different coding system will be applied in chips that have a different number of taps. In a 32-tap component, for instance, data is still sent in groups of eight bits, but only the first five bits define a *tap address*, while the remaining three are interpreted as commands to the chip.

Most 256-tap chips use an SPI protocol in which two eight-bit bytes are sent, the first being interpreted by the chip as a command, while the second specifies a tap address. Each manufacturer may use a different set of command codes, and these will vary among chips even from the same manufacturer.

Most commonly, three wires are used for data transmission and control (causing these chips to be described as *3-wire* programmable potentiometers).

CS is usually, but not always, pulled low to activate the digital potentiometer for input. A series of low or high states is then applied to the data-input pin. Each time the clock input changes state (usually on the rising edge of the clock pulse) the state of the data input is copied to a **shift register** inside the chip. After all the bits have been clocked in, CS can change from low to high, causing the contents of the shift register to be copied into a decoder section of the chip. The first bit received becomes the most significant bit in the decoder. The value of the eight bits is decoded, and the chip connects the W pin directly to the corresponding tap along the ladder of 255 internal resistors.

I2C Protocol

The I2C specification is controlled by NXP Semiconductors (formerly Philips), but can be used in commercial products without paying licensing fees. Only two transmission lines are required: one carrying a clock signal, the other allowing bidirectional data transfer synchronized with the clock (although many digital potentiometers use the I2C connection only to receive data). The pins are likely to be identified by the same acronyms as the pins on a chip that uses SPI protocol.

As in SPI, a command byte is followed by a data byte, although the command set differs from that of SPI and will also differ among various I2C chips. Full implementation of I2C allows multiple devices to share a single bus, but this capability may remain unused.

Up/Down Protocol

This simpler, asynchronous protocol does not require a clock input. The chip will respond to data pulses that are received at any speed (up to its maximum speed), and the pulse widths can be inconsistent.

Each pulse moves the wiper connection one step up or down the ladder. While this has the advantage of simplicity, the taps are not addressable, and consequently the wiper cannot skip to any tap without passing through intervening taps incrementally. This is not an inconvenience when the potentiometer controls audio gain, which is a primary application.

In some chips, an increment pin, usually labeled INC, receives pulses while the high or low state of a second pin, usually labeled U/D, determines whether each pulse will step the wiper up the ladder or down the ladder.

In other chips, pulses to an Up pin will step the wiper up the ladder, while pulses to a Down pin will step the wiper down the ladder.

Either of these chip designs can be referred to as a *two-wire* type. If an additional chip-select pin is included (labeled CS on datasheets), this type of digital potentiometer can be referred to as a *three-wire* type. The chip select pin is likely to be active-low, meaning that so long as it has a high state, the chip will ignore incoming signals.

The CAT5114 shown in Figure 8-6 uses an U/D pin. It contains 31 resistors, is available in 8-pin DIP or surface-mount formats, and can be powered by 2.5VDC to 6VDC. Each of its logic inputs draws only 10μA.

In six-pin chips the INC pin is omitted, one of the H, L, or W pins will be omitted, and the U/D pin will function differently. When CS is pulled low, the chip checks the state of the U/D pin. If it is high, the chip goes into increment mode; if it is low, the chip goes into decrement mode. So long as CS remains low, each transition of the U/D pin from low to high will either increment or decrement the wiper position, depending on the mode that was sensed initially. When CS goes high, further transitions on the U/D pin will be ignored until CS goes low again, at which point the procedure repeats.

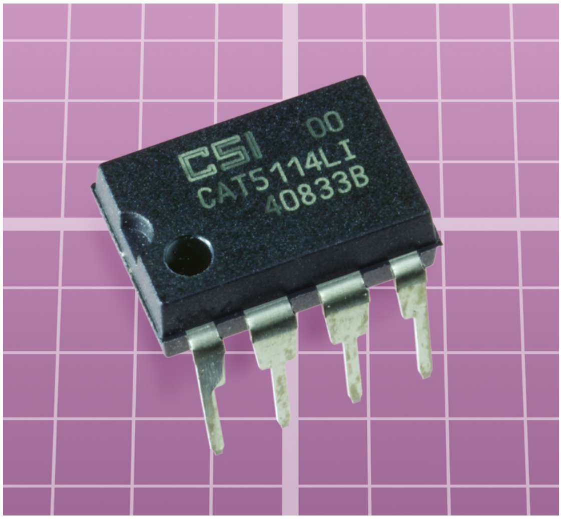

Figure 8-6. *This digital potentiometer contains 31 resistors and uses the simplest up/down protocol to step from one tap to the next.*

The chip does not provide any feedback regarding the position of its wiper, and consequently a control device such as a microcontroller cannot know the current wiper position. If the chip has nonvolatile memory (as is the case in many up/down digital potentiometers), it will resume its previous wiper location at power-up, but here again a control device will have difficulty determining what that position is. Therefore, in its basic form, an up/down chip is only appropriate for simple tasks, especially in response to up/down pushbuttons.

Other Control Systems

A few digital potentiometers use a parallel interface. Because they are relatively uncommon, they are not included here.

Connections and Modes

Some variants of digital potentiometers minimize the chip size and number of connections by limiting accessibility to the internal resistor ladder. In a chip designed to function in *rheostat mode*, the W pin is eliminated and the chip moves an internal connection point to change the resistance between the H and L pins.

In some variants, the low end of the ladder is permanently, internally connected with ground, and the L pin is omitted. In other variants, one end of the ladder is unconnected inside the chip.

A chip designed to function in *voltage divider mode* will include all three pins—H, L, and W—except in some instances where the low end of the ladder is grounded internally.

Variants are shown in Figures 8-7, 8-8, 8-9, and 8-10. Because some pins may be omitted, and there is no standardization of function among the pins that do exist, circuits and chips must be examined carefully prior to use.

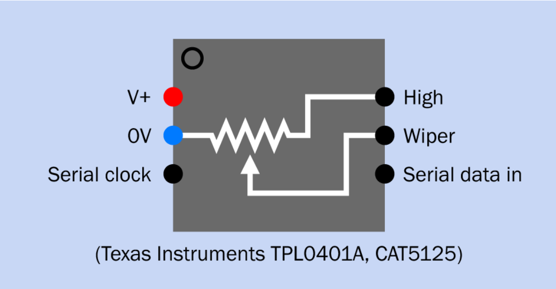
V+
0V
Serial clock
High
Wiper
Serial data in
(Texas Instruments TPL0401A, CAT5125)

Figure 8-7. *Some digital potentiometers minimize chip size and provide specialized functionality by eliminating pins. In the variant shown here, the W pin provides a voltage between H and an internal ground connection. The chip is controlled via I2C serial protocol.*

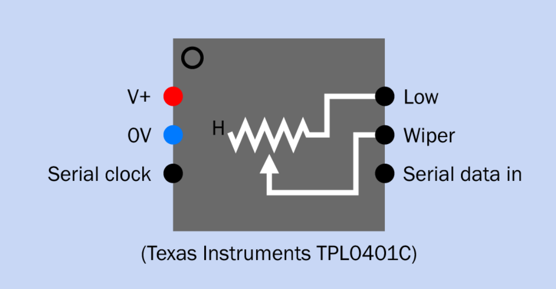
V+
0V
Serial clock
H
Low
Wiper
Serial data in
(Texas Instruments TPL0401C)

Figure 8-8. *In this variant, the H end of the internal resistor ladder is allowed to float inside the chip, and the digital potentiometer functions as a rheostat. The chip is controlled via I2C serial protocol.*

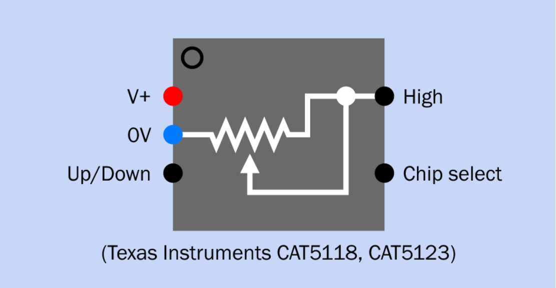
V+
0V
Up/Down
High
Chip select
(Texas Instruments CAT5118, CAT5123)

Figure 8-9. *This variant provides a variable resistance between the H pin and an internal connection with negative ground. Pin 5 is omitted. The chip is controlled by up/down pulses.*

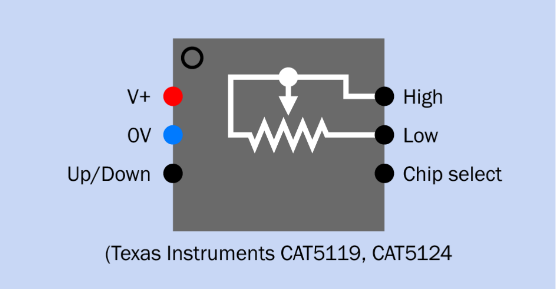
V+
0V
Up/Down
High
Low
Chip select
(Texas Instruments CAT5119, CAT5124

Figure 8-10. *This variant provides a variable resistance between H and L pins, without allowing either end of the resistor ladder to float. The W pin is omitted, as the wiper is tied internally to the H pin. The chips listed are controlled by up/down pulses.*

Values

A primary limitation of digital potentiometers is that they cannot withstand significant current. This may prevent them from being substituted for an analog potentiometer unless changes are made in the circuit. H, L, and W pins are usually unable to source or sink continuous, sustained current exceeding 20mA.

Wiper resistance is the resistance that is added internally by the wiper. This is nontrivial; it is often around 100Ω, and can be as high as 200Ω.

Typical end-to-end resistance of the ladder of internal resistors may range from 1K to 100K. Values of 1K, 10K, and 100K are common.

While the number of taps is likely to be a power of two in chips where the taps are addressable, up/down chips are not so constrained and may contain, for example, 100 taps.

The end-to-end resistance of a whole ladder may vary by as much as 20% from one sample of a chip to the next. Among resistor ladders in digital potentiometers sharing the same chip (i.e., in dual or quad chips) the variation will be much smaller.

Almost all digital potentiometers are designed for a supply voltage of 5V or less. The H and L pins are not sensitive to polarity, but the voltage applied to either of them must not exceed the supply voltage.

How to Use It

While most microcontrollers contain one or more analog-digital converters that change an analog *input* to an internal numeric value, a microcontroller cannot create an analog *output*. A digital potentiometer adds this functionality, although applications will be restricted by its limitation on current.

An up/down digital potentiometer can be controlled directly by a pair of **pushbuttons**, one of which will increase the resistance value while the other will reduce it. The pushbuttons must be *debounced* when used in this way. An alternative to pushbuttons is a **rotational encoder**, which emits a stream of pulses when its shaft is turned. In this case, an intermediate component (probably a microcontroller) will usually interpret the pulse stream and change it to a format that the digital potentiometer can understand.

Where a digital potentiometer is used in audio applications, it should be of the type that moves the wiper connection from one tap to another during a *zero crossing* of the audio signal (i.e., that is, at the moment when the AC input signal passes through 0V on its way from positive to negative or negative to positive). This suppresses the "click" that otherwise tends to occur during switching. Potentiometers with this feature may include phrases such as "glitch free" in their datasheets.

Digital potentiometers that are intended primarily for audio applications often have 32 taps spaced at intervals of 2dB. This will be sufficient to satisfy most listeners.

Achieving Higher Resolution

For sensitive applications where a resolution with more than 1,024 steps is required, multiple digital potentiometers with different step values can be combined. One way of doing this is shown in Figure 8-11. In this circuit, the wipers of P2 and P3 must be moved in identical steps, so that the total resistance between the positive power supply and negative ground remains constant. These two potentiometers could be contained in a dual chip, and would receive identical up/down commands. P1 is at the center of the voltage divider formed by P2 and P3, and is adjusted separately to "fine tune" the output voltage that is sensed at point A.

If all three of the potentiometers in this circuit contain 100 taps, a combined total of 10,000 resistance steps will be possible.

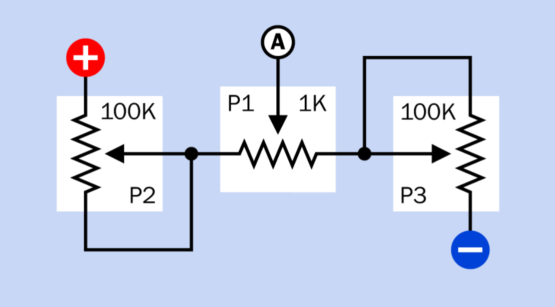

Figure 8-11. *If all three digital potentiometers in this schematic have 100 taps, and the wipers of P2 and P3 are moved in synchronization, the voltage measured at point A can have a high resolution of up to 10,000 steps.*

What Can Go Wrong

Noise and Bad Inputs

Because a digital potentiometer is capable of receiving data at speeds as high as 1MHz, it is sensitive to brief input or power fluctuations, and can misinterpret them as instructions to move the wiper—or can misinterpret them as command codes, in a component using SPI or I2C serial protocol.

To minimize noise in the power supply, some manufacturers recommend installing a 0.1µF capacitor as close as possible to the power supply pin of the component. In addition, it is obviously important to provide clean input signals. This means thorough debouncing of any electromechanical switch or pushbutton inputs.

Wrong Chip

The wide diversity of input protocols and pinouts creates many opportunities for installation error.

Up/down, SPI, and I2C protocol require totally different pulse streams. Many manufacturers offer components that are distinguished from each other by just one or two digits in their part numbers, yet have radically different functionality.

If more than one specific type of digital potentiometer may be used during circuit development, they should be stored carefully to avoid inadvertant substitutions. Using the wrong chip may be particularly confusing in that an inappropriate input protocol will still produce some results, although not those which were intended.

Controller and Chip Out of Sync

As noted in the discussion of data transmission protocols, most digital potentiometers are not capable of providing feedback to confirm the position of the internal wiper. A designer may wish to include a power-up routine which establishes the state of the digital potentiometer by resetting it to a known position, at one end of its scale or the other.

Nonlinear Effects

While the end-to-end resistance of the resistor ladder inside a digital potentiometer is not likely to be affected significantly by changes in temperature, the resistance at the wiper is more heat sensitive.

In an up/down chip, there can be differential errors between incremental and decremental modes. In other words, if a tap is reached by stepping up to it incrementally, the resistance between the W pin and H or L may not be quite the same as if the same tap is reached by stepping down to it decrementally. The difference may not be significant, but may be puzzling for those who are unfamiliar with this phenomenon.

Some differences may be found among resistors in a ladder. That is, in a supposedly linear digital potentiometer, each resistor may differ in value slightly from the next.

Data Transfer Too Fast

When using a microcontroller to send data to a digital potentiometer, a small delay may be necessary between pulses, depending on the microcontroller's clock speed. A digital potentiometer may require a minimum pulse duration of 500ns. Check the manufacturer's datasheet for details.

integrated circuit > analog > timer

8

timer

A device that creates a single timed pulse, or a series of timed pulses with timed intervals between them, is properly known as a *multivibrator*, although the generic term **timer** has become much more common and is used here.

Three types of multivibrator exist: *astable*, *monostable*, and *bistable*. The behavior of *astable multivibrators* and *monostable multivibrators* is described in detail in this entry. A timer chip can also be made to function as a bistable multivibrator. This is described briefly below, but it is not a designed function of a timer. The primary discussion of bistable multivibrators will be found in the entry of this encyclopedia dealing with **flip-flops**.

OTHER RELATED COMPONENTS

- **flip-flop** (See Chapter 11)

What It Does

A *monostable* timer emits a single timed pulse of fixed length in response to a triggering input that is usually of shorter duration. Many monostable timers are also capable of running in *astable* mode, in which the timer spontaneously emits an ongoing stream of timed pulses with timed gaps between them. A dual-mode timer can run in either mode, determined either by external components attached to it, or (less commonly) by changing the status of a mode selection pin.

Monostable Mode

In monostable mode, the timer emits a pulse in response to a change from high to low voltage (or, less commonly, from low to high voltage) at a *trigger pin*. Most timers respond to a *voltage level* at the trigger pin, but some are insensitive to any persistent pin state and only respond to a *voltage transition*. This is known as *edge triggering*.

The pulse generated by the timer may consist of a change from low to high (or, less commonly, from high to low) at an output pin. The length of the pulse will be determined by external components, and is independent of the duration of the triggering event, although in some cases, an output pulse may be prolonged by *retriggering* the timer prematurely. This is discussed below.

At the end of the output pulse, the timer reverts to its quiescent state, and remains inactive until it is triggered again.

A monostable timer can control the duration of an event, such as the time for which a light remains on after it has been triggered by a motion sensor. Alternatively, the timer can impose a delay, such as the interval during which a paper towel dispenser refuses to respond after a towel has been dispensed. A timer can also be useful to generate a clean pulse in response to an unstable or noisy input, as from a manually operated pushbutton.

Astable Mode

In astable mode, a timer will generally trigger itself as soon as power is connected, without any need for an external stimulus. However, the output can be suppressed by applying an appropriate voltage to a *reset pin*.

External components will determine the duration of each pulse and the gap between it and the next pulse. The pulse stream can be slow enough to control the flashing of a turn signal in a 1980s automobile, or fast enough to control the bit rate in a data stream from a computer.

Modern timer circuits are often incorporated in chips that have other purposes. The flashing of a turn signal in a modern car, for instance, is now likely to be timed by a microcontroller that manages many other functions. Still, chips that are purely designed as timers remain widely used and are very commonly available in numerous through-hole and surface-mount formats.

How It Works

The duration of a single pulse in monostable mode, or the frequency of pulses in astable mode, is most commonly determined by an external *RC network* consisting of a resistor in series with a capacitor. The charging time of the capacitor is determined by its own size and by the value of the resistor. The discharge time will be determined in the same way. A **comparator** inside the timer is often used to detect when the potential on the capacitor reaches a *reference voltage* that is established by a voltage divider inside the chip.

Variants

The 555 Timer

An eight-pin integrated circuit manufactured by Signetics under part number 555 was the world's first fully functioned timer chip, introduced in 1972. It combined two comparators with a **flip-flop** (see Chapter 11) to enable great versatility while maintaining excellent stability over a wide range of supply voltages and operating temperatures. Subsequent timers have been heavily influenced by this design. A typical 555 timer chip is shown in Figure 9-1.

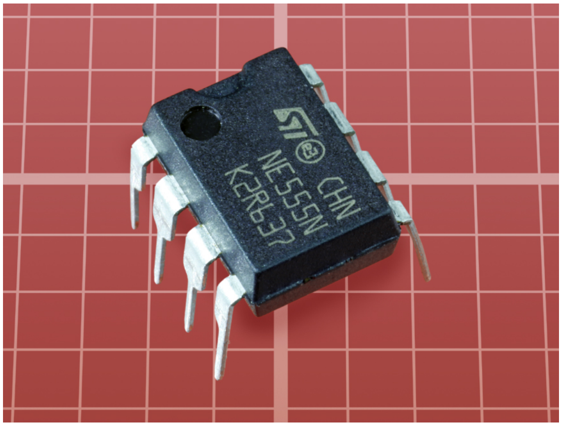

Figure 9-1. *A typical 555 timer chip. Functionally identical versions in which the "555" identifier is preceded or followed by different letter combinations are available from many different manufacturers.*

The 555 was designed by one individual, Hans Camenzind, working as an independent consultant for Signetics. According to a transcript of an interview with Camenzind maintained online at the Transistor Museum, "There was nothing like it at the time. You had to use quite a few discrete components—a comparator, a Zener diode or even two. It was not a simple circuit."

The 555 timer quickly became the most widely used chip in the world, and was still selling an annual estimated 1 billion units three decades after its introduction. It has been used in spacecraft, in intermittent windshield wiper controllers, in the early Apple II (to flash the cursor), and in children's toys. Like many chips of its era, its design was unprotected by patents, allowing it to be copied by numerous manufacturers.

The initial version was built around **bipolar transistors**, and consequently is referred to as the *bipolar version* or (more often) the *TTL version*, this being a reference to *transistor-transistor logic* protocol. Within a few years, CMOS versions based around **MOSFETs** were developed. They reduced the ability of the chip to sink or source current at its output pin, but consumed far less power, making them better suited to battery-operated products. The CMOS versions were and still are pin-compatible with the original bipolar version, both in through-hole and surface-mount formats. Their timing parameters are usually the same.

555 Monostable Operation

The internal functionality of a 555 timer wired to run in monostable mode is illustrated in Figure 9-2 with the chip seen from above. The pins are identified in datasheets by the names shown. To assist in visualizing the behavior of the chip, this figure represents the internal flip-flop as a switch which can be moved by either of two internal comparators, or by an input from the Reset pin.

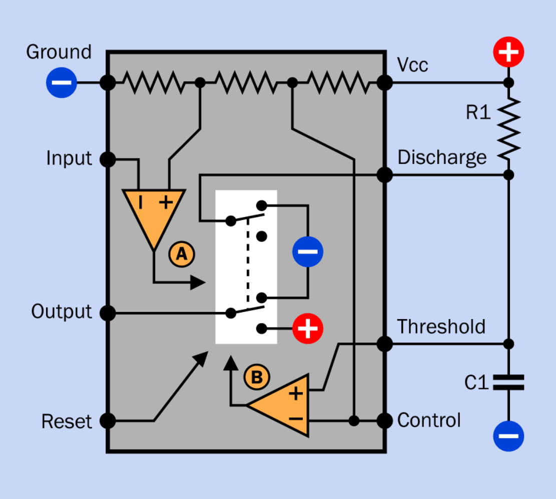

Figure 9-2. *The internal functions of a 555 chip, with its flip-flop represented as a switch that can be moved by either of two comparators, or by a low voltage on the Reset pin. An external resistor and capacitor, shown as R1 and C1, cause the timer to run in monostable (one-shot) mode, generating a single high pulse when the state of the Input pin is pulled from high to low.*

Inside the chip, three resistances of 5K each are connected between V+ (positive supply voltage) and negative ground. It has been suggested that the part number of the 555 chip was derived from these three 5K resistors, but Hans Camenzind has pointed out that Signetics was already using three-digit part numbers beginning with the number 5, and probably chose the 555 part number because the sales department had high expectations for the chip and wanted its number to be easily memorable. (A similar rationale explains the part number of the 2N2222 transistor.)

The resistances inside the timer function as a *voltage divider*, providing a reference of 1/3 of V+ to the noninverting pin of Comparator A and 2/3 of V+ to the inverting pin of Comparator B. (See Chapter 6 for an explanation of the functioning of comparators.)

When power is initially supplied to the timer, if the Input pin is at a high state, Comparator A has a low output, and the flip-flop remains in its “up” position, allowing the Output pin to remain in a low state. The flip-flop also grounds the lower end of R1, which prevents any charge from accumulating on capacitor C1.

If the state of the Input pin is pulled down externally to a voltage less than 1/3 of V+, Comparator A now creates a high output that changes the flip-flop to its “down” position, sending a high signal out through the Output pin. At the same time, C1 is no longer grounded, and begins to charge at a rate determined by its own size and by the value of R1. When the charge on the capacitor exceeds 2/3 of V+, it activates Comparator B, which forces the flip-flop into its “up” position. The Output pin goes low, C1 discharges itself into the Discharge pin, and the timer’s cycle is at an end.

The low voltage on the Input pin of the timer must end before the end of the output cycle. If the voltage on the Input pin remains low, it will re-trigger the timer, prolonging the output pulse.

A pullup resistor may be used on the Input pin to avoid false triggering, especially if an external electromechanical **switch** or **pushbutton** is used to pull down the Input pin voltage.

The Reset pin should normally be held high, either by being connected directly to positive supply voltage (if the reset function will not be needed) or by using a pullup resistor. If the Reset pin is pulled low, this will always interrupt an output pulse regardless of the timer's current status.

If a voltage higher or lower than 2/3 of V+ is applied to the Control pin, this will change the reference voltage on Comparator B, which determines when the charging cycle of C1 ends and the discharge cycle begins. A lower reference voltage will shorten each output pulse by allowing a lower charge limit for C1. If the control voltage drops to 1/3 of V+ (or less), the capacitor will not charge at all, and the pulse length will diminish to zero. If the control voltage rises to become equal to V+, the capacitor will never quite reach that level, and the pulse length will become infinite. A workable range for the control voltage is therefore 40% to 90% of V+.

Because the Control pin is an input to the chip, it should be grounded through a 0.01µF ceramic capacitor if it will not be used. This is especially important in CMOS versions of the timer.

A defect of the bipolar 555 is that it creates a *voltage spike* when its Output pin changes state. If it will be sharing a circuit with sensitive components, a 0.01µF bypass capacitor should be added as closely as possible between the V+ pin and negative ground. The voltage-spike problem was largely resolved by the CMOS 555.

555 Astable Operation

In Figure 9-3, the 555 timer chip is shown with external components and connections to run it in astable mode. The pin names remain the same but have been omitted from this diagram because of limited space. The labeling of the two external resistors and capacitor as R1, R2, and C1 is universal in datasheets and manufacturers' documentation.

When the timer is powered up initially, capacitor C1 has not yet accumulated any charge. Consequently, the state of the Threshold pin is low. But the Threshold pin is connected externally with the Input pin, for astable operation. Consequently, the Input pin is low, which forces the flip-flop into its "down" state, creating a high output. This happens almost instantaneously.

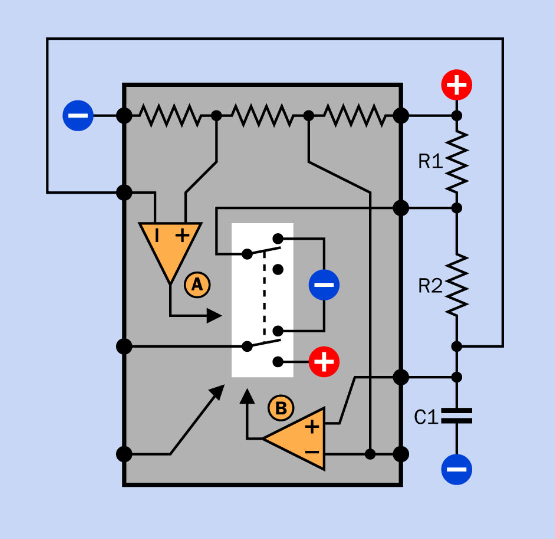

Figure 9-3. *The internal functions of a 555 chip, with two external resistors and a capacitor wired to run the timer in astable (free-running) mode.*

While the flip-flop is "down," the Discharge pin is not grounded, and current flowing through R1 and R2 begins to charge the capacitor. When the charge exceeds 2/3 of positive supply voltage, Comparator B forces the flip-flop into its "up" position. This ends the high pulse on the Output pin, and starts to drain the charge from the capacitor through R2, into the Discharge pin. However, the voltage on the capacitor is still being shared by the Input pin, and when it diminishes to 1/3 of V+, the Input pin reactivates Comparator A, starting the cycle over again.

The functions of the Reset and Control pins are the same as in monostable mode. Because voltage applied to the Control pin changes the length of each pulse and the gaps between pulses, it has the effect of adjusting the frequency of the output in astable mode.

When power is first connected to the timer, C1 must initially charge from an assumed state of zero potential to 2/3 V+. Because subsequent cycles will begin when the capacitor is at 1/3 V+, the first high output pulse from the timer will be slightly longer than subsequent output pulses. This is unimportant in most applications, especially because the rate at which a capacitor accumulates charge is greater when beginning from 0V than when it has reached 1/3 V+. Still, the longer initial pulse can be noticeable when the timer is running slowly.

Because the capacitor charges through R1 and R2 in series, but discharges only through R2, the length of each positive output pulse in astable mode is always greater than the gap between pulses. Two strategies have been used to overcome this limitation. See "Separate Control of High and Low Output Times" on page 80.

556 Timer

The 556 consists of two 555 bipolar-type timers in one package. An example of the chip is shown in Figure 9-4. The pinouts are shown in Figure 9-5. Although 556 timers have become relatively uncommon compared with the 555, they are still being manufactured in through-hole and surface-mount versions by companies such as Texas Instruments and STMicroelectronics, under part numbers such as NA556, NE556, SA556, and SE556 (with various letters or letter pairs appended). Each timer in the chip has its own set of inputs and outputs, but the timers share the same V+ and ground voltages.

558 Timer

This 16-pin chip is now uncommon, and many versions have become obsolete. It has been identified by a part number such as NE558 although different prefix letters may be used. The NTE926, shown in Figure 9-6, is actually a 558 timer.

The chip contains four 555 timers sharing a common power supply, common ground, and common control-pin input. For each internal timer, the Threshold and Discharge functions are connected internally, so that the timers can only be used in one-shot mode. However, one timer can trigger another at the end of its cycle, and the second timer can then retrigger the first, to create an astable effect.

Each timer is edge-triggered by a voltage transition (from high to low), instead of being sensitive to a voltage level, as is the case with a 555 timer. Consequently the timers in the 558 chip are insensitive to a constant (DC) voltage.

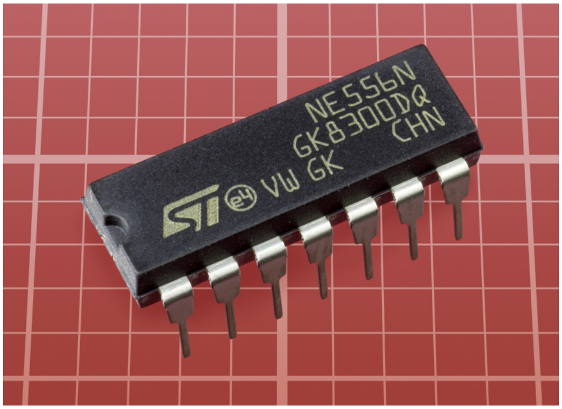

Figure 9-4. *An example of the 556 timer chip.*

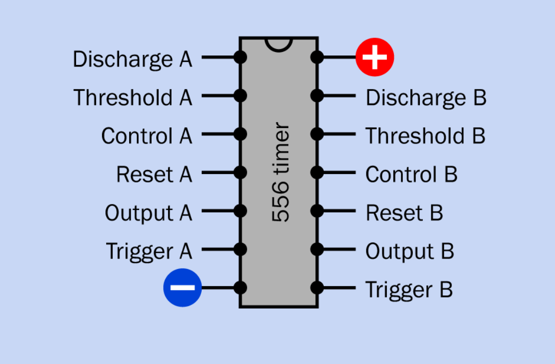

Figure 9-5. *The 556 timer contains two separate 555 timers sharing the same power supply and ground. The pin functions for timer A and timer B are shown here.*

The output from each timer is an open collector, and therefore requires an external pullup resistor. Each output is capable of sinking up to 100mA.

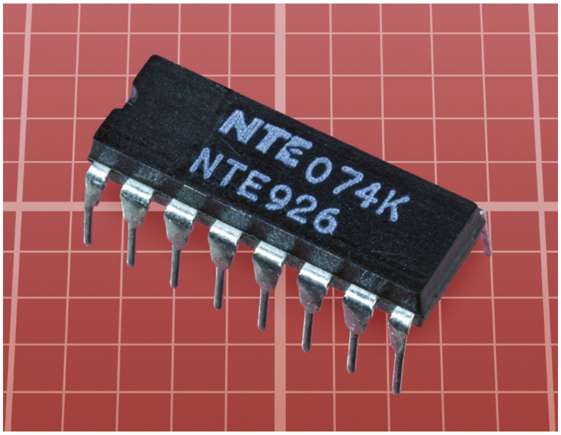

Figure 9-6. *The NTE926 is a 558 timer chip.*

CMOS 555 Timer

While the part numbers of many CMOS versions are significantly different from part numbers of the bipolar versions, in some instances the CMOS numbers are only distinguished by a couple of initial letters. The ST Microelectronics TS555 series and Texas Instruments TLC555 series, for example, use MOSFETs internally. The ST Microelectronics SE555 series and Texas Instruments SA555 series use bipolar transistors internally.

One way to distinguish between the two types, when searching a website maintained by a parts supplier, is to begin by looking generically for a "555 timer" and then add a search filter to show chips either with a minimum power supply of 3VDC (which will be CMOS) or with a minimum power suply of 4.5VDC (which will be bipolar).

CMOS versions of the 555 timer do not create the power spike that is characteristic of the bipolar versions during output transitions. The CMOS chips can also be powered by a lower voltage (3VDC, or 2VDC in some cases), and will draw significantly less current in their quiescent state. They also require very little current for threshold, trigger, and reset functions.

The wiring of external resistors and capacitors to the CMOS version of the chip, and the internal voltage levels as a fraction of V+, are identical to the original 555 timer. Pin functions are likewise identical. The only disadvantages of CMOS versions are their greater vulnerability to static discharge, and their lower output currents. The TLC555, for instance, will source only 15mA (although it can sink 10 times that amount). Other manufacturers have different specifications, and datasheets should be checked carefully.

5555 Timer

The 5555 contains a digital **counter** that enables it to time very long periods. Its full part number is 74HC5555 or 74HCT5555, although these numbers may be preceded or followed by letter combinations identifying the manufacturer. It is not pin-compatible with a 555 timer.

Two input pins are provided, one to trigger the timer on a rising edge, the other on a falling edge, of the input pulse. The inputs are Schmitt-triggered.

The timer is rated for 1Hz to 1MHz (using an external resistor and external capacitor). The counter section can divide the pulse frequency by values ranging from 2 to 256. For longer timed periods, different settings on the digital control pins will divide the frequency by values ranging from 2^{17} through 2^{24} (131,072 through 16,777,216). This enables the timer to achieve a theoretical pulse length lasting for more than 190 days. The timer will accept a clock input from an external oscillator to achieve better accuracy than is available with a resistor-capacitor timing circuit.

7555 Timer

This 8-pin chip is a CMOS version of the 555 timer, manufactured by companies such as Maxim Integrated Products and Advanced Linear Devices. Its characteristics are similar to those of CMOS 555 timers listed above, and the pinouts are the same.

7556 Timer

This 14-pin chip contains two 7555 timers, sharing common power supply and ground connections. Pinouts are the same as for the original 556 timer, as shown in Figure 9-5.

4047B Timer

This 14-pin CMOS chip was introduced in an effort to address some of the quirks of the 555 timer while also providing additional features. It runs in either monostable or astable mode, selectable by holding one input pin high or another input pin low. In astable mode, its duty cycle is fixed at approximately 50%, a single resistor being used for both charging and discharging the timing capacitor. An additional "oscillator" output runs twice as fast as the regular output.

In monostable mode, the 4047B can be triggered by a positive or negative transition (depending on which of two input pins is used). It ignores steady input states and will also ignore additional trigger pulses that occur during the output pulse. However, a retrigger pin is provided to extend the output pulse if desired.

Complementary output pins are provided, one being active-high while the other is active-low.

To time very long periods, the 4047B was designed to facilitate connection with an external counter.

The power supply for the 4047B can be as low as 3VDC. Its maximum source or sink output current is only 1mA when powered at 5VDC, but up to 6.8mA when powered at 15VDC.

The chip is still available from manufacturers such as Texas Instruments (which markets it as the CD4047B) in through-hole and surface-mount formats. However, despite its versatility, the 4047B is less popular than dual monostable timers, described in the next section.

Dual Monostable Timers

Various timers that run only in monostable mode are available in dual format (i.e., two timers in one chip). This format became popular partly because two monostable timers can trigger each other to create an astable output, in which the pulse width, and the gap between pulses, can be set by a separate resistor-capacitor pair on each timer. This allows greater flexibility than is available when using a 555 timer.

Most dual monostable timer chips are edge-triggered by a change in input voltage, and will ignore a steady DC voltage. Consequently, the output from one timer can be connected directly to the input of another, and no coupling capacitors are necessary.

As in the 4047B, the user has a choice of two input pins for each timer, one triggered by a transition from low to high, the other triggered by a transition from high to low. Similarly, each timer has two outputs, one shifting from low to high at the start of the output cycle, the other shifting from high to low.

The values of a single resistor and capacitor determine the pulse duration of each timer.

Dual monostable timers often have the numeric sequence 4528 or 4538 in their part numbers. Examples include the HEF4528B from NXP, the M74HC4538 from STMicroelectronics, and the MC14538B from On Semiconductor. The 74123 numeric sequence identifies chips that have a very similar specification, with chip-family identifiers such as HC or LS inserted, as in the 74HC123 and 74LS123, and additional letters added as prefix or suffix. The pinouts of almost all these chips are identical, as shown in Figure 9-7. However, Texas Instruments uses its own numbering system, and datasheets should always be consulted for verification before any connections are made.

Many chips of this type are described as "retriggerable," meaning that if an additional trigger pulse is applied to the input before an output pulse has ended, the current output pulse will be extended in duration. Check datasheets carefully to determine whether a chip is "retriggerable" or will ignore new inputs during the output pulse.

The 74HC221 dual monostable vibrator (pictured in Figure 9-8) functions very similarly to the components cited above, but has slightly different pinouts.

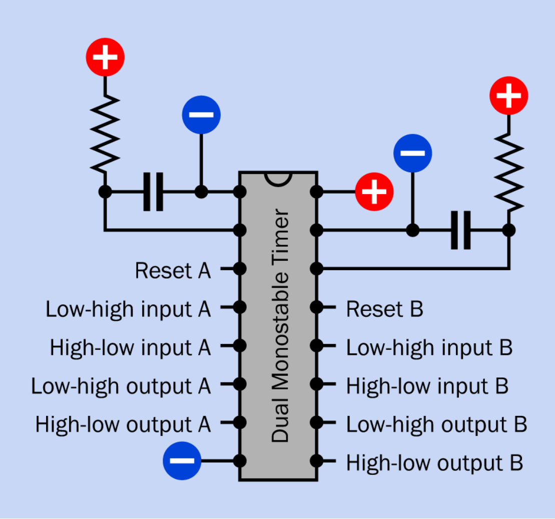

Figure 9-7. *Pin functions for most 4528, 4538, and 74123 series of dual monostable timer chips. An RC network is shown connected for each timer. Note that Texas Instruments uses different pinouts on its versions.*

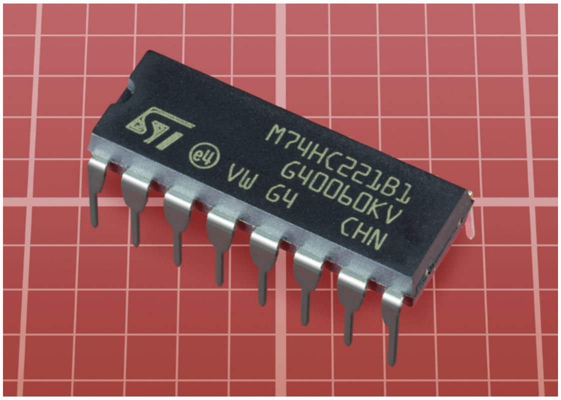

Figure 9-8. *A dual-timer chip containing two monostable multivibrators that can function in astable mode if they are connected externally to trigger each other.*

Values

555 Timer Values

The original bipolar version of the 555 timer was designed to operate using a wide range of positive supply voltages, from 4.5VDC to 16VDC. CMOS versions vary in their recommended V+ values, and datasheets must be consulted for verification.

The output of a bipolar 555 is rated to source or sink up to 200mA. In practice, the maximum current will be lower when the timer is powered at the low end of its range, around 5VDC. Attempting to source more than 50mA will pull down the voltage internally, affecting operation of the timer.

CMOS versions all impose restrictions on output current, allowing higher values for sinking than sourcing. Again, datasheets must be consulted for the values, which vary widely from one component to another.

The voltage measured on the output pin, when it is used for sourcing current, will always be lower than the power supply voltage, and a 1.7V drop is commonly specified for bipolar versions. In practice, the voltage drop that is actually measured may be less, and will vary according to the load on the output.

The voltage drop does not increase significantly with a higher supply voltage, and because it is a relatively constant value, it becomes less significant when a higher value for V+ is used.

CMOS versions of the 555 timer achieve a claimed output source voltage that is only 0.2V less than the power supply.

When choosing values for R1 and R2, a minimum for each resistor is 5K, although 10K is preferred. Lower values will increase power consumption, and may also allow overload of the internal electronics when the chip sinks current from C1. A typical maximum value for each resistor is 10M.

A high-value capacitor may cause the timer to function less accurately and predictably, because large capacitors generally allow more *leakage*. This means that the capacitor will be losing charge at the same time that it is being charged through R1 + R2. If these resistors have high values, and the capacitor has a value of 100µF or more, the rate of charge may be so low that it is comparable with the rate of leakage. For this reason, a 555 timer is not a good choice for timing intervals much greater than a minute. If a large-value capacitor is used, tantalum is preferable to electrolytic.

The minimum practical value for a timing capacitor is around 100pF. Below this, performance may not be reliable.

Although some CMOS versions may enable fast switching, the shortest practical output pulse for a 555 timer is around 10 microseconds. On the input pin, a triggering pulse of at least 1 microsecond should be used.

Time Calculation in Monostable Mode

If R1 is measured in kilohms and C1 is measured in microfarads, the pulse duration, T, in seconds, of a 555 timer running in monostable mode can be found from this simple formula:

```
T = 0.0011 * R1 * C1
```

This relationship is the same in all versions of the 555. Figure 9-9 provides a quick and convenient way to find the pulse value using some common values for R1 and C1. Resistors can be obtained with tolerances below plus-or-minus 1%, but capacitors are often rated with an accuracy of only plus-or-minus 20%. This will limit the accuracy of the pulse values shown in the chart.

Time Calculation in Astable Mode

If R1 and R2 are measured in kilohms and C1 is measured in microfarads, the frequency of pulses, F (measured in Hz) of a 555 timer running in astable mode can be found from this simple formula:

```
F = 1440 / ( ( R1 + (2 * R2) ) * C1)
```

This relationship is found in all versions of the 555. Figure 9-10 shows the frequency for common values of R2 and C1, assuming that the value of R1 is 10K. In Figure 9-11, a value of 100K is assumed for R1.

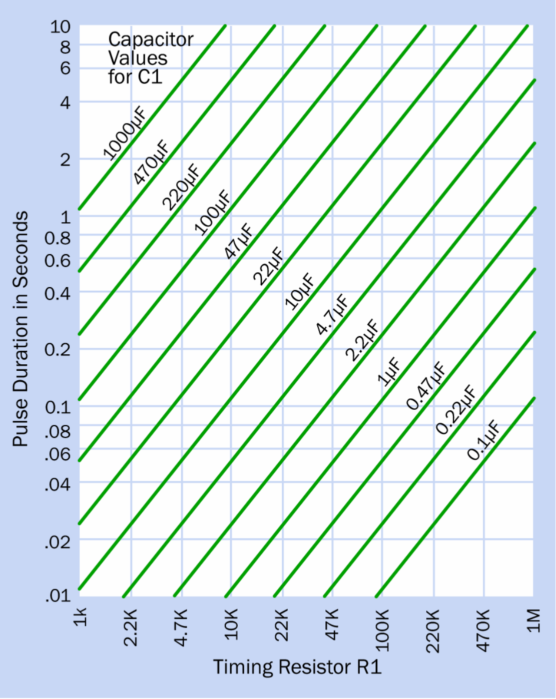

Figure 9-9. *To determine the pulse duration of a 555 timer running in monostable mode: find the value of R1 on the horizontal scale, follow its vertical grid line upward to the intersection with a green line which corresponds with the value of capacitor C1, and read across to the vertical scale providing the duration in seconds. Both axes are logarithmic.*

Dual Monostable Timers

Dual chips such as the HEF4528B from NXP, the M74HC4538 from STMicroelectronics, the MC14538B from On Semiconductor, and the 74HC123 from Texas Instruments have widely varying requirements for power supply. Some accept a limited range from 3VDC to 6VDC, while others tolerate a range of 3VDC to 20VDC. When powered with 5VDC their required input and output states are compatible with those of 5V logic chips.

Output pins of these chips source and sink no more than 25mA (much less in some instances). Because there are so many variants, they cannot be summarized here, and datasheets must be consulted for details.

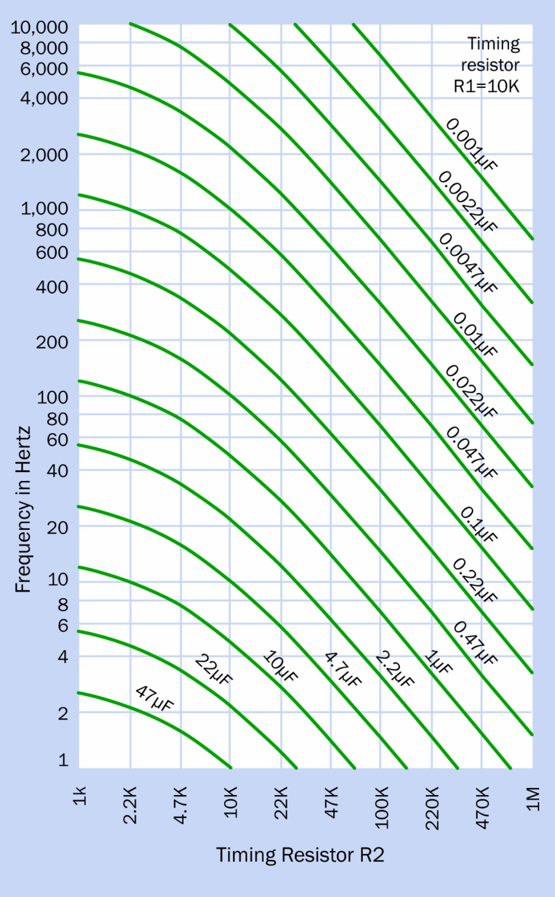

Figure 9-10. *To obtain the frequency of a 555 timer running in astable mode, when R1 has a value of 10K: find the value of R2 on the horizontal scale, follow its vertical grid line upward to the intersection with a green curve which corresponds with the value of capacitor C1, and read across to the vertical scale providing the frequency in Hertz. Both axes are logarithmic.*

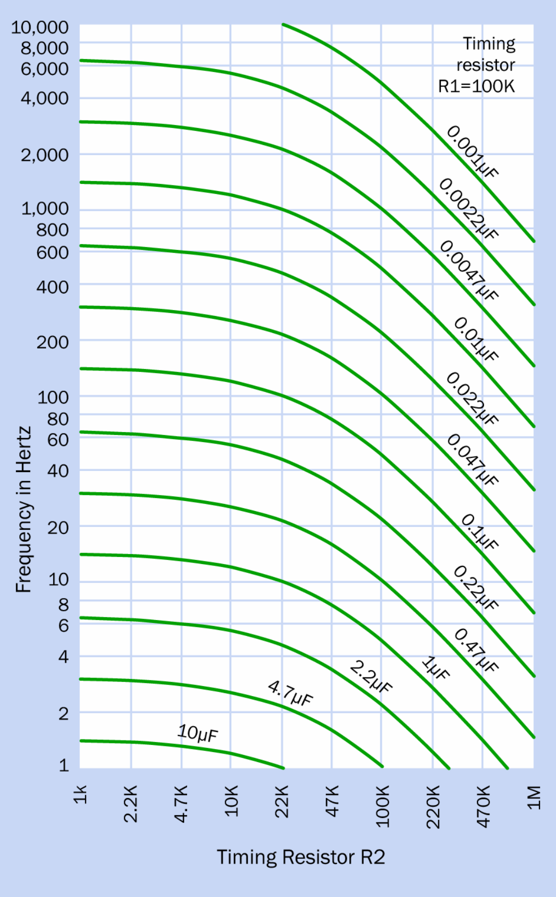

Figure 9-11. *To obtain the frequency of a 555 timer running in astable mode, when R1 has a value of 100K: find the value of R2 on the horizontal scale, follow its vertical grid line upward to the intersection with a green curve which corresponds with the value of capacitor C1, and read across to the vertical scale providing the frequency in Hertz. Both axes are logarithmic.*

As these timers are all monostable, and each timer uses just one resistor and one capacitor, the only formula required is to give the pulse time as a function of these two variables. If R is the resistor value in ohms, and F is the capacitor value in farads, and K is a constant supplied by the manufacturer, the pulse time T, in seconds, is found from the formula:

```
T = R * F * K
```

K ranges between 0.3 and 0.7 depending on the manufacturer and also on the voltage being used. Its value should be found in the manufacturer's datasheet. If R is measured in megohms and F is measured in microfarads, the formula is still valid, as the multipliers cancel each other out.

Generally speaking, these dual monostable CMOS timers are not intended for pulse duration exceeding 1 minute.

The timing capacitor should be no larger than 10µF, as it discharges directly and rapidly through the chip.

How to Use It

Where a timer is required to drive a load such as a relay coil or small motor directly, the original TTL version of the 555 timer will be the only choice. Even in this instance, a protection diode must be used across the inductive device.

For smaller loads and applications in chip-to-chip circuits, CMOS versions of the 555, including the 7555, use less power, cause less electrical interference, and are pin-compatible while using the same formulae to calculate frequency in astable mode or pulse duration in monostable mode. They are of course more vulnerable to static discharge, and care must be taken to make a connection to every pin (the capacitor that grounds the Control pin, if Control is not going to be used, is mandatory).

In dual monostable timers, unused rising-edge trigger inputs should be tied to V+ while unused falling-edge trigger inputs should be tied to ground. A Reset pin that will not be used should be tied to V+, unless that entire timer section of the chip will be unused, in which case the pin should be grounded.

To measure durations longer than a few minutes, a timer which incorporates a programmable counter to divide the clock frequency is the sensible choice. See the description of the 5555 timer that was included earlier in this entry.

The original bipolar version of the 555 remains a robust choice in hobby applications such as robotics, and its design allows some versatile variations which may even be used in logic circuits. A variety of configurations are shown in the schematics below.

555 Monostable Mode

The basic schematic for a 555 timer running in monostable mode is shown in Figure 9-12. In this particular example, a pushbutton that is liable to suffer from *switch bounce* is connected to the Input pin of the timer, which responds to the very first connection made by the pushbutton and ignores the subsequent "bounces," thus producing a "clean" output. To avoid retriggering, which results in a prolonged output pulse, the timer's output should exceed the time for which the button is likely to be pressed. The output should also exceed the duration of any possible switch bounce, which can otherwise create multiple output pulses. In the schematic, an LED is attached to the timer output for demonstration purposes.

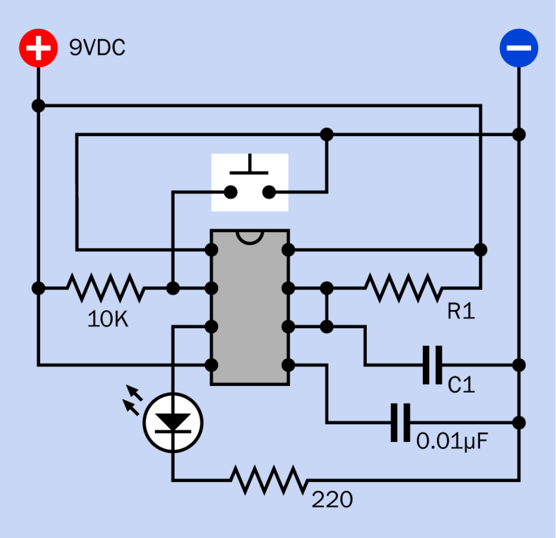

Figure 9-12. *The basic monostable configuration of a 555 timer. This particular circuit debounces an input from a pushbutton switch and converts it to a clean pulse of fixed duration, powering an LED for demonstration purposes.*

This circuit is shown on a breadboard in Figure 9-13. The red and blue wires, at the top of the photograph, supply 9VDC to the board. R1 is 1M, while C1 is 1µF, creating a pulse of just over 1 second. A tactile switch, just above the timer, provides the input.

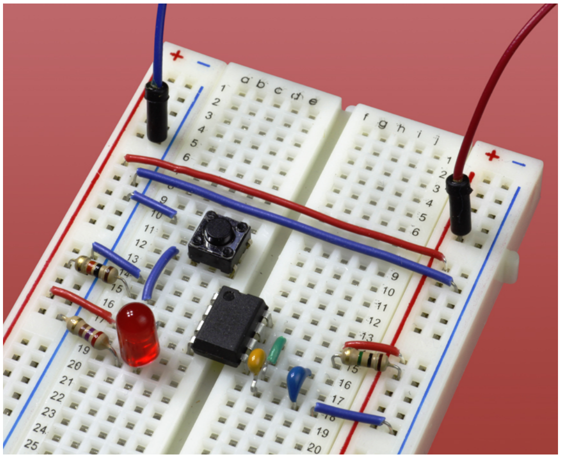

Figure 9-13. *The basic monostable configuration for a 555 timer, mounted on a breadboard.*

555 Astable Mode

A basic schematic for a 555 timer running in astable mode is shown in Figure 9-14. Once again, an LED is attached to the output for demonstration purposes. If the pulse rate exceeds the persistence of vision, a small loudspeaker can be used instead, in series with a 47Ω resistor and a 100µF capacitor.

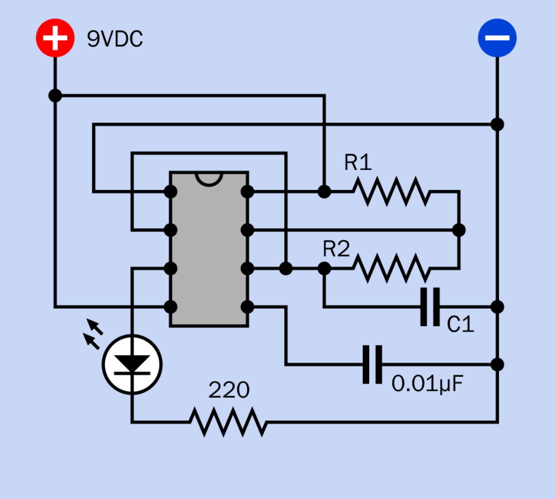

Figure 9-14. *A 555 timer with external connections and components causing it to run in astable (free-running) mode.*

Separate Control of High and Low Output Times

In Figure 9-15, a bypass diode has been added around R2. The capacitor now charges primarily through R1, as the diode has a much lower effective resistance than R2. It discharges only through R2, as the diode blocks current in that direction. Consequently, the length of the high output pulse can be adjusted with the value of R1 only, while the length of the low output pulse can be adjusted with the value of R2 only. The duration of the high output can be lower than, or equal to, the duration of the low output, which is not possible with the basic configuration of components in Figure 9-14.

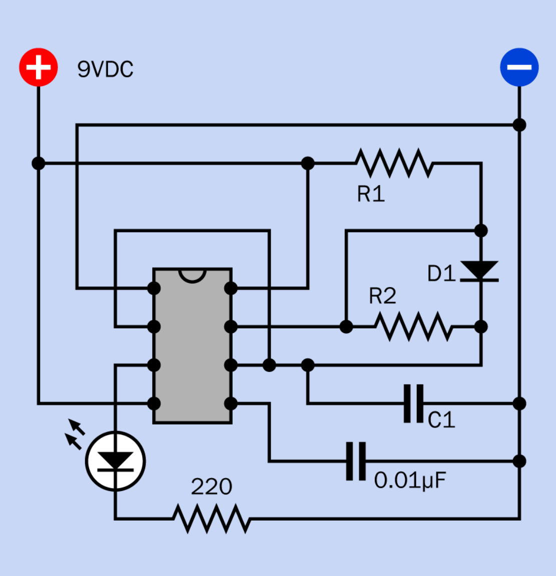

Figure 9-15. *In this circuit, a diode bypasses R2, so that the "on" time and the "off" time of the 555 timer can be set independently of each other, with R1 and R2, respectively.*

555 Fifty Percent Astable Duty Cycle: 1

In Figure 9-16, the circuit enables a fixed astable output duration of approximately 50% high and 50% low. Initially, C1 has no charge, pulling the Input of the timer low, and causing it to begin a cycle with a high pulse from the Output pin, as usual. In this demonstration circuit, the output illuminates an LED. At the same time, resistor R1 is attached to the output and charges C1. When the voltage on C1 reaches 2/3 of V+, this is communicated to the timer Input pin, which ends the "high" cycle and initiates low status on the Output pin. This starts to sink the charge from C1, through R1. When the voltage drops to 1/3 V+, this initiates a new cycle. Because only one resistor is used to charge and discharge the capacitor, we may imagine that the charge and discharge times should be identical. However, a higher load on the output will probably pull down the output voltage to some extent, lengthening the charge time. Conversely, a load on the Output pin that has low resistance will probably sink at least some of the charge from the capacitor, shortening the discharge cycle.

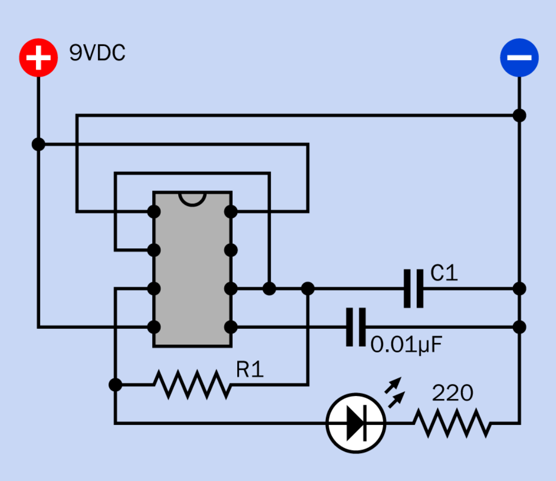

Figure 9-16. *This configuration provides an approximate 50-50 on-off duty cycle at the output pin, although the precise duration will depend on the load.*

555 Fifty Percent Astable Duty Cycle: 2

In Figure 9-17, a small modification of the basic astable circuit shown in Figure 9-14 provides another way to enable a 50% duty cycle. Compare the two schematics, and you will see that just the connection between R1 and R2 has been altered so that C1 now charges only through R1, and discharges only through R2. However, in this configuration the capacitor is discharging into a voltage divider created by the two resistors. Empirical adjustment of the resistor values may be necessary before the duty cycle is precisely 50%.

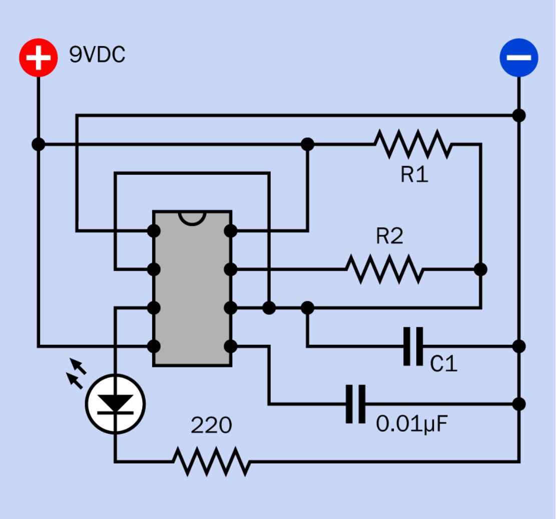

Figure 9-17. *An alternative configuration to provide an approximate 50-50 on-off duty cycle in a 555 timer.*

Use of the 555 Control Pin

In Figure 9-18, a potentiometer and two series resistors allow a varying voltage to be applied to the Control Pin. This will lengthen or reduce both the charge and the discharge times of the timing capacitor. If values for the capacitor and its associated resistors are chosen to create a frequency of approximately 700Hz, a 10K potentiometer should demonstrate more than an octave of audible tones through the loudspeaker. Other components can be substituted for a potentiometer, creating possibilities for producing pulse-width modulation. Alternatively, if a large capacitor is added between the Control pin and ground while a second 555 timer, running slowly in astable mode, applies its output to the Control pin, the charging and discharging of the capacitor will apply a smoothly rising and falling voltage. If the first 555 timer is running at an audio frequency, the output will have a "wailing siren" effect.

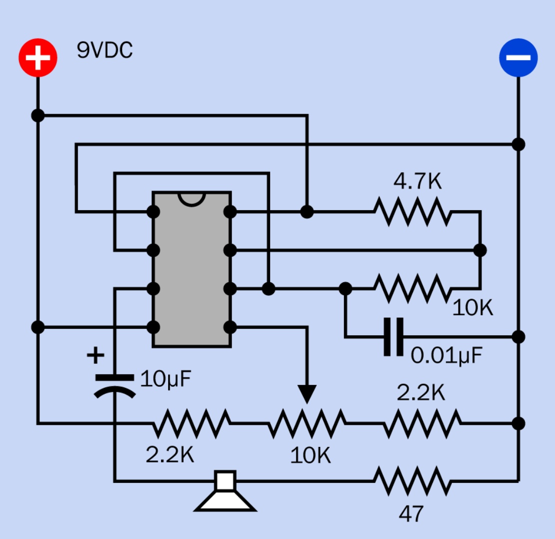

Figure 9-18. *A circuit that allows adjustment of the astable 555 frequency by increasing or lowering the voltage on the Control pin.*

Figure 9-19 shows the components specified in Figure 9-18 mounted on a breadboard.

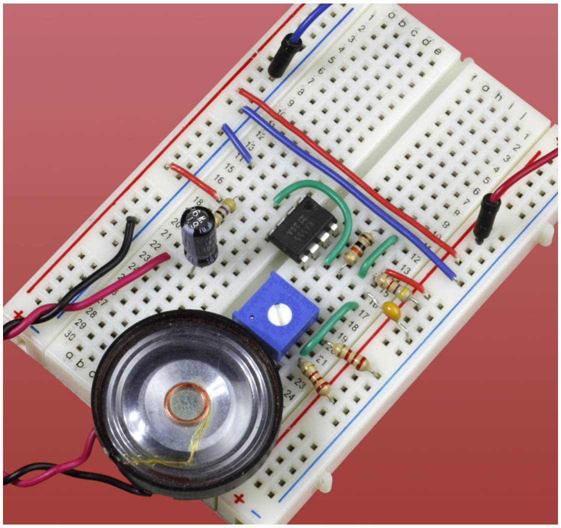

Figure 9-19. *The components in the previous schematic are shown here mounted on a breadboard. They will generate an audio output ranging between approximately 425Hz and 1,075Hz. A lower value for the timing capacitor will shift the audio range higher in frequency.*

555 Flip-Flop Emulation

The flip-flop inside a 555 timer can be accessed to control the timer's outputs. In Figure 9-20, pushbutton switch S1 applies a negative pulse to the Input pin, creating a high output from the timer, which illuminates LED D1. Normally the pulse length would be limited by the charge time of a capacitor attached to the Threshold pin, but in this circuit there is no capacitor, and the Threshold pin is hard-wired to negative ground. So, it never rises to 2/3 of positive power, and the output from the timer remains high indefinitely.

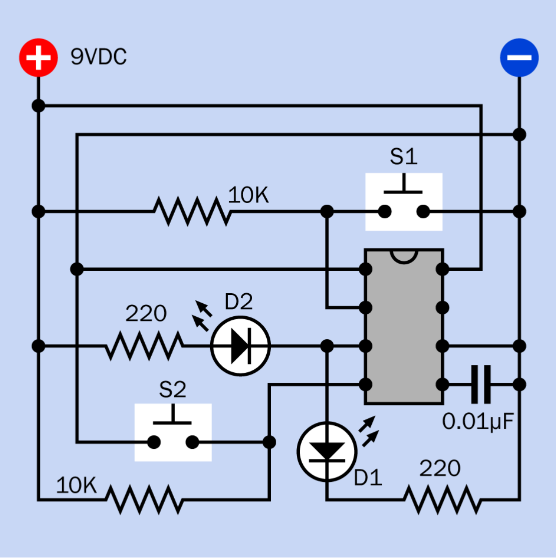

Figure 9-20. *A 555 timer can have its timing features disabled so that it functions as a flip-flop.*

However, if S2 is pressed, it grounds the Reset pin of the timer, which ends the high output and pulls the Output pin down to a low state. D1 goes out and D2 lights up, as the timer is now sinking current through it. When S2 is released, the timer output remains low and D2 remains illuminated, because the Input pin is held high by a pullup resistor. Therefore, the timer now functions in bistable mode, as a flip-flop. While this may be seen as an inappropriate use of the chip, because its full functionality is being disabled, its ability to deliver substantial current and to tolerate a wide range of supply voltages may make it more convenient to use than a digital flip-flop. See Chapter 11 for more information about flip-flops.

A 555 timer emulating a flip-flop is shown on a breadboard in Figure 9-21.

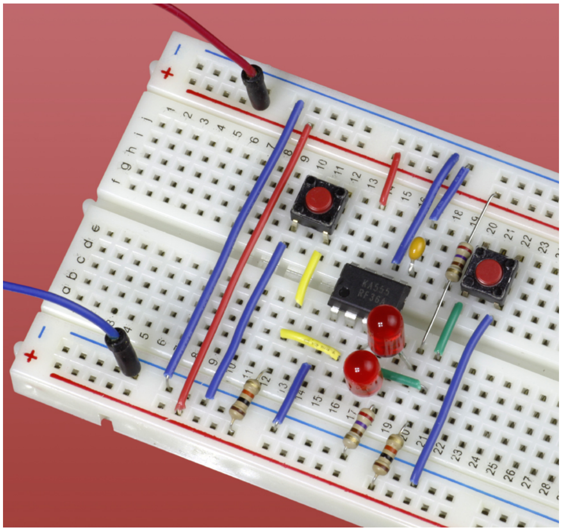

Figure 9-21. *The schematic in which a 555 timer acts as a flip-flop is shown here adapted for a breadboard.*

555 Hysteresis

The comparators inside a 555 timer enable the chip to produce hysteresis. In Figure 9-22, the Input pin and the Threshold pin are shorted together, and C1, the timing capacitor, is omitted. A 10K potentiometer, wired as a voltage divider, delivers a voltage to the Input pin ranging smoothly from V+ to negative ground. As the input dips below 1/3 V+, the Output pin goes high, lighting LED D1. Now if the input voltage gradually rises, the output remains high, even as the input rises above 1/3 V+. The output state is "sticky" because the timer does not end an output pulse until the Threshold pin tells it to, by reaching 2/3 V+. When this finally occurs, the Output pin goes low, D1 goes out, and D2 comes on, sinking current into the Output pin.

Suppose, now, the input voltage starts to go down again. Once again the output state is "sticky" because it remains low until the Input pin drops below the 1/3 level. When that happens, the output finally flips back to a high state, D2 goes out, and D1 comes on.

In the "dead zone" between 1/3 and 2/3 of supply voltage, the timer remains in its current mode, waiting for the input to stray outside of those limits. This behavior is known as *hysteresis*, and is of special importance when processing a varying signal, such as the voltage from a temperature sensor, to control an on/off device such as a thermostat. In fact the 10K potentiometer in this demo could be replaced with a thermistor or a phototransistor, wired in series with a resistor to create a voltage divider which will have an input range compatible with the 555 timer. The hysteresis can then be adjusted by varying the supply voltage that powers the timer, as this will change the values of 1/3 V+ and 2/3 V+. Alternatively, varying the voltage on the Control pin will affect the hysteresis.

A **comparator** can provide much more versatile control of hysteresis by using positive feedback (see Chapter 6 for additional details). But the 555 timer provides a quick-and-simple substitute, and its greater ability to source or sink current enables it to be connected with a wider range of other components.

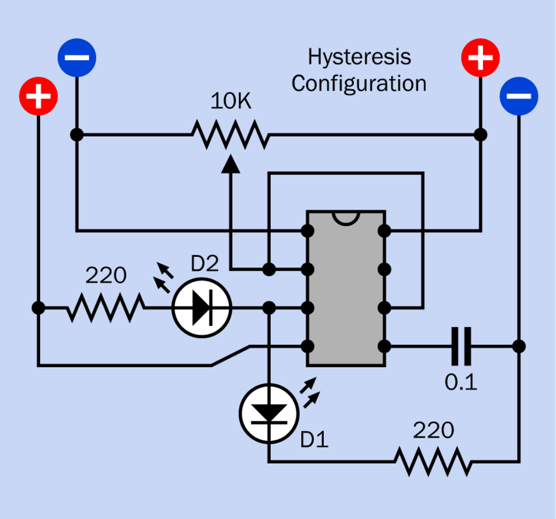

Figure 9-22. *A 555 timer wired so that it creates hysteresis, when supplied by a variable input voltage.*

555 and Coupling Capacitors

As previously noted, when a basic bipolar 555 timer (and some of its variants) is wired in monostable mode, it will retrigger itself indefinitely if its input remains low. One way to avoid this is by using a coupling capacitor. This will pass a transition from high to low, but will then block a steady subsequent voltage. In Figure 9-23, a phototransistor in series with a resistor provides a variable voltage to the noninverting input of a comparator. The reference voltage of the comparator is adjusted with a potentiometer, and resistor R3 provides positive feedback, ensuring that the output from the comparator will be quick and clean. The output from the 555 timer goes through a transistor to the relay, shown at the bottom.

It is important to see the function of the coupling capacitor, C3, with the pullup resistor, R2, which holds the Input pin of the 555 timer high by default. When the output from the comparator drops from high to low, C3 passes this transition to the Input pin of the timer, momentarily overcoming the positive potential, and triggering the timer. After the timer responds, however, C3 blocks any continuation of low voltage from the comparator. Pullup resistor R2 resumes its function of holding the input high, and prevents the timer from being retriggered.

555 Loudspeaker Connection

A small 8-ohm loudspeaker can be driven from the output of a bipolar 555 timer running in astable mode, but should be isolated from it with a 10µF to 100µF capacitor. A series resistor of 47Ω (minimum) should be used. See Figure 9-24.

Burst Mode

It is sometimes useful to create a short beep of fixed length in response to a button-press. The beep should terminate even if the button is held down. This “burst mode” can be achieved with the circuit in Figure 9-25, where the button connects power to a bipolar-type 555 timer running in astable mode, and an RC network applies a decreasing potential to a 47µF capacitor, which is wired to the Reset pin of the timer. The resistor in series with the capacitor will vary the length of the beep. When voltage to the pin drops below approximately 0.3V, output from the timer stops and cannot restart until the button is released.

A resistor of greater than 1.5K may not allow the input value at the reset pin to fall below the voltage, which is necessary to enable a reset. If a lower power supply voltage than 9VDC is used, the resistor value should be higher—for example, a 5VDC power supply works well with a 1.5K to 2K resistor.

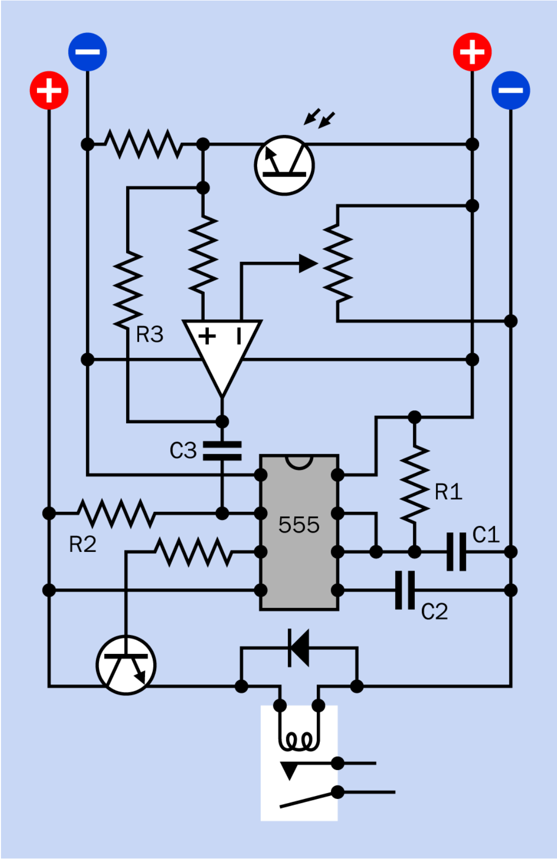

Figure 9-23. *A coupling capacitor (C3) is used in this circuit to isolate the 555 timer from a sustained low input from the comparator. The capacitor only passes a transition from high to low. The rest of the time, the pullup resistor (R3) holds the input high.*

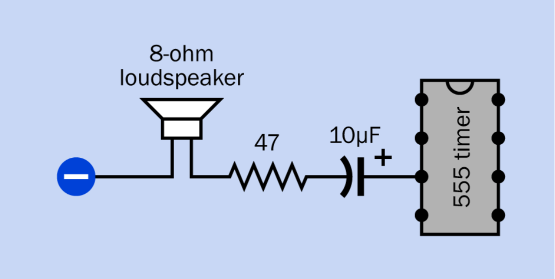

Figure 9-24. *A small 8-ohm loudspeaker can be attached through a capacitor and a resistor to the output of a bipolar 555 timer.*

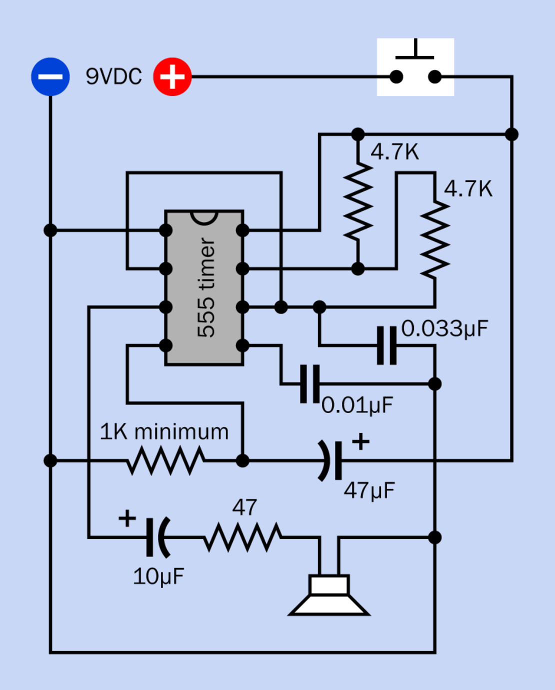

Figure 9-25. *An RC circuit, wired to apply a decreasing voltage on the Reset pin of a bipolar 555 timer, will shut off the timer shortly after it is powered up. This can be used to create a fixed-length beep in response to a button press of any duration.*

Figure 9-26 shows the components installed on a breadboard.

"You Lose" Game Sound

A timer is a simple, cheap way to create a variety of simple game sounds. The schematic in Figure 9-27 makes a groaning sound as the 100µF capacitor wired to the Control pin of a bipolar-type 555 gradually charges through the 1K resistor. Note that if a larger resistor is paired with a smaller capacitor, the effect will differ. The 150K resistor is included to discharge the capacitor reasonably quickly in time for the next cycle.

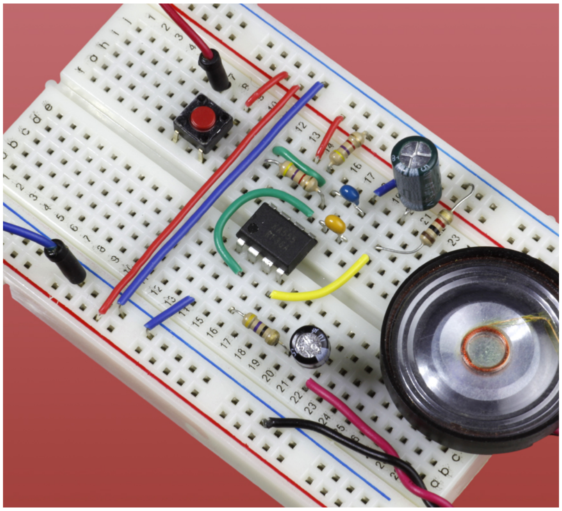

Figure 9-26. *The "burst mode" circuit installed on a breadboard with a miniature loudspeaker.*

What Can Go Wrong

Dead Timer

Like any chip, the 555 can be damaged by overvoltage, excessive source current or sinking current, static electricity, incorrectly applied polarity of power supply, and other forms of abuse. The TTL version of the timer is fairly robust, but the CMOS type much less so. Check for obvious errors such as lack of supply voltage, incorrect or ambiguous input voltages, and unusual current draw (too high, or none at all, at the V+ pin). Use the meter probes on the actual pins of the chip, in case there is a break in the wiring that feeds them. Because timer chips are cheap, a reserve supply of them should be maintained.

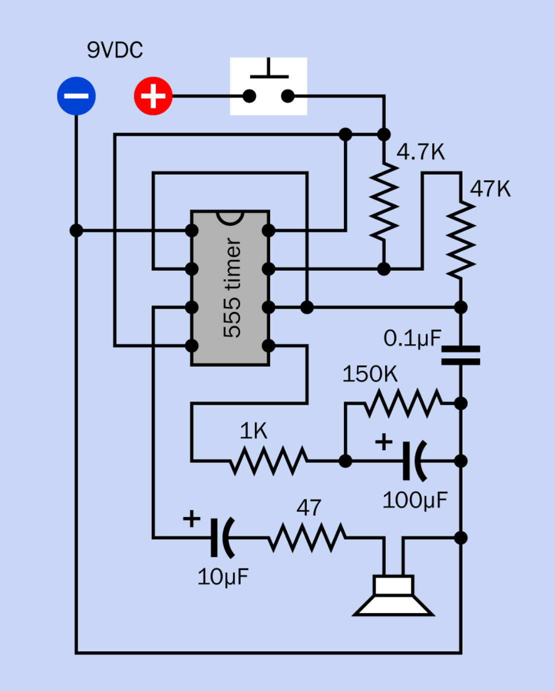

Figure 9-27. *An RC circuit, wired to apply an increasingly positive voltage to the Control pin of a bipolar timer running in astable mode, will gradually pull down the frequency at the Output pin, creating a sound that may be useful in simple game applications.*

CMOS Confused with Bipolar

The part numbers of some bipolar chips are very similar to those of some CMOS versions, and the chips look physically identical. But the CMOS version is easily overloaded, as it may source only 10mA to 20mA maximum while the TTL version is capable of 200mA. Make sure that your chips are carefully labeled when they are stored.

The Pulse that Never Ends

If a 555 timer responds correctly to a high-to-low transition on the input pin, but the output pulse continues indefinitely, check the voltage on pin 6 to see if the timing capacitor is charging above 2/3 of V+. While a 555 can run from 5VDC, a high-current device on the Output pin can pull down the voltage inside the chip to the point where the capacitor never charges sufficiently to end the cycle.

Also check that the input transition from high to low lasts for a shorter time than the pulse. A persistent low input can retrigger the timer.

Erratic Chip Behavior

Possible causes include:

- Floating pins. The Input pin, in particular, should always be connected with a defined voltage (via a 10K pullup resistor, if necessary), and must not be allowed to float at an indeterminate potential.
- Voltage spikes. A timer can be triggered by transients from other components, especially inductive loads. If the input to a monostable timer dips for even a fraction of a second, the timer will initiate a new cycle. A *protection diode* should be used in conjunction with an inductive load.
- Voltage spikes can also introduce variations in the pulse train from an astable timer.
- TTL versions of the 555 timer will tolerate a wide range of supply voltage, but if a voltage regulator is not used, fluctuations in voltage can have unpredictable consequences.

Interference with Other Components

Because the bipolar version of a 555 timer creates a voltage spike when its output changes state, it can interfere with the normal function of other components, especially CMOS chips. A 0.1µF bypass capacitor can be applied between the timer's V+ pin and ground.

Erratic Behavior of Output Devices

If a 555 timer powers an output device such as a relay, and the relay is not opening or closing in a reliable manner, first check that it is receiving sufficient voltage. If the 555 timer is powered with 5VDC, its output will be only around 4VDC.

This problem can be avoided by using the output from the timer to control the voltage on the base of a transistor which switches a separate source of power to the relay coil.

Fatal Damage Caused by Inductive Loads

While it is possible to drive an inductive load such as a small motor or relay directly from a TTL 555 timer, two precautions should be taken. First, the motor or the coil of the relay should have a clamping diode added around it, as is standard practice. Second, because the output of the timer is capable of sinking current as well as sourcing current, it can be protected from sinking back-EMF by inserting a diode in series with the load. This is illustrated in Figure 9-28.

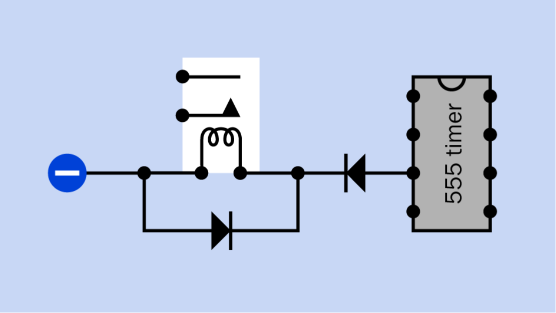

Figure 9-28. *In addition to a standard protection diode clamped around an inductive load such as a relay coil, the 555 timer can be protected from back-EMF by adding a diode in series. The series diode must of course be rated to carry sufficient current through the coil. When choosing a relay, allowance must be made for the voltage drop that will be imposed by the series diode.*

logic gate

10

Only basic **logic gates** are included in this entry—that is, components that perform a Boolean logic operation on two to eight inputs (or one input, in the case of an inverter) to create a single high or low logical output.

OTHER RELATED COMPONENTS

- **flip-flop** (see Chapter 11)

What It Does

A **logic gate** is a circuit that delivers an output, either high or low, depending on the states of its two inputs, either or both of which can be high or low.

Some gates may have more than two inputs, and an *inverter* only has one input, but the basic gates all conform with the two-input, one-output model. The components that constitute a logic gate are almost always etched into a wafer inside a silicon chip.

In a digital computer, a *high logic state* is traditionally close to 5VDC and represents a value of 1 in *binary arithmetic*, while a *low logic state* is traditionally close to 0VDC and represents a binary 0. Modern devices may use a lower voltage for the high state, but the principle is still the same.

A small network of logic gates can perform binary addition, and all other operations in a digital computer are built upon this foundation.

Origins

The concept of digital logic originated in 1894, when English mathematician George Boole announced his invention of a form of algebra (now referred to as *Boolean algebra*) to analyze combinations of two logical states that could be interpreted as "true" and "false." This concept had few practical applications until the 1930s, when Claude Shannon saw that because a basic switch has two states, Boolean algebra could enable analysis of complex networks of switches that were being used in telephone systems.

Because the state of a switch could also be used to represent the values 0 or 1 in binary arithmetic, and because a transistor could function as a switch, Boolean algebra was implemented in solid-state digital computing equipment.

How It Works

While conventional arithmetic uses *arithmetical operators* to represent procedures such as addition or multiplication, Boolean algebra uses *Boolean operators*. The operators of special interest in digital electronics are named AND, NAND, OR, NOR, XOR, and XNOR.

Although each gate actually contains multiple transistors, it is represented by a single logic symbol, as shown in Figure 10-1. The names of the Boolean operators are customarily printed all in caps. A gate requires a power supply and a connection with negative ground, separate from its inputs, but these connections are omitted from gate schematics because they are assumed to exist.

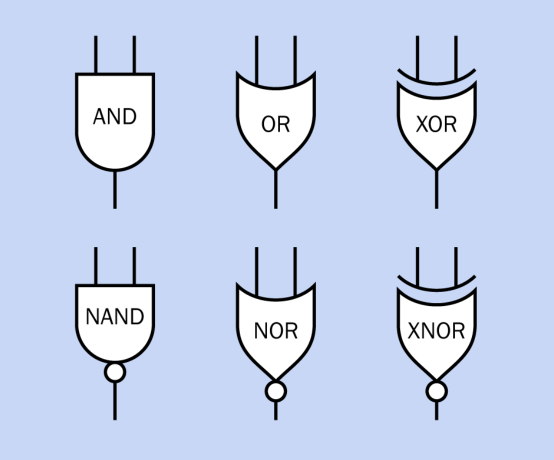

Figure 10-1. *Six types of two-input logic gates are used in digital electronics, although the XNOR gate is rare, as it has few applications. The names are customarily printed in uppercase letters.*

The functions of the gates with two inputs can be defined in electrical terms. In Figure 10-2, the four possible combinations of inputs are tabulated in the left column, with red indicating a high input and black indicating a low input. The corresponding output from each gate is shown beneath its name. This kind of tabulation is known as a *truth table*, as it is derived from Boolean algebra which originally concerned itself with "true" and "false" states.

Input states of a two-input gate		Gate Outputs					
		AND	NAND	OR	NOR	XOR	XNOR
●	●	●	🔴	●	🔴	●	🔴
●	🔴	●	🔴	🔴	●	🔴	●
🔴	●	●	🔴	🔴	●	🔴	●
🔴	🔴	🔴	●	🔴	●	●	🔴

Figure 10-2. *The four possible combinations of input states in a 2-input logic gate are shown at left. The corresponding output from each gate is shown beneath its name. Red indicates a high state, while black indicates a low state.*

The truth table assumes that *positive logic* is being used. Negative logic is very uncommon, but if it were used, the red dots in the truth table would correspond with low inputs and outputs, while the black dots would correspond with high inputs and outputs.

Inversion

The small circles appended to the outputs of NAND, NOR, and XNOR gates mean that the output of each gate is inverted compared with the AND, OR, and XOR gates. This can be seen by inspection of the output states shown in Figure 10-2. The circles are known as *bubbles*.

Sometimes logic symbols are shown with a bubble applied to one input, as in Figure 10-3. In these cases, the circle indicates that an input must be inverted. More than one gate may be needed to achieve this logic function in an actual circuit. The style is often used to show the inner workings of an IC, using a minimum number of logic symbols.

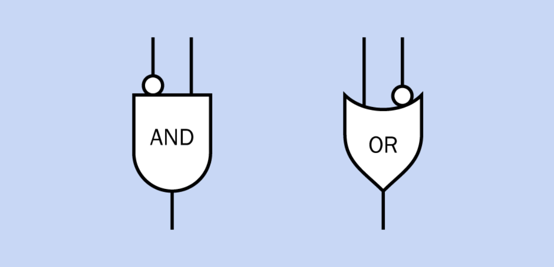

Figure 10-3. *The circle in a logic gate symbol indicates that a signal is being inverted. Circles can be inserted at gate inputs, but in a real circuit a separate inverter is likely to be needed to create this effect.*

Single-Input Gates

Two gates exist that have a single input and a single output, shown in Figure 10-4. The *buffer* should not be confused with the symbol for an **op-amp** or a **comparator**. (Those components always have two inputs.) The output state of a buffer is the same as its input state, but the component may be useful to deliver more current or to isolate one section of a circuit from another.

When a bubble is appended to a buffer, it becomes a NOT gate, more commonly known as an *inverter*. Its function is to create an output state that is opposite to its input state.

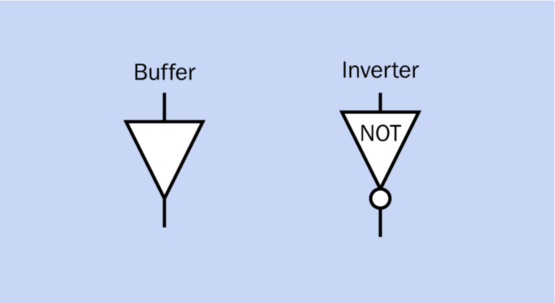

Figure 10-4. *The two logic gates that have only one input and one output. Note that in some schematics showing internal logic of ICs, the bubble on an inverter may be found on the input side instead of the output side.*

Gates with More than Two Inputs

AND, NAND, OR, and NOR gates can have any number of inputs, as suggested in Figure 10-5, although practical factors usually limit the inputs to a maximum of eight.

Input states of a gate with more than two inputs	Gate Outputs			
	AND	NAND	OR	NOR
All low	⚫	🔴	⚫	🔴
All high	🔴	⚫	🔴	⚫
At least 1 low and at least 1 high	⚫	🔴	🔴	⚫

Figure 10-5. *The previous table has been modified to show the outputs from logic gates that have more than two inputs. XOR and XNOR gates are not included in the table, because a strict interpretation of their logic requires that a unique output state exists if one input is high while the other is low.*

The rules can be summarized like this:

- Output from an AND gate: Low if any of its inputs is low, high if all of its inputs are high.
- Output from a NAND gate: High if any of its inputs is low, low if all of its inputs are high.
- Output from an OR gate: High if any of its inputs is high, low if all of its inputs are low.
- Output from a NOR gate: Low if any of its inputs is high, high if all of its inputs are low.

In the case of XOR and XNOR gates, their logic requires that a unique output state must exist if one input is high while the other input is low.

In fact, so-called three-input XOR gates do exist, an example being the 74LVC1G386 chip, in which the output is high if all three inputs are high, or if one input is high, but not if two inputs are high or no inputs are high. Further discussion of more-than-two-input XORs is outside the scope of this encyclopedia.

Boolean Notation

For reference, the original written notation for Boolean operators is shown in Figure 10-6. Unfortunately, the notation for these operators was never properly standardized, and in more than one instance, multiple symbols acquired the same meaning. The letters P and Q are often, but not always, used to represent two input states that can be true or false.

- The use of a horizontal line above a symbol, to indicate that its state has been reversed, has carried over to datasheets where this notation can show that an output state from any digital chip is inverted. The line is known as a *bar*.

Arithmetical Operations

Suppose we wish to sum two binary numbers, each containing two digits. There are four digits altogether, and depending on their values, there are 16 different possible addition sums, as shown in Figure 10-7.

If A0 and B0 represent the rightmost digits of the two numbers being added, and S0 is the sum of those two digits, inspection of the figure shows that the sum can be derived using just three rules:

1. If A0 = 0 and B0 = 0, then S = 0.
2. If A0 and B0 have opposite states, then S0 = 1.
3. If A0 = 1 and B0 = 1, then S0 = 0, and carry 1 to the next place left.

If A0 and B0 are the two inputs to an XOR logic gate, the output of the gate satisfies all three rules, except the need to carry 1 to the next place left. This last function can be satisfied with an AND gate. The function of two gates is known as a *half adder*, and is shown in the top section of Figure 10-8.

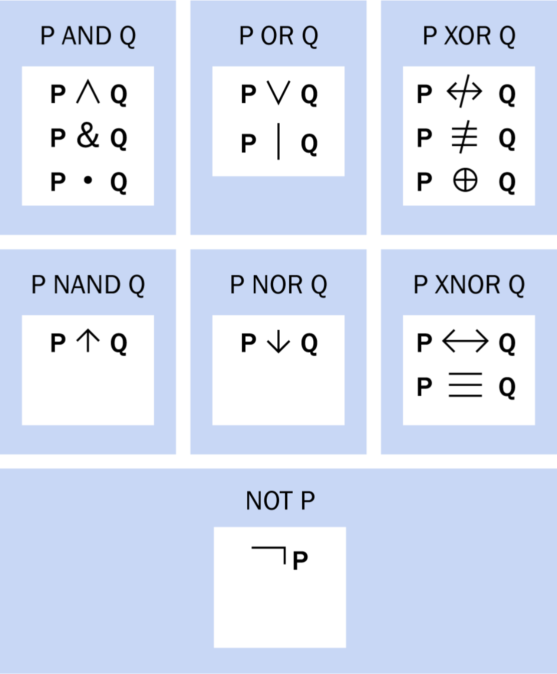

Figure 10-6. *Boolean operators as they have been expressed in written notation. Lack of standardization has resulted in more than one symbol representing some of the operators.*

When we consider the next pair of binary digits to the left, the situation now becomes more complicated, because we may be carrying 1 into this addition sum from the previous stage, and we still need to be able to to carry 1 out (if necessary) to the next stage. An assembly of five logic gates can deal with this, and their combination is known as a *full adder*. This is shown in the bottom section of Figure 10-8.

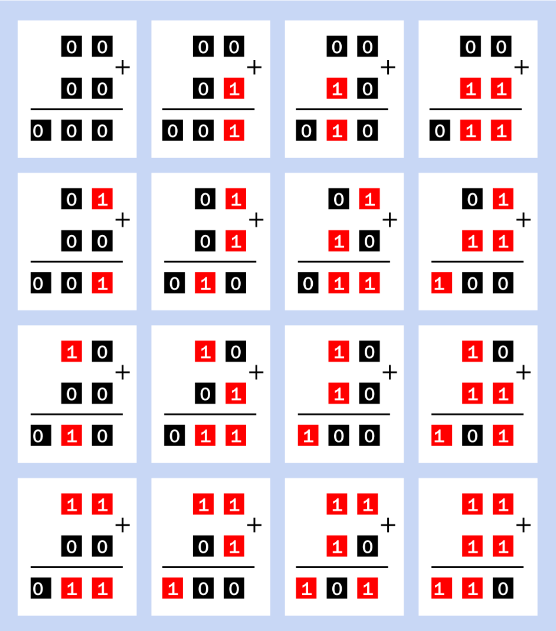

Figure 10-7. *Sixteen different addition sums are possible, when summing two binary numbers of two digits each.*

The combination of XOR and AND gates shown in Figure 10-8 is not the only one that works to add binary numbers. However, it may be the most intuitively obvious.

Other Operations

Binary arithmetic remains the most important application of logic gates, but individually packaged gates are seldom used for that purpose anymore. They were long since subsumed into large multifunction computing chips.

Single gates still have application in small systems, or to modify the inputs and outputs of microcontrollers, or to convert the output from one complex digital chip to make it compatible with the input of another. This last application is often referred to as *glue logic*.

Applications for single gates are discussed in "How to Use It" on page 103.

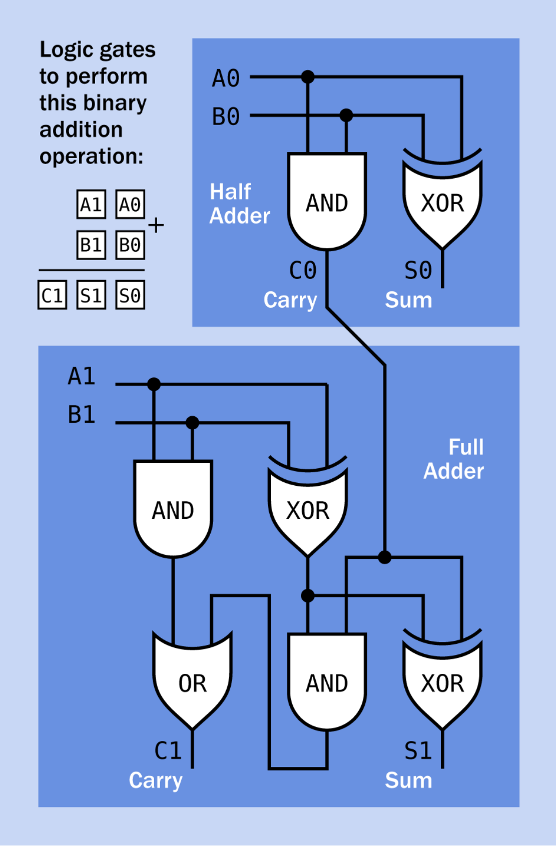

Figure 10-8. *Logic gates can be used to add binary numbers, using a high input or output to represent a binary 1 and a low input or output to represent a binary 0. This schematic shows one possible way for gates to add two two-digit binary numbers.*

Variants

Chips containing logic gates were introduced in the 1960s. The 7400 NAND chip, from Texas Instruments, was the first of a series that became so influential, the same basic part numbers (with letters added before, after, and among the digits) are still used today. An example of a currently available through-hole 7400 chip is shown in Figure 10-9.

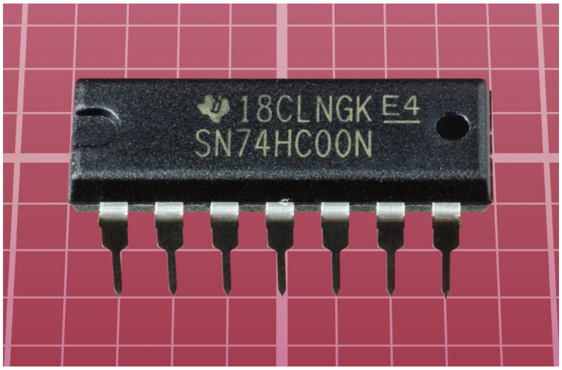

Figure 10-9. *A modern version of a 7400 chip containing four NAND gates.*

Initially, these chips conformed with a *transistor-transistor logic* (*TTL*) standard that had been invented at TRW in 1961 and introduced in commercial products by Sylvania in 1963. It established the now-familiar standard of 5VDC for the power supply. Many logic chips now use other voltages, but the term "high" still means an input or output that is near to the supply voltage, while "low" means an input or output that is near to negative ground. The exact definition of "near" will be found in datasheets for the chips.

The *7400 series* was successful partly because it was engineered for compatibility. The output from one gate could be connected directly to the input of another gate, with a few bypass capacitors added on a circuit board to suppress voltage spikes caused by rapid switching. Earlier components had not been so easy to interface with each other. The new standard dominated the industry to the point where dozens of manufacturers started making chips that conformed with it, and a single board could mix-and-match chips from multiple vendors.

Because many logic chips acquired part numbers that began with 74, they are often referred to as the 74xx series, where other digits (sometimes more than two) can be substituted for xx. This avoids ambiguity, as the very first chip in this format was a NAND gate that had 7400 as its actual part number. In the text below, 7400 will refer to that specific chip, whereas 74xx will refer to the whole series of chips.

RCA introduced a competing family of logic gates in 1968, using CMOS transistors. As each part number began with a 4 and contained four digits, this was referred to as the *4000 series*. The CMOS chips were slower and more expensive, but tolerated a wider range of power supply voltages (3V to 12V, initially). Their biggest advantage was that they used much less current. This was important, as TTL chips created a lot of waste heat. The lower power consumption of CMOS also enabled one chip to control the inputs of many others, which simplified circuit design. This one-to-many relationship is known as *fanout*.

Ultimately, CMOS chips transcended their early limitations. While they were reserved initially for battery-powered devices in which very low power consumption was more important than speed, CMOS is now used almost everywhere, still maintaining its advantage of low current (almost zero, in fact, while a chip is quiescent) while equalling the speed of TTL. However, CMOS logic chips are very often pin-compatible with the old TTL components, and modern CMOS part numbers are often derived from the old 74xx series.

Most CMOS logic chips in the old 4000 series are still available, and may be used in situations where a power supply greater than 5VDC is convenient.

Part Numbers

As the performance of semiconductors gradually improved, successive *families* of logic chips were introduced, identified by one-letter, two-letter, or three-letter acronyms. The acronym was inserted into the part number, so that a 7400 NAND gate in the HC (high-speed CMOS) family became a 74HC00 NAND gate.

Because these chips were available from multiple sources, the part number was also preceded with one or more letters indicating the manufacturer. And because each chip was manufactured in different versions (for example, some complied with military specifications, while others didn't), letters were also appended to the end of the part number. Today, the appended letters may indicate whether the chip is of the old through-hole format, or conforms with a more recent surface-mount format.

Summing up:

- Prefix: manufacturer ID.
- Numerals, omitting any letters in the middle: Chip functionality.
- Middle letters: Chip family.
- Suffix letters: Package format.

Thus, for example, the actual part number for a 74HC00 NAND chip could be SN74HC00N, where the SN prefix indicates that it is manufactured by Texas Instruments and the N suffix means that it is in plastic dual-inline-pin (DIP) format. (The SN prefix was introduced by Texas Instruments in the earliest days of integrated circuits as an acronym for "semiconductor network," meaning that multiple transistors were "networked" on a wafer of silicon. Other manufacturers used their own schemes for part numbering, and so SN became exclusively identified with Texas Instruments.)

The system of augmenting part numbers has been further extended by inserting 1G, 2G, or 3G immediately after the family identifier, to indicate surface-mount chips that contain one, two, or three logic gates. If the "G" identifier is missing, the chip usually has four logic gates, which was the standard used in the original 74xx series. This rule applies even in surface-mount formats, where the surface-mount pads of four-gate chips have the same functions as the pinouts of the original TTL versions (except in the case of square-format surface-mount chips, which are not discussed here).

When searching a catalog to find a chip by its part number, it helps to remember that searching for a 7400 chip may not find any hits, but searching for a 74HC00 (or any other valid number containing a family identifier) is much more likely to be understood.

A key to understanding part numbers is shown in Figure 10-10. The upper part of the figure is a guide to interpreting numbers on a generic basis, while the lower part interprets the specific part number shown.

Families

As of 2013, the HC family in the 74xx series has become so widely used, it can be considered the default in the traditional DIP 14-pin format. Incremental improvements are still being made, and new families are being introduced, primarily in surface-mount formats which use lower power-supply voltages (down to around 1VDC).

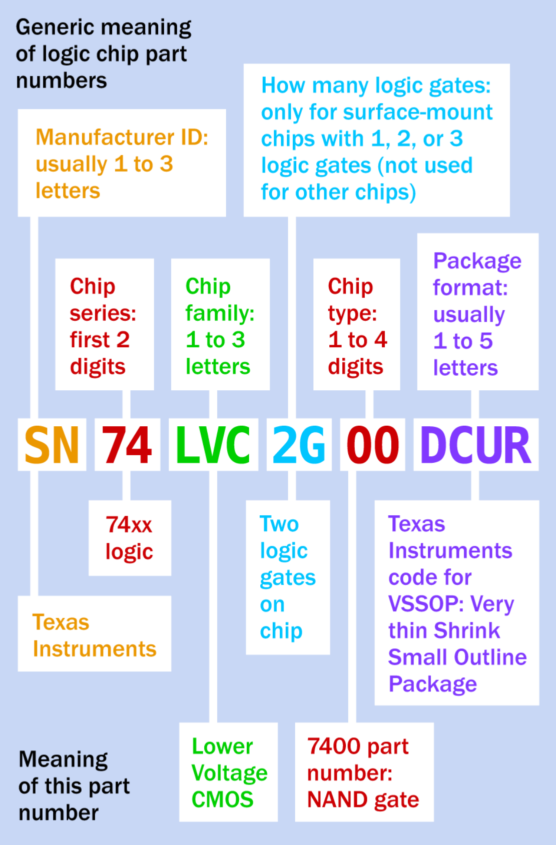
Generic meaning of logic chip part numbers
Manufacturer ID: usually 1 to 3 letters
How many logic gates: only for surface-mount chips with 1, 2, or 3 logic gates (not used for other chips)
Chip series: first 2 digits
Chip family: 1 to 3 letters
Chip type: 1 to 4 digits
Package format: usually 1 to 5 letters
SN 74 LVC 2G 00 DCUR
74xx logic
Two logic gates on chip
Texas Instruments code for VSSOP: Very thin Shrink Small Outline Package
Texas Instruments
Meaning of this part number
Lower Voltage CMOS
7400 part number: NAND gate

Figure 10-10. *How to interpret the segments of a logic chip part number in the 74xx family (in this case, a 7400 NAND gate).*

Here is an historical summary of the most important chip families.

- 74xx: Original series of bipolar TTL chips.
- 74Hxx: Bipolar TTL, high speed, about twice as fast as the original 74xx chips, but twice the power consumption.
- 74Lxx: Bipolar TTL, lower power consumption than the original TTL, but also much lower speed.
- 74LSxx: Bipolar TTL, lower power with Schottky input stages, faster than original TTL. Some LS chips are still being manufactured.
- 74ASxx: Bipolar TTL, Advanced Schottky, intended to supercede the 74Lxx.
- 74ALSxx: Bipolar TTL, Advanced Low Power Schottky, intended to supercede the 74LSxx.
- 74Fxx: Bipolar TTL, Faster.
- 74HCxx: CMOS high-speed emulation of 74LSxx.
- 74HCTxx: CMOS but with similar high-state input voltage threshold to bipolar TTL chips, for compatibility.
- 74ACxx: Advanced CMOS.
- 74ACTxx: Advanced CMOS emulation of TTL with similar high-state input voltage threshold to TTL, for compatibility.
- 74AHCxx: Advanced Higher-Speed CMOS, three times as fast as HC.
- 74VHCxx: Very High Speed CMOS.
- 74AUCxx, 74FCxx, 74LCXxx, 74LVCxx, 74ALVCxx, 74LVQxx, 74LVXxx: Various specifications, many using power supply voltages of 3.3V or below.

In the 4000 series, an early significant improvement was the 4000B family, which allowed a higher power supply limit (18V instead of 12V) and was much less susceptible to damage by static discharge. The 4000B family almost totally replaced the old 4000 family, and most 4000B chips are still available, as they are useful in situations where a power supply delivers more than 5VDC.

- When it is referenced casually, the B at the end of a chip number in the 4000 series may be omitted. When the number is listed in a catalog, the B is included.

Chips with 45 as their first two digits were introduced as a new generation, but were not widely adopted. After that, the 4000 series ceased to evolve, and CMOS chips adopted 74xx part numbers, distinguishing themselves by the insertion of letter groups in the center of the number.

To add to the confusion, some 4000 series part numbers were appended to 74xx part numbers, so that, for example, the 74HCT4060 is designed to be compatible with the old 4060B chip.

Family Interoperability

One of the most important issues relating to chip families is their differing specifications for a low-state voltage and a high-state voltage in inputs and outputs.

The original 74xx TTL series, using a 5VDC power supply, used these approximate specifications:

- Output: 74xx voltage representing a low state (at most 0.4V to 0.5V)
- Input: 74xx input voltage interpreted as a low state (maximum 0.8V)
- Output: 74xx voltage representing a high state (at least 2.4V to 2.7V)
- Input: 74xx input voltage interpreted as a high state (minimum 2V)

This provided a safe margin of error of at least 0.4V when chips were communicating with each other.

In the CMOS 4000 family, however, logic chips required a minimum input of 3V to 3.5V to be interpreted as a high state. The minimum acceptable output from a TTL chip was below this level, creating problems if anyone should try to use the output from a TTL chip to communicate with an input on a CMOS chip.

One solution is to add a 4.7K pullup resistor to the TTL output, guaranteeing that it won't fall too low. But this wastes power, and the need for the resistor is easily forgotten. Another option is to use the HCT or ACT family of CMOS logic. The "T" in these family names indicates that they have been engineered to share the input standards of the old TTL chips. They still deliver the same high output as other types of CMOS, making them seem to be the best possible solution. Unfortunately, it does entail a compromise: the "T" chips are more sensitive to noise, among other factors.

- Ideally, chip families should not be intermingled.

Gates per Chip

Each of the original 74xx chips contained multiple gates within the limits of a uniform 14-pin through-hole format. The gates that were most commonly used had two inputs, and there were four of these gates per chip.

However, the desire for miniaturization, and the use of automatic chip-placement and soldering equipment, made one-gate and two-gate logic chips desirable and practical in surface-mount format. (Three-gate surface-mount chips exist, but are sufficiently unusual that they are not described in this encyclopedia.)

Two Inputs, Single Gate

Where a chip contains just one logic gate, it is almost always a surface-mount component, and the part number has 1G in the middle to indicate "one gate." Pad functions are shown in Figure 10-11. The layout is standardized for all logic gates, with the exception of XNOR gates, which are not manufactured in surface-mount format.

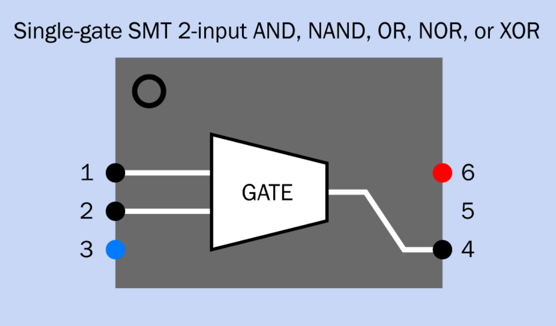

Figure 10-11. *Internal configuration and solder-pad functions for a two-input surface-mount single-gate logic chip that can contain an AND, NAND, OR, NOR, or XOR gate. XNOR gates are not manufactured in this format.*

In the figure, a gate is shown in generic form, indicating that it may be an AND, NAND, OR, NOR, or XOR gate, depending on the part number of the chip. Inputs are on the left of the gate, while its output is on the right. The chip does not have a solder pad in position 5, but the pad at top right is identified as pin 6 for consistency with the numbering pattern in other surface-mount components where six pads are common.

The generic part numbers for single-gate surface-mount two-input logic chips are shown here, with letter x indicating that letter sequences are likely to be inserted to indicate manufacturer, logic family, and chip format:

- AND gate: x74x1G08x
- OR gate: x74x1G32x
- NAND gate: x74x1G00x
- NOR gate: x74x1G02x
- XOR gate: x74x1G86x

Three Inputs, Single Gate

AND, NAND, OR, and NOR single gates are available with more than two inputs. Their output is determined by rules shown in Figure 10-5. XOR and XNOR gates are not included in the table, because a strict interpretation of their logic requires that a unique output state exists if one input is high while the other is low.

The pad functions for a surface-mount single-gate logic chip with three inputs are shown in Figure 10-12. The generic part numbers for these chips are shown below. Again, each x indicates that letter sequences are likely to be inserted to indicate manufacturer, logic family, and chip format.

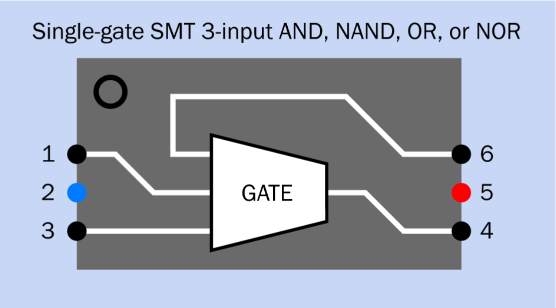

Figure 10-12. *Internal configuration and solder-pad functions for a three-input surface-mount single-gate logic chip that can contain an AND, NAND, OR, or NOR gate.*

The generic part numbers for single-gate surface-mount three-input logic chips are shown here, with each x indicating that letter sequences are likely to be inserted to indicate manufacturer, logic family, and chip format:

- AND: x74x1G11x
- NAND: x74x1G10x
- OR: x74x1G32x
- NOR: x74x1G27x

Single Gate, Selectable Function

A few surface-mount chips can emulate a variety of two-input gates, by using appropriate external connections. The internal logic of one example, with generic part number x74x1G97x (an actual example would be Texas Instruments SN74LVC1G97), is shown in Figure 10-13. Depending which pin is grounded and which other pins are used as inputs, the chip can emulate all five of the most commonly used gates. To achieve this, however, some inputs have to be inverted.

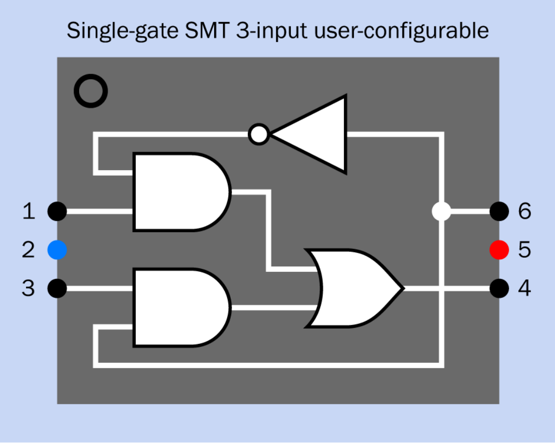

Figure 10-13. *Internal configuration for a configurable surface-mount chip that can emulate various two-input logic gates, depending which inputs are used and which are grounded. Some inputs have to be inverted to emulate some gates.*

Two Inputs, Dual Gate

Two-input surface-mount AND, NAND, OR, NOR, and XOR gates are available in dual layout (two gates per chip). The internal logic and pad functions are shown in Figure 10-14. The generic part numbers for these chips are shown here. Again, each x indicates that letter sequences are likely to be inserted to indicate manufacturer, logic family, and chip format.

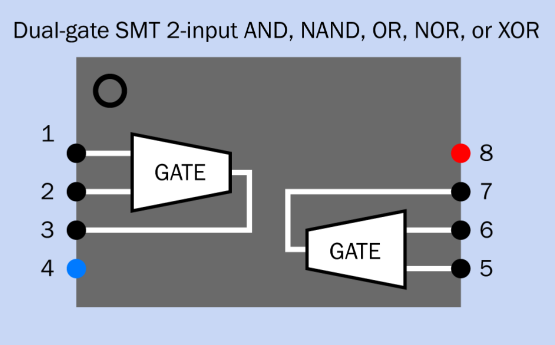

Figure 10-14. *Internal configuration and solder-pad functions for a two-input surface-mount dual-gate logic chip that can contain two AND, NAND, OR, NOR, or XOR gates. XNOR chips are not manufactured in this format.*

The generic part numbers for dual-gate surface-mount two-input logic chips are shown below, with each x indicating that letter sequences are likely to be inserted to indicate manufacturer, logic family, and chip format:

- AND: x74x2G08x
- NAND: x74x2G00x
- OR: x74x2G32x
- NOR: x74x2G02x
- XOR: x74x2G86x

Original 74xx 14-Pin Format

Each of the original 74xx TTL chips contained multiple gates within the limits of a uniform 14-pin chip format. The available options were, and still are:

- Quad 2-input: Four gates with two inputs each
- Triple 3-input: Three gates with three inputs each
- Dual 4-input: Two gates with four inputs each
- Dual 5-input: Two gates with five inputs each
- Single 8-input: One gate with eight inputs

The five-input chips have become so uncommon that they are not described in this encyclopedia.

Quad Two-Input 74xx Pinouts

14-pin DIP 74xx quad two-input logic chips are available in AND, NAND, NOR, XOR, or XNOR versions, all of which have an internal layout shown in Figure 10-15. The layout is unchanged in surface-mount format. The gates are shown in generic form, as the layout remains the same regardless of which type of gate is in the chip. All the gates in any one chip are of the same type. The four connections leading to a gate are its inputs, while the single connection from a gate is its output.

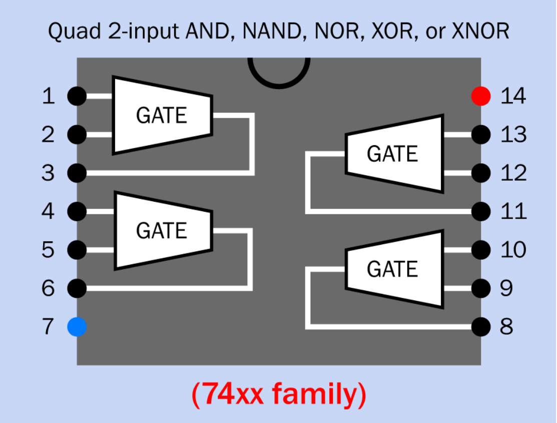
Quad 2-input AND, NAND, NOR, XOR, or XNOR
1
2
3
4
5
6
7
14
13
12
11
10
9
8
GATE
GATE
GATE
GATE
(74xx family)

Figure 10-15. *In a 14-pin quad two-input 74xx logic chip, the AND, NAND, NOR, XOR, and XNOR versions all share this generic layout.*

- The 14-pin quad two-input OR chip has different pinouts from all the other 74xx logic chips. It is shown in Figure 10-16.

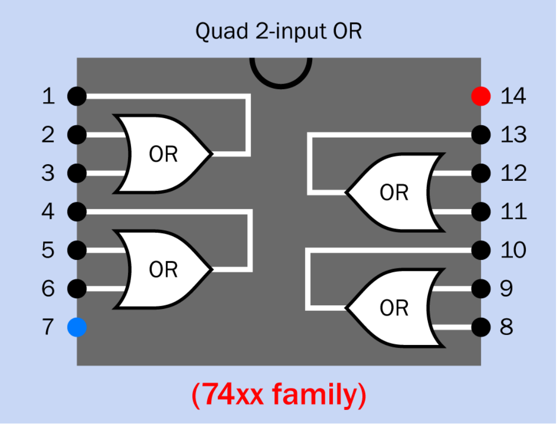
Quad 2-input OR
1
2
3
4
5
6
7
14
13
12
11
10
9
8
OR
OR
OR
OR
(74xx family)

Figure 10-16. *In a quad two-input 74xx OR chip, this layout is used, which is different from that used in all the other quad two-input logic gates.*

Triple Three-Input 74xx Pinouts

The AND, NAND, and NOR versions of a 14-pin DIP 74xx triple three-input logic chip all have an internal layout shown in Figure 10-17. The layout is unchanged in surface-mount format. The gates are shown in generic form, as the layout remains the same regardless of which type of gate is in the chip. All the gates in any one chip are of the same type. Three connections leading to a gate are its inputs, while a single connection from a gate is its output.

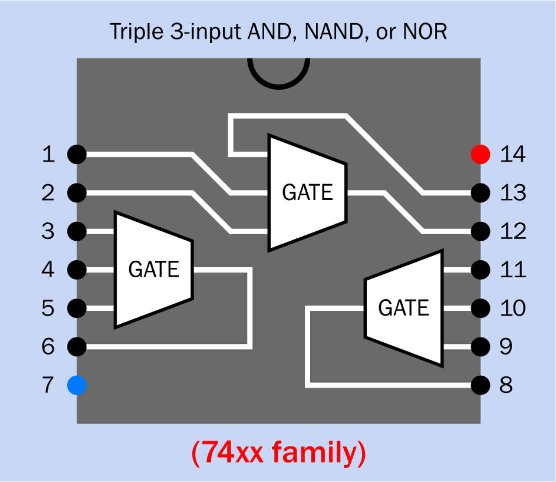
Triple 3-input AND, NAND, or NOR
1
2
3
4
5
6
7
14
13
12
11
10
9
8
GATE
GATE
GATE
(74xx family)

Figure 10-17. *In a 14-pin triple three-input 74xx logic chip, the AND, NAND, and NOR versions all share this generic layout.*

- The 14-pin triple three-input OR chip has different pinouts from all the other 74xx logic chips. It is shown in Figure 10-18.

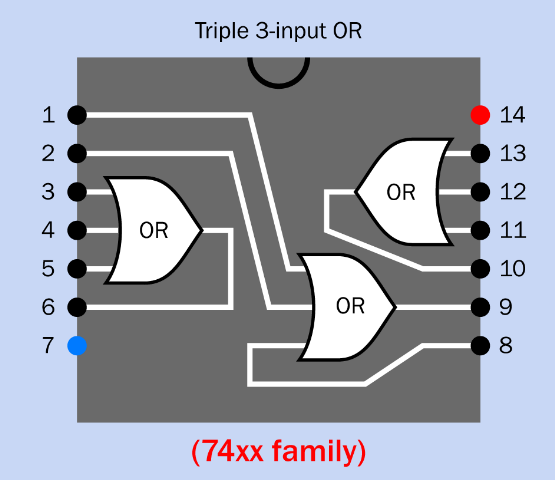
Triple 3-input OR
1
2
3
4
5
6
7
14
13
12
11
10
9
8
OR
OR
OR
(74xx family)

Figure 10-18. *In a triple three-input 74xx OR chip, this layout is used, which is different from that used for all the other triple three-input logic gates.*

Dual Four-Input 74xx Pinouts

A 14-pin DIP 74xx dual four-input logic chip contains two four-input gates. The AND, NAND, and NOR versions all have an internal layout shown in Figure 10-19. The layout is unchanged in surface-mount format. The gates are shown in generic form, as the layout remains the same regardless of which type of gate is in the chip. All the gates in any one chip are of the same type.

- There is no OR chip of the 14-pin dual four-input type.

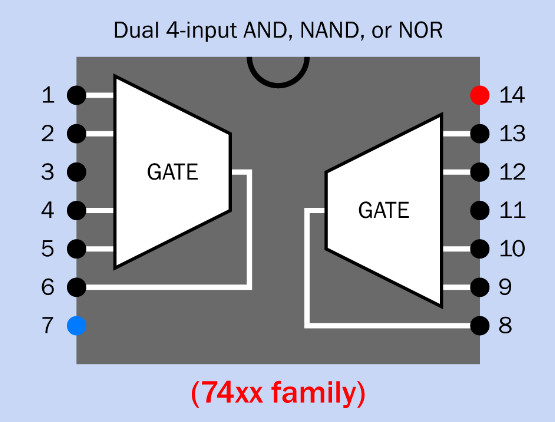

Figure 10-19. *In a 14-pin dual four-input 74xx logic chip, the AND, NAND, and NOR versions all share this generic layout. There is no 74xx OR chip with four inputs per gate.*

Single Eight-Input 74xx Pinouts

A 14-pin DIP 74xx single eight-input NAND chip contains one eight-input gate, as shown in Figure 10-20. The layout is unchanged in surface-mount format.

- There is no AND chip of the 14-pin single eight-input type.

A 14-pin eight-input logic chip in the 74xx series, able to function as both an OR and a NOR, is shown in Figure 10-21. The output from the NOR gate is connected with pin 13, but also passes through an inverter to create an OR output at pin 1. (Because a NOR gate is equivalent to an inverted-OR, when its output is inverted again, it returns to being an OR.)

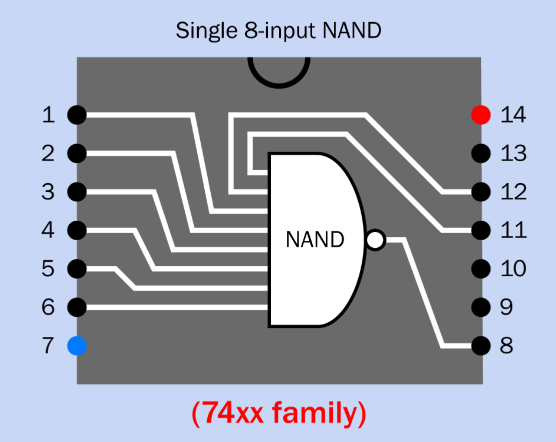

Figure 10-20. *The internal layout of single eight-input NAND chip in the 14-pin 74xx series. There is no 74xx AND chip with eight inputs per gate.*

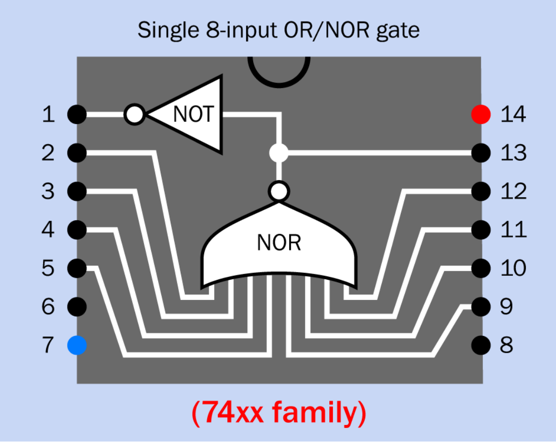

Figure 10-21. *The internal layout of single eight-input OR/NOR chip in the 14-pin 74xx series. Pin 13 has the NOR output, while pin 1 has the OR output.*

The following list shows the generic part numbers for DIP and surface-mount versions of 14-pin logic chips in the 74xx series that have two or more inputs per gate. As before, an x indicates that letter sequences are likely to be inserted to indicate manufacturer, logic family, and chip format.

- Quad 2-input AND: x74x08x
- Quad 2-input NAND: x74x00x
- Quad 2-input OR: x74x32x
- Quad 2-input NOR: x74x02x
- Quad 2-input XOR: x74x86x
- Quad 2-input XNOR: x74x266x
- Triple 3-input AND: x74x11x
- Triple 3-input NAND: x74x10x
- Triple 3-input OR: x74x4075x
- Triple 3-input NOR: x74x27x
- Dual 4-input AND: x74x21x
- Dual 4-input NAND: x74x20x
- Dual 4-input NOR: x74x4002x
- Single 8-input NAND: x74x30x
- Single 8-input OR/NOR: x74x4078x

74xx Inverters

Single, dual, and triple inverter packages in the 74xx series are available in surface-mount format only. Their internal arrangement is shown in Figures 10-22, 10-23, and 10-24.

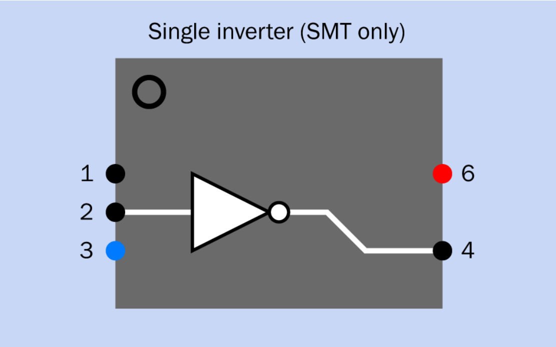

Figure 10-22. *The internal layout of a 74xx series logic chip containing one inverter. This is available in surface-mount format only. Pin 5 is absent. Pin 1 is not connected.*

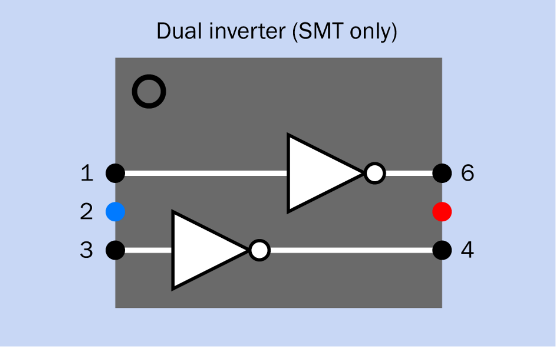

Figure 10-23. *The internal layout of a 74xx series logic chip containing two inverters. This is available in surface-mount format only.*

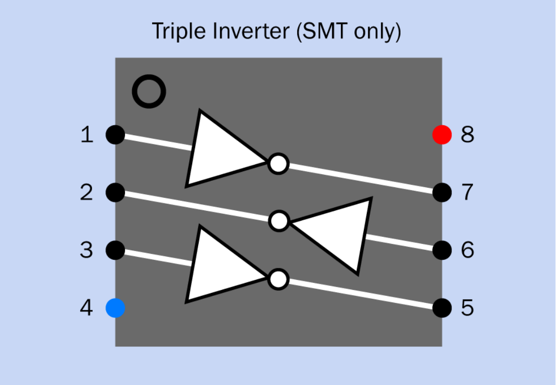

Figure 10-24. *The internal layout of a 74xx series logic chip containing three inverters. This is available in surface-mount format only.*

In the 14-pin format, a hex inverter chip (containing six inverters) is available, as shown in Figure 10-25. The layout is the same for DIP and surface-mount formats.

Generic part numbers for inverter chips are as follows:

- Single inverter: x74x1G04x
- Dual inverter: x74x2G04x
- Triple inverter: x74x3G14x
- Hex inverter: x74x04x

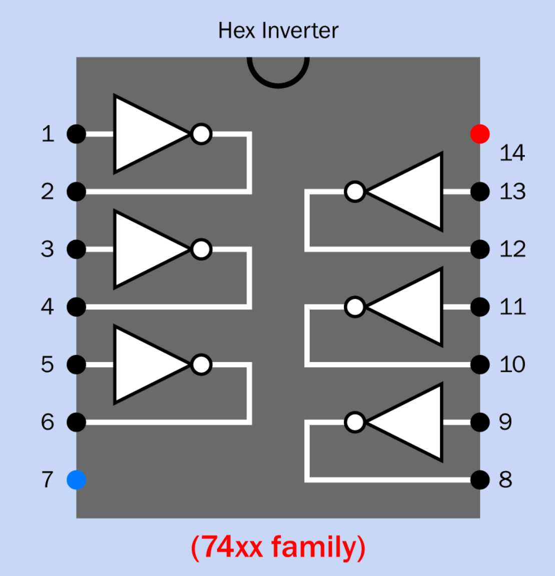

Figure 10-25. *The internal layout of a 14-pin 74xx hex inverter logic chip, containing six inverters. This layout is the same for DIP and surface-mount versions.*

Additional Variations

Some chips in the 74xx series (both DIP and surface mount versions) have variants with open drain or open collector outputs, while others have inputs that are configured as Schmitt triggers. These variants will be found as hits when searching supplier websites for logic chips by gate name and number of inputs.

Pinouts in the Original 4000 Series

Each of the original 4000 CMOS chips contained multiple gates within the limits of a uniform 14-pin chip format. The available options were, and still are:

- Quad 2-input: Four gates of two inputs each
- Triple 3-input: Three gates of three inputs each
- Dual 4-input: Two gates of four inputs each
- Single 8-input: One gate of eight inputs

In the 4000 family, 14-pin quad two-input logic chips are available in AND, OR, NAND, NOR, XOR, or XNOR versions, all of which have an internal layout shown in Figure 10-26. The gates are shown in generic form, as the layout remains the same regardless of which type of gate is in the chip. All the gates in any one chip are of the same type. The four connections leading to a gate are its inputs, while the single connection from a gate is its output.

Unlike the 74xx family, the quad two-input OR chip in the 4000 family has the same pinouts as the other types of quad two-input logic chips.

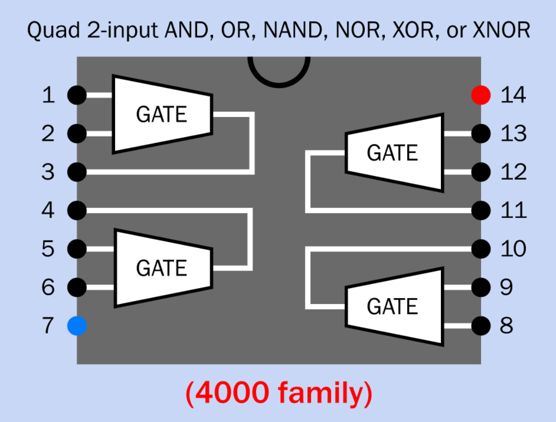

Figure 10-26. *In the 4000 family, the AND, OR, NAND, NOR, XOR, and XNOR versions of a quad two-input logic chip all share this generic layout.*

In the 4000 family, a 14-pin triple three-input logic chip contains three three-input gates. The AND, OR, NAND, and NOR versions all have an internal layout shown in Figure 10-27. The gates are shown in generic form, as the layout remains the same regardless of which type of gate is in the chip. All the gates in any one chip are of the same type. The three connections leading to a gate are its inputs, while a single connection from a gate is its output.

Unlike the 74xx family, the triple three-input OR chip in the 4000 family has the same pinouts as the other types of triple three-input logic chips.

In the 4000 family, a 14-pin dual four-input logic chip contains two four-input gates. The AND, NAND, OR, and NOR versions all have an internal layout shown in Figure 10-28. The gates are shown in generic form, as the layout remains the same regardless of which type of gate is in the chip. All the gates in any one chip are of the same type. Each pair of connections leading to a gate are its inputs, while the single connection from a gate is its output.

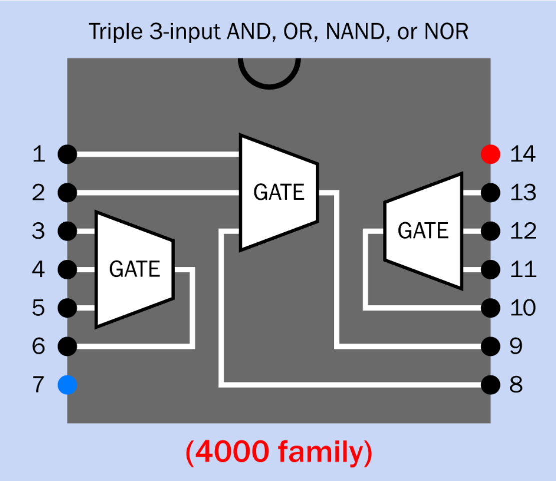

Figure 10-27. *In the 4000 family, the AND, OR, NAND, and NOR versions of a triple three-input logic chip all share this generic layout.*

Note that the 4000 family does have a dual four-input OR chip, whereas the 74xx family does not.

In the 4000 family, a 14-pin eight-input logic chip with AND and NAND outputs is available, as shown in Figure 10-29.

The following list shows the generic part numbers for 14-pin logic chips in the 4000 family that have two or more inputs per gate (in actual part numbers, letters will be substituted where an x appears):

- Quad 2-input AND: x4081x
- Quad 2-input NAND: x4011x
- Quad 2-input OR: x4071x
- Quad 2-input NOR: x4001x
- Quad 2-input XOR: x4070x
- Quad 2-input XNOR: x4077x
- Triple 3-input AND: x4073x
- Triple 3-input NAND: x4023x
- Triple 3-input OR: x4075x
- Triple 3-input NOR: x4025x
- Dual 4-input AND: x4082x
- Dual 4-input NAND: x4012x
- Dual 4-input OR: x4072x
- Dual 4-input NOR: x4002x
- Single 8-input AND/NAND: x4068x

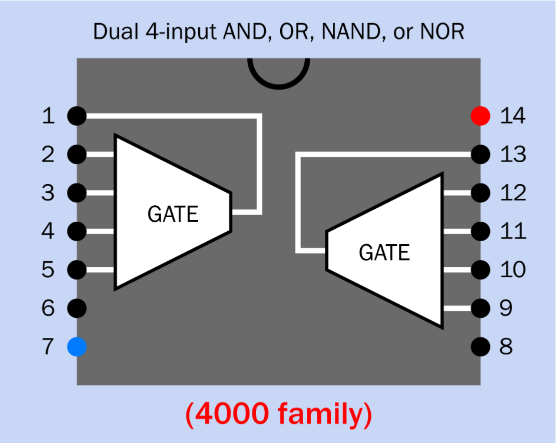

Figure 10-28. *In the 4000 family, the AND, OR, NAND, and NOR versions of a dual four-input logic chip all share this generic layout.*

4000 Series Inverters

In the 4000 family, the 4069B is a 14-pin hex inverter chip (containing six inverters), as shown in Figure 10-30. This has the same pinouts as the x74x04x chip.

How to Use It

Which Family

In DIP format, the HC family has existed for more than 30 years, and has become established as a widely used default choice.

In surface-mount formats, the choice of family will largely be determined by the choice of supply voltage.

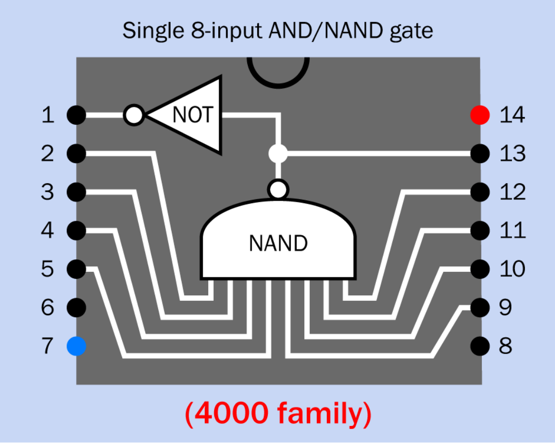

Figure 10-29. *In the 4000 family, a single eight-input AND/NAND chip has this internal layout. The inverted output from the NAND gate becomes an AND output from pin 1 of the chip.*

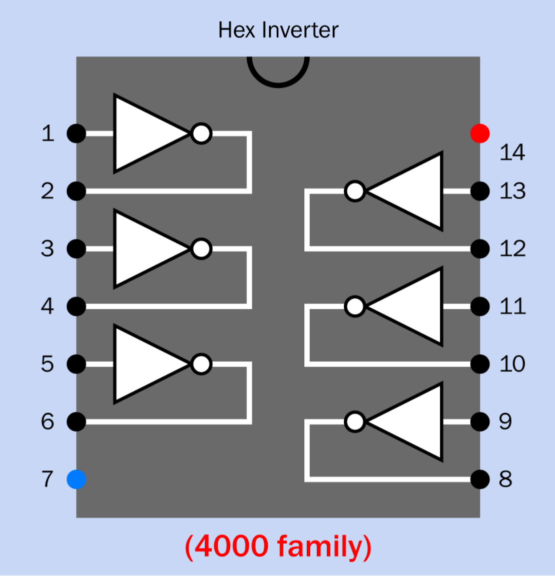

Figure 10-30. *The internal layout of a 14-pin 4069B hex inverter logic chip, containing six inverters. This layout is the same as for the x74x04x chip.*

Although the 4000 series is now more than 40 years old, it may still be useful where a 5VDC power supply is not required for other reasons in a circuit and would be added purely to power a 74xx series logic gate or other digital chip. If a circuit contains a 9VDC or 12VDC relay, for instance, a Darlington pair may be used with that voltage to drive the relay, and an old-school 4000 series logic chip could share the same supply. The relay coil would need a clamping diode to protect the logic chip from transients.

Applications

The output from a logic chip may be used as an input for a microcontroller, to enable multiple inputs to share one pin. An eight-input NAND gate, for instance, could combine the inputs from eight normally on motion sensors. If just one sensor responds to an intrusion, the gate output would change from high to low.

Logic gates may be useful in any simple device that has to respond to a single, specific combination of inputs. A digital combination lock is one example; games of chance are another. Most simple dice simulations use logic gates to convert the output from a counter to drive a dice-pattern of LEDs.

A logic gate may be used as an interface between an electromechanical **switch** and a circuit containing digital chips. A 10K pullup or pulldown resistor prevents the gate input from floating when the switch is open. A buffer can be used for this purpose, or an inverter, or any "spare" gate on a logic chip that is already in the circuit. One input of the chip can be tied to the positive power supply or negative ground, to create an appropriate input from the chip when the switch, attached to the other input, is opened or closed.

A jam-type **flip-flop** can be used to *debounce* a switch input. See Chapter 11 for details. If two NOR or two NAND gates are unused in a circuit, they can form a flip-flop.

In the original CMOS 4000 family, a positive output may be capable of driving an LED if the current does not exceed 5mA with a power supply of 5VDC or 10mA with a power supply of 10VDC. Note that the output voltage will be pulled down significantly by these loads. In the 74HCxx family, chips can source or sink as much as 20mA, but here again the output voltage will be pulled down. Note that the total limit for all outputs from a 74HCxx chip is around 70mA.

The output from a logic chip can be passed through a buffer such as the 7407, which has an open-collector output capable of sinking as much as 200mA. This enables direct drive of modest loads, so long as they are not inductive.

Solid-state relays and **optocouplers** can be driven directly from logic chips, as they draw very little current. A solid-state relay can switch 50A or more.

What Can Go Wrong

Two problems are common when using CMOS digital chips: damage from *static electricity*, and erratic behavior caused by *floating pins*.

Static

The early 4000 series CMOS chips were especially vulnerable, but more recent CMOS designs generally include diodes at the inputs, which reduces the risk. Still, logic chips should be protected by inserting them into anti-static foam or enclosing them in conductive wrappers until they are installed in a board. While handling chips, it is good practice to be grounded, ideally using a wrist-mounted ground wire.

Floating Pins

Any pin which is unconnected in a logic chip is considered to be “floating,” and can pick up signals by capacitive coupling, possibly disrupting the behavior of the chip and also causing power consumption, as the ambiguous pin state will tend to prevent that gate in the chip from entering quiescent mode.

Generally speaking, input pins in a TTL logic chip that are not being used for any purpose should be tied to the positive voltage supply, while unused CMOS pins should be tied to negative ground.

Family Incompatibilities

As previously noted, older TTL logic chips may deliver a “high” output voltage that is lower than the minimum expected by newer CMOS logic chips. The best option is not to mix families, but if chips are stored carelessly, some intermingling can occur. Part numbers should be checked if one chip appears to be ignoring output from another.

Overloaded Outputs

If a circuit calls for a logic chip with an open-collector output, and a regular chip is used by mistake, it will almost certainly be damaged.

Output Pulled Down

If the output from one logic chip is connected with the input of another logic chip, and if the output from the first chip is also connected to an **LED**, the LED may pull down the output voltage so that the second chip will not recognize it as a high state. As a general rule, a logic output can drive an LED, or can drive another logic chip, but not both. Very-low-current LEDs, which draw as little as 2mA, may be acceptable.

Incorrect Polarity and Voltages

Logic chips can be knocked out by applying incorrect polarity, or voltage to the wrong pin, or the wrong voltage. Modern logic chips tolerate a very limited voltage range, and a 74xx series chip will be irrevocably damaged if it is used where a 4000 series chip was specified for a power supply higher than 6VDC.

If a chip is inserted upside-down, it will probably be damaged when voltage is applied.

Bent Pins

Like all through-hole chips, DIP logic chips can be inserted accidentally with one or more pins bent underneath the chip. This error is very easy to miss. The bent pins will not make contact with any socket that is used, and the chip will behave unpredictably. Check for proper pin insertion with a magnifying glass if necessary.

Unclean Input

Logic chips expect a clean input without voltage spikes. A 555 timer of TTL type generates spikes in its output which can be misinterpreted as multiple pulses by the input of a logic chip. A CMOS-type 555 timer is more suitable for connection with logic chips.

If a pushbutton, rotational encoder, or electromechanical switch provides a high or low input, the input must be debounced. In hardware, this is traditionally done with a **flip-flop**. It can also be done with code in a microcontroller.

Analog Input

The input of a logic chip can be connected directly with a thermistor, phototransistor, or similar analog component, but only if there is some certainty that the voltage at the input pin will remain within the range that is acceptable to the chip. In the case of a phototransistor, for example, it should be exposed to a limited, known range of light intensity.

In general, it is best to avoid applying intermediate-voltage signals to a digital logic input, as they can create unpredictable output, or output of an intermediate voltage. A **comparator** can be placed between the analog source and the digital logic chip, or a logic chip with a Schmitt-trigger input can be used.

flip-flop

11

The term **flip-flop** is sometimes printed with a space instead of a hyphen, but the hyphenated form seems to predominate in the United States. Therefore, the hyphen is included here. The term *flipflop* (with neither a hyphen nor a space) is sometimes seen, but is unusual. The acronym *FF* is confined mostly to logic diagrams or schematics.

The term *latch* is sometimes used interchangeably with *flip-flop* but is assumed here to describe a minimal asynchronous circuit that responds immediately and transparently to an input. A flip-flop can function as a latch and also as a synchronous device which is opaque, meaning that the input does not flow directly through to the output.

OTHER RELATED COMPONENTS

- **counter** (see Chapter 13)
- **shift register** (see Chapter 12)

What It Does

Transistors enable logic gates; logic gates enable flip-flops; and flip-flops enable many mathematical, storage, and retrieval functions in digital computing. Most flip-flops today are embedded in much larger integrated circuits that have complex functions. However, they are still available as separate components in chip form, and will be discussed on that basis here.

A flip-flop is the smallest possible unit of memory. It can store a single bit of data, represented by either a high or low *logic state*. (A full explanation of logic states is included in the **logic gate** entry. See Chapter 10.) Flip-flops are especially useful in **counters**, **shift registers**, and *serial-to-parallel converters*.

A flip-flop circuit can be classified as a form of *bistable multivibrator*, as each of its outputs is stable in one of two states until an external trigger stimulates it to "flip" from one state and "flop" into the other. (For a comprehensive discussion of monostable and astable multivibrators, see the **timer** entry in Chapter 9.)

An *asynchronous* flip-flop will respond immediately to a change of input, and can be used for applications such as debouncing the signal from an electromechanical **switch** or building a *ripple* **counter**. More often, a flip-flop is *synchronous*, meaning that a change in input state will be unrecognized until it is enabled by a low-to-high or high-to-low transition in a stream of pulses from an external *clock*.

How It Works

Every flip-flop has two outputs, each of which may have a high or low state. When the flip-flop is functioning normally, the outputs will be in opposite logical states, one being high while the other is low. These outputs are typically identified as Q and NOT-Q (the latter term meaning a letter Q with bar printed above it, sometimes referred to verbally as "Q-bar"). In datasheets and other documents where a bar symbol cannot be represented easily above a letter, the NOT-Q output may be represented as letter Q with an apostrophe after it, as in Q'.

Almost always, in a schematic diagram, a flip-flop is represented by a simple rectangle, with inputs and outputs identified by letters and other marks. Because a description of the inner workings is necessary before the different types of flip-flop can be understood, schematic symbols for various flip-flops will not be introduced until "Variants" on page 116.

The simplest flip-flop contains two logic gates whose function can be most easily understood if the inputs are controlled by a SPDT switch. It can be created from two NAND gates or two NOR gates, as described next. This type of component can be described as:

- *asynchronous*: Will accept data on an impromptu basis, as it is not synchronized with a clock.
- *jam-type*: Colloquial equivalent of *asynchronous*. The input is jammed in at any time, forcing an immediate change of output.
- *transparent*: The input state flows straight through to the output.

NAND-Based SR Flip-Flop

Figure 11-1 shows two NAND gates attached to a SPDT switch, with two pullup resistors. When either of the NANDs has a floating input from the switch, the pullup resistor attached to that input will maintain it in a high state. The data inputs for the NAND gates are labeled S and R, meaning Set and Reset, giving this component its name as an *SR* flip-flop:

- In a NAND-based SR flip-flop, a low state is considered an active logic input, as indicated by the bar placed above each letter.
- A high state is considered an inactive logic output.

The schematic style in this figure, with diagonally crossing conductors, is universally used and easily recognizable. The equivalent schematic in Figure 11-2, which might be created by circuit-drawing software, has the same functionality but would not be immediately recognizable as a flip-flop. The "classic" crossed-conductor representation is preferable.

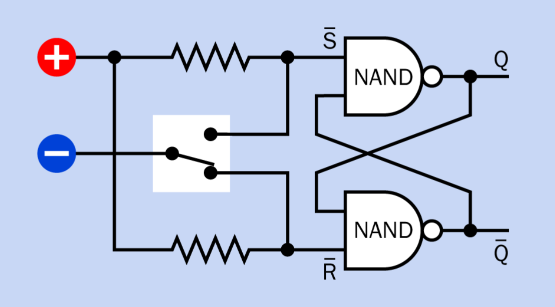

Figure 11-1. *The schematic for a simple NAND-based SR-type flip-flop, with a switch and pullup resistors added to control two inputs.*

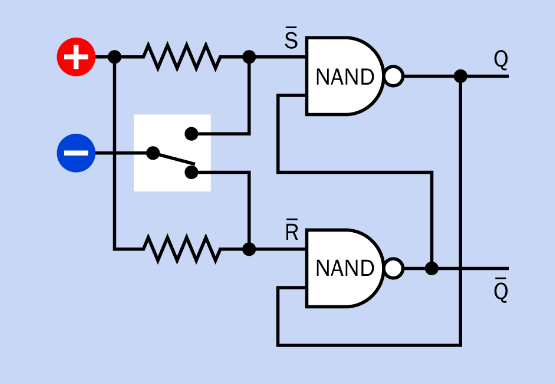

Figure 11-2. *An alternative component layout for an SR flip-flop, functionally identical to the previous schematic, but not so easily recognizable. The layout with a pair of diagonally crossing conductors has become so ubiquitous, it should be considered to be a standard.*

The first step toward understanding the behavior of flip-flops is to recall the relationship between the two inputs and the output of NAND or NOR gates. This is shown in Figure 11-3, where red indicates a high logic state and black indicates a low logic state.

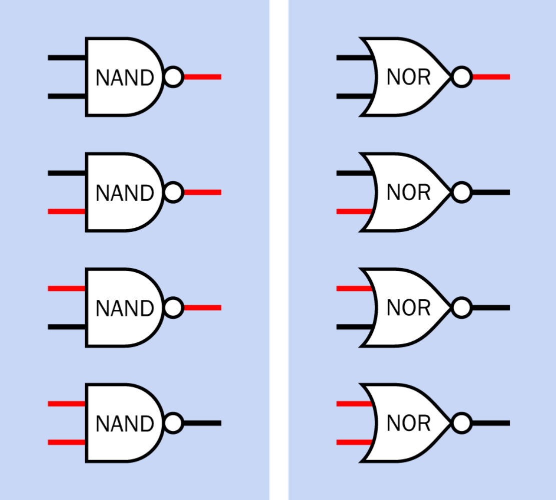

Figure 11-3. *The four possible input combinations for a NAND gate and a NOR gate, with the corresponding logical outputs. A flip-flop can be built from two NANDs or two NORs.*

The behavior of a NAND gate can be summarized:

- Both inputs high: Output low.
- Other input combinations: Output high.

Figure 11-4 shows a series of snapshots of the SR flip-flop circuit as the switch moves from one position, through an intermediate state where it makes no connection, to the other position. Remember that in this circuit, the active logical input state is low, and the active logical output state is high.

In the top panel, the pullup resistor of the lower NAND is overwhelmed by the direct connection to negative ground, which holds the R input in a low state. The other input of this gate is irrelevant, because the output from a NAND will be high if either of its inputs is low. So, the lower NAND has a high output, which feeds back to the secondary input of the upper NAND gate. The S input of this gate is high, because of the pullup resistor. Because both inputs of this gate are now high, its output is low, which feeds back to the lower gate. The lower gate doesn't change its output, because either of its low inputs is enough to keep its output high. So, the circuit is in equilibrium. A high state on the NOT-Q output is known as the *Reset* state for a NAND-based flip-flop.

The second panel shows what happens if the switch now moves up into a neutral, disconnected position. The R input of the lower NAND now becomes high, because of the pullup resistor. But this NAND still has one low input, supplied by the output of the upper gate, so its output remains high, and the circuit is still in equilibrium. This is known as the *Hold* state for the NAND circuit.

Suppose the switch bounces to and fro between the states shown in the first two panels. The output from the circuit won't change. This shows that the circuit provides a method for eliminating *switch bounce*—the very fast, momentary spikes that occur when the mechanical contacts of a switch open and close.

The third panel shows what happens if the switch now moves to its upper position. The top input of the upper NAND gate is now pulled low. Consequently, its output goes high. This feeds back to the lower gate. Its other input is high because of the pullup resistor. With both of its inputs high, its output goes low. The gate outputs have flipped and swapped values. A high state on the Q output is known as the *Set* state for a NAND-based flip-flop.

The circuit still remains in equilibrium even if the switch returns to its central, disconnected position shown in the bottom panel. Therefore, the debouncing capability of the circuit works equally well for both positions of the switch.

NOR-Based SR Flip-Flop

Figure 11-5 shows a similar circuit using two NOR gates attached to an SPDT switch. Because the NOR gates function differently, this circuit uses active-high input logic, and pulldown resistors are needed instead of pullup resistors. The output from the circuit still uses active-high logic, and is identical with the NAND-based circuit in this respect, although the relative positions of the Q and NOT-Q outputs have been swapped.

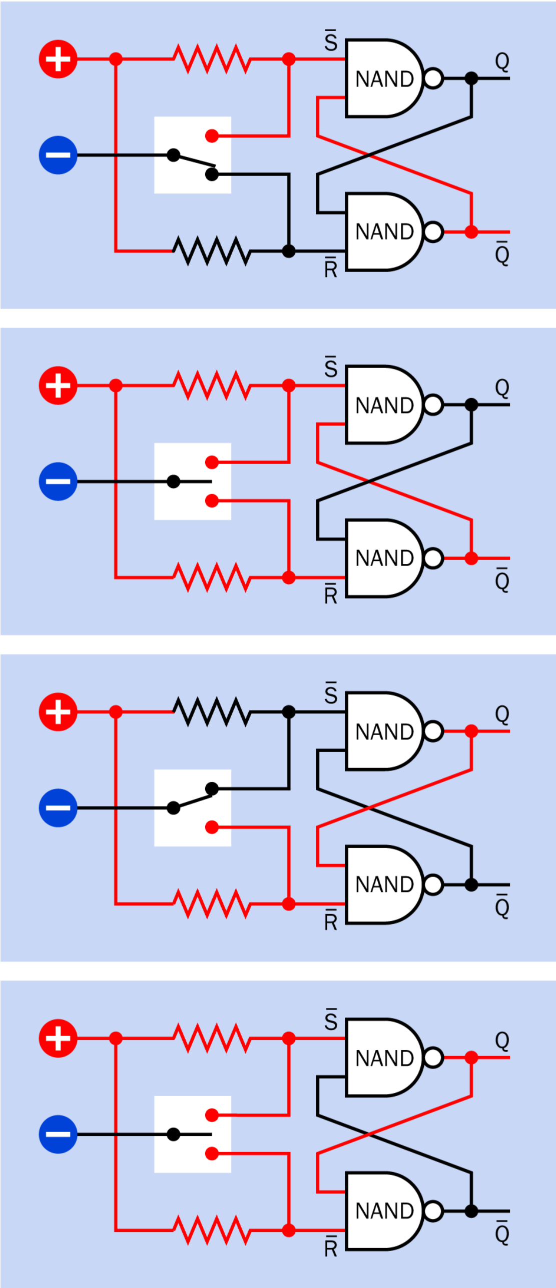

Figure 11-4. *Four snapshots of transitions in a NAND-based SR flip-flop as the switch moves down and up through an intermediate no-connection zone. See text for details.*

- In a NOR-based SR flip-flop, a high state is considered an active logic input, as indicated by the absence of a bar placed above the letters S and R.
- A high state is considered an active logic output.

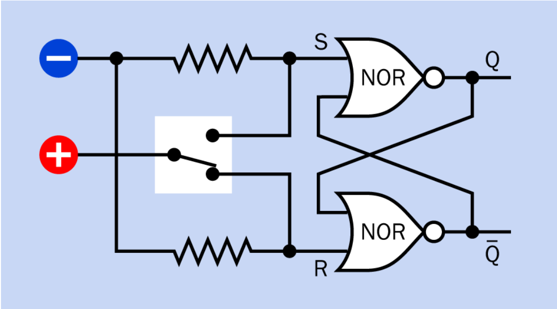

Figure 11-5. *The schematic for a simple SR flip-flop using NOR gates instead of NANDs.*

In the case of the NOR gate:

- Both inputs low: Output high.
- Other input combinations: Output low.

Figure 11-6 shows a series of snapshots as the switch moves from one position to the other, through intermediate states where it makes no connection. Remember that in this circuit, the active logical state is high at both the inputs and the outputs.

In this circuit, as in the previous circuit using NAND gates, it will ignore switch bounce, allowing the gate outputs to remain stable.

Forbidden States

Either of the circuits described so far depicts an SR flip-flop, regardless of whether it is NAND-based or NOR-based. Its input and output states are summarized in Figure 11-7. However, as this table suggests, there are some input states that create problems.

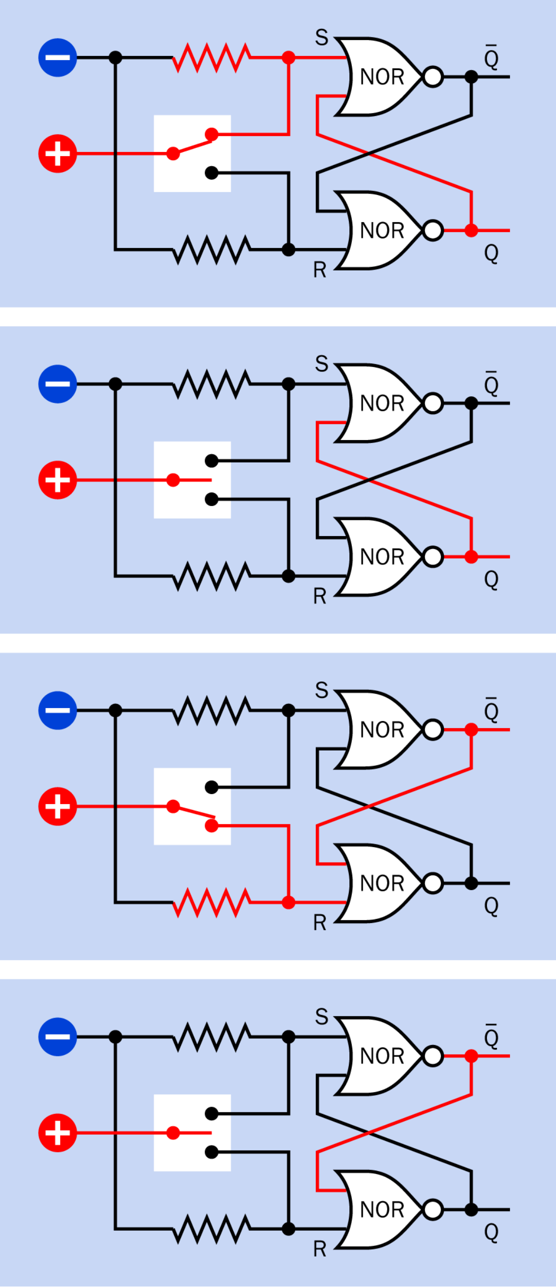

Figure 11-6. *Four snapshots of a NOR-based SR flip-flop, showing the consequence of changing switch positions, comparable with the NAND-based flip-flop.*

Flip-Flop Inputs		Flip-Flop Outputs			
		NAND-based		NOR-based	
S	R	Q	$\overline{Q}$	Q	$\overline{Q}$
⚫	⚫	🔴 Problem 🔴		Same as Previous	
⚫	🔴	🔴	⚫	⚫	🔴
🔴	⚫	⚫	🔴	🔴	⚫
🔴	🔴	Same as Previous		⚫ Problem ⚫	

Figure 11-7. *A table of input states and the consequent output states for NAND-based and NOR-based SR flip-flops.*

In either the NAND-based flip-flop or the NOR-based flip-flop, the output when the switch is in its unconnected center position will remain the same as when the switch was in its previous position. This is the usefulness of the flip-flop: it remembers the previous state. These situations are identified as “Same as Previous” in the table.

The pullup resistors (in a NAND-based flip-flop) and pulldown resistors (in a NOR-based flip-flop) are intended to guarantee that both inputs will be high (NAND) or both inputs will be low (NOR) even when the switch makes no connection. Therefore, it should be impossible for both inputs to be low (NAND) or high (NOR).

But what happens if the circuit is powered up with the switch in the unconnected position? One input of each gate is controlled by the output of the other gate. But what will those outputs be?

In the NAND-based version, the outputs from the NANDs will be low while the chips are powering up. As soon as the NAND chips are functioning, each of them will sense that it has one input high and one input low, so it will change its output to high.

But now that each chip has a high output, it will feed back to the secondary input of the other chip. Now both chips have both inputs high. This will cause them both to change their outputs to low—but this will feed back again, flipping the outputs back to high again. In fact, if the gates are absolutely identical, the circuit will oscillate very rapidly. This is sometimes known as *ringing*.

In real life, the gates will not be absolutely identical, and eventually one of them will respond fractionally ahead of the other, tipping the circuit into the state shown either in the second panel or the fourth panel in Figure 11-4. But which chip will win? There is no way of knowing. This is known as a *race condition*, and the winner is unpredictable.

A similar but opposite situation occurs in the NOR-based flip-flop if it is powered up with the switch in the disconnected position, and the S and R outputs are both low, because of the pulldown resistors. Here again it will be a race condition.

We can address the problem by making a rule that the switch must always be in one position or the other when the flip-flop is powered up. But what if there is a faulty switch? Or what if a power interruption occurs while the switch is changing position?

Another problem occurs if the switch makes one contact a fraction before it breaks the other contact. This would result in both S and R inputs being low, in a NAND flip-flop. The same state could occur if a separate logic circuit is driving the S and R inputs, and an error causes it to make S and R both low. This is shown in Figure 11-8. Because the output from a NAND gate is always high if at least one of its inputs is low, both gates now have a high output, and the circuit is stable.

The problem is, the states of the outputs from a flip-flop should always be opposite to each other. If both of them are high, this can create logic problems in the rest of the circuit attached to the flip-flop.

- In a NAND-based SR flip-flop, if S and R are both low, this is known as a *forbidden state* or a *restricted combination*.

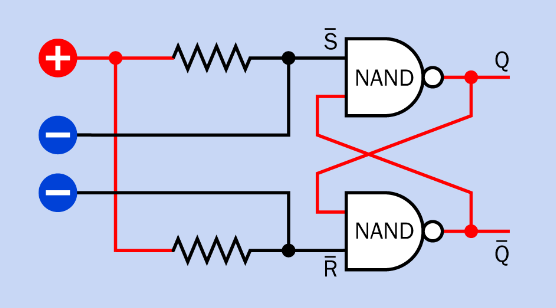

Figure 11-8. *What happens when both S and R inputs to a NAND flip-flop are low as a result of an error in a separate control circuit.*

A similar problem afflicts a NOR-based SR flip-flop, except that the forbidden state will occur when the S and R inputs are both high.

- In a NOR-based SR flip-flop, if S and R are both high, this is a *forbidden state* or a *restricted combination*.

The SR flip-flop is useful as a switch debouncer, but for computing applications, it is vulnerable to errors.

The JK Flip-Flop

Because the name of the JK flip-flop shares the initials of Jack Kilby, who won a Nobel prize for his fabrication of the world's first integrated circuit, some people speculate that this type of flip-flop was named after him. The attribution seems implausible, and may have gained currency simply because a flip-flop was the first device that Kilby happened to build when he was developing an integrated circuit.

Regardless of how it came to be named, the JK design is shown in Figure 11-9. This is commonly referred to as a JK *latch*. The electromechanical switches that were shown driving the SR flip-flop, along with pullup or pulldown resistors, are no longer included, because the inputs at positions J and K are assumed to come from other devices that have properly defined high and low states. Their behavior may be unpredictable, but neither of them will ever have a floating state.

This is a *gated* circuit, meaning that an additional input stage blocks direct access to the output stage, and it is also a *synchronous* circuit, as it uses a train of pulses at a clock input. Two three-input NAND gates are placed in front of a NAND-based SR flip-flop, and they address the problem of simultaneous identical inputs by using crossover feedback from the second stage to the first stage (via the conductors at top and bottom of the schematic).

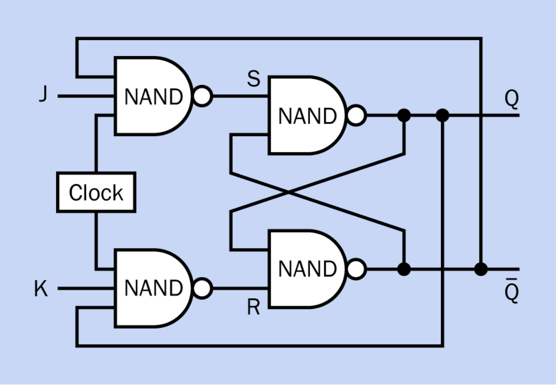

Figure 11-9. *The basic circuit for a clocked JK flip-flop, using two additional NAND gates prepended to an SR flip-flop.*

Versions of a JK flip-flop are possible using NOR gates, but are less common. Only the NAND-based version will be considered here.

In the case of a three-input NAND gate:

- All three inputs high: Output low.
- Other input combinations: Output high.

Because of the additional pair of NANDs, the circuit now recognizes a high input as logically active, instead of the low-active input in the previous SR flip-flop using NAND gates. Consequently, two simultaneous high inputs might be expected to create the type of forbidden state that was caused by two simultaneous low inputs previously. However, in Figure 11-10, the top and bottom panels show that simultaneous high inputs at J and K will support two possible valid outputs, where the state at Q is always opposite to the state at NOT-Q. In fact, when both inputs are high, a positive pulse on the clock input will *toggle* the outputs (i.e., they will switch places). In fact, the toggling will continue so long as the clock input is high. Consequently, this type of flip-flop is intended for use with short clock pulses.

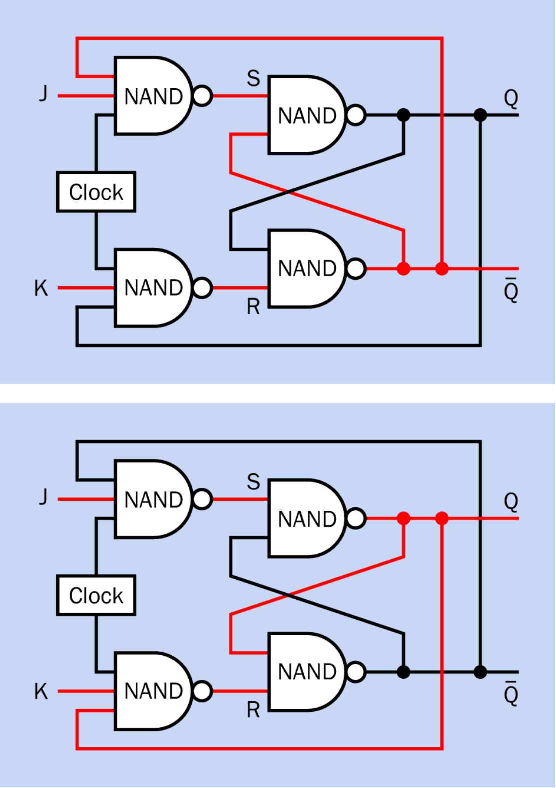

Figure 11-10. *When the J input and the K input are both high, this no longer causes a forbidden state. The combination will toggle the outputs of the flip-flop between the two states shown here.*

Master-Slave Flip-Flop

A more stable form is shown in Figure 11-11 where yet another stage has been added, this one being a "master" to the first. In fact, this configuration is known as a *master-slave* flip-flop, the slave stage being driven by the master stage but remaining inactive until a low clock input at the master stage passes through an *inverter* to become a high clock input at the slave stage. The master and slave stages thus take turns, one being activated by a high clock pulse while the other is activated by the low part of the pulse cycle. The output from the slave stage cannot feed back to the master stage while the clock pulse is still high, and thus the timing issue in the single-stage JK latch is eliminated. Because the master-slave version of the JK configuration is not *transparent*, it is correctly known as a flip-flop rather than a latch.

In addition, Preset and Clear inputs may be added to override the clock to Set or Reset the outputs. These inputs are active-low.

Figure 11-12 summarizes the behavior of a JK master-slave flip-flop that is triggered by the falling edge of each clock pulse (shown as a downward-pointing arrow in the Clock column of the table). Note that the output will be delayed while the slave stage waits for the second part of each clock cycle.

The letter X in the table indicates that the state in that cell is irrelevant.

When J and K are both low, the states of Q and NOT-Q will remain the same as in the previous cycle, and this is still referred to as a *Hold* state. When J and K are both high, the outputs toggle, meaning that their new states will be opposite to the previous states.

D-Type Flip-Flops

A D-type flip-flop places an inverter between two inputs to guarantee that they will always be in opposite states, and uses a clock signal to copy their states to a pair of logic gates.

When an inverter is added between the inputs in this way, either an SR flip-flop or a JK flip-flop can become a D-type flip-flop. Figure 11-13 shows the simplest possible D-type circuit, added to a basic SR flip-flop. Only one data input is now required (customarily labeled D), because it drives the other through the inverter.

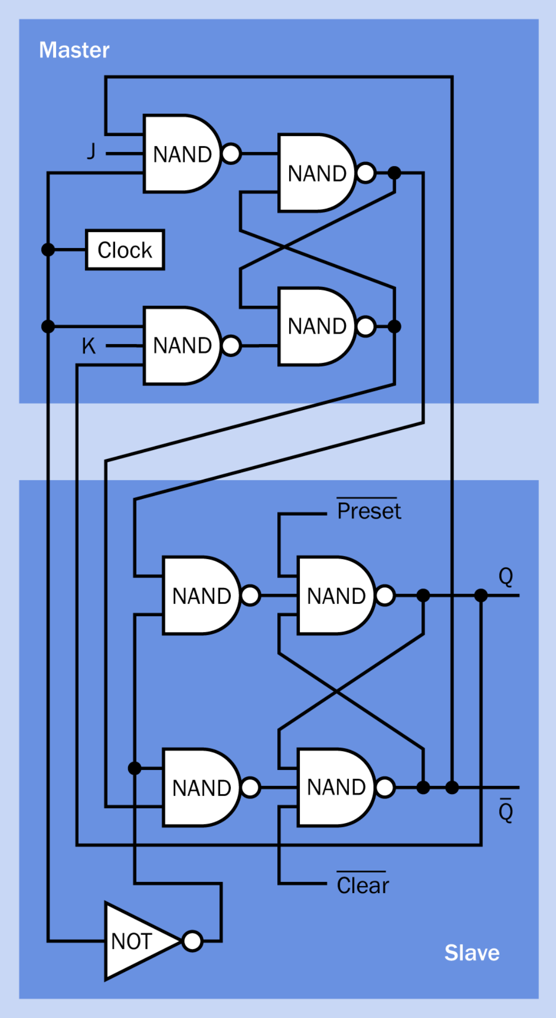

Figure 11-11. *A master-slave circuit that drives one flip-flop with another.*

Flip-Flop Inputs					Outputs	
Clock	Preset	Clear	J	K	Q	$\overline{Q}$
X	●	🔴	X	X	🔴	●
X	🔴	●	X	X	●	🔴
↓	🔴	🔴	●	●	Same as Prev	
↓	🔴	🔴	●	🔴	●	🔴
↓	🔴	🔴	🔴	●	🔴	●
↓	🔴	🔴	🔴	🔴	Toggle	

Figure 11-12. *A table showing inputs and outputs for a JK master-slave flip-flop.*

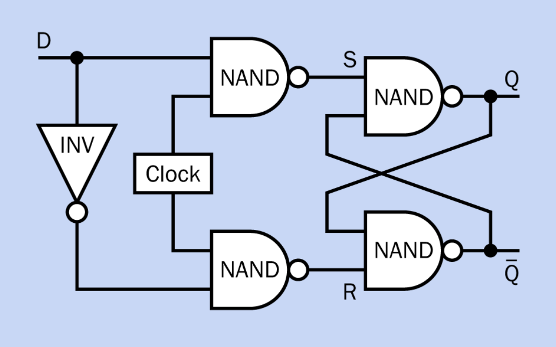

Figure 11-13. *A simple D-type flip-flop. The inverter guarantees that the state of one input will always be opposite to the state of the other.*

Figure 11-14 uses snapshots to show how the circuit responds to changing input and clock conditions. Initially, in the top panel, the data input is high, the clock input is high, and the Q output is high. In the second panel, the clock goes low, causing the output from the upper NAND gate in the input stage to change from low to high. But the upper NAND gate in the output stage still has one low input, so its state remains unchanged. In fact, the S and R inputs of the output NANDs are now both high, which creates the hold condition.

In the third panel, the D input changes from high to low, but this has no effect so long as the clock is low. The D input can fluctuate repeatedly, and nothing will happen until the clock goes high, as shown in the fourth panel. Now the clock copies the new D input state through to the output.

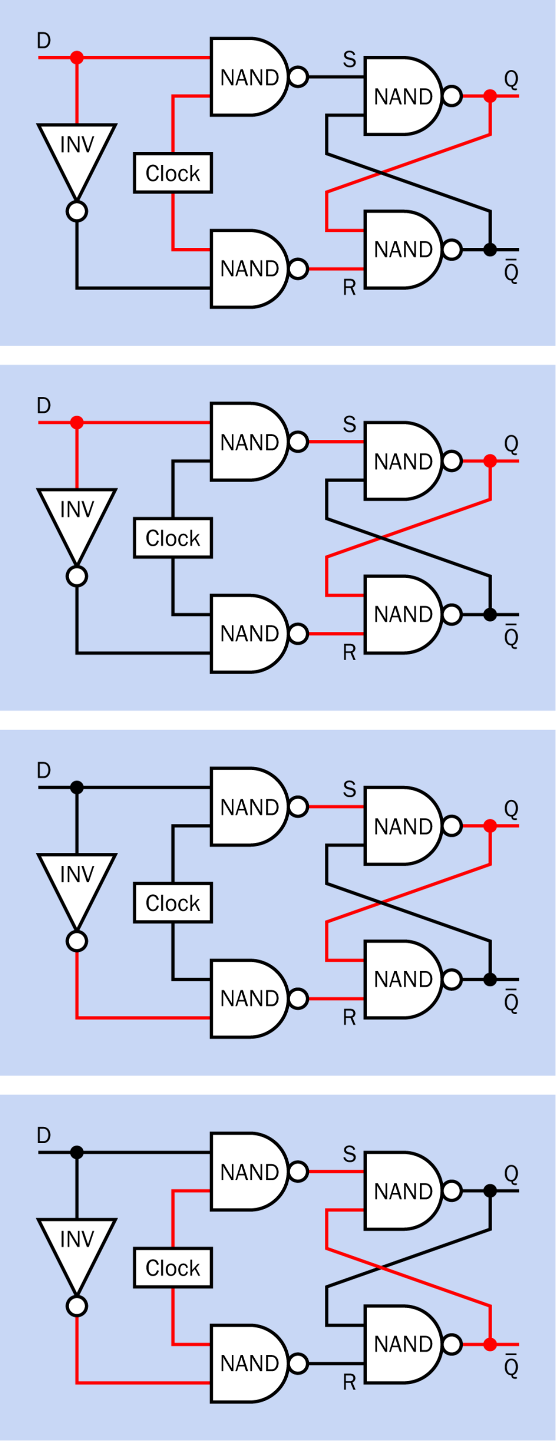

Figure 11-14. *Four snapshots showing the behavior of a D-type flip-flop.*

Summary

- An SR flip-flop can be used for switch debouncing, but in other applications it can enter an unacceptable race condition if its inputs and power supply are not carefully controlled.
- A JK flip-flop is gated, meaning that an SR circuit is preceded with an input stage and a clock input. This eliminates the race condition, adds the ability to toggle the outputs, but requires a very brief clock input. The circuit is edge-triggered.
- A master-slave flip-flop consists of two flip-flops, one driving the other. They can be JK type or SR type. The first flip-flop is activated by a positive clock state, while the second is activated by the subsequent negative clock state. Timing issues are resolved.
- A D-type flip-flop is gated with an inverter between the inputs, so that they cannot be simultaneously high or low. Consequently, only one input, labeled D, is needed. A high state on the D input causes a Set condition, while a low input causes a Reset condition, but only when the clock copies the status of the inputs through to the outputs. The status of the outputs remains stable (the flip-flop enters a hold condition) after the clock goes low.
- The JK circuit used to be widely used, because of its versatility. The D-type circuit now predominates.
- A T-type (toggling) flip-flop exists but is uncommon, and is not included in this encyclopedia.
- Many flip-flop circuits exist in addition to the ones that have been illustrated here. Only the most commonly cited circuits have been included.

A chip containing two positive-edge triggered D-type flip-flops is shown in Figure 11-15. Each flip-flop in this component has its own data, set, and reset input and complementary outputs.

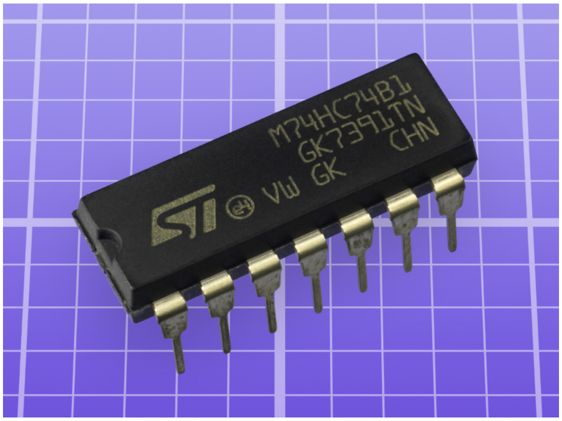

Figure 11-15. *This chip contains two positive-edge triggered D-type flip-flops.*

Variants

A selection of schematic symbols representing flip-flops is shown in Figure 11-16. Letters S, R, J, K, or D define the type of flip-flop. Q and NOT-Q are the outputs. CLK is the clock input but may alternatively be identified with letter E, meaning *Enable*. SRCK or SCLK may also identify it, the abbreviations being intended to mean “serial clock.

A triangle preceding CLK indicates that the flip-flop is positive-edge triggered. A circle, properly termed a *bubble*, preceding the triangle, indicates that the flip-flop is negative-edge triggered. In other locations, the bubble indicates that the input (or output) is inverted; it means the same thing as a bar printed above the text abbreviation, and indicates active-low logic. Synchronous inputs are shown on the left side of the flip-flop with the CLK input, while asynchronous inputs (if any) are shown above and below the flip-flop rectangle.

Using these guidelines, the examples in Figure 11-16 can be decoded:

1. An unclocked SR flip-flop with active-low inputs (probably NAND-based).
2. An unclocked SR flip-flop with active-high inputs (probably NOR-based).

3. An SR flip-flop with active-high inputs, pulse-triggered by an active-high clock input.
4. A JK flip-flop with active-high inputs, edge-triggered by a rising-edge clock input. The bubble on the lower Q output means the same thing as a letter Q with a bar printed above it.
5. A D-type flip-flop pulse-triggered by an active-low clock input.
6. A D-type flip-flop edge-triggered by a falling-edge clock input.
7. A JK flip-flop with active-high inputs, edge-triggered by a rising-edge clock input, with asynchronous active-low Preset and Clear inputs.

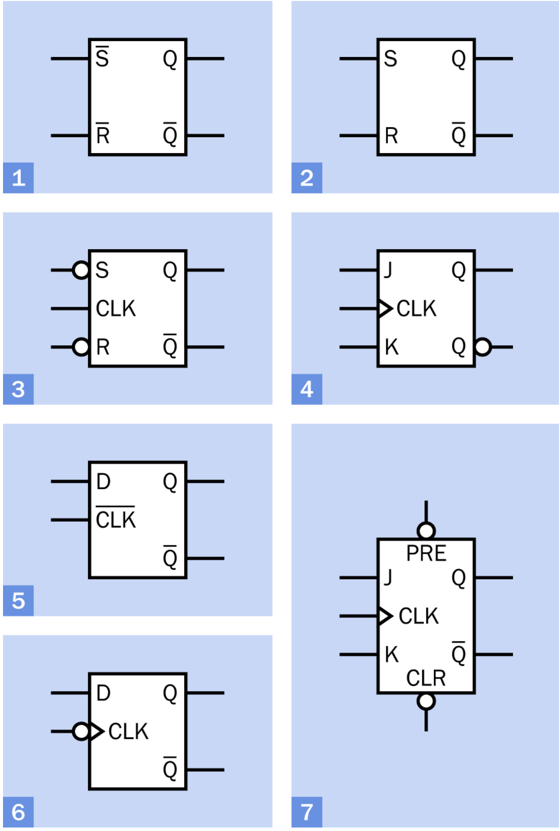

Figure 11-16. *The schematic symbol for a flip-flop is an annotated rectangle. See text for an explanation of the letters and marks.*

Packaging

Only about 10% of the flip-flops listed by a typical parts warehouse are through-hole chips. The rest are now surface-mount. Still, even if the search is narrowed further to through-hole packages in the 74xx and 4000 series, at least 100 types still exist. They provide opportunities in education and prototyping work, even though they are less often used as standalone components.

A package often contains more than one flip-flop. Dual and quad arrays are common. The flip-flops may be independently clocked, or may share a single clock input; datasheets should be checked carefully for details. Octal flip-flops, such as the D-type 74x273, are intended for use as eight-bit registers.

Many of the older flip-flops are numbered in the 74xx series of logic chips. See Chapter 10 for a detailed guide to this numbering system and the various logic families. D-type flip-flops include 74x74, 74x75, 74x174, and 74x175, where an acronym for the logic family is substituted for the x. Old-style CMOS flip-flops include the 4042B D-type latch, the 4043B quad NOR SR flip-flop, and the 4044B quad NAND SR flip-flop. The last two are synchronous, and both allow two Set inputs, labeled S1 and S2 in the datasheet.

Examples of JK flip-flops include the 74x73, 74x76, and 74x109.

Values

As is the case with other logic chips, most flip-flops in the through-hole 74xx series are intended for 5VDC power supply while the older 4000 series may tolerate up to 18VDC. Surface-mount versions may use voltages as low as 2VDC.

See “Variants” on page 93 for a discussion of acceptable high and low logic input voltages. On the output side, the 4000 series chips are able to source less than 1mA at 5VDC, but the 74HCxx series can manage around 20mA.

If a flip-flop is used for high-speed operation, the following values must be considered:

- t_S Setup time: The minimum time in nanoseconds for an input to be constant before the next clock pulse can process it.
- t_H Hold time: The minimum time in nanoseconds for an input to persist after the active edge of a clock pulse that has processed it. The interaction between a clock pulse and an input state takes a brief but measurable amount of time; errors may occur if the clock is given less than that amount of time to do its job.
- t_{CO} Clock-to-output: The elapsed time after an active clock edge, before the output changes. This is a function of the internal workings of the chip, and may be broken down into low-to-high and high-to-low output transitions, as follows.
- T_{PLH} Propagation to Low-to-High: The elapsed time after an active clock edge, before a low-to-high swing occurs at an output. This may not be identical to T_{PHL}.
- T_{PHL} Propagation to High-to-Low: The elapsed time after an active clock edge, before a high-to-low swing occurs at an output. This may not be identical to T_{PLH}.
- f_{MAX} Maximum clock frequency for reliable operation.
- $t_{W(H)}$ The minimum high clock pulse width in nanoseconds.
- $t_{W(L)}$ The minimum low clock pulse width in nanoseconds.

In a shift register or counter, where multiple flip-flops are cascaded but they share the same clock, the t_{CO} of one flip-flop must be shorter than the hold time of the next flip-flop, to allow the input of data to be complete before the window of opportunity is over.

How to Use It

The asynchronous SR flip-flop is of primary use in debouncing switches. Examples are the single MAX6816, dual MAX6817, and octal MAX6818.

D-type flip-flops are widely incorporated in frequency dividers, which are used to count pulses and display a binary output. If the NOT-Q output is wired back to the D input, the pulse stream to the clock input will have the following effect:

1. Suppose the initial D state is low and the initial state of the NOT-Q output is low.
2. The first high clock pulse propagates the low D state into the flip-flop.
3. The next low clock state forces the NOT-Q output high. This feeds back and creates a high D input.
4. The second clock pulse propagates the high D state into the flip-flop.
5. The next low clock state pulls the NOT-Q output low. This feeds back and creates a low D input.

The sequence then repeats. Only one high output is generated at NOT-Q (or at Q) for every two clock pulses; thus the circuit can become a divide-by-two **counter**. If the Q output is tapped to serve as the clock input for another flip-flop, that circuit now has a divide-by-four output. A series of many flip-flops can be chained together, so long as the propagation of signals along the chain is fast enough to occur before the next clock pulse. This is known as an *asynchronous counter*.

For more information on the use of counters, see Chapter 13.

While flip-flops have tended to be integrated with other components in digital computing, they are still used as registers where 8 or 16 bits of serial data must be assembled at a time, prior to being disseminated as parallel data.

What Can Go Wrong

Ambiguous Documentation

For reasons which are unclear, instructional texts and tutorials can be erratic when describing flip-flops:

- A truth table may fail to clarify whether the circuit uses active-high or active-low logic.
- Truth tables from different sources are often inconsistent in their representation of current and future output states, and may even fail to include the clock status in a clocked flip-flop.
- Tutorials may include logic diagrams for some types of circuit, but not others.
- NOR gates may be used, without any mention that NAND gates can also be used (and may be more common or convenient).
- The active-low or active-high status of inputs in an SR flip-flop may not be shown.

Bearing this in mind, manufacturer datasheets should be consulted whenever possible as the primary source of information.

Faulty Triggering

In many cases, a flip-flop designed for edge triggering can give erroneous results if it is level-triggered, and vice versa. Rising-edge-triggered flip-flops must be distinguished from falling-edge-triggered flip-flops. As always, it is important for similar parts that have similar functions to be stored separately.

Metastability

The behavior of flip-flops has been described in this entry under ideal conditions, where they are operating well within parameters established by the manufacturer. In reality, non-ideal scenarios may occur, especially where inputs such as data and clock, or clock and reset, are almost simultaneous. This may be difficult to avoid if a signal is received from an external source such as a sensor, with no way to control its arrival time. If the input occurs within the setup time or the hold time of a clock pulse, the flip-flop may be unable to determine whether the input precedes or follows the clock.

This may lead to *metastability*, meaning an unpredictable output and/or oscillations that take several clock cycles to settle into a stable state. If the output from a flip-flop may be used by two separate components with slightly different response times, one may interpret the oscillating output as a high state while the other interprets it as low. In a computing circuit, metastability can lead to calculation errors or a system crash. To avoid these issues, limits in datasheets should be observed. Attention should be paid to the manufacturer specifications for minimum setup time and hold time, so that the circuit has sufficient opportunity to recognize a signal and respond.

One solution to metastability is to connect multiple flip-flops in series, all sharing a common clock signal. This will tend to filter out irregularities, at the expense of requiring additional clock cycles if the flip-flops are not transparent.

Metastable-hardened flip-flops minimize metastability but cannot eliminate it completely.

Other Issues

Problems that tend to affect digital chips generally are listed in the section of the entry on logic gates (see "What Can Go Wrong" on page 105).

shift register

12

The term **shift register** is rarely hyphenated. In this encyclopedia, no hyphen is used.

A shift register can function as a *queue*, but this term is more usually applied to software. When the output from the last stage of a shift register is connected back to its input, it can function as a *ring counter*, but that application is described in the **counter** entry of this encyclopedia.

Component catalogs sometimes list shift registers as binary ripple **counters**, instead of giving them their own section. In this encyclopedia, a binary counter is considered to have binary-weighted outputs (with values 1, 2, 4, 8…. in decimal notation) and is described in the **counter** entry. A shift register has outputs that are not necessarily binary-weighted.

OTHER RELATED COMPONENTS

- **flip-flop** (see Chapter 11)
- **counter** (see Chapter 13)
- **multiplexer** (see Chapter 16)

What It Does

A *register* is a component (or a small section of computer memory) that stores information. The smallest unit of information is one *bit* (i.e., one *binary digit*) with a value 1 or 0 that can be represented by a high or low logic state. A **shift register** most commonly is designed to store eight bits, although some store four.

Each bit is memorized by the status of a **flip-flop** inside the register. For a detailed description of flip-flops, see Chapter 11. When a pulse from an external *clock* is received by the shift register, all of the bits in storage are moved along one step, from each flip-flop to the next. The high or low status of an input pin at that moment is *clocked in* to the first flip-flop, while the bit in the last flip-flop is overwritten by the bit preceding it. A diagram representing the function of a basic four-bit shift register is shown in Figure 12-1.

Note that the status of the input pin is ignored until the moment when a clock pulse copies it into the first flip-flop. In the figure, when the input pin has a brief high state that ends immediately before clock pulse three, the high state is ignored.

A shift-register chip is shown in Figure 12-2.

Because the functionality of a shift register is now often incorporated in much larger logic chips, it is less widely used as a stand-alone component than it used to be. It is still useful for purposes of serial-parallel or parallel-serial conversion, and for small tasks such as scanning a matrix-encoded keyboard or keypad. It also has educational applications and can be used in conjunction with a microcontroller.

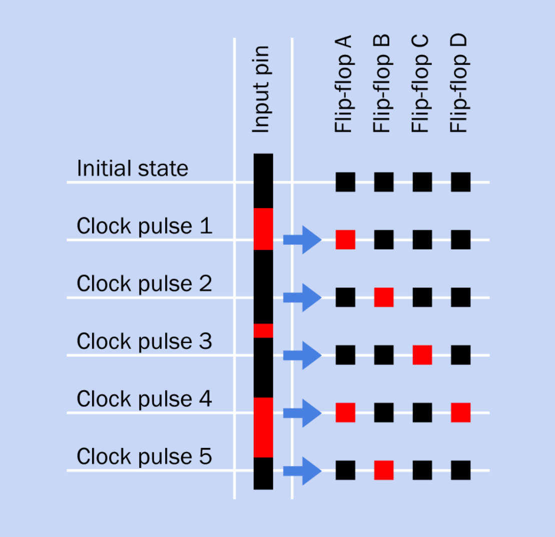
Input pin
Flip-flop A
Flip-flop B
Flip-flop C
Flip-flop D
Initial state
Clock pulse 1
Clock pulse 2
Clock pulse 3
Clock pulse 4
Clock pulse 5

Figure 12-1. *The function of a four-bit shift register in which each flip-flop may be set to a high or a low state, represented here with red or black squares. After a high bit is clocked into the chip, it is moved one space along by each subsequent clock pulse.*

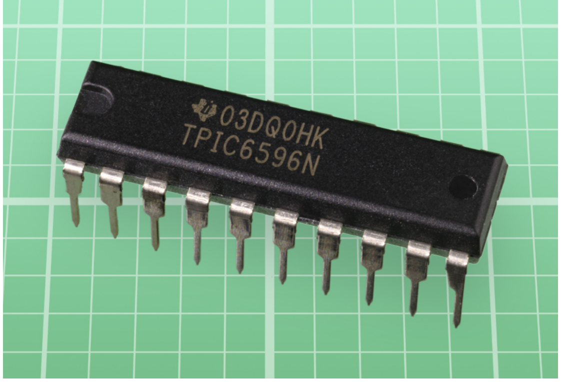
03DQ0HK
TPIC6596N

Figure 12-2. *This 8-bit shift-register chip is unusual in that it uses "power logic," in which open-drain outputs enable it to drive relatively high-current devices. It can sink up to 250mA at each of its output pins, at up to 45VDC.*

Schematic Representation

No specific symbol exists for a shift register. It is represented in a schematic by a simple rectangle, often (but not always) with control inputs on the left, data inputs arrayed along the upper edge, and data outputs along the lower edge. An example is shown in Figure 12-3, along with a diagram showing the physical chip and its pinouts. The meaning of the abbreviations identifying the inputs, outputs, and control functions will be described in "How It Works" on page 122.

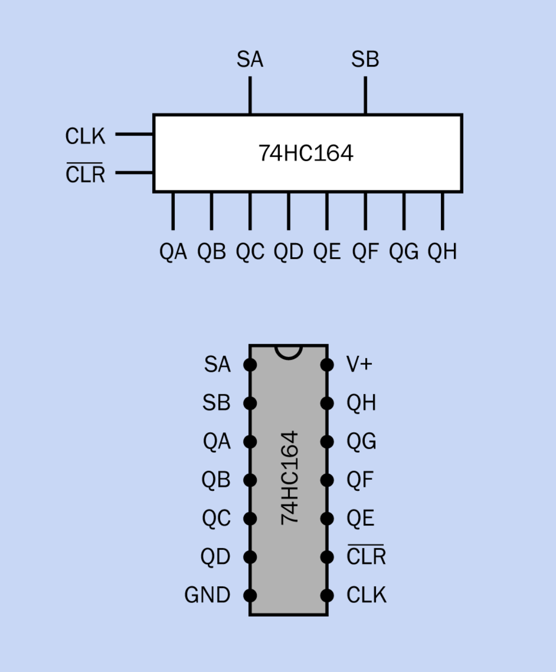
SA
SB
CLK
CLR
74HC164
QA QB QC QD QE QF QG QH
SA
SB
QA
QB
QC
QD
GND
V+
QH
QG
QF
QE
CLR
CLK
74HC164

Figure 12-3. *Typical schematic representation of a shift register, compared with the pinouts of the actual component.*

The schematic symbol representing a shift register may appear superficially similar to the physical form of the chip which contains it, but the physical layout of the pins is unlikely to be the same.

How It Works

A shift register generally consists of a chain of D-type flip-flops. See the entry describing **flip-flops** in Chapter 11 for a detailed explanation of this component.

The simplest shift register functions as a *serial-in, serial-out* device, abbreviated with the acronym *SISO*. Because the first bit that enters it will be the first to leave at the opposite end, it can also be described as a *first-in, first-out* data storage device, using the acronym *FIFO*.

The basic connections between flip-flops in a four-bit SISO shift-register are shown in Figure 12-4. The D input in each section refers to the fact that it is a D-type flip-flop. The primary output from each flip-flop is identified with letter Q.

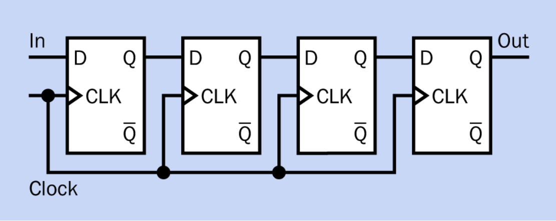

Figure 12-4. *The simplest shift register is a serial-in, serial-out (SISO) device. This example contains four D-type flip-flops.*

Each clock input is labeled CLK. When the output of each flip-flop is coupled to the input of the next flip-flop, and both share the same clock signal, the clock signal will cause the state of the third flip-flop to be sent to the fourth, the output of the second to be copied to the third, the output of the first to the second, and the input state will be copied to the first.

Abbreviations and Acronyms

The shift register will usually have an additional input that forces an immediate "clear" of all the registers, regardless of the clock state at that moment. This input is usually labeled CLR and will have a bar printed above it if it is active-low (which is the usual convention). If there is a pin labeled MR (meaning "Master Reset"), it will have the same function as CLR.

Because its effect is independent of the clock state, the clear signal is described as an *asynchronous* input.

While the abbreviation CLK is frequently used to identify the clock input, SCLK is also used (meaning "serial clock"), and occasionally the abbreviation CP may be found, meaning "clock pulse" input. If the shift register contains two stages, one to clock data in and the second to clock data out, they may be separately clocked, in which case they will be identified with different abbreviations. These are not standardized, but should be explained in the manufacturer's datasheet. No matter which abbreviation is used for a clock input, it will have a bar printed above it if the input is active-low.

Shift registers are generally *edge triggered*, meaning that the rising or falling edge of a clock pulse triggers the bit-shifting operation. If the component responds to a clock transition from low to high, it is *rising-edge triggered*. If it responds to a transition from high to low, it is *falling-edge triggered*, and this may be indicated in the schematic by a small circle, properly known as a *bubble*, preceding the triangle which indicates that this is an edge-triggered device.

Most shift registers are positive-edge triggered.

Parallel Outputs and Inputs

In many shift registers, data may be read out in parallel (from all flip-flops simultaneously), using pins provided for this purpose. In this mode, the shift register can function as a *serial-parallel converter* (*serial in, parallel out*, represented by the acronym *SIPO*). A simplified schematic of the internal connections is shown in Figure 12-5.

Where parallel outputs are provided, they are often identified as QA, QB, QC, and so on (moving from left to right) but may alternatively be described as Q1, Q2, Q3, Q4, and so on.

In a schematic, the input pin is conventionally shown as being at the left end of the component. Often two inputs are provided, connected internally as inputs to a NAND gate. The inputs are likely to be labeled A and B, but may alternatively be named SA and SB, indicating that they are serial inputs. S1 and S2 are alternative classifications. If parallel inputs exist, they may be identified as PA, PB, PC, and so on.

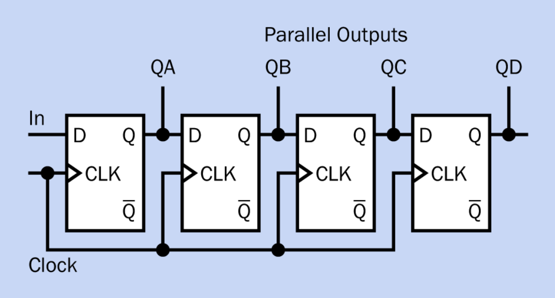

Figure 12-5. *Many shift registers have pins connected to points along the chain of flip-flops. These connections enable data to be read from the shift register in parallel.*

If serial data is supplied asynchronously, as in the illustration in Figure 12-1, it will be ignored until the shift register is triggered by the next clock pulse. The input state at that moment will then be copied into the first flip-flop, while the data that is already being stored in the shift register will be moved along the chain. In datasheets, this is customarily represented by a diagram such as the one in Figure 12-6. This diagram assumes that the shift-register is rising-edge triggered. Note that a brief fluctuation in the input which does not coincide with a clock-trigger event will be ignored.

Variants

Serial In, Serial Out

A basic SISO shift register allows only for serial input (at one end of the chain of flip-flops) and serial output (at the other end of the chain). No pins are available for parallel output of data.

This type of component usually permits 64-bit storage, where parallel output is simply impractical, as too many pins would be required. An example is the 4031B chip. This includes provision for recirculation of bits, so that it will also function as a ring counter (see Chapter 13 for a discussion of this function). As is always the case with logic chips, the part number will be preceded by letter(s) identifying the manufacturer, and a suffix will distinguish variants of the chip.

Another type of SISO shift register is programmable. It will store any number of bits from 1 through 64, determined by a binary number applied in the form of high/low states to five pins reserved for this purpose. An example is the 4557B.

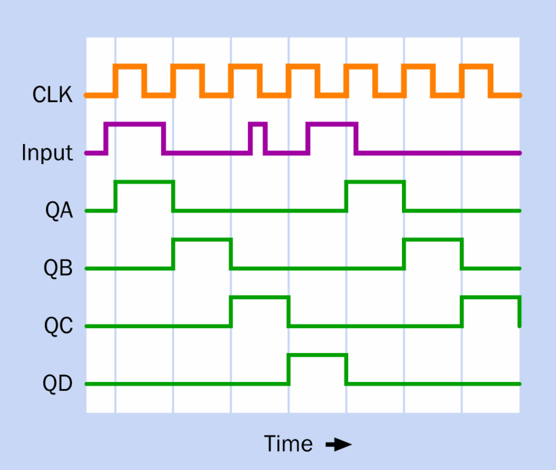

Figure 12-6. *In a rising-edge-triggered shift register, the high or low state of an asynchronous input (purple line) is copied into the first flip-flop of a shift register by each clock pulse (orange line). Brief fluctuations that do not coincide with a rising clock pulse are ignored. Existing data in the register is shifted from one flip-flop to the next.*

Serial In, Parallel Out

The majority of serial-input shift registers allow parallel output from points along the chain in addition to serial output at the end of the chain. These chips almost all are 8-bit registers. Typically two inputs are provided, one of which can be used to receive bits that recirculate from the end of the chain, back to the beginning. Widely used examples are the 4094B and the 74x164, where an acronym identifying the logic family will be substituted for the x.

Parallel In, Serial Out

A minority of shift registers are able to function as *parallel-serial converters* (*parallel in, serial out*, represented by the acronym *PISO*). Typically this type of chip allows *jam-type* parallel data input, meaning that the data is forced into the flip-flops via a separate pin for each of them. Parallel input is enabled by the status of a serial/parallel control pin. When the control pin reverts to its opposite status, each clock pulse will now shift data along the chain of flip-flops, allowing it to be read from the final output one bit at a time. Thus, data can be entered into the chip in parallel and read out of it serially. Examples are the 4014B and 4021B. Both are 8-bit.

Parallel In, Parallel Out

Shift registers that permit parallel output in addition to parallel input are almost all of the *universal* type, described in the next section.

Universal

A *universal* shift register is capable of all four modes of operation: SISO, SIPO, PISO, and PIPO. The four modes of the component are selected by the high or low status of two *mode select* pins. In addition, this component may have the ability to shift the register states either left or right. A *bidirectional* shift register has this same capability, and may also have PISO and PIPO capability, depending on the chip. Examples are the 74x195 and 74x299, where an acronym identifying the logic family will be substituted for the x in the number.

Universal shift registers are almost all 4-bit or 8-bit. They often have relatively complicated features, such as access to internal JK flip-flops, or pins that are multiplexed to provide different functionality depending whether an enable pin is held high or low. Datasheets must be checked carefully to ensure correct use.

Dedicated shift registers of SIPO or PISO type will be easier to use.

Values

As is the case with other logic chips, most flip-flops in the through-hole 74xx series are intended for 5VDC power supply while the older 4000 series may tolerate up to 18VDC. Surface-mount versions may use voltages as low as 2VDC. See the section on logic gates in Chapter 10 for a discussion of acceptable high and low logic-input states. On the output side, the 4000 series chips are able to source less than 1mA at 5VDC, but the 74HCxx series can usually manage around 20mA.

If a shift register is used for high-speed operation, the following values must be considered (identical notation, and similar values, are found in specifications for flip-flops):

- t_S Setup time: The input state of a shift register must exist for a very brief period before the clock trigger that processes it. This period is known as the *setup time*. In the 4000 series of chips, recommended setup may be as long as 120ns. The value will be much lower in 74xx chips.
- t_H Hold time: The minimum time in nanoseconds for an input to persist after the active edge of a clock pulse that has processed it. In many shift registers, no hold time is necessary, as the chip has already been activated by the rising edge of the clock pulse.
- t_{CO} Clock-to-output: The elapsed time after a clock trigger, before the output changes. This is a function of the internal workings of the chip, and may be broken down into low-to-high and high-to-low output transitions, as follows.
- T_{PLH} Propagation to Low-to-High: The elapsed time after an active clock trigger, before a low-to-high swing occurs at an output. This may not be identical to T_{PHL}.
- T_{PHL} Propagation to High-to-Low: The elapsed time after an active clock trigger, before a high-to-low swing occurs at an output. This may not be identical to T_{PLH}.
- f_{MAX} Maximum clock frequency for reliable operation. In the older design of 4000 series chips, 3MHz may be recommended with a power supply of 5VDC. Higher frequencies are possible with a higher voltage power

supply. Frequencies as high as 20MHz are possible in the 5VDC 74HC00 series.

- $t_{W(H)}$ The minimum high clock pulse width in nanoseconds. In the older design of 4000 series chips, 180ns may be recommended with a power supply of 5VDC. Shorter pulses are possible with higher voltage power supply. Pulses as short as 20ns are possible in the 5VDC 74HC00 series.
- $t_{W(L)}$ The minimum low clock pulse width in nanoseconds. This is likely to be the same as $t_{W(H)}$.

Power Considerations

Shift registers conform with the usual power-supply requirements for logic families. These are described in detail in the **logic gate** entry in Chapter 10. Likewise, the ability of a shift register to source or sink current is usually determined by its logic family. In a few cases, however, shift registers have an additional *open-drain* output stage for each register, capable of sinking currents as high as 250mA. The Texas Instruments TPIC6596 shown in Figure 12-2 is an example. When an open-drain output is connected with a logic device whose input cannot be allowed to float indeterminately, a *pullup resistor* must be added.

Three-State Output

A chip may have a *three-state output* (also known as *tri-state output*, a term which was trademarked but is now used generically). This means it will be capable of changing its outputs so that instead of sourcing or sinking current in a logical high or low state, they can have a high impedance. The chip then becomes "invisible" to others which may be sharing the same output bus. The high-impedance state is usually applied to all outputs from the shift register simultaneously when enabled by a separate pin, often identified as *OE*, meaning *output-enable*. Examples of three-state shift registers are the 74x595 or the 4094B chip.

The high-impedance state can be thought of as being almost equivalent to switching the outputs of the shift register out of the circuit. Consequently, if other components sharing the bus are also in high-impedance output mode, the state of the bus will "float," with uncertain results. To avoid this, a pullup resistor of 10K to 100K can be used on each bus-line.

Where the internal components of a shift register are shown in a datasheet, a three-state output is usually represented with a buffer symbol or inverter symbol that has an additional control input located on its upper edge, as shown in Figure 12-7. This should not be confused with the similar placement of a positive power supply input to an amplifier or op-amp. (Schematics showing the interior elements of a logic chip almost never include power-supply connections.)

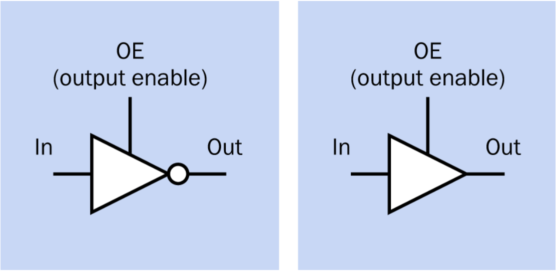

Figure 12-7. *A shift register may be capable of a three-state output, where high impedance is an option additional to the usual high or low logic state. An output enable pin allows this. It is typically shown as an additional input to an inverter (left) or buffer (right) inside the shift-register chip.*

How to Use It

The SISO application of a shift register can be used simply to delay the transmission of data by storing it and moving it from one flip-flop to the next before it is read out of the end of the chain.

The SIPO application of a shift register (serial in, parallel out) may be useful where a microcontroller has insufficient outputs to control multiple devices. Serial data can be sent from a single microcontroller output to the input of a shift register. The chip can then drive a separate device from each of its parallel output pins. If there are eight devices, the microcontroller can send a sequence of eight bits, each of which will control the on/off status of one device when the bits are read out of the shift register in parallel. If more devices are used, an additional shift-register can be daisy-chained to the output from the first.

Clock signals can be supplied from the microcontroller, along with a signal to the clear input of the shift register, if desired. Alternatively, the old bit states in the shift register can simply be "clocked out" and replaced with a new set of serial data. During the process of "bit banging," the parallel outputs of the shift register can remain connected directly with the output devices if the clock speed from the microcontroller is fast enough, as devices such as relays will not respond to extremely brief pulses.

For generic shift registers that do not have open-drain outputs, a buffer will be needed to provide sufficient current for any device using more current than an LED.

If a shift register is configured for PISO mode (parallel in, serial out) it can be placed on the input side of a microcontroller, polling a variety of devices and feeding their states into the microcontroller serially.

Dual Inputs

Where a shift register has two serial inputs (as is often the case), they are almost always linked as inputs to an internal NAND gate. This allows the output from the end of the chain of flip-flops to be connected back to the beginning of the chain, if the shift register is to function as a ring counter. However, if this function is not used and a single input is required, the two inputs to the shift register can be tied together. In this configuration, the input becomes active-low. The two possible configurations are shown in Figure 12-8. It is important never to leave an input *floating*, or unconnected.

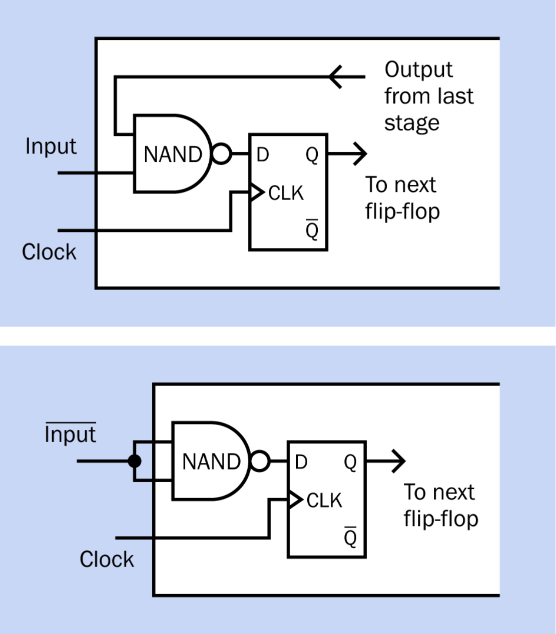

Figure 12-8. *Two possible configurations where a shift register allows two inputs linked with an internal NAND gate.*

Preloading the Shift Register

Where a shift register will be used to output a single recirculating bit (or in similar applications), the component must be preloaded with a high state in its first register. This may require a one-shot (monostable) timer which is activated only when the circuit is powered up.

Polling a Keyboard

Two shift registers can be used to scan the data lines in a matrix-encoded keyboard or keypad. This is often known as *polling* the keyboard. Provided the scan rate is sufficiently fast, the user experiences a seemingly immediate response to a key-press.

While the full schematic is too large and complex to be included here, many examples can be found online.

Arithmetical Operations

Shift registers were traditionally used to perform arithmetical operations on binary numbers. If the number is represented by eight bits (i.e., one byte) with the most significant digit on the left, shifting the bits one space to the right will have the effect of dividing the byte value by 2. If the bits are shifted one space to the left, the byte value will be multiplied by 2 (provided an additional register is available to store the most significant bit after it has been shifted). This concept is illustrated in Figure 12-9.

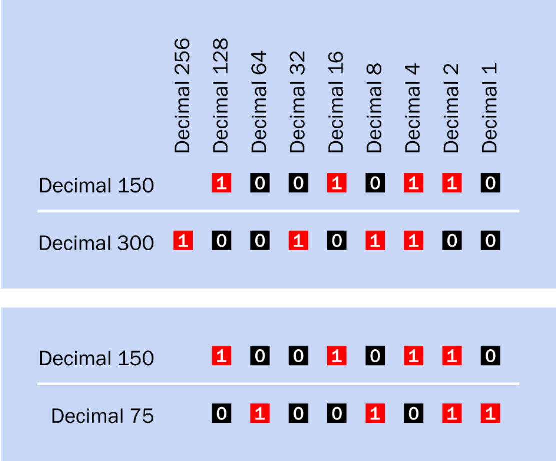
Decimal 256
Decimal 128
Decimal 64
Decimal 32
Decimal 16
Decimal 8
Decimal 4
Decimal 2
Decimal 1
Decimal 150 1 0 0 1 0 1 1 0
Decimal 300 1 0 0 1 0 1 1 0 0
Decimal 150 1 0 0 1 0 1 1 0
Decimal 75 0 1 0 0 1 0 1 1

Figure 12-9. *In the upper section of this diagram, a binary number represented by eight bits in a shift register is multiplied by 2 by shifting all the bits one space to the left. In the lower section, the same binary number is divided by 2 by shifting all the bits one space to the right. The binary values are shown in decimal notation to the left.*

In the upper section of the figure, the binary number 10010110 (chosen arbitrarily) is represented in the eight flip-flops of a shift register. The decimal place value of each digit is indicated. Adding up the place values of the 1s in the number, the total is 128 + 16 + 4 + 2 = 150. Below the white line, the digits have been shifted one place to the left, with the leftmost digit carried over to an additional location, while a zero is inserted in the rightmost location. Assuming that the additional place at the leftmost location has a place value of 256, the total is now 256 + 32 + 8 + 4 = 300.

In the lower section of the figure, the same binary number has been shifted one space to the right, with a 0 introduced in the leftmost location. The decimal value is now 64 + 8 + 2 + 1 = 75.

While this application for shift registers was common during development of digital computing in the 1960s and 1970s, the shift register as a separate component became less common subsequently, as its functionality was acquired by modern CPU chips.

Buffering

A shift register may also be used as a *buffer* between two circuits where the clock speeds are different. Digits are clocked in by the first circuit, then clocked out by the second. Some shift registers allow two clock inputs and can be used for this purpose.

What Can Go Wrong

Problems that tend to affect digital chips generally are listed in the entry on logic gates (see "What Can Go Wrong" on page 105).

Confusing Classification

Because of the functional similarity to a binary ripple **counter**, a shift register is sometimes listed by component suppliers as a counter. In fact, a binary counter will almost always have outputs that have place values 1, 2, 4, 8.... and upward, while the outputs from a shift register will not have place values.

When searching for a shift register, it can be found by specifying a "counting sequence" of serial to parallel, serial to serial, parallel to serial, or parallel to parallel. If the "counting sequence" is simply up or down, the component is a counter, not a shift register.

Inadequate Setup Time

Each flip-flop in a shift register must have a stable input state before the next triggering event shifts the data. If this setup time is reduced below the minimum specified in the datasheet, results will be unpredictable.

Unconnected Input

Because many shift registers have a choice of two inputs to the same chain of internal flip-flops, it is easy to leave one of them unconnected by accident. A floating input will be vulnerable to any stray electromagnetic fields, and is almost certain to create random effects.

Output Enable Issues

The output enable pin on a shift register that has three-state logic outputs is usually active-low. Consequently, if the pin is left unconnected, the logic outputs may go into high-impedance mode, or will fluctuate unpredictably. Where three-state outputs are not required, a safe course of action will be to avoid using three-state chips.

Floating Output Bus

If a pullup resistor is omitted from a bus that is shared by three-state chips, the results will be unpredictable. Even if the circuit design seems to guarantee that at least one chip will have a high or low output on the bus, a pullup resistor should still be included.

counter

13

The term **counter** is used here to mean a digital-logic chip. A counter could be built from discrete transistors, but this approach is obsolete. Counters may also be devised from parts such as multiple relays, or a solenoid advancing a ratchet wheel, but such electromechanical devices are not included in this encyclopedia.

In this encyclopedia, a counter by definition has binary-weighted outputs with values 1, 2, 4, 8.… in decimal notation. The exception to this rule is a *ring counter*, which does not have binary-weighted outputs but is included here because its name identifies it as a counter. A **shift register** may be used as a ring counter, but is more versatile and has many other functions; hence it has a separate entry.

Gray code counters, in which successive outputs differ by only one binary digit, are not described in this encyclopedia.

OTHER RELATED COMPONENTS

- **flip-flop** (see Chapter 11)
- **shift register** (see Chapter 12)

What It Does

A counter can be used to count events, or can measure time in convenient intervals if it is connected with a component such as a *quartz crystal* that operates at a precise and reliable frequency. The counter receives input pulses (usually referred to as a *clock input*) and counts a predetermined number of them before restarting from the beginning. It will repeat in this fashion so long as power is connected, and the clock pulses continue, and a reset signal is not supplied.

Almost all counters create some form of output during the count. Most commonly, the output is a pattern of high and low states expressing the number of clock pulses in binary code. Where a counter counts to a very high number before recycling, some intermediate binary digits may be omitted.

While standalone counter chips are not as widely used now as in the early days of computing, they still find application in industrial processes, small devices, and education, and can be used to control incremental devices such as stepper motors. They can be used in conjunction with microcontrollers.

Schematic Representation

No specific logic symbol exists for a counter. It is most often shown in a schematic as a rectangle with clock input(s) and clear input(s) on the left and outputs on the right. An example appears in Figure 13-1, above a representation of the physical chip and its pinouts. The meaning of the abbreviations identifying the inputs, outputs, and control functions will be found in "How It Works" on page 132. Because the two MR inputs for this particular counter are ANDed inside the chip, the AND symbol is included with the counter symbol.

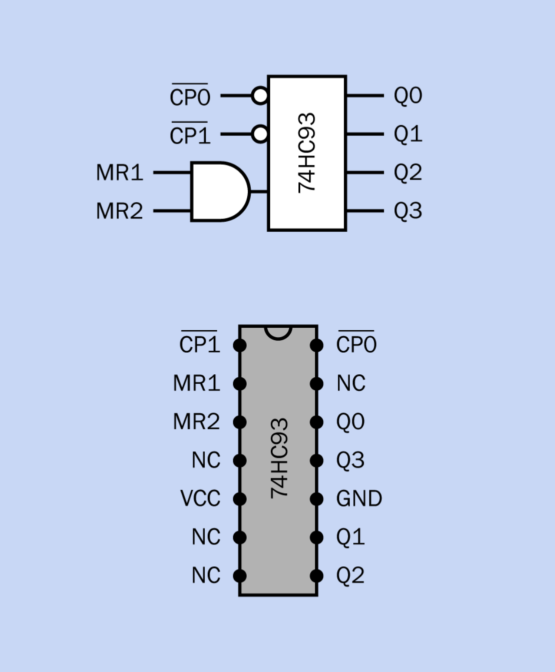

Figure 13-1. *Typical schematic representation of a counter, compared with the pinouts of the actual component.*

A counter chip is shown in Figure 13-2.

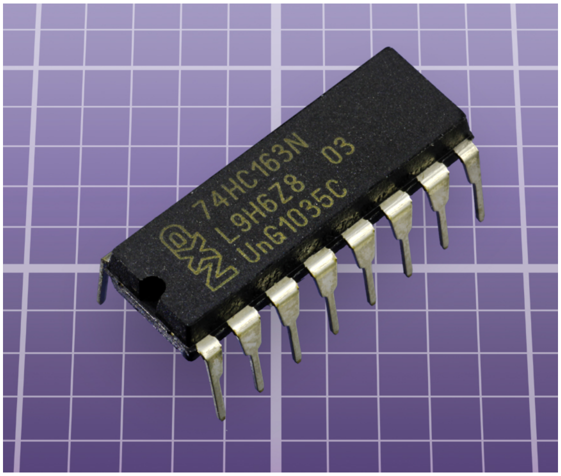

Figure 13-2. *The 74HC163 shown in this photograph is a 4-bit synchronous counter capable of being preloaded with a starting value, and able to do a synchronous reset.*

How It Works

A counter is built from a chain of **flip-flops**, with each one triggering the next. JK, T-type, or D-type flip-flops may be used. For a thorough description of a flip-flop, see Chapter 11. In Figure 13-3, a D-type flip-flop is shown, triggered by each rising clock pulse.

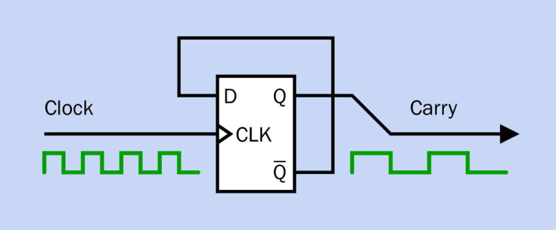

Figure 13-3. *When the complementary (NOT-Q) output from a D-type flip-flop is connected back to its input, the Q output frequency is half of the clock input frequency. See text for additional details.*

Initially the Q output of the flip-flop is low, so its NOT-Q output (identified by Q with a bar above it) is high. This feeds back to the D input, but has no effect until the rising edge of the next clock pulse copies the high D input to the Q output. The Q output is now latched high while the NOT-Q output is latched low and feeds back to the D input. The triggering event has passed, so the low D input does not have any immediate effect. The rising edge of the next clock pulse copies the low state of the D input to the output, and changes the NOT-Q output to high, causing the cycle to repeat. As a result, the output frequency of the flip-flop is one-half of the input frequency from the clock. If the output is carried to the next flip-flop to become its clock input, once again the frequency will be divided by two.

Modulus and Modulo

The *modulus* of a counter is the number it will count up to, before it repeats. This is sometimes written incorrectly as *modulo*.

In fact, *modulo* is the name of an arithmetical operation, often abbreviated as *MOD* (usually capitalized, even though it is not an acronym). This operation consists of a division sum in which the *remainder* from the division is the result of the operation. Thus 100 modulo 5 gives a result of 0, because there is no remainder when 100 is divided by 5. But 100 modulo 7 gives a result of 2, because 2 is the remainder of the division operation.

To exacerbate the confusion, *MOD* is also used as an adjective referring to the modulus of a counter. Thus a MOD-4 counter has a modulus of 4, and a MOD-16 counter has a modulus of 16. As a general rule, when a counter is being described, *modulo* and *MOD* will mean the same thing as *modulus*. This may be confusing to people such as computer programmers who are already familiar with the correct usage of MOD as an arithmetical operator.

In a counter, to obtain a modulus that is not a power of two, logic gates inside the chip can intercept a particular value (such as 1010 binary, which is 10 decimal) and use this as a signal to restart the count at zero. External connections to the chip can achieve the same purpose.

Pin Identifiers

Abbreviations and acronyms are used in datasheets to identify pin functions. These identifiers have not been standardized, and many variants exist.

CLK is the abbreviation most commonly used for the clock input, sometimes alternatively shown as CK or CP. If it is active-low, or if its falling edge will be active, a bar will be printed above it. Where a printed font does not permit an underscore to be placed in this way, CLK' (the abbreviation followed by an apostrophe) may be used instead. Often two or more stages of a counter can be separately clocked, and the input pins will be identified with abbreviations such as CLK1 and CLK2, or 1CLK and 2CLK, or CKA and CKB, or CP1 and CP2, or similar.

Where a clock input is edge-triggered, this is indicated by a small triangle. The triangle can be seen in Figure 13-3.

CLR designates a pin which will clear the count and reset it back to zero. This signal is often active-low, indicated by a bar printed above the abbreviation.

In a schematic, a small circle, properly known as a *bubble*, may be placed at any input which is active-low. On a clock input, the circle indicates that it is falling-edge triggered. See Figure 11-16 for various implementations of symbols with flip-flop schematics.

The CLR operation may be *synchronous* (the pin state will not be recognized until the next clock pulse) or *asynchronous* (in which case the pin state overrides the clock and resets the counter immediately). MR stands for "Master Reset," and has the same function as CLR.

Where two or more counters (or multiple stages within one counter) can be reset separately, more than one clear input will be shown, and may be identified with abbreviations such as CLR1 and CLR2, or MR1 and MR2.

Output pins will almost always be identified as Q0, Q1, Q2 … or QA, QB, QC … up to the maximum necessary to express the modulus. If two or more counters are included in one chip, outputs may be prefixed with an appropriate number. Thus 2Q3 would be the third output in the second counter. Multiple counters in one chip are identified with numbers starting from 1.

Where internal flip-flops are shown, they will have identifiers such as FF1 or FF2. Each flip-flop will have its own clear function, identified as C or CD (the latter meaning "clear data"), and may have inputs labeled D1, D2, D3… in a D-type flip-flop or J and K in a JK flip-flop. See Chapter 11 for an explanation of flip-flop inputs and outputs.

The input to a counter is always imagined to begin from the left, and consequently the leftmost flip-flop shown in an internal schematic will express the least significant bit of the current value of the count, even though a binary number is written with the least significant bit in the rightmost place.

If a counter is capable of receiving parallel data as an input (explained below) it will have a pin labeled PE for parallel enable. It may also have a CE or CET pin, for count enable.

As is generally the case in logic chips, VCC or V+ are typically used to identify the positive power supply pin, while GND or V- will identify the negative-ground pin. NC means that a pin has no internal connection at all, and consequently requires no external connection.

Variants

All counter chips use binary code internally, and the number of *bits* (*binary digits*) in the counter's modulus will be the same as the number of internal flip-flops. A 4-bit counter (the usual minimum) will have a modulus of 2^4 which is 16. A 21-bit counter (the maximum typically available) will have a modulus of 2^{21} which is 2,097,152. For higher moduli, counters can be chained together, each sending a carry signal to the next. This is known as a *cascade*.

Multiple counters, with different moduli, may be chained in a single chip. For example, in a digital clock that displays hours and minutes using the 60Hz frequency of an American domestic power supply as its timebase, the initial counting stage will have a modulus of 60, to count individual seconds. The next counting stages will have moduli of 60, 10, and 6, so that they can count from 00 to 59 minutes. Additional stages in the chip will tally hours.

A counter with a *parallel input* can be preloaded with an initial value (in binary code) from which it may count up or down. A *parallel-enable* pin may put the counter into a mode where the number can be *jam loaded*, meaning that it is jammed into the counter regardless of the clock state. Other types of counter are loaded synchronously.

Ripple versus Synchronous

In a *ripple counter* each internal flip-flop triggers the clock input of the next, so that their states change in a rapid but incremental sequence from the input to the output. This is also known as an *asynchronous* counter. Because the final state will not be valid until the clock pulse has rippled all the way through the counter (and through additional counters if they are cascaded together), a ripple counter will tend to suffer from a *propagation delay* of up to a microsecond. Ripple counters may also create output spikes or momentary transient count values that are invalid. Therefore, they are more suitable for applications such as driving a numeric display than for interfacing at high speed with other logic chips.

In a *synchronous counter*, all the flip-flops are clocked simultaneously. A synchronous counter is better suited to operation at high speed.

Of the counter chips available today, about half are synchronous and half are asynchronous.

Ring, Binary, and BCD

A counter that activates output pins one at a time sequentially is said to have a *decoded output*. It is often referred to as a *ring counter*. It has the same number of output pins as its modulus. An example is the 4017B chip.

A *binary counter* is more common and has an *encoded output*, meaning that it will express the running total of the count in binary code through *weighted outputs* that typically have (decimal) values of 1, 2, 4, 8, and so on. A modulus-8 counter (often referred to as an *octal counter*) will require three outputs which represent the binary numbers 000, 001, 010, 011, 100, 101, 110, and 111 (decimal 0 through 7) before going back to 000 and repeating.

A *modulus-16* counter, also known as a *hexadecimal counter* or a *divide-by-16 counter*, will have a binary output represented by four output pins, counting from 0000 through 1111 (decimal 0 through 15). Four-digit binary counters are very common, and their outputs are compatible with other components such as a **decoder**, which converts a binary-number input into a ring-counter-style output.

A *decade counter* is a modulus-10 binary counter. It is described as having a *binary-coded decimal* output (often expressed with the acronym *BCD*), using four weighted output pins which represent the numbers 0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, and 1001 (decimal 0 through 9) before repeating. Because this counter skips binary outputs from 1010 through 1111 (decimal 10 through 15), it is said to have a *shortened modulus*.

Figure 13-4 shows a schematic diagram of JK flip-flops in a decade ripple counter. The J and K inputs are all tied to the positive power supply, as this causes the clock input to toggle the output high and low. Note that because the primary input is always shown at the left end of the component, the least significant output bit (Q0) is in the leftmost position.

To intercept binary 1010 (decimal 10), an internal NAND gate is used. Its output goes low when its two inputs, from Q1 and Q3, go high. The output from the NAND immediately activates the CLR function on all the flip-flops, so that as soon as the decade counter reaches 1010 (decimal 10), it resets itself to 0.

In this particular chip, the preload for each flip-flop is tied to the positive power supply, so that it is always inactive. In some counters, the preload feature of each flip-flop is accessible via pins outside the chip. This creates the potential hazard of preloading the counter with one of the numbers that it normally skips (for instance, 11 decimal in a decade counter). This is referred to as an *invalid number* or *disallowed state*. (This use of the term “state” refers only to the binary number stored in the counter’s flip-flops. It has nothing to do with the high-state or low-state voltages used to represent binary 0 or 1.)

The counter’s datasheet should include a *state diagram* showing how the counter will deal with this situation. It may reset itself to a valid value after a maximum of two steps, but this can still cause confusion, depending on the application.

The state diagram for a 74HC192 counter is shown in Figure 13-5.

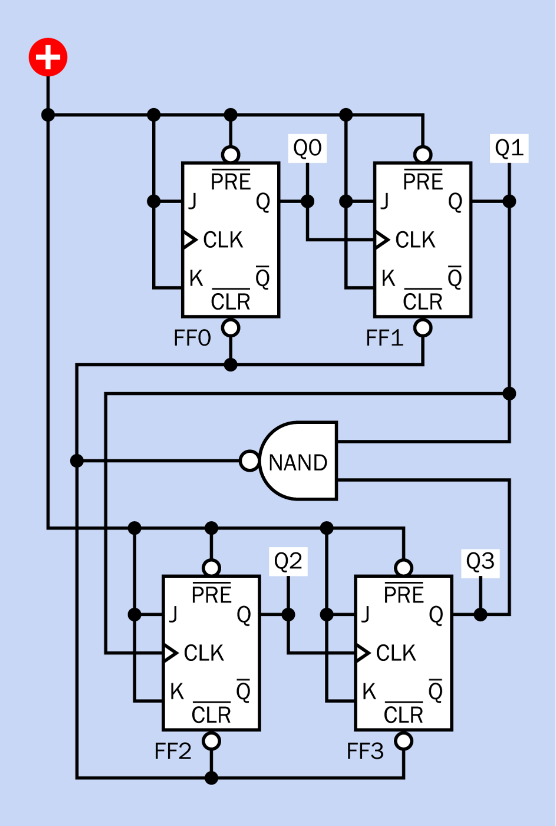

Figure 13-4. *The internal logic of a synchronous decade counter that uses JK flip-flops.*

Clock Sources

The clock input may be provided by a **timer** chip or by an *RC network*, which has the advantage of being able to run at a relatively low speed for purposes where this is desirable. It may alternatively be provided by a *quartz crystal* oscillating at a much higher frequency such as 1MHz. Successive counters may be necessary to reduce this value, depending on the application.

In some counters, the clock is built into the chip. More commonly, a resistor and capacitor may be used externally to establish a clock rate in conjunction with logic gates inside the chip. The datasheet for this type of component will include a formula for calculating the clock frequency from the resistor and capacitor values. The 4060B chip is an example.

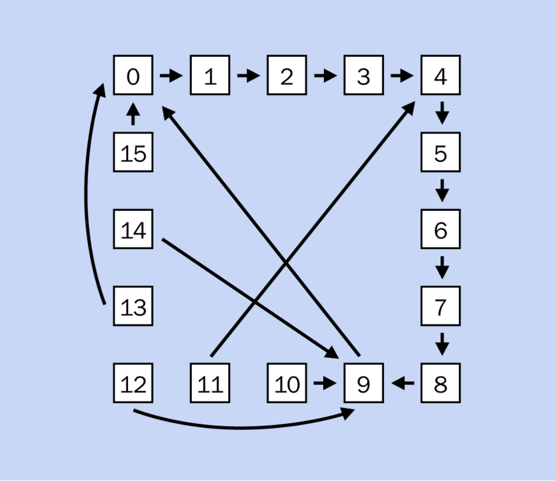

Figure 13-5. *A state diagram shows the transitions that a counter will make from each number to the next (in decimal notation), including the transitions which enable it to exit from disallowed states. This example is for a 74HC192 chip.*

Rising Edge and Falling Edge

A counter may be designed to be triggered either by the rising edge or the falling edge of the clock input, or by its high or low logic state. Generally speaking, ripple counters use the falling edge, so that the final output from one counter can become the clock input of the next. In other words, when the most significant digit of the first counter changes from a high to low logic state, this transition toggles the least significant bit of the second counter.

Synchronous counters generally use the rising edge of the clock input. If multiple synchronous counters are cascaded, they must all share the same clock signal, and will all change their flip-flop states simultaneously.

Multiple Stages

It is common for a counter chip to contain two or more *stages* with differing moduli. To take a common example, a divide-by-2 stage and a divide-by-5 stage that are both present in a single chip can be used to create a decade counter by connecting external pins. The extra stages provide a choice of moduli if they are used individually.

Single and Dual

Counter chips may contain two counters of the same modulus. This is known as a *dual* counter. Dual 4-bit counter chips are common. Each counter can be used separately, or they can be cascaded, in which case the total modulus will be found by multiplying the individual moduli together.

High-State, Low-State, and Three-State

Almost all counters use positive logic where a 1 is represented by a high state and 0 by a low state. Some counters allow an additional output state which has a high impedance and is equivalent to an open circuit. This feature is useful when two or more chips share the same output bus. It is discussed in the entry for **shift registers** in "Three-State Output" on page 126.

Descending Output

Most components only create an ascending count. The output can be converted to a descending count by passing each binary state through an inverter, but this will only work properly if the modulus is equal to the number of states. In a BCD counter, its inverted outputs will count from decimal 15 to decimal 6, not from decimal 9 to decimal 0.

A few counters are available which are designed to create a correct descending count. Other counters are available which allow the user to set the mode to ascending or descending. Examples are the 74x190 or 74x192 (where an acronym for the chip family will be substituted for the letter x).

A descending output is useful in combination with a parallel input, where a user may set an initial value from which the counter will descend to 0. With suitable logic, this can enable a user-specified delay period.

Programmable Counters

A programmable counter can usually allow a modulus ranging from 2 to more than 10,000. The counter counts down by dividing an initial number repeatedly with a value that is preset with binary inputs. An example is the 4059B chip.

Examples

Many counter specifications date back to the 4000 family of logic chips. Versions of them subsequently became available in the 74xx series, often with the old 4000 part number preceded by 74x (where x is replaced by a designation of the logic family). For example, a version of the 4518B dual BCD chip can be obtained as the 74HC4518. As is the case with all logic chips, this part number will be preceded by letter(s) designating the particular manufacturer, with a suffix added to differentiate minor variants of the chip. The 74xx series has the advantage of higher speed and a greater ability to source or sink current at its output pins.

Most of the original CMOS chips, such as the 4518B, are still available, even in surface-mount versions. These offer the possible advantage of being able to use a higher power supply voltage.

Many counters offer multiple options such as different modulus values that can be selected by external pin connections. Some chips are tolerant of slow clock frequencies; others are not. Most are edge-triggered, but a few are level triggered. Some, such as the 4518B mentioned above, allow a choice of a rising-edge clock input and falling-edge clock input on different pins. For a specific application, it is really necessary to read a variety of datasheets to select the chip that is most suitable.

Values

As is the case with other logic chips, most counters in the through-hole 74xx series are intended for 5VDC power supply while the older 4000 series may tolerate up to 18VDC. Surface-mount 74xx versions may use voltages as low as 2VDC.

See the section on logic gates in Chapter 10 for a discussion of acceptable high and low logic-input states. On the output side, the 4000 series chips are able to source or sink less than 1mA at 5VDC, but the 74HCxx series can usually manage around 20mA.

A few counters are capable of delivering more power through additional output stages that can drive LEDs. The 4026B decade counter is still being manufactured, capable of powering modest 7-segment displays. The 4033B has the additional option of blanking any leading zeros in a multidigit display. Other chips that were designed for direct connection to LED numerals have become obsolete as the need for this application has diminished. The 74C925, 74C926, 74C927, and 74C928 are examples. They may still be found from surplus outlets, but should not be specified in new circuit designs.

What Can Go Wrong

The entry that deals with problems affecting shift registers (see "What Can Go Wrong" on page 128), describes issues which also affect counters. The entry that deals with logic chips (see "What Can Go Wrong" on page 105), describes problems affecting all types of logic chips. In addition, the potential problems listed below are specific to counters.

Lock-Out

This is the condition which occurs if a counter with a shortened modulus is loaded with a binary state that is out of its range. Consult the datasheet and study its state diagram to determine the most likely outcome if this problem occurs.

Asynchronous Artifacts

Because the flip-flops in an asynchronous (ripple) counter do not change simultaneously, they create very brief false outputs while the ripple process is taking place. In a 4-bit counter, the binary number 0111 (decimal 7) should be followed by 1000 (decimal 8). However, the rightmost digit (i.e., the least significant bit) will change to a 0 initially, creating 0110 as a momentary binary output (decimal 6). The carry operation will then change the next digit to a 0, creating 0100 (decimal 4). The carry operation continues, changing the next digit to a 0, creating 0000. Finally the operation completes by creating 1000 as the correct output.

These intermediate states on the output pins are often referred to as *glitches*. Because they are extremely brief, they will be indetectable when a counter is used to drive a display. They can cause significant issues, however, if the outputs of the counter are connected with other logic chips.

Another type of asynchronous problem will occur if the clock speed is sufficiently high that a new pulse is received at the first flip-flop before the ripple of changing states has passed all the way through to the final flip-flop. This will result in a different brief invalid value on the output pins.

Noise

Old TTL-type counters, such as the 74LSxx series, are especially noise-sensitive. Adding a 0.1µF or 0.047µF bypass capacitor as close to the power supply pin as possible is recommended. Breadboarding counters of this type may result in errors if a high-frequency clock is used, because conductors such as patch-cords are liable to pick up noise. Modern 74HCxx counters are preferable.

encoder

14

In this encyclopedia, an **encoder** is a digital chip that converts a decimal-valued input into a binary-coded output.

The term "encoder" may alternatively refer to a **rotational encoder** (also known as a *rotary encoder*) which has a separate entry in Volume 1 of this encyclopedia. The term may also describe a *code hopping encoder*, which is an encryption device used in keyless entry systems for automobiles.

OTHER RELATED COMPONENTS

- **decoder** (see Chapter 15)
- **multiplexer** (see Chapter 16)

What It Does

An encoder is a *logic chip* that receives an input consisting of an active logical state on one of at least four input pins, which have decimal values from 0 upward in increments of 1. The encoder converts the active pin number into a binary value represented by logic states on at least two output pins. This behavior is opposite to that of a **decoder**.

Encoders are identified in terms of their inputs and outputs. For example:

- 4-to-2 encoder (four input pins, two output pins)
- 8-to-3 encoder (eight input pins, three output pins)
- 16-to-4 encoder (sixteen input pins, four output pins)

In the early days of computing, encoders processed interrupts. This application is now rare, and relatively few encoder chips are still being manufactured. However, they are still useful in small devices—for example, if a large number of inputs must be handled by a microcontroller that has insufficient pins to receive data from each individually.

Schematic Symbol

Like other logic-based components, the encoder does not have a specific schematic symbol and can be represented by a plain rectangle as in Figure 14-1, with inputs on the left and outputs on the right. The bars printed above some of the abbreviations indicate that an input or output is active-low. In this chip, the 74LS148, all inputs and outputs are active-low.

Generally speaking, inputs labeled D0, D1, D2… are used for data input, although they may simply be numbered, with no identifying letter. The encoded outputs are typically identified as Q0, Q1, Q2… or A0, A1, A2… with Q0 or A0 designating the least significant bit in the binary number.

Pins labeled E and GS are explained in the following section.

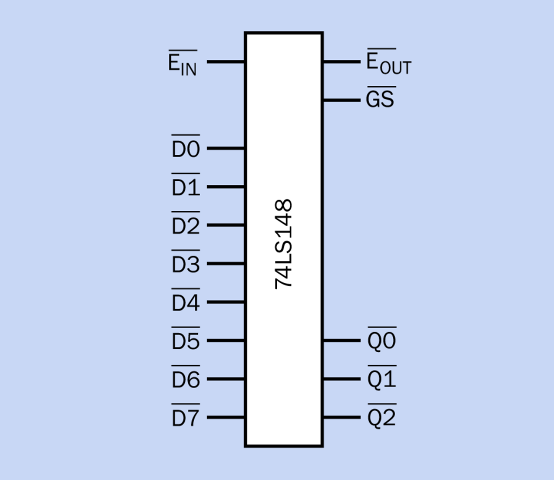

Figure 14-1. *While no specific schematic symbol exists for an encoder chip, this style is commonly used. Shown here is a 16–to–4 encoder with active-low inputs and outputs.*

Similar Devices

The similarities and differences between encoder, decoder, multiplexer, and demultiplexer can cause confusion.

- In an **encoder**, an active logic state is applied to one of four or more input pins, while the rest remain in an inactive logic state. The input pin number is converted to a binary code which is expressed as a pattern of logic states on two or more output pins.
- In a **decoder**, a binary number is applied as a pattern of logic states on two or more input pins. This value determines which one of four or more output pins will have an active logic state, while the rest remain in an inactive logic state.
- A **multiplexer** can connect a choice of multiple inputs to a single output, for data transfer. The logic state of an enable pin, or a binary number applied as a pattern of logic states to multiple control pins, chooses which input should be connected with the output pin. The alternative term *data selector* evokes the function of this device more clearly.
- An analog multiplexer may allow its inputs and outputs to be swapped, in which case it becomes a **demultiplexer**. It can connect a single input to one of multiple outputs, for data transfer. The logic state of an enable pin, or a binary number applied as a pattern of logic states to multiple control pins, chooses which output should be used. The alternative term *data distributor* evokes the function of this device more clearly.

How It Works

An encoder contains **logic gates**. The internal logic of an 8-to-3 encoder is shown in Figure 14-2, where the darker blue rectangle represents the chip. The switches in this figure are external and are included only to clarify the concept. An open switch is imagined to provide an inactive logic input, while a single closed switch provides an active logic input. (Multiple active inputs can be handled by a *priority encoder*, described below).

Each input switch has a numeric status from 1 to 7. The switch with value 0 does not make an internal connection, because the output from the OR gates is 000 by default.

The logic state of each OR output represents a binary number, weighted with decimal values 1, 2, and 4, as shown at the bottom of the figure. Thus, if switch 5 is pressed, by tracing the connections it is clear that the outputs of OR gates 4 and 1 become active, while the output from gate 2 remains inactive. The values of the active outputs thus sum to 5 decimal.

Figure 14-3 shows the outputs for all possible input states of a 4-to-2 encoder. Figure 14-4 shows the outputs for all possible input states of an 8-to-3 encoder. These diagrams assume that a high logic state is an active logic state, on input or output. This is usually the case.

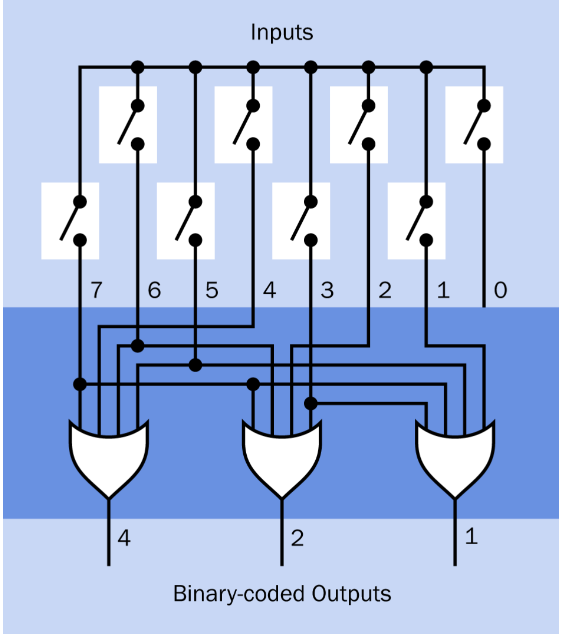
Inputs
7
6
5
4
3
2
1
0
4
2
1
Binary-coded Outputs

Figure 14-2. *A simplified simulation of the internal logic of an 8-to-3 encoder. The dark blue rectangle indicates the space inside the chip. The external switches are included only to clarify the concept. An encoder chip would have an Enable line to create an active output.*

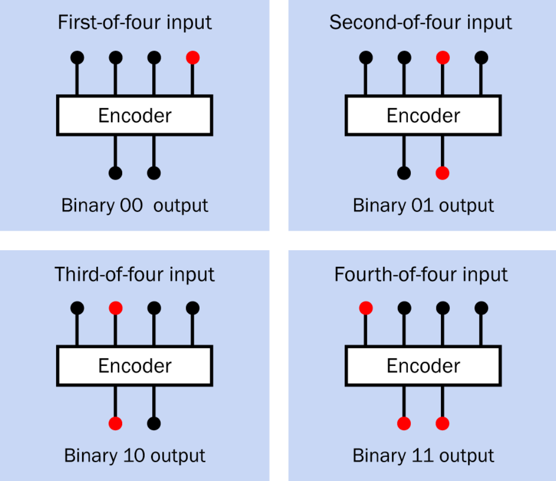
First-of-four input
Encoder
Binary 00 output
Second-of-four input
Encoder
Binary 01 output
Third-of-four input
Encoder
Binary 10 output
Fourth-of-four input
Encoder
Binary 11 output

Figure 14-3. *The four possible inputs of a 4-to-2 encoder (top of each panel) and the encoded outputs (below).*

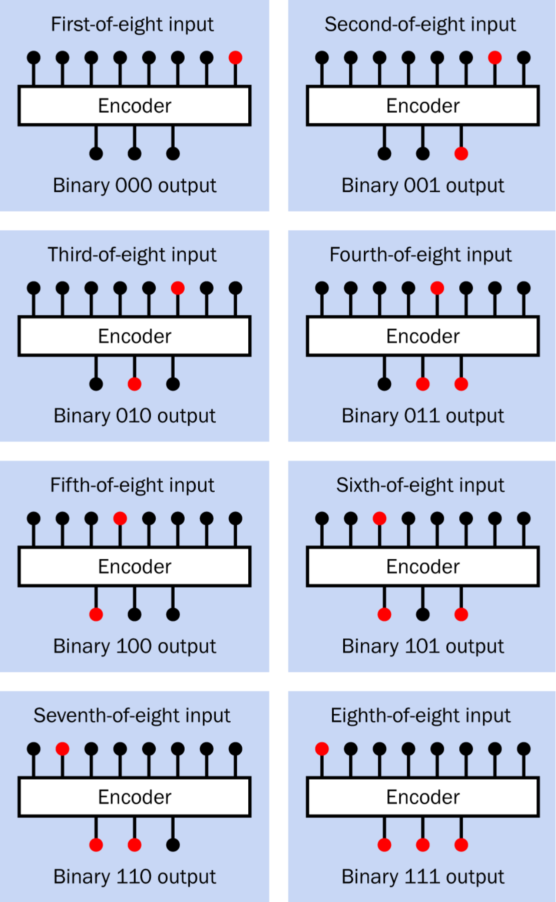
First-of-eight input
Encoder
Binary 000 output
Second-of-eight input
Encoder
Binary 001 output
Third-of-eight input
Encoder
Binary 010 output
Fourth-of-eight input
Encoder
Binary 011 output
Fifth-of-eight input
Encoder
Binary 100 output
Sixth-of-eight input
Encoder
Binary 101 output
Seventh-of-eight input
Encoder
Binary 110 output
Eighth-of-eight input
Encoder
Binary 111 output

Figure 14-4. *The eight possible inputs of an 8-to-3 encoder (at the top of each panel), and the encoded outputs (below). Note that one input of an encoder must always be logic-high. All logic-low inputs are not a valid state.*

Unlike ripple counters, where propagation delays can reduce the overall response time of the component, decoders respond within two or three nanoseconds.

Variants

A *simple encoder* assumes that only one input pin can be logically active at a time. A *priority encoder* assigns priority to the highest-value input pin if more than one happens to receive an active input. It ignores any lower-value inputs. An example is the 74LS148, which is an 8-to-3 chip.

A few encoders feature *three-state* outputs (also known as *tri-state*), in which a high-impedance or "floating" output state is available in addition to the usual high and low logic states. The high-impedance state allows multiple chips to share an output bus, as those that are in high-impedance mode appear to be disconnected. This is useful if two or more encoders are cascaded to handle a larger number of inputs.

Values

As is the case with other logic chips, most encoders in the through-hole 74xx series are intended for 5VDC power supply while the older 4000 series may tolerate up to 18VDC. Surface-mount versions may use voltages as low as 2VDC.

See the section on logic gates in Chapter 10 for a discussion of acceptable high and low input states. On the output side, the 4000 series chips are able to source less than 1mA at 5VDC, but the 74HCxx series can manage around 20mA.

How to Use It

Suppose that a microcontroller should respond to an eight-position rotary switch. Because the switch cannot be turned to more than one position at a time, all of its eight contacts can be connected with the inputs on an encoder, which will deliver a 3-bit binary number to three inputs of the microcontroller. Code inside the microcontroller then interprets the pin states.

This is shown in Figure 14-5. Pulldown resistors would be needed on the input pins of the encoder, to prevent them from floating when they are not connected by the rotary switch. They have been omitted from this diagram for simplicity. Debouncing the switch would be handled by the microcontroller.

Other forms of input may be used instead of a rotary switch. For example, the outputs from eight comparators or eight phototransistors could be passed through an encoder.

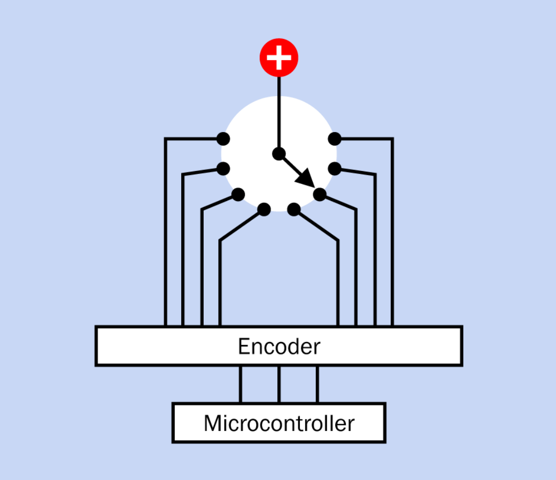

Figure 14-5. *Output from an eight-input rotary switch could be connected through an 8-to-3 encoder to provide input to a microcontroller using a reduced number of pins. Pulldown resistors have been omitted for simplicity.*

Cascaded Encoders

Encoders are often provided with features to facilitate handling additional inputs via multiple chips. Typically, a second Enable pin is provided, as an output that connects with the Enable input of the preceding chip. This preserves the priority function, so that an input on the second chip prevents any additional input to the first chip from affecting the output. In a datasheet, the enable pins may be labeled E_{IN} and E_{OUT}, or E_I and E_O.

In addition, a GS pin will be included, meaning "Group Select." It is logically active only when the encoder is enabled and at least one input is active. The GS pin of the most-significant encoder provides an additional binary digit.

The outputs from two encoders can be linked via OR gates, as shown in Figure 14-6, where the lower chip's GS output provides the most significant bit of a four-bit binary number.

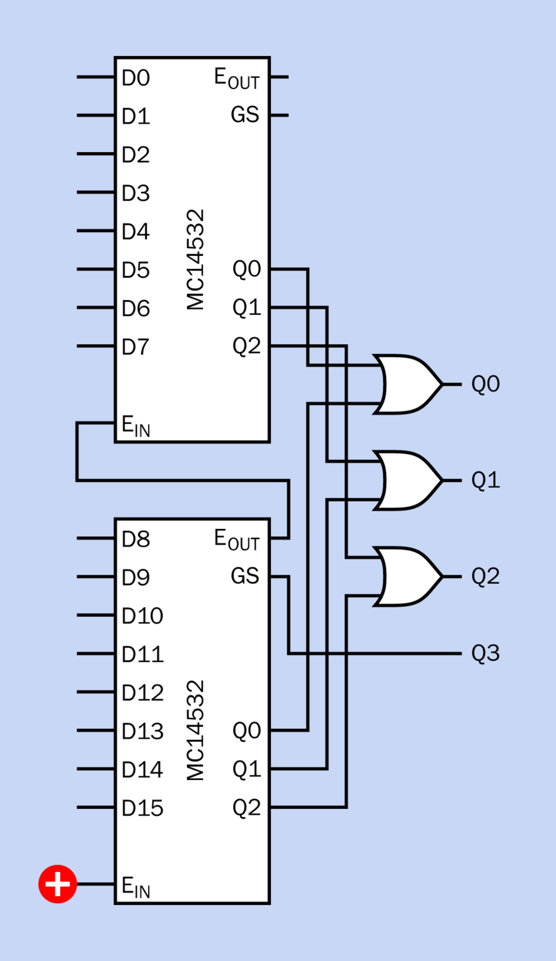
D0
D1
D2
D3
D4
D5
D6
D7
E_{IN}
E_{OUT}
GS
MC14532
Q0
Q1
Q2
Q0
Q1
Q2
Q3
D8
D9
D10
D11
D12
D13
D14
D15
E_{IN}
E_{OUT}
GS
MC14532
Q0
Q1
Q2

Figure 14-6. *Two eight-bit encoders can be cascaded to handle 16 separate inputs. In this example, the encoders use active-high logic.*

What Can Go Wrong

Problems that are common to all digital chips are summarized in the section on logic gates in "What Can Go Wrong" on page 105.

See "What Can Go Wrong" on page 149 in the entry describing **decoders** for a list of more specific problems that also afflict encoders.

decoder

15

In this Encyclopedia, a **decoder** is a digital chip that receives a binary-coded input and converts it to a decimal output by applying a logic state to one of a sequence of pins, each of which is assigned an integer value from 0 upward.

The term "decoder" also refers to components and devices that have other functions, such as decoding audio or video formats. These functions are not included here.

OTHER RELATED COMPONENTS

- **encoder** (see Chapter 14)
- **multiplexer** (see Chapter 16)

What it Does

A decoder receives a binary-coded number on two or more input pins. It *decodes* that number and expresses it by activating one of at least four output pins.

The behavior of a decoder with a two-bit binary input is shown in four sequential snapshots in Figure 15-1, where the least significant bit of the input is on the right in each diagram, and the output moves from right to left.

Figure 15-2 shows a similar sequence in a decoder where various values of a three-bit input are decoded to create an eight-pin output.

One sample state of a four-bit decoder is shown in Figure 15-3.

All of these figures assume that a high state represents an active input or output. In a few chips, a low state is used to represent an active output.

Decoders with 2, 3, or 4 input pins are common. To handle a binary input greater than 1111 (decimal 15), decoders can be chained together, as described below.

Manufacturers' datasheets often describe decoders in terms of their inputs and outputs. Typical examples would include:

- 2-to-4 decoder (two input pins, four output pins)
- 3-to-8 decoder (three input pins, eight output pins)
- 4-to-10 decoder (for converting *binary-coded decimal* to decimal output)
- 4-to-16 decoder (also known as a *hex decoder*).

Input Devices

The input pins of a decoder can be driven by a counter that has a binary-coded output. A decoder can also be driven by a microcontroller, which may have an insufficient number of output pins to control a variety of devices. Two, three, or four of the outputs can be used to represent a binary number which is passed through the decoder to activate the devices one at a time, perhaps with transistors or Darlington arrays introduced to handle the load. This is suggested in Figure 15-4.

A **shift register** can be used for a similar purpose, but often has only one pin for input. This pin must be supplied sequentially with a serial pattern of bits that will match the desired high/low states of the output pins. The relative advantage of this system is that a shift register can generate any pattern of output states. A one-of-many decoder can activate only one output at a time.

LED Driver

A special case is a *seven-segment decoder* designed to drive a seven-segment **LED display** numeral. A binary-coded decimal number on four input pins is converted to a pattern of outputs appropriate for lighting the segments of the display that will form a number from decimal 0 through 9.

Schematic Symbol

Like other logic-based components, the decoder does not have a specific schematic symbol and is represented by a plain rectangle as in Figure 15-5, with inputs on the left and outputs on the right. The bars printed above the E and LE abbreviations (which stand for Enable and Latch Enable, respectively) indicate that they are active-low. In this chip, the 74HC4514, all outputs are active-high, but in a related 4-to-16 decoder, the 74HC4515, all outputs are active-low. In both of these chips, the Enable pin is held low to activate the outputs. The Latch Enable pin freezes the current state of the outputs (i.e., it latches them) when it is held low.

Generally speaking, pins labeled A0, A1, A2… in a datasheet are often the binary inputs (although A, B, C… may be used), with A0 designating the least significant bit. Outputs are usually labeled Y, and are activated in sequence from Y0 when the binary input starts counting upward.

Similar Devices

The similarities and differences between encoder, decoder, multiplexer, and demultiplexer can cause confusion.

- In a **decoder**, a binary number is applied as a pattern of logic states on two or more input pins. This value determines which one of four or more output pins will have an active logic state, while the rest remain in an inactive logic state.
- A **multiplexer** can connect a choice of multiple inputs to a single output, for data transfer. The logic state of an enable pin, or a binary number applied as a pattern of logic states to multiple control pins, chooses which input should be connected with the output pin. The alternative term *data selector* evokes the function of this device more clearly.
- An analog multiplexer may allow its inputs and outputs to be reversed, in which case it becomes a **demultiplexer**. It can connect a single input to one of multiple outputs, for data transfer. The logic state of an enable pin, or a binary number applied as a pattern of logic states to multiple control pins, chooses which output should be used. The alternative term *data distributor* evokes the function of this device more clearly.

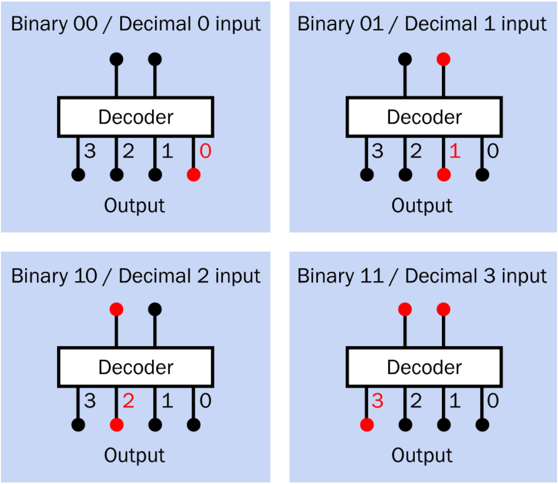
Binary 00 / Decimal 0 input
Decoder
3
2
1
0
Output
Binary 01 / Decimal 1 input
Decoder
3
2
1
0
Output
Binary 10 / Decimal 2 input
Decoder
3
2
1
0
Output
Binary 11 / Decimal 3 input
Decoder
3
2
1
0
Output

Figure 15-1. *A decoder with two input pins can interpret their binary-number representation to create an active logic state on one of four output pins.*

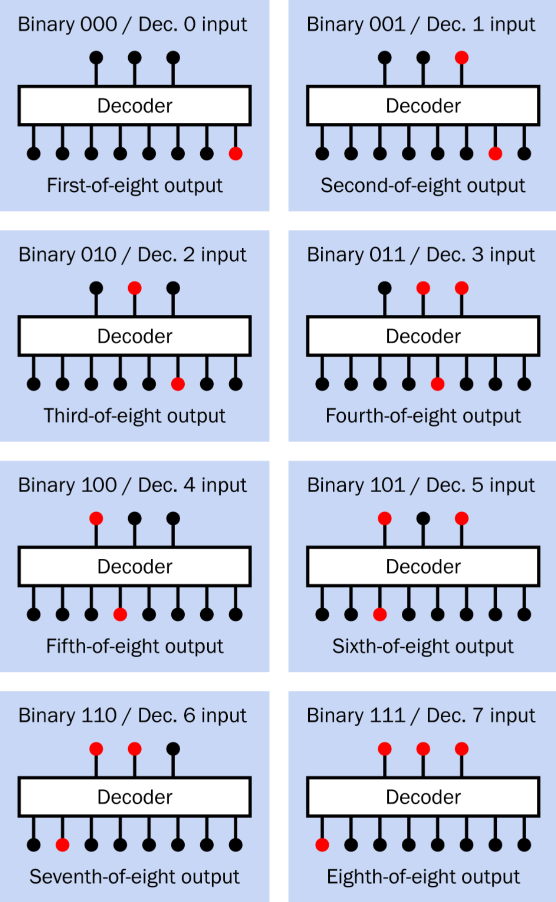
Binary 000 / Dec. 0 input
Decoder
First-of-eight output
Binary 001 / Dec. 1 input
Decoder
Second-of-eight output
Binary 010 / Dec. 2 input
Decoder
Third-of-eight output
Binary 011 / Dec. 3 input
Decoder
Fourth-of-eight output
Binary 100 / Dec. 4 input
Decoder
Fifth-of-eight output
Binary 101 / Dec. 5 input
Decoder
Sixth-of-eight output
Binary 110 / Dec. 6 input
Decoder
Seventh-of-eight output
Binary 111 / Dec. 7 input
Decoder
Eighth-of-eight output

Figure 15-2. *A decoder with three input pins can interpret their binary-number representation to create a high logic state on one of eight output pins.*

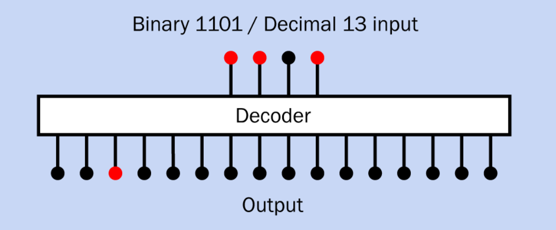
Binary 1101 / Decimal 13 input
Decoder
Output

Figure 15-3. *A decoder with four input pins can interpret their binary-number representation to create a high logic state on one of 16 output pins. Only one of the 16 possible states is shown here.*

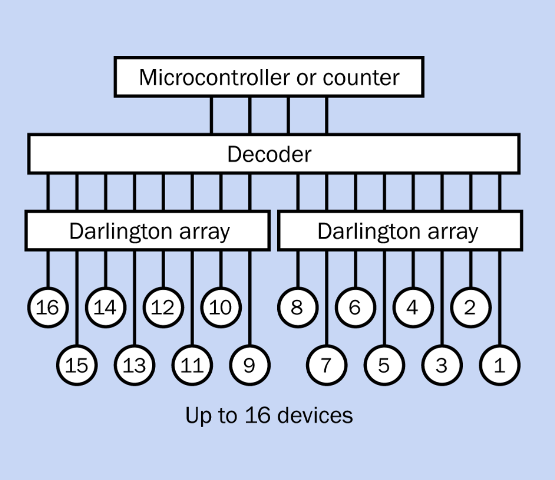
Microcontroller or counter
Decoder
Darlington array
Darlington array
16
14
12
10
8
6
4
2
15
13
11
9
7
5
3
1
Up to 16 devices

Figure 15-4. *Four outputs from a binary counter or microcontroller can be used by a decoder to activate one of up to 16 output devices.*

A photograph of a 74HC4514 decoder chip appears in Figure 15-6.

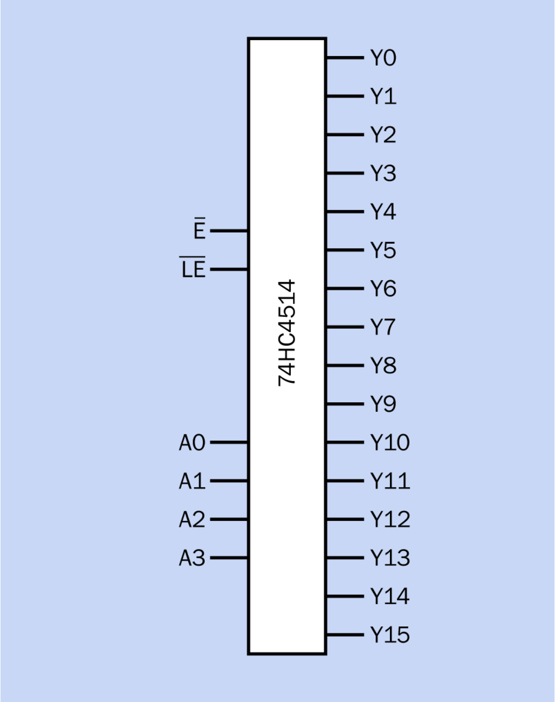
$\overline{E}$
$\overline{LE}$
A0
A1
A2
A3
74HC4514
Y0
Y1
Y2
Y3
Y4
Y5
Y6
Y7
Y8
Y9
Y10
Y11
Y12
Y13
Y14
Y15

Figure 15-5. *While no specific schematic symbol exists for a decoder chip, this style is commonly used. Shown here is a 4-to-16 decoder.*

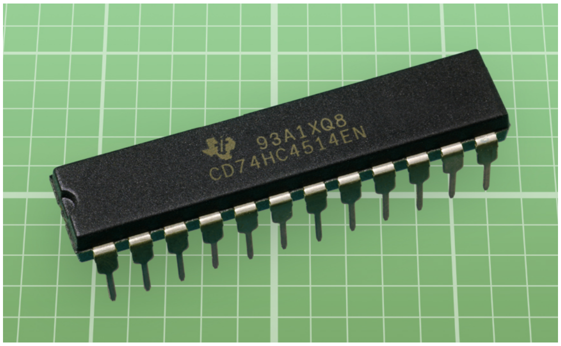

Figure 15-6. *The 24-pin 74HC4514 decoder chip processes a 4-bit input and represents it by making one of its 16 output pins active-high.*

How It Works

A decoder contains logic gates, each of which is wired to respond to a unique binary pattern of inputs. (In the case of a seven-segment decoder, the internal logic is more complicated.) Figure 15-7 shows the logic of a 2-to-4 decoder. The darker blue area contains the components inside the chip. The external switches are included only to clarify the function of the decoder. An open switch is imagined to provide a low logic input, while each closed switch provides a high logic input.

Unlike ripple counters, where propagation delays can reduce the overall response time of the component, decoders function within two or three nanoseconds.

Variants

Decoder variants have not proliferated with time, and relatively few are available. Most are 3-to-8, 4-to-16, and binary-coded-decimal types.

The 7447 and 74LS47 are seven-segment decoders that have an open-collector output capable of driving a 7-segment display directly. The 7448 is similar but also contains built-in resistors and a capability to blank out leading zeros in a display. However, some suppliers now list the 74LS48 as obsolete. It may be still available from old stock, but should not be specified in new circuits.

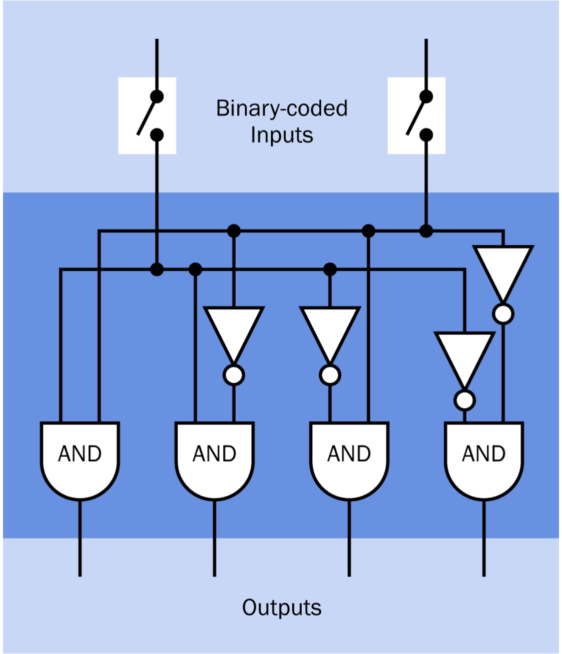

Figure 15-7. *A simplified simulation of the logic in a decoder. An actual chip would have an Enable line to activate the output. The dark blue rectangle indicates the space inside the chip.*

Although 74LS47 is still being manufactured, and is available in surface-mount as well as through-hole format, a version is not available in the widely used HC family of 74xx chips. Care must be taken to satisfy the input voltage requirements of the 74LS47 when driving it with 74HCxx chips.

Values

As is the case with other logic chips, most decoders in the through-hole 74xx series are intended for 5VDC power supply while the older 4000 series may tolerate up to 18VDC. Surface-mount versions may use voltages as low as 2VDC.

See the section on logic gates in Chapter 10 for a discussion of acceptable high and low input states. On the output side, the 4000 series chips are able to source or sink less than 1mA at 5VDC, but the 74HCxx series can manage around 20mA.

How to Use It

The original applications for decoders in computer circuits have become uncommon, but the chips can still be useful in small appliances and gadgets where multiple outputs are controlled by a **counter** or microcontroller.

Although 16 is usually the maximum number of outputs, some chips are designed to allow expansion. The 74x138 (where a chip family identifier such as LS or HC can be substituted for the letter x) is a 3-to-8 decoder with two logic-low Enable pins and one logic-high Enable. If a value-8 binary line is applied to the low-enable of one chip and the high-enable of another, the first chip will be disabled when the line goes high to indicate that the binary number 1000 has been reached, and the second chip can continue upward from there by sharing the same three less-significant-bit inputs. As many as four chips can be chained in this way.

What Can Go Wrong

Problems that are common to all digital chips are summarized in the section on logic gates in "What Can Go Wrong" on page 105.

Glitches

Although a decoder typically functions faster than a ripple counter, it suffers the same tendency to introduce brief *glitches* in its output. These are momentary invalid states which occur while processes inside the chip that are slightly slower are catching up with other processes that reach completion slightly faster. A brief *settling time* is necessary to ensure that the output is stable and valid. This will be irrelevant when powering a device such as an **LED indicator**, which will not display such brief transients. The problem may be more important if the output from the decoder is used as an input to other logic chips.

If the input to a decoder is derived from a ripple counter, the input may also contain glitches, which can cause erroneous outputs from the decoder. It is better to use a synchronous counter on the input side of a decoder.

Unhelpful Classification

Online parts suppliers tend to list decoders under the same category heading as encoders, multiplexers, and demultiplexers, making it difficult to find what you want. Under this broad subject heading (which will include thousands of chips), if you search by selecting the number of inputs relative to the number of outputs that you have in mind, this will narrow the search considerably.

Active-Low and Active-High

Chips with identical appearance and similar part numbers may have outputs that are either active-low or active-high. Some may offer a latch-enable pin, while others have enable pins that must be pulled low or forced high to produce an output. Accidental chip substitution is a common cause of confusion.

multiplexer

16

May be abbreviated as a *mux* (this term is sometimes printed all in caps), and may be referred to alternatively as a *data selector*. Some sources maintain that a multiplexer has no more than two channels, whereas a data selector has more, but there is no consensus on this, and datasheets continue to use the term "multiplexer" predominantly.

Analog multiplexers are usually bidirectional, and thus will function equally well as *demultiplexers*. Consequently, this encyclopedia does not contain a separate entry for demultiplexers.

OTHER RELATED COMPONENTS

- **encoder** (see Chapter 14)
- **decoder** (see Chapter 15)

What It Does

A multiplexer can select one of two or more input pins, and connect it internally with an output pin. Although it is an entirely solid-state device, it behaves as if it contains a **rotary switch** in series with a SPST switch, as shown in Figure 16-1. A binary code applied to one or more Select pins chooses the input, and an Enable pin establishes the connection with the output. The Select and Enable functions are processed via an internal section referred to as a *decoder*, not to be confused with a **decoder** chip, which has its own entry in this encyclopedia.

All multiplexers are digitally controlled devices, but may be described as either *digital* or *analog* depending how they process the input signal. A digital multiplexer creates an output that is adjusted to logic-high or logic-low within the limits of its logic family. An analog multiplexer does not impose any processing on the voltage, and passes along any fluctuations. Thus, it can be used with alternating current.

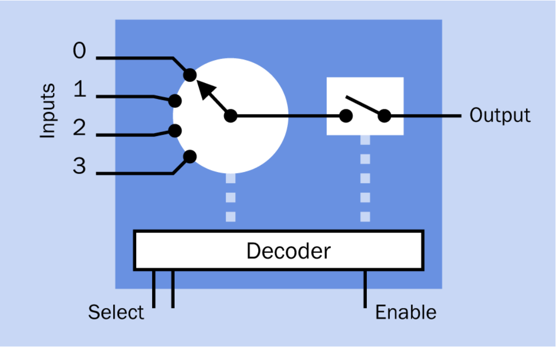

Figure 16-1. *A multiplexer functions as if it contains a rotary switch. The switch position is determined by a binary number applied to external Select pins. The internal connection is completed by applying a signal to an Enable pin.*

Because an analog multiplexer merely switches a flow of current, it can be *bidirectional*; in other words, it can function as a *demultiplexer*, in which case the input is applied to the pole of the (imaginary) internal switch and outputs are taken from the terminals.

Differential Multiplexer

A *differential* multiplexer contains multiple switches that are differentiated from one another (i.e., they are electrically isolated, although they are controlled by the same set of select pins). A differential multiplexer is conceptually similar to a rotary switch with two or more decks controlled by a single shaft. See Figure 16-2.

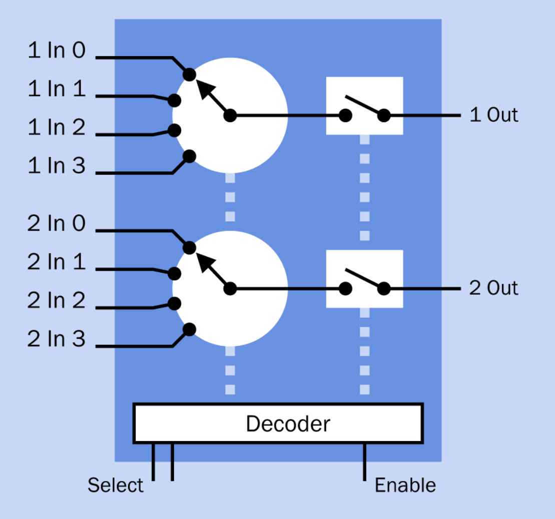

Figure 16-2. *A differential multiplexer contains two or more electronic switches that are differentiated from one another, similarly to the decks on a rotary switch. Although the channels into each switch are typically numbered from 0 upward, the switches are numbered from 1 upward.*

A bidirectional dual 4-channel differential analog multiplexer is shown in Figure 16-3.

Modern multiplexers are often found switching high-frequency data streams in audio, telecommunications, or video applications.

Similar Devices

The similarities and differences between multiplexer, demultiplexer, encoder, and decoder can cause confusion:

- A **multiplexer** can connect a choice of multiple inputs to a single output, for data transfer. The logic state of an enable pin, or a binary number applied as a pattern of logic states to multiple control pins, chooses which input should be connected with the output pin. The alternative term *data selector* evokes the function of this device more clearly.
- An *analog* multiplexer may allow its inputs and outputs to be reversed, allowing it to become a **demultiplexer**, connecting a single input to one of multiple outputs, for data transfer. The logic state of an enable pin, or a binary number applied as a pattern of logic states to multiple control pins, chooses which output should be used. The alternative term *data distributor* evokes the function of this device more clearly.

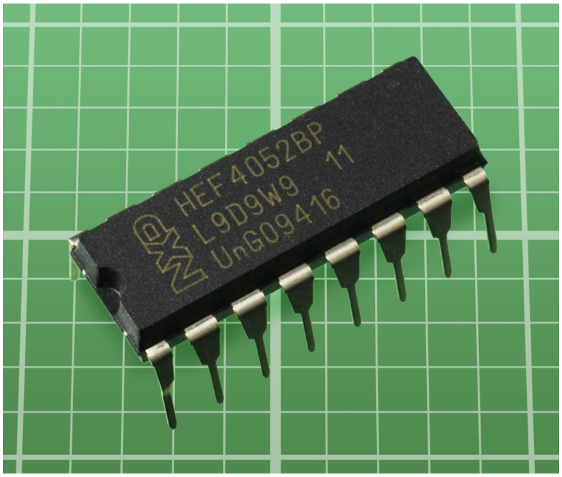

Figure 16-3. *This CMOS chip contains two four-channel differential analog multiplexers.*

- In an **encoder**, an active logic state is applied to one of four or more input pins, while the rest remain in an inactive logic state. The input pin number is converted to a binary code which is expressed as a pattern of logic states on two or more output pins.
- In a **decoder**, a binary number is applied as a pattern of logic states on two or more input pins. This value determines which one of four or more output pins will have an active logic state, while the rest remain in an inactive

logic state. A digital multiplexer does not allow reversal of its inputs and outputs, but a decoder functions as if it were a digital demultiplexer.

How It Works

The multiple inputs to a multiplexer are referred to as *channels*. Almost always, the number of channels is 1, 2, 4, 8, or 16. A 1-channel component is only capable of “on” or “off” modes and functions similarly to a SPST switch.

If there are more than two channels, a binary number will determine which channel is connected internally. The number of channels is usually the maximum that can be identified by the number of select pins, so that 2 pins will control 4 channels, 3 pins will control 8 channels, and 4 pins (the usual maximum) will control 16 channels.

In multiplexers with three or more channels, an enable pin is usually still present to activate or deactivate all the channels simultaneously. The enable feature may be described alternatively as a *strobe*, or may have an inverse function as an *inhibit* pin.

Although a rotary switch is helpful in conceptualizing the function of a multiplexer, a more common representation (sometimes in datasheets) is an array of SPST switches, each of which can be opened or closed by the decoder circuit. A typical example, depicting a dual differential multiplexer, is shown in Figure 16-4. Note that the internal decoder can only close one switch in each channel at a time.

The switch analogy is appropriate in that when an output from a multiplexer is not connected internally (i.e., its switch is “open”) it is effectively an open circuit. However, some multiplexers contain *pullup resistors* to give each output a defined state. This can be an important factor in determining whether the multiplexer is suitable for a particular application.

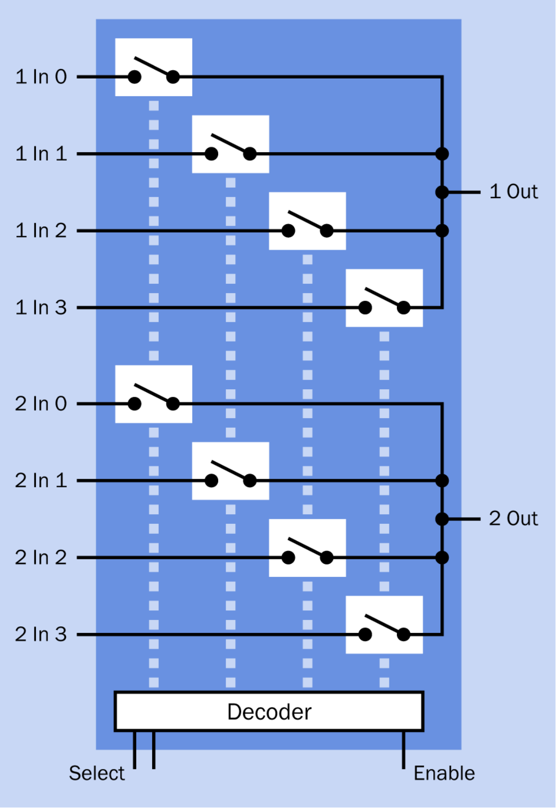

Figure 16-4. *The internal function of a dual multiplexer is commonly represented as a network of SPST switches, each of which is controlled by decoder logic.*

A digital multiplexer actually contains a network of logic gates, shown in simplified form in Figure 16-5.

A demultiplexer has internal logic shown in simplifier form in Figure 16-6.

Schematic Symbol

In a schematic, a multiplexer and demultiplexer may be represented by a trapezoid with its longer vertical side oriented toward the larger number of connections. This is shown in Figure 16-7. However, this symbol is falling into disuse.

More often, as is the case with most logic components, a multiplexer or demultiplexer is represented by a rectangle with inputs on the left and outputs on the right, as shown in Figure 16-8. The distinction between inputs and outputs is problematic, however, in an analog multiplexer which will allow data flow to be reversed.

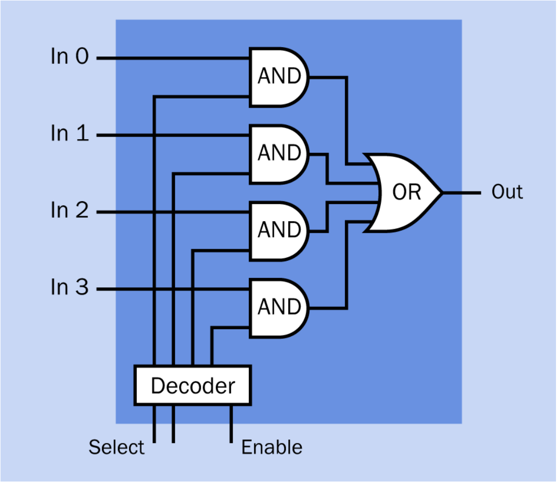
In 0
In 1
In 2
In 3
AND
AND
AND
AND
OR
Out
Decoder
Select
Enable

Figure 16-5. *A simplified representation of the logic gates in a digital multiplexer.*

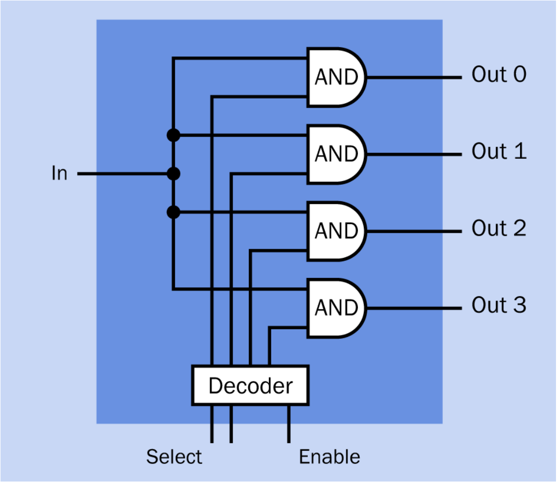
In
AND
AND
AND
AND
Out 0
Out 1
Out 2
Out 3
Decoder
Select
Enable

Figure 16-6. *A simplifier representation of the logic gates in a digital demultiplexer.*

Pin Identifiers

The lack of standardization in the identification of pin functions is perhaps more extreme in the case of multiplexers than for other types of logic chips.

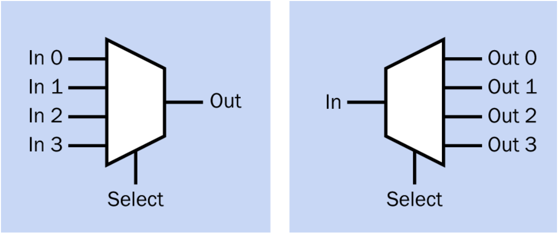
In 0
In 1
In 2
In 3
Out
Select
In
Out 0
Out 1
Out 2
Out 3
Select

Figure 16-7. *The traditional symbol for a multiplexer (left) and demultiplexer (right). The trapezoid is oriented with its longer vertical side facing the larger number of connections. This symbol is falling into disuse.*

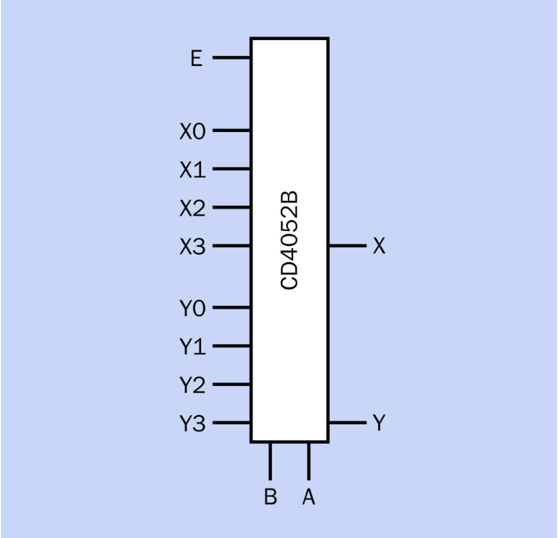
E
X0
X1
X2
X3
Y0
Y1
Y2
Y3
CD4052B
X
Y
B
A

Figure 16-8. *A simple rectangle is most often used as a schematic symbol for a multiplexer, but the abbreviations assigned to pin functions are not standardized. See text for details.*

An output enable pin will be shown as E or EN, or occasionally OE. It may alternatively be described as an inhibit pin, labeled INH, or sometimes will be called a strobe. The function is the same in each case: one of its logic states will enable the internal switches, while its other logic state will prevent any internal switches from closing.

Switch inputs may be labeled S0, S1, S2… or X0, X1, X2… or may simply be numbered, almost always counting up from 0. Where two or more sets of switches coexist in one package, each set of inputs may be distinguished from the others by preceding each identifier with a numeral or letter to designate the switch, as in 1S0, 1S1, 1S2… or 1X0, 1X1, 1X2… (Switches are generally numbered from 1 upward, even though their inputs are numbered from 0 upward.) Outputs may be identified using the same coding scheme as inputs, bearing in mind that the inputs and outputs of an analog multiplexer usually are interchangeable. Some manufacturers, however, prefer to identify each multiplexer output by preceding it with letter Y. Alternatively, Z1, Z2, Z3… may identify the outputs from switches 1, 2, 3… Fortunately, datasheets usually include some kind of key to this grab-bag of abbreviations.

Control pins are often identified as A, B, C… with letter A representing the least significant bit in the binary number that is applied to the pins.

Voltages can be confusing in multiplexers. Components intended for use with digital inputs are straightforward enough, as the supply voltage will be identified as V_{CC} and is typically 5VDC for through-hole packages (often lower for surface-mount), while negative ground is assumed to be 0VDC. However, where a multiplexer may be used with AC inputs in which the voltage varies above and below 0V, supply voltages above and below 0VDC are also possible—such as +7.5VDC and −7.5VDC, to take a random example. Three power-supply pins may be provided for this purpose. The positive supply will usually be identified as V_{DD} (the D refers to the Drain in the internal MOSFETs). A V_{EE} pin may be at 0VDC or at a negative value equal and opposite to V_{DD}. The E in this abbreviation is derived from Emitter voltage, even though the component may not contain a bipolar transistor with an emitter. Customarily, a V_{SS} pin (the S being derived from the Source in the internal MOSFETs) will be at 0VDC, and other voltages will be measured above and below this baseline. This ground pin may alternatively be labeled GND.

As is customary in logic chips, low-active control pins will have a bar printed above their identifiers, or an apostrophe will be placed after an identifier if the font does not permit printing the bar. Alternatively, low-active pins may be represented by showing a small circle, properly referred to as a *bubble*, at the input or output point of the symbol for the multiplexer. Note that analog inputs and outputs are neither high-active nor low-active; they merely pass voltages through.

Variants

Most multiplexers are “break before make” devices, where one input is disconnected before the next input is connected. However, some exceptions exist, and datasheets should be checked for this. It can be a significant issue, because make-before-break switching will briefly connect external devices with each other, through the chip.

Many multiplexers can tolerate control voltages above the usual high value in a logic circuit—as high as 15VDC in some cases. The voltage that is switched by the multiplexer may be the same as the control voltage, or may be higher.

Some analog multiplexers have *overvoltage protection* that allows them to withstand input voltages that are twice or three times the recommended maximum.

Datasheets may mention “internal address decoding,” meaning that the binary number input, specifying a channel to be switched, is decoded inside the chip. In fact, virtually all multiplexers now have on-chip address decoding, and this feature should be assumed to exist, regardless of whether it is mentioned.

Values

The voltage to be switched will usually be referred to as the *input voltage*, V_{IN}.

An analog multiplexer should not be subjected to current exceeding the value that it is designed to switch. This is known as the maximum *channel current*. A typical value would be 10mA, although many modern surface-mount components are designed for currents in the microamp range.

The *on-resistance* is the resistance imposed by the analog multiplexer on the signal flowing through it. While modern, specialized analog multiplexers may have an on-resistance as low as 5Ω, these are relatively unusual. An on-resistance of 100Ω to 200Ω is more common. This value will vary within a component depending on the power supply voltage and the voltage being switched. It will increase slightly as V_{IN} deviates above (or below) 0V, will increase substantially for lower values of supply voltage, and will increase significantly with temperature.

The curves in Figure 16-9 show on-resistance of an analog multiplexer varying with input voltage, with three different power supplies: plus-and-minus 2.5VDC (described in the graph as a "spread" of 5VDC), plus-and-minus 5VDC (a "spread" of 10VDC), and plus-and-minus 7.5VDC (a "spread" of 15VDC). These curves were derived from a datasheet for the MC14067B analog multiplexer; curves for other chips will be different, although the basic principles remain the same.

Switching time is an important consideration in high-speed applications. The "on" and "off" times specified in a datasheet (often as t_{ON} and t_{OFF}) are a function of the propagation delay from the control input to the toggling of the switch, and are generally measured from the halfway point of the rising or falling edge of the control input, to the 90% point of the output signal level.

Leakage current is the small amount of current (often measured in picoamperes) that the solid-state switch will pass when it is in its "off" state. This should be insignificant except when very high-impedance loads are used.

Separate switches inside a multiplexer may have characteristics that differ slightly from one another. Differences in on-resistance between adjacent switches can be important when switching parallel analog signals. A datasheet should mention the extent to which switches have matched characteristics, and may define the maximum deviation from one another using the abbreviation R_{ON} even though this same term may be used, confusingly, to denote the on-resistance of each individual switch.

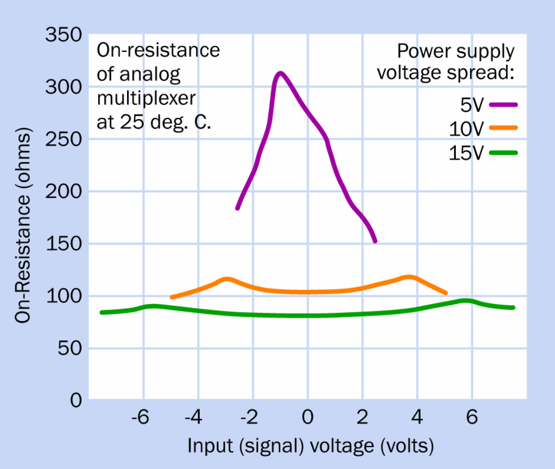

Figure 16-9. *Variations in on-resistance in an analog multiplexer. Each voltage "spread" is the difference between positive supply voltage and an equal-and-opposite negative ground voltage. Thus a "spread" of 10VDC means plus and minus voltages of 5VDC. (Curves derived from On Semiconductor datasheet for MC14067B analog multiplexer.)*

How to Use It

A multiplexer may be used as a simple switch to choose one of multiple inputs, such as a choice of input jacks on a stereo system. A dual differential multiplexer is useful in this application, as it can use a single select signal to switch two signal paths simultaneously.

A multiplexer can also be used as a digital volume control by switching an audio signal among a variety of resistances, similar to a **digital potentiometer**. In this application, the possible presence of pullup resistors inside the multiplexer must be considered.

Where a microcontroller must monitor a large number of inputs (for example, a range of temperature sensors or motion sensors), a multiplexer can reduce the number of input pins required. Its data-select pins will be cycled through all the possible binary states by the microcontroller, to select each data input in turn, while its single-wire output will carry the analog data to a separate pin on the microcontroller which performs an analog-digital conversion.

Conversely, a demultiplexer (i.e., an analog multiplexer such as the 4067B chip which can be used in demultiplexer mode) can be used by a microcontroller to switch multiple components on and off. Four outputs from the microcontroller can connect with the control pins of a 16-channel demultiplexer, counting from binary 0000 through binary 1111 to select output pins 0 through 15. After selecting each pin, the microcontroller can send a high or low pulse through it. The process then repeats. (A **decoder** can be used in the same way.)

Other Application Notes

Multiplexers may be *cascaded* to increase the inputs-to-outputs ratio.

Modern multiplexers are found on computer boards where they choose among video output ports, or as PCI express channel switches.

A multiplexer may be used as a parallel-to-serial converter, as it samples multiple channels and converts them into a serial data stream.

In telecommunications, a multiplexer can sample voice signals from multiple separate inputs and combine them into a digital stream that can be transmitted at a faster bit rate over a single channel. However, this application goes far beyond the simple uses for multiplexers described here.

What Can Go Wrong

Problems that are common to all digital chips are summarized in the section on logic gates (see "What Can Go Wrong" on page 105).

Pullup Resistors

While they are often necessary to prevent connections from floating, pullup resistors built into a multiplexer may have unexpected consequences if the user is unaware of them.

Break Before Make

For most applications, it is desirable for each internal solid-state switch to break one connection before making a new one. This avoids the possibility of separate external components being briefly connected with each other through the multiplexer. Datasheets should be checked to verify that a multiplexer functions in break-before-make mode. If it doesn't, the enable pin can be used momentarily to disable all connections before a new connection is established.

Signal Distortion

Where a multiplexer is passing analog signals, signal distortion can result if the on-resistance of multiple internal switches varies significantly at different voltages. A datasheet for an analog multiplexer should usually include a graph showing on-resistance over the full signal range. The flatter the graph is, the less distortion the component will create. This is often described in datasheets as R_{ON} Flatness.

Limits of CMOS Switching

Although most multiplexers are built around CMOS transistors, their switching speed may be insufficient for video signals, and their on-resistance may vary enough to introduce distortion. Multiplexers are available with complementary bipolar switching for very high-speed applications. They impose some penalties in cost and power consumption.

Transients

Switch capacitance inside a multiplexer can cause transients in the output when the switch changes state. An allowance for *settling time* may be necessary. This will be additional to the switching speed claimed by the datasheet.

LCD

17

The full term *liquid-crystal display* is seldom used. Its acronym, **LCD**, is much more common. Sometimes the redundant combination **LCD display** is found. All three terms refer to the same device. In this encyclopedia, the first two words in *liquid-crystal display* are hyphenated because they are an adjectival phrase. Other sources often omit the hyphen.

The acronym **LED** (for **light-emitting diode**) is easily confused with **LCD**. While both devices display information, their mode of action is completely different.

OTHER RELATED COMPONENTS

- **LED display** (see Chapter 24)

What It Does

An LCD presents information on a small display panel or screen by using one or more segments that change their appearance in response to an AC voltage. The display may contain alphanumeric characters and/or symbols, icons, dots, or pixels in a *bitmap*.

Because of its very low power consumption, a basic monochrome LCD is often used to display numerals in battery-powered devices such as digital watches and calculators. A small liquid-crystal display of this type is shown in Figure 17-1.

Color-enabled, backlit LCDs are now frequently used in almost all forms of video displays, including those in cellular telephones, computer monitors, game-playing devices, TV screens, and aircraft cockpit displays.

How It Works

Light consists of electromagnetic waves that possess an electric field and a magnetic field. The fields are perpendicular to each other and to the direction in which the light is traveling, but the field polarities are randomly mixed in most visible radiation. This type of light is referred to as *incoherent*.

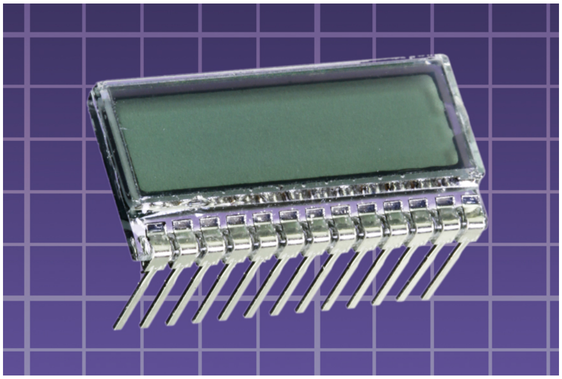

Figure 17-1. *A small, basic monochrome LCD.*

Figure 17-2 shows a simplified view of an LCD that uses a backlight. Incoherent light emerges from the backlight panel (A) and enters a vertical polarizing filter (B) that limits the electric field vector. The polarized light then enters a liquid crystal (C) which is a liquid composed of molecules organized in a regular helical structure that rotates the polarity by 90 degrees when no voltage is applied to it. The light now passes through a horizontal polarizing filter (D) and is visible to the user.

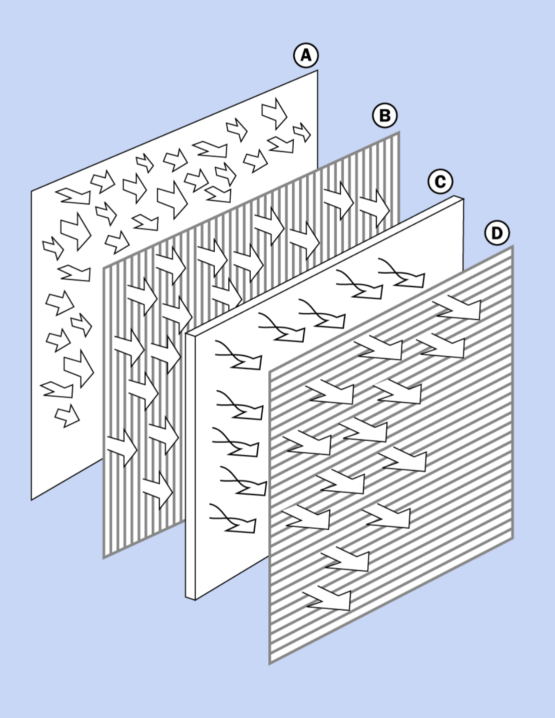

Figure 17-2. *The combination of two polarizers and a liquid crystal appears transparent when voltage is not applied. See text for details.*

- A liquid crystal itself does not emit light. It can only modify light that passes through it.

Figure 17-3 shows what happens when voltage is applied to the liquid crystal via transparent electrodes (not included in the figure). The molecules reorganize themselves in response to the electric potential and allow light to pass without changing its polarity. Consequently, the vertically polarized light is now blocked by the front, horizontally polarized filter, and the display becomes dark.

A liquid crystal contains ionic compounds that will be attracted to the electrodes if a DC voltage is applied for a significant period of time. This can degrade the display permanently. Therefore, AC voltage must be used. An AC frequency of 50Hz to 100Hz is common.

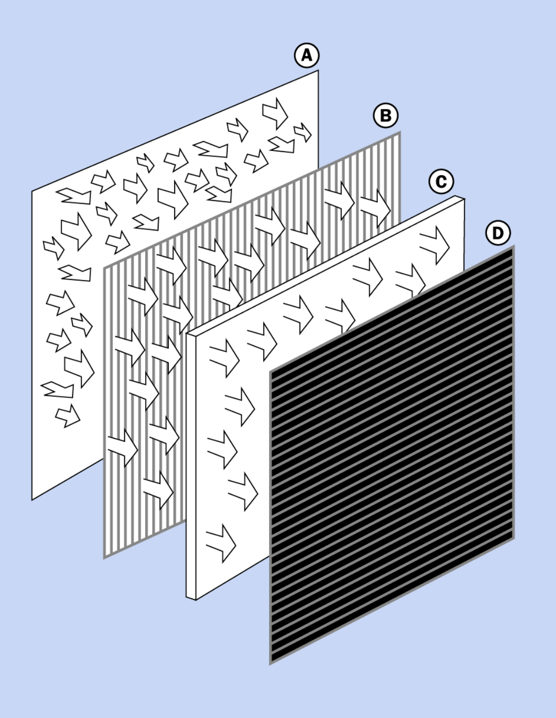

Figure 17-3. *The LCD appears dark when voltage is applied. See text for details.*

Variants

A *transmissive LCD* requires a backlight to be visible, and is the type illustrated in Figure 17-2. In its simplest form, it is a monochrome device, but is often enhanced to display full color by adding red, green, and blue filters. Alternatively, instead of a white backlight, an array of pixel-sized red, green, and blue **LEDs** may be used, in which case filters are unnecessary.

Backlit color LCDs have displaced *cathode-ray tubes*, which used to be the default system in almost all video monitors and TVs. LCDs are not only cheaper but can be fabricated in larger sizes. They do not suffer from *burn in*, where a persistent unchanging image creates a permanent scar in the phosphors on the inside of a tube. However, large LCDs may suffer from dead pixels or stuck pixels as manufacturing defects. Different manufacturers and vendors have varying policies regarding the maximum acceptable number of pixel defects.

In a *reflective LCD*, the structure is basically the same as that shown in Figure 17-2 except that a reflective surface is substituted for the backlight. Ambient light enters from the front of the display, and is either blocked by the liquid crystal in combination with the polarizing filters, or is allowed to reach the reflective surface at the rear, from which it reflects back through the liquid crystal to the eye of the user. This type of display is very easily readable in a bright environment, but will be difficult to see in dim conditions and will be invisible in darkness. Therefore, it may be augmented with a user-activated light source mounted at the side of the display.

A *transreflective LCD* contains a translucent rear polarizer that will reflect some ambient light, and is also transparent to enable a backlight. While this type of LCD is not as bright as a reflective LCD and has less contrast, it is more versatile and can be more energy efficient, as the backlight can be switched off automatically when ambient light is bright enough to make the display visible.

Active and Passive Types

An *active matrix* LCD adds a matrix of thin-film transistors to the basic liquid-crystal array, to store the state of each segment or pixel actively while the energizing AC voltage transitions from positive to negative. This enables a brighter, sharper display as *crosstalk* between adjacent pixels is reduced. Because *thin-film transistors* are used, this is often described as a *TFT* display; but the term is interchangable with *active matrix*.

A *passive matrix* LCD is cheaper to fabricate but responds sluggishly in large displays and is not so well suited to fine gradations in intensity. This type of component is used primarily in simple monochrome displays lacking intermediate shades of gray.

Crystal Types

Twisted Nematic (TN) are the cheapest, simplest type of LCD, allowing only a small viewing angle and average contrast. The appearance is limited to black on gray. The response rate is relatively slow.

Super Twisted Nematic (STN) displays were developed in the 1980s for passive LCDs, enabling better detail, wider view angle, and a faster response. The natural appearance is dark violet or black on green, or dark blue on silver-gray.

Film-compensated Super Twisted Nematic (FSTN) uses an extra coating of film that enables a pure black on white display.

Double Super Twisted Nematic provides further enhancement of contrast and response times, and automatic contrast compensation in response to ambient temperature. The appearance is black on white. This display requires backlighting.

Color Super Twisted Nematic (CSTN) is an STN display with filters added for full color reproduction.

Seven-Segment Displays

The earliest monochrome LCDs in devices such as watches and calculators used seven segments to display each numeral from 0 through 9. This type of LCD is still used in low-cost applications. A separate control line, or electrode, connects to each segment, while a *backplane* is shared by all the segments, connecting with a *common* pin to complete the circuit.

Figure 17-4 shows a typical seven-segment display. The lowercase letters *a* through *g* that identify each segment are universally used in datasheets. The decimal point, customarily referred to as “dp,” may be omitted from some displays. The array of segments is slanted forward to enable more acceptable representation of the diagonal stroke in numeral 7.

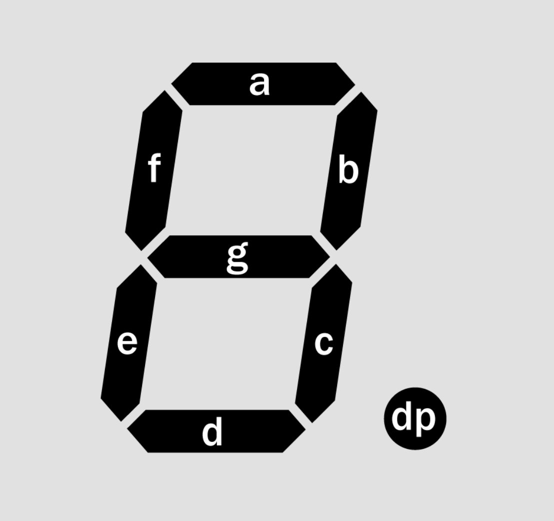

Figure 17-4. *Basic numeric display format for LCD numeric displays (the same layout is used with LEDs). To identify each segment, lowercase letters are universally used.*

Seven-segment displays are not elegant but are functional and are reasonably easy to read, as shown in Figure 17-5. Letters A, B, C, D, E, and F (displayed as A, b, c, d, E, F because of the restrictions imposed by the small number of segments) may be added to enable display of hexadecimal values.

In appliances such as microwave ovens, very basic text messages can be displayed to the user within the limitations of 7-segment displays, as suggested in Figure 17-6.

The advantage of this system is low cost, as 7-segment displays are cheap to fabricate, entail the fewest connections, and require minimal decoding to create each alphanumeric character. However, numbers 0, 1, and 5 cannot be distinguished from letters O, I, and S, while letters containing diagonal strokes, such as K, M, N, W, X, and Z, cannot be displayed at all.

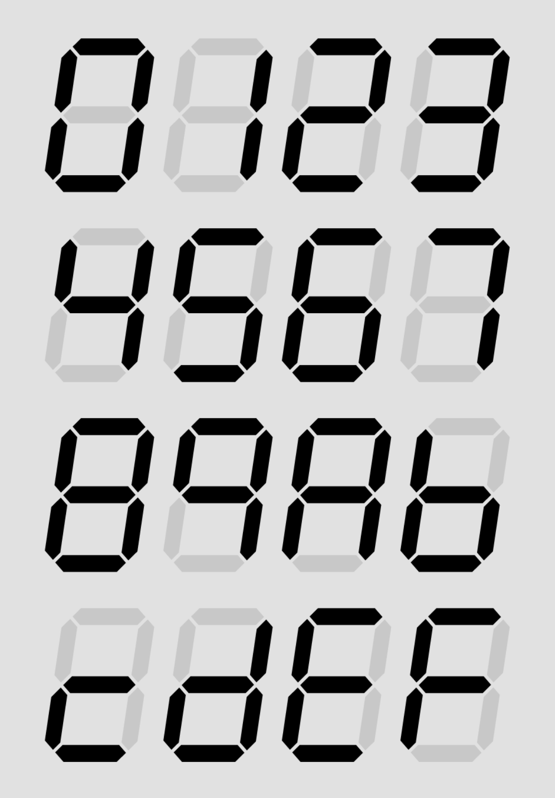

Figure 17-5. *Numerals and the first six letters of the alphabet created with a 7-segment display.*

Additional Segments

Alphanumeric LCDs were developed using 14 or 16 segments to enable better representation of letters of the alphabet. Sometimes these displays were slanted forward, like the 7-segment displays, perhaps because the style had become familiar, even though the addition of diagonal segments made it unnecessary. In other cases, the 14 or 16 segments were arrayed in a rectangle. See Figure 17-7.

The same words represented in Figure 17-6 are shown in Figure 17-8, using 16-segment LCDs. Clearly, the advantage gained by enabling diagonal strokes entailed the disadvantage of larger gaps in the letters, making made them ugly and difficult to read.

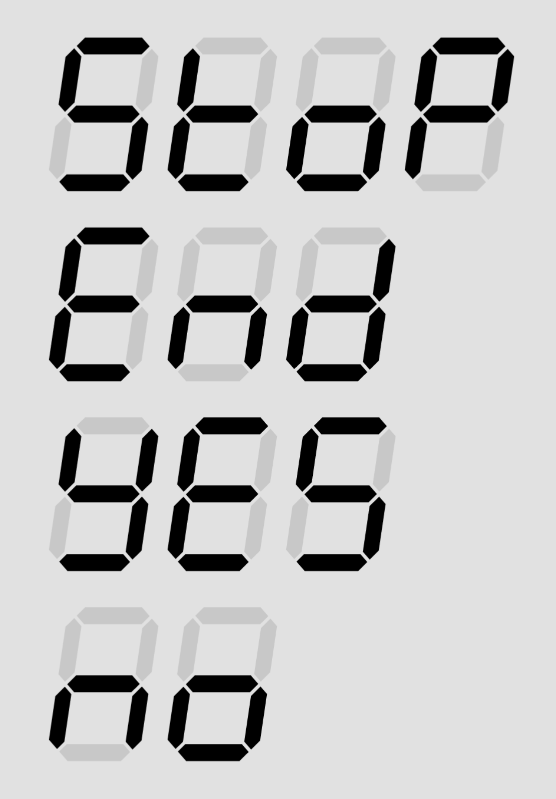

Figure 17-6. *Basic text messages can be generated with 7-segment displays, although they cannot contain alphabetical letters that use diagonal strokes.*

A full character set using 16-segment LCDs is shown in Figure 17-9. This conforms partially with the ASCII coding system, in which each character has an identifying numeric code ranging from 20 hexadecimal for a letter-space to 7A hexadecimal for letter z (although this character set does not attempt to represent lowercase letters differently from uppercase). The ASCII acronym stands for *American Standard Code for Information Interchange*.

Because backlit LCDs had become common by the time 16-segment displays were introduced, the characters were often displayed in light-on-dark or "negative" format, as suggested in this figure. LEDs, of course, have always used the light-on-dark format, as an LED is a light-emitting component.

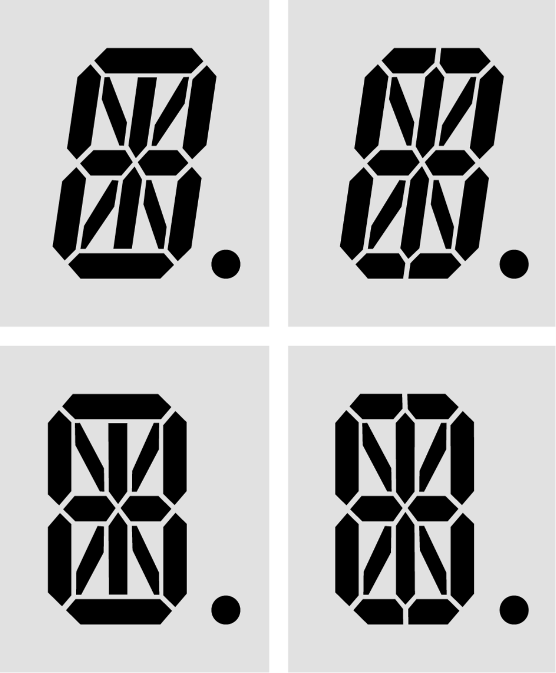

Figure 17-7. *LCDs using 14 segments (left) and 16 segments (right) were introduced to represent a full alphabet in addition to numerals. Sometimes these displays were slanted forward, like the previous 7-segment type, even though this was no longer necessary to represent the number 7.*

Dot-Matrix Displays

The 16-segment displays were never widely popular, and the declining cost of microprocessors, LCD fabrication, and ROM storage made it economic to produce displays using the more easily legible 5x7 dot-matrix alphabet that had been common among early microcomputers. Figure 17-10 shows a dot-matrix character set that is typical of many LCDs.

Because the original ASCII codes were not standardized below 20 hexadecimal or above 7A hexadecimal, manufacturers have represented a variety of foreign-language characters, Greek letters, Japanese characters, accented letters, or symbols using codes 00 through 1F and 7B through FF. The lower codes are often left blank, allowing user installation of custom symbols. Codes 00 through 0F are often reserved for control functions, such as a command to start a new line of text. There is no standardization in this area, and the user must examine a datasheet for guidance.

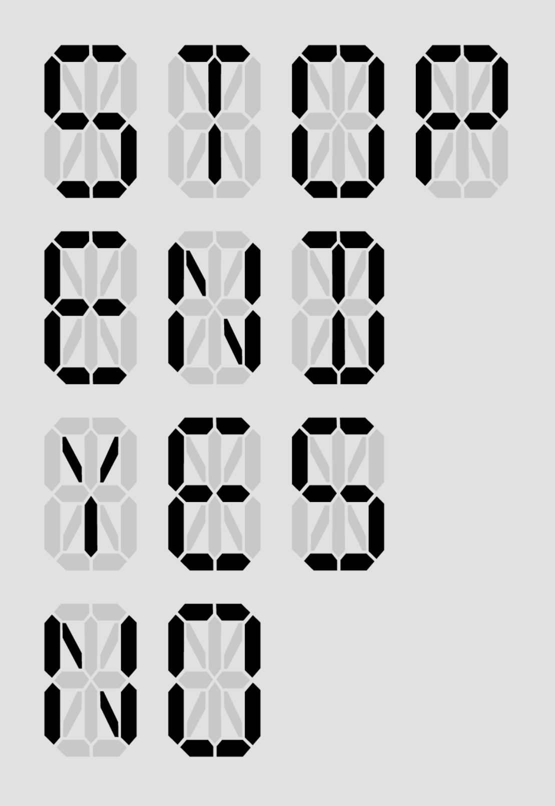

Figure 17-8. *The same text messages shown previously using 7-segment LCDs are shown here using 16-segment displays.*

Dot-matrix LCDs are usually packaged in arrays consisting of eight or more columns and two or more rows of characters. The number of columns is always stated before the number of rows, so that a typical 8 x 2 display contains eight alphanumeric characters in two horizontal rows. An array of characters is properly referred to as a *display module*, but may be described, confusingly, as a *display*, even though a single seven-segment LCD is itself a display. A 16x2 display module is shown from the front in Figure 17-11 and from the rear in Figure 17-12.

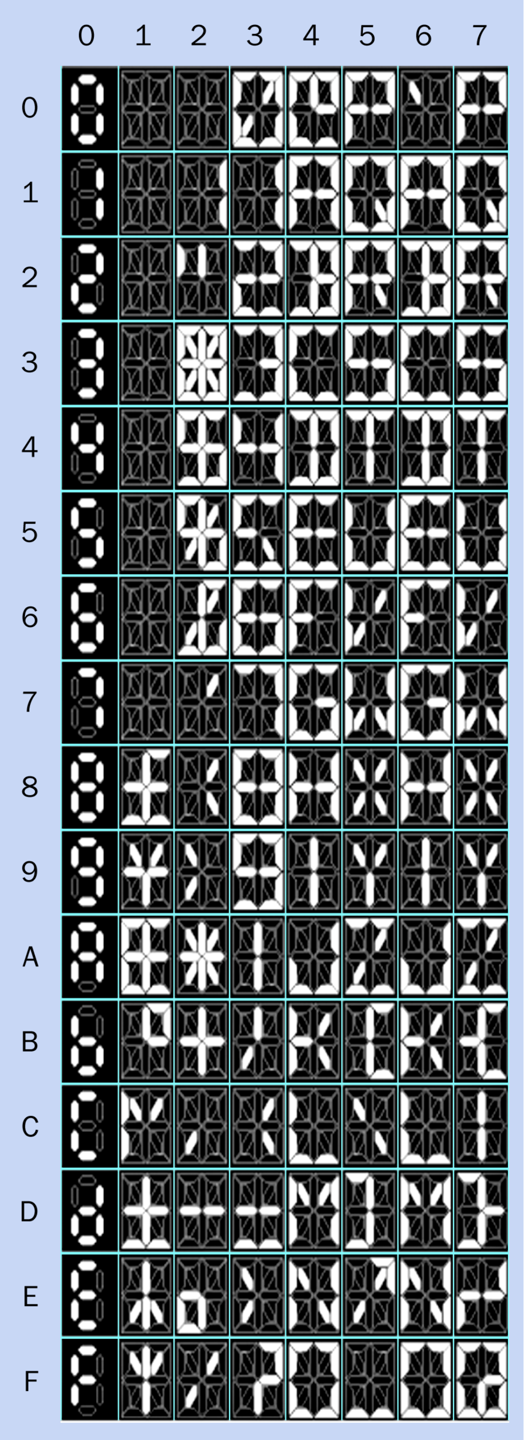

Figure 17-9. *A full character set using 16-segment LCDs.*

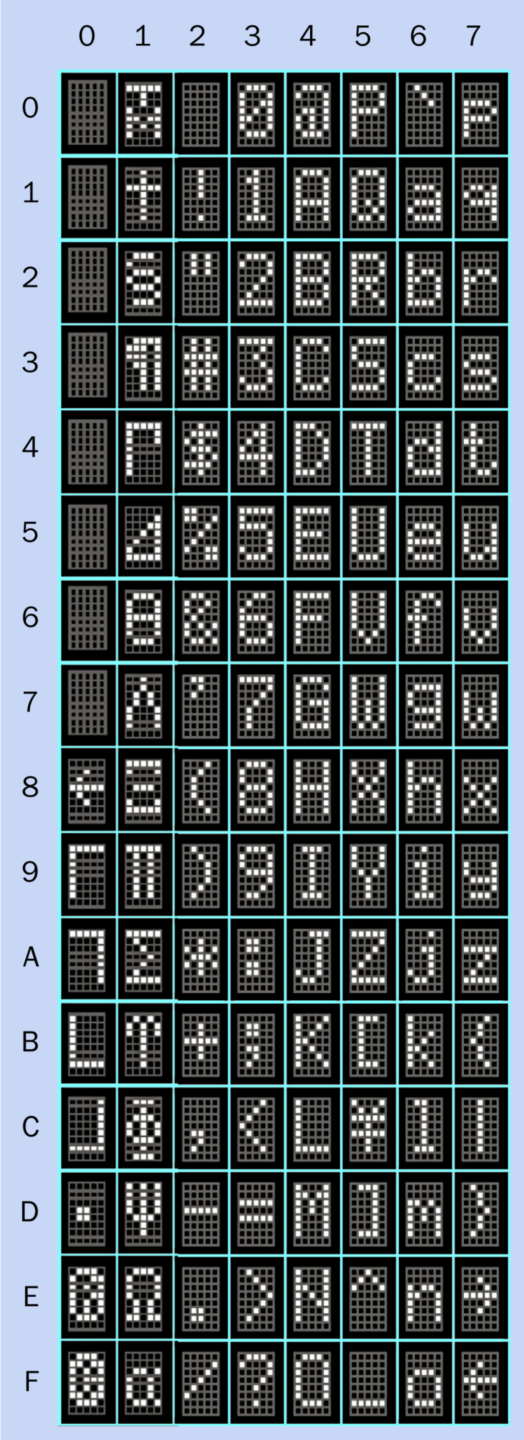

Figure 17-10. *A dot-matrix character set typical of LCDs capable of displaying a matrix of 5×7 dots.*

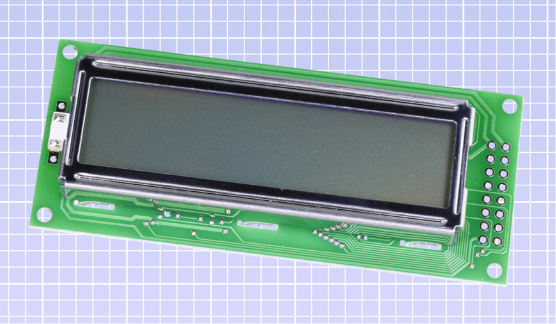

Figure 17-11. *A 16x2 LCD display module seen from the front.*

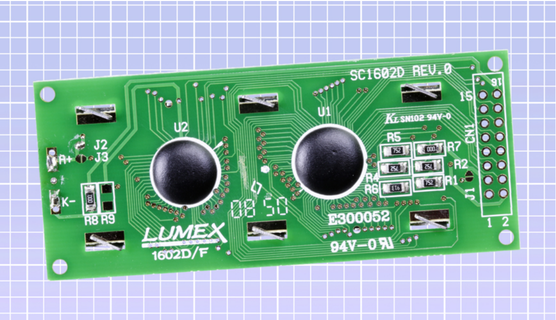

Figure 17-12. *The same 16x2 LCD display module from the previous figure, seen from the rear.*

Multiple-character display modules have been widely used in consumer electronics products such as audio components and automobiles where simple status messages and prompts are necessary—for example, to show the volume setting or broadcast frequency on a stereo receiver. Backlighting is almost always used.

Because the cost of small, full-color, high-resolution LCD screens has been driven down rapidly by the mass production of cellular phones, color displays are likely to displace monochrome dot-matrix LCD display modules in many applications. Similarly, touchscreens will tend to displace pushbuttons and tactile switches. Touchscreens are outside the scope of this encyclopedia.

Color

The addition of filters to create a full color display is shown in simplified form in Figure 17-13.

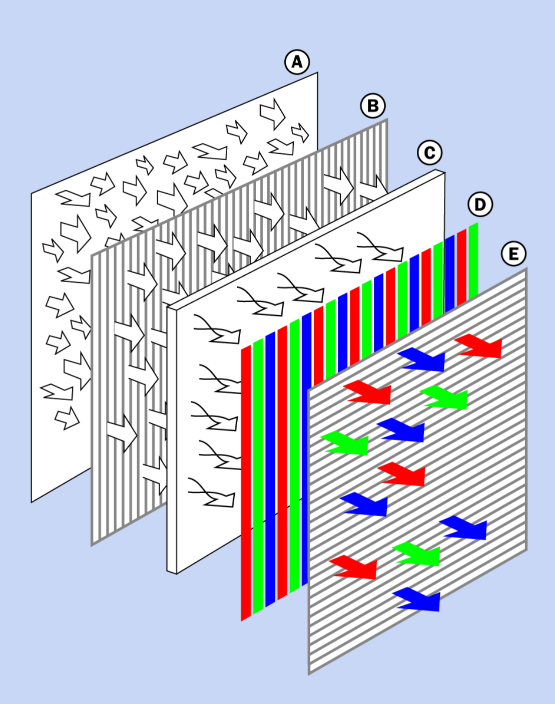

Figure 17-13. *The addition of red, green, and blue color filters, in conjunction with variable density liquid crystal pixels, enables an LCD full-color display.*

Red, green, and blue are almost always used as primary colors for transmitted light, because the combination of different intensities of these *RGB* primaries can create the appearance of many colors throughout the visible spectrum. They are said to be *additive* primaries, as they create brighter colors when they are combined. The principle is illustrated in Figure 17-14.

The use of the word "primaries" to refer to red, green, and blue can cause confusion, as full-color printed materials use a different set of *reflective* primaries, typically cyan, magenta, and yellow, often with the addition of black. In this *CMYK* system, additional layers of pigment will absorb, or subtract, more visible frequences. See Figure 17-15.

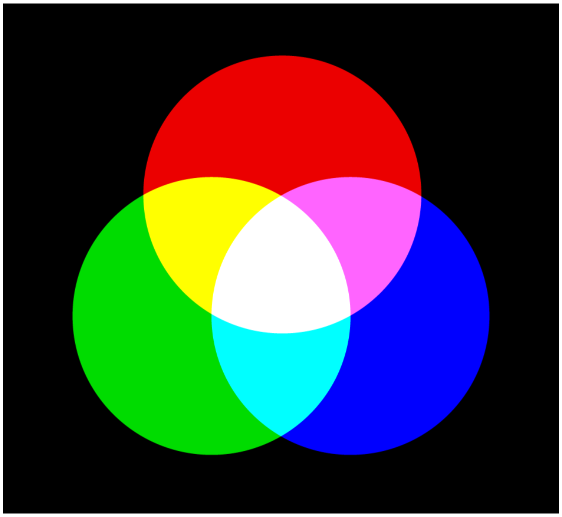

Figure 17-14. *When colors red, green, and blue are transmitted directly to the eye, pairs of these additive primaries create secondary colors cyan, magenta, and yellow. Combining all three additive primaries creates an approximation of white light. This can be verified by viewing a color monitor with a magnifying glass.*

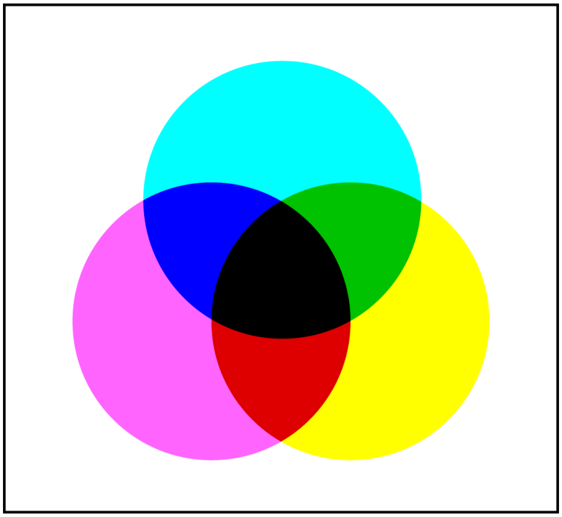

Figure 17-15. *When ink colors cyan, magenta, and yellow are superimposed on white paper and are viewed in white light, pairs of these subtractive primaries create secondary colors red, green, and blue. Overprinting all three subtractive primaries creates an approximation of black, limited by the reflective properties of available pigments. Black ink is usually added to provide additional contrast.*

The complete range of colors that can be created as a combination of primaries is known as the *gamut*. Many different RGB color standards have been developed, the two most widely used being *sRGB* (almost universal in web applications) and *Adobe 1998* (introduced by Adobe Systems for Photoshop, providing a wider gamut). None of the available systems for color reproduction comes close to creating the full gamut that can be perceived by the human eye.

Backlighting Options

For monochrome LCDs, **electroluminescent** backlighting may be used. It requires very low current, generates very little heat, and has a uniform output. However, its brightness is severely limited, and it requires an inverter that adds significantly to the current consumption.

For full-color LCDs, **fluorescent** lights were originally used. They have a long lifetime, generate little heat, and have low power consumption. However, they require a relatively high voltage, and do not work well at low temperatures. Early flat screens for laptop computers and desktop monitors used *cold-cathode fluorescent panels.*

Subsequently, white light-emitting diodes (**LED**s) were refined to the point where they generated a range of frequencies that was considered acceptable. Light from the LEDs passes through a diffuser to provide reasonably consistent illumination across the entire screen. LEDs are cheaper than fluorescent panels, and allow a thinner screen.

High-end video monitors use individual red, green, and blue LEDs instead of a white backlight. This eliminates the need for colored filters and produces a wider gamut. So-called *RGB* LCD monitors are more expensive but are preferred for professional applications in video and print media where accurate color reproduction is essential.

Zero-Power Displays

Some techniques exist to create LCDs that require power only to flip them to and fro between their transparent and opaque states. These are also known as *bistable* displays, but have not become as widely used. They are similar in concept to *e-ink* or *electronic paper* displays, but the principle of operation is different.

How to Use It

So long as an LCD consists of just one numeral, it can be driven by just one decoder chip that translates a binary-coded input into the outputs required to activate the appropriate segments of the LCD. The evolution of multi-digit displays, alphanumeric displays, dot-matrix displays, and graphical displays has complicated this situation.

Numeric Display Modules

An LCD consisting of a single digit is now a rare item, as few circuits require only one numeral for output. More commonly, two to eight numerals are mounted together in a small rectangular panel, three or four numerals being most common. A typical digital alarm clock uses a four-digit numeric display module, incorporating a colon and indicators showing AM/PM and alarm on/off. Other numeric display modules may include a minus sign.

Modules that are described as having 3.5 or 4.5 digits contain three full digits preceded by a numeral 1 composed of two segments. Thus, a 3-digit module can display numbers from 000 through 999, while a 3.5-digit display can display numbers from 000 through 1999, approximately doubling the range.

Numeric display modules of the type described here do not contain any decoder logic or drivers. An external device, such as a microcontroller, must contain a lookup table to translate a numeric value into outputs that will activate the appropriate segments in the numbers in a display, with or without decimal points and a minus sign. To avoid reinventing the wheel, a programmer may download code libraries for microcontrollers to drive commonly used numeric display modules. It is important to remember, though, that segments in monochrome LCDs must be activated by AC, typically a square wave with a frequency of 30Hz to 90Hz.

An alternative is to use a decoder chip such as the 4543B or 4056B, which receives a binary-coded decimal input (i.e., 0000 through 1001 binary, on four input puts) and translates it into an output on seven pins suitable for connection with the seven segments of a 7-segment display. The 4543B requires a square-wave input to its "phase" pin. The square-wave must also be applied simultaneously to the backplane of the LCD, often identified as the "common" pin on datasheets. Pinouts for the 4543B are shown in Figure 17-16.

The 4543B includes provision for "display blanking," which can be used to suppress leading zeros in a multidigit number. However, the lack of outputs to control a minus sign or decimal point limits the decoder to displaying positive integers.

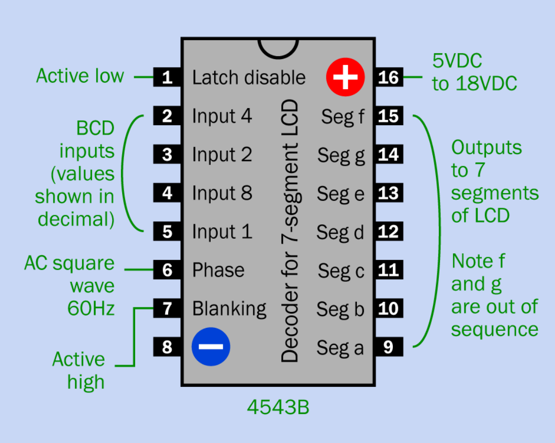

Figure 17-16. *Pinouts for the 4543B decoder chip, which is designed to drive a seven-segment numeric LCD.*

The power supply for a 4543B can range from 5VDC to 18VDC, but because the logic-high output voltage will be almost the same as that of the power supply, it must be chosen to match the power requirements of the LCD (very often 5VAC).(((

To drive a three-digit numeric display module, a separate decoder chip can be used to control each digit. The disadvantage of this system is that each decoder requires three inputs, so that a three-digit display will require nine outputs from the microcontroller.

To deal with this issue, it is common to *multiplex* a multi-digit display. This means that each output from the decoder is shared among the same segments of all the LCD numerals. Each LCD numeral is then activated in sequence by applying AC voltage to its common pin. Simultaneously, the decoder sends the data appropriate to that LCD. This process must be fast enough so that all the digits appear to be active simultaneously, and is best managed with a microcontroller. A simplified schematic is shown in Figure 17-17. It can be compared with a similar circuit to drive LED displays, shown in Figure 24-13.

Alphanumeric Display Module

Arrays of dot-matrix LCDs that can display alphabetical characters as well as numerals require preset character patterns (usually stored in ROM) and a command interpreter to process instructions that are embedded in the data stream. These capabilities are often built into the LCD module itself.

While there is no formal or de facto standard, the command set used by the Hitachi HD44780 controller is installed in many displays, and code libraries for this set are available for download from sites dedicated to the Arduino and other microcontrollers. Writing code from scratch to control all aspects of an alphanumeric display is not a trivial chore. The Hamtronix HDM08216L-3-L30S is a display that incorporates the HD44780.

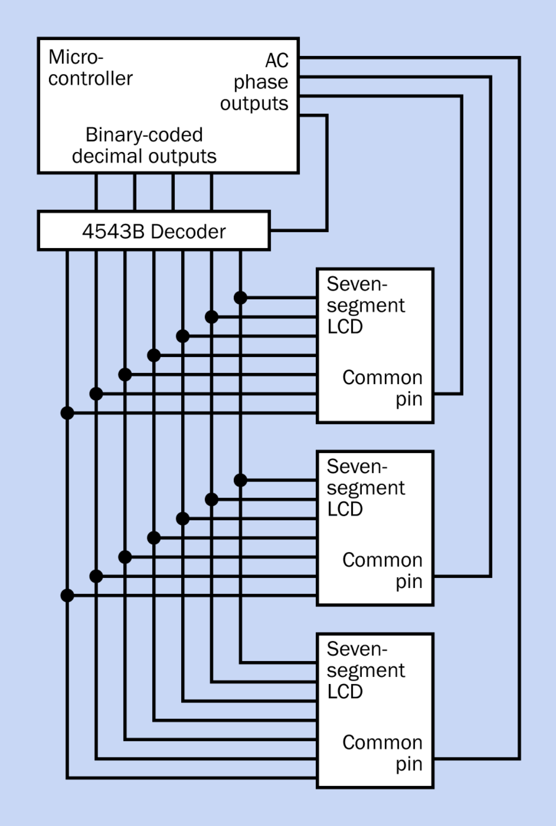

Figure 17-17. *When two or more numeric displays are multiplexed, a control device (typically, a microcontroller) activates each of them in turn via its backplane (common terminal) while sending appropriate data over a shared bus.*

Regardless of which standard is used, some features of alphanumeric display modules are almost universal:

- Register select pin. Tells the display whether the incoming data is an instruction, or a code identifying a displayable character.
- Read/write pin. Tells the display whether to receive characters from a microcontroller or send them to a microcontroller.
- Enable/disable pin.
- Character data input pins. There will be eight pins to receive the 8-bit ASCII code for each displayable character in parallel. Often there is an option to use only four of these pins, to reduce the number of microcontroller outputs necessary to drive the display. Where four pins are used, each 8-bit character is sent in two segments.
- LED backlight pin. Two may be provided, one connected to the anode(s) of the LED backlight, the other to the cathode(s).
- Reset pin.

Embedded instruction codes can be complex, including commands to reposition the cursor at a specific screen location, backspace-and-erase, scroll the display, and erase all characters on the screen. Codes may be included to adjust screen brightness and to switch the display between light-on-dark (negative) and dark-on-light (positive) characters.

Some display modules also have graphics capability, allowing the user to address any individual pixel on the screen.

Because of the lack of standardization in control codes, manufacturer's datasheets must be consulted to learn the usage of a particular alphanumeric display module. In addition to datasheets, online user forums are a valuable source of information regarding quirks and undocumented features.

What Can Go Wrong

Temperature Sensitivity

Liquid crystals vary in their tolerance for low and high temperatures, but generally speaking, a higher voltage may be necessary to create a sufficiently dense image at a low temperature. Conversely, a lower voltage may be necessary to avoid "ghosting" at a high temperature. An absolutely safe operating temperature range is likely to be 0 through 50 degrees Celsius, but check the manufacturer's datasheet for confirmation. Special-purpose LCDs are available for extreme temperatures.

Excessive Multiplexing

A twisted nematic display is likely to perform poorly if its duty cycle is greater than 1:4. In other words, more than four displays should not be multiplexed by the same controller.

DC Damage

An LCD can be damaged quickly and permanently if it is subjected to DC current. This can occur by accident if, for example, a timer chip is being used to generate the AC pulse stream, and the timer is accidentally disconnected, or has an incorrect connection in its RC network. Check timer output with a meter set to measure AC volts before allowing any connection to the common pin of an LCD.

Bad Communications Protocol

Many alphanumeric display modules do not use a formal communications protocol. Duplex serial or I2C connection may not be available. Care must be taken to allow pauses of a few milliseconds after execution of embedded commands, to give the display sufficient time to complete the instruction. This is especially likely where a command to clear all characters from the screen has to be executed. If garbage characters appear on the screen, incorrect data transfer speed or lack of pause times may be to blame.

Wiring Errors

This is often cited by manufacturers as the most common cause of failure to display characters correctly, or lack of any screen image at all.

incandescent lamp

18

The terms *incandescent light*, *incandescent bulb*, and *incandescent light bulb* are often used interchangeably with **incandescent lamp**. Because the term "lamp" seems to be most common, it is used here. A *panel-mounted indicator lamp* is considered to be an assembly containing an incandescent lamp.

A *carbon arc*, which generates light as a self-sustaining spark between two carbon electrodes, can be thought of as a form of incandescent lamp, but is now rare and is not included in this encyclopedia.

OTHER RELATED COMPONENTS

- **LED area lighting** (see Chapter 23)
- **LED indicator** (see Chapter 22)
- **neon bulb** (see Chapter 19)
- **fluorescent light** (see Chapter 20)

What It Does

The term *incandescent* describes an object that emits visible light purely as a consequence of being hot. This principle is used in an **incandescent lamp** where a wire *filament* glows as a result of electric current passing through it and raising it to a high temperature. To prevent oxidation of the filament, it is contained within a sealed bulb or tube containing an inert gas under low pressure or (less often) a vacuum.

Because incandescent lamps are relatively inefficient, they are not considered a wise environmental choice for area lighting and have been prohibited for that purpose in some areas. However, small, low-voltage, panel-mount versions are still widely available. For a summary of advantages of miniature incandescent lamps relative to **light-emitting diodes** (LEDs) see "Relative Advantages" on page 179.

Schematic symbols representing an incandescent lamp are shown in Figure 18-1. The symbols are all functionally identical except that the one at bottom right is more likely to be used to represent small panel-mounted indicators.

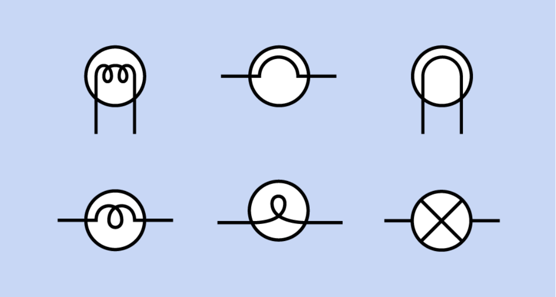

Figure 18-1. *A variety of symbols can represent an incandescent lamp. The one at bottom right may be more commonly used for small panel-mounted indicators.*

The parts of a generic incandescent light bulb are identified in Figure 18-2:

A: Glass bulb.

B: Inert gas at low pressure.

C: Tungsten filament.

D: Contact wires (connecting internally with brass base and center contact, below).

E: Wires to support the filament.

F: Internal glass stem.

G: Brass base or cap.

H: Vitreous insulation.

I: Center contact.

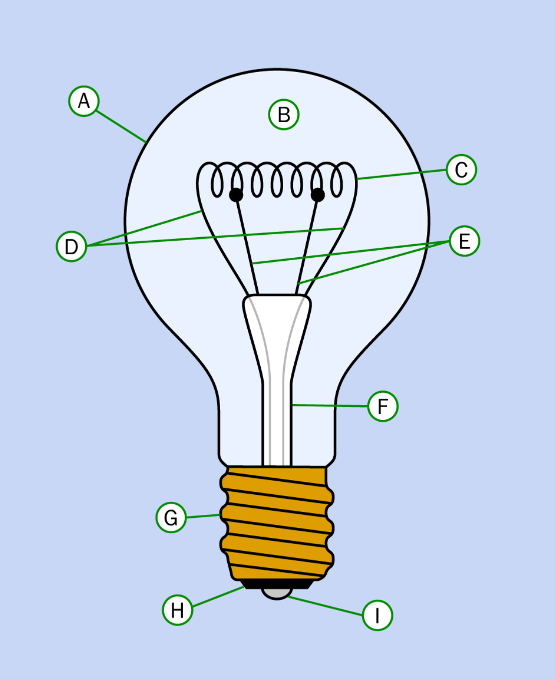

Figure 18-2. *The parts of a typical incandescent lamp (see text for details).*

History

The concept of generating light by using electricity to heat a metal originated with Englishman Humphrey Davy, who demonstrated it with a large battery and a strip of platinum in 1802. Platinum was thought to be suitable because it has a relatively high melting point. The lamp worked but was not practical, being insufficiently bright and having a short lifespan. In addition, the platinum was prohibitively expensive.

The first patent for an incandescent lamp was issued in England in 1841, but it still used platinum. Subsequently, British physicist and chemist Joseph Swan spent many years attempting to develop practical carbon filaments, and obtained a patent in 1880 for *parchmentized thread*. His house was the first in the world to be illuminated by light bulbs.

Thomas Edison began work to refine the electric lamp in 1878, and achieved a successful test with a carbonized filament in October 1879. The bulb lasted slightly more than 13 hours. Lawsuits over patent rights ensued. Carbonized filaments were used until a tungsten filament was patented in 1904 by the German/Hungarian inventor Just Sándor Frigyes and the Croatian inventor Franjo Hanaman. This type of bulb was filled with an inert gas, instead of using a vacuum.

Many other pioneers participated in the effort to develop electric light on a practical basis. Thus it is incorrect to state that "Thomas Edison invented the light bulb." The device went through a very lengthy process of gradual refinement, and one of Edison's most significant achievements was the development of a power distribution system that could run multiple lamps in parallel, using filaments that had a relatively high resistance. His error was insisting on using *direct current* (DC) while his rival Westinghouse pioneered *alternating currrent* (AC), enabling power transmission over longer distances through the use of **transformers**. The use of AC also enabled Tesla's brushless induction motor.

By the mid-1900s, most incandescent bulbs used tungsten filaments.

How It Works

All objects emit electromagnetic radiation as a function of their temperature. This is known as *black body radiation*, based on the concept of an object that absorbs all incoming light, and thus does not reflect any sources from outside itself. As its temperature increases, the intensity of the radiation increases while the wavelength of the radiation tends to decrease.

If the temperature is high enough, the wavelength of the radiation enters the visible spectrum, between 380 and 740 nanometers. (A nanometer is one-billionth of a meter.)

The melting point of tungsten is 3,442 degrees Celsius, but a lamp filament typically operates between 2,000 and 3,000 degrees. At the higher end of this scale, evaporation of metal from the filament tends to cause deposition of a dark residue on the inside of the bulb, and erodes the filament more rapidly, to the point where it eventually breaks. At the lower end of this scale, the light will be yellow and the intensity will be reduced.

Spectrum

The color of black-body radiation is measured using the Kelvin temperature scale. The increment of 1 degree Kelvin is the same as 1 degree Celsius, but the Kelvin scale has a zero value at *absolute zero*. This is the theoretical lowest conceivable temperature, at which there is complete absence of heat. It is approximately –273 degrees Celsius.

From this it is evident that if K is a temperature in degrees Kelvin and C is a temperature in degrees Celsius:

`K = C + 273` (approximately)

Calibration of light sources in degrees Kelvin is common in photography. Many digital cameras allow the user to specify the *color temperature* of lights that are illuminating an indoor scene, and the camera will compensate so that the light source appears to be pure white with all colors in the visible spectrum being represented equally.

Some computer monitors also allow the user to specify a white value in degrees Kelvin.

Color temperature is used in astronomy, because the spectrum of many stars is comparable with that of a theoretical black body.

A color temperature of 1,000 degrees K will have a dark orange hue, while 15,000 degrees K or higher will have a blue hue comparable to that of a pale blue sky. The color temperature of the sun is approximately 5,800 K. Interior lighting is often around 3,000 K, which many people find acceptable because it creates pleasant flesh tones. An incandescent bulb described by the manufacturer as "soft white" or "warm" will have a lower color temperature than one which is sold as "pure white" or "paper white."

Graphs showing the emission of wavelengths at various color temperatures are shown in Figure 18-3. The rainbow section indicates the approximate range of visible wavelengths between ultraviolet, on the left, and infrared, on the right. For purposes of clarity, the peak intensity for each color temperature has been equalized. In reality, increasing the temperature also increases the light output.

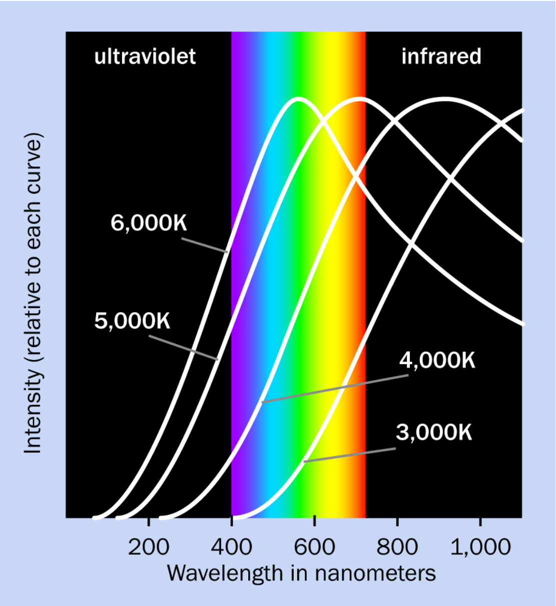

Figure 18-3. *Approximate peak wavelengths for black-body radiation at various color temperatures in degrees Kelvin. The curves have been adjusted so that their peak values are equalized. Adapted from an illustration in the reference book Light Emitting Diodes by E. Fred Schubert.*

Non-Incandescent Sources

So long as light is generated by heating a filament, plotting the intensity against wavelength will result in a smooth curve without irregularities. A higher Kelvin value will simply displace and compress the curve laterally without changing its basic shape to a significant degree.

The introduction of **fluorescent** sources and, subsequently, light-emitting diodes (**LEDs**) has complicated this scenario. Because they are *luminescent* rather than *incandescent*, they do not generate an evenly weighted, continuous range of wavelengths.

LEDs tend to emit monochromatic light, meaning that it is tightly centered around just one color. A "white" LED is really a blue LED in which a phosphor coating on the semiconductor die is excited to create light over a broader range. A fluorescent light tends to create *spectral lines* which show up as sharp peaks at a few wavelengths determined by the mercury inside the bulb. Figure 18-4 illustrates these problems.

The human eye tends to compensate for the yellow emphasis of incandescent lamps and for the irregularities in spectra emitted by other light sources. Also, the eye is often unable to distinguish between "white" light created as a mix of all the visible wavelengths, and light that appears white even though it is dominated by a few isolated wavelengths from a fluorescent source.

However, when the eye views colors that are illuminated by a source that has gaps in its spectrum, some of the colors will appear unnaturally dull or dark. This is true also if an imperfect source is used as a backlight to create colors on a video monitor. Colors rendered by different light sources are shown in Figure 23-7 and subsequent figures.

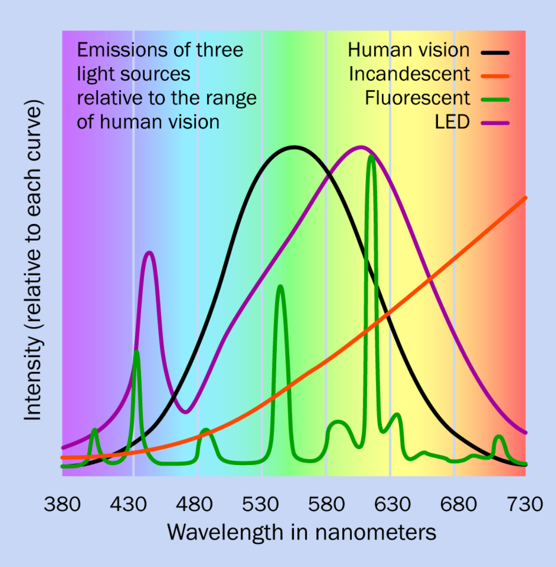

Figure 18-4. *The relative performance of three light sources compared with sensitivity of the human eye to the visible spectrum. Note that the range of wavelengths on the horizontal scale in this figure is not the same as the range in the previous figure. The color assigned to each curve is arbitrary. Adapted from VU1 Corporation.*

Photography is adversely affected by the use of LEDs or fluorescents as a light source. Reds, for example, can seem dark when lit by white LEDs, while blues can be inappropriately intense. Because the source does not have an emission curve comparable to that of an incandescent light, the auto-white balance feature of a digital camera may be unable to address this problem, and it cannot be resolved by entering a different Kelvin number manually.

The fidelity with which a light source is capable of displaying the full visible spectrum is known as the *color rendering index* (CRI), ranging from a perfect score of 100 down to 0 or even lower (sodium-vapor street lighting has a negative value). Computing the index requires standard reference color samples and has been criticized for generating scores that do not correlate well with subjective assessments.

Incandescent bulbs can have a CRI of 100, while an uncorrected "white" LED may score as low as 80.

Power Consumption

Approximately 95% of the power consumed by an incandescent lamp generates heat instead of visible light. This wastage of power in room lighting is compounded by the power consumption of air conditioning to remove the heat from enclosed spaces in hot climates. While the heat from incandescent lamps does reduce the need for space heating in cold environments, heat is delivered more efficiently by using systems designed for that purpose. Consequently, greater energy efficiency can be achieved with a light source that generates less heat, regardless of ambient air temperature.

Variants

Miniature Lamps

Prior to the development of **LED**s, all light-emitting panel-mounted indicators were either **neon bulbs** or **incandescent lamps**. The use of neon is limited by its need for a relatively high voltage.

Miniature incandescents were the traditional choice for battery-powered light sources, and at the time of writing are still used in cheap flashlights. Variants are available that are as small as a 5mm LED, with a claimed life expectancy that is comparable, although they draw more current to generate an equivalent light intensity, because much of their power is wasted in infrared wavelengths.

The photograph in Figure 18-5 is of a miniature lamp terminating in pins spaced 0.05" apart. The total height of the lamp, including its ceramic base, is less than 0.4," while its diameter is just over 0.1". It draws 60mA at 5V and is rated for 25,000 hours.

The photograph in Figure 18-6 is of a lamp of similar size and power consumption, but terminating in wire leads and rated for 100,000 hours. It emits 0.63 lumens.

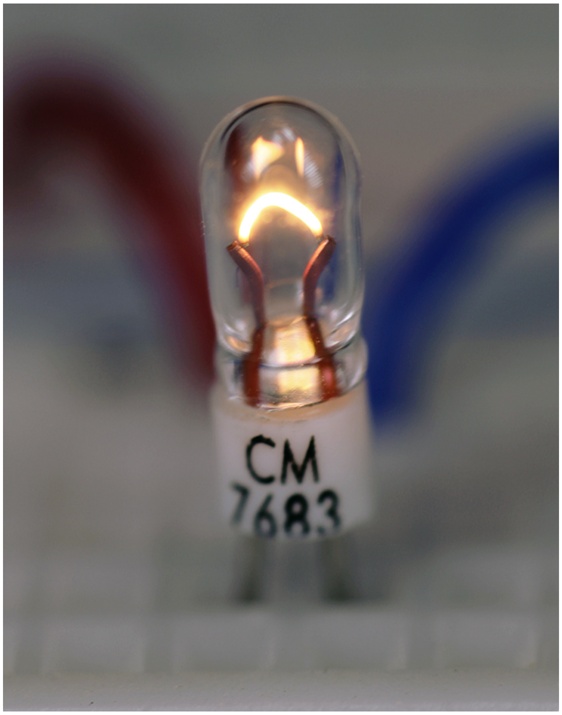

Figure 18-5. *A miniature lamp less than 0.4" high, terminating in pins spaced 0.05" apart.*

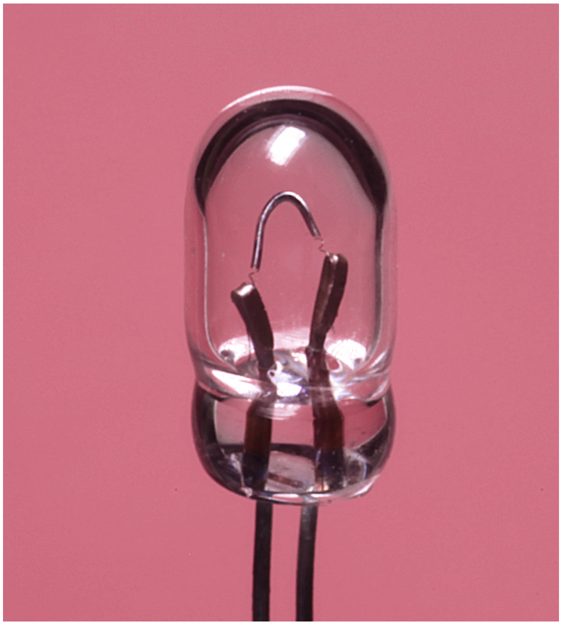

Figure 18-6. *This lamp is 0.25" high and terminates in wire leads.*

The lamp pictured in Figure 18-7 is slightly larger, with a glass envelope about 0.25" diameter. It is rated for less than half the lifetime of the lamp in Figure 18-6 but emits three times as much light —a typical tradeoff. Various base styles are available.

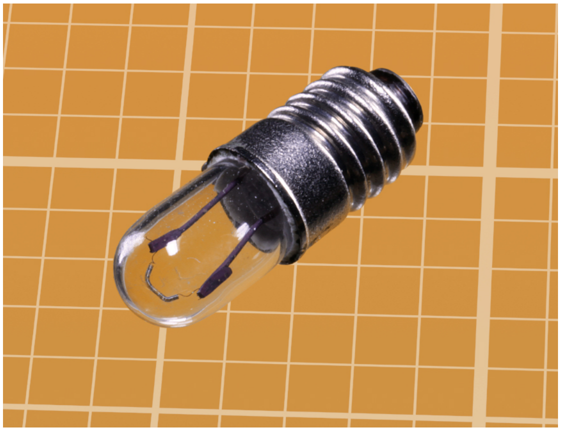

Figure 18-7. *This lamp has a glass envelope about 0.35" high. Its screw-in base makes it easier to replace than an LED.*

In the United States, the light output from miniature incandescent lamps may be measured in lumens, but is more often rated in *mean spherical candlepower* (MSCP). An explanation of light measurement is included in "MSCP" on page 178.

Lamp lenses provide a quick and simple way to add color to a miniature incandescent lamp. Usually the lens is cylindrical with a hemispherical end cap, and is designed to push-fit or snap-fit over a small lamp. Even when the cap is translucent, it may still be referred to as a lens.

Panel-Mount Indicator Lamps

This term often refers to a tubular assembly containing a miniature lamp, ready for installation.

The enclosure is often designed to snap-fit into a hole drilled in the panel. If the incandescent bulb inside the enclosure cannot be replaced, the component is said to be "non-relampable." Figure 18-8 shows a 12-volt panel-mount indicator lamp.

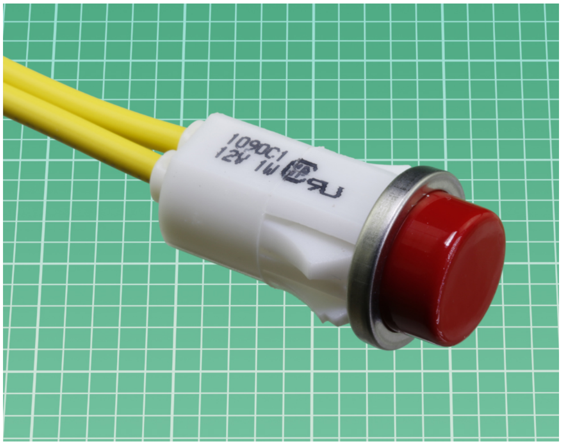

Figure 18-8. *This panel-mount indicator lamp is designed to push-fit into a hole 1/2" in diameter. The bulb inside it is not replacable, causing the assembly to be classified as "non-relampable."*

Halogen or Quartz-Halogen

This is a type of incandescent lamp containing gases under pressure in which halogens such as iodine or bromine cause evaporated tungsten atoms to be redeposited on the filament. A halogen lamp can therefore operate at a higher temperature, creating a light that is less yellow and brighter than that from a comparable incandescent lamp. It also enables a smaller bulb, but requires an envelope of borosilicate-halide glass (often termed *fused quartz*) instead of regular glass. A halogen lamp will be slightly more efficient than an incandescent bulb of the same wattage, and will last longer.

Halogens are available in a variety of formats. The small bulb pictured in Figure 18-9 consumes 75W, emitting 1,500 lumens at 3,000 degrees Kelvin. The light intensity is claimed to be equivalent to that of a 100W incandescent bulb. It has a mini-candelabra base.

Oven Lamps

Oven lamps are designed to withstand the high temperature in an oven. Typically they are usable with ambient temperatures up to 300 degrees C. A common power rating is 15W.

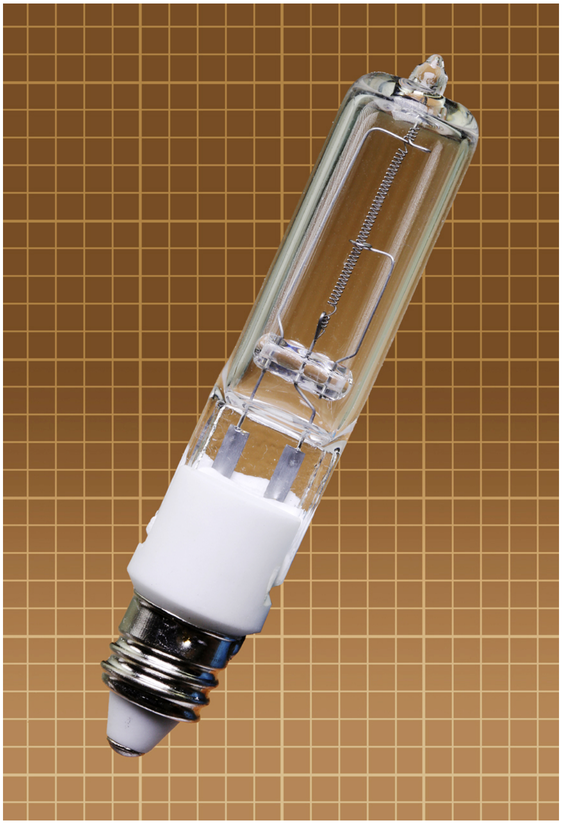

Figure 18-9. *A halogen bulb slightly more than 2" in length, designed for 115VAC.*

Base Variants

Miniature lamps are available with a wide variety of connection options, including wire terminals, single-contact bayonet, double-contact bayonet, miniature screw base, and fuse style. Most of these options require a matching socket.

Screw-in lamps for room illumination are common in household lighting in the United States and many other countries (but not in the UK, where bayonet fittings are used). The US socket size is designated by letter E followed by a number that gives the socket diameter in millimeters. Common sizes are E10, E14 and E27.

A *bayonet base* is fitted with two small lugs protruding on opposite sides. The lamp is secured by pushing it in and twisting it to engage the lugs in slots in the socket. The advantage of a bayonet base is that the bulb is less likely to become loose as a result of vibration.

A *pin base* consists simply of a pair of pins that will push-fit into small holes in a socket.

A *flange base* has a flange that engages in a socket where flexible segments will retain it.

A *wedge base* is forced between two contacts which retain the bulb by friction.

Some indicator lamps terminate simply in long, thin leads that can be soldered.

Values

While the power consumption of full-size incandescent lamps is rated in watts, small indicator lamps are rated in milliamps at the voltage for which they are designed. Miniature lamps may require specific voltages ranging from as low as 2V to 24V. A higher voltage generally necessitates a longer filament, which may entail a larger bulb.

The light that a lamp will emit can be measured in two ways: either as the power of the lamp (not its power consumption, but its radiating power), or as the light delivered to a specific area at a specific distance. These two measurements may differ because a lamp may concentrate its light in a beam, as in the case of a reflector bulb or an LED.

Power

Flux, in watts, is a measurement of energy flow in joules per second. The total radiating power of a lamp, in all wavelengths, in all directions, is known as its *radiant flux*. Because invisible wavelengths are of little interest when assessing the brightness of a lamp, the term *luminous flux* is used to describe the apparent brightness of the lamp in the visible spectrum. The unit for luminous flux is the *lumen*.

The human eye is most responsive to yellow-green hues in the center of the spectrum. Consequently, the measurement of luminous flux is weighted toward green at a wavelength of 555 nanometers. Red and violet are considered to have low luminous flux, while infrared and ultraviolet have a zero value.

When considering a value expressed in lumens, remember:

- Lumens are a measure of the total radiated power output of a light source, in all directions, in the visible spectrum only, weighted toward the characteristics of the human eye.
- The number of lumens of a light source does not define the direction in which the light is shining, or its uniformity.
- The abbreviation for lumen is *lm*.

A conventional incandescent lamp that consumes 100W of electricity is likely to have a light output of about 1,500 lumens. A 40W fluorescent tube can have a light output of about 2,600 lumens.

Illuminance

The *illuminance* of a light source is defined as the luminous flux per unit of area. This can be thought of as the brightness of a surface illuminated by the source.

Illuminance is measured in *lux*, where 1 lux = 1 lumen per square meter. For accurate calibration, the illuminated surface should be spherical in shape, and must be located 1 meter from the light source, with the source at the geometrical center of the sphere.

Illuminance used to be measured in *foot-candles*, where 1 foot-candle was 1 lumen per square foot.

- The number of lumens per square meter (lux) does not define the size of the illuminated area, only the brightness per unit of area.
- A lamp that has a tightly focused beam can achieve a high lux rating. When selecting a lamp for an application, the angle of dispersion of the beam must be considered in conjunction with its lux rating.

Intensity

A *candela* measures the luminous flux within an angle of dispersion. The angle is three-dimensional, and can be imagined as the sharpness of a point of a cone, where the light source is at the point and the cone represents the dispersion of light.

The three-dimensional angle of dispersion is measured in *steradians*. If a light source is at the center of a sphere that has a radius of 1 meter, and is illuminating one square meter of the surface of the sphere, the angle of dispersion is 1 steradian.

- A source of 1 lumen which projects all its light through a dispersion angle of 1 steradian is rated at 1 candela.
- The number of candelas does not define the angle of dispersion, only the intensity within that angle.
- A light source rated for 1,000 candelas could have a power of 10 lumens concentrated within an angle of 0.01 steradians, or could have a power of only 1 lumen concentrated within an angle of 0.001 steradians.
- There are 1,000 millicandelas in 1 candela. The abbreviation for candela is *cd* while the abbreviation for a millicandela is *mcd*.
- LEDs are often rated in mcd. The number describes the intensity of light within its angle of dispersion.

MSCP

Although the term *candlepower* is obsolete, it has been redefined as being equal to 1 candela. *Mean spherical candlepower* (MSCP) is a measurement of all the light emitted from a lamp in all directions. Because the light is assumed to be omnidirectional, it fills $4 * \pi$ (about 12.57) steradians. Therefore 1 MSCP = approximately 12.57

lumens. In the United States, MSCP is still the most common method of rating the total light output of a miniature lamp.

Efficacy

The *radiant luminous efficacy* (abbreviated *LER*) assesses how effective a lamp is at channeling its output within the visible spectrum, instead of wasting it in other wavelengths, especially infrared. LER is calculated by dividing the power emitted in the visible spectrum (the *luminous flux*) by the power emitted over all wavelengths.

Thus, if VP is the power emitted in the visible spectrum, and AP is the power emitted in all wavelengths:

```
LER = VP / AP
```

LER is expressed in *lumens per watt*. It can range from a low value of around 12 lm/W for a 40W incandescent bulb to 24 lm/W for a quartz halogen lamp. Fluorescent lamps may average 50 lm/W. LEDs vary, but can achieve 100 lm/W.

Efficiency

The *radiant luminous efficiency* (abbreviated *LFR*) of a lamp measures how good its radiant luminous efficacy is, compared with an imaginary ideal lamp. (Note the difference between the words “efficiency” and “efficacy.”) LFR is determined by dividing the radiant luminous efficacy (LER) by the maximum theoretical LER value of 683 lm/W, and multiplying by 100 to express the result as a percentage. Thus:

```
LFR = 100 * ( LER / 683 )
```

The LFR ranges from around 2% for a 40W bulb to 3.5% for a quartz halogen lamp. LEDs may be around 15% while fluorescents are closer to 10%.

How to Use It

When first introduced, LEDs were limited by their higher price, lower maximum light output, and inability to display blue or white. The price difference has disappeared for small indicators, while gaps in the color range have been filled (although the color rendering index of LEDs is still inferior).

Brightness remains an advantage for large incandescents relative to LEDs, as they are more upwardly scalable. However, fluorescents and vapor lamps have an advantage for very high light output, as in the lighting of big-box stores or parking lots. Thus the range of applications for incandescent bulbs is diminishing, especially because common types are now illegal for domestic light fixtures in many parts of the world.

Relative Advantages

When choosing whether to use an incandescent lamp or an LED, these advantages of an incandescent lamp should be considered:

- The intensity can be adjusted with a **triac**-based dimmer. Regular fluorescents cannot be dimmed, while LEDs often require different dimmer circuitry.
- The intensity can also be adjusted with a rheostat. The output from fluorescents cannot.
- Easy white-balance correction. LEDs and fluorescents do not naturally produce a consistent output over the visible spectrum.
- Can be designed to operate directly from a wide range of voltages (down to around 2V and up to around 300V). A higher voltage entails a longer filament wire, which may require a larger bulb. LEDs require additional components and circuitry to use higher voltages.
- Incandescent bulbs are more tolerant of voltage fluctuations than LEDs. With battery operation, the incandescent will still provide some reduced light output when the voltage has diminished radically. LEDs will not perform at all at currents lower than their threshold.
- An incandescent is nonpolarized and may be socketed, which simplifies user replacement.

LEDs are polarized and are usually soldered in.

- Can be powered by AC or DC without any modification or additional circuitry. LEDs require DC, which must be provided through a transformer and rectifier, or similar electronics, if AC power is the primary source.
- Can be equally visible from a wide range of viewing angles. LEDs have restricted viewing angles.
- The heat output from an incandescent bulb may occasionally be useful (for example in a terrarium, or in incubators for poultry).
- Trouble-free switching. Fluorescents tend to hesitate and blink when power is applied, and they require a *ballast* to energize them. The lifespan of fluorescents is reduced by frequent switching.
- No low-temperature problems. Incandescent lamps are not significantly affected by low temperatures. Fluorescents may not start easily in a cold environment, and may flicker or glow dimly for 10 minutes (or more) until they are warm enough to function properly.
- Easy disposal. Fluorescent lights contain small quantities of mercury that are an environmental hazard. They should not be mixed with ordinary trash. Compact fluorescent lamps (CFLs) and LEDs used for room lighting will be packaged with electronics that should ideally be recycled, although this is not very practical. Incandescent bulbs impose the least burden on the environment when they are thrown away.

However, the incandescent lamp has some obvious disadvantages:

- Relatively inefficient.
- More susceptible to vibration.
- More fragile.
- Likely to have a shorter natural life expectancy than LEDs, fluorescents, or neon bulbs, although the lifetime of a small panel indicator can be equal to that of an LED if a low color temperature is acceptable.
- Requires a filter or tinted glass envelope to generate colored light. This further reduces the lamp's efficiency.
- Cannot be miniaturized to the same degree as an LED indicator.

Derating

The lifespan of a lamp can be greatly extended by choosing one with a higher current rating or using it at a lower voltage. The light output will be reduced, and the color temperature will be at a lower Kelvin number, but in some situations this tradeoff may be acceptable.

The graphs in Figure 18-10 suggest that if the voltage of a hypothetical miniature lamp is reduced to 80% of the manufacturer's recommended value, this can make the lamp last 20 times as long. Note, however, that this will cut the light intensity to 50% of its normal value.

Conversely, using 130% normal voltage will give 250% of the normal light output, while shortening the life of the lamp to 1/20 of its normal value. Naturally these figures are approximations that may not apply precisely to a specific lamp.

What Can Go Wrong

High Temperature Environment

If an incandescent lamp is used in an environment hotter than 100 degrees Celsius, the life of the lamp is likely to be reduced by the "water cycle." Any water molecules inside the glass envelope will break down, allowing oxygen to combine with the tungsten filament to form tungsten oxide. The tungsten is deposited on the inside of the glass while the oxygen is liberated and begins a new cycle.

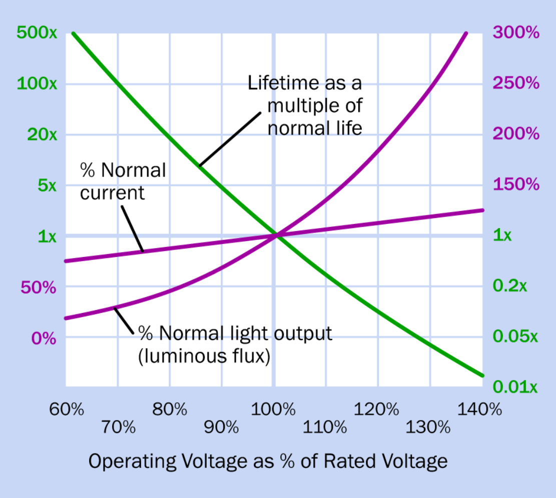

Figure 18-10. *The life expectancy of a hypothetical miniature lamp is very strongly influenced by voltage. Applying only 60% of the rated voltage can make a lamp last 500 times its normal lifespan, although it will greatly reduce light output. Note that the vertical axes apply to curves of the same color. Adapted from "Characteristics of Miniature Lamps" from Toshiba Lighting and Technology Corporation.*

Fire Risk

The partially evacuated bulb of an incandescent lamp provides some separation and protection from the heat in the filament, but if the bulb cannot disperse heat by radiation or convection, its temperature can rise to the point where it ignites flammable materials.

Halogen lamps have an elevated fire risk because they operate at a higher temperature and are smaller, providing less surface area to disperse the heat. They also contain gases under seven to eight atmospheres of pressure. Thermal stress can cause a halogen bulb to shatter, and fingerprints on the glass can increase this risk.

Current Inrush

When an incandescent lamp is first switched on, its filament has one-tenth the resistance that it will exhibit when it becomes hot. Consequently, the lamp will take a large initial surge of current, which stabilizes after about 50 milliseconds. This should be considered if one or more small lamps shares a DC power supply with components such as logic chips that may be sensitive to voltage fluctuations.

Replacement Problems

Because of the limited life of incandescent lamps, they should be installed in such a way that they are easy to replace. This can be an issue with panel indicators, where disassembly of a device may be necessary to reach the lamp.

The range of small incandescent lamps is diminishing, and may continue to diminish in the future. Future availability of replacement lamps should be considered when designing a circuit. When building equipment in small quantities, spare lamps should be purchased for future use.

neon bulb

19

The terms **neon bulb**, *neon indicator*, and *neon lamp* tend to be used interchangeably. In this encyclopedia, a neon *bulb* is defined as a glass capsule containing two electrodes in neon gas (or a combination of gases in which neon is present). A neon *lamp* is an assembly containing a neon bulb, usually using a plastic tube with a tinted transparent cap at one end. A neon *indicator* is a miniature neon lamp that is usually panel-mounted.

Large-scale neon tubes used in signage are not included in this encyclopedia.

OTHER RELATED COMPONENTS

- **incandescent lamp** (see Chapter 18)
- **fluorescent light** (see Chapter 20)
- **LED indicator** (see Chapter 22)

What It Does

When voltage is applied between two electrodes inside a neon bulb, the inert gas inside the bulb emits a soft red or orange glow. This color may be modified by using a tinted transparent plastic cap, known as a *lens*, in a *neon lamp* assembly.

A neon bulb is usually designed for a power supply of 110V or higher. It functions equally well with alternating or direct current.

The schematic symbols in Figure 19-1 are commonly used to represent either a neon bulb or a neon lamp. They are all functionally identical. The black dot that appears inside two of the symbols indicates that the component is gas filled. The position of the dot inside the circle is arbitrary. Even though all neon bulbs are gas filled, the dot is often omitted.

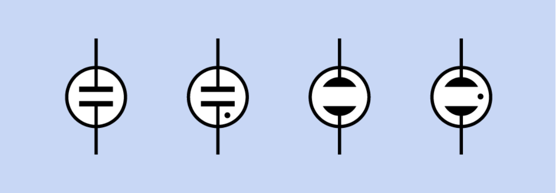

Figure 19-1. *Any of these symbols may represent a neon bulb or a neon lamp. The dot in two of the symbols indicates that the component is gas filled. All neon bulbs are gas filled, but the dot is often omitted.*

The photograph in Figure 19-2 shows a neon bulb with a series resistor preattached to one lead. Many bulbs are sold in this configuration, because a resistor must be used to limit current through the bulb. The bulb has no polarity and can be used on an AC or DC power supply. The same bulb is shown in its energized state in Figure 19-3.

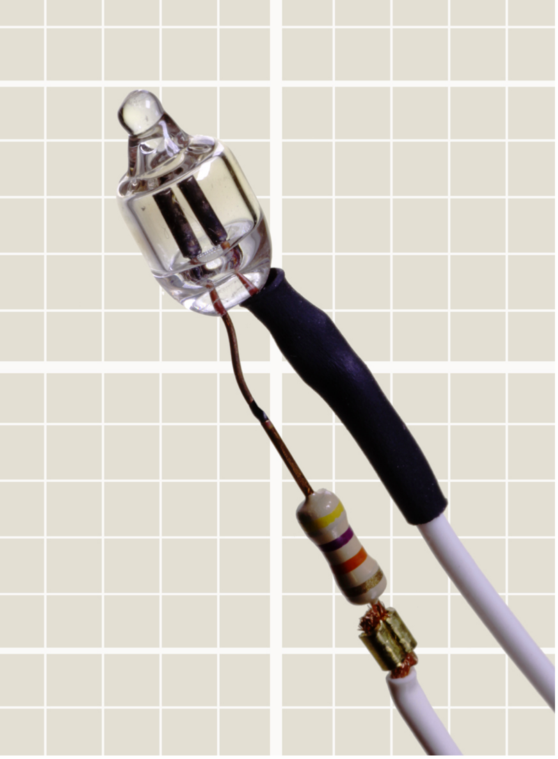

Figure 19-2. *A typical neon bulb with series resistor attached to one lead.*

How It Works

Construction

The parts of a neon bulb are illustrated in Figure 19-4. When the bulb is fabricated, it begins as a glass tube. The leads are made of *dumet*, consisting of a copper sheath around a nickel iron core. This has the same coefficient of expansion as glass, so that when the glass is heated and melted around the leads, it forms a seal that should be unaffected by subsequent temperature fluctuations. This area is known as the *pinch* in the tube.

Nickel electrodes are welded onto the leads before the leads are inserted into the tube. The electrodes have an emissive coating that reduces the minimum operating voltage. The glass tube is filled with a combination of neon and argon gases, or pure neon for higher light output (which reduces the life of the component). The top end of the glass tube is heated until it melts, and is pinched off. This creates a distinctive protrusion known as the *pip*.

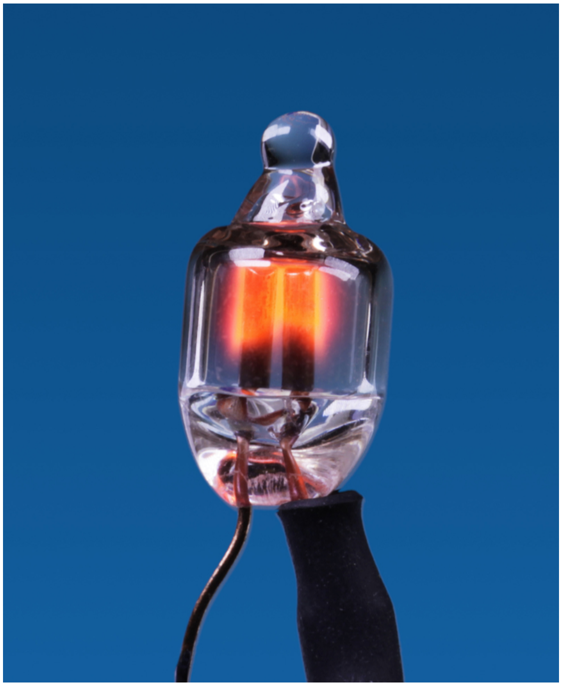

Figure 19-3. *The same bulb from the previous photograph, energized with 115VAC.*

Ionization

When a voltage is applied between the leads to the bulb, the gas becomes ionized, and electrons and ions are accelerated by the electric field. When they hit other atoms, these are ionized as well, maintaining the ionization level. Atoms are excited by collisions, moving their electrons to higher energy levels. When an electron returns from a higher level to a ground state, a photon is emitted.

This process begins at the *starting voltage* (also known as the *striking voltage*, the *ignition voltage*, or the *breakdown voltage*) usually between 45V and 65V for standard types of bulb, or between 70V and 95V for high-brightness types.

When the bulb is operating, it emits a soft radiance known as a *glow discharge* with a wavelength ranging from 600 to 700 nanometers.

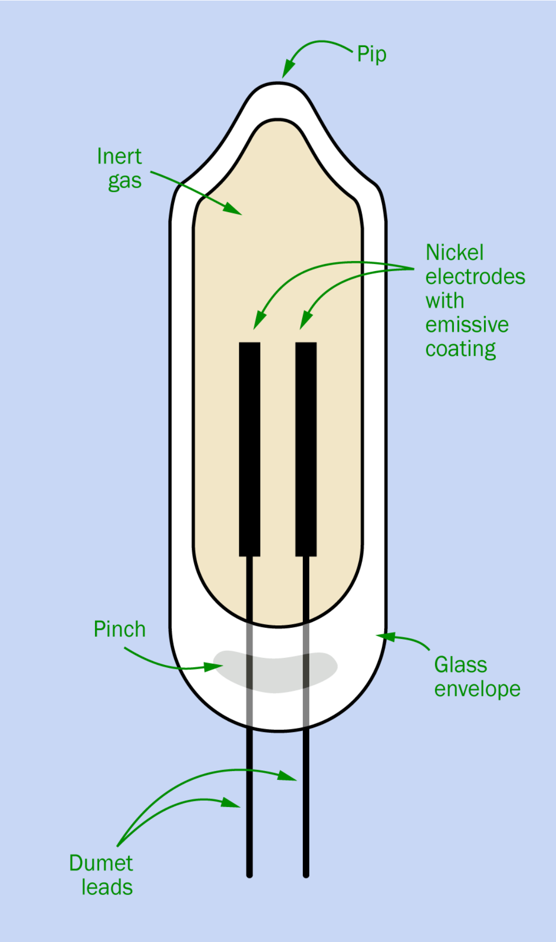

Figure 19-4. *The parts of a neon bulb. See text for details.*

The ionization of the gas allows current to flow through it. This will continue even if the power supply is reduced by 10 to 20 volts to a level known as the *maintaining voltage*.

Negative Resistance

When the glow discharge persists below the starting voltage, this is a form of *hysteresis*, meaning that the neon bulb tends to "stick" in its on state. It remains on while its power supply decreases to the maintaining voltage, but once it switches off, it will "stick" in its off state until the power supply increases again above the maintaining voltage to the starting voltage. The concept of hysteresis is discussed in the entry on **comparators**. See Figure 6-2.

A neon bulb is said to have *negative resistance*. If the current is allowed to increase without restraint, the resistance eventually decreases while the current increases further. If this runaway behavior is not controlled, the bulb will destroy itself.

This behavior is characteristic of gas-discharge tubes generally. A graph showing this appears in Figure 19-5. Note that both scales are logarithmic. Also note that the curve shows how current will be measured in response to voltage. If the voltage is reduced after it has increased, the transitional events shown by the graph will not recur in reverse order. This is especially true if arcing is allowed to begin, as it will almost certainly destroy the component.

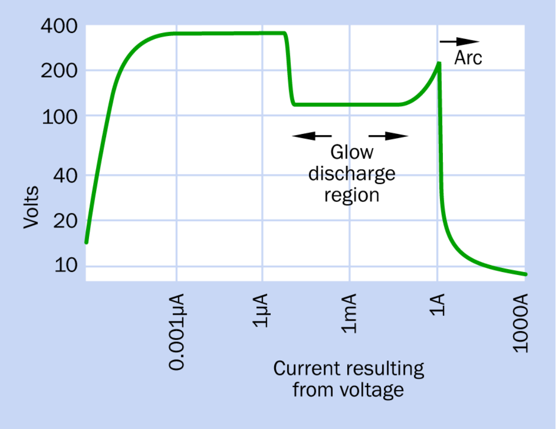

Figure 19-5. *A gas discharge tube, such as a neon bulb, is said to have a negative resistance, as current passing through it tends to increase uncontrollably after the gas is ionized and becomes conductive. (Derived from measurements made by David Knight, on a web page named after his radio ham call sign, G3YNH.)*

A neon bulb can be controlled very simply with a series resistor that maintains it in gas-discharge mode. To understand the operation of the resistor, consider the combination of the lamp and the resistor as a voltage divider, as shown in Figure 19-6. Before the lamp begins to pass current, it has an almost infinite resistance. Therefore, the voltage on both sides of the resistor will be approximately equal, the bulb passes almost no current, and it remains dark.

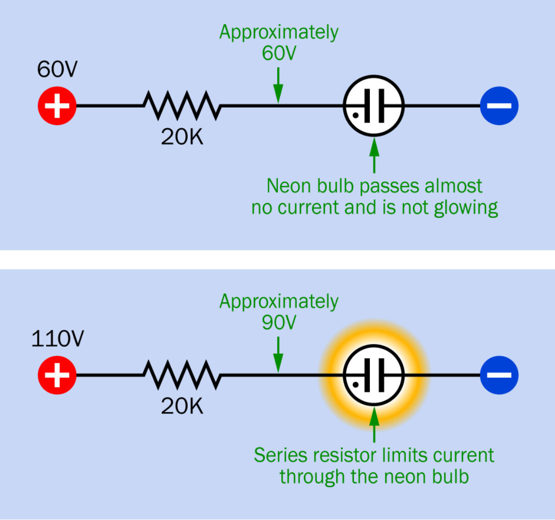
Approximately 60V
60V
20K
Neon bulb passes almost no current and is not glowing
Approximately 90V
110V
20K
Series resistor limits current through the neon bulb

Figure 19-6. *A series resistor is essential to limit the current through a neon bulb.*

After the lamp begins to pass current, the requirement now is for the series resistor to reduce the voltage from the supply level (probably around 110V) to the maintaining level (probably around 90V). This means that the desired voltage drop is 20V, and if the manufacturer's specification tells us that the lamp should pass 1mA (i.e., 0.001 amps), R, the value of the series resistor, is given by Ohm's Law:

```
R = 20 / 0.001
```

Thus, the value for R is 20K. In fact, the value of a resistor supplied with a neon bulb may range from 10K to 220K, depending on the characteristics of the bulb and the supply voltage that will be used.

Now if the bulb's effective internal resistance falls radically, the resistor still limits the currrent. In a hypothetical worst-case scenario, if the bulb's resistance drops all the way to zero, the resistor must now impose the full voltage drop of 110V, and the current, I, will be found by Ohm's law:

```
I = 110 / 20,000
```

That is, about 5mA, or 0.005A.

Neon tubes used in signage require a more sophisticated voltage control circuit which is not included in this encyclopedia.

How to Use It

The use of a neon bulb for an indicator lamp is primarily limited to situations where domestic supply voltage (115VAC or 220VAC) is readily available. "Power on" lights are the obvious application, especially as neon indicators can accept AC. The switch shown in Figure 19-7 is illuminated by an internal neon bulb. The rectangular indicator in Figure 19-8 is designed to run on domestic supply voltage, and its internal bulb and resistor can be clearly seen through the green plastic. The assembly in Figure 19-9 is about 0.5" in diameter, which is the lower limit for neon indicators.

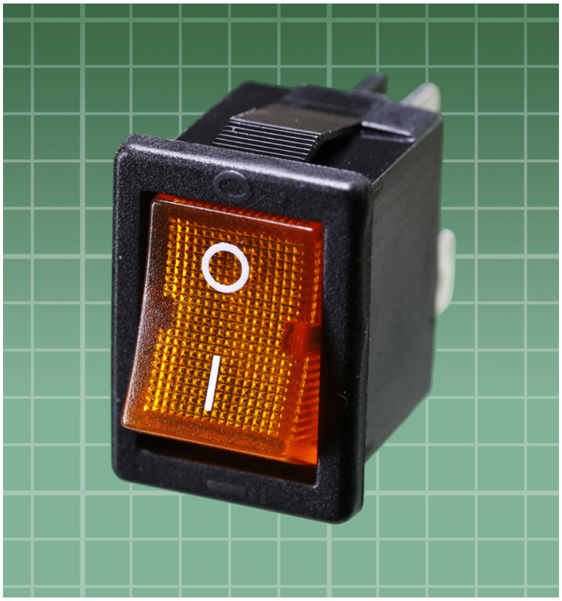

Figure 19-7. *This power switch is illuminated by an internal neon bulb.*

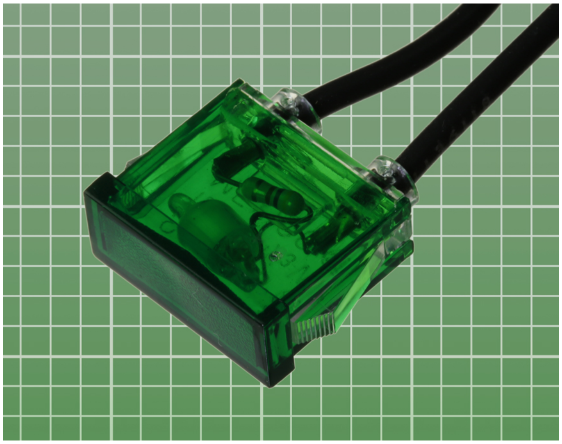

Figure 19-8. *The neon bulb and its series resistor are visible inside this indicator.*

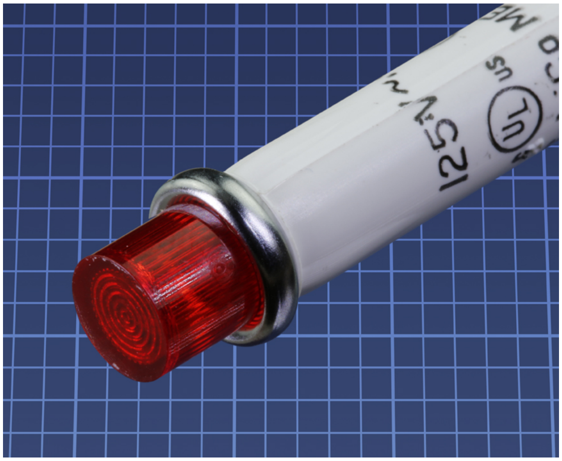

Figure 19-9. *A relatively small neon indicator lamp, designed for insertion in a hole 0.5" diameter.*

Limited Light Output

Neon bulbs have a light output of around 0.06 lumens per milliamp of consumed power (standard brightness type) or 0.15 lumens per milliamp of consumed power (high brightness type).

Comparing this value with the intensity of **LED** indicators is difficult. Their light output is customarily measured in *millicandelas* (mcd), because LED indicators almost always include a lens that focuses the light, and the candela is a measurement of luminous flux within an angle of dispersion. Moreover, because the intensity of neon indicators is not of great interest in most applications, datasheets usually do not supply an intensity value.

One way around the problem of comparisons is to use the standard of *radiant luminous efficacy* (LER), which is defined in the entry on incandescent lamps (see "Efficacy" on page 179). A standard-brightness neon bulb has an LER of about 50 lumens per emitted watt of luminous flux. A light-emitting diode may reach an LER of 100 lm/W. However, a neon bulb operates typically around 1 mA while an LED indicator may use 20mA. Therefore, a typical LED indicator may appear to be 30 to 50 times brighter than a typical neon bulb.

Consequently, neon may be an inferior choice in a location where there is a high level of ambient light. Direct sunlight may render the glow of a neon indicator completely invisible.

Efficiency

Because a neon bulb does not use a lot of power and generates negligible heat, it is a good choice where current consumption is a consideration (for example, if an indicator is likely to be on for long periods). The durability and low wattage of neon bulbs, and their convenient compatibility with domestic power-supply voltage, made them a favorite for night-lights and novelty lamps in the past. Figure 19-10 shows an antique bulb containing an ornamental electrode, while Figure 19-11 is a piece of folk art, approximately 1" in diameter, mounted on a plug-in plastic capsule containing a neon bulb.

Ruggedness

Neon bulbs are a good choice in difficult environments, as they are not affected by vibration, sudden mechanical shock, voltage transients, or frequent power cycling. Their operating temperature range is typically from -40 to +150 degrees Celsius, although temperatures above 100 degrees will reduce the life of the lamp.

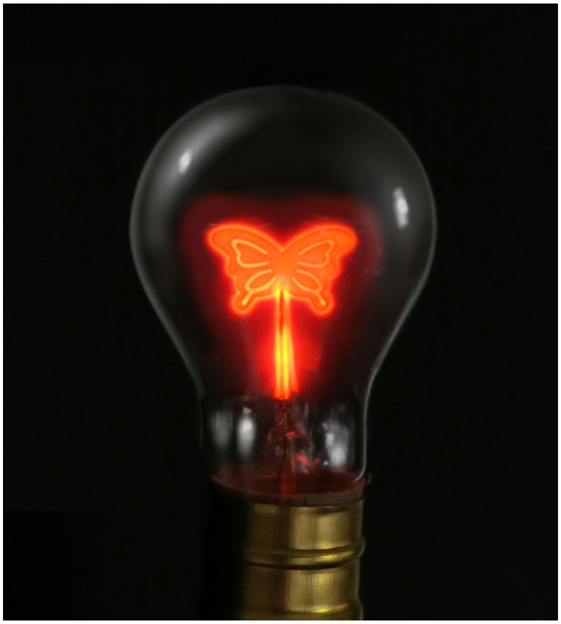

Figure 19-10. *In bygone decades, ornamental neon bulbs with specially shaped electrodes were popular.*

Figure 19-11. *Neon folk art survives in this hand-painted night-light sold in a Florida tourist shop.*

Power-Supply Testing

When driven by DC current, only the negative electrode (the *cathode*) of a neon bulb will glow. When AC current passes through the bulb, both terminals will glow.

If a bulb (with series resistor) is placed between the "hot" side of a domestic AC power supply and ground, the bulb will glow. If it is placed between the neutral side of the supply and ground, it will not glow.

These features enable a neon bulb to be used for simple power-supply testing.

Life Expectancy

The metal of the electrodes gradually vaporizes during everyday use of a neon bulb. This is known as *sputtering* and can be observed as the glass capsule becomes darkened by deposition of vaporized metal. The electrodes will have a more limited life in a lamp used with DC voltage, where sputtering affects only the cathode. Using AC, the electrodes take turns functioning as the cathode, and vaporization is distributed between both of them.

Failure of a neon lamp can occur as sputtering erodes the electrodes to the point where the maintaining voltage will increase until it almost reaches the level of the power supply. At this point, the bulb will flicker erratically.

Failure can also be defined as a gradual reduction in brightness to 50% of rated light output, caused by accumulated deposition in the glass capsule. Because deposition occurs more heavily on the sides of the bulb, a longer apparent life is possible if the bulb is mounted so that it is viewed from the end.

Typically, neon bulbs are rated for 15,000 to 25,000 hours (two to three years of constant operation). However, the life can be greatly increased by a slight reduction in voltage, which may be achieved by substituting a series resistor with a slightly higher value.

The relationship between operating life and resistor value is shown below. If LA is the normal operating life, LB is the extended operating life, RA is the normal resistor value, and RB is a higher resistor value:

```
LB = LA * ( RB / RA ) ^3.3
```

For example, if a normal resistor value is 20K, and it is increased to 22K, the life of the lamp should increase by a factor of slightly more than 1.4.

Variants

A typical neon bulb terminates in leads, and a lamp assembly often has solder tabs, although it may have a base with a screw thread, flange, or bayonet pins for insertion into a compatible socket. A lamp assembly that does not use a base will either snap-fit into a hole of appropriate size and shape, or may be retained with a nut that engages with a plastic thread on the cylinder of the lamp.

Some neon bulbs or lamp assemblies terminate in pins for direct insertion into a printed circuit board.

Almost all neon bulbs operate either in the 100V to 120V range or in the 220V to 240V range.

Light intensity is expressed either as “standard” or “extra-bright,” although datasheets usually do not define those terms.

Nixie Tubes

Nixie tubes, first marketed in 1955, were used to display numerals from 0 through 9 in the days before LEDs took over this capability. They are no longer being manufactured.

Each numeral was physically formed from metal and functioned as an electrode inside a tube filled with a neon-based gas mixture. The typographical elegance of the digits and their aesthetically pleasing glow made Nixies enduringly popular. With a long lifespan, vintage tubes are still usable and can be purchased cheaply from sources such as eBay. Many originate in Russia, where Nixie-type displays were manufactured into the 1980s. The Russian tubes can be identified by their use of a numeral 5 that is a numeral 2 turned upside-down.

Nixie tubes typically require 170VDC. This creates a challenge for a power supply and switching, and can be a safety hazard.

Figure 19-12 shows six Nixie-type tubes repurposed for use as a 24-hour digital clock.

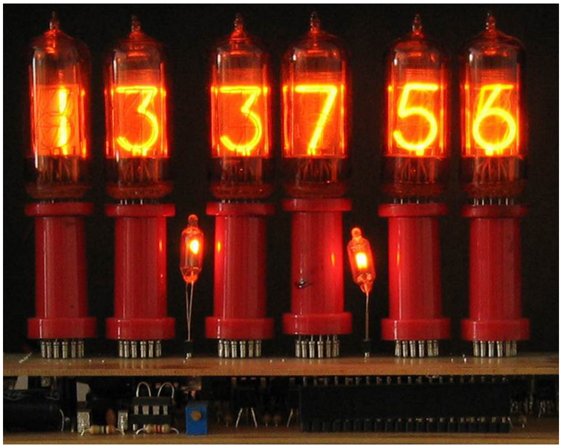

Figure 19-12. *A 24-hour clock using Nixie-type tubes. Source: Wikipedia, public domain.*

What Can Go Wrong

False Indication

Because a neon bulb requires so little power, it may be energized by induced voltages from elsewhere in a circuit, especially if inductive components such as transformers are used. To prevent this, a high-value resistor can be placed in parallel with the bulb, in addition to the series resistor that must always be used.

Failure in a Dark Environment

Because a neon bulb requires a minimal amount of light to initiate its own photon emissions, it may take time to start glowing in a very dim environment, and may not light at all in total darkness. A few bulbs include a small amount of radioactive material that enables them to self-start in complete absence of ambient light.

Premature Failure with DC

The life expectancy quoted in datasheets for neon bulbs usually assumes that they are powered by AC. Because DC results in faster vaporization of the electrodes, the expected lifetime should be reduced by 50% if DC power will be used.

Premature Failure through Voltage Fluctuations

Because the deterioration of a neon bulb accelerates rapidly with current, a sustained voltage that passes slightly more current can radically reduce the expected lifespan.

Replacement

Replacement can be an issue with panel indicators, where disassembly of a device may be necessary to reach the bulb. Bear in mind, however, that an easily removable bulb becomes vulnerable to tampering.

fluorescent light

20

This entry deals primarily with *fluorescent tubes* (infrequently but sometimes described as *fluorescent lamps*), and *compact fluorescent lamps* (CFLs) that are marketed as a substitute for **incandescent lamps**. *Cold-cathode fluorescent lamps* (CCFLs) are also mentioned.

Vacuum fluorescent devices have a separate entry in this encyclopedia. A fluorescent tube or CFL does not contain a vacuum.

Although the diode(s) in a white **LED area lighting** unit are coated with a layer of fluorescent phosphors, they are not categorized here as fluorescent lights, and have their own entry.

A **neon bulb** resembles a fluorescent light in that it is a *gas-discharge* device, but the interior of its glass envelope is usually not coated with fluorescent phosphors, and therefore it has its own entry.

OTHER RELATED COMPONENTS

- **incandescent lamp** (see Chapter 18)
- **LED area lighting** (see Chapter 23)
- **vacuum fluorescent** devices (see Chapter 25)
- **neon bulb** (see Chapter 19)

What It Does

Fluorescent tubes or *compact fluorescent lamps* (CFLs) are primarily used for area lighting. A partially disassembled CFL appears in Figure 20-1, showing the control electronics that are normally hidden inside the base.

There is no standardized schematic symbol to represent a fluorescent light. Figure 20-2 shows three commonly used symbols for a fluorescent tube on the left, and three symbols for a CFL on the right. Note that two of the symbols for a CFL are the same as those for an **incandescent lamp**, shown in Figure 18-1.

How It Works

Luminescence is the emission of light as a result of a process that does not require heat. (The opposite phenomenon is *incandescence*, in which heating causes an object to emit light; see Chapter 18 for a description of **incandescent lamps**.)

Fluorescence is a form of luminescence. It occurs when electrons in a material are energized and then make a transition back to ground level, at which point they radiate their energy as visible light. The incoming energy can consist of other light at a higher frequency. Some creatures, including species of arachnids and fish, will fluoresce when they are lit with ultraviolet light.

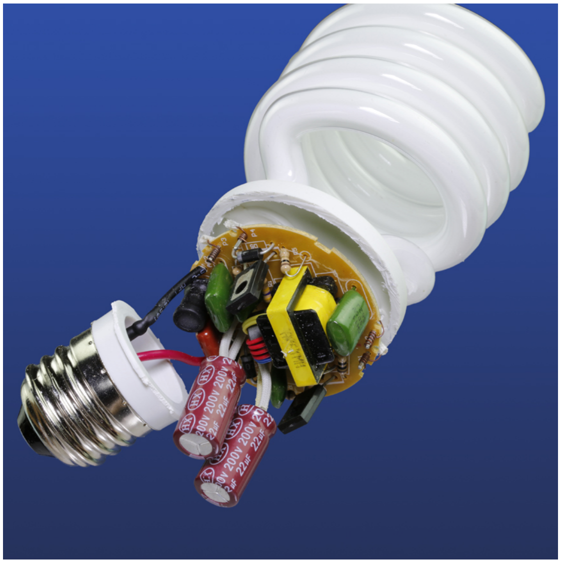

Figure 20-1. *A compact fluorescent lamp with its base cut away to reveal the control electronics.*

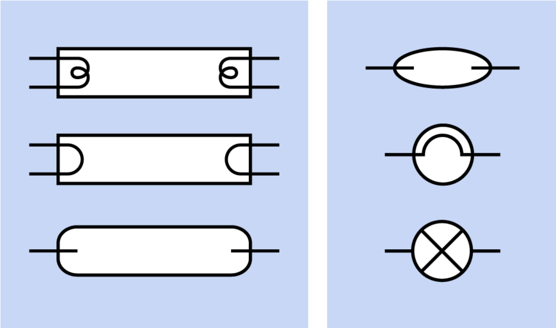

Figure 20-2. *Schematic symbols to represent fluorescent tubes and bulbs are not standardized. See text for details.*

A *fluorescent tube or lamp* contains a very small amount of mercury vapor that can be stimulated to emit ultraviolet light. This encounters a thin layer of *phosphors* coating the inner surface of the glass enclosure. The light causes the phosphors to *fluoresce*, emitting a diffuse radiance in the visible spectrum.

The tube or lamp also contains one or more inert gases such as argon, xenon, neon, or krypton at about 0.3% of normal atmospheric pressure. Two electrodes inside the glass enclosure are made primarily from tungsten, which can be preheated to initiate ionization of the gas. Confusingly, both electrodes are often referred to as *cathodes*.

The function of the gas is not to emit light, but to conduct electric current, so that free electrons may encounter mercury atoms, raising their electrons briefly to a higher energy level. When one of these electrons reverts from its unstable energized state to its previous energy level, it emits a photon at an ultraviolet wavelength.

Figure 20-3 provides a diagram showing the interior of a fluorescent tube.

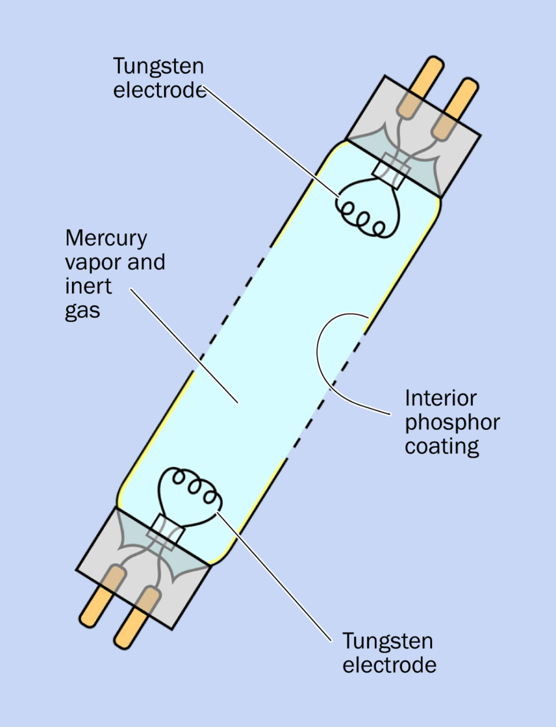

Figure 20-3. *The basic parts of a fluorescent tube.*

Ballast and Starter

Heating the tungsten electrodes is necessary but not sufficient to trigger ionization. A high-voltage pulse is also needed when the light is switched on. In a typical 48″ tube, the pulse may range from 200V to 300V.

After current flow has been established, the gas, which is now a plasma, enters a phase of negative resistance. Current passing through it will tend to increase even if the voltage decreases. This process must be controlled to prevent the formation of an *arc*, which will destroy the electrodes. (A similar process occurs in any gas discharge tube, such as a **neon bulb**, and is described in a graph in Figure 19-5.)

To heat the electrodes, ionize the gas, and then control the current, the fixture for a fluorescent tube contains components that are separate from the tube. In their simplest, traditional form, these components consist of a *starter* and a *ballast*. The starter is a neon bulb that contains a bimetallic strip serving as a normally closed switch. It allows current to flow through the electrodes in series, to heat them. The basic circuit is shown in Figure 20-4.

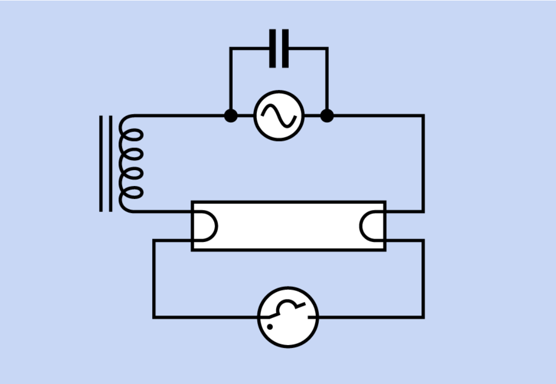

Figure 20-4. *The traditional circuit to trigger ionization of the gas in a fluorescent tube uses a starter (shown at the bottom as a neon tube containing a bimetallic strip, which serves as a switch) and ballast (an inductive load, shown at left).*

The starting process may not be immediately successful, in which case the starter may repeat several times in succession, causing the tube to flicker before its discharge becomes stable. In a cold environment, the tube will have more difficulty starting.

After the tube becomes conductive, current between the electrodes bypasses the starter. At this point, the *ballast* limits the current to prevent an arc from forming. The simplest form of ballast is a coil that functions as an **inductor**.

In a more modern system, an *electronic ballast* replaces the starter-ballast combination. It not only applies the initial surge of high current but also raises the 50Hz or 60Hz frequency of the power supply to 10KHz or more. This increases the efficiency of the tube and eliminates any visible flickering of the light.

All compact fluorescent bulbs (CFLs) contain electronic ballasts. The small components visible in Figure 20-1 are the ballast.

Flicker

When a fluorescent tube uses a conventional ballast and is illuminated with 50Hz or 60Hz AC, the glow discharge stops each time the current flow passes through the zero point in its cycle. In fact, the ionized gas in the tube cannot conduct until it is close to the maximum voltage, and stops conducting when the voltage rolls off. Consequently, the voltage across the tube fluctuates in an approximate square wave, and the light output begins and ends very abruptly. Although this occurs 100 times per second on a 50Hz supply and 120 times per second on a 60Hz supply, some people complain that the flicker is noticeable and can induce headaches.

The rapid on-off discharge is hazardous when it illuminates rotating parts in machinery, as a stroboscopic effect can make the parts seem to be stationary. To mitigate this effect, adjacent tubes in a fixture are powered by separate supplies that are out of phase. This is done either by using a three-phase power supply or by adding an LC circuit to the supply for one of the tubes.

Variants

The traditional type of ballast is also known as a *rapid-start ballast*. By preheating the electrodes, it reduces damage to them that otherwise tends to occur during the starting process. A tube designed for use with a rapid-start ballast has two contacts at each end, and is referred to as a *bi-pin* tube.

An electronic ballast is also known as an *instant-start ballast*. It does not preheat the electrodes, and a tube designed to work with it has only one pin at each end.

CCFLs

A *cold cathode fluorescent lamp* (CCFL) may resemble a miniature fluorescent tube, typically measuring 2mm to 5mm in diameter. The tube may be straight or bent into a variety of shapes. It works on the same principle as a full-size fluorescent tube, containing mercury vapor and one or more inert gases, with an interior coating of phosphors to enable fluorescence. CCFLs are available in many colors and many shades of white.

As its name implies, the electrodes in a CCFL are not heated to establish ionization. Instead, a very high voltage (1,000VAC or more) is applied, dropping to 500VAC to 600VAC after the flow of current has been established. Because CCFLs have been often used to backlight laptop computer screens, inverter circuits are commonly available that create a high-frequency output at a high voltage from an input that can range from 3VDC to 20VDC. The inverter also includes provision to dim the CCFL by using *pulse-width modulation*.

Some CCFLs are designed for illumination of small spaces—for example, the interior of a display case. A few CCFLs look exactly like CFLs and can be used in light fixtures. Some may be compatible with the type of dimmer designed for incandescent lamps.

A CCFL usually has a limited light output compared with that of a conventional fluorescent tube, but has the advantage of working better at low temperatures. Some are designed for signage and exterior lighting in cold-weather locations.

They have a relatively long lifetime of up to 60,000 hours. A hot-cathode fluorescent lamp may fail between 3,000 and 15,000 hours.

Any tube or bulb that uses unheated electrodes to ionize a gas is technically a cold-cathode device, but will not be identified as a CCFL unless it also has an inner layer of phosphors to achieve fluorescence.

It is important to match a tube with the type of ballast installed in a fixture. This is not an issue with CFLs, as they have the appropriate ballast built in.

Sizes

Straight bi-pin tubes are sold in the United States in the following standard sizes:

- T5: 5/8″ diameter. A more modern tube, but still with tungsten electrodes that serve to heat it.
- T8: 1″ diameter. Very often 24″ or 48″ in length, consuming 18W or 36W respectively.
- T12: 1-1/2″ diameter.
- T17: 2-1/8″ diameter.

CFLs are sold in a very wide variety of configurations.

Comparisons

Fluorescent lights have significant advantages and disadvantages. On the plus side:

- After the fixture containing the ballast has been paid for, a tube is relatively cheap. A CFL or an LED light does not have this advantage, as the electronics are built in and will be discarded when the light fails.
- Fluorescent lights have a longer life than incandescent bulbs.
- Fluorescent lights are available in a wide range of shades of white.
- Fluorescent tubes create a diffuse radiance that is ideal for general lighting using ceiling-mounted fixtures. They do not cast harsh shadows.

On the minus side:

- Fluorescents were traditionally more energy-efficient than any other light source, but **LED area lighting** is now more efficient in some designs. LEDs are expected to become more efficient in the future.
- A fluorescent tube with a traditional type of ballast may cause complaints of flickering. By comparison, an LED light uses DC, and an incandescent bulb retains sufficient heat between power cycles so that it does not appear to flicker.
- Fluorescent flicker creates problems when shooting video.
- The fluorescent emission spectrum has sharp peaks that give the lighting an unnatural look.
- In applications that require a defined beam of light, a fluorescent source cannot be used.
- Conventional ballasts can create radio interference, especially in the AM band.
- Because fluorescent tubes and bulbs contain mercury, they require proper disposal, which can incur fees.
- Even an instant-on fluorescent light tends to hesitate briefly when it is switched on.
- The lifespan of a fluorescent light is greatly reduced if it is cycled on and off frequently. An incandescent bulb is less severely affected by cycling, and an LED light is not affected at all.
- Fluorescent lights have difficulty starting at low temperatures.

Values

Brightness

The intensity of a fluorescent light is measured in *lumens per watt*. Because invisible wavelengths are of little interest when assessing brightness, *luminous flux* is used to describe apparent brightness in the visible spectrum. The unit for luminous flux is the *lumen*. Additional information about light measurement is included in the entry describing incandescent lamps (see “Power” on page 177).

Spectrum

The spectrum of photons emitted from mercury vapor in a fluorescent light has wavelengths that peak at 253.7 nanometers and 185 nanometers. (A *nanometer*, customarily abbreviated as nm, is one-billionth of a meter.) These wavelengths are invisible, being in the ultraviolet range, but when the light is transposed into the visible spectrum by the layer of phosphors, “spikes” in the range of wavelengths are still present. For a comparison of output curves for incandescent, fluorescent, and LED lights, see the graph in Figure 18-4.

Various formulations for the phosphors in a tube or CFL attempt to modify the character of the light to suit the human eye, but none of them looks as “natural” as the radiance from an incandescent bulb, probably because the characteristics of incandescent light are very similar to those of sunlight.

What Can Go Wrong

Unreliable Starting

At a low temperature, the mercury inside a fluorescent tube may be slow to vaporize. At very low temperatures, vaporization may not be possible at all. Until the mercury vaporizes, fluorescence will not occur.

Terminal Flicker

As a tube ages, it may start to conduct current only in one direction, causing it to flicker visibly. As it ages more, the gas discharge becomes even less reliable, and the flicker becomes erratic. Eventually, the gas discharge fails completely. In this state, a tube may show only a dim light at each end, in proximity to the tungsten electrodes.

Cannot Dim

Neither the older style of “conventional” ballast nor a modern electronic ballast will respond appropriately to a dimmer of the type designed for incandescent bulbs. This may be an important factor when an incandescent bulb is swapped out for a CFL.

Burned Out Electrodes

Like the tungsten filament in an **incandescent lamp**, the tungsten electrodes in a fluorescent tube suffer progressive erosion. This is evident when a black tungsten deposit forms on the inside of the tube at one or both ends.

Ultraviolet Hazard

Some critics of CFLs maintain that the complex shape of a coiled or zig-zag tube tends to permit small imperfections in the internal phosphor coating, potentially allowing ultraviolet light to escape. If this occurs, and if a CFL is used in a desk fixture in close proximity to the user, ultraviolet light could elevate the risk of skin cancer.

laser

21

The term *maser* was coined in the 1950s to describe a device that used stimulated emission to amplify microwaves. When a device using similar principles amplified visible light in 1960, it was termed an *optical maser*. However, that term is now obsolete, having been replaced with **laser**. This term is always printed in lowercase letters, even though it is an acronym for Light Amplification by Stimulated Emission of Radiation.

The invented verb *to lase* is derived from *laser* and is used to describe the process of generating laser light, with the past participle *lased* and present participle *lasing* sometimes being used.

Thousands of laser variants exist. Because of space limitations, this entry will concentrate primarily on *laser diodes*, which are the smallest, most common, and most affordable type.

OTHER RELATED COMPONENTS

- **LED indicator** (see Chapter 22)

What It Does

A **laser** generally emits a thin beam of intense light, often in the visible spectrum, and usually in such a narrow range of wavelengths, it can be considered *monochromatic*. The light is also *coherent*, as explained below.

Light output from a laser has three important attributes:

- Intensity. A high-powered laser can deliver energy to a very small, well-defined area, where it may be capable of burning, cutting, welding, or drilling. Large lasers may also be used as weapons, or for power transmission.
- Collimation. This term describes a beam of light that has parallel boundaries, and therefore does not disperse significantly when passing through a transparent medium such as air, glass, or a vacuum. A laser beam can have such excellent collimation, it can be used in precision measuring devices, and has been transmitted over very long distances, even from the Earth to the Moon, where astronauts placed reflectors during the Apollo missions.
- Controllability. Because the beam can be generated with eletrical power, its intensity can be modulated rapidly with relatively simple electronic circuits, enabling applications such as burning microscopic pits in the plastic of a CD-ROM or DVD.

Laser diodes are now more common than all other forms of lasers. They are found in pointers, printers, barcode readers, scanners, computer mice, fiber-optic communications, surveying tools, weapon sights, and directional lighting sources. They are also used as a light source to trigger more powerful lasers.

No generic symbol is used for a laser, but a laser diode is often represented with the same symbol that is used for a light-emitting diode. See Figure 22-2 in the entry for **LED indicators**.

How It Works

A laser is built around a *gain medium*, which is a material that can amplify light. The medium can be a solid, liquid, gas, or plasma, depending on the type of laser.

Initially, an input of energy provides stimulation for some atoms in the gain medium. This is known as *pumping* the laser. The energy input can come from a powerful external light source, or from an electric current.

Stimulation of an atom raises the quantum energy level of an electron associated with the atom. When the electron collapses back to its former energy state, it releases a photon. This is known as *spontaneous emission*.

If one of the photons encounters an atom that has just been excited by the external energy source, the atom may release two photons. This is known as *stimulated emission*. Beyond a threshold level, the number of released photons can increase at an exponential rate.

If two parallel reflectors are mounted at opposite ends of the gain medium, they form a *resonant cavity*. Light bounces to and fro between the reflectors, while pumping and stimulated emission amplifies the light during each pass. If one of the mirrors is partially transparent, some of the light will escape through it in the form of a laser beam. The partially transparent mirror is known as the *output coupler*.

Laser Diode

A laser diode contains an **LED**. (See "How It Works" on page 207 for a more detailed description of the function of an LED.) The p-n junction of the diode functions as the resonant cavity of the laser. Forward bias injects charges into the junction, causing spontaneous emission of photons. The photons, in turn, cause other electrons and electron-holes to combine, creating more photons in the process of stimulated emission. When this process crosses a threshold level, current passing through the diode causes it to *lase*.

The original patent for a laser diode was filed by Robert N. Hall of General Electric in 1962, and the diagram in Figure 21-1 is derived from the drawing in that patent, with color added for clarity.

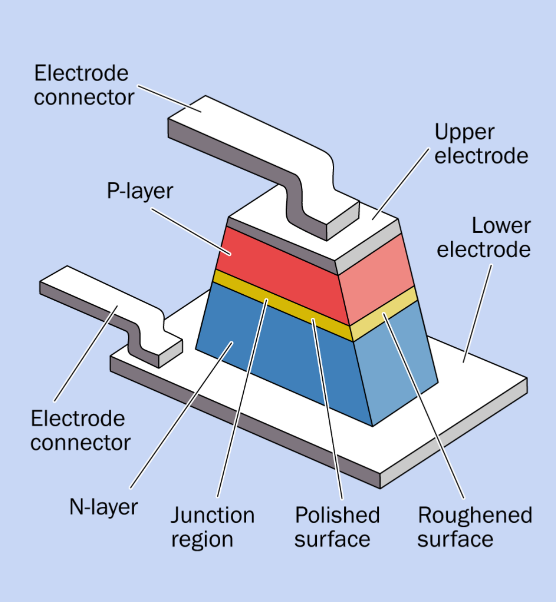

Figure 21-1. *The original design for a laser diode, from the patent filed in 1962.*

In the figure, the junction shown as a yellow layer forms the resonant cavity in which lasing occurs. It measures only 0.1 microns thick (the diagram is not drawn to scale). Its vertical front side is highly polished, and is parallel to the back side, which is also highly polished. Thus, photons reflect between these two vertical sides. The slanted face visible in the figure, and the other slanted face opposite it, are oriented and roughened to minimize internal reflection between them.

Figure 21-2 shows a simplified cross-section of the laser diode.

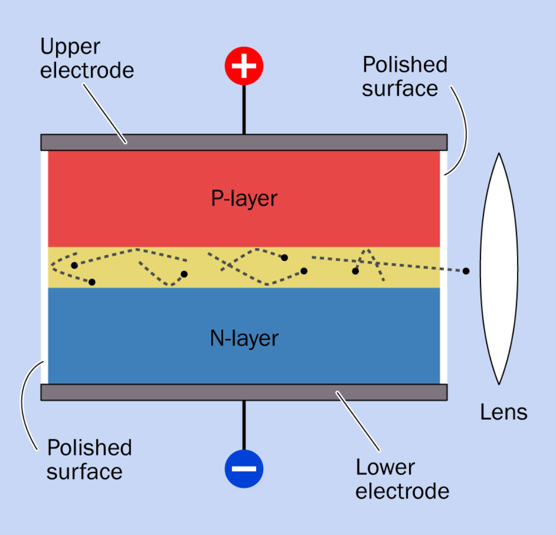

Figure 21-2. *Simplified cross-section of a laser diode.*

Figure 21-3 shows a cross-section of the diode installed in a component sold as a laser. It includes a photodiode to sense the intensity of light emerging through the polished rear end of the laser diode. External electronics are necessary to control the intensity of the laser, using feedback from the photodiode.

The component has three pins (shown pale yellow in the figure), one connecting to the photodiode, another connecting to the p-type layer of the laser diode, and the third being common to the n-type layer of the laser diode and the ground side of the photodiode.

A photograph of a laser diode is shown in Figure 21-4. Note the three pins, comparable to the pins shown in Figure 21-3, indicating that this component requires external control electronics.

In Figure 21-5, a laser is shown with a surface-mount chip adjacent to the solder pad connecting the blue wire. The presence of this chip, with only two wires, indicates that this component has its own control electronics and requires only a DC power supply.

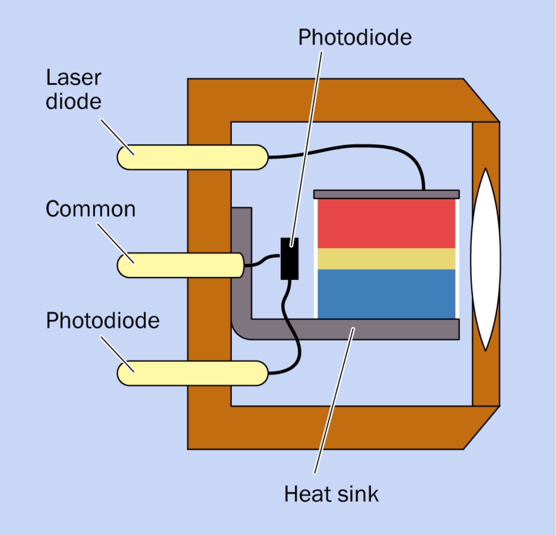

Figure 21-3. *A laser diode is typically mounted with a photodiode to provide feedback for a driver circuit, to control the current consumed by the laser.*

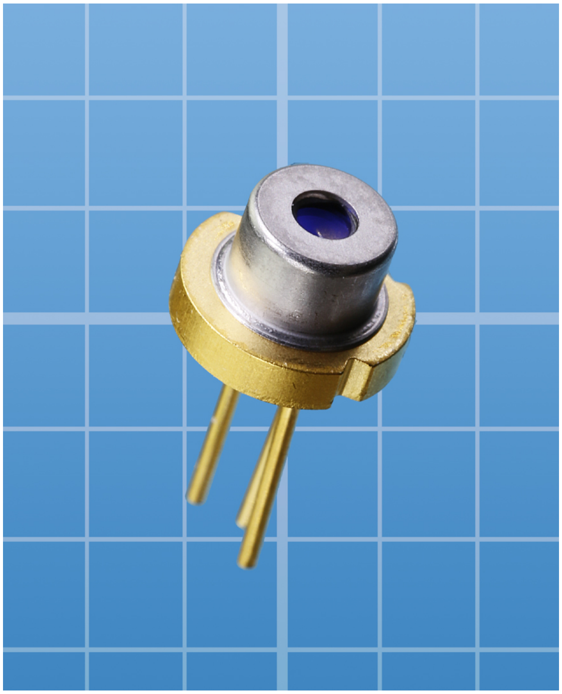

Figure 21-4. *Lite-On 505T laser diode that emits light at 650nm. Power consumption 5mW at 2.6VDC. As indicated by the graph squares, this component is only about 0.2" in diameter.*

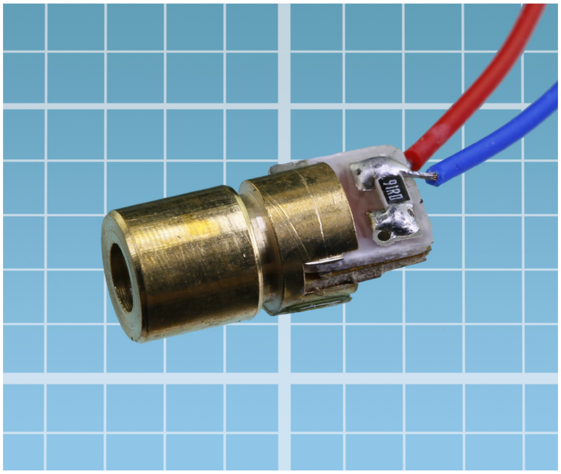

Figure 21-5. *This laser incorporates its own control electronics and requires only a 5VDC power supply. It draws 30mA and generates an output up to 5mW.*

Coherent Light

The emission of *coherent light* by a laser is often explained by suggesting that wavelengths are synchronized with each other. In fact, there are two forms of coherence that can be described approximately as *spatial coherence* and *wavelength coherence*.

If an observer looks up at a cloudy sky, the eye will perceive light radiating chaotically from many distances and directions. Thus, the light is not spatially coherent. The light also consists of many wavelengths, and thus it is not wavelength-coherent.

The filament of an incandescent lamp is a much smaller source of light, but still large enough to generate a profusion of light emissions that are spatially incoherent. The light also includes many different wavelengths.

Suppose a barrier containing a very tiny hole is placed in front of the **incandescent lamp**. If the aperture is very small, an observer on the far side will see the light as a point source. Consequently, the light that emerges from it is now spatially coherent, and will not have chaotically overlapping waves. If the light then passes through a filter, its wavelengths also will become coherent. This is suggested in Figure 21-6 where the light source is an incandescent lamp emitting a wide range of wavelengths.

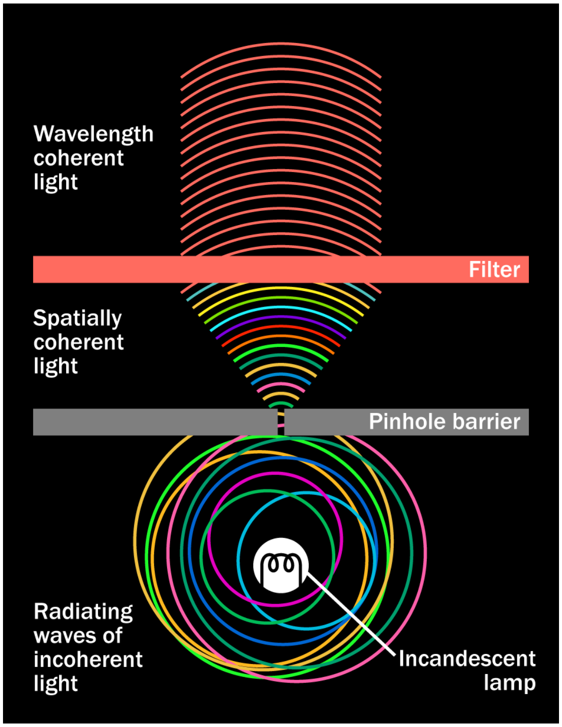

Figure 21-6. *An incandescent lamp, at the bottom of the figure, emits incoherent light at many wavelengths (exaggerated here for clarity). When it passes through a pinhole, it becomes spatially coherent. When it then passes through a colored filter, it becomes wavelength coherent.*

The small amount of light emerging through a pinhole is inevitably much dimmer than light from the original source. A laser, however, amplifies its light output, as well as tending to behave like a point source. The “hall of mirrors” effect of the parallel reflective surfaces in the resonant cavity causes much of the light to shuttle to and fro over a long distance before it emerges through the output coupler. Any light that deviates significantly from the axis of the laser will not escape at all, because the deviations will be cumulative with each reflection. Thus, the light from a laser appears to come from a point source at an almost infinite distance.

Because of the particular geometry of a light-emitting diode, the output from a laser diode is not naturally collimated, and tends to spread by an angle of around 20 degrees. A lens must be used to focus the beam.

Variants

Lasers are sold generally as fully assembled tools for a specific purpose. A very brief summary of CO2, fiber, and crystal lasers is included here.

CO2 Lasers

The gain medium is primarily carbon dioxide but also contains helium and nitrogen, with sometimes hydrogen, water vapor, and/or xenon. The laser is electrically pumped, causing a gas discharge. Nitrogen molecules are excited by the discharge and transfer their energy to the CO2 molecules when colliding with them. Helium helps to return the nitrogen to base energy state and transfer heat from the gas mixture.

CO2 lasers are infrared, and are commonly used in surgical procedures, including ophthalmology. Higher powered versions have industrial applications in cutting a very wide range of materials.

Fiber Lasers

Light is pumped via diodes and amplified in purpose-built glass fibers. The resulting beam has a very small diameter, providing a greater intensity than CO2 lasers. It can be used for metal engraving and annealing, and also for working with plastics.

Crystal Lasers

Like fiber lasers, they are pumped by diodes. These compact lasers are available in a very wide variety of wavelengths, covering the whole visible spectrum, infrared, and ultraviolet. They find applications in holography, biomedicine, interferometry, semiconductor inspection, and material processing.

Values

The output power of a laser is measured in watts (or milliwatts). This should not be confused with the power consumed by the device.

In the United States, any device sold as a laser pointer is limited to a power output of 5mW. However, laser diodes packaged similarly to laser pointers can be mail-ordered with an output of 200mW or more. The legal status of these lasers may be affected by regulations that vary state by state.

In a CD-RW drive that is capable of burning a disc, the diode may have a power of around 30mW. A laser mounted in a CD-ROM assembly is shown in Figure 21-7.

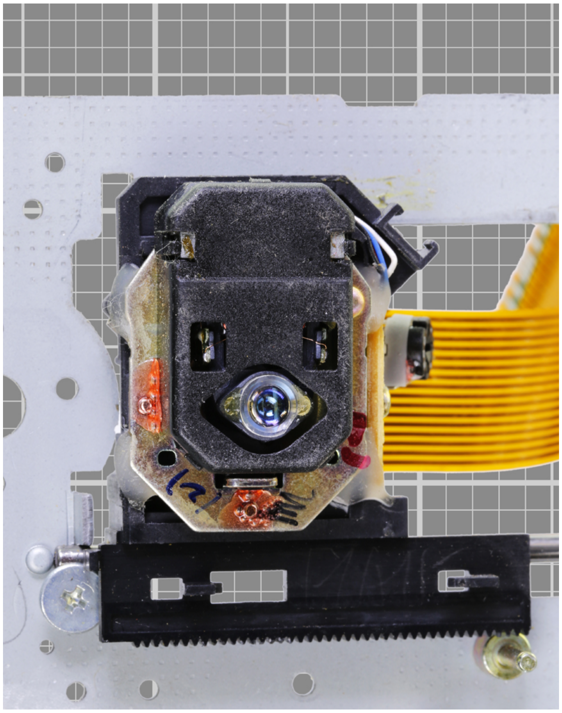

Figure 21-7. *An assembly incorporating a laser for reading a CD-ROM.*

Lasers have such a narrow range of wavelengths, they are given specific output values in nanometers. A laser in an optical mouse may have a wavelength of 848nm; in a CD drive, 785nm; in a bar-code reader, 670nm; in a modern laser pointer, 640nm; in a Blu-ray disc player, 405nm.

How to Use It

While powerful lasers in a laboratory setting have exotic applications, a typical low-power laser diode has become so affordable (costing less than $5 in some instances, at the time of writing) it can be considered merely as a useful source of a clearly defined light beam, ideal for detecting the position of a movable mechanical component or the presence of an intruder.

Generic light-emitting diodes are made with a view angle (i.e., a dispersion angle) as low as 3 degrees, but the beam is soft-edged compared with the precise boundary of a laser beam, and cannot be used reliably in conjunction with sensors at a distance of more than a few inches.

Laser diodes that are sold as components may or may not have current-limiting control electronics built in. Applying power to the laser diode directly will result in thermal runaway and rapid destruction of the component. Drivers for laser diodes are available separately as small, preassembled circuits on breakout boards.

For many applications, it may be simpler and cheaper to buy a laser diode as an off-the-shelf product. A laser pointer provides an easy way to get a source of laser light, and if it would normally be driven by two 1.5V batteries, it can be adapted to run off a 5V supply by using a 3.3V voltage regulator.

Common Applications

In addition to being used with PowerPoint presentations and in conjunction with position sensors, laser pointers have other applications:

- Astronomy. A high-powered laser beam is visible even in clear air as a result of interaction with air molecules. This is known as *Rayleigh scattering*. The phenomenon allows one person to point out a star (or planet) for another person. Because celestial objects are so far away, parallax error is not detectable by two people viewing the beam while standing next to each other. A laser pointer may also be mounted on a telescope to assist in aiming the telescope at an object of interest. This is easier than searching for an object through an eyepiece.
- Target acquisition. Lasers are commonly used on firearms to assist in targeting, especially in low-light conditions. Infrared lasers can be used in conjunction with infrared viewing goggles.
- Survival. A small laser can be included in emergency supplies to signal search teams. A laser can also be used to repel predatory animals.

What Can Go Wrong

Risk of Injury

Lasers are potentially dangerous. Those that have an infrared or ultraviolet output are more dangerous than those with a visible beam, as there is no visual warning that the laser is active. A laser is capable of scarring the retina, although controversy exists regarding the power output that should be considered a high risk.

If a project incorporates a laser, it should be switched off while building or testing the device. It may be advisable to wear protective glasses that block laser light even when an experimenter feels confident that a laser is switched off.

Active lasers should never be pointed at people, vehicles, animals (other than dangerous animals), or oneself.

Inadequate Heat Sink

Lasers may be designed and rated for intermittent use. The burner assembly for a CD-ROM drive, for instance, will be rated for pulsed power, not continuous power. Read datasheets carefully, and provide an adequate heat sink.

Uncontrolled Power Supply

A diode laser that does not have a feedback system in place to control the flow of current can self-destruct.

Polarity

Both the light-emitting diode and the photodiode in a three-pin laser package can be damaged by incorrect polarity of applied power. Pin functions should be checked carefully against datasheets.

LED indicator

22

In this encyclopedia, an **LED indicator** is defined as a component usually 10mm or smaller in diameter, made of transparent or translucent epoxy or silicone, most often containing one *light-emitting diode*. It is purposed as a status indicator in a device, rather than as a source of illumination, and is sometimes referred to as a *standard LED*.

LED indicators that emit infrared and ultraviolet light are included in this entry. LEDs that are designed to illuminate large interior or exterior areas are discussed in a separate entry as **LED area lighting**. They are sometimes described as *high-brightness LEDs* and almost always emit white light.

The term **light-emitting diode** is becoming less common, as the acronym **LED** has become ubiquitous. The acronym does not usually include periods between the letters.

The words "light emitting" are hyphenated here, as they form an adjectival phrase, but in everyday usage the hyphen is often omitted, and no definitive rule seems to exist.

Originally, a standard LED contained only one diode, but may now include multiple diodes, either to emit additional light or to provide a range of colors. In this encyclopedia, a single epoxy or silicone capsule is still considered to be an **LED indicator** regardless of how many diodes it contains. By contrast, any component consisting of multiple separately discernible light-emitting diodes, as in a seven-segment numeral, a 14- or 16-segment alphanumeric character, a dot-matrix character, or a display of multiple characters, is listed in a separate entry as an **LED display**.

OTHER RELATED COMPONENTS

- **LED area lighting** (see Chapter 23)
- **LED display** (see Chapter 24)
- **incandescent lamp** (see Chapter 18)
- **neon bulb** (see Chapter 19)
- **laser** (see Chapter 21)

What It Does

An **LED indicator** emits light in response to a small current, typically around 20mA (but sometimes much less), at a voltage lower than 5VDC. It is usually molded from epoxy or silicone that may be colorless and transparent (often referred to as *water clear*), or colorless but translucent, or tinted and transparent, or tinted and translucent.

The color of the light is initially determined by the chemical compounds used internally, and by their dopants; therefore, a water-clear LED may emit colored light.

Ultraviolet LEDs are usually water-clear. Infrared LEDs often appear to be black, because they are opaque to the visible spectrum while being transparent to infrared.

When an LED indicator is described as being *through hole,* it has leads for insertion into holes in a circuit board. The term does not mean that the indicator itself is meant to be pushed through a hole in a panel, although this may also be done. The LED is cylindrical with a hemispherical top that acts as a lens. The leads are relatively thick, to conduct heat away from the component. A dimensioned diagram of a typical LED measuring 5mm in diameter is shown in Figure 22-1.

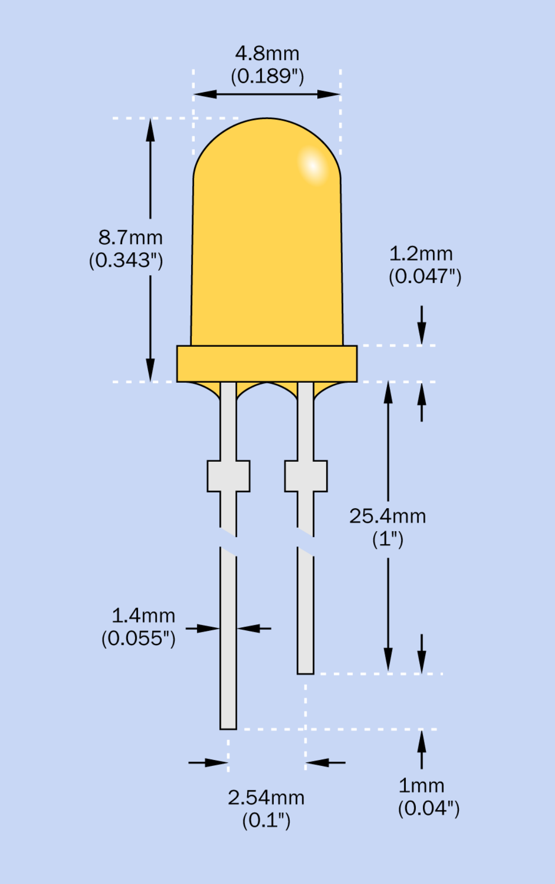

Figure 22-1. *Dimensions of a typical 5mm LED. The longer wire connects with the anode, while the shorter wire connects with the cathode. Adapted from a datasheet published by Lite-On Technology Corporation.*

An LED indicator that is not the through-hole type is usually a surface-mount component. LEDs for surface mounting are mostly rectangular and can be as small as 1mm x 0.5mm. They may require a *heat sink*.

Schematic Symbols

Figure 22-2 shows a variety of symbols that are commonly used to represent an LED. The triangle at the center of each symbol points in the direction of conventional (positive-to-negative) current flow—from the anode to the cathode. Each pair of arrows radiating away from the diode indicates emitted light. Wavy arrows are sometimes used to represent infrared (thermal) radiation. Often, however, an infrared LED is represented in exactly the same style as an LED that emits visible light. With the exception of the wavy arrows, the various styles of schematic symbol are functionally identical and do not identify different attributes of the component such as size or color.

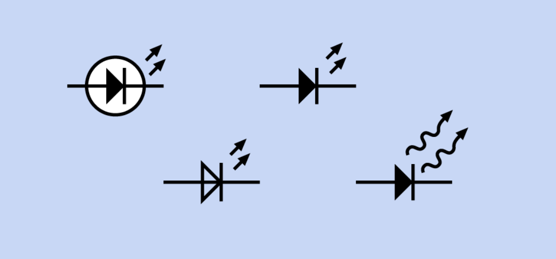

Figure 22-2. *Various symbols may be used to represent an LED. See text for details.*

Common Usage

LED indicators have mostly displaced **neon bulbs** and miniature **incandescent lamps** for the purpose of showing the status of a device. They are found in industrial control panels, home audio systems, battery chargers, washer/dryers, and many other consumer-electronics products. Higher output variants are used in flashlights, traffic signals, taillights on automobiles, and for illumination of subjects that are being photographed. LED indicators may be assembled in large numbers in attention-getting displays such as Christmas lights.

Red, orange, yellow, green, and blue are the basic standard colors. LEDs that appear to generate white light are common, but they do not emit an evenly weighted spectrum of wavelengths. See "Non-Incandescent Sources" on page 174 for a discussion of this topic.

How It Works

An LED, like any **diode**, contains a semiconductor *PN junction* that conducts current only in the forward direction (i.e., from the more-positive side of a power supply to the more-negative side). The diode becomes conductive above a *threshold voltage* sufficient to force electrons in the n-type region and holes in the p-type region to combine with each other. Each time this occurs, energy is released. The energy liberated by one electron-hole combination creates a *photon*, or one quantum of light.

The amount of energy released depends on the *band gap*, which is a property of the semiconductor material. The band gap is the smallest energy that can create an electron-hole pair. The energy determines the light's wavelength, and thus the color.

The band gap also determines the threshold voltage of the LED. For this reason, LEDs of different colors have widely different threshold voltages.

Because an LED will often be used in devices where the DC power supply exceeds the maximum forward voltage, a *series resistor* is customarily used as a simple way to restrict current through the diode.

The light emitted by a colored LED indicator tends to include only a narrow range of wavelengths. However, the addition of a phosphor coating to the diode can broaden the output. This technique is used to make the light from a blue LED appear white, as shown in Figure 22-3. Most white LEDs are actually blue LEDs with a colored phosphor layer added. See the section on **LED area lighting** in Chapter 23 for a more detailed discussion of this topic.

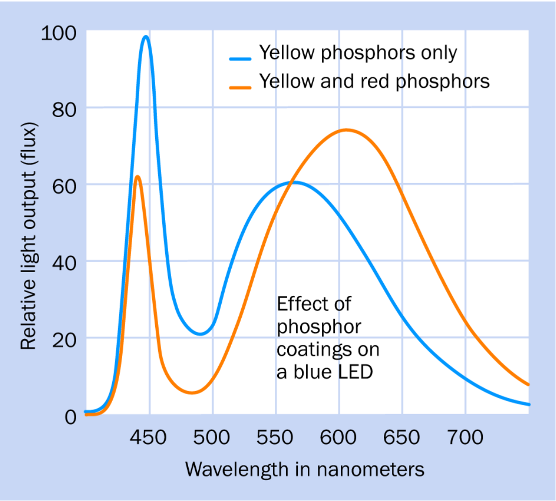

Figure 22-3. *Increasing the range of emitted wavelengths by adding phosphors to a blue LED. Source: Philips Gardco Lighting.*

Multicolor LEDs and Color Mixing

If red, green, and blue light sources are mounted extremely close together, the eye perceives them as a single source, of a color determined by their combined relative intensities. This system of additive color mixing is shown in Figure 17-14 in the entry dealing with LCDs. It is used in LED indicators that contain red, green, and blue light-emitting diodes in a single epoxy or silicone capsule.

While most video monitors use white LEDs or **fluorescent lights** to form a backlight for an **LCD** video screen, some high-end monitors use a matrix of very tiny red, green, and blue LEDs, because the combination of these separate colors generates a wider *gamut* of color wavelengths. The concept of gamut is discussed in "Color" in the **LCD** entry. The tiny LEDs in a backlight cannot be considered as indicators, but indicators are used for this purpose in billboard-sized video displays.

Variants

LED indicators vary widely in size, shape, intensity, view angle, diffusion of light, wavelength of light, minimum and maximum forward voltage, and minimum and maximum forward current.

Size and Shape

The original sizes for round LED indicators were 3mm, 5mm, or (more rarely) 10mm in diameter. Today, through-hole LEDs are sold in many intermediate sizes, although 3mm and 5mm are still most widely used.

The traditional round LED indicator is now augmented with square and rectangular shapes. In a parts catalog, a pair of dimensions such as 1mm × 5mm suggests that the LED is rectangular.

Intensity

The light intensity of an LED is usually expressed in *millicandelas*, abbreviated *mcd*. There are 1,000 mcd in a candela. For more information about units for measurement of light, see "Intensity" on page 178.

The candela measures the *luminous flux*, or visible radiant power, contained within a specified angle of dispersion, usually referred to as the *view angle*. This can be imagined as the rotated angle at the apex of a cone, where the cone defines the "spread" of the light, and the source is at the apex.

If a diode is emitting a fixed amount of luminous flux, the rating in mcd will increase with the inverse square of the view angle. This is because the light delivered to an area in front of the LED will become more intense as the angle becomes smaller. The use of mcd to rate the brightness of an LED can be misleading if it is not considered in comparison with the view angle.

For example, suppose an LED is rated at 1,000 mcd and has a view angle of 20 degrees. Now suppose the same diode is embedded in a different epoxy or silicone capsule with a lens that creates a view angle of only 10 degrees. The LED will now be rated at 4,000 mcd, even though its total power output is unchanged.

- To compare the brightness of two LED indicators meaningfully, they should share the same view angle.

Four through-hole LED indicators with a wide range of specifications are shown in Figure 22-4. From left to right: water-clear white generic, 10mm; Vishay TLCR5800 5mm (emitting red, even though the capsule is water-clear), rated for 35,000mcd with 4 degrees view angle; Everlight HLMPK150 5mm red diffused, rated for 2mcd with 60 degrees view angle; and Chicago 4302F5-5V 3mm green, rated for 8mcd at 60 degrees view angle, containing its own series resistor to allow direct connection with a 5VDC power supply.

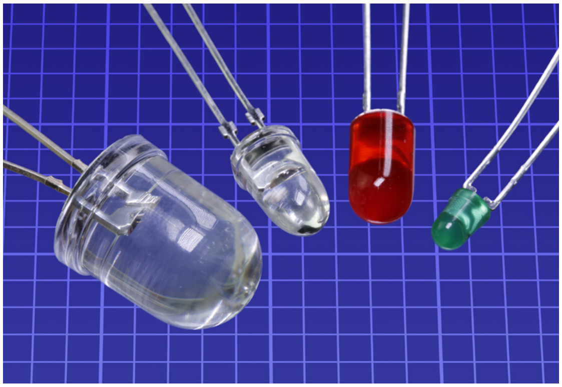

Figure 22-4. *Four assorted LED indicators with very different specifications. See text for details.*

Efficacy

The *radiant luminous efficacy* (LER) of an incandescent light source compares how effective it is at channeling its output within the visible spectrum, instead of wasting it in other wavelengths, especially infrared. Note that the word *efficacy* has a different meaning from *efficiency*. The LER acronym may help to avoid confusion.

LER is expressed in lumens per watt, and in an incandescent bulb it is calculated by dividing the power emitted in the visible spectrum (the *lumi-*

nous flux) by the power emitted over all wavelengths. This is described in detail on "Efficacy" on page 179 in the entry dealing with incandescent lamps.

In an LED indicator, almost all the radiation can be within the visible spectrum, but some power is wasted by generating heat internally. The efficacy varies depending on the type of LED; thus a red-orange indicator can have an efficacy of 98% while a blue LED will be probably below 40%.

Diffusion

Some LED indicators use epoxy or silicone that is formulated to be translucent or "cloudy" instead of transparent. They diffuse the light so that it is not projected in a defined beam, has a softer look, and has an approximately equal intensity when viewed from a wider range of angles.

"Clear" and "diffused" are options that must be taken into account when choosing LEDs from an online catalog, unless the user is willing to turn a clear LED into a diffuse LED by applying some sandpaper.

Wavelength and Color Temperature

The wavelength of light is measured in *nanometers* (abbreviated *nm*), a nanometer being 1 billionth of a meter. The visible spectrum extends from approximately 380nm to 740nm. Longer wavelengths are at the red end of the spectrum, while shorter wavelengths are at the blue end.

A typical LED emits a very narrow range of wavelengths. For example, Figure 22-5 shows the emission from a standard red LED indicator manufactured by Lite-On. Graphs of this type are typically included in manufacturers' datasheets.

Because a red LED stimulates the cones in the eye that respond to red light, it "looks red" even though the color is not comparable with the natural red that is seen, for instance, in a sunset. That natural color actually contains an additional spread of wavelengths.

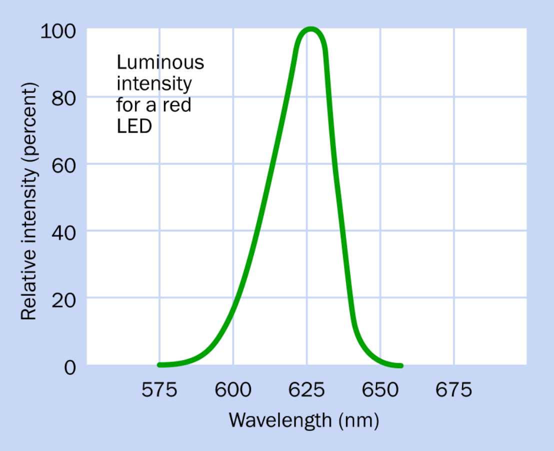

Figure 22-5. *The narrow range of wavelengths emitted by a typical red LED indicator.*

The following list shows the ranges of peak output values, in nanometers, for the most commonly available basic LED indicators (LEDs that emit other wavelengths are available, but they are less common):

- Infrared LED: 850 to 950
- Red LED: 621 to 700
- Orange LED: 605 to 620
- Amber LED: 590 to 591
- Yellow LED: 585 to 590
- Green LED: 527 to 570
- Blue LED: 470 to 475
- Ultraviolet LED: 385 to 405

Figure 22-6 shows this list graphically, omitting infrared and ultraviolet LEDs.

For almost 30 years, blue LEDs were a laboratory curiosity of little practical value, as efficiencies were stuck around 0.03%. An efficiency of more than 10% was finally achieved in 1995. Blue LEDs were marketed soon afterward.

However, when yellow phosphors are added to create the impression of white light by spreading the output over the whole visible spectrum, the wavelengths around 500nm are still not well represented, as suggested in Figure 22-3.

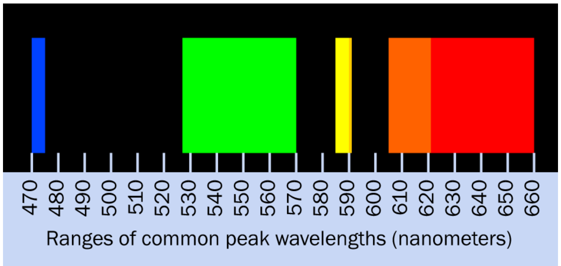

Figure 22-6. *Ranges for peak wavelengths of the most commonly used LEDs. (Source: Survey of approximately 6,000 through-hole LEDs stocked at www.mouser.com.)*

Fluorescent lights perform even more poorly than white LEDs, as can be seen in Figure 18-4 in the entry describing **incandescent lamps**.

Because white LEDs do not emit a single peak of wavelengths, their color is expressed in color temperature rather than nanometers. The concept of color temperature is explained in "Spectrum" on page 173. White LEDs are available rated from 2,800 to 9,000 degrees Kelvin, and are discussed in more detail in the **LED area lighting** entry in this encyclopedia.

Internal Resistor

To eliminate the chore of adding a series resistor to limit current through an LED, some indicators are sold with a series resistor built in. They may be rated for use with 5VDC or 12VDC, but are externally indistinguishable from each other. They are also externally indistinguishable from LEDs that do not contain series resistors. Figure 22-7 shows two 3mm LEDs, the one on the right containing its own series resistor, the one on the left being a generic LED without a series resistor.

Because of the nonlinear response of a diode, LEDs with or without internal resistors cannot be distinguished from each other reliably with a multimeter. If the meter is set to measure ohms, typically it will give an "out of range" error to all types of LED. If it is set to identify a diode, the reading will not tell you if the LED contains a resistor.

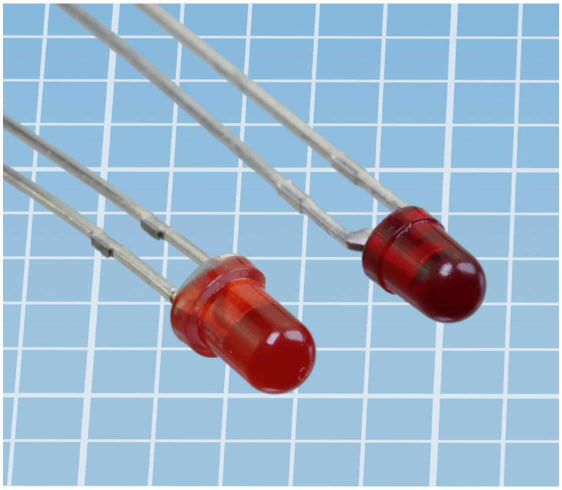

Figure 22-7. *An LED (left) that does not contain its own series resistor is usually indistinguishable from one that does (right).*

One way to determine whether an LED contains an internal series resistor would be to connect it with a variable power supply through a multimeter set to measure mA. Carefully increase the supply voltage from zero until the meter shows a current of 20mA. If the LED does not contain a series resistor, the supply voltage will be close to the recommended forward voltage for that type of LED (no lower than 1.6V for a red LED, and no higher than 3.6V for a white LED). If the LED does contain a series resistor, the supply voltage will be higher. This procedure is time consuming, but may be worthwhile to evaluate multiple LEDs that are known to be identical.

Multicolored

The leads for an LED indicator containing two or more diodes can be configured in several ways:

- Two leads, two colors. Two diodes are mounted internally in parallel, but with opposite polarity.
- Three leads, two colors. Two diodes share a common anode or common cathode.
- Four leads, three colors (RGB). Three diodes share a common anode or common cathode.

- Six leads, three colors. Three diodes, each with its own pair of leads, separate from the others.

Infrared

Most infrared emitters are LEDs that generate wavelengths longer than 800nm. They are found in handheld remotes to control consumer-electronics devices such as televisions and stereo systems, and are also used in some security systems, although *passive infrared motion detectors*, which assess infrared radiation from sources such as people or vehicles, are more commonly used for this purpose.

In conjunction with an infrared emitter, an infrared sensor is necessary, and must be sensitive to the same wavelength. To prevent false positives, the emitter modulates its output, typically with a carrier frequency between 10 and 100kHz. Remotes often use carrier frequencies of 30 to 56kHz. At the receiving end, the signal is processed with a band-pass filter matching the modulation frequency. Many different pulse-coding schemes are used, and no particular standard is dominant.

Ultraviolet

Because ultraviolet radiation can damage the eyes, LED indicators that emit ultraviolet light are potentially dangerous and should be used with caution. A yellow eyeshield can be worn to block the short wavelengths.

Ultraviolet light can be used to cure some adhesives and dental filling material. It can also kill bacteria, and can detect fluorescent print on bank notes, to check for counterfeiting. Ultraviolet flashlights are sold to detect some species of pests, such as scorpions, which fluoresce in response to ultraviolet light.

Values

The specification for an LED will include the wavelength of emitted light, luminous intensity, maximum forward voltage and current, maximum reverse voltage and current, and working values for voltage and current. All these values are important when choosing an indicator for a specific function.

White LEDs for room lighting or external use are calibrated differently. See the entry for **LED area lighting** in Chapter 23.

Forward Current

About half of all the thousands of available types of LED indicators are rated for a typical forward current of 20mA to 25mA. Absolute maximum ratings may be twice as high, but should not generally be applied.

The light intensity of a typical 5mm red LED indicator is plotted against its forward current in Figure 22-8. Note that current and light intensity have an approximately linear relationship up to the typical working current of 20mA. Even above this point, to the absolute maximum of 50mA, the light intensity rolls off only a very small amount.

Although an LED indicator can be dimmed by controlling the current passing through it, the current does not have a linear relationship with the applied voltage, and the indicator will stop functioning completely when the voltage drops below the threshold required by the diode. Consequently, LEDs are commonly dimmed by using *pulse-width modulation*.

Because of the nonlinear response of a diode, LEDs with or without internal resistors cannot be distinguished from each other reliably with a multimeter. If the meter is set to measure ohms, typically it will give an “out of range” error to all types of LED. If it is set to identify a diode, the reading will not tell you if the LED contains a resistor.

Low-Current LEDs

Indicators that require a very low forward current are convenient for direct connection to output pins of logic chips and other integrated circuits. Although a single output from an HC family chip is capable of supplying 20mA without damaging the chip, the current will pull down the output voltage, so that it cannot be used reliably as an input to another chip while also lighting the LED.

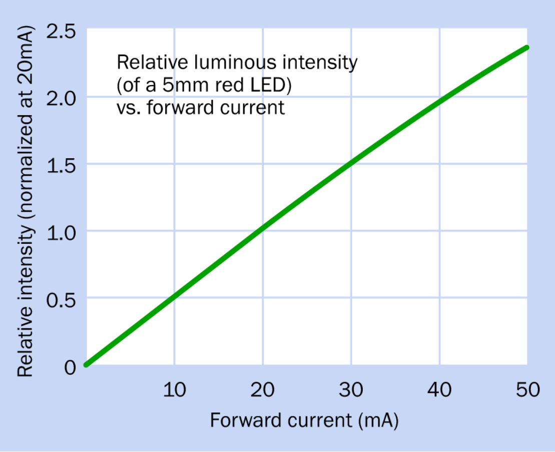

Figure 22-8. *The relationship between forward current and light intensity of a typical 5mm LED indicator is approximately linear up to the 20mA operating current, and almost linear up to the absolute maximum of 50mA.*

Various LED indicators drawing 2mA or 1mA are available, with intensities typically ranging between 1.5mcd and 2.5mcd. This low light output is still bright enough for viewing in a lab-bench environment. Low-current blue LEDs are not available. The only LEDs that draw as little as 1mA are red, as this is the most efficient type.

Using a higher value series resistor with a generic LED will of course reduce its current consumption, and some light will be visible so long as the forward voltage across the LED remains at its minimum level or above.

Forward Voltage

Red is the color that requires not only the least forward current, but the lowest forward voltage. In the range of 1.6VDC to 1.7VDC, all the LEDs are red. Typical forward voltages for various colors are shown here:

- Infrared LED: 1.6V to 2V
- Red LED: 1.6V to 2.1V
- Orange LED: 1.9V to 2.1V
- Amber LED: 2V to 2.1V
- Yellow LED: 2V to 2.4V
- Green LED: 2.4V to 3.4V
- Blue LED: 3.2V to 3.4V
- Ultraviolet LED: 3.3V to 3.7V
- White LED: 3.2V to 3.6V

Color Rendering Index

The *color rendering index* (CRI) evaluates the fidelity with which a light source is capable of displaying the full visible spectrum. It ranges from a perfect score of 100 down to 0 or even lower (sodium-vapor street lighting has a negative value). Computing the index requires standard reference color samples and has been criticized for generating scores that do not correlate well with subjective assessments.

Incandescent bulbs can have a CRI of 100, while an uncorrected white LED may score as low as 80.

Life Expectancy

Because the light output from an LED tends to decrease very gradually with time, the life expectancy is often defined as the number of hours required for the output to diminish to 70% of its output when new. Life expectancy is commonly stated on datasheets for high-brightness white LEDs, but is often omitted from datasheets for LED indicators.

Unlike incandescent lamps and fluorescent lights, LEDs do not have a shorter lifespan if they are frequently cycled on and off.

Light Output and Heat

The light intensity of an LED, measured in mcd, can vary from a few mcd to a maximum of 40,000mcd. Intensities above 30,000mcd generally are achieved by limiting the view angle to 15 degrees or less. Because the candela is weighted toward the central, green segment of the visible spectrum, green LEDs are likely to have a relatively high mcd rating. LEDs rated between 20,000mcd and 30,000mcd, with a view angle of 30 degrees, are almost all green.

Datasheets may often include a *derating curve* showing the lower limit that should be placed on forward current through an LED indicator when its temperature increases. In Figure 22-9, the LED should be operated only within the boundary established by the green line.

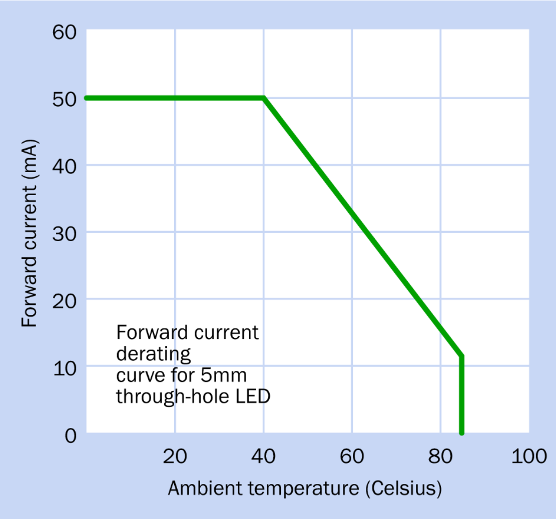

Figure 22-9. *Safe operation of an LED entails limiting the forward current if the temperature increases. The green line shows the boundary for operation of this particular component.*

View Angle

An LED formed from transparent epoxy or silicone (either water-clear or tinted) will create a well-defined beam with a view angle as narrow as 4 degrees or as wide as 160 degrees (in a few instances). The most common view angles for LED indicators are 30 degrees and 60 degrees.

Datasheets for LED indicators often include a *spatial distribution* graph showing the relative intensity of the light when viewed at various angles from the axis of the LED. The spatial distribution graph in Figure 22-10 is for an LED with a view angle defined as 40 degrees. This is the angle at which the relative luminous intensity diminishes to 50%.

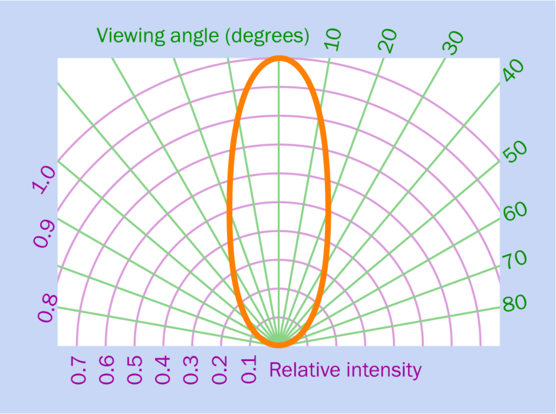

Figure 22-10. *A spatial distribution graph shows the relative intensity of light from an LED at various view angles.*

The view angle is of special concern in devices such as flashlights, where the spread of the beam affects the functionality.

How to Use It

Like all semiconductor devices, LEDs can be impaired by excess forward current and may break down irreversibly if subjected to excess reverse voltage. Their limits for reverse voltage are much lower than those of a rectifier diode. They are also vulnerable to heat, but are not particularly vulnerable to static electricity.

Polarity

A through-hole LED will have two leads of unequal length. The longer lead connects internally with the *anode* of the diode, and should be wired externally to the “more positive” side of a power source. The shorter lead connects internally with the *cathode* of the diode, and should be wired externally to the “more negative” side of a power source.

To remember the functions of the leads, consider that the plus sign would be twice as long as a minus sign if its horizontal and vertical stroke were disassembled and placed end to end.

If a round LED has a flange around its base, a flat spot in the flange will be closest to the cathode side of the component.

Series Resistor Value

Because the effective internal resistance of a diode is not a constant value at different voltages, a trial-and-error approach may be necessary to determine the ideal value for a series resistor with an LED indicator. For this purpose, a trimmer potentiometer can be used with a sample LED while measuring the current through it and the voltage drop across it. A fixed-value resistor can then be substituted. If the choice is between a resistor value that is a little too high and a value that is a little too low, the higher value resistor should be used.

An approximate value can be found using a very simple formula in which R is the resistor value, V_{CC} is the supply voltage, V_F is the forward voltage specified for the LED, and I is the desired current:

$$R = (V_{CC} - V_F) / I$$

Normally a series resistor rated at 1/4 watt will be acceptable, and 1/8 watt may be used in 5VDC circuits. However, care should be taken with a power supply of 9V or higher. Suppose an LED is rated for 1.8V forward voltage at 20mA. In a 5V circuit, the voltage drop across the series resistor will be:

```
V = 5 - 1.8 = 3.2
```

Therefore, the resistor must dissipate 3.2V * 20mA = 64mW. This is comfortably below the 125mW rating of a 1/8 watt resistor. However, with a 9V power supply, the voltage drop across the series resistor will be:

```
V = 9 - 1.8 = 7.2
```

Now the resistor must dissipate 7.2V * 20mA = 144mW. This exceeds the 125mW limit for a 1/8 watt resistor.

LEDs in Parallel

If multiple LEDs are to be driven in parallel, and none of them has to be switched individually, it is naturally tempting to save time by using a single series resistor for all of them. In these circumstances, assess the maximum current carefully and multiply by the voltage drop imposed by each of the LEDs, to determine the wattage of a series resistor.

Linking dissimilar LEDs in parallel is not recommended, because the threshold voltage decreases with increasing temperature. The hottest LED will therefore receive the largest current, and thus become even hotter. Thermal runaway can result.

LEDs containing their own series resistors can safely be wired in parallel.

Multiple Series LEDs

A series resistor wastes current by dissipating it as heat. In an application where two or more LED indicators will be illuminated simultaneously, the LEDs can be connected in series with a lower-value resistor, and three LEDs in series may eliminate the need for a resistor completely, depending on the voltage of the power supply. Here again a trimmer potentiometer should be used to determine an ideal value for any series resistor that may be necessary.

Comparisons with Other Light Emitters

Because LED indicators have largely replaced neon bulbs and miniature incandescent lamps, comparisons are of limited importance at this point. The situation regarding **LED area lighting** is different in that it is still competing actively with fluorescent lights and, in some instances, halogen. A list of advantages and disadvantages for high-intensity white LEDs is given in "Comparisons" on page 223. The advantages of incandescent lamps are listed in "Relative Advantages" on page 179.

Other Applications

LEDs are used in **optocouplers** and in **solid-state relays**. Usually an infrared LED is embedded inside a chip or a plastic module, and emits light through an interior channel to activate a phototransistor. This arrangement provides electrical isolation between the switching signal and the switched current.

Some sensors use an LED paired with a phototransistor at opposite sides of a U-shaped plastic mount. A sensor of this type can monitor industrial processes or may be found inside a photocopy machine, to detect the presence of a sheet of paper.

What Can Go Wrong

Excessive Forward Voltage

Like any diode, the LED has a *threshold voltage* in the forward direction. If this threshold is exceeded, the effective internal resistance of the LED falls very rapidly. Current rises equally rapidly, and quickly damages the component, unless it is protected by an appropriate series resistor.

Excessive Current and Heat

Exceeding the recommended value for forward current, or allowing an LED to overheat, will shorten its lifetime and cause a premature dimming of light output. LEDs generally require some current limiting or regulation (most commonly with a series resistor). They should not be connected directly to a voltage source such as a battery, even if the battery voltage matches the voltage of the diode. The exception to this rule is if the internal resistance of the battery is high enough to limit the current, as in the case of button-cell batteries.

Storage Issues

LEDs of different types are often indistinguishable from each other. They can also be indistinguishable from photodiodes and phototransistors. Careful storage is mandatory, and reusing LEDs that have been breadboarded may cause future problems if they are wrongly identified.

Polarity

If the leads on an LED indicator are trimmed, and if the indicator lacks a flange in which a flat spot will identify the cathode, the component is easily misused with reversed polarity. If it is connected with a component that has limited current sourcing capability (for instance, the output pin of a digital chip), the LED will probably survive this treatment. However, maximum reverse voltage is often as low as 5VDC. To minimize the risk of errors, the anode lead can be left slightly longer than the cathode lead when they are trimmed for insertion in a breadboard or perforated board.

Internal Resistors

As previously noted, it is difficult to distinguish an LED that contains its own series resistor from another LED that does not. The two types should be stored separately, and should be reused circumspectly.

LED area lighting

23

The term **LED area lighting** is used in this encyclopedia to describe a white LED source that is bright enough to illuminate rooms, offices, or outdoor areas. It may also be used in desk lamps or table lamps as *task lighting*. LEDs for these purposes may be categorized as *high-brightness*, *high-power*, *high-output*, or *high-intensity*. A complete fixture containing at least one light source is properly known as a *luminaire*, although the term is not uniformly applied and is sometimes written incorrectly as a *luminary*.

The full term *light-emitting diode* is not normally applied to an LED used for area lighting. For this purpose, the LED acronym has become universal. Periods are not normally placed between the letters.

While an LED area-lighting package may contain more than one diode, it is still categorized here as a single source. By contrast, any component consisting of multiple separately discernible light-emitting diodes, as in a seven-segment numeral, a 14- and 16-segment alphanumeric character, a dot-matrix character, or a display of multiple characters, is listed in a separate entry as an **LED display**.

The term *OLED* is an acronym for *Organic Light-Emitting Diode*, a thin panel in which an organic compound is contained between two flat electrodes. Despite its functionality as a form of LED, its design is similar to that of thin-film electroluminiscent light sources. Therefore it is discussed in the entry on **electroluminescence**.

OTHER RELATED COMPONENTS

- **LED indicator** (see Chapter 22)
- **incandescent lamp** (see Chapter 18)
- **fluorescent light** (see Chapter 20)
- **neon bulb** (see Chapter 19)
- **electroluminescence** (see Chapter 26)

What It Does

High-brightness white LEDs provide a plug-compatible alternative to **incandescent lamps**, *halogen lighting*, and **fluorescent lights** for work spaces and the home.

At the time of writing, products are still evolving rapidly in the field of LED area lighting. A shared goal of manufacturers is to increase efficiency while reducing retail price to the point where high-brightness LEDs will displace fluorescent tubes for most low-cost lighting applications.

A wall-mounted LED reflector-bulb that emulates a halogen fixture is shown in Figure 23-1. A small LED floodlight for exterior use is shown in Figure 23-2. An early attempt to package an LED area light in a traditional-style bulb is shown in Figure 23-3. Within a decade, as LED area lighting continues to evolve, some of these examples may look quaint. Configurations are evolving, with final results that remain to be seen.

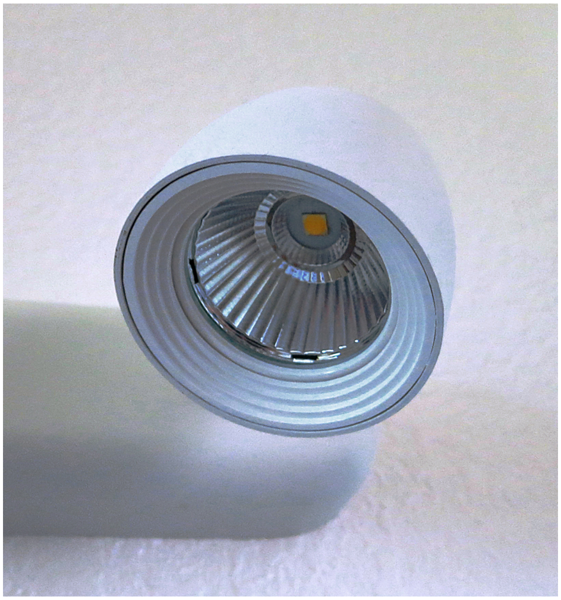

Figure 23-1. *A small LED reflector-light emulating a halogen fixture. Note the square of yellow phosphors mounted on the diode.*

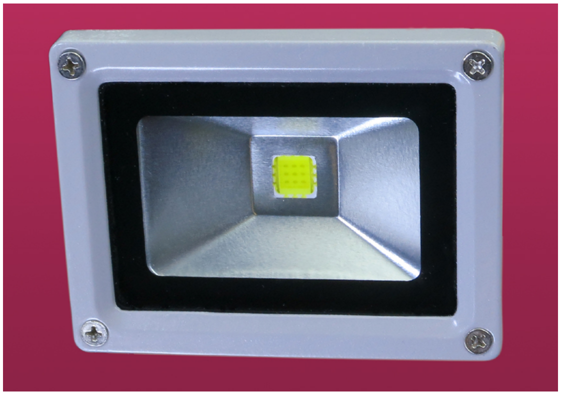

Figure 23-2. *A floodlight for exterior use. Nine LEDs are assembled behind the yellow phosphors. The steel frame measures about 4" by 3".*

Trends in Cost and Efficiency

The *luminous flux* of a source is the total power that it radiates in all directions, within the visible spectrum. The unit that measures luminous flux is the *lumen*. For a more detailed discussion of this topic, see "Power" on page 177. Since 1965, the cost per lumen of light from a given color of LED has decreased by about a factor of 10, while the maximum number of lumens emitted by an LED package has increased by a factor of 20, during each decade. This is known as Haitz's Law, named after Dr. Roland Haitz of Agilent Technologies. Figure 23-4 illustrates it graphically.

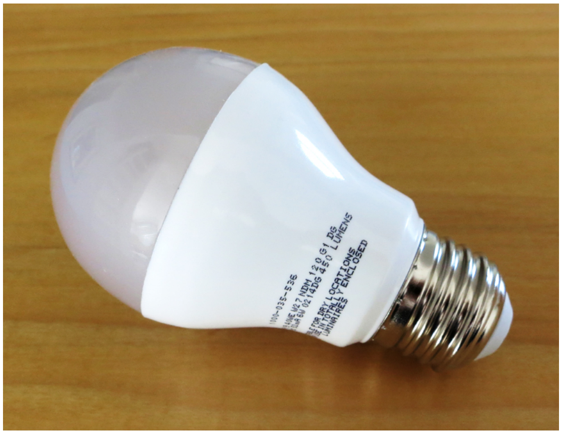

Figure 23-3. *An LED light bulb. Unlike an incandescent bulb, it focuses the illumination in one direction, like a reflector-light. Consuming only 6W, it is claimed to be equivalent to a 40W incandescent bulb.*

Schematic Symbol

Schematic symbols that are commonly used to represent an LED are shown in Figure 23-5. The symbol remains the same regardless of the size or power of the component, but architectural plans may represent any type of light using the circle-and-X symbol at bottom right.

How It Works

A high-brighteness LED functions on the same basis explained in the entry describing **LED indicators**. Photons are emitted when electrons are sufficiently energized to cross a PN junction and combine with electron-holes.

An LED that appears white, or off-white, actually emits blue light that is re-radiated over a wide range of wavelengths by adding a layer of yellow phosphors to the chip. A cutaway diagram of an

LED chip (properly known as a *die*), mounted under a silicone lens, is shown in Figure 23-6.

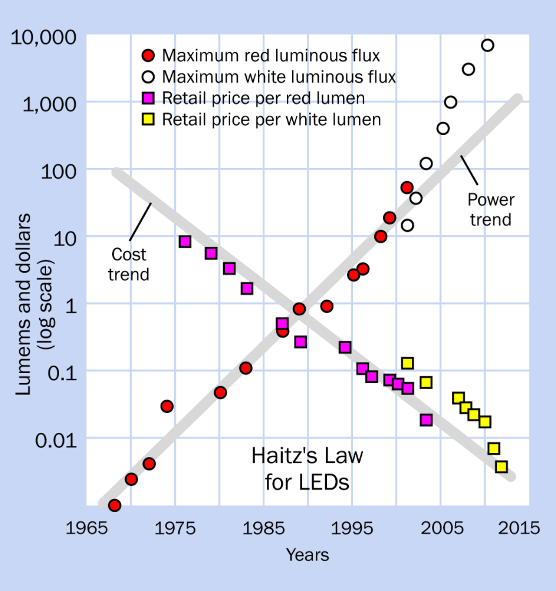

Figure 23-4. *The increase in light output (luminous flux, in lumens) of a single LED compared with the decrease in cost-per-lumen during the years since 1965. The vertical logarithmic scale measures both dollars and lumens. Source: Philips Gardco site-lighting fact sheet with additional data from a "Strategies in Light Report" published by Semiconductor Equipment and Materials International in 2013.*

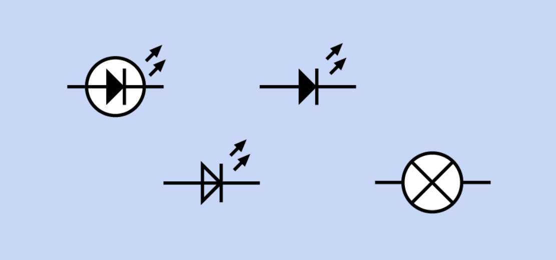

Figure 23-5. *The symbol for an LED remains the same regardless of its size and power, but architectural plans may use the circle-and-X symbol at bottom right for any type of light fixture.*

LEDs are mass-produced by etching them into crystals that are then cut into *wafers* before being subdivided into *dies*, like silicon chips. Most of the blue LEDs that form the basis of white lighting use sapphire crystals as their substrate. The crystal may range in diameter from two inches to six inches. Large sapphire wafers are also finding potential applications in camera lens covers and scratch-resistant cover plates for cellular phones.

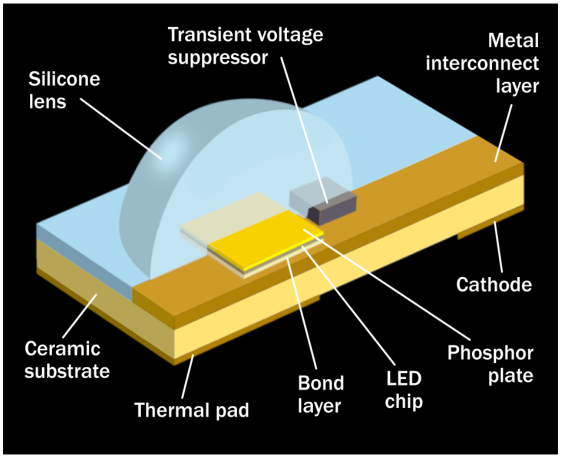

Figure 23-6. *Cutaway diagram of a high-brightness white LED. Adapted from Philips Lumileds Technical Reference document.*

While a die for an LED indicator may be 0.3mm x 0.3mm, a die in a high-brightness LED is often 1mm x 1mm. The size is limited by technical issues involving total internal reflection of the generated light.

The precise color of the light is adjusted by adding red phosphors to the yellow phosphors. This reduces the overall efficiency of the LED by around 10% but creates a "warmer" radiance. A graphical illustration of this principle is shown in Figure 22-3, in the entry on LED indicators.

The *color temperature* of white or offwhite light is measured in degrees Kelvin, typically ranging from 2,500K to 6,500K, where a lower number represents a light with more red in it and a higher number represents a light with more blue in it. This system of measurement was originally used with **incandescent bulbs** to define the temperature of the filament, which determined its color. See "Spectrum" on page 173 for a detailed explanation.

Visible Differences

The effects of different types of illumination are compared in Figure 23-7. To create this figure, first a color chart was prepared in Photoshop and printed on high-gloss photo-grade paper with a Canon Pro9000 Mark II inkjet printer, which has separate colors for red and green in addition to cyan, pale cyan, magenta, pale magenta, yellow, and black.

The color chart was then photographed twice with a Canon 5D Mark II, using a fixed white balance of 4000K. The first exposure was made with "daylight spectrum" LED lighting (claimed color temperature of 6500K) while the second was made with halogen lighting (claimed color temperature of 2900K). The photographs were adjusted in Photoshop for levels only, to fill the available range of 256 values. The two exposures show how the same chart would appear when viewed under the different lights, if the human eye did not adjust itself at all. Note the large area of the LED exposure which is rendered in shades of blue or purple. Also note the dullness of the reds. This confirms the everyday belief that "daylight spectrum" LEDs tend to have a cold, purplish cast while incandescents have a warmer, yellow look.

The same camera was then used to make two more exposures, this time with the white balance set to 6500 for LED lighting and 2900 for halogen lighting, which would be the recommended standard procedure, suggesting the kind of compensation that the human eye also tends to make for different ambient lighting. The result is shown at Figure 23-8. The LED version has improved, but the reds and yellows are still muted. The halogen version also looks better than before, but the magenta end of the spectrum has too much yellow in it. These images show the limits of white-balance correction for indoor photography.

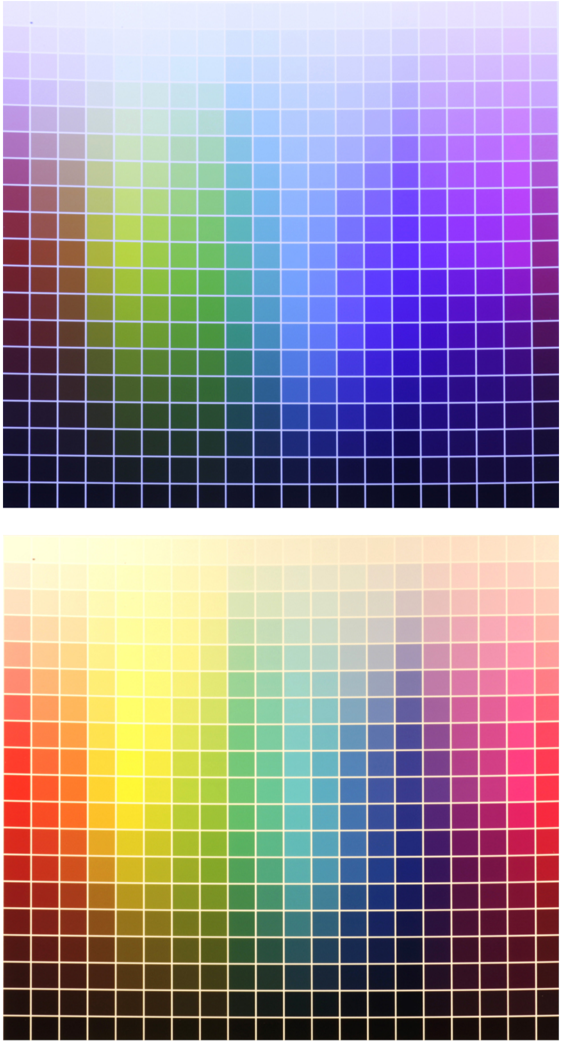

Figure 23-7. *The same printed color chart viewed with "daylight white" LEDs (top) and halogen lighting (bottom), without any compensation to allow for the different light spectra. A fixed white balance of 4000K was used for both pictures.*

Side-by-Side Comparison

Because the human eye is much better at comparing colors when they are adjacent to each other, another color chart was prepared using just six color bars of fully saturated red, yellow, green, cyan, blue, and magenta, with paler and darker versions above and below. The bars were separated with large white gaps. The chart was photographed first with the white balance set to

6500 under "daylight white" LED lighting and then again with the white balance at 2900 for halogen lighting. In Photoshop, the bars from the halogen version were copied and pasted beside the bars from the LED version to facilitate an A-B comparison. The result is shown in Figure 23-9.

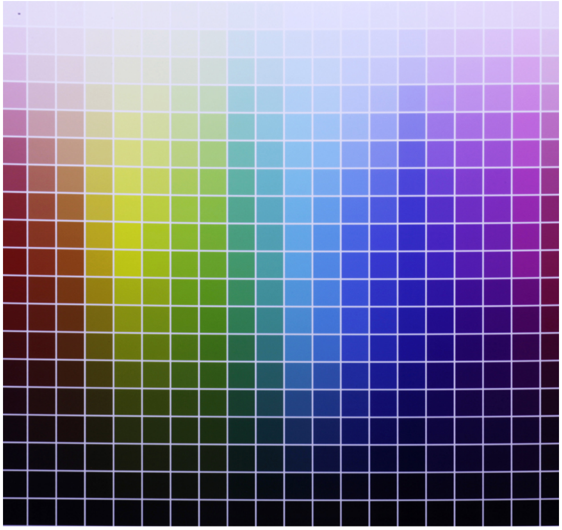

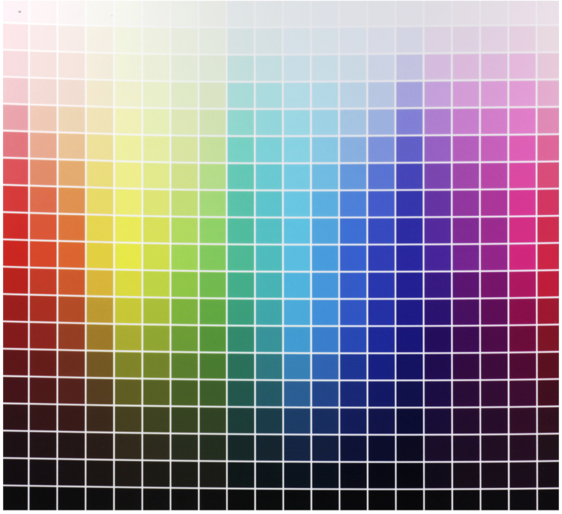

Figure 23-8. *The same color chart as before, photographed with appropriate color temperature settings of 6500K (top, using "daylight-spectrum" LEDs) and 2900K (bottom, using halogen).*

In each pair of colors, LEDs lit the one on the left, and halogen lights lit the one on the right. This figure shows the dramatic difference at the red end of the spectrum, and the poor reproduction of yellows by LED lighting. However, the LED rendering of green is better, and likewise the rendering of magenta, except where its darker version is concerned. Among the pale versions of the colors, the LED lights produce much less density (i.e., they have a brighter look) in the blues, greens, and cyans. The low densities will show up as pale highlights in a photograph of an object, and the picture will tend to have excessive contrast. This will also contribute to the "harsh" look of "daylight white" LED lighting which may be perceived by the eye.

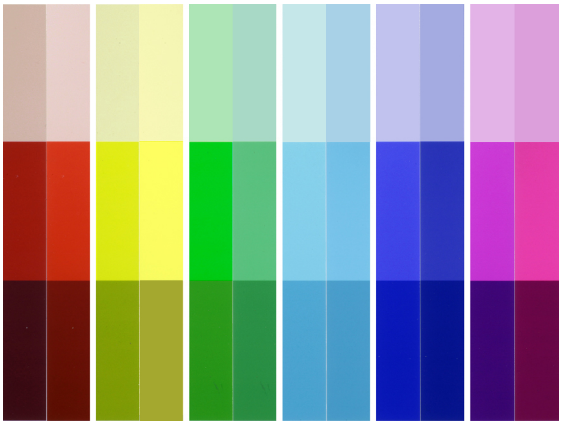

Figure 23-9. *A range of six fully saturated colors, with lighter and darker shades added above and below, photographed first with "daylight spectrum" LEDs and then with halogen lights, after which the two sets of colors were paired for easy comparison. The LED version is on the left in each pair.*

Halogen is deficient at the blue-violet end of the spectrum, even when the camera has an appropriate white-balance setting. Photographers can correct this using image-editing software. LED "daylight spectrum" lights are more difficult to correct. LEDs classified as "warm" should reproduce reds better, but may not do so well with blues.

Diffuse light from a uniformly cloudy sky may be the most ideal form of lighting for photographing objects, but this is of little help for people who work (or take photographs) under artificial lights.

LED lights that contain separate red, green, and blue emitters may perform better, but create a different problem, in that shadows will tend to have color fringes caused by the small offsets between the colored emitters.

Heat Dissipation

An LED is less than 100% efficient because not all electrons mate with electron holes. Some manage to bypass the semiconductor junction; some recombine without generating light; and some transfer their energy to other atoms. In each instance, waste heat is created. While the heat in an incandescent bulb is mostly dissipated by radiation, an LED must get rid of the heat almost entirely by conduction, typically through a *heat sink*. This complicates the design of a fixture, because the integrity of the pathway to dispose of the heat must be retained when the LED bulb or tube is replaced.

Efficacy

The *radiant luminous efficacy* (LER) of an incandescent light source measures how effective it is at channeling its output within the visible spectrum instead of wasting it in infrared radiation. LER is expressed in lumens per watt, and in an incandescent bulb, it is calculated by dividing the power emitted in the visible spectrum (the *luminous flux*) by the power emitted over all wavelengths. This is described in detail in "Efficacy" on page 179 in the entry dealing with incandescent lamps.

In an LED indicator, almost all the radiation can be contained within the visible spectrum, which suggests that its efficacy should be 100%. However, because some waste heat is still created internally, the efficacy is calculated by dividing the light output, in lumens, by the power input, in watts, at the voltage required by the LED. (Lumens can be converted directly to watts, and therefore this division makes a comparison between similar units).

In an LED lighting fixture that contains its own electronics to convert higher voltage AC to lower voltage DC, the power consumption of the fixture is measured not at the diode, but at the input side of the electronics. Therefore, the inefficiency of the electronics reduces the efficacy value of the lighting unit.

Dimming

An incandescent bulb is very sensitive to reduction in power. It becomes radically inefficient, emitting perhaps 1% of its normal light output if the power is reduced to 40%.

LEDs have an almost linear response to the supplied power. Usually a triac-based dimmer will not work well with LED area lighting, and a dimmer designed for LEDs must be substituted, using pulse-width modulation.

Ultraviolet Output

The gas plasma in a fluorescent light generates ultraviolet wavelengths that are shifted to the visible spectrum by the phosphor coating inside the glass envelope. Imperfections in the phosphor coating can potentially allow leakage of ultraviolet light, causing some researchers to claim that the use of CFLs (compact fluorescent lighting) for close-up work with desk lamps can increase the risk of developing some forms of skin cancer. (This claim remains controversial.)

LED manufacturers are quick to point out that white LEDs do not emit any ultraviolet radiation. Figure 23-10 shows spectral power distribution curves derived from measurements of three high-brightness Color Kinetics LEDs manufactured by Philips. The manufacturer states categorically that "The LED-based color and white light products made by Color Kinetics do not emit outside the visible spectrum." Infrared radiation is also negligible.

Color Variation

The *correlated color temperature* (CCT) is determined by finding the conventional incandescent color temperature which looks most similar to the light from a white LED. Unfortunately, because the CCT standard is insufficiently precise, and because small manufacturing inaccuracies can occur, two LED sources with the same CCT number may still appear different when they are side by side. While the human eye adjusts itself to overall color temperature, it is sensitive to differences between adjacent sources. If two or more white LEDs in a lighting fixture do not have identical spectra, the difference will be noticeable.

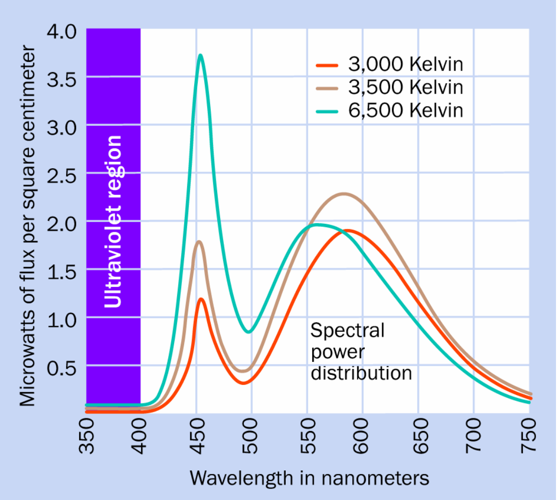

Figure 23-10. *Spectral power distribution curves for three high-brightness white LED lamps showing no ultraviolet emissions. (Adapted from a graph in a white paper published by Color Kinetics Incorporated.)*

To address the issue, manufacturers introduced the concept of "binning," in which lights are subclassified to tighter specifications and are assigned bin numbers based on their measured characteristics. The Philips Optibin system, for instance, assesses the light from various angles, as well as perpendicularly to the source. This is especially important where a large area such as a building lobby is painted white and is lit by high-brightness LEDs that must appear uniform in color temperature.

Variants

LED area lighting products are often designed to emulate the form factors of incandescent bulbs, halogen reflector bulbs, or fluorescent tubes. The standard screw-in base of an LED light bulb, the pin-base of a miniature 12V LED reflector bulb, and the pins on an LED tube enable easy migration to the newer technology.

Strip lights are unique to LED lighting systems. They are thick, flexible plastic ribbons in which are embedded a series of LEDs. For area lighting, the LEDs are white, and the strips can contain necessary control electronics for conversion of AC power. The strips can be placed behind ledges or moldings to provide soft, even illumination of the ceiling above.

Strip lights are also available for 12VDC power, to create lighting effects in customized automobiles and trucks. These strip lights are available in various colors in addition to white. Many have multicolor capability and can be controlled with a handheld remote.

Comparisons

The advantages of an **incandescent lamp** are listed in "Relative Advantages" on page 179, while advantages of **fluorescent lights** are listed in "Comparisons" on page 194. These lists can be compared with the following advantages for LED area lighting:

- While the life of an incandescent lamp for room lighting can be as little as 1,000 hours, LED area lighting typically claims up to 50,000 hours.
- The lifetime of an incandescent bulb is the average time it can emit light before catastrophic failure. The lifetime of an LED is the average time it can emit light before gradually dimming to 70% of its rated output. This is a much gentler, less inconvenient failure mode that does not require immediate replacement.
- Unlike a fluorescent light or incandescent bulb, the LED does not contain hot tungsten that fails as a result of erosion.

- Unlike a fluorescent light, an LED does not contain mercury, and therefore does not require special recycling arrangements that entail associated fees.
- While fluorescents can have difficulty starting in low temperatures, an LED is not sensitive to a cold environment.
- Bright LEDs are available in a wide range of colors that do not require filtering. Filters greatly reduce the efficiency of incandescent bulbs when they are used in applications such as traffic signals or rear lights on automobiles.
- High-brightness LEDs can be dimmable. Fluorescent lights are usually not dimmable, or perform poorly in this role.
- LEDs are inherently directional, because the die radiates light at an angle of 90 degrees to its plane. This makes it ideal for ceiling mounting, where as much light as possible should be directed downward. A fluorescent tube or incandescent bulb often requires a reflector which reduces the overall efficiency.
- LEDs are insensitive to cycling. The life expectancy of an incandescent bulb or (especially) a fluorescent tube is reduced by cycling it on and off.
- No flickering. Fluorescent tubes may start to flicker as they age.
- No electrical interference. Fluorescent tubes can interfere with AM radio reception and some audio devices.
- Safe from breakage. LED area lighting does not necessarily use any glass.

However, high-brightness LEDs still have some barriers to overcome:

- Cost. In the United States, before 60W incandescent bulbs were legislated out of existence, they could be sold profitably for less than $1 each. A T8 fluorescent tube, measuring 1” diameter and 48” long, currently costs between $5 and $6 (retail) but has a life expectancy in the region of 25,000 hours, and uses only 20% of the power of an incandescent bulb to generate two to three times as much light. Clearly the fluorescent tube is a more economical choice, despite the price of the electronics that must be included in the fixture to start the tube. By comparison, currently the purchase price of an LED tube is three times that of a fluorescent tube. It may last twice as long, but is not significantly more efficient, generating perhaps 100 lumens per watt while a fluorescent is typically capable of 90 lumens per watt. Prototype high-brightness LEDs have exceeded 200 lumens per watt, and should be competitive with fluorescents by 2020, but even then, migration will take time.
- Heat sensitivity. Heat reduces the light output and the lifespan of LED fixtures.
- Placement issues. Because LEDs are heat sensitive, they must be installed in locations that do not become excessively hot, their heat sinks must be correctly oriented, and they must have adequate ventilation.
- Color shift. Heat and age may cause the color temperature of an LED to shift slightly, as the color is usually derived from two types of phosphors.
- Nonuniformity. Manufacturing inconsistencies can cause LEDs of the same type to display slightly different color temperatures. Fluorescents and incandescents are more uniform.
- Lower heat output than incandescents. While this is an advantage from the point of view of efficiency, it can be a disadvantage in applications such as traffic signals or airport runway lighting where waste heat can help to keep the lights free from snow or ice.

Values

Although the output from an LED area light is directional, while the output from an incandescent bulb or a fluorescent light is omnidirectional, the intensity is measured the same way in each instance, using *lumens*. This unit expresses the total light emission, without taking directionality into account. (The intensity of **LED indicators** is calibrated in candelas, which measure the power within an angle of dispersion; but candelas are not used for area lighting.)

Typical values for incandescent bulbs are 450 lumens for a power consumption of 40 watts, 800 lumens for a consumption of 60 watts, 1,100 lumens for a consumption of 75 watts, and 1,600 lumens for a consumption of 100 watts. Because much of the output from an incandescent bulb may be wasted by using inefficient reflectors or allowing the light to shine in directions where it is not needed, a high-brightness LED rated at 1,000 lumens may actually appear brighter than a 75-watt incandescent bulb.

A T8 fluorescent tube measuring 48″ long by 1″ in diameter consumes only 32 watts but emits almost 3,000 lumens—when it is new. This output gradually diminishes by as much as 40% over the lifetime of the tube.

Incandescent bulbs deliver between 10 and 15 lumens per watt, approximately. A new fluorescent tube produces around 80 to 90 lumens per watt, and LED area lighting at the time of writing can provide 100 lumens per watt, under real-world conditions.

What Can Go Wrong

Wrong Voltage

Many high-brightness LED lighting units can be used with either 115VAC or 230VAC. There are exceptions, however. Check the specifications to make sure. Also, it is important to avoid applying domestic supply voltage to 12V LED miniature reflector-bulbs that are intended to replace 12VAC halogen bulbs of the same size.

Overheating

If a high-brightness LED fixture is equipped with a heat sink, this must be exposed to freely flowing air. Any vanes on the heat sink should be oriented vertically to encourage convection, and the fixture must not be placed in an enclosure. Overheating will radically shorten LED life.

Fluorescent Ballast Issues

A fluorescent fixture contains a *ballast* to limit the tendency of the tube to draw excessive current. The ballast is contained in a plastic box attached to the back of the frame in which the tube is mounted.

A *magnetic ballast* contains a coil, and is bypassed by an additional *starter* that applies unlimited current for one second when the power is switched on, preheating the tube to initiate plasma discharge.

An *electronic ballast* performs the same function without a separate starter.

Some LED tubes designed as substitutes for fluorescent tubes may allow a magnetic ballast to remain in the circuit, but may not tolerate an electronic ballast. Other LED tubes require any type of ballast to be unwired from the circuit. The unwiring operation will require disconnection of a couple of wires by removing wire nuts (assuming that the fixture has been designed to comply with U.S. building codes). The wires are then reconnected to apply power directly to the tube, and the wire nuts are reapplied to complete the new connection. The ballast can remain passively in the fixture.

Failing to remove the ballast and/or the starter from a fluorescent fixture before installing an LED tube that requires direct connection to the power supply can damage the tube. Connecting the power incorrectly to the LED tube may result in it failing to light up. Documentation supplied with the LED tube should provide guidance for disconnecting the ballast and connecting the tube. Note that the pin functions on LED tubes are not standardized at this time.

Misleading Color Representation

Because the spectrum of a white LED is not evenly weighted across all wavelengths, it will fail to represent some colors accurately, as shown previously. This can be important if LEDs are used to illuminate full-color printing or artwork, or if they are installed in stores selling merchandise such as clothes, furnishings, or food.

LED display

24

In this encyclopedia, a component consisting of multiple separately discernible light-emitting diodes, such as a seven-segment numeral, 14- or 16-segment alphanumeric character, a dot-matrix character, or a display module containing multiple characters, is categorized as an **LED display**. The term *light-emitting diode* is hardly ever used to describe an LED display, as the LED acronym has become ubiquitous. The acronym does not usually include periods between the letters.

An **LED indicator** is defined here as a component usually 5mm or smaller in diameter, made of transparent or translucent epoxy or silicone, most often containing one *light-emitting diode*. It is purposed as a status indicator in a device, rather than as a source of illumination, and is sometimes referred to as a *standard LED.*

LEDs that are designed to illuminate large living or working areas are discussed in a separate entry as **LED area lighting**. They are sometimes referred to as *high-brightness LEDs* and almost always emit white light.

The term *OLED* is an acronym for *Organic Light-Emitting Diode*, a thin panel in which an organic compound is contained between two flat electrodes. Despite its functionality as a form of LED, its design is similar to that of thin-film electroluminiscent light sources. Therefore it is discussed in the entry on **electroluminescence**.

OTHER RELATED COMPONENTS

- **LED indicator** (see Chapter 22)
- **LED area lighting** (see Chapter 23)
- **vacuum-fluorescent** (see Chapter 25)
- **electroluminescence** (see Chapter 26)
- **LCD** (see Chapter 17)

What It Does

An LED display presents information on a panel or screen by using multiple segments that emit light in response to a DC current, almost always at a voltage ranging between 2VDC and 5VDC. The display may contain alphanumeric characters and/or symbols; simple geometrical shapes; dots; or pixels that constitute a *bitmap*.

A *liquid-crystal display*, or **LCD**, serves the same purpose as an LED display and may appear very similar, except that a liquid crystal reflects incident light while an LED emits light. The increasing use of backlighting with LCDs has made them appear more similar to LED displays.

There is no schematic symbol to represent an LED display. Where a segmented display is used, often the segments are represented with drawn outlines.

The simplest, most basic, and probably the best-known example of an LED display is the *seven-*

segment numeral, one of which is shown in Figure 24-1. This is a Kingbright HDSP-313E with a character height of 0.4".

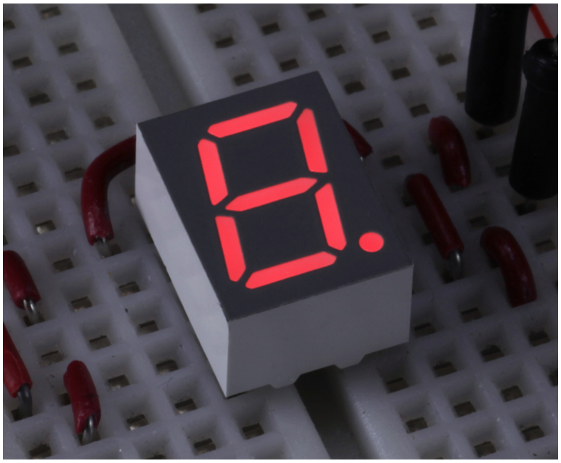

Figure 24-1. *The most basic LED display, able to create numerals from 0 through 9 using seven light-emitting segments that can be illuminated individually. An eighth segment forms the decimal point.*

How It Works

The process by which an LED generates light is explained in "How It Works" on page 207, in the entry dealing with **LED indicators**. Each light-emitting diode in an LED display is functionally the same as the diode in an LED indicator.

LEDs must be driven with DC. This is a primary distinction between an LED display and an LCD, which requires AC.

Variants

LCD comparisons

LCDs and LED displays can look very similar. This raises the obvious question: which is appropriate for a particular application?

LCDs (without backlighting) are more appropriate for applications such as digital watches and solar-powered calculators where power consumption must be minimized. They are capable of running for years from a single button cell. LCDs are easily visible in bright ambient light, where LED displays are not. LCDs can also be designed to display complex pictographic shapes and symbols, while the segments of an LED display are more constrained to be simple in shape.

An LCD is more likely to be affected by temperature than an LED, and powering it entails some slight inconvenience, because it requires an AC source that is unlikely to be useful elsewhere in a circuit. If the LCD uses LED backlighting, it will also require a low-voltage DC power source for the backlight. An LED display is easier to use in that it can be driven directly from a microcontroller or logic chip, with only some series resistors to limit the current, and the addition of transistors to provide additional power where necessary.

Seven-Segment Displays

Early seven-segment LED displays were used in digital calculators, before LCDs became an affordable, practical alternative that greatly extended battery life. Initially, the size of the diodes was limited, sometimes requiring magnifying lenses to make them legible.

Seven-segment displays are still used in some low-cost applications, although LCDs have become more common.

Figure 24-2 shows how the segments are identified with letters *a* through *g*. This scheme is used universally in datasheets, and is also used for LCDs. The decimal point, customarily referred to as "dp," is omitted from some displays. The segments are slanted forward to enable more acceptable reproduction of the diagonal stroke in numeral 7.

Although seven-segment displays are not elegant in appearance, they are functional and are reasonably easy to read. They also enable the representation of hexadecimal numbers using letters A, B, C, D, E, and F (displayed as A, b, c, d, E, F because of the restrictions imposed by the small number of segments), as shown in Figure 24-3.

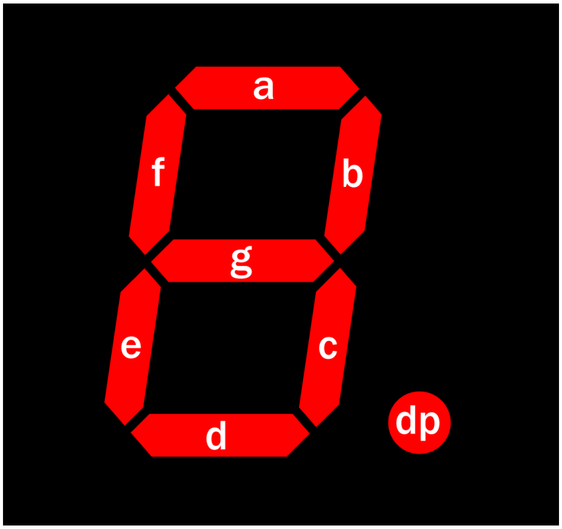

Figure 24-2. *A seven-segment LED display. The lowercase identifying letters are universally used in datasheets.*

In appliances such as microwave ovens, very basic text messages can be displayed to the user within the limitations of seven-segment displays, as suggested in Figure 24-4.

Numbers 0, 1, and 5 cannot be distinguished from letters O, I, and S, while letters containing diagonal strokes, such as K, M, N, V, W, X, and Z, cannot be displayed at all.

Multiple Numerals

Displays consisting of a single numeral are now rare, as few applications require only one digit. Displays of two, three, and four digits are more common, as shown in Figure 24-5.

Additional Segments

Displays with 14 or 16 segments were introduced in an effort to enable the representation of all the letters of the alphabet. The segment layout of these LED displays is identical to that of comparable LCDs. The differences between 14-segment and 16-segment displays are shown in Figure 24-6. Some are angled forward like seven-segment displays, even though the addition of diagonal segments makes this unnecessary for display of characters such as numeral 7.

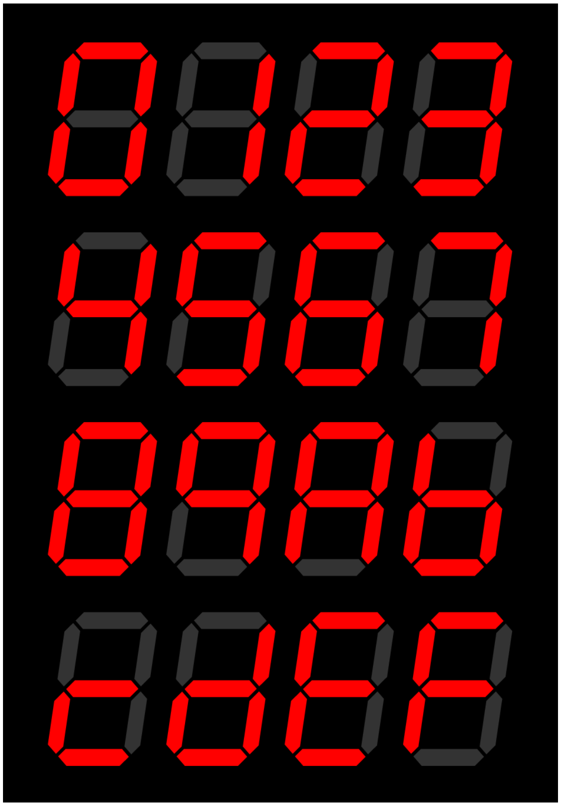

Figure 24-3. *Numerals and the first six letters of the alphabet created with seven-segment displays.*

Figure 24-7 shows the scheme for identifying the segments of a 16-segment display. This naming convention is used in all datasheets. The lowercase letters that were customary with seven-segment displays are usually abandoned in favor of uppercase, perhaps to avoid confusion with the letter L. Note that letter I is omitted from the sequence.

For a complete alphanumeric character set enabled by a 16-segment display, see Figure 17-9 in the entry discussing LCDs.

An example of a 16-segment alphanumeric LED display is shown in Figure 24-8, mounted on a breadboard and wired to show the letter N. This is a Lumex LDS-F8002RI with a character height of 0.8″. The component is still available at the time of writing, but in limited quantities.

Generally speaking, 16-segment displays were never very popular, because the gaps between adjacent segments impaired legibility. LED versions remain more readily available than LCD versions, but dot-matrix displays allow a better-looking, more easily legible alphabet, with the added possibility of simple graphics.

Dot-Matrix Displays

In the 1980s, some personal computers used a video character set in which each letter, numeral, punctuation mark, and special character was formed on a video screen from a fixed-size matrix of dots. A similar alphabet is now used in LED dot-matrix displays (and LCDs, as shown in Figure 17-10).

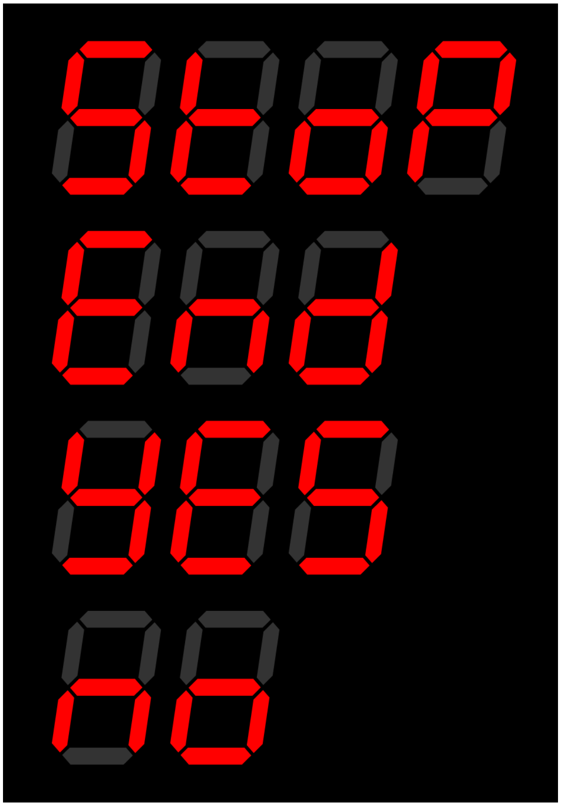

Figure 24-4. *Basic text messages can be generated with seven-segment displays, although they cannot represent alphabetical letters containing diagonal strokes.*

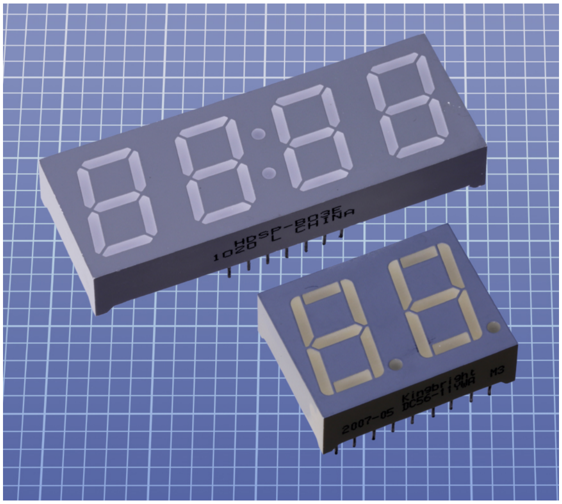

Figure 24-5. *Multiple seven-segment LED displays are often combined in a single component. Top: An Avago 2.05VDC 20mA display designed for a clock. Bottom: A Kingbright two-digit display which draws 20mA at 2.1VDC. The unlit outlines of the numerals would normally be hidden behind panels that are tinted to the same colors emitted by the LED segments when lit.*

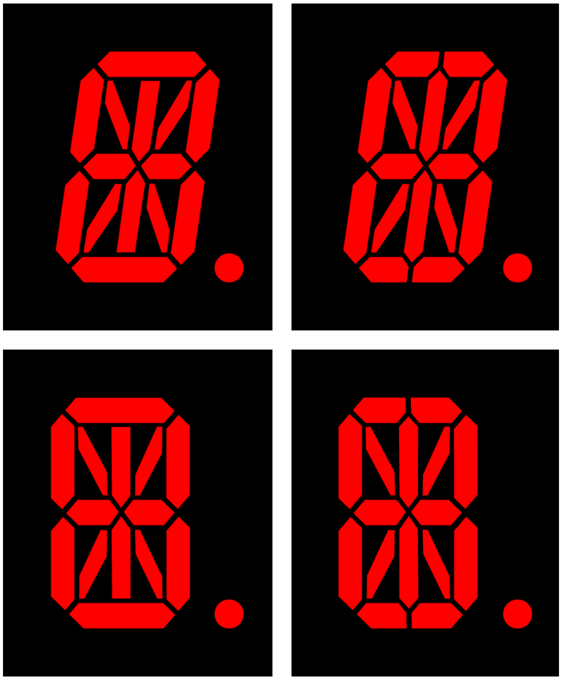

Figure 24-6. *Layouts for 14-segment and 16-segment alphanumeric LEDs are identical to those of LCDs.*

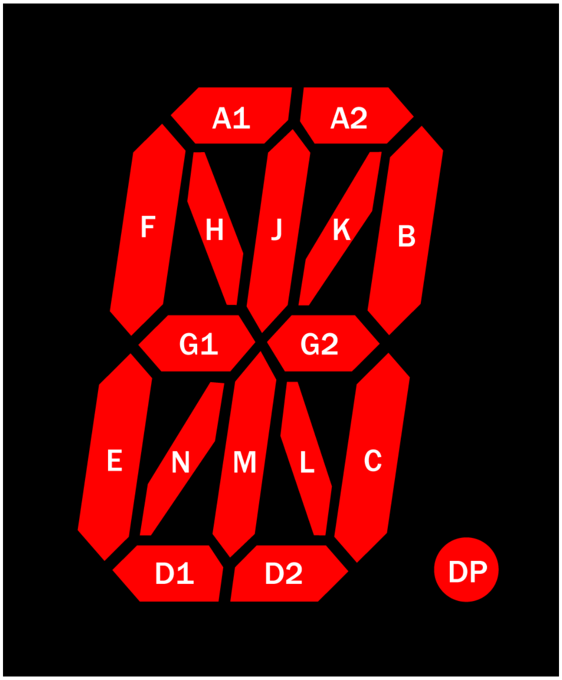

Figure 24-7. *The scheme for identification of segments in a 16-segment alphanumeric LED display.*

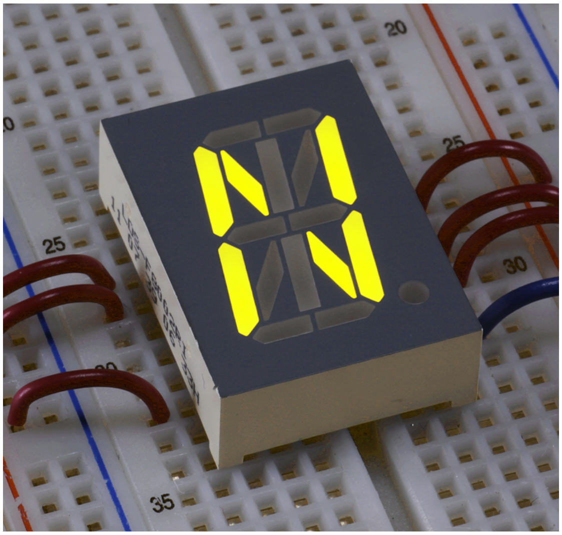

Figure 24-8. *A 16-segment alphanumeric LED display showing the letter N.*

Alphanumeric dot-matrix characters are often grouped in two or more rows with eight or more characters per row. The number of characters is always listed before the number of rows, so that an 8x2 display would contain eight alphanumeric characters in two horizontal rows. This type of component is properly described as a *display module*.

Display modules are used in consumer electronics products such as a stereo receiver where simple status messages and prompts are necessary —for example, to show the tone control settings or the frequency of a radio station. Because the cost of small, full-color, high-resolution LCD screens has been driven down rapidly by the mass production of cellular phones, and because these high-resolution screens are much more versatile, they have already displaced dot-matrix display modules in many automobiles and are likely to follow a similar path in other devices.

Pixel Arrays

The 8x8 pixel array of LED dots shown in Figure 24-9 measures 60mm square (slightly more than 2") and contains 64 LEDs, each approximately 5mm in diameter. Similar arrays are available in other sizes and with different numbers of dots. Displays of the same type may be assembled edge-to-edge to enable scrolling text or simple graphics.

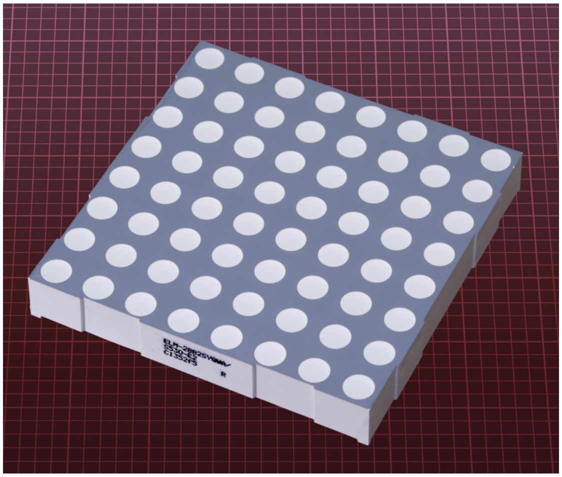

Figure 24-9. *An 8x8 matrix of LED dots measuring more than two inches square.*

Multiple Bar Display

A bar display is a row of small rectangular LEDs in a single component. It may be used for digital representation of an analog signal. The higher the voltage of the signal, the more bars will be illuminated. A typical application would be to show the signal strength of an input to an audio recorder. Ten bars are often used, as in the display shown in Figure 24-10, but multiple components can be combined end to end.

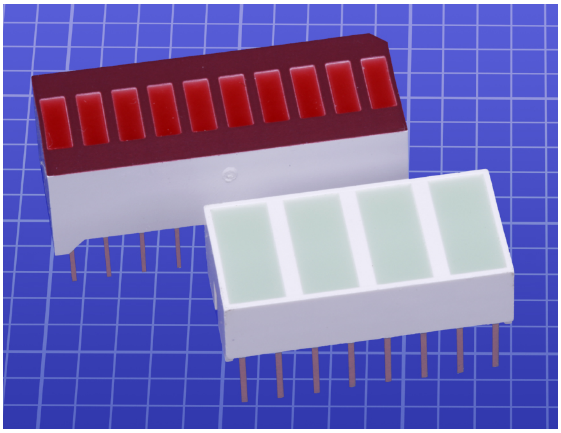

Figure 24-10. *Two LED bar displays in which segments can be lit individually.*

Single Light Bar

A light bar can be thought of as a single-source LED, as it is configured as a single square or rectangle. It is mentioned here, rather than in the entry for single-source LED indicators, because variants may be subdivided into two, three, four, or (sometimes) more discrete sections. These variants are often included in the same datasheet as the monolithic version.

A light bar contains multiple LEDs (often, four in number) behind a translucent panel that provides evenly diffused radiance.

Values

The values for most LED displays are basically the same as for LED indicators, in terms of color, brightness, current consumption, and voltage. See "Values" on page 211 for information.

Multiple-character dot-matrix LED display modules may have different requirements for forward voltage and forward current, depending on drivers that are incorporated in the module. Because there is no standardization for these modules, it will be necessary to consult the manufacturer's datasheet.

How to Use It

Seven-Segment Basics

The diodes in a seven-segment LED display share either a *common anode* or a *common cathode*, the latter being more frequently used. The two types of internal wiring are provided for convenience only. Externally, the displays function identically.

A schematic suggesting the internal wiring and pinouts of a typical ten-pin common-cathode display is shown in Figure 24-11. The pins are numbered as seen from above. Appended to each number is the identity of the segment to which it is connected. Pins 3 and 8 are connected with the cathodes of all the internal LEDs. Both of these pins should be used, to serve as heat sinks for the display.

Note that series resistors are not included inside the display and must be added externally. Their value will be determined by the power supply, to limit the forward current and forward voltage through the LEDs to the extent specified by the manufacturer.

An encapsulated *resistor array* containing either seven or eight resistors in an SIP or DIP chip can be used instead of individual resistors. A seven-segment LED display would require the type of resistor array in which both ends of each resistor are accessible.

Where two or more numerals are combined in a single component, this type of display is likely to have two horizontal lines of pins. In this case, pin 1 will be at the bottom-left corner, seen from above. As always, the pins are numbered counterclockwise, seen from above.

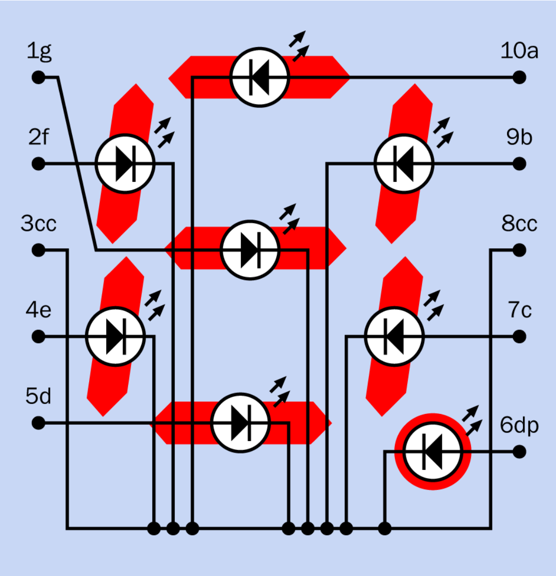
1g
10a
2f
9b
3cc
8cc
4e
7c
5d
6dp

Figure 24-11. *A schematic view of internal connections and pinouts of a seven-segment common-cathode LED display. The numbers refer to the pins of the component, seen from above. The 1 pin may also have a mark beside it on the component, for identification. The orientation of the display can be deduced if there is a decimal point, as this should be at the bottom-right corner.*

Where three or more numerals are combined in a single component, the pinouts may be designed for multiplexing rather than individual access to every segment of each numeral. A four-digit clock display, for instance, may have seven pins that connect in parallel to respective segments in all of the numerals, and four additional pins that can ground each numeral in turn, so that they can be selected sequentially.

Driver Chips and Multiplexing

Illuminating the appropriate segments in a single numeral can be done directly from a microcontroller, or through a driver chip such as the well-known and widely used 4543B that converts a binary-coded decimal input into appropriate segment output patterns. The chip can source sufficient current to drive each segment through a series resistor. Its pinouts are shown at Figure 24-12.

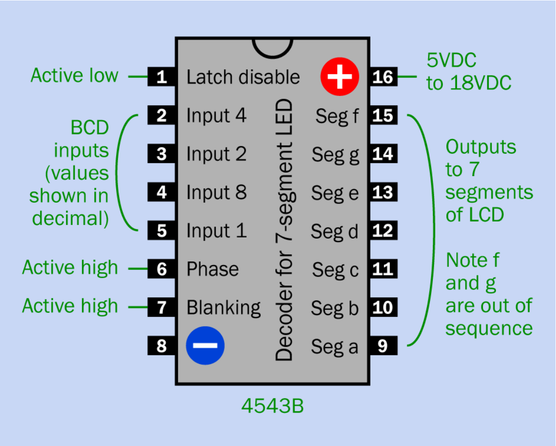
Active low
1
Latch disable
16
5VDC
to 18VDC
BCD
inputs
(values
shown in
decimal)
2
Input 4
3
Input 2
4
Input 8
5
Input 1
Decoder for 7-segment LED
Seg f
15
Seg g
14
Seg e
13
Seg d
12
Outputs
to 7
segments
of LCD
Active high
6
Phase
Seg c
11
Active high
7
Blanking
Seg b
10
Note f
and g
are out of
sequence
8
Seg a
9
4543B

Figure 24-12. *Pinouts of the 4543B seven-segment LED driver chip.*

When used in conjunction with a microcontroller, the 4543B can drive several seven-segment displays by multiplexing them. The basic schematic to achieve this is shown in Figure 24-13, omitting optional features such as leading-zero blanking or connections for a decimal point. The microcontroller sends the binary code for the first numeral and simultaneously grounds the common cathode of that numeral through a transistor, which is needed because as many as seven segments of the numeral may be passing current in parallel. The microcontroller then sends the binary code for the second numeral, and grounds it; then sends the binary code for the third numeral, and grounds it; and the cycle repeats. So long as this process is performed at sufficient speed (at least 50Hz), persistence of vision will create the illusion that all the numerals are active simultaneously. The circuit can be compared with a similar circuit to drive LCDs, shown in Figure 17-17.

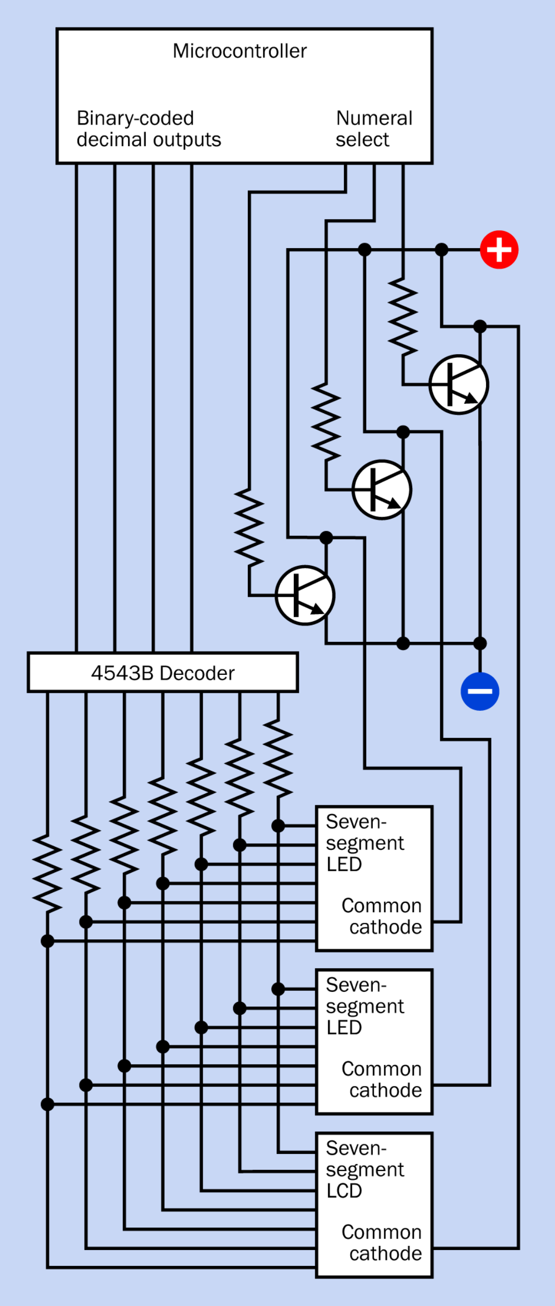

Figure 24-13. *A basic, simplified circuit for driving multiple seven-segment LED displays by multiplexing them.*

The disadvantage of this system is that the microcontroller must update the numerals constantly while performing other duties. To reduce this burden, a "smarter" driver such as the MC14489 can be used, controlling up to five 7-segment digits, or the Intersil ICM7218, which can control up to eight 7-segment digits.

The MC14489 controller receives data serially, using SPI protocol, and handles the details of addressing the LEDs. Because it contains latches to sustain the displayed data, a microcontroller only needs to communicate with the driver when the displayed information needs to be updated.

The ICM7218 is a more sophisticated chip, available in several variants, one of which can receive data on an 8-bit bus and run the seven-segment displays in hexadecimal mode.

Sixteen-Segment Driver Chip

The MAX6954 by Maxim can drive up to eight 16-segment alphanumeric LED displays using a scheme known as Charlieplexing, named after a Maxim employee named Charlie Allen who came up with the concept as a way of reducing the pin count required for multiplexing. Other Maxim controllers use this same protocol, which is transparent to the user.

A microcontroller sends data serially via I2C protocol to the MAX6954, which contains a variety of features. It can drive 14-segment and 7-segment displays as well as 16-segment displays, and contains a 104-character alphabet for each of them. Setting up a microcontroller to send the various necessary command codes to the MAX6954 is not a trivial matter, and bearing in mind the probably impending end-of-life of 16-segment displays, a better option may be to use dot-matrix LED display modules that have controller logic built in.

Dot-Matrix LED Display Modules

A dot-matrix LED display module requires data to define a character set, and a command interpreter to process instructions that will be embedded in a serial data stream. These capabilities are provided either by separate chips or (more often) are incorporated into the LED display module itself.

The SSD1306 is a monochrome graphical controller capable of I2C or SPI serial communication, or parallel communication. When this capability is built into a display module, only one of these types of communication may be activated.

The SSD1331 is a color graphical controller with similar communication capabilities.

The WS0010 is a monochrome controller, compatible with HD44780, which is designed to control LCDs.

Typical controller functions are summarized in "Alphanumeric Display Module" on page 168. Because there is no standardization in this field, precise details must be found in manufacturers' datasheets.

Pixel Arrays

The connections inside an 8x8 pixel array are shown in Figure 24-14, where the schematic symbols for LEDs have been replaced by gray circles for space reasons. To illuminate one LED, power is supplied to the intersection where it resides. In the figure, each vertical conductor (identified as A1, A2 . . . A8) can power the anodes of a column of eight LEDs, while each horizontal conductor (identified as C1, C2 . . . C8) can ground the cathodes of a row of eight LEDs. If only one vertical conductor is connected with positive power while one horizontal conductor is grounded, only one LED will light up, at the intersection of the active conductors.

A problem occurs if we wish to illuminate two LEDs. Suppose they are located at (A3,C2) and (A6,C5). Unfortunately, providing power to them will also result in activating LEDs at (A3,C5) and (A6,C2), as shown in Figure 24-15, where the yellow circles represent LEDs that have been switched on.

The answer to this problem is to rasterize the process. In other words, data is supplied on the array one line at a time, as in the process by which a TV picture is generated. If this is done quickly enough, persistence of vision will create the illusion that the LEDs are illuminated simultaneously.

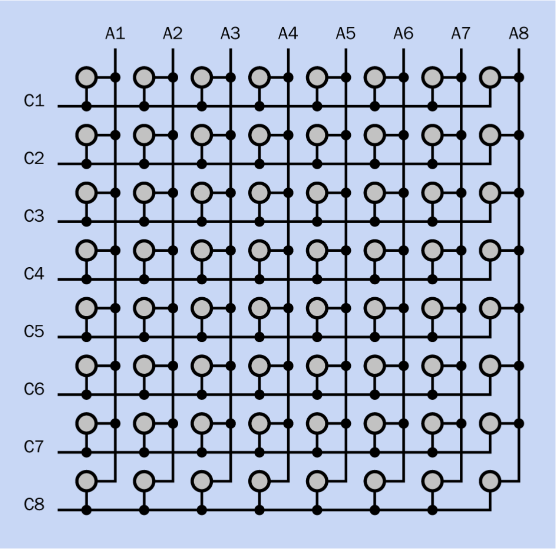

Figure 24-14. *Internal connections in the 8x8 matrix. Each gray circle represents an LED.*

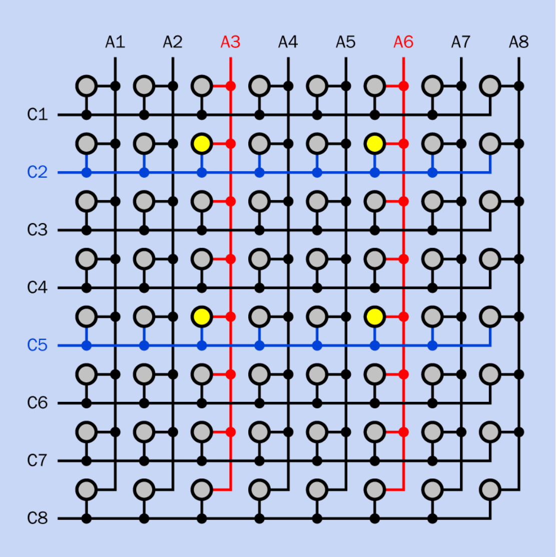

Figure 24-15. *An attempt to illuminate LEDs at (A3,C2) and (A6,C5) will also activate the LEDs at (A3,C5) and (A6,C2).*

A form of multiplexing is used to achieve this. One row of LEDs is connected to negative ground for a brief interval. During this interval, the anodes of selected LEDs are powered momentarily. Then the next row is grounded, and selected LEDs along that row are powered momentarily. This process is repeated for all eight rows before being repeated.

If several 8x8 matrices are assembled edge to edge, their horizontal conductors can be common to all of them. A horizontally scrollable display (sometimes referred to by the archaic term, *electric newspaper*) would then be possible, although the circuit design would be nontrivial.

Multiple Bar Display Driver

The LM3914 is a driver for a bar display that compares an analog input with a reference voltage and provides power to the segments of a multiple bar display, ranging from 2mA to 30mA, adjustable to match the specification of the display that is being used. The chip can generate either a "thermometer" effect, as more outputs are activated when the analog input increases, or a "moving dot" effect, in which only one output is on at a time.

One-Digit Hexadecimal Dot Matrix

While multi-character dot-matrix LED display modules are a versatile way to display prompts and numbers, a simpler component is sometimes sufficient. The Texas Instruments TIL311 is a minimal dot-matrix LED display that receives a binary value from 0000 through 1111 on its four input pins and generates the output in hexadecimal form, using numerals 0 through 9 and letters A through F. The sixteen possible outputs in the dot-matrix display are shown in Figure 24-16. Although this component is no longer being manufactured, it is widely available from many sources, especially in Asia. It eliminates the series resistors and controller chip that are customary for a seven-segment display, and has a better-looking output.

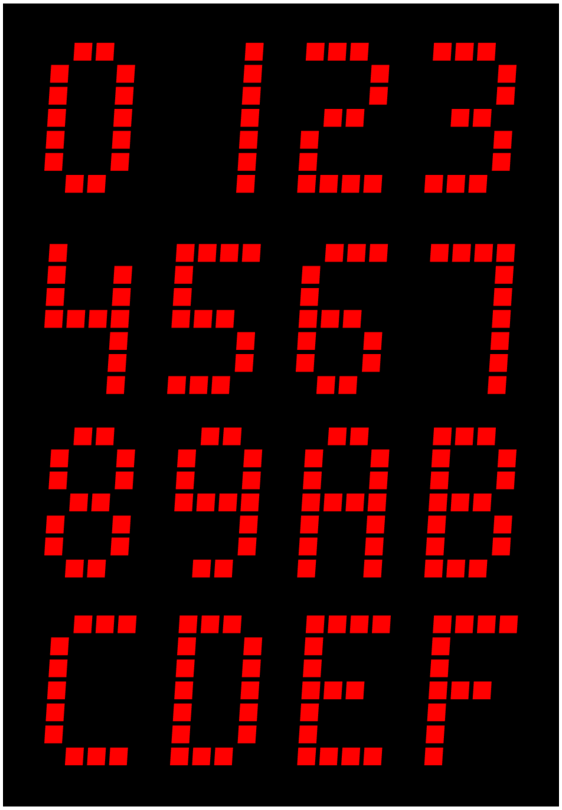

Figure 24-16. *Sixteen possible outputs that can be displayed by the Texas Instruments TIL311 to show a hexadecimal value in response to a four-digit binary input.*

A sample of the TIL311 is shown in Figure 24-17 displaying the number 2.

If two or more of these chips are put together, they can be multiplexed to display multi-digit decimal or hexadecimal integers.

The chip features two decimal points, one to the left of the displayed numeral, and one to the right. If they are activated, they require their own series resistors to limit the current.

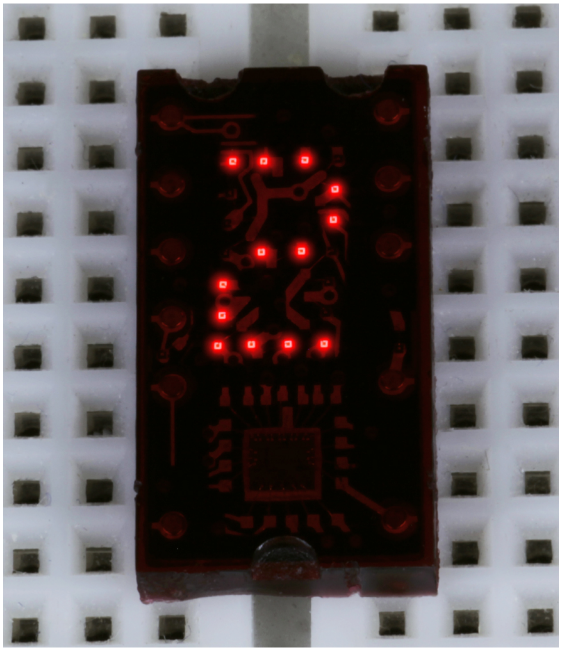

Figure 24-17. *The Texas Instruments TIL311 can be driven directly by a microcontroller or counter chip, with no series resistors necessary. It can generate a hexadecimal output.*

What Can Go Wrong

Common Anode versus Common Cathode

An LED display containing a common cathode is usually identical in appearance to a display containing a common anode, and the two versions will be distinguished by only one digit or letter in their part numbers. Because LED displays have a limited tolerance for reverse voltage, part numbers should be double-checked before applying power.

Incorrect Series Resistance

A common error is to assume that only one series resistor is necessary for a seven-segment LED display, either between the common cathode pin and ground, or, if there is a common anode, between that and the positive power supply. The problem is that if the resistor is suitable for a single LED, its value will be too high when several segments of the display are sinking current or drawing current through it. If its value is reduced, it will be too low when only two segments are using it (as when generating the number 1).

To provide equal illumination of all the segments, each must have its own series resistor.

Multiplexing Issues

When several displays are multiplexed, they naturally appear dimmer, creating a temptation to compensate by upping the current. Because current is only being applied to each display intermittently, a natural assumption is that a higher current can be safely used.

This may or may not be true. When running an LED device with pulsed current, the peak junction temperature, not the average junction temperature, determines the performance. At refresh rates below 1kHz, the peak junction temperature is higher than the average junction temperature, and the average current must therefore be reduced.

Datasheets must be checked to determine whether a device is designed with multiplexing in mind and, if so, what the recommended peak current is. Very often this value will be accompanied by a maximum duration in milliseconds, and a calculation may be necessary to determine the refresh rate, bearing in mind how many other LED displays are being multiplexed in the same circuit at the same time.

Irresponsible multiplexing will shorten the life of an LED display or burn it out.

25

vacuum-fluorescent display

The term **vacuum-fluorescent display** is seldom hyphenated, but the first two words are hyphenated here as they constitute an adjectival phrase. The acronym *VFD* is becoming increasingly popular, although it is ambiguous, being also used to identify a *variable frequency drive*. In both instances, the acronym is printed without periods between the letters.

The entry in this encyclopedia dealing with **fluorescent lights** does not include VFDs, because their purpose and design are very different. A VFD is an informational display, often showing numerals and letters, while a fluorescent light merely illuminates a room or work area. Although a VFD does use fluorescent phosphors, they are printed onto light-emitting segments of the display instead of being applied to the inside surfaces of a glass envelope.

OTHER RELATED COMPONENTS

- **LED indicator** (see Chapter 22)
- **LCD display** (see Chapter 17)
- **electroluminescence** (see Chapter 26)

What It Does

A **vacuum-fluorescent display** or *VFD* superficially resembles a backlit monochrome **LCD** or an **LED display**, as it can represent alphanumeric characters by using *segments* or a *dot matrix*, and can also display simple shapes. It is often brighter than the other information display systems, and can emit an intense green phosphorescent glow that some people find aesthetically pleasing, even though a grid of very fine wires is superimposed internally over the displayed image.

There is no specific schematic symbol to represent a vacuum-fluorescent display.

How It Works

The display is mounted inside a sealed capsule containing a high vacuum. A widely spaced series of very fine wires, primarily made of tungsten, functions as a *cathode*, moderately heated to encourage electron emission. The wires are often referred to as *filaments*.

A **fluorescent light** uses AC, and both of its electrodes are often confusingly referred to as cathodes. A VFD uses DC, and its cathode array has the function that one would expect, being connected with the negative side of the DC power supply.

Opposite the cathode, just a few millimeters away, is an anode that is subdivided into visible alphanumeric segments, symbols, or dots in a matrix. Each segment of the anode is coated with *phosphors*, and individual segments can be separately energized via a substrate. When electrons strike a positively charged anode segment, it emits visible light in a process of *fluorescence*. This behavior can be compared with that of a *cathode-ray tube*. However, the cathodes in a VFD are efficient electron emitters at a relatively low temperature, while the cathodes in a cathode-ray tube require substantial heaters.

Anode, Cathode, and Grid

A *grid* consisting of a mesh of very fine wires is mounted in the thin gap between the filaments of the cathode and the segments of the anode. A simplified view of this arrangement is shown in Figure 25-1.

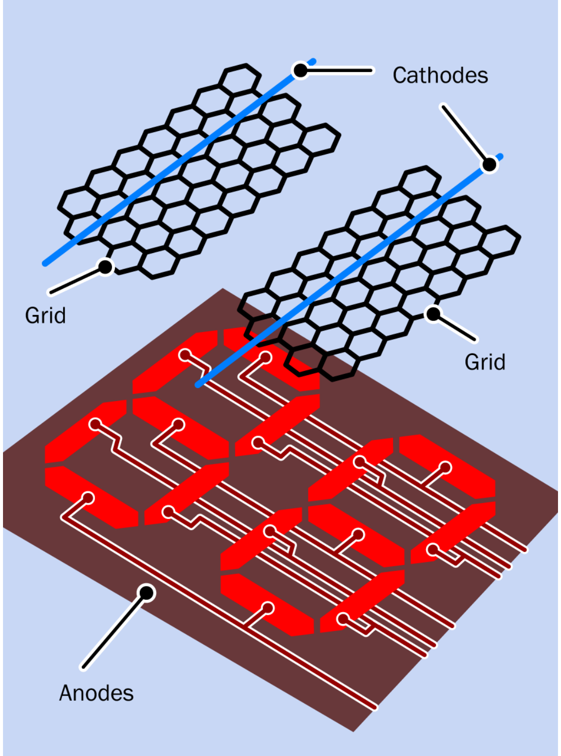

Figure 25-1. *The basic elements of a vacuum-fluorescent display.*

The polarity of the charge on the grid controls and diffuses electrons emitted by the cathode. If a grid section is negatively charged, it repels electrons and prevents them from reaching the sections of the anode beneath it. If the grid section is positively charged, it encourages electrons to reach the anode. Thus, the grid functions in the same way as the grid in a triode vacuum tube, but its conductors are so thin, they are barely visible.

How to Use It

Electronic calculators used vacuum-fluorescent displays during the 1970s, before LED displays and LCDs became more competitive. Purely numeric VFD modules are still available as strings of digits, although they are becoming uncommon and have been replaced by alphanumeric dot-matrix modules where each VFD character is mounted in its own glass module on a separate substrate.

Figure 25-2 shows the interior of a Commodore calculator from the 1970s, with its nine-digit vacuum-fluorescent display enclosed in one glass capsule.

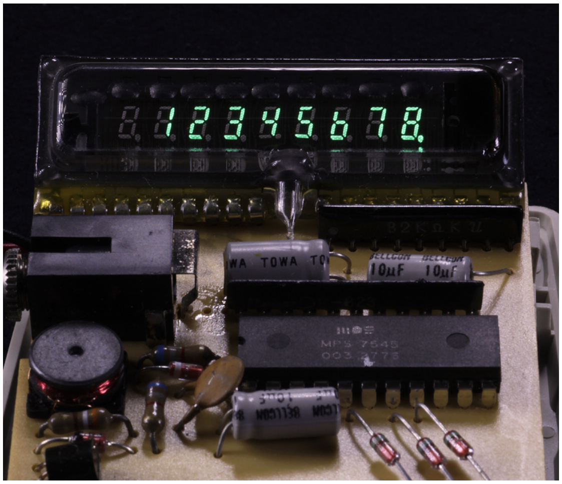

Figure 25-2. *The vacuum-fluorescent display from a 1970s Commodore calculator.*

A closeup of three digits from the previous figure appears in Figure 25-3, showing the grid superimposed above each numeral.

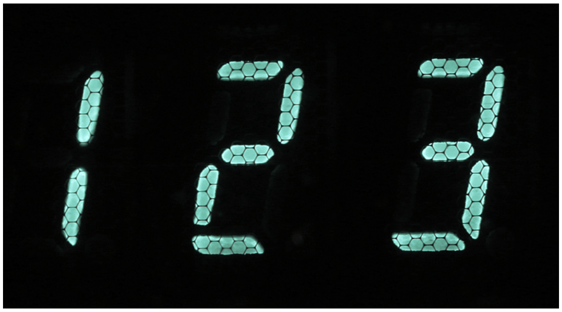

Figure 25-3. *Three digits from the previous figure, showing the grid that controls their illumination.*

A tinted filter of the same color as the display is usually placed in front of it, to conceal some of its workings. Thus, the Commodore calculator used a green filter in front of its green numerals. Figure 25-4 shows two seven-segment numerals from another device, with the filter removed. This reveals not only the grid but also the horizontal wires that function as the cathode. Connections between the segments of the numerals and a backplane are also visible.

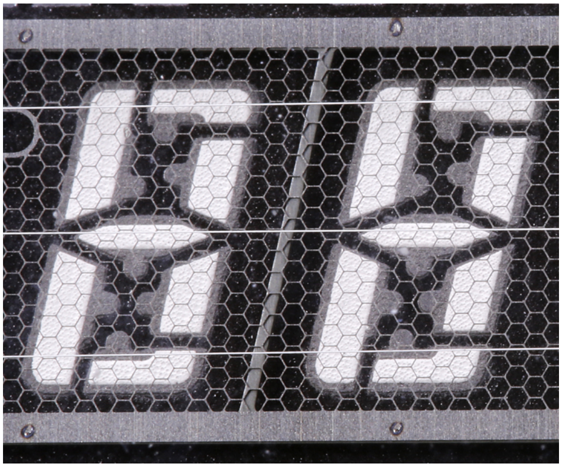

Figure 25-4. *Seven-segment numerals viewed without a colored filter, revealing the cathode (horizontal wires) and the grid (wire mesh).*

Modern Application

A modern VFD module is likely to be mated with a driver that converts 5VDC to the higher voltage (typically 50VDC to 60VDC) required for the display. Built-in logic may offer the option to receive data via an 8-bit parallel bus or with SPI serial protocol, and will contain a character set. A typical display resolution is 128 x 64 pixels.

The combination of a grid and a segmented anode enables a VFD to be controlled by *multiplexing*. For instance, in a display of four seven-segment numerals, the same equivalent segments in all four numerals can be connected in parallel while a separate grid covers each numeral. When each grid is positively energized, it selects the corresponding numeral, and the on-off segment patterns appropriate to that numeral are supplied. This procedure is repeated for each numeral in turn. Persistence of vision makes it appear that they are all active simultaneously.

Variants

Color

Although a VFD cannot provide a full-color display, selected anode segments can be coated with different phosphor colors, which can fluoresce simultaneously. Two or three individual colors are typically used, as in the display for a CD player where color helps to distinguish a variety of different functions. A closeup of a portion of the display from a CD player (with color filter removed) appears in Figure 25-5.

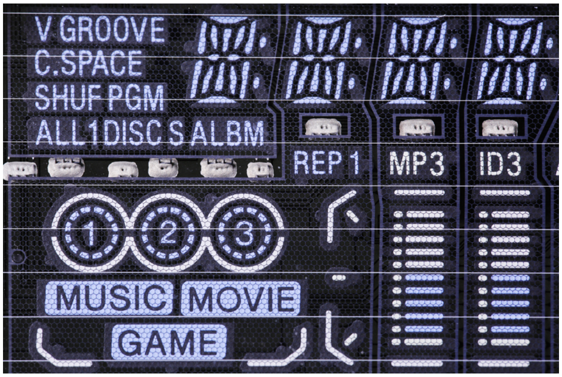

Figure 25-5. *The lefthand section of a vacuum-fluorescent display from a CD player.*

Character Sets and Pictorial Design

In the past, VFDs have combined seven-segment numerals in the same display as custom-shaped anodes. Solid-state gain meters in an audio amplifier, for instance, have used numerals beside a pictorial representation of gain levels resembling analog meters. The look and layout of a display of this type has been unique to a particular product.

Modern VFDs tend to use a generic dot-matrix display in which a character set in firmware dictates how patterns of dots are grouped to form numbers, letters, symbols, or icons.

The appearance of character sets generated with generic segments and dot-matrix arrays is thoroughly discussed and illustrated in the entry describing liquid-crystal displays in Chapter 17. VFD alphanumeric modules are identical in visual design to LCD modules, even though the internal electronics are different.

Comparisons

Two advantages of a VFD are that it functions well at low temperatures (unlike an LCD) and has sufficient brightness and contrast to be usable in sunlight (unlike many LED displays). It can be viewed from almost any angle.

Typical applications have included digital instrumentation in automobiles, information displays in audio and video consumer-electronics equipment, and numerical readouts in vending machines, medical devices, and some digital clocks.

Because a VFD requires a relatively high voltage, has significant power consumption, can show only a limited range of fixed colors, and is more expensive than LED displays or LCDs, its popularity has declined since the end of the 1990s.

What Can Go Wrong

Fading

VFDs gradually fade with age, as a result of reduced electron emission from the electrodes or diminishing performance of the phosphor coatings. Increasing the working voltage can prolong the life of a display.

electroluminescence

25

The field of **electroluminescent** devices is sometimes referred to as *EL*. The same acronym can also be applied as an adjective to an individual electroluminescent device, as in, for example, "an EL panel."

An *organic light-emitting diode*, more commonly known by its acronym *OLED*, is included in this entry because it is technically an electroluminescent device and its design concept is similar to that of an electroluminescent panel. Generic LEDs are also technically electroluminescent, but are not commonly described as such, and have their own entries in this encyclopedia under the subject categories **LED indicator**, **LED area lighting**, and **LED display**.

OTHER RELATED COMPONENTS

- **LED indicator** (see Chapter 22)
- **LCD display** (see Chapter 17)
- **fluorescent light** (see Chapter 20)
- **vacuum-fluorescent** display (see Chapter 25)

What It Does

An electroluminescent device configured as a *panel*, *ribbon*, or *rope-light* contains phosphors that emit light in response to a flow of electricity.

Panels can be used as backlights for LCD displays or, more often, as always-on low-power devices such as exit signs and night lights. Ribbons and rope lights (the latter being also known, more accurately, as *light wires*) are used mainly as recreational novelties. They can be battery powered through a suitable voltage converter. A battery-powered rope light can be wearable.

Thin-film OLED electroluminescent panels are used in small video screens in handheld devices. At the time of writing, OLED TV screens measuring 50" or more have been demonstrated, but are not yet economic for mass production.

No specific schematic symbol exists to represent any electroluminescent device or component.

How It Works

Luminescence is the emission of light as a result of a process that does not require heat. (The opposite phenomenon is *incandescence*, in which heating causes an object to emit light; see Chapter 18 for a description of **incandescent lamps**.)

Electroluminescence is luminescence resulting from stimulation by electricity. This very broad definition really includes devices such as **LED**s, although they are hardly ever described in those terms. Electroluminescence generally refers to panels, films, or wires where electrodes are in direct contact with light emitters such as phosphors.

The exception is an *organic LED*, usually known by its acronym *OLED*, which is frequently described as an electroluminescent device, perhaps because its configuration as a sandwich of thin, flat layers resembles an electroluminescent panel. Two of the layers are semiconductors, and they interact as light-emitting diodes.

Phosphors

A *phosphor* is a compound such as zinc sulfide that will emit light when it receives an energy input from another light source or from electricity. Typically the compound must be mixed with an *activator* such as copper or silver.

For many decades, TV sets and video monitors were built around *cathode-ray tubes* in which the interior of the screen, at the front of the tube, was coated with phosphors. A beam of electrons that fluctuated in intensity generated a picture on the screen by drawing it as a series of lines.

Derivation

The term *phosphor* is derived from *phosphorescence*, which in turn comes from the name of the element *phosphorous*, which will glow when it oxidizes in moist air. (These terms were established before other forms of luminescence were discovered and understood. The behavior of phosphorous is really an example of *chemiluminscence*.)

For our purposes, a phosphor is a compound that is capable of fluorescence or electroluminescence.

Variants

Panels

Electroluminescent panels using phosphor powder, sometimes referred to as *thick phosphor*, are a popular choice where a constant, uniform, low light output is acceptable.

An electric potential is established between two films that act as electrodes, separated by a layer of phosphor crystals. Some manufacturers refer to this configuration as a *light-emitting capacitor* because the structure resembles a capacitor, even though that is not its purpose. The front film is transparent, allowing light to escape.

An electroluminescent panel can be powered by AC or DC but requires at least 75V. Its power consumption is self-limiting, so that no control electronics are required other than a voltage converter if battery power is used.

The phosphors generate a constant, evenly distributed luminescence over the entire area, although the output is not very intense. Applications include night-lights, exit signs, and backlighting for wristwatches.

Panelescent electroluminescent lighting by Sylvania was used for instrument panel displays in some car models such as the Chrysler Saratoga (1960 through 1963) and Dodge Charger (1966 through 1967). It is still used for night-lights. *Indiglo* electroluminiscent displays are still widely used in wristwatches.

The interior components of a disassembled electroluminescent night-light are shown in Figure 26-1. The panel emits a natural pale green glow. A separate blue or green filter passes the glow while blocking other colors of incident light that would otherwise reflect off the panel.

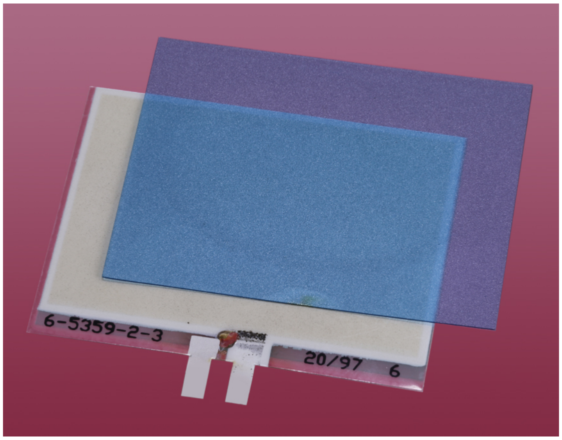

Figure 26-1. *The two interior components of an electroluminiscent night-light: the luminescent panel, and a separate translucent filter.*

Electroluminescent night-lights were popular in the 1970s and 1980s, often featuring cartoon characters to appeal to children. Figures 26-2 and 26-3 show the same night-light in its daytime off-state and its night-time on-state, respectively.

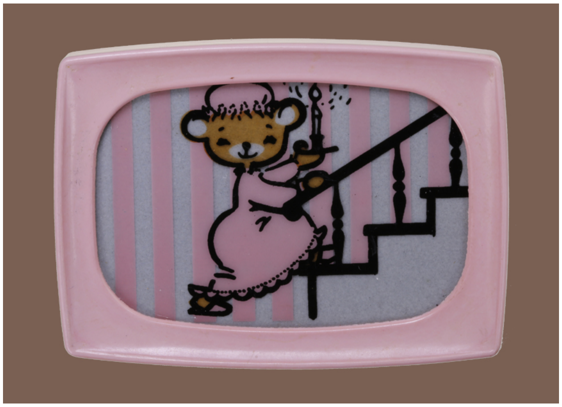

Figure 26-2. *A vintage Panelescent brand night-light, several decades old, in its off-state.*

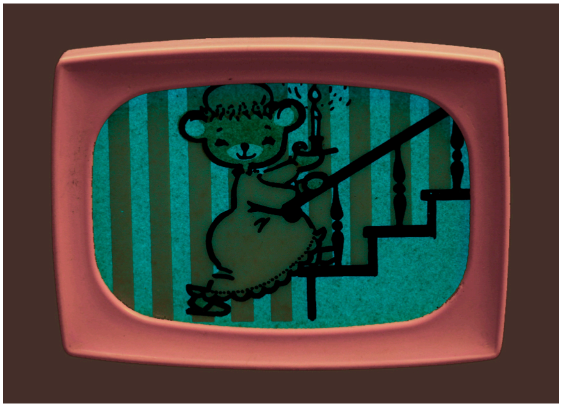

Figure 26-3. *The same night-light, with its green radiance visible under conditions of low ambient light.*

Advantages of electroluminescent panels include the following:

- Low current consumption. One US manufacturer claims that a single exit sign will use electricity costing less than 20 cents per year, while the annual cost of a night-light will be less than 3 cents per year.
- Long life, up to 50,000 hours.
- Self-regulating; no control circuitry required.
- Omnidirectional light output.
- Very wide operational temperature range, between approximately -60 and +90 degrees Celsius.
- Can be plugged directly into a wall outlet.

Disadvantages include:

- Limited light output.
- Very limited choice of colors.
- Not very efficient, 2 to 6 lumens per watt (although the low light output naturally entails low power consumption).
- Gradual reduction in phosphor performance over time.
- High voltage required: 60V to 600V. Ideal for plugging into a wall outlet, but requires a converter when used with battery-powered devices.

Flexible Ribbons

The light-emitting layers inside a night-light are somewhat flexible, and can be made more flexible by reducing their thickness. The result is an electroluminescent ribbon that has some novelty value, and may be used for customizing automobiles. Figure 26-4 shows a ribbon about 1.5" wide and 12" long, designed for 12VDC power applied through an inverter.

Rope Light

A rope light or wire light may resemble a *glowstick*. However, a glowstick generates light from chemiluminescence (chemical reactions that release photons), while a rope light uses electricity.

Figure 26-5 shows a rope light powered by two AA batteries connected through an inverter.

At the center of the rope light is a conductor that serves as one electrode. It is coated in phosphors, and the layer of phosphors is protected by a transparent sheath. One or more thin wires is wrapped around the sheath in a spiral, with large gaps between one turn and the next. These wires serve as the second electrode. The wires are enclosed in transparent insulation that forms an outer sheath.

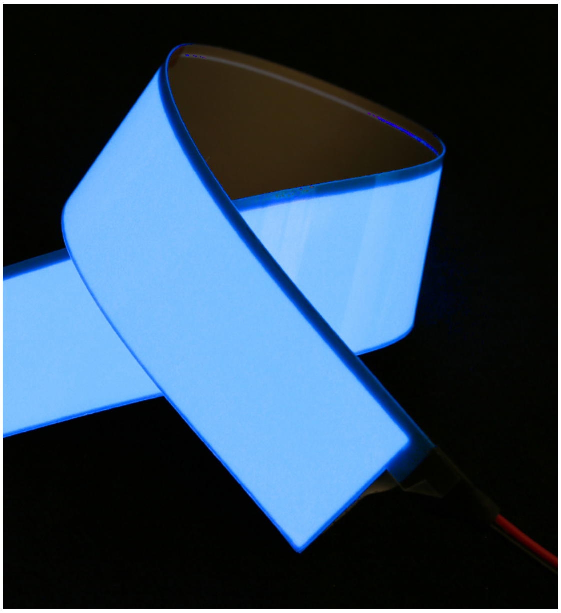

Figure 26-4. *A 12" length of electroluminescent ribbon.*

When AC is applied between the electrodes, the layer of phosphors emits light that radiates out in the gaps between the thin wires. The color of the light can be modified by using tinted outer insulation.

OLED

An OLED uses two thin, flat electrodes, somewhat like a thick-phosphor electroluminescent panel, except that it contains more layers and is capable of generating more light. The layers in an OLED are "organic" in that they consist of chemically organic molecules containing carbon and hydrogen atoms and generally do not contain heavy metals.

While an LCD video monitor or TV screen must have a separate backlight, an OLED generates its own light. This reduces the thickness of the display to a few millimeters and makes it potentially more efficient.

The semiconductor layers are subdivided into pixels, each functioning as a light-emitting diode, while additional layers carry a matrix of conductors for pixel addressing. In an AMOLED, the conductors form an active matrix, while in a PMOLED, they form a passive matrix.

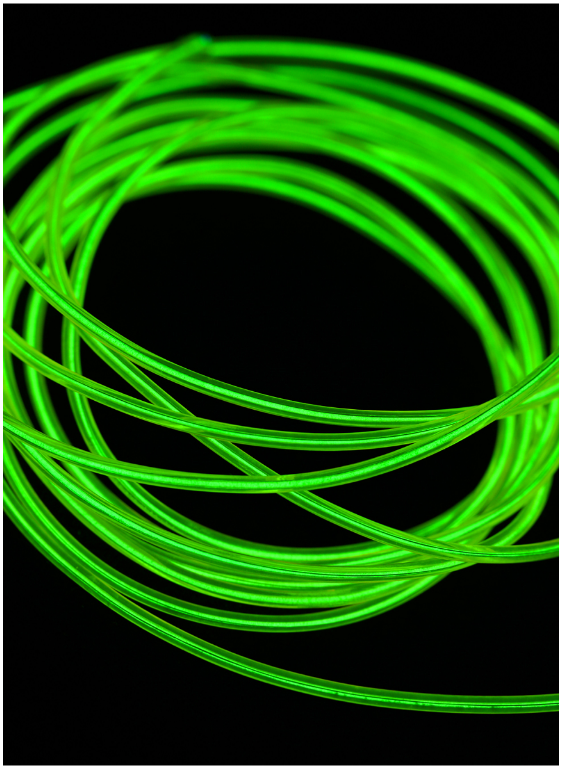

Figure 26-5. *A length of glowing rope light, also known as a light wire.*

In an active matrix, each pixel is backed with a *thin-film transistor* to store its state while the energizing voltage transitions. This is often described as a *TFT* display; but the term is interchangable with "active matrix."

In a passive matrix, each pair of conductors simply supplies current to a pixel. This is cheaper and easier to fabricate but is less responsive.

The terms "active matrix" and "passive matrix" have the same meaning as when used to describe a **liquid-crystal display**.

Monochrome OLED display modules with dot-matrix characters are currently available from China for just a few dollars. Although they appear superficially similar to LCD modules, they generate pure white-on-black characters.

Small full-color OLED screens are used in smartphones and on camera backs, but at the time of writing, large OLED screens are not a mature technology, partly because of production costs. A great variety of chemicals and layer configurations have been tried, and the application of pixels to a substrate has been attempted with vacuum deposition through a shadow mask and with a system similar to inkjet printing. Pixels that emit red, green, and blue light have also been used. Filtered pixels have been used. One dominant process has not yet emerged.

Longevity and brightness have been problems. Where red, green, and blue diodes have been used, the different colors deteriorate at different rates. While the human eye tolerates an overall reduction in brightness, it does not tolerate a slight color shift caused by blue pixels, for instance, losing brightness more rapidly than red pixels.

Because OLED screens promise to be thinner, lighter, and brighter, and may eliminate the need for a fragile glass substrate, there is a strong incentive to develop this technology, which seems likely to gain dominance in the future.

OLED panels may also become a source of diffuse, shadowless room lighting or office lighting when practical problems have been solved and costs have fallen significantly.

transducer

27

The term **transducer** is used here to describe a *noise-creating device* that is driven by external electronics. By comparison, an **audio indicator** (discussed in the next entry) contains its own internal electronics and only requires a DC power supply. Either of these components is often described as a *beeper* or *buzzer*.

A **speaker**, more properly termed a *loudspeaker*, is an electromagnetic transducer but is seldom described in those terms. It has a separate entry in this encyclopedia and is defined here as a *sound reproduction device* that is larger and more powerful than a typical transducer and has a more linear frequency response.

While piezoelectric transducers formerly used crystals, only the more modern piezoelectric type that uses a ceramic wafer will be considered here.

Some transducers convert sound into electricity, but these are categorized as *sensors*, and will be discussed in Volume 3. The only transducers discussed in this entry are those that convert electricity into sound.

OTHER RELATED COMPONENTS

- **audio indicator** (see Chapter 28)
- **headphone** (see Chapter 29)
- **speaker** (see Chapter 30)

What It Does

An audio **transducer** is a device that can create an *alert*. It requires an AC signal that is supplied by external electronics, and in its simplest form may be referred to as a *buzzer* or a *beeper*.

Audio alerts are used in microwave ovens, washer/dryers, automobiles, gasoline pumps, security devices, toys, phones, and many other consumer products. They are often used in conjunction with touch pads, to provide audio confirmation that a tactile switch has been pressed.

The schematic symbols in Figure 27-1 can be used to represent any kind of audio alert, including **indicators**, which contain their own electronics to generate a simple tone or series of tones. Type A is probably the most popular symbol. Types B and C often appear with the word "buzzer" printed beside them for clarification. D and E are really symbols for a **speaker**, but are often used for an alert. F is the symbol for a *crystal*, now sometimes used to indicate a piezoelectric noise maker. G specifically represents an electromagnetic transducer, but is seldom used.

How It Works

A circular diaphragm is glued at its edges inside a cylindrical plastic enclosure, usually measuring from around 0.5" to 1.5" in diameter. The enclosure is sealed at the bottom but has an opening at the top, so that sound can emerge from the upper side of the diaphragm without being partially cancelled by sound of opposite phase that is emitted from the underside of the diaphragm. The enclosure also amplifies the sound by resonating with it, in the same way that the body of a guitar or violin amplifies a note being played on the strings.

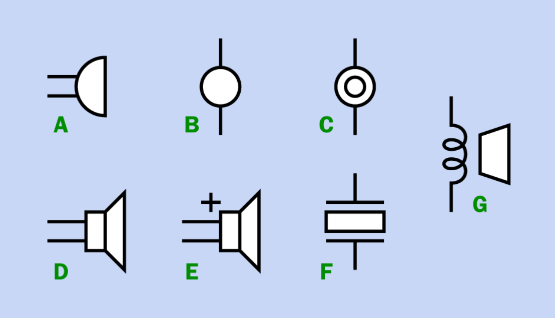

Figure 27-1. *An assortment of symbols which can represent a transducer or an indicator. See text for details.*

The diaphragm is activated either electromagnetically or piezoelectrically, as described next.

Externally, a transducer may be indistinguishable from an audio indicator such as the one pictured at Figure 28-1.

Variants

Electromagnetic

An electromagnetic transducer contains a diaphragm that is usually made of plastic. Mounted on it is a smaller *ferromagnetic disc* that responds to the fluctuating field from AC passing through a coil. When the diaphragm vibrates, it creates pressure waves that are perceived by the human ear as sound.

A car horn is a particularly loud form of electromagnetic transducer.

Piezoelectric

A piezoelectric transducer contains a diaphragm consisting of a thin brass disc on which is mounted a *ceramic wafer*. When an AC signal is applied between the piezoelectric wafer and the disc, the disc flexes at that frequency.

The term *piezo* is derived from the Greek *piezein*, which means "to squeeze or press."

Ultrasonic Transducer

The diaphragm in an *ultrasonic transducer* vibrates at a frequency above the range of human hearing. This component may be electromagnetic, piezoelectric, or crystal-based. Often it is used in conjunction with an ultrasonic receiver as a distance measuring device. The two components can be sold pre-mounted on a breakout board. An output from the board can consist of a pulse train where the pulse duration is proportional to the distance between the transducer and the nearest sound-reflecting object.

An ultrasonic transducer is pictured in Figure 27-2. Its internal components are shown in Figure 27-3.

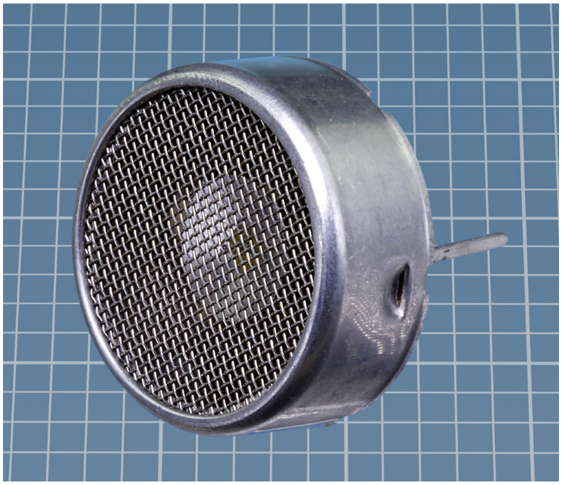

Figure 27-2. *The exterior of an ultrasonic transducer.*

Submersible ultrasonic transducers may be used in cleaning systems, where they agitate a liquid that dislodges dirt or debris. Ultrasonic transducers are also used in echo-sounding and sonar equipment with marine applications.

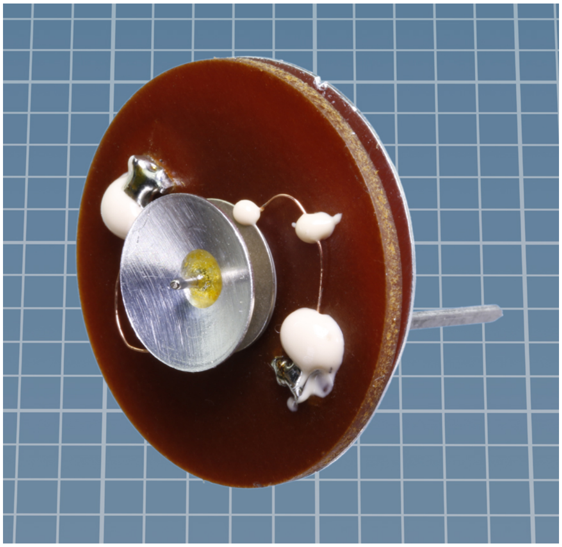

Figure 27-3. *Inside an ultrasonic transducer, a small aluminum cone is the sound radiating element. The white blobs are adhesive to secure the thin wires.*

Formats

Some transducers are available in surface-mount format, measuring about 0.5″ square or less. Because the resonant frequency is related to the size of the component, surface-mount transducers usually generate a high-pitched beep.

Values

Frequency Range

Audio frequency is measured in Hertz, abbreviated Hz, named after Heinrich Rudolf Hertz, the first scientist to prove the existence of electromagnetic waves. The H in Hz is capitalized because it refers to a real name. One thousand Hertz can be written as 1 kiloHertz, almost always abbreviated as 1kHz (note that the k is lowercase).

The human ear is often described as being able to detect sounds between 20Hz and 20kHz, although the ability to hear sounds above 15kHz is relatively unusual and diminishes naturally with age. Sensitivity to all frequencies can be impaired by long-term exposure to loud noise.

The most common frequencies applied to audio transducers range between 3kHz and 3.5kHz. Piezoelectric elements are inefficient for generating sounds below 1kHz, but electromagnetic transducers are better able to generate lower frequencies. Their response curve can be approximately flat to frequencies as low as 100Hz.

Sound Pressure

Sound pressure can be measured in Newtons per square meter, often abbreviated as Pa. Newtons are units of force, while Pa is an abbreviation of Pascals.

The *sound pressure level* (SPL) of a sound is not the same as its sound pressure. SPL is a logarithmic value, to base 10, in units of decibels (dB), derived from the pressure of a sound wave relative to an arbitrary reference value, which is 20 micro-Pascals (20μPa). This is the agreed minimum threshold of human hearing, comparable to a mosquito at a distance of three meters. It is assigned the level of 0dB.

Because the decibel scale is logarithmic, a linear increase in the decibel level of a sound does not correspond with a linear increase in actual sound pressure:

- For each additional 6dB in the SPL, the actual sound pressure approximately doubles.
- For each additional 20dB in the SPL, the actual sound pressure is multipled by 10.

Bearing in mind that 0dB corresponds with the reference sound pressure of 20μPa, an SPL of 20dB represents a sound pressure of 200μPa (that is 0.0002Pa), and so on.

Many tables show an estimated decibel level for various noise sources. Unfortunately, these tables may contradict each other, or may fail to mention the distance at which a sound is measured. Figure 27-4 shows estimates derived by averaging eight similar tables. It should be viewed as an approximate guide.

Decibels	Noise Example
140	Jet engine at 50 meters
130	Threshold of pain
120	Loud rock concert
110	Automobile horn at 1 meter
100	Jackhammer at 1 meter
90	Propeller plane 300 meters above
80	Freight train at 15 meters
70	Vacuum cleaner
60	Business office
50	Conversation
40	Library
30	Quiet bedroom
20	Leaves rustling
10	Calm breathing at 1 meter
0	Auditory threshold

Figure 27-4. *Approximate decibel values for some sound sources (averaged from a selection of eight similar charts).*

Sometimes the claim is made that an increase of +10 on the decibel scale will correspond with a subjective experience that the noise is "twice as loud." Unfortunately, this statement cannot be quantified.

Weighted Sound Values

Subjective assessment of sound is complicated by the nonlinear frequency response of the human ear, which causes some frequencies to seem "louder" than others, even though their sound pressure is the same. The frequency weighting of the ear can be determined by playing a reference tone of 1kHz at 20dB and then doing an A-B comparison with a secondary tone at another frequency, asking the subject to adjust the gain of the secondary tone up or down until the two tones seem equally loud.

This procedure is performed for a range of frequencies. The test is then repeated with a louder 1kHz reference tone, at 30dB. Repetitions continue to a final reference tone of 90dB.

The resulting curves are known as *equal-loudness contours*. An averaged set, from multiple sources, has become an international standard with ISO number 226:2003. The curves shown in Figure 27-5 are derived from that standard. The curves show that the sound pressure of lower frequencies must be boosted by a significant amount to sound as loud as a 1kHz frequency, while a frequency around 3kHz must be reduced slightly, because it tends to sound louder than all others.

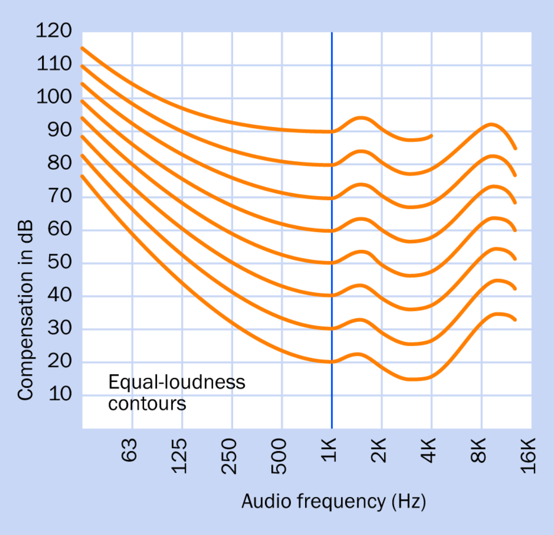

Figure 27-5. *Equal loudness contours derived from ISO 226:2003. See text for details.*

Although the accuracy of equal-loudness contours is controversial, they have been the basis of a widely used weighting system to adjust dB values to represent subjective perceptions of loudness. This *A-weighting* system remains the best-known and most widely applied audio standard in the United States, even though it has been criticized for assigning too little value to sounds that are brief in duration. If a sound level is expressed in dBA, it is A-weighted, meaning that the sounds to which the ear is least sensitive are assigned a value that is lower than their measured value. Thus, a tone of 100Hz has a dBA value about 20dB lower than its dB value, because the human ear is relatively insensitive to low-pitched sounds. dBA values are used in regulations that limit noise in the work place and other environments.

Unweighted Values

If sound intensity is expressed in dBSPL, it is a measurement of the actual Sound Pressure Level and has not been adjusted with the A-weighting system. A graph of unadjusted dbSPL values will display low frequencies as if they are more intense than the ear will perceive. In practical terms, subjective perception of low-end rolloff will be even more severe than the graph makes it appear.

If sound intensity is expressed merely in dB, probably it is unweighted and should be considered as dBSPL.

From a practical point of view, when choosing a tone for a transducer, a 500Hz tone may sound relatively mellow and not subjectively loud. A 3.5kHz tone can be a good attention-getting signal, as the ear is most sensitive in that range.

Transducers generally have a sound pressure rating in dBSPL ranging between 65dBSPL to 95dBSPL, with just a few products that can make more or less noise.

Measurement Location

The sound pressure from an audio alert will naturally diminish if the measurement point moves farther away. Therefore, any rating in decibels should be expressed with reference to the distance at which the measurement is made.

Measurement locations may be expressed in centimeters or inches, and may vary from 10cm to 1 meter, even in datasheets for different devices from the same manufacturer. If the measurement distance doubles, the SPL diminishes by approximately 6dB.

Limitations

A piezoelectric transducer is not intended as a sound reproducer, and does not have a smooth or flat frequency response. The curve for the Mallory PT-2040PQ is not unusual, reproduced in Figure 27-6. This component measures about 3/4" in diameter, is rated for 5VDC, and uses only 1.5mA to generate 90dB (measured at a distance of 10cm). Like many piezoelectric audio devices, its response peaks around 3500kHz and diminishes above and below that value, especially toward the low end. While it is perfectly adequate as a "beeper," it will not reproduce music successfully.

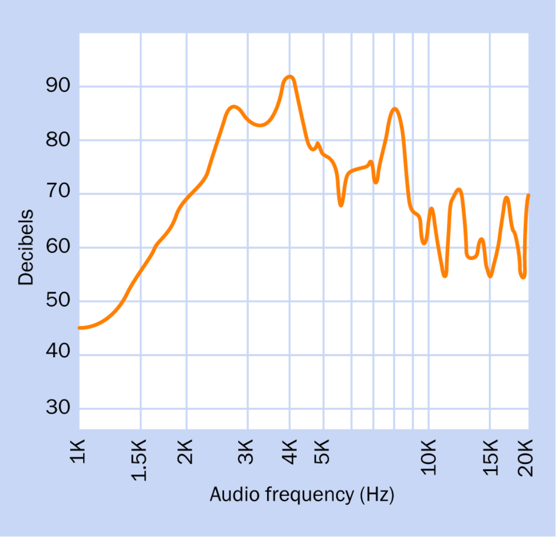

Figure 27-6. *The frequency response from a typical small piezoelectric transducer.*

An electromagnetic transducer is better able to generate low frequencies than a piezoelectric transducer. It has a low impedance that may be suitable in some circuits. However, it is slightly heavier than a comparable piezoelectric transducer, uses much more power, and as an AC device containing a coil, it can create electromagetic interference or may cause fluctuations in the circuit as an inductive load. It is also vulnerable to magnetic interference from elsewhere, while a piezoelectric transducer is not.

While an electromagnetic transducer can be used to reproduce speech or music, and will do a better job than a piezoelectric transducer, its performance will still be dissatisfying. A miniature speaker is more appropriate for the task.

Voltage

Transducers are typically designed to work with voltages ranging from 5VAC to 24VAC. The ceramic wafer in a piezoelectric transducer usually cannot withstand voltages much above 40VAC, and its sound output will not increase significantly above 30VAC.

Current

Typical piezoelectric transducers use less than 10mA and generate negligible heat. An electromagnetic transducer may draw as much as 60mA.

How to Use It

Appropriate Sound Intensity

An alert should be chosen with reference to the environment in which it will be used. To be easily heard, it should be at least 10 dB louder than ambient background noise.

Volume Control

Sound pressure can be lowered by reducing the voltage. Because a transducer does not consume much current, a *trimmer* can serve as a volume control. Alternatively, a rotary switch with a set of fixed-value resistors can select preset sound values.

AC Supply

Although a transducer is an AC device, it is unlikely to be designed for voltage that fluctuates positively and negatively either side of a neutral value. Typically it is intended for voltage that fluctuates between 0V (ground) and the rated positive value of the power supply, and its pins, wires, or terminals are usually marked accordingly. If it has wire leads, the red lead should be connected to the more-positive side of the supply. If it has pins, the longer pin should be more positive.

The alternating signal for a transducer can be supplied by any simple oscillator or astable multivibrator circuit. For a given peak voltage, a square wave will generate a louder signal than a sinusoidal wave. A simple 555 timer circuit can be used, with a second monostable timer to limit the duration of the beep if necessary. An astable 555 can be used to test the transducer and select the audio frequency that sounds best.

Self-Drive Transducer Circuit

If a transducer has three wires or pins, it is probably a *self-drive* type. The datasheet may identify its inputs as M, G, and F, meaning Main, Ground, and Feedback. The Feedback terminal is connected with a section of the diaphragm which vibrates 180 degrees out of phase with the Main terminal. This facilitates a very simple external drive circuit, such as that in Figure 27-7, where the frequency is determined by the transducer's resonant frequency.

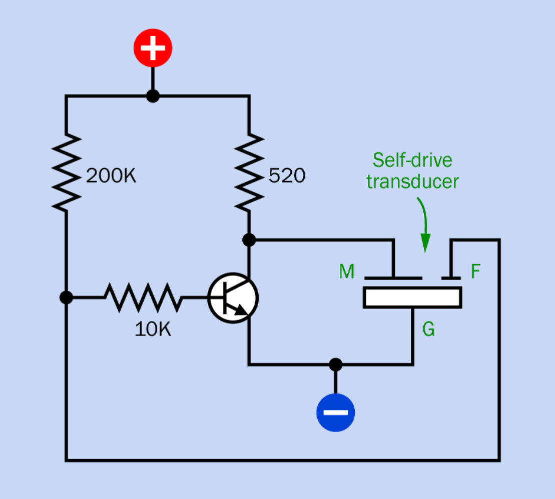

Figure 27-7. *A circuit to control a self-drive type of piezoelectric transducer.*

What Can Go Wrong

Overvoltage

Mallory Sonalerts, one of the largest producer of piezoelectric alerts, states that in the "vast majority" of returned products, the failure was caused by excessive voltage, often in the form of a transient voltage spike.

Leakage

If an alert makes a small, low-volume sound when it is supposed to be off, some current is leaking through it. Less than 1mA may be enough to cause this problem. According to one manufacturer, it can be fixed by placing a 30V Zener transient voltage suppressor diode in series with the alert, or by wiring a small **incandescent lamp** in parallel with the alert.

Note that when the alert is activated, the full supply voltage will be seen at the lamp.

Component Mounting Problems

Some alerts are packaged with mounting holes, but many are not. Those with pins can be soldered into a board, but those without must be glued in place or inserted into a cavity from which they cannot shake loose. Silicone adhesive is recommended, but care must be taken to avoid any of it dripping into the alert before it sets.

Moisture

If an alert will be used in a location where it is vulnerable to moisture, it should be of a type that is sealed against the environment. Even a sealed unit should ideally be oriented so that it faces slightly downward.

Transducer-Indicator Confusion

Externally, a transducer and an indicator often look identical, and some of them are not marked with a manufacturer's part number. Damage can be caused by applying DC to a transducer or AC to an indicator. If both types of parts are kept in inventory, they should be carefully labeled.

Connection with a Microcontroller

A piezoelectric transducer can be driven by a microcontroller, but an electromagnetic transducer is not appropriate in that role, because of its relatively higher current consumption and its behavior as an inductive load.

audio indicator

28

An **audio indicator** is defined here as a noise-creation device that generates a simple tone or series of tones. Unlike a **transducer**, which requires an external source of AC to determine its audio frequency, an indicator contains its own electronics and requires only a DC power supply. Either of these components is often described as a *beeper* or *buzzer*.

While piezoelectric alerts formerly used crystals, only the more modern piezoelectric type that uses a ceramic wafer will be considered here.

OTHER RELATED COMPONENTS

- **transducer** (see Chapter 27)
- **headphone** (see Chapter 29)
- **speaker** (see Chapter 30)

What It Does

When DC power is applied to an **audio indicator**, in its simplest form it creates a continuous or intermittent tone of a fixed frequency. This is called an *alert*.

Audio alerts are used in microwave ovens, washer/dryers, automobiles, gasoline pumps, security devices, toys, phones, and many other consumer products. They are often applied with touch pads, to provide audio confirmation that a tactile switch has been pressed.

A few indicators are programmed to create a two-tone sound, or multiple-tone sequences.

See Figure 27-1 in the previous entry for an assortment of schematic symbols that may be used to represent either an alert or a transducer.

How It Works

A circular diaphragm is glued at its edges inside a cylindrical plastic enclosure, usually measuring from around 0.5" to 1.5" in diameter. The enclosure is sealed at the bottom but has a small hole at the top, so that sound can emerge from the upper side of the diaphragm without being partially cancelled by sound of opposite phase that is emitted from the underside of the diaphragm. The enclosure also contains electronics to generate one or more audio tones, and amplifies the sound by resonating with it, in the same way that the body of a guitar or violin amplifies a note being played on the strings.

A PUI XL453 piezoelectric audio indicator is pictured in Figure 28-1, fully assembled on the right, and with its circuit board and diaphragm removed on the left. This indicator creates a pulsed tone at 3.5kHz with a sound pressure of 96dB. It draws 6mA at 12VDC and measures approximately 1" in diameter.

For more information about the measurement of sound frequency and pressure, see "Frequency Range" on page 251 and "Sound Pressure" on page 251 in the previous entry.

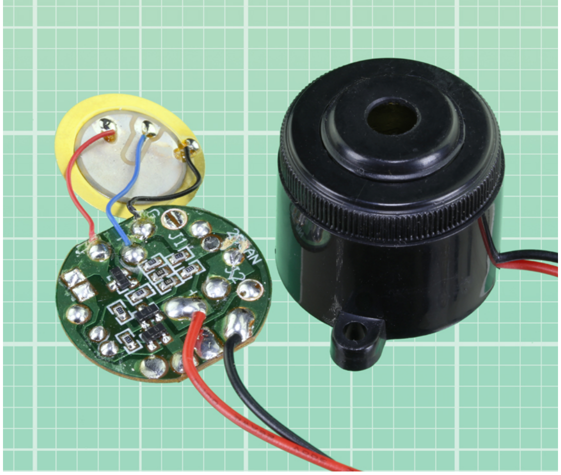

Figure 28-1. *A typical piezoelectric audio indicator.*

Externally, an audio indicator may be indistinguishable from a transducer. However, internally, an indicator is almost always a piezoelectric device, in which a *ceramic wafer* is mounted on a thin brass diaphragm. The term *piezo* is derived from the Greek *piezein*, which means to squeeze or press.

A transducer (described in the previous entry) is a piezoelectric or electromagnetic alert that does not usually contain its own circuitry and must be driven by an external source of AC, which establishes the audio frequency.

The distinction between an indicator and a transducer is often unclear in parts catalogs, where all alerts may be identified as *buzzers*, even though they mostly beep rather than buzz.

Audio Frequency

For a discussion of audio frequency, see "Frequency Range" on page 251 in the previous entry.

History

Probably the earliest form of electrically activated alert was the door bell, in which a 6VDC battery-powered solenoid pulled a spring-loaded lever terminating in a small hammer. The hammer struck the bell, but the motion of the lever also opened a pair of contacts, cutting off power to the solenoid. The lever sprang back to its rest position, which closed the contacts and repeated the cycle so long as power was supplied through an external pushbutton.

Subsequent systems used a small loudspeaker powered by AC house current through a step-down transformer. This created a buzzing sound and may have been the origin of the term "buzzer."

Small components that made a beeping sound only became common when digital equipment required a simple, cheap way to confirm user input or attract attention to the status of a device.

Variants

Sound Patterns

Because an audio indicator contains its own electronics, the manufacturer has the freedom to create various patterns of sound output.

The default is a steady tone. Other common variants include an intermittent tone and a dual tone that fluctuates rapidly between two frequencies. This is sometimes referred to as a *siren*. A few variants can generate an output pattern consisting of several tones in sequence, or effects such as warbling or whooping sounds, which are used mainly in alarm systems.

Formats

Some audio indicators are available in surface-mount format, measuring 1/2" square or less. Because the resonant frequency is related to the size of the component, surface-mount alerts usually make a high-pitched beep.

Panel-mount and board-mount formats range from about 1/2" to 1.5" in diameter. A small audio alert designed to be mounted on a circuit board is shown in Figure 28-2, with its top removed on the right to expose the brass diaphragm glued around the edges. The same component is shown with its plastic enclosure removed completely in Figure 28-3.

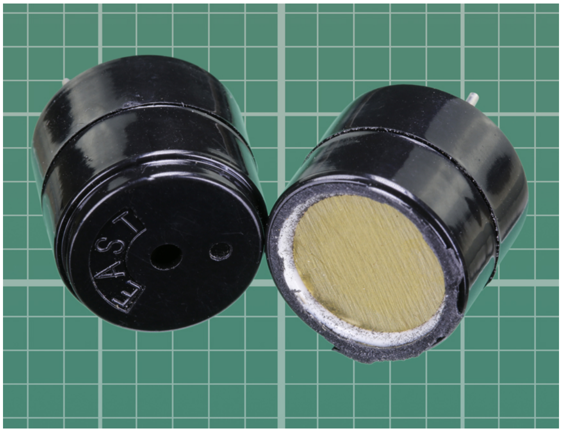

Figure 28-2. *An audio indicator approximately 0.5" in diameter, partially disassembled on the right, revealing its brass diaphragm.*

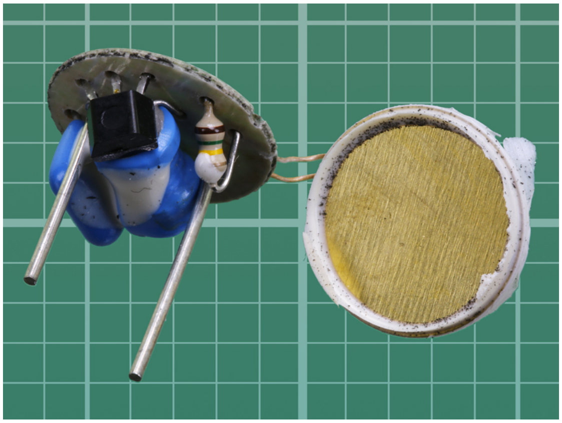

Figure 28-3. *The same indicator from the previous photograph, with its enclosure completely removed.*

Values

For an explanation and discussion of sound pressure and its measurement in decibels, see "Sound Pressure" on page 251 in the previous entry.

Audio indicators generally have a sound pressure rating in dBSPL ranging between 65dBSPL to 95dBSPL, with just a few products that make more or less noise. At 120dB and above, most products are packaged as alarm sirens ready for installation, often with a small horn attached. Their power consumption can be 200mA or more, and they are many times the price of a simple indicator designed for circuit-board mounting.

Voltage

An audio indicator containing its own electronics will almost always be rated somewhere in the range from 5VDC to 24VDC. Sirens intended for use with burglar alarms are often designed for 12VDC or 24VDC, as these are popular values for security systems with battery backup. However, in addition to a rated voltage, a datasheet may specify a wide range of acceptable operating voltages. For example, an indicator with a *rated* voltage of 12VDC may have an *operating* voltage of 3VDC to 24VDC. Naturally, the sound intensity will vary with the voltage, but not as much as one might assume. The graph at Figure 28-4 shows that the sound output from an alarm, measured in decibels, increases by only 8dB when voltage increases by almost a factor of five. Of course, the decibel scale is not linear, but human perception of sound is not linear, either.

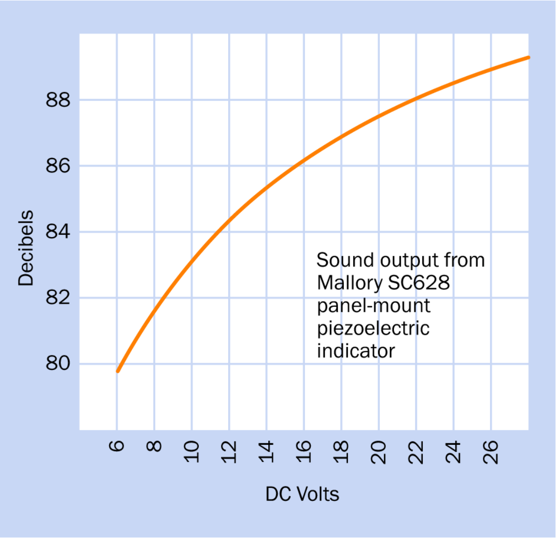

Figure 28-4. *Variation of sound output relative to voltage, in a commonly used piezoelectric indicator.*

Current

Typical piezoelectric indicators use less than 10mA (often as little as 5mA) and generate negligible heat.

Frequency

The most common frequencies for indicators range between 3kHz and 3.5kHz. Piezoelectric elements are inefficient for generating sounds below 1kHz.

Duty Cycle

Piezoelectric alerts generate very little heat and can be run on a 100% duty cycle.

If an alert will be pulsed briefly, the minimum pulse time is 50ms. A shorter duration will merely generate a clicking sound.

How to Use It

Appropriate Sound Intensity

An indicator should be chosen with reference to the environment in which it will be used. To be easily heard, it should be at least 10 dB louder than the ambient background noise.

Volume Control

Sound intensity can be reduced by reducing the voltage. Because an indicator does not consume much current, a trimmer can serve as a volume control. Alternatively, a rotary switch with a set of fixed-value resistors can select preset sound values.

However, in many indicators, variations in voltage may have relatively little effect on sound output, as shown in Figure 28-4.

Wiring

An indicator requires DC voltage. Because the indicator contains a transistor, polarity of the power supply is important. If the indicator has leads attached, the one intended for connection to the positive side of the power supply will be red. If it has pins, the longer pin will be for the positive connection.

What Can Go Wrong

The potential problems in an indicator are the same as those for a transducer. See "What Can Go Wrong" on page 254 in the previous entry.

headphone

29

The term **headphone** is used here to include almost any device that fits into or over the ear for the purpose of sound reproduction. (*Hearing aids* are not included.) Because headphones are used in pairs, the term is usually pluralized.

The term *phones* is fairly common as a colloquial diminution of *headphones* but is not used here.

An *earphone* used to be a single sound reproduction device designed for insertion into the ear, but has become rare. Pairs of *earbuds* are now common.

Because this encyclopedia assigns more emphasis to electronic components than to consumer products, this entry provides only a superficial overview of fully assembled headphones, and deals more with the drivers inside them, their principles of operation, and the general topic of sound reproduction.

OTHER RELATED COMPONENTS

- **transducer** (see Chapter 27)
- **speaker** (see Chapter 30)

What It Does

A headphone converts fluctuations of an electric signal into pressure waves that the human ear perceives as sound. It can be used for reproduction of music for entertainment purposes, or for speech in telecommunications, broadcasting, and audio recording.

Two symbols for headphones are shown in Figure 29-1. The symbol on the left shows a single headphone or earphone; when this symbol is flipped horizontally, it can represent a microphone. The pictographic symbol on the right has been used for many decades, but is still often found in schematics.

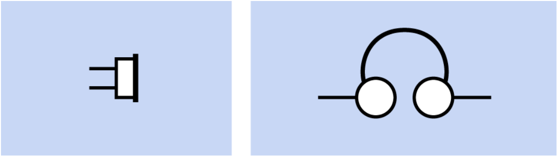

Figure 29-1. *Schematic symbols for a single earphone or headphone (left) and a pair of headphones (right).*

How It Works

Audio Basics

Sound is transmitted as pressure waves through a medium that is usually air but can be a gas, fluid, or solid. The speed of transmission will vary with the density and other attributes of the medium. Small hairs in the inner ears, known as *cilia*, vibrate in sympathy with pressure waves and transmit nerve impulses to the brain, which interprets the impulses as sound.

Three quantities describe the propagation of any type of wave, including a sound wave: its frequency (customarily represented with letter f), its speed of propagation (represented with letter v, for velocity), and its wavelength from peak-to-peak (represented by the Greek letter lambda, which appears as this λ symbol).

The relationship is defined by a very simple equation:

```
v = λ * f
```

Velocity is usually measured in meters per second, wavelength in meters, and frequency in Hertz, abbreviated Hz. One cycle per second is 1Hz. The H is always capitalized, as it refers to the name of Heinrich Rudolf Hertz, the first scientist to prove the existence of electromagnetic waves. One thousand Hertz can be written as 1 kilo-Hertz, almost always abbreviated as 1kHz (note that the k is lowercase).

The human ear is often described as being able to detect sounds between 20Hz and 20kHz, although the ability to hear sounds above 15kHz is relatively unusual and diminishes naturally with age. Sensitivity to all frequencies can be impaired by long-term exposure to loud noise.

Naturally occurring sounds can be converted to fluctuations in voltage by a **microphone**, which will be found listed as a *sensor* in Volume 3 of this encyclopedia. Artificial sounds can be generated as voltage fluctuations by oscillators and other electronic circuits. In either case, the output fluctuations can range between an upper limit set by a positive supply voltage and a lower limit established by electrical ground (which is assumed to be 0 volts). Alternatively, the fluctuations can range between the positive supply voltage and an equal and opposite negative supply voltage, with 0V lying midway between the two. This option can be less convenient electrically but is a more direct representation of sound, because sound waves fluctuate above and below ambient air pressure, which can be considered analogous to a ground state.

The concept of positive and negative sound waves is illustrated in Figure 29-2 (originally published in the book *Make: More Electronics*).

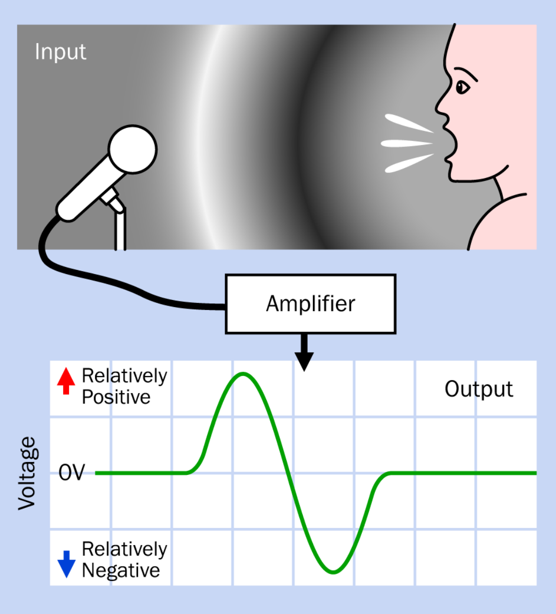

Figure 29-2. *The use of positive and negative voltages to represent a wave of high sound pressure followed by a trough of lower pressure.*

The topic of sound amplification is explored in detail in the entry on *op-amps* in Chapter 7.

A headphone inverts the function of a microphone by converting electricity back into air-pressure waves. This is done electromagnetically (moving a diaphragm in response to an electromagnet) or electrostatically (moving a membrane in response to electrostatic force between two charged electrodes).

Variants

Moving Coil

The most enduringly popular type of headphone uses a coil attached to a *diaphragm*. This is known as a *moving-coil* headphone, as the coil moves with the diaphragm. It can also be referred to as having a *dynamic driver* or *dynamic transducer*, "dynamic" referring to the movement of the coil.

The moving-coil concept is illustrated in Figure 29-3. The coil slides into a deep, narrow, circular slot in a magnet that is attached to the plastic frame of the headphone. The diaphragm is supported at its edges by a flexible rim. Variations in current passing through the coil create a fluctuating magnetic field that interacts with the field of the fixed magnet, causing the diaphragm to move in and out. A very similar configuration is used in many **loudspeakers**. Detail modifications may be made to increase efficiency, reduce production costs, or enhance sound quality, but the principle remains the same.

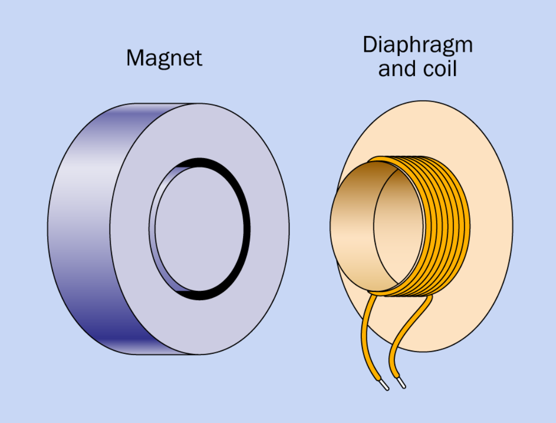

Figure 29-3. *The basic elements of a moving-coil headphone.*

The internal element of a headphone is shown in Figure 29-4. A plastic diaphragm is visible, measuring slightly less than 2" in diameter. The magnet and coil are concealed underneath.

The element in the previous figure is normally enclosed in an assembly such as the one in Figure 29-5, which incorporates a soft padded rim to rest upon the ear.

In an effort to achieve a more balanced frequency response, some designs use two moving-coil drivers in each headphone, optimized for low frequencies and high frequencies, respectively.

Earbuds, described after the next section, often use a miniaturized version of the moving-coil design.

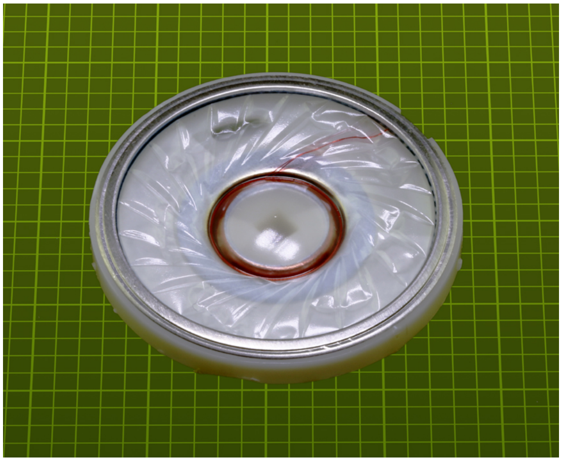

Figure 29-4. *The sound reproducing element removed from a headphone.*

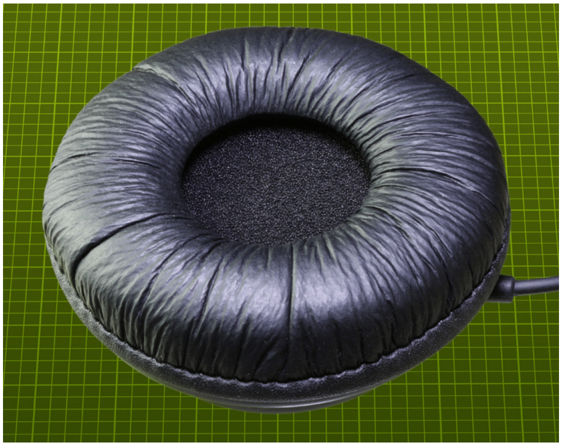

Figure 29-5. *The sound reproducing element from the previous figure is normally packaged inside this enclosure.*

Other Types

Electrostatic headphones use a thin, flat diaphragm suspended between two grids that function as electrodes. A fluctuating potential between the grids, coupled with a reverse-phase voltage on the diaphragm, will vibrate the diaphragm, generating pressure waves. A relatively high voltage is necessary to achieve this, anywhere from 100V to 1,000V, supplied through a conversion unit between the headphones and an amplifier. Electrostatic headphones are known for low distortion and an excellent high frequency response, at some extra cost.

Electret headphones work on a similar principle, except that the membrane is permanently charged, and a high voltage is not required. Electret headphones tend to be small, inexpensive, and not of high sound quality.

A *balanced armature* design, often referred to by the acronym *BA*, uses a pivoting magnet that is claimed to increase efficiency while reducing stress on a diaphragm. BA drivers can be extremely compact, contained within a sealed metal enclosure measuring less than 10mm x 10mm x 5mm. They are commonly used in conjunction with *in-ear* earphones, described in the next section.

Mechanical Design

Circumaural headphones use large soft pads to encircle the ear and block external noise. Their size tends to make them heavy, requiring a well-designed headband to provide comfortable support. *Supra-aural* headphones are smaller and lighter, resting on the ears instead of enclosing them. They cannot exclude ambient noise, and may have inferior bass response compared with the circumaural type.

Open-back headphones, also known as *acoustically transparent*, are favored by some audiophiles because their vented outer surfaces are thought to create a more natural sound, similar to that of a **speaker**. The open backs naturally allow ambient noise to intrude, but also allow the sound generated by the headphones to be heard by others in a room. *Closed-back* headphones contain their sound and provide more insulation against ambient noise.

Earbuds rest just within the outer folds of the ear, facing inward like a pair of tiny **speakers**. They are easily dislodged and provide very little insulation against ambient noise. Their use became common after the introduction of Apple's iPod. A pair of earbuds, one of them with its plastic cover removed, is shown in Figure 29-6.

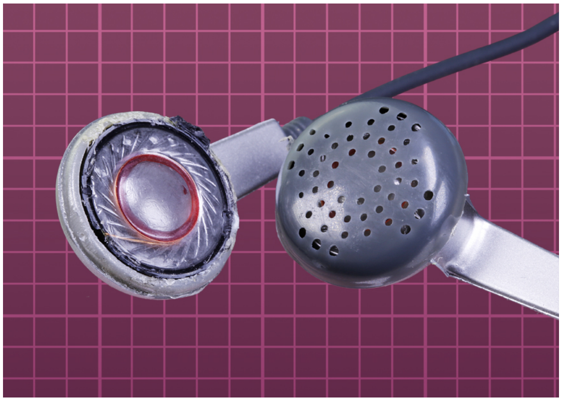

Figure 29-6. *A pair of earbuds, one with its cover removed to show the sound reproducing element, which closely resembles the diaphragm in a full-sized headphone.*

In-ear headphones are designed for insertion into the ear canal, often using a soft sheath that conforms with the ear like an earplug. This sheath is disposable for hygienic reasons, and because it may lose some of its plasticity with use. It excludes most ambient noise, and by minimizing the air gap between the driver of the headphone and the ear drum enables a high quality of sound reproduction.

In-ear headphones are also known as *in-ear monitors*, *IEMs*, *ear canal headphones*, *earphones*, and *canalphones*. A pair of in-ear headphones is shown in Figure 29-7, one of them with its foam sheath removed. The rectangular silver-colored object in the headphone on the left contains a transducer to create sound pressure.

A *headset* consists of one or two headphones plus a flexible microphone that extends to the promiximity of the mouth of the user.

Noise-cancelling headphones, popularized by Bose, monitor external noise with a built-in microphone and generate sound of opposite phase, to provide some cancellation. They are particularly effective on jet aircraft, where background noise tends to be consistent.

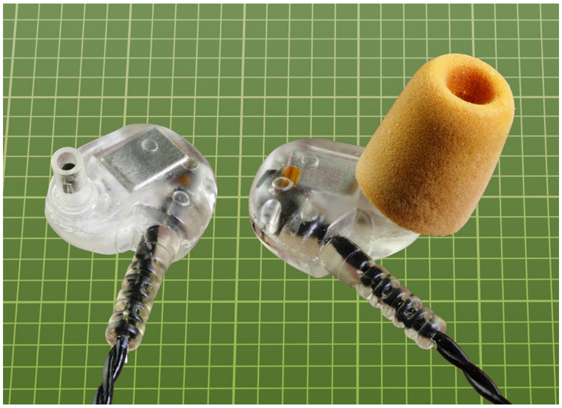

Figure 29-7. *A pair of in-ear headphones, supplied with disposable foam plugs that conform flexibly with the ear canal. The headphone on the left is shown with its plug removed.*

Although an *earphone* is almost obsolete, it is still obtainable from specialty suppliers. It has a high impedance, making it suitable for use with a *crystal-set radio*. An earphone is pictured in Figure 29-8.

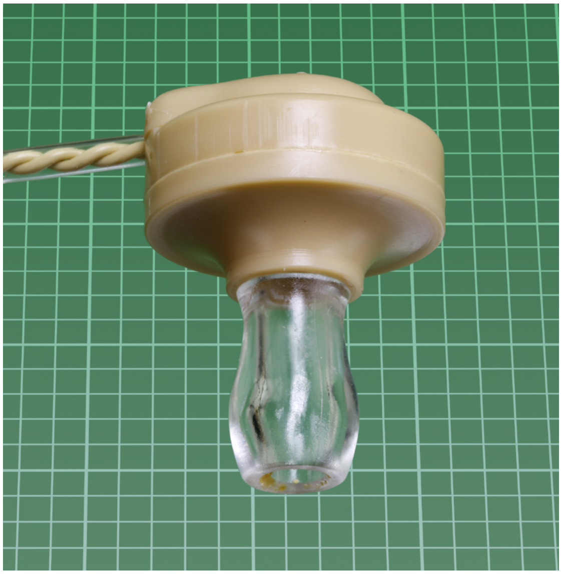

Figure 29-8. *A vintage earphone of the type suitable for use with a crystal-set radio.*

Values

Intensity

Sound pressure is measured in decibels. For a complete explanation and discussion of weighted and unweighted decibel scales, see "Sound Pressure" on page 251 in the **transducer** entry.

Frequency Response

A plot of sound pressure as a function of frequency shows the *frequency response* of a headphone. Measuring the sound pressure meaningfully is a challenge, because the ear canal will add coloration to the sound and can amplify some frequencies while masking others. Ideally, measurement should be done at the ear drum, but this is not feasible. Consequently, high-end headphones are evaluated by making sound measurements inside simulated ear canals in a dummy human head.

A comparison between a high-quality $500 audio product and a transducer that is sold as a component for less than $1 illustrates the difference in frequency response; see Figure 29-9. The Sennheiser headphones have a smooth response that rises toward the low end, compensating for the lack of bass response that tends to be a problem in headphones, and the relative insensitivity of the human ear to low frequencies. The fluctuations at the high end are within about 5dB.

By comparison, the Kobitone emphasizes the range between 3kHz and 4kHz because its primary task is to be heard, and these are the frequencies where human hearing is most sensitive. Its low-frequency response trails off (although is still much better than that of a piezoelectric transducer, where the low response typically diminishes by 40dB to 50dB). The low-frequency output of the Kobitone is actually impressive bearing in mind that the component is only 9mm in diameter. It draws 60mA at 5VAC.

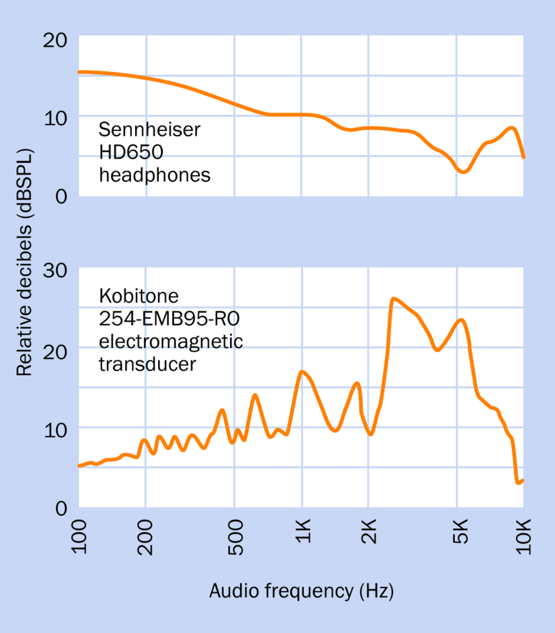

Figure 29-9. *Comparison between frequency responses of a $1 electromagnetic transducer intended as an audio alert and a $500 pair of headphones intended for sound reproduction. The upper graph is derived from a review online at headroom.com; the lower graph is from the manufacturer's datasheet.*

Some manufacturers of audio reproduction equipment prefer not to supply frequency response curves. Instead they may claim, for example, that the frequency response of a product ranges from 100Hz to 20kHz. This claim means very little unless it is accompanied by a range of sound pressure levels. If the frequency response is consistent within a range of, say, plus-or-minus 5dB, this may be acceptable. If the range is plus-or-minus 20dB, it is not acceptable. The ability to reproduce a high note or a low note is not useful if the sound is too faint to hear.

Distortion

The *total harmonic distortion* (THD) of any audio equipment measures its tendency to add spurious *harmonics* of a single frequency. If headphones are required to reproduce a pure 1kHz sinewave, they will also tend to create an additional 3kHz tone that is an artifact. This can be caused by the mechanical behavior of a vibrating diaphragm. The human ear recognizes distortion as a fuzzy or rasping sound. A square wave theoretically contains all the harmonics that are odd multiples of its fundamental frequency, and sounds extremely distorted.

THD should be less than 1% in good-quality audio devices.

Impedance

The electrical impedance of headphones is relevant in that it should match the output specification of the amplifier that drives them.

What Can Go Wrong

Overdriving

Headphones can be damaged by overdriving them. Because a low frequency requires larger excursions of a diaphragm to transmit the same energy as a high frequency, headphones are especially vulnerable to being damaged by bass at high volume.

Hearing Damage

Human hearing can be damaged by prolonged listening to headphones at a high volume. Some controversy remains regarding an acceptable limit for sound pressure.

Mismatched Impedance

If the impedance of headphones does not match the output of the amplifier driving them, distortion or a skewed frequency response can result. This is known as *mismatching*.

Incorrect Wiring

In most consumer products, a pair of headphones will share a common ground. While the connections in a typical three-layer jack plug have been standardized, hand-wired repairs or extensions should be tested carefully. Incorrect wiring will cause unpredictable results.

speaker

30

The term **speaker** is a diminution of *loudspeaker*. The full word is now so rarely used, some catalogs do not recognize it as a search term. This encyclopedia acknowledges contemporary usage by using **speaker** rather than *loudspeaker*.

A fully assembled consumer product can be referred to as a "speaker," but it also contains one or more individual components that are described as "speakers." To resolve this ambiguity, referring to the components as *drivers* is helpful, but this practice can create more ambiguity because other types of components are also called "drivers." The only real guide to the meaning of *speaker* is the context in which it is used.

For the purposes of this entry, a speaker is a *sound reproduction device*, distinguished from a typical electromagnetic **transducer** by being larger and more powerful, with a more linear frequency response. A transducer may be used as a *noise-creating device* to provide an alert, informing the user of the status of a piece of equipment. Because some speakers have been miniaturized for use in handheld products, they may be used as transducers, allowing some overlap between the two categories.

Because this encyclopedia assigns more emphasis to electronic components than to consumer products, this entry provides only a superficial overview of fully assembled speakers, and deals more with the drivers inside them, their principles of operation, and the general topic of sound reproduction.

OTHER RELATED COMPONENTS

- **headphone** (see Chapter 29)
- **transducer** (see Chapter 27)

What It Does

A speaker converts fluctuations of an electric signal into pressure waves that the human ear perceives as sound. It can be used for entertainment purposes or to provide information in the form of spoken words or distinctive sounds (as in the case of a miniature speaker in a cellular phone, playing a ring tone).

The internationally accepted schematic symbol for a speaker is shown in Figure 30-1.

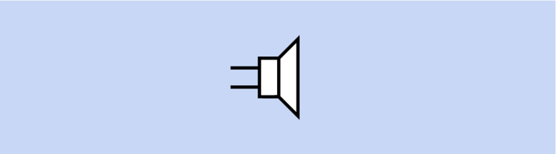

Figure 30-1. *Only one symbol exists to represent a speaker. This is it.*

How It Works

For a summary of basic concepts and terminology relating to sound and its reproduction, see "Audio Basics" on page 261 in the previous entry.

Construction

A speaker contains a *diaphragm* or *cone* with a coil attached to it. Fluctuations of current through the coil interact with a permanent magnet, causing the speaker to emit pressure waves that are proportionate with the current. The design is similar in concept to that of a headphone, shown diagrammatically in Figure 29-3. The primary difference is that a speaker of around 2″ or more will use a cone rather than a flat diaphragm. The cone shape is more rigid and creates a more directional sound.

A 2″ speaker rated for 1/4W with a 63Ω coil is shown in Figure 30-2, undamaged on the left but with its cone cut out on the right. The neck of the cone, which is normally inserted in the circular groove in the speaker magnet, is shown with the inductive coil wrapped around it.

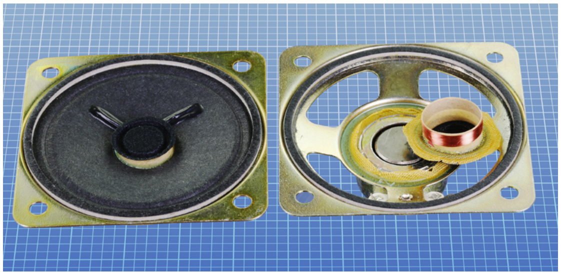

Figure 30-2. *On the left is a 2″ speaker. On the right, its cone has been cut away to reveal the magnet, with a circular groove in it. The neck of the cone, which normally slides into the groove, is shown removed.*

A speaker with a cone 4″ in diameter is shown from the rear in Figure 30-3.

A miniature surface-mount speaker is shown from the front and from the rear in Figures 30-4 and 30-5. It measures just under 0.4″ diameter and was made for Motorola. Its power rating is 50mW.

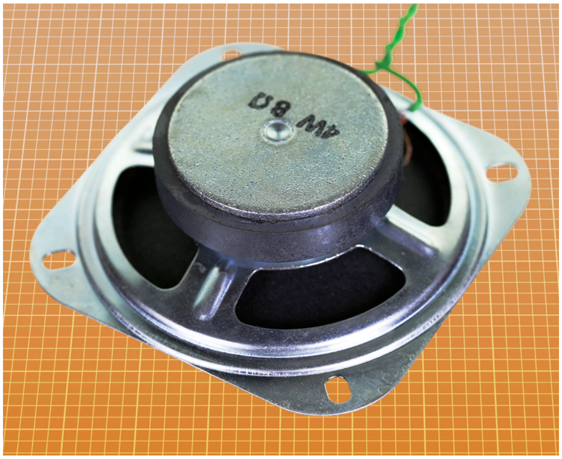

Figure 30-3. *The back side of a speaker with a cone measuring approximately 4″ in diameter. Its magnet is the large round section that is uppermost. This unit is rated for 4W and has an impedance of 8Ω.*

A speaker designed for a cellular phone is shown in Figure 30-6. Note the close resemblance in design to the driver used in an earbud, shown in Figure 29-6 in the previous entry.

In the past, speaker cones were made from tough, fibrous paper. Modern cones are more likely to be plastic, especially in small sizes.

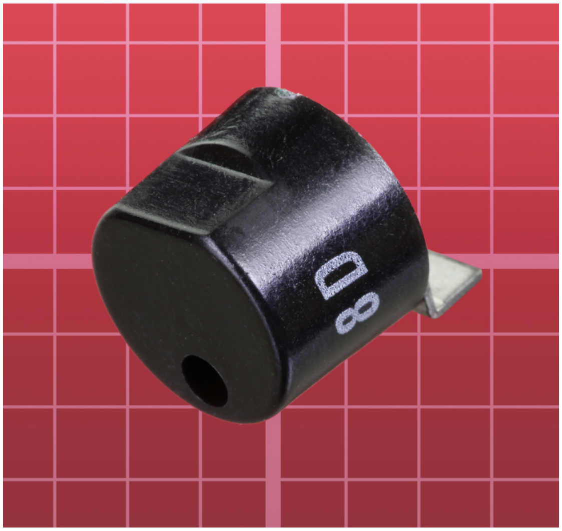

Figure 30-4. *Front view of a surface-mount speaker measuring less than 0.4″ diameter.*

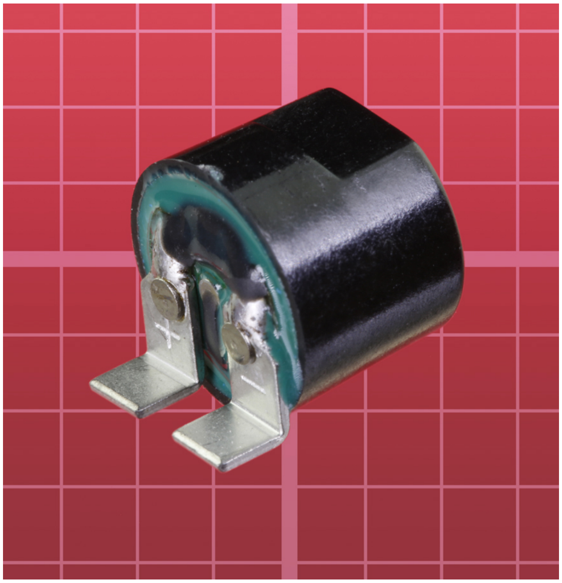

Figure 30-5. *Rear view of the speaker shown in the previous figure.*

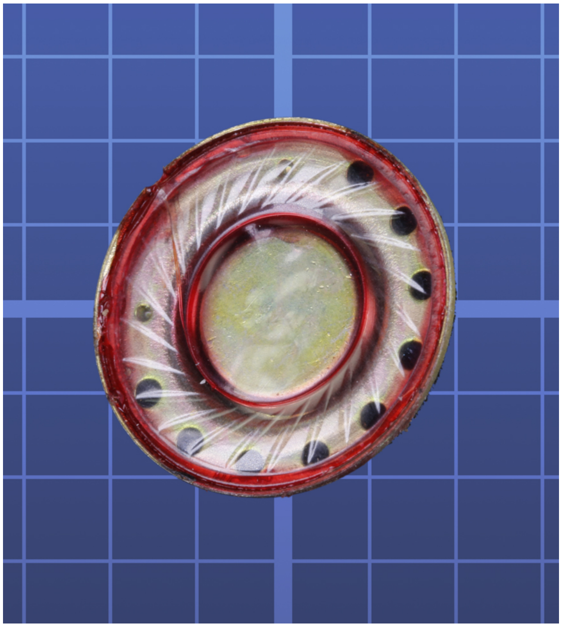

Figure 30-6. *A miniature speaker measuring slightly more than 1/2" diameter and only 0.13" thick, designed for use in a cellular phone. It has an impedance of 150Ω.*

Multiple Drivers

Generally speaking, a large-diameter speaker cone is more effective than a small cone at moving the greater volumes of air associated with reproduction of bass notes. However, the inertia of a large cone impairs its ability to vibrate at high frequencies.

To address this problem, a large speaker and a small speaker often share a single enclosure. A *crossover network* using coils and capacitors prevents low frequencies from reaching the small speaker and high frequencies from reaching the large speaker. The basic principle is shown in the simplified schematic in Figure 30-7.

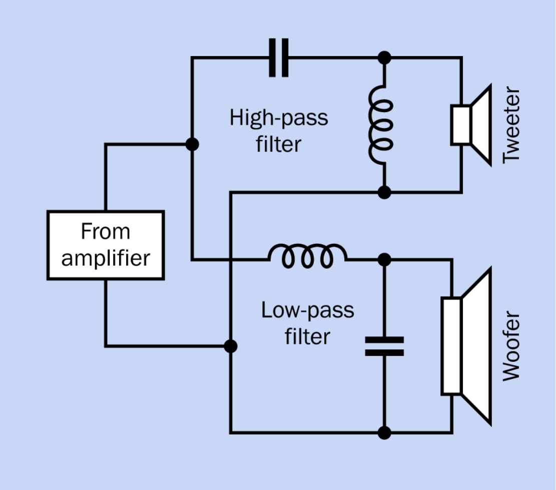

Figure 30-7. *The basic principle of a crossover network.*

Because the crossover network must be "tuned" to match the characteristics of the speakers, and because the combined sound pressure of the speakers must be relatively consistent over a wide range of frequencies, an actual network usually includes additional components.

Because the audio output from an amplifier consists of alternating current, polarized capacitors cannot be used. Polyester capacitors are common.

The small speaker in a pair is known as a *tweeter* while the large speaker is a *woofer*. Although these appellations were whimsically coined, they have endured.

More than two speakers may be combined in an enclosure, in a wide variety of configurations.

Venting

A speaker radiates pressure waves from the back side of its cone as well as from the front, and because the waves from front and back are opposite in phase, they will tend to cancel each other out.

In a miniature speaker, this problem can be addressed simply by sealing the section of the enclosure at the rear. For larger components, a more efficient enclosure can be designed with a *vent* or *reflex port* at the front. Pressure waves from the back of the speaker are diverted over a sufficient distance inside the cabinet so that by the time they emerge through the port, they are approximately in phase with low frequencies from the front of the speaker, although the back wave will lag the front wave by one wavelength.

This design is referred to as a *bass-reflex enclosure*, and was almost universal in high-fidelity components until amplifiers became increasingly powerful during the 1960s. At that point, Acoustic Research, located in Massachusetts, marketed a product line in which speaker enclosures were sealed, the argument being that when an amplifier can deliver 100W per channel, efficiency is no longer an issue, and a sealed enclosure can eliminate compromises associated with a bass-reflex design.

Acoustic Research referred to their concept as “air suspension,” as the cushion of air in the sealed cavity helped to protect the speaker by limiting its excursion. This configuration is now often referred to as a *closed-box speaker*. Some audiophiles argue that it must always be inherently superior to a bass-reflex design, partly because of the one-wavelength lag time associated with a reflex port. However, as in many aspects of sound reproduction, the debate is inconclusive.

Resonance

The enclosure for a speaker will tend to have a dominant resonant frequency. This should be lower than the lowest frequency that the speaker will reproduce; otherwise, the resonance will emphasize some frequencies relative to others, creating unwanted peaks in the response.

One reason why high-quality speakers tend to be physically heavy is to reduce their resonant frequency. A modern Thiel speaker assembly, for instance, uses a front panel of particle board that is a full 2″ thick. However, heavy enclosures are expensive to transport and inconvenient to locate or relocate in the home.

To address this problem, a tweeter and a woofer can be mounted in separate boxes. The enclosure for the tweeter can be very small, lightweight, and suitable for placement on a shelf, while the heavy box for the woofer can go on the floor. Human senses have difficulty locating the source of low-frequency sound, so the woofer can be located almost anywhere in a room. In fact, its single speaker can serve both stereo channels.

This configuration has become the default for computer speakers. It is also used in home-theater systems, where the woofer has now become a subwoofer capable of very low frequency reproduction.

Miniature Speakers

If an electronics project has an audio output, and the circuit board will be sharing an enclosure with a small speaker, the size of the box and the material from which it is fabricated will affect the sound quality significantly. A box made from thin hardwood may add resonance that sounds pleasing, if the speaker is being used just for simple electronic tones. By comparison, a metal box may sound “tinny.” A box fabricated from a plastic such as ABS will be relatively neutral, provided the plastic is reasonably thick (1/4″ being preferable).

Variants

Electrostatic Speaker

The principle of an electrostatic speaker is the same as that of an electrostatic headphone. A charged membrane is stretched between two grids in front of it and behind it that act as electrodes. Because the membrane is so light, it responds with very little latency, and its large surface area creates a diffused sound that many audiophiles find pleasing. However, a high voltage is required to drive electrostatic speakers, and they are not cheap.

Powered Speakers

A unit containing its own driver electronics is referred to as a *powered speaker*, and is used almost universally with desktop computers, because the computer itself does not contain a power amplifier. Powered speakers may also enable a more versatile crossover network.

A subwoofer may have its own amplifier allowing control of the cutoff frequency above which the speaker will not attempt to reproduce sound. The electronics can include protection for a speaker against being overdriven.

Wireless Speakers

A wireless link between a stereo receiver and its speakers will eliminate the speaker wires that are normally necessary. However, the speakers themselves must be powered, and will have to be wired to electric outlets.

Innovative Designs

The need for small speakers in consumer products such as laptop computers has encouraged innovative designs. The speaker in Figure 30-8 is just 1" square, and its shape is easier to accommodate in a small product than the traditional circular speaker. In Figure 30-9, the interior of the same speaker shows that inductive coils are applied to a square plastic diaphragm.

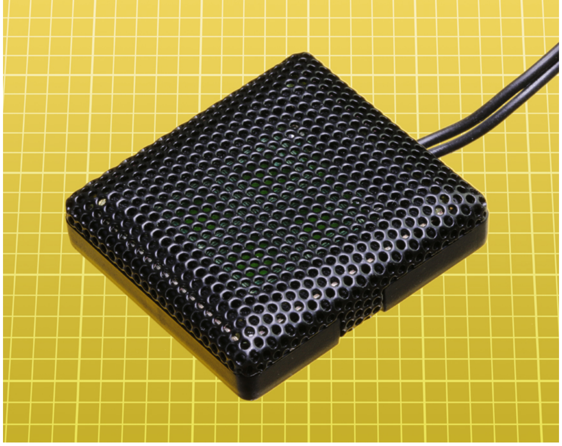

Figure 30-8. *A speaker 1" square, suitable for use with a small electronic device.*

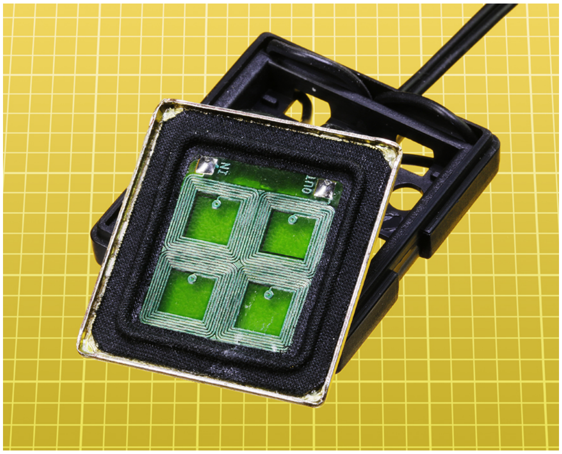

Figure 30-9. *The speaker from the previous figure, opened to show its inductive coils applied to a square plastic diaphragm.*

Values

The typical *impedance* for speakers in audio systems is 8Ω. Small speakers may have a higher impedance, which can be useful when driving them from devices that have limited power, such as a TTL-type 555 timer.

In the United States, the diameter of a circular speaker is usually expressed in inches. Speakers larger than 12" are rare for domestic use. A 4" speaker used to be considered minimal because of its limited low-end frequency response, but much smaller speakers have become common in portable devices.

The low-end frequency response of a miniature loudspeaker designed to be surface-mounted on a circuit board will be very poor. The graph in Figure 30-10 was derived from data supplied by the manufacturer.

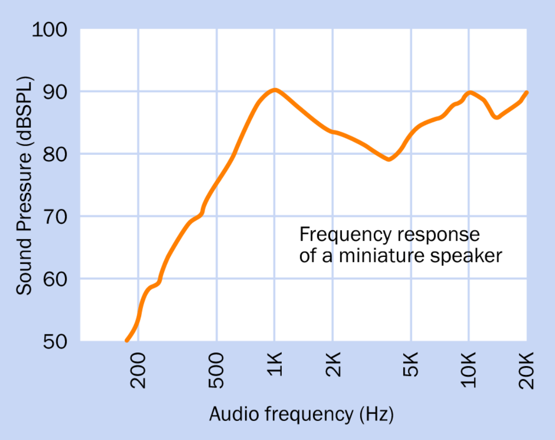

Figure 30-10. *Frequency response for a speaker measuring 15mm x 15mm x 5mm. Small dimensions and lack of an enclosure result in a negligible low-end response.*

Power rating for speakers is in watts, measured on a root-mean-square (RMS) basis.

Sensitivity is measured in decibels, at a distance of one meter, while a speaker is reproducing a single constant tone with a power input of 1W. A speaker assembly designed for undemanding home use may be rated at 85dB to 95dB.

Efficiency is a measure of sound power output divided by electrical power input. A value of 1% is typical.

What Can Go Wrong

Damage

As is the case with headphones, the most common problem affecting a speaker is damage caused by overdriving it. Because a low frequency requires larger excursions of a speaker cone to transmit an amount of energy comparable to that of a high frequency, loud bass notes can be hazardous to the cone. On the other hand, if an amplifier generates distortion (perhaps because it, too, is being overdriven), the harmonics created by the distortion can damage high-frequency speakers.

Magnetic Field

Even a small speaker (measuring 2" or less) contains a magnet that is sufficiently powerful to cause problems if it is in close proximity to other components, especially if sensors such as reed switches or Hall-effect switches are being used. Initial circuit testing should be done with the speaker as far away as possible, to eliminate it as a source of interference.

Vibration

Solder joints will be stressed if they are subjected to low-frequency vibration from a speaker. Loose parts may rattle, and parts that are bolted into place may become unbolted. The speaker itself may become loose. Thread-locker such as Loc-Tite should be applied to nuts before they are tightened.

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To Brian Jepson

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Preface

This third and final volume of the *Encyclopedia of Electronic Components* is devoted entirely to sensors.

Two factors have caused very significant changes in the field of sensors since the 1980s. First, features such as antilock braking, airbags, and emissions controls stimulated the development of low-priced sensors for automotive applications. Many of these sensors were fabricated in silicon as MEMS (microelectromechanical) devices.

The second wave began in 2007 when MEMS sensors were installed in the iPhone. A modern phone may contain almost a dozen different types of sensors, and their size and price have been driven down to a point that would have been unimaginable 20 years previously.

Many MEMS sensors are now as cheap as basic semiconductor components such as a voltage regulator or a logic chip, and they are easy to use in conjunction with microcontrollers. In this Encyclopedia, we have allocated significant space to this segment of the market, hoping that the specific products that we have chosen will remain popular and available for at least the next decade.

In addition, we have devoted space to older components where durability has been proven.

Purpose

While much of the information in this volume can be found dispersed among datasheets, introductory texts, Internet sites, and technical briefings published by manufacturers, we believe there is a real need for a durable resource that assembles all the relevant data in one place, properly organized and verified, including details that may be hard to find elsewhere.

This volume may also serve a useful purpose by attempting to categorize and classify components in a field that is remarkably chaotic. For example, is an *object presence sensor* different from a *proximity sensor*? Some manufacturers seem to think so; others disagree. Understanding the distinctions and the underlying principles can be important if you are trying to decide which sensor to use.

Sensor terminology can also be confusing. To take another example, what is the difference between a *reflective interrupter*, a *reflective object sensor*, a *reflective optical sensor*, a *reflective photointerrupter*, and an *opt-pass sensor*? These terms are used in various datasheets to describe components that are all *retroreflective sensors*. Understanding the proliferating variety of terminology can be essential if you simply want to find something in a product index.

Organization

As in volumes 1 and 2, this volume is organized by subject. For example, if you want to measure temperature, you'll find the entries for a thermistor and a thermocouple next to each other, in an entire section devoted to the sensing of heat. This will help you to compare capabilities and choose the component that best suits your application.

The subject path leading to each sensor is shown at the top of the first page of each entry. For gas flow rate, for instance, you would follow this path:

```
fluid > gas > flow rate
```

Note that the word "fluid" is properly used to include gases as well as liquids.

Exceptions and Conflicts

Unfortunately, some sensors are not easily categorized. There are four problems in this area.

1. What Does a Sensor Really Sense?

A GPS chip is a radio receiver, picking up transmissions from satellites. Does this mean it should be categorized as a sensor of radio waves? No, its purpose is to tell you your location. Therefore, it is categorized as a location sensor. This leads to the first general rule: sensors are categorized by their primary purpose. Secondary purposes may be found in the index.

2. How Many Sensors Are in a Sensor?

Many surface-mount chips perform more than one sensing function. For example, an inertial measurement unit (often identified by its acronym, *IMU*) can contain three gyroscope sensors and three accelerometers—and may contain three magnetometers, too. How should it be categorized?

The answer is that an IMU will be mentioned in more than one entry in the Encyclopedia, because it performs more than one function; but it will not have its own separate entry, because each entry in the Encyclopedia is for a single primary sensing function.

The names of multisensor chips are, of course, included in the index.

3. How Many Stimuli Can One Sensor Sense?

A single sensing element may be used in multiple different types of sensors. The most notable example is the Hall-effect sensor, which can be found in magnetometers, object presence sensors, speed sensors, current sensors, and dozens more. Modern automobiles can contain Hall-effect sensors everywhere from the ignition system to the trunk-locking mechanism. If you are using a hard drive with rotating platters, it probably contains a Hall-effect sensor to monitor the speed of rotation. If you have a generic computer keyboard, each keypress is probably detected with a Hall-effect sensor.

Bearing this in mind, how should a Hall-effect sensor be classified? And where should you expect to find an explanation of how it works?

The answer is that where different types of components contain the same type of sensing element, the entry for each component will include a cross-reference to one location where the sensing element is explained in detail.

This location will be chosen for its relevance. Thus, Hall-effect sensors are explained in the entry for **object presence** sensors, because this is their primary function. While it is true that a Hall-effect sensor works by detecting a magnetic field, that is not its most common application.

4. Too Many Sensors!

Wikipedia lists more than 100 general types of sensors, and even that list is probably not complete. Consequently, we had to pick and choose. Some of the decisions may seem arbitrary, but all of them were made on the grounds of practicality. There were three principles for deciding what to include and what to leave out.

1. Is it a component? We are more interested in board-mounted components than in packaged products that happen to contain sensors. For instance, a thermocouple is often enclosed in a tubular steel probe, and its wire is often plugged in to a specially designed meter that displays temperature. While we do include a photograph of a probe, we are primarily interested in the welded wires of the thermocouple inside it.
2. How much does it cost? An industrial ultrasonic sensor to check items on a factory conveyor belt will be sealed into a module with a waterproof grommet around a shielded cable—which is all very nice, but will not be very affordable. This Encyclopedia is more interested in board-mountable components for one-tenth of the price.
3. How many people are likely to want it? The stock of each type of sensor was checked on component vendor sites. If a sensor wasn't in the inventory, or if only a couple of variants were stocked, we concluded that the limited demand probably didn't justify including it here. For example, a Ferraris acceleration sensor responds to eddy currents in a rotating motor shaft, as a way of measuring vibration in the shaft. This is a really interesting device, but is unlikely to be on most people's shopping lists.

Volume Contents

Having explained the organization of this book and our decisions to include or omit various components, we now present a summary of the contents of all three Encyclopedia volumes:

Volume 1

Power; electromagnetic devices; discrete semiconductors.

The *power* category includes sources of electricity and methods to distribute, store, interrupt, convert, and regulate power. The *electromagnetism* category includes devices that exert force linearly, and others that create a turning force. *Discrete semiconductors* include the primary types of diodes and transistors. See Figure P-1 for a contents listing.

Primary Category	Secondary Category	Component Type
power	source	battery
	connection	jumper
		fuse
		pushbutton
		switch
		rotary switch
		rotational encoder
	moderation	relay
		resistor
		potentiometer
		capacitor
		variable capacitor
	conversion	inductor
		AC-AC transformer
		AC-DC power supply
		DC-DC converter
		DC-AC inverter
	regulation	voltage regulator
electro-magnetism	linear output	electromagnet
		solenoid
	rotational output	DC motor
		AC motor
		servo motor
		stepper motor
discrete semi-conductor	single junction	diode
		unijunction transistor
	multi-junction	bipolar transistor
		field-effect transistor

Figure P-1 *The subject-oriented organization of categories and entries in Volume 1 of this Encyclopedia.*

Volume 2

Thyristors (SCRs, diacs, and triacs); integrated circuits; light sources, indicators, and displays; and sound sources.

Integrated circuits are divided into analog and digital components. *Light sources, indicators, and displays* are divided into reflective displays, single sources of light, and displays that emit light. *Sound sources* are divided into those that create sound, and those that reproduce sound. A contents listing for Volume 2 appears in Figure P-2.

Volume 3

All the most common types of sensing devices, including those that detect location, presence, proximity, orientation, oscillation, force, load, human input, liquid properties, gas types and concentrations, pressure, flow rate, light, heat, sound, and electricity. A contents listing for Volume 3 appears in Figure P-3.

Method

Reference Versus Tutorial

As its title suggests, this is a reference book, not a tutorial. A tutorial such as *Make: Electronics* begins with elementary concepts and builds sequentially toward concepts that are more advanced. A reference book assumes that you may dip into the text at any point, learn what you need to know, and then put the book aside. If you choose to read it straight through from beginning to end, you will find some repetition, as each entry is intended to be self-sufficient, requiring minimal reference to other entries.

Theory and Practice

This book is oriented toward practicality rather than theory. We assume that the reader mostly wants to know how to use electronic components, rather than why they work the way they do. Consequently we do not include detailed proofs of formulae or definitions rooted in electrical theory.

Primary Category	Secondary Category	Component Type
discrete semi-conductor	thyristor	SCR
		diac
		triac
integrated circuit	analog	solid-state relay
		optocoupler
		comparator
		op-amp
		digital potentiometer
		timer
	digital	logic gate
		flip-flop
		shift register
		counter
		encoder
		decoder
		multiplexer
light source, indicator or display	reflective	LCD
	single source	incandescent lamp
		neon bulb
		fluorescent light
		laser
		LED indicator
		LED area lighting
	multi-source or panel	LED display
		vacuum-fluorescent
		electroluminescence
sound source	audio alert	transducer
		audio indicator
	reproducer	headphone
		speaker

Figure P-2 *The subject-oriented organization of categories and entries in Volume 2.*

Primary Category	Attribute to be Sensed	Type of Sensor
spatial	location	GPS
		magnetometer
	presence	object presence
		passive infrared
	distance	object proximity
		linear position
	orientation	rotary position
		tilt
		gyroscope
		accelerometer
mechanical	oscillation	vibration
	force	force
	human input	single touch
		touch screen
fluid	liquid	liquid level
		liquid flow rate
	gas/liquid	pressure
	gas	gas concentration
		gas flow rate
radiation	light	photoresistor
		photodiode
		phototransistor
	heat	NTC thermistor
		PTC thermistor
		thermocouple
		RTD
		semiconductor
		infrared temperature
	sound	microphone
electricity	metering	current
		voltage

Figure P-3 *The subject-oriented organization of categories and entries in Volume 3.*

Sensor Output

In Volumes 1 and 2 of the *Encyclopedia*, each entry included hints on how to use a component. However, many sensors have identical forms of output, which are processed in a similar way. To avoid repetition, general guidance for using nine principal types of sensor outputs has been placed in Appendix A at the back of this volume.

For example, many sensors provide an analog voltage output that varies with the phenomenon that is being sensed. In Appendix A, you will find suggestions on how to adjust the range of the output, if necessary, or how to digitize it with an analog-to-digital converter.

You will also find a comparison between serial protocols such as I2C and SPI, both of which are commonly used when a microcontroller communicates with a digital sensor via a bus.

Glossary

In the world of sensors, many terms tend to recur. *Hysteresis* is one; *MEMS* is another. Rather than define these terms repeatedly, some quick definitions are gathered in a Glossary. Please remember the existence of the glossary if you encounter a term that is unfamiliar. See Glossary.

In many instances, terms that are italicized in the text are defined in the glossary.

Typographical Conventions

Within each entry, **bold type** is used for the first occurrence in each entry of the name of a component that has its own entry elsewhere. Other important electronics terms or component names may be presented in *italics*.

The names of components, and the categories to which they belong, are all set in lowercase type, except where a term is normally capitalized because it is an acronym or a trademark, or contains a proper noun. The term *Hall effect*, for instance, has an initial cap because it is named after a person named Hall. The term *GPS* is all in caps, because it is an acronym; but *psi* (meaning pounds per square inch) remains in lowercase, because even though it is an acronym, the lowercase form is more common.

The situation is different when specifying units that are named after electrical pioneers. All of these units should be lowercased when spelled out. Thus, when referring to the SI unit of force, it is "the newton." However, where a unit named after a person is abbreviated, the abbreviation is capitalized, as in N for newtons, Hz for hertz, Pa for pascals, and A for amperes.

Mathematical Syntax

In mathematical formulae, we have used the style that is common in programming languages. The * (asterisk) is used as a multiplication symbol, while the / (forward slash) is used as a division symbol. Where some terms are in parentheses, they must be dealt with first. Where parentheses are inside parentheses, the innermost ones must be dealt with first. Consider this example:

```
A = 30 / (7 + (4 * 2) )
```

You would begin by multiplying 4 times 2, to get 8; then add 7, to get 15; then divide that into 30, to get the value for A, which is 2.

Visual Conventions

Figure P-4 shows the conventions that are used in the schematics in this book. A black dot always indicates a connection, except that to minimize ambiguity, the configuration at top-right is avoided, and the configuration at top-center is used instead. Conductors that cross each other without a black dot do not make a connection. The styles at bottom right are sometimes seen elsewhere, but are not used here.

All the schematics are formatted with pale blue backgrounds. This enables components such as switches, transistors, and LEDs to be highlighted in white, drawing attention to them and clarifying the boundary of the component. The white areas have no other meaning.

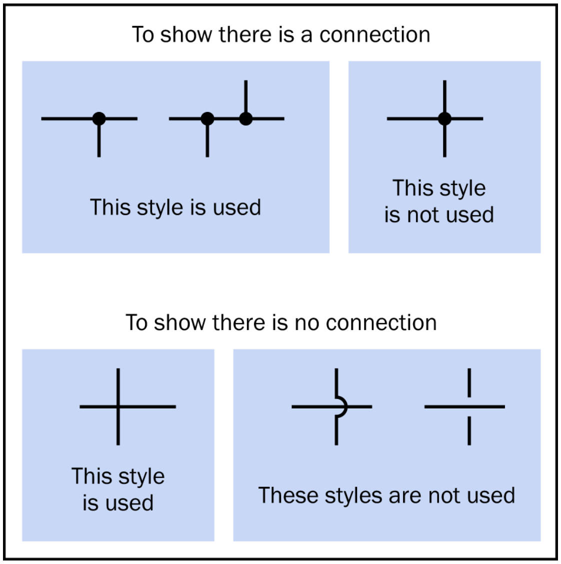
To show there is a connection
This style is used
This style is not used
To show there is no connection
This style is used
These styles are not used

Figure P-4 *Visual conventions that are used in the schematics in this book.*

Units and Backgrounds

So long as the United States clings stubbornly to the habit of expressing dimensions in inches, there is a good argument to follow this custom in books intended for an American audience. With this in mind, Volumes 1 and 2 mostly avoided metric units of length. However, as time passed, the books were translated for use in many parts of the world where the inch is regarded as an anachronism.

Recognizing that we now have an international audience, we have used the metric system throughout this volume (with very few exceptions, such as a photograph of an American plumbing fixture that is designed to fit 3/4" pipe). For readers who are metrically impaired, here are some units of length, and their abbreviations:

- 1 nanometer (nm)
- 1 micrometer (μm) = 1,000nm
- 1 millimeter (mm) = 1,000μm
- 1 centimeter (cm) = 10mm
- 1 meter (m) = 100cm = 1,000mm

A micrometer is also known as a *micron*.

The basic conversion factor from meters to inches is 0.0254. Thus:

- 1 inch = 2.54cm = 25.4mm
- 1/1000 inch = 25.4µm

Sometimes 1/1000 inch is called a *mil*.

In many of the component photographs, a graph-paper background is included. Each square in these backgrounds is 1mm.

To avoid confusion, please remember that a few of these same component photographs appeared in books such as *Make: More Electronics*, where the background grid was in tenths of an inch. Captions to photographs in this volume will remind you that millimeters are now used.

Background colors in the photographs were chosen for contrast with the colors of the components, or for visual variety. They have no other significance.

Component Availability

The world of sensors is changing rapidly, and we have no way of knowing if a component will enjoy a long production run. We recommend checking availability at the following suppliers, which we used frequently during the preparation of the book:

- *http://www.mouser.com*
- *http://www.jameco.com*
- *http://www.sparkfun.com*
- *http://www.adafruit.com*

For obsolete parts, or those that are nearing the end of their commercial life, eBay can be very useful. Alternatively, new substitutions for old parts are often listed at *http://www.mouser.com*.

Issues and Errata

There are three situations where the reader and the writer may want to communicate with each other.

- We may want to tell you if the book contains a mistake of some significance. This is *us-informing-you* feedback.
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Responses in the past have been generally positive, but in a couple of cases people have been annoyed over small issues such as being unable to find a part online. Help is available on this kind of topic, if you need it. All you have to do is send a request to *make.electronics@gmail.com*.

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You can access the errata page at *http://bit.ly/encyclopedia-electronic-components-v3*.

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To comment or ask technical questions about this book, send email to:

bookquestions@oreilly.com.

Acknowledgments

Datasheets and tutorials maintained by component manufacturers were considered the most trustworthy sources of information online. In addition, component retailers, college texts, crowd-sourced reference works, and hobbyist sites were used. The following books provided useful information:

Boylestad, Robert L. and Nashelsky, Louis: *Electronic Devices and Circuit Theory*, 9th edition. Pearson Education, 2006.

Braga, Newton C.: *CMOS Sourcebook*. Sams Technical Publishing, 2001.

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In addition, three individuals provided special assistance. Our editor, Brian Jepson, was immensely helpful in the development of this book. Philipp Marek reviewed the text for errors, and Erico Narita collaborated on the Photoshop work.

GPS

1

The acronym **GPS** properly refers to the entire Global Positioning System, including satellites and ground-based control installations. However, a *GPS sensor* consists of a surface-mount chip that processes signals from GPS satellites using a small rectangular antenna, often mounted on top of a *GPS chip*.

A *GPS module* is usually a small board on which a GPS sensor is mounted with additional components. A *GPS receiver* is a device including a data display and other features, such as memory, in addition to a GPS module. In casual colloquial usage, someone who refers to "a GPS" usually means a GPS receiver.

GPS is almost always capitalized without periods.

OTHER RELATED COMPONENTS

- **magnetometer** (see Chapter 2)

What It Does

The Global Positioning System is a navigational aid jointly funded by the U.S. Department of Defense and the U.S. Department of Transportation, while being maintained by the U.S. Air Force. Signals from GPS satellites can be received and processed by modules in a wide variety of equipment ranging from aircraft to wristwatches. The signals provide location data, and may also be used as an accurate time reference.

Schematic Symbol

There is no specific schematic symbol for a GPS chip. It is likely to be shown as a box containing abbreviations that define pin functions, similar to any integrated circuit chip.

GPS Segments

The Global Positioning System consists of three segments:

The space segment

This originally required 24 communications satellites, but was revised in 2011 to require 27, to provide better global coverage. As of August 2015, there were actually 31 satellites in service, with additional "spares" that can be activated if necessary. The satellites occupy orbits 12,500 miles above the Earth, allowing each of them to circle the planet twice in 24 hours. Specifications are maintained online.

The control segment

This includes a master ground-based control station, an alternate master control station, 12 command and control antennas, and 16 monitoring sites, all maintained by the U.S. Air Force.

The user segment
This consists of receiving devices, including those that are government-owned and those that are privately owned.

How It Works

Each satellite carries multiple atomic clocks that maintain precise time, and a pseudo-random number generator in the form of a linear-feedback **shift register** (see Volume 2).

A GPS receiver can distinguish the signals from at least four satellites by comparing their received pseudo-random bit sequences, and can compute the receiver's distance to each satellite by comparing the arrival times of satellite signals.

When a satellite appears above the horizon, it approaches a receiver. After passing overhead, it moves away. This relative motion causes a *Doppler shift* in the received frequency, which the receiver circuit must take into account.

GPS satellites transmit on several frequencies simultaneously. The one for civilian use is 1575.42 MHz, called L1. Another one, 1227.6 MHz, called L2, is reserved for military use.

Variants

A GPS chip generally processes input from an antenna and provides output through solder pads. The antenna is often integrated as a ceramic square or rectangle mounted above the chip, but many chips can also process input from an external antenna. Figure 1-1 shows a GPS chip with a metal shield that is easily mistaken for an antenna. In Figure 1-2, the GPS sensor does incorporate a ceramic antenna.

Some GPS chips contain flash memory for internal data logging, although this is not a standard feature.

Suppliers such as Adafruit and Sparkfun offer GPS modules mounted on breakout boards for easier connection with other components, as shown in Figure 1-2. Some breakout boards also include provision for battery backup with a button cell.

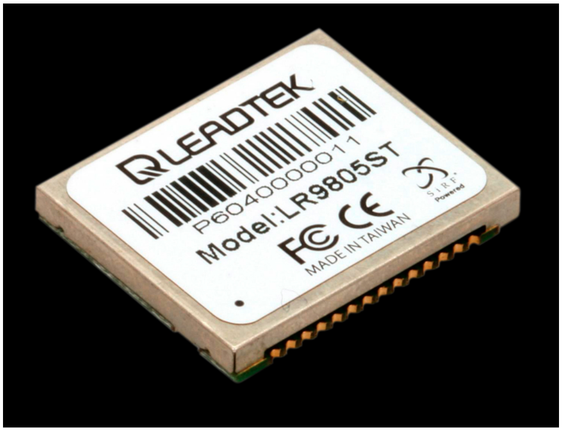

Figure 1-1 *A GPS sensor. This surface-mount chip is hidden beneath a metal shield.*

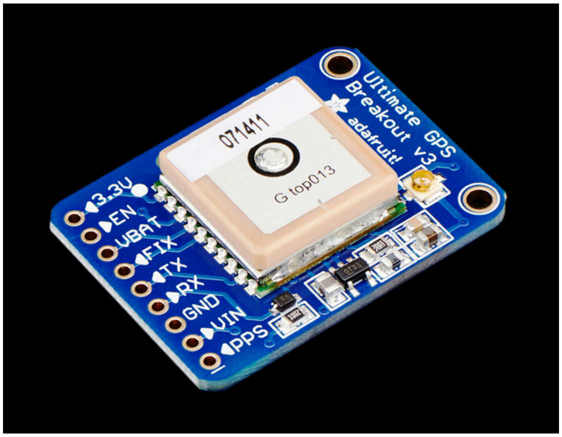

Figure 1-2 *A breakout board offered by Adafruit, incorporating a GPS sensor.*

GPS capability is almost always included in modern smartphones and tablets. It is used in handheld devices for navigation on foot, and in devices designed to be mounted in motor vehicles. Cars offer GPS capability as an option accessed via a built-in screen.

A *GPS tracker* is a device that may lack a display and simply logs its position to internal memory, from which data can be downloaded to a computer later. Many (older) handheld GPS receivers have a connector giving access to a serial or USB port, and provide data in the same NMEA format as the GPS modules described below.

After the Global Positioning System became widely used, other competing systems were introduced. These include the European Galileo, the Russian GLONASS (an acronym for Global Navigation Satellite System), and the Chinese Beidou. As of 2015, GLONASS had become fully operational. Some receivers, including those in cellular phones, compare signals from GPS and GLONASS satellites to achieve higher accuracy.

Values

Sensitivity is expressed usually in dBm, meaning the power ratio in decibels (dB) of the measured power referenced to one milliwatt (mW).

Time to First Fix (TTFF) is the time required to obtain an initial fix from a satellite.

Number of channels is the number of satellites that a GPS receiver can track simultaneously. Early GPS receivers could sense only four channels. Modern units may be able to deal with 22.

Power consumption may be measured in milliwatts. For example, the FGPMMOPA6H GPS standalone module by G.top claims power consumption of 82mW during acquisition of satellite signals and 66mW while tracking subsequently. At a typical voltage of 4VDC, the chipset consumes about 20mA and approximately 17mA, respectively.

Form factor. This is the size of a chip, often determined by the dimensions of the ceramic antenna on top of it. Dimensions may be 15mm x 15mm or larger.

Update rate. The number of position measurements per second. While 1 update per second is often sufficient, some chips generate updates more rapidly. The frequency of updates is expressed in hertz.

Output type. This is often TTL-level serial providing NMEA data. The baud rate can vary and is often selectable.

Supply voltage. Often below 5VDC.

Current consumption. Higher during satellite acquisition.

How to Use It

A GPS module requires only a DC power supply, and will start outputting data as soon as it has identified satellites that are currently within range.

Data provided by a GPS module uses a rather slow and primitive plain-ASCII protocol known as NMEA, developed by the National Marine Electronics Association. Each block of data is known as a *sentence*, and can be parsed independently of previous and subsequent sentences. The default transmission rate is 4,800 bits per second, using 8 bits to identify an ASCII character, no parity, and 1 stop bit. However, some GPS modules use a serial rate of 9,600 bps or faster.

A sentence begins with a two-letter abbreviation defining the type of device employing the sentence. For a GPS device, the abbreviation is GP. The sentence continues with another abbreviation of three characters or more, describing the type of data being transmitted, so that numeric values in the sentence can be interpreted correctly.

The remainder of a sentence consists of letters and numerals in plain ASCII, with values separated by commas. A sentence cannot contain more than 80 characters. A sentence will specify the latitude, longitude, and altitude of the GPS, and a value defining the time when the readings were derived from satellite signals. Some sentence data structures are proprietary, established by the device manufacturer, and will begin with the letter P.

A GPS device may send a variety of different sentence types in succession, to overcome the 80-character sentence length limit. Each sentence will be preceded with an identifier. Sentence types and data contents will be defined in a manufacturer's datasheet.

Output from GPS chips may be compatible with a microcontroller. Output from a GPS breakout board will almost certainly be compatible, and the board is likely to have its own voltage regulator. The microcontroller can receive serial data from the GPS chip, can stop the GPS chip via its enable pin, and can start and stop internal logging of data in flash memory on the GPS chip if this feature is available.

Code libraries are available online for a microcontroller, to enable it to receive and interpret serial data from a GPS device.

Pulse per Second Output

As the GPS positioning depends on calculating distances from the time it takes for a radio signal to travel, accurate timekeeping is needed. When a GPS receiver obtains a fix for its position, it will get a value for the current time as well. This makes GPS receivers usable to supply time and frequency standards. Most receiver modules report the time together with the position. Many also provide a special PPS output, which produces one pulse per second, precisely synchronized with the satellites in view.

The accurate time provided by the GPS receiver can be used to *discipline* a crystal oscillator. This means measuring the crystal oscillator frequency relative to a GPS-provided reference, and continuously adjusting the crystal frequency to keep it stable.

What Can Go Wrong

Problems generally affect chips and modules rather than devices.

Electrostatic Discharge

The patch antenna on a GPS chip connects with the chip via an RF input. If the antenna is subjected to an electrostatic discharge, the chip can be permanently damaged. Likewise, damage will result if a discharge is applied to the RF input, for example through a soldering iron. The chip must be grounded before any work is done involving the RF input.

Failure to Ground Properly

The ground solder pad on a chip, or the ground pin on a breakout board, must make contact before voltage is applied to other pads or pins.

Cold Joints

The patch antenna on a GPS chip can function as a heat sink, increasing the risk of cold solder joints when the chip is being mounted on a board.

Restricted Availability

U.S. regulations limit the export of some GPS devices capable of rapid positional updates that could be usable in military aircraft or missiles. Other restrictions also apply. Suppliers may be inconsistent in their refusal to allow purchase of restricted items outside of the United States.

Inability to Detect Satellites

Any GPS device may fail to detect satellite signals if its view of the sky is obstructed. Reception is usually possible through window glass, but may not be available through walls, a roof, heavy tree cover, and other natural obstructions.

Exceeding Maximum Velocity or Altitude

Security regulations limit the capability of GPS devices to function above 60,000 feet or at greater than 1,200 miles per hour. Outside of these limits, the GPS device will not provide data. This may affect applications in amateur rocketry or high-altitude balloons.

2

magnetometer

This entry deals only with magnetic sensors that respond to the Earth's magnetic field. Small magnetic sensors such as the ubiquitous *Hall sensor* may be used for many other purposes, such as determining the position or rotational speed of mechanical components. These applications involve **object presence** sensing; see Chapter 3. In that entry, Hall sensors are discussed at "Hall-Effect Sensor".

In the past, a **magnetometer** was a bulky measurement device incorporating knobs or other controls and some form of display. While that use of the word is still common, this entry deals only with chip-based magnetic sensors.

OTHER RELATED COMPONENTS

- **accelerometer** (see Chapter 10)
- **gyroscope** (see Chapter 9)
- **GPS** (see Chapter 1)

What It Does

A traditional compass consists of a thin magnetized strip of metal balanced on a pivot. It aligns itself with the Earth's magnetic field.

A *scalar magnetometer* measures the total strength of a magnetic field. A *vector magnetometer* can measure the strength in a specified direction. In particular, it can provide a numeric output describing the angle between the orientation of the measuring device and the Earth's magnetic poles.

Chip-based magnetometers are usually vector-type, containing three sensors mounted orthogonally—that is, each of them at 90 degrees to the other two. Suitable software can interpret the analog readings from the sensors to calculate magnetic north or south regardless of the angle at which the instrument is being held, relative to the ground.

Schematic Symbol

There is no specific schematic symbol for a magnetometer.

IMU

A **gyroscope** measures the rate of rotation of the enclosure in which it is mounted. This is properly known as the *angular velocity*. A gyroscope will also respond to changes in the rate of rotation. It does not measure linear motion or a static angle of orientation.

An **accelerometer** measures variations in linear motion and will also measure its own static orientation relative to the force of gravity. If an accelerometer rotates around its own axis, it will not measure angular velocity.

When an accelerometer and a gyroscope are contained in the same package, optionally with a magnetometer, they may be described as an *IMU* (inertial measurement unit), which can provide necessary data to maneuver aircraft, spacecraft, and watercraft, especially when **GPS** signals are unavailable.

Applications

Magnetometers are found in handheld equipment such as digital compasses, cameras, and cellular phones. They are usually surface-mount chips that are manufactured in large quantities and may be used in conjunction with microcontrollers. For the hobby-electronics community, or for experimental product development, a magnetometer may be mounted on a breakout board for ease of use. A board using a Honeywell HMC5883L is shown in Figure 2-1.

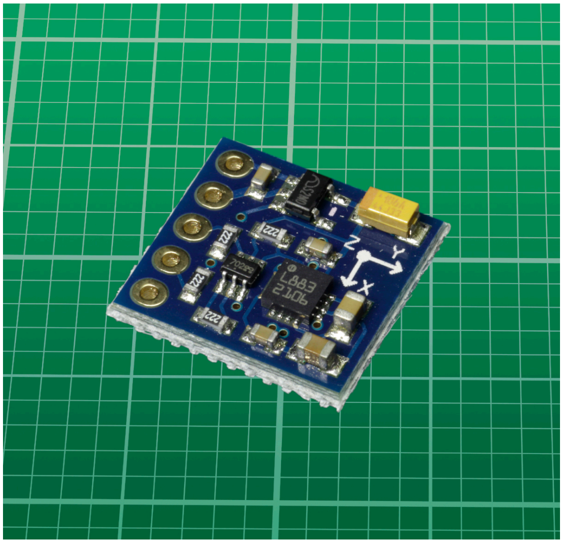

Figure 2-1 *The Honeywell HMC5883L 3-axis magnetometer mounted on a breakout board. The background grid is in millimeters.*

How It Works

An explanation of magnetometers requires an understanding of the fundamentals of magnetism.

Magnetic Fields

A magnetic field is often represented by *field lines* that show the strength and vector of the field. Field lines associated with a simple permanent magnet are shown in Figure 2-2, where the strength, or *flux density*, at any point, is indicated by the spacing the lines, while the angle tangential to a line indicates its vector. (For an extended discussion of magnetism, see **electromagnet** in Volume 1.)

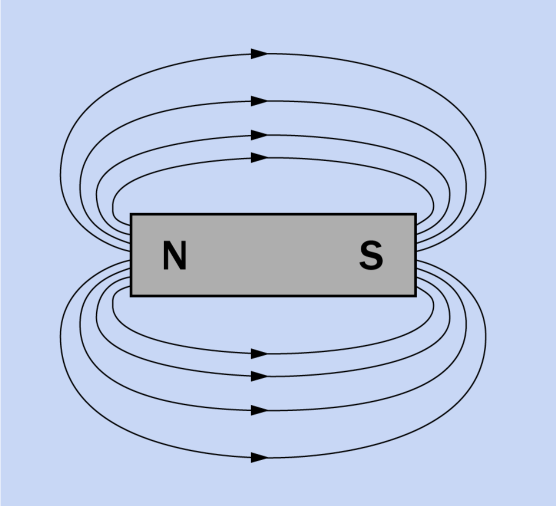

Figure 2-2 *Field lines representing magnetic flux created by a bar magnet. Space between the field lines is inversely proportional to flux density. In reality this is a three-dimensional effect, and a more accurate representation would show the magnet and field lines revolved around the axis of the magnet.*

The flux density of a magnetic field is usually represented by the letter B, and is measured in *newton-meters per ampere*, more commonly referred to as *teslas* (T). An older unit of measurement was gauss (G), 1 tesla being equivalent to 10,000 gauss. Some datasheets still refer to gauss.

The Earth's magnetic field is believed to result from convection currents in the outer liquid of the Earth's core. The strength of this field varies from 25 to 65 microteslas (0.25 to 0.65 gauss) depending on the location where it is measured. To a very rough approximation, the Earth behaves as if a giant bar magnet connects the magnetic north pole and the magnetic south pole. See Figure 2-3.

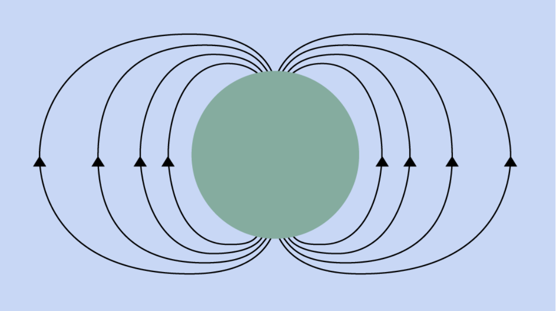

Figure 2-3 *The magnetic field of the Earth approximately resembles the field around a bar magnet.*

Note that in northern and southern latitudes, the field lines angle steeply down toward the surface, while the lines are approximately parallel with the surface near the equator. Consequently a magnetometer held tangentially to the surface of the Earth will tend to measure a stronger horizontal field near the equator than near the poles.

The varying angle of the field lines tangential to the Earth is known as their *inclination*. Variations in field strength can be used to determine an approximate location, although the **GPS** (Global Positioning System, using satellites) enables this much more accurately.

Confusion results from the fact that the nothern magnetic pole of the Earth actually behaves as a south pole, while the southern magnetic pole behaves as a north pole. That is, when a permanent magnet is free to rotate, its north pole will orient itself toward the so-called northern magnetic pole of the Earth, even though opposite poles attract. The northern pole of the Earth should therefore be thought of as the pole that attracts the north end of a compass.

Earth's Axes

Planet Earth revolves around an imaginary line referred to as the *axis of rotation*. This line is close to, but not quite coincident with, the *magnetic axis* connecting the magnetic north pole and magnetic south pole, as shown in Figure 2-4.

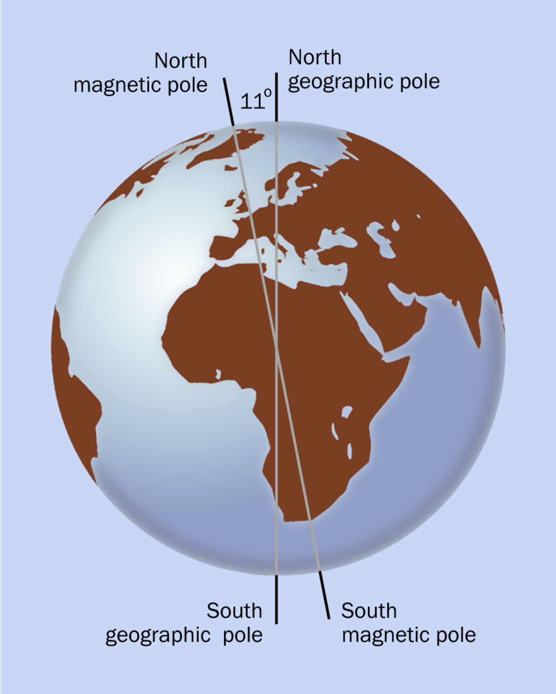

Figure 2-4 *The angle between the magnetic axis and the rotational axis of the Earth is approximately 11 degrees.*

Magnetic declination is the angle between the magnetic north pole and the geographical north pole, as perceived by an observer. This angle will vary depending on the observer's location on the surface.

Because of declination, the direction of magnetic force at points on the surface of the planet will vary with latitude and longitude, as shown in Figure 2-5. In this figure, the *magnetic meridians* are shown in red, superimposed on the *geographical meridians* shown in green. Magnetic meridians show the direction of magnetic force, while geographic meridians are drawn between the ends of the axis of rotation of the Earth. While there is an approximate correlation between the two, in some areas, especially near the north and south poles, the discrepancy can be more than 40 degrees.

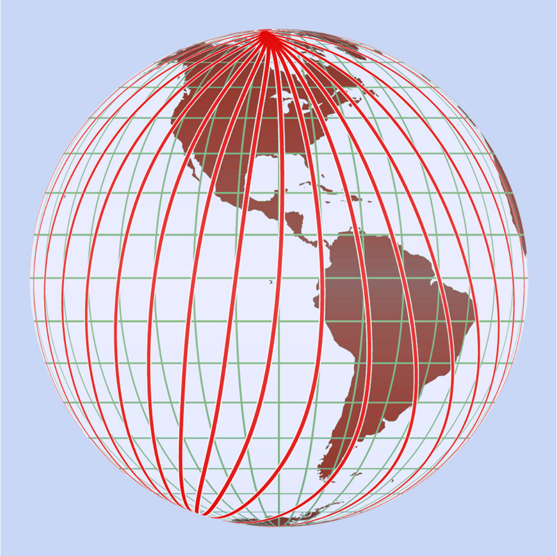

Figure 2-5 *The red lines indicate the direction in which a compass would be likely to point to magnetic north. The green lines connect the geographical poles of the planet. (From Wikimedia Commons.)*

Standard declination tables for locations on the Earth are available, and these values must be added to, or subtracted from, the reading from a compass or magnetometer to determine the direction of geographical north. Navigational systems customarily express the heading of a vehicle or vessel relative to geographical north, as shown in Figure 2-6.

Coil Magnetometer

Current flowing through a wire creates a magnetic field with flux density that is directly proportional to the current in amperes. Conversely, a changing magnetic field will induce current in a wire. This principle is used in a *coil magnetometer*, which can detect buried objects when the coil moves above them. A *rotating coil magnetometer* can determine magnetic field strength while remaining in a stationary position. However, the coil in a coil magnetometer must be relatively large.

Hall Effect and Magnetoresistance

In modern handheld devices, a magnetometer will generally use either the *Hall effect* (see "Hall-Effect Sensor") or *magnetoresistance*, described here.

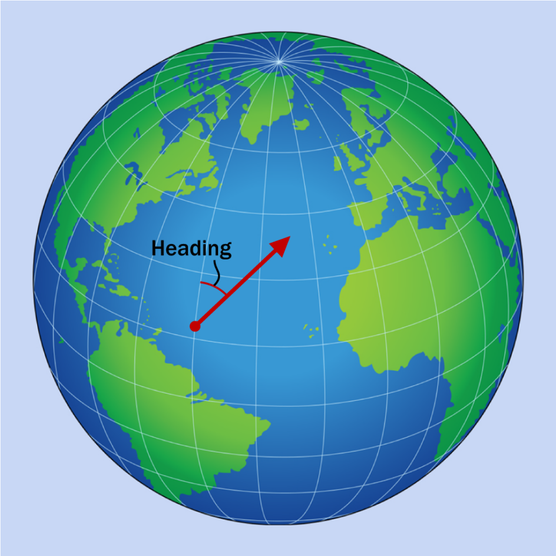

Figure 2-6 *Heading is an angle usually calculated relative to geographical north, sometimes referred to as "true north."*

Magnetoresistance is a phenomenon where the resistance of a material changes fractionally when it is exposed to a magnetic field. This is capable of yielding greater accuracy than Hall-effect sensors, but has tended to be more expensive.

Orthogonally oriented sensors contained in a surface-mount chip are aligned with axes identified with letters X, Y, and Z. These sensors are analog devices whose values are converted to digital values by an onboard *analog-to-digital converter* (ADC). The values are stored in *registers* that are available to other devices, often via the *I2C* protocol, which is widely used by microcontrollers.

Typically there will be two eight-bit registers for each axis, one defining the high byte and the other defining the low byte for the digital value. In reality the ADC is likely to use 10 to 13 bits, with the remaining 6 to 3 bits being unused.

Variants

The Freescale Semiconductor FXMS3110 is a typical low-cost chip containing a 3-axis magnetometer sensor. Many chips now additionally include a 3-axis accelerometer sensor. An example is the LSM303 by STMicroelectronics, which is sold on a breakout board by Adafruit. See Figure 2-7.

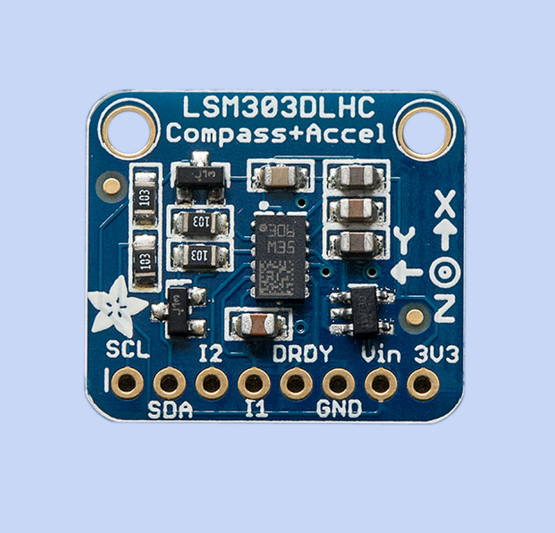

Figure 2-7 *The LSM303 is a chip manufactured by STMicroelectronics. It is shown here on a breakout board from Adafruit.*

See Chapter 10 for an explanation of the function of accelerometers.

The InvenSense MPU-9250 is a highly sophisticated IMU, including a 3-axis **gyroscope** in addition to a 3-axis magnetometer and 3-axis accelerometer.

A processing unit in the MPU-9250 reconciles the nine variables, and the digital output can be accessed via I2C or SPI protocol at speeds up to 1MHz. All functions of the chip are contained within a package measuring less than 3mm square.

See Chapter 9 for additional details about the functioning of a gyroscope.

How to Use It

A basic 3-axis magnetometer sensor such as the HMC5883L can be tested with a microcontroller that can receive data from its registers via I2C protocol. This is relatively easy with an Arduino, which was designed to be I2C-capable.

Several breakout boards are available with the HMC5883L mounted on them. Many of these boards contain a voltage regulator, allowing a 5VDC power supply to be used even though the chip is designed for a typical supply of 2.5VDC.

In addition to the power supply, the breakout board only requires two connections for I2C communication, to its SCL pin (serial clock input) and SDA pin (serial data input/output). If basic I2C software is installed on the microcontroller, it will read digital values from the magnetometer registers. If additional software is used, it will convert the values to magnetic flux densities in microteslas for the X, Y, and Z axes. Code libraries to achieve these goals are widely available online.

A more sophisticated chip such as the InvenSense MPU-9250 can be used similarly, but yields additional data for conversion. Here again, code libraries can be found online. The slightly older MPU-9150 is sold on a breakout board with downloadable code from Sparkfun.

What Can Go Wrong

Bias

Magnetometers are sensitive to their environment, which can induce *magnetometer bias* of two types.

Hard-iron bias is primarily caused by magnetized material inside the device containing the magnetometer. Because this effect is usually unvarying, compensating for it is relatively easy. *Soft-iron bias* is caused by interaction between variations in the Earth's magnetic field and materials inside a magnetometer that can be magnetized.

A common example of soft-iron bias would be power lines, generating a magnetic field that can affect model aircraft and drones using magnetometers for navigation.

Mounting Errors

Placement of a chip-based magnetometer on a circuit board is critical. The field effects of transformers or relays must be taken into account, and even the low voltage and low current in a circuit trace can create a magnetic field sufficient to disturb a chip. No traces on any layer of the board should pass across the footprint of the chip. A magnetometer should not be mounted within a ferromagnetic case.

object presence sensor

3

An **object presence** sensor may also be described as an *object detector* or *detection sensor*.

The term **proximity** sensor may be applied to this component. However, in this Encyclopedia a proximity sensor has the capability of estimating the distance to a target. See Chapter 5. An object presence sensor merely detects whether an object is within a preset range, and does not provide additional information.

Optical and *magnetic* object-presence sensors are described and compared in this entry. *Ultrasonic sensors* are described in the entry dealing with proximity sensors, because they tend to be used for distance measurement rather than just for detection. Other methods of object presence sensing, including *capacitive*, *doppler*, *inductive*, *radar*, and *sonar*, are not included in this Encyclopedia.

A sensor that detects an object by receiving light reflected from it is categorized as a *reflective* sensor, and is included in this entry. (If a module includes a light source as well as a light sensor, it is properly categorized as *retroreflective*, although that term is not always used.)

A sensor that detects an object when it interrupts a beam of light is a *transmissive* sensor, and is included in this entry. It may also be described as a *through-beam* sensor or as an *optical switch*.

A sensor that responds to the motion of an object that emits infrared radiation is a **passive infrared** motion sensor, also described by its acronym, PIR, and often referred to simply as a *motion sensor*. It has its own separate entry. See Chapter 4.

Phototransistors and **photodiodes** may be used as sensing elements in presence sensors. These components have their own entries as light sensors. See Chapter 22 and Chapter 21.

OTHER RELATED COMPONENTS

- **proximity** sensor (see Chapter 5)
- **passive infrared** sensor (see Chapter 4)

What It Does

An **object presence** sensor verifies the presence or absence of an object within a predetermined range, without necessarily measuring how far away it is or how fast it is moving. The object may be described as a *target*.

Object presence sensing is often used to verify the correct function of an automated system—for example, the placement of objects on a conveyor belt. It can also be used to count objects as they pass a sensor.

Some types of security systems use presence sensors to sound an alarm if an intruder interrupts a beam of light. They can verify that a door or window is closed. They may also function as a limit switch to control the operation of a motor.

Schematic Symbol

In schematics, an optical presence sensor may be indicated with the symbol for an LED, plus the symbol for a **phototransistor**, with one or two arrows connecting them, as shown at top-left in Figure 3-1. Wavy-line arrows may indicate an infrared connection.

A **photodiode** may be substituted for a phototransistor, as shown at top-right in the figure.

A magnetic sensor may be shown with the symbol for a *Hall-effect sensor*, as in the lower half of Figure 3-1.

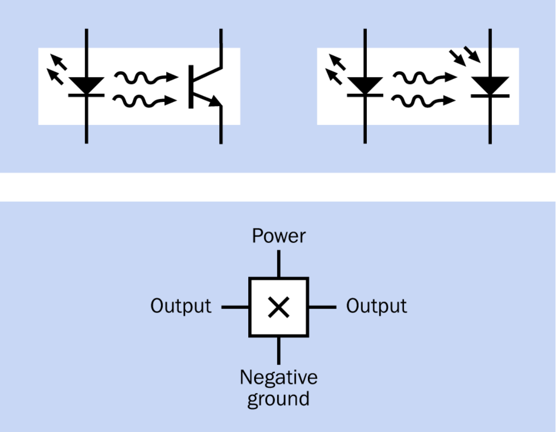
Power
Output
Output
Negative ground

Figure 3-1 *Top: two possible schematic symbols for an optical presence sensor, using a phototransistor (left) or photodiode (right). Other variants are possible. Bottom: the schematic symbol for a Hall-effect sensor, commonly used in a magnetic sensor.*

Variants

To assist the reader in comparing different options for detecting the presence of an object, this entry includes two primary variants: *optical* and *magnetic*.

The optical sensors are divided into *transmissive* and *reflective* (including *retroreflective*). The magnetic sensors are *reed switches* and *Hall-effect sensors*. A chart showing the categories and subcategories is shown in Figure 3-2.

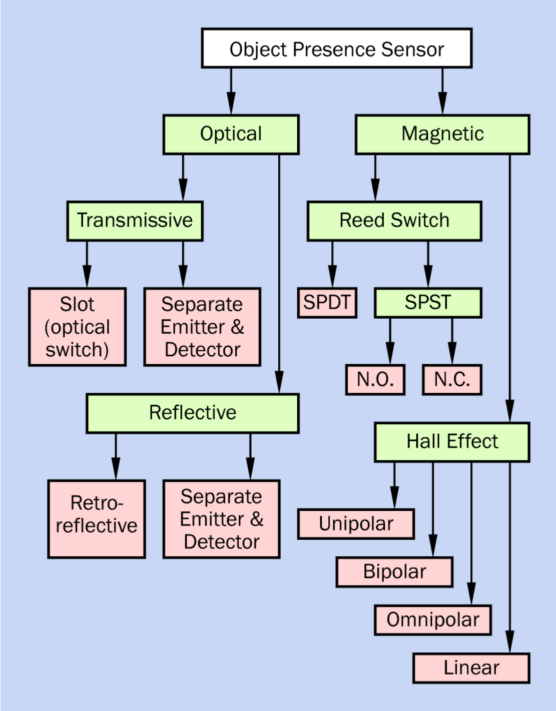
Object Presence Sensor
Optical
Magnetic
Transmissive
Reed Switch
Slot (optical switch)
Separate Emitter & Detector
SPDT
SPST
N.O.
N.C.
Reflective
Hall Effect
Retro-reflective
Separate Emitter & Detector
Unipolar
Bipolar
Omnipolar
Linear

Figure 3-2 *Categories of object presence sensors discussed in this entry. Other types of object presence sensors exist, but are less common, and are not included here.*

Optical Detection

A *transmissive optical sensor*, also known as a *through-beam sensor*, is really a pair of components, one emitting light and the other receiving it. The sensor is triggered if an object interrupts or reflects the light beam, as shown in Figure 3-3.

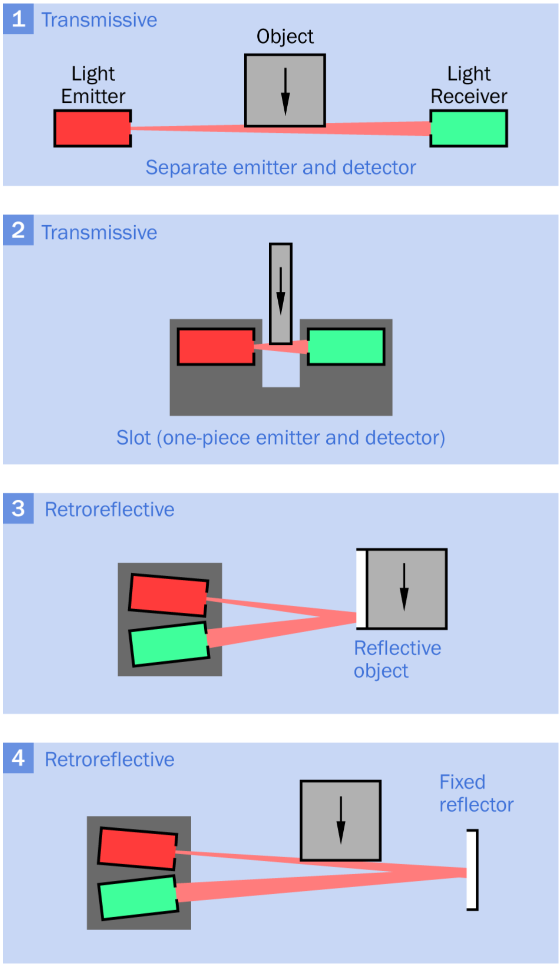

Figure 3-3 *Various configurations of optically activated object presence sensors. See text for details.*

If the light emitter and the light detector face each other across a small gap, they may be contained in a single module (usually with a slot in it) as shown in section 2 of Figure 3-3. This is often referred to as an *optical switch* (not to be confused with the solid-state switching devices used in telecommunications). It is sometimes described as a *photointerruptor* or *photointerrupter*.

A *reflective optical sensor* also consists of a light emitter and a light detector, but they are placed adjacent to each other, facing in the same general direction. When they are mounted in one module, as is often the case, the arrangement is properly known as a *retroreflective sensor*. Either way, the combination may be triggered in one of two ways:

- An object passing in front of the light beam reflects it back to the detector. The object must be naturally reflective (for example, glass containers or white boxes on a conveyor), or must have a reflective patch applied to it, or the light source must be bright enough to reflect from an object that is not highly reflective. This configuration is shown in section 3 of Figure 3-3.
- A stationary reflector can be mounted opposite the light emitter, in which case a detector beside the light emitter is triggered when an object interrupts the reflected light beam. This configuration is shown in section 4 of Figure 3-3.

Transmissive Optical Sensors

A light source and light detector may be sold as separate components in a matched pair. An example is the Vishay TCZT8020, shown in Figure 3-4. These components are small, each measuring no more than 5mm x 3mm. They are designed to be placed just a few millimeters apart. The light source is an infrared LED, while the detector is a **phototransistor** (see Chapter 22 for information about phototransistors).

The source and detector are both designed to use 5VDC. Output from the phototransistor is an open collector. Current through the collector must not exceed 50mA, and must be limited by a pullup resistor of 100 ohms or more. Current through the source must not exceed 60mA, and must be limited by an appropriate series resistor.

Details on using an open-collector output will be found in the Appendix. See Figure A-4.

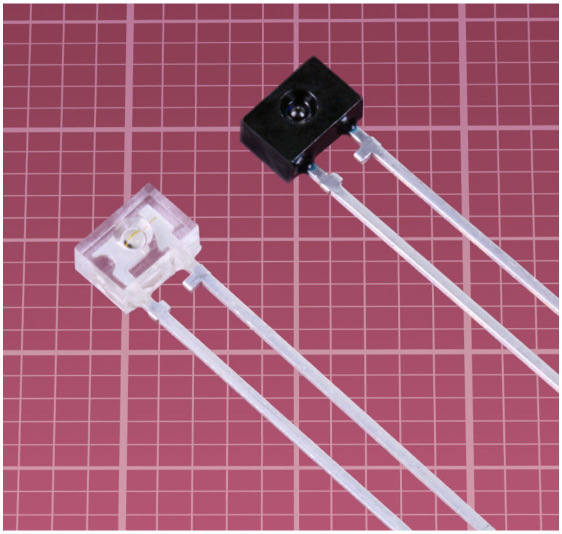

Figure 3-4 *A matched light source and light detector, for use as a transmissive optical sensor. The background grid is in millimeters.*

The Omron EE-SX range includes a variety of configurations of light source and detector separated by a 5mm slot in one module. The source is an infrared LED, and the detector is a phototransistor.

The Omron components tolerate a wide range of supply voltages, from 5VDC to 24VDC, with no series resistor necessary for the LED. Open-collector output from the phototransistor can tolerate 50mA to 100mA, depending on the particular version of the sensor. A red indicator LED is illuminated when an object blocks the slot in the sensor. Some versions have a high output when the slot is open, while others have a high output when the slot is closed. Because of their various features, these sensors are relatively expensive.

A much cheaper optical switch is the Everlight ITR9606 (described by the manufacturer as an "opto interrupter"). It is pictured in Figure 3-5. This is intended as a 5V device and has an open-collector output. It requires a series resistor for the LED and a pullup resistor for the open-collector output. Many similar detectors are available.

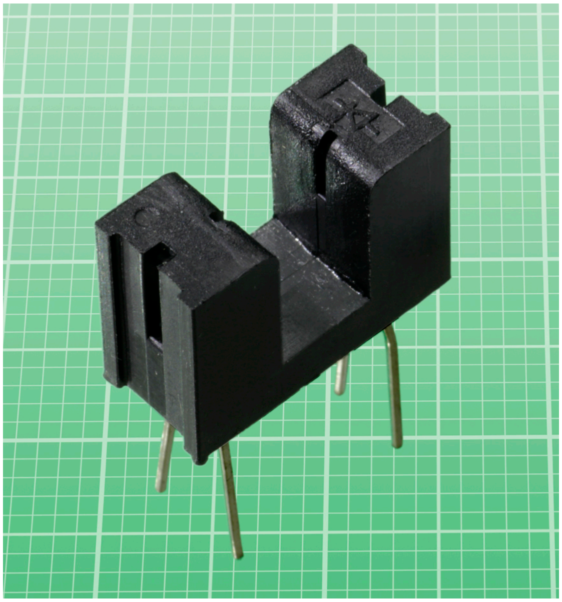

Figure 3-5 *A low-cost transmissive sensor, more commonly known as an optical switch. The background grid is in millimeters. The slot in the sensor is about 5mm wide.*

For longer-distance detection, an infrared receiver can be mounted separately from an infrared LED. The TSSP77038 from Vishay detects infrared light from as far away as 50cm, and pulls its open collector output low in response. The light must be modulated at 38kHz.

Polulo Robotics and Electronics sells a very affordable breakout board containing a TSSP77038 receiver paired with an infrared LED modulated by a 555 timer. It is shown in Figure 3-6. Because this board contains a light source as well as a light detector, it is really a retroreflective sensor.

Where distances exceeding 1 meter are involved, a laser coupled with a phototransistor that is shielded from ambient light may be necessary.

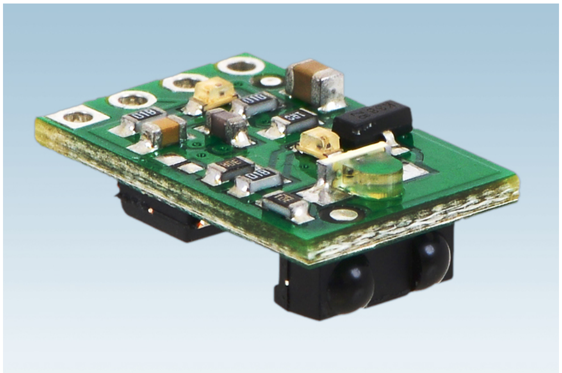

Figure 3-6 *The Vishay TSSP77038 installed with an appropriate light source on a breakout board from Polulo Robotics and Electronics.*

Retroreflective Optical Sensors

As is the case with a transmissive object detector, the retroreflective type may be listed by vendors as an *optical switch*. Other terms used in datasheets include *reflective interrupter*, *reflective object sensor*, *reflective optical sensor*, *reflective photointerrupter*, *opt-pass sensor*, and *photomicrosensor (reflective)*. The remarkable lack of standardization in terminology creates a problem when searching online for these devices. Why so many different names evolved for the exact same component is unclear.

Many retroreflective object-detection sensors are available in packages ranging from 5mm x 5mm to 10mm x 10mm in size. Almost all of these modules are analog devices using an infrared LED as the light source and a phototransistor as the sensor, with an open-collector output. (For more information about phototransistors, see Chapter 22.)

With a suitable pullup resistor, the output voltage will be proportional with the inverse of the distance. If V is the voltage, d is the distance, and k is a conversion factor:

```
V = k * ( 1 / d)
```

While many of the smaller modules are surface-mount, some have leads, as shown in Figure 3-7. A major limitation of these small components is that they have a very limited range, typically less than 5mm. They can only be used in applications such as process control where the position of a target is controlled and predictable.

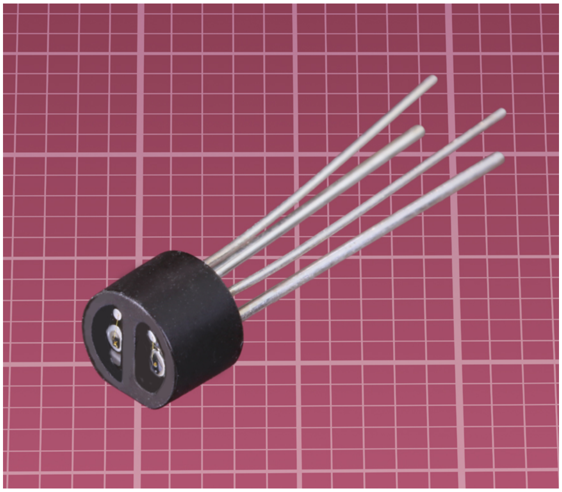

Figure 3-7 *The Rodan RT-530 is a small object-presence sensor with a limited range typical of this type of retroreflective component. The background grid is in millimeters.*

Another example of a retroreflective sensor in a small package is the Optek OPB606A shown in Figure 3-8. The background grid is in millimeters.

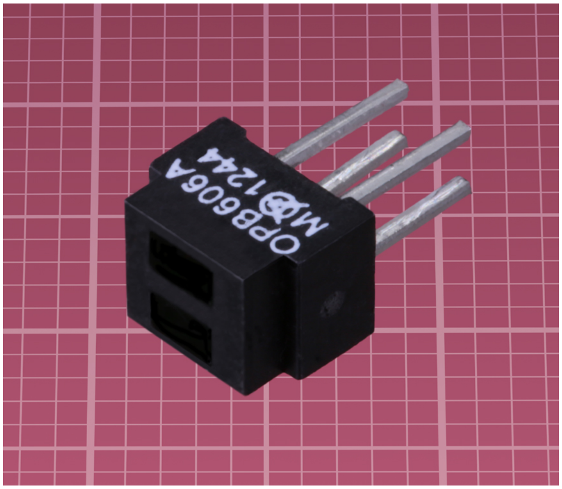

Figure 3-8 *The Optek OPB606A. The background scale is in millimeters.*

A retroreflective module, with a lensed LED and lensed phototransistor to focus the outgoing and reflected beams, is the Vishay TCRT5000 shown in Figure 3-9.

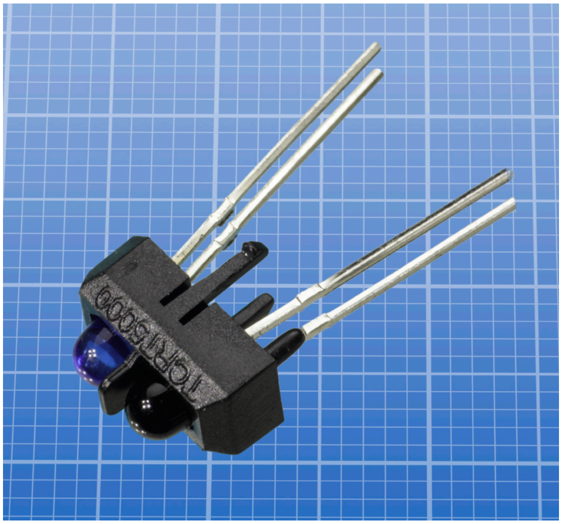

Figure 3-9 *The Vishay TCRT5000 retroreflective sensor. The background grid is in millimeters.*

Retroreflective modules that have a greater range tend to be physically larger, less common, and more expensive. Sharp makes a popular series. Some part numbers and distance sensing limits are: GP2Y0D805Z0F (5mm to 5cm), GP2Y0D810Z0F (2cm to 10cm), and GP2Y0D815Z0F (5mm to 15cm). Figure 3-10 shows the GP2Y0D810Z0F mounted on a small breakout board from Polulo Robotics and Electronics. The board is useful, as the pins on the sensor are spaced only 1.5mm apart. The size of the board is approximately 8mm x 20mm.

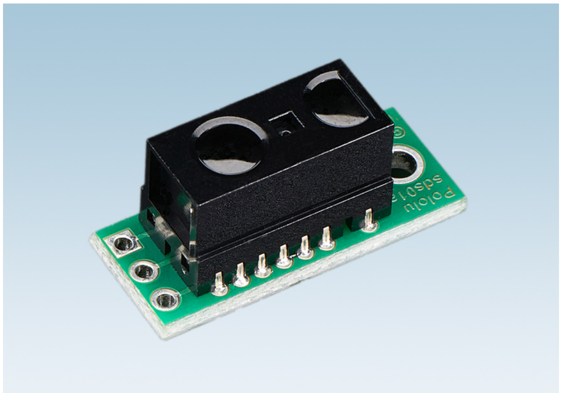

Figure 3-10 *The Sharp GP2Y0D810Z0F detection sensor mounted on a board from Polulo Robotics and Electronics. From a photograph by Adafruit Industries.*

Each of the detection sensors in this series is described in Sharp datasheets as a “Distance Measuring Sensor Unit,” but in fact they do not measure distance. A single output is normally logic-high and drops to logic-low when a target is within range. Sharp refers to this as a “digital” output, but in fact it is binary, and should not be confused with the digital buffer on a more sophisticated proximity sensor that contains an analog-to-digital converter and provides a numeric output.

It is important to distinguish the Sharp object-presence sensors listed above from the range of Sharp **proximity** sensors described in the entry in Chapter 5. The proximity sensors are physically larger, and most have an analog output that varies with the distance of a target.

Magnetic Sensors

Prepackaged magnetic sensing units are sold in many configurations for industrial and military applications. Although they may be referred to as “magnetic sensors,” they are outside the scope of this Encyclopedia. Here we discuss board-mounted components. Almost always, they use a *reed switch* or a *Hall-effect* sensor as their sensing elements.

Reed Switch

A reed switch is a magnetically activated mechanical switch. It consists of two metallic contacts in a small enclosure that is usually a glass capsule. The contacts are magnetic, and move in response to a magnetic field. A permanent magnet is used to activate the switch. Two reed switches are shown in Figure 3-11.

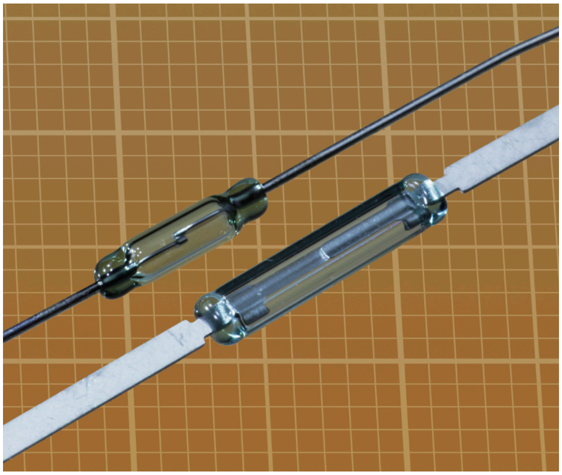

Figure 3-11 *Two SPST reed switches. Although the contacts may seem to be touching, in fact they are separated by a tiny gap, and these switches are the normally open type. The background grid is in millimeters.*

A reed switch exhibits a small amount of *hysteresis*, because the magnetic field strength required to overcome the mechanical resistance of the springy contacts is greater than the field strength required to keep them closed.

Very small electromagnetic relays that only switch a very low current may use a coil-activated reed switch. For purposes of this Encyclopedia, such a component is considered to be a relay, not a sensor. For more information about **relays**, see the entry in Volume 1.

The most common everyday application for a reed switch is in an alarm system that is triggered by an intruder entering a building. A magnet in a sealed plastic enclosure is attached to a door or window, while a reed switch, in another sealed plastic enclosure, is attached to the frame, very close to the magnet. Typical components of this type are shown in Figure 3-12. A diagram illustrating the mode of operation appears in Figure 3-13.

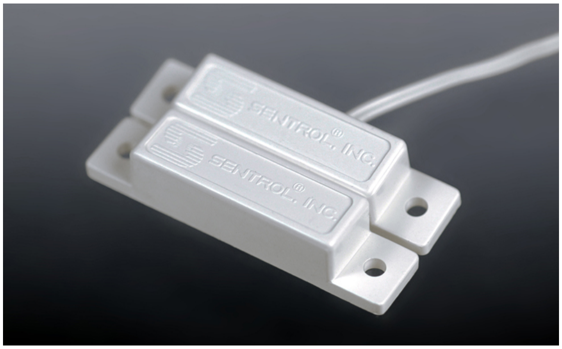

Figure 3-12 *A typical alarm sensor to detect the opening of a door or window. The nearer module contains a magnet, while the module behind it contains a reed switch.*

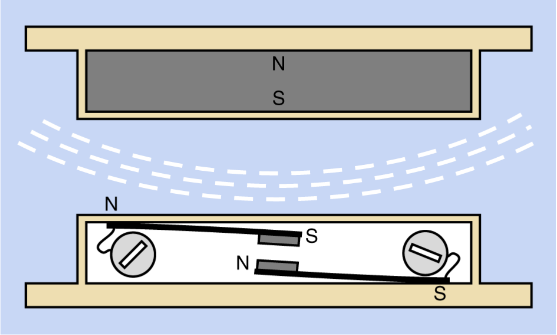

Figure 3-13 *The dashed white lines suggest the magnetic field that closes the contacts of a reed switch.*

So long as the alarmed door or window remains closed, the magnet activates the reed switch. If the door or window is opened, the magnet moves away from the reed switch, and its contacts relax. Usually in this application the reed switch is the normally open type, and is held in its closed state by the magnet. This allows multiple switches to be wired in series, completing a circuit. If a single switch opens, the circuit is broken, and an alarm is triggered.

Reed Switch Variants

Most reed switches are SPST, either normally open or normally closed, although normally open variants are more common. Some switches are SPDT, although this variant is relatively rare. An example of a SPDT reed switch is shown in Figure 3-14.

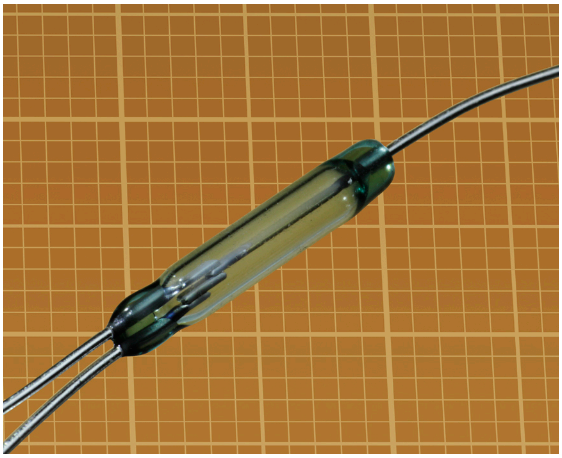

Figure 3-14 *A SPDT reed switch. The background grid is in millimeters.*

The physical size of a reed switch tends to vary roughly in proportion with its current-switching capability.

Reed switches are most commonly supplied with axial leads. A minority are available for surface-mount applications.

Some reed switches are packaged in a plastic pod to provide physical protection for the glass capsule.

Reed Switch Values

The datasheet for a reed switch is likely to contain the following values:

Pull-in: The minimum magnetic field strength required to activate the switch, often measured in ampere-turns.

Drop-out: The maximum magnetic field strength that allows the contacts of the switch to relax, often measured in ampere-turns. Pull-in will be a higher value than drop-out.

Maximum switching current: While a few industrial reed switches can switch as much as 100A, they are uncommon and expensive. A common value for a reed switch about 15mm long is 500mA.

Maximum carry current: If specified, it will be higher than the switching current.

Maximum switched power: Because a reed switch can be used with alternating current, its switching capability may be expressed in watts, or as VA (volts multiplied by amps). 10VA is a common value.

Maximum voltage: While reed switches are most often used with low voltages, some are rated to switch up to 200V.

How to Use a Reed Switch

While an optical object presence sensor may be supplied in a single package containing a light emitter and a light detector, a reed switch always requires an activating magnet that is mounted separately. For reliable operation, the maximum distance between the switch and the magnet is usually restricted to a few millimeters.

The orientation of a magnet that activates a reed switch is not crucial, but will affect the sensitivity of the switch. A manufacturer's datasheet should be consulted for information about optimal magnetic polarity.

As in other mechanical switches, the contacts in reed switches vibrate very briefly when opening or closing. This is known as *contact bounce*, and can be misintepreted as a series of separate signals by digital logic or a microcontroller. *Debouncing* with hardware designed for that purpose, or software (in a microcontroller), may be necessary. See the entry on **switches** in Volume 1.

Hall-Effect Sensor

A Hall-effect sensor responds to a magnetic field by generating a small voltage, usually amplified by a transistor included in the package with the sensor.

When a Hall sensor is in its “off” state (i.e., not triggered by a magnetic field), the sensor creates high resistance between the collector of an internal NPN transistor and negative ground. Consequently, if voltage through a pullup resistor is applied to the collector, the voltage on the collector will be high.

When the sensor is in its “on” state, the resistance drops, the voltage supplied to the collector from the pullup resistor is shunted to ground, and the output voltage appears to go low. As a general rule:

- Activated Hall sensors appear to have a low output.
- Inactive Hall sensors appear to have a high output.

Information about using open-collector outputs is contained in the Appendix. See Figure A-4.

The clean output, reliability, small size, and cheapness of Hall sensors have encouraged their use in devices as different such as hard drives, cameras, keyboards, and automobiles. They are useful in almost any situation where a sensor must detect a mechanical operation at close range. Three through-hole Hall sensors are shown in Figure 3-15. Surface-mount versions are much smaller.

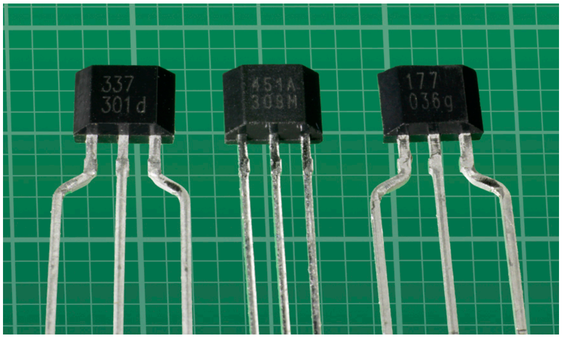

Figure 3-15 *Three through-hole Hall-effect sensors. The background grid is in millimeters.*

How a Hall-Effect Sensor Works

When current is flowing through the length of a conductor, and a magnetic field is applied across the width of the conductor, the field generates a force causing electrons and electron holes to accumulate asymmetrically on opposite sides. This is known as the *Hall effect*.

The voltage difference between the electron-rich and electron-depleted zones is known as the *Hall voltage*. It is proportional to the magnetic field, and inversely proportional to the density of free electrons in the material. For this reason, the Hall effect is easiest to observe in semiconductors, where the density of electrons or electron holes is low.

Hall sensor components contain amplifier circuitry in addition to the sensing element itself. Typically there is an open-collector output, and a comparator or Schmitt trigger to provide some hysteresis.

Hall-Effect Sensor Variants

Four primary variants of Hall sensors are widely used.

Unipolar Hall Sensor

This is activated when an external magnetic field exceeds a threshold value. When the field diminishes, the sensor switches off. Unipolar sensors are available in versions activated by the north magnetic pole or south magnetic pole.

Bipolar Hall Sensor

Proximity to one magnetic pole will switch it on. Proximity to the opposite magnetic pole will switch it off. The sensor remains in its current state (on or off) in the absence of a magnetic field.

Omnipolar Hall Sensor

Proximity to a strong magnetic field of either polarity will switch it on. Removal of the magnetic field will switch it off. An omnipolar sensor can be thought of as a pair of unipolar sensors mounted in opposite directions and with their (open-collector) outputs wired together. This component functions similarly to a reed switch, although of course it still requires a power supply.

Linear Hall Sensor

Also known as an *analog* Hall sensor, its output voltage varies in proportion to an external magnetic field instead of switching cleanly between high and low states. When no magnetic field is detected, the output is half of the sensor's supply voltage. In response to one magnetic polarity, the output can drop almost to zero. The opposite polarity can increase the output almost to supply voltage.

The output from a linear sensor usually is supplied from the emitter of an internal NPN transistor, not the collector. A minimum 2.2K resistor should be connected between output and ground.

The variable output can be interpreted as a measurement of distance between the sensor and a magnet. In this mode, a Hall sensor functions as a **proximity** sensor. However, it is not usually capable of measuring a distance of more than 10mm.

Other Applications

Hall sensors are incorporated in other types of components. A **magnetometer**, for example, may contain Hall sensors.

Additional discussion of Hall-effect sensors, with test circuits, will be found in the book *Make: More Electronics*, from which some of the figures here have been excerpted.

Values

Magnetic field at operating point is the minimum field necessary for the output to switch on. It is measured in tesla or gauss, and the abbreviation B_{OP} is used.

Magnetic field at release point is the maximum field that allows the output to switch off. It is measured in tesla or gauss, and the abbreviation B_{RP} is used.

Magnetic field range may be specified for linear (analog) Hall sensors.

Supply voltage may range as widely as 3VDC to 20VDC, or may be restricted between 3VDC to 5.5VDC. Check datasheets carefully.

Sourcing or sinking capability for the open-collector output is typically 20mA.

How to Use a Hall-Effect Sensor

Hall sensors are often made in 3-pin packages. Through-hole variants are usually made of black plastic and look like TO-92 transistors, but are slightly smaller.

Surface-mounted variants are common.

A typical through-hole Hall sensor has one bevelled face and a flat face on the opposite side. The bevelled face may be referred to as the "front" of the component in a datasheet. The sensor responds when an appropriate magnetic pole is brought close to the front face of the sensor.

The part number printed on the front of the sensor may be abbreviated as three digits. The code below this usually refers to the date of manufacture.

A simple circuit for a Hall sensor resembles a typical circuit for a phototransistor. Positive supply voltage and negative ground are applied to two of the three leads. Positive voltage is also applied, through a pullup resistor, to the third lead, which is the open-collector output (except in the case of a linear Hall sensor, described previously). The output pin is then tapped as the output from the sensor, to be applied to a component that will not draw more than 20mA.

Configuration of Object Presence Sensors

While most of the following suggestions relate specifically to Hall-effect sensors, some general principles may be applied to optical sensors.

Linear Motion

A presence sensor can be activated when the triggering source (such as light or a magnet) approaches it directly. This is sometimes referred to as *head-on mode*. Alternatively, triggering can be arranged when the source moves past the sensor. This is sometimes referred to as *slide-by mode*. The two modes are illustrated in sections 1 and 2 of Figure 3-16.

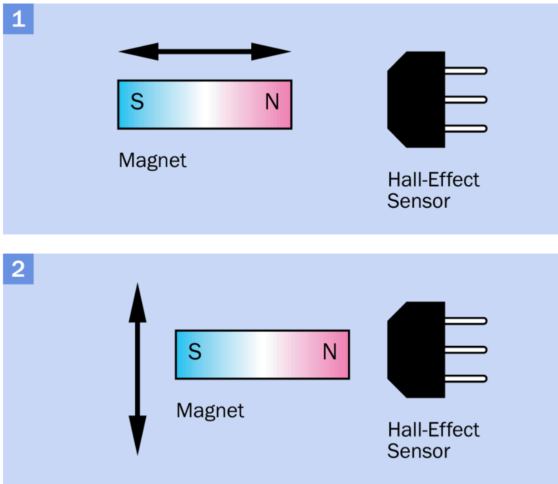

Figure 3-16 *Section 1 of this figure illustrates a presence sensor being used in head-on mode, while section 2 illustrates slide-by mode.*

Slide-by mode may be preferred because it eliminates the risk of damage to the sensor if overshoot occurs in head-on mode.

In slide-by mode, using a bipolar Hall-effect sensor, two magnets can be placed together with opposite polarity, creating a very steep transition in the overall magnetic field. This minimizes the risk of imprecise triggering. Using neodymium magnets, the triggering point can be adjusted with a precision of 0.01mm or better. See Figure 3-17.

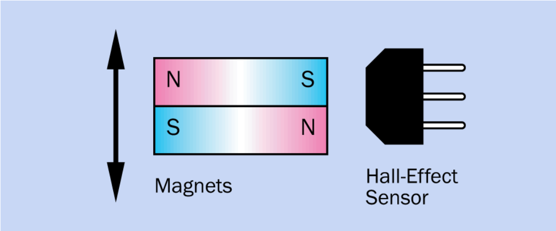

Figure 3-17 *In slide-by mode, two magnets with opposite polarity can be put together to create a very precise transition in a bipolar Hall-effect sensor.*

Sensing by Interruption

An *optointerrupter* is sensitive to an object passing between the light source and the light sensor. A comparable arrangement can be used with a Hall-effect sensor or a reed switch, but only if the interrupting object is thin and ferrous. This configuration is known as a *ferrous vane interruptor*.

Note that the magnet will exert significant force on the ferrous vane. This becomes an issue in sensors where the mechanical force is limited—for example, in paper-path sensors in a photocopy machine.

Additional information about the detection and measurement of moving objects will be found in the entry describing **linear position** sensors. See Chapter 6.

Angular Motion

One or more magnets can be used with a Hall-effect sensor to detect the angular motion, relative angular position, or absolute angular position of a rotating part. This data can be used to determine its speed of rotation. Some techniques to achieve this are described in the entry describing **rotary position** sensors. See Chapter 7.

Sensor Comparisons

Advantages of Optical Presence Sensors

- Not affected significantly by magnetic fields that can interfere with operation of a Hall-effect sensor or a reed switch.
- May be contained in a small, all-in-one package.
- Some optical sensors can operate over a distance of 50cm.
- Very well suited to sensing an object that blocks the light source (the *optointerrupter* configuration).

Disadvantages of Optical Presence Sensors

- Must have clear line-of-sight with the object and/or a reflector.
- Performance will be degraded by accumulation of dust or dirt.
- Limited lifetime of LED light source, if used continuously.
- May be accidentally triggered or impaired by some types of ambient light.
- Often requires a load resistor for the LED as well as a pullup resistor for the open-collector output.
- Range of acceptable voltage is usually narrow.

Advantages of a Reed Switch

- No polarity.
- No additional components required, other than a magnet.
- Able to switch AC or DC.
- Able to switch to voltages as high as 200V in some cases.
- Can be maintained by a magnet in open or closed state indefinitely without any power consumption.
- Many variants are capable of switching 500mA, and higher-current types are available.
- Can be activated through nonmagnetic materials (plastic, paper).
- Not significantly affected by dust or dirt that can degrade performance of an optical switch.

Disadvantages of a Reed Switch

- Requires a separate magnet (which must be placed carefully to avoid affecting other components).
- Cannot be miniaturized to the same extent as a surface-mount chip.
- Glass envelope is easily damaged.
- Arcing may occur between contacts.
- Will not work reliably when the activating magnet is more than a few millimeters from the switch.
- Can be activated accidentally by other magnetic fields.
- When sensing an object that comes between the switch and a magnet, only a ferrous object can be used.
- Must be debounced when connected with a logic chip or controller.

Advantages of a Hall Effect Sensor

- Robust solid-state component.
- Can be miniaturized for surface-mount applications.
- Very low cost.
- Fast response.
- No contact bounce.

- Extremely durable, with an almost unlimited lifetime.
- Not significantly affected by dust or dirt that can degrade performance of an optical switch.
- Low cost.

Disadvantages of a Hall Effect Sensor

- Requires a separate magnet (which must be placed carefully to avoid affecting other components).
- Open-collector output typically limited to 20mA or less.
- May be vulnerable to magnetic fields.
- When sensing an object that comes between the switch and a magnet, only a ferrous object can be used.

What Can Go Wrong

Optical Sensor Issues

Deterioration of LEDs

Most object presence sensors depend on infrared LEDs as a light source. An LED has many virtues (discussed in Volume 2), but does tend to suffer from gradual reduction in light output over a period of years. In a device such as a photocopy machine, which is used intermittently and may have an “economy” or “sleep” mode in which most of its components are powered down, LED-based detectors should last almost indefinitely. In other applications where an LED is powered continuously, its light output will diminish significantly in 3 to 5 years. Bearing this in mind, an optical sensor should be chosen to operate well below its light-detection limits.

Object Too Close

Some optical and ultrasonic detectors triangulate on an object; that is, the light emitter and light sensor are angled slightly toward each other (as shown in sections 3 and 4 of Figure 3-3). The signal output from the sensor will peak at the distance where the emitter and sensor focus at a point. Consequently the output voltage will diminish when the object comes closer, which may create the misleading impression that the object is moving further away. To avoid spurious readings, detectors should not be used with objects that are closer than the minimum distance specified by the manufacturer.

Reed Switch Issues

Mechanical Damage

Bending the axial leads on a reed switch can easily fracture the glass envelope. Reed switches must be handled with care.

Contact Bounce

If the switch is wired to the input of a logic chip or microcontroller, contact bounce when the switch opens or closes is likely to be misinterpreted as multiple switching events. Debouncing will be necessary, either by additional components or by insertion of a momentary delay in the code embedded in a microcontroller.

Arcing

When switching high voltages or currents, an arc may be created briefly between the switch contacts, most often when they are moving from the closed to the open state. The arc erodes the contacts of the switch. Inductive loads make the arcing problem worse. If the switched voltage is kept below 5V arcing generally does not occur, extending the life of the switch.

passive infrared sensor

4

In coloquial speech, the term *motion sensor* is usually understood to mean a **passive infrared** motion sensor.

The acronym *PIR* is often used for a passive infrared sensor. It is always capitalized, without periods.

Object presence sensors and **proximity** sensors require an active source of a magnetic field, ultrasound, or infrared radiation. A passive infrared sensor does not require any such source, and responds passively to heat radiated from the object that is being detected.

OTHER RELATED COMPONENTS

- **object presence** sensor (see Chapter 3)
- **proximity** sensor (see Chapter 5)

What It Does

A **passive infrared** motion sensor, often described as a *PIR*, detects *black-body radiation*, which all objects emit as a function of their temperature relative to absolute zero. The sensor responds to infrared radiation centered around a wavelength of 10µm (10 microns, or 10,000nm). This is the approximate body temperature of people and animals.

The word "passive" in the term "passive infrared" refers to the behavior of the detector, which receives infrared radiation passively. **Proximity** sensors must generate their own infrared radiation actively, which is interrupted or reflected by nearby objects. See Chapter 5.

Schematic Symbols

Schematic symbols that are sometimes used to represent a passive infrared motion sensor are shown in Figure 4-1.

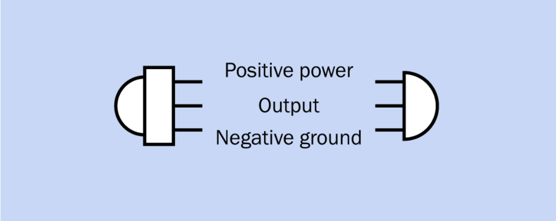

Figure 4-1 *Schematic symbols that may represent a passive infrared motion sensor. The orientation (pointing left or right) is arbitary. The pin sequence may vary.*

Applications

Motion-sensitive outdoor lighting almost always is based around a PIR. Similarly, a security system may sound an alarm or activate a video camera when a PIR indicates human activity.

Wildlife monitoring systems use PIRs to start a video camera that can then run for a preset interval.

Warning systems for automobiles have been developed that use a rear-facing PIR to detect pedestrians.

Industrial indoor lighting may use PIRs that switch the lights on automatically when people enter a room, and then switch the lights off (after a timed delay) when people are no longer detected in the room. The goal is to prevent wastage of energy as a result of employees forgetting to switch the lights off.

How It Works

A PIR module contains multiple components. Most visible is an array of at least 15 small lenses that focus infrared light from zones in the environment onto a *pyroelectric detector*, also known as a *pyroelectric sensor*. The response of the detector is processed by an amplifier, so that the signal can trigger an electromechanical **relay** or **solid-state relay** (see Volume 2). The relay operates an external device such as a light or an alarm.

Additional circuitry may allow the user to control the sensitivity of the PIR module and the length of time that the relay remains closed. The user may also be able to set the time of day when the PIR is active, or an additional **phototransistor** can shut down the PIR during daylight hours. If a phototransistor is included, its sensitivity is adjustable. For more information about phototransistors, see Chapter 22.

Pyroelectric Detector

The pyroelectric detector is actually a type of *piezoelectric* device. It is based around a wafer of lithium tantalate, which generates a small voltage in response to incident thermal radiation. However, like other piezoelectric components, it does not respond to a steady-state input, and must be activated by a transition. This distinguishes it from other types of light sensors, such as an infrared **photodiode**, in which the response is consistently related to a temperature input.

The response of a pyroelectric detector is suggested by the graphs in Figure 4-2.

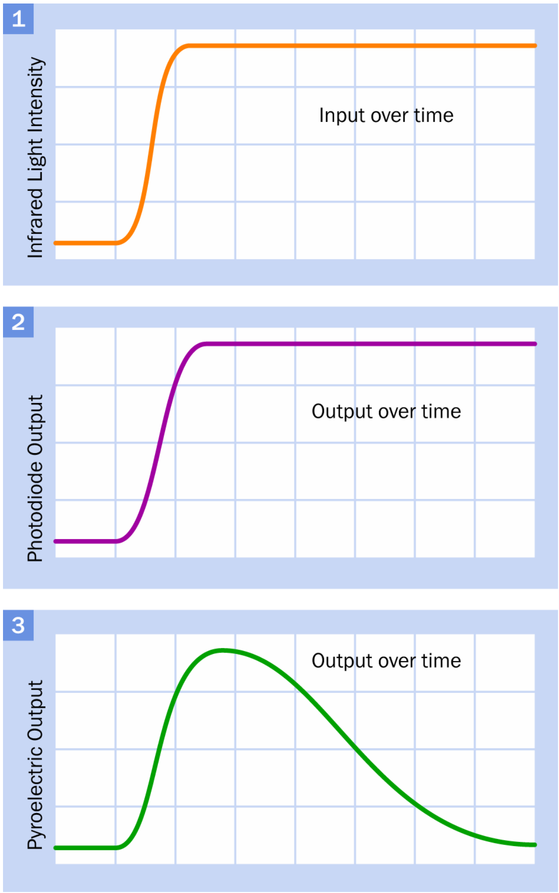

Figure 4-2 *Top: incident infrared light intensity. Center: the voltage output from a hypothetical photodiode. Bottom: the voltage output from a hypothetical pyroelectric detector.*

A pyroelectric detector in a PIR module is mounted in a sealed metallic container, as shown in Figure 4-3. The rectangular window in the detector is usually made of silicon, which is opaque to visible wavelengths but transparent to long-wave infrared radiation.

Elements

The pyroelectric detector used in a PIR contains at least two *elements* with opposite polarities, connected in series. If a sudden change in temperature affects both elements equally, their responses will cancel each other out. Thus, the detector ignores changes in ambient temperature. However, if a source of infrared radiation in the appropriate waveband affects one element before the other, the detector will emit two pulses of opposite polarity. See Figure 4-4.

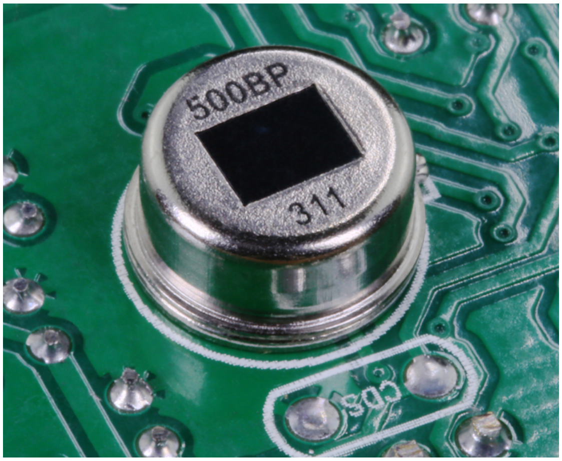

Figure 4-3 *A pyroelectric detector mounted on a small circuit board in a passive infrared radiation sensor.*

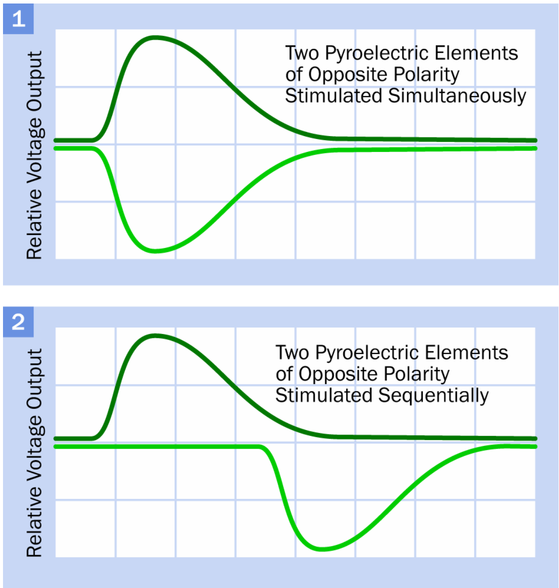

Figure 4-4 *Top: in a pyroelectric detector, if a change in temperature affects two elements of opposite polarity simultaneously, their voltages cancel each other out. Bottom: if one element is triggered before the other, the detector emits a signal.*

Lenses

Lenses are used to trigger the elements sequentially. Each lens faces toward one visible zone in the target area. When a source of infrared radiation moves from one zone to the next, it energizes the elements alternately, creating an output.

In some PIRs, four pyroelectric elements are used instead of two, to provide better coverage. The pairs of sensors may be wired in series or in parallel, but the principle remains the same.

The lenses are molded into a polyethylene dome that is often white and covers the pyroelectric detector. The dome appears smooth on the outside, but fine patterns of concentric ridges are molded on the inside. These are *fresnel lenses*, which are much cheaper, smaller, lighter, and easier to fabricate than conventional optical lenses. A fresnel lens introduces some distortion and aberration, but these defects are unimportant in a PIR.

Figure 4-5 illustrates the principle of a simple fresnel lens. The first section of this figure shows a conventional optical lens with one flat side and one curved side. A distant object emits almost-parallel beams of infrared light that are focused by the lens. Section 2 shows the same lens divided into segments that are stacked with no space between them. They behave in exactly the same way as the original lens. In section 3, each segment has been reduced in width, but because the optical faces still have the same geometry, they will still have the same function, although a small amount of distortion will be added by the reduction in width. This is a fresnel lens, which found an early application in lighthouses, where it greatly reduced the weight of very large glass lenses that focused the beam.

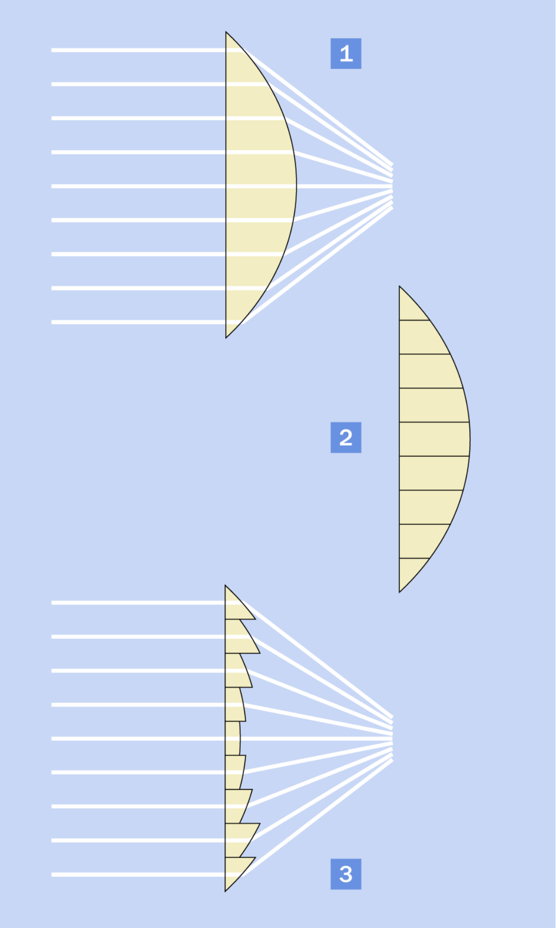

Figure 4-5 *Principle of a fresnel lens. See text for details.*

The same principle can be applied to a lens in which both surfaces are curved, as shown in Figure 4-6. In practice this will introduce more imperfections in the image, although some compensation is possible by adjusting the exact shape of the lens.

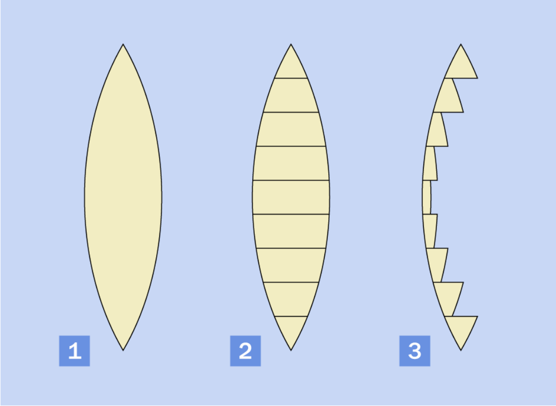

Figure 4-6 *The principle of a fresnel lens applied to a conventional lens in which both surfaces are curved.*

Figure 4-7 shows three curved fresnel lenses placed edge-to-edge, seen from above. In section 1 of this figure, infrared rays from a distant source are focused by the first lens onto the right-hand element of a pyroelectric sensor. In section 2, the external source has moved laterally, and the rays now focus on the left-hand element. In section 3, the source has moved into the zone covered by the centrally located fresnel lens, which focuses on the right-hand element again. The fluctuating inputs will trigger the sensor.

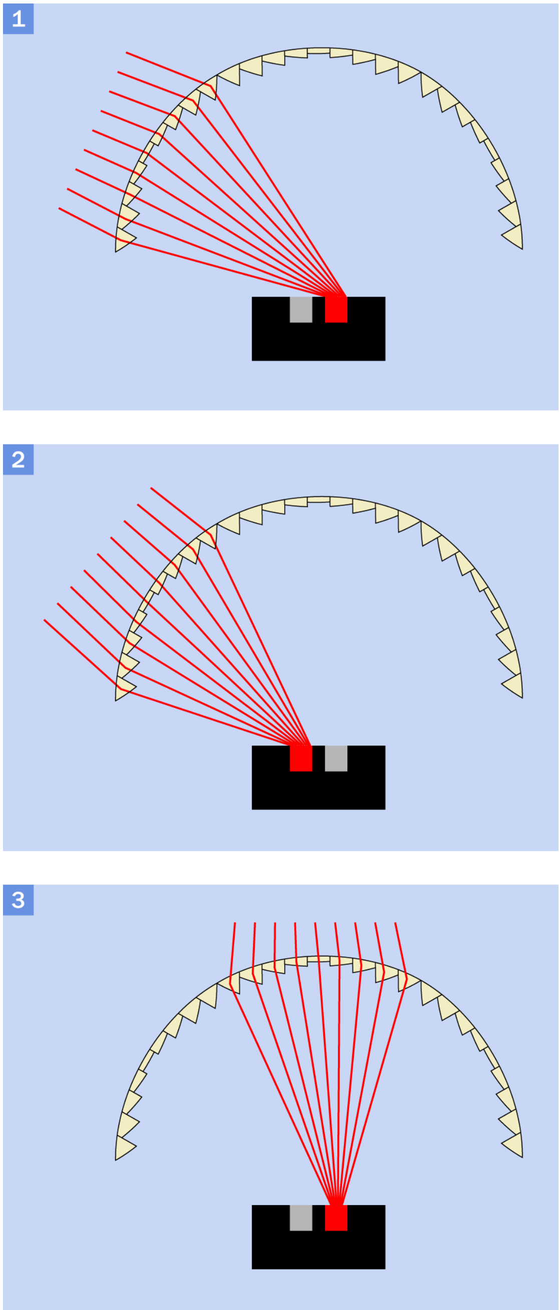

Figure 4-7 *Sections 1, 2, and 3 show fresnel lenses focusing an external source of infrared radiation on individual elements of a pyroelectric sensor.*

PIRs may combine fresnel lenses in a variety of patterns. Figure 4-8 shows an evenly weighted mosaic that would be suitable for a motion detector mounted on a ceiling, facing directly downward. Figure 4-9 shows a pattern weighted toward lateral motion, providing less sensitivity for motion above and below the primary band.

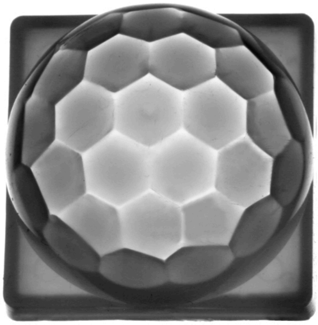

Figure 4-8 *An evenly weighted mosaic of fresnel lenses.*

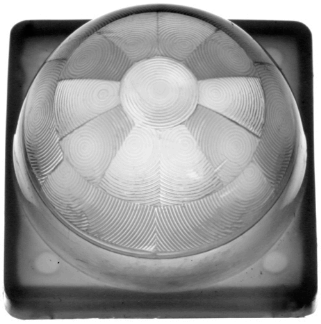

Figure 4-9 *A mosaic weighted more toward sensing lateral motion. The grooves of the fresnel lenses are visible.*

Variants

PIR sensor modules are available mounted on a small board such as the one shown in Figure 4-10 from Parallax, Inc. The detection range is 5 to 10 meters, selected by a jumper on the board. The three pins visible in the photograph are for power supply (3VDC to 6VDC), ground, and output. The output can source up to 23mA with a 5VDC power supply. Power consumption of the module is only 130µA when it is idle, or 3mA when it is active but has no load.

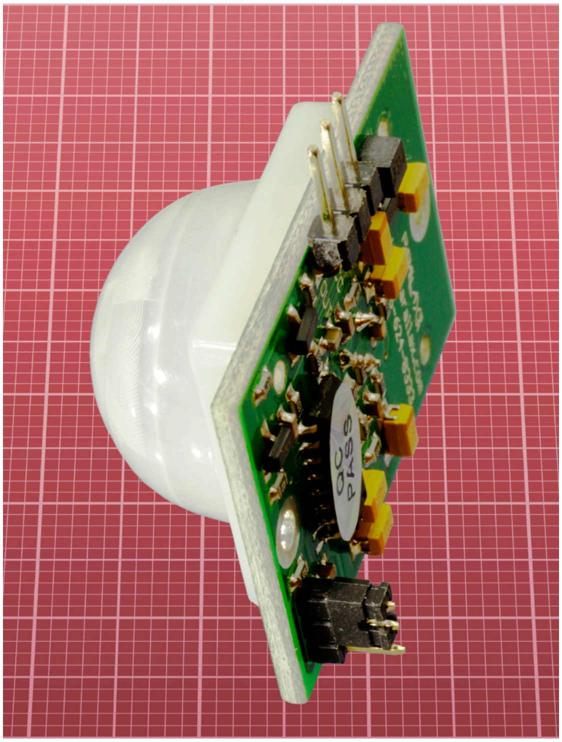

Figure 4-10 *A passive infrared detector mounted with basic necessary components on a small board.*

A board of this type still requires additional components to set the "on" time for a light or alarm, and to deactivate the PIR during daylight hours.

Various lens patterns are available, sold separately.

A PIR can be bought as a single component containing two elements and FET transistors to amplify the signal. Surface-mount and through-hole versions are available, requiring a typical power supply of 3VDC to 15VDC.

However, a PIR bought as a "bare" component requires significant external circuitry, using comparators or op-amps. Circuit design is nontrivial, entailing practical problems such as op-amps being sensitive to voltage spikes caused by activating a relay that shares the same power supply.

An easier alternative is an all-in-one detector, lens, and control circuit such as the Panasonic AMN31111, which is ready for board mounting. Its small output current of 100µA would be capable of activating a solid-state relay. Similar Panasonic PIRs offer a variety of ranges, sensitivities, and supply voltages.

The AMN31111 is in Panasonic's AMN series. There are many type numbers for combinations of analog or digital output, lens shape, and black or white lens. A selection of lens shapes, derived from the manufacturer's datasheet, is shown in Figure 4-11.

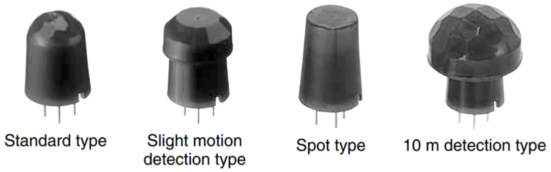

Figure 4-11 *Four lenses from the Panasonic AMN series of passive infrared sensors.*

What Can Go Wrong

Temperature Sensitivity

In warmer weather, objects in the field of view of a PIR will tend to be warmer, and the temperature difference between them and human skin will diminish. This can degrade the performance of a PIR.

Detector Window Vulnerability

The silicon window on a detector is vulnerable to dirt or grease. Avoid touching the component if it is not protected by lenses.

Moisture Vulnerability

Water absorbs far-infrared light. Consequently, condensation on the lens or detector can degrade performance, and a PIR may not function in heavy rain or snow.

proximity sensor

5

Proximity sensors that use infrared, ultrasound, and capacitance are described here. This Encyclopedia does not include proximity sensors that use magnetism, inductance, or other methods of determining distance.

Sometimes proximity sensors are referred to as *distance sensors*. An ultrasonic proximity sensor may be described as a *range finder* or a *ranger*.

High-end ultrasound proximity sensors sold as large, sealed modules with cabling can monitor the status of industrial processes. These commercial units are outside the scope of the Encyclopedia.

A sensor that detects whether an object is present, but does not measure the distance to it, is considered to be an **object presence** sensor and has its own separate entry. See Chapter 3. Many devices that are sold as proximity sensors or distance sensors actually do not provide meaningful distance data, and therefore in this Encyclopedia they are included with presence sensors.

Phototransistors and **photodiodes** may be used as sensing elements in proximity sensors. These components have their own entries as light sensors. See Chapter 22 and Chapter 21.

OTHER RELATED COMPONENTS

- **object presence** sensor (see Chapter 3)
- **passive infrared** sensor (see Chapter 4)

What It Does

A proximity sensor measures the distance between itself and a physical object that is often described as the *target*. The output from the sensor may be analog (voltage), serial data, or pulse-width modulation. It may be transmitted via a serial protocol such as SPI, TTL, or I2C, and may be stored as digital data in a register that is accessed by a microcontroller, using I2C. For additional details about protocol, see Appendix A.

Schematic Symbols

Either of the schematic symbols in Figure 5-1 may represent a proximity sensor, but are not used consistently. The sensor may also be represented as a rectangle containing text describing its function.

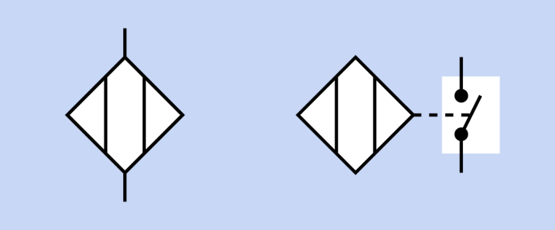

Figure 5-1 *Two ways to represent a proximity sensor in a schematic.*

Applications

In robotics, a proximity sensor can prevent a collision between a robot and an object or barrier in front of it. Some sophisticated proximity sensors can provide sufficient data for software to map the entire environment, but are outside the scope of this entry.

Proximity sensors can also be used in alarm systems, or for liquid-level sensing in storage tanks, or in automobiles to sound a warning if the driver is backing into an obstacle (although these devices are being augmented with rear-view video monitors).

In handheld devices, proximity sensors are used to sense the presence of the user's hand or face —for example, to shut down the display when a person raises a phone to talk into it.

Variants

This entry is subdivided to describe proximity sensors that use ultrasound, infrared light, and capacitance.

Ultrasound

An ultrasonic proximity sensor functions by emitting a short burst of sound and then listening for echoes from objects in front of it.

The sound is created by a **piezoelectric transducer** (see Volume 2) at a frequency between 30kHz and 50kHz, well above the range that can be detected by the human ear. The transducer may do dual duty as a microphone, sending and receiving sound on an alternating basis; or a second transducer, serving as a microphone, may be mounted beside the emitter on a small circuit board. The economically priced HC-SR04 is an ultrasound proximity detector popular in the robotics community, working reliably in the range of 2cm to 5m.

A board on which the sensor is mounted may include a microcontroller to measure the delay between propagation of a pulse and reception of the echo. Distance to the reflecting object is then calculated using the speed of sound in air at sea level, which is approximately 340 meters per second.

Infrared

An infrared proximity sensor requires a beam of infrared light from an LED that may be incorporated in the sensing module or mounted separately. Light reflects from the target and is detected by a **phototransistor** or **photodiode**. From the angle of the reflected light, onboard electronics can calculate the distance to the target by a process known as *triangulation*. See Figure 5-2. (This diagram is simplified. An actual sensor may use a linear array of photodiodes to assess the angle of the returning light beam.)

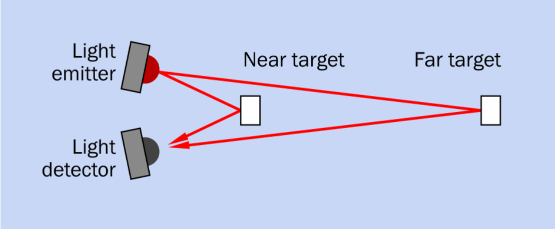

Figure 5-2 *An infrared proximity sensor determines the distance to an object by assessing the angle of reflected light.*

To reduce the risk of false positives, light from the LED contains only a narrow range of infrared wavelengths. Also, it is modulated at a frequency recognized by sensing circuitry in the module.

Relative Advantages

Ultrasound Devices

- Generally more suitable for detecting objects that are more than 1 meter away.
- Unaffected by direct sunlight, fluorescent tubes, and other light sources that can interfere with infrared devices.
- More accurate, often capable of placing objects within 5mm.
- Able to measure the distance to liquids and transparent objects, which may not be easily detected with infrared.

Infrared Devices

- Physically smaller—especially surface-mount versions.
- Able to measure the distance to soft objects, which may not be easily detected by ultrasound.
- More appropriate for targets that are closer than 10mm.
- More affordable.

Ultrasonic Examples

The proximity sensor in Figure 5-3 is a low-priced model, popular in the robotics community. Manufactured by MaxSonar, it uses a single element to send and receive. The manufacturer claims that it can detect a 6mm (quarter-inch) dowel 1.8 meters directly in front of it, and a 9cm dowel at 3.3 meters. This performance is beyond the capability of almost all infrared sensors.

MaxSonar offers a variety of sensors that appear physically very similar but have different range capabilities. Each has three outputs that can be accessed simultaneously: serial data at 9,600bps, analog voltage, and pulse-width modulation.

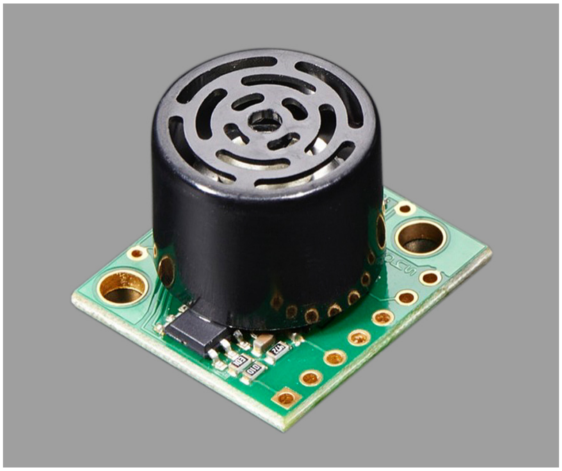

Figure 5-3 *The MaxSonar MB1003 can detect large solid objects as far away as 5 meters. Photo derived from an image by Adafruit.*

The serial output uses the RS232 protocol and consists of the letter R followed by four ASCII-coded numerals representing the measured range in millimeters. Thus, R1000 would indicate an object at 1 meter distance.

The analog voltage ranges linearly from 293mV when sensing an object at 300mm to 4,885mV for an object at 5,000mm.

The pulse-width output sends pulses ranging from 300μs indicating an object 300mm away to 5,000μs indicating an object 5 meters away.

The unit incorporates a temperature sensor that compensates for the lower density of air when its temperature increases. Weatherproofed versions are available. The power supply is 5VDC and must be smoothed.

Imports

Some international sources offer minimal paired ultrasound components at a very low price, such as the HC-SR04 from Cytron Technologies in Malaysia. See Figure 5-4.

Sound dispersion of the transducer is claimed to be plus-or-minus 15 degrees, and the claimed range is up to 4 meters. The module requires a triggering input pulse that must last at least 10μs. This prompts it to emit eight rapid ultrasound signals at 40kHz. The module measures the response time and applies a high state to its echo pin for a duration that is proportional with the distance measured. An external microcontroller must time the duration, then divide by a factor of 58 to obtain distance in centimeters.

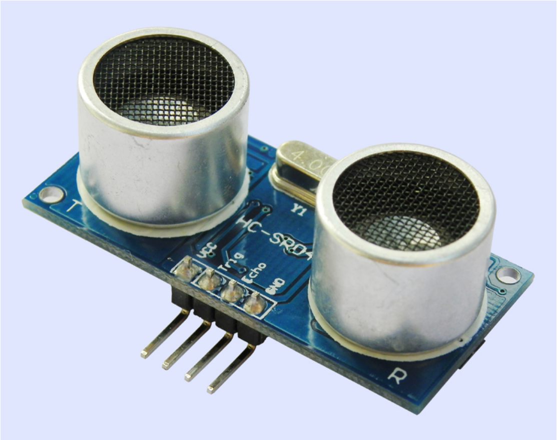

Figure 5-4 *The HC-SR04 is a very low-cost import that can provide acceptable performance when used with an external microcontroller.*

Many online sources offer simple code libraries for Arduino or PICAXE microcontrollers for use in conjunction with the HC-SR04.

Individual Elements

Individual ultrasonic components such as those shown in Figure 5-5 are available from many vendors. The user must add circuitry to generate a high frequency for a short duration, amplify the microphone signal, measure the time difference, and calculate distance.

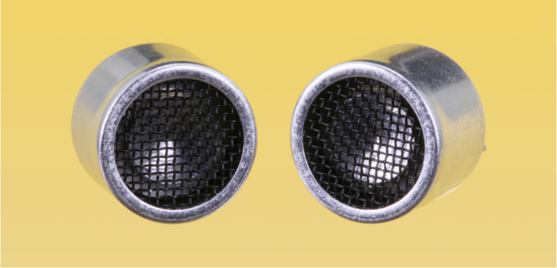

Figure 5-5 *These components, listed as the "40TR12B-R ultrasonic sensor kit" by the online supplier Jameco, could form the basis of a DIY ultrasonic proximity sensor.*

Infrared Examples

Sharp manufactures four infrared proximity sensors that are widely regarded as accurate and easy to use. They are popular in the robotics community. Their part numbers and ranges are:

- GP2Y0A51SK0F (20mm to 150mm)
- GP2Y0A21YK0F (10cm to 80cm)
- GP2Y0A02YK0F (20cm to 150cm)
- GP2Y0A60SZLF (10cm to 150cm).

The GP2Y0A60SZLF is the most recent product, with the most impressive specification. The GP2Y0A21YK0F is shown in Figure 5-6.

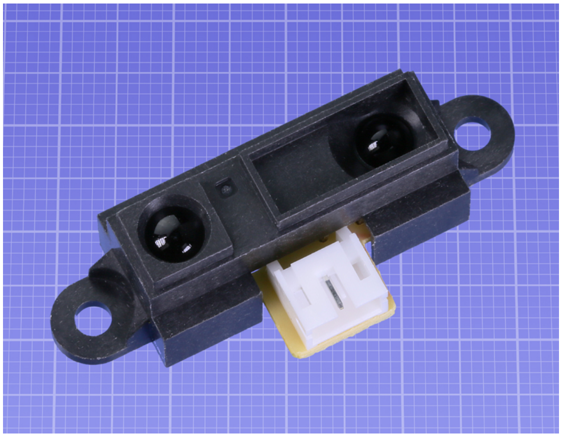

Figure 5-6 *The Sharp GP2Y0A21YK0F infrared proximity sensor. The background grid is in millimeters.*

Sharp describes these sensors as having an *analog output*. The voltage on an output pin varies in inverse proportion with the distance being measured. The relationship is illustrated by the graph in Figure 5-7, derived from the manufacturer's datasheet for model GP2Y0A02YK0F.

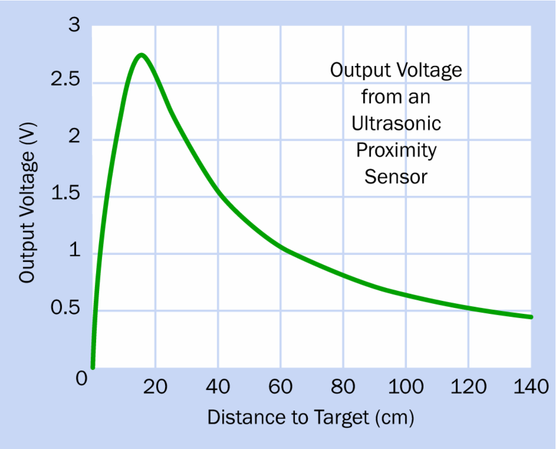

Figure 5-7 *Relationship between output voltage and target distance for a Sharp infrared proximity sensor, derived from the manufacturer's datasheet.*

The Sharp sensors can work with 5VDC. They consume around 30mA, except for the GP2Y0A60SZLF, which uses less current. Because the infrared LED functions in bursts, the manufacturer recommends protecting other components sharing the power supply by placing a 10μF capacitor across the sensor supply pins.

Trends in Infrared Proximity Sensing

Like many other types of sensors, proximity sensors have been affected by the huge market for handheld devices.

Handheld applications have had four consequences:

Miniaturization

Infrared proximity sensors are now commonly found in surface-mount chips measuring 5mm × 3mm or smaller.

Onboard processing

The status of a photodiode can be processed by a microcontroller on the same chip, to determine what the sensor is really "seeing." Input from an included ambient light sensor is factored into the evaluation.

Cost reduction

While chip-based proximity sensors have become increasingly sophisticated, their unit cost has plummeted, so that they are now actually much cheaper than simpler devices such as the Sharp analog sensors described above.

Complexity

Modern sensors must be programmed with a complex variety of instructions, and their coded output must be interpreted with a separate microcontroller running its own program. Whether this compensates for the low price and added functionality is something for the individual developer or experimenter to decide.

The Silicon Labs Si1145/46/47 series are chips with the kind of sophisticated capabilities required for handheld devices. An external microcontroller communicates with the sensor via an I2C connection, and can instruct it to adjust its distance range (from 1cm to more than 50cm), its analog-to-digital conversion sensitivity, and its current-sinking capability for up to 3 external LEDs. The chip incorporates ultraviolet sensing and ambient-light sensing capability. Its I2C connection can run at up to 3.4Mbps. Because its light output is pulsed for only 25.6μs every 800ms at 180mA, the average power consumption is only 9μA, assuming a supply voltage of 3.3VDC.

For additional details about protocols such as I2C, see Appendix A.

In addition to its use in handheld devices, the manufacturer suggests applications including heart-rate monitoring, pulse oximetry, and display backlighting control. These applications require only a subset of the features built into the sensor, but its price is so low, it may be cost-effective even when many of its capabilities are unused.

Proximity sensors with comparable specifications are available from many manufacturers. Examples are the Vishay VCNL4040 and the Avago HSDL-9100. Figure 5-8 shows the Silicon Labs SI1145 on the left, and the Avago HSDL-9100 on the right.

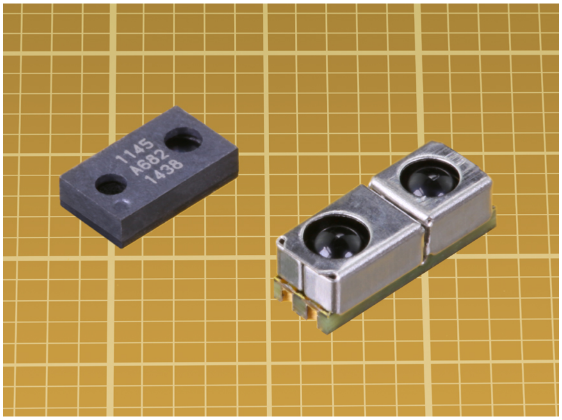

Figure 5-8 *Two sophisticated surface-mount proximity sensors with digital output. Left: Silicon Labs SI1145. Right: Avago HSDL-9100. The background grid is in millimeters.*

Several guidelines must be observed when using this kind of sensor. First and most obviously, if an external LED is used, it must have a peak wavelength compatible with the photodiode in the sensor. The LED must be placed as near as possible to the photodiode, as reducing the separation increases the sensitivity; but crosstalk between the photodiode and LED must be minimized, usually by placing a thin barrier between them that is barely taller than the higher component.

If the light emitter and/or light sensor are protected behind a transparent glass or plastic panel, it must have minimal resistance to infrared wavelengths, and its thickness must be chosen in compliance with guidelines in the sensor datasheet. To prevent light from reaching the sensor by reflection from the rear of the panel, a thin, opaque tube can be installed between the LED and the panel.

A sensor of this type may be configurable with a “detection scheme,” meaning high and low sensing threshold levels appropriate to the object that is likely to be detected. Determining this may be a process of trial and error.

Capacitive Displacement Sensor

This is also known as a *capacitive linear displacement sensor*. It should not be confused with a capacitive **single touch** sensor, a human-input device that has its own entry. See Chapter 13.

A **capacitive displacement** sensor measures the distance between itself and a target that must be electrically conductive. Unlike optical or ultrasound position sensors, no additional source of light, sound, or other radiation is required. Unlike a magnetic position sensor, it does not require a separate permanent magnet. It simply measures its electrical capacitance with the target.

High-precision capacitive displacement sensors are used mainly for industrial process management. Lower-precision variants are much less expensive and can be used as **object presence** sensors to determine if an object is anywhere within a specified range.

A typical maximum range would be 10mm. For larger distances, optical and ultrasound sensors are more appropriate.

A selection of cylindrical sensor probes is shown in Figure 5-9.

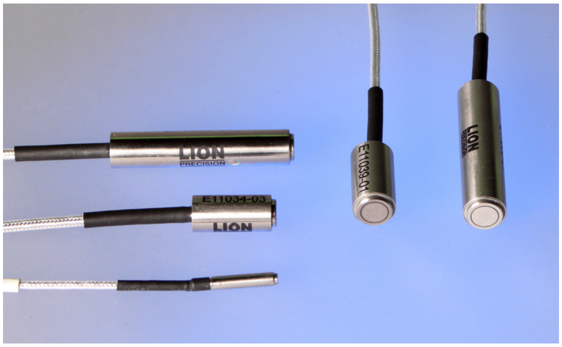

Figure 5-9 *Some high-precision capacitive displacement sensors from Lion, which builds them into cylindrical probes ranging from 3mm to 18mm in diameter.*

Applications

The high-precision variant of this type of sensor is commonly used during the production of small devices, such as disk drives. It can also measure vibration of a rotating metal part, such as a motor shaft, and may maintain automatic focus of a microscope.

Lower-precision variants can be used for applications such as counting objects on a conveyor.

When used to measure materials thickness, the sensor finds applications in checking automobile brake rotor fabrication and the thickness of silicon wafers.

How It Works

When two plates of electrically conductive material are placed opposite each other, they possess capacitance. This means that they have an electrical storage capacity enabled by accumulation of opposite charges on each plate.

The capacity is directly proportional to the plate area, inversely proportional to the distance between the plates, and is affected by the medium separating the plates, known as the *dielectric*.

If the plate area and dielectric remain constant, the distance between the plates will be the only factor affecting the capacitance. Therefore, the distance between the plates can be calculated by measuring the capacitance.

Measurement can be performed by evaluating the *displacement current* that passes through the dielectric from one plate to another when a pulse of voltage is applied. (Hence the term "capacitive displacement" in the name of this type of sensor.)

A detailed explanation of displacement current is included in the second edition of *Make: Electronics*.

The sensor itself functions as one plate of the capacitor while the target functions as the opposite plate. Alternating current is applied as a rapid series of pulses, and the current that passes between the plates is proportional to the distance between them.

Ideally, the target should be grounded to the current source. However, since AC is being used, capacitive coupling of the target to the current source is also possible, so long as the additional capacitor has a value of 0.1µF or higher.

Sources of Error

To obtain a meaningful measurement, the electric field from the sensor is focused on the target. Some dispersion will still occur, and the combination of sensor and target must be compatible. A target typically should be flat and should have a larger surface area than the sensor.

Humidity can affect sensor performance, as it changes the value of the dielectric. Temperature can affect performance, partly because it causes small dimensional variations in the sensor and the target.

The surface of the sensor and the surface of the target should be precisely parallel, because the spot where the field hits the target will be elongated if the target is tilted relative to the sensor. Elongation increases the capacitive area and affects the accuracy of measurement.

This type of sensor can also measure the thickness of a nonconductive material, if the material is a thin sheet that can be interposed between two sensors. In this mode the material functions as a dielectric, and its thickness will affect the AC current passing through it.

While lower-precision capacitive displacement sensors are relatively unusual, they can potentially serve as a relatively affordable and simple **object presence** sensor, so long as the target is conductive and will not be damaged by passing a small alternating current at a relatively low voltage.

Values

A high-precision capacitive displacement sensor can measure distances usually ranging from 0.25mm to 10mm with an accuracy that can be better than 0.05mm. High voltages are not required, with a supply of plus-or-minus 15V being common.

The sensing element, often referred to as a *probe*, is usually plugged into a custom-designed control unit that converts the capacitance measurement into a variable output voltage. The performance is then expressed in millimeters per volt. Thus if the voltage varies by 5V over a distance of 1mm, the sensor is rated as providing 0.2mm per volt.

What Can Go Wrong with Optical and Ultrasound Proximity Sensors

Object Too Close

Because both types of proximity sensors (ultrasonic and infrared) may include emitters that are angled toward the distance range for which they are designed, they may fail to “see” an object that is closer. Consequently the sensor will provide no response, or may detect a different object that is further away. In either case, if the sensor is being used on a moving device, the device may collide with the undetected near object.

Multiple Signals

If two or more sensors and emitters are used concurrently, their combined signals can interfere with each other and create inaccurate readings.

Inappropriate Surfaces

Ultrasonic proximity sensors are intended to identify a single object that is closer to the sensor than other objects, within a narrow beam dispersion angle. Multiple objects, complex surfaces, soft surfaces such as clothing or furnishings, or an unusual configuration of interior walls can create inaccurate readings.

Infrared sensors may be unable to “see” liquids or transparent objects, and may give different assessments of distance depending on the properties of a surface. Human skin, for example, is a poor reflector, as it absorbs some infrared radiation.

Environmental Factors

An ultrasonic transducer uses a very small moving diaphragm to generate sound. Like any system containing moving parts, it will be vulnerable to moisture or excessive humidity, and may need to be protected.

After a device is built and tested indoors, in a controlled environment, it is likely to behave differently if it is moved outside where the temperature is significantly higher or lower.

Deterioration of LEDs

As noted in the section on presence sensors (see Chapter 3), LEDs tend to suffer from gradual reduction in light output over time. The performance of an infrared proximity sensor may deteriorate over a period of years, depending on how intensively it is used.

linear position sensor

A **linear position** sensor may also be described as a *linear displacement sensor* or a *linear position transducer*. It is sometimes categorized as a type of **proximity** sensor, but in this Encyclopedia a proximity sensor emits a signal and receives an echo to measure the distance from itself to an object. By comparison, a linear position sensor measures the position of a sliding object within a stationary enclosure.

An **object presence** sensor can be considered as a form of linear position sensor, but it only responds to the presence of an object, without measuring its position.

OTHER RELATED COMPONENTS

- **proximity** sensor (see Chapter 5)
- **object presence** sensor (see Chapter 3)
- **rotary position** sensor (see Chapter 7)

What It Does

Control of a mechanical device may require accurate and timely information about the position of a movable part in the device. A **linear position** sensor can be used for this purpose.

Three attributes are likely to be of interest:

- Position
- Direction of motion
- Speed of motion

Typically a linear position sensor measures only the first attribute. Additional electronics may calculate the second and third attributes by taking multiple position readings. Thus a *speed sensor* is very likely to be built around a position sensor, and therefore this Encyclopedia does not have a separate entry for speed sensors.

Applications

Robotic arm positioning, wing flap and rudder positions on an aircraft, computer-controlled machine tools, 3D printers, and automobile seat position sensors are some of the many applications.

Schematic Symbol

In a schematic, a linear position sensor may be represented by symbols for the sensing elements that are inside it (potentiometer, LED, phototransistor, or others).

How It Works

Linear potentiometers, *magnetic linear encoders*, *optical linear encoders*, and *linear variable differential transformers (LVDTs)* are described here. Other options are available, but they tend to be more specialized, and are not included.

Linear Potentiometer

For a full description of **potentiometers**, see Volume 1.

A linear potentiometer, often referred to as a *slider potentiometer*, contains an electrical resistance in the form of a straight section of *track*. The track may be a strip of *resistive polymer* or (less often) may consist of an insulator with a coil of nichrome wire wrapped around it.

For sensing purposes, the potentiometer is wired as a voltage divider, and a fixed potential is applied across its full length, as shown in Figure 6-1. A *wiper* slides along the track, sensing a voltage that varies linearly with the wiper's position. Output from the wiper can be used directly to control an analog indicator such as a meter, or can be processed by an analog-to-digital converter.

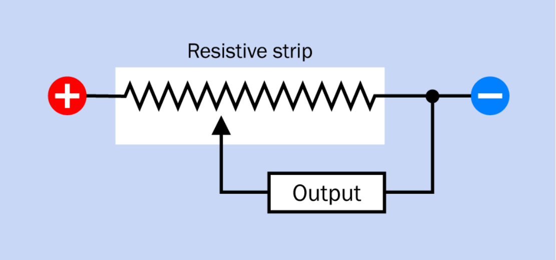

Figure 6-1 *A linear potentiometer can consist of a fixed track with a known voltage applied at each end, and a movable wiper.*

For audio applications, a slider potentiometer may have resistance that varies logarithmically with the position of the wiper. However, this type of component is not generally used as a position sensor.

For sensing purposes, the potentiometer is usually protected by a long, narrow box or tube through which a rod slides on sealed bearings. An example is shown in Figure 6-2.

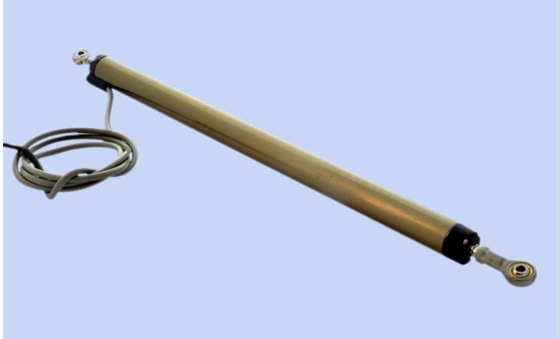

Figure 6-2 *A linear potentiometer contained in a tube with sealed bearings.*

Small linear potentiometers for position sensing are available from companies such as Bourns. The one shown in Figure 6-3 is about 20mm long, and the rod that slides through it has a travel of approximately 10mm. The component is available with resistance values ranging from 1K to 50K, and its power rating is 1/8 watt. The manufacturer claims a life expectancy of 500,000 cycles.

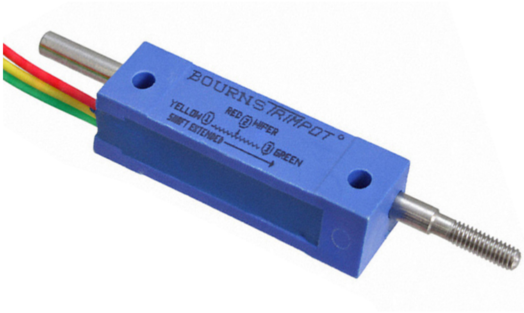

Figure 6-3 *A miniature linear potentiometer. The body is about 20mm long.*

A linear potentiometer is simple, inexpensive, compact, and requires few additional components. The track contains a lubricant, but inevitably some wear occurs as a result of motion of the wiper. Life expectancy will be reduced by vibration or by contamination with dirt or moisture.

A linear potentiometer may rarely be described as a *linear potentiometric sensor*.

Magnetic Linear Encoders

A ferrous rod or strip can be magnetized with alternating north and south poles. When it slides past a single bipolar Hall-effect sensor, it generates a pulse train from the sensor that can be interpreted to provide positional information. The principle of the component is shown in Figure 6-4. (Magnetic rotary encoders also exist; see "Rotary Encoders".)

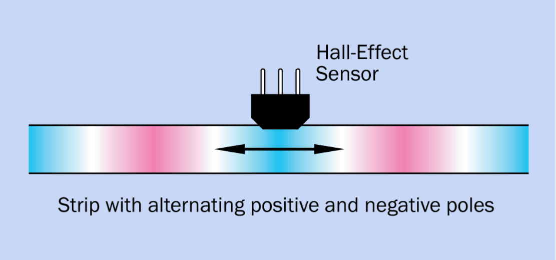

Figure 6-4 *When a strip magnetized with alternating north and south poles slides past a sensor, the pulse train from the sensor can be decoded to indicate the relative position of the strip.*

The sensing element may be described as a *read head*. If two are used, with a spacing equal to half the interval between the north and south poles on the strip, the phase difference between the pulse trains from the sensors will indicate the direction in which the magnetized strip is moving. This is shown in Figure 6-5.

The combination of pulse trains is known as *quadrature*, because there are four possible combinations: A and B both high, A and B both low, A high and B low, or A low and B high. The same principle is used in an optical rotary position sensor; see Figure 7-6.

This type of linear position sensor is often described as a *magnetic encoder*, meaning that the position of the sliding part is encoded in a series of pulses. Relatively high resolution is possible, as the north and south poles on a strip of ferrous material can be as close as 2mm. Optical encoders may use the same principle; see "Optical Linear Encoders".

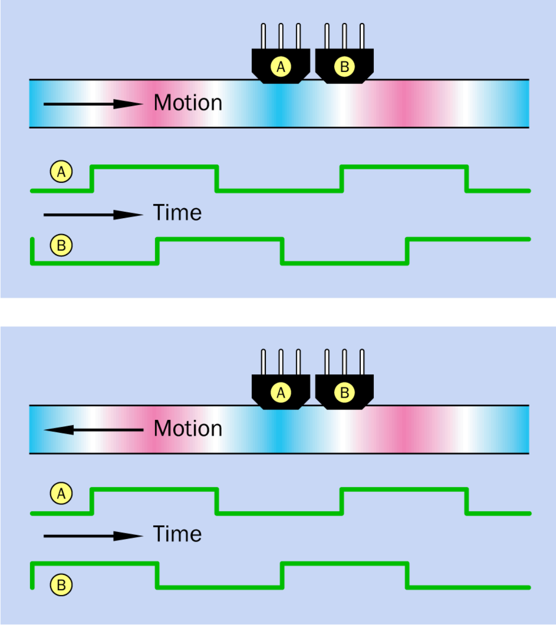

Figure 6-5 *Pulse trains from Hall-effect sensors A and B are shown in green. The phase difference between them can be interpreted to show the direction in which the magnetized strip is moving.*

The sensor can be built into a module containing an analog-to-digital converter that provides numeric output defining the position of the read head.

In an *absolute* magnetic encoder, nonvolatile memory can store the digitized position when the device is switched off. An *incremental* magnetic encoder does not store this information, and will require at least one additional *home sensor* to detect when the encoder is at either end of its travel. At power-up, an initialization routine moves the magnetized strip until the home sensor is triggered.

For details of Hall-effect sensors see "Hall-Effect Sensor".

Optical Linear Encoders

The operation of an optical linear encoder is identical to that of the magnetic linear encoder described immediately above, except that a sliding *optical grating* is used in conjunction with a light source and a detection device such as a **phototransistor** or **photodiode** that functions as the read head. The principle is shown in Figure 6-6. The grating may be described as a *codestrip*.

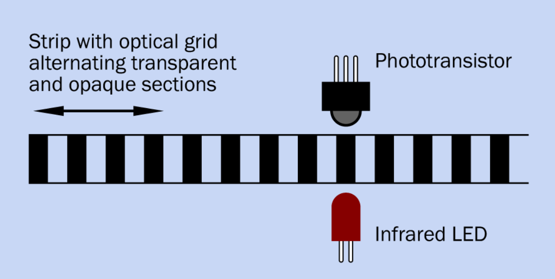
Strip with optical grid alternating transparent and opaque sections
Phototransistor
Infrared LED

Figure 6-6 *An optical linear encoder uses the same general principle as a magnetic linear encoder.*

For details of phototransistors, see Chapter 22. For details of photodiodes, see Chapter 21.

An example of a low-cost optical linear encoder is the Avago HEDS-9 series, which consists of a horseshoe-shaped module with an LED in one arm and an array of photodiodes in the opposite arm. When a codestrip passes between the arms, the module emits two pulse trains from internal comparators. The pulse trains are 90 degrees out of phase, and can be interpreted to show which way the codestrip is moving.

These sensors have a body measuring approximately 10mm wide and are designed to read opaque/transparent intervals ranging from 1.5 to 7.87 cycles per millimeter. The output rate can be as high as 20kHz. No pullup resistor is required on the output, as a 2.5K resistor is integrated.

A *codewheel* may be used, in which case the module senses rotation instead of linear motion. This is described in detail in the entry on **rotary position** sensors. See Chapter 7.

Linear Encoder Applications

Optical or magnetic linear encoders are found in some laboratory equipment, machine tools, and industrial robots. The mean time between failures can range from 100,000 to 1,000,000 hours. Optical encoders must be sealed to provide good protection from dust and dirt.

Linear Variable Differential Transformers

This type of sensor, often referred to by the acronym LVDT, tends to be used in industrial environments where great reliability is required under severe conditions. Examples are high-temperature steam valves and nuclear reactor control mechanisms. However, the robust, frictionless design suggests other possible applications, and custom fabrication is a possibility.

Figure 6-7 illustrates the general principle. Three coils are wound sequentially around a (nonmagnetic) stainless-steel tube, enclosed in a second tube also made of stainless steel. The coils act as transformers with the variable voltage ratio determined by the position of a solid iron armature that slides through them.

The center coil is the primary winding, to which AC is applied between 2kHz to 50kHz, depending on the application. (The frequency must be at least ten times the maximum rate of motion of the armature.) The iron armature is attached to a nonmagnetic rod. The voltages on the secondary windings provide the output from the sensor.

While more than one wiring arrangement is possible, the most common schematic is shown in Figure 6-8. The secondary coils are in series, with one of them reversed, so that the phase of the output is inverted as the armature moves from one end of its travel to the other. The phase detector responds to the phase difference by creating a DC output that varies with movement of the armature. All the functions shown in the schematic are available on a single integrated circuit chip.

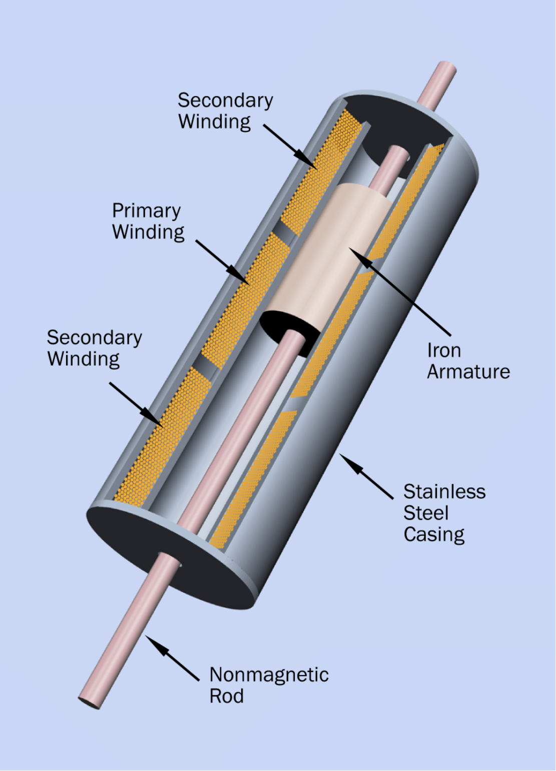
Secondary Winding
Primary Winding
Secondary Winding
Iron Armature
Stainless Steel Casing
Nonmagnetic Rod

Figure 6-7 *Cutaway drawing showing the internal design of a linear variable differential transformer, in which the position of a sliding iron armature determines the voltage induced in the secondary windings.*

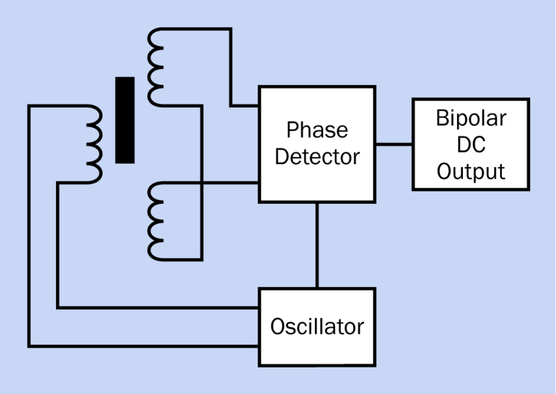
Phase Detector
Bipolar DC Output
Oscillator

Figure 6-8 *Typical schematic for using a linear variable differential transformer.*

An example of a linear variable differential transformer is shown in Figure 6-9.

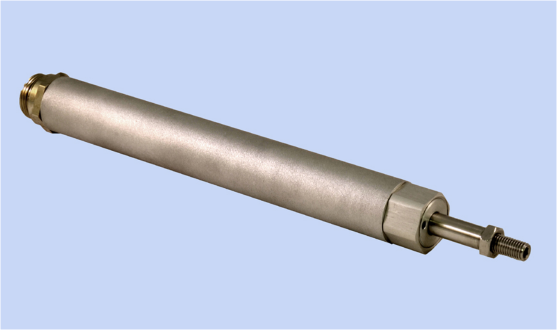

Figure 6-9 *External view of a linear variable differential transformer.*

What Can Go Wrong

Mechanical Issues

Any sliding mechanism will involve friction, and will be vulnerable to wear and tear, resulting in looseness that will degrade its accuracy. In addition, optical systems are vulnerable to dust and dirt.

LED Longevity

Light output of an LED diminishes over a period of years if the LED is "always on." This will limit the life of the sensor.

rotary position sensor

7

Alternative terms for **rotary position** sensor are *rotary sensor*, *rotational position sensor*, *angular position sensor*, and *angle sensor*.

The terms *rotary* and *rotational* are used interchangeably. In this entry, an attempt has been made to use the term that is most common for each specific application. For example, "rotary position sensor" versus "rotational encoder."

A few sensors are available that specifically measure *rotary speed*, but generally a rotary speed sensor uses information from a rotary position sensor. Therefore, this Encyclopedia does not include a separate entry for rotary speed sensing.

A **rotational encoder** can be used as a rotary position sensor. It is mentioned briefly here but is described in more detail in Volume 1 of this Encyclopedia in the entry describing **switches**.

OTHER RELATED COMPONENTS

- **linear position** sensor (see Chapter 6)

What It Does

Control of a mechanical device may require accurate and timely information about the orientation of a rotating part in the device. A **rotary position** sensor can be used for this purpose.

A sensor may be capable of measuring three attributes:

- Angular orientation
- Direction of rotation
- Speed of rotation

Typically a rotary position sensor measures only the first attribute. Additional electronics are required to calculate the second and third attributes by taking multiple position readings. Thus a *speed sensor* is very likely to be built around a position sensor, and therefore, this Encyclopedia does not have a separate entry for speed sensors.

Applications

In robotics, a rotary position sensor is commonly used to show the orientation of a pivoting arm or strut. It can also be used as a limit switch on a motor.

Specific applications include solar array positioning, remotely piloted vehicles, guidance and navigation, antenna positioning, and wind turbine pitch control.

Pulses from a rotary position sensor are used to measure speed of rotation in vehicles, industrial processes, and aviation. Small rotary speed sensors are built into devices such as cooling fans and computer hard drives.

Schematic Symbol

In a schematic, a rotary position sensor may be represented by symbols for the sensing elements that are inside it (potentiometer, LED, phototransistor, and others).

Potentiometers

Single-turn and multiturn potentiometers may be used as rotary position sensors. For basic information about **potentiometers**, see the entry describing this component in Volume 1.

Arc-Segment Rotary Potentiometer

An *arc-segment rotary potentiometer* is often referred to simply as a "potentiometer," as this type is more common than the multiturn type or the linear type. When used as a sensor, it can measure a turn angle that is less than 360 degrees.

This component contains a resistor in the shape of an arc, referred to as the *track.* It may be a strip of *resistive polymer* or (less often) may consist of an insulator with a coil of nichrome wire wrapped around it.

For sensing purposes, the potentiometer is wired as a voltage divider, and a fixed potential is applied along the full length of the track, as shown in Figure 7-1. A *wiper* slides along the track, sensing a voltage that varies linearly with the wiper's angular position. Output from the wiper can be used directly to control an analog indicator such as a meter, or can be processed by an analog-to-digital converter.

For audio applications, an arc-segment potentiometer may have resistance that varies logarithmically with the position of the wiper. However, this type of component is not generally used as a position sensor.

Low-cost potentiometers were traditionally used as volume or tone controls in stereo systems. When a potentiometer is designed for use as a sensor, it tends to be more ruggedly built and better protected against dust, dirt, and moisture. Its advantages are that it is simple, inexpensive, compact, and requires few additional components.

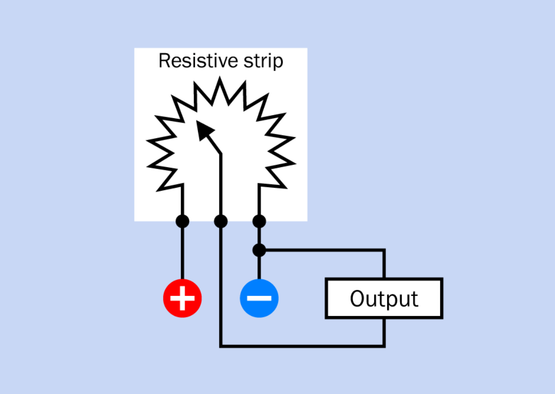

Figure 7-1 *An arc-segment potentiometer consists of a fixed track in the shape of an arc with a known voltage applied at each end, and a movable wiper.*

The major disadvantage is that although the track contains a lubricant, some wear will gradually result from friction with the wiper. Life expectancy will be further reduced if there is vibration or contamination with dirt or moisture.

End Stops

An arc-segment potentiometer usually has *end stops* to prevent the wiper from running off either end of the track. Typically, these stops limit rotation to around 300 degrees.

A few arc-segment potentiometers allow unrestricted rotation. The Bourns 6639 series is an example, although the wiper still passes through a "dead zone" of 20 degrees between the start and end of its track. An application for this type of potentiometer could be as a direction sensor for a weather vane.

Multiturn Rotary Potentiometer

A spiral track, which resembles a coil spring, enables a rotary potentiometer to make multiple turns. The wiper rotates inside the track and follows its contour. A potentiometer of this type will still be calibrated in degrees; thus, a 10-turn component may be listed as allowing an *electrical travel* of approximately 3,600 degrees.

The exterior of a multiturn rotary potentiometer is shown in Figure 7-2.

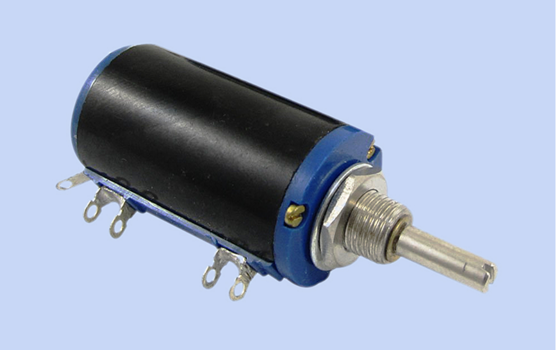

Figure 7-2 *A multiturn rotary potentiometer. Each pair of solder tags is attached internally to one end of the internal coiled track. The smaller tag at the far end connects with the wiper.*

A simpler type of multiturn potentiometer is intended for use as a trimmer—a small potentiometer that can be mounted on a circuit board to allow adjustment or calibration, often during the manufacturing process. This type of trimmer contains a worm gear that engages with a spur gear internally. The wiper is mounted on the spur gear. It has no applications as a sensor, but is mentioned here to avoid ambiguity, as it is probably the component that is most commonly referred to as a "multiturn potentiometer."

Magnetic Rotary Position Sensor

Externally, a modern magnetic rotary position sensor may look very much like an arc-segment rotary potentiometer. Internally, a permanent magnet is attached to the base of the shaft, and one or more **Hall-effect** sensors are mounted on a small circuit board immediately below the magnet, in the bottom of the enclosure. A simplified diagram appears in Figure 7-3.

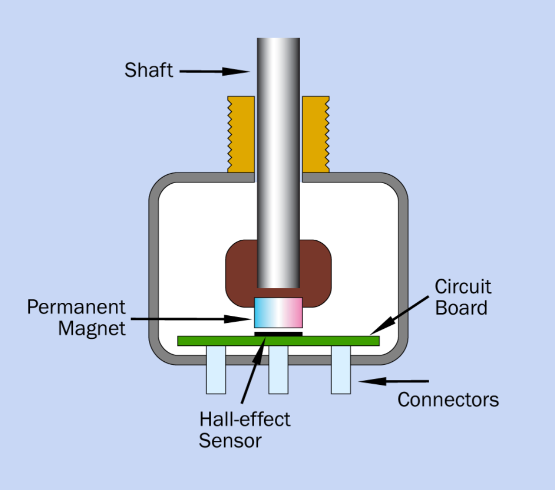

Figure 7-3 *Simplified interior view of a magnetic rotary position sensor.*

For more information about Hall-effect sensors, see "Hall-Effect Sensor".

A magnetic rotary position sensor may be described as a *noncontacting* sensor. Two views of an example are shown in Figure 7-4.

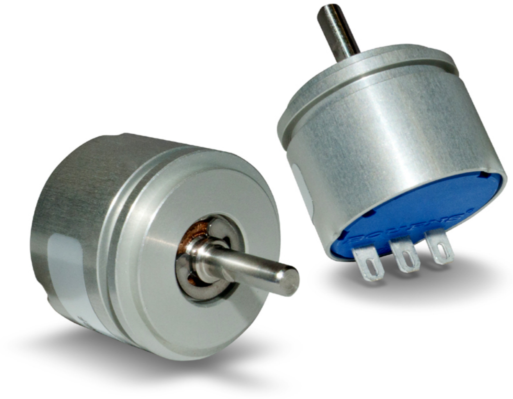

Figure 7-4 *Two views of a Bourns AMS22 magnetic rotary position sensor.*

The AMS22 sensor shown in Figure 7-4 has an analog output ranging from 0.1VDC to 4.9VDC when powered with 5VDC. A noncontacting sensor of this type will cost three to four times as much as a conventional potentiometer, but has the great advantage of extreme durability, with the manufacturer claiming a life of 50 million shaft rotations. A disadvantage is its low-current output, limited to 10mA. The maximum rotation speed of its shaft is 120rpm.

Rotary Position Sensing Chips

Chips of the type used in a magnetic rotary position sensor are available as individual components, many of which have advanced features. For example, the AM8192B angular magnetic encoder by RLS is a 44-pin surface-mount chip containing Hall sensors that detect the orientation of a permanent magnet above or below the chip. Various outputs provide information such as sine or cosine of the turn angle, incremental pulses, and digitized output via an SPI interface.

Rotary Encoders

Many rotating position sensors communicate their angle of rotation with an output that consists of a pulse train or some other coded signal. This type of rotary sensor is known as a *rotary encoder* or *rotational encoder*. (Linear encoders also exist; see "Magnetic Linear Encoders".)

The simplest version of this component is a *mechanical encoder* containing two small electromechanical switches that are activated, out of phase, by a toothed wheel attached to the rotating shaft. This component is described in detail in Volume 1 of the Encyclopedia, where it is categorized as being a form of **switch**. Its low cost and simplicity has made it popular for rotary controls on car radios and small stereo systems, but its switches have a limited life expectancy and create a "noisy" output that must be *debounced* if connected with a logic chip or microcontroller. Typically the microcontroller will include a pause of up to 50ms in its program code to allow time for the switch contacts to settle (although some manufacturers claim only 5ms).

Confusingly, a mechanical encoder is often identified only as a "rotational encoder," even though optical and magnetic rotational encoders also exist, as described immediately below. As a general rule, if a component is described simply as a rotational encoder, it probably contains electromechanical switches.

Optical Rotary Encoders

This type of component works on the same principle as an *optical linear encoder* of the type described in "Optical Linear Encoders". The difference is that a *codewheel* is used instead of a *codestrip*. Typically the codewheel is supplied by the manufacturer of the component that is designed to read it.

A *transmissive* codewheel is shown in Figure 7-5. The distance between the light emitter and the light detector has been exaggerated in this diagram for clarity.

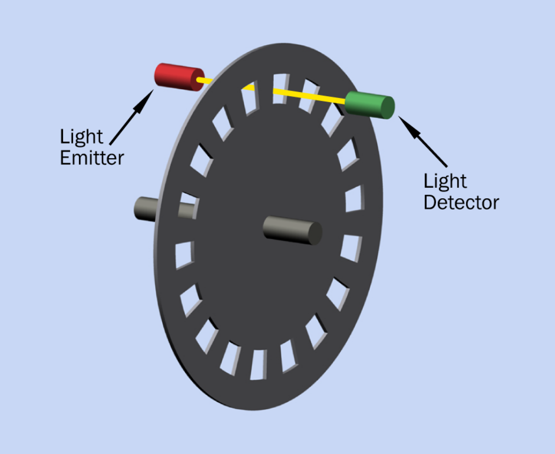

Figure 7-5 *A light-transmissive codewheel for use in an optical rotary encoder.*

Some optical rotary encoders use a *reflective* codewheel, in which case alternating sections of the wheel are light-absorptive and light-reflective, and the emitter and detector are both on the same side of the wheel.

If only one light emitter and light detector are used, the pulse train from the sensor reveals how many increments the wheel has turned relative to its previous position.

A single sensor cannot indicate the direction of rotation, but if a second emitter-sensor pair is added, 90 degrees out of phase with the first, a microcontroller can assess the phase difference between pulse streams to determine which way the wheel is turning. This principle is illustrated in Figure 7-6 where one transmitter-detector pair is located in position A and another is in position B. The resulting pulse trains, for clockwise and counterclockwise rotation of the wheel, are shown in green. The combination of pulse trains is known as *quadrature*, because there are four possible combinations: A and B both high, A and B both low, A high and B low, or A low and B high.

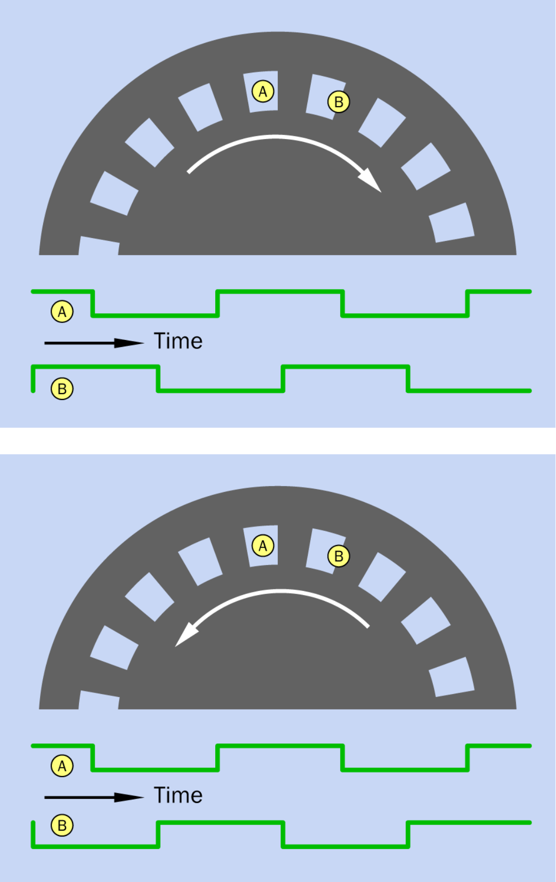

Figure 7-6 *With transmitter-detector pairs mounted at positions A and B, the phase difference between their pulse trains can show the direction of rotation of the wheel.*

This is the same principle as illustrated for a magnetic linear position sensor in Figure 6-5.

An alternative system of quadrature for an optical rotary encoder uses two separate tracks on the disc, each having an equal number of opaque and transparent sections, but half an interval out of phase.

Any system that reveals the relative motion of the wheel, but cannot determine its absolute angular position, is an *incremental sensor*.

Optical Products

High-end optical rotary encoders may use discs with as many as 600 sequential opaque and transparent segments to provide extremely high resolution. They are outside the scope of this Encyclopedia.

Moderately priced optical encoders are available as shaft-driven assemblies very similar in external appearance to potentiometers. Typically they have four terminals, one pair for power and ground connections and another pair for quadrature output from the two internal sensors, usually identified as A and B in datasheets. Some encoders also contain an on-off switch that is activated by pressing the shaft, in which case two additional terminals will be provided.

Bourns is a leading manufacturer of this type of encoder, an example being the EM14, which is mounted in a box-shaped body measuring 14mm square. It uses a 5VDC power supply and provides pulses of 4VDC minimum with intervals of 0.8VDC maximum. Variants are available with 8 to 64 pulses per revolution. Intended for audio applications, this type of encoder has a maximum rotation speed of 120rpm.

An example of an optical rotary encoder from a German manufacturer is shown in Figure 7-7. Its resolution is 25 pulses per rotation. The rectangular package measures approximately 19mm × 25mm. The power supply can be 3.3VDC or 5VDC.

Optical rotary encoders of this type cost about five times as much as mechanical rotary encoders at the time of writing, but their longevity and their clean output signals make them an attractive alternative, and the price difference may diminish over time.

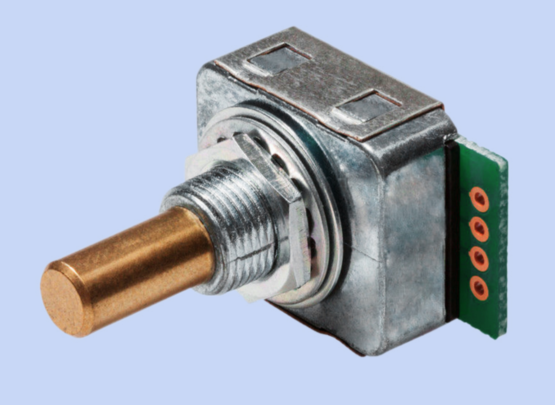

Figure 7-7 *A compact incremental optical rotary encoder in the MRB25 series from Megatron Elektronik AG & Co.*

Encoders such as the Avago HEDS-9 series are not protectively enclosed, and require assembly with a codewheel supplied by the manufacturer. See Figure 6-6 for additional information.

A more basic optical rotary encoder, shown in Figure 7-8, is sold by Cytron Technologies as an *optical switch* mounted on a small board, with a separate codewheel consisting of a slotted disc. This low-cost kit is intended for use in DIY robotics. More information about optical switches will be found in the entry dealing with **optical presence** sensors. See Figure 3-3.

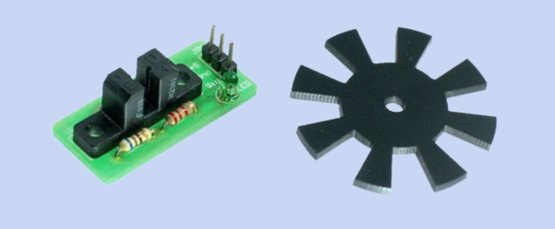

Figure 7-8 *A bare-bones optical encoder for DIY robotics.*

Computer Mouse Principles

The original design of a computer mouse, with a hard rubber ball, contained two optical rotary encoders oriented at right angles to each other. Each of them used a transmissive codewheel. The rolling ball turned the codewheels as the mouse was moved across a desktop, and electronics in the mouse converted the outputs from the encoders into a pulse train that could be interpreted by a computer. Figure 7-9 shows the primary components.

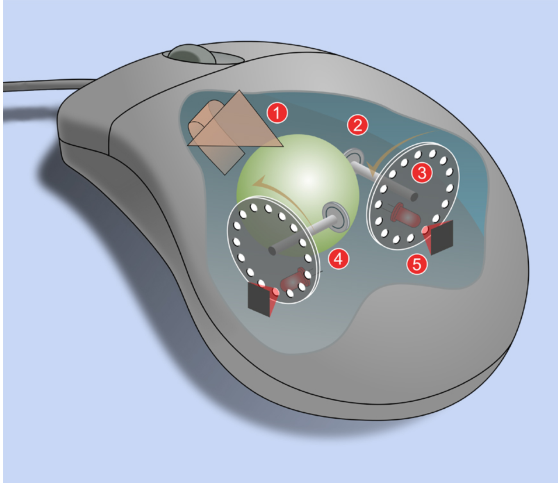

Figure 7-9 *From Wikimedia Commons, this rendering by Jeremy Kemp shows (1) rotation of the ball, (2) a roller touching the ball, (3) a transmissive optical codewheel, (4) an infrared LED that shines through a second codewheel, and (5) a sensor detecting the pulses of light.*

An *optical mouse* works on a different principle, maintaining a monochrome image of the desk surface on an optical array that functions like a very low-resolution camera sensor. Electronics in the mouse detect displacement of the image as the mouse is moved.

Rotational Speed

Incremental rotary encoders, which only supply relative data, are adequate in many applications, especially speed measurement, where a microcontroller can compare a pulse stream from a sensor with a target frequency, and can also provide feedback to control motor speed appropriately. This is convenient when a stepper motor is being used, or a DC motor that is controlled with pulse-width modulation. (See the entry on **motors** in Volume 1.)

Toothed wheels or magnetized wheels are commonly used to measure speed of rotation in applications ranging from automobile transmissions to computer disk drives.

While a second sensor can be added to determine the direction of rotation, this still does not provide information about the absolute orientation of a part.

Absolute Position

If associated electronics are equipped with nonvolatile memory, it may be used to store a sensor-wheel position from one session to the next. This may be sufficient in noncritical applications such as volume control in a car radio or stereo system.

Alternatively, an additional single window in an optical wheel can activate a *home sensor*. When the device is powered up, the wheel is turned until the home sensor is triggered, at which point the orientation of the wheel is known, and subsequent pulses from rotation sensor(s) will add or subtract angular information.

The pulse generated by a home sensor may be described in datasheets as a *reference signal* or *index signal*. In the early days of desktop computers, each 5.25-inch floppy diskette was perforated with an index hole for this purpose.

The Gray Code

For greater reliability in determining absolute position, an optical wheel can be divided into several concentric tracks, each of which contains a different coded sequence and is assigned its own light emitter and light sensor. The sensors are arranged in a radial line to scan the disc as it rotates. Since each detector will provide either a signal or no signal, output from the set of sensors can be combined to create a binary number.

Figure 7-10 shows binary codes from 0000 through 1111, corresponding with decimal numbers 0 through 15, where a white square is equivalent to a numeral 1 and a black square is equivalent to a numeral 0.

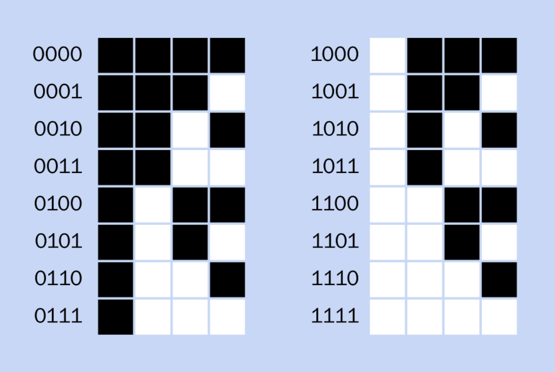

Figure 7-10 *Binary codes from 0000 through 1111, using white to represent 1 and black to represent 0.*

Figure 7-11 shows this system mapped onto a codewheel. The red circles indicate the locations of four stationary light detectors, which begin by providing a reading of 0000, since they coincide with four opaque areas of the wheel. Now if the wheel makes 1/16th of a full rotation in the direction of the arrow, the detectors will register 0001. If the wheel continues to rotate, the detectors will count in binary up to 1111 before the sequence repeats.

The problem with this design is that small manufacturing inaccuracies and other imperfections will result in some light detectors responding fractionally more quickly than others as the wheel rotates. This will occur in transitions where two or more adjacent segments of the wheel change between transparency and opacity. For instance, where 0011 is followed by 0100, transient values of 0010, 0001, 0111, 0110, or 0101 are possible. Although they will be brief, these values may trigger associated electronics.

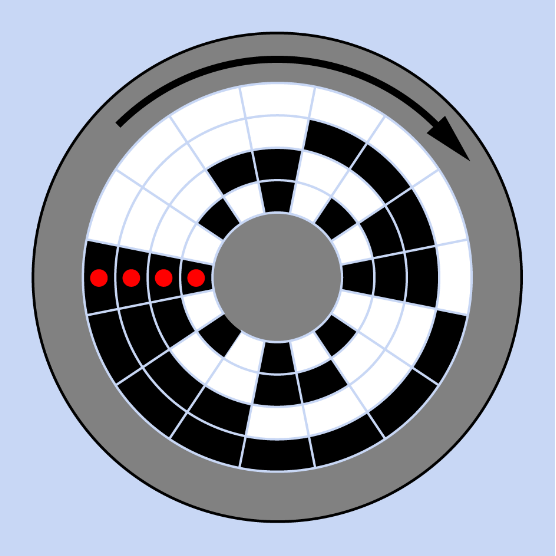

Figure 7-11 *The binary sequence mapped onto a code-wheel as areas of opacity and transparency. Red circles indicate light detectors.*

To eliminate this problem, a different code sequence can be used in which only one of the four sensors is allowed to make a transition from each value to the next. This is called a *Gray code*, and eliminates the issue of simultaneous transitions. A commonly used Gray code is shown in Figure 7-12.

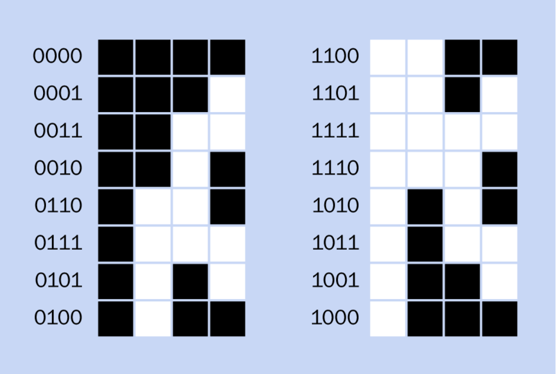

0000	■	■	■	■	1100	□	□	■	■
0001	■	■	■	□	1101	□	□	■	□
0011	■	■	□	□	1111	□	□	□	□
0010	■	■	□	■	1110	□	□	□	■
0110	■	□	□	■	1010	□	■	□	■
0111	■	□	□	□	1011	□	■	□	□
0101	■	□	■	□	1001	□	■	■	□
0100	■	□	■	■	1000	□	■	■	■

Figure 7-12 *A Gray code that allows only one binary digit to change in each transition from one value to the next.*

Magnetic Rotary Encoders

If a ferrous wheel is magnetically polarized in multiple domains, its rotation can be detected by a Hall-effect sensor in much the same way that a wheel divided into transparent and opaque sections can be assessed by light detectors and emitters. This is illustrated in Figure 7-13, where magenta and cyan bands indicate north and south magnetic poles.

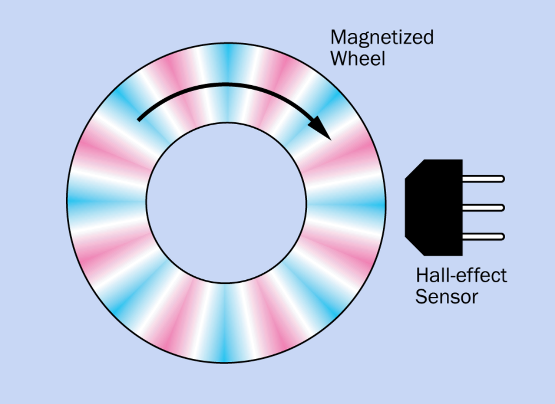

Figure 7-13 *A Hall-effect sensor can detect the rotation of a wheel that is divided into multiple north and south magnetic poles.*

See "Hall-Effect Sensor" for information about Hall-effect sensors.

An additional Hall sensor can be added, offset from the first, as in Figure 7-14. Once again the phase difference between the pulse trains can be used to determine the direction of rotation.

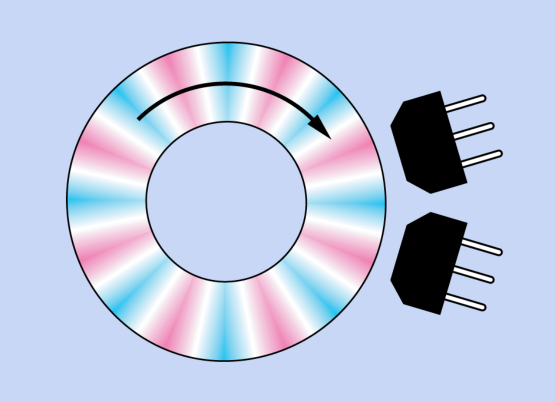

Figure 7-14 *Direction of rotation of the wheel can be deduced from the phase difference between the pulse trains from two sensors.*

Alternatively, a toothed wheel can be used, as suggested in Figure 7-15.

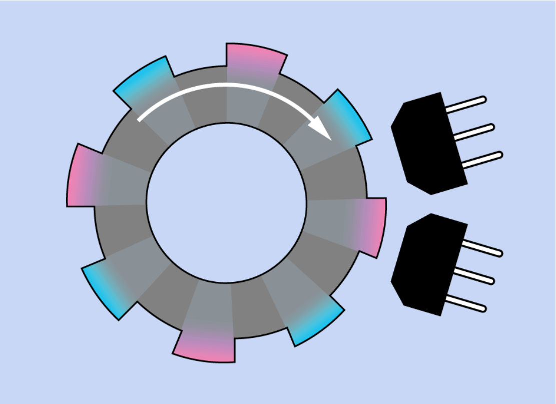

Figure 7-15 *A toothed wheel can trigger a Hall sensor if the teeth are magnetized.*

Another option is to mount a pair of magnets on a nonmagnetic wheel, with a Hall-effect sensor in the center. If it is a sensor with an analog output, the voltage will fluctuate smoothly between positive and negative, relative to the power supply for the sensor. Alternatively, a bipolar Hall-effect sensor can be used to provide a binary output. The concept is illustrated in Figure 7-16. An advantage of this configuration is that it provides approximate information about the absolute position of the wheel.

The two magnets will provide usable linear sensor outputs over a span of plus-or-minus 30 degrees of rotation, approximately. Additional magnets or sensors can produce a more complex output that would be decoded by a microcontroller.

How to Use It

An optical or rotary encoder is well suited for use with a microcontroller program that can count pulses, compare pulse trains, or interpret a Gray code. The microcontroller then takes appropriate action. For example, if a rotational encoder is used to control the gain of an audio amplifier, the microcontroller determines the direction and angle through which the encoder turns, and can respond by changing the value of a **digital potentiometer** (see Volume 1).

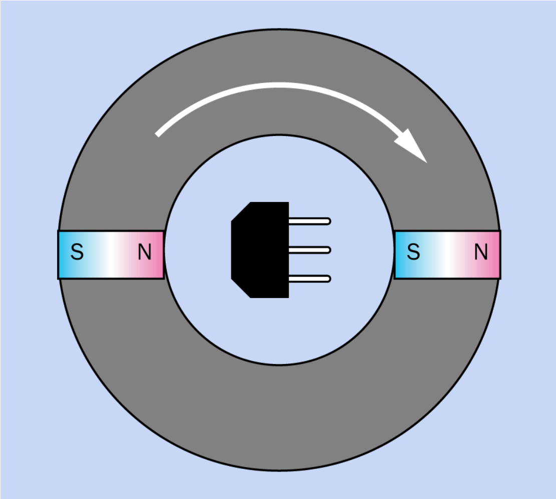

Figure 7-16 *A Hall-effect sensor can detect the angle of rotation of a ring on which two magnets are mounted as shown.*

Integrated circuit chips are available to convert a sequence of quadrature signals into an up-pulse or a down-pulse, thus eliminating the chore of achieving this with a microcontroller program. The LS7183 by LSI Computer Systems is an example.

What Can Go Wrong

Wiring Errors

If two sensors are used to detect the direction of rotation of a rotary encoder, and outputs from the sensors are accidentally swapped, the component will seem to work normally except that the indicated direction will be inverted.

Coding Errors

Microcontroller code that interprets quadrature signals must be fast enough to keep up with the pulse streams. If a microcontroller is performing other tasks, an interrupt may be necessary for processing the rotational data. This should not be a significant problem when interpreting human input from a knob or dial, but for a motor-driven encoder, pulse counting in hardware may be a better alternative.

Ambiguous Terminology

Rotational encoders are often referred to simply as "encoders," because they are more common than linear encoders. When searching for an encoder, check each datasheet carefully to determine which type you are dealing with.

tilt sensor

8

A *tilt switch* is defined here as an electromechanical switch, while a *tilt sensor* uses electronics. Both types are included in this entry.

A *tipover switch* is very similar to a tilt switch and uses the same principles. Therefore, it is included in this entry.

Some manufacturers' datasheets refer to tilt sensors as *tip sensors*. Some Asian supply catalogues refer to tilt switches as *breakover switches*.

An **accelerometer** can measure the angle at which it is held relative to the downward force of gravity, but it has additional capabilities. Therefore, it has its own separate entry in this Encyclopedia.

An *inclinometer* measures the incline, or positive slope, from an observation point to the top of an object such as a building or tree. The height of the object can be calculated from the angle. A *clinometer* can additionally measure a decline, or negative slope. These measurement devices are fully featured products as opposed to sensors, and are not included in this Encyclopedia.

OTHER RELATED COMPONENTS

- **accelerometer** (see Chapter 10)
- **vibration** sensor (see Chapter 11)

What It Does

Three principal types of tilt sensor exist.

1. Single axis, single output. The sensor responds to being tilted around one horizontal axis, relative to the downward force of gravity.
2. Dual axis, dual output. The sensor contains two sensing elements at 90 degrees to each other. Each has an output determined by its angle of tilt from vertical around one axis.
3. Dual axis, single output. A single sensor responds to an angle of tilt from vertical around any horizontal axis.

A *tilt switch* is usually of the third type, and is defined here as containing an electromechanical or electronic switch that opens or closes a connection. Most tilt switches are SPST (normally open) or SPST (normally closed). A minority are DPDT.

A *tipover switch* is a type of high-current tilt switch that cuts power to a device such as an electric heater when it is tipped over.

This Enclopedia defines a *tilt sensor* as being an electronic component, as opposed to an electromechanical component. The distinction is often observed in datasheets, but not always.

Schematic Symbol

No specific schematic symbol is generally used for any variant of a tilt sensor. It can be represented with an annotated switch symbol.

How It Works

Because a tilt switch is a simpler device than a tilt sensor, it will be described first.

The most common type of tilt switch consists of a cylindrical metal or plastic enclosure, often measuring about 5mm by 15mm, containing two spherical steel balls that may be nickel-plated or gold-plated. When the switch is tilted, the balls eventually run downhill, and the lower ball completes an electrical connection between two contacts or between a single contact and the metal enclosure of the switch. The second ball is included to add weight and suppress vibration in the first.

Figure 8-1 shows a switch manufactured by Comus Global, rated for 0.25A at 60VAC or 60VDC, maximum. The body of the switch measures approximately 10mm x 5mm, and the switch is activated when tilting -10 degrees from horizontal. It is deactivated when tilting +10 degrees. A scale drawing of the interior is shown in Figure 8-2.

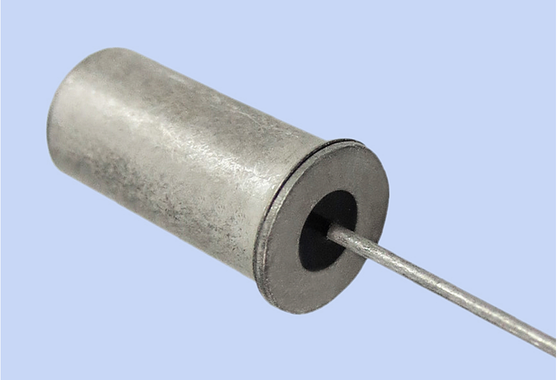

Figure 8-1 *The CW1300 tilt switch manufactured by Comus Global.*

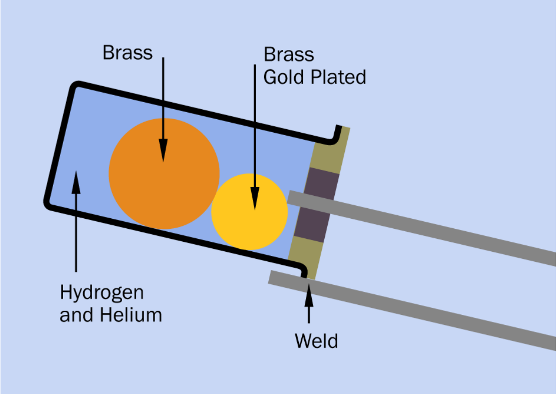

Figure 8-2 *Interior of the CW1300 tilt switch, from a scale drawing supplied by the manufacturer. The lower lead is welded to the shell of the sensor. The leads may be inserted in a circuit board.*

Figure 8-3 shows three common internal configurations of a generic tilt switch. The top version has axial leads and uses the metal shell of the switch to complete the circuit. The center version has radial leads, with a plastic shell. The bottom version has radial leads, one of which is attached to the metal shell to complete the circuit.

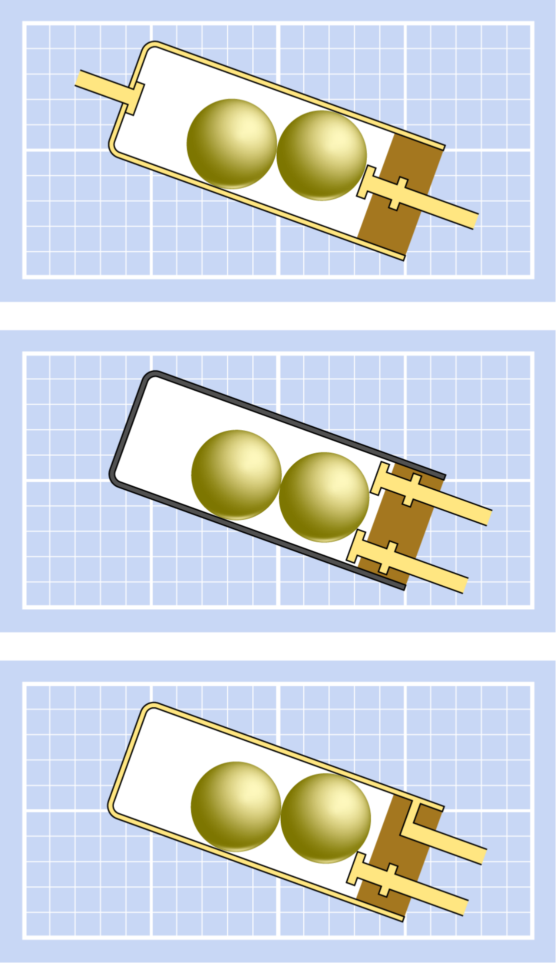

Figure 8-3 *Three variants of a generic ball-operated tilt switch. The graph-paper scale is in millimeters.*

Figure 8-4 shows the parts of a disassembled tilt switch.

Simplified Version

Where size is not a significant consideration, a tilt switch can be created by attaching a pivoting, weighted arm to a small snap-action switch.

Applications

An old-style (nonelectronic) thermostat may contain a tilt switch attached to the end of a bimetallic strip coiled into a spiral. When the strip bends in response to a drop in temperature, the switch closes its contacts, activating a relay that starts a heating unit. If the temperature rises, an additional set of contacts in the same relay may activate an air-conditioning unit. In old thermostats, the tilt switch may contain mercury in a glass tube, which should be handled with caution.

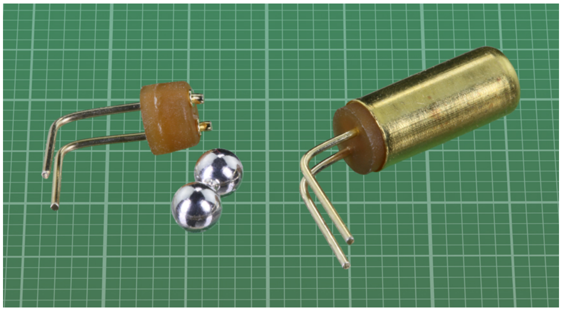

Figure 8-4 *At right, a tilt switch. At left, the cap removed, and the two balls that make internal contact. The background grid is in millimeters.*

A tilt switch may detect the opening of a door or window in a simple alarm system.

Tilt switches have been used in automobiles to switch on the interior light in the trunk when its lid is opened.

A normally closed tilt switch is often used to stop the inflow of granular material to a bin when it is almost full. This is colloquially known as a *bin switch*. In industrial applications of this kind, the switch is activated by a long lever that has a ball mounted at the end. The switch assembly is physically large. See Figure 8-5.

A normally open tilt switch may operate a valve or start a pump when the liquid in a tank drops below a certain point. If the switch uses a float to sense the level of the liquid, it is often known as a *float switch*. This is described in the entry on liquid level sensors. See Chapter 15.

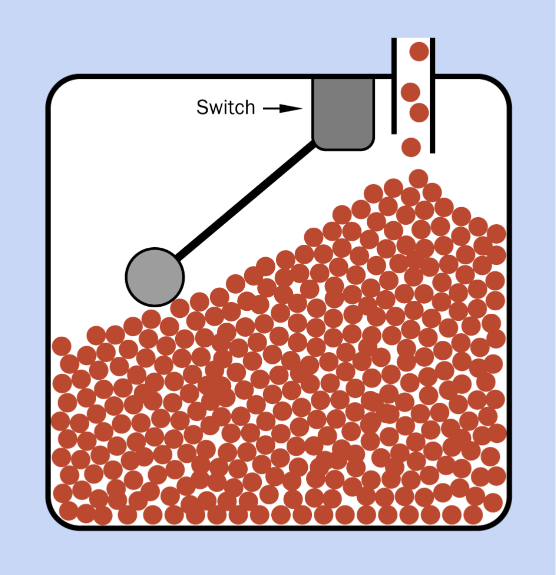

Figure 8-5 *The flow of granular material into a bin can be sensed and stopped by a tilt switch of this type, often known as a bin switch.*

A *tipover switch* may use the simplified system of a weighted arm that activates a snap-action switch. When used in conjunction with a room heater, the switch must handle substantial current.

A motorcycle may contain a tipover switch to stop the electric fuel pump if the motorcycle falls on its side.

Four tilt switches placed in a cross-shaped pattern on a flexible mount can be used as the basis of a very simple game controller, with a joystick mounted in the center.

Variants

The three configurations of ball-type tilt switches shown in Figure 8-3 are functionally interchangeable and can be chosen for convenience of their leads in fitting the circuit.

Mercury Switches

Early tilt switches contained a blob of mercury in a glass bulb. When the bulb was tilted, the mercury rolled to the end and made an electric connection between two metal contacts that penetrated the bulb.

A small mercury switch is shown in Figure 8-6. This type of sensor became less common after many countries classified mercury as an environmental hazard and established regulations restricting its use.

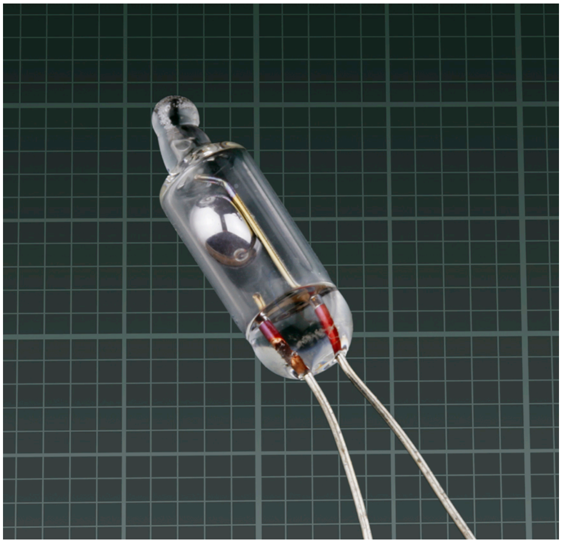

Figure 8-6 *Small mercury switch rated for 0.3A at 24VDC or 24VAC. Larger mercury switches can switch more power; 1A at 230V is common. The background grid is in millimeters.*

Mercury is an excellent electrical conductor. It remains in a liquid state between about -38 degrees Celsius and +356 degrees Celsius, and has very high surface tension, encouraging it to form a single blob instead of breaking up into small droplets. Because free space in the bulb is filled with an inert gas to prevent oxidation of the electrodes, a mercury switch can have a very long operating life. In the United States in the 1970s, some light switches were sold containing mercury switches with a claimed life expectancy of 100 years.

Pendulum Switch

This type of switch, now relatively rare, was found in vintage pinball machines. It consists of a pendulum about 5cm long, suspended inside a steel ring about 1cm in internal diameter. If the machine was rocked sufficiently to bring the pendulum in contact with the ring, the game was cancelled and the word “Tilt” appeared on the display. Consequently this was referred to as a tilt switch, although really it was a form of **vibration** sensor with a long period of oscillation.

Magnetization

Some tilt switches use a steel ball that is weakly magnetized, so that it will seat itself more firmly when it rolls into a circular depression or ring. This type of switch must be tilted back through a larger angle to dislodge the ball. Therefore it will exhibit greater *hysteresis*.

Tilt Sensors

Unlike a tilt switch, a tilt sensor is not built around an electromechanical switch.

The principle of a rolling ball has been miniaturized and encapsulated in a small enclosure (10mm square or smaller), in which the ball rolls to interrupt a beam from an internal LED shining on a phototransistor. Examples are found in the Panasonic AHF series. Internal circuitry ensures a clean on-off signal, free from the switch bounce that is a problem in basic ball-type tilt switches. However, the switch requires a power supply, and the open-collector output must be used with a pullup resistor. By comparison, a simple electromechanical tilt switch can be wired directly to the device that it controls.

Diagrams from the Panasonic datasheet show the three types of AHF sensor available for vertical, horizontal, and reverse mounting. In each case, the ball (dotted circle) rests in a shallow cup (dotted curve) where it obstructs the beam from an internal LED (not shown). See Figure 8-7. An exterior view of the AHF22 is shown in Figure 8-8.

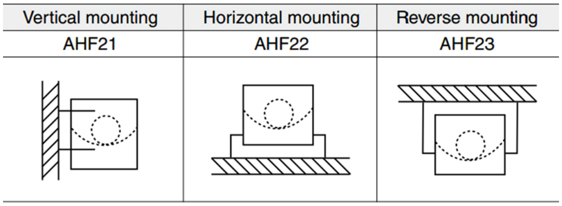

Figure 8-7 *Three types of Panasonic tilt sensor, from the manufacturer’s datasheet. See text for details.*

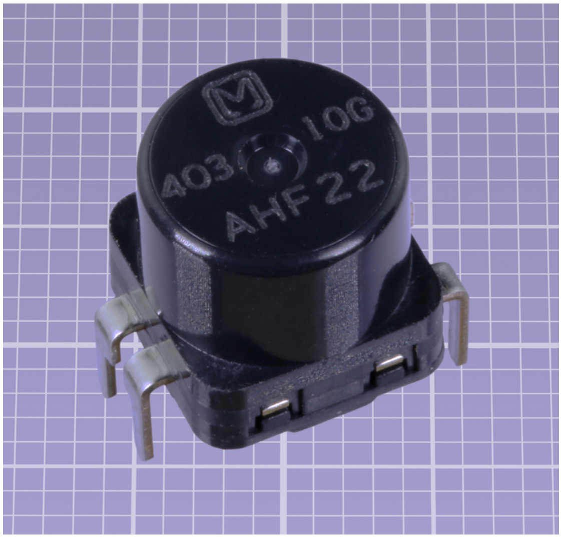

Figure 8-8 *Exterior view of the Panasonic AHF22 tilt sensor. The background grid is in millimeters.*

Two-Axis Tilt Sensors

The Rohm RPI-1035 is a surface-mount tilt sensor about 4mm square, with two phototransistor outputs that indicate which axis the sensor is tilting around. The outputs can be interpreted as a 2-bit binary number, with its four possible states indicating the rotation of the switch around two axes at 90 degrees to each other. Switches of this type were developed to indicate the orientation of consumer-electronic devices such as digital cameras, but more sophisticated sensors containing accelerometers are becoming price-competitive.

Surface-mount 2-axis tilt sensors have been made available on small breakout boards that are easy to use experimentally. An example is the Parallax 28036 shown in Figure 8-9.

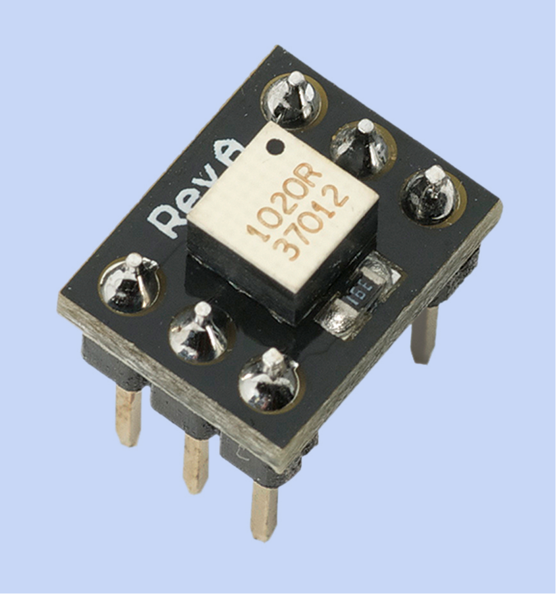

Figure 8-9 *A 2-axis tilt sensor mounted on a breakout board available from Parallax.*

The behavior of the rolling-ball sensor at the heart of this board is shown in Figure 8-10. The sensor contains a square cavity in which the ball is depicted as a blue circle. At one corner of the cavity is a red LED, while two phototransistors, labeled A and B, are at the corners on the left and right. When the sensor is held as in section 1 of the figure, with the LED at the top and the ball resting at the bottom, both phototransistors have a high output as they receive light from the LED.

In section 2 of Figure 8-10, the sensor has been turned through 90 degrees. The ball now prevents light from reaching sensor B, while phototransistor A is still active. In section 3 of the figure, the sensor has been turned through another 90 degrees, so that the ball prevents light from escaping from the LED, and both phototransistors are now dark. In section 4, the ball obstructs phototransistor A but not phototransistor B.

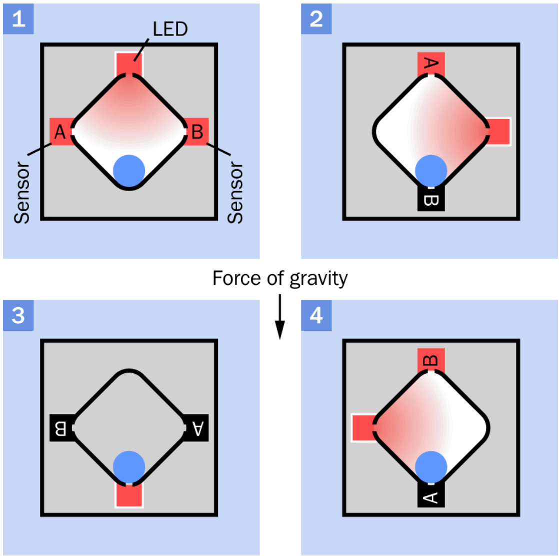

Figure 8-10 *The rolling-ball sensor inside the Parallax 28036. See text for details.*

Suppose that the sensor is placed flat on a horizontal surface. The sensor will now respond to being tipped either way around two horizontal axes. This justifies its description as a 4-directional tilt sensor, although its design suggests that it may have been intended for use as described above, rotating through four positions around one horizontal axis.

Values

A heavy-duty tilt switch can be rated as highly as 10A at 240VAC. More commonly, a tilt switch about 15mm long can be expected to switch about 0.3A at 24VAC or 24VDC.

The *operating angle* is the angle through which the switch must be turned to activate it, relative to its normal rest position.

The *return angle* is the angle to which the switch must be returned to deactivate it. Hysteresis results from the return angle being smaller than the angle that activates the sensor.

Tilt sensors with an open-collector output will specify maximum forward current for the internally mounted LED (usually no greater than

50mA), the maximum collector-emitter voltage at the output (typically 30V), and the maximum collector current (often 30mA). An explanation of open-collector outputs is given in Appendix A (see "3. Analog: Open Collector").

How to Use It

An electromechanical tilt switch can be connected directly between a power supply and a device, so long as the device does not draw more current than the switch is rated to handle. Note that inductive loads such as motors draw an initial surge that can be at least twice the operational rating, while relays may be more likely to create a voltage spike when disconnecting. Switches should be chosen accordingly. For more discussion of this topic, see **switch** in Volume 1.

A small tilt switch can be used in conjunction with a relay or transistor to amplify its signal sufficiently to drive a larger load.

If an electromechanical tilt switch is connected to an electronic device such as a microcontroller or logic chip, output from the switch will have to be *debounced* to prevent a series of brief voltage spikes that can cause false triggering when the switch turns on or off. A debouncing logic circuit or chip can be used, or the program code in a microcontroller can introduce a wait period of up to 50 milliseconds to allow the contacts to settle.

Mercury switches are much less likely to create a noisy output than rolling-ball switches, and may require little or no debouncing.

For an application that must sense rotation around two or three axes, multiple single-axis tilt switches can be combined. A microcontroller or logic gates will be necessary to evaluate signals from the switches, to determine the orientation.

What Can Go Wrong

Contact Erosion

If a ball-type tilt switch is subjected to current that exceeds its specification, arcing may erode its contacts, and they will become less reliable, especially if the contacts are plated with a thin metallic film that is eroded. For additional information on arcing in switches, see the **switch** entry in Volume 1.

Random Signals

During the brief time when a ball-type tilt switch is turning from one position to the other, vibration of the ball(s) inside it is likely to create erratic, random signals. If the output from the switch is being evaluated by a microcontroller, a debouncing routine may be insufficient to prevent the random signals from being sensed, and some programming will be necessary to ignore the signals during this transitional phase. If the switch is connected directly to a relay, the intermittent signals may occur sufficiently rapidly that the relay will ignore them.

Environmental Hazard

A device that incorporates a mercury switch may have to be re-engineered in the future if the availability of mercury switches becomes unreliable as a result of tighter environmental regulations. For the same reason, the end user may have difficulty replacing a mercury switch if it fails. Therefore, a ball-type tilt switch should be used instead of a mercury switch in any newly designed device.

Requirement for Gravity

Because a tilt switch depends on gravity to roll a ball or move a blob of mercury, it will not work in low-gravity, reversed-gravity, or zero-gravity conditions—for example, in a rocket during the unpowered phase of ascent and descent, or in an aircraft that performs aerobatic maneuvers. Performance of a tilt switch in a vehicle that accelerates or decelerates suddenly may also be unreliable. Likewise, it cannot be used on a small boat.

Requirement for Stability

A tilt switch will tend to give erroneous results in a location where there is significant vibration or where the object containing the switch may be turned or repositioned unpredictably by the user.

gyroscope

Historically, a **gyroscope** always contained a spinning disc. Some devices for navigation still depend on rotating elements, but they are outside the scope of this Encyclopedia. This entry deals primarily with *vibrating gyroscopes*, also known as *resonator gyroscopes*, that are MEMS devices contained within silicon chips.

OTHER RELATED COMPONENTS

- **accelerometer** (see Chapter 10)
- **GPS** (see Chapter 1)
- **magnetometer** (see Chapter 2)

What It Does

A **gyroscope** resists rotation around any axis at right angles to its own axis of rotation or vibration. Consequently, if the gyroscope is allowed to move freely on gimbals in a sealed enclosure, the gyroscope will tend to maintain its orientation while the enclosure can rotate freely around it.

Taking this concept a step further, if the enclosure is mounted in an aircraft, the aircraft's rotation around two axes can be determined by referring to the gyroscope. If additional gyroscopes are added orthogonally to the first, the aircraft's rotation around all three axes can be determined.

A gyroscope does not measure linear motion in any direction, or any static angle of orientation.

Schematic Symbol

A chip-based gyroscope, magnetomer, or accelerometer may be represented in a schematic as a rectangular box containing abbreviations to identify pin functions (as in any integrated circuit chip).

IMU

An **accelerometer** measures variations in linear motion and will also measure its own static orientation relative to the force of gravity. If an accelerometer rotates around its own axis, it will not measure angular velocity.

A **magnetometer** measures the magnetic field surrounding it, and may be sufficiently sensitive to determine its orientation relative to the Earth's magnetic field.

When an accelerometer and a gyroscope are contained in the same package, optionally with a magnetometer, they may be described as an *IMU* (inertial measurement unit), which can provide necessary data to maneuver aircraft, spacecraft, and watercraft, especially when **GPS** signals are unavailable.

Applications

The first chip-based gyroscope was used in automobiles in 1998 as a yaw sensor in a skid-control system. Subsequent automotive applications include active suspension control, air bag sensors, rollover detection and prevention, and navigation systems.

Gyroscopes may be installed in military ordnance to provide backup in case an onboard **GPS** system fails, possibly as a result of radio jamming.

Handheld 3D game controllers and headsets may use gyroscopes to control images displayed to the viewer. A digital camera may employ a gyroscope to provide image stabilization. Gyroscopes are usually found in quadcopters or drones, are used to stabilize two-wheeled vehicles such as the Segway, and are used in robotics.

How It Works

The traditional form of gyroscope is a rotating wheel, which will resist turning forces perpendicular to its own axis of rotation. In Figure 9-1, three directions at right angles to each other are defined in the bottom-right corner of the diagram as X, Y, and Z. The wheel is rotating around the X axis, as shown by the green arrow. It will resist any turning force around the Y axis (red arrows) or the Z axis (yellow arrows).

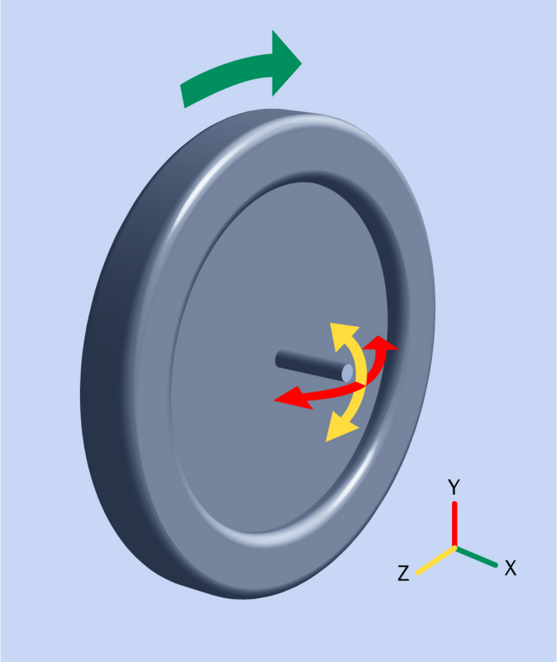

Figure 9-1 *In a traditional gyroscope, a wheel that is rotating (shown by the green arrow) will resist a turning force on either of the axes (shown by red and yellow arrows) perpendicular to its axis of rotation.*

Vibrating Gyroscope

A vibrating fork can be substituted for a wheel. In Figure 9-2 a fork is secured at its base while its tines are induced to vibrate toward each other and away from each other, as suggested by the double-ended arrow. In a chip-based gyroscope, this vibration is induced piezoelectrically or by static electricity.

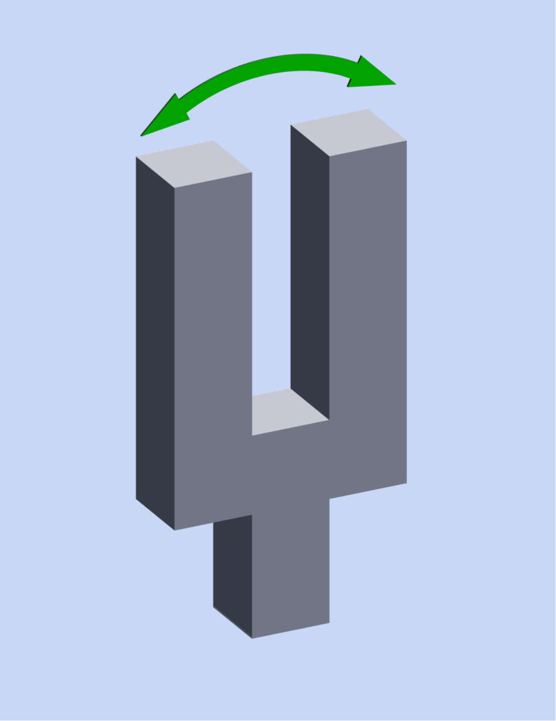

Figure 9-2 *A vibrating fork (green arrows) can be substituted for a rotating wheel in a gyroscope.*

Now suppose a turning force is applied around the vertical axis at the base of the fork, as suggested by the lower arrow in Figure 9-3.

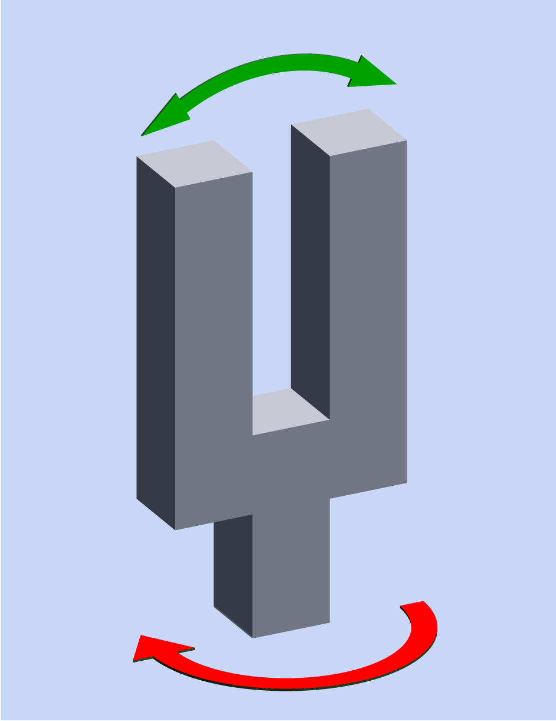

Figure 9-3 *A turning force is applied to the base of the fork around a vertical axis, as shown by the lower arrow.*

The angular momentum of the vibrating tines causes them to resist this turning force, and consequently they will tend to bend, as shown by the yellow arrows in Figure 9-4. The amount of their deflection can be measured capacitively. This system is used in many chip-based gyroscope systems, and may be referred to as a *vibrating gyroscope* or a *resonator gyroscope*.

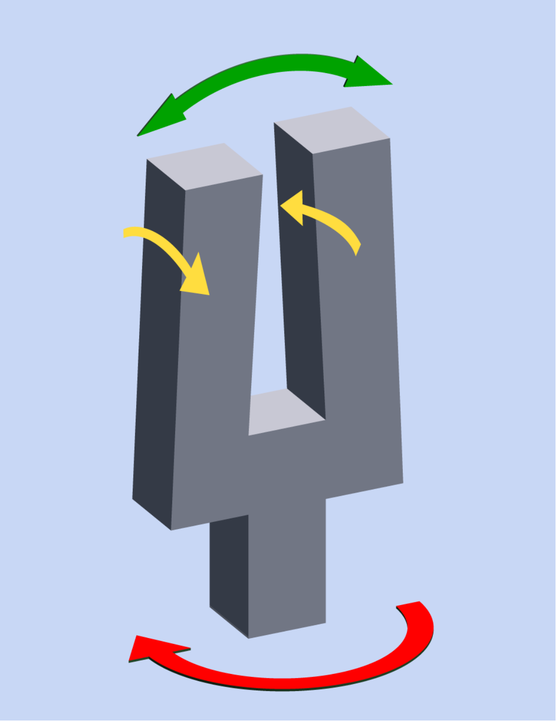

Figure 9-4 *The angular velocity of the rotating fork causes deflection of its vibrating tines, shown by the yellow arrows.*

An assembly of microscopic forks can be etched into a silicon chip. In Figure 9-5, an electron micrograph shows the interior of this type of chip. It contains three rotational sensors, responding to the X, Y, and Z axes of motion. These sensors respond to *pitch* (rotation around the X axis), *roll* (rotation around the Y axis), and *yaw* (rotation around the Z axis).

Fork-based sensors are analog devices whose values are converted to digital values by an onboard *analog-to-digital converter* (ADC). The values are stored in registers that are available to other devices, often via the I2C protocol, which is widely used by microcontrollers.

For additional details about I2C, see Appendix A.

Typically there will be two 8-bit registers for each axis. Each register stores the binary equivalent of a signed integer, where the positive or negative value represents the direction and magnitude of deflection, usually in degrees per second (dps).

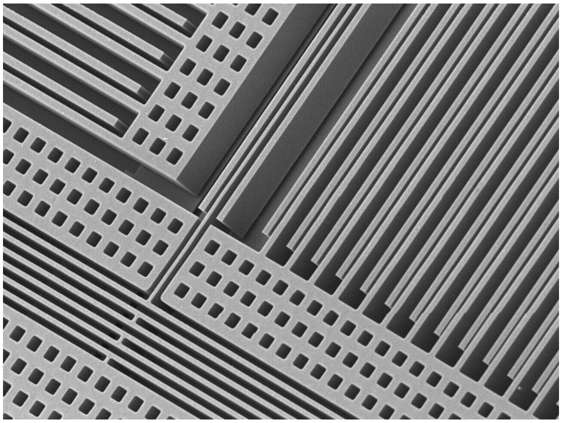

Figure 9-5 *Electron micrograph of the STMicroelectronics LIS331DLH vibrating gyroscope installed in the Apple iPhone 4. The parallel plates at bottom-left function as a spring, while the elements at top-left and at right measure capacitance as their orientation varies according to rotational velocity. Photo courtesy of MEMS Journal published by Chipworks*

Variants

The L3G420D by STMicroelectronics is a 3-axis gyroscope-only chip. It communicates via the SPI or I2C protocol, is approximately 4mm square, and can measure rotational rates up to plus-or-minus 2,000 degrees per second.

The Freescale FXAS21002C has a similar specification. Gyroscope-only chips of this type have fallen in price to the point where they are comparable to the retail cost of everyday components such as a small-signal relay or an audio amplifier on a chip.

IMUs

Chips that only contain gyroscopes are becoming less common as the cost of adding accelerometers decreases.

Gyroscopes and accelerometers are complementary, as gyroscopes are insensitive to linear motion or the Earth’s gravity, but accelerometers can measure the rate of change of linear motion and orientation of the chip relative to the Earth. Software can combine this data to calculate the shape of the path being described by a device containing the chip, in addition to the changing velocity of the chip along that path.

The InvenSense MPU-6050 is a common 3-gyroscope, 3-accelerometer chip. It also includes an interface for connecting an external 3-axis magnetometer. The SPI and I2C communications protocols are supported. The MPU-6050 has been a popular choice in the hobby-electronics community, so that Arduino-compatible code to interpret its data is available from many sources. Breakout boards are available with the MPU-6050 installed. An example is the Sparkfun SEN-11028 shown in Figure 9-6.

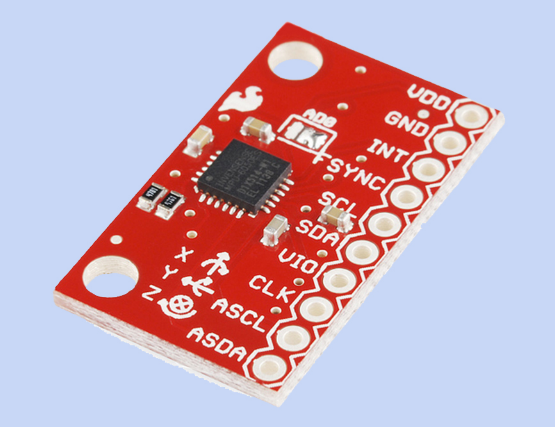

Figure 9-6 *A breakout board from Sparkfun, providing easy access to the InvenSense MPU-6050 chip combining three gyroscopes and three accelerometers.*

Values

The *rotational velocity* of a gyroscope element is usually expressed in degrees of rotation per second (dps), and sometimes in rotations per minute (RPM).

A datasheet will specify the number of sensor axes (usually 3), supply voltage (3.3VDC is common), maximum digital-low and minimum digital-high output voltages, and power consumption in normal mode and sleep mode. Power consumption is usually less than 10mA.

The *dynamic range* is the maximum forward and reverse rotational velocity, which usually will not exceed plus-or-minus 2,000 degrees per second. Lower ranges may be user-selectable. The advantage of selecting a lower maximum rate of change is that it can be converted to a digital value with higher precision.

The *sensor resonant frequency* will be several kilohertz, and must be higher than the frequency of any vibration that is applied to the sensor during use.

The *communications protocol* is usually I2C and SPI may be offered as an option, with a selectable digital output data rate.

Bias temperature coefficient describes the effect of temperature on the gyroscope.

The *resolution* of the gyroscope relates to the number of bits used in the digital output from the onboard ADC. A 16-bit resolution is common.

How to Use It

Using a smart chip such as the MPU-6050, the circuit designer can take advantage of its onboard digital motion processor (DMP). Still, obtaining orientation information from the contents of registers on the MPU-6050 is nontrivial. Online sources and code libraries are necessary. The book *Make: Sensors* contains code listings for the Raspberry Pi as well as the Arduino.

What Can Go Wrong

Temperature Drift

Vibrating materials at the heart of a chip-based gyroscope are likely to change their behavior with temperature. Typically the chip will contain a temperature sensor, the value of which can be used to adjust the output value of the gyroscope.

Mechanical Stress

Stress can be induced when a surface-mount chip is soldered to a board. The vibrating parts of a chip-based gyroscope may be adversely affected. Datasheets will supply information regarding maximum acceptable temperature during the soldering process.

Vibration

Because a chip-based gyroscope depends on the consistent behavior of internal vibrating parts, external vibration can degrade its accuracy. Sensor design can minimize the effects of vibration, but the datasheet should be consulted for details.

Placement

A gyroscope should be placed on a circuit board near a hard mounting point where deflection of the board will be minimized.

accelerometer

10

OTHER RELATED COMPONENTS

- **GPS** (see Chapter 1)
- **gyroscope** (see Chapter 9)
- **tilt** sensor (see Chapter 8)
- **vibration** sensor (see Chapter 11)

What It Does

Acceleration is the rate at which velocity changes over time. If a car takes 10 seconds to increase its speed from 30kph to 40kph relative to the road on which it is traveling, it is accelerating at an average of 1kph each second. If it then reduces its speed back to 30kph during another 10-second interval, it is decelerating at the same rate—although deceleration is really just negative acceleration.

While a car is accelerating, passengers will feel a lateral force exerted on them. Similarly, astronauts in a rocket that blasts off will feel a downward force. According to Einstein's theory of equivalence, forces resulting from acceleration are indistinguishable from the force of gravity.

Consequently, a sensor that measures acceleration can also measure gravity. This sensor is an **accelerometer**. Its output may be measured in *gravities*, abbreviated with the letter g (not to be confused with the usage of G to measure the strength of a magnetic field in gauss).

If three accelerometers are mounted orthogonally (at 90 degrees to each other), their readings can reveal:

- The direction of acceleration of a moving object.
- If an object has been dropped and is falling freely.
- Which way up it is being held in a stationary position.
- The severity of an impact when a moving object collides with some other object.

IMU

A **gyroscope** measures the rate of rotation of the enclosure in which it is mounted. This is properly known as the *angular velocity*. A gyroscope will also respond to changes in the rate of rotation. It does not measure linear motion or a static angle of orientation.

A **magnetometer** measures the magnetic field surrounding it, and may be sufficiently sensitive to determine its orientation relative to the Earth's magnetic field.

When an accelerometer and a gyroscope are contained in the same package, optionally with a magnetometer, they may be described as an *IMU* (inertial measurement unit), which can provide necessary data to maneuver aircraft, spacecraft, and watercraft, especially when **GPS** signals are unavailable.

Schematic Symbols

A chip-based accelerometer may be represented in a schematic as a rectangular box containing abbreviations to identify pin functions, as in any integrated circuit chip. No specific symbol is used for any of these components.

Applications

In the past, accelerometers were laboratory devices that calibrated the performance of cars, airplanes, and other types of vehicles. Measuring the ability of car tires to withstand cornering forces was an application where an accelerometer was used.

Miniaturization of accelerometer elements, coupled with a radical reduction in their cost, has enabled them to be installed in small electronic devices ranging from smartphones to hard drives.

In a phone or a camera, accelerometers can determine which way up the user is holding the device. The camera can rotate the picture appropriately, and the orientation of the picture can be saved with its image data.

In an external hard drive containing rotating platters, accelerometers can protect the read-write heads by rapidly parking them during the fraction of the second that elapses between someone dropping the hard drive and its impact with the floor.

Accelerometers can be installed in a 3D mouse or virtual-reality headset to determine its orientation and motion. This enables a video image to be updated appropriately. For example, the Nintendo Wii Remote has been marketed with an ADXL330 accelerometer.

In an automobile, an accelerometer can trigger the deployment of an air bag when the deceleration caused by an impact exceeds a threshold level.

How It Works

The simplest conceptual model of an accelerometer consists of a mass attached to one end of a coiled compression spring. The other end of the spring is anchored in an object whose acceleration is being measured. The mass can only move along the same axis as the spring.

Figure 10-1 shows three views of a simplified accelerometer, which is a sealed tube shown in dark red. In the center image, the accelerometer is in its rest state. The top image shows the mass (a dark blue square) responding when the tube accelerates from left to right. The third image shows it decelerating (that is, undergoing negative acceleration, or acceleration from right to left). Using an ideal spring, the displacement of the mass will be proportional to the rate of acceleration, within reasonable limits. The displacement can be measured optically or capacitively.

Note that the rest state will resume when the acceleration stops, regardless of constant motion in any direction. An accelerometer only measures a *change* in velocity. It does not measure a constant velocity.

An accelerometer cannot measure rotation around its own axis of movement. Therefore, it may be used in conjunction with a **gyroscope**, which measures angular velocity.

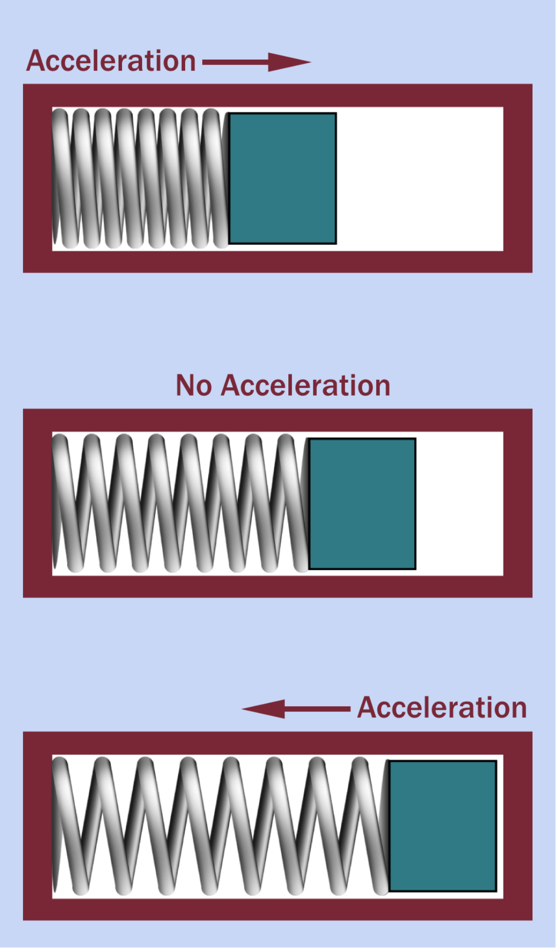

Figure 10-1 *Simplified view of an accelerometer consisting of a sealed tube (dark red outline) with a spring anchored to it at left. A small mass (dark blue) is attached to the right end of the spring. The mass responds to acceleration of the tube.*

Gravity and Free Fall

If a device containing the simplified accelerometer described previously rests on the ground, and is mounted vertically as in the left section of Figure 10-2, gravity acting on the mass will apply a force to one end of the spring, while the other end is restrained. The accelerometer will now measure 1g as a downward force.

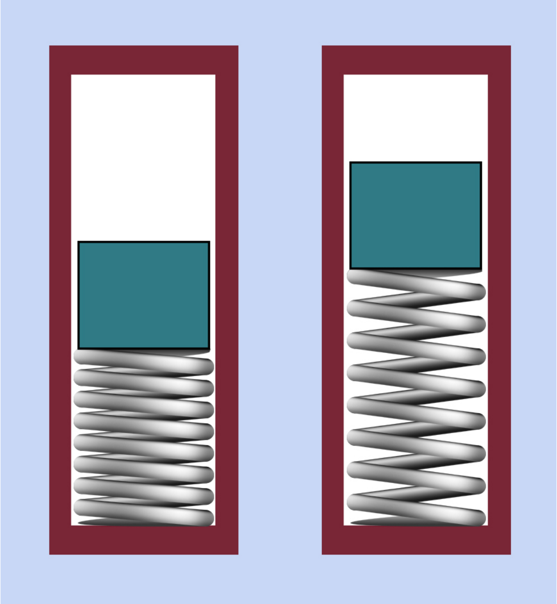

Figure 10-2 *Left: an accelerometer resting on the ground measures 1g, as the force of gravity pulls the mass downward. Right: in free fall, the accelerometer measures 0g.*

If the device is dropped so that it falls freely under the influence of gravity, it is in *free fall* and will accelerate at approximately 9.8 meters per second each second. This is usually written as 9.8m/sec^2, or can be described as 1 gravity, often expressed as 1g.

An accelerometer in free fall will measure 0g, as shown on the right in Figure 10-2, because all parts of the accelerometer are now accelerating equally under the force of gravity.

If three accelerometers are assembled orthogonally, and if one accelerometer is vertical, and the device is held motionless relative to the Earth, the vertical sensor will show 1g while the other two accelerometers will show 0g. If the device is dropped, all sensors will show 0g.

Rotation

If a device containing three accelerometers is turned over, and is not in free fall, accelerometers mounted orthogonally will show values that vary depending on their alignment with the force of gravity.

Calculation

The force acting upon an object will cause a rate of acceleration that can be calculated by Newton's Second Law of Motion, provided that the object can move freely and is not being subjected to any additional forces, such as the force of gravity. If F is the force, m is the mass of the object, and a is the acceleration:

```
F = m * a
```

And therefore:

```
a = F / m
```

If the mass is restrained by a spring whose compression or extension has an approximately linear relationship to the force applied to it, acceleration can be calculated as a function of the linear displacement of the mass.

These statements ignore relativistic effects that are insignificant unless ultra precise time and motion measurement may be involved.

In a real-world accelerometer, movement of the mass will require some form of damping to prevent it from oscillating.

Variants

Accelerometer prices dropped radically after 2010. In an effort to maintain profitability, manufacturers have loaded more features onto chips. While a 2-axis accelerometer such as the Memsic 2125 seemed a good option when first introduced, it is now facing obsolescence as 3-axis accelerometer chips that also contain 3-axis gyroscopes have become ubiquitous—and no more expensive.

Early chip-based accelerometers provided analog outputs where voltage was proportional with acceleration and could be processed by a comparator. On some breakout boards, such as the Dimension Engineering DE-ACCM6G, which used the STMicroelectronics LIS244ALH chip, a comparator was included (see Figure 10-3).

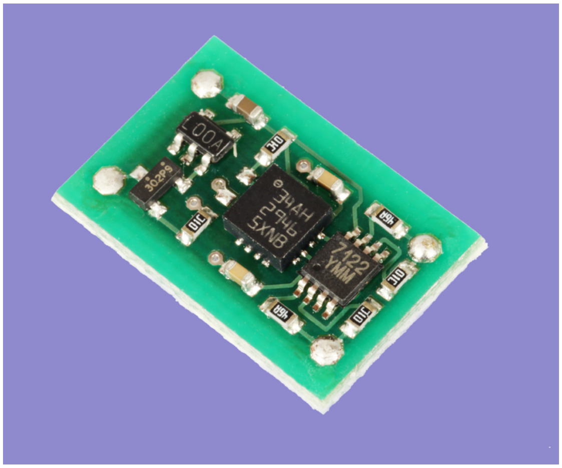

Figure 10-3 *A relatively early, relatively expensive breakout board using the 2-axis accelerometer LIS244ALH chip by STMicroelectronics. It has been superceded by chips that combine accelerometers, gyroscopes, and processors to provide a digital output.*

Because this board allowed a maximum output of only 0.83mA, it was only suitable for high-impedance logic chips or a microcontroller. However, because the output was analog, it could be passed through another comparator for direct connection to a piezo beeper to create a device that would sound an alarm when tilted. This is shown in Figure 10-4.

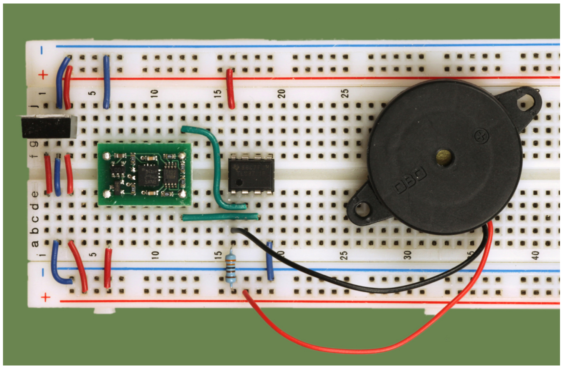

Figure 10-4 *Connecting the analog output from the DE-ACCM6G 2-axis comparator breakout board through a comparator to a piezo beeper.*

Many chips now contain gyroscopes as well as accelerometers. The electron micrograph in Figure 10-5 shows the interior of a chip of this kind, where the zig-zag shapes are “springs” etched into the die, the large areas patterned with dots are masses that can respond to various forms of motion, and the parallel plates are capacitive sensors.

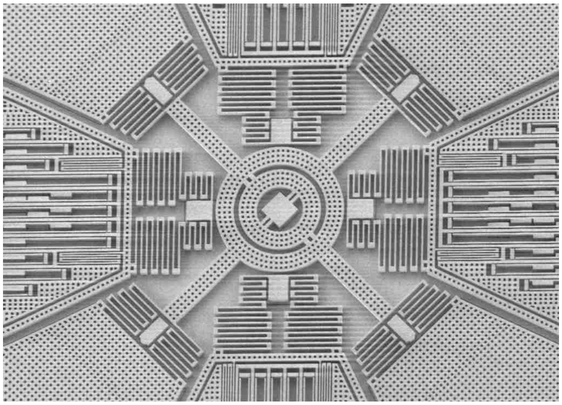

Figure 10-5 *Interior of a chip combining gyroscopes with accelerometers.*

The complexity of a chip combining two types of sensors creates a need for more complicated code to process the six outputs. Consequently most accelerometer chips now have their own onboard ADCs, and digital registers for communication with microcontrollers via the I2C communication protocol. Some chips also have onboard processing to interpret the mix of data. However, microcontrollers still need code to make sense of the data.

The hobby-electronics community has responded. A breakout board such as the LSM9DS0 from Adafruit, using a chip from STMicroelectronics that shares that same part number, tries to make this extremely complex chip accessible to experimenters. Shown in Figure 10-6, the LSM9DS0 contains a 3-axis magnetometer in addition to a 3-axis gyroscope and a 3-axis accelerometer.

The datasheet for the LSM9DS0 runs to more than 70 pages. At the time of writing, Adafruit is still refining code for the Arduino to make the features of this chip accessible.

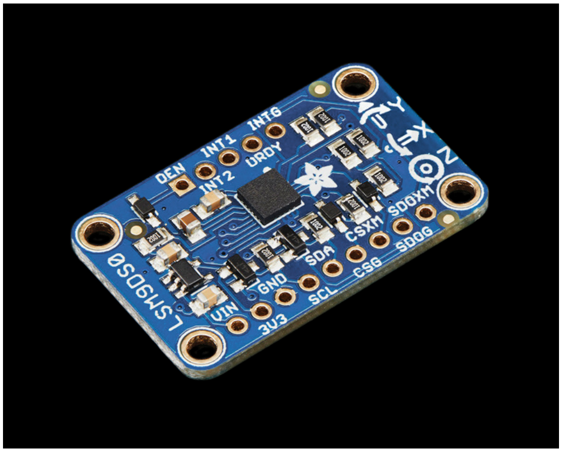

Figure 10-6 *This breakout board from Adafruit is built around an LSM9DS0 chip that combines accelerometers with gyroscopes and magnetometers.*

Despite the complexity of the LSM9DS0 chip, the breakout board sells for approximately the same price, at the time of writing, as the DE-ACCM6G 2-axis analog-output magnetometer four years ago. In the future we may expect IMU prices to fall still further, so that this type of multifunction chip becomes the default, and users simply ignore the functions that they don’t need.

Values

Current consumption will vary depending on the activity of the chip, and may be broken down for different types of sensors on multisensor chips. A modern accelerometer may typically draw less than 1mA. Gyroscope power consumption will be greater, as a segment of the chip will be maintained in a state of vibration.

Linear acceleration measurable by an accelerometer is customarily expressed in gravities, abbreviated g. Current generations of chips may be able to measure as much as plus-or-minus 16g, but because the value is converted internally to a digital quantity, smaller accelerations will not be expressed so accurately. Therefore the measurement range for acceleration is usually user-selectable by sending an appropriate code to the chip. Ranges may include plus-or-minus 2g, 4g, 6g, 8g, and 16g.

Sensitivity defines the smallest increment of acceleration measurable by the least significant bit (LSB) in an output register, for each of the acceleration ranges. In a range of plus-or-minus 2g, the internal 16-bit ADC may be capable of measuring 0.06 milligravities. When the range is reset to plus-or-minus 16g, the smallest increment may be around 0.7 milligravities.

The measurable range of gravities should not be confused with the maximum acceleration that the chip can tolerate without suffering internal mechanical damage, either while it is powered or unpowered. This will be more than 1,000g provided the duration is brief, and would only be experienced during an impact.

Linear acceleration sensitivity change versus temperature is usually expressed as a percentage, such as plus-or-minus 1.5%.

Output type will be analog or digital. If digital, the data protocol will be I2C or SPI. If I2C, the address of the device should be configurable. The data transfer rate is typically at least 100kHz, and this also may be configurable to different rates.

For additional details about protocols such as I2C, see Appendix A.

What Can Go Wrong

Mechanical Stress

Stress can be induced when a surface-mount chip is soldered to a board. The moving parts in a chip-based accelerometer may be adversely affected. Datasheets will supply information regarding maximum acceptable temperature during the soldering process.

Other Problems

If the accelerometer function is combined with other sensing functions such as magnetometer or gyroscope, see Chapter 2 or Chapter 9 for additional cautions about potential problems affecting these kinds of sensors.

vibration sensor

11

An **accelerometer** can measure some aspects of vibration. However, this entry deals primarily with mechanical devices (often described as *vibration switches*) and piezoelectric devices (often described as *vibration sensors*) that are solely intended to measure vibration.

A *vibrometer* measures vibration using a laser beam aimed at a reflective spot applied to a surface. It is usually a laboratory instrument, beyond the scope of this Encyclopedia.

OTHER RELATED COMPONENTS

- **accelerometer** (see Chapter 10)
- **tilt** sensor (see Chapter 8)
- **force** sensor (see Chapter 12)

What It Does

A vibration sensor responds to repetitive mechanical motion. Most versions contain two switch contacts that are normally open and will close if the sensor vibrates in its designed frequency range. In some sensors, the frequency range and sensitivity are manually adjustable.

Large sensors are used as automatic shutdown switches responding to excessive vibration in machinery, and may be capable of switching substantial currents (10A or higher). Smaller versions can shut down domestic appliances such as a washing machine that is seriously out of balance during a spin cycle.

A vibration sensor can be used as a simple user-input device in toys and games.

A shock sensor can detect abuse of a sensitive device, for example, by including the sensor and a data logger when the device is transported.

Schematic Symbols

Either of the symbols in Figure 11-1 may represent a piezoelectric or piezoresistive vibration sensor, but they also represent other piezo-based devices.

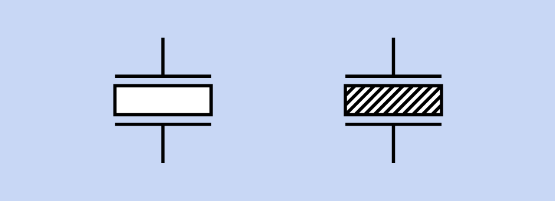

Figure 11-1 *Either of these symbols may represent a piezoelectric or piezoresistive device, including (but not limited to) vibration sensors that operate on this principle. The symbol on the left is more common.*

Variants

Vibration sensors use a wide variety of detection methods.

Pin-and-Spring

Probably the simplest type of sensor consists of a small, thin pin in the center of a miniature coil spring. The spring is anchored at its base, but its other end is free to vibrate. If the vibration reaches a sufficient amplitude, the spring touches the pin, completing a circuit between the two leads of the device.

An example is shown in Figure 11-2, where two identical sensors are shown, one of them cut open to reveal the gold-plated rod and spring inside. This sensor is rated for 10mA at up to 12VDC.

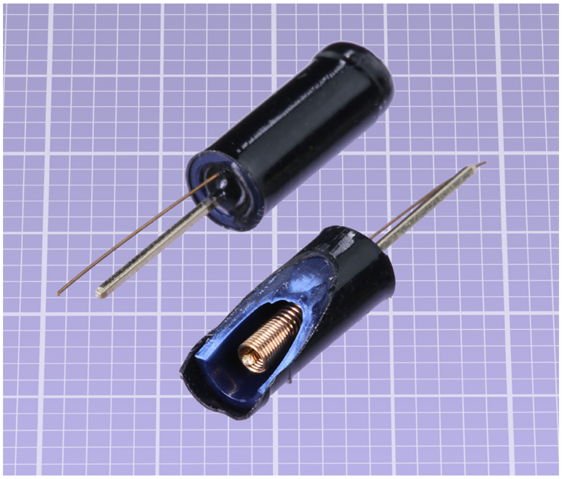

Figure 11-2 *When the spring in this sensor vibrates, it touches the pin that is centered in it. The background grid is in millimeters.*

Advantages of this system are low cost, ability to respond along two out of three axes, no power supply requirement, and ability to switch AC or DC. However, because the internal contact is extremely brief, it must be connected with a latching component of some type. A flip-flop could be used, or a 555 timer. The switch may also be connected with an input pin on a microcontroller, provided a pullup or pulldown resistor is used to prevent the input from floating when the switch is open.

Externally, the packaging of a pin-and-spring vibration sensor is almost indistinguishable from a small **tilt** sensor that contains one or two spherical metal balls. The tilt sensor may respond to vibration, but only of a large amplitude and low frequency.

A miniature board containing a pin-and-spring vibration sensor, comparator, and trimmer potentiometer for sensitivity control is sold cheaply by the Chinese supplier Elecrow as their product SW-18015P, shown in Figure 11-3. Elecrow also offers a wide range of other low-cost sensors.

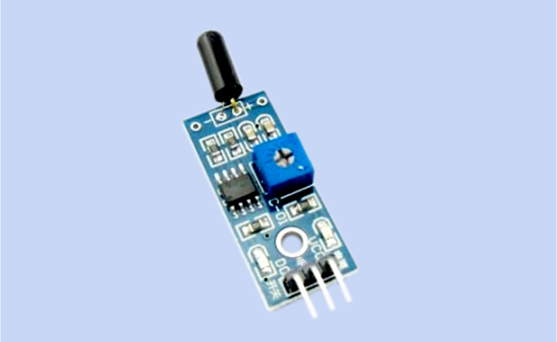

Figure 11-3 *A pin-and-spring vibration sensor mounted on a board with sensitivity control.*

Piezoelectric Strip

The LDT0-028K by Measurement Specialties is a section of piezoelectric polymer film laminated to a polyester substrate. The film is designed to be anchored at one end, allowing the other end to vibrate. An unweighted version and a weighted version are shown in Figure 11-4, each measuring about 13mm x 25mm. Addition of the weight alters the resonant frequency of the sensor.

Deflection of about 2mm is sufficient to generate a surprising 7VDC between the two leads. Larger deflections will generate higher voltages. The manufacturer suggests that direct connection to a CMOS component is possible. An op-amp may be used for signal conditioning.

A piezoelectric device of this type only generates voltage during the process of deflection. If the strip is held in a curved position, its output diminishes to zero.

This sensor has a resonant frequency around 170Hz when there is no weight attached to its free end.

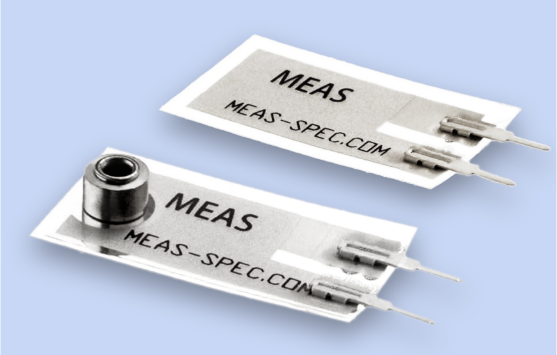

Figure 11-4 *Two versions of the LDT0-028K vibration sensor from Measurement Specialties, one with an added weight to lower its resonant frequency.*

Chip-Based Piezoelectric

The Murata PKGS series is an example of a surface-mount piezoelectric shock sensor. Measuring only about 1mm x 2mm x 4mm it has an analog output designed for connection through an op-amp. The manufacturer suggests application in a hard-disk drive to block read-write operations when vibration occurs. Similarly, these shock sensors may be used in CD-ROM or DVD drives. They may also be installed in cash dispensing machines to sound an alarm if vandalism occurs.

Toshiba's TB6078FUG is a similar product. Note that because these devices contain electronic components, they require a power supply (usually 3.3VDC to 5VDC) for operation.

"Mousetrap" Type

Some vibration switches rely on a simple system of leverage that is comparable to a mousetrap, in that a relatively small stimulus releases a strong spring. In Figure 11-5 the upper part of the figure shows the switch at rest, held in its position by a powerful spring and by the weight of a mass attached to a pivoted arm. In the lower part of the figure, severe vertical vibration has caused the assembly to move up and down with sufficient energy to overcome the tension in the spring while the inertia of the mass has resisted the motion. Consequently the arm has moved past the position where the spring is aligned with the pivot, and the spring now acts to hold the arm against a snap-action switch. A system of this type is used in sensors on some power-station cooling towers, where the loss of a large fan blade can result in major vibration.

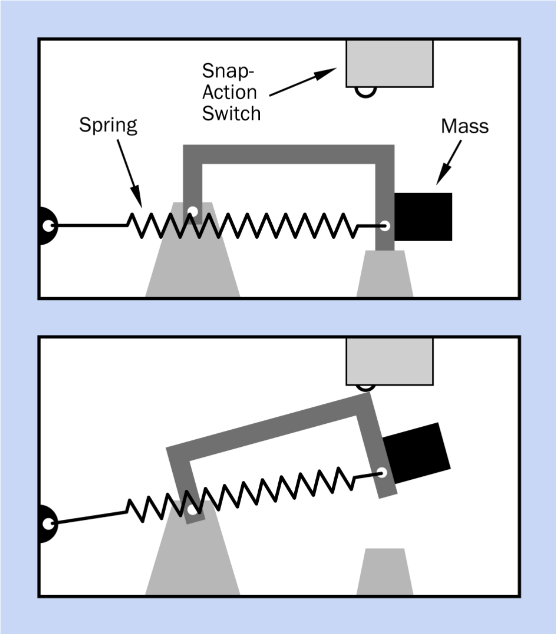

Figure 11-5 *A spring-loaded vibration sensor.*

Magnetic

Typically this method is used to detect excessive vibration in machines or other devices containing heavy rotating mechanical components. The sensor may be physically large, moving switch contacts that are designed to handle currents of 1A or significantly more.

In one system, a steel ball is retained by a permanent magnet that is barely powerful enough to prevent the ball from falling. Excessive low-frequency vibration will dislodge the ball, which falls and completes a circuit between two contacts. This activates a relay that powers down the piece of machinery that is vibrating.

The ball may be spaced a small distance from the magnet by a beveled nonmagnetic seat, and the seat may be movable with an external screw. This will adjust the sensitivity of the switch. After the switch has been triggered, it must be reset, which may entail using an external lever to raise the ball back to its location near the magnet.

Another magnetic system is shown in Figure 11-6, where a magnet on a vertical arm can be displaced by horizontal vibration, and an inertial mass on a spring-loaded horizontal rod can also dislodge the magnet in response to vibration along the other two axes.

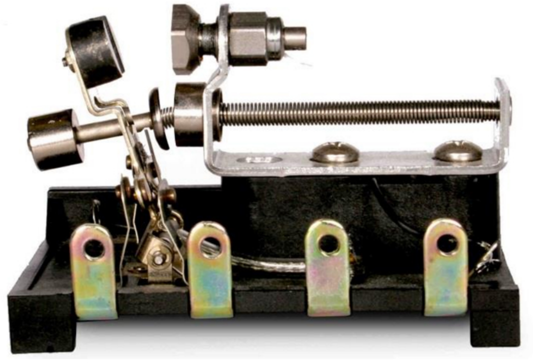

Figure 11-6 *A magnetic vibration switch. See text for details.*

Mercury

A small *mercury switch* may be used as a vibration sensor, although this application is uncommon. See Chapter 8 for more information about mercury switches.

Values

Measurement of vibration is a complex science of special interest in mechanical design, especially in areas such as the powertrain and suspension geometry in an automobile. Only a few fundamentals will be summarized here.

Primary Variables

The four primary variables in vibration are frequency, displacement, velocity, and acceleration. Frequency describes how rapidly the vibration occurs; displacement describes how far the vibrating object moves in each direction; velocity describes how fast it moves during each cycle; and acceleration describes how rapidly the velocity changes during each cycle. Different types of sensors can be chosen for their responsiveness to each attribute.

Figure 11-7 shows the theoretical relationships between displacement, velocity, and acceleration plotted against the frequency of vibration. The y axis of this graph (the vertical axis) is often labeled “amplitude,” but in reality it is being used to measure three different units, as shown. The curves indicate that if the velocity of vibration remains constant while frequency increases, acceleration must increase as a function of the frequency while displacement decreases. The acronym “rms” denotes that the values are measured as the “root mean square” of their fluctuations.

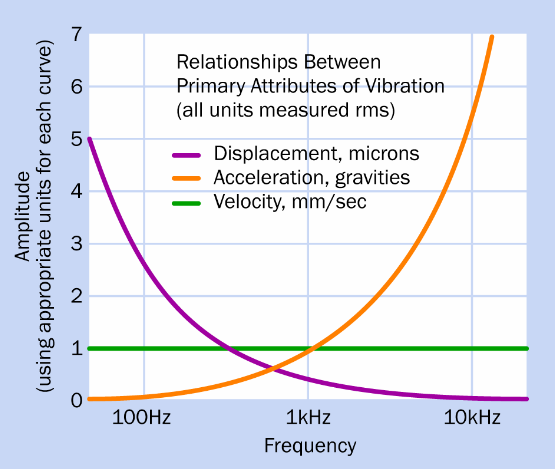

Figure 11-7 *Theoretical relationships among the primary attributes of vibration.*

Mechanical sensors or switches that respond to displacement are best suited to low frequencies, while piezoelectric sensors that are sensitive to acceleration are best suited to higher frequencies. Serious mechanical problems tend to result in low-frequency vibrations, while wear on bearings and in gear trains will be more likely to create high-frequency vibration.

Dynamic Attributes

Datasheets for small piezoelectric sensors may only show basic values such as the voltage range that is likely to be created.

Small mechanical sensors of the pin-and-spring type will be rated for maximum voltage and switching current. Typical values may be around 12V (AC or DC) and 10mA, indicating that the output from this type of sensor should be used with an op-amp, microcontroller, logic chip, solid-state relay, or other semiconductor with a high-impedance input.

Sensors that are manufactured for industrial applications will be rated for attributes such as measurable acceleration range (in gravities), temperature sensitivity, frequency response, resonant frequency, capacitance, and power requirement.

The sensitivity of piezoelectric sensors is usually expressed in mV/g. This type of sensor will require a comparator to process the tiny amount of current that it creates.

How to Use It

If a vibration sensor has an analog output requiring a comparator, the output from the comparator is likely to be of the open-collector type. This will require a pullup resistor of a value that provides an appropriate voltage for the next stage in the circuit. For more information about comparators, see Volume 2. For more information about the use of an open-collector output, see “3. Analog: Open Collector”.

A *coupling capacitor* can remove the DC component from the comparator output, allowing only the frequency of vibration to pass through. The choice of capacitor value will depend on the frequency.

When using a piezoelectric sensor with analog output, a 10M resistor may be installed across its two terminals to reduce voltage drift.

The primary challenge in getting a vibration sensor to work successfully will be matching it to the source of vibration. Manufacturers’ datasheets for chip-sized sensors often provide very little information about the optimal values for their products. Peak performance will occur when the natural resonant frequency of a sensor is close to the frequency of vibration that it must detect. Trial and error may be necessary.

A sensor must be mounted appropriately. Most sensors are directional, at least to some extent, and many will not respond significantly to vibration at 90 degrees to their primary axis of sensitivity. Their performance will also diminish if they are placed too far from the vibration source, or if they are mounted on a flexible or yielding surface that will tend to absorb vibration.

While industrial vibration switches may be adjusted manually, the response of small devices designed for circuit-board mounting can only be tweaked using external components to filter out unwanted signals from the sensor.

What Can Go Wrong

Long Cable Runs

The output from a piezoelectric vibration sensor is primarily an AC signal, fluctuating at the frequency of the vibration. Long cabling, or inadequately shielded cabling, can potentially introduce capacitive effects that can degrade the sensor signal. This issue will only affect higher frequencies.

Interference

Sensor signals can also be affected by electromagnetic interference from power lines, transformers, and large motors. This is a significant issue, as a primary application for industrial vibration sensors is to measure vibration created by motors.

Correct Grounding

For large sensing equipment, grounding may be important to shield cables that transmit data. In an industrial environment, however, grounding is primarily motivated by safety considerations, and an electrical ground can carry unwanted interference. Ground loops may be created if there are multiple ground points. Ideally, a "ground tree" should be used, where there is only one primary grounding point, and grounds to equipment branch out from it.

Fatigue Failure

In installations where some vibration normally exists, cables should be anchored properly to minimize the risk of fatigue failures.

force sensor

12

A *load cell* or *load sensor* is generally intended to measure a static load, while a *force sensor* can respond dynamically. However, this semantic distinction is not always observed. This entry differentiates between load cells and force sensors but includes them both.

Traditional types of *hydraulic* and *pneumatic* load sensors are not electronic devices. They are outside the scope of this Encyclopedia.

Capacitive, *ultrasonic*, *magnetic*, *optical*, and *electrochemical* force sensors are relatively unusual, and are not included in this Encyclopedia.

A force sensor is occasionally described as a **pressure** sensor, but that term is ambiguous, as it is more often used in conjunction with fluids. This Encyclopedia assumes that a pressure sensor only measures gas or liquid pressure. See Chapter 17.

A **vibration** sensor reacts to rapidly changing forces, but usually cannot measure them accurately, and is simply triggered when vibration exceeds a threshold. See Chapter 11.

Impact sensors that measure the force of a collision are outside the scope of this Encyclopedia.

A sensor designed to respond to a single touch from a fingertip is considered a human-input device and is discussed in the **single touch** sensor entry. See Chapter 13.

OTHER RELATED COMPONENTS

- **vibration** sensor (see Chapter 11)
- **single touch** sensor (see Chapter 13)

What It Does

A **force** sensor measures physical force that is applied to it, either by a person or by an object. Many force sensors respond rapidly and can measure fluctuating forces.

A *load cell* or *load sensor* is usually intended to measure the static weight of an object.

Applications

In robots, force sensors can provide feedback to limit the grip of a mechanical hand. They can also provide haptic feedback for a surgeon performing robotic surgery. In the future, force sensors may find increasing application in agriculture, as mechanized handling of fruit and other foods requires a carefully controlled gripping force.

In medicine, the use of force sensors to evaluate muscle strength in hands or limbs can be important as an indicator of neurological problems or to monitor progress in occupational therapy. Thin force sensors can be installed in shoes to check the weight distribution of each foot. They can also be used for entertainment purposes, to light LEDs in sneakers.

A force sensor may respond to a single-touch user input. See Chapter 13 for more information about **single touch** sensors. Some video game controllers use resistive force sensors to measure the amount of pressure applied to a button. The PlayStation is an example. (Old PlayStation DualShock 2 controllers are a salvageable source of pressure-sensitive buttons.)

Load sensors are used to weigh industrial products, and are also used domestically in kitchen and bathroom scales.

A load sensor can also detect human presence —for example, in the passenger seat of an automobile, where an air bag must not deploy if a young child is present, or in a hospital, to monitor the number of times the patient gets out of bed.

Schematic Symbol

No specific schematic symbol is used for either a force sensor or a load sensor. If a force sensor uses a piezoelectric or piezoresistive element, it may be represented by the symbol shown in Figure 11-1, which is used for many piezo devices.

How It Works

Two methods of force measurement are commonly used: resistive and piezoelectric.

A *piezoelectric* force sensor uses a piezoelectric element, often consisting of a quartz crystal, to convert force to a small voltage that can be amplified. However, this type of sensor only responds to changes in force. If a constant load is applied, the output peaks quickly and then gradually diminishes to zero.

Resistive force sensors change their electrical resistance when force is applied. They include *metallic strain gauges* and *plastic-film* sensors in which two layers of conductive ink are pressed together.

In SI (standard international) units, the force needed to activate a sensor is measured in newtons, abbreviated with a capital letter N. A newton is defined as the force that would accelerate a mass of 1 kilogram at 1 meter per second each second. More practically, in the gravitational field at the surface of the Earth, 1N = about 100 grams of weight. There are about 28 grams in an ounce; thus 1N is slightly less than 4 ounces.

Strain Gauge

A strain gauge is often made from metallic foil applied to an insulating flexible backing. The backing is glued to a shaped piece of metal, usually steel or aluminum, which is designed to flex slightly under pressure and may be referred to as a *spring*, even though it is often one solid object. Its deflection will be related to the force imposed on it.

The maximum deformation of the spring under a strain gauge is usually 500 to 2,000 parts per million (ppm) when subjected to the maximum force that it is designed to measure. A change of 1ppm is referred to as a *microstrain* (abbreviated μe).

The strain gauge has no polarity, and functions like a force-controlled **potentiometer** (see Volume 1). The ratio of the change in its resistance to the change in the strain that it experiences is called the *gauge factor*. For metal foil gauges, the gauge factor is usually around 2.0. This is an approximately linear relationship.

The most common type of foil pattern is shown in Figure 12-1. In the figure, if a stretching force is applied horizontally, the multiple thin sections of foil are slightly elongated, and their resistance increases within the limits of elasticity of the foil. This effect is multiplied by the number of sections. If the stretching force is applied vertically, the sections are merely separated slightly, and the result is negligible.

Wheatstone Bridge Circuits

The very small changes in resistance in a strain gauge must be amplified to be usable, and the first step is to use a Wheatstone bridge circuit. The simplest form of this circuit is shown in Figure 12-2.

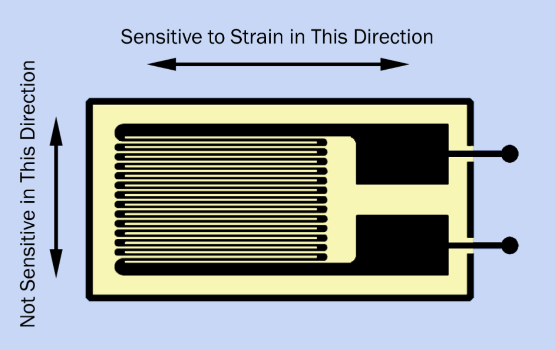
Sensitive to Strain in This Direction
Not Sensitive in This Direction

Figure 12-1 *The pattern of metallic foil used in a typical strain gauge.*

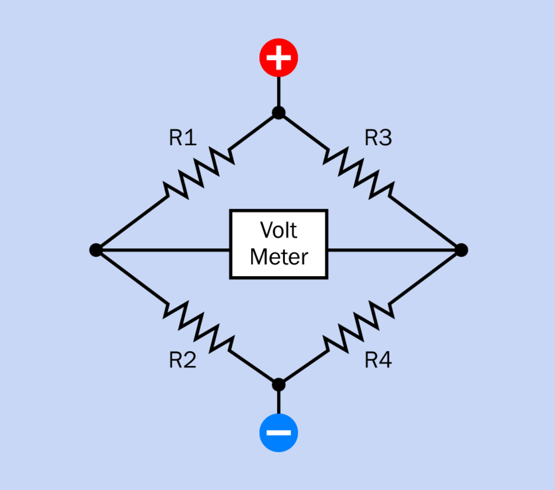

Figure 12-2 *A demonstration version of the basic Wheatstone bridge circuit that is often used to detect small changes in a resistance.*

Each pair of resistors (R1 + R2, and R3 + R4) functions as a voltage divider. If all the resistors have an exactly equal value, the voltage at the midpoint of each pair will be identical, and the volt meter at the center will have a zero reading. However, if the value of one resistor changes slightly, the meter will register the imbalance. This circuit is commonly used because of its sensitivity to small variations.

In Figure 12-3 two strain gauges have been substituted for resistors R3 and R4. The upper strain gauge has been mounted so that it experiences an increase in force at the same time that the lower strain gauge experiences a decrease, usually because one gauge is mounted on the top side of a flexing element while the other gauge is mounted on the underside.

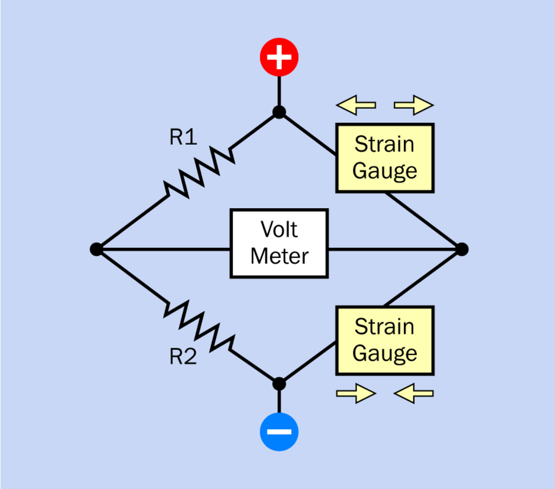

Figure 12-3 *Two strain gauges, oppositely oriented, can be used as resistances in the Wheatstone bridge circuit.*

Using two strain gauges in this way doubles the sensitivity of the Wheatstone bridge circuit. The configuration is known as a "half Wheatstone" force sensor, and will have three connecting wires. One will be black, one will be red, and the third will be a different color. The red and black wires are for connection to the power supply, as shown in the schematic, while the third wire is common and should be considered as an output.

If an additional two strain gauges are inserted in the Wheatstone bridge circuit, this is now a "full Wheatstone" force sensor (see Figure 12-4). Note, however, the diagonally symmetrical orientations of the strain gauges, necessary to multiply their effect.

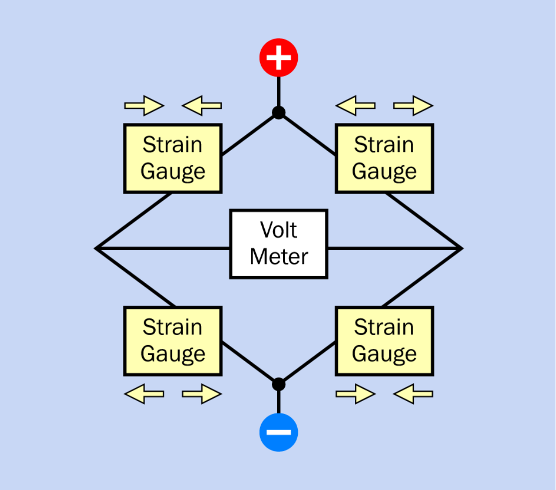

Figure 12-4 *Two additional strain gauges create a "full Wheatstone" circuit.*

A typical digital bathroom scale contains two half-Wheatstone force sensors, wired to create a full-Wheatstone configuration.

The force sensors shown in Figure 12-5 are rated for up to 50kg each, and can thus weigh up to 100kg if they are combined in a scale. In this figure, one sensor has been turned over to show its underside. The strain gauges are hidden in each sensor where the steel sections overlap.

Wheatstone Bridge Errors

Where more than one strain gauge is used in a Wheatstone bridge, they should ideally have identical performance. Since this is impossible as a result of manufacturing tolerances, some error correction is built into devices using multiple strain gauges.

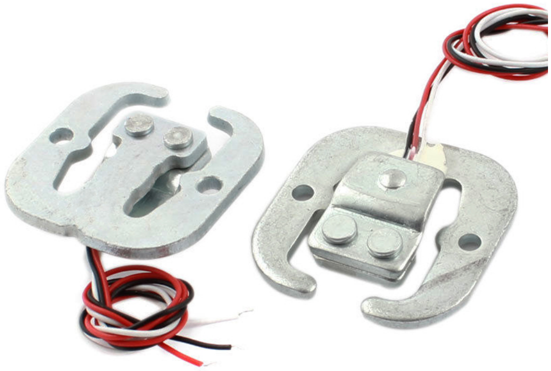

Figure 12-5 *Two force sensors suitable for a bathroom scale, each containing a pair of strain gauges that will flex oppositely under load.*

Strain-Gauge Amplification

The voltage output from a Wheatstone bridge circuit is given by the following formula, where V_{IN} is the supply voltage, V_{OUT} is the output, and R1 through R4 are the resistance values that were used in Figure 12-2.

$$V_{OUT} = [(R3/(R3+R4)) - (R2/(R1+R2))] * V_{IN}$$

The good news is that the output when a strain gauge is used will vary linearly with the load applied. The bad news is that it will be very small.

To amplify it, an op-amp such as the AD620 is often recommended. Using external resistors, its amplification factor can be adjusted from 1:1 to 10,000:1. Alternatively a chip such as the HX711 by Avia Semiconductor contains a 10-bit analog-to-digital converter and is specifically designed for use in weighing scales. Its digital output uses a very simple serial format. Sparkfun sells a breakout board incorporating this chip. See Figure 12-6.

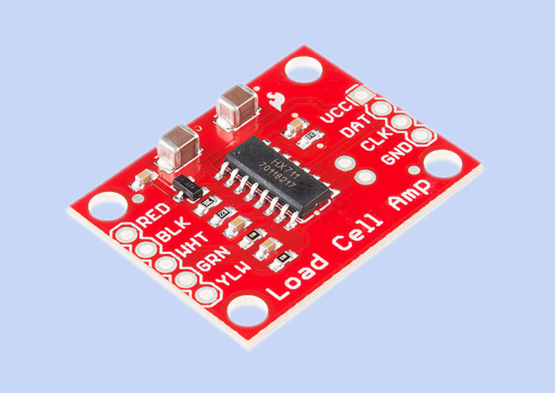

Figure 12-6 *Sparkfun HX711 breakout board for the HX711 amplifier chip, specifically designed for a full-Wheatstone array of strain gauges in a force sensor.*

Other Strain-Gauge Modules

Strain gauges are built into a variety of sensor modules. Figure 12-7 shows a selection, all of which are available from Sparkfun. Many more can be found online.

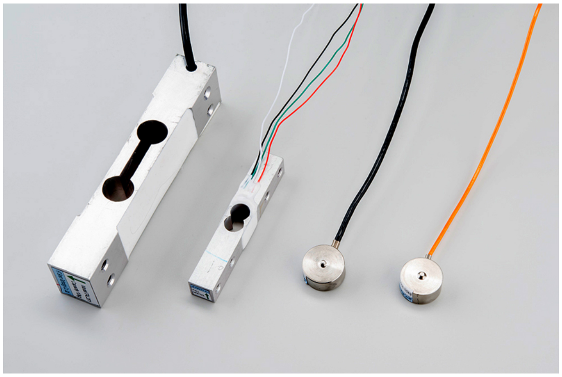

Figure 12-7 *A selection of load cells containing strain gauges, available from Sparkfun.*

Plastic-Film Force Sensors

Plastic-film resistive sensors contain two layers of conductive ink, sealed between two layers of thin, transparent plastic film. The resistance between the ink layers diminishes when they are pressed together. It may vary from as little as 30K when fully loaded to more than 1M when unloaded.

Like a strain gauge, this sensor has no polarity and requires no power supply.

Examples of this type of sensor are shown in Figures 12-8 and 12-9. Other shapes and sizes are available. Manufacturers include Tekscan, whose product is named FlexiForce; Alpha Electronic, in Taiwan; and Interlink Electronics.

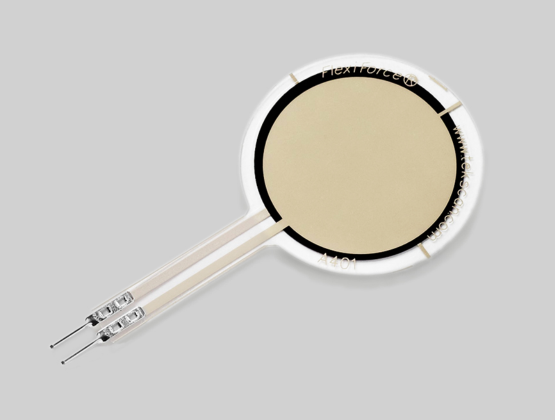

Figure 12-8 *A FlexiForce A401 resistive film sensor made by Tekscan, Inc. Its sensing area is 25.4mm in diameter (1 inch) and is rated to measure up to 111N (25lbs).*

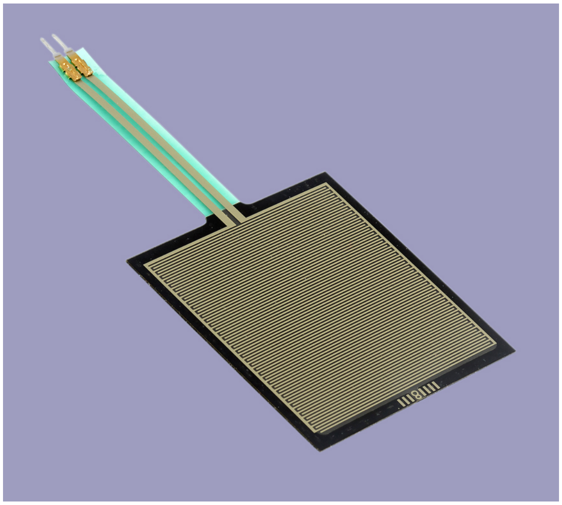

Figure 12-9 *An Interlink FSR406 resistive film sensor. Its sensing area is slightly less than 40mm square, and is rated to measure up to 20N (4.5lbs).*

Plastic-film sensors should not be confused with film-based piezoelectric vibration sensors, which are described in the **vibration** entry (see "Piezoelectric Strip"). Those sensors provide a transient output when they flex rapidly. The resistive sensors provide a stable output in response to a steady load.

Deformative Force Sensors

A sheet of natural or silicone-based rubber can be impregnated with conductive particles. The conductivity of the sheet may not change significantly when it is compressed, but if it is separated from a metal plate by a mesh of thin nylon fibers, compression will result in greater conductivity by pushing the rubber into the gaps between the fibers. See Figure 12-10.

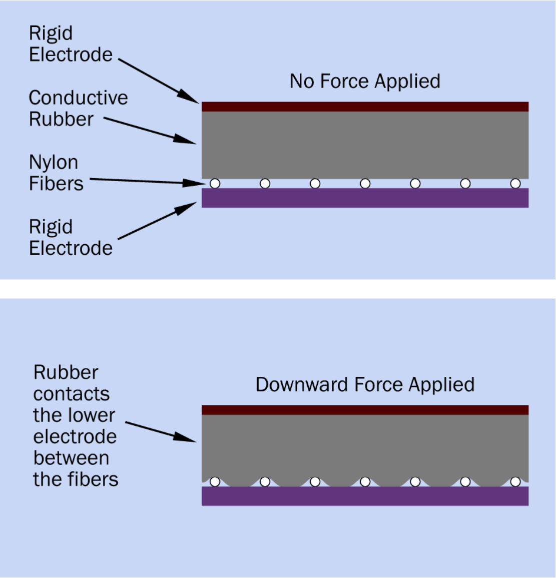

Figure 12-10 *In the top image, a flexible conductive layer is separated from an underlying rigid electrode by nylon mesh. In the lower image, a load applied to the flexible layer has forced more of it into contact with the electrode, reducing the resistance between them.*

Improvised Resistive Sensors

Polyethylene film impregnated with carbon particles is available under the brand name Velostat, owned by 3M. Although it was developed as an antistatic packaging material for semiconductors, it can be used to make a DIY force sensor. When the material is stretched, the embedded particles are more dispersed, and electrical resistance increases. When the material is compressed, its resistance is reduced.

Antistatic foam of the type used to package CMOS components can be used in the same way, although some types behave like memory foam, being slow to recover from pressure. The foam can be sandwiched between a pair of copper-plated circuit boards as electrodes.

How to Use It

Plastic-Film Resistive Force Sensors

The conductivity of a plastic-film sensor has an almost linear relationship with the force applied. In other words, if F is the force and I is the current:

```
I = k * F
```

where k is a constant determined by the characteristics of the materials used.

By Ohm’s Law, R = V / I where V is the voltage drop across a resistance of value R. By substitution, using k * F instead of I:

```
R = V / (k * F)
```

Therefore, if a constant voltage is applied across the force sensor, the resistance of the sensor will be proportional to the reciprocal of the force (i.e., 1 / F). These relationships are shown in Figure 12-11.

For convenient measurement, it will be helpful if the resistance of the sensor can be converted to a voltage output that varies linearly with the force applied. To achieve this, a resistive force sensor of this type is customary amplified with an **op-amp** (see Volume 2). Using the schematic shown in Figure 12-12, the amplification ratio, A, is found from this formula:

```
A = 1 + (R2 / R1)
```

where R2 if the potentiometer, and R1 is the resistive force sensor. Therefore, the output from the op-amp should have an approximately linear relationship with the force applied to the sensor.

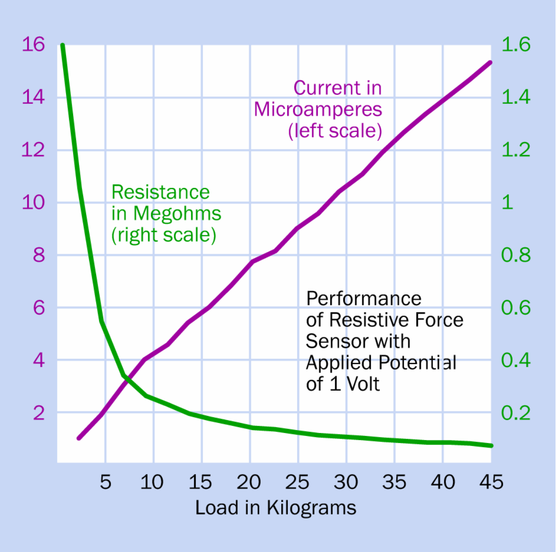

Figure 12-11 *The relationship between force, current, and resistance in a flexible resistive sensor, assuming a constant voltage of 1V is applied across it (derived from FlexiForce Sensors User Manual).*

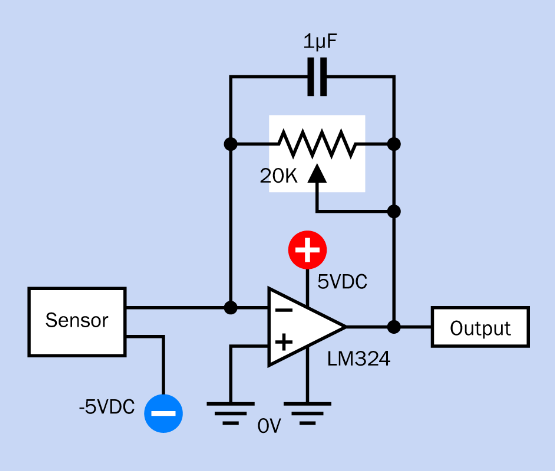

Figure 12-12 *An amplification circuit with an output that is approximately linear with force applied to a resistive film sensor.*

The capacitor in this circuit is added to suppress noise that the circuit might otherwise pick up.

An alternative is to wire a resistive sensor in series with a capacitor, and connect the other side of the capacitor to a comparator that has adjustable feedback. The resistance of the sensor will determine how quickly the capacitor charges. However, because of the mathematics describing the charge rate, the output from the comparator would not be linear with the force on the sensor. Also, provision would be necessary to discharge the capacitor intermittently.

Values

Film-Based Force Sensors for User Input

A very light pressure with a fingertip could be around 50g. A more defined finger-press would be 250g, and a heavy push with a finger would be around 1kg.

The Interlink range of flexible force sensors requires a minimum pressure of 0.2N, or about 20g. Similarly, Alpha products range from a minimum of 10g to 30g.

These specifications suggest that film-based force sensors may be used for one-touch user input, but the no-load resistance will be at least 1M, and more than 10M in some instances. A small amount of pressure is unlikely to reduce this electrical resistance much below 500K. Using an op-amp or comparator to detect that difference and convert it into a reliable on-off output may be vulnerable to noise and power-supply disturbance.

Another consideration is that film-based sensors provide no tactile feedback. For these reasons, and because film-based products are described by their manufacturers as “force sensors” rather than as “touch sensors,” they are included in this entry rather than in Chapter 13. That said, they may be considered as an option for one-touch user input where they are appropriate—for instance, in games where players are likely to slap or hit a sensor vigorously.

Specifications for Film-Based Force Sensors

Durability of film-based sensors is excellent, with manufacturers claiming that performance is not degraded after 1 million applications of a 20kg load. Sensors have no polarity, will function using voltages from 1V to 15V in most cases, and have a response time of less than 5ms. They do not generate, and are not vulnerable to, electromagnetic interference.

Important attributes when evaluating film-type sensors are their limits of tolerance for applied force, and resistance values at each end of the range. Unfortunately these values are poorly documented for many sensors, or may be unspecified.

Maximum force may range from 20N to 440N, depending on the brand and model of sensor.

Electrical resistance is at least 1M when unloaded, and may be as high as 20M.

Accuracy ranges from plus-or-minus 2% to plus-or-minus 5% from one application of force to the next, depending on the model of sensor and the manufacturer. If force is not applied each time in exactly the same area of the sensor, results will vary. If a sensor is swapped with another sensor of the same type, sensor-to-sensor consistency will be uncertain. Therefore, film-based force sensors are not a good choice for applications where accuracy is important.

Sensors may be rated for 5% to 10% hysteresis.

The area of active detection may range from about 4mm wide (FlexiForce sensors) to more than 40mm wide (Interlink FSR-406).

Strain Gauges

Strain gauges are not sold as individual components by most electronics suppliers. They are sometimes available as surplus parts or from sites such as eBay, where specifications range from 100 ohms to 1K as the resistance when no load is applied.

A load sensor on which a strain gauge has been preinstalled is much easier to use, and will be plug-compatible with an appropriate amplifier chip as previously described.

What Can Go Wrong

Soldering Damage

The pins on plastic-film resistive sensors are embedded in thin plastic. Heat from a soldering iron can easily damage this plastic. Heat-sink alligator clips should be used while soldering, or the pins can be socketed instead of soldered.

Bad Load Distribution

Film-based sensors will not provide accurate readings if a load is imposed unevenly or inconsistently, or extends outside the detection area. A *puck* consisting of a small, rigid disc may be interposed between the source of the force and the sensor, to distribute the load within the maximum area. A puck may also be referred to as a *shim*.

Similarly, the sensor must be mounted on a flat, smooth surface, and if this is not available, a rigid plate should be interposed.

Water Damage

Although film-based sensors are enclosed in plastic, they are not waterproof. Immersion may cause the layers to delaminate.

Temperature Sensitivity

Because electrical resistance tends to vary with temperature, readings from resistive force sensors will vary with temperature.

Ambient temperatures of 70 degrees Celsius and above may damage a film-based sensor.

Leads Too Long

Although film-based sensors are supplied with a variety of lead lengths enclosed in the laminated layers of flexible plastic, the leads may be too long for a particular application. If they are trimmed, wires cannot be attached with solder, as it will melt the plastic. Conductive epoxy should be used.

single touch sensor

13

This entry only describes *capacitive* touch sensors. A *conductive* sensor, which uses the fingertip to complete a circuit between two exposed contacts, is not very common, and is not included here.

The type of touch sensor described in this entry requires no physical pressure for activation. It should not be confused with a resistive or piezoelectric **force** sensor that requires pressure. See Chapter 12.

An integrated circuit chip that processes a signal from a *touch pad* is often described as a *touch sensor*, even though it does not contain a sensing element. This entry describes it as a "touch sensor chip" to eliminate ambiguity, and refers to touch input elements as "touch pads."

Touch pads that contain *tactile switches* or *membrane switches* are described in the entry discussing **switches** in Volume 1. All types of switches are described in that volume, with the exception of a *reed switch*, which is magnetically activated and is therefore categorized as a sensor.

Capacitive touch sensors are sometimes referred to as *capacitive proximity sensors*, because they sense the proximity of a human fingertip. In this Encyclopedia, and in most other sources, a **proximity** sensor measures distance, not touch. See Chapter 5.

A *capacitive displacement sensor* employs the same principle as a capacitive touch sensor, but is used to detect the position of an object, not for human input.

OTHER RELATED COMPONENTS

- **force** sensor (see Chapter 12)
- **touch screen** (see Chapter 14)

What It Does

A *touch pad* detects the presence of a human fingertip (or other part of the body) and signals an integrated circuit chip, which is very often termed a *touch sensor*, even though it does not contain a sensing element itself. The chip creates an output to signify that human touch has been recognized.

A keypad of the type found on microwave ovens may appear similar to an array of touch pads, but is more likely to contain *membrane switches* or *tactile switches*, which are described with other forms of switches in Volume 1. The type of touch pad described in this entry requires no physical force and contains no parts that move or flex when pressed.

A modern **touch screen** is usually a capacitive device and can be thought of as an array of touch pads. See Chapter 14.

Applications

Capacitive touch sensors have become common as their cost has fallen relative to simpler components that respond to being pressed.

A touch sensor can be used to start or stop a process, or to power up or power down a device. Multiple sensors may be found wherever user input of a few alphanumeric characters is required. Because touch pads can be completely sealed, they are useful where hygiene is important.

Specific applications include the activation of a backlight in a handheld device, wake-up from standby, ear detection in a cellular telephone, control of medical devices, and activation of interior lighting in some automobiles.

The absence of moving parts or electrical contacts means that a touch pad is more reliable than any type of electromechanical switch. A disadvantage is that it provides no tactile feedback, and therefore will require a visual or audible confirmation when it responds to input. Lack of tactile feedback makes touch pads unsuitable for computer keyboards and other key-entry devices where rapid typing is required.

When the capacitive elements of a touch pad are transparent, it can be mounted in front of a screen.

Schematic Symbols

Either of the schematic symbols in Figure 13-1 may sometimes be used to represent a touch sensor, but not on a consistent basis.

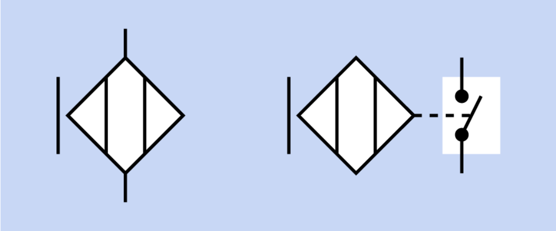

Figure 13-1 *Two possible schematic symbols that may represent a touch sensor.*

How It Works

The two plates in a capacitor are separated by an insulator known as the *dielectric*. Paper, plastic, glass, air, and other insulators can serve this purpose. Although no electrical connection exists between the plates, AC passes through the dielectric as a field effect.

Electrical capacitance exists between any pair of electrical conductors. The human body has high electrical resistance but still is electrically conductive, and therefore has capacitance with other conductive objects.

A touch pad can function as one side of a capacitor, with a fingertip functioning as the other side. In this mode, AC can pass from the touch pad and through the human body to ground. The current is very small, but fluctuations can be detected by an appropriately designed integrated circuit chip, or by a microcontroller.

The precise characteristics of a dielectric will affect the performance of a capacitor to some extent, but will not prevent it from working. Therefore a touch pad can function even when it is shielded behind a protective layer of glass or plastic, as is often the case.

A touch sensor chip generates pulses of low-voltage AC and sends them to a touch pad. The chip detects any variation in the current through the touch pad, indicating the presence of a fingertip. Where an input occurs, the chip changes its output, which usually requires a microcontroller for processing.

How to Use It

Touch sensor chips are available in as many as 40 different formats and configurations. All of them are surface-mount. For breadboarding, an experimenter can use breakout boards that have sensor chips installed. Figure 13-2 shows a product from Adafruit that is capable of addressing 12 touch pads. Its output is accessible from a microcontroller via the I2C protocol. For additional details about protocols such as I2C, see Appendix A.

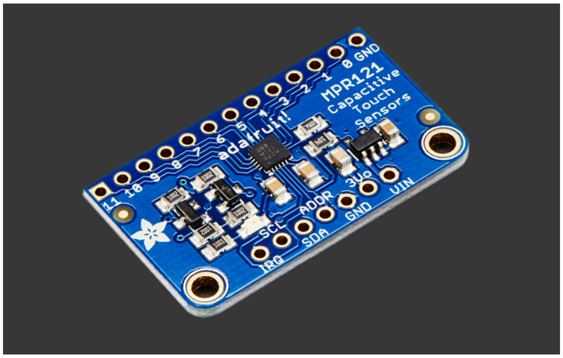

Figure 13-2 *A capacitive touch sensor chip on a breakout board from Adafruit.*

Similar breakout boards are available from Sparkfun, and from large online vendors such as *http://www.mouser.com* (where they are categorized as *development tools*).

While most touch sensor chips require a microcontroller, a few are available with the same number of output pins as touch-pad input pins, and each output pin will transition between logic-high and logic-low when an input on the corresponding pin is detected. Another breakout board from Adafruit, the AT42QT1070, uses this simple system.

A library exists for Arduino that enables two pins to sense touch on a piece of aluminum foil.

It can also work with conductive ink or paint.

Obtaining Touch Pads

Sensor chips are widely available as components, and are very inexpensive. On the other hand, touch pads are not common as components, probably because a touch pad is usually created as a pattern of copper traces etched onto a circuit board by a device manufacturer.

Touch pads from hobby-electronics sources usually include touch sensor chips. Sparkfun offers a 12-key keypad on this basis, and also a 9-key keypad designed as a “touch shield” for use with the Arduino. Both of the Sparkfun products are shown in Figure 13-3. They include the same MPR121 touch sensor chip as the breakout board from Adafruit shown in Figure 13-2, and require an I2C connection with a microcontroller.

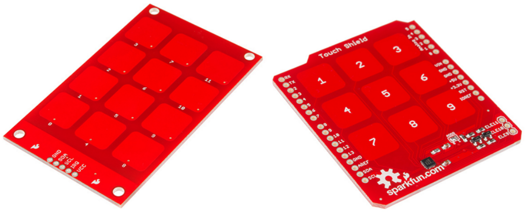

Figure 13-3 *Two capacitive keypads from Sparkfun, the one on the right designed as an Arduino shield.*

Because a capacitive touch pad is usually mounted inside an enclosure, the appearance of the bare touch pad as a component is unimportant. The outside of the enclosure can be printed with a design showing key outlines.

Individual Touch Pad

Adafruit sells the AT42QT1010 touch pad that emulates a momentary switch. Its output transitions from logic-low to logic-high when a finger presence is detected, and transitions back to logic-low when the finger is removed.

An alternative, shown in Figure 13-4, toggles between a logic-high and logic-low output and latches in each state with each single key press.

Both of these keypads contain sensor chips to generate the output.

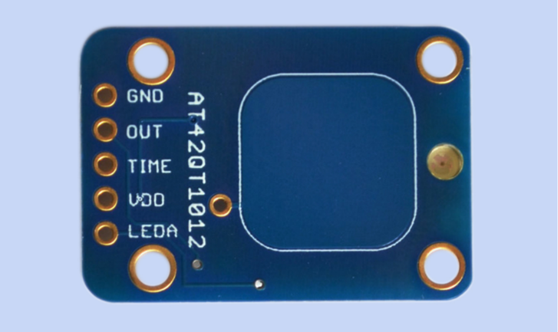

Figure 13-4 *The output from the AT42QT1012 sensor chip on this touch pad from Adafruit toggles between logic-high and logic-low each time the pad is touched.*

Wheels and Strips

A touch wheel uses a circular pattern of conductive traces, often referred to as *electrodes*, to receive finger input. A simple configuration is shown in Figure 13-5. The traces interlock without making contact with each other, so that moving the finger in a circular motion creates a capacitive input that rises and falls sequentially on each element. In the figure, three sections are used, each colored differently here for purposes of clarity. Other touch wheels may contain more sections.

Firmware that is designed to interact with wheel-shaped touch pads will generally assume that two electrodes are receiving input at one time. The firmware attempts to calculate the position and motion of the finger by assessing the relative capacitance of adjacent segments. Ideally the capacitance values should vary linearly and complementarily; that is, from a 50-50 value at a midpoint between two segments, the progression should change to 60-40, 70-30, and so on, as the finger moves around the wheel.

A *touch potentiometer* consists of multiple touch pads, usually arrayed in a straight line. This may be described as a *touch strip*. An example is made by GHI Electronics and sold by Robot Shop as their L12 Capacitive Touch Module, shown in Figure 13-6.

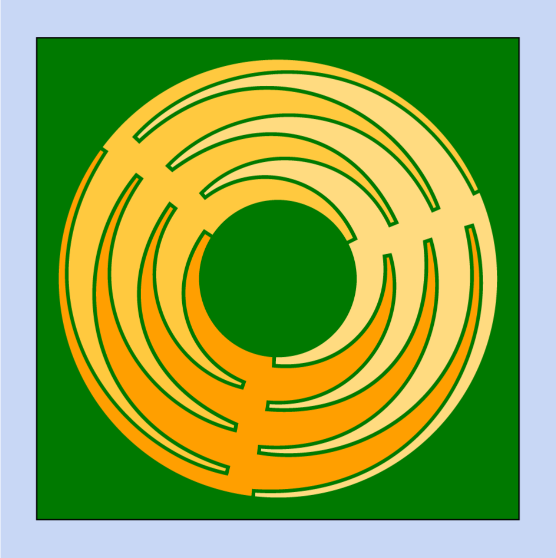

Figure 13-5 *A touch wheel created by copper traces on a circuit board (green). Each section is colored differently, for purposes of clarity.*

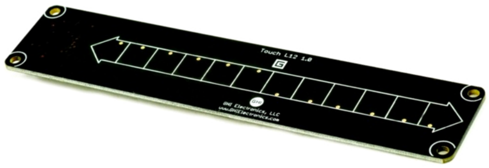

Figure 13-6 *Multiple capacitive touch pads arrayed as a strip, made by GHI Electronics.*

Design Considerations

A simple touch pad is often surrounded by additional copper that is grounded and may be described as a *shield* or a *guard*. The capacitance of a fingertip (spaced above the electrode by a layer of plastic or glass that functions as the dielectric) interferes with the field between the electrode and the shield.

The underside of the circuit board is often plated and grounded to protect the touch pad from electromagnetic interference. This, too, can be referred to as a shield or a guard. The ground plating can be in a hatched pattern to reduce its capacitance with the electrode above.

Layout of a circuit involving a single touch sensor chip can affect its performance significantly. A touch sensing device may have to be "tuned" to detect finger presence reliably.

A long trace between the touch sensor and an electrode will tend to pick up noise and will increase capacitance.

The distance between adjacent traces from multiple touch pads must be maximized to reduce capacitance between them. If output from a sensor chip uses the I2C or SPI digital protocol, any trace carrying that digital signal should be at least 4mm from input traces. If they cross, they should be at 90 degrees to each other.

Electrodes should not be shaped to resemble numbers or other characters printed above them. A single basic electrode should be circular.

What Can Go Wrong

Insensitive to Gloves

Gloves are a challenge for touch-sensor design, as they alter the dielectric and the distance between the electrode and the finger. Capacitive touch sensors may not work at all with some types of gloves. However, special gloves containing metallic threads are available.

Stylus Issues

A nonconductive stylus cannot activate a touch pad.

Conductive Ink

Ink that prints the shapes of touch pads on the exterior of a device should be nonconductive.

touch screen

14

The term **touch screen** is written as two words in this Encyclopedia. In many sources, the words are concatenated as "touchscreen."

The two words are hyphenated here when they function as an adjective, but not otherwise. In manufacturers' datasheets where the two words are used, they are not usually hyphenated.

OTHER RELATED COMPONENTS

- **single touch** sensor (see Chapter 13)
- **force** sensor (see Chapter 12)

What It Does

A touch screen is a video display with embedded touch sensing. The screen reports the position of the touch, and is used as a pointing device as an alternative to a mouse or trackpad. Some touch screens report pressure as well as position.

Touch screens are widely used in smartphones and tablets, and also in some laptop computers. Smaller, simpler touch screens may be found in office equipment such as photocopiers.

Schematic Symbol

No specific schematic symbol is used to represent a touch screen.

Variants

Early designs used infrared LEDs recessed into the edges of a frame around a screen. A matching photodiode picked up the focused beam from each LED. The presence of a fingertip was detected when it interrupted one or more of the beams. This system was not capable of high resolution, but was adequate for detecting user input at predefined locations.

Most touch screens currently are either resistive or capacitive.

Resistive Sensing

A resistive touch screen consists of two transparent layers that can be installed over a separate video display.

Each of the layers has uniform electrical resistance. Pressure from a fingertip on the outer layer (which we can refer to as layer 1) forces it to make contact at a point with the inner layer (referred to here as layer 2).

Two vertical electrodes connect with layer 1 along its left and right edges. Two horizontal electrodes connect with layer 2 along its top and bottom edges. When voltage is applied between the vertical electrodes on layer 1, the layer acts as a horizontal voltage divider. The voltage at the point where the layer is being pressed is applied to layer 2, and can be read from either of the electrodes on layer 2, so long as the metering has a much higher impedance than that of the layer. The voltage is decoded as a value for the horizontal position on layer 1.

An external switching device now repeats the procedure, except that it applies voltage to layer 2, and reads it from layer 1 to supply a value for the vertical position on layer 2. The sequence is illustrated by the top and bottom sections of Figure 14-1.

Because only four connections are necessary, this is referred to as a *four-wire* resistive touch screen. Five-wire variants exist, but are less common, and are not included in this entry.

Advantages of a resistive screen include:

- Simplicity. Only four connections are necessary, and the layers of the screen do not have to be subdivided into separate conductors.
- Low cost, relative to capacitive touch screens.
- Will respond equally well if a user wears gloves or uses a stylus.

Disadvantages of a resistive screen include:

- Some resistive versions require a stylus input instead of finger pressure.
- Resistive screens only respond to a one-location input. Two-finger gestures are not supported.
- Contact bounce occurs when the flexible layer is pressed against the underlying layer, and voltage spikes may be associated with switching power to the screen. To address this issue, firmware in a microcontroller may have to take a median value from several rapid readings.
- The flexible membrane is vulnerable to damage from sharp objects.

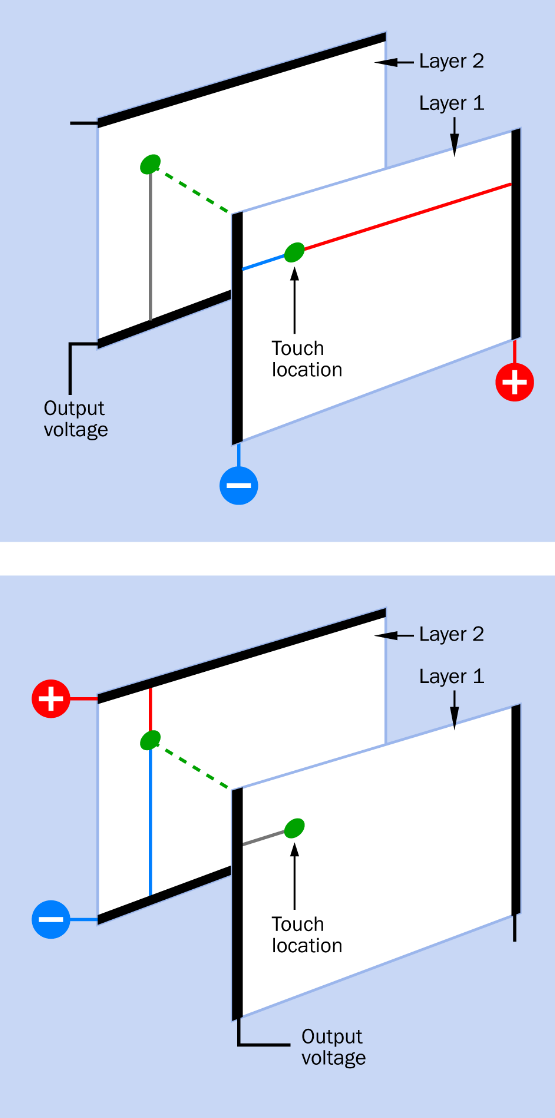

Figure 14-1 *Sections of a resistive touch screen are shown displaced for clarity. In reality they would be separated by a very small gap, allowing one section to make contact with the other in response to finger pressure.*

Capacitive Sensing

A capacitive touch screen can consist of an array of **single touch** sensors printed onto a glass panel as vertical and horizontal lines of transparent conductive ink.

Alternatively, a small capacitive screen can measure the tiny amount of current drained by a fingertip from four sources located at corners of the screen.

For more information about capacitive touch sensing, see the entry on touch sensors in Chapter 13.

Screens Available as Components

A wide variety of screens can be found in diagonal sizes ranging from 2 inches upward. Onboard electronics can be suitable for connection with a microcontroller using the I2C and SPI protocols, or USB. Different screen resolutions are available.

An example of a 3.5-inch touch screen with 320x200 resolution, mounted on a breakout board that can be used with a breadboard and an Arduino, is shown in Figure 14-2.

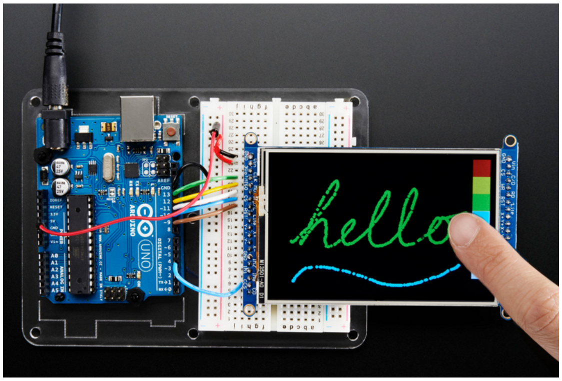

Figure 14-2 *An Arduino-compatible touch screen mounted on a breakout board, available from Adafruit.*

A 7-inch resistive touch screen that can be mounted on a separate video display is shown in Figure 14-3. It can be used with the STMPE610 controller chip, which converts resistive screen values into digital coordinates and can be accessed by a microcontroller over both SPI and I2C. This surface-mount chip is available on a breakout board.

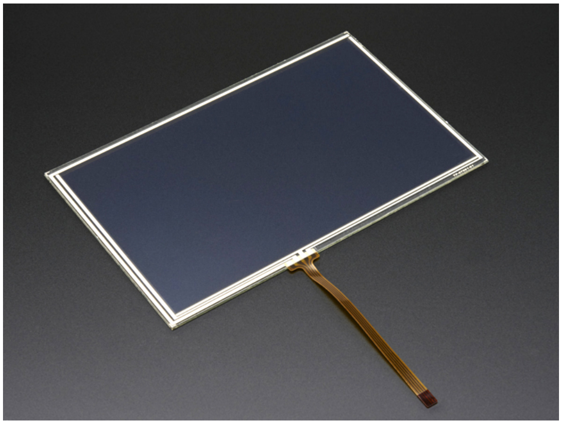

Figure 14-3 *This resistive touch screen is intended for use as a layer applied to a 7-inch video display. The screen is available from Adafruit.*

When choosing a touch screen as a component for a DIY project, the availability of microcontroller code libraries for reading and refreshing the display is an important consideration.

liquid level sensor

15

Level indicators that contain no electronic components are not included in this entry.

Specialized industrial level-sensing equipment is generally outside the scope of this Encyclopedia. This entry discusses small-scale, lower-cost sensors.

Liquid volume can be assessed by measuring liquid pressure at the bottom of a reservoir. Sensors for this purpose are discussed in the entry describing **gas/liquid pressure** sensors. See Chapter 17.

OTHER RELATED COMPONENTS

- **liquid flow rate** sensor (see Chapter 16)
- **gas/liquid pressure** sensor (see Chapter 17)

What It Does

Measuring the volume of liquid in a storage vessel or reservoir is such a fundamental task, countless methods have been devised, of which only the simplest and most common will be discussed here.

A liquid level sensor can have a binary output, meaning that it signals when the volume rises above or falls below a level that can be preset or reset. Often the sensor will be connected to a pump or valve that maintains a relatively constant volume in a container.

Alternatively a sensor can indicate the actual stored volume, either with an analog output or in digital increments.

Schematic Symbols

Three variants of a schematic symbol for a simple liquid level sensor are shown in Figure 15-1. They are not always used, however, and a sensor may be shown simply as an annotated switch.

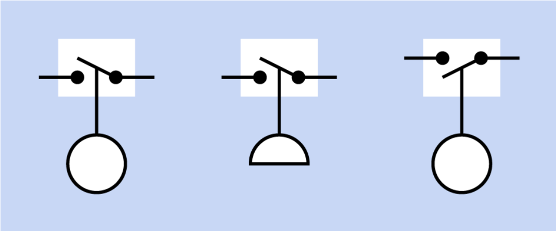

Figure 15-1 *Three variants of a schematic symbol to represent a liquid level sensor. The rightmost symbol indicates that a rising level closes, rather than opens, a switch.*

Applications

The fuel gauge in a vehicle is one of the most commonly encountered applications of a liquid level sensor. The water tank in a recreational vehicle or boat may use similar electronics. In industry, the choice of a sensor will be influenced by the type of liquid that is being stored, the desired accuracy, the temperature range, and whether the storage tank is sealed or open to atmospheric pressure.

How It Works

Desirable attributes of any liquid-level sensor include resistance to vibration, some damping to average out fluctuations caused by turbulence or sloshing in the liquid, resistance to chemical reactions with the liquid, and few moving parts that may require maintenance if the sensor is inside a sealed tank. Desirable attributes of an analog float sensor include a linear response, and some hysteresis if the application requires it.

This entry compares a variety of sensing strategies.

Binary-Output Float Sensor

The term "binary output" is used here to describe an output that only has two states (on and off, or logic-high and logic-low). The simplest type of liquid-level sensor with a binary output consists of a donut-shaped float that contains a permanent magnet and is free to slide vertically up and down a sealed tube containing a reed switch. The tube is supported on a bracket that can be mounted on the wall or the lid of the vessel containing the liquid.

The tube and float must be nonmagnetic, and the float must have a significantly lower specific gravity than the liquid that is being used ("significantly" because the float requires sufficient buoyancy to carry the weight of the magnet and overcome any friction between itself and the tube). A diagram illustrating this configuration is shown in Figure 15-2.

To change the level setting of the sensor, the bracket may be mounted on a screw thread to adjust its vertical position.

The reed switch can be normally open or normally closed, as needed to respond to a rising or falling liquid level. For basic information about reed switches, see "Reed Switch". Additional, detailed information about reed switches is included in the book *Make: More Electronics*.

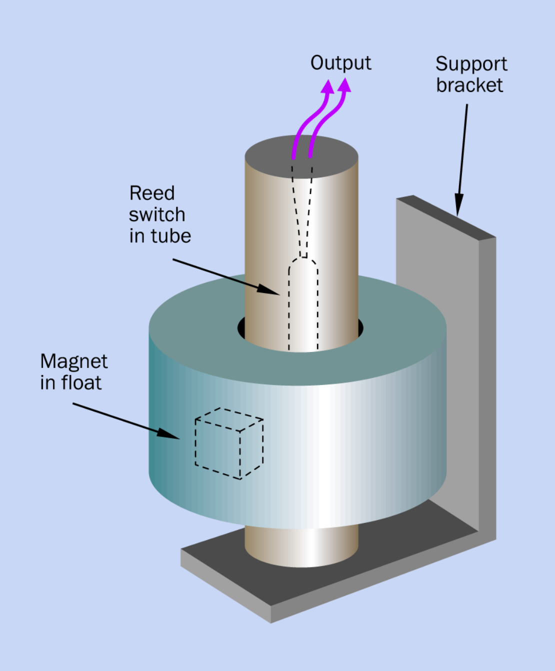

Figure 15-2 *The principal parts of a basic binary-output float sensor.*

For increased reliability, a Hall-effect sensor could be substituted for a reed switch. See "Hall-Effect Sensor" for general information about Hall-effect sensors.

Another binary-output float sensor is shown in Figure 15-3. This is a sealed plastic capsule containing a snap-action switch and a steel ball. The cable is attached to the underside of the top of a tank, and the capsule dangles into liquid in the tank. A separate weight (not shown) has a hole in the middle, and is threaded over the wire. The weight keeps the wire approximately in a vertical position as it dangles into the tank.

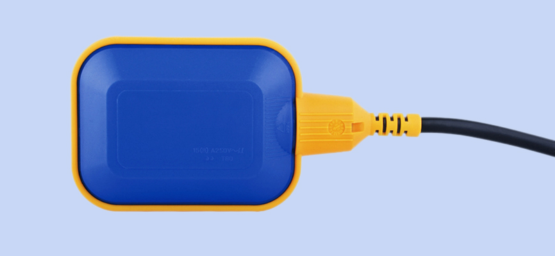

Figure 15-3 *An air-filled float that switches external power depending on its orientation.*

Figure 15-4 shows the components inside the float. When the liquid level in the tank falls, the float adopts the position shown on the left in the figure. The ball drops against a lever that closes a snap-action switch, which starts an external pump to replenish the tank. As the liquid level rises, the buoyancy of the air-filled float changes its orientation to that shown on the right in Figure 15-4. The ball drops and the switch opens, stopping the pump.

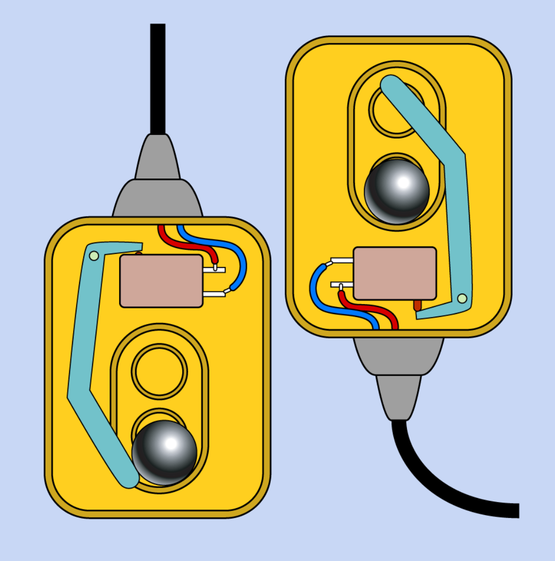

Figure 15-4 *Internal components of the float shown in the previous figure.*

Two circular indents on the inner surface of the plastic capsule prevent the ball from rolling erratically if there is turbulence in the liquid. They also provide some hysteresis.

Analog-Output Float Sensor

The simplest type of liquid-level sensor with an analog output consists of a float on an arm attached to a potentiometer, as shown in Figure 15-5. This very basic design was used in fuel tanks in vehicles for many decades. Disadvantages include a nonlinear response and the limited life expectancy characteristic of potentiometers. Some compensation for the nonlinear response can be made by using an analog fuel gauge with a nonlinear scale.

For more information about potentiometers, see "Arc-Segment Rotary Potentiometer".

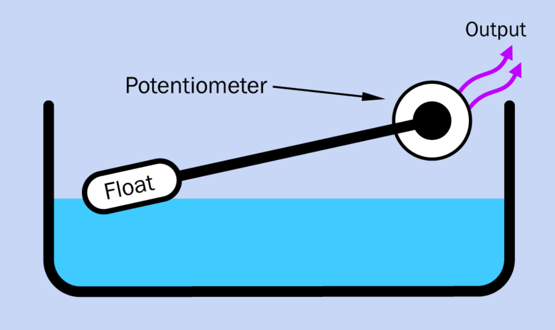

Figure 15-5 *A basic float sensor with an analog output.*

Incremental-Output Float Sensor

A schematic diagram for a simple float sensor with incremental output is shown in Figure 15-6. A magnet embedded in a donut-shaped float, similar to that shown in Figure 15-2, interacts with a sequence of reed switches installed in the central tube. The switches are spaced at equal intervals and apply power between resistors of equal value wired in series. This system has been used in motorcycle and automobile fuel tanks, where the switches may be enclosed in a (nonmagnetic) stainless-steel tube. The accuracy is limited by the number of reed switches.

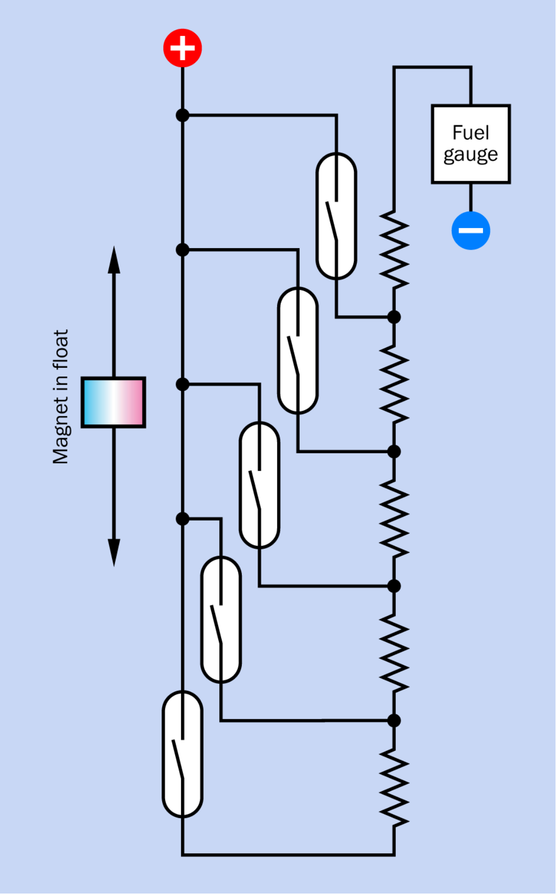

Figure 15-6 *A float sensor with incremental output.*

Displacement Level Sensors

If a heavy object, described as the *displacer*, is suspended in liquid, the effective weight of the object diminishes as the liquid rises up around it. This occurs because according to Archimedes' Principle, the upward buoyant force is equal to the weight of liquid that the object displaces. The displacer is suspended from a load sensor that measures its weight. Analog output from the sensor will be approximately linear with liquid level.

For a simplified diagram showing a displacement level sensor using this concept, see Figure 15-7.

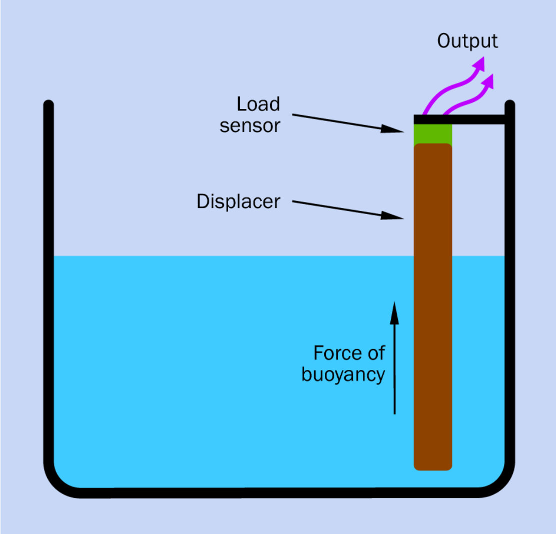

Figure 15-7 *A displacement sensor. The displacer is heavier than the liquid around it, but its effective weight diminishes as the liquid rises.*

For more information on load sensors, see Chapter 12.

Ultrasonic Level Sensors

An ultrasonic sensor can be used to measure the level of liquid in a reservoir, as shown in Figure 15-8. For more information about this type of sensor, see the entry discussing proximity sensors in Chapter 5. A disadvantage of using ultrasound for liquid level sensing is that the speed of sound will be affected by any vapor given off by a volatile liquid.

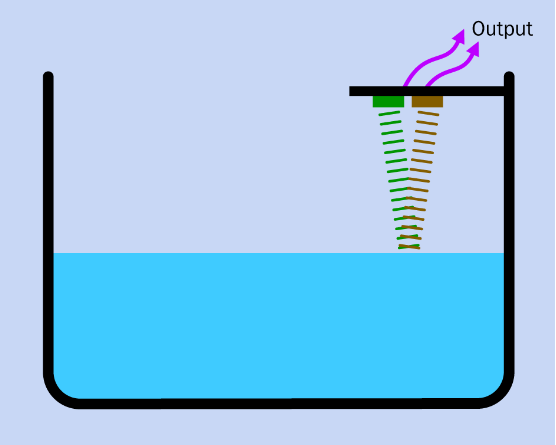

Figure 15-8 *An ultrasonic proximity sensor can measure the level of liquid in a reservoir.*

Reservoir Weight

The weight of a reservoir can be measured to assess the volume of liquid in it. This can be done by mounting the reservoir on load sensors. However, pipes leading to and from the reservoir must be designed so that they do not add or subtract any significant weight. Figure 15-9 suggests an arrangement, although the outflow will still change the weight to some extent depending on the amount of suction that is applied. For more information on load sensors, see Chapter 12.

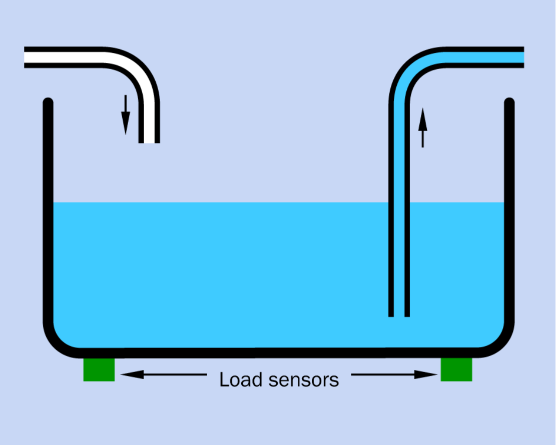

Figure 15-9 *Using load sensors to assess the weight of liquid in a reservoir requires that the weight of plumbing should not be imposed on the structure of the reservoir.*

Pressure Sensing

A differential pressure sensor can be added to a pipe near the bottom of a reservoir. The sensor measures the difference between the liquid pressure and ambient air pressure. See Figure 15-10.

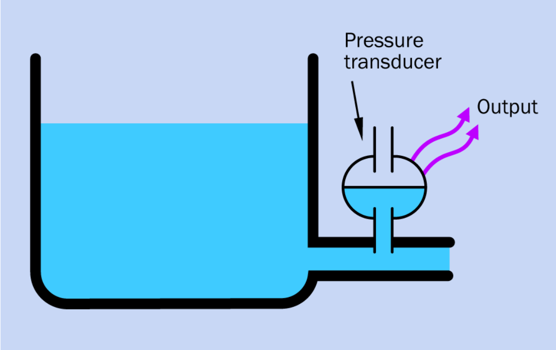

Figure 15-10 *A pressure sensor can assess the volume of liquid in a reservoir.*

This arrangement assumes that the reservoir is vented so that air pressure above the liquid level is equal to air pressure at the sensor. If the reservoir is not vented, a pipe must connect the reference port on the sensor with the space above the liquid.

The reservoir must have straight, vertical sides for the pressure to be directly proportional to the liquid volume.

Liquid volume can also be assessed by measuring the pressure inside a container, near the bottom. A submersible pressure sensor can be used, typically consisting of a watertight capsule fitted with a diaphragm that connects with an internal strain gauge. The sensor is lowered on a cable that also contains an air line. Because pressure in a liquid is affected by atmospheric pressure above the surface of the liquid, the sensor requires an air line so that its measurements are relative to the outside air.

Submersible pressure sensors are useful where access is limited—for example, when measuring fluctuations in an open-air municipal water reservoir.

What Can Go Wrong

Turbulence

Surface turbulence consisting of ripples, waves, or sloshing of liquid will tend to occur when a reservoir is refilled rapidly or is subjected to lateral movements as a result of being mounted in a moving vehicle. To minimize output fluctuations, some *damping* is desirable.

Baffles consisting of perforated plates inside the reservoir are a common strategy, as shown in Figure 15-11. In the upper section of the figure, lateral acceleration causes submersion of a float sensor in the reservoir. In the lower section, perforated baffles minimize the problem.

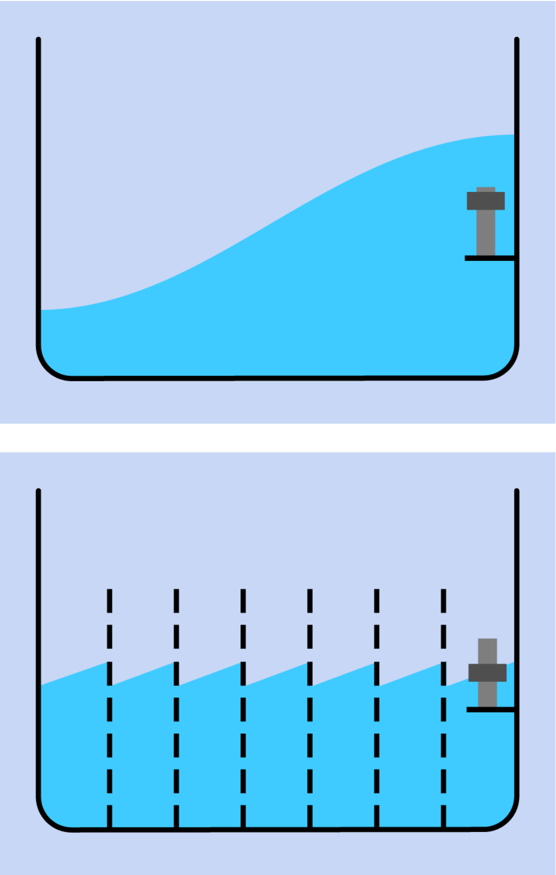

Figure 15-11 *Insertion of perforated baffles in a reservoir minimizes the sloshing that otherwise tends to occur when the reservoir is subject to lateral motion.*

Sensors that measure the weight or pressure of a liquid are less susceptible to turbulence. In a displacement sensor, the weight of the displacer provides a damping effect.

Tilting

All level sensors will tend to give inaccurate readings when a reservoir is tilted. A float sensor will be affected less if it is mounted centrally in a reservoir, because the reservoir will tilt around the sensor, as shown in Figure 15-12.

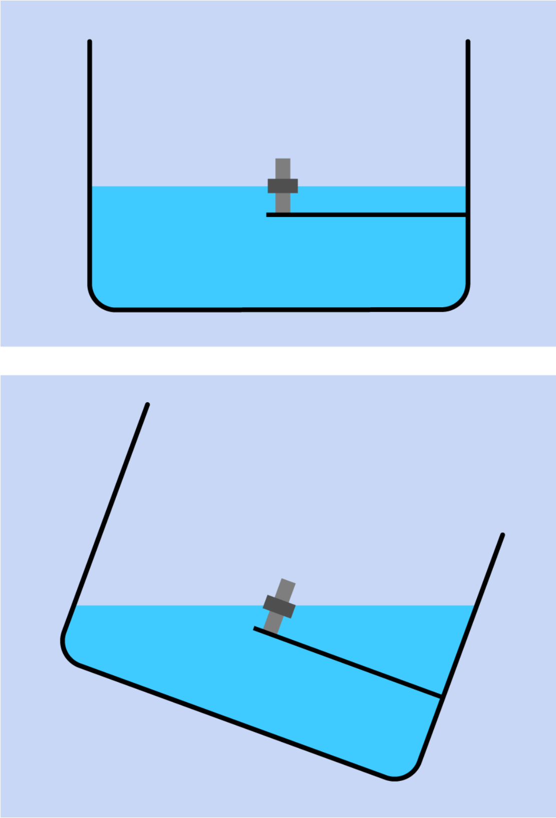

Figure 15-12 *If a float sensor is mounted centrally in a reservoir, it will be significantly less affected if the reservoir tilts.*

liquid flow rate sensor

16

Flow rate sensors that contain no electronic components are not included in this entry.

Some methods of liquid flow sensing can also be applied to gases, but sensors are usually designed for one application or the other. Therefore, gas flow sensors have their own entry. See Chapter 19.

Many liquid flow rate sensors are large devices designed for industrial applications. This entry focuses on lower-cost solid-state sensors.

OTHER RELATED COMPONENTS

- **liquid level** sensor (see Chapter 15)
- **gas/liquid pressure** sensor (see Chapter 17)
- **gas flow rate** sensor (see Chapter 19)

What It Does

A liquid flow rate sensor measures the rate at which liquid flows past or through the device. A water meter is an example of a flow rate sensor.

A sensor may have a binary output, meaning that it signals when flow stops or starts, or if its rate rises above or falls below a level that can be preset or reset. However, most flow meters have an analog output that varies with the volume per unit of time.

Measuring the flow rate of a liquid can be challenging if the viscosity is very high, the liquid is chemically reactive, or the rate is very low. Such factors may require specialized equipment that is outside the scope of this Encyclopedia.

This entry compares the most popular sensing strategies.

Schematic Symbols

Many specialized symbols are used in flow diagrams to represent pumps, valves, and sensors. Typically they involve a single letter or an X in a circle. These symbols are not generally found in electronic schematics, and therefore they are not included here.

Paddlewheel Liquid Flow Rate Sensors

The simplest and most common liquid flow rate sensor uses a *paddlewheel*, also referred to as a *rotor*, that is mounted with its axis of rotation at 90 degrees to the direction of liquid flow. An example is the Koolance INS-FM16 shown in Figure 16-1. This sensor is intended for use in an aftermarket cooling system for the CPU in an overclocked desktop computer, but can be used in any system where the rate of flow ranges from 0.5 to 15 liters per minute. The paddlewheel has a pair of magnets mounted in it, activating a *reed switch* that is mounted in a sealed enclosure beneath the wheel. (For more information regarding reed switches, see "Reed Switch" in the entry describing **object presence** sensors.)

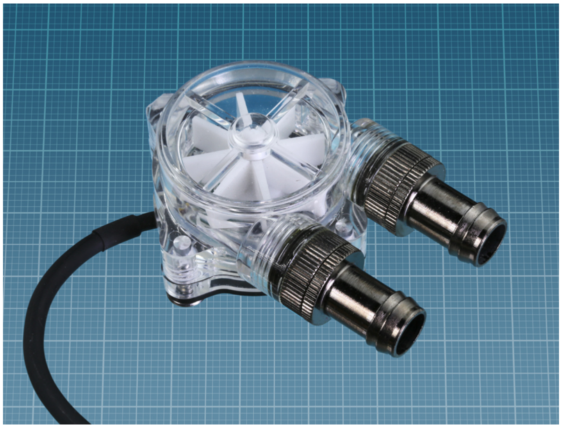

Figure 16-1 *A low-cost, simple paddlewheel sensor designed for rates of 0.5 to 15 liters per minute. The background grid is in millimeters.*

While the reed switch in the Koolance flow sensor inevitably suffers from contact bounce, it has the advantage of simplicity and can be used in conjunction with appropriate hardware or microcontroller code to debounce the pulse stream.

As in any device with a rotating part, friction and wear will afflict a paddlewheel sensor, especially because the bearings are often in the chamber through which the liquid passes. This eliminates the possibility for roller bearings. Typically a plain bearing is used, consisting of a pin that engages in a hole in the casing. Friction wears the bearing surface, creating a larger gap, which allows the rotor to vibrate or bounce instead of spinning smoothly. Flow resistance increases and accuracy is degraded.

In modern designs, the mass of the rotor is minimized to reduce the friction. Also, if the shaft is horizontal (but still at 90 degrees to the direction of the flow), buoyancy of the rotor in the liquid can reduce friction still further, as suggested in Figure 16-2. Ideally, the density of the rotor and the density of the liquid will be the same.

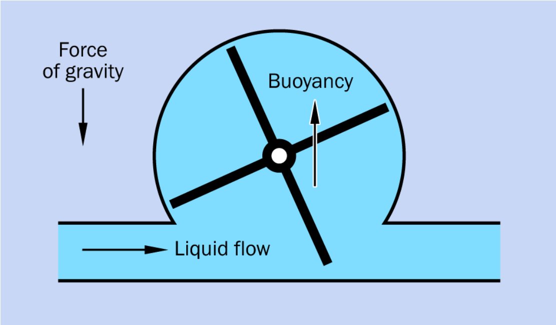

Figure 16-2 *In this configuration, friction on the rotor bearings is mitigated by taking advantage of the buoyancy of a low-density rotor in the liquid that passes through.*

The U-shaped flow path in the Koolance sensor in Figure 16-1 maximizes the responsiveness of the rotor, but an inline path is more common. An example is shown in Figure 16-3.

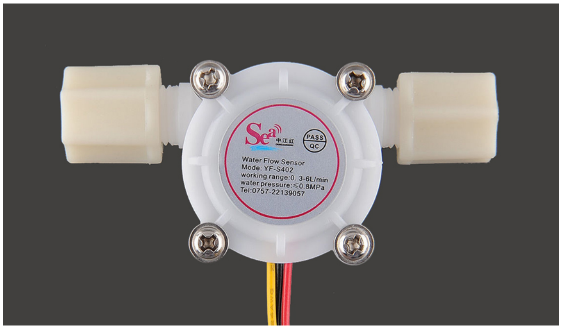

Figure 16-3 *An inline flow sensor rated for 3 to 6 liters per minute.*

Turbine Flow Rate Sensors

In a turbine-type sensor, two or more spiral blades are attached to a hub that rotates around an axis in line with the liquid flow, as shown in Figure 16-4. A magnet in each spiral blade triggers a reed switch or Hall-effect sensor mounted in a bracket that suspends the turbine from the interior walls of the tube.

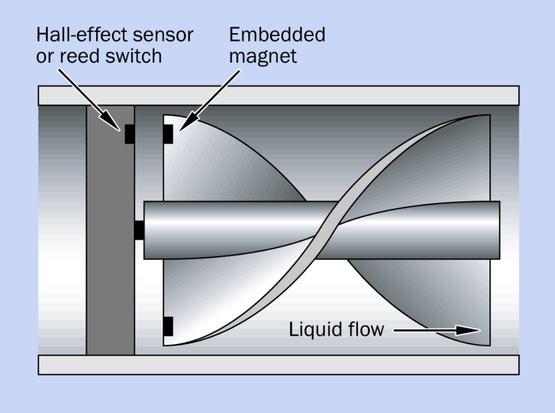

Figure 16-4 *Simplified view of a turbine flow rate sensor mounted inside a tube.*

The support bracket often consists of four struts, which impose resistance to liquid flow. The bearings suffer from the same kinds of problems as the bearings in a paddlewheel sensor, and must withstand additional load resulting from the inline force exerted by flow. Overall, while the turbine type of sensor is popular in laboratory equipment, it has disadvantages that are not shared by the bulkier paddlewheel type.

Limitations of Paddlewheels and Turbines

Both the paddlewheel and turbine types of sensors require a minimum flow to overcome the friction in their bearings. Below this minimum, liquid will find its way around the rotor without turning it. Even when the flow exceeds the minimum, response of the rotor is likely to be nonlinear as a result of turbulence and other factors.

Above a limit stated by the manufacturer, turbulence increases to the point where output from the sensor is no longer meaningful. Wear on the bearing will also increase with flow rate.

A significant problem for these types of sensors is that they do not respond well to sudden variations in flow. The paddlewheel, in particular, has inertia as a function of the diameter of the rotor, and will take some time to spin up in response to an increase in flow. Conversely, when the flow diminishes, the paddlewheel will tend to overrun.

The viscosity of the liquid passing through a paddlewheel or turbine sensor will have a very significant effect on its performance.

Thermal Mass Liquid Flow Rate Sensor

The thermal-mass system is commonly used when volumes are extremely low. The system is illustrated in Figure 16-5. A tube containing liquid is fabricated from a heat-conductive metal such as aluminum. It is enclosed in a larger tube, and the gap between them is filled with thermal insulation. A temperature sensor such as a thermistor measures the temperature of liquid entering the system. A second sensor, combined with a small resistive heater in the form of a coil around the tube, is placed downstream. Liquid passing through the tube will tend to remove heat more effectively at higher flow rates, and the difference in temperature between the two sensors is a logarithmic function of the flow rate.

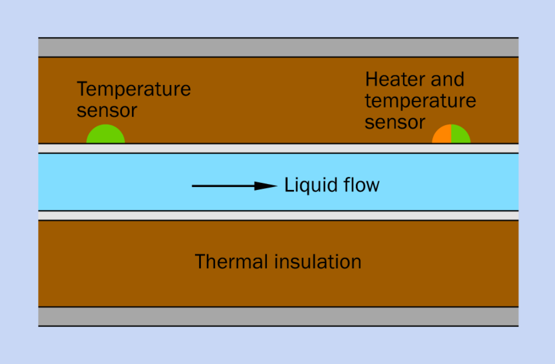

Figure 16-5 *In this type of low-flow sensor, the temperature differential between the two sensors is a logarithmic function of the flow rate.*

Variants of this system use slightly different tube configurations and sensor placement, but the principle is the same. Its advantages include the lack of any moving parts, and the avoidance of any probes intruding into the liquid, which is desirable in biochemical and medical applications.

The same principle is applied in many **gas flow rate** sensors. See "Mass Flow Rate Sensing".

Sliding Sleeve Liquid Flow Switch

This sensor is used in some domestic systems, where flow-activated water heating is required. A vertical section of brass (nonmagnetic) water pipe contains a sliding inner sleeve that incorporates a magnet. An external reed switch is activated when the sleeve is moved by water flowing through it. When the flow stops, the sleeve is returned to its rest position by the force of gravity.

Sliding Plunger Liquid Flow Switch

Figure 16-6 shows an exploded view of a similar device, using a plastic plunger that slides inside a nylon plumbing fixture designed for 3/4-inch pipe. The plunger contains a magnet and is restrained by a compression spring and a circular perforated plate. When water flow is sufficient to overcome the resistance of the spring, the plunger slides far enough for the magnet to activate a reed switch sealed into the external housing.

Ultrasonic Liquid Flow Rate Sensor

This type of sensor passes ultrasound through a liquid in a pipe. The speed of sound through the liquid is affected by the flow rate, and external electronics translate this lag time into a value for volume-per-minute. The system adjusts for variations in temperature that also affect the speed of sound.

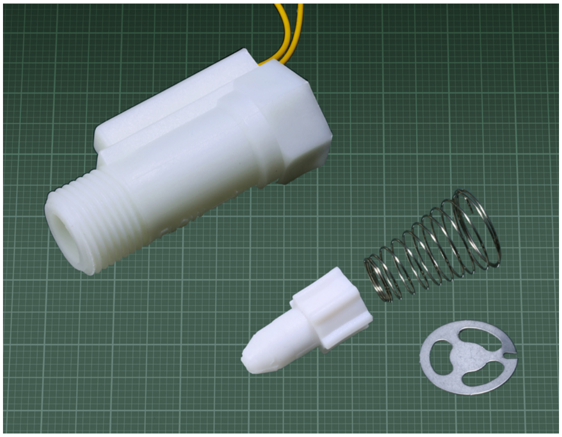

Figure 16-6 *Parts of a flow switch. The small plunger is inserted into the pipe and retained with the perforated plate and compression spring.*

Various configurations are available, some allowing ultrasound sources and detectors to be clamped to the outside of a pipe, as shown in Figure 16-7. To eliminate other variables, one ultrasound pulse is transmitted in the same direction as the flow, followed by another pulse contrary to the flow, and the difference between the two transmission times is used as an indicator of the flow rate.

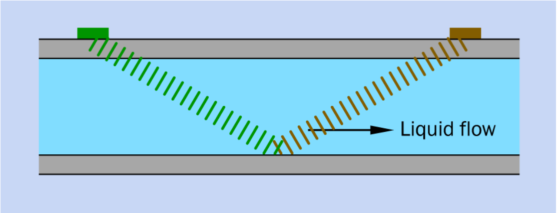

Figure 16-7 *Some ultrasound flow sensors are designed to be clamped externally to a pipe.*

Magnetic Liquid Flow Sensor

A magnetic field is induced in a metal pipe by a coil generating its field perpendicular to flow. The inside of the pipe is lined with nonconductive material in which two electrodes are mounted. Because water containing ions is conductive, the flow of water through the magnetic field induces a small potential difference between the electrodes. This voltage can be used as an indication of the flow rate.

To eliminate external factors that would also affect the potential difference, the polarity of current through the coil around the pipe alternates rapidly. The induced field remains the same regardless of the direction of the current.

A magnetic flow sensor should not be confused with a magnetic flow *switch.* Various types of switches are made, including large, heavy-duty devices where flow moves a magnet that triggers a shutoff valve. This type of industrial device is outside the scope of the Encyclopedia.

Differential Pressure Liquid Flow Meter

In this system, a pipe contains a perforated plate or some similar constrictor that partially obstructs the flow of liquid. Pressure is measured by a pair of pressure transducers placed before and after the constrictor. The pressure difference is an indicator of flow, because it increases as the flow rate increases.

This system was developed originally for large industrial applications but has been miniaturized and etched into silicon to measure very small flow rates. The Omron D6F-PH is an example, measuring less than 3cm square. It contains digital correction to enable a close-to-linear output. Because of its small size, it can be used only for slow flow rates, or as a bypass sensor. The general concept of a bypass sensor is illustrated in Figure 19-7, in the entry discussing gas flow sensors.

What Can Go Wrong

Vulnerability to Dirt and Corrosive Materials

MEMS liquid flow rate sensors containing very delicate, very small sensing elements are very vulnerable to contamination with dirt. Liquids should be filtered to minimize this risk. A manufacturer's datasheet should provide information about the use of corrosive or chemically active liquids.

gas/liquid pressure sensor

17

Pressure measurement devices that do not contain any electronics, such as a nondigital tire-pressure gauge or a mercury manometer, are outside the scope of this Encyclopedia.

Many pressure sensing methods can be used with both gases and liquids. To avoid duplication, gas pressure sensors and liquid pressure sensors do not have separate entries. Both types are described here.

This entry deals almost exclusively with MEMS components. It does not include pressure measurement devices sold as industrial products.

Some manufacturers and vendors use the term *pressure sensor* to describe a component that measures mechanical load or force. In this Encyclopedia, the term only describes components that measure liquid or gas pressure. Mechanical load cells and force sensors will be found in the section on **force** sensors. See Chapter 12.

OTHER RELATED COMPONENTS

- **liquid level** sensor (see Chapter 15)
- **liquid flow rate** sensor (see Chapter 16)
- **gas flow rate** sensor (see Chapter 19)

What It Does

A pressure sensor measures the force exerted by a gas or liquid, often in a container or pipe.

Static pressure is measured under conditions that change slowly or not at all. *Dynamic pressure* is subject to fluctuations. Pressure sensors tend to be designed for one condition or the other.

Schematic Symbols

Many specialized symbols are used in flow diagrams to represent pumps, valves, and sensors, including pressure sensors. Typically they involve a single letter or an X in a circle. These symbols are not generally found in electronic schematics, and therefore they are not included here.

Applications

Barometric sensors are found in barometers and weather stations. Altimeters are really a specialized form of barometric sensor, used in airborne vehicles. Gas pressure sensors have many industrial applications, and are used to monitor tire inflation in vehicles and the output from air compressors. They may also measure liquid pressure indirectly, as in a blood-pressure cuff.

Liquid pressure sensors are widely used to measure oil pressure in automobile engines and hydraulic braking systems. They have medical applications, and monitor water pressure in municipal systems and pumped supplies.

Design Considerations

As a result of random molecular movement, gases will tend to disperse to fill a container. After a gas reaches equilibrium, the pressure will be almost equal in all directions, affected only slightly by gravity. Where a gas is in a sealed, rigid container, pressure will vary linearly with temperature.

A liquid will tend to accumulate at the bottom of any container under the force of gravity. Liquid pressure in a container will be highest at the bottom, because of the weight of liquid above it. However, because almost all liquids are not easily compressible, they transmit force from any point in a container to any other point, including the sides of a container.

Units

Pressure is measured as force per unit area, which can be expressed in a confusing variety of units.

In the United States, gas and liquid pressure are still often expressed in pounds per square inch, abbreviated as PSI, or more often as psi, or sometimes as lb/in^2.

In standard international (SI) units, 1 bar of pressure is approximately equal to atmospheric pressure at sea level. Millibars are popular among meteorologists, 1 millibar being 1/1000 of a bar, equivalent to 100 pascals, where 1 pascal = 1 newton per square meter.

A bar is equivalent to 14.504 psi.

Blood pressure is measured in millimeters of mercury, because mercury manometers were used for this purpose originally. Atmospheric pressure may also be measured in millimeters of mercury, because the earliest barometers used a tube containing mercury. In the United States, some sources still refer to inches of mercury.

How It Works

Pressure sensing usually entails three stages.

1. A *sensing element* translates pressure into the mechanical displacement of a flexible part.
2. A *transducer* converts mechanical displacement into an electrical effect, either modifying resistance or creating a small voltage or current.
3. Electronics are used for *signal conditioning*. This may entail modifying a nonlinear signal, or may convert an analog output to a digital output.

As pressure sensors are increasingly taking the form of MEMS devices, all three stages may be combined in one silicon chip.

Basic Sensing Elements

Figure 17-1 shows four types of sensing elements that are used, or have been used, to convert pressure into mechanical motion. In each case, a green arrow shows where gas or liquid is introduced under pressure. 1: A Bourdon tube flexes under pressure, increasing its radius. The tube is hollow, open at one end and sealed at the other. 2: A coiled Bourdon tube uncoils partially under pressure, causing the top end to rotate. 3: A simple flat diaphragm. 4: A ribbed diaphragm.

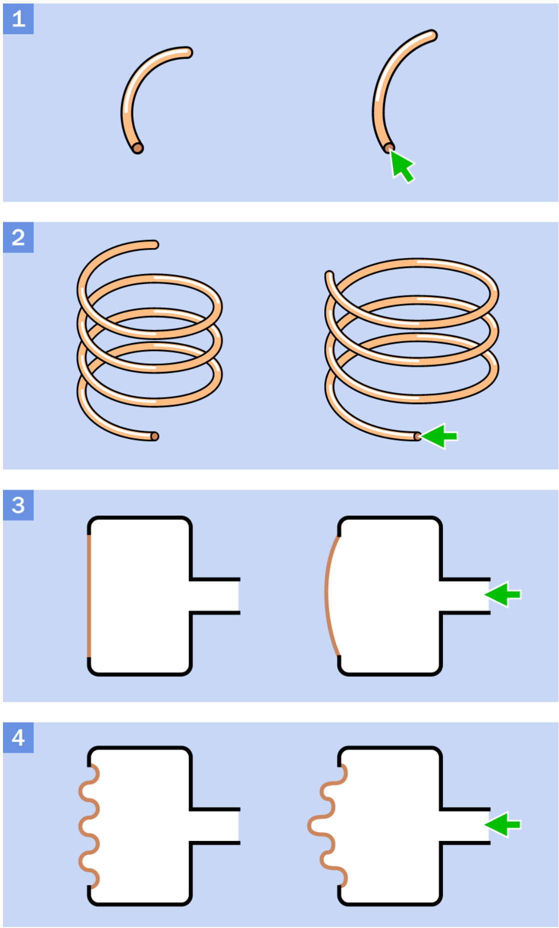

Figure 17-1 *Sensing elements. See text for details.*

The sensing elements numbered 1 and 2 are less likely to be used in modern systems, although a coiled Bourdon tube may be used to turn a potentiometer in low-cost oil-pressure sensing designs. Number 3 is well suited to MEMS devices, as it can be etched into silicon using the principle illustrated in Figure 17-2.

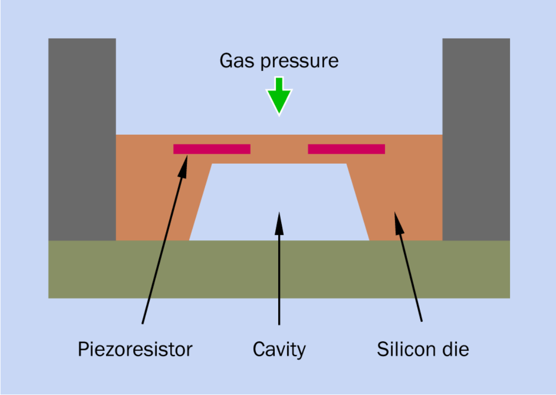

Figure 17-2 *A section of a flat-diaphragm pressure sensor, viewed from the side. An aperture in the top face of the chip allows air to enter. The sensor is etched into silicon, and the deflection of the wafer is measured using embedded piezoresistors.*

Relative Measurement

Pressure is a relative measurement. It is expressed relative to a *reference pressure* of some kind. Three types of measurement are commonly used:

1. *Absolute pressure*, relative to the zero value of a vacuum.
2. *Gauge pressure*, relative to ambient pressure (that is, pressure in the environment around the sensor). Air pressure is the reference source for gauge pressure, and a *vent* is incorporated into the sensing system.
3. *Differential pressure*. In this case, the pressure being measured is relative to some other pressure—for example, the pressure differential between two sealed tanks.

Figure 17-3 illustrates these three measurement types.

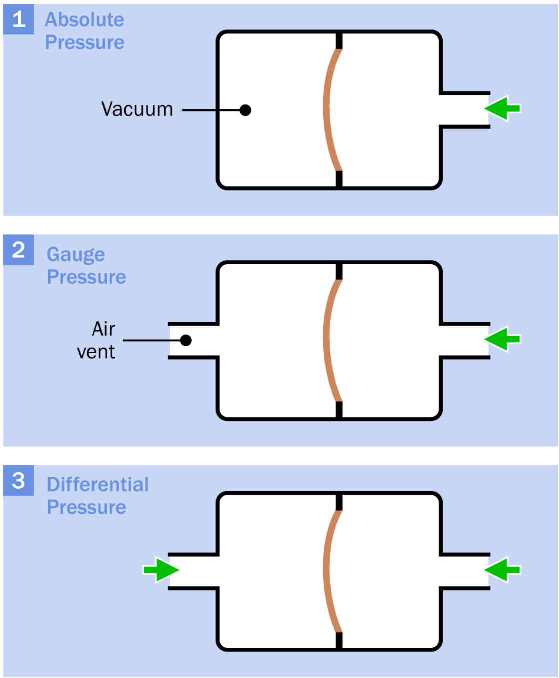

Figure 17-3 *Three ways in which pressure is measured.*

Variants

Ambient Air Pressure

A *barometric* sensor measures the pressure of air around it. This is an absolute value, relative to a vacuum.

The earliest barometers consisted of a tube sealed at one end, containing mercury. No air was allowed to enter the tube. It was inverted so that its open end was immersed in a small reservoir that was open to the air, the pressure of which supported the column of mercury in the tube. Thus, the height of the column was ratiometrically equivalent to atmospheric pressure. Because low air pressure is often an indicator of inclement weather, a barometer was a very simple tool for weather forecasting.

A modern barometric sensor consists of a chip with a vent hole in its upper surface, allowing ambient air pressure to reach a sensor inside the chip. A popular example has been the Bosch BMP085, shown soldered onto a breakout board in Figure 17-4. The BMP180 has a very similar specification, the primary difference being that it is designed for a SPI bus instead of I2C. For additional details about protocols such as SPI and I2C, see Appendix A.

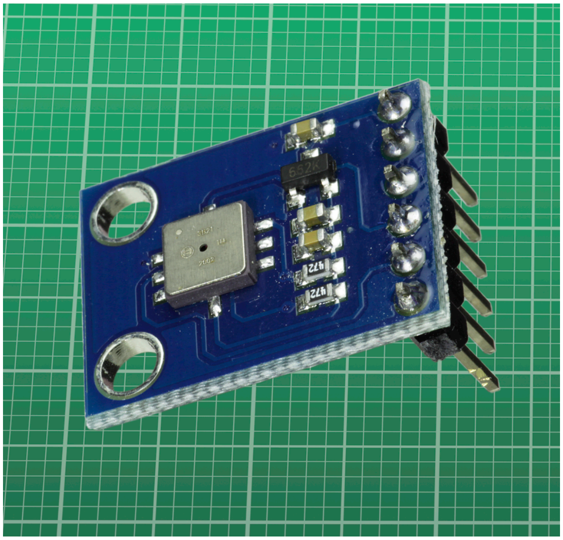

Figure 17-4 *A Bosch barometric sensor on a breakout board. The background grid is in millimeters.*

This sensor uses a supply voltage ranging from approximately 2VDC to 3.5VDC, but a breakout board includes a voltage regulator that tolerates a 5VDC supply. The output is digitized for access by a microcontroller, but the format is quite complex and consists of raw data that must be converted to air pressure by applying a formula. The manufacturer offers free code in the C language for this purpose. A thermometer that is built into the chip enables temperature compensation.

Subsequent products from Bosch include the BME280, which adds a humidity sensor. Breakout boards using this and other barometric chips are available from sources such as Sparkfun and Adafruit, where Arduino code libraries to interpret the data are available for download.

Altitude

A barometric sensor can be used to determine altitude. At sea level, air pressure is approximately 101kPa (kilopascals), or 760 millimeters of mercury. At 5,000 meters altitude, air pressure drops to 56kPa. The transition is nonlinear, changing most rapidly at lower altitudes.

Air pressure will be affected by temperature and weather conditions. Weather is unlikely to affect the value by more than plus-or-minus 1%, and temperature has a smaller effect; but the barometric sensor can be reset to a zero point based on current temperature and weather data.

Gas Pressure

Thousands of board-mountable gas pressure sensors are available from retail component suppliers. The need to make connections via tubing imposes a minimum size limit on these parts. Many have a through-hole format, but even the surface-mount variants can be relatively large (e.g., 10mm × 10mm). Most tend to have barbed tubing ports, the "barbs" being ridges to retain push-on flexible tubing. Output may be analog or digital, the digital protocol being designed for I2C, SPI, or plain TTL serial buses.

These components are designed for pressures ranging up to 500kPa (kilopascals). Some manufacturers use psi in their specifications, while others use bars and millibars, and a few state gas pressures equivalent to inches of water.

Dual-ported gas sensors for differential pressure measurement can be used for gauge measurement (i.e., relative to ambient air) if one port is left open. Absolute pressure sensors have only one port, as they measure pressure relative to a vacuum maintained inside the chip, behind the diaphragm.

- Some gas pressure sensors can do dual duty as liquid pressure sensors, but others cannot, and datasheets must be consulted carefully, as online vendors may not include this information prominently.

The sensor in Figure 17-5 by All Sensors Corporation is designed for flexible tubing with 1/16" internal diameter (1.6mm). Its pin spacing is 0.1" (2.54mm), making it breadboardable. This sensor is intended for gases only, but has a "10-inch" water-equivalent rating, meaning that it can tolerate a maximum pressure equivalent to that of a 10-inch (25.4cm) column of water.

When supplied with up to 16VDC, an internal Wheatstone bridge circuit provides an analog output that varies ratiometrically by a few millivolts over the full range of measurable pressures (the exact specification depending on the power supply). The output may be amplified with an external op-amp. Although this is a differential sensor, it can provide gauge pressure if one of the ports is left open.

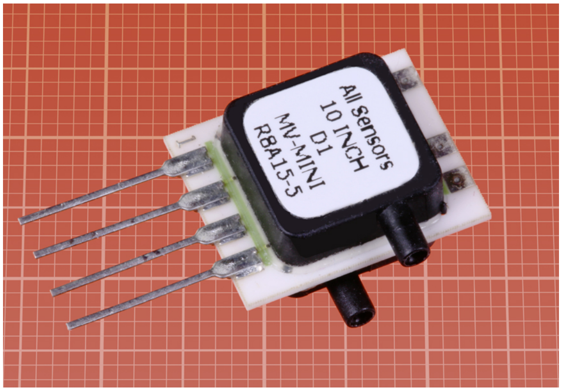

Figure 17-5 *A gas pressure sensor for use with 1/16" (1.6mm) internal diameter flexible tubing. The background grid is in millimeters.*

The larger sensor in Figure 17-6 is in the ADCA range from All Sensors Corporation, designed for flexible tubing with 1/8" internal diameter (3.2mm). This is intended for gases only, and has a "5-inch" water-equivalent rating. It requires a 5VDC power supply and has an internal op-amp that provides an output that varies ratiometrically by 0.2VDC (centered on 4VDC) over the range of measurable differential pressures. Like its smaller cousin, it can provide gauge pressure if one of the ports is left open.

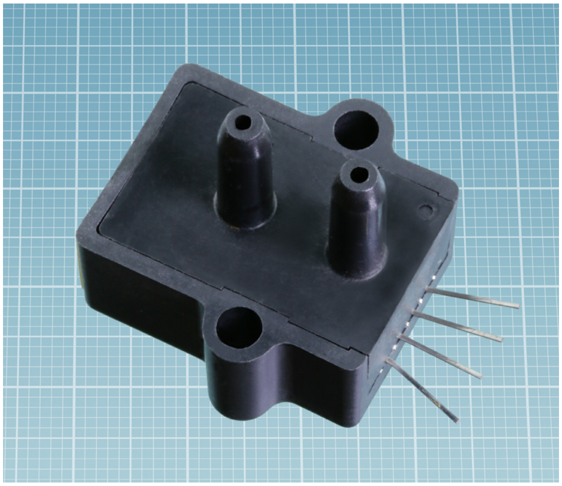

Figure 17-6 *A gas pressure sensor for use with 1/8" (3.2mm) internal diameter flexible tubing. The background grid is in millimeters.*

What Can Go Wrong

Vulnerability to Dirt, Moisture, and Corrosive Materials

MEMS pressure sensors containing very delicate, very small sensing elements must inevitably come into direct contact with gases and, in some cases, liquids. Datasheets will provide warnings regarding humidity and corrosive fluids, but the risk of contamination with dirt remains. Liquids should be filtered to minimize this risk.

Barometric sensors have a hole in the package, exposing the sensor element to the ambient air. This vent must be protected from direct contact with the environment.

Light Sensitivity

If light is allowed into the vent hole in a barometric sensor, it can create photocurrents in the chip. This will affect accuracy.

gas concentration sensor

18

Humidity sensors and *vapor sensors* are included in this entry, as they measure concentrations of a liquid while it is in its gas phase.

Sophisticated *industrial sensors* are available for accurate gas sensing, but this entry deals almost entirely with lower-cost solid-state sensors that are often classified as *board-mount* components.

OTHER RELATED COMPONENTS

- **gas/liquid pressure** sensor (see Chapter 17)

What It Does

Small semiconductor-based gas sensors provide a low-cost method for detecting specific gases in ambient air. The sensors vary their electrical resistance or capacitance in response to the concentration of the gas. They may be used in conjunction with an alarm system that will sound if gases such as *propane* or *carbon monoxide* exceed a preset level, or if the concentration of *oxygen* drops below a preset level.

Because vapor consists of a liquid in its gas phase, gas sensors can respond to vapor, as in the case of *alcohol sensors*.

A *humidity sensor* measures the amount of water vapor in the air, which can be important in refrigeration, HVAC (heating, venting, and air conditioning), medical equipment, meteorology, and storage rooms where art objects, antiques, or paper archives must be preserved in an environment that is neither too dry nor too moist, and is held at a constant temperature. Humidity control can be important also in climates where growth of mold is a concern. Humidity sensors are also used in automobile climate control and windshield defogging, and in the storage of food, fabrics, wood products, and medications.

High humidity coupled with high temperature contributes to the decomposition of many substances, while low humidity can cause desiccation. High humidity can also create damage if it causes materials to expand as a result of taking up moisture.

Many methods have been devised to detect individual gases, but semiconductor sensors are now dominant in applications where accuracy and gas-specificity are not crucial.

Schematic Symbol

No specific schematic symbol exists to represent a semiconductor gas sensor.

Semiconductor Gas Sensors

During the development of transistors in the 1950s, engineers noticed that semiconductor p-n junctions were sensitive to the presence of some gases in the atmosphere. This was regarded as a problem, which was solved by encapsulating transistors to prevent their exposure.

During the 1980s, Japanese law required installation of sensors in every home to detect hazardous concentrations of propane gas. This encouraged the development of cheap, long-lasting components that took advantage of semiconductor sensitivity.

Tin oxide is widely used in a variety of solid-state gas sensors. A sintered layer of the compound is deposited on a ceramic substrate in combination with other compounds such as antimony oxide. The granular layer functions as an n-type semiconductor in which electron transfer increases when certain gases are adsorbed among the grains. When the gas concentration diminishes, oxygen atoms displace the gas molecules, and the sensor returns to its original state. It is unimpaired by being activated, and has a life expectancy of at least 5 years during active (powered) use.

Each sensor includes a tiny resistive heater that is necessary for the chemical reaction to occur. Voltage must be applied to two pins that are connected with the heater. Two other pins connect internally with the sensing element. The resistance between these pins will vary with presence of the target gas; thus, this type of component has a resistive output.

It is a feature of semiconductor gas sensors that they tend to suffer from *cross-sensitivity*. That is, one sensor may respond to more than one gas. Manufacturers control this problem to some extent by adding filtering material around the semiconductor element, or by adjusting the proportions of dopants used in the semiconductor. Datasheets should be consulted carefully to see if a sensor may give false positives as a result of other gases that are likely to be present in the area where it will be used.

Figure 18-1 shows an MQ-5 propane sensor from Hanwei Electronics. The component also responds to methane, hydrogen, alcohol, and carbon monoxide, but with much less sensitivity. The manufacturer recommends calibrating the sensor by using a resistor ranging from 10K to 47K in series with the output resistance.

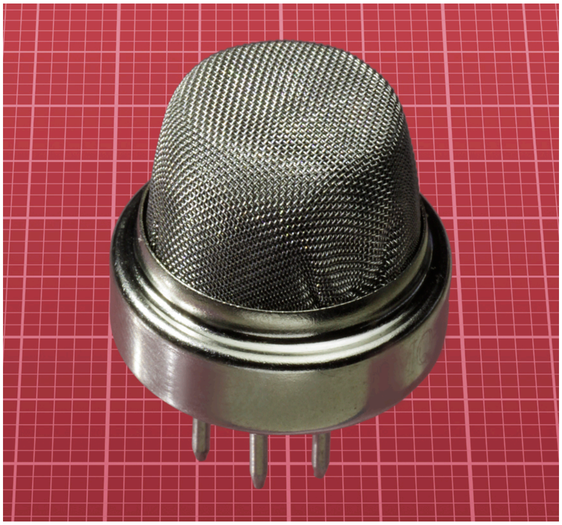

Figure 18-1 *A propane gas sensor. The background grid is in millimeters.*

Figure 18-2 shows an MQ-3 alcohol sensor, also manufactured by Hanwei. It has some sensitivity to benzene, but this is unlikely to be a problem, as benzene is seldom present in significant concentrations in ambient air. However, the response of the sensor to alcohol varies with temperature and humidity. Consequently this component can only be used as a “breathalyzer” if the user can be satisfied with an approximate response.

Semiconductor gas sensors are also available for detecting methane, carbon monoxide, hydrogen, ozone, and other gases.

These components are not low-current devices. Typically the internal heater in the Hanwei range has a resistance of slightly more than 30 ohms, and will draw 150mA to 160mA at 5V (i.e., slightly less than 1W). Because the heater is a simple resistive device, it can be used with AC or DC. The output resistance of the sensor can also be assessed with an AC or DC signal.

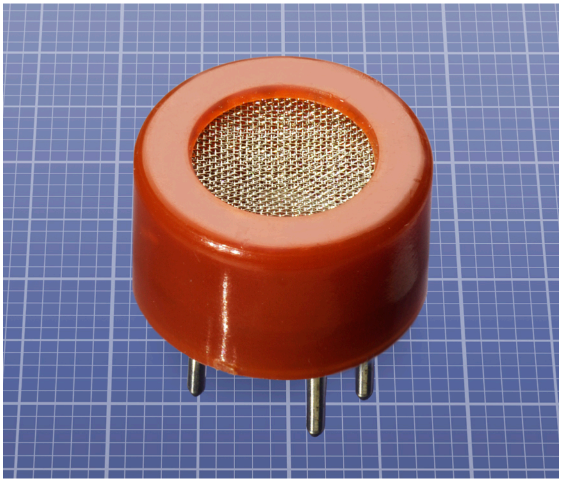

Figure 18-2 *An alcohol sensor. The background grid is in millimeters.*

A breakout board from Parallax simplifies the use of Hanwei gas sensors. The board is shown in Figure 18-3. It is compatible with carbon monoxide, propane, methane, and alcohol sensors, each of which can be plugged into a socket on the board. Two trimmers establish the sensitivity and the trip point for the sensing element, and the TTL output is then logic-high when a gas is detected, and logic-low otherwise.

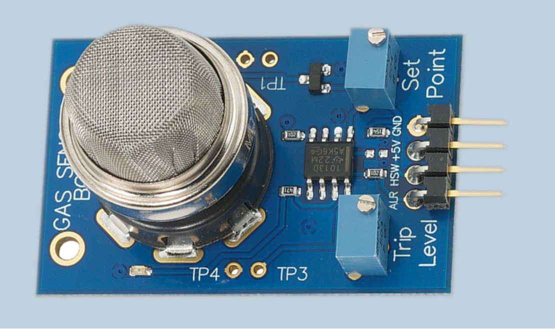

Figure 18-3 *A Parallax breakout board to simplify the use of Hanwei gas sensors.*

Oxygen Sensors

Oxygen sensors are often built using a membrane made of zirconium dioxide. This material has the property that it can transport oxygen ions when heated. One setup is to have a zirconium membrane separating the gas to be measured from ambient air. This is a type of fuel cell, called a concentration cell or Nernst cell. If the oxygen concentration differs between the two sides of the membrane, oxygen ions will flow through it. Only oxygen ions can move—not neutral oxygen atoms or molecules. The ions are negatively charged, so the transport will lead to a potential difference over the cell, which can be measured with platinum electrodes.

To comply with emissions regulations, automobiles sense the oxygen level of exhaust gases. This data controls the fuel-air ratio in the fuel injection system. Too much air results in the formation of nitrogen oxides, while too little air results in excessive carbon monoxide.

Humidity Sensors

Moisture content of the air is expressed in three different ways:

Absolute humidity

This is the weight of water vapor in a fixed volume of air. It is measured in grams per cubic meter in the metric system. An absolute humidity sensor is properly called a *hygrometer*.

Dew point

If a sample of air is cooled without a change of pressure, the dew point is the temperature at which moisture will start to condense. The dew point is a way of describing how humid the ambient air is currently, as water will condense more readily in humid conditions.

Relative humidity

This is often referred to by its acronym, RH. If temperature, pressure, and volume of a sample of air remain constant, relative humidity is the ratio between the current value of absolute humidity and the hypothetical level where the addition of water vapor would result in condensation. The ratio is expressed as a percentage. Thus, if moisture is already condensing in an air sample, relative humidity is 100%. If an air sample contains half the weight of moisture required for condensation to begin, relative humidity is 50%. If there is no moisture at all in the air, relative humidity is 0%.

Colloquial usage of the term "humidity" usually means relative humidity, and sensor output is usually convertible to this value. However, some absolute humidity sensors do exist.

Dew-Point Sensor

Historically, meteorologists used a *chilled mirror hygrometer*, in which a metal mirror was exposed to the atmosphere and cooled until the surface was seen to become misty with condensation. The temperature where this occurred was the dew point.

This system is still used in conjunction with an LED and a **phototransistor**. The LED is positioned so that its light reflects from a mirror, directly onto the phototransistor. The mirror is cooled until mist starts to form, which diffuses the reflected light and causes a well-defined change in output from the phototransistor.

Although the formula linking dew point with relative humidity is complex, a simplified approximation is available that is reasonably accurate so long as the relative humidity is 50% or greater. If RH is the relative humidity, t is the current temperature, and t_D is the dew-point temperature at which mist forms:

$$RH = 100 - (5 * (t - t_D)) \text{ approx.}$$

Although a chilled-mirror dew-point sensor has a reputation for being accurate, it is heavy, expensive, and impractical for most applications outside of meteorology.

Absolute Humidity Sensors

An absolute humidity sensor may use two NTC (negative temperature coefficient) **thermistors** in a Wheatstone bridge circuit. One thermistor is sealed in a compartment containing dry nitrogen, with zero humidity. The other is exposed to the atmosphere. Current passing through the thermistors raises their temperature to at least 200 degrees Celsius. Because heat radiates less efficiently when there is moisture in the air, the exposed thermistor will run hotter, and its resistance will be higher, at higher levels of humidity. This type of sensor is used in clothes dryers and wood kilns, among other applications.

See Chapters 23 and 24 for more information about thermistors.

Relative Humidity Sensors

Two main types of sensing elements are used to measure relative humidity: resistive and capacitive.

In a *resistive* sensing element, a thin layer of polymer, salt, or other hygroscopic substance is deposited on a substrate consisting of ceramic or other unreactive material. When the substance absorbs water, its electrical conductivity increases. Voltage is applied to the sensing element, and AC is used to avoid polarizing it. The current flow is processed externally, with conversion to DC followed by linearization, meaning that the current is processed to establish an almost linear relationship with gas concentration, with temperature compensation factored in. Alternatively, these functions can be performed by hardware built into the sensor, and a digital value for relative humidity can be accessed by an external microcontroller.

In a *capacitive sensor*, once again a thin film of polymer or metal oxide is deposited on a ceramic or glass substrate, but the film functions as a *dielectric* between two metal electrodes that serve as the plates of a capacitor. The dielectric value changes as the film absorbs moisture, and this causes the capacitance to vary, typically by 0.2pF to 0.5pF for each 1% change in relative humidity. This is almost a linear relationship extending over the entire range from 0% to 100% relative humidity.

The actual capacitance value at 50% relative humidity is likely to be between 100pF and 500pF. The sensor may be excited with AC from an external source, or can be incorporated in a chip that derives AC from a DC power supply and provides a digital output.

To determine the dew point or absolute humidity from a value for relative humidity, ambient temperature must also be measured. A chip such as the Si7005 from Silicon Labs includes a temperature sensor with a relative-humidity sensor based around a capacitor in which polyimide film forms the dielectric. If condensation forms, an on-chip heater will cause it to evaporate so that normal operation can resume. Data from the chip is supplied via an I2C interface.

Humidity Sensor Output

When the output is analog, resistance or capacitance of the internal sensing element is available via two pins or solder pads on the sensor. The analog value must be converted to a value for relative humidity by performing a calculation that takes the current temperature into account. The component may or may not include a temperature sensor.

With a digital output, an internal analog-to-digital converter can be accessed by a microcontroller via serial, I2C, or SPI interface. Alternatively, the sensor may communicate values using pulse-width modulation. Either way, the output is a value for relative humidity, calculated on the chip with reference to an onboard temperature sensor.

Analog Humidity Sensor

The Humirel HS1101 is a low-cost analog-output humidity sensor that varies its internal capacitance between approximately 160pF and 200pF as relative humidity increases from 0% to 100%. The response is almost linear, with the curve steepening slightly when humidity exceeds 80%. The component is shown in Figure 18-4.

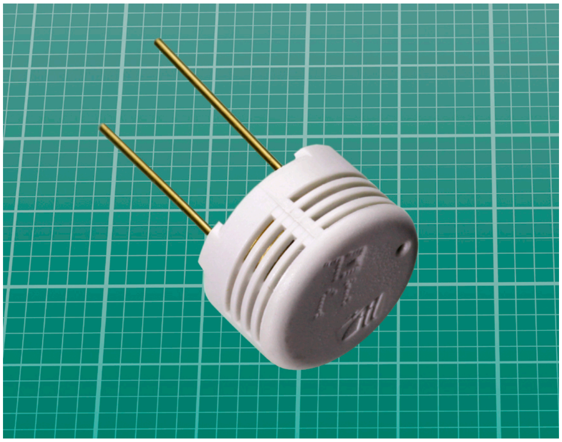

Figure 18-4 *A Humirel HS1101 humidity sensor. The background grid is in millimeters.*

The manufacturer claims a recovery time of 10 seconds after 150 hours of condensation. In other words, the performance of the sensor should be restored to its original specification.

A microcontroller can evaluate the output by measuring the charge time of the internal capacitor in the sensor. If the sensing element is wired in parallel with a 10M resistor, this will allow the capacitor to discharge before the microcontroller charges it again. A 220-ohm series resistor should be used between the microcontroller and the sensor, to limit the charge current. This circuit is illustrated in Figure 18-5.

Alternatively, the sensor manufacturer suggests using the capacitance value to control the output frequency of a 555 timer. A counter or microcontroller may be used to count the number of pulses per unit of time.

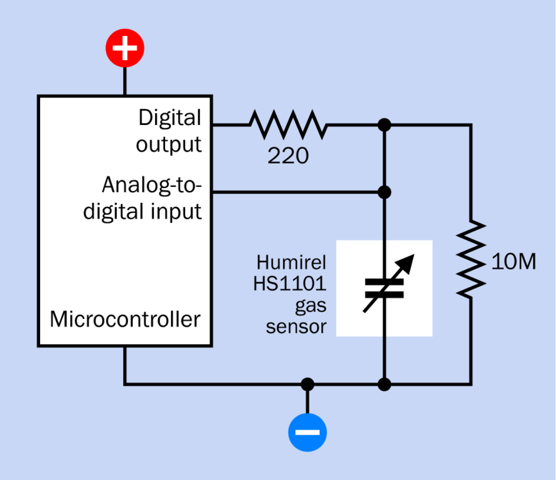

Figure 18-5 *Using a microcontroller to measure the charge time of a gas sensor with capacitive output.*

The Honeywell HIH4030 is a surface-mount humidity sensor with a more convenient analog voltage output that increases almost linearly from approximately 0.8VDC at 0% humidity to 3.8VDC at 100% humidity, assuming a 5VDC power supply. The sensor is available on a miniature breakout board from Sparkfun, shown in Figure 18-6.

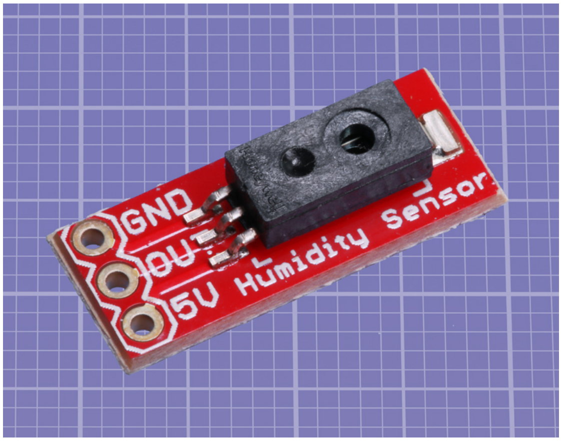

Figure 18-6 *The Honeywell HIH4030 on a breakout board from Sparkfun.*

Design Considerations

As relative humidity is temperature-dependent, a relative-humidity sensor must have the same temperature as the air it measures. Many datasheets recommend that when a sensor is mounted on a printed circuit board, slots should be milled around it to minimize heat transfer to it. The sensor should also be mounted as far away as possible from heat-generating components.

Where a capacitive humidity sensor with an analog output is located some distance from the electronics that will process its output, shielded cables or twisted pair cables should be used to minimize capacitance in the wiring. A decoupling capacitor between the supply voltage and ground close to the sensor can help to keep the supply voltage stable.

Digital Humidity Sensor

The AM2302, available from Adafruit, is a capacitive humidity sensor with a digital output accessible by a microcontroller via the I2C protocol. Onboard electronics calculate relative humidity with reference to an included temperature sensor. This component is pictured in Figure 18-7.

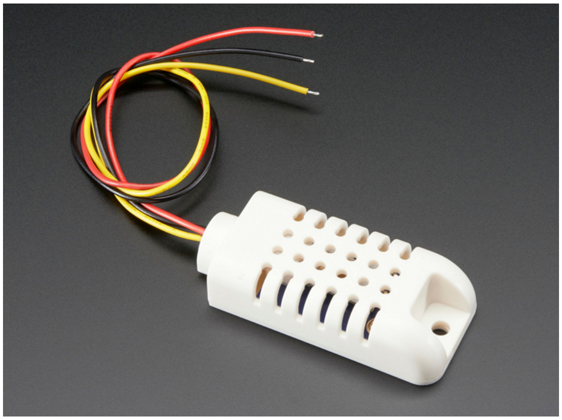

Figure 18-7 *A low-cost humidity sensor with temperature-compensated digital output. From a photograph by Adafruit.*

What Can Go Wrong

Contamination

A semiconductor gas sensor can be damaged by exposure to volatile chemical vapors. This would be unusual in a domestic environment, but is still an important consideration, as there will be no obvious indication that damage has occurred.

Recalibration

If a humidity sensor is exposed to very high humidity where condensation occurs, some datasheets advise a baking procedure, where the sensor is placed in warm, dry air for several hours and then allowed to rehumidify.

Soldering

Semiconductor gas sensors should be soldered quickly and at a controlled temperature, to minimize heat transfer.

gas flow rate sensor

19

Sensors that contain no electronic components are not included in this entry.

A **gas flow rate** sensor may often be described as a *mass flow* sensor or *mass flow rate* sensor. Although it measures volume rather than mass, the mass of gas can be calculated so long as its temperature and pressure are controlled.

Some methods of gas flow sensing can also be applied to liquids, but sensors are usually designed for one application or the other. Therefore, **liquid flow rate** sensors have their own entry. See Chapter 16.

An *anemometer* is a gas flow rate sensor that measures air speed. It is included in this entry.

Many gas flow rate sensors are large devices designed for industrial applications. This entry focuses mostly on lower-cost solid-state sensors that are often classified as *board-mount* components.

OTHER RELATED COMPONENTS

- **liquid flow rate** sensor (see Chapter 16)

What It Does

A **gas flow rate** sensor measures the volume of gas flowing past or through the device, usually inside a pipe. In most applications, users wish to know the mass of the gas that is passing per unit of time. Consequently a gas flow rate sensor is very often identified as a *mass flow rate* sensor. If it functions by heating the gas and measuring the heat dissipation, it is a *thermal mass flow rate sensor*.

A sensor that measures the flow of open air is often described as an *anemometer*. Its output will be expressed as a velocity, not as a volume or mass.

Applications

Mass flow rate sensors are used frequently for laboratory and medical applications, although the reliability and affordability of thermal mass flow rate sensors is now making them attractive for metering municipal gas supplies.

Anemometers are used mostly in meteorology, aviation, and on boats.

Schematic Symbol

Many specialized symbols are used in flow diagrams to represent pumps, valves, and sensors, but they are not schematic symbols of the type generally found in electronic circuit diagrams, and are not included here.

How It Works

Because an anemometer functions so differently from a gas flow rate sensor that is enclosed in a pipe, the two types of sensors will be discussed separately.

Anemometer

The name of this device is derived from the Greek word *anemos*, meaning "wind." The *cup anemometer* was invented in 1846, using four hemispherical cups attached to horizontal arms rotating on a vertical shaft. The rate of rotation was proportional to wind speed over a substantial range, but the conversion factor between wind speed and RPM varied depending on the size of the cups and their distance from the shaft.

Anemometer design was simplified to three cups in 1926 and was modified in 1991 by adding a tag to one cup. This causes the speed of rotation to fluctuate as the tag rotates through the wind stream, and the direction of the wind can be calculated from the speed fluctuations. Not all anemometers rely on this principle, however, and a separate wind vane can be used to determine wind direction.

The basic design of a modern anemometer is illustrated in Figure 19-1.

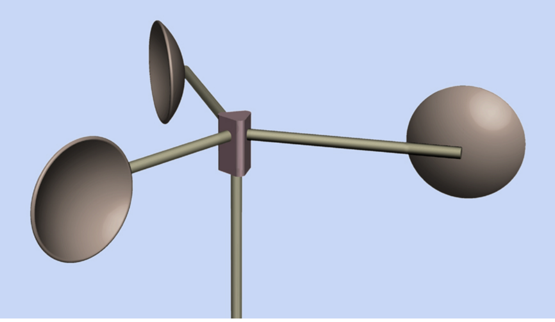

Figure 19-1 *The basic design of a metereological cup anemometer.*

Anemometers traditionally used a mechanical counter to log the number of rotations, which were checked at fixed intervals to derive the wind speed. The output of a modern anemometer may be achieved by generating AC or DC power, or from *Hall-effect sensors* (see "Hall-Effect Sensor" for a full discussion of Hall-effect sensors).

Handheld Anemometer

A digital handheld anemometer for personal use is shown in Figure 19-2. A cup anemometer made by Vaavud for use with a mobile phone (with appropriate software) is shown in Figure 19-3.

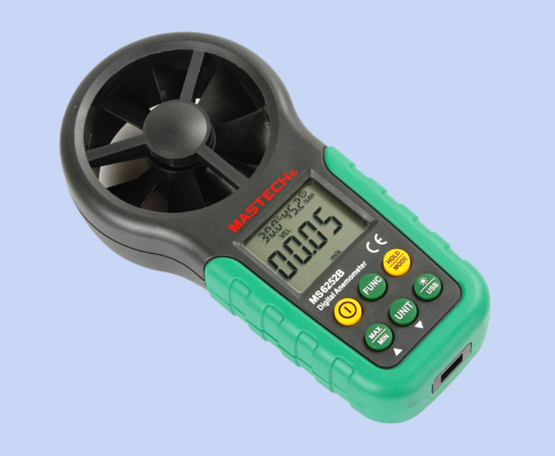

Figure 19-2 *A handheld digital anemometer.*

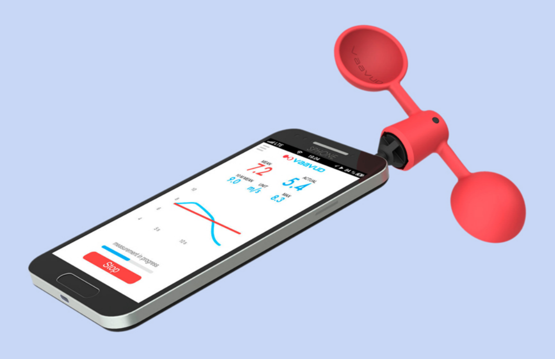

Figure 19-3 *A cup anemometer sold as an accessory for smartphones.*

Ultrasound Anemometer

The movement of air affects the speed of sound, enabling calculation of both wind direction and wind velocity by using an array of ultrasound emitters and receivers. The lack of rotating parts promises greater reliability, and in Figure 19-4 an ultrasound anemometer manufactured by Biral Metereological Sensors also includes heaters so that it will be immune to snow or ice accumulation during freezing conditions.

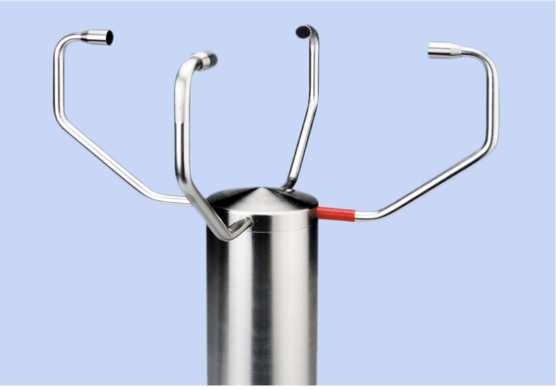

Figure 19-4 *Made by Biral Metereological Sensors, this anemometer uses ultrasound to determine wind speed and direction.*

Ultrasound anemometers have been built on a DIY basis by hobbyists, typically using off-the-shelf ultrasound emitters and an Arduino to decode the signals. Several of these projects are documented online.

Hot Wire Anemometer

A hot wire anemometer measures the cooling effect of the air. It heats a thin wire by passing current through it, and measures the heating power needed to keep the temperature constant.

It is also possible to keep either the voltage over the wire or the current constant, and to assess the wire temperature. The temperature can be measured directly or calculated from the wire's resistance, which increases as the wire gets hotter.

Mass Flow Rate Sensing

A mass flow rate sensor measures the flow speed of a gas. When this is multiplied by the density, the mass flow rate can be calculated.

Most sensors of this type heat the gas and are categorized as *thermal mass flow rate* sensors. The gas passes over a *thermopile* (consisting of several thermocouples wired in series), then a heater, and then another thermopile. These components are miniaturized and can be etched into a chip measuring 2mm square or less.

The temperature difference between the two thermopiles increases as the flow of gas becomes faster and transports more heat to the second thermopile. This is known as the *heat transfer principle*, illustrated in Figure 19-5.

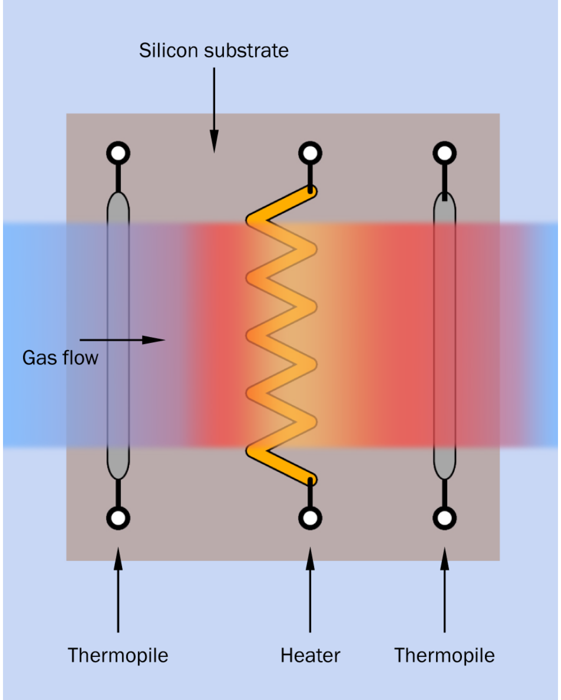

Figure 19-5 *In a thermal mass flow sensor, the flow of gas heats the thermopiles disproportionately, and the temperature difference can be used to evaluate the rate of flow.*

This principle is used also in a liquid thermal mass flow rate sensor, described in "Thermal Mass Liquid Flow Rate Sensor".

An example of a thermal mass flow rate sensor is shown in Figure 19-6.

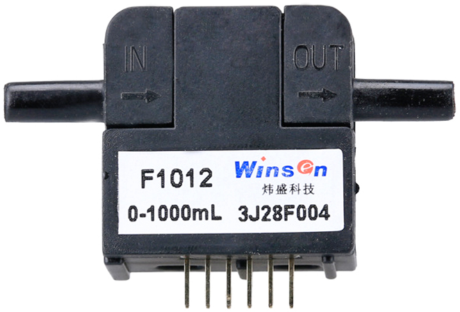

Figure 19-6 *A thermal mass flow rate sensor made by the Chinese manufacturer Zhengzhou Winsen Electronic Technology Co. Ltd.*

Applications

In medicine, mass flow rate sensors are used in anesthesia delivery, respiratory monitoring, sleep apnea machines, ventilators, and other devices. Industrial uses include air-to-fuel ratio measurement, gas leak detection, and gas metering.

While the metering of municipal gas supplies was traditionally done with all-mechanical devices, MEMS-based meters are replacing many of the 400 million mechanical gas meters estimated to exist worldwide.

Units

Mass flow rate sensors are often rated in SLM, meaning standard liters per minute. A "standard liter" has a temperature of 0 degrees Celsius and a pressure of 101.325 kPa (kilopascals). This pressure is equivalent to that of air at sea level. Because temperature and pressure are specified, the mass of a gas in a standard liter can be calculated by knowing the density of the gas. Thus SLM is a way of measuring mass flow, even though it is a measurement of volume.

The acronym SLPM is also used, but it means the same thing as SLM. SLs and SLPs are measurements of standard liters per second, while SCCM refers to standard cubic centimeters per minute.

Measuring Higher Volumes

MEMS sensors are typically equipped with inflow and outflow nozzles suitable for flexible tubing of 3mm or 5mm internal diameter. The nozzles are "barbed," meaning that they have ridges to retain the tubing.

Small tubing can only deal with low flow rates. A few sensors are threaded for standard plumbing pipes, and can accept volumes of up to 10 liters per minute. They are a minority. A low-rate sensor can still be used to measure higher volumes if it is supplied with just a percentage of the primary flow. This principle is illustrated in Figure 19-7, where an adjustable vane in the main pipe creates a pressure differential. A narrower, constricting section of pipe could have a similar effect, but it would not be adjustable.

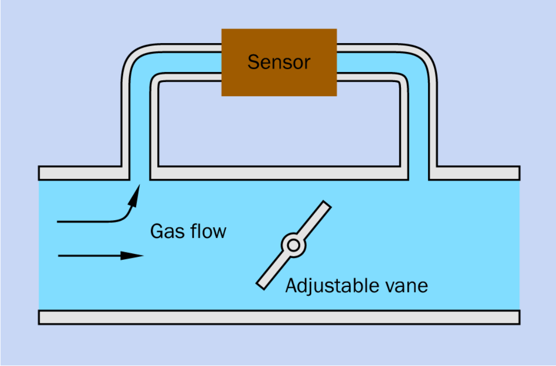

Figure 19-7 *A vane in a primary pipe can divert a percentage of the flow to a sensor.*

Output

Many mass flow sensors have an analog output consisting of a voltage that varies ratiometrically with gas flow. With a typical 5VDC power supply, output voltage may vary from around 1VDC to 4VDC.

Some sensors now incorporate analog-to-digital converters and data processing to provide SLM digital values, accessible from a microcontroller via an I2C interface.

What Can Go Wrong

The primary risk for gas flow rate sensors is damage caused by particles and contaminants in the gas stream. A 5-micron filter is recommended. A *dust segregation system* can also be used, consisting of a small compartment containing semicircular centrifugal chambers. Dust tends to follow the outer edge of the flow path, while the flow sensor is placed on the inner side of the path.

photoresistor

20

A **photoresistor** has a function similar to that of a **phototransistor**, but as its name implies, it is a purely passive component that varies its resistance in response to light.

The term *photocell* was used formerly, but has been displaced by the term **photoresistor**, which describes its function more accurately. The term *photoconductive cell* is sometimes used, or *light-dependent resistor* (or its acronym, *LDR*).

OTHER RELATED COMPONENTS

- **resistor** (see Volume 1)
- **photodiode** (see Chapter 21)
- **phototransistor** (see Chapter 22)

What It Does

Formerly known as a *photocell*, a **photoresistor** is a disc-shaped component with two leads. When light falls on the surface of the disc, resistance between the leads will diminish. Some photoresistors have a resistance in darkness as high as 10 megohms. A few have a resistance in bright light as low as 500 ohms, although several kilohms would be more common.

A photoresistor is less sensitive to light than a **phototransistor** or **photodiode**, and unlike them it is a passive component with no polarity. It presents equal resistance to current in either direction, and may be used with DC or AC.

Because cadmium sulfide is commonly used in this component and is regarded as hazardous to the environment, photoresistors are now unavailable in some regions (notably, Europe). However, at the time of writing, they are still available from many Asian sources, and from some importers in the United States.

Schematic Symbol

Six schematic symbols for a photoresistor are shown in Figure 20-1. They are functionally identical, regardless of whether the single slanting arrow across the resistor symbol is omitted.

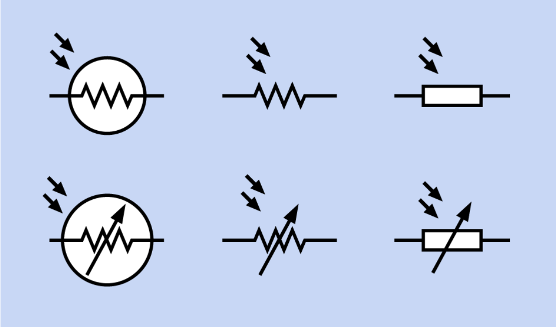

Figure 20-1 *All six symbols for a photoresistor are functionally identical.*

How It Works

Cadmium sulfide is a semiconductor. When exposed to light, more charge carriers are excited into states where they are mobile and can participate in conduction. As a result, electrical resistance decreases.

Construction

A closeup of a photoresistor appears in Figure 20-2. The brown material is a layer of cadmium sulfide deposited onto a ceramic base. The silver material is a conductive compound evaporated onto the cadmium sulfide to form two interlocking electrodes, in a pattern that maximizes the length of the boundary between each of them and the semiconductor. The electrodes connect with leads projecting from the back of the component.

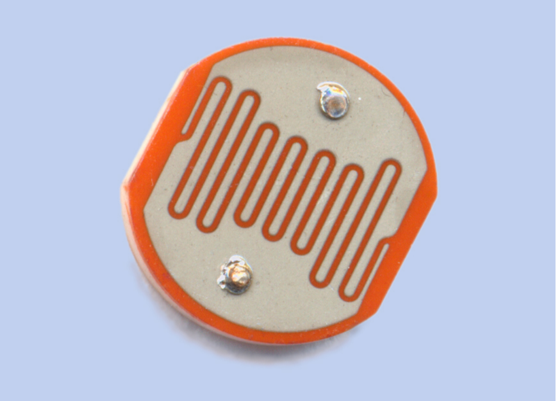

Figure 20-2 *Closeup of a photoresistor. Two interlocking electrodes are mounted on a brown semiconductor layer.*

Variants

Figure 20-3 shows a variety of photoresistors, illustrating the range of sizes available. Small photoresistors may be less than 5mm in diameter; large ones may be 25mm in diameter. The size generally suggests the ability of the component to pass current.

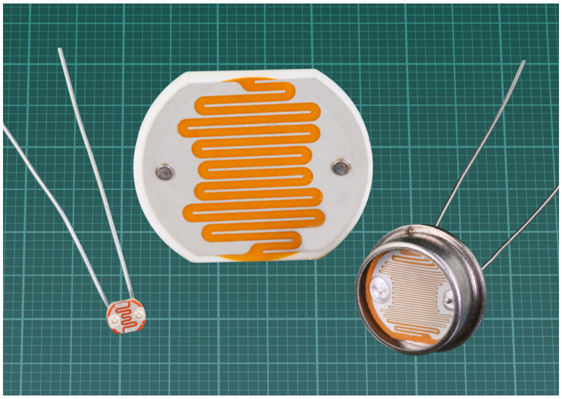

Figure 20-3 *Photoresistors are available in a wide range of sizes. The component in the center is shown at the same scale as the others. Generally speaking, larger components are able to conduct higher currents. The background grid is in millimeters.*

Photoresistors in Optical Isolators

An *optical isolator*, popularly known as an *optocoupler*, contains an LED opposite to a photoresistor, in a sealed package. This is discussed in Volume 2. A *Vactrol* is a similar component, except that the LED is placed opposite to a photoresistor. An example is shown in Figure 20-4.

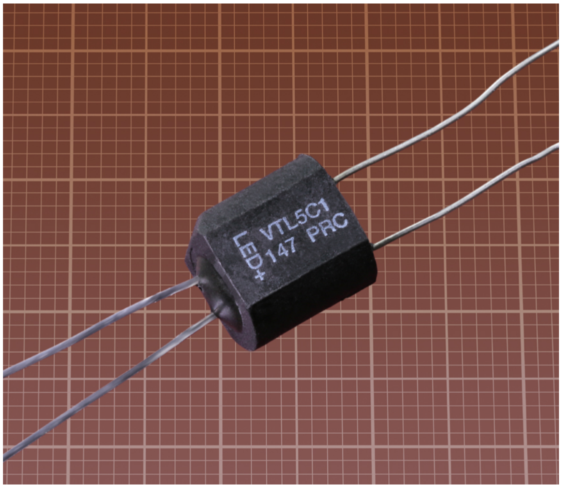

Figure 20-4 *A Vactrol, containing an LED opposite to a photoresistor. The background grid is in millimeters.*

Vactrol is a brand name owned by its initial manufacturer, Vactec. It was developed to control a vacuum tube, hence its name. In the 1950s, Vactrols were used in guitar amplifiers to control tremolo.

Because of the relatively slow response time of a photoresistor, and its sensitivity to temperature, optical isolators based on photoresistors are not used in digital devices. They still retain some utility in audio components and music equipment, where the ability of the photoresistor to pass AC is an advantage and its response time is adequate.

Values

Datasheets for a few photoresistors can still be found from some suppliers, such as Digi-Key, but are mostly unobtainable, as major semiconductor companies have stopped making these components. Vendors may quote basic values, but in the absence of part numbers or a manufacturer name, a buyer cannot verify the information.

The resistance range can be determined by testing a sample component. A typical range would be from 50K in a light intensity of 10 lux, up to 1M in darkness. Maximum power dissipation is likely to range from 100mW for a small photoresistor to 500mW for a large one.

Maximum voltage may be as high as 200V, but photoresistors will work just as well at low voltages.

Comparisons with a Phototransistor

Slower response

A photoresistor typically takes several milliseconds to respond to bright light, and can require more than 1 second to regain its dark resistance. A phototransistor is much more responsive, and a photodiode is faster still.

Narrower range of resistance

The maximum resistance of a photoresistor is almost always significantly lower than the effective maximum resistance of a phototransistor in darkness, and the minimum resistance is likely to be significantly higher than that of a phototransistor in bright light.

Greater current-carrying capacity

Often a photoresistor is rated for twice as much current as the output from a phototransistor.

Not directional

Because a photoresistor is not packaged with a lens, it is sensitive to incident light from anywhere in front of it. If an application requires that light sensitivity should be confined within a narrow angle while the component is insensitive to incident light from other directions, a phototransistor or photodiode should be used.

Temperature dependent

The resistance of a photoresistor varies more with temperature than the effective resistance of a phototransistor.

Cost

At this time, photoresistors are likely to be more expensive than phototransistors.

Lack of information

Photoresistors are often sold without means of checking their specification in a datasheet.

How to Use It

While the effective resistance of phototransistors and photodiodes varies with the applied voltage, photoresistors present the same resistance for a particular light intensity regardless of the voltage applied. This property has made them suitable for use in “stomp box” guitar-effects pedals.

Because the minimum resistance of a photoresistor in bright light tends to be relatively high, and because its response time is quite slow, it is suitable primarily as an analog component rather than as a switch.

In principle, any resistor in a circuit can be replaced by a photoresistor, and its smooth response to light variations would make it suitable, for example, as the resistance in an RC oscillator circuit, where it would determine the charge time of a capacitor. The frequency of the circuit would thus become light-dependent.

Cadmium sulfide photoresistors respond most actively to wavelengths of light ranging from 400nm to 800nm. This is especially important where an **LED indicator** is used as a light source, as LEDs often emit an extremely narrow range of wavelengths. (See the entry for LED indicators in Volume 2.)

Choosing a Series Resistor

To convert light intensity into a voltage, a photoresistor can be connected in series with a regular resistor, to form a voltage divider. There are two ways to do this, as shown in Figure 20-5. On the left side of this figure, light falling on the photoresistor will cause the output voltage to rise. On the right side, light will cause the output to drop.

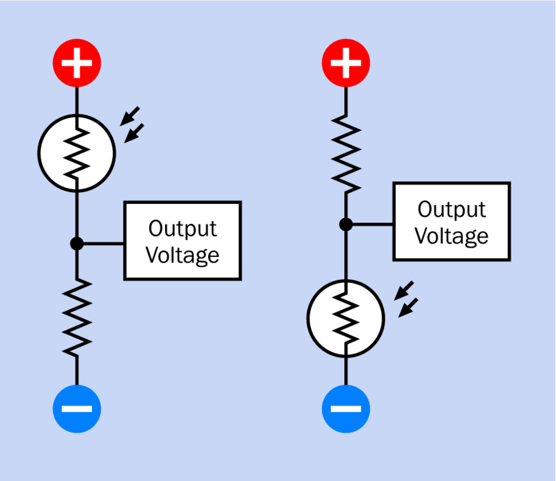

Figure 20-5 *Using a photoresistor to create a variable voltage. See text for details.*

If R_{MIN} is the minimum photoresistor value in the brightest light that will be used, and R_{MAX} is the maximum value in the dimmest light that will be used, a simple formula can be used to find R_S, the optimum value for a series resistor, which will provide the widest range of voltage values at the center of the voltage divider:

$$R_s = \sqrt{R_{min} * R_{max}}$$

What Can Go Wrong

Overload

Because a datasheet may be unavailable, a photoresistor may have to be used on a trial-and-error basis. A test-to-destruction approach may be necessary to determine the limits of the component.

Excessive Voltage

Exceeding the maximum rated voltage for a photoresistor, even for a short time, can cause irreversible damage. Depending on the component, overvoltage can range from 100V to 300V.

Confusion Among Components

Because photoresistors often have no part numbers printed on them and may be sold in miscellaneous assortments, one component may be easily confused with another that has different characteristics. Where two or more photoresistors are used in one device, their characteristics should be measured to determine whether they are functionally identical.

photodiode

21

OTHER RELATED COMPONENTS

- **diode** (see Volume 1)
- **photoresistor** (see Chapter 20)
- **phototransistor** (see Chapter 22)

What It Does

Light falling on a **photodiode** causes it to generate a very small current. This is often called the *photovoltaic effect*. The component functions like a solar panel; in fact, a solar panel can be thought of as being an array of very large photodiodes.

Often, a DC power source is used to apply *reverse bias* to a photodiode. This enables the component to deliver more current. It is now operating in *photoconductive* mode.

Schematic Symbols

Schematic symbols for a photodiode are shown in Figure 21-1. Wavy arrows are often (but not always) used to indicate infrared light.

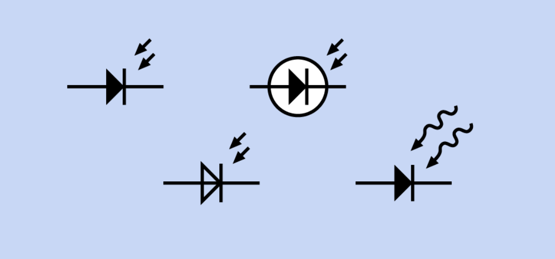

Figure 21-1 *Symbols representing a photodiode.*

Applications

The rapid response of photodiodes makes them suitable for use in optical disc drives, telecommunications, infrared data transfer, digital cameras, and optical switches. Many sensors in this Encyclopedia use a photodiode. **Proximity** sensors, optical encoders, and light meters are examples.

How It Works

When light falls on a semiconductor, it can excite an electron to a higher energy state. The electron then becomes mobile, and leaves behind an *electron hole* (See the entry discussing **diodes** in Volume 1.)

In photovoltaic mode, incident light creates pairs of electrons and electron holes in the semiconductor material. The electrons move to the cathode of the diode while the holes move to the anode, creating voltage between the two. Note that this happens to some extent even in the absence of visible light, as the photodiode may respond to infrared radiation. The tiny amount of current created without visible light is called *dark current*.

In photoconductive mode, light falling on the photodiode creates pairs of electrons and electron holes in the semiconductor material. These will move in opposite directions due to the bias voltage, which means a small current flows through the diode.

Photoconductive mode enables a faster response than photovoltaic mode, because reverse-bias voltage makes the depletion layer wider, which in turn decreases the capacitance. (The same effect is used in *capacitance diodes*.)

Simplified circuits showing the component in photovoltaic mode and photoconductive mode appear in Figure 21-2.

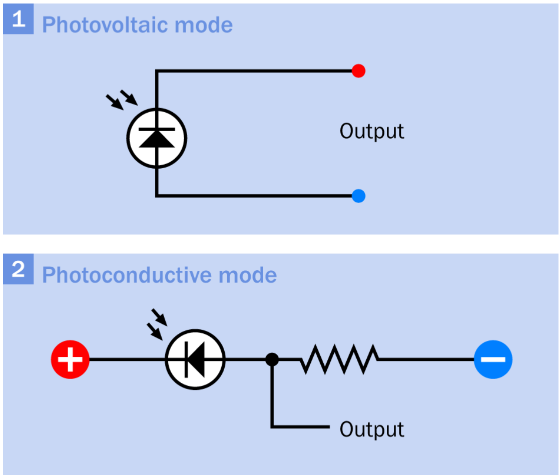

Figure 21-2 *Two modes in which a photodiode may be used. In photovoltaic mode, voltage between the two pins must be measured.*

Variants

PIN Photodiodes

Like *PIN diodes*, PIN photodiodes incorporate an undoped (intrinsic) semiconductor layer between the p- and n-doped layers. They are more sensitive and have faster responses than regular PN photodiodes. Many of the photodiodes available are of the PIN type.

Avalanche Diodes

When light enters the undoped region of the avalanche photodiode, it triggers the creation of electron-hole pairs. When electrons migrate toward the *avalanche region* of the diode, the cumulative field strength increases their velocity to the point where collisions with the crystal lattice create further electron-hole pairs.

This behavior causes the avalanche diode to be more sensitive than a PIN photodiode. However, the sensitivity also makes it vulnerable to electrical noise, and it is significantly affected by heat. A guard ring is added around the p-n junction, and a heat sink is often used.

Packages

Many surface-mount and through-hole versions are available. A selection is shown in Figure 21-3 and Figure 21-4. While a through-hole photodiode may look indistinguishable from a through-hole 3mm or 5mm LED, versions are available without lenses, and some are sensitive to incident light coming from the side (they are referred to as *side-looking* or *side-view* variants).

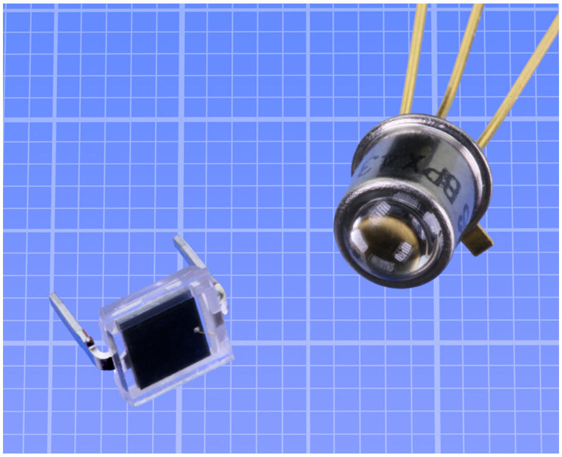

Figure 21-3 *Two sample photodiodes. Left: top-view unfiltered Vishay BPW34. Right: Osram BPX43 in metal can suitable for temperatures up to 125 degrees Celsius.*

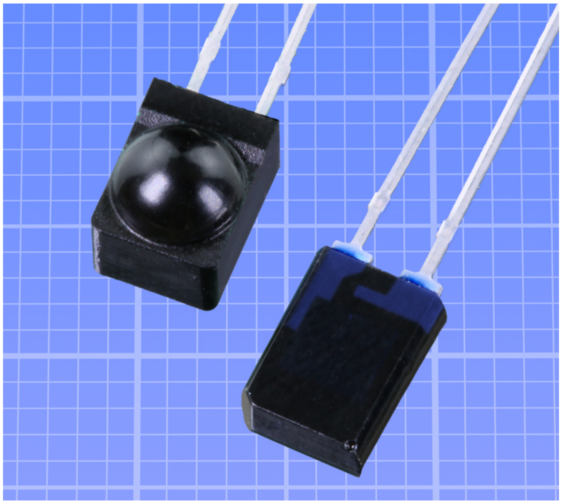

Figure 21-4 *Two side-looking photodiodes. Left: Vishay BPV22NF with lens. Right: Vishay BPW83 without a lens. Both have daylight-blocking filters.*

Wavelength Range

In order for a photon to be detected by the photodiode, it must carry enough energy to be able to create an electron-hole pair. This energy is a property specific to the semiconduct material, and is known as its *band gap*. Additionally, the epoxy packaging of the photodiode may be designed to block some wavelengths of light. Often, an application will require that the component should only respond to infrared light, not visible light.

Photodiode Arrays

A *photodiode array* has several photodiodes mounted in a row or in a grid, for imaging or measurement applications. A row of photodiodes may be used in a flatbed scanner, where it is moved relative to the reflective object being scanned.

In some arrays, photodiodes are available with color filters preinstalled, to facilitate full-color scanning using the transmitted primary colors.

Output Options

Because the output from a photodiode must be processed to be usable, options exist to convert it to a more convenient form, such as a wider range of voltages, a square wave signal where the frequency is proportional with light input, or a binary value accessible by a microcontroller via a serial bus such as I2C. For a discussion of sensor outputs see Appendix A.

Specific Variants

Light to Frequency

The Taos TSL235R is a 3-pin, through-hole chip. It combines a photodiode with logic that creates a square-wave pulse train in which frequency is proportional to the light intensity.

Logarithmic Light Meter

The Sharp GA1A1S202WP light sensor has an output voltage that changes logarithmically with the light level. This gives the sensor a large dynamic range, from 3 lux to 55,000 lux, without requiring a high-resolution analog-to-digital converter. (Human perception of light and sound levels is approximately logarithmic.) This is a surface-mount chip, but is available on a breakout board from Adafruit.

Ultraviolet to Analog

The ML8511 from Lapis Semiconductor combines an ultraviolet-sensitive photodiode with an op-amp that provides an output voltage from approximately 1V to 3V, varying with ultraviolet intensity. A breakout board containing this surface-mount chip is available from Sparkfun and many other sources.

Ultraviolet to Digital

The SI1145 from SiLabs combines ultraviolet sensing with data processing to create a UV index, readable from a microcontroller with I2C. Adafruit offers it on a breakout board.

Color to Digital

The Taos TCS3414FN module contains photodiodes sensitive to red, green, blue, and clear (no filtering). Four 16-bit analog-to-digital converters, one for each channel, provide a digital output accessible over an I2C bus. This module can be used to determine the color of ambient light with some accuracy.

Color to Analog

The Taos TCS3200 also uses red, green, blue, and clear photodiodes but encodes the output from each as a square wave in which the frequency corresponds with the light intensity. The surface-mount chip is available on a breakout board from Robot Shop, shown in Figure 21-5.

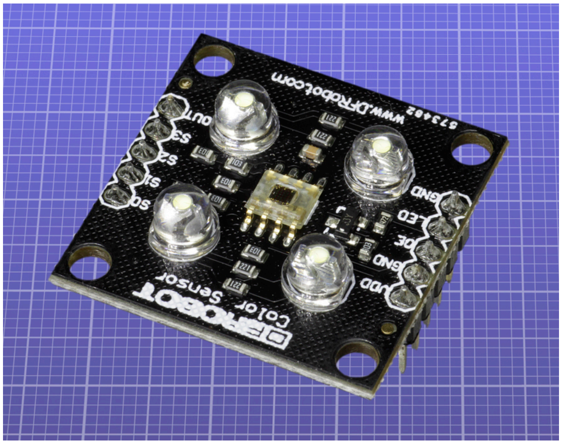

Figure 21-5 *This breakout board from Robot Shop uses the Taos TCS3200 chip to analyze the color of incident light.*

Values

Abbreviations found in datasheets are included in the list below, with values in parentheses for an Osram SFH229FA infrared photodiode, which resembles a 3mm through-hole LED. It has a peak sensitivity of 880nm and appears black to the human eye, being opaque to wavelengths of light shorter than 700nm, the red end of the visible spectrum.

In Figure 21-6 the SFH229FA is shown beside the SFH229, which has the same peak sensitivity of 880nm but is encapsulated in an untinted module, allowing a sensitivity that tapers gradually to below 400nm, in the green part of the visible spectrum. With the exception of their spectral range, the two photodiodes have identical specifications.

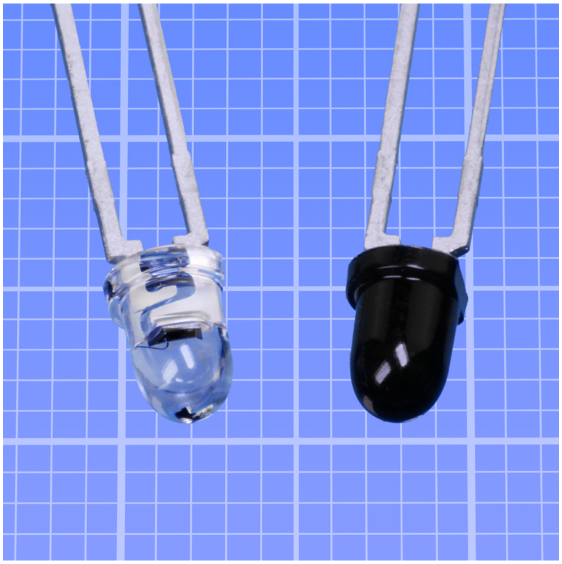

Figure 21-6 *Osram infrared photodiodes SFH229 (left) and SFH229FA (right). The background grid is in millimeters.*

- Typical forward voltage: V_F (1.3V)
- Typical photocurrent: I_P (20µA)
- Maximum power dissipation: P_{TOT} (150mW)
- The *half angle* is measured from the axis of the photodiode to the angle at which the sensitivity has dropped by 50% (plus or minus 17 degrees)
- Dark current: I_R (50pA)
- Wavelength of maximum sensitivity: $\lambda_{S\ MAX}$ (880nm)
- Response speed is the rise and fall time of photocurrent: t_r and t_f (10ns)

Infrared photodiodes exist with a variety of peak wavelengths. They are designed to function in conjunction with an LED that has a matching wavelength.

The angle of sensitivity depends on the geometry of the package.

Rise and fall speeds are important for high-speed measurement, signaling, or data transfer. The rise and fall time of a typical photodiode can be 1,000 times faster than that of a phototransistor. See "Values" in Chapter 22 for a comparison. Note also that the dark current of a photodiode is much lower than that for a phototransistor.

How to Use It

In photoconductive mode, the photodiode can be connected in series with a suitable resistor so that a voltage divider is formed, as shown in Figure 21-2. The voltage at the output will then vary almost linearly with the intensity of the light.

In the photoconductive mode of operation, the output signal is generally measured in millivolts and microamperes. This signal needs to be amplified, usually with an **op-amp** (described in Volume 2).

Figure 21-7 shows simplified schematics for a standard voltage amplifier, in section 1, and a transimpedance amplifier, in section 2.

A transimpedance amplifier measures the current through the photodiode and converts it into a voltage, without the need for a voltage divider. Advantages include less noise, and no need to determine the value of a voltage-divider resistor.

The output voltage of this amplifier is calculated by using this simple formula:

$$V = R * I_P$$

R is the value of the feedback resistor, which determines the gain of the amplifier.

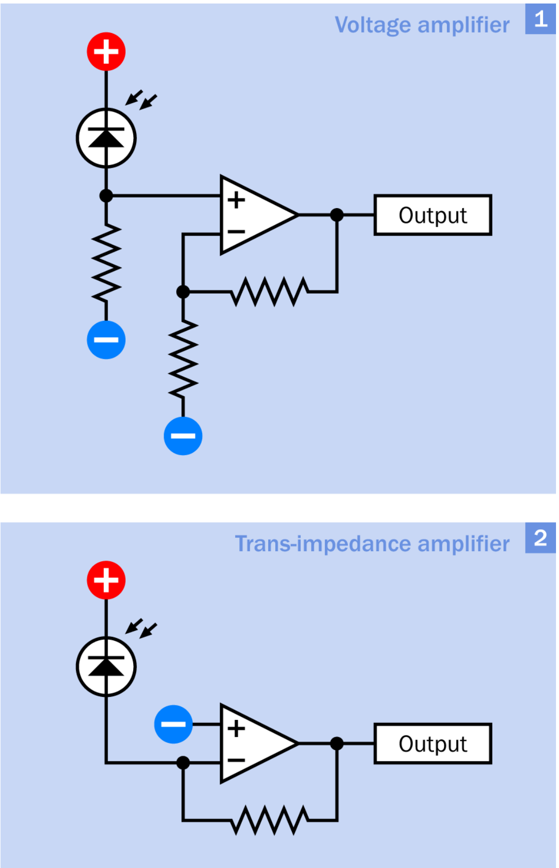

Figure 21-7 *Simplified op-amp circuits for use with photodiodes.*

What Can Go Wrong

Photodiodes can be hard to distinguish from phototransistors and LEDs, in particular infrared ones. They are typically not marked with type numbers. Using a meter may not be helpful, as regular LEDs behave similarly to photodiodes.

Decision procedure:

1. Does the component conduct in either direction while shielded from light? If so, it is a diode and not a phototransistor or photodiode.
2. Pass a weak current (e.g., 4mA) in the forward direction. If it emits visible or infrared light, it's an LED. (Infrared light may be visible when using a digital camera, or can be detected with a known phototransistor or photodiode.) If the package is clear but cloudy so that the die cannot be seen, it is probably a white LED in which the cloudiness is the fluorescent pigment converting blue light into white.

phototransistor

22

OTHER RELATED COMPONENTS

- **photodiode** (see Chapter 21)
- **photoresistor** (see Chapter 20)
- **passive infrared** sensor (see Chapter 4)
- **transistor** (see Volume 1)

What It Does

A **phototransistor** is a transistor controlled by exposure to light. (**Transistors** are described in Volume 1.) It can be either a bipolar transistor or field-effect transistor (FET), and its body is often superficially similar in appearance to a 3mm or 5mm **photodiode** or **LED indicator** encased in resin or plastic. (LED indicators are described in Volume 2.) However, some phototransistors are encased in a metal shell with a window in it.

The window or the plastic body is either transparent to visible light, or may appear black if the component is intended for use only with infrared while blocking visible wavelengths. A selection of phototransistors is shown in Figure 22-1 (left: Optek/TT Electronics OP506A with a broad spectral response centered around 850nm; center: Vishay TEKT5400S with a side-view lens; right: Vishay BPW17N).

Typically a phototransistor has two leads that connect internally with its collector and emitter (or source and drain, in the case of an FET). The base of the transistor (or the gate of an FET) responds to light and controls the flow of current between the leads.

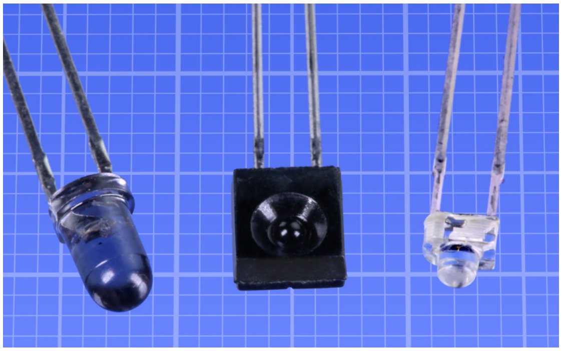

Figure 22-1 *A variety of phototransistors. The background grid is in millimeters. See text for details.*

In the absence of light, a bipolar phototransistor permits leakage between collector and emitter of 100nA or less. When exposed to light, it conducts up to 50mA. This alone differentiates it from a photodiode, which cannot pass much current.

Schematic Symbols

Symbols for a phototransistor are shown in Figure 22-2. They are functionally identical, with the exception of type C, where an additional connection to the base is included. Often (but not always), wavy arrows indicate infrared light.

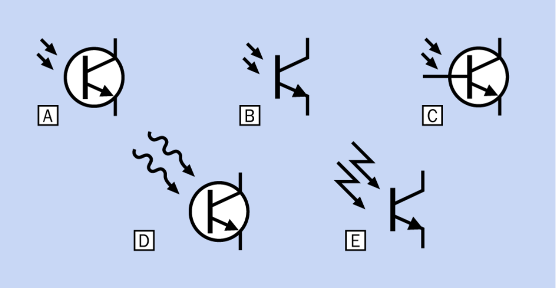

Figure 22-2 *Schematic symbols for a phototransistor.*

Applications

A phototransistor may be used for light measurement or as a light-sensitive switch.

Often the output from a phototransistor is used in conjunction with a *microcontroller* containing an analog-to-digital converter.

Where a clean on-or-off signal is required, a phototransistor can drive the input of a logic chip that contains a *Schmitt trigger*, or it can be processed by a **comparator**.

An *optocoupler* or **solid-state relay** (described in Volume 1) usually contains a phototransistor that is activated by an internal LED. Its purpose is to switch current while electrically isolating one section of a circuit from another.

How It Works

Like a photodiode, the phototransistor responds to light when the light generates electron-hole pairs in the semiconductor material. For a bipolar NPN phototransistor (the most common variant), the important region for pair generation is the reverse-biased collector-base interface. Photocurrent generated here acts as current injected into the base of an ordinary transistor, and permits a larger current to pass from the collector to the emitter.

The behavior of a phototransistor can be visualized as being similar to a photodiode controlling an ordinary bipolar transistor, as shown in Figure 22-3.

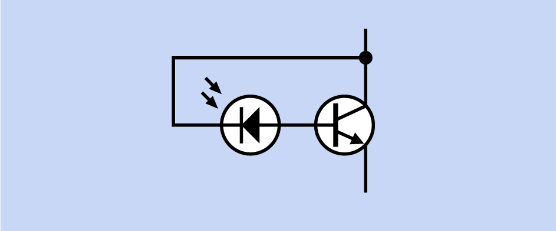

Figure 22-3 *A phototransistor is functionally similar to a photodiode controlling an ordinary transistor.*

Variants

While surface-mount variants are very widely available, through-hole packaging also remains common. When encapsulated like an LED indicator, a phototransistor gathers light from a relatively narrow angle. Variants with a flat surface are sensitive to light from almost any direction in front of the component.

Optional Base Connection

The base of a phototransistor is usually not accessible. However, some variants provide a base connection (or gate connection, in an FET) in addition to the collector and emitter (or the source and drain, in an FET). This third connection allows the application of a bias current, which can prevent low light levels from triggering the transistor.

Photodarlington

A photodarlington is a pair of bipolar transistors, the first being sensitive to light while the second acts as an amplifier for the first. This configuration is very similar to that of a *Darlington transistor* (described in Volume 1). The two-stage design makes it more sensitive to light than a regular phototransistor, but makes the response slower and less linear.

PhotoFET

A field-effect phototransistor is sometimes identified as a *photoFET*. They are relatively uncommon as separate components, but are used in optocouplers, because they have some interesting properties:

- Provided the applied voltage is low enough (less than 0.1V) the photoFET works as a controllable resistance—in contrast to bipolar transistors, where the current is controlled, and is relatively independent of the applied voltage.
- The FET transistor is symmetrical, functioning similarly for signals of either polarity. This makes an FET optocoupler suitable for AC signals.

Values

Abbreviations found in datasheets are included in the list below, with values in parentheses for an Osram SFH300FA infrared photodiode, which resembles a 5mm through-hole LED. It has a peak sensitivity of 880nm and appears black to the human eye, being opaque to wavelengths of light shorter than 700nm, the red end of the visible spectrum.

In Figure 22-4 the SFH300FA is shown beside the SFH300, which has the same peak sensitivity of 880nm but is encapsulated in an untinted module, allowing a sensitivity that tapers gradually to 450nm, in the green part of the visible spectrum. With the exception of their spectral range, the two phototransistors have identical specifications.

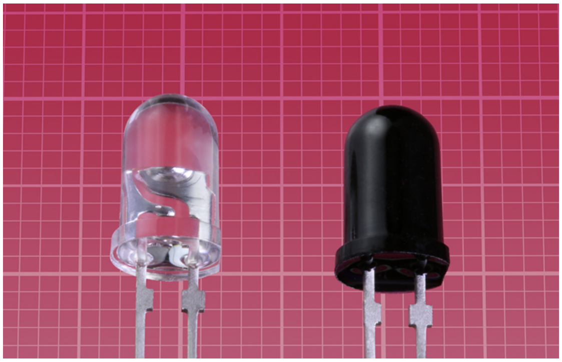

Figure 22-4 *Osram infrared phototransistors SFH300 (left) and SFH300FA (right). The background grid is in millimeters.*

- Maximum collector-emitter voltage: V_{CE} (35V)
- Maximum collector current: I_C (50mA)
- Maximum power dissipation: P_{TOT} (200mW)
- The *half angle* is measured from the axis of the photodiode to the angle at which sensitivity has dropped by 50% (plus or minus 25 degrees)

The angle of sensitivity depends on the geometry of the package. For phototransistors that resemble an LED indicator, with a rounded end that acts as a lens, typical values are plus-or-minus 20 degrees.

- Dark current (when the phototransistor receives no incident light): I_{CE0} (1nA)
- Wavelength of maximum sensitivity: $\lambda_{S\ MAX}$ (880nm)

Infrared phototransistors exist with a variety of peak wavelengths. They are designed to function in conjunction with an LED that has a matching wavelength.

- Response speed is the rise and fall time of photocurrent: t_r and t_f (10 µs)

Behavior Compared to Other Light Sensors

An extended list of comparisons between a photoresistor and a phototransistor will be found in the entry on **photoresistors**. See "Comparisons with a Phototransistor".

A photodiode has a close-to-linear electrical response over a much wider range of intensities of light than a phototransistor. Consequently, photodiodes tend to be the component of choice in applications where measurement of light must be wide-ranging and precise.

Photodiodes can pass less current than a phototransistor, but also tend to draw less current, making them appropriate in battery-powered devices that must draw as little current as possible.

Rise and fall speeds are important for high-speed measurement, signaling, or data transfer. The rise and fall time of a typical phototransistor can be 1,000 times slower than that of a photodiode. See "Values" in Chapter 21 for a comparison. Note also that the dark current of a phototransistor is much higher than that for a photodiode.

The ability of a phototransistor to sink 20mA to 50mA at its output is useful where it will be connected to a component that has relatively low impedance. For instance, a phototransistor can drive a piezoelectric audio transducer directly, or an LED indicator.

Unlike a photodiode, a phototransistor is a solid-state switch. Its saturation voltage (listed in datasheets as $V_{SE(SAT)}$ as described above) is the voltage drop between collector and emitter, and seldom exceeds 0.5V.

Binning

Small variations that occur during the fabrication process can cause inconsistency in the performance of phototransistors that share the same part number. To provide a more consistent response, manufacturers use *binning*, meaning that units sharing the same bin number are likely to share a tighter tolerance. (The same concept is used to minimize variations in **LED area lighting**, described in Volume 1.)

Datasheets will provide information on the availability and meaning of bin numbers, if available.

Bins with higher photocurrents typically have longer response times.

How to Use It

Most phototransistors are bipolar devices with an *open collector output*. That is, the collector of the transistor is accessible from one of the two leads, making it "open" to being used. See Figure A-4 for general instructions on using an open-collector output. A summary relating to phototransistors is included here.

The schematic in Figure 22-5 shows the basic concept. The resistor is referred to as a *pullup resistor*. When the phototransistor is receiving very little light, its effective resistance is high. Consequently almost all the current flowing through the pullup resistor will go to any device attached to the output, and the output voltage will seem to be "high."

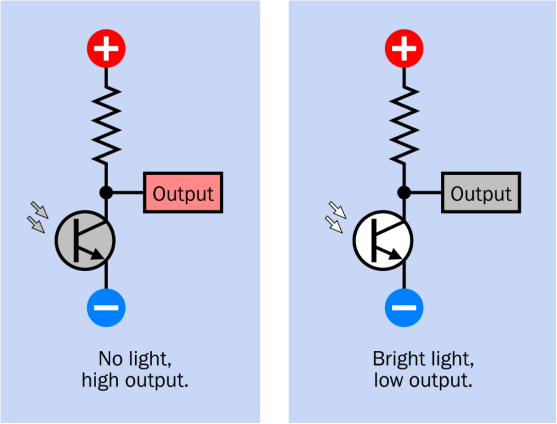

Figure 22-5 *How an open-collector output works.*

If the phototransistor is exposed to a significant light source, the effective resistance between the collector and emitter drops dramatically, and the phototransistor will sink current to ground. Consequently, the output will seem to be "low."

The pullup resistor is necessary between the power source and the collector pin to protect the phototransistor from sinking excessive current when it is exposed to light. The ideal value of the resistor will depend partly on the impedance of any device attached to the output.

In this scenario, exposure to light causes low output whereas darkness causes high output. What if we wish to have it the other way around?

The protective resistor can be moved to the emitter pin, where it becomes a pulldown resistor. It will still protect the phototransistor from passing excessive current, so long as the output is connected to a high impedance. The output is taken from the emitter pin, and will transition from low to high when the component is exposed to light. This is illustrated in Figure 22-6.

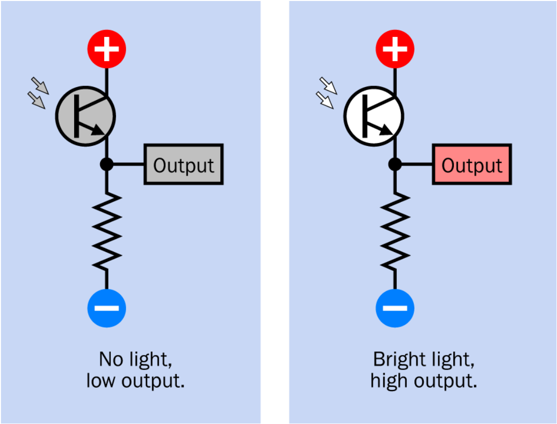

Figure 22-6 *Moving the resistor and taking an output from the emitter pin inverts the behavior of a phototransistor. Any device attached to the output must have a relatively high impedance to protect the phototransistor from excessive current.*

Output Calculation

Using an open-collector output, the photocurrent is almost independent of the applied voltage V_{CE}, provided that the voltage is higher than the saturation voltage $V_{CE(SAT)}$, which is typically between 0.4V and 0.5V.

If the pullup resistor has value R, the voltage across it is

$$U = R * I_P$$

where I_P is the photocurrent passed by the phototransistor.

When choosing R, one should consider the range of currents expected in the light conditions that will be measured, and the voltage range suitable for the next stage of the circuit. 10K is a reasonable starting point (e.g., when measuring light intensity with a microcontroller's analog input). The resistor value can be reduced from there, if necessary.

The value of the pullup resistor must also be chosen to restrict current within the limits specified by the phototransistor datasheet. A value for the resistor guaranteed to be safe is

```
R = V / I~MAX~
```

where V is the supply voltage and I_{MAX} is the maximum allowed current. With this value, the resistor limits the current to the highest allowed value, even if the phototransistor is brightly illuminated and assumed to conduct perfectly.

When V = 5V and I_{MAX} = 15mA, R should be at least 330 ohms.

What Can Go Wrong

Visual Classification Errors

Phototransistors can be visually similar to LEDs and photodiodes. They are easily confused, as neither type of component is usually marked with any identification number. The entry for **photodiodes** describes a system for distinguishing the three types of components. See "What Can Go Wrong" in Chapter 21.

Output Out of Range

The output voltage from a phototransistor will depend on the intensity of incident light, the value of any pullup resistor that is used, and the supply voltage. While a circuit is being developed, the light range may seem predictable, but in actual use the output range may not fall within expectations.

NTC thermistor

23

PTC thermistors, in which the resistance increases as the temperature increases, have a separate entry. See Chapter 24.

A *resistance temperature detector* or **RTD** has a resistance that increases as its temperature increases, but it is not usually classified as a thermistor, because its sensing element is fabricated differently. Its entry will be found at Chapter 26.

Semiconductor temperature sensors and **thermocouples** each have their own entries.

Infrared temperature sensors and **passive infrared** motion sensors have their own entries. They are *noncontact* temperature sensors that respond to infrared radiation.

OTHER RELATED COMPONENTS

- **PTC thermistor** (see Chapter 24)
- **infrared temperature** sensor (see Chapter 28)
- **passive infrared** motion sensor (see Chapter 4)
- **semiconductor** temperature sensor (see Chapter 27)
- **thermocouple** (see Chapter 25)
- **RTD** (resistance temperature detector) (see Chapter 26)

What It Does

An NTC thermistor is the most common type of discrete-component temperature sensor, and is usually the most affordable. Its resistance diminishes as its temperature increases. This behavior is referred to as a *negative temperature coefficient*, which is the source of the acronym NTC.

This is a simple, passive component that is not polarized. It requires no separate power supply, but an external device must pass a small AC or DC current through it to determine its resistance. This is known as an *excitation current*.

Schematic Symbols

Schematic symbols for a thermistor are shown in Figure 23-1. Those in the top row may still be found in the United States, but are being replaced by the European variants in the second row. The addition of -t° to the symbol indicates an NTC type of thermistor, while +t° indicates that it is the PTC type, with a positive coefficient (see Chapter 24). If no indication is shown, the thermistor is likely to be the NTC type.

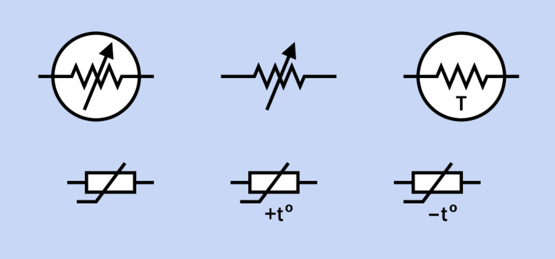

Figure 23-1 *Schematic symbols representing a thermistor. Letter t preceded by a plus or minus sign indicates whether the thermistor is the PTC or NTC type, respectively.*

Applications

Thermistors monitor temperature in air-conditioning systems, clothes washers, refrigerators, pool and spa controls, dishwashers, toasters, and other domestic devices. They are used in laser printers, 3D printers, industrial process controls, and medical equipment.

As many as 20 thermistors may be found in a modern automobile, measuring temperature in locations ranging from the transmission to the ambient air in the passenger compartment.

Comparison of Temperature Sensors

In this Encyclopedia, contact temperature sensors, which measure temperature by making contact with the source, are divided into five main categories, each of which has a separate entry. For convenience, these categories are listed in a comparative summary at the end of this entry. See "Addendum: Comparison of Temperature Sensors".

How an NTC Thermistor Works

Although the term *thermistor* suggests that it is a thermally sensitive resistor, in fact an NTC thermistor is a semiconductor.

Some metal oxides, such as ferric oxide or nickel oxide, become n-type semiconductors when they are treated with dopants. The exact mix is a proprietary secret of each manufacturer. Raising the temperature of this kind of material increases the number of charge carriers in it, promoting electron mobility and thus lowering its effective resistance.

To create a thermistor, the metal oxide mix is heated until it melts and turns into a ceramic. Typically a thin sheet is cut into small pieces for individual sensors. After two leads are connected, the assembly is dipped into epoxy or encapsulated in glass. The most common packages consist of a glass bead, surface-mount chip, or ceramic disc.

Figure 23-2 shows three NTC thermistors. At left is a Murata NXFT15XH103FA2B100 approximately 1mm in diameter, with a reference resistance of 10K and a tolerance of plus-or-minus 1%. At center is a Vishay NTCALUG03A103GC rated 10K at 2%, fitted with a mini-lug. At right is a TDK B57164K153K rated 15K and 3%.

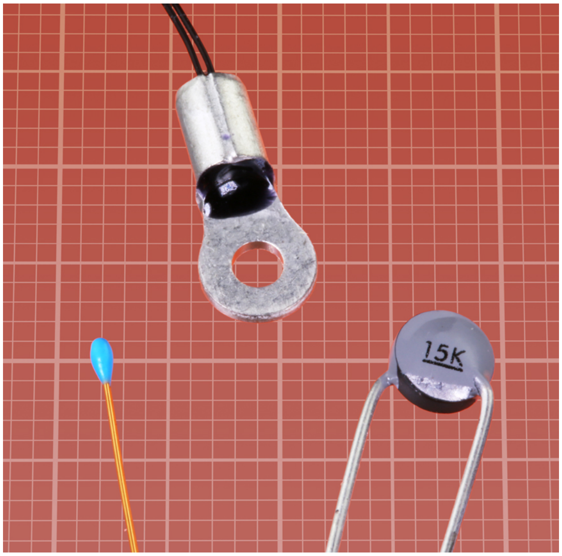

Figure 23-2 *Sample NTC thermistors. See text for details. The background grid is in millimeters.*

Output Conversion for Temperature Sensing

Ideally, the electrical behavior of a temperature sensor should be a linear function of temperature. Thermistors fail in this respect, as their resistance is an approximately inverse exponential function. This is illustrated in Figure 23-3, where the measured resistance of a thermistor rated for 5K at 25 degrees is plotted against temperatures from 0 degrees to 120 degrees Celsius.

- In many datasheets, graphs of this kind may appear flatter because they are customarily plotted against a vertical logarithmic scale.

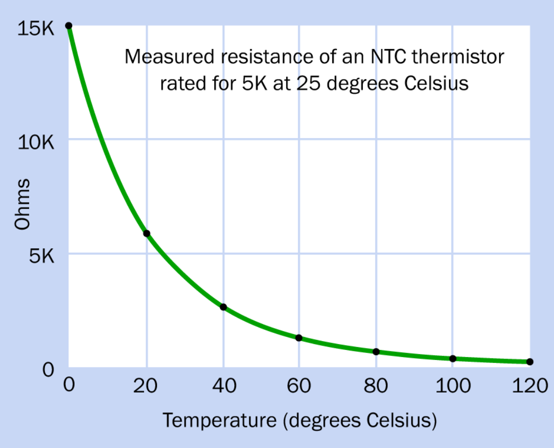

Figure 23-3 *Resistance of a thermistor from 0 to 120 degrees Celsius.*

To monitor the resistance of a thermistor, it can be placed in a simple voltage divider as shown in Figure 23-4, where the fluctuating resistance of the component creates a fluctuating voltage at point A.

- The voltage can be used as an input to a microcontroller that contains an analog-to-digital converter. Alternatively it can be connected directly to a solid-state relay, or amplified with an op-amp, or can be passed through a comparator to create an adjustable switching threshold.

Although this circuit is a voltage divider, it is also known as a *half bridge*, as it is half of a Wheatstone bridge.

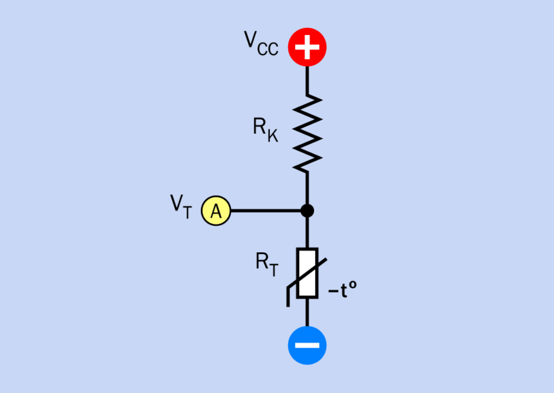

Figure 23-4 *A half-bridge circuit for determining the resistance of a thermistor.*

If V_{CC} is the supply voltage, V_T is the measured voltage at point A, R_T is the resistance of the thermistor, and R_K is the constant value of the series resistor, the basic formula for a voltage divider looks like this:

$$V_T = V_{CC} * (R_T / (R_T + R_K))$$

By transposing terms, a formula can be derived to obtain a value for R_T from the measured voltage and the value of R_K:

$$R_T = (R_K * V_T) / (V_{CC} - V_T)$$

Choosing a Series Resistor

The value for R_K in the formula should be chosen to provide a reasonably wide response over the range of temperatures for which the thermistor is likely to be used. To calculate R_K, another formula must be applied. If R_{MIN} is the resistance of the thermistor at the lowest likely temperature, and R_{MAX} is its resistance at the highest likely temperature:

$$R_k = \sqrt{R_{min} * R_{max}}$$

(This is the same formula as suggested in Figure 20-5 to find the value of a series resistor for use with a photoresistor.)

Wheatstone Bridge Circuit

The half-bridge circuit has the disadvantage that it does not compensate for nonlinearity of a thermistor. Voltage values will change rapidly at the low end of the temperature range, but will change more slowly at the high end, requiring an analog-to-digital converter with a high degree of accuracy to distinguish one voltage value from the next.

A full Wheatstone bridge circuit has a nonlinear output that compensates, somewhat, for the inverse nonlinearity of the thermistor. Referring to the circuit shown in Figure 23-5, the three resistors R_K are chosen using the formula above.

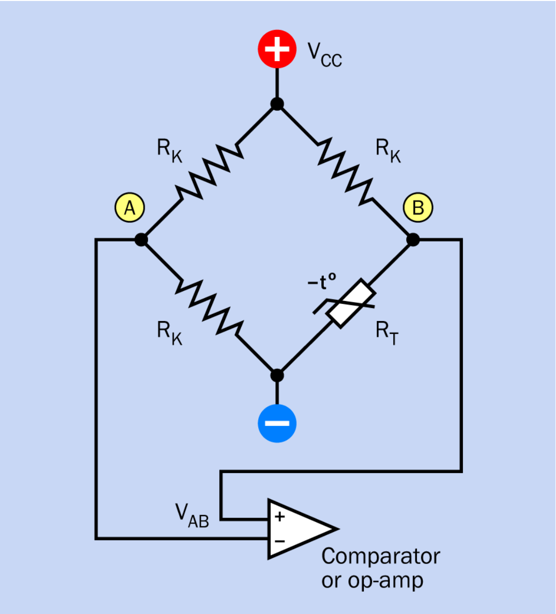

Figure 23-5 *A thermistor may be placed in a full Wheatstone bridge circuit. Outputs A and B are often connected with the two inputs of an op-amp or comparator.*

A standard formula provides the relationship between R_T, the resistance of the thermocouple; V_{CC}, the supply voltage; R_K, the fixed resistances; and V_{AB}, the output voltage measured between points A and B:

$$V_{AB} = (V_{CC} / 2) * (R_T - R_K) / (R_T + R_K)$$

From this formula, a version can be derived to calculate R_T by measuring the output voltage, V_A:

$$R_T = R_K * (V_{CC} + (2*V_{AB})) / (V_{CC} - (2*V_{AB}))$$

- The polarity of V_{AB} is reversible, depending on whether R_T is greater or less than R_K. To accommodate this, A and B can be connected to the two inputs of a comparator or op-amp.

Deriving the Temperature Value

After the resistance of the thermistor has been calculated, it can be converted to a temperature value. The datasheet for a thermistor will usually provide a table showing temperature values tabulated against resistance values, so that a lookup table can be created in a microcontroller program.

Alternatively, a datasheet usually includes constants that can be inserted in a resistance-to-temperature conversion equation, but this is nontrivial and requires natural logarithms, which may not be available in a language implemented on a particular microcontroller.

Inrush Current Limiter

NTC thermistors with appropriate characteristics can be used to limit the inrush of current that tends to occur when a circuit is switched on and large capacitors in the power supply charge very quickly.

An *inrush current limiter* is also known as a *surge limiter*, or may be referred to by its acronym, *ICL*. It is an NTC thermistor whose initial resistance diminishes rapidly as its temperature increases.

While NTC thermistors are the type most often used for inrush limiting, PTC thermistors can serve this purpose if wired differently. See "PTC Inrush Current Limiting". The remainder of this discussion refers only to NTC current limiters.

A suitable NTC thermistor can be placed as shown in the simplified schematic in Figure 23-6, where a rectified AC source is connected with a DC-to-DC converter, and a large smoothing capacitor is used. Initially the thermistor has resistance that is sufficient to limit current and generate heat. But the rise in temperature causes the resistance of the thermistor to fall. Eventually it reaches a steady state where it remains sufficiently warm to maintain a low resistance that imposes a negligible load on the circuit.

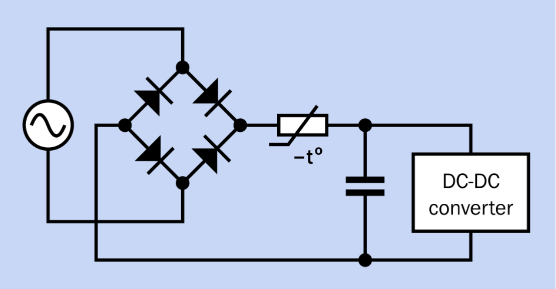

Figure 23-6 *Placement of an NTC thermistor that is designed for inrush current limiting.*

In thermistors that are used for temperature measurement, self-heating is an undesirable attribute. By contrast, an inrush current limiter depends on self-heating to perform its function.

The TDK B57237S509M inrush limiter, shown in Figure 23-7, is rated for 5A and has an initial resistance of 5 ohms at 25 degrees Celsius while not passing current. When tested with a 2,800µF capacitor at 110VAC, its resistance drops to a minimum of 0.125 ohms at 5A. The relationship between current and resistance is shown in Figure 23-8.

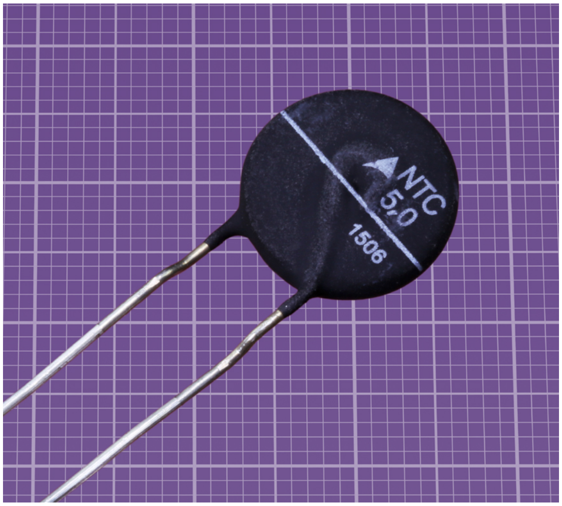

Figure 23-7 *A TDK B57237S509M NTC thermistor designed as an inrush current limiter, rated 5 ohms at 5 amps. The background grid is in millimeters.*

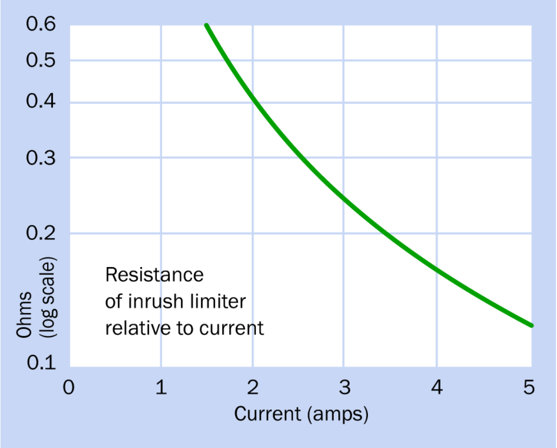

Figure 23-8 *This graph shows the relationship between resistance and current in a TDK B57237S509M inrush limiter.*

Restart

If a protected device is switched off momentarily and is then switched on again, the thermistor cannot provide protection, as it has not had time to cool down and regain its resistance. However, during the 30 seconds to 2 minutes required for heat in the thermistor to dissipate, smoothing capacitors are unlikely to lose much of their charge. Therefore, if the device is restarted, an inrush of current should not occur.

Thermistor Values

Datasheets for thermistors may be more complex and cryptic than for many components.

When examining a datasheet, first check to see if the thermistor is described as being suitable for temperature measurement or inrush current limiting. A component designed for temperature measurement will not survive inrush current, while one designed for inrush current limiting will have a very low resistance making it unsuitable for temperature measurement.

Time and Temperature

In most datasheets, lowercase letter t is used for values relating to time, whereas an uppercase T is used for values relating to temperature. Unfortunately, T may also be used as an abbreviation for "thermistor."

Resistance and Response

Letter R often means resistance, but may indicate response time, depending on the context in which it is used. For example, R_T is the resistance of a thermistor, and t_R is a response time.

Kilohms and Kelvin

Letter K may be used to represent temperature in degrees Kelvin, 0 degrees on the Celsius scale being approximately 273 degrees Kelvin. However, letter K is also used to represent thousands of ohms, sometimes in the same datasheet. In both instances, K is capitalized.

Reference Temperature

This is the temperature at which many attributes of the component are measured, such as its temperature coefficient and resistance. Usually the reference temperature is 25 degrees Celsius, but in some cases it may be 0 degrees, and other values are occasionally used. The term is abbreviated T_{REF}.

Reference Resistance

The reference resistance for a thermistor (sometimes described as its nominal resistance) may be referred to as R_R, and is the resistance at the reference temperature. It may be referred to as the "R value," but in thumbnail product descriptions it can be cited simply as "Resistance."

In datasheets, R25 or R_{25} is the resistance at 25 degrees Celsius. If this is the reference temperature, R_R and R_{25} will be the same.

Dissipation Constant

DC is the *power dissipation constant*, a ratio normally expressed as milliwatts per degree Celsius (written as mW/°C). This is a measurement of how much thermal power the thermistor can transfer to the environment for a 1 degree increase in temperature.

Temperature Coefficient

TC may be used as an acronym for the *temperature coefficient*, which represents the sensitivity of the thermistor. (Sometimes TCR is used instead of TC, the letter R denoting resistance. The two acronyms both mean the same thing.) The value is the percentage change in resistance for each change in temperature of 1 degree Celsius. Thus, if the resistance of a thermistor drops from 800 ohms to 768 ohms when the temperature increases from 28 to 29 degrees Celsius, TC = -4%. For NTC thermistors, which have a resistance that decreases when temperature increases, the temperature coefficient is negative. However, the minus sign may be omitted.

The coefficient may be expressed in parts per million (abbreviated ppm) instead of as a percentage. To convert parts per million to a percentage, divide by 10,000. Thus, a figure of 50,000ppm is equivalent to 5%.

Thermal Time Constant

Unfortunately TC is also used to represent the thermal *time constant*. If T_D is the temperature difference between the thermistor's initial temperature and a new, higher ambient temperature in which it finds itself, TC is the time it takes for the thermistor to add 63.2% of T_D to its current temperature. TC is expressed in seconds, and is defined without power being applied to the thermistor. A low thermal time constant is characteristic of a physically small thermistor that acquires heat rapidly. (TC is very similar to the concept of a time constant for a capacitor acquiring charge. See the entry on **capacitors** in Volume 1.)

Tolerance

The *tolerance* of a thermistor is a measure of its accuracy, usually at 25 degrees Celsius, unless a range of temperatures is stated. A thermistor rated for 5K, with a tolerance of plus-or-minus 1% at 25 degrees, may be found to have an actual resistance ranging from 4,950 to 5,050 ohms at that temperature. Some thermistors have a tolerance of plus-or-minus 20%. A tolerance better than plus-or-minus 1% is relatively rare.

Temperature Range

The *working temperature range* of any thermistor that uses silicon dioxide is usually between about -50 and +150 degrees Celsius (slightly wider for versions encapsulated in glass, and slightly narrower if accuracy is important).

Switching Current

For a thermistor with a nonlinear response, the switching current is the approximate current that forces a sharp transition in resistance. It is represented by I_S.

Power Limitations

Operating current is the maximum current recommended to avoid self-heating. The *power rating* is the maximum allowed power (usually 100mW to 200mW).

Interchangeability

To measure temperature reliably, two thermistors of the same type, from the same manufacturer, should display the same characteristics. This is known as *interchangeability*. A value of plus-or-minus 0.2 degrees Celsius is common for a modern thermistor, but is not often mentioned in a datasheet.

What Can Go Wrong

Self-Heating

Self-heating can affect the accuracy of an NTC thermistor that is used for temperature measurement. To get accurate temperature readings, keep the current as small as possible. When the resistance of a thermistor is at the high end of its range, brief pulses of current can be used.

Heat Dissipation

Where a thermistor is used for inrush current limiting, it will create some heat during the whole time that a device is switched on. If insufficient air space is allowed between the thermistor and other components, they may be affected.

Lack of Heat

An NTC thermistor will sometimes fail as an inrush current limiter. In very cold climates, it may never become warm enough for its resistance to drop to an acceptable level. Conversely, in a very hot location (such as close proximity to a hot-water pump) it may not get cool enough to provide adequate initial protection.

Addendum: Comparison of Temperature Sensors

A chart illustrating the five main types of contact sensors, and their variants, is shown in Figure 23-9.

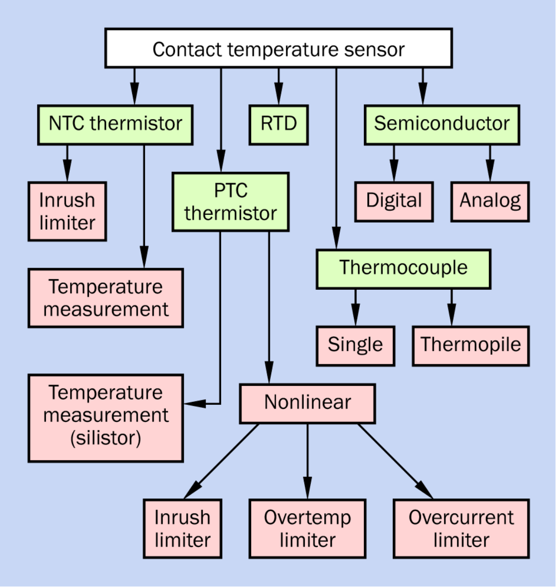

Figure 23-9 *Five types of contact temperature sensors (green boxes) and the variants (red).*

NTC Thermistor

The electrical resistance of an **NTC thermistor** diminishes as its temperature increases. Thus, it has a *negative temperature coefficient*, which is the source of the acronym NTC.

An NTC thermistor is traditionally used where low cost and simplicity are desirable and a relatively limited temperature range is acceptable (often -50 to +150 degrees Celsius). It has the advantage of familiarity, having existed in its present form for many decades. It remains the lowest-cost option among the various types of temperature sensors, and can be connected directly with an external device such as a solid-state relay, in which case no microcontroller is necessary.

PTC Thermistor

The sensing element for a positive-coefficient thermistor is a polycrystalline compound that increases in resistance very rapidly above a threshold temperature. This makes it suitable for blocking a high current to prevent circuit overload.

A *silicon temperature sensor*, sometimes called a *silistor*, can be considered as a PTC thermistor, in that it is a resistive component with a positive temperature coefficient. Its sensing element is etched into silicon.

PTC thermistors are passive, nonpolarized components with two leads or solder pads. For more information about them, see Chapter 24.

Thermocouple

This sensor consists of two wires made from different metals, joined at one end. The differing thermoelectric properties of the wires creates a very small voltage between their free ends. Thermocouples have the widest range of any contact sensor. They are simple, robust, and free from self-heating effects, as they consume no power. Their response is rapid, but very nonlinear, and their sensitivity is limited. They are used in industry and in laboratories, often plugged into a panel meter that combines a digital temperature display with hardware to decode the signal from the type of thermocouple being used.

For more information about thermocuples, see Chapter 25.

Resistance Temperature Detector

Often known by its acronym **RTD**, and sometimes referred to as a *Resistive Temperature Device*, it commonly uses a sensing element fabricated from pure platinum, nickel, or copper. The element may consist of wire wound around a core, or a very thin film deposited on an insulating substrate.

An RTD has a positive temperature coefficient, as its resistance increases while its temperature increases. It is very accurate and stable, providing an almost linear output, especially near the center of its range. However, its sensitivity is often one-tenth of that of an NTC thermistor.

Like a thermistor or a thermocouple, an RTD is a passive device, able to operate at a wide range of voltages and requiring no power supply. It is nonpolarized, with two leads or solder pads.

For more information about resistance temperature detectors, see Chapter 26.

Semiconductor Temperature Sensor

This is a chip-based sensor that requires no additional components to linearize its output, as linearization is performed in the chip.

The temperature range is similar to that of an NTC thermistor, but the output is a variable voltage with a positive temperature coefficient of about 20mV per degree Celsius, supplied by a built-in op-amp. Response time is 4 to 60 seconds.

This type of sensor requires a power supply, typically of 5VDC or less. It does not have to be calibrated before use, as it is trimmed during the production process to achieve accuracy that can be better than that of a thermistor. Manufacturers may claim plus-or-minus 0.15 degrees over the whole temperature range, which is usually -50 degrees Celsius to +150 degrees, but may be less for variants in which accuracy is more important.

The linear analog output is very convenient for use with a microntroller that has an analog-to-digital converter, and the relatively low cost makes this type of sensor increasingly competitive with thermistors.

An analog-to-digital converter may be included on the sensor chip, in which case it is often described as a *digital temperature sensor* or *digital thermometer*, with an output in degrees Celsius (or, sometimes, Fahrenheit) accessible via I2C or SPI bus. For additional details about protocols such as I2C and SPI, see Appendix A.

A *digital thermostat* or *thermostatic switch* is a semiconductor temperature sensor with a binary output that transitions from logic-high to logic-low (or vice-versa) if the temperature goes above a maximum or below a minimum level. The level can be programmed into the chip.

Semiconductor temperature sensors are identified with a variety of other names. For more information, see Chapter 27.

PTC thermistor

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A *silistor*, or *silicon-based thermistor*, is included in this entry as a form of **PTC thermistor**.

A *resettable fuse* is not quite the same as a PTC thermistor. For more information, see the entry on **fuses** in Volume 1.

NTC thermistors, in which the resistance decreases as the temperature increases, have a separate entry. See Chapter 23.

A *resistance temperature detector* or **RTD** has a resistance that increases as its temperature increases, but it is not usually classified as a thermistor, because its sensing element is fabricated differently. Its entry will be found at Chapter 26.

Infrared temperature sensors, **semiconductor temperature** sensors, and **thermocouples** each have their own entries.

OTHER RELATED COMPONENTS

- **infrared temperature** sensor (see Chapter 28)
- **semiconductor** temperature sensor (see Chapter 27)
- **thermocouple** (see Chapter 25)
- **NTC thermistor** (see Chapter 23)
- **RTD** (resistance temperature detector) (see Chapter 26)

What It Does

The electrical resistance of a PTC thermistor increases as its temperature increases. Variants can measure temperature or can protect circuits by detecting excessive heat or current.

Because a PTC thermistor is a resistive sensor, it has no polarity. Current may flow through it in either direction, or AC may be used.

Schematic Symbols

The schematic symbol for a PTC thermistor is very similar to the symbol for an NTC thermistor. See Figure 23-1.

Comparison of Temperature Sensors

In this Encyclopedia, contact temperature sensors are divided into five main categories, each of which has a separate entry. For convenience, a comparative summary is included in the entry for

NTC thermistors. See "Addendum: Comparison of Temperature Sensors". Also see Figure 23-9.

PTC Overview

PTC thermistors can be subdivided into two groups:

- *Linear*, with a chip-sized silicon-based sensing element. They are sometimes referred to as *silistors*. The component has a very linear response and is used for temperature measurement. It may be connected directly to a microcontroller.

- *Nonlinear*, mostly using a sensing element containing barium titanate in a polycrystalline compound that increases in resistance very sharply above a threshold temperature. This type of sensor may be described as a *switching thermistor*, because its nonlinear output can activate a switching device.

The sensing elements in positive-coefficient thermistors are different in principle from the element in an NTC thermistor.

Nonlinear thermistors are used in two different ways:

Externally heated

The thermistor responds to ambient heat or to the temperature of a device to which it is attached. It can be used to protect a circuit or a motor from overheating. Current through the thermistor is minimized to avoid self-heating.

Internally heated

The thermistor responds to its own temperature caused by current passing through it. It can activate a warning signal or shut down equipment in the event of a short circuit. It can also control current for starting a motor or a fluorescent tube, and is sometimes used as a source to create localized heat.

Silistor for Temperature Measurement

A silicon-based PTC thermistor, sometimes known as a *silistor*, provides a highly desirable, almost linear relationship between temperature and resistance. A popular example is the KTY81 series from NXP, a sample of which is shown in Figure 24-1.

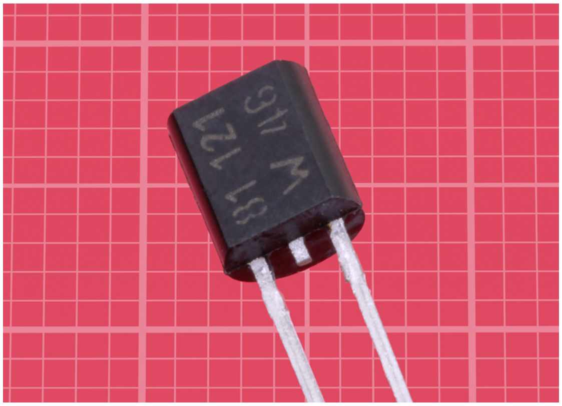

Figure 24-1 *A KTY81 thermistor from NXP. The background grid is in millimeters. Note the amputated center lead.*

The response of this thermistor is shown in Figure 24-2.

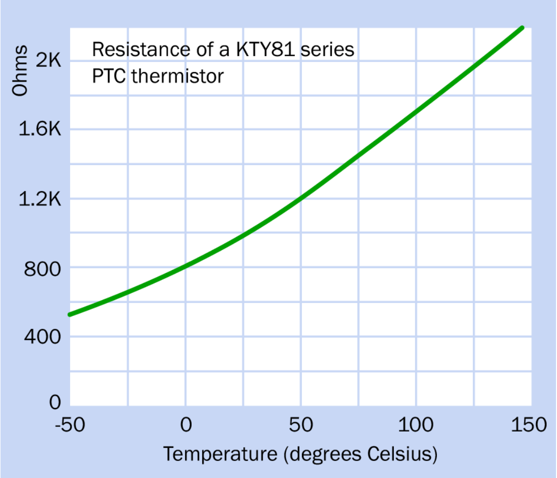

Figure 24-2 *Resistance of the KTY81 thermistor in response to temperature.*

Note that this graph is plotted with a linear vertical scale, unlike the performance curves for many thermistors that are plotted with a log scale. The log scale tends to make a response curve look flatter.

The sensor is a silicon chip designed on the "spreading resistance principle," in which current fans out from a metal contact through a thin layer of silicon to a metallized bottom plane. This effect progresses less actively as the temperature increases. Although the result is partly dependent on polarity, a second metal contact is biased in the opposite direction, and when the two active regions of the chip are wired in series, the result is a component that has no polarity.

- The almost-linear output of this type of sensor makes it easy to use with a microcontroller that has a built in analog-to-digital converter.

Tolerance ranges from plus-or-minus 1% to 5%, depending on the temperature. Variants have a typical reference resistance of 1K or 2K. The temperature coefficient is commonly about 1%, which is considerably lower than that of a typical NTC thermistor, where 4% is common.

- Guidance on reading thermistor datasheets will be found in the entry describing NTC thermistors. See "Thermistor Values".

For correct operation, a typical silistor requires a current ranging from around 0.1mA to 1mA.

- The lower sensitivity and slightly higher price of a PTC temperature-measurement thermistor, compared with an NTC thermistor, may explain why the NTC type seems to remain more popular, with many more variants available. In addition, the NTC type is much more tolerant of variations in current.

- Silistors continue to find some automotive applications, measuring oil temperature, transmission temperature, and climate control, among other parameters.

As a simple strategy to determine its resistance, a series resistor can be used with a PTC sensor to create a voltage divider. The circuit is identical to that used for NTC thermistors. See "Output Conversion for Temperature Sensing".

RTDs

A *resistance temperature detector* or **RTD** is sometimes classified as a PTC thermistor. However, it has a different type of pure-metal sensing element, much lower sensitivity, and is discussed in a separate section of this Encyclopedia. See Chapter 26.

Nonlinear PTC Thermistors

Over-Temperature Protection

This type of nonlinear thermistor is externally heated, but has a switching function. If it is incorporated among other components on a circuit board, its output can be used to activate a warning signal, or can trigger a relay to shut down the circuit until the temperature subsides. This is of special interest for battery chargers where excessive heat can often be a problem, but is also useful in electronic devices generally.

To avoid the possibility of self-heating, current passing through the thermistor must be minimized to a few milliamps.

Some thermistors in the Vishay PTCSL series will make a transition at a temperature as low as 70 degrees Celsius. Others will be triggered by temperatures above 100 degrees. A typical response curve is shown in Figure 24-3, where resistance rises from 100 ohms at 25 degrees to around 1K at the transitional reference temperature of 90 degrees, and reaches at least 4K at 105 degrees.

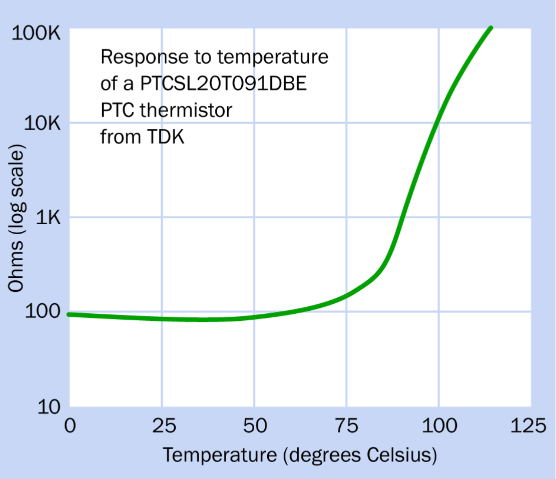

Figure 24-3 *The relationship of resistance to heat in an over-temperature protection thermistor.*

To respond to this transition, the manufacturer recommends a Wheatstone bridge circuit with its outputs connected to a comparator, as suggested for an NTC thermistor in Figure 23-5. The comparator can then activate a signal or a relay.

A picture of the PTCSL20T091DBE thermistor appears in Figure 24-4.

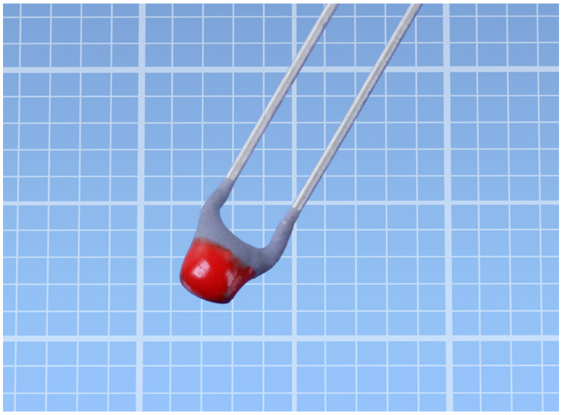

Figure 24-4 *A thermistor in the PTCSL range from TDK. It is color coded using a proprietary scheme by the manufacturer to indicate a reference temperature of 90 degrees Celsius. The background grid is in millimeters.*

This type of thermistor can tolerate a maximum of 30V (AC or DC).

Over-Current Protection

This type of nonlinear thermistor is a substitute for a fuse, as it responds to internal heat created by current passing through it. If the flow of current is excessive, the resistance of the thermistor increases, throttling the flow. When the over-current problem is resolved, the thermistor returns to its normal state. Whereas a fuse must be placed in a location allowing replacement, the thermistor is unharmed by its transition and does not have to be replaced.

Over-current may occur as a result of failure of other components, such as a rectifier diode or a capacitor, or can occur in situations such as a DC motor locking up.

The B598 series from TDK can tolerate voltages over 240V, AC or DC. They typically respond when currents exceed 100mA to 1A, depending on the specific component (a few fall outside that range), and many can withstand 1A to 7A. The B59810C0130A070 pictured in Figure 24-5 is switched by 980mA, can tolerate as much as 7A, and has a reference resistance of 3.5 ohms, rising above 10K when excessive current causes sufficient heat.

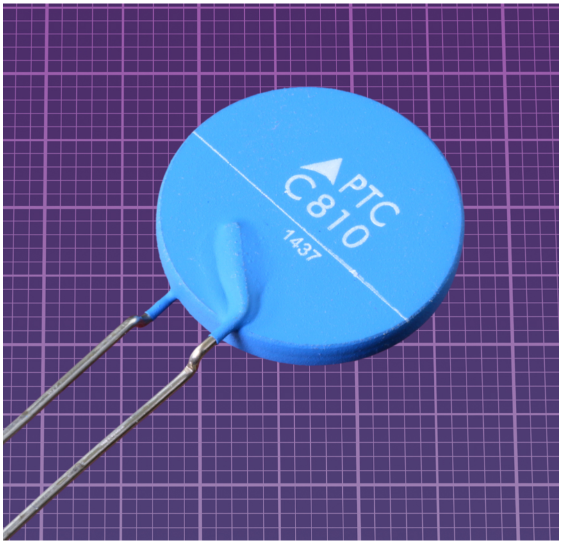

Figure 24-5 *A large over-current protection PTC thermistor. The background grid is in millimeters.*

An over-current thermistor of this type remains wired into the power supply for a device on a permanent basis. Its reference resistance will generate some heat, which is why this type of component is usually restricted to applications where the triggering current is below 1A.

The Murata PTGL07BD220N3B51B0 pictured in Figure 24-6 provides over-current protection with a reference resistance of 22 ohms, has a trip current of 200mA, and tolerates a maximum of 1.5A.

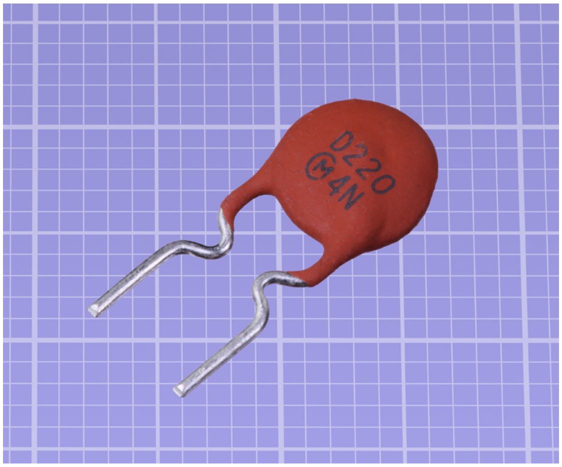

Figure 24-6 *An over-current protection PTC thermistor with a trip current of 200mA. The background grid is in millimeters.*

PTC Inrush Current Limiting

This nonlinear thermistor responds to internal heat caused by an inrush of current when power to a device is switched on. The inrush occurs when current flows rapidly into smoothing capacitors, charging them very rapidly. This can overload a power supply and shorten its life expectancy.

NTC thermistors are traditionally used as inrush limiters. The initially high resistance of this type of component blocks the surge in current, but as heating occurs, the resistance of the NTC thermistor drops rapidly. It remains in the circuit, imposing a relatively small load while the device functions normally. For more details of this application, see "Inrush Current Limiter" in the entry discussing NTC thermistors.

However, an NTC thermistor used in this way will waste some power. Suppose a supply of 120VAC is being used. If the power consumption of a device is 1,000W, the current will be approximately 8A. An NTC thermistor that has a resistance of 0.2 ohms while running warm will introduce a voltage drop of approximately 1.6V, consuming about 13W. This power loss will be greater in applications where the current is even higher—for example, in an electric vehicle recharging station.

To eliminate the loss, a timed bypass relay can be added around the thermistor. The relay closes automatically after a short interval, eliminating the power loss. This is known as *active inrush current limiting*.

However, in this arrangement, an ordinary resistor could be used instead. But in that case, why not use a PTC thermistor that has a reference (cold) resistance of 50 ohms or more? This not only limits the inrush current, but provides additional protection. If a smoothing capacitor in the circuit suffers a short circuit, or if the bypass relay fails to close, excess current passing through the PTC thermistor quickly raises its resistance, protecting the rest of the circuit.

The B5910 series of PTC thermistors from TDK is designed for inrush current limiting. They are packaged in a flame-retardant phenolic resin plastic case, as shown in Figure 24-7. The B59105J0130A020 has a reference resistance of 22 ohms that rises quickly beyond 10K when the temperature exceeds 120 degrees Celsius, as shown in Figure 24-8. This type of component is robust enough to withstand a complete short circuit across a 220-volt supply.

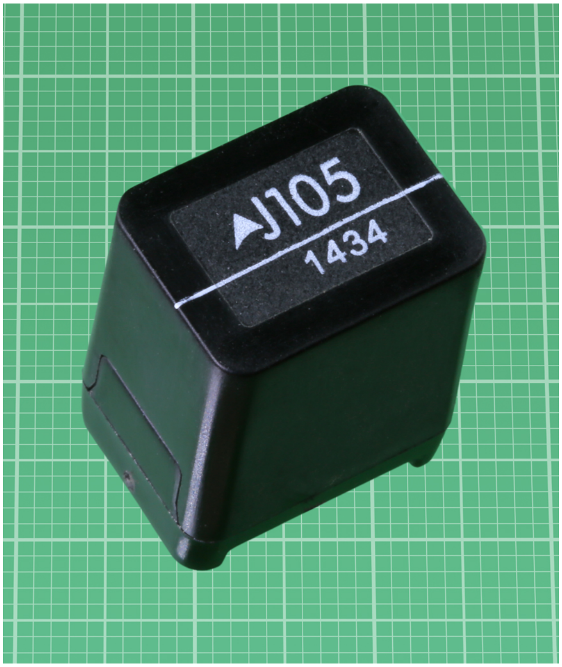

Figure 24-7 *This inrush current-limiting PTC thermistor by TDK is packaged in a flame-retardant case. The background grid is in millimeters.*

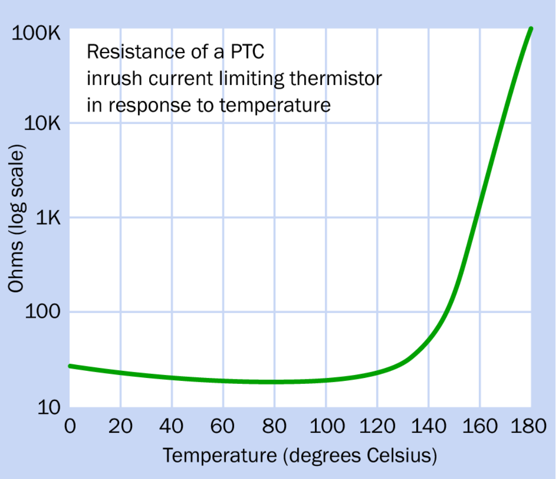

Figure 24-8 *Relationship of resistance to temperature in a PTC inrush current limiting thermistor. Note that the vertical axis has a logarithmic scale.*

PTC Thermistor for Starting Current

In some applications an initial inrush of current is actually necessary and desirable. An air conditioning compressor, for example, requires a surge of high current for "torque assist" when it is starting from a rest state.

High-current PTC thermistors may be used in this kind of situation. The Vishay PTC305C series is an example. These are heavy-duty components that have a switching time of about half a second, a maximum voltage rating of 410VAC or more, and a current rating from 6 to 36 amps.

The PTC thermistor has a relatively high temperature while the motor is running, and must be allowed time to cool before a restart is possible after shutdown. A waiting time of 3 to 5 minutes is imposed by a thermostat or separate time-delay relay.

PTC Thermistor for Lighting Ballast

The starting sequence for a fluorescent lamp requires that current should flow through the cathode heater initially. The thermistor allows this by bypassing a capacitor. Within less than a second, the resistance of the thermistor rises to block current. By this time, the heater has done its job and the lamp runs from high-frequency AC.

PTC Thermistor as a Heating Element

For small applications, a heating element can be made from a PTC thermistor, using its internal resistance to create heat. It has the advantage of being self-limiting, as its resistance rises with temperature. The TDK 5906 series is an example, shown in Figure 24-9. The component is approximately 12mm in diameter, and is designed to be clamped in place, not soldered. It has automotive applications for diesel fuel preheating and spray nozzle defrosting. Residential applications include vaporizers for air fresheners.

The initial resistance is as low as 3 or 4 ohms, rising very quickly at a transition temperature ranging from 70 to 200 degrees Celsius, depending on the specific component.

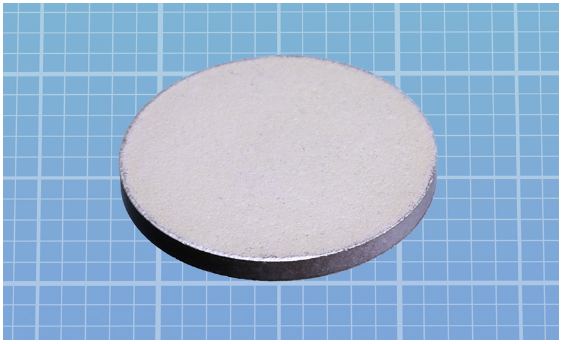

Figure 24-9 *This TDK B59060A0060A010 heating element is a PTC thermistor whose resistance rises rapidly around 80 degrees Celsius. Rated for 12VDC, it is intended for automotive applications. The background grid is in millimeters.*

What Can Go Wrong

Self-Heating

Self-heating may affect the accuracy of a temperature sensor. To get accurate readings, keep the current small. When the resistance of a thermistor is at the high end of its range, brief pulses of current can be used.

Heating Other Components

In cases where the self-heating of thermistors serves a useful purpose, as in surge protectors and when used for delays, the heat can damage nearby components or materials.

thermocouple

25

Because a *thermopile* is an assembly of thermocouples, it is included at the end of this entry. Other types of temperature sensors have their own entries.

OTHER RELATED COMPONENTS

- **NTC thermistor** (see Chapter 23)
- **PTC thermistor** (see Chapter 24)
- **semiconductor** temperature sensor (see Chapter 27)
- **RTD** (resistance temperature detector) (see Chapter 26)
- **infrared temperature** sensor (see Chapter 28)

What It Does

A **thermocouple** measures temperature by using a pair of wires made from dissimilar metals. At one end of each wire, they are joined together, often by welding them. The differing thermoelectric characteristics of the wires generates a very small voltage between their free ends, from which the temperature of the joined ends can be derived.

No power supply is needed for a thermocouple, but the voltage that it generates is extremely small (measured not just in millivolts, but microvolts) and very nonlinear, requiring hardware and/or software to convert it to a temperature value. Laboratory equipment or integrated circuit chips are available for this purpose.

Different types of thermocouples are available to measure different temperature ranges, and each type has its own characteristics, requiring appropriate conversion.

A "raw" thermocouple looks very unimpressive, as it merely consists of two wires welded together at one end. This is illustrated in Figure 25-1. The full length of the photocouple is shown in Figure 25-2.

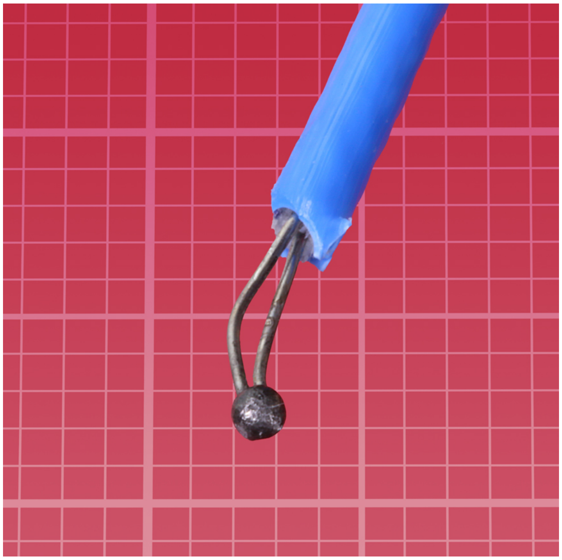

Figure 25-1 *Closeup of the welded wires in a K-type thermocouple. The background grid is in millimeters.*

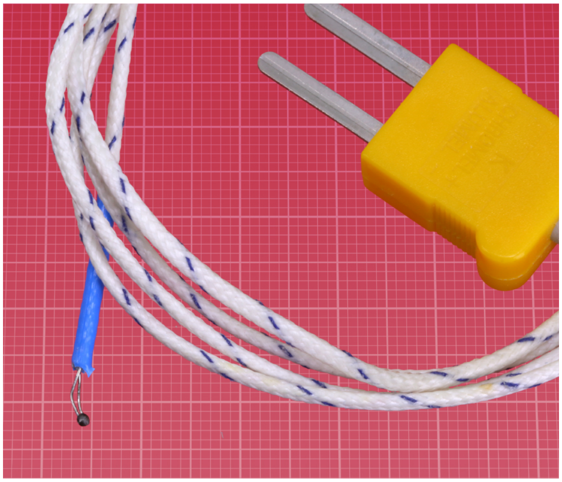

Figure 25-2 *Overview of the thermocouple in the previous photograph.*

A thermocouple sold as a commercial product is likely to be enclosed in a probe, as shown in Figure 25-3.

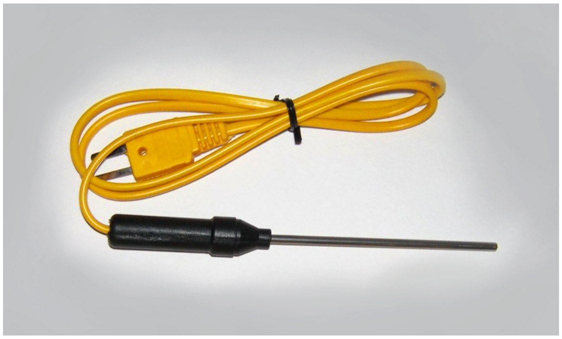

Figure 25-3 *A probe that contains a thermocouple.*

Schematic Symbol

A schematic symbol that is often used to represent a thermocouple is shown in Figure 25-4. Because this component does not consume current, the plus and minus signs do not mean that power should be applied to the wires. The positive sign indicates which wire will generate a higher voltage than the wire with the negative sign.

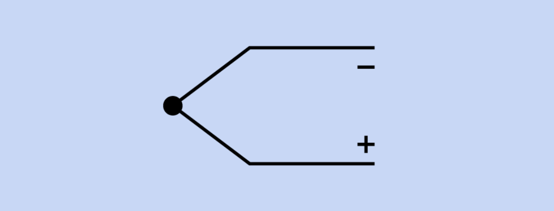

Figure 25-4 *A symbol that is often used for a thermocouple.*

Comparison of Temperature Sensors

In this Encyclopedia, temperature sensors are divided into five main categories, each of which has a separate entry. For convenience, a comparative summary is included in the entry for **NTC thermistors**. See "Addendum: Comparison of Temperature Sensors" for an overview. Also see Figure 23-9.

Thermocouple Applications

Thermocouples have a wider range than any other form of contact temperature sensor, some types being capable of measuring up to 1,800 degrees Celsius. The main limitation is the ability of the joint between the wires to withstand the heat. Appropriate insulation must be used, but segments of ceramic tube are marketed to serve this purpose if necessary.

The very small thermal mass of a thermocouple enables a rapid response to temperature fluctuations. No self-heating occurs, because the thermocouple consumes no power. It is simple and robust. However, its response is very nonlinear, and the tiny voltages involved are vulnerable to corruption by electrical noise. Accuracy is usually not better than plus-or-minus 0.5 degrees Celsius, and may be less at low temperatures.

Thermocouples are commonly found in laboratories and in some industrial applications, such as monitoring the temperature in a blast furnace or inside an internal combustion engine.

They may also measure temperatures as low as -200 degrees, but at temperatures below -100 degrees the temperature coefficient diminishes to the point where voltage increments are less than 30µV per degree Celsius.

How a Thermocouple Works

When one end of a piece of wire is maintained at a temperature that is different from the other end, the temperature gradient along the wire creates a small electromotive force that manifests itself as a difference in electrical potential between one end of the wire and the other. This is known as the *Seebeck effect*, named after the man who discovered it. The magnitude of the potential will depend on two factors: the temperature difference between the ends of the wire, and the type of wire that is used.

Figure 25-5 illustrates the concept. Part 1 of this figure shows two wires, named A and B. The left ends of the wires are heated to the same temperature, T_X, while the right ends remain at a cooler temperature, T_Y. Because the wires are composed of different metals, the voltage drop across each wire will be different.

To make this model useful, some factors must be eliminated. In part 2 of Figure 25-5, the hot ends of the wires have been welded together. This now guarantees that they share the same temperature and the same voltage, V_X. We do not yet know what these X values are.

In part 3 of the figure, the cold ends of the wires are clamped in an isothermal block, which keeps them at an equal temperature, still represented as T_Y. The block is not electrically conductive, so the cold ends of the wires still have different voltages, V_A and V_B. We cannot measure these voltages directly, because they are relative to V_X, which is unknown. However, a volt meter can measure V_A and V_B relative to each other.

The volt meter will have its own voltage gradient on its wires, and possibly a temperature gradient too, but both of these wires are made of the same metal (probably copper) and share the same temperature gradient. Therefore, their effects will be equal.

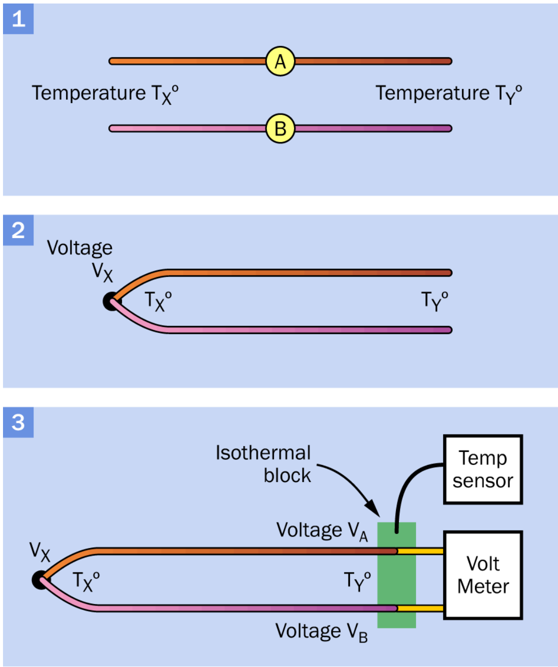

Figure 25-5 *Basic principles of a thermocouple. See text for details.*

A mathematical relationship exists between the temperature gradient and the voltage difference in each thermocouple wire. Suppose K_A is a constant or function that enables the voltage difference in wire A to be determined from its temperature gradient, and K_B serves the same function for wire B. Suppose T_{DIF} is the difference in temperature between T_X and T_Y. We may state:

$$K_A * (T_{DIF}) = V_X - V_A$$

$$K_B * (T_{DIF}) = V_X - V_B$$

By subtracting the second equation from the first and rearranging the terms, we get:

$$T_{DIF} * (K_A - K_B) = V_X - V_A - V_X + V_B$$

The two V_X terms cancel out, leaving $V_B - V_A$ on the right. We can recognize $V_B - V_A$ as the voltage difference measured by the meter. Call it V_M. So:

$$T_{DIF} = V_M / (K_A - K_B)$$

This enables calculation of the temperature difference between the ends of the wires, based on the meter reading and the conversion factor for each wire, which can be found experimentally. Because T_Y is being held at a known, constant value, we can determine the value of T_X:

$$T_X = T_Y + T_{DIF}$$

Thermocouple Details

When the thermocouple was first invented, the cold ends of the wires were placed in a bath of ice and water, forcing them to acquire and maintain a known temperature of 0 degrees Celsius.

The advent of accurately calibrated thermistors made it possible simply to measure the temperature of the cold ends. In this way, a thermistor enables a thermocouple to work. This prompts the question: why not just use the thermistor to measure T_X, and throw away the thermocouple? The reason is that a thermistor has a more limited range, seldom being used for temperatures above 150 degrees Celsius.

Note that the "hot end" of the thermocouple wires does not actually have to be hotter than the "cold end," even though those terms are commonly used. The equation to find T_X works just as well if T_Y is higher than T_X. The temperature difference will simply have a negative value instead of a positive value.

Because "hot" and "cold" are misleading terms, modern documents generally refer to the "measurement junction" and the "reference junction" of the wires. Note, however, that the wires are not actually joined with each other at the reference junction.

A common misconception is that voltage is generated where the wires are joined at the measurement junction. This is not correct. The voltage is a function of the temperature gradient between the measurement junction and the reference junction in each wire. Therefore, the way in which the wires are joined is irrelevant, provided there is an electrical connection between them. They can be welded, soldered, brazed, or crimped together.

How to Use It

Where a thermocouple is used in a laboratory, typically each wire is insulated, and they terminate in a plug that is inserted in a meter. The reference junction is hidden inside the meter, along with some electronics to decode the temperature data. The meter must have a setting that is appropriate to the specific type of thermocouple being used, so that the conversion factors are correct.

Because the type of metal in each wire must be consistent all the way from the measurement junction to the reference junction, other types of wires cannot be used to extend the reach of a thermocouple. Any extension must use wires made from the same metals. Connectors, also, must have pins and sockets that match the types of metals in the wires.

An extension wire for a thermocouple is shown in Figure 25-6.

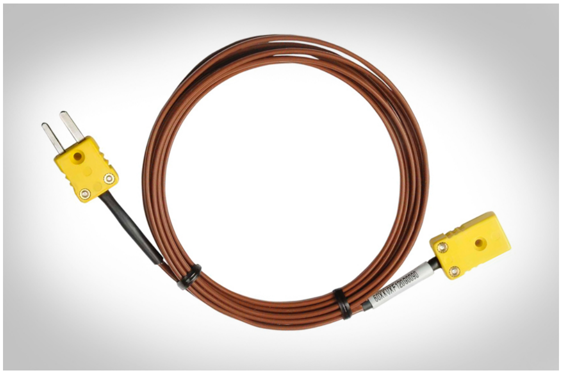

Figure 25-6 *Extension wire for a type K thermocouple. Note the polarized plug.*

Types of Thermocouples

Thermocouples are identified by ANSI standard codes consisting of single letters of the alphabet, shown below. Temperature ranges are approximate, in Celsius, with minimums rounded up and maximums rounded down to the nearest 50 degrees. Some data sources recommend narrower temperature ranges for practical use.

K type

-250 to +1,350 degrees. Most popular type of thermocouple. Positive wire is a nickel-chromium alloy, negative wire is a nickel-aluminum alloy. Commonly used in 3D printers.

J type

-200 to +1,200 degrees. Positive wire is iron, negative wire is a copper-nickel alloy. The iron wire is magnetic and vulnerable to corrosion. This thermocouple is not recommended for low temperatures, even though it is theoretically capable of measuring them.

T type

-250 to +400 degrees. Recommended for cryogenic applications. Positive wire is copper, negative wire is a copper-nickel alloy.

E type

-250 to +1,000 degrees. Most sensitive type, with the highest temperature coefficient. Positive wire is a nickel-chromium alloy, negative wire is a copper-nickel alloy.

N type

-250 to +1,300 degrees. An alternative to the K type, more stable at higher temperatures. Positive wire is a nickel-chromium-silicon alloy, negative wire is a nickel-silicon-magnesium alloy.

R type

-50 to +1,750 degrees. For high-temperature applications. Positive wire is a platinum-rhodium alloy, negative wire is platinum. Very low temperature coefficient.

S type

-50 to +1,750 degrees. For high-temperature applications. Positive wire is a platinum-rhodium alloy, negative wire is platinum. Very low temperature coefficient.

Seebeck Coefficients

Datasheets for thermocouples list the Seebeck coefficient, which is the temperature coefficient caused by the Seebeck effect, measured in microvolts per degree. In other words, the value provided by a Seebeck coefficient is the number of additional microvolts that a thermocouple will generate for an increase in 1 degree Celsius.

Each type of thermocouple has a different coefficient, and because thermocouples tend to have a very nonlinear response, the coefficients will vary with temperature. Figure 25-7 shows the variations for six types of thermocouples, over a range from -400 to +1,400 degrees Celsius. It is important to understand that the vertical scale shows the coefficient for each type of thermocouple—that is, the *change* in voltage, not the *actual* voltage, at temperature values along the horizontal axis.

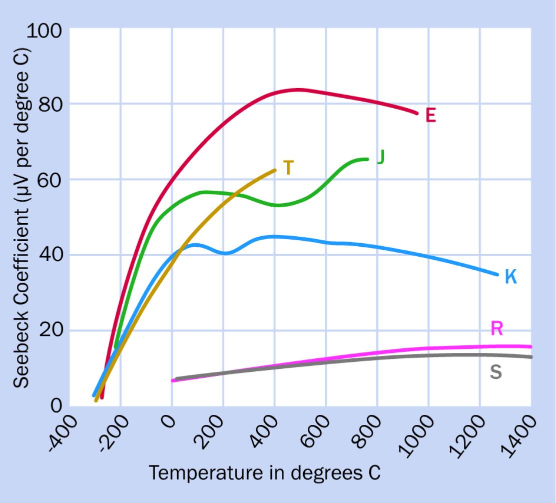

Figure 25-7 *The Seebeck (temperature) coefficient for six types of thermocouples. Partially derived from a datasheet published by Analog Devices.*

R and S type thermocouples have a relatively consistent response, but cannot achieve great accuracy, because the voltage increment is so small for each change in temperature. The K type thermocouple does relatively well between 0 and 1,200 degrees, but the J type only performs adequately between 0 and 800 degrees, while the T and E types are quite inconsistent.

For lower voltage readings, electrical noise becomes an issue. Thermocouple wires are often twisted together, and may also be shielded, to reduce sensitivity to noise. The electronics that decode the thermocouple voltage should include a filter to reject 50Hz or 60Hz interference from wiring in the vicinity.

Chips for Output Conversion

Meters that are designed to interpret the output from a thermocouple and display a temperature tend to be expensive, and may not be convenient for a custom-built application. Fortunately integrated circuit chips are now available to amplify the thermocouple output and apply signal conditioning to create an almost linear response.

The AD8494 and AD8496 from Analog Devices are precalibrated by laser wafer trimming to match the characteristics of J type thermocouples, while the AD8495 and AD8497 match the characteristics of K type. The chips require a power supply of at least 3VDC and have an analog output of 5mV per degree Celsius, enabling measurement over a range of almost 1,000 degrees. They require a very low supply current of 180µA. The manufacturer claims an accuracy of plus-or-minus 2 degrees Celsius.

The chip contains a temperature sensor which should be at the same temperature as the reference junction of the thermocouple. This means that the reference junction (typically, at the socket where a thermocouple plug is inserted) should be as close to the chip as possible, and the chip should be protected from heat created by other components. Any difference in temperature between the reference junction and the chip will create a temperature measurement error.

The MAX31855K chip from Maxim Integrated Products is another thermocouple-to-digital converter. It linearizes the output from the thermocouple and digitizes it as a temperature that is accessible by a microcontroller via a serial SPI bus. Breakout boards with this chip are available. The last letter of the chip number specifies the thermocouple type. Variants for J, K, N, T, S, and R are available.

The AD8495 is mounted on a breakout board from Adafruit, and the MAX31855K is mounted on a breakout board from Sparkfun. These boards are pictured in Figure 25-8.

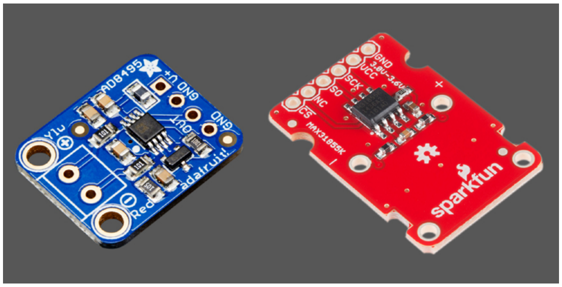

Figure 25-8 *Thermocouple amplifier/conversion chips from Adafruit (left) and Sparkfun (right).*

Thermopile

A thermopile is an assembly of thermocouples connected in series, as suggested in Figure 25-9, where a hot area is shown on the left and a cooler area is shown on the right. The figure assumes that the orange-colored wires have a voltage difference of 5mV from left to right, as a result of the temperature difference, while the purple-colored wires only have a voltage difference of 1mV from left to right. Therefore, the voltage difference between each reference junction and the next is 4mV, as shown on the right side of the figure. So long as the temperature difference exists, the voltage differences will be cumulative, totaling 16mV between top and bottom in this example.

Note that the multiple thermocouple junctions are not electrically connected with each other in each temperature zone.

In reality, more thermocouples than this will be added, and the voltage differences may be lower.

Generally a thermopile is not sold as a separate component from retail suppliers, but is built into other devices. It may be used to generate small amounts of current from a heat difference, as in an infrared thermometer. It can also be used as a safety device to shut down a gas supply if a burner is not lit. See Chapter 28.

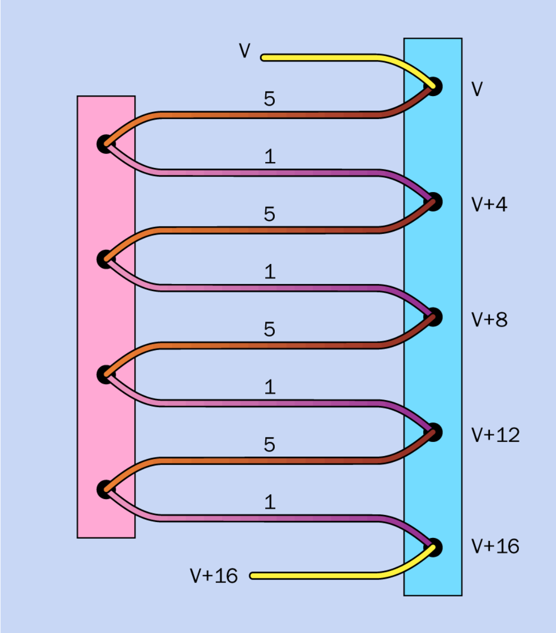

Figure 25-9 *The operating principle of a thermopile. The numbers represent mV, but are chosen arbitrarily as an example.*

What Can Go Wrong

Polarity

The output from a thermocouple has polarity. If this is not observed, an error will result.

Electrical Interference

Thermocouple wires are vulnerable to electrical interference, and should be a twisted pair or, ideally, shielded.

Metal Fatigue and Oxidation

The wire used in some thermocouples tends to be relatively brittle, and cannot withstand much flexing. Also, some metals or alloys are vulnerable to oxidation.

Using the Wrong Type

Different types of thermocouples have totally different characteristics. The electronics to decode the signal from a thermocouple must be matched to the type of thermocouple being used. The plugs on the ends of the thermocouple wires are often retained with screws. A detached plug should be replaced immediately, to avoid the error of attaching it to the wrong type of thermocouple.

Heat Damage from Creating a Thermocouple

If a thermocouple is made from two wires on a DIY basis by welding the tips of the wires together, minimal heat must be used to avoid degrading the alloys in the wires.

RTD (resistance temperature detector)

26

RTD is an acronym, either for *resistance temperature detector* or *resistive temperature device*. No definitive information seems to exist regarding which term is correct, but *resistance temperature detector* is more common.

Occasionally an RTD may be described as a *PTC thermistor*, but its sensing element is different, consisting of pure metal wire or film.

OTHER RELATED COMPONENTS

- **thermocouple** (see Chapter 25)
- **NTC thermistor** (see Chapter 23)
- **PTC thermistor** (see Chapter 24)
- **semiconductor** temperature sensor (see Chapter 27)
- **infrared temperature** sensor (see Chapter 28)

What It Does

A *resistance temperature detector*, also known as a *resistive temperature device*, is usually referred to as an **RTD**. It has a positive temperature coefficient (that is, its resistance increases as its temperature increases) but differs from a **PTC thermistor** in that its sensing element is pure metal instead of a semiconductor.

Comparison of Temperature Sensors

In this Encyclopedia, temperature sensors are divided into five main categories, each of which has a separate entry. For convenience, a comparative summary is included in the entry for **NTC thermistors**. See "Addendum: Comparison of Temperature Sensors" for an overview. Also see Figure 23-9.

RTD Attributes

Positive attributes of RTDs include:

- Accuracy, often plus-or-minus 0.01 degrees Celsius. This very small tolerance allows excellent interchangeability.
- Stability, with a response that drifts by as little as 0.01 degree per year.
- The output is an almost linear function of temperature, making them easily used with a microcontroller.
- Immunity to electrical noise.
- Reasonably rapid response to temperature changes (about 1 to 10 seconds).

Undesirable attributes include:

- Temperature coefficient about one-tenth of that of an NTC thermistor.
- To measure the resistance, some current must pass through the sensor, raising the possibility of self-heating (as in the case of other temperature sensors, with the exception of a thermocouple).
- Relatively high cost, especially of the wire-wound type.

The resistance curves for three generic NTC thermistors are shown in Figure 26-1, plotted against the resistance for a generic platinum RTD that has a reference resistance of 100 ohms at 0 degrees Celsius. Note that this graph is unlike many that illustrate the response of NTC thermistors, in that its vertical scale is not logarithmic.

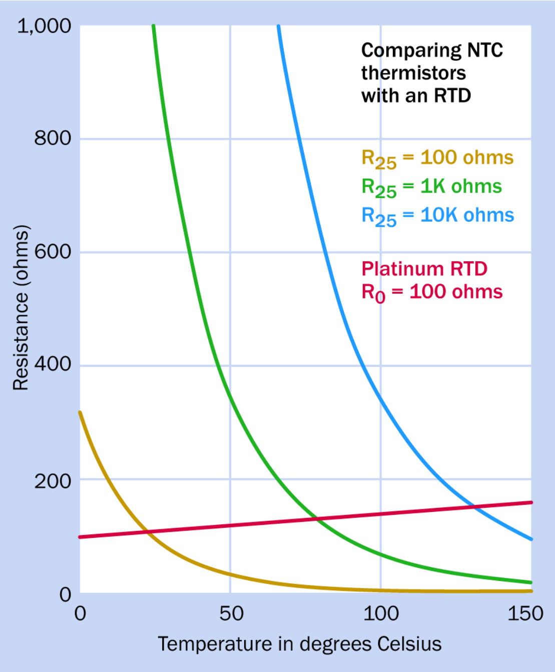

Figure 26-1 *The brown, green, and blue curves show the resistance of three generic NTC thermistors varying with temperature. The red line shows the resistance of a platinum RTD. Derived from a diagram created by Texas Instruments.*

Schematic Symbol

There is no specific schematic symbol for an RTD. Often the symbol for a thermistor may be used. See Figure 23-1.

Applications

Because of its high accuracy, an RTD may be used where precision is important. It can calibrate other temperature sensors, and may measure the temperature of a reference junction of a thermistor. However, it requires sensitive electronics for signal conditioning, because of its low temperature coefficient.

How It Works

An RTD exploits the fractional increase in electrical resistance of a metal film, metal filament, or (in some cases) a carbon film, when the temperature of the metal rises. In its simplest form, an RTD is a 2-wire device with no polarity.

The sensing element is often made from platinum, as this has a linear response to temperature over a wide range. High-quality RTD sensors with a wide temperature range usually consist of platinum wire that is wound around a glass or ceramic core. Smaller sensors may be fabricated from a thin layer of platinum evaporated onto an insulating substrate. Nickel may be substituted for platinum, and has a more sensitive but less linear response.

The wire-wound type is usable at temperatures as high as 500 Celsius (up to 1,000 degrees for some platinum-element types). Some variants are able to measure temperatures as low as -250 degrees.

DIN 60751 is an international standard defining the performance of platinum RTDs. It specifies a reference resistance of 100.00 degrees at 0 degrees, and a temperature coefficient between 0 degrees and 100 degrees. Outside of this range, a formula defines the response.

The response is almost precisely linear, ranging from 100 ohms at 0 degrees to approximately

138 ohms at 100 degrees. The temperature deviation from a straight line, between 0 and 100 degrees, is no more than plus-or-minus 0.8 degrees.

However, current through the RTD must be restricted to avoid self-heating. A range of 0.5mA to 1mA is recommended.

Variants

Some RTDs are potted in glass or resin, as shown in Figure 26-2. This shows an RTD in the TFPTL range from Vishay, containing a nickel thin-film sensing element with a temperature coefficient of about 0.4% and a tolerance of 0.01%. It is available with a very wide range of reference resistances, from 100 ohms to 5K (measured at 25 degrees Celsius). The temperature range is -55 to +70 or -55 to +150 degrees, and the maximum voltage is 30V to 40V, depending on the specific component.

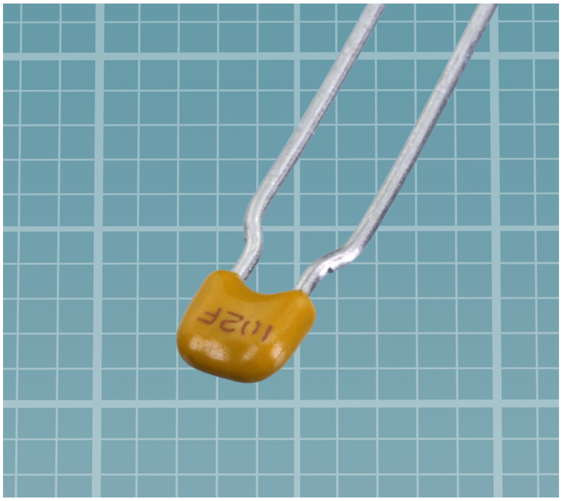

Figure 26-2 *An RTD in the TFPTL series from Vishay. The background grid is in millimeters.*

The flat package shown in Figure 26-3 may be encased in a protective sheath of plastic or silicone rubber, and can be used for surface temperature sensing where the component is glued to the exterior of a flat-sided container. This figure shows an RTD in the L420 range from Heraeus Sensor Technology, containing a platinum thin-film sensing element with a temperature coefficient of 0.385%. It is available in reference resistances of 100, 500, and 1,000 ohms (measured at 25 degrees Celsius). The temperature range is -50 degrees to +400 degrees.

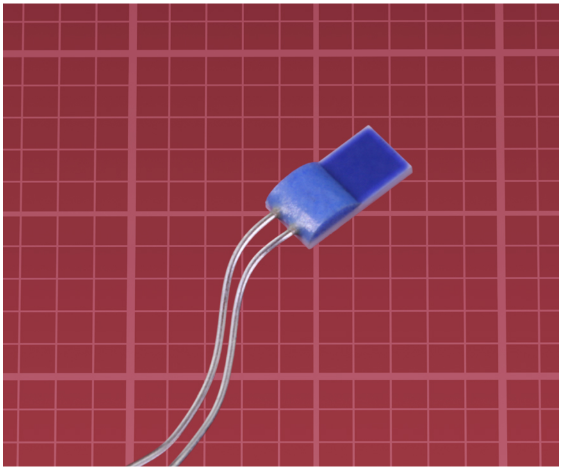

Figure 26-3 *An RTD in the L420 series from Heraeus. The background grid is in millimeters.*

Wiring

The leads to an RTD can be a source of error. If a simple 2-wire configuration is used, the leads will have an unknown resistance that will be affected by temperature, just as the element inside the RTD will have a temperature-sensitive resistance.

To enable temperature compensation, a three-wire design can be used. Figure 26-4 illustrates the principle. In the first section of this figure, resistances R_A and R_B remain unknown. In the second section, the resistances of R_B and R_C can be found by passing a test current through one wire and back through the other, bypassing the component. Assuming that all of the leads are identical in length and composition, the resistance of $R_A + R_B$ will be equal to that of $R_B + R_C$.

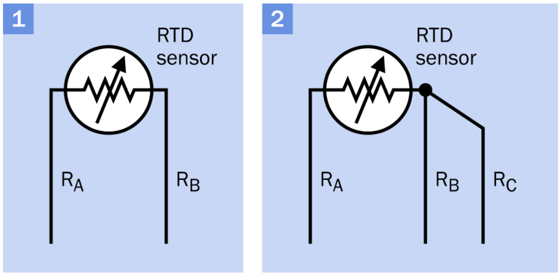

Figure 26-4 *A three-wire configuration enables temperature compensation for the leads to an RTD. See text for details.*

RTD Probe

For practical applications, an RTD sensor is often packaged inside a probe that can be indistinguishable from the type of probe used with a **thermocouple**. However, a thermocouple always uses two wires, as the wires themselves create the voltage. An RTD often uses three wires, as shown in Figure 26-5. This particular sensor is sold for use in a "Brew-Magic" system for brewing craft beer on a commercial basis.

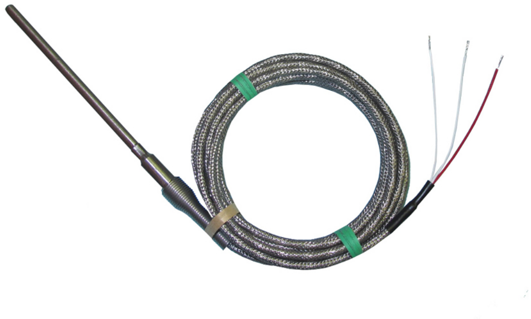

Figure 26-5 *A three-wire RTD is packaged inside this steel probe.*

Signal Conditioning

To process the signal of an RTD, a chip such as the LM75 from National Semiconductor can be used. This is calibrated for connection with a platinum RTD. Internally it converts the resistance of an RTD to a value of 5mV per degree Celsius. This then passes through an analog-to-digital converter on the chip, creating a digital value that can be read via an I2C bus.

What Can Go Wrong

Self-Heating

Self-heating is an issue for RTDs, just as it is for thermistors. Current through an RTD should be limited to 1mA, especially when measuring low temperatures.

Insulation Affected by Heat

The resistance of insulation on the wires leading to a sensor can change with temperature, leading to incorrect resistance readings. This is a more likely source of problems for RTDs than for thermistors, as RTDs are often used at higher temperatures and have a lower temperature coefficient.

Incompatible Sensing Element

If signal conditioning is applied to an RTD that has an incompatible sensing element, temperature readings will be incorrect. For example, an RTD with a nickel element should not be used with signal conditioning designed for a platinum element.

semiconductor temperature sensor

27

This type of sensor may also be referred to as a *bandgap temperature sensor*, a *diode temperature sensor*, a *chip-based temperature sensor*, or an *IC temperature sensor*.

The unfortunate term *integrated silicon-based sensor* is sometimes used, which can be confused with *silicon temperature sensor* (also known as a *silistor*), which is a type of **PTC thermistor**. See Chapter 24.

Some vendors do not divide temperature sensors into clear categories. Semiconductor temperature sensors may be classified as *board-mount* temperature sensors, even though many of them have leads and are not specifically designed to be mounted on circuit boards.

A semiconductor temperature sensor with a digital output is sometimes described as a *digital temperature sensor* or *digital thermometer*. This can be misleading, as the outputs from other types of temperature sensors may be digitized with appropriate components.

OTHER RELATED COMPONENTS

- **thermocouple** (see Chapter 25)
- **NTC thermistor** (see Chapter 23)
- **PTC thermistor** (see Chapter 24)
- **infrared temperature** sensor (see Chapter 28)
- **RTD** (resistance temperature detector) (see Chapter 26)

What It Does

A **semiconductor** temperature sensor is an integrated circuit chip incorporating a sensing element composed of transistor junctions. It has an approximately linear response and is easy to use, in some cases being designed for direct connection with a microcontroller, requiring no additional components.

In analog variants, the output consists either of voltage or current that varies with temperature. These components have a positive temperature coefficient, except for a few CMOS variants where a voltage output diminishes as temperature increases.

Digital variants are becoming more common, creating a numeric output accessible by a microcontroller.

In almost all semiconductor temperature sensors, the characteristics of silicon dioxide limit the temperature range to approximately -50 to +150 degrees Celsius (sometimes less).

This type of component is not (yet) as low in cost as a thermistor, but can include its own amplification, signal processing, and (optionally) analog-to-digital conversion on one chip.

Comparison of Temperature Sensors

In this Encyclopedia, temperature sensors are divided into five main categories, each of which has a separate entry. For convenience, a comparative summary is included in the entry for **NTC thermistors**. See "Addendum: Comparison of Temperature Sensors" for an overview. Also see Figure 23-9.

Semiconductor Temperature Sensor Applications

When a semiconductor temperature sensor is used in surface-mount format, it can measure the temperature of the board on which it is mounted. This enables protection from overheating, often in power supplies.

Because the sensing elements and signal processing circuits are all chip-based, they can be transplanted into other types of sensors. For example, a gas pressure sensor or a proximity sensor can have onboard compensation using a semiconductor temperature sensor. They have also been built into computer CPUs such as the Pentium series from Intel.

Some variants are manufactured in a three-lead TO-92 package, appearing superficially similar to bipolar transistors. They are suitable for remote temperature sensing, and have automotive applications such as measuring the temperature of the transmission, engine oil, or cabin interior. They may also be found in some heating and air-conditioning systems, and some kitchen equipment.

Schematic Symbol

No unique schematic symbol has been developed for a semiconductor temperature sensor. It may be represented by a rectangle containing text abbreviations to represent pin functions, similar to other types of integrated circuit chips.

In the case of a sensor with an output consisting of current that varies with temperature, the sensor may be shown as a *current source*, using the symbol in Figure 27-1. However, this symbol is not specific to temperature sensors; it is used for any component that is a current source.

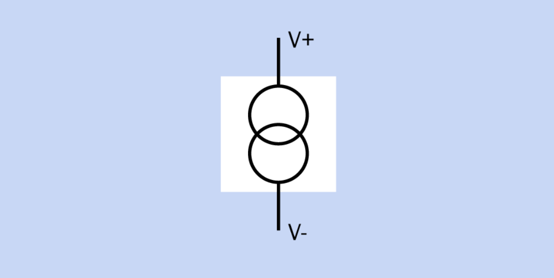

Figure 27-1 *A temperature sensor whose output consists of current varying with temperature may be shown in a schematic as a current source, using this symbol.*

Attributes

Desirable attributes of a semiconductor temperature sensor include:

- Easy to use. Few or no external components may be required, and little or no signal processing.
- Factory-calibrated, with an almost linear response.
- Versions with a digital output are easy to add to any system that already has an I2C bus. For additional details about protocols such as I2C, see Appendix A.

Undesirable attributes of semiconductor temperature sensors include:

- Limited temperature range, the same as thermistors.
- Self-heating issues, especially in versions where signal-processing functions are built into the same chip.

- Not as rugged as some types of temperature sensors.

For an explanation of terminology used for temperature sensors in datasheets, see "Thermistor Values".

How It Works

When a constant current is flowing through a p-n junction in a diode, the voltage across the diode will change by about 2mV for each change in temperature of 1 degree Celsius. This can be demonstrated by the simple circuit shown in section 1 of Figure 27-2.

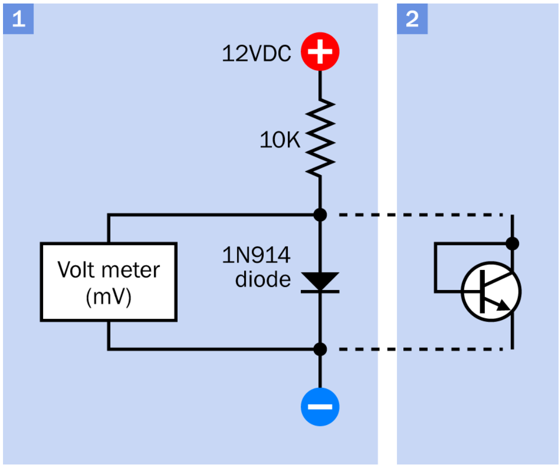

Figure 27-2 *Left, a basic circuit for demonstrating the temperature sensitivity of a diode. Right, an NPN transistor can be substituted to emulate the diode.*

Similarly, the voltage across the p-n junction in an NPN transistor varies with temperature, if the current is constant. A transistor can be substituted for a diode as suggested in section 2 of Figure 27-2. Integrated circuit chips that contain transistors can measure temperature by exploiting this phenomenon.

CMOS Sensors

Some semiconductor temperature sensors use CMOS instead of bipolar transistors. The general concept is similar, but they are described separately, below. See "CMOS Semiconductor Temperature Sensors".

Multiple Transistors

The heat sensitivity of a bipolar transistor can be defined with an equation. If the base-emitter voltage is V_{BE}, q is the charge of an electron, k is a constant (known as Boltzmann's constant), T is the temperature in degrees Kelvin (relative to absolute zero), I_C is the collector current, and I_S is the saturation current (which is less than I_C):

$$V_{BE} = ((k*T) / q) * \log_e (I_C / I_S)$$

The term $\log_e$ means, "the logarithm to base e of the expression in parentheses."

Because k and q have known values, the base-emitter voltage turns out to be proportional to the logarithm of the collector current divided by the saturation current. However, the saturation current depends on the geometry of a transistor, and varies with temperature in a nonlinear way.

To eliminate the factor of saturation current, one transistor can be compared with another transistor that has a larger emitter area. This enables the derivation of a new equation that specifies temperature while getting rid of the troublesome saturation currents, with their nonlinear behavior.

However, it may not be easy to fabricate two transistors, in the same silicon chip, that have the same characteristics except that the emitter area of one is bigger than that of the other. It is much easier to add multiple transistors in parallel, each of them identical to the first. The total emitter area will then be equal to the area in one transistor multiplied by the number of transistors.

In Figure 27-3, assuming all the transistors are at the same temperature in addition to being of identical specification, we can now write two equations. The figure allows room to show only three transistors, but suppose there are N of them. If V_{BE0} is the base-emitter voltage of transistor Q0, on the left, and V_{BEN} is the aggregate base-emitter voltage of the N transistors on the right:

$$V_{BE0} = ((k*T) / q) * \log_e (I_C / I_S)$$

$$V_{BEN} = ((k*T) / q) * \log_e (I_C / N*I_S)$$

From these, an equation can be derived that gets rid of I_C and I_S:

$$V_{BE0} - V_{BEN} = ((k*T) / q) * \log_e (N)$$

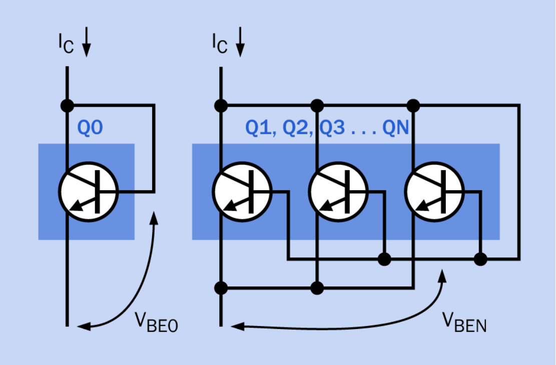

Figure 27-3 *Comparing the base-emitter voltage of one transistor with a set of identical transistors can enable measurement of temperature regardless of the collector current and saturation currents, so long as all the transistors are at the same temperature. See text for details.*

PTAT and the Brokaw Cell

Now if a comparator is added to control the current, a circuit known as the Brokaw Cell is created, shown in Figure 27-4. This is also known generically as a *bandgap temperature sensor*. (A couple of resistors have been omitted for the sake of simplicity.)

Typically, N = 8. That is, there is a set of eight transistors in addition to Q0 (only three being shown here). The voltage difference in the previous equation, V_{BE0} - V_{BEN}, now appears across R2 in the figure, and the voltage across R1 is *proportional to absolute temperature*, often referred to by its acronym, *PTAT*. This voltage can be found from this equation:

$$V_{PTAT} = ((k*T)/q) * \log_e(N) * (2*R1/R2)$$

The Brokaw Cell was the basis of the AD580 chip introduced in 1974 by Analog Devices, and the principle is now used very widely in semiconductor temperature sensors.

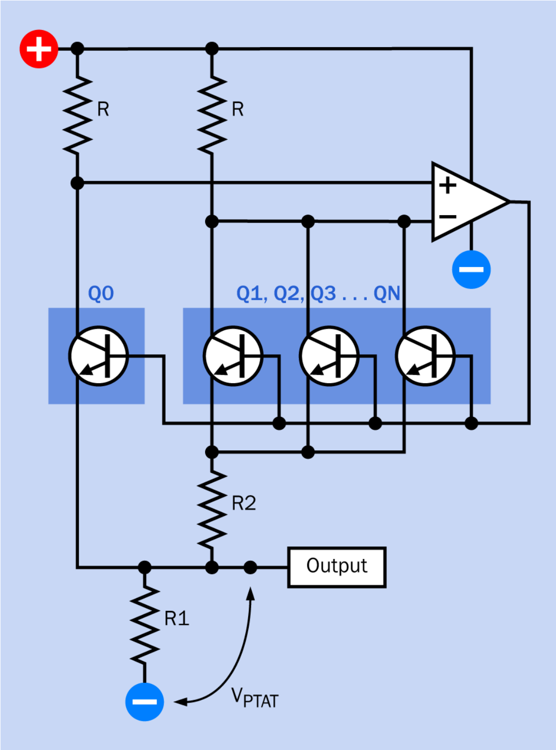

Figure 27-4 *The Brokaw Cell. See text for details.*

Variants

Three output types are used:

- Analog voltage output (voltage varies with temperature).
- Analog current output (current varies with temperature).
- Digital output.

A fourth type creates an output in the form of a square wave, either with a frequency or wavelength proportional to temperature. The Maxim MAX6576 and MAX6577 are examples. However, this type of output is so rare, it is not described in detail here.

Some semiconductor temperature sensors are CMOS-based, and have a voltage output with a negative temperature coefficient. They are described separately. See "CMOS Semiconductor Temperature Sensors".

Analog Voltage Output

LM35 Series

The LM35 is a typical, widely used semiconductor temperature sensor, available from Analog Devices, Texas Instruments, and other manufacturers. Its output voltage changes by 10mV per degree Celsius over a range of approximately -50 degrees to +150 degrees. Accuracy is stated to be plus-or-minus 0.25 degrees at room temperature and plus-or-minus 0.75 degrees over the whole range.

The sensor can be obtained packaged like a transistor, in a TO-92 plastic capsule or metal can. It is also available as a surface-mount component, or in a TO-220 package, like a 5V voltage regulator, as shown in Figure 27-5.

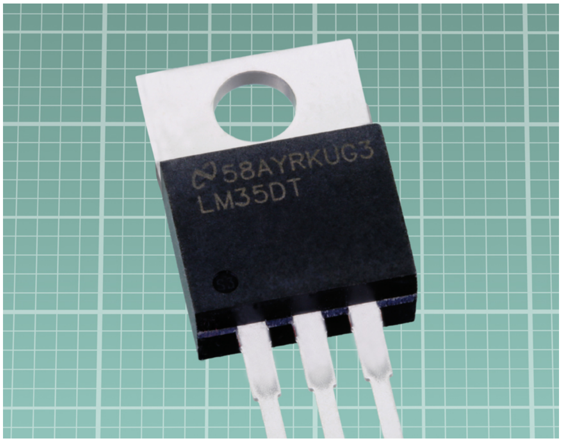

Figure 27-5 *This version of the LM35 can be used to measure surface temperature when secured with a bolt. The background grid is in millimeters.*

This is a three-wire component, two pins or solder pads being used for the power supply while the third serves as the sensor output. The supply voltage typically ranges from 4V to 30V. Necessary current consumption is only 60μA, which minimizes self-heating.

Because this device is specifically designed for the Celsius temperature range, its output is scaled to 0mV at 0 degrees. A pulldown resistor can be added to measure temperatures below zero.

A bypass resistor of 200 ohms between the output and ground is recommended as a precaution against capacitive effects in the cable run.

The LM34 is almost identical to the LM35, except that its output changes by 10mV per degree Fahrenheit instead of 10mV per degree Celsius.

LM135 Series

Although this sensor contains multiple NPN junctions, the manufacturer describes it as behaving like a zener diode in which the breakdown voltage is directly proportional to absolute temperature. The output increases by 10mV per degree over a range from -55 to +150 degrees Celsius.

For the LM135, the manufacturer claims an error of less than plus-or-minus 1 degree Celsius between 0 and 100 degrees. For the LM235 and LM335, in the same product series, the temperature range is narrower, the accuracy is lower, and the price, also, is lower. An LM335 sensor is shown in Figure 27-6.

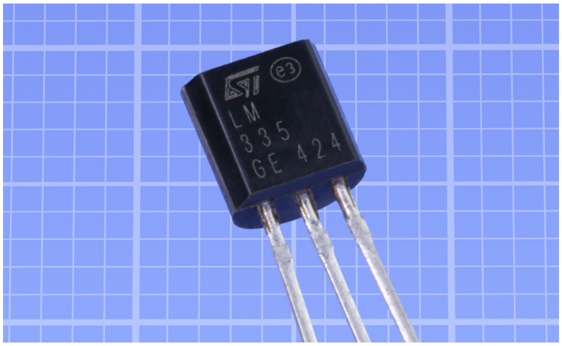

Figure 27-6 *A sample of the LM335 temperature sensor in a TO-92 package. The background grid is in millimeters.*

The sensor is available in a TO-92 package (plastic, like a transistor) or a TO-46 (metal can). It is also manufactured in a surface-mount format. The negative terminal is connected directly to ground, while the positive terminal is connected through a series resistor to the positive side of a power supply that can range from 5V to 40V. The third terminal, labeled "ADJ" on datasheets, allows for the output to be adjusted. Figure 27-7 shows the basic circuit. The value of R1 can be chosen to establish an optimal current of 1mA through the sensor, although a range of 400μA to 5mA is tolerable.

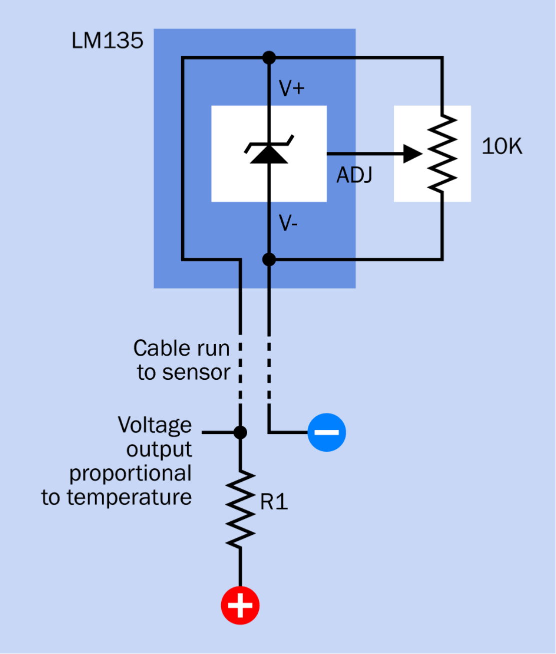

Figure 27-7 *Basic schematic for using an LM135, including output adjustment. Because the sensing element behaves like a zener diode, it is represented with the zener symbol.*

Analog Current Output

Fewer components exist using output current to measure temperature. The output is applied to a grounded resistor, and the voltage across the resistor then changes with current from the sensor.

The useful aspect of a current output is that its accuracy is unaffected by a cable run as long as 200 or 300 feet. Therefore, this type of component is appropriate as a remote sensor.

LM234-3 Series

This is a three-wire sensor, two wires being used for bias power supply and ground (labeled V+ and V- on the datasheet) and a third (labeled R) that delivers current proportional to temperature. The current from pin R passes through an external resistor to ground, and the voltage across this resistor varies by 214μV per degree Kelvin. A bias voltage ranging from 1V to 40V is required.

A sample of the LM234 is shown in Figure 27-8.

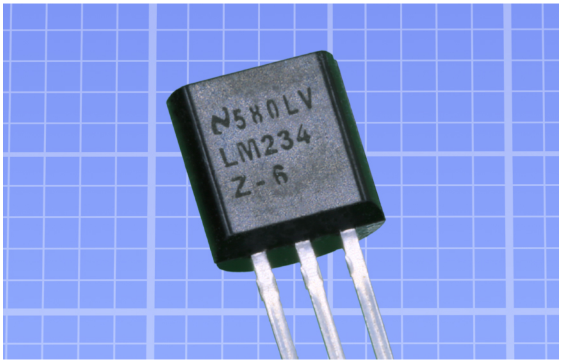

Figure 27-8 *The LM234Z temperature sensor in a TO-92 package. The background grid is in millimeters.*

If the component is used for remote sensing, the resistor should be 230 ohms and can be connected directly between pin R and pin V- of the sensor at the far end of a wire run. At the "home" end of the wire run, temperature output is taken from above a 10K resistor that is placed between the return wire and ground, as shown in Figure 27-9. With these component values, the output voltage will change by 10mV per degree Kelvin.

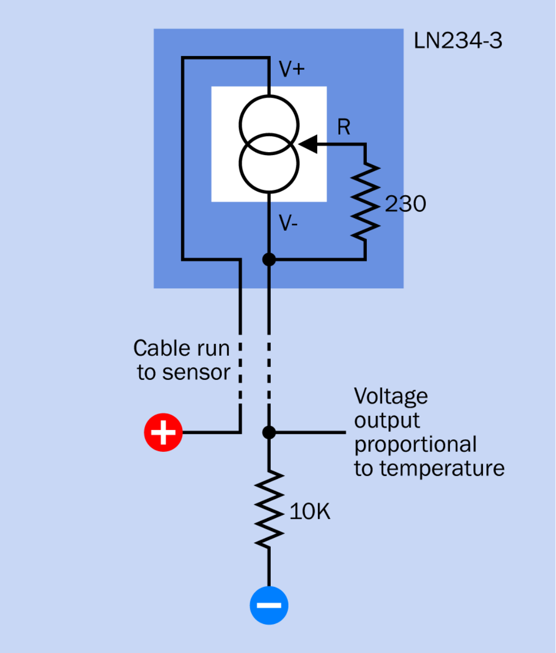

Figure 27-9 *Using an LM243-3 sensor with a current output that varies with temperature.*

The LM234-3 can be encapsulated in a plastic TO-92 package or a TO-46 metal can. A surface-mount version is also available.

The claimed accuracy is plus-or-minus 3 degrees. The temperature range is -25 degrees to +100 degrees.

AD590 Series

The Analog Devices AD590 (successor to the original AD580) is a current-output sensor that uses only two wires. Like the LN234-3 it is available in a TO-46 metal can, but with one lead making no internal connection. It also can be bought in a two-wire "flatpack," or as a surface-mount chip (with eight solder pads, only two of which are connected).

Using a supply voltage of 4V to 30V, the sensor's high-impedance output changes by 1μA per degree Kelvin. Voltage supply variations produce very small errors in the output current; substituting 10V for 5V creates a deviation of only 1μA.

Figure 27-10 shows an application for the AD590 using a resistor and a trimmer to adjust the scale factor. When properly set up, this circuit provides an output that changes by 1mV per degree Kelvin.

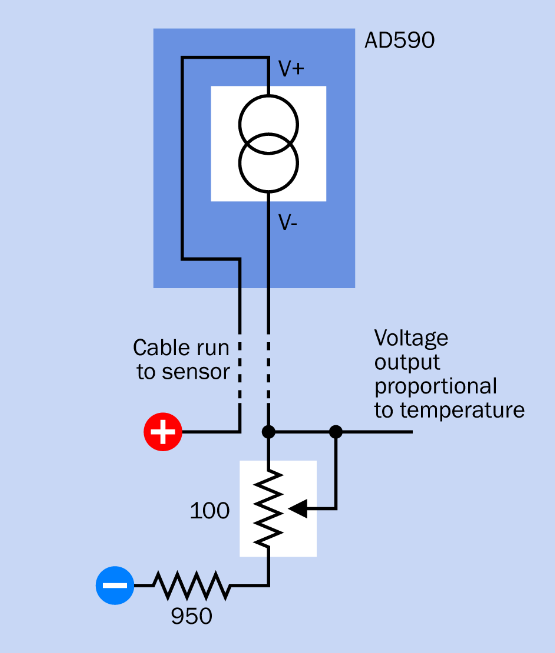

Figure 27-10 *The simplest circuit allowing fine adjustment for use with an AD590 sensor.*

Digital Output

Some of the most popular examples of semiconductor temperature sensors with digital output include the TMP102 series from Texas Instruments, MCP9808 series from Microchip, LM73 series from Texas Instruments and National Semiconductor, and DS18B20 series from Maxim. All of these components can measure a range typical of semiconductor temperature sensors, from approximately -50 to +150 degrees Celsius. Most of them claim an accuracy in the region of plus-or-minus 1 degree over the full range or 0.5 degree in the 0 to 100 range. With the exception of the Maxim DS18B20, which uses its own unique protocol, the components communicate via either the I2C or SMBus protocol.

TMP102 Series

This is available only in a surface-mount format. It has fewer features than the other sensors listed here, and is less accurate, claiming plus-or-minus 3 degrees Celsius over its maximum range of -40 to +125 degrees Celsius. However, it is less expensive. (For greater accuracy, the TMP112 is available.) This is a low-voltage chip requiring 1.4V to 3.6V as its power supply, drawing a quiescent current of 10μA. Temperatures are stored in a 12-bit or 13-bit format that requires some conversion, as a single bit represents 0.0625 degrees Celsius. An alert pin is activated when the measured temperature deviates above or below limits that are preset by the user. No hysteresis adjustment is available for the alerts. The TMP102 is available on a breakout board from Sparkfun, as shown in Figure 27-11.

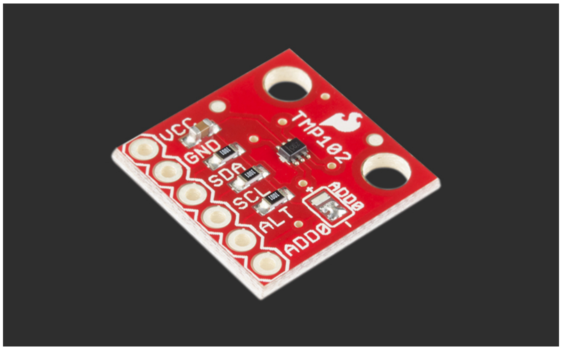

Figure 27-11 *The Texas Instruments TMP102 on a breakout board from Sparkfun.*

MCP9808 Series

This multifunction sensor is available either as a regular surface-mount component, or as a surface-mount with an exposed “thermal pad.” It conforms with the I2C bus standard at up to 400kHz, allowing up to 16 sensors to share the same bus. The chip has a variety of temperature alert features, including high and low limits that can activate a dedicated “alert” pin, and a hysteresis value that can be set for the limits, to ignore brief temperature excursions. The chip can be put into “comparator mode,” where it simply provides logic-high or logic-low output if the temperature is above or below a user-specified value. This feature makes the chip operate as a thermostat. Temperature resolution is user-selectable. The temperature storage format requires some conversion to obtain a Celsius value, to deal with negative values and fractional values. However the chip is available on a breakout board from Adafruit, as shown in Figure 27-12, and an Arduino code library is available.

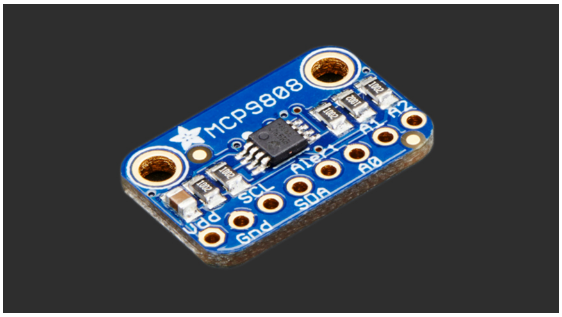

Figure 27-12 *The Microchip MCP9808 on a breakout board from Adafruit.*

LM73 Series

This sensor is only available in surface-mount format. It conforms with the I2C bus standard at up to 400kHz. Its temperature resolution can be set to 11, 12, 13, or 14 bits. An “alert” pin becomes active if the temperature exceeds a preprogrammed limit. An “address” pin can select one of three device addresses by being held in logic-high, ground, or disconnected status. The chip can be put into shutdown mode when power conservation is necessary.

DS18B20 Series

Unlike most digital sensors, this is a three-wire component, because it uses Maxim’s proprietary “1-wire bus” with a unique protocol. The bus allows access to a 2-byte register storing digital output from the temperature sensor, but also allows the user to perform other functions, such as setting the resolution of an onboard analog-to-digital converter (which has a maximum resolution of 12 bits), setting a high-temperature and low-temperature alarm, and allowing the sensor to be identified, as each component has a unique 48-bit serial number in ROM.

The chip can draw sufficient power from the data bus to operate, so long as the bus is held high by a 4.7K pullup resistor. (Maxim describes this as “parasite power.”) An internal capacitor sustains the chip briefly while the bus is used for its normal purpose of transferring data, but if the bus has low voltage for more than 480μs the chip will reset itself. The “parasite power” feature also will not work above 100 degrees Celsius. Perhaps recognizing that this system may create more problems than it solves, Maxim has also given the component a normal power input pin.

The DS18B20 is available in the TO-92 package and two sizes of surface-mount chip. Its lack of a standard I2C bus, and its use of complicated proprietary codes, create a steep learning curve. Still, it remains a popular sensor, and an Arduino code library for it is available online.

CMOS Semiconductor Temperature Sensors

CMOS variants of semiconductor temperature sensors have appeared relatively recently compared with the bipolar variants. They draw a very low quiescent current (typically, a few microamps) and can work with a power supply from 5.5VDC down to 2.2VDC, making them suitable for handheld battery-powered devices. An analog output is common. Popular examples are the LM20 and the LMT86 series.

Like bipolar sensors, the LMT86 sensors have a limited temperature range, between approximately -50 and +150 degrees Celsius. Again, like the bipolar sensors, they are available optionally in TO-92 and surface-mount packages. A significant difference is that the output has a negative temperature coefficient, diminishing by 10mV per degree Kelvin, because of the characteristics of CMOS semiconductors. The claimed accuracy is plus-or-minus 0.25 degrees Celsius. The output voltage covers a range of about 2V, diminishing from 0.5V below the supply voltage at -50 degrees Celsius.

A sample of the LMT86 is shown in Figure 27-13.

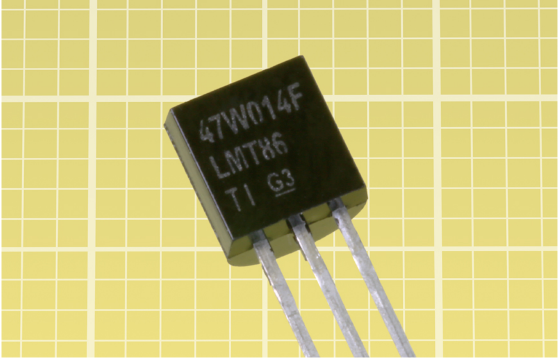

Figure 27-13 *A sample of the LMT86 CMOS temperature sensor. The background grid is in millimeters.*

What Can Go Wrong

Different Temperature Scales

Some voltage-output sensors create an output convertible to degrees Kelvin, while others use degrees Celsius. While the temperature degrees are the same in each scale, a component with an output in millivolts may assign 0mV either to 0 degrees Celsius or 0 degrees Kelvin (equivalent to -273.15 degrees Celsius). The advantage of using a Kelvin scale is that it avoids the problem of negative temperature values.

Rarely, a sensor may use degrees Fahrenheit.

Interference in Cable Runs

Sensors with a voltage output are susceptible to electrical interference. Twisted-pair or shielded cable runs are recommended when sensors are placed remotely.

For the Maxim DS18B20, which uses a 1-wire bus, multiple sensors should be connected along one run of wire (linear topology) instead of each sensor being connected to a central point (star topology). If the cable lengths are longer than a few meters, the topology starts to matter.

Latency

The packaging of semiconductor temperature sensors can create latency in their response time. While a thermocouple consists only of a pair of wires joined by a small dot of melted metal, a TO-92 semiconductor package adds thermal mass that will slow the response considerably. Moreover, copper leads will conduct heat from a circuit board if the board is warmer than its environment.

Surface-mount chips have a very low mass, but must be soldered to some kind of board, even if it is a very small one.

Generally, other types of sensors may be appropriate where rapid response is necessary.

Processing Time

In a sensor with a digital output, the onboard analog-to-digital converter will add a small delay before the data becomes available, and during that delay, the component cannot respond to a new temperature. The output from an analog device may be more suitable for rapid detection of temperature variations.

infrared temperature sensor

28

An **infrared temperature** sensor is sometimes described as a *thermopile*. In reality the sensor module *contains* a thermopile. In this Encyclopedia, a thermopile is considered to be a separate component, described in the entry discussing **thermocouples**. See "Thermopile" in Chapter 25.

Other terms that are sometimes used for an infrared temperature sensor are *contactless thermometer* or *infrared thermometer*. This Encyclopedia classifies a thermometer as a commercially marketed product, not a component.

Devices such as a *radiation pyrometer*, *IR pyrometer*, *optical pyrometer*, or *thermal imager* provide ways of measuring infrared radiation, but are outside the scope of this Encyclopedia.

A **passive infrared** motion sensor (PIR) can detect infrared radiation, but only responds to fluctuations in intensity. An infrared temperature sensor measures the steady-state value of incident radiation.

OTHER RELATED COMPONENTS

- **passive infrared** motion sensor (see Chapter 4)
- **thermocouple** (see Chapter 25)

What It Does

Most temperature sensors discussed in other entries in this Encyclopedia are *contact sensors*, meaning that to measure the temperature of an object, liquid, or gas, they must make contact with it. In situations where contact is not possible or desirable, an **infrared temperature** sensor can be used. It responds to the *black-body radiation* (sometimes known as *characteristic radiation*) that is emitted by all materials above absolute zero (0 degrees Kelvin). This varies with temperature as a result of the movements of molecules.

Situations where noncontact sensors may be preferable to contact sensors include:

- An object is inconveniently located or too far away.
- The temperature of a large area must be measured.
- Contact with a small object would change the temperature of the object. The act of measurement would change the value being measured.
- The object is corrosive, abrasive, or otherwise liable to damage a sensor.
- The object is moving or vibrating.
- The surface of the object must not be contaminated (for example, unprotected foods).

- The temperature of the object is lower than around -50 degrees Celsius or higher than 1,300 degrees Celsius.

However, noncontact sensors have some limitations:

- Normally, only the surface temperature of a target can be measured.
- The optics of the sensor must be protected from dust, dirt, and liquid.
- The target must be clearly visible, in line-of-sight.
- Air pollution will degrade the temperature measurement. Some gases, such as carbon dioxide, will tend to absorb infrared radiation.
- The sensor will be affected by other sources, including reflected, transmitted, and convective heat.
- While an infrared sensor can theoretically respond to a very wide range of temperatures, in practice separate sensors of differing sensitivity are needed to cover a full range.
- Different types of materials emit differing intensities of black-body radiation, even if they are at the same temperature. Some compensation is necessary, or the surface of the object may have to be painted.

Applications

Handheld contactless thermometers were an early application for noncontact sensors.

In astronomy, the thermal radiation from the Sun and other stars is of interest to astronomers.

More recently, the declining cost of an infrared temperature sensor, and the ease of deploying it, have made it appropriate in consumer products. A significant area of adoption is in notebook computers and handheld devices, where processor performance must be balanced against the need to prevent the case from becoming too hot to hold comfortably. In this kind of application, gluing a sensor to the interior of the case would be a manual operation during the production process and would require a wired connection. An infrared temperature sensor mounted on the circuit board, viewing the underside of the case, can achieve the same objective more simply.

A contactless sensor is also very useful for measuring the temperature of rotating objects, such as heating rollers in a laser printer.

Schematic Symbol

No specific schematic symbol exists for an infrared temperature sensor.

How It Works

While nanometers (abbreviated nm) are generally used to measure visible wavelengths, the longer wavelengths of far-infrared are often measured in micrometers (abbreviated µm). The measurable infrared values are defined as ranging from 0.7µm to 14µm, corresponding to peak emissions from a black body ranging in temperature from 200 degrees Kelvin to 6,000 degrees Kelvin (about -70 to +5,700 Celsius).

Unfortunately an object does not emit just one wavelength of black-body radiation for each temperature value. It emits a spread of wavelengths that becomes wider as the temperature increases. However, the peak intensity also increases with temperature, when measured as *spectral radiance*, which is defined as watts per steradian, per micrometer of wavelength. (A steradian is the solid angle at the top of a cone, in this case the cone being of emitted radiation.) Because the intensity increases, it can be used to calculate the temperature.

Figure 28-1 illustrates this concept. Note that both of the axes have logarithmic scales.

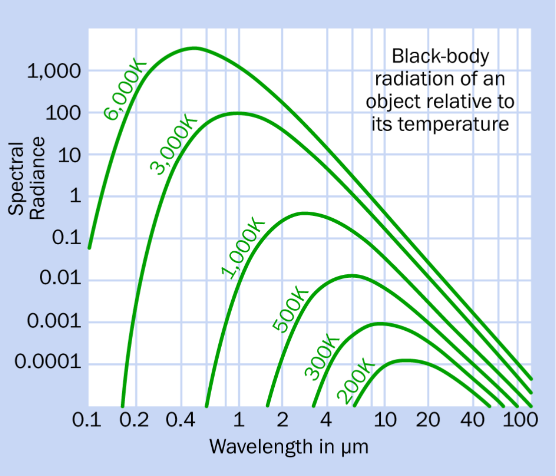

Figure 28-1 *The increase in intensity, and the widening spread of wavelengths, of black-body radiation emitted by one object at six different temperatures (in degrees Kelvin).*

All the curves are for one object. Each curve is specific to one temperature in degrees Kelvin, showing how the intensity of emitted radiation varies with wavelength. Note that radiation at wavelengths shorter than 0.7μm is within the visible spectrum; thus, objects at 1,000 degrees Kelvin, or hotter, may be seen to glow visibly.

Because of the wide variety of intensities and temperatures, an infrared sensor that is ideal for measuring a temperature of 1,000 degrees Kelvin will not provide an accurate result at 200 degrees Kelvin. The peak spectral radiance at 1,000 degrees is more than 10,000 times the peak at 200 degrees. Also, the curves in the figure are for an "ideal" object emitting pure black-body radiation. In reality, glass, plastic, and many other materials have a much lower *emissivity*, meaning that they emit less radiation, and are classified as *gray bodies*. A metallic object with a polished surface may emit one-tenth of true black-body radiation.

These issues cannot be ignored, but may be dealt with by relatively simple strategies. Infrared sensors will be rated according to their suitability for different temperature ranges, and the emissivity of the object being measured can be determined by consulting standard tables. Alternatively, the object can be spray-painted with special black paint (such as "Senotherm" or "3-M Black") that has a known emissivity of about 0.95 of pure black-body radiation. Alternatively, a specially formulated black sticker may be applied to the object that is being measured, so long as its temperature is within reasonable limits.

However, a basic infrared temperature sensor will not function reliably if it is pointed randomly at a variety of objects that vary widely in temperature. Specialized, expensive industrial devices incorporate compensation to deal with these issues, but they are outside the scope of this Encyclopedia.

Thermopile

A typical low-cost, chip-based infrared temperature sensor contains a *thermopile* consisting of multiple thermocouples etched into silicon and connected in series. The concept of a thermopile is illustrated in Figure 25-9, where a brief explanation is included.

The configuration of the thermopile is arranged so that the hot junctions of its thermocouples are all clustered in a small central area, where they receive incoming radiation through a window (often made of silicon) that is transparent to infrared wavelengths. The cold junctions are dispersed around the periphery, where they are shielded from incoming radiation. One way to visualize this is shown in Figure 28-2, although this is not a literal depiction of an actual sensor.

Instead of using alternating types of wire, as in a **thermocouple**, a chip-based thermopile often uses alternating segments of n-type and p-type silicon. The hot junctions are mounted on a thin film that has very little heat capacity, while the cold junctions are mounted on a thicker substrate that acts as a heat sink.

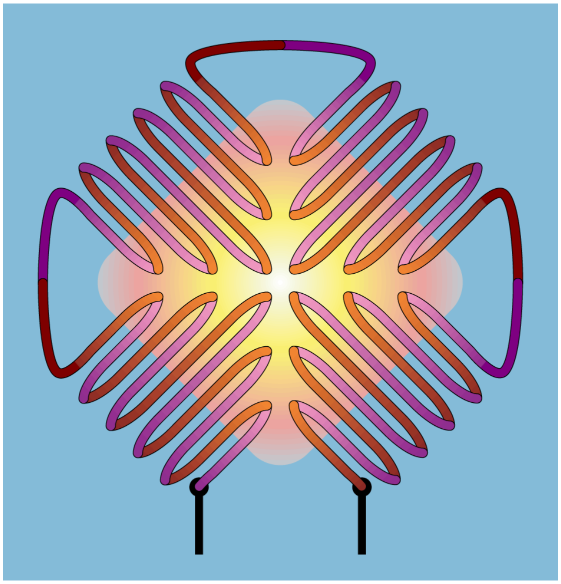

Figure 28-2 *Simplified diagram of the thermopile configuration inside an infrared sensor chip. Radiation arriving through a window in the chip affects the thermocouple junctions in the central region, while junctions around the edges remain at a lower temperature.*

Temperature Measurement

The voltage generated by the thermopile is related to the difference in temperature between the hot and cold thermocouple junctions. Thus there are three interrelated variables: hot temperature, cold temperature, and voltage. To calculate one variable, we must know the other two.

The hot temperature is what we wish to know. Therefore we must establish the voltage (which can easily be measured) and the cold temperature. The cold temperature can be determined by adding a thermistor inside the chip.

Typically an infrared temperature sensor with an analog output will have two pins that provide access to the internal thermistor, so that its temperature can be calculated from its resistance. Another two pins provide the voltage between the ends of the thermopile.

Interpreting and reconciling these values is not a trivial matter, especially bearing in mind that the thermistor has a negative temperature coefficient and a nonlinear output, and the thermopile will also have some nonlinearity. To simplify this situation, some infrared temperature sensors incorporate electronics to perform the necessary calculations and provide a digital output. This output can be converted to degrees of temperature by some fairly simple mathematical operations in an external microprocessor.

Variants

Two types of sensors are popular. One is surface-mounted, such as the TMP006, shown in Figure 28-3. This type generally has a digital output. The other type is a discrete component with four leads, such as the Amphenol ZTP135, shown in Figure 28-4. Discrete components may have either an analog or a digital output.

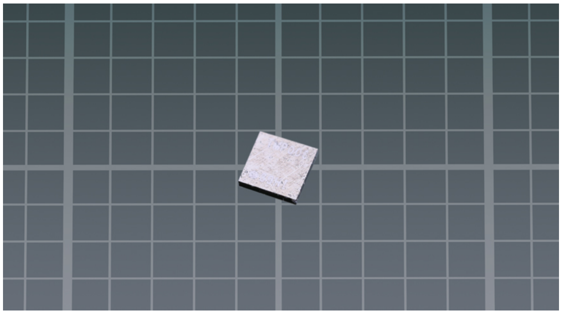

Figure 28-3 *A surface-mount infrared temperature sensor with digital output. Eight tiny solder pads are located on the underside. The background grid is in millimeters.*

Both types of sensors allow infrared light to enter through an area that is opaque to the visible spectrum but transparent to the appropriate range of wavelengths.

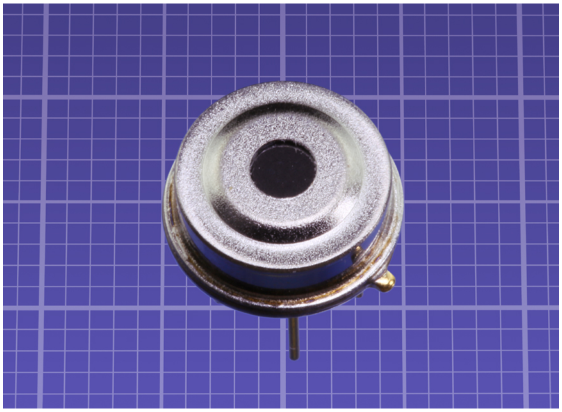

Figure 28-4 *A through-hole infrared temperature sensor with analog output. The background grid is in millimeters.*

The ZTP135 has an analog output shown in Figure 28-5.

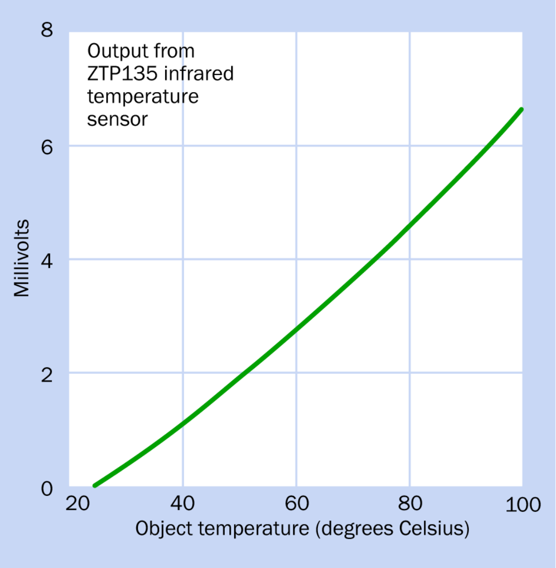

Figure 28-5 *Analog output from an infrared temperature sensor.*

The TMP006 is only about 1.5mm square, but is available on a breakout board from Sparkfun. Its successor, the TMP007, is available on a breakout board from Adafruit, shown in Figure 28-6.

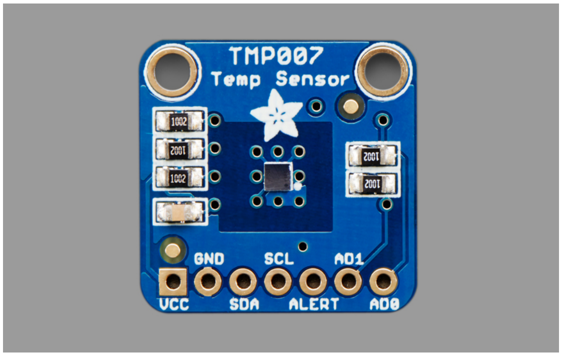

Figure 28-6 *The TMP007 sensor mounted on a breakout board from Adafruit.*

Surface-Mount Specifications

The TMP006 and TMP007 require a supply voltage that can range from 3.3V to 5V. These chips support the SMBus and I2C bus protocols, using a bus address that can be user-selected. An internal analog-to-digital converter uses 1 least-significant bit to represent 1/32nd of a degree Celsius, and data is saved as a 14-bit signed integer. Up to 16 temperature samples can be averaged internally.

Measurable temperature range is -40 to +125 degrees Celsius. Some hysteresis is built in. The TMP007 supports an alert mode if temperature falls above or below a user-specified threshold.

Sensor Arrays

Using multiple thermopile sensors arrayed in a line or a grid, with an array of lenses, it is possible to capture an image of temperature variations over a surface or a scene. This is known as *thermal imaging*. It can detect heat leakage from buildings, indicating poor insulation, or can locate hot spots in electronic circuits. Heimann Sensor has pioneered the miniaturization of a 31 x 31 grid of thermopile sensors in a single TO-8 or TO-39 package.

Values

Temperature Range

Chip-based infrared temperature sensors are typically designed for a range from about -20 degrees Celsius to about +125 degrees Celsius. Their peak sensitivity is to wavelengths between 4µ and 16µm.

Other types of infrared temperature sensors can have a much wider temperature range, but are more costly.

Field of View

Often referred to by its acronym, *FOV*, the field of view is the angle at the apex of an imaginary cone extending outward from the sensor, defining a boundary where the sensitivity diminishes below 50% of the value directly in front of the sensor. Greek letter ϕ may be used to represent the angle between the surface of the cone and the center line, while θ represents the angle between the opposite surfaces of the cone (i.e., 2 * ϕ). This is shown in Figure 28-7. θ is usually the angle defined as field of view.

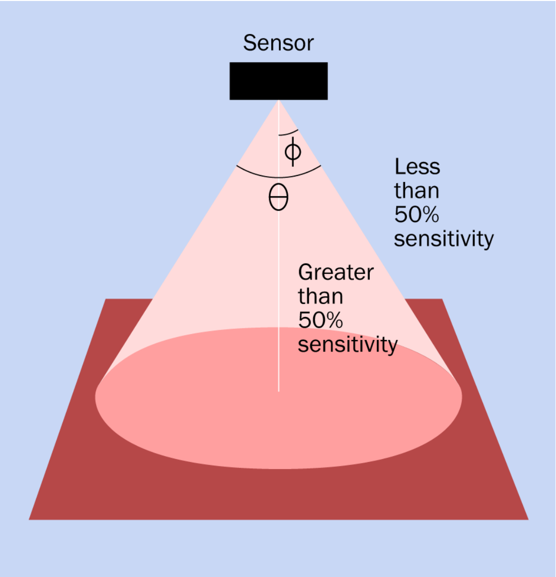

Figure 28-7 *Measurement of the field of view from a sensor, defined as the boundary of an imaginary cone where sensitivity drops below 50%.*

Because most infrared temperature sensing components do not have a lens, they are sensitive over a wide angle. The field of view is typically 90 degrees.

What Can Go Wrong

Inappropriate Field of View

The object being evaluated must fill the field of view of the sensor, to avoid measuring other objects around it.

Reflective Objects

A reflective object has lower infrared emissivity, and also may provide misleading output if the sensor is actually measuring thermal radiation reflected in the surface of the object in front of it. In a permanent installation, such as inside a device, the surface to be measured may have to be painted to reduce its reflectivity.

Glass Obstruction

Because glass is opaque to the spectrum of infrared that is of interest, temperature cannot be measured through a glass window. Silicon is opaque to visible wavelengths but is transparent to wavelengths longer than 2µm.

Multiple Heat Sources

Heat is transferred by convection, conduction, and radiation. While an infrared temperature sensor is designed to be sensitive to radiation, it will also respond to other heat sources. Warm or cold air currents will affect its response, and so will heat conducted through the material on which it is mounted. Careful placement of the sensor is important. A shield around the sensor, with a small hole in the center, can prevent convection, while correct location on a circuit board can minimize conduction.

Thermal Gradients

An infrared temperature sensor should be mounted in a stable environment where it will not be exposed to thermal gradients (one side being hotter than another). This asymmetry can cause inaccurate readings.

microphone

29

OTHER RELATED COMPONENTS

- **speaker** (see Volume 2)
- **headphone** (see Volume 2)

What It Does

The sensation of sound is created by rapid waves of air pressure impinging upon the eardrum. A microphone can convert these pressure waves into an alternating electrical signal that can be amplified, recorded, broadcast, transmitted through wires, and reproduced as sound by a headphone or speaker. The principle is illustrated in Figure 29-1. (For more information about sound reproduction, see the entries on **headphone** and **speaker** in Vol. 2.)

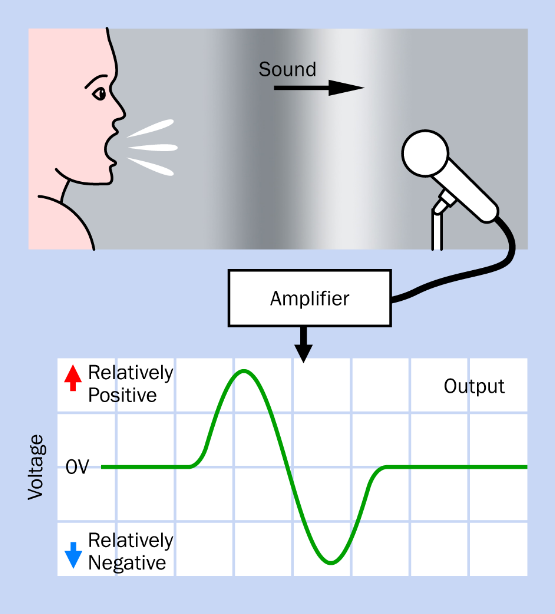

Figure 29-1 *The principle of converting pressure waves into an alternating electrical signal (adapted from an illustration in Make: More Electronics).*

Schematic Symbol

Various schematic symbols for a microphone have been used during the decades since its invention. A selection is shown in Figure 29-2. Each symbol assumes that sound is traveling from left to right. This is important when interpreting the symbol at top right, which can represent an earphone when it points in the opposite direction. Unfortunately, some schematics do not conform with this rule.

The two symbols at the bottom, showing a capacitor inside the microphone, should be reserved for condenser or electret microphones.

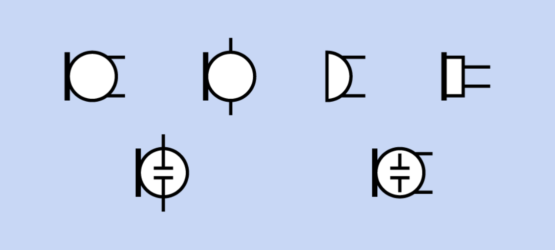

Figure 29-2 *A selection of schematic symbols that represent a microphone.*

How It Works

Some types of microphones generate a small voltage, while others have a fluctuating resistance that modulates a DC current.

Carbon Microphone

This was a very early attempt to reproduce sound. It contained carbon granules whose packing density increased and decreased in response to air pressure waves. When the density increased, the resistance between the granules diminished, and vice-versa. The principle is illustrated in Figure 29-3, and was patented by Thomas Edison in 1877 for use in telephones. As late as the 1950s (and even later in some countries), wired telephone handsets contained carbon microphones. Their bandwidth was extremely limited.

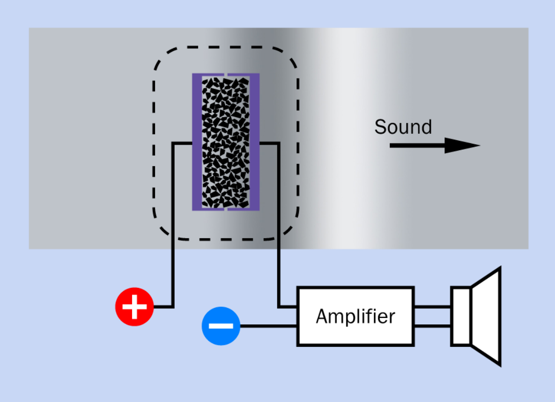

Figure 29-3 *The principle of a carbon microphone.*

Moving-Coil Microphone

Also known as a *dynamic* microphone, this consists of a very small, light coil of thin wire on a cylindrical tube that can vibrate along the axis of a permanent magnet. This principle is illustrated in Figure 29-4. A diaphragm is attached to the front of the tube, and responds to air pressure waves that penetrate the perforated enclosure of the microphone. Movements of the coil around the magnet create small alternating currents in the wire. The inertia of the coil, tube, and diaphragm, and the force needed to overcome the interaction between the coil and the magnet, impose a limit on the high-frequency response of this design.

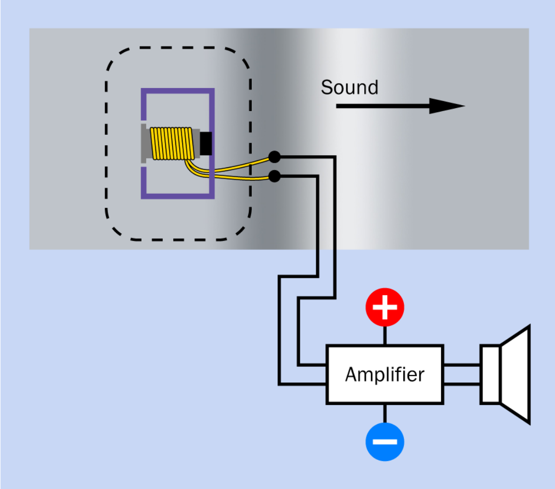

Figure 29-4 *The principle of a moving-coil microphone.*

Condenser Microphone

This type of microphone contains two thin discs or plates that form a capacitor. (In the early days of electricity, a capacitor used to be known as a condenser. The terminology has persisted for microphones.) An equal and opposite charge is applied to the plates. One plate is flexible, and as it responds to pressure waves, the capacitance between it and the other, rigid plate fluctuates. If the charge on the plates is kept approximately constant while the capacitance fluctuates, the voltage across the capacitor fluctuates also. These fluctuations can be amplified, as suggested in Figure 29-5.

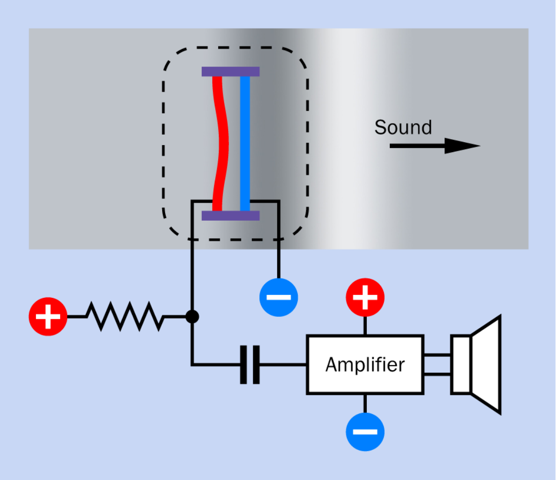

Figure 29-5 *The principle of a condenser microphone.*

Electret Microphone

This works on the same principle as a condenser microphone, except that its plates are made from a ferroelectric material that retains an electrical charge, just as iron will retain a magnetic polarization. The name of the microphone is derived from "electrostatic" and "magnet." While early electret microphones were of poor quality, they have evolved to rival condenser microphones, and are extremely affordable. Because the electret creates very small currents, it usually includes a transistor or op-amp in its package to boost the signal, and has an open-collector output. The basic circuit for an electret is shown in Figure 29-6. For more information about using an open-collector output, see Figure A-4.

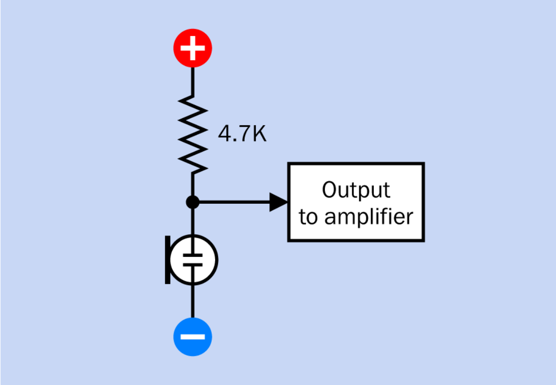

Figure 29-6 *The basic circuit for using an electret microphone.*

An example of a low-cost electret microphone is shown in Figure 29-7. This type of component is sold either with leads attached, or with solder pads.

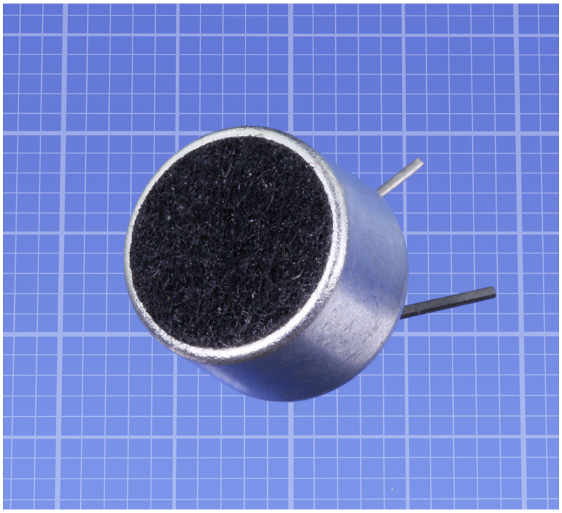

Figure 29-7 *A generic electret microphone. The background grid is in millimeters.*

MEMS Microphone

This type, often used in mobile phones, is a capacitive device that works on the same principle as a condenser microphone, although the component is etched in silicon and has a diaphragm that measures only about 1mm square. Many MEMS microphones have an analog output that is amplified in the same chip. Others have a digital output, using *PDM encoding*. This reduces the analog signal to a very fast bit stream, in which the density of the bits represents the amplitude of each fluctuation in a sound wave. PDM is an acronym for *pulse density modulation*. It requires an external clock signal to time the bit stream.

A breakout board from Sparkfun, on which is mounted an Analog Devices ADMP401 MEMS microphone with a preamplifier, is shown in Figure 29-8.

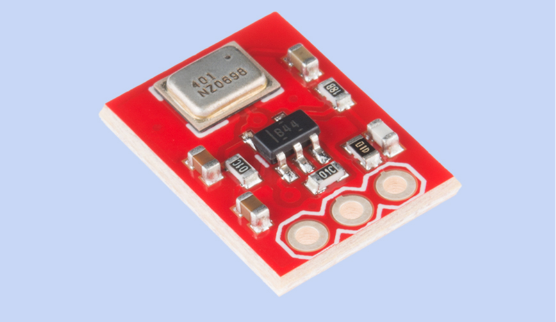

Figure 29-8 *A breakout board for a MEMS microphone (the metal-clad rectangular component at the far end).*

Piezoelectric Microphone

This has also been known as a *crystal* microphone. It contains a diaphragm that functions as a transducer. When it flexes in response to pressure waves, the mechanical energy is transformed into a small amount of electrical energy. Piezoelectric microphones were replaced by the moving-coil type in domestic audio devices when vacuum tubes were replaced with transistors, but may still be used as contact microphones to amplify acoustic musical instruments, or to trigger the playback of digitally sampled musical sounds.

Other variants include *ribbon* microphones (which were common in recording studios in the 1950s and 1960s, but have become rare), *laser* microphones, and *fiber-optic* microphones. They are not sufficiently common to be included in this entry.

Values

Sensitivity

Sound pressure is a complicated topic, explored in detail in the **transducer** entry in Volume 2. It can be measured in pascals, where 1 pascal = 1 newton per square meter.

The *sound pressure level* is a different concept. It measures the *relative* intensity of a sound, in a logarithmic scale calibrated in *decibels* (abbreviated dB). The reference value for this relative scale is 20 micropascals, considered to be the threshold of human hearing, comparable to a mosquito three meters away. This is assigned the value of 0dB.

From this point upward, the actual sound pressure doubles for each additional 6dB. A table of noise sources and their approximate decibel values is shown in Figure 29-9. This is derived from averaging eight similar tables, which are not always consistent in their estimates. It is an approximate guide only.

Decibels	Noise Example
140	Jet engine at 50 meters
130	Threshold of pain
120	Loud rock concert
110	Automobile horn at 1 meter
100	Jackhammer at 1 meter
90	Propeller plane 300 meters above
80	Freight train at 15 meters
70	Vacuum cleaner
60	Business office
50	Conversation
40	Library
30	Quiet bedroom
20	Leaves rustling
10	Calm breathing at 1 meter
0	Auditory threshold

Figure 29-9 *Decibel values for some common sound sources. Reproduced from Volume 2 of this Encyclopedia.*

The decibel unit is important when understanding the specifications of microphones, because it is used to measure their response. Microphone sensitivity is established with a standard input sine wave of 1kHz in frequency and 94dB in intensity (equivalent to 1 pascal in actual sound pressure), measured at the microphone. The sensitivity of an analog microphone is then defined as the number of decibels in an output signal of 1V. Because the output is an AC signal, voltage is measured as a root-mean-square (RMS) value.

For digital microphones, sensitivity is measured as the decibels that can be reproduced by a full-scale digital output. This value is abbreviated as dBFS.

Directionality

A microphone that has a directional response is desirable in many situations. Often, for example, sounds in front of the microphone are more important than sounds from behind the microphone. The directionality of a microphone (sometimes referred to as its *directivity*) is usually represented with a *polar graph* in which the microphone is seen from above, and its sensitivity to sounds from various directions is shown with a curve such as those in Figure 29-10. The circles are drawn at intervals of 5dB, with 0dB at the periphery and -30dB at the center. The precise response for an individual microphone should be shown in its documentation.

Frequency Response

Every microphone tends to be more sensitive to some sound frequencies than others. A manufacturer will provide a graph showing this sensitivity, in decibels, plotted against sound frequency on a logarithmic horizontal axis. Theoretically, human hearing extends from around 20Hz to 20kHz, but few people are actually capable of hearing the high end of that range, and 15kHz may be a more realistic limit for a young person, diminishing to 10kHz with middle age.

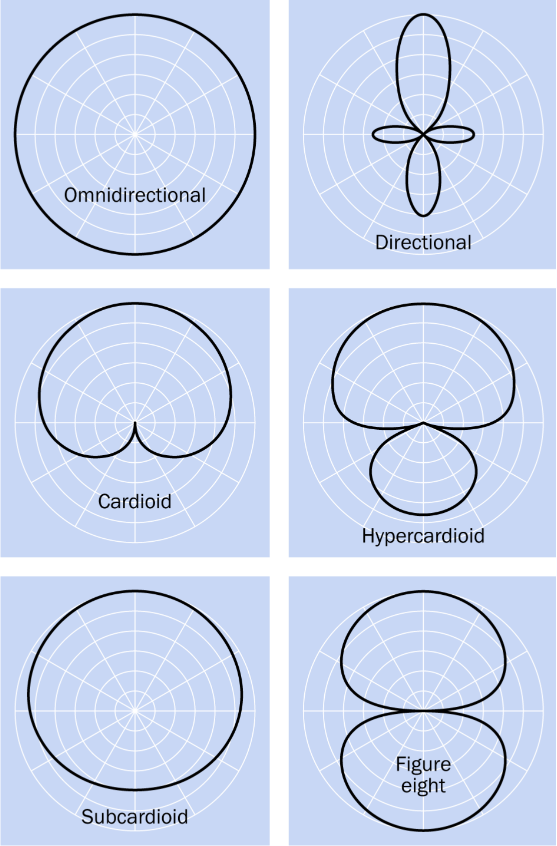

Figure 29-10 *Six generic sensitivity patterns. Individual microphones will deviate somewhat from these generic curves.*

An ideal flat response would show that a microphone is equally sensitive to all frequencies. In reality, *rolloff* usually occurs at low frequencies, and will eventually occur at high frequencies, although it may be preceded by a rise in response. If the central section of a curve is flat within plus-or-minus 1dB, this is a level of performance that was attained only by expensive studio microphones in the past. Electrets and MEMS microphones can now provide equivalent frequency response for $1 or $2 apiece, as opposed to the hundreds or even thousands of dollars that used to be necessary for professional equipment.

The response curve shown in Figure 29-11 is for the eMerging i436, an electret microphone sold in a module as an accessory to enable high-quality recordings on handheld devices. The rise around 15kHz may have been introduced deliberately by the manufacturer to compensate for reduced sensitivity of the human ear in that range.

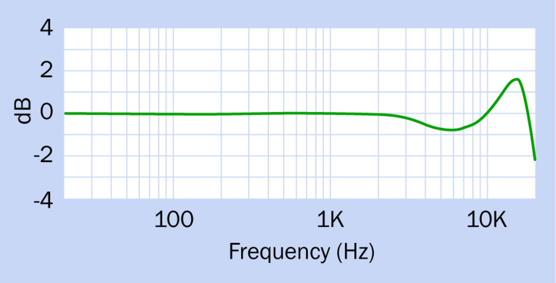

Figure 29-11 *Frequency response for an electret microphone.*

Impedance

The impedance value for a microphone is a function of its resistance, capacitance, and inductance. An amplifier input will also have an impedance rating, and for ideal power transfer between microphone and amplifier, the impedance values should be identical. However, a more important consideration in audio equipment is to avoid voltage loss between the output device (in this case, the microphone) and the input device (the amplifier). To achieve this, the output device should have a low impedance, while the input device should have a high impedance. Most microphones are rated at 150 to 200 ohms, while an amplifier may be rated at 1.5K to 3K.

Total Harmonic Distortion

When an audible sine wave is converted to an electrical output by a microphone (and by its preamplifier, if one is included in the module), the output may become corrupted by some multiples of the basic frequency. These are known as *harmonics*, and they are considered as a distortion of the signal. Total harmonic distortion, measured by a spectrum analyzer over the entire frequency range, should ideally be less than 0.01%.

Signal-to-Noise Ratio

Often abbreviated as S/N or SNR, the signal-to-noise ratio in a microphone is measured in decibels, and should be 60dB or higher.

What Can Go Wrong

Cable Sensitivity

Audio amplification is always vulnerable to electrical noise, which tends to be amplified along with the signal. Small signals from microphones require the use of shielded cables to reduce hum and other types of interference.

Noisy Power Supply

For similar reasons, power supplies must be as free as possible from voltage spikes and other fluctuations.

current sensor

30

The entry describes components that can be installed to monitor current on an indefinite basis. It does not include test equipment, such as test meters or multimeters.

A *current transformer* may be used to measure current, but is not included in this Encyclopedia.

OTHER RELATED COMPONENTS

- **voltage** sensor (see Chapter 31)

What It Does

A current sensor measures the flow of electricity through a wire or a device, and supplies an output that can be interpreted either visually or by a microcontroller to provide a reading in amperes or fractions of an ampere.

Applications

Current sensing is important in industrial applications such as the control of high-powered motors. It can be used to monitor the performance of an inverter, or for everyday purposes such as monitoring the long-term power consumption of an appliance. During product development, a current sensor can indicate the power consumption of a circuit as it changes with modifications.

This entry describes three methods to measure current: an ammeter, series resistor, and Hall sensor. While other methods exist, they are outside the scope of this Encyclopedia.

Ammeter

An ammeter that is sold as a standalone device with leads for circuit testing is often described as a *test meter*. Its functionality is usually built into a *multimeter*. Test meters and multimeters are outside the scope of this Encyclopedia.

An ammeter designed for permanent installation in a device or prototype is a type of *panel meter*, such as the one shown in Figure 30-1. This traditional-style analog meter may be less expensive than the many digital types that are available. It uses a magnetic field created by current flowing through a coil to pull a needle across a scale, against the force of a spring.

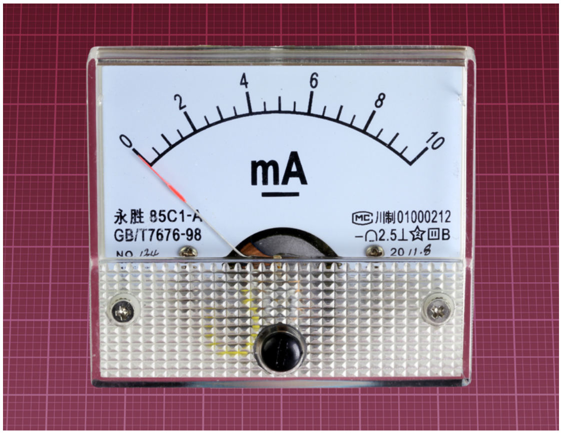

Figure 30-1 *A traditional-style analog ammeter.*

A digital ammeter allows a wider range of values to be viewed more easily. The meter from Adafruit in Figure 30-2 has a range of 0A to 9.99A, at voltages from 4.5VDC to 30VDC. The meter can be powered parasitically from the currents that it is measuring, or can use a separate isolated 5VDC supply.

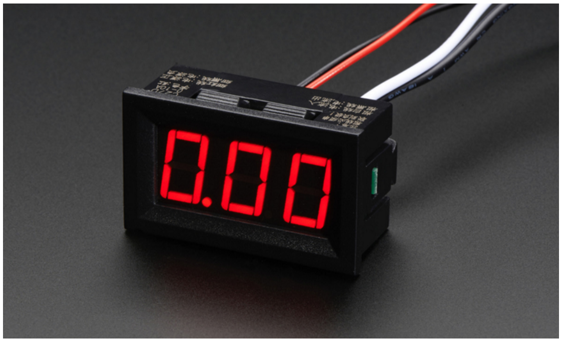

Figure 30-2 *A panel-mount digital ammeter that can measure up to 9.99A.*

Schematic Symbol

An ammeter may be represented in a schematic with the letter A inside a circle, as shown in Figure 30-3.

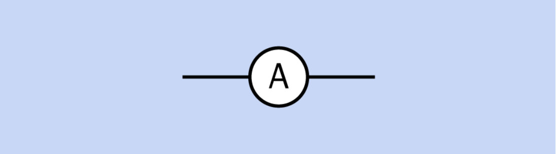

Figure 30-3 *An ammeter may be represented like this in a schematic.*

Ammeter Wiring

Two ways to use an ammeter in a circuit are illustrated in Figure 30-4, where the load may be any equipment, device, or component that provides some electrical resistance. Because current is the same at all points in a simple circuit, the current that the meter measures flowing through itself will be the same as the current flowing through the load, and the sequence of components is immaterial.

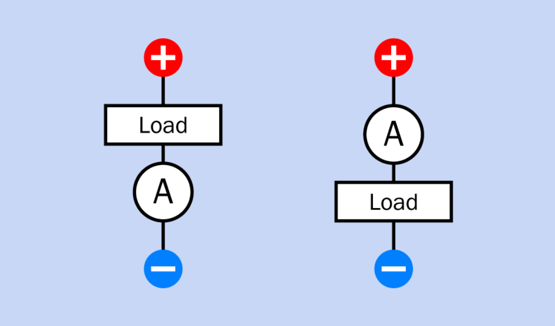

Figure 30-4 *Two options for placement of an ammeter in a circuit.*

However, regardless of the placement of the meter, the process of measuring current will inevitably change the value of the current being measured. This is because the ammeter imposes some internal resistance of its own. The resistance is extremely low, and may be considered negligible for loads of more than a few ohms.

- The low internal resistance of an ammeter means that it must never be connected in parallel with a load, or directly across a power source.

A disadvantage shared by analog and digital meters is that they are not usually interchangeable between AC and DC.

Series Resistor

The current flowing through a load can be calculated by measuring the voltage across a series resistor that is inserted between the load and its ground connection. The concept is illustrated in Figure 30-5.

Using Ohm's law, if U is the voltage drop, I is the current, and R is the value of the resistor:

```
I = U / R
```

This tells us that for a fixed value of R, current is proportional to voltage. Therefore, measuring the voltage enables calculation of the current, so long as the value of R is known.

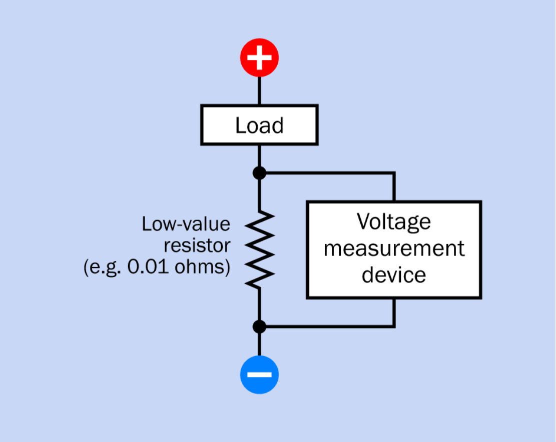
Load
Low-value resistor (e.g. 0.01 ohms)
Voltage measurement device

Figure 30-5 *A basic circuit for measuring current as a function of the voltage drop across a small-value resistor. The load in this figure is any circuit or device with a relatively higher resistance. The voltage measurement device could be a microcontroller or analog-to-digital converter.*

Suppose that R has a very small value, which is trivial compared with the resistance of the load. Consequently, the current in Figure 30-5 will be mainly determined by the load, and we may consider the value of the current to be almost the same with or without the addition of R. In that case, the voltage drop across the resistor will be smaller if R is smaller. A smaller voltage drop will not be as easy to measure, but a lower resistance will result in less wastage of power.

If P is the power:

$$P = R * I^2$$

An example may help to make this clear. Suppose the resistor has a value of 0.5 ohms, and the voltage drop across it is measured to be 1V. Ohm’s law shows that current flow is 1 / 0.5 = 2A. The power formula shows that P = 0.5 * 4 = 2W.

To waste less power, the value of the resistor should be reduced further. Suppose a resistor of 0.01 ohms is used, and the voltage drop across it is measured as 0.02 volts. The current is 0.02 / 0.01 = 2A, as in the preceding example, but the power dissipation is now only 0.01 * 4 = 0.04W, which is negligible.

But are resistors available that have values measured in fractions of an ohm?

Current-Sense Resistors

In fact, many *current sense* resistors are available, with values of 0.1 ohms, 0.001 ohms, 0.0001 ohms, and many in between. Some resistors have values measured in micro-ohms. Examples are shown in Figures 30-6, 30-7, and 30-8.

Measuring a small voltage drop is easily done by using a microcontroller. However, the connection to the microcontroller must be made as near to the resistor as possible, to eliminate the additional resistance of wires or circuit-board traces. For this reason, precision current-sense resistors may be equipped with four terminals. Two are wider, and are meant for connection to the flow of current. The other two are narrow, for measuring the voltage over the resistor. With this *4-point* configuration, voltage drop over the resistor can be measured as close to it as possible. The 0.001-ohm surface-mount resistor in Figure 30-8 is designed for 4-point measurement.

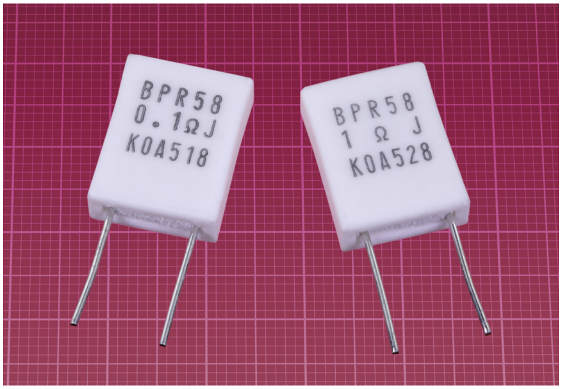

Figure 30-6 *Two current resistors manufactured by KOA Speer. Left: 0.1 ohms, 5W, 5%. Right: 1 ohm, 5W, 5%. The background grid is in millimeters.*

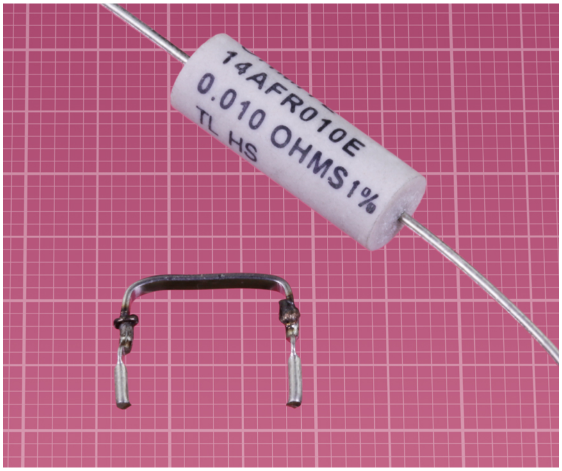

Figure 30-7 *Two styles of current resistors rated for 0.01 ohms. Bottom left: A plug-in version from TT Electronics, rated 1W and 5%. Top right: Ohmite, 4W, 1%. The background grid is in millimeters.*

Resistors that have the lowest values and are intended to tolerate high current may consist of just a metallic strip welded to solderable pins. This type of component is sometimes called an *open-air resistor*. It is commonly used in multimeters, for measuring currents up to 10A or above.

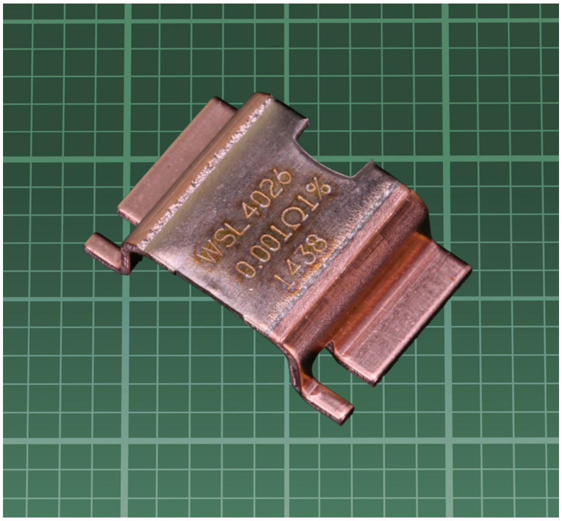

Figure 30-8 *This Vishay 4-terminal surface-mount current resistor is rated for 0.001 ohms, 3W, 1%. The background grid is in millimeters.*

Voltage Measurement

Some chips are designed for amplifying the voltage drop across a current-sensing resistor. An example is the Texas Instruments INA169.

A few chips contain an analog-to-digital converter in addition to the amplifier. The INA219 by Texas Instruments is designed to measure voltage as well as current, on the "high side" of a circuit—that is, between the positive power supply and the power input of the circuit. It makes its digital data available over an I2C bus.

For additional details about protocols such as I2C, see Appendix A.

Measuring current from the voltage drop across a series resistor offers the advantages of simplicity, ability to work with AC or DC, and low cost (although some resistors of extremely low value can be relatively expensive). A possible disadvantage is that the measurement circuit is not isolated from the circuit whose current is being measured.

Hall-Effect Current Sensing

The principle of a Hall-effect sensor is explained in the entry for **object presence** sensors. See "Hall-Effect Sensor". Normally this type of sensor is activated by an external permanent magnet, but it can also react to the magnetic field generated by current flowing through a wire.

Because the field generated around a wire is proportional with the current, the analog output voltage generated by a linear Hall-effect sensor can also be proportional with the current.

Hall-effect sensors for this specific purpose are available in 8-pad surface-mount packaging. The current to be measured passes through a copper conductor that is embedded in the chip. An example is Allegro's ACS712, for AC or DC currents up to 30A. The internal resistance of the current path through this chip is stated as 1.2 milliohms, and the path is isolated from the sensing circuitry.

Three variants of the chip are available, for currents of plus-or-minus 5A, 20A, and 30A. Depending on which variant is used, the output will range from 66mV to 185mV for each increase of 1A in the current path. Because the current path is isolated, the chip requires a separate power supply of 5VDC.

The 5A version of the AVS712 can be bought on breakout boards from Sparkfun. In Figure 30-9, the board at top-left contains only the ACS712, while the board at lower-right adds an op-amp with sensitivity control, to amplify the voltage output when measuring small currents.

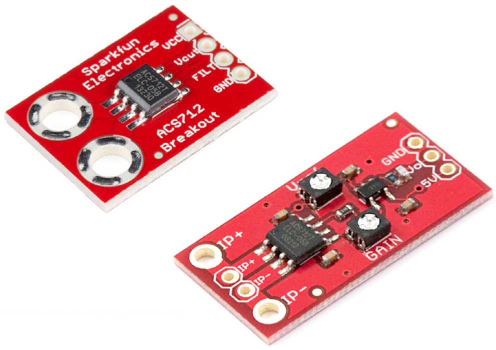

Figure 30-9 *Breakout boards using the AVS712 Hall-effect current sensor. The one at lower-right includes an op-amp to amplify small signals.*

What Can Go Wrong

Confusing AC with DC

A panel meter that is designed only to measure DC should not be used with AC, and vice-versa. Erroneous readings or damage to the meter may result.

Magnetic Interference

A disadvantage of Hall-effect current sensing is that the sensor can be affected by stray magnetic fields. Because a Hall-effect chip is responding to very small magnetic effects, it is vulnerable to interference. Consult the manufacturer's datasheet carefully regarding correct placement of a chip on a circuit board.

Incorrect Meter Wiring

The correct wiring of an ammeter is in series with a load, not in parallel with a load. This may seem an elementary error, but is easy to make if an ammeter and a volt meter are both being used, and they look similar.

Because some panel meters are not fused, applying an ammeter directly across a power supply, without any series resistance, may result in immediate and hazardous destruction of the meter.

Incorrect wiring can also occur when using a digital meter that has four wires emerging from it: two for current testing and two for a separate power supply. This issue is especially important when measuring substantial currents (above 1A).

Current Out of Range

Attempting to measure a current that exceeds the range of an ammeter may damage the meter or blow its internal fuse, if it has one.

voltage sensor

31

The entry describes the type of component that can be installed to monitor voltage on an indefinite basis. It does not include test equipment, such as test meters or multimeters.

OTHER RELATED COMPONENTS

- **current** sensor (see Chapter 30)

What It Does

A voltage sensor measures the electrical potential between any two points in a circuit, or the voltage supplied by a power source, and provides data in volts or fractions of a volt. It should not be confused with an *analog-to-digital converter*, which is not a sensor in itself, but can process the voltage output from a sensor by digitizing it. More information about analog-to-digital conversion is in the Appendix. See Appendix A.

Applications

Voltage measurement is important in conjunction with all types of power supplies, to verify their performance. A volt meter may also be used to show the output from various types of analog sensors that have voltage output.

A graphical display may be used in audio equipment to indicate signal level, which can be proportional with voltage.

Volt Meter

A volt meter that is sold as a standalone device with leads for circuit testing is often described as a *test meter*. Its functionality is usually built into a *multimeter*. Test meters and multimeters are outside the scope of this Encyclopedia.

A volt meter designed for permanent installation in a device or prototype is a type of *panel meter*, which is described here.

An antique analog panel meter is shown in Figure 31-1.

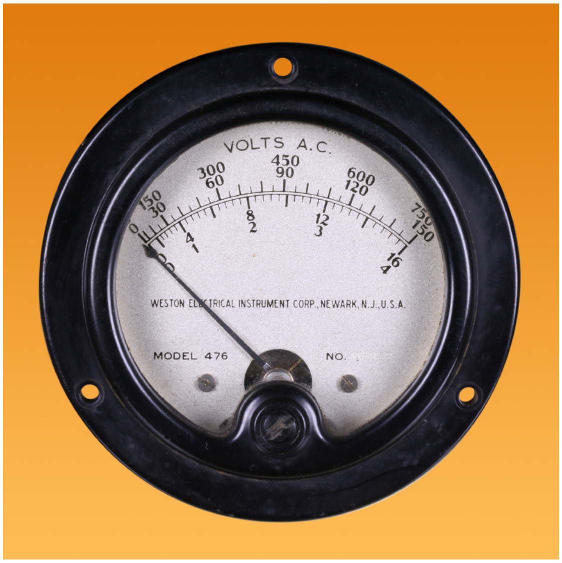

Figure 31-1 *An antique analog volt meter.*

The four scales on the dial correspond with separate input terminals at the rear of the unit. The unequally divided scales are a simple way to compensate for the nonlinear response of the mechanical movement inside the meter.

Modern analog volt meters are still manufactured, and may be cheaper than their digital equivalents. However, a digital volt meter allows a wider range of values to be viewed more easily. The meter in Figure 31-2, sold as a low-cost battery tester, measures voltages from 4VDC to 13VDC to an accuracy of two decimal places. It needs no separate power supply.

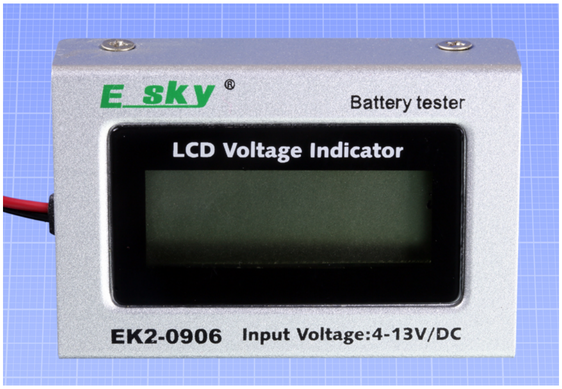

Figure 31-2 *A panel-mount digital volt meter.*

Sometimes the number of digits in a volt meter is specified as ending with one-half, as in 3.5 or 3-1/2 digits. This means that the most significant (leftmost) digit can only be a 1 or a blank. The extra "half digit" may seem inconsequential but doubles the range of displayable values. For example, a 2-digit display can only show 100 values, from 0 to 99. A 2-1/2-digit display can show 200 values, from 0 to 199.

Schematic Symbol

A volt meter may be represented in a schematic with the letter V inside a circle, as shown in Figure 31-3.

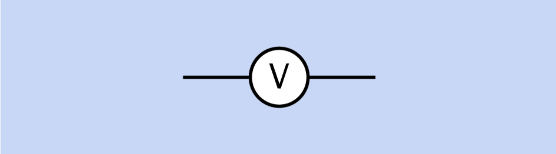

Figure 31-3 *A volt meter may be represented like this in a schematic.*

Volt Meter Wiring

Two ways to use a volt meter in a circuit are illustrated in Figure 31-4, where the load may be any equipment, device, or component that provides some electrical resistance.

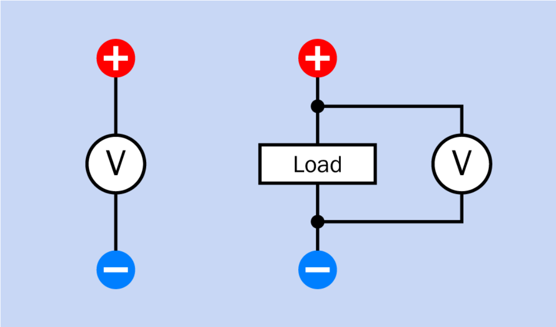

Figure 31-4 *Two options for placement of a volt meter.*

On the left side of the figure, a volt meter may be connected directly across a power source, because the internal resistance of the meter is so high, it will draw very little current. In this configuration, the meter measures the voltage of a source when the source is virtually unloaded.

On the right, the meter can measure the voltage drop across a load, or can measure the voltage across any component, or group of components, that are a subset of the load.

A disadvantage shared by dedicated analog and digital volt meters is that they are not usually interchangeable between AC and DC.

How It Works

An analog volt meter usually contains a built-in, high-value fixed resistance, and an ammeter measuring the current passing through it. The current sensed by the ammeter is then converted to a reading in volts.

Suppose that R represents the fixed resistance, U is the voltage drop across the resistance, and I is the current flowing through it. Ohm's Law tells us:

```
U = I * R
```

The formula shows that if the resistance is fixed, the voltage will vary in proportion with the current, and therefore can be calculated from it.

Load-Related Inaccuracy

When the meter is measuring the voltage drop created by a load that has high resistance comparable to the internal resistance of the meter itself, the meter will not give an accurate reading. Figure 31-5 illustrates this problem.

On the left side of the figure, two resistors 10M each are wired in series between a 9VDC power source and negative ground. Because the resistors are equal, each of them imposes an equal voltage drop of 4.5V.

On the right side of the figure, an additional 10M resistance has been added in parallel with the lower resistor. When two resistors of values R1 and R2 are wired in parallel, their total resistance, R, is given by this formula:

```
1 / R = ( 1 / R1 ) + ( 1 / R2 )
```

Therefore, the total resistance in the bottom half of the circuit is now 5M instead of 10M, and the voltage drop across the upper resistor becomes twice the voltage drop across the two lower resistors.

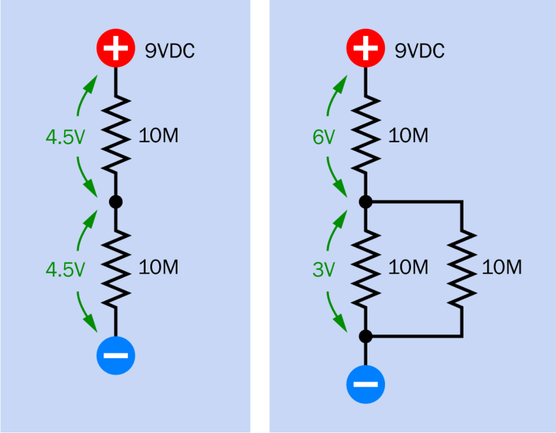

Figure 31-5 *If a meter measuring the voltage drop across a load has an internal resistance comparable to that of a load, the meter will not give an accurate reading. See text for details.*

Now suppose that the additional 10M resistor is actually the fixed resistance inside a volt meter. In fact, many volt meters do have an internal resistance of around 10M. Because the meter has reduced the resistance in the bottom half of the circuit by a factor of 2, it measures the voltage drop as 3V. If the meter had an ideal, infinite resistance, it would give the correct value of 4.5V. In the real world, that is impossible.

Bar Graph

Sometimes it is useful to represent voltage with a graphical display. A *bar graph* component makes this possible, and is often used in audio equipment.

The bar graph can consist of a row of *LEDs*. In a component designed for this purpose, there are usually 10 or more. To represent 0 volts, all the LEDs remain dark. More LEDs are illuminated as the voltage increases.

Because the bar graph itself only contains LEDs, a driver is necessary to convert voltage into the "rising thermometer" effect. Examples are the LM3914 (linear), the LM3915 (logarithmic, 3 dB per step), and the LM3916 (using VU or Volume Units, for audio). Each of these components has 10 LED outputs, and is fabricated using a chain of resistors as a multitap voltage divider, with 10 comparators.

A driver can be set to show only one LED corresponding with the current voltage level, or (more commonly) a cumulative string of LEDs from zero upward. Some bar graphs also contain different colored LEDs, such as green for the first 7, yellow for the next 2, and red for the final one.

A microcontroller containing an analog-to-digital converter can be used to illuminate a bar graph, instead of a driver chip.

An example of a bar graph is the Avago HDSP-4830, shown in Figure 31-6.

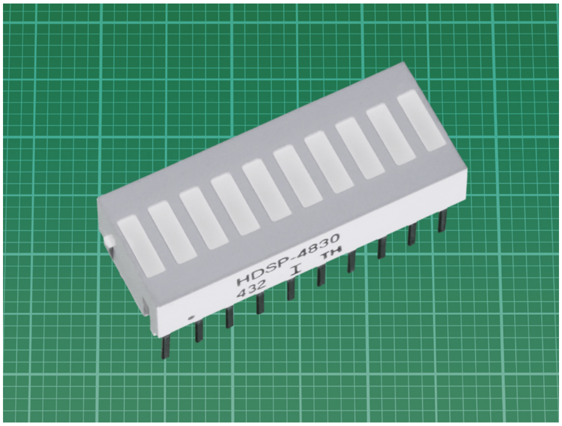

Figure 31-6 *A bar graph LED display, which can be used to represent voltage. The background grid is in millimeters.*

What Can Go Wrong

Confusing AC with DC

A panel meter that is designed only to measure DC should not be used with AC, and vice-versa. Erroneous readings or damage to the meter may result.

High Circuit Impedance

When a meter is measuring the voltage drop across a high-value resistance, it will give an inaccurate reading, as it is diverting a significant proportion of the current.

Voltage Out of Range

Attempting to measure a voltage that exceeds the limited range of a meter can damage the meter or blow its internal fuse, if it has one. Attempting to measure a voltage that is at the very low end of a meter's range will result in an inaccurate value.

Voltage Relative to Ground

If one input to a digital meter is connected with ground, the meter will only be able to measure voltage in a circuit relative to ground.

Sensor Output

A

This appendix provides some basic information about nine forms of sensor outputs, and the ways in which they can be processed. Other types of encoded output exist, but those examined here are the ones most likely to be found.

Figure A-1 provides an overview. Every sensor initially creates an analog output, which is sometimes connected directly to an output pin. In thermistors and photoresistors, for example, the internal resistance of the component constitutes its output. In many sensors, however, the behavior of the sensing element is processed internally to create voltage, open collector, encoded pulse stream, or current output.

If the sensor is chip-based, it may process the analog sensor response internally to create a binary output or a digital output.

In this Encyclopedia, the term "binary output" means "an output that has two states," usually logic-low or logic-high. The states may be accessible via an output pin, or may be processed internally to create a pulse stream. In that case the stream fluctuates between the two states as a way of encoding an analog value with pulse-width modulation (PWM) or frequency. Other types of encoding are also possible, but are unusual.

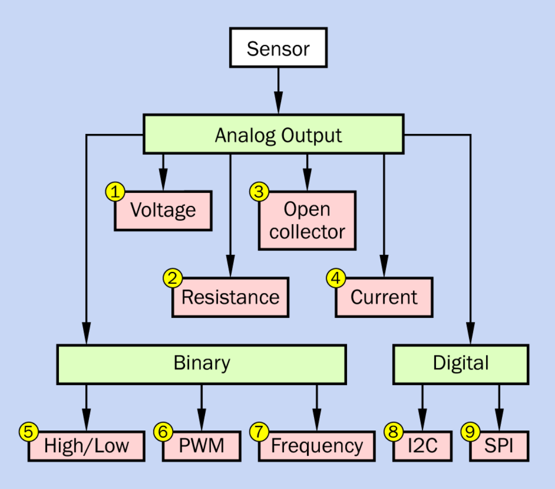

Figure A-1 *Nine possible types of output from sensors. The primary categories are highlighted in green.*

The term *digital output* is used here to mean one or two bytes of data that are stored in a register (memory location) in the sensor chip. While other forms of output are "always on" and can be accessed at any time from an output pin, a digital output is usually not available until an external device, such as a microcontroller, sends an instruction to the sensor chip, telling it to return the data. This two-way communication usually is handled by the I2C or SPI protocols (other protocols exist, but are less common).

Analog Outputs

Voltage is by far the most common form of analog output. Other forms of analog output can easily be converted to a voltage value, using the simple techniques described here.

1. Analog: Voltage

Direct Connection: Analog-to-Analog

An analog voltage output can be connected directly to an analog input, so long as the range is compatible and the sensor can provide sufficient current. Examples of external analog devices would be an analog volt meter, a light source or sound source that changes intensity, or a transistor or op-amp that will amplify the output for other audio/visual purposes.

If the voltage output from the sensor rises above a usable range, it can be converted to a lower value by applying it across two resistors connected in series to form a voltage divider. This is shown in Figure A-2.

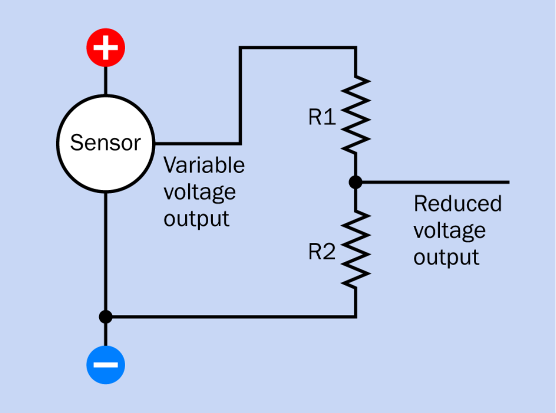

Figure A-2 *Using a voltage divider to reduce the range from a sensor.*

The values of R1 and R2 can be derived from this basic formula, where V_{SEN} is the voltage from the sensor and V_{OUT} is the output from the voltage divider:

Example A-1

$$V_{OUT} = V_{SEN} * (R2 / (R1 + R2))$$

The impedance of the device used for voltage sensing must be high relative to the values of R1 and R2. Note also that if the analog voltage out from the sensor varies linearly with the phenomenon being sensed, this relationship is likely to be disturbed by the voltage divider.

Analog-to-Binary Conversion

The term "binary" is used here to mean an output that can be in one of two states, such as logic-high and logic-low.

A varying analog voltage output can be simplified by passing it through a component that transforms the signal into binary form. This may be done by using a logic chip with a *Schmitt trigger* input, a *zener diode*, or a **comparator**. (For a description of comparators, see the entry in Volume 2.) A comparator provides desirable features such as adjustable positive feedback to create hysteresis. It may be used, for example, to convert a slowly changing signal from a phototransistor while the sun is setting, to a high/low output that can activate a relay to switch on a light.

Analog-to-Digital Conversion

The analog voltage output from a sensor can be digitized by an external analog-to-digital converter (ADC), either inside a microcontroller or by a separate ADC chip.

If a microcontroller is used, a sensor may often be wired directly to an input pin that connects internally with an ADC. A program in the microcontroller can then assess the integer output from the ADC and either execute a conditional statement or convert the value to a format appropriate for another device, such as a digital display.

If an ADC chip is used, there are thousands to choose from. A few basics:

- A *flash* converter contains a row of comparators with different reference voltages generated with a chain of equal resistors. The comparator outputs are fed into a priority **encoder** that outputs a binary number. This system is very fast but has limited resolution.

- A *successive approximation* converter uses a single comparator, comparing the input voltage with the output from a DAC. The binary number that is supplied to the DAC is determined one bit at a time, from the most significant to the least significant bit, using the comparator's result to determine if the bit should be 0 or 1. These bits are stored in a register, called a successive approximation register (SAR). When the process finishes, the SAR contains a binary representation of the input voltage. This type of ADC can achieve high resolution (many bits) at the cost of lower conversion speed.
- In a *dual slope* converter, a capacitor is charged for a fixed time, with a rate proportional to the input voltage, then discharged at a known rate while measuring time by counting clock pulses. The resulting count is the ADC output.

  The name of the converter is derived from the voltage on the capacitor.
- A *voltage-to-frequency* converter uses a voltage-controlled oscillator to produce pulses with a frequency proportional to the input voltage. If the pulses are counted over a fixed time interval, the count is proportional to the signal level.

The number of the bits in the output from an ADC must be sufficient to digitize the input voltage range with desired accuracy. Because the voltage range may contain unexpected peaks, a cautious strategy is to use many more bits than are necessary. However, this means that for most of the time, only a few bits will be used to represent the low end of the voltage range, and accuracy will suffer.

For example, suppose a voltage input normally ranges from 0V to 2V, with occasional brief excursions to 8V. An 8-bit ADC can provide 256 digital values to represent input voltages. If the values are spread uniformly over the full 8V input range, the least significant bit can measure 1/32nd of a volt, or about 31mV. Smaller voltage fluctuations will be ignored. On the other hand, if the 256 values are used to measure a range of just 2 volts, the least significant bit can measure 1/128th of a volt, or slightly less than 8mV—but voltages higher than 2V will be clipped.

An ADC will typically require a reference voltage, and will digitize the range from 0V to that voltage. The reference voltage must be chosen with the issues of accuracy and range in mind.

A microcontroller may provide a feature in its language to perform automatic scaling of an analog input within limits set by a variable in program code. This is done by comparing the input with a selectable voltage level, such as the voltage of the power supply, an externally supplied voltage, or a fixed built in reference. While the ADC in the microcontroller normally digitizes values from 0V to the supply voltage for the chip, the conversion routine can instruct the microcontroller to use its full number of bits (often, 10) to digitize an input range from 0V to 1V.

For a higher sample rate, an ADC chip may be connected with the microcontroller over an I2C or SPI bus.

2. Analog: Resistance

Resistance-to-Voltage Conversion

A sensor that changes its resistance as it responds to its environment can be placed in a *voltage divider* to provide an analog voltage output. This is illustrated in Figure A-3.

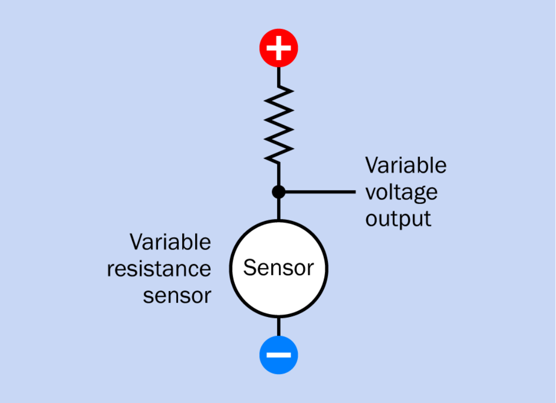
Variable
voltage
output
Variable
resistance
sensor
Sensor

Figure A-3 *The basic principle of putting a variable-resistance sensor in series with a fixed resistance, to create a voltage divider.*

To choose the value for the series resistor, if R_{MIN} and R_{MAX} are the minimum and maximum resistance values for the sensor, the optimum value R_S for the series resistor, to produce the widest variation in voltages, will be found from this formula:

$$R_s = \sqrt{(R_{min} * R_{max})}$$

When the sensor has been set up in this way, the output can now be processed in the same way as any analog voltage output from a sensor.

The datasheet of the sensor should be consulted to make sure that a series resistor value does not allow any chance of the sensor being damaged by excessive current.

3. Analog: Open Collector

Many sensor packages or modules include a bipolar transistor that has an *open-collector* output (or *open drain*, if a CMOS transistor is used). The transistor may or may not be incorporated in an internal **op-amp** (described in Volume 2). Either way, the principle is the same.

Figure A-4 shows a sensor, in darker blue, that has one connection for positive power, another connection for negative ground, and a third connection to the collector of the internal transistor.

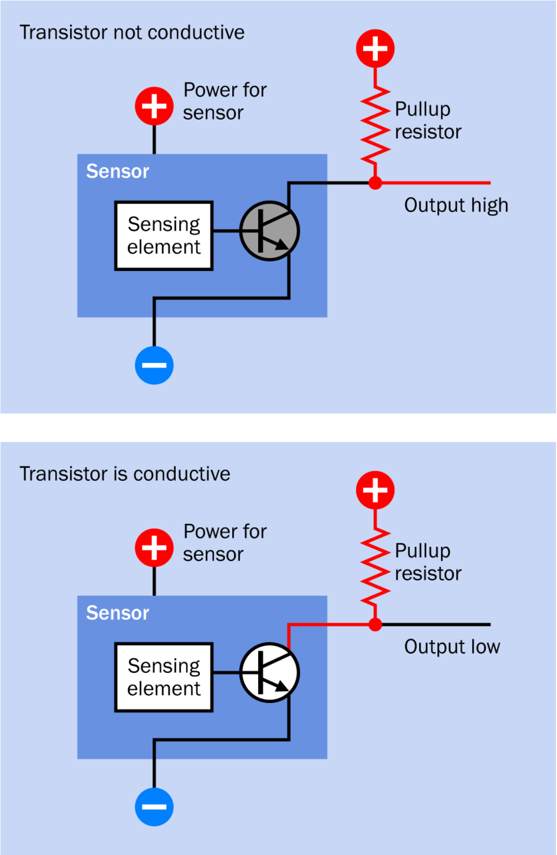
Transistor not conductive
Power for
sensor
Pullup
resistor
Sensor
Sensing
element
Output high
Transistor is conductive
Power for
sensor
Pullup
resistor
Sensor
Sensing
element
Output low

Figure A-4 *How to use an open-collector output from an internal transistor.*

In the upper section of the figure, the sensing element is not applying voltage to the base of the internal transistor, and the transistor only conducts a tiny amount of leakage current. Power applied to it through an external *pullup resistor* cannot reach negative ground in any significant quantity, and therefore it can provide a voltage input to a high-impedance device such as a microcontroller, or can power a component such as an LED, which draws relatively little current (20mA or less).

In the lower section of the figure, the sensing element is now applying voltage to the base of the transistor, drastically lowering its effective resistance. The transistor diverts current from the pullup resistor to ground, and the output appears to go low.

The type of sensing element will determine whether the transistor becomes conductive or nonconductive when the element detects a stimulus.

The value that should be chosen for the pullup resistor will depend on the impedance of any device attached to the open-collector output. A 10K resistor may be appropriate for use with a device such as a microcontroller, which has very high impedance. At the other extreme, if the device is an LED, a 330-ohm resistor may be necessary. The value of the pullup resistor must be sufficiently low to enable reliable operation, but sufficiently high to prevent excessive current from passing through the internal transistor when it becomes conductive (20mA is a common maximum value).

The voltage from the open collector can be processed in the same way as any analog voltage output from a sensor.

An open-collector output may be used when the outputs from multiple devices share the same bus. One device can drive the bus without the problem of other devices attempting to hold the bus voltage high.

4. Analog: Current

Relatively few sensors provide an output consisting of variations in current. Some semiconductor temperature sensors function in this way. The output current can be converted to a voltage output simply by placing a fixed series resistor, as shown in Figure A-5.

The voltage at the point shown, relative to negative ground, will vary linearly with the current. The value of the resistor should be defined in a datasheet for the sensor.

The voltage can now be processed in the same way as any analog voltage output from a sensor.

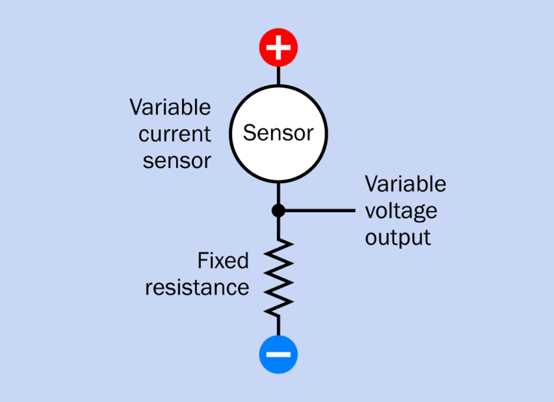

Figure A-5 *How to convert the output from a variable-current sensor.*

5. Binary: High/Low

A sensor that provides a binary output (that is, an output that is either logic-high or logic-low) can be connected directly with a microcontroller, if the voltage range is compatible. Program code in the microcontroller can then test the pin to establish its state. Note that some microcontrollers require a 3.3VDC power supply, while sensor chips may use 5VDC.

A binary output can also be used to control a solid-state relay, or an electromagnetic relay if transistor amplification is used. The output may be sufficient to power an LED indicator.

6. Binary: PWM

PWM is an abbreviation for *pulse-width modulation*. The sensor emits a stream of square-wave pulses with a fixed frequency, but the width of each pulse varies with the stimulus to which the sensor is responding. The width of each high pulse, relative to the wavelength between the start of one pulse and the start of the next, is called the *duty cycle*. A duty cycle of 0% means that there are no pulses at all. With a duty cycle of 100%, there are no gaps between pulses, so the output is high all the time. With a duty cycle of 50%, the duration of each high pulse is the same as the duration of the gap between pulses.

Various microcontrollers offer different ways to decode a PWM pulse stream. The most basic way is for a program to check an input pin repeatedly, as fast as possible, until a high state is detected. The microcontroller copies the value of its internal clock into a variable, then continues to check the input repeatedly until the pulse ends. The pulse duration that has been measured can be converted to a sensor value with a formula or lookup table.

This system is not recommended, as the microcontroller may miss the next pulse while it is converting the value of the previous pulse. To address this problem, a microcontroller language may offer a function that blocks execution of code while waiting for a pulse. The pulseIn() function on the Arduino is an example of this feature. However, the microprocessor must now spend most of its time waiting for a pulse instead of doing useful work.

A better solution is to write a program that is interrupt-driven.

Another option for decoding PWM is to use a low-pass filter that converts the pulse stream into an analog voltage, although some ripples will tend to remain.

Finally PWM can be used directly to power an LED or a DC motor, with transistor amplification as required. The speed of the motor or the brightness of the LED will vary with the duty cycle.

7. Binary: Frequency

Here again, the pulseIn() function on the Arduino may be used, so long as the frequency is a square wave with a known duty cycle.

8. Digital: I2C

In digital electronics, a *bus* is a communal pathway for sharing data among components or devices. The *I2C bus* is an abbreviation for *inter-integrated circuit* bus, developed originally by Philips in 1982. (Philips has since been subsumed into NXP Semiconductors.) The correct notation for I2C is I^2C, and it is spoken as "I-squared-C." However, the term is very commonly written as I2C.

The I2C standard defines a data sharing protocol that is limited to 400kHz (with some exceptions) and designed to work on a small scale, almost always within one device, and usually on one circuit board. It is a low-cost, simple design. Data is transmitted serially over two wires, and the devices sharing the bus are connected in parallel.

Typically there is one *master* device on the bus, and a number of *slave* devices. Masters and slaves can both transmit information, but the master normally initiates communication. It also emits a clock signal for synchronization of data.

A sensor is a slave device that can be interrogated by a microcontroller in its role as the master device. Because multiple slave devices can share a bus, the microcontroller needs a way to identify the slave that it wishes to talk to, and each slave is assigned a unique address for this purpose. Often a slave will allow the user to modify the last two bits of the address, so that up to four identical devices can share a bus.

Code libraries to support the I2C protocol are available for most microcontrollers, and communication with a sensor that uses I2C should simply require knowledge of the sensor's I2C address. However, the data registers in a sensor can be quite elaborate, requiring careful study of the manufacturer's datasheet. Multiple procedures may be required to set functions on a device (such as the sensitivity range of an accelerometer, or the threshold for a temperature alarm). Multiple procedures may also be required to read data out of a sensor (such as two bytes to define a temperature, and several bytes to obtain time as well as location readings from a GPS module).

9. Digital: SPI

SPI is an acronym for serial peripherals interface, a standard introduced by Motorola that serves a similar function to the I2C bus, described immediately above. The SPI standard is slightly more sophisticated, enabling duplex communication and higher data transfer speeds. However, SPI requires a minimum of three wires shared by all devices on the bus, and an additional device-selection line for each slave device. The benefit of the extra device lines is that devices are easier to select and address than on an I2C bus, where more program statements are required. As is the case for I2C, code libraries for microcontrollers are widely available to support SPI. However, the requirement for SPI to use three pins on a microcontroller, plus an additional pin for each slave device, is a disadvantage.

More sensors have I2C capability than SPI capability. The SPI protocol is potentially much faster than I2C.

A sensor that is SPI-enabled will almost certainly be available in a similar version that uses I2C. An increasing number of chip-based sensors support both protocols.

Glossary

This glossary is not comprehensive. It contains only the technical terms that have been used most frequently in this book in conjunction with sensor attributes.

ADC Analog-to-digital converter, which accepts a varying signal (usually, a voltage) as an input, and converts it to a digital value in the form of a binary number. This number is likely to have a high limit ranging from 255 decimal to 65535 decimal. Many microcontrollers contain their own ADC, which is multiplexed to assess the inputs on several pins. On an Arduino Uno, the ADC creates a digital value ranging from 0 through 1,023.

analog output When a sensor creates a voltage or varies its resistance without steps or increments, as a function of the phenomenon that it is measuring, this is an analog output.

binary output In this Encyclopedia, the term "binary output" describes a sensor output that only has two states: logic-high and logic-low, or on and off. The term is used in some datasheets, but more often a binary output is described, misleadingly, as an analog output.

breakout board A small printed-circuit board containing one or more integrated circuit chips, usually surface-mounted. The board makes the features of the chips easier to access, because it has pins or connectors with 2.54mm (0.1") spacing for convenient experimental use with a breadboard. Additional features may be included, such as a voltage regulator.

chip-based sensor This term is used in the Encyclopedia to describe a sensor that is etched into a silicon chip and usually has signal conditioning components and circuitry built in.

contact bounce The tiny and rapid vibrations of mechanical switch contacts, when the switch opens or closes. If the switch is connected with a digital device such as a logic chip, debouncing hardware may be necessary, to allow the contacts time to settle. If the switch is connected with a microcontroller, a delay from 5ms to 50ms may be written into program code. Different switches have widely different settling times.

decibel A unit that expresses relative power or intensity, often (but not exclusively) applied to audible sound. The decibel is one-tenth of a bel, and is abbreviated dB, with the B capitalized because it is derived from the name of Alexander Graham Bell. Because dB is a logarithmic unit, the scale has no zero origin. However, 0dB may be assigned arbitrarily to any intensity, in which case lower intensities will have a negative value. An increase of 3dB corresponds to a doubling of sound intensity (acoustic energy). However, when a sound is sensed by the human ear and evaluated by the brain, its subjective loudness doubles when the intensity increases by 10dB.

dielectric The insulating layer separating two plates in a capacitor.

hysteresis The difference between thresholds for switching an output on and off. When a sensor exhibits hysteresis, it may be unresponsive to a stimulus slightly above or below its equivalent current value. This may be useful to eliminate numerous responses to very small stimuli —for example, in a room thermostat.

I2C Interintegrated circuit bus. Sometimes written as I^2C, and often referred to verbally as "I-squared-C." A communications protocol that is often used between a microcontroller and other components on a circuit board. For a description, see "8. Digital: I2C" in the Appendix.

IMU Inertial measurement unit, consisting of three accelerometers and three gyroscopes, sometimes with the addition of three magnetometers. It can be used as a navigational aid. It may also be used in handheld user input devices, such as game controllers.

Kelvin A temperature scale, often abbreviated with the letter K, in which each degree is equivalent to a Celsius degree, but 0 degrees is at absolute zero—the temperature at which materials have no heat energy at all. 273 degrees K is approximately equal to 0 degrees C.

MEMS Microelectromechanical system, i.e., an integrated circuit chip that also contains tiny moving parts. For example, a MEMS accelerometer is built around microscopic springs that respond to accelerative forces.

newton A unit of force named after Isaac Newton, abbreviated with the capital letter N. A force of 1N will accelerate a mass of 1kg at a rate of 1 meter per second each second.

open collector output Many sensors have an open collector output, or contain an op-amp that has an open collector output. The output pin is attached to the collector of an internal transistor, with its emitter connected to negative ground. Positive voltage applied through a pullup resistor to the open collector will be grounded when the internal transistor is conducting current, but will be available for other devices when the transistor is off. See "3. Analog: Open Collector".

orthogonal Angled at 90 degrees. Three orthogonal elements in a sensor will all be angled at 90 degrees to each other.

pascal A unit of pressure equivalent to 1 newton of force per square meter.

PIR Passive infrared sensor. See Chapter 4.

pullup resistor A resistor that pulls up an output or input voltage in the absence of a signal. May be used in conjunction with an **open collector output**.

quadrature An encoding system for output from a pair of sensors. If the sensors are identified as A and B, four output combinations are possible: A high and B low; A high and B high; A low and B high; A low and B low. A common application is to show the direction of movement of a magnetic or optical pattern past the sensor pair.

reference temperature The temperature at which the output signal of a temperature sensor is measured. This is often listed in a datasheet.

register A section of memory that stores a digital value (usually 1 or 2 bytes in a sensor).

target Any object that is being detected by a motion sensor, proximity sensor, or presence sensor.

temperature coefficient The percentage increase or decrease in the value of a sensor as a result of unit change in temperature (usually 1 degree Celsius). Often abbreviated as TC. The value may be resistance, voltage, or current, depending on the sensor. The temperature coefficient should be negative if the value of the sensor diminishes when its temperature increases. If it is expressed in parts per million, abbreviated ppm, it can be converted to a percentage by dividing by 10,000.

Wheatstone bridge A network of four resistors. At least one of the resistors has an unknown value, while the others have precisely known reference values. The network enables calculation of the unknown value. See Figure 12-2.

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(54) **MAGNETIC VORTEX WORMHOLE GENERATOR**

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(57) **ABSTRACT**

This invention relates to a magnetic vortex generator which has the ability to generate negative mass and a negative spring constant which, according to Einstein's General Theory of Relativity, is required in order to create a stable wormhole between our space and hyperspace. Two separate, but electrically connected, toroidal coils of differing radii, carry magnetic flux in opposite directions about their common centerline. According to Maxwell's equation, this produces bucking electric fields along said centerline. Because the two solenoids have different radii, the parallel spring constant of both coils is negative. The negative mass together with the negative spring constant produce a real resonant frequency which can distort the spacetime curvature due to the creation of powerful spikes of negative mass. This phenomenon, similar to the common electrical thunderstorm, opens up a wormhole into hyperspace through which low-density hyperspace energy can enter into our dimension. This energy finds many application in new types of power supplies, inertia-less and mass-less spacecraft, vehicles that can travel light-years by moving out of dimension through hyperspace, surgery-less medical tables, cranes for lifting heavy objects, cold-welded crystals for crystal rotors, folding space waveguides, and electromagnetic field propulsion vehicles using highly relativistic fields.

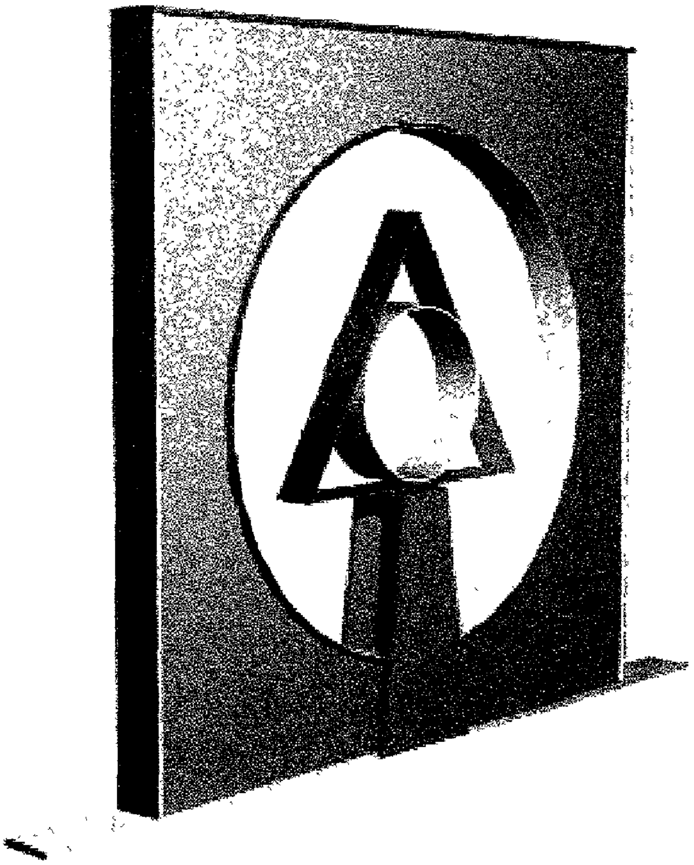

Figure 1

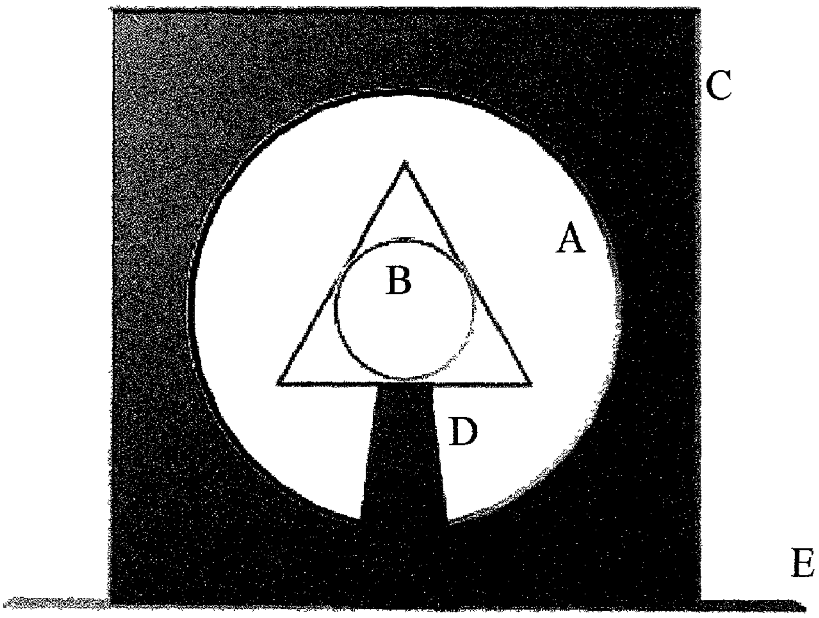

Figure 2

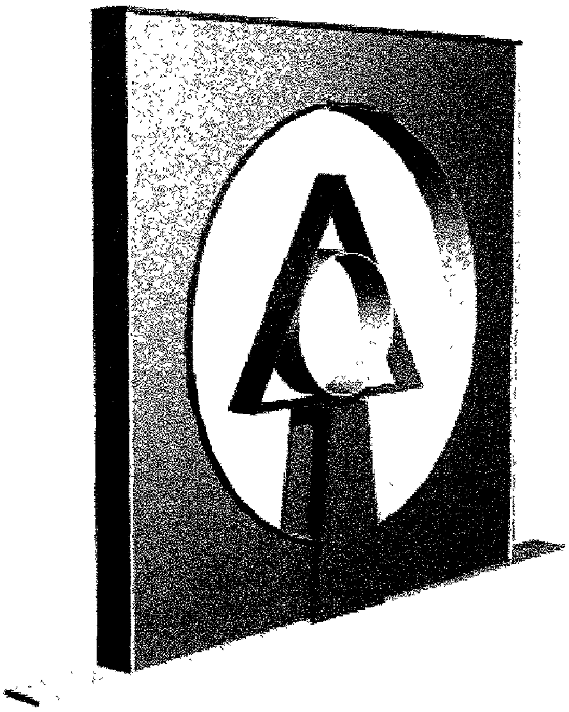

Figure 3

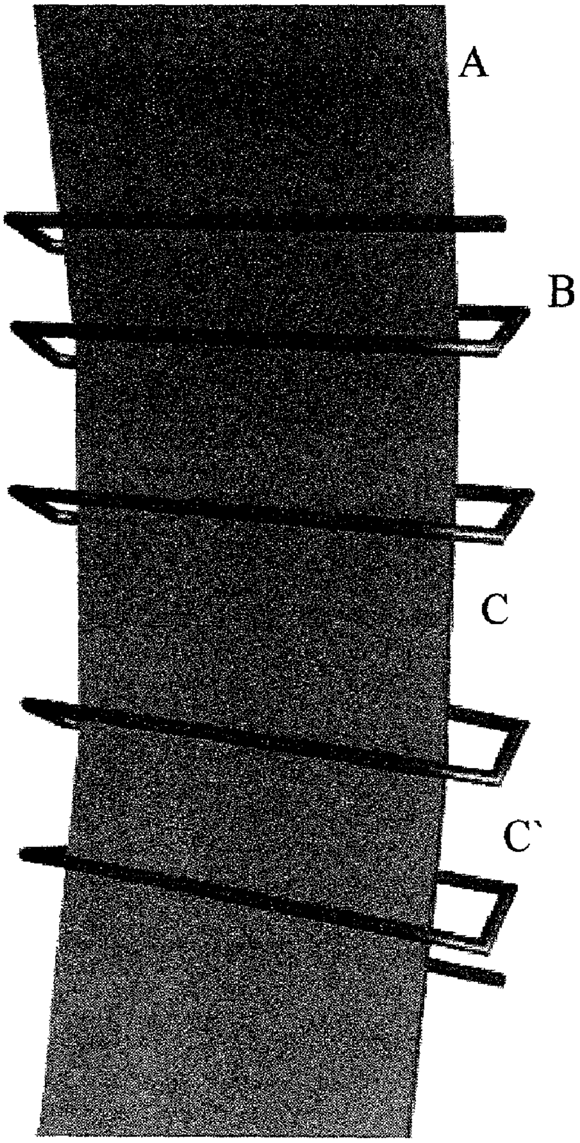

Figure 4

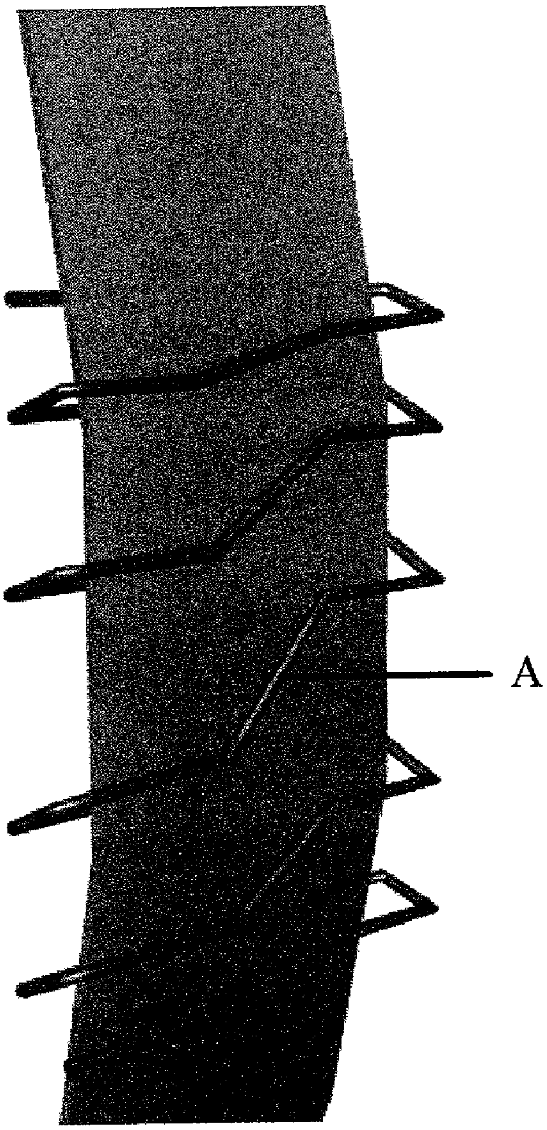

Figure 5

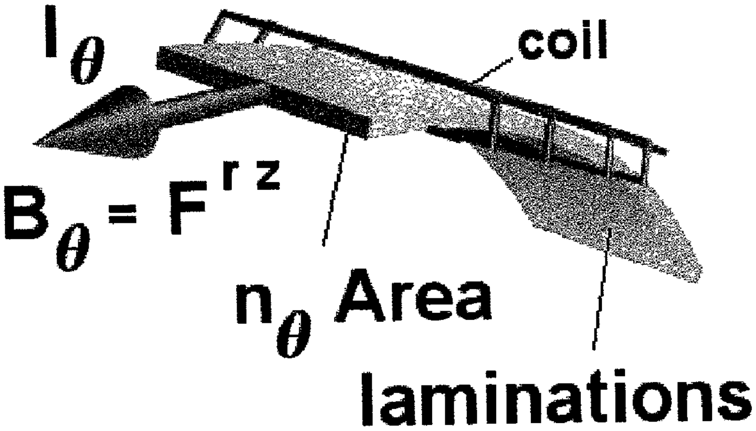

I_θ
coil
$B_\theta = F^{rz}$
n_θ Area
laminations

Figure 6

$$F^{\mu\nu} = \begin{array}{c|cccc} & t & r & \theta & z \\ t & 0 & 0 & 0 & 0 \\ r & 0 & 0 & 0 & B_\theta \\ \theta & 0 & 0 & 0 & 0 \\ z & 0 & -B_\theta & 0 & 0 \end{array}$$

Figure 7

$$k^z = \frac{\text{coul}}{\text{sec}} \cdot \text{m}^2 \cdot \frac{1}{\text{m}^2} \cdot \frac{\text{kg}}{\text{sec} \cdot \text{coul}} = \frac{\text{newton}}{\text{m}} = \frac{\text{force}}{\text{m}}$$

Figure 8

$$k^z = \frac{1}{(r+a)^2} - \frac{1}{r^2} = -a \frac{(2 \cdot r + a)}{\left[(r+a)^2 \cdot r^2\right]}$$

Figure 9

$$g_{\alpha\beta} = \begin{array}{c|cccc|} & t & r & \theta & z \\ t & -1 & & B(\cos\theta - \sin\theta) & 0 \\ r & 0 & 1 & 0 & 0 \\ \theta & B(\cos\theta - \sin\theta) & 0 & r^2 & 0 \\ z & 0 & 0 & 0 & 1 \end{array}$$

Figure 10

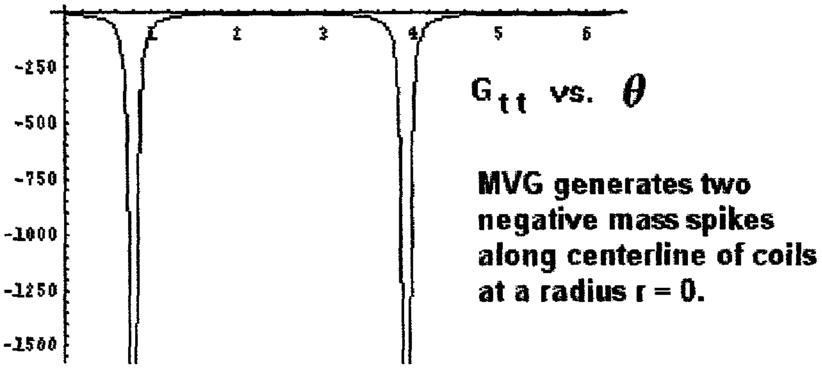

Figure 11

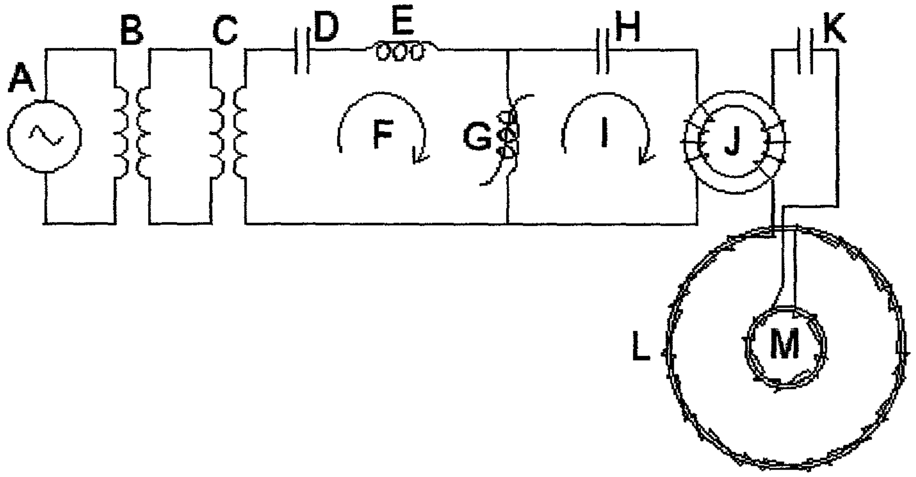
A
B
C
D
E
F
G
H
I
J
K
L
M

Figure 12

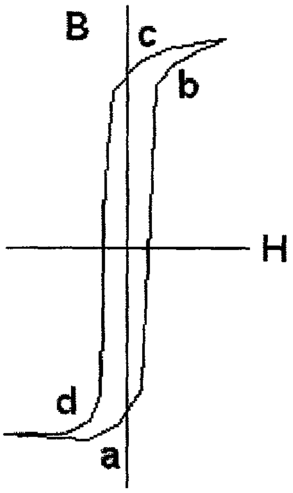

MAGNETIC VORTEX WORMHOLE GENERATOR

BRIEF SUMMARY OF THE INVENTION

[**0001**] This invention, which is the subject of my present application, is comprised of two solenoids wound with a common wire in opposite directions on two separate toroidal curved-sheet transformer laminates of differing radii. The smaller solenoid is mounted along the centerline of the larger solenoid. This circular magnetic geometry creates linear bucking electric fields along the centerline of the coils. Because the magnetic flux in the laminates travels in opposite directions along arcs of differing radii in the two coils, a negative mass and a negative spring constant are generated by the system. From the theory of gravitational physics, a negative mass is prerequisite to producing a wormhole because it allows the throat of the wormhole to remain open and stable. The creation of the wormhole is facilitated by the appearance of a negative spring constant which allows the spacetime curvature to resonate to such a degree that said wormhole develops between our dimension and another co-dimension of hyperspace. Because the physics constants of hyperspace are different from ours, the wormhole allows hyperspace energy having a low speed of light to enter our dimension. Because electromagnetic fields obey the Lorentz transformation, it is now possible with this lower velocity of light to create huge relativistic fields which can drive the new electromagnetic field propulsion vehicles.

BACKGROUND OF THE INVENTION

[**0002**] The idea for this coil configuration comes from the observation of powerful thunderstorms, as described by physicist Dr. Richard Feynman in his *Lectures on Physics,* a copy of which is enclosed as a reference. Upon reading his explanation, I realized that the thunderstorm is actually a hyperspace physics phenomenon.

[**0003**] After the passage of a large lightning storm, people have observed that a car tire rim has merged with the trunk of a tree growing in the ground. Due to the large branches of the tree, there is no possible way that it could slide down the branches and around the trunk. It was observed also that a straw of wheat became embedded in the hard wood of a telephone pole. It turns out that the thunderstorm offers an explanation as to how this can occur.

[**0004**] After reading Feynman's explanation, it can be seen that the key to this phenomenon is that there is a downward and an upward lightning bolt, sometimes occurring together if the leader branches into two paths. Bolts of lightning also like to strike tall objects such as telephone poles or trees. Now an electrical current moving downward produces a clockwise magnetic B field, as seen from above. On the return stroke, the current is moving upward which produces a counterclockwise magnetic B field. Thus the thunderstorm produces two huge bucking magnetic B fields which is the magnetic geometry of this magnetic vortex generator. Using my tetrahedron diagram, I will then show that the low density hyperspace energy with its low speed of light is able to pull the rim out of dimension so that it can merge with the tree at the moment the lightning strikes.

SUMMARY OF THE INVENTION

[**0005**] It is the object of this invention to produce two toroidal oppositely-directed magnetic flux fields in two separate yet electrically connected solenoids of differing radii. Because the lines of flux are traveling in toroidal, curved-sheet transformer laminates along arcs of different curvature, the fields produce what is known in gravitational physics as negative mass. Negative mass has the property that if you project it onto a hot surface, the surface will cool rather than heat up. The negative mass, together with the resonance of the spacetime curvature involving a negative spring constant, create a wormhole into hyperspace. This interdimensional connection allows low speed of light hyperspace energy into our dimension which can be used to decrease the weight of an object, or produce huge relativistic electromagnetic fields that can be used to drive the new electromagnetic field propulsion spacecraft.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[**0006**] Not Applicable.

A BRIEF DESCRIPTION OF THE DRAWINGS

[**0007**] **FIG. 1**. Front view of magnetic vortex generator.

[**0008**] **FIG. 2**. Perspective view of the magnetic vortex generator.

[**0009**] **FIG. 3**. The non-linear coil winding on the interior face of the laminations.

[**0010**] **FIG. 4**. The non-linear coil winding on the exterior face of the laminations showing that there is an electrical current component in the theta direction.

[**0011**] **FIG. 5**. The coil variables for the tensor calculation of the negative spring constant.

[**0012**] **FIG. 6**. The Faraday electromagnetic tensor showing the position of the magnetic field in the {r,z} slots.

[**0013**] **FIG. 7**. The units of the spring constant.

[**0014**] **FIG. 8**. The parallel spacetime spring constant.

[**0015**] **FIG. 9**. The cylindrical g metric tensor including the magnetic fields.

[**0016**] **FIG. 10**. A plot of the mass term G_n for Einstein's G curvature tensor showing that two negative mass spikes are created along the centerline of the generator. Negative mass is required to keep open the throat of the wormhole.

[**0017**] **FIG. 11**. Circuit diagram for the magnetic vortex generator.

[**0018**] **FIG. 12**. BH curve for non-linear SuperMalloy toroidal core. From the equation, $B=\mu H$, the slope of the line is equal to the permeability $\partial B/\partial H=\mu$.

DETAILED DESCRIPTION OF THE INVENTION

[**0019**] 1. The fact that negative mass is required to keep the throat of a wormhole open has been shown to be valid by physicist Dr. Kip Thorne in the enclosed reference physics paper. The key point of this invention is that if you have a negative mass, you also require a negative spring constant in order to get a real frequency and vice versa. The angular frequency of vibration is equal to the square root of the spring constant K divided by the mass M, or $\omega=\sqrt{K/M}$. If the mass is negative, and the spring constant is positive, the frequency is imaginary. Therefore, in order to get a real frequency, the spring constant has to be negative also.

[0020] 2. Referring to **FIG. 1**, the magnetic vortex generator consists of a large toroidal solenoid (A) and its support structure (C), a smaller toroidal coil (B) with its support structure (D) which holds the coil along the centerline of the larger coil. The entire structure sits on a base (E).

[0021] 3. The two solenoids are wound with a common wire in opposite directions on two separate toroidal curved-sheet transformer laminations of differing radii. From the right hand rule, a changing circular magnetic field in the direction of the fingers produces a linear electric field in the direction of the thumb. Because there are two coils producing two magnetic fields in opposite directions, there are two bucking electric fields down the centerline of the coils. This duplicates the thunderstorm conditions. A perspective view of the generator is shown in **FIG. 2**.

[0022] 4. A enlarged view of the non-linear coil winding is shown in **FIG. 3**. The wire (B) is wound around the thin transformer laminations (A) with a non-linear coil spacing as shown by the difference in spacing between length (C) and (C'). On this inner side of the coil, the wire is wound straight across where it can be seen that the wire is normal to the edge of the laminations. Not shown are two strips of Velcro which keep the wire aligned and offset from the tape-covered metal laminations.

[0023] 5. Since the wire is straight across on this side, the opposite side has to have the wire run in a diagonal manner as seen in **FIG. 4A**. In terms of cylindrical coordinates, the components of the electrical current in the coil flow in the z-direction across the breadth of the lamination and in the O-direction around the lamination.

[0024] 6. The reason for the non-linear spacing is to preserve the vector potential of the coil. The vector potential is a more important field than the magnetic field because it can extend out past the windings of a long solenoid. If you look at the units, it is the field momentum per charge or kilogram meter per second coulomb. Notice that the derivative of the vector potential with respect to time is an electric field, while a derivative with respect to length is the magnetic field. The inductance of the coil times the current density is equal to the vector potential. Thus the inductance gradient of the coil times the current per meter is the magnetic field. So the non-linear coil picks up an additional magnetic field around the coil besides the one created in the laminations by the winding itself

[0025] 7. Taking a closer look at the coil in **FIG. 5**, it is constructed of thin laminations taped together to form a cylindrical shape with a wire coil wrapped around it. This creates a magnetic field in the theta θ direction within the laminations. Because the coil is wrapped as a helix, there is a current component I_θ in the theta direction. The cross-sectional area Area through which the magnetic flux flows times a normal vector n in the theta direction is the tensor area n_θ Area. If the radius of the coil is r, then the curvature K is $1/r^2$ pointing in the radial direction. Because there are two coils with differing radii, the generator has two curvatures associated with it.

[0026] 8. In the geometry of electromagnetism, the magnetic field is part of the electromagnetic Faraday tensor $F^{\mu\nu}$ which is a 4 by 4 spacetime matrix having rows and columns of time t, radius r, angle θ and height z in cylindrical coordinates. The first index μ refers to the row, and the second index v refers to the column. The diagonal of the matrix is zero. The first row and column belong to the electric field. All the other slots are filled by the components of the magnetic field. The B_θ component is located in the complementary slots of r and z as shown in **FIG. 6**. Now a tensor product can be written with the available variables I^θ no Area $K_r F^{rz}=k^z$. This says that the current around the loop in the theta direction times the lamination area vector in the theta direction times the curvature K of the coil in the radial direction times the magnetic field in the theta direction is equal to a spring constant in the z-direction, or normal to the plane of the coil. All the tensor components cancel out except for the z-direction. That is, the coil produces a spacetime spring constant through the center of the coil where there are resonant bucking electric fields. So the coil is creating a magnetic spring. The units of the spring constant are shown in **FIG. 7** as force per meter.

[0027] 9. Because there are two coils operating in opposite directions in regions of differing curvature, there are two parallel spring constants generated along the centerline. Two springs in parallel sum, but the inner coil is negative due to the triple product of negative signs of current, field and area. Looking at the front view of the coils, the right hand rule shows the field going counterclockwise with the thumb pointing along the electric field in the positive z-direction. The inner coil with the field going in the clockwise direction has the electric field in the negative z-direction. Therefore the outer coil's positive spring constant sums with the inner coil's negative spring constant to produce an overall negative spring constant as shown in **FIG. 8**. The inner coil has a radius r, and the spacing between the outer and inner coil is a. In this design, the inner radius is 1, and the outer radius is 3 which is the magic ratio in physics of 1/3. That makes length a equal to 2. Substituting r=1 and a=2 into the spring constant equation shows that the ratio is negative 8/9. That is, the spring constant is negative as previously asserted. If the spring constant is negative, it must produce negative mass in order to have a real frequency of resonance. Since it produces negative mass, then it can produce a wormhole as shown by Dr. Kip Thorne.

[0028] 10. The geometry of hyperspace physics is based on the geometry of the tetrahedron which is circumscribed by the sphere. The corners of the tetrahedron touch the sphere at a latitude of 19.47122063° which turns out to be, in terms of planet cosmology, the location where all the large volcanoes and vortices occur on Earth, Mars, Jupiter, Uranus and Neptune. Furthermore, the cosine squared of this angle is 8/9, which is the spring constant ratio for the magnetic vortex generator. That is, the coil is interacting with the geometry of spacetime which is why it is such an effective wormhole generator. As will be demonstrated later, the tetrahedral geometry of hyperspace shows that the electron and proton are one and the same particle. This is a new discovery in science coming out of this research. The diagram also shows that when the speed of light is reduced, due to the low density of energy coming into our dimension through the wormhole, Planck's constant divided by the speed of light puts the electron at the boundary between space and hyperspace. That is, the electron and the proton go out of dimension which is the reason that the car tire rim can become merged with the tree. The ramifications of this magnetic vortex generator are enormous. It means developing new types of crystals through interdimensional merging which will be needed in the development of these spacecraft and their crystal rotors. It means the possibility of teleporting spacecraft through hyperspace over distances of light years using the new folding space waveguides. It means light-weight or inertia-less spacecraft which can be accelerated at hundreds of thousands of g's. It means the ability to lift extraordinary loads in construction work. It means surgery-less medical tables where tumors can be pulled directly out of the patient's body.

[**0029**] 11. Because we have a magnetic spring, then there is some resonant frequency at which the coil can be operated in order to create a large spacetime distortion. It is this distortion that creates the wormhole into hyperspace. From this it follows that the wormhole attaches to a low pressure region with a magnetic monopole. Because pressure is linear mass times the speed of light squared divided by area, a low pressure signifies a low speed of light and less dense matter. What this means is that opposite polarity spacetime curvature at two ends of an electrode will produce a voltage along the electrode, effectively creating a power supply. The reason for this is that spacetime curvature, as shown by Einstein's General Theory of Relativity equation $G_{\alpha\beta}=8\pi T_{\alpha\beta}$, is equal to the square of the electromagnetic fields in the stress-energy tensor T. So the curvature on the ends of the electrode appear as voltages and the system acts as a battery supply to power the spacecraft.

[**0030**] 12. The other characteristic of the magnetic vortex generator is that it can pull objects out of dimension allowing the object to apparently move through solid walls. The object doesn't actually move through the wall because the object is not in the same dimension as the wall; it just appears that way. Moving out of dimension and then back again on the other side of the wall would effectively move the object through the wall for all intents and purposes.

[**0031**] 13. The tetrahedron diagram is a physics diagram which plots the natural logarithm of mass to the natural logarithm of wavelength. The product of mass times wavelength is equal to Planck's constant divided by the speed of light. So the product of the electron mass times its wavelength is equal to the proton mass times its wavelength is equal to the Planck mass times the Planck wavelength. The Planck wavelength is the bottom dimensional limit of the universe. We live in the Planck box which is bounded by the Planck wavelength and Planck mass. Outside this box is hyperspace.

[**0032**] 14. Because logarithms sum, the sum of the log of the mass plus the log of the wavelength is a constant sum. Thus the electron and proton and Planck mass slide on a 45° line known as the base constant which is equal at the axes to the log of Planck's constant divided by the speed of light. Planck's constant is measured in joule-sec so that multiplying it by the frequency 1/second of light gives the energy of the photon particle.

[**0033**] 15. Planck's constant is equal to the Planck wavelength times the Planck mass times the speed of light. The 45° base constant is Planck's constant divided by the speed of light, which means that the speed of light cancels out top and bottom, leaving the area of the Planck box as the value of the base constant. Hyperspace has a low linear mass compared to our dimension. Therefore, Planck's constant is reduced when this energy enters our dimension through the wormhole created by the generator. And the base constant is also so reduced. In terms of logs, this means that the 45° base line becomes more negative and moves to the right on the diagram. As it does so, the base line intersects the electron at the Planck wavelength which is the separation point between space and hyperspace. That is, the electron moves out of dimension. Because the electron and proton are one and the same particle, as shown in reference tetrahedron diagram tet0565, the proton and hence the entire atom is taken out of dimension as well.

[**0034**] 16. All of this can be seen more easily graphically on the tetrahedron diagram itself, referring to reference tetrahedron diagram tet3025. The 45° line which intersects the electron at point (b) is the base constant for our dimension. As you can see, this base line intersects the horizontal axis at a value of −95.91546344 which is the log of Planck's constant h divided by the speed of light. Because Planck's constant is proportional to the linear mass, it is reduced in value by the low density hyperspace energy and, in terms of logs, becomes more negative. This moves the base line to the right at a value of around minus **105**. The new base line intersects the electron at point (a) which is located on the Planck wavelength that is the boundary between space and hyperspace. Thus the electron at point (a) goes out of dimension.

[**0035**] 17. It was inferred previously that a negative spring constant meant a negative mass was produced by the wormhole generator. This can actually be calculated using Einstein's General Theory of Relativity. The calculation starts with the g metric tensor which is a spacetime measurement of distance in terms of time t, radius r, horizontal angle θ and length z. This 4 by 4 matrix is shown in **FIG. 9** where the diagonal line has a signature in cylindrical coordinates of values equal to $\{-1, 1, r^2, 1\}$. All the other terms of the matrix are zero except for the magnetic fields in the two coils. Because the field is changing sinusoidally with time in the theta direction, the field has to go into the $\{t, \theta\}$ and $\{\theta, t\}$ slots of the matrix. Because the field in the inner coil is in the negative direction compared to the outer coil, and including a 90° phase shift between the two fields, a suitable magnetic field function would be $B(\cos(\theta)-\sin(\theta))$.

[**0036**] 18. Using a general relativity software package, Einstein's G curvature tensor can be calculated for this particular metric. The first term G t in the upper left hand slot in the corner is the mass term for the tensor. All the other terms are either electromagnetic fluxes or pressure terms involving the squares of the fields.

[**0037**] 19. Referring to **FIG. 10, a** plot of the mass as a function around a small circle shows that two negative mass spikes occur around the circumference of the circle. Because the radius is almost zero, the two spikes are actually coincident.

[**0038**] 20. This next section shows the electrical system used to drive the magnetic vortex generator. Referring to **FIG. 11**, the system is driven by a sinusoidal voltage source (A) into a 1:1 turns isolation transformer (B). The voltage is stepped up into the range of thousands of volts using a step-up hi-pot transformer (C). The first loop consists of a direct current blocking capacitor (D), a transformer choke (E), a variable inductance (G) and the current in the loop (F). The variable inductance is a coil winding on a toroidal core wound with thousandth-inch thick SuperMalloy tape. This coil acts as a magnetic switch due to its variable permeability.

[**0039**] 21. Referring to the accompanying drawing in **FIG. 12**, the slope of the BH curve is actually the permeability of the core. At point (a) on the curve, the slope is very low and therefore the permeability is very small. The resistance of the coil is the frequency of the current times the inductance of the coil. If the permeability is small, then the inductance is low, which means that the coil resistance is low initially. With a low resistance in the coil, current (F) flows through the winding rather easily. Then the coil goes from point (a) to point (b) where the permeability and resistance increase. This change in resistance from a low to a high value dumps the magnetic energy into capacitor (H). Then the non-linear coil saturates between points (b) and (c) where again the coil has a small slope and the coil resistance switches to a low value. Capacitor (D) then dumps its charge (I) through coil (G) producing a large voltage spike in the input and output winding of transformer toroidal coil (J). The magnetic flux in coil (J) then produces a voltage spike in coils (L) and (M) of the magnetic vortex generator. The frequency of oscillation of the generator is determined by capacitor (K) and the overall inductance of the two coils. The diagram shows that the winding is non-linear and in opposite directions going from outer coil to the inner coil.

[**0040**] 22. Frequency of oscillation has to be kept under 20 MHz in order to create a soft wormhole that connects to low pressure regions of hyperspace. The pressure regions of hyperspace are similar to the pressure produced by a dam holding water. The upper surface of the water, where there is no water pressure, is analogous to the black void into which our universe is expanding. In the middle of the dam, there is a region just above us having a lower water pressure which corresponds to the low density hyperspace energy. This analogy is not perfect because the many frequencies of hyperspace are quantized, as we know from quantum physics, rather than being a continuous spectrum of lower and lower frequencies down to the zero frequency of the black void.

What I claim as my invention is

1. A magnetic vortex generator which can generate negative mass according to Einstein's General Theory of Relativity, which is a tested and proven theory. As a result of this theory, it can be shown that negative mass is required to create a stable wormhole between space and hyperspace. Without the negative mass, the throat would close.

2. The generator consists of two solenoids wound with a common wire in opposite directions on two separate toroidal curved-sheet transformer laminates of differing radii. The smaller solenoid is mounted along the centerline of the larger solenoid.

3. According to Maxwell's equations, said geometrical and magnetic arrangement produces linear bucking electric fields along the centerline of said coils. Since curvature and the square of the electromagnetic fields are one and the same phenomenon according to Einstein's spacetime curvature tensor $G=8\pi T$, this resonance of the electric fields causes a resonance of the spacetime curvature and the opening of the wormhole.

4. Due to the fact that the magnetic flux travels within the laminations at a curvature equal to the inverse of the radius squared, each coil produces a spring constant which depends on the current, lamination area, magnetic field strength and the individual curvature of each coil.

5. Due to the fact that the flux travels in opposite directions in each solenoid, the spring constant of the outer coil is positive, and the spring constant of the inner coil is negative. These two spring constants, one positive and one negative, add in parallel to create a negative spring constant for the generator. Because the frequency of resonance is equal to the square root of the negative spring constant divided by the negative mass, the resonant frequency is positive real.

6. This process of creating and keeping open the wormhole allows low density hyperspace energy to enter our dimension. Because the linear mass is lower, Planck's constant, equal to the Planck mass times the Planck wavelength times the speed of light, is reduced to such an extent that the electron is moved out of dimension. Because the electron and proton are one and the same particle, when considering a path through space and hyperspace, the proton is also moved out of dimension. Thus this process of moving the atom in and out of dimension using the magnetic vortex generator has the ability to create cold-welded crystals, new types of materials and new ways to cold solder one disparate material to another.

7. As a consequence of said process, highly relativistic electromagnetic fields can be created because the velocity of light has been reduced considerably. These fields than can be used to produce life in the new class of electromagnetic propulsion vehicles.

8. As a consequence of said process, refrigeration systems can be created because negative energy cools rather than heats.

9. As a consequence of said process, power supplies can be made such that a differential spacetime curvature on the ends of a carbon electrode can create a differential voltage similar to a regular chemical battery.

10. As a consequence of this process, surgery-less medical tables can be fabricated whereby tumors can be pulled directly from the patient's body.

11. As a consequence of this process, the negative mass produced by the generator can offset the mass of a spacecraft to create a mass-less, inertia-less vehicle which can accelerate at hundreds of thousands of g's.

12. As a consequence of this process, the folding space waveguide becomes a reality whereby hyperspace energy, which has a low spring constant, can be easily folded and curved using powerful, relativistic electromagnetic fields. Spacecraft will be able to teleport themselves out-of-dimension over huge distances measured in terms of light-years.

13. Because the wormhole opens up an interdimensional connection to hyperspace having a magnetic monopole, a radial magnetic field is created. As a consequence of this process, a changing magnetic monopole field crossed with a changing electric field can produce a toroidal electromagnetic flux around the circular hull of the spacecraft. As a consequence of the merger of these two fields, a spacetime curvature G_{zz} is produced over the hull of the spacecraft which creates a tension or lift force which enables the spacecraft to ascend, hover or descend.

14. An electrical system, comprised of a variable frequency generator and amplifier, an isolation transformer and voltage step-up transformer, drives a non-linear inductance which switches on and off the current in the output circuit in such a manner as to produce large voltage spikes through magnetic vortex generator. The generator responds by producing two large negative mass spikes close to the centerline of the two coils.

15. The winding on each coil of the generator has a non-linear spacing to enhance the magnetic field and to reduce the interwinding coil capacitance.

16. The ratio of the radius of the small coil to that of the larger coil is 1/3, which is the magic ratio in physics. This creates a spring constant that is proportional to 8/9. The square of the cosine of the tetrahedral angle of 19.47° is equal to this ratio. Also the ratio of the area-to-volume ratio of the circumscribing sphere of a tetrahedron to the area-to-volume ratio of the tetrahedron is also 1/3. And the corners of the tetrahedron touch the circumscribing sphere at 19.47°. All the large volcanoes and vortices on Earth, Mars, Jupiter, Uranus and Neptune are located at this latitude. Thus this invention is more effective in developing a wormhole because it is tuned geometrically to the tetrahedral geometry of space.

* * * * *

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(54) **FULL BODY TELEPORTATION SYSTEM**

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B64C 39/00 (2006.01)

(52) **U.S. Cl.** **244/62**

(57) **ABSTRACT**

A pulsed gravitational wave wormhole generator system that teleports a human being through hyperspace from one location to another.

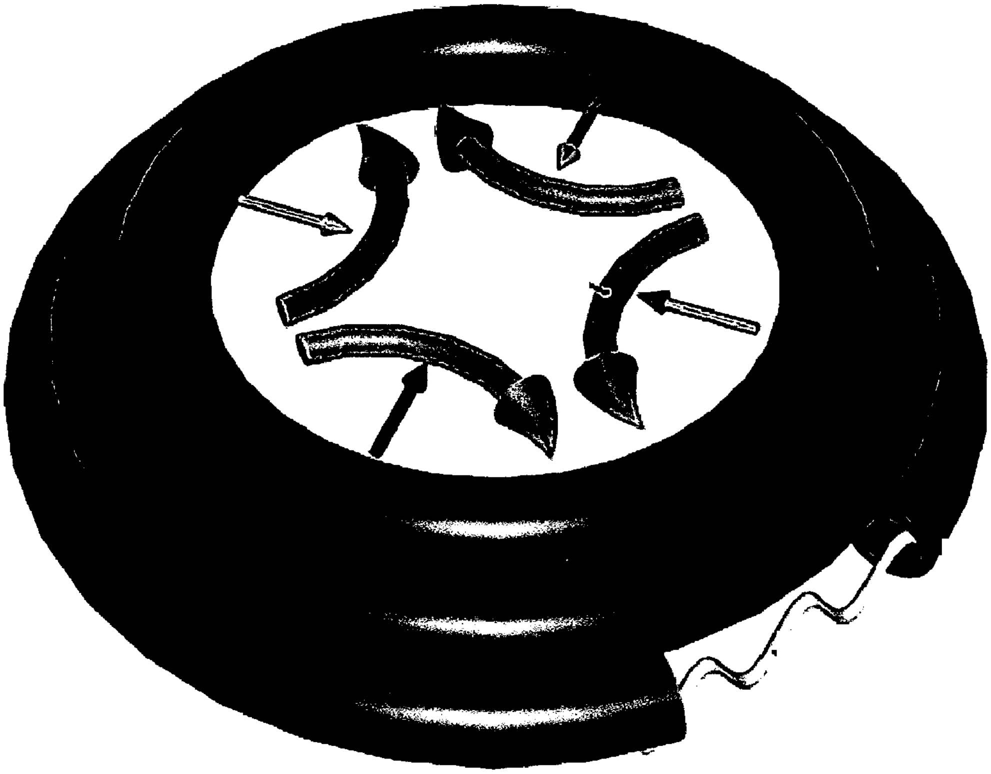

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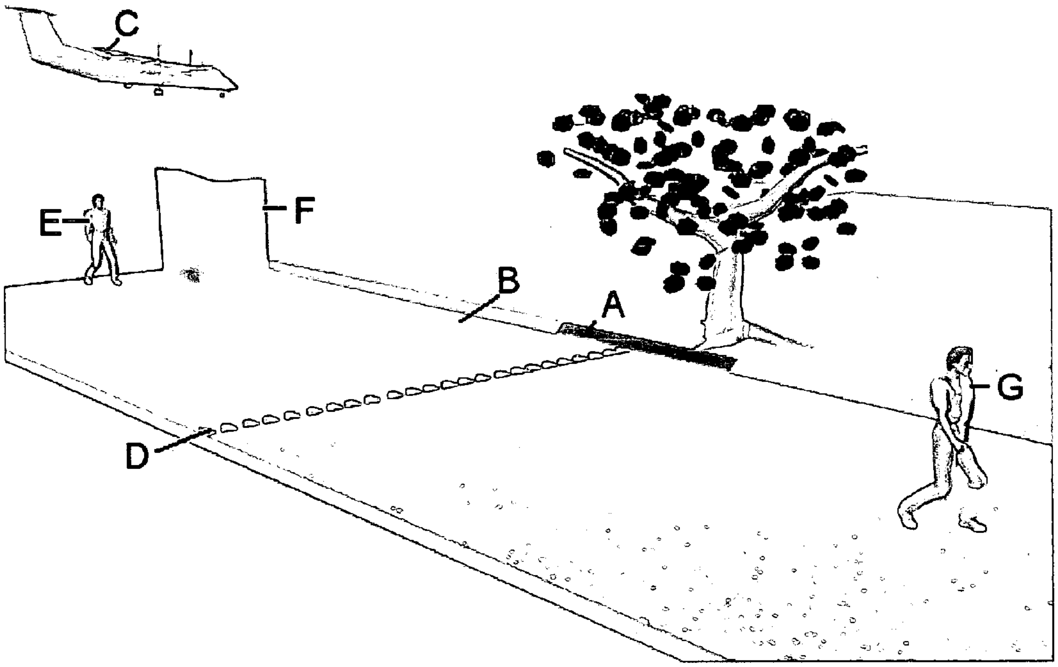

Figure 2

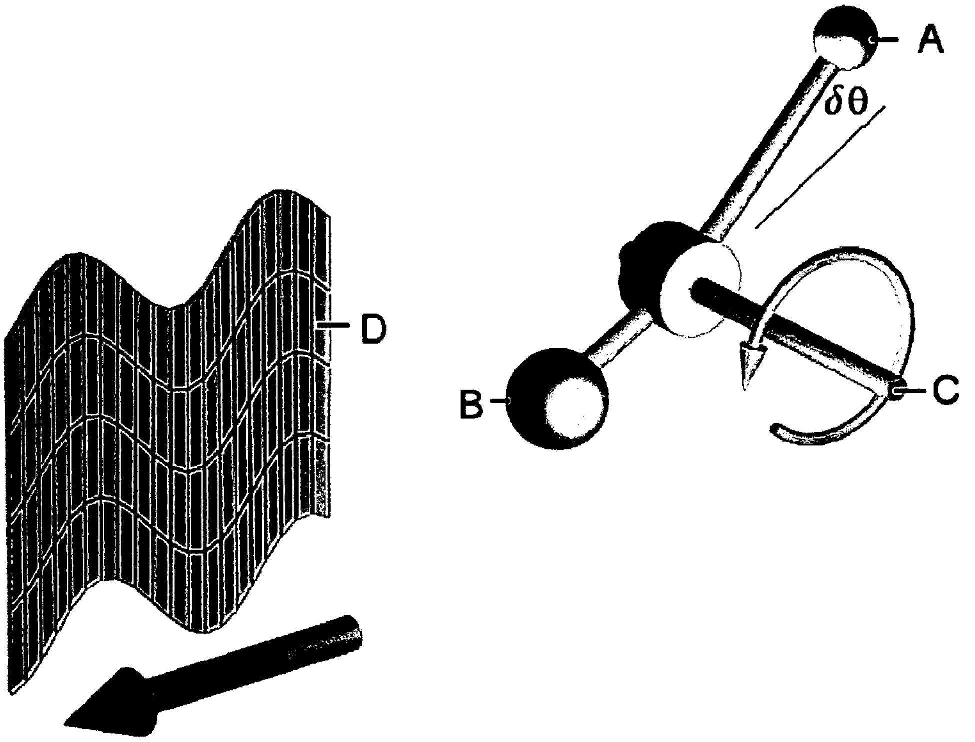

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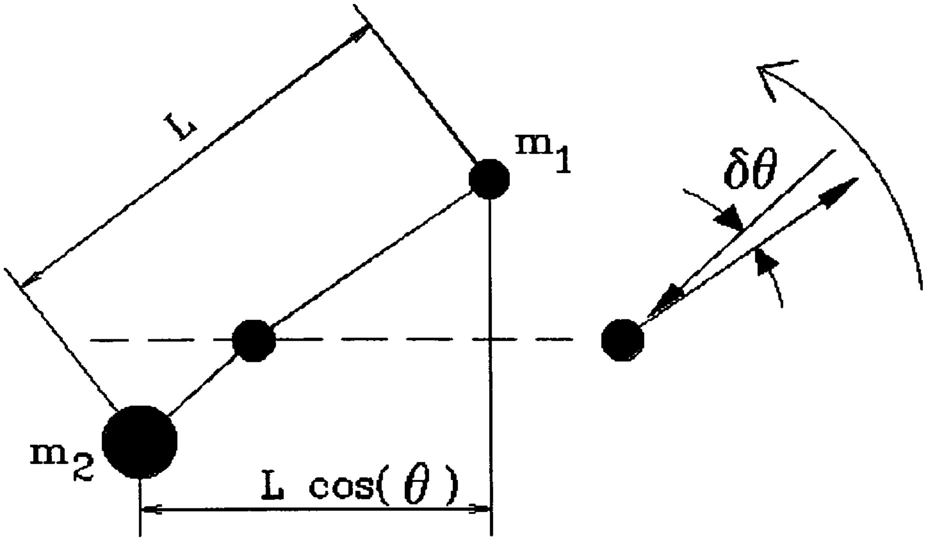
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m_1
$\delta\theta$
m_2
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Figure 4

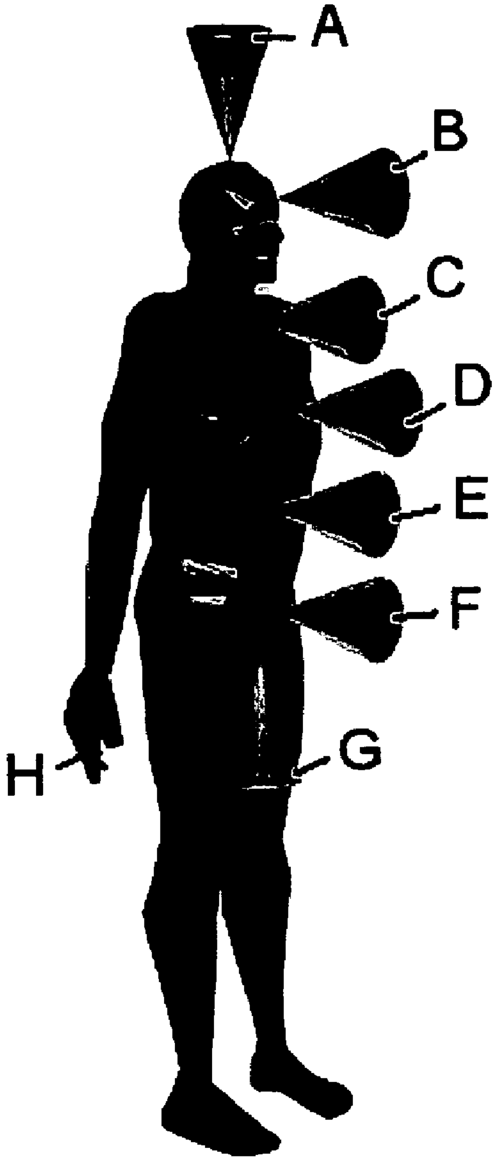

Figure 5

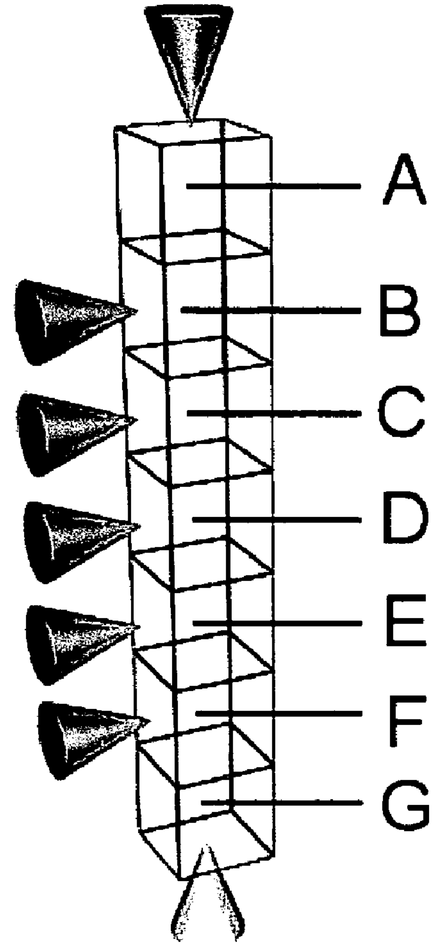

Figure 6

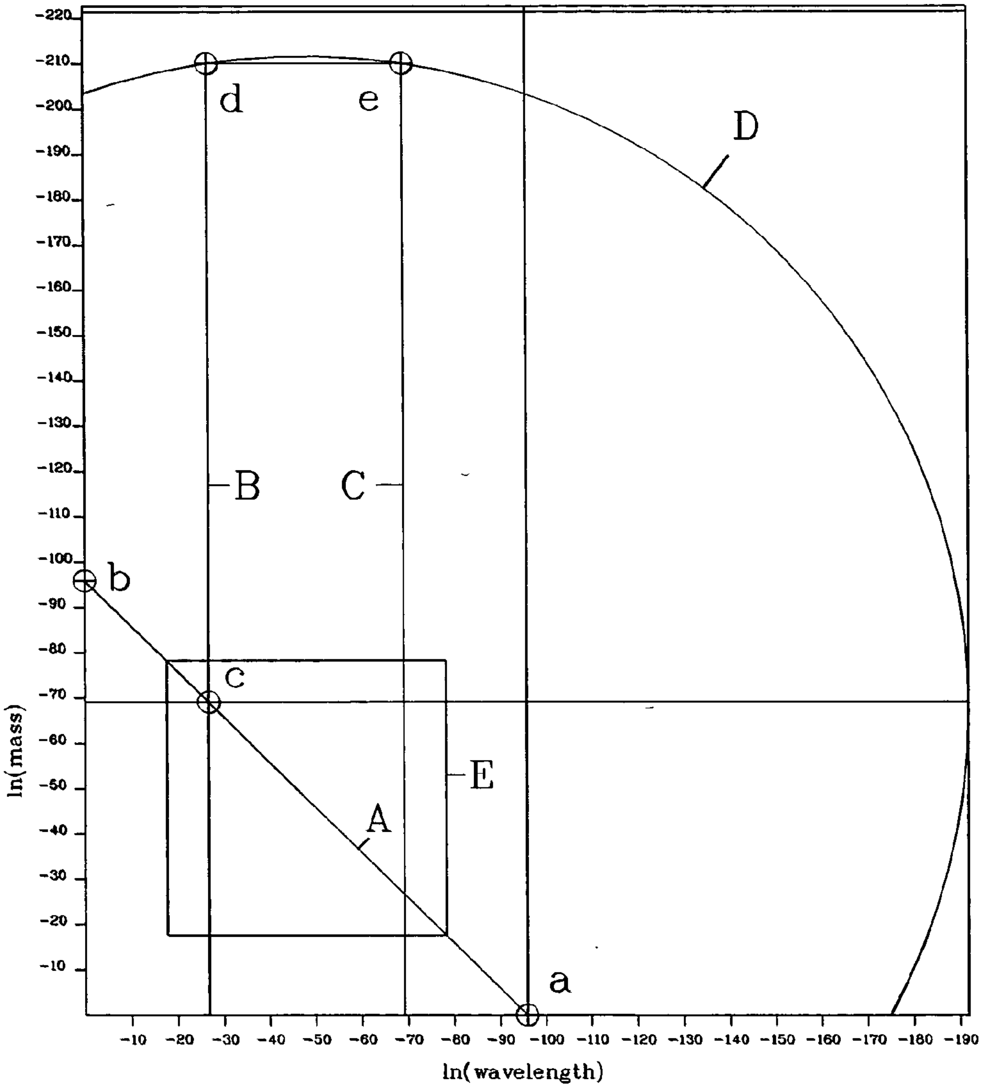

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ln(mass)
d
e
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a
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ln(wavelength)

Figure 7

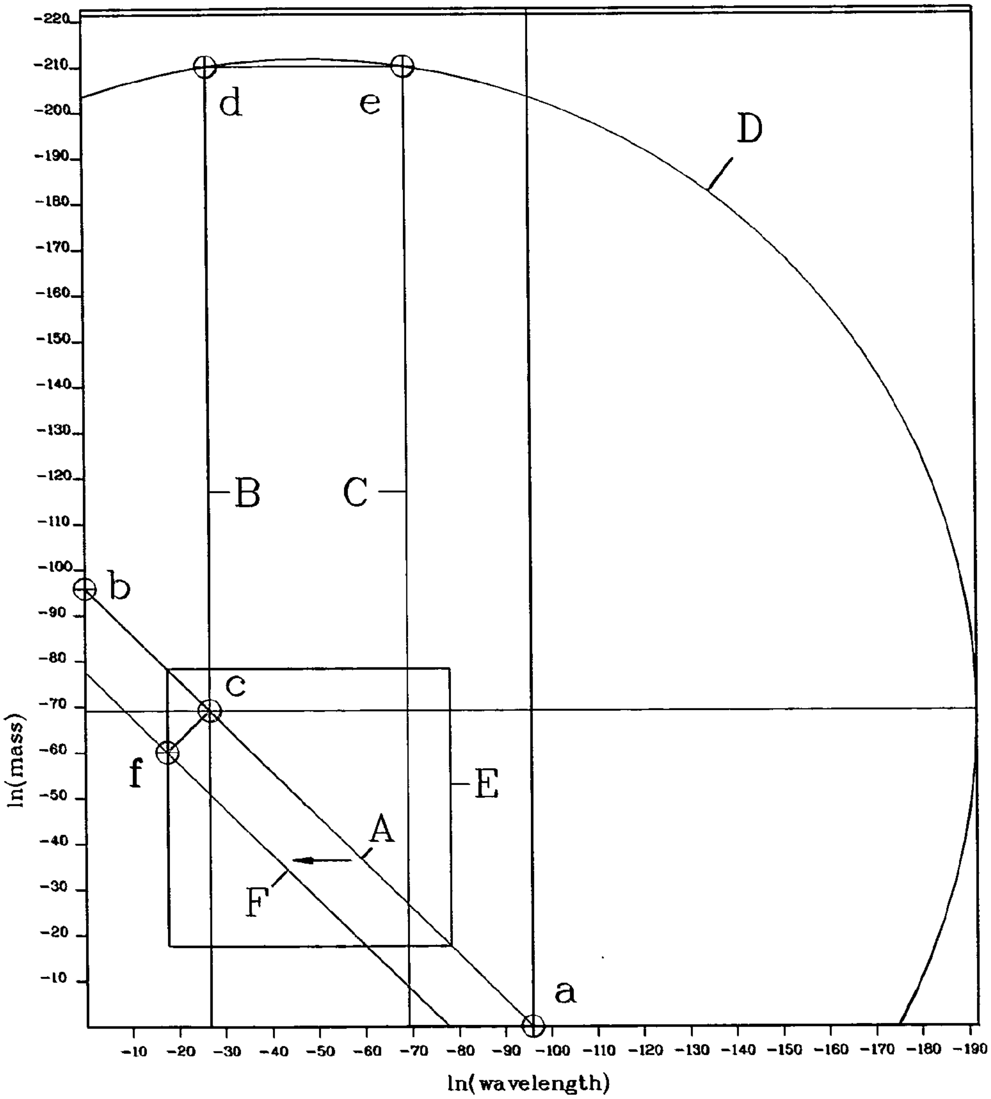
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Figure 8

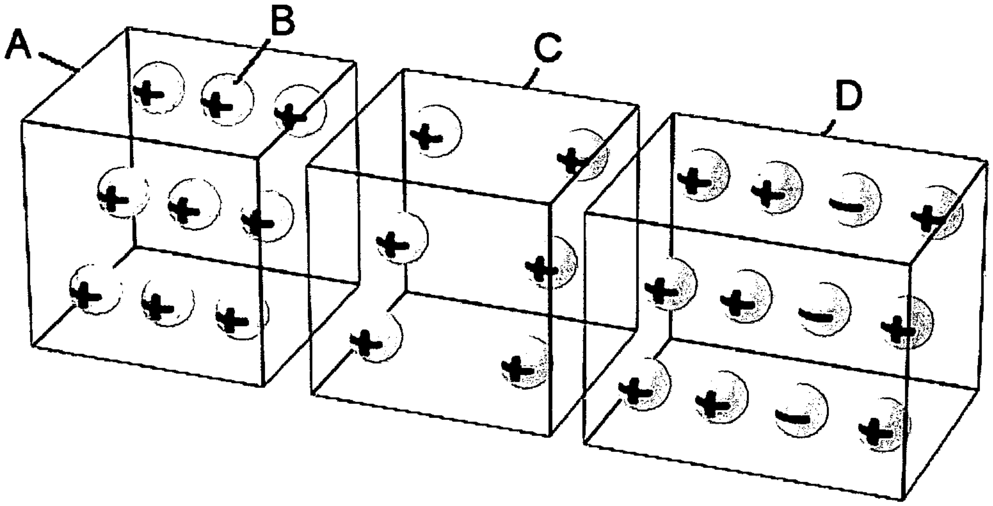

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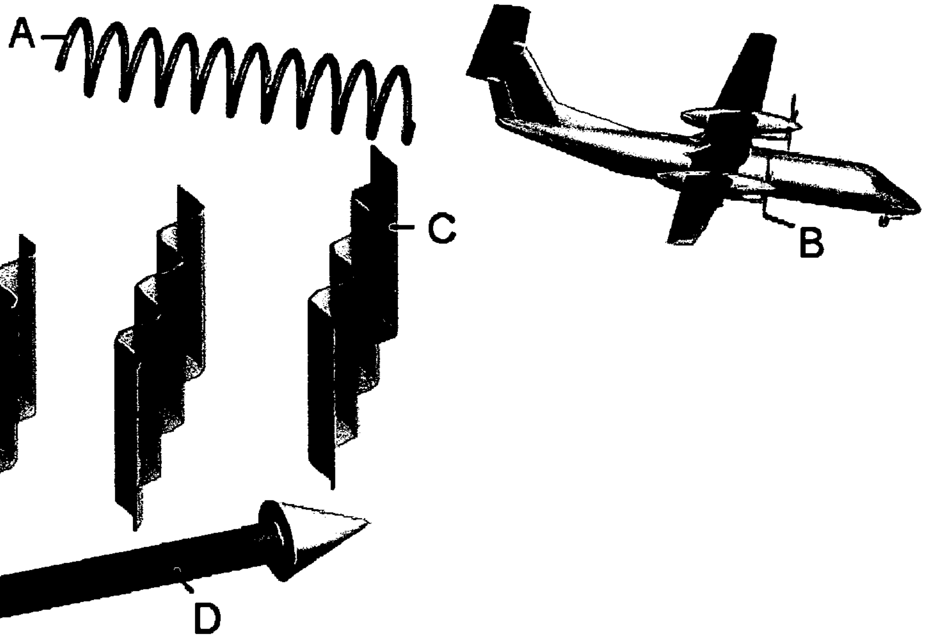

Figure 10

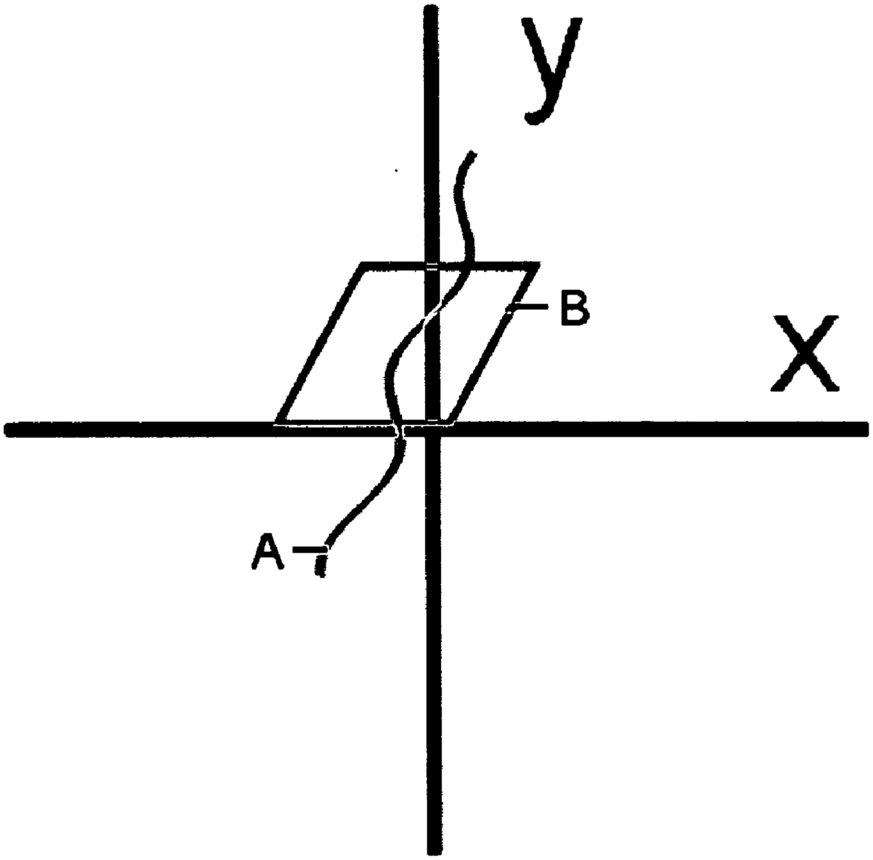

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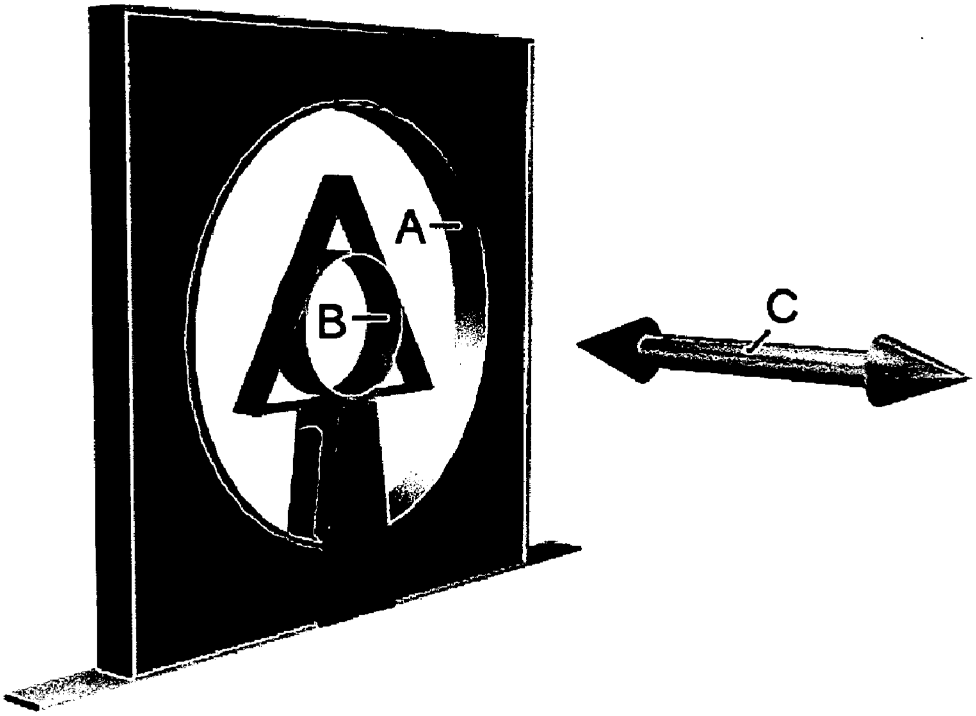

Figure 12

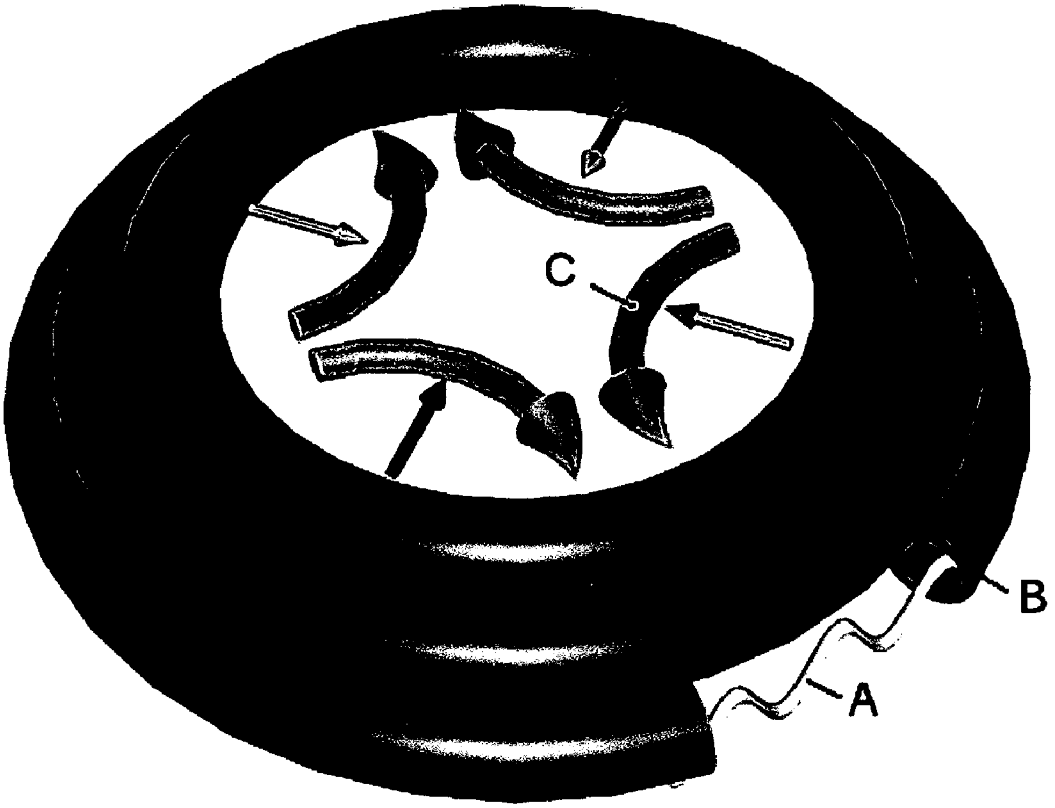

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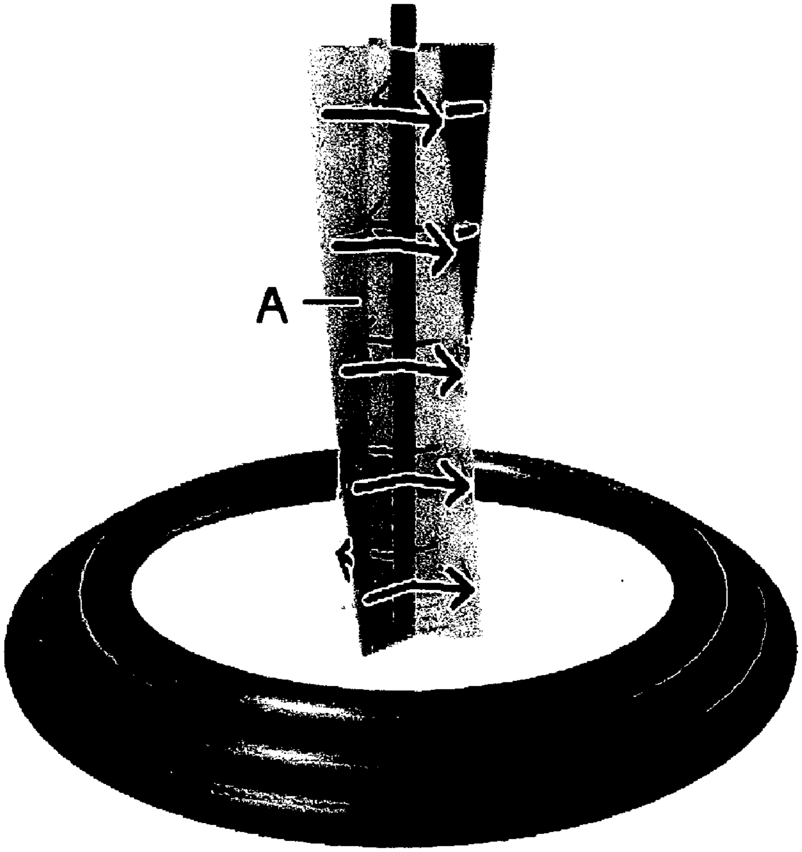

Figure 14

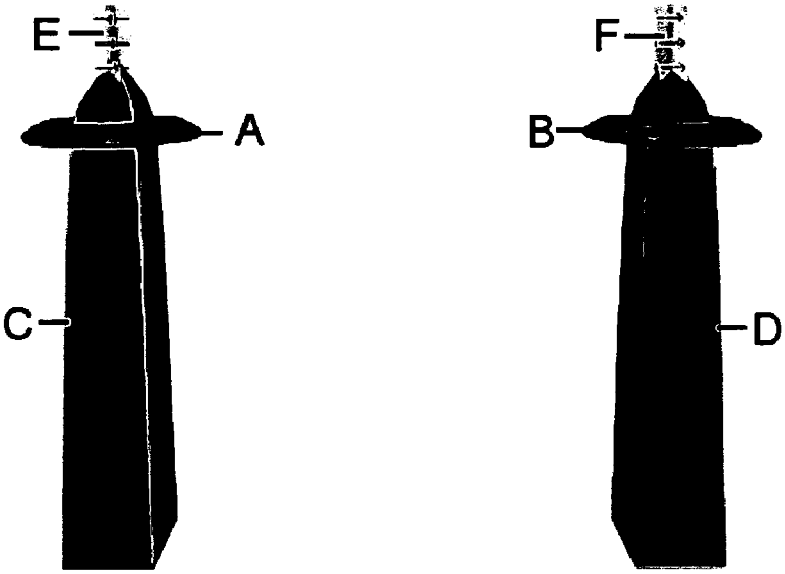

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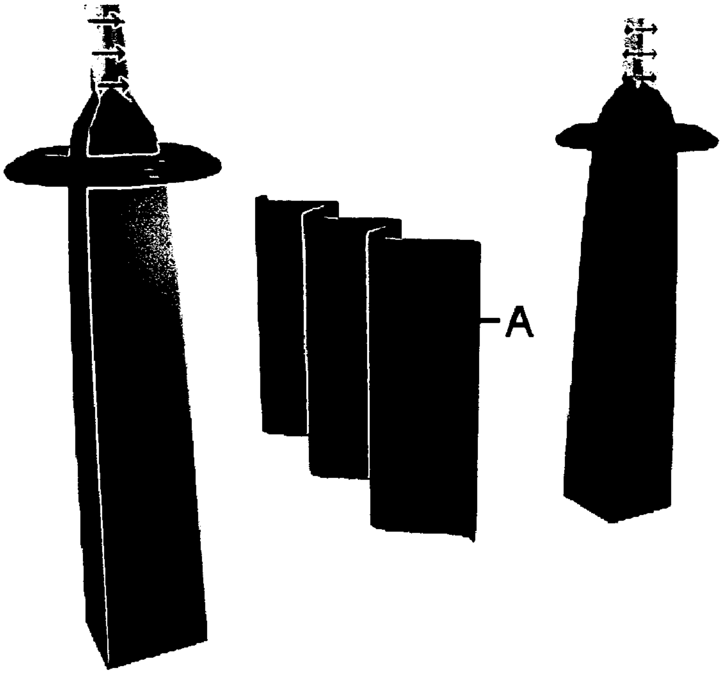

Figure 16

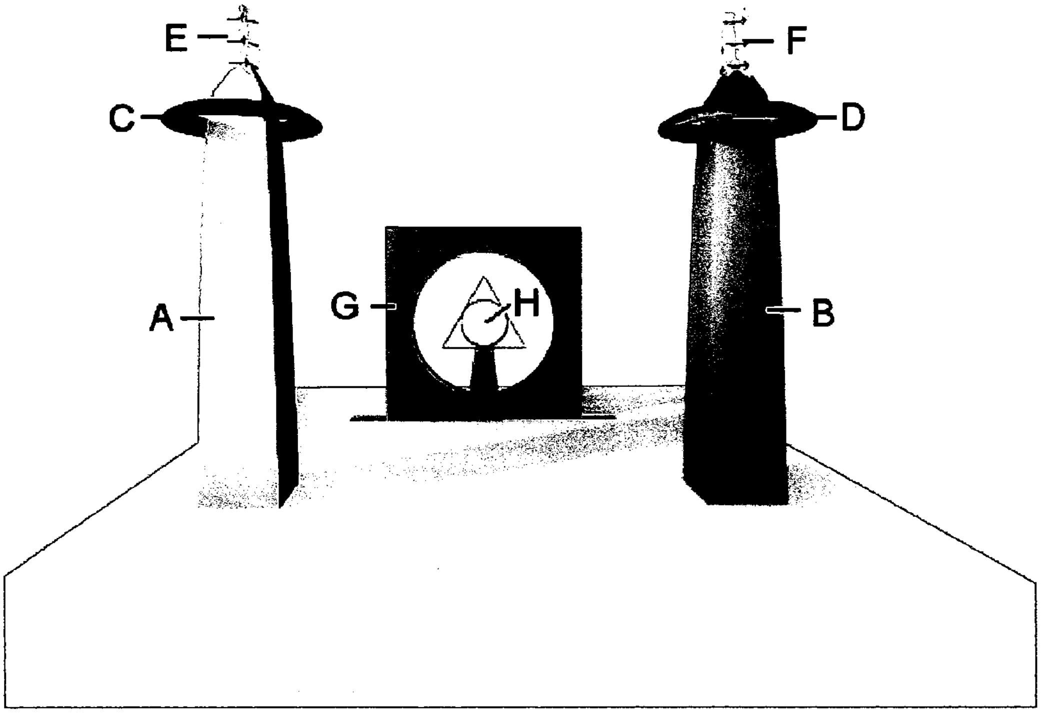

FULL BODY TELEPORTATION SYSTEM

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is a system that teleports a human being through hyperspace from one location to another using a pulsed gravitational wave traveling through hyperspace.

BACKGROUND OF THE INVENTION

[0002] The basis for this invention is an event, referring to **FIG. 1**, occurring on May 2, 2004, in which the inventor ("he") personally experienced a full-body teleportation while walking to the bus stop (A) along a road (B) that runs perpendicular to the nearby commercial airport runways where planes are landing. There is a wide iron grating (D) for water drainage that crosses the road at the center of the bus stop. The grating width is such that one has to make a concerted effort to jump across it in order to get from one side to the other. Approximately 50 meters from the iron grating, he (E) felt a vertical wave (F), similar to a flag waving in the breeze, traveling down the street toward the bus stop. The wave velocity was about 1 meter per second, which was slightly faster than his walking speed. In the next instance, he (G) found himself down the street near the corner of the next block. Realizing that he had passed the bus stop, he turned around to see the iron grating approximately 50 meters up the street in back of him. Because there was no recollection of having jumped across the iron grating nor of having passed the bus stop's yellow marker line, he realized that he had been teleported a distance of 100 meters while moving along with the traveling wave. It was obvious that the wave was pulsed because the front edge overtook the inventor, moved with him momentarily, and then the back edge of wave left him as it moved on down the street. While contemplating this sequence of events, he then looked up and saw in a span of a few seconds a twin-turboprop airplane (C) in the distance crossing above the road while making a shallow descent in order to land at the airport.

[0003] It took a number of days in order to understand this sequence of events. The explanation involves knowledge of a wide range of subjects such as gravitation physics, hyperspace physics, wormhole electromagnetic theory and experimentation, quantum physics, and the nature of the human energy field.

[0004] It is obvious from the above scenario that the airplane momentarily crossing perpendicular to the road generates the aforementioned pulse. Because the airplane has an engine on each wing, there are two propellers which conceivably are rotating out-of-phase with each other. That is, the blade of one propeller could be pointing up and the equivalent blade on the other engine could be pointing in a slightly different direction. Notice that the tip of the blade traces out a helix as the plane is landing.

[0005] In gravitation physics, referring to **FIG. 2**, it is known that two masses of mass m**1** and m**2** (A,B) attached by lever arms slightly offset by an angle δθ along the radial direction to the rotating shaft (C), will produce a gravitational wave (D) traveling perpendicular to the shaft. The mass and wave are referred to as the source and receptor respectively. Referring to a side view looking along the shaft **FIG. 3**, the product of the mass m times the angular acceleration a is a constant such that $m\mathbf{1}a\mathbf{1}$ is equal to $m\mathbf{2}a\mathbf{2}$. The distance between the masses is length L, which makes an angle θ with the horizontal axis. The difference in time of travel to the receptor gives rise to a difference in phase δθ equal to the angular velocity ω of the rotating shaft times the length L times the cosine of the angle θ

$$\delta\theta=\omega L\cos(\theta)$$

[0006] At the receptor, the amplitude of the wave is equal to the mass times the acceleration times the phase difference divided by the radius r to the receptor

$$A=\frac{m_1a_1}{r}\delta\theta\approx\left(\frac{m\omega L\sin(\theta)}{r}\right)(\omega L\cos(\theta))=\frac{m\omega^2L^2\sin(2\theta)}{r}$$

Even though the turboprop airplane engines have a high rotational speed and a large separation distance between masses, the gravitational wave which is produced is small and not noticed. The problem is that the gravitational constant G in this dimension has such a small value equal to the speed of light c squared divided by the linear mass Ω of the universe

$$G=\frac{c^2}{\Omega}=\frac{(299792458\ \mathrm{m/s})^2}{1.346812891\cdot10^{27}\ \mathrm{kg/m}}=6.673200002\cdot10^{-11}\ \frac{\mathrm{m}^3}{\mathrm{kgs}^2}$$

[0007] On the other hand, a gravitational wave traveling in hyperspace would be magnified enormously due to the face that the linear mass is so small. The magnitude of the gravitational constant in hyperspace can be estimated in the following manner. At the beginning of the 20th century, a man's parents were dying of tuberculosis. With their permission, he placed them and their beds on weighing scales. When each one passed away, each scale registered a drop in mass equal to 0.071 kilograms. This is the mass of the hyperspace energy being which resides in the physical body. Because hyperspace is co-dimensional with our dimension, the energy being interpenetrates the body and controls its movement.

[0008] Referring to **FIG. 4**, a human being has seven vortices (A through G) which are aligned along the centerline of the body. Each vortex is actually a co-gravitational field K which causes a pendulum placed in the field to spin in circles. For this reason, the K field has units of inverse seconds similar to an angular velocity. The vortex transports energy from our dimension to the energy being located in hyperspace. The gravitational field g and the co-gravitational field K are equivalent gravitationally to the electric E field and the magnetic B field found in electromagnetism. The equivalent gravitational solution to an electromagnetic problem can be obtained by substituting the following gravitational constants for the electromagnetic constants

Electromagnetic	Gravitational
q (charge)	m (mass)
ρ (volume charge density)	ρ (volume mass density)
σ (surface charge density)	σ (surface mass density)
λ (line charge density)	λ (line mass density)
J (convection current density)	J (mass current density)

-continued

Electromagnetic	Gravitational
E (electric field)	g (gravitational field)
B (magnetic field)	K (co-gravitational field)
ϵ_0 (permittivity of space)	$-1/4\pi G$
μ_0 (permeability of space)	$-4\pi G/c^2$
$-1/4\pi\epsilon_0$ or $-\mu_0 c^2/4\pi$	G (gravitational constant)

[0009] Referring to **FIG. 5**, each vortex is connected through the pineal gland by light cords to a separate hyperspace quantum well having its own frequency and dimension. The reason for this separation is that the conical spiritual eye, attached to vortex B, has to have its own energy structure which is different from vortex (A) which is connected to the quantum energy field in which the mental processes are developed. Due to the high speed of light in our dimension, the quantum wells are the size appropriate to molecules and atoms. In hyperspace, where the speed of light is one meter per second, the quantum wells are huge and can be manipulated. This manipulation has shown that the quantum wells are in the shape of a cube about a meter on a side. This makes the whole structure about seven meters tall for a volume of seven cubic meters. Thus the mass density ρ of hyperspace is about

$$\rho_h = \frac{.071\ \text{kg}}{7\ \text{m}^3} = .01\ \frac{\text{kg}}{\text{m}^3}$$

which per unit area is the same value. Therefore the hyperspace gravitational constant is equal to

$$G_h = \frac{c^2}{\Omega_h} = \frac{\left(1\ \frac{\text{m}}{\text{s}}\right)^2}{.01\ \text{kg/m}} = 100\ \frac{\text{m}^3}{\text{kgs}^2}$$

The enormous magnification of the gravitational constant is therefore of the order of

$$\frac{G_h}{G} = \frac{100}{6.6732\cdot 10^{-11}} \approx 1.5\cdot 10^{12}$$

The question is how does this amplified gravitational wave created by the rotating propellers and turbines get into hyperspace from our dimension?

[0010] The answer comes from experiments done using the ancient Chinese form of breathing known as Chi Kung. Using this breathing technique, we have been able to levitate the human body over six feet in the air. The internal temperature of the stomach is around 200 degrees Fahrenheit. By simultaneously squeezing the diaphragm to bring hot air up through the lungs, and breathing through the nose to bring cold air down, rotating vortices are generated in the lung passages when these two air masses meet and twist around each other as depicted in the famous Yin-Yang diagram. Because the lung has variable diameter passages from the large diameter at the throat to the final small air sacs, there is a spectrum of rotating frequencies.

[0011] From quantum physics it is known that if there is a temperature fluctuation occurring among a group of harmonic oscillators in the environment, then Planck's reduced constant $\hbar$ is increased by the cotangent of the constant times the frequency ω of the oscillator divided by twice Boltzmann's constant k times the temperature T

$$\hbar = \hbar\coth\left(\frac{\hbar\omega_n}{2kT}\right)$$

[0012] The effect of increasing Planck's constant, referring to **FIG. 6**, can be seen in the tetrahedron diagram. This diagram, of which there are now over 4000, plots the natural logarithm of mass on the vertical axis versus the natural logarithm of wavelength on the horizontal axis. In terms of mathematics, it is a subspace logarithmic manifold which projects geometrically the physics constants into our **4**D spacetime dimension. That is, it is the geometry of the tetrahedron circumscribed by the sphere that determines the mass of the proton and electron. The mass of the electron times its wavelength is equal to the mass of the proton times its wavelength which in turn is equal to Planck's constant h divided by the speed of light c

$$m_e\lambda_e = m_p\lambda_p = \frac{h}{c}$$

Taking the natural logarithm of the above equation shows that the mass plus the wavelength is equal to what is termed the base constant

$$\ln(m_e) + \ln(\lambda_e) = \ln\left(\frac{h}{c}\right) = -95.91546344$$

which is represented in **FIG. 6** by the 45 degree line (A) from point (a) on the horizontal axis to the vertical axis at point (b). The electron is located at point (c) which is the intersection of the electron wavelength (B) with line (A). The electron wavelength (B) reflects off the sphere (D) at points (d) and (e) and returns along line (C) as the electron mass. As shown in tetrahedron diagram tet0565, stored in the Library of Congress, the clockwise path of the electron transitions into the counter-clockwise path of the proton showing that the electron and proton are one and the same particle. Because the electron and proton travel in opposite directions along the path, they have the same charge but of opposite sign.

[0013] Our dimension is represented by Planck box (E) which is bounded by the Planck mass and the Planck wavelength. The Planck mass is equal to the linear mass of the universe times the Planck length which is the bottom limit of our dimension. The Planck wavelength is 2π times the Planck length. Notice that the electron is located within the Planck box.

[0014] Referring to **FIG. 7**, if there is an increase in Planck's constant due to the temperature fluctuations among the harmonic oscillators, the 45 degree base line (A) moves to the left on the tetrahedron diagram as shown by line (F).

Because of the increase in the base constant, there is a corresponding increase in the electron mass and wavelength. The electron moves from point (c) to point (f) which places it at the edge of the Planck box (F) which is the boundary between space and hyperspace. At point (f), the electron is essentially no longer in our dimension.

[0015] Referring to **FIG. 8**, imagine a box (A) filled with nine electron oscillators (B). If Planck's constant is increased near the three oscillators in the middle, these electrons will leave this dimension. This leaves six oscillators as shown in the box (C). However, box (C) is the equivalent of box (D) in which there are still nine positive mass oscillators together with 3 negative mass oscillators. Thus there is an accumulation of negative energy ($-\rho$) when information is lost from the environment to another dimension.

[0016] Dr. Kip Thorne, who co-authored the book *Gravitation* with Dr. Archibald Wheeler of Princeton University, has shown in a General Relativity spacetime curvature calculation that negative energy is required to open and stabilize the throat of a wormhole between space and hyperspace. The accumulation of negative energy in the aforementioned example generates wormholes between into hyperspace. Hyperspace has a low energy density because of the reduced speed of light in that dimension. Ordinarily, energy would not flow from hyperspace to space because space has a higher potential than the potential of hyperspace. This, of course, is the reason that the body vortices can flow energy into the energy field of the human being who is located in hyperspace. By creating negative energy, the potential becomes reversed such that low density hyperspace energy flows into our dimension as seen by the positive head

$$PE=\rho_{hyperspace}-(-\rho_{space})=+2\rho$$

The low-density energy fills the body which allows a human being to float upwards like a helium balloon as verified by Chi Kung breathing as well as spinning on a motorized platform known as the Chakra Vortex Accelerator. The latter device resulted in the first mechanical means to produce anti-gravity.

[0017] The process of creating spinning thermal fluctuations is the same as found in the hot air vortices created by the jet airplanes landing at the airport near the road where the full-body teleportation occurred. Large vortices are created over the wing of the airplane at the same time that the turbine engines are spinning hot vortices into relatively cold air. These conditions produce wormholes between space and hyperspace. It takes a twin turboprop airplane landing behind the jet to generate the gravitational wave in the region where the wormholes have formed. The gravitational wave then traverses the wormholes into hyperspace, becoming highly amplified due to the change in linear mass and speed of light. Because the propeller blades are co-linear with the road, the gravitational wave travels in the direction along the road where it was encountered by the inventor.

[0018] From experiments with cavitating bubbles (see patent application Cavitating Oil Hyperspace Energy Generator), it was found that it is possible to produce a wormhole if the surfaces of the bubble collapse asymmetrically. A symmetric collapse of a spherical bubble produces enormous spacetime curvature distortions. An asymmetric collapse, using a magnetic field to distort the collapse, produces, in addition to the same severe spacetime distortions, negative energy as the bubble collapses. Due to some General Relativity considerations, the wormhole that is created starts rotating in a manner similar to the beacon light produced by a lighthouse.

[0019] Referring to **FIG. 9**, due to the forward helical motion (A) of the propellers (B) as the airplane crosses the road, the pulsed gravitational wave (C) is skewed backward at an angle (D). Due to the wormholes created by the presence of thermal vorticity fluctuations generated by the wing and turbines of the airplane, this skewed wave moves into hyperspace where it is highly magnified and detected by the inventor.

[0020] Referring to top view **FIG. 10**, the gravitational wave (A) causes a skewed compression and expansion of the hyperspace quantum wells (B) which constitute the human energy being. Due to this asymmetric distortion in the xy-plane, the quantum wells take the physical body out of dimension as long as the wave pulse is traveling with the human energy field. Once the back edge of the gravitational wave moves on past the quantum wells, the body is then brought back into dimension.

SUMMARY OF THE INVENTION

[0021] It is the object of this invention to teleport a human being from one location to another by creating a pulsed gravitational wave traveling through hyperspace that asymmetrically compresses and expands the quantum wells of the human energy being. This spacetime curvature distortion of the hyperspace quantum wells pulls the physical body out of dimension such that the human being is teleported along with the wave. As the pulsed wave moves on past the quantum wells, the human is brought back into dimension at some distant location. The invention requires (1) a device that will generate a wormhole between space and hyperspace, and (2) a device that will generate a gravitational wave which can be inserted through the wormhole.

[0022] Referring to **FIG. 11**, a magnetic vortex wormhole generator has already been developed which generates a wormhole between space and hyperspace as described in a previous patent application entitled Magnetic Vortex Wormhole Generator. Using this generator, it was found that smoke blown through one side of the coil does not appear on the other side of cylindrical coil. The smoke flows through the wormhole and appears in a hyperspace co-dimension. It was this experiment that resulted in making first contact with the androids of the Grey aliens who told me, in a remote viewing session, that "We saw you blowing smoke into hyperspace."

[0023] The wormhole generator consists of two concentric cylindrical coils (A,B), one of larger radius than the other, made of thin transformer iron laminate wrapped in opposite directions with one continuous wire driven by a sinusoidal current. The solenoidal coil generates a magnetic field through the laminate. Because the electrical current flows in opposite directions at different radii through the two windings, bucking electric fields (C) are created along the centerline of the generator. These radially-offset magnetic fields and bucking electric fields, as shown by a calculation using Einstein's General Theory of Relativity, generate both an enormous spiking spacetime curvature and negative energy at small radius along the centerline where the wormhole is formed. The gravitational wave generator is then coupled to this wormhole generator.

[0024] Referring to **FIG. 12**, it is known from gravitation physics that injecting an electromagnetic wave (A) into a hollow toroidal waveguide (B) produces a hyperbolic spacetime curvature stress (C) in the plane of the waveguide. The tips of the arrows indicate compression and the tail of the arrows indicate expansion or stretching of spacetime. The reason for this spacetime curvature is because the waveguide forces the electromagnetic wave to curve around and travel in a circle. Spacetime has to compensate for this toroidal-generated stress by creating hyperbolic lines of stress in the inner plane of the toroid so that the overall spacetime curvature is zero. For a greater gravitational effect, three toroidal waveguides, phased 120 degrees apart, are used to seal off the curvature.

[0025] Referring to **FIG. 13**, the three toroids create a rotating, twisting, vertical propagating gravitational field (A) through the centerline of the toroids provided that the period of the electromagnetic wave is twice the period of the gravitational wave. This phase relationship is adjusted by selecting the correct radius for the frequency of the monochromatic wave.

[0026] In order to effectively use this gravitational wave, referring to **FIG. 14**, three phased toroidal waveguides (A,B) are mounted at the top of each of two identical square granite obelisks (C,D). The two obelisks are offset by a short distance between them. As the vertical gravitational wave rotates around along the vertical axis inside the obelisk, the edges of the square obelisks are compressed and expanded such as to create two cylindrical asymmetric gravitational waves traveling radially outward.

[0027] Referring to **FIG. 15**, these waves meet to form a plane gravitational wave (A) which travels down the centerline between the two obelisks.

[0028] Referring to **FIG. 16**, the full body teleportation system consists of the twin granite obelisks (A,B) on which are mounted near the top of each the toroidal waveguides (C,D) which produce the pulsed gravitational waves (E,F) that run the length of the obelisks. Because the gravitational wave is rotating inside the obelisk, the granite stone undergoes a very small asymmetrical compression and expansion. A cylindrical gravitational wave propagates out from each obelisk such that along the centerline between the two there is generated a plane gravitational wave. This wave enters the wormhole (H) created by the magnetic vortex generator which is located a short distance from and parallel to the obelisks. The wave is amplified by a factor of almost 10^{13} when it enters the hyperspace co-dimension.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0029] **FIG. 1**. Perspective view of site where full-body teleportation occurred.

[0030] **FIG. 2**. Perspective view of gravitational wave generator.

[0031] **FIG. 3**. Planar view of gravitational wave generator.

[0032] **FIG. 4**. Perspective view of seven vortices of human energy being.

[0033] **FIG. 5**. Perspective view of seven large quantum wells of human energy being.

[0034] **FIG. 6**. Tetrahedron diagram showing Planck's constant and electron.

[0035] **FIG. 7**. Tetrahedron diagram showing electron moving out of dimension.

[0036] **FIG. 8**. Perspective view showing production of negative energy.

[0037] **FIG. 9**. Perspective view of skewed gravitational wave produced by propellers.

[0038] **FIG. 10**. Planar view of skewed quantum wells deformed by gravitational wave.

[0039] **FIG. 11**. Perspective view of magnetic vortex wormhole generator.

[0040] **FIG. 12**. Perspective view of hyperbolic lines of stress generated by toroidal waveguide.

[0041] **FIG. 13**. Perspective view of rotating, twisting, propagating gravitational wave generated by toroidal waveguides.

[0042] **FIG. 14**. Perspective view of toroidal waveguides attached to obelisks.

[0043] **FIG. 15**. Perspective view of gravitational wave generated by obelisks.

[0044] **FIG. 16**. Perspective view of magnetic vortex wormhole generator and obelisk gravitational wave generator.

DETAILED DESCRIPTION OF THE INVENTION

[0045] 1. The obelisks are quarried out of granite stone and cut with a large-diameter diamond saw that is used in highway construction. The beveled piece at the top is cut separately and cemented in place. A tapered aluminum bracket holds the toroids in place.

[0046] 2. The electronics for the magnetic vortex generator are similar to that used in the patent application Magnetic Vortex Wormhole Generator.

[0047] 3. The electronics for the toroidal waveguides is the familiar stub and coaxial cable driven by an amplifier and pulsed variable-frequency generator.

I claim:

1. A full body teleportation system consisting of:

generating a pulsed gravitational wave which propagates through a magnetic vortex wormhole generator; and

generating a wormhole with the magnetic vortex generator whereby the pulsed gravitational wave traverses through the wormhole and enters into hyperspace where the wave is enormously magnified due to the lower speed of light in that dimension.

2. The method of claim 1, wherein the step of generating the pulsed gravitational wave comprises:

using two granite stone obelisks;

mounting monochromatic-wave toroidal waveguides on top of each obelisk to create a rotating, twisting, propagating gravitational wave through the vertical axis of each obelisk; and

creating a cylindrical compression and expansion in each obelisk to produce a plane gravitational wave traveling down the centerline between the two obelisks.

3. The method of claim 1, wherein the step of generating a wormhole into hyperspace comprises:

using two concentric cylindrical solenoidal coils of different radii connected by a single wire wrapped in opposite directions on thin iron transformer laminate;

generating bucking electric fields down the centerline of the vortex generator which creates a spacetime curvature distortion with negative energy in accordance with Einstein's General Theory of Relativity.

4. A teleportation system comprising:

generating a gravitational wave traveling through hyperspace which interacts with the human energy being; and

pulling the human energy being and physical body out of dimension when interacting with the pulsed gravitational wave such that the person is teleported from one location to another through hyperspace and back again into our **4**D spacetime dimension.

* * * * *

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(54) **TRIANGULAR SPACECRAFT**

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(57) **ABSTRACT**

A spacecraft having a triangular hull with vertical electrostatic line charges on each corner that produce a horizontal electric field parallel to the sides of the hull. This field, interacting with a plane wave emitted by antennas on the side of the hull, generates a force per volume combining both lift and propulsion.

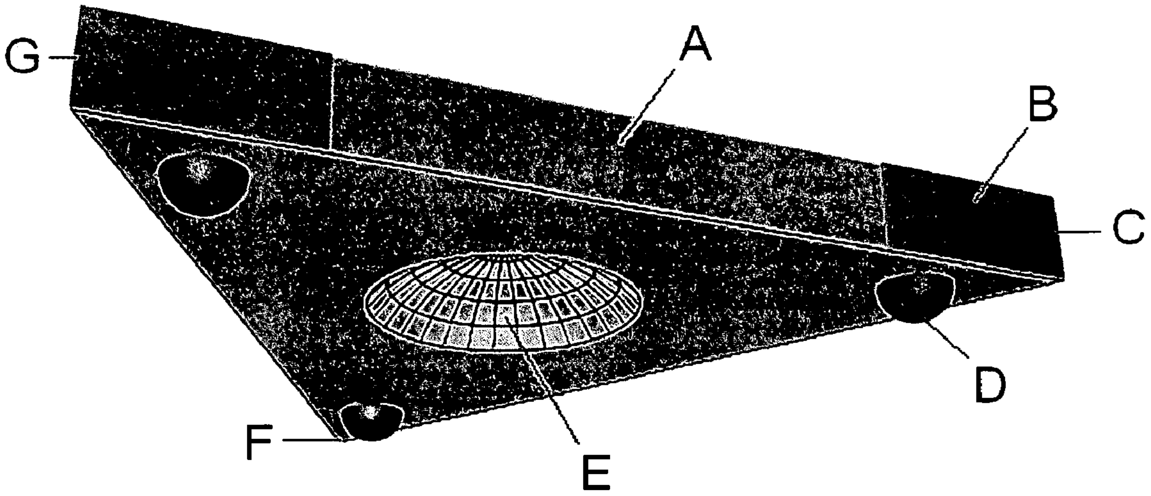

Figure 1

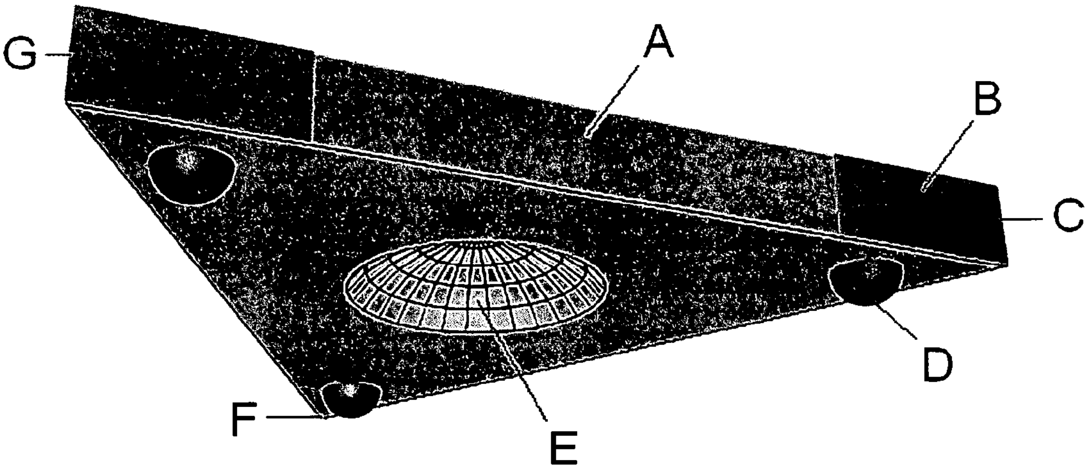

Figure 2

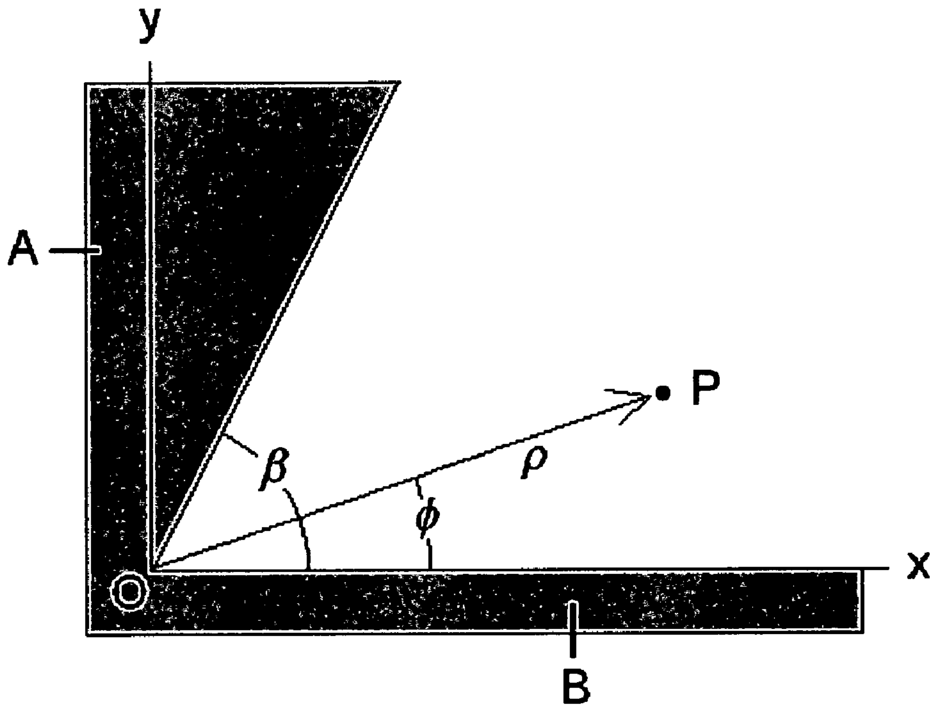

Figure 3

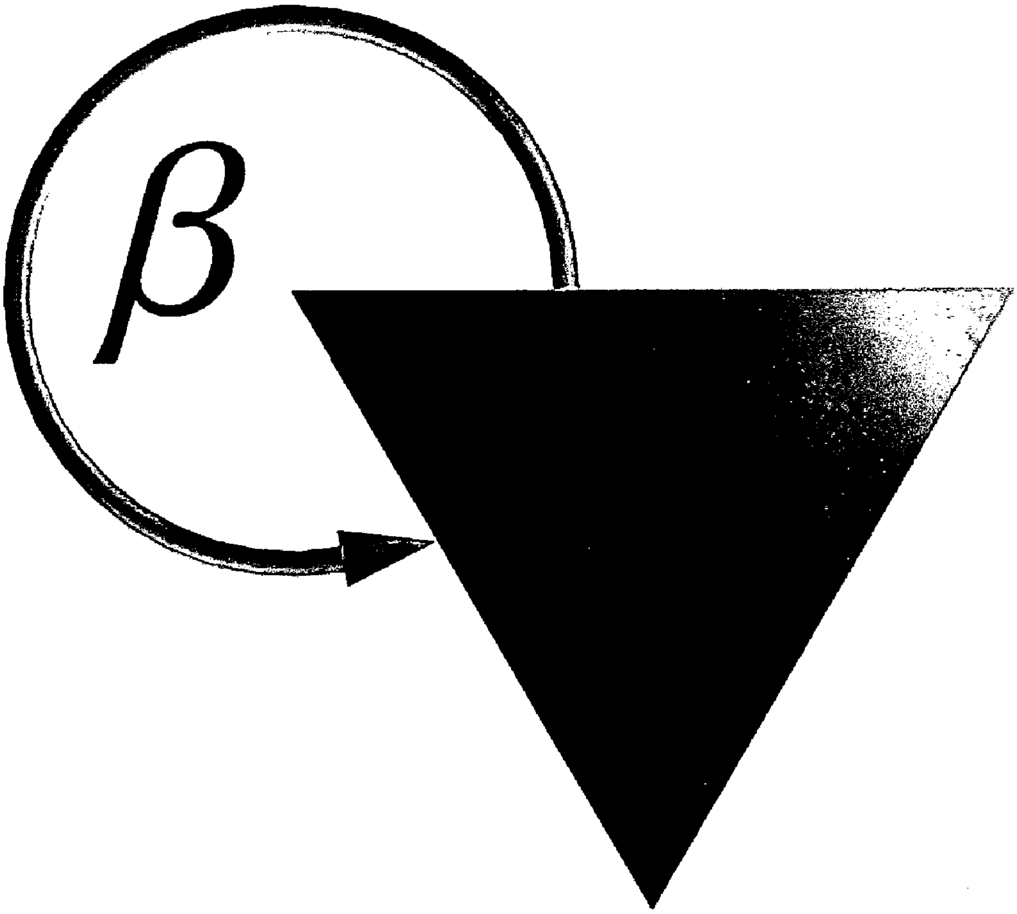

Figure 4

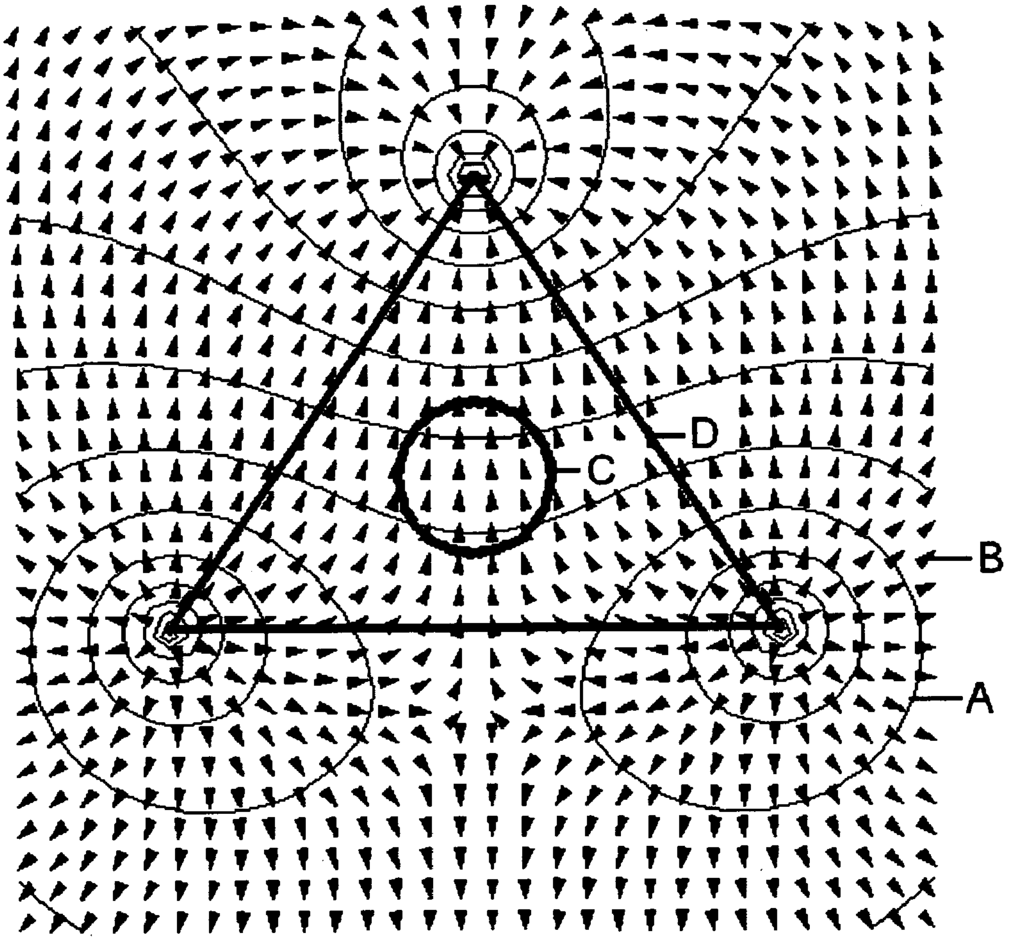

Figure 5

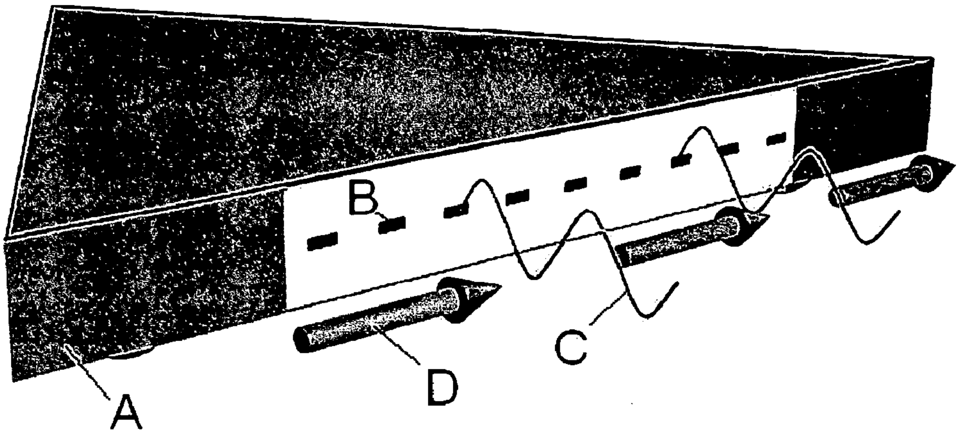

Figure 6

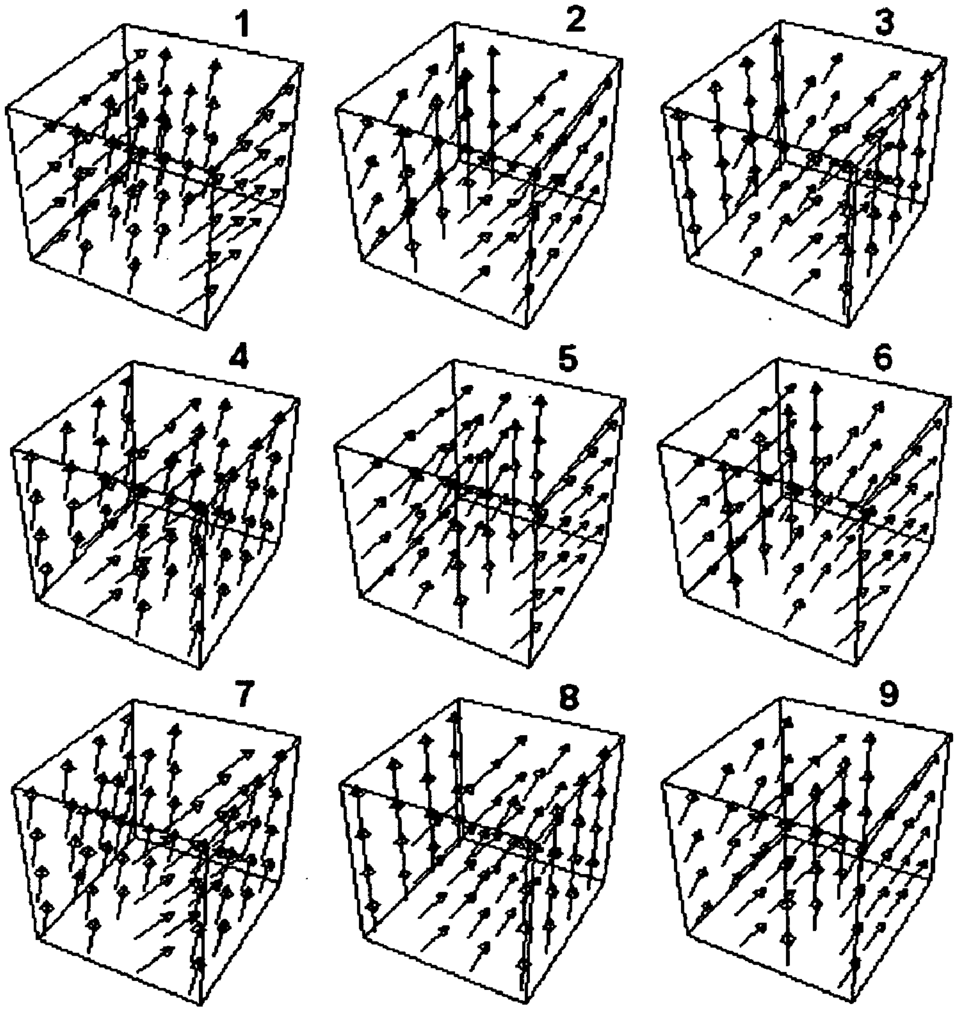

Figure 7

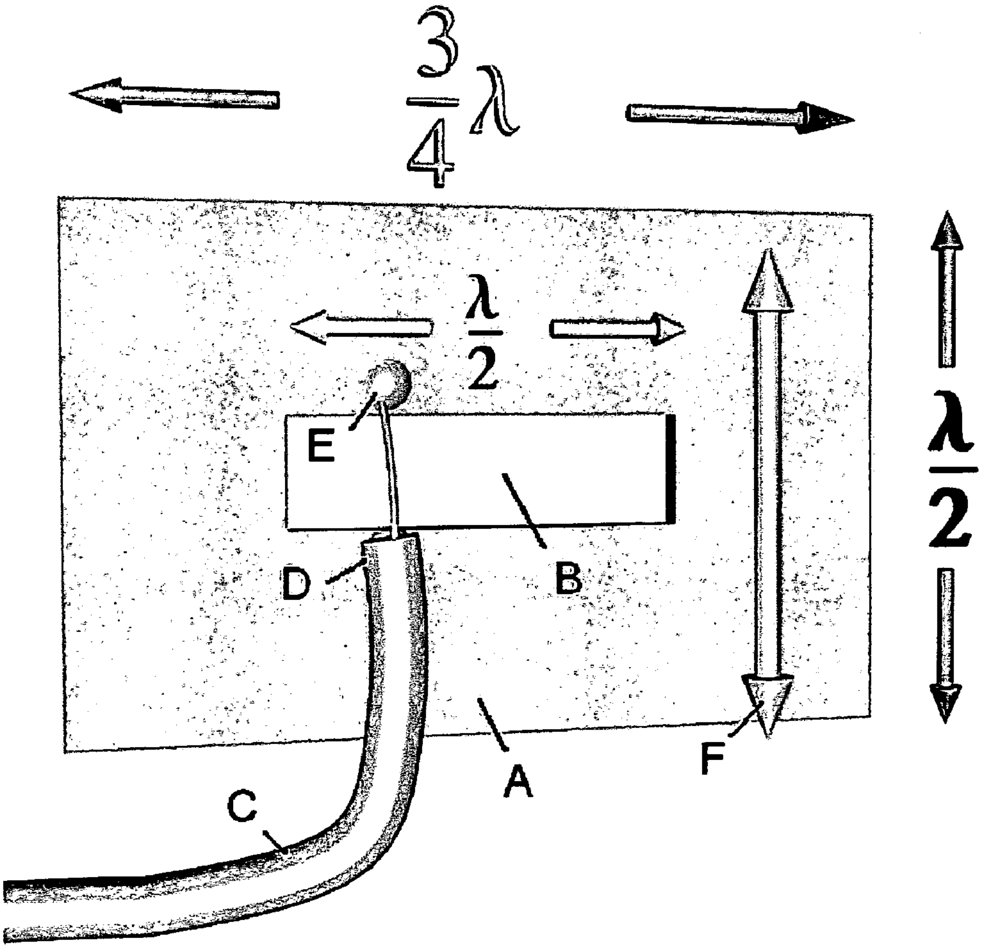
$\frac{3}{4}\lambda$
$\frac{\lambda}{2}$
E
B
D
$\frac{\lambda}{2}$
A
F
C

TRIANGULAR SPACECRAFT

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is a spacecraft having a triangular hull with vertical electrostatic line charges on each corner. The line charges create a horizontal electric field that, together with a plane wave emitted by antennas on the side of the hull, generates a force per volume providing a unique combination of both lift and propulsion.

BACKGROUND OF THE INVENTION

[0002] Referring to **FIG. 1**, the spacecraft has a hull in the shape of an equilateral triangle. A parabolic antenna (E) is centrally located in the bottom of the hull. An array of horizontal slot antennas is located along the side of the hull (A). Each back corner (F,G) has a corner conducting plate which is charged to a positive voltage +V. The forward corner (C) has a conducting plate charged to a negative voltage −V. A motion control hemisphere (D) is located on the bottom surface in each of the three corners.

[0003] Referring to **FIG. 2**, two planes (A,B) intersect at the origin O at an opening angle β. Each plane (x,y) is charged to a voltage V. The potential at point P is determined in polar coordinates $\{\rho\phi\}$. The Laplace equation for the potential Φ in polar coordinates is given by:

$$\frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\rho\frac{\partial\Phi}{\partial\rho}\right)+\frac{1}{\rho^2}\frac{\partial^2\Phi}{\partial\phi^2}=0$$

Using a separation of variables solution, the potential is given as the product of two functions:

$$\Phi(\rho,\phi)=R(\rho)\Psi(\phi)$$

which when substituted into the Laplace equation becomes:

$$\frac{\rho}{R}\frac{d}{d\rho}\left(\rho\frac{dR}{d\rho}\right)+\frac{1}{\Psi}\frac{d^2\Psi}{d\phi^2}=0$$

Since the two terns are separately functions of ρ and ϕ respectively, each one has to be constant with the sum of the constants equal to zero:

$$\frac{\rho}{R}\frac{d}{d\rho}\left(\rho\frac{dR}{d\rho}\right)=v^2 \quad \frac{1}{\Psi}\frac{d^2\Psi}{d\phi^2}=-v^2$$

These two equations have solutions:

$$R(\rho)=a\rho^{v+b\rho-v}$$

$$\psi(\phi)=A\cos(v\phi)+B\sin(v\phi)$$

The azimuthal angle ϕ is restricted to a value in the range $0\leqq\phi\leqq\beta$. The boundary condition is that the potential Φ is equal to V for any radius ρ when $\phi=0$ and $\phi=\beta$. This means that v has to be an integer value of π so that the sine function is zero:

$$\sin(v\beta)=\sin\left(\frac{m\pi}{\beta}\beta\right)=\sin(m\pi)=0 \quad m=1,2\ldots$$

which in turn means that the coefficient A of the cosine term has to be zero in the solution above. Choosing b=0 makes the general solution for the potential equal to:

$$\Phi(\rho,\phi)=V+\sum_{m=1}^{\infty}a_m\rho^{m\pi/\beta}\sin(m\pi\phi/\beta)$$

which shows that when the angle is zero, the sine is zero and the potential is V. If the angle is β, then there is a multiple of π such that the sine is zero again.

[0004] Because the series involves positive powers of the radius, for small enough ρ, only the first term $m=1$ in the series is important. Thus around $\rho=0$, the potential is approximately

$$\phi(\rho,\phi)\approx V+a,\rho^{\pi/\beta}\sin(\pi\phi/\beta)$$

[0005] The electric field component is the negative gradient of the potential:

$$E_\phi(\rho,\phi)=-\frac{1}{\rho}\frac{\partial\Phi}{\partial\phi}=-\frac{\pi a_1}{\beta}\rho^{(\pi/\beta)-1}\cos(\pi\phi/\beta)$$

The surface charge distribution σ at $\phi=0$ and $\phi=\beta$ is equal to the electric field perpendicular to the surface times the permittivity of space ϵ_0:

$$\sigma(\rho)=\varepsilon_0E_\phi(\rho,0)=-\frac{\varepsilon_0\pi a_1}{\beta}\rho^{\frac{\pi}{\beta}-1}$$

Notice that if angle of intersection β is less than π, then the equation says that there is a very small radius to a positive power which means little charge density accumulation.

[0006] Referring to **FIG. 3**, the value of β, in the case of the triangular hull, is equal to 360° less 60° for a total of 300° or:

$$\beta=\frac{300}{180}\pi=\frac{5}{3}\pi$$

$$\rho^{\frac{\pi}{\frac{5}{3}\pi}-1}=\frac{1}{\rho^{\frac{2}{5}}}$$

which says that there is a charge density singularity to the two fifths power for small radius. Thus, the corner plates on the hull create a huge line charge density along the sharp vertical corner edge. The equation for the potential of a line charge density is given as:

$$\Phi(x,y)=-\frac{\lambda}{2\pi\varepsilon_0}\mathrm{Ln}((x-x_0)^2+(y-y_0)^2)$$

where λ is the charge per unit length in the vertical z-direction, and x_0 and y_0 are the location of the line charge in the xy-plane.

[0007] Referring to **FIG. 4**, the triangular hull (D) is plotted together with the potential contours (A) and the electric field arrows (B) created by the three corner line charges. The line charges are perpendicular to the paper. Notice that the electric field arrows are parallel crossing the center parabolic antenna (C). The electric field is also parallel to the sides (D) of the triangle.

[0008] Referring to **FIG. 5**, along the side of the triangle (A), an array (B) of horizontal slot antennas emit electromagnetic waves that have a vertically polarized electric E field (C). These traveling waves interact with the electric field (D) produced by the line charges on the corners of the triangle.

[0009] Using differential forms mathematics, this combination of fields is represented by the Hodge star of the differential of the wedge product of the two fields. The antenna electromagnetic field is a combination of a traveling magnetic field B_w, and electric field E_w. The stationary field E created by the line charges is perpendicular to the traveling wave.

$$*d(E\wedge(B_w+E_w\wedge dt))\frac{\varepsilon}{c}=\frac{\text{force}}{\text{volume}}$$

where ϵ is the linear capacitance of space and c is the speed of light. Thus there is a force per volume around the hull.

[0010] This combination of fields produces a spacetime curvature as determined by Einstein's General Theory of Relativity. The traveling electric field has an amplitude in the vertical z-direction and travels in the x-direction

$$E_{\mathrm{w=Ez}}\cos(x-t)$$

The Faraday electromagnetic tensor contains all the electric and magnetic fields in all the {x,y,z} directions. The first row and first column contain the two electric fields

$$F^{\alpha}_{\beta}=\begin{array}{c|cccc|} t & 0 & E_x & 0 & E_z\cos(x-t) \\ x & E_x & 0 & 0 & 0 \\ y & 0 & 0 & 0 & 0 \\ z & E_z\cos(x-t) & 0 & 0 & 0 \end{array}$$

The stress exerted on spacetime occurs in the xx, yy and zz-direction as calculated from the stress-energy tensor T of gravitational physics

$$4\pi T^{\mu\nu}=F^{\mu\alpha}F^{\mu}_{\alpha}-\frac{1}{4}g^{\mu\nu}F_{\alpha\beta}F^{\alpha\beta}$$

where g is the metric tensor for Cartesian space

$$g_{\alpha\beta}=\begin{array}{c|cccc|} t & -1 & 0 & 0 & 0 \\ x & 0 & 1 & 0 & 0 \\ y & 0 & 0 & 1 & 0 \\ z & 0 & 0 & 0 & 1 \end{array}$$

where the diagonal components are the coefficients of the elementary spacetime length ds squared

$$(ds)^2=-(dt)^2+(dx)^2+(dy)^2+(dz)^2$$

The calculation produces three stresses T^{xx},T^{yy} and T^{zz} in their respective {x,y,z} directions.

[0011] Referring to **FIG. 6**, these three stresses are plotted together as a **3**D vector field animated over time in nine frames. The graphs show that there is a lift force as depicted by the vertical arrows as well as a force of propulsion as shown by the interspersed horizontal arrows. With the passage of time, these vectors exchange places with each other so that the lift becomes the propulsion and vice versa, creating a wavy stress-energy field around the hull.

SUMMARY OF THE INVENTION

[0012] This invention is a spacecraft with a triangular hull having charged flat plates on the vertical corners of the three sides. The two rear corners are charged to a potential V. The forward corner is charged to a potential −V. The 60° angle on the corner creates a line charge density singularity that produces a huge horizontal electric field pointing from the back to the front of the craft which is also parallel to the sides of the triangle. An array of horizontal slot antennas located on the sides of the triangular hull produce an electromagnetic wave with the electric field polarized in the vertical direction. This combination of fields produces a spacetime force in both the vertical and horizontal directions such that the spacecraft receives a lift force and a force of propulsion.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1**. Perspective view of triangular spacecraft.

[0014] **FIG. 2**. Drawing of the intersection of two charged plates in order to calculate the charge density in the corner.

[0015] **FIG. 3**. Perspective view of the corner angle β for the equilateral triangle.

[0016] **FIG. 4**. Planar **2**D graph showing the electric field produced by three line charges on the corners of the triangular hull.

[0017] **FIG. 5**. Perspective view of electric field produced by the linear charge interacting with the traveling electromagnetic wave produced by the slot antenna.

[0018] **FIG. 6**. **3**D vector animation of the lift and thrust force generated by the fields.

[0019] **FIG. 7**. Perspective view of slot antenna.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring to **FIG. 7**, the antenna (A) is made out of sheet copper in which a rectangular horizontal slot (B) has been notched out using a die press and sheet metal fixture. A coaxial cable from the amplifier and frequency generator is attached across the slot by soldering the outer cable (D) to one side of the slot and the inner cable (E) to the other side of the slot. This creates the positive and negative charges across the gap which forms the vertical electric field (F) which radiates out perpendicularly to the copper sheet.

[0021] Although the invention has been described with reference to specific embodiments, such as a particular antenna system, those skilled in the art will appreciate that many modifications and variations are possible without departing from the teachings of the invention. All such modifications and variations are intended to be encompassed within the scope of the following claims.

1. A spacecraft comprised of the following components:

(a) a triangular hull in the form of an equilateral triangle;

(b) two copper plates attached on opposite vertical sides at each of the three corners of the hull (**1***a*) such that a sharp vertical edge is formed where they come together;

(c) an electrostatic generator used to charge the back two copper-cladded corners (**1***b*) to a high positive voltage, and the third forward copper-cladded corner to a high negative voltage;

(d) a horizontal slot antenna array mounted-on the sides of the hull; and

(e) a frequency generator, antenna and coaxial cables to drive the antenna array (**1***d*).

2. To create, by claims (**1***a*, **1***b*, **1***c*), an intense vertical line charge at the corners (**1***b*) and a horizontal electric field that that is parallel to the sides of the hull (**1***a*);

3. To create, by claims (**1***d*,**1***e*), an electromagnetic wave with a vertically polarized electric field traveling outward from the side of the hull (**1***a*); and

4. To create, by claims (**2**,**3**), an interaction of the electrostatic field (**2**) with the electromagnetic wave (**3**) such that a combined spacetime curvature pressure is generated on the hull in the upward and forward direction to produce lift and propulsion respectively.

* * * * *

March 25, 1969 W. C. BROWN ET AL 3,434,678

MICROWAVE TO DC CONVERTER

Filed May 5, 1965 Sheet 1 of 3

FIG. 1

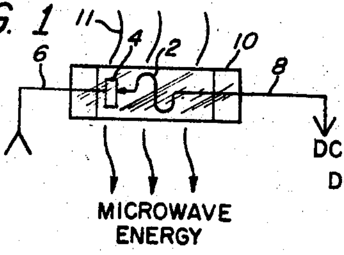
11
4
2
10
6
8
DC
MICROWAVE ENERGY

FIG. 2

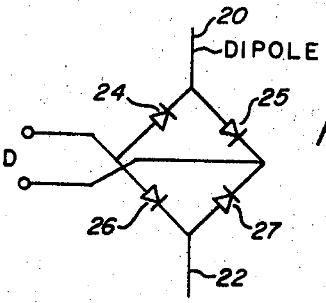
20
DIPOLE
24
25
DC LOAD
26
27
22

FIG. 3

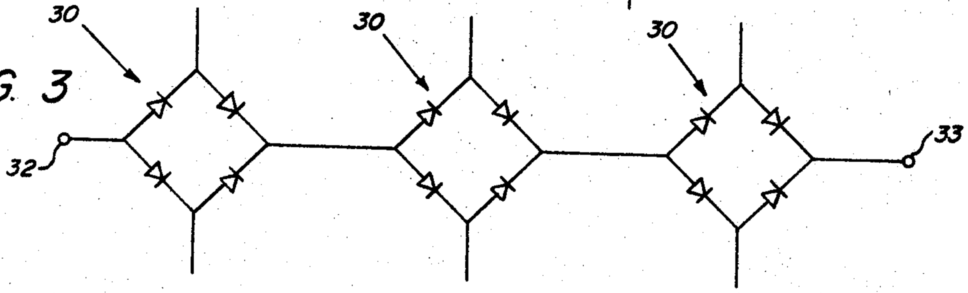
30
30
30
32
33

FIG. 4

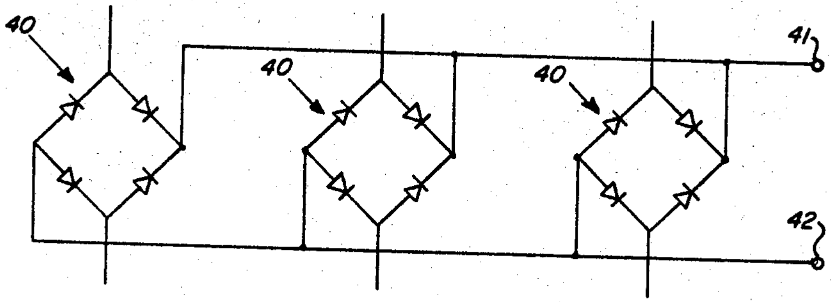
40
40
40
41
42

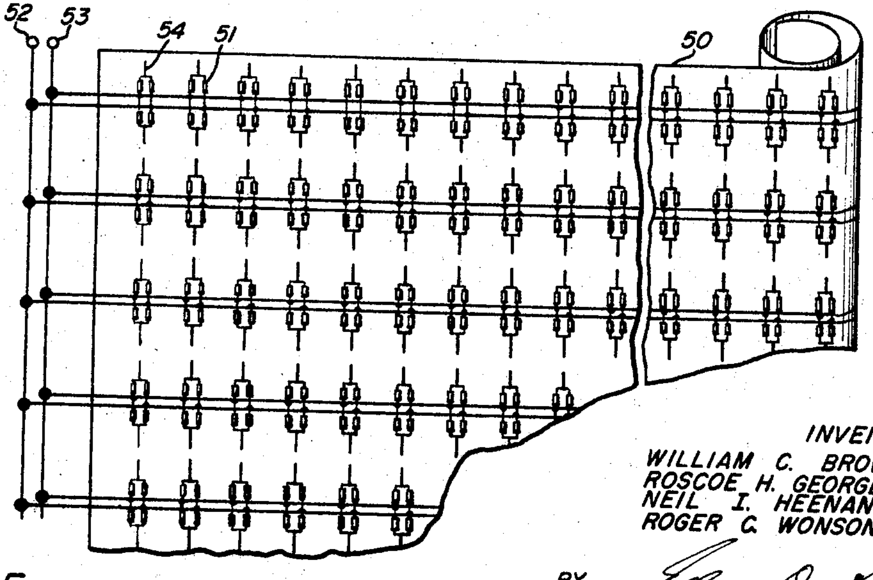
52
53
54
51
50

FIG. 5

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FIG. 7

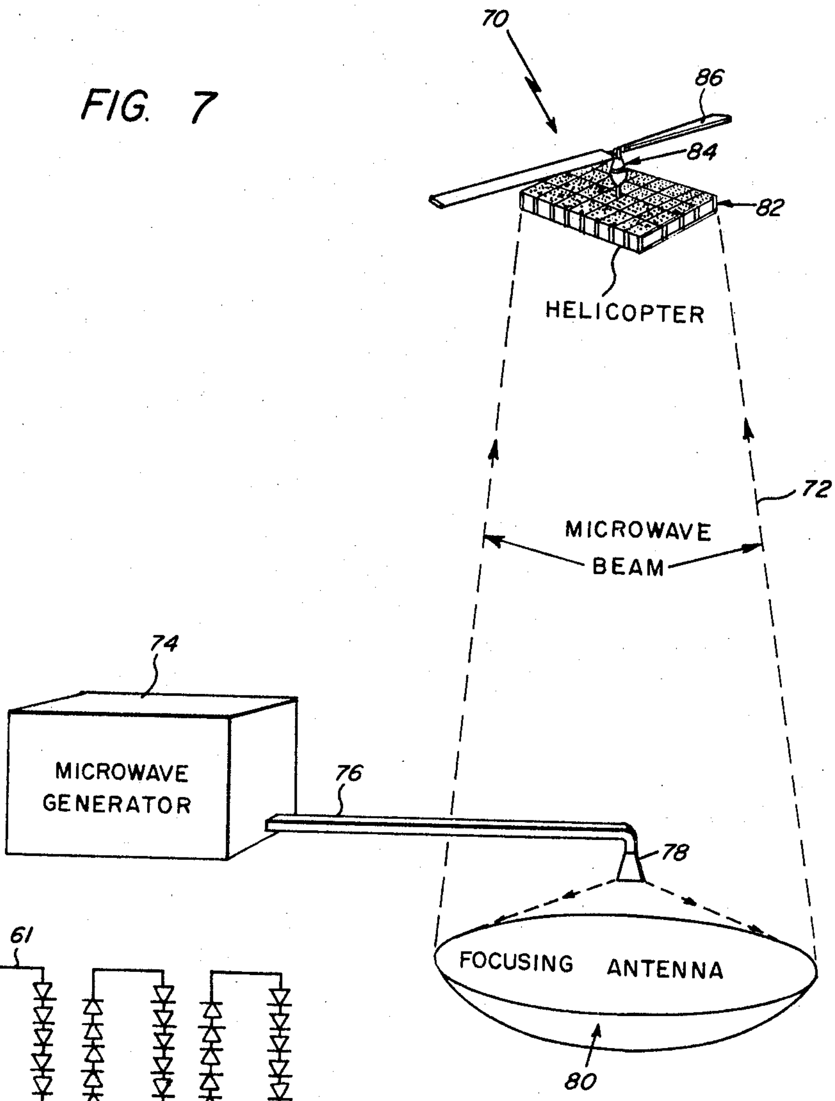
70
86
84
82
HELICOPTER
72
MICROWAVE
BEAM
74
MICROWAVE
GENERATOR
76
78
FOCUSING ANTENNA
80

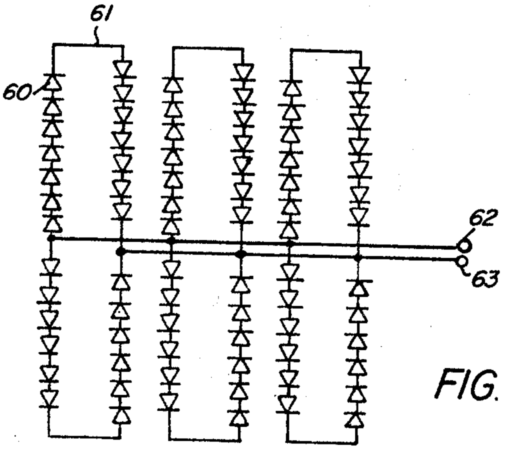

FIG. 6

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MICROWAVE TO DC CONVERTER

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Sheet 3 of 3

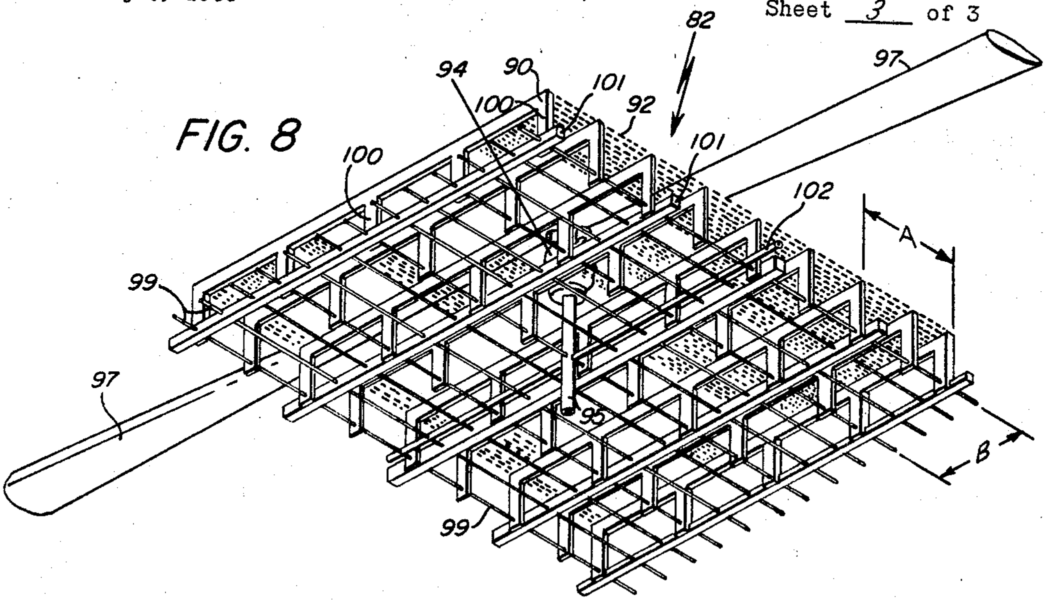
82
94
90
101
100
92
100
101
97
102
A
99
97
95
99
B

FIG. 8

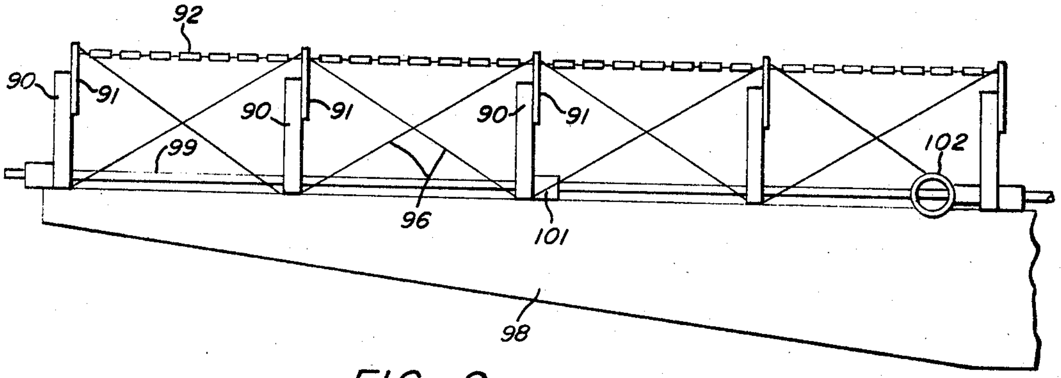
92
90
91
90
91
90
91
99
102
96
101
98

FIG. 9

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MICROWAVE TO DC CONVERTER

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Filed May 5, 1965, Ser. No. 453,415
Int. Cl. B64g *1/00*
U.S. Cl. 244—1 **3 Claims**

ABSTRACT OF THE DISCLOSURE

A combined antenna and conversion mechanism for reception of beamed high frequency electromagnetic energy in space including a large array of unidirectional current semiconductor rectifier devices. A self-supporting space vehicle utilizing the rectified DC electrical energy for propulsion is disclosed in an illustrative embodiment.

The present invention relates in general to the transfer of energy by means of an electromagnetic wave beam and more particularly to interception and rectification of such energy into low frequency electrical DC energy with a high degree of efficiency.

Improved technology in the field of microwave energy generation at superpower levels has resulted in the realization of electrical energy transmission over considerable distances for remote energization of devices or vehicles without the aid of wires. The transmission of microwave electromagnetic energy into space has been commonly employed in the radar pulse echo systems for the detection and orientation of desired objects within a predetermined scanning range of a transmitting antenna. Beams of a similar nature may now be employed for other useful purposes and the advantages attendant the utilization of electromagnetic energy in the microwave region in contrast with other wavelengths may now be enumerated.

Microwaves have been generally defined as high frequency radio waves whose wavelength is less than 30 centimeters, with a lower wavelength limit on the order of 1 millimeter sometimes being applied to what is commonly referred to as the "microwave region." The superiority of high frequency microwaves is due in part to the fact that it is generally desirable to focus the transmitted energy so as to achieve a high power density at a remote point or area with respect to a given power source. In accordance with the laws of optics, the sharpness of the microwave beam produced by a transmitting antenna varies as the ratio of antenna dimensions to the wavelength of the transmitted energy. Therefore, for a given or desired power density or beam sharpness, a decrease in the wavelength of the transmitted energy permits a corresponding decrease in the dimensions of the antenna. From the standpoint of mechanical considerations, it is desirable to employ small antennas and other components, and it is therefore advantageous to employ high frequency energy of very short wavelength. In addition, the difficulties encountered in long wave transmission as a result of natural and man-made interference or noise do not occur with any appreciable significance at microwave frequencies. Further, in aerospace applications with considerable distances separating the transmitter at an earth or mother planet location and the employment of shorter wavelength beamed energy is preferred since longer wave signals will generallly be reflected at certain altitudes by reflecting layers in the atmosphere.

In view of certain losses due to absorption which may occur in the atmosphere, microwaves in the region having the approximate bounds of 2 and 30 centimeters are

readily adaptable to the convenient radiation of power to remote points without the utilization of wires. The preferred wavelengths are of the order of 5 or 10 centimeters to provide efficient focusing with existing transmitting antenna systems which may be maintained at a reasonable size. An illustrative device of the superpower high frequency microwave generators operative in the desired band is the so-called Amplitron which is an amplifier having a broad bandwidth and excellent performance characteristics for the focusing of the beam. Such devices are capable of producing 15 or 20 kilowatts of average continuous wave power in the neighborhood of 10 centimeters in wavelength with capabilities expected in the region of 500 kilowatts or more average power with 50 megawatts peak power. A complete description of such devices may be had by referring to Patent No. 2,933,723 issued Apr. 19, 1960 to William C. Brown and assigned to the assignee of the present invention.

With microwave energy capable of being generated and directed over longer distances conversion of such high frequency electromagnetic energy is of paramount concern. One conversion mechanism in the prior art involves direct conversion of such energy into heat which may then be utilized directly or indirectly for propulsion or generation of flight-producing forces. Examples of such devices for heat energy exchange as well as space vehicles utilizing such energy may be noted in Patent No. 3,174,705, issued Mar. 23, 1965, to D. Schiff et al., as well as U.S. Letters Patent No. 3,083,528, issued Apr. 2, 1963 and No. 3,114,517, issued Dec. 17, 1963, to William C. Brown. The heat exchanger method of conversion of electromagnetic energy into useful power is limited by the overall efficiencies of approximately 25 percent in the conversion of heat into mechanical or electrical work. Desirable, therefore, would be the direct rectification of the high frequency electromagnetic energy into low frequency electrical energy for the operation of many useful aerospace devices as well as systems.

The present invention has for its primary object the conversion of high frequency electromagnetic energy in the microwave region directly into low frequency electrical energy.

A further object of the present invention is the provision of a combined nondirectional receiving antenna and microwave electromagnetic energy to low frequency electrical energy conversion means in a unitary structure.

A still further object of the present invention is a provision of a new and novel combined nondirectional receiving antenna and microwave to DC energy converter for aerospace applications.

Another object of the present invention is the provision of a new and novel nondirectional receiving antenna and microwave to DC energy converter having a high degree of efficiency.

Still another object of the present invention is the provision of a new and novel aerospace vehicle with nondirectional receiving antenna and microwave to DC energy converter means with said vehicle being capable of being supported by its own energy generation means at a distance spaced apart from the power generation means.

In accordance with the teachings of the present invention, the above and other objects are achieved by the employment of efficient unidirectional microwave power rectifiers and dipole antenna means. Such rectifying devices, while being individually limited in power-handling capabilities, normally in the order of fractions of watts, have been found to be highly efficient means for the rectification of microwave power when assembled in large numbers in various arrays. It is interesting to note that the observed collective efficiency was on the order of 40 to 70 percent. In an illustrative embodiment, point-contact semiconductor diodes were arranged in four arm bridge connected networks with the networks interconnected in various configurations such as series, parallel and series-parallel.

In discussing aerospace applications, an additional problem is encountered in the beaming of microwave energy to a remote point and the interception and utilization of such electrical energy. In such applications the advantages of a vehicle which may be maintained in space for indeterminate periods of time without employing a local fuel source are readily apparent. Such devices could readily provide communication networks, surveillance functions using radar techniques along with numerous other functions. The acapture of the beamed high frequency electromagnetic energy raises the need for an efficient antenna means capable of intersecting the beam at high altitudes. Conventional techniques employed in microwave radar usage such as receiving antenna horns are capable of intersecting only a small portion of the beam energy and add considerable weight in applications involving heavier-than-air vehicles. In an exemplary embodiment of the invention a space vehicle, namely a helicopter, is disclosed for either moving flight or a stationary location with self-supporting electrically operative propulsion means. The semi-conductor diode rectifier arrays have been demonstrated to fulfill the receiving antenna functions as well as the electrical energy rectification means in a highly efficient manner. Such combined antenna and rectifier means has also assisted in reduction of the weight problem in airborne devices. Further, it has provided a nondirectional means for the interception of the microwave energy to thereby reduce the problems of focusing inherent in prior art directional horn type receiving antennas.

With the above features, advantages and objects in mind the invention will now be described by reference to the following detailed description together with the accompanying drawings in which:

FIG. 1 is a perspective view of an illustrative diode rectifier;

FIG. 2 is a schematic circuit diagram of a bridge connected diode network with dipole antenna means;

FIG. 3 is a schematic circuit diagram of a plurality of bridge connected networks arranged in series;

FIG. 4 is a schematic circuit diagram of a parallel bridge connected network array;

FIG. 5 is a perspective view of an illustrative embodiment of a combined antenna and rectifier array in a folded or rolled up configuration;

FIG. 6 is a schematic circuit diagram illustrating the bridge connected diode array incorporated in the aerospace vehicle shown in FIG. 7;

FIG. 7 is a schematic representation in elevation illustrative of a heavier-than-air aerospace vehicle incorparating the structure of the present invention;

FIG. 8 is a perspective view of the aerospace vehicle embodiment as viewed from the under portion thereof; and

FIG. 9 is an enlarged partial view in elevation of a portion of the illustrative embodiment shown in FIG. 8.

FIG. 1 illustrates a point-contact semiconductor diode rectifier of the type employed in radar microwave receiver apparatus to rectify returned radar pulses. Any of the high burnout semiconductor diodes having high rectification characteristics are preferred and are commercially available, such as the 1N82 or 1N830. The rectifying junction is formed by whisker element **2** contacting the semiconductor element **4** respectively connected to leads **6** and **8**. Silicon is preferred over germanium for element **4** because of its ability to operate at higher temperatures and thereby handle higher powers. Envelope **10** houses the rectifying elements and may be of a hermetically sealed dielectric material or combination metal and ceramic composition. The inherent characteristic of such diode rectifiers is that the microwave energy is intercepted and rectified in a unidirectional manner and the line **11** indicate pictorially the rays of the beamed electromagnetic microwave energy in a plane normal to the envelope. In FIG. 2 a full-wave bridge connected diode network is illustrated with the forward direction of the rectified DC electric current indicated by the direction of the arrow symbols. The network shown consists of half-wave dipoles **20** and **22** each terminated with a diode rectifier element **24** to **27** in an arm of the bridge connected network. The dipole elements **20** and **22** are of the half-wave configuration and may be spaced apart from each other a one-half wavelength at the frequency of the beamed electromagnetic energy.

Referring now to FIG. 3, an array of bridge connected diode networks each with the half-wave dipoles are shown connected in series. Each network is referred to by the numeral **30** and is similar in the bridge connections to the single element network shown in FIG. 2. The DC output of the collective rectified energy is coupled by means of terminals **32** and **33**. In FIG. 4, a similar number of individual bridge connected diode-dipole networks are shown connected in a parallel array. Each network is indicated by the numeral **40**, and the output terminals are indicated as **41** and **42**.

Any number of diode-dipole networks may be provided and in FIG. 5 such a multi-element array is illustrated by mounting on a flexible material **50** which may be rolled or folded into any desired package or enclosed within a capsule to be launched and released at a predetermined point in space. Any flexible material which is pervious to electromagnetic energy is preferred. The total power desired would be the determining factor in a number of individual diode-dipole elements required. In this embodiment, the bridge connected networks **51** are connected in parallel to the output load indicated by terminals **52** and **53**, and representative measurements of electrical characteristics have shown that approximately five watts of DC electrical energy is realizable for each square foot of area of the combined antenna-rectifier. While the dipole elements **54** have been indicated in a particular array, it is within the scope of the invention to stagger the placement of such dipoles to increase the over-all efficiency of the antenna-rectifier.

To further increase the DC powder output, the full-wave bridge connected networks are preferably arranged with a plurality of diodes in series in each arm of the bridge. An illustrative schematic circuit diagram of such a configuration is shown in FIG. 6 wherein seven diodes **60** are shown in each arm of the bridge circuit and are connected in series for a total of twenty-eight diodes in each bridge network. The dipole members will then be the substantially U-shaped end portions **61** at the ends of each brace of seven diodes. In the illustration three such twenty-eight diode bridge networks are shown connected in parallel to terminals **62** and **63**. This closer spacing and compact arrangement has been shown to be a source of improved power output and is capable of a high degree of reliability through the redundant nature of the parallel series connections within each bridge network. If one of the diode rectifiers fails to function the over-all voltage drop across this element would be divided among the six remaining diode rectifiers. If any of the connecting wires between the diode elements should break, the adjacent arms of the other bridge assemblies would take the additional load due to the close proximity of the respective arms to each other. In addition, it is possible to have a number of open connections or inoperative diodes dispersed throughout the array without any serious impairment in performance.

In relation to the array concept to be hereinafter described it may be stated that within a six inch square area ten such individual bridge networks each containing twenty-eight diode rectifiers for a total of 280 diode rectifiers may be deployed in such a manner as to provide maximum exposed area for each diode as well as the connecting leads. Such an arrangement will be hereinafter referred to as a "module" and a DC output in excess of fourteen watts has been measured for such a module. Any number of such modules could be connected provided for a desired power yield and this module concept readily lends itself to use in certain aerospace applications now to be described.

In FIG. 7 a propelled type of space vehicle **70** is shown wholly supported by means of the transfer and rectification of continuous wave electromagnetic energy via a microwave beam **72**. The source of the microwave energy which may be of the Amplitron type device as described in the aforementioned issued Patent No. 2,933,723 is indicated as **74**. This energy is fed by waveguide means **76** to a transmitting horn **78** to illuminate an ellipsoidal beam forming focusing antenna **80** for the transmission of the microwave beam **72**. It will be appreciated by those skilled in the art that the representations of the microwave generation and transmitting antenna means are pictorial representations to illustrate the usage of the invention in diagrammatic form and the present invention is not limited to any particular source of microwave energy or transmitting antenna assembly. It may be stated the reflector of the antenna assembly is considerably larger than most of the reflectors of the prior art in order to focus a large amount of the microwave power at high altitudes for use in the transfer of energy to space vehicles. Such antenna assemblies may be partially supported in a large hollowed area on the earth's surface or other convenient means of support.

The space vehicle or helicopter **70** can be described as a main body member supporting antenna-rectifier means **82** including a large number of the so-called modules connected together and rigidly supported in a planar parallel array. A motor **84** is supported by the combined body member and the receiving antenna-rectifier means and actuates the rotor **86** of conventional design employed in such self-propelled hovering vehicles. The disclosed vehicle provides for the illumination of the planar array of the semiconductor diode dipole elements by the microwave beam and the direct conversion of the microwave power transmitted by the beam into usable electrical energy for the self-propulsion of the device without any local fuel supply being required.

FIGS. 8 and 9 illustrate a space vehicle **82** comprising a plurality of the combined receiving antenna-rectifier module means for interception and rectification of the electromagnetic microwave energy beam emanating from an earth or mother planet source. A planar array of the antenna-rectifier modules is mechanically supported by means of structural members **90** of any lightweight wood or metal. Insulators **91** positioned coextensive with the members **90** support the diode rectifier array and avoid interference with the receiving and electrical performance characteristics by the structural support members. Carrying forward the module concept of 280 diode rectifiers to provide an approximate power output of 14 watts, it was noted that any number of such modules may be coupled together since the individual module outputs are relatively insensitive to a wide range of load resistances connected to the common output terminals. To achieve the desired electrical output of approximately 120 volts and 250 watts of power, subgroups of four modules each were assembled and parallel connected with an approximate 30 volts available for each subgroup. Four such subgroups were series-connected to result in a total of 4,480 diode rectifiers or 16 modules assembled in a two foot square self-supporting planar parallel array structure. The individual diode rectifiers connected in each arm of the bridge network are indicated by the numeral **92**. An exemplary module configuration would extend within the area delineated by the dotted lines and reference letter A on one side and similar dotted lines and reference letter B on the other side.

A motor **94** is connected to the DC side of the overall array and may be additionally supported by tubular member **95**. A shaft and propulsion means consisting of rotor blades **97** provide for the upward lift of the overall vehicle for the self-supporting of same in space applications. Additional structural support such as interlaced rigging **96** of a high tensile strength material such as nylon or steel wire, as well as bracing member **98**, may be employed for strengthening of the body means to withstand the vibrational forces and downwash from the propulsion means.

In accordance with the well known technology of microwave transmission the combined array of diode rectifiers and propulsion means presents a specific load impedance which must be suitably matched to the transmitted microwave energy beam to result in maximum efficiency. In aerospace applications a mismatch of approximately ten to one may be evident. Matching of the load impedance to a value of approximately 377 ohms as the free space value will be provided by a plurality of coplanar parallel metallic rod members **99** disposed in a grating array in front of the diode rectifiers a predetermined distance. Rod members **99** are linearly disposed and extend in a similar direction as the assembled diode rectifiers. A selected frontal spacing of one-quarter of the wavelength of the microwave frequency being transmitted has been experimentally determined to be suitable for impedance matching purposes. An approximate spacing of two inches between the respective members was preferred for a selected microwave frequency of 2,450 megacycles. Each of the members **90** are provided with lateral sections **100** to support the elongated bar members **101** which in turn maintain the rod members **99** in the desired position. A tubular member **102** of a lightweight metal may also be provided to combine with the motor support member **95** for structural support.

The combined antenna-rectifier array provides a source of electrical energy to render any space vehicle self-supporting. The diode rectifier elements when assembled in the antenna array have been found to be nondirectional with respect to interception of the beamed microwave energy. This represents a large step forward in the utilization of high power microwave energy over the prior art horn-type receiving antennas which must be accurately focused and pointed in a particular direction for the reception of any energy. The connections between the respective members of the diode rectifier array and deployment in the parallel configuration serves to provide maximum exposed area. Such connections and in particular the end loop portions adjacent the terminus of each arm of the bridge networks serves as an efficient dipole for the interception of the microwave energy.

Although it is not intended as a full explanation of the high degree of efficiency attained with the disclosed antenna-rectifier array, it is believed that the whisker elements within the semiconductor diodes themselves are a contributing factor and may function as additional dipole elements. The disclosed embodiment functioned efficiently when illuminated by microwave energy generating a vertically polarized beam. Hence, an efficient and light weight energy conversion apparatus is disclosed which may be self-supporting without the requirement of a large local fuel supply payload.

It may be within the purview of the invention to use the available rectified electrical energy for performing many functions in addition to the actuation of the propulsion means. Hence, communications' payloads may be maintained at predetermined positions in space in a hovering attitude utilizing a portion of the electrical energy available. Relay signals to other such vehicles or return signals to ground stations would then be within the realm of possibility. Such available energy may also be employed for servomechanisms, stabilizing and countertorque systems for the navigation of such vehicles.

The electrical efficiencies realized with the combined receiving antenna and rectifier means have also provided certain weight advantages over other energy converters in aerospace applications. Examples of such converters would be heat exchangers or solar cells. In comparison to the present invention where five to eight pounds per kilowatt of energy realized is a normal characteristic, other energy conversion means weigh in the vicinity of 150 pounds per kilowatt of realizable energy. The inherent advantages of the present invention are therefore apparent. While the technology in the diode rectifier art is being continually advanced, new diode power rectifiers as well as integrated circuit techniques are readily available to future configurations of the present invention. The so-called Schottky barrier diodes could be employed to produce combined antenna-rectifier means weighing even less than two pounds per kilowatt of available energy.

Although the foregoing detailed description has referred to DC power rectification it will be evident that with suitable circuit components low frequency AC energy may also be made available. In addition, other propulsion means may be readily substituted using electrical energy. The embodiments disclosed herein are illustrative only and other modifications or alterations will be apparent to those skilled in the art which do not depart from the scope of the broadest aspects of the present invention as defined in the appended claims.

What is claimed is:

1. A space vehicle comprising:

body means;

said body means including spaced structural support members;

combined antenna and DC electrical energy rectification means for the interception and rectification of incident high frequency electromagnetic microwave energy carried by said support members in a planar parallel array;

said rectification means comprising a plurality of four arm full-wave bridge connected rectifier circuit networks each having a plurality of unidirectional semiconductors in each arm;

said networks being electrically interconnected to common output terminals;

electrically operable propulsion means comprising a motor and rotor members carried by said body means and connected to said terminals for the utilization of said rectified DC energy; and

means for matching the load impedance of said combined antenna and electrical energy rectification means to the incident microwave energy.

2. A space vehicle according to claim 1 wherein said load impedance matching means are arranged in a coplanar array coextensive with said antenna and energy rectification means array, and spaced therefrom a distance of approximately one-quarter of a wavelength at the frequency of the microwave energy.

3. A space vehicle according to claim 2 wherein said load impedance matching means comprise a plurality of parallel disposed elongated metallic members.

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Teleportation of Entangled Coherent States through Visual Pathways in the Human Brain

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Abstract:
In this paper we have proposed a new model for visual consciousness based on the premise there exists a quantum teleportation mechanism between the eye and the brain. In our model, some open questions will be answered.

1) Introduction:

Schrödinger's book "What is life?" has had an enormous influence on the development of molecular biology [1]. His insight has since then inspired many researchers to investigate the molecular basis of a living organism [2,3,4]. Several researchers have noticed the sweeping consequences that would follow from the discovery that living organisms might process information quantum mechanically, either at the bio-molecular level, or the cellular/neuronal level [5,6,7,8,9]. Computational models of the behavior of networks of neurons are still mainly based on the integrate-and-fire model of neural function. Mainstream cognitive neuroscience typically ignores the role of quantum physical effects in the neural processes underlying cognition and consciousness. However, many unsolved problems remain, suggesting the need to consider new approaches. Recent contributions to the investigations of quantum effects in the human brain are due to Jibu and Yasue, Pribram, Lockwood, Mavromatos and Nanopoulous, Hameroff and Penrose, and Stapp [10]. These authors have proposed models in which the operation of consciousness is associated with some sort of explicit wave function collapse. There have been numerous suggestions that consciousness is a macroscopic quantum effect possibly involving superconductivity, superfluidity, electromagnetic fields, Bose-Einstein condensation or some other physical mechanism. Perhaps the most specific model developed thus far is that of Penrose and Hameroff and it asserts that quantum information processing takes place in microtubules (MTs). It has been argued that MTs can process information similarly to a cellular automaton, and hence Hameroff and Penrose suggest that neuronal MTs may operate as a quantum computer.

In this paper, we investigate visual information transfer from a quantum information point of view. Theoretically we consider the conscious observer looking at a quantum system and propose that the state of this system is reported via superposed photons. We address the question whether the observer can receive the exact same state of this system quantum mechanically in his/her brain or this quantum state collapses before reaching the brain. Below we investigate the problem in detail.

2) Evolution of Information from the Eye to the Brain

We assume that a conscious observer directs his/her attention to a quantum system. For simplicity we consider this system to be a manifestation of the celebrated *Schrödinger's cat*. This system can exist in two states: Live$|L\rangle$, or Dead$|D\rangle$.

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$$\psi_{sys} = \frac{1}{\sqrt{2}}(|L\rangle + |D\rangle) \qquad (2\text{-}1)$$

The state of this system is then reported via superposed photons. 4% of these photons are reflected from the cornea. 50% of remaining photons are dissipated through ocular media absorption. Other photons enter the 200-250 μm thick retina. There, photons interact with the photoreceptors in the rods and cons layer after 80% loss due to retinal transmission [11],[12]. In this case, we consider just a few remaining photons which are in a superposed quantum state. The key question here is whether this quantum state of photons can be reported to the brain.

When this state interacts with the last layer of retina, according to Thaheld, this superposed photon undergoes a wavefunction collapse. On the other hand, photons can be absorbed and then transformed into classical signals. Here, we use the symbols introduced by Tegmark [13] for the observer. The symbol $|\ddot{\_}\rangle$ denotes the state for which the information on photons is not received by the brain and thus the observer is amphoteric. The symbol $|\ddot{\smile}\rangle$ stands for the state in which the information received in the brain reports that the cat is alive (and the observer is happy). Finally, the symbol $|\ddot{\frown}\rangle$ corresponds to the state in which the information received in the brain indicates that the cat is dead (and the observer will be sad). It means that:

$$U|\ddot{\_}D\rangle = |\ddot{\frown}D\rangle \qquad (2\text{-}2\text{-}a)$$

$$U|\ddot{\_}L\rangle = |\ddot{\smile}L\rangle \qquad (2\text{-}2\text{-}b)$$

Where $U = \exp\left[-\frac{i}{\hbar}\int H_{photon-brain}\,dt\right]$.

Now, we consider another state in which the brain interacts with itself. Penrose and Hameroff have proposed a model of consciousness involving quantum computation with objective reduction in *microtubules* (or MTs) within the brain's neurons (see Figure 1) [14],[15],[16],[17]. MTs are cylindrical polymers comprised of the protein tubulin which organize numerous cellular activities including neuronal motor transport. According to Hameroff and Penrose, switching of tubulin conformational states is governed by quantum mechanical forces within each tubulin interior, and an essential feature of the Orch OR model is that tubulins may exist in quantum superpositions of two or more conformations. Therefore, these states could function as quantum bits, or "qubits" by interacting non-locally (through their entanglement) with other tubulin qubits so that MTs may act as quantum computers. When sufficiently many entangled tubulins are superposed for long enough to reach Penrose's OR threshold given by E=h/T, an objective reduction (OR) "conscious event" occurs as stated in the Orch-OR model.

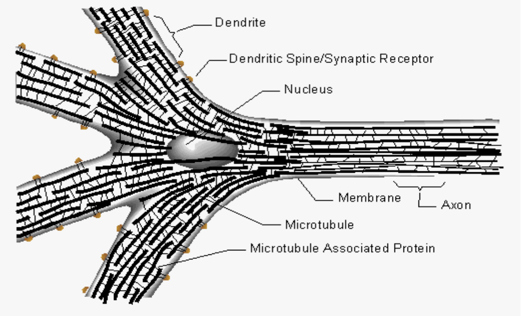
Dendrite
Dendritic Spine/Synaptic Receptor
Nucleus
Membrane
Axon
Microtubule
Microtubule Associated Protein

Figure 1 **Representation of MTs inter a brain neuron. The Orch OR model suggests that the main information processing is implemented in these structures.**

If previous evolution is described by Penrose's self-collapse in the brain (i.e. Orch-OR), MTs in the neurons of the brain collectively evolve and then collapse (i.e. conscious event) to one of the happy or sad states. It mathematically means that:

$$U|\ddot{\_}\rangle = \frac{1}{\sqrt{2}}(|\ddot{\smile}\rangle + |\ddot{\frown}\rangle \qquad (2\text{-}3)$$

where $U = \exp[-\frac{i}{\hbar}\int H_{brain}\, dt]$.

If we compare this state (2-3) and the state which has the information about the photon (2-2), we can say that there's a great amount of correlation between the retina and the visual cortex, because their result should be identical. We know that in accordance with the Einstein-Podolsky-Rosen (EPR) pair, when two entities originate from a common source they can be entangled with each other. Retina has a similar layered structure as the gray-matter top layers of the cerebral cortex of the brain. In fact, retina is an extension of the central nervous system (the brain and spinal cord) that forms during embryonic development. One reason why scientists are interested in retinal processing is that retina is an accessible part of the brain that can be easily stimulated with light [18]. Thus, we can say that retina and visual cortex are entangled with each other. The other argument for this entanglement is that the image of a system is inverted on the retina but it is perceived in the brain directly. As we know, in two entangled entities when one has a property in some direction the other exhibits that property but in the opposite direction. Thus retina receives an inverted image, while it is received in the visual cortex upright. This property is special to entanglement.

The human body is made up of many organs, which themselves are made up of many millions of cells. How can such a system, with millions, or even billions, of parts function effectively and coherently? This is a no small feat as even small-size human societies often undergo periods of turbulence and trouble due to conflict and poor organization. Now some scientists think that quantum coherence in MTs is a major factor responsible for our bodies, and especially our brains, being so efficiency. Here, we intend to describe visual processing on the basis of quantum information theory.

3) Generation of Entangled Coherent States

Centrioles and cilia, which are microtubular structures, are involved in photoreceptor functions in single cell organisms and primitive visual systems. Cilia are also found in all retinal rod and cone cells. The dimensions of centrioles and cilia are comparable to the wavelengths of visible and infrared light (see Figure 2) [50]. Moreover, cytoskeletons are found mostly among the retina and the visual cortex in the cells of the optic nerve. Cytoskeletal structures of the centrioles can be expected to vibrate like a harmonic oscillator in its ground state. Vibrational dynamics of MT's has been the subject of a recent paper where typical frequency ranges have been discussed [19].

When a photon interacts with a centriole, its electric field can displace the potential of the harmonic oscillator and then releases it, thus generating coherent states [20]. It means that:

$$D(\alpha)|0\rangle = |\alpha\rangle \qquad (3\text{-}1)$$

Where $D(\alpha)$ is the displacement operator; $D(\alpha) = e^{\alpha a^\dagger - \alpha^* a}$, and $|0\rangle$ is the ground state of harmonic oscillator, and $|\alpha\rangle$ is the coherent state: $|\alpha\rangle = e^{-\frac{|\alpha|^2}{2}} \sum_{n=0}^{\infty} \frac{\alpha^n}{\sqrt{n!}} |n\rangle$.

Hameroff [21] and Penrose [22] have suggested that MTs inside cells permit long-range quantum coherence, enabling quantum information processing to take place at the sub-cellular level. They use this hypothesis to develop their theory of consciousness. Cells interconnected by gap junctions form networks which fire synchronously, behaving like one giant neuron [23], and possibly accounting for synchronized neural activity such as coherent 40 Hz waves [24]. Marshall [25] suggested that coherent quantum states known as Bose-Einstein condensation occurred among neural proteins [26], [27], [28]. Other issues, such as preconscious-to-conscious transitions were identified by Stapp [29] with the collapse of a quantum wave function in presynaptic axon terminals [7]. The other reason for coherence of these structures is that light is an electromagnetic wave and thus is vibrational, and according to Froehlich's theory [44],[45],[46] it can take these cytoskeletal structures (i.e. nonlinear structures composed of electric dipoles) into one mode of frequency and coherence.

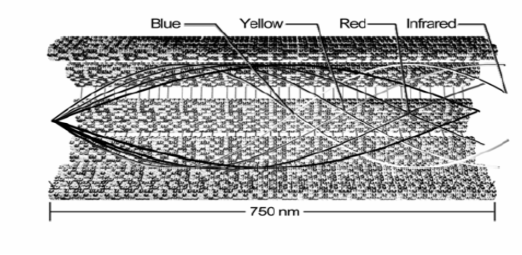

Figure 2 Representation of one centriole, the dimensions of centrioles are comparable to wavelengths of visible and infrared light.

Centrioles are two cylinders composed of MTs which are perpendicular to each other and in accordance with the Hameroff theory of the origin of cancer [30], centrioles are entangled with each other. Because of this entanglement, when a coherent state $|\alpha\rangle$ is generated in one centriole, in the other it will generate state $|-\alpha\rangle$. Now, we can say that after interaction of photons with centrioles, they generate "entangled coherent states" in these structures in the retina, i.e.:

$$|\varphi\rangle_{12} = (A|\alpha\rangle_1|\alpha\rangle_2 - B|-\alpha\rangle_1|-\alpha\rangle_2\ ) \qquad (3\text{-}2)$$

where $|\varphi\rangle_{12}$ is an entangled coherent state in centrioles with two modes 1 and 2. QED-cavity model of MTs [31] describes that coherent modes of electromagnetic radiation can be sustained in the interior of the MTs. These modes are provided by the interaction of the electric dipole moments of the ordered-water molecules in the interior of MTs with quantized electromagnetic radiation [32],[33]. Jibu, et. al.[49], have proposed that the quantum dynamical system of water molecules and the quantized electromagnetic field confined inside the hollow MT core can manifest a specific collective dynamical effect called superradiance [34] by which the MT can transform any incoherent, thermal and disordered molecular, atomic or electromagnetic energy into coherent photons inside the MT. Furthermore, they have also shown [49] that such coherent photons created by superradiance penetrate perfectly along the internal hollow core of the MT as if the optical medium inside it were made "transparent" by the propagating photons themselves. This is referred to as the quantum phenomenon of self-induced transparency [35]. Superradiance and self-induced transparency in cytoskeletal MTs can lead to "optical" neural holography [36]. Neurons (and maybe also other cells) may contain microscopic coherent optical supercomputers with enormous capacity. Thus Jibu, et. al.[49], suggest that MTs can behave as optical waveguides which result in coherent photons. They estimate that this quantum coherence is capable of superposition of states among MT spatially distributed over hundreds of microns. These in turn are in superposition with other MTs hundreds of microns away in other directions and so on. With the above conclusions $|\varphi\rangle_{12}$ can produce those photons which produced itself, thus if the state $|\varphi\rangle_{12}$ can be restored in the brain, it will reproduce the photons which were absorbed in the retina.

Additional arguments in favor of the feasibility of production of photons in the brain can be found in the conclusions of the paper [37], which also asserts that there exists a neural activity-dependent ultra-weak photon (biophoton) emission in the brain. Thus there is the possibility to restore the initial state of the photon in the brain after absorption in the eye. This process can be implemented through teleportation mechanism between retina and the visual cortex as will be discussed in the following sections.

4) The Decoherence Problem

The important question about the quantum processing in the living systems is: how is it possible for MTs to process information quantum mechanically while the environment surrounding them is relatively hot, wet and noisy?

According to the Orch-OR model, microtubular structures in the neurons of the brain process information quantum mechanically and to avoid decoherence, like lasers maintain quantum coherence against thermal noise. Water within cells is itself not truly liquid, but has been shown to be, to a large extent, ordered [38]. Most of the ordered water in the cell in fact surrounds the cytoskeleton [39]. MTs and other cytoskeletal components are embedded in cytoplasm which exists in alternating phases of (1) “sol” (solution, liquid); and (2) “gel” (gelatinous, solid). Among the most primitive of biological activities, “sol-gel transformations” within neurons and other living cells are caused by assembly and disassembly of cytoskeletal actin (e.g. regulated by calcium ions through the protein calmodulin, in turn regulated by MTs). Sol-gel transformations are essential in basic cellular activities such as (“amoeboid”) movement, growth and synaptic formation and neurotransmitter vesicle release [40], [41]. Transitions can occur rapidly (e.g. 40 sol-gel cycles per second), and some actin gels can be quite solid, and withstand deformation without transmitted response [42]. Cyclical encasement of MTs by actin gels may thus be an ideal quantum isolation mechanism. In the gel phase of cytoplasm, the water ordering surfaces of a MT are within a few nanometers of actin surfaces which also order water. Thus bundles of MTs encased in actin gel may be effectively isolated extending over the radius of the bundle, on the order of hundreds of nanometers. There are many mechanisms which can protect these structures against decohering factors. In general, Quantum states of tubulin/MTs are protected from environmental decoherence by biological mechanisms which include phases of actin gelatin, plasma-like Debye layering, coherent pumping and topological quantum error correction [54]. Moreover, quantum spin transfer between quantum dots connected by benzene rings (the same structures found in aromatic hydrophobic amino acids) is more efficient at warm temperature than absolute zero[43]. It is conjectured that the “flexibility” of the resonant benzene electrons is advantageous to quantum processes by harnessing ambient thermal energy. MTs may possibly utilize nonspecific thermal energy for "laser-like" coherent pumping, for example in the GHz range by a mechanism of "pumped phonons" suggested by Froehlich [44,45,46].

5) What is the mechanism of Teleportation?

According to the definition of teleportation as stated in [47], in the process of quantum teleportation, one can construct an exact replica of the original unknown quantum state at a cost of destroying the original state. Therefore, to call a quantum state transfer operation- quantum teleportation, the process should not only generate output states with better qualities than what can be done classically but also obey the no-cloning theorem [48].The quantum state of a system can be transmitted from a location to a distant one using only classical information provided that a quantum channel exists between the sender and the receiver. Sharing entangled states between the two parties opens the necessary quantum channel. Research in quantum state transfer, especially the quantum teleportation, has emerged as one of the major research areas of theoretical and experimental quantum mechanics. Assume that Alice wants to send Bob an unknown quantum state but when she receives this state she does not know anything about that unless she affects it and collapses it to classical state, or in other hand she destroys that quantum state. She just can send classical signals to Bob through classical channel, but if there is a shared entangled channel between Alice and Bob, Bob can construct initial quantum state with the help of classical signal which is sent by Alice and quantum channel between them. This operation is implemented by operating special unitary operators. For more details see [47]. Here, we want to simulate visual information transfer with teleportation mechanism. We know that when photon penetrates the retina, it changes to action potentials or electrical signals and these classical signals are sent to the brain for interpretation. It means that *retina* (Alice) wants to send the *brain* (Bob) a *photon state* (unknown quantum state), but *retina* (Alice) absorbs it (collapses the quantum state) and changes it to *action potential* (classical state) and send it through *membranes of axons of the brain neurons* (classical channel). *Brain* (Bob) can reconstruct the initial *state of photon* (unknown quantum state) to process it to emerge consciousness. Our arguments for this simulation are below conclusions:

Orch OR [14], [15]: There is quantum processing in the neurons of the brain (there is a quantum channel between retina and brain)

Tegmark [13]: Displacement of ions through membranes of brain neurons is a classical phenomenon (action potentials are classical signals and membranes of neurons are classical channels).

Thaheld [11],[12]: Superposed photons do collapse in the retina (the quantum state is collapsed by the sender [Alice]).

We assert that they describe different aspects of the teleportation mechanism. We simulate visual consciousness with the teleportation mechanism as shown in Table 5-1.

Table 5- 1 Simulation of the transferring visual information from the eye to the brain to the Teleportation mechanism.

Human Brain	***Quantum Teleportation Mechanism***
Retina	Alice
Membrane of axons in neurons	Classical channel
Cytoskeletal structures	Entangled channel (quantum channel)
Visual cortex	Bob
Action potentials	Classical signals

Now we want to investigate this teleportation mechanism via teleporting of entangled coherent states through visual pathways in more details. We will show how photon states are constructed in the visual cortex.

6) Teleportation of Entangled Coherent States through Visual Pathways

Super radiance and self induced transparency [49] besides Froehlich oscillations can cause the coupling of MT dynamics over wide areas and take them into a superposition and a coherent state. While in superposition, tubulins communicate with entangled tubulins in the same manner, and in MTs in neighboring neurons, and through macroscopic regions of the brain via tunneling through gap junctions and possibly tunneling nanotubes [50]. As we have already said, retina and the visual cortex are entangled with each other. Thus there is a quantum channel between retina and the visual cortex which is composed of microtubular structures. MTs interact with membrane structures mechanically by linking proteins, chemically by ions and second messenger signals, and electrically by voltage fields. The transduction of light into electrical signals takes place in the photoreceptors. Except for the ganglion cells, none of the retinal cells display action potentials [51].

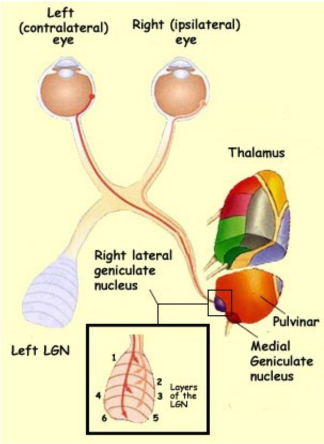

Figure 3 The LGN is a laminated structure, having 6 layers. Contralateral fibers and ipsilateral fibers couple in the LGN. The ipsilateral fibers of the optic nerve terminate in laminae 2,3 and 5 of LGN, while the contralateral fibers terminate in laminae 1, 4 and 6.[52]

Axons leaving the temporal half of the retina traverse the optic nerve to the optic chiasm, where they join the optic tract and project to ipsilateral structures. Axons leaving the nasal half of the retina cross the midline at the chiasm and terminate in contralateral structures. This arrangement means that all the axons in the optic tract carry information about the contralateral visual field. Axons of the optic tract terminate in three areas of the central nervous system, the lateral geniculate nucleus (i.e. LGN), the superior colliculus and the pretectal area. The trajectory through the LGN is the largest most direct and clinically most important pathway by which visual information reaches the cerebral cortex. About 80% of the optic tract axons synapse in the LGN. The LGN is a laminated structure, having 6 layers. Contralateral fibers and ipsilateral fibers couple in the LGN. The ipsilateral fibers of the optic nerve terminate in laminae 2,3 and 5 of LGN, while the contralateral fibers terminate in laminae 1, 4 and 6 of LGN (see Figure 3). There are about 10^6 neurons in each LGN, all of which project to the ipsilateral occipital cortex (area 17) as the optic radiations. The portion of the cerebral cortex that receives LGN axons is called the striate cortex and is usually labeled V1 to designate it as the primary visual cortical area (Figure 3). Virtually all information in the visual system is recognized as being processed by V1 first, and then passed out to higher order systems [53]. The upper visual cortex receives signals from the lower visual field and similarly, lower visual cortex process information from the upper visual field. The right visual cortex processes the left field of view and vice versa (see figure 4).

Now, we investigate the information transfer through visual pathways. The important model among quantum models about the processing in the human brain is the Orch-OR model which is based on the structure of the cytoskeleton. As already said this model asserts that the main processing in the neurons of the brain is performed in the MTs and the nature of the processing is mainly quantum mechanical. The processing unit in this model is *tubulin* which can be in a superposed state. Tubulins act like qubits in quantum computers. *Max Tegmark* believes that there is no quantum processing in the human brain. He has calculated decoherence times for every superposition state which can be possible in the neurons of the brain [13]. In his opinion, superposition states include ions such as Na^+ which are "in" and "out" of the membrane of axon. On the other hand, Na^+ ions are in the superposition of "in" and "out" with a separation distance comparable to the membrane thickness. He has considered three factors which can destroy this superposition state in neurons. *Collisions with the neighboring ions, Collisions with the water molecules* and *Interaction with distant ions* are the factors which Tegmark investigated for decoherence. He has estimated 10^{-19} s and 10^{-20} s for decoherence times. It is clear that above times are very small for the brain processes such as seeing, thinking, speaking and the other cognitive processes. Typically, dynamical timescales for neuron firing and cognitive processes are in the range of 10^{-4} to 1 seconds, whereas decoherence timescales are many orders of magnitude shorter. Thus, action potentials should be regarded as classical signals or the displacement of ions through the membrane of axons should be investigated classically. It is remarkable that Tegmark has also calculated decoherence time for MTs, but he has used wrong assumptions about these structures (for more details see [54]) and we just accept his calculations about action potentials. Thaheld [11], [12] believes that the wave function of any superposed photon state or states is always objectively changed within the complex architecture of the eye, and any incident photons have to run a very daunting gauntlet before they are even converted or transduced to retinal ganglion cell spike trains (To learn more about Thaheld arguments, the reader is referred to refs. [55,56,57]). According to Thaheld, the quantum state of photons does collapse in the retina and it does not reach the brain.

Is Thaheld right? Is not there any mechanism to rebuild the quantum state of photons in the brain? Here we accept that the states of photons collapse in the retina but we believe that they can be restored in the visual cortex via the teleportation mechanism.

Now, the question is how can it be possible to restore the exact state of photons in the brain while its state is collapsed in the retina. The other question which one may ask is: if this state is reported through action potentials how is this information reported to the brain and how can it interpret action potentials to obtain the exact state of the photons? Our solution to the above problems involves the teleportation of entangled coherent states through visual pathways. The state of the photon is teleported from the eye to the brain. On the other hand, the state of the photon is transferred via some "cut-and-paste" mechanism from the eye to the brain. But how is it possible?

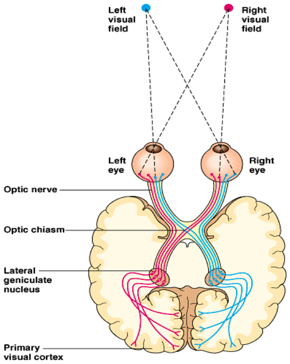

Figure 4 Visual pathways from the eye to the brain. See crossing of pathways.

We concluded before that retina and the visual cortex are entangled. Also we explained how the entangled coherent state is generated in the retina. Now, we want to formulate the process of information transfer from the retina to V1. The state (3-2) with two modes 1 and 2 should be teleported to V1. After the interaction of light with retina, modes 3, 4 and 5, 6 are generated through microtubular structures between retina and V1, and thus they produce entangled coherent channels between retina and V1. It means that the channels are:

$$|\psi\rangle_{35} = \frac{1}{\sqrt{N_\alpha}}(|\alpha\rangle_3|\alpha\rangle_5 - |-\alpha\rangle_3|-\alpha\rangle_5) \qquad (6\text{-}1)$$

$$|\phi\rangle_{46} = \frac{1}{\sqrt{N_\alpha}}(|\alpha\rangle_4|\alpha\rangle_6 - |-\alpha\rangle_4|-\alpha\rangle_6) \qquad (6\text{-}2)$$

Where N_α is the number of tubulins in each channel. Each mode is reported via a special fiber through visual pathways. All of the neurons which are collected in the LGN are divided into two major pathways: ipsilateral fibers and contralateral fibers. Information transfer in the contralateral fibers takes longer than information transfer in ipsilateral fibers because contralateral fibers have crossing relative to ipsilateral fibers and then they have longer lengths than ipsilateral fibers. On the other hand, contralateral fibers have a retarded phase relative to ipsilateral fibers. Now we want to answer the following questions. What is this phase difference? What is the role of this crossing? And how does crossing restore the initial state in the retina?

7) *The Role of Phase Shift to Restore Information in LGN*

When the information is collapsed in the retina, action potentials are produced. The shape of action potentials is the same for each neuron, but the main problem is which neurons are fired, or in other words which neurons carry action potentials and information. Consider two fibers selected from ipsilateral fibers and two fibers selected from contralateral fibers. The two ipsilateral fibers are called 1 and 2, and the two contralateral fibers are called 3 and 4 while the two fibers from the LGN to V1 are called 5 and 6 which are selected from the group of magnocellular and parvocellular fibers. Now, we start from the retina. The state of centrioles and channels is:

$$
\begin{gathered}
|\psi'\rangle = |\varphi\rangle_{12} \otimes |\psi\rangle_{35} \otimes |\phi\rangle_{46} \\
= \frac{1}{N'_{\propto}}(A|\alpha\rangle_1|\alpha\rangle_2|\alpha\rangle_3|\alpha\rangle_4|\alpha\rangle_5|\alpha\rangle_6 \\
-A|\alpha\rangle_1|\alpha\rangle_2|\alpha\rangle_3|-\alpha\rangle_4|\alpha\rangle_5|-\alpha\rangle_6 \\
-A|\alpha\rangle_1|\alpha\rangle_2|-\alpha\rangle_3|\alpha\rangle_4|-\alpha\rangle_5|\alpha\rangle_6 \\
+A|\alpha\rangle_1|\alpha\rangle_2|-\alpha\rangle_3|-\alpha\rangle_4|-\alpha\rangle_5|-\alpha\rangle_6 \\
-B|-\alpha\rangle_1|-\alpha\rangle_2|\alpha\rangle_3|\alpha\rangle_4|\alpha\rangle_5|\alpha\rangle_6 \\
+B|-\alpha\rangle_1|-\alpha\rangle_2|\alpha\rangle_3|-\alpha\rangle_4|\alpha\rangle_5|-\alpha\rangle_6 \\
+B|-\alpha\rangle_1|-\alpha\rangle_2|-\alpha\rangle_3|\alpha\rangle_4|-\alpha\rangle_5|\alpha\rangle_6 \\
-B|-\alpha\rangle_1|-\alpha\rangle_2|-\alpha\rangle_3|-\alpha\rangle_4|-\alpha\rangle_5|-\alpha\rangle_6) \qquad (7\text{-}1)
\end{gathered}
$$

All of the above states are collected in the LGN. But here the role of action potentials is very important. They determine which fibers are fired. If fibers 1 and 2 carry action potentials, then it shows that information passes through ipsilateral fibers. Thus to select information from the LGN to send it via fibers 5 and 6 to V1 there is no need for phase difference (or to apply the phase shift operator on the states) and thus the state of (3-2) can be transferred like its first state through fibers 5 and 6. In the formulation (7-1) we see that if fibers x and y are fired, the expression with $|\alpha\rangle_x|\alpha\rangle_y$ should be selected from the terms with coefficients +A besides the expression $|-\alpha\rangle_x|-\alpha\rangle_y$ from the terms with coefficients $-B$. Hence,

$$1,2\ firing \xrightarrow{yields} |\phi'\rangle_{56} = A|\alpha\rangle_5|\alpha\rangle_6 - B|-\alpha\rangle_5|-\alpha\rangle_6 \qquad (7\text{-}2)$$

In another state, if fibers 1 and 4 are fired it means that one fiber is selected from ipsilateral fibers and the other is from contralateral fibers, thus they have phase difference with respect to each other. Hence,

$$1,4\ firing \xrightarrow{yields} |\phi'\rangle_{56} = A|\alpha\rangle_5|-\alpha\rangle_6 - B|-\alpha\rangle_5|\alpha\rangle_6 \qquad (7\text{-}3)$$

To restore initial information, the operator

$$R(\varphi) = e^{-i\pi a^{\dagger}{}_{6}a_{6}}$$

should operate on the state in LGN in which fibers 1 and 4 have conveyed action potentials. This operator changes the ket $|\alpha\rangle_6$ to $|-\alpha\rangle_6$ and vice versa. It means that fiber 4 has a π radian phase difference with respect to fiber 1, and this phase difference can restore the exact state of the photon. If fibers 2 and 3 are fired, this yields:

$$2,3\ firing \quad \xrightarrow{yields} \quad |\phi'\rangle_{56} = A|-\alpha\rangle_5|\alpha\rangle_6 - B|\alpha\rangle_5|-\alpha\rangle_6 \qquad (7\text{-}4)$$

In this case the operator

$$R(\varphi) = e^{-i\pi a^{\dagger}{}_{5}a_{5}}$$

should be involved. For the case of 3 and 4 firing, this yields,

$$3,4\ firing \quad \xrightarrow{yields} \quad |\phi'\rangle_{56} = A|-\alpha\rangle_5|-\alpha\rangle_6 - B|\alpha\rangle_5|\alpha\rangle_6 \qquad (7\text{-}5)$$

in which case the operator

$$R(\varphi) = e^{-i\pi(a^{\dagger}{}_{5}a_{5}+a^{\dagger}{}_{6}a_{6})}$$

should be involved. In this case we see that the main path is that of ipsilateral fibers which are direct to each eye and fibers 3 and 4 both have a π radian phase difference with it. We also know that there are two LGNs and the left and right V1. Now, another question emerges. How do these two left and right parts in V1 can instantaneously receive information? To answer this question, we can say that the synaptic β-neurexin/neuroligin-1 adhesive protein complex is claimed to be a device mediating entanglement between the cytoskeletons of the cortical neurons. Thus the macroscopic coherent quantum state can extend through large brain cortical areas [58].

We see that crossing or rotation of neurons in the visual pathways has an important role in restoring information in the brain. Maybe rotations or crossings of neurons throughout the body are there for this very reason.

8) Discussion

In general, we can briefly summarize our approach by listing the following properties:

1- It can combine the Orch-OR model with Tegmark's approaches and the Thaheld conclusion in a compact physical model which is called Teleportation.
2- It investigates visual pathways from atomic scales to macroscopic scales. This approach includes classical descriptions as well as new answers to open questions.
3- It explains why the shape of action potentials stays the same. Classical models state that "sensations" are action potentials that reach the brain via sensory neurons, and "perception" is the awareness and interpretation of the sensation. It is reasonable to assume that the constant shape of action potentials cannot result in different profiles of information. Thus the shape of information should be due to neurons. In this approach MTs are the representatives of information carriers. In our approach action potentials just determine which neurons fire and which do not.
4- It describes why neurons cross at some point. This crossing causes a phase shift relative to a special pathway. In teleportation of entangled coherent states the phase shift operators can rebuild initial information.

5- It explains that how the inverted image on the retina is perceived in the brain as upright.
6- It can describe how different information can be simultaneously perceived as a binding nature of conscious experience. This can be done via quantum parallel processing.
7- It explains how the brain of the observer can receive quantum information from the environment. We can see that there still exists this possibility that the mind can play the main role in the measurement problem, and this is in accord with what London, Bauer, von Neumann and Wigner (initially) asserted.

9) Conclusions

In this paper we have theoretically demonstrated the plausibility of a quantum teleportation mechanism between the eye and the brain which can describe different aspects of visual processing through visual pathways. Our model covers both quantum and classical aspects of neuroscience. This mechanism can combine some features of the Orch-OR model with Tegmark's conclusions and Thaheld's belief in one general model.

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Teleportation Physics Study

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14. ABSTRACT

This study was tasked with the purpose of collecting information describing the teleportation of material objects, providing a description of teleportation as it occurs in physics, its theoretical and experimental status, and a projection of potential applications. The study also consisted of a search for teleportation phenomena occurring naturally or under laboratory conditions that can be assembled into a model describing the conditions required to accomplish the transfer of objects. This included a review and documentation of quantum teleportation, its theoretical basis, technological development, and its potential applications. The characteristics of teleportation were defined and physical theories were evaluated in terms of their ability to completely describe the phenomena. Contemporary physics, as well as theories that presently challenge the current physics paradigm were investigated. The author identified and proposed two unique physics models for teleportation that are based on the manipulation of either the general relativistic spacetime metric or the spacetime vacuum electromagnetic (zero-point fluctuations) parameters. Naturally occurring anomalous teleportation phenomena that were previously studied by the United States and foreign governments were also documented in the study and are reviewed in the report. The author proposes an additional model for teleportation that is based on a combination of the experimental results from the previous government studies and advanced physics concepts. Numerous recommendations outlining proposals for further theoretical and experimental studies are given in the report. The report also includes an extensive teleportation bibliography.

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FOREWORD

This Special Technical Report presents the results of a subcontracted study performed by Warp Drive Metrics, Las Vegas, NV, under Contract No. F04611-99-C-0025, for the Air Force Research Laboratory (AFRL)/Space and Missile Propulsion Division, Propellant Branch (PRSP), Edwards AFB, CA. The Project Manager for AFRL/PRSP was Dr. Franklin B. Mead, Jr.

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Glossary

AEC	Average Energy Condition
AFRL	Air Force Research Laboratory
AU	Astronomical Unit
BBO	Beta (β)-Barium Borate
CGS	Centimeter-Gram-Second
CIA	Central Intelligence Agency
DARPA	Defense Advanced Research Projects Agency
DEC	Dominant Energy Condition
DIA	Defense Intelligence Agency
DNA	Deoxyribo Nucleic Acid
DoD	Department of Defense
EPR	Einstein, Podolsky and Rosen
ESP	Extrasensory Perception
eV	Electron Volt
FRW	Friedmann-Robertson-Walker
FTL	Faster-Than-Light
IBM	International Business Machines
INSCOM	Intelligence and Security Command
IR	Infrared
MeV	Mega-Electron Volt
MKS	Meter-Kilogram-Second
NEC	Null Energy Condition
NLP	Neuro-Linguistic Programming
NMR	Nuclear Magnetic Resonance
NSA	National Security Agency
PK	Psychokinesis
PPN	Parameterized Post-Newtonian
PRC	Peoples Republic of China
PV-GR	Polarizable-Vacuum Representation of General Relativity
QED	Quantum Electrodynamics
QISP	Quantum Information Science Program
R&D	Research and Development
SAIC	Science Applications International Corporation
SEC	Strong Energy Condition
SRI	Stanford Research Institute
USSR	Union of Soviet Socialist Republics
UV	Ultraviolet
WEC	Weak Energy Condition
ZPE	Zero-Point Energy
ZPF	Zero-Point Fluctuations

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This study would not have been possible without the very generous support of Dr. Frank Mead, Senior Scientist at the Advanced Concepts Office of the U.S. Air Force Research Laboratory (AFRL) Propulsion Directorate at Edwards AFB, CA. Dr. Mead's collegial collaboration, ready assistance, and constant encouragement were invaluable to me. Dr. Mead's professionalism and excellent rapport with "out-of-the-box" thinkers excites and motivates serious exploration into advanced concepts that push the envelope of knowledge and discovery. The author owes a very large debt of gratitude and appreciation to both Dr. David Campbell, Program Manager, ERC, Inc. at AFRL, Edwards AFB, CA, and the ERC, Inc. staff, for supporting the project contract and for making all the paperwork fuss totally painless. Dr. Campbell and his staff provided timely assistance when the author needed it, which helped make this contract project run smoothly.

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Preface

The Teleportation Physics Study is divided into four phases. Phase I is a review and documentation of quantum teleportation, its theoretical basis, technological development, and its potential application. Phase II developed a textbook description of teleportation as it occurs in classical physics, explored its theoretical and experimental status, and projected its potential applications. Phase III consisted of a search for teleportation phenomena occurring naturally or under laboratory conditions that can be assembled into a model describing the conditions required to accomplish the disembodied conveyance of objects. The characteristics of teleportation were defined, and physical theories were evaluated in terms of their ability to completely describe the phenomenon. Presently accepted physics theories, as well as theories that challenge the current physics paradigm were investigated for completeness. The theories that provide the best chance of explaining teleportation were selected, and experiments with a high chance of accomplishing teleportation were identified. Phase IV is the final report.

The report contains five chapters. Chapter 1 is an overview of the textbook descriptions for the various teleportation phenomena that are found in nature, in theoretical physics concepts, and in experimental laboratory work. Chapter 2 proposes two quasi-classical physics concepts for teleportation: the first is based on engineering the spacetime metric to induce a traversable wormhole; the second is based on the polarizable-vacuum-general relativity approach that treats spacetime metric changes in terms of equivalent changes in the vacuum permittivity and permeability constants. These concepts are theoretically developed and presented. Promising laboratory experiments were identified and recommended for further research. Chapter 3 presents the current state-of-art of quantum teleportation physics, its theoretical basis, technological development, and its applications. Key theoretical, experimental, and applications breakthroughs were identified, and a series of theoretical and experimental research programs are proposed to solve technical problems and advance quantum teleportation physics. Chapter 4 gives an overview of alternative teleportation concepts that challenge the present physics paradigm. These concepts are based on the existence of parallel universes/spaces and/or extra space dimensions. The theoretical and experimental work that has been done to develop these concepts is reviewed, and a recommendation for further research is made. Last, Chapter 5 gives an in-depth overview of unusual teleportation phenomena that occur naturally and under laboratory conditions. The teleportation phenomenon discussed in the chapter is based on psychokinesis (PK), which is a category of psychotronics. The U.S. military-intelligence literature is reviewed, which relates the historical scientific research performed on PK-teleportation in the U.S., China and the former Soviet Union. The material discussed in the chapter largely challenges the current physics paradigm; however, extensive controlled and repeatable laboratory data exists to suggest that PK-teleportation is quite real and that it is controllable. The report ends with a combined list of references.

1.0 INTRODUCTION

1.1 Introduction

The concept of teleportation was originally developed during the Golden Age of 20th century science fiction literature by writers in need of a form of instantaneous disembodied transportation technology to support the plots of their stories. Teleportation has appeared in such SciFi literature classics as Algis Budry's *Rogue Moon* (Gold Medal Books, 1960), A. E. van Vogt's *World of Null-A* (Astounding Science Fiction, August 1945), and George Langelaan's *The Fly* (Playboy Magazine, June 1957). The Playboy Magazine short story led to a cottage industry of popular films decrying the horrors of scientific technology that exceeded mankind's wisdom: *The Fly* (1958), *Return of the Fly* (1959), *Curse of the Fly* (1965), *The Fly* (a 1986 remake), and *The Fly II* (1989). The teleportation concept has also appeared in episodes of popular television SciFi anthology series such as *The Twilight Zone* and *The Outer Limits*. But the most widely recognized pop-culture awareness of the teleportation concept began with the numerous *Star Trek* television and theatrical movie series of the past 39 years (beginning in 1964 with the first TV series pilot episode, *The Cage*), which are now an international entertainment and product franchise that was originally spawned by the late genius television writer-producer Gene Roddenberry. Because of *Star Trek* everyone in the world is familiar with the "transporter" device, which is used to teleport personnel and material from starship to starship or from ship to planet and vice versa at the speed of light. People or inanimate objects would be positioned on the transporter pad and become completely disintegrated by a beam with their atoms being patterned in a computer buffer and later converted into a beam that is directed toward the destination, and then reintegrated back into their original form (all without error!). "*Beam me up, Scotty*" is a familiar automobile bumper sticker or cry of exasperation that were popularly adopted from the series.

However, the late Dr. Robert L. Forward (2001) stated that modern hard-core SciFi literature, with the exception of the ongoing *Star Trek* franchise, has abandoned using the teleportation concept because writers believe that it has more to do with the realms of parapsychology/paranormal (a.k.a. psychic) and imaginative fantasy than with any realm of science. Beginning in the 1980s developments in quantum theory and general relativity physics have succeeded in pushing the envelope in exploring the reality of teleportation. A crescendo of scientific and popular literature appearing in the 1990s and as recently as 2003 has raised public awareness of the new technological possibilities offered by teleportation. As for the psychic aspect of teleportation, it became known to Dr. Forward and myself, along with several colleagues both inside and outside of government, that anomalous teleportation has been scientifically investigated and separately documented by the Department of Defense.

It has been recognized that extending the present research in quantum teleportation and developing alternative forms of teleportation physics would have a high payoff impact on communications and transportation technologies in the civilian and military sectors. It is the purpose of this study to explore the physics of teleportation and delineate its characteristics and performances, and to make recommendations for further studies in support of Air Force Advanced Concepts programs.

1.2 The Definitions of Teleportation

Before proceeding, it is necessary to give a definition for each of the teleportation concepts I have identified during the course of this study:

- *Teleportation* – SciFi: the disembodied transport of persons or inanimate objects across space by advanced (futuristic) technological means (adapted from Vaidman, 2001). We will call this *sf-Teleportation*, which will not be considered further in this study.

- *Teleportation* – psychic: the conveyance of persons or inanimate objects by psychic means. We will call this *p-Teleportation*.

- *Teleportation* – engineering the vacuum or spacetime metric: the conveyance of persons or inanimate objects across space by altering the properties of the spacetime vacuum, or by altering the spacetime metric (geometry). We will call this *vm-Teleportation*.

- *Teleportation* – quantum entanglement: the disembodied transport of the quantum state of a system and its correlations across space to another system, where *system* refers to any single or collective particles of matter or energy such as baryons (protons, neutrons, etc.), leptons (electrons, etc.), photons, atoms, ions, etc. We will call this *q-Teleportation*.

- *Teleportation* – exotic: the conveyance of persons or inanimate objects by transport through extra space dimensions or parallel universes. We will call this *e-Teleportation*.

We will examine each of these in detail in the following chapters and determine whether any of the above teleportation concepts encompass the instantaneous and or disembodied conveyance of objects through space.

2.0 vm-TELEPORTATION

2.1 Engineering the Spacetime Metric

A comprehensive literature search for vm-Teleportation within the genre of spacetime metric engineering yielded no results. No one in the general relativity community has thought to apply the Einstein field equation to determine whether there are solutions compatible with the concept of teleportation. Therefore, I will offer two solutions that I believe will satisfy the definition of vm-Teleportation. The first solution can be found from the class of traversable wormholes giving rise to what I call a true "stargate." A stargate is essentially a wormhole with a flat-face shape for the throat as opposed to the spherical-shaped throat of the Morris and Thorne (1988) traversable wormhole, which was derived from a spherically symmetric Lorentzian spacetime metric that prescribes the wormhole geometry (see also, Visser, 1995 for a complete review of traversable Lorentzian wormholes):

$$ds^2 = -e^{2\phi(r)}c^2dt^2 + [1-b(r)/r]^{-1}dr^2 + r^2d\Omega^2 \qquad (2.1),$$

where by inspection we can write the traversable wormhole metric tensor in the form

$$g_{\alpha\beta} = \begin{pmatrix} -e^{2\phi(r)} & 0 & 0 & 0 \\ 0 & [1-b(r)/r]^{-1} & 0 & 0 \\ 0 & 0 & r^2 & 0 \\ 0 & 0 & 0 & r^2\sin^2\theta \end{pmatrix} \qquad (2.2)$$

using standard spherical coordinates, where c is the speed of light, $\alpha,\beta \equiv (0 = t, 1 = r, 2 = \theta, 3 = \varphi)$ are the time and space coordinate indices ($-\infty < t < \infty$; r: $2\pi r$ = circumference; $0 \le \theta \le \pi$; $0 \le \varphi \le 2\pi$), $d\Omega^2 = d\theta^2 + sin^2\theta d\varphi^2$, $\phi(r)$ is the freely specifiable redshift function that defines the proper time lapse through the wormhole throat, and $b(r)$ is the freely specifiable shape function that defines the wormhole throat's spatial (hypersurface) geometry. Such spacetimes are asymptotically flat. The Einstein field equation requires that a localized source of matter-energy be specified in order to determine the geometry that the source induces on the local spacetime. We can also work the Einstein equation backwards by specifying the local geometry in advance and then calculate the matter-energy source required to induce the desired geometry. The Einstein field equation thus relates the spacetime geometry terms comprised of the components of the metric tensor and their derivatives (a.k.a. the Einstein tensor) to the local matter-energy source terms comprised of the energy and stress-tension densities (a.k.a. the stress-energy tensor). The flat-face wormhole or stargate is derived in the following section.

2.1.1 Wormhole Thin Shell Formalism

The flat-face traversable wormhole solution is derived from the thin shell (a.k.a. junction condition or surface layer) formalism of the Einstein equations (Visser, 1989; see also, Misner, Thorne and Wheeler, 1973). We adapt Visser's (1989) development in the following discussion. The procedure is to take two copies of flat Minkowski space and remove from each identical regions of the form $\Omega \times \Re$, where Ω is a three-dimensional compact spacelike hypersurface and $\Re$ is a timelike straight line (time axis). Then identify these two incomplete spacetimes along the timelike boundaries $\partial\Omega \times \Re$. The resulting spacetime is geodesically complete and possesses two asymptotically flat regions connected by a wormhole. The throat of the wormhole is just the junction $\partial\Omega$ (a two-dimensional space-like hypersurface) at which the two original Minkowski spaces are identified (see Figures 1 and 2).

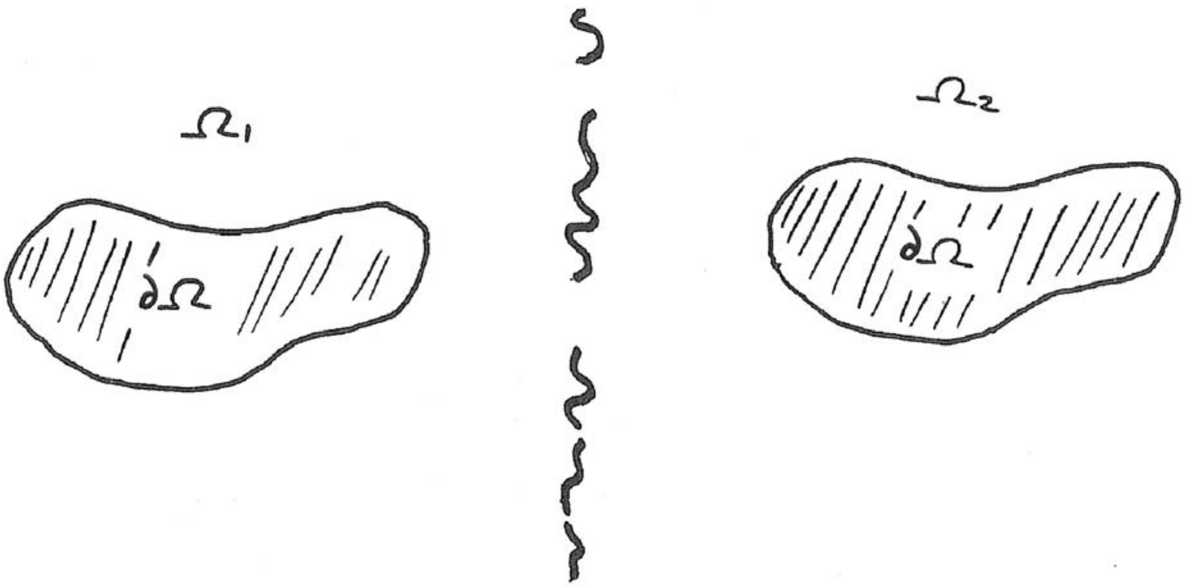
Ω_1
$\partial\Omega$
Ω_2
$\partial\Omega$

Figure 1. Diagram of a Simultaneous View of Two Remote Compact Regions (Ω_1 and Ω_2) of Minkowski Space Used to Create the Wormhole Throat $\partial\Omega$, Where Time is Suppressed in This Representation (adapted from Bennett et al., 1995)

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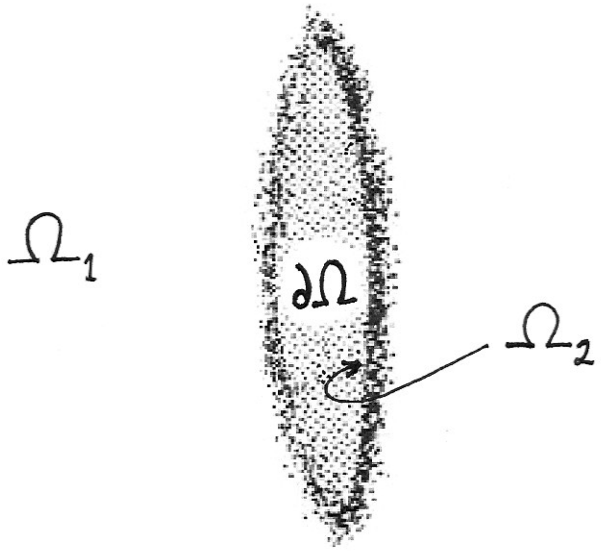

Figure 2. The Same Diagram as in Figure 1 Except as Viewed by an Observer Sitting in Region Ω_1 Who Looks Through the Wormhole Throat $\partial\Omega$ and Sees Remote Region Ω_2 (Dotted Area Inside the Circle) on the Other Side

The resulting spacetime is everywhere Riemann-flat except possibly at the throat. Also, the stress-energy tensor in this spacetime is concentrated at the throat with a δ-function singularity there. This is a consequence of the fact that the spacetime metric at the throat is continuous but not differentiable, while the connection is discontinuous; thus causing the Riemann curvature to possess a δ-function singularity (causing undesirable gravitational tidal forces) there. The magnitude of this δ-function singularity can be calculated in terms of the second fundamental form on both sides of the throat, which we presume to be generated by a localized thin shell of matter-energy. The second fundamental form represents the extrinsic curvature of the ∂Ω hypersurface (i.e., the wormhole throat), telling how it is curved with respect to the enveloping four-dimensional spacetime. The form of the geometry is simple, so the second fundamental form at the throat is calculated to be (McConnell, 1957):

$$\begin{aligned} K^{i\ \pm}_{\ j} &= \pm\begin{pmatrix} \kappa_0 & 0 & 0 \\ 0 & \kappa_1 & 0 \\ 0 & 0 & \kappa_2 \end{pmatrix} \\ &= \pm\begin{pmatrix} 0 & 0 & 0 \\ 0 & 1/\rho_1 & 0 \\ 0 & 0 & 1/\rho_2 \end{pmatrix} \end{aligned} \qquad (2.3),$$

where $i,j = 0,1,2$ and $K^{i\pm}_{j}$ is the second fundamental form. The full 4×4 matrix $K^{\alpha}{}_{\beta}$ has been reduced to 3×3 form, as above, for computational convenience because the thin shell (or hypersurface) is essentially a two-surface embedded in three-space. The overall ± sign in equation (2.3) comes from the fact that a unit normal points outward from one side of the surface and points inward on the other side. We hereafter drop the ± sign for the sake of brevity in notation. The quantities κ_0, κ_1, and κ_2 measure the extrinsic curvature of the thin shell of local matter-energy (i.e., the stuff that induces the wormhole throat geometry). Since the wormhole throat is a space-like hypersurface, we can exclude time-like hypersurfaces and their components in the calculations. Therefore we set $\kappa_0 = 0$ in equation (2.3) because it is the time-like extrinsic curvature for the time-like hypersurface of the thin shell of matter-energy. As seen in equation (2.3) κ_1 and κ_2 are simply related to the two principal radii of curvature ρ_1 and ρ_2 (defined to be the eigenvalues of K^{i}_{j}) of the two-dimensional spacelike hypersurface ∂Ω (see Figure 3). It should be noted that a convex surface has positive radii of curvature, while a concave surface has negative radii of curvature.

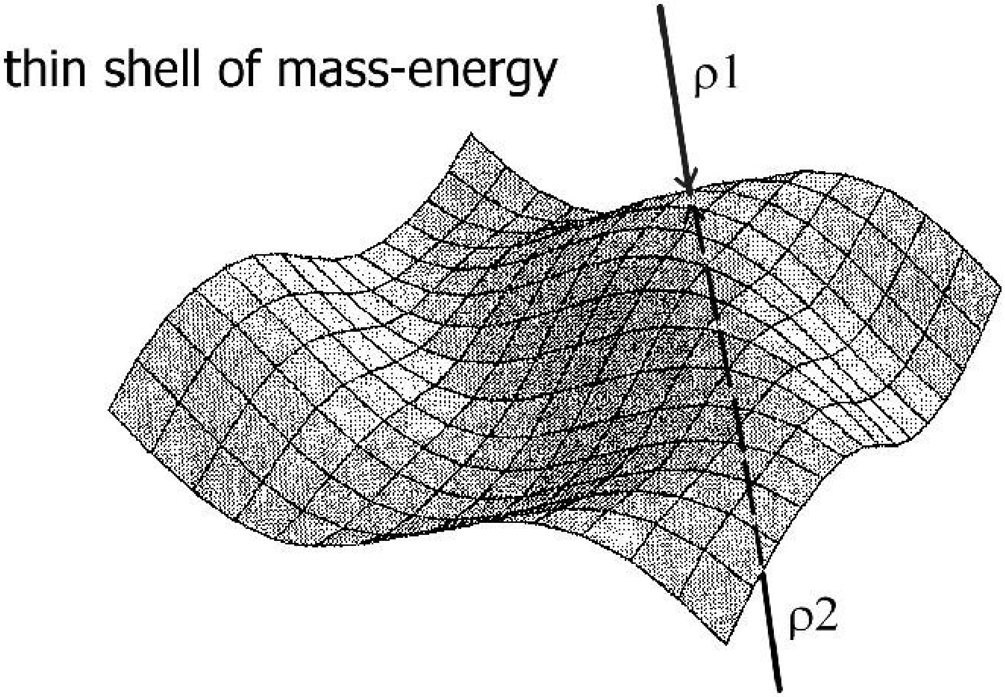
thin shell of mass-energy
ρ1
ρ2

Figure 3. A Thin Shell of (Localized) Matter-Energy, or Rather the Two-Dimensional Spacelike Hypersurface $\partial\Omega$ (via (2.3)), Possessing the Two Principal Radii of Curvature ρ_1 and ρ_2

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It is a standard result of the thin shell or junction condition formalism that the Einstein field equation may be cast in terms of the surface stress-energy tensor S^i_j of the thin matter-energy shell localized in $\partial\Omega$ (note: we are exploiting the symmetry of the wormhole with respect to interchange of the two flat regions Ω_1 and Ω_2):

$$S^i{}_j = -\frac{c^4}{4\pi G}\left(K^i{}_j - \delta^i{}_j K^k{}_k\right) \quad (2.4),$$

where G is Newton's gravitational constant and δ^i_j is the (three-dimensional) unit matrix. K^k_k is the trace of equation (2.3):

$$\begin{aligned} K^k{}_k &= Tr\, K^i{}_j \\ &= \frac{1}{\rho_1} + \frac{1}{\rho_2} \end{aligned} \qquad (2.5)$$

and

$$\delta^i{}_j K^k{}_k = \begin{pmatrix} \frac{1}{\rho_1}+\frac{1}{\rho_2} & 0 & 0 \\ 0 & \frac{1}{\rho_1}+\frac{1}{\rho_2} & 0 \\ 0 & 0 & \frac{1}{\rho_1}+\frac{1}{\rho_2} \end{pmatrix} \quad (2.6).$$

Substituting (2.3) and (2.6) into (2.4) gives (after simplification):

$$S^i{}_j = \frac{c^4}{4\pi G}\begin{pmatrix} \frac{1}{\rho_1}+\frac{1}{\rho_2} & 0 & 0 \\ 0 & 1/\rho_2 & 0 \\ 0 & 0 & 1/\rho_1 \end{pmatrix} \quad (2.7).$$

The thin matter-energy shell's surface stress-energy tensor may be interpreted in terms of the surface energy density σ and principal surface tensions ϑ_1 and ϑ_2:

$$S^i{}_j = \begin{pmatrix} -\sigma & 0 & 0 \\ 0 & -\vartheta_1 & 0 \\ 0 & 0 & -\vartheta_2 \end{pmatrix} \quad (2.8).$$

Thus we arrive at the Einstein field equation by equating (2.8) and (2.7) and multiplying both sides by –1:

$$\begin{pmatrix} \sigma & 0 & 0 \\ 0 & \vartheta_1 & 0 \\ 0 & 0 & \vartheta_2 \end{pmatrix} = -\frac{c^4}{4\pi G}\begin{pmatrix} \frac{1}{\rho_1}+\frac{1}{\rho_2} & 0 & 0 \\ 0 & 1/\rho_2 & 0 \\ 0 & 0 & 1/\rho_1 \end{pmatrix} \qquad (2.9),$$

which gives the final result

$$\sigma = -\frac{c^4}{4\pi G}\left(\frac{1}{\rho_1}+\frac{1}{\rho_2}\right) \qquad (2.10a)$$

$$\vartheta_1 = -\frac{c^4}{4\pi G}\frac{1}{\rho_2} \qquad (2.10b)$$

$$\vartheta_2 = -\frac{c^4}{4\pi G}\frac{1}{\rho_1} \qquad (2.10c).$$

These are the Einstein equations. Equations (2.10a-c) imply that (for ∂Ω convex) we are dealing with ***negative*** surface energy density and ***negative*** surface tensions. This result is in fact the primary matter-energy requirement for traversable wormholes, as was proved by Morris and Thorne (1988), and later by Visser (1995), within the paradigm of classical Einstein general relativity. The negative surface tension (= *positive outward pressure*, a.k.a. gravitational repulsion or antigravity) is needed to keep the throat open and stable against collapse. The reader should **not** be alarmed at this result. Negative energies and negative stress-tensions are an acceptable result both mathematically and physically, and they manifest gravitational repulsion (antigravity!) in and around the wormhole throat. One only needs to understand what it means for stress-energy to be negative within the proper context. In general relativity the term "*exotic*" is used in place of "*negative*." The effects of negative energy have been produced in the laboratory (the Casimir Effect is one example). In short, negative energy arises from Heisenberg's quantum uncertainty principle, which requires that the energy density of any electromagnetic, magnetic, electric or other fields must fluctuate randomly. Even in a vacuum, where the average energy density is zero, the energy density fluctuates. This means that the quantum vacuum can never remain truly empty in the classical sense of the term. The quantum picture of the vacuum is that of a turbulent plenum of virtual (i.e., energy non-conserving) particle pairs that spontaneously pop in and out of existence. The notion of "zero energy" in quantum theory corresponds to the vacuum being filled with such fluctuations going on. This issue is further elaborated on and clarified in greater detail in Appendix A. We will also revisit this in Section 2.2. Finally, it should be noted that for the analysis in this section we assumed an ultrastatic wormhole [i.e., $g_{00} \equiv 1 \Rightarrow \phi(r) = 0$ in equation (2.1)] with the "exotic" matter-energy confined to a thin layer, and we dispensed with the assumption of spherical symmetry.

We can now build a wormhole-stargate and affect *vm-Teleportation* such that a traveler stepping into the throat encounters **no** exotic matter-energy there. This will require that our wormhole be flat shaped. To make the wormhole flat requires that we choose the throat ∂Ω to have at least one flat face (picture the thin shell in Figure 3 becoming a flat shell). On that face the two principal radii of curvature become $\rho_1 = \rho_2 = \infty$ as required by standard geometry. Substituting this into equations (2.10a-c) gives

$$\sigma = \vartheta_1 = \vartheta_2 = 0 \qquad (2.11),$$

which is a remarkable result. A further consequence of this is that now $K^i_j = 0$, thus making the Riemann curvature and stress-energy tensors (Riemann: $R^\alpha{}_\beta \sim K^\alpha{}_\beta$; stress-energy: $T^\alpha{}_\beta \sim K^\alpha{}_\beta$) at the throat become zero such that the associated δ-function singularities disappear there. This means that a traveler encountering and going through such a wormhole will feel no tidal gravitational forces and see no exotic matter-energy (that threads the throat). A traveler stepping through the throat will simply be ***teleported*** into the other remote spacetime region or another universe (note: the Einstein equation does not fix the spacetime topology, so it is possible that wormholes are inter-universe as well as intra-universe tunnels). We construct such a *teleportation* stargate by generating a thin shell or surface layer of "exotic" matter-energy much like a thin film of soap stretched across a loop of wire.

2.1.2 "Exotic" Matter-Energy Requirements

Now we have to estimate the amount of negative (or exotic) mass-energy that will be needed to generate and hold open a *vm-Teleportation* wormhole. A simple formula originally due to Visser (1995) for short-throat wormholes using the thin shell formalism gives:

$$\begin{aligned} M_{wh} &= -\frac{r_{throat}c^2}{G} \\ &= -(1.3469x10^{27}\,kg)\frac{r_{throat}}{1\,meter} \qquad (2.12), \\ &= -(0.709\,M_{Jupiter})\frac{r_{throat}}{1\,meter} \end{aligned}$$

where M_{wh} is the mass required to build the wormhole, r_{throat} is a suitable measure of the linear dimension (radius) of the throat, and $M_{Jupiter}$ is the mass of the planet Jupiter (1.90×10^{27} kg). Equation (2.12) demonstrates that a mass of $-0.709\ M_{Jupiter}$ (or -1.3469×10^{27} kg) will be required to build a wormhole 1 meter in size. As the wormhole size increases the mass requirement grows negative-large, and vice versa as the wormhole size decreases. After being alarmed by the magnitude of this, one should note that M_{wh} is **not** the total mass of the wormhole as seen by observers at remote distances. The non-linearity of the Einstein field equations dictates that the total mass is zero (actually, the total net mass being positive, negative or zero in the Newtonian approximation depending on the details of the negative energy configuration constituting the wormhole system). And finally, Visser et al. (2003) have demonstrated the existence of spacetime geometries containing traversable wormholes that are supported by ***arbitrarily small quantities*** of exotic matter-energy, and they proved that this was a general result. In Section 2.3 we will discuss how or whether we can create such a wormhole in the laboratory.

2.2 Engineering the Vacuum

Engineering the spacetime vacuum provides a second solution that also satisfies the definition of vm-Teleportation. The concept of "*engineering the vacuum*" was first introduced to the physics community by Lee (1988). Lee stated:

"*The experimental method to alter the properties of the vacuum may be called vacuum engineering…If indeed we are able to alter the vacuum, then we may encounter some new phenomena, totally unexpected.*"

This new concept is based on the now-accepted fact that the vacuum is characterized by physical parameters and structure that constitutes an energetic medium which pervades the entire extent of the universe. We note here the two most important defining properties of the vacuum in this regard (Puthoff et al., 2002):

- Within the context of quantum field theory the vacuum is the seat of all energetic particle and field fluctuations.

- Within the context of general relativity theory the vacuum is the seat of a spacetime structure (or metric) that encodes the distribution of matter and energy.

We begin our look into this concept by examining the propagation of light through space. We know from quantum field theory that light propagating through space interacts with the vacuum quantum fields (a.k.a. vacuum quantum field fluctuations). The observable properties of light, including the speed of light, are determined by these interactions. Vacuum quantum interactions with light lead to an effect on the speed of light that is due to the absorption of photons (by the vacuum) to form virtual electron-positron pairs followed by the quick re-emission (from the vacuum) of the photon (see Figure 4). The virtual particle pairs are very short lived because of the large mismatch between the energy of a photon and the rest mass-energy of the particle pair. A key point is that this process makes a contribution to the observed vacuum permittivity ε_0 (and permeability μ_0) constant and, therefore, to the speed of light c [$c = (\varepsilon_0\mu_0)^{-1/2}$].

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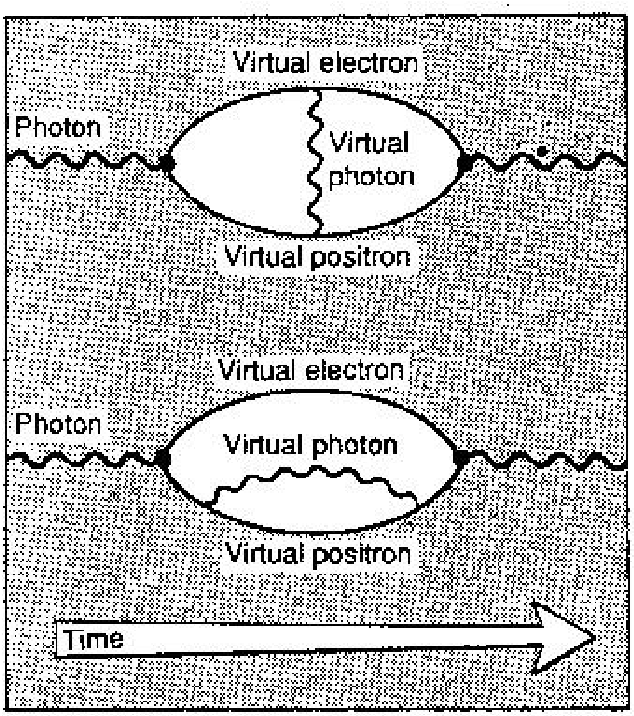
Virtual electron
Photon
Virtual photon
Virtual positron
Virtual electron
Photon
Virtual photon
Virtual positron
Time

Photons can change into a variety of short-lived, or "virtual", particles. as they fly through the vacuum. The processes above, represented by Feynman diagrams, are "two-loop"' processes. They affect light's speed

Figure 4. A Schematic of Vacuum Quantum Field Fluctuations (a.k.a. Vacuum Zero Point Field Fluctuations) Involved in the "Light-by-Light" Scattering Process That Affects the Speed of Light (from Chown, 1990)

The role of virtual particle pairs in determining the ε_0 (μ_0) of the vacuum is analogous to that of atoms/molecules in determining the relative permittivity ε (and μ) of a dielectric material. We know that the absorption/re-emission of photons by atoms/molecules in a transparent medium (note: there are no strongly absorbing resonances, so the atoms/molecules remain in their excited states for a very short time before re-emitting photons) is responsible for the refractive index of the medium, which results in the reduction of the speed of light for photons propagating through the medium. This absorption/re-emission process is also known in physics as a scattering process. We know from experiment that a change in the medium leads to a change in ε (μ), thus resulting in a change of the refractive index. The key point arising from this analogy is that a modification of the vacuum produces a change in ε_0 (μ_0) resulting in a subsequent change in c, and hence, a corresponding change in the vacuum refraction index.

Scharnhorst (1990) and Latorre et al. (1995) have since proved that the suppression of light scattering by virtual particle pairs (a.k.a. coherent light-by-light scattering) in the vacuum causes an ***increase*** in the speed of light accompanied by a decrease in the vacuum refraction index. This very unique effect is accomplished in a Casimir Effect capacitor cavity (or waveguide) whereby the vacuum quantum field fluctuations (a.k.a. zero-point fluctuations or ZPF) inside have been modified (becoming anisotropic and non-translational invariant) to satisfy the electromagnetic boundary conditions imposed by the presence of the capacitor plates (or waveguide walls). The principal result of this modification is the removal of the electromagnetic zero-point energy (ZPE) due to the suppression of vacuum ZPE modes with wavelengths longer than the cavity/waveguide cutoff ($\lambda_0 = 2d$, where d = plate separation; see Figure 5). This removal of free space vacuum ZPE modes suppresses the scattering of light by virtual particle pairs, thus producing the speed of light increase (and corresponding decrease in the vacuum refraction index). We know from standard optical physics and quantum electrodynamics (QED) that the optical phase and group velocities can exceed c under certain physical conditions, but dispersion always ensures that the signal velocity is $\leq c$. But recent QED calculations (see, Scharnhorst, 1990 and Latorre et al., 1995) have proved that in the Casimir Effect system, the dispersive effects are *much weaker* still than those associated with the increase in c so that the phase, group and signal velocities will therefore *all increase* by the same amount. Note that, in general, no dispersion shows up in all of the modified vacuum effects examined by investigators.

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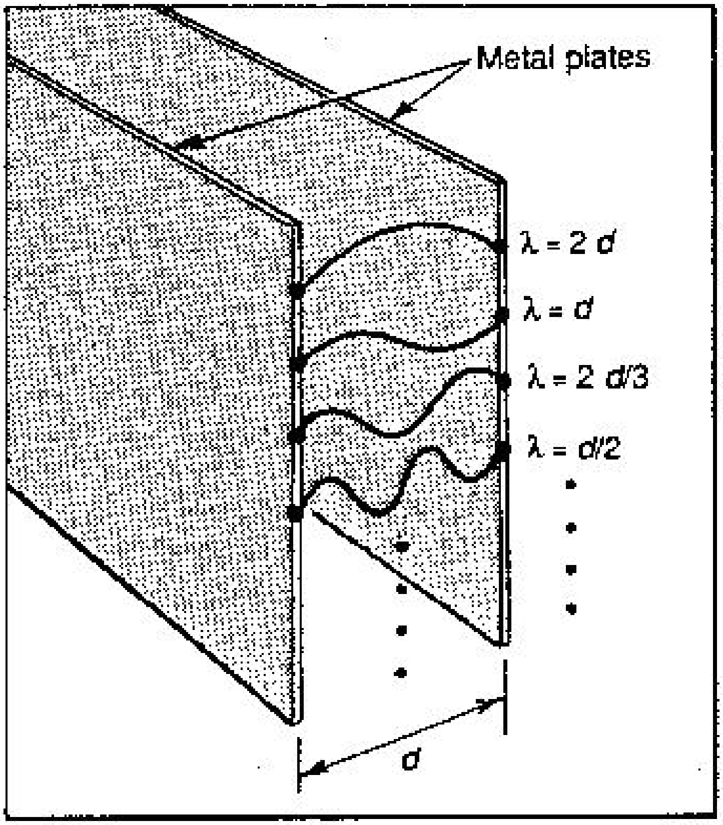

Casimir effect: the vacuum is full of virtual photons, but photons with wavelengths (λ), more than twice the separation of the plates, are excluded from the space between them. The imbalance pushes the plates together

Figure 5. A Schematic of the Casimir Effect Cavity/Waveguide (from Chown, 1990)

Examples demonstrating the increase in light speed (decrease in vacuum refraction index) via the Casimir Effect vacuum and other modified vacuum effects, as well as those effects producing a decrease in light speed (increase in vacuum refraction index), are described as follows. The vacuum modification effect on the speed of light described in the previous paragraph is (Scharnhorst, 1990):

$$\begin{aligned}\frac{c_\perp^{\;*}}{c_0} &= \left(1+\frac{11}{2^6\bullet(45)^2}\frac{e^4}{(m_e a)^4}\right) \qquad (\hbar = c_0 = \varepsilon_0 = \mu_0 = 1) \\ &= \left(1+\frac{11\pi^2}{8100}\alpha^2\frac{1}{(m_e a)^4}\right) > 1\end{aligned} \qquad \text{(2.13),}$$

where $c_\perp^{\;*}$ is the (modified) speed of light propagation perpendicular to the Casimir Effect capacitor plates, c_0 is the speed of light in free space (3×10^8 m/s in MKS units), m_e is the electron mass, α is the fine structure constant ($\approx 1/137$), e is the electron charge ($e^2 = 4\pi\alpha$ in quantum field theory natural units), a is the plate separation, $\hbar$ is Planck's reduced constant, and ε_0 is the vacuum permittivity constant. The condition $\hbar = c_0 = \varepsilon_0 = \mu_0 = 1$ stresses that (2.13), and all the equations that follow, are in quantum field theory natural units. The speed of light and vacuum refraction index measured parallel to the plates is unchanged from their free space values ($c_{||} = c_0$, $n_{||} = n_0 = 1$). The modified vacuum refraction index measured perpendicular to the plates is (Scharnhorst, 1990):

$$n_\perp = \left(1-\frac{11}{2^6\bullet(45)^2}\frac{e^4}{(m_e a)^4}\right) < 1 \qquad (\hbar = c_0 = \varepsilon_0 = \mu_0 = 1) \qquad \text{(2.14).}$$

Equations (2.13) and (2.14) show that in general $n_\perp < 1$ and $c_\perp^{\;*} > c_0$. But $c_\perp^{\;*} \rightarrow c_0$ and $n_\perp \rightarrow 1$ when $a \rightarrow \infty$ as expected, since we are now allowing all of the vacuum ZPE modes to re-enter the Casimir cavity in this case.

We now survey the additional examples of modified vacuums which increase/decrease light speed (from Latorre et al., 1995):

- For light (photons) propagating in a Friedmann-Robertson-Walker (FRW) vacuum (i.e., a homogeneous and isotropic Robertson-Walker gravitational background with Friedmann cosmology):

$$\frac{c^*}{c_0} = \left(1+\frac{11}{45}\alpha G\frac{\rho_r + p}{m_e^{\;2}}\right) > 1 \qquad (\hbar = c_0 = \varepsilon_0 = \mu_0 = 1) \qquad \text{(2.15),}$$

where c^* is the modified vacuum speed of light, G is Newton's constant, ρ_r is the energy density and p is the pressure of a radiation-dominated universe ($p = \rho_r/3$). Here the speed of light is increased.

- For light (photons) propagating in a homogeneous and isotropic thermal vacuum:

$$\frac{c^*}{c_0} = \left(1-\frac{44\pi^2}{2025}\alpha^2\frac{T^4}{m_e^{\;4}}\right) < 1 \qquad (\hbar = c_0 = \varepsilon_0 = \mu_0 = k_B = 1) \qquad \text{(2.16),}$$

where T is the temperature of the vacuum and k_B is the Boltzmann constant. Here the speed of light is decreased.

- ☐ For light (photons) propagating in an anisotropic vacuum given by an external constant uniform magnetic field ***B***:

$$\frac{c_{\|}^*}{c_0} = \left(1 - \frac{8}{45}\alpha^2 \frac{\mathbf{B}^2}{m_e^4}\sin^2\theta\right) < 1 \qquad (\hbar = c_0 = \varepsilon_0 = \mu_0 = 1)$$
$$\frac{c_{\perp}^*}{c_0} = \left(1 - \frac{14}{45}\alpha^2 \frac{\mathbf{B}^2}{m_e^4}\sin^2\theta\right) < 1 \qquad (2.17),$$

where the speed of light is decreased in this vacuum for polarizations coplanar (||) with and perpendicular (⊥) to the plane defined by ***B*** and the direction of propagation, and θ is the angle between ***B*** and the direction of propagation. Latorre et al. (1995) calculated the polarization-average of (2.17) to give the averaged (modified) speed of light in the B-field:

$$\frac{c^*}{c_0} = \left(1 - \frac{22}{135}\alpha^2 \frac{\mathbf{B}^2}{m_e^4}\right) < 1 \qquad (\hbar = c_0 = \varepsilon_0 = \mu_0 = 1) \quad (2.18).$$

- ☐ For light (photons) propagating in an anisotropic vacuum given by an external constant uniform electric field ***E***, the polarization-averaged modified speed of light is:

$$\frac{c^*}{c_0} = \left(1 - \frac{22}{135}\alpha^2 \frac{\mathbf{E}^2}{m_e^4}\right) < 1 \qquad (\hbar = c_0 = \varepsilon_0 = \mu_0 = 1) \qquad (2.19).$$

Here the speed of light is decreased.

Equations (2.16) – (2.19) are the result of vacuum modifications that populate the vacuum with virtual or real particles that induce coherent (light-by-light) scattering, which reduces the speed of massless particles. By examining the form of equations (2.13) and (2.15) – (2.19) Latorre et al. (1995) discovered that the low energy modification of the speed of light is proportional to the ratio of the modified vacuum energy density (as compared to the standard vacuum energy density, $\rho_{vac} = 0$) over m_e^4, with a universal numerical coefficient and the corresponding coupling constants. And a general rule became apparent from their analysis that is applicable to modified vacua for massive and massless quantum field theories, for low energy:

$c^* > c_0$ (vacuum refraction index < 1) when the modified vacuum has a lower energy density
$c^* < c_0$ (vacuum refraction index > 1) when the modified vacuum has a higher energy density
$c^* = c_0$ (vacuum refraction index = 1) when the vacuum is free (or un-modified) with $\rho_{vac} = 0$

The first two rules explain the sign of the change of the speed of light. From this rule and the mathematical commonality between the form of (2.13) and (2.15) – (2.19) Latorre et al. (1995) found a single unifying expression to replace these equations:

$$\frac{c^*}{c_0} = 1 - \frac{44}{135}\alpha^2 \frac{\rho}{m_e^4} \qquad (\hbar = c_0 = \varepsilon_0 = \mu_0 = 1) \qquad (2.20),$$

where ρ is the energy density of the modified vacua under consideration such that $\rho \rightarrow \rho_E \sim \boldsymbol{E}^2$ for the electric field vacuum, $\rho \rightarrow \rho_B \sim \boldsymbol{B}^2$ for the magnetic field vacuum, and $\rho \rightarrow \rho_T \sim \pi^2 T^4$ for the thermal vacuum. If the vacuum is a FRW gravitational vacuum, then one has to substitute one factor of α in (2.20) by $-m_e^2 G$ and $\rho \rightarrow \rho_r$. Equation (2.13) for the Casimir Effect vacuum studied earlier is recovered when $\rho \rightarrow \rho_{\text{Casimir}} = -(\pi^2/240)a^{-4}$.

Let us recast (2.20) into a more useful form. We subtract one from both sides of (2.20), do some algebra, and thus define the ratio of the change in the speed of light Δc in a modified vacuum to the speed of light in free space c_0:

$$\frac{c^*}{c_0} - 1 = \frac{c^* - c_0}{c_0} \equiv \frac{\Delta c}{c_0}$$

$$\frac{\Delta c}{c_0} = -\frac{44}{135}\alpha^2 \frac{\rho}{m_e^{\,4}} \qquad (\hbar = c_0 = \varepsilon_0 = \mu_0 = 1) \quad (2.21).$$

Equations (2.20) and (2.21) are in quantum field theory natural units, which is completely undesirable for estimating physically measurable values of $\Delta c/c_0$. We thus transform or "unwrap" (2.20) and (2.21) back into MKS or CGS units by making the following substitutions (Puthoff, 2003)

$$\rho \text{ (natural units)} \rightarrow \frac{\rho}{\hbar c} \text{ (MKS or CGS units)}$$

$$m_e \text{ (natural units)} \rightarrow \frac{m_e c}{\hbar} \text{ (MKS or CGS units)},$$

and after some algebra and rearranging we arrive at the final result:

$$\frac{c^*}{c_0} = 1 - \frac{44}{135}\alpha^2 \frac{\rho}{m_e c_0^{\,2}} \left(\frac{\hbar}{m_e c_0}\right)^3 \qquad (2.22)$$

and

$$\frac{\Delta c}{c_0} = -\frac{44}{135}\alpha^2 \frac{\rho}{m_e c_0^{\,2}} \left(\frac{\hbar}{m_e c_0}\right)^3 \qquad (2.23),$$

where all quantities are now in MKS or CGS units. We chose the former units so that $c_0 = 3\times10^8$ m/s, $\hbar = 1.055\times10^{-34}$ J-s, $m_e = 9.11\times10^{-31}$ kg, and $\alpha = 1/137$. Note that the ratio of the modified vacuum energy density to the electron rest-mass energy has the dimension of $(volume)^{-1}$ while the quantity in the bracket is the cubed Compton wavelength of the electron having the dimension of (*volume*), and the product of these is dimensionless.

An excellent example for estimating the magnitude of the change in the speed of light (in a modified vacuum) is the Casimir Effect vacuum, since Casimir Effect experiments are common and widespread such that this would be ideal to experimentally test (2.23). We substitute the Casimir vacuum energy density $\rho_{\text{Casimir}} = -(\pi^2 \hbar c_0/240)a^{-4}$ (in MKS units) into (2.23), do the algebra, insert the MKS values for the physical constants, and make further simplifications to get:

$$\begin{aligned}\frac{\Delta c}{c_0} &= -\frac{44}{135}\alpha^2\left(-\frac{\pi^2}{240}\frac{\hbar c_0}{a^4}\right)\frac{1}{m_e {c_0}^2}\left(\frac{\hbar}{m_e c_0}\right)^3 \\ &= \frac{11}{8100}\alpha^2\pi^2\left(\frac{\hbar}{m_e c_0 a}\right)^4 \qquad (2.24), \\ &\approx \left(1.59\times10^{-56}\right)a^{-4}\end{aligned}$$

where a (the plate separation) is in meters. Another useful equation is:

$$c^* = \left(1+\frac{\Delta c}{c_0}\right)c_0 \qquad (2.25),$$

where we make the substitution $c^* \to c_\perp^*$ for the present case. H. E. Puthoff and the author (Puthoff, 2003) compared the third line in (2.24) with equation (26) in Scharnhorst (1990) and discovered that the result cited there is in error, because the numerical coefficient is four orders of magnitude too small (Scharnhorst originally pointed out this error to Forward, 1996).

We now set $a = 10^{-6}$ m (1 μm) and we get $\Delta c/c_0 \approx 10^{-32}$ and $c_\perp^* \approx c_0$, which is a horrifically small 1 part in 10^{32} change that we cannot hope to measure at present. But for $a = 10^{-10}$ m (1 Å) we get $\Delta c/c_0 \approx 10^{-16}$ and $c_\perp^* \approx c_0$, which is a 1 part in 10^{16} change that could be measurable at present or in the very near future using high precision laser technology. Last, for $a = 1.1229\times10^{-14}$ m (11.229 fm or ≈ 11 times the nuclear diameter; 1 fm = 10^{-15} m) we find that $\Delta c/c_0 \approx 1$ and $c_\perp^* \approx 2c_0$. We are not able to do technical work at nuclear distances at this time; however, that could change as ultrahigh precision measurement technology continues to evolve. The threshold for the onset of significant changes in light speed occurs when $a < 10^{-12}$ m. This result is generally true for the other modified vacua surveyed in (2.15) – (2.19), since accessible (everyday) values for electric and magnetic field strengths, thermal temperatures and radiation densities are not large enough to overcome the size of the electron mass to create a measurable effect. However, there is a class of ultrahigh intensity tabletop lasers that have achieved such extreme electric and magnetic field strengths and temperatures that it may now be possible to consider using them to explore vacuum modification effects in the lab. We will return to this theme in a later section.

•**Key Point**: As disappointing as the Casimir Effect vacuum (and other modified vacua) results are, it should be strongly pointed out that special relativity theory says that if in one inertial reference frame an object travels only one part in 10^{16} (or even one part in 10^{32}) times faster than c_0, then one can find another reference frame where departure and arrival times of the object are simultaneous, and thus the velocity is ***infinite***. This is what motivates us to look at a teleportation mechanism based on engineering of the vacuum.

•**Technical Notes**:

- Equation (2.15) is interpreted as an increase in the speed of light due to a decrease in the number of vacuum ZPE modes. However, this effect is totally unrelated to light-by-light scattering in the vacuum because the gravitational background "squeezes" (as in squeezed quantum optics states; see Davis, 1999a) the ZPE modes, therefore reducing the vacuum energy density. We further note that the coefficient of 11 is the same for the gravitational vacuum as for the other modified vacua examples based on QED. This factor also appears in the coefficient of the Euler-Poincare characteristic spin-½ contribution to the gravitational trace anomaly (Birrell and Davies, 1982). It is beyond the scope of this study to consider the deep connections between quantum field theory and gravitation.

- We have excluded from our survey the Latorre et al. (1995) results pertaining to all other (high or low energy) modifications of the speed of massless particles. That is because the other examples invoked different QED theories possessing massless ($m_e = 0$), massive and intrinsic mass scales that introduced complex correction terms (beyond the leading low energy terms surveyed above) which are mass-related or running mass-related, and they introduced no new speed modification effects (beyond the low energy electron-positron virtual pair contributions); or no genuine speed modification was possible (especially for the massless Quantum Chromodynamic sector involving pseudo-Goldstone particles).

- There is ongoing (very noisy) controversy within the physics community over the effects of $c^* > c_0$ on causality. As this topic is beyond the scope of this study, I will make three points in this regard: 1) There are no grounds for microcausality violations in accordance with Drummond and Hathrell (1980). 2) A new definition of causality is in order for FTL (faster-than-light) phenomena. 3) Investigators have found that time machines (a.k.a. closed timelike curves) do not affect Gauss's theorem, and thus do not affect the derivation of global conservation laws from differential ones (Friedman et al., 1990). The standard conservation laws remain globally valid while retaining a natural quasi-local interpretation for spacetimes possessing time machines (for example, asymptotically flat wormhole spacetimes). Thorne (1993) states that it may turn out that causality is violated at the macroscopic scale. Even if causality is obeyed macroscopically, then quantum gravity might offer finite probability amplitudes for microscopic spacetime histories possessing time machines. Li and Gott (1998) found a self-consistent vacuum for quantum fields in Misner space (a simple flat space with closed timelike curves), for which the renormalized stress-energy tensor is regular (in fact zero) everywhere. This implies that closed timelike curves could exist at least at the level of semi-classical quantum gravity theory. Therefore, FTL causality paradoxes are just a reflection of our ignorance or inadequate comprehension of the physics of chronology and causality.

In this section we have shown how "vacuum engineering" can modify the speed of light, and how this can, in principle, lead to vm-Teleportation. The vacuum modification concepts summarized above lead us to a formal theory that implements the concept of vacuum engineering within a framework that parallels general relativity theory. This theory is called the Polarizable-Vacuum Representation of General Relativity. In the next section we will introduce and summarize this theory.

2.2.1 The Polarizable-Vacuum Representation of General Relativity

The polarizable-vacuum representation of general relativity (a.k.a. PV-GR) treats the vacuum as a polarizable medium of variable refractive index (Puthoff, 1999a, 2002a, b; Puthoff et al., 2002) exemplifying the concept of the vacuum modification (or vacuum engineering) effects surveyed and discussed in the previous section. The PV-GR approach treats spacetime metric changes in terms of equivalent changes in the vacuum permittivity and permeability constants (ε_0 and μ_0), essentially along the lines of the "$TH\varepsilon\mu$" methodology (see Appendix B for a brief description of this) used in comparative studies of alternative metric theories of gravity (Lightman and Lee, 1973; Will, 1974, 1989, 1993; Haugan and Will, 1977). Such an approach, relying as it does on parameters familiar to engineers, can be considered a "metric engineering" approach. Maxwell's equations in curved space are treated in the isomorphism of a polarizable medium of variable refractive index in flat space (Volkov et al., 1971); the bending of a light ray near a massive body is modeled as due to an induced spatial variation in the refractive index of the vacuum near the body; the reduction in the velocity of light in a gravitational potential is represented by an effective increase in the refractive index of the vacuum, and so forth. This optical-engineering approach has been shown to be quite general (de Felice, 1971; Evans et al., 1996a, b).

As recently elaborated by Puthoff (1999a, 2002a, b; Puthoff et al., 2002) the PV-GR approach, which was first introduced by Wilson (1921) and then developed by Dicke (1957, 1961), can be carried out in a self-consistent way so as to reproduce to appropriate order both the equations of general relativity and the match to the standard astrophysics weak-field experimental (PPN parameters and other) tests of those equations while posing testable modifications for strong-field conditions. It is in application that the PV-GR approach demonstrates its intuitive appeal and provides additional insight into what is meant by a curved spacetime metric.

Specifically, the PV-GR approach treats such measures as the speed of light, the length of rulers (atomic bond lengths), the frequency of clocks, particle masses, and so forth, in terms of a variable vacuum dielectric constant K in which the vacuum permittivity ε_0 transforms as $\varepsilon_0 \rightarrow K\varepsilon_0$ and the vacuum permeability transforms as $\mu_0 \rightarrow K\mu_0$ (see also, Rucker, 1977). In a planetary or solar gravitational potential $K = exp(2GM/rc_0^2) > 1$ (M is a local mass distribution, r is the radial distance from the center of M) while $K = 1$ in "empty" or free asymptotic space (Puthoff, 1999a, 2002a, b; Puthoff et al., 2002). In the former case, the speed of light is reduced, light emitted from an atom is redshifted as compared with a remote static atom (where $K = 1$), clocks run slower, objects/rulers shrink, etc. See Table 1.

Table 1. Metric Effects in the PV-GR Model When $K > 1$ (Compared With Reference Frames at Asymptotic Infinity Where $K = 1$; adapted from Puthoff et al., 2002**)**

Variable	**Determining Equation** (subscript 0 is asymptotic value where $K = 1$)	$K > 1$ *(typical mass distribution, M)*
modified speed of light $c^*(K)$	$c^* = c_0/K$	speed of light < c_0
Modified mass $m(K)$	$m = m_0K^{3/2}$	effective mass increases
modified frequency $\omega(K)$	$\omega = \omega_0K^{-1/2}$	redshift toward lower frequencies
modified time interval $\Delta t(K)$	$\Delta t = \Delta t_0K^{1/2}$	clocks run slower
modified energy $E(K)$	$E = E_0K^{-1/2}$	lower energy states
Modified length $L(K)$	$L = L_0K^{-1/2}$	objects/rulers shrink
dielectric-vacuum "gravitational" forces $F(K)$	$F(K) \propto \nabla K$	attractive gravitational force

When $K = 1$ we have the condition that $c^* = c_0$ (vacuum refraction index = 1), because the vacuum is free (or un-modified, and $\rho_{vac} = 0$) in this case. When $K > 1$, as occurs in a region of space possessing a gravitational potential, then we have the condition that $c^* < c_0$ (vacuum refraction index > 1), because the modified vacuum has a higher energy density in the presence of the local mass distribution that generates the local gravitational field. This fact allows us to make a direct correspondence between the speed of light modification physics discussion in Section 2.2 and the underlying basis for the physics of the PV-GR model. Under certain conditions the spacetime metric can in principle be modified to reduce the value of K to below unity, thus allowing for faster-than-light (FTL) motion to be physically realized. In this case, the local speed of light (as measured by remote static observers) is increased, light emitted from an atom is blueshifted as compared with a remote static atom, objects/rulers expand, clocks run faster, etc. See Table 2. We therefore have the condition that $c^* > c_0$ (vacuum refraction index < 1) because the modified vacuum has a lower energy density. In fact, Puthoff (1999a, 2002a) has analyzed certain special

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black hole metrics and found $K < 1$ from the model. We will return to this theme later. In what follows we briefly review and summarize the key points and equations from the development of the PV-GR model, and we refer the reader to Puthoff (1999a, 2002a, b) for more extensive discussion and derivations.

Table 2. Metric Effects in the PV-GR Model When $K < 1$ (Compared With Reference Frames at Asymptotic Infinity Where $K = 1$; adapted from Puthoff et al., 2002**)**

Variable	**Determining Equation** (subscript 0 is asymptotic value where $K = 1$)	$K < 1$ *(typical mass distribution, M)*
modified speed of light $c^*(K)$	$c^* = c_0/K$	speed of light > c_0
modified mass $m(K)$	$m = m_0 K^{3/2}$	effective mass decreases
modified frequency $\omega(K)$	$\omega = \omega_0 K^{-1/2}$	blueshift toward higher frequencies
modified time interval $\Delta t(K)$	$\Delta t = \Delta t_0 K^{1/2}$	clocks run faster
modified energy $E(K)$	$E = E_0 K^{-1/2}$	higher energy states
modified length $L(K)$	$L = L_0 K^{-1/2}$	objects/rulers expand
dielectric-vacuum "gravitational" forces $F(K)$	$F(K) \propto \nabla K$	repulsive gravitational force

We begin by recalling that in flat space electrodynamics, the electric flux vector ***D*** in a linear, homogeneous medium can be written

$$\begin{aligned}\mathbf{D} &= \varepsilon\mathbf{E} \\ &= \varepsilon_0\mathbf{E} + \mathbf{P} \\ &= \varepsilon_0\mathbf{E} + \alpha_V\mathbf{E}\end{aligned} \quad (2.26),$$

where ε is the permittivity of the medium, the polarization ***P*** corresponds to the induced dipole moment per unit volume in the medium whose polarizability per unit volume is α_V, and ***E*** is the electric field. The identical form of the last two terms naturally leads to the interpretation of ε_0 as the polarizability per unit volume of the vacuum. The quantum picture of the vacuum, where it has been shown that the vacuum acts as a polarizable medium by virtue of induced dipole moments resulting from the excitation of virtual electron-positron particle pairs (Heitler, 1954), completely justifies the interpretation that the vacuum is a medium. Note that there are other virtual particle pairs in the vacuum that also contribute to this picture; however, it is the electron-positron pairs that dominate the others, as shown in Section 2.2. The basic postulate of the PV-GR model for curved space conditions is that the polarizability of the vacuum in the vicinity of localized mass-energy distributions differs from its asymptotic free space value by virtue of vacuum polarization effects induced by the presence of the local mass-energy. Thus the postulate for the vacuum itself is

$$\begin{aligned}\mathbf{D} &= \varepsilon\mathbf{E} \\ &\equiv K\varepsilon_0\mathbf{E}\end{aligned} \quad (2.27),$$

where K (a function of position) is the modified dielectric constant of the vacuum due to the induced vacuum polarizability changes under consideration. Equation (2.27) defines the transformation $\varepsilon = K\varepsilon_0$.

Table 1 shows the various quantitative effects a polarizable vacuum (in the presence of positive mass-energy distributions) has on the various measurement processes important to general relativity. The effects demonstrated in the middle and right columns demonstrate the basis of the polarizable vacuum approach to general relativity. Table 2 shows what effects are manifested when negative mass-energy distributions induce vacuum polarizability changes that lead to FTL phenomenon. Experimental observations impose constraints on the model causing key physical constants to remain constant even with variable polarizability present in the local space. Puthoff (1999a, 2002a, b) has shown that the fine structure constant is constrained by observational data to remain constant within a variable polarizable vacuum, and this constraint actually defines the transformation $\mu = K\mu_0$. The elementary particle charge e is also taken to be constant in a variable polarizable vacuum because of charge conservation. And $\hbar$ remains a constant by conservation of angular momentum for circularly polarized photons propagating through the (variable polarizability) vacuum. The remaining constant of nature is the speed of light, and although the tables showed how this was modified in variable polarizability vacuums, it is interesting to see how this modification comes about. In a modified (variable polarizability) vacuum the speed of light is defined, as it is in standard electrodynamics, in terms of the permittivity and permeability by:

$$\begin{aligned} c^* &\equiv (\varepsilon\mu)^{-1/2} \\ &= (K\varepsilon_0 \bullet K\mu_0)^{-1/2} \\ &= (K^2\varepsilon_0\mu_0)^{-1/2} \\ &= \frac{1}{K}(\varepsilon_0\mu_0)^{-1/2} \\ &= \frac{c_0}{K} \end{aligned} \qquad (2.28),$$

where the permittivity/permeability transformations and the free space (un-modified vacuum) definition for c_0 were inserted. Note that (2.28) can be re-written as $c^*/c_0 = 1/K$, and this is to be compared with (2.22). Thus we see from (2.28), and by comparison with (2.22), that K plays the role of a variable refractive index under conditions in which the vacuum polarizability is assumed to change in response to general relativistic-type influences. One further note of interest is that the permittivity/permeability transformations also maintains constant the ratio

$$\sqrt{\frac{\mu}{\varepsilon}} = \sqrt{\frac{\mu_0}{\varepsilon_0}} \,,$$

which is the impedance of free space. This constant ratio is required to keep electric-to-magnetic energy ratios constant during adiabatic movement of atoms from one position in space to another of differing vacuum polarizability (Dicke, 1957, 1961). And this constant ratio is also a necessary condition in the $TH\varepsilon\mu$ formalism for an electromagnetic test particle to fall in a gravitational field with a composition-independent acceleration (Lightman and Lee, 1973; Will, 1974, 1989, 1993; Haugan and Will, 1977).

Now we make the “crossover connection” to the standard spacetime metric tensor concept that characterizes conventional general relativity theory, as originally shown by Puthoff (1999a, 2002a, b). In flat (un-modified or free) space the standard four-dimensional infinitesimal spacetime interval ds^2 is given (in Cartesian coordinates with subscript 0) by

$$ds^2 = -c_0{}^2 dt_0{}^2 + \sum_{i=1}^{3} dx_{i0}{}^2 \qquad (2.29),$$

where $i \equiv (1 = x,\ 2 = y,\ 3 = z)$. This metric means that measuring rods and clocks are non-varying wherever one goes in spacetime to make measurements. However, this has been shown to be incorrect in general relativity theory, so the length and time transformations (between proper and coordinate values) given in the tables (middle columns) indicate that measuring rods and clocks do vary when placed in regions where $K \neq 1$. Therefore, we replace the time and space differentials in (2.29) with the length and time transformations in the tables into (2.29), and derive the general relativistic spacetime interval

$$ds^2 = -\frac{1}{K} c_0{}^2 dt^2 + K\left(\sum_{i=1}^{3} dx_i{}^2\right) \qquad (2.30).$$

Note that observers within a $K \neq 1$ region will always measure the speed of light to be c_0. Equation (2.30) defines an isotropic coordinate system, which is a common and useful way to represent spacetime metrics in general relativity studies. By inspection the metric tensor is written

$$g_{\alpha\beta} = \begin{pmatrix} -1/K & 0 & 0 & 0 \\ 0 & K & 0 & 0 \\ 0 & 0 & K & 0 \\ 0 & 0 & 0 & K \end{pmatrix} \qquad (2.31).$$

The Lagrangian density for matter-field interactions in a vacuum of variable K is given by Puthoff (1999a, 2002a, b) as

$$\begin{aligned} L_d = &-\left[\frac{m_0 c_0{}^2}{\sqrt{K}}\sqrt{1-\left(\frac{v}{c_0/K}\right)^2} + q\Phi - qA_i v^i\right]\delta^3(\mathbf{r}-\mathbf{r}_0) \\ &-\frac{1}{2}\left(\frac{\mathbf{B}^2}{K\mu_0} - K\varepsilon_0\mathbf{E}^2\right) - \frac{c_0{}^4}{32\pi G}\frac{1}{K^2}\left[(\nabla K)^2 - \frac{1}{(c_0/K)^2}\left(\frac{\partial K}{\partial t}\right)^2\right] \end{aligned} \qquad (2.32),$$

where the first term is the Lagrangian density for a free particle of mass m_0, charge q and 3-vector velocity $\boldsymbol{v}$ ($v = |\boldsymbol{v}|$, 3-vector components are labeled by i) interacting with electromagnetic fields via the electromagnetic field 4-vector potential $A_\mu = (\Phi, A_i)$ (note that $\delta^3(\mathbf{r} - \mathbf{r}_0)$ is the delta function that locates the point particle at position $\mathbf{r} = \mathbf{r}_0$); the second term is the Lagrangian density for the electromagnetic fields themselves, and the last term is the Lagrangian density for K (treated here as a scalar variable). This last term emulates the Lagrangian density for the gravitational field. Equation (2.32) does not include any quantum gauge field interaction terms because it is beyond the scope of the present incarnation of the PV-GR approach to include them. We can obtain the equations of particle motion in a variable dielectric vacuum by performing the standard variations of the Lagrangian density $\delta(\int L_d\, dx\, dy\, dz\, dt)$ with respect to the particle variables. However, we are more interested in obtaining the "master equation" for K by varying the Lagrangian density with respect to K, and Puthoff (1999a, 2002a, b) gives the result:

$$\begin{aligned}&\nabla^2\sqrt{K}-\frac{1}{\left(c_0/K\right)^2}\frac{\partial^2\sqrt{K}}{\partial t^2}\\ &=-\frac{8\pi G}{c_0^{\;4}}\sqrt{K}\left\{\frac{\left(m_0c_0^{\;2}/\sqrt{K}\right)}{\sqrt{1-\left(\dfrac{v}{c_0/K}\right)^2}}\,\frac{1}{2}\left[1+\left(\frac{v}{c_0/K}\right)^2\right]\delta^3(\mathbf{r}-\mathbf{r}_0)\right. \qquad (2.33).\\ &\left.+\frac{1}{2}\left(\frac{\mathbf{B}^2}{K\mu_0}+K\varepsilon_0\mathbf{E}^2\right)-\frac{c_0^{\;4}}{32\pi G}\frac{1}{K^2}\left[(\nabla K)^2+\frac{1}{\left(c_0/K\right)^2}\left(\frac{\partial K}{\partial t}\right)^2\right]\right\}\end{aligned}$$

This equation describes the generation of general relativistic vacuum polarization effects due to the presence of matter and fields. By inspecting the right-hand side of the equation, we observe that changes in K are driven by the mass density (1st term), electromagnetic energy density (2nd term), and the vacuum polarization energy density itself (3rd term). In fact, the 3rd term emulates the gravitational field self-energy density. Note that the 2nd and 3rd terms in (2.33) appear with opposite signs with the result that electromagnetic field effects can counteract the gravitational field effects. Puthoff found that (2.33) gives the solution $K = exp(2GM/rc_0^2)$ in the vicinity of a static spherically symmetric (uncharged) mass M (in the low velocity limit $v << c_0$, $\partial K/\partial t = 0$, $\boldsymbol{E} = \boldsymbol{B} = 0$, $q = 0$), which reproduces to appropriate order the standard general relativistic Schwarzschild spacetime metric for the weak gravitational field conditions prevailing in the solar system. This solution guarantees that $K > 1$ near mass concentrations.

Of major importance to the present study are solutions giving $K < 1$ so that teleportation can be realized. Puthoff has found one such solution by studying the case of a static spherically symmetric mass M with charge Q familiar from the study of the Reissner-Nordstrϕm spacetime metric. In this case Puthoff found the result

$$K=\left[\cos\left(\frac{\sqrt{b^2-a^2}}{r}\right)+\frac{a}{\sqrt{b^2-a^2}}\sin\left(\frac{\sqrt{b^2-a^2}}{r}\right)\right]^2 \qquad \left(b^2>a^2\right) \qquad (2.34),$$

where $a^2 = (GM/c_0^2)^2$, $b^2 = Q^2G/4\pi\varepsilon_0 c_0^4$, and r is the radial distance from the center of M. And in this case (2.34) gives $K < 1$, which shows that FTL solutions are available in the PV-GR approach (as they are also in the Einstein theory). (For $a^2 > b^2$ the solution is hyperbolic-trigonometric and describes the standard Reissner-Nordstrϕm metric where $K > 1$.)

Generally speaking, in Einstein general relativity the Reissner-Nordstrϕm metric can be manipulated along with two shells of electrically charged matter to form a traversable wormhole (Schein and Aichelburg, 1996). But there are two drawbacks to this. The first is that the scheme involves dealing with the collapsed state of the stellar matter that generates the metric (a.k.a. Reissner-Nordstrϕm black hole) along with the unpleasant side effects that are encountered, such as the crushing singularities and multiple (unstable) event horizons. Second, the traversable wormhole is an eternal time machine connecting remote regions of the same universe together. Now there are no black hole solutions found in the PV-GR model because in that approach stellar matter collapses smoothly to an ultra-dense state and without the creation of singularities and event horizons (Puthoff, 1999b).

In either case, the Reissner-Nordstrϕm metric does not offer a viable mechanism for vm-Teleportation. We are more interested in examining other PV-GR cases (where $K < 1$ or even $K << 1$)

that emulate the effects of traversable wormhole metrics that do obey the vm-Teleportation definition, such as the example presented in Section 2.1. Equation (2.33) suggests that we search for a vacuum engineering concept that exploits electromagnetic fields to alter the vacuum dielectric constant *K* to induce the desired vm-Teleportation effect in the modified vacuum. (However, we can insert other source terms that will lead to the desired result.) We envision this particular teleportation concept to resemble Figure 2. [Note: Before this report went to press H. E. Puthoff, C. Maccone and the author discovered a number of $K < 1$ solutions to equation (2.33) that uniquely meet the definition of vm-Teleportation and FTL motion. We discovered that the generic energy density required to generate $K < 1$ solutions must be negative, and that the total energy density of the system as seen by remote observes is approximately zero. This unique result compares very well with the traversable wormhole mass-energy density requirements discussed in Section 2.1.2. This discovery will be the subject of a forthcoming paper.]

2.3 Conclusion and Recommendations

The concept we envision for vm-Teleportation is that animate or inanimate objects would be placed inside an environmentally enclosed vessel that would simply be moved into the teleportation device. The "teleporter" would be activated, and the vessel would almost immediately disappear and then reappear at the remote destination as if it were briefly moving through a portal or "stargate." The teleportation device might be required to operate in the vacuum of space outside of the Earth's atmosphere. We have shown two practically equivalent ways to implement vm-Teleportation. There is the manipulation of spacetime geometry via exploiting negative (i.e., quantum vacuum zero point) energy as shown by Einstein's general relativity theory, and there is the modification of the vacuum dielectric constant as shown by the PV-GR model. Both have a great deal of theoretical foundation to begin exploring experimentally. The PV-GR model needs additional theoretical work for the present application, but it is now mature enough for experimental exploration.

There already is extensive theoretical, and more importantly, experimental research proving that the vacuum can be engineered (or physically modified) so that the vacuum ZPE can be exploited (via the Casimir Effect, for example) to extract electrical energy or actuate microelectromechanical devices (see for example, Ambjϕrn and Wolfram, 1983; Forward, 1984, 1996, 1998; Puthoff, 1990, 1993; Cole and Puthoff, 1993; Milonni, 1994; Mead and Nachamkin, 1996; Lamoreaux, 1997; Chan et al., 2001, and the references cited therein). But most of this research involves very low energy density regimes, which are much too low for our purposes. The Mead and Nachamkin (1996) device is actually designed to extract electrical energy from the higher frequency/higher energy density ZPE modes. However, new ultrahigh-intensity lasers became available in the 1990s that have achieved extreme physical conditions in the lab that are comparable to the extreme astrophysical conditions expected to be found in stellar cores and on black hole event horizons (Perry, 1996; Mourou et al., 1998; Perry, 2000). The power intensity of these lasers has reached the point to where they actually probe QED vacuum physics and general relativistic physics, and they have even modified the vacuum itself. The lasers were originally called petaWatt lasers (operating range of 10^{14} – 10^{18} Watts/cm^2 at femtosecond pulses), but they have now reached power intensity levels in the 10^{25} – 10^{30} Watts/cm^2 range. The lasers were made possible by a novel breakthrough called "chirped pulse amplification" whereby the initial low energy/low power intensity laser beam is stretched, amplified and then compressed without experiencing any beam distortions or amplifier damage. This laser system was initially designed as a large-optics beam-line power booster for the NOVA laser fusion experiment at Lawrence Livermore National Laboratory. But researchers found a way to shrink the optics down to tabletop scale, and one can now own and operate a tabletop ultrahigh-intensity laser for ≈ \$500,000. The dimensions of the optical bench used by the University of California-San Diego is ≈ 5 m × 12 m (or ≈ 60 m^2; see Mourou et al., 1998). In tabletop lab experiments ultrahigh-intensity lasers have generated >> gigagauss magnetic fields, ≥ 10^{16} Volt/cm electric field strengths, >> terabar light pressures and >> 10^{22} m/sec^2 subatomic particle accelerations. These ultrahigh-intensity tabletop lasers are thus the ideal instrument with which to explore the fundamental physics underlying the two possible concepts for vm-Teleportation.

There are several ideas on how to generate negative energy in the lab that could potentially be extracted and concentrated in the proper fashion to induce the traversable flat-face wormhole outlined in Section 2.1.1 or induce the $K < 1$ condition (in the PV-GR model) outlined in Section 2.2.1. The schemes for generating negative energy are:

- Casimir Effect (described in Section 2.2): This is the easiest and most well known way to generate negative energy in the lab. The energy density $\rho_{\mathrm{Casimir}} = -(\pi^2 \hbar c_0/240)a^{-4}$ within a Casimir capacitor cavity is negative and manifests itself by producing a force of attraction between the capacitor plates. This has been measured in the lab (see above references). Forward (1998) proposes a mechanism for the endless extraction of energy from the vacuum in a Casimir cavity by cyclic manipulation of the cavity dimensions.

- Moving Mirror: Negative quantum vacuum energy can be created by a single moving reflecting surface (a moving mirror). If a mirror moves with increasing acceleration, then a flux of negative energy emanates from its surface and flows out into the space ahead of the mirror (Birrell and Davies, 1982). However, this effect is known to be exceedingly small, and it is not the most effective way to generate negative energy.

- Optically Squeezed Laser Light: Negative quantum vacuum energy can also be generated by an array of ultrahigh intensity lasers with an ultrafast rotating mirror system. In this scheme a laser beam is passed through an optical cavity resonator made of lithium niobate crystal that is shaped like a cylinder with rounded silvered ends to reflect light. The resonator will act to produce a secondary lower frequency light beam in which the pattern of photons is rearranged into pairs. This is the quantum optical "squeezing" of light effect. (See Section A.2 in Appendix A for a complete definition and description of squeezed quantum states.) Therefore, the squeezed light beam emerging from the resonator will contain pulses of negative energy interspersed with pulses of positive energy. Another way to squeeze light would be to manufacture extremely reliable light pulses containing precisely one, two, three, etc. photons apiece and combine them together to create squeezed states to order. Superimposing many such states could theoretically produce bursts of intense negative energy. For the laser beam resonator example we find that both negative and positive energy pulses are of $\approx 10^{-15}$ second duration. We could arrange a set of rapidly rotating mirrors to separate the positive and negative energy pulses from each other. The light beam is to strike each mirror surface at a very shallow angle while the rotation ensures that the negative energy pulses are reflected at a slightly different angle from the positive energy pulses. A small spatial separation of the two different energy pulses will occur at some distance from the rotating mirror. Another system of mirrors will be needed to redirect the negative energy pulses to an isolated location and concentrate them there.

- Gravitationally Squeezed Vacuum Energy: A natural source of negative quantum vacuum energy comes from the effect that gravitational fields (of astronomical bodies) in space have upon the surrounding vacuum. For example, the gravitational field of the Earth produces a zone of negative energy around it by dragging some of the virtual particle pairs (a.k.a. virtual photons or vacuum ZPF) downward. This concept was initially developed in the 1970s as a byproduct of studies on quantum field theory in curved space (Birrell and Davies, 1982). However, Hochberg and Kephart (1991) derived an important application of this concept to the problem of creating and stabilizing traversable wormholes, and their work was corrected and extended by Davis (1999a). They proved that one can utilize the negative vacuum energy densities, which arise from *distortion of the electromagnetic zero point fluctuations* due to the interaction with a prescribed gravitational background, for providing a violation of the energy conditions (see

Section A.1 in Appendix A). Hochberg and Kephart (1991) showed that the squeezed quantum states of quantum optics provide a natural form of matter having negative energy density. And since the vacuum is defined to have vanishing energy density, anything possessing less energy density than the vacuum must have a negative energy density. The analysis, via quantum optics, shows that gravitation itself provides the mechanism for generating the squeezed vacuum states needed to support stable traversable wormholes. The production of negative energy densities via a squeezed vacuum is a necessary and unavoidable consequence of the interaction or coupling between ordinary matter and gravity, and this defines what is meant by gravitationally squeezed vacuum states. The magnitude of the gravitational squeezing of the vacuum can be estimated from the squeezing condition, which simply states that substantial gravitational squeezing of the vacuum occurs for those quantum electromagnetic field modes with *wavelength* (λ in meters) > *Schwarzschild radius* (r_S in meters) of the mass in question (whose gravitational field is squeezing the vacuum). The Schwarzschild radius is the critical radius, according to general relativity theory, at which a spherically symmetric massive body becomes a black hole; i.e., at which light is unable to escape from the body's surface. We can actually choose any radial distance from the mass in question to perform this analysis, but using the Schwarzschild radius makes equations simpler in form. The general result of the gravitational squeezing effect is that as the gravitational field strength increases the negative energy zone (surrounding the mass) also increases in strength. Table 3 shows when gravitational squeezing becomes important for example masses. The table shows that in the case of the Earth, Jupiter and the Sun, this squeeze effect is extremely feeble because only ZPF mode wavelengths above 0.2 m – 78 km are affected. For a solar mass black hole (radius of 2.95 km), the effect is still feeble because only ZPF mode wavelengths above 78 km are affected. But note from the table that quantum black holes with Planck mass will have enormously strong negative energy surrounding them because all ZPF mode wavelengths above 8.50×10^{-34} meter will be squeezed; in other words, all wavelengths of interest for vacuum fluctuations. Black holes with proton mass will have the strongest negative energy zone in comparison because the squeezing effect includes all ZPF mode wavelengths above 6.50×10^{-53} meter. Furthermore, a black hole smaller than a nuclear diameter ($\approx 10^{-16}$ m) and containing the mass of a mountain ($\approx 10^{11}$ kg) would possess a fairly strong negative energy zone because all ZPF mode wavelengths above 10^{-15} meter will be squeezed.

Table 3. Substantial Gravitational Squeezing Occurs When $\lambda \geq 8\pi r_S$ (For Electromagnetic ZPF; adapted from Davis, 1999a**)**

Mass of body	Schwarzschild radius of body, r_S	ZPF mode wavelength, λ
Sun = 2.0×10^{30} kg	2.95 km	≥ 78 km
Jupiter = 1.9×10^{27} kg	2.82 m	≥ 74 m
Earth = 5.976×10^{24} kg	8.87×10^{-3} m	≥ 0.23 m
Typical mountain ≈ 10^{11} kg	≈ 10^{-16} m	≥ 10^{-15} m
Planck mass = 2.18×10^{-8} kg	3.23×10^{-35} m	≥ 8.50×10^{-34} m
Proton = 1.673×10^{-27} kg	2.48×10^{-54} m	≥ 6.50×10^{-53} m

•**Recommendations**:

- Theoretical Program 1: A one to two year theoretical study (cost ≈ \$80,000) should be initiated to explore the recently discovered $K < 1$ (FTL) solutions to equation (2.33) in order to define, characterize and model the negative energy density source(s) that induce the FTL vacuum modification. The study should also identify potential lab experiments designed to test theoretical predictions.

- Theoretical Program 2: A one to two year study (cost ≈ $80,000) should be initiated to conduct a detailed review of the negative energy generation schemes summarized above to define their characteristics, performances and requirements. The study should develop technical parameters for each of the schemes in order to identify potential lab experiments.

- Experimental Program 1: An experimental study should be conducted to test Forward's (1998) Casimir energy extraction proposal. An experiment definition study will be required to estimate the experimental method, procedure, equipment needs and costs.

- Experimental Program 2: An experimental study using ultrahigh-intensity lasers should be conducted to test the Optically Squeezed Laser Light proposal. An experiment definition study will be required to estimate the experimental method, procedure, equipment needs and costs.

- Experimental Program 3: An experimental study using ultrahigh-intensity lasers should be conducted to probe QED vacuum physics and vacuum modification as well as test elements of the PV-GR model. A starting point for this program would be to use such lasers to perform the Ding and Kaplan (1989, 1992, 2000; see also, Forward, 1996) experiment. This is an important fundamental physics experiment to do, because it can distinguish between the rival quantum vacuum electromagnetic ZPE fluctuation and fluctuating charged particle source field theory models, which would settle the acrimonious debate over whether the vacuum really fluctuates or not. R. L. Forward (1999) told the author that a Nobel Prize rides on performing this experiment and settling the issue once and for all. The Ding and Kaplan proposal is already designed to probe QED vacuum physics and vacuum modification. [The essence of the Ding and Kaplan proposal is to demonstrate that a form of photon-photon scattering predicted by QED gives rise to 2^{nd}-harmonic generation of intense laser radiation in a DC magnetic field due to the broken symmetry of interaction (in the Feynman "box" diagram approximation). This effect is possible only when the field system (optical wave + DC field) is inhomogeneous, in particular when a Gaussian laser beam propagates in either a homogeneous or inhomogeneous DC magnetic field. In other words, a vacuum region is filled with a DC magnetic field that polarizes the virtual particle pairs (a.k.a. virtual photons) in the vacuum. This polarized vacuum then scatters incident ultrahigh-intensity laser photons of frequency ν (energy E), thereby generating outgoing photons of frequency 2ν (energy $2E$).] An experiment definition study will be required to estimate the experimental method, procedure, equipment needs and costs.

- Experimental Program 4: An experimental study using ultrahigh-intensity lasers should be conducted to establish the extreme physical conditions necessary to test the strong-field limit of general relativity with an emphasis on generating spacetime curvature and negative energy in order to induce a putative micro-wormhole. (Experimental Programs 3 and 4 could be done together to determine whether Puthoff's PV-GR theory or Einstein's general relativity theory is the correct model for nature.) A Nobel Prize is in the offing if this question were to be addressed and settled. An experiment definition study will be required to estimate the experimental method, procedure, equipment needs and costs.

3.0 q-TELEPORTATION

3.1 Teleportation Scenario

Future space explorers and their equipment will need to easily and quickly travel from an orbiting spacecraft to the surface of some remote planet in order to get their work done, or military personnel in the United States need to easily and quickly travel from their military base to another remote location on Earth in order to participate in a military operation, or space colonists will need quick transport to get from Earth to their new home planet. Instead of using conventional transportation to expedite travel the space explorer, military personnel or space colonist and/or their equipment go into the "Teleporter" (a.k.a. "Transporter" in Star Trek lingo) and are "beamed down" or "beamed over" to their destinations at light speed. The mechanism for this teleportation process is hypothetically envisioned to be the following:

1. Animate/inanimate objects placed inside the teleporter are scanned by a computer-generated and -controlled beam.

2. The scan beam encodes the entire quantum information contained within the animate/inanimate object(s) into organized bits of information, thus forming a digital pattern of the object(s).

3. The scan beam then dematerializes the object(s) and stores its pattern in a pattern buffer, thus transforming the atomic constituents of the dematerialized object(s) into a matter stream. Alternative 1: The dematerialization process converts the atoms into a beam of pure energy. Alternative 2: The scan beam does not dematerialize the object(s).

4. The teleporter then transmits the matter/pure energy stream and quantum information signal in the form of an annular confinement beam to its destination. Alternative: Only the quantum information signal is transmitted.

5. At the receiving teleporter the matter/pure energy stream is sent into a pattern buffer whereby it is recombined with its quantum information, and the object(s) is rematerialized back into its original form. Alternative 1: The receiving teleporter recombines the transmitted quantum information with atoms stored inside a reservoir to form a copy of the original. Alternative 2: The quantum information is reorganized in such a way as to display the object on some three-dimensional (holographic) visual display system.

Problem: This generic scenario is modeled after teleportation schemes found in SciFi. There are a lot of important little details that were left out of the teleportation process because we simply do not know what they are. This technology does not yet exist. And we are left with the question of which one of the alternative processes identified in items 3 – 5 one wants to choose from. The above scenario is only an outline, and it is by no means complete since it merely serves to show what speculation exists on the subject. The above scenario describes a speculative form of what we call *q-Teleportation*.

There are questions to be addressed in the above scenario. Does the teleporter transmit the atoms and the quantum bit information signal that comprises the animate/inanimate object or just the quantum bit information signal? There are $\approx 10^{28}$ atoms of matter combined together in a complex pattern to form a human being. How does one transmit this much information and how do we disassemble that many atoms? Computer information gurus would insist that it is not the atoms that matter but only the bits of information representing them when considering the transmission of large "bodies" of information. But are humans simply the sum of all the atoms (and the related excited atom quantum states) that comprise them? We could possibly learn to reconstitute a beam of atoms into a chemically accurate human being. However, would this also include the reconstruction of a person's consciousness (personality, memories, hopes, dreams, etc.) and soul or spirit? This question is beyond the scope of this study to address, but it is nevertheless one of the most important concepts awaiting a complete scientific understanding.

For the teleporter to process and transmit the quantum bit information signal that encodes the animate/inanimate object's pattern will require stupendous digital computer power. For each atom comprising the object we must encode its location in space (three position coordinates), its linear and angular momentum (three vector components for each quantity), and its internal quantum state (electron orbital-energy levels and their excitation/de-excitation and ionization states, binding to other atoms to form molecules, molecular vibrational/rotational states, bound nuclei states, spin states for electrons and nuclei, etc.), etc. If we assume that we can digitally encode all of this information for a single atom with a minimum of one kilobyte (1 byte = 8 bits, 1 bit ≡ 0 or 1) of data, then we will require a minimum of 10^{28} kilobytes to encode and store an entire human being (in three-dimensions). To digitally store and access this much information at present (and for the foreseeable future) is nontrivial. It will take more than 2,400 times the present age of the universe (≈ 13 billion years) to access this amount of data using commercially available computers (operating at ≈ 10 gigabyte/sec). Top-of-the-line supercomputers will not reduce this time significantly. The computer technology needed to handle such a large data storage requirement simply does not exist. The largest commercially available computers can store ≈ 40 gigabytes on a single hard drive. We will need ≈ 10^{20} of these hard drives to store the encoded information of just one human being. Also, wire and coaxial/fiber optic cables do not have the physical capacity to transmit this amount of data between devices. These numbers will not be significantly different for macroscopic inanimate objects. The information processing and transfer technology required for the teleportation system may become possible in 200 – 300 years if improvements in computer storage and speed maintains a factor of 10 – 100 increase for every decade. There is speculation that emergent molecular, bio-molecular (DNA-based systems) and quantum computer technology may achieve the performances required for a teleportation system. In the former case molecular dynamics mimics computer logic processes and the ≈ 10^{25} particles in a macroscopic sample will all act simultaneously, making for far greater digital information processing and transfer speeds. Researchers have given no formal performance estimates for this emergent technology. In the latter case quantum computing would take advantage of entangled quantum states of subatomic matter or photons, whereby digital logic processes would occur at light speed. This technology is in its infancy, and there has been no clear direction on what performance levels will be possible in the future. This topic will be discussed further in Section 3.2.3.

In the above teleportation scenario we might consider dematerializing animate/inanimate objects into a matter stream consisting of only the object's constituent atoms or atomic subcomponents (protons, neutrons and electrons) and transmitting them at the speed of light (or close to it). To push atoms or subatomic particles to near the speed of light will require imparting to them an energy comparable to their rest-mass energy, which will be at a minimum of one order of magnitude larger than the amount of energy required to break protons up into free quarks. The energy required to completely dematerialize (or dissolve) matter into its basic quantum constituents or into pure energy is alone stupendous. At first one will have to impart to every molecule within the object an energy that is equivalent to the binding energy between atoms (atomic binding energy ~ chemical energy ~ *several* eV) in order to break apart the molecules comprising the object's macro-structure. After this an energy equivalent to nuclear binding energies (≈ *several* × 10^6 times atomic binding energy, or ≈ *several* MeV) must be imparted to every free atomic nucleus inside the object in order to break apart the protons and neutrons residing within each nucleus. And last, an energy equivalent to the binding energy that holds together the three quarks residing within each proton and neutron must be imparted to each of the free protons and neutrons within the object. According to the Standard Model and experimental data, the quark binding energy is practically infinite. But all is not lost, because the Standard Model also predicts that if we could heat up the nuclei to ≈ 10^{13} °C (≈ 10^6 times hotter than the core temperature of the Sun, or ≈ 10^3 MeV), then the quarks inside would suddenly lose their binding energies and become massless (along with other elementary matter). This heat is also equivalent to the rest-mass energy of protons and neutrons. Therefore, to heat up and dematerialize one human being would require the annihilation of the rest mass-energy of all 10^{28} protons-neutrons or the energy equivalent of 330 1-megaton thermonuclear bombs. Compare this stupendous explosive energy with the explosive yield of the largest thermonuclear bomb ever detonated on Earth, which was a 50-megaton bomb that was built by Andrei Sakharov in the USSR and detonated on October 30, 1961; it was called "Tzar Bomba." Its first incarnation (ca. early October 1961) comprised a uranium fusion tamper, which gave an estimated explosive yield of ≈ 100 megatons. But the weapon was too heavy (27 metric tons) for a bomber to carry, so the tamper was replaced by one made of lead, which reduced both the weight and the yield. In the end we see that it is not a trivial problem to simply heat up and dematerialize any human or inanimate objects. The technology to do so does not exist unless we invoke new physics to get around the energy requirement.

Finally, we must consider the resolution and aperture of the optics required to scan and transmit the animate/inanimate object's matter (or energy) stream. The Heisenberg quantum uncertainty principle fundamentally constrains the measurement resolution of conjugate observable quantities, such as position and momentum or energy and time. The measurement of any combination of (conjugate) observables with arbitrarily high precision is not possible, because a high precision measurement of one observable leads to imprecise knowledge of the value of the conjugate observable. The quantum uncertainty principle makes it impossible to measure the exact, total quantum state of any object with certainty. The scan resolution of a teleportation system is defined by the wavelength of light used to illuminate the object's atomic/subatomic constituents and record their configurations. To resolve matter at atomic/subatomic distance scales requires that the energy of the scanner light (photons) be extremely large (according to the uncertainty principle); and during the scan this large light energy will be conveyed to the constituents, causing them to drastically change their speed and direction of motion. This means that it is physically impossible to resolve an object's atomic/subatomic particle components and their configurations with the precision necessary to accurately encode and later recreate the object being teleported. To resolve atomic/subatomic particles requires wavelengths smaller than the size of these constituents, which will typically be 1 Å – 1 fm. Such wavelengths are in the gamma ray part of the spectrum, and this becomes a major technical problem for us because at present there is no gamma ray electro-optics with which to work with. Now consider the example of teleporting an object from the surface of a planet back to its spacecraft in orbit some *several* × 10^2 – 10^3 km away. The optical aperture required to illuminate and scan an object with ≈ 1 Å – 1 fm resolution from orbit will be >> *several* × 10^2 – 10^3 km. If we are to consider teleporting an object from planet to planet or from star to star then the aperture required will be >> *several* × 10^8 – 10^{13} km. These technical problems are truly insurmountable unless totally new physics becomes available.

3.2 Quantum Teleportation

It turns out that there does in fact exist a form of teleportation that occurs in nature despite the numerous technical roadblocks described in the previous section. It is called *quantum teleportation*, which is based on the well-known concept of quantum entanglement. Erwin Schrödinger coined the word "entanglement" in 1935 in a three-part paper (Schrödinger, 1935a, b, c, 1980). These papers were prompted by the Einstein, Podolsky and Rosen (1935; denoted hereafter as EPR) paper that raised fundamental questions about quantum mechanics, whereby Einstein had loudly complained that quantum mechanics allowed physical processes resembling "spooky action at a distance" to occur. EPR recognized that quantum theory allows certain correlations to exist between two physically distant parts of a quantum system. Such correlations make it possible to predict the result of a measurement on one part of a system by looking at the distant part. On this basis, EPR argued that the distant predicted quantity should have a definite value even before being measured, if quantum theory is complete and respects locality (a.k.a. causality). EPR concluded that, from a classical perspective, quantum theory must be incomplete because it disallows such definite values prior to measurement. Schrödinger's perspective on this argument gives the modern view of quantum mechanics, which is to say that the wavefunction (a.k.a. quantum state vector) provides all the information there is about a quantum system. In regards to the nature of entangled quantum states, Schrödinger (1935a, b, c, 1980) stated that, "The whole is in a definite state, the parts taken individually are not." This statement defines the essence of pure-state entanglement. Schrödinger went on to give a description of quantum entanglement by introducing his famous cat experiment.

To better understand the concept of quantum entanglement/teleportation we will focus on the quantum wavefunction (a.k.a. quantum state function). Any quantum system such as a particle that possesses a position in space, energy, angular and linear momentum, and spin is completely described by a wavefunction. This is usually symbolized in a variety of ways, and we choose to represent a generic wavefunction using the traditional "bra-ket" notation of quantum mechanics: $|\varphi\rangle$. Anything that we want to know about the particle is mathematically encoded within $|\varphi\rangle$. As we discussed in the previous section the wavefunction can never be completely known because there is no measurement that can determine it completely. The only exception to this is in the special case that the wavefunction has been prepared in some particular state or some member of a known basis group of states in advance. By measuring one of the properties of a quantum system, we can get a glimpse of the overall quantum state that is encoded within $|\varphi\rangle$. According to the quantum uncertainty principle the act of doing such a measurement will destroy any ability to subsequently determine the other properties of the quantum system. So the act of measuring a particle actually destroys some of the information about its pristine state. This makes it impossible to copy particles and reproduce them elsewhere via quantum teleportation. However, it turns out that one can recreate an unmeasured quantum state in another particle as long as one is prepared to sacrifice the original particle. The trick is to exploit the EPR process to circumvent the quantum uncertainty principle.

As discussed previously, EPR discovered that a pair of spatially separated quantum sub-systems that are parts of an overall quantum system can be "entangled" in a non-local (i.e., non-causal) way. When two particles come into contact with one another, they can become "entangled." In an entangled state, both particles remain part of the same quantum system so that whatever you do to one of them affects the other one in a predictable fashion. More precisely, a measurement on one of the entangled sub-systems puts it into a particular quantum state, while instantaneously putting the sub-system with which it is entangled into a corresponding quantum state, while the two sub-systems are separated by arbitrarily large distances in spacetime (even backwards in time!). A simple example of this phenomenon is to prepare a pair of photons in the same quantum state such that they are entangled, and then allow them to fly apart to remote locations without any form of communication occurring between them along their journey. Measuring the polarization of one of the pair of entangled photons induces the other photon, which may be light-years away, into the same state of polarization as that which was measured for its entangled twin. The basic operation of quantum teleportation can be described as determining the total quantum state of some large quantum system, transmitting this state information from one place to another, and making a perfect reconstruction of the system at the new location. In principle, entangled particles can serve as "transporters" of sorts. By introducing a third "message" particle to one of the entangled particles, one could transfer its properties to the other one, without ever measuring those properties.

Historically, quantum entanglement was never reconciled with the quantum uncertainty principle and the requirement of locality (or causality) in observed physical phenomena, thus it became a paradox in quantum theory. A three-decade debate began following the appearance of the EPR paper over whether quantum entanglement (a.k.a. "spooky action at a distance") was a real quantum phenomenon or not, and this debate came to be called the "EPR dilemma." Einstein's only solution to the dilemma was to suggest that quantum mechanics was incomplete and needed a reformulation to incorporate local hidden-variables that can account for observed physical phenomena without violating causality. Bell (1964) later solved the EPR dilemma by deriving correlation inequalities that can be violated in quantum mechanics but have to be satisfied within every model that is local and complete. Such models are called "local hidden-variable models." Bell showed that a pair of entangled particles, which were once in contact but later moved too far apart to interact directly (i.e., causally), can exhibit individually random behavior that is too strongly correlated to be explained by classical statistics. Bell's inequalities make it possible to test whether local hidden-variable models can account for observed physical phenomena in lab experiments. Groundbreaking experimental work by Aspect et al. (1982a, b) along with further theoretical and experimental work done by others (Freedman and Clauser, 1972; Aspect, 1983; Aspect and Grangier, 1985; Hong and Mandel, 1985; Bennett and Wiesner, 1992; Tittel et al., 1998a, b; Tittel and Weihs, 2001) demonstrated violations of the Bell inequalities, which therefore invalidated the local hidden-variable models. The key result of recent theoretical and experimental work is that an observed violation of a Bell inequality demonstrates the presence of entanglement in a quantum system.

3.2.1 Description of the q-Teleportation Process

The experimental work of Bennett et al. (1993) followed by the theoretical and experimental work of others (Vaidman, 1994; Kwiat et al., 1995; Braunstein, 1996; Braunstein and Kimble, 1998; Pan et al., 1998; Stenholm and Bardroff, 1998; Zubairy, 1998; Vaidman and Yoran, 1999; Kwiat et al., 1999) made the breakthrough that was necessary to demonstrate the principle of quantum teleportation in practice. It was a remarkable technical breakthrough that settled, once and for all, the nagging question of whether quantum entanglement could be used to implement a teleportation process to transfer information between remotely distant quantum systems non-causally (i.e., at FTL speed). It is easy to describe how quantum teleportation works in greater detail. Figure 6 compares conventional facsimile transmission with the quantum teleportation process seen in Figure 7. In a conventional facsimile transmission the original document is scanned, extracting partial information about it, but it remains more or less intact after the scanning process. The scanned information is then sent to the receiving station, where it is imprinted on new paper to produce an approximate copy of the original. In quantum teleportation (Figure 7) one scans out part of the information from object A (the original), which one wants to teleport, while causing the remaining, unscanned, part of the information in A to pass, via EPR entanglement, into another object C which has never been in contact with A. Two objects B and C are prepared and brought into contact (i.e., entangled), and then separated. Object B is taken to the sending station, while object C is taken to the receiving station. At the sending station object B is scanned together with the original object A, yielding some information and totally disrupting the states of A and B. This scanned information is sent to the receiving station, where it is used to select one of several treatments to be applied to object C, thereby putting C into an exact replica of the former state of A. Object A itself is no longer in its original initial state, having been completely disrupted by the scanning process. The process just described is teleportation and not replication, and one should not confuse the two. There is a subtle, unscannable kind of information that, unlike ordinary information or material, can be delivered via EPR correlations/entanglement, such that it cannot by itself deliver a meaningful and controllable message. But quantum teleportation delivers exactly that part of the information in an object that is too delicate to be scanned out and delivered by conventional methods.

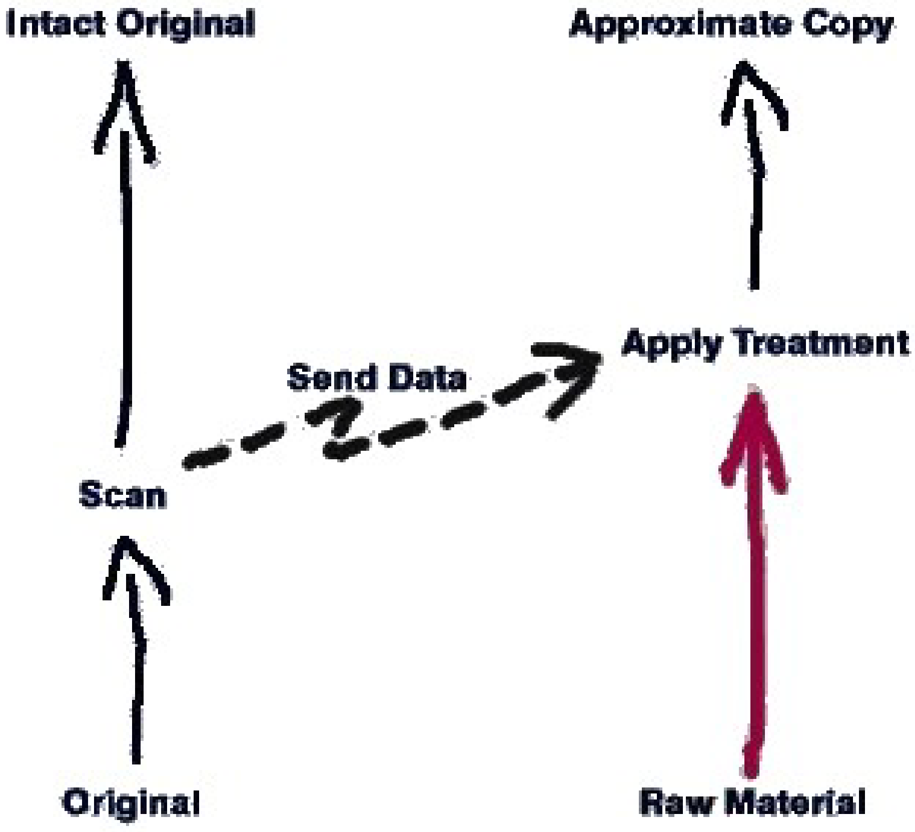
Intact Original
Approximate Copy
Apply Treatment
Send Data
Scan
Original
Raw Material

Figure 6. Classical Facsimile Transmission (Modified IBM Press Image)

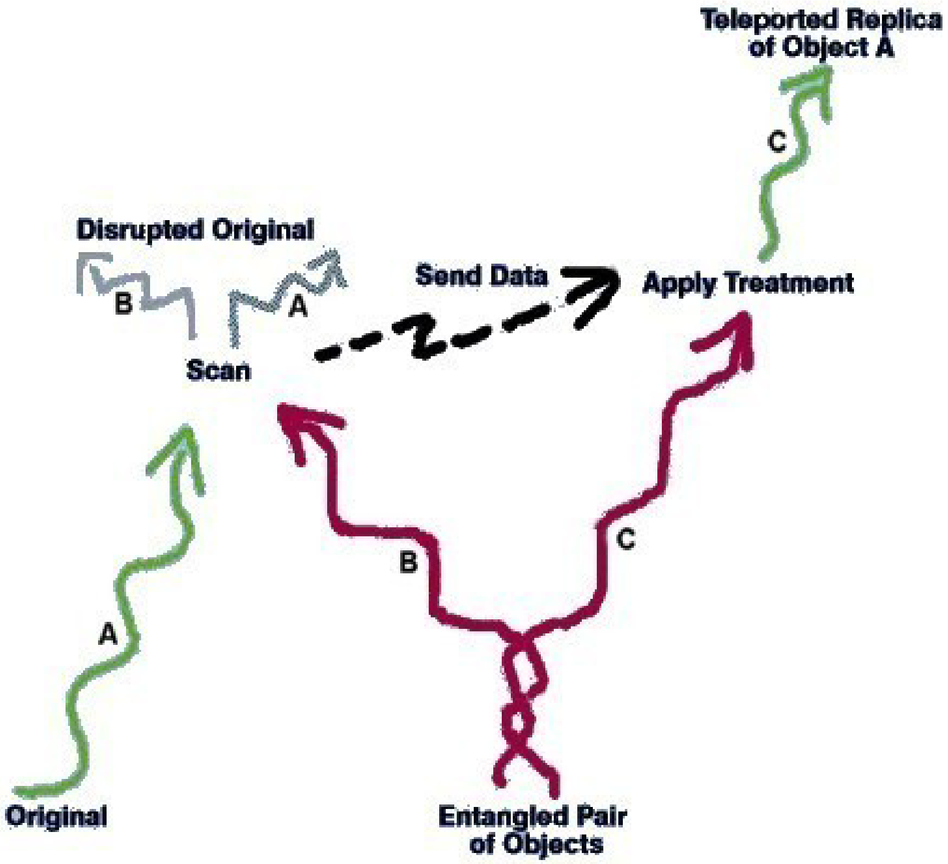
Teleported Replica of Object A
C
Disrupted Original
B
A
Send Data
Apply Treatment
Scan
B
C
A
Original
Entangled Pair of Objects

Figure 7. Quantum Teleportation (Modified IBM Press Image)

We now go one more final step to give a simplified outline of the actual teleportation process according to Bennett et al. (1993). They propose a multistep procedure by which any quantum state $|\chi\rangle$ of a particle or a photon (that correspond to an N-state system) is to be teleported from one location to another. For example, $|\chi\rangle$ might be a two-level system that could refer to the polarization of a single photon, the nuclear magnetic spin of a hydrogen atom, or the electronic excitation of an effective two-level atom. The following scenario outlines the q-Teleportation process in a very simplified way:

1. Prepare a pair of quantum subsystems $|\varphi\rangle$ and $|\psi\rangle$ in an EPR entangled state so that they are linked together. $|\varphi\rangle$ and $|\psi\rangle$ are maximally entangled and together constitute a definite pure state superposition even though each of them is maximally undetermined or mixed when considered separately.

2. Transport $|\varphi\rangle$ to the location of the teleportation transmitter and transport $|\psi\rangle$ to the location of the teleportation receiver. (In the technical literature the transmitter is called "Alice" and the receiver is called "Bob.") The transmitter and receiver can be many light years apart in space. Note that the two subsystems are non-causally correlated via entanglement, but they contain no information about $|\chi\rangle$ at this point. The two subsystems represent an open quantum channel that is ready to transmit information.

3. Now Alice brings the teleported state $|\chi\rangle$ into contact with the entangled state $|\varphi\rangle$ and performs a quantum measurement on the combined system $|\chi\rangle|\varphi\rangle$. Bob and Alice have previously agreed upon the details of the quantum measurement.

4. Using a conventional classical communication channel, Alice transmits to Bob a complete description of the outcome of the quantum measurement she performed on $|\chi\rangle|\varphi\rangle$.

5. Bob then subjects $|\psi\rangle$ to a set of linear transformations (i.e., suitable unitary rotations) that are dictated by the outcome of Alice's quantum measurement. The quantum subsystem Bob originally first received is no longer in state $|\psi\rangle$ after the linear transformations because it is now in a state identical to the original state $|\chi\rangle$. Therefore, $|\chi\rangle$ has in effect been teleported from Alice to Bob.

Bennett et al. (1993) showed in their experimental work that this scheme requires both a conventional communication channel and a non-causal EPR channel to send the state $|\chi\rangle$ from one location to another. In addition to this, a considerable pre-arrangement of entangled states and quantum measurement procedures is required to make the process work. Bennett et al. (1993) analyzed the information flow implicit in the process and showed that Alice's measurement does not provide any information about the quantum state $|\chi\rangle$. All of the quantum state information is passed by the EPR link between the entangled particle states $|\varphi\rangle$ and $|\psi\rangle$. We can think of the measurement results as providing the "code key" that permits the EPR information to be decoded properly at Bob's end. And because the measurement information must travel on a conventional communications channel, the decoding cannot take place until the code key arrives, insuring that no FTL teleportation is possible.

The q-Teleportation scheme teleports the state of a quantum system without having to completely measure its initial state. The outcome of the process is that the initial quantum state $|\chi\rangle$ is destroyed at Alice's location and recreated at Bob's location. It is very important for the reader to understand that it is the *quantum states* of the particles/photons that are destroyed and recreated in the teleportation process, and not the particles/photons themselves. The quantum state or wavefunction contains the information on the state of a particle, but is not a directly observable physical quantity like mass-energy. The quantum information contained within a state is available in the form of probabilities or expectation values.

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Therefore, q-Teleportation *cannot* teleport animate or inanimate matter (or energy) in its physical entirety. However, some experts argue that because a particle's or a photon's quantum state is its defining characteristic, teleporting its quantum state is completely *equivalent* to teleporting the particle/photon even though the original particle's/photon's quantum state (and defining characteristic) was completely destroyed in the process (more on this in Section 3.3). Therefore, no quantum cloning is possible and we are left with a (near-perfect) copy of the now-destroyed original after teleportation (Wootters and Zurek, 1982; Barnum et al., 1996). And finally, classical information itself *cannot* be teleported faster than the speed of light via the non-causal EPR channel; however, quantum information can (more on this in Section 3.2.3).

3.2.2 Decoherence Fundamentally Limits q-Teleportation

Finally, the reader must understand that the q-Teleportation scenario described in the previous section was simplified because we unrealistically assumed that Alice and Bob shared an EPR entangled pair that was free of noise or decoherence. Decoherence is the process, whereby an object's quantum states degrade when information leaks to or from the environment (i.e., environmental noise) through stray interactions with the object. In reality, Alice and Bob have quantum systems that interact directly or through another mediating quantum system like two ions in an ion trap that interact through phonon modes of the trap, or Rydberg atoms in a laser cavity that interact via photons (Sackett, 2001; Raimond et al., 2001). Decoherence degrades the fidelity of the quantum link (i.e., the set of pure EPR entangled pairs) between two quantum systems, thus introducing a certain level of error in the exchange of quantum information between the systems.

In a real-world example of an application of q-Teleportation to quantum computation (discussed in the next section), we can devise an array of interconnected ion traps with each trap holding a small number of ions that are coupled by ions that are moved between the traps or by traveling photons (Wineland et al., 2002). The quantum link (or EPR interaction) between a pair of systems is subject to noise or decoherence through photon loss or heating of the phonons. At present, decoherence imposes a fundamental limit on our ability to perform quantum information processing. Research is continuing on whether decoherence can be reduced, circumvented, or otherwise be (partially or totally) eliminated. Dür and Briegel (2003) have taken the first step towards this goal at rudimentary level by showing that fault-tolerant quantum computation can be achieved in the presence of very high noise levels occurring in the interaction link between small quantum systems, if one assumes that local quantum processing on each end is nearly error free. They showed that the interaction link can have an error rate of two-thirds.

3.2.3 Recent Developments in Entanglement and q-Teleportation Physics

Quantum teleportation physics is still in its infancy. Both theoretical and experimental developments are advancing in many different directions, but are far from maturity at this point in time because the field is still evolving at present. Technical applications of entanglement and q-Teleportation are just becoming conceptualized for the first time, while a small number of basic physics breakthroughs and their related applications are in experimental progress at present. The research community is still in the process of discovering the full nature of entanglement and q-Teleportation, its rules, and what roadblocks nature has in store for its applications and further progression. The literature cited in this study is by no means complete, and only represents a subset of the entire field, because the research is still evolving.

An important application of quantum entanglement and q-Teleportation was the discovery made by Shor (1994, 1997) that computation with quantum states instead of classical bits can result in large savings in computation time. For example, the best algorithms take exponentially more resources to factor ever-larger numbers on a classical computer. A 500-digit number needs 10^8 times as many computational steps to factor as a 250-digit number. The latter classically requires $\approx 5\times10^{24}$ computational steps, or about 150,000 years computing time at terahertz speed, to factor. Shor found a polynomial-time quantum algorithm that solves the problem of finding prime factors of a large integer.

He showed that his algorithm rises only polynomially so that a 500-digit number takes only eight times as many computational steps to factor as a 250-digit number. And by using the quantum factoring algorithm, a 250-digit number requires only $\approx 5\times10^{10}$ steps or < 1 second to factor at terahertz speed, so that a 500-digit number will take ≤ 1 second to factor. No classical polynomial-time algorithm for this problem exists at present. This breakthrough generated a cottage industry of research into quantum computing and quantum information theory.

IBM (2001) constructed a prototype quantum computer that uses the nuclear spins of seven atoms that are part of a large molecule with the iron-based chemical composition $H_5C_{11}O_2F_5Fe$. The computer uses entangled nuclear spins for storage and has a capacity of seven qubits (qubits are defined in the bulleted list in the next two paragraphs below). All of the Fluorine atoms in the large molecule are Fluorine isotope 19 and two of the Carbon atoms are Carbon isotope 13. All the other non-hydrogen atoms have even isotope numbers and no nuclear spins. The objective of the prototype quantum computer was to factor the number 15 into its two prime factors 3 and 5 by using Shor's quantum factoring algorithm. The quantum computation required that a sample of $\approx 10^{18}$ of the large molecules be placed in a magnetic field and manipulated by nuclear magnetic resonance (NMR) techniques. This mechanism allows the spins to function as qubits, whereby Schor's algorithm can be performed via manipulation of the NMR fields. NMR was used to implement quantum computing in this prototype, because the nuclear spins are well isolated from decoherence as a result of the very long decoherence time (the time after which quantum coherence is lost due to environmental noise) in the system.

To factor larger numbers will require a system that uses more than seven qubits. It is estimated that a quantum computer using ≈ 36 qubits could very quickly perform computations that would require a conventional computer ≈ 13 billion years to perform. And such a computer could solve one of the technical problems of human teleportation discussed in Section 3.1. However, a scale-up in the number of qubits is difficult because the IBM prototype has reached the technology limit of NMR quantum computing. The prototype's operation requires that all of the qubits must be in the same molecule. And molecules with more than seven spins that can be used as qubits are not feasible at present. However, there are alternative technologies for quantum computing that show promise for scaling up the number of qubits. The technologies of nuclear spin orientation of single atom impurities in semiconductors, electron spin orientation in quantum dots, and the manipulation of magnetic flux quanta in superconductors all show promise of providing a basis for scalable quantum computers. Finally, the primary technical problem in quantum computing at the present time is decoherence, and this must be eliminated or otherwise mitigated before new quantum technology can become competitive with conventional computer technology.

A byproduct of the recent quantum computing and information research is that a modern theory of entanglement has emerged. Researchers now treat entanglement as a quantifiable physical resource that enables quantum information processing and computation. Entanglement is no longer treated as a paradox of quantum theory. It has been recently discovered that (Nielsen and Chuang, 2000; Nielsen, 2003; Terhal et al., 2003):

- various kinds of pure and mixed entangled states may be prepared in addition to the simple pure-state superpositions that was described in the previous section

- the members of an entangled group of objects do not have their own individual quantum states, only the group as a whole has a well-defined state (i.e., "the whole is greater than the sum of its parts")

- entangled objects behave as if they were physically connected together no matter how far apart they actually are, distance does not attenuate entanglement in the slightest – it has been demonstrated that information can be teleported over 40 km using existing technology (H. Everitt, Army Research Office, 2000)

- if something is entangled with other objects, then a measurement of it simultaneously provides information about its partners

- some quantum systems can have a little entanglement while others will have a lot

- the more entanglement available, the better suited a system is to quantum information processing

- decoherence degrades the fidelity of the quantum link (i.e., the set of pure EPR entangled pairs) between two quantum systems, thus introducing a certain level of error in the exchange of quantum information between the systems; thus limiting our ability to perform quantum information processing (see more on this issue in the next paragraph below)

- mixed entangled states may be measured, distilled, concentrated, diluted, and manipulated

- the basic resource of classical information is the bit (i.e., the two values 0 and 1), while quantum information comes in quantum bits (i.e., qubits) that are described by their quantum state; qubits can exist in superpositions that simultaneously involve 0 and 1, thus giving them an infinite range of values; groups of qubits can be entangled; qubits must be insulated against decoherence, so that the coherent state of the quantum system in a quantum computer is preserved for a time that is long enough to set up a calculation, perform it, and read out the results

- quantum computers processing qubits or entangled qubits can outperform classical computers; functional requirements of quantum computers:

    - they must have the ability to initialize any qubit in a specified state, and to measure the state of a specific qubit
    - they must have universal quantum gates, which are logical elements capable of arranging any desired logical relationship between the states of qubits
    - they must also have a processor capable of interlinking quantum gates to establish rules and boundary conditions for their inter-relationships – in a quantum computation, the arrangement of quantum gates connects the qubits in a logical pattern, according to a program or algorithm, and after an interval the qubits assigned to the result are read out

- quantum error correction codes exist, whereby qubits are passed through a circuit (the quantum analogue of logic gates) that will successfully fix an error in any one of the qubits without actually reading what all the individual qubit states are; no qubit cloning is required

- a completely secure quantum key can be generated and distributed (for communication and decoding of encrypted messages) using entangled photons has been demonstrated (Tittel et al., 2000; Jennewein et al., 2000; Naik et al., 2000); any eavesdropper's attempt to intercept the quantum key will alter the contents in a detectable way, enabling users to discard the compromised parts of the data

- in an experiment which verified that EPR entanglement obeys Special Relativity (Seife, 2000; Scarani et al., 2000; Gisin et al., 2000; Zbinden et al., 2000a, b), and involving a photon detector moving at relativistic speeds (for example, Bob moves away from Alice at close to the speed of light), investigators determined that quantum information via EPR photon pair entanglement must travel > 10^7 times light speed (the photon detectors were 10.6 km apart)

- investigators are still developing quantitative laws of entanglement to provide a set of principles for understanding the behavior of entanglement and how it is used to do information processing

- investigators are working to develop an understanding of the general principles that govern complex quantum systems such as quantum computers

Other developments are equally as interesting or compelling. For example, the quantum state of the object we wish to teleport does not have to describe single microscopic systems like photons, ions, atoms or electrons. Quantum states can describe large collections of atoms like chemical compounds, humans, planets, stars, and galaxies. Hartle and Hawking (1983) even derived the quantum wavefunction of the Universe in closed form, although, it was extremely simplified and excluded the presence of quantum matter-energy. So it has become possible to consider teleporting large quantum systems. We summarize the more recent spectacular developments in the following:

- Generation of entanglement and teleportation by Parametric Down-Conversion (Bouwmeester et al., 1997; Zeilinger, 2003): EPR entangled photon pairs are created when a laser beam passes through a nonlinear β-barium borate or BBO crystal. Inside the crystal (BBO, for example) an ultraviolet photon (λ = 490 nm) may spontaneously split into two lower energy infrared photons (λ = 780 nm), which is called parametric down-conversion. The two "down-conversion" photons emerge as independent beams with orthogonal polarizations (horizontal or vertical). (The orthogonal polarization states represent a classic example of the discrete quantum state variables that can be teleported. Other examples of discrete quantum variables that have been teleported using other schemes include the nuclear magnetic spin of a hydrogen atom, electronic excitations of an effective two-level atom, elementary particle spins, etc.) In the two beams along the intersections of their emission cones, we observe a polarization-entangled two-photon state. For the experimental realization of quantum teleportation, it is necessary to use pulsed down-conversion. Only if the pulse width of the UV light, and thus the time of generating photon pairs is shorter than the coherence time of the down-converted photons, then interferometric Bell-state analysis can be performed. In this type of experiment, the pulses from a mode-locked Ti:Saphire laser have been frequency doubled to give pulses of ≈ 200 fs duration (1 fs = 10^{-15} second). The interfering light is observed after passage through IR filters of 4 nm bandwidth giving a coherence time of ≈ 520 fs. After retroflection during its second passage through the crystal, the UV pulse creates another pair of photons. One of these will be the teleported photon, which can be prepared to have any polarization. Beam splitters and photon detectors are used to perform the Bell-state analysis during the standard teleportation process that ensues. See Figure 8 for a schematic showing the layout of a standard parametric down-conversion entanglement-teleportation experiment.

- Teleportation of squeezed states of light and continuous quantum state variables (Furusawa et al., 1998; Sørensen, 1998; Braunstein and Kimble, 1998; Opatrný et al., 2000; Braunstein et al., 2001; Zhang et al., 2002; Bowen et al., 2002; Bowen et al., 2003; Zeilinger, 2003): Squeezed light (see Section A.2 in Appendix A) is used to generate the EPR entangled beams, which are sent to Alice and Bob. A third beam, the input, is a coherent state of unknown complex amplitude. This state is teleported to Bob with a high fidelity only achievable via the use of quantum entanglement. Entangled EPR beams are generated by combining two beams of squeezed light at a 50/50 beam splitter. EPR beam 1 propagates to Alice's sending station, where it is combined at a 50/50 beam splitter with the unknown input state, in this case a coherent state of unknown complex amplitude. Alice uses two sets of balanced homodyne detectors to make a Bell-state measurement on the amplitudes of the combined state. Because of the entanglement between the EPR beams, Alice's detection collapses Bob's field (EPR beam 2) into a state conditioned on Alice's measurement outcome. After receiving the classical result from Alice, Bob is able to construct the teleported state via a simple phase-space displacement of the EPR field 2. Quantum teleportation in this scheme is theoretically perfect, yielding an output state which equals the input with a fidelity $F = 1$. In practice, fidelities less than one are realized due to imperfections in the EPR pair, Alice's Bell measurement, and Bob's unitary transformation. By contrast, a sender and receiver who share only a classical communication channel cannot hope to transfer an arbitrary quantum state with a fidelity of one. For coherent states, the classical teleportation limit is $F = 0.5$, while for light polarization states it is $F = 0.67$. The quantum nature of the teleportation achieved in this case is demonstrated by the experimentally determined fidelity of $F = 0.58$, greater than the classical limit of 0.5 for coherent states. The fidelity is an average over all input states and so measures the ability to transfer an arbitrary, unknown superposition from Alice to Bob. This technique achieves the teleportation of continuous quantum state variables, as opposed to the discrete quantum state variables used in the Bennett et al. (1993) teleportation protocol and its variants. The teleportation of a squeezed state of light from one beam of light to another demonstrates the teleportation of a continuous feature (of light) that comes from the superpositions of an infinite number of basic states of the electromagnetic field, such as those found in squeezed states. This line of research also involves the experimental demonstration of the mapping of quantum states from photonic to atomic media via entanglement and teleportation. Hald et al. (1999) reported on the experimental observation of a spin-squeezed macroscopic ensemble of 10^7 cold atoms, whereby the ensemble is generated via quantum state entanglement/teleportation from non-classical light to atoms.

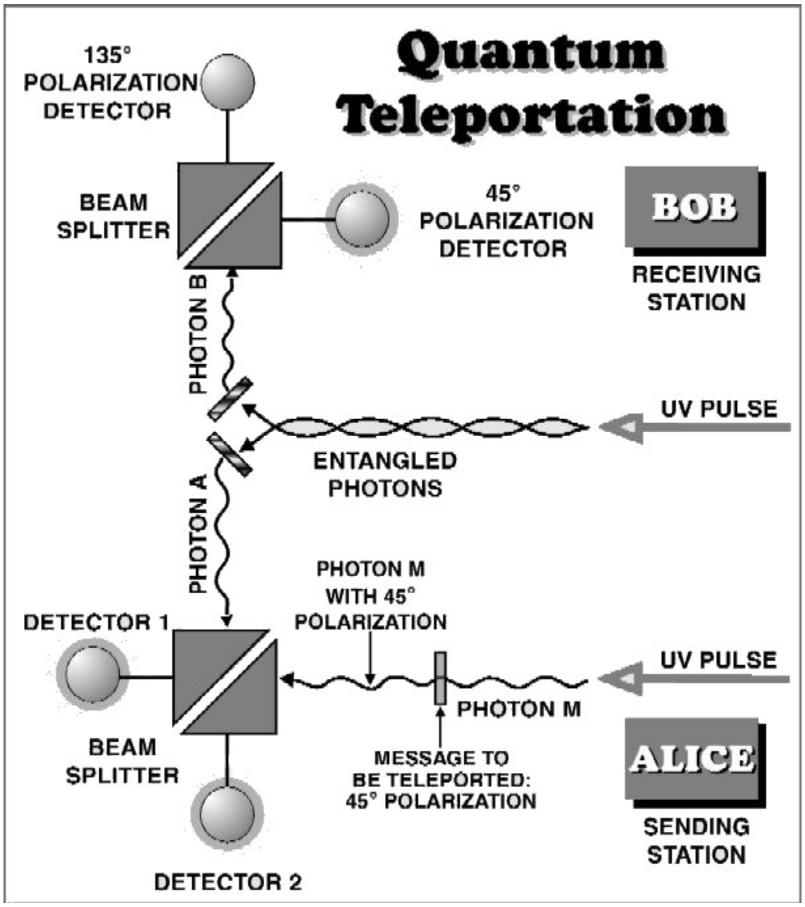
Quantum Teleportation
135° POLARIZATION DETECTOR
BEAM SPLITTER
45° POLARIZATION DETECTOR
BOB
RECEIVING STATION
PHOTON B
UV PULSE
ENTANGLED PHOTONS
PHOTON A
PHOTON M WITH 45° POLARIZATION
DETECTOR 1
UV PULSE
PHOTON M
ALICE
BEAM SPLITTER
MESSAGE TO BE TELEPORTED: 45° POLARIZATION
SENDING STATION
DETECTOR 2

Figure 8. Quantum Teleportation (From www.aip.org)

At the sending station of the quantum teleporter, Alice encodes a "messenger" photon (M) with a specific state: 45 degrees polarization. This travels towards a beam splitter. Meanwhile, two additional entangled photons (A and B) are created. The polarization of each photon is in a fuzzy, undetermined state, yet the two photons have a precisely defined interrelationship. Specifically, they must have complementary polarizations. For example, if photon A is later measured to have horizontal (0 degrees) polarization, then the other photon must collapse into the complementary state of vertical (90 degrees) polarization. Entangled photon A arrives at the beam splitter at the same time as the message photon M. The beam splitter causes each photon to either continue toward detector 1 or change course and travel to detector 2. In 25% of all cases, in which the two photons go off into different detectors, Alice does not know which photon went to which detector. This inability for Alice to distinguish between the two photons causes quantum weirdness to kick in. Just by the very fact that the two photons are now indistinguishable, the M photon loses its original identity and becomes entangled with A. The polarization value for each photon is now indeterminate, but since they travel toward different detectors Alice knows that the two photons must have complementary polarizations. Since message photon M must have complementary polarization to photon A, then the other entangled photon (B) must now attain the same polarization value as M. Therefore, teleportation is successful. Indeed, Bob sees that the polarization value of photon B is 45 degrees: the initial value of the message photon.

- Entanglement of Atoms (Hagley et al., 1997; Sackett et al., 2000): EPR entanglement at the level of atoms has been experimentally demonstrated using rubidium atoms prepared in circular Rydberg states (i.e., the outer electrons of the atom have been excited to very high energy states and are far from the nucleus in circular orbits). The experimental apparatus produces two entangled atoms, one atom in a ground state and the other atom in an excited state, physically separated so that the entanglement is non-local. And when a measurement is made on one atom, let us say the atom in a ground state, then the other atom instantaneously presents itself in the excited state – the result of the second atom wave function collapse, thus determined by the result of the first atom wave function collapse. This work is now evolving towards the demonstration of entanglement for molecules and larger entities followed by teleportation of their states. Bose and Home (2002) have improved on this concept by proposing a single, simple generic method by which any atoms, ions and macroscopic objects can be entangled and teleported.

- Teleportation of an Atomic State via Cavity Decay (Bose et al., 1999; Sackett et al., 2000): It has been shown how the state of an atom trapped in a cavity can be teleported to a second atom trapped in a distant cavity simply by detecting photon decays from the cavities.

- Biological Quantum Teleportation (Mavromatos et al., 2002): There are several obstacles to teleporting large complicated objects, especially biological entities. Decoherence is the primary obstacle. That is because observable quantum effects in biological matter is thought to be strongly suppressed due to the macroscopic nature of most biological entities and the fact that such systems live at near room temperature, and there is always contact between biological entities and the environment (the source of decoherence). These conditions result in very fast collapse of pertinent quantum wavefunctions to one of the allowed classical states of the biological entity. Mavromatos et al. (2002) propose a daring model that predicts dissipationless energy transfer along shielded macromolecules at near room temperatures as well as quantum teleportation of states across microtubules and perhaps neurons. It is proposed that under certain circumstances it is in principle possible to obtain the necessary isolation against environmental decoherence, so that meso/macroscopic quantum coherence, and entanglement extending over scales that are larger than the atomic scale, may be achieved and maintained for times comparable to the characteristic times for biological and cellular processes. Microtubules are comprised of tubulin that is a common polar protein found in the cytoskeleton of eukariotic cells, which is especially enriched in brain tissue. The model treats microtubules as quantum mechanically isolated high-Q QED cavities, exhibiting properties analogous to those of electromagnetic cavities routinely used in quantum optics. The model builds a microtubule network that achieves quantum teleportation of coherent quantum states, leading to decoherence-resistant bulk quantum information processing and computing within the biological matter. It is speculated that the model can explain how consciousness works, and how the brain processes and computes information.

- Teleportation of a laser beam with embedded radio signal (Bowen et al., 2003): The teleportation of a laser beam from one part of a lab to another has been demonstrated. Investigators embedded a radio signal into a laser beam, then disintegrated the beam and reassembled it a meter away, virtually instantaneously. The laser beam was destroyed in the teleportation process, but the radio signal survived. The laser light at one end of an optical communications system was disassembled and its replica was recreated elsewhere in the lab. Even though the laser beam did not survive teleportation, its encoded message did. This system could be used to transport secure data, such that it could become possible to construct a perfect cryptography system. When two

Approved for public release; distribution unlimited.

parties want to communicate with one another, one can enable the secrecy of the communication to be absolutely perfect.

- Entanglement and Teleportation of a Macroscopic Ensemble of Atoms (Julsgaard et al., 2001): Expanding upon the earlier work of Hald et al. (1999) and Sackett et al. (2000), investigators experimentally demonstrated the entanglement of two macroscopic objects, each consisting of a cesium gas sample containing $\approx 10^{12}$ atoms. Entanglement is generated via interaction of the samples with a pulse of light, which performs a non-local Bell measurement on the collective spins of the samples. The entangled spin-state can be maintained for 0.5 milliseconds. The teleportation of macro-ensemble atom quantum states is expected to follow this experiment. This work is evolving towards the experimental demonstration of the Bose and Home (2002) proposal, which proved that there is a single generic process that can entangle and teleport any atoms, ions and macroscopic objects.

- Entanglement/teleportation of internal state and external motion information of atoms (Opatrný and Kurizki, 2001): Investigators propose an experiment for transmitting an atom's full information, including its "external" states, such as its energy of motion. This procedure replicates the quantum features of the external motion of a particle. For example, if particle-to-be-teleported C yielded a diffraction pattern after passing through two slits, then the same pattern would be produced by particle B, which receives the teleported information. The researchers propose the following idea: Dissociate a very cold molecule with a laser pulse into two atoms (called A and B). Then manipulate the two atoms so that they become entangled: each one is in a fuzzy state individually, but has a precisely defined relationship with its partner. Then let one of the entangled particles (such as A) collide with particle C, whose unknown state should be teleported. After their collision, the momentum values of the collision partners A and C are measured. With that information, the researchers know how to "kick" and deflect atom B, so that the motion of B precisely emulates that of particle C. The investigators say that state-of-the-art equipment for studying atomic collisions and quantum effects makes this experiment difficult, but feasible, to do. If this proposal proves to be correct, then the implication is that it will become possible to experimentally expand this concept to the teleportation of a large ensemble of atoms, such that the entire physical motion and quantum states of the ensemble can be teleported. This could lead to the future development of a teleportation process similar to what was discussed in Section 3.1.

- Laser-like Amplification of Entangled Particles and Entangled-Photon Lasers (Lamas-Linares et al., 2001): Entangled particles are notoriously difficult to create in bulk. To create entangled photons, for example, researchers use the parametric down-conversion technique to send laser light through a barium borate crystal. Passing through the crystal, a photon sometimes splits into two entangled photons (each with half the energy of the initial photon). However, this only occurs for one in every ten billion incoming photons. To increase the yield, researchers added a step: they put mirrors beyond the crystal so that the laser pulse and entangled pair could reflect, and have the chance to interact. The entangled pair and reflected laser pulse interfere constructively to generate fourfold more two-photon pairs or interfere destructively to create zero pairs. Following these steps, the researchers increased production of two-photon entangled pairs, and also of more rare states such as four-photon entangled quartets. This achievement could represent a step towards an entangled-photon laser, which would repeatedly amplify entangled particles to create greater yields than previously possible, and also towards the creation of new and more complex kinds of entangled states.

This list is by no means complete as new developments in this field continue to arise.

3.3 Conclusion and Recommendations

Given the incredible advancements that have been made in the entanglement and teleportation of macroscopic objects the size of 10^{12} atoms, we are still very far away from being able to entangle and teleport human beings (and even simpler biological entities such as cells, etc.) and bulk inanimate objects (tools, technical equipment, pencils and pens, weapons platforms, communications devices, personal hygiene supplies, etc.). There still remain four essential problems:

- One needs an entangled pair of such bulk objects.
- The bulk objects to be entangled and teleported must be in a pure quantum state (as in a Bose-Einstein condensate, for example). And pure quantum states are very fragile.
- The bulk objects to be entangled and teleported must be extremely isolated from the environment to prevent the onset of decoherence.
- The Bell-state measurement of animate or inanimate objects during entanglement/teleportation will require extracting an amount of information (in bits) that equals or exceeds the number of atoms contained within the object. This infers that the computer storage and processing requirements to entangle and teleport a complete bulk object will be astronomically huge (recall the discussion in Section 3.1).

It is difficult to imagine how we can achieve an extreme level of environmental isolation for an object, let alone a living being that breathes air and radiates heat. Experiments with atoms and larger objects must be done in a high vacuum to avoid collisions with molecules. Thermal radiation from the walls of a teleportation apparatus would easily disturb a tiny amount of matter. At present, decoherence imposes a fundamental limit on quantum entanglement and teleportation. Decoherence is the primary reason why we do not routinely see any quantum effects in our everyday world. Research is continuing on whether decoherence can be reduced, circumvented, or otherwise be eliminated. And some minor progress has been made in that direction.

In q-Teleportation it is the ***quantum states*** of the objects that are destroyed and recreated, and not the objects themselves. Therefore, q-Teleportation ***cannot*** teleport animate or inanimate matter (or energy) in its physical entirety. However, some experts argue that because an object's quantum state is its defining characteristic, teleporting its quantum state is completely ***equivalent*** to teleporting the object, even though the original object's quantum state (and defining characteristic) was completely destroyed in the process. This goes to the heart of what is meant by identity. When an object has all the right properties and features, it will be the same object that one observes whether it was observed now or 24 hours ago. Quantum physics reinforces the point that objects of the same type in the same quantum state are indistinguishable from each other. One should, according to this quantum principle, be able to swap all the atoms in a particular object with the same atoms from a mound of raw materials, and reproduce the original object's quantum states exactly with the end result that the new object is identical to the original. Last, we do not know how to put a human being into a pure quantum state or what doing so would mean for biological functioning (including brain function), but we do know how to put $\leq 10^{12}$ gas atoms/ions and a beam of photons into a pure state in practice. Further research will be required to ascertain whether microbiological and higher-level biological systems, in addition to bulk inanimate matter, can be put into pure quantum states and entangled/teleported.

To perform a Bell-state measurement on (bulk) animate or inanimate objects, during the entanglement/teleportation process, to extract and encode its information will require extracting an amount of information (in bits) that equals or exceeds the number of atoms contained within the object. An object containing a few grams of matter will require the extraction of $> 10^{28}$ bits of data. A simple virus of $\approx 10^7$ atoms would require the extraction of $\geq 10^8$ bits of information during the entanglement/teleportation process, whereas the extraction of a minimum of 10^{28} kilobytes will be required to encode and store an entire human being. This is beyond the capability of present digital electronic computer technology to store and process. It is difficult to see how far computer technology will advance towards meeting this requirement.

It is difficult to fathom what will be in store for the teleportation of human beings given some possible future technology. What about the effects of the q-Teleportation process on the human consciousness, memories and dreams, and the spirit or soul? We know from quantum physics that "the whole is greater than the sum of its parts." So what happens to the fundamental characteristics of a human being when he/she steps into the teleporter-transmitter, where their quantum states (i.e., their complete identity) are destroyed during the quantum entanglement/teleportation process, and then their copy is created at the teleporter-receiver an instant later? What will things be like during the entanglement process? Will a teleported individual's consciousness, memories and dreams, and spirit/soul be successfully and accurately teleported or not? This is a major ethical and technical question that will have to be addressed by future research.

•**Recommendations**:

- Broad-spectrum Quantum Computing Technology Development Program: At present, the Quantum Information Science Program (QISP) is coordinated by the U.S. Army Research Office with funding and support from the Army, the National Security Agency, DARPA, and the Office of the Deputy Director of Defense for Research and Engineering. The Naval Research Lab and the CIA are both involved in their own programs. The CIA vets new commercial development of computer technology and computer information processing via its In-Q-Tel company (reference 44). This includes R&D on quantum entanglement and teleportation for computer, information processing and secure communications. QISP was funded for $19 million in 1999. The program involves 34 projects by researchers at 21 universities, three government laboratories and two corporate laboratories. QISP goals include building a quantum computer, developing quantum information processing, and further advances in quantum teleportation. The AFRL should join QISP and provide partnership funding on the order of $1 million per year. An alternative to this would be for AFRL to collaborate with In-Q-Tel and participate in its technology R&D venture capital programs. This R&D investment would allow the Air Force to acquire very advanced quantum physics and related technological applications that can support its mission. The R&D investment benefits would include the development and implementation of quantum computing/information processing and secured quantum communications technology, which can significantly enhance the performance and security of Air Force computing and communication systems infrastructure, and aerospace weapons systems.

- Quantum Cryptography: A dedicated research program should be implemented to develop a mature quantum cryptography technology. Theoretical and experimental work is in progress among a small number of select groups (QISP, In-Q-Tel, universities, etc.), but this field is not advancing fast enough for practical applications to become available to meet increasing adversarial threats against secured military and intelligence communications. The goal of proposed quantum cryptography research is to bring the theoretical and experimental foundation of quantum cryptography and secure quantum information processing to maturity, and to fully develop and implement quantum entanglement/teleportation-based cryptography technology. Recent experimental work has demonstrated that a completely secure quantum key can be generated and distributed for the communication and decoding of encrypted messages using entangled photons. Any eavesdropper's attempt to intercept the quantum key will alter the contents in a detectable way, enabling users to discard the compromised parts of the data. There is much more work that needs to be done in this area. I recommend that the AFRL implement a

$1 million/year program for five years in order to advance the state-of-art in quantum cryptography technology.

- Quantum Decoherence: Decoherence is the primary reason why we do not routinely see any quantum effects in our everyday world. And it imposes a fundamental limit on quantum entanglement and teleportation via the interaction between entangled/teleported quantum systems and their local environment. In order to advance quantum entanglement/teleportation physics and develop applied technologies, it is necessary that a research program be implemented by the AFRL to explore whether decoherence can be significantly reduced, circumvented, or otherwise be eliminated. An insufficient number of small university groups have slowly made minor progress in this direction. I recommend that a $500,000 - 750,000 per year R&D program be conducted for five years to overcome this technical challenge.

- Pure Quantum States: In order to entangle and teleport quantum particles and bulk objects, they both must be prepared in a pure quantum state. And pure quantum states are very fragile to decoherence. A technical challenge for entanglement/teleportation physics is whether the requirement for pure quantum states can be relaxed and how much decoherence will play a role in this situation, what technical challenges will arise when increasing the size of entangled/teleported matter to larger macroscopic scale ($>> 10^{12}$ atoms), and whether matter of mixed composition (such as a gas or Bose-Einstein condensate of mixed atomic elements) can be entangled/teleported in both pure and mixed quantum states. I recommend that a $250,000 – 500,000 per year research program be conducted for five years to study this problem.

- Entangling Bulk Matter and Bell-State Measurement to Extract Information: Recent experiments demonstrated the entanglement of two macroscopic objects, each consisting of a cesium gas sample containing $\approx 10^{12}$ atoms. Entanglement was generated via interaction of the samples with a pulse of light, which performs a non-local Bell measurement on the collective spins of the samples. In order to push the envelope on this development and take it to higher practical levels, it will be necessary to ascertain the limit on the size and composition of bulk matter entanglement (given the decoherence and pure-state constraints); and to determine what other quantum states can be used for entanglement, what other Bell-state measurement techniques can be used, and whether multiple quantum states can be entangled. The chief technical challenge is the computer technology that will be required to facilitate the huge amount of data that must be extracted, processed and stored from bulk matter quantum states during the Bell-state measurement process. I recommend that a $500,000 – 1 million per year research program be implemented for five years in order to explore these questions and ascertain what solutions may be technically available, and to develop such solutions.

- Biological Quantum Teleportation: The Mavromatos et al. (2002) theoretical model for biological entanglement and teleportation is a remarkable concept that could result in the development of a workable physics theory of consciousness. The model has potential applications to advanced quantum computing/information processing physics and the physics of psi phenomena (see Chapter 5). A research program should be implemented to continue the Mavromatos et al. (2002) work and bring their model to theoretical maturity. It is recommended that this program be funded at $500,000 – 800,000 per year for five years. A parallel or follow-up program should be implemented to experimentally test this model and ascertain any useful technological applications. One application that should be explored in the proposed research program is advanced, ultra-fast, ultra-high-capacity quantum computing and information processing using natural and/or artificial biological systems. The parallel or follow-up experimental research program should be funded at $800,000 – 1.5 million per year for five years.

- FTL Communication: Experiments verifying that EPR entanglement obeys Special Relativity (Seife, 2000; Scarani et al., 2000; Gisin et al., 2000; Zbinden et al., 2000a, b) determined that quantum information via EPR photon pair entanglement must travel > 10^7 times light speed. Can this mechanism be exploited to achieve FTL communication? If so, then the potential military and commercial applications will be revolutionary, and the science and industry of communications will be forever transformed. A comprehensive theoretical and experimental research program should be implemented to answer this question. It is recommended that this program be funded at $700,000 – 1 million per year for five years. A modest experiment definition study should be funded at $80,000 for one year to delineate the most promising experimental approaches to be used for the larger research program. [There is much controversy and debate over FTL (a.k.a. superluminal) signals/communication, and the reader should see the selected superluminal references in the Teleportation References section of this study.]

- ➢ New Entanglement/Teleportation Breakthroughs: The most exciting developments in quantum teleportation physics has included the teleportation of a laser beam with an embedded radio signal, the teleportation of squeezed states of light (and hence, continuous quantum state variables), the teleportation of photon states to atoms/ions (from light to matter!), the entanglement of two similar/dissimilar quantum particles that are created by two (independently) different particle sources, the laser-like amplification of entangled particle/photon pairs, parametric down-conversion entanglement and teleportation (of discrete quantum state variables), quantum cryptography with unbreakable keys, the teleportation of quantum information at speeds > 10^7 times light speed, the entanglement and teleportation of macroscopic (10^{12} atoms) matter quantum states, etc. There is also the yet-untested proposal to entangle/teleport the external physical motion and internal quantum state information of atoms. This shows that quantum physics sets no apparent limit on what it is that can be teleported/entangled and how it is to be teleported/entangled, or where it is to be teleported/entangled. At present teleportation technology requires fiber optic and coaxial cables to teleport quantum state information from one location to another. Can we avoid the use of cables and teleport through free space? [Note: Before this report went to press, Aspelmeyer et al. (2003) reported their outdoor experiment that demonstrated the distribution of quantum entanglement (of laser photons) via optical free-space links to independent receivers separated by 600 m across the Danube River (during inclement nighttime weather), with no line of sight between them. This experiment is revolutionary and begins the step toward conducting satellite-based distributed quantum entanglement.] We have not discovered all the possibilities that nature has in store for us. The present breakthrough discoveries will likely introduce novel military and intelligence technology applications in the near and far future. But further R&D must be conducted in order to discover new applications for these recent breakthroughs, to make additional breakthroughs and discoveries, and to advance the state-of-art in quantum teleportation physics to meet future challenges to the Air Force mission. I recommend that a two-track R&D program be implemented over five years. The first track should be funded at $250,000 – 750,000 per year for the purpose of developing new entanglement/teleportation breakthroughs in quantum teleportation physics. The second track should be funded at $750,000 – 1.5 million per year for the purpose of developing applications for any new breakthroughs with the proviso that such applications benefit the Air Force mission and have commercial dual-use capability to leverage advance technology in the private sector.

4.0 e-TELEPORTATION

4.1 Extra Space Dimensions and Parallel Universes/Spaces

A literature search for proposed e-Teleportation concepts based on the conveyance of objects through extra space dimensions and/or parallel universes/spaces has yielded only one result (see Section 4.2). The present state-of-art in research on parallel universes/spaces and extra space dimensions has been strictly limited to the work on developing a grand unified quantum field theory and a quantum theory of gravity, whereby the former necessarily includes the latter. Quantum gravity/unified field theory research has been evolving since the 1920s when Kaluza and Klein published the first papers to describe a model for the unification of gravity with electrodynamics. Many of the more prominent theories today invoke extra spatial dimensions, the existence of parallel universes/spaces, or both in order to quantise gravity and/or to unify gravity with the other forces of nature. It is beyond the scope of this study to provide an in-depth review of all of the research that has been done in this area, so we list below a select few of the historically prominent models that have largely gained a secure foothold in present-day research:

- Kaluza-Klein Electromagnetic-Gravity Unification Theory/Modern Kaluza-Klein Gravity Theories (Kaluza, 1921; Klein, 1926; de Sabbata and Schmutzer, 1983; Lee, 1984; Appelquist et al., 1987; Kaku, 1993, 1994; Overduin and Wesson, 1998): It was originally suggested that Maxwellian electrodynamics and Einstein gravitation could be unified in a theory of five-dimensional Riemannian geometry, where the gravitational and electromagnetic potentials together would determine the structure of spacetime. The fifth space dimension is curled up into a ball of space with a radius slightly larger than 10^{-35} m, and it was originally regarded as having no physical significance because it was simply a mathematical tool used to catalyze unification. At present, the generic name of Kaluza-Klein stands for a wide variety of approaches to quantising and unifying gravitation with other quantum fields using any number of dimensions greater than four.

- Superstring Theories (Green, 1985; Kaku, 1988, 1993, 1994): These theories come in a wide variety of interrelated concepts, and they are a highly evolved form of Kaluza-Klein theories. They are based on the dynamics of string-like fundamental quanta, whereby the observed fundamental particles are manifested by the vibrational ground or excitation states of a quantum string (open or closed loop). The superstrings are $\approx 10^{-35}$ m (i.e., the Planck length) in size. There are different versions of these theories that require ten, eleven or twenty-six extra space dimensions to unify and quantise gravity, whereby the extra dimensions are curled up (i.e., compactified) into balls of space with a radius $< 10^{-35}$ m. These theories later evolved into versions that are now called F- and M-theory. The mathematics behind this class of theories is very ugly, and it is difficult for even the best superstring theorists to make simple or sophisticated calculations and predictions. And so far, this class of quantum gravity theories has escaped experimental verification.

- D-Brane and 3-Brane Theories/Parallel Spaces (Rubakov and Shaposhnikov, 1983a, b; Polchinski, 1995; Antoniadis et al., 1998; Randall and Sundrum, 1999a, b; Weiss, 2000; Pease, 2001; Arkani-Hamed et al., 1998, 2000, 2002): D-brane theory is a recent incarnation of the original superstring theories in which open strings, corresponding to the fundamental particles of the standard model (quarks, leptons, gauge bosons), have their free ends stuck on a (hypersurface) membrane called a D-brane (D = Dirichlet boundary conditions). But the graviton, which corresponds to a closed loop of string, can propagate in all the dimensions. It provides both unification and quantization of gravity by assuming that there are n new spatial dimensions in addition to the three infinite spatial dimensions we know about. And the extra space dimensions are $\approx 10^{-35}$ m in extent. A very recent alternative version of this model is called "3-brane" theory. In this theory, each of the n extra space dimensions is of finite extent $R \approx 2\times10^{(32/n)-17}$ centimeters. The space spanned by the new dimensions is called "the bulk." In this theory, the particles of the standard model live within our familiar realm of three spatial dimensions, which forms a three-dimensional (hypersurface) membrane or "3-brane" within the bulk. The propagation of electroweak and strong nuclear forces is then confined to our 3-brane. However, at distances (r) less than R, gravity (via gravitons) propagates in the full $(3 + n)$-dimensional space, whereby its strength falls as $r^{-(2+n)}$ with increasing separation r. When $r > R$, the gravitational force reverts to its normal Newtonian r^{-2} falloff because there is no longer any extra-dimensional space for it to spread into. If $n = 1$, then the size of the extra-dimension would have to be $R \approx 2\times10^{15}$ cm (or 2×10^{10} km = 133.3 AU; 1 AU = 1.5×10^{8} km is the mean Earth-Sun distance) in order to account for the weakness of gravity, but an extra space dimension this large would have already made itself obvious in the observed dynamics of the solar system. For this reason, investigators have discounted the possibility that $n = 1$. If $n = 2$, then the size of both extra space dimensions would have to be $R \approx 0.2$ cm (or 2 mm). In any case, inconspicuous neighboring 3-branes may be separated from the 3-brane we live on by only a fraction of a millimeter, or even much smaller distances, across the higher-dimensional bulk. Such neighboring 3-branes may be distant folds of our own 3-brane, with the same physics, but able to influence us across shortcuts through the bulk. Or they may be completely separate 3-branes possessing their own fundamental laws and parameters of nature that are completely different from our own. Several tabletop Cavendish-type experiments are now looking for sub-millimeter deviations from Newtonian gravitation as a first step towards verifying 3-brane theory, and other experiments are now being planned or are already underway (Pease, 2001). At present the preliminary experimental results have been negative for the existence of extra space dimensions, and the experimental data suggests that two extra space dimensions are now constrained to length scales << 0.2 – 0.3 millimeters while seven extra space dimensions can be no larger than 2 femtometers (Pease, 2001).

- Parallel Universes/Parallel Spaces (Everett, 1957; Wheeler, 1957, 1962; DeWitt, 1970; DeWitt and Graham, 1973; Jammer, 1974; Davies, 1980; Wolf, 1988; Kaku, 1994; Visser, 1995 and Section 2.1): There are only two other research tracts that are concerned with parallel universes besides 3-brane theory. The first tract is the traversable wormhole research that was discussed in Section 2.1. Traversable wormholes can connect many different universes in the "multiverse" (i.e., a conglomeration of many universes), and these are called inter-universe wormholes. However, traversable wormhole physics (a.k.a. Einstein's General Relativity Theory) does not provide a physical prescription for the existence and nature (i.e., fundamental parameters and physical laws) of other putative universes. The difference between inter-universe and intra-universe (i.e., two distant regions of one universe are connected with each other) wormholes arises only at the level of global geometry and global topology. Local physics near the throat of a traversable wormhole is insensitive to issues of intra-universal or inter-universal travel. An observer in the vicinity of the throat, while making local measurements, would not be able to tell whether he was traveling to another universe or to a remote part of our own universe. And one cannot rely on the topological (as opposed to geometrical) information to determine which is the case, because topological information is not enough to uniquely characterize an inter-universe connection. And General Relativity Theory does not fix the topology of spacetime, so we cannot ascertain the existence of other universes. [Note: Traversable wormholes are also geometrically possible for higher dimensional spaces.] The second tract is the "Many Worlds" interpretation of

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quantum theory. This version of quantum theory requires the simultaneous existence of an infinite number of equally real worlds, all of which are more-or-less causally disjoint, in order to interpret consistently the relationship between observed phenomena and observers. The theory was proposed in an attempt to overcome a number of deep paradoxes inherent in the interpretation of the theory of measurement and quantum theory. The Many Worlds theory argues that quantum theory requires the existence of a "superspace" of worlds spanning the range of all possible quantum observations (or quantum measurements). Through our acts of measurement we are imagined to trace a path through the mesh of possible outcomes. All the "worlds" are causally disjoint, and the uncertainty of quantum observation can be interpreted as an artifact of our access to such a limited portion of the superspace of possible worlds. The evolution in the superspace as a whole is entirely deterministic.

At present, none of the theoretical concepts outlined above have been brought to a level of technical maturity, where it becomes meaningful to ascertain whether any form of e-Teleportation is theoretically possible between extra space dimensions and different or parallel universes/spaces. However, as mentioned in the item on parallel universes/parallel spaces, there is the exception that traversable wormholes (three- and higher-dimensional) provide a solid physics principle for the implementation of teleportation between parallel universes/spaces. And traversable wormholes can be devised to connect 3-branes together. See Section 2.1 for the discussion on teleportation via traversable wormholes. Also, Kaluza-Klein theories, superstring theories and D-brane theory all have the common feature that their extra space dimensions are $\leq 10^{-35}$ m in extent, which makes it impossible for any useful form of macroscopic-level teleportation to occur between space dimensions. Last, it is not yet possible to do theoretical calculations or even experimentally verify most of these theories. Three-brane theory is the best parallel space theory there is, with the possibility that macroscopic-level teleportation is possible between space dimensions (only if the extra space dimension(s) has length scale(s) >> millimeters). But this theory is still in the stage of maturing theoretically and achieving experimental verification (or falsification). Therefore, we can go no further in this section.

4.2 Vacuum Hole Teleportation

An unusual teleportation concept has been proposed by Leshan (1999, 2002), which describes the teleportation of objects throughout our universe by using the geometrical properties of spacetime. The proposal posits that there is a "zero-space" that exists outside the boundary of our universe, whereby this zero-space is a "point form" space, where the distance between any two points is always equal to zero. Leshan also calls this space a "hole." Further requirements and assumptions of the model are:

- time does not exist as a property in zero-space
- the cosmological principle (i.e., there are no privileged frames relative to another place or point in the universe) requires that the boundary or border of the universe must pass through every point of space
- virtual holes (or zero-space) in spacetime must exist at every point of the universe, which are also called "vacuum holes"
- vacuum holes exist as virtual particles

The last item is interesting because it implicitly says that vacuum holes (a.k.a. zero-space) must also be virtual particles, and in Section 2.2 we showed that virtual particles are a representation of the vacuum ZPF. Therefore, this infers that vacuum holes can be considered to be vacuum zero-point fluctuations in

Leshan's model. Thus, a teleportation mechanism can arise in this model because distances between zero-space and any other point in the universe are zero, so that the vacuum holes can potentially exist at every point in the universe simultaneously. Therefore, if an object is sent "out of the universe" and into a vacuum hole (a.k.a. zero-space), then the object can appear at random at any spacetime point in the universe.

The mechanism for teleportation in this model is:

- to send an object outside of the universe by creating a closed surface (i.e., "hole sphere"), which consists of vacuum holes, around the object;
- while inside the hole sphere, the object then ceases to exist because objects cannot really exist outside of the universe;
- however, the object simultaneously exists at any other remote location in the universe (via the cosmological principle) at the instant it became enclosed by the hole sphere;
- therefore, it has been teleported to some remote location in the universe

Leshan points out that the teleportation device must curve spacetime so that the starting and destination points in the universe coincide, and the curved geometry must be similar to that of a black hole for an instant, so that a channel between the two points can be formed. (This sounds suspiciously like creating a traversable wormhole via an Einstein-Rosen bridge, which can be made traversable by perturbing the Schwarzschild spacetime metric an infinitesimal amount.) There is no space to traverse, so therefore there will be no passage of time during teleportation. The only expenditure of energy in this teleportation scheme is the energy that will be needed to curve spacetime.

This teleportation concept is very convoluted. Leshan does not offer any further explanations that are useful nor does he offer any precise technical description for the vacuum holes, and how they are to be produced and manipulated. There is also no mathematical physics derivation published by Leshan to support this concept. I am totally unable to evaluate this concept in the absence of a rigorous theoretical framework. This concept is too sketchy and full of technical "holes" to seriously consider it any further for this study. The reader should note that it has already been demonstrated that traversable wormholes are the best physical principle available to implement teleportation between universes and extra space dimensions.

4.3 Conclusion and Recommendations

At present, none of the theoretical concepts explored in this chapter have been brought to a level of technical maturity, where it becomes meaningful to ascertain whether any form of e-Teleportation is theoretically possible between extra space dimensions and different or parallel universes/spaces. However, there is the exception that traversable wormholes (three- and higher-dimensional) provide a solid physics principle for the implementation of teleportation between parallel universes/spaces. And traversable wormholes can be devised to connect 3-branes together. Kaluza-Klein, superstring and D-brane theories do not allow for any useful form of macroscopic-level teleportation to occur between space dimensions, because these theories require that the extra space dimensions be $\leq 10^{-35}$ m in extent. Last, it is not yet possible to do theoretical calculations to make predictions or even to experimentally verify most of these theories. Three-brane theory is the best parallel space theory there is with the possibility that macroscopic-level teleportation is possible between space dimensions. But this theory is still in the stage of maturing theoretically and getting experimental verification.

•**Recommendations**:

- The recommendations outlined in Section 2.3 are relevant to the investigation of the possibility for e-Teleportation.

5.0 p-TELEPORTATION

5.1 PK Phenomenon

P-Teleportation is a form of psychokinesis (or PK) similar to telekinesis but generally used to designate the movement of objects (called apports) through other physical objects or over great distances. Telekinesis is a form of PK, which describes the movement of stationary objects without the use of any known physical force. And PK is essentially the direct influence of mind on matter without any known intermediate physical energy or instrumentation. Rigorously controlled modern scientific laboratory PK, and related psychic (a.k.a. “psi”, “paranormal” or parapsychology), research has been performed and/or documented by Rhine (1970), Schmidt (1974), Mitchell (1974a, b, see also the references cited therein), Swann (1974), Puthoff and Targ (1974, 1975), Hasted et al. (1975), Targ and Puthoff (1977), Nash (1978, see also the references cited therein), Shigemi et al. (1978), Hasted (1979), Houck (1984a), Wolman et al. (1986, see also the references cited therein), Schmidt (1987), Alexander et al. (1990), Giroldini (1991), Gissurarson (1992), Radin (1997, see also the references cited therein), Tart et al. (2002), Shoup (2002), and Alexander (2003).

A well-known theoretical/experimental/operational program directed by H. E. Puthoff, R. Targ, E. May and I. Swann was conducted at SRI International and the NSA, and sponsored at various times by the Central Intelligence Agency (CIA), the Defense Intelligence Agency (DIA), and the Army Intelligence and Security Command (INSCOM) over more than two decades; and the program was later carried on by E. May at SAIC (Alexander, 1980; Puthoff, 1996; Targ, 1996; Schnabel, 1997; Tart et al., 2002). This was called the Remote Viewing program, and it was a compartmentalized special access program possessing a variety of codenames during its 22 years of operation. Remote viewing involves precognition and clairvoyance, and it allows a practitioner to acquire information irrespective of intervening distance or time. The Remote Viewing program ended in 1994 and President W. J. Clinton officially declassified it in 1995. The reader should note that the very first U. S. military-intelligence R&D programs on psi, PK and mind control were conducted by H. K. (Andrija) Puharich, M.D., L.L.D during his military service at the Army Chemical and Biological Warfare Center at Fort Detrick, Maryland in the 1940s-50s. Puharich had an interest in clairvoyance and PK, and dabbled in theories for electronically and pharmaceutically enhancing and synthesizing psychic abilities. While in the Army, Puharich took part in a variety of parapsychology experiments, and he lectured Army, Air Force and Navy groups on possibilities for mind warfare. He was a recognized expert in hypnotism and microelectronics.

PK phenomenon was also explored in the Remote Viewing program. Col. J. B. Alexander (USA ret.) credits professional aerospace engineer Jack Houck for “capturing PK phenomenon and transitioning it into an observable form” (Houck, 1982, 1984a, b; Alexander et al., 1990; Alexander, 2003). During the past three decades, Houck (along with Alexander) held a number of PK sessions, whereby attendees are taught the PK induction process, and initiate their own PK events using various metal specimens (forks, spoons, etc.). Individuals were able to completely bend or contort their metal specimens with no physical force being applied whatsoever. Numerous government science advisors and senior military officials took part in and/or witnessed these events, which took place at the Pentagon, at officers’ or scientists’ homes, and at one quarterly INSCOM retreat attended by the commanding general and a group of colonels and generals commanding INSCOM units around the globe. Spontaneous deformation of the metal specimens was observed at the PK session conducted during the INSCOM retreat, causing a great deal of excitement among those present. Other notable trained observers were also present at this session, and they critically reviewed the events. Psychic Uri Geller (1975) is the original model for demonstrating

PK metal bending. During a talk that he gave at the U.S. Capitol building, Uri caused a spoon to curve upward with no force applied, and then the spoon continued to bend after he put it back down and continued with his talk (Alexander, 1996). Jack Houck continues doing extensive experimental work and data collection on micro- and macro-PK phenomena. Scientifically controlled PK experiments at the Princeton University Engineering Anomalies Research Laboratory were conducted by Robert Jahn (Dean Emeritus of the School of Engineering), who reported that repeatedly consistent results in mentally affecting material substances has been demonstrated in the lab (Jahn and Dunne, 1987). In the 1980s, Jahn attended a meeting on the PK topic at the Naval Research Laboratory, and warned that foreign adversaries could exploit micro- or macro-PK to induce U.S. military fighter pilots to lose control of their aircraft and crash.

Very early investigations of, and experiments on, p-Teleportation occurred during the 19th and early 20th centuries. Many cases that were studied, and the experiments that were performed, were undoubtedly due to fraud, and few experiments have occurred under controlled conditions during that period. However, most of the credible, scientific reports of p-Teleportation phenomenon and related (controlled) experiments occurred in the late 20th century (see for example, Alexander et al., 1990; Radin, 1997). Some of that scientific work involved the investigation of Uri Geller and a variety of other recurrent spontaneous PK phenomena (Hasted et al., 1975; Puthoff and Targ, 1975; Targ and Puthoff, 1977; Nash, 1978; Wolman et al., 1986). Psychics Uri Geller (1975) and Ray Stanford (1974) claimed to have been teleported on several occasions. Most claimed instances of human teleportation of the body from one place to another have been unwitnessed. There are also a small number of credible reports of individuals who reported being teleported to/from UFOs during a UFO close encounter, which were scientifically investigated (Vallee, 1988, 1990, 1997). But there are a larger number of such reports that are anecdotal, whereby the witness data tends to be unreliable. However, we will confine our discussion to the controlled laboratory experiments that have been performed and reported.

One of the more interesting examples of controlled experiments with Uri Geller was one in which he was able to cause a part of a vanadium carbide crystal to vanish (Hasted et al., 1975). The crystal was encapsulated so it could not be touched, and it was placed in such a way that it could not be switched with another crystal by sleight of hand. A more spectacular series of rigorously controlled (and repeatable!) laboratory experiments occurred in the Peoples Republic of China (PRC). In September 1981, an extraordinary paper was published in the PRC in the journal Ziran Zazhi (transl.: Nature Journal), and this paper was entitled, "Some Experiments on the Transfer of Objects Performed by Unusual Abilities of the Human Body" (Shuhuang et al., 1981). The paper reported that gifted children were able to cause the apparent teleportation of small objects (radio micro-transmitters, photosensitive paper, mechanical watches, horseflies, other insects, etc.) from one location to another (that was meters away) without them ever touching the objects beforehand. The experiments were operated under exceptionally well-controlled conditions (both blind and double-blind). The researchers involved included not only observers from various PRC colleges and medical research institutes, but also representatives from the PRC National Defense Science Commission. Because of the involvement of the latter, it was deemed necessary that an unclassified Intelligence Information Report be prepared by the DIA (see Shuhuang et al., 1981), which included a detailed English translation of the article.

Additional research carried out by the Aerospace Medicine Engineering Institute in Beijing was reported in the July 1990 issue of the Chinese Journal of Somatic Science (Kongzhi et al., 1990; Jinggen et al., 1990; Banghui, 1990), which was also translated into English by the DIA. Reported in several articles are experiments involving the videotaping and high-speed photography of the transfer of test specimens (nuts, bundles of matches, pills, nails, thread, photosensitive paper, chemically treated paper, sponges dipped in $FeCl_3$, etc.) through the walls of sealed paper envelopes, double layered KCNS type paper bags, sealed glass bottles and tubes with sealed caps, and sealed plastic film canisters without the walls of any of these containers being breached. All of the Chinese experiments reported using gifted children and young adults, who possessed well-known extraordinary PK ability, to cause the teleportation of the various test specimens. In all the experimental cases that were reported, the test specimens that were teleported were completely unaltered or unchanged from their initial state, even the insects were unaffected by being teleported. The experiments were well controlled, scientifically recorded, and the experimental results were always repeatable.

The Chinese papers are all extremely interesting and very well written, and they show photographs and schematic diagrams of the various experimental setups. The experimental protocols were explained in lengthy detail, and thorough data and statistical analysis were presented in the results. The combined results from the several Chinese experiments showed that:

- different research groups designed different experimental protocols, used different gifted psychics, used different sealed containers, and used different test specimens (live insects, bulk inanimate objects, and even radio micro-transmitters were used to track the location of the specimens) that were to be teleported;

- the time required for the teleportation of test specimens through various barriers was anywhere from a fraction of a second to several minutes, and this was not dependent on the test specimen that was used, the sealed container that was used (or its barrier thickness), which experimental protocol was used, or which psychic was being used

- the high-speed photography/videotaping recorded in one series of experiments that test specimens would physically "meld" or blend with the walls of sealed containers; and recorded in a different series of experiments that test specimens would simply disappear from inside the container only to reappear at another location (after seconds to several minutes of time transpired), such that the test specimen did not actually undergo total material disintegration/reintegration during teleportation – this data is important, because without the aid of electronic monitoring instruments, the average person's sensory organs and usual methods of detection are temporarily unable to perceive the test specimen's (ambiguous) existence during the teleportation process;

- the radio micro-transmitter used as a test specimen in one series of experiments (Shuhuang et al., 1981) transmitted a radio signal to several stationary electronic instruments/receivers, so that the specimen could be tracked and monitored (via signal amplitude and frequency measurements) during the teleportation process; the experimenters discovered that there was large fluctuations in the intensity (in both amplitude and frequency) of the monitored signal to the effect that it would either completely disappear or become extremely weak (to the extent that the monitoring instruments could scarcely detect it) – it was discovered that there was a definite correlation between the change in strength (i.e., radical frequency shifts were observed) of the monitored radio signal and the teleportation of the test specimen, such that the weak or absent signal indicated that the specimen was "nonexistent" (or in an altered physical state) during teleportation (note: the monitored signal amplitude and frequency of the micro-transmitter specimen were stable before and after teleportation);

- before and after "passing through the container wall/barrier", the test specimen and the container's wall/barrier are both complete solid objects;

- the gifted psychics were never allowed to see (they were blindfolded in many experiments) or touch each of the test specimens or the sealed containers before and after experiments were conducted, and only the experimenters touched the specimens and containers (using both blind and double-blind protocols);

- the experimental results were all repeatable

- the conditions for fraud and sleight of hand were totally eliminated, and multiple independent outside witnesses (technical and military-intelligence experts) were present at all times to ensure total fidelity of the experiments

The experimental radio micro-transmitter and high-speed photography/videotaping data offer an important clue on what the teleportation mechanism is, and this will be discussed further in Section 5.1.1. The Chinese were unable to offer any significant physics hypothesis that could explain their results. Some researchers stated that it is necessary to invoke a new physics, which somehow unifies the human consciousness (i.e., physics of consciousness) with quantum and spacetime physics, in order to understand p-Teleportation and related PK phenomena. The researchers were amazed by their repeated results, and were barely able to fathom the altered "state of being" that test specimens underwent during teleportation.

It is also important to point out that during the Cold War the DIA produced three (now declassified) reports on the parapsychology research of the Soviet Union and its Warsaw Pack allies (LaMothe, 1972; Maire and LaMothe, 1975; DIA Report, 1978; other related studies were reported by Groller, 1986, 1987). The purpose of the reports was to collate and summarize collected intelligence, describe in great detail, and assess the Soviet Union and Warsaw Pact R&D on parapsychology and paraphysics. The reports outlined the history of pre-revolutionary (Czarist) Russian, and WWII and post-WWII era Soviet R&D on psychotronics, human mind/behavior control, and the entire spectrum of parapsychology. The Soviet information also mentions the psychotronic/parapsychology R&D materials that Soviet military forces took from various Nazi research centers in and around Germany at the end of WWII. The entire spectrum of parapsychology phenomena was explored by the Soviets, which resulted in the generation of a wealth of experimental data and related scientific research literature. One DIA report noted that there was an East versus West science debate in the Soviet literature over whether paranormal phenomenon and related experimental data was real or even scientifically sound in comparison to western scientific practice and philosophy. Another DIA report lists the names and affiliations of all the researchers, as well as the names of the various Soviet and Warsaw Pact research centers, that were involved. Also, Pratt (1986) reviews and summarizes the history of Soviet psychotronics research.

The U.S. military-intelligence establishment was concerned with the possibility that the Soviets and their Warsaw Pact allies were conducting psychotronics and mind control R&D in order to discover how to exploit and control powerful phenomena that could be used against the U.S. and its allies. LaMothe (1972) chronicled how the Soviets had been researching methods of influencing human behavior for over sixty years. The Soviets and their allies extensively explored an influence technology that they called "controlled offensive behavior", which is defined as "research on human vulnerability as it applies to methods of influencing or altering human behavior" (LaMothe, 1972). Also, LaMothe (1972) describes the revolutionary techniques the Soviets studied to influence human behavior, which included: sound, light, color, odors, sensory deprivation, sleep, electromagnetic fields, biochemicals, autosuggestion, hypnosis, and parapsychology phenomena (such as psychokinesis, telekinesis, extrasensory perception-ESP, astral projection, clairvoyance, precognition, and dream state, etc.). The LaMothe (1972) report became an aid in the development of countermeasures for the protection of U.S. and/or allied personnel.

Psychotronics is the general term that was used in the former Soviet Union/Warsaw Pact countries to categorize many psychic phenomena undergoing scientific research. The conclusions that were reached in the DIA reports are that within the category of psychotronics, the Soviets identified two discrete skills (LaMothe, 1972):

- bioenergetics: those phenomena associated with the production of objectively detectable effects such as psychokinesis, telekinesis, levitation effects, transformations of energy, i.e. the altering or affecting of matter

- bioinformation: those phenomena associated with the obtaining of information through means other than the normal sensory channels (i.e., ESP), such as telepathy, precognition, and clairvoyance, i.e., using the mind to tap into the thoughts of others or to acquire present or future information about objective events in the world

These phenomena involve using the mind and/or some "field" of the body to affect other minds and inanimate objects irrespective of intervening distance or elapsed time, and without engaging any conventional tools. Bioenergetics and bioinformation are two classifications that form a single branch of science the Soviets preferred to call biocommunications. Soviet biocommunications research is primarily concerned with exploring the existence of a definite group of natural phenomena controlled by laws that are not based on any known (energetic) influence. The types of biocommunication (a.k.a. psychotronics) phenomena includes special sensory biophysical activities, brain and mind control, telepathic communications or bioinformation transceiving, bioluminescent and bioenergetic emissions, and the effects of altered states of consciousness on the human psyche. Psychotronics and remote viewing provide capabilities that have obvious intelligence applications. The Soviets and their Warsaw Pact allies invested millions of dollars in psychotronics R&D because they understood this, and saw the potential payoff for military and intelligence applications.

The U.S. response to Soviet psychotronics R&D programs was the Remote Viewing program. In addition, the U.S. Army began the JEDI Project in 1983, which sought to increase human potential using teachable models of behavioral/physical excellent by unconventional means (Alexander et al., 1990). The JEDI Project was essentially a human-performance modeling experiment based on neuro-linguistic programming (NLP) skills, whereby advanced influence technologies to model excellence in human performance was used. The program ran under the auspices of the Army INSCOM and the Organizational Effectiveness School, and was sponsored by a U.S. government interagency task force. Finally, it should be pointed out that the program had successfully trained several hundred people, including members of Congress (such as Al Gore, Jr. and Tom Downey), before being terminated.

There is a wealth of factual scientific research data from around the world attesting to the physical reality of p-Teleportation and related anomalous psi phenomena (Mitchell, 1974b; Targ and Puthoff, 1977; Nash, 1978; Radin, 1997; Tart et al., 2002). The skeptical reader should not be so quick to dismiss the subject matter in this chapter, because one must remain open-minded about this subject and consider p-Teleportation as worthy of further scientific exploration. The psychotronics topic is controversial within the western scientific community. The debate among scientists and scientific philosophers is highly charged at times, and becomes acrimonious to the point where reputable skeptical scientists cease being impartial by refusing to examine the experimental data or theories, and they prefer to bypass rational discourse by engaging in ad hominem attacks and irrational "armchair" arguments.

P-Teleportation and related phenomena are truly anomalous, and they challenge accepted modern scientific paradigm. Lightman and Gingerich (1991) wrote, "Scientists are reluctant to change paradigms for the purely psychological reasons that the familiar is often more comfortable than the unfamiliar and that inconsistencies in belief are uncomfortable." And theories change over time when anomalies enter the picture. Anomalies are particularly helpful for they point to the inadequacies of an old model and point the way to a new one. Anomalous scientific facts are unexpected and difficult to explain within an existing conceptual framework. Kuhn (1970) describes scientific discovery as a complex process, in which an anomalous fact of nature is recognized, and then followed by a change in conceptual framework (i.e., paradigm) that makes the new fact no longer an anomaly. Kuhn stated that, "Discovery commences with the awareness of anomaly, that is, with the recognition that nature has somehow violated the pre-induced expectations that govern normal science." This statement neatly describes exactly what transpired during the historical revolution that took place in physics between the classical mechanics/electrodynamics age in the 19th century and the quantum/atomic/nuclear/relativistic age in the 20th century. And this isn't the only time in human history that scientific paradigms have dramatically changed. The discovery of p-Teleportation already commenced in the 20th century, so let us continue the discovery and create a new physics paradigm for the 21st century.

5.1.1 Hypothesis Based on Mathematical Geometry

The Chinese researchers reported in their teleportation experiments that high-speed photography/videotaping recorded test specimens physically “melding” or blending with the walls of sealed containers, and in a different series of experiments the test specimens would simply disappear from inside the container only to reappear at another location (after seconds to several minutes of time transpired). They also reported in the series of radio micro-transmitter experiments that there were large fluctuations in the intensity (in both amplitude and frequency) of the monitored signal to the effect that it would either completely disappear or become extremely weak (to the extent that the monitoring instruments could scarcely detect it); and they discovered that there was a definite correlation between the change in strength (i.e., radical frequency shifts were observed) of the monitored radio signal and the teleportation of the radio micro-transmitter, such that the weak or absent signal indicated that the specimen was “nonexistent” (or in an altered physical state) during teleportation. This data is important because without the aid of electronic monitoring instruments, the average person’s sensory organs and usual methods of detection are temporarily unable to perceive the test specimen’s (ambiguous) existence during the teleportation process. This data offers an important clue on what the teleportation mechanism is.

It is beyond the scope of this study to propose a complete self-consistent physics theory of consciousness/mind, which explains how the mind can activate p-Teleportation and related psychotronics phenomena. This topic has been under study in recent decades by a legion of medical science, bio- and neuro-physiology, psychology, mathematics, philosophy, and physics experts. Many different theories with varying degree of theoretical maturity and self-consistency have been proposed over the years, and most of them have not yet been experimentally tested for various reasons. However, some first-order experimental work has been done (Mitchell, 1974b; Targ and Puthoff, 1977; Wolman et al., 1986; Radin, 1997; Tart et al., 2002). Ironically, quantum mechanics theory, and the related physics of quantum entanglement and teleportation, has become the primary focus of all of the physics theories of consciousness/psychotronics that have been recently proposed (see for example, Shan, 2003). Wolman et al. (1986) and Radin (1997) provide a review and discussion on recent theories and experiments that are based on quantum physics theory (see also, Walker, 1974; Targ and Puthoff, 1977; Mitchell, 1999, and the references cited therein; Tart et al., 2002). It appears that the physics of q-Teleportation (Chapter 3) has tremendous relevance to the physics of p-Teleportation and psychotronics.

In the following I propose a parsimonious first-order hypothesis that can explain the gross features of both the Chinese p-Teleportation data and the other reported p-Teleportation phenomena. But I will refrain from including any role that might be played by quantum phenomena since the scientific community has not yet settled that particular issue. (However, it is apparent that quantum theory and quantum phenomena will likely play a key role in a formal physics theory of PK and psychotronics.)

First-Order Hypothesis:

- ☐ Fact 1: The mature discipline of mathematical geometry developed the properties of higher dimensional spaces (Reichenbach, 1957; Manning, 1977; Rucker, 1977). An example of one such property that is of relevance to the hypothesis: One can visualize a four-dimensional world by using color as the 4th dimension. We can think of a three-dimensional world, whereby objects pass through one another if their colors (i.e., four-dimensional locations) are different (Reichenbach, 1957). For example, color can be used as a 4th dimension to see how a knot in three-dimensions can be untied in a 4th spatial dimension without moving the ends of the cord. That is because a cord cannot stay knotted in four-dimensional space, because the extra degree of freedom will cause any knot to slip through itself. Two other interesting and relevant examples are that the links of a chain may be separated unbroken in the 4th dimension, and a flexible sphere may be turned inside out without tearing in the 4th dimension (Manning, 1977; Rucker, 1977).

- ❑ Proposition 1 and Fact 2: It has been proposed that our space actually possesses a slight four-dimensional hyperthickness, so that the ultimate components of our nervous system are actually higher dimensional, thus enabling the human mind/brain to imagine four-dimensional space (Hinton, 1888, 1904; Rucker, 1977). If this is the case, then the three-dimensional nets of neurons that code thoughts in our brain may form four-dimensional patterns to achieve four-dimensional thought. The "bulk" space in 3-brane theory (see Section 4.1), and experimental data from the Remote Viewing program (see Section 5.1), provide support for this concept. Can we see into the 4th dimension and have four-dimensional thoughts? Yes, we can. Proof (see, Rucker, 1977, 1984): If you look at a Necker cube for a while, it spontaneously turns into its mirror image and back again. If you watch it do this often enough, the twinkling sort of motion from one state to the other begins to seem like a continuous motion. But this motion can only be continuous if it is a rotation in four-dimensional space. The mathematician August F. Möbius discovered in 1827 that it is in fact possible to turn a three-dimensional solid object into its mirror image by an appropriate rotation through four-dimensional space (a.k.a. hyperspace rotation). Thus, it is actually possible for our minds to perform such a rotation. Therefore, we can actually produce four-dimensional phenomenon in our minds, so our consciousness is four-dimensional. Rucker (1984) shows another dramatic example of being able to see into the 4th dimension via a "Neck-A-Cube."

- ❑ Fact 3: Another property of higher dimensional geometry (Reichenbach, 1957; Rucker, 1977, 1984) is that one can move through solid three-dimensional obstacles without penetrating them by passing in the direction of the 4th (spatial) dimension. The 4th dimension is perpendicular to all of our normal three-dimensional space directions, and so our three-dimensional enclosures have no walls against this direction.

- ❑ Conclusion and Hypothesis: Therefore, the results of the Chinese p-Teleportation experiments can simply be explained as a human consciousness phenomenon that somehow acts to move or rotate test specimens through a 4th spatial dimension, so that the specimens are able to penetrate the solid walls/barriers of their containers without physically breaching them. No real dematerialization/rematerialization of the specimens takes place. The intensity fluctuations of the radio micro-transmitter specimen's electromagnetic signal, and the apparent blending of the other specimens with the walls of their containers, represent the passage of the specimens through a 4th spatial dimension. During teleportation the radio signals emitted by the micro-transmitter became weak/non-existent and fluctuated, because they were spreading out into the 4th dimension and became undetectable in our three-dimensional space. The weak signals that were ("barely") detected represent the leakage of a portion of the radio signal back into our three-dimensional space from the 4th dimension during teleportation. The observed blending of the other specimens with the walls of their containers is how the movement/rotation of the specimens through the 4th dimension was visually interpreted by the mind (along the lines of the Necker cube or Neck-A-Cube examples).

5.2 Conclusion and Recommendations

We will need a physics theory of consciousness and psychotronics, along with more experimental data, in order to test the hypothesis in Section 5.1.1 and discover the physical mechanisms that lay behind the psychotronic manipulation of matter. P-Teleportation, if verified, would represent a phenomenon that could offer potential high-payoff military, intelligence and commercial applications. This phenomenon could generate a dramatic revolution in technology, which would result from a dramatic paradigm shift in science. Anomalies are the key to all paradigm shifts!

•**Recommendations**:

- There are numerous supporters within the U.S. military establishment who comprehend the significance of remote viewing and PK phenomenon, and believe that they could have strategic implications. Bremseth (2001), a U.S. Navy SEAL, attended the Marine War College and studied the Remote Viewing program, and interviewed many of the former program participants. Bremseth then wrote his thesis on the topic, and concluded that the evidence supported continued research and applications of remote viewing. A research program improving on and expanding, or implementing novel variations of, the Chinese and Uri Geller-type experiments should be conducted in order to generate p-Teleportation phenomenon in the lab. The performances and characteristics of p-Teleportation need to be delineated in order to develop a refined hypothesis. Such a program should be designed so that an operational model for p-Teleportation can be developed and implemented as a prototype. An experimental program similar in fashion to the Remote Viewing program should be funded at $900,000 – 1,000,000 per year in parallel with a theoretical program funded at $500,000 per year for an initial five-year duration. The role of quantum physics theory and related quantum phenomena (i.e., entanglement and teleportation) in p-Teleportation and psychotronics should be explored in this program (see for example, the Biological Quantum Teleportation recommendation in Section 3.3). An experiment definition study should be conducted first to identify and propose the best experiments for this program, which should be funded at $80,000 for one year.

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APPENDIX A – A Few Words About Negative Energy

A.1 A General Relativistic Definition of Negative or Exotic Energy

We saw in equations (2.10a-c) that the surface energy and stress-tension densities of the material required to create and thread a traversable wormhole must be "negative." For surface stress-energy, and volume stress-energy in general, this is "negative" in the sense that the material we must deploy to generate and thread the traversable wormhole must have an energy density (ρc^2, ρ = mass density) that is less than the stress-energy density (τ), or we can write this condition as: *mass-energy* $\rho c^2 \le$ *stress-energy* τ. On the basis of this condition, we call this material property "exotic." Therefore, the term "negative" is just a misnomer in this context. The condition for ordinary, non-exotic forms of matter that we are all familiar with is *mass-energy* $\rho c^2 >$ *stress-energy* τ. This condition represents one version of what is variously called the weak (WEC), null (NEC), average (AEC), dominant (DEC), strong (SEC) or "standard" energy conditions (that are mere hypotheses!), which allegedly forbid negative mass-energy density and gravitational repulsion (antigravity) between material objects to occur in nature. Hawking and Ellis (1973) formulated these energy conditions in order to establish a series of mathematical proofs in their study of the application of general relativity theory to cosmology and black hole physics.

However, there are general theorems of differential geometry that guarantee that there must be NEC violations (meaning exotic matter-energy is present) at a wormhole throat (Visser, 1997). In view of this, it is known that static radial electric or magnetic fields are borderline exotic when threading a wormhole, if their tension were infinitesimally larger, for a given energy density (Herrmann, 1989; Hawking and Ellis, 1973). Other exotic (energy condition violating) matter-energy fields are known to be squeezed quantum states of the electromagnetic field and other squeezed quantum fields (see Section A.2 for the discussion on squeezed quantum states), gravitationally squeezed vacuum electromagnetic zero-point energy (see Section 2.3 for the discussion on Gravitationally Squeezed Vacuum Energy), Casimir (electromagnetic zero-point) energy and other quantum fields/states/effects. These examples represent forms of matter-energy that possess negative energy density. Since the vacuum is defined to have vanishing energy density, anything possessing less energy density than the vacuum must have a negative energy density. With respect to creating wormholes, these have the unfortunate reputation of alarming physicists. This is unfounded since all the energy condition hypotheses have been experimentally tested in the laboratory and experimentally shown to be false - 25 years before their formulation (Visser, 1990 and references cited therein). Further investigation into this technical issue showed that violations of the energy conditions are widespread for all forms of both classical and quantum matter-energy such as planets, stars, black holes, neutron stars, people, space dust clouds, etc. (Davis, 1999b; Barcelo and Visser, 2002). In addition, Visser (1995) showed that all (generic) spacetime geometries violate all the energy conditions. Violating the energy conditions commits no offense against nature.

A.2 Squeezed Quantum States and Negative Energy

In quantum mechanics the energy (E) and frequency (ν) of a quantum oscillator system, such as electromagnetic radiation (or light), are interchangeable via the Planck relation $E = h\nu$ ($h = 2\pi\hbar$). And from the Heisenberg quantum uncertainty principle, we know that the conjugate variable to the frequency is the oscillator phase (φ), such that $\Delta\nu\Delta\varphi \ge \hbar$ is obeyed. Phase is difficult to measure and is ignored in characterizing complex quantum systems.

Recent theoretical and experimental work has shown that in many quantum systems the limits to measurement precision imposed by the quantum vacuum zero-point fluctuations (ZPF) can be breached by decreasing the frequency noise at the expense of increasing the phase noise (thus maintaining $\Delta\nu\Delta\varphi \geq \hbar$), while at the same time the variations in frequency, and therefore the energy, are reduced below the ZPF such that the energy becomes "negative." "Squeezing" is thus the control of quantum fluctuations and corresponding uncertainties, whereby one can squeeze the variance of one (physically important) observable quantity provided the variance in the (physically unimportant) conjugate variable is stretched/increased. The squeezed quantity possesses an unusually low variance, meaning less variance than would be expected on the basis of the equipartition theorem. We can exploit quantum squeezing to extract energy from one place in the ordinary vacuum at the expense of piling up excess energy elsewhere (Morris and Thorne, 1988).

Appendix B – *TH*εμ Methodology

In the formalism of the *TH*εμ methodology, the functions *T* and *H* are introduced by requiring that the Lagrangian for the motion of particles (with charge e_a and mass m_{0a} for the a^{th} particle), under the joint action of gravity and the electromagnetic field A_α ($\alpha \equiv$ spacetime vector components), be expressed in the canonical form

$$L = \sum_a \int \left(-m_{0a}\sqrt{T - H{v_a}^2} + e_a A_\alpha {v_a}^\alpha \right) dt + \left(8\pi\right)^{-1} \int \left(\varepsilon \mathbf{E}^2 + \mu^{-1}\mathbf{B}^2 \right) d^3x\, dt \qquad \text{(B.1);}$$

where the arbitrary functions *T*, *H*, ε, and μ are functions of the metric (a.k.a. gravitation field), ${v_a}^\alpha$ is the a^{th} particle four-vector velocity, and A_α is the electromagnetic field four-vector potential, ***E*** and ***B*** are the electric and magnetic field strengths, and (B.1) is in geometrodynamic natural units ($\hbar = c_0 = G = \varepsilon_0 = \mu_0 = 1$). The Lagrangian characterizes the motion of charged particles in an external gravitational field by the two functions *T* and *H*, and characterizes the response of the electromagnetic fields to the external gravitational field by the two functions ε and μ. For all standard (metric) theories of gravity, the four functions are related by

$$\varepsilon = \mu = \sqrt{\frac{H}{T}} \qquad \text{(B.2);}$$

and ***every*** metric theory of gravity satisfies this relation, such that the Einstein Equivalence Principle is satisfied.

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Time Travel: Time Dilation

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In this paper I discuss the theory and actuality of the effects of Time Dilation, as predicted by Einstein's Special Relativity. Alongside this the research investigates the visible, experiential effects of most personal form of Time Travel from a personal, phenomenological perspective, illustrated through digital media.

The body of work, this paper and an accompanying book of modified digital images, recalls the Hafele-Keating experiment of October 1971 and parallels the Quantified Self experiments of diary photography and personal analytics in a holistic, interconnected way.

The work tracks 12 months of air travel and illustrates with practical data the physics and mathematics behind the theory and actuality of Time Dilation. The research combines the interdisciplinary worlds of Computer Arts with Data and Scientific Visualisation to create a tangible collision between the visualisation of the personal and illustration of theory

The observations are documented in ethnographic, photo essay illustrations as an investigation into the mathematics and physics of personal and interpersonal time. Using situated imaging presented as a practice-based body of work to communicate the abstract world of very small time periods and the direct relevance of Einstein's work on the personal and perceptual world we inhabit. Contrasting Newtonian mechanics and Einsteinian space-time the work seeks to illustrate the personal nature of how the reality of time travel influences every aspect of the interpersonal

Time dilation. Time travel. General relativity. Special relativity. Visual thinking. Photography. Visualisation. Practice-based research. Art.

1. INTRODUCTION

In 1971 two American researchers, J.C. Hafele and R. E. Keating, conducted an experiment.

They placed two caesium atomic clocks on passenger airplanes and flew them in opposite directions around the globe to test a hypothesis first posited in Einstein's theory of special relativity.

Their aim was to measure the effects of relativity on these highly accurate devices - the predictions indicated that the eastward flying clock would lose 40ns and the westward gain 275ns. A nanosecond is equal to one billionth of a second (10^{-9} or $^{1}/_{1,000,000,000}$ s). To compare, one nanosecond is to one second as one second is to 31.7 years.

> During October, 1971, four cesium atomic beam clocks were flown on regularly scheduled commercial jet flights around the world twice, once eastward and once westward, to test Einstein's theory of relativity with macroscopic clocks. From the actual flight paths of each trip, the theory predicted that the flying clocks, compared with reference clocks at the U.S. Naval Observatory, should have lost 40+/-23 nanoseconds during the eastward trip and should have gained 275+/-21 nanoseconds during the westward trip ... Relative to the atomic time scale of the U.S. Naval Observatory, the flying clocks lost 59+/-10 nanoseconds during the eastward trip and gained 273+/-7 nanosecond during the westward trip, where the errors are the corresponding standard deviations. These results provide an unambiguous empirical resolution of the famous clock 'paradox' with macroscopic clocks. (Hafele & Keating 1972)

The results showed that compared to stationary clocks in the laboratory the eastward clock lost 59ns and the westward gained 273ns. Whilst there has been discussion of the accuracy and therefore reliability of the measurements the experiment is commonly held up as one of the first to give practical evidence of the physical effects of time dilation.

2. SPECIAL RELATIVITY AND TIME DILATION

In special relativity Einstein States that the duration of time will pass at different rates when comparing an object at rest versus an object in motion. The greater the velocity of the object in motion, the closer to the speed of light, c, the greater the effect of what is known as 'time dilation'

The effect of this phenomenon is significant at speeds close to the constant of light speed but becomes exponentially less as the object in question approaches rest.

$$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Figure 1: *The mathematical relationship of time, velocity and the speed of light describing Time Dilation*

Unless our velocity is a substantial fraction of the constant speed of light the dilation effect (γ) is approximately 1. This, combined with our extremely limited lifespan is why we don't immediately notice time dilation at ordinary speeds. The fastest speed most humans will achieve, an airplane travelling near the speed of sound, gives a time dilation where $\gamma = 1.0000000000005$.

In other words, 1 second for a passenger on the plane would pass as 1.0000000000005 seconds for a stationary observer.

Time effectively passes more slowly for the traveller relative to the observer.

3. THE REALITY OF THE EFFECT

Whilst there is discussion of the validity of the results of the 1971 Hafele & Keating experiment, particularly around the 'corrections' made to their data at publication, their initial observations are clearly aligned with the predicted results to be expected from the mathematics for time dilation.

As Reinhardt *et al* (2007) note:

> Time dilation is one of the most fascinating aspects of special relativity as it abolishes the notion of absolute time

In their 2007 paper they investigate the effects of time dilation with even more accurate atomic clocks, adding more experimental evidence consistent with special relativity. There are also numerous other experiments, such as those into muon decay, that provide additional practical evidence that the effect described is real and measurable.

Figure 2: *Over Dorset: Duration 55 minutes*

4. IMPLICATIONS FOR EVERYDAY LIFE

The practical implications for everyday life at first appear intangible when one considers the seemingly miniscule time periods being discussed. Even taking some of the most extreme examples one can imagine being feasible, such as that of a cosmonaut living in a fast low earth orbit, circumnavigating the earth every 90 minutes gives γ of approximately 1.0000000003.

If one considers our astronaut in orbit for two years, the Time Dilation due to special relativity would give an increase in lifespan of approximately 20 milliseconds. A millisecond is a thousandth (10^{-3} or $^{1}/_{1,000}$) of a second.

This gap of 20 milliseconds, or two hundredths of a second, are suddenly well within human scale perception and understanding. This is a common measured gap in motor racing and fast sports like downhill skiing. Even the record for the 100m sprint is now is 9.58 seconds, run by Usain Bolt at the World Athletics championships in Berlin in 2009.

Scales in milliseconds are spaces and durations that even humans with our modest lifespans can perceive and understand.

As Ed Lu, Science Officer on the International Space Station writes, from orbit, in his blog post on experiments in 'Relativity':

> After our 6 months in space, we will have actually aged slightly less than everyone else on the ground because of an effect called time dilation. It isn't by much (about 0.007 seconds), but it is one side benefit of flying in space!

Though the effects of time dilation at human scale speeds are often imperceptibly small they are nonetheless real. Seeing the implications of this reflected in everyday life reveals the truly personal nature of the time travel that we undertake in everything we do.

The realisation that time dilation is a tangible and observable phenomena that affects ourselves and everything around us was given heightened poignancy by spending large amounts of time flying at altitude and high speed. Observing the curvature of our planet and seeing the dark sky at the edge of space overhead, watching the mountains and deserts as they slid effortlessly under the wings of successive aeroplanes. Being able to observe the size of the individual against the backdrop of a macro-cosmic scale all the while reflecting on the fact that to a subatomic particle travelling near the speed of light, the universe is about four weeks old and it can be crossed in a matter of months.

> Nature can produce even larger particle energies. Some particles striking the Earth's upper atmosphere have energies that exceed 2*1020 eV. If such particles are protons (with mass of about 1 GeV), their speeds would be 0.999 999 999 999 999 999 999 995 c. For them, γ is 1011. Now the age of the universe is about 13 billion years for us, but for such particles, the age of the universe would be about (13 billion years/1011), ie about a month. Such a particle could cross the visible universe in a matter of months (their time).

This twist of perspective, the deliberate 'making strange' that Shlovsky (1917) describes occurs when translating the abstract of the macrocosmic to the intimacy of the personal. The act of comparing and contrasting macro-scale physics and mathematics with recordings of human scale observations evidence reveals useful and potentially significant insights into the nature of the world we actually inhabit.

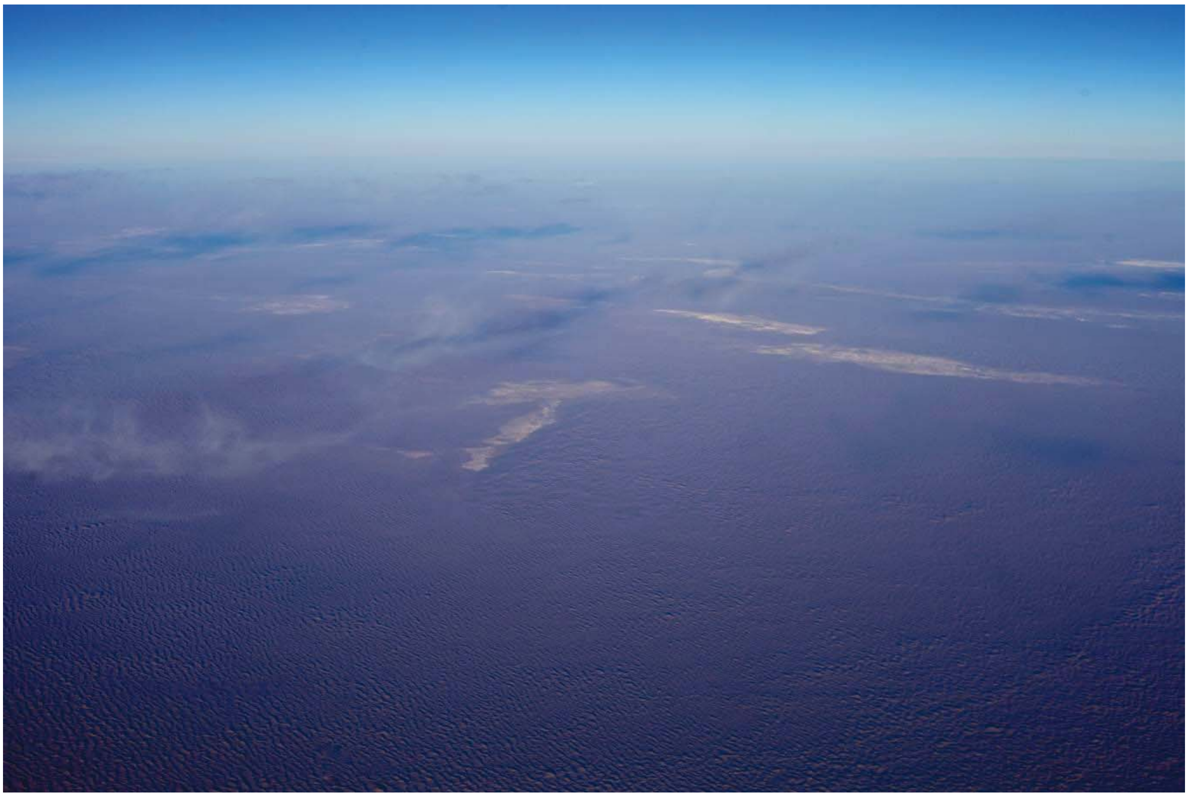

Figure 3: *Sunset over Northern China. Duration: 10 hours 50 minutes*

5. THE PICTORIAL AS PRACTICE-BASED RESEARCH

As Blevis (2011) so eloquently puts it, as an introduction to the extensive list of uses of digital imagery in design thinking.

> **Visual thinking** is the use of imagery and other visual forms to make sense of the world and to create meaningful content. Digital imagery is a special form of visual thinking, one that is particularly salient for HCI and interaction design

Alongside the descriptions of digital imagery as a *'form of information'* and a '*shared and externalised memory and cognition'* (Blevis 2012) I would argue that practice-based research, when used as an investigative tool, can assist in revealing and documenting subtle but important non-verbal evidence and also provide compelling and persuasive arguments within presentation of research findings and conclusions. The research approach taken in this area is explicitly practice-based, rooted within contemporary lens based digital media and video art. The investigative material presented as the counterpart to this research paper was collated from hundreds of minutes of digital video and several hundreds of digital still images taken while airborne on commercial passenger aircraft during January - December 2013. Taken over the course of 44 flights, totalling over 80 hours airborne the visual material is published as a 42 page visual essay, also containing text elements and descriptions taken from this academic paper.

Figure 4: *Sunset over London. Duration: 55 minutes*

6. REALISATION OF EFFECT ON THE PERSONAL

Having recorded the number of flights, durations and distances the calculations based upon the mathematics of special relativity, as discussed earlier show that.

Given 44 flights totalling 85 hours and 20 minutes or approximately 5120 minutes flying time. gives 307,200 seconds of travel per year.

If $\gamma = 1.0000000000005$ when travelling at or near the speed of sound, gives a dilation of 0.0000001536 seconds.

To slip one second from base reference, such as the clock sat on my kitchen table I need to travel at my present annual rate for 6,510,416 Years.

Or to put it a different way, travel for a little over 260,000 years to slip one frame out of sync on a standard rate video camera.

7. CONSIDERING PHOTOGRAPHY IN EVIDENCE

When collating the increasing amounts of video and photographic material recorded whilst airborne, travelling at or near the speed of sound, the overwhelming sensation of velocity, of speed, of travel is ever-present. Viewed at a macro scale the visual material illustrates this distancing, sliding nature of objects moving in a larger framework. It supports the realisation that the terra firma so often taken as a baseline for observation is in itself only a small part of a larger perspective. The perspective that the proprioceptive nature of our observations of time, informed by the physicality of the form we have evolved and the life span perspective we consider as a norm and useful context are challenged by the linking of these measurable effects. The effects of the micro-scale variations in time seen in contrast to the macro-scale movement around the curve of the earth.

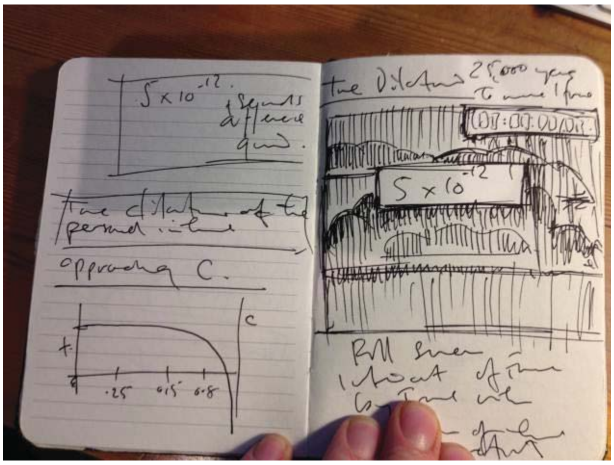
5×10^{-12}
seconds difference
Time dilation of the period in time approaching C.
c
.25
.5
.8
Time Dilation 25,000 years
01:00:00/00
5×10^{-12}

Figure 5: *An airplane travelling near the speed of sound gives a time dilation where γ = 1.0000000000005*

The visual material, when presented as an adjunct to the evidence of the universal but intimately personal nature of the effects of time dilation help communicate the simple fact that we are all time travelling. Pursuing our own clearly delineated paths and durations relative to each other. Rather than there being one universal time that exists everywhere, for everyone, all at the same moment the personal implication that there is real evidence to prove that this is an illusion is both moving and compelling.

Sitting in an airline seat riding at the edge of space, looking down on the oceans, seas, cities, forests and deserts, seeing terra firma for the illusion that it is. Not a constant underlying grid of space and time - the universal yard stick and the universal clock, such as Newtonian physics promised as it replaced the Aristotelian events-make-time view of the world that had reigned before in popular consciousness.

Realising that the H&K caesium clock from 1971 could be sat beside me, ticking away in its own little timetrack, ticking to a completely separate rhythm than its counterpart clock sat on my kitchen table at home. Realising that the slipping and sliding of our lives against each other is our own intimate version of time travel, we all move forward as future becomes present becomes past but the durations we experience, and that actually occur, and when ***now*** happens is subtly different for everyone. The time we each experience actually does expand and contract as we move in space.

Figure 6: *Frost over Mongolia. Duration: 10 hours 55 minutes*

The illusion of the Newtonian ideal of a universal timescale, the idea of a 'universal now' is disappearing and being replaced by the ideas of general relativity. Of a universe full of individual 'nows' all unique and all moving independently. This change is akin to seeing the universe of unique, individual 'nows' at a human, personal scale and seeing a life travelling, sliding, back and forth in time against the 'nows' of those around one.

The important element this body of work seeks to describe is not physics or even a discussion of physics but an explanation of physics and the revelatory moment of seeing it in 'real' experienced life. This work seeks to relate that revelatory moment and articulate it with the artefacts, the book and the paper, telling the story of seeing how each and every one of us is travelling in time, independently, uniquely, every day.

> To see a World in a Grain of Sand
> And a Heaven in a Wild Flower,
> Hold Infinity in the palm of your hand
> And Eternity in an hour. (William Blake)

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St. Clair (43) **Pub. Date: Dec. 18, 2003**

(54) ROTOR INDUCTANCE PROPULSION SYSTEM

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(52) **U.S. Cl.** **244/172**

(57) ABSTRACT

The invention is a spacecraft having a circular, domed hull around which dual electrically-charged rotors one above the other are counter-rotating on the edge of the hull. Embedded in the hull are three solenoids which create a positive vector potential at the rotors. The surface charge density times the radius times the vector potential times the area of the rotors creates an angular momentum in the vertical direction. This angular momentum produces a positive spacetime curvature over the dome of the hull and a negative spiking spacetime compression over the rotors. By machining circumferential grooves of decreasing height along the radius of the rotor, a negative surface inductance is generated. This negative inductance gradient times the negative spacetime compression time the rotor current density squared times the rotor area squared is a positive lift force on the spacecraft.

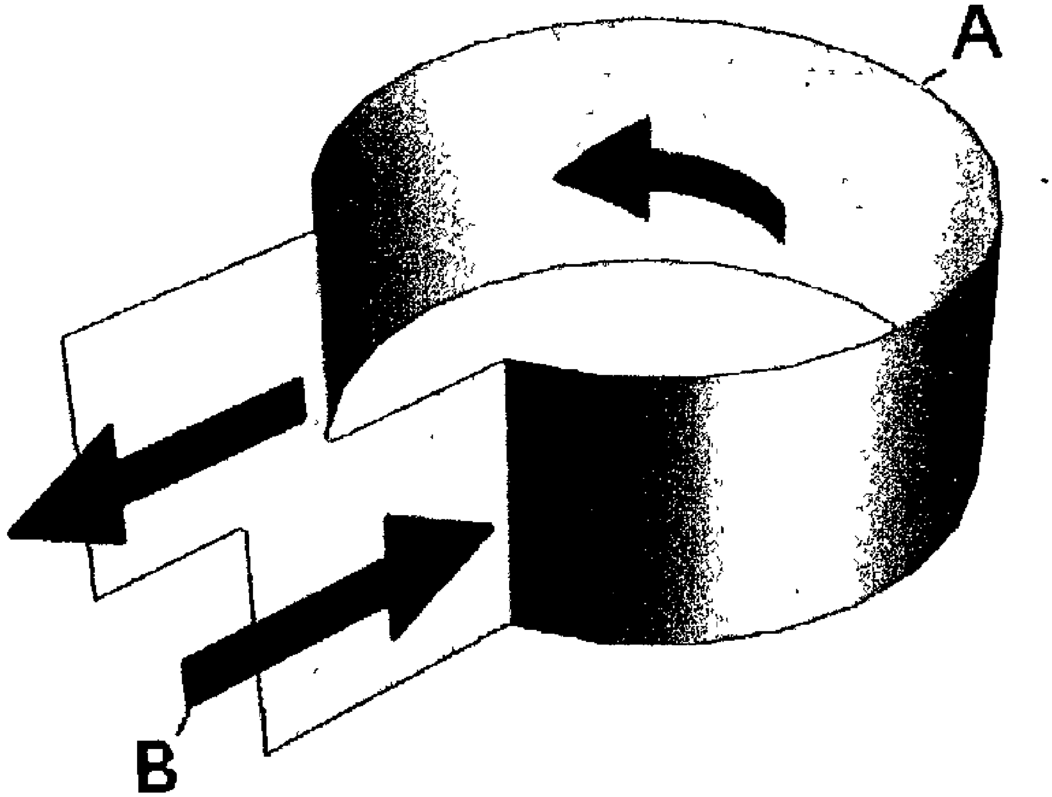

Figure 1

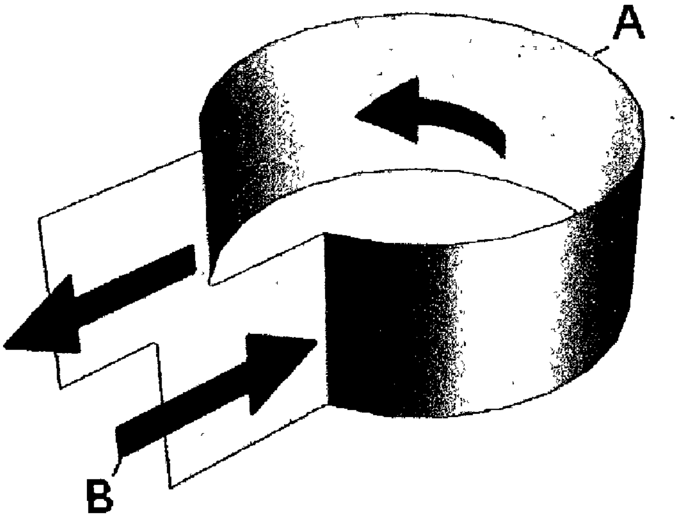

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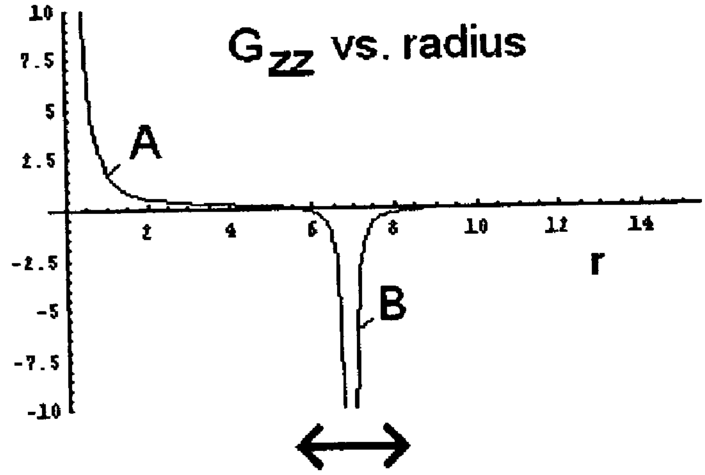

Figure 3

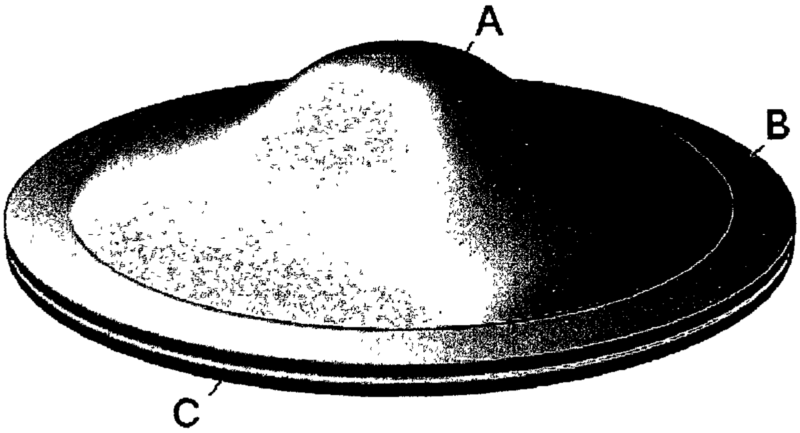

Figure 4

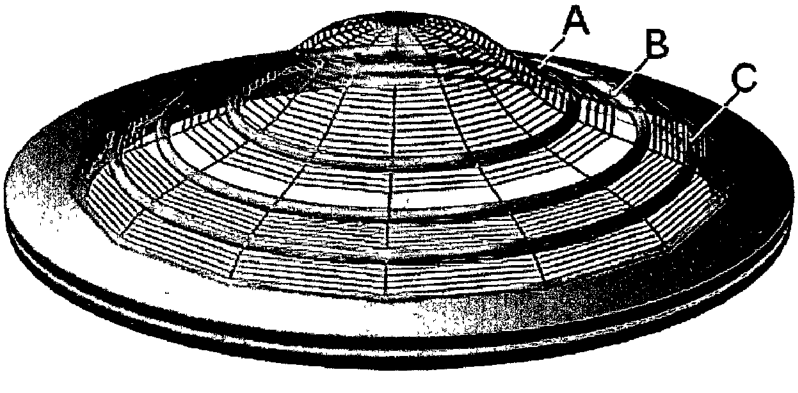

Figure 5

$$A = \frac{n\,I\,a^2}{2\varepsilon_0 c^2}\frac{1}{r'}$$

Figure 6

$$A \equiv \frac{1}{\mathrm{m}}\frac{\mathrm{coul}}{\mathrm{sec}}\mathrm{m}^2\,\frac{\mathrm{m}^2\mathrm{kg}\,\mathrm{m}}{\mathrm{coul}^2\,\mathrm{sec}^2}\,\frac{\mathrm{sec}^2}{\mathrm{m}^2}\,\frac{1}{\mathrm{m}} = \frac{\mathrm{kg}\,\mathrm{m}}{\mathrm{sec}\,\mathrm{coul}}$$

Figure 7

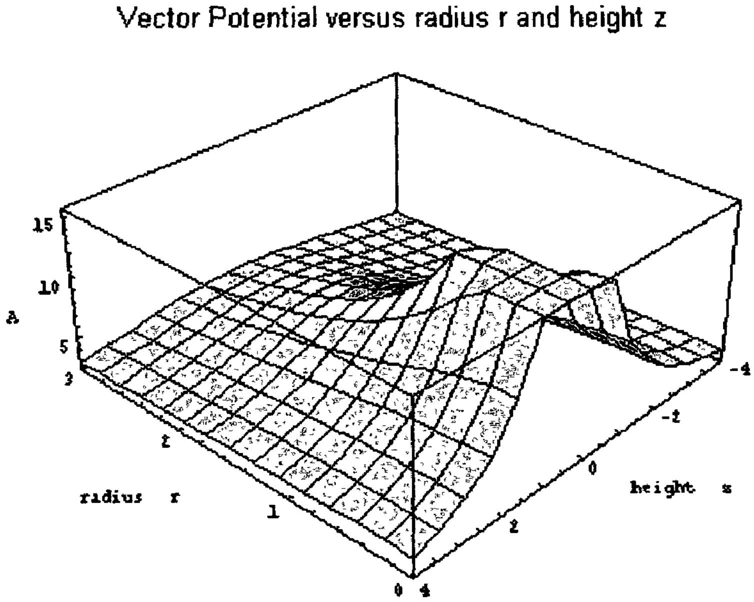

Vector Potential versus radius r and height z

Figure 8

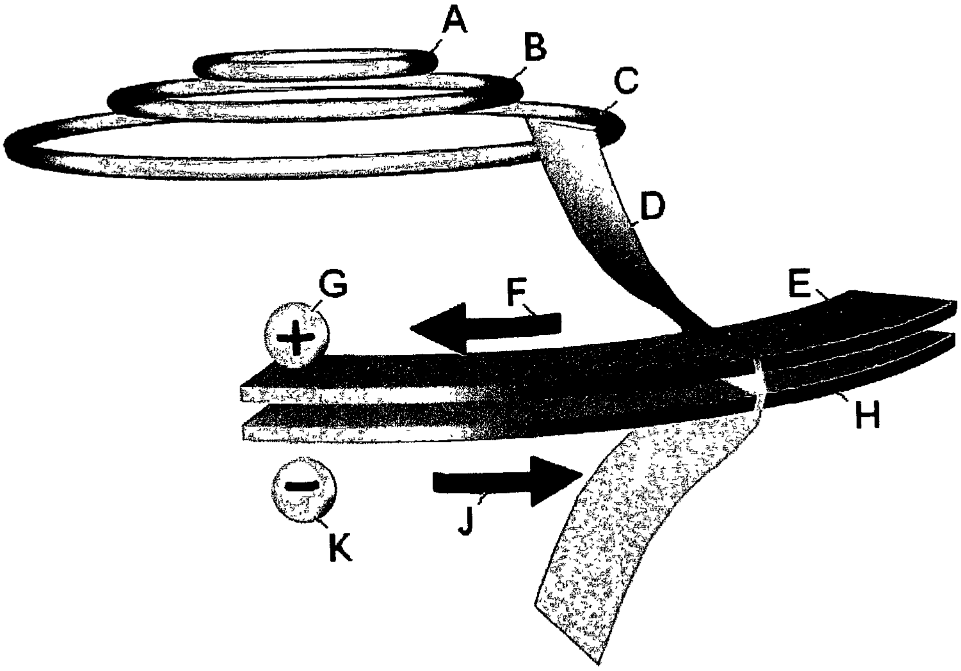
A
B
C
D
E
F
G
H
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K

Figure 9

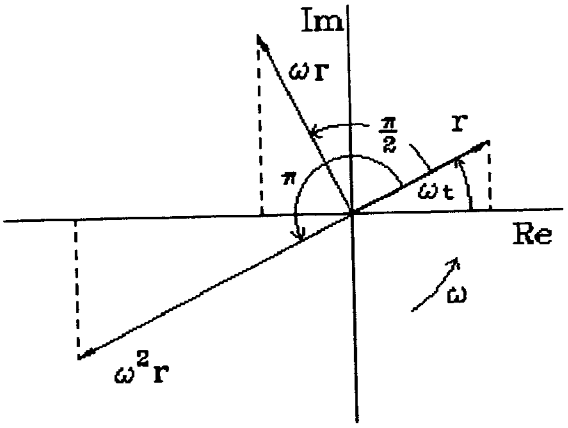
Im
ωr
$\frac{\pi}{2}$
r
π
ωt
Re
ω
$\omega^2 r$

Figure 10

$$
\begin{aligned}
S_k &= \left[-\sigma r e^{i\omega t} + \sigma r e^{-i\omega t}\right] \frac{n I a^2}{2\varepsilon_0 c^2} \frac{n_z \mathrm{area}}{r'} \\
&= -\left[e^{i\omega t} - e^{-i\omega t}\right] \left[\sigma r \frac{n I a^2}{2\varepsilon_0 c^2} \frac{n_z \mathrm{area}}{r'}\right] \\
&= -\left[e^{i\omega t} - e^{-i\omega t}\right] K
\end{aligned}
$$

Figure 11

$$
S \equiv \frac{\mathrm{coul}}{\mathrm{m}^2}\,\mathrm{m}\,\frac{1}{\mathrm{m}}\,\frac{\mathrm{coul}}{\mathrm{sec}}\,\mathrm{m}^2\,\frac{\mathrm{m}^2}{\mathrm{coul}^2}\,\frac{\mathrm{kg\,m}}{\mathrm{sec}^2}\,\frac{\mathrm{sec}^2}{\mathrm{m}^2}\,\frac{\mathrm{m}^2}{\mathrm{m}} = \frac{\mathrm{kg\,m}^2}{\mathrm{sec}}
$$

Figure 12

$$
e^{i\omega t} - e^{-i\omega t} = 2 i \mathrm{Sin}[\omega t]
$$

Figure 13

$$
S_k = -2 i K \mathrm{Sin}[\omega t]
$$

Figure 14

$$ds^2 = \ldots - 4\frac{S}{r}dtd\theta = \ldots 8\frac{iK\,\mathrm{Sin}[\omega t]}{r}dtd\theta$$

Figure 15

$$g_{\mu\nu} = \begin{array}{c|cccc|} & t & r & \theta & z \\ t & -1 & 0 & 4\frac{iK\,\mathrm{Sin}[\omega t]}{r} & 0 \\ r & 0 & 1 & 0 & 0 \\ \theta & 4\frac{iK\,\mathrm{Sin}[\omega t]}{r} & 0 & r^2 & 0 \\ z & 0 & 0 & 0 & 1 \end{array}$$

Figure 16

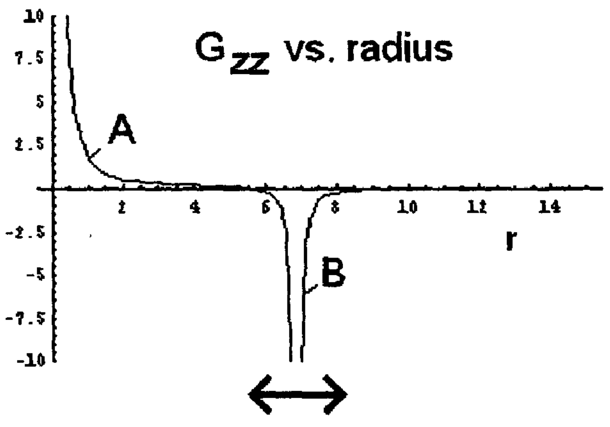

Figure 17

$$\text{Magnetic Energy} = -L\,K\,J^2\,A^2$$

Figure 18

$$\text{Magnetic Energy} \equiv -\frac{\text{kg}\,\text{m}^2}{\text{coul}^2}\,\frac{1}{\text{m}^2}\,\frac{\text{coul}^2}{\text{sec}^2\,\text{m}^2}\,\text{m}^4 = -\frac{\text{kg}\,\text{m}^2}{\text{sec}^2} = -\text{joule}$$

Figure 19

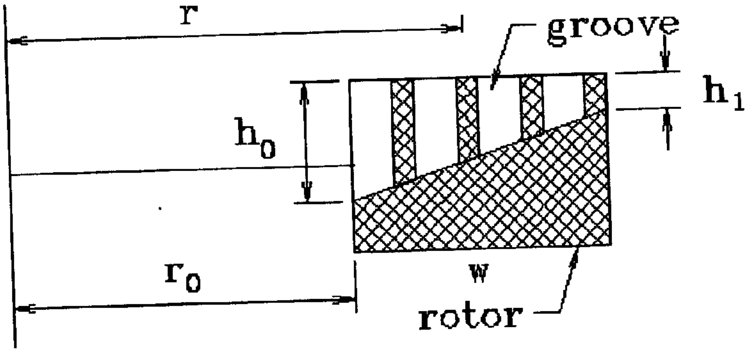

Figure 20

$$h = h_0 - (r - r_0)\left(\frac{h_0 - h_1}{W}\right)$$

Figure 21

$$\frac{dL}{dr} = \mu n^2 2\pi w \frac{\partial}{\partial r}\left(r\left(h_0 - (r - r_0)\left(\frac{h_0 - h_1}{w} \right) \right) \right)$$

$$\frac{dL}{dr} = \mu n^2 2\pi w\left(h_0 - \frac{(h_0 - h_1)(2r - r_0)}{w} \right)$$

Figure 22

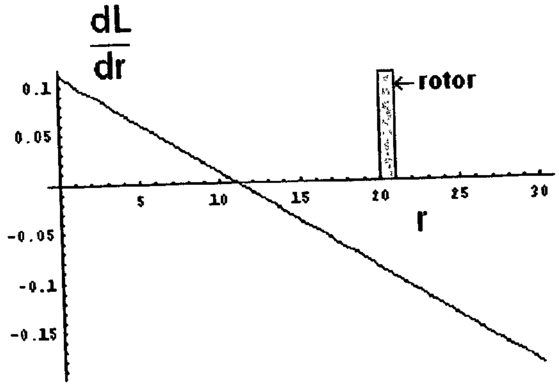

Figure 23

$$F = \frac{dL}{dr} K_c J^2 A^2 = \frac{kg\,m}{coul^2}\frac{1}{m^2}\frac{coul^2}{sec^2\,m^2} m^4 = \frac{kg\,m}{sec^2} = newton$$

ROTOR INDUCTANCE PROPULSION SYSTEM

BRIEF SUMMARY OF THE INVENTION

[0001] The invention, which is the object of my present application, is a spacecraft with a circular, domed hull around which are located dual electrically-charged counter-rotating rotors. The top surface of the upper rotor is etched with circular metallic grooves which give the rotor a surface inductance. The groove height decreases from the inside radius to the outside radius of the rotor giving it a radial inductance gradient. The surface charge density times the angular velocity produces a current density. The counter-rotating rotors produce a negative spacetime curvature over the rotors. The negative surface inductance gradient times the negative spiking spacetime curvature times the current density squared times the area squared is the positive lift force on the rotor.

REFERENCE WORKS

[0002] *Gravitation*, Wheeler

[0003] *Traveling-Wave Tubes*, The Bell System Technical Journal, Vol. XXIX, January 1950, No. 1, J. R. Pierce.

[0004] *The Magnetron as a Generator of Centimeter Waves*, The Bell System Technical Journal, Vol. XXV, April 1946, No. 2, J. B. Fisk, H. D. Hagstrum, P. L. Hartman.

[0005] *Lectures on Physics*, Richard Feynman

[0006] *Geometry of Electromagnetism*, Paul Hammond

BACKGROUND OF THE INVENTION

[0007] I was reading several articles about the development of the magnetron during World War II in the Bell System Technical Journal. I was trying to understand why the device resonates because it must contain a spring constant which would arise from an inductance and capacitance due to the geometry of the cavity. As given by Feynman, inductance of a solenoid is the permeability of space times the turns per length squared times the volume of the solenoid. Referring to **FIG. 1**, the magnetron cavity (A) has a circular region connected to a planar region. The electrical current flows on the sides of the cavity shown by the arrows (B). In this case, there is only one turn per height of the cavity times the volume of the cavity times the permeability which produces the inductance. The two planar regions produce a capacitance across the ends which creates the resonant frequency.

[0008] From my previous patent application Dual Rotor Propulsion System I know that the two rotors produce a current density in the angular direction along the rotor. If I spread out the magnetron cavity into a circular groove around a rotor, then the current would flow on the side walls enclosing the groove volume. The rotors also produce a spacetime curvature profile as shown in **FIG. 2**. Curve (A) is a positive spacetime curvature tension over the dome. Curve (B) is a negative spiking spacetime curvature over the rotors. The curvature is measured in inverse meter squared. So the surface inductance times the negative curvature times the current density squared times the rotor area squared is magnetic energy. The differential of the magnetic energy would be a force. So there has to be a gradient of the surface inductance. The volume element of a groove is equal to the circumferential length times the height times the width of the groove. The easiest is to vary the height with radius. Since the curvature is negative, the gradient has to be negative as well in order to get a positive lift force. Thus the height goes from large to small from the inside to the outside radius.

SUMMARY OF THE INVENTION

[0009] The invention relates to a spacecraft with a domed, circular hull of elliptical cross-section having dual electrically-charged counter-rotating rotors located one above the other on the edge of the hull. The upper rotor is positively charged and rotates clockwise with a negative angular velocity per the right-hand rule. The lower rotor is negatively charged and rotates with a positive angular velocity. The current density is the surface charge density times the velocity of the rotor. This particular combination of velocity and charge produces an angular momentum which creates a negative spiking spacetime curvature over the rotors.

[0010] The top surface of the rotor is etched or machined with circular grooves around the rotor. This creates a surface inductance which is equal to the permeability of space times the turns per length squared times the volume of the groove. In this case, there is only one turn per height of the groove. If the height of the groove decreases from one groove to the next, then there is a negative surface inductance gradient in the radial direction. So the lift force on the rotors would be the negative surface inductance gradient times the negative spacetime curvature times the current density squared times the rotor area squared.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0011] Not Applicable.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0012] **FIG. 1**. Perspective of magnetron cavity.

[0013] **FIG. 2**. Spacetime curvature G_{zz} over hull and rotor.

[0014] **FIG. 3**. Perspective view of spacecraft with dual rotors.

[0015] **FIG. 4**. Wire frame view of three solenoids.

[0016] **FIG. 5**. Vector potential equation for solenoid.

[0017] **FIG. 6**. Units of vector potential.

[0018] **FIG. 7**. 3D graph of vector potential using three solenoids.

[0019] **FIG. 8**. Perspective of vector potential along rotors.

[0020] **FIG. 9**. Rotor mechanics diagram using exponential representation.

[0021] **FIG. 10**. Angular momentum equation due to vector potential and rotating charged rotors.

[0022] **FIG. 11**. Units of angular momentum.

[0023] **FIG. 12**. Exponential equation for twice imaginary sine of the angle.

[0024] **FIG. 13**. Angular momentum equation for g metric tensor.

[0025] **FIG. 14**. Angular momentum term for elemental line length ds^2.

[0026] **FIG. 15**. The g metric tensor containing the angular momentum.

[0027] **FIG. 16**. The spacetime curvature tension G_{zz} versus radius due to angular momentum.

[0028] **FIG. 17**. Magnetic energy equation.

[0029] **FIG. 18**. Units of magnetic energy.

[0030] **FIG. 19**. Cross-section of rotor showing groove height gradient.

[0031] **FIG. 20**. Equation for the height h of the rotor groove as a function of radius.

[0032] **FIG. 21**. Equation for the groove inductance gradient.

[0033] **FIG. 22**. Plot of the groove inductance gradient as a function of radius showing that it is negative at the rotor.

[0034] **FIG. 23**. Lift force on rotors due to inductance gradient, compression curvature, rotor current density and area.

DETAILED DESCRIPTION OF THE INVENTION

[0035] 1. Referring to **FIG. 3**, the spacecraft has a circular, domed hull of elliptical cross-section with dual electrically-charged counter-rotating rotors one above the other on the edge of the hull.

[0036] 2. Referring to **FIG. 4**, embedded within the hull are three solenoids or current loops carrying a constant electrical current in the positive sense per the right-hand rule.

[0037] 3. Referring to **FIG. 5**, Feynman has shown that the vector potential {A} of a solenoid is equal to the number of turns per length {n} times the current {I} times the radius of the solenoid {a} squared divided by half the permittivity of space {ϵ_0} times the speed of light {c} squared times the radius {r'} prime from the center of the coil to some location in space such as the rotors. It has been found by physicists Bohm and Aharanov that the vector potential field is not confined to an infinitely long solenoid as is the magnetic B field. The vector potential has units of kilogram-meter per second-coulomb as seen in **FIG. 6**.

[0038] 4. Referring to **FIG. 7**, the three solenoids of varying radius and area produce a positive vector potential at the centerline of the rotors as seen in the graph.

[0039] 5. This graph is then rotated ninety degrees so that it can be located in relation to the rotors as seen in **FIG. 8**. The vector potential (D), which is created by solenoids (A,B,C), passes through rotors (E) and (H). Rotor (E), which has a positive charge (G), is rotating clockwise (F), and rotor (H), which has a negative charge (K), is rotating counter-clockwise (J).

[0040] 6. Referring to **FIG. 9**, rotor mechanics uses the exponential function for the harmonic motion of the rotor. The radius is {$r\ e^{i\omega t}$} which when differentiated with respect to time becomes a velocity {$i\ \omega\ r\ e^{i\omega t}$} where the imaginary {i} is a 90° phase lead which makes the velocity tangential to the rotor.

[0041] 7. The rotor surface charge {σ sigma} is rotating around at some radius {r}. For the upper rotor the surface charge density is positive (+σ} but the rotor has a negative angular velocity {−ω}. For the lower rotor, the surface charge density is negative {−σ} but the rotor has a positive angular velocity {+ω}. So the combined surface charge rotation is {$-\sigma\ r\ e^{i\omega t}+\sigma\ r\ e^{-i\omega t}$}. This charge rotation times the positive vector potential due to the solenoids times the rotor surface area is equal to angular momentum S as shown in **FIG. 10**. The units are given in **FIG. 11**. The angular momentum is equal to the negative of the difference of the exponentials times a constant. I then recalled that this difference is equal to twice imaginary sine of the angle as shown in **FIG. 12**.

[0042] 8. Referring to **FIG. 13**, the angular momentum is equal to minus two times the imaginary number times a constant times the sine of the rotational angle. In most of my spacecraft designs, the electromagnetic fields determine the flow rate of angular momentum. When the flow rate is integrated with respect to time, the angular momentum becomes imaginary. In this invention, the angular momentum is imaginary due directly to the rotors. The importance of being imaginary is that the radius resonates with the angular momentum. In some spacetime curvature equations, the denominator has a term equal to the radius to the fourth power plus twice the square of the angular momentum. In spacetime units, angular momentum is viewed as meter squared. So the square of imaginary angular momentum is negative angular momentum equal to negative meters to the fourth power. So at some radius, these two terms are equal, the denominator goes to zero, and the spacetime curvature becomes infinitely-large, creating a huge spike.

[0043] 9. This next section calculates the spacetime curvature from the equation for the angular momentum.

[0044] 10. Referring to **FIG. 14**, the elemental length ds^2 is curved by the presence of the angular momentum which is one of the energies, such as mass, charge, and electromagnetic fields, that Einstein showed can curve spacetime. Because the angular momentum is pointing in the vertical z-direction, due to the direction of the unit normal vector to the surface of the rotor, it rotates around in the angular direction {dtdθ} as found in cylindrical coordinates {t,r,θ,z}.

[0045] 11. In gravitational physics there is a g metric tensor which is a measure of length in spacetime coordinates. It is a 4 by 4 matrix with rows and columns equal to the cylindrical coordinates. Referring to **FIG. 15**, the diagonal of the matrix is {$-1,1,r^2,1$} where the minus one corresponds to time which is Einstein's convention. Half the angular momentum goes in the {tθ} slot of the g metric tensor, and the other half goes in the {θt} slot.

[0046] 12. From this g metric tensor, Einstein's G curvature tensor can be calculated in the various directions. In Einstein's General Theory of Relativity, his equation is G=8πT where G is the spacetime curvature measured in inverse meter squared, and the T tensor is the stress-energy-momentum matrix containing all the electromagnetic pressures, mass and momentum components that curve spacetime. The spacetime curvature tension G_{zz} in the vertical direction, as a function of radius, is shown in **FIG. 16**. A positive curvature indicates that there is a spacetime tension over the hull which produces lift. The curvature has a large positive spike over the dome of the hull (A) which means that there is a large lift force over the center of the hull. The curvature then falls off and spikes with a negative spacetime curvature compression over the rotors (B). This curvature also oscillates back and forth a short distance due to the sinusoidal term. The problem is to convert this compression into a lift force which this invention solves.

[0047] 13. This next section shows how the spacetime compression over the rotors generates lift.

[0048] 14. As I mentioned, I have been reading some of the World War II magnetron scientific papers of the Bell System Technical Journal. It turns out that inductance of a solenoid is equal to the permeability of space times the number of wire turns per length squared times the volume of the solenoid. Imagine having a copper strip in the shape of the magnetron cavity in **FIG. 1**. The electrical current (B) flows around the height of the strip (A), so there is only one turn per the height. Then that is multiplied by the volume of the cavity and permeability to get the inductance. The inductor is storing magnetic energy equal to half the inductance times the current squared. In this invention, current density J in amp per meter is used rather than current. So taking a hint from this information, the magnetic energy would have to be related to the inductance times the square of the current density times the area squared of the rotor and times the negative spacetime curvature. The curvature is measured in inverse meter squared. That product produces a negative magnetic energy when in fact I want a positive force. This means that there has to be an inductance gradient in the equation instead of pure inductance and, furthermore, the gradient has to be negative in order to cancel out the negative sign of the compression curvature.

[0049] 15. The equation for the magnetic energy in terms of the inductance $\{\mathcal{L}\}$, curvature {K}, current density {J} and area {A} is shown in **FIG. 17** with the units in **FIG. 18**. The inductance in the equation is proportional to the volume of the circular groove in the top surface of the rotor. That volume is equal to {2π r h w} where {h] is the height of groove (depth) and {w} is the width located at some radius {r}. In terms of machining, it would be more difficult to machine a variable width groove rather than a deeper groove of a constant width. So I am going to say the gradient is in the radial direction with the height of the groove decreasing going from the inside radius to the outside radius as depicted in **FIG. 19**.

[0050] 16. **FIG. 20** gives the equation for the height of the groove along the radius of the rotor.

[0051] 17. **FIG. 21** gives the inductance gradient by differentiating the inductance with respect to the radius. The initial groove height ho is not very large, and the inductance gradient becomes negative at the rotor as seen in the graph of **FIG. 22**.

[0052] 18. Referring to **FIG. 23**, the lift force on the rotor is now positive due to the combined negative inductance gradient times the negative spacetime compression. The square of the negative current density is positive also. This means that that the top surface of the lower rotor can also have a surface inductance gradient which would double the lift force.

What I claim as my invention is:

1. A spacecraft having a circular, domed hull with dual electrically-charged counter-rotating rotors one above the other located on the edge of hull.

2. Said hull having embedded within it three or more solenoids which generate a positive vector potential at the rotors.

3. Said upper rotor having a positive surface charge density, and rotating clockwise in the negative direction per the right-hand rule.

4. Said lower rotor having a negative surface charge density, and rotating counterclockwise in the positive direction per the right-hand rule.

5. Said rotor surface charge density and velocity creating a negative current density on both rotors.

6. Said vector potential and rotating surface charge density on rotors generating an angular momentum in the vertical direction.

7. Said angular momentum, generating a spacetime curvature tension over the dome of the hull, and a negative oscillating spacetime curvature compression over the rotors.

8. Said rotors having circumferential grooves of decreasing height machined into the top surface of the rotors in order to create a negative surface inductance gradient.

9. Said negative surface inductance gradient times the negative spacetime curvature compression times the rotor current density squared times the rotor area squared generating a positive lift force on the spacecraft.

* * * * *

US 20060014125A1

(19) **United States**
(12) **Patent Application Publication**
St. Clair
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(43) **Pub. Date: Jan. 19, 2006**

(54) **WALKING THROUGH WALLS TRAINING SYSTEM**

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Publication Classification

(51) **Int. Cl.**
G09B 19/00 (2006.01)
(52) **U.S. Cl.** **434/258**

(57) **ABSTRACT**

This invention is a training system which enables a human being to acquire sufficient hyperspace energy in order to pull the body out of dimension so that the person can walk through solid objects such as wooden doors.

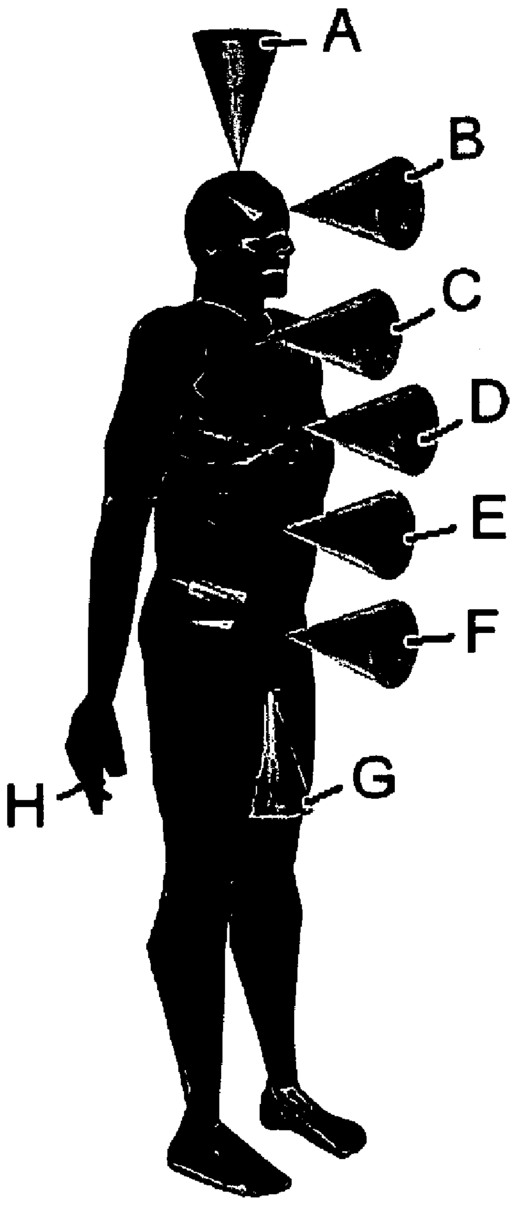

Figure 1

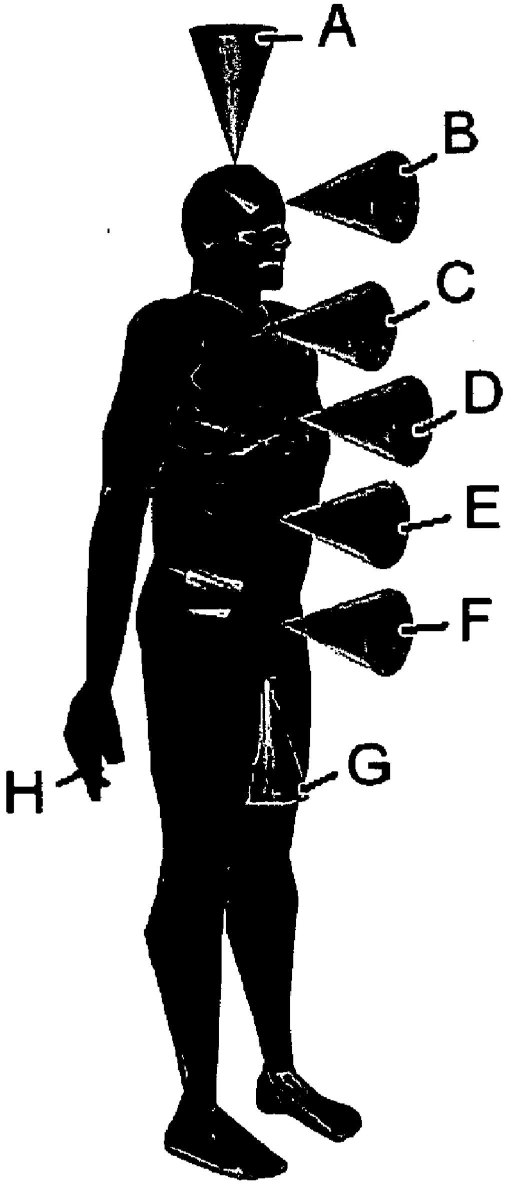

Figure 2

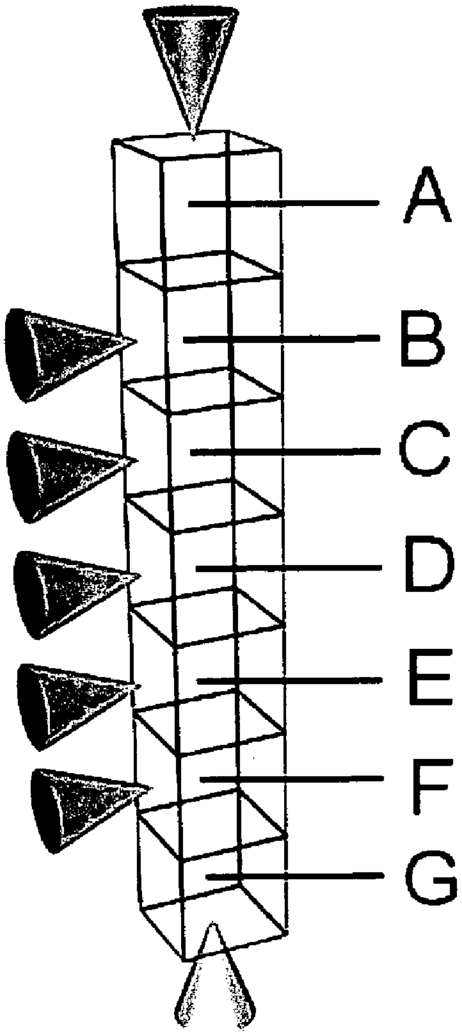

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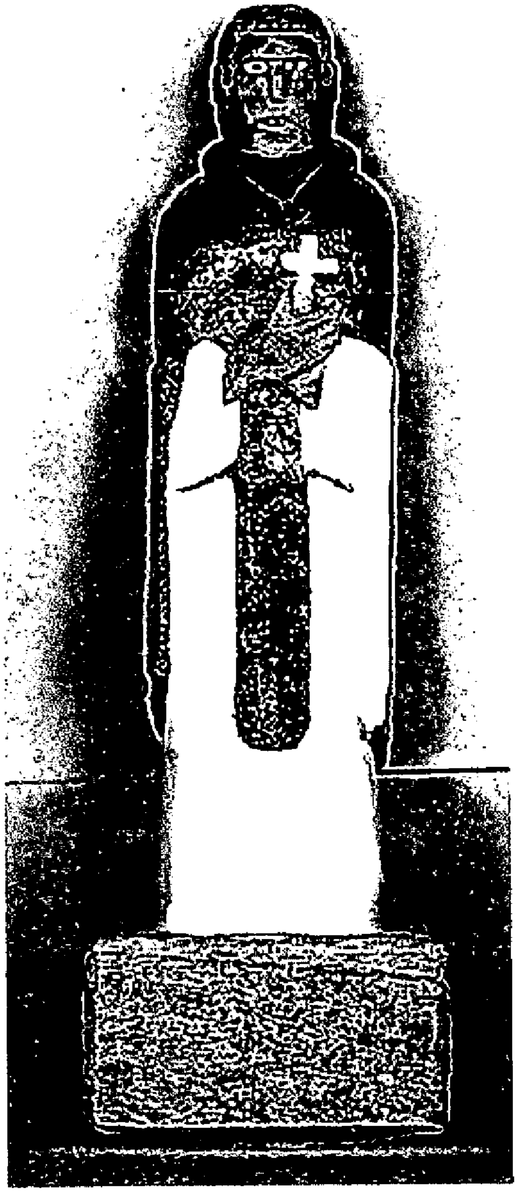

Figure 4

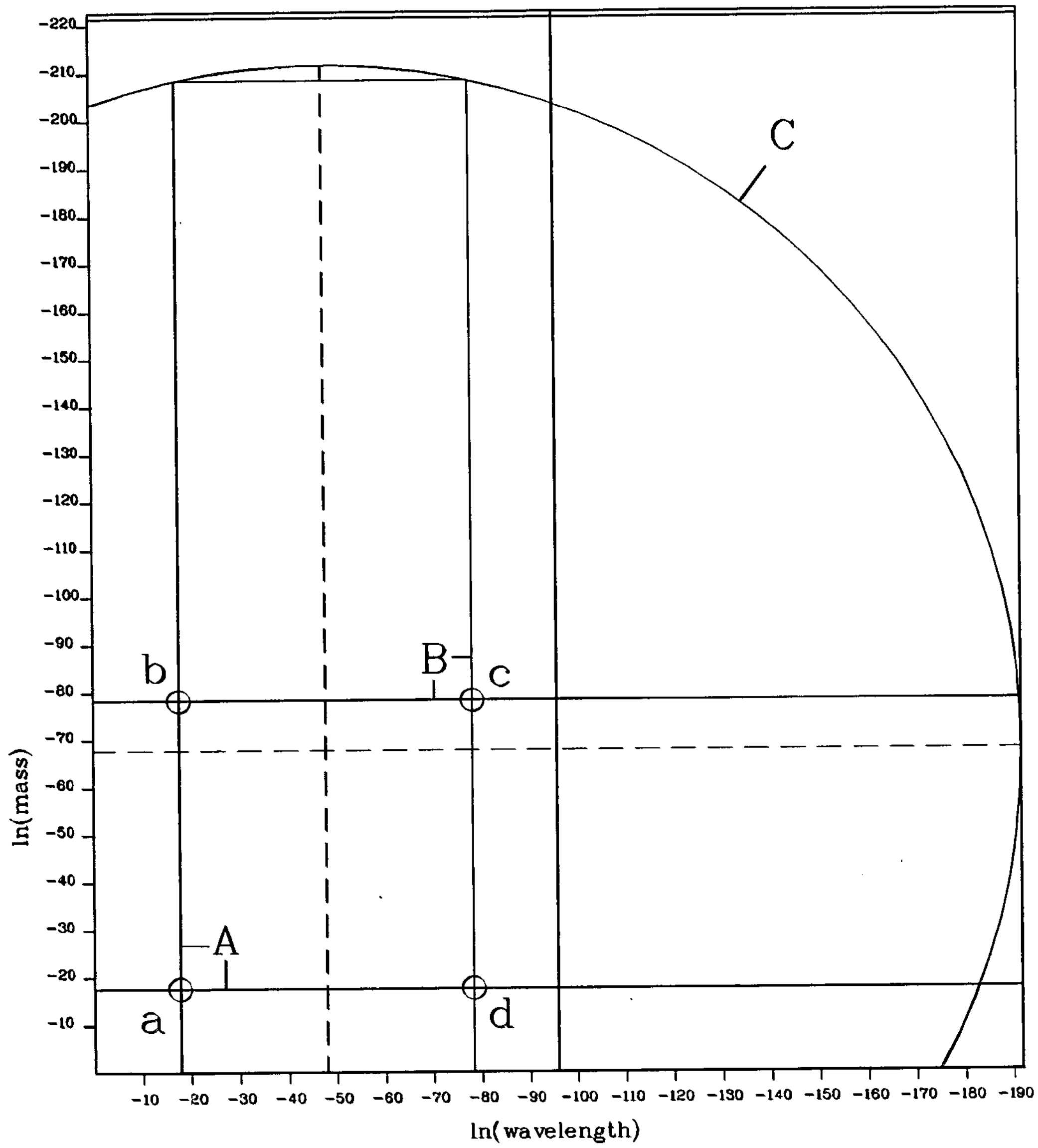
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Figure 5

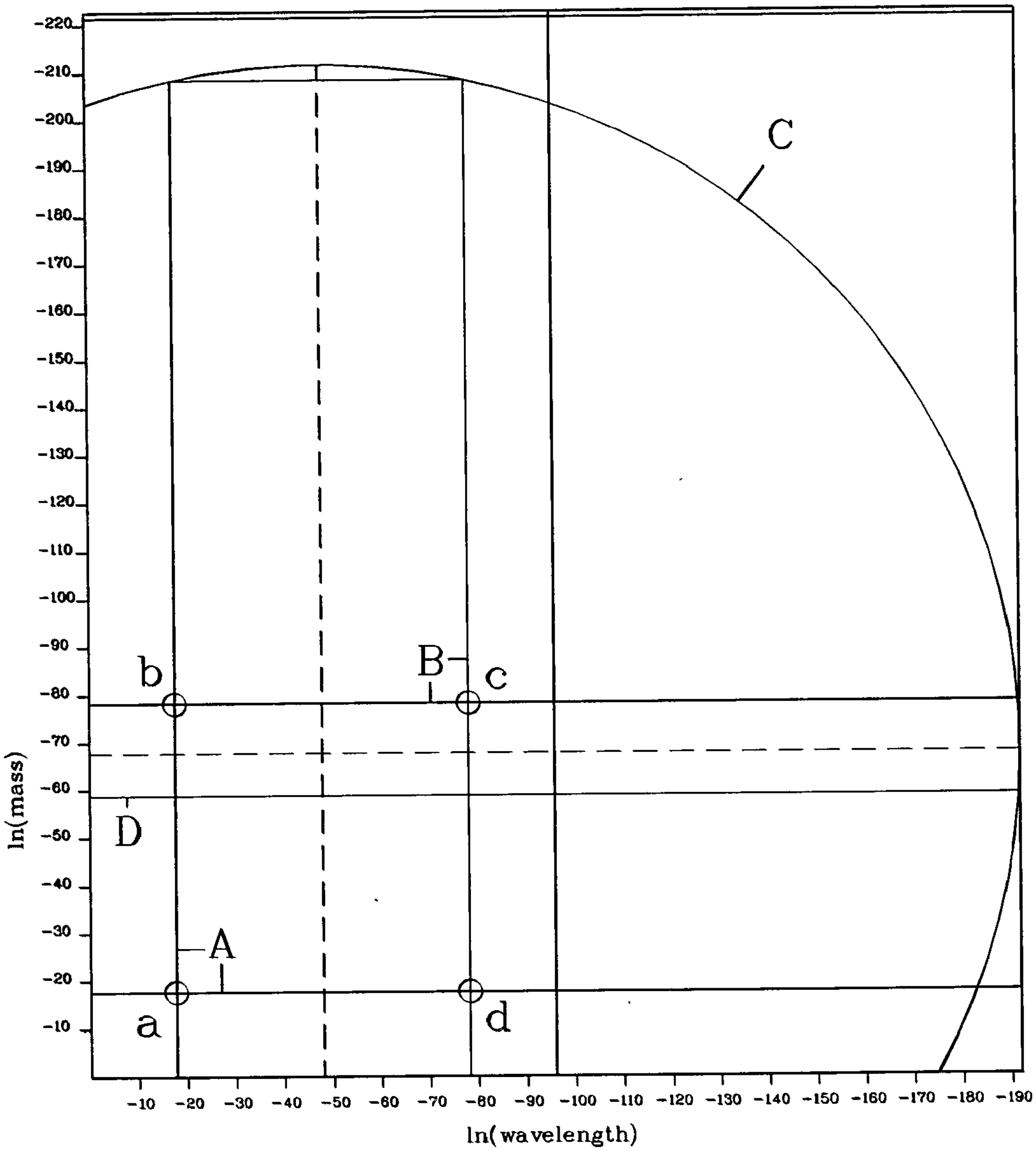
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Figure 6

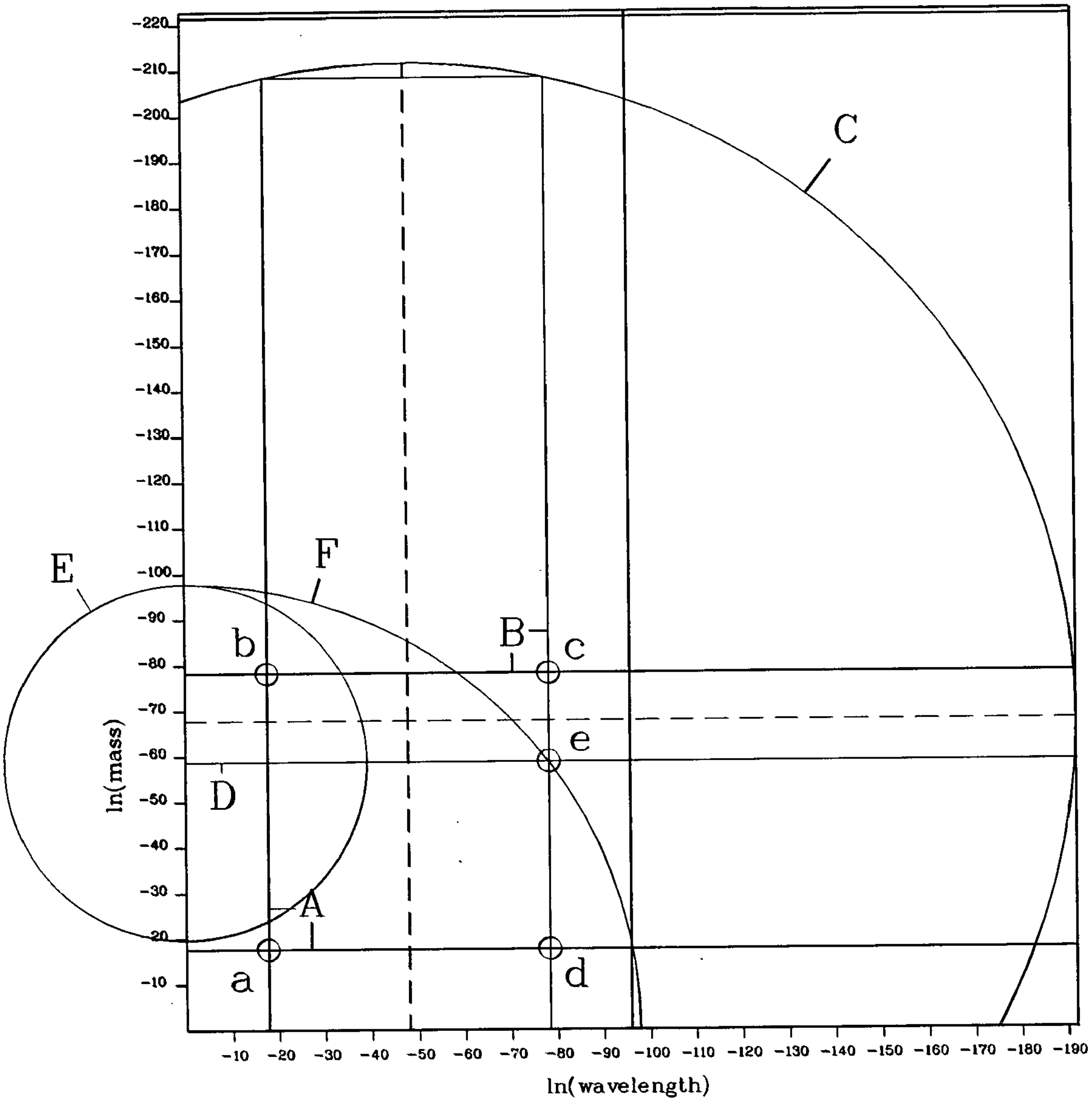

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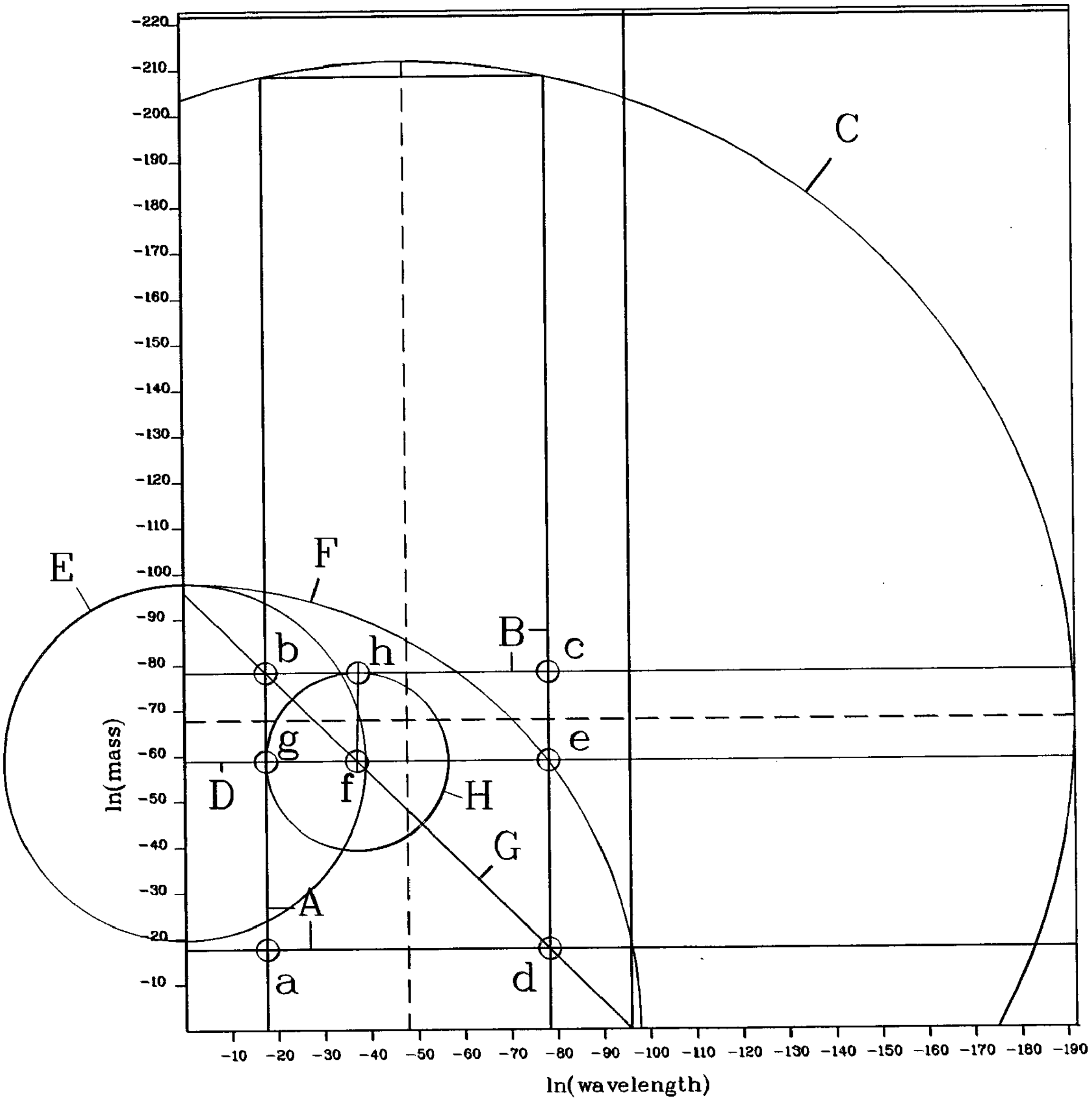
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Figure 8

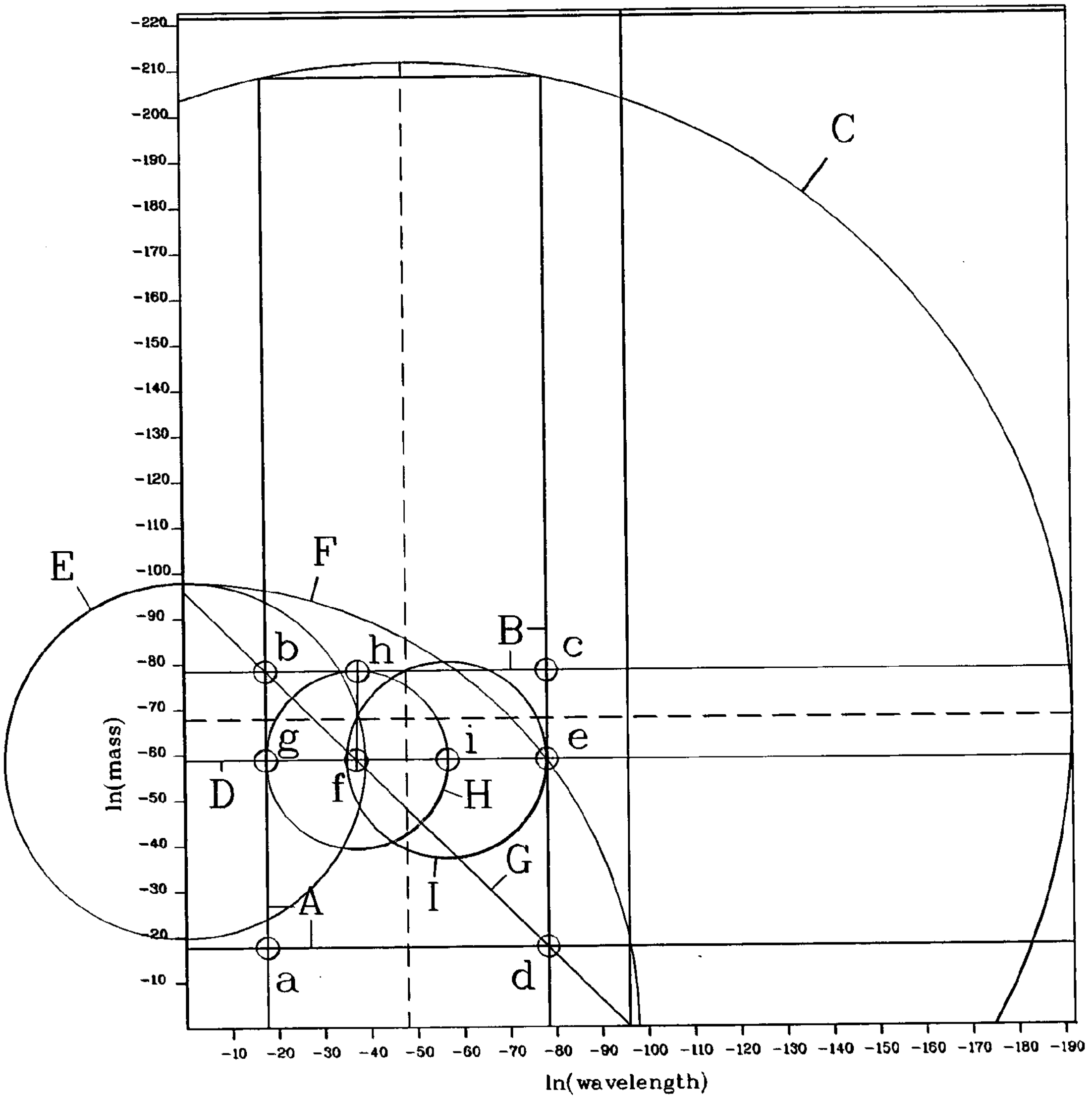
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Figure 9

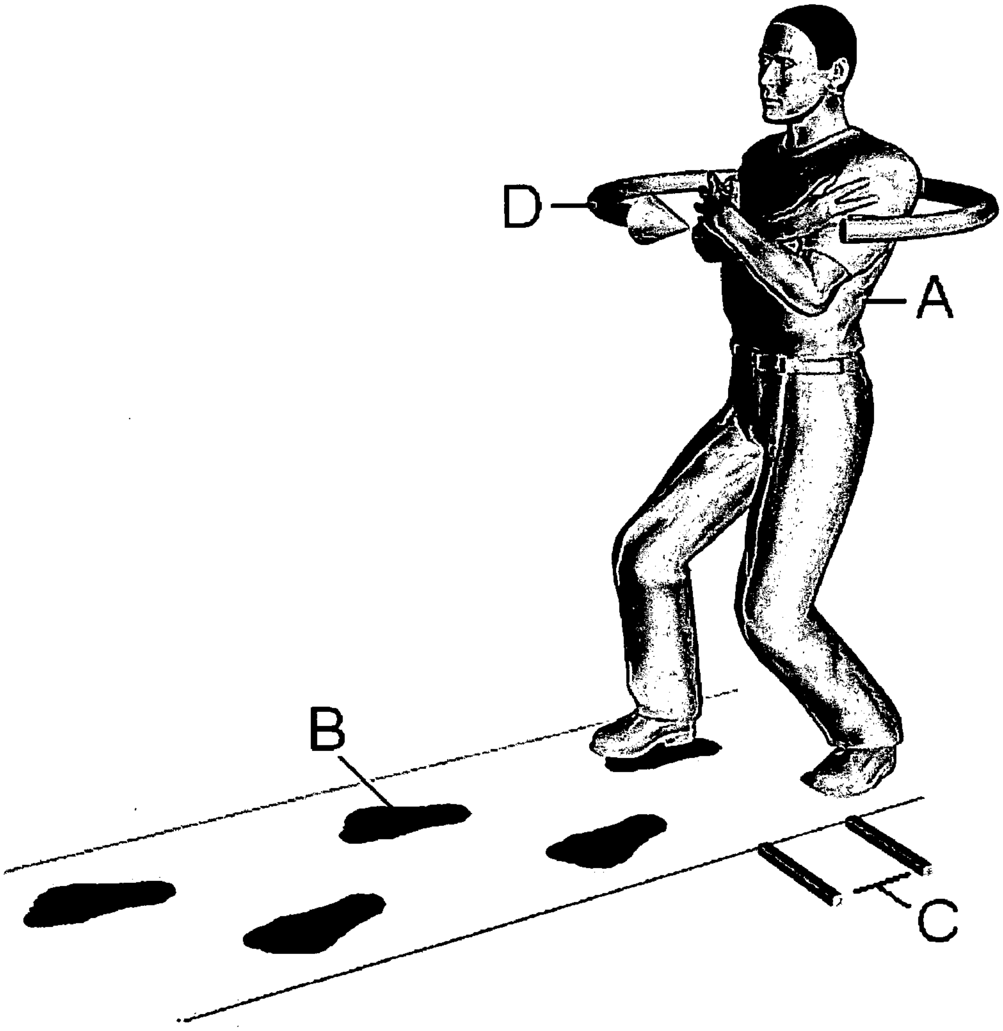

Figure 10

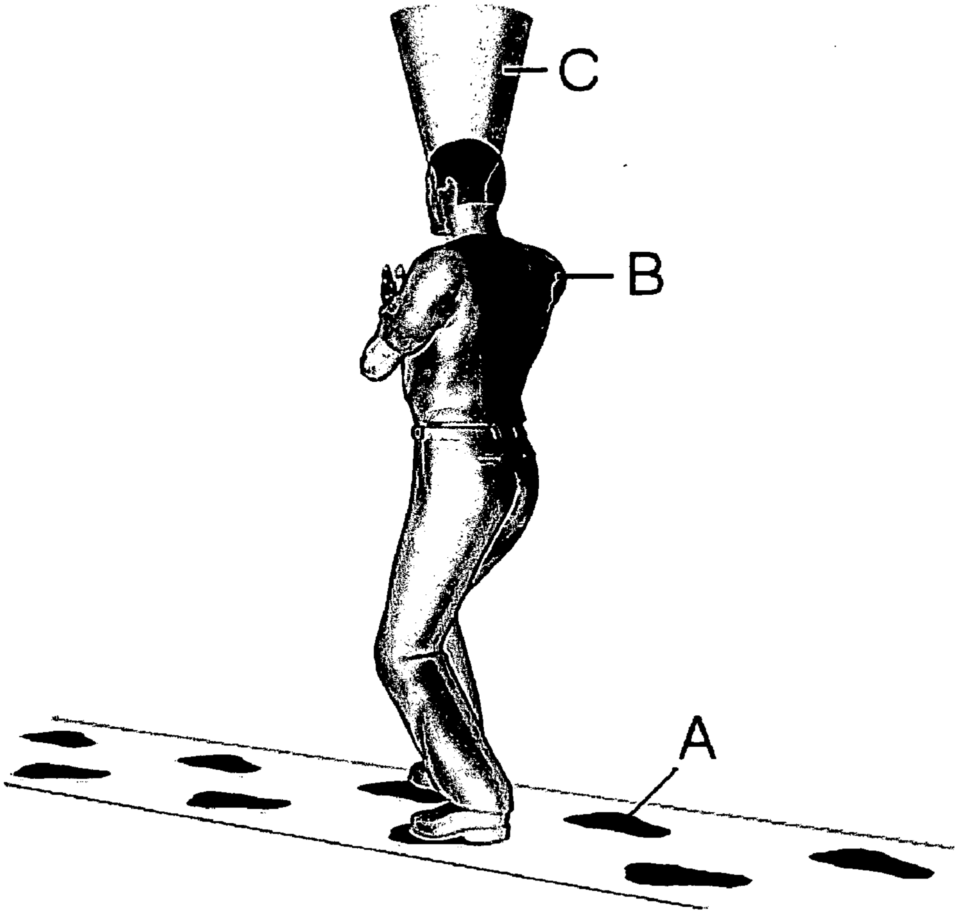

Figure 11

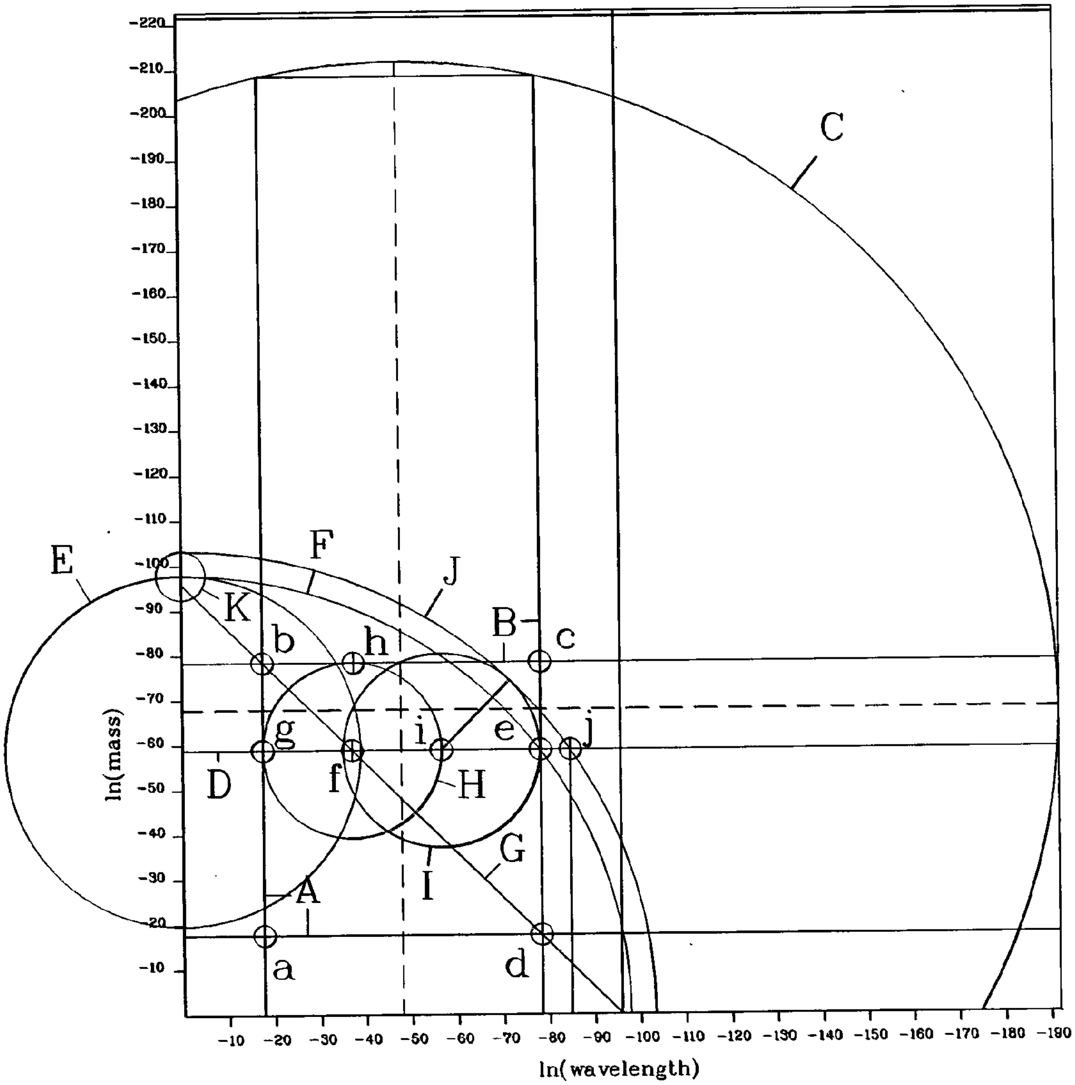
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Figure 12

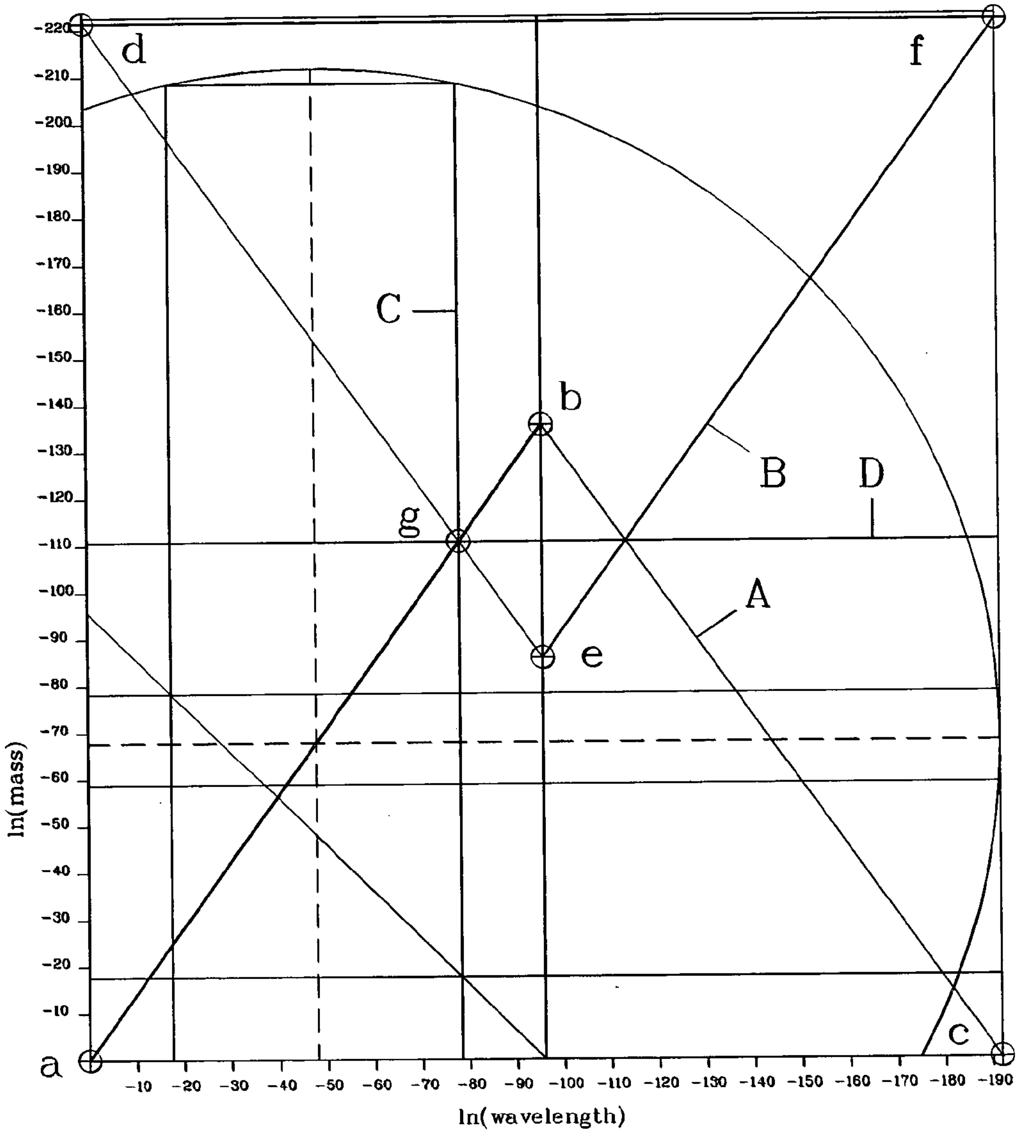
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Figure 13

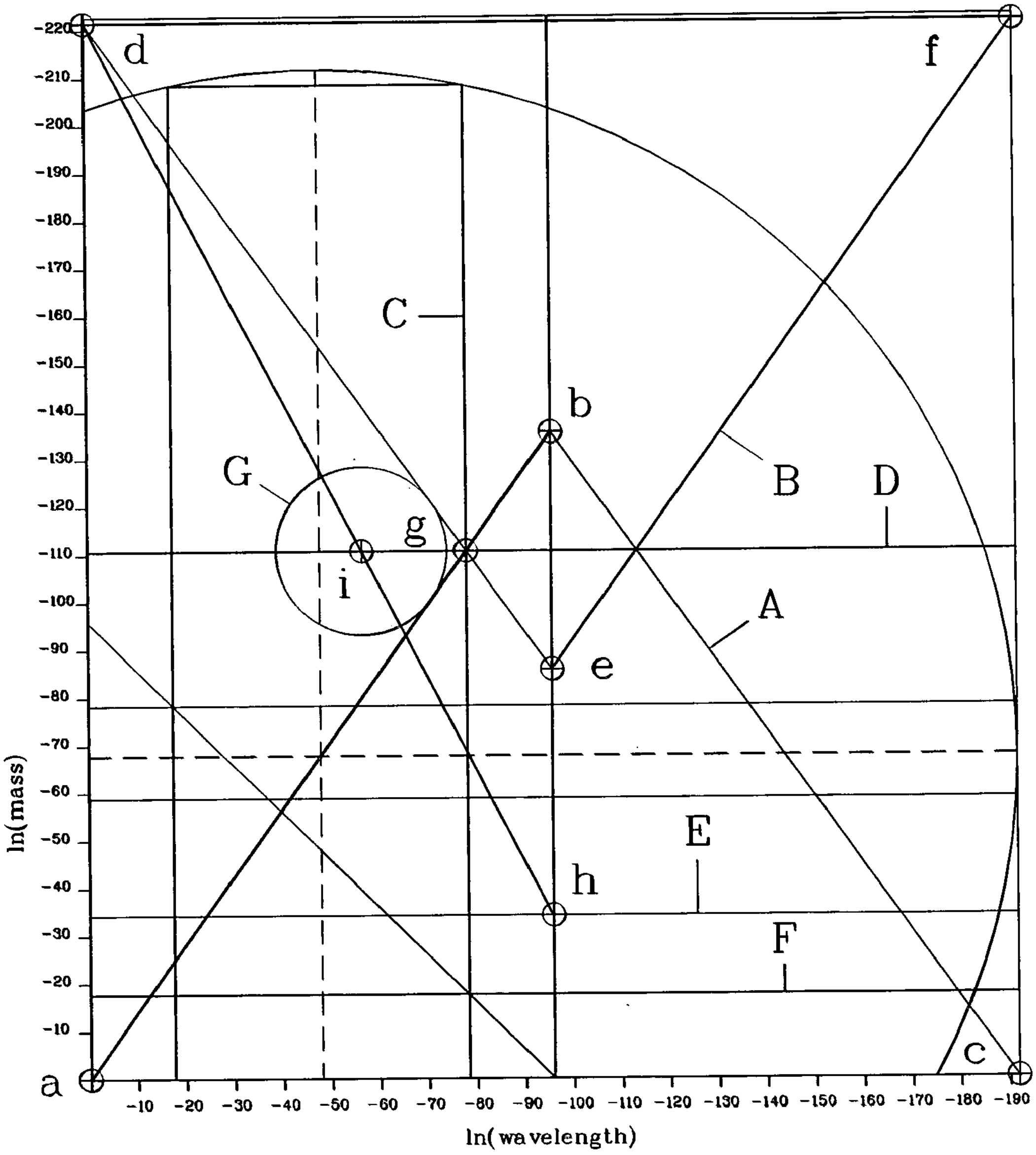
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-40
-30
-20
-10
ln(wavelength)
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190

Figure 14

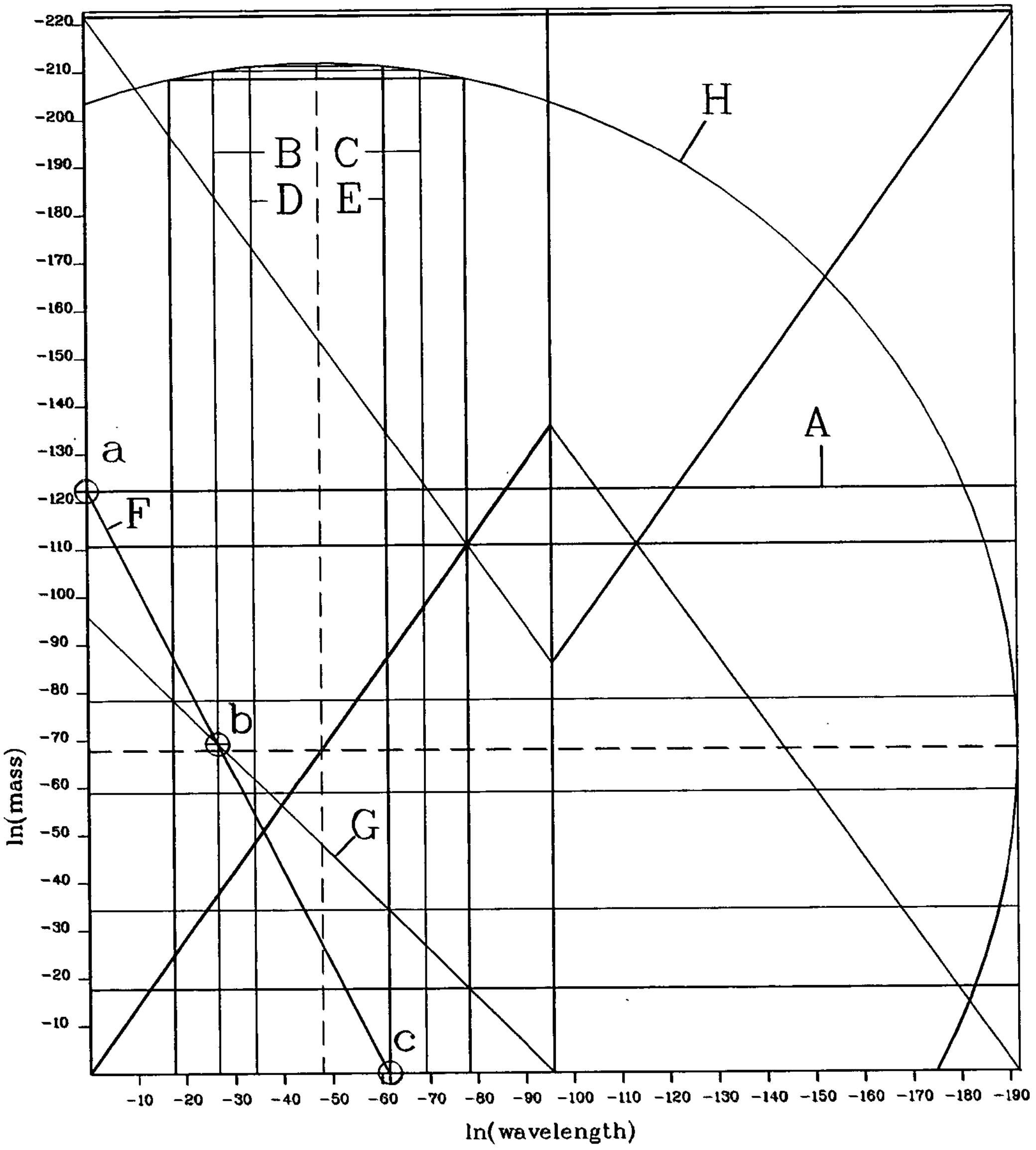
-220
-210
-200
-190
-180
-170
-160
-150
-140
-130
-120
-110
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
ln(mass)
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190
ln(wavelength)
H
B
C
D
E
A
a
F
b
G
c

Figure 15

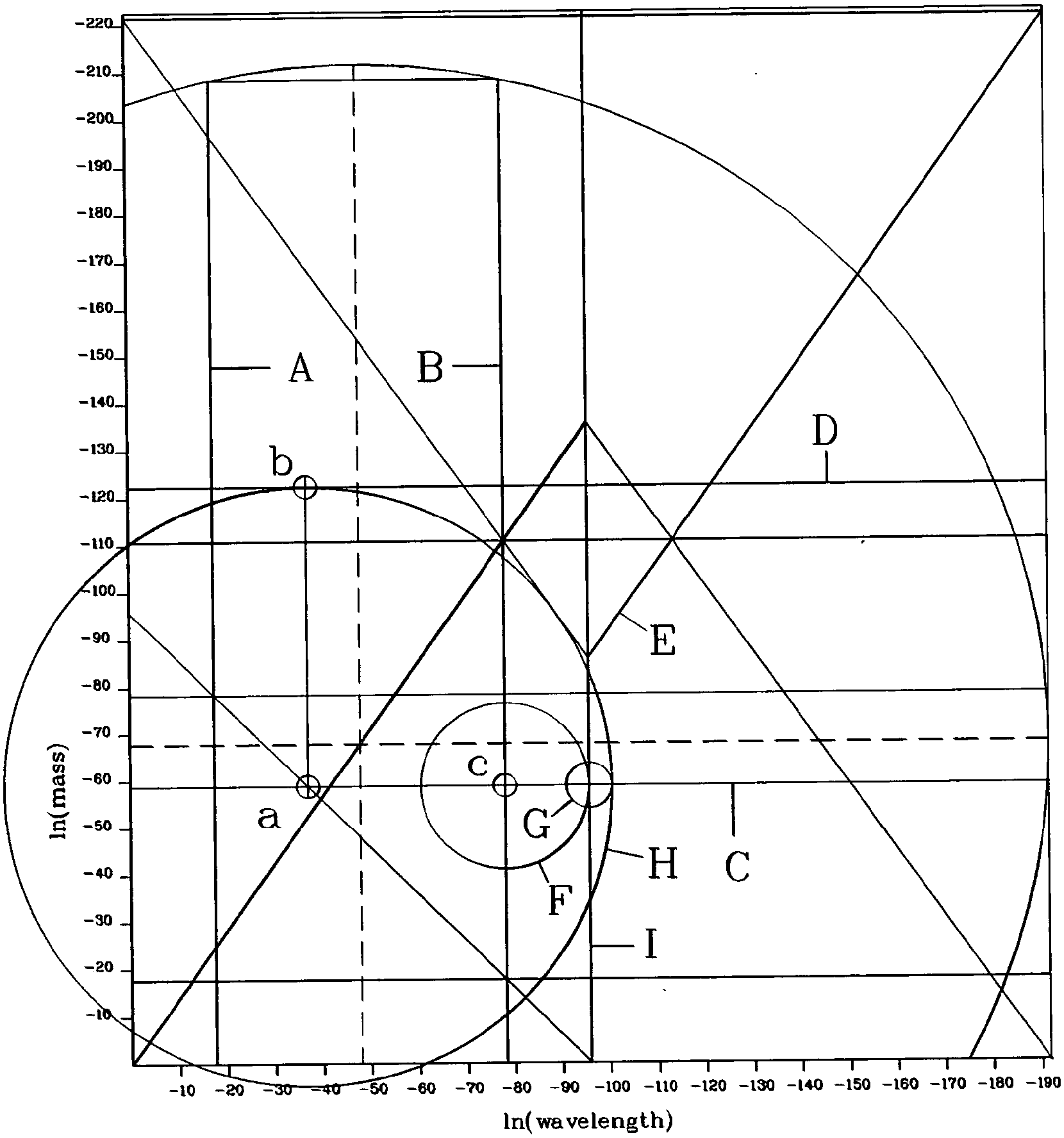
-220
-210
-200
-190
-180
-170
-160
-150
-140
-130
-120
-110
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
ln(mass)
A
B
D
b
E
c
a
G
F
H
C
I
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
ln(wavelength)

Figure 16

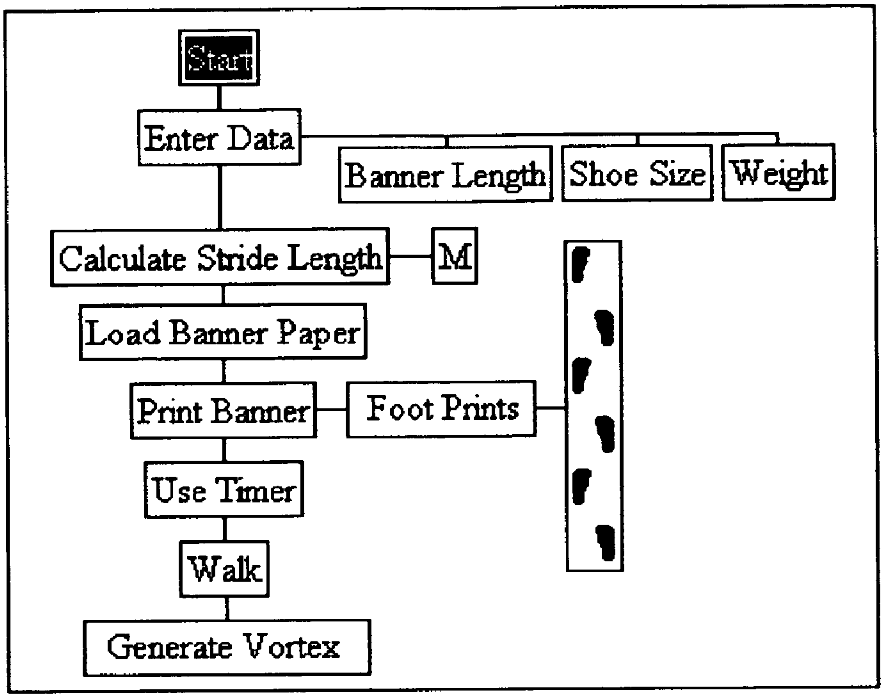
Start
Enter Data
Banner Length
Shoe Size
Weight
Calculate Stride Length
M
Load Banner Paper
Print Banner
Foot Prints
Use Timer
Walk
Generate Vortex

Figure 17

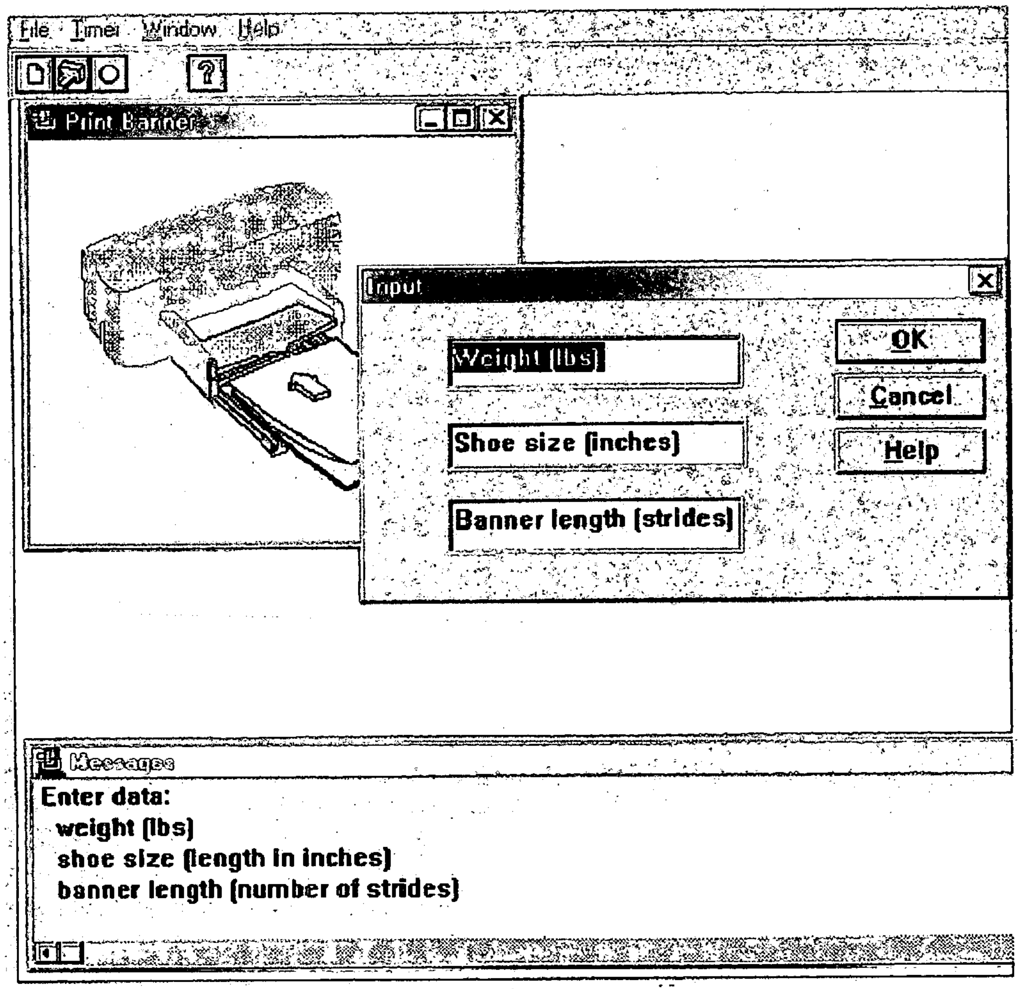
File Timer Window Help
Print Banner
Input
OK
Cancel
Help
Messages

Weight (lbs)

Shoe size (inches)

Banner length (strides)

Enter data:
weight (lbs)
shoe size (length in inches)
banner length (number of strides)

Figure 18

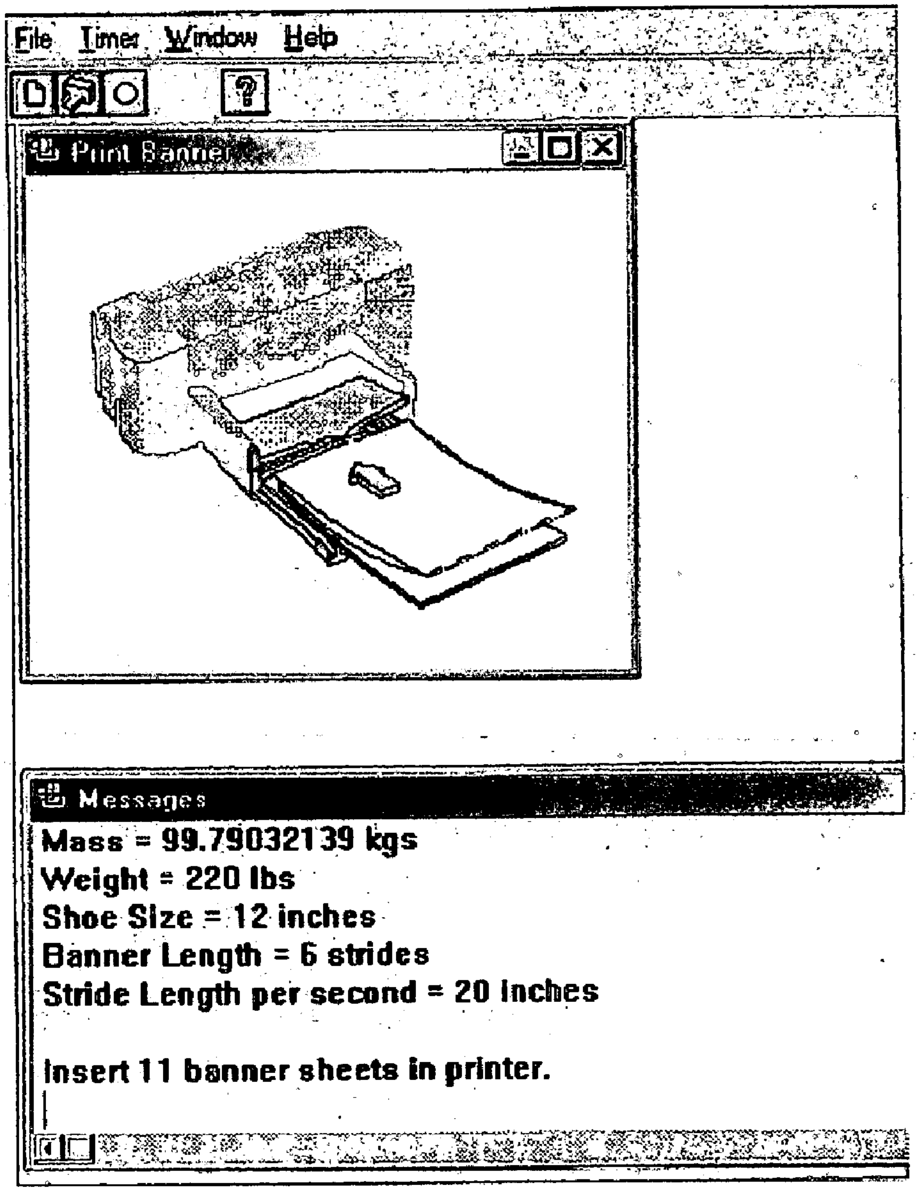
File
Timer
Window
Help
Print Banner
Messages

```
Mass = 99.79032139 kgs
Weight = 220 lbs
Shoe Size = 12 inches
Banner Length = 6 strides
Stride Length per second = 20 Inches

Insert 11 banner sheets in printer.
```

Figure 19

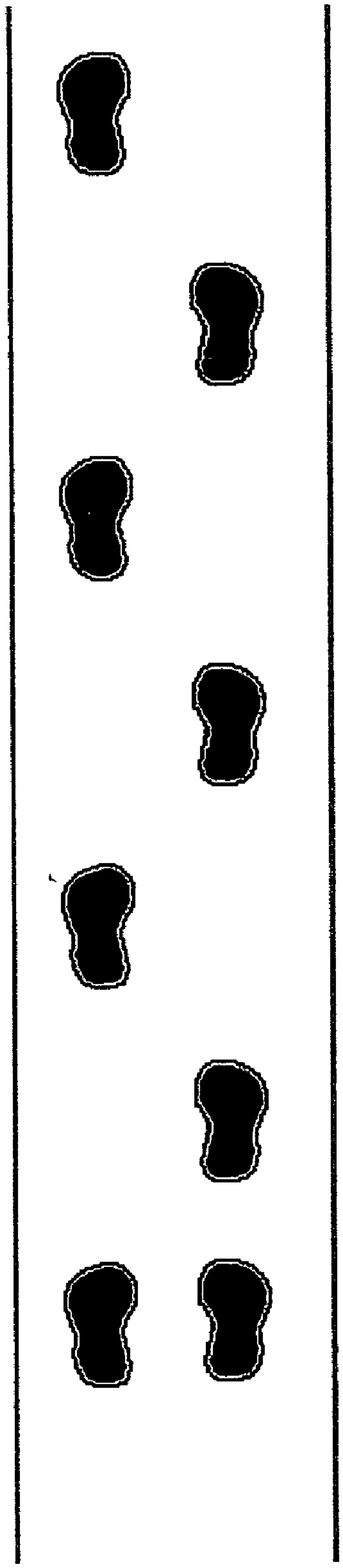

Figure 20

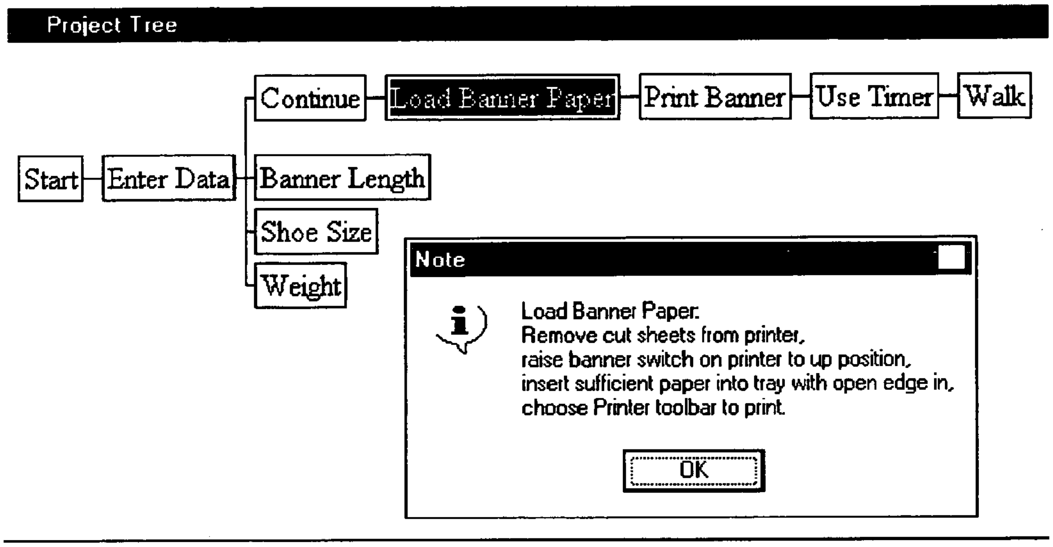
Project Tree
Start
Enter Data
Continue
Load Banner Paper
Print Banner
Use Timer
Walk
Banner Length
Shoe Size
Weight
Note
OK

Load Banner Paper:
Remove cut sheets from printer,
raise banner switch on printer to up position,
insert sufficient paper into tray with open edge in,
choose Printer toolbar to print.

WALKING THROUGH WALLS TRAINING SYSTEM

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is a training system that enables a human being to acquire sufficient hyperspace energy in order to pull the body out of dimension so that the person can walk through solid objects such as wooden doors.

BACKGROUND OF THE INVENTION

[0002] A human being is a hyperspace energy being living in a physical container or body that is comprised of 67% water. This high percentage of water makes this invention possible. Referring to **FIG. 1**, the hyperspace energy being receives energy from our dimension through seven vortices that run the length of the body. Each vortex connects to a separate hyperspace dimension having its own particular frequency. This arrangement allows for the development of seven modular energy components corresponding to the mind, spiritual eye, voice, body, abdomen, plasma energy ball (battery), and ground connection.

[0003] Vortex (A), known as the top vortex, supplies energy to the mind and provides a channel of communication to other entities in the universe. This channel has been tested up to 100,000 light years which is the diameter of the galaxy.

[0004] Vortex (B), known as the spiritual eye, has a hollow cone-like appearance surrounded by white, misty, low-density hyperspace energy. Because the eye is modular, the mind can project it to vast distances, a process known as remote viewing.

[0005] Vortex (C), known as the voice and hearing module, can also be projected to enormous distances in order to communicate verbally with other entities. Using the proper remote viewing instruments, it is possible to project both the eye and verbal modules to see and talk at the same time.

[0006] Vortex (D), known as the heart vortex, provides protective energy to the upper internal organs, arms and hands.

[0007] Vortex (E) provides protective energy for the lower organs such as the intestines, liver and kidneys.

[0008] Vortex (F), known as the battery of the body, consists of an orange-colored plasma energy ball about one to two inches in diameter. The body becomes paralyzed if this ball is removed from the body. When the hyperspace energy being leaves the body, the vortices close and the battery takes over in order to keep the body functioning. This vortex also plays a role in the creation of the astral energy baby that attaches to the fertilized egg.

[0009] Vortex (G) is the ground vortex which rotates in the counter-clockwise direction in order to provide an energy ground for the electrical circuit. All the other vortices rotate in the clockwise direction as seen from the front such that energy flows into the vortex according to the right-hand rule of physics.

[0010] Vortex (H) is the hand vortex which rotates counterclockwise on the right hand and clockwise on the left hand as seen looking at the palm. Thus there is a rotating flow of hyperspace energy between the two hands when the palms are facing each other.

[0011] Referring to **FIG. 2**, each vortex feeds energy into its own hyperspace module shown by the lettered box. In terms of quantum mechanics, each box is actually a potential energy well in which each module develops separately. At the time of death of the body, these modules are joined together as a single energy being. The process is powered by the plasma energy ball battery which also contains the logical instructions for assembly.

[0012] Different people, as tested by the pendulum on the hand vortex, have different vortex sizes. Three people were tested. The first person had almost no rotational movement showing very little energy. The second person had a vortex radius of one inch. Another had a vortex radius of four inches which covered his entire hand. The latter also has the ability to lift another human being, lying prone on a table, off the table by flowing low-density hyperspace energy into the person through the hand vortices. He has also experienced walking through a solid wooden door with a dog at his side. What this means is that there is a way, as described in this invention, of creating large energy vortices which will enable a person to acquire sufficient energy to walk out of dimension through solid objects such as wooden doors.

[0013] Researching the historical records, referring to the statue in **FIG. 3**, a humble black Catholic Dominican friar of the Santo Rosario Convent, by the name of San Martin de Porres, living in Peru in the 1500's, also developed this ability to walk through doors. For his beatification, many witnesses came forward to recount his extraordinary abilities. For example, a witness, who worked in the Convent, went to the cell of San Martin to ask for something to eat. When he reached the cell, he saw San Martin leaving with some medications apparently to heal someone sick. The witness waited by the open door of the cell for his return. After having waited awhile without being distracted by anything else, he saw said venerable brother fray Martin come out from his cell from the inside and call him by name. The witness was terrified, not understanding how this was possible.

[0014] The woman who gave me the statue told me that he would walk miles and miles each day to visit the poor. The task of walking means that there is a velocity involved. Because the body has mass, then there is a mass times a velocity, or momentum, involved in this ability. Notice also that the statue shows him walking with his right arm crossed over his left arm in the form of an X.

[0015] What this walking momentum means in terms of physics is given in the following analysis. The human body consists of 67% water. A water molecule consists of two hydrogen atoms and one oxygen atom having the atomic formula H_2O. The atomic weight of one atom of hydrogen is 1.008 awu. The atomic weight of one atom of oxygen is 16.000 awu. The molecular weight of one atom of water is therefore:

Weight of two atoms of hydrogen 2 × 1.008 awu =	2.016 awu
Weight of one atom of oxygen 1 × 16.000 awu =	16.000 awu
	18.016 awu

The formula weight is just the atomic weight expressed in grams. Thus the formula weight of water would be 18.016

grams or 0.018016 kilograms. According to Avogadro's law, the formula weight contains $N=6.02\times10^{23}$ molecules. Thus the mass of one water molecule is the formula weight divided by the number of molecules:

$$\text{mass} = \frac{.018016\text{ kg}}{N} = 2.99269103\cdot 10^{-26}\text{ kg}$$

$$\ln\left(\frac{\text{mass}}{1\text{ kg}}\right) = -58.77103943$$

[0016] According to Einstein's Special Theory of Relativity, energy is equal to the mass times the speed of light squared. The energy of a photon is equal to Planck's constant h times the frequency f of the photon. Equating these two energies shows that

$$E = \text{mc}^2 = hf = h\frac{c}{\lambda} = \frac{h}{c}\frac{c^2}{\lambda}$$

$$\Rightarrow m\lambda = \frac{h}{c}$$

$$\Rightarrow \ln(m) + \ln(\lambda) = \ln\left(\frac{h}{c}\right) = \text{base} = -95.91546344$$

which says that the natural logarithm of the mass plus the natural logarithm of the wavelength is equal to the natural logarithm of Planck's constant divided by the speed of light c, known as the base constant in the tetrahedron diagram. This diagram plots the mass versus wavelength in natural logarithms. Notice that the left hand side of the equation is the sum of mass and wavelength, so the right hand side must also be the same.

$$\ln\left(\frac{h}{c}\right) = \ln\left(\frac{\Omega\Lambda\ 2\pi\Lambda\ c}{c}\right) = \ln(\Omega\Lambda) + \ln(2\pi\Lambda)$$

where ΩΛ, known as the Planck mass, is the linear mass Ω of the universe times the bottom dimensional limit of the universe Λ, and 2πΛ is the bottom dimensional wavelength, known as the Planck wavelength. That is, our dimension is bounded by the Planck box having sides Planck mass and Planck wavelength. These boundaries have values:

$\ln(\Omega\Lambda)=-17.64290101$

$\ln(2\pi\Lambda)=-78.27256243$

[0017] Referring to **FIG. 4**, these two lines are plotted on the tetrahedron diagram. The Planck mass line (A) reflects off the sphere (C) and returns as the Planck wavelength (B) which shows the dual nature of quantum physics. This creates the Planck box (a,b,c,d) which is the boundary of our dimension.

[0018] Referring to **FIG. 5**, the mass of the water molecule is plotted as horizontal line (D) on the diagram. The energy of the water molecule is the mass times the speed of light squared.

$E=mc^2$

$\ln(c)=19.51860099$

$\ln(mc^2)=\ln(m)+2\ln(c)$

[0019] Referring to **FIG. 6**, a circle (E), having a radius equal to the speed of light squared, centered on the mass of the water molecule at the vertical axis, generates a circle (F), centered at the origin, that intersects (e) the mass of the water molecule at the Planck wavelength. That is, this intersection point sits right on the Planck box boundary between space and hyperspace. The radius of circle (F) is actually the mass of the water molecule divided by the speed of light squared.

$$E = \frac{m}{c^2} = m$$

$$\Rightarrow \frac{1}{c^2} = 1$$

$$\Rightarrow c = 1\frac{\text{meter}}{\text{sec}}$$

$$\ln(c) = 0$$

Taking the positive square root, the speed of light is one meter per second at the Planck boundary. The experiments with brain hemisphere resonance show that the resonant frequency of the human energy field is between 1 Hz to 5 Hz which is well below the hearing threshold of 20 Hz. Because the traveling wave has a wavelength of 0.3048 m and the speed of light is unity at the boundary, the frequency should be

$$f = \frac{c}{\lambda} = \frac{1\frac{m}{\text{sec}}}{.3048\ m} = 3.28\text{ Hz}$$

which is within the middle of the experimental male range. At this resonant frequency, the human energy being pops out of the body. This represents only a first stage in the development of the energy being. But what is really wanted is to have both the physical body and the energy field move out of dimension together as San Martin did.

[0020] Referring to **FIG. 7**, the 45° base line (G) is added to the diagram. Notice that the Planck mass intersects (b,d) the Planck wavelength on this line because they sum to the base constant. The mass of the water molecule crosses this line at point (f). A circle, centered (f), with a radius equal to the speed of light, is tangent to the Planck wavelength (h) and the Planck mass (g). Since mass times velocity is momentum, the diagram says that the momentum of the water molecule is tangent to the boundaries of the Planck box which separates space from hyperspace. In order to get to point (e) from the momentum of the water molecule, a second circle is added to the momentum.

[0021] Referring to **FIG. 8**, a circle (I), centered on the water molecule mass at the speed of light circle (i), is made tangent to the Planck wavelength at point (e). The momentum M of space is equal to the Planck mass times the Planck scale times the speed of light. At point (e), the speed of light is unity, so that the momentum is just the Planck mass in momentum units:

$$M = \Omega\Lambda c = 2.176634194 \cdot 10^{-8}\ \mathrm{kg}\frac{m}{s}$$

Circle (I) has a radius equal to

$$\mathrm{ratio} = e^{21.572952} = 2338912700$$

Therefore the walking momentum in order to get to point (e) is the momentum of space M times this ratio

$$M_w = M \cdot \mathrm{ratio} = 50.909573606\ \mathrm{kg}\frac{m}{\mathrm{sec}}$$

The stride length L per second that a person of mass W has to walk is the walking momentum divided by the mass W times a period T of one second

$$L = \frac{M_w}{W}T$$

For a person with a mass W of 99.79 kg (220 pounds), then the stride length L is 20.08 inches or one foot and eight inches. The person has to walk this length in one second on each foot.

[**0022**] Looking at the statue of San Martin, his arms are crossed over each other. The vortex of the right hand points backward, and the left hand vortex points forward due to the reversed rotation. Referring to **FIG. 9**, this creates a rotational energy channel (D) around his body (A). The stride length (C) is calculated according to the body mass, and then a banner printout is made showing where the footprints (B) are to be placed each second. The question is: "What happens when one walks the walk?".

[**0023**] On the very first experiment, referring to **FIG. 10**, what happens is that, after taking only six strides on the banner printout (A), a huge spinning vortex (C) develops over the top of the head and the vertex locks onto the heart vortex in the center of the chest (B). In everyday life, this vortex is not created because normal walking is much faster and the hands are held at the side of the body. The energy rush through the pineal gland is so intense that one feels immediately sleepy and starts yawning excessively due to the increased flow of melatonin.

[**0024**] After practicing with the banner printout, long walks were made through the park. In this case, a vertical white line rotated around a vertical axis located about six feet perpendicular to the path on the right side of the body. When the walking speed was correct, this white line would lock onto the centerline of the body. Speeding up or down caused the white line to lose synchronization and rotate away. This white line is related to the ability to levitate the body. San Martin had so much energy that, according to witness testimony, he could float horizontally in the air with his head resting against the bowed head of Christ on a carved wooden cross. Thus San Martin's energy sources were channeling energy from Christ, collective broom energy as described in a separate patent application, and the walking momentum vortex energy.

[**0025**] During the early part of the 20th century, a man's parents were lying in bed dying of tuberculosis. With their permission, he placed a weighing scale under each of their beds. When they passed away, he found that each scale registered a loss in weight of 2.5 ounces. This is equivalent to 0.071 kg, which is the mass of the human energy being.

[**0026**] After conducting a number of experiments with water vortices draining from a cylindrical tank, it can be stated from Bernoulli's theorem that the potential energy plus the kinetic energy is a constant

$$gz + \frac{1}{2}mv^2 = const$$

The shape of the inner surface of the water circulation has a velocity proportional to the inverse of the radius, so the shape of the surface is

$$(z - z_0) = \frac{k}{r^2}$$

which says that the height of the vortex is proportional to the inverse of the square of the radius.

[**0027**] The hand vortex area ratio between the second test subject and the third test subject is equal to the square of their radii:

$$\mathrm{ratio} = \frac{(1\ \mathrm{in})^2}{(4\ \mathrm{in})^2} = \frac{1}{16}$$

Because the speed of light at the boundary was determined to be one meter per second, the energy of the third test subject is

$$E = \left(\frac{.071\ \mathrm{kg}}{16}\right)\left(\frac{1\ \mathrm{m}}{\mathrm{sec}}\right)^2 = 4.4375 \cdot 10^{-3}\ \mathrm{joule}$$

$$\ln(E) = -5.417664124$$

[**0028**] Referring to **FIG. 11**, a circle (K), having this radius, is added to the energy of the water molecule (E), to produce augmented energy circle (J). This circle (J) intersects the mass of the water molecule outside the Planck box at point (j). This means that the increased hyperspace energy moves the water molecule, and hence the body, out of dimension. Furthermore, circle (J) is tangent to the walking momentum ratio circle (I) which keeps the geometry locked together.

SUMMARY OF THE INVENTION

[**0029**] It is the object of this invention to create a training system that allows a person to develop the ability to walk around out of dimension, passing through solid objects. This invention is based on one of the most remarkable relationships between the water molecule and the boundary between space and hyperspace. The mass of the water molecule is equal to the energy of the water molecule at this boundary. Because the body is composed of 67% water, the body sits on the boundary such that any additional increase in energy would move the body out of dimension into hyperspace. Because human beings are actually hyperspace energy beings living in physical bodies, the additional energy required to move the body out of dimension comes from increasing the energy of the hyperspace being. One source of this energy comes from walking cross-handed at the proper velocity in order to generate a large hyperspace energy vortex that flows energy into the potential wells of the hyperspace being. This increased hyperspace energy will then allow the person to walk around out of dimension through solid wooden doors. Because the door and the person are in two slightly different dimensions at the same moment, it appears that the person is walking through the door. After passing through the closed door, the person then returns to our dimension and emerges in the interior of the closed-door room.

[0030] This technique can be used in reverse to heal an infected hand instantaneously. A salve made from the St.Mary's herb is applied to the skin of the infected hand. The hyperspace energy then flows through the right-hand vortex such that the infected hand and the salve are taken slightly out of dimension. What happens is similar to when a short piece of straw is embedded in a hard wooden telephone pole as a tornado passes over the pole. The straw and pole are taken out of dimension such that they briefly merge together. As the tornado moves on, both objects come back to dimension merged together. Thus the salve (straw) is merged with the bacteria (pole) in hyperspace such that the bacteria is killed instantly. Removing the hand vortex brings the infected hand back into dimension cured.

[0031] Based on this information and the results of many experiments, this invention creates a large vortex by walking at a certain velocity with the hands crossed over the chest. The proper walking momentum is created by a computer program that inputs the person's weight, shoe length, and the number of strides to be taken. The program then prints out a banner showing the footprints where the person has to step each second. When a person obtains sufficient energy from these methods, the person is then tuned to the subspace geometry of the universe as will be shown using the tetrahedron physics diagram.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0032] **FIG. 1**. Energy vortices of the human body.

[0033] **FIG. 2**. Seven potential wells fed by the energy vortices of the body.

[0034] **FIG. 3**. Carved wooden statue of San Martin de Porres who could walk through solid wooden doors.

[0035] **FIG. 4**. Tetrahedron diagram showing boundaries of the Planck box of dimension.

[0036] **FIG. 5**. Tetrahedron diagram showing mass of water molecule.

[0037] **FIG. 6**. Tetrahedron diagram showing water molecule energy and mass are equal at the Planck box boundary.

[0038] **FIG. 7**. Tetrahedron diagram showing that water molecule momentum is tangent to the boundaries of the Planck box.

[0039] **FIG. 8**. Tetrahedron diagram showing the momentum ratio required to reach the Planck wavelength boundary from the water momentum.

[0040] **FIG. 9**. Perspective view of crossed-hand momentum walking using banner printout.

[0041] **FIG. 10**. Perspective view of vortex generated by momentum walking.

[0042] **FIG. 11**. Tetrahedron diagram showing how additional hyperspace energy supplied to the potential wells of the hyperspace energy being enables the human body to be pulled out of dimension.

[0043] **FIG. 12**. Tetrahedron diagram showing the inverted tetrahedrons whose crossing represents the merging of two worlds between space and hyperspace.

[0044] **FIG. 13**. Tetrahedron diagram showing that the proton wavelength is determined by the Planck mass tangent to the inverted tetrahedrons.

[0045] **FIG. 14**. Tetrahedron diagram showing that the mass of the universe determines the electron and proton elementary particles.

[0046] **FIG. 15**. Tetrahedron diagram showing that momentum walking together with the increased energy of the hyperspace energy being is tangent to the mass of the universe.

[0047] **FIG. 16**. Computer program block diagram for printing banner footprints.

[0048] **FIG. 17**. Computer program input dialog window.

[0049] **FIG. 18**. Computer program calculation of stride length per second.

[0050] **FIG. 19**. Six-stride screen banner printout for 220 lb. person.

[0051] **FIG. 20**. Project tree showing help information by double clicking on node.

DETAILED DESCRIPTION OF THE INVENTION

[0052] 1. Referring to **FIG. 12**, a tetrahedron (A, path abc) is added to the diagram. The tip of the tetrahedron (e) falls on the base constant which is equal to Planck's constant divided by the speed of light. A second tetrahedron (B, path def) is inverted around horizontal line (D) which has a geometrical relationship to the base constant. The line is located at

$$\text{centerline} = \frac{2}{\sqrt{3}}\ln\left(\frac{h}{c}\right) = -110.7536373$$

Notice that the intersection of the two inverted tetrahedrons (g) occurs at the Planck wavelength which is the boundary between space and hyperspace. Line (D) is referred to as the merging of two worlds or the connecting of two worlds, a phrase obtained by means of remote viewing. That is, it is the dividing line between space and hyperspace. This is the reason that the two boundaries intersect at this point.

[0053] Referring to **FIG. 13**, the proton wavelength (E) is added to the diagram. The proton wavelength has a value of the electron wavelength divided by 1836.1527

$$\ln(\lambda_p) = \ln\left(\frac{\lambda_e}{1836.1527}\right) = -34.26005901$$

A line (hd), from the base constant at the proton wavelength (h), to the corner of the inverted tetrahedron (d), intersects the merging of two worlds line at point (i). A circle, with a radius equal to the Planck mass (G), centered (i), is tangent to the inverted tetrahedrons. Thus the proton is defined by the base constant and the geometry of subspace. The reason that the proton is tangent to both tetrahedrons is because the electron and proton follow one single path between space and hyperspace. Thus there is only one single particle in nature. Because the particle enters our space at two different locations, we see the one particle as two distinct elementary particles. This relationship can be seen in Library of Congress tetrahedron diagram tet0565.

[0054] Referring to **FIG. 14**, the mass of the universe MU is equal to the linear mass Q of the universe times the radius R of the universe which is 10^{26} meters

$$\ln(MU)=\ln(\Omega R)=122.3347509$$

as shown on the diagram as line (A). The electron wavelength (B) reflects off the circumscribing sphere (H) and returns as the electron mass (C). The distance between reflection points is the hyperspace charge which is equal to the charge of space less the electron charge. So the electron goes from wavelength to electric charge to mass. The proton wavelength (D) reflects off the sphere and returns as the proton mass (E) which intersects the horizontal axis at point (c). A line (abc) from the mass of the universe at the vertical axis (a) to the proton at the horizontal axis (c) intersects the electron (b) which determines the electron's mass and wavelength since this point is on the 45° base line. What this means is that cosmology determines the values of the elementary particles.

[0055] Referring to **FIG. 15**, the mass of the water molecule (C) intersects the 45° base line at point (a). A circle (F), with a radius equal to the Planck mass is centered on point (c) at the Planck wavelength boundary (B) where the mass of the water molecule numerically equals the energy of the water molecule and where the speed of light is unity. The Planck mass is tangent to the base constant which is the vertical centerline (I) of the diagram. The large circle (H), centered (a) on the water molecule, is tangent to the mass of the universe (b) and tangent to the inverted tetrahedron (E). The difference between this circle (H) and the base constant (I) is the energy the hyperspace being has to acquire in order to be tuned to the mass and geometry of subspace. This difference, shown as circle (G), has a mass

$$m=e^{-4.792671}\text{ kg}=8.29\cdot 10^{-3}\text{ kg}$$

Thus the hand vortex radius ratio has to be the square root of the mass of the hyperspace energy being divided by this tangent mass, or:

$$r = \sqrt{\frac{.071\text{ kg}\cdot 1\text{ in}^2}{e^{-4.792671}\text{ kg}}} \approx 3\text{ inches}$$

which is a vortex radius that is three times larger than that of a normal person, but one inch smaller than the third test subject who had a hand vortex radius of 4 inches. This is the reason that the third test subject was able to walk through walls and teleport to other locations because his energy was sufficiently large enough to cross over the inverted tetrahedron into a co-dimension of hyperspace. Notice also that dotted circle (J) with a radius equal to the mass of the water molecule, centered (c) on the boundary, is tangent to the tetrahedron (K). This makes the combined geometry tangent to the inverted tetrahedrons and the mass of the universe.

[0056] 2. Referring to **FIG. 16**, a computer program generates a banner printout with footprints spaced for walking according to the weight, shoe size and length of banner desired. Some banners could fit in a small room, or be placed on the floor of a long corridor. As shown in the block diagram the program inputs these three variables with error checking. Then the program calculates the stride length L per second from the equation

$$L = \frac{M}{W}T$$

[0057] 3. In the above equation, the value of the momentum M, as determined by the tetrahedron diagram, is preferably 50.9095736 kg m/s. The weight of the person is converted to mass W in kilograms. The stride period is preferably 1 second. Referring to **FIG. 17**, the data is entered in the dialog input window.

[0058] 4. Once the stride length has been calculated, the program displays the stride length and the required number of banner sheets in the message window, as seen in **FIG. 18**.

[0059] 5. The print banner menu is selected and the foot prints are printed on continuous banner paper. A six-stride scaled screen version of the banner is shown in **FIG. 19**. The banner paper is then placed on the floor, and a one-second beeping timer is activated from the toolbar or menu. The person then walks beside the printed foot prints, taking one stride per beep, which produces the correct walking momentum to generate the hyperspace vortex. The vortex, which forms in only six strides, brings additional hyperspace energy into the quantum potential wells of the hyperspace energy being.

[0060] 6. A help system consists of a project tree which explains the various steps in using the program. Double mouse clicking on a project tree node displays the help instructions in a dialog window as shown in **FIG. 20**.

[0061] 7. In summary, the purpose of the training system is to substantially increase the energy of a human being who will then have the capability of walking through walls, body levitation, instantaneous healing of infections, full-body teleportation to another location, remote viewing at vast distances in terms of light-years, and looking into hyperspace co-dimensions. The third test subject and I have been able to experience all the above phenomena. He did it through augmenting his energy, and I have done it through the application of electromagnetic fields, by spinning on my vortex accelerator machine and using this invention.

I claim:

1. A training method comprising the steps of:

generating a banner having a plurality of footprints spaced at regular intervals wherein the banner is placed on the ground;

generating a periodic audible signal, whereby the audible signal repeats at a regular interval of time equal to the period; and

walking on the banner by tracing the footprints spaced at regular intervals, wherein one step is made with each audible signal.

2. The method of claim 1, wherein the step of generating the banner further comprises:

providing a person's actual mass in kilograms; and

determining the stride length based upon the following equation:

$$L=(M/W)*T$$

where L is the stride length in meters, M is a constant of approximately 50.91, W is the mass of the person in kilograms, and T is the period of the audible signal in seconds, and

wherein the footprints on the banner are spaced at the stride length.

3. The method of claim 2, wherein the audible signal is a beep and the period of the audible signal is one second.

4. A training method for a person comprising the steps of:

generating an audible signal having a fixed period;

generating a banner having regularly spaced indicia for identifying preferred step locations, wherein the distance between adjacent indicia is determined by the following formula:

$$L=(M/W)*T$$

where the distance between adjacent indicia in meters is L, a constant of 50.9095736 is equal to M, the person's mass in kilograms is W, and the fixed period in seconds is T; and

walking on the marked path by stepping upon each of the regularly spaced indicia wherein one step is made with each period of the audible signal.

5. The training method of claim 4 wherein the fixed period is one second.

6. The training method of claim 5, wherein the regularly spaced indicia are footprints.

* * * * *

US 20030209636A1

(19) **United States**
(12) **Patent Application Publication**
St.Clair
(10) **Pub. No.: US 2003/0209636 A1**
(43) **Pub. Date: Nov. 13, 2003**

(54) **BOBBIN ELECTROMAGNETIC FIELD PROPULSION VEHICLE**

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(21) Appl. No.: **10/142,583**

(22) Filed: **May 9, 2002**

Publication Classification

(51) **Int. Cl.**^{7} **B64G 1/32**

(52) **U.S. Cl.** **244/166**

(57) **ABSTRACT**

This invention relates to a spacecraft which generates its own magnetic moment and magnetic field gradient in order to produce lift on the hull. The magnetic moment is generated by a large area solenoid located in the hull. A toroidal core wrapped with electrical bobbins at intervals along said core produces a traveling magnetic wave along its surface. This magnetic wave creates a spacetime curvature, similar to a tilted plate, which causes the formation of a magnetic field gradient. Power is not critical because the system uses a magnetic vortex wormhole generator to lower the speed of light in order to efficiently create highly relativistic fields due to Lorentz transformation.

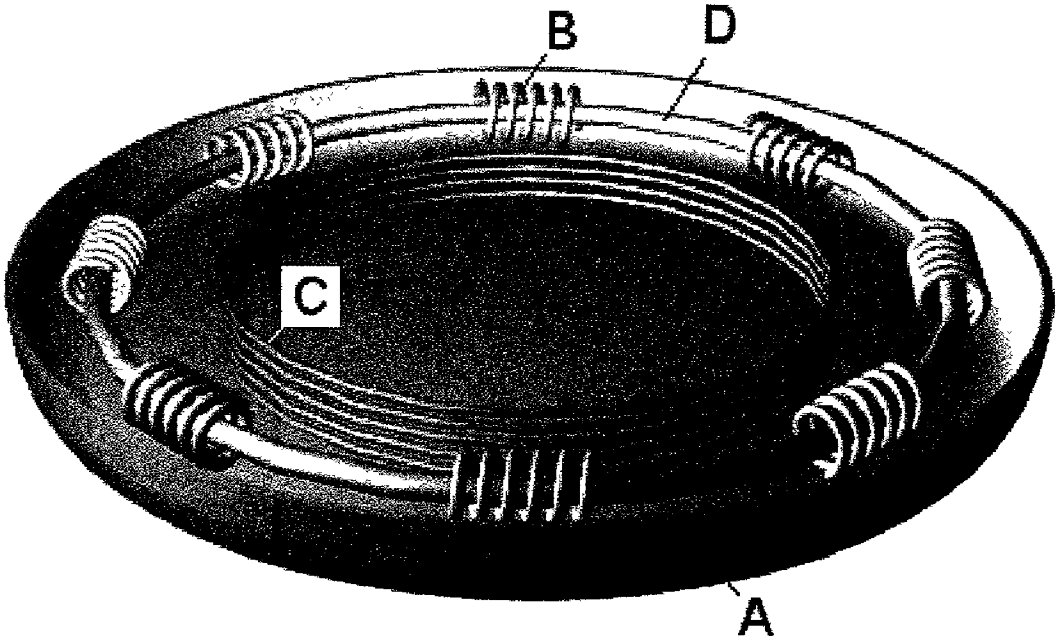

Figure 1

$$\text{Force} = \mu \cdot \frac{\partial B_z}{\partial z} = \text{amp} \cdot \text{m}^2 \frac{\text{kg}}{\text{sec} \cdot \text{coul} \cdot \text{m}} = \frac{\text{coul}}{\text{sec}} \cdot \text{m}^2 \cdot \frac{\text{kg}}{\text{sec} \cdot \text{coul} \cdot \text{m}} = \frac{\text{kg} \cdot \text{m}}{\text{sec}^2} = \text{newton}$$

Figure 2

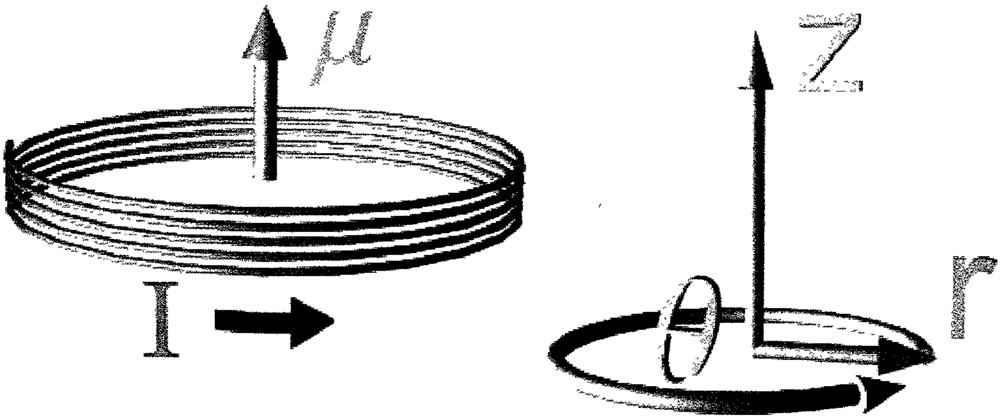

Figure 3

$$B_Z = \mu n I$$

Figure 4

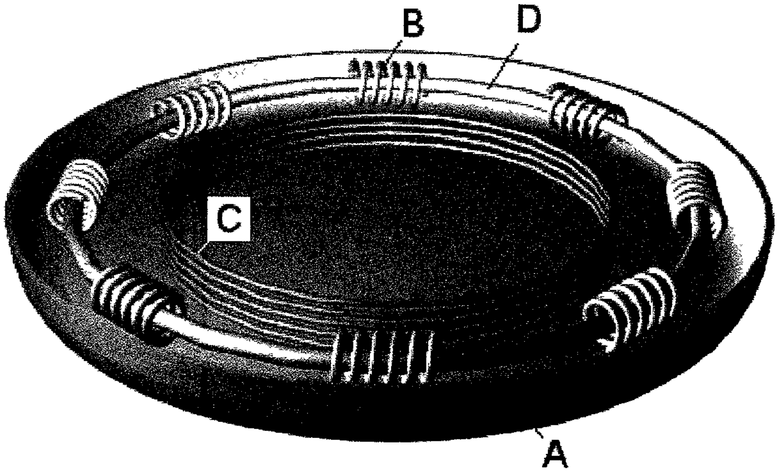

Figure 5

$$v = \sqrt{\frac{\omega}{\sigma\mu}}$$

Figure 6

$$g_{\alpha\phi} = \begin{array}{c|cccc|} & t & r & \theta & z \\ t & -1 & 0 & \mathrm{Sin}[\theta - t] & 0 \\ r & 00 & 1 & 0 & 0 \\ \theta & \mathrm{Sin}[\theta - t] & 0 & r^2 & 0 \\ z & 0 & 0 & 0 & 1 \end{array}$$

Figure 7

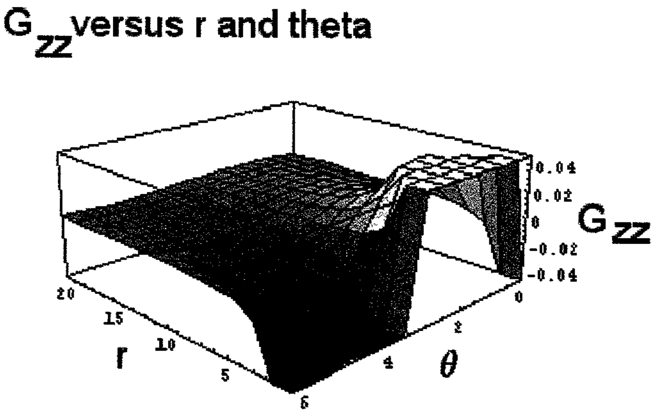

Figure 8

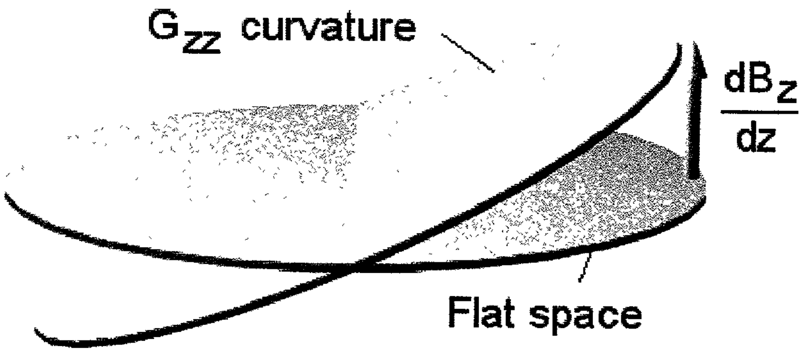
G zz curvature
dB z
dz
Flat space

BOBBIN ELECTROMAGNETIC FIELD PROPULSION VEHICLE

BRIEF SUMMARY OF THE INVENTION

[0001] This invention, which is the subject of my present application, is comprised of a toroidal core around which are wound a plurality of electromagnetic bobbins. The bobbins are pulsed electrically to create an amplified magnetic wave that travels around the core. At the same time, a circular electrical conductor carrying direct current creates a magnetic field around its area which results in the formation of a magnetic moment. This magnetic moment, together with the spacetime curvature distortion created by the traveling magnetic wave, produces a lift force on the vehicle.

REFERENCE PAPERS

[0002] Levitron, Hones, U.S. Pat. No. 5,404,062.

[0003] *Geometry of Electromagnetic Systems,* Paul Hammond, page 179.

BACKGROUND OF THE INVENTION

[0004] The idea for this invention comes from experiments I have done using thin transformer laminations wound in intervals with bobbins of wire connected to a frequency generator. Pulsing the bobbins electrically creates a slow traveling magnetic wave along the surface of the lamination. The velocity of the wave, as shown by Hammond in the reference paper, is the square root of the frequency divided by the conductivity and permeability of the material. From Einstein's General Theory of Relativity, this type of wave around the circumference creates a spacetime curvature distortion in the vertical direction that looks like a tilted plate. The magnetic field traveling around the circumference has to follow this curvature. This creates a magnetic gradient in the z-direction which together with the magnetic moment developed by a solenoid produces lift on the vehicle.

SUMMARY OF THE INVENTION

[0005] It is the object of this invention to create a magnetic field gradient and magnetic moment in order to produce a lift force on the hull of a vehicle. The magnetic field gradient is produced by a traveling magnetic wave which produces a tilting-plate spacetime curvature around the hull. The magnetic moment is created by a simple circular wire carrying direct current around its area.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0006] Not Applicable.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0007] **FIG. 1**. The lift force on the vehicle is equal to a magnetic moment times the magnetic field gradient.

[0008] **FIG. 2**. Magnetic moment μ created by direct current I flowing counterclockwise around the wire coil. Cylindrical coordinates are shown to the right.

[0009] **FIG. 3**. The wire coil solenoid creates a magnetic field in the z-direction equal to the permeability of space times the number of turns per length of the solenoid times the current in the windings.

[0010] **FIG. 4**. Perspective view of bobbin spacecraft.

[0011] **FIG. 5**. Magnetic wave velocity along core.

[0012] **FIG. 6**. The g metric tensor in cylindrical coordinates with the sinusoidal wave function in the $\{t,\theta\}$ slots.

[0013] **FIG. 7**. The spacetime curvature G_{zz} in the vertical direction created by the magnetic wave traveling around the core.

[0014] **FIG. 8**. Tilted plate spacetime curvature showing magnetic gradient.

DETAILED DESCRIPTION OF THE INVENTION

[0015] 1. Referring to the equation in **FIG. 1**, the lift force on the bobbin spacecraft is equal to its magnetic moment times its magnetic field gradient. The magnetic moment has units of electrical current, measured in amps, times the area enclosed by the current. Thus the units of the magnetic moment are amp$-$m^2. The magnetic moment can be created by a large, circular coil of wire carrying direct current I as shown in **FIG. 2**. The spacetime cylindrical coordinates $\{t, r, \theta, z\}$ are shown to the right of the drawing where t is time, r the radius, the horizontal angle θ, and the vertical height z.

[0016] 2. The wire coil solenoid also produces a magnetic field in the vertical z-direction equal to the permeability of space μ times the number of turns per unit length of the solenoid n, times the current I in the winding. The equation is shown in **FIG. 3** which can be developed from Ampere's law that the magnetic field around a loop is equal to the current passing through the loop.

[0017] 3. Referring to **FIG. 4**, the bobbin spacecraft consists of a large, horizontal, highpermeability toroidal core (D) wrapped at intervals with electrical bobbins (B) which can be pulsed electrically to create a traveling magnetic wave around the core. Interior to this core is a large direct current solenoid (C) which produces said magnetic field in the z-direction. These devices are enclosed in a circular hull (A) containing the coils on the outer rim and a cabin area in the center.

[0018] 4. Referring to **FIG. 5**, the velocity of the magnetic wave on the surface of the core is equal to the square root of the wave frequency ω divided by the conductivity a times the permeability μ of the core material. When the first bobbin is pulsed, a wave starts to propagate along the surface of the core. As the wave passes the second bobbin in sequence, another electrical pulse is generated to amplify the wave. After many cycles, the wave traveling around the core becomes larger and larger in amplitude.

[0019] 5. A traveling wave has a wave function equal to a sinusoidal function with an argument of the angle θ around the periphery less the time t, or $\mathrm{Sin}[\theta-\omega t]$.

[0020] 6. In gravitational physics, there is a g metric tensor which is a measure of length in spacetime coordinates. When mass or electromagnetic fields are involved in a certain region of space, a curvature of space is created. The curvature of space can then be calculated directly from this metric tensor. The result is Einstein's G curvature tensor which shows the spacetime distortion. The g metric tensor is a 4 by 4 matrix having rows and columns equal to time t, radius r, angle theta, and vertical height z. The diagonal from top left to bottom right has a signature equal to $\{-1, 1, r^2, 1\}$.

[0021] 7. Because the magnetic wave traveling around the core is varying with time t in the theta direction, the wave function has to go into the $\{t,\theta\}$ and $\{\theta,t\}$ slots of the metric tensor, as shown in **FIG. 6**.

[0022] 8. From this metric tensor, Einstein's G curvature tensor is calculated using a general relativity software program. The spacetime curvature in the vertical z-direction is contained in the G_{zz} component. A 3D plot of this curvature with respect to radius and theta is shown in **FIG. 7**. The axis on the right side is the angle around the periphery, and the axis on the left is the radius which goes from 0 to 20 meters. The vertical axis of the graph is the spacetime curvature in the vertical z-direction. The center of the vertical axis is zero. At a small radius, there is a sinusoidal curvature which is positive from 0 to π and which is negative from π to 2π. What this looks like is a tilted plate as depicted in **FIG. 8**.

[0023] 9. In flat spacetime with no electromagnetic fields or mass, the curvature would be the horizontal plate as seen **FIG. 8**. Due to the traveling magnetic wave, the spacetime curvature looks like the tilted plate. The flat-space magnetic field was pointing up in the vertical direction, having no divergence and no gradient. In curved spacetime, however, the magnetic field becomes tilted just like the plate and a magnetic gradient dB_z/dz is created. This spacetime curvature gradient of the magnetic field times the magnetic moment of the second coil produces a lift force on the hull which is anchored to these coils.

What I claim as my invention is:

1. A spacecraft that generates a magnetic moment and a magnetic field gradient in the vertical direction in order to create a lift force on the hull.

2. A toroidal core wrapped with electrical bobbins at intervals around the core whose purpose is to create and amplify a magnetic wave that travels along the surface of the core.

3. A circular, direct-current carrying solenoid, located radially inside the toroidal core, to create the magnetic moment.

4. Said magnetic surface wave creates a spacetime curvature, similar to a tilted plate, which produces a magnetic field gradient in the vertical direction.

5. A circular hull, with interior cabin, electrical power supply to drive the coils, and a computer to calculate and sequence the activation of the electrical bobbins.

6. Magnetic sensors, in the form of small coils, located on the toroidal core which can detect the velocity and position of the traveling magnetic wave as feedback to the computer control system.

7. A magnetic vortex generator, either rotating magnet or dual coil, to produce a wormhole through which low linear mass and low speed of light hyperspace energy can enter the hull in order to create highly relativistic electromagnetic fields.

8. A variable current generator to modulate the direct current in the coil so as to produce a variable magnetic moment that can control lift, hover and descent.

9. An electrical power supply using mechanical flywheel stored energy together with a large area capacitor, resupplied with energy by solar cells located on the outer surface of the hull.

* * * * *

US 20040164824A1

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(12) **Patent Application Publication** (10) **Pub. No.: US 2004/0164824 A1**
St. Clair (43) **Pub. Date: Aug. 26, 2004**

(54) **HYPERSPACE ENERGY GENERATOR**

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(22) Filed: **Feb. 21, 2003**

Publication Classification

(51) **Int. Cl.^{7}** **H01P 3/06**
(52) **U.S. Cl.** **333/243**

(57) **ABSTRACT**

This invention is a braided gold wire coaxial cable of micron size which generates hyperspace energy by coupling to the tetrahedral geometry of subspace, dimension and the Planck mass.

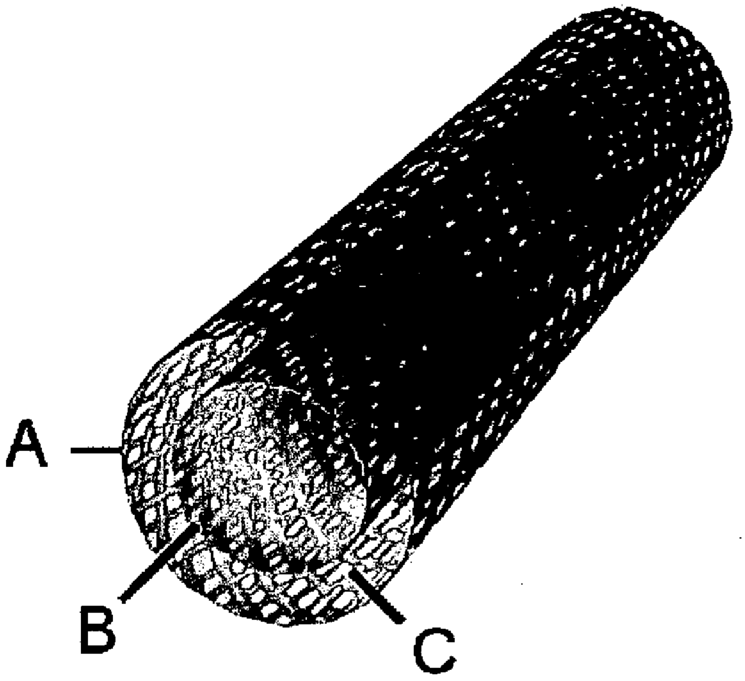

Figure 1

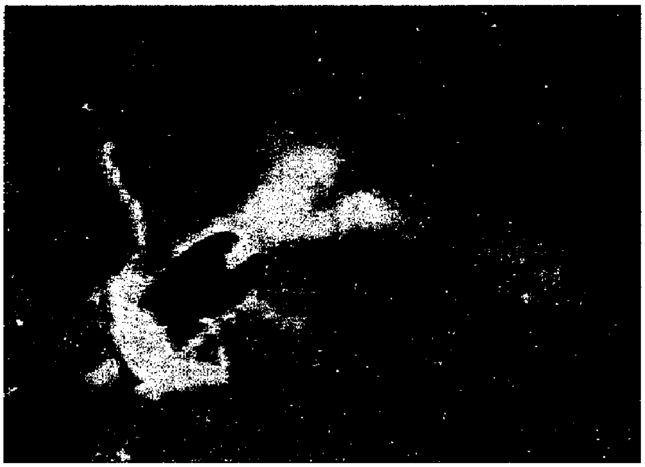

Figure 2

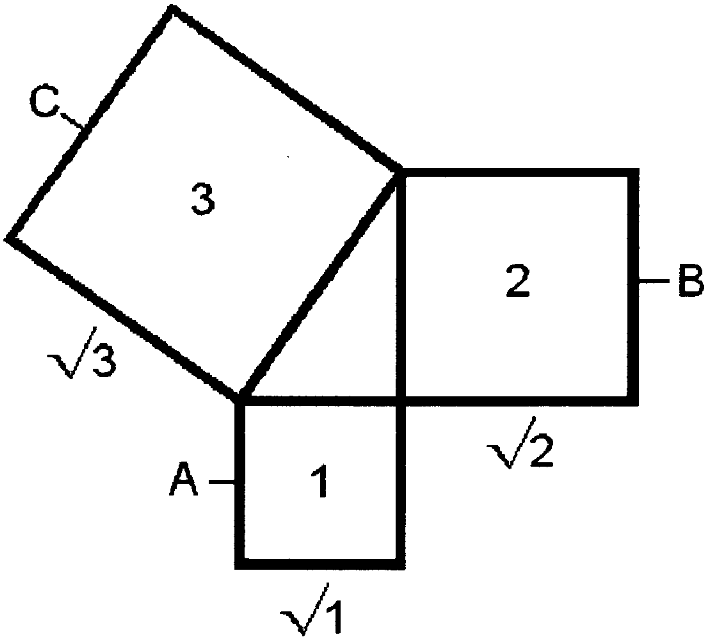

Figure 3

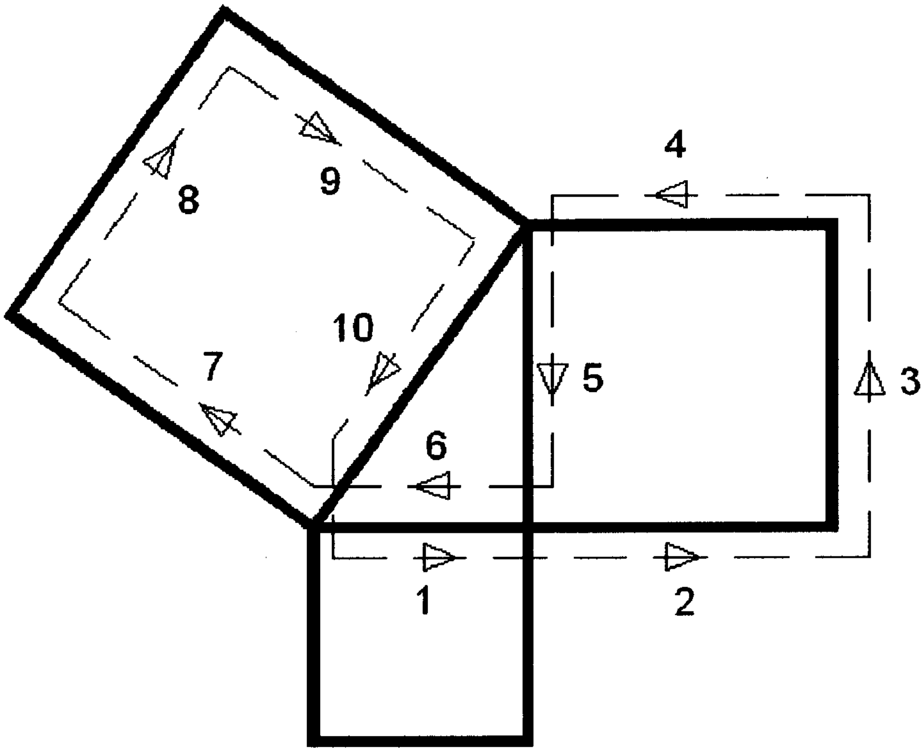
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Figure 4

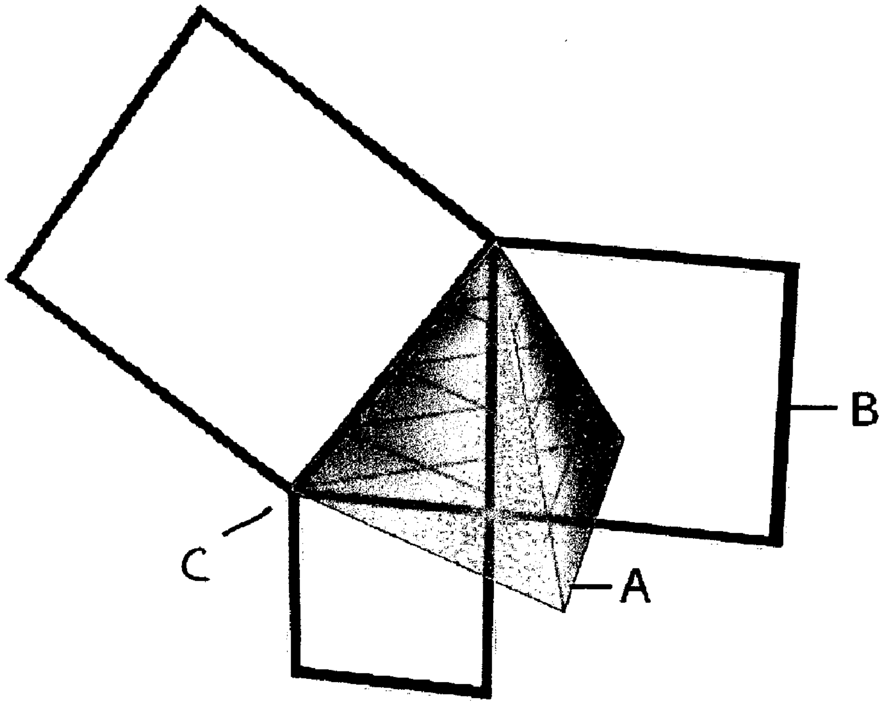

Figure 5

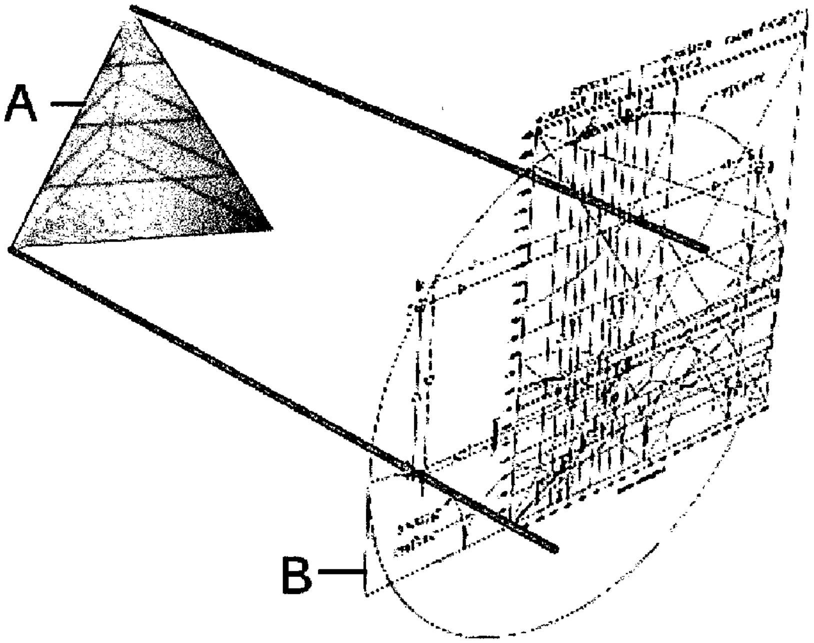

Figure 6

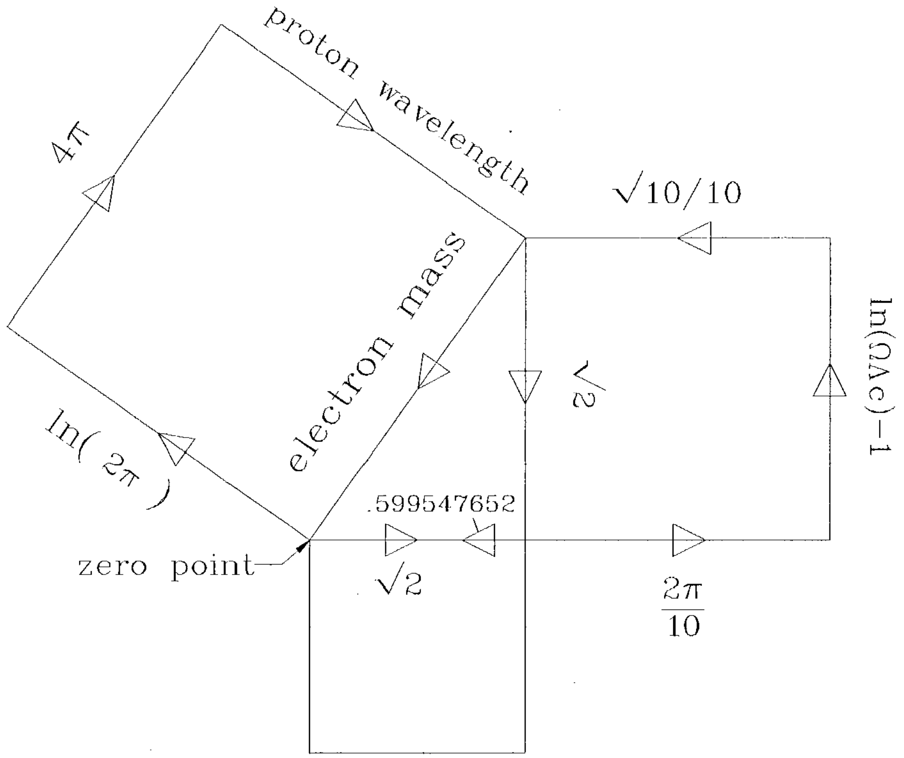
proton wavelength
4π
electron mass
ln(2π)
√10/10
√2
ln(Ω∧c)−1
.599547652
zero point
√2
2π/10

Figure 7

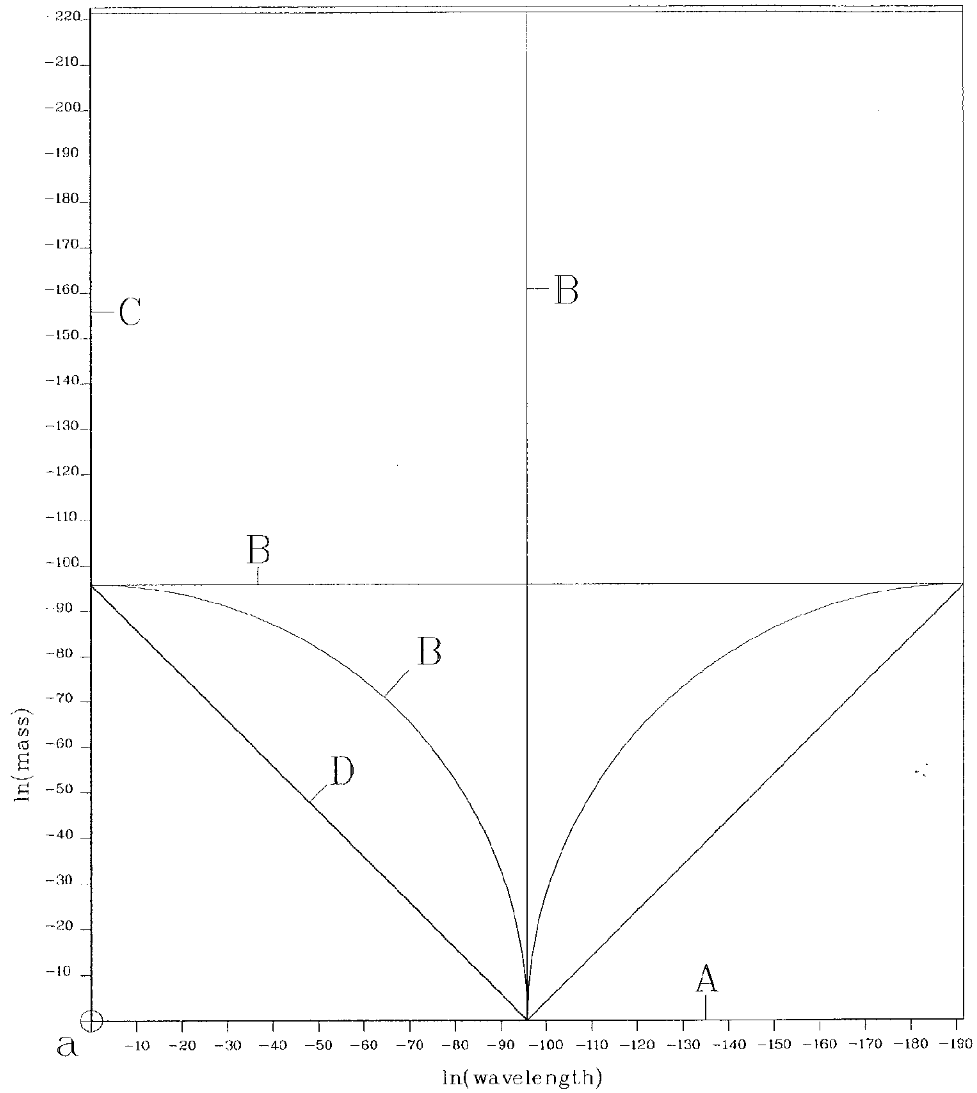
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ln(mass)
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ln(wavelength)

Figure 8

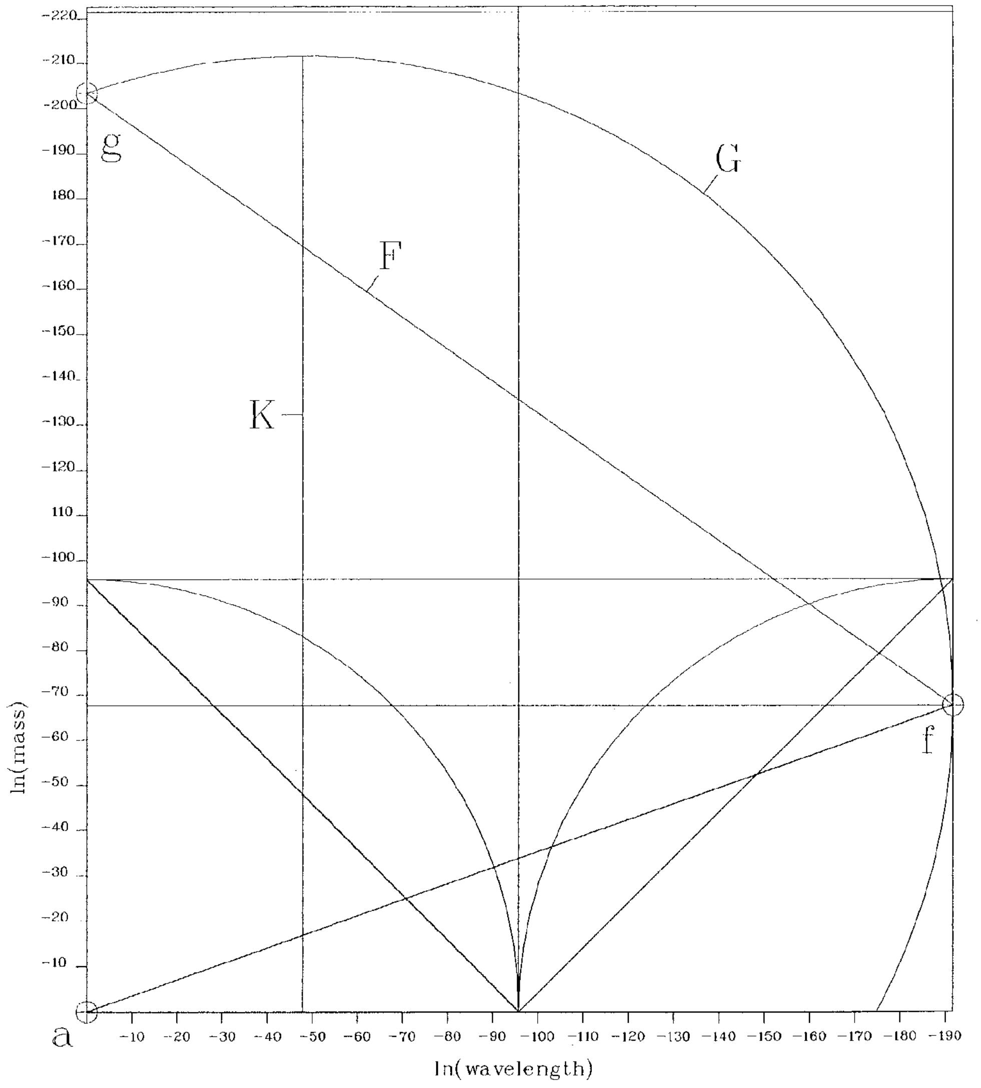
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ln(wavelength)

Figure 9

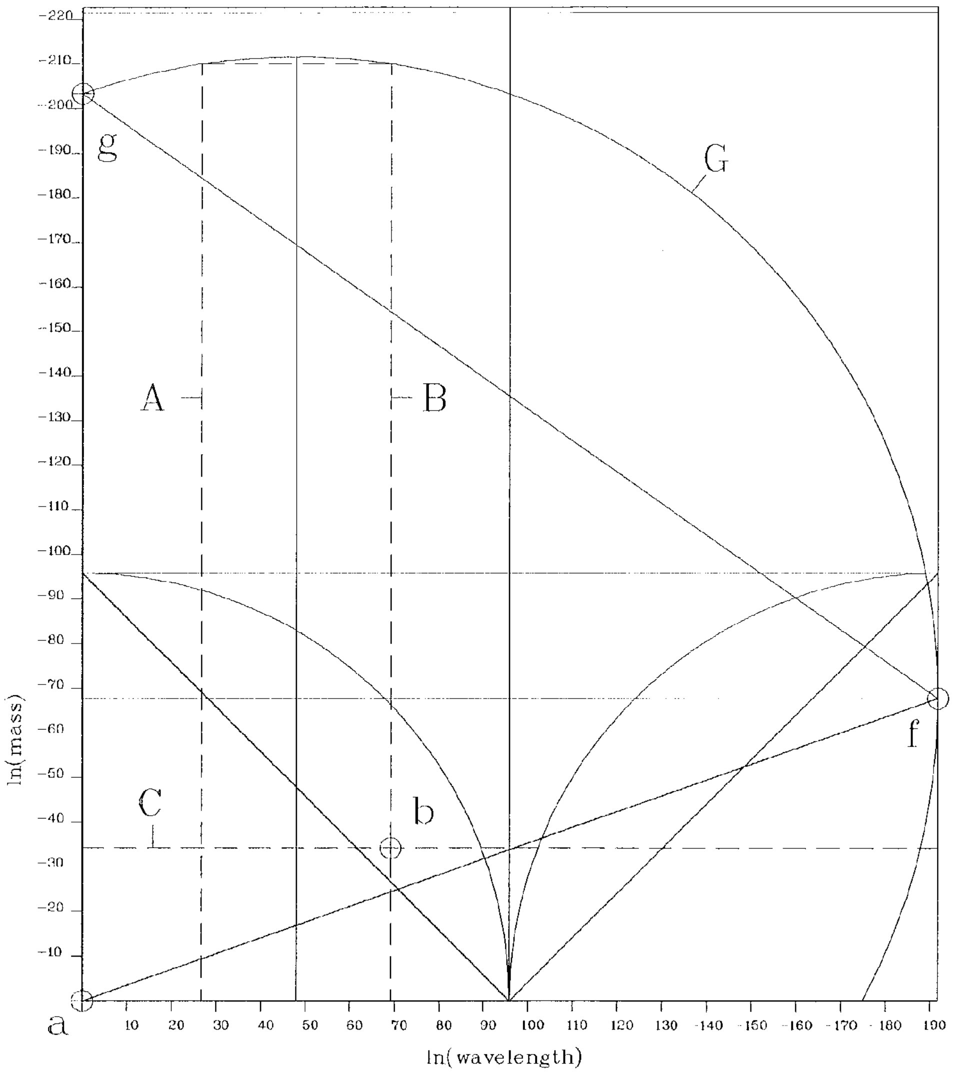
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Figure 10

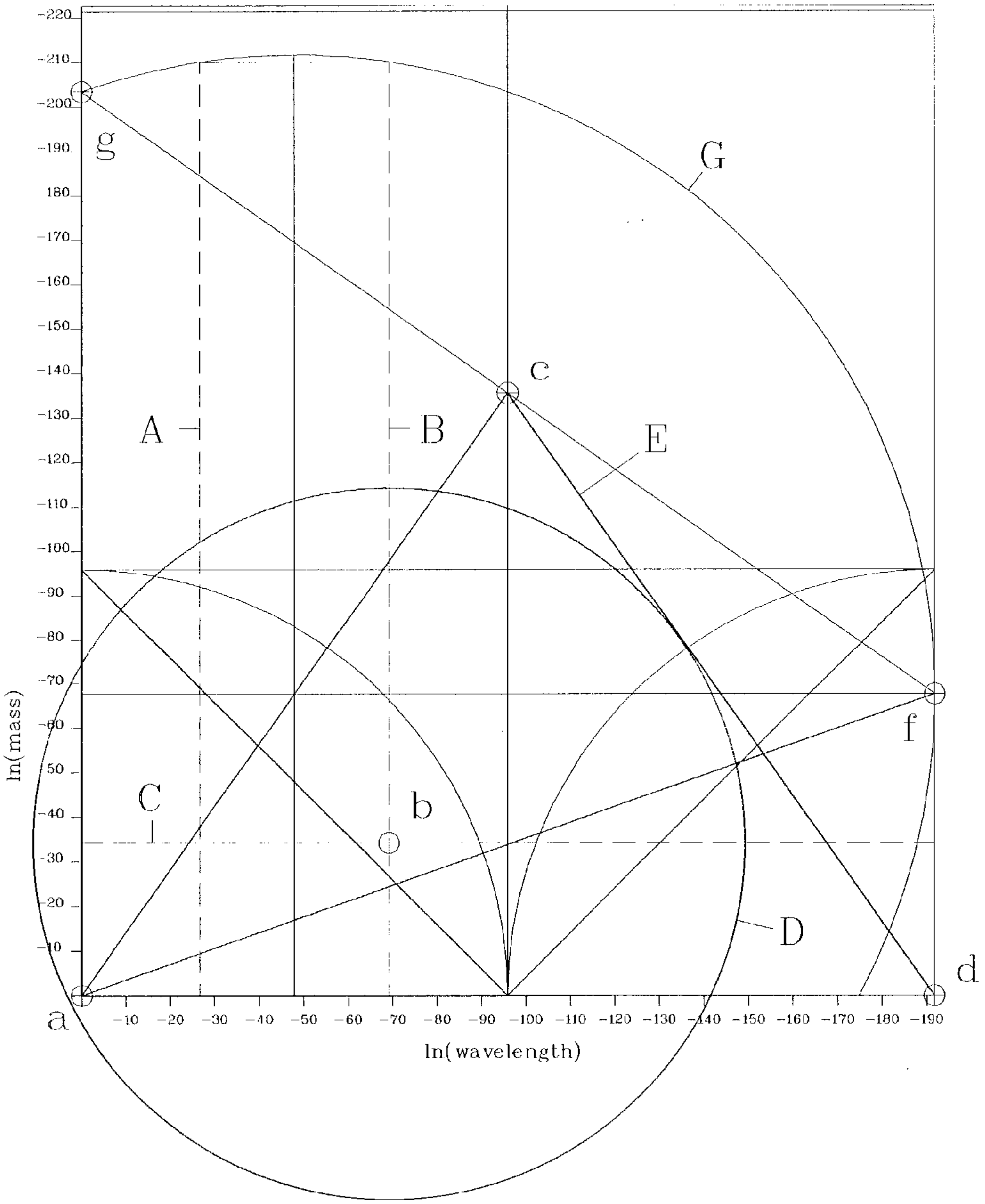
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Figure 11

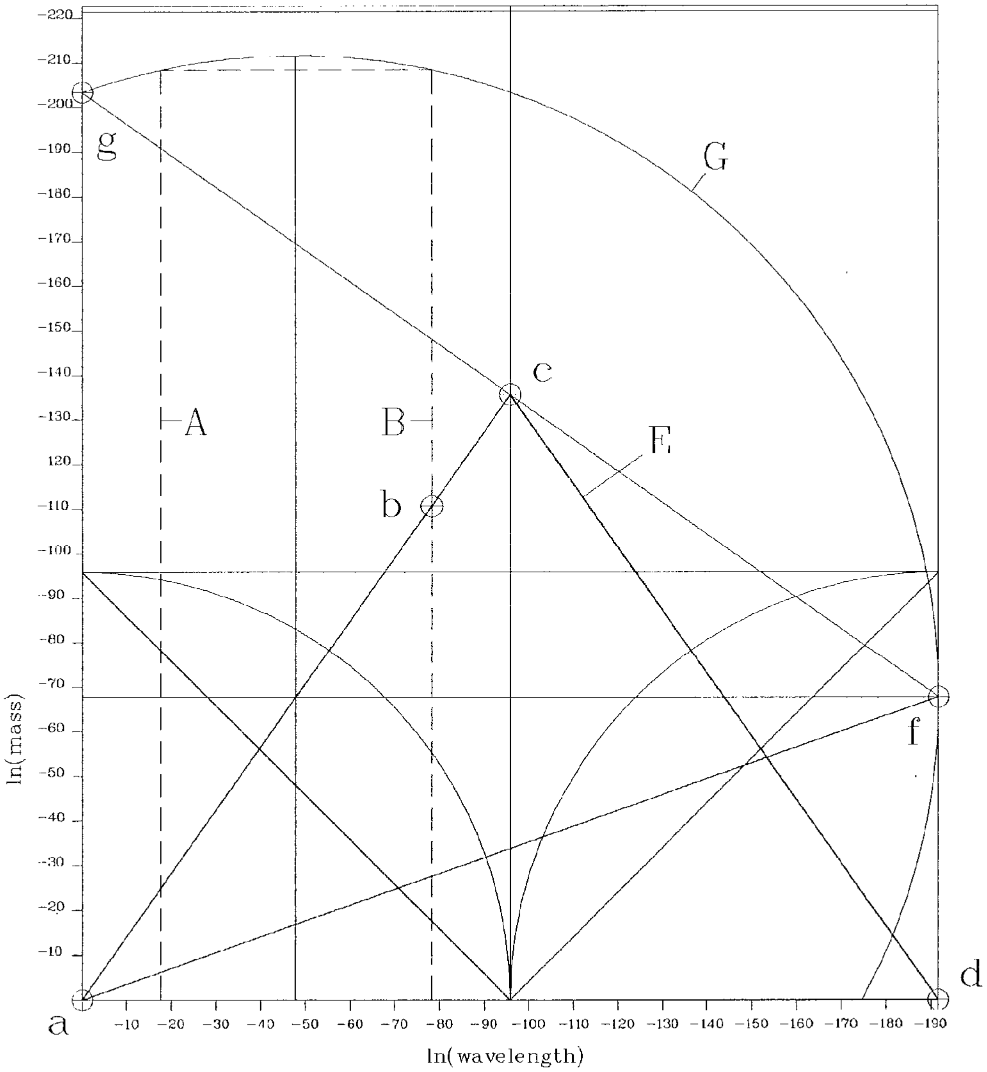
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ln(mass)
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ln(wavelength)

Figure 12

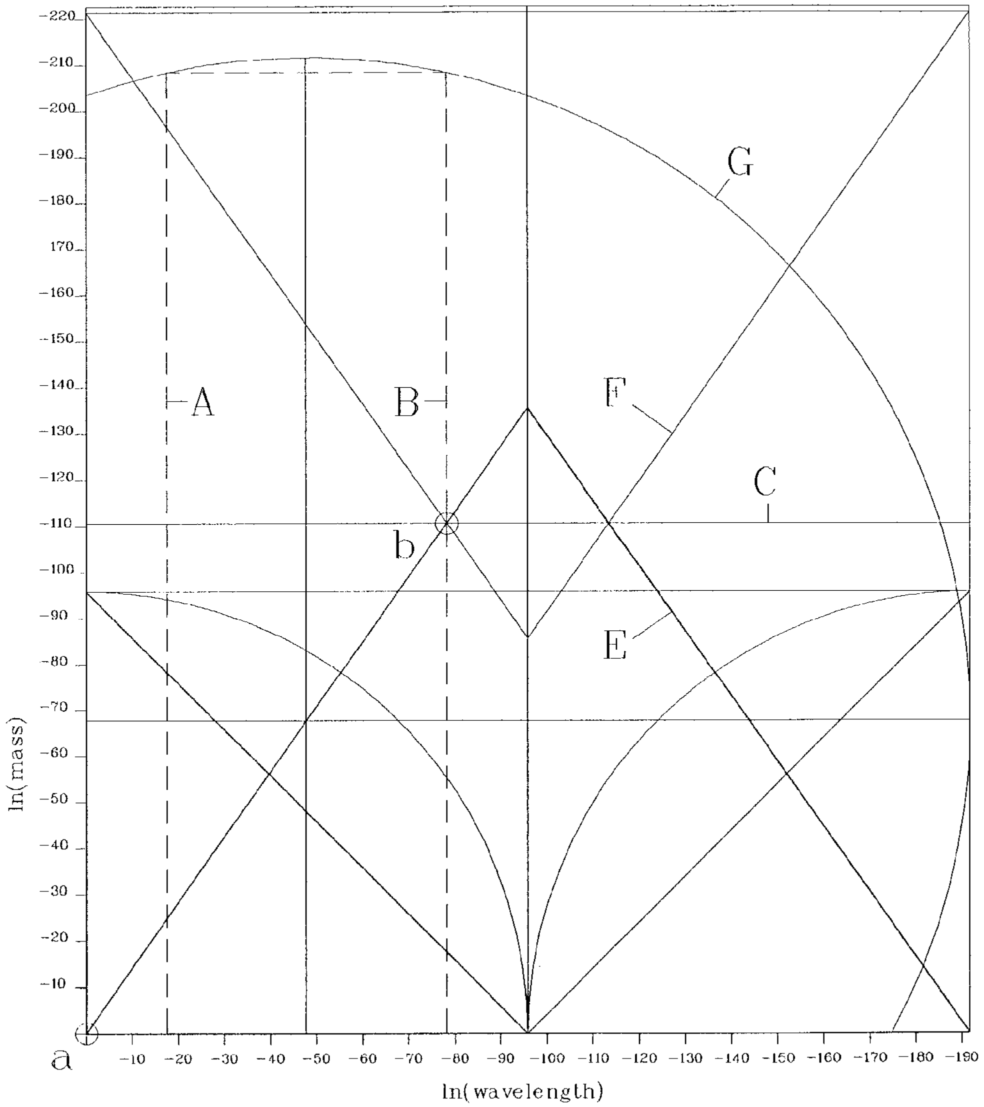
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ln(mass)
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ln(wavelength)

Figure 13

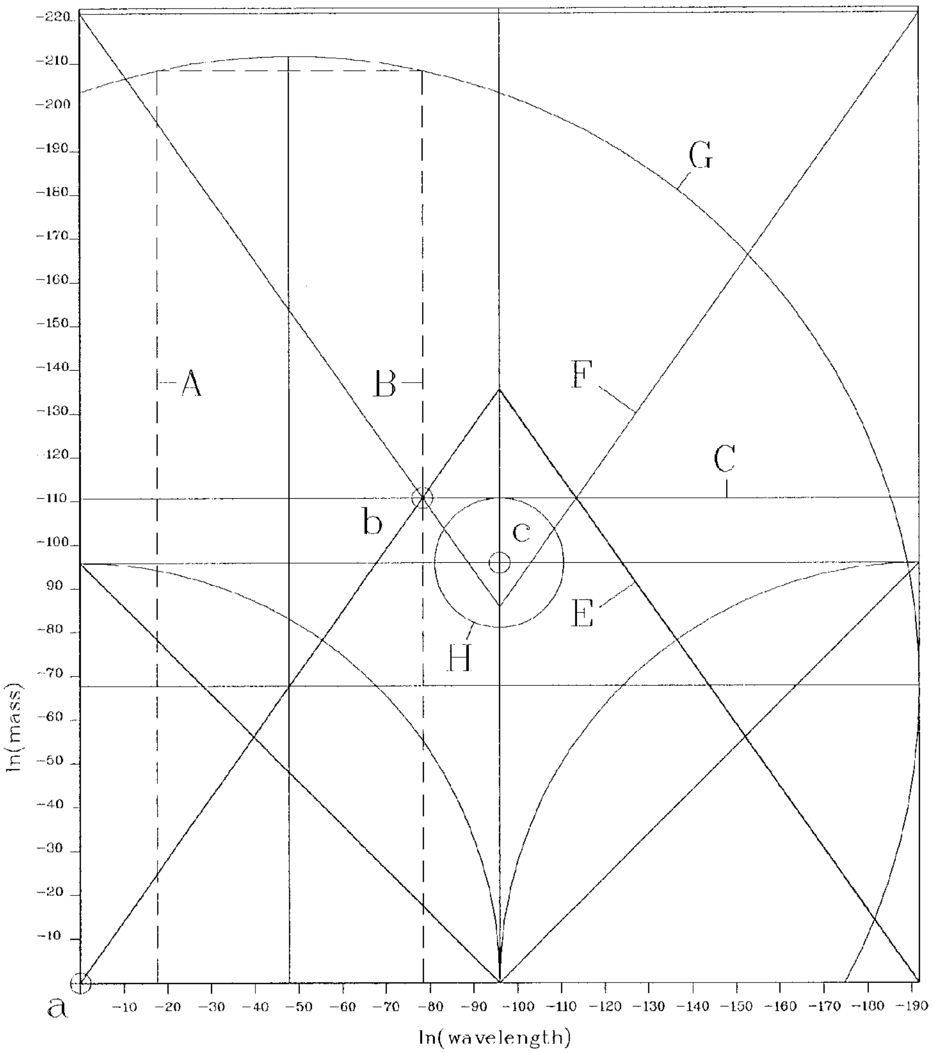
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ln(mass)
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-190
ln(wavelength)
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C
E
F
G
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b
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Figure 14

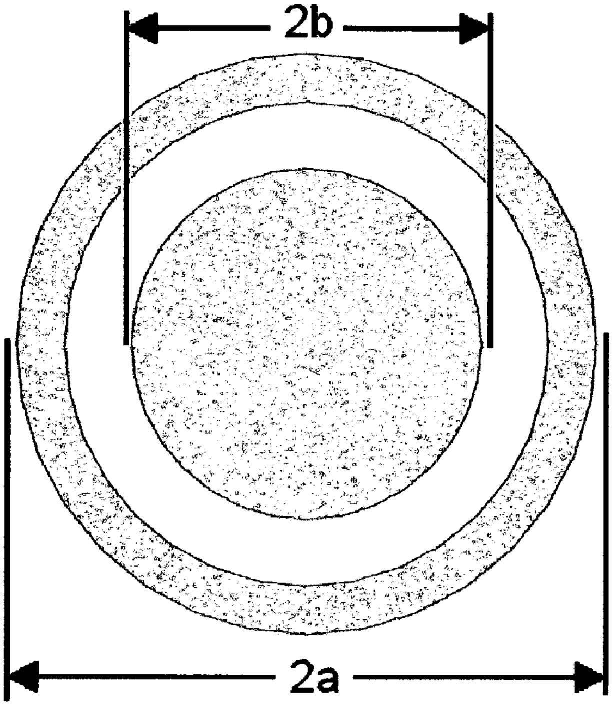

Figure 15

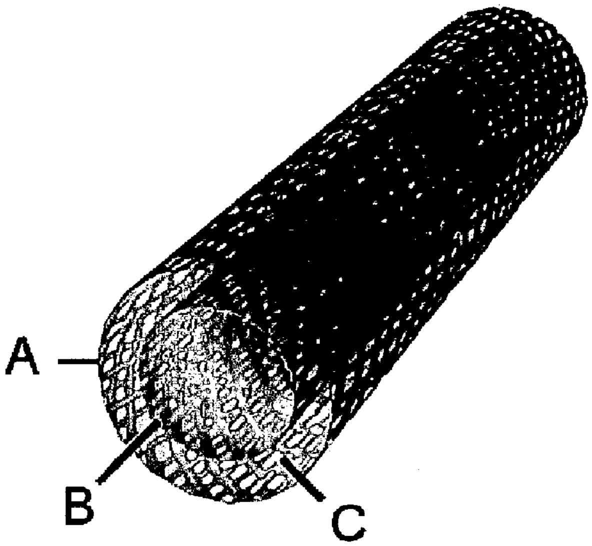

HYPERSPACE ENERGY GENERATOR

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is a braided gold wire coaxial cable of micron size which generates hyperspace energy.

BACKGROUND OF THE INVENTION

[0002] Electrical experiments with micron-sized braided gold wire coaxial cable show that it is capable of generating substantial amounts of hyperspace energy. Referring to the electron microscope photograph shown in **FIG. 1**, the white mist emanating from the cable is low-density hyperspace energy that is flowing in from a co-dimension of our universe. The dimensions of the cable are of such a particular size as to couple the cable to the tetrahedral geometry of subspace, the dimension of space, the Planck mass and the linear inductance of the universe.

[0003] According to physicist Dr. Edward Witten of Princeton University, space has twenty-four dimensions, of which ten dimensions are non-redundant. Imagine taking a path around the Pythagorean triangle, as known as the planar tetrahedron, with sides equal to $\{\sqrt{1}, \sqrt{2}, \sqrt{3}\}$ as shown in **FIG. 2**. There are three squares denoted the one-square (A), the two-square (B) and the three-square (C). Each square has four sides. The edge of each square can be traversed in two directions. Thus the total number of dimensions is

$$dim_{total}=2\cdot(4+4+4)=24$$

[0004] Referring to **FIG. 3**, there is a path starting at the corner of the triangle, along the one-square (**1**), around the two-square (**2,3,4,5**), back along the one-square (**6**), around the three-square (**7,8,9,10**) and back to the corner of the triangle. The numbering of the edges shows that there are ten edges. Because the path is traversed in only one direction, the number of reduced dimensions is

$$dim_{reduced}=1\cdot(10)=10$$

[0005] Referring to **FIG. 4**, the planar tetrahedron (B) forms one edge of the three-dimensional tetrahedron (A). Rotating the planar tetrahedron ±120° produces the other two edges. The tetrahedron has four faces which are equilateral triangles. The ten dimensional path starts and ends at (C), the corner of the tetrahedron known as the zero point.

[0006] Referring to **FIG. 5**, the projection of the 3D tetrahedron (A) onto a plane is called the tetrahedron diagram (B) which is the main diagram of the new geometrical physics known as Δphysics. All the constants of physics can be derived geometrically from the tetrahedron diagram and its associated planar tetrahedron. An example of this is shown in **FIG. 6** where the edges are given specific constants related to tetrahedral geometry, dimension, curvature, and the mass and wavelength of the elementary particles such as the electron and proton. The ten dimensional path includes the following constants

[0007] a. electron wavelength

[0008] b. proton wavelength

[0009] c. 47π The solid angle of the sphere. The tetrahedron is circumscribed by a sphere.

[0010] d. ln(2π) The natural log of the curvature. The subspace geometry is a logarithmic manifold. The tetrahedron diagram plots the logarithm of mass versus the logarithm of wavelength.

[0011] e. 0.599547652 A constant related to fractal dimension and the speed of light factor 2.99792458.

[0012] f. $\sqrt{2}$ The edge of the two-square.

[0013] g. $\sqrt{10}/10$ The square root of ten dimensions per 10 dimensions.

[0014] h. ln(ΩΛc)−1 The natural log of the momentum of space less one.

[0015] i.

$$\frac{2\pi}{10}$$

[0016] The curvature of space per 10 dimensions.

[0017] j. $\sqrt{2}$ The edge of the two-square.

[0018] The length of each edge is multiplied by the constant assigned to that edge. The ten edges have the order of $\{\sqrt{1}, \sqrt{2}, \sqrt{2}, \sqrt{2}, \sqrt{1}, \sqrt{3}, \sqrt{3}, \sqrt{3}, \sqrt{3}\}$. What subspace geometry does is to multiply the edge length, such as $\sqrt{1}$, times the square root of two $\sqrt{2}$. Then it takes the square root of that number and multiplies it by the next edge, which is $\sqrt{2}$, times the curvature per 10 dimensions

$$\frac{2\pi}{10}.$$

[0019] It then takes the square root of that number and so on. In equation form, this looks like the following calculation

$$\sqrt{3a\sqrt{3b\sqrt{3c\sqrt{3d\sqrt{1e\sqrt{2f\sqrt{2g\sqrt{2h\sqrt{2i\sqrt{1j}}}}}}}}}} = 80.1104395$$

[0020] where the letters correspond to those in the list of constants. The square root sum total is equal to the Planck scale Λwhich is the bottom dimensional limit of the universe. The sum of the ten constants per a speed of light circumference is equal to unity

$$\frac{\sum\limits_{n=10} s_n}{2\pi\ln(c)} = 1.000000000$$

[0021] where the log of the speed of light is

$$\ln(c)=\ln(299792458)=19.51860099$$

[0022] and multiplying by 2π is the circumference of a circle with a radius equal to the speed of light.

[0023] Referring to **FIG. 7**, the tetrahedron diagram plots the natural logarithm of mass on the vertical axis (C) versus the natural logarithm of wavelength on the horizontal axis (A). The reason for this is that the mass of the electron times its wavelength is equal to the mass of the proton times its wavelength which in turn is equal to Planck's constant h divided by the speed of light, known as the base constant (B). If two numbers multiply, they sum in logarithms. In subspace geometry, the sum of the logarithm of the mass of the electron plus the logarithm of the wavelength is equal to the logarithm of the base constant which has a value of −95.91546344.

$$\ln(m_{electron}) + \ln(\lambda_{electron}) = \ln\left(\frac{h}{c}\right) = -95.91546344$$

[0024] What this means is that the mass and wavelength slide on a 45° base line (D) which has end points on the vertical and horizontal axes equal to the base constant.

[0025] Referring to **FIG. 8, a** line (af) drawn from the origin at the tetrahedral angle of 19.47122063, equal to the asin(⅓), creates a tetrahedron (F) along path (afg). This tetrahedron is circumscribed by a sphere (G) with sphere diameter (K).

[0026] The Planck scale path calculation showed that the electron mass and the proton wavelength were the last two edges. The electron mass has a value of

$$\ln(m_e) = -69.17083217$$

[0027] and the electron wavelength has a value of

$$\ln(\lambda_E) = -26.74463127$$

[0028] Referring to **FIG. 9**, the electron wavelength (A) is plotted as a vertical line on the tetrahedron diagram. The wavelength reflects off the circumscribing sphere (G), and returns as the electron mass (B). So the diagram incorporates the concepts of both classical physics (point mass particles) and quantum mechanics (wave particles).

[0029] The proton wavelength has a value of

$$\ln(\lambda_p) = -34.26005901$$

[0030] The proton wavelength (C) is plotted as a horizontal line in order to get the intersection (b) with the electron mass.

[0031] Referring to **FIG. 10, a** circle (D) with a radius equal to the Planck scale is drawn centered (b) on the intersection of the electron mass with the proton wavelength, which are the last two edges of the Planck scale calculation. A line (ac) from the origin to the intersection of the base constant with the rotated tetrahedron creates the vertical tetrahedron (acd). As can be seen, the Planck scale is tangent to the tetrahedron on side (cd). This tetrahedron is the projection of the 3D tetrahedron shown before in **FIG. 5**. What this means is that the tetrahedral geometry of subspace determines the bottom limit of our universe. And this bottom limit, called the Planck scale, contains within itself the mass and wavelength of the elementary particles, curvature, dimension and planar tetrahedral geometry. Tetrahedron diagram tet0565 shows that the electron and proton are one and the same particle because the electron path rotates counterclockwise around the curvature and then returns clockwise as the proton path. This path occurs moving through space and hyperspace. Because the single particle enters our universe from hyperspace at two different positions, we see it as two distinct particles. Thus the tetrahedron diagram shows that hyperspace exists.

[0032] The speed of light is equal to the inverse of the square root of the permeability μ of space times the permittivity ϵ of space

$$c = \sqrt{\frac{1}{\mu\varepsilon}}$$

[0033] The permeability is linear inductance or inductance per length which you would find in a solenoid for example. The permittivity is linear capacitance or capacitance per length which you find in a capacitor. In an electrical circuit, the inductance and capacitance form a resonant circuit. The resonance frequency can be changed by changing the inductor or capacitor. In a similar manner, the speed of light is not constant, but can be lowered by increasing the permittivity. Hyperspace energy has a high permittivity and therefore a low speed of light. This low speed of light gives hyperspace energy a luminescent quality which is seen as a white mist **(FIG. 1)**.

[0034] From Einstein's General Theory of Relativity, the stress pressure T on spacetime is proportion to the square of the ratio of the electric field E to the speed of light c.

$$T = \left(\frac{E}{c}\right)^2$$

[0035] Thus substantially lowering the speed of light creates an enormous spacetime pressure which can be used to generate the lift force on electromagnetic field propulsion vehicles. Furthermore, the electric field is subject to the Lorentz transformation

$$E = \frac{E_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

[0036] The electric field E_0 moving in a frame velocity of v, can quickly attain relativistic proportions because the speed of light could be 1 meter per second, rather than the enormous value in our universe of 299792458 meters per second. Thus one would like to permeate the hull of the electromagnetic field propulsion vehicle with this hyperspace energy in order to increase the electric field and hence the spacetime curvature around the hull which produces the enormous lift force on the vehicle. The method of bringing in this hyperspace energy is to use braided gold wire coaxial cable which is coupled to the geometry of subspace. The subspace geometry is contained in the Δphysics tetrahedron diagram.

[0037] Just as space has a linear inductance and linear capacitance, it also has a linear mass Ω or mass per meter.

Physicist Dr. John A. Wheeler of Princeton likes to invert this and call it "mom" for meter of mass. The Planck mass is equal to the Planck scale Λtimes the linear mass Ω

$$\ln(m_{\mathrm{Plank}})=\ln(\Omega\Lambda)=-17.64290101$$

[0038] Planck's constant h is equal to 2π times the Planck scale squared times the linear mass Ω times the speed of light c.

$$h=2\pi\Lambda^2\,\Omega c=2\pi\Lambda(\Omega\Lambda)c$$

[0039] which shows that Planck's constant is actually the circumference of a circle of radius Planck scale times the Planck mass times the speed of light. The base constant is therefore

$$\mathrm{base}=\frac{h}{c}=\frac{2\pi\Lambda(\Omega\Lambda)c}{c}=(2\pi\Lambda)(\Omega\Lambda)=-95.91546344$$

[0040] which is an area, known as the Planck box, bounded by the Planck wavelength (2πΛ) and the Planck mass. Everything outside the Planck box is hyperspace. Everything inside the Planck box is our universe. Thus the boundary between space and hyperspace is the Planck wavelength and the Planck mass. In logarithms, notice that the Planck mass and Planck wavelength, just like the electron and proton, sum to the base constant.

[0041] Referring to **FIG. 11**, the Planck mass (A) and the Planck wavelength (B) are plotted on the diagram and reflected off the sphere. The Planck wavelength intersects the tetrahedron at (b) which is the boundary between space and hyperspace known as the centerline of the diagram. The centerline has a value equal to the base times the square root of 4/3.

$$centerline=\sqrt{\frac{4}{3}}\;base=-110.7536373$$

[0042] Referring to **FIG. 12**, the centerline (C) is drawn on the diagram and the tetrahedron (E) is mirrored (F) across the centerline to indicate the co-dimensions of hyperspace.

[0043] Referring to **FIG. 13, a** circle (H), centered at the base at the base (c), tangent to the centerline (C), has a radius equal to base times the square root of 4/3 less one

$$R=\left(\sqrt{\frac{4}{3}}-1\right)base=14.83817383$$

[0044] This is the length that has to traversed in order to cross over the centerline from the base constant of our universe to the co-dimension of hyperspace. Furthermore, the Planck mass, which is the other boundary, has to be crossed in order to get to either axis as seen by the length between the vertical axis and line (A). It can be looked at also as the length needed to go from the Planck wavelength (B) to the tangent point of circle (H) in order to reach the center of the mirror tetrahedrons.

SUMMARY OF THE INVENTION

[0045] This invention is a braided gold wire coaxial cable of micron size that is coupled to the subspace geometry of the universe for the purpose of bringing in low-density hyperspace energy into our universe from the co-dimensions of hyperspace. The dimensions of the coaxial cable are of such particular size as to enable it to couple to the ten dimensions of space, the 3:1 geometrical ratio of the tetrahedron, the coaxial wave function based on the logarithm of the ratio of the outer radius to the inner radius of the cable, the length between the base constant of our universe and the centerline between mirror tetrahedrons, and the geometrical relationship between the Planck mass and the linear inductance of the cable.

[0046] Referring to **FIG. 14**, the coaxial guide has an outer braided conductor (A) and an inner braided conductor (B) in which the outer and inner conductors are at radii a and b respectively. The linear inductance L of the cable is equal to the natural logarithm of the ratio of the radii times the permeability μ of space divided by the curvature 2π

$$L=\ln\left(\frac{a}{b}\right)\frac{\mu}{2\pi}$$

[0047] It can be shown that the ratio of the area-to-volume ratio of the tetrahedron to the area-to-volume ratio of its circumscribing sphere is 3:1. It is also the ratio of the area of the three-square to the area of the one-square on the planar tetrahedron. It is also the tetrahedral angle asin(⅓) equal to 19.47122063°. It is also a maximum work condition between the velocity ratio of a fluid stream and a moving vane such as in turbomachinery. So the first constraint on the radii is

$$\exp\left(\ln\left(\frac{a}{b}\right)+1\right)\equiv 3$$

[0048] The second constraint is that the radius c of the circle, equal to the difference between the base constant and the centerline, is related to ten dimensions. The value of the radius projected into our universe is

$$c=\left(\sqrt{\frac{4}{3}}-1\right)\mathrm{base}=.3596358547\cdot\mathrm{microns}$$

[0049] and the dimensional constraint is

$$\left[\ln(c)+\ln\left(\frac{1}{a}\right)\right]^2=10$$

[0050] The coaxial wave function constraint is

$$\frac{\ln(a)^2}{2\pi\ln\left(\frac{a}{b}\right)} \equiv \ln(c)^2$$

[0051] The linear inductance of the coaxial cable has to be such that it gets geometrically across the Planck mass which is the second boundary of our Planck box

$$\exp\left(\ln(\Omega\Lambda) - \ln\left(\frac{\ln\left(\frac{a}{b}\right)}{2\pi}\mu\right) + 1\right) \equiv 3$$

[0052] With these four subspace constraints, the outer radius a and inner radius b of the cable are

[0053] a=8.342461828 microns

[0054] b=7.559058141 microns

[0055] so the cable has an outside diameter of roughly 16 to 17 microns.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0056] Not Applicable.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0057] **FIG. 1**. Electron microscope photograph of the coaxial cable and hyperspace mist.

[0058] **FIG. 2**. The planar tetrahedron.

[0059] **FIG. 3**. The ten dimensional path around the planar tetrahedron.

[0060] **FIG. 4**. The relationship between the planar tetrahedron and the 3D tetrahedron.

[0061] **FIG. 5**. Projection of the 3D tetrahedron onto a plane to create the tetrahedron diagram.

[0062] **FIG. 6**. Dimension, geometry, curvature and elementary particles that make up the ten dimensional Planck scale path.

[0063] **FIG. 7**. Tetrahedron diagram showing base constant.

[0064] **FIG. 8**. Tetrahedron diagram showing rotated tetrahedron and circumscribing sphere with electron mass and wavelength reflecting off sphere.

[0065] **FIG. 9**. Tetrahedron diagram showing intersection of electron mass with proton wavelength which are components of the Planck scale path.

[0066] **FIG. 10**. Tetrahedron diagram showing Planck scale tangent to tetrahedron.

[0067] **FIG. 11**. Tetrahedron diagram showing Planck mass and Planck wavelength intersecting tetrahedron.

[0068] **FIG. 12**. Tetrahedron diagram showing mirror tetrahedrons across centerline, the boundary between space and hyperspace.

[0069] **FIG. 13**. Tetrahedron diagram showing distance between the base constant and the centerline used to calculate the dimensions of the coaxial cable.

[0070] **FIG. 14**. End view of coaxial cable showing radii a and b used in the subspace geometry constraints in order to couple to hyperspace.

[0071] **FIG. 15**. Perspective view of braided gold wire coaxial cable.

DETAILED DESCRIPTION OF THE INVENTION

[0072] 1. Referring to **FIG. 15**, the coaxial cable has a braided gold wire outer conductor (A) and a braided gold wire inner conductor (B) separated by a dielectric (C). The open braiding promotes the conduction of the electromagnetic wave while allowing the hyperspace mist to seep out of the braid and permeate the surrounding material in which it is embedded.

[0073] 2. The radius of the outer conductor a and the radius of the inner conductor b have the following values in order to couple the cable to the tetrahedral geometry of subspace.

[0074] a=8.342461828·microns

[0075] b=7.559058141·microns

[0076] 3. Even though the wire size is very small, the cable can be made in limited lengths using the new nanotechnology and silicon micromotors.

I claim:

1. A coaxial cable which has:

- a) a braided gold wire outer conductor of radius 8.34 microns;
- b) a braided gold wire inner conductor of radius 7.56 microns;
- c) a thin dielectric separator between the two conductors; and
- d) an open weave to allow the hyperspace mist to seep out of the cable and permeate the surrounding material in which the cable is embedded;

2. A specific relationship between the physical dimensions of the coaxial cable, given in items (**1***a*) and (**1***b*), to the following tetrahedral subspace couplings:

- a) the ratio of the area-to-volume ratio of the tetrahedron to the area-to-volume ratio of its circumscribing sphere, equal to 3:1, with a coupling to the natural logarithm of the ratio of the radii of the conductors;
- b) the ratio of the area of the three-square of the planar tetrahedron to the area of the one-square, equal to 3:1, with a coupling to the Planck mass and the linear inductance of the cable;
- b) the distance between the base constant and $\sqrt{4/3}$ times the base constant, equal to −14.83817383 in natural logarithms, with a coupling to the outer radius of the

conductor, the ten dimensions of space, and the co-dimensions of hyperspace; and

c) the wave function of the coaxial guide given in terms of item (**2***c*), the natural logarithm of the ratio of the radius of the outer conductor to the radius of the inner conductor, and the curvature 2π.

* * * * *

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(54) **ELECTRIC DIPOLE MOMENT PROPULSION SYSTEM**

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(52) **U.S. Cl.** **60/203.1**

(57) **ABSTRACT**

A spacecraft propulsion system utilizing a rotating octagon of trapezoidal electrically charged flat panels to create an electric dipole moment that generates lift on the hull.

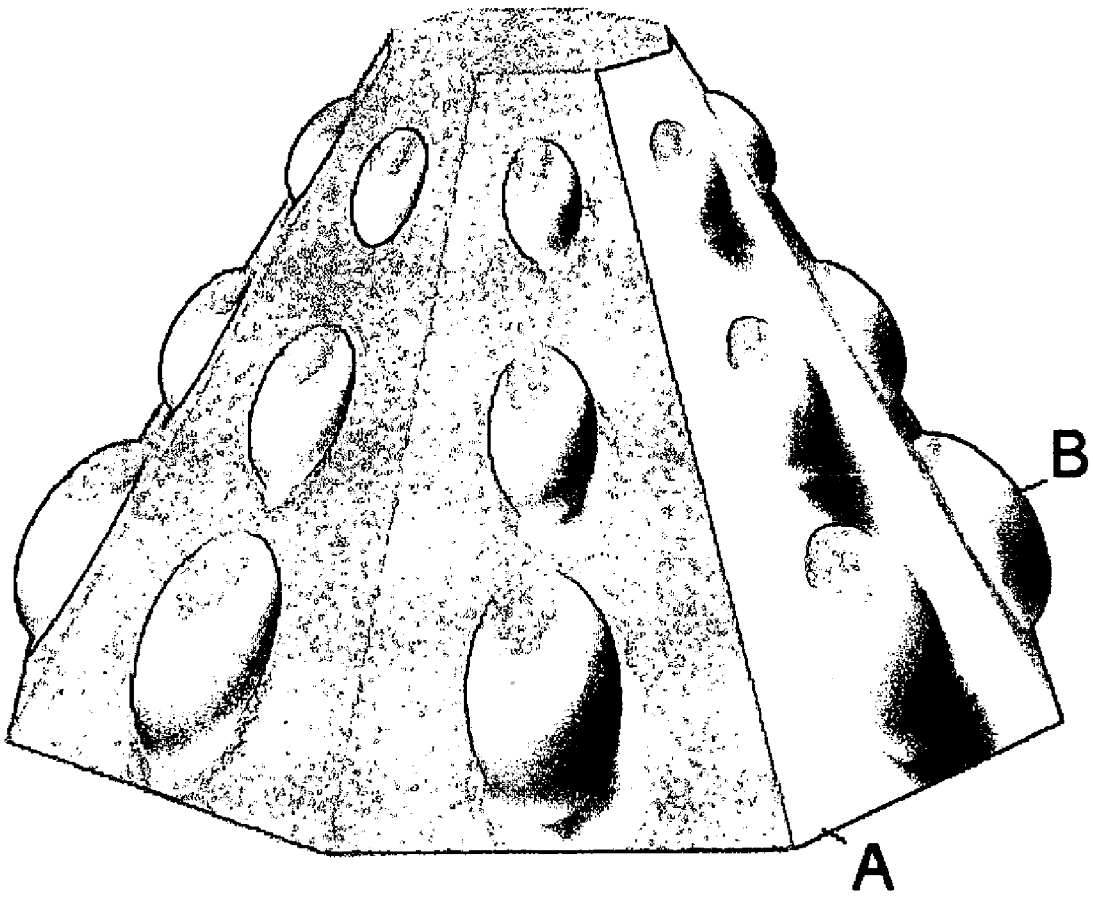

Figure 1

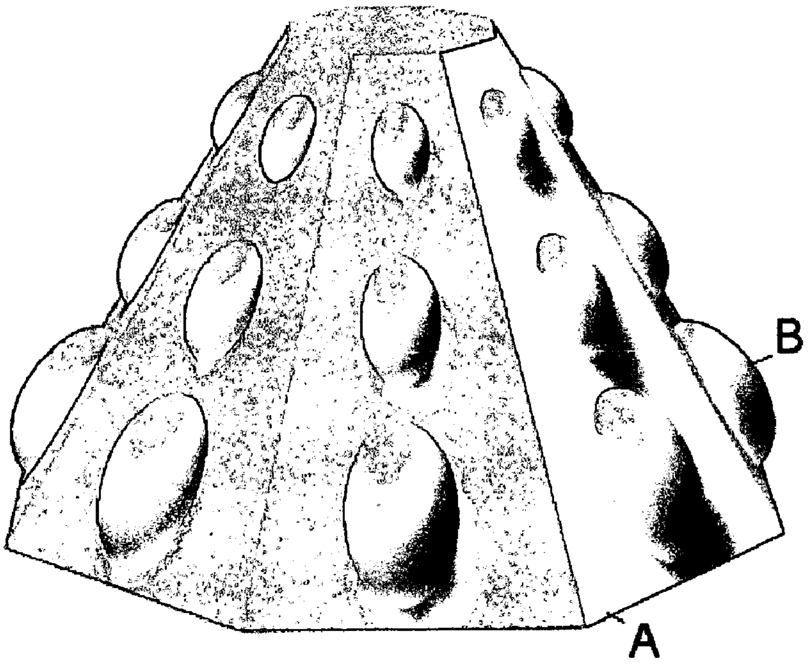

Figure 2

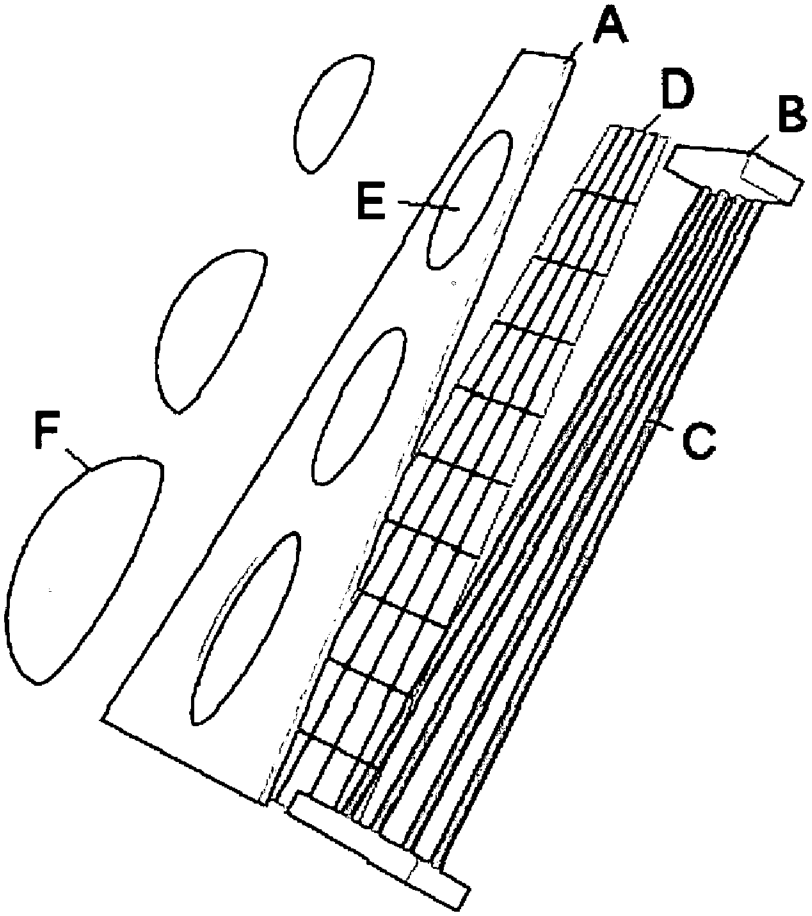

Figure 3

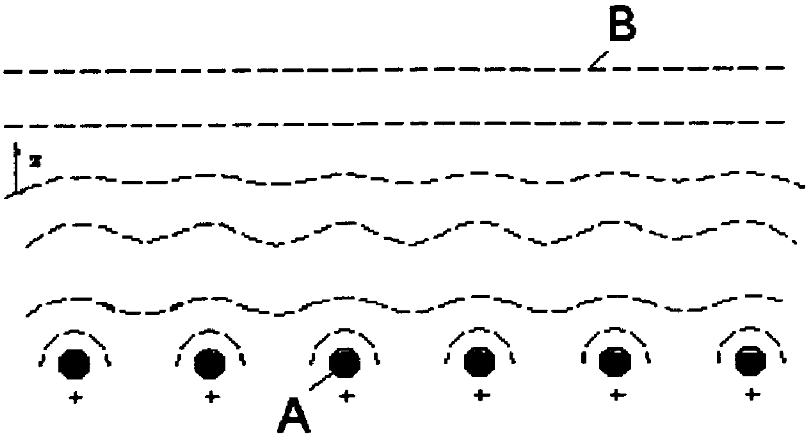

Figure 4

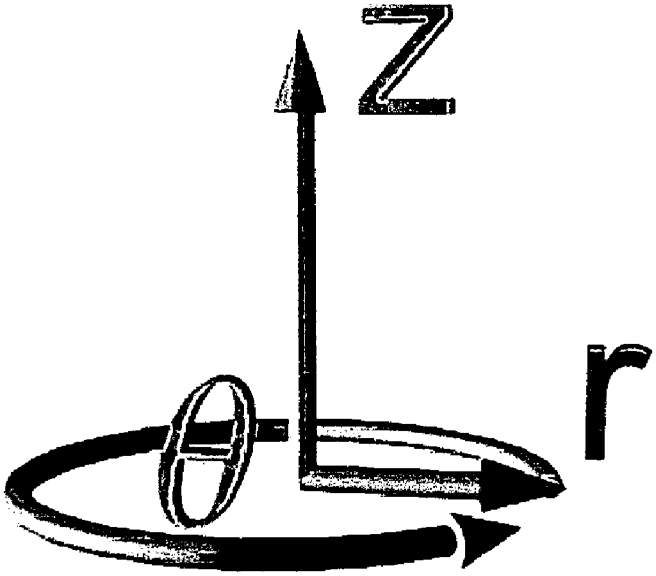

Figure 5

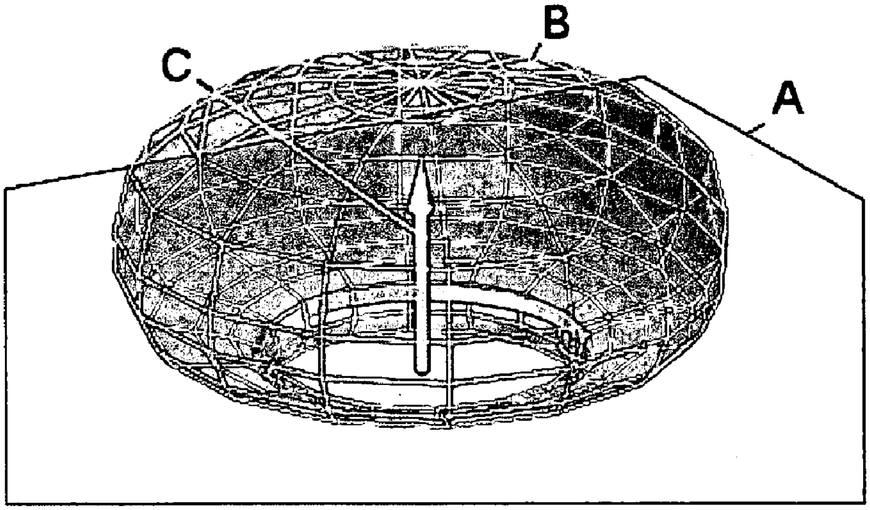

Figure 6

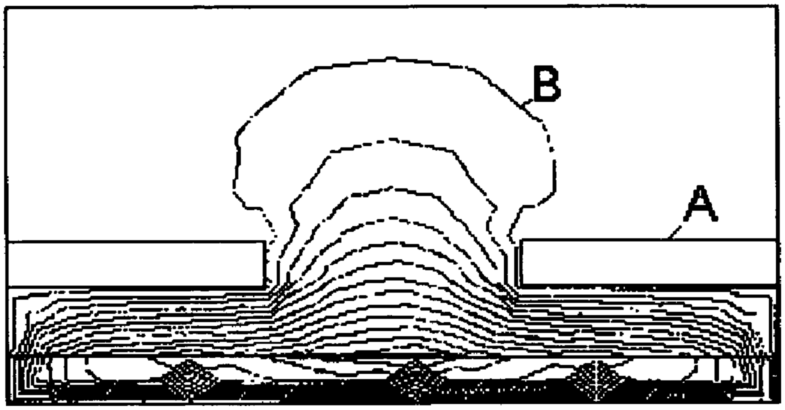

Figure 7

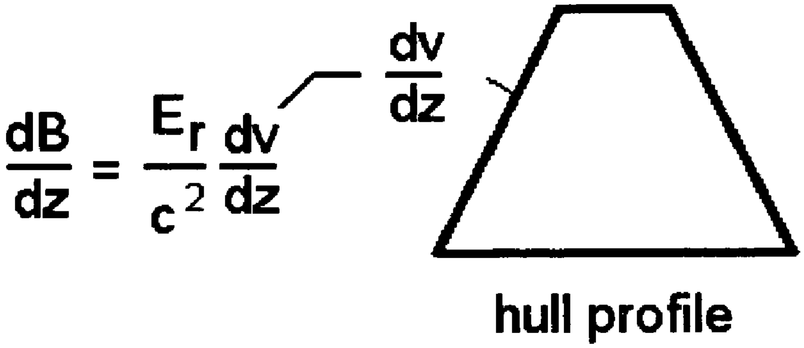
$\frac{dB}{dz} = \frac{E_r}{c^2}\frac{dv}{dz}$
$\frac{dv}{dz}$
hull profile

Figure 8

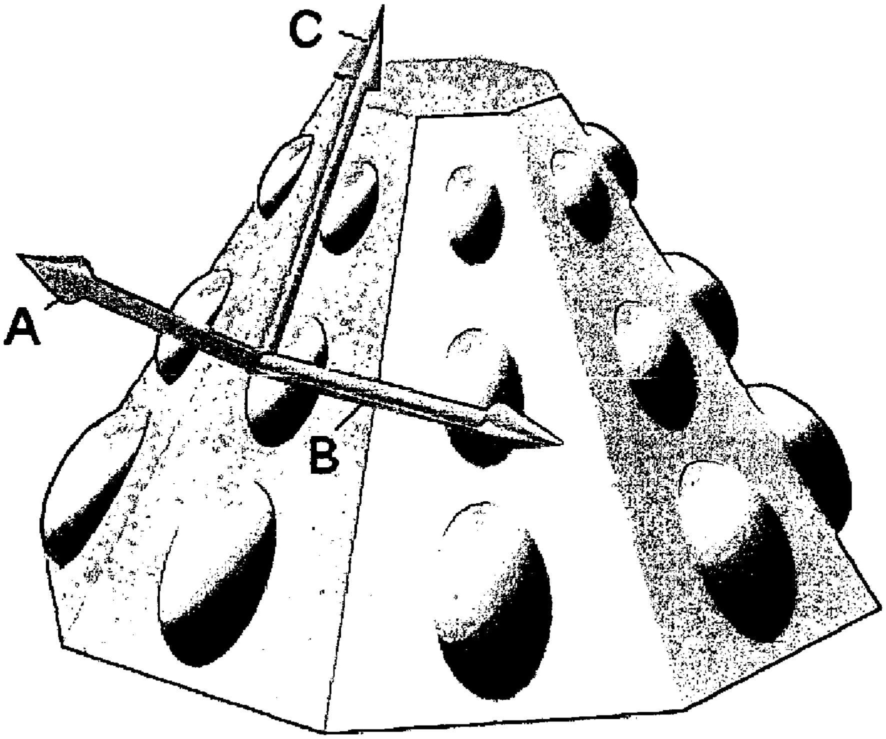

Figure 9

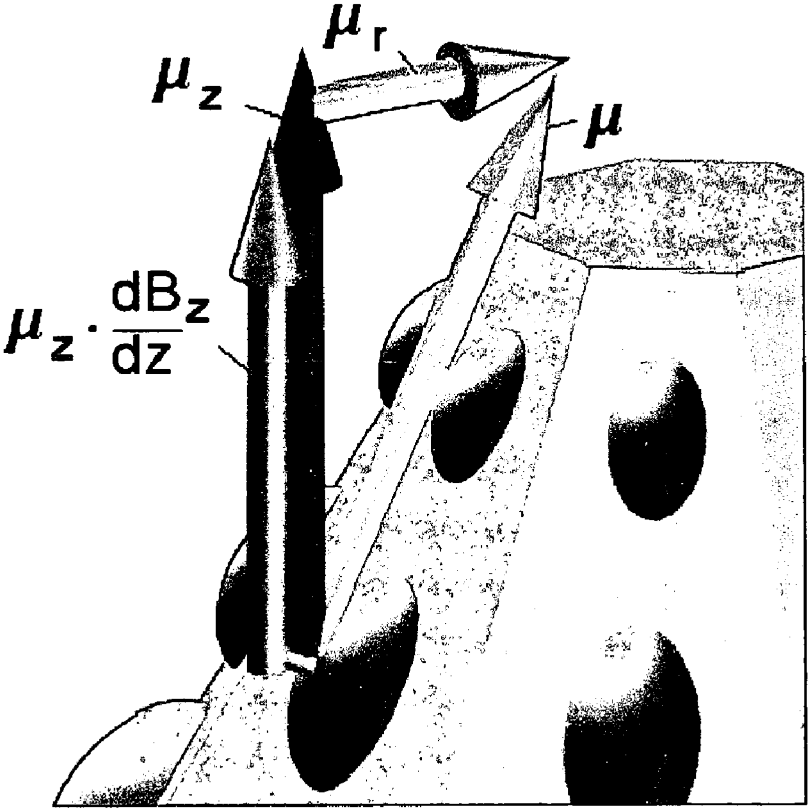
μ_r
μ_z
μ
$\mu_z \cdot \frac{dB_z}{dz}$

Figure 10

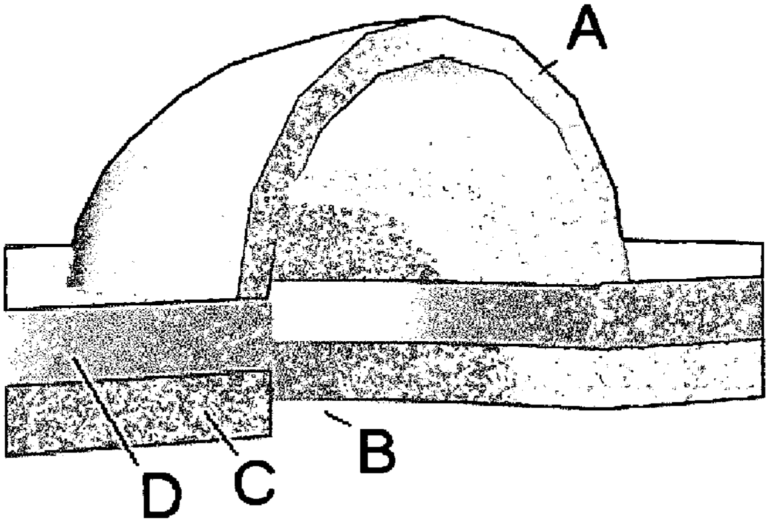

Figure 11

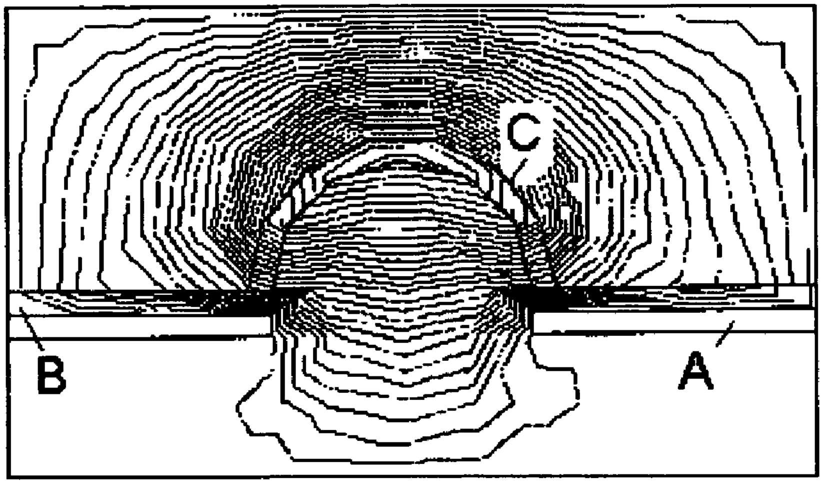

ELECTRIC DIPOLE MOMENT PROPULSION SYSTEM

BRIEF SUMMARY OF THE INVENTION

[0001] The invention is a spacecraft utilizing trapezoidal electrostatically charged flat plate panels which form a pyramidal hull. A panel contains three holes each of which produces a potential energy ellipsoidal bubble that creates an electric dipole moment. The rotation of the hull generates a magnetic moment and a magnetic field gradient in the vertical direction that produces a lift force on the spacecraft.

BACKGROUND OF THE INVENTION

[0002] It is known from electrodynamics that a hole in a conducting plane forms a potential energy bubble. This bubble creates an electric dipole moment from which it is possible to develop a magnetic moment. A rotating tilted hull produces a velocity gradient that generates a magnetic field gradient in the vertical direction. This combination produces a lift force on the spacecraft. A very large potential energy bubble is produced provided that the hole protrudes out of the plate in an ellipsoidal shape. Furthermore, a double cladding, in which each layer around the hole has a different permittivity, confines the field to the outside of the hull for even better results.

[0003] The planar potential energy is created by a grid of electrically charged wires or rods running the length of each panel. A circular potential energy from each rod very quickly sums to form a flat sheet of energy which emerges from the hole to form the potential energy bubble.

SUMMARY OF THE INVENTION

[0004] The invention relates to a spacecraft utilizing a rotating octagon of trapezoidal electrically charged flat plate panels to form a hull in the shape of a pyramid. Each panel has three protruding ellipsoidal bubbles that produce an electric dipole moment from a planar potential energy field created by a group of charged rods parallel to the panel. Because the panels are tilted and the hull is rotating, there is a tangential velocity gradient in the vertical direction. This creates the magnetic moment. Because the hull rotates, the radial electric field produces a magnetic field gradient in the vertical direction. This combination of magnetic moment and magnetic field gradient produces a lift force on the hull of the spacecraft.

[0005] On the underside of each panel is a group of high voltage electrically charged rods which run parallel to the panel. These wires or rods produce a planar electrical potential field underneath the holes in the panel. This potential energy field then bubbles out of the holes in the panel to create a large ellipsoidal potential energy field above the hull. The potential energy bubble carries an electric dipole moment which when rotated with the hull generates a magnetic moment in the vertical direction.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0006] **FIG. 1**. Perspective view of electric dipole moment spacecraft.

[0007] **FIG. 2**. Perspective exploded view of one panel with the ellipsoidal domes, flat hull panel with three holes, the charged rod grid and the planar potential energy field.

[0008] **FIG. 3**. Planar view of flat potential energy field produced by electrically charge wire rods.

[0009] **FIG. 4**. Perspective view of cylindrical coordinates $\{r, \theta, z\}$.

[0010] **FIG. 5**. Perspective view of ellipsoidal potential energy field emerging from hole in plate which produces an electric dipole moment.

[0011] **FIG. 6**. Planar view of field lines of potential energy bubble emerging from plate hole.

[0012] **FIG. 7**. Planar view of sloping hull profile needed to get a velocity gradient.

[0013] **FIG. 8**. Perspective view of hull showing electric dipole moment, the tangential velocity of the hull, and the magnetic moment.

[0014] **FIG. 9**. Perspective view of the magnetic moment components in the radial and vertical direction whereby the lift force is generated by the dot product of the vertical magnetic moment with the magnetic field gradient.

[0015] **FIG. 10**. Perspective view of cross section of dome showing two layer cladding with different permittivities to enhance potential energy field.

[0016] **FIG. 11**. Planar view of enhanced potential energy field with two layer cladding.

DETAILED DESCRIPTION OF THE INVENTION

[0017] 1. Referring to **FIG. 1**, the spacecraft is a rotating octagon of trapezoidal electrostatically charged flat panels which form a closed hull (A). Each panel has three ellipsoidal domes (B) of varying size centrally located along the major length of the panel. The purpose of the dome is to create a large ellipsoidal potential energy bubble over the hull which develops an electrical dipole moment. Because the hull is rotating, a magnetic moment is created in the vertical direction. A magnetic field gradient created by the rotating electric field on the hull in combination with the magnetic moment produces a lift force on the hull.

[0018] 2. Referring to **FIG. 2**, the trapezoidal hull panel (A) contains three ellipsoidal holes (E). A group of wires or rods (C) running parallel to and just underneath the panel are electrically charged to a high voltage at the end terminals (B). The rods produce a planar potential energy field (D) just under the holes in the panel. The field emerges from the holes in the shape of an ellipsoidal bubble and is amplified by an ellipsoidal dome (F) on the outside of the hull.

[0019] 3. Referring to **FIG. 3**, the group of parallel rods (A) are given a linear charge λ in units of charge per meter. The electric field E developed by the rod is the linear charge divided by the circumference of a circle of radius r around the wire times the permittivity ϵ of space. The analysis of this arrangement shows that within a few grid width spacings, the potential energy field ϕ due to the electric field E_0 has become planar (B) in the z-direction given by the equation

$$\phi = -E_0 z$$

[0020] 4. Referring to **FIG. 4**, the following analysis is done in cylindrical coordinates {r,θ,z}.

[0021] 5. Referring to **FIG. 5**, the ellipsoidal potential energy (B) emerges through the hole in the panel plate (A). In doing so it creates an electrical dipole moment (C) shown by the arrow normal to the hole area.

[0022] 6. Referring to **FIG. 6**, the bubble (B) emerges through plate (A).

[0023] 7. Because the bubble has the shape of an ellipse, the centroid y of the bubble would be four thirds the radius a divided by π as given by

$$\bar{y}_{ellipse} = \frac{4}{3}\frac{a}{\pi}$$

[0024] The electric dipole moment is then given as the charge q times the centroid y. The charge of the hole is equal to the permittivity E times the electric field E emerging from the hole times the area of the hole of radius a

$$q = \varepsilon_0 E \pi a^2 \frac{\text{coul}^2}{\text{m}^2\ \text{newton}} \frac{\text{newton}}{\text{coul}}\ \text{m}^2 = \text{coul} = \text{charge}$$

[0025] 8. The electric dipole moment p is the centroid y times the charge q

$$p = qy = \varepsilon_0 E \pi a^2 \frac{4}{3}\frac{a}{\pi} = \frac{4}{3}\varepsilon_0 E a^2\ \text{coul}\cdot\text{meter}$$

[0026] The electric dipole moment p times the hull velocity v is equal to a magnetic moment μ which is what creates the lift force on the hull

$\mu = pv$ amp·m^2

[0027] 9. The rotating hull creates the electric dipole moment velocity so that the entire hull develops a magnetic moment. In tensor notation, the magnetic moment μ is in the vertical z-direction because there is a radial component of the electric dipole moment times the velocity. The velocity is the radius r in the radial direction times the angular velocity ω in the z-direction

$\mu^z = p_r x^r \omega^z$

[0028] 10. The force F on the hull is the gradient of the dot product of the magnetic moment μ with the magnetic B field

$F = \nabla(\mu \cdot B)$

[0029] 11. By electrically charging the hull of the vehicle, a radial electric field is produced. By rotating the hull, the radial electric field changes with time. Thus Maxwell's equations will involve the curl of the magnetic field in the radial direction because the radial electric field is varying with time

$$(\nabla \times B)_r = \frac{1}{c^2}\frac{\partial E_r}{\partial t}$$

[0030] 12. The cross product involves the magnetic field in the theta direction which is zero

$$\frac{1}{r}\frac{\partial B_z}{\partial \theta} - \frac{\partial B_\theta}{\partial z} = \frac{1}{c^2}\frac{\partial E_r}{\partial t} = \frac{1}{r}\frac{\partial B_z}{\partial \theta}$$

[0031] Substituting the derivative of the electric field E

$E_r = E_0 e^{i\omega t}$

[0032] and integrating with respect to angle theta gives the vertical magnetic field B as the tangential velocity v times the radial electric field E divided by the speed of light c squared

$$B_z = \frac{v}{c^2} E_r$$

[0033] 13. The force on the hull is the gradient of the magnetic moment μ times the magnetic field B. In the equation for the magnetic field, the only available variable to work with in order to get a gradient of the magnetic field comes from the velocity.

$$\frac{dB_z}{dz} = \frac{E_r}{c^2}\frac{dv}{dz}$$

[0034] 14. Referring to **FIG. 7**, because the hull is in the shape of a pyramid, the velocity is a function of the height z of the hull. Using eight flat sides keeps the radial electric field pointing in the same direction in each panel. Each panel has three domes to produce the magnetic moment for a total of 24 magnetic moment generators.

[0035] 15. Referring to **FIG. 8**, the electric dipole moment (A) points in the radial direction, the rotating hull produces a tangential velocity (B), and the result is a magnetic moment (C) along the panel.

[0036] 16. Referring to **FIG. 9**, because the magnetic moment is parallel to the panel, there are vertical and radial components of the magnetic moment. The vertical magnetic moment creates the dot product with the magnetic field gradient, which is equal to the lift force.

[0037] 17. **FIG. 10** shows a cross-section of the dome (A) and the plate hole (B) with double cladding to enhance the field. The upper cladding (D) has a low relative permittivity in the range of 2 to 40, and the lower layer has a high relative permittivity in the range of 1200 to 4000.

[0038] 18. Comparing **FIG. 11** to **FIG. 7**, this dome and cladding configuration creates a much larger electric dipole moment compared to a hole in the plate. The wavy lines are the equi-potential energy lines from the dome (C) and the upper layer (B) and the lower level (A).

I claim:

1. A spacecraft propulsion system comprising:

a rotating octagon of trapezoidal electrostatically charged flat panels which form a closed sloping hull in the shape of a pyramid;

panels each having three holes covered by three ellipsoidal domes of varying size centrally located along the major length and axis of each panel; and

a grid of high voltage electrostatically charged rods located on the interior side of each panel such that a planar potential field is produced parallel to and under each panel hole.

2. The domes, holes and rotating charged hull of method 1 producing:

an ellipsoidal potential energy field emerging from the holes and generating an electric dipole moment on the outside of the hull;

a magnetic moment in the vertical direction due to the rotating electric dipole moment; and

a rotating electric field in the radial direction which generates a corresponding magnetic field gradient in the vertical direction proportional to the velocity gradient of the sloping panels of the hull.

3. A lift force on the spacecraft hull generated by:

the magnetic moment times the gradient of the magnetic field in the vertical direction; and

a dual surface layer hull cladding having different permittivities which enhance the electric dipole moment whereby the upper cladding has a low relative permittivity in the range of 2 to 40, and the lower layer has a high relative permittivity in the range of 1200 to 4000.

* * * * *

US 20060038081A1

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St. Clair (43) **Pub. Date: Feb. 23, 2006**

(54) **ELECTRIC DIPOLE SPACECRAFT**

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Publication Classification

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B64G 1/40 (2006.01)

(52) **U.S. Cl.** **244/171.5**

(57) **ABSTRACT**

This invention is a rotating spacecraft that produces an electric dipole on four rotating spherical conducting domes perturbing a uniform spherical electric field to create a magnetic moment interacting with the gradient of a magnetic field that generates a lift force on the hull.

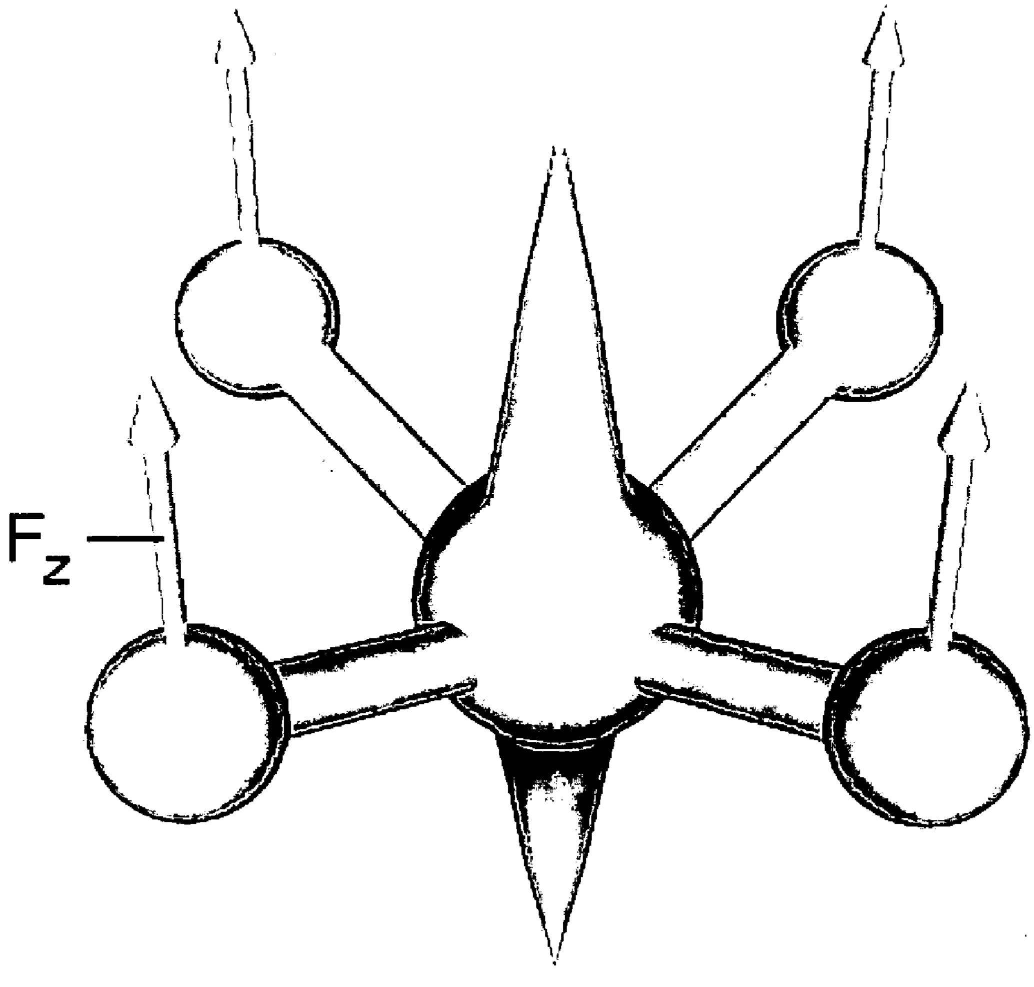

Figure 1

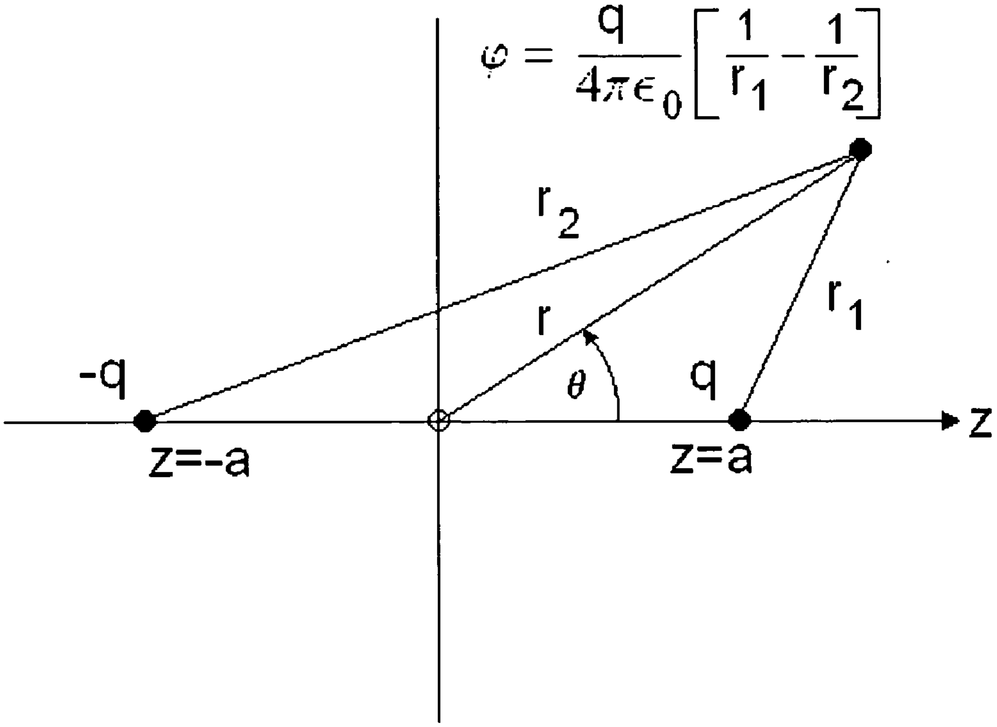
$\varphi = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$
r_2
r
r_1
θ
-q
q
z=-a
z=a
z

Figure 2

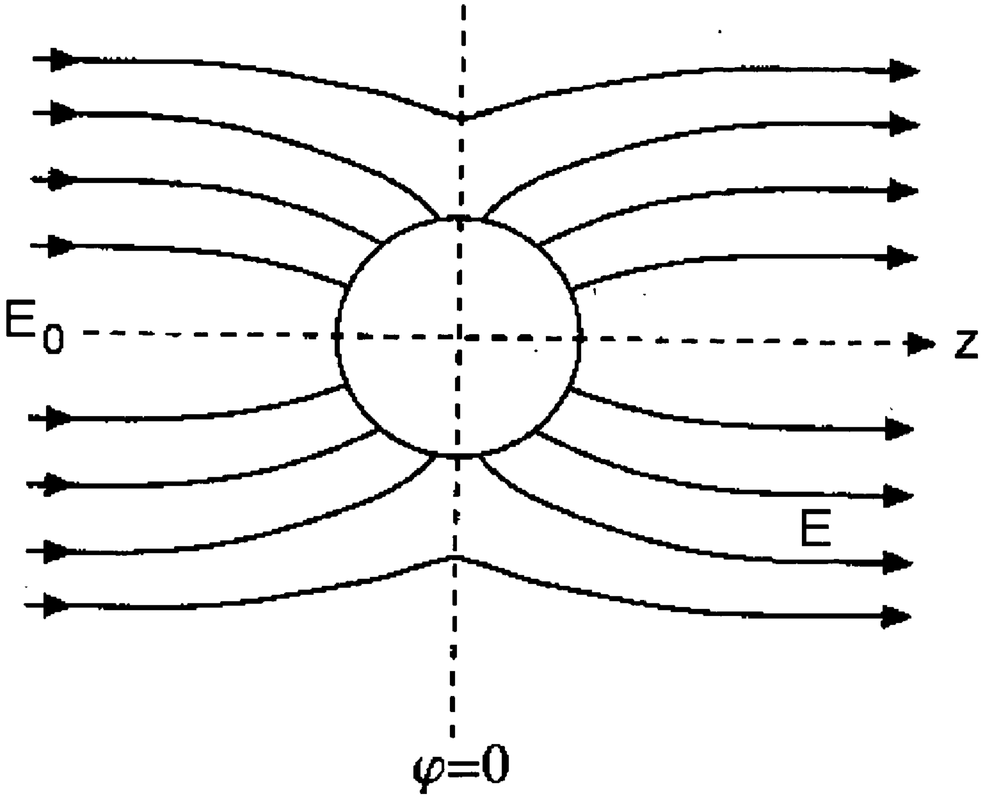
E_0
z
E
$\varphi=0$

Figure 3

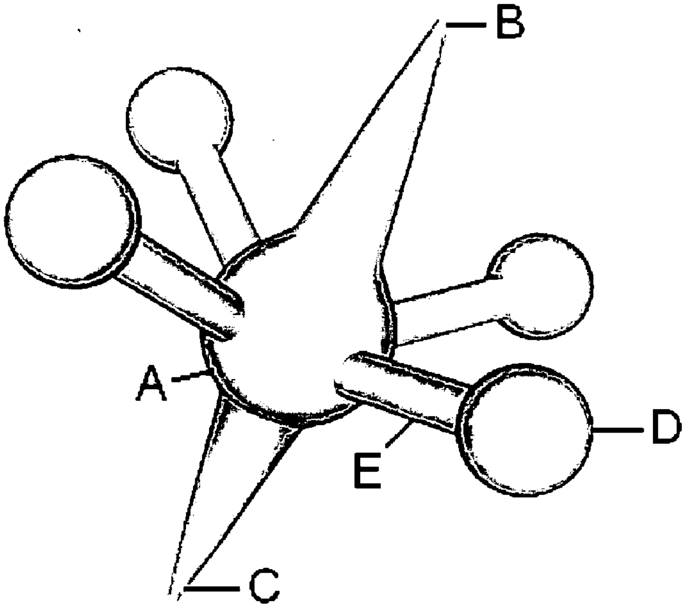

Figure 4

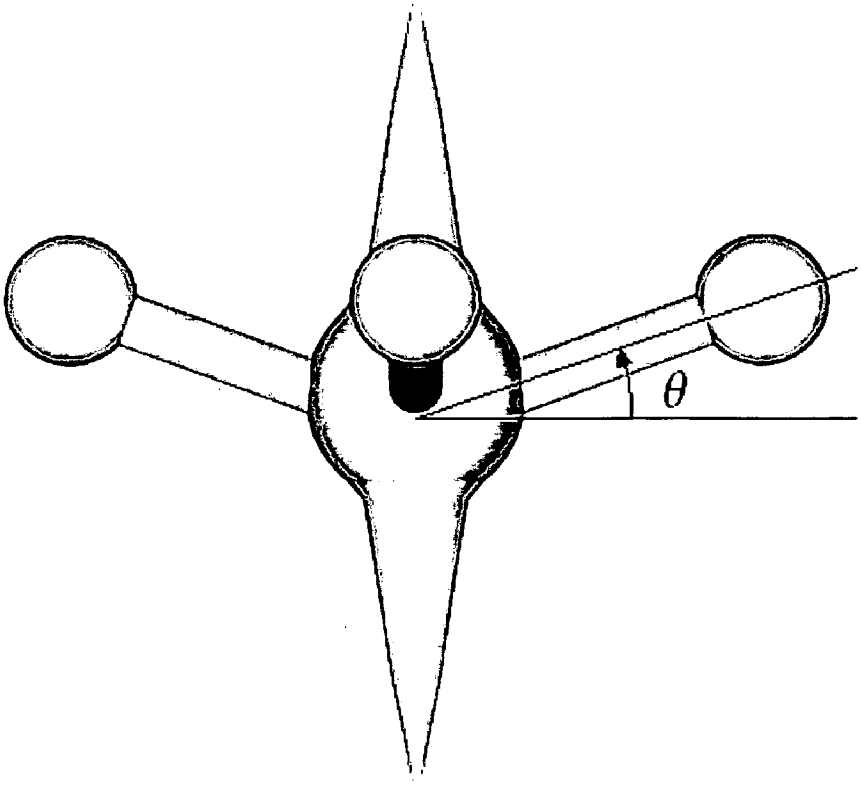

Figure 5

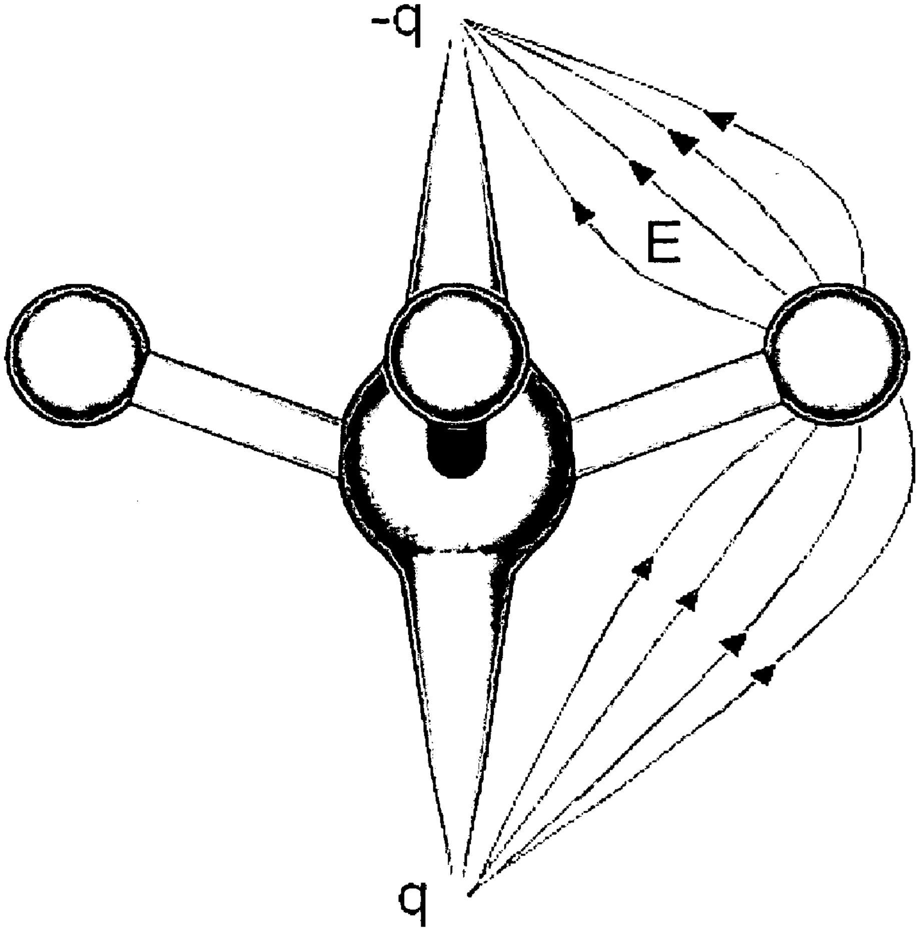

Figure 6

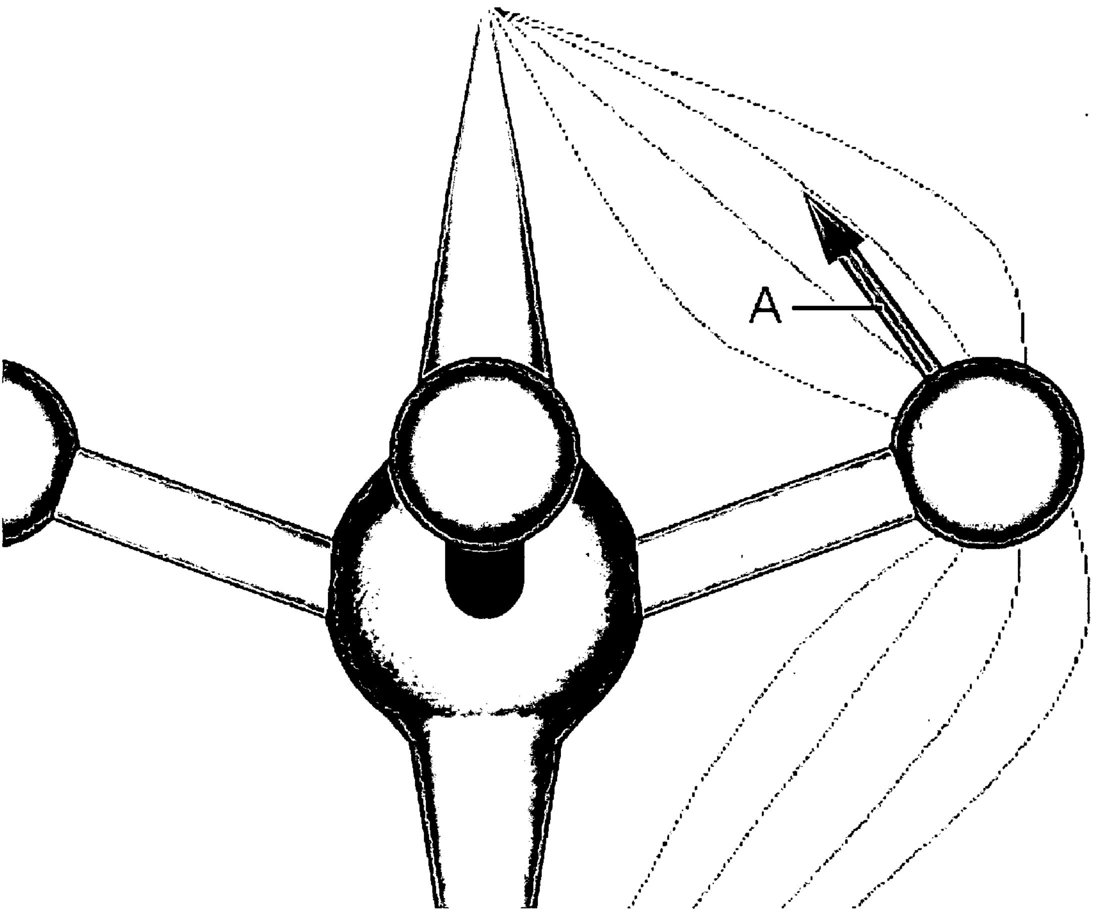

Figure 7

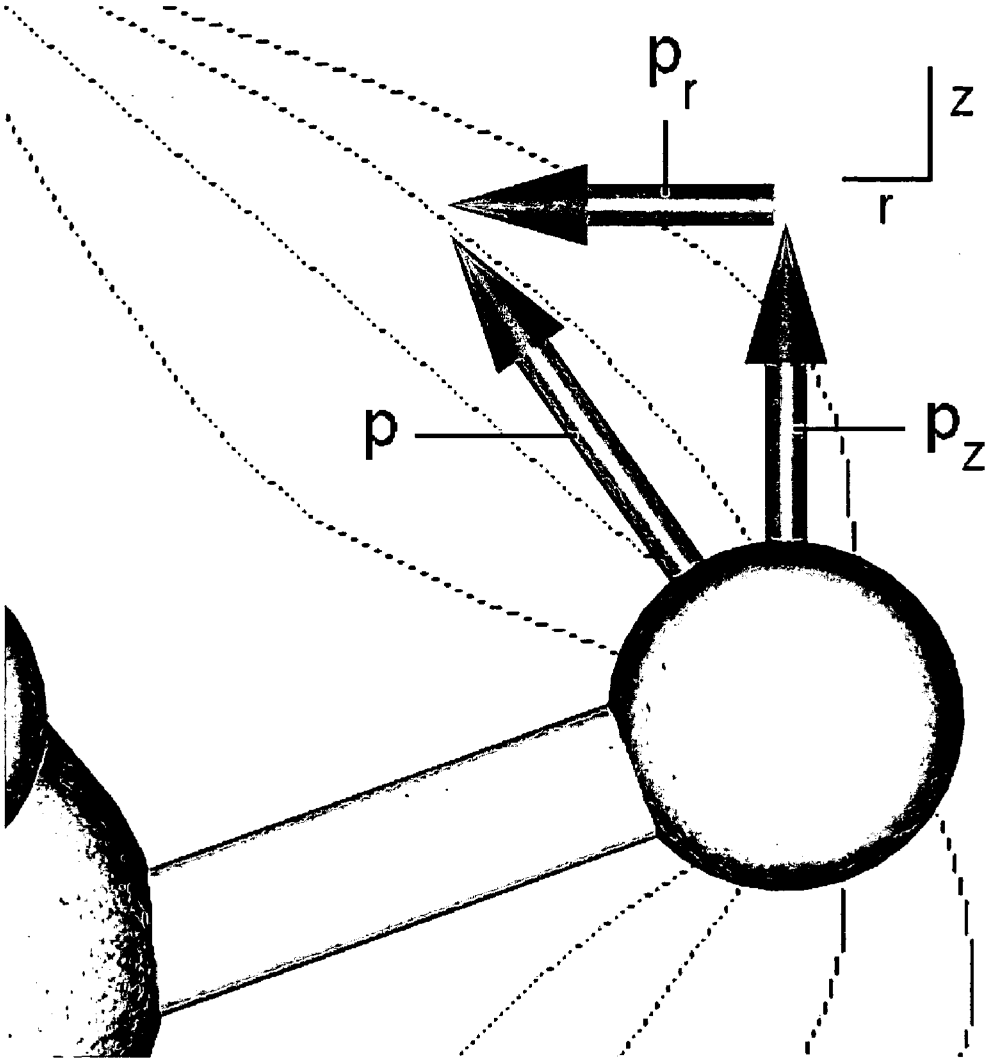

Figure 8

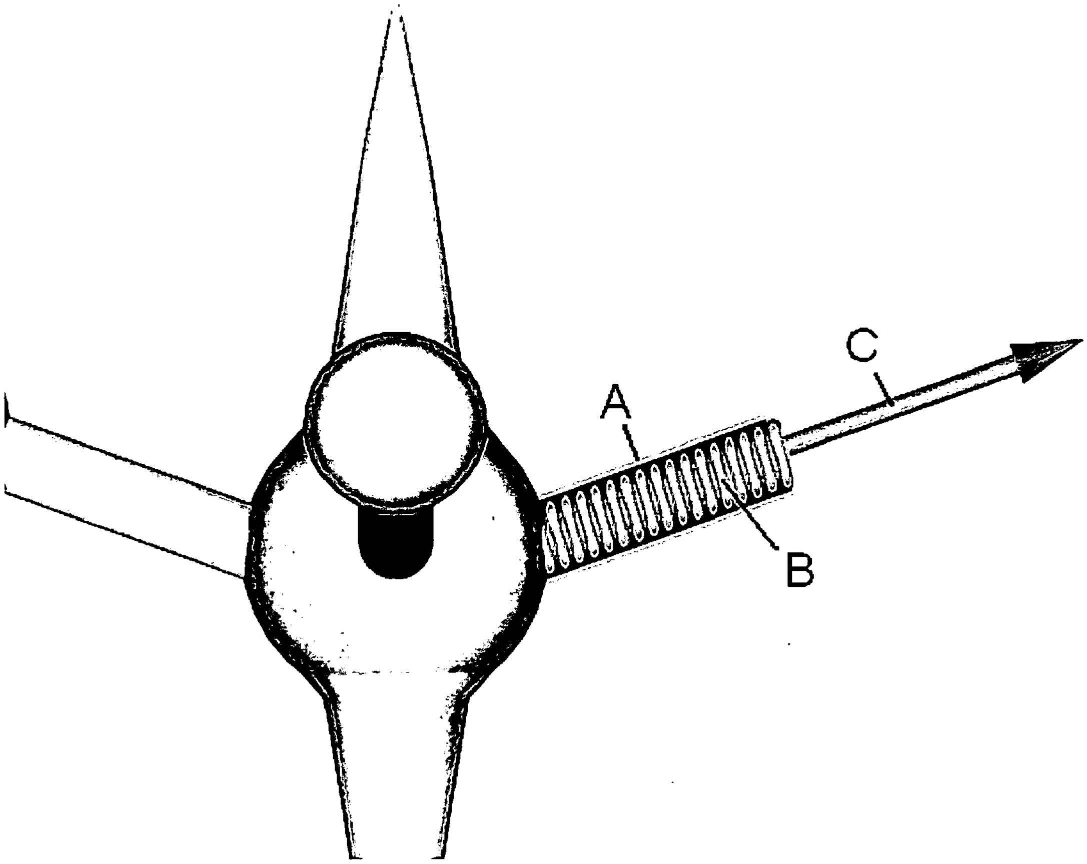

Figure 9

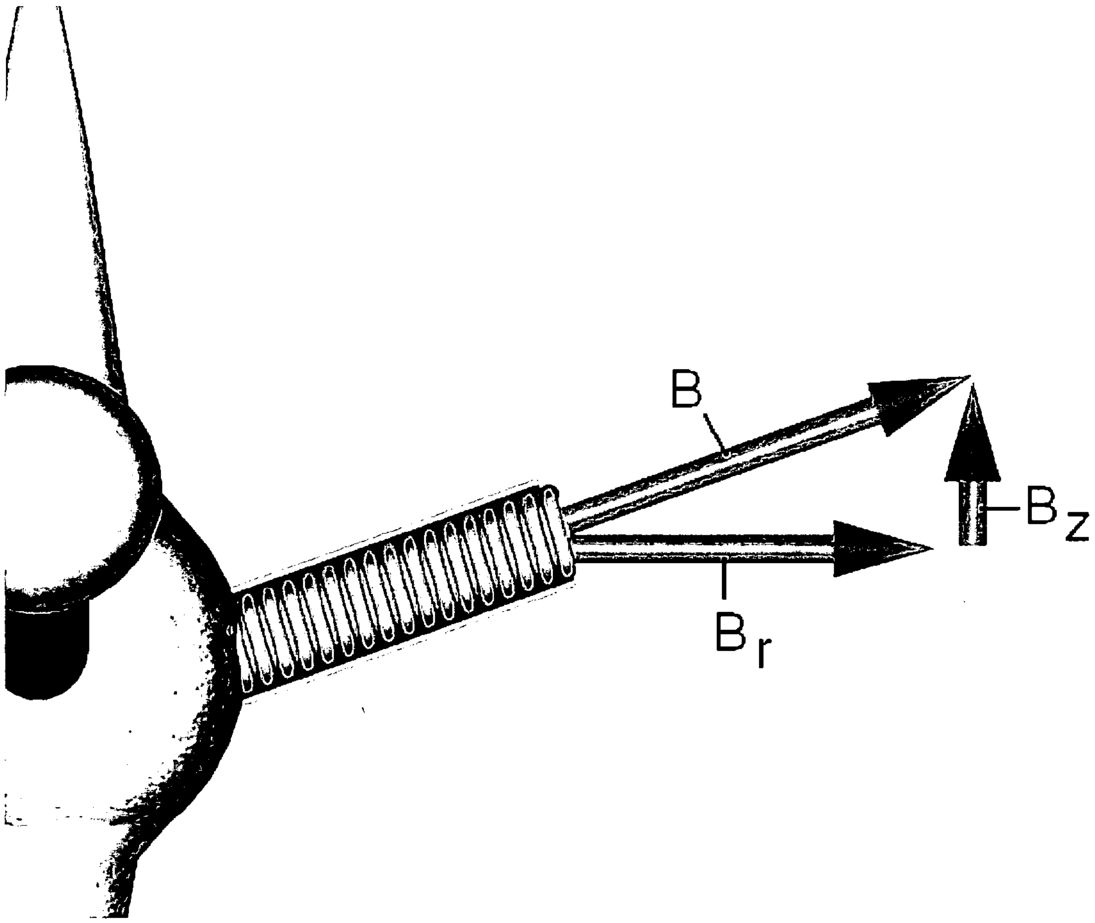

Figure 10

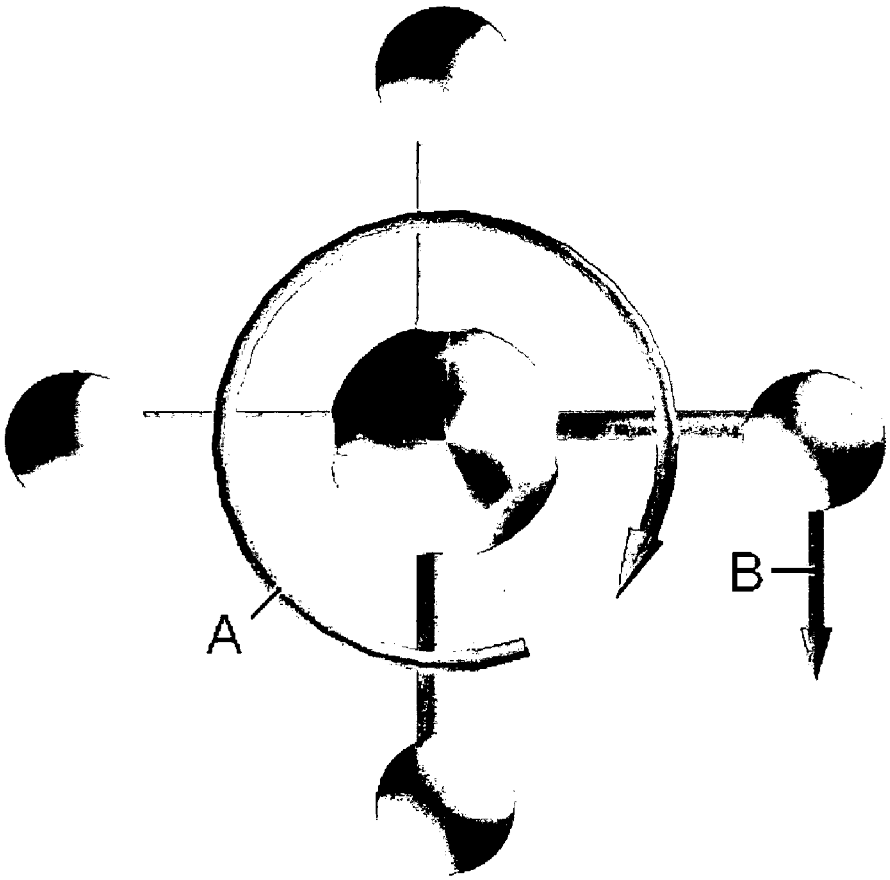

Figure 11

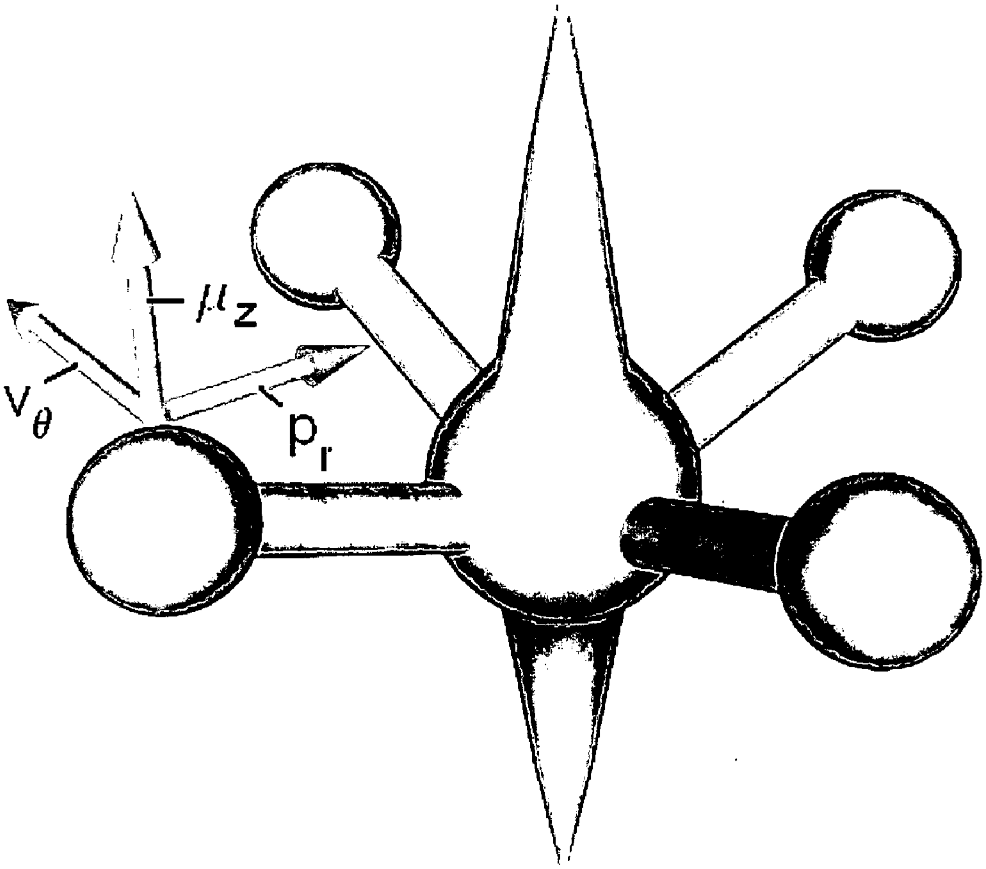
μ_z
v_θ
p_r

Figure 12

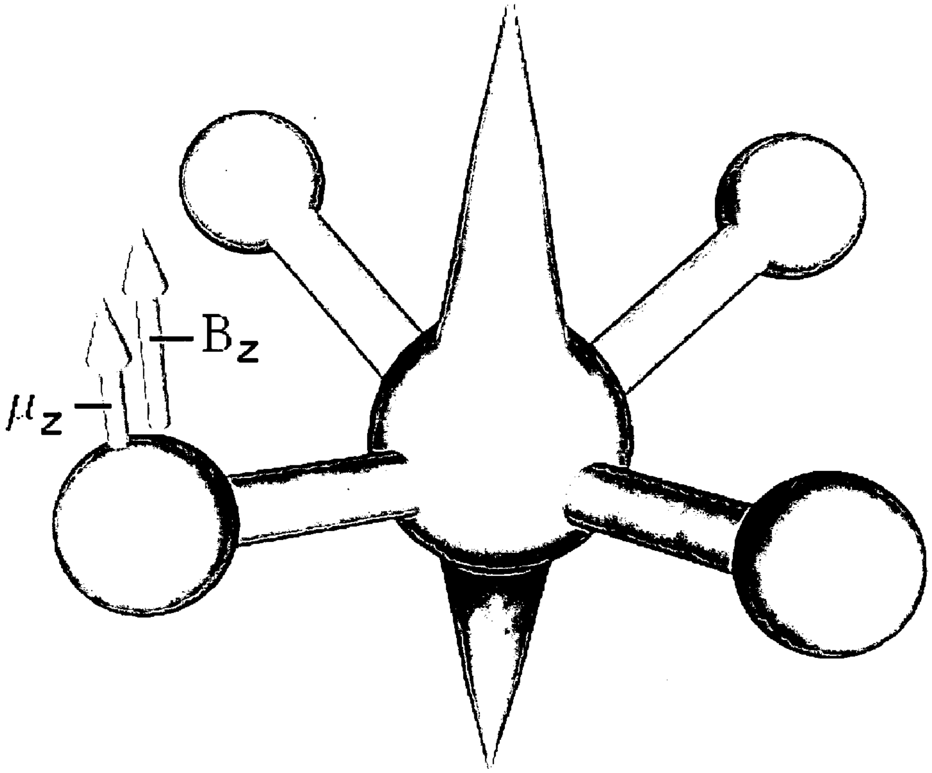

Figure 13

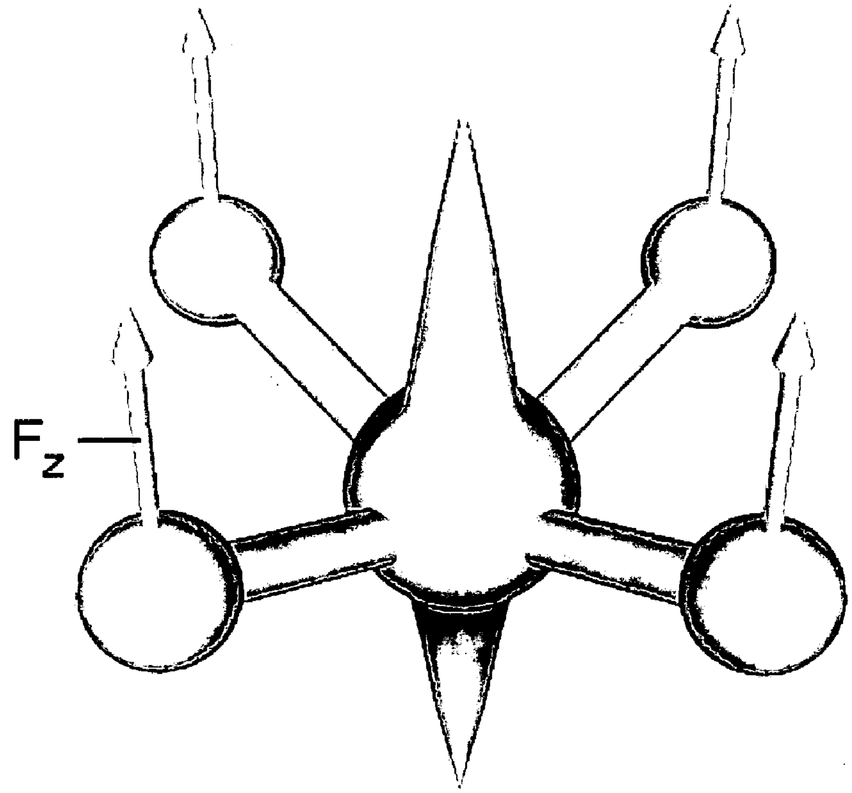

Figure 14

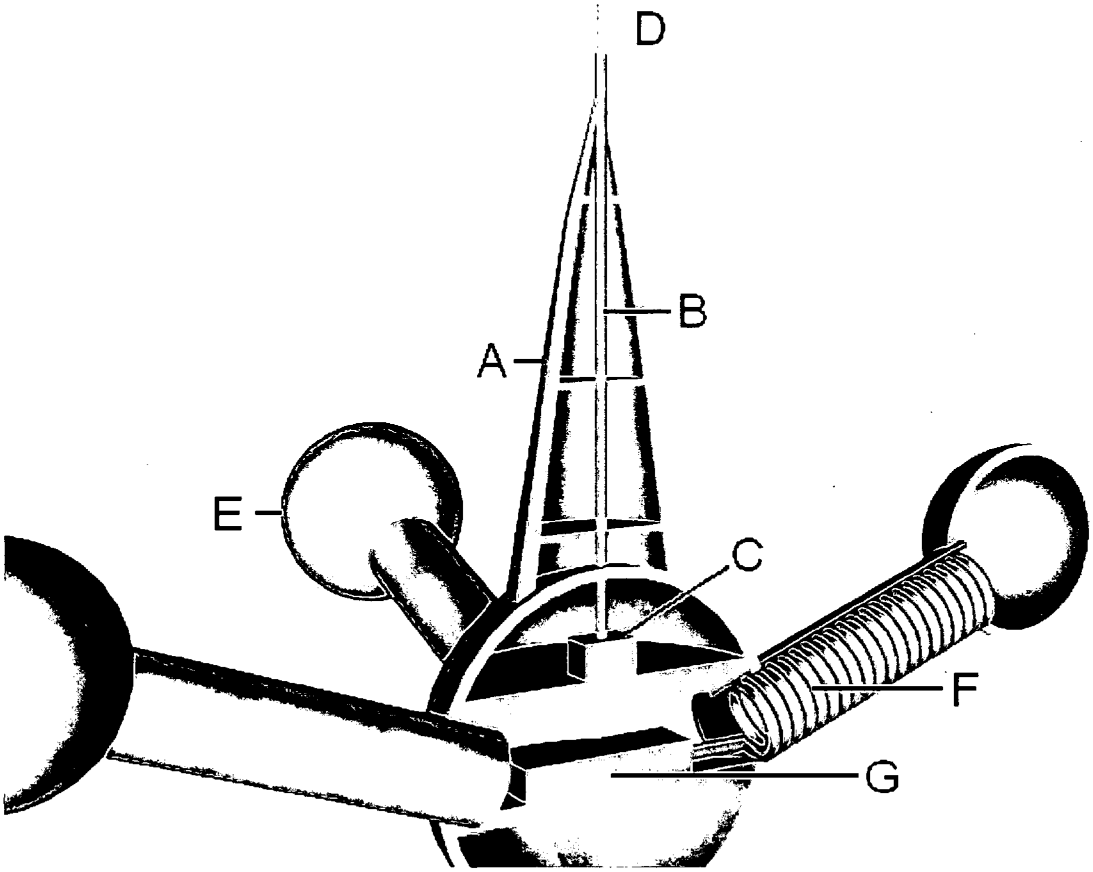

ELECTRIC DIPOLE SPACECRAFT

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is a rotating spacecraft that utilizes four spherical conducting domes perturbing a uniform electric field in order to create a lift force by means of a magnetic moment times the gradient of a magnetic field.

BACKGROUND OF THE INVENTION

[0002] An electric dipole p is two electrical charges of opposite sign {q, −q} separated by a distance a.

$p=qa=\text{coulomb}\cdot\text{meter}$

[0003] If this dipole is moving with a velocity v, it produces a magnetic moment μ.

$$\mu = pv = qav = \text{coulomb meter}\frac{\text{meter}}{\text{sec}} = \frac{\text{coulomb}}{\text{sec}}\text{meter}^2 = IArea$$

[0004] The magnetic moment is equal to a current I circulating around an area. The magnetic field B has units of kilogram per second per charge coulomb.

$$B = \frac{\text{kg}}{\text{sec } coul}$$

[0005] The gradient of the magnetic field in the vertical direction z has units of

$$\frac{\text{dB}}{dz} = \frac{\text{kg}}{\text{sec } coul \text{ meter}}$$

[0006] This gradient interacting with a magnetic moment creates a force F measured in newtons.

$$F_z = \mu\frac{\text{dB}}{dz} = \frac{coul\ \text{m}^2}{\text{sec}}\frac{\text{kg}}{\text{sec } coul\ m} = \frac{\text{kg } m}{\text{sec}^2} = \text{newton}$$

[0007] In terms of vectors, the force is equal to

$F=\nabla(\mu\cdot B)$

which is the gradient ∇ of the dot product (·) of the magnetic moment with the magnetic field. This means that the magnetic moment has to be aligned with the field. The lift force on the spacecraft would then be the magnetic moment in the vertical z-direction μ_z times the magnetic field in the z-direction B_z. For constant magnetic moment, the gradient affects the magnetic field only, resulting in the same force equation

$F_z=\nabla(\mu_z\cdot B_z)=\mu_z\nabla B_z$

[0008] Referring to **FIG. 1**, the electric dipole has a positive charge q located on the z-axis at a distance a from the origin of the graph. A second negative charge −q is located at a distance −a from the origin. The positive charge produces an electrostatic potential ϕ_1 at a radius r_1 equal to the charge q divided by 4π times the permittivity of space ϵ_0

$$\varphi_1 = \frac{q}{4\pi\varepsilon_0}\frac{1}{r_1}$$

where the permittivity is linear capacitance, measured in farads per meter. The electrostatic potential has units of volts

$$\varphi = \frac{coul}{\left(\frac{\text{farad}}{\text{meter}}\right)}\frac{1}{\text{meter}} = \frac{coul}{\text{farad}} = \text{volt}$$

because the charge in coulombs held by a capacitor is equal to the capacitance, measured in farads, times the capacitor voltage. Because the second charge has the opposite sign, the potential ϕ_2 at a radius r_2 to the same point in space is

$$\varphi_2 = \frac{-q}{4\pi\varepsilon_0}\frac{1}{r_2}$$

[0009] The total potential ϕ at some point in space is equal to the sum of the two potentials, or

$$\varphi = \varphi_1 + \varphi_2 = \frac{q}{4\pi\varepsilon_0 r_1} - \frac{q}{4\pi\varepsilon_0 r_2} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

[0010] As seen in the diagram, the point of space is a distance r from the origin. Using the law of cosines, radius r_1 can be written as

$$r_1 = (r^2 + a^2 - 2ar\cos(\theta))^{\frac{1}{2}} = r\left(1 + \left(\frac{a}{r}\right)^2 - 2\left(\frac{a}{r}\right)\cos(\theta)\right)^{\frac{1}{2}} = r(1 - 2xt + t^2)^{\frac{1}{2}}$$

where t is the ratio of the charge location over the radius, and x is cos(θ). The potential for positive charge q_1 can be written

$$\varphi_1 = \frac{q}{4\pi\varepsilon_0}\frac{1}{r_1} = \frac{q}{4\pi\varepsilon_0}\frac{1}{r}(1 - 2xt + t^2)^{-1/2}$$

[0011] Dropping the factor $q/4\pi\epsilon_0 r$, the square root can be expressed in terms of the Legendre polynomial $P_n\cos(\theta)$ of the nth power

$$g(t, x) = (1 - 2xt + t^2)^{-1/2} = \sum_{n=0}^{\infty} P_n(x)t^n$$

where the absolute value of t is less than one. The polynomial coefficients of t^n can be obtained by using the binomial theorem to expand the generating function g(t,x) as

$$(1-2xt+t^2)^{-1/2}=\sum_{n=0}^{\infty}\frac{(2n)!}{2^{2n}(n!)^2}(2xt-t^2)^n$$

which evaluates to

$$\frac{0!}{2^0(0!)^2}(2xt-t^2)^0+\frac{2!}{2^2(1!)^2}(2xt-t^2)^1+\frac{4!}{2^4(2!)^2}(2xt-t^2)^2$$

$$1t^0+xt^1+\left(\frac{3}{2}x^2-\frac{1}{2}\right)t^2+\text{order}(t^3)$$

[**0012**] The first three Legendre polynomials are therefore

$$P_0=1$$

$$P_1=x$$

$$P_2=\frac{1}{2}(3x^2-1)$$

[**0013**] The electrostatic potential for both charges of the electric dipole is

$$\varphi=\frac{q}{4\pi\varepsilon_0}\frac{1}{r}\left\{\left(1-2\left(\frac{a}{r}\right)\cos(\theta)+\left(\frac{a}{r}\right)^2\right)^{-1/2}-\left(1+2\left(\frac{a}{r}\right)\cos(\theta)+\left(\frac{a}{r}\right)^2\right)^{-1/2}\right\}$$

[**0014**] The potential can be evaluated in terms of the Legendre polynomials as

$$\begin{aligned}\varphi&=\frac{q}{4\pi\varepsilon_0 r}\left[\sum_{n=0}^{\infty}P_n(\cos(\theta))\left(\frac{a}{r}\right)^n-\sum_{n=0}^{\infty}P_n(\cos(\theta))(-1)^n\left(\frac{a}{r}\right)^n\right]\\&=\frac{2q}{4\pi\varepsilon_0 r}\left[P_1(\cos(\theta))\left(\frac{a}{r}\right)+P_3(\cos(\theta))\left(\frac{a}{r}\right)^3+\dots\right]\end{aligned}$$

[**0015**] The first and most dominant term when the radius is much greater than location a is equal to

$$\varphi=\frac{2aq}{4\pi\varepsilon_0}\frac{P_1(\cos(\theta)0}{r^2}$$

which is the electric dipole potential and 2aq is the dipole moment

$p=2aq$

[**0016**] Now imagine a constant electric field E_0 which is perturbed by a conducting sphere of radius a. The unperturbed electrostatic potential outside the sphere would the negative of the electric field times the radius times the Legendre polynomial, or

$\phi_1=-E_0 r P_1$

[**0017**] The electrostatic potential perturbed by the charges is the voltage E_0a times the radius a times the a of the dipole moment times the Legendre polynomial divided by the radius squared

$$\varphi_2=E_0 aaa\frac{P_1}{r^2}=E_0a^3\frac{P_1}{r^2}$$

[**0018**] The total potential outside the sphere is the sum of the two potentials equal to

$$\varphi=-E_0rP_1+E_0a^3\frac{P_1}{r^2}=-E_0P_1\left(r-\frac{a^3}{r^2}\right)=-E_0rP_1\left(1-\left(\frac{a}{r}\right)^3\right)$$

[**0019**] Referring to **FIG. 2**, the previously uniform electric field is shown perturbed by the neutral conducting sphere. The center of the sphere is taken as the origin and the z-axis is oriented parallel to the original uniform field.

[**0020**] The electric field induces a surface charge density σ on the sphere equal to the negative of the permittivity of space times the gradient of the electrostatic potential

$$\sigma=-\varepsilon_0\frac{\partial\varphi}{\partial r}|_{r=a}=3\varepsilon_0E_0\ \cos(\theta)$$

[**0021**] The electric field also induces an electric dipole moment on the sphere equal to the

$$p=\frac{qa}{r}\cdot\frac{2a^2}{r}=4\pi\varepsilon_0E_0a^3$$

with units of coulomb-meter. If this sphere is rotating around a central axis at a velocity v, it will create a magnetic moment μ equal to the dipole moment times the velocity.

μ=pv

with units of ampere-meter^2.

SUMMARY OF THE INVENTION

[**0022**] As shown in the preceding background section, a neutral conducting sphere placed in a uniform electric field will generate a magnetic moment when rotated around a central axis. The electric field can be created by two points charges of opposite sign separated by a distance between them.

[**0023**] Referring to **FIG. 3**, the spacecraft has a spherical cabin (A) to which are attached cone-shaped electrostatic towers (B,C) above and below the cabin along the direction of travel in the z-direction. Because the electric field goes from the positive charge to the negative charge, the tip of the lower tower has a positively charged electrode, and the upper tower has a negatively charged electrode. Four equally-spaced neutral conducting spheres (D) are connected to the cabin by non-conducting tubes (E). The tubes make an angle with the cabin such that the distance (CD) is greater than distance (DB). The angle θ of the tube with respect to the cabin can be seen in side view **FIG. 4**.

[0024] Referring to **FIG. 5**, the charges create a uniform spherical field between the towers. The conducting spheres perturb this field such that the electric field (E) points toward the upper tower in a manner similar to that shown previously in **FIG. 2**.

[0025] Referring to **FIG. 6**, the conducting sphere produces an electric dipole moment (A) pointing at an angle toward the upper tower.

[0026] Referring to **FIG. 7**, by the law of addition of vectors, the electric dipole $\bar{p}$ can be represented by two orthogonal vectors pointing in the vertical z-direction p_z and in the inward radial direction p_r.

[0027] Referring to **FIG. 8**, the hollow tube (A) connecting the cabin with the conducting sphere contains a spiral-wound electrical solenoid (B) which produces a magnetic field (C). This magnetic field B can be decomposed into two orthogonal vectors pointing in the vertical z-direction B_z and in the outward radial direction B_r as shown in **FIG. 9**.

[0028] Referring to top-view **FIG. 10**, the spacecraft has a clockwise angular velocity ω (A) which gives the conducting sphere a velocity v as shown by the vector (B). By the right-hand rule of physics, the angular velocity vector points in the negative z-direction. The angular velocity in the z-direction crossed with the radius r in the radial direction produces a velocity v in the clockwise θ-direction using cylindrical coordinates {r,θ,z}.

$$v_\theta = w_z \times r_r = -\omega r$$

[0029] Referring to **FIG. 11**, the negative radial dipole moment p_r crossed with the negative velocity v_θ of the sphere produces a positive magnetic moment μ_z in the z-direction.

$$\mu_z = p_r \times v_\theta = (-p_r)(-v_\theta) = pv$$

[0030] Referring to **FIG. 12**, the magnetic field B_z in the vertical z-direction is dotted with the magnetic moment μ_z in the z-direction to produce a force F_z in the vertical z-direction on each conducting sphere **(FIG. 13)**.

$$F_z = \nabla(\mu_z \cdot B_z) = \mu_z \nabla B_z$$

[0031] The magnetic field that is produced by the solenoid actually curves away and around. Thus there is a gradient of the field in the z-direction.

[0032] The force can also be expressed in tensor notation. The magnetic B field in the vertical direction is part of an electromagnetic 4×4 matrix Faraday tensor F

$$F^\alpha_\beta = \begin{array}{r|cccc|} & \beta = t & r & \theta & z \\ \alpha = t & 0 & 0 & 0 & 0 \\ \alpha = r & 0 & 0 & B_z & 0 \\ \alpha = \theta & 0 & -B_z & 0 & 0 \\ \alpha = z & 0 & 0 & 0 & 0 \end{array}$$

which shows that the magnetic field is located in slot $F^r{}_\theta$ of the Faraday tensor. In tensor notation the subscripts and superscripts have to match up on both sides of the equation. Matching subscripts and superscripts on the same side of the equation cancel. In this case, the electric dipole moment is in the radial direction p_r. The velocity can be represented as a time derivative of the θ-coordinate x^θ or

$$v^\theta = \frac{\partial x\theta}{\partial t}$$

[0033] Thus the force component in the z-direction becomes

$$F_z = p_r v^\theta F^r_{\theta,z} = (-p)(-v)\frac{\partial B_z}{\partial z} = pv\frac{\partial B_z}{\partial z}$$

where the angular and radial tensor components cancel and comma-z (, z) represents differentiation of the magnetic field in the z-direction.

[0034] The spacecraft design also has an inherent motion control system for moving in various directions. If the magnetic field of one solenoid arm is increased or decreased, the force on that sphere will be increased or decreased. Thus the spacecraft can turn in a particular direction.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0035] **FIG. 1**. Electric dipole.

[0036] **FIG. 2**. Uniform electric field perturbed by electric dipole.

[0037] **FIG. 3**. Perspective view of spacecraft.

[0038] **FIG. 4**. Angle of solenoid tube.

[0039] **FIG. 5**. Electric field perturbed by conducting sphere.

[0040] **FIG. 6**. Electric dipole generated by conducting sphere.

[0041] **FIG. 7**. Orthogonal vector components of electric dipole.

[0042] **FIG. 8**. Magnetic field produced by tube arm solenoid.

[0043] **FIG. 9**. Orthogonal vector components of magnetic field.

[0044] **FIG. 10**. Angular velocity of hull.

[0045] **FIG. 11**. Magnetic moment produced by radial electric dipole and sphere velocity.

[0046] **FIG. 12**. Dot product of the magnetic moment with the magnetic field.

[0047] **FIG. 13**. Vertical lift force on all four conducting spheres.

[0048] **FIG. 14**. Perpective view of spacecraft interior.

DETAILED DESCRIPTION OF THE INVENTION

[0049] 1. Referring to the cut-away view **FIG. 14**, the construction of the spacecraft is a thin-wall insulating thermoplastic having a dielectric constant in the range of 20 kilovolts per millimeter (A). An insulated electrode (B) runs from the cabin power supply and high-voltage transformer

(C) to the tip of each tower (D). The four spheres (E) are silver plated to make them conducting. The tube solenoids (F) are driven by a direct current power supply (G).

[0050] 2. The present model uses 3D computer design software and stereolithography fabrication techniques to create the thin-wall, low-weight, hollow structure of the hull. The computer model is sliced into many thin horizontal slices. A laser, mounted on an x-y table, draws out the slice on a table immersed in a bath of liquid polymer. Due to its sensitivity to the light, the liquid polymerizes. The table is then lowered a few thousandths of an inch more and the process is repeated. Thus making hollow spherical and conical shapes is extremely easy to do. Parts can be designed and stored in *.STL stereolithography files for transmission by Internet e-mail to the service bureau machine shop which sends the finished parts back the next day by express mail.

I claim:

1. A spacecraft comprising:

a. a spherical cabin;

b. an electrostatic conical tower mounted on top of item (**1***a*), supporting a vertically-mounted negatively-charged insulated electrode at the tip of the tower;

c. an electrostatic conical tower mounted on the bottom of item (**1***a*), supporting a vertically-mounted positively-charged insulated electrode at the tip of the tower;

d. a vertical electric dipole created by items (**1***b*) and (**1***c*);

e. a high-voltage transformer to drive item (**1***d*), mounted in item (**1***a*);

f. four tubular arms, mounted at 90° around and extending at an angle from item (**1***a*);

g. four solenoids, each of which is mounted axially inside item (**1***f*);

h. a direct current power supply to drive item (**1***g*);

i. four silver-plated conducting spheres, each of which is mounted on the end of item (**1***f*);

2. an electrostatic lift system that:

a. produces a uniform spherical electric field by means of item (**1***d*) which envelopes item (**1***i*);

b. produces a perturbed electric field due to the presence of item (**1***i*);

c. produces an electric dipole moment in the direction of item (**1***b*) due to items (**2***a*) and (**2***b*);

d. produces a vertical magnetic moment due to the clockwise angular velocity of item (**1***a*) combined with item (**2***c*);

e. produces a vertical lift force on item (**1***i*) due to item (**2***d*) combined with the magnetic field gradient in the vertical direction produced by item (**1***g*); and

f. creates a motion control system by varying the current to item (**1***g*) in order to increase or decrease the effect of item (**2***e*) on a particular item (**1***i*).

* * * * *

US 20060144035A1

(19) **United States**
(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0144035 A1**
St. Clair (43) **Pub. Date: Jul. 6, 2006**

(54) **PHOTON SPACECRAFT**

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(21) Appl. No.: **11/027,969**

(22) Filed: **Jan. 3, 2005**

Publication Classification

(51) **Int. Cl.**
F03H 1/00 (2006.01)
(52) **U.S. Cl.** **60/203.1**; 60/204

(57) **ABSTRACT**

A spacecraft propulsion system utilizing photon particles to create negative energy over the hull in order to generate a lift force on the hull.

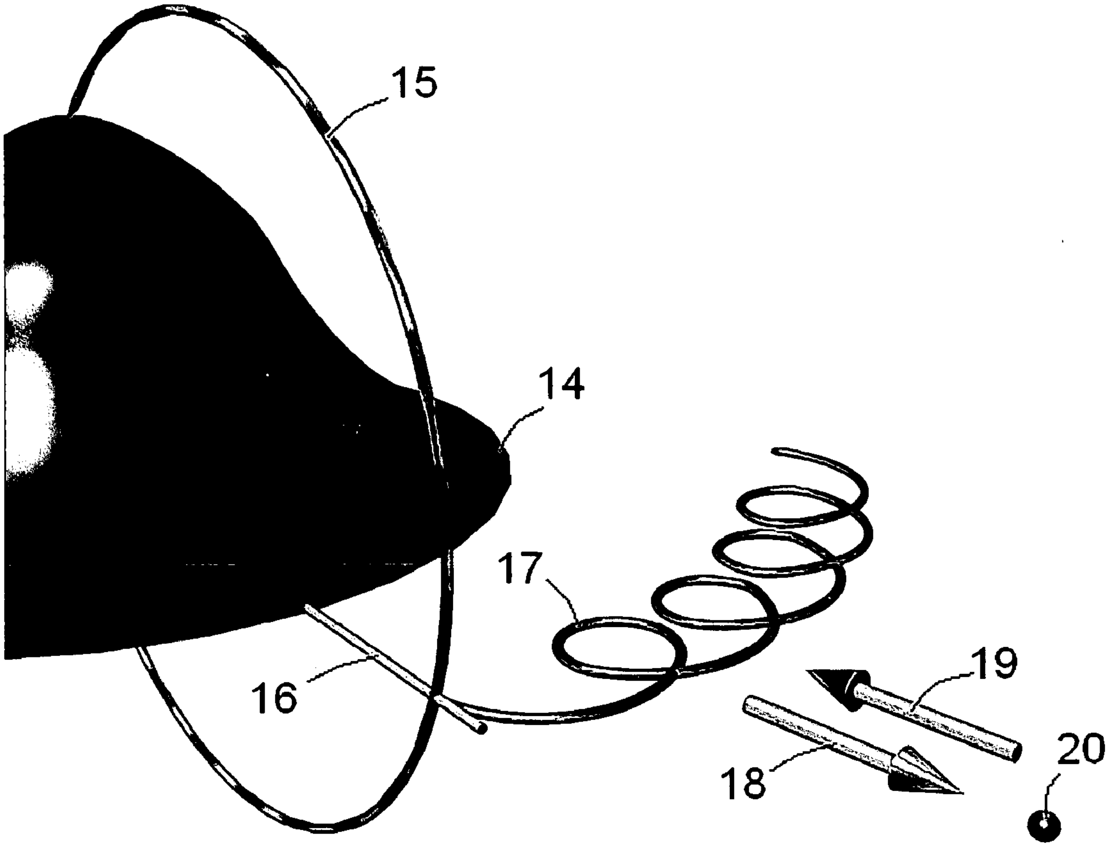

Figure 1

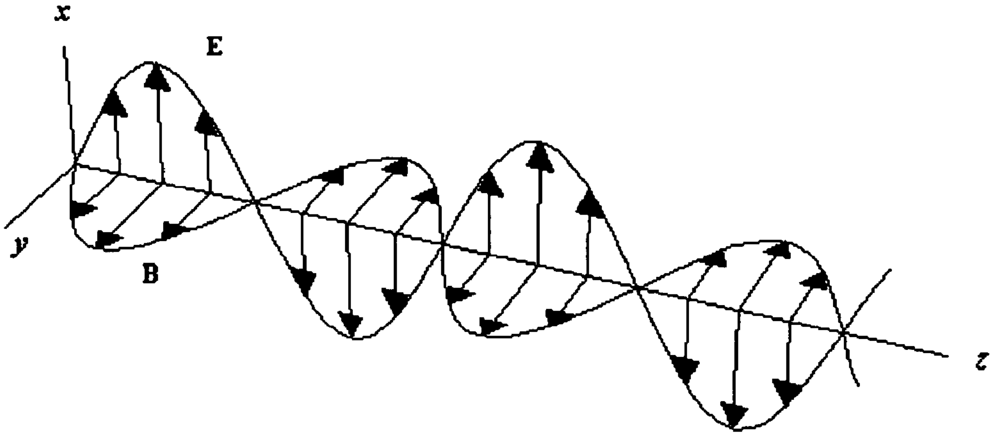

Figure 2

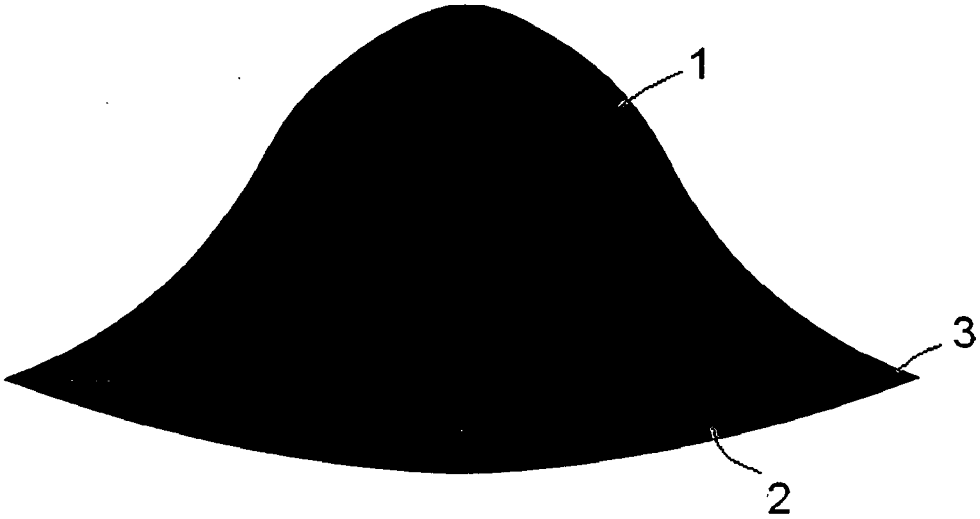

Figure 3

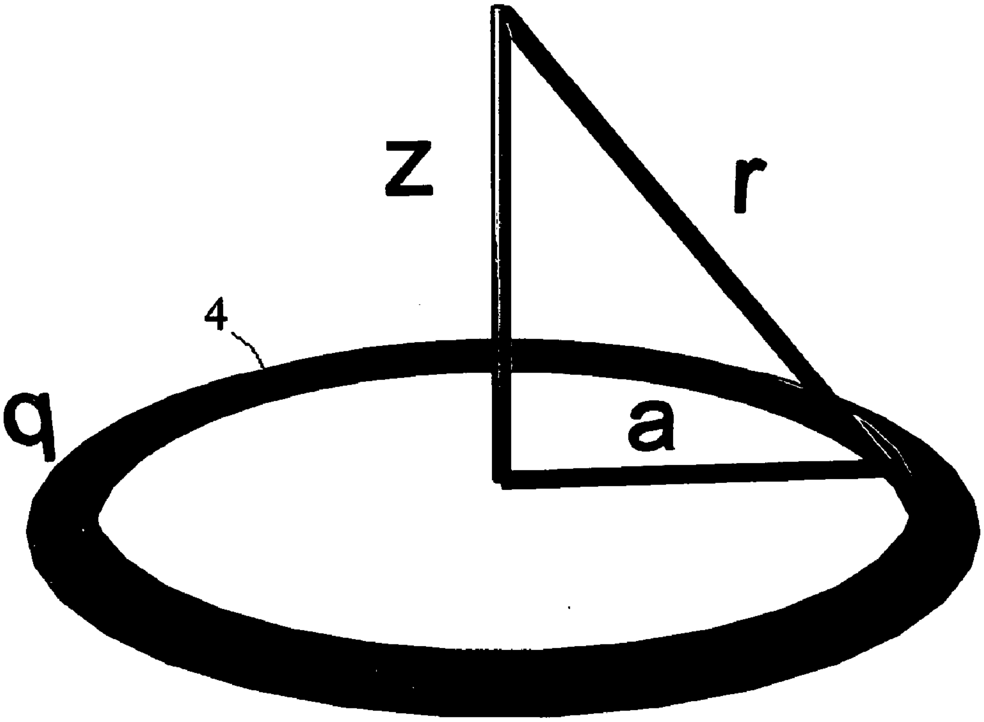

Figure 4

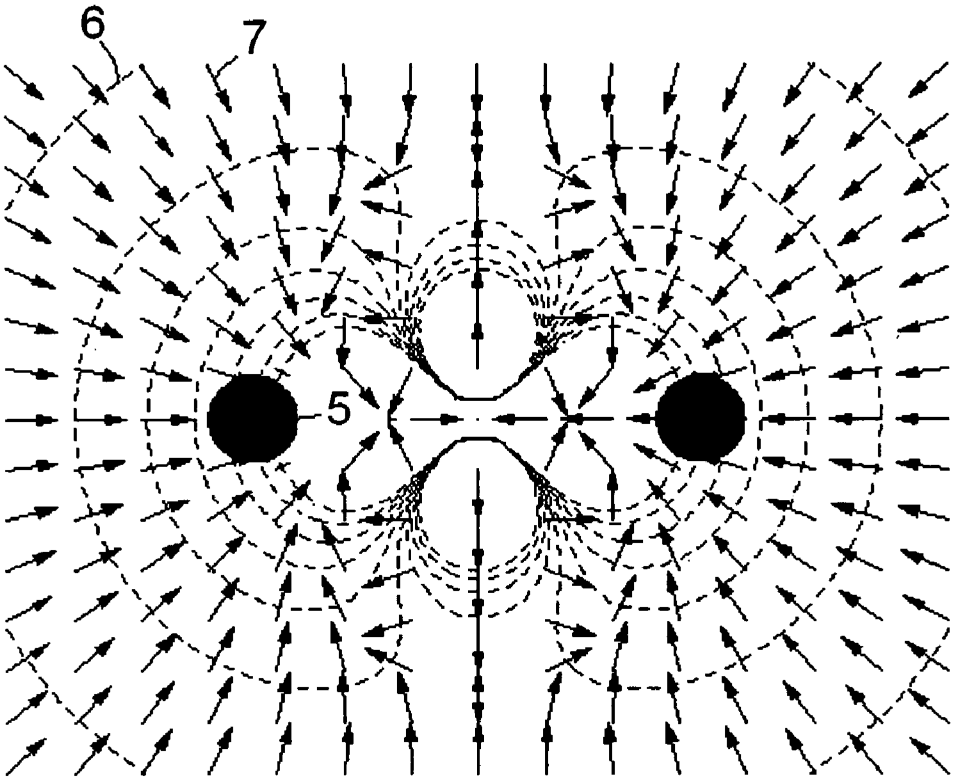

Figure 5

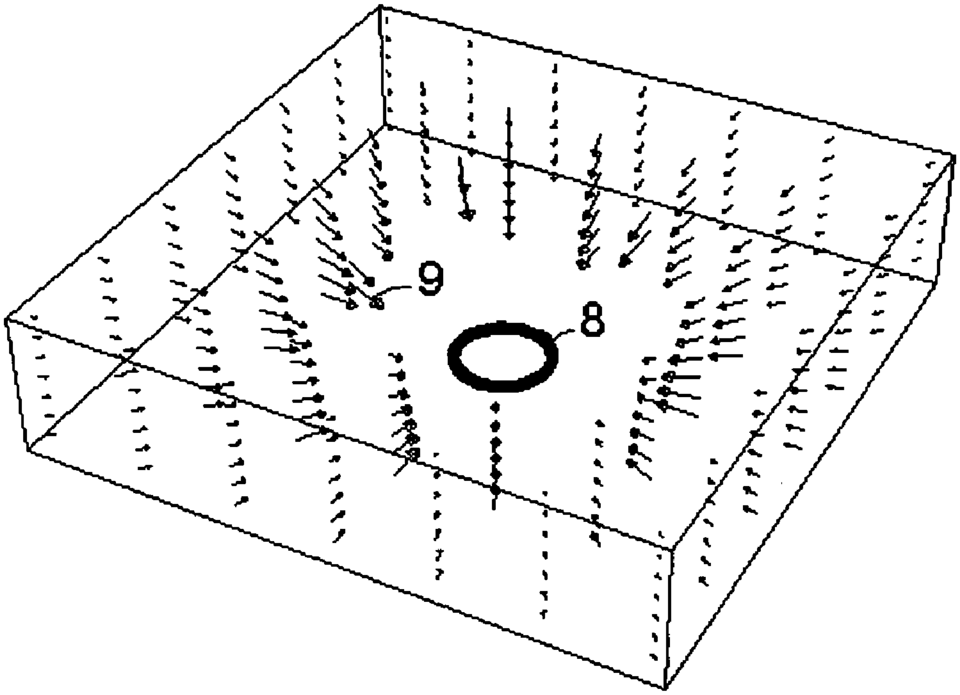

Figure 6

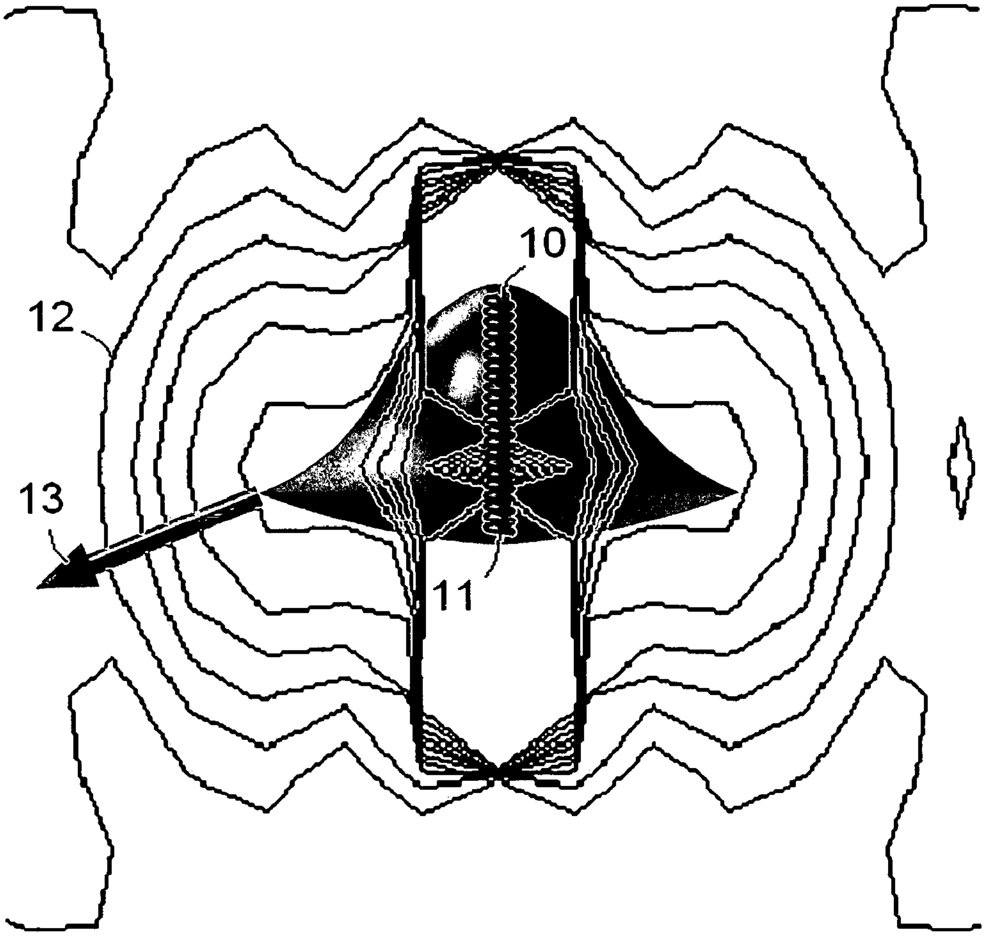

Figure 7

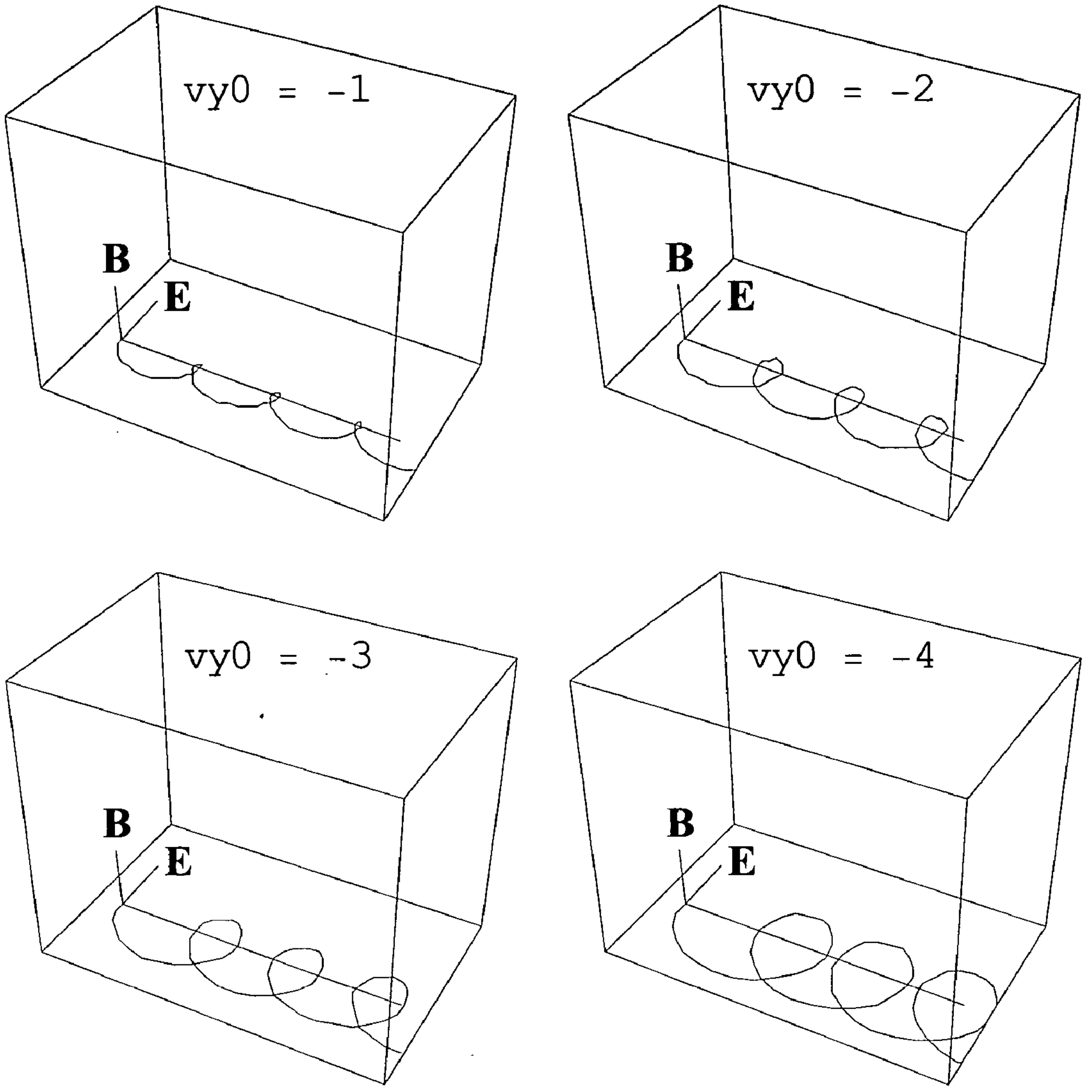
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Figure 8

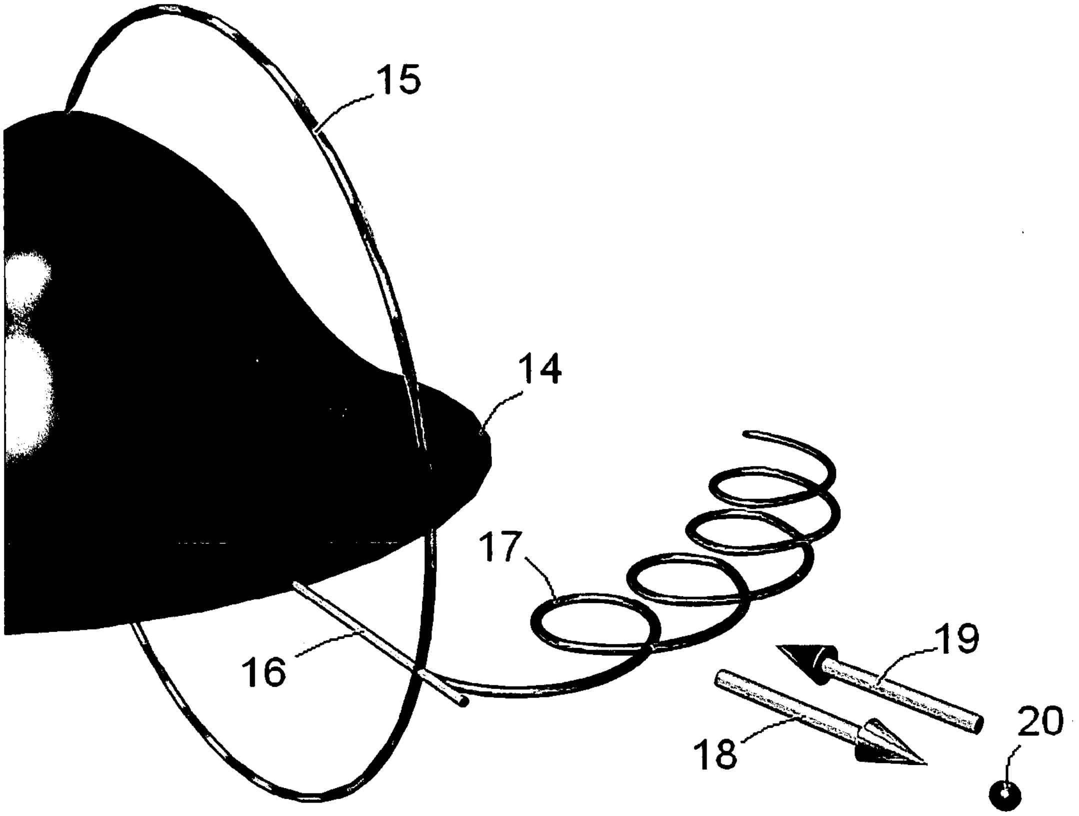
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Figure 9

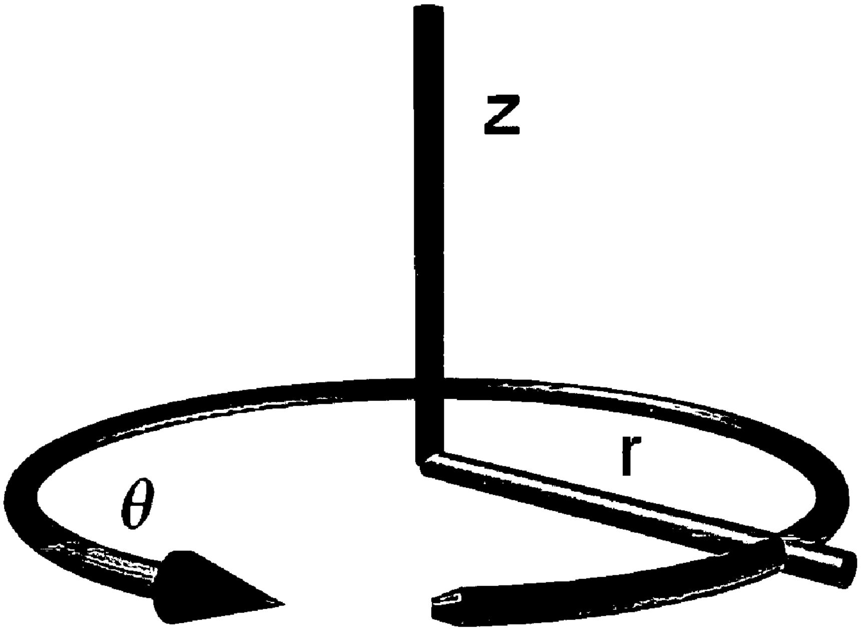

PHOTON SPACECRAFT

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is a spacecraft propulsion system that employs photon particles to generate a field of negative energy in order to produce lift on the hull.

BACKGROUND OF THE INVENTION

[0002] Referring to **FIG. 1**, an electromagnetic wave traveling in the z-direction consists of an electric E field vibrating in the x-direction and a magnetic flux density B field vibrating at right angles in the horizontal y-direction. The energy-stress-momentum of this photon can be analyzed using Einstein's General Theory of Relativity and the Faraday F tensor. The Faraday tensor is a 4×4 matrix containing the electromagnetic wave components as shown here in general where c is the speed of light

$$F^{\alpha}_{\beta}=\begin{array}{c|cccc|} t & 0 & \frac{E_x}{c} & \frac{E_y}{c} & \frac{E_z}{c} \\ x & \frac{E_x}{c} & 0 & B_z & -B_y \\ y & \frac{E_y}{c} & -B_z & 0 & B_x \\ z & \frac{E_z}{c} & B_y & -B_x & 0 \end{array}$$

For this particular photon, this tensor is

$$F^{\alpha}_{\beta}=\begin{array}{c|cccc|} t & 0 & \frac{E_x}{c} & 0 & 0 \\ x & \frac{E_x}{c} & 0 & 0 & -B_y \\ y & 0 & 0 & 0 & 0 \\ z & 0 & B_y & 0 & 0 \end{array}$$

[0003] The elemental spacetime length ds squared is equal to sum of the squares of the Cartesian elemental lengths

$$(ds)^2=-(dt)^2+(dx)^2+(dy)^2+(dz)^2$$

The coefficients of this equation, $\{-1,1,1,1\}$ are the diagonal components of the g metric tensor

$$g_{\alpha\beta}=\begin{array}{c|cccc|} t & -1 & 0 & 0 & 0 \\ x & 0 & 1 & 0 & 0 \\ y & 0 & 0 & 1 & 0 \\ z & 0 & 0 & 0 & 1 \end{array}$$

The stress-energy-momentum tensor T can then be calculated for the photon using the Faraday tensor and the g metric tensor in the following equation from gravitation physics

$$4\pi T^{\mu\nu}=F^{\mu\alpha}F^{\nu}_{\alpha}-\frac{1}{4}g^{\mu\nu}F_{\alpha\beta}F^{\alpha\beta}$$

The stress-energy-momentum tensor indicates the curvature of space due to the application of electromagnetic fields, mass, angular momentum and charge. The mass of the Earth, for example, generates a negative curvature of spacetime such that objects fall toward the mass. The T tensor, which is also a 4×4 matrix, contains the momentum or flux terms in the first row and first column. The normal pressure stress is located along the diagonal. The shearing stresses are located off the diagonal. The energy term is in the upper left corner as depicted here,

$$T^{\mu\nu}=\begin{array}{c|cccc|} t & \text{energy} & flux_x & flux_y & flux_z \\ x & -flux_x & pressure_x & shear_{xy} & shear_{xz} \\ y & -flux_y & shear_{yx} & pressure_y & shear_{yz} \\ z & -flux_z & shear_{zx} & shear_{zy} & pressure_z \end{array}$$

[0004] Since $B^2=E^2/c^2$, the stress-energy-momentum tensor for the photon is therefore

$$T^{\mu}_{\nu}=\begin{array}{c|cccc|} t & \frac{-E^2}{c^2} & 0 & 0 & \frac{+E^2}{c^2} \\ x & 0 & 0 & 0 & 0 \\ y & 0 & 0 & 0 & 0 \\ z & \frac{-E^2}{c^2} & 0 & 0 & \frac{+E^2}{c^2} \end{array}$$

This remarkable result shows that the photon is actually a negative energy particle (top left corner) which is pushed along by a positive pressure wave (lower right corner). The particle has a positive flux (upper right corner) in the z-direction, as well as a balancing negative flux in the lower left corner so that the overall momentum of the universe remains the same. All four components cancel and we see the photon as a massless particle moving at the speed of light.

[0005] Thus the key idea behind this invention is that it is possible to cancel out the pressure term and leave a stationary vibrating electromagnetic field of negative energy over the hull of the spacecraft. The importance of negative energy is that it is a prerequisite to generating wormholes between space and hyperspace.

[0006] Hyperspace consists of the those co-dimensions which have different physics constants such as a low speed of light. The existence of hyperspace, which has a white misty look, is not a well-known scientific concept. Experiments with our magnetic vortex wormhole generators, hyperspace torque generator, full body levitation using Chi Kung breathing, arm levitation by spinning the co-gravitational K field, full body teleportation through hyperspace a distance of 100 meters using a pulsed gravitational wave, jumping into hyperspace, having a plate of toast enfold off the breakfast table and disappear into thin air, walking through walls and doors out-of-dimension, looking into other dimensions, remote viewing through subspace to distances of 100,000 light years, and other electromagnetic experiments carried out by co-researchers, have shown us the reality and existence of hyperspace.

[0007] Referring to **FIG. 2**, the spacecraft consists of an upper (**1**) and lower (**2**) hull attached by ceramic insulators to a circular ring (**3**). The ring provides support and is attached to an outer sharp-edged rim which is electrostatically charged to a potential −V. The purpose of the charged rim is to generate a radial electric E field around the vehicle.

[0008] Referring to **FIG. 3**, the radius of the ring (**4**) is equal to a. The distance from a point on the ring to the z-axis is r. The potential on the z-axis is therefore the charge divided by the distance,

$$potZ = \frac{q}{\sqrt{a^2 + r^2}}$$

This potential is expanded as a series in terms of inverse radius r

$$potZout = \frac{35qa^8}{128r^9} - \frac{5qa^6}{16r^7} + \frac{2qa^4}{8r^5} - \frac{qa^2}{2r^3} + \frac{q}{r}$$

The potential outside the ring can be written in terms of the Legendre polynomials P

$$Vout = \sum_{n=0}^{s} \left(\frac{a}{r}\right)^{n+1} A[n] LegendreP[n, \mathrm{Cos}(\theta)]$$

where s is the number of terms in the expansion. By equating the known particular solution potZout on the z-axis with the general Vout solution, the coefficients A[n] are found to be

$$A(0) = \frac{q}{a}$$

$$A(1) = 0$$

$$A(2) = \frac{-q}{2a}$$

$$A(3) = 0$$

which are substituted back into the Vout equation to get the potential outside the ring.

[0009] Referring to **FIG. 4**, the potential (dotted lines **6**) looking at a slice through the ring (**5**) is shown together with the electric E field. The negative gradient of the potential is the electric field (**7**) shown by the direction of the arrows. The importance of this diagram is that the electric field points in the radial direction toward the negatively charged ring. The force on an electron is the electron charge times the electric field

$$F = q_e E_r = -/q_e|(-|E_r|) = +F$$

Because the electron charge is negative and the radial field points in the negative direction toward the ring, the force on the electron is positive. Thus the electron moves away from the ring in the positive radial direction. A 3-dimensional plot of the ring (**8**) and the electric field (**9**) is shown in **FIG. 5**.

[0010] The stress-energy-momentum generated by a radial electric field is calculated using the Faraday F tensor

$$F_{\alpha}^{\beta} = \begin{vmatrix} 0 & E_r & 0 & 0 \\ E_r & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{vmatrix}$$

The g metric tensor has to be given in spherical coordinates {r,θ,ϕ}

$$g_{\alpha\beta} = \begin{vmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & r^2 & 0 \\ 0 & 0 & 0 & r^2 \sin(\theta)^2 \end{vmatrix}$$

where θ is the angle from the vertical to the radius r. The stress tensor T^{rr} along the radial direction is

$$T^{rr} = \frac{E_r^2}{8\pi c^2}$$

which shows that the pressure is negative along the radial line equal to the square of the radial electric field divided by the square of the speed of light. Because the field is squared, it doesn't matter that the electric field points in the negative direction. The square makes it positive, but the overall curvature pressure is negative. Thus this negative pressure cancels out the positive pressure propelling the photon along. The second key idea of the invention is how to generate this photon moving in the radial direction.

[0011] It has been known for a long time in physics that an electron moving in a circular path will emit photons in a process known by the German word Bremsstrahlung which is translated as "breaking radiation." There are several types of radiation such as classical Bremsstrahlung involving a charged particle making a collision with another charged or uncharged particle in which photons are emitted. The quantum mechanical Bremsstrahlung involves the sudden appearance or disappearance of a charged particle which also emits radiation. In space, having a field of wormholes in which the electrons are spiraling down into hyperspace would result in the emission of photons by the quantum mechanical method. Also, in the atmosphere, having collisions with air molecules results in emission of photons in the classical way.

[0012] In order to get the electrons to spiral around and emit photons, a crossed electromagnetic field is used as shown by the following equation

$$F = q(E_r + v_r \times B_\theta)$$

where the velocity v is in the positive radial direction due to the force of the electric field. The velocity crossed with a magnetic flux density B field in the θ-direction makes the electron move sideways back and forth in a wiggling motion.

[0013] Referring to **FIG. 6**, a direct current solenoid (**10**), represented by multiple current loops, running vertically through the center of the hull, generates a magnetic field that curves around the outside of the hull, as shown by contour lines (**12**). The north pole (**11**) is at the bottom of the hull. A radial arrow (**13**) from the electrostatically-charged rim is perpendicular to the magnetic field lines. The cross product in the force equation becomes the electron radial velocity times the magnetic field $v_r B_\theta$.

[**0014**] Referring to **FIG. 7**, the electric field is in the y-direction and the magnetic field is in the z-direction. The flat looping path in the x-direction is the motion of the electron. The electron, which has a negative charge, starts to move in the direction opposite to that of the electric field. In this particular diagram, the electron acquires a velocity in the negative y-direction. Then a sideways force in the x-direction is produced due to the cross product of the velocity with the magnetic field times the negative charge

$$-q(-v_y \times B_z)=+F_x$$

Depending on the magnitude of the velocity, various size loops can be produced.

[**0015**] In terms of the hull coordinates, because the flat loop is in the plane of the electric field which points in the radial direction, the electron emits light in the radial direction. This condition means that the negative radial pressure created by the electric field cancels the radial pressure of the photon. Thus the photon becomes a stationary vibrating quantum of negative energy. This has the appearance of a luminescent light source. The stress tensor for this condition is therefore

$$T_\mu^\nu = \begin{vmatrix} -\frac{E^2}{c^2} & 0 & 0 & \frac{E^2}{c^2} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -\frac{E^2}{c^2} & 0 & 0 & 0 \end{vmatrix} = -\frac{E^2}{c^2}\text{residual negative energy}$$

[**0016**] residual negative energy

which leaves a residual negative energy per photon.

[**0017**] Referring to **FIG. 8**, the negatively charged rim (**14**) produces a radial electric field (**16**) that crosses the magnetic B field (**15**) of the solenoid. Electrons emitted by the charged rim then encounter this crossed field which makes them spiral (**17**) around the hull. Because of the tight loop, the electron emits Bremsstahlung radiation in the radial direction (**18**). The positive pressure field of the photon, which is directed in the radial direction, is canceled by the negative pressure field (**19**) created by the electric field. Because the photon energy is negative, a stationary vibrating electromagnetic quantum of negative energy (**20**) surrounds the hull.

[**0018**] This negative energy and the pressure stress created by the electromagnetic fields open up wormholes between space and hyperspace. The potential head is positive from hyperspace into space because the energy of hyperspace is more positive than the negative energy field. The low-density hyperspace energy fills the hull and its surrounding space with a white misty hyperspace energy which makes the spacecraft lighter in mass, and therefore lighter in weight within a gravitational field. The actual physics is more complicated still because the electrons find that the resistance of hyperspace is lower than the resistance of space. Thus they spiral down the wormholes which results in a sudden disappearance of charge. The quantum mechanical effect of this is to radiate even more photons which in turn produce even more negative energy.

[**0019**] The lift on the hull is generated by the radial electric field. In cylindrical coordinates, the g metric tensor is

$$g_{\alpha\beta} = \begin{vmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & r^2 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

Using this metric tensor, the pressure stress in the vertical direction T^{zz} is

$$T^{zz} = \frac{E^2}{8\pi c^2}$$

which is a positive curvature over the hull. The mass of Earth produces a negative curvature in which objects fall toward the mass. By counteracting this negative curvature with a more than positive curvature, lift is developed on the spacecraft. Because the negative energy lowers the effective mass of the vehicle, the acceleration is large with a modest electric field. Moreover, in our dimension, the speed of light is 299792458 meters per second. Hyperspace energy has a speed of light equal to one meter per second. Thus the stress is amplified by a factor of

$$A = \left(\frac{299792458\,m/s}{1m/s}\right)^2 \approx 9 \cdot 10^{16}$$

Because electromagnetic fields are relativistic, motion in a low-velocity-of-light energy field amplifies their strength.

SUMMARY OF THE INVENTION

[**0020**] It is the object of this invention to create a spacecraft propulsion system that produces wormholes between space and hyperspace using negative energy in order to generate lift on the hull. It was discovered in the Riemannian curvature calculations of gravitation physics that negative energy is required to keep open the throat of the wormhole. From experiments with the magnetic vortex wormhole generator, it is known that the proper combination of electromagnetic fields, together with this negative energy, can create a wormhole through which smoke can be blown into hyperspace.

[**0021**] Referring to **FIG. 9**, the directions of force, velocity, and electromagnetic fields are referred to in the cylindrical coordinate system $\{r,\theta,z\}$. An electrostatically charged sharp-edged ring in the θ-direction around the hull of the spacecraft produces a radial electric field. A vertical solenoid in the z-direction through the center of the hull produces a magnetic field which is perpendicular at the rim to the electric field. With the current in the solenoid flowing in the clockwise (−θ) direction, using the right-hand rule, the magnetic field points in the upward z-direction outside the rim. Because the rim is charged to a negative voltage, the electric field points toward the hull in the negative radial (−r) direction. Electrons emitted by the rim travel outward (+v) because the charge on the electron is negative which, together with the negative electric field, produces a positive radial force. The radial force on the electron causes it to acquire a velocity which interacts with the magnetic field. The cross product of the velocity (+v) with the positive (+B) magnetic field produces a sideways force on the electron in the negative θ-direction. However, because the charge on the electron is negative, the force is

$$F=-q\{v_r,0,0\}\times\{0,0,B_z\}=\{0,qB_zv_r,0\}$$

which is positive in the θ-direction. It is this sideways force that produces a flat spiraling or looping motion whereby the electron emits photons, known in German as Bremsstahlung radiation, in the radial direction. The photon, which is actually a quantum of negative energy, has a positive radial pressure which propels it along. Because the radial electric field produces a negative pressure in the radial direction, the two opposite fields cancel in the radial direction to form a residual stationary vibrating negative energy. Thus the hull becomes surrounded by negative energy which, together with the pressure stresses created by the electric field, generates wormholes between space and hyperspace.

[0022] The gravitational potential between hyperspace and space is positive because the hyperspace energy is more positive than the negative energy around the hull. Thus the low-density, low-speed-of-light hyperspace energy flows through the wormhole and fills the hull. This has the effect of reducing the effective mass of the hull. Because the electric field generates a positive pressure over the hull in the vertical z-direction, there is an upward force on the vehicle due to the pressure times the hull area. Since the vehicle has a low mass, there is a modest upward acceleration on the spacecraft equal to the force divided by mass.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0023] **FIG. 1**. Perspective view of an electromagnetic wave.

[0024] **FIG. 2**. Perspective view of spacecraft.

[0025] **FIG. 3**. Perspective view of charged ring.

[0026] **FIG. 4**. Planar plot of the radial electric field produced by charged ring.

[0027] **FIG. 5**. Perspective view of radial electric field around ring.

[0028] **FIG. 6**. Planar view of magnetic flux density field contour lines.

[0029] **FIG. 7**. Perspective view of electron motion in crossed electric and magnetic fields.

[0030] **FIG. 8**. Perspective view of production of negative energy around hull.

[0031] **FIG. 9**. Perspective view of cylindrical coordinate system {r,θ,z}.

DETAILED DESCRIPTION OF THE INVENTION

[0032] 1. The hull is made from a single sheet of aluminum which has been stretched to its yield point by hydraulic cylinders. An upper and lower die is CNC machined to the profile of the hull. The soft sheet is then clamped in the die where it takes on the smooth shape of the hull without any wrinkles. The hull is extremely rigid after forming and does not require any structural reinforcements.

[0033] 2. A section of the aluminum ring is made in a 3D computer graphics program. The model is stored as a stereolithography file (*.stl). The computer model is then sent via Internet e-mail to the stl server who prints the part in an ultraviolet light-cured polymer. The part is returned the next day by Express Mail. Using a rubber blanket mold to create several ring sections, the entire ring is assembled together in another wooden mold box having thin circular laminate-coated particulate wall boards on either side of the ring. Then a liquid rubber mold is poured on top of the ring and allowed to harden overnight at room temperature. Since the rubber mold is flexible, the ring can be extracted fairly easily. This ring model is then sent to the foundry where it is cast in aluminum using the lost wax process in which a wax mold evaporates out of the sand casting. We are also experimenting with non-magnetic copper casting metals containing beryllium having good conductivity.

[0034] 3. A 11.5 cm plastic pipe is mounted on a rotating fixture driven slowly by a microcontoller, stepper motor, and power electronics board. Using a large diameter insulated wire, such as a 17 AWG with a wire diameter of 0.127 cm, the wire is wound slowly on the pipe and expoxied so that the windings don't come loose. The solenoid is then mounted vertically in the hull supported by the support ring and driven by a current generator located nearby on the test rig.

[0035] 4. The ring is driven by a high voltage electrostatic generator similar to the night vision scope high voltage power supplies. The ring charge is isolated from the hull by ceramic insulators.

I claim:

1. A spacecraft propulsion system comprising the components:

an aluminum horizontal circular structural support ring;

an aluminum hull in the shape of a high dome on top and shallow dome on the bottom attached to the circular support ring using ceramic insulators;

an electrostatically negatively-charged sharp-edged circular ring, preferably of non-magnetic aluminum or copper, attached with ceramic insulators to the outside of the support ring;

a solenoid mounted through the center of the hull in the vertical direction and attached to the center of the support ring;

an electrostatic high-voltage generator to drive the outer electrostatic ring; and

a direct high-current generator to drive the solenoid.

2. The method of claim 1, wherein a negative radial electric field is generated around the hull by placing a negative potential on the sharp-edged electrostatic ring using the electrostatic generator.

3. The method of claim 1, wherein the current-driven solenoid generates a vertical magnetic field around the hull with the north pole of the solenoid facing down through the bottom of the hull which causes the magnetic flux density field to point up outside the rim.

4. The method of claim 1, wherein electrons are emitted radially by the sharp edge of the charged ring.

5. The methods of claims **2**, **3** and **4**, wherein the crossed electromagnetic fields cause the electrons to spiral around in flat loops during which photons are emitted in the radial direction.

6. The methods of claims **2** and **5**, wherein the negative radial pressure created by the electric field cancels the positive radial pressure of the photon to leave a residual quantum of negative energy per photon around the hull.

7. The methods of claims **2** and **6**, wherein the pressure stress created by the electric field, and the negative energy combine to form wormholes between space and hyperspace.

8. The method of claim 7, wherein low-density hyperspace energy of a higher gravitational potential flows through the wormholes to fill the hull and surrounding space around the hull with the effect of reducing the effective mass of the spacecraft.

9. The method of claim 2, wherein the electric field generates a positive pressure in the vertical direction over the hull which together with the hull surface area, generates an upward lift force on the hull.

10. The method of claim 6, wherein the negative energy, having a low light speed, amplifies the strength of the electromagnetic fields and pressure stress fields.

11. The methods of claims **4** and **7**, wherein the electrons spiral down the low resistance wormholes into hyperspace such as to create a sudden disappearance of electrical charge which quantum mechanically causes a large emission of additional photons.

* * * * *

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St.Clair (43) **Pub. Date: Oct. 14, 2004**

(54) **CAVITATING OIL HYPERSPACE ENERGY GENERATOR**

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Publication Classification

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(52) **U.S. Cl.** **244/10**

(57) **ABSTRACT**

A hyperspace energy generator that uses cavitating oil bubbles within a magnetic field in order to create wormholes between space and hyperspace for the purpose of permeating the hull of a spacecraft with low-density hyperspace energy.

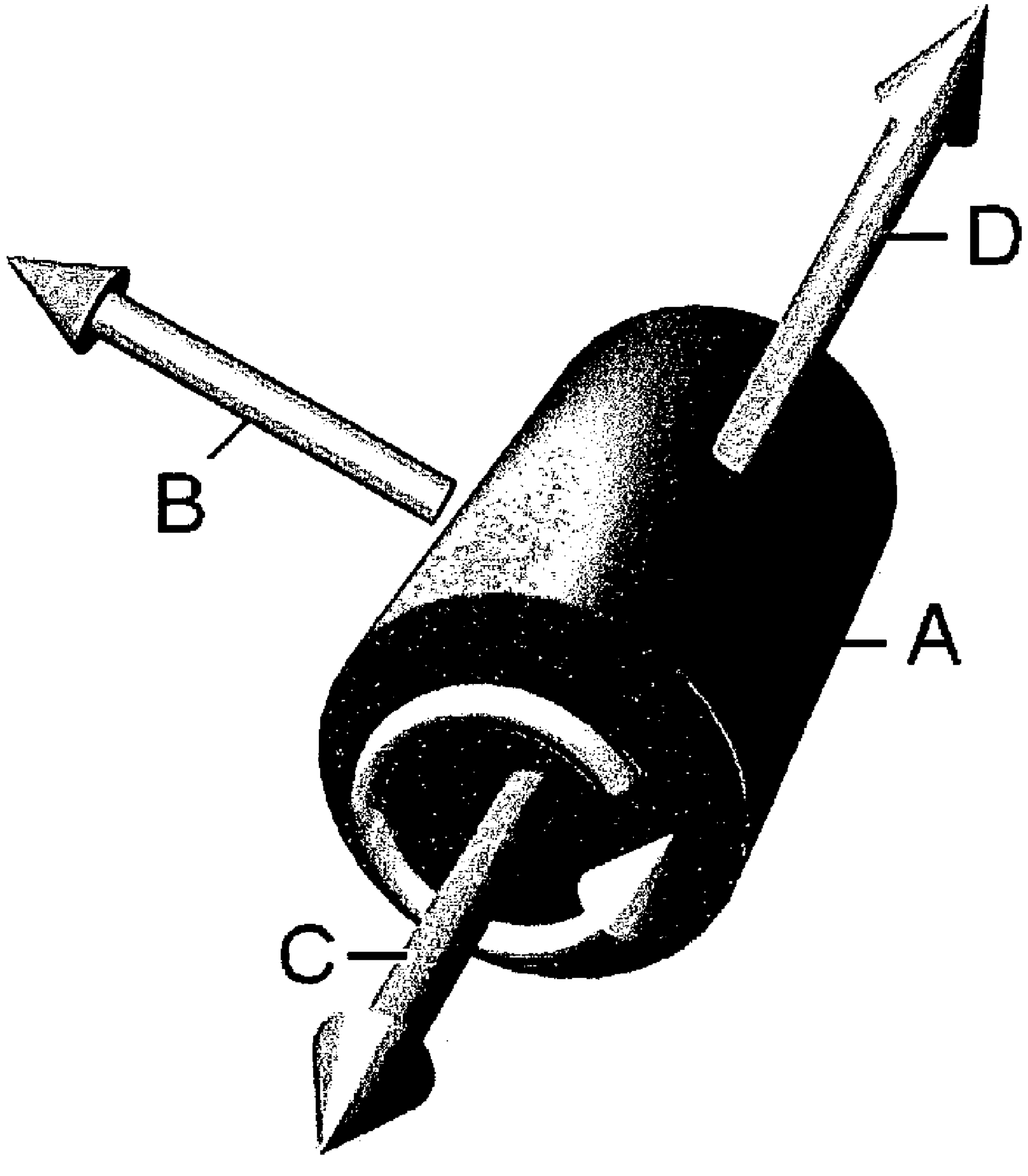

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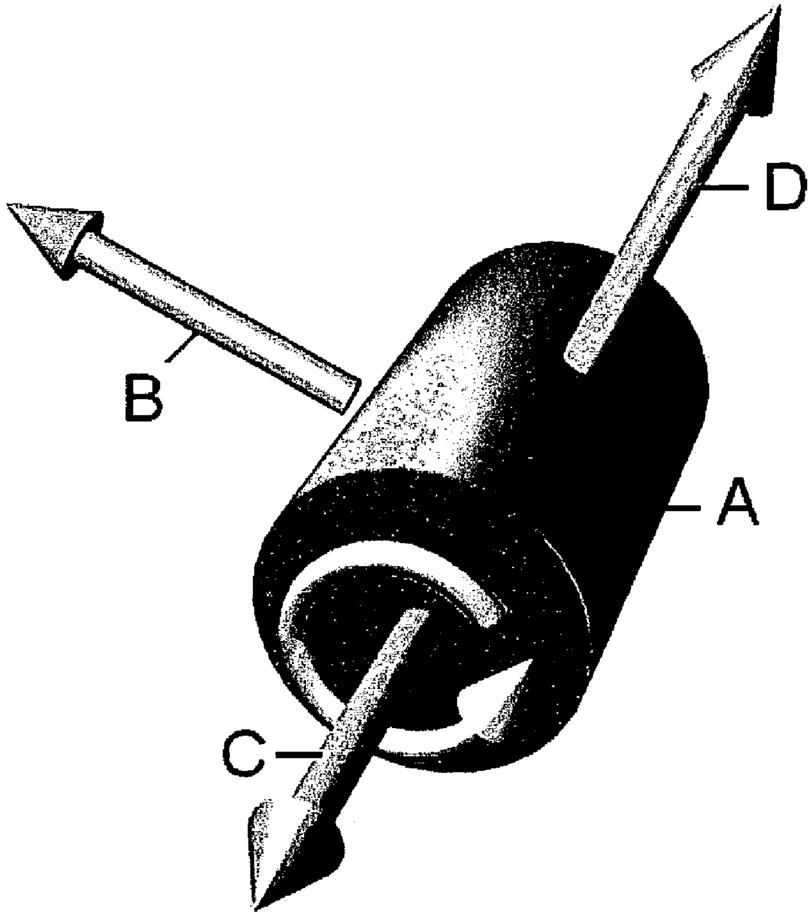

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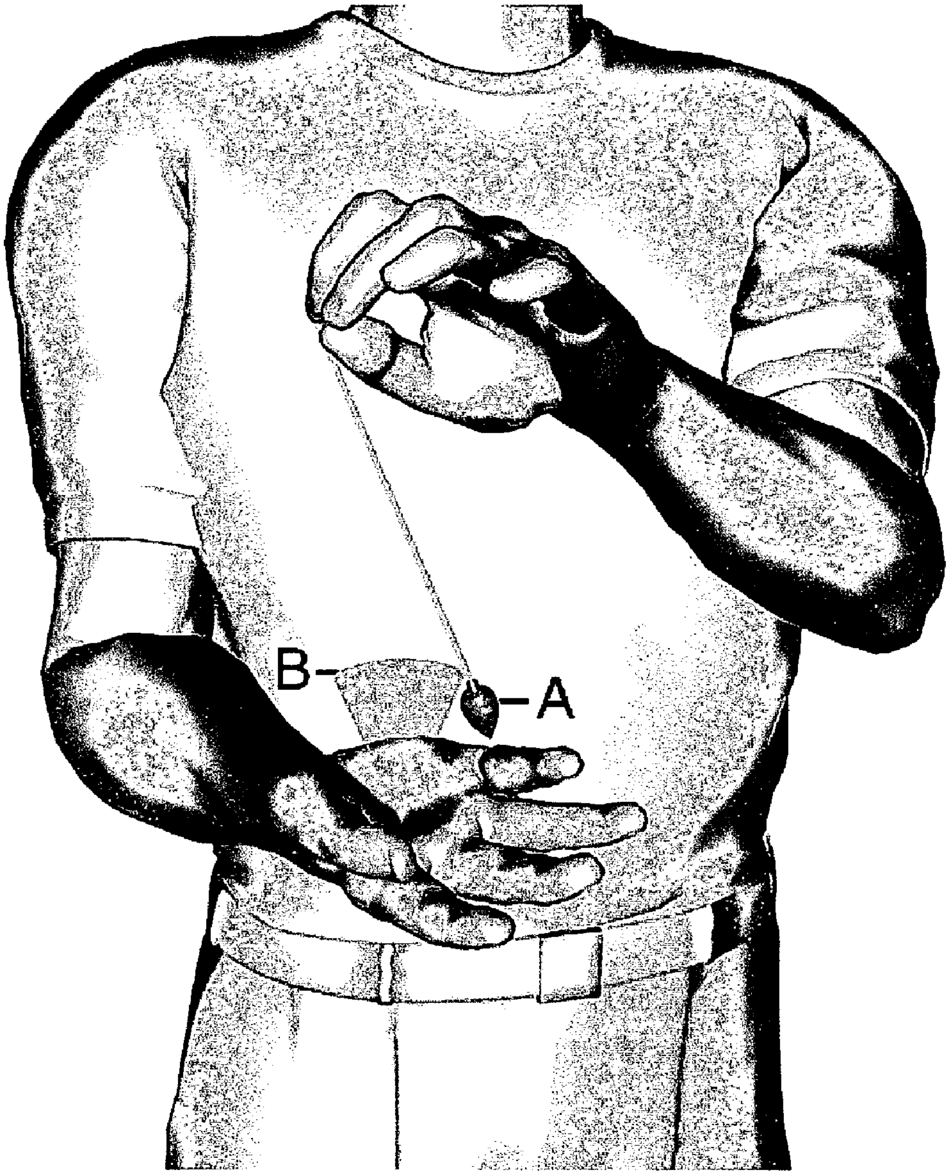

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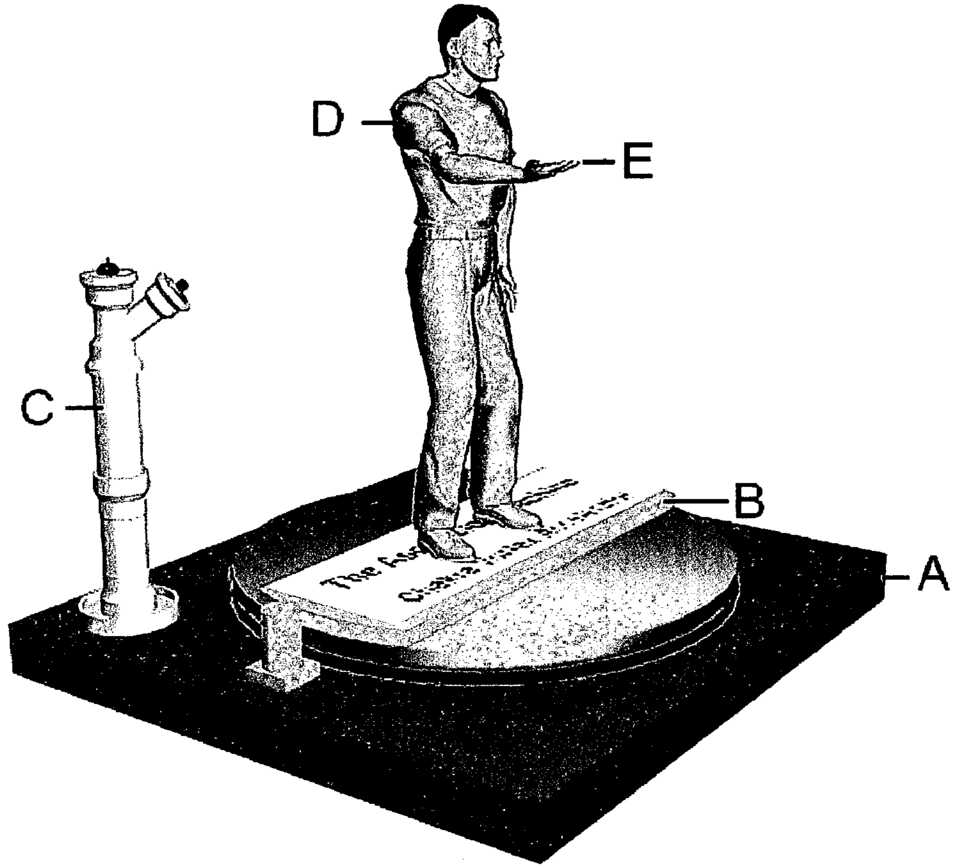

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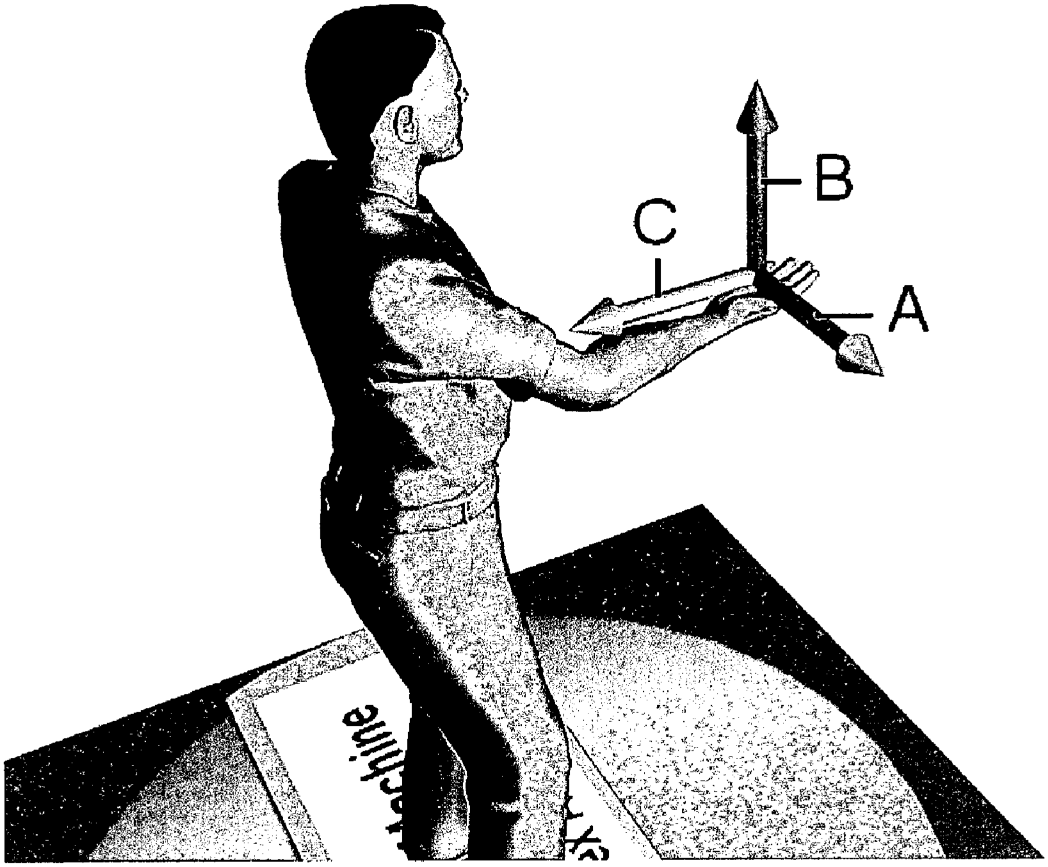
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Figure 5

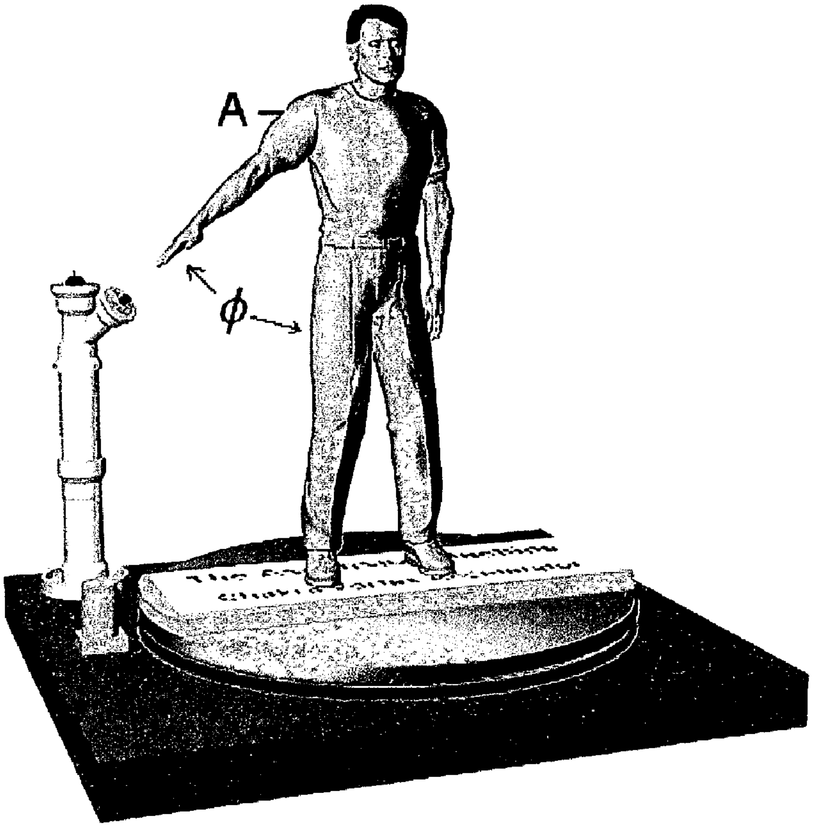

Figure 6

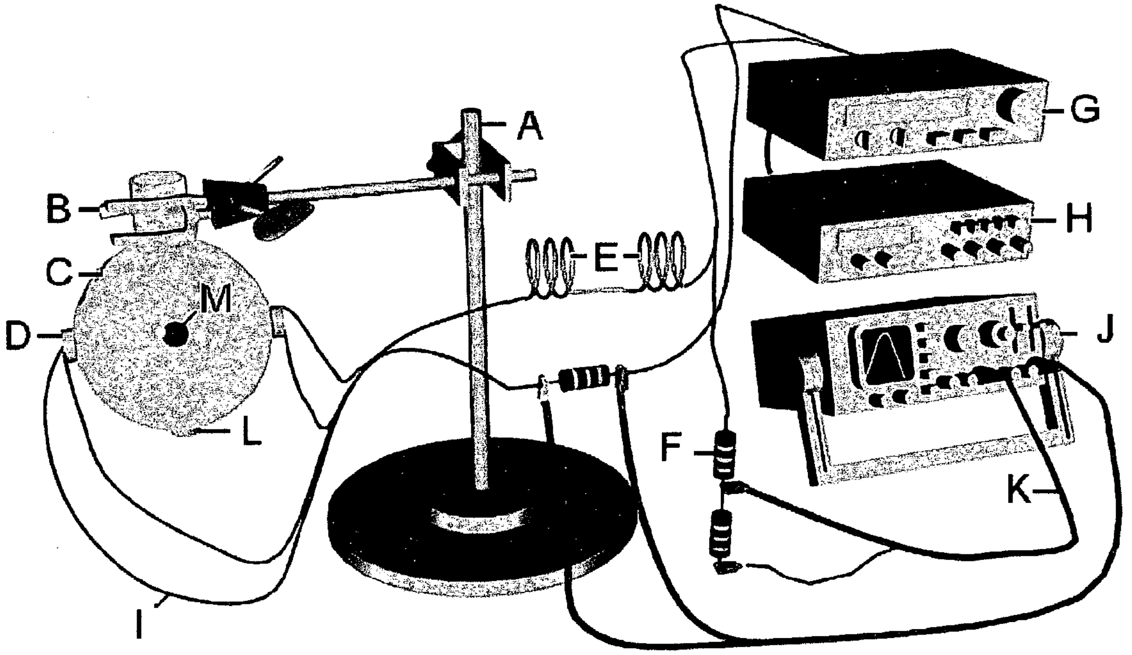
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Figure 7

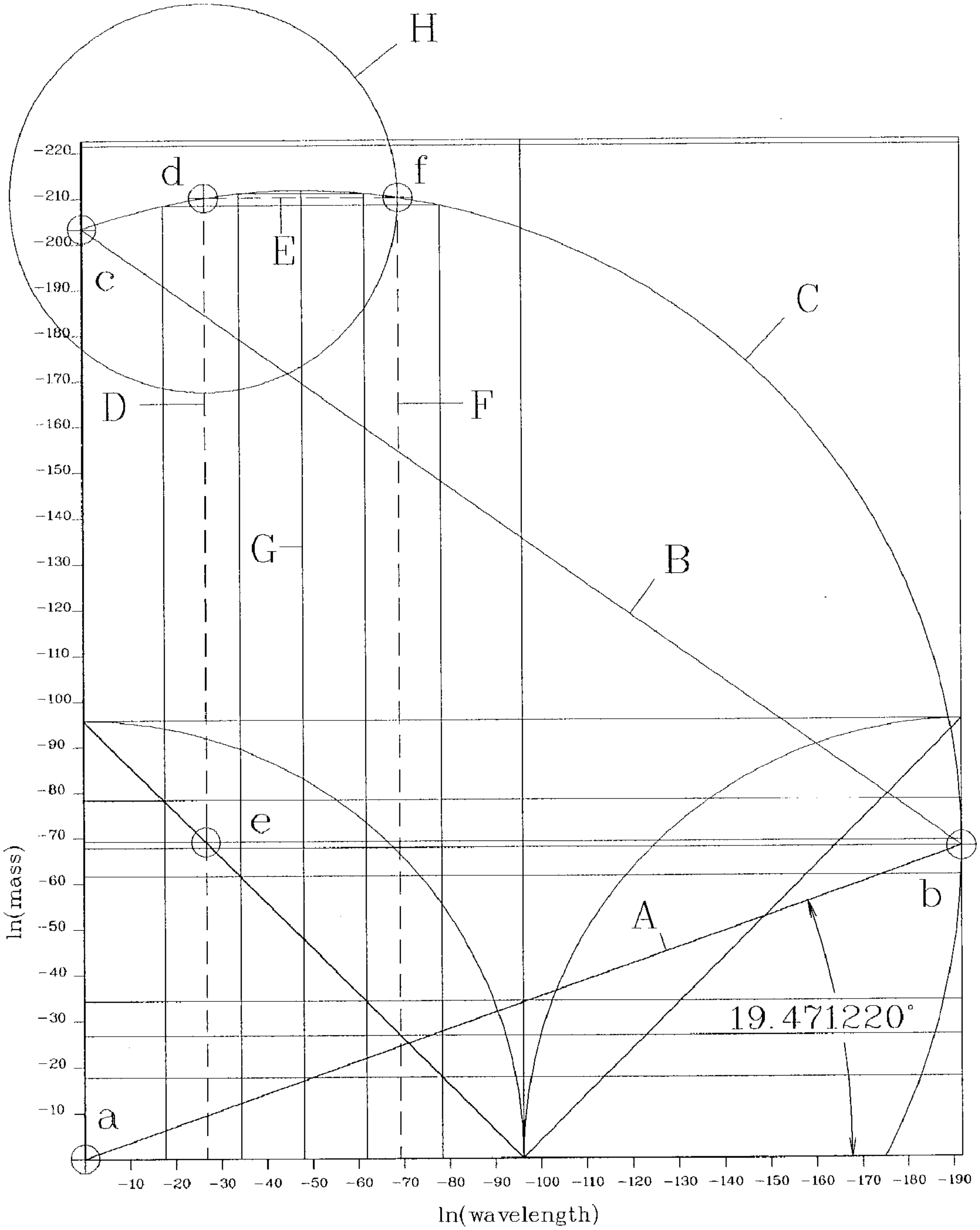
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Figure 8

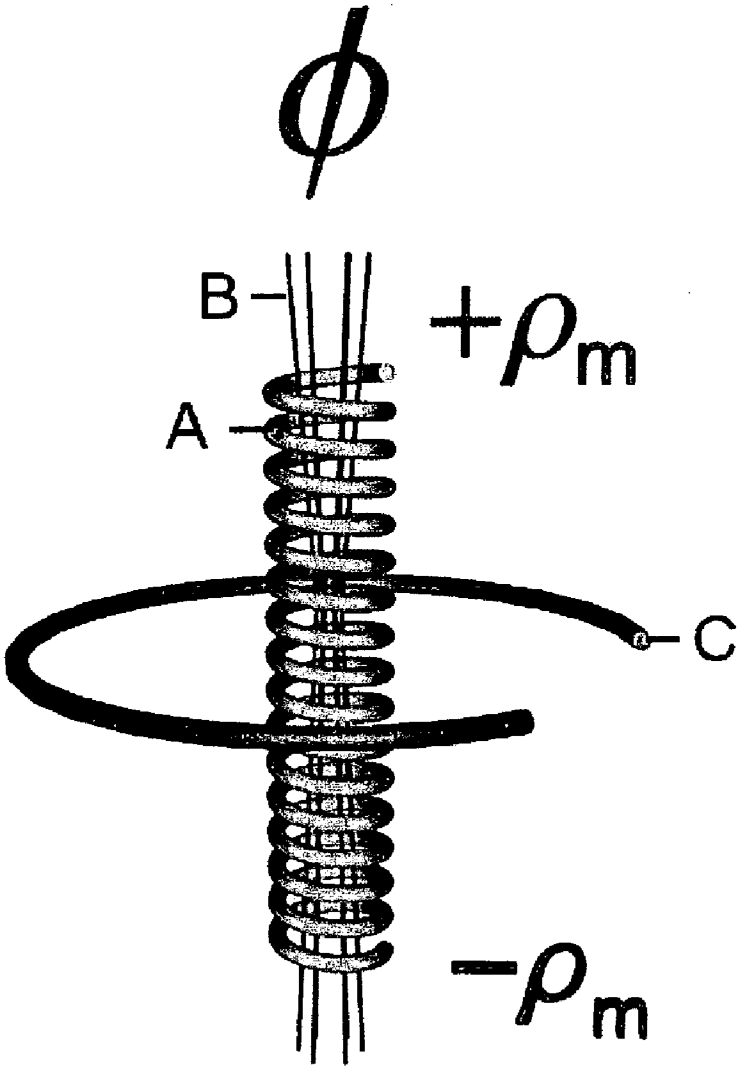
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Figure 9

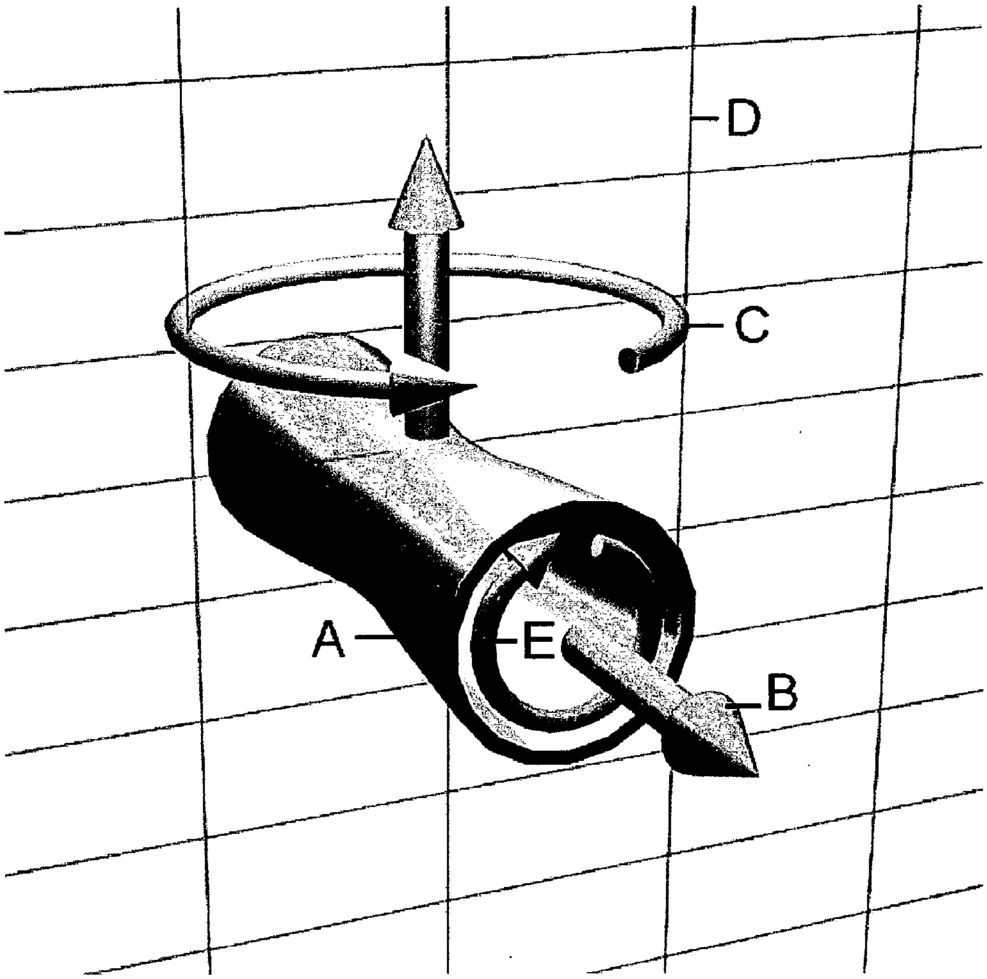

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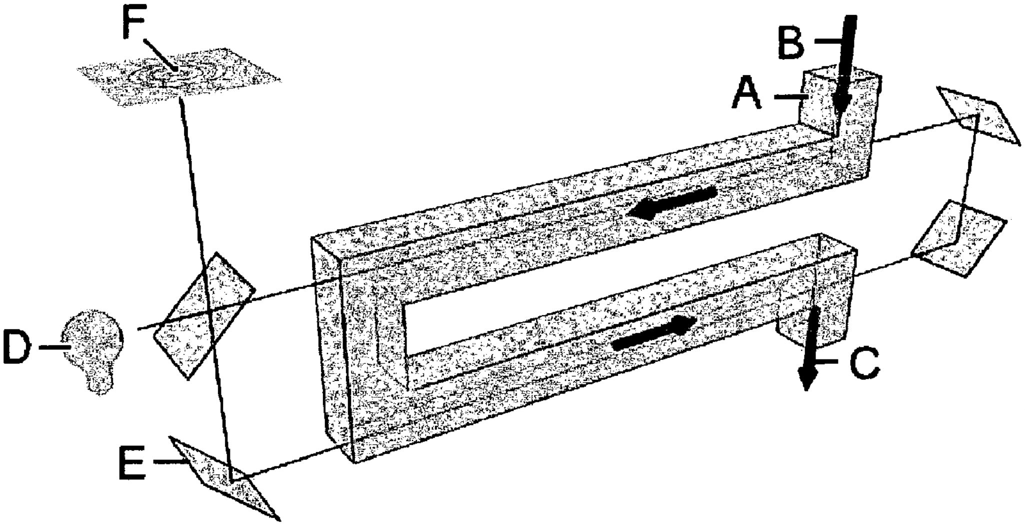

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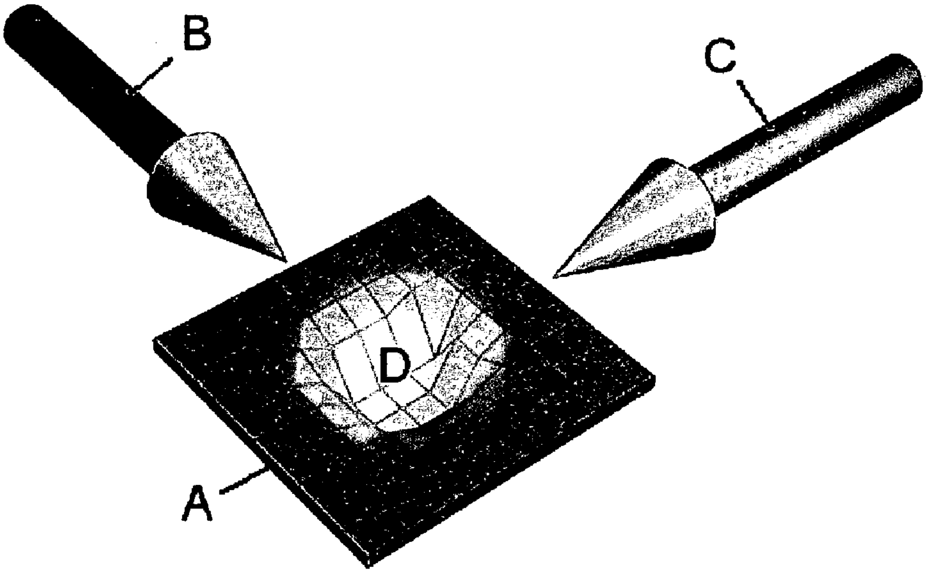

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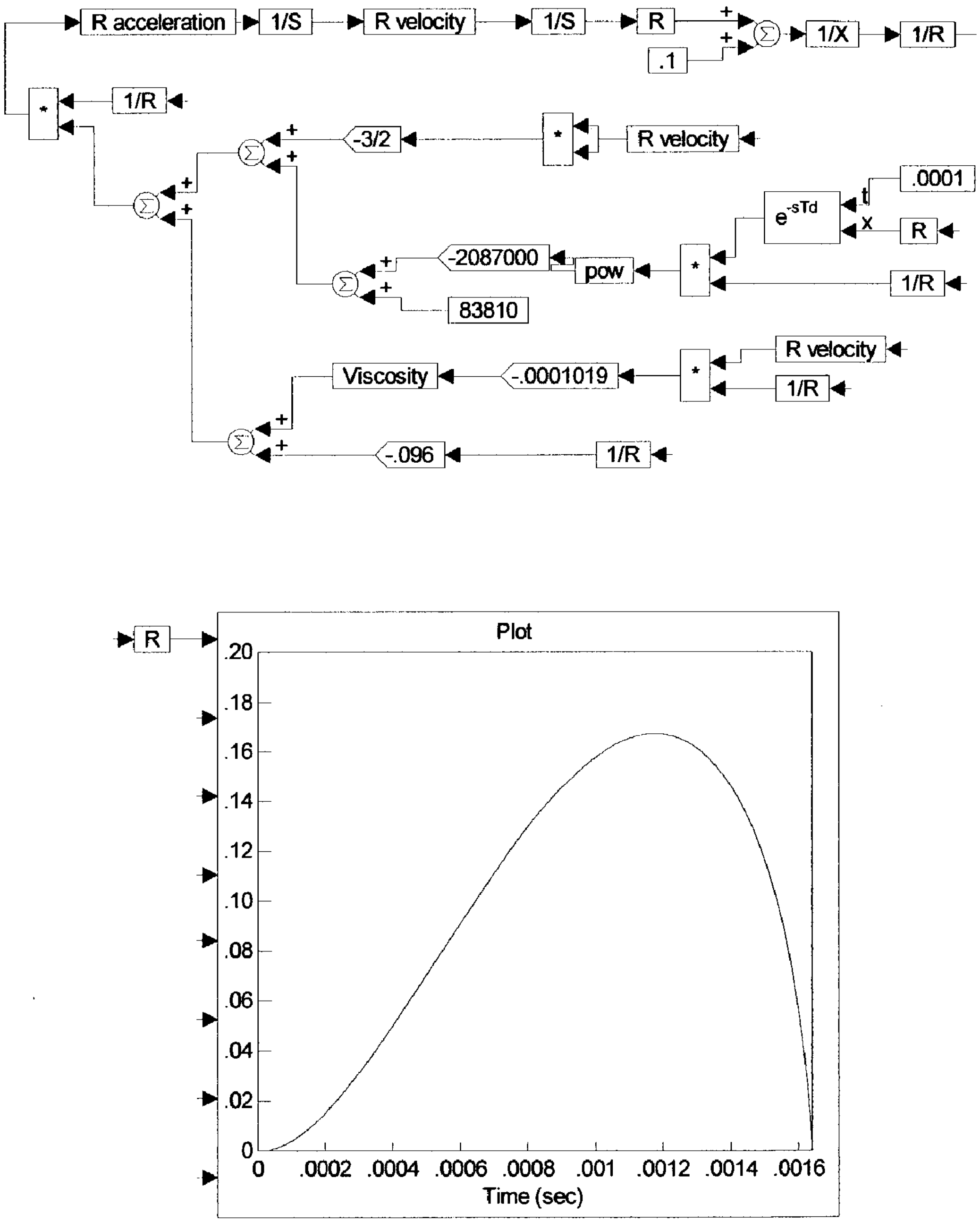
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+
+
.0001
e^-sTd
t
x
R
-2087000
pow
*
1/R
Σ
+
+
83810
R velocity
Viscosity
-.0001019
*
1/R
Σ
+
+
-.096
1/R
R
Plot
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
0
.0002
.0004
.0006
.0008
.001
.0012
.0014
.0016
Time (sec)

Figure 13

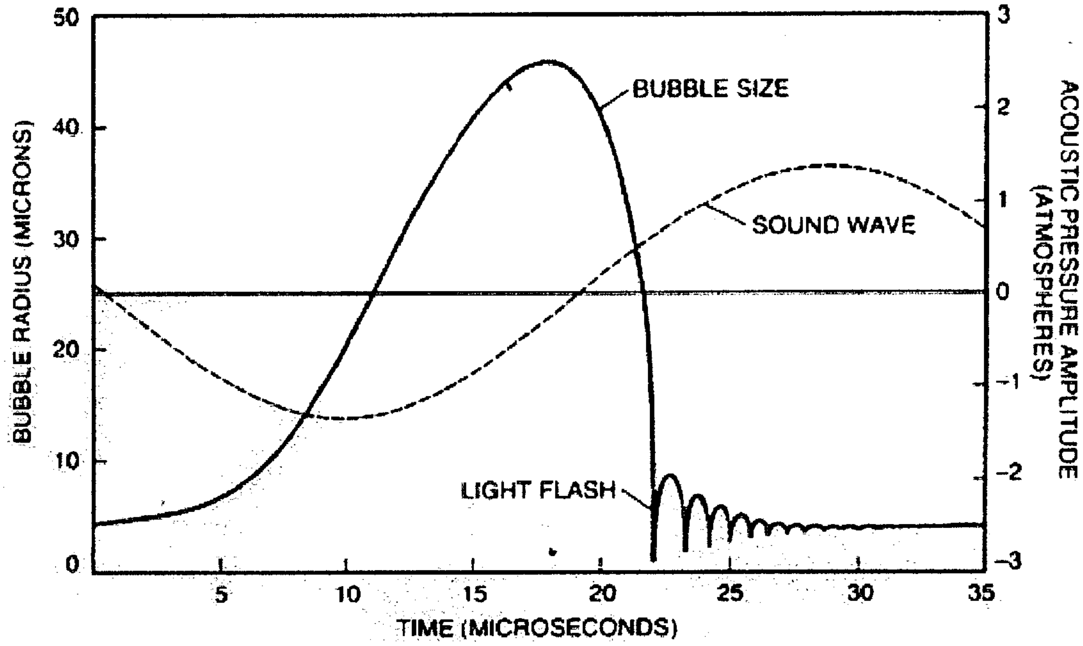
BUBBLE RADIUS (MICRONS)
50
40
30
20
10
0
ACOUSTIC PRESSURE AMPLITUDE (ATMOSPHERES)
3
2
1
0
−1
−2
−3
BUBBLE SIZE
SOUND WAVE
LIGHT FLASH
5
10
15
20
25
30
35
TIME (MICROSECONDS)

Figure 14

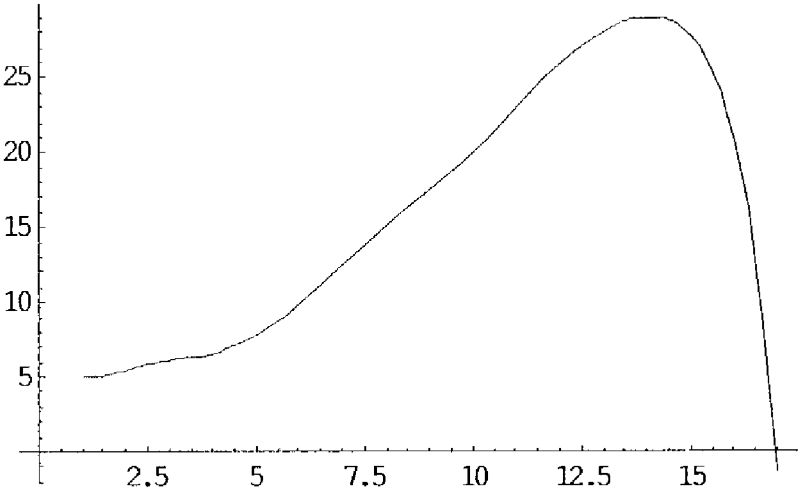

Figure 15

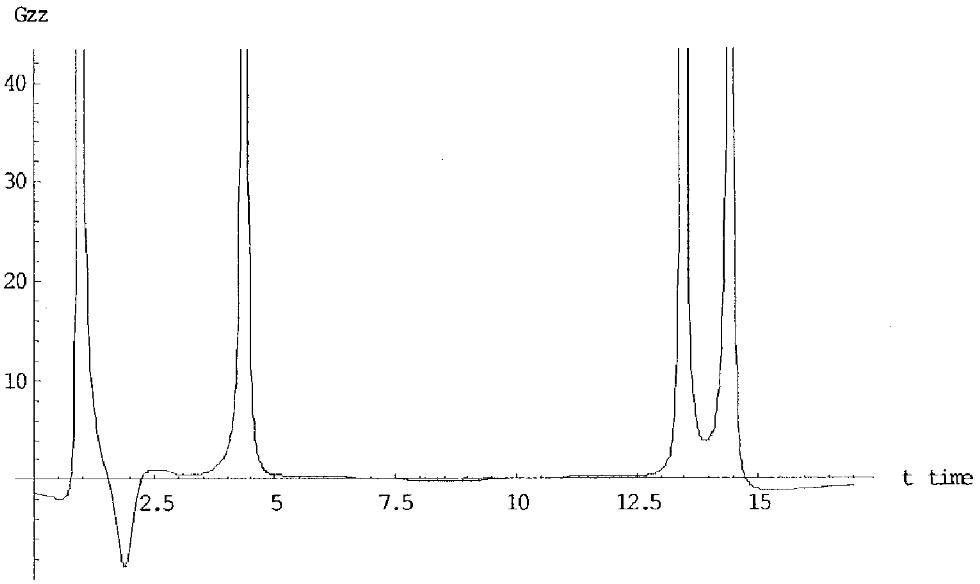

Figure 16

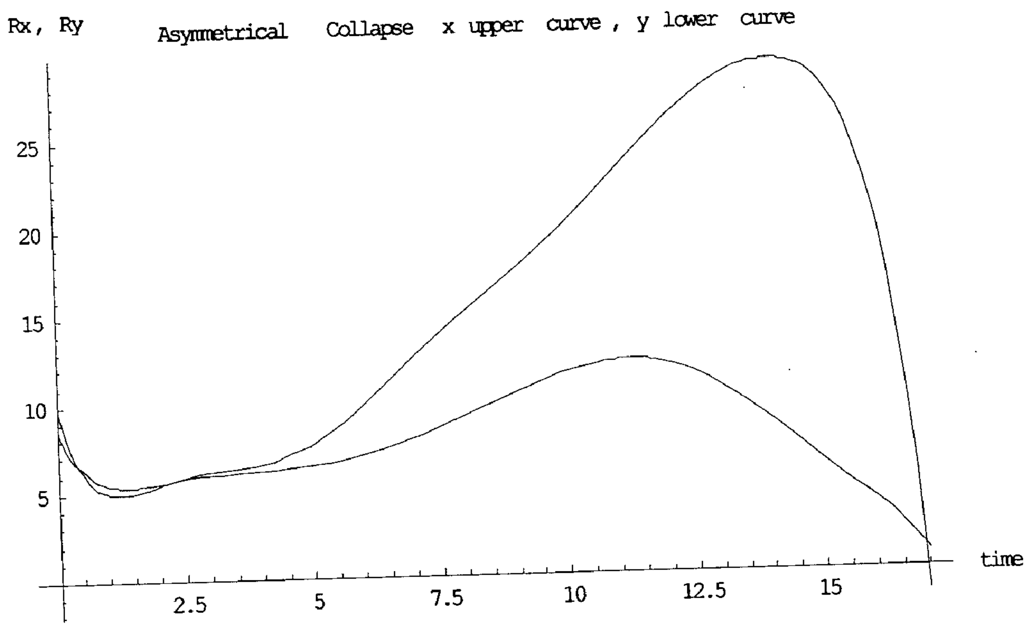
Rx, Ry
Asymmetrical Collapse x upper curve , y lower curve
25
20
15
10
5
2.5
5
7.5
10
12.5
15
time

Figure 17

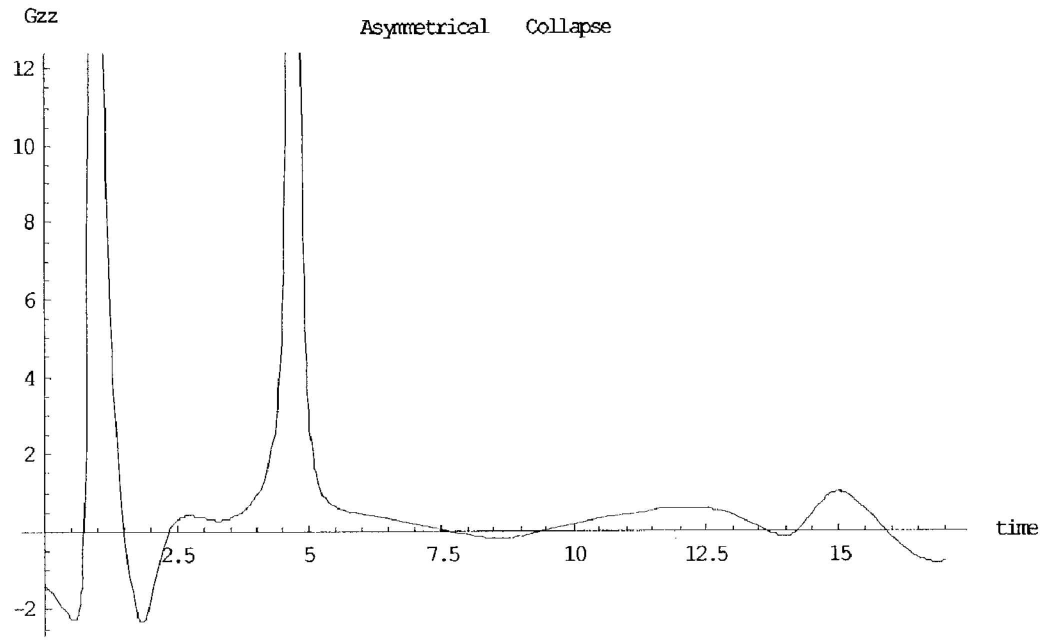

Figure 18

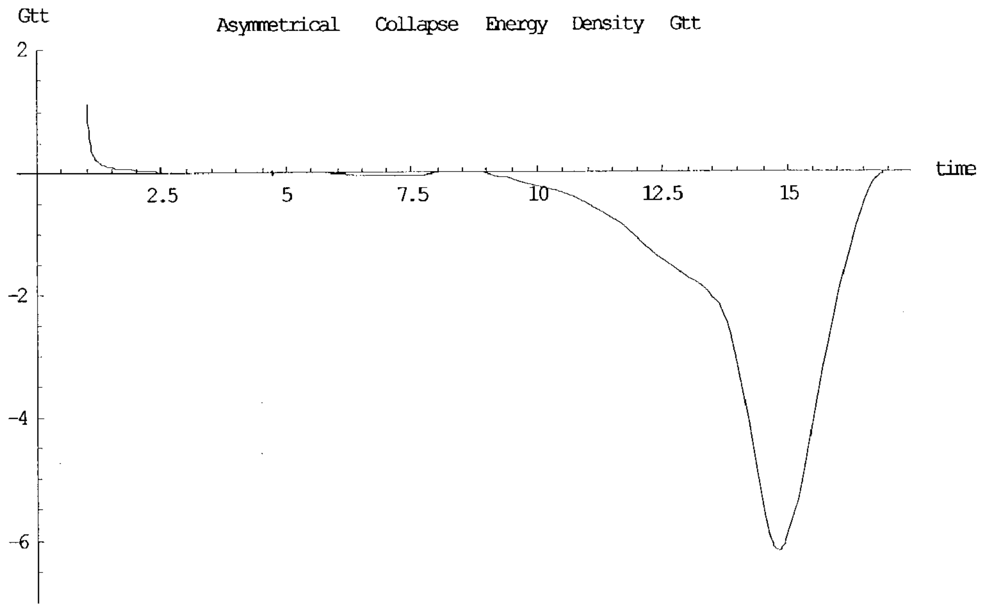
Gtt
Asymmetrical Collapse Energy Density Gtt
2
-2
-4
-6
2.5
5
7.5
10
12.5
15
time

Figure 19

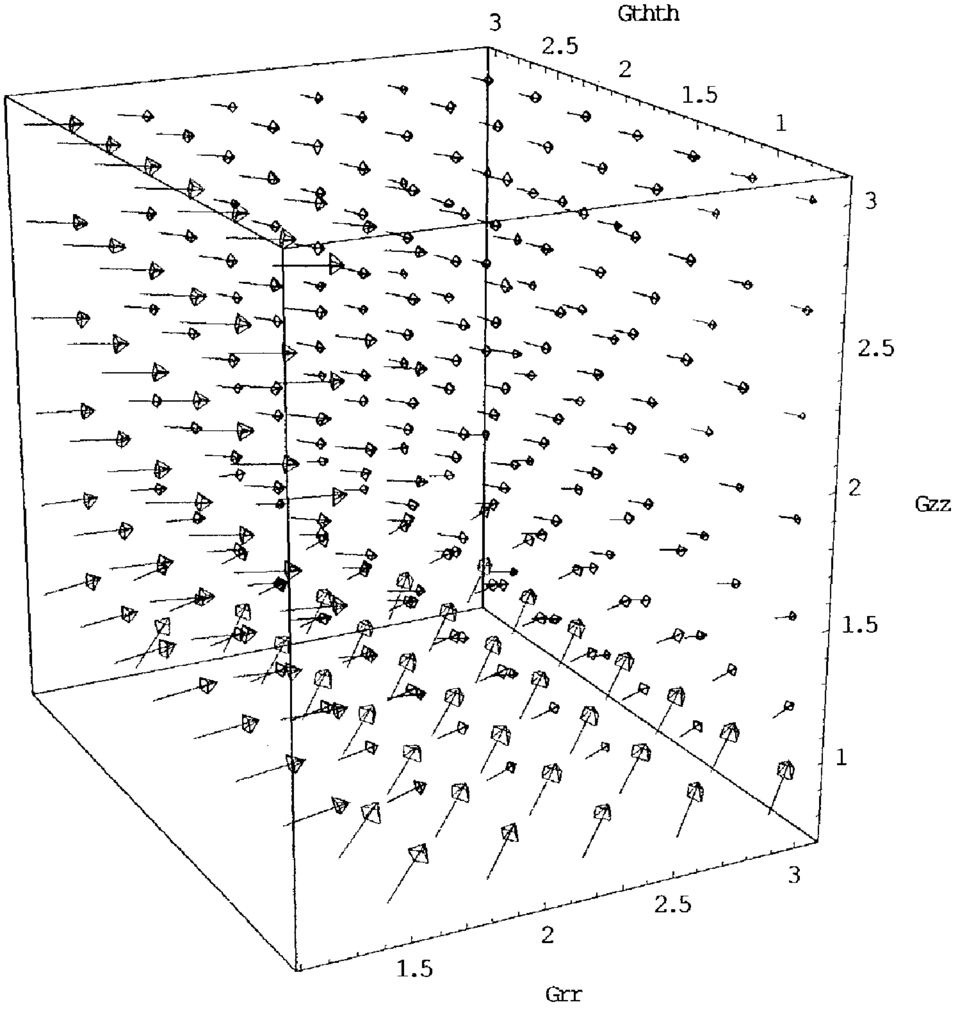

Figure 20

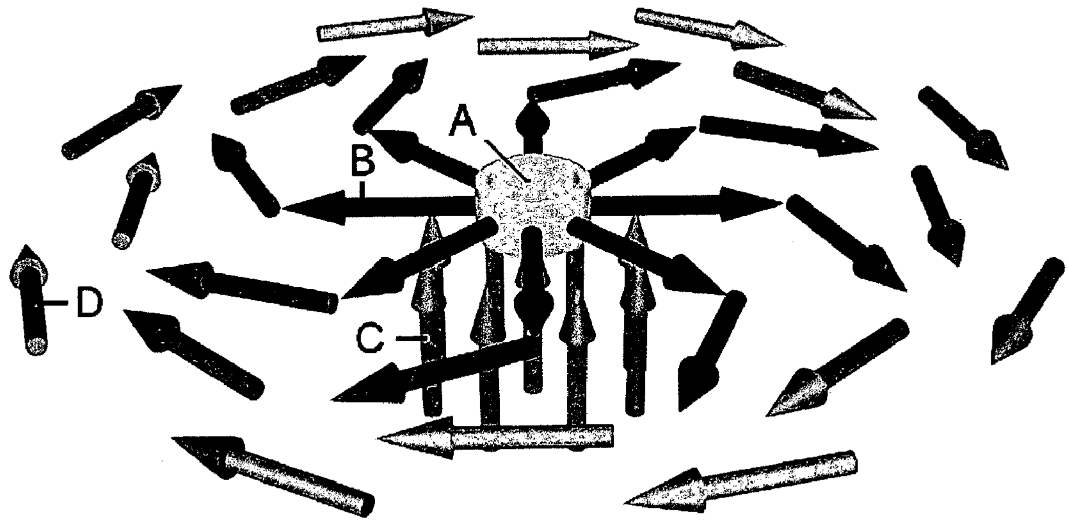

Figure 21

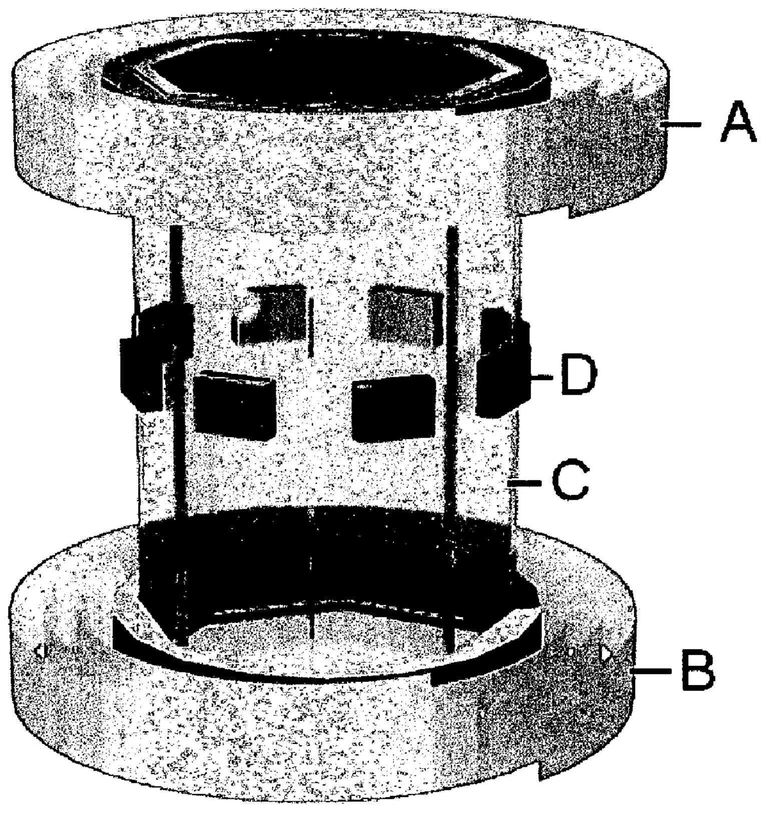

Figure 22

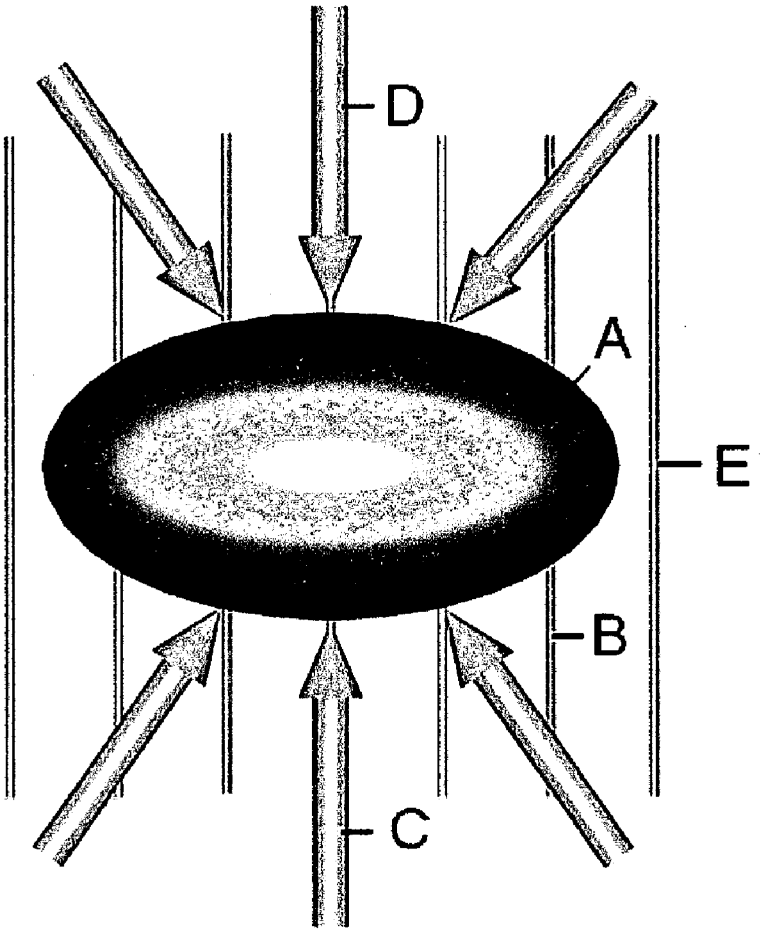

Figure 23

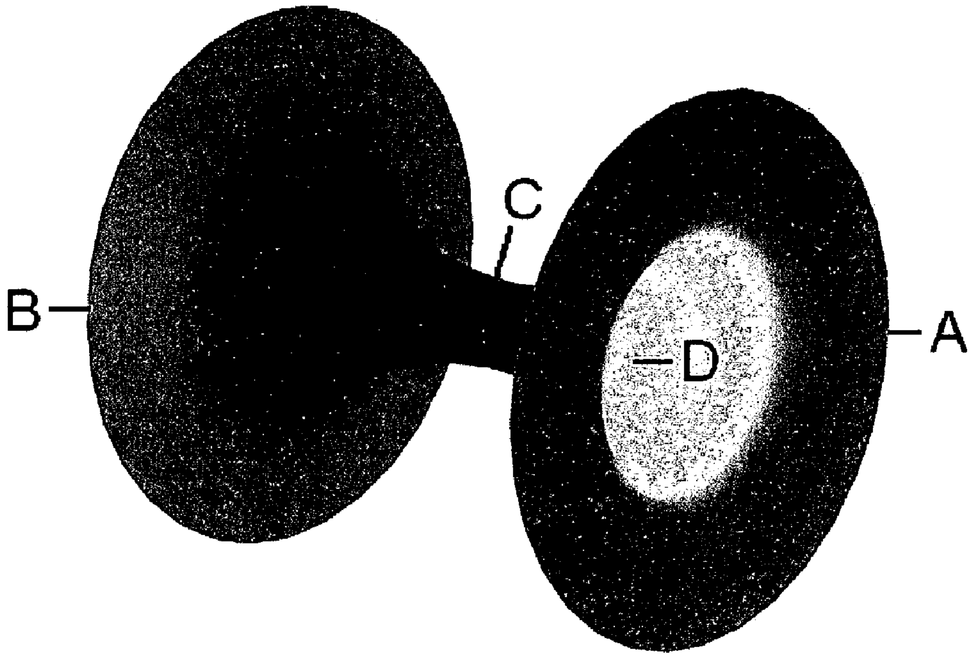

Figure 24

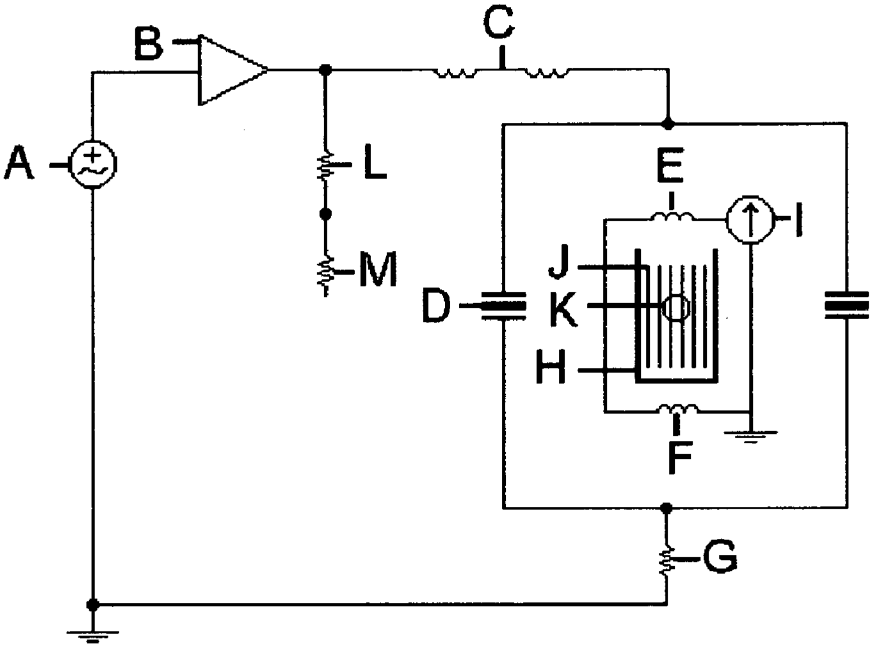
C
B
A
L
M
E
I
J
D
K
H
F
G

CAVITATING OIL HYPERSPACE ENERGY GENERATOR

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is a hyperspace energy generator that uses cavitating oil bubbles within a magnetic field in order to create wormholes between space and hyperspace for the purpose of permeating the hull of a spacecraft with low-density, low-speed-of-light hyperspace energy.

BACKGROUND OF THE INVENTION

[0002] As shown by physicist Dr. John Archibald Wheeler of Princeton University, there is a second term in Newton's gravitational equation which includes an additional force depending on whether or not the body is spinning.

$$F=mg+m(v\times\Omega)$$

[0003] where F is the force, m the mass, g the acceleration of gravity, v the forward velocity of the body, and Ω the angular velocity of the body. Referring to **FIG. 1**, a rotating cylinder (A) is moving with a velocity (B) while spinning counterclockwise as shown by the angular velocity vector (C). The velocity crossed with the angular velocity vector produces a force in the upward direction (D).

[0004] Referring to **FIG. 2**, a pendulum (A) held in the left hand over the right hand will spin in the counterclockwise direction due to the hyperspace energy vortex (B) emanating from the palm of the right hand. This vortex arises because human beings are hyperspace energy beings that live in physical containers located in this universe. The vortex might be considered a wormhole between space and hyperspace. Notice that the angular momentum vector of the vortex points up out of the palm of the hand. If the hand were spinning from left to right, then there would be a force exerted, as shown by the above equation, that would bring hyperspace energy into the right arm.

[0005] Referring to **FIG. 3**, in order to test this hypothesis, a Chakra Vortex Accelerator was built for the purpose of spinning this hand vortex. The motor-driven machine has a base (A) on which is mounted a warehouse palletizing ring and platform (B). A control column (C) has a speed control and on/off switch. A person (D) stands on the platform with his right arm outstretched and palm facing upward (E). The platform spins from left to right.

[0006] Referring to **FIG. 4**, the velocity vector (A) points to the right. The angular momentum vector of the rotating chakra energy vortex points up. The cross product A×B=C produces a force that brings in high permeability hyperspace energy into the arm.

[0007] Referring to **FIG. 5**, after spinning 99 times per day for a few months, it was noticed that the right arm (A) would remain out at an angle ϕ from the body without making any exertion to do so. The left arm, which was not receiving the energy, remained at the side of the body. That is, the low-density hyperspace energy in the right arm was making the arm lighter and producing a subsequent anti-gravitational effect. The conclusion was that it might be possible to invent some device which would produce large amounts of hyperspace energy. This would make possible relativistic electromagnetic fields which can be used to produce the lift force for electromagnetic field propulsion vehicles.

[0008] Then in the February 1995 issue of *Scientific American*, an article appeared entitled *Producing Light from a Bubble of Air* which gave the details for producing sonoluminescence from a cavitating bubble using a kit for sale containing the piezoelectric transducers. Referring to **FIG. 6**, the experimental setup includes a ring stand (A) with a three-finger clamp (B) holding a 100 milliliter flask containing degassed water produced by a Walsh vacuum/pressure pump. Piezoelectric drive transducers (D) are mounted on the sides of the flask in order to create sound pressure waves which create the cavitation bubble (M) in the center of the flask. The transducers are connected by insulated wire (I) to a pair of inductors (E) having a mutual inductance between them. These inductors are driven by a frequency generator (H) connected to an audio amplifier (G). The oscillation signals are picked up by the oscilloscope (J) which is connected to the resistors (F) using the probes (K). The piezoelectric drive transducers act electrically as capacitors. The inductors are wired in series with the capacitance such that the combination resonates at the frequency at which acoustic resonance occurs. Bubbles introduced into the flask tend to coalesce in the center of the flask Above a certain sound intensity, the bubble will collapse and emit a dim light visible to the unaided eye in a darkened room, a process called sonoluminescence.

[0009] Further research showed that there were some earlier doctoral theses available. One of them by Dr. Steven DeWitt Horsburgh entitled *Radial Instabilities of a pulsating air bubble in water* mentioned a most interesting observed phenomenon of the surface oscillations called a "beaconing effect." When a bubble exhibited a stable or long-lived shape oscillation lasting more than two minutes, the bubble had a tendency to slowly precess. The precession rate was on the order of a few hertz which can be taken to mean around 3 Hz. Visually, the beacon looked like a light house beacon. It was a very obvious effect and when the beacon crossed the photodiode, the output voltage increased by at least an order of magnitude.

[0010] Upon reading this, it became apparent that sonoluminescence is involved with gravitational hyperspace physics. Einstein's theory says that inertia is a manifestation of the geometry of spacetime. It also says that geometry is affected by the presence of matter to an extent proportional to the factor G/c^2 where G is the gravitational constant and c is the speed of light. The inverse of this factor is the linear mass Ω of the universe. A spherical shell of mass m with a radius R will create a drag angular velocity on a pendulum equal to

$$\omega_{drag}=\frac{4}{3}\frac{G}{c^2}\frac{m_{shell}}{R_{shell}}\omega_{shell}=\frac{4}{3}\frac{\frac{m_{shell}}{\Omega}}{R_{shell}}\omega_{shell}$$

[0011] The mass of the shell divided by the linear mass (mass per length) converts the mass into a length which is then divided by the radius of the shell which is also a length. The numerical factor 4/3 is found only by a detailed calculation. The calculation, starting from a flat background spacetime manifold, showed the effect of the moving current of mass on the metric. Expressed in polar coordinates, the metric acquires a non-zero coefficient $g_{\phi t}$. Inserted into the equation for geodesic motion, this off-diagonal metric coefficient gives rise to a precession according to the above equation. The numerical factor corresponds to a pendulum located anywhere inside the rotating shell of mass.

[0012] In other doctoral theses, books and physics articles on cavitation, light is emitted after the bubble starts to collapse. A very sharp peak of light is produced which lasts in terms of picoseconds. Thus this type of sonoluminescence is very different than the beaconing effect where the bubble remains stable for long periods of time. The beaconing effect is actually a rotating wormhole between space and hyperspace.

[0013] Briefly what happens is that there is ionized gas in the bubble which releases electrons. As the electrons spiral down through the wormhole from space into hyperspace, they give off light. This situation puts the electrons in contact with the charge of hyperspace. Space has a charge which is equal to the sum of the electron charge q_e and the hyperspace charge q_h. The charge of space q is equal to the Planck mass times a conversion factor between mass and charge. The Planck mass is equal to the linear mass Ω of the universe times the bottom dimensional limit of the universe known as the Planck scale Λ. The conversion factor is the square root of the gravitational constant G times the permittivity of space ϵ. The permittivity is linear capacitance or capacitance per unit length. Thus the charge of space is

$$q=\Lambda\Omega\sqrt{G\epsilon}=q_e+q_h$$

[0014] Because the electron comes in contact with the hyperspace charge, the drag angular velocity in the above equation has to be modified. Notice that if the angular velocity of the shell is modified by the electron fine structure constant α, and the mass involved is the mass of the electron, moving through a radius into hyperspace of the Planck scale Λ, then the drag angular velocity would be

$$\omega_{drag}=\frac{4}{3}\frac{\frac{m_{electron}}{\Omega}}{\Lambda}\omega_{shell}\frac{1}{\alpha}$$

[0015] The angular frequency of the shell is 2π times the electron frequency f_e.

$$\omega_{shell}=\omega_{electron}=2\pi f_e$$

[0016] The inverse of the electron fine structure constant α is equal to Planck's reduced constant ℏ times the speed of light c times the factor 4π times the permittivity of space ϵ divided by the square of the charge of the electron q_e.

$$\frac{1}{\alpha}=\frac{\hbar c 4\pi\varepsilon}{q_e^2}n=137.037916527$$

[0017] Planck's constant is equal to the Planck scale Λ squared times the linear mass Ω times the speed of light.

$$\hbar=\Lambda^2\Omega c$$

[0018] Notice that the fine structure constant has a square in it and Planck's constant also has a square. If the electron charge were traveling through the Planck scale into hyperspace, then there would be a linear charge equal to the electron charge divided by the Planck scale

$$\frac{1}{\alpha}=\frac{\hbar c 4\pi\varepsilon}{q_e^2}n=\frac{\Lambda^2\Omega c\, c\, 4\pi\varepsilon}{q_e^2}n=\frac{4\pi\Omega\varepsilon c^2}{\left(\frac{q_e}{\Lambda}\right)^2}n$$

[0019] The constant equal to the linear mass Ω times the permittivity times the square of the speed of light is actually the square of the linear charge χ of space. So the fine structure constant can be written

$$\frac{1}{\alpha}=4\pi n\frac{(\chi)^2}{\left(\frac{q_e}{\Lambda}\right)^2}=4\pi n\frac{\left(\frac{q}{\Lambda}\right)^2}{\left(\frac{q_e}{\Lambda}\right)^2}=4\pi n\left(\frac{q}{q_e}\right)^2=4\pi n\left(\frac{q_h+q_e}{q_e}\right)^2=$$
$$4\pi n\left(\frac{q_h}{q_e}+1\right)$$

[0020] So the electron fine structure constant is related to the ratio of the charge of hyperspace to the charge of the electron, which is the reason that the equation had to be modified. The electron moving across the Planck scale wormhole is modified by the hyperspace charge it is seeing in a hyperspace co-dimension. This confirms that the beaconing effect is a rotating wormhole into hyperspace.

[0021] The electron fine structure constant is actually the fastest velocity in the Bohr atom. The fine structure constant is the ratio of the electron orbital velocity to the speed of light.

$$\alpha=\frac{v_n}{c}$$

[0022] where the permitted quantized n orbital speeds are v_n/n or v/1, v/2, v/3 and so on. Using a value of v/3, the fine structure constant would be

$$\frac{1}{\alpha}=\frac{3c}{v}=4\pi n\left(\frac{q_h}{q_e}+1\right)=12\pi\left(\frac{q_h}{q_e}+1\right)$$

[0023] which when substituted into the drag angular frequency equation

$$\omega_{drag}=\frac{4}{3}\frac{\frac{m_e}{\Omega}}{\Lambda}2\pi f_e\,12\pi\left(\frac{q_h}{q_e}+1\right)=17.809\ \frac{\text{radians}}{\text{sec}}$$

[0024] The frequency of precession is

$$f_{drag}=\frac{\omega_{drag}}{2\pi}=2.83\text{ Hz}$$

[0025] which is close to the 3 Hz observed in the experiment. The ionized electrons are moving at a slower velocity in the bubble. The 1/3 ratio could also come from the subspace tetrahedron geometry where the tetrahedral angle is determined by this ratio

$$\theta = \operatorname{asin}(1/3) = 19.47122063°$$

[0026] This is an alternative possibility because this angle determines the charge of hyperspace according to the tetrahedron diagram of Δphysics. In geometrical physics, all the constants of physics are determined geometrically by the tetrahedron. The tetrahedron diagram plots the natural logarithm of mass versus the natural logarithm of wavelength. The tetrahedron is circumscribed by a sphere which reflects the electron wavelength into the electron mass. Thus the diagram combines the dual reality of classical physics, involving point mass particles, and quantum physics, involving wave-like particles. The scientific discovery that the electron and the proton are one and the same particle was made using this diagram. It also shows that hyperspace exists.

[0027] Referring to the tetrahedron diagram in **FIG. 7**, a line drawn at the tetrahedral angle produces the tetrahedral lines (A,B) along path (abc). This tetrahedron is circumscribed by sphere (C) with diameter (G). The electron wavelength (vertical dotted line D) reflects off the sphere (d,f) and returns as the electron mass (F). The distance (df) between reflection points is equal to the natural logarithm of the hyperspace charge. It can be shown that the electron charge is related to the geometry around the top of the sphere. Part of the geometry is outside the sphere which makes the charge immune to relativistic velocities.

[0028] Referring to **FIG. 8**, a current-carrying solenoid (A) produces a magnetic flux (B) through the center of the coil. The end of the solenoid behaves like a magnetic monopole. One end has a positive magnetic charge density $+\rho_m$ and the other has a negative magnetic charge density $-\rho_m$. One of Maxwell's electromagnetic equations states that the divergence of the magnetic field is equal to the magnetic charge density.

$$\nabla \cdot B = \rho_m = +\rho_m - \rho_m = 0$$

[0029] Because the magnetic field is solenoidal, the sum of the charges in our spacetime is equal to zero, which is the usual Maxwell equation. In the case of the wormhole, one pole of the magnetic flux is in our spacetime and the other pole is in a co-dimension of hyperspace. In our universe, there is a net magnetic charge density, and Maxwell's equation becomes

$$\nabla \cdot B = \rho_m$$

[0030] When working with bar magnets, bringing two north poles together shows that there is a spring constant involved. The electrons on the surface of the pole spin in the same direction which creates an electrical current around the surface. The magnetic pole strength g is therefore a spring constant K divided by the current per area J.

$$g = \frac{K}{J} \equiv \frac{kg\,m}{s^2}\frac{1}{m}\frac{s\,m^2}{q} = \frac{kg\,m^2}{s\,q}$$

[0031] The magnetic charge density is then the pole strength per volume V or

$$\rho_m = \frac{g}{V} = \frac{kg\,m^2}{s\,q}\frac{1}{m^3} = \frac{kg}{m\,s\,q}$$

[0032] The divergence of the magnetic field has units of

$$\nabla \cdot B = \frac{1}{m}\frac{kg}{s\,q}$$

[0033] which are the units of the magnetic charge density. Notice that the units can also be formatted as a pressure per electrical current in the wire.

$$\rho_m = \frac{kg}{s\,q\,m} = \frac{kg\,m}{s^2\frac{q}{s}m^2} = \frac{\text{force}}{\text{area}}\frac{1}{I} = \frac{\text{pressure}}{\text{current}}$$

[0034] The current flowing through the coils of the solenoid, or around the pole face of the bar magnetic creates a pressure on spacetime. And it is this pressure that can punch through spacetime into hyperspace. Referring again to **FIG. 8**, an electrical charge winding n times around the end of the spacetime solenoid, as seen by path (C), is equal to the charge divided by Planck's constant times the pole flux

$$2\pi n = \frac{q}{\hbar}\int_{Surface} B = \frac{q}{\hbar}\Phi$$

[0035] which shows that the flux Φ is quantized by the winding number n

$$\Phi = n\frac{2\pi\hbar}{q} = n\frac{h}{q}$$

[0036] where the flux is equal to the winding number n times Planck's constant h divided by the charge. Since the flux is the pole strength in webers, the pole strength g has a value of

$$g = n\frac{h}{q}$$

[0037] The magnetic charge density is the pole strength divided by the Planck volume or

$$\rho_m = \frac{g}{\Lambda^3} = n\frac{h}{q}\frac{1}{\Lambda^3} = n\frac{2\pi\Lambda^2\Omega c}{q\Lambda^3} = \frac{2\pi n}{\Lambda}\frac{\Omega c}{q} = 2\pi n\frac{B}{\Lambda}$$

[0038] The magnetic B field of space divided by the Planck length of the wormhole, acting as a linear magnetic field, times the winding number is equal to the magnetic charge density.

[0039] Referring to **FIG. 9**, the wormhole (A), connecting space and hyperspace (D), is precessing (C) in the counterclockwise direction with the angular velocity vector in the vertical z-direction. The magnetic flux (B) through the wormhole is in the radial direction. The mouth of the wormhole is an area with a normal vector in the radial direction also. This arrangement creates an electric field which circulates around the interior periphery of the wormhole. Maxwell's equation says that the curl of the electric field E is equal to the negative time rate of change of the magnetic B field.

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

[0040] This equation is difficult to manage in differential form. As both Maxwell and Feynman have said, it is better to use the integral form involving Stokes' theorem where the area da is converted into a line integral ds which goes well with Maxwell's idea of flux linkage.

$$\int_{surface} (\nabla \times E) \cdot n\, da = \oint E \cdot ds = -\frac{\partial}{\partial t} \int_{surface} B \cdot n\, da = -\frac{\partial}{\partial t} \Phi = -\Phi\, \omega_{drag}$$

[0041] The flux Φ, which is precessing around at the drag angular velocity calculated previously, is equal to the negative of the electric field around the interior perimeter (E) of the wormhole. This is the reason that the beaconing effect lasts for such a long length of time. The force on the electron is equal to the charge of the electron times the electric field. Because the charge is negative, the electron rotates counterclockwise in the opposite direction to that of the electric field. The electrons continuously circulate around the inside periphery of the wormhole. Quantum theory predicts that any radiated electromagnetic energy from an accelerated electron will give off one or more discrete quanta, or photons. The electron is accelerating because it is moving in a circular path. Because the water vapor is ionized in the cavitating bubble due to shock waves, surface oscillations and high temperatures, there are huge numbers of electrons available for producing an intense light which, as registered by the photodiode, increased by an order of magnitude when the beacon rotated by the photodiode.

[0042] From gravitational physics it is known that negative energy has to be produced in order to create a wormhole. Most experimenters are using collapsing spherical bubbles that do not produce negative energy and therefore do not produce the beaconing effect. This next background section shows that if the bubble collapses asymmetrically, then negative energy is produced.

[0043] Referring to an experiment carried out by Fizeau, **FIG. 10**, water flows (B,C) in opposite directions in two tubes of water (A). A light beam from a lamp (D) is projected through both tubes using half-silvered mirrors (E). Fizeau measured an interference (F) between light propagating with the flow and light swimming against the current, indicating that the flow of the medium does affect light propagation. A moving medium turns out to drag light to an extent quantified by a dragging coefficient

$$\alpha = 1 - \frac{1}{n^2}$$

[0044] where n is the index of refraction of the medium. Einstein's addition theorem of velocities states

$$v = \frac{v' + u}{1 + \frac{v'u}{c^2}} = \frac{\frac{c}{n} + u}{1 + \frac{cu}{nc^2}} = \frac{\frac{c}{n} + u}{1 + \frac{u}{nc}}$$

[0045] In the limit of slow flows compared with the speed of light in a vacuum, the effective velocity of light v in the medium flowing at a velocity u is

$$v \approx \left(\frac{c}{n} + u\right)\left(1 - \frac{u}{nc}\right) \approx \frac{c}{n} + \alpha u$$

[0046] The relationship between cavitating bubbles and light dragging is that when the bubble collapses, the surface has a tremendous acceleration and velocity which creates internal shockwaves that bounce back and forth within the medium. At the same time, the water vapor and air are ionized which creates short bursts of light. Thus there is light that is being dragged along by the collapsing surface of the bubble. This moving medium appears to light as a change in the metric of spacetime resembling, it turns out, a gravitational field. The velocity of the medium affects the elemental length ds^2 of spacetime as given by the metric for light dragging

$$ds^2 = c^2 dt^2 - dx^2 + k(c^2 dt^2 - u \cdot dx)^2$$

[0047] where k is equal to

$$k = \frac{\alpha}{c^2 - u^2}$$

[0048] and dx is the elemental length in the {dx,dy,dz} directions. The velocity u in the dot product is equal to the velocities {ux,uy,uz} in the x, y and z-directions. Expanding the equation produces the following metric

$$ds^2 = (1+k)dt^2 + (ku_x{}^2 - 1)dx^2 + (ku_y{}^2 - 1)dy^2 - dz^2 - 2ku_x dx dt - 2ku_y dy dt + 2ku_x u_y dx dy$$

[0049] where velocity uz is zero and the speed of light is equal to one.

[0050] The dt^2 energy density term is modified by one plus the k factor. Thus the index of refraction of the medium, the speed of light and the overall light dragging velocity u affects the energy density. It can be shown that the speed of light in hyperspace is much lower. The difference of the squares of the velocities in the denominator creates the possibility for amplification of this term.

[0051] The factors of the elemental lengths are then inserted into the g metric tensor which is then used to calculate the spacetime distortion generated by the collapsing bubble. The g metric tensor is a 4×4 matrix having rows and columns that correspond to the elemental lengths {t, x, y, z}.

$$g_{\alpha\beta} = \begin{array}{c||cccc||} & \beta = t & \beta = x & \beta = y & \beta = z \\ \alpha = t & 1+k & -ku_x & -ku_y & 0 \\ \alpha = x & -ku_x & ku_x^2-1 & ku_xu_y & 0 \\ \alpha = y & -ku_y & ku_xu_y & ku_z^2-1 & 0 \\ \alpha = z & 0 & 0 & 0 & -1 \end{array}$$

[0052] In Einstein's General Theory of Relativity, the G curvature tensor, which is a 4×4 matrix having units of inverse meter squared, is equal to a stress-energy-momentum T tensor that is calculated from the electromagnetic fields. The stress tensor T combines energy density, electromagnetic flux, and pressure terms in one matrix.

$$G=8\pi T$$

[0053] Most of the physics constants are linear constants such as linear mass which is mass per unit length. The permittivity of space ϵ is linear capacitance or capacitance per meter. The permeability of space μ is linear inductance or inductance per meter. The speed of light converts time into meters. What this means is that energy, pressure and momentum can all be converted into meters using these linear constants. The inverse squared of the length in meters is the curvature which is measured in units of m^{-2}.

[0054] Referring to **FIG. 11**, a square bubble (A) in the xy plane collapses with a velocity in the x-direction (C), and a velocity in the y-direction (B). This produces a curvature in the vertical z-direction (D). The curvature in the z-direction is the curvature tensor component G_{zz}. which can be computed directly from the g light dragging metric tensor. The result of the calculation is an equation in terms of the velocity, acceleration and the time rate of change of the acceleration, known as jerk.

[0055] Because the profile of the bubble radius expanding and collapsing with time has been published by those researching cavitation, it is possible to differentiate the profile to get the velocity, acceleration and jerk. These equations can then be inserted into the equation for the G curvature tensor.

[0056] The radius R of the bubble depends on the air density inside the bubble ρ, the viscosity of the water μ, the pressure of the P of the environment, the surface tension σ of the water, the ratio of specific heats γ, and the velocity $\dot{R}$ and acceleration $\ddot{R}$ of the bubble radius.

$$R\ddot{R} + \frac{3}{2}\dot{R} + \frac{4\mu}{\rho}\frac{\dot{R}}{R} + \frac{2\sigma}{\rho R} + \frac{P_0}{\rho} - \left(P_0 + \frac{2\sigma}{R_0}\right)\left(\frac{R_0}{R}\right)^{3\gamma} = 0$$

[0057] Referring to **FIG. 12**, the above equation for the bubble radius is shown in the feedback simulation program. The diagram starts by solving the equation for the acceleration which is then integrated twice (1/S) to get the velocity and position. These variables are then fed back to the input through the various constants involving the viscosity, surface tension, pressure and air density. The graph at the bottom of the simulation shows the bubble radius with time.

[0058] Referring to **FIG. 13**, the bubble profile with time is reproduced from the *Scientific American* article mentioned previously. This profile was then fitted with a polynomial equation which is plotted in **FIG. 14**. By differentiating the equation, the velocity, acceleration and jerk are obtained which can then be inserted into Einstein's G curvature tensor.

[0059] Referring to **FIG. 15**, the curvature component in the vertical direction G_{zz} is plotted with respect to time. In the *Scientific American* plot, the light flash occurs at the end of the collapse marked "LIGHT FLASH" around 22 microseconds (**FIG. 13**). This corresponds to the two intense positive curvature G_{zz} spikes at the end of the collapse. This represents a symmetrical spherical bubble collapse where the velocities are the same in the x and y directions.

[0060] The energy density component G_{tt} for this symmetrical collapse is given by

$$G_{tt} = \frac{-2u_y^2a_x^2 + 4u_xu_ya_xa_y - 2u_x^2a_y^2}{4(u_x^2 + u_y^2 - 2)}$$

[0061] Looking at this carefully, notice that if the velocity in the x-direction u_x is equal to the velocity in the y-direction u_y, and the acceleration in the x-direction a_x is equal to the acceleration in the y-direction, then the equation reduces to zero.

$$G_{tt} = \frac{-2u^2a^2 + 4u^2a^2 - 2u^2a^2}{8(u^2 - 1)} = 0$$

[0062] which means that the symmetrical collapse with equal velocities does not produce any negative energy with which to create the wormhole. Only sharp pulses of light are emitted at the end of the bubble collapse where the intense positive curvature spikes are encountered. In order to get the rotating wormhole beaconing effect, the velocities have to be different.

[0063] Referring to **FIG. 16**, the bubble is given an asymmetrical profile as shown by the two curves. The upper curve is in the x-direction, and the lower curve is in the y-direction. The collapse in the y-direction is not as severe.

[0064] Referring to **FIG. 17**, the asymmetrical collapse has the curvature spikes at the beginning similar to the symmetrical case of **FIG. 15**. Notice that there are no spikes at the end of the collapse. However, the energy density is much different.

[0065] Referring to **FIG. 18**, the energy density G_{tt} is plotted as a function of time. Rather than being zero as in the symmetrical case, there is a large region of negative energy density as the bubble collapses. This negative energy is what creates the wormhole. Because there are no large curvature spikes at the end of the collapse, the wormhole bubble is stable and precesses for a few minutes.

[0066] Experiments with the pendulum show that some people have much larger auras than others. The pendulum swings over the entire hand. One particular person who has enormous vortices was working in a television repair shop. When a television set is brought in to the shop, the large capacitor has to be discharged first. The repairman with the large chakra vortices was standing behind a second repairman who was approaching the television set. As the second repairman got closer to the set, an enormous streaming blue spark sailed over his head and zapped the first technician. Hyperspace has a much higher permittivity than our spacetime. The resistance of space R is equal to the square root of the permeability μ over the permittivity ϵ.

$$R = \sqrt{\frac{\mu}{\varepsilon}}$$

[0067] Since the technician with the large chakra vortices was producing large quantities of hyperspace energy, his resistance was very much lower due to his larger permittivity. The spark grounded on his body. The free electrons, which are created by ionization of the hydrogen atoms of the water vapor, see a very low path of resistance and flow toward the wormhole. There they are trapped in accelerated motion due to the presence of the circular electric field and give off substantial numbers of photons which produces the beaconing lighthouse effect.

[0068] The elemental length ds^2 in cylindrical coordinates {t, r, θ, z} for a mass M is given by

$$ds^2 = -\frac{dt^2}{1-\frac{M}{r}} + \left(1-\frac{M}{r}\right)dr^2 + r^2 d\theta^2 + dz^2$$

[0069] The mass M distorts the radius r of the elemental length which is what gives the mass a curvature or gravitational field. Negative energy, which is produced at the end of the bubble collapse, is equal to a negative mass times the speed of light squared. Thus mass M in the equation goes to negative mass, or M→−M. Furthermore, negative energy inverts the mass factor so that the metric becomes

$$ds^2 = -\left(1+\frac{M}{r}\right)dt^2 + \frac{dr^2}{1+\frac{M}{r}} + r^2 d\theta^2 + dz^2$$

[0070] The g metric tensor contains the factors of the elemental lengths along the matrix diagonal

$$g_{\alpha\beta} = \left\| \begin{matrix} -\left(1+\frac{M}{r}\right) & 0 & 0 & 0 \\ 0 & \frac{1}{1+\frac{M}{r}} & 0 & 0 \\ 0 & 0 & r^2 & 0 \\ 0 & 0 & 0 & 1 \end{matrix} \right\|$$

[0071] As before, Einstein's G curvature tensor in the radial G_{rr}, angular $G_{\theta\theta}$, and vertical z-direction G_{zz} is calculated from this negative energy g metric tensor.

[0072] Referring to the 3D G curvature plot in **FIG. 19**, the strength of the curvature is given by the length of the arrow, and the direction of the curvature is given by the arrow. The curvature in the radial direction G_{rr} is along the bottom axis from the box corner origin to the right. The curvature in the angular direction $G_{\theta\theta}$ is the bottom axis from the origin to the left. The height of the box is the curvature in the vertical direction G_{zz}. Notice in general that the curvature is perpendicular to the left face (θz-plane) and then starts to curve to the right and begins to point toward the right face (rz-plane). On the bottom face (rθ-plane) there is an upward vertical curvature.

[0073] In cylindrical coordinates, the θz-plane is actually a vertical tube of radius r. So at small r, the curvature is perpendicular to the tube. At larger radius, the curvature starts to point in the θ-direction, wrapping around the tube. At small radius, there is also a vertical curvature parallel to the sides of the tube.

[0074] Referring to **FIG. 20**, the curvature in cylindrical coordinates is seen to be the structure of the wormhole. The wormhole (A) is formed due to the radial pressure (B) which pulls open the wormhole. One end of the tube connects to hyperspace, and the other end connects to our spacetime. There is also a shearing pressure (D) along the sides of the tube which slices spacetime open and helps shape the tube. Moving outward along the radius, the curvature turns sideways and produces a shearing pressure (D) in the θ-direction which gives the wormhole a vortex appearance. These wormholes can also be very large, enabling one to peer into a co-dimension as attested to by the inventor.

SUMMARY OF THE INVENTION

[0075] As described in the previous section, the cavitating bubble has to collapse asymmetrically in order to generate the negative energy which creates the wormhole. In order to collapse asymmetrically, the forces on the bubble surface have to be unequal. The force on the bubble is given in terms of the a dragging coefficient, the bubble radius R, the surface charge density D_r, the magnetic B field in spherical coordinates $\{B_r, B_\theta, B_\phi\}$. The fields are integrated over the entire solid angle Ω of the bubble to determine the force F.

$$F_r = -\left(1-\frac{1}{n^2}\right)\frac{R^2}{2}\oint d\Omega\left[\left(1+\frac{1}{n^2}\right)(D_r^2 + B_r^2 - B_\theta^2 - B_\phi^2)\right]$$

[0076] The integration of the tangential components of the magnetic field such as $\{B_\theta, B_\phi\}$ over the solid angle of the bubble will sum to zero. The surface charge density D_r and the radial magnetic field B_r are the only fields which can be used to create an unbalanced force. If there is no surface charge density, then the force equation reduces to

$$F_r = -\alpha\frac{R^2}{2}\oint d\Omega\left[(2-\alpha)\left(\frac{\chi^2}{\Omega_m}B_r^2\right)\right]$$

[0077] where the conversion constant is the linear charge squared divided by the linear mass of the universe χ^2/Ω_m.

[0078] In this invention, referring to **FIG. 21**, the magnetic field is created by two cylindrical solenoids (A,B) which are wrapped around the top and bottom of the glass container (C). The container has flat sides in the shape of an octagon. Each solenoid consists of a continuous roll of very thin sheet copper which are separated by beaded mylar line. The mylar beads separate the sheets electrically and provide air cooling to the coil which can get rather hot. This makes it easy to assemble the coil because the copper roll and mylar line are wound together as the solenoid is formed. The lines of magnetic flux flow vertically through the container yet do not interfere with the transducers (D) which are mounted on the flat sides of the container.

[0079] Referring to **FIG. 22**, the cavitating bubble which forms in the liquid in the container experiences a vertical magnetic field (B) due to the two solenoids. These flux lines create a radial force on the top and bottom of the bubble (D,C). The flux lines on the outside (E) do not create any radial force because they are tangential to the surface. The spherical bubble flattens into an asymmetrical ellipsoidal shape (A) which enables the creation of the wormhole and lighthouse beaconing effect.

[0080] Referring to **FIG. 23**, the spacetime curvature of the wormhole (D) creates a tunnel (C), known as the throat of the wormhole, between flat space in our universe (A) and flat hyperspace (B) which exists in a co-dimension of our universe. In general, the co-dimensions have different physics constants. Going back to the chakra vortices of the human energy field, the vortices remove energy from space and deliver it to several hyperspace co-dimensions. This energy builds up human aura modules at different frequencies in astral space. Astral space has a very low speed of light and small linear mass. This is the reason that human beings can leave their bodies and pass through solid concrete walls, or project their spiritual eye to remote locations for viewing. On the other hand, the linear mass and speed of light of space is very much greater than hyperspace. Therefore, the pressure of the space is much greater than the pressure in hyperspace. In terms of the wormhole with a throat area A, the pressure would be the linear mass times the speed of light squared over the area

$$P_{space} = \frac{\Omega_s c_s^2}{A}$$

[0081] The pressure of hyperspace on the other side of the wormhole is

$$P_{hyperspace} = \frac{\Omega_h c_h^2}{A}$$

[0082] Because the linear mass and the speed of light of hyperspace are lower than that of space, there is a positive net pressure going into hyperspace.

$$P_{net} = P_{space} - P_{hyperspace}$$

[0083] This is the reason that the human vortices can obtain energy from this universe. Because the cavitating bubble produces negative energy, the linear mass is negative on the side of space. The pressure equation is then given by

$$P_{net} = -\frac{P_s}{A} - \frac{P_h}{A} = -\frac{P_s + P_h}{A}$$

[0084] which shows that there is a reverse pressure going from hyperspace into our space. The asymmetrical cavitating bubble generates hyperspace energy. The hyperspace energy flowing into our universe also gives the light generated by the wormhole a soft white misty look.

[0085] There are many reasons for generating this hyperspace energy. Electromagnetic fields are subject to the Lorentz transformation which involves comparing the frame velocity with that of the velocity of light.

$$E' = \frac{E}{\sqrt{1 - \frac{v^2}{c^2}}}$$

[0086] If the ratio of the velocity v to the velocity of light c is close to unity, then huge relativistic fields can be produced. These fields can curve spacetime to such an extent that a large lift force can be produced on the hull of an electromagnetic field propulsion vehicle.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0087] Not Applicable.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0088] **FIG. 1**. Rotating cylinder demonstrating additional lift force.

[0089] **FIG. 2**. Use of the pendulum.

[0090] **FIG. 3**. The Ascension Machine, Chakra Vortex Accelerator.

[0091] **FIG. 4**. Hyperspace energy brought into body by rotation of hand chakra.

[0092] **FIG. 5**. Antigravitational effect using low density hyperspace energy.

[0093] **FIG. 6**. Sonoluminescence experiment.

[0094] **FIG. 7**. Tetrahedron diagram showing hyperspace charge.

[0095] **FIG. 8**. Magnetic monopole.

[0096] **FIG. 9**. Precessing wormhole.

[0097] **FIG. 10**. Fizeau light dragging experiment.

[0098] **FIG. 11**. Asymmetrical velocity collapse of bubble radius generates wormhole.

[0099] **FIG. 12**. VisSim feedback simulation of the collapsing bubble.

[0100] **FIG. 13**. Cavitating bubble radius as a function of time.

[0101] **FIG. 14**. Digitized bubble radius of **FIG. 13**.

[0102] **FIG. 15**. Spiking spacetime curvature of collapsing bubble.

[0103] **FIG. 16**. Dual velocity profile required to produce negative energy.

[0104] **FIG. 17**. Spacetime curvature for dual velocity collapse.

[0105] **FIG. 18**. Negative energy generated from asymmetrical collapse of bubble.

[0106] **FIG. 19**. 3D plot of spacetime curvature using negative energy.

[0107] **FIG. 20**. Wormhole vortex.

[0108] **FIG. 21**. Perspective of cavitation tank equipped with magnetic coils.

[0109] **FIG. 22**. Flattening of bubble by magnetic field.

[0110] **FIG. 23**. Hyperspace energy generated by reverse pressure gradient of wormhole.

[0111] **FIG. 24**. Solenoid and transducer driving circuits.

DETAILED DESCRIPTION OF THE INVENTION

[0112] 1. Referring to **FIG. 24**, the transducer driving circuit uses a frequency generator (A) driving a linear amplifier (B) into a pair of variable inductors (C) which resonate with the capacitance of the transducers (D) attached to the sides of the octagonally-shaped glass container (H). Resistors (L,M,G) provides voltage measuring points for the oscilloscope.

[0113] A DC current source (I) drives the two solenoids (E,F) which produce a vertical magnetic field (J) through the container. The magnetic field produces an asynmetrical force on the bubble surface (K) such that the collapsing bubble produces negative energy. The spacetime curvature produced by the light dragging of the collapsing bubble surface, together with the negative energy, create a wormhole between space and hyperspace. The negative spacetime energy produces a negative pressure which brings low-density hyperspace energy into our dimension.

I claim:

1. A hyperspace energy generator having:

a) a glass container in the shape of an octagon acting as the resonating chamber;

b) two piezoelectric transducers, mounted and operating acoustically as a pair on opposite sides of item (1a);

c) an opaque oil-like liquid with a high index of refraction filling item (1a) acting as the resonating liquid in which the cavitating bubbles are formed;

d) two thin sheet copper solenoids, located on top and bottom of item (1a), that produce a vertical magnetic field through items (1a) and (1c);

e) two variable inductance coils for creating a resonant frequency with item (1b);

f) a linear amplifier driving items (1b) and (1e);

g) a variable frequency generator driving item (1e);

h) a direct current electrical generator driving item (1d);

2. a cavitation system which:

a) produces one or more cavitating bubbles that collapse asymmetrically due to the differential force exerted on the bubble surface by the presence of a vertical magnetic field generated by item (1d) referred to above;

b) generates negative energy due to light dragging of the collapsing bubble surface;

c) creates wormholes between space and hyperspace due to the presence of item (1b);

d) generates a negative pressure between space and hyperspace that forces low-density hyperspace energy into our dimension; and

3. optional dual electrically-charged plates that:

a) are mounted on the sides of item (1a);

b) create a differential electric charge density across the bubble surface for the purpose of creating an additional method of asymmetrical bubble surface collapse.

* * * * *

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(54) ROTATING ELECTROSTATIC PROPULSION SYSTEM

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(52) **U.S. Cl.** **244/172**

(57) ABSTRACT

This invention relates to a spacecraft propulsion system utilizing thrusters comprised of a motor-driven electrostatically charged cylinder rotating within an electrostatically charged annular ring for the purpose of creating a spacetime curvature stress-energy tension in the horizontal direction. The thrusters are augmented by magnetic vortex generators, either embedded in the cylinders or located above each thruster, for the purpose of increasing the permittivity of space by permeating each thruster with low density hyperspace energy generated by a wormhole created between our space and hyperspace. A combination of three thrusters mounted on the underside of the hull of the spacecraft provide thrust and yaw motion control.

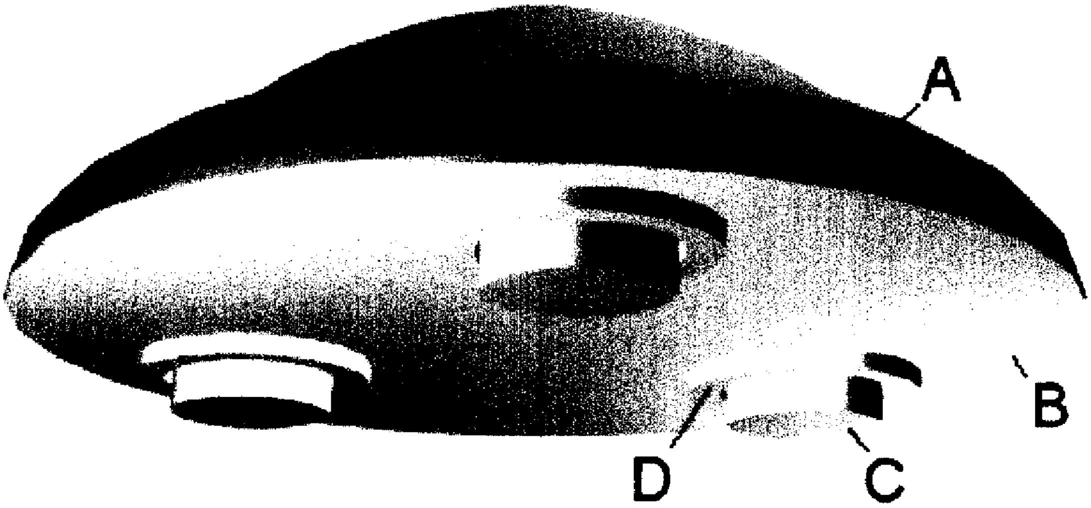

Figure 1

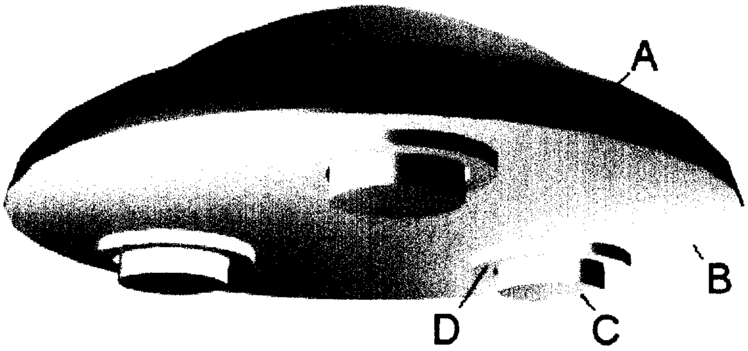

Figure 2

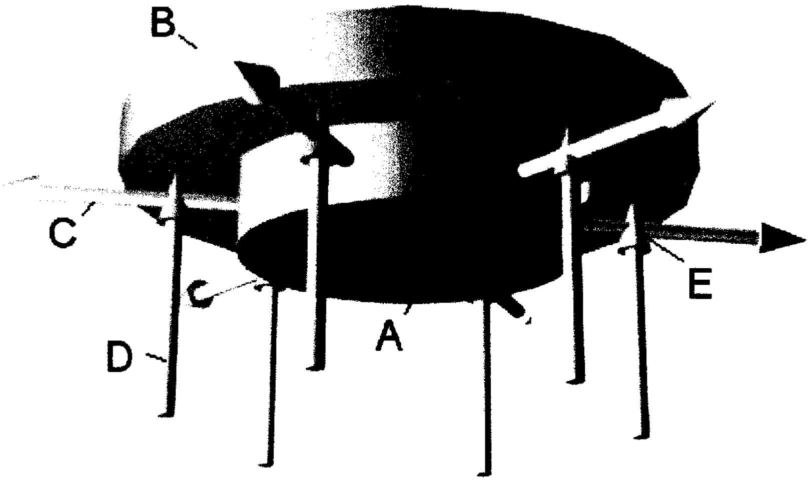

Figure 3

$$T^{zr} = -\frac{\varepsilon_0}{\Omega c^2}\frac{E_z E_r}{4\pi} = \frac{\mathrm{coul}^2}{\mathrm{m}^2\mathrm{n}}\frac{\mathrm{n}}{\mathrm{coul}}\frac{\mathrm{n}}{\mathrm{coul}}\frac{\mathrm{m}}{\mathrm{kg}}\frac{\mathrm{s}^2}{\mathrm{m}^2} = -\frac{\mathrm{kg\,m}}{\mathrm{s}^2}\frac{\mathrm{s}^2}{\mathrm{kg\,m}^3} = \frac{-1}{\mathrm{m}^2}$$

Figure 4

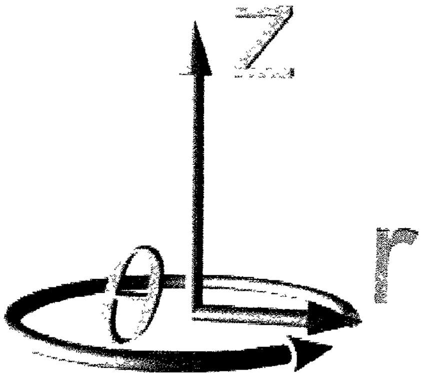

Figure 5

$$F^{\alpha}{}_{\beta} = \begin{array}{c|cccc|} t & 0 & E_r & 0 & E_z \\ r & E_r & 0 & 0 & 0 \\ \theta & 0 & 0 & 0 & 0 \\ z & E_z & 0 & 0 & 0 \end{array}$$

Figure 6

$$T^{zr} = -\frac{E_r E_z}{4\pi}$$

Figure 7

$$\frac{d}{dt} S_r = \varepsilon_0\, \varepsilon_{r\,t\,z} x^t T^{zr} n_r \mathrm{Area} = \varepsilon_0\, t \frac{E_r E_z}{4\pi} n_r \mathrm{Area}$$

Figure 8

$$\frac{\mathrm{coul}^2}{m^2\, n} \sec \frac{n}{\mathrm{coul}} \frac{n}{\mathrm{coul}} m^2 = \mathrm{kg} \frac{m}{\sec^2} \sec = \mathrm{kg} \frac{m}{\sec}$$

Figure 9

$$\frac{d}{dt} S_{r,t} = \frac{\varepsilon_0}{4\pi} e^{i\,\omega\, t} E_r E_z\, \mathrm{area} + \frac{i\varepsilon_0}{4\pi} e^{i\,\omega\, t} E_r E_z\, t\, \omega\, \mathrm{area}$$

Figure 10

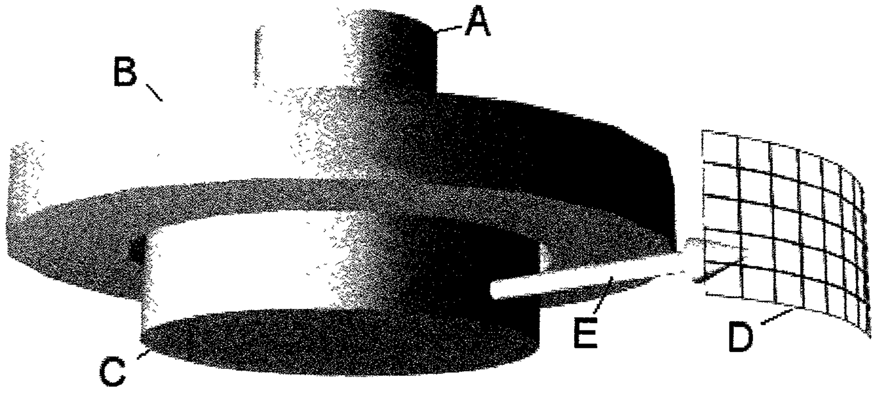

Figure 11

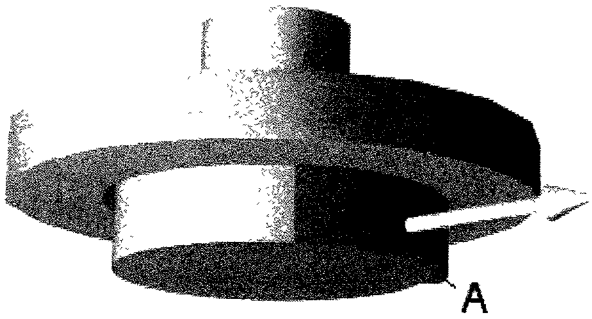

Figure 12

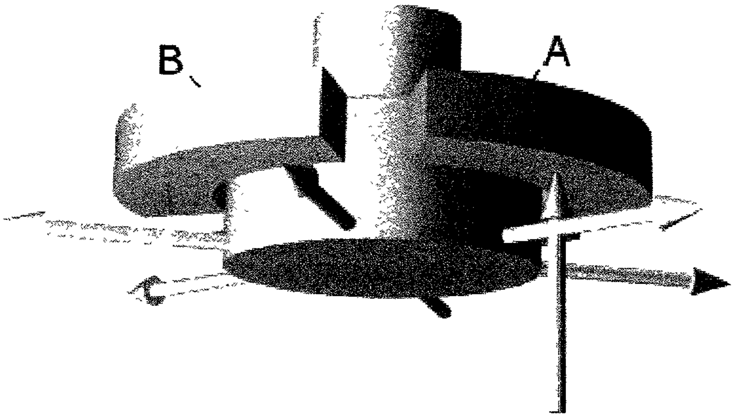

ROTATING ELECTROSTATIC PROPULSION SYSTEM

BRIEF SUMMARY OF THE INVENTION

[**0001**] The invention, which is the object of my present application, is a spacecraft propulsion system which develops a spacetime curvature tension utilizing a combination of a rotating radial electrostatic field and a fixed vertical electrostatic field. The two fields create a stress-energy T^{zr} gradient in the radially direction which is equal to force. The radial field is created on the side of a charged rotating cylinder on the underside of the hull. The vertical field is created by an annular charged ring concentric with the cylinder. Three rotating cylinders are located in a triangle on the bottom of the hull in order to produce a force in any direction in the horizontal plane.

REFERENCE PAPERS

[**0002**] *Gravitation*, Wheeler, page 80.

BACKGROUND OF THE INVENTION

[**0003**] When working with Maxwell's equations in tensor notation, it became apparent that a tensor can change identity depending on what permutation of variables is involved. For example, one single equation can involve both charge density and current density. And all of Maxwell's equations can be reduced to just two equations.

[**0004**] In the tensor equation for momentum, if the lever arm is length then the equation is equal to the flow rate of angular momentum. If the lever arm is time, then you get linear momentum. And if the field rotates with time, then the time rate of change of linear momentum is a force which is the basis for this invention.

[**0005**] Einstein said that mass curves space and space tells mass how to move. In this sense, generalized mass can be mass, electromagnetic fields, charge or angular momentum which create a spacetime curvature that produces a force on the spacecraft.

SUMMARY OF THE INVENTION

[**0006**] The invention relates to a spacecraft utilizing a rotating electrostatically charged cylinder and a concentric annular charged ring to create a stress-energy spacetime curvature in the horizontal plane on the spacecraft's underside hull. A motor drives the rotating cylinder which extends below the hull. A charged surface produces an electric field in the direction normal to the surface. The vertical and rotating electric fields combine to create a rate of change of linear momentum which creates a horizontal propulsive force on the hull.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[**0007**] Not Applicable.

A BRIEF DESCRIPTION OF THE DRAWINGS

[**0008**] **FIG. 1**. Perspective view of spacecraft hull (A) with the three electrostatically charged rotating cylinders (C) surrounded by their annular charge rings (D) extending down on the underside of the hull (B).

[**0009**] **FIG. 2**. Perspective view of individual thruster showing rotating cylinder and ring.

[**0010**] **FIG. 3**. Stress-energy tension created by two electric fields and having units of curvature.

[**0011**] **FIG. 4**. Cylindrical spacetime coordinates $\{t, r, \theta, Z\}$.

[**0012**] **FIG. 5**. Faraday electromagnetic F tensor containing electric fields in the radial and vertical directions.

[**0013**] **FIG. 6**. Stress-energy tensor T showing it is equal to the product of the two electric fields divided by 4π.

[**0014**] **FIG. 7**. The tensor equation for flow rate of angular momentum S.

[**0015**] **FIG. 8**. The units are linear momentum due to the time lever arm.

[**0016**] **FIG. 9**. The rate of change of linear momentum is the horizontal force produced by the two electric fields.

[**0017**] **FIG. 10**. The angular momentum flows through an area whose normal vector is in the radial direction.

[**0018**] **FIG. 11**. Cylinder with only one electrostatically charged segment.

[**0019**] **FIG. 12**. Annular ring with three individual segments which can be charged separately to create a force in a particular direction.

DETAILED DESCRIPTION OF THE INVENTION

[**0020**] 1. Referring to **FIG. 1**, the spacecraft comprises an upper hull (A) with three rotating electrostatically charged cylinders (C) with their concentric annular electrostatically charged rings (D) located on the spacecraft's bottom hull (B).

[**0021**] 2. In a closer view of one of the cylinders seen in **FIG. 2**, motor-driven rotating cylinder (A) has an electrostatically charged surface which produces an electric field (C) normal to said surface. The fixed, electrostatically charged annular ring (B), which is concentric with the cylinder, produces a vertical electric field (D) normal to its surface. This crossed field (E) creates a negative spacetime curvature tension which is the product of the two fields divided by 4π as seen in the equation, **FIG. 3**.

[**0022**] 3. Notice that the equation involves the permittivity of space ϵ_0 divided by the linear mass of the universe Ω and the speed of light. This produces units of inverse meter squared which is the spacetime curvature. In Einstein's General Theory of Relativity, the spacetime curvature tensor is equal to the stress-energy tensor or $G=8\pi T$ where G is the curvature, and T is the product of the electromagnetic fields. The problem with this equation, which has been resolved with this invention, is that the linear mass Ω times the speed of light c is an enormous number. Even with the square of enormous electric fields, the curvature would be too small even to notice, and little force would be generated.

[**0023**] 4. In another patent application of mine entitled Magnetic Vortex Generator, it was shown that a rotating cylinder containing embedded and stacked bar magnets produces a negative mass and negative spacetime spring constant. It can be shown that this combination produces a small wormhole or interdimensional connection between our space and hyperspace along the centerline of the rotating cylinder. Co-dimensions of hyperspace have different physics constants. A low pressure region of hyperspace has a very low mass density and a very low speed of light. The wormhole allows this low density hyperspace energy to enter into our space and permeate the cylinder and annular ring. The permittivity is proportional to the inverse of the speed of light squared. The hyperspace speed of light, obtained from my tetrahedron physics diagram, is 8971 meters per second. The speed of light in our dimension is 299792458 meters per second. As shown by the enclosed reference calculation, the hyperspace permittivity is about a trillion times larger. Because the force is equal to this new permittivity times the electric fields squared times the area around cylinder, the force is greatly amplified by this increase in the permittivity of space.

[0024] 5. It is pertinent to this invention how the stress-energy is created due to the two electric fields in the vertical and radial direction. In gravitational physics, there is a Faraday F tensor which contains all the components of the electromagnetic fields. It is a 4 by 4 matrix whose rows and columns correspond to the coordinates of spacetime which in cylindrical coordinates are $\{t, r, \theta, z\}$ where t is time, r the radius, theta the horizontal angle and z the vertical height. These coordinates are shown in **FIG. 4**.

[0025] 6. The radial electric E_r field and the vertical electric E_z field can be inserted into the Faraday tensor seen in **FIG. 5**. The sign of the vertical field is positive because it points in the positive z-direction due to the fact that the annular ring has a negative charge. The cylinder has a positive charge. This produces the negative stress-energy tensor T^{zr} as drawn in **FIG. 6**.

[0026] 7. In order to calculate the force on the cylinder, it is necessary to calculate the flow rate of angular momentum. Momentum is mass times velocity or mass meter per second. If the mass is moving in a circle, then there is a lever arm times the momentum which makes it mass meter squared per second. If this is differentiated with respect to time, then a flow rate of angular momentum is produced with units of mass meter squared per second squared. As mentioned previously, tensors have this dual nature where depending on the permutation of the variables, it means one thing or another. In this case, the lever arm will be time, rather than length which converts the flow rate of angular momentum into just linear momentum. If you change linear momentum with respect to time, then you get a force.

[0027] 8. The flow rate of angular momentum S is shown in **FIG. 7**. The force has to be against the area whose normal vector is in the radial direction which is also the direction of the momentum. So S has an r subscript indicating that it flows in the radial direction. The permutation tensor ϵ has three subscripts which keeps track of the tensor notation. The first subscript is the same as the momentum subscript. Permutations of the coordinate variables which are in order have a plus one sign. Permutations which are in reverse order have a minus one sign. Permutations in which the variable are repeated are zero. For example, $\epsilon_{tr\theta z}=-\epsilon_{rt\theta z}$ because the r and t are in reverse order in cylindrical coordinates. Because the permutation tensor starts with r, then we can have permutations such as {r,t,z} which is a reverse order negative permutation. This negative sign cancels the negative sign of the stress tensor. The reason this permutation is chosen is because the first subscript on the stress-energy tensor is now z. Because the normal to the area is in the radial direction, then the stress-tensor matches the electric fields that we have available, which are also in the zr-direction.

[0028] 9. In this case, the second subscript of the permutation tensor is time, rather than length. So the units become, as shown in **FIG. 8**, those of linear momentum. To me, this was very surprising. Then I realized that the radial electric field rotates with time which means the differential of the linear momentum produces a force on the hull. In exponential notation, the radial electric field rotates with Exp[iωt]. This is multiplied by the time lever arm, so the term that has to be differentiated is $t\ e^{i\omega t}$. The time lever arm saves the differentiation by making one term real so that the force is real. This is shown in **FIG. 9**. The units of the first term are real newtons. In the second term, the time t multiplied by the frequency cancels out in terms of units, so the units are still force, but imaginary

[0029] 10. There is an area involved in the force equation which is depicted in **FIG. 10**. The charged rotating cylinder (C) located inside the charged annular ring (B) is driven by motor (A). The radial electric field (E) is normal to the area (D) whose normal vector is also in the radial direction. The angular momentum flows through this area which surrounds the cylinder. In doing so, it curves spacetime which produces the force.

[0030] 11. If the radial electric field is continuous around the cylinder, then the net force is zero. Referring to **FIG. 11**, one section (A) of the rotating cylinder is charged, which means that there is a force once per cycle in a selected direction depending on when the annular ring is charged. The other option, referring to **FIG. 12**, is that the annular ring is divided up into two or three sections with the feature that the charge can be turned on (A) or off (B) on a particular segment. As the rotating electric field goes around, one of the annular ring sections will have an electric field in order create a force on that side.

[0031] 12. Since there are three force cylinders, this allows for yaw motion control so that the hull of the spacecraft can pivot to change direction. After the directional change, the two back cylinders can be synchronized to produce thrust in the forward direction.

[0032] 13. There could also be a polarity change for the vertical electric field such that a positive stress-energy is produced which would reverse the direction of the thrust.

What I claim as my invention is:

1. A spacecraft propulsion system utilizing three electrostatically charged motor-driven cylinders each one of which rotates within a charged annular ring to produce a spacetime stress curvature tension in the horizontal plane on the underside of the hull.

2. Said rotating cylinder comprised of bar magnets embedded in the cylinder and stacked in groups at intervals around the periphery of the cylinder with the purpose of increasing the permittivity of space by permeating the cylinder and ring with low linear mass, low speed of light hyperspace energy by means of a wormhole between our space and hyperspace. The larger permittivity is to increase the force. Said technique is contained in my patent applications Magnetic Vortex Wormhole Generator and Magnetic Vortex Generator.

3. Said rotating cylinder and annular ring having a suitable metal surface for forming and maintaining the electrostatic charge.

4. Said rotating cylinder having one or more segments which can be electrostatically charged individually or together to produce a force in a particular direction.

5. Said annular ring having one or more segments which can be electrostatically charged individually or together to produce a force in a particular direction.

6. A combination of three such thrusters providing a force in any particular direction or for yaw motion control.

7. Electric polarity switching of the fields in order to reverse the spacetime curvature and therefore change the direction of thrust.

8. The use of a magnetic vortex generator located above each thruster in order to permeate the cylinders and rings with low density hyperspace energy which would substitute for the embedded magnets in each cylinder.

* * * * *

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St. Clair (43) **Pub. Date: Apr. 6, 2006**

(54) **REMOTE VIEWING AMPLIFIER**

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(52) **U.S. Cl.** **359/896**; 359/894

(57) **ABSTRACT**

An apparatus which enhances the ability of a person to perform remote viewing by connecting the human spiritual eye to the tetrahedral geometry of subspace.

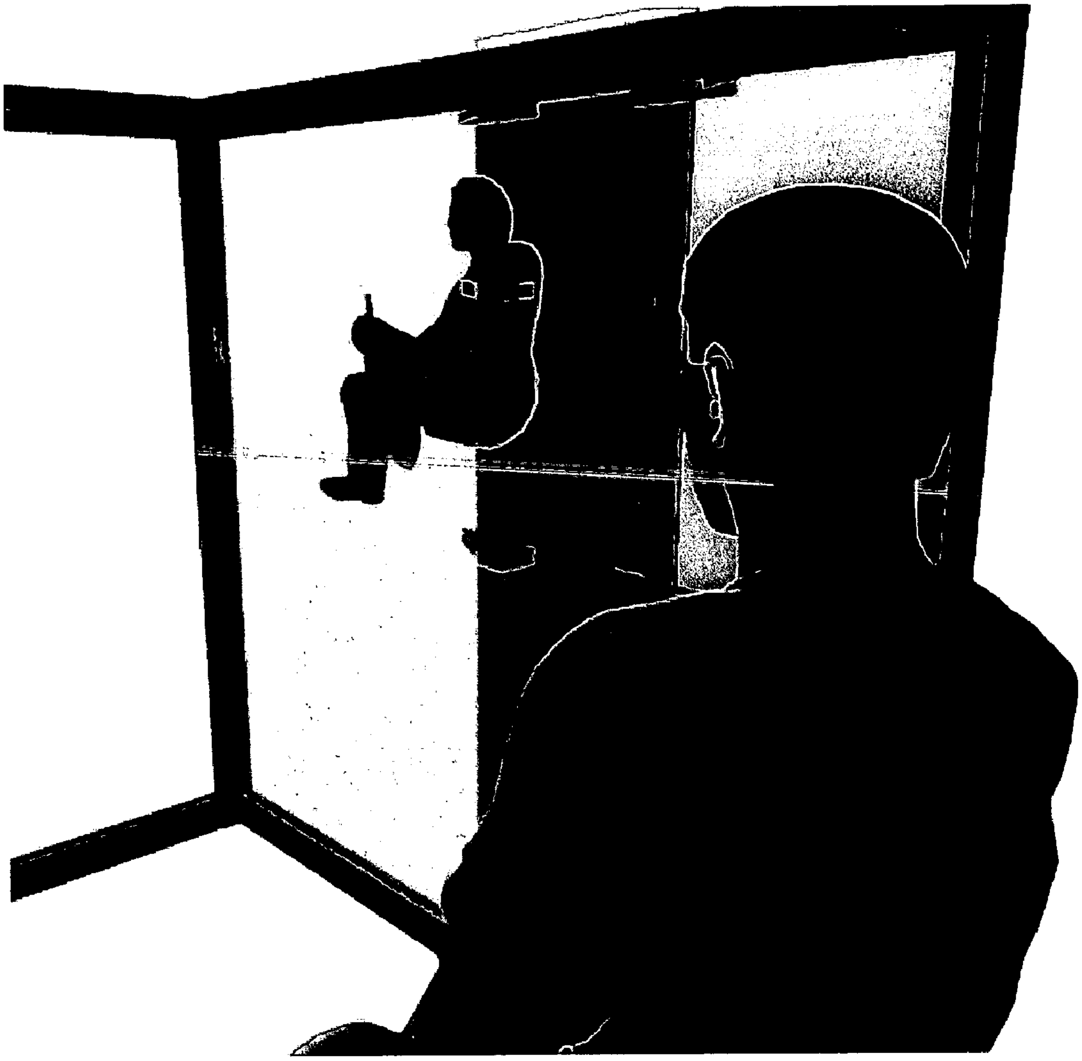

Figure 1

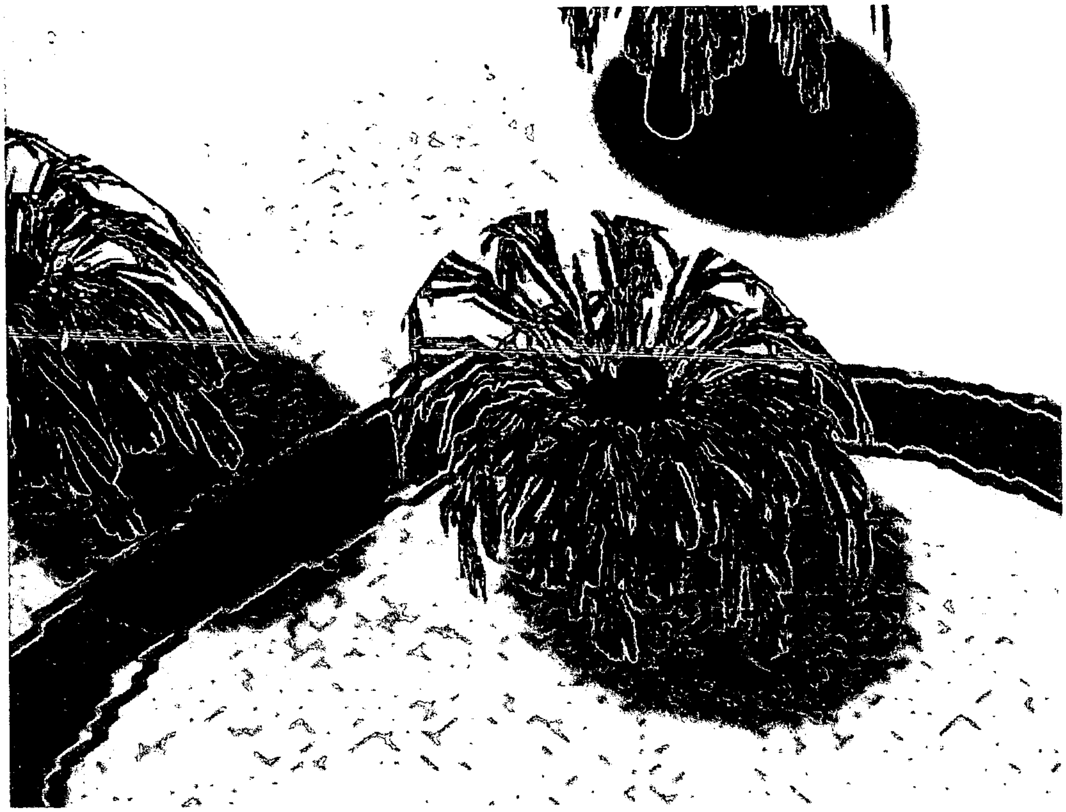

Figure 2

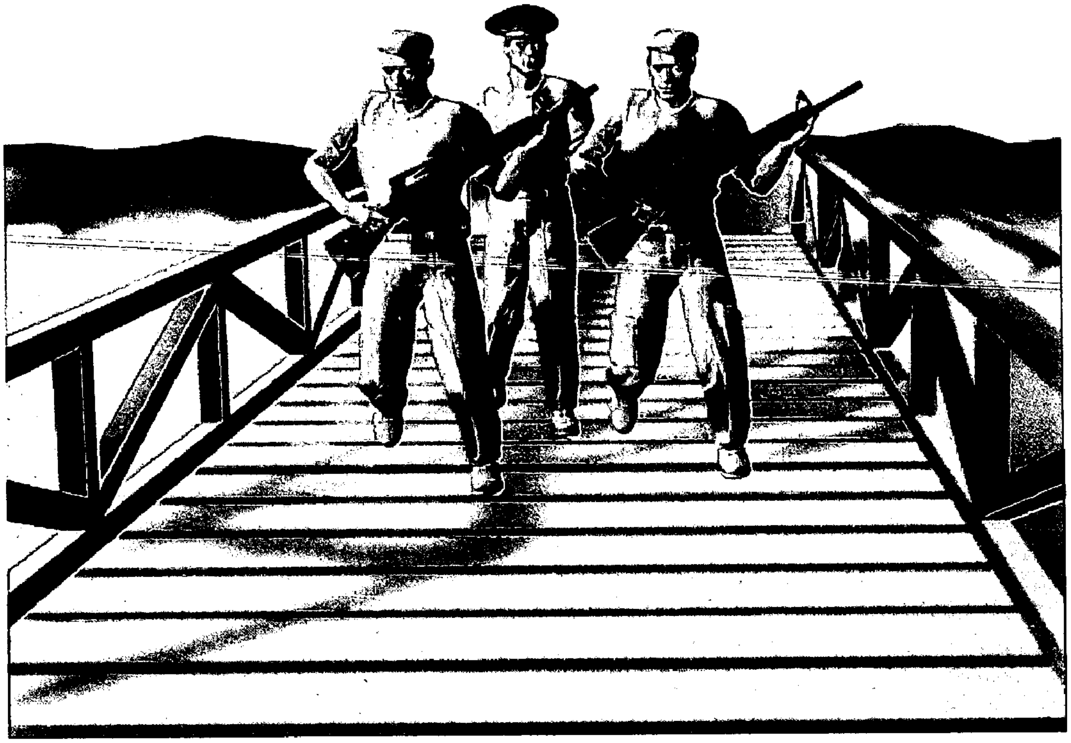

Figure 3

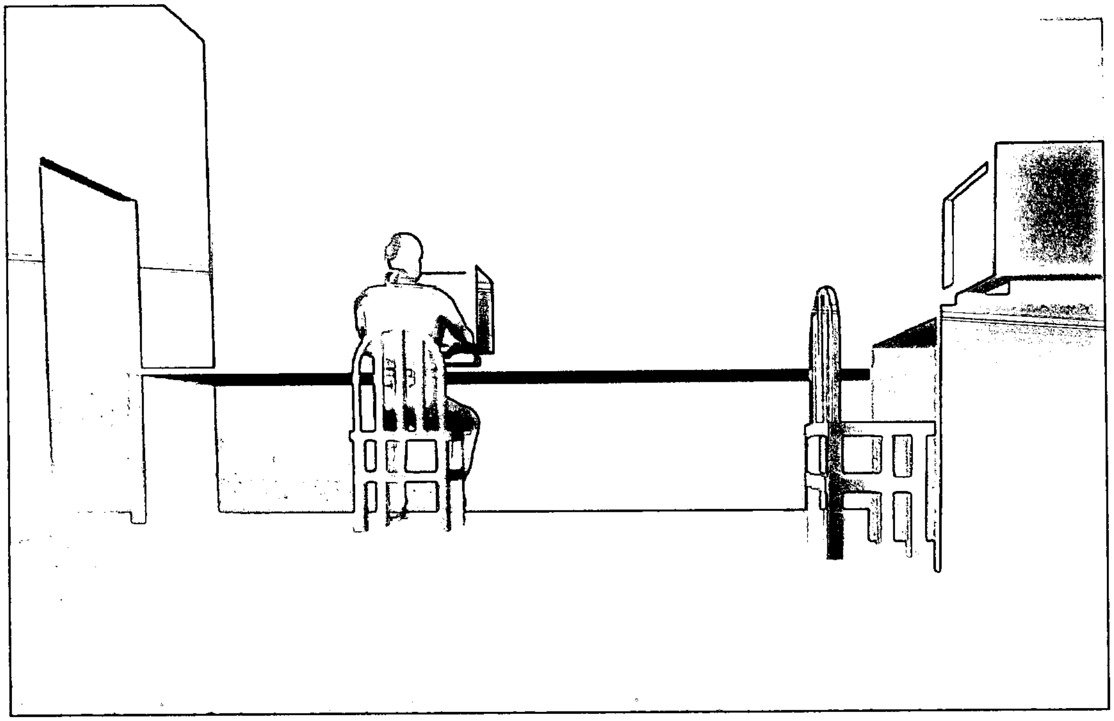

Figure 4

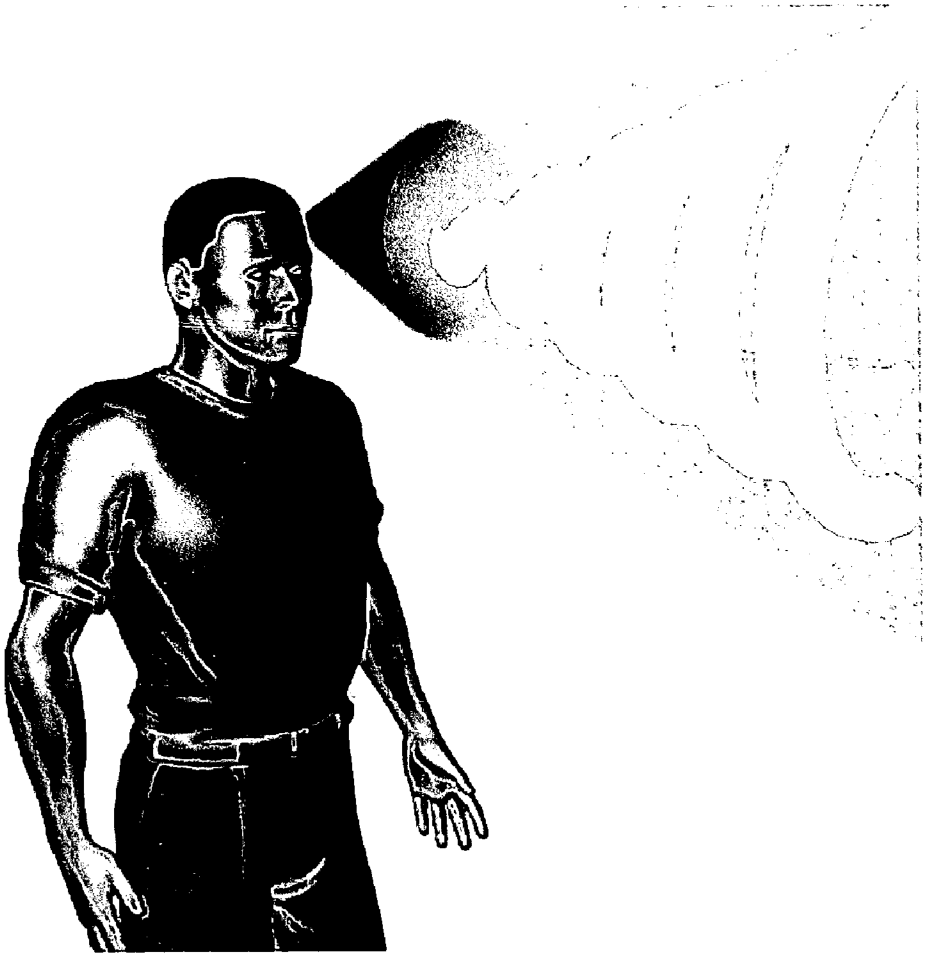

Figure 5

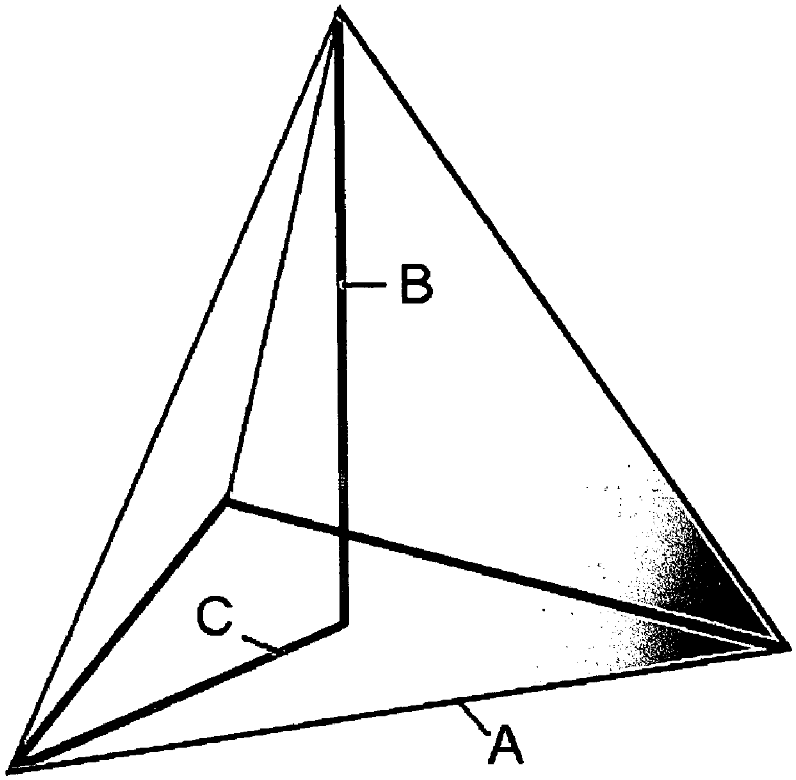

Figure 6

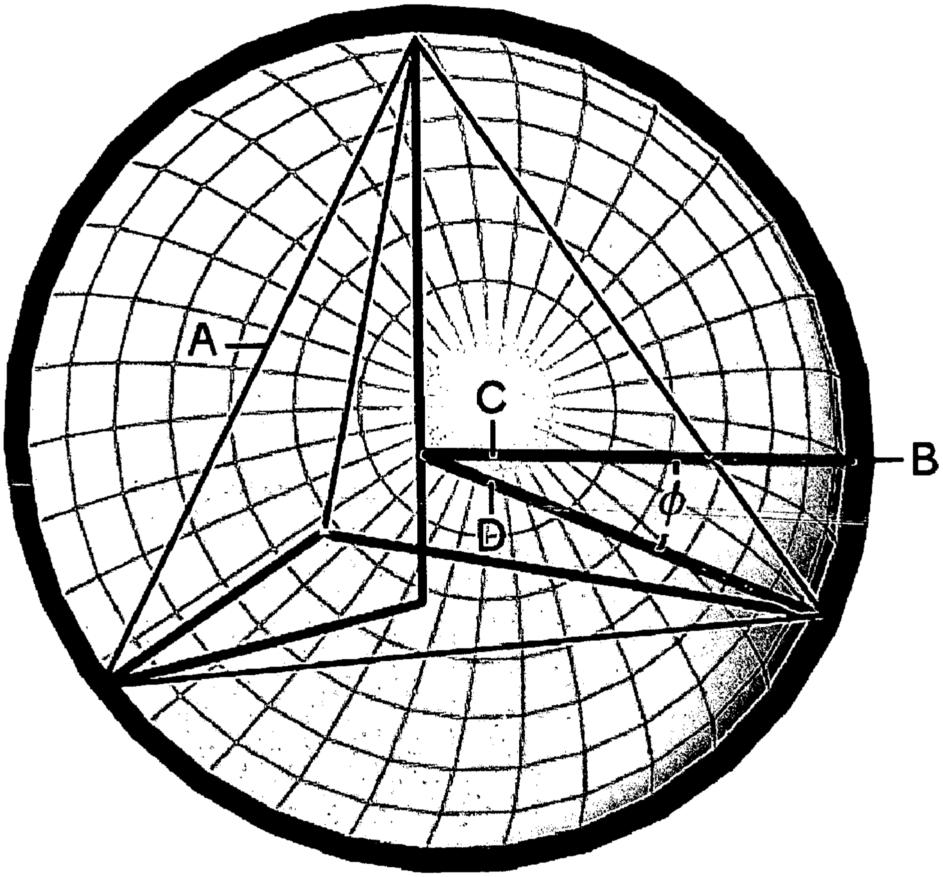

Figure 7

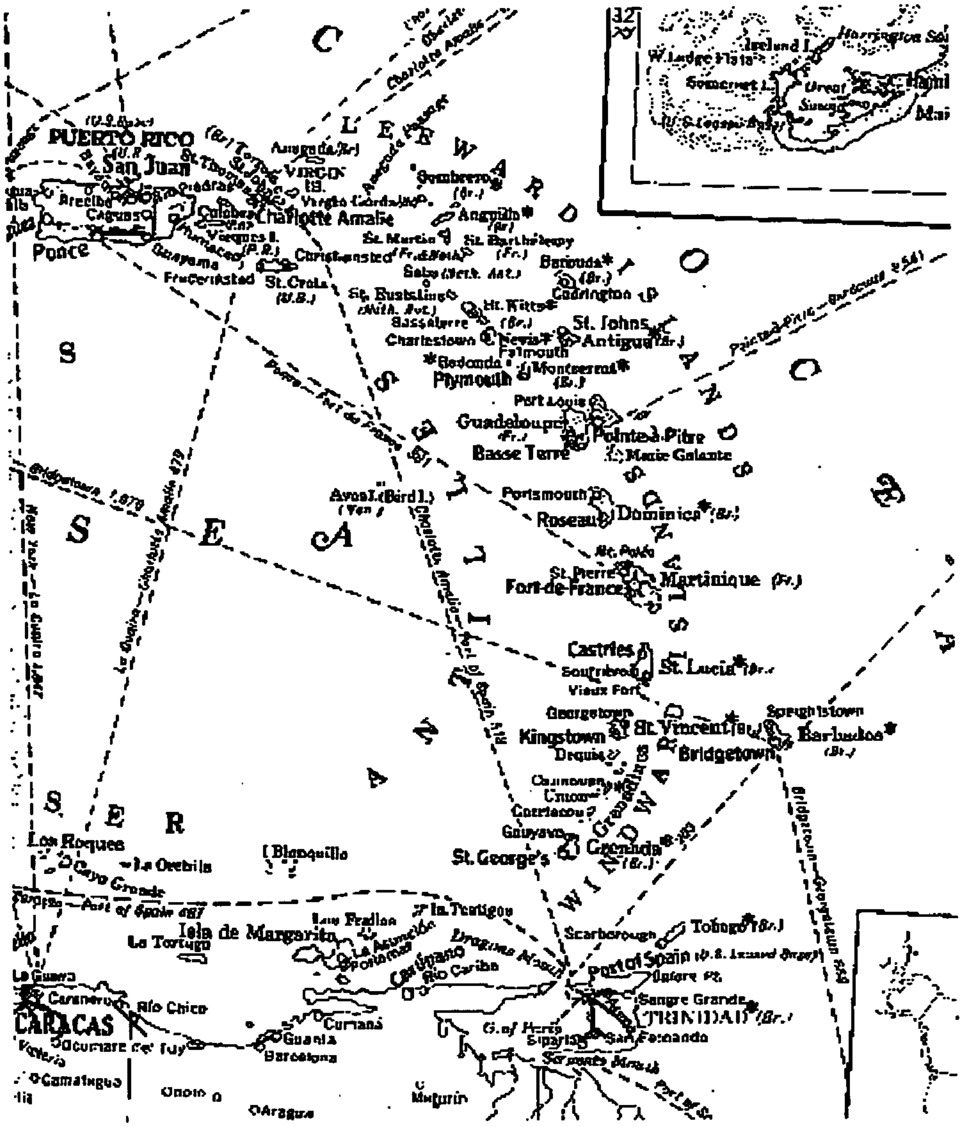
CARIBBEAN SEA
PUERTO RICO
San Juan
Ponce
Charlotte Amalie
Anguilla
St. Martin
St. Barthélemy
Barbuda
St. Johns
Antigua
Montserrat
Plymouth
Guadeloupe
Pointe-à-Pitre
Basse Terre
Marie Galante
Dominica
Roseau
Martinique
Fort-de-France
Castries
St. Lucia
Kingstown
St. Vincent
Barbados
Bridgetown
Grenada
St. George's
Tobago
Scarborough
Port of Spain
TRINIDAD
Isla de Margarita
CARACAS
LEEWARD ISLANDS
WINDWARD ISLANDS

Figure 8

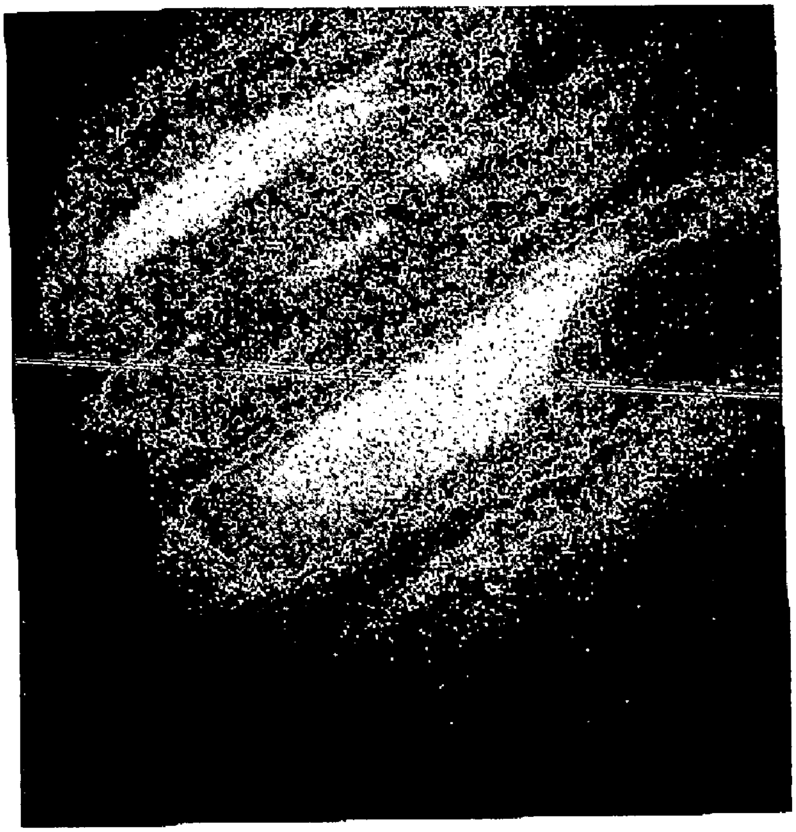

Figure 9

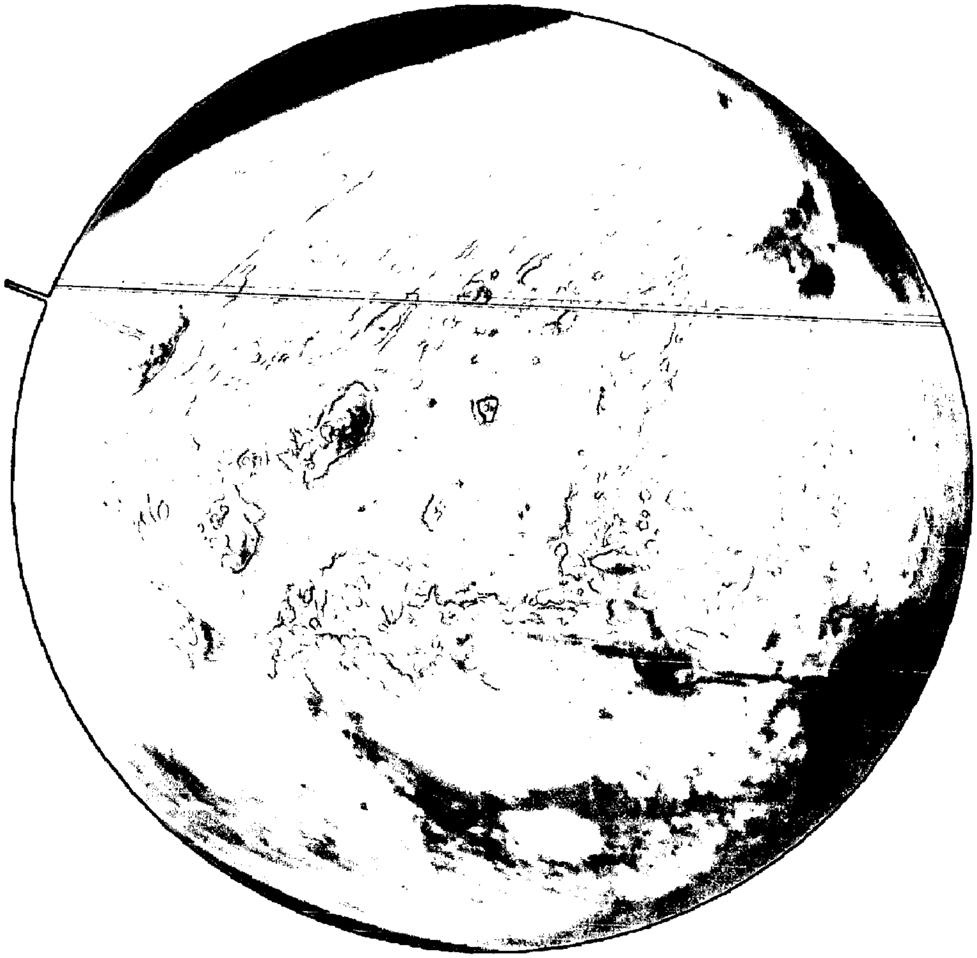

Figure 10

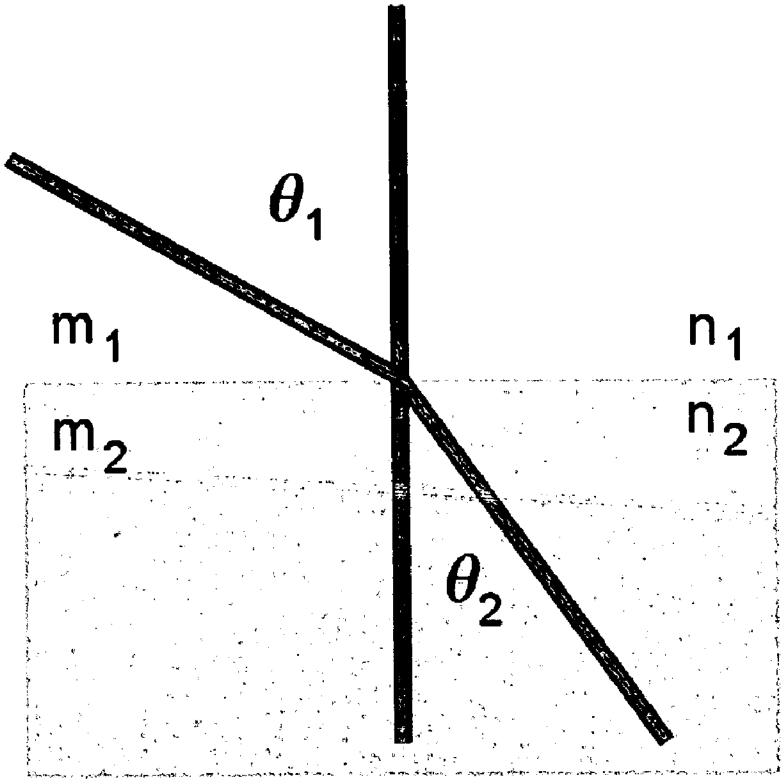
θ_1
m_1
n_1
m_2
n_2
θ_2

Figure 11

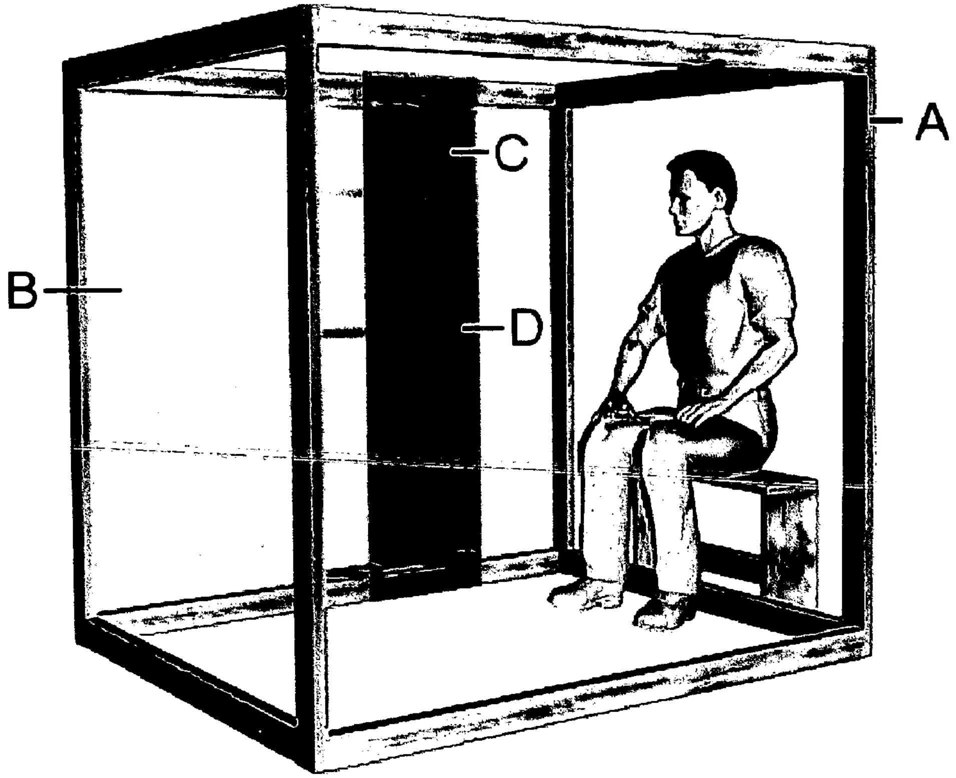

Figure 12

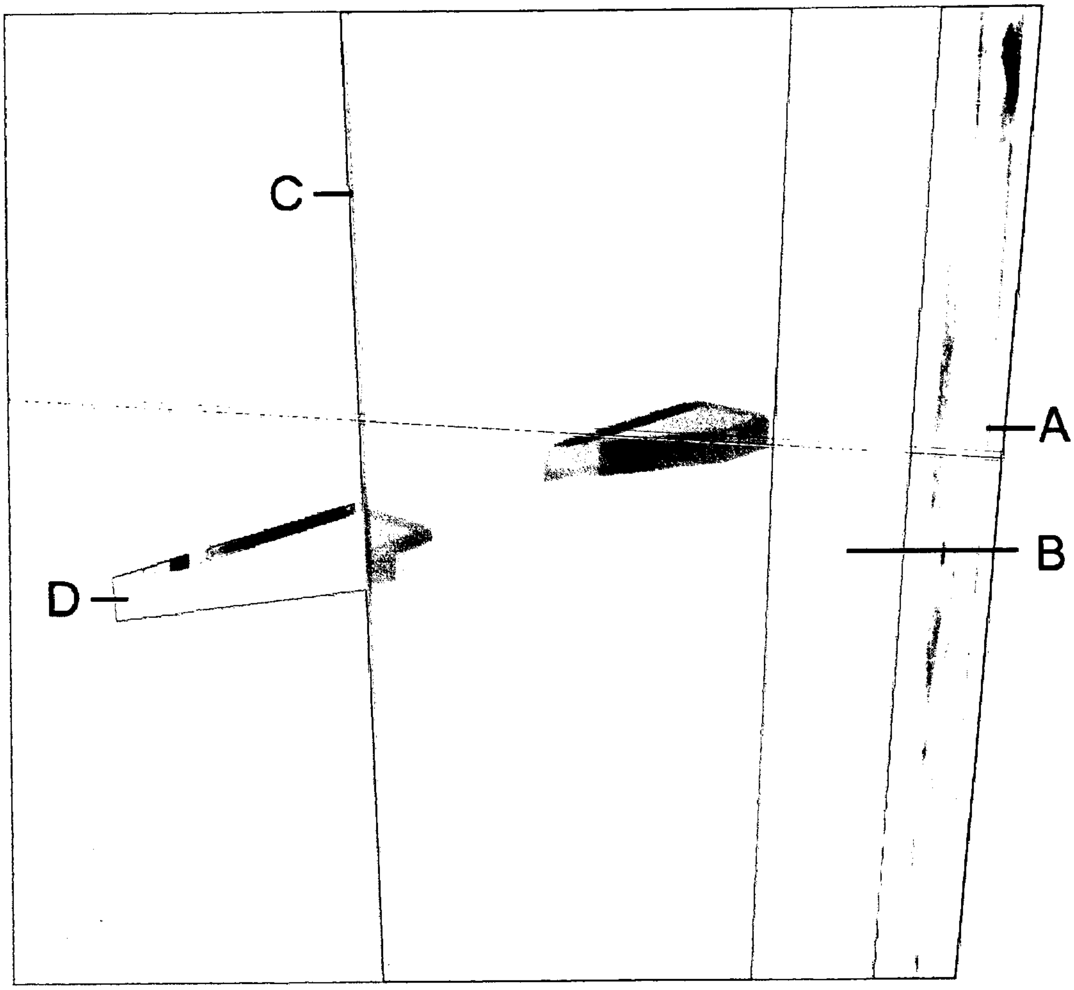

Figure 13

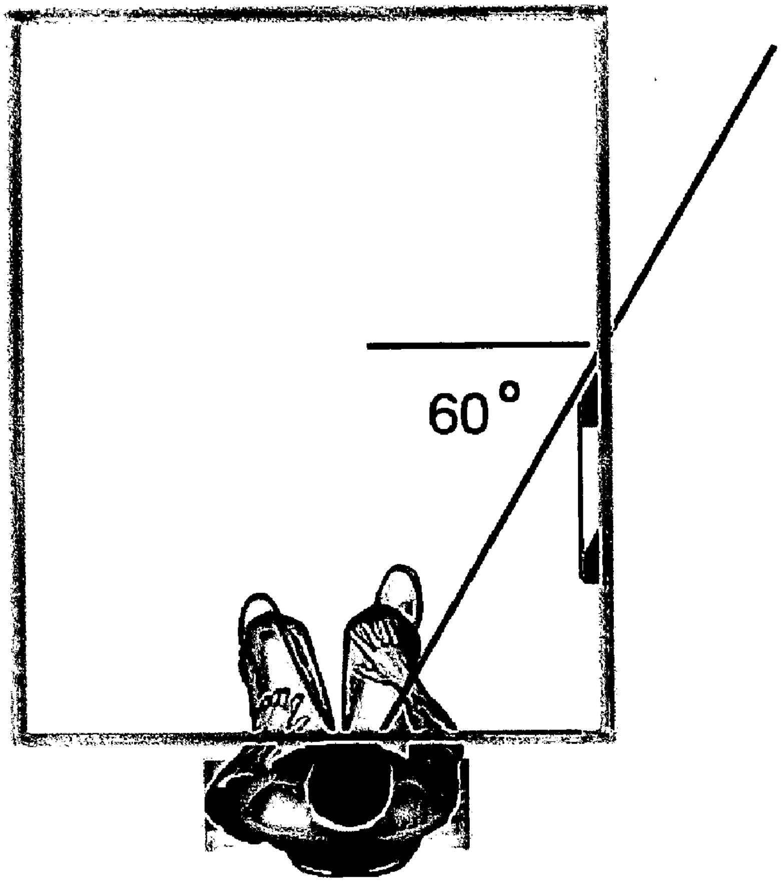

Figure 14

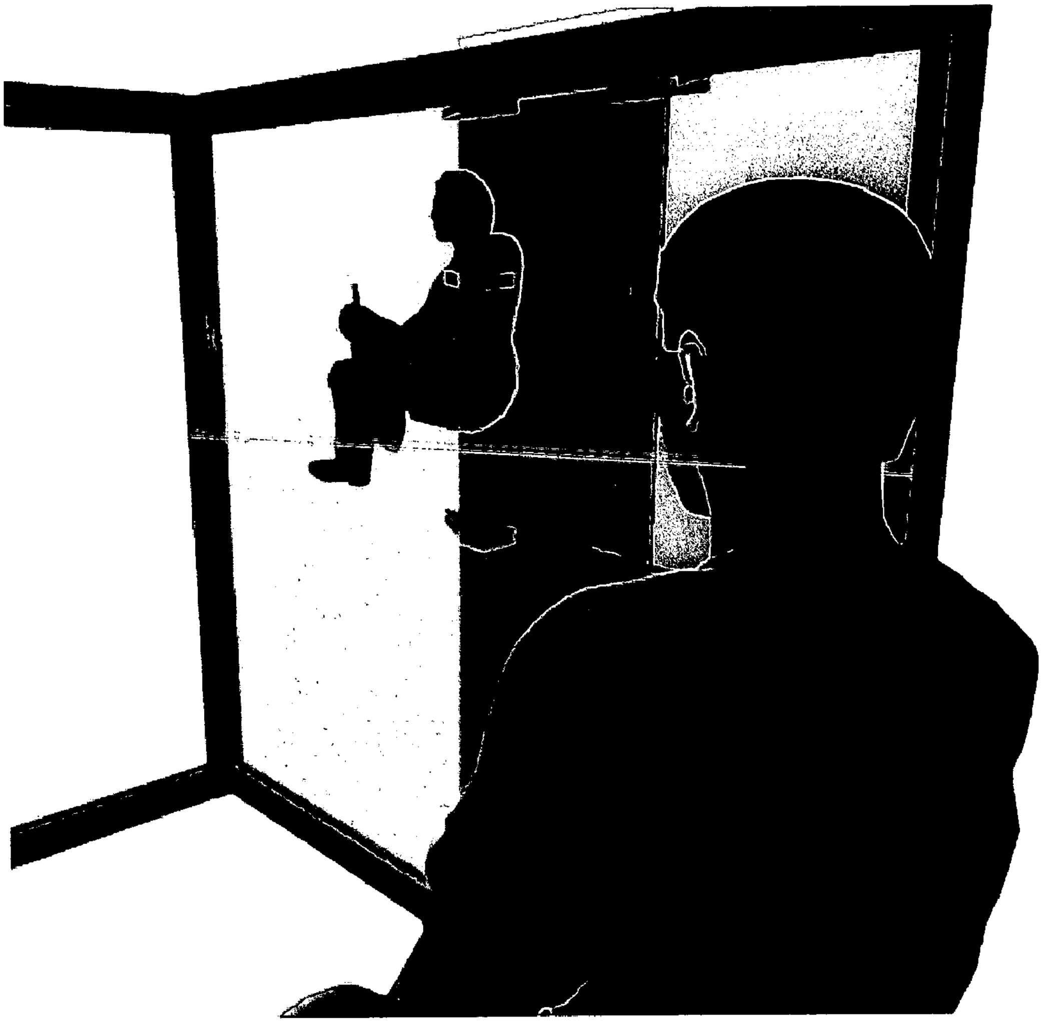

REMOTE VIEWING AMPLIFIER

BRIEF SUMMARY OF THE INVENTION

[0001] This invention enhances the ability of a person to perform remote viewing by connecting the spiritual eye to the tetrahedral geometry of subspace.

BACKGROUND OF THE INVENTION

[0002] Remote viewing is the projection of spiritual modules of the human energy field to distant locations in order to see, communicate and interact with other entities who live in subspace, space and hyperspace co-dimensions of the universe.

[0003] One of my first remote viewings was made at night to a distance of 10,000 miles on the sunlit side of the earth. My spiritual eye and body projected together while my mental facilities remained in my physical body. I found myself looking down on a palm tree from a height of about one hundred feet. The palm tree had several coconuts in it as seen in **FIG. 1**. I then gave the command to lower myself to the ground. At that moment I went sailing down past the coconuts, barely missing the tree! Finding myself on a pathway through the tropical forest, I then came to an extremely long wooden bridge which crossed over a river gorge. On the other side of the bridge I could see three soldiers running toward me as shown in **FIG. 2**. The two soldiers in front were carrying rifles and wearing light blue berets. The man running behind them was wearing an officer's cap with a red band. My first reaction was that I was going to be shot. I edged over on the right side of the wooden railing. They ran right past without seeing me. I then asked to see the building that these soldiers were guarding. Everything went dark, and then I found my spiritual eye peeking out of the floor of a computer room as seen in **FIG. 3**. There was one man using a computer on the opposite side of the room near an open door. He got up from his chair and came over to sit in front of a second computer located a few feet from where I was located. From the glare of the computer monitor, I could clearly see his face. Everything went dark as my spiritual eye and body projected back to my physical body.

[0004] Another time my spiritual eye, spiritual body and mind were standing outside the closed front door of my condominium. Upon patting my legs with my hands, I couldn't find the keys in my trousers. When I looked down, I realized I wasn't in my physical body. I then shot through two solid walls of concrete and returned to my awakening body.

[0005] What these two examples show is that the human spiritual energy system is modular. The reason it is modular is because there are seven hyperspace co-dimensions, each vibrating at a slightly different frequency, which receive energy from space through seven vortices located along the physical body. Over a lifetime, these vortices build up the human aura. Because all energy systems have to be grounded, the remaining six modules are the legs, body, arms/hands, voice, eye and mind. When the entire group is out-of-body as a single entity, then the soul energy powers the body in a manner similar to a battery. The soul looks like a two-inch diameter orange ball of plasma. If the soul is removed from the body, then the body becomes paralyzed except for a small movement of the eyelids. Upon death, all these separate modules are assembled into a single energy being. A light cord from the soul provides the battery power and information required to join these modules together. A second light cord from the pituitary gland transfers the modules into the energy being for assembly. This energy information transfer is the reason that people in a near-death situation say they saw their entire life flash before them.

[0006] Moving to a larger picture of things that are happening in the galaxy, I was able to make contact with the Pleiadian Federation which is located about 400 light years from earth. The Federation is a group of over one hundred intelligent beings that were brought to the Pleiades from around the galaxy. One member of the Federation calls itself the Intelligent Insect Beings. They are the ones who fly the black triangles over Belgium and France for the purpose of evacuating human beings back to the Pleiades for relocation on a planet called Earth II. The reason for this evacuation was that it was not known if it would be possible to win the battle of Revelations, which would take place about two years later here on earth.

[0007] As could be expected, the humans were angry and hysterical at being abducted. So the Intelligent Insect Beings asked me if I could calm them down. I was in telepathic communication with them, and they were in telepathic communication with their computer system, which meant that I could have my thoughts displayed to the humans on the computer monitor. It turned out that one woman was from Central America and only spoke Spanish. The Intelligent Insect Beings didn't speak Spanish so they thought there would be no way I could communicate with her. So I told them that I would spell the Spanish words letter-by-letter and she could then read my message. Since most Spanish people are Catholics, I thought a religious message would be of importance to her. I spelled out the phrase, "Que Dios te bendiga." which means, "May God bless you." I also asked the two beings to put their hands together in a form of prayer, and the woman followed suit. At that moment the Intelligent Insect Beings were reading her mind to understand her emotional state. They said, "She is crying tears . . . " After a slight but tense pause, they continued, "of joy!" They said the woman had a big smile on her face and was successfully transitioned into her new life.

[0008] One year later, the Blond Aliens of the hundred member council of the Pleiadian Federation remote viewed me so that I could celebrate with them the success of their mission to earth. The Blond Aliens, which is not their real name, fly the Beamship spacecraft. This hyperspace vehicle can teleport itself to any location in the galaxy. It dematerializes into the black void for an instance and then rematerialize anywhere in the galaxy. This ship can be seen in Billy Meier's video from Switzerland along with a picture of their envoy, Semjase.

[0009] Just recently I had a demonstration of the Beamship's ability. I heard an emergency distress call by a commander of a spacecraft who said that they had a fire onboard their spacecraft. I immediately remote viewed a Federation maintenance mothership, they got the frequency and location of the ship, and dispatched the Beamship in time to rescue the commander. The burned-out cables, which had caused the fire, were repaired by the Federation and the commander arrived home safely on his planet in his own spacecraft.

[0010] The Federation then received a message from the commander saying that he wanted his planet to join the Federation now that there was this type of communication available. So the Federation visited his planet for the signing ceremony, and I was invited to attend the proceedings by remote view. Word got around about this, and within three weeks another 20 planets joined the Federation for the same reason.

[0011] At one ceremony, which was attended by Admiral Third Class of the Pleiadian Defense Department, His Highness of the planet was signing the document of incorporation. At that moment, I could see him signing, so I exclaimed, "He is signing with his left hand." The Admiral was almost apoplectic at hearing this. After giving her the signed document, His Highness held up his hand and asked me how many fingers he was holding up. He had a fist so I said none. Then he put his index finger out and I said one. He then made a fist again and I said none. Then he held out all fingers and I said five. The Admiral said that he had a big smile on his face as he went to announce the agreement because he knew, even though his planet was located **90,000** light years away on the other side of the galaxy, he could instantly communicate any problems to the Federation. So this is the importance of developing inventions that can enhance our remote viewing ability because one day it will mean that we can become a vital part of the Pleiadian Federation.

SUMMARY OF THE INVENTION

[0012] Referring to **FIG. 4**, the spiritual eye of the human energy system is located at the pituitary gland in the forehead. It has the shape of a hollow cone which is composed of the misty white energy of hyperspace. Light coming into this vortex is then transferred by a light cord to a visual energy module which is located in a co-dimension of hyperspace. Because these modules are interconnected by light cords, the mind module is able to interpret the visual pattern the eye is seeing. More importantly, the mind can give logical instructions to this spiritual eye module for it to rotate around or move in a particular direction.

[0013] The reason that hyperspace has a white misty look to it is that the speed of light is very much less than the speed of light in our spacetime. The Lorentz transformation says that the distance L is shortened relativistically to a distance L' in a way related to the ratio of the velocity v of the object to the velocity of light c.

$$L' = L\sqrt{1 - \frac{v^2}{c^2}}$$

If the velocity of light is very low, then a small velocity creates an enormous contraction in length. By moving through hyperspace, therefore, enormous distances can be traversed. And this is the reason that it is possible to project the spiritual eye, voice and hearing to remote locations in the galaxy.

[0014] The universe is composed of subspace, space and hyperspace which are co-dimensions of each other. Subspace is defined by the geometry of the tetrahedron which is a four-sided solid whose faces are equilateral triangles having three 60° angles. Referring to **FIG. 5**, a tetrahedron whose sides are the square root of three (A), has a height of the square root of two (B), and base length equal to the square root of one (C). This forms the basic number set $\{\sqrt{1}, \sqrt{2}, \sqrt{3}\}$.

[0015] Referring to **FIG. 6**, the tetrahedron (A) is circumscribed by the sphere (B). Rod (C) is the sphere radius. A second rod (D), of equal length to rod (C), from the center of the sphere to the corner of the tetrahedron makes an angle ϕ of

$$\phi = \mathrm{ArcSin}\left(\frac{1}{3}\right) = 19.47122063^\circ$$

So the four corners of the tetrahedron touch the sphere.

[0016] This tetrahedral geometry can be seen throughout the planets of the solar system Referring to **FIG. 7**, the islands of the Caribbean curve down from Puerto Rico to Venezuela forming an island vortex. The low density hyperspace energy releasing from the corner of the tetrahedron softens the rock mantle. The hot magma then rises through the rock with the least resistance. This creates a circular arc of volcanic islands along the edge of the vortex.

[0017] Referring to **FIG. 8**, the Giant Red Spot of Jupiter is located at a southern latitude of 19.5°. This vortex is so large that the entire earth can fit in it.

[0018] Referring to **FIG. 9**, the Olympus Mons volcano is located at a northern latitude of 19.5° as shown by the marker. This volcano is the size of France. Notice the fallen plume of volcanic debris toward the north east.

[0019] The double harmonic of the tetrahedral angle is twice 19.5° or 39° which is the location of the Silver Bridge in Point Pleasant, West Va. A large wormhole opened up around the bridge during Christmas rush hour when the bridge was full of cars. Due to the low density hyperspace energy, the rivets holding the cables down popped loose and all the cars were dumped into the river. A computer simulation using Schrodinger's quantum mechanics equation for a particle in a potential well shows that as the energy becomes less dense, the particle is no longer contained in the potential well. The electron jumps out. Thus the atomic bonds are broken which softens the rivets. This is the first time that there has been an understanding of the failure mechanism of this bridge.

[0020] After downloading from the Internet several pages of the index of refraction of a wide range of materials, I noticed that the index of refraction for Plexiglas was 1.50. Another source said it was 1.51. One of the Internet sites had a movable flashlight which showed the incident ray and the refracted ray. For Plexiglas, surprisingly enough, the incident ray was coming in at an angle of 60° to the normal, and the light was refracted at 35.26°, both of which are tetrahedral angles. The angle of the equilateral face of the tetrahedron is of course 60°. The angle at the top of tetrahedron is the arc-cosine of the ratio of the height over the edge length.

$$\theta = \mathrm{ArcCos}\left(\frac{\sqrt{2}}{\sqrt{3}}\right) = 35.26^{\circ}$$

According to Snell's law, the index of refraction n, times the sine of the angle $\sin(\theta_1)$ of the ray leaving material m_1, is equal to the index of refraction n_2 times the sine of the angle of refraction $\sin(\theta_2)$ of the ray entering material m_2. Referring to **FIG. 10**, the equation is

$$n_1 \sin(\theta_1)=n_2 \sin(\theta_2)$$

The index of air n_1 is equal to one. The index n_2 of Plexiglas is 1.50. If the incident ray is at $\theta_1=60°$ to the normal, then the output angle is

$$\theta_2 = \mathrm{ArcSin}\left[\frac{n_1}{n_2}\mathrm{Sin}(\theta_1)\right] = \mathrm{ArcSin}\left[\frac{2}{3}\frac{\sqrt{3}}{2}\right] = 35.26^{\circ}$$

which is equal to the angle of the tetrahedron.

[0021] Then I recalled several months earlier that I had gone to the Subway restaurant to get a sandwich. I was sitting by the Plexiglas window communicating with the Admiral whose mothership was in earth orbit. She mentioned that they were bringing two people aboard. At that moment I looked out through the window and I could see both of them clearly and easily through my spiritual eye. To my amazement, I saw both of the captives start to pull out guns from behind their backs. I then projected by spiritual hands which resulted in preventing the attack on the security guards. To say the least, the Admiral was rather surprised at these events. She then asked me to look at the design of the window because she thought it had something to do with my enhanced remote viewing capabilities. Looking at the Plexiglas, I noticed that on the edge of the large window pane there was a shorter piece of Plexiglas which was mounted parallel to the window pane. This smaller panel acted to protect the yellow neon fluorescent tube. I took the measurements of the design using a piece of paper that I found near the table.

[0022] I then went home and designed up a mounting bracket with my 3D computer software. I had already installed the stereolithography software that converts the design to the *.STL file format. How stereolithography works is that it slices the design into many thin horizontal sections. The machine has a platform which is mounted in a bath of liquid polymer. An ultraviolet laser, mounted on an xy-table, then traces out the slice. Because the liquid polymer is light sensitive, it polymerizes immediately into solid plastic. Then the platform is lowered a few thousandths of an inch and the second slice is added. This process eventually builds up the complete 3D part. Using the Internet, the *.STL file is sent by e-mail to the stereolithography service provider who returns the part overnight. So the next day I had the piece from which I made a plastic mold and several additional pieces for mounting the Plexiglas bracket on a full sheet of Plexiglas that I ordered locally. It never occurred to me to measure the angles, so after I got the index of refraction for Plexiglas, I measured the incident angle and it turned out to be 61°. So then I realized that the spiritual eye was being diffracted across these two Plexiglas plates which connected it to the tetrahedral geometry of subspace. Because subspace is the foundation of space, this created a much more efficient route for remote viewing. The result is that this invention has allowed me to make contact with 430 alien civilizations. Since then I have been awarded the Aphysics prize for my work in the invention and elaboration of the tetrahedron diagram of which there are now over 4000 graphs. The scientific discoveries contained in the diagram are (1) the electron and proton are one and same particle, (2) the existence of hyperspace, (3) how mass can be taken out of dimension, (4) cosmology determines the elementary particles, (4) all the physics constants and the tetrahedral geometry are contained in the two 360° circles of the infinity symbol and (5) all the physics constants are determined geometrically and projected from a subspace manifold into our dimension. For my work in Revelations, I was awarded four beautiful galloping riderless white horses of the Apocalypse.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0023] **FIG. 1**. Remote viewing the top of a palm tree containing several coconuts.

[0024] **FIG. 2**. Remote viewing three soldiers running across a wooden bridge.

[0025] **FIG. 3**. Remote viewing computer building that soldiers were guarding.

[0026] **FIG. 4**. Spiritual eye of human aura.

[0027] **FIG. 5**. Tetrahedron.

[0028] **FIG. 6**. Tetrahedron circumscribed by sphere.

[0029] **FIG. 7**. Caribbean volcanic island vortex.

[0030] **FIG. 8**. Giant Red Spot on Jupiter.

[0031] **FIG. 9**. Olympus Mons volcano on Mars.

[0032] **FIG. 10**. Snell's Law of Refraction.

[0033] **FIG. 11**. Perspective view of remote viewing station.

[0034] **FIG. 12**. Wedge-shaped spacers for diffraction panel.

[0035] **FIG. 13**. Remote viewing angle.

[0036] **FIG. 14**. A remote viewing session taking place on a planet located 90,000 light years from earth on the other side of the galaxy showing His Highness signing with his left hand the document that allows his planet to become a member of the Pleiadian Federation.

DETAILED DESCRIPTION OF THE INVENTION

[0037] 1. Referring to **FIG. 11**, the remote viewing station is a rectangular box wooden frame (A) on which is mounted on one side a large sheet of Plexiglas (B). The diffraction panel (C), made of a shorter length of Plexiglas, is mounted with acrylic glue on the Plexiglas sheet using clear polyoptic molded plastic spacers (D).

[0038] Referring to **FIG. 12**, the wedge-shaped spacers (D) hold the diffraction panel (C) to the sheet of Plexiglas (B). The angle of the wedge is 30° which makes the incident angle 60° to the normal.

[0039] Referring to the top view perspective **FIG. 13**, sitting on the wide bench, the remote viewer can adjust his sight along the wedge for proper alignment at an angle of 60°. Due to the 1.50 index of refraction of Plexiglas, the spiritual eye is diffracted across the edge of the first panel and then refracted across the second panel at the tetrahedral angle of 35.26°.

[0040] Referring to **FIG. 14**, the remote viewing image is seen superimposed on the large sheet of Plexiglas which acts as the viewing screen.

I claim:

1. A remote viewing station comprising:

(a) a rectangular box frame made of wood having a length of six feet, a width of four feet and a height of six feet;

(b) a large sheet of quarter inch Plexiglas, having an index of refraction of 1.50, mounted on the right side of item (1a);

(c) several wedge-shaped clear plastic spacers, three inches in width and eight and a half inches in length, having a wedge angle of 30° that are mounted on the interior right side of item (1b);

(d) a shorter sheet of quarter inch Plexiglas, having a length of one and a half feet, mounted on item (1c) parallel to item (1b);

(e) a wide bench on which the remote viewer sits so that the remote viewer can align his sight along the wedge angle of item (1c);

2. A remote viewing amplifier that:

(a) diffracts the spiritual eye of the remote viewer across the edge of item (1d) at an incident angle of 60° to the normal;

(b) refracts the spiritual eye at 35.26° to the normal due to the refractive index of item (1a) according to Snell's Law of Refraction; and

(c) aligns the spiritual eye with the tetrahedral geometry of subspace due to the diffraction/refraction combination of item (2a) and (2b).

* * * * *

US 20060145019A1

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(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0145019 A1**
St. Clair (43) **Pub. Date: Jul. 6, 2006**

(54) **TRIANGULAR SPACECRAFT**

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Publication Classification

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B64G 1/40 (2006.01)
(52) **U.S. Cl.** **244/171.5**

(57) **ABSTRACT**

A spacecraft having a triangular hull with vertical electrostatic line charges on each corner that produce a horizontal electric field parallel to the sides of the hull. This field, interacting with a plane wave emitted by antennas on the side of the hull, generates a force per volume combining both lift and propulsion.

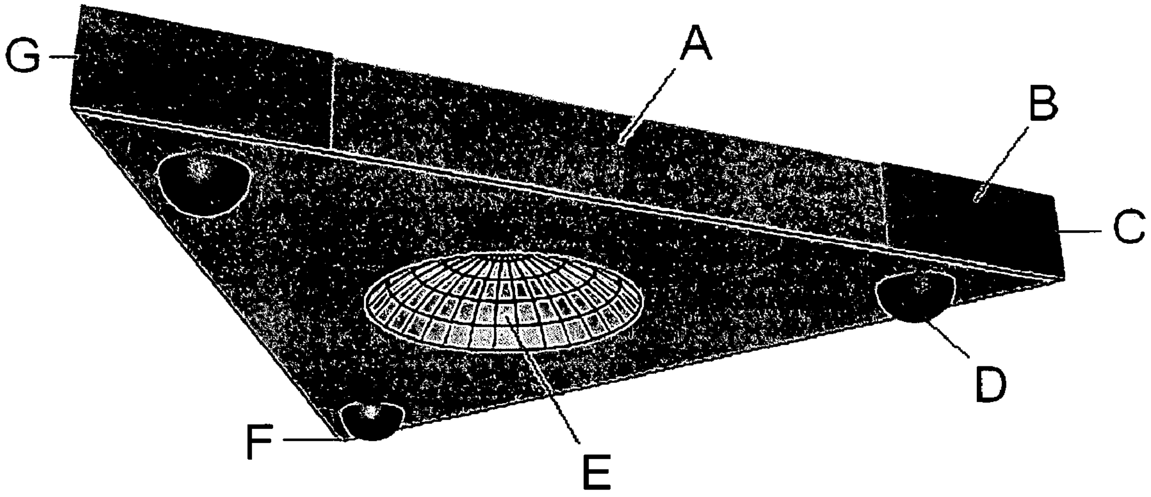

Figure 1

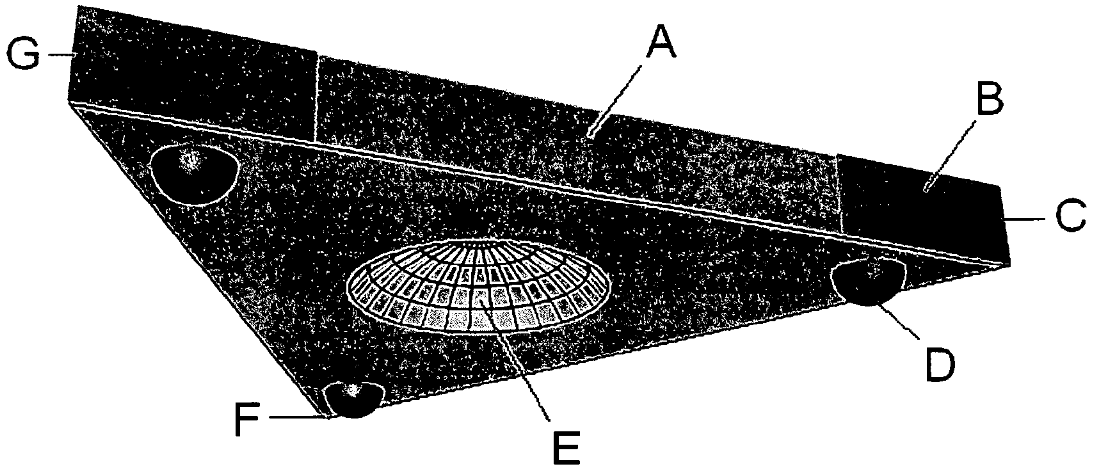

Figure 2

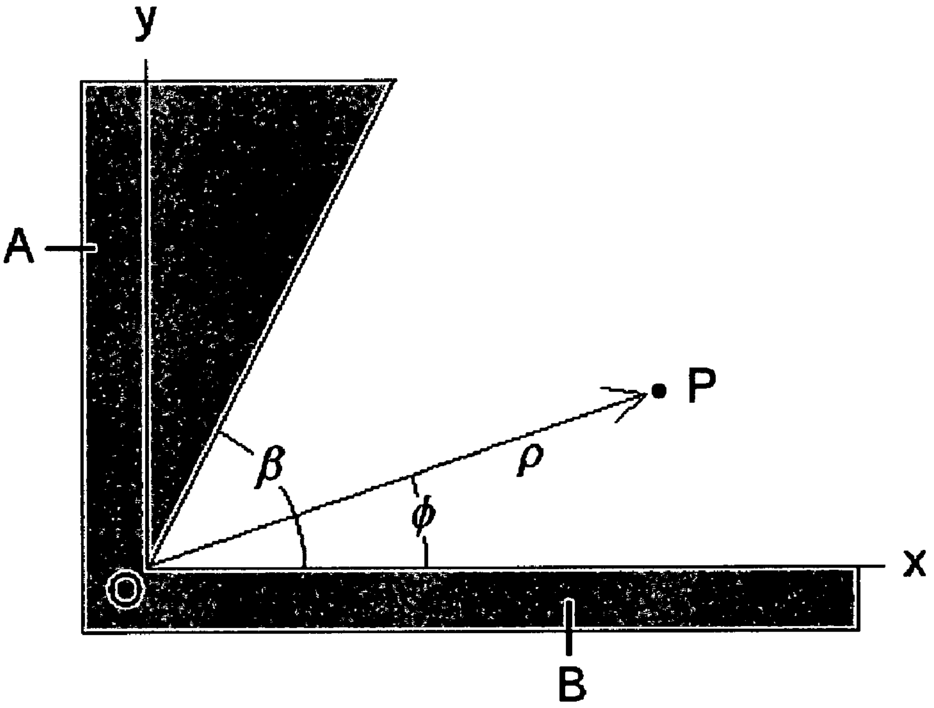

Figure 3

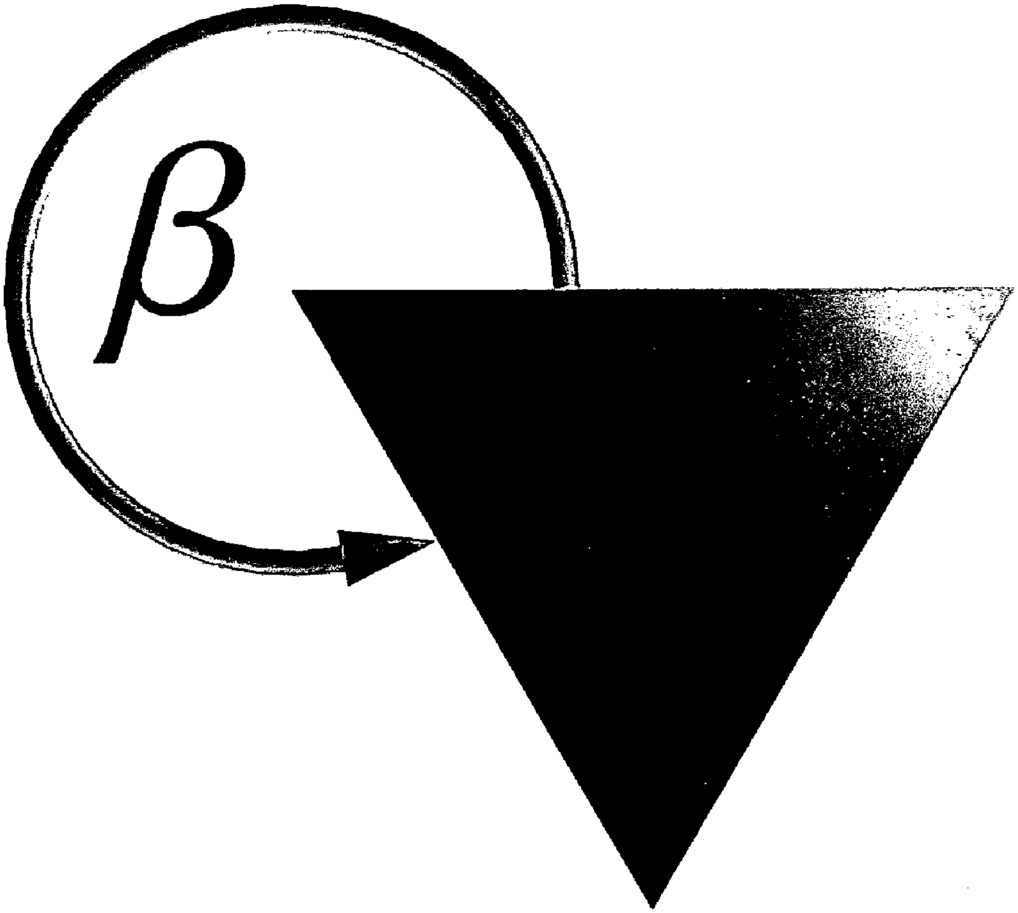

Figure 4

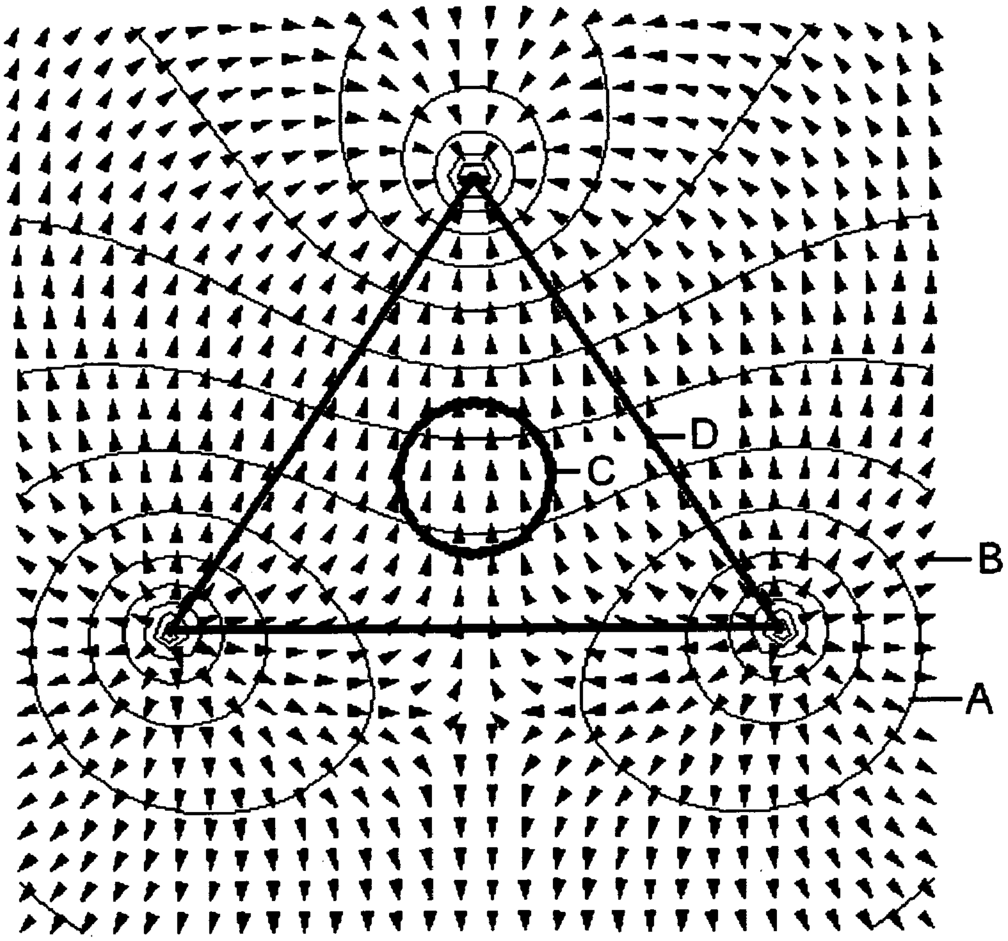

Figure 5

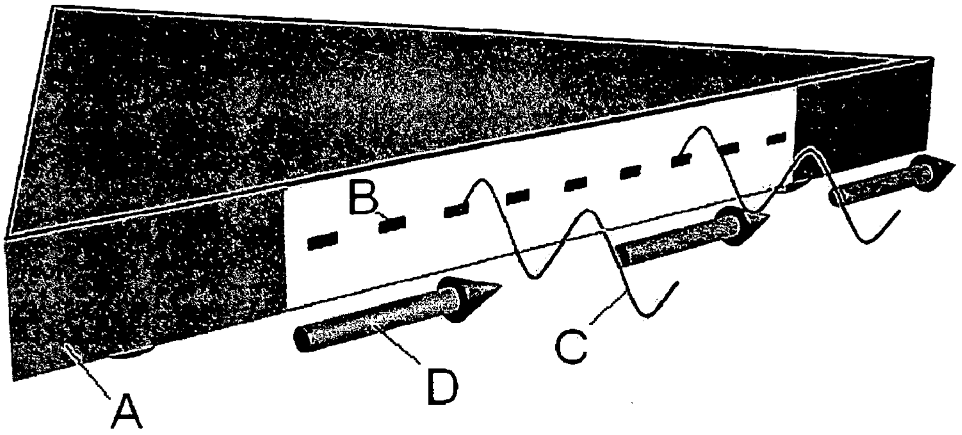

Figure 6

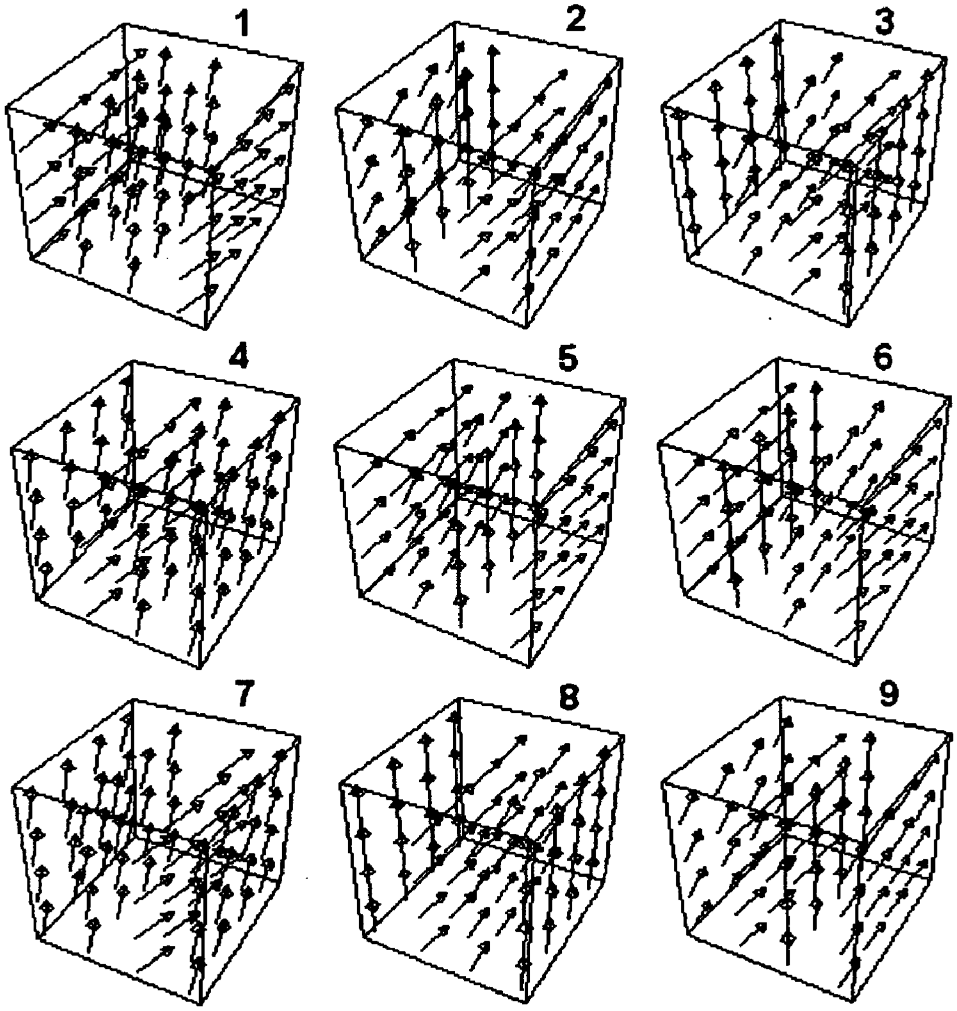

Figure 7

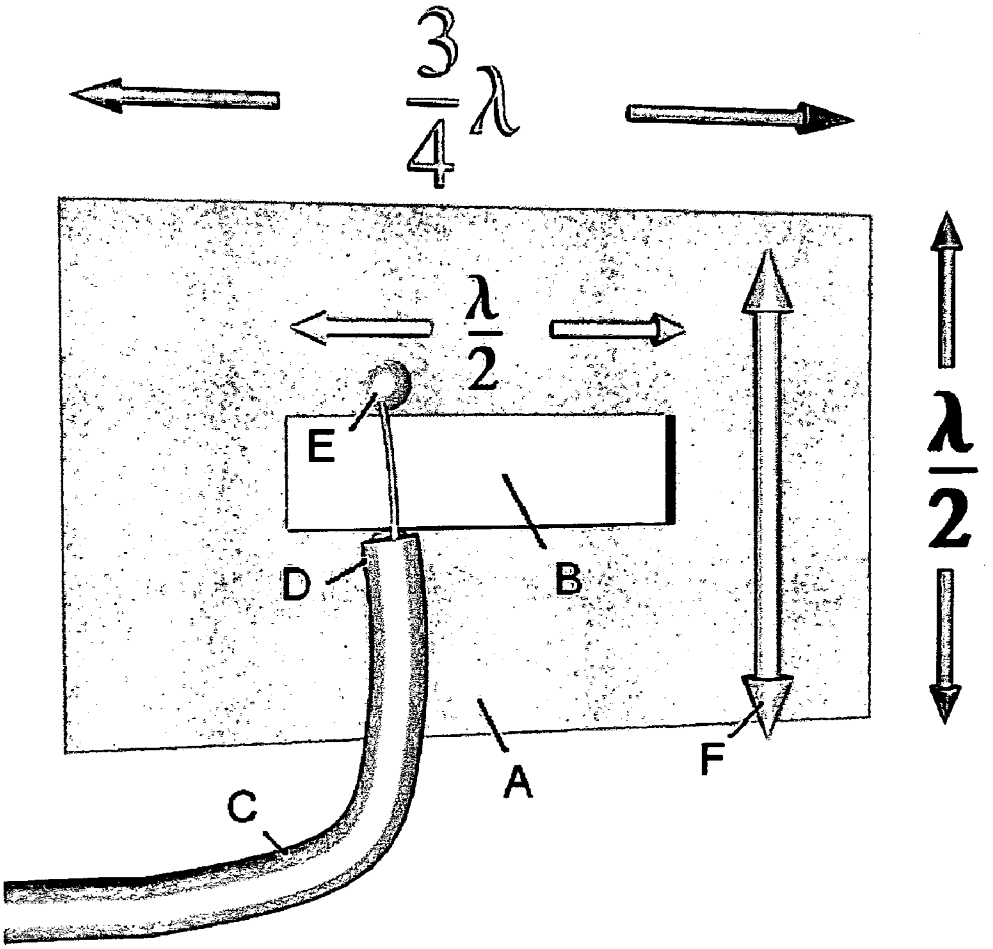
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$\frac{\lambda}{2}$
$\frac{\lambda}{2}$
A
B
C
D
E
F

TRIANGULAR SPACECRAFT

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is a spacecraft having a triangular hull with vertical electrostatic line charges on each corner. The line charges create a horizontal electric field that, together with a plane wave emitted by antennas on the side of the hull, generates a force per volume providing a unique combination of both lift and propulsion.

BACKGROUND OF THE INVENTION

[0002] Referring to **FIG. 1**, the spacecraft has a hull in the shape of an equilateral triangle. A parabolic antenna (E) is centrally located in the bottom of the hull. An array of horizontal slot antennas is located along the side of the hull (A). Each back corner (F,G) has a corner conducting plate which is charged to a positive voltage +V. The forward corner (C) has a conducting plate charged to a negative voltage −V. A motion control hemisphere (D) is located on the bottom surface in each of the three corners.

[0003] Referring to **FIG. 2**, two planes (A,B) intersect at the origin O at an opening angle β. Each plane (x,y) is charged to a voltage V. The potential at point P is determined in polar coordinates {ρϕ}. The Laplace equation for the potential Φ in polar coordinates is given by:

$$\frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\rho\frac{\partial\Phi}{\partial\rho}\right)+\frac{1}{\rho^2}\frac{\partial^2\Phi}{\partial\phi^2}=0$$

Using a separation of variables solution, the potential is given as the product of two functions:

$$\Phi(\rho,\phi)=R(\rho)\Psi(\phi)$$

which when substituted into the Laplace equation becomes:

$$\frac{\rho}{R}\frac{d}{d\rho}\left(\rho\frac{dR}{d\rho}\right)+\frac{1}{\Psi}\frac{d^2\Psi}{d\phi^2}=0$$

Since the two terns are separately functions of ρ and ϕ respectively, each one has to be constant with the sum of the constants equal to zero:

$$\frac{\rho}{R}\frac{d}{d\rho}\left(\rho\frac{dR}{d\rho}\right)=v^2 \quad \frac{1}{\Psi}\frac{d^2\Psi}{d\phi^2}=-v^2$$

These two equations have solutions:

$$R(\rho)=a\rho^{v+b\rho-v}$$

$$\psi(\phi)=A\cos(v\phi)+B\sin(v\phi)$$

The azimuthal angle ϕ is restricted to a value in the range $0\leqq\phi\leqq\beta$. The boundary condition is that the potential Φ is equal to V for any radius ρ when ϕ=0 and ϕ=β. This means that v has to be an integer value of π so that the sine function is zero:

$$\sin(v\beta)=\sin\left(\frac{m\pi}{\beta}\beta\right)=\sin(m\pi)=0 \quad m=1,2\ldots$$

which in turn means that the coefficient A of the cosine term has to be zero in the solution above. Choosing b=0 makes the general solution for the potential equal to:

$$\Phi(\rho,\phi)=V+\sum_{m=1}^{\infty}a_m\rho^{m\pi/\beta}\sin(m\pi\phi/\beta)$$

which shows that when the angle is zero, the sine is zero and the potential is V. If the angle is β, then there is a multiple of π such that the sine is zero again.

[0004] Because the series involves positive powers of the radius, for small enough ρ, only the first term $m=1$ in the series is important. Thus around ρ=0, the potential is approximately

$$\phi(\rho,\phi)\approx V+a_1\rho^{\pi/\beta}\sin(\pi\phi/\beta)$$

[0005] The electric field component is the negative gradient of the potential:

$$E_\phi(\rho,\phi)=-\frac{1}{\rho}\frac{\partial\Phi}{\partial\phi}=-\frac{\pi a_1}{\beta}\rho^{(\pi/\beta)-1}\cos(\pi\phi/\beta)$$

The surface charge distribution σ at ϕ=0 and ϕ=β is equal to the electric field perpendicular to the surface times the permittivity of space ϵ_0:

$$\sigma(\rho)=\varepsilon_0E_\phi(\rho,0)=-\frac{\varepsilon_0\pi a_1}{\beta}\rho^{\frac{\pi}{\beta}-1}$$

Notice that if angle of intersection β is less than π, then the equation says that there is a very small radius to a positive power which means little charge density accumulation.

[0006] Referring to **FIG. 3**, the value of β, in the case of the triangular hull, is equal to 360° less 60° for a total of 300° or:

$$\beta=\frac{300}{180}\pi=\frac{5}{3}\pi$$

$$\rho^{\frac{\pi}{\frac{5}{3}\pi}-1}=\frac{1}{\rho^{\frac{2}{5}}}$$

which says that there is a charge density singularity to the two fifths power for small radius. Thus, the corner plates on the hull create a huge line charge density along the sharp vertical corner edge. The equation for the potential of a line charge density is given as:

$$\Phi(x,y)=-\frac{\lambda}{2\pi\varepsilon_0}\mathrm{Ln}((x-x_0)^2+(y-y_0)^2)$$

where λ is the charge per unit length in the vertical z-direction, and x_0 and y_0 are the location of the line charge in the xy-plane.

[0007] Referring to **FIG. 4**, the triangular hull (D) is plotted together with the potential contours (A) and the electric field arrows (B) created by the three corner line charges. The line charges are perpendicular to the paper. Notice that the electric field arrows are parallel crossing the center parabolic antenna (C). The electric field is also parallel to the sides (D) of the triangle.

[0008] Referring to **FIG. 5**, along the side of the triangle (A), an array (B) of horizontal slot antennas emit electromagnetic waves that have a vertically polarized electric E field (C). These traveling waves interact with the electric field (D) produced by the line charges on the corners of the triangle.

[0009] Using differential forms mathematics, this combination of fields is represented by the Hodge star of the differential of the wedge product of the two fields. The antenna electromagnetic field is a combination of a traveling magnetic field B_w, and electric field E_w. The stationary field E created by the line charges is perpendicular to the traveling wave.

$$*d(E\wedge(B_w+E_w\wedge dt))\frac{\varepsilon}{c}=\frac{\text{force}}{\text{volume}}$$

where ϵ is the linear capacitance of space and c is the speed of light. Thus there is a force per volume around the hull.

[0010] This combination of fields produces a spacetime curvature as determined by Einstein's General Theory of Relativity. The traveling electric field has an amplitude in the vertical z-direction and travels in the x-direction

$$E_{w-Ez}\cos(x-t)$$

The Faraday electromagnetic tensor contains all the electric and magnetic fields in all the {x,y,z} directions. The first row and first column contain the two electric fields

$$F^{\alpha}_{\beta}=\begin{array}{c|cccc|} t & 0 & E_x & 0 & E_z\cos(x-t) \\ x & E_x & 0 & 0 & 0 \\ y & 0 & 0 & 0 & 0 \\ z & E_z\cos(x-t) & 0 & 0 & 0 \end{array}$$

The stress exerted on spacetime occurs in the xx, yy and zz-direction as calculated from the stress-energy tensor T of gravitational physics

$$4\pi T^{\mu\nu}=F^{\mu\alpha}F^{\mu}_{\alpha}-\frac{1}{4}g^{\mu\nu}F_{\alpha\beta}F^{\alpha\beta}$$

where g is the metric tensor for Cartesian space

$$g_{\alpha\beta}=\begin{array}{c|cccc|} t & -1 & 0 & 0 & 0 \\ x & 0 & 1 & 0 & 0 \\ y & 0 & 0 & 1 & 0 \\ z & 0 & 0 & 0 & 1 \end{array}$$

where the diagonal components are the coefficients of the elementary spacetime length ds squared

$$(ds)^2=-(dt)^2+(dx)^2+(dy)^2+(dz)^2$$

The calculation produces three stresses T^{xx},T^{yy} and T^{zz} in their respective {x,y,z} directions.

[0011] Referring to **FIG. 6**, these three stresses are plotted together as a **3**D vector field animated over time in nine frames. The graphs show that there is a lift force as depicted by the vertical arrows as well as a force of propulsion as shown by the interspersed horizontal arrows. With the passage of time, these vectors exchange places with each other so that the lift becomes the propulsion and vice versa, creating a wavy stress-energy field around the hull.

SUMMARY OF THE INVENTION

[0012] This invention is a spacecraft with a triangular hull having charged flat plates on the vertical corners of the three sides. The two rear corners are charged to a potential V. The forward corner is charged to a potential −V. The 60° angle on the corner creates a line charge density singularity that produces a huge horizontal electric field pointing from the back to the front of the craft which is also parallel to the sides of the triangle. An array of horizontal slot antennas located on the sides of the triangular hull produce an electromagnetic wave with the electric field polarized in the vertical direction. This combination of fields produces a spacetime force in both the vertical and horizontal directions such that the spacecraft receives a lift force and a force of propulsion.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1**. Perspective view of triangular spacecraft.

[0014] **FIG. 2**. Drawing of the intersection of two charged plates in order to calculate the charge density in the corner.

[0015] **FIG. 3**. Perspective view of the corner angle β for the equilateral triangle.

[0016] **FIG. 4**. Planar **2**D graph showing the electric field produced by three line charges on the corners of the triangular hull.

[0017] **FIG. 5**. Perspective view of electric field produced by the linear charge interacting with the traveling electromagnetic wave produced by the slot antenna.

[0018] **FIG. 6**. **3**D vector animation of the lift and thrust force generated by the fields.

[0019] **FIG. 7**. Perspective view of slot antenna.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring to **FIG. 7**, the antenna (A) is made out of sheet copper in which a rectangular horizontal slot (B) has been notched out using a die press and sheet metal fixture. A coaxial cable from the amplifier and frequency generator is attached across the slot by soldering the outer cable (D) to one side of the slot and the inner cable (E) to the other side of the slot. This creates the positive and negative charges across the gap which forms the vertical electric field (F) which radiates out perpendicularly to the copper sheet.

[0021] Although the invention has been described with reference to specific embodiments, such as a particular antenna system, those skilled in the art will appreciate that many modifications and variations are possible without departing from the teachings of the invention. All such modifications and variations are intended to be encompassed within the scope of the following claims.

1. A spacecraft comprised of the following components:

(a) a triangular hull in the form of an equilateral triangle;

(b) two copper plates attached on opposite vertical sides at each of the three corners of the hull (**1***a*) such that a sharp vertical edge is formed where they come together;

(c) an electrostatic generator used to charge the back two copper-cladded corners (**1***b*) to a high positive voltage, and the third forward copper-cladded corner to a high negative voltage;

(d) a horizontal slot antenna array mounted-on the sides of the hull; and

(e) a frequency generator, antenna and coaxial cables to drive the antenna array (**1***d*).

2. To create, by claims (**1***a*, **1***b*, **1***c*), an intense vertical line charge at the corners (**1***b*) and a horizontal electric field that that is parallel to the sides of the hull (**1***a*);

3. To create, by claims (**1***d*,**1***e*), an electromagnetic wave with a vertically polarized electric field traveling outward from the side of the hull (**1***a*); and

4. To create, by claims (**2**,**3**), an interaction of the electrostatic field (**2**) with the electromagnetic wave (**3**) such that a combined spacetime curvature pressure is generated on the hull in the upward and forward direction to produce lift and propulsion respectively.

* * * * *

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(43) **Pub. Date: Jun. 1, 2006**

(54) **PERMANENT MAGNET PROPULSION SYSTEM**

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(52) **U.S. Cl.** **105/49**

(57) **ABSTRACT**

This invention is a propulsion system for a train that uses permanent magnets mounted on a rotating iron cylindrical plate carrying a radial current in order to create a spacetime curvature distortion which pulls the locomotive along the track.

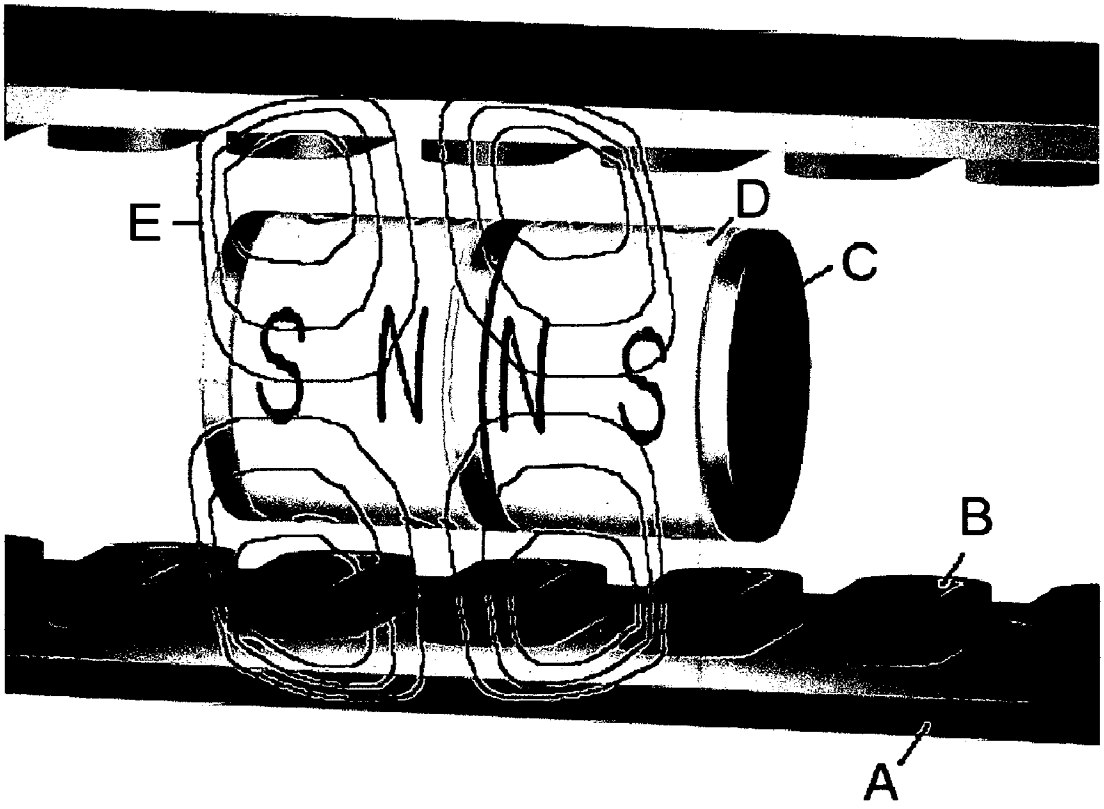

Figure 1

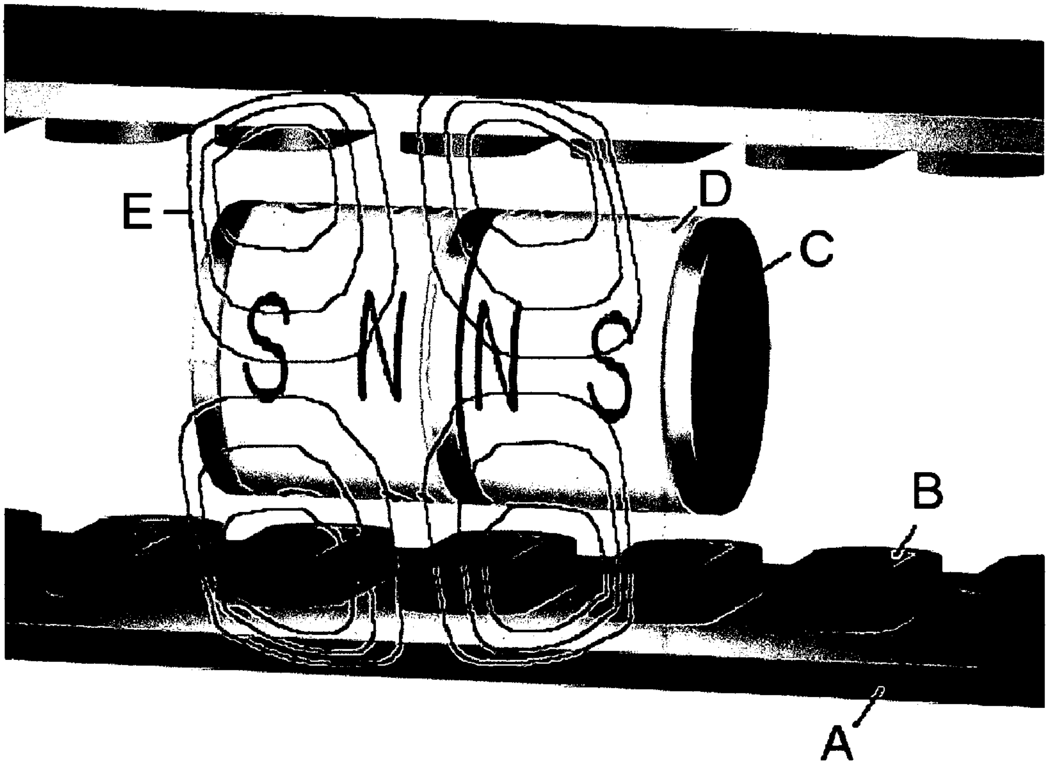

Figure 2

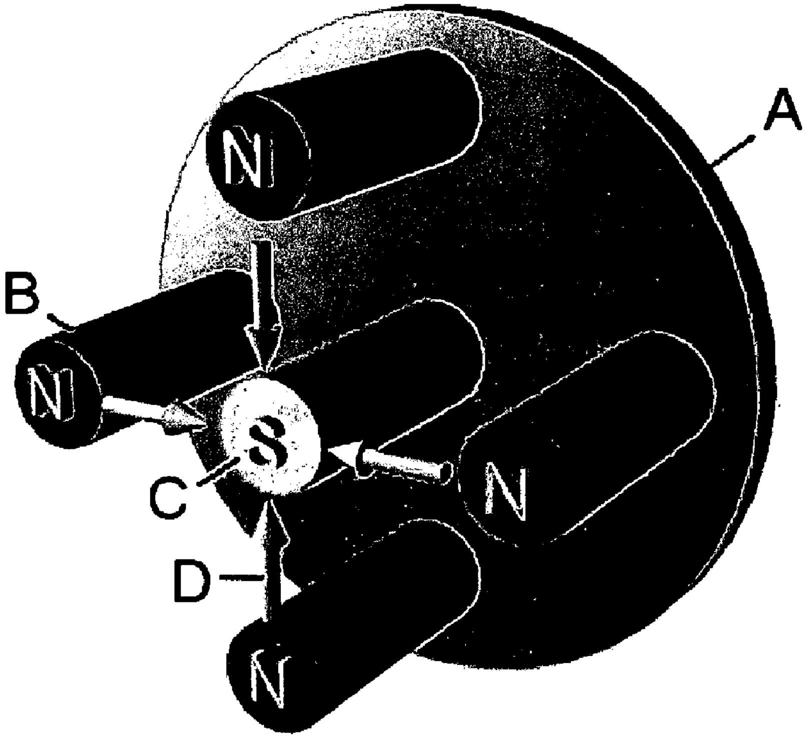

Figure 3

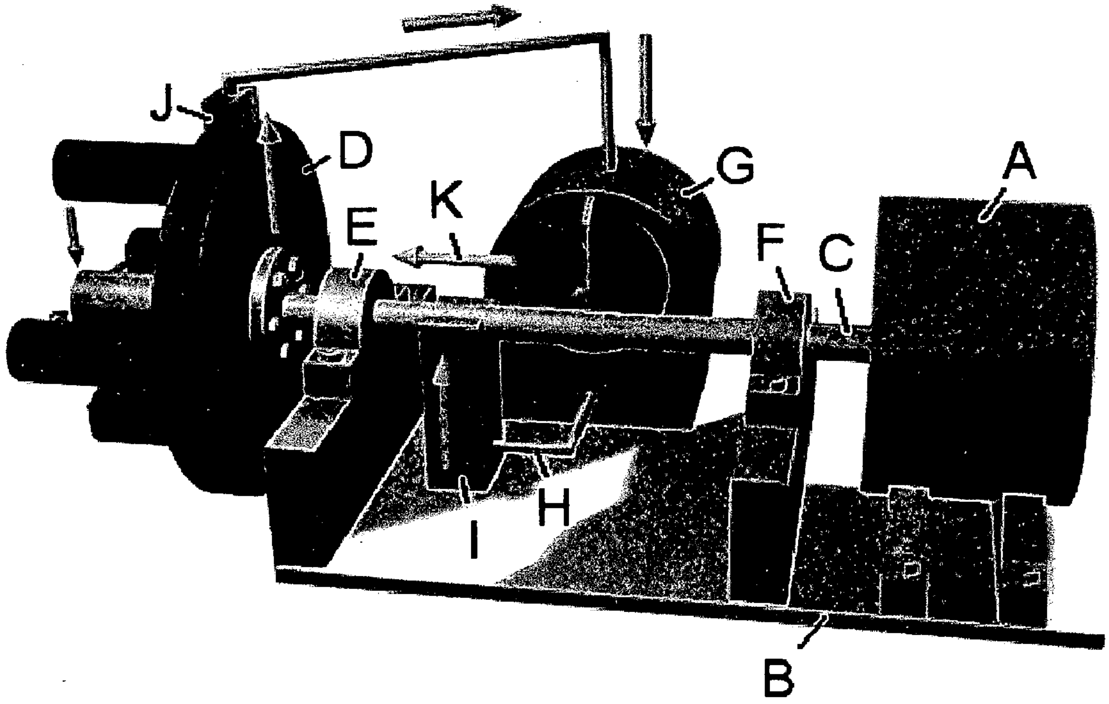
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Figure 4

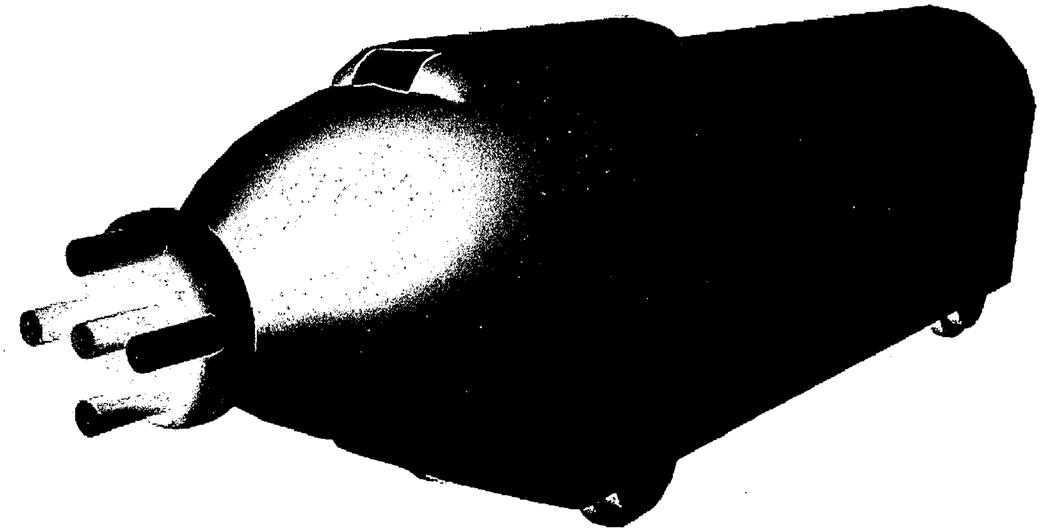

PERMANENT MAGNET PROPULSION SYSTEM

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is a propulsion system for a train that utilizes spinning cylindrical magnets in order to create a spacetime pressure distortion ahead of the vehicle that pulls the locomotive along the track.

BACKGROUND OF THE INVENTION

[0002] At the present time, referring to **FIG. 1**, proposed permanent magnet propulsion systems use a dual railway track (A) supporting a series of coil windings (B) located along the track. The vehicle is attached to two permanent magnets (D) between steel pole pieces (C). The north pole of each magnet faces the interior pole piece such that the magnetic flux path (E) follows the center pole piece up through the railway bed and then back to the south pole of the magnet. As the magnets move along the track, the coil windings are activated at the correct time by Hall sensors. With the coil energized as a north pole, the permanent magnet north pole is repelled which drives the vehicle along the track The problem with this design, and other similar designs, is that it is not practical to wind huge numbers of sensor-activated electrical coils along a steel track.

[0003] From Einstein's General Theory of Relativity, it is known that a spacetime curvature pressure develops perpendicular to direction of vibration of the electric and magnetic field. As an example, the photon has an electric field vibrating in the vertical y-direction and a magnetic field vibrating in the horizontal x-direction. The spacetime curvature pressure is therefore along the z-axis of radiation which pushes the negative mass of the photon along. Thus in order to create a spacetime curvature pressure in the z-direction along the track which would pull the train forward, a magnetic flux density field is required in the radial direction.

[0004] Referring to **FIG. 2**, four equally-spaced north permanent magnets (B) surrounding a centrally-located south permanent magnet (C) are mounted on an iron cylinder which acts as the radial flux return path. The magnetic flux density field (D) is in the radial direction from the north pole to the south pole. In order to provide strength, the magnets are molded onto a steel shaft and coated with epoxy so that they don't rust. During the molding process, a capacitor-discharge magnetizer is used to create the magnetic field of the magnet.

[0005] In Cartesian coordinates {−ct,x,y,z}, the elemental spacetime length ds squared is the sum of the squares of the incremental lengths {cdt,dx,dy,dz}

$$(ds)^2=-(dt)^2+(dx)^2+(dy)^2+(dz)^2$$

where the speed of light c is unity. The coefficients (−1,1,1,1) of this equation make up the g metric 4×4 tensor

$$g_{\alpha\beta}=\begin{array}{c|cccc|} & [t & x & y & z] \\ t & -1 & 0 & 0 & 0 \\ x & 0 & 1 & 0 & 0 \\ y & 0 & 0 & 1 & 0 \\ z & 0 & 0 & 0 & 1 \end{array}$$

[0006] The Faraday electromagnetic tensor contains the magnetic fields which determine how the spacetime length ds is curved. For a magnetic flux density field in the x-direction, Bx, and a magnetic flux density field in the y-direction, By, the Faraday tensor is

$$F^{\alpha}_{\beta}=\begin{array}{c|cccc|} & t & x & y & z \\ t & 0 & 0 & 0 & 0 \\ x & 0 & 0 & 0 & -By \\ y & 0 & 0 & 0 & Bx \\ z & 0 & By & -Bx & 0 \end{array}$$

The stress-energy-momentum tensor T, which determines how space is curved, is calculated from the following equation

$$4\pi T^{\mu\nu}=F^{\mu\alpha}F^{\nu}_{\alpha}-\frac{1}{4}g^{\mu\nu}F_{\alpha\beta}F^{\alpha\beta}$$

The stress-energy in the z-direction ahead of the locomotive is

$$T^{zz}=\frac{B_x^2+B_y^2}{8\pi}=\frac{B_r^2}{8\pi}$$

where the sum of the squares of the fields in the x and y directions is the radial B field. In Einstein's General Relativity Theory, the curvature G tensor is equal to the stress-energy tensor divided by 8π. The G tensor is the curvature of space having units of inverse radius squared.

$$G=\frac{T}{8\pi}$$

Therefore the curvature G_{zz} generated along the z-direction ahead of the train is proportional to the square of the magnetic flux density field

$$G_{zz}=\frac{1}{r^2}=\frac{G\varepsilon}{c^2}\frac{B_r^2}{8\pi}=\frac{1}{meter^2}$$

where G is Newton's gravitational constant (not to be confused with the curvature tensor), ϵ is the linear capacitance of space, and c is the speed of light. The linear mass of space Ω is the speed of light c squared divided by the gravitational constant G, so that the equation can be written as

$$\frac{G\varepsilon}{c^2}\frac{B_r^2}{8\pi}=\frac{\varepsilon}{\Omega}\frac{B_r^2}{8\pi}=\frac{1}{\frac{\Omega}{\varepsilon}}\frac{B_r^2}{8\pi}$$

where the conversion factor is the square of the magnetic vector potential A

$$\sqrt{\frac{\Omega}{\varepsilon}} = \frac{\text{kgm}}{seccoul} = A$$

which is actually the momentum per charge. Therefore the curvature equation can be written as

$$\frac{1}{r^2} = \frac{1}{8\pi}\left(\frac{B_r}{A}\right)^2$$

This equation shows that it is necessary to create a magnetic vector potential together with the radial magnetic flux density field in order to create a curvature of space. Looking at the units of A shows that it is a mass momentum per charge

$$A = \frac{\text{kg}}{sec}\frac{m}{coul} = \frac{m\omega^2 r}{I}$$

or a mass m rotating with angular velocity c) per current along the radius. In terms of the invention, what this means is that the mass of the iron cylinder has to be rotating and there has to be a radial electrical current I in order to produce the linear charge along the radius. The differential mass dm depends on the circumference times the differential radius dr, the mass density p, and the length L of the cylinder

$$dm=\rho 2\pi rLdr$$

so that the magnetic vector potential becomes

$$A = \int_0^R \frac{\rho 2\pi rL\omega^2 r}{I}dr = \frac{2}{3}R^3\rho\pi L\frac{\omega^2}{I}$$

The value of A for the iron cylinder is

$$L = .2m$$

$$\rho = 7866\frac{kg}{m^3}$$

$$R = 1m$$

$$\omega = 2\pi f = 6.28\ \text{sec}^{-1}$$

$$I = 3000000\ \text{amp}$$

$$A = .04335\frac{kgm}{\text{sec}coul}$$

$$Br = 1.2tesla$$

$$\frac{1}{8\pi}\left(\frac{Br}{A}\right)^2 = 30.47m^2$$

$$r_{curvature} = \sqrt{8\pi}\left(\frac{A}{Br}\right) = .181m$$

What makes this possible is that the new N-machines can easily generate a minimum of 6 million amps which is twice the value of the electrical current above.

[0007] Referring to **FIG. 3**, the assembly consists of a large induction motor (A) mounted on the train's base plate (B) driving a motor shaft (C) attached to the iron cylinder (D). The shaft is held in place by two thrust bearings mounted in two pillow blocks (E,F). The current-generating N-machine (G) is electrically connected by a copper bus (H) to a copper-beryllium brush (I) on the motor shaft with a similar return brush (J) on the edge of the iron cylinder. The current (K) flows through the motor shaft to the center of the rotating cylinder and then radially outward to the edge. The magnetic flux density flows from the north poles of the outer permanent magnets to the central south pole, along the central magnet to the center of the rotating cylinder and then radially outward to the south poles of the outer magnets.

[0008] The thrust F developed is the radius of curvature of spacetime r_c calculated above times the magnet flux density field times the current I

$$F = \frac{r_c B_r I}{\sqrt{8\pi}} \approx 30000lbf$$

Using conservation of tensor coordinates, the radius of curvature is in the z-direction, the magnetic flux density field is in the radial direction and the current is in the radial direction

$$F^z = x^z B_r I^r$$

where the radial indices cancel, leaving the z-index as the direction of the force.

SUMMARY OF THE INVENTION

[0009] It is the object of this invention to create a spacetime curvature in front of a train locomotive in order to pull the vehicle along the track It is known from gravitational physics that a spacetime curvature is generated perpendicular to the direction of vibration of the electric and magnetic field. A radial magnetic field, which can be produced by permanent magnets attached to the flat faces near the rim of a iron cylinder rotating about the z-axis, will create a curvature in the z-direction. Four cylindrical north-pole-oriented magnets produce a radial magnetic flux density with is channeled into a central cylindrical south-pole-oriented magnet. The flux lines then flow radially outward through the steel rotating cylinder and reconnect with the south poles of the four outer magnets. The rotating iron cylinder generates the equivalent of a magnetic vector potential when an electrical current flows from the center of the cylinder to the edge. This current is generated by an N-machine current generator. The square of the magnetic flux density divided by the magnetic vector potential is equal to the spacetime curvature. The square root of the inverse of the spacetime curvature is the radius of curvature. The thrust developed is this radius of curvature times the magnetic flux density field times the current.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1**. Perspective view of proposed permanent magnetic propulsion system using coil windings on the steel track.

[0011] **FIG. 2**. Perspective view of permanent magnet rotor assembly.

[0012] **FIG. 3**. Perspective view of system showing motor drive, N-machine and permanent magnet rotor.

[0013] **FIG. 4**. Perspective view of locomotive and rotor/magnet assembly.

DETAILED DESCRIPTION OF THE INVENTION

[0014] 1. The permanent magnets are made of neodymium-iron-boron material which is heated to its melt temperature and injection molded around a steel shaft threaded at one end while at the same time a pulsed magnetic field is applied to the material using a charge-discharge magnetizer. Because of the iron in the material, a coat of epoxy is applied to the magnet in order to protect it from the environment. Holes are drilled into the iron plate 90° apart near the rim, threaded, and then the steel shaft with the magnet is then inserted. Another hole is drilled and tapped in the center of the circular plate for attaching the south pole magnet which is used as the return path for the magnetic flux.

[0015] 2. Another easier way to make the magnets is to purchase short lengths of tubular NdFeB magnets and then stack them on the steel shaft with a cylindrical iron pole piece on the end of the shaft. The pole piece then holds the magnets down in place when the shaft is threaded into the plate.

[0016] 3. Referring to **FIG. 4**, the propulsion system is mounted inside the train cabin such that the rotor/magnet assembly extends out in front of the locomotive where the spacetime curvature is generated.

I claim:

1. A train propulsion system consisting of the following components:

a. a rotating iron cylindrical plate rotor of high relative permeability driven by an induction motor and horizontal steel motor shaft mounted in pillow block thrust bearings;

b. four cylindrical magnets, each molded to a steel support shaft threaded into the iron plate at 90° intervals around the rim of the plate with their north poles facing away from the plate;

c. a fifth cylindrical magnet molded to a steel support shaft which is threaded into the center of the iron plate with the south pole facing away from the plate;

d. an N-machine current generator supplying a radial electrical current from the center of the rotating plate by means of a copper-beryllium brush on the motor shaft (**1**a) and another similar brush on the outside edge of the rotor.

e. a locomotive train on which the components are mounted such that the rotor/magnet assembly extends out in front of the locomotive with the rotor's angular velocity vector pointing along the track.

2. a closed magnetic flux path along a radial path in air from the north poles of the four outer magnets (**1**b) to the south pole of the central magnet (**1**c), through the center magnet and then radially outward through the rotor (**1**a), returning back through the four outer magnets, such that the flux and electrical current (**1**d) flow in the same outward radial direction through the rotor.

3. the creation of a spacetime curvature due to claims (**1**a through **2**) that produces a large force on the locomotive equal to the radius of the spacetime curvature times the flux times the current.

* * * * *

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(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0180473 A1**

St. Clair (43) **Pub. Date: Aug. 17, 2006**

(54) **WATER ENERGY GENERATOR**

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(21) Appl. No.: **11/060,037**

(22) Filed: **Feb. 17, 2005**

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C25D 5/34 (2006.01)
(52) **U.S. Cl.** **205/210**

(57) **ABSTRACT**

A water energy generator that generates electricity using a magnetic vortex wormhole generator and a water injector/vacuum chamber to produce low density hyperspace energy that causes the hydrogen atoms of water molecules to decay into electron pairs.

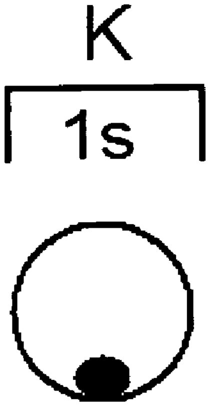

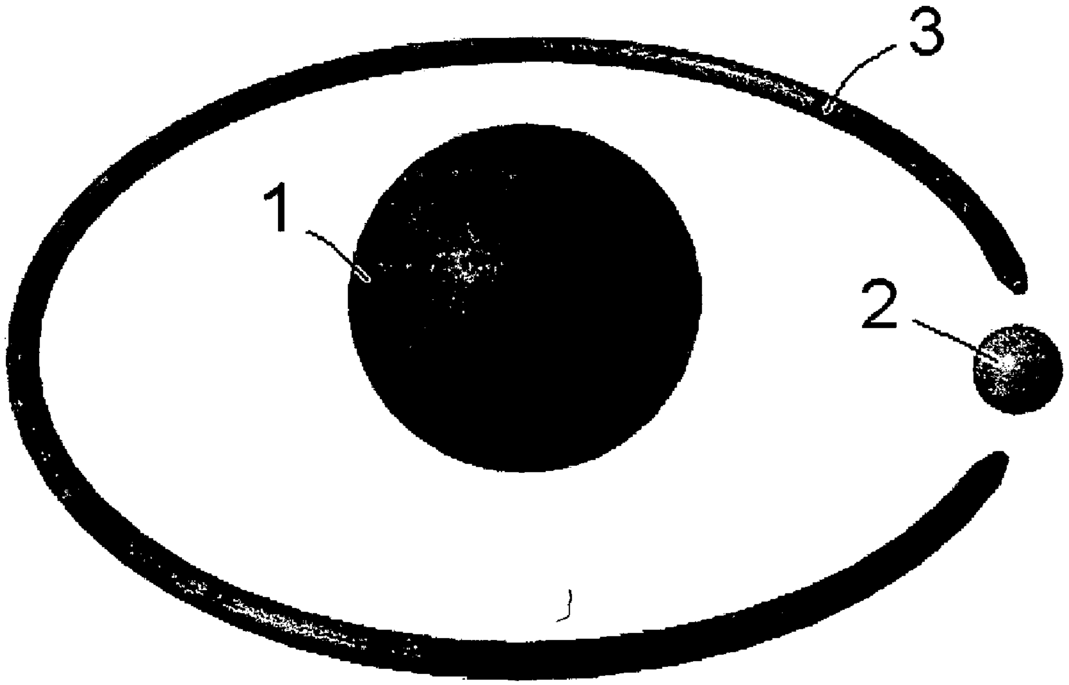

Figure 1

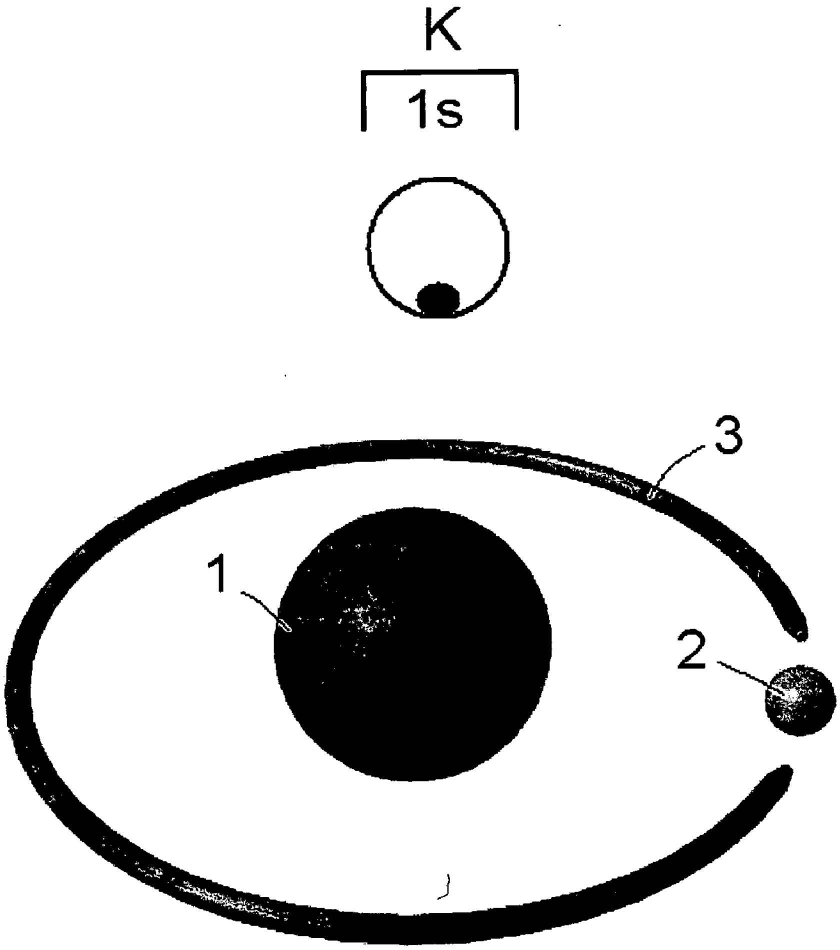

Figure 2

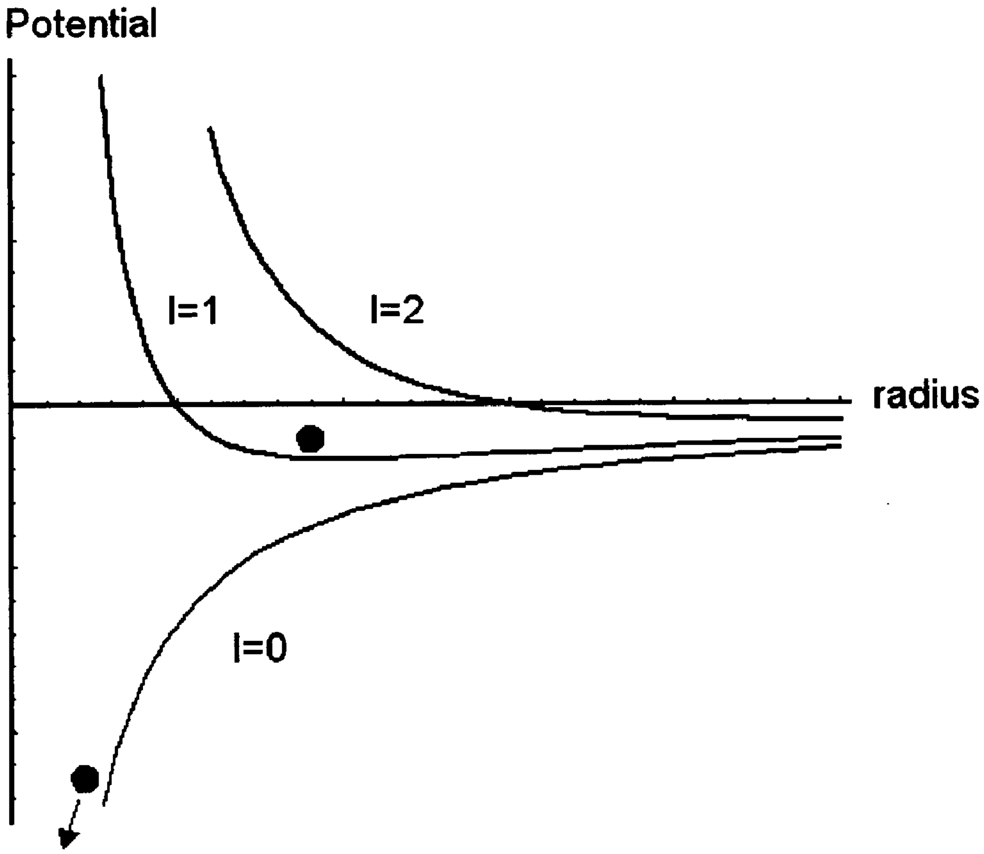

Figure 3

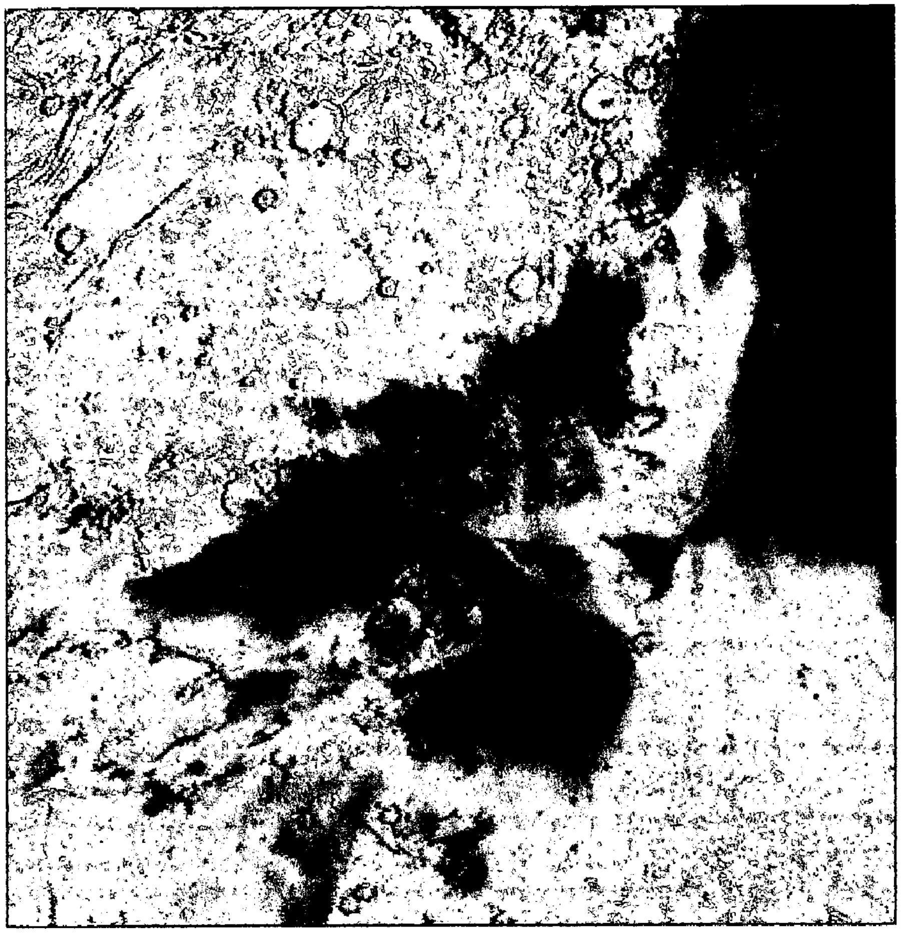

Figure 4

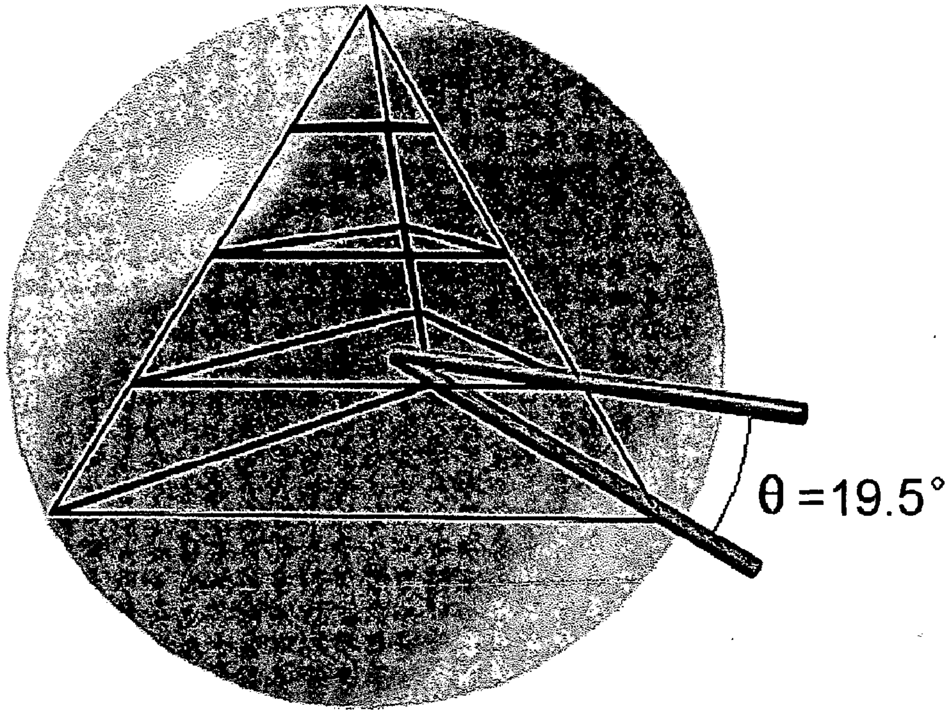

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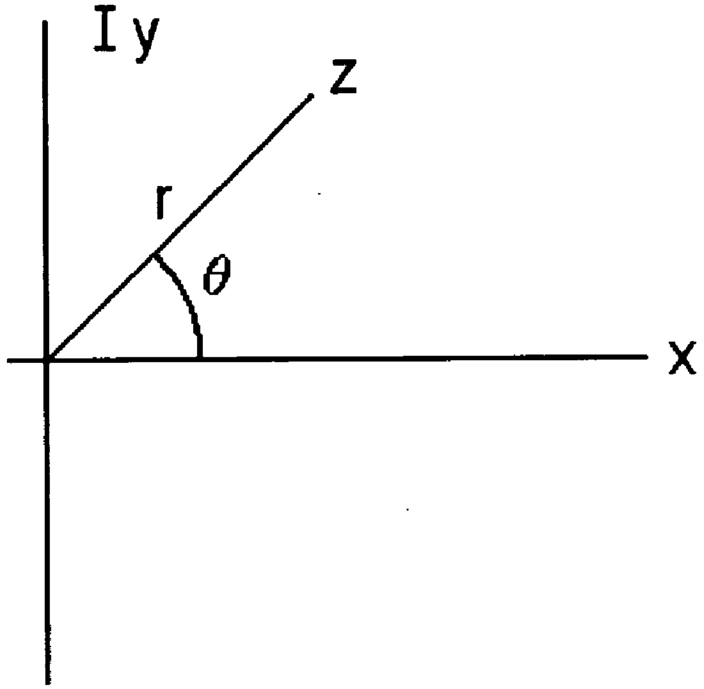

Figure 6

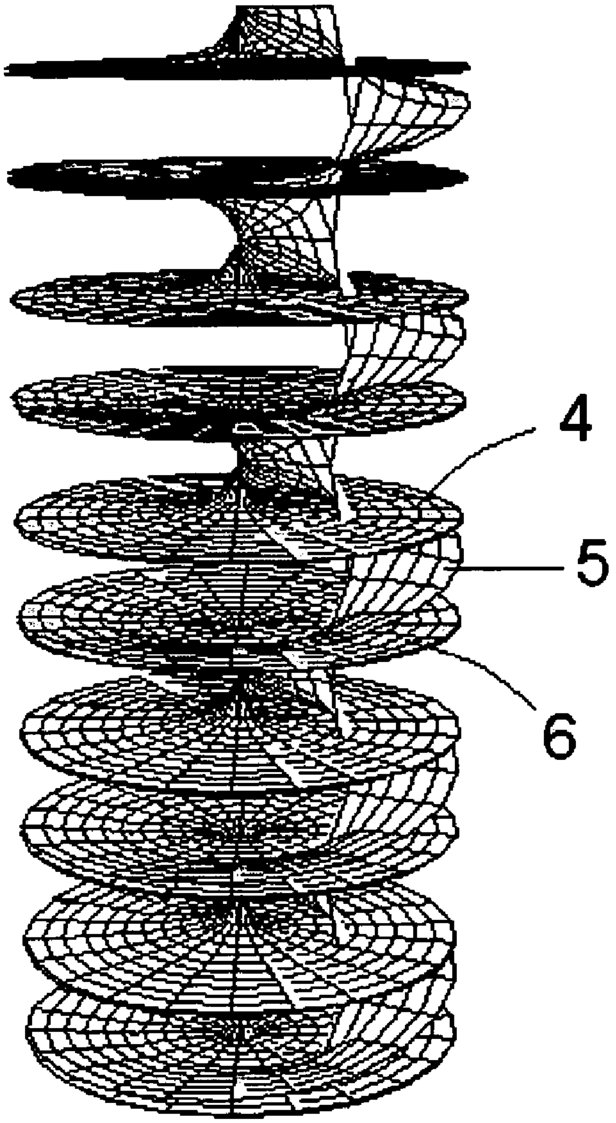

Figure 7

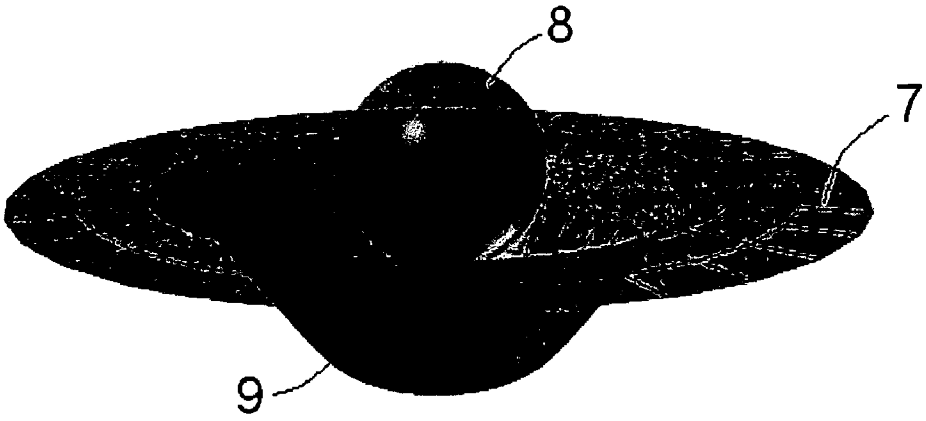

Figure 8

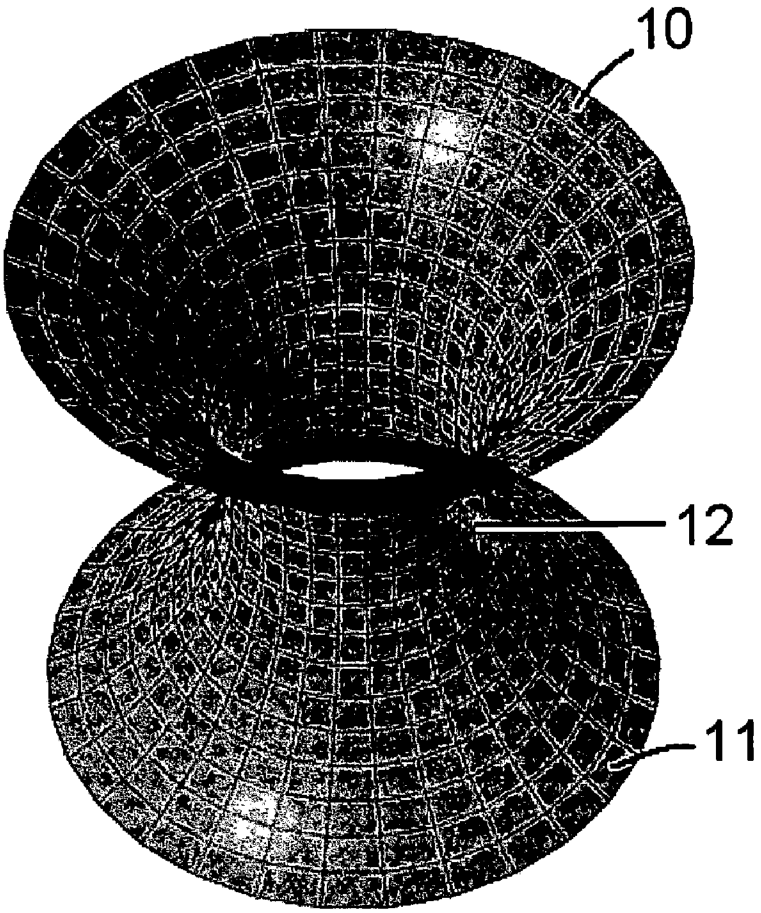

Figure 9

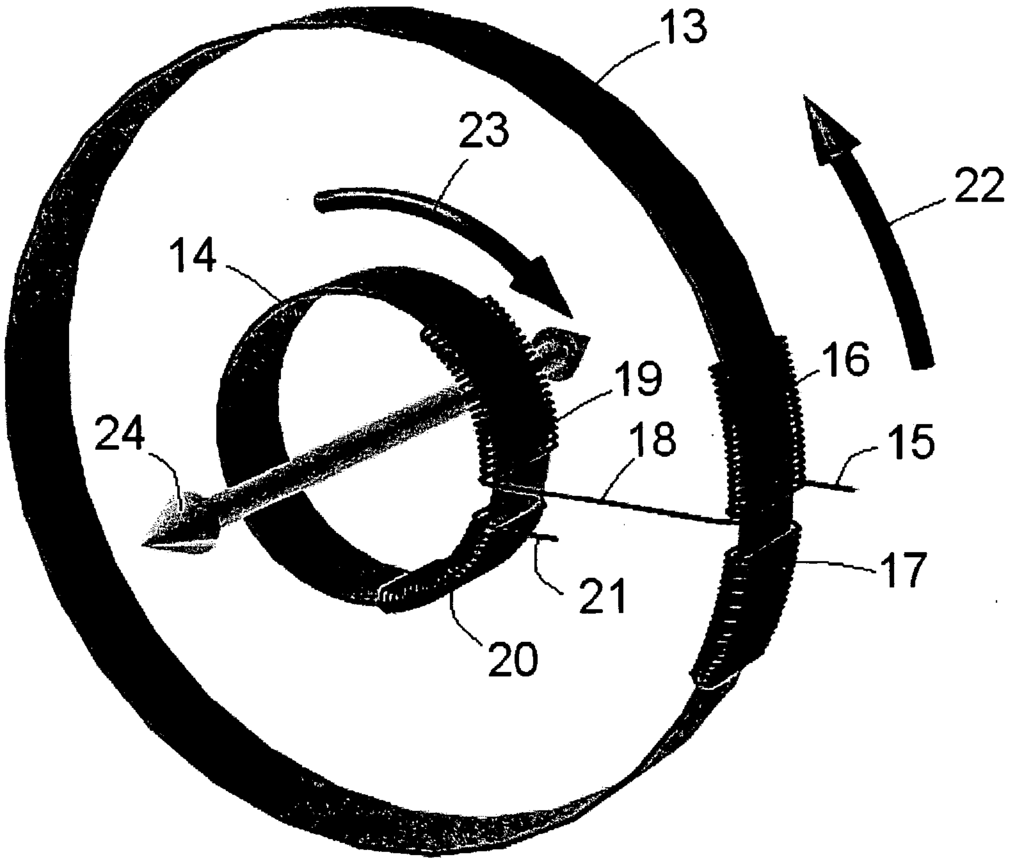
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Figure 10

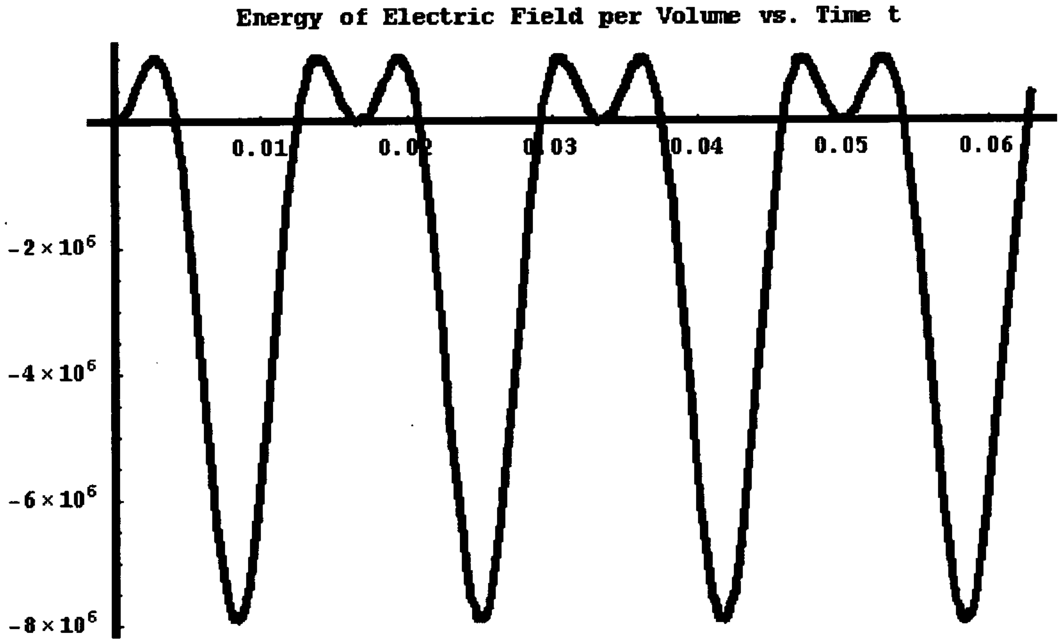
Energy of Electric Field per Volume vs. Time t
0.01
0.02
0.03
0.04
0.05
0.06
-2 × 10^6
-4 × 10^6
-6 × 10^6
-8 × 10^6

Figure 11

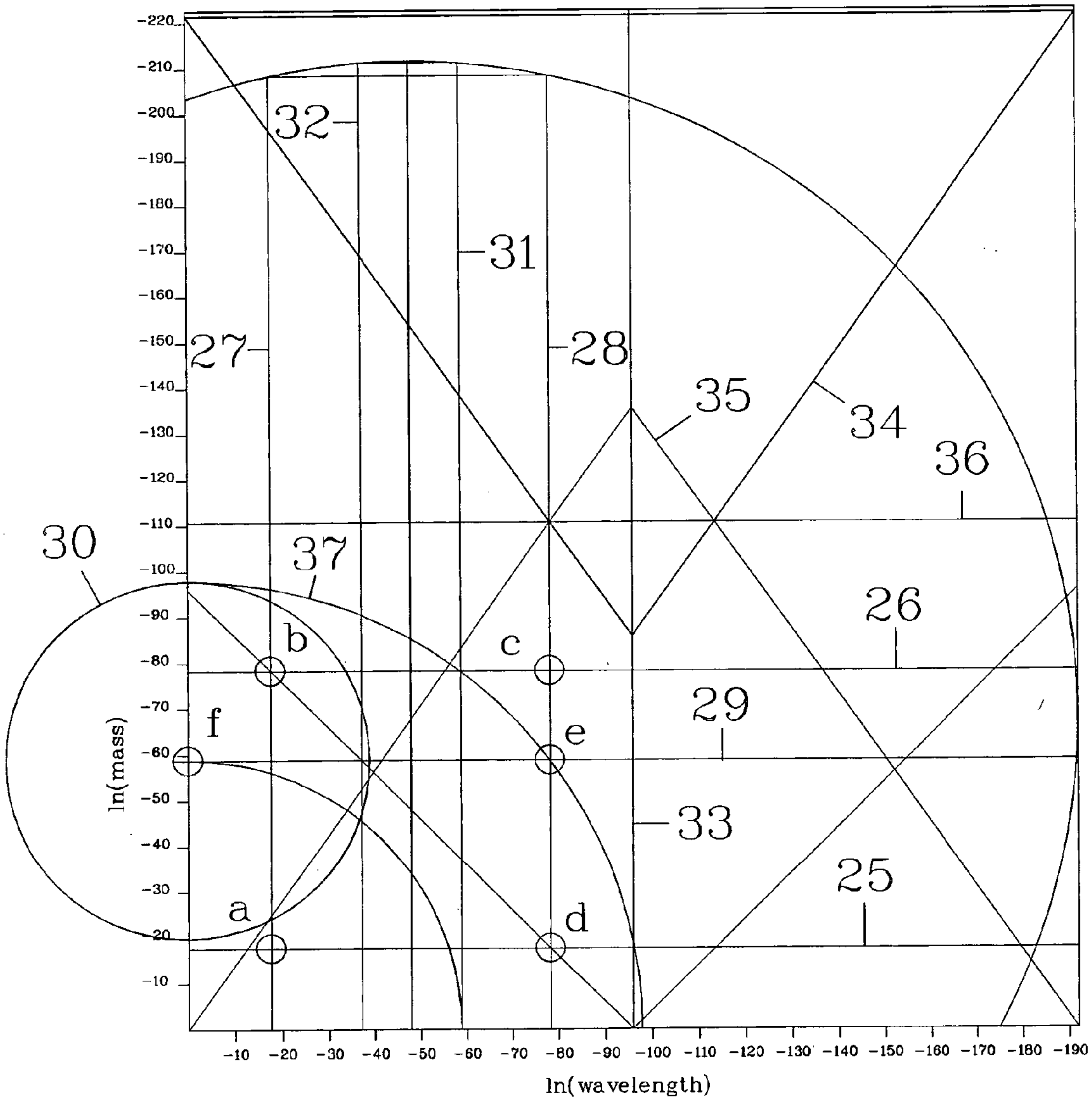
-220
-210
-200
-190
-180
-170
-160
-150
-140
-130
-120
-110
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
ln(mass)
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
ln(wavelength)
32
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25
a
b
c
d
e
f

Figure 12

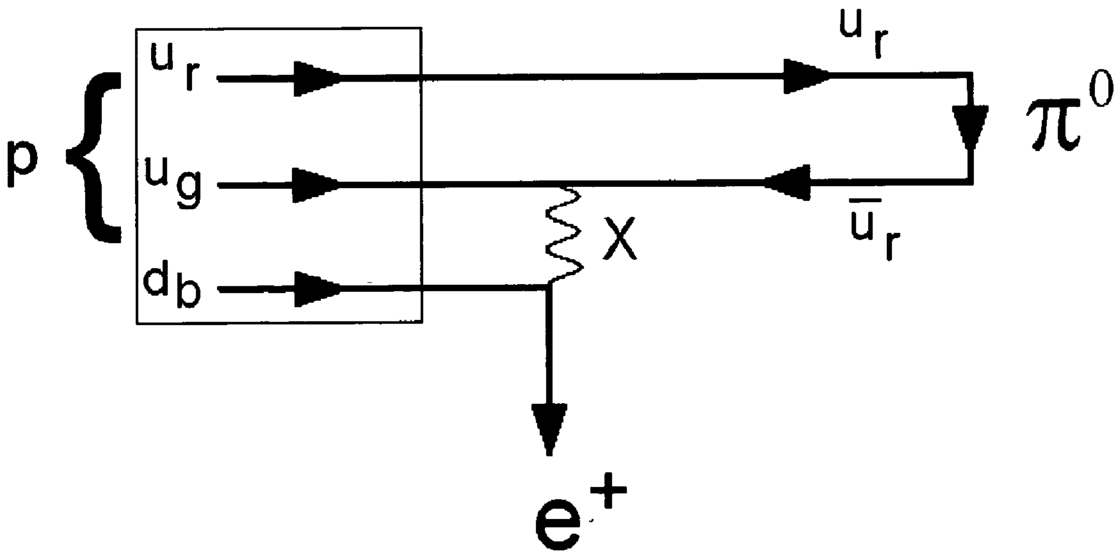
p
u_r
u_g
d_b
u_r
π^0
$\bar{u}_r$
X
e^+

Figure 13

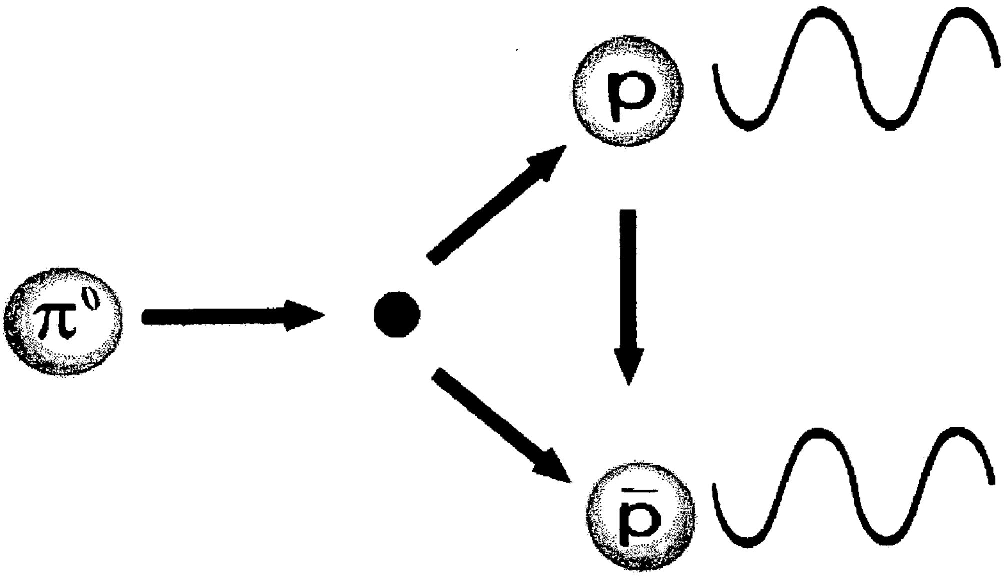

Figure 14

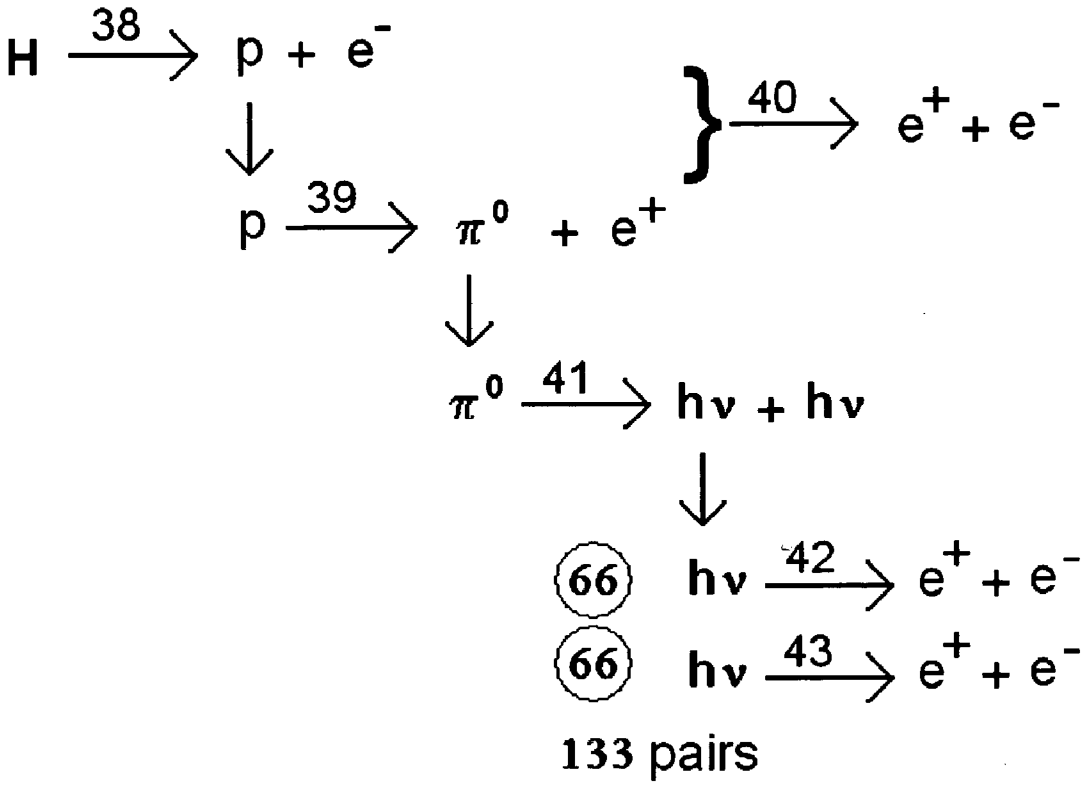
H 38 → p + e⁻
p 39 → π⁰ + e⁺
40 → e⁺ + e⁻
π⁰ 41 → hν + hν
66 hν 42 → e⁺ + e⁻
66 hν 43 → e⁺ + e⁻
133 pairs

Figure 15

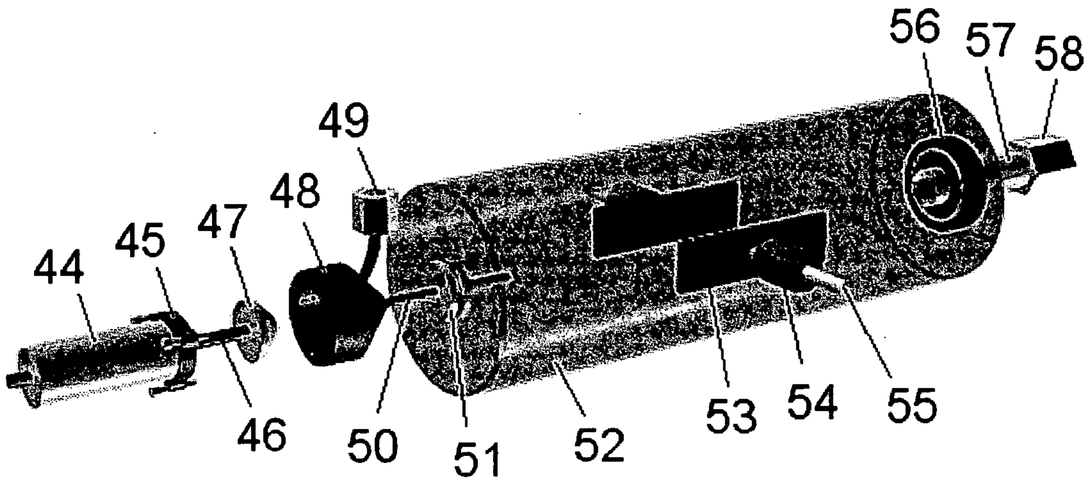
44
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Figure 16

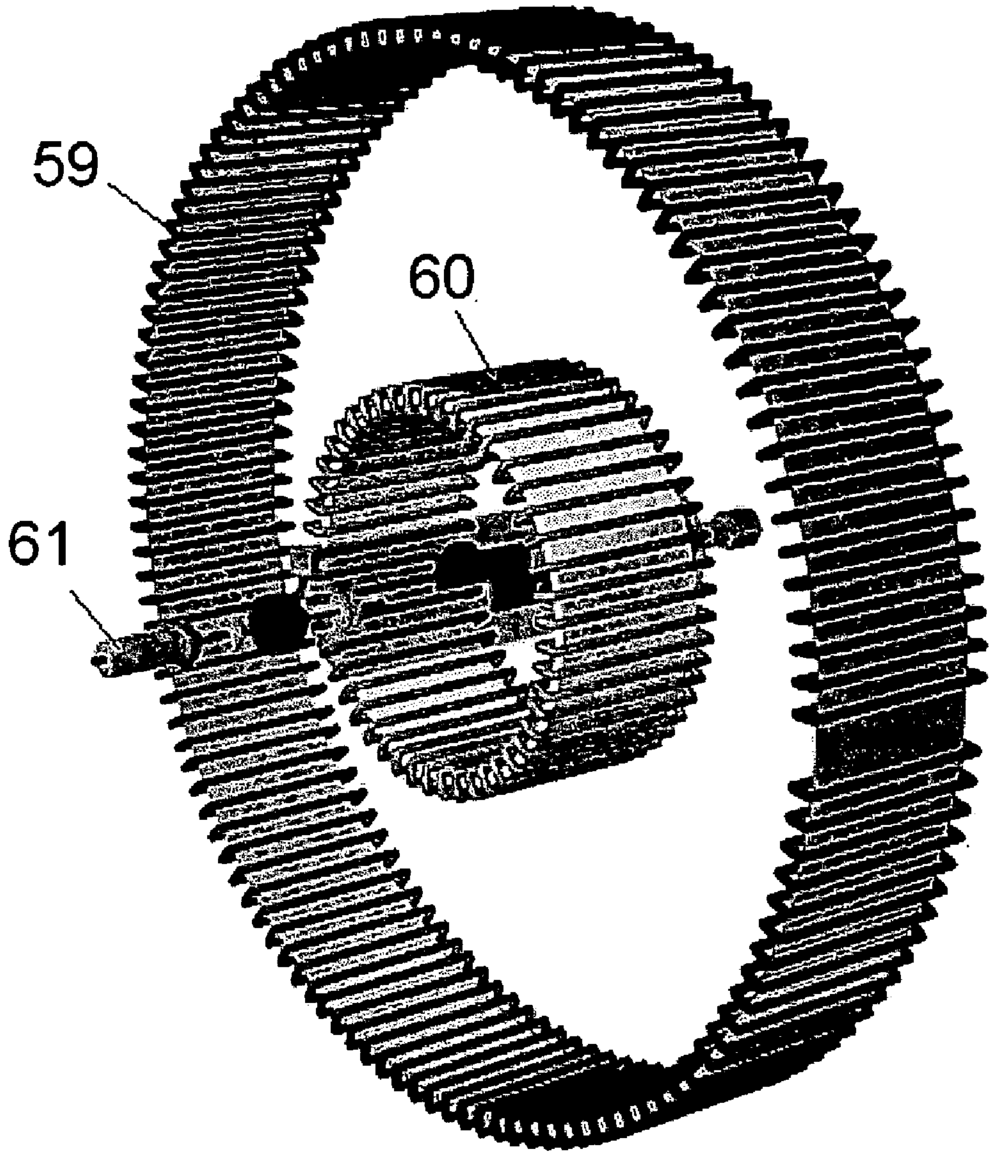

Figure 17

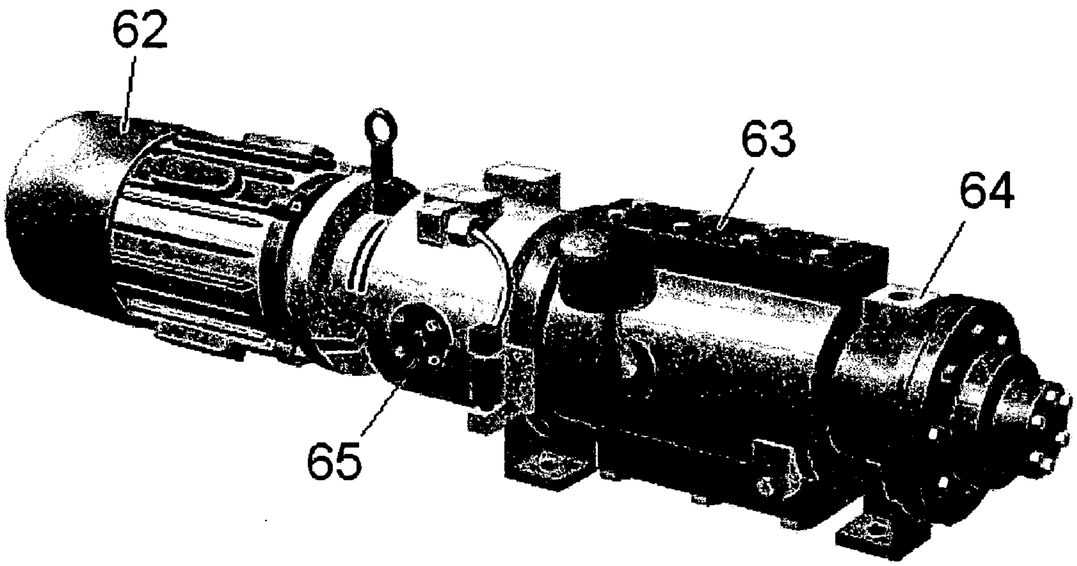

WATER ENERGY GENERATOR

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is an energy generator that uses the transition through wormholes of the hydrogen atoms of water molecules to break the bonds of the atoms and convert the protons into photons and electrons which can be collected for energy.

BACKGROUND OF THE INVENTION

[0002] A molecule of water consists of two hydrogen H atoms and one atom of oxygen O which has the chemical formula

H_2O

The hydrogen atoms can be separated from the oxygen atom by electrolysis. In this process, a direct current of electricity, such as from a battery, is passed through water decomposing it into hydrogen and oxygen. Pure water, however, is a poor conductor of electricity. It is therefore necessary to add some substance to form a solution that will conduct an electric current. Such a solution that will conduct electric current is called an electrolytic solution. A small amount of sulfuric acid or sodium hydroxide is added to the water to form an electrolytic solution. Water electrolyzed yields hydrogen plus oxygen

Water->hydrogen+oxygen

$2H_2O \rightarrow 2H_2+O_2$

Because this invention is to be used on spacecraft, the oxygen can be used for breathing and the hydrogen can be used to produce energy that will be used to create the electromagnetic fields which provide lift and propulsion.

[0003] Referring to **FIG. 1**, a single hydrogen atom consists of one proton (1) in the nucleus and one electron (2) moving in an orbital (3) around the nucleus. In quantum physics notation, there is only one main K shell and one orbital containing a single electron in the 1 s subshell. An orbital is an energy level containing one or two electrons in a subshell of an atom. Only a total of two electrons may be placed in one orbital with the added constraint that the electrons spin in opposite directions. Looking at the 1 s orbital, it can be seen that only half of it is occupied. What this means is that it is possible to add another hydrogen atom in which its electron occupies the other position in the orbital to from the hydrogen molecule H_2.

[0004] In 1925, a physicist by the name of Edwin Schrodinger developed a wave equation, which bears his name, that models the hydrogen atom. Even though the classical picture of **FIG. 1** showing a distinct electron orbiting the proton is easy to visualize, in reality the electron is a wavefunction Ψ whose square indicates the probability of finding the electron at a particular point. This then was the start of quantum physics where it was found that the electron energy can only take on certain discrete values.

[0005] A traveling wave moving in the positive x-direction can be represented by the function $\Psi_1=\Psi_1(x,t)$ of the form

$$\Psi_1=A_1\cos(2\pi(x/\lambda-v\,t))$$

where x is the distance along the x-axis, A the wave amplitude, λ the monochromatic wavelength, v the velocity of the wave and t time.

[0006] A similar monochromatic wave moving to the left can be represented by

$$\Psi_2=A_2\cos(2\pi(x/\lambda+v\,t))$$

where the sign of the velocity is reversed. The superposition of these traveling waves results in a standing wave, or stationary waves, of the form

$$\Psi=\Psi_1+\Psi_2=A\cos(2\pi x/\lambda)\cos(2\pi v\,t)$$

which is now a product of a spatial-dependent term A $\cos(2\pi x/\lambda)$, and a time-dependent term $\cos(2\pi v\ t)$. Taking the partial derivative of Ψ twice with respect to x

$$\frac{\partial^2\Psi}{\partial x^2}=-\left(\frac{2\pi}{\lambda}\right)^2\Psi$$

The momentum p of a particle is equal to Planck's constant h divided by the mass m of the particle

$$p=h/\lambda=\frac{2\pi\hbar}{\lambda}$$

where h bar is the reduced Planck constant. Thus Schrodinger's equation can be written as

$$\frac{\partial^2\Psi}{\partial x^2}=-\frac{p^2}{\hbar^2}\Psi$$

For a particle whose potential energy is V(x), the total energy is the kinetic energy K plus the potential energy

$$E=K+V=(p^2/2m)+V$$

Therefore,

$$p^2=2\ m\ (E-V)$$

and Schrodinger's equation becomes

$$\frac{\hbar^2}{2m}\frac{\partial^2\Psi}{\partial x^2}+(E-V)\Psi=0$$

The potential V is just the Coulomb potential of the product of two charges e divided by the radius r between them

$$V=\frac{e^2}{4\pi\varepsilon r}$$

where ϵ is the linear capacitance of space. A general wavefunction can be separated into a radial R part and a spherical harmonics part Y

$$\Psi=R_{n,1}Y_{1,m}(\theta,\phi)$$

where the first term is called a radial wavefunction which describes the "in-out" motion of the electron. When Schrodinger's equation is separated, it is found that the radial part of the wavefunction, R, must be a solution of the quantized differential equation

$$\frac{\hbar^2}{2mr}\frac{d^2(rR)}{dr^2}+\left(E-\frac{l(l+1)\hbar^2}{2mr^2}+\frac{e^2}{4\pi\varepsilon r}\right)R=0$$

This can be expressed in a simpler form by defining the function

f=rR

which is then found to satisfy the equation

$$\frac{\hbar^2}{2m}\frac{d^2f}{dr^2}+(E-V_{eff})f=0$$

where the effective potential is given by

$$V_{eff}=\frac{l(l+1)\hbar^2}{2mr^2}-\frac{e^2}{4\pi\varepsilon r}$$

where the 1's are the quantum orbital numbers. For s orbitals equal to 1=0, the effective potential is just the electrostatic potential of the nucleus. For 1 greater than zero, the first term is equal to the kinetic energy owing to the angular motion of the electron at a distance r and with angular momentum √1(1+1)h.

[0007] Referring to **FIG. 2**, the effective potential is graphed as a function of radius r and the orbital numbers. For orbital number l=0, which is the lower of the three curves, the potential does not provide a stable position for the electron (black disk) and the negatively-charged electron just crashes into the positively-charged proton nucleus as shown by the arrow. For orbital l=1, the first term is called the centrifugal repulsion which together with the electrostatic potential provides for a stable position for the electron as seen in the middle curve. The potential energy is negative which creates a slight valley in which the electron obtains a stable orbit. Higher orbital numbers l=2 produce a similar valley potential further out on the radius. The l=1 orbital does not allow the electron to come near the proton which provides for a stable hydrogen atom. So the key to this invention is how to destabilize this hydrogen atom energy system and produce usable energy which can propel the electromagnetic spacecraft and run other hyperspace inventions. Refer to my patent applications such as Dipole Moment Spacecraft, Dual Potential Hull Spacecraft, Photon Spacecraft, Electromagnetic Field Propulsion System, Full Body Teleportation, Magnetic Vortex Wormhole Generator, Electric Vortex Wormhole Generator, Sulfur S8 Wormhole Generator, Cavitating Oil Hyperspace Energy Generator, Rotor Inductance Propulsion System and Triangular Spacecraft.

[0008] Many of these patent applications involve wormholes and hyperspace which are not well-known concepts in the scientific community. Hyperspace consists of those dimensions which are co-dimensional with our spacetime. The reason I know about hyperspace is because (1) I have been in hyperspace on a number of occasions and have experienced Einstein's time dilation according to his General Theory of Relativity, (2) I have experienced more than one full-body hyperspace teleportation over a distance of 100 meters, (3) we have been able to create a wormhole between space and hyperspace with the magnetic vortex wormhole generator in which smoke was blown through one side of the coil into hyperspace, a first contact verified by the Grey Aliens, (4) I have seen the green mist associated with moving out of dimension and crossing over into hyperspace, (5) I have looked into another dimension and have seen another building, a car and a man who waving at me in the presence of an artificially-intelligent Cyborg with the "high-tech look" from the Pleiadian Defense Department, (6) I can remote view through hyperspace subgeometry to distances of 100,000 light years to the edge of the galaxy and have made first contact with around 500 extraterrestrial civilizations involving the use of patent applications such as Remote Viewing Amplifier, Quantum Dot Energy Cylinder and Walking Through Walls Training System, (7) I am the only person on Earth who has communicated with the designers of the crop circles found in England and explained their design to them in terms of subspace geometry, (8) I can walk through walls as a hyperspace energy being, and (9) I have discovered how anti-gravity is possible using low density hyperspace energy, not to mention all the other research work on these electromagnetic field propulsion vehicles. For my work in developing the geometry of the subspace manifold known as the tetrahedron diagram, I was given the Aphysics award by the Admiral, who is third in line to the Admiralty of the Pleiadian Defense Department. For my work in Revelations, she awarded me four beautiful galloping white riderless horses of the Apocalypse. The reason that the Pleiadian Defense Department was involved was that the Admiral had the task of creating the energy being that would protect the subspace manifold during the battle of Revelations which took place in the year 2001. So these are some of my personal experiences in the field of hyperspace physics.

[0009] As to the scientific aspect of hyperspace physics, observations of the solar system have noted that large vortices occur on the planets at a latitude of ±19.5°. On the planet Jupiter, for example, the Giant Red Spot vortex, which is the size of two planets like Earth, is located at −19.5° latitude.

[0010] Referring to **FIG. 3**, the Olympus Mons volcano, which is the size of France, occurs in the northern hemisphere at 19.5°. The plume of volcanic ash can be seen being blown to the upper right.

[0011] Here on Earth, just north of me at +19.5° in the Caribbean, there is a slow moving rock mantle vortex that curves the islands down toward Venezuela. Since the tetrahedron has three corners, another corner occurs at 120° to the west where the Marshall Islands are located. The reason that the volcanic islands form is that low density hyperspace energy softens the atoms and molecules to such an extent that the atomic bonds are broken. The hot magma from the core has an easier path to the surface through the soft rock compared to the hard rock of surrounding areas. As the vortex rotates, the rising hot magma creates volcanoes which form the chain of islands.

[0012] As another example of this, the Silver bridge, which is located at a double harmonic of 39° between Ohio and West Virginia, collapsed because a large wormhole opened up and flooded the bridge with low density hyperspace energy. The metal rivets softened and pulled out of the plates holding down the suspension cables. Thus the roadway tilted to one side and all the cars fell into the river.

[0013] If you look at the quarried granite polygonal megalithic stone blocks that were used to build Machu Picchu, the blocks are put together as though they were soft putty. They fit together perfectly. Machu Picchu, or Great Picchu, is the Quichua name for a sharp peak which rises ten thousand feet above the sea. How this was achieved is described in my patent application *Rotating Magnetic Vortex Generator* which shows that rotating permanent magnets can create a wormhole between space and hyperspace. The low density hyperspace energy then floods the block as to make it weightless. The block is then floated up from the quarry which is 2500 feet below Machu Picchu. The huge 1000-ton blocks found in the platform at Baalbek in the Cedar Mountains of Lebanon were also lifted into position in this manner.

[0014] Using a technique called Chi Kung breathing, not necessarily known to the Chinese, one of our researchers has been able to levitate himself to a height of six feet. He might have gone higher but he lost his balance and his arm touched a nearby metal pipe. He then floated back to the ground. Contracting the abdominal muscles causes hot air to rise in the lungs while at the same time cold air is inhaled through the nose. This combination of hot and cold air mixing together creates environmental oscillators having a temperature fluctuation. This changes Planck's constant such that the body goes out of dimension and low density hyperspace energy fills the body.

[0015] The final example comes from Biblical times. Jesus and his father Joseph were both carpenters. A chair that Joseph had made for a client was found to be too small. So Jesus placed his hands on either side of the chair and stretched the chair to fit. The phrase in Spanish is "mas silla" which means that Jesus made more chair. In the dictionary, the Spanish word for putty is "masilla." The reason that Jesus could do this is that he passed hyperspace energy through his hand vortices which softened the wood. See my patent application called *Hyperspace Torque Generator* which shows this in more detail. The hand vortex is actually a planar co-gravitational K field that can rotate a pendulum around in circles. This solenoidal field corresponds to the magnetic H field. The electric field corresponds to the linear gravitational g field. The equations are identical for both sets of fields. I learned that Jesus actually reincarnated here on Earth in order to identify the planet on which the battle of Revelations would take place.

[0016] In summary, these are some examples as to how low density hyperspace energy can soften and break the bonds of atoms and molecules.

[0017] As mentioned previously, the astronomical observations suggest that the structure of the universe is related to the tetrahedron. Referring to **FIG. 4**, the corners of a tetrahedron circumscribed by a sphere, touch the sphere at an angle of 19.47122063°. The ratio of the area-to-volume ratio of the sphere to the area-to-volume ratio of the tetrahedron is ⅓ which is the magic ratio in physics. The arcsin(⅓) is 19.47°.

[0018] In order for all the physics constants to be projected into our universe and the co-dimensional hyperspace dimensions, there has to be a tetrahedral subspace manifold. The only mathematical function which allows multiple rotations of the complex plane is the logarithmic function Log[z].

[0019] Referring to **FIG. 5**, the complex number z in the complex plane is equal to x+I y where x and y are real constants and $I^2=-1$. The complex number z can also be written in terms of a radius and an angle

$$z=r\ \mathrm{Exp}[I\ \theta]$$

Because the angle can rotate more than once in 2π m multiples, the complex number z is actually

$$z=r\ \mathrm{Exp}[I(\theta+2\pi\ m\ )]$$

Taking the logarithm of z

$$\mathrm{Log}[z]=\mathrm{Log}[r]+I(\theta+2\pi m)$$

[0020] Referring to **FIG. 6**, it can be seen that it is not possible to go around multiple times on the same surface due to a branch cut along the origin where Log[0] is undefined. What happens is that as you rotate around on surface (4) and get to the origin, you go down along the branch (5) to the next hyperspace plane (6). Thus the universe is composed of many hyperspace co-dimensions. From personal experience, I estimate that the distance separating the two dimensions is about 3 meters when I was looking into another dimension at the man waving at me. The physics is even more complicated because there is a Lorentz dimensional transformation in which higher dimensions appear smaller and lower dimensions appear larger. In one case I was looking at a huge mothership at a much higher dimension and it looked like a tiny toy model spacecraft. They fired a laser cannon at me, and I then curved space which made the beam change course. You can see why I was awarded the four horses.

[0021] The antilog of Log[z] is

$$e^{\mathrm{Log}[z]}=z=re^{I\ \omega t}$$

where the angle is the angular frequency ω times the time t. The subspace geometry remains stationary or fixed, but the projection of the antilog into our dimension generates a system which is frequency dependent. This is why we get oscillating fields.

[0022] From Einstein's General Theory of Relativity, it is known that various kinds of energy can curve spacetime such as mass, electromagnetic fields, angular momentum and electrical charge. The elemental spacetime length ds in cylindrical coordinates {t,r,θ,z}, known as the Schwarzschild metric, shows that spacetime can be curved using mass M and charge Q

$$(ds)^2=-(dt)^2\left(1-\frac{2M}{r}+\frac{Q^2}{r^2}\right)+\frac{dr^2}{\left(1-\frac{2M}{r}+\frac{Q^2}{r^2}\right)}+(rd\theta)^2+(dz)^2$$

where you can see that the elemental time dt is dilated by the mass M and the elementary radius dr is reduced. I have actually experienced this time dilation in which, as I was jumping into hyperspace, I was hit by a car which broke my shoulder. When I came back into dimension which appeared to be a few seconds later, I found that I had an 8-inch blood ring down the right side of my chest. My shoulder blade, which sticks up about two inches, is still broken to this day.

[0023] Referring to **FIG. 7**, flat space (**7**) can be curved (**9**) by a massive body (**8**) such as a planet. For example, the mass of the Earth gives space a negative curvature such that objects tend to fall toward the center of the mass (bowl). On the other hand, using electromagnetic fields, it is possible to produce a positive curvature such that a spacecraft rises by falling upward.

[0024] Referring to **FIG. 8**, if the fields are intense enough, then a wormhole (**12**) forms between space (**10**) and hyperspace (**11**). This depiction is called an embedding diagram because there is no open space going through the wormhole. An object traversing the wormhole moves along the surface from one dimension to another. In order to open the throat (**12**) of the wormhole, negative energy is required. Referring to my patent application Dual Potential Hull Spacecraft, negative energy is produced by the interaction of a microwave beam with an oscillating magnetic H field. In terms of differential forms mathematics, this is given as the Hodge Star * of the differential d of the wedge ^ product of the magnetic H field with the electromagnetic wave {B,E}

$$*d(H\wedge(B+E\wedge dt))=\frac{\partial(-\rho)}{\partial t}$$

which says that there is an increasing rate of change of negative energy (−ρ). Due the presence of negative energy together with the spacetime curvature pressure produced by the electromagnetic fields, wormholes open up between space and hyperspace. There is a positive gravitational potential between hyperspace and space because the low density hyperspace energy is more dense than the negative energy in this dimension. Thus the hyperspace energy flows into our dimension which reduces the mass of the spacecraft. The upward spacetime pressure stress over the hull due to the electromagnetic fields creates a lift force on the nearly massless vehicle. Because the hyperspace energy has a speed of light equal to one meter per second, the electromagnetic fields become relativistically strong since they obey the Lorentz transformation. Due to the low mass, high spacetime lift pressure and strong EM fields, the vehicle can attain very high rates of acceleration.

[0025] Another method to produce a wormhole is to use bucking magnetic fields which is described in my patent application *Magnetic Vortex Wormhole Generator.* In gravitation physics, the Faraday F tensor, which is a 4×4 spacetime metric {t,x,y,z}, contains all the components of the electromagnetic fields in the various spatial directions {x,y,z}

$$F^{\alpha}_{\beta}=\begin{array}{c|cccc|}
t & 0 & E_x & E_y & E_z\\
x & E_x & 0 & B_z & -B_y\\
y & E_y & -B_z & 0 & B_x\\
z & E_z & B_y & -B_x & 0
\end{array}$$

where contravariant index a refers to the rows, and the covariant index β refers to the columns. For example, the component $F^t_x=E_x$ is the electric field in the x-direction. If there were two magnetic bucking fields in the x-direction the Faraday tensor would be

$$F^{\alpha}_{\beta}=\begin{array}{c|cccc|}
t & 0 & 0 & 0 & 0\\
x & 0 & 0 & 0 & 0\\
y & 0 & 0 & 0 & B_x-B_x\\
z & 0 & 0 & -(B_x-B_x) & 0
\end{array}=\begin{vmatrix}0&0&0&0\\0&0&0&0\\0&0&0&0\\0&0&0&0\end{vmatrix}$$

which says that the Faraday tensor is zero. Thus no spacetime curvature is generated from two bucking magnetic fields at the same position. On the other hand, if the two bucking magnetic fields are concentric at different radii, then the Faraday tensor becomes

$$F^{\alpha}_{\beta}=\begin{array}{c|cccc|}
t & 0 & 0 & 0 & 0\\
x & 0 & 0 & 0 & 0\\
y & 0 & 0 & 0 & B_x\delta(x_1)-B_x\delta(x_2)\\
z & 0 & 0 & -(B_x\delta(x_1)-B_x\delta(x_2)) & 0
\end{array}$$

which is not zero due to the presence of the Kronecker δ delta function which locates the fields at different positions. The spacetime stress-energy-momentum tensor T is then computed from the following equation

$$4\pi T^{\mu\nu}=F^{\mu\alpha}F^{\nu}_{\alpha}-\frac{1}{4}g^{\mu\nu}F_{\alpha\beta}F^{\alpha\beta}$$

where g is the metric tensor containing the coefficients of the elemental spacetime length ds. With the mass M and charge Q term equal to zero, there being just electromagnetic fields involved, the g metric tensor in cylindrical coordinates becomes

$$g_{\alpha\beta}=\begin{array}{c|cccc|}
t & -\left(1-\frac{2M}{r}+\frac{Q^2}{r^2}\right) & 0 & 0 & 0\\
r\ \theta & 0 & \left(1-\frac{2M}{r}+\frac{Q^2}{r^2}\right)^{-1} & 0 & 0\\
z & 0 & 0 & r^2 & 0\\
 & 0 & 0 & 0 & 1
\end{array}$$

$$=\begin{vmatrix}-1&0&0&0\\0&1&0&0\\0&0&r^2&0\\0&0&0&1\end{vmatrix}$$

[0026] Referring to **FIG. 9**, the magnetic vortex generator has two concentric, thin, flat cylindrical silicon-iron cores (**13**,**14**), each consisting of a stack of three 0.020 inch thick transformer laminations wrapped with insulating tape. Using insulated magnetic wire, a flat helical coil (**16**) is wrapped counter-clockwise around the outer laminations. The coil receives power through connection (**15**). The winding then continues around the core until coil (**17**) where the wire (**18**) is extended to the inner core and the wrapping of coil (**19**) proceeds in the clockwise direction. The inner core wrapping terminates on coil (**20**) with the extension of the second power connection (**21**). Because the coils are wound in opposite directions, the generator produces two bucking magnetic fields at different radii (**22**,**23**).

[**0027**] According to Maxwell's electromagnetic equations, the curl of the magnetic flux density B field times the square of the speed of light squared is equal to the rate of change of the electric E field

$$c^2\nabla xB = \frac{\partial E}{\partial t}$$

Multiplying both sides by the elemental area of the core and integrating over the area

$$c^2\int_0^{r_0}\nabla xBdA = \frac{\partial}{\partial t}\int_0^{r_0}E\cdot ndA = \frac{\partial}{\partial t}\int_0^{r_0}E\cdot n2\pi rdr$$

The curl of the field can be converted into a line integral around the core contour using Stokes' Theorem

$$c^2\int_0^{r_0}\nabla xBdA = c^2\oint_{r_0}B\cdot ds = c^2\int_0^{2\pi}Br_0d\theta$$

[**0028**] The magnetic flux density B field oscillates with angular frequency ω

$$B=B_0e^{I\omega t}$$

Substituting this into the equation and integrating over time for the inner core field

$$-c^2\int_0^t\int_0^{2\pi}B_0e^{I\omega t}r_0d\theta = \int_0^{r_0}E2\pi rdr = E\pi r_0^2$$

This can be solved for the electric E field that is produced by the oscillating magnetic flux density B field

$$E_0 = \frac{2IB_0c^2(-1+e^{I\omega t})}{r_0\omega}$$

The electric field for the outer core is the same equation except that the opposite sign of the magnetic flux density B field and the radius **r1**

$$E_1 = \frac{-2IB_0c^2(-1+e^{I\omega t})}{r_1\omega}$$

Adding these two fields together is the total electric field E

$$E = E_0 + E_1 = \frac{-2B_0c^2(-1+\mathrm{Exp}(I\omega t))(r_0-r_1)}{r_0r_1\omega}$$

The electrostatic energy of the field is equal to half the linear capacitance of space times the summation over the volume of the dot product of the electric field with itself

$$U = \frac{\varepsilon}{2}\int E\cdot EdV$$

Because the electric field points in the z-direction out of the coil, the dot product is actually the square of the electric field.

[**0029**] Referring to **FIG. 10**, the energy U per volume is plotted as a function of time with a radius ratio r_1/r_0 of 3/1. As the graph shows, the magnetic vortex wormhole generator produces mostly negative energy which is required in order to create the wormholes. Because the stress-energy-momentum T tensor is also the square of the electric field, this graph gives the spacetime curvature pressure. Thus the electric field produces both the pressure and negative energy required to open up wormholes between space and hyperspace.

[**0030**] Going back to the effective potential equation,

$$V_{eff} = \frac{l(l+1)\hbar^2}{2mr^2} - \frac{e^2}{4\pi\varepsilon r}$$

it can be seen that the first term is divided by the mass of the particle. In current gravitation physics, the mass of the particle is invariant with velocity. It does not obey the Lorentz transformation. The mass is related to the energy E of the particle and its momentum p by

$$m^2=E^2-p^2$$

In different inertial frames moving with a relative velocity v, the energy and the momentum obey the Lorentz transformation, but no matter what the relative motion, the mass of the particle is constant. In the first term of the effective potential, the mass is constant which leaves just Planck's constant.

[**0031**] Having worked for over ten years on the subspace manifold, known as the tetrahedron diagram, I found a most incredible intersection on the diagram when working with the water molecule. The water molecule has two hydrogen atoms and one oxygen atom as mentioned previously. The atomic weight of one atom of hydrogen is 1.008 atomic weight units (awu). The atomic weight of oxygen is 16.000 awu. Therefore the molecular weight of water is

$$\text{Weight of two atoms of hydrogen } 2\times 1.008\ awu = 2.016\ awu$$

$$\text{Weight of one atom of oxygen } 1\times 16.000\ awu = \frac{16.000\ awu}{18.016\ awu}$$

The gram molecular weight is the atomic weight expressed in grams, so there are 18.016 grams in Avogadro's number of molecules. So the mass per molecule in logs is

$$\mathrm{Log}\left[\frac{18.016\ \mathrm{gram-mol}\Big/\left(1000\ \frac{\mathrm{gm}}{\mathrm{kg}}\right)}{6.02\times10^{23}\ \mathrm{mol}}\right]=-58.77103943$$

[0032] Referring to **FIG. 11**, the tetrahedron diagram plots the natural logarithm of mass versus the natural logarithm of wavelength. The reason for this is that mass times wavelength is equal to Planck's constant divided by the speed of light c, known on the diagram as the base constant. At the present time there are over 4000 diagrams which are copyrighted in the Library of Congress. In logarithms, the product of two numbers is the sum of the two numbers. This means that the sum of the mass and the wavelength are equal to the base constant which has a value of

$$\ln[m]+\ln[\lambda]=\ln[h/c]=-95.91546344=\text{base constant}$$

Our dimension has a lower limit on mass and length known respectively as the Planck mass and the Planck wavelength. The Planck mass is the linear mass Ω of the universe times the Planck scale Λ. The Planck wavelength is circumference of a circle of radius Planck scale. In terms of logs, the Planck mass and Planck wavelength are

$$\text{Planck mass}=\ln(\Omega\Lambda)=-17.64290101$$

$$\text{Planck wavelength}=\ln(2\pi\Lambda)=-78.27256243$$

[0033] When these values are plotted on the tetrahedron diagram shown in **FIG. 11**, the Planck box (abcd) is formed which are the boundaries of our dimension in subspace. The line numbering is as follows

Planck mass	25, 27
Planck wavelength	26, 28
mass of water molecule	29, 31
speed of light squared circle	30
base constant	33
inverted tetrahedrons	34, 35
centerline	36

The energy of the water molecule, circle (**37**), is equal to the sum of the water molecule mass (**29**) plus the speed of light squared circle (**30**). The energy circle (**37**) intersects the mass of the water molecule (**29**) at the Planck wavelength (**28**, point e), which is the boundary between space and hyperspace. What this means is that the mass is equal to the energy at the Planck box boundary. The only way that this is possible is if the speed of light c is equal to one meter per second

$$E=m\ c^2=m\ c=1\ \text{meter/second}$$

A water molecule traversing a wormhole into hyperspace undergoes a change in the speed of light from 299792458 m/s to 1 m/s.

[0034] Planck's constant $\hbar$ is equal to the Planck mass ΩΛ times the Planck scale Λ times the speed of light c.

$$\hbar=\Omega\Lambda\Lambda c$$

By having the speed of light go to 1 m/s, the orbital term in the effective potential V_{eff} is reduced by a factor of the speed of light squared equal to 9×10^{16}. This unbalances the equation to such an extent that only the Coulomb potential term remains.

$$\frac{l(l+1)\hbar^2}{2mr^2}\ll\text{coulomb term}$$

The electron is attracted to the proton nucleus because the centrifugal term no longer provides a stable orbit for the electron. Thus the atomic binding is destroyed and the water molecule becomes soft as putty.

[0035] Referring to **FIG. 12**, the collision of the electron with the proton together with the enormous change in the proton's energy causes the proton p to become unstable and decay. According to the Standard Model of particle physics, the elementary particles are composed of smaller particles known as quarks. The six quarks have been named up u, down d, strange s, charm c, top t, and bottom b. The subscript on the quark indicates one of three colors {red r, blue b, green g). As shown in the diagram, the proton is composed of three quarks $\{u_r, u_g, d_b\}$, two of which are up quarks of which one is red and the other green, and a third blue down quark. The proton p decays into a positron e^+ which is an electron with a positive charge, and a neutrally-charged pion π^0 particle through the exchange of an X boson particle. The pion has a mass between the electron and the proton.

$$p\rightarrow\pi^0+e^+$$

[0036] Referring to **FIG. 13**, the pion π^0 then decays into a proton p and antiproton $\bar{p}$ which annihilate each other to produce two photons shown on the right by the traveling waves. So the overall energy exchange is

$$p\rightarrow\frac{2hv}{c^2}+e^+$$

where hv is the energy per gamma photon with frequency v. The electron of the hydrogen atom would then annihilate the positron for additional photon energy.

[0037] Referring to **FIG. 14**, the hydrogen H atom is composed (**38**) of the proton and electron as seen in the upper left corner. The proton decays (**39**) into the neutral pion and a positron. The electron from the hydrogen atom and this positron form one electron pair (**40**). The pion then decays (**41**) into two gamma photons which produce an electron pair production energy cascade into 132 pairs (**42**,**43**) for a total of 133 electron pairs. These electrons can then be captured electrostatically and used for the production of electricity.

[0038] Referring to **FIG. 15**, the electrons are captured with the water droplet injector . The plunger (**46**) of a spring-loaded cylindrical solenoid (**44**) is attached to a tapered piston (**47**). By means of ring collar and bolts (**45**), the solenoid is bolted to the injector (**48**). A supply of purified water is attached to the water inlet connection (**49**). When the solenoid is activated, it pulls back slightly so that water can enter the valve. When the solenoid is deactivated, the piston forces the water droplet out through the nozzle (**50**) into a cylindrical glass vacuum chamber (**52**). Two cylindrical glass disks (**51**) hold the nozzle in place. On the other end of the vacuum chamber is the sealed-tube connection (**56**,**57**,**58**) to the vacuum pump. In the middle of the vacuum chamber, two metal plates (**53**) are attached through sealed glass collars (**54**) to electrical pins (**55**). The plates are electrostatically-charged with opposite charges so as to form a capacitor. This creates an electrical field between the plates which attracts the electrons to the positively-charged plate.

[0039] Referring to **FIG. 16**, the vacuum tube and water injector (**61**) are mounted along the centerline of the inner (**60**) and outer (**59**) magnetic vortex wormhole generator coils. The low density hyperspace energy traversing the wormhole along the centerline of the coils causes the injected water molecules to soften and decay into a cascade of electrons. The oscillating electric field along the centerline causes the electrons to vibrate back and forth. The crossed electric field between the charged capacitor plates causes the electrons to flow toward the positively-charge plate in order to produce electricity.

[0040] Referring to **FIG. 17**, the vacuum tube is connected to the vacuum pump through a hose connection to the pump air inlet (**64**). A 5 Hp electric motor (**62**) drives dual rotating flights of screws which trap the air and move it toward the exhaust outlet (**65**) shown with no muffler. On a spacecraft operating in the vacuum of outer space, this component would not be needed.

SUMMARY OF THE INVENTION

[0041] It is the object of this invention to generate electricity by using low density hyperspace energy to soften water molecules such that the atomic binding is broken which causes the hydrogen nucleus to decay into a cascade of electron pairs. These electrons are then collected on a positively-charged plate in order to produce electricity. The water molecules are softened by flooding them with low density hyperspace energy that is produced by a magnetic vortex wormhole generator. The generator creates negative energy and a spacetime curvature along the centerline of two concentric coils. This combination opens up wormholes along the centerline. Because the gravitational potential of low density hyperspace energy is greater than the negative energy, the hyperspace energy flows through the wormhole from hyperspace into our dimension. The hyperspace energy has a speed of light equal to one meter/second. This causes a change in Planck's constant h such that the proton orbitals of the hydrogen atom are unable to produce a centrifugal repulsion which keeps the electron in orbit. The Coulomb potential term dominates and the electron is attracted to the proton. Due to the vast change in the speed of light, and the collision of the electron with the proton, the proton becomes unstable and decays into a neutral pion and a positron. The pion then decays into two gamma photons which produce a large cascade of electron pairs.

[0042] A water injector, consisting of a solenoid-activated valve and nozzle, injects water droplets into a vacuum chamber which is positioned along the centerline of the two concentric coils where the wormholes form. Due to the low density hyperspace energy passing through the wormholes into our dimension, the water molecules soften and decay into electrons which are collected on an electrostatically-charged capacitor plate having a positive charge located in the glass vacuum chamber.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0043] **FIG. 1**. Perspective view of hydrogen atom K shell.

[0044] **FIG. 2**. Graph showing potential binding energy of hydrogen atom.

[0045] **FIG. 3**. Perceptive view of Olympus Mons volcano at +19.5° Mars latitude.

[0046] **FIG. 4**. Perspective view of tetrahedron inscribed in sphere.

[0047] **FIG. 5**. Graph showing complex plane.

[0048] **FIG. 6**. Perspective view of hyperspace co-dimensions of logarithmic manifold.

[0049] **FIG. 7**. Perspective view of embedding diagram showing curvature of space caused by a mass.

[0050] **FIG. 8**. Perspective view of wormhole embedding diagram.

[0051] **FIG. 9**. Perspective view of coils of magnetic vortex wormhole generator.

[0052] **FIG. 10**. Graph showing that generator produces negative energy.

[0053] **FIG. 11**. Tetrahedron diagram showing that the speed of light at the Planck box boundary at the water molecule is one meter/second.

[0054] **FIG. 12**. Perspective view of proton decay into neutral pion and positron.

[0055] **FIG. 13**. Perspective view of pion decaying into two gamma photons.

[0056] **FIG. 14**. Diagram showing decay of the hydrogen atom into electrons.

[0057] **FIG. 15**. Perspective view of water injector and vacuum chamber.

[0058] **FIG. 16**. Perspective view of vacuum chamber mounted along centerline of magnetic vortex wormhole generator.

[0059] **FIG. 17**. Perspective view of vacuum pump used to evacuate vacuum chamber.

DETAILED DESCRIPTION OF THE INVENTION

[0060] 1. The coils of the magnetic vortex wormhole generator are made of three stacks of 0.020 inch silicon-iron transformer laminates. These are washed to remove the oil, and then wrapped with insulating tape in order to keep the laminations together. Using a very long bench made of wooden planks and 2×4 sawhorses, the outer coil is wrapped counter-clockwise right to left using a large spool of 14 AWG magnetic wire. A thin spacer is used between windings in order to reduce the winding capacitance. Once the outer coil is wound, the wire is continued to the second inner coil which is wrapped clockwise, leaving enough wire between coils such that when the coils are mounted in the wooden frame, the coil is one continuous winding having an input and output connection. Using an inductance meter, the inductance of the coil is measured. Using a standard frequency of 60 Hz, the capacitance of a sheet metal capacitor is calculated such that the generator is electromagnetically resonant at this frequency. The generator is connected to the line voltage by a 1:1 isolation transformer which is connected to a small primary coil wrapped on a toroidal core whose similar secondary coil is connected to the sheet metal capacitor and inductance coil. Resonance is achieved by adjusting the spacing and overlap of the sheet metal.

[0061] 2. The vacuum chamber is made of a glass tube with sufficient wall thickness to withstand the vacuum pressure. A number of glass blowing techniques are used to make the glass-electrode connection for the capacitor plates. Then circular pieces of glass plate are cut out and ground to the inside diameter of the tube, fitted with the nozzle and vacuum connection, and then heat sealed to the chamber. The chamber and water injector are then attached to a wooden bracket mounting which is doweled and glued to the wooden frame of the generator.

I claim:

1. A water energy generator system comprising the components:

a magnetic vortex wormhole generator and driving resonant electrical circuit;

a water droplet injector;

a vacuum chamber and vacuum pump; and

an electrostatic electron capture system.

2. By means of claim (**1**), a magnetic vortex wormhole generator comprising two concentric cylindrical coils of different radii wound in opposite directions, made of thin sheet silicon-iron transformer laminations wound with one continuous length of magnetic wire providing a single input and single output connection to the driving electrical circuit.

3. By means of claim (**2**), a coil winding method and oscillating driving circuit producing bucking electric fields along the centerline of the generator normal to the coils which create a spacetime curvature pressure and negative energy.

4. By means of claim (**3**), the generation of wormholes between space and hyperspace along the centerline of the generator such that low density, low speed of light hyperspace energy flows through a positive gravitational gradient from hyperspace to space.

5. By means of claim (**1**), a water injector comprising a solenoid-activated water valve, water supply connection, seal and nozzle for injecting water droplets into the vacuum chamber.

6. By means of claims (**5**) and (**4**), the softening and particle decay of the water molecules by the hyperspace energy into neutral pions, positrons, gamma photons and finally a cascade of electron pairs.

7. By means of claims (**6**) and (**1**), the capture of the electrons on electrostatically charged capacitor plates located in the vacuum chamber for the purpose of producing electrical energy.

8. By means of claims (**1**) and (**2**), a resonant electrical driving circuit comprising a line isolation transformer connected to a primary coil wound on a toroidal coil whose secondary output coil is connected to a capacitor and the inductance coil of the generator such that the capacitance of the capacitor and the inductance of the coil form a highly resonant electrical circuit.

* * * * *

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(54) **MAGNETIC MONOPOLE SPACECRAFT**

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(52) **U.S. Cl.** **60/203.1**

(57) **ABSTRACT**

A spacecraft propulsion system that utilizes a dual method of providing lift on the hull by means of magnetic monopoles and electromagnetic spacetime curvature pressure.

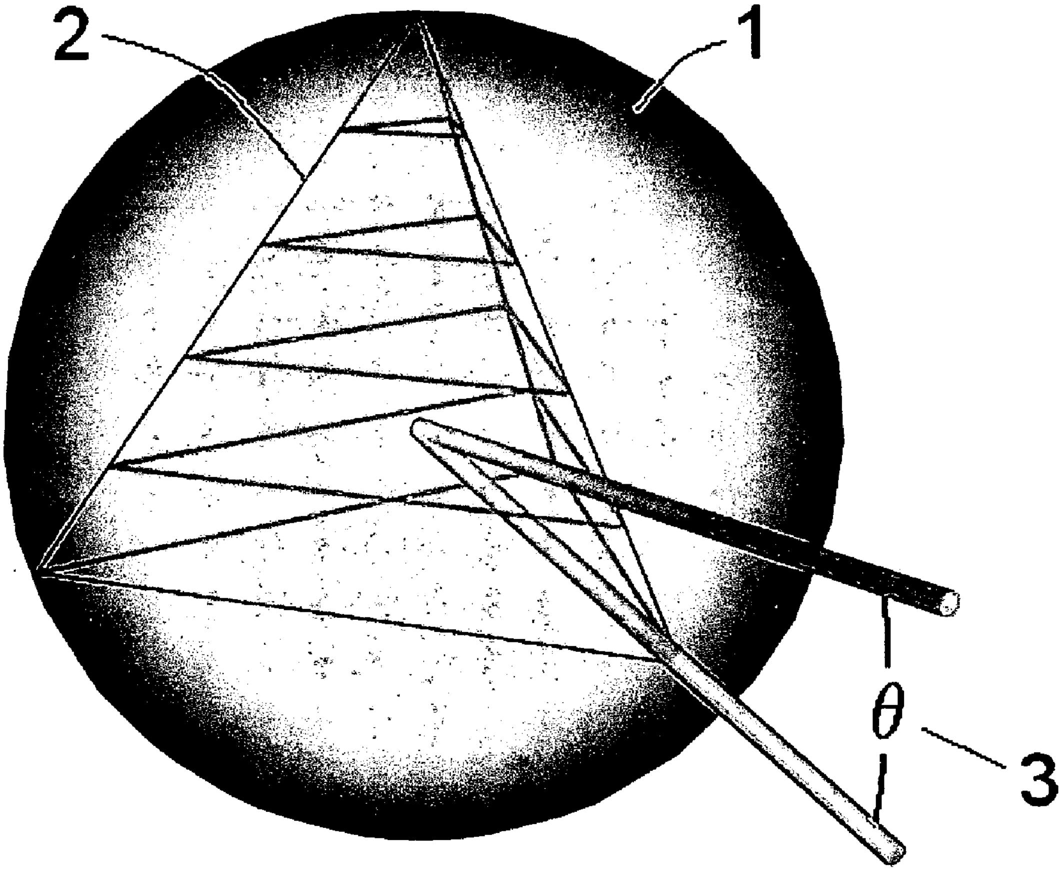

Figure 1

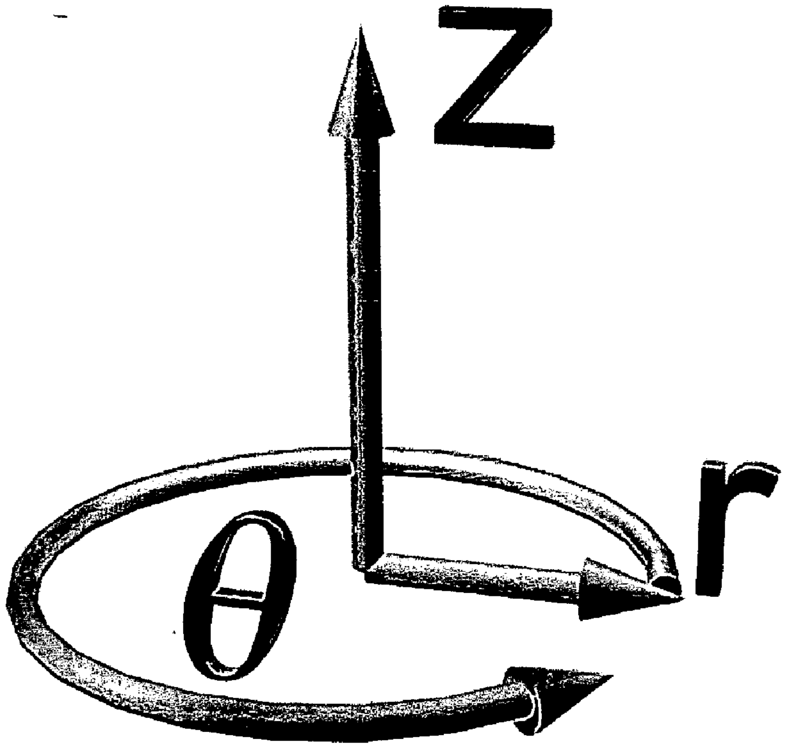

Figure 2

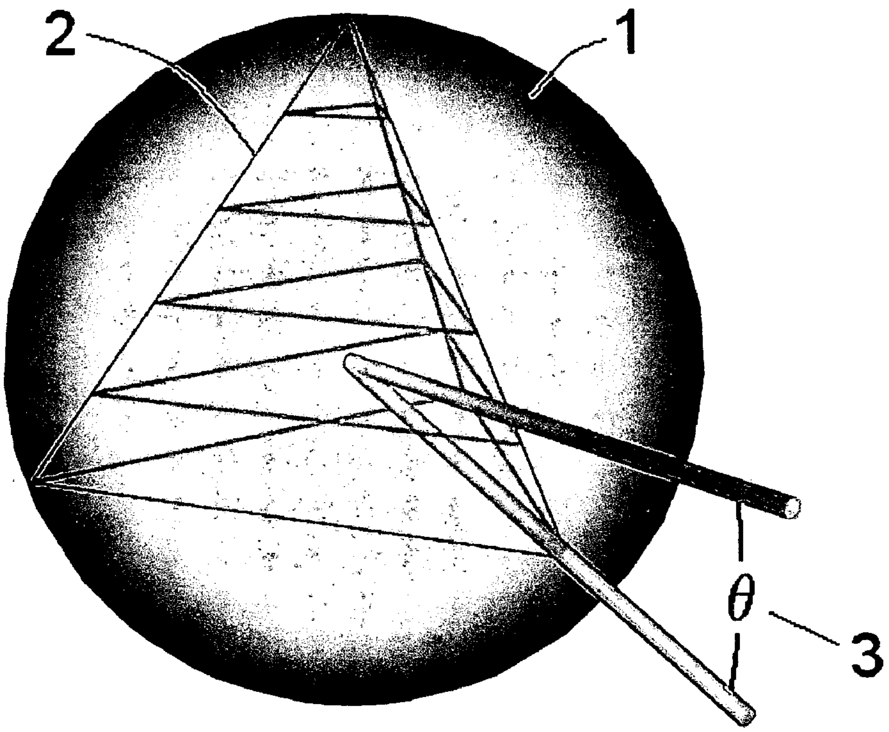

Figure 3

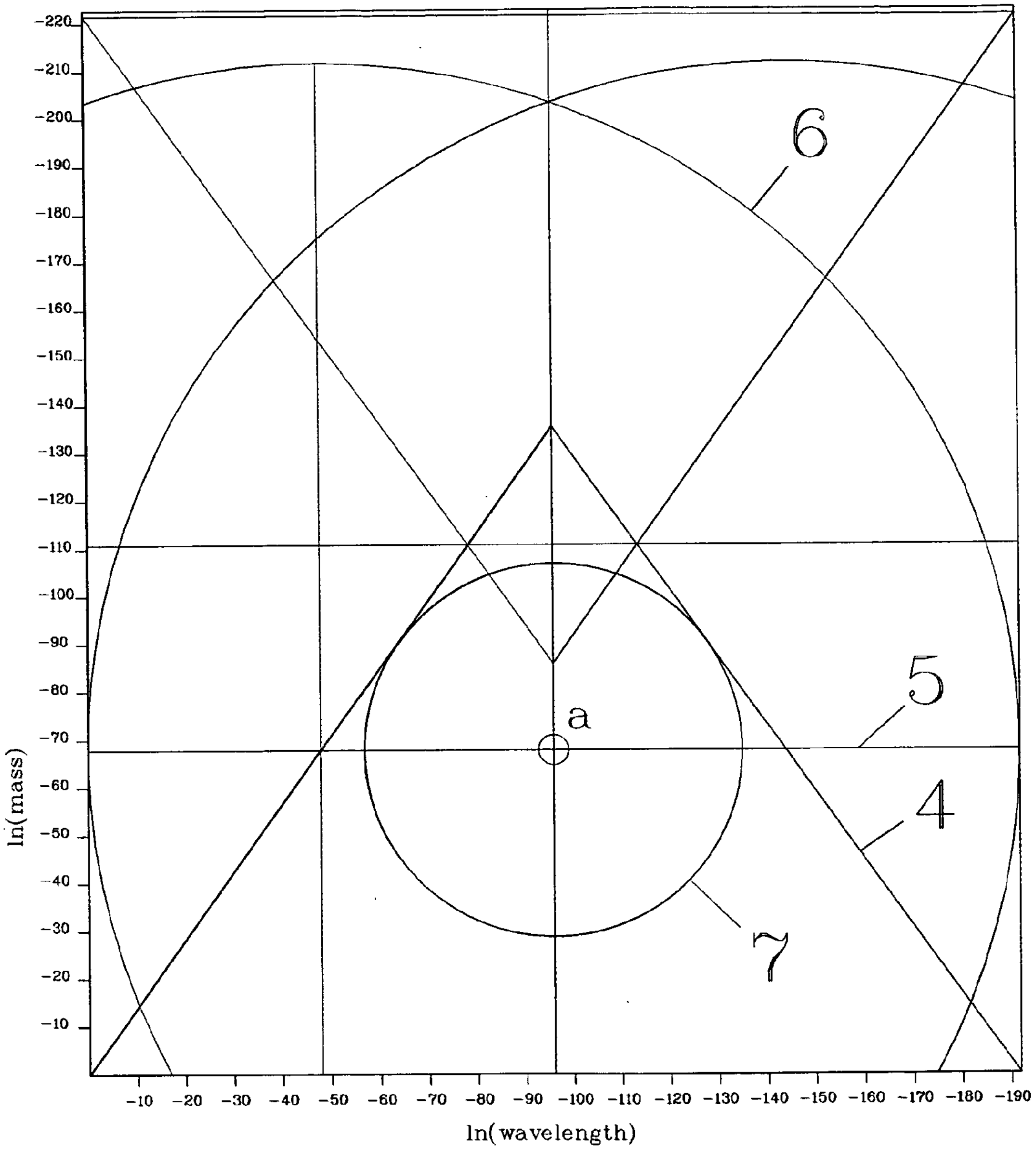
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-70
-60
-50
-40
-30
-20
-10
ln(mass)
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
ln(wavelength)
6
5
4
7
a

Figure 4

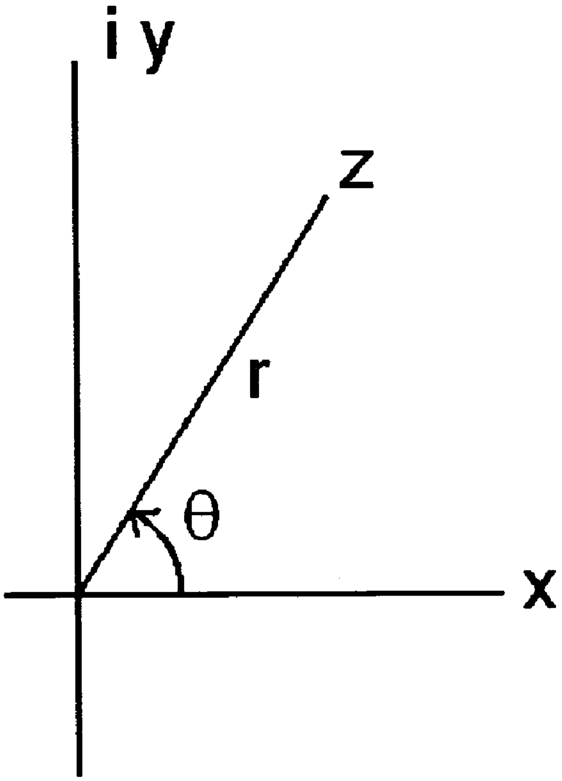

Figure 5

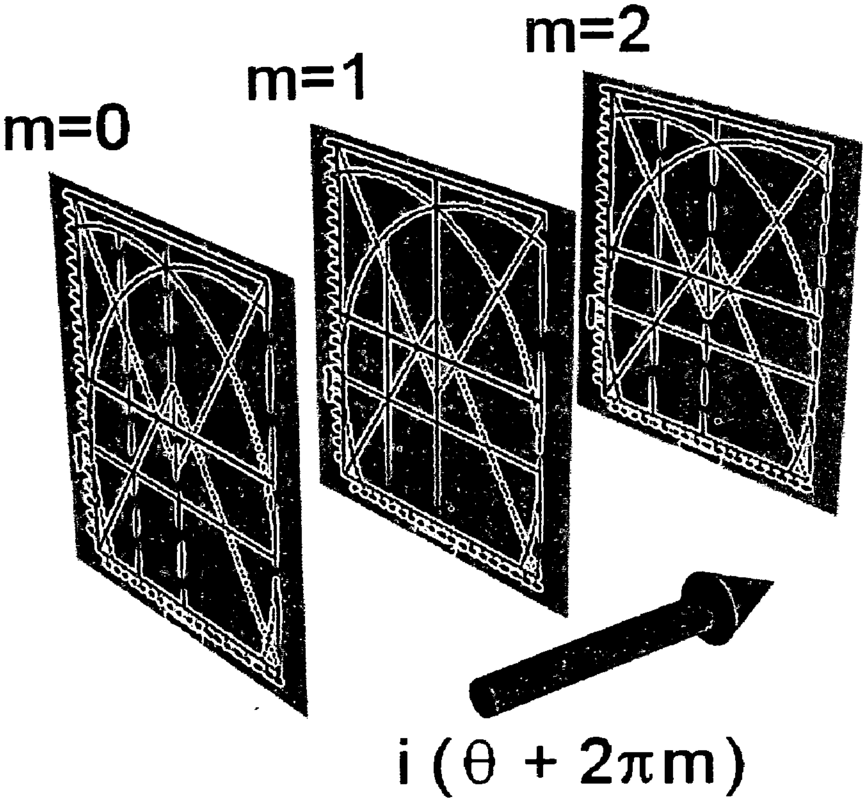
m=0
m=1
m=2
i (θ + 2πm)

Figure 6

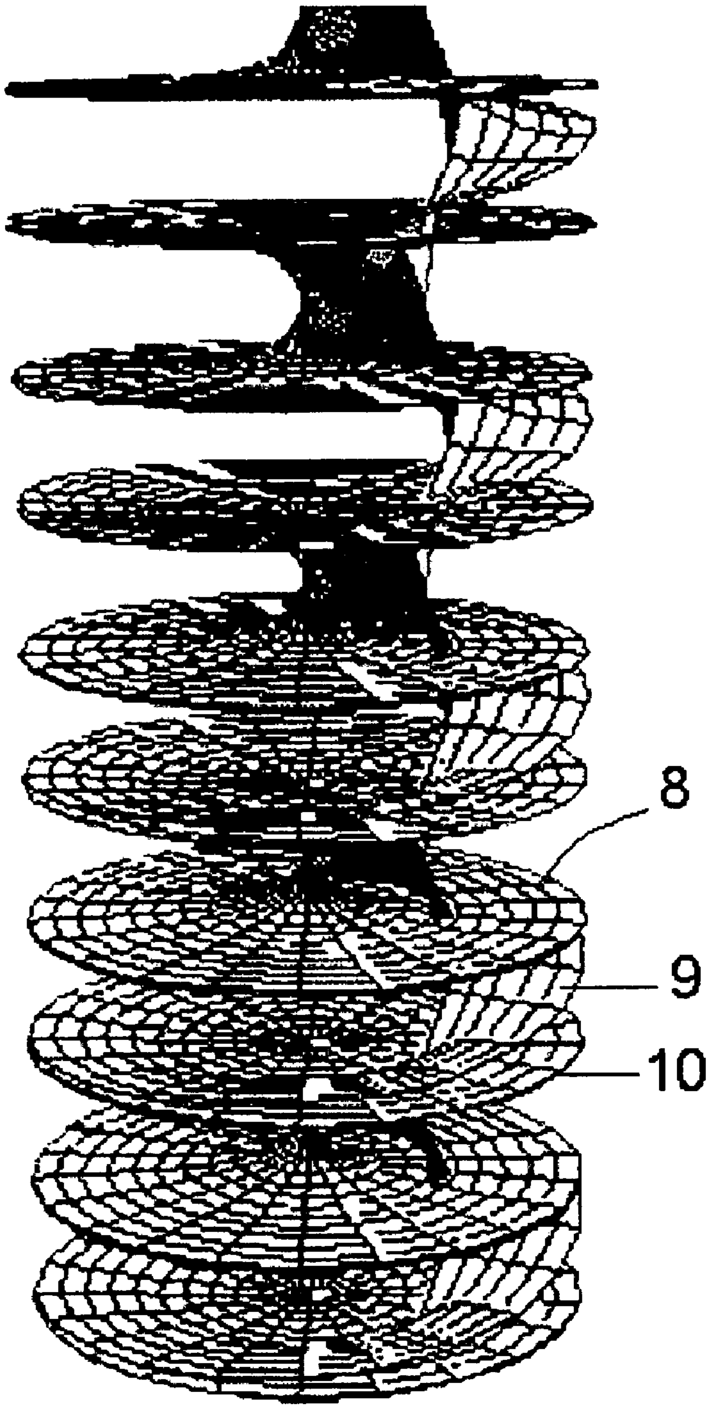

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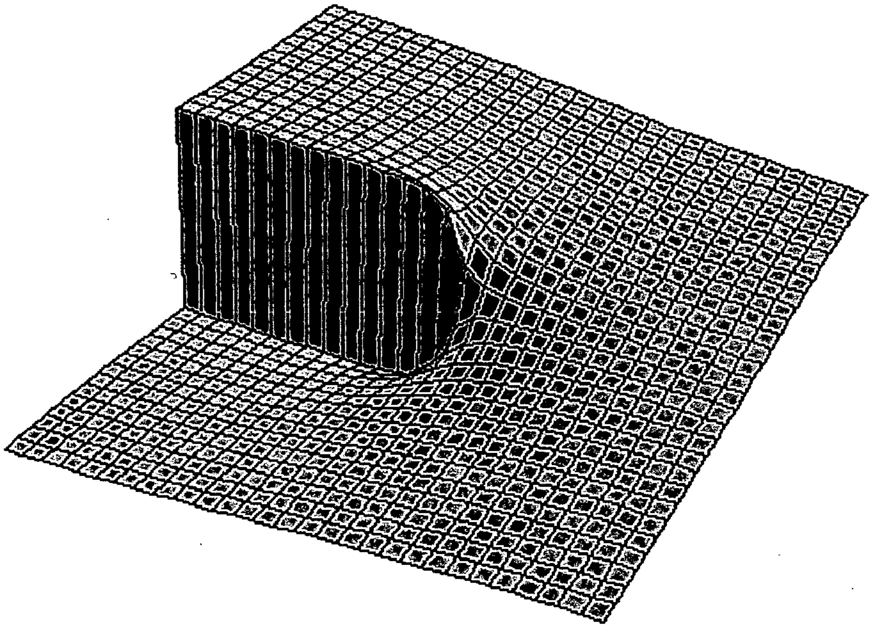

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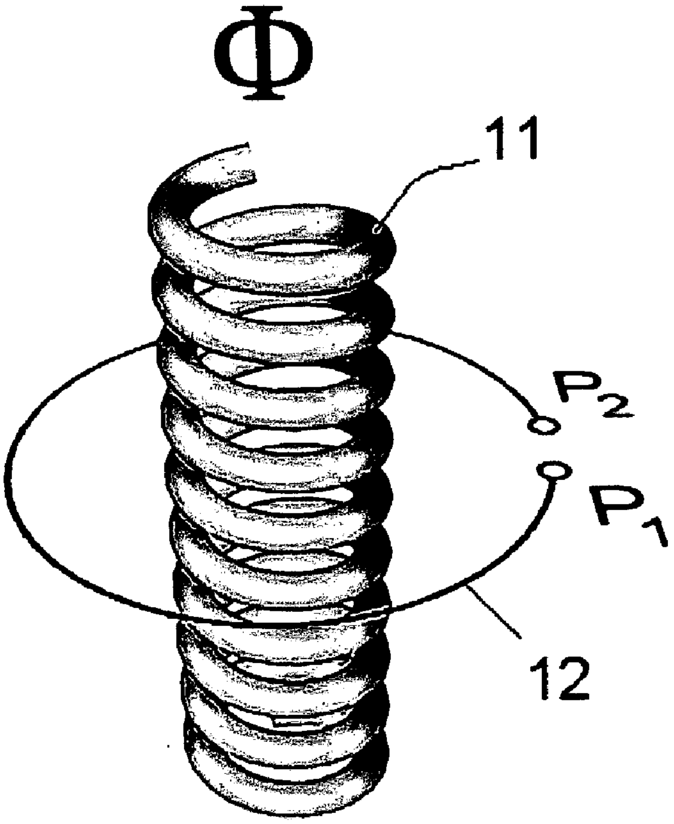
Φ
11
P_2
P_1
12

Figure 9

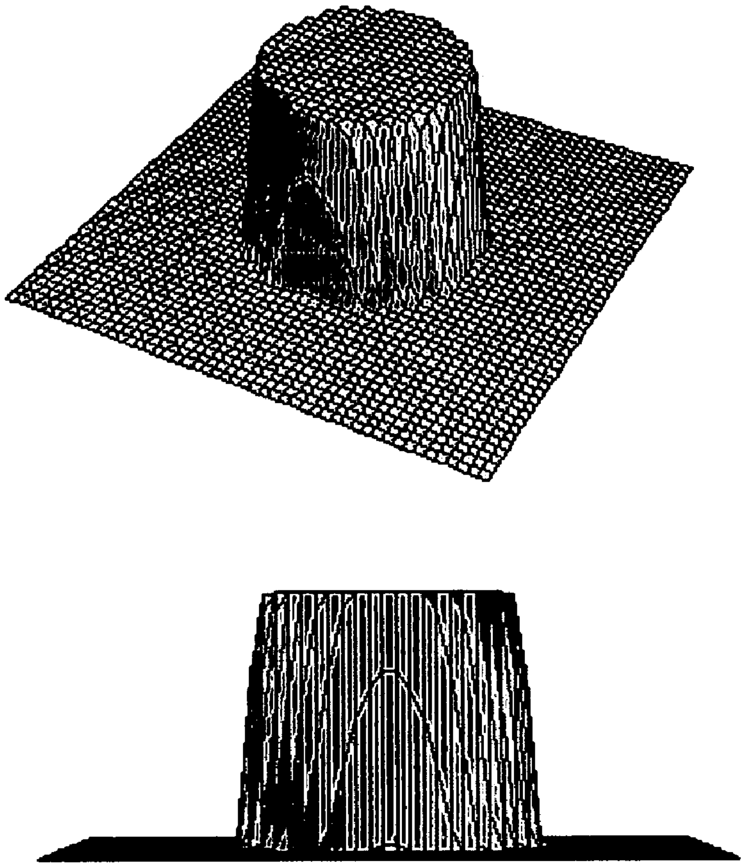

Figure 10

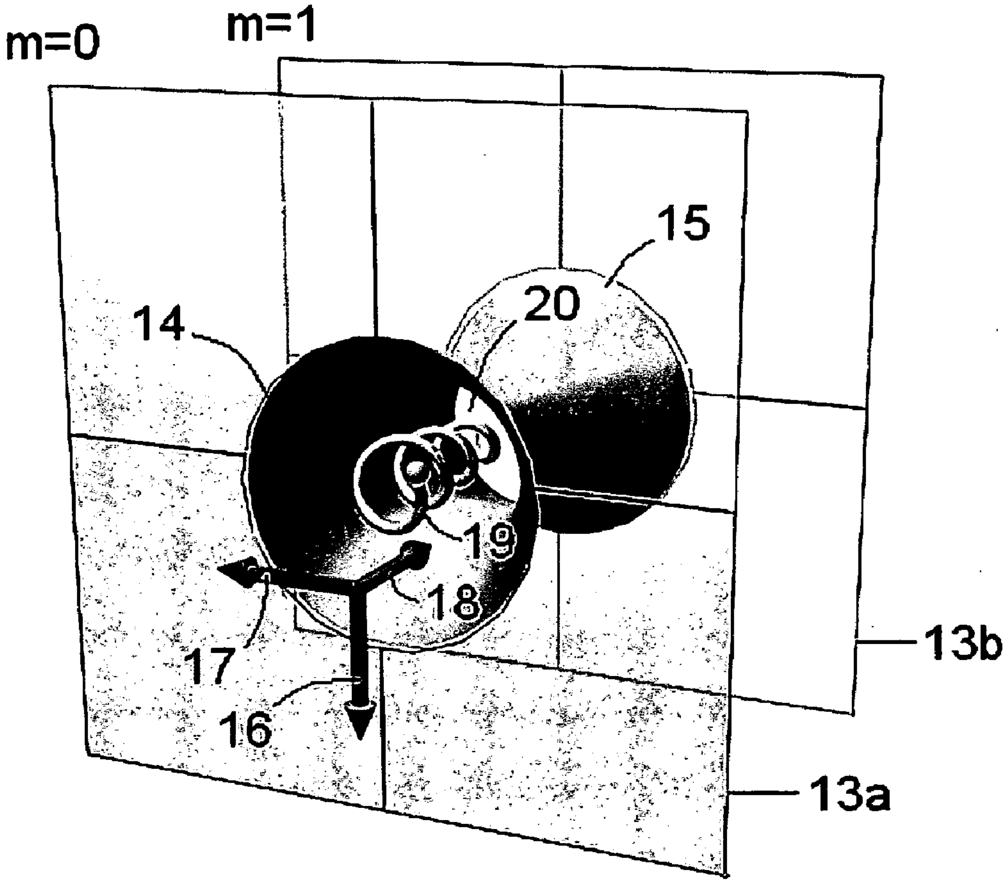
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13b
13a

Figure 11

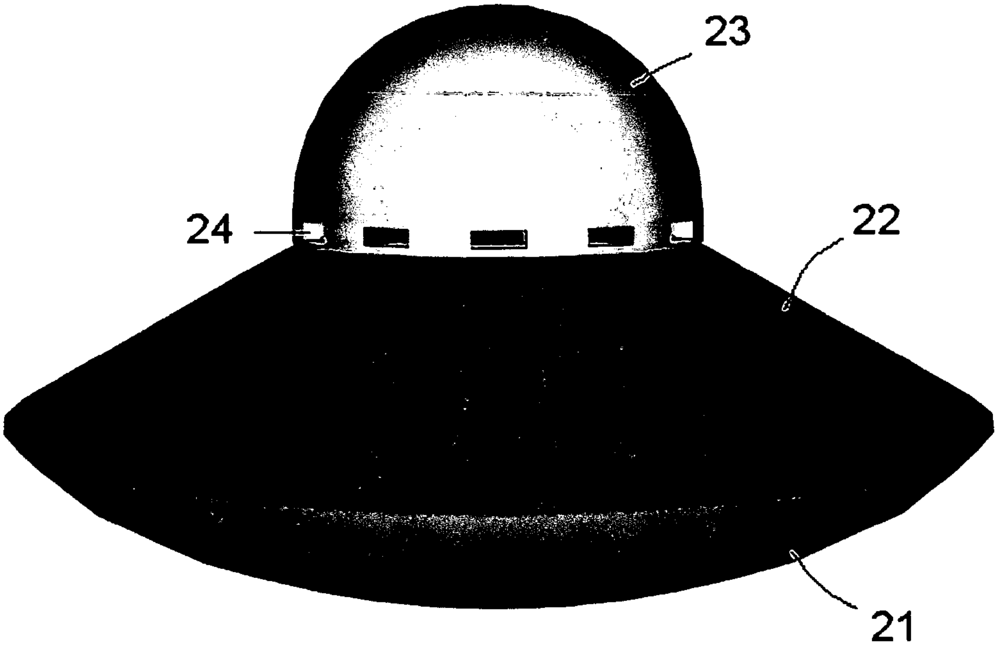

Figure 12

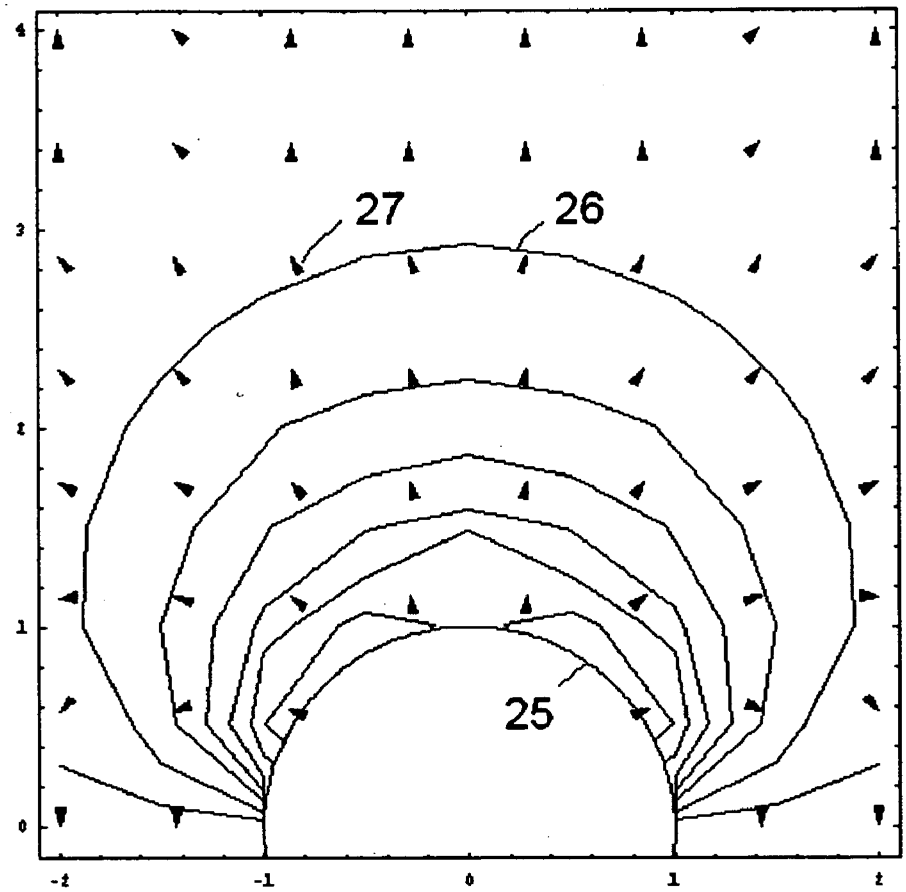

Figure 13

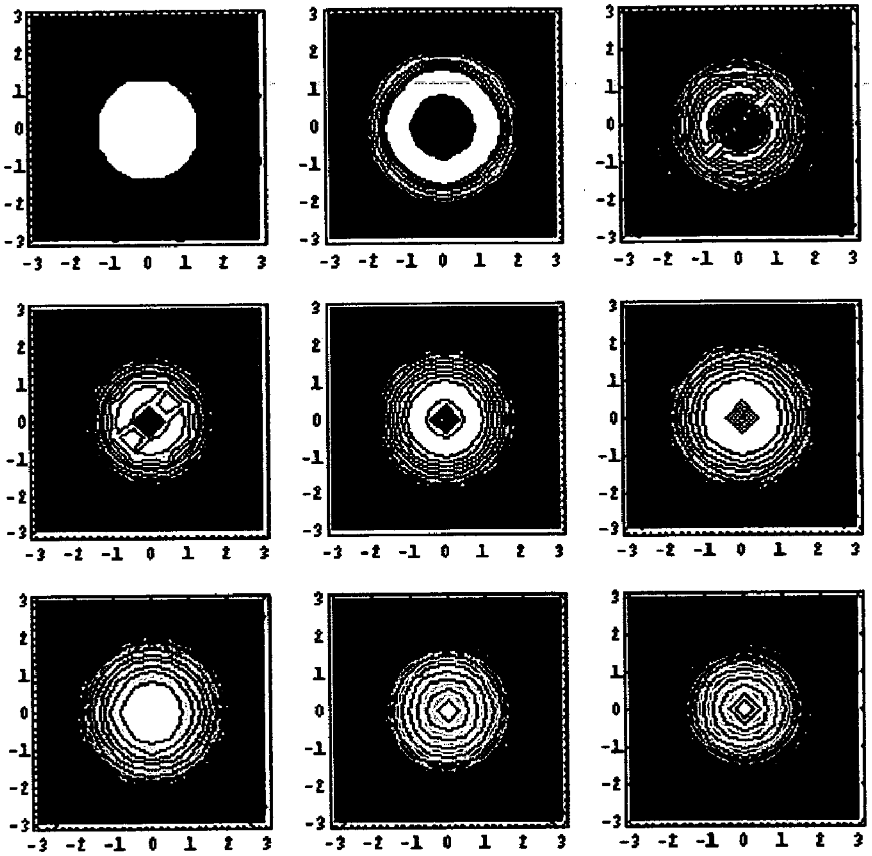

Figure 14

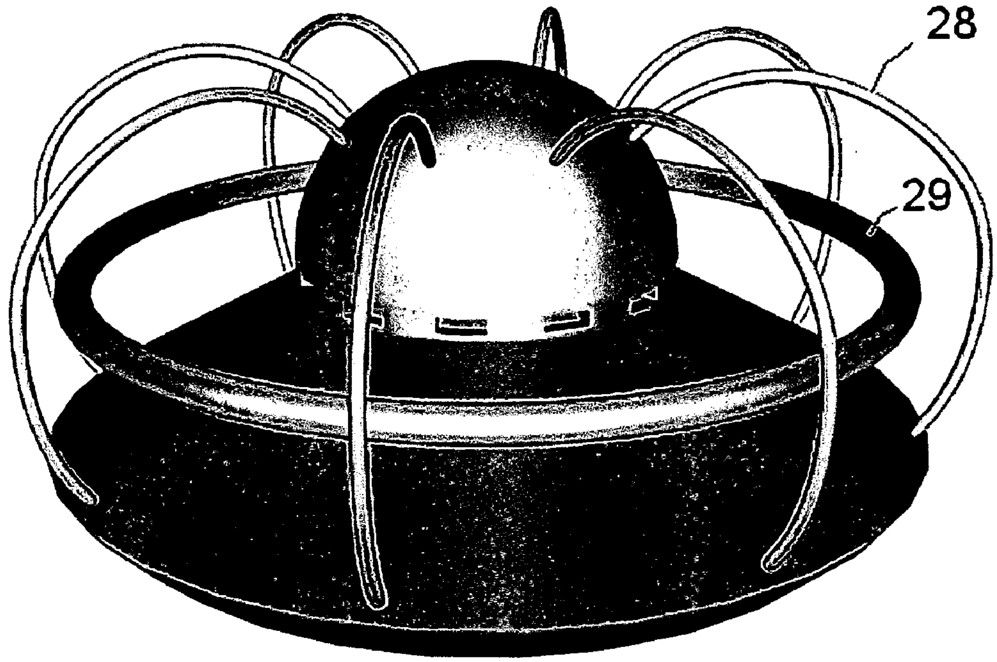

Figure 15

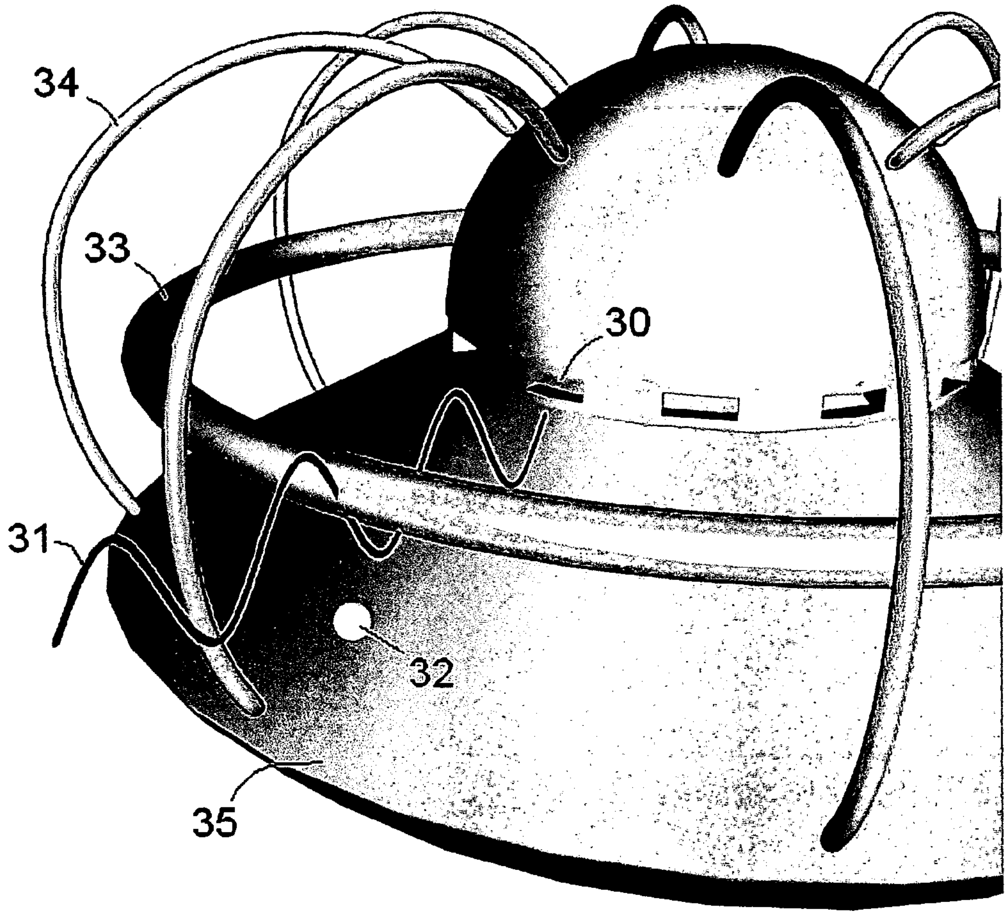
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33
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31
32
35

Figure 16

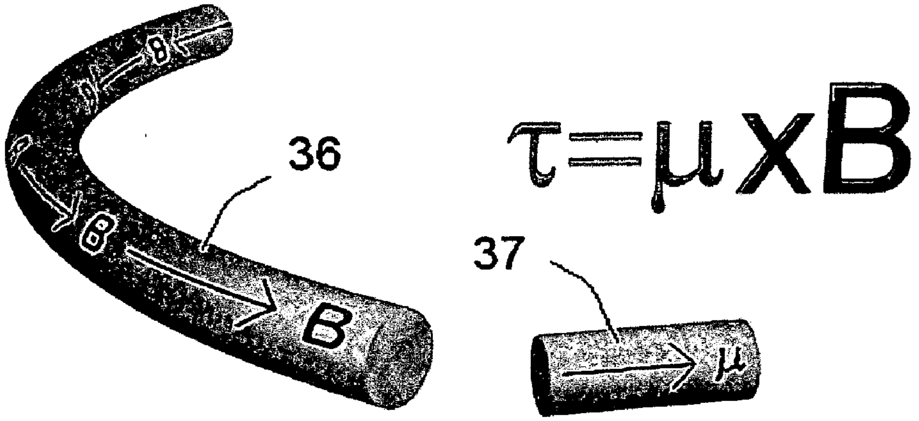
B
B
36
τ=μxB
37
B
μ

Figure 17

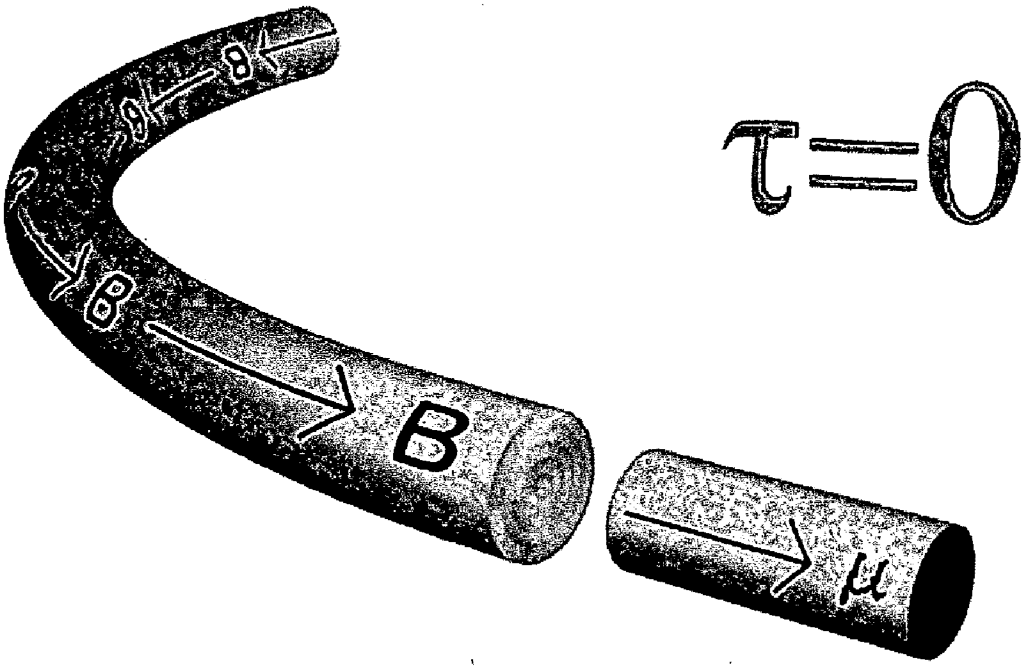

Figure 18

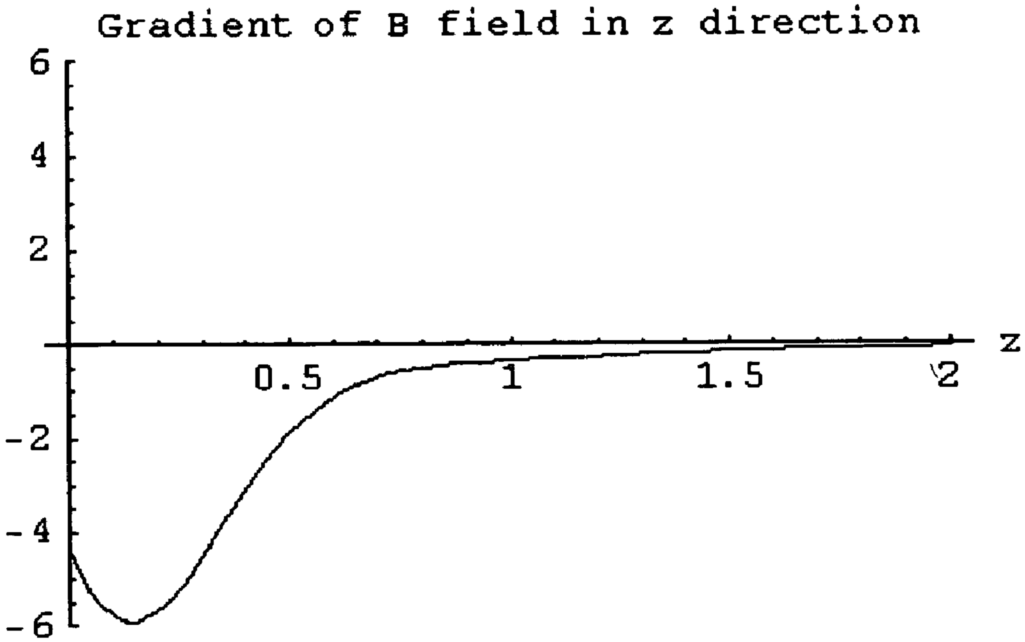

MAGNETIC MONOPOLE SPACECRAFT

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is a spacecraft propulsion system that generates a field of wormholes which are threaded with a magnetic field. Acting as two attracting magnets, the spacecraft's north magnetic field is attracted to the constantly regenerating south magnetic monopoles of the wormholes which provides lift on the hull.

BACKGROUND OF THE INVENTION

[0002] According to one of Maxwell's electromagnetic equations, the curl of the electric E field is equal to the negative time rate of change of the magnetic flux density B field.

$$\overline{V} \times E = -\frac{\partial B}{\partial t}$$

The curl can be thought of as a circulation around a closed loop specified by the right-hand rule where the fingers curl in the direction of the electric field and the thumb represents the changing magnetic flux density field through the area of the loop. At no time is the electric field diverging around the loop. That is, the divergence of the curl is zero which is a well-known vector operation

$$div\ \mathrm{curl}E = \frac{\partial}{\partial t}(divB) = 0$$

The partial derivatives of divB are zero at all points in space. Performing the integration, therefore, the divergence of B is equal to a constant

div B=constant

[0003] Referring to **FIG. 1**, the following discussion is made in cylindrical coordinates {r,θ,z}. In cylindrical coordinates, the divergence of the radial B field, div B, is equal to a constant C

$$Br'[r] + \frac{Br[r]}{r} = C$$

where the prime (') represents differentiation with respect to the radius r. The solution to this equation resides in determining the constant C. In the vacuum of space without any wormholes, the constant C is zero. Because the spacecraft is surrounded by a field of wormholes, there is a magnetic flux density field threading each one. That is, each wormhole is actually a magnetic monopole, and therefore the entire field of monopoles constitutes a large magnet with one pole in this dimension and the other pole in the hyperspace dimension.

[0004] The concept of the wormhole involves a new type of scientific thinking involving the creation of a gateway between our spacetime and that of a hyperspace co-dimension. The gateway is created electromagnetically as shown by my patent applications Rotating Magnetic Vortex Generator, Magnetic Vortex Wormhole Generator, and Sulfur 8 Wormhole Generator. The gateway can also be created ultrasonically through bubble cavitation as shown in my patent application Cavitating Oil Hyperspace Energy Generator. In one experiment, smoke was blown through one side of the coil of the magnetic vortex wormhole generator and no smoke came out the other side. The smoke was blown through the wormhole into another dimension.

[0005] The existence of hyperspace is not generally known in the scientific community. The reason it exists can be thought of in the following manner. Referring to **FIG. 2**, the corners of a tetrahedron (**2**) circumscribed by a sphere (**1**) touch the sphere at an angle (**3**) of −19.47°. Looking at the planets of the solar system, the Giant Red Spot vortex of Jupiter, which can hold two planets the size of Earth, is located at this angle. On Mars, the Olympic Mons volcano, which is the size of France, is located at north 19.5° Here in the Caribbean there is a slow moving rock mantle vortex at north 19.5° that curves the islands down toward Venezuela. So the geometry of space is related to the tetrahedron. What this suggests is that there is a subspace manifold whose tetrahedral geometry projects all the constants of physics into our dimension.

[0006] Referring to **FIG. 3**, this subspace geometry is shown in the tetrahedron diagram which plots the natural logarithm of mass on the vertical axis versus the natural logarithm of wavelength on the horizontal axis. With this diagram, it is possible to visualize the entire universe on a single sheet of paper. Triangle (**4**) is the tetrahedron whose vertical centerline shown by the small π circle (a) is equal to Planck's constant h divided by the speed of light c, known as the base constant. The base constant in logs is equal to −95.91546344. Line (**5**) is the diameter of the sphere (**6**). A circle (**7**), centered on (a), with a radius equal to the speed of light squared, is tangent to the tetrahedron. It can be shown that all the constants of physics, such as the speed of light squared and the Planck mass and the Planck wavelength, are determined geometrically by this logarithmic subspace tetrahedral geometry.

[0007] Referring to **FIG. 4**, the complex plane consists of a real horizontal axis, and a complex vertical axis where the value of the complex number z is given by a radius r and an angle θ

$$z=re^{i(\theta+2\pi m)}$$

The logarithm of z is

$$\mathrm{Log}[z]=\mathrm{Log}[r]+i(\theta+2\pi m)$$

where m is an integer m=0,1,2 . . . corresponding to multiple rotations of 2π. What this means in terms of the tetrahedron diagram, referring to **FIG. 5**, is that there are multiple diagrams separated by 2π rotations. Each multiple is another hyperspace dimension. Only the log manifold has this characteristic. Referring to **FIG. 6**, the hyperspace dimension, shown as 2π circular surface (**8**), has a cut (**9**) on the undefined Log[0] origin line such that another hyperspace dimension is created below it (**10**).

[0008] Referring to **FIG. 7**, this branch cut does not bring one back to the original surface nearing the origin. It takes one down to another level of the universe into another hyperspace dimension. I can attest personally that I have been able to look into another hyperspace co-dimension as well as jump into another dimension.

[0009] Furthermore, Dr. Stephen Hawking of Cambridge University has shown that our dimension is connected to a wormhole through complex time. That is, the hyperspace dimension is rotated forward by 90° which makes it orthogonal to us. While this is the mathematical explanation as to why there are hyperspace co-dimensions, I can attest personally to the fact, as described in my patent application Full Body Teleportation, that I was teleported through hyperspace and returned to our dimension over a distance of 100 meters. Because hyperspace exists, it is then possible, using electromagnetic fields, to open wormholes between our dimension and other hyperspace dimensions.

[0010] Referring to **FIG. 8**, the constant C in the magnetic flux density B field equation is determined as follows. The end of a solenoid (**11**) is equivalent to a local magnetic source of flux Φ which represents the wormhole. A charge (**12**) encircling the solenoid has the same value at P_1 and P_2 but there is a phase difference of 2 π n where n is an integer equal to the number of times the charge encircles the solenoid. The change in phase is equal to the charge q divided by Planck's reduced constant times the flux for a solenoid of radius r=R

$$\Delta\theta = 2\pi n = \frac{q}{\hbar}\Phi = \frac{q}{\hbar}B\pi R^2$$

Solving for the magnetic flux density field threading the wormhole

$$B = \frac{2\pi nh}{q\pi R^2}$$

The differential equation becomes

$$Br'[r] + \frac{Br[r]}{r} = C[2]$$

Solving the equation for the radial field Br

$$Br[r] = \frac{C[2]r}{2} + \frac{C[1]}{r}$$

Equating this Br field with the B field and solving for the C[2] constant

$$C[2] = \frac{-2[-2\hbar n + qrC[1]]}{qr^2}$$

Substituting for C[2], the C[1] constant drops out and therefore the wormhole magnetic flux density field becomes a constant inside the throat radius R

$$Br = \frac{2hn}{qR^2}$$

but the divergence moving from outside to inside the radius is a constant due to the discontinuity.

[0011] Referring to **FIG. 9**, the wormhole has a constant cylindrically-shaped magnetic field of radius R with a negative south pole due to the negative charge on the electron, Using a wormhole radius equal to one hundred times the electron radius with n equal to 10 turns, the magnetic flux density B field has a magnitude of 1.4×10^6 tesla.

[0012] Referring to **FIG. 10**, the wormhole surface (**14**) is a connection through a throat area (**20**) between space and hyperspace (**13**) to another surface in hyperspace (**15**). The electron path (**19**) is actually spiraling down the surface of the wormhole. The magnetic flux density field (**18**) points into the wormhole such that the cross product of the electron velocity (**16**) with the field (v×B) points toward the outside rim of the wormhole. Because the electron has a negative charge, the force (**17**) on the electron (−q v×B) is inward toward the centerline of the wormhole. Since one pole of the field is in space, and the other pole is in hyperspace, the wormhole appears to us as a magnetic monopole. The key to this invention is how to generate this magnetic wormhole field.

[0013] Referring to **FIG. 11**, the aluminum spacecraft is constructed of a flattened, shallow spherical lower hull (**21**), a circular upper hull with a flat sloping surface (**22**), a spherical dome cupola (**23**), and a cylindrical section (**24**) housing a circular array of radial microwave waveguides. Surfaces (**22**) and (**23**) are electrically charged, using high-voltage transformers, to an alternating electrostatic potential such that the potential on the dome is +V when the sloping hull has a −V potential and vice versa. This creates an electric field from the positively charged surface to the negatively charged surface.

[0014] Referring to **FIG. 12**, the dome (**25**) is charged to a positive potential. The spherical potential lines (**26**) emanate from the dome and curve around toward the sloping hull. The negative gradient of this potential field is the electric E field (**27**) which is perpendicular to the potential lines. The electric field lines from the dome then terminate on the sloping hull which can be seen in the lower right hand comer of the graph.

[0015] Looking down from above at the top of the dome, referring to **FIG. 13**, the oscillating electric field generates a circular oscillating magnetic field around the hull at various elevations. The last two graphs in the right-hand comer are near the top of the dome as seen by the smaller radius contour lines.

[0016] Referring to **FIG. 14**, the oscillating electric field lines (**28**) are between the dome and the sloping hull. The oscillating magnetic field (**29**) encircles the hull at the level of the microwave waveguides.

[0017] From gravitation physics, it is known that negative energy is required to open up the throat of the wormhole. In terms of differential forms mathematics, the negative energy is created by wedging the magnetic field with the radial microwave beams of the waveguides. This generates an increasing time rate of change of negative energy ρ as shown by

$$*d(B^\wedge(B_{wave}+E_{wave}dt))=\frac{\partial(-\rho)}{\partial t}$$

where (*) is the Hodge Star operator, (d) the differential operator and (ˆ) the wedge operator which joins the circular magnetic flux density B field with the electromagnetic wave (B_{wave}, E_{wave}).

[0018] Referring to **FIG. 15**, the interaction of the circular magnetic field (**33**), generated by the oscillating electric field (**34**), interacts with the radial electromagnetic field of the microwave beams (**31**) of the waveguides (**30**) to generate negative energy (**32**) over the sloping hull (**35**).

[0019] This combination of fields also creates the wormhole field over the hull. The spacetime curvature pressure T in the vertical z-direction is equal to the square of the circular magnetic flux density field

$$T^{zz}=\frac{B^2}{8\pi}$$

This stress-energy-momentum tensor can be thought of as a spacetime curvature proportional to the inverse of the radius squared, or as a pressure term which acts on the surface area of the hull. Thus there is the combination of a pressure stress and negative energy which creates the wormhole field over the sloping hull. Even though the magnetic flux density B field is oscillating, it is the square of the field which creates the stress. Thus the tension is still in the positive vertical z-direction.

[0020] Due to the low speed of light of hyperspace, the hyperspace energy is low density. Thus there is a positive gravitational potential between hyperspace and our dimension such that the hyperspace energy flows through the wormholes and onto the hull of the spacecraft. When this happens, a white mist forms over the hull. The effect of the hyperspace energy is to lessen the mass of the spacecraft, and relativistically increase the strength of the electromagnetic fields due to the smaller speed of light.

[0021] Referring to **FIG. 16**, the circular magnetic flux density field (**36**) is interacting with the magnetic monopole (**37**). The monopole acts as one pole of a magnet and therefore has a magnetic moment equal to the area times the electrical current circulating through it as the electrons move from our dimension into hyperspace. The great physicist Maxwell (**1870**) pointed out that the energy associated with charges and poles is potential energy and that therefore these objects tend to move in a direction that will decrease the potential energy, similar to a brick sliding down an inclined plane. Now to reduce the potential energy is the same as to reduce the field which gives a measure of the potential energy. If two like charges are brought together they strengthen one another's field, while opposite charges reduce one another's field. Thus like charges repel and unlike ones attract.

[0022] However, the energy associated with electric currents is not potential but kinetic in origin, because it is associated with moving charges. Now in mechanics it is well known that bodies move in a direction to increase their kinetic energy, if there is a source of external energy. The magnetic field of currents is a measure of kinetic energy and currents will try to move in a direction that will increase the field. Thus similarly-directed currents attract and unlike currents repel. In **FIG. 16**, the monopole will act so as to increase the field of the circular magnetic B field generated by the spacecraft. The monopole will then rotate into alignment with the flux tube. This increases the field strength of the flux tube. There is a torque τ on the monopole equal to the cross product of the magnetic moment with the B field

$$\tau=\mu\times B$$

[0023] Referring to **FIG. 17**, when the monopole is aligned with the flux tube, the cross product is zero and there is zero torque on the monopole. Notice that even if the oscillating B field points in the opposite direction, there is still zero torque since the torque depends on the sine of the angle between them. The sin(0°) or sin(180°) is the same zero value. With the monopole aligned with the flux tube, the kinetic energy is now maximized. That is, both the flux tube and the monopole point in the θ-direction.

[0024] The magnetic B field can be represented as a vector having three components. The only component is in the angular direction

$$B=\{B_r,B_\theta,B_z\}=\{0,\ B_\theta(z),\ 0\}$$

where the field varies, as was seen in **FIG. 13**, in the vertical z-direction. The magnetic monopole field also points in the θ-direction

$$\mu=\{0,\mu_\theta(z),0\}$$

where there is a negative gradient of the monopole field in the z-direction due to the location of the microwave waveguides near the sloping hull.

[0025] The force F on the monopole is the gradient of the monopole's magnetic moment μ with the magnetic flux density B field

$$F=\nabla(\mu\cdot B)=\{0,\ 0,\ \mu_\theta\, B_\theta'(z)+B_\theta(z)\mu_\theta'(z)\}$$

which says that there is a force on the monopole in the z-direction equal to the magnetic moment times the gradient of the magnetic field in the z-direction plus the magnetic field times the gradient of the magnetic moment in the z-direction.

[0026] Referring to **FIG. 18**. differentiating the magnetic field in the z-direction shows that the gradient is negative outside the hull. This can also be seen visually in **FIG. 13** where the graphs decrease in intensity.

[0027] A negative gradient for both the magnetic moment and the field means that the force on the monopole is negative. The force on the tube connected to the hull is therefore the negative of a negative, yielding a positive lift force.

$$F_{monopole}=-\{0,\ 0,|\mu_\theta B_\theta'(z)+B_\theta(z)\mu_\theta'(z)|\}=-F_{tube}$$

$$F_{tube}=+\{0,\ 0,|\mu_\theta B_\theta'(z)+B_\theta(z)\mu_\theta'(z)|\}$$

which says there is an upward lift force on the hull due to the combination magnetic monopole and flux tube. This lift force is in addition to the vertical lift force generated by the spacetime curvature created by the electromagnetic fields themselves.

SUMMARY OF THE INVENTION

[0028] This invention is a spacecraft propulsion system that utilizes electromagnetic fields and microwaves to generate negative energy and a spacetime curvature over the hull. The hull consists of a hemispherical dome, a circular array of radial microwave waveguides, a sloping flat hull, and a shallow spherical hull on the bottom. Alternating current high voltage transformers connected to the dome and the sloping hull generate a curving oscillating electric field between the dome and the sloping hull. Due to this oscillation, a horizontal circular oscillating magnetic flux density B field is created around the dome.

[0029] By firing the microwaves at right angles to the B field, negative energy is created over the hull. The negative energy and spacetime curvature pressure generate wormholes between space and hyperspace. Because hyperspace has a low speed of light and positive gravitational potential, low density hyperspace energy flows through the wormholes and onto the hull. The effect of the hyperspace energy is to lessen the mass of the vehicle and to increase the strength of the electromagnetic fields. Because the resistance of hyperspace is less than the resistance of space, electrons spiral down the wormholes into hyperspace. This creates a magnetic field through the wormhole with one pole in our dimension and the other pole in hyperspace. Thus a field of magnetic monopoles is created over the hull.

[0030] The magnetic monopoles, which represent kinetic energy, align themselves with the magnetic flux tubes in order to maximize the total magnetic field. Because there is a gradient of the monopoles and field in the vertical direction, a negative force develops on the monopoles equal to the gradient of the dot product of the magnetic moment of the monopole with the B field. Thus the opposite reaction is a positive force on the flux tubes attached to the hull which is equivalent to bringing the north pole of a magnet together with the south pole of a second magnet. Because the hull constantly regenerates the wormhole field, the hull experiences a constant upward lift force. This is in addition to the lift generated by the spacetime curvature pressure which is proportional to the square of the magnetic flux density B field.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0031] **FIG. 1**. Perspective view of cylindrical coordinate system $\{r, \theta, z\}$.

[0032] **FIG. 2**. Perspective view of tetrahedron circumscribed by sphere.

[0033] **FIG. 3**. Tetrahedron diagram showing speed of light squared is determined by the tetrahedron.

[0034] **FIG. 4**. Complex number z representation in the complex plane.

[0035] **FIG. 5**. Perspective view showing multiple log manifold hyperspace dimensions.

[0036] **FIG. 6**. Perspective view of orthogonal hyperspace dimensions.

[0037] **FIG. 7**. Perspective view of Log[z] showing cut along origin.

[0038] **FIG. 8**. Perspective view of charge phase shift around a magnetic flux.

[0039] **FIG. 9**. Perspective view of wormhole magnetic flux density B field.

[0040] **FIG. 10**. Perspective view of magnetic monopole wormhole.

[0041] **FIG. 11**. Perspective view of spacecraft.

[0042] **FIG. 12**. Graph showing electrostatic potential and electric field over dome.

[0043] **FIG. 13**. Animation showing circular magnetic field around dome at increasing elevation.

[0044] **FIG. 14**. Perspective view of electric and magnetic fields around hull.

[0045] **FIG. 15**. Perspective view of generation of negative energy.

[0046] **FIG. 16**. Perspective view of monopole misaligned with flux tube with torque.

[0047] **FIG. 17**. Perspective view of monopole aligned with flux tube at zero torque.

[0048] **FIG. 18**. Graph showing negative gradient of flux tube in the z-direction.

DETAILED DESCRIPTION OF THE INVENTION

[0049] 1. The aluminum hull is made by a technique called stretch forming which uses hydraulic cylinders to stretch a large sheet of aluminum to its yield point. This makes the aluminum sheet soft and pliable. Using a die which has been CNC machined to the desired hull profile, the sheet is then die pressed into a very rigid, smooth and lightweight structure requiring no other support. There are actually three dies consisting of a spherical dome, sloping hull, and shallow spherical dome.

[0050] 2. The rest of the hull consists of a cylindrical hull with a radius equal to the upper dome. A segment of this hull is designed on a 3D computer graphics program and stored as a stereolithography *.stl file. The file is then transmitted over the Internet to a server who prints up the part on an xy-plotter with an ultraviolet laser and ultraviolet light sensitive polymer bath. The computer model is sliced by a special program into many thousands of slices which are printed one over the other until the part is completed. The server returns the part next day by Express Mail. Several parts are then molded using liquid plastic such as to form the complete ring. A sand mold is then constructed from all the molds to form a plastic cylindrical hull having the waveguide slots molded into it. The waveguide silver-coated aluminum boxes are then installed in the slots and connected to the frequency generators and amplifiers. The purpose of the plastic waveguide cylinder is to separate the electrostatic charges on the dome and the sloping hull In this particular case we used a dome from another spacecraft design which saved on the cost of the die.

I claim:

1. A spacecraft propulsion system consisting of the following components:

- a lower hull made of aluminum sheet having a shallow spherical profile;
- a circular flat sloping hull made of aluminum sheet attached to the top of the lower hull on the periphery;
- an electrically-insulated plastic-molded tubular cylindrical hull containing slots for mounting an array of radial microwave waveguides, attached to top of the flat sloping hull;
- a hemispherical cupola in the shape of a dome made of aluminum sheet mounted on top of the insulated cylindrical hull;
- an array of rectangular microwave waveguides mounted in the waveguide slots of the cylindrical hull;
- a high-voltage alternating current transformer with one side electrically attached to the upper dome and the other side electrically attached to the flat sloping hull; and
- a frequency generator and amplifier to drive the microwave waveguides.

2. By means of claim (**1**), an oscillating electric field is created between the upper dome and the sloping hull using the high-voltage alternating current transformer.

3. By means of claim (**2**), an oscillating circular magnetic flux density field is generated around the sloping hull and upper dome.

4. By means of claims (**1**) and (**3**), negative energy is generated by the radial microwave beams of the waveguide array impinging on the circular magnetic flux density field around the hull.

5. By means of claim (**3**), a positive spacetime curvature pressure constituting a lift force is developed over the hull in the vertical direction proportional to the square of the field.

6. By means of claims (**4**) and (**5**), a field of wormholes between space and hyperspace are generated over the hull.

7. By means of claim (**6**), due to the positive gravitational potential between hyperspace and space, low-density hyperspace energy flows through the wormholes onto the hull to reduce the mass of the spacecraft and strengthen relativistically the electromagnetic fields.

8. By means of claim (**6**), electrons, emitted by the charged hulls, spiraling down the wormholes, generate a field of magnetic monopoles with one pole in space and the other in hyperspace.

9. By means of claims (**6**) and (**3**), the magnetic monopoles maximize their kinetic field energy by aligning with the magnetic flux tube.

10. By means of claim (**9**), the gradient in the vertical direction of the dot product of the magnetic moments of the monopoles with the magnetic flux density field is a negative force on the monopoles and an equal but opposite positive lift force on the magnetic flux tubes attached to hull.

11. By means of claims (**10**) and (**5**), a dual method of providing apositive lift force on the spacecraft is constituted.

* * * * *

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(54) METHOD OF GRAVITY DISTORTION AND TIME DISPLACEMENT

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(52) **U.S. Cl.** .... **505/166**; 505/180; 434/300; 73/382 G; 505/164

(57) **ABSTRACT**

A method for employing sinusoidal oscillations of electrical bombardment on the surface of one Kerr type singularity in close proximity to a second Kerr type singularity in such a method to take advantage of the Lense-Thirring effect, to simulate the effect of two point masses on nearly radial orbits in a 2+1 dimensional anti-de Sitter space resulting in creation of circular timelike geodesics conforming to the van Stockum under the Van Den Broeck modification of the Alcubierre geometry (Van Den Broeck 1999) permitting topology change from one spacelike boundary to the other in accordance with Geroch's theorem (Geroch 1967) which results in a method for the formation of Godel-type geodesically complete spacetime envelopes complete with closed timelike curves.

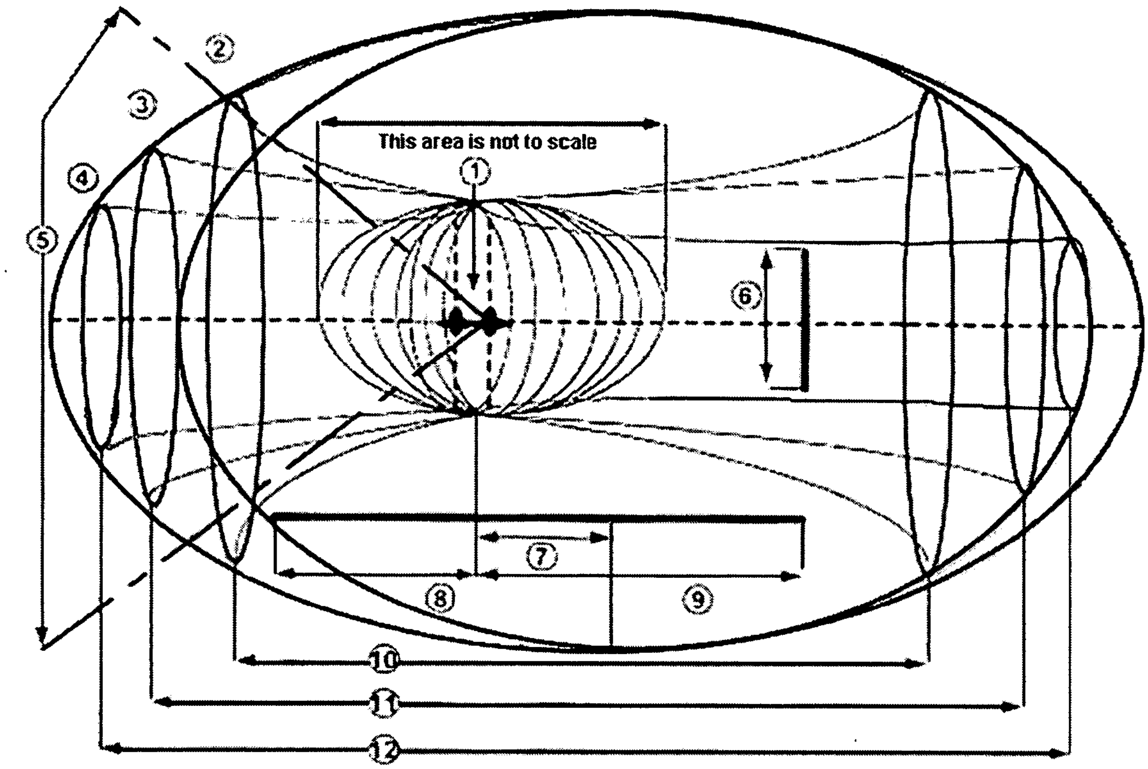

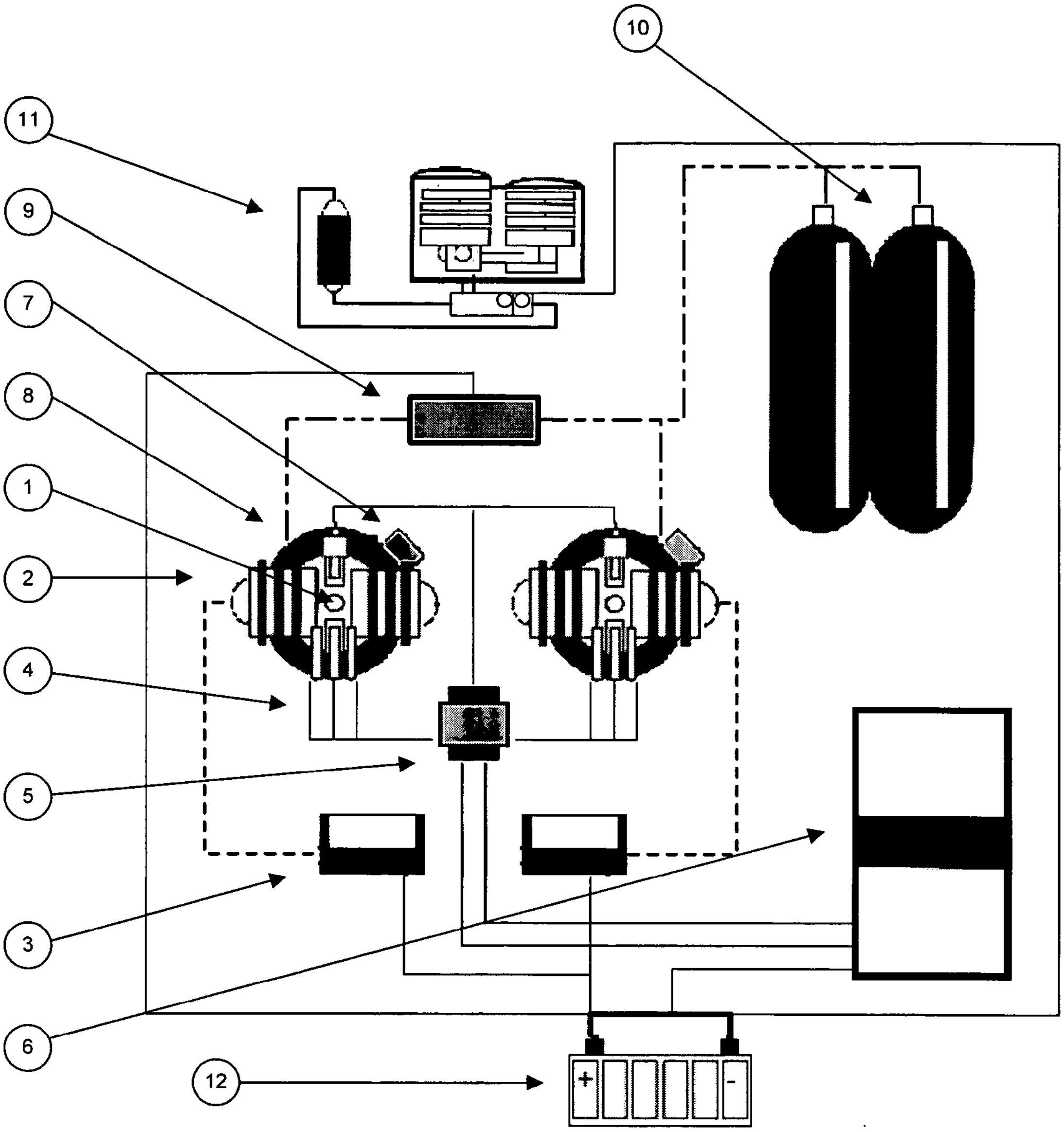
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Figure 1

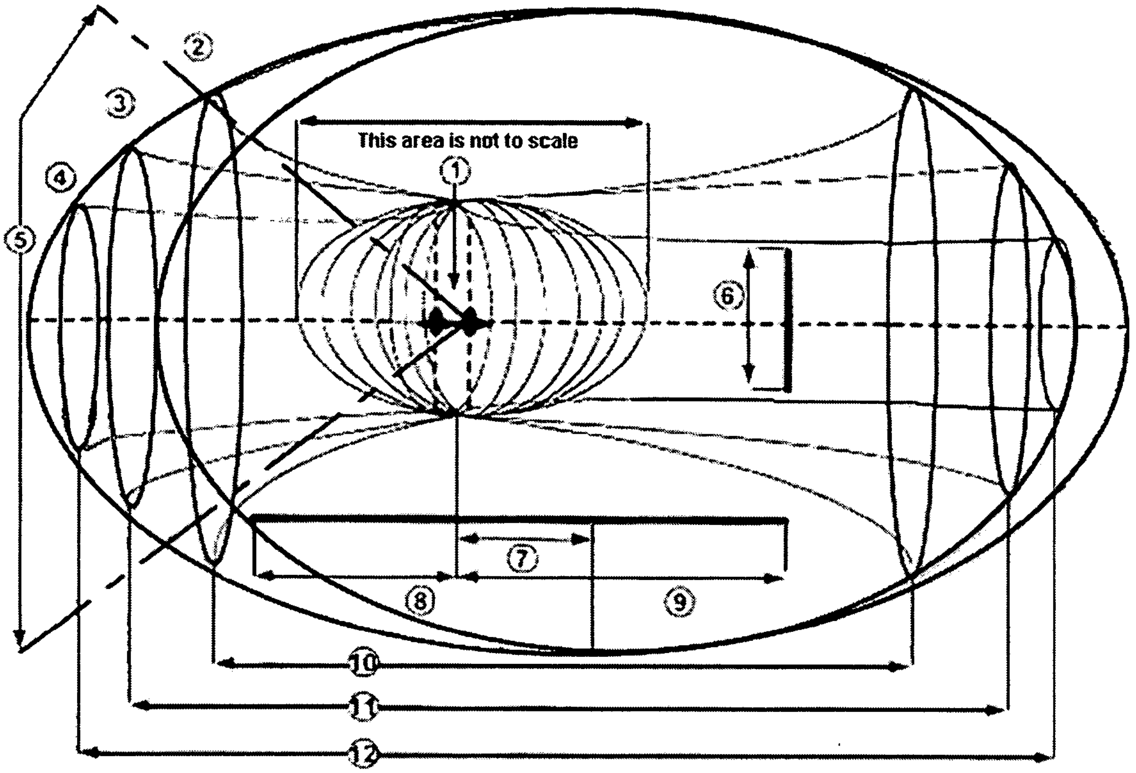
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Figure 2

METHOD OF GRAVITY DISTORTION AND TIME DISPLACEMENT

FIELD OF THE INVENTION

[0001] The present invention relates to the use of technical time displacement devices, which operate by the modification of gravitational fields. These drive systems do not depend on the emission of matter to create thrust to take advantage of time dilation, but rather create a change in the curvature of space-time, in accordance with general relativity. This allows travel across topologies by warping space-time, to produce a topology change from one spacelike boundary to the other in accordance with Geroch's theorem (Geroch 1967)

THEORETICAL BACKGROUND OF THE INVENTION

[0002] The concept of gravity should be examined in the light of quantum gravity and in turn as a component of quantum physics itself. The fundamental minimal quantum of energy in quantum physics is Planck's constant; h. Thus in accordance with the energy equivalence formula $E=mc^2$, the fundamental minimum quantity of mass (m_q) can therefore be derived, from known constants by; $m_q=h/c^2$ (1). Taking this minimal mass, it is possible to show that the formation of all matter, the forces of nature and indeed space-time itself derive from this single quintessential quantity.

[0003] Thus if the number of quintessences in a system is; $n_q=m/m_q$: then the total Energy of the system is more logically given by, the energy of a single quintessence (h); directly multiplied by the number of quintessences (n_q) in that system, thus

$$E=hn_q=mc^2 \qquad (1\ a).$$

[0004] Furthermore, this minimal mass, termed quintessence, can form the basis of the existence of a quantum gravitational field in the form of a space-time lattice, from which quantum gravity may be derived from first principles. Furthermore, the conglomeration of these quintessences also accounts for the formation of the elementary particles and the forces acting between them, as in superstring theory. This concept explains the formation of matter and the forces of nature on a quantum mechanical basis and directly explains the existence of wave particle duality. Thus as $n_q=m/m_q$; the frequency of light and matter (f) is determined, directly, from the number of constituent quintessences. This leads automatically to the fundamental equation, derived from (1), $f=n_q=E/h$, where n_q is the number of quintessences, which leads directly to the frequency of both light and matter. This in turn leads directly to a Universal wave equation for matter and light $\lambda=c/\beta n_q=hc/\beta E$ (2), where β is the relative directional velocity, v/c. As the momentum, $p=\beta\times E/c$, then this equation also gives the standard de-Broglie wave equation, $\lambda=h/p$ in agreement with current theory and experiments[1].

[0005] Using the Universal wave equation, the standard equation for special relativity, $m'=m_o/(1-\beta^2)^{1/2}$, derives from first principles. Also from these observations, a modified Dirac wave equation may be derived, $E\psi=(-j\beta\cdot\nabla+\beta m)\psi$ (2a), the results of which have been recently verified by a paper in which the orbitals of electrons were experimentally directly visualised[2]. Moreover, a fundamental equation for general relativity can be formulated, where G is the gravitational constant and r_q is the given radius of quintessence; $G=9(r_q)^2c^4/\lambda\beta E$ (3), such that the Universal wave equation is in direct agreement with general relativity[3]. Thus special and general relativity and quantum mechanics can be unified.

[0006] From here it is possible to proceed in a number of ways; the geometric structure of the electron and the forces of Nature may be derived from first principles and in turn the structure of the quarks, including the top and bottom, otherwise known as truth and beauty can be seen. Moreover, the presence of a space-time lattice results in an understanding of quantum EPR effects. By allowing a theoretical flow of energy through the space-time lattice it can be shown that:

[0007] Energy is not bound by space-time

[0008] Thus logically accounting for phenomena such as entanglement and quantum tunnelling. Quintessence can also be used to explain, logically, the inner physics of a black hole, the missing mass of the Galaxy, the continuing expansion of the Universe, Guth's inflationary theory and the Big Bang. Hence, it is now possible to understand the Universe, including space-time, matter and the forces of nature from the radius, mass and vibration of a single quantity, quintessence.

[0009] With this understanding of space-time, matter and the forces of Nature, and in particular gravity, it is possible to demonstrate that the modification of gravitational fields, and in turn the warping of space-time, can be technically readily achieved.

[0010] Using standard equations for special relativity, $m'=m_0/(1-\beta^2)^{1/2}$, it can be demonstrated that by differentially increasing the velocity of electrons, by applying a differential current, their mass can be increased in a specific way. In turn by increasing the mass of electrons, by general relativity, the number of gravitons emitted from these electrons can be modulated. By multiplying this effect using an ultracentrifugational device the differential graviton emission can be manifestly amplified. This in turn, in accordance with general relativity, will cause a change in the curvature of space-time.

[0011] This effective warping of space-time does not, of necessity, imply superluminal velocities, but does allow the creation of warp drive systems, which do not depend on the creation of thrust by the ejection of material as used in current space technologies.

Part 1—Fundamental Laws of Physics

[0012] Quintessential Mass

[0013] The quantum physical, minimum component of energy is Planck's constant; h. To define the minimal component of mass, using the standard energy equivalence formula; $E=mc^2$, such a minimal mass (m_q) would be required to have the value equivalent to; $m_q=h/c^2$ (1). The total mass of a system (m) would then be; $m=n_qm_q$, where (n_q) is the number of these minimal units. Thence, the total energy of a system can be derived from the minimal energy; h, multiplied by the number of these energy units (n_q). Thus as, $E=mc^2$, then also $E=m_qn_qc^2$ and substituting $m_q=h/c^2$, the energy equivalence formula has the more logical formulation; $E=hn_q$(1a). Thus the energy of a system is equivalent to the minimal energy unit; h, multiplied by the number of those minimal energy units (n_q).

[0014] Taking this minimal mass/energy, it is possible to show that all matter, the forces of nature and space time can be constructed from this single quintessential quantity. Moreover, using this quantity the laws of physics can be derived from first principles. Thus, a priori, all components of the physical universe, including space-time, can be constructed from this minimal mass component, termed quintessence.

[0015] Wave Particle Duality

[0016] If the presence of quintessence accounts for the structure of matter and if matter itself forms from the number of quintessences, then the frequency of matter and thus wave particle duality directly arises from first principles. Specifically the wavelength of matter derives from the vibration of quintessence from which it is constituted. Thus the frequency (f) and in turn the wavelength of light and matter is directly equivalent to the number of quintessences contained within it. We find that the actual frequency of light can be directly derived from first principles from the effective mass of the photon (m,) and thus by the number of quintessences (n_q) it contains.

[0017] Thus for light conventionally:

$$f=E/h$$

[0018] and if $E=mc^2$, and $h=m_qc^2$, then

$$f=m_\gamma c^2/m_qc^2$$

and

$$f=m_\gamma/m_q=n_q$$

Thus

$$f=n_q \tag{4}$$

[0019] Thus the formula for the frequency of light E=hf is now readily explained by the observation that the frequency is determined quite directly from the number of quintessences n_q within the photon.

[0020] The wavelength is thus also given by:

$$\lambda=c/f=m_{qc}/m_\gamma=h/p$$

[0021] We can now show that the frequency of matter also has the same derivation from quintessence, as has the frequency of light. The frequency of matter is again equivalent to the number of quintessences it contains. Thus the wave particle duality of matter itself can be explained by its composition from quintessence. The amount of quintessences contained within a electron sphere will depend on the number of quintessences constituting the electron and those passing through it as a result of its relative velocity β^2 (where $\beta=v/c$); effectively its relativistic momentum (p). The frequency will then be related to the total number of quintessences. Thus for matter,

$$f=\beta^2n_q \tag{4a}$$

[0022] Thus it is possible to derive the conventional de Broglie wave equation for matter from first principles. Thus, as $\lambda=v/f$, we have:

$$\lambda=v/\beta^2n_q \tag{5}$$

[0023] thus as $n_q=E/h$

$$\lambda=hc/\beta E \tag{2}$$

[0024] and as conventionally $\beta E/c=p$, then for matter:

$$\lambda=h/p$$

[0025] Provided that in the de Broglie equation, the momentum of the object is calculated using the relativistic mass, thus accounting for the total number of quintessences n_q in an object, this gives an accurate value for the wavelength of matter[1].

[0026] Thus the wavelength of matter follows directly from its constituents, quintessence. As matter is made of quintessence, similarly to light, its frequency depends on the number of quintessences n_q within it, traveling relative to the speed of light. Moreover, $\lambda=hc/\beta E$, underpins a fundamental relationship between wavelength and energy. Furthermore, this is mathematically the same as the term $\lambda=hv/\beta^2E$, giving a relativistic expression for the wavelength of matter, from which the relativistic equations may be directly derived

[0027] Wave Equations

[0028] The derivation of wave particle duality from first principles also now allows the derivation of a modified wave equation for matter.

[0029] To derive his wave equation Shrodinger commenced with the de Broglie equation using momentum (p). For lower energies the momentum of an electron is conventionally derived from the kinetic energy of the electron and the mass of the electron m_0. Thus conventionally:

$$E_k=\frac{1}{2}mv^{1/2} \quad \text{and} \quad p=m_0v$$

Thus

$$E_k=p^2/2m_0$$

then

$$p=\sqrt{(E_k\cdot 2m_0)}$$

[0030] and conventionally, the de Broglie equation can also be written as:

$$\lambda=h/p=h/\sqrt{(E_k\cdot 2m_0)}$$

[0031] In turn the Shrodinger wave equation directly derives from the square of the above classical non relativistic term for kinetic energy:

$$\lambda^2=h^2/E_k\cdot 2m_0$$

$$\text{thus } E_k=\frac{h^2}{2m}\cdot\frac{1}{\lambda^2}$$

$$\text{As } E=E_k+V$$

$$\text{then } E\psi=-\frac{h^2}{2m}\cdot\frac{d^2\psi}{dx^2}+V\psi=jh\cdot\frac{d\psi}{dt}$$

[0032] However, the Shrodinger equation, may be refined by taking into account relativity. Thus the true values for the energy are given by the relativistic momentum (p).

[0033] A fundamental relativistic wave equation for ψ, and its logical derivation may now be developed through the concept of quintessence as a fundamental constituent of matter.

[0034] The amount of quintessences in the electron is determined by the number of quintessences forming the electron at rest, plus the amount of quintessences passing through it due to its relativistic velocity, which will determine the relativistic momentum (p) of a particle.

[0035] The frequency of matter can now be readily calculated from first principles to give a more accurate result. Thus as matter is made of quintessence, similarly to light, its frequency is equal to the number of quintessences n_q within it. The wavelength will depend on its velocity travelling relative to the speed of light and thus multiplied by the relative velocity compared to c(β=v/c);

[0036] Hence for matter as previously shown:

$$\beta=v/\beta^2 n_q=hc/\beta E \tag{2}$$

[0037] And conventionally

$$E=(p^2c^2+m_0^2c^4)^{1/2}$$

[0038] Using these equations, we can now, also, reformulate the Shrodinger wave equation, which has the advantage that relativity can be treated in a quantum mechanical way. Thus if the wave energy of matter is defined as:

$$E_\lambda=\frac{\beta\sqrt{p^2c^2+m_0^2c^4}}{c^2}$$

thus

$$E_\lambda=\sqrt{(\beta^2p^2/c^2)+\beta^2m_0^2}$$

[0039] which in complex space generalises to

$$E_\psi=(-j\beta\cdot\nabla+\beta m)_\psi \tag{2a}$$

[0040] As the term

$$\alpha=\frac{e^2}{hc}4\pi\varepsilon_0;$$

also represents the ground state ratio of the velocity of the electron to c. Thus α=β=v/c=1/137.

[0041] Thus, also

$$E_\psi=(-j\alpha\cdot\nabla+\beta m)_\psi$$

[0042] This is thus the standard relativistic equation that Dirac was able to construct from the Shrodinger wave equation. This relativistic equation can be derived from the modified wave equation. This takes into account the relative mass energy which the quintessential wave equation contains.

[0043] Where importantly the term β·m is the mass m, multiplied by the ratio of the relative velocity to light β=v/c, and the term a is also essentially the relative velocity of the electron.

[0044] The Dirac equation was an empirical formula which worked mathematically, nevertheless even Dirac admitted it was not logically understood. The importance of these equations is that they show that the existence of quintessence allows the waveparticle duality of matter to be explained and mathematically derived from first principles, Thus the frequency of matter or even light is simply determined by the number of quintessences it contains.

[0045] Indeed, a recent publication in Nature has suggested that the direct visualisation of the orbitals of electrons shows that these are in very close agreement with theory. However, there is a significant departure from theory, in the interstitial molecular regions, suggesting that the higher velocities of the electrons obey the modified Dirac equation. Thus these orbitals were in keeping with the modified Dirac equation, which itself may be derived from the wave equation above, λ=hc/βE

[0046] The Shrodinger wave equation will approximate to the correct values until v approaches c. Indeed the Shrodinger equation will give similar answers as that derived from equation, under most experimental conditions.

[0047] However, equation 2 and its derivative may have advantages over standard Shrodinger theory with relativistic speeds. Furthermore, equation 2, conceptually shows that the wave particle duality of matter derives from the principle that the frequency of matter is directly equal to the number of quintessences it contains. Importantly it also mathematically allows relativity and quantum mechanics to be united.

[0048] With v≅c, the modified Dirac equation will yield more accurate results, particularly compared with the Schrodinger equation. We also find that the equation λ=hc/βE is equivalent to the de Broglie wave equation, λ=h/p, provided we use the relativistic mass in the de Broglie equation. Given this, these equations yield accurate experimental results.

[0049] Thus we find that the modified formulation of de Broglie wave equation λ=hc/βE leads directly to a modified Dirac relativistic wave equation and is supported by recent experiments which measure the wavelength of matter and demonstrate the electron orbitals experimentally from these wave equations for matter.

[0050] Wave Particle Duality and Relativity

[0051] From here it is possible to proceed in several ways using the relativistic wave equation. It is apparent that the reintroduction of the term for relative velocity into the wave equations will enable the reintroduction of special relativity into quantum mechanics. In particular we should now be able to derive the term

$$\sqrt{\left(1-\frac{v^2}{c^2}\right)}$$

as a special case of quantum mechanics.

[0052] Thus if:

$$\lambda=hc/\beta E$$

As $E=\sqrt{p^2c^2+m_0^2c^4}$, squaring

$$\lambda^2=\frac{h^2c^2}{\beta^2\cdot(p^2c^2+m_0^2c^4)}$$

-continued

Conventionally $p^2c^2 = \frac{E^2v^2}{c^2}$

then

$$\lambda^2 = \frac{h^2c^2}{\beta^2 \cdot ((E^2v^2/c^2) + m_0^2c^4)}$$

Thus as $\beta^2 = \frac{v^2}{c^2}$ and $m_0^2c^4 = E_0^2$, then:

$$\beta^4E^2 + \beta^2E_0^2 = \frac{h^2c^2}{\lambda^2}$$

hence $\beta^4E^2 = h^2c^2 \cdot \frac{1}{\lambda^2} - \beta^2m_0^2c^4$ thus

$$\beta^2 = \frac{h^2c^2}{\beta^2E^2} \cdot \frac{1}{\lambda^2} - \frac{\beta^2m_0^2c^4}{\beta^2E^2}$$

As $E^2 = m^2c^4$

$$\beta^2 = \frac{h^2c^2}{\beta^2m^2c^4} \cdot \frac{1}{\lambda^2} - \frac{\beta^2m_0^2c^4}{\beta^2E^2}$$

Substituting $h = m_qc^2$

$$\beta^2 = \frac{m_q^2c^6}{\beta^2m^2c^4} \cdot \frac{1}{\lambda^2} - \frac{\beta^2m_0^2c^4}{\beta^2E^2}$$

As $m_q/'m = 1/n_q$ (eq. 2)

$$\beta^2 = \frac{c^2}{\beta^2n_q^2} \cdot \frac{1}{\lambda^2} - \frac{\beta^2m_0^2c^4}{\beta^2E^4}$$

Thus if $f = \beta^2n_q$; (eq. 7a)

$$\beta^2 = \frac{v^2}{f^2} \cdot \frac{1}{\lambda^2} - \frac{\beta^2m_0^2c^4f^2}{\beta^2E^2}$$

As $1/\lambda^2 = f^2/v^2$

$$\beta^2 = \frac{v^2}{f^2} \cdot \frac{f^2}{v^2} - \frac{\beta^2m_0^2c^4f^2}{\beta^2E^2}$$

Thus

$$\beta^2 = 1 - \frac{\beta^2m_0^2c^4}{\beta^2E^2}$$

As $E^2 = m^2c^4$

$$\beta^2 = 1 - \frac{m_0^2}{'m^2}$$

Hence

$$m_0/'m = (1-\beta^2)^{1/2}$$

Thus

$$'m = m_0 \Big/ \left[1 - \frac{v^2}{c^2}\right]^{1/2}$$

[0053] Thus this derivation now allows relativity as a universal case of the quintessential wave nature of matter.

[0054] The original premises on which special relativity was based were: that the speed of light is a constant and that all observers are equal. As the speed of light has dimensions of length and time but not apparently of mass, the relativistic change in mass is not accounted for. Using quintessence logically and directly accounts for the relativistic mass changes.

[0055] Moreover, relativity can be derived from the de Broglie equation, and visa versa, directly, thus linking relativity and quantum mechanics by taking into account the existence of quintessence mass.

[0056] Hence, it is now possible to derive the relativistic equations for mass and in turn for space and time from the quintessential wave equation, thus deriving special relativity as a universal case of quantum mechanics and thus uniting special relativity and quantum mechanics. This now allows a further understanding of the nature of space-time.

[0057] The Space-Time Lattice

[0058] The understanding of the true nature of space-time and how it is formulated in three dimensions of real space is crucial. To simply assume that space-time exists, and thence not to question the nature of that existence, denies a deeper understanding of the universe.

[0059] In order to understand the nature of space-time itself, at the quantum level a further look at the nature light and the photon is necessary. Since Einstein's description of light as a particle (the photon) and the description of the photoelectric effect, the standard picture of light as simply a wave can, no longer be applied. If light was to exist as a photon, it could not exist in one dimension, as ordinary waves do, it would need to be three dimensional, with the addition of time. Let us suppose, in this case, that a photon is a three dimensional helical ringlet of light, travelling in the x vector, and spinning around the x-axis. Conventionally this ringlet has a radius; $r=\lambda/2\pi$. The ringlet itself would be vibrating in the y and z vectors. The vectors x, y and z would represent the photon, the substance of which, would be travelling in the x direction and oscillating in the y and z vectors, which would represent oscillatory energy. This in turn would allow it to act as a wave, and create oscillatory electromagnetic fields.

[0060] It is important to re-examine space-time itself in this light, this would have one directional vector with two vector dimensions of energy, one of capacitance and one of electrical permeability, thus accounting for the well known constants of free space; the permittivity of free space (ϵ_0) and the permeability of free space (μ_0) respectively. The vector dimension of direction x, would be the direction of travel and those "quintessences" travelling in an outwardly direction would account for none other than the expansion of the universe. Three of these quintessences would naturally constitute three dimensional visible space-time. These constituents of space-time would interact with the generations of the other vector dimensions reciprocally. Thus one quintessence would sweep out one vector of permeability and one vector of permittivity, through which the other two quintessences could travel, and vica versa, creating a three dimensional space-time lattice.

[0061] The permittivity of free space, (ϵ_0) which is equivalent to capacitance, would as with capacitance plates, be determined by the effective separation between quintessences. The permeability of free space (μ_0) is in fact a force, measured as $4\pi\times10^{-7}$ N/A^2, would result from the force produced by the vibration of quintessence and would be dependent on the density of quintessence. Hence these two parameters would be reciprocal and thus the product of these two would therefore be a constant, which is recognised as none other than the speed of light.

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

[0062] This space time lattice would in effect be created by quintessences travelling in all directions with a speed of c within the lattice. The quintessences of the space time lattice would in effect produce a non-static ether. A non-static ether is fully compatible with special and general relativity. Indeed such an ether explains how space time can be curved as in general relativity. Furthermore, the existence of a non-static ether, was espoused by Einstein in his University of Leyden lecture on general relativity of May 5, 1920. In Einstein's own words;

[0063] "According to the general theory of relativity space without ether is unthinkable."

[0064] Recent evidence from a number of sources now strongly support the presence of this non-static ether, in the form of quintessence. An editorial from a major journal states "combined with other observations such as those of distant Supernova, the QMAP results corroborate the prevailing theory of inflation with the twist that the Universe is only one third matter (both ordinary and dark) and two thirds quintessence, a form of energy possibly inherent in empty space".

[0065] If we take into account the existence of quintessence and as such a three dimensional space-time lattice, matter which is intrinsically made of constituents of charge would interact with this lattice to produce the effects of mass. Mass would be perceived as a result of matter (whose constituent particles appear to contain charge) interacting with this lattice directly due to the inhibition of motion by the lattice's electrical permeability and permittivity vectors, which would form the existence of complex space. These quintessences would in the direction in the y and z vectors produce small vibrations of the order of the Planck length (10^{-35} m), whilst passing through the vectors of permeability and permittivity, thus producing the effects of mass.

[0066] The vibration would endow quintessence itself a (non rest) mass m_q equivalent, to the minimal mass of:

$$m_q = h/c^2 = 7 \times 373 \times 10^{-51}\ \text{kg}\cdot\text{sec} \tag{1}$$

[0067] The presence and magnitude of Planck's constant (h) and especially the speed of light (c) is thus explained. Indeed, the speed of light

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

is not in itself a fundamental quantity.

[0068] As the energy equivalence formula is $E=mc^2$, the minimal mass of a single quintessence, would thus be the minimal mass, h/c^2, hence again:

$$m_q = h(\mu_0 \epsilon_0) = h/c^2 = 7.373 \times 10^{-51}\ \text{kg}\cdot\text{sec} \tag{1b}$$

or

$$m_q c^2 = h \tag{1c}$$

[0069] It is postulated by general relativity that the shape of space time itself can be altered, indeed the presence of the space time lattice now allows this to be altered by altering the density of quintessence. It is further clear that if quintessences underly the structure of the space-time lattice, they may also underly the structure of matter itself.

[0070] With regards a single quintessence, this passing through an energy vector of the space-time lattice would appear as a vibrating string. In a similar way to string theory, the conglomeration of these quintessences would produce the constituents of ordinary matter. Thus the general equation for the number of quintessences (n_q) in an object of mass (m) would be

$$m/m_q = n_q$$

[0071] The mass of the electron (m_e) for example, would be directly determined by the number of quintessences in the electron, multiplied by the mass of quintessence.

[0072] Quintessence and Complex Space

[0073] Quintessence is postulated to constitute the fundamental nature of space-time. Three quintessences each travelling in their respective x vectors at 90° to each other would create three dimensional real space-time. These quintessences would in the direction in their respective y and z vectors produce small vibrations of the order of the Planck length (10^{-35} m), this would create the vector dimensions of permeability and permittivity. The result would give space-time 9 dimensions of space as in superstring theory. However, unlike superstring theory the six hidden dimensions would not be "curled up so as to be so small as to be invisible" these six dimensions would be present in complex space. Thus, only three of these dimensions would represent ordinary three dimensional particulate space time i.e. three dimensional objects. The other six dimensions produced by the vibrations of quintessence would form complex space.

[0074] The mathematics of complex space, using imaginary $\sqrt{-1}$ or (j) numbers, is assumed in the standard formulation of the Shrodinger wave equation. Thus the presence of complex space is an integral part of quantum mechanics.

$$-\frac{h^2}{2m} \cdot \frac{d^2\psi}{dx^2} + V\psi = jh \cdot \frac{d\psi}{dt}$$

[0075] The mathematics of complex space is also an essential and integral part of the principles and application of modern electronic and control engineering. Indeed it has been well recognised for some time that each direction vector in electronic engineering can, be associated with complex vectors.

[0076] As this complex space consists of the vectors of permittivity and permeability it would only be "felt" by charged particles as in the electron. Nevertheless, as all particles are fundamentally composed of charged particles the effects of complex space would be felt by endowing these particles with mass and in turn kinetic energy.

[0077] In conventional complex space, a 2 dimensional Cartesian Argand diagram is mathematically used. However, in order to formulate the equations for particles a three dimensional Argand diagram is essential. This will have three dimensional vectors, one real vector and two imaginary vectors. Three of these diagrams will be required to fully describe the nature of particles, each with a real vector in the x, y and z vectors, respectively. Nevertheless, in the instance below the real vector is the x vector and the two imaginary vectors are given by $({}_jy,{}_jz)$

[0078] The Three Dimensional Argand Diagram

[0079] The beauty of a three dimensional Argand diagram is that the complex conjugate (i.e. the mirror image which confers mathematical reality on the coordinates) is formed by the value of the minus coordinate in the other complex vector dimension. Thus the complex conjugate of $(C_x^{1/2}+{}_jc_y^{1/2}+{}_{-j}c_z^{1/2})$ is $(c_x^{1/2}+{}_jc_y^{1/2}+{}_jc_z^{1/2})$. These two sums when multiplied thus give a real number solution.

[0080] Furthermore it is clear that nine dimensions of space time are necessary in the general relativistic equations. By including complex space we thereby create the nine dimensional spacial metrictensor and the metric energy tensor of matter necessary for computations for general relativity From here we can begin to understand the true structure of matter.

[0081] Energy and the Space-Time Lattice

[0082] The presence of numerous experimental data for quantum tunnelling. and indeed the recent observations by Nicholas Gisin, on the entanglement of distant photons now returns us to EPR experiments.

[0083] Using the quintessential modification of the de Broglie wave equation, gives us an insight into these teleportation and EPR effects.

[0084] As

$$\lambda=hc/\beta E \tag{2}$$

and

$$E=hn_q \tag{1a}$$

then

$$\lambda=c/\beta n_q \tag{2b}$$

[0085] Importantly, as indicated by equation (2b), energy having no quintessence; would have a wavelength of infinity. Specifically pure energy containing no quintessences, would have a lambda of infinity. According to quantum mechanics an infinite wavelength would result in the probability of that energy being anywhere. As energy itself has no electrical charge it would not be impeded by the permittivity and permeability of the three dimensional space-time lattice. Moreover, energy would not be detectable in three dimensional space-time, unless it interacted with matter, as in the EPR experiments. Indeed, energy is not observed when not bound to any form of mass or particle. Thus equation 9d, takes us to our original assertion

[0086] Energy is Not Bound by the Space-Time Lattice

[0087] Thus, as the EPR experiments suggest the existence of energy separate from matter and thus separate from the three dimensional space-time lattice, it is interesting to find that experiment suggests the existence of free energy in a continuum separate from space time to produce the effects of quantum teleportation

[0088] This is not, however, teleportation across an additional dimension, this is a term to describe in partially familiar terms the dissociation of energy from the three dimensional space-time lattice. As time is inextricably linked to each dimension of space, the effects of energy would be inextricably linked to the events, such as the creation of virtual particles, we see interacting within space-time.

[0089] It is unlikely that observers have any direct day to day experience to explain quantum events. Nevertheless, quantum physics may have given us a window into the hitherto hidden workings of the Universe. Thereby, the mystery of the uniformity of the Universe, across distances which the speed of light could not apparently traverse, is readily explained by the fact that the free energy contained in the Universe is not bound by the space-time lattice.

[0090] In the case of light, due to the exceedingly small masses involved, there would be relatively easy exchange of matter with free energy within a photon. This would make the photon the ideal experimental tool to look for energy which is not bound by matter and in turn energy which is not bound in space-time. Indeed, very recently Furusawa et at. have reported to have observed the transference of energy as photons from A to B, without those photons traversing space-time. This finding which has been supported using other experimental techniques, is very important as it suggests the existence of such a quantum continuum.

[0091] We have already seen strong experimental data using photons, atomic spins and other data for quantum teleportation which have recently been published which support these findings. According to the above equations the teleportation would vary in a predictable fashion, as with photons, in line with the wavelength of the light used, relative to the size of vibration of quintessence. As regards matter, the results do confirm that the effect of quantum tunnelling is indeed dependant on the wavelength of matter and the size of that matter.

Part II—Particle Physics

[0092] Electron Structure

[0093] Understanding the electron is fundamental to the understanding of the elementary particles. The hidden nature of the electron may recently have been revealed through observations by Horst Stormer, Daniel Tsui and Robert Laughlin for which a Nobel prize has recently been awarded. They describe a quasi electron particle of charge ⅓e. This has been described on a quantum basis as a vortex of energy, bound as a quasi particle in one dimension x, but not bound in the other two dimensions y and z, allowing dispersion in space-time as a vortex. What is more intriguing are the experimental conditions in which this occurs. First of all a two dimensional electron gas is created and held between two capacitance plates. A magnetic force is then applied in the remaining dimension, virtually creating a one dimensional passage through which only a quasi electron appears to be able to pass.

[0094] Given the presence of charge of ⅓e, then three of these quasi electrons could form an entire electron in three dimensional visible space time. Nevertheless, each would have energy and hence a wave function which would be present in the other vectors. This electron could thus follow the probability functions as described by the Shrodinger wave equation for ψ (otherwise termed as "essence" by Shrodinger)

[0095] If the mass of the electron (m_e) is constituted from quintessence, using the formula:

$$m_e/m_q=n_q$$

[0096] Then an electron would be constituted from:

$$\frac{9.11\times10^{-3}\ \text{kg}}{7.373\times10^{-51}\ \text{kg}\cdot\text{sec}}=1.235\times10^{20}\ \text{quintessences/sec.}$$

[0097] Thus taking into account the mass-energy content of quintessence (m_q) it is independently possible to derive the magnitude of the charge of an electron (e) using the following equation.

$$e=\sqrt{\frac{m_q\varepsilon_0}{\left(\frac{4}{3}\right)\pi hc}}=1.61\times10^{-19}C$$

[0098] This is in close agreement with the experimentally observed charge on the electron of 1.602×10^{-19} C.

[0099] Interestingly substituting $m_q=h/3c^2$ in the above equation we have:

$$e=\sqrt{\frac{\varepsilon_0}{3\left(\frac{4}{3}\pi c^3\right)}}\qquad(6)$$

[0100] This can also be written as

$$e=\sqrt{\frac{\varepsilon_0}{3\left(\frac{4}{3}\right)\pi c^3}}\qquad(6a)$$

[0101] Equation (6) has a number of very special implications, if re-examined, firstly three of these quasi electron spheres appear to be required to constitute the charge of the electron. More intriguingly, it indicates that the charge is related to the volume of a sphere with an apparent radius of c. Thirdly it indicates that the square of the charge of an electron (e) is proportional to the permittivity of free space (so). The charge given from equation (3) is in close agreement with the measured charge of the electron. Furthermore a more exact value for the charge of the electron (to seven decimal places) can be deduced by taking into account the gravitational field of the Earth (see Gravity and the Charge of the Electron). Furthermore the charge of the electron (e) can now be derived from first principles. Thus, equation (3) corroborates the evidence that the electron is indeed composed of three quasi electrons in keeping with recent experimental findings.

[0102] The significance of the electron, composed of three spheres each with a radius of c, is not immediately clear, but can be understood if the frequency of rotation of the electron is taken into account. Thus if the diameter of the electron was approximately 10^{-19} m, then its spin would need to be

$$\frac{1}{c}\times10^{-15}$$

m approx. eq. 10^6 cycles/sec. Thus given a very high rotation rate an electron could have an effective radius of 1/c and still occupy subatomic sizes. Indeed these observations might be used to estimate the rate of rotation of the quasi electron and its size (see Appendix 1).

[0103] With regards a single quintessence, this passing through an energy vector of the space-time lattice would appear as a vibrating string. In a similar way to string theory, the conglomeration of these quintessences would produce the constituents of ordinary matter. The electron, for example, would be constituted from approximately 1.235×10^{20} quintessences.

[0104] The dimensions of the equation for the electron can be readily resolved by considering each of the three vector dimensions. The exact dimensions of the equation need to be considered in the light of the nature of space-time itself. These dimensional equations help explain the nature of matter. Indeed the equation for the electron may be necessary for the full understanding of gravity

[0105] Complex Space and Electron Structure

[0106] The presence of complex space also now further explains the conformation of the electron, and its formulation at the quantum level, and the presence of particles, anti-particles and their spin up and spin down characteristics.

[0107] Indeed the short form equation for the charge of the electron (−e) can now be rewritten as a metric tensor with three dimensions in real space and six in complex space.

[0108] Thus if three of the x, y and z vectors are in real space and six vectors in complex space, where c is the speed of light in the real space vector, ${}_jc$ is the speed of light in the complex vector and ${}_{-j}c$ is the complex conjugate of ${}_jc$, thus the electron can be mathematically represented by the equation:

$$-e=\varepsilon_{qe}\Big/\left(\frac{4}{3}\pi\right)^{1/2}\cdot\begin{matrix}(c_x)^{1/2}\cdot(jc_y)^{1/2}\cdot(-jc_z)^{1/2}\\ +\quad+\quad+\\ (-jc_x)^{1/2}\cdot(c_y)^{1/2}\cdot(jc_z)^{1/2}\\ +\quad+\quad+\\ (jc_x)^{1/2}\cdot(jc_y)^{1/2}\cdot(c_z)^{1/2}\end{matrix}$$

[0109] Which now elegantly gives the real number solution

$$e = \frac{\varepsilon_{qe}}{3\sqrt{\left(\frac{4}{3}\right)\pi c^3}}$$

[0110] Where $e=\epsilon_{qe}$ is given as the permittivity of free space for a single quasi electron Equation 4 represents a "complex" tensor

[0111] Whilst the two dimensional Argand diagram has four quadrants, the three dimensional Argand diagram has eight cubic sectors. Two of these cubic sectors are diametric opposites and can represent "real" particulate objects. These have the primary coordinates x, y, –z; as in the electron described above, and the –x, –y, z, with the real vector x now having a minus sign. These two "real" cubic sectors, therefore, mathematically represent particles and their anti-particles.

[0112] The mathematical presence of the two primary diagonal mirror images (x, y, –z and –x, –y, z) now allow the introduction of the concept of antiparticles. This extension of the maths into a three dimensional Argand diagram thus results in the automatic formulation of the maths of anti-particles. Thus the charge of the positron ($^{+}$e) is formulated by the shortened form equation, where the real vectors now each have the minus sign, and therefore exist in the –x, –y, z sector of the three dimensional Argand diagram.

$$e = \varepsilon_{qe} \Big/ \left(\frac{4}{3}\pi\right)^{1/2} \cdot \begin{array}{c} -c_x^{1/2} \cdot_{-j} c_y^{1/2} \cdot_j c_z^{1/2} \\ {}_j c_x^{1/2} \cdot -c^{1/2y} \cdot_{-j} c_z^{1/2} \\ {}_{-j} c_x^{1/2} \cdot j c_y^{1/2} \cdot -c_z^{1/2} \end{array}$$

[0113] The three dimensional Argand diagram also accounts for chirality and indeed the up and down spin of the electron. There are two other "real" primary coordinates in the Argand diagram, these are themselves the partial mirror images of the above coordinates (i.e. x, –y, z and –x, y, –z). In particular the y axis is of the opposite sign, thus in particles the y axis is in the downward direction, to form down spin particles and in anti-particles in the up direction, to form the antiparticle The up spin electron is given by eq. 8 and hence the down spin electron (–e|↓≦) is given by the equation

$$-el\downarrow\rangle = \varepsilon_{qe} \Big/ \left(\frac{4}{3}\pi\right)^{1/2} \cdot \begin{array}{c} c_x^{1/2} \cdot_{-j} c_y^{1/2} \cdot_j c_z^{1/2} \\ {}_j c_x^{1/2} \cdot c^{1/2y} \cdot_{-j} c_z^{1/2} \\ {}_{-j} c_x^{1/2} \cdot j c_y^{1/2} \cdot -c_z^{1/2} \end{array} \tag{9}$$

[0114] Thus the three dimensional Argand diagram accounts directly for the presence of antiparticles and the spin up and spin down particles seen in nature. It also accounts for the necessity of the electron to form a square root spherical object, as complex space depends on √–1, otherwise known as j.

[0115] Electron Pairing and Superconductivity

[0116] As the quintessences making up the electron are in a square root conformation, each of these quasi electrons would have a tendancy to pair to form an entire sphere.

[0117] The square root sphere structure of electrons with up and down spins can now superimpose to produce a complete sphere of varying extents. This produces electron pairing as seen at the atomic and molecular levels. It also accounts for the Pauli exclusion principle. This pairing thus accounts for the reactivity of the valence electrons and the electron probability densities, which in turn accounts for the existence of chemistry.

[0118] Furthermore, it is possible to account directly for superconductivity from first principles. For if both the complex and real vectors of the electron combine completely, the product of an up and down spin electron form a perfect superimposed sphere with radius c, with a charge of 2.59×10^{-38} C, denoted by the formula:

$$e^2 = \frac{\varepsilon o}{3\left(\frac{4}{3}\pi c^3\right)} = 2.59\times10^{-38}C \tag{6b}$$

[0119] As with standard superconducting theory, superconductivity can be explained by the formation of "Cooper" electron pairs, where the electrons are forced to pair by the presence of positive crystal charge in particular formation, at supercooled temperatures. In addition the electron pair now forms a stable entity whose angular momentum cancels.

[0120] It additionally becomes clear that the charge of two separate electrons (2e) is 3.2×10^{-19} C, but the charge of the combined electrons (e^2) is 2.59×10^{-38} C. This electron pair thus appears to have 19 orders of magnitude less charge than the electron and in turn 19 orders of magnitude less resistance. It is this effective reduction in charge and in turn resistance, which may account for superconductivity. When observed directly any electrical interaction with the Cooper electron pair will, however, result in the release of the full charge of both electrons, so that the full electrical charge put in will be equal to that coming out of the apparatus.

[0121] The Fine Structure Constant

[0122] Intruiginty from our knowledge of the electron we can further define the term .alpha., the fine structure constant; from the structure of the electron. Thus as the standard term

$$\alpha = \frac{e^2}{hc\times 47\pi\varepsilon_0};$$

substituting the term

$$e^2 = \frac{\varepsilon_0}{3(4/3)\pi c^3} \tag{eq. 6}$$

and

$$h = m_q c^2 \tag{eq. 1}$$

we find:

$$\frac{2\pi}{\alpha} = m_q[3(4/3\pi c^3)]^2$$

*or

$$\frac{2\pi}{\alpha} = \frac{m_q e^4}{\varepsilon_0^2}$$

[0123] For brevity we may represent the quasi electron structure as $(4/3)\pi c^3=\theta$; to signify its threefold symmetry, thus

$$\frac{2\pi}{\alpha} = m_q(3\theta)^2 \tag{10}$$

[0124] Indicating that the fine structure constant of the electron (a) is indeed related to its dimensional structure. Again taking into account the effects of gravity the fine structure constant can be derived from first principles to nine decimal places (see Gravity and the Charge of the Electron).

[0125] Fundamental Forces and Particle Structure

[0126] In order to understand the fundamental forces and the nature of fundamental particles, an overview is required. Thus, there are three major forces; strong, electro-weak and gravity, each mediated by three force particles the gluon, photon and graviton respectively. These in turn, influence three types of particle, the quark, lepton, and by general relativity space-time itself. Each of these are composed of particles with multiples of charge of ⅓, which are themselves in three generations, and are present in three dimensions of real space. It is important that a comprehensive view of nature explains this threefold symmetry.

[0127] Using the Standard Model of particles, it is well accepted there exist quark particle charges of −⅓, −⅔ and +⅓ and +⅔ in quarks and anti-quarks. Given that each particle is made up of three quarks the presence of these fractional charges support the association of the fractional charges in this way to form three dimensional charged particles. In stable particles each of the three quarks would have a vector in one dimension, giving the three quarks together an existence in three dimensional visible space time. The particles that bind the quarks (gluons) are themselves required, in stable particles, to have three different color charges, one color in each dimension, for the particle to exist in three dimensional space-time. Furthermore, there are three generations of quarks (and indeed leptons).

[0128] The Standard Model (or a modification of this) and in particular the observation of quarks and indeed quasi electrons with fractional charge of ⅓ and ⅔ in both cases, indicates that particles are constituted from the equivalent of three of these quasi particles to form an electron and quarks to form baryons. In the normal three dimensions the energy would be carried by the particle, However, because each particle is constituted of three quasi particles and in each quasi particle or quark one visible dimension would be the direction vector, in the other two hidden dimensions of each vector the waves would carry energy. Thus each particle would be associated with vibration, which would account for wave particle duality and Heisenberg's uncertainty principle in three dimensional visible space-time.

[0129] These observations lead us directly to the previous postulate that the structure of the electron is composed of none other than three (root) spheres, and that this equation for the electron allows the determination of the charge of the electron from first principles, thus:

$$e = \frac{\varepsilon 0^2}{[3(4/3\pi c^3)]} \tag{6}$$

[0130] In addition the mass of the proton (m_p) can be directly calculated from the ratio of the mass (m_e) of the electron, given by the equation:

$$\frac{m_e}{m_p} = 5.45\times 10^{-4} = 3\frac{\pi}{\sqrt{c}} \tag{11}$$

[0131] Strictly we should write,

$$\frac{m_e}{m_p + m_e} = 3\pi\sqrt{c};$$

which is much more elegant.

[0132] Which now gives

$$\frac{m_e}{m_p} = \frac{1}{\sqrt{c}/3\pi - 1} = 5.4462\times 10^{-3}$$

[0133] This is in very close agreement with the experimentally derived ratio of the proton to electron masses which is also; 5.4462×10^{-3}

[0134] Thus the correlation factor between theory and experiment has a maximum error <0.00001.

[0135] If we combine equation 3:

$$e = \sqrt{\frac{\varepsilon_0}{3(4/3)\pi c^3}}$$

and equation 13:

$$\frac{m_e}{m_p} = 3\frac{\pi}{\sqrt{c}}$$

the positive charge of the proton (e_p) is given by:

$$e_p=\sqrt{\frac{\varepsilon_0}{3(4/3)\pi c^3}}\times m_e\times 3\frac{\pi/\sqrt{c}}{m_p}=e \tag{12}$$

[0136] The stable nuclear proton conformation can thus be represented by the short form equation:

$$p=3^{+}\sqrt{3(4/3)\pi c^{3}}\times 3(\pi/\sqrt{c}) \tag{13}$$

[0137] This forms a stable 3×3 conformation as with the stable electron structure.

[0138] Importantly the term ($\pi/\sqrt{c}$) is the 90° solution to the Shrodinger wave equation for an electron confined in a space with radius c!.

[0139] Thus the standard equation for an electron confined in a one dimensional box is given by:

$$E\psi(x)=-\frac{h^2}{2m}\frac{d^2\psi(x)}{dx^2}$$

[0140] If the one dimensional box has a length 2L the quantum amplitude (A) can only be non zero between x=0 and X=2L and the standard solution for the amplitude is none other than:

$$A=(1/L^{1/2})$$

[0141] Thus in one dimension the standard solution to the Shrodinger wave equation is:

$$\psi(x)=(\pi/L^{1/2})\mathrm{Sin}\ x/L$$

[0142] Thus not only is the electron charge derived from the equation for three spheres each with a radius of c (eq. 3); but the proton mass and charge can also be derived from the standard solution to the Shrodinger wave equation for a an electron confined in a space of radius c!.

[0143] The term ($\pi/c^{1/2}$) itself would thus most logically represent the gluon which is present in the proton. These gluons would bind the quasi electrons together to form the fundamental particles

[0144] The masses of all the known particles, including the up and down quarks, the W boson, the muon, charm, strange, the tauon, truth and beauty can thus also be derived from first principles in this fashion, and have the quasi electron as their basic constituent particle (see Appendix 1).

[0145] Thus the structure of the muon (μ) can also be derived from the ratio of the mass of the electron (m_e) and the mass of the muon (m_μ):

$$m_e/m_\mu=4.7\times 10^{-3}=c^{1/3}$$

Thus

$$\mu=\epsilon_0{}^{1/2}\times m_e/m_\mu\times 3^{-}(4/3=\pi c^{3})^{1/2}\times(\pi/c^{1/3})$$

[0146] Where the charge of the muon is in this equation equivalent to that of the electron e. In this case ($\pi/c^{1/3}$) can be considered to represent a specific high energy photon. Thus the structure of the muon, written in short form is:

$$\mu=3^{-}(4/3\pi c^{3})^{1/2}\times(\pi/c^{1/3}). \tag{14}$$

[0147] Moreover the structure of the tauon can be calculated from the ratio of the mass of the electron and that of the Tauon (1.79 Mev);

[0148] Thus

$$0.511\ \mathrm{Mev}/1.79\ \mathrm{Gev}=2.85\times 10^{-4}$$

$$m_e/m_r=(\pi/c)^{1/3}\times(\pi/c)^{1/9}=2.85\times 10^{-4}$$

[0149] As the charge of the tauon is equivalent to the charge of the electron, hence the structure of the Tauon is given by the above equation

$$e_\tau=\epsilon_{qe}\times(m_e/m_\tau)\times 3^{-}(4/3\pi c^{3})^{1/2}\times(\pi/c)^{1/3}\times(\pi/c)^{1/9}=e$$

[0150] This equation accurately predicts the charge −1; and mass of the Tauon (.~1.78 Gev). Thus the structure of the Tauon can in short form be given by the equation

$$\tau=-3(4/3\pi c^{3})^{1/2}\times(\pi/c)^{1/3}\times(\pi/c)^{1/9} \tag{15}$$

[0151] Furthermore a more exact value for the mass of the muon and tauon can be deduced by taking into account the gravitational field of the Earth in a similar way to identifying the exact charge of the electron. In addition it may be necessary to take into account a possible mass value of the neutrino to arrive at a precisely accurate mass value of the muon and tauon. Nevertheless, the mathematical proof of these short form equations lies in the fact that they can very closely identify the charge and the masses of these particles, from first principles, as in equations.

[0152] Overall the mathematical geometrical structure of all the particles can be derived from the quasi electron, which is in turn derived from quintessence. Thus, the short form particle structures can now be derived from first principles. This includes the quasi electron (qe) and electron (e), from which the quarks (u,d) and in turn the stable proton (p) and stable neutron (n) and alpha particle (a) respectively are derived. The general structure of the force carrying bosons the photon. (g) and the gluon (γ) and the intermediate vector boson (W) can be given. It will also intriguingly be possible to derive, according to their generation, the structure of the strange (s) charm (c), beauty (b, or bottom) and truth (t or top) quarks directly from the structure of the muon (μ) and Tauon (τ) respectively.

[0153] Using the term $\Theta=(4/3\pi c^{3})$, where, −/+ represents the charge of the quasi electron, we find:

[0154] 1st Generation:

$$(q_e)={}^{-}\Theta^{1/2} \tag{6c}$$

$$e=3^{-1/2} \tag{6}$$

$$d={}^{-}\Theta^{1/2}\cdot 3(\pi/c^{1/2}) \tag{16}$$

$$u=2^{+}\Theta^{1/2}\cdot 3(\pi/c^{1/2}) \tag{17}$$

$$s={}^{-}\Theta^{1/2}\cdot 3(\pi/c^{1/2}) \tag{18}$$

[0155] 2nd Generation

$$\mu=3^{-}\Theta^{1/2}\cdot(\pi/c^{1/3}) \tag{14}$$

$$c=2^{+}\Theta^{1/2}\cdot(\pi/c^{1/3})\cdot(\pi/c^{1/4}) \tag{19}$$

$$b={}^{-}\Theta^{1/2}\cdot(\pi/c^{1/9})\cdot(\pi/c)^{1/4} \tag{20}$$

[0156] 3rd Generation

$$\tau=3^{-}\Theta^{1/2}\cdot(\pi/c)^{1/3}\cdot(\pi/c)^{1/9} \tag{15}$$

$$t=2^{+}\Theta^{1/2}\cdot(\pi/c)^{1/3}\cdot(\pi/c)^{1/9}\cdot(\pi/c)^{1/4} \tag{21}$$

[0157] Particle Gluons (g):

$$g_1=(\pi/c^{1/2}) \tag{22}$$

$$g_2=(\pi/c)^{1/2} \tag{22a}$$

$$g_3=(\pi/c^{1/4}) \tag{22b}$$

$$g_4=(\pi/c)^{1/4} \tag{22c}$$

[0158] Particle Photons (.gamma.):

$$\gamma_1=(\pi/c^{1/3}) \tag{23}$$

$$\gamma_2=(\pi/c)^{1/3} \tag{23a}$$

$$\gamma_3=(\pi/c^{1/9}) \tag{23b}$$

$$\gamma_4=(\pi/c)^{1/9} \tag{23c}$$

[0159] Intermediate Vector Boson ($W^{+/-}$):

$$W^+=3^+\Theta^{1/2}\cdot 2(\pi/c^{1/6})^6 \tag{24}$$

$$W^-=3^-\Theta^{1/2}\cdot 2(\pi/c^{1/6})^6 \tag{25}$$

[0160] Stable* Proton:

$$p=3^+\Theta^{1/2}\cdot 3(\pi/c^{1/2}) \tag{13}$$

[0161] Stable* Neutron:

Stable * Neutron:

$$n = \begin{matrix} {}^+\Theta\downarrow^{1/2}\cdot 2(3\pi/c^{1/2})\cdot{}^-\Theta\uparrow^{1/2} \\ {}^+\Theta\downarrow^{1/2}\cdot 2(3\pi/c^{1/2})\cdot{}^-\Theta\uparrow^{1/2} \\ {}^+\Theta\downarrow^{1/2}\cdot 2(3\pi/c^{1/2})\cdot{}^-\Theta\uparrow^{1/2} \end{matrix}$$

* Stable nucleonic neutron and proton conformations differ slightly from the Standard Model, this is due to the sharing of quasi electron and quasi positron particles within the nucleus, which allows stabalisation of these particles by the formation of stable 3×3 structures. The Standard conformations which describe non-nucleonic neutrons and protons are additionally given in Appendix 1.

[0162] Alpha particle (α):

$$\text{Alpha particle }(\alpha) := \alpha = \begin{matrix} [3^+\Theta]\downarrow^{1/2}\cdot 2(3\pi/c^{1/2})\cdot[3^-\Theta]\uparrow^{1/2} \\ [3^+\Theta]\uparrow^{1/2}\cdot 2(3\pi/c^{1/2})\cdot[3^-\Theta]\downarrow^{1/2} \\ [3^+\Theta]\downarrow^{1/2}\cdot 2(3\pi/c^{1/2})\cdot[3^-\Theta]\uparrow^{1/2} \end{matrix} \tag{27}$$

[0163] The mathematical proof for these structures and their decay mechanisms is lengthy and is thus fully contained in Appendix 1. All the particle structures are accurately mathematically defined by the masses of these particles.

[0164] The structure of these particles all contain the quasi electron and thus the metric tensor structure necessary in the formulation of the gravitational equations is sustained. The respective forces created by the gluon and the photon are important as they tell us the behaviour of matter and also lead to the likely structure of the graviton

[0165] Particle Spin and Size

[0166] The significance of the electron, composed of three spheres each with a radius of 1/c, is not immediately clear, but can be understood if the frequency of rotation of the electron is also taken into account. Knowing the structure of the electron has led us to deduce its charge and thus may lead us estimate its size and spin. Thus these observations might be used to calculate the radius and rate of rotation of the electron.

[0167] Let us suppose, that nature is truly beautiful, and that the radius of the fundamental quasi electron is indeed 1/c, and in turn the radius was balanced by the velocity of rotation 2π/c. This can be directly confirmed mathematically by taking into account the known spin of the electron, h/4π. Thus the actual spin of the electron may be calculated form the known energy of the spin.

[0168] The radius of the electron is not up till now known, but the radius of a quark has been estimated, and this is the radius derived from deep inelastic collisions of the proton. These estimates reveal a radius of approx. $r_p=1.18\times10^{-15}$ m This value may be used to assist in confirming the spin of the proton in revolutions per sec. (revs) and in turn the spin and size of the electron. Firstly we may proceed to estimate the spin of the proton. Thus as h=E·t (Joules×sec) and h=E·t=F·d·t (Joules×sec), then the spin;

$$h/4\pi=F\cdot d\cdot t \tag{28}$$

[0169] As F=ma, where $\alpha=(\text{revs}\cdot 2\pi)^2 r_p$ and m=the mass of the proton, then

$$h/4\pi=m(revs\cdot 2\pi)^2 r_p\cdot d\cdot t$$

[0170] The actual distance (d) traveled in a circle of half integer spin in 1 second is: $\text{revs}\cdot\pi r_p$ thus:

$$h/4=m(revs\cdot 2\pi)^3 r_p^{\,2}/2$$

[0171] Hence:

$$revs=[h/m(2\pi)^4 r_p^{\,2}]^{1/3}$$

[0172] Taking the effective mass the proton as 1.6726×10^{-27} kg, then the rate of spin of the proton in revolutions/sec is:

$$revs=5.65\times10^6 \text{ cycles/sec}$$

[0173] From the frequency of the specific rotation of the proton, given the half integer spin associated with the proton, we can thus mathematically confirm the relationship between the radius of a particle and its spin:

$$r_p\times revs/2=1/c \tag{29}$$

[0174] Furthermore, the fundamental radius of 1/c seen in geometric structure the quasi electron, is also reflected in the rotation rate and radius for the proton, thus as above 1/c÷½ revs=1.85×10^{-15} m. Moreover, this means the actual half integer velocity of rotation is none other than 2π/c in metres/sec. So that the particle is in harmonic balance.

[0175] Using the fundamental formula h/4π=F·d·t, it is possible to obtain accurate estimates of the radius and spin rates of the electron, or indeed any particle, using the same principle of harmonic balance. Using the formula:

$$revs=[h/m(2\pi)^4 r_e^{\,2}]^{1/3}$$

[0176] It appears there are two unknowns, the radius if the electron and its revolution rate, however, in accordance with the equation, r_p=2/c.revs, which gives the revolution rate of the proton, the same principle may also be used for the electron, by substituting r_e=2/c.revs, such that:

$$revs=hc^2/4m_e(2\pi)^4 \tag{30}$$

[0177] Taking the mass of the electron 9.109382×10^{-31} kg, the rate of revolution of the electron is:

$$revs=1.048\times10^{10} \text{ cycles/sec}$$

[0178] Which gives a predicted radius of the electron as

$$r_e=6.336\times10^{-19}\text{ cycles/sec}$$

[0179] So the half integer rotation velocity (revs.πr) is 2π/c !, for the electron in keeping with the harmonic balance of the electron.

[0180] The same principle may be used to obtain an accurate estimate of the spin and radius of the muon, or any other particle. Using the above formula

$$revs=hc^2/4m_e(2\pi)^4 \tag{31}$$

[0181] Then as the mass of the muon is 1.8823×10^{-28} kg then the revs of the muon $f_\mu=5.070\times10^{-7}$ cycles/sec and the radius r_μ is thus 1.316×10^{-16} m.

[0182] It is now possible to begin to explain how the muon and the other subatomic particles are formed. If a quasi electron is complexed with another structure the total geometric structure needs to maintain harmonic balance. So the frequency of rotation would need to match geometric structure with which the quasi electron was complexed

[0183] Intriguingly we find asymptotic convergence for the formulas for frequency and mass occurs, when the geometric structure complexed with the quasi electron has the structure represented by ($\pi/c^{1/3}$) [giving the frequency divided by two, because the single integer spin of the force carrying particles compares to a half integer spin for the muon]. So that

$$(f_r3\pi/2)^{1/3}=f_\mu$$

[0184] When the ratio of the masses of the electron (m_e) and muon (m_μ) are related, such that:

$$m_e(3\pi/c^{1/3})=m_\mu$$

[0185] Indeed we find that (allowing for the neutrino) this ratio is very close to the actual ratio of the mass of the electron to the mass of the muon, determined experimentally.

[0186] Furthermore, we have seen that these geometric structures, representing harmonics of the speed of light, which either match the frequency or the amplitude of vibration of the quasi electron, mathematically define the masses of the particles and the fundamental forces of Nature.

Part III—Quantum Gravity

[0187] Quantum General Relativity

[0188] Given the overall energy "complex" energy tensor structure of the electron and the metric tensor, assumed in general relativity, the quantum nature of gravity itself can now be explored. The spherical complex tensor for the electron and the positron give the mathematical quantum structure and energy tensor for all the other particles. Together with the time dimension these nine space dimensions account for the 10 parameters present in the metric tensor necessary to formulate the equations for gravity using Riemann geometry and thus forms the basis of quantum gravity. Intriguingly the metric tensor at each point in space time is required to consist of a collection of ten numbers, Consequently, ten dimensional space-time hypotheses, such as this or superstring theory, do automatically yield general relativity.

[0189] Furthermore, the mathematical representation of the graviton and the gravitational constant may be directly estimated from the knowledge of the mass and radius of quintessence. Thence, the force of the vibrations of quintessence lead directly to quantum gravity.

[0190] The radius of quintessence should be approximately in keeping with the Planck length estimate (r), which is conventionally derived from the standard dimensional equation:

$$r_q^2\cong Gh/c^3 \tag{32}$$

[0191] Given the nine spacial parameters present in the metric tensor, used in general relativity we find that the actual formula for r_q^2 is mathematically in agreement with theory when:

$$9r_q^2=Gh/c^3 \tag{33}$$

[0192] This again supports the 9 dimensional view of space and the size of the vibrations of quintessence can thus be estimated.

$$r_q=1.35\times10^{-35}\text{ m} \tag{33a}$$

[0193] This value is in agreement with the Planck length. Indeed if the above equation is correct then we find that we can derive the standard equation for the general relativistic increase in radius, r', (eq. 34) directly from first principles and arrive at a more fundamental equation for quantum gravity. As

$$r'=G\cdot M/3c^3 \tag{34}$$

[0194] By substituting eq. 33) into equation 34, a fundamental relationship between r' and M is obtained.

$$r'/3r_q^2=GMc^3/Ghc^3=Mc/h$$

[0195] And substituting the quintessential equation, $h=m^qc^2$ (eq. 1) then:

$$r'/3r_q^2=M/m_qc=n_q/c \tag{35}$$

[0196] Hence the ratio of the change in radius to that of the radius of quintessence squared, is proportional, by a factor of c, to the ratio of the mass M of an object to that of the mass of quintessence, effectively the number of quintessences. Thus the change in radius, r' due to gravitation, is related to none other than the ratio of the mass and radius of an object to the mass and the square of the radius of quintessence. Thus again the gravitational change in radius is directly related to the number of quintessences.

[0197] Naturally, this would be exactly what would be logically expected if quintessence, like the equation for the charge of the electron (eq. 6) forms from a root sphere. Thus the change in spacial radius of a normal sphere is dependant on the square of the quintessential radius.

[0198] This increase in apparent radius represents none other than the (gravitational) binding energy for quintessence.

[0199] The meaning of the above dimensional equation (33) might itself be further understood by substituting the mass of quintessence (where $m_q=h/c^2$) into the equation. Thus in nine dimensions the gravitational constant (G) may be more logically given as,

$$9(\pi r_q^2/m_q)=G\pi/c \tag{36}$$

[0200] Where πr_q^2 is the cross sectional area of quintessence and m_q is the effective mass of quintessence, and thus

($\pi r_q^2/m_q$) represents the effective mass per unit area which quintessence exerts. This equation reduces to:

$$9r_q^2/m_q=G/c \tag{37}$$

[0201] From this we may derive the standard general relativistic relationship for the apparent change in radius (r') around a mass (M), from an understanding of the mass m_q and number (n_q) of quintessences. As $m_q=M/n_q$, then:

$$3r_q^2=G{\cdot}M/3c{\cdot}n_q \tag{38}$$

[0202] Then if

$$n_q=r'c/3r_q^2 \tag{39}$$

[0203] thus directly substituting for n_q in eq. 38:

$$r'=G{\cdot}M/3c^2 \tag{34}$$

[0204] The importance of this is that the gravitational change in radius now logically derives from equation 36, which describes the gravitational force as resulting directly from the mass of quintessence exerted/per unit area of quintessence.

$$9(\pi r_q^2/m_q)=G{\cdot}\pi/c \tag{36}$$

[0205] Thus equation 34 is the conventional equation for the general relativistic increase in radius (r') in a gravitational field, which is here derived from the underlying nature of quintessence. Thus the gravitational constant is derived from the mass and radius of vibration squared of quintessence from first principles.

[0206] Indeed it is apparent that a more fundamental equation for gravitation now exists, for equation (39) is mathematically accurate and numerically agrees with eq. 34:

$$r'/3r_q^2=n_q/c \tag{39}$$

[0207] These equations may be readily mathematically verified. If in accordance with standard general relativity, the apparent increase in radius r' is:

$$r'=GM/3c^2 \tag{34}$$

[0208] Then given that the mass of the Earth is 5.9745×10^{24} kg;

$$r'=1.478\times10^{-3}\text{ m}$$

[0209] Accordingly if $r'=3r_q^2{\cdot}n_q/c$; (eq. 39). Given the number of quintessences n_q constituting the Earth is M_E/m_q, then

$$n_q=5.9745\times10^{24}/7.3725\times10^{-5}=8.104\times10^{74}$$

[0210] As $r_q^2=1.823\times10^{-70}$ (eq. 33a) then:

$$r'=1.478\times10^{-3}\text{ m}$$

[0211] Thus equation 39 gives the same answer as the standard equation and may be understood on a logical basis. Indeed the meaning of c in the equation may be understood as it has been previously shown as being the basis for the radius of matter (eq. 6). Hence the general relativistic change in radius, r', is none other than the effective binding energy for quintessence.

[0212] Quantum Gravity and Wave Particle Duality

[0213] Quantum gravity can now be readily linked with quantum mechanics, indeed any observations which are self consistent must be able to do so easily.

[0214] The frequency of light has been previously derived

$$f=E/h=n_q$$

[0215] Thus the formula for the frequency of light (E=hf) has previously been explained theoretically by the simple observation that the frequency is determined quite directly from the number of quintessences (n_q) within the photon. The same principle has also been shown to apply to matter.

[0216] Let us now follow these equations for matter by calculating the wavelength of a photon from the Gravitational constant as an example; and also as a test of these observations and to demonstrate that the gravitational equations can also apply to the quantum world.

[0217] If

$$n_q=r'c/3r_q^2 \tag{39a}$$

[0218] where r' is the general relativistic increase in radius, and r_q is the radius of quintessence (eq. 33). Where $f=E/h=n_q$, substituting for n_q, then the frequency of the photon f_γ(where $\beta=1$) is given by:

$$f_\gamma=r'c/3r_q^2$$

[0219] Using the standard equation, $r'=GM/3c^2$ (eq. 34); we may substitute for r', thus we have:

$$f_\gamma=GM/9r_q^2c\ \text{15 Thus}$$

$$f_\gamma=\frac{G}{9r_q^2c^3}\cdot m_\gamma c^2\text{ and as }E=m_\gamma c^2;$$

$$f_\gamma=\frac{GE}{9r_q^2c^3} \tag{40}$$

Indeed as $9r_q^2=Gh/c^3$, then $f_\gamma=E/h=n_q$

[0220] It is possible to also demonstrate that the same relationship holds for the wave equation for matter. If we take the relativistic wave energy of matter, which has been previously derived,

$$f=\beta^2n_q$$

[0221] This includes the term for the number of quintessences flowing through the electron, in the complex vectors of space-time, to give the relativistic electron momentum (p) and a term for the rest mass, thus substituting into (40)

$$f_\gamma=\frac{GE}{9r_q^2c^3} \tag{40}$$

[0222] As $f=\beta^2n_q$ for matter then the equation expands to:

$$f_m=\frac{G}{9r_q^2c^3}\cdot\beta^2E\text{ As }\lambda=v/f,\text{ then}$$

$$\lambda=\frac{9r_q^2c^3v}{G\beta^2E} \tag{41}$$

[0223] Then the equation again reduces to:

$$G = \frac{9r_q^2c^4}{\lambda\beta E} \tag{3}$$

[0224] Equations 3, 40 and 41 are important as they show that the quantum wavelength of any particle of rest mass m can be derived from the gravitational constant G. Thus linking quantum mechanics to quantum gravity.

[0225] It is therefore important to confirm the numerical accuracy of the above equation (40). We can do this by comparing the result to the standard computation of the de Broglie equation, in a range where de Broglie itself is likely to be most accurate; which according to these observations is in the low energy range (see section on Wave Particle Duality).

[0226] If we take an electron with an energy of 0.1 KeV the wavelength is conventionally given (where the kinetic energy of the electron E_k is given by the product of the charge of the electron (C) and the potential applied eV=0.1 Kev), by the standard equation:

$$\lambda = h/p = h/(E_k \cdot 2m_0)^{1/2} \text{ thus}$$

$$\lambda = 6.63\times10^{-34}/[1.602\times10^{-19}\times1\times10^{2}\times18.22\times10^{-31}]^{1/2}$$

$$\text{hence}$$

$$\lambda \cong 1.23\times10^{-10}m \text{ Using}$$

$$\lambda = \frac{9r_q^2c^4}{G\beta E} \text{ Where } E = \gamma m_0c^2 \tag{3a}$$

[0227] At 0.1 Kev, electron velocity is 6×10^{6} r/sec, thus $\beta=2\times10^{-2}$ and $\gamma=1/(1-v^2/c^2)^{1/2}=1.0002$. Thus:

$$\gamma = \frac{9\times1.82\times10^{-70}\times80.78\times10^{32}}{6.76\times10^{-11}\times\beta\times1.0002\times9.11\times10^{-31}\times8.998\times10^{16}}$$

$$\lambda = 1.21\times10^{-10}m$$

[0228] Divergence between the de Broglie equation and the above equation (2) occurs at intermediate and high energies where it is generally accepted that the standard de Broglie equation may be less accurate. The values for eq. 2 and de Broglie are compared to recent experiments, which demonstrate a relativistic curvilinear plot for wavelengths of matter in keeping with eq. 40.

[0229] The de Broglie equation in the non-relativistic format yields a simple log/linear scale, which is not in keeping with relativity; whereas eq. 3 is dependent on relativity and mathematically accounts for both relativity in calculating the wavelength. Indeed recent experiment on quantum tunnelling through a wire mesh strongly suggests that the relationship between energy and wavelength is relativistically curvilinear(ref 1). Furthermore equation 3a suggests a fundamental relationship between energy (E), relative velocity (v/c=.β), gravity (G) and the quantum wavelength (λ)

$$\lambda = \frac{9r_q^2c^4}{G\beta E} \text{ Indeed as } {}^9r_q^2 = Gh/c^3\text{, then} \tag{3a}$$

$$\lambda = hc/\beta E \tag{2}$$

[0230] Equation 2 is the very same as the Universal wave equation derived form first principles for the wavelength of tight and matter, which allowed a relativistic solution to the equations for wave particle duality (see Wave Particle Duality). This now indicates that these quintessential equations are compatible with relativity, quantum mechanics and quantum gravity.

[0231] Graviton Structure

[0232] From these observations, if the value for the gravitational constant is substituted into the equation (35) we may now estimate the probable geometric structure of the gravitation, which is the force particle mediating gravity by acting on quintessence. Thus the Gravitational constant has been previously derived from the vibration of quintessence by the equation:

$$G\cdot(\pi/c)=9(\pi r_q^{\,2}/m_q) \tag{36}$$

[0233] This is in accurate agreement with the value for G(6.67×10^{-11} N m^2 kg^{-2}). This suggests that the most probable mathematical representation of the graviton (ϕ), the third force carrying particle is

$$\phi=(\pi/c) \tag{42}$$

[0234] Thus the gravitational constant (G) can be given by the mass and radius of quintessence and the structure of the graviton

$$G=9\pi r_q^{\,2}/\phi m_q \tag{43}$$

[0235] This shows the gravitational force to be related to the fundamental radius of quintessence space time, and the graviton.

[0236] Quantised General Relativity

[0237] The classical general relativistic formula, as given by Einstein is:

$$R_{\mu\nu}-1/2g_{\mu\nu}R=-\kappa T_{\mu\nu}$$

[0238] Where R is effectively the curvature of space-time, $R_{\mu\nu}$ denotes the contracted Riemann tensor of curvature and $T_{\mu\nu}$ is the "energy tensor" of matter.)

[0239] If we substitute the energy tensor matrix of the electron (eq. 9)×time, for the energy tensor of matter $T_{\mu\nu}$; and the metric tensor of the space-time lattice×time for the contracted Riemann tensor we can arrive at the same solutions for general relativity.

[0240] Furthermore, in his published paper on General Relativity, Einstein. defined the constant κ as:

$$\kappa=8\pi G/c^2$$

[0241] Therefore Einstein's equation should be written as

$$R_{\mu\nu} - 1/2g_{\mu\nu}R = \frac{8\pi G}{c^2}\cdot T_{\mu\nu} \tag{43}$$

[0242] Einstein himself was apparently not happy about the right hand component of the equation. However, we find that this part of the equation can now be explained and quantised by substituting the gravitational constant, $G=9\pi r_q^2/\phi m_q$, (eq. 42a),

[0243] Giving:

$$R_{\mu\nu}-1/2g_{\mu\nu}R=-\frac{8\pi^2 9r_q^2}{\varphi m_q c^2}\cdot T_{\mu\nu} \tag{44}$$

[0244] By substituting $m_q\cdot c^2=h$, and further substituting h=h/2π, we arrive at a quantised solution to Einstein's equations. Where A_q is the surface area of quintessence ($A_q=4\pi r_q^2$); φ is the graviton [φ=(π/c)] and h is Plancks constant. thus:

$$R_{\mu\nu}-1/2g_{\mu\nu}R=-\frac{9A_q}{\varphi\hbar}\cdot T_{\mu\nu} \tag{45}$$

[0245] The gravitational equation can now be further understood on a logical basis. The term $A_q=(4\pi r_q^2)$, where represents standard term for the surface area of a sphere of quintessence for the 9 space dimensions of the space time lattice, h is the energy content of quintessence×time and φ is the graviton, thus the right hand term now represents a true "metric energy tensor" of matter.

[0246] This leads directly to the standard solution to the field equations, for the general relativistic increase in radius r' of an object, where A is the surface area of a sphere of a given mass M, such that

$$r=\sqrt{(A/4\pi)}-r=GM/3c^2 \tag{34}$$

[0247] Furthermore, although equation 45, gives the same solutions as Einstein's equation, which is essentially correct, the difference is that the equation is now dependant upon Planck's constant (h), and moreover the radius of quintessence, which now defines a quantised solution to the equations.

[0248] Graviton Force Characteristics

[0249] Similar to the photon, the previously derived equation (42) for the graviton [φ=(π/c)] appears to also mathematically represent a helical ringlet of quintessence, but with a spin of 2. For the photon, taking the direction of motion as the x vector and its axis of spin also as the x vector, would account for the electromagnetic force and its attraction and repulsion characteristics. In the case of the gluon component ($\pi/c^{1/2}$), if the direction vector is x, then the axis of spin would be in the y vector, the same as quasi electrons, accounting for the particle binding characteristics of the gluon force. In the case of the graviton, if the direction of motion was in the x vector, the graviton spin axis would be in the z vector thus, as will be demonstrated, accounting for the gravitational force.

[0250] The spin axis of the graviton can also be derived using the known characteristics of the electron. If an electron is travelling in the x direction, then its spin axis is determined by the by the sign of the $_j$y vector (up or down). This view is in agreement with conventional theory, which indicates that the electron spin is similar to a rotating planet orbiting the sun, (the electron even appears to have orbital precession). As the electron passes through the space-time lattice, this spin would generate the formation of gravitons. This would occur as a result of the ejection of the excess quintessence passing through the electron. As the electron spins, the ejection of these gravitons would occur at a tangent to the electron's direction of motion. The ejection of the gravitons would occur, similarly to the ejection of energy of a pulsar or quasar, through the equivalent of the north and south poles of the electron. Thus, propelling the graviton in the direction of the electrons y vector. The ejection of the graviton would re-orientate and impart a specific angular momentum to the gravitons which would thus end up spinning on its own z axis. If for instance the graviton is released from an up spin electron the graviton will be rotating clockwise and its leading edge will displace quintessence downwards. In turn this will provide an upwards force.

[0251] This picture accounts for Fleming's left hand rule, is logical and provides an explanation for the magnetic force around a wire. According, to the left hand rule if the direction of the current is in the x vector, the magnetic field is in the z vector, and the force is upwards, in the y vector, in accordance with the above model. Therefore, this particular spin axis and the structure of the graviton results in its force characteristics. As the graviton is very small compared to the electron and both have different rather rapid spin axis it is difficult for these to bind and interact. Nevertheless, because the graviton has a spin of 2, and as it spin axis is perpendicular to its direction of motion, in the z vector, it readily displaces space-time quintessence to produce gravity. Thus because the graviton is able to displace space-time, it is capable of escaping a black hole. How else could the effects of gravity be felt beyond a black hole?

[0252] Quantum Gravity and Electromagnetism

[0253] With the above electron model of graviton production the nature of magnetism can be understood from first principles, Furthermore, the presence of a space-time lattice links relativity, and the forces of gravity with the electromagnetic and other forces of Nature. Indeed, evidence for these links may first date back to the 1820's, when Andre Ampere first defined the Amp. The force of attraction between two parallel wires 1 metre apart each carrying 1 Amp in a vacuum was defined as none other than the permeability of free space (2×10^{-7} N per metre of conductor). Thus conventionally the magnetic field strength around a long straight wire is given as:

$$B=\mu_0 I/2\pi r$$

[0254] Where I is the current and μ_0 is the permeability of free space ($4\pi\times10^{-7}$ N A^{-2})

[0255] The attraction between two wires both carrying negative charge is, however, counterintuitive as negative charges should repel. A conventional explanation overcomes this by invoking the presence of a magnetic field which is created by the current by the production of virtual photons. Thus we appear to have an explanation for the effects of magnetism which involves virtual photons, however, these photons are not observed. More accurately, according to conventional special relativity the magnetic field is none other than the electric field viewed relativistically.

[0256] A more satisfactory explanation, therefore, lies in the interaction between the electrons and the space time lattice. The moving electrons in the two wires interact with the lattice to produce gravitons; which are in phase when both streams of electrons are traveling in the same direction. The gravitonic waves interact constructively to disperse the space time lattice between the wires and induce an attractive force between the two wires, which produces in effect the permeability of free space. Thus this force results from the vibration of quintessence itself.

[0257] Conversely in two wires with current going in opposite directions the graviton waves are in anti-phase and would interact destructively between the wires. The gravitonic waves traveling radially outward from the wires would, however, disperse the lattice outside the two wires and produce apparent repulsion between the wires, which is exactly what is observed. These effects of electricity suggest that gravitons act as waves and that phase is important.

[0258] This effect is also seen with the north and south poles of ferromagnets. Nevertheless, with matter other than iron, cobalt or nickel, the graviton emission cannot be phased as the atoms are unable to align and magnets do not appear to exist with other materials.

[0259] In ordinary magnetic system the release of gravitons from the north pole would be exactly balanced by those released from the south pole of the magnet and hence there would be no net force on the magnet until an external magnet or electrical current were applied.

[0260] Overall the magnitude of the forces in electrical systems where electrical conduction occurs are well defined by the permeability and permittivity of free space μ_0, and ϵ_0. Where v is the constant velocity of the charge and ϵ is the electric field produced by the charge.

$$B=[\mu_0\epsilon_0]v\cdot\epsilon$$

[0261] These observations suggest that the forces of electricity which produce magnetism are indeed related to the permittivity and permeability of free space and that these quantities are exerted by an apparent vacuum. Thus the effects of magnetism could be explained by none other than the phased effects of gravitational waves on the space time lattice.

[0262] Electromagnetism is of further interest to quantum gravity, particularly if we combine the standard equations, $B=\mu_0 I/2\pi r$ and $B=[\mu_0\epsilon_0]v\cdot\epsilon$, substituting for B we have:

$$2\pi r=I/\epsilon_0 v\epsilon \tag{46}$$

[0263] Thus $2\pi r$ is proportional to the inverse of ϵ_0. Thus as space time is dispersed by gravitons the permittivity field will increase in the same way capacitance increases with separation of plates. Because of the inverse relationship between ϵ_0 and $2\pi r$, as ϵ_0 increases the circumference of a circle and the apparent ratio of π is to r, will appear to diminish in accordance with general relativity. This not an actual diminution in the circumference of a circle but the effective reduction of the resistance to motion in a circular path in this field.

[0264] Incidentally, the above observations, also lead us directly to Schrödinger's formula for the average equilibrium distance (r) between an electron with charge (e) in orbit around a proton, which is conventionally given by:

$$r=n^2 4\pi h^2\epsilon_0/me^2$$

[0265] Where ϵ_0 is again the permittivity of free space, m is the mass of the electron and n is an orbital integer, h is Planck's constant and e is the charge of the electron. Furthermore if $e=[\epsilon_0/3(4/3\pi c^3)]^{1/2}$ (eq. 3); then the equation at n=1, for the electron orbital radius elegantly simplifies to:

$$r=4h^2c^3/m$$

[0266] Hence the orbital radius of the electron is related to spin of the electron (h) and its mass (m).

[0267] Quantum Gravity and the Charge of the Electron

[0268] The equation for the charge of the electron (eq. 1) contains the term so (permittivity of free space) which according to these observations should vary in a gravitational field.

$$e=[\epsilon_0/3(4/3\pi c^3)]^{1/2} \tag{6a}$$

[0269] If we combine the standard equations, $B=\mu_0 I/2\pi r$ and $B=[\mu_0\epsilon_0]v\cdot\epsilon$, substituting for B we have:

$$2\pi r=I/\epsilon_0 v\epsilon \tag{46}$$

[0270] Thus $2\pi r$ is proportional to the inverse of ϵ_0. Thus as space time is dispersed by gravitons the permittivity field will increase in the same way capacitance increases with separation of plates. Because of the inverse relationship between ϵ_0 and $2\pi r$, as ϵ_0 increases the circumference of a circle and the apparent ratio of π to r, will appear to diminish in accordance with general relativity.

[0271] Thus ϵ_0 rises when space-time is dispersed by the gravitons that produce the gravitational field, This occurs in a similar way to the process by which capacitance increases with separation of plates in a capacitor.

[0272] Nevertheless, as c is a constant and as $c=[\mu_0\epsilon_0]^{-1/2}$, then if ϵ_0 rises then μ_0 falls. This is entirely consistent as μ_0, which represents the force that quintessence exerts, would be reduced if the quintessence space time lattice is dispersed.

[0273] Furthermore, as $\mu_0=4\pi\times10^{-7}$ N A^{-2}; then as μ_0 falls, then the apparent ration π to r, also falls in a gravitational field. This is largely the same as stating, as does general relativity, that the apparent radius r', rises in a gravitational field. So this view is consistent with general relativity.

[0274] Nevertheless, to derive an exact value for the charge of the electron we must account for gravity in the above equation. We will take the specific example of the Earth's gravitational field in order to obtain the exact value for the electron. If in accordance with standard general relativity, the apparent increase in radius r' is:

$$r'=GM/3c^2 \tag{34}$$

[0275] Then given that the mass of the Earth is 5.9745×10^{24} kg; then

$$r'=1.47864\times10^{-3}\text{ m}$$

thus

$$2\pi r'=9.29057\times10^{-3}$$

[0276] Which is the incremental factor by which ϵ_0 must increase in Earth's gravitational field. So to correct ϵ_0 to account for gravity, ϵ_0 must be divided by the incremental factor, $2\pi r'$. Similarly as effectively π decreases in a gravitational field, to correct π to account for gravity it must be multiplied by this incremental factor. So the equation for an electron in a zero gravitational field is:

$$e=[\epsilon_0/3(4/3\pi c^3)]^{1/2}\div(1+2\pi r')=1.6022\times10^{-19}\text{ C} \tag{6b}$$

[0277] This now gives the charge of the electron as measured in a zero gravitational field as 1.6022×10^{-19} C, which is the same as that measured on Earth. Notably these observations appear to suggest that the charge of the electron is the same irrespective of the gravitational field.

[0278] Virtually unlimited degrees of accuracy for the charge of the electron and for the fine structure constant (α), may be achieved by taking into account 2nd and nth order gravitometric effects. Thus if we take into account the effect of gravity upon the radius of the Earth it is also important to take into account an effect upon the instruments with which we measure quantities, this would be a second order gravitometric effect. Thus taking into account 2nd order effects (r''), we have a very small, but nevertheless relevant change, such that: $r''=r'(1+2r')$. Thus $2r''=9.3180486\times10^{-3}$, and thus:

$$e=[\epsilon_0/3(4/3\pi c^3)]^{1/2}\div(1+2\pi r'')=1.6021765\times10^{-19}\text{ C} \tag{6c}$$

[0279] This agrees exactly to the nearest 7 decimal places with the maximum accuracy of the experimental value for the charge of the electron. Furthermore by taking into account the nth order gravitometric effect, it is theoretically possible to predict accuracy for the charge of the electron to 3n decimal places. This mathematically accuracy confirms the structure of the electron from first principles and indeed the theoretical effects of gravity on the permittivity of free space (ϵ_0).

[0280] This returns us directly to the fine structure constant for the electron which is conventionally given by: $\alpha=e^2/hc\cdot4\pi\epsilon_0$. If $\alpha=e^2=\epsilon_0/3(4/3\pi c^3)$, accordingly the quintessential equation for α is structurally given by: $2\pi/\alpha=m^q[3\Theta]^2$ (where $\Theta=4/3\ \pi c^3$; see The Structure of the Electron and Matter), we must now take into account the effects of gravity, as above, thus:

$$2\pi\alpha/m_q[3\Theta]^2\div(1\_\_2\pi r'')^2=0.007297353$$

[0281] Where the gravitational term for the increase in radius r'' allows the mathematical derivation of $\alpha=0.007297353$, and the above equation is in agreement with the conventional experimental value for $\alpha=0.007297353$ to the nearest 9 decimal places.

[0282] Hence the term $(1\_\_2\pi r'')^2$ is in accordance with these observations for the effect of gravity on electromagnetic forces. To a maximum accuracy governed by current knowledge of the mass of the Earth and the Gravitational constant and thus the term for the gravitational increase in radius r'. These observations can also be used to accurately predict the magnetic moment of the electron

[0283] Thus the presence of the fine structure constant can now be further understood, by deriving the constant from first principles; specifically from the actual dimensional conformation for the charge of the electron: $e=[\epsilon^0/3(4/3\pi c^3)]^{1/2}$ (eq. 6).

[0284] Overall the fine structure constant α (allowing for the term r' which is the general relativistic increase in the radius of the Earth due to gravitation) is given by none other than the formula for the mass of quintessence and from the structure of the electron, which can now be derived from first principles to seven decimal places or more.

[0285] Quantum Gravity and the Electron Magnetic Moment

[0286] The theoretical origin and nature of magnetism remains obscure in current electromagnetic theory. An explanation suggests these magnetic effects are produced by photons, although no photons have ever been observed. To get round this difficulty it is postulated by physics that magnetism results from "virtual" photons. However, Maxwell's equation for electromagnetism states that the photon has no net magnetic effect.

$$\delta B_x/\delta B_y/\delta y+\delta B_z/\delta z=0$$

[0287] Thus magnetism could not, by the above standard equation, be derived from a photon real or virtual.

[0288] In addition observational data suggests that black holes have powerful magnetic fields and as in theory photons are unable to escape from black holes (except for small quantities in the form of Hawking radiation), it would be difficult to explain these magnetic fields on the basis of photon emission.

[0289] Einstein postulated that magnetism was merely due to special relativity .sup.(ref 17). The postulate for the nature of magnetism in these current observations, states that the magnetic force results from relativity due to none other than the phased emission of gravitons (why postulate two invisible forces, magnetism and gravity, when one, the graviton, will do). This view as previously discussed (Quantum Gravity and Electromagnetism) is entirely compatible with standard relativity(ref 19). Thus with the graviton origin of magnetism, the equation for the magnetic moment of the electron should have an expression in terms of quintessence and in turn the gravitational force and in particular the graviton.

[0290] The standard term for the magnetic moment of the Bohr Magneton (SIB) is:

$$\mu B=eh/4\pi m_e$$

[0291] In standard quantum mechanics the Bohr Magneton, μB, however, needs to be corrected to agree with experiment. The "correction factor" is termed "ϵ"; where $\epsilon=(\alpha/2\pi)-0.328\alpha^2/\pi^2=0.001159641$. Thus theory reveals μ_e, the magnetic moment of the electron where:

$$\mu_e=(eh/4\pi m_e)[1+(\alpha/2\pi)-0.328\alpha^2/\pi^2]$$

[0292] The conventional derivation of the term ϵ above, is given from the fine structure constant, ($\alpha/2\pi$) which is theoretically consistent. However, a rather arbitrary mathematical correction term; $0.328\alpha^2/\pi^2$ needs to be used in this standard equation. This appears ad hoc and needless to say, more accurate measurements show, the electron magnetic moment to the Bohr magneton ratio, $1+\epsilon=1.001159652$, which suggests the correction factor is indeed incorrect. Nevertheless, this correction factor is essential for "renormalisation" and thus for quantum mechanics to work.

[0293] Quantum gravity readily explains the discrepancy between the theoretical Bohr Magneton (μB) and the actual measured magnetic moment of the electron (μ_e). In accordance with the above chapter (Quantum Gravity and the Charge of the Electron)

[0294] Thus the significant mathematical discrepancies can be removed by accounting for the effects of quantum gravity.

[0295] Thus taking the charge of the electron (e), using the equation for the Bohr magneton and the effects of quantum gravity such that gravitational change in radius is r". The magnetic moment of the electron is given by:

$$\mu_e=(eh/4\pi m_e)(1+[\alpha/2\pi\div(1+r'')])$$

[0296] This gives an electron magnetic moment to Bohr magneton ratio of 1.00115968. Thus the mathematical term for the magnetic moment of the electron is given, avoiding the arbitrary and dubious term $0.328\alpha^2/\pi^2$ used in the standard equation, simply by accounting for quantum gravity.

[0297] It is now possible to unite the equations for gravity and magnetism by substituting the fundamental key equations of quantum gravity. Thus if: $h=3m_qc^2$ (eq. 1b) and $m_e=m_qn_q$ (eq. 2). Then we can express the magnetic moment of any particle with the charge of the electron, including the proton, in terms of the number of quintessences (n_q) in that particle.

$$\mu B=ec^2/(4/3\pi n_q); \tag{47}$$

[0298] Given that the postulated structure of the graviton is: ($\phi=\pi/c$) (eq. 42), then substituting we have

$$\mu B=3ec/4\phi n_q \tag{48}$$

[0299] Showing that the equations for the magnetic moment are compatible with the gravitational equations given earlier. Principally, the quintessential equations now allow the determination of the magnetic moment of any charged object from the equation for the graviton and directly from the number of quintessences it contains. In conventional physics the magnetic moment of the electron requires a correction factor, $(1+(\alpha/2\pi c)-0.328\alpha^2/\pi^2)$, to derive the correct experimental value. These observations herein, indicate that the correction factor is more logically (1+r"), where r" is the general relativistic increase in radius around a gravitational body. This suggests that magnetism is not only affected by gravity, but can, as shown as above, be derived using the quantum gravitational equations.

[0300] Quantum Gravity and Special Relativity

[0301] Ordinary matter passing through the lattice would produce gravitons which would interact with space-time as described by general relativity. The quantity of gravitons would be determined by the apparent mass and in turn these would apparently curve space time. The geometry of this "curvature" is elegantly described by general relativity using Riemann geometry, specifically using metric tensors. Intriguingly the metric tensor is not a single number, but at each point in space time it is required to consist of a collection of ten numbers, Consequently, ten dimensional space-time hypotheses, such as this or superstring theory, may automatically yield general relativity

[0302] General relativity is indeed very elegant, nevertheless there was a logical step yet to answer. That is, how do gravitons shape space time? This can now be readily answered by considering the interaction of a three dimensional space time lattice with gravitons themselves to produce the effects of gravity. The effects of gravity are as such to compel a body in motion towards the gravitational object and to a much smaller extent visa versa. This effect can only be produced If gravitons repel quintessence (the constituents of the 3D lattice). Indeed, it has been stated that in order to explain cosmic inflation and the "flatness" of the Universe that quintessence must shun (or be shunned by) matter.

[0303] In descriptive terms a body close to a large mass will have a tendency to move toward it because the three dimensional lattice would be less dense as it approached the surface of the large mass. Overall there would be less resistance to motion in the direction of the large mass, and the motion in this direction would be facilitated by the vibration of quintessence.

[0304] In general relativity the principle governing motion is the geodesic of least distance, this can be re-expressed using similar equations using least action. Furthermore, the concept of motion due to the vibrations of quintessence is more logically and experimentally compelling.

[0305] These observations can now be used to link general and special relativity. Thus as we approach the speed of light, the mass of an object travelling through the space-time lattice would approach infinity, directly because the number of quintessences passing through a body would increase with increasing velocity, hence the equation:

$$m'=m_0/(1-v^2/c^2)^{1/2} \tag{50}$$

or

$$m'=m_0/(1-v^{2\,[\mu_0\epsilon_0]})^{1/2} \tag{50a}$$

[0306] In turn this would generate increasing gravitons and accordingly this would explain the observed effects of special relativity. Time itself is due to passage through the space-time lattice, and where the space-time lattice is dispersed by gravitons, time and length are reduced with increasing velocity and hence increasing space-time lattice dispersion, similar to the way in which gravity alters space-time

[0307] As a result:

$$t'=t(1-v^2/c^2)^{1/2},\ l'=l(1-v^2/c^2)^{1/2}$$

[0308] Thus resulting in the effects of special relativity.

[0309] Quintessence and Black Holes

[0310] To address the relationship of the space-time lattice to gravity directly, it is important to discuss the concept of quintessence with regard to general relativistic equations. The standard general relativistic equation for the apparent increase in radius (r) due to the curvature of space time around a gravitational object, which has also been previously derived from first principles (eq. 36), is:

$$r'=GM/3c^2 \tag{34}$$

[0311] This can also thus be written as:

$$3r'=GM[\mu_0\epsilon_0] \tag{51}$$

[0312] This standard equation, is in keeping with the above observations. Specifically, as the mass increases, ϵ_0 increases, in turn the radius will appear to increase (relative to π).

[0313] The above observations now allow us to examine the effects with regard to the interior of black holes themselves. The event horizon would represent a critical density for quintessence, in which light could not escape. The Schwarzschild radius would now be given by:

$$R_s=2GM[\mu_0\epsilon_0]$$

[0314] The event horizon will occur at the point at which there is less resistance to circular motion than motion in a straight or partially curved line. Given that π is proportional to $1/\epsilon_0$. The event horizon should occur when the permittivity has increased by a factor of π.

[0315] Effectively because the permittivity of free space rises, π decreases. This is entirely in keeping with general relativity which predicts the effective change in the ratio of the radius to the circumference as given by the conventional equation, where r', is again the apparent change in radius.

$$r=GM/3c^2$$

[0316] Hence π will effectively decrease as we approach the event horizon of a black hole, When π decreases to 1, the circular circumference is equal to the diameter and moreover, inside this limit it is shorter for light to travel in a circle. Thus light cannot escape the event horizon.

[0317] This can give us great insights into the workings of space-time, for flat Euclidean space the standard equation is:

$$e^{i\pi}=-1$$

[0318] In accordance with general relativity, the ratio of the radius to the circumference changes in a gravitational field, and effectively π=1, at the event horizon, thus the boundary condition for the shape of space-time at the event horizon now has the direct equation:

$$e^{f}$$

[0319] Within a black hole as the permittivity of space increases by a factor of 2π an object within it will complete two rotations rather than travel in a straight line. In effect exceeding the speed of light by 2π. Hence, the condition for space-time is represented by the equation:

$$e^{i/2}$$

[0320] Thus an increase in the permittivity of free space by a minimum factor of π, to produce a black hole is estimated to result from an increase in mass by a factor of approx. 10^6 (the ratio of the mass of the earth and that of a putative black hole).

[0321] Continuing with the subject of a black hole, according to the model inside the black hole, the gravitons produced by the matter present would be in equilibrium with the density of the space-time lattice. Increasing the rate of rotation of the matter in the black hole for instance would thus increase the production of gravitons and its effective mass and increase the radius of the event horizon. A density gradient of the space-time lattice would continue to exist within the black hole. Progressively closer to the center of a black hole matter itself would be increasingly compressed and the spherical structure of the quasi electron would be predicted to collapse. This collapse would result in the formation of an exotic form of matter in the form of pure quintessence in a black hole.

[0322] This pure quintessence would produce the singularity at the centre of the black hole. The larger the black hole in terms of mass the more pure quintessence would exist at its core.

[0323] Quintessence and the Big Bang

[0324] Quintessence theory not only predicts the occurrence of the Big Bang, but allows a prediction for the value of the entire mass of the Universe, from first principles.

[0325] In accordance with quintessence theory the big bang resulted from the explosion of an immense black hole singularity, which was constituted from pure quintessence.

[0326] On the basis of quintessence, there will be a critical mass for Big Bang event; thus if entire space-time between quintessence is compacted so that no further quintessence can be accommodated, the addition of further quintessence would destabilize the immense black hole, resulting in the Big Bang.

[0327] It is possible to predict this critical mass, using the radius of quintessence as a benchmark. Given the nine spatial parameters present in the metric tensor, used in general relativity we find that the actual formula for the radius of quintessence; r_q^2, is mathematically in agreement with general relativistic theory when:

$$9r_q^2=Gh/C^3 \tag{33}$$

[0328] This again supports the 9 dimensional view of space (so crucial in superstring theory). Moreover, the size of the vibrations of quintessence can thus be calculated as:

$$r_q=1.35\times10^{-35}\text{ m} \tag{33a}$$

[0329] The volume of each quintessence is thus:

$$4/3\pi r_q^3=1.0306\times10^{-104}\text{ m}^3 \tag{33b}$$

[0330] So to be accommodated within unit volume of space time, with no intervening apparent space time, (given that each of 9 overlapping quintessences are required) would require approx.

$$9\times10^{104}\text{ quintessences}$$

[0331] As the mass of quintessence is $m^q=h/c^2=7.373\times10^-$ 51 kg sec (eq. 1). Then the mass of the Universe, to two decimal places, is:

$$1.18\times10^{53}\text{ kg} \tag{33c}$$

[0332] This is in close agreement with a recent estimate of the mass of the Universe from COBE and other satellite data, which estimates the mass to be 100 trillion trillion trillion trillion tonnes (10^{53} kg)

[0333] Moreover, the early formation of the galaxies can be readily explained, it is likely that in such a big bang some very small black holes might have prevailed and that these formed the seeds of the galaxies we see today.

[0334] The event horizon, calculated from the Schwartzschild radius, of such an immense black hole is about 10^{26} m, which would have allowed Guth's inflationary component to the early expansion of the Universe.

[0335] In addition, inflation may result directly from the observation that once electrons have formed from the primordial soup of quintessence, they emit gravitons which in turn repel space time, which might also result in another cosmic inflationary cycle.

[0336] Most importantly quintessence theory explains the Big Bang from first principles and is capable of accurately predicting the mass of the Universe.

[0337] The Nature of Energy

[0338] These observations allow a fundamental understanding of energy. The quantum physical, minimum component of energy is Planck's constant; h. To define the minimal component of mass, using the standard energy equivalence formula; $E=mc^2$, such a minimal mass (m_q)

would be required to have the value equivalent to; $m_q=h/c^2$ (1). The total mass of a system (m) would then be; $m=m_q n_q$, where (n_q) is the number of these minimal units. Thence, the total energy of a system can be derived from the minimal energy; h, multiplied by the number of these energy units (n_q). Thus as, $E=mc^2$, then also $E=m_q n_q c^2$ and substituting $m_q=h/c^2$, the energy equivalence formula has the more logical formulation;

$$E=hn_q \tag{1a}$$

[0339] Thus the energy of a system is equivalent to the minimal energy unit; h, multiplied by the number of those minimal energy units (n_q)

[0340] This leads directly to a deeper understanding of wave particle duality and the wave nature of matter.

[0341] This is encapsulated by the quintessential energy formulae

[0342] As conventionally $\beta \cdot E/c=p$, then

$$\lambda=h/p=hc/\beta E \tag{2}$$

and

$$E=hn_q \tag{1a}$$

then

$$\lambda=c/\beta n_q \tag{2b}$$

[0343] Importantly, as indicated by equation (2b), energy having no quintessence; would have a wavelength of infinity. Specifically pure energy containing no quintessences, would have a lambda of infinity. According to quantum mechanics an infinite wavelength would result in the probability of that energy being anywhere. As energy itself has no electrical charge it would not be impeded by the permittivity and permeability of the three dimensional space-time lattice. Moreover, energy would not be detectable in three dimensional space-time, unless it interacted with matter, as in the EPR experiments. Indeed, energy is not observed when not bound to any form of mass or particle.

[0344] Thus equation 2b, takes us to our original assertion regarding the existence of pure energy.

[0345] Energy is not Bound by the Space-Time Lattice

[0346] Thus, as the EPR experiments suggest the existence of energy separate from matter and thus separate from the three dimensional space-time lattice, it is interesting to find that experiment suggests the existence of free energy in a continuum separate from space time and matter to produce the effects of quantum teleportation.

[0347] This is not, however, teleportation across an additional dimension, this is a term to describe in partially familiar terms the dissociation of energy from the three dimensional space-time lattice. As time is inextricably linked to each dimension of space, the effects of energy would be inextricably linked to the events, such as the creation of virtual particles, we see interacting within space-time. It is unlikely that observers have any direct day to day experience to explain quantum events. Nevertheless, quintessence theory may have given us a window into the hitherto hidden workings of the Universe. Thereby, the mystery of the uniformity of the Universe, across distances which the speed of light could not apparently traverse, is readily explained by the fact that the free energy contained in the Universe is not bound by the space-time lattice.

[0348] In the case of light, due to the exceedingly small masses involved, there would be relatively easy exchange of matter with free energy within a photon. This would make the photon the ideal experimental tool to look for energy which is not bound by matter and in turn energy which is not bound in space-time. Indeed, very recently Furusawa et al. have reported to have observed the transference of energy as photons from A to B, without those photons traversing space-time. This finding which has been supported using other experimental techniques, is very important as it suggests the existence of such free energy.

[0349] Overall, quintessence theory gives an a priori explanation for the concept of mass, the elementary particles, the forces of nature and quantum effects. It can equally be used logically to explain the inner physics of a black hole, the missing mass in the Galaxy, the expansion of the Universe, Guth's inflationary theory and predicts the Big Bang, from first principles.

[0350] Part IV: Applied Theory with the Intent to Create Closed Timelike Curves

[0351] Electron Bombardment of the Photosphere to Induce Gravitational Shift

[0352] Leveraging the above relationship between mass and quintessence we derive that if an electromagnetic radiation with velocity v strikes the event horizon singularity of rest inertial mass mi, and U is the electromagnetic energy absorbed by the singularity, then, according to Maxwell's prediction, a momentum q=U/v is transferred to it. Mass shift $d \cdot m_b$, dependent on the external electromagnetic energy, equals the inertial mass shift dependent on the increment of energy in the particle. Since in this case the inertial mass shift does not depend on velocity V, i.e., it is related only to the momentum q absorbed, it can be obtained by making p=0 in variation $\Delta H=H'-H=c[q^2+(m_i c)^2]^{1/2}-(m_i c)^2$ from the particles inertial Hamiltonian. Consequently, the expression of d_{m_p}, is written as:

$$d_{m_p}=\Delta H/c^2=m_i\sqrt{1+U/m_i c^2\left[\varepsilon_r u_{r/2}\left\{\sqrt{1+d/w\varepsilon^2+1}\right\}^2=1\right.}$$

[0353] Comparing now the expression of m_i and m_g we have $m_g=m_i-2dm_b$. By replacing m_b in this equation, given by equation above, we obtain the expression of the correlation between gravitational mass and inertial mass, i.e.,

$$m_g=m_t-2\sqrt{1+U/m_t c^2\left[\sqrt{\varepsilon_r u_{r/2}\{[d/we]^2+1\}^2-1}\right.}\cdot m_t$$

[0354] We see that only in the absence of electromagnetic radiation on the event horizon (U=0) is the gravitational mass equivalent to the inertial mass. Note that the electromagnetic characteristics, e, m and s do not refer to the singularity itself, but to the outside medium around the singularity (photosphere) in which the incident radiation is propagating.

[0355] Stable CTC Solution From Modified M-Theory

[0356] Our innovation is a method of creating an event where a dual membrane or dual boundary condition exists. We do this using generalization from a Misner space which has been modified if one analytically continues the maximal extended Misner Metric so that $ds^2=-du^2+dw^2+(dx^2)^2+(dx^3)^2$ to the Euclidean section so that u=iota zeta we obtain a Misner instanton on the section where w and zeta are both real. The Euclidean time, t, and the closed spacelike coordinate are both periodic, the later having a period of $2\Pi t^2$. Going back to the Lorentzian sector we find that the period of the closed coordinate becomes linearly dependent on the physical time. Using automorphic fields in the Hadamard function one can obtain a quantized condition for time. This gives us a figure on the order of the Plank time. This confines such a stable wormhole condition to the general area of the Plank scale in its modified form which is that area defined by the Membrane itself. As such, these Plank scale wormholes are the true source of the true virtual aspects of the vacuum and quintessence. The effects of the dual singularity system can be viewed as an overlap zone of two distinct space-times which have boundary conditions on both sides. As an object accelerates towards C it is this same boundary or horizon that object encounters when the Time defined horizon solution for the universe is imposed. At this point drawing upon Van Den Broeck's alterations for this space-time geometry to create a single closed Friedman-Robertson-Walker spacetime the space-time geometry can be represented by this equation $ds^2=dct^2-B^2[(dx-\beta fdct)^2]+dy^2+dz^2$ B can be any function that is large near the displacement device. We then consider this transformation as extended to four dimensional space-time with arbitrarily time dependent acceleration. We also present the device frame energy density T00 from a four dimensional calculation and note that the 4d classical calculation is everywhere finite.

[0357] Consider an Alcubierre interval given according to a remote frame's cylindrical coordinates by:

$$ds^2=(1-\beta^2 f^2)dct^2+2bfdctdz-dz^2-dr^2-r^2df^2$$

where f is a function that is 1 at the location of the device and zero far from it.

[0358] Starting out with the first transformation $z'=z-\grave{o}ct$ beta dct. Where b is first expressed here as a function of time ct. With some algebra for simplification this results in

$$ds^2=[1-\beta^2(1-f)^2]dct^2-2b(1-f)dctdz'-dz^2-dr^2-r^2df^2$$

Let g=1−f and this becomes

$$ds^2=[1-\beta^2 g^2]dct^2-2bgdctdz'-dz'^2-dr^2-r^2df^2$$

[0359] Notice that this returned the original intervals form with a reversal on the sign of b and a reversal of the boundary conditions for g. Now we notice that at r=0, this interval becomes the interval for special relativity transformed to cylindrical coordinates. Thus, we have found a transformation to a frame based local to the device. One can also verify that in these coordinates the relevant affine connections vanish at r=0. a further proposed modification to this field we will reintroduce a time dilation term into the devices frame's interval. Only we will use different boundary conditions for it. We will keep A=1 both at the location of the device, and far from it, but allow it to become large in the warped region. This is achieved by the simplest means possible in the proposed field generation method. Since rotating kerr singularity under bombardment would produce an equal negative energy region. With the effect focused outward away from the device slightly by the relative alignment of the kerr singularity the actual inward going portion of such fields would overlap and cancel their effect out in the region of the device. This yields a space normal time region, which is again restored at the fringes of the outward going field. From the standpoint of a geometric picture of space-time around the device and extending outwards one has actually created a dual event horizon situation as far as time goes. The inner one is the shell of the canceled out field inside of which normal time flow is restored. The outer one is formed at the boundary where normal time resumes and within which we have a negative energy field.

SUMMARY OF THE INVENTION

[0360] The present invention is A method for the generation of a pseudo 2+1 dimensional anti-de Sitter space (DeDeo & Gott 2002) using two Kerr type positively charged rotating dilation singularities where one singularity is maintained as a axis of rotation or "reference" singularity, and the other "target" singularity is subjected to a differential electron flow so as to simultaneously pass above the photosphere of said singularity in its direction of rotation—prograde orbit—and contrary to its direction of rotation—retrograde orbit—to release a directed flow of gravitons in a sinusoidal oscillation simulating a rotational effect of the "target" singularity around the axis of rotation provided by the "reference" singularity, resulting in the creation of timelike curves in a compact time-oriented manifold permitting topology change from one spacelike boundary to the other in accordance with Geroch's theorem (Geroch 1967) which results in a method for the formation of G odel-type geodesically complete spacetime envelopes complete with closed timelike curves.

BRIEF DESCRIPTION OF THE DRAWINGS

[0361] **FIG. 1** is a schematic representation of the mechanism employed to house the components necessary to generate a 2+1 dimensional anti-de Sitter space, resulting in the creation of timelike curves in a compact time-oriented manifold

[0362] **FIG. 2** is a schematic representation of the G odel-type geodesically complete spacetime envelope created by the mechanism complete with closed timelike curves

DETAILED DESCRIPTION OF THE INVENTION

[0363] Principles of Gravity Distortion Time Displacement Systems

[0364] The theoretical understanding of quantum gravity allows the design of time displacement systems from first principles. It is unlikely that gravitons or Kerr singularities can be controlled in a precise way using current technology. Nevertheless, an understanding of three dimensional space-time and matter, does allow the design of elementary displacement systems. That is, systems whose displacement rely on direct warping space-time as opposed to the ejection of material to provide thrust resulting in time dilatational effects.

[0365] The background for these systems are already partially understood and quintessence theory allows their further development. For this invention, the formation of black holes in the laboratory represents a crucial step in understanding the mechanisms that underlay gravitational physics and in turn the warping of space-time. The existence of black holes permits the localized application of the Axial torsion Spin-Rotation Coupling Effect (Zhang & Beesham 2002) resulting in a Rotating Frame with Relativistic Factor (Zhang 2003) which can be used in the creation of a Alcubierre space time bubble under the Van Den Broeck modification of the Alcubierre geometry (Van Den Broeck 1999) resulting in a method for the generation of a pseudo 2+1 dimensional anti-de Sitter space (DeDeo & Gott 2002) using two Kerr type positively charged rotating dilation singularities where one singularity is maintained as a axis of rotation or "reference" singularity, and the other "target" singularity is subjected to a differential electron flow so as to simultaneously pass above the photosphere of said singularity in its direction of rotation and contrary to its direction of rotation to release a directed flow of gravitons in a sinusoidal oscillation simulating a rotational effect of the "target" singularity around the axis of rotation provided by the "reference" singularity. In this instance the space-time lattice would be repelled by gravitons in such a way as to disperse space-time quintessence in a circular fashion around each of the singularities, producing multiple event horizons around the simulated axis of rotation provided by the reference singularity.

[0366] The release of gravitons from the target singularity is controlled by differentially governing the electron flow across the photosphere with the use of powerful electric currents. In turn the differential direction of flow across the photosphere of gravitons would determine the direction of motion through the space time lattice and the resulting time displacement from one spacelike boundary to the other in accordance with Geroch's theorem (Geroch 1967) when implementing this approach it is important to remember that the black hole is not excited by the smashing of the clump as it "hits" the horizon. The hole is rather excited when the metric perturbation associated with the clump is "felt" by the background metric. The excitation event therefore constitutes a smooth process whereby in-fall of a clump from .rmb and through r+ serves as a source in the Teukolsky (1973) equation for small perturbations to the Kerr geometry (with appropriate boundary conditions at r+ and r∞). This is an important distinction with a great deal of relevance to the practical engineering of the displacement unit since we need to gauge the "driving" of QNR modes in terms of an e_ective coupling from clump in-fall.

[0367] What results is a method for resonant driving of the quasi-normal ringing (QNR) wave modes of the Kerr geometry of the target singularity. The micro black hole hyper-accreting at rates ÿ M. 1 M□sec. 1 from a neutrino cooled disk is pushed through to oscillate near resonance of its (l,m=2, 2) quadrupole QNR frequency due to the in-fall of compact mass over-densities from the cusp in e_ective potential on a dynamical time scale. This mode is induced via induced magneto-rotationally induced fluid dynamics in the ultra-relativistic region of the flow bounded from below by the marginally bound orbit radius: rmb If the QNR modes are fed resonantly for a few seconds of hyper-accretion, the enhanced amplitude of the oscillations yields a very high rate of energy deposition into gravitational waves. Indeed, the integrated energy deposition is large enough to "evaporate" the equivalent of a factor of a few times the total rest mass-energy of a single clump into gravitational waves, which in turn interact with the reference singularity

[0368] Application of the method described in the previous section results in translation outside of the cosmological horizon, where F(R)<0. The topology of the resulting geodesic, for large constant R, is mathematically equivalent to a Euclidean cylinder of the condition R×Sn where T is the coordinate along the cylinder. I± are located outside the future/past cosmological horizons, where R is timelike and T is spacelike. In the case of a rotating Kerr black hole, there are two circular photon orbits that can exist in the equatorial plane and be exploited to create a tipler sinusoid. One is a prograde orbit moving in the same direction as the black hole's rotation, while the other is a retrograde orbit moving against the black hole's rotation. Their radii are respectively given by

$$r1=2M(1+\mathrm{Cos}(2/3\ \arccos(-|\alpha|/M)))$$

$$r2=2M(1+\mathrm{Cos}(2/3\ \arccos(|\alpha|/M)))$$

where a is the angular momentum per unit mass of the black hole. The orbits fall in the range M greater or equal to r1 greater or equal to 3M greater or equal to r2 greater or equal to 4M The fact that a prograde photon or in or case cooper pair with Bose characteristics orbits the black hole at a smaller radius than a retrograde one can be attributed to the well-known Lense-Thirring effect, i.e., the dragging of inertial frames due to the black hole's rotation which we control and influence via electromagnetic induced load coupling with the open magnetic field lines threading the BH horizon. This dragging would cause charged cooper pairs to revolve around the black hole relative to a static observer at infinity. Thus, to such an observer, a prograde cooper pair would have to orbit at a smaller radius to compensate for the 'extra' angular momentum acquired, while a retrograde one would have to orbit at a larger radius to compensate for the 'lost' angular momentum. Indeed, in the limit of zero rotation, these two orbits coincide at r D 3M, giving the single circular orbit of the Schwarzschild black hole. Now, recall that orbits around the Schwarzschild black hole are necessarily confined to a plane passing through its center, because of the spherical symmetry of the space-time. However, the Kerr black hole space-time has only an axial symmetry (in addition to being stationary), and this raises the possibility of non-planar orbits. One could, for example, contemplate the existence of spherical Boseon orbits—orbits with constant coordinate radii that are not necessarily confined to the equatorial plane—around the Kerr black hole. Such orbits would be a nontrivial generalization of the two circular photon orbits that lie in the equatorial plane. At first it may seem a little surprising that such spherical orbits could even exist, but there is an interesting reason as to why they are possible. Note that an object in a spherical orbit would, in addition to moving around the black hole in the azimuthal direction, be undergoing some periodic motion in the latitudinal direction. This is only possible if there is a conserved quantity associated with motion in this direction, just as angular momentum is necessarily conserved by its rotational motion in the azimuthal direction. (This result can be seen, for example, using action-angle variable) Now, because the Kerr space-time has only axial symmetry, geodesics in it should have only two constants of motion, namely energy and angular momentum. However, Carter discovered the remarkable fact that geodesics in the Kerr space-time possess a third constant of motion. It turns out that Carter's new constant governs the motion of geodesics in the latitudinal direction, although it is not related to any obvious space-time symmetry. Thus, spherical timelike orbits, which assume eigenlike properties around the Kerr black hole, are possible and when coupled with charged Bosons may be exploited to manipulate the relative event horizons of the "target" singularity. The location and the temperature of the modified event horizon depend on the time, charge and angle of incidence of the cooper pairs. The Fermionic spectrum of Dirac particles displays a spin-rotation coupling effect due to the interaction between the particles with spin-1=2 and the black holes with rotation. The effects arise from the interaction between the spin of Dirac particles and the rotation of the evaporating black holes. The feature of this spin-rotation coupling effect is its dependence on different helicity states of coupled particles with spin-½ and its irrelevance to the mass of particles.

[0369] In order to design a mechanism for time displacement exploiting the Carter asymettry cited above we utilize two positively charged top spin rotating kerr type black holes aligned on demand to create a simulated rotational effect around a central axis provided by the "reference" singularity. In the case of the Kerr blackhole (singularity), this is accomplished by an inverse Blandford-Znajek (BZ) process utilizing the magnetic flux of open field lines connecting the horizon and an induced remote load. (Ding-Xiong Wang, Kan Xiao & Wei-Hua Lei, 2001) permitting the microscopic blackhole (singularity) to be rotated along its horizontal axis in at relativistic centrifugational speeds. A differential current is then applied in such a way as to pass through the entire photosphere in the desired direction. As a result the gravity field can be manipulated by three factors that affect it in distinct ways. Adding electric charge to the singularities increases the diameter of the inner event horizons. Adding mass to the singularities increases the area of gravitational influence around the singularities. Rotating and positioning the polar axis of the singularities affects and alters the resulting gravity sinusoid

[0370] In order to create a sinusoid capable of inducing a topology change from one spacelike boundary to the other in accordance with Geroch's theorem The electric charge in the upper half of the photosphere would be maximised. The electrons will have a vector in the left to right direction as the singularity spins clockwise. If a maximised current is applied to the singularity in the same direction this will result in a increase in the velocity of the electrons relative to the centre of gravity of the singularity, due to the flow of current. In turn, according special relativity and to the space-time lattice model, this wilt result in an increase in the relativistic mass if the electrons and in turn by general relativity an increase in the release of gravitons.

[0371] Conversely in the lower half of the singularity the electrons will have a vector of motion in the right to left direction due to the spin of the singularity. This will be relativistically slowed by the differential current applied in the same direction as the current above, and hence in the opposite direction to the direction of rotation. The charge can be separately applied and adjusted to ensure that the electrons are relativistically stationary relative to the centre of gravity. In turn this will minimize the relativistic mass and result in a decrease in the release of gravitons for the lower half of the singularity.

[0372] The overall result will be a greater release of gravitons in one direction and a lesser release of gravitons in the converse direction. The effect will be enhanced by the use of a multi-phasic current simultaneously applied. This will result in the release of multi-phasic gravitons which will disperse space time in the singularity with increase in density in the converse this effect can also be produced and supplemented with the use radio frequency pulses, The radio frequency pulses must be designed to produce a change in the spin of the particle to enhance the release of gravitons in the desired direction

[0373] With the use of large currents the drift velocity of the electrons across the photosphere could be greatly increased. Within this region the electrical resistance is virtually eliminated. Thereby allowing large currents to be induced with minimum total power output.

[0374] The result is the production of cooper paired electrons of high speed and hence high relativistic mass in the desired half of the singularity, whilst producing low speed and thus low mass paired electrons at the converse of the singularity, in accordance with special relativity. The imbalance in the rotating singularity will be continuously present creating a dynamic warping of space-time. In effect, the differential current flow, will produce differential graviton production and in turn, by general relativity, the warping of space-time

[0375] As the cooper pairs cross the photosphere, accretion of the Bose particles results. Near-hole accretion across the target singularity is then motivated by magneto-rotationally induced, ultra-relativistic disk dynamics in the region of the flow bounded from below by the marginally bound geodesic radius rmb. As the particles impelled have high spin values, a largely coherent magnetic field in this region has the dynamical implication of compact mass segregation at the displacement nodes of the non-axisymmetric, MRI modes. This results in prolific gravitational wave emission coincident with the gamma-ray stage. The gravitational wave emissions are then manipulated to influence the reference singularity to produce a variable gravitational sinusoid which is then used to mathematically approximate the gravametric distortion, inducing a topology change from one spacelike boundary to the other in accordance with Geroch's theorem.

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[0529] Appendix A: The Synthetic creation of micro singularities. Throughout this patent application the creation of micro singularities has been maintained. While at first glance this may seem to be a deficiency in the patent application it is in fact an engineering problem that is in the process of being solved. In the International Journal of Theoretical Physics 41 (11): 2073-2090, November 2002 L. J. Garay published "Black Holes in Bose-Einstein Condensates". In this article Garay showed that there exist both dynamically stable and unstable dilute-gas Bose-Einstein condensates that, in the hydrodynamic limit, exhibit a behavior completely analogous to that of gravitational black holes. This discovery coupled with creation of color glass condensate (CGC) an extreme form of nuclear matter in which a nucleus travels at near-light (relativistic) speed which flattens like a pancake in its direction of motion and spawns a large number of gluons hold the key to high energy singularity formation.

I claim:

1. A method for the generation of a pseudo 2+1 dimensional anti-de Sitter space comprising the steps of:

creating two Kerr type positively charged rotating dilation singularities, including the steps of

maintaining one of the singularities as a axis of rotation reference singularity,

maintaining the other of the singularities as a target singularity, and

subjecting the target singularity to a differential electron flow so as to simultaneously pass the differential electron flow above a photosphere of said target singularity in a direction of rotation thereof and contrary to the direction of rotation thereof, in order to release a directed flow of gravitons in a sinusoidal oscillation simulating a rotational effect of the target singularity around the axis of rotation provided by the reference singularity.

2. A method of generating a force around a body, comprising the steps of:

employing sinusoidal oscillations of electrical bombardment on the surface of one Kerr type reference singularity in close proximity to a second Kerr type target singularity to take advantage of the Lense-Thirring effect, wherein the electrical currents employed in the bombardment are passed simultaneously across the photosphere of said reference singularity in its direction of rotation and contrary to its direction of rotation to release a directed flow of gravitons in a sinusoidal oscillation simulating a rotational effect of the target singularity around the axis of rotation provided by the reference singularity;

creating timelike curves in a compact time-oriented manifold of Godel-type geodesically complete spacetime envelope under the Van Den Broeck modification of the Alcubierre geometry, resulting in the creation of timelike curves in a compact time-oriented manifold permitting topology change from one spacelike boundary to the other in accordance with Geroch's theorem.

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St. Clair

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(54) **CHI ENERGY AMPLIFIER**

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(52) **U.S. Cl.** **343/720**; 343/767

(57) **ABSTRACT**

A Chi energy amplifier that utilizes a co-gravitational K field to generate a flow of hyperspace energy into or out of a ceramic dome containing a slot antenna.

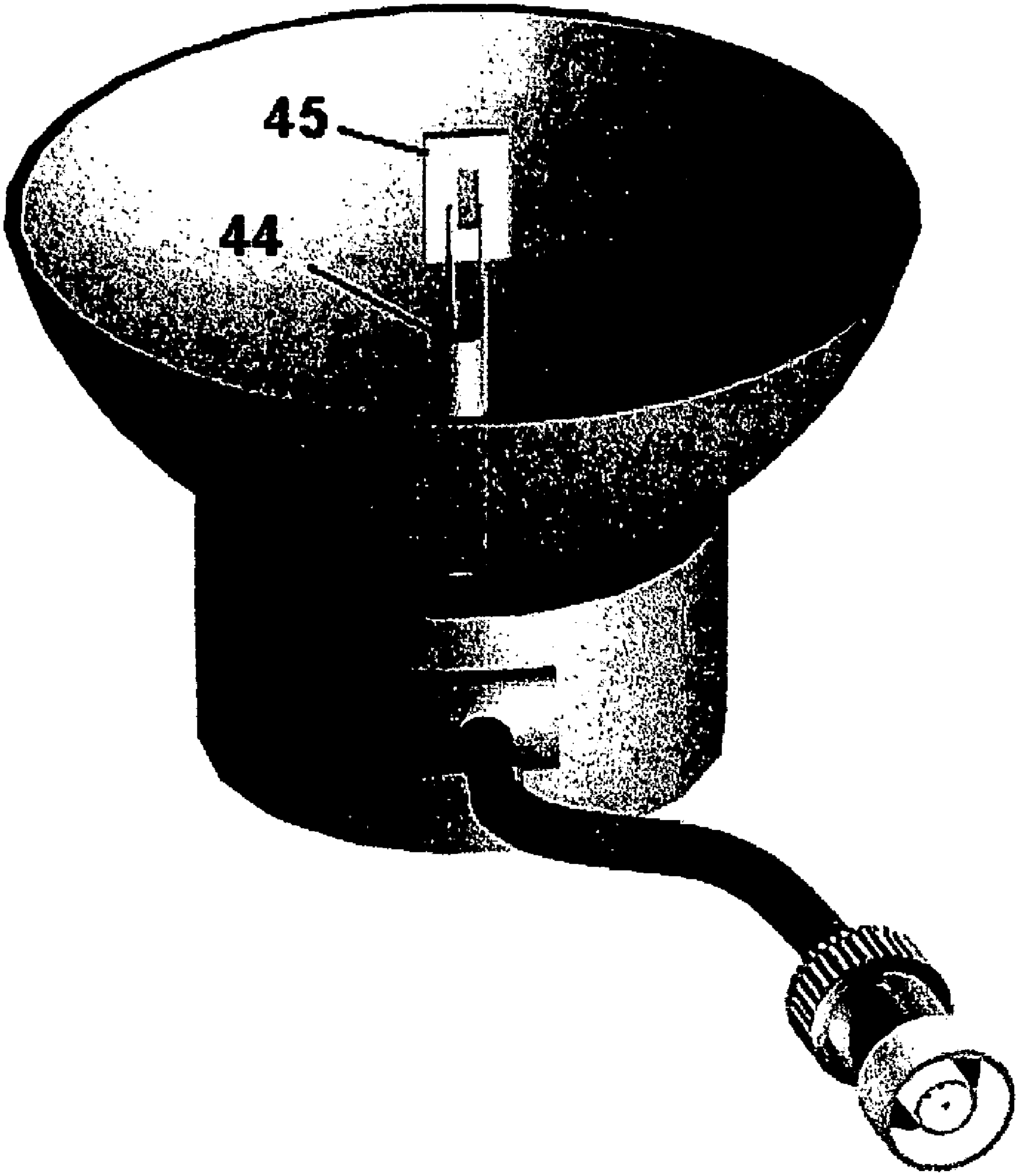

Figure 1

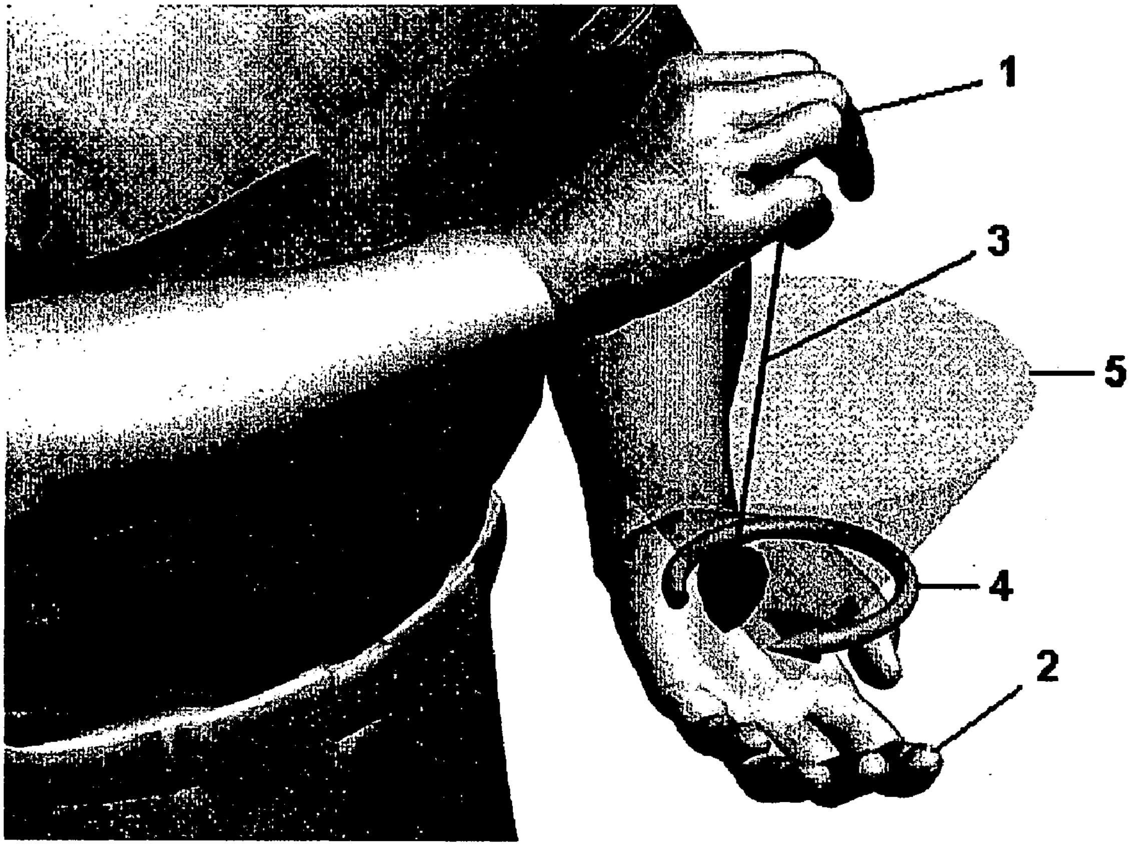

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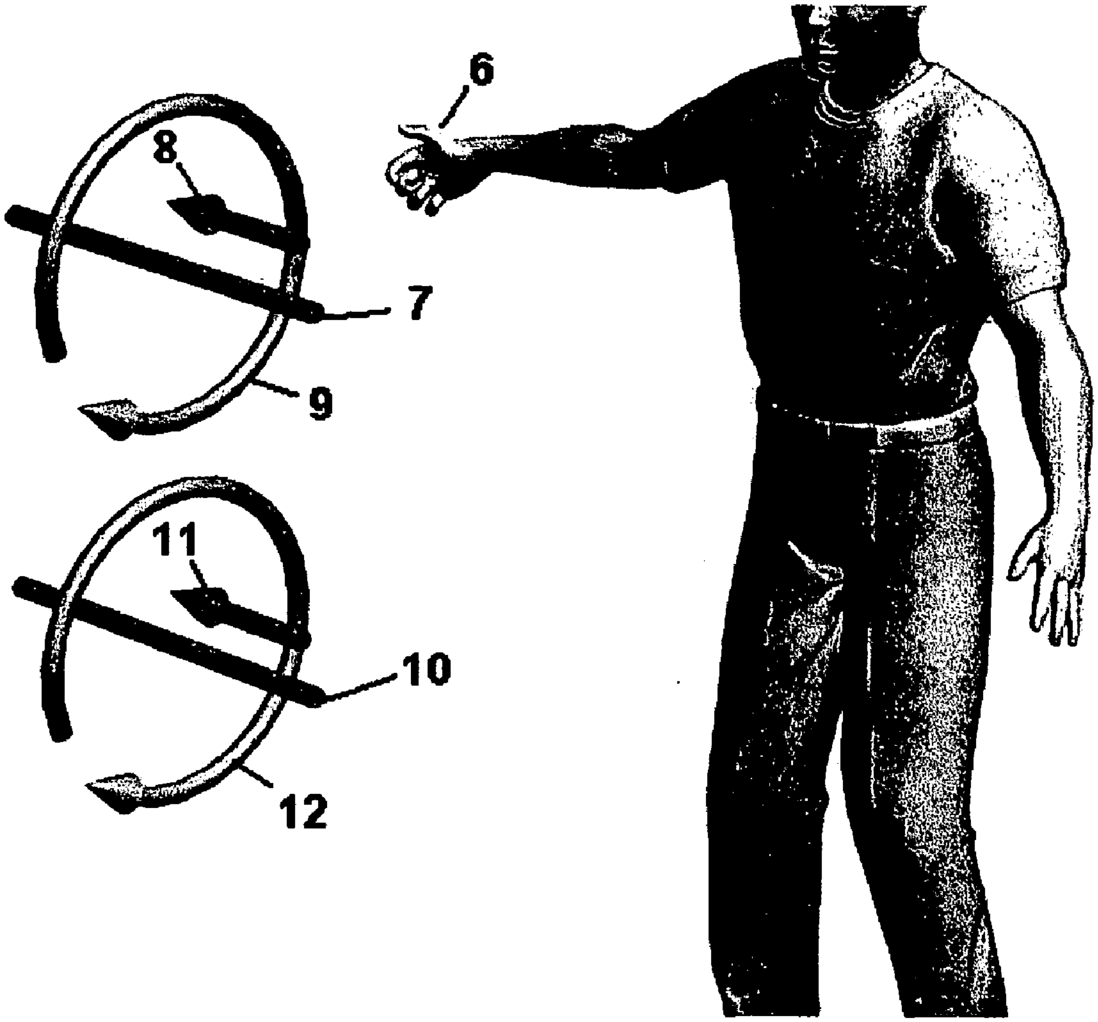
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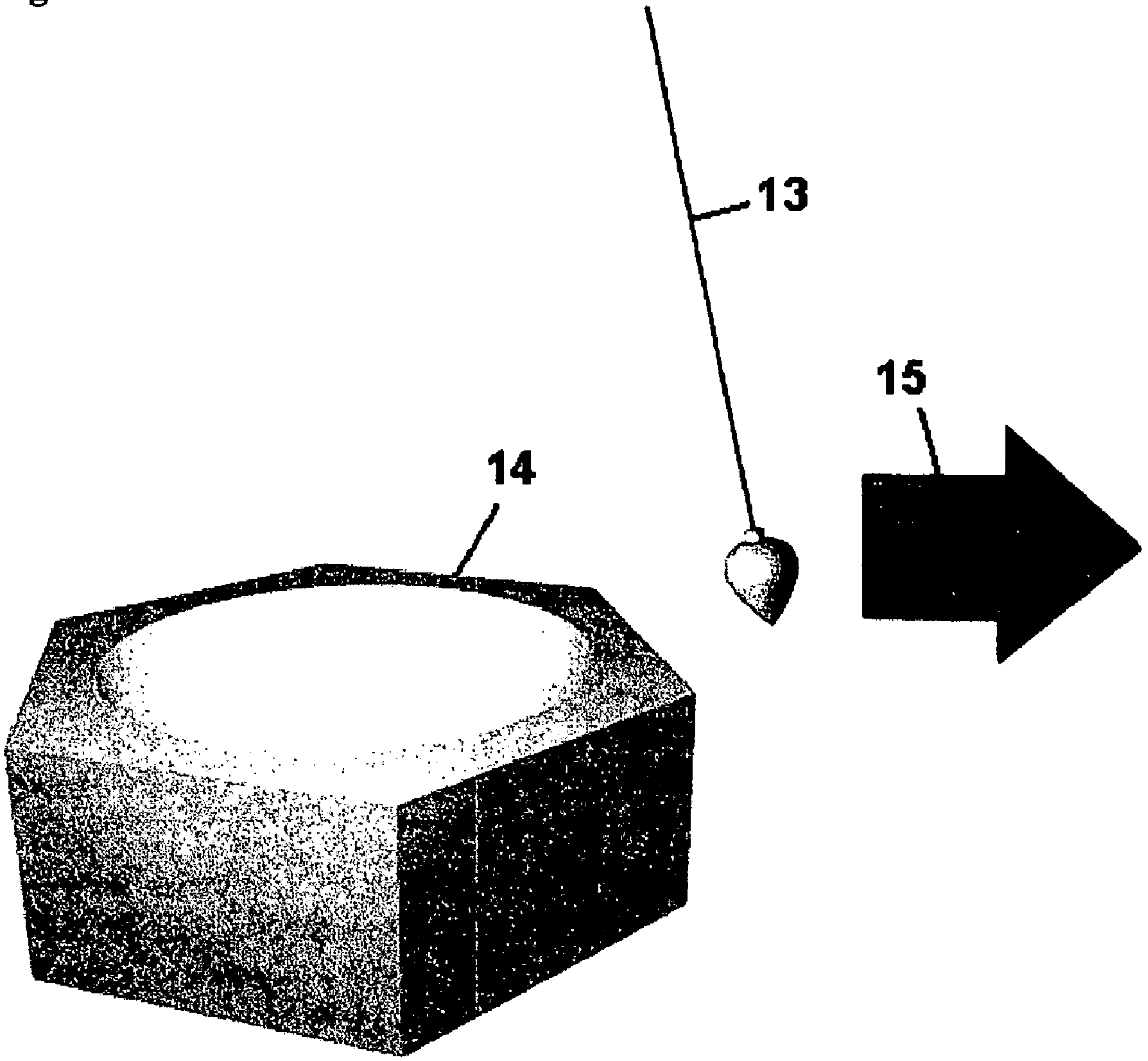

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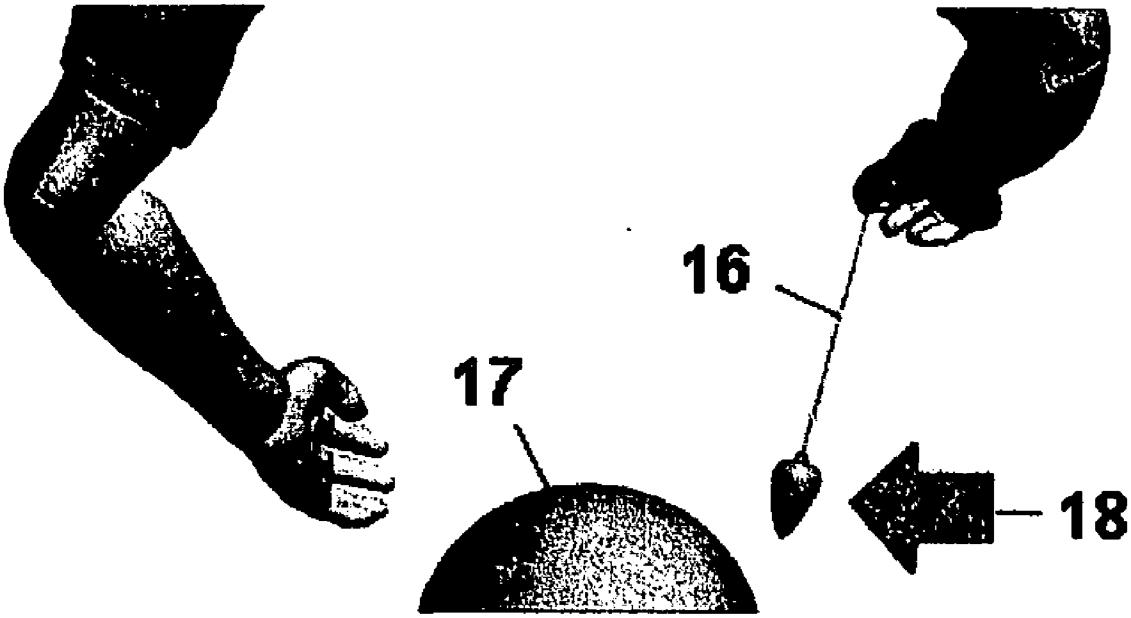

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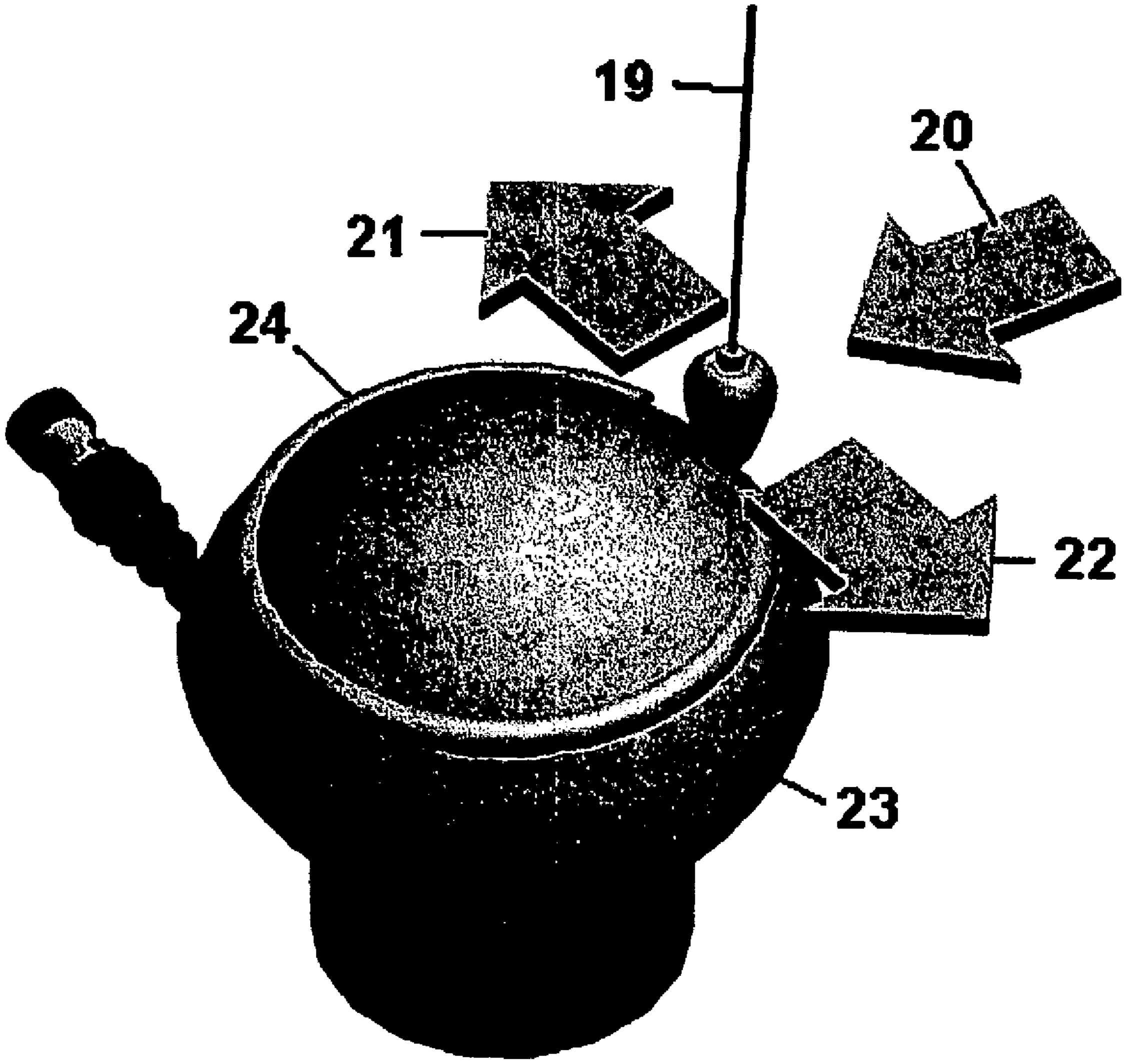
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Figure 6

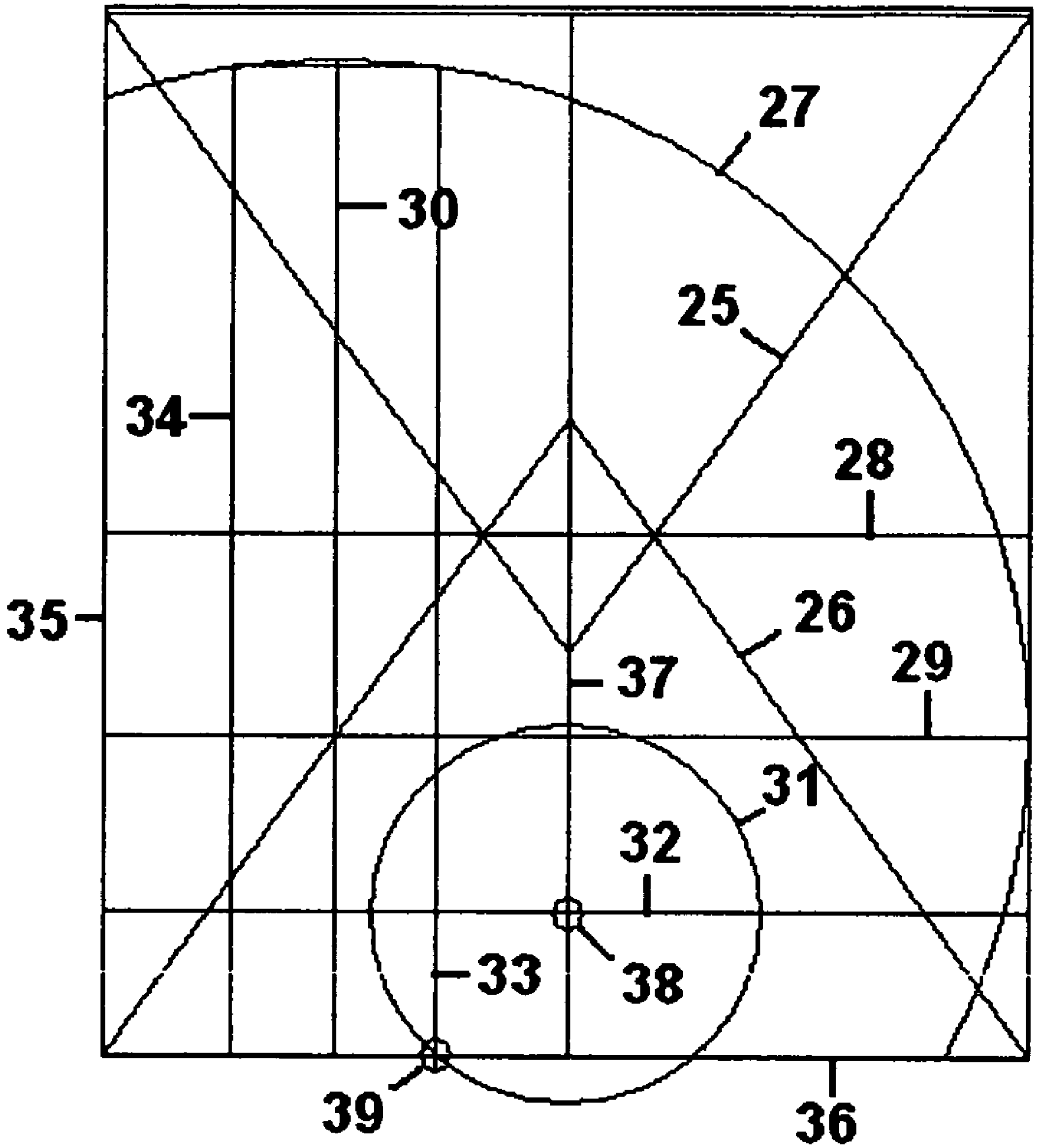
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Figure 7

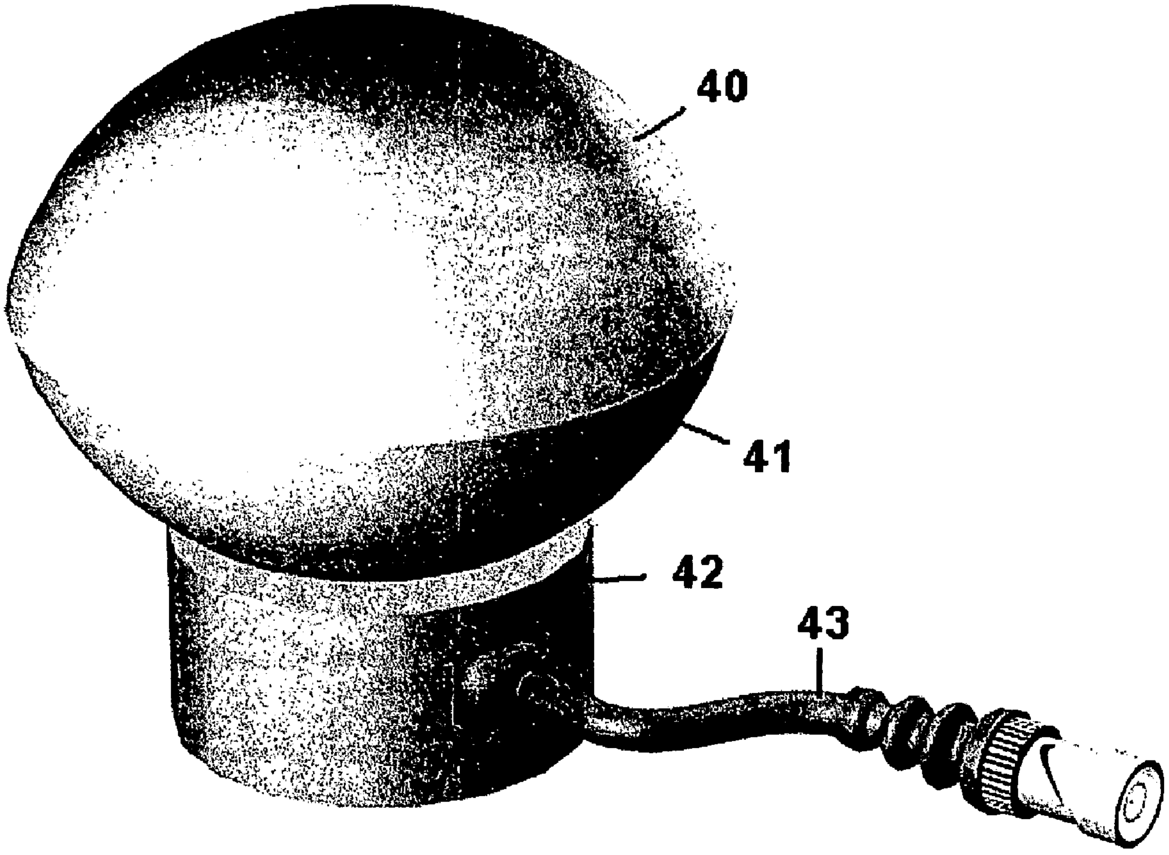

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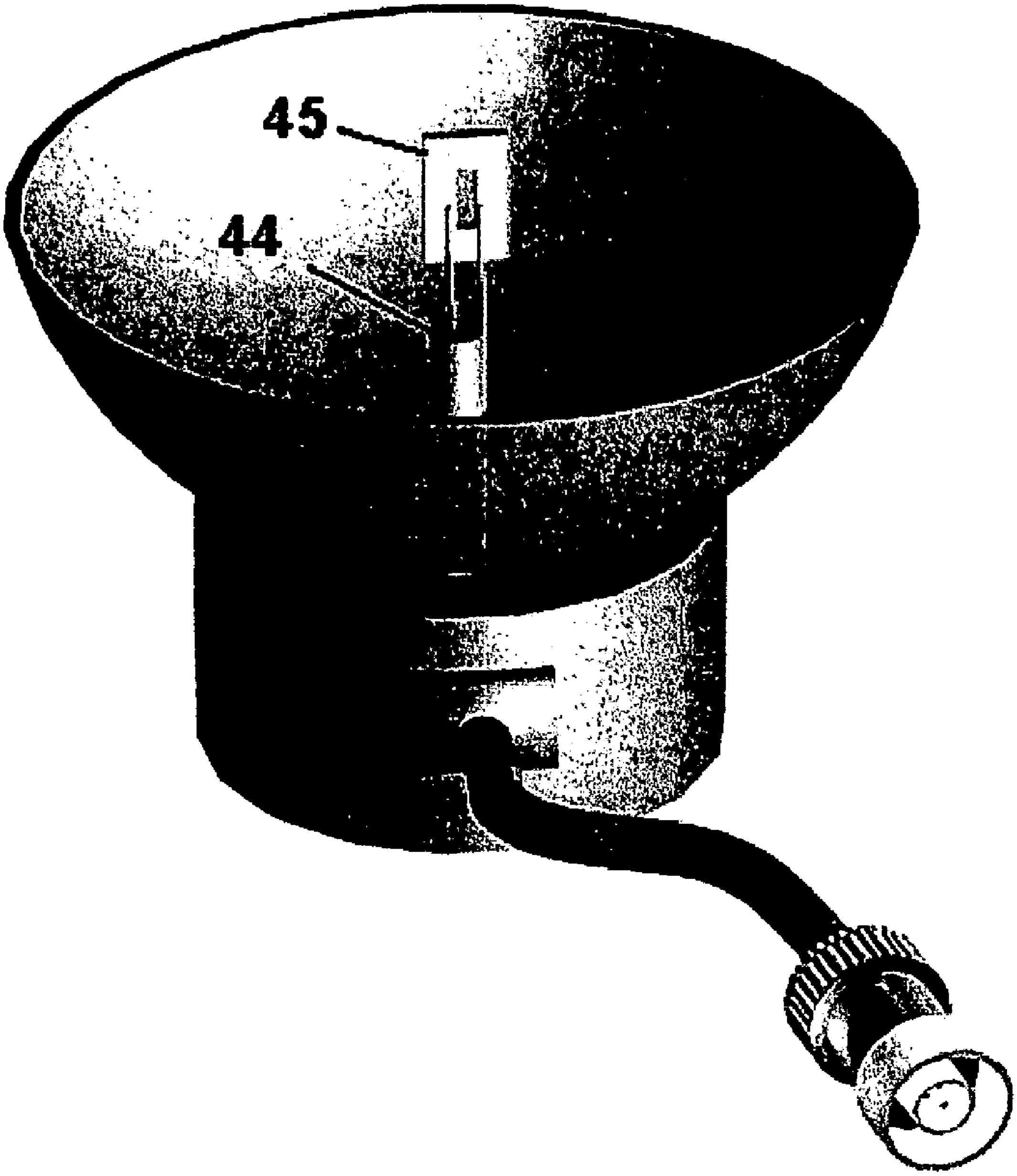

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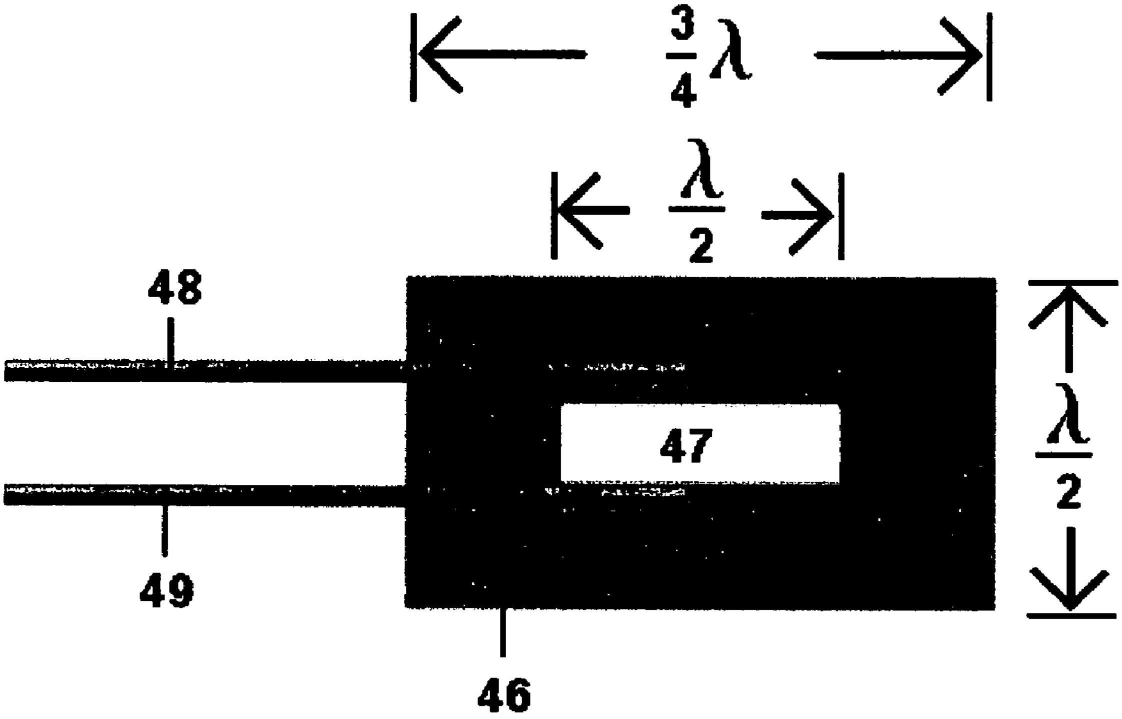
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Figure 10

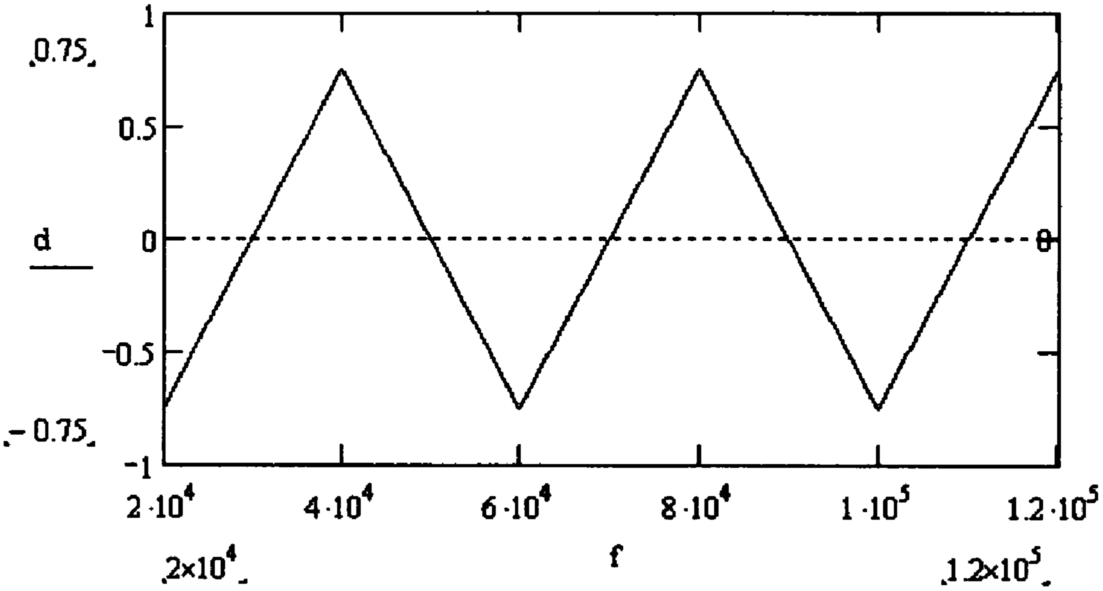
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Figure 11

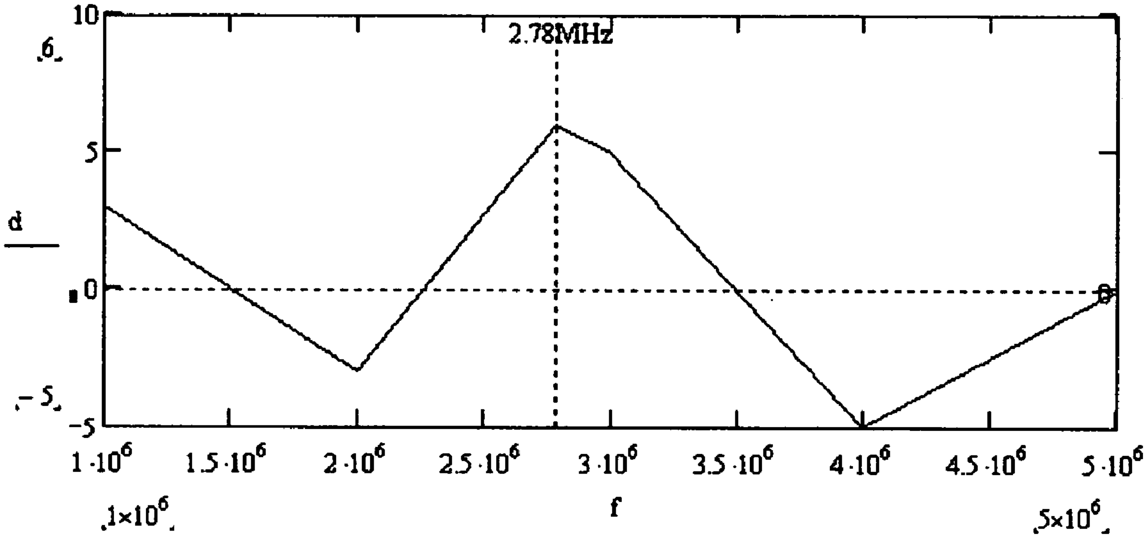
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Figure 12

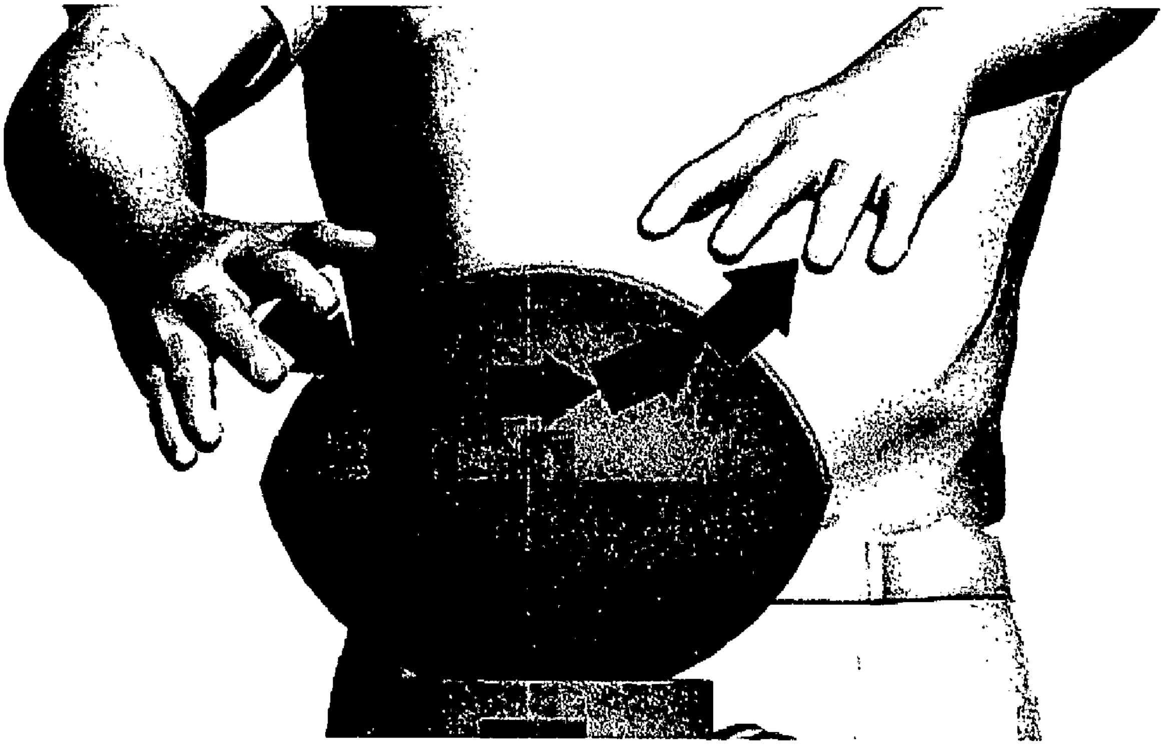

CHI ENERGY AMPLIFIER

BRIEF SUMMARY OF THE INVENTION

[0001] This invention is an energy amplifier that controls the direction of the second co-gravitational K field by means of a slot antenna located in a resonating sphere. The hyperspace mass flow rate entering into this dimension is determined by the frequency of the antenna. This energy flow is used to increase the energy of the human energy field known as Chi.

BACKGROUND OF THE INVENTION

[0002] Referring to FIG. **1**, a pendulum suspended by a string (**3**) is held by the string with the right hand (**1**) over the upright palm of the left hand (**2**). The pendulum swings in circles shown by the clockwise direction of the arrow (**4**). The pendulum swings at a constant frequency at about 1 to 2 Hz. What this means is that there is a second gravitational K field (**5**) that can cause a mass to rotate in circles.

[0003] Everyone is familiar with the linear gravitational g field which is defined as Newton's gravitational constant G times the mass of the earth divided by the square of the radius of the earth. This is the field that causes objects to accelerate radially toward the earth's surface. Newton's gravitational constant G is equal to the speed of light c squared divided by the linear mass Ω of the universe. The speed of light is

$$c = 299792458\,\frac{\text{meters}}{\text{second}}$$

$$\Omega = 1.346812891\cdot 10^{27}\,\frac{\text{kilograms}}{\text{meter}}$$

$$G = \frac{c^2}{\Omega} = 6.673200002\cdot 10^{-11}\,\frac{meter^3}{second^2\,\text{kilogram}}$$

The mass and radius of the earth are

[0004]

$$ME = 5.977\cdot 10^{24}\ \text{kilograms}$$

$$RE = 6371.03\,10^3\ \text{meters}$$

$$g = G\frac{ME}{RE^2} = 9.82\,\frac{\text{meters}}{second^2}$$

[0005] From electromagnetism, the electric E field is linear and the B magnetic field is circular or forms closed loops. The electric field starts and ends on electric charges. Since there are two electromagnetic fields, it makes sense that there are also two gravitational fields. A flow of electric current through a straight wire causes a circular magnetic B field to form around the wire. In a similar manner, a flow of mass through a channel causes a circular gravitational K field to form around the channel.

[0006] Referring to FIG. **2**, the right hand rule (**6**) shows that if the flow is along the direction of the thumb of the right hand, then the field curls around in the direction of the fingers. If an electric current is flowing through the wire (**7**) in the direction of arrow (**8**), then a counter-clockwise magnetic field circles the wire shown by arrow (**9**). In the bottom view, a mass flowing through a channel (**10**) in direction (**11**) generates a counter-clockwise gravitational K field shown by arrow (**12**). This field is the reason that the pendulum swings in circles. The gravitational K field only exists if there is a mass flow. In the wire there is also an electric field driving the electrons, so it must be that there is a g gravitational field driving the mass along the channel.

[0007] The correspondence between electromagnetic and gravitational constants must be the following:

Electric	Gravitational
Charge q	Mass m
Electric Field E	Gravitational Field g
Magnetic Field B	Co-gravitational Field K
Linear Electric Charge λ	Linear Mass Ω
Permittivity of Space ϵ_0	$-1/4\pi G$
Permeability of Space μ_0	$-4\pi G/c^2$
Convection Current Density J	Mass Current Density J

[0008] Maxwell's equation for the curl or circulation of B involves the current density J and an electric field E changing with time t

$$\nabla\times B = \mu_0 J + \frac{1}{c^2}\frac{\partial E}{\partial t}$$

The corresponding gravitational equation is therefore

[0009]

$$\nabla\times K = -\frac{4\pi G}{c^2}J + \frac{1}{c^2}\frac{\partial g}{\partial t}$$

[0010] If the g field is constant with time, then the circulation of the K field only depends on the mass density flow through the channel. Notice the minus sign in front of the first term which says that if energy is entering our dimension through a channel, then the K field is in the counterclockwise direction as indicated by the pendulum. As seen in FIG. **1**, the energy is leaving through the left hand because the rotation is clockwise. On the right hand, the pendulum rotates in the counterclockwise direction indicating that energy is coming from the hand. Thus there is a flow of energy between the hands known as the Chi energy. The purpose of this invention is to amplify this energy.

[0011] The g gravitational field is due to a negative space-time curvature created by the mass of the earth. In many physics books this is depicted as a bowl. So the idea was to acquire a ceramic kiln which could produce ceramic bowls using earthenware clay and a bowl mold. The curvature created by the bowl, if any, could be detected by the pendulum.

[0012] Referring to FIG. **3**, a pendulum (**13**) held in the right hand with the left hand near the side of the concave mold (**14**) starts to swing toward the right, away from the plaster mold as shown by arrow (**15**).

[0013] Referring to FIG. **4**, a pendulum (**16**) held in the right hand over a positive curvature dome (**17**) swings toward the top of the dome as shown by arrow (**18**).

Supposedly the K gravitational field rotates in circles, but these experiments showed that the pendulum movement was radial.

[0014] Referring to FIG. **5**, the pendulum (**19**) swings radially (**20**) toward the top of the dome (**23**) because the forces (**24**) around the dome counteract each other as shown by arrows (**21**, **22**). Thus there is no sideways pressure on the pendulum.

[0015] The next question was what is the value of the co-gravitational K constant? In electromagnetism the electric field is the speed of light times the magnetic field. So the g gravitational field should be the speed of light times the co-gravitational K field.

$$\begin{aligned} K &= \frac{g}{c} \\ &= \frac{1}{c}G\frac{MU}{RU^2} \\ &= \frac{1}{c}\frac{c^2}{\Omega}\frac{MU}{\frac{MU}{\Omega}RU} \\ &= \frac{c}{RU} \end{aligned}$$

$$\ln(K) = -40.34861143$$

[0016] where the radius RU of the universe is 10^{26} meters and c is the speed of light. The speed of light divided by the radius is angular frequency measured in Hz. Recall that the pendulum over the hand has a frequency f of 1 Hz which makes the angular frequency o equal to 2π radians per second since ω=2πf So the question is whether or not this value of K means anything in terms of hyperspace physics?

[0017] The universe has a geometrical sub-manifold based on the tetrahedron. All the physics constants of the universe are determined by this tetrahedral geometry. As shown in diagram tet0565 stored in the Library of Congress, the electron and proton are one and the same particle. There is a continuous clockwise path from the electron wavelength, through electric charge to electron mass and returning out-of-dimension back along a counterclockwise path as the proton. Because the paths are in opposite directions, the proton has a positive charge and the electron has the opposite negative charge. Because this path crosses into our dimension from hyperspace, we see two different particles. Thus Nature only has one particle. The tetrahedron diagram also shows that our dimension is offset from the origin of the diagram by the Cabibbo angle which is found in particle physics. Our dimension is determined by the Planck mass and the Planck wavelength which are the bottom limits of our dimension, known as the Planck box. If the proton mass is centered on the Planck mass, a tangent line to the circle can only be made by using the down quark and up quark which comprise the proton (duu). And the tangent line is drawn at the Cabibbo angle. So the diagram verifies some important experimental physics data.

[0018] Referring to FIG. **6**, the tetrahedron diagram is drawn with a vertical axis (**35**) corresponding to the natural logarithm of mass. The horizontal axis (**36**) is the natural logarithm of wavelength. The inverted tetrahedrons (**25**, **26**) cross at the centerline (**28**) which is known through remote viewing as "the merging of two worlds." The centerline is the separation point between space and hyperspace. The circumscribing sphere (**27**) has a horizontal diameter (**29**) and a vertical diameter (**30**). The electron wavelength (**34**) reflects off the sphere and returns as the electron mass (**33**).

[0019] Because the K co-gravitational field is related to circular or spinning motion, as well as vorticity per area, it might be imagined that it has something to do with the spinning electron. The energy E of the electron is equal to the mass m_e of the electron times the speed of light c squared.

$$\begin{aligned} m_e &= 9.1093897\cdot 10^{-31}\ \text{kilogram} \\ c &= 299792458\cdot\frac{\text{meter}}{\text{second}} \\ E &= m_e c^2 \\ \ln(E) &= -30.13363019 \end{aligned}$$

[0020] The tips of the inverted tetrahedrons pass through the base constant, vertical line (**37**), which is equal to Planck's constant h divided by the speed of light.

$$h = 2.210260685\cdot 10^{-42}\ \text{kilogram meter}$$

$$\text{base} = \ln\left(\frac{h}{c}\right) = -95.91546344$$

[0021] On the tetrahedron diagram, the co-gravitational circle K (**31**) is centered on the base (**37**) at the electron energy (**32**) shown by the small π circle at the intersection (**38**). As can be seen, the K circle determines the electron mass (**33**) at the horizontal axis (**36**) as shown by intersection (**39**). Because the electron is the proton, it also sets the constants of the proton such as wavelength, charge and mass. Thus the K co-gravitational field determines our elementary particles. Because these particle paths go in and out of dimension, it means that hyperspace exists. And because the K field is circular, depending on the direction of the energy flow, another purpose of this invention is to control the direction of the field.

SUMMARY OF THE INVENTION

[0022] Referring to FIG. **7**, the Chi energy amplifier consists of two ceramic domes (**40**, **41**) resting one on the other such as to form a hollow internal clam-like structure. The domes are mounted on a cylindrical ceramic base (**42**) containing a reinforced passageway for the coaxial cable and BNC connector (**43**). The BNC connector plugs into the frequency generator (not shown) which has a frequency range of 0.4 Hz to 5 MHz.

[0023] Referring to FIG. **8** with the upper dome removed, the coaxial cable (**44**) extends vertically through the base into the lower dome. The cable is soldered to a slot antenna (**45**). The center conductor of the cable is soldered to the left side of the slot and the ground shielding is soldered to the right side of the slot. Thus there is a voltage difference on the two sides which produces an oscillating electric field across the slot which radiates electromagnetic energy into the hollow dome.

[0024] A close-up of the slot antenna is shown in FIG. **9**. The antenna is a 0.050" thick copper sheet (**46**) with a width of ¾ wavelength by a height of ½ wavelength. A slot (**47**) of ½ wavelength is electric-discharge machined into the copper sheet (**47**). The center conductor (**48**) from the coaxial cable is soldered to the top of the slot. The ground wire (**49**) is soldered to the bottom of the slot. This configuration produces a voltage difference between the inner top and bottom surfaces of the slot. The frequency generator produces an oscillating voltage across the slot which generates an electric field that radiates from the antenna into the ceramic cavity.

[0025] The wavelength of the antenna and the dimensions of the ceramic cavity have to be tuned to the geometry of our dimension. Newton's gravitational constant G is equal to

$$\ln(G) = -23.4303342$$

$$f = e^{23.4303432} * \mathrm{Hz} = 15\ Ghz$$

$$\lambda = \frac{c}{f} = .020\text{ meter} = .787\text{ inch}$$

$$\text{slotwidth} = \frac{\lambda}{2} = .393\text{ inch}$$

$$\text{antennawidth} = \frac{3}{4}\lambda = .590\text{ inch}$$

The frequency of the antenna is the inverse of the gravitational constant. The reason for this is that when a circle of radius natural logarithm G is centered on the proton on the tetrahedron diagram, the circle intersects the corner of the Planck box which bounds our dimension between space and hyperspace. It is the low-density hyperspace energy that the amplifier will bring into this dimension.

[0026] The size of the ceramic cavity based on the angular frequency $\omega = 2\pi f$ is

$$\frac{\frac{\omega^2}{c^2} + \frac{1}{ab}}{\frac{\omega^2}{c^2} + ab\left(\frac{\omega^2}{c^2} - \frac{1}{a^2}\right)\left(\frac{\omega^2}{c^2} - \frac{1}{b^2}\right)} = \frac{\tan\left(\frac{\omega}{c}(b-a)\right)}{\omega}\frac{c}{b-a}$$

where b is inside radius of the cavity, a is the radius of an object at the center of the cavity and c is the speed of light. Using the object radius as a=0.020 meter to account for the antenna, the inside radius of the cavity is b=4.25 inches which is the size of the 8.5 inch diameter ceramic dome using ¼ inch thick clay. The frequency is then equal to

$$f = \ln\left(\frac{\omega}{2\pi}\right) = 23.45$$

which is close to the inverse of the gravitational constant G of −23.43. Thus the amplifier is tuned to the gravitational constant of the universe both in size of the cavity and the frequency of the slot antenna. Using a SMD surface mount capacitor and inductor in the picofarad and nanohenry range, it is possible to get up to this high frequency, but it was found that it was not necessary because the amplifier works at lower frequencies that are pulsed.

[0027] Referring to FIG. **10**, the swinging movement of the pendulum measured in inches at the side of the dome is plotted against a range of frequencies from 20 kHz to 120 kHz. At 20 kHz, the pendulum swings ¾ inch away from the dome. Then at 40 kHz, the pendulum swings ¾ inch toward the dome. This pattern is repeated until 120 kHz. What this means is that the amplifier can control the direction of the co-gravitational field using frequency. The tetrahedron diagram shows that this phenomenon is related to the two axes of the circumscribing sphere of the tetrahedron.

[0028] Referring to FIG. **11**, the swinging of the pendulum is plotted for a range of frequencies from 1 MHz to 5 MHz. At a frequency of 2.78 MHz the pendulum was swinging strongly from the vertical to the horizontal, a distance of six inches. On the tetrahedron diagram, the distance from our base constant to the centerline between inverted tetrahedrons is equal to 14.838168. This corresponds to a frequency of

$$f = e^{14.838168} * \mathrm{Hz} = 2.780574169\ \mathrm{MHz}$$

which is close to the experimental value.

[0029] Referring to FIG. **12**, the Chi energy flowing between the hands, shown by the arrows, is amplified by placing the hands across the dome. This energy from the right hand mixes with the hyperspace energy entering the dome from hyperspace. The combined energy is then absorbed in the left hand vortex. The effects of this amplified energy are simply amazing and have to be experienced to appreciate what it means.

A BRIEF DESCRIPTION OF THE DRAWINGS

[0030] FIG. **1**. Perspective view of pendulum movement over left hand vortex.

[0031] FIG. **2**. Perspective view of right hand rule of physics showing similarity between electromagnetism and gravity.

[0032] FIG. **3**. Perspective view of plaster mold cavity showing negative curvature.

[0033] FIG. **4**. Perspective view of dome showing positive curvature.

[0034] FIG. **5**. Perspective view of dome showing radial pendulum movement.

[0035] FIG. **6**. Graph of co-gravitational K field on tetrahedron diagram.

[0036] FIG. **7**. Perspective view of Chi Energy Amplifier with BNC coaxial cable.

[0037] FIG. **8**. Perspective view of slot antenna in dome.

[0038] FIG. **9**. Perspective view of slot antenna showing dimensions.

[0039] FIG. **10**. Graph of pendulum movement versus frequency of antenna, 20 KHz.

[0040] FIG. **11**. Graph of pendulum movement versus frequency from 1 MHz to 5 MHz.

[0041] FIG. **12**. Perspective view of amplifying Chi energy.

DETAILED DESCRIPTION OF THE INVENTION

[0042] The dome of the amplifier is made of red earthenware clay from Minnesota having a cone 06 kiln firing temperature of 1828° F. over a period of 7.5 hours. The clay is placed between two hardwood ¼ inch thick slats. It is then rolled flat with a rolling pin. The sheet of clay is cut in half and one half is placed in a 9-inch diameter bowl mold using a soft sponge to push it into position. The second half is then added to the first with the seam between worked flat with a metal kidney and elephant ear sponge. The top of the mold is scrapped flat to create the bowl shape. The moist clay is left to dry for one day after which it falls out of the mold due to shrinkage. After completely drying, the dome is then placed in a kiln which runs the computer-controlled cone 06 temperature firing profile. A preheat at 180° F. for one hour is required to make sure the dome is completely bone dry. It takes 7 to 8 hours to fire the dome with another 12 hours to cool down naturally.

[0043] The base is also made of ¼ inch clay. A circular shape is cut out and fitted with a ribbon of extruded clay from a clay gun to make the cylindrical wall. Using a hole cutter made of hollow tubing, a hole is made in the side of the base for the coaxial cable. The second lower dome has a hole cut in the bottom when the clay is leather hard.

[0044] A 0.050" thick copper sheet is EDM machined to cut a half wavelength slot in the copper. The inner conductor of the coaxial cable is soldered using silver epoxy to the one side of the slot. The ground shielding of the cable is silver epoxied to the other side of the slot. The other end of the coaxial cable has a BNC connector which plugs into the frequency generator.

[0045] The pendulum is made out of soft brass rod and machined on a lathe into a plumb bob shape. A hole is drilled in the stem to hold the 6" long string.

I claim:

1. A Chi energy amplifier comprising:

a. a hollow ceramic dome in the shape of a clam shell with a hole in the lower half that provides access to a coaxial cable;

b. a cylindrical ceramic base on which the dome is mounted with holes that provide access for a coaxial cable into item (a);

c. a slot antenna soldered to the coaxial cable, located midway inside item (a), such that the inner conductor of the cable is soldered to one side of the slot and the ground shielding is soldered to the other side of the slot;

d. a frequency generator connected to the other end of the coaxial cable by means of a BNC connector for the purpose of providing an oscillating voltage to item (c);

e. an electromagnetic wave generated by items (c, d) that resonates inside item (a);

f. a co-gravitational K field generated by items (a, b, c, d, e) whose direction can be controlled by the frequency of item (d); and

g. a flow of hyperspace energy into or out of the dome due to item (f).

* * * * *

455-619 AU 233 EX
FIP8106 OR 685,958

55

No. 685,958. **Patented Nov. 5, 1901.**

N. TESLA.

METHOD OF UTILIZING RADIANT ENERGY.

(Application filed Mar. 21, 1901.)

(No Model.)

Electric steping motor
energized by corpuscular
energy from sun

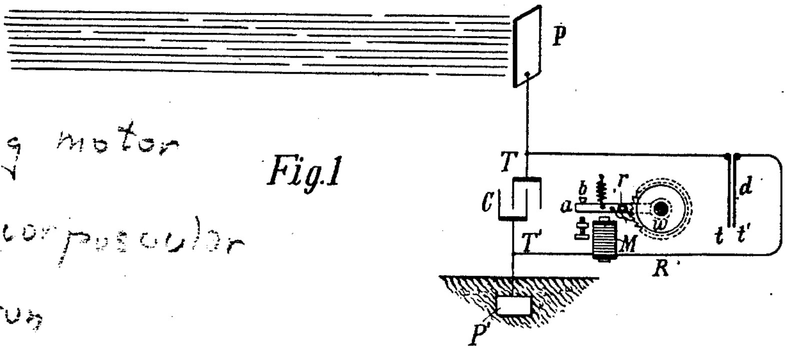

Fig.1

No refs.

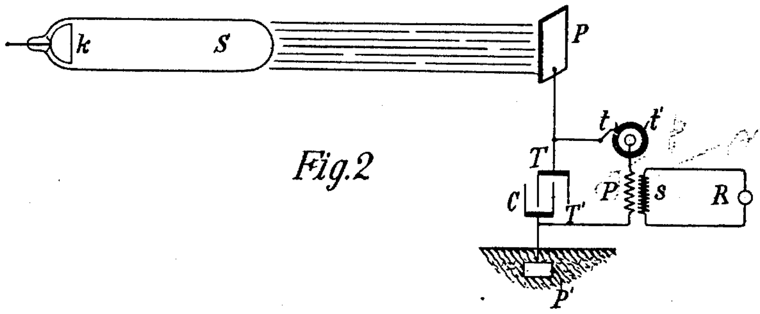

Fig.2

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Nikola Tesla, Inventor
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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF UTILIZING RADIANT ENERGY.

SPECIFICATION forming part of Letters Patent No. 685,958, dated November 5, 1901.

Application filed March 21, 1901. Serial No. 52,154. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Methods of Utilizing Radiant Energy, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

It is well known that certain radiations—such as those of ultra-violet light, cathodic, Roentgen rays, or the like—possess the property of charging and discharging conductors of electricity, the discharge being particularly noticeable when the conductor upon which the rays impinge is negatively electrified. These radiations are generally considered to be ether vibrations of extremely small wave lengths, and in explanation of the phenomena noted it has been assumed by some authorities that they ionize or render conducting the atmosphere through which they are propagated. My own experiments and observations, however, lead me to conclusions more in accord with the theory heretofore advanced by me that sources of such radiant energy throw off with great velocity minute particles of matter which are strongly electrified, and therefore capable of charging an electrical conductor, or even if not so may at any rate discharge an electrified conductor either by carrying off bodily its charge or otherwise.

My present application is based upon a discovery which I have made that when rays or radiations of the above kind are permitted to fall upon an insulated conducting body connected to one of the terminals of a condenser, while the other terminal of the same is made by independent means to receive or to carry away electricity, a current flows into the condenser so long as the insulated body is exposed to the rays, and under the conditions hereinafter specified an indefinite accumulation of electrical energy in the condenser takes place. This energy after a suitable time interval, during which the rays are allowed to act, may manifest itself in a powerful discharge, which may be utilized for the operation or control of mechanical or electrical devices or rendered useful in many other ways.

In applying my discovery I provide a condenser, preferably of considerable electrostatic capacity, and connect one of its terminals to an insulated metal plate or other conducting body exposed to the rays or streams of radiant matter. It is very important, particularly in view of the fact that electrical energy is generally supplied at a very slow rate to the condenser, to construct the same with the greatest care. I use by preference the best quality of mica as dielectric, taking every possible precaution in insulating the armatures, so that the instrument may withstand great electrical pressures without leaking and may leave no perceptible electrification when discharging instantaneously. In practice I have found that the best results are obtained with condensers treated in the manner described in a patent granted to me February 23, 1897, No. 577,671. Obviously the above precautions should be the more rigorously observed the slower the rate of charging and the smaller the time interval during which the energy is allowed to accumulate in the condenser. The insulated plate or conducting body should present as large a surface as practicable to the rays or streams of matter, I having ascertained that the amount of energy conveyed to it per unit of time is under otherwise identical conditions proportionate to the area exposed, or nearly so. Furthermore, the surface should be clean and preferably highly polished or amalgamated. The second terminal or armature of the condenser may be connected to one of the poles of a battery or other source of electricity or to any conducting body or object whatever of such properties or so conditioned that by its means electricity of the required sign will be supplied to the terminal. A simple way of supplying positive or negative electricity to the terminal is to connect the same either to an insulated conductor, supported at some height in the atmosphere, or to a grounded conductor, the former, as is well known, furnishing positive and the latter negative electricity. As the rays or supposed streams of matter generally convey a positive charge to the first condenser-terminal, which is connect-

RADIANT ENERGY.

EXAMINER

ed to the plate or conductor above mentioned, I usually connect the second terminal of the condenser to the ground, this being the most convenient way of obtaining negative electricity, dispensing with the necessity of providing an artificial source. In order to utilize for any useful purpose the energy accumulated in the condenser, I furthermore connect to the terminals of the same a circuit including an instrument or apparatus which it is desired to operate and another instrument or device for alternately closing and opening the circuit. This latter may be any form of circuit-controller, with fixed or movable parts or electrodes, which may be actuated either by the stored energy or by independent means.

The rays or radiations which are to be utilized for the operation of the apparatus above described in general terms may be derived from a natural source, as the sun, or may be artificially produced by such means, for example, as an arc-lamp, a Roentgen tube, and the like, and they may be employed for a great variety of useful purposes.

My discovery will be more fully understood from the following detailed description and annexed drawings, to which reference is now made, and in which—

Figure 1 is a diagram showing typical forms of the devices or elements as arranged and connected in applying the method for the operation of a mechanical contrivance or instrument solely by the energy stored; and Fig. 2 is a diagrammatical representation of a modified arrangement suitable for special purposes, with a circuit-controller actuated by independent means.

Referring to Fig. 1, C is the condenser, P the insulated plate or conducting body, which is exposed to the rays, and P′ another plate or conductor, all being joined in series, as shown. The terminals T T′ of the condenser are also connected to a circuit including a receiver R, which is to be operated, and a circuit-controlling device *d*, which in this case is composed of two very thin conducting-plates *t t′*, placed in close proximity and very mobile, either by reason of extreme flexibility or owing to the charater of their support. To improve their action, they should be inclosed in a receptacle from which the air may be exhausted. The receiver R is shown as consisting of an electromagnet M, a movable armature *a*, a retractile spring *b*, and a ratchet-wheel *w*, provided with a spring-pawl *r*, which is pivoted to armature *a*, as illustrated. The apparatus being arranged as shown, it will be found that when the radiations of the sun or of any other source capable of producing the effects before described fall upon the plate P an accumulation of electrical energy in the condenser C will result. This phenomenon, I believe, is best explained as follows: The sun as well as other sources of radiant energy throw off minute particles of matter positively electrified, which, impinging upon the plate P, communicate an electrical charge to the same. The opposite terminal of the condenser being connected to the ground, which may be considered as a vast reservoir of negative electricity, a feeble current flows continuously into the condenser, and inasmuch as these supposed particles are of an inconceivably small radius or curvature, and consequently charged to a relatively very high potential, this charging of the condenser may continue, as I have found in practice, almost indefinitely, even to the point of rupturing the dielectric. Obviously whatever circuit-controller be employed it should operate to close the circuit in which it is included when the potential in the condenser has reached the desired magnitude. Thus in Fig. ② when the electrical pressure at the terminals T T′ rises to a certain predetermined value the plates *t t′*, attracting each other, close the circuit connected to the terminals. This permits a flow of current which energizes the magnet M, causing it to draw down the armature *a* and impart a partial rotation to the ratchet-wheel *w*. As the current ceases the armature is retracted by the spring *b* without, however, moving the wheel *w*. With the stoppage of the current the plates *t t′* cease to be attracted and separate, thus restoring the circuit to its original condition.

Many useful applications of this method of utilizing the radiations emanating from the sun or other source and many ways of carrying out the same will at once suggest themselves from the above description. By way of illustration a modified arrangement is shown in Fig. 2, in which the source S of radiant energy is a special form of Roentgen tube devised by me having but one terminal *k*, generally of aluminium, in the form of half a sphere with a plain polished surface on the front side, from which the streams are thrown off. It may be excited by attaching it to one of the terminals of any generator of sufficiently-high electromotive force; but whatever apparatus be used it is important that the tube be exhausted to a high degree, as otherwise it might prove entirely ineffective. The working or discharge circuit connected to the terminals T T′ of the condenser includes in this case the primary *p* of a transformer and a circuit-controller comprising a fixed terminal or brush *t* and a movable terminal *t′* in the shape of a wheel with conducting and insulating segments which may be rotated at an arbitrary speed by any suitable means. In inductive relation to the primary wire or coil *p* is a secondary *s*, usually of a much greater number of turns, to the ends of which is connected a receiver R. The terminals of the condenser being connected as indicated, one to an insulated plate P and the other to a grounded plate P′, when the tube S is excited rays or streams of matter are emitted from the same, which convey a positive charge to the plate P and condenser-terminal T, while terminal T′ is continuously receiving negative electricity from the plate

P′. This, as before explained, results in an accumulation of electrical energy in the condenser, which goes on as long as the circuit including the primary p is interrupted. Whenever the circuit is closed, owing to the rotation of the terminal t', the stored energy is discharged through the primary p, this giving rise in the secondary s to induced currents which operate the receiver R.

It is clear from what has been stated above that if the terminal T′ is connected to a plate supplying positive instead of negative electricity the rays should convey negative electricity to plate P. The source S may be any form of Roentgen or Lenard tube; but it is obvious from the theory of action that in order to be very effective the electrical impulses exciting it should be wholly or at least preponderatingly of one sign. If ordinary symmetrical alternating currents are employed, provision should be made for allowing the rays to fall upon the plate P only during those periods when they are productive of the desired result. Evidently if the radiations of the source be stopped or intercepted or their intensity varied in any manner, as by periodically interrupting or rythmically varying the current exciting the source, there will be corresponding changes in the action upon the receiver R, and thus signals may be transmitted and many other useful effects produced. Furthermore, it will be understood that any form of circuit-closer which will respond to or be set in operation when a predetermined amount of energy is stored in the condenser may be used in lieu of the device specifically described with reference to Fig. 1, and also that the special details of construction and arrangement of the several parts of the apparatus may be very greatly varied without departure from the invention.

Having described my invention, what I claim is—

1. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations, and the other armature by independent means, and discharging the condenser through a suitable receiver, as set forth.

2. The method of utilizing radiant energy, which consists in simultaneously charging a condenser by means of rays or radiations and an independent source of electrical energy, and discharging the condenser through a suitable receiver, as set forth.

3. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations, and the other by independent means, controlling the action or effect of said rays or radiations and discharging the condenser through a suitable receiver, as set forth.

4. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations and the other by independent means, varying the intensity of the said rays or radiations and periodically discharging the condenser through a suitable receiver, as set forth.

5. The method of utilizing radiant energy, which consists in directing upon an elevated conductor, connected to one of the armatures of a condenser, rays or radiations capable of positively electrifying the same, carrying off electricity from the other armature by connecting the same with the ground, and discharging the accumulated energy through a suitable receiver, as set forth.

6. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations, and the other by independent means, and effecting by the automatic discharge of the accumulated energy the operation or control of a suitable receiver, as set forth.

NIKOLA TESLA.

Witnesses:
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RICHARD DONOVAN.

New Energy Technologies

Published by Faraday Laboratories Ltd. Issue #3 (6) 2002

Research on advanced propulsion systems and new energy sources

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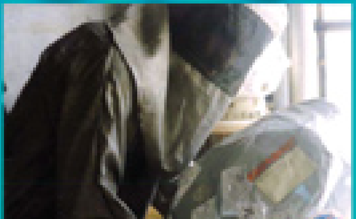

Editorial

Dr. Chernobrov and NET editor Olga Leontyeva.

The head of the Moscow research group "Kosmopoisk" Dr. Vadim A. Chernobrov (our readers certainly remember his articles on experiments with time) has recently visited the editorial office of New Energy Technologies in Saint-Petersburg, Russia. His visit was caused by discussion on the Time Machine project (investigation of active properties of time), started under agreement with Faraday Labs Ltd. Our magazine will inform readers on the topic in later issues.

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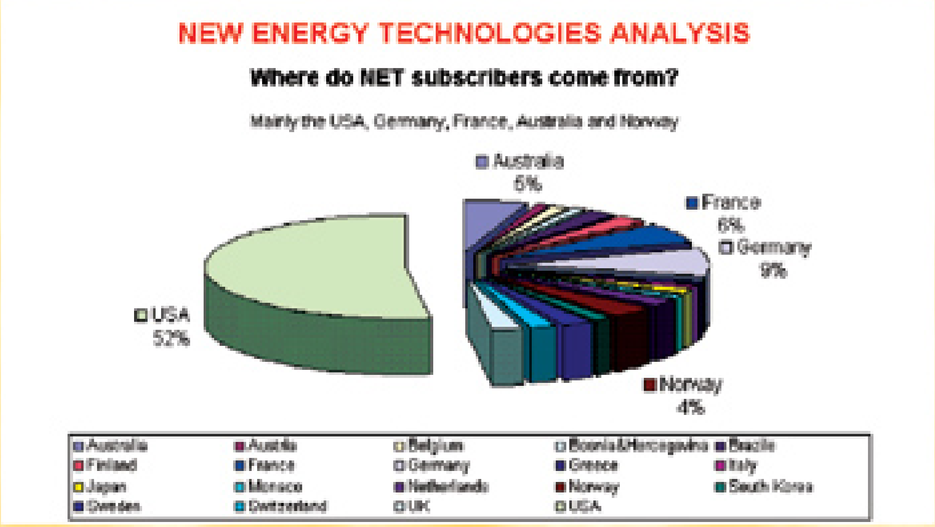

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John Christie (left) is the co-founder, CEO and chairman of Lutec (Aust.) Pty Ltd.

Ludwig (Lou) Brits (right, above) is the co-founder, managing director and head of development of Lutec (Aust.) Pty Ltd. He is Chairman and director of TTI Pty Ltd. TTI Pty Ltd is a state government recognised R.A.P. (remote area power) system provider.

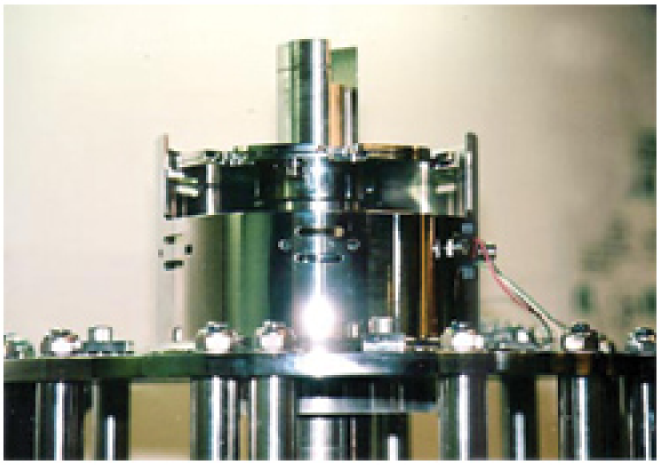

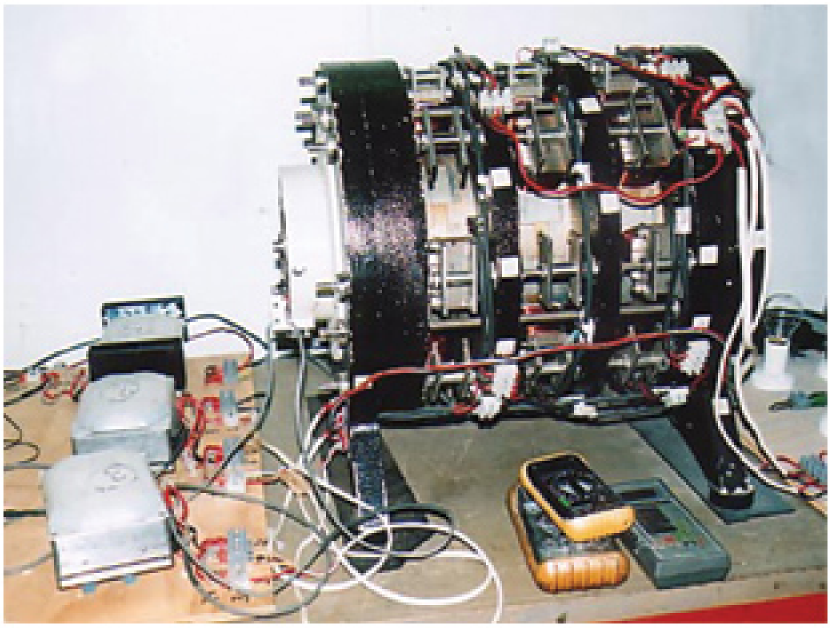

Electrogravity

by Tim Ventura
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In this issue a report by Tim Ventura, USA on experimenting with asymmetrical capacitors.
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consequence of many commonly accepted concepts and dogmas of the modern "scientific perspective of natural phenomena". This crisis situation in modern physics is a direct consequence of many conservative scientific viewpoints, unfortunately supported and protected by modern official academic science. The evolution of our consciousness has been influenced by many undoubtedly well known experts and has been evolving for a long time in the environment of specific scientific vacuum and requires immediate revival. Even methods used for dissemination of new knowledge should be improved, if one actually wishes to accelerate the progress of Humankind.

The perspective for practical applications of new previously unknown scientific phenomena and effects looks very attractive, and they may be achieved by cooperative efforts of the human intellect. New breakthrough technologies of the 21st Century will require serious changes of many commonly accepted concepts and dogmas in fundamental physics. This process of progressive development cannot be stopped.

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Large-Scale Sakharov Condition

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Abstract

Recent far reaching theoretical results have used the quantum vacuum noise as a fundamental electromagnetic radiation field to derive a frequency (ω) dependent version of Newton's gravitational coupling term, $G(\omega)$. This paper reconciles the cut-off frequency with the observed cosmological constant, and then briefly puts forward a realizable laboratory test case in the 10 - 100 MHz frequency range. One analogy is drawn between the classical vacuum energy experiments with attraction between two closely spaced plates (Casimir cavity) and the arbitrarily dense material boundaries possible in Bose condensates, such as irradiation at MHz frequencies of superfluid helium or superconductors.

Theoretical Background

Zel'dovich [1] first suggested that gravitational interactions could lead to a small disturbance in the (non zero) quantum fluctuations of the vacuum and thus give rise to a finite value of Einstein's cosmological constant in agreement with astrophysical data. Using dimensional analysis and the suggestion by Zel'dovich, Sakharov [2] derived a value for Newton's gravitational constant, G, in only one free parameter, frequency, ω:

$$G \sim c^5 \Big/ h \int \omega d\omega \sim 1 \Big/ \int \omega d\omega$$

where c is the speed of light and h is the Planck constant. The free parameter in frequency when integrated over all values from zero to high frequencies must contain the usual integration cutoff value (Planck frequency on observable electromagnetic phenomenon).

Puthoff [3] and others [4 5] have extended Sakharov's condition in a relativistically consistent model to determine constants of proportionality. His model derives an acceleration term in first order expansion (in flat space time), then equates inertial and gravitational mass (by the equivalence principle) to make contact with the gravitational constant, G, directly as:

$$G = \left(\pi c^5 / h\omega_c^2\right) \sim 1 / \int \omega d\omega$$

which is the Sakharov condition [2,3]. This paper revisits the meaning of the cutoff frequency, ω_c,for radiation interactions, of which the quantum vacuum [6-10] and

Planck frequency are only the leading terms, and for which linear combinations of forces can introduce other plausible frequencies. One purpose of this reexamination is whether the resulting gravitational coupling constant, G, can be reconciled with the anticipated energy density of the universe [11] without resorting to extreme space time curvature and thus yield enough critical density to contain the expansion of the universe. Finally we particularize the case to the high-density fluctuations possible in Bose condensates [12], a potential experimental test case for how the effects of vacuum noise might manifest observably.

One far-reaching consequence of the vacuum energy model is the attractive force of gravity becomes reducible to the radiative interaction between oscillating charges, e.g. the zero point field (ZPF) applied to subatomic charges. Mass and inertia arise from the fundamentally electromagnetic ZPF oscillations.

This random background gives the usual quantum mechanical energy spectrum from particle field effects:

$$\rho(\omega)d\omega \sim \omega^3 d\omega$$

a very important dimensional relationship, since the third power in frequency avoids anomalous Doppler shifts from velocity boosts, or stated alternatively is the correct spectra for a Lorentzian (non accelerated) invariant radiation field [13].
More specifically, the energy spectrum [3] can be written as:

$$\rho(\omega)d\omega = [\omega^2 / \pi^2 c^3][h\omega / 2]d\omega =$$
$$= h\omega^3 / 2\pi^2 c^3 d\omega \sim \omega^3 d\omega$$

which is an expression in the first parenthesis of the density of the normal modes and in the second parenthesis of the average energy per mode. When this energy density is integrated over all frequencies, the ω^3 divergence produces well known infinities in the integration limit of high frequencies, thus an assumed cutoff frequency (appropriate to experimental observation limits at the Planck frequency), is usually introduced:

$$\omega_\rho = \left(c^5 / hG\right)^{1/2}$$

For mass, m, moving in an accelerated reference frame $g = -a = Gm/r^2$, the resulting energy spectrum includes a gravitational spectral shift [3],

$$\Delta\rho'(\omega)d\omega = h\omega / 2\pi^2 c^5 [Gm / r^2]^2 d\omega \sim 1 / r^4 d\omega$$

a kind of short range ($1/r^4$) gravitational energy shift, but electromagnetic in origin when zero point fluctuations are included. (N.B. To account for equal gravitational mass effects in neutrons and protons, the ZPF oscillations must involve subatomic charges, or 'parton' effects. The assumption derives from high frequency interactions of ZPF wherein these subatomic particles are asymptotically free to oscillate as independent or free particles as quantum noise).

A further far reaching consequence [3] is mass itself becomes interpretable as a dependent quantity derived from a damped (with decay constant Γ) oscillation driven by random ZPF:

$$m = \Gamma c^3 / G = 2h\Gamma / \pi^2 c^3 \int \omega d\omega$$

with the only two free parameters, the damping factor Γ, and again the frequency, ω. The internal kinetic energy of the system contributes to the effective mass.

This leads to an overall average spectral density, written in terms of mass as:

$$\Delta\rho'(\omega) = m^2 c^5 \omega / 2h\omega_c^4 r^4$$

for the electromagnetic field distribution near ($1/r^4$) to the mass, m, which in detail is half electric and half magnetic.

One additionally attractive feature is the correspondence between this derivation and the view of gravity as a dynamical scaleinvariance breaking model (e.g. symmetry breaking near the Planck mass energy [14]). A final result includes the force calculation between two ZPF radiation oscillators of the correct form yielding Newton's average force law

$$< F > = -Gm^2 / r^2$$

Thus, for a Newtonian force to first order in a flat space time, Sakharov [2] could be credited for proposing gravity as not a fundamentally separate force and Puthoff [3] and co workers [4-5] applied the vacuum electromagnetic field to equate gravity to a long-range radiation force (e.g. van der Waals like force). Higher order oscillatory gravity modes vary as $\left(\sin[\omega_o / \omega_c]\right)^2$.

To first order, a weak G coupling constant, $G = \left(\pi c^5 / h\omega_c^2\right)$, appears for high frequency cutoff at the Planck scale. A corollary in analogy to electromagnetic shielding by ordinary matter can be rationalized as the problem of frequency mismatch at high Planck frequencies, e.g. ZPF cannot be fundamentally shielded. In other words, frequency mismatch precludes gravity shielding by matter.

The purpose here is to revisit the only free parameter, the frequency cutoff, more in the spirit of a mass resonant frequency. The motivation for this approach can be summarized as: 1) the generality of other complementary radiation effects without relying on ZPF alone (e.g. other isotropic, homogeneous radiation sources); 2) the weak coupling constant, G, yields a vastly smaller than observed size of the universe (e.g. too small cosmological constant) when the Planck frequency is used as a cutoff value; and (3) the particle mass, $m = \Gamma c^3/G$, can be viewed as a renormalized or 'dressed' mass with a resonant interaction potential that is frequency dependent in its coupling constant, G, and with 'bare' mass that is large, $m_o \sim \left(m_\rho^2 / m\right)$, where the experimentally unobservable, $m_\rho = \left(hc / G\right)^{1/2}$ is the Planck mass.

In particular, why this large 'bare' mass does not generate a large gravitational field is not a unique anomaly in the Sakharov derivation, since similarly large vacuum point energies are common to field theories. The important point is that the derivation $G(\omega)$ is general however to any isotropic radiation field with the Lorentz invariant energy spectra $\left[\rho(\omega) \sim \omega^3\right]$, thus the candidates for the cutoff frequency of the particular radiation source can be interpreted as a Planck scale only if the rest mass, m_o, is not composed of many terms, rather than just the ZPF leading term. Since the ZPF is akin to a van der Waals force [3 5], polarizability (in charge and mass) must be considered, but without also excluding any number of linear combinations that might have alternative cutoff frequencies, ω_c, or damping terms, Γ, 'ala particle physics interpretations for resonant masses during renormalization. In other words, once a gravitational energy spectrum, $\rho(\omega)$ is postulated that is Lorentzian invariant, many fundamental sizes (or corresponding frequency values) are smeared (or dressed) by any number of characteristic frequencies between zero and the high frequency electromagnetic (Planck) cutoff ω_ρ. Quite simply, is the expression, $\omega_c = \omega_\rho$, a requirement for all radiation sources?

Many types of particle oscillations may satisfy the general requirements of a Sakharov condition, each having a characteristic mass (and energy) as in calculating the mass of any fundamental particle at its resonant frequency (including underlying partial charges or dense bosons). This brings the calculation to a consideration of the high density fluctuations characteristic of a Bose condensate [15 19]. While the high density variation may intrinsically be of interest, the exploration has more to do with reconciling the ZPF interpretation of the Sakharov condition with the observed cosmological constant [14].

A "top down" view of calculating the cutoff frequency imposes the self consistency test for the cosmological constant, Λ, from the outset. To calculate, the total frequency integrated energy density of the universe must be included:

$$\rho(E) = \int \rho(E) dE = h\omega_c^4 / 8\pi^2 c^3$$

which must have a mass equivalent, contribute to the universe's curvature, and thus have a fundamental relation to the critical density to contain the expansion of the universe [14 15]. The mass - equivalent ZPF to reach the universe's critical density [15], $\rho \sim 10^{-29}$ g cm^{-3} would necessarily limit the cutoff frequency for gravity to the value, $\omega_c < 7 \cdot 10^7 s^{-1}$, or between 10 -100 MHz.

A higher frequency greatly overshoots the cosmological constant, Λ, and induces extreme curvature in the universe. This problem has been cited frequently and stated most bluntly, as either ZPF or the cosmological constant requires revision. The relevance here arises from similarly large positive coupling terms in quantum gravity [15], which also generate a local gravitational Instability for typical upper limits on the cosmological constant, $\Lambda/8\pi G < 10^{12}$ cm^{-4}.

Rather than to dwell on the inconsistencies that plague attempts to reconcile quantum gravity, we particularize the problem to a case where the restriction to Planck scale becomes less clew, namely the high density fluctuations and universal scaling introduced in a Bose condensate. A Bose condensate, such as superfluid helium or superconductors [15 19], becomes of potential interest, mainly because of its arbitrarily dense boundaries and the classic Casimir experiment [20 22] which allows such dense material boundaries (two closely spaced conducting plates), if available, to modulate the background quantum fluctuation of ZPF. In other words, the matter-ZPF interaction becomes measurable by the observed attraction between two material boundaries. What dense boundaries might generate in Bose condensates remains a subject of great interest.

The significant case to investigate is whether Casimir-like interactions [20 22] will not only couple to ZPF radiation at a scale comparable to the quantum noise (or other radiation field), but also alter the value imposed by the Sakharov condition for G. It remains an open question whether this potential coupling interaction shares, as in ordinary critical phenomenon, the density correlation function, Φ, that is both independent of the coupling strength (or universal in renormalization) and consistent with the observed average energy density of the visible universe.

Thus the purpose here has bow to restate the Sakharov condition in the gravitational coupling constant, G, based on its only free parameter, a frequency cutoff, ω_c. Any potential relevance arises from similarly large values for the positive coupling term in quantum gravity, which generate conditions for a local gravitational instability for typical upper limits on the constant, $\Lambda/8\pi G < 10^{12}$ cm^{-4}.

To restate the Sakharov condition, matter in the vacuum provides boundaries for reduced ‘Casimir like’ modes available for otherwise isotropic radiation from quantum fluctuations (broad spectral noise). That this view reproduces Einstein gravity has been examined, including the full relativistic derivation [4-5]. The details of the appropriate mass, however, remain buried in the kinetic energy of general internal particle (‘parton’) motion [3]. Any appeal to a specific parton representation is limited only by essentially free particles with high frequency interactions, including underlying partial charges or dense bosons. The basis of considering arbitrarily high-density fluctuations in Bose condensate in analogy to the ZPF-Casimir experiment remains both an empirical and theoretical case to examine. There exist laboratory scale cases [15-19] where resonant radiation in the required 10-100 MHz range appear to produce anomalous effect for such Bose condensates as superconductors, but further work to confirm these results would be needed. In other contexts, these effects have been discussed as the Schiff-Barnhill effect for superconductors interacting with a gravitational field [23], but for the static rest moss rather than an effective mass in a conduction band.

Experimental Propositions

J. Weber [24,25] proposed the use of a superconducting Bose condensate for gravity wave detection, principally because of its potentially higher signal to noise ratio in carrying electrical signals upon length dilations in a relativistic framework for gravity waves travelling near the speed of light. W. Weber and Hickman [26] derived an experimentally testable relation based on torquing of a charged capacitor parallel to a gravity field, with

$$\tau = 2E_g / \pi[\alpha / (1-\alpha)^{1/2}]$$

where the capacitor will rotate relative to the gravity vector, for $\alpha = 2GM / rc^2$, is Schwarzschild radial coordinate $[dR = dr(1-\alpha)^{1/2}]$, E_g is dependent on the capacitor charge and geometry of the plates, $E_g = [Q^2 d/2\varepsilon WL(1-\alpha)^{1/2}]$, for a plate separation, and radial dimensions,W and L, charge Q, and ε the permittivity of free space. For plate separations of 2 mm on Earth, the maximum torque is approximately $\tau = 10^{-12}$ Nm, when charged to 2/3 dielectric breakdown. While not entirely promising for detection of such low torques, the large separation (2 mm) distance between capacitative plates naturally prompts generalization to the classic Casimir force [21] experiments only recently confirmed experimentally [20]. In particular, we rewrite the torque values to include the frequency terms derived with the Sakharov condition

$$[G = (\pi c^5 / h\omega_c^2)]:$$

$$\alpha = 2M\pi c^3 / h\omega_c^2 r$$

The appeal of this formulation is that a frequency dependent torque is derived, which further makes contact with proposals to modulate the Casimir capacitative plates for continuous extraction of energy [27]. This result requires further investigation experimentally, particularly to compare with previous reports for anomalies in AC- tuned electrical capacitors [28].

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The Problem of Electron and Physical Properties of Time:
To the Electron Technologies of the 21st Century

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> ***"...it is necessary to periodically subject to the deepest revision the principles, which were recognized as final and were no longer discussed".***
> ***Louis de Broglie***

Abstract

The results of an approach based on the synthesis of standard quantum electrodynamics and of the ideas of self-organization in physical systems are briefly outlined. The quantum model of electron as an open self-organizing system is constructed, with the physical mechanism of self-organization consisting in the back influence of the own field created by electron on the same electron. The own field is considered as a physical property of electron, intrinsically inherent in electrically charged matter, which is included in the definition of the particle from the very beginning. The own field of electron endows the particle with wave properties and represents a bearer of superluminal signals, which can be used for the creation of qualitatively new communication systems. Because of the inseparable link between space and time, the force in relativistic mechanics is the cause of change not only of the velocity of particle, but also of the course of time along the particle's trajectory. For this reason the flow of time in some area of space depends on the character of physical processes, occurring in it, and, therefore, time can be controlled by slowing down or accelerating its course with the help of material processes. The conclusions of the paper are not in conflict with the special theory of relativity (STR); they are a direct consequence of relativistic equations of motion and represent an essential development of the generally accepted notions about space and time. At present all the necessary prerequisites are available, both theoretical and technical, for the practical mastering of the own fields of particles and of the physical properties of time.

1. Introduction. The Problem of Electron and Future Outlook

Electrodynamics, what is this? What is its value for man? Electrodynamics is the theory of electromagnetic interaction, one of four interactions existing in nature. Its role in the life of society is seen from the fact that the most part of natural phenomena, which we encounter at every step, is of electromagnetic origin: it is due to the interaction of electromagnetic field with electrically charged particles entering into atoms and molecules. It is fair to say that electromagnetism plays a crucial role in the life of mankind as it determines the ways of technical advance of society [1].

The key problem of quantum electrodynamics is the problem of electron, which can be formulated as follows: to construct from the first principles a non-contradictory model of electron, which takes into account experimental facts, i.e. to find the dynamical equation capable of describing the unique physical properties of electron, its internal structure, its behaviour when it interacts with electromagnetic field.

Electron was discovered a little more than 100 years ago, in 1897. With discovering the electron the revolution in physics began, which has resulted in unprecedented technical advance of society. The summit of development was reached in the middle of the 1950s and then the long period of evolutional development followed, when new physical principles were used to describe various physical processes and phenomena. The violent development of physics became slower in the 1970s and was replaced by stagnation in the subsequent years. The stagnation in electrodynamics continuing already over a period of several decades is gradually giving place now to a new ascent. The new scientific revolution is starting, which is associated with electron again, much as it happened hundred years ago. The reason is that electron is the most unique particle storing in itself the deepest mysteries of nature and the degree, to which they are disclosed, determines the wants to stay anonymous, until his patent application is done and university verification tests will be done). The claims are: 1200 Watts coil out with about 1076.4 Watts in into the driving motor at 3450 RPM. 8 amps 117volts at no load 9.2 amps 117 volts at full load. The output of about 1200 Watts is already a total overunity operation! As they just increase the input power by about 140 Watts only between idle and load state and they get 1200-Watts output it seems indeed a case, where Lenz law is violated! This generator also has NO motor effect! If you supply current to the coil, the permanent magnet in the center will not rotate; cause the flux just stays inside the toroid core! There you can see, that the back drag does not influence the mechanical rotation of the magnet!" Stefan used very good criterion to prove high efficiency of the design: **There is no back-torque effect! It is most important aspect of Gramm's generator.** You can contact directly Stefan Hartmann: Keplerstr. 11 B, 10589 Berlin, Germany. Tel: +49 30 345 00 497, FAX: +49 30 345 00 498 email: harti@harti.com info@ccard.net (Please, note: Dr. Harman referred to my old web site www.time-machine.spb.ru which is closed now).

So, basic principles of MEG and Φ-machines are the same. It was patented more than 100 years ago. Primary magnetic flux is topologically separated in two (or more) fluxes, which are mutually compensated in the ring core. Advantages of MEG are absence of moving parts since special input coils produce changes of primary flux. Also level of saturation in ferromagnetic material obviously should be corresponding to intensity of primary magnetic field, which is created by the permanent magnet, Fig.4.1.

Besides MEG the same principle can be (and already was!) realized in many other systems. So, there is no any news in the USA patent #6,362,718 granted for "The Motionless Magnetic Generator". What did they claim? You can find it in the patent: "The first input coil and the first output coil **extend around portions of the first magnetic path**, while the second input coil and the second output coil **extend around portions of the second magnetic path.**" Yes, it is the same bi-directional principle we discussed above: two parts of the magnetic flux and each coil produce effect to reduce flux due to this superposition.

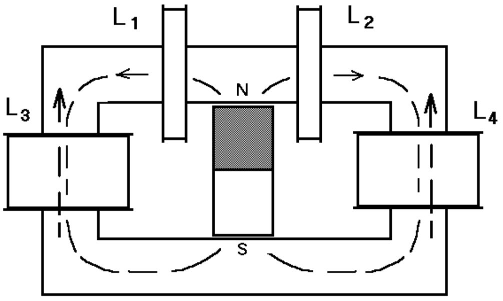

Fig.4.1

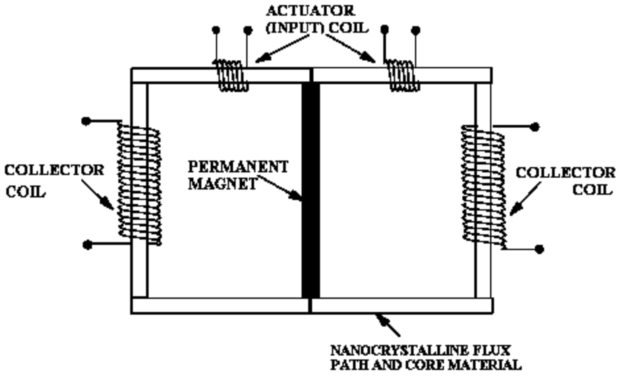

Fig.4.2
Diagram of prototype by Bearden.

In conclusion I'd like to confirm our sincere interest to develop joint work with all new energy research teams if they are not trying to obscure the issue of the technology by means of complex theoretical constructions and common words about zero point energy.

Matter as a Resonance Longitudinal Wave Process

Alexander V. Frolov

Abstracts

There is experimental data on gravitation anomalies for cases of resonance irradiation of the Bose condensates (superfluid helium or superconductor) at 10-100 MHz frequencies. It is developed by the author in frames of his aether theory that can be used for practical applications in aerospace and new energetics.

ZPF or aether fluctuations

The fundamental electromagnetic radiation field (Zero Point Field) ZPF or the quantum vacuum noise is a recently accepted physical notion. In the article [1] David Noever and Christopher Bremner used it to derive a frequency – dependent version of Newton's gravitational coupling term G. On the other hand we can consider the quantum vacuum noise as aether fluctuations. Dr. Alexander Mishin [2] described experiments on registration of these processes by means of special equipment. Both approaches (ZPF and aether fluctuation) allow to conclude that mass and inertia arise from these oscillations. However if we are considering the oscillation as some aether process then we can assume and describe some physical mechanism of this process.

One of consequence of the vacuum energy model, which is described in [1] is that "the attractive force of gravity becomes reducible to the radiative interaction between oscillating charges..." Let's clarify which kind of radiation can be created by oscillating electric charges.

There are many different sources to find the answer on this question and one of them is the article by Prof. Kirill P.Butusov [3] on symmetrization of Maxwell's equations and practical methods of generation of longitudinal waves in vacuum. So, ZPF model has a direct relation with the aether model since indirectly it leads to the question of longitudinal waves in vacuum. Physically they are waves of density of energy and in the aether model the waves are areas of more dense and more rarefied aether. Let's note that there are standing waves besides moving waves.

To consider the interaction of some mass particles and the fundamental field the notion of subatomic charges "partons" was introduced [1]. So, the mass itself "becomes interpretable as a dependent quantity derived from a damped oscillation driven by random ZPF" [1]. The authors wrote about "internal kinetic energy" of the mass particle and it can be considered as a function of ZPF oscillation frequency. In the aether theory of mass there is a similar notion of "aether vortex", which represents some cyclical process of some frequency and it is possible to calculate its kinetic energy. This aether vortex model of matter elements allows to assume real methods to change parameters of vortex and to get changes in parameters of existence of the matter. On the other hand we can discuss the possibility to change some physical parameters of aether in areas of the vortex to get the same result. This possibility follows from the well-known N.Kozyrev's experiments, which were named "investigation of active properties of time". N.Kozyrev used chronal (temporal) approach in his theory. We have to change his notion "the density of time" to "the density of aether" to get a direct link between his experiments and the aether theory of mass.

N.Kozyrev and others have [4,5,6] experimentally demonstrated that irreversible processes in matter produced changes of aether density in the area of the experiment. Detectors of different type can register this change. It is obviously that any matter element (i.e. the aether vortex) in this area of changed aether density should get more inner (kinetic) energy or slow the inner motion. From the chronal point of view these are changes of inner time of this matter element.

Gravity shield

One more interesting point that is discussed in the article by Noever and Bremner [1] is a problem of gravity shield. The authors show that resonance interaction with ZPF produces "the particle mass" and it can be viewed as "a renormalized or "dressed" mass with a resonant interaction potential. Similar resonance approach is used in the conception of de Broglie's matter waves. Also the authors [1] mentioned the existence of an experimentally unobservable mass. In this case ZPF cannot be fundamentally shielded by matter since "frequency mismatch precludes gravity shielding by matter" [1]. The only way to get screening of ZPF fluctuations seems to be very complex: it is necessary to provide frequency matching for whole wavelength band of the oscillations.

I think some specialization is necessary here to explain experimental gravity anomalies with Bose condensates experiments (superfluid helium or superconductors): **special process in matter can be used as the gravity screen and this approach does not involve the frequency-matching problem.**

We have concluded above that any matter element is a resonance process and its energy is derived from ZPF. It is useful to note that these are longitudinal wave oscillations of energy density in aether. In this case, the gravity shield problem can be solved in frames of the aether vortex conception of matter.

The longitudinal wave is a moving (or standing) areas of rarified and thickened aether. Let's consider the moving wave, which is responsible for gravitation attraction effect. How can we stop, re-direct or reflect longitudinal wave in aether by means of aether vortexes (matter elements)? **We can produce interaction with this wave only by means of other longitudinal waves.**

In macro-level this idea can be realized as longitudinal wave generator. Electromagnetic processes, which can be used as sources of directed longitudinal waves, are known and some of them are described in [3]. In other way the gravity shield can be produced as longitudinal waves generated by natural aether vortexes (i.e. by matter elements) if the matter exist in a special exited state, for example for cases of resonance irradiation of superfluid helium or superconductor at 10-100 MHz frequencies.

Matter element as resonance process

In [1] the authors wrote that it is possible to calculate "the mass of any fundamental particle at its resonant frequency." There is the question: what is the general basis of whole spectrum of stable elements masses?

In 1996 the author published the article "The concept of mass process" [7]. At first in this work physical sense and notion of 3-dimensional curvature was introduced. By analogy with known mathematical notion of linear curvature $\rho_1 = \frac{1}{r}$ (where r is radius) and uniform surface curvature $\rho_2 = \frac{2}{r}$ it was proposed to calculate curvature of a 3-dimensional space as

$$\rho_3 = \frac{3}{r} \qquad (1)$$

The radius r in this case means that in a 3-space there is some periodical process. In other words, 3-dimensional matter is a resonance process.

Further, de Broglie used formulations E=hf and E=pc (where p is momentum, h is Planck constant, f is frequency and c is velocity of light) to derive the following:

$$hf=pc \qquad (2)$$

that allows us to get the well-known formulation

$$\lambda = \frac{h}{p} \qquad (3)$$

There is another logical branch of this idea that leads to the understanding of the mass properties of matter as a resonance process. Instead of E=pc in [7] it was proposed to use E=mc^2. In strength of the wave-particle duality we can write the equation

$$mc^2 = hf \qquad (4)$$

and from this equation the mass can be presented as resonance electromagnetic oscillations

$$m = \frac{h}{c^2} f \qquad (5)$$

Let's note that f=1/T, where T is some period of oscillation. So, we can write the following

$$m = \frac{h}{c^2} \frac{1}{T} \qquad (6)$$

where $\frac{h}{c^2}$ is new constant between mass and period of time.

There is an important conclusion: any mass is a process and there is some period of time, which corresponds to this mass. In other words, there is no physical sense of time separate from some process of existence of mass. Product mass and period is a constant value, which was named as a chronal constant

$$mT = \frac{h}{c^2} = const \qquad (7)$$

The chronal constant is a parameter of some real space and it is equal to $0.73725 \cdot 10^{-50} [Js^2 / m^2]$

Also in this work [7] there was a demonstration of several examples of newly discovered physical law: spatial curvature of some natural objects (proton, planet, DNA molecule) is a whole number. There is some analogy with the nuclear physics notion of wave number. From this fact we can assume that main natural matter elements exist in main resonance states. For example, if Bohr radius is 0.52917 Angstrom, then we can find the wave-length $l = \pi d$ and the linear curvature is $\rho = 1/l = 3.0075 \cdot 10^9$ (m) and 3-dimensional curvature of this object is $\rho = 3/l = 1.0025 \cdot 10^9$ (m) that is unit of mater, corresponding to simplest atom, i.e. unit matter engine. Let's note that it is near the unit and some distortion of 0.0025 means non-ideal resonance state of the system.

Calculations for planet Earth in [7] were based on the known period of orbital rotation T=31557600 sec that corresponds to frequency of electromagnetic oscillations

$$f = 1/T = 3.168861 \cdot 10^{-8} (1/s) \qquad (8)$$

and wave-length

$$\lambda = c/f = 9.46... \cdot 10^{16} (m) \qquad (9)$$

The curvature (if this wave-length is considered as radius of the resonator) is following wave number

$$\rho = 1057.00 \cdot 10^{-20} (1/m) \qquad (10)$$

Also we can use other known data about the planet. Daily rotation period of our planet is known T=86400 sec and we can calculate its wavelength $\lambda = 3469{,}82(m)$ and corresponding curvature (wave-number). Sure, it is also a whole number with a good accuracy:

$$\rho = 2882 \cdot 10^{-7} (1/m) \qquad (11)$$

The laws of physics in macro cosmos and micro cosmos are similar. From these calculations it was assumed that whole formation of mass spectrum of stable chemical elements of matter is determined by similar physical mechanism.

Creation of mass

In short we can summarize that technology of longitudinal waves in aether is a real basis for creation of matter with mass and inertia properties. N. Tesla used this method to produce different objects: from ball lightning up to electrons. Velimir Abramovic says in his article [8]: "The principle of resonance and harmonic oscillation of aether seems to be so clear that all problems of modern physics, especially a problem of energy conversion, will be solved with its development. By means of his vacuum tube Tesla got protons, electrons and neutrons directly from aether and reproduced them at any distance. Instead of giving a possibility to the bundle of protons to move through space to some place, he created conditions for momentary appearance of arbitrary quantity of particles in the given place."

Any objects can be classified as aether vortex and parameters of this vortex determine its mass, electric charge and other properties of matter.

The "parton" as element of matter in [1] is a useful tool for description of physical properties of aether.

Longitudinal waves in Woodward's experiment

In [1] the authors state that resonant radiation in the required 10-100 MHz range appears to produce anomalous effects for such Bose condensates as superconductors. In my opinion it is a particular case of discussed above technology of longitudinal waves in aether due to possibility of transformation of transverse electromagnetic waves in longitudinal waves in the superconductors. This transformation in plasma is a well known physical mechanism.

More facts to prove this idea: by Woodward [9] there is a special requirement, i.e. the frequency of mechanical vibrations should be twice the frequency of electrical oscillations in the capacitor, which demonstrates the weight anomalies. But from the other hand it is a common rule for creation of longitudinal weaves in plasma! Also it is a necessary condition for generation of parametrical oscillations! So, we can assume that basis of the effects in [1] and [9] is a generation of longitudinal wave in aether.

Conclusion

Any element of matter can be considered as resonance process of aether oscillations, which are longitudinal waves. There is an analogy with description of these longitudinal waves and well-known matter waves by de Broighl. Experimenting on the longitudinal waves generation and especially experiments on standing waves to get gradient of aether pressure allows to develop gravity control technology.

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Gerlovin’s Theory of Activation

Alexander V. Frolov

It is a review of the famous book by Ilia L. Gerlovin “Basis of unified theory of all interactions in matter”published in 1990, St.Petersburg, Russia. We hope this article let you discover some new aspects of physical vacuum structure to develop more new experimental methods. Comments made by Alexander V. Frolov, Editor.

In [1] the author wrote about different methods to activate water solutions: mechanical, thermal, acoustic, magnetic and electrical. One of the known methods is an activation by means of electrohydraulic method. There is also some information about activation of other mediums, mainly liquids, but also some gases and solid bodies.

There are no theoretical explanations of these facts to explain all aspects of these phenomena. Furthermore, complexity of interpretation of these phenomena in frames of common physical notions induced some scientists to announce these phenomena as non-existing and “illegal”.

Ilia L. Gerlovin formulated the physical principles of theory of activation of mediums on the basis of new physical theory, the Theory of Fundamental Field (TFF). These principles are based on his two important conclusions from the TFF:

a) “Space around us is not empty, physical vacuum consists of material physical objects, i.e. elementary particles of vacuum (EPV). These particles are responsible for main activation processes;
b) Force interactions between atoms in molecule, between molecules in crystals has not spherical symmetry in the crystals of solid bodies, but an axial symmetry and the interactions are changing in time with very high frequency of about 10^{18} Hz. This feature of force interactions also makes its own contribution to the activation of mediums.” [1, p. 314]

So, it was assumed that the phenomenon of activation of mediums can be defined as anisotropy of force interactions, which leads to **“meta-stable state, which can be called *structurally activated state of the given structure”.***

Here is some difference in principle between chemical term “activation”, which characterizes a transformation of molecule or atom in some active state with an increased energy, which is sufficient to provide a chemical reaction. It is ***energy activation*. Gerlovin described new notion, a *structural activation:* “This phenomenon can be classified as some change of structure of activation object. With this, energy of molecule can have no changes, and *active properties***

Coupled with aetherodynamics time conception, which was suggested by Alexander V. Frolov, the works on the control of space-time parameters gain the possibility for development and commercial application. As a theoretical basis there are those N. Kozyrev works where his conception of "time density" are replaced by that of "aether density" according to Frolov.

In September 2002, Faraday Labs Ltd Company plans to complete testing of the first experimental system, and to start the patenting and research of applied aspects, first of all in medicine.

Physical Principles of the Time Machine

Alexander V. Frolov

Experimental success of research team headed by Dr. Vadim A. Chernobrov, Moscow was reported in [1]. The time course can be controlled as rate of any process in local space-time (inner space of the Time Machine). It can be decelerated or accelerated by means of special "converging electromagnetic waves". Ordinary waves move from the source whereas special "converging waves" move to some central point, i.e. into the focus of the system. In Chernobrov's design of the Time Machine this process is organized by means of several spherical envelops, which consist of several electromagnets. Electronic control unit controls the processes in this design. Dr. Chernobrov reported about 3% change of the time course in 4th version of the system, which was tested with a human inside. The goal of Dr. Chernobrov's work is to research the medical aspects and experimental investigation of the principles. Several important conclusions were obtained from the project: the time course can be controlled and character of the changes is different for acceleration and deceleration mode.

Other known publication and research projects on the same topic seem to be very far from any commercial and practically useful application. Obviously the topic is very new and fantastic for most of scientific community and at first we have to clarify the physical principles of the time control project, which is started by Faraday Labs Ltd.

In this project we believe that notion of time is one of possible description of real physical properties of our Universe. So, it is not mathematical abstraction but some aspect of physical reality and we can discover some physical properties of time. Russian astrophysicist N. A. Kozyrev [2] developed a theory of active properties of time and according to his point of view there are two properties: time course and time density. Prof. Kozyrev demonstrated experimentally that time density in area of some process (changes of matter) is dependent on entropy parameters of the processes. In [3] it was demonstrated that Kozyrev's experiments could be interpreted in aether theory and it has led to simple physical conclusions and clear experimental perspectives: **time course and its density can be explained and controlled as parameters of aether.** Directions of aether flow and density of aether are subjects of experimenting with non-reversible changes in matter, for example, in crystallization or melting processes. Also it is possible to use special electromagnetic processes, for example, Chernobrov's "converging waves" or other longitudinal waves as methods of aether compression or rarefaction. If we assume that process of existence of elements of matter physically can be explained as aether vortex processes then its rate is a parameter of **aether income/outcome balance** (aether inflow in element of matter and aether outflow from the element of matter). It was also described in Time Rate Control (TRC) theory [3]. To control this balance it is necessary to develop technology of longitudinal waves generation, its focusing and resonance effects. The previous research and experimenting on the topic has been made by N. Tesla.

Let's assume that we have some technology to change parameters of time course. How should we organize this local space-time (what is spatial topology of the design)? There is a very interesting experiment to get the answer: rotation of a heavy cone (for example, lead cone) entrains surrounding aether, so a vortex appears, which is a toroidal formation of aether (rings). The rings can exist in space for a long period. The further question is: Why does the beam of light (laser beam) directed to the cone by tangent create a luminous ring? We can assume that due to natural properties of photons (light propagates along the geodesic line in space) some autonomous closed toroidal space should be created in such experiment. The next thought is: since space and any matter exist in time then we can speak about some autonomous time. The general conclusion is to be the following: autonomous 4-dimensional space-time can be created as toroidal aether vortex.

Here is point to note some aspects of research project by Prof. Robert Mallett, Connecticut University, USA. In fact, sometime next year, he hopes to produce the first piece of technology that eventually will allow him to build a time machine. By Mallett it will be a device that employs lasers "to twist space". Why is he going to close the beam of light? His theoretical background is knowledge about black holes, i.e. understanding of the connection between gravity and curvature of space-time. In Einstein's theory both matter and energy can bend space and time. So Prof. Mallett assumes that curvature of space-time can be changed not only by mass (like a black hole) but it can be affected by energy of photons. This has led Prof. Mallett to consider the possibility of using a circulating beam of light to twist space and to create closed loops in time. It is predicted that a spinning neutral particle, when placed in the ring, is dragged around by the resulting gravitational field [4]. From the first view it is the same approach we have considered above (experiment with aether toroidal rings). But proposals by Prof. Mallett differ in principle from the aether conception.

The main aspect of this technology is a creation of autonomous (self-closed) toroidal space-time. Autonomous geodesic world line of this space-time is self-closed. Any photon should be circulating in this system due to its properties: photon is always moving along the straight line of the space.

More deep understanding of this technology follows from the explanation of photon as oscillation of aether. Any photon can be considered as result of relative motion of the matter (observer) in absolute space (immovable aether). Usually a photon is considered as moving object in space. But we can assume that observer is in the motion and the photon is oscillations of the absolute space (immovable aether). Which approach is more real one? Sure, it is more easy to consider a photon as moving object but let's remember fact of our real motion in the Universe and fact of the Universe expansion.

So, ideas by Prof. Mallett are very far from the **aether nature of the time phenomenon.** He follows the black holes theory and general understanding of space-time distortion due to mass or energy presence. Also he knows that a light beam should be closed in a ring. However Prof. Mallett is very far from physical basis of the effects. **The key of time rate control is technology of artificial aether flow, creation of aether vortex systems (AVS), management on density and direction of aether flow.** There are several technical methods to produce it. Any light beam should be curved in self-closed "light ring" if it is placed in a toroidal aether vortex and we can say that this system has own space-time.

What does "some changes of time course" mean? We can measure it as some changes of standard rate of oscillation process, for example, some stable wavelength of laser beam or quartz oscillations. There is a well-known experiment with two atomic clocks (one of the clocks is placed on the roof of some building and another one is placed on surface of planet). Due to vertical component of gravity the time course should be different and it can be measured. How can we organize difference in these measurements if both atomic clocks are placed in the same altitude?

It is necessary to consider gravity nature in frames of the aether conception. Two atomic clocks demonstrate difference in measurements due to difference in aether flow density. Hence, by means of aetherodynamics methods it is possible to control the rate of oscillation processes in the atomic clocks and in any matter (i.e. time course itself).

The aetherodynamics methods have a clear analogy with electrodynamics: **motion of charge produce field and there is the induction law**. Really, classical electrodynamics can be considered as particular case of the aetherodynamics. So, physical sense of any field is stress or deformation (it is some static field) or oscillations of aether.

Let's introduce the notion of chronal (temporal) charge to consider some technical aspects. In electrodynamics we assume an electric charge as element of matter with positive or negative electric properties and we have to compare it with some reference (zero charge or test charge). Let's note that in any case we have to consider "charge of some particle" but not an "abstract charge". So, we can postulate that any element of matter has **zero chronal charge** if it is moving from Past in Future with standard (usual for measurements of surface of our planet) time course. If the time course (i.e. existence of some element of matter) is decelerated then it can be measured as decrease of standard oscillation frequency of the matter. Time course acceleration means some increase of standard oscillation frequency of the matter. Let's determine that in the first case it is negative chronal charge and in the second case it is some positive chronal charge. Atomic clock is one of possible methods to measure zero chronal charge or to find some relative positive or negative difference.

It is predicted here that motion of chronal charge should produce a chronal field. Some provisional data was received by Frolov from simple experiments on the rotation of a heat source. Accelerated motion of chronal charge (changes of density of chronal current) should produce aethero-induction effect that is an analogy (or more general case) of Faraday's induction effect. This effect can be detected as secondary (induced) deceleration of time course in nearest area of accelerated time matter. Another case is a secondary (induced) acceleration of time course in the nearest area of decelerated time matter.

Technical realization of aethero-induction method seems to be very close to idea, which is described in classical epic "Back to the Future". At first, it is necessary to create or to collect some chronal charge in a "flux condenser" and then to accelerate it in space up to some velocity. According to the aether conception, this creation of the chronal charge is a real technical process.

It is assumed that estimated chronal effects are demonstrated as some threshold field, i.e. space-time has some stable discrete energy levels and changes of its curvature should have discrete threshold mode. All new aspects disclosed in this paper are the subject of a patent process. Faraday Labs Ltd organizes experimental program on the topic. Practical application of this technology is new energy systems and propulsion methods.

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investigated completely yet. It was found also that harmful effect on biological systems is not related to the process of movement in Time itself but is a result of the difference of the Time rate value in various parts of a body (a biological system).

Inside of the laboratory setup it was also discovered that Time could be changed with some inertia. Areas of space having different Time rates have vague borders. With sufficient difference in Time rate the human can see an area with a different Time rate as some white mist. Higher the difference – the mist is denser, that can be used as an alarm signal for biological systems. It is possible to consider Time-travel as possible and (after experiments with mice) there are reasons to suppose it will be safe for travelers if they follow certain rules. It is especially necessary to emphasize: the trips through Time (due to new discovered properties of Time) can't affect the Past and they can't change our past history. All the so-called paradoxes for the traveler in Time (for example when "he meets himself in the Past" or "he kills his grandfather in his childhood" have clear solutions in 3-dimensional Time.

It is possible to consider as a proven fact that Time has more than one dimension, i.e. O. Bartini's theoretical calculations are confirmed by these experiments: Time has 3 dimensions. Hence our Earth world can be considered as a 6-dimensional object: length, width, height, age or date of Time, variant of a History or erosion of Time, density or rate of Time. The concept of "the Arrow of Time" as fourth dimension (moment of Time) is a particular case of the concept of sixth dimension (rate of Time) that leads to the physical concepts of gravitation and energy and they are simultaneously connected. Concepts of the " Einstein-Rosen bridges" known since 1916 or "worm-holes" introduced into science by John Willer in the 50's, are travels in 5th and 6th dimensions, i.e. the "classical" Time travels, which were described by H. Wells.

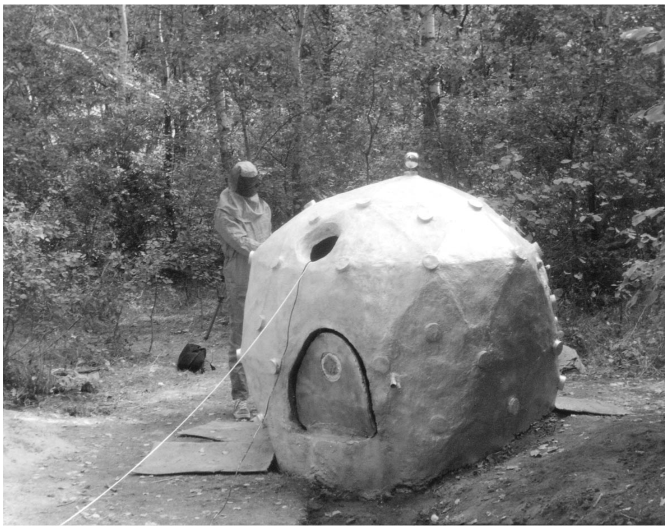

Editor's: As the reader could note, the author does not disclosure the secrets of the TM design. From the photo you can see the electromagnets, which form the regular stereometrical construction as well as the cables from the TM to the control unit. Dr. Chernobrov mentioned the converging electromagnetic waves only. So, to understand how it works, it is necessary to get a clear notion of the converging electromagnetic waves. Let's imagine the ripple effect created by a stone in the water. The waves move from a central point to periphery. The converging waves are just an opposite process: the waves move from periphery to the central point. Is it possible in Nature? Yes, sure. Dr. Chernobrov wrote: "Let's throw a hoop on the water and inside of the hoop we'll see converging waves." The Time Machine technology by Dr. Chernobrov is based on the similar principle.

Time Machine Project

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May 29, 2002

Faraday Labs Ltd and Dr. Vadim Chernobrov have signed the agreement on scientific-research work on investigation of active properties of time.

In the course of the previous experimental works, carried out by Dr. Chernobrov's research team during the period from 1984-2002, four versions of Time Machine had been made and tested. At these devices (the biggest system is about 1 meter in diameter) the effects of deceleration and acceleration of time course were created and measured. The principles of control of time course velocity were based on the interconnection of electromagnetic processes and physical properties of space-time. Special electromagnets, operating in pulse mode, are placed at the spherical frame. They create the so-called "converging wave", which by Alexander Frolov is a longitudinal wave in nature.

Alexander V. Frolov, General Director Faraday Labs Ltd and Ph. Dr. Vadim A. Chernobrov have just signed the Contract

Coupled with aetherodynamics time conception, which was suggested by Alexander V. Frolov, the works on the control of space-time parameters gain the possibility for development and commercial application. As a theoretical basis there are those N. Kozyrev works where his conception of "time density" are replaced by that of "aether density" according to Frolov.

In September 2002, Faraday Labs Ltd Company plans to complete testing of the first experimental system, and to start the patenting and research of applied aspects, first of all in medicine.

Physical Principles of the Time Machine

Alexander V. Frolov

Experimental success of research team headed by Dr. Vadim A. Chernobrov, Moscow was reported in [1]. The time course can be controlled as rate of any process in local space-time (inner space of the Time Machine). It can be decelerated or accelerated by means of special "converging electromagnetic waves". Ordinary waves move from the source whereas special "converging waves" move to some central point, i.e. into the focus of the system. In Chernobrov's design of the Time Machine this process is organized by means of several spherical envelops, which consist of several electromagnets. Electronic control unit controls the processes in this design. Dr. Chernobrov reported about 3% change of the time course in 4th version of the system, which was tested with a human inside. The goal of Dr. Chernobrov's work is to research the medical aspects and experimental investigation of the principles. Several important conclusions were obtained from the project: the time course can be controlled and character of the changes is different for acceleration and deceleration mode.

Other known publication and research projects on the same topic seem to be very far from any commercial and practically useful application. Obviously the topic is very new and fantastic for most of scientific community and at first we have to clarify the physical principles of the time control project, which is started by Faraday Labs Ltd.

In this project we believe that notion of time is one of possible description of real physical properties of our Universe. So, it is not mathematical abstraction but some aspect of physical reality and we can discover some physical properties of time. Russian astrophysicist N. A. Kozyrev [2] developed a theory of active properties of time and according to his point of view there are two properties: time course and time density. Prof. Kozyrev demonstrated experimentally that time density in area of some process (changes of matter) is dependent on entropy parameters of the processes. In [3] it was demonstrated that Kozyrev's experiments could be interpreted in aether theory and it has led to simple physical conclusions and clear experimental perspectives: **time course and its density can be explained and controlled as parameters of aether.** Directions of aether flow and density of aether are subjects of experimenting with non-reversible changes in matter, for example, in crystallization or melting processes. Also it is possible to use special electromagnetic processes, for example, Chernobrov's "converging waves" or other longitudinal waves as methods of aether compression or rarefaction. If we assume that process of existence of elements of matter physically can be explained as aether vortex processes then its rate is a parameter of **aether income/outcome balance** (aether inflow in element of matter and aether outflow from the element of matter). It was also described in Time Rate Control (TRC) theory [3]. To control this balance it is necessary to develop technology of longitudinal waves generation, its focusing and resonance effects. The previous research and experimenting on the topic has been made by N. Tesla.

Let's assume that we have some technology to change parameters of time course. How should we organize this local space-time (what is spatial topology of the design)? There is a very interesting experiment to get the answer: rotation of a heavy cone (for example, lead cone) entrains surrounding aether, so a vortex appears, which is a toroidal formation of aether (rings). The rings can exist in space for a long period. The further question is: Why does the beam of light (laser beam) directed to the cone by tangent create a luminous ring? We can assume that due to natural properties of photons (light propagates along the geodesic line in space) some autonomous closed toroidal space should be created in such experiment. The next thought is: since space and any matter exist in time then we can speak about some autonomous time. The general conclusion is to be the following: autonomous 4-dimensional space-time can be created as toroidal aether vortex.

Here is point to note some aspects of research project by Prof. Robert Mallett, Connecticut University, USA. In fact, sometime next year, he hopes to produce the first piece of technology that eventually will allow him to build a time machine. By Mallett it will be a device that employs lasers "to twist space". Why is he going to close the beam of light? His theoretical background is knowledge about black holes, i.e. understanding of the connection between gravity and curvature of space-time. In Einstein's theory both matter and energy can bend space and time. So Prof. Mallett assumes that curvature of space-time can be changed not only by mass (like a black hole) but it can be affected by energy of photons. This has led Prof. Mallett to consider the possibility of using a circulating beam of light to twist space and to create closed loops in time. It is predicted that a spinning neutral particle, when placed in the ring, is dragged around by the resulting gravitational field [4]. From the

Kozyrev-Dirak Radiation
Its influence on animals

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In the experiment with animals, that were made in the Center of Oncology Researches (COR) at the Russian Academy of Medical Sciences (RAMS), on the applying of Kozyrev-Dirak's Focused Radiation (KDFR), it has been found that KDFR decreases the quantity of glucose in the blood, reduces its tenacity, promotes the strengthening of immunity and the rise of the quantity of marrow cells.

Introduction

This time researchers in Russia and abroad experiment on ball lightnings by means of nonoriented circuits, which are similar to the electric analogues of Mobius band, also by means of Klein bottle and their combinations. Non-oriented fields are investigated very intensively now. Accordingly, organisms of the researchers, who observe the interactions of such fields with a matter, are also changed, thus they should take it into account on making such experiments. The aim of the article is to show in which way the fields of nonoriented circuits influence on animal and human organism. Besides the article has for its object the prevention of negative consequences, which can appear for experimenters through the research process.

Experiments with animals that were carried out in 1992-1993 in Russian Academy of Medical Sciences (RAMS) had not been published in proper time because there were no quantitative methods of radiation detection. Later, in 1996 they were developed [1] and KDFR parameters were measured in that geometry, which were applied in RAMS. In 1998 powerful and super-powerful KDRF sources were obtained. These sources were applied (and are applied now) in the researches at the controlled radioactive decay [2]. Kozyrev and Nasonov [3] and later also Lavrentyev with the collaborators [4,5] have proved experimentally that the Sun and some stars generate the radiation, which has early unknown properties. We suggest that the radiation, discovered by Kozyrev [3], and the radiation, which is researched by us and by other experimenters with nonoriented circuits, are of the same phenomenon. At first, it should be noted that on interaction between Kozyrev-Dirak radiation (KDR) and a matter made it colder. As it was demonstrated above [1], cooling effect can be explained by matter re-magnetization under the influence of KDFR beam (adiabatic demagnetization). According to the still unpublished data, KDFR bunch destroys matter lattice by the way of it's moving. However, after a couple of week matter reconstructs it to the almost tabulated points, without defects, blockness and other damages, which are peculiar to other natural crystal structures. **In the definite sense nature demonstrates the way to rejuvenate compound structures**. As it is well known, vital functions of biological systems on the Earth depend on the structure and composition of water. Therefore, we have a right to expect considerable changes in the vital functions of biological organisms under the influence of KDFR.

Experimental Devices

In experiments with animals there were applied the devices, which concentrated KDR (KDCR) and had 50 Wtt aggregate electrical power. The description is presented in [2].

KDFR indication was obtained by calorimetric method [1], along the way of movement of the main bunch (with 10 cm across diameter) and at angle of 45° from the geometrical axis of a device.

Researches of Bleeding Duration

Let us consider KDFR influence on the blood composition of animals. At the experiment 24-28 gram weighting, pelletized fed male mice were used. In the process of the experiment it was discovered that 3 and 4 hour processing of mice with KDFR at the distance 2.5 m and at the presence of animals in the sphere of maximum radiating power, caused some changes of fibrillation system. The bleeding duration was determined according to Duke method. Two groups of animals were used at the experiments: a group with 4-hour duration of KDRF processing and a group with 6-hour duration. Time of bleeding was considered in dynamics at 1, 2, 7, 14, 21, 28 and 35 day (Fig. 1). The bleeding duration of the intact animals was determined by the value 128±11 sec. After the applying of KDFR there was noticed some increase of bleeding duration to 261±15 sec and 223±21 sec on the first day after the stopping of the influence. In the subsequent periods bleeding duration gradually decreases up to the level of physiological norm. The whole normalization of the index is observed at the animals, which were processed by KDFR during 4 and 6 hours, on 28-35 day up to 115±12 and 133±18 sec correspondingly. In the process of observations at the animals, the correlation between time of fibrillation and periods of KDRF processing of the animals has not been revealed (Fig. 1).

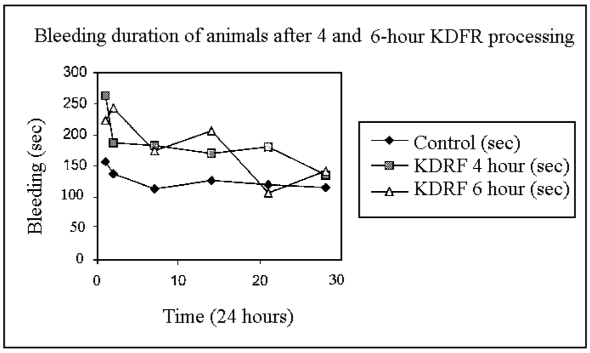

Fig.1

In the course of the experiment the strongly marked chronometric hypocoagulation was discovered due to the extension of the parameter "K" or, probably, because of the change of aggregation properties of platelets (Table 1).

For the determination of biochemical indexes serum was obtained from 5-8 ml of rats' venous blood. Beforehand (24 hours before the slaughter), forage was taken away from the animals. The determination of biochemical indexes was provided by means of biochemical analyzer HITACHI. As a result of the experiment it was determined that at the first day after influence of KDRF there was a tendency of decrease of the glucose content (Table 2). Other indexes varied in the limit of physiological norm.

Table 1 Parameters of thromboflexogramm after KDFR, 4 hours

Animal #	Parameters of thromboflexogramm			Fibrio gene	Fibrinal activity
	R (sec)	K (sec)	Ma (mm)		
1	72	∞	10	-	-
2	102	∞	18	-	-
1	90	∞	10	275	75
2	180	150	52	315	90
1	180	∞	5	-	100

Table 2 KDFR influence on the glucose content in blood of the rats

Time (days) after the experiment	KDFR 4 hours (mmole/l)	Test (mmole/l)	KDFR 6 hours (mmole/l)	Test (mmole/l)
1	3.14	6.12	6.39	7.27
10	7.59	9.35	8.90	6.69
30	6.05	6.69		

Research of haemopoiesis system

Several criteria were considered: the dependence of biological effect on the distance, on the power flux density, on the duration of processing. Besides, KDRF influence on mice survival was considered.

At the experiment 24-28 gram weighting, pelletized fed male mice were used. The marrow was examined in the dynamic at 1, 3 and 7 day after KDFR influence. Six animals were taken on each point. After the decapitation of the mouse their thighbones were taken out and after that the absolute number of myelokaryocytes was calculated by the standard method in Goryaev chamber.

Dependence of the biological effect on the distance

In all experiments the maximum flux density along the geometrical axis of KDCR device was a constant. There were used four temporal modes of the influence (1, 2, 3, 4 hours) and three points of long distance between KDSR and the biological object (0.5; 1.5; and 2.5 m). At 0.5 m distance there were no differences in the number of marrow cells in comparison with the control cells. With the increase of distance between KDCR and the object from 0.5 to 1.5 m some tendency to the increase of the number of marrow cells up to the 7th day was observed. Four-hour KDRF processing caused the increase of the number of karyocytes up to $29.99 \pm 1.25 \times 10^6$ ($P<0{,}001$). Thus, any dependence of the biological effect on the exposition has not been revealed. For instance, at the 7th day after one hour of the exposition the number of karyocytes was equal to $28.45 \pm 1.87 \times 10^6$ at the same time after 3-hour processing it came to $27.65 \pm 0.74 \times 10^6$. Alongside with the change of the distance to the biological object from 1.5 to 2.5 m the tendency towards the increase of the number of marrow cells has kept within the same limits $28.27 \pm 1.32 \times 10^6$ and $29.57 \pm 0.88 \times 10^6$.

Dependence of the biological effect on the power flux density

The comparative investigation of KDFR influence on the biological object in the coverage of KDCR (along its geometric axis) and outside the coverage has demonstrated that alongside with the increase of the radiation intensity there was a tendency towards the decrease of stimulative influence of KDFR on haemopoiesis.

Dependence of the biological effect on the duration of processing

On processing the animals at distances up to 2.5 m from KDCR and on increase of exposition to 3-4 hours it is possible to obtain reliably significant difference in the number of marrow cells from the physiological norm to the 7th day.

KDRF influence on the survival of mice

The experiments, determining the survival reaction of animals, were made by means of gamma radiation. 30-day survival is the criterion of determination. Conditions for the experiments are the following: in the coverage of KDCR and aside the coverage, (the distance between the KDCR and the object is 2.5 m in the coverage of KDCR and 0.5m outside the coverage). Time of influence is 4 hours. Animals of both sex were used. Two groups of animals were used. The test group was put to the gamma radiation in the diapason of doses, which caused marrowy syndrome, i.e. from 7.5 to 8.5 Gr. The second group of animals after the irradiation in the same diapason of doses was repeatedly processed with KDFR. Time of the influence is 4 hours at 7.5 Gr gamma radiation on 15 mice in one bath and 8.5 Gr on 15 mice in another bath. Total gamma radiation of the animals was made by means of the source ^{137}Cs with the dosage rate of 5.2 Gr/min. Gamma radiation in this dose diapason causes death of the animals during the development of the marrowy syndrome, i.e. from the 6th to the 20th day along with the aplasia of haematogenic tissue. Combination of gamma radiation and KDFR sometimes leads to the slight increase of the number of survived animals. If the animals are irradiated by gamma rays at first and then by KDFR, the death control at 7.5 Gr radiation is equal to 5.5% from the total number of the animals and at the following KDFR processing 16% of the irradiated animals die. However, 67% of the animals in the tested group have died after KDFR processing and after the coming next gamma radiation with 8.5 Gr total dose. And in the group, which was processed with KDFR, only 46% of the animals died.

Immunity strengthening

For the investigation of KDFR influence the following tests were chosen: activity of natural killers and T-killers, which had been obtained by the immunization in vitro in the unidirectional mixed culture of lymphocytes and also in the reaction of blast transformation on the specific mitogen [6, 7]. All tests were made on the 7th day after a single KDFR influence. Unfortunately, data have been obtained with the applying of radioisotope preparations. Though the experiments of this kind were successful and though they have demonstrated the increase of some immune reactions' level, there is a certain doubt in the relevancy of radioisotopes application [2]. Thus the series of experiments was made. These experiments were aimed at the investigation of KDFR influence on the development of the swelling process. The aim of the experiment is the investigation of KDFR influence on the development of Ehrlich cancer and sarcoma-37, which were repeatedly inoculated to mice. At the first stage of the experiment there was a single KDFR influence on the mice repeatedly inoculated with sarcoma-37, on the 2nd day after the repeated inoculation of the swelling cells to the animals. The repeated inoculation was made intramuscularly in a right thigh, in a dose 10^6 of cells per a mouse. Time of KDFR influence for the first group of animals was equal to 1 hour; for the second one it came to 2 hours; and for the third one it came to 4 hours. Each group consisted of 6 animals. The test group consisted of six mice with repeatedly inoculated sarcoma-37 and which had not been processed with KDFR. As a result, the average lifetime of tested animals was equal to 9 days. The average lifetime of animals of KDFR groups came to 48 days (for 1-hour KDFR influenced group); to 12 days (for 2-hour group); and to 31 days (for 4-hour group). Thus, the average lifetime of the experimental group came to 29 days. Besides, in the group, which has been processing with KDFR during 1 hour, **the half of mice had survived (three of six mice).**

At the second stage of the experiment the repeated (5 times during 2 hours) KDFR influence on the mice was applied. These mice have been inoculated with sarcoma-37 at seven days before the beginning of the influence. As a result, the average lifetime of the animals was equal to 27 days, and for the mice, which were processed with fivefold KDFR influence, the average lifetime was equal to 76 days. The obtained results are the evidence of inhibition of swelling development for the animals, which were processed with KDFR influence. This leads to the increase of lifetime of such animals in comparison with the test. **Thereby, at a great extent the results of the previous experiments on the strengthening of immune status after KDFR influence were confirmed.**

Results and discussion

Let us make a conclusion. At the KDFR influence on animals' organism the following effects were observed: decrease of blood viscosity; strongly pronounced hypocoagulation; decrease of contents of glucose. Increase in the number of karyocytes and the extended lifetime of the animals, infected with Ehrlich cancer and sarcoma-37 were also observed.

As for human being, the researches in this area have not been carried out yet and they are still confined to the single observations. It is possible to give an example from the author's practice. In 1975 nonoriented circuit of 3kWtt power was examined. Field strength was measured. The author of the article had been working in the field for about 8 hours. And after five hours after the experiment I had felt bad. That time it was nothing known about the influence of the new radiation on human organism. The arrived ambulance has quickly diagnosed that I was close to hypoglycemic coma. On several hours after the intravenous glucose injection, my state has become normal. **Now we know that before the experiments with powerful KDFR bunches it is necessary to eat sugar.** Thus we believe that the data, which were obtained after the experiments with animals, can be applied to a human being. We can suggest that the manifestation of the symptoms of the KDFR influence on human organism depends on the power of the applied source, on the total mass of the organism and on the time of it in the coverage of the irradiation. From aforesaid it is clear that the experiment with powerful KDFR sources is far from being harmless and it is better to make it distantly after exclusion of man presence near experimental stands and devices. At the same time it is quite obvious that on applying of small capacity and fixed time of irradiation it is possible to develop methods for curing of human diseases, which are considered now as incurable (for instance of diabetes, some diseases of haematogenic system, of cancer and possibly of AIDS.

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Effect of Magnetic Blow Wave Field on Wine Systems

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Introduction

Authors communicate the data on influence of Magnetic Blow Wave (MBW) field on several wineproducts. It was found, that MBW did not lead to significant changes in the major components of the wineproduct (sugar, organic acids, minerals). At the same time the taste and aroma of treated wine become more pleasant; content of heavy alcohols and wine stone in the treated samples was less than in non treated ones. A mechanism of transformations was also discussed.

Keywords: *Magnetic Blow Wave (MBW), Wineproduct, GLC of aroma compounds and ethanol, HPLC of sugars, Atomic Absorption Spectrometry (AAS) of minerals, Heavy alcohols and aldehydes, Wine stone, Turbidity tendency, Organoleptic evaluation*

Magnetic Blow Wave (MBW) was obtained for the first time during the investigations on ball lighting generation under the laboratory conditions (Shakhparonov 1994). MBW as a physical object is interesting because of some facts, which suggest that MBW is a magnetic monopole. The MBW can also interact with the matter and transforms it in a definite way. Typical example is an elementary carbon in the form of graphite, which is transformed by such magnetic treatment into ferromagnetic substance (ibid). The graphite, which is initially diamagnetic, transforms to paramagnetic one with general radiation doze of about $7 \cdot 10^{19}$ neutrons/cm^2. Other types of radiations could not affect this way (Svoistva 1975). So one unit of MBW can be considered as $1 \cdot 10^5$ of neutron masses. This fact may be regarded as an indirect evidence for assuming that MBW and magnetic monopole are the same things. In the absence of excited radioactivity a slow MBW [$v/c < 1 \cdot 10^4$] occurs, which does not ionize atoms (Devons, 1963). Therefore, their interaction with the matter can be observed only indirectly. No data exist on the interaction of MBW with organic substances. The experiments and results reported in the present communication may be a starting point for development of technology and to formulate the methods for vintage wine and best quality spirit production.

Materials and Methods

Assuming that MBW and magnetic monopole are the same things, a number of conditions were selected for all experiments. The MBW source and the samples were placed in the same axis and the axis was oriented according to magnetic meridian direction. Such magnetic orientation is appropriate, as the energy of magnetic monopole theoretically increases in a magnetic field (Devons, 1963). All of samples were placed at 250 cm distance from MBW source, in hermetically closed glasses. It should be noticed that MBW could penetrate through many other barriers, for example into cast iron reservoir with wall thickness of 5 cm (Amaldi, 1970).

The quality investigations were made by using of standard equipment. HPLC, equipped with refractometric detector was used for sugars estimation. Separation of organic acids in forms of their ethyl esters and acid esters was carried out chromatographically using a column packed with polyethylenglycol succinate and the following temperature option: initial temperature is 120°C, final temperature is 220°C, temperature growth rate: 8°/min. GLC was also employed for determination of ethanol. Minerals content conclusion: in order to obtain complete information about any system, it should be destroyed. However, destruction of tissues of the man in order to get information about their state is a too high price to pay for the information about his health.

However, the above Van Hoven's criterion can be satisfied with the minimum influence, when the cells are not destroyed and the atoms of these cells, being primary sources of torsion spectrums to be registered, are bring into the non-equilibrium state by means of outer disturbing influence.

In order to choose the frequency of the disturbing torsion influence correctly, it is necessary to take into account the role of water in physical and biochemical organization of tissues of the human organism.

At the same time, it is necessary to take into account the resonance torsion frequencies of various human organs. Finally, it turns out that the signal of torsion disturbance should be rather sophisticated considering both these factors. The TORDI system is a ready-to-use production device. Nevertheless, it is important to understand that the model is not the limit of scientific and technical potential incorporated in it and that enhanced variants of the system will appear with the course of time.

Summing up, I would like to draw your attention once more to the fact that work on torsion technologies is not limited by the directions that were discussed here. Actually, as it was pointed out in the beginning, on-going development includes all branches of economy, industry, agriculture and medicine, as well as all problems of everyday life. Technologies that we mentioned are the forerunner of the fact that the mankind is on the threshold of the age of torsion technologies, which, we believe, will change our life in the 21st century more than all the scientific and technical revolutions of the 20th century.

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The Electrical Vortex Non-Solenoidal Fields

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A mistake was found in the electrodynamics: it is detected that all electrodynamics' postulates corresponds to the experimental facts, but vortex electric fields has unclosed inductive lines.

When the magnet is moving, then the current of magnetic induction is moving together with it. From known velocity of motion $\mathbf{v}$ and the value of magnetic induction $\mathbf{B}$, it is possible to calculate the intensity $\mathbf{E}$ of appearing vortex field according to electrodynamics formula of transformation of fields $\mathbf{E}=\mathbf{vB}$.

If to change the $E=vB$ on induction $D=\varepsilon_0E$ in formula of fields' transformation, that will get $D=\varepsilon_0Bv$, where D is electric induction, B is magnetic induction, v is velocity of motion, ε_0 is electric constant.

Herewith the appearing electric induction is always transverse to the direction of motion. It is possible to formulate the rule of origin for electric induction under the condition of rectilinear motion: if to dispose the right hand palm so four fingers shows the motion direction of the magnetic flow (the field), connected with moving magnet, and the vector B fells into palm, then the moved aside big finger will indicate the direction of vector D. The given rule is like the rule for Lorenz' force, but on the contrary (the difference is in frame). In the first case the charge moves, but the magnet rests. Here the magnet moves, but the charge, which points the direction for lines of force of electric induction, is immovable. So, there it is the rule for left hand, but here, on the contrary, it is the rule for right hand. Thereby, if the charge moves, but the magnet is immovable, then the rule of left hand uses for determination of the force. But if the magnet moves, but the charge rests, then the rule of right hand uses for determination of the force.

The origin of electric force is connected with that, the vortex electric field $D=\varepsilon_0 Bv$ appears around moving magnet (the magnetic field does not act on immovable charges).

In common literature on electrodynamics there is no any difference between electric vortex field and solenoidal field, but these are different notions. The sign of solenoidal field is the closed lines of electric induction (the flow of vector D through the closed surface is a zero), but for the vortex field the sign is following: the work of forces can be different from zero under the condition of motion along a closed line. That is to say, the vortex fields can agitate the rotational currents.

From the electrodynamics textbook: "The work of forces of vortex electric field can be different from zero, when the electric charge is moving along a closed line."

For instance, when the magnet moves, the vortex electric field appears and this field can be solenoidal or not, depending on magnet's orientation. Let's take such example: the magnet moves evenly, rectilinearly, and it's poles are oriented transversely to direction of motion. According to the rule of origin for electric induction ($D=\varepsilon_0 Bv$ that is the rule of right hand), the appearing vortex electric flow is not a solenoidal, since the lines of electric induction are not closed. Its begins in one conditional area of disturbance (+), accompanies the moving magnet, and it finish in another area of disturbance (-). For presentation it is enough to consider only two areas (+) and (-), represented on Fig.1. These dissimilar areas of disturbance appears because that flow of magnetic induction inside the magnet has the inverse direction, that outside the magnet.

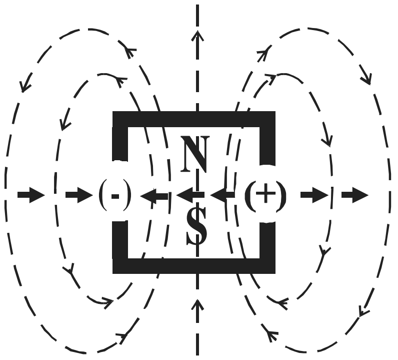

Fig.1

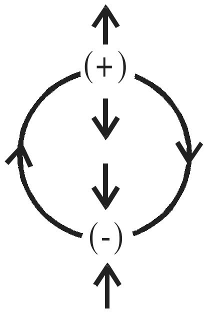

Fig.2

That moving disturbance of electric and magnetic fields presents itself as transverse electromagnetic disturbance. Also, it is necessary to notice, that under such magnet's motion, the appearing vortex electric field is not closed, but the current of electric displacement, connected with it, is closed (a currents are always closed). In given example, for clarity, it is possible to present a intensity of electric field through the Lorenz' force, if to take the frame, in which the magnet rests, and the test charge moves.

On the Fig.1 the moving magnet is conditionally represented (motion is toward to the text, magnet is moving away). N and S are poles of magnet. The direction of lines of electric induction, appearing when the magnet is moving, specified by arrows → and ←. Part of the lines begins in positive area (+) and finishes in negative area (-), the areas are placed on the ends of magnet. **The flow of electric induction through closed surface is not a zero; that is to say, these areas of disturbance are moving electric charges.**

From the electrodynamics textbook again: "The flow of vector D through any closed surface is equal to algebraic amount of external charges, covered by this surface. In the electrodynamics these postulates has the same role, as Newton' laws in classical mechanics."

Thereby, according to postulate, it is necessary to consider the appearing dissimilar areas of disturbance (+) and (-) to electric charges, or it is necessary to change the postulate.

It is interesting, that a part of lines of electric induction, which placed frontal and behind magnet, starts and finish at infinity, since the distribution of magnetic induction around magnet has not determined borders.

For clarity, it is possible to make following calculation. For instance, the coil (loop or turn) with current, as a magnet, moves evenly and rectilinearly, but its magnetic poles are oriented transversely on motion direction. Under such motion the lines of electric induction are not closed, and the dissimilar areas of electric field's disturbance appears in space on the edges of this coil.

On Fig.2 the moving coil with current is conditionally represented. It moves from left to right side of the page. The arrows on the coil indicate the direction of current. The appearing dissimilar areas of disturbance of electric field are marked by signs (+) and (-). Knowing, that in medium of the coil $B=\mu_0 I/2r$ and according to $D=\varepsilon_0 Bv$, it is possible to find the electric induction, appearing in the center, between two dissimilar areas $D=\varepsilon_0\mu_0 Iv/2r$, where I is current in the coil, r is radius of the coil, v is velocity of motion, ε_0 is electric constant, μ_0 is magnetic constant. The electromagnetic disturbances in transverse electromagnetic waves has the similar field construction, there also dissimilar areas of disturbance of electric field exists, that is to say the lines of electric inductance are not closed. Only the currents of electric displacement and magnetic induction are closed.

Let's consider another example: magnet moves rectilinearly, but its poles are oriented longitudinally to direction of motion. According to the rule for origin of electric induction ($D=\varepsilon_0 Bv$ is the rule of right hand), the appearing rotational electric flow is solenoidal, since in this case the inductive lines become closed lines. **Usually in books on the electrodynamics such moving magnet is considered, and the wrong conclusion is thereof done, that vortex electric field is always**

solenoidal, herewith it is forgotten, that poles of the magnet can be oriented not only along the direction of motion, but across also.

From the electrodynamics textbook: "The vortex electric field differs from electrostatic field that it is not related with any electric charges and its lines of intensity are closed lines."

From theory and from experiments it follows, that under transverse motion of magnet the lines of disturbance of vortex electric field can be unclosed and, accordingly, the flow of induction through the closed surface is not a zero. Then there is a direct discrepancy to facts in modern electrodynamics. It is strange, but for the whole history of researches in magnetism the transverse magnet's motion was not is considered. It leads to revising of electrodynamics' postulates, which plays such role in electrodynamics, as the Newton's laws plays in classical mechanics. The postulates, giving invalid belief about field processes, accordingly, do not allow to make some correct calculations. Fallaciousness of these postulates was one of the reasons, on which the electrodynamics could not to consider and to calculate the discrete electromagnetic waves (photons), where the magnetic field also is the transverse field (the field construction and calculation of photons are represented on the page http://www.comail.ru/~alemanov). **That is to say, not only particles has the charges, but areas of disturbance of field (without particles) are the charges also,** where the flow of electric induction through the closed surface is not a zero. Thereby, the vortex electric fields can be not only as closed flows of induction, but as well as inducted electric charges, accordingly, the laws for electric charges are valid for induced electric charges also. For instance, in the law of conservation of charge: if somewhere the area of disturbance with positive sign appears, that negative area appears also.

From the electrodynamics textbook: "The vortex electric field is generated by the variable magnetic field. Its force lines are always closed, like force lines of magnetic field."

But before this fundamental postulate, confirming, that force lines of vortex electric field are always closed, it was necessary to consider all variants of change for the magnetic field, including the variant of the transverse motion of the magnet. That is to say, the consideration of physical processes could not be unilateral. Faraday considered the longitudal motion of magnet and discovered the electromagnetic induction, but the transverse motion of magnet that have the principle importance for understanding of field processes in electrodynamics was not considered. Thereby, the longitudal motion of magnet brings to arising a vortex electric field with closed force lines, but transverse motion of magnet brings to arising a vortex electric field, where the lines of forces are not closed. In this case it lead to induced electric charges. It is necessary to notice, that this is first mistake, detected in electrodynamics postulates for all time of existence of electrodynamics.

From the electrodynamics textbooks: "...Gauss' theorem is valid not only for electrostatics, but also for electrodynamics, which using a variable in time electromagnetic fields. We are not sure if this hypothesis is valid or it is not valid... Only the experiment can give the answer on this question. The whole collection of experimental facts speaks in favor of this hypothesis." But, unfortunately, the experiment with transverse motion of magnet was not considered seriously in this textbook.

(Editor's note: Well-known Searl's experiments and Godin & Roshchin's experiments are based on such transverse motion of magnets (rollers). In Alemanov's article it was demonstrated that in this case the experiment should lead to induced electric charges. Really it was detected in experiments. Hence this missed aspect of electrodynamics is very important for development of the new energy technologies.)

Gravito-Inert Mass

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Nature of mass is one of the important problems of modern physics. It is accepted to consider that the mass of elementary particle is determined by fields, which are connected with it (electromagnetic, nuclear and others). However, we didn't create any quantitative theory of mass. There is no theory to explain why masses of elementary particles form a discrete spectrum of values and to allow determining this spectrum.

Mass (m) is a physical value, one of characteristics of matter, which defines its inert and gravitational properties. Accordingly, we distinguish inert mass (m_i) and gravitational mass (m_g).

Inert mass (m_i) characterizes dynamical properties of a body, its property to accelerate under the action of the force $(\vec{F}_i)$ and according to the second Newton's law is considered to be constant coefficient of proportionality for the given body between $\vec{F}$ and acceleration $\vec{a}$.

$$\vec{F}_i = m_i\vec{a} \qquad (1)$$

Gravitational mass (m_g) is a source of gravity field. Every body creates its gravity field, which is

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The Principle of Self-Organization, which can be formulated as follows: any material object represents an open self-organizing system whose internal structures are formed with the participation of the whole universe. Apparently, the Principle of Self-Organization, incorporated in nature as one of the integral properties of matter, is nothing more nor less than a spirit (or absolute idea, or creator) which operates the world and creates all its variety.

Physical Mechanism of Nuclear Reactions at Low Energies

V.P. Oleinik* and Yu.D. Arepjev

> *Tell me what the electron is,*
> *and I shall explain to you everything else.*
> *W. Thomson*

Abstract

The physical mechanism of nuclear reactions at low energies caused by spatial extension of electron is considered. Nuclear reactions of this type represent intra-electronic processes, more precisely, the processes occurring inside the area of basic localization of electron. Distinctive characteristics of these processes are defined by interaction of the own field produced by electrically charged matter of electron with free nuclei. Heavy nucleus, appearing inside the area of basic localization of electron, is inevitably deformed because of interaction of protons with the adjoining layers of electronic cloud, which may cause nuclear fission. If two or more light nuclei occur "inside" electron, an attractive force will appear between the nuclei that may result in the fusion of nuclei. The intra-electronic mechanism of nuclear reactions is of a universal character. For its realization it is necessary to have merely a sufficiently intensive stream of free electrons, i.e. heavy electric current, and as long as sufficiently a great number of free nuclei. This mechanism may operate only at small energies of translational motion of the centers of mass of nuclei and electron. Because of the existence of simple mechanism of nuclear reactions at low energies, nuclear reactor turns out to be an atomic delayed-action bomb, which may blow up by virtue of casual reasons, as it has taken place, apparently, in Chernobyl. **The use of cold nuclear reactions for production of energy will provide mankind with cheap, practically inexhaustible, and non-polluting energy sources.**

Introduction

Nuclear reactions at low energies, occurring in physical and biological systems, and, in particular, the cold fusion (CF) of nuclei, attract ever increasing attention (see review articles [1,2]). This is explained by the fact that research on CF (in what follows, by cold fusion we shall understand any nuclear reactions at low energies) opens up the way to the solution of the problem which was set more than 50 years ago in the field of controlled thermonuclear reactions (CTR) and which has not been solved that is the problem to provide mankind with cheap fuel. An important point is that CF allows to create not only cheap, but also non-polluting energy sources, as nuclear reactions at low energies are not accompanied by radiations dangerous to health (γ-radiations, streams of fast neutrons and other particles). Note that the energetic problem facing mankind is presently of special interest in connection with the fact that, according to expert evaluations, the oil-and-gas resources in the world will suffice only for some decades. For this reason the study of CF is among the most important problems of physics.

It is necessary to note that, relying on the standard theory of nuclear reactions describing nuclear processes in vacuum, experts in the field of nuclear physics, engaged in CTR, reject the very possibility of existence of nuclear fusion at low energies. Two basic objections are raised against CF:

1. at low energies the penetrability of Coulomb barrier around nuclei is so small that the probability of nuclear fusion is practically equal to zero;
2. distinction between the atomic and nuclear energy scales is so great that the energy, which might be evolved as a result of nuclear fusion, could not be transferred directly to atomic lattice; therefore the energy above should be emitted in the form of streams of γ-quanta, fast neutrons and other particles. However, such streams of sufficient intensity have not been registered.

The answer to the first objection against existence of CF is that at the heart of CF are nuclear processes occurring in environment, and the basic role is played here, apparently, by collective effects caused by interaction of nuclei with particles of environment in which the nuclear reaction takes place. The laws governing the behavior of interacting nuclei in vacuum are inapplicable to the description of CF of nuclei [3]. Nuclear reactions occurring at low energies submit to completely different laws, which can be established only provided that collective effects mentioned above are taken into account. For this reason the standard theory of nuclear reactions in vacuum can by no means refute the existence of CF.

As to the impossibility of transferring the energy between levels of various scales, we can give an example of the phenomenon of sonoluminescence (luminescence of a liquid when a sound wave causing cavitation passes through it) [4], in which the energy transfer from an acoustic wave to electromagnetic field occurs with appreciable probability in spite of the fact that the distinction between energies of acoustic phonons and quanta of light reaches 11 orders.

As early as 10 years ago J. Schwinger, the Nobel winner and the known expert in the field of the theory of elementary particles and quantum electrodynamics, asserted that it is impossible to deny the reality of CF phenomenon [3,4]. Since then the CF phenomenon for nuclei was repeated hundreds times in laboratories all over the world, tens of patents on the ways of energy generation on the basis of CF were registered and enormous number of experimental works were published, which not only confirmed the existence of effect, but also contained its detailed analysis.

The most convincing evidence for the existence of nuclear reactions at low energies seems to give the mass-spectrometric research of reaction products [5] as well as research on biological systems [6]. Detailed study of electric explosion of foil made of especially pure materials in water, described in [5], suggests that at electric discharges transformation of chemical elements occurs. Study of optical spectrum of plasma arising at discharge and of the mass-spectrometric analysis of sediments, which remained after the discharge, shows that in plasma there is an appearance of a significant number of chemical elements which were not presented in the initial material of explosive foil and electrodes and also that the isotope structure of the foil material changes appreciably. The change of experimental conditions, for example, of energy contribution in foil, its mass and dimensions results only in redistribution of intensity of plasma spectral lines, i.e. in the change of statistical weight of chemical elements in plasma, but the composition of chemical elements remains unchanged and it essentially depends on the material of foil. As it is seen from the received results, nuclear reactions, which take place at electric discharge, are not accompanied by the occurrence of a neutrons stream and γ-radiation and proceed at low energies of atomic nuclei.

The research mentioned above as well as many others, carried out by different researchers in different laboratories, **allow to draw a conclusion that existence of nuclear reactions at low energies is reliably established.**

The development of research on CF is hampered by the absence of theory of the phenomenon. As noted by Schwinger [3,4], the situation in CF is closely parallel to that one in high-temperature superconductivity: reality of the last, as a result of careful experimental research, is completely established, though theory of the phenomenon is absent till now.

In [5], to account for the transformation of chemical elements, the hypothesis is put forward that at the electric explosion of foil in the plasma channel magnetic monopoles are formed which may overcome the Coulomb barrier even at insignificant kinetic energy due to the great magnitude of their magnetic charge. The monopole, appearing not far from a nucleus, causes its polarization: those nucleons of the nucleus, which are situated more close to the monopole, experience stronger influence of the last, than the nucleons situated on the opposite side of the nucleus. As a result, a deformation of the nucleus arises (the nucleus is lengthened), which may result in nuclear fission.

Obvious drawback of this mechanism of nuclear reactions is that magnetic monopoles have yet to be found out in nature.

Numerous attempts to construct a consistent theory of CF (see reviews [1,2]) have not been crowned with success. As it was noted above, for the CF to be described, the account of the collective effects may be important caused by interaction of nuclei with environment, in which nuclear reaction takes place. But does it suffice to take into account these effects in order that the theory of the phenomenon is constructed? The analysis of the experiments on transformation of chemical elements at low energies and on the CF of nuclei suggests that the discussed phenomenon does not fall within the domains of exotic ones: it seems to occur in nature constantly, at every step, in both physical and biological systems. Therefore, it is natural to expect that nuclear reactions at low energies should have a simple physical explanation.

However such explanation, which is not beyond the scope of existing representations, is yet to be found. Does not it mean that we are facing here the situation similar to that which has arisen in physics at the end of the 19th century and which has been figuratively described in the words: on the light sky of physics there are only two small dark clouds – the radiation of absolutely black body and the Michelson experiments? Let us remind that in order for these clouds to be removed, it has taken the revision of physical notions about electromagnetic field as well as about space and time.

As is noted in [8], there is a simple physical mechanism of nuclear transformations at low energies which existence follows from the quantum theory of electron as an open self-organizing system [9]. If two or the greater number of light nuclei appear inside free electron, more precisely, inside the area of basic localization of the particle, because of interaction of nuclei with electrically charged matter of electronic cloud, a force of attraction appears between the nuclei which may result in fusion of nucleus. This means that **cold nuclear reaction represents an intra-electronic process** which character is defined by physical properties of the own field produced by electrically charged matter of electron. The purpose of this paper is more detailed consideration of the mechanism above stemming from the spatial extension of electron.

In section 2 physical ideas are formulated and basic results are schematically presented of quantum theory of electron as an open self-organizing system. The theory outlined is necessary to elucidate the origin of the mechanism resulting in the occurrence of nuclear reactions of fusion and fission at low energies. The essence of the developed approach consists in that **the own field created by electron is treated as a congenital, integral physical property of electron, intrinsically inherent in the particle by the very nature of things and for this reason the own field and self-action are included in the definition of the particle** at the initial stage of formulating the theory. As is seen from the received results, electron represents a quantum (elementary excitation) of the field of electrically charged matter. It is a solition, which physical and geometrical properties are described by the non-linear and non-local dynamical equation similar to the known Dirac equation.

In section 3 the application of quantum model of self-organizing electron to nuclear reactions at low energies is considered. It is noted that because of the presence of simple physical mechanism of nuclear reactions at low energies, which is of a universal character, nuclear reactors represent, in effect, nuclear delayed-action bombs, which from time to time may blow up by virtue of the casual reasons. Hence, though nuclear stations may provide mankind with energy, however atomic engineering is a very dangerous way of energy production. The only acceptable way of solving the energetic problem consists in the use of nuclear reactions at low energies.

Quantum model of electron as an open self-organizing system

The basis for the standard formulation of quantum electrodynamics (QED) is the hypothesis that electron is a structureless point particle which does not experience self-action. This assumption results in serious difficulties – the divergences of mass and charge of electron and the impossibility to explain stability of the particle (see, for example, [10-12]).

The difficulties mentioned above are very serious. According to Dirac, **the difficulties of QED "in view of their fundamental character can be eliminated only by radical change of the foundations of the theory, probably, radical to the same extent as transition from the Bohr orbits theory to modern quantum mechanics"** ([13], p. 403). "Correct conclusion", Dirac emphasizes, "is that the basic equations are incorrect. They should be changed in such a way that divergences do not appear at all".

The main reason of occurrence of difficulties is the assumption that electron is a point-like particle. Therefore, abandonment of this hypothesis is inevitable. As an analysis of the problem shows, the key to constructing a consistent quantum theory of electromagnetism lies in taking account of the Coulomb self-action of electron, i.e. the back action of the own field created by charged particle in environmental space upon the same particle. In the special case that the particle is at rest in an inertial reference frame, own field of the particle turns into static Coulomb field.

E.Schrödinger who suggested the historically first physical interpretation of quantum mechanics put one of the boldest ideas concerning the problem of electron forward. According to Schrödinger's hypothesis, the quantity $e|\Psi(\boldsymbol{r})|^2$ (e and $\Psi(\boldsymbol{r})$ are charge and wave function of electron, respectively) is the density of spatial distribution of electron's charge and, consequently, **the linear sizes of electron are the same as those of atom** [14,15]. However, they did not succeed in substantiating the interpretation and, for this reason, it was rejected by the majority of physicists [16].

An important step to the correct understanding of the physical nature of electron was made by A. Barut and by his collaborators [16-18] who formulated and developed quantum theory of electromagnetic processes on the basis of self-energy picture (the Self-Field QED). Using expression for the total own energy of electron, they managed to calculate the Lamb shift and other radiative corrections and to show that radiative phenomena may be described in terms of the action function, without using the second quantization method. As is pointed out by Barut [17], "the correct quantum equation of motion for radiating electron is not the Dirac or the Schrödinger equation for bare electron, but an equation containing an additional non-linear self-energy term".

New lines of approach to the problem of electron are offered in [9, 19-24]. The formulation of electrodynamics is considered which represents a synthesis of standard quantum electrodynamics and ideas of the theory of self-organization [25]. The physical mechanism of self-organization of electron consists in self-action. Taking into account the self-action means that electron is treated as a feedback system.

Let us outline schematically the results of the formulation of quantum electrodynamics in which electron is an open self-organizing system.

Editor's note: The authors develop mathematics by using Lagrangian functions, 7 equations. You can contact the authors for more information about.

Thus, the negative result is received: we have tried to take into account self-action of electron in a natural way by supplementing the Lagrangian function with the self-energy term, but we came to an equation that has no reasonable physical solutions at all. This result seems to mean that the standard theoretical scheme reaches here the limits of its applicability and so, remaining in its framework, it is impossible to solve the problem of electron and elucidate the physical nature of electromagnetic interaction.

Essentially new point, which is introduced in [9] into quantum mechanics consists **in the replacement of the model of isolated system described by harmonic oscillator with the model of open system**. Let us advance the arguments indicating the inevitability of using the model of open system as a basis of the description of interaction between microparticles [26].

Note, first of all, that quantum particle theory based on the use of the models of isolated system is, strictly speaking, physically meaningless. Really, any observation conducted on a system represents a process of interaction of the system with the means of observation. But in case of microparticles (quantum particles) this interaction is not weak and consequently it is inadmissible to neglect it, i.e. microparticles should be necessarily considered as essentially non-isolated systems.

A starting point of the standard formulation of quantum mechanics is the physical idea that interaction between physical fields can be reduced to collision of the particles corresponding to these fields, the particles before and after collision being considered as free ones. According to these representations, quantum mechanics is based on the notions of "bare", non-interacting particles, with the interaction between them being considered as an additional factor which can only insignificantly alter the physical properties of non-interacting particles. However, such an approach to interaction between physical fields is obviously of an idealized character because particles constantly interact "with vacuum as with some kind of physical medium in which the particles move" [27]. Interaction of particles with vacuum fluctuations is not small and it cannot be removed.

It is well also to bear in mind that the necessary intermediary at studying micro-objects are the means of observations (the devices) with the classical field corresponding to them which should be taken into account in consistent quantum theory [28]. Inclusion in theoretical scheme of arbitrarily weak classical external field results in occurrence of non-zero width Γ of energy levels of "dressed" particles. The basic impossibility to isolate a real particle from vacuum fluctuations of the field and from the classical sources connected to the means of observation is indicative, thus, of necessity to take into account the non-zero width of energy levels of real particles [26].

The use of the harmonic oscillator model, when describing the interaction of electromagnetic radiation with substance, seems to be the main source of serious difficulties of the standard formulation of quantum theory, as such an approach means apparent neglect of those physical processes which, proceeding constantly, are responsible for inseparable coupling of real physical system to surrounding medium. Introducing artificial notion about switching on and switching out of interaction of oscillator with radiation field, we are able to calculate within the framework of existing theory the width of energy levels of oscillator, but we cannot assert with certainty that such an approach results in correct description of interaction.

From the reasoning given above it is seen that they are the models with energy levels of non-zero width that should form the basis for the description of interaction of radiation with substance. It is necessary to formulate such a quantum theory, which would take into account the energy levels of non-zero width Γ. The case in point is that one should introduce an infinitesimal damping Γ into the initial set of equations describing interaction of charged particles with electromagnetic field. Such an approach means the violation in infinitesimal of homogeneity of physical system relative to translations in time. Necessity of violating the homogeneity of time follows from that fact that in the usual approach (with $\Gamma = 0$) the states of the system of interacting fields have degeneracy of infinitely large multiplicity in relation to time translations. According to the fundamental Bogoliubov's concept of quasi-averages [29], when describing the behavior of degenerate systems, one should include into Hamiltonian an infinitesimal term removing degeneracy. In the theory presented here degeneracy of states of quantized fields relative translations in time is removed by introducing the infinitesimal damping Γ into Lagrangian. Thereby the degeneracy under study is removed already in the initial, zero-order approximation, which is of fundamental importance for the approach based on perturbation theory.

Formulation of the physical idea that quantum friction arises at the very elementary level - at the level of one particle is given in monograph [26]. Impossibility to isolate real particle from the surrounding world is that property which should be taken into account already in the one-particle theory (for each kind of particles), even before switching on the interaction with other particles. Model of the particle as an open system ($\Gamma \neq 0$) is attractive owing to the fact that from the very beginning the degeneracy of states relative to time translations is absent in it, the degeneracy, which is removed in standard approach by taking into account the interaction of particle with vacuum field fluctuations and classical fields. The basis for the developed formulation is the fundamental concept of quasi-averages supplemented with the requirement that the equations of motion of the particle with $\Gamma \neq 0$ follow from the action principle. It should be emphasized that the non-zero damping Γ is introduced into electrodynamics with the aim to establish the structure of the Lagrangian function, which takes into account the property of openness of physical system. After establishing the structure, the limiting transition $\Gamma \to 0$ is fulfilled.

In our opinion, the development of quantum theory will be inevitably connected with the use of models of open system; as such models reflect more completely the physical essence of interrelations in the real world. It is necessary, thus, to define more exactly the concept of openness of physical system, which, on the one hand, would describe real system accurately enough and, on the other, would be simple enough to describe the particular physical processes.

As open system has the richer physical contents in comparison with isolated system, some essentially new mathematical ideas are needed for its description. First of all, it is necessary to increase the number of independent dynamical variables describing the particle as open system. In papers [9,19-24], as a basis for the description of self-acting electron, the simplest model of open system is used which can be described by the Morse-Feshbach-Bateman Lagrangian function [30,31] and which was successfully used for the description of dispersive medium (the review of articles, in which applications of the model of open system to electrodynamics of dispersive medium are considered, is given in monograph [26]). In this model the number of dynamical variables is doubled as compared with the isolated system, namely, to each dynamical variable of "bare" particle, Ψ, there correspond two dynamical variables, which are denoted by Ψ and $\tilde{\Psi}$. These quantities are considered as components of the wave function describing the quantum state of self-acting particle. One of them, say, Ψ, corresponds in a sense to the particle alone (to the "bare" particle) and the other, $\tilde{\Psi}$, to the surrounding medium, in which the particle moves.

Editor's note: You can contact the authors directly for more information (8-16 equations).

Equation (16) coincides in its appearance with the usual Dirac equation for charged particle in an external field described by 4-potential . However, in reality, it differs essentially from Dirac's equation. The distinction consists in that **equation** (16) **is non-linear and non-local**, with the non-locality being of both spatial and time character. Potential ($A_{||}$) and vortex ($A_{\perp}$) components of the 4-potential, entering equation (16), differ from each other by their physical nature: the former describes the Coulomb field and is expressed quadratically in terms of the wave function components of electron, and the latter describes transverse electromagnetic waves and is expressed in terms of vortex electromagnetic field. As a detailed analysis shows, solutions to the basic dynamical equation describe the clots of self-acting electrically charged matter, localized in space, i.e. the particle is a soliton.

The internal energy spectrum of electron is discrete with an indefinitely large number of levels, and to each value of internal energy E_k (k is the set of quantum numbers) there correspond certain linear dimensions and geometrical form of the region of localization of electron's charge. Dimensions and the number of extreme of wave function increase with increasing the value of energy E_k. The distribution of electric charge of atomic electron in the ground state consists of the range of basic localization with the linear dimensions of the order of Bohr radius a_0 ($a_0 \sim 10^{-10} m$) and of the tail stretching up to infinity. It is essential that because of non-linearity of the dynamical equation of electron, wave function does not obey the superposition principle. By virtue of this, electron acquires the properties of absolutely rigid body: the perturbation acting on electron at an instant of time in the range of basic localization becomes known at the next instant $t + 0$ at any distance from the particle.

In Fig. 1 the results of calculation are represented schematically, carried out on the basis of equation (13), of the distribution of electric charge in atomic and free electrons in the ground (a) and first excited (b) states.

According to [9,19], the atom represents a system of nuclear and electronic solitons interacting with each other, the internal energy spectrum of the hydrogen atom, due to electromagnetic interaction, being of a zoned character. The occurrence of zoned structure of energy spectrum of hydrogen atom is explained as follows. Free nucleus, because of existence of Coulomb self-action, has a discrete internal energy spectrum. As the interaction of nucleus with electron is small in comparison with the energy of Coulomb self-action of the nucleus, it can be taken into account by perturbation theory. From here it follows at once that each energy

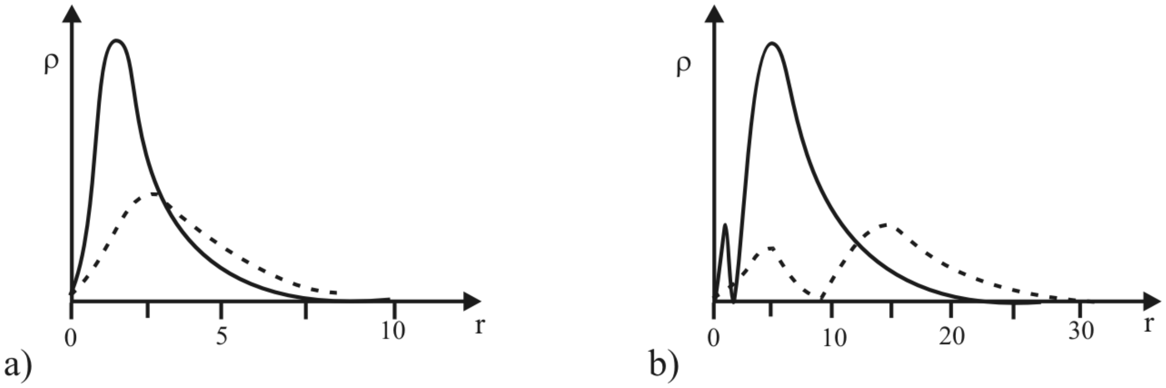

Fig. 1. Density of electric charge (ρ) of electron in the ground state (a) and in the first excited state (b): the continuous lines correspond to electron in the hydrogen atom, and the dotted ones to free electron, r is the distance from the center of mass of electron measured in Bohr radii.

level of free nucleus is split in a zone. There are indefinitely many zones (Balmer's replicas) and in each of them there are indefinitely many energy levels. The lowest zone coincides with the usual Balmer spectrum.

Physical mechanism of nuclear reactions at low energies

The quantum theory presented above schematically of electron as an open self-organizing system is indicative of the existence of the following mechanism of nuclear reactions at low energies [8].

If there occur in the region of basic localization of free electron, which linear sizes in the ground state of the particle are several times as large as those for hydrogen atom (see Fig. 1), two or the greater number of nuclei, each of them attracts on itself the adjoining areas of electronic cloud, resulting in compression of the electronic cloud as a whole. As a result, there appears automatically an attraction of the nuclei, which proved to be "inside" electron, on each other (see Fig. 2).

Calculation shows that the Coulomb barrier around nuclei is deformed, its height decreases and the probability of penetration through the barrier accordingly increases due to tunnel transition. Under certain conditions this process may result in fusion of nuclei. Obviously, the process in question can occur only at small energies of translational motion of the centers of mass of electron and nuclei: nuclei should be "inside" electron long enough for them to have time to come nearer to each other as a result of electron-nuclear interaction. This mechanism of nuclear fusion is of a universal character. In order for it to be realized, it is necessary to have only a stream of free electrons intensive enough, i.e. heavy electric current, and as long as sufficiently great number of free nuclei.

If heavy nuclei appear "inside" free electron, owing to their interaction with the electronic cloud there occurs polarization of nuclei. Because the own field of electron interacts with protons more strongly than with neutrons, nuclei are deformed (become extended), and this process may result in the decomposition of nuclei to fragments (in nuclear fission).

As is noted in [7], the official version of the reasons for Chernobyl accident contains serious contradictions, a number of facts concerning the accident has no convincing explanations, and this circumstance forces to search for the true reasons for the happening, since

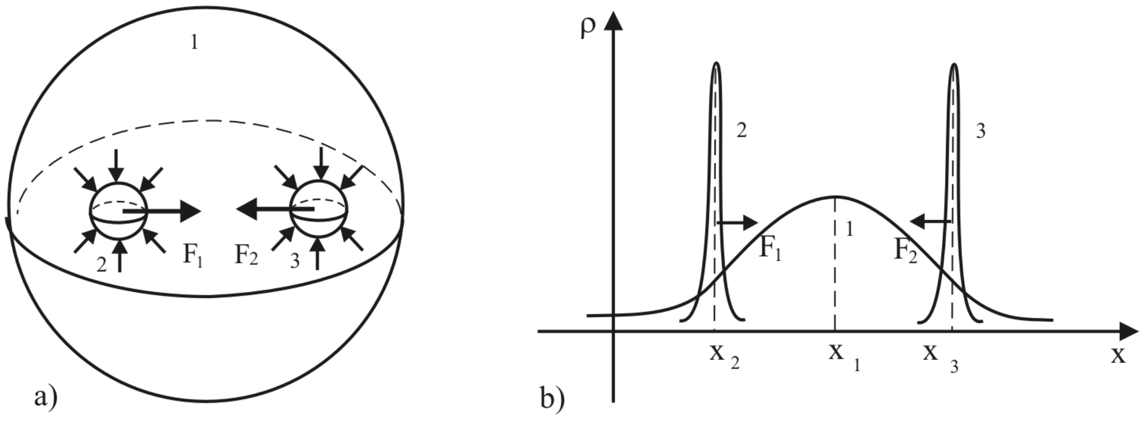

Fig. 2.
The schematic image of interaction of nuclei with electronic cloud: (a) 1 is the region of basic localization of electron, 2 and 3 are nuclei, F_1 and F_2 are the attractive forces between nuclei, which appear at the expense of electronic cloud compression induced by Coulomb forces; (b) ρ is the charge density, 1 is electronic soliton, 2 and 3 are nuclear solitons, X_n (n=1, 2,3) are coordinates of the centers of mass of particles.

"not having understood the mechanism of the one tragedy, we sooner or later shall become witnesses of the other". The authors hypothesize that the reason of the accident was penetration into the nuclear reactor of magnetic monopoles, which have caused the decay of nuclei ^{238}U, and this has resulted in production of delayed neutrons, growth of power output of the reactor and explosion. As an argument in favor of the assumption, the fact is presented that nucleus ^{238}U are disintegrated under the action of "strange" radiation appearing at explosion of foil.

In the opinion of the authors of [5,7], "strange" radiation is created by those magnetic monopoles, which form bound states with nuclei of atoms. These compound particles give the abnormally wide tracks similar to those of a creeping caterpillar, and also the tracks of complicated shape reminiscent of spirals and gratings. Character of tracks changes when imposing magnetic field, which, as the authors believe, is an argument in favor of the assumption above. There are also some special tracks very similar to scratches and ink spots. "Strange" radiation is of spherical form, it resembles a ball lightning, and its duration is more than ten times as great as that of the current pulse arising at electric discharge. With the course of time the luminous sphere (the ball-like plasma formation) is dividing into many small "balls".

It is our opinion that "strange" radiation is caused by free electrons in excited state arising in the area of electric discharge. According to [9, 19], linear sizes of the region of basic localization of such electrons can make many tens of sizes of atom. The heavy nucleus, for example, the nucleus ^{238}U, appearing inside the electronic cloud, is inevitably deformed because of interaction of protons with adjoining layers in the distribution of electric charge of electron, and this deformation can cause nuclear fission. If two or the greater number of light nuclei appears "inside" electron, then attractive forces arise between nuclei, which may result in fusion reaction. When electric discharge is strong enough, the areas of basic localization of some electrons can overlap, and if a nucleus lands in the area of overlap, because of Coulomb attraction of nucleus on the adjoining layers of electronic clouds, a bound state may be formed, of two electrons and the nucleus, characterized by the relative stability and significant spatial extension.

Obviously, if the concentration of free electrons is great enough, there may be formed some relatively stable bunch of plasma consisting of great number of free electrons and nuclei, which in virtue of chaotic movement of nuclei and because of the absence of preferred directions should have approximately spherical form. Let us note that atomic electrons, belonging to additional energy zones of atom (Balmer's replicas associated with nuclear self-action, see Section 2) can contribute to "strange" radiation.

As is seen from above, to account for the reasons for Chernobyl accident, there is no need to involve magnetic monopoles. The scenario of development of events during the accident, described in [7], seems to be quite plausible if only to understand by initiators of nuclear fission not hypothetical monopoles but free electrons, which powerful pulse might arise as a result of electric discharge in the region of turbo-generators.

The existence of simple physical mechanism of nuclear reactions at low energies, indicated in this paper, implies that nuclear reactors are, in effect, nuclear delayed-action bombs, which will blow up from time to time. Explosion of nuclear reactor may take place because of casual short circuit at an electric subcircuit, owing to which there appears an intensive stream of free electrons. This stream, having got for any reasons in nuclear reactor, may initiate explosion of the reactor. It follows from here that though nuclear stations may provide mankind with cheep energy, atomic energetics represents a very dangerous way of producing energy (as well as the energetics using controlled thermonuclear fusion). The only acceptable way of resolving the energetic problem consists in the use of nuclear reactions at low energies.

According to the results obtained, nuclear reactions at low temperatures occur "inside" electron under the action of own field of particle. Hence, to elucidate physical mechanism of CF, it is necessary to study in detail intra-electronic processes and physical properties of own fields of particles. Note that the own field, by its physical properties, essentially differs from the field of electromagnetic waves: this is the field of standing waves of matter, it is of purely classical character and may not be reduced to the set of photons. The own field of charged particle plays in nature a special role, consisting in that it transforms environmental space into the physical environment (physical vacuum) with the properties of absolutely rigid body [32].

As it was repeatedly noted in the literature [1,2], experiments on CF are badly reproduced, and this fact gives rise to doubt the very existence of the phenomenon. Bad reproducibility of results seems to be explained by the fact that CF depends upon great number of parameters: upon electric current density, concentration of free nucleus, concentration of impurities and dislocations in samples, sizes of samples etc. In order to obtain reproducibility of results, it is necessary that all these parameters, describing the environment in which nuclear reactions occur, be the same in various experiments, but to achieve this as a difficult task.

In conclusion we shall dwell upon the problem of linear dimensions of electron, which is of special interest in connection with the mechanism of nuclear reactions indicated here. The inference that the dimensions of electron in the ground state of atom are of the order of Bohr radius, i.e. of the order of atomic dimensions, following from dimension considerations [9,19] and confirmed by quantum model of electron, seems completely unexpected. At first sight, it is in conflict with both the theory of quarks and experimental data on scattering of electrons. According to quark models, the radius of electron corresponding to its quark structure makes up the quantity of the order of 10^{-22} m [33]. It is necessary to emphasize, however, that the above-mentioned magnitude of linear dimensions of electron refers to the internal structure induced by Coulomb field. The last is long-distance and consequently the linear dimensions of internal structures produced by it (i.e. spatial inhomogeneities in the distribution of electric charge in various quantum states) should considerably exceed the dimensions of quark structures connected with electron. There seems to exist a hierarchy of internal structures of particle produced by Coulomb forces, nuclear forces, inter-quark interactions etc. characterized by the smaller and smaller linear sizes.

As to the experiments on scattering of high energy electrons, according to which the internal structure of electron is not manifested up to distances of the order of $10^{-16} \div 10^{-17}$ m, two arguments, at least, can be adduced in favor of that there is no contradiction here with the experiment. Firstly, in experiments on scattering, investigators were trying to register the details of internal structure of electron within intervals much smaller than Bohr radius, which is why it is not surprising that results of experiments proved to be negative: at high energies electrons behave like point particles, their internal structure has no time to be manifested. Secondly, the results of experiments were analyzed from the point of view of standard representations about electron, which refer to a point particle, but are obviously inapplicable to real, self-acting electron. According to the predictions of quantum theory of electron as an open self-organizing system, real electron is a special object - soliton, i.e. such a cloud of electrically charged substance which, when interacting with other particles, tends to keep its sizes and geometrical form.

At present there is as yet no scattering theory of this kind of particles and for this reason it is impossible to predict with certainty how can the internal structure of electron be manifested in experiments on scattering.

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The Evolution of Lifter Technology

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INTRODUCTION

Readers of the electric-spacecraft journal might know a little about the Lifter technology popularized recently be Jean-Louis Naudin, but they probably don't know the whole story. In the short amount of time that has transpired since the publication of that article, this technology has both literally and figuratively taken off – going from a "proof-of-concept" prototype by Naudin to an international group of researchers investigating how to give the lifter higher-performance and greater efficiency. With the first commercial products now on the horizon, if you haven't taken the time to read up on lifter technology, this is the perfect time to do so. . .
To give you a complete up-to-date overview of where this technology is, where it is going, and what I think it is capable of, let me start with the basics – an overview of how I became involved with Electrogravity research and what eventually led me to become involved with lifter technology.

MY BACKGROUND

I started college at 16 years old, back in 1992 – at the same time, I purchased a kit containing "hoverboard plans" from Hovertech, Inc. The moment that I received that $20 white-manilla envelope in October 1992 was the moment that I became involved with what has now been nearly 10 years of electrogravity research.

I worked with Bill Butler – the president and chief-scientist of Hovertech – on a variety of different antigravity, Electrogravity, and levitation ideas from approximately 1992 through 1996. While putting in my college time, I was also taking distinct advantage of the enormous college library at Western Washington University to read up on everything that might possibly relate to Electrogravity. I read books on standard electronics and physics theory alongside with books by the masters of this science, such as TT Brown and Nikola Tesla.

Bill and I played with several different ideas – many of them only peripherally related to Electrogravity. For instance, I published a manuscript initially in 1996 describing Tesla's theory on how to reliably produce Ball-Lightning using a standard Tesla coil – the information courtesy of WWU's excellent library. Bill also assisted me with obtaining video footage of a Searl-effect conference that he attended in Denver in the early 90's – this footage was an excellent overview of Searl's design and construction concepts for what he believes is the next major technological step in aviation and space travel.

Bill and I eventually found different paths, and in some ways drifted apart. Bill moved into Geomagnetic levitation research and started intense investigation on the patents of How Wachspress and the magnetic dipole levitator. I went to more traditional technologies – eventually becoming a UNIX system administrator for AT&T Wireless.

I hadn't heard from Bill Butler in about 6 months when he sent me a short email containing the words "hey, check this out" – and a link to Jean-Louis Naudin's "Lifter Experiments" home-page. I visited the site, watched all of the video clips, and then watched them again. This was the technology that I had been waiting for!

LIFTER TECHNOLOGY

I can say without a doubt that the lifter technology is completely revolutionary, but you might not realize how profoundly revolutionary it is until you've stopped to think about it for a bit. What is it about the lifter that makes it so unique, especially when so many inventions claim to produce more and better electromagnetic thrust? The answer is simple – the lifter works repeatedly.

Jean-Louis Naudin started a figurative bonfire when he decided to replicate a "proof-of-concept" experiment by a small Huntsville, AL aerospace contracting firm. The lifter initially came into being in the mind of Jeff Cameron – the chief scientist of Transdimensional Technologies – in the 1970's from experiments conducted with high-power military and research-grade lasers. A device in the lasers called a "pre-ionizer" was used to apply a high-voltage to the lasing-medium to facilitate better performance. Repeated operation of the pre-ionizer had a common side-effect of horribly twisting the wire and foil combination out of shape, which required a decent amount of work to repair.

Jeff Cameron realized that the torsional effect on the pre-ionizer was a side-effect of some unknown force acting on the pre-ionizer apparatus, and he began a long-term investigation into what was causing the apparatus to deform. His eventual results indicated that a force in the foil collector in the pre-ionizer was causing a net-thrust in the entire pre-ionizer apparatus that was making it twist and move on its mounts within the laser – the lifter came to him later as a three-dimensional device to demonstrate this force.

Naudin's genius became readily apparent not through a giant breakthrough in technology, but rather in a more subtle fashion – he replicated the lifter experiments of Transdimensional Technologies and published videos, articles, and complete construction plans on his website to allow others to do the same. In a manner similar to the open-source software movement, Naudin had taken an incredible scientific find that might have otherwise been overlooked and done and incredibly charitable and intelligent thing – he gave it away for others to play with. By following Naudin's instructions, inventors all over the globe began to slowly replicate the

Transdimensional Technologies experiments and thereby validate the proof of concept that Jeff Cameron had created to show that his "mystery force" was real after all. Naudin of course took advantage of these replications of the experiment by showcasing them on his own website – which in turn lends additional credibility to his research.

As far as technology goes, the lifter demonstrates that science and engineering have more than their share of humorous irony. For the years that I researched Electrogravity and antigravity claims, all of the devices that I had seen required something "magic" to make them work. For instance, Bob Lazar's UFO-claims could have been reverse-engineered except that they require 'element 115' to make them work – an element chemically related to Bismuth that is theorized to potentially have electrogravitic properties. I will come back to the possible electro-gravitational properties of Bismuth in a bit, as it turns out that this element may in fact provide some use for future lifter technology.

The Searl-effect disc is an even better example of the "magic" usually involved with building a working Electrogravity device. Searl's ideas seem valid enough, but although he supposedly demonstrated several working prototypes in the 1950's, he is currently pursuing millions of dollars in research funding in to replicate those experiments in a modern-day setting.

The irony involving lifter technology is that while inventors all over the world have been searching for the perfect electro-gravitational device for decades, the possible working proof of concept for many of these theories has been sitting in front of us the whole time – the lifter costs less than $10 in parts to build, and none of them are magic – in fact, for my experiments, all of them were at stores within 2 blocks of my house — balsa wood from the craft store, aluminum foil from the supermarket, 30-gauge magnet wire from the local Radio Shack, and an old computer monitor for the high-voltage power-supply.

LIFTER PHYSICS

Whether or not Jeff Cameron knew it at the time he constructed his lifter prototype, what he was actually building was a 3 dimensional representation of a drawing on a patent application by TT Brown in the 1950's. In the patent application, the drawing shows a positively charged wire suspended over a grounded foil body which was meant to demonstrate the most basic Biefeld-Brown effect generator. While Brown's drawing is a little different than Jeff's design, the resemblance is uncanny enough to indicate that both of these men had the same basic force in mind.

TT Brown's patent indicates that this Biefeld-Brown effect generator works due to a gradient electrostatic-field between the wire and the foil – in essence, these two elements compose a low-efficiency, high-voltage air-gap capacitor in which the difference in geometries between the two capacitive elements generates a net-directional force from the larger element towards the smaller element. Jeff Cameron seems to have a practical axiom that goes along with this scientific philosophy, which is that there must be both a leakage current and a capacitance between the wire and the foil in order for the lifter to function.

Conventional physics says that two capacitor elements of different sizes will not generate a net-directional force, so what gives? This is actually the thinking that convinced me to abandon my research into Biefeld-Brown effect technology in 1996 – physics says it doesn't work. What the books say will happen is that since the wire can only maintain a lower-capacitance than the foil, the overall capacitance between the two elements will be reduced to be equivalent to that on the smallest element (or plate) in the capacitor. This, of course, assumes a 2-element series-wired capacitor, such as the lifter.

I can give you the conventional physics answer to this small riddle by simply saying that the lifter uses a manifestation of ion-wind. This would state that the electrons crossing the air-gap cause a breeze that causes thrust – since the breeze would be traveling down from the wire to the foil, the thrust would be up, as demonstrated in testing. In the ion-wind explanation, the electrons are emitted from small-diameter of the positively charged wire in such great abundance that they move a significant airflow down to the foil where they are absorbed and transported electrically back to the HV power-supply's electrical ground.

Conventional physics would seem to have the theoretical answer to why the lifter causes lift, but in the experimental setting, which is what we now have an abundance of thanks to Jean-Louis Naudin, the conventional physics explanation doesn't suffice. Experimentally, there are several deviations from the ion-wind explanation that seem to invalidate it. For instance, if you completely contain the lifter in a plastic-enclosure, it will still generate lift – this would not be the case if a breeze was responsible for lifting the device. How could it be, if the breeze is limited to the inside of an enclosure which itself is levitating?

A more compelling proof that Biefeld-Brown is something other than ion-wind comes from Purdue University, where the lifter experiment was replicated inside a vacuum-enclosure with positive results. While ion-propulsion can work in space, it usually assumes that there is argon, krypton, or other noble gas to be used as the propellant – the vacuum enclosure showed that with no gas available for transport the lifter showed a moderate improvement in performance.

The vacuum enclosure tests are definitely compelling evidence that something else is going on other than ion-wind – at least compelling enough for NASA to file patent number 6,317,310 – "Apparatus and Method for Generating Thrust using a Two Dimensional, Asymmetrical Capacitor Module". The NASA patent description – which can be accessed from Naudin's lifter website – is as vague is it is compelling in that NASA is basically requesting a patent on any technology that generates force using two geometrically dissimilar capacitive plates. Disregarding the fact that this patent was issued nearly 50 years after TT Brown's patent using nearly identical descriptions and pictures, and also disregarding the fact that NASA also doesn't understand why the lifter generates thrust, it seems apparent the this phenomena is gaining credibility in engineering circles while physicists seemingly continue to deny that anything is going on.

THE EVOLUTION OF LIFTER TECHNOLOGY

Every good movie always has a sequel, and in technology, if at first a major government agency 'liberates' your idea, it may seem that a sequel is in order. In the case of the lifter, it would appear that the NASA patent would cover this technology to at least some degree – at least until someone overturns this patent under the prior-art rule – which means that the next generation has to be considerably more advanced to escape having the research and development be forfeit to the government.

The pursuit of more advanced versions of the lifter technology is currently underway by several independent inventors, as well as Transdimensional Technologies themselves. Most of the private research by inventors has delved into improving the current lifter design to produce a greater force output and utilize less power to do so. Because the lifter is so simplistic in design, many of these enhancements have been of a very basic nature.

Jean-Louis Naudin was the first independent inventor to do serious work with improving the technology behind the lifter – and even so, the majority of his work has utilized similar materials in more complex arrangements. Naudin has demonstrated dramatically increased lifting forces by building a "lifter inside a lifter" for demonstration purposes. Naudin has also done a great deal of work in taking breaking up the concept of the single triangular lifter into a parallel series of lifting cells – which means that these cells, working in parallel, can contributed to greater stability and higher force output than any single lifting element.

Saviour – an independent inventor working with Jean-Louis Naudin – has done some of the most interesting improvements on lifter design since those by Naudin himself. Saviour's concerns have not focused around the "bigger is better" philosophy that many inventors have stuck by – he has done several experiments to determine the radiation output, remote-controlled applications development, and materials analysis and improvement on the lifter that others have not had the time or expertise to conduct.

A recent experiment by Saviour demonstrates just how this gentleman's foresight is helping other experimenters – Saviour substituted nichrome heating wire for the common lightweight wire used for the emitter, and demonstrated that the lifting force greatly increased when a higher potential 12-volt charge was used to heat the emitter wire in conjunction with the standard high-voltage charge coming off it.

Transdimensional Technologies – the developers of the initial lifter design – are taking the approach to optimizing lifter performance to another level. They are currently not-so-secretly working on a 2nd generation lifter, which will consist of a 1-piece layered material to replace the current wire and foil design.

The layered material approach to the lifter is an idea that Jeff Cameron may or may not have had after some lengthy discussions with Travis Taylor – the man responsible for testing some anomalous materials known as "Art's Parts".

Art's Parts were some pieces of material sent by an unknown person to the Art Bell radio talk-show with a note stating that the they were pieces of UFO wreckage taken from the often-cited "Roswell crash" in 1947. Whether or not the pieces of material actually came from that crash is unknown, but Art Bell did the honorable thing by sending them to an acquaintance in US Army research named Travis Taylor for a professional scientific investigation.

Taylor, who apparently tested the materials after-hours in a world-class research lab to avoid potential classification by his superiors, used an electron-microscope to determine that the layered materials were actually pieces of metal – containing several hundred microscopically thin layers of magnesium and bismuth. Taylor also tested the layered-metal with a high-voltage apparatus, which seemed to indicate that when a voltage was applied to the material, the layered metal would move – and in some cases levitate.

Taylor reported his findings to Art Bell and sent video clips of his high-voltage experiments, which eventually made it back to a permanent home on the Art Bell radio show website. In addition, Taylor conveyed his belief that the only manner in which the pieces of metal could properly be produced was through an advanced form of electron-deposition technology, due (apparently) to an absence of oxygen-molecules between the different layers of metals. Additionally, the layers of metal were too thin to have been mechanically produced.

Jeff Cameron indicated that Transdimensional Technologies maintained some contact at one point in time with Travis Taylor, apparently as professional colleagues in the defense community in Huntsville, AL. I am not an expert on this relationship, other than to say that to the best of my knowledge these two individuals knew and contacted each other, and that this is how Jeff Cameron might have come up with the 2nd generation lifter idea.

ADVANCED LIFTER TECHNOLOGY

As an inventor, I couldn't care less whether or not the idea for the technology came from a crashed UFO. To be perfectly honest, I'm not what you would call a "believer" anyways, although I have often wondered about it. My point is not to attempt to lend any credibility to "Art's Parts", but rather to tie in the properties of the anomalous material's high-voltage movement with the underlying theory of lifter operation.

Even mentioning a UFO in a respected publication or article is the kiss of death in today's world – and I wouldn't do it if it wasn't an intricate part of the story. The other interesting thought is that the layered material is once again partially composed of Bismuth – which is thought to possibly have some of the same electro-gravitational properties as Bob Lazar's Area 51 "element 115". Is there a similarity, or merely a coincidence between a claim that hasn't gained credibility and a technology currently under development?

The lifter in its own right is essentially a layered material. One of those layers is the emitter wire, which is highly charged with about 30kV worth of electrons, another layer is the air-gap, which is approximately 3 cm in height, and the final layer is an electrically-grounded "skirt" of aluminum foil that surrounds the lifter. It is also reasonable to expect that there are only two possible forces at work in the lifter – one of which being a possible ion-wind effect moving down from the emitter to the foil, and the other being a possible Biefeld-Brown effect, moving up through the foil to the emitter.

There are a few shortcomings in the lifter as a design that might be overcome if we could transition the layered material from one containing an air-gap to one that does not. For instance, the lifter is currently a rather delicate object, in that having a wire under tension as the emitter makes construction difficult for future automated assembly. Additionally, because the air-gap requires struts to support the emitter wire, a trade off involving the weight versus the strength of the struts is additionally involved in any current implementation of lifter technology.

Some of the other changes that would be helpful to implement when transitioning lifter technology from one type of air-gap to another are changes in the materials used to increase the dielectric capacity. High-K dielectric materials may be used to increase the displacement of electrons in the material to enhance charge transport. And since increasing the dielectric potential of the layered materials also increases the breakdown resistance, it means that thinner materials can be used.

Designing a lifter without an air gap would accommodate lower voltage requirements between the foil and the emitter. The voltage would not have to create the large e-field gradient to create a leakage current across such a large void. Therefore the overall voltage across the device could be greatly reduced, without much cost in thrust. A lower operating voltage in turn means that a lower-output power-supply can be used for a given amount of current, which increases the overall efficiency.

Transdimensional Technologies recent research is utilizing the layered materials approach to eliminate the air-gap and substitute for it high-k dielectric materials that may allow higher overall performance. Although they have not yet released details about the exact composition or thickness of the materials that they are working with, they claim to currently have a 10% reduction in weight using a low-voltage current across the thickness of their newest device.

FUTURE LIFTER TECHNOLOGY

Thanks to the tremendous amount of research being done on lifter technology by Transdimensional Technologies and a loosely affiliated group of inventors around the world, the future of lifter technology seems very bright at this point.

Transdimensional hopes to release some breakthrough research to allow replication of their newest 2nd generation experiments in the very near future, and along with that stands the massive body of research and advancements being done by inventors and researchers such as Jean-Louis Naudin, Saviour, the Lifters-group, and myself.

My personal goals are to attempt to assist Transdimensional Technologies in popularizing this technology to increase awareness of it and help "spread the word" about what it is and how it can potentially help the world.

Imagine if instead of getting in your car and driving through the usual maze of thoroughfares and side streets you were able to simply type in your destination and have a flying vehicle take you there automatically. The lifter technology offers to potential to transform the current transportation market by offering point-to-point aerial transport without the need for roads or freeways.

Additionally, unlike the magnetic-levitation ("Maglev") technologies that are currently being promoted as the future of transportation, the lifter does not require a specially constructed and exorbitantly expensive track to operate – the greatly reduces the per-unit cost on the technology and opens the door for wider adoption by the general public for transportation solutions.

Other individuals are currently working to see if lifter technology may offer cost-effective methods of transport into space, which would reduce the cost greatly and allow a one-piece, reusable method of moving things into orbit.

LIFTER RESOURCES

All of the research involved with the lifter technology is available to the public on the internet. The list of resources below are some of the better and more common resources to obtain detailed lifter information.

American Antigravity
→ http://tventura.hypermart.net

→ The author's website that includes video clips, complete instructions, and other related lifter information.

Jean-Louis Naudin's "Lifter Experiments Website"
→http://jnaudin.free.fr
→ A very in-depth website containing video clips, complete instructions,

World-Wide Lifter Replications
→ http://jnaudin.free.fr/html/lftwrld.htm
→ An overview with photos and video from many of the independent inventors who have replicated the lifter experiments.

Transdimensional Technologies, Inc
→http://www.tdimension.com
→ The home page for Transdimensional Technologies, the developers of the lifter design.

Blaze Labs (Saviour's Research Website)
→http://bel.150m.com
→An excellent site on research into lifter enhancements, radiation testing, sealed devices, power supplies, and other topics relating to lifter technology.

Lifter Builders Group
→ http://groups.yahoo.com/group/Lifters
→ An email group for the exchange of research findings for those interested in building lifters or staying current on the state of the technology.

NASA Patent #6,317,310
→ The NASA patent regarding obtaining thrust from an asymmetrical two-dimensional capacitor, grant Nov 13, 2001.

Research on the Capacitance Converter of Environmental Heat to Electric Power

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Nickolay E. Zaev works on creation of the prototypes of converter energy, which do not require any fuel. The direct conversion of environmental heat to electric power is possible in the processes of "charge-discharge" in non-linear condensers or by means of "magnetization-demagnetization" of ferrites. Such converters of energy create cold and electric power without any fuel.

Theory of the converter, results of early experiments on the generation of microwatt power, methods and features of research are given in this article. The methods of generation of a few watts power are described in details. The possibilities and difficulties of creation of powerful capacitance converters are discussed in this article.

I. Grounds of research.

1.1. From positions of orthodox physics there is no subject of research. It is evident that the energy of charging (C) A_c condenser C_x is always equal or more than the energy of discharging (D) A_d, i. e. always $A_c \geq A_d$. Only the advanced analysis shows that it is not always true. Exactly, in C_x, where $\frac{\partial C}{\partial V} < 0$ an inequality $A_d > A_c$ is possible, and in C_x, where $\frac{\partial C}{\partial V} < 1$, then the work $A_c > A_d$. Therefore we should discuss the nonlinear capacitors (NC). In the end of 1969 I noticed a systematic inequality $A_d > A_c$ during the measurement of A_c and A_d of many capacitors with different dielectrics. Theoretical grounds and results of measurements of this phenomenon are given in the publications in 1984 [1], [2, page 73]. On the industrial standards NC (varicond), ceramic condensers VK2-ZSH, $4 \cdot 6{,}8 \cdot 10^{-9}\mu F$ with an optimal voltage about 95 V it was stated that $\frac{A_d}{A_c} \sim 1{,}21$ with the power to about $98 \cdot 10^{-6}$ Wt and "generated" extra power is equal to $21 \cdot 10^{-6}$ Wt.

1.2. In [1] and [2] the strict theoretical proofs of realization of $A_d > A_c$ (there are four of them) are given. On $1 m^3$ of dielectric $|A_d| - |A_c| = -\frac{1}{2} a \cdot \varepsilon_0 \cdot E_c{}^3$ (E_c is an intensity of the field, V/m; ε_0 is a dielectric constant of vacuum, a is a coefficient of nonlinearity of the capacitor). Below we state one more proof more connected with the parameters of circuit.

It is well known that with the charge of a linear capacity from the source of constant voltage V_0=const through the resistor R=const it gets an energy $A_c = \frac{C \cdot V_0{}^2}{2}$ exactly equal to the output energy in the time of charging t_c. The output energy irradiated from the load R is a Joule heat $\Theta = R \cdot \int_0^{t_c} i^2 \cdot dt$ [3, page 546]. If NC (nonlinear condenser) is charged, then there are no proofs of such equation. The NC are the variconds or other capacitors, which have $\frac{\partial C}{\partial V} > 0$ in the interval $V = 0 \div V_k$. For the variconds V_k is some voltage, which corresponds to the maximum C_v. If $V > V_k$, then $\frac{\partial C}{\partial V} < 0$. For some other capacitors V_k is a voltage breakdown.

For further consideration let's believe that in the operating area of the given sample of varicond a function

Reality and Consciousness in Education and Activity

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Relation of thought to existence is the main question of philosophy as science on general laws of Nature was formulated but it still did not interpreted and solved in the frames of generally accepted logic standards. The ways to solve it lead to futile discussions of materialists and idealists, to senseless disputes of determinists with eclectics and apologists of the "chance". This discussion lost its sense without a determination of terms under discussion and condemned debaters to have subjective "gustatory" senses, which were changing while aging and depended on the extent of received and conceived knowledge. Such is the situation in this link of World studying, which does not allow creating a logic chain of reasoning in the understanding of cognizable things.

A paradoxicality of all things that happen is connected with incorrect translations and interpretation of wisdom of ancient philosophers and scornful attitude both to the knowledge of distant past and classical heritage, which highlighted the elements of natural-science approach to Weltanschauung.

According to Plato, **an ideal thing** is a visual thing, which can be felt by our organs of sense. Therefore, the understanding of objective reality is mediated by the crowd of our feelings in such a way that perception of reality by means of these feelings gives us a notion of the World. Hence, **our notions about reality are the subject of research in science, but not the World itself, i.e. the World outside of our consciousness.** So, what should be studied in our notions about the World? Let us refer to the wisdom of ancient scientists again: " The World is given in motion and its laws are the laws of motion". Then, we should speak about laws, order, i.e. about relation and interrelation in the phenomena of motion. This is the distinctness in notions and actions (determinism) to predetermine further development of reality cognition logic, i.e. what has an influence on us and determines specific character of our perception. Further we can speak about formation of ideas about reality, which require some premises, principles to organize these ideas. These principles are given in classical heritage, in "Dialogues" by G. Galilee [1] and "Mathematical principles of natural philosophy" by I. Newton [2]. A notion of force as a measure for momentum was introduced, which manifests in action and disappears from the body after the action is over, and the body keeps its new state due to the inborn "inertia force". **But the force itself cannot do anything without its application with a certain speed.** Then we introduce a notion of action as a product of acting force F_A and the speed of action V_A.

We offer a law of interaction, which determines the interaction between action of the cause and the effect appeared during this action as a reaction, i.e. the product of the force of reaction F_R and the speed of reaction V_R. Thus, this interaction between the cause and the effect is determined by the transfer of action from one object to another in equal quantity, but with appearance of new quality, which is determined by specificity of interacting objects according to fundamental law of interaction:

$$F_AV_A=-F_RV_R.$$

Unfortunately, an incorrect interpretation of interaction manifestation as an opposite counteraction became strong in our mind. This manifestation is perceived as a compensation of cause by action of the effect. Moreover, the incorrect way of writing of the mathematical form of Newton's third law manifestation established in textbooks and scientific literature due to the incorrect translation as $F_A=-F_C$. This very tragic situation for the science suppressed the development of logic in description of processes. Chance and statistic approach to the description of phenomena has taken place in our perception. This approach is based on the model of non-interacting elements, in which there is no order stipulated by the interrelation of elements. The science has developed this model and its properties, and this fact predetermined the evolution of notions about real World.

This ideology penetrated in mathematics, which for sake of physics began to study properties of objects, but not operations with them. Moreover, a possibility to reflect specific character of real physical processes in the interconnection of cause-effect relations by mathematical operations is not realized. It is essential, that fundamental law of interaction establishes manifestation and description of elementary act of cause and effect interrelation, **the law of manifestation of a Fact.** It means that order in the World is conceived through manifestation of concrete facts. The action of law of interaction lies in the basis of these facts.

So, there is a conclusion: the World is perceived through the discrete manifestation of motion forms evolution. Hence, the discrete mathematics of finite discrete aggregate can be applied to describe the World, but not the continual mathematics, which lies in the basis of traditional orthodox physics. All these circumstances lead to numerous problems and difficulties in description of our notions of reality, to the plenty of used principles, which are in contradiction to each other, as R. Feinmann noticed once [3].

And what we can get from determinism, which is based on fundamental law of interaction, law of cause and effect interrelation? **The change of force value in a reaction takes place, i.e. the change of value of the potential gradient, i.e. the change of energy**

concentration. This circumstance is visually demonstrated by the operation of Archimedean lever as well as in all phenomena of the real World. This is Archimedean lever, where the loss of speed takes place, but there is a gain in force. And the load raised on a lower height than the way, which was made by the applied force, will give a huge power during its free fall. This power is higher in so many times, in how many times the time of the load fall is less than the time of action spent on its raising! And this is the fact, which determines specific character of **creation in the real World**. We should attribute both quantitative and qualitative characteristics to energy. This is the side of energy manifestation, which is reflected in Plank's formula: energy is proportional to frequency.

Manifestation of fundamental law of interaction also lies in the basis of general universal regularity of evolution of real many-particle systems with the change in external conditions. This process develops in multistage way, and on the each stage the logarithm of the ratio between the event happened and the event to happen always is equal to the work of external forces. In other words, the relation of the event happened to the resource is in exponential dependence on the initial conditions and extent of external influence. Exponential character of development of processes is the evidence that Nature develops according to the law, which conserves itself during evolution. This regularity, which manifests everywhere, can be naturally called **the Principle of Order.**

Fundamental law of interactions and Principle of Order appeared to be enough to describe and understand phenomena in the observed World. And it is natural to expect that this principle of Nature manifest in finer World also. This World includes lower and higher frequencies, which are not available for us yet to watch this wide-range frequency-wave emanating Universe.

From all aforesaid we should make a conclusion that the logic, which exists in the traditional physical tool, appeals to the model and principles of the World of non-interacting elements using the range of regularities, which also reflect some features of the real World, but they do not include fundamental law of interaction and Principle of Order, which are necessary and sufficient to describe reality. Descriptions existing in traditional physics are phenomenological ones and concern only those aspects of the phenomena under investigation, which do not include possible qualitative changes during development of processes, because the main property of real processes of interactions (creation of new energy property) was excluded.

The current situation in physics had a strong influence on formation and development of other sciences, other fields of knowledge, since the logic of reflection of cause-effect links was initially excluded. These are the links to determine existence, i.e. existence of constant creation of the World. All these circumstances give grounds to fundamentally revise educational programs, first of all, in physics, philosophy, mathematics, chemistry and biology. A change to the offered logic of cognition, which is based on the Principle of Order and fundamental law of interaction, will fundamentally change our notions about the World as well as will open big opportunities for new technique and technology. A Man has got huge opportunities in cognition and existence, but due to his immorality and features of incorrect aims in the logic of cognition he cannot use these gifts of Nature. We present wider and deeper view on the World and a Man in it, which allow analyzing, watching and operating with those fields of reality, which manifest in finer World, World of higher-frequency energies and other structures of fields. Logic of cognition had not touched these structures yet.

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Old New Energy

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Two kinds of energy, accumulated energy [1] and free energy [2], are considered as an inexhaustible source of natural energy created by Nature itself. It is ecologically clean and possible to be renewed in natural conditions.

The energy accumulated in substance is released as a result of partial decay of substance in elementary particles. At that, the acquired defect of mass is so small that it does not change chemical properties of substance and is compensated in natural conditions. Physical mechanism of energy-release lies in the fact that an electron in plasma layerwise takes sufficiently smaller elementary particles (electrino) from positively charged atoms or fragments of substance (ions). Electrino give their kinetic energy to plasma, heat it up and move beyond the bounds of reaction zone in the form of thermal and optical radiation. There is no substance, which could not take part in such process of energy-release, i.e. phase transfer of higher form (PTHF). The most appropriate, available and low-cost substances are air and water, which play the role of nuclear fuel in PTHF. It is turned out that usual combustion is also a process of PTHF, in which oxygen is a nuclear fuel and organic fuel is a donor of electrons. In the process of combustion oxygen atoms get the defect of mass equal

concentration. This circumstance is visually demonstrated by the operation of Archimedean lever as well as in all phenomena of the real World. This is Archimedean lever, where the loss of speed takes place, but there is a gain in force. And the load raised on a lower height than the way, which was made by the applied force, will give a huge power during its free fall. This power is higher in so many times, in how many times the time of the load fall is less than the time of action spent on its raising! And this is the fact, which determines specific character of **creation in the real World**. We should attribute both quantitative and qualitative characteristics to energy. This is the side of energy manifestation, which is reflected in Plank's formula: energy is proportional to frequency.

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There is a possibility to use energy properties both of oxygen and nitrogen of free air in the process of PTHF. To do this it is necessary to destroy nitrogen molecule at least in atoms or smaller fragments by some initiating influence. It is achieved by electrical discharge, magnetic flow, explosion and other means. These means consume much less energy than produced in PTHF. In particular, such processes were achieved in combustion engines. Such nitrogen mode of operation and combustion is accompanied by oxidation to H_2O, but not to CO_2, which is more effective in energy and ecological aspects. Accordingly, the power of engine increases and organic fuel is saved. Exhausts from this process mainly contain water vapor [3].

PTHF processes with excessive power release (more than consumed power) were also obtained in heat-generators operating with water.

Free energy diffused in the surrounding space could be transformed into mechanical, electrical or another kind of energy by means of vibration-resonance, electromagnetic and other energy systems. Classification of these systems as well as physical mechanism of energy transformation is given in [2]. The known Searl's engines can serve as an example of energy systems working with free energy.

The developed physical mechanisms of energy-release processes will allow to create industrial, stably operating, ecologically clean energy systems, which do not consume organic and nuclear kinds of fuel, harmful for humankind.

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On General Nature of Forces

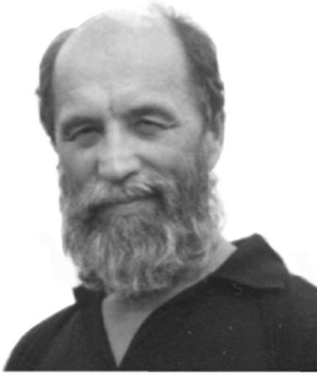

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Introduction

In techniques and in our life we got used to certain physical notions concerning force. We usually use these notions in creation of automobiles, airplanes, rockets and other techniques, but we don't think about **the origin of forces** in general. Usually appearance of force in continuum is connected with presence of momentum gradient.

A number of works, which describe various versions about origin of a force appeared [1, 2, 5, 8, 17, 21, 22, 23, 25, 30, 35, 36, 38, 39]. Different mechanisms of appearance of force are considered in these articles. Usually they consider origin of a force in one of the fields, which are: electromagnetic, gravitational and others. **There was a theoretical attempt to connect the force initiation with energy gradient [33]. Experimental proof of force initiation due to energy gradient was obtained in the works [7, 38].**

Below we made an attempt to show the general regularity of force initiation, which is connected with non-uniform distribution of energy in space. With this process, physical nature of any kind of energy and specific mechanism of force initiation does not play any role. These are only particular cases of general nature of force initiation.

General nature of forces

We are surrounded by space, which is full of energy. Here we mean the energy of any nature: mechanical, thermal, electromagnetic and others. Energy is related with material world and its value is connected with the volume.

Any particle (volume) of continuum has energy:

$$A = A(x, y, z, t) \qquad (1)$$

where *x, y, z* are Eighler's coordinates of the center of particle, *t* is time.

Transmission of energy from one point of space to another one can take place by various methods, both in connection with energy transmission by material particle itself (which is a "carrier" of energy in this case) and without such transmission (for example, with wave motion). For the volume degenerated in ideal point the energy will be zero. That's why it is more comfortable to operate with the energy density concluded in the increasing constantly. We are the first who analytically got the law of gravity of the masses from the known equation of thermal conductivity. Appeared that on the relatively small distances (in the bounds of the Sun System) the law of gravity by Newton remains valid, but on the larger distances the sudden decrease goes on (Gauss integral), which naturally solves the famous Zelinger's paradox of gravity.

As a conclusion we should note that in the bounds of a stable galaxy of a spiral kind there is the circulation of ether. Ether moves from the periphery of the galaxy to its center (nucleus) by two spiral branches. This becomes apparent as a weak magnetic field (8-10 micro Gauss). In the nucleus of the galaxy there is the impact of two strings as well as there is formation of the spiral toroidal circles (protons). Then the protons form the adjoined vortexes around themselves (electron shells) and from the proton- hydrogen gas the stars are forming, which are moving to the periphery by the same branches. There they dissolve in ether at the periphery since the protons will loose their energy and stability due to the viscosity. Ether which have got the freedom will return to the nucleus of the galaxy and this process is going on in our galaxy for hundreds milliard years and it will keep going until the new center of vortex formation will begin to concentrate ether. Then the new galaxy will appear and our galaxy will disappear. But it will not happen soon and we have enough time to understand that we should return to the concept of ether in modern science.

Experimental Demonstration
of Cosmic Influence on the Earth Life in N.A. Kozyrev's Researches
("On the Influence of Time on Matter")

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Editor's note: this article represents a part of the big scientific conception "World models in the new scientific progress". On applying of this conception a great number of practical technical devices have been created (as an example of such device we offer the description of universal electrical bio-heater, which was created by the group of researchers from Bishkek, Kyrgyz Science Technical Center "Energy" during the *work on ceramic electroconvector).*

We have to note that the position of our editorial board concerning "time" and Kozyrev's work is not in a good correlation with the authors' one.

Nicolay Alexandrovich Kozyrev scientifically and experimentally discovered the action of relations' interconnection, which was falsely named as time. Time cannot cause action because it is absolute and does not have any physical sense (Samat Kadyrov. Monograph "Theory of unified field").

Author's note: relations' interconnection is an interaction of structurally similar objects. It is a nuclear resonant gain-frequency process: in a stationary electric field, which is modeled by systematic organization, there is a development of similar to structural one, in-focus rays of powerful regular coherent radiations. These coherent radiations are determined by properties of chemical components of interrelated substances.

According to N.A. Kozyrev, it is ought to expect not identical density of relations' interconnection in space. Some processes decrease density; others on the contrary increase density of relations' interconnection. Action of the increased density is weakened according to the law of reversed squared distances; it is shielded by a solid matter, at thickness about 5cm, and is reflected by a mirror, according to the familiar optics law. The action of the decreased density on a detector is shielded, but does not reflected by a mirror. Properties of a matter can be changed under the influence of relations' interconnection. In this sense there is a big advantage in changes of electric current conductivity of resistor, which is brought into Witson bridge and is located near some process. For instance, in order to increase density it is useful to realize the process of evaporation of a volatile liquid; and for density decrease the process of cooling of a warmed-up agent can be realized. Due to these processes, change of conductor resistance is actually realized with opposite signs. Increase of density of the conductor with positive temperature coefficient leads to decrease of its resistance. At negative temperature coefficient there is an effect of the opposite sign, in the direction of changes, caused by temperature changes. Such correspondence to fall in temperature should be observed at changes of other properties of a matter, **because disorder in a matter structure is reduced along with fall in temperature**. The researches have shown the following results at the resistor, which was situated near processes of acetone evaporation on cotton wool and of solution of sugar in water. The relative resistance change of resistor was observed at the 6th or 5th digit after comma (or even at the 4th digit if resistors had especially high temperature coefficient).

There is now a possibility to study the Universal World not only by means of the investigated spectrum of electromagnetic oscillations, but also through physical properties of relations' interconnection.

At many researches the influence of relations' interconnection on resistor electroconductivity was investigated. Acetone evaporation (at 10-15 cm distance from the resistor) was applied there as the process, which controls sensitivity of a system. However, the process of evaporation can influence on the resistor not only with density increase, but also due to temperature increase that occurs at evaporation. In order to take into consideration this cooling effect, (in the area of evaporating acetone) temperature was measured by Beckman mercurial thermometer with 0.01°C multiplying factor. The first experiments (without thermal protection) have shown the fall in temperature by several hundredth of degree. This fall was enough to cause the changes of resistor electroconductivity. However, the thermometer had been keeping on the demonstration of practically the same fall in temperature at thermal insulation of the resistor. The thermometer reacted on the radiation of relations' interconnection at acetone evaporation.

The part of the thermometer with a placed in a pasteboard tube mercury tank was laid round with cotton wool and put into a glass retort. The experimental process was fulfilled near the retort, and the reading of mercury altitude in capillary was determined by the scale of the thermometer through the closed window in the next room. The mercury altitude was decreased at dissolution of sugar in water (with steady temperature) and it was increased at the release of the squeezed spring, which was placed near the thermometer.

The radiation of the relations' interconnection was observed from many stars. It is caused by the inner processes, which take place on these heavenly bodies. The Sun (with its turbulent processes) radiates the relations' interconnection besides the searched electromagnetic radiation. Actually, if sunlight is recovered with a thin screen, the significant influence on the resistor will be discovered. The influences of the Sun to the Earth through the relations' interconnection become doubtless. These influences of the Sun should have a particular significance in vital functions of organisms, because it brings the beginning for life support. The totality of the researches demonstrates the dependence of matter state from the changes of the general background of the relations' interconnection. The drift of the devices (that show daily changes) usually stops about at midnight and then changes its direction. As for the seasonal course, there is a density decrease of the relations' interconnection in spring and summer; and there is an increase of it in autumn and winter. It is connected with the absorption of the relations' interconnection by the vital functions of plants and with the return of it at their fading. There are indications at the seasonal changes of chemical processes. For instance, reaction of polymerization has more difficulties in its realization in springtime. V. Zhvirilis observations of minimum and maximum light admission by means of the crossed Nickolya prisms can be explained by the crystalline reconstruction of these prisms.

By Kozyrev, as being invisible, vital source is disseminated everywhere in Nature, thus possibility of its accumulation is the only necessary thing. Such a possibility is realized in vital organisms because all vital functions counteract to the usual course of systems' destruction. The ability of organisms to keep and accumulate this counteraction is the reason, which determines the great role of biosphere for the Earth life. But even if we assume, that spreading of life in Space is one of its peculiar properties, biosphere will not have a decisive significance.

Cosmic bodies (and first of all stars) can serve as the reservoir, which gathers vital source. Enormous stocks of energy flow out of stars in a very weak degree through the radiation of comparatively cold external layers. Inner stars energy is preserved so well, that even at the lack of supplement, matter of the Sun would become cold only at one third degree per year. For the Universe the creative source carries the relations' interconnection. Thus cosmic bodies are necessary for support of life.

Author's note: We apprehend relation's interconnection as natural radioactive background. In fact, it is a nuclear resonance gain-frequency interaction of inertial masses that depends on living systems, especially on its rituals and that regulates its survival. Cosmic bodies regulate this process. Humanity is able to control nature only obeying to natural laws. In-focus beams of powerful laser streams are formed in the electric field of living system organisms. The creation of proton-antiproton pair in the living cells, alongside with the process of the absolute release of energy serves as a creative vital force. The process of radiation, support, absorption of energy by the organization (assembly of particles) is realized through the relation's interconnection and regulates its total mass.

Humanity is able to control nature only obeying to natural laws.

Life without Diseases and Old Aging Preventive Electrical Heater with Programmed Features

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Universal electrical bio-heater is intended for heating of rooms and preventive clearing of an air atmosphere from disease-producing organisms at continuous exposition (continuous work). The principle of its work fundamentally differs from those of the existing analogues. Carbon crystals are in the basis of bio-heater, which makes it environmentally appropriate.

Bio-heater represents a range of ceramic cylinders, jointed with metal plates on top and underneath. These plates play the role of load-carrying structure. It is used in production areas and living rooms for heating alongside with destruction of pathogen microorganisms. One bio-heater with 0,2 kWtt power is oriented for heating of the area with volume 35-45m^3 (in the future production of modernized models powered from solar cells is planned).

As distinct from the usual oil heater, preventive electrical bio-heater destructs agents of infectious diseases, whereas, according to the researches, oil heater stimulates their reproduction.

Absolute ecological cleanness is obtained by release of the quarters from the effect of increased atmospheric dampness with the temperature, appropriate to sanitary code. Any type of mold or fungus disappears in the quarter and in the future these forms do not renew their existence (even after removal of bio-heater).

The absence of injurious radiations is attained by the following: features of raw material, which is used during the process of electrical bio-heater production; radiation is normal during bio-heater working. Pollution-free temperature influence is attained by favorable infrared radiation.

Among the other properties of electrical bio-heater there are following: fire-safety; explosion proof; chemical inertness; enormous effectiveness from the point of view of electric energy demand. Structural simplicity facilitates its durability; there is nothing in bio-heater to be broken.

Technical aspects (applied Know How): In the process of technologic production of ceramic cylinders, from which bio-heater is consisted, **diamond-like cellular ceramic structure** with superimposed combination of atoms of lattice elements is created. Rhythmic work of cells, which form ceramic mixture, leads to resonance and creates a kind of blow wave (at micro level). This blow wave physically destroys microorganisms that have no calcium framework. It is related only to those microorganisms that are agents of infectious diseases, such as: staphylococcus, enterococcus, enterobacterium, etc. Thus parameters of the evoked blow wave coincide with vibration frequency of the definite types of bacterium and elementals. These blow waves cause the similar effect in room near of bio-heater, e.g. colonies of microorganisms are noticeably decreased there (even at the absence of bio-heater in the nearest room).

Due to its self-organization, bio-heater works in the range of living systems, it is approached to them. There is a realization of active connection with living coaly forms of biological systems. Actually the work of bio-heater is adjusted to them. Bio-heater properties can be programmed at the process of its production.

Bio-heater is a patented product. Patent KR #464 MKI C 04 V 33/24 “Ceramic mixture, possessing heat-radiating properties”. Application #20010075.1 at Patent KR #464 MKI C 04 V 33/24 “The way of creation of energy, renewable, programmed hard-phase ceramic-carbon mass structure”. Application at Patent KR #464 MKI C 04 V 33/24 “Technology of producing of electrical heaters with anti-resonant air prophylactic effect”.

Finale product (FP) purchase is not more expensive than those of existent models of electrical heaters. Cost value is noticeably brought down on organization of the scaled production. It is ought to take into consideration that from all existent types of heating, from the customer’s point of view, this one is the most energy-efficient. Manufacturing of such bio-heaters can be organized on the base of acting industrial production of ceramic fabrics. It will require some expenses. Moreover production service is rather cheap because there is no need in maintenance staff.

Electrical bio-heater can be applied everywhere, where there is a need in: a) economical heating; b) decrease of air moisture; c) disinfections of rooms.

As for the life cycle of bio-heater it does not become obsolete morally and technically. It is produced from the materials, which are not liable to wear.

The invention has a certificate of KR Gosstandart. From the end of 1998 the first unimproved modification of bio-heater (with power 0,6 KWtt) were put into serial production in Bishkek (with small test production runs). This time bio-heaters are readily used as medical equipment in hospitals and maternity hospitals in Bishkek. **Inventor: Alexandra L. Belyaeva.**

Technical Report

The comparison of quantity of heat energy, required for heat of rooms, and of heat quantity, which is produced by Belyaeva's electroconvector.

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Editor's note: this calculatious demonstrates the advantages of the device, which at 340 Wtt energy consumption produces about 700 Wtt of heat power.

The calculation of heat output, coming from the ceramic electroconvector to a room, was based on the basis of research statement of EVNA-0.2/220 electroconvector's influence on air micro flora of industrial rooms at 23.10.01. - 06.11.01. period.

The researchers were carried out in the arbitrary room in a four-storied large-panel building. This room was on the 3rd floor, with facing east windows. The room was of 52.5 m^3 air-space, 3.5 m height and 15 m^2 area. The calculation of heat, was made on the basis of "Methods for calculation of the requirement in heat and electric energy of buildings". These methods were registered by Department of Justice of Kyrgyz Republic on 08.09.2000, #154. According to the normative data, temperature of inner air (t_{in}) in the room must be equal to +20° C. In Bishkek planned specified temperature of external air (t_{ex}) for heating is minus 23°C. The average temperature of heating period is t_{av}= -0.9°C, specific heat characteristic of the building is:
q=0.4 Kcal/m^3 h °C.

Medium quantity of heat energy, which is required for heating, is determined by the formula:

$$Q_{av}heating = q \cdot V \cdot \left(t_{in} - t_{ex}\right) \cdot 1.12 \cdot$$
$$\cdot \left[\left(t_{in} - t_{av}\right) \div \left(t_{in} - t_{av}\right)\right] \text{Kcal/h}$$

$$Q_{av}heating = 0.4 \cdot 52.5 \cdot (20+23) \cdot 1.12 \cdot$$
$$\cdot \left[(20+0.9) \div (20+23)\right] = 492 \text{Kcal/h}$$

Thus at the average annual temperature of the heating period, which is: t_{av}= - 0.9°C, the quantity of heat energy required for this room, comes to 492 Kcal/h.

According to the research statement, the trials of the electroconvector with 200Wtt power were carried out at the following external air temperature: +10.2°C; +8.5°C; +10°C; +6.6°C. The calculation data and results of its examination are brought together in a table. The parameters of electroconvector with 340Wtt power are demonstrated in the same table.

Table 1
Table of determination of heat entry and heat consumption's correspondence in the experimental room

#	External air temperature, °C	Inner air temperature °C	Normative heat consumption KWtt (Gcal/h)	Experimentalheat consumption KWtt (Gcal/h)	Percentage depending on normative heat consumption %	Economy of heat energy kWtt (Gcal/h) comparing with power consumption of the device 0.2 kWtt (0.000172 Gcal/h)	Economy of heat energy kWtt (Gcal/h) comparing with power consumption of the device 0.34 kWtt (0.000292 Gcal/h)
1	- 0.9	+20	0.572 (0.000492)		100	-	
2	+10.2	+20	0.267 (0.00023)		100	-	
	+10.2	+16		0.158 (0.000136)	59	0.2-0.158=0.042	0.34-0.158= =0.182
3	+8.5	+20	0.314 (0.00027)		100		
	+8.5	+17		0.233 (0.000200)	74	0.2-0.233=-0.033	0.34-0.233= =0.107

4	+10	+20	0.273 (0.000235)		100		
	+10	+23		0.355 (0.000305)	130	0.2-0.355=-0.155	0.34-0.355= =-0.015
5	+6.6	+20	0.366 (0.000315)		100		
	+6.6	+19		0.338 (0.000291)	92	0.2-0.338=-0.138	0.34-0.338= =0.002

Calculation data demonstrate a considerable economy of heat energy at daily unevenness of external air temperature.

Heat productivity of the new structure of electric convector with 340Wtt power was calculated on the assumption on the suggestion that heating of the room is carried out by the irradiation at the process of heat exchange.

$$E = \varepsilon \cdot C_{\text{o}} \cdot T^4 \cdot 10^{-8} \quad \text{Wtt/m}^2$$

where: C_0 =5.67 Wtt/m^2 K^4 is a radiant emittance of blackbody, ε=0.93 is an emissitivity factor of the surface of earthenware duct tube; T=70°C=343 K is the temperature of the surface of earthenware duct tube.

On substitution of the known values into the formula we get:

$$E = 0.93 \cdot 5.67 \cdot 343^4 \cdot 10^{-8} = 727 \ \text{Wtt/m}^2$$

As the area of irradiation surface is equal to S=0.96 m^2, then quantity of heat, which is evolved by the convector, comes to:

$$E_k = S \cdot E = 0.96 \cdot 727 = 698 \ \text{Wtt (or 600 Kcal/h)}$$

The quantity of heat, which is required for the heating of the room, is 492 Kcal/h (at the external air temperature equal to minus 0.90 and temperature in the room equal to plus 200).

Thus, electric convector with 340 Wtt power is able to heat totally the room with 60m3 area.

Editors note: 340 input and 700 output!!!

Longitudinal Waves in Vacuum: Creation and Research

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The author presents a new elegant system, which is the symmetrized Maxwell's equations. In practice it gives a possibility to create the longitudinal waves in vacuum. This system is of great importance in telecommunications and aerospace technigue.

There is a stable paradigm in electrodynamics that the existence of the longitudinal waves in vacuum is impossible. This paradigm played its negative role preventing scientific minds from solving this problem. However, Maxwell was not as categorical in his opinion on this question as his following were.

Particularly he wrote: "Science of electromagnetism as well as optics is not able to confirm or deny the existence of longitudinal oscillations."

Maxwell's dynamic equations are usually considered as partial derivatives in time. However, the total derivative in time includes the so called substantial derivative, which was shown in the equations for the moving coordinate system. In particular, one of these equations was written by Maxwell himself to explain the phenomenon of electromagnetic induction discovered by Faraday. This induction takes place in the conductor moving across the field lines of electromagnetic field:

$$\vec{\mathrm{E}} = \vec{\mathrm{V}} \times \vec{\mathrm{B}}\,; \qquad \text{(I)}$$

Other equations were obtained later by other scientists. In the table I below Maxwell's equations are given in a split form. Their static and dynamic parts are given separately as well as the equations for moving and fixed coordinate systems. Such matrix concept of Maxwell's equations allowed finding their incompleteness. Really, the analysis of the matrix shows its high symmetry. However, full symmetry of the system of equations is broken by the absence of the equation (X). It seems to be strange and calls a desire to remove this defect in such an elegant system of equations.

A new equation is introduced in the Table 1 for the full symmetry of the matrix:

$$\nabla \cdot \rho = -\frac{1}{c^2} \cdot \frac{\partial \vec{j}}{\partial t}\,; \qquad \text{(X)}$$

Fundamental Properties of Aether

Alexander M. Mishin

Author's note: In the article the principles determining major properties of aether are formulated on the basis of an empirical material.

Real aether [1-6], the primary and superfine essence of which is still a secret, has turned out to be absolutely non-standard superfluid three-dimensional material medium, which simultaneously is at solid, liquid and gas phases. The first master phase of aether is a specifically solid absolute space or an energetical "bottom" of the Universe ("celestial stronghold"). At that the solid phase is considered as mesomorphic vortical-wave structure, which has particular holographic properties. Classical matter represents to be one of the stable and energetic space-time levels of the Universe. Aether vortexes exceed all conceivable space scales, have quasi-material properties and create a great number of stereo-dynamic subspaces (parallel worlds).

The first basic principle, to which aether entirely follows, is the principle of the least disturbance (the least action). Many well-known and unknown physics laws are the subsequent of this principle. In particular, any motion in macroscopic aether happens in such a way to minimize the interaction with the matter of our world, with zero moment of the disturbance momentum. In the classical physics this principle has been reflected as Le Shatelye principle, as variation principle, laws of thermodynamics etc.

The second principle is the principle of fractality, which confirms the similarity of forms and properties of quantum aether vortex structures regardless of their space scale. This principle also determines the Universe as stereodynamically multivariate system in the form of hierarchy of vortical-wave structures of the unified aether (fractal matreshka). On the researching of the macroscopic objects of the Universe it is possible to make a conclusion about microcosm structure if taking into account the changes of frequencies and velocities of action transmission.

In the third place there is a principle of physical autonomy, which confirms that any solitary mass (for example a planet) creates aether system. The particular principle of relativity, which reflects one of the fractal properties of the Universe, can be applied to this system. Such autonomous mass becomes similar to the miniuniverse with its aether subspaces, which repeat the basic phases of the Universe spectrum in more narrow (which depends on the size of mass) frequency band of space-time frequencies. Thus, in the local system of the Earth solid aether reproduces the structure of gravitational field with energy "bottom" in the mass center. As the result such spherical body occurs to be an energy drain and warms up from within.

The fourth is the principle of interaction between matter and vortex-wave forms, which do not depend to the spectral part of the Universe, that is quasimatter. This is the principle of new interaction in nature. The value of energy interaction in each experiment diminishes in time according to exponential law that is explained by the forming of energy informational or adaptation barrier, which separates parallel worlds and reflects the properties of vortex tenacity of aether as superfluid medium. At that, time of interaction is proportional to the size of quasimatter and the barrier for the earthly conditions is lowered at the indefinite period, on the assumption of only thrice-repeated observation of forces (triad law).

According to this principle, aether dynamic experiments in the earth laboratory do not have classical repeatability that, from the one hand, gives occasion to doubts in the objectivity and scientific character of the non-traditional experiments and from another hand it is the most reliable test feature of macroscopic aether motions. Biosystems have special relations with this principle.

The fifth is the principle of many-dimensional autobalance of forces. All vortex and linear motions of macroscopic aether organize themselves in the way that in the band of space-time spectrum of the local system (usually with the aid of fluid and gas aether) occurs to be self-balanced, that is they have zero resulting impulse and the moment of impulse due to the existence of the proportionate antivortexes and antistreams of another spectral structure at the same space volume. The self-balanced vortex structures and streams are practically closed for the outer watch from the direction of our material world, at least with respect to the methods of classical physics. The principle of autobalance of forces reflects aether properties as unified synergetic system and has a significant applied meaning.

Let call the principle of viability of aether dynamic systems as the sixth principle. Only a stereodynamic multivariate system is a viable one, that is a system, which during a definite period of time has the opportunity, called as life cycle, to realize interconcerted self-oscillating processes of vortex-wave character simultaneously at different phase states (subspaces, layers) of aether. The most important features of such a system are its space-time quasimaterial (vortex-wave) broadbandness and finite time of existence, which is determined by the conditions of creation of the energy-informational barrier. Self-oscillation regime demands the presence of an energy source, oscillatory circuit (a pendulum) of any character, intensive process (of negative tenacity) and a channel of positive feedback (negative entropy).

In the sense, referred above, any material system is viable and occurs to be a big system in the form of coordinated community of multivariate subsystems. In its turn each big system as a part of the hierarchy is a constituent of bigger system, until everything is embraced by the Biggest System, that is the Universe.

The seventh principle of the universal energy interchange is the physical realization of the law of unity and struggle of oppositions. This principle determines spontaneous creation of thermodynamic and antigravitation potentials. Any local matter mass (a body), situated in the open space, creates an exchange process with the surrounding aether volume in the way that more fine-structure fluid aether is absorbed by the body, and the less power-consuming gas aether is radiated. As the result the body as a heat engine gets energy due to the cooling of aether exteriors. At that, antigravitation forces acts between bodies and aether exteriors, which have different temperature.

This principle, which establishes the existence of antipodes of the second law of thermodynamics and Newtonian attraction, is realized mainly in cosmic scales and explains in which way the energy is created in the bowels of planets and stars and why the Universe is stable as regards to gravitation. Obviously, the most unexpected for the modern Physics is the discovery of non-traditional nuclear processes where conditional reactions of decay and fusion occur at the usage of quasimatter.

More deep research of new experimental results and of the stated above scientific principles lets to determine the priority-driven strategic tendencies in Physics, to open more entirely the laws of mechanics and thermodynamics of many-dimensional aether, including the theory of non-traditional waves and new types of electromagnetism. At that, the supreme aim is the research of differences in aetherodynamics laws on the Earth (in a laboratory) and in outer space, the unknowing of these differences has caused logical insularity, false all-sufficiency of classical physics, which had refused as “not wanted” the aether conception and fundamental Universal laws.

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Irving Langmuir and Atomic Hydrogen

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Editorial

In this paper Dr. Nicholas Moller describes the history of development of Atomic Hydrogen technologies in details. It is remarkable that this technology can be applied not only for welding processes but also as a clean free energy source. It is important to note that in this case the hydrogen process does not involve a consumption of hydrogen, which is not combusted in the process. Atomic hydrogen is not really a fuel but rather a medium, gateway or a super-conductor of ZPE form the vacuum of space, converting ZPE radiation and ultra-high frequency electrical energy into infrared (heat) radiation.

Irving Langmuir.

This is the story of Irving Langmuir who was the first to develop a theory on Atomic Hydrogen on the basis of empirical research and experimentation. His work in this field lasted from 1909 to 1927. During this period he was employed by the Research Laboratory of General Electric Company. Patents and discoveries developed by Langmuir during his time with General Electric were to a considerable extent instrumental in laying the foundations for what is today one of the largest corporations in the world.

The question that gave birth to this article, is why his work and discoveries on Atomic Hydrogen were the only work that received hardly any attention at all and why his revolutionary breakthrough was deprived of world attention for almost 100 years? This question becomes even more relevant when taking into consideration the high standing he enjoyed with his contemporaries (including being awarded the Nobel Prize in Chemistry) and it is better to make it distantly after exclusion of man presence near experimental stands and devices. At the same time it is quite obvious that on applying of small capacity and fixed time of irradiation it is possible to develop methods for curing of human diseases, which are considered now as incurable (for instance of diabetes, some diseases of haematogenic system, of cancer and possibly of AIDS.

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Effect of Magnetic Blow Wave Field on Wine Systems

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Introduction

Authors communicate the data on influence of Magnetic Blow Wave (MBW) field on several wineproducts. It was found, that MBW did not lead to significant changes in the major components of the wineproduct (sugar, organic acids, minerals). At the same time the taste and aroma of treated wine become more pleasant; content of heavy alcohols and wine stone in the treated samples was less than in non treated ones. A mechanism of transformations was also discussed.

Keywords: *Magnetic Blow Wave (MBW), Wineproduct, GLC of aroma compounds and ethanol, HPLC of sugars, Atomic Absorption Spectrometry (AAS) of minerals, Heavy alcohols and aldehydes, Wine stone, Turbidity tendency, Organoleptic evaluation*

Magnetic Blow Wave (MBW) was obtained for the first time during the investigations on ball lighting generation under the laboratory conditions (Shakhparonov 1994). MBW as a physical object is interesting because of some facts, which suggest that MBW is a magnetic monopole. The MBW can also interact with the matter and transforms it in a definite way. Typical example is an elementary carbon in the form of graphite, which is transformed by such magnetic treatment into ferromagnetic substance (ibid). The graphite, which is initially diamagnetic, transforms to paramagnetic one with general radiation doze of about $7\cdot10^{19}$ neutrons/cm^2. Other types of radiations could not affect this way (Svoistva 1975). So one unit of MBW can be considered as $1\cdot10^5$ of neutron masses. This fact may be regarded as an indirect evidence for assuming that MBW and magnetic monopole are the same things. In the absence of excited radioactivity a slow MBW [$v/c < 1\cdot10^4$] occurs, which does not ionize atoms (Devons, 1963). Therefore, their interaction with the matter can be observed only indirectly. No data exist on the interaction of MBW with organic substances. The experiments and results reported in the present communication may be a starting point for development of technology and to formulate the methods for vintage wine and best quality spirit production.

Materials and Methods

Assuming that MBW and magnetic monopole are the same things, a number of conditions were selected for all experiments. The MBW source and the samples were placed in the same axis and the axis was oriented according to magnetic meridian direction. Such magnetic orientation is appropriate, as the energy of magnetic monopole theoretically increases in a magnetic field (Devons, 1963). All of samples were placed at 250 cm distance from MBW source, in hermetically closed glasses. It should be noticed that MBW could penetrate through many other barriers, for example into cast iron reservoir with wall thickness of 5 cm (Amaldi, 1970).

The quality investigations were made by using of standard equipment. HPLC, equipped with refractometric detector was used for sugars estimation. Separation of organic acids in forms of their ethyl esters and acid esters was carried out chromatographically using a column packed with polyethylenglycol succinate and the following temperature option: initial temperature is 120°C, final temperature is 220°C, temperature growth rate: 8°/min. GLC was also employed for determination of ethanol. Minerals content was examined with Atomic Absorption Spectrometry (AAS). Electronic spectra of samples were obtained with double beams UV Vis spectrophotometer equipped with permanent wavelength scanning. Redox potential was measured with EV-74 potentiometer.

The aroma alterations in the wine samples were investigated by GLC method after preliminary concentration of aromas by solid phase adsorption. The concentration was carried out by barbotation of inert gas (nitrogen) through liquid and consecutive catching of volatiles with tube trap, filled by Polysorb 1 sorbent (Lur'e 1972). The well-known analogue of Polysorb 1 is Porapak Q. The tube may be regarded as a short chromatographic column, and volatiles go through it according to their retention times. The choice of sorbent was motivated by the fact, that retention times of water and ethanol was rather small (ibid). Thus, a concentration process can be ended at the moment, when water and ethanol have passed through the column, as the other volatiles remained bonded. The aroma desorption was made with ethyl ester. The analysis of the concentrates obtained was carried out with gas chromatograph equipped with flame ionisation detector (FID), column 3 m x 3 mm, packed by Carbovax M on the Supelcoport. Temperature for the analysis was programmed from 100 to 190°C with increase of 1°/min. Isothermal conditions in the borders had durations of 2 and 40 min respectively. The "mild" conditions of separation were also employed (initial oven temperature was 80°C with isothermal condition duration 5 min, temperature growth rate 1°/min, final temperature 150°C and isothermal condition duration 40 min).

Optical activity was tested with Spectropol at D line of Na (580 nm). The samples were evaluated organoleptically by a group (12 persons) of workers from Russian Institute of Canning Industry. Turbidity tests were made under the methods of Valuiko et al (1987). In some cases, qualitative tests were completed by MPL turbiditymetric measurements. Before testing samples were filtered. Determinations of heavy alcohols and aldehydes contents were carried out in accordance to National Standard (GOST, 5363-67) as follows below. Determination of the constituents of "heavy spirits"(i pentanol, i butanol) was based on reaction of the sample with salicylic aldehyde in a presence of H_2S0_4. Rose colour develops if sample contains the heavy alcohols. The density was measured with Vis-photometer and the quantative determination was carried out using standard graph made with mixture solution of i pentanol and i butanol. A method for determination of aldehydes content is based on a reaction of fuchsine sulphite. The developed colour was measured with Vis-photometer. Calibrating plot constructed basing on typed solutions was used for quantification.

Results and Discussion

Investigations of wine quality changes after MBW treatment were performed using two samples of portwine ("Zemfira") type wine. Sample 1 was a reference (non treated) and sample 2 was treated with MBW.

In both samples, the fructose and glucose levels were practically the same and amounted to 43.8 ± 3,32.22.5 g/*l* respectively. Sucrose and maltose were absent. Total sugar content was 76.0 g/1 though the level marked on the label was 80 g/*l*. It is thus apparent that the treatment of wine with MBW does not lead to noticeable changes of sugars content. Results of organic acids determinations are given in the Table 1.

Table 1
Main organic acids content, g/1

Acid	Treated wine	Initial wine
Lactic	0.0265	0.00187
Oxalic	0.010	0.0088
Succinic	0.209	0.18
Malic	4.56	4.22
Tartric	0.0805	0.0895
Citric	0.401	0.483

Standard deviation for the determination method was estimated as 7 %. This fact shows that differences in organic acids content are not significant. It should be noted that a tendency of slight increase in light acids (up to malic) in the treated wine was observed in contrast to noticeable change in more heavy acids. The ethanol content of both of samples was 181 and 184 g/*l* for non treated and treated samples, respectively, though the label on the bottle indicated 190 g/*l* concentration. Standard deviation was 5 %. Thus, MBW treatment does not lead to significant changes in alcohol content.

Atomic Absorption Spectrometry (AAS) data indicated that the samples were practically identical in terms of K, Na, Ca, Mg, Fe, Cu and Zn contents (data are not shown).

Similarly, spectra of treated and non treated wines, diluted 150 times before photometring, were practically identical, thereby pointed out that polyphenols are unchanged.

When wine is industrially treated with IR or microwave heating, ultrasonic, ultraviolet and g radiation, different reactions occur and there include redox reaction, esterification, condensation, hydrolysis, Maillard reactions, etc (Kishkovsky 1988). Most of reactions are accompanied by redox potential changing. Increase in Redox potential points out the increase in concentration of oxidants, i.e. oxygen, peroxides, and other compounds, which are electron acceptors. Redox decrease is a result of oxidation processes (ibid). Redox potential was practically constant ($\Delta E=$ 145 mV and 150 mV in samples # 1 and 2 respectively). Evidently, oxidation processes, like they occurred during heat treatment, were absent during the MBW treatment.

One of the important reactions to be considered is the Maillard reaction. Essentially it appears in form of browning, decrease in reducing sugars and amino acids, and new aromas formation. While our result evidences on absence of irrelevant aromas, alterations of wine colour, and sugar content, thereby indicating insignificant contribution of Maillard reaction on wine quality changes due to MBW treatment. Technological treatment often leads to esters accumulation that improves wine aroma. It's well known that the most important in this context are the esters of C_6-C_{14} fatty acids (Kishkovsky 1988). During heat treatment, storage and other physical influences, different kinds of acid esters accumulate. These have weaker aroma than esters of fatty acids. But their appearance proves the existence of esterification processes. A comparison of aromas chromatograms of the samples 1 and 2 proves occurrence of changes in concentrations of the individual substances (increasing of peaks length with retention times of 13.10, 100.9; decreasing of peaks length of 54.85 min). An order of peaks exit of different volatiles is given in the Table 2.

Table 2

Exit order of different volatiles

Exit order, from published data for Carbovax 20 M	Retention time in our experiments, min	Exit order, from published data for Carbovax 20 M	Retention time in our experiments, min
Acet aldehyde	3.8	i-Pentanol	23.56
Ethyl acetate	4.71	i-Amyl butyrate	
Diacetyl	4.82	Acetone	
Methanol	4.91	n-Pentanol	27.92
Ethanol	6.01	i-Amyl valerate	
n-Propanol		Ethyl lactate	
i-Butanol	13.58	Ethyl caprilate	52.6
Butyl acetate	13.59	Acetic acid	
i-Butyl acetate		Diethyl succinate	
Ethyl valerate		Ethyl laurate	
n-Butanol	17.73	Phenyl ethanol	
Amyl acetate	20.70	Diethyl malate	

A comparison of retention times of components with peaks of standard substances of wine aroma indicates that butyl acetate and i-butanol are very close to peak 2. Data on chromatographic separation with mild condition showed that i butanol and butyl acetate peaks exited simultaneously. Organoleptic evaluation recorded a nice smell in the treated wine, thereby due to the formation of butyl acetate. Data indicated the presence of ethyl malate, ethyl tartrate and ethyl citrate in the samples, in addition to two peaks corresponding to ethyllactate and ethyl oxalate. The large experiment error does not allow any inference on changes of their height after magnetic treatment. Identification of peaks with retention time factor especially in such complex system is not unquestionable. However, the best way is to use the chromato mass spectrometer, which allows inference according to their individual mass-spectrum.

Organoleptic evaluation can depend on aliphatic alcohols content. Determination with GLC shows (Table 3), that their quantity in the both samples is rather small with respect to average values taken from literature for this type of wines. Thus such changes can not be recognized with such evaluation. For both of samples pH was equal to 4.0.

Table 3
Aliphatic alcohols content, mg/1

Alcohol	Sample #1	Sample # 2	Average literature values (Kishkovsky 1988)
Methanol			80-350
i-Propanol			0,3-3
n-Propanol	less than 20		5-50
i-butanol	less than 20	less than 20	20-100
n-Butanol	less than 10	less than 10	2-10
i-Pentanol	less than 20	less than 20	100-250

The results of optical activity measurements indicated, that both samples are not optical active. Filtration, clarification and dilution could not change the optical activity. Perhaps, there is a compensation of different forms of D- and L- compounds in the samples, thus total activity was very close to zero, and magnetic influences could not change equilibrium between the forms.

Organoleptic evaluation of more delicate taste and aroma of the treated sample with respect to non treated one, MBW treated sample as more complete, harmonic, noble, and natural in contrast untreated sample was recorded as excessively bitter and sour in spite of practically the same pH of samples.

It is interesting to test the tendency of wine to make a different kind of turbidity after the MBW treatment. Data showed that both samples were not positive for protein turbidity. In term of reversible colloid turbidity formation, after storage at 7.5°C for 1 day, the MBW treated sample was homogeneous, in contrast to the formation of different phases with different refractometric numbers in untreated sample. Both the phases in untreated sample were liquid, with a density very close to each other, but the borders of phases were like broken lines when crystallization begins in crystallization process. This alteration in untreated sample may be due to micelle state changes or of structurization of product.

The tendency test for polysaccharide turbidity based on the reaction with phenol in presence of H_2S0_4 and determination of the derivative formed by photometrically, indicated, that difference in concentrations of polysaccharide in the both samples are very small, the levels being 119 and 106 mg/*l* for untreated and treated samples respectively. These values are close to range of polysaccharide stability (150-200 mg/*l*), and thus do not allow any conclusion on changes of relative stability of the samples. A tendency for polyphenols turbidity, due to polyphenols associates precipitation upon addition of salt did not show differences. Turbidity, as determined in MPL apparatus, was 15 FEM as against value of 0.2 FEM before testing in untreated sample. These numbers were respectively 14 and 0.3 FEM for treated sample. Thus it indicates that both the samples are very stable with respect to polyphenols turbidity and that the magnetic treatment does not lead to alteration in the polyphenols stability.

The data on the colloid stability indicate, that both the samples showed rather high resistance against protein, polysaccharide and polyphenols turbidities. Besides, treated sample showed higher stability with respect to reversible colloid turbidities.

It is interesting to investigate as to how heavy alcohols and aldehydes, which are often produced, when low-grade technology is used, are affected by magnetic treatment. For these studies, a system of simple mixture, consisting only of spirit and water, was used. Commercial vodka bottled in standard 0.5 l bottles and artificial solutions, containing 40 % of food derived rectified spirit were used. Data showed, that MBW treatment significantly influenced the heavy alcohols content, as the reduction in heavy alcohol was more than two times. In addition, it reduced aldehydes by more than 3 times in vodka, and more than 30 % in rectified spirit. Data indicate that efficiency of aldehydes removal is higher when the sample contained higher level of aldehydes. Thus, the MBW treated vodka and rectified spirit will be better than untreated one. It is however stressed that untreated samples were also recorded as good by sensory panel. So, limits for aldehydes are usually present in high quality vodka established by National Standard (GOST 5363- 67) are 6 - 15 mg/*l*. Thus the organoleptic evaluation of samples does not allow to find difference in aldehyde levels in these samples.

Table 4

The main results of heavy alcohols and aldehydes determination (mg/1) in vodka and solution, contained 40 % of rectified spirit

Substance	Non-treated vodka	Treated vodka	Non-treated spirit	Treated spirit
Alcohols	8.7	2.55	3.38	1.5
Aldehydes	1.5	0.4	0.6	0.4

Sediments formation and its character were also evaluated. The sediment in treated grape juice was dense and more dark, the formless, non crystalline sort, and gel like form. The volume of the sediment occupied up to 30% of total volume. The sediment did not sink or float, nor it stick to the walls of glass. It was found that 100 ml of juice gave about 155 mg of dry sediment. Microscopic investigations showed an absence of any kind of bacteria or fungi in the sediments.

The effects of high energy of magnetic influences on sediment were also investigated. The experiments were carried out with “Portwine Erevanski, vol. 0.5 1, white, spirit content 19 vol %, sugar 10 %, prepared according to GOST (National Standard) 7208-84”. Crystalline sediment appeared on the walls and especially on the bottom of the bottle after the BMW treatment. An amorphous precipitate was also presented, and it can be separated by decantation. Crystalline sediment, after washing with ethanol and drying to constant weight, weighted 69.2 mg, and was of bright brown colour. A tartrate content as a tartrate acid, of the sediment was 59% mass. If it is considered as a tartar (a wine stone) of potassium sodium tartrate, then tartar content in sediment works out to be 86%. If it is considered as a tartar of dipotassium tartrate, tartar content in sediment will be 93%.

Generalization of data shows the positive effect of magnetic treatment on the wine samples, leading to harmonic taste of treated wine and absence of non pleasant tastes. Most of the changes were found to bein the flavour and taste components, which were minor substances in the product. For example esters concentration changes during the treatment. At the same time the content of major components, such as sugars, organic acids, particularly, heavy organic acids, and especially ethanol remain constant. It seems logical from kinetic point of view, when simple processes, like esterification, are preferable with respect to many stages reactions, and reactions with high activation energies, which can go at hard conditions. Also, it seems logical that magnetic treatment may influence on electrical state of colloid species. Thus magnetic treatment can be considered as mild, selective in the comparison with many other physical methods. Nevertheless, the changes lead to acceptable energetical and nutritious value of the product. Data show that difficult problems, such tartar removal, can be solved by MBW treatment.

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The Fundamentals of the New Principle of Motion

By The Group Studying Inertialess Natural Processes (GSINP)
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The concepts of active and passive interaction between the moving object and the space form the basis of the new principle of motion.

So as to be more understandable, let's consider what is the old principle of motion. For this we will use the concept of a moving object and the space in which the object is moving. Naturally, material objects and the space can't interact between each other directly, because the space is the philosophical category. In this case we can understand physical essence of natural phenomena easily. In our view, the material objects interact with some fundamental energy of space (FAM), which fills all space with a different density. Thus the energy (FAM) is inalienably connected with the space. One of the first names of this energy is "ether" in the early scientific works. So, for the simplicity we will accept that the object and the space interact between each other.

Thus, all existing methods of motion which have been invented by mankind till the present time are based on activity of the material object that means the one expends some energy to produce the motion, and at the same time space is passive, it means that space does not need to spent any energy to move the object. And so in common case space tries to keep the object in the former state interfering with accelerated movements of the object (in accordance with **the 1st , the 2nd and the 3rd Newton's laws**).

It should be noticed that such method of motion (for the speed, which is much less than the speed of light) takes place both in animate and inanimate natures. In this case the level of energy of motion and reaction of space (or an environment) are not very high. Incidentally, the energy of object can be of different types: electrical, chemical, biochemical, mechanical etc. The common consequence of this type of motion is existence of the ***inertia***. The classical physics can't answer the question: "what is inertia?» The same situation is applied to the concept of ***mass,*** which is closely connected with inertia. The classical physics says that ***the mass is a measure of inertia.***

There is the new principle of motion of material object: the object is passive and space is active. In this case it's more favorably for space in the energy aspect to move the passive object and to spent some power then to keep the object in the present place in the former state of immobility (in accordance with **the 1st, the 2nd and the 3rd Newton's laws**). And so we should introduce **the 4th law of** Newton's **mechanics**. It says that ***there are the systems of coordinates in which the body is moving not rectilinearly with acceleration when this body is in the state of immobility***.

The basic and the main differences of the offered principle of motion from the existing methods at the end of the XX century are the following:

1) The absence of inertia of motion;

2) There are no limits for the speed of motion;

3) The absence of "fuel reserves" "on board" of the moving material object.

Nikola Tesla and Instantaneous Electric Communication

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Nikola Tesla (1856-1943), an outstanding inventor, was and still remains one of the most mysterious persons in the history of electrophysics. Whereas the most scientists were moving together in direction of microparticles investigations, as the basis of matter structure and of nature itself, he was going in opposite direction. He had a keen interest in the investigation of electric charge of the Earth as a whole. He was looking for the ways to influence on it, to control its state and methods of its regulation.

Therefore, exactly, the most of his searches, experiments, the purpose of constructions and buildings, created according to his conceptions, cause perplexity and misunderstanding of scientists even in nowadays.

The most mysterious of his main experiments were made in USA after 1904. After Nikola Tesla death in 1943, all his diaries and records over a period from 1904 year had mysteriously disappeared. Probably they were stolen (it was known, what to take). Lost records could “cast light” on one of the most “strange” of his buildings in the form of the enough tall tower, on the top of which a specially created toroidal transformer was placed. This transformer could create there a huge electric potential up to the billion volts.

Nikola Tesla switched on this tower-device, what caused the fright and even panic in mind of people from nearby settlements. Of course! Because of very high electric potential there began air ionization, which spread very high to the atmosphere accompanying by the effect of color play. Such luminous, color-playing sky caused even a horror of people, who knew nothing about the experiment made and its goals. They did not guess that Tesla by means of the electric charge, created of the tower, was influencing on the electric charge of the Earth as a whole (about 600000 Coulomb). There was a global scale in Nikola Tesla’s investigations.

There is no point in detailed analysis of the fact that the potential of the tower top influenced on the Earth charge. Interaction of charges-balls with the distortion of field lines, distortion-distribution of charge on their surfaces, induced charge, is beautifully described even in school physics textbooks. In Nikola Tesla investigations the Earth had the role of one of the charged balls. It was possible by changing of charge on the tower to deform electric charge distribution on the whole Earth surface at once. This deformation (electric currents) could be fixed at once in every point of the Earth surface. It is alluring to use this effect for data transfer telecommunication, both on the Earth, and in space.

After such introduction the question “How does the system of instantaneous electric communication for any distance look like and work?” is still opened. First of all, the readers need to know, that such instantaneous communication is possible in principle. The proving it theoretical calculations, are rather difficult for popular interpretation. Some part of readers can take it on trust, and those who are most interested in can apply to works of Oleinik V.P. (quantum physics) the professor from Kiev Polytechnic University. At the minimum there are two necessary works: Oleinik V.P. “Faster-than-light transfer of a signal in electrodynamics. Instantaneous action-at-a-distance in modern physics” (Nova Science Publishers. Inc. New York. 1999) and Oleinik V.P. “Latest development of quantum electrodynamics: self-organizing electron, faster-than-light signals, dynamical heterogeneity of time.” (Physical vacuum and nature. 4. 3-17. 2000).

“PC” magazine has devoted a rather significant article entitled “Computers and teleportation” to V.P. Oleinik works, concerning instantaneous electric communication (“PC” #6, 2000). Note, that the author of the given article has also found the possibility of instantaneous electric communication, but by means of materialistic methods, absolutely different from Oleinik’s ones, what is most important – two different solutions point to the possibility of this communication. “PC” #6, 2000 in the article “Circles on fields” cited mathematical formulae of the structure of electron electro-magnetic field as an illustration (it refers to the Earth too) that the author of this article has got.

The most attentive readers of that article could notice, that one vector Hz absolutely “ignores” Special Theory of Relativity, since its mathematical expression does not include the velocity of light, whereas it presents in other vectors as a product of electric and magnetic conductivity. Magnetic line of this Hz vector goes to infinity and returns back from infinity. It surrounds the whole Universe. It is alluring to use exactly this (Hz) line for the **instantaneous** communication for any distance.

It is not so difficult to do it. In the Fig. 1 the easiest and most available for understanding line of the **instantaneous** electric communication is shown. A rotating charged dielectric ball (an “electron”, isn’t it?) is used as transmitter. The ball can be electrically charged up to the limit of charge flow-out into the ambient space. Around the charged rotating ball there appears electro-magnetic field, entirely analogous to the electro-magnetic field of the Earth (and of the electron too). The central magnetic line Hz goes to the infinity and returns

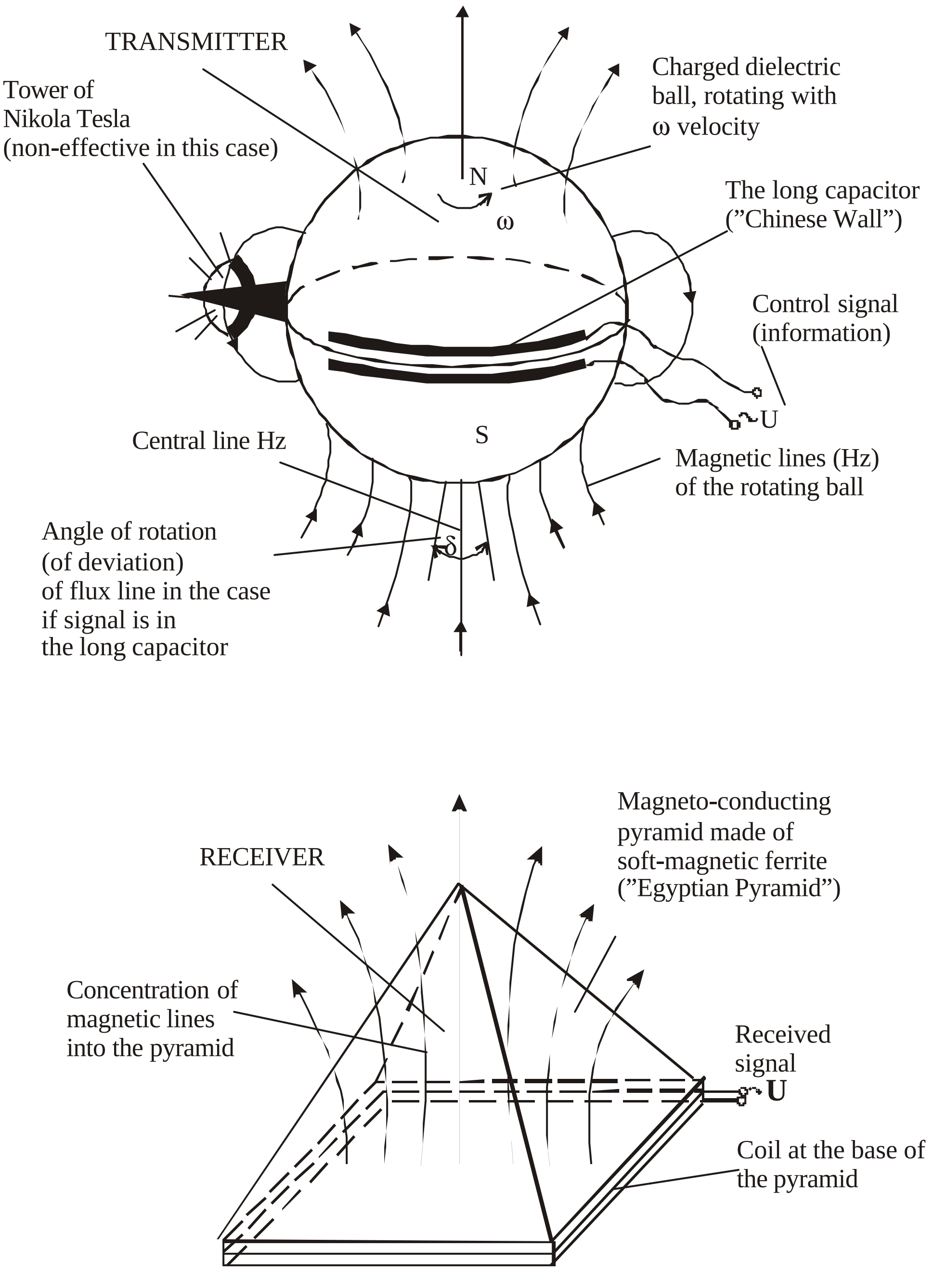
TRANSMITTER
Tower of
Nikola Tesla
(non-effective in this case)
Charged dielectric
ball, rotating with
ω velocity
N
ω
The long capacitor
("Chinese Wall")
Control signal
(information)
U
S
Central line Hz
Magnetic lines (Hz)
of the rotating ball
Angle of rotation
(of deviation)
of flux line in the case
if signal is in
the long capacitor
δ
RECEIVER
Magneto-conducting
pyramid made of
soft-magnetic ferrite
("Egyptian Pyramid")
Concentration of
magnetic lines
into the pyramid
Received
signal
U
Coil at the base of
the pyramid

Fig.1

Line of the instantaneous electric communication on the basis of rotating charged ball and pyramid

back from it to the opposite side of the ball. In the same way the central magnetic line of the Earth (Hz) goes from one pole to the infinity through the whole Universe and returns from it to the center of the opposite pole.

If by the information to force the rotating ball (electron) to "wag by tail" (by Hz vector) which stretches through the whole Universe, then this "wagging" can be controlled instantly in every point of the Universe. While the rotating ball has a steady distribution of the surface charge, the line Hz does not change its dynamic position in the Universe.

If such distribution of the surface charge is broken, space position of the line Hz also will change. On mounting the Tower of Nikola Tesla on the surface of rotating ball and measuring the potential on this tower in time with an information it is possible to change the charge distribution on the ball, and, respectively, the space position of central magnetic line (Hz) in the whole Universe at once. Big disadvantage of the Tesla tower is that maximum influence on charge is executed in the point under the tower, and farther it began decreasing roughly (exponentially), according to physics laws.

Hence it is advisable to influence on the whole surface of charged ball, but not on some point of it. It is possible to influence at once on the very big part of surface by the long capacitor, placed on the perimeter (equator) of the charged rotating ball. Because of optimality reasons, this capacitor length should not exceed a quarter of the ball perimeter (equator) length. Charging and discharging this long capacitor on the ball equator by the data signal, only the position (angle 5) will be changed, not a value of the infinitely long magnetic line (Hz) in the Universe. It is a data transfer.

The natural question appears: "How to make on the Earth the most powerful transmitter for the **instantaneous** electric communication?" The answer suggests itself: "It is necessary to use the Earth itself as a rotating charged ball." It is not effective to use Nikola Tesla's Tower to deform the Earth electric charge. To place on the Earth very long (about thousands km) capacitor is quite easier. However, it must be placed not on the equator exactly, but moved a little bit because of the initial heterogeneity of the Earth surface charge distribution, caused by the presence of continents and oceans. It will be necessary to find the line of electric equator, where the amount of charge north and south of it is similar. This line will not be ideally straight and will be situated near the 30th parallel.

As a matter of fact, this grand capacitor is already built, but is half-broken. This capacitor is very well known – it is a Great Chinese Wall. The ancient, powerful Chinese Tzcin' Shi Huandi empire adapted and used it (capacitor) for the protection from nomads incursions. How unexpectedly and originally it is! In this case the electric iron would be the best tool for spiking. It is clear enough that the charged ball (as well as the Earth) will "wag by tail", which stretches through the whole Universe and does not change its energy, but only changes its position in space in time with information. Now we can go on to the question, concerning the way to control the Earth "wagging by tail" in the Universe, and thus to read information **instantaneously** in any point of the Universe.

In the Fig. 1 it is shown the input device of the electric communication receiver, made of the magnet sensitive material (it can be soft-magnetic ferrite) in the form of pyramid, with the proportions of well-known Egypt pyramids. Magnetic field lines of the far space pass through the pyramid from the top to the base and are concentrated by pyramid. If there is no signal (the "wagging by tail" of the far planet-transmitter is absent), then the magnetic flow, coming through the pyramid, does not change, and induced voltage in the coil, placed in the base of the pyramid, is absent (no information). If "wagging by tail" begins, then the magnetic flow, coming through the pyramid, will change, and it will cause the appearance of voltage on the coil in the base of the pyramid in time with the information.

Thus, the signal is received instantly. Here it is necessary to remind once again the difference between the instantaneous and usual radio transmission. The usual radio transmitter for the transmission of the information uses the **energy** distortion of space by the information. This energy change in space happens with the velocity of light and hence there is the loss of time for information passing. In the considered case there is no **energy** change in space, there is only a change of magnetic lines position (Hz).

This is exactly the vivid and fundamental difference between the usual electric communication and the instantaneous one. **In other words, in usual transmitter during the fixed time interval there is the change of signal energy (instantaneous value), whereas in instantaneous transmitter there is no this change (only information). This is exactly the fundamental difference.**

Evidently, to receive instantly the signal from the opposite part of our Galaxy, we need rather big pyramid, in order to concentrate a big amount of field lines into the oscillatory circuit under the pyramid. The question can appear: why the pyramid, why not a cone? The point is that lines of the Earth magnetic field (the very lines that compass needle reacts on) in the any place of the pyramid horizontal section have the same density of distribution and are directed strictly parallel to the pyramid base. The cone in its horizontal section cannot provide such uniformity of distribution that is why it is not advisable to use it. From the space magnetic field lines pass through and concentrate in the pyramid strictly at right angle to the pyramid base.

This is the riddle of pyramids wonderwork. Any person coming into a pyramid, at the same moment feels the change of mental and physical condition of organism; whish is very different from that it was before the entering into a pyramid. Of course! Visitors come inside, into concentrated magnetic field lines of the powerful and functioning magnetic core of the receiving electric circuit, what is absent outside the pyramid.

It is strange, but most of tourists are afraid of the ill effect, which can be produced by electrical systems on their health, but there they stand in a queue to feel this effect in pyramids. Concentration and division of magnetic field lines are the easy and effective way to reject a noise, created by the Earth magnetic field.

It is clear, pyramids should be oriented very thoroughly, so that lines of the Earth magnetic field would be strictly parallel to the base and to the opposite (East-West) sides of pyramid. To get such exactness of orientation in modern conditions is very problematically.

The most convenient place to build a pyramid (pyramids) is on the electric equator, in the place of its intersection with the electric meridian. Such place is located in Egypt, near its capital Cairo. And again we meet a paradox: such pyramids are already built on the Earth, but they are half-broken. And Egypt was not less powerful than the ancient Chinese empire.

The Egyptian dynasty of Pharaohs has "completed" and adapted pyramids to burial-vaults, where mummies of dead Pharaohs were buried. Perhaps, it is even more incredible than in China. The impression is given that ancient powerful civilizations on the Earth had a competition between themselves, who will use radio-engineering constructions for instantaneous galactic communication in the most incredible way. Let's give to a reader an opportunity to select a "winner".

It must be noted that «PC» already published information that the Chinese Wall and Egyptian Pyramids are radio engineering constructions, intended for the instantaneous galactic communication (PC #114, 1997, etc).

There appears an interest in the possibility to produce very simple and manufacturable systems of instantaneous electric communication right now. Radio-electronic industry can produce them, but still does not guess about it.

Furthermore, such systems of instantaneous electric communication can be created at home, and even senior pupils are capable to use them. In the Fig. 2 there is shown the construction of instantaneous electric communication line in comparison with the usual one. It can be produced even at home conditions. Two permanent magnets, connected between each other by analogous poles, are used as transmitting circuits.

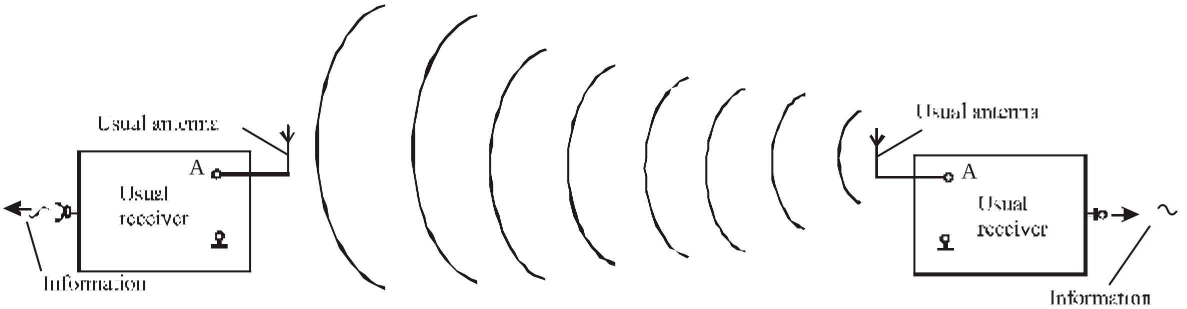
Usual antenna
A
Usual receiver
Information
Usual antenna
A
Usual receiver
Information

Line of the usual (Einsteinian) radio communication

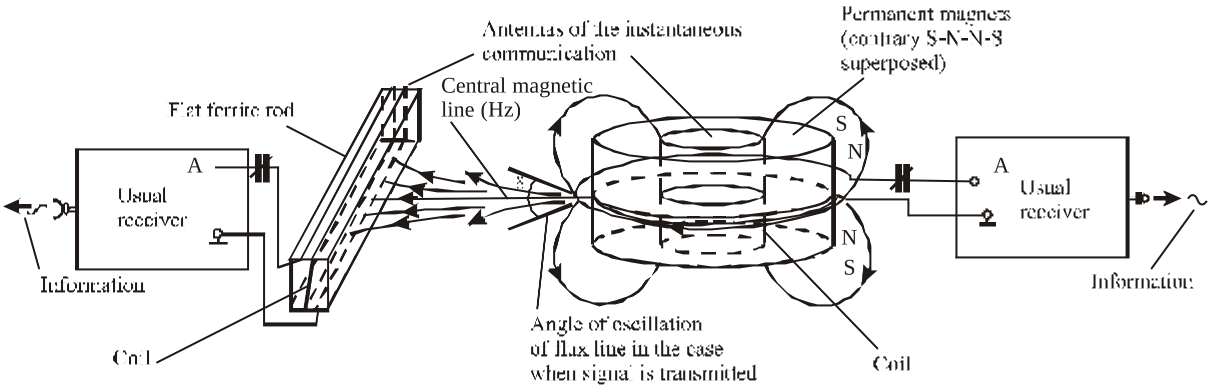
Antennas of the instantaneous communication
Permanent magnets (contrary S-N-N-S superposed)
Central magnetic line (Hz)
Flat ferrite rod
A
Usual receiver
Information
S
N
N
S
A
Usual receiver
Information
Coil
Angle of oscillation of flux line in the case when signal is transmitted
Coil

Line of the instantaneous (Maxwellian) radio communication

Fig. 2

Transformation of the usual line of communication of usual receiver-transmitter into the instantaneous one

Permanent magnets can be replaced by electromagnets. In the magnet connection point there is a coil, which while the signal passing through it will change its position (angle 5) in the space of the central magnetic line (Hz), coming out from the place of two magnets connection. Receiving circuit is available to be made of the flat ferrite, but coil must be winded along, through butt-ends of core, so that the whole internal part of the coil would be maximal (in area extent) filled by ferrite.

The obtained coil can be completely "winded" (screened) by flat ferrite of big size. For more clearness of the experiment the central magnet line of transmitting part must be directed strictly along the axis of the receiving coil.

Now, if we give the alternating voltage (information) from transmitter to the transmitting coil, fixed on the permanent magnet, then the receiver, connected to the circuit of the transmitting coil, placed on the flat ferrite, will detect an alternating voltage (information). Maximum effect is achieved at the resonance (coincidence of transmitter and receiver frequencies).

It is checked. It works. The dullest experts in radio-electronic (after the reading above) can rejoin, without making an experiment, that it is an absolute nonsense that any communication is out of the question. Coils with absolutely perpendicular axes, besides one of them is screened, do not interact with each other.

And here the most interesting thing starts. In the Fig.2 as it was mentioned above, the usual communication line and the instantaneous one were compared. The usual transmitter cannot generate the vector Hz that is why systems of usual and instantaneous communication cannot see each other in strict sense. What does it mean? It means, that in the same city it is possible to transmit on the one-carrier frequency ("what a nightmare!") two absolutely different television channels without any noises of one to another.

Usually by frequency match of a transmitter to the working frequency of another one, the radio communication is broken, but here it does not happen. Here some additional explanation should be given. As the vector Hz, which "ignores" the theory of Einstein is received from Maxwell equations, it follows that the usual (Einsteinian) system and the instantaneous (Maxwellian) one work on mutually perpendicular electromagnetic field lines (vectors).

In the Fig. 2 such difference is shown clearly. These are just "jokes" of complex numbers, when one value is absolutely perpendicular to another and nevertheless together they form a single whole. In other words it means, that two greatest persons in science Einstein and Maxwell as a matter of fact are something like "Siamese twins", completely grown together at the angle of 90 degrees, even by heads. On the one hand every one is on his own, but nevertheless they are the common (complex) organisms.

Hence there are a lot of misunderstandings on happened phenomena. How many scientists tried to find some mistakes of Einstein? They produced very convincing proofs concerning instantaneous interactions in nature. These scientists did not suspect that time and still do not guess now that they already for a long time are "walking" in the complex physics, which still does not exist. Einstein and Maxwell ("Siamese twins"), each occupies his own part of the complex number (complex physics) and they cannot be already taken off from there.

The only third, free "vacancy" is left to throw on the both of them at once the common "collar" and "reins", i.e. to fasten them ("twins") together by module and argument as any complex number. In this case no matter how the one part of complex number "ignore" the other one, only its argument will change, and module always will be equal to the conditional unit. Only this single fact in principle changes the conception about "appearance" and "disappearance" of elementary particles! Even considered instantaneous and usual communications on the same receivers and transmitters in a complex conception (complex physics) eliminate appeared "misunderstandings" of all kinds.

Advantages of the instantaneous (Maxwellian) electric communication are especially evident during the connection with long-distance spacecraft. At present in the interval between sending of control signal to the station in region of Solar System peripheral planets and getting the reply it is possible to have a small break for dinner (it is very convenient).

In the case of the instantaneous electric communication use, duty operators will have "no dinner". Moreover, the system of instantaneous electric communication can realize two-way communication underwater and from underwater to overland. It is clear that input and output circuits of such system must be covered by slushing composite for the protection from aggressive effect of the salt sea-water. Such systems of instantaneous communication are very required to submarines.

Now, when readers know and understand the principle of operation of instantaneous (Maxwellian) electric communication systems and their advantages over usual ones (Einsteinian), we can only wait, when radio-electronic industry will start to produce these very required systems.

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The Unified Gravitation Theory

(The unified super-principle, which controls the Universe)

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(Editor's comments by Alexander V. Frolov)

A forum of the leading USA physicians took place in the White House in March 1998 in presence of President Clinton. There was only one question: "When will the nature of Gravitation be opened?"

The well-known USA physician-astrologer S. Hoking declared that it possibly would occur in twenty years and it would be **the Unified Theory of All.** So, the scientific world by default called it the greatest discovery of the future.

Some time later a new hypothesis pretending to this discovery has got its birth in Orenburg. Despite this fact this hypothesis would gain recognition and status of the **Greatest Discovery of Mankind** only by 2018 that was predicted by S. Hoking.

To present day there have been written a lot of hypotheses on this problem but they haven't been recognized. Many scientists consider our Universe as living and functioning according to the unified and rigid laws in Macro and Microworld, which provides automatic regulations of all its processes due to **circulation of radiant energy of the Universe life in cosmic space**. This energy is inexhaustible and environmentally clean, and Mankind may learn using it in the nearest time for the welfare and for prevention of **contradirectional irreversible ecological** catastrophe.

There is no alternative for humankind to escape and it will not appear in the future. Only cosmic energy will save us. From the book "Secret Doctrine" by E.P. Blavatskaya we can get complete information about the fact that a highly developed civilization of Atlases on the Earth had a "**General Theory of All**" yet 10-12 thousand years before our civilization. They had no automobiles, but instead they had flying objects (aircrafts) "Vimana" of various types as well as ships and submarines, on which they also used **Cosmic energy.**

While reading an abstract in General Soviet Encyclopedia, I got acquainted with the theory of "Aether wind", which was abolished in the beginning of the XX century, and then I understood that this theory contains a deposit to discover the nature of gravitation.

The nature of gravitation is the only one and there are no alternatives in theoretical as well as in physical sense. When scientific world of entire planet abolished the theory of "Aether wind", it lost the possibility to discover the nature of gravitation. The XX century was marked by a revolutionary development of scientific and technical progress, but there was an almost 100-year stagnation in cognition of the Universe elements.

The theory of "Aether wind" supposed that all Cosmos is filled with aether particles flying with the speed of light (these particles are "neutrino" according to modern understanding). **The role of gravitation, carrier of light and retarding medium in Cosmos** was attributed to this motion of particles.

But this theory allowed chaotic motion of particles, which is impossible in mechanism of the Universe, which is adjusted up to automatic mode. Besides, motion of these particles is not possible without an absolute buffer unit, which prevents their head-on collision at the speed of 600000 km/sec (it is thermonuclear explosion and death of matter, i.e. the Universe). E.P. Blavatskaya wrote that Cosmos is filled with radiant energy of the Universe life, luminophore, electromagnetic aether. Thereby she predicted a ready solution to make correction in the uncompleted theory of "aether wind". On the basis of above stated and due to the **un-assumed dawning up,** the theory of "aether wind" was completed. It was the ground to develop a hypothesis of radiant "aether wind". Particles of this wind (neutrino) are electromagnetic particles and move with the speed of light in all directions as **contradirectional paired single-stream flows** (like electrical current in twin-wire cable). Due to this, an absolutely stable concentration of these beams in cosmic space is provided according to the principle "what has come in, the same has gone out".

The hypothesis formulates new views on the problem of structure of elements of the Universe material world.

Some separate conclusions do not match the views of modern scientific thought on the problems of physical principles of material world structure and functioning of the Solar system.

List of topics of the hypothesis

1. The hypothesis disclosures the operating environment of a super-mechanism, which controls the Universe (it is a radiant "aether wind").

2. It disclosures the nature of retarding mechanism of flying objects in Cosmos (its name is Lorenz-Fitzgerald compression).

3. It proves the absence of Universal gravity and beams of light as we usually conceive it. (The beams of aether wind collide and compress matter. An alternative to the notion about beams of light is a temperature wave impulse on the beam of aether wind. It explains why the speed of light doesn't depend on the speed of the source of light. Light is a "passenger" on the beam of "aether wind").

4. This hypothesis disclosures the mechanism of stablization of rotary and orbital movement of the Universe matter in macro- and micro world due to retarding medium in Cosmos.

5. It disclosures the mechanism of reverse rotation of Venus due to the forces of autorotation.

6. It disclosures the mechanism of reverse orbital movement of planets and satellites of planets. (Such a planet had not been opened yet, but there are 6 satellites in the Solar system, which move counter to the others, and it is not an occasion, but **a particular case of the effect of aether wind beams**).

7. It disclosures a real nature of Tungusska catastrophe. (There were about 100 hypotheses, but **neither of them** was recognized to be true).

8. It disclosures **the nature of gravitation** and gives an explanation that gravitation can be:
    - usual (vertical);
    - horizontal;
    - circular

It is important to note: not the entire matter takes part in gravitation, but 1/3, i.e. 33,3% of matter.

9. It disclosures the **nature of Levitation** and proves that 1 liter of water on the surface of the Earth can have the weight from 0 up to 3 kg.

10. It disclosures the role of gyroscope effect in life support of the Universe. The gyroscope effect allows transformation of translation energy of radiant "aether wind" to the rotational energy for practical needs of humankind.

11. This hypothesis gives scientific and technical recommendation for creation of cosmic energy converters.

12. It gives scientific and technical recommendation for producing of levitation effects for any technical systems.

13. It disclosures the possibility of cosmic flights with the super-light speed.
14. It explains experiments on metering of horizontal gravitation (The first experiment was made on February 27, 1999).

15. It disclosures the particle (neutrino) of original matter of the Universe and gives its characteristic. (Ancient thinkers called modern "neutrino" as "Aether", and it was not occasionally, because its diameter is in 10^{25} times smaller than atom's diameter.

All matter of the Universe consists of the same indivisible particles "neutrino" presented by three groups:
- "energy" group, which is in the beams of "aether wind";
- building group, which forms the part of any micro particle;
- free group (neutral-reserve) as a building material for new matter and operating environment of all electromagnetic processes.

All neutrino of three groups rotate with the speed of 3×10^{43} rps (equatorial speed of neutrino is equal to the speed of light).

Fields are formed in every particle as a result of rotation:
- strong field of a small volume doesn't allow particles to close up;
- weak field of a big volume is a general mechanism of gravitation.

As scientists write at the present time, the World is subdivided on a dense world (which we can see) and fine world (invisible). At that the density of such world is in 10^{15} times less than density of water.

It is known in science that all matter of the Universe both great and small rotates and is a gyroscope. Particles of matter get rotation with their birth, thus the fields are born in them simultaneously. **Matter cannot exist without rotation, which generates fields.**

All mechanism of interaction between three groups of particles is based on the mutual repulsion. This is the only mechanism, which always and automatically is able to create the necessary stable interval between the particles and only this mechanism provides the function of gravitation.

Many scientists of the late XX came close to the discovery of the nature of gravitation, but they didn't accept a thought to conceive **the motion of aether particles as a pair-counter flow**. And there are three necessary conditions to realize gravitation:

1. The particles should have the fields of repulsion.
2. The contradirectional flows should envelop the particle of matter from two sides.
3. While one beam is passing a matter mass then the force of fields should decrease and gravitation effect should appear.

Mechanism of gravitation

Gravitation appears due to the intersection *(Editor's note: interference)* of fields, produced by beams particles and fields of the visual matter. As it was mentioned above, the beams are paired and contradirectional. Usually the beams in cosmos are mutually balanced and they do not call gravitation effects.

But on the surface of the Earth the contradirectional beams are not similar in their power. The powerful beams come from above, i.e. they only penetrate the atmosphere, and the weakened beams come from below, i.e. they penetrated all the Earth. Thus, gravitation appears.

Gravitation is a unique property of "aether wind" beams to loose part of their power during penetrating of matter mass. **Gravitation** is the difference of forces of contradirectional beams. *(Editor's note: Really other authors reported this idea also. I cannot find who was the first in discussion about gradient of aether as nature of gravitation.)*

Horizontal gravitation

As a particular case, there is **horizontal** gravitation on the surface of the Earth. It appears on the boundary between lowland (of the sea) and plateau. In this case one beam goes above the surface of the Earth (water), and the counter beam penetrates mountain range and weakens. The first measurements of horizontal gravitation effect were made on February 27, 1999 on the route Orenburg – Samara at 49 km before Syrtinskiy slope.

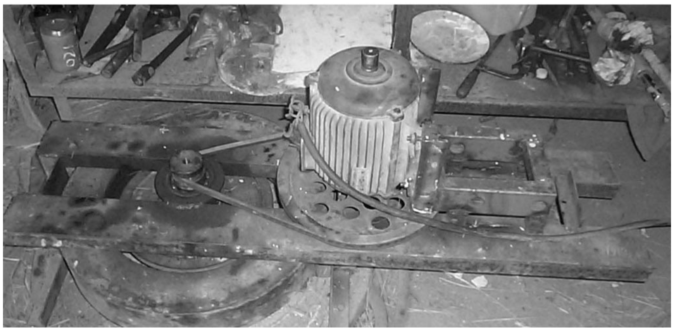

A leaden load (0,5 kg) on the float (a piece of foam plastic) moved on the water surface (not in the sea but in basin) towards the mountain.

Horizontal gravitation is much more weaker than usual gravitation, but it can reach the value that makes water to flow at some angle upwards.

Circular gravitation

Only fast-rotating bodies can create circular gravitation.

All bodies rotate by their orbits around the Sun in the open space of Solar system **due to circular gravitation guided by rotating the Sun.** Furthermore; circular gravitation always is direct (co-directional to the Sun rotation) and reversed gravitation on the periphery of Solar system. A planet with reverse orbital movement had not been discovered until now, but 6 satellites of planets in the Solar system have reversed orbital movement.

Here is the proof of the fact that circular gravitation appears only around the fast-rotating bodies and **slow-rotating bodies, for example, the planets Venus and Mercury cannot form circular gravitation**, that's why they have no satellites.

Our Sun is a prototype of mechanism to transform translation energy of aether wind beams into rotary energy.

(Editor's note: According to Kozyrev, any star is a transformer of time (chronal type of energy) into heat energy. Really, the aether wind can be considered as the chronal type of energy in our understanding and for our usual three-dimensional measurement equipment. To my mind it is a clear link to notion of 4-dimensinal objects, i.e. the time. ***Time can be described by parameters of the aether wind, i.e. its velocity, direction and density. So, we can say that quantitatively time can be described by formulations for kinetic energy of the aether movement. From the other hand it is equivalent of heat energy, which can be measured by usual methods after transformation of the longitudinal waves of the aether in transverse electromagnetic waves).***

Therefore, any mechanical disk rotating very fast will create a circular gravitational field, which is able to rotate all bodies in the direction of the disk (for example, a rim mounted on its bearing co-axially with rotating gyroscope). I designed and tested a similar device in January 2000. A gyroscope (of 200 mm diameter and 3 mm thick) was over-speeded up to 18 thousand rpm. Rotation of gyroscope called slow (but with a good momentum) rotation of the rim of 15 kg weight.

The gyroscopes with the mass of 0,5 kg, 15 kg and 90 kg were tested during summer of 2001. All them called rotation of the rims.

(Editor's note: There are other experimental facts. Fast rotation of mass should produce rotation of some part of nearby aether. Self-closed aether forms vortex and if photon is trapped by this vortex, then

experimenters can see "ring of light" near rotating mass. The rings or self-closed photos can exist in the same place after the mass was stopped or removed away.)

Nowadays gyroscopes in military devices are over-speeded up to hundreds of thousands of rpm. The more rates the gyroscope has, the more energy the rim will produce if it is connected to some generator. But these research works led to single-valued conclusions that gyroscopes themselves cannot produce big quantity of additional cosmic energy not jointly with permanent electromagnets. The Sun as well as planets has natural electromagnetism and their circular gravitation increases in many times due to the presence of electromagnetic fields.

(Editor's note: I think it is obviously that a rotating magnet can involve into the rotation much more quantity of aether than any simple rotating mass. In some theories any magnetic field is considered as circulation of aether particles.)

Electromagnetic fields are the unique boosters of circular gravitation. So, the gyroscopes themselves cannot produce necessary quantity of cosmic energy per unit mass of gyroscope without using of electromagnetism.

In October 2001, I got a copy of 24 patents description. There were patents on "perpetual motion machines". But since such "perpetual motion machines" cannot exist in reality, then we can explain them as gyroscopical transformers of cosmic energy. Efficiency of these transformers varies from 150% up to 10^6 % and practically all of them work using gyroscope. But nowadays only the transformer (Bauman's machine) works in Switzerland, in Maethernitha theological community, Linden city. Some systems have been working from 1980 and producing total power of 750 kWtt, the gyroscopes of 2m diameters are provided with constant magnets.

Besides, there are ready transformers of cosmic energy in Russia. The Professor of Moscow State University, Academician of Russian Academy of Natural Science Leonid Leskov spoke about them in the first half of 2001. He actually said that Mr. Chubais does not allow innovation of energy transformers, which are ready for commercialization (see newspaper "Raduga", Samara, July 2001).

I assume that any kinds of such transformers work on the energy produced by "Aether wind" beams. Perhaps our earth ancestry (Atlases) used this energy to fly as well as extraterrestrials. I remember information about flying platforms, which were designed in Germany in 1943-1945. Nowadays there are publications that there are not less than 10 captured extraterrestrial's spacecrafts on the Earth, and some samples were tested in Russia and the USA.

On the basis of all above-mentioned it becomes extremely clear that the main secret of Nature was discovered, and let's representatives of conservative science don't pull the wool over people's eyes to prove that "it is impossible". It is possible! Physics is an experimental science in its main part, and there is no completed theory until now.

As a result, I'd like to make some conclusions: The secret of Gravitation nature was discovered not in connection with new scientific investigation, but due to dawning up and understanding of the fact that gravitation since earliest times was produced by "Aether winds", which fill all cosmic space. Instead of improvement of "Aether wind" theory, academician science abolished it and forgot it such as some scientists of nowadays don't have an idea of it. While abolishing of "Aether wind" theory, scientific world spent 100 years in vain to find an alternative to it. A real Cosmic scientific and technical progress was slowed down during this term. Without this progress all humankind will kill environment of the Earth in 30-40 years!

Rush hours for humankind to turn to cosmic energy came, we have not even an hour to wait, and otherwise we will loose a chance to survive. Today the scientific and technical level is such that taking into consideration the buildup made by inventors – enthusiasts, who created more than 50 types of Cosmic energy transformers, it is possible to begin repetition work in one year. Now there is the only barrier to do it, i.e. market relations in energetics developed during last 100 years.

Let's look into near Future. The process of energy resources (coal, oil, gas) formation in bowels of the Earth took hundreds million years. There was period of clean ecology in the World Ocean, on land and in the atmosphere. **And all it catastrophically had been diminishing during 2-nd half of the XX century**. **There are about 40 years for our civilization to reach the boundary of having no chance to support normal life on the Earth.** An irreversible process of struggle for survival using underground environment and protection from mortal ecology will begin. Our close posterity will not forgive us this betrayal.

Is there any solution? Yes, there is.

It is necessary to publish the descriptions of all "perpetual motion machines" models as well as unprofitable publication of short technical documentation in the Internet and magazines, which will give a chance to many companies, research groups and individuals to re-produce them. But at first we should choose the models, which are the most reasonable in technology and prime cost. Such a way of replication of the models will give people confidence, interest and reliable information on existence of inexhaustible salutary cosmic energy. And the victory will be the reward for courageous, enterprising and advanced people.

which generates electrical voltage $E_{\updownarrow} = \ell \frac{dB_{rot}}{dt}$ in the structure of vacuum. This voltage generates Gravitational Impulse itself $G = 4\pi E_{\sigma} S \cdot (\Delta r_g)^2$, where $\Delta r_g = e_0 \frac{E_{\updownarrow}}{b}$.

The supposed "Gravitational Impulse" in the experiment by Podkletnov is modeled by a quarter of cosine curve.

Duration of this curve is determined by the decrease of magnetic field "trapped" into the superconductor due to the partial heating of semi-conductor emitter after plasma passed the discharge of 2MV with the current strength of 10000 A. The formula of the model is the following:

$$X'' = Ae^{-2\pi f_0 D_0 t}\cos(2\pi f_0 \sqrt{1-D_0^2}\,t) \qquad (1)$$

the calculation is made for the frequencies of 30, 3, 0,3 and 0,03 Hz and acceleration of 12 m/sec^2, which appears for the mass of the pendulum 30 g with the force horizontally to gravitation 0,03·12=0,36 N.

It can be supposed that it is necessary to make more careful solution of the problem to find the effect on the pendulum by its reaction, which is known from experiment. We should apply the more correct use of spectral method of solution of differential equation for the pendulum with setting of impulse effect. Further, having the recording of temporal function of magnetic field by Hall-effect devices and using Maxwell formulas, we should find electrical field acting in physical vacuum. This field will give us the force of gravitational impulse.

The experiment by V. Roshchin and S. Godin is simpler for physical modeling (Editor's note: the author assumes it is simpler than Podkletnov's effect). All input and output parameters are known to the authors, i.e. force of the magnets, frequency of variable magnetic field in the local place of space vacuum, change of gravity. Furthermore, there are known cylindrical formations of magnetic "loops" around the device and their approximate arrangement with the intervals divisible by the half of rotor radius. Effects of temperature decrease at 8° C in cylindrical atmospheric formations can be simply explained by adiabatic decrease of air pressure due to the decrease of gravitation between molecules of air. Formulas for estimation of decrease of gravitational and inertial forces are the same that for Podkletnov's experiment:

$$E_{\updownarrow} = \ell \frac{dB_{rot}}{dt}, \qquad (2)$$

$$G = 4\pi E_{\sigma} S \cdot (\Delta r_g)^2, \text{ where } \Delta r_g = e_0 \frac{E_{\updownarrow}}{b}. \qquad (3)$$

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New Sources of Energy from the Point of View of Unitary Quantum Theory

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Abstract

The Unitary Quantum Theory (UQT) is a new version of the field quantum theory, which has been developed by the principal author (Prof. L.Sapogin) of this paper for over 25 years. The theory is directly related to the problem of new energy sources, and this paper can be of interest for Journal of New Energy for it is the UQT (and not the classical Newton mechanics or the modern standard quantum mechanics) that provides a theoretical basis for the development of new sources of energy and for the explanation of the operation principles of the existing and functioning over unity devices.

The fundamental provisions of the UQT and a number of results received on the basis of it were published in many scientific journals and reported at international conferences (see [1-6], etc.). Generally, the UQT as expressed by the language of formulae and equations represents a new mathematical model of interaction and movement of elementary particles in the form of a complicated system of non-linear integral-differential equations, an important property of this model principally defines the trajectories and velocities of the particle movement in space (unlike the standard quantum theory, which directly defines only the probabilities of the presence of the particles at a certain point in space). Another, and the most essential (for the problem of new energy sources) property of the UQT is the absence of the energy conservation laws and the impulse for single particles in it. That is why the UQT makes theoretically possible processes of energy generation as if from nothing, if they are regarded from the classical mechanics point of view or the standard quantum theory (while the UQT is able to explain the phenomenon), as well as creation of a device with efficiency above 1. In other words, the UQT provides for a theoretic possibility of making a perpetual mobile!

In the 1970's, when the UQT started to be developed, there was nearly no data of the observed phenomena, or any experimental results confirming this unusual theory. Today, such data are abundant. For example, such processes can be named as generation of excessive heat energy during cavitation of very small water bubbles; generation of excessive electric energy in an anomalous gas discharge; excess generation of electric energy when electric current passes through proton-conducting ceramics, etc. Besides, and still more important, operating devices that have been created much more energy than it was necessary for these devices functioning: electric current generators "Testatica" (Switzerland); thermal cell CETI (J.Patterson, USA); heat generators (Yu.S. Potapov, Moldavia, J.Griggs, USA); electric current generators (P.Correa, A.Correa, Canada); electric engines on magnetic ceramics (Japan), and others. The said phenomena and operation principles of the above-mentioned devices can be explained with the help of the UQT.

In this paper we will also touch upon such an important problem as cold nuclear fusion. The feasibility of this nuclear process, which is categorically denied by the standard quantum theory and nuclear physics specialists, was predicted by the author of the UQT as far back as in 1983. This phenomenon was discovered in 1989 (electrochemical experiments, M.Fleischmann, S.Pons). Many subsequently received experimental data confirmed the existence of nuclear reactions under very small energies, of nuclear transmutations in plants and biological objects, very slightly connected with generation of energy [7-8]. From the point of view of the UQT, which provides an explanation of the cold nuclear fusion mechanism, this process can be applied in practice (after the relevant devices are designed) for generation of energy, for production of isotopes, and for nuclear waste liquidation.

Introduction

Inventors, as well as swindlers of all kinds, had long ago been trying to construct, or at least design, a *perpetual mobile*, i.e. an imaginary machine that produced work without any outside energy. Peter the Great even founded the Imperial Russian Academy of Sciences for such research, but the modern Russian Academy of Sciences does not like to recollect this circumstance. On the other hand, the French Immortals in 1755 decided not to consider any *perpetual mobile* projects at all, and, as we would see, were quite right as regards the Newton mechanics. The brilliant success of the classic mechanics has strengthened still more the sacred belief of the mankind in the Divine Infallibility of the Conservation Laws, and today it is nearly indecent to express any doubts about these laws.

Let us first of all find out the origin of the conservation laws in ordinary mechanics. Practically any textbook will tell you that the Energy Conservation Law (ECL) follows from the homogeneity of time, the Impulse Conservation Law from the homogeneity of space, and the Angular Momentum Conservation Law from the isotropy of space. That is why many people have an impression that the conservation laws themselves follow only from the quality of time and space, which is today an undoubtedly relativistic notion. But, for example, the angular momentum is not a relativistic notion. So, such a narrow approach is not altogether correct, and it is necessary to turn to the second Newton law, or the equation of relativistic dynamics and the system insularity. However, *the qualities of the time and space ensue exactly from the analysis of the Newton mechanics*, though they are often construed incorrectly. Let us remind you the correct interpretation.

Homogeneity of time suggests that *if at any two moments of time two similar experiments are made in similar closed loop systems, the results thereof will not differ.*

Homogeneity and isotropy of space mean that *if a closed loop system is moved from one part of space to another, or is oriented differently, nothing will change.*

The making of the fundamental energy and impulse conservation laws from the Newton equation is very simple. Let us put down the main equation of dynamics as

$$\mathbf{F} = \frac{d\mathbf{P}}{dt}$$

For closed loop system $\mathbf{F}=0$ (no external forces operating) and the equation integral will be $\mathbf{P} = Const$ the impulse conservation law.
Now let us take the main equation of dynamics as:

$$\mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{v}}{dt}$$

and multiply it scalarwise by $\mathbf{v}$

$$\mathbf{F}\cdot\mathbf{v} = m\frac{d\mathbf{v}}{dt}\mathbf{v} = \sum_{i=1}^{3} m\frac{dv_i}{dt}v_i = \sum_{i=1}^{3} m\frac{d}{dt}\left(\frac{v_i}{2}\right) = \frac{d}{dt}\left(\frac{mv^2}{2}\right)$$

where v is the module of the velocity vector $\mathbf{v}$. For closed loop system $\mathbf{F}=0$, and the equation integral will be

$$\frac{mv^2}{2} = Const$$

one of the forms of the energy conservation law. From the definition of the angular momentum for a particle,

$$\mathbf{L} = [\mathbf{r} \times \mathbf{P}]$$

Differentiating both parts by *t,* we get

$$\frac{d\mathbf{L}}{dt} = \left[\frac{d\mathbf{r}}{dt} \times \mathbf{P}\right] + \left[\mathbf{r} \times \frac{d\mathbf{P}}{dt}\right]$$

Since the impulse vector is parallel to the velocity vector, the first bracket will equal to zero. On the basis of the resultant equation and the definition of central force as not creating any momentum, we get

$$[\mathbf{r} \times \mathbf{F}] = 0 \quad \text{or} \quad \mathbf{L} = Const.$$

In case of the central force in an unclosed system, the angular momentum is preserved by value and direction. The angular momentum conservation law for a closed loop system results in the same way as the impulse conservation law from the equation of the rotary motion dynamics:

$$\mathbf{M} = \frac{d\mathbf{L}}{dt}$$

For a closed loop system, the momentum of external forces $\mathbf{M}=0$ and the integral of the equation will be the angular momentum conservation law

$$\mathbf{L} = Const$$

In relativistic dynamics the emergence of the energy and impulse conservation laws separately can be easily received from the relativistic ratio for energy and impulse

$$E^2 = P^2c^2 + m^2c^4$$

Term m^2c^4 is an invariant, i.e. the same in all reference systems. In other words, it is a certain constant. This equation can be represented in a slightly different form

$$E^2 - P^2c^2 = Const$$

For the equation to be valid, it is required that

$$E = Const \text{ and } P = Const$$

and this none the other but conservation laws for energy and impulse.

Strictly, relativistic mechanics has a conservation law for 4-impulse vector P^{μ}, but we will not dwell on these details, because small energies are what we are interested in.

In the classical theory, the energy conservation law states that the energy of a closed loop system remains unchanged, so, if the energy of such a system is designated at a moment *t=0* as E_0, and at the moment *t* as E_t, $E_0 = E_t$.

Conservation laws in ordinary quantum mechanics

The standard quantum theory formulates the energy conservation law in the same way. In quantum mechanics we have the same movement integrals as in classic mechanics. A certain value *L* will be a movement integral, if

$$\frac{d\hat{L}}{dt} = \frac{\partial \hat{L}}{\partial t} + \left[\hat{H}, \hat{L}\right] = 0 \qquad (1)$$

Since $\left[\hat{H}, \hat{L}\right]$ is defined by commutator of operator $\hat{L}$ and of Hamilton's operator, any value *L*, *not depending explicitly on time*, will be the movement integral, if its operator commutes with the Hamilton's operator. When value *L* does not explicitly depend on time, the first item in (1) turns to zero. There remains

$$\frac{d\hat{L}}{dt} = \left[\hat{H}, \hat{L}\right] = 0 \qquad (2)$$

and for the movement integrals not explicitly depending on time the Poisson quantum bracket equals zero. From (1) and (2) it follows that the average value of the movement integrals does not depend on time:

$$\frac{d}{dt}(L) = 0$$

All good papers on the quantum theory prove that probability $w(L_n, t)$ to find at any moment *t* any value of the movement integral, i.e. L_n, does not depend on time. Further, is constructed as the movement integrals not explicitly dependent on time. Since operators $\hat{\mathrm{L}}$ and $\hat{\mathrm{H}}$ commute, they have common proper functions, which are functions of stationary states. Let us note that the latter follows from solutions of the equation without time, which was received from the full equation with imposition of requirement

$$\Psi(\mathbf{r}, t) = \Psi_0(\mathbf{r}) \exp\left(i \frac{E}{t}\right)$$

equivalent to search of only periodic solutions. Further, quite naturally, *there appeared an equation without time with actually imposed conservation laws, because now nothing depends on time*. Expansion by such proper functions looks as follows:

$$\hat{L}\Psi_n = L_n\Psi_n \qquad \hat{H}\Psi_n = E_n\Psi_n$$

where

$$\Psi(x,t) = \sum_n c_n \Psi_n(x) \exp\left(-i \frac{E_n}{\hbar} t\right) = \sum_n c_n(t) \Psi_n(x) \qquad (3)$$

$$c_n(t)=c_n\exp\left(-i\frac{E_n}{\hbar}t\right)=c_n(0)\exp\left(-i\frac{E_n}{\hbar}t\right)$$

Since (3) is expansion into proper functions of operator $L_{n'}$, probability does not depend on time:

$$w(L_n,t)=|c_n(t)|^2=|c_n(0)|^2=Const$$

Since energy is a movement integral and probability *w (E,t)* to find at a moment *t* an energy value equaling E, does not depend on time, then:

$$\frac{dw(E,t)}{dt}=0$$

Let us note once again that it is *the probability to find a certain value that does not depend on time, but not the value itself, which for any separate event is accidental and can assume a wide range of values.*

The quantum energy conservation law in the above form suggests a possibility of defining energy at a given moment without subjecting it to uncontrolled change, which raised no doubts in classic mechanics. But in the quantum theory the energy, without changing its value, can only be measured to

$$\Delta E\geq\frac{\hbar}{\tau}$$

where τ - is measurement duration. Formally, it does not present any difficulties for the energy conservation law, since energy is a movement integral, and we have much time to make long measurement. For example, let us make measurements during time τ, then leave the system to itself for time *T*, and then define energy again. The classic quantum energy conservation law states that the result of the second measurement will coincide with the result of the first measurement to $\Delta E\approx\frac{\hbar}{\tau}$. But even in the ordinary quantum theory all this is not consistent enough. For the real vacuum fluctuations can interfere, that always influences the results of a single process, but their influence disappears after the passage to an ensemble of events. Here we have a violation of the conservation law due to vacuum fluctuations, though existence of movement integrals, unlike in the Unitary Quantum Theory (UQT).

The generally accepted quantum theory carefully avoids the question of conservation laws for individual events in the case of small energies. This question is either not discussed at all, or it is said that *the quantum theory does not describe individual events. Yes, it does describe individual events, but it can only predict a probability of this or that result.* It is clear that in this case there are no conservation laws for individual events (it is wrong to speak about it in case of an accidental result of an individual event), and they appear only after the averaging by large ensembles of events. Essentially, it can easily be proved that classic mechanics follows from quantum mechanics after summing up by a large number of particles, because for a sufficiently big mass, the length of the de Broglie wave becomes much less than the body dimensions, and no quantum-wave qualities can be talked about.

Conservation laws in Unitary Quantum Theory

In the UQT [1-14] any quantum particle is not a point, but a source of field like in the ordinary quantum mechanics, but it represents a bunched field (wave packet) of a certain unified field. The dispersion equation of such a nonlinear field turned out to be such that the wave packet (particle) during its movement periodically appears and disappears, and the envelope of this process coincides with the de Broglie wave. Numerous particles during their periodic disappearance (spreading in the Universe) are repeated appearance from vacuum fluctuations. A theory of quantum measurements has been built, and the probability interpretation follows from the mathematical formalism of the quantum theory [10,11], and it is not postulated as in conventional quantum mechanics. Unfortunately, the main UQT equation turned out very complicated, for it is a system of 32 nonlinear integral-differential equations, which could require for their solution some new mathematical methods. But from this the relativistically invariant Hamilton-Jacoby equation, and the Dirac equation system strictly follow.

Papers [13,14] give a solution of the simplified scalar integral-differential UQT equation, which gave a localized solution for the form of a wave packet representing a particle. It turned out that the integral from a bilinear combination of such a solution for the whole volume gives with the precision of 0.3% the value of a non-dimensional elementary electric charge [13,14], which was essentially its first theoretical calculation. Then, this solution in the form of a periodically appearing and disappearing wave packet (which square describes the density of a spatial charge) can be replaced by an oscillating charged particle [15-18], the movement whereof will be described by the conventional Newton equations:

$$m\frac{d^2\mathbf{r}}{dt^2}=-2Q\mathbf{GRAD}U(\mathbf{r})\cos^2\left(\frac{mt}{2\hbar}\left(\frac{d\mathbf{r}}{dt}\right)^2-\frac{m\mathbf{r}}{\hbar}\frac{d\mathbf{r}}{dt}+\varphi_0\right)\quad(4)$$

$$m\frac{d^2\mathbf{r}}{dt^2}=-2Q\mathbf{GRAD}U(\mathbf{r})\cos^2\left(-\frac{m\mathbf{r}}{\hbar}\frac{d\mathbf{r}}{dt}+\varphi_0\right)\quad(5)$$

where *m, Q,* $\mathbf{r}$ - mass, charge, and radius-vector of the particle, $U(\mathbf{r})$ – external potential, φ_0 - initial phase.

Since $\mathrm{E}=-\mathrm{GRAD}U$, and a magnetic field also exists, the Lorenz force should also be calculated for $\mathbf{F}=\frac{Q}{c}[\mathbf{v}\times\mathbf{H}]$, but in the electromagnetic wave **E** and **H** are equal, and for small energies value $\frac{v}{c}\to 0$, and force **F** can be ignored. Both these equations produce qualitatively similar results for different problems, but the first non-autonomous equation evidently does not have any movement integrals at all, and any hope for analytical solutions is very unreal. But for the second autonomous equation such hope still exists. Let us note that these equations describe more accurately the experimental results of scattering on the coulomb potential than the classic Rutherford formula! Application of these equations for the tunnel effect and scattering on short potential also produces correct results, but in this case passage through a high barrier (tunnel effect) will be defined by the initial phase. Of greatest interest, however, is the harmonic oscillator problem.

It is possible that a change in the properties of a material point in the process of its movement is just another step in the material point movement theory. In conventional mechanics this idea is not altogether new. There are Meshchersky's equations for bodies with a changing mass, and Tsiolkovsky's equation for a rocket. But so far, in the conventional quantum theory, the particle has a permanent and stable in space and time set of properties, and in the UQT all the parameters of the particle are changed and oscillate during movement.

It should be noted that *Newton did not introduce the notion of a material point at all,* and it would be ridiculous to think that he was not able to have this natural and rather trivial idea. Most probably, and it is not by chance, for today many troubles of the field quantum theory are rooted in the approach to the particle, as to the point, the most vivid example being a large bouquet of divergences. Nevertheless, this approach is very convenient and should only be used correctly. Let us also remember, that in accordance with the Newton corpuscular theory, beams of light were to be regarded as a flow of certain particles. They are emitted by a shining body in all directions and move in an empty space or a homogeneous medium evenly and straight, i.e. in the same way as the ordinary material particles do in the absence of any external or interaction forces. Newton explained reflection and refraction of light beams on the surface of border between two homogeneous mediums by the effect of certain forces on this border, in the direction perpendicular to the surface. These forces changed the normal velocity component, but did not touch upon the tangential one, which allowed to derive the reflection and refraction laws. However, the inability of such a theory to account for the light partial reflection and passage phenomena, as well as the Newton rings (which he himself discovered), led him to bouts (or fits) theory, which is quite modern, although nearly forgotten. Newton believed that for full explanation of all the processes it was necessary to suggest that some light particles could experience reflection bouts, and others – passage bouts. Let us imagine light falling to a flat surface, which is partially, reflects and partially passes. With quantum description of this phenomenon, a particle connected to the falling wave at the time of hitting the surface has a certain probability of passing or being reflected, and Newton simply used the word "bouts" in place of the word "probability".

It is absolutely clear that all descriptions of processes by the equation with an oscillating charge will be an approximation, because it is evident that no movement equations for a material point can describe even the simplest interference processes on a semi-transparent mirror, during which a material particle should be divided in two parts which will later eliminate each other by destructive addition. It is surprising, but the numerical solution of the problem of scattering on a short potential (the Ramsauer effect) for equations (4) and (5) gives the correct diffraction picture! But if we want to describe an individual particle correctly in the conventional quantum mechanics, the picture becomes inexact and purely probabilistic. At every given moment of time a particle can exist in only one of the mutually incoherent states, because one particle cannot move in different directions simultaneously (it cannot have many impulses at the same time). Nevertheless, there seems to exist a whole class of processes, where description with the help of equations (4) and (5) have certain sense. It is well known that in all experiments the local energy and impulse conservation law in individual quantum processes are true only under high-energy values. But under small energy values it is not so, at least because of the ratio of uncertainties and the probabilistic character of all the quantum theory predictions, and the idea of a global, not local ECL, is invisibly present in the quantum mechanics, and is certainly far from new.

In the strict UQT and the quantum measurement theory, a great role belongs to unavoidable vacuum fluctuations. It is clear that these fluctuations are totally unpredictable and non-invariant in relation to space and time translations. The same can be said otherwise: there are no habitual properties of time and space in this theory. Space-time is now not homogeneous and not isotropic. For example, if the system is transferred to a new point in space, or a certain experiment is repeated at another time, at the point where particle parameters are studied, and it interacts with the macro-device, a new value of vacuum fluctuations (different from the previous one) can appear and produce a different result. Of course, all this is only true for small energies and individual events.

Still more destructive is the UQT for the notion of a closed system. For individual events under small energy values this notion is simply unacceptable for the following reason: vacuum fluctuation at the location of the particle (e.g. in a potential pit) can be sharply changed at any moment. It can be caused by different factors – the nature of vacuum fluctuations itself, or the tunnel effect of another random particle.

Sometimes it is stated that conservation laws follow from the Nether theorem, though these results are present in the works by D. Gilbert and F. Klein. For any physical system, the movement equations from which can be received from the variation principle, each one-parametric continuous transformation that leaves the variation functional invariant, corresponds to one differential conservation law, and there exists a clearly conserved value. It is easy to see, however, that vacuum fluctuations imposed on the varied function (integral of Lagrangian) do not in sum remain unchanged during parametric transformations (at least today it seems so), and this consideration does not work without preliminary of ensemble.

And now we are in for a little philosophy. The local Energy Conservation Law (ECL) in individual processes follows from the Newton equations for closed systems. It would be naive to think that its local formulation will be preserved forever, and would be a bad mistake to transfer the ECL from the Newton mechanics to the quantum processes without any changes, because the latter are more fundamental.

References to the first principle of thermodynamics are, strictly speaking, groundless, because this principle is a postulate. For example, well-known Russian mathematician N. Luzin, in a letter to an inventor wrote that the first principle of thermodynamics is the result of unsuccessful attempts of the mankind at building a *perpetual mobile*, and strictly follows from nothing. *Today it may be said with a great degree of certainty that no sophisticated machine in the framework of the Newton mechanics can be a perpetual mobile,* and the decree of the French Academy of 1755 not to consider any *perpetual mobile* projects is still valid. We will only add that now it is valid only for those projects that are based exclusively on the Newton mechanics.

There is the tendency in modern physics to reduce ECL, especially in theory, to the rank of a secondary derivation from the movement equations (movement integrals). Some physicists restrict the ECL to the framework of the first principle of thermodynamics, others, like D. Blokhintsev [37], think it quite probable that with the development of a new theory the form of the ECL will undergo certain changes. F. Engels wrote in his "Dialectics of Nature": "...none of the physicists actually regard the ECL as an eternal and absolute law of nature, a law of spontaneous transformation of the movement forms of the matter and the quantitative constancy of this movement in all its transformations". But many people do not share this opinion. M. Bronstein in his book "Structure of Matter" wrote: "The ECL is one of the main laws of the Newton mechanics. Nevertheless, Newton did not ascribe to this law the general character that this law actually possesses. The reason for this *erroneous* (italicized by authors) opinion of Newton of the ECL is very interesting...". It is now clear that in view of the above, such an opinion was not at all erroneous. Let us remind you that Newton predicted many things, even the UQT, in his "bouts theory".

On the other hand, the authors of quantum mechanics realized that there was no conservation law for single quantum processes under small energies at all. The idea that the construction of ECL, together with the second law of thermodynamics, was a statistical law, true only on the average and inapplicable to individual processes with small energy, first occurred to Schroedinger, and later to Bohr, Kramers, Slater, and Gamov. In 1923 Bohr, Kramers and Slater made a desperate attempt to develop the theory, where the energy and impulse conservation laws in case of scattering would be true only statistically, on an average for long periods of time, but would be inapplicable to elementary events. Lev Landau even called it "Bohr's wonderful idea".

Later, however, the authors gave up this approach and, besides, this idea at that time did not follow from the quantum theory equations, and the authors, *to come out of the predicament, simply declared that quantum mechanics did not describe individual events at all*. Thus, the most vivid paradox of the quantum science was removed by a simple ban on thinking about it! But the ingenious idea that conservation laws do not apply to individual quantum processes and emerge only after the averaging by the ensemble of particles remains alive. This idea might have been a little premature, and, possibly, should be a little different.

The Unitary Quantum Theory (UQT), on the contrary, individual particles, and the difference in their behavior is accounted for by the initial phase of the wave function. In this case, local conservation laws do not exist for a single particle, and measuring the initial phase or some other parameters for an individual particle is quite a different matter. It is not true that the UQT has given up probabilistic description. Probabilistic interpretation remains, but the probability now is strongly dependent on the initial phase. Although the equations with an oscillating charge can determinately predict a particle's behavior, the measurements can be made only with the help of a macro device, which will give only a probabilistic result. Impossibility to determinate measurements does not change anything, for the UQT provides for a possibility of influencing the probability value, which was earlier unavailable. The existing Von Neumann theorem about hidden parameters does not effect our result, but the relevant discussion is too cumbersome, and we will leave it out.

*In other words, **all the requirements**, wherefrom the classical conservation laws follow, are now absent. We can hardly expect the conservation laws for individual particles to be preserved under small energies in such a situation.* Today we are convinced that the classical energy, impulse and angular momentum conservation laws for individual quantum objects are not valid under small energy values because of periodic appearances and disappearances of the particle. All direct experimental tests of the conservation laws were made for large energy values, and for small energies of an individual particle only probabilistic results can be received, and, in this case, it would be indecent even to recall the conservation law.

Energy generation and perpetual mobile

Let us make the following imaginary experiment. For simplification purposes we will use in our reasoning a certain quantum ball-particle. When a classical ball approaches a wall (perpendicularly for simplification), the speed of the reflected ball is always equal to the initial speed (we ignore friction and regard the ball and the walls as absolutely elastic). In the case of a quantum ball, the speed of the reflected ball will acquire in different experiments with absolutely equal initial conditions a whole range of values: some balls will be reflected at a speed greater than the initial speed, others – at a speed equal or lower than the initial speed, and all this is described by quantum mechanics.

Let us ask the following question: what if a second wall is found, parallel to the first one, in order for the ball to increase its speed after each reflection from the wall? Then we will have increased ball energy without any special efforts on our part. Such phenomena appear in the problem of particle oscillations in a potential pit (not necessarily parabolic) on the basis of equations (8) and (9), when four types of solutions are possible, three of which are most important for us: stationary, "maternity home", and "crematorium". In the two latter solutions traditional conservation laws do not work. These solutions are presented in Fig. 1. Such oscillator behavior explains many experimental facts. From the physical point of view, it means that in stationary solutions with fixed discrete energies (conventional quantum mechanics) the speed of the particle reflected from the wall will be equal to the speed of the falling particle. If the speed of the particle is decreased after each reflection, it will mean the "crematorium" solution, and if it increases, the "maternity home". Scenarios for situations will depend on the initial phase of the wave function and the particle energy. In ordinary situations the "crematorium" and "maternity home" solutions always compensate each other, and we find conservation laws.

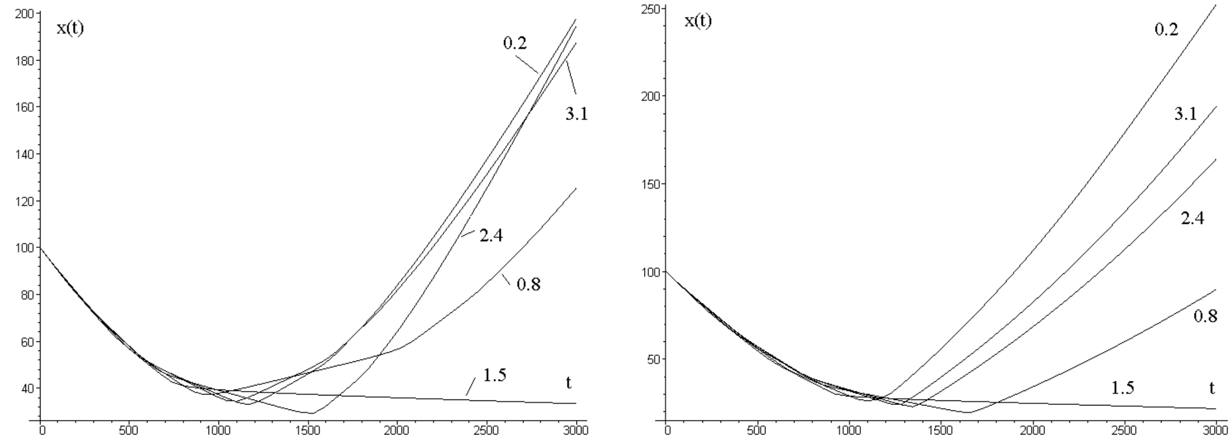

Fig. 1. Dependence of the distance between the moving charge and the nucleus on time for autonomous and non-autonomous equations.

The task of the future developers of new energy systems of the 21st century will consist in creating such initial conditions for a great number of particles making up a body that only the "maternity home" solution would be realized, and the "crematorium" solution would, if possible, be suppressed.

It follows from the above that if the unitary quantum theory ideas are applied correctly, there is no fundamental taboo for a perpetual mobile. Such a taboo, as it was shown, does not formally exist even in conventional quantum mechanics (no conservation laws for individual processes with small energies), and, in order to generate energy, they should be somehow accumulated (all random processes with excess energy should be grouped together). But conventional quantum mechanics refuses to describe individual events and is unable to offer any ways for such grouping. The unitary quantum theory seems to offer such an opportunity.

However, the great idea of free energy generation was distorted by effort of some research associations interested to keep their stability degree, that everyone who started speaking about it was considered to be a crazy man.

Modern experimental physics has verified the correctness of conservation laws either for very large energies in individual quantum events, or for big macroobjects, when automatic averaging by ensemble is made, but the area of very small energies for individual events today is a *terra incognita*.

In order to see how the conservation laws for reflection (repulsion) of an individual particle from the Coulomb heavy nucleus with different values of the initial phase are violated, we have solved numerically one-dimensional equations (8) and (9) under the different initial conditions:

$$\hbar = 1, m = 1,\ 2Zze^2 = 1,\ x_0 = 100,\ V_{x0} = -0.1$$

In the Fig. 2 the distances between the moving particle and repulsive nucleus are shown as a time function, for different initial phases in cases of non-autonomous and autonomous equations.

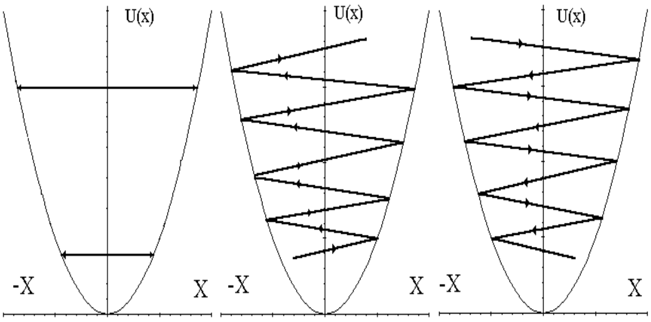

Conventional solution Mathernity home solutions Crematorium solutions

Fig.2 Three types of solutions for oscillator

It is evident from the calculations that the speed of a reflected particle can be equal, lower or higher than the speed of a falling particle. This situation seems to be true for all potentials.

Calculations were also made for other potentials: harmonic oscillator, Yukawa, Gauss, dipole, hyperbolic secant, and Wood-Saxon, and the quality results were nearly the same. If we sum up the impulse of all the particles falling with different phases and compare it with the summarized impulse of all the reflected particles, the summarized reflected impulse, for example, for the Coulomb potential, will be several percent higher than the summarized impulse of the falling particles. For other potentials such a small deviation can even be in the opposite direction. On the whole, this problem is very complicated and requires additional research, because all this is also dependent in quite a complex way on the initial conditions (initial speed, phase and distance).

Philosophically, any categorical taboos, like the impossibility of creating a *perpetual mobile*, are absolutely unacceptable. If everyone is convinced of it forever, the conservation laws and *perpetual mobile* taboos will remain unshakable as long as the human civilization exists. Of course, the funeral of the Conservation Laws can be very prolonged. Anyway, we are not going to do it, and our article might be just a cleanup for the future tomb, and the splendid funeral with all the necessary honors will be organized by future generations. *On the other hand, these laws will never die out completely and will surely be applied, but such spheres of science and technology will appear, though small at first, where these laws are not valid.*

The truth should be accepted irrespective of where it comes from. Words of F. Engels from the “Dialectics of Nature” will be quite appropriate here: “When the solar system ends its life circle and shares the fate of all the finite things, when it falls victim to death, what will happen next? Thus, we come to a conclusion that the heat emitted into the universe should have an opportunity, in a way yet to be established by the natural sciences, to turn into another form of movement, where it can be accumulated again and start functioning. And in this casethe main problem that prevented transformation of dead suns , back to red-hot nebulas will disappear”.

The question of whether the conservation law exists in global form (we have already proved its not being local) remains open, because nothing leads to it except the inertia of the human mind. This inertia was based on the Newton laws, which were replaced by quantum laws. This mental inertia leads to a situation, when in case excessive energy is generated during solution of movement equations, a question arises how it can happen, and where it comes from. Of course, if a particle (e.g. a photon) falls on a semitransparent mirror, the packet is divided into two halves, which, due to imposition of vacuum fluctuations, will be recorded by photomultipliers as full-fledged photons [1-5]. The result is that energy is taken as if from vacuum: two photons appear in place of one. Another photon can be divided on the mirror into two halves, but they will not be recorded by the meters, and the energy will allegedly pass into vacuum. So, at one time we borrowed energy from vacuum, and then gave the same amount of energy back to vacuum at another place. You can think like that, and this process might take place. But if we consider the equation with an oscillating charge, the energy and impulse conservation laws are not valid there for solution of the movement problem, and vacuum fluctuations have nothing to do with it at all. As for the question of where the energy comes from, it is the result of our mental inertia, and is, essentially, an atavism imposed by the Newton mechanics. But the latter appears as a result of an extreme passage from quantum mechanics, which is more fundamental.

It is interesting to note that there is a bomb in the logical definition itself of the energy conservation law. If energy is something that cannot appear or disappear and always simply passes from one form to another, the only value satisfying this condition is zero. We are far from assuming that energy does not exist. But the problem of existence is solved differently in different philosophical systems, and the mathematical approach seems to be the most correct one: *an object exists if it is free from contradictions*. Energy has bad luck in this case, for under such an approach it should be zero.

Some cosmologists (for example, British prof. Fred Hoyle) are very willing to have a process, in accordance with which the Universe has certain places where energy appears from other certain places, in which it is eliminated. Besides, any philosopher at least a little bit familiar with astronomy, looking at the bright night sky, will see the birth of matter and its expansion into a still greater space. But for this purpose the Global Energy Conservation Law is superfluous and only denies what is observed. The head reels…

Cold Nuclear Fusion and Nuclear Transmutation.

Let us approach the epoch-making experiments made by Fleischmann and Pons in March 1989 [30] from the positions of the equation with an oscillating charge. One of the authors predicted in 1983 [9] the possibility of such nuclear reactions under very small energies. Without going into well-known details, we will sum it up very briefly: cold nuclear fusion exists, and there are no people or theories capable of giving a clear explanation. The chain of various mechanisms meant to explain this intriguing phenomenon is growing, but few really believe in them. The reason is as follows.

When a charged particle interacts with the nucleus, the potential energy is like in Fig. 3, where the right top part of the curve is conditioned by mutual Coulomb repulsion between the nucleus and the charged particle.

The repulsion potential will be

$$U(r)=\frac{Zze^2}{r}$$

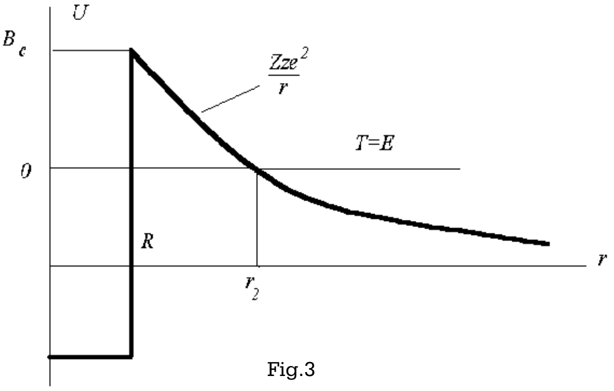

Fig.3

where Z – charge of the nucleus, and z – charge of the approaching particle, e – charge of the electron, r – distance between the particle and nucleus. When $r=R$ (critical distance), then the potential energy curve goes sharply down, which is due to the emergence of intense nuclear gravitation, the potential whereof today appears more complex than could be imagined mathematically. If the charged particle overcomes the Coulomb barrier with a height of

$$B_c=\frac{Zze^2}{R}\approx\frac{Zz}{\sqrt[3]{A}}MeV$$

it will further get into the nuclear gravitation area and a nuclear reaction will take place.

Let us look at the nuclear interaction of a charged particle with kinetic energy $T<B_c$. From the point of view of classical mechanics, there will be no nuclear reaction in this case, because the particle will approach the nucleus and at a certain distance $r<R$ from the top of the Coulomb barrier will turn back and be reflected from it. However, from the point of view of quantum mechanics, there exists a tunnel effect, and the probability of such a tunnel passage, or transparency of potential barrier D is described by a well-known formula:

$$D\approx\exp\left(-\frac{2}{\hbar}\int_{r_1}^{r_2}\sqrt{2\mu(U-T)}dr\right) \qquad (6)$$

where $\mu=\frac{Mm}{M+m}$ is reduced mass. The bottom integration limit r_1 coincides with the nucleus radius R, and the top limit r_2 can be found from the condition $T=\frac{Zze^2}{r_2}$. After integration we will get

$$D=\exp(-2g\gamma)$$

where $g=\frac{R}{\lambdabar_{B_c}}$; $\gamma=\sqrt{\frac{B_c}{T}}\arccos\left(\sqrt{\frac{T}{B_c}}\right)-\sqrt{1-\frac{T}{B_c}}$,

and value $\lambda_{B_c}=\frac{h}{\sqrt{2mB_c}}$, the de Broglie wavelength corresponding to the kinetic energy of the particle equal to the barrier height $T=B_c$. If $T<<B_c$, expression (6) is easily transformed to look as

$$D=\exp\left(-\frac{2\pi RB_c}{\hbar v}\right)=\exp\left(-\frac{2\pi Zze^2}{\hbar v}\right) \qquad (7)$$

where v is velocity.

Let us now see what the shocking cold nuclear fusion will look like on the basis of the above considerations. The deuteron energy in an ordinary electrolytic Fleischmann-Pons cell will be about 0.025 eV, and the height of the Coulomb barrier for this case is $B_c=\frac{Zze^2}{\sqrt[3]{A}}=0.8MeV$. In classical mechanics it would be just naive to talk about overcoming such a barrier with a height dozens times greater than the kinetic energy. Let us now see how the tunnel effect will improve the situation. Let us assess the value of g and γ for the case of collision between two deuterons with such energy:

$$g=\frac{R\sqrt{2mB_c}}{\hbar}=1.9;$$

$\gamma=\sqrt{\frac{B_c}{T}}\arccos\left(\sqrt{\frac{T}{B_c}}\right)-\sqrt{1-\frac{T}{B_c}}\approx 8883$ and the probability of such a process will be $\exp(-2\cdot 1.9\cdot 8883)\approx 10^{-7328}$, i.e. practically pure zero. The fusion cross-section will be defined by the product of nuclear cross-section and the tunneling probability:

$$\sigma=\sigma_{nucl}D$$

and, in the case under review, is also a very small value. If the clash parameter of deuterons is not zero, the emergence of centrifugal potential

$$U = \frac{\hbar^2 l(l+1)}{2mr^2}$$

will still further lower the probability of such interaction.

It is these very circumstances that make the nuclear physics scientist think that there is no cold nuclear fusion as such. For example, such a serious and responsible edition as Encyclopedia Britannica 2001 found no place for the notion of cold nuclear fusion at all. Such an official position can be understandable only from the point of view that quantum mechanics is absolutely true and unshakable. Despite this, for the 12 years since the Fleischmann-Pons experimental discovery, nearly 30 international conferences have been devoted to this subject, there are lots of books and magazines on this subject, and the number of articles on the problem is nearing ten thousand. Today the situation is gradually developing in the positive direction, and the research in the field of hot nuclear fusion, which has already wasted over $90 billion for 45 years, is slowly coming to naught.

But today there exist well known experimental data on cold nuclear fusion. They are numerous and various. We will dwell only upon the most important and sufficiently reliable results. Thus, the classical view of electrolysis of a palladium cathode saturated with heavy hydrogen in heavy water identifies an anomalous quantity of heat energy up to 3 kWt/cm^3, or up to 200 Mj per small sample. Products of nuclear reaction have also been found: tritium (10^7 - 10^9t/s), neutrons with energy of 2.5 MeV (10-100n/s), and helium. Absence of He^3 among the reaction products shows that heat is not generated by reaction $d+p$. Besides, emission of charged particles ***(p, d, t, γ)*** is observed. Similar processes are observed in case of a gas discharge on a palladium cathode, of phase passage in different crystals saturated with heavy hydrogen, irradiation of deuterium mixture with a powerful sound or ultrasound flow, in cavitating microbubbles in heavy water, in a tube with palladium powder saturated with heavy hydrogen under a pressure of 10-15 atm., etc. In certain reactions (e.g. $d+t \rightarrow \alpha + p$) neutrons of 14 MeV are absent, and such a strange situation occurs in other cases too. Activity of Li^6 , Li^7 in reactions with heavy hydrogen and protons failed to be discovered, whereas reaction

$$K^{39} + p \rightarrow Ca^{40}$$

was well recorded even in biological objects. But the most intriguing fact of all these processes is the shortage of nuclear reaction products for explanation of the emerging heat effects. Thus, in certain cases the number of nuclear reaction products (tritium, helium, neutrons, quanta) should be millions of times greater in order to account in some way for the quantity of the generated heat. Generation of such a big amount of energy cannot be accounted for by either chemical or nuclear reactions, or by phase passages. The well-known interaction $d+d$ goes along three channels:

D + D —> T (1.01) + p (3.03) (Channel 1)
D + D —> He (0.82)+ n(2.45) (Channel 2)
D + D —> He + γ(5.5). (Channel 3)

All these reactions are exothermal. The third channel has a very small probability. It was experimentally discovered that they could occur under very small energies. In a molecule D_2 the equilibrium position between atoms is 0.74A and in accordance with the conventional quantum theory, these two deuterons could accidentally enter a nuclear fusion reaction. But the interaction value is very small $\lambda_{D_2} = 10^{-64} c^{-1}$. There is a known estimate that in the water of all seas and oceans there are 10^{43} deuterons, and in 10^{14} years there will be only one fusion.

It follows from the aforesaid that the main problem impeding the occurrence of the $d+d$ reaction lies in the existence of a very high Coulomb barrier. Our approach allows for this problem to be solved, and there is such an opportunity in the UQT. The UQT equation solutions show that the distance to which deuterons can approach each other is strongly dependent on the phase of the wave function (by the way, it is absolutely clear intuitively).

Let us consider the one-dimensional problem [15-18,31]. There is a stationary nucleus with charge *Ze* at the point of origin, and another nucleus is approaching it along axis x (charge *ze*, mass *m*) at a certain initial velocity. The non-autonomous and autonomous equations of such a problem will look as follows:

$$m\frac{d^2x}{dt^2} = -\frac{2Zze^2}{x^2}\cos^2\left(\frac{m}{2\hbar}\left(\frac{dx}{dt}\right)^2 t - \frac{m}{\hbar}\frac{dx}{dt}x + \varphi_0\right) \quad (8)$$

$$m\frac{d^2x}{dt^2} = -\frac{2Zze^2}{x^2}\cos^2\left(-\frac{m}{\hbar}\frac{dx}{dt}x + \varphi_0\right) \quad (9)$$

Since an analytical solution was not found for all the areas of initial phases , numerical methods were applied with the following initial values: $Z=z=1$, $e=1$, $m=1$, $x_0=-10$, $\hbar=1$ for different initial velocities and initial phase values. As had been expected, braking or acceleration of the particle happens only when the charge is large. But at the last stage, under certain initial phases close to $\frac{\pi}{2}$, a wonderful process occurs: velocity, charge and repulsing force are very small. Due to phase ratios, the small charge is not changed for a long time, which means that the particle (or rather what is left of it) is not influenced by any forces, and it is crawling at a permanent small speed for a very long time ("the snail effect") inside the field of another particle, and can come very close to the center. Such movement with a very small charge and a small speed can last for several hours, and disconnection of the external field will not effect this movement. This process reminds of quiet and invisible scout penetration into the enemy territory. This phenomenon occurs only in certain phase areas, and can be conveniently called a phase hole, which is illustrated in Fig. 4 resulting from the solution of equation (8).

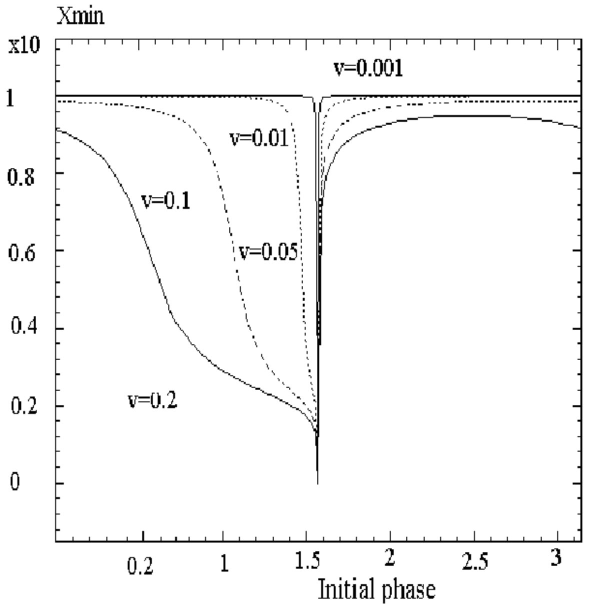

Fig.4. Distance to the turning point of the moving charge depending on the initial phase value for different initial velocities.

Let us note in passing that now we can account for one of the nuclear physics anomalies, which has a tendency to be totally ignored. Under a nucleon energy of 1 MeV, its velocity is 10^9 cm/s, nuclear radius is 10^{-12} cm, and the passage time of the nucleus is 10^{-21}s, but the time period in which the nucleon passes is usually anomalously long - 10^{-14} and even more, and it is absolutely unclear what the nucleon is doing in the nucleus so long. In our model it is easily explained by the "snail effect".

For the same equation, the minimum distance was calculated between the charges dependent on velocity (Fig. 5) for different initial phase values. For comparison, Fig. 5 also shows the result of the classical calculation based on the Coulomb law. It is obvious from Fig. 4 and 5 that the minimum distance to which charges can approach each other is nearly independent of kinetic energy, but with reduction of speed the initial phase area width is reduced as well. In other words, reduced energy brings also reduced probability of a nuclear reaction.

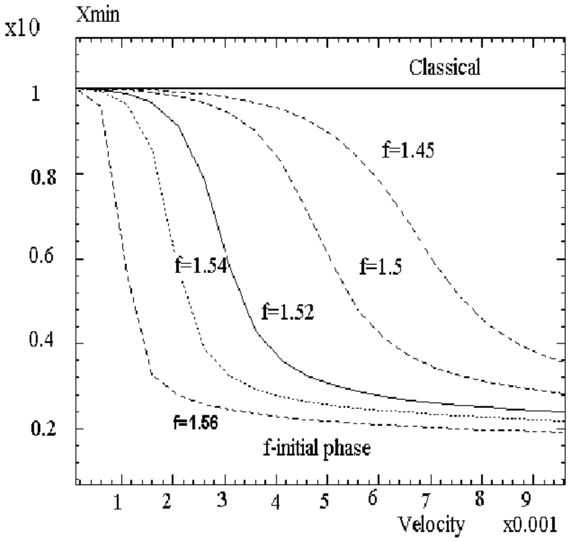

Fig.5 Minimum distance between charges depending on the initial velocity for different initial phase values.

The same results are true for the autonomous equation (9). Under the conventional quantum theory, the ratio of the reaction speeds in the tritium and neutron channels should be close to unity: $\frac{t}{n}=1$. But in many experiments on cold nuclear fusion this value is very different from unity and equals $\frac{t}{n}=10^9$. In different experimental situations it is reproduced by different experimental groups with a very high accuracy. This very intriguing problem has so far received no simple explanation. Let us dwell on a possible cause for such aphenomenon. With a small velocity in the phase hole, neutrons are affected by nuclear gravitation forces, and protons are affected by electrostatic repulsion forces. Under the effect of this momentum, the deuteron will have enough time to turn in such a way that the neutron parts of the deuteron would faceeach other. After the neutron gravitation the nuclear forces will be saturated, which will weaken the proton connection, and one of the protons will leave the system. This reaction can be conditionally presented in the following form:

$$d+d \to p+(n+d) \to p+t$$

This reminds of the Oppenheimer-Phillips effect.

It is well known, however, that under big energies, the probabilities of the first and second reaction channels are the same, and this phenomenon should somehow be accounted for. Increased probability of the neutron channel with growing energy can be connected with the appearance of secondary neutrons in the reaction *T + D = He + n (14.1 MeV).* In a deuterium-rich environment, a big part of the resultant tritons will pass to neutrons in the process of this reaction, which has a cross-section of 5 barns under an energy value of 70 KeV. According to assessments in [32], the number of such secondary neutrons per one triton is $7.9\cdot10^{-12}, 1.7\cdot10^{-9}, 2.7\cdot10^{-6}$ for energy tritons 10, 20 and 100 KeV respectively. Thus, the prevalence of $\frac{t}{n}>10^6$ can be expected only in those reactions, where tritium is born with energies over 40 KeV.

It should not be assumed, however, that the phase hole phenomenon in its whole area leads to a nuclear reaction. It can be assumed that reduction of the Coulomb repulsion is followed by reduction of strong interaction. But how? Today nobody knows the exact equation of the strong interaction potential. Besides, the particle approaches the turning point $X_{\min}$ is rather "thin". Will it be able to take part in a full-fledged nuclear reaction, or will it fly through, like it happens with the electron in the s – states of the atom? There are very narrow phase areas, when soon after the particle stops the charge grows quickly and is sharply accelerated. The charge can even be maximum in the nuclear force effect area. May be, it is this narrow phase area that is responsible for cold nuclear fusion, and in case of strong interactions the phase hole mechanism must be operating as well.

It was discovered long ago that nuclear transmutations have a mass character (especially in plants and biological objects), but they have little to do with energy generation. Examples of such reactions:

$$Mn^{55} + p \to Fe^{56} \;;\; Al^{27} + p \to Si^{28} \;;$$
$$P^{31} + p \to S^{32} \,; K^{39} + p \to Ca^{40}$$

In reactions of this type, a very slow proton (with practically zero kinetic energy) penetrates the nucleus in the above-mentioned way and remains there. *No intranuclear energy is generated, because both before and after the reaction the nucleus remains a stable object.* In classical nuclear physics, the nucleus usually became unstable after it was penetrated by a charged nucleon with a large kinetic energy and always broke into parts, and the nuclear debris had an even greater kinetic energy. Reactions of the above type were considered impossible under small energies and for this reasons were not studied by classical nuclear physics. It seems to be *a completely new type of nuclear transmutations, not recognized by modern nuclear science, but experimentally discovered rather long ago.* Today there is a great deal of experimental material confirming mass nuclear transmutation phenomena. Moreover, there are many projects of neutralizing nuclear excess with the help of this technology. Journals *Infinite Energy, New Energy, Cold Fusion, Fusion Facts*, etc. and Internet are full of such projects.

Of course, a change in the nuclear charge will result in restructuring of electronic atom shells, but the energy related to this process will be about several electron-volts and is nothing in comparison with the energies of nuclear reactions from several to hundreds million electron-volts. By the way, nuclear engineers are accustomed to such energy ranges in nuclear reactions. It was this circumstance that made them deny *a priori* all nuclear processes in biology, because under such energy values of the debris dozens and hundreds thousand of complex biological molecules will be destroyed.

Quite a long time ago, Lois C. Kervran [33] wrote a book about nuclear transmutations in biology, and now, nearly 20 years later, its second edition was published! It gives, evidently for the first time, numerous *experimental* data of the above-mentioned phenomena. The reaction of the official science is very interesting. For example, well-known physicist Karl Sagan, after reading the book about such *experimental* data, advised Kervran to read elementary textbooks in nuclear physics!

Some time later a research was made by Panos T. Pappas [58], who studied one of the well-observed nuclear reactions in biological cells:

$$Na_{23}^{11} + O_{16}^{8} = K_{39}^{19}$$

Classical biology has long known about the existence of equilibrium, when the ratio between the number of *K* and *Na* ions is maintained with greatest accuracy despite the shortage or even absence of K ions in food. Later, in work [59] this nuclear reaction was even called the life equation, and the existence of such nuclear reactions in biological objects was proved by M.Sue Benford with the help of direct physical methods.

All thermonuclear fusion programs are based on blunt heating and compression of the reacting material. Despite the progress achieved, the head of the works in England, Dr. Alan Gibson [34], established several years ago that the model reactor design would be created not earlier than in 50 years. Today, this point of view is generally accepted. Even if the reactor is once made (although the authors have grave doubts about it), it will be very complicated, expensive, and harmful for the environment.

Classical approaches have so far not yielded any positive results, despite multi-billion investments and a great number of physicists, engineers, service personnel, and managers involved. It is only natural that this army of researchers is a potential impediment for all alternative projects of new power engineering. It has been noted that *"viability" of any idea is proportionate to the number of people involved and investments made.* For these reasons, the Fleischmann-Pons works were given a hostile reception in the USA and other countries.

All the controlled thermonuclear fusion programs are accompanied with the adjective "controlled", although there is no control whatever. It is simply that the initial quantity of the reacting substance is *prudently* made very small. For example, a ball of lithium deuteride during laser reduction has a diameter of several mm. So far no one has been seriously considering the question of utilizing the energy of an explosion of such a ball, which is approximately equal to the energy of an explosion of a box of antitank grenades.

The straightforward approach to fusion used by the modern science is very natural, because quantum mechanics has no methods of influencing this process. The future of really controlled nuclear fusion systems may be not on the way of primitive and blunt method of heating and compression of the material, but following UQT on the way of using collisions of nuclei having small energy and corresponding fine adjustment of the wave function phase.

It is essentially possible in case of imposition of the external controlling electromagnetic field on the reacting system, which contains quasi-fixed ordered deuterium atoms and free deuterons. The same properties can be demonstrated by special atomic grid geometry. Diffraction scattering of a deuteron flow on such grids will lead to automatic deuteron selection by energies and phases.

It seems that in the Fleischmann-Pons electrochemical experiments such an ordered system existed in the *Pd-D* grid, and some phasing occurred, which accounts for the results of these experiments [30].

Today it appear to us that the cold nuclear fusion processes will be effectively used for nuclear waste liquidation and production of isotopes.

Many researchers [35,36] discovered that the quantity of heat generated in the process of electrolysis of ordinary water on nickel electrodes (there is no hope for nuclear reactions in such systems) is the same as in the electrolytic cell with heavy water. It confirms other measurements, which showed that the quantity of nuclear reaction products is millions times less than is required for such an amount of generated heat, and its origin remains a mystery.

Further we will give certain concrete data demonstrating the phase values of a deuteron with an oscillating charge, under which the deuteron can approach the nucleus to a critical distance of 10^{-12} cm or less, i.e. giving the data to estimate the value of the above-mentioned phase "hole" in the interval $(0,\pi)$ of the phase change.

Assume that the stationary nucleus with the charge q is placed to the coordinate origin x=0 and the deuteron with the same charge q is placed at the initial moment t=0 to the point $x_0 < 0$on the x-axis, and the deuteron velocity equals $\dot{x}_0 = v_0 > 0$. The units of mass, length and time are chosen in such a way that $m=1, \hbar=1, c=1$ (*m* - deuteron mass, *c* - light velocity). Charge *q* equals 0.085137266. Our units are connected (to 4 significant figures) with the system (kg, m, s) as follows:

1 mass unit = 3.345×10^{-27}kg,
1 length unit = $1.049\cdot 10^{-16}$ m,
1 time unit = $3.502\cdot 10^{-25}$ s.

The electron velocity corresponding to its energy of 1eV equals $5.931\cdot 10^{7}$ cm/s. The deuteron velocity corresponding to such energy will be assumed to be 3680 times less, and in our units it will be $5.372\cdot 10^{-7}$ (if $c = = 3\cdot 10^{10}$ cm/s). Then the deuteron movement towards the nucleus is described by the equation

$$\ddot{x} = -\frac{2q^2}{x^2}\cos^2\left(\frac{1}{2}(t+t_*)\dot{x}^2 + x\dot{x} + \varphi_0\right), \qquad (10)$$

where the parameter t_* is defined under the condition that the argument of cosine equals φ_0 for $t=0, x=x_0, \dot{x}=\dot{x}_0$ (thus $t_* = -(2x_0)/\dot{x}_0$), and this parameter may be considered as the initial moment of so called local time.

In the interest for us are namely solutions of eq. (10) under very small deviation ε from phase φ_0 and so we put $\varphi_0 = \frac{\pi}{2} + \varepsilon$ and rewrite eq.(10) in the following form:

$$\ddot{x} = -\frac{a}{x^2}\sin^2\left(\frac{1}{2}(t+t_*)\dot{x}^2 + x\dot{x} + \varepsilon\right), \qquad (11)$$

where *a* = 0.0144967 Let the initial x_0 to be equal - 500000 of our length units (i.e. approximately $5\bullet 10^{-9}$ cm) and the initial deuteron velocity v_0 to be equal to the velocity v_{00} corresponding to the deuteron energy of 1 eV or less. But it turned out that the precision of numerical integration of this equation under such initial conditions and under values $|\varepsilon| = 10^{-15}$and less is small and besides the interval of the integration must be very large. That is why this equation also had to be transformed by passing to "slow" time $\tau = |\varepsilon| t$ to the equation relative to the variable $w = \left(\frac{dx}{d\tau}\right)^2$ as a function of *x:*

$$\frac{dw}{dx} = -\frac{2a}{x^2}\left\{\frac{1}{\varepsilon^2}\sin^2\left[|\varepsilon|\left(\frac{1}{2}(\tau+\tau_*)w + x\sqrt{w} \pm 1\right)\right]\right\}, \qquad (12)$$

where $\tau_* = -(2x_0)/\sqrt{w(x_0)}$ and +1 if ε >0, and -1 if ε < 0. It must be added also the equation for τ as a function of *x* :

$$\frac{d\tau}{dx} = \frac{1}{\sqrt{w}}. \qquad (13)$$

The system of equations (12, 13) is, so to say, a "model" system describing fairly accurately the deuteron movement under all values of |ε| from 10^{-24} to 10^{-6}. Numerical integration of this system was fulfilled under different values of e and under following initial conditions:

$$w(x_0) = 2.103, \tau(x_0) = 0, x_0 = -500000, \tau_* = 689573.18 \qquad (14)$$

It may be noted that the initial deuteron velocity v_0 equals 1.450172 (following the relation $\dot{x}_0 = |\varepsilon|\sqrt{w(x_0)}$) for given initial $w(x_0)$ and for |ε| = 10^{-7}, i.e. such velocity is approximately 3.7 times less than velocity v_{00} corresponding the deuteron energy of 1eV. If $|\varepsilon| = 10^{-6}$ then the velocity v_0 is approximately 2.7 times greater than velocity v_{00} .

It turned out that the numerical tables for values of w, τ obtained under different values of $\varepsilon < 0$ in the interval (-10^{-24}, -10^{-6}) don't differ essentially from each other. The following table is true to three-four significant figures for τ and $\dot{x}/|\varepsilon| = \sqrt{w}$:

x	τ	$\dot{x}/\vert\varepsilon\vert$
-500 000	0	1.450
-50 000	$1.426 \cdot 10^6$	0.0493
-500	$1.002 \cdot 10^7$	0.000489
-200	$1.067 \cdot 10^7$	0.000440
-100	$1.090 \cdot 10^7$	0.000425
-80	$1.100 \cdot 10^7$	0.000423

If reducing the table values of x to centimeters, we obtain the following corresponding approximate values:

$$5 \cdot 10^{-9}, 5 \cdot 10^{-10}, 5 \cdot 10^{-12}, 10^{-12}, 0.8 \cdot 10^{-12}$$

The time interval ΔT , in which the deuteron reaches the critical distance 10^{-12} *cm* from the center, is $67350/|\varepsilon|$ of our time units or $(1.090 \cdot 10^7/|\varepsilon|) \cdot 3.502 \cdot 10^{-25}$ seconds. If nuclear forces are not taking into account then the deuteron may approach the distance less 10^{-12} *cm* .

We present here the table, where are given the initial deuteron velocities v_0 in velocities shares v_{00} and the corresponding time intervals ΔT (in seconds) for different values of ε.

ε	$\frac{v_0}{v_{00}}$	ΔT (s)
-10^{-6}	2.7	$3.82 \cdot 10^{-12}$
-10^{-7}	0.27	$3.82 \cdot 10^{-11}$
-10^{-22}	$0.27 \cdot 10^{-15}$	$3.82 \cdot 10^{4}$ (≈ 10.6 hours)
-10^{-23}	$0.27 \cdot 10^{-16}$	$3.82 \cdot 10^{5}$ (≈ 10.6 hours)

Let us note that the given data change essentially under positive values of ε (10^{-6}, 10^{-7}, etc.). There is some asymmetry of solutions behavior under negative and positive values of ε. The calculations show the minimum distance $|x|_{\min}$ more than 500 of our lengths units even for relative big initial $w(x_0)$ = 10000. Thus, if we limit ourselves to the condition that the deuteron energy is not over $(0.27)^2$ eV at a distance of $5 \cdot 10^{-9}$ cm from the central nucleus, and the whole process of deuteron movement towards the nucleus does not exceeds approximately 10.5 hours, then the interval $(\frac{\pi}{2} - 10^{-7}, \frac{\pi}{2} - 10^{-23})$ is approximately the sought phase "hole" in the whole interval ($(0, \pi)$) of phase change φ_0 in eq. (10).

If many deuterons with the energy not more than $(0.27)^2$eV at the distance $5 \cdot 10^{-9}$ *cm* from the nucleus are equally distributed along their phases φ_0 , the ratio of the length of this "hole" to π, equaling approximately $0.3 \cdot 10^{-7}$, is equal to a share (or a relevant percentage of $0.3 \cdot 10^{-5}$) of deuterons overcoming the Coulomb barrier.

The above figures express at least the order of probability of the cold nuclear fusion occurrence, and this order is absolutely incompatible with the figures in the classical quantum mechanics mentioned above. Let us note once again that a one-dimensional problem was solved, and in case of an accurate analysis (not zero sighting distance will be taking into account) this probability will be lower. Let us also pay attention to the large time intervals ΔT calculated if $|\varepsilon|$ is very small. It explains well the effect (observed by many researchers) of continuation of cold nuclear fusion reactions during even many hours after the disconnection of the voltage in the electrolytic cell. This effect was named even "life after death".

As for the analysis of the deuteron movement with the help of the autonomous equation, the calculations lead to initial velocities v_0 , exceeding the above mentioned numbers, although the general motion picture is the same. But the autonomous equation is interesting, because in the area of those values $x, \dot{x}$, under which the product $x\dot{x}$ is modulo small, it is possible to replace $\sin(x\dot{x})$ with $x\dot{x}$, and the eq.(11) under $\varepsilon = 0$ to replace with simplified equation (describing the deuteron motion from initial point $x_0 > 0$ to center)

$$\ddot{x} = a\frac{(x\dot{x})^2}{x^2} = a\dot{x}^2$$

This equation has a very simple analytical solution. Without giving very simple calculations, we will present the final formulas.

Let us take the following initial conditions:

$$x(0) = x_0 > 0, \quad \dot{x}(0) = -v_0 < 0$$

Then

$$\dot{x}(t) = -\frac{v_0}{1 + av_0 t}, x(t) = x_0 - \frac{1}{a}\ln(1 + av_0 t)$$

It follows from these formulas that the velocity of a particle moving in accordance with the initial equation never turns to zero, and under

$$t = t_* = \frac{\exp(ax_0) - 1}{av_0}$$

$x(t_*) = 0$, i.e. the particle reaches the center of the nucleus, its velocity at this moment being

$$\dot{x}(t_*) = \frac{-v_0}{1 + av_0t_*} = -v_0 \exp(-ax_0) \text{ ,}$$

so that it *passes through the nucleus and moves further.*.

For example, let $a=0.0144967$, $x_0 = 1000$ ($\approx 10^{-11}$ cm), $\dot{x}(0) = 5.37 \cdot 10^{-10}$ (≈ 16 cm/s).

Under such initial data, the product $x\dot{x} = -0.0000537$, so it is quite possible to replace $\sin(x\dot{x})$ with $x\dot{x}$.
In this case,

$$t_* \approx 2.3 \cdot 10^7 \qquad (\approx 8 \cdot 10^{-18} \text{ s}),$$

$$\dot{x}(t_*) \approx -29.9 \cdot 10^{-17} \qquad (\approx 9 \cdot 10^{-6} \text{ cm/s})$$

These figures fit well into the reasonable framework, so the autonomous model can also be of use for the movement analysis in the problem under review. The phenomenon of particle passage through the Coulomb potential accounts very well for the existence of pendulum orbits in the Bohr-Sommerfeld model, when in states *1s,2s,3s* etc. the electron passes through the nucleus. Such states in the strict theory and experiment have no impulse, so in the Bohr-Sommerfeld model they were discarded as absurd. Now they have a right to existence. Further, the experimental data for angular distribution of non-elastic scattering by nuclear reactions (including reactions with heavy ions) reveal the big amplitude of the scattering forward. It is impossible to explain such effect by the formation of intermediate nuclei but it is may be explained from the viewpoint of our UQT.

General Principles of Creating New Energy Sources

In the ancient classical *perpetual mobile* idea it is supposed that energy is just created and not taken from outside (impossibility of *a perpetual mobile* is the first law of thermodynamics). There have appeared lately many articles and even books dwelling on the idea of energy generation from vacuum. We are not in complete agreement with many of these works, and we will dwell only on some of them, which, in our view, can be of interest. One of the main ideologists of this completely new sphere in science are Daniel C. Cole and Harold E. Puthoff, and their first serious work entitled «Extracting energy and heat from the vacuum» was published in Physical Review E, vol. 48, #2, (1993). In this work authors use the Casimir forces [60] making them produce useful work. The appearance of such forces in vacuum is understandable intuitively: if in a stormy sea we put vertically into the water two big parallel plates, on the outside part of these plates the waves will hit them at random, and between the plates there will be no waves. Then, the hitting of the waves outside the plates will produce a gravitation force between them (the Casimir force discovered experimentally long ago), which the authors of this interesting work are going to exploit. It is easily seen that in this idea energy is generated from vacuum fluctuations.

Our approach is altogether different. When the equation with an oscillating charge was solved for the quantum oscillator, 4 types of solutions were discovered. For us only two of them matter – "crematorium" and "maternity home". In one solution ("crematorium") the particle slowly falls to the bottom of the pit and finally turns into a "specter" (under the strict unitary quantum theory it disappears, spreads about the Universe and contributes to vacuum fluctuations everywhere). In the other solution ("maternity home") the particle can even be born of a very small fluctuation, or accumulate a sufficiently big energy. Let us underline once again that both these processes are not at all logically connected. In other words, there are such systems where energy will disappear completely (electrolytic baths), or increase unlimitedly (it might be our Universe).

It is the energy conservation law that presents the strongest impediment in all cosmological approaches. However, universes with birth of matter have long existed in scientific cosmology independently of us. There is known the theory of British astronomer Fred Hoyle based on the idea of continued creation of matter from nothing. The question of whether such an approach is realized in nature and whether the energy emitted by quasars is the result of work produced by a certain gigantic pit, is the most intriguing question of the future.

It is yet unclear whether the values of appearing and disappearing energy in these solutions are equal. But neither in the strict UQT nor in the equation with an oscillating charge vacuum (as a big set of random oscillations) is needed for energy generation. Of course, UQT admits of such an energy exchange with vacuum. For example, during split of a photon on a semitransparent mirror, at one time both halves of the photon will not be registered and will give their energy to the vacuum and disappear for the observers for good, at another time there will appear two photons out of one, and the lacking energy will be taken from vacuum. But *the movement equations (4) and (5) themselves know nothing about vacuum and can generate energy due to their nature* (they are noninvariant relative to the coordinate translations) and the conservation laws we are so accustomed to do not exist for them.

Let us remind you once again that the latter follow from the Newton equations, and the Newton equations result from averaging by a big number of events, while for individual events of small energies no conservation laws in quantum physics exist.

In other words, it can be said philosophically that a motion of a small wave packet, once started, will give birth to other movements (energy) and, consequently, to matter. Since most various and breath-taking speculations are possible, up to the creation of a universe, we will stop here.

Thus, the generated or disappearing energy in our approach can be manifest not only in the changes of the particle velocity during movement in a certain potential, but in the appearance or disappearance of the particles themselves as well. A change of the particle velocity in movement is most easily discoverable, and it is the velocity increase that can be used for generation of heat or electric current. There can be energy systems, which exploit the fact itself of charge oscillation and the consequence of it. It is very probable that these phenomena, contradicting the most fundamental laws of modern science, have been long discovered and even applied. But these are the very phenomena that are the easiest to be exploited at the first stage of development of such new energy technologies.

When an energy generation mechanism is used, crematorium-type solutions should be suppressed. But all the quantum processes are built on the basis of elementary acts, and each of them is impossible to be controlled separately. But if the probabilities of such processes are controlled, they, being multiplied by the great number of participants in the process, automatically become macroscopic variables of quantum kinetics, and the process itself becomes possible. It can easily be achieved, if process participants with correlated initial phases are selected.

Let us remind you that the Newton and relativistic classical mechanics follow from the strict UQT, while the Newton movement equations with the resultant energy and impulse conservation laws follow from the oscillating charge equation with averaging by the particle ensemble composing a classical body (material point). But these conservation laws are nonexistent for individual microparticles in our theory, and they appear only in case of averaging by the ensemble of particles. Thus, if the energy-generating processes are accumulated, and the processes where energy disappears are suppressed, a classical *perpetual mobile* can be created.

But the UQT and the oscillating charge equation have other differences not only from the equations of classical mechanics, but also from some equations of electrostatics and electrodynamics.

There is a fundamental theorem of circulation for the electric field. Let us dwell on it in more detail. Let us have a vector field **E,** which can be an electrostatic or a gravitation field.

$$\mathbf{E} = \mathrm{P}(\mathrm{x},\mathrm{y},\mathrm{z})\mathbf{i} + \mathrm{Q}(\mathrm{x},\mathrm{y},\mathrm{z})\mathbf{j} + \mathrm{R}(\mathrm{x},\mathrm{y},\mathrm{z})\mathbf{k}$$

Line integral

$$\Gamma = \oint_l \left(\mathrm{P}\,dx + \mathrm{Q}\,dy + \mathrm{R}\,dz\right) = \oint_l \mathbf{Edl} \qquad (15)$$

is called circulation of vector field **E** by contour *l*. Of course, circulation depends not only on **E**, but also on the passage direction accepted in contour *l*; by changing the passage direction we will change the circulation sign. Form (15) is convenient for mathematicians, but for our purposes we will present equation (15) in a different way. If both parts of equation (15) are multiplied by electric charge *q,* on the right we will get the integral of force *q***E** by way **dl,** i.e. work for moving the charge along a closed loop contour. It is well known that this value is zero.

$$\int_l q\mathbf{Edl} = \mathbf{0} \qquad (16)$$

If this value were not zero, an energy source could be created. For this purpose a charge should be moved in electric field **E** from point *a*, located in the high voltage area of the field, to point *b,* located in low voltage area of the field, and then back, but along another route. The values of work from $a \rightarrow b$ and from $b \rightarrow a$ would be different, and we could extract work from the field without making any changes in the system. When the charge is constant, it is certainly true, so for a macroscopic constant charge this theorem is an analog of the energy conservation law. The authors have not come across such an interpretation of the energy conservation law in other works. If the charge is microscopic, then in the UQT it changes, depends on time, coordinate and velocity, so work from $a \rightarrow b$ and from $b \rightarrow a$ will be different, in this case work can in principle be extracted from the field without any changes made in the system.

Discussion of Experimental Results

Let us now get down to explaining some very unusual experimental results, which the authors have nothing to do with, and which they sometimes regard rather skeptically. The point is that the sphere of new energy sources is the headache of all the human civilization, and in this sphere, like nowhere else, the dividends can be exorbitantly high, and for this reason there are in this sphere a lot of swindlers (even among the theoreticians) and simply erring people. The official science of the world does not so far believe in such research, but the most suspicious fact is the great multiplicity of such works. The authors are not inclined to regard all these people as swindlers or erring, because the UQT can offer a beautiful and simple interpretation of certain phenomena.

There are strange plants with the efficiency over 100%. They are even manufactured in small quantities and are rated among energy-saving devices already termed over unities. Japanese researchers take these problems very seriously, and the leading role in studying this problem belongs not to the USA, but to Japan, which even finances many US institutes in this framework. The total Japanese expenditures for this research exceed $200.000.000 a year. It can be forecast that with the Japanese mentality and the state policy of exporting not natural resources, but superhigh technologies and intellect, Japan will find itself among the leading countries early in the 21st century. We think that our readers will not be surprised to hear that Russia has not allocated a single cent for this program, and all research was made on pure enthusiasm.

In the USA such works do not get official governmental support either (like, for example, the dying out hot nuclear fusion problem), but a great number of private firms and individual businessmen are conducting large-scale research. The following US journals are devoted to the subject: *Journal of New Energy, Infinite Energy, Cold Fusion, New Energy News, Fusion Facts*, and *NET-Journal* (Switzerland).

Switzerland, Italy, Germany, and France are also among the countries where the new energy problems are seriously researched from the cold nuclear fusion point of view.

A very young sphere of power engineering has emerged and is quickly developing, which researches many new energy sources. In future those new energy-saving sources will first be used, which will considerably differ from the existing ordinary energy transformers in that they will generate additional energy that can be used in the interests of the mankind. The development of civilization will then be limited not by long-expected reduction of natural fuel resources, but by heat pollution of the environment.

Let us enumerate just a few of the new energy directions:
1. The Patterson fuel cell (CETI).
2. Supermagnet-superengines of Takahashi, Aspden and Adams
3. Swiss plant Testatika.
4. Engines operating on water.
5. Hypersound Griggs pump, the Potapov and Schaffer heat generators.
6. Schoulder and Fox cluster systems.
7. N – machines of Farade, Bruce de Palma, Newman, Searl, Tewari, etc.
8. PAGD reactor of Canadian researchers P. Correa and A. Correa.

This list can be complemented with the surprising experimental results received by physicists A. Samgin and A. Baraboshkin (Russia, Institute of High-Temperature Electrochemistry under the Russian Academy of Sciences, Ekaterinburg) [24,25] and T.Mizuno [26] (Japan). They appear to have used, totally independently of each other, special proton-conducting ceramics, which, when electric current runs through them, generate a thousand times more heat energy than the electric energy consumed. In some experiments by T.Mizuno this value even exceeded 70000(!). T. Mizuno in a personal talk with one of the authors of this report said that he feared very much the radiation sickness. But no α, β, γ radiation or nuclear debris was found, and the nuclear processes are not responsible for such energy generation. Such proton-conducting (or, to be more exact, deuteron-conducting) ceramics was made using the power metallurgy methods by agglomeration under high temperatures. In other words, all the chemical processes in it had long been over. The origin of such an amount of excessive energy is absolutely incomprehensible in the framework of conventional science, for they cannot be accounted for either by nuclear or chemical reactions, or by phase passages. At first the authors of this experiment supposed nuclear fusion reactions of the D+D type. At our request, A. Samgin replaced heavy hydrogen (deuterium) during ceramics production with ordinary hydrogen. If the effect of such huge energy generation was connected with the nuclear D-D reactions, all the anomalous heat effects would have disappeared, but they persisted. After such a large quantity of energy was generated, the tablet disintegrated into powder.

These effects can easily be explained by UQT from the harmonic oscillator theory point of view. When the tablet is agglomerated, there remain in it some caverns of a size of hundreds Angstrom units. When direct or alternating current flows through it, the protons and deuterons in their movement (there are few electrons in such ceramics) get into these caverns, and a process can start which is described by the “maternity home” solution. A particle accumulating energy, oscillates in such a pit, and finally the energy will be sufficient both for heating and for destruction of the pit walls (tablet turning into powder). The same processes seem to be taking place in a palladium electrolytic cell with heavy water, and in a nickel electrolytic cell with ordinary water, which accounts for anomalously large heat generation, not related to nuclear processes.

It would be good to verify experimentally the dependence of the tunnel effect on the initial phase. But it seems us that it is more important for our opponents, since both cold nuclear fusion (CNF) and discovery of nuclear transmutations *(which, from the point of view of modern science, are even more absurd than the existence of CNF*) evidently cannot be accounted for in any other way. Besides, such a direct experiment is of a fundamental value. There are today a lot of people and groups in the world, who pin great hope on exploiting the nuclear transmutation phenomenon for the purposes of processing and recycling of nuclear wastes, and the question of industrial generation of tritium for military purposes using CNF methods was under consideration in Los-Alamos. Internet magazines are full of such information. We are not giving Internet addresses here, because everything is constantly changing in this live system.

Let us analyze some of the above-mentioned devices. The first, the oldest and the most mysterious information was information about internal combustion engines operating on water.

Let us give just one example. When we were students, one of our teachers, the late Professor G.V. Dudko (1959) told us that in 1951 he had participated in the testing of an internal combustion engine [39,55-57]. The device represented a hybrid of a diesel and an ordinary carburetor engine, where a gas of petrol was needed to start it and then ignition was switched off, and an ordinary fuel pump sprayed into the cylinder warmed up and strongly compressed water with special additives (which the inventor himself put into the tank in small quantities, and which, as we now understand, represented the principal secret). The engine was installed on a boat. The researchers were riding for two days in the Azov Sea, and only water vapor was the engine exhaust. Professor Dudko himself drew the water fuel overboard and poured it into the tank. They needed much water, several buckets a day, but there was no shortage of it… The question of why, if everything was so great, these engines are still not in use, can occur only to a person who has never lived in Russia.

From the point of view of the solutions of the harmonic oscillator problem, the following theoretical possibility exists [40,44,47,55-57]: if water with the necessary additives (which, evidently, represent the secret of many invented engines operating on water) is compressed and sprayed into the cylinder, each drop of water, when it gets into the cylinder after being compressed, will start dilating and will pass by inertia the equilibrium position. As a result, caverns (empty volumes) can be formed in it, with a size of several dozen of Angstrom units. If a free proton (or some other microparticle) gets into such a cavern in the required phase (it is supposed that the task of the additive is exactly this), the "maternity home" solution will be realized and some of the drops will explode… Later we heard and read many times about various Russian inventors, who had successfully created and tested engines operating on ordinary water with some mysterious additives.

Of course, the possibility of catalytic water decomposition with small energy consumption before spraying into the cylinder is not at all excluded. There are films and information in Internet about testing of cars operating on water, which is catalytically (with small energy consumption) decomposed into oxygen and hydrogen. Such power engineering would be ecologically absolutely clean, and the only restriction would lie in heat pollution of the environment.

An ideal solution for the motor transport could also lie in use of some new types of electric energy generators. The UQT even admits of the possibility, which was long observed in the experiments of Nicolas Tesla and in those made by Canadian physicists the Correas, who even received a patent for a system generating energy from vacuum fluctuations (as they believe) [45]. The readers could have got acquainted with our detailed theory of these processes in [46]. But the ideal system for the automobile would certainly be Testatika.

Any imagination will be amazed at the thermal cell CETI created by James Patterson, USA [27], in which takes place the electrolysis of specially made nickel balls in ordinary water. The US paper «Fortean Times» [1] 85, 1995, wrote about it: "December 4, 1995 will go down into history. On this day a group of independent experts from 5 US universities was testing a new source of energy with a stable output heat power of 1.3 kWt. The consumed electrical energy was 960 times smaller". All experts note that the generated heat is of mysterious origin and cannot be explained by chemical or nuclear reactions, as well as by phase passages. The US ABC TV showed on February 7 and 8 1996 in the «Nightline» and «Good Morning America» cycles of programs about the development by Patterson of a new energy source generating hundreds of times more energy than it consumes. The mysterious nature of the generated heat was again underlined. It is interesting [34] that Motorola tried to buy the CETI patent from its authors for $20.000.000, but met with a refusal. We are sure that Motorola had invested a certain amount of money into the study of this problem before making such a serious offer. All that happens within the Patterson element has nothing to do with nuclear reactions (although Patterson told one of the authors that he was of a different view), and, in our opinion, can be accounted for by exactly the same processes as were described above for proton-conducting ceramics.

The sonoluminescence phenomenon, when certain liquids start shining if weak ultrasound is run through them, also looks very mysterious. No satisfactory explanation has so far been found for this experimentally proved phenomenon, discovered by Moscow University Professor S.N. Rzhevkin in 1933. As Nobel Prize winner Professor Yulian Schvinger said, "it has no right to exist, but it does exist" [38]. This phenomenon can also be explained from the above-mentioned positions.

There are also heat generators (Yu. Potapov [21-23], Moldavia, James J.Griggs [28], and Huffman [29], Schaffer - USA). In them many cavitating bubbles are formed during circulation of ordinary water, in which excessive energy is generated, with the output to input energy ratio approaching 1.7. In these experiments and plants no chemical or nuclear reactions can take place, and thousands of Potapov's heat generators have been manufactured for heating homes. In such devices (they are very different in appearance) a great number of cavitating bubbles are created in a flow of water. This is achieved either with the help of interrupting the water flow with a special rotor (J.Griggs, Huffman, Schaffer), or the water flow is twirled by a special helix and then enters the zone of sharp dilation, where cavitating bubbles are formed (Yu. Potapov). In general, it should be said that cavitation remains a great puzzle for theoretical hydrodynamics and science. For example, forged multi-ton screw propellers of big nuclear submarines under certain operation modes and geometry of the surrounding forms can be destroyed by cavitation within only a few hours. It happens because of huge energy generated in cavitating bubbles.

Under certain values of phase and energy, a particle in the pit, each time reflecting from the walls, will have a greater velocity than that of a falling particle (this is within the uncertainty relation), and after many reflections will accumulate a fairly big energy which will be generated in the form of heat or bremsstrahlung when the pit is destroyed, and, finally, the energy of the oscillations of such a particle accumulated in the pit will always be transformed into heat in an ordinary solid body or a liquid. This physical idea immediately accounts for both sonoluminescence (although for sonoluminescence in general this mechanism is less primitive), and energy generation in proton-conducting ceramics, nickel during electrolysis in ordinary water (CETI element), and water bubbles of commercial heat generators. The theory predicts that the samples should be fissure due to increased pressure on the walls of the potential pit with the growth of energy, which fact also takes place, since both ceramic samples and nickel balls in the CETI element finally disintegrate. It is evidently for these reasons that any metal containing much hydrogen in its grid becomes fragile and is quickly destroyed, which fact is well known to engineers.

The small number of experiments does not so far allow for making concrete conclusions as to what particles generate energy in pits (microbubbles). Besides, for at least an electron to disappear a pit of about 0.5 MeV is required, while in a solid body the pits are about several eV deep, and what seems to happen is only loss of kinetic energy, and not disappearance of particles. The fact that this process requires very deep potential pits, which do not exist in a solid body, does not change the essence of the matter.

Of course, under ordinary conditions, both competing solutions usually take place at once: “maternity home” and “crematorium”, which compensate for each other and the energy is preserved. For energy generation, the “maternity home” solution should prevail. Both these processes take place simultaneously and compete with each other, but, formally, they are not connected in space and time. The complexity of the energy generation problem lies in suppressing the “crematorium” solution by a careful selection of different parameters and promoting the “maternity home” solutions. So far we cannot say for sure what the optimum dimensions of such cavitating bubbles are, or which object oscillates in them, because for this purpose special experiments are needed, which so far have not been staged.

Of course, the inexorable Robber in the form of the Carnot principle stands in the way of transformation of the heat generated in a heat generator or ceramics into electrical or mechanic energy. In accordance with this principle, all mechanic or electrical energy can be transformed into heat, but the reverse process is always connected with big losses.

If there are experiments and plants in which energy generation contradicting the conventional conservation laws is discovered, there should also exist opposite ones, where energy disappears completely, i.e. the “crematorium” solution prevails. It proved to be true. There are such modes during electrolysis in electrolytic baths, under which the temperature of the solution in the bath is strongly reduced for unaccountable reasons, and this fact has no explanation at all. This phenomenon long ago was noted by attentive industrial engineers, and it is called the “bath-freezing” mode [49,50]. Chinese physicist Swe-Kai Chen from Taiwan in his experiments [48] stably observed the same phenomena. It is quite easily explained: a particle with a velocity exceeding the most probable velocity in this distribution gets into caverns on electrodes and after some oscillations reduces its velocity, which becomes smaller than the most probable one, and then the particle leaves the cavern at a small speed, and the same process can happen to another energetic particle. This leads to the cooling of the cell in the case of such mass processes.

The problem of ferromagnet magnetization (the Easing model) can also be reduced to the orientation of a magnetic doublet by the external magnetic field, and then it is essentially the harmonic oscillator equation with a slightly different return force ($F = \frac{\mu}{r^3}$) and all the conclusions made earlier remain in effect. That is why magnetization should also produce energy generation effects. This proved to be true. For the general public everything began on May 17, 1996, when Frode Olsen from the research group “Free Energy” showed on the Norwegian TV (TV2) a surprising film about a “dynamic sculpture” made by artist and sculptor Reidar Finsrud from Skaarer, Norway. The author of this “dynamic sculpture” *had no idea about physics* and had been making it for 12 years. Einstein’s idea of how discoveries are made conveniently comes to mind at this point: everyone knows that a certain thing cannot be done, but there is a man who does not know it, and it is he who makes the discovery.

This “dynamic sculpture” accompanied by an “explaining” poster «*perpetual mobile*» represents an iron well-polished ball with a diameter of 2.7 inches weighing about 2 pounds. The ball is rolling along a circle on close guides resembling two parallel skids with a diameter of 25 inches past the poles of three permanent magnets, where it is magnetized. In the area of three permanent magnets three more mobile magnets are installed on special mobile 5-inch long levers, and these magnets, when the ball passes them, are slightly inclined (due to the ball gravitation) and, after the ball passes them, are raised by the holding springs (sway like yokes). The ball makes a complete turn in 3 seconds. All this magic (***they say the ball had been rolling along the close contour for more than a year***) does not have any sources of energy and is installed for everyone to see in a Norwegian picture gallery on a special stand covered with a glass cover. The authors only saw a good TV film about this installation and were mostly surprised at the fact that the ball had not stopped during uninterrupted shooting (about 20 minutes).

We are well acquainted with circus tricks, but it is absolutely incomprehensible how such a trick could be staged using some secret methods. It is clearly seen that the ball in its movement always partially transfers its energy to the three long swaying pendulums, but there is no way to use them for pushing the ball and making up for friction, this being the only trick that could, in our view, be applied here. All the rest is clearly visible and contains nothing suspicious.

Let us estimate the generated energy. At an initial speed of about 1m/s the ball stops after 30 seconds, if all the magnets are removed. It means that the energy consumed in 30 seconds is about 0.5 joules, or 1/60 Watt. The total energy generated in a month is 43,200 joules, and this is huge energy, much greater than that of a good shell!

It is clear (if the word is relevant here at all) that when the ball is approaching the permanent magnet and the process of magnetization is going on, it is accelerated, but when it mechanically gets past the equilibrium position and, moving away from the magnets, becomes demagnetized, the gravitation (which now starts slowing the ball down) will be slightly less than it was at the moment of the ball's acceleration. This small difference in forces provides for small positive work to overcome friction. Energy generation and similar things during magnetization had been *predicted* by one of the authors in magazines *Infinite Energy* vol.1, No.2, p.38, (1995); *Proceedings of the ICCF*5, p.361, April 9-13, (1995), Monte-Carlo; *Cold Fusion*, No 11, p.10, (1995); *Chinese Journal of Nuclear Physics* (vol. 19, ^{1}2, 1997). The quantum-mechanic processes are very complicated, but some of them can be understood.

All keen physicists were quick to understand it, and J. Naudin in France made a similar, but much simpler experiment. A ball of a soft magnetic material is swaying along parallel U-formed skids in a system of four magnets. Near the bottom of the U-form there is a small smooth step. It may have been made to make the magnetization and demagnetization processes different in time, which is very important. If there are no magnets, nothing interesting happens and oscillations are quickly (in a few seconds) damped. If the magnets are present, oscillations go on up to 3 hours 27 minutes. It appears that in this case the author failed to find good material and parameters of the plant, so friction was not compensated completely. In all these experiments demagnetization of permanent magnets does not happen, because the experiment is repeated many times with the same results.

And now a few vague words about demagnetization processes. During magnetization of the ball, the magnetic moments of its atoms are oriented (like the hands of a compass) along the field lines. When the ball leaves the magnetic field area, the atom magnetic moments are disoriented under the influence of the heat motion, and it becomes demagnetized. In the unitary quantum theory the share of the oriented magnetic moments in the external field can be bigger than in the conventional quantum mechanics (the "maternity home" solution), and the ball gravitation can be stronger due to it. Disorientation of these moments happens similarly in both theories. It seems to be for this reason and due to the difference in magnetization and demagnetization time that a difference in magnetic forces occurs when the ball approaches the magnet or moves off from it.

The scientists of the older generation will remember that a similar toy was shown in the 30's to David Gilbert, who said it was the most interesting thing he had ever seen. A question arises as to why it has not yet been realized. We do not know a physical-mathematical answer to this question, and it is not our task to analyze the social reasons of this phenomenon. Japan has a different mentality, and there is a governmental program for generating energy from permanent magnets. Takahashi [51] even seems to have made an electric engine with an efficiency of up to 318%!

Still more mysterious is the long-known problem of energy shortage in many biochemical reactions with ferments (enzymes). For example, in the well-studied reaction of disintegration of polysaccharides in the presence of lysozyme the following happens: a polysaccharide molecule gets into a special cavern in a big lysozyme molecule, and some time later its debris are thrown out of it (Fig. 6). The broken binding energy of the polysaccharide is about 3 eV, while the energy of the heat movement is only 0.024 eV. From the standard science point of view, it is absolutely unclear where lysozyme takes the energy to break the polysaccharide. No satisfactory mechanism for explanation of such reactions (and they are very numerous) was found, and all this was "swept under the carpet", as physicists say. The UQT provides for a completely new look at the catalytic processes, which has an incomprehensible source of energy reducing the molecule activation energy. From our point of view, this process is a variant of the "maternity home" solution for oscillator.

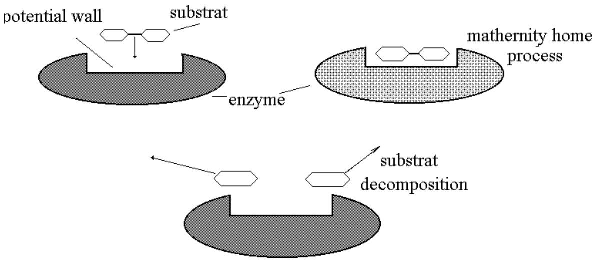

Fig.6. Break of polysaccharide molecule by lysozyme.

The most surprising thing is that in all the cases generation of excessive energy cannot be accounted for by chemical reactions or phase passages. If nuclear reactions do sometimes happen (which should not be according to modern science), they can account for only a hundredth or a thousandth share of the generated heat energy. There is no doubt that all these are effects of new physics, for in the framework of the old physics all this is simply unexplainable.

But the existence of a plant that produces *out of nothing* about 10 kilowatt of direct current electric energy with a voltage of 300 V seems nearly impossible. The story was described by one of the authors in three different magazines, and we will just give a brief resume [52-54].

In summer 1999, at the invitation of Swiss physicists (Director of the Institute of New Energy Sources in Egerkinhen Adolph Schneider), one of the authors visited several research organizations. It is interesting that there is such an institute in small Switzerland, and there is none in big Russia. The purpose of the invitation was very simple: to explain the operation of a plant generating energy out of nothing, i.e. a *perpetual mobile*. In Switzerland such plants are called Testatik Machine M/L Converter from religious group «Methernitha» (Address: Methernitha, CH-3517 Linden, Switzerland, phone: ++41 31 97 11 24).

Such machines exist today in the Swiss town of Linden near Bern. Part of the town belongs to the Religious Christian Community, which is fenced and heavily guarded. There are about 250 members of the Community, many of them are physicists, graduates of the universities of Geneva, Lozanne, Bern. It is not only a research laboratory, they have their own TV center, a film studio, a small furniture plant, shops, garages, residential blocks, and support services. You will probably have guessed that this community does not consume any energy, and this is the most accurate fact in the whole story, for the inquisitive journalists have found out that no money from them comes to the accounts of the local power station, which provides power for all the town. In a cellar of one of the houses they have a power station that produces energy… out of nothing. The author of this inexhaustible source of free direct current energy is Swiss physicist Paul Baumann. Let us briefly describe these fantastic plants: they are of four types (sizes) with capacities of 0.1, 0.3, 3 and 10 kWt. Externally, the plant resembles very much the standard electrostatic machine with Leyden jars often used in physical demonstrations. There are two acryl disks with 36 pasted narrow sectors of thin aluminum, which rotate in different directions. In the first samples ordinary gramophone records were used for disks. The machine is started by pushing the disks in different directions by fingers. The rotation speed is 50-70 turns per minute. After the start disks rotate independently and can be easily stopped by hand, the direct current voltage is about 300-350 V, and the current is up to 30A. The mechanical energy used for rotation (only 100 mWt, according to measurements made by Austrian Professor S. Marinov) is hundreds of thousand times smaller than the generated electrical energy. The biggest plant for 10 kWt has plastic disks with a diameter of over 2 m, the smallest one – 20 cm, the weight of the plants is small enough, the 3-kWt machine weighing about 20 kg.

The charge separation process (which consumes energy!) practically does not slow down the disks. Connection of a load in the form of a 200-Wt bulb does not change the rotation speed either. No cooling or heating of the air or machine parts during long operation takes place, only a slight smell of ozone is felt. The system is noiseless, compact, environment-friendly, and can be installed anywhere.

The Community management thinks, and quite rightly, that wide spread of such systems in the world will lead to a heat explosion, because all the energy generated by the mankind finally finds itself in an energy dump (is transformed into heat), and all this can finally lead to overheating of the environment. They absolutely do not believe (and not without grounds) in the capability of the mankind as a whole to negotiate reasonable use of this invention, and they think that the harm caused by it will be greater than from nuclear, bacteriological, or conventional weapons. Their main idea for the mankind is to live in balance with the environment and to make full use of the energy of the wind, the sun, the water, etc. For this reason the Community is heavily guarded, and they are not going to donate their main discovery to the mankind.

Professor Stephan Marinov visited the Community twice (in July 1988 and in February-March 1989). He was even given such a plant with a capacity of 100 Wt (300 V, 0.3A), which he studied in his laboratory. As far as we now know, even the inventor of this machine does not fully understand its operation principle, so he contacted Marinov out of sheer curiosity of a scientist.

In 1989 Professor Marinov published a book “Thorny Path to Truth – Documents of Violation of Conservation Laws” in International Publishers East-West. The book contains a lot of photos, a measurement report, and a description of the plant. He also organized a research group called “Free Energy” within the Community (Methernitha Group Stephan Marinov Free Energy).

There are very interesting words in this book: “I can state without any doubts that this machine is a classical *perpetual mobile* in its pure form. After the initial push, it goes on rotatingby itself for an indefinitely long time, constantly producing electrical energy in the amount of 100 Watt… It is still unclear, however, how it all can happen…”. As far as we know, nobody has managed to build a similar plant elsewhere.

We have an approximate idea of how the plant operates. The idea is as simple and ingenious as that of the wheel, which is absent from the surrounding nature, so the inventor could not borrow the idea. We will just show that the existence of such a plant is in full conformity with the UQT. It is natural that the plant operates on the basis of the charge separation principle. Let us have two metal spherical surfaces with a hole, isolated from the earth and from each other. If, with the help of an insulated stick, we transfer the first electron from Ball A to the internal surface of Ball B through the hole, a difference of potentials will occur, and if we transfer the second and the subsequent electrons, Ball A will attract the transferred charge, while Ball B will repulse it, and energy will have to be spent during the transfer of charges (Fig. 7).

Let us remind you that under the existing circulation theorem (16), the charge transfer work will consume the same amount of energy as will later be generated during the passage of electric current resulting from charge separation. But in the UQT the circulation theorem (16) for *an individual elementary charge* is not valid. Thus, we can select the time and route, along which the charge will be transferred in such a way, that

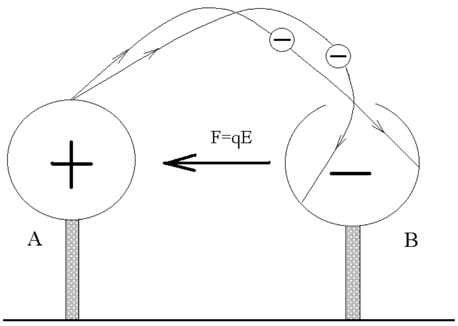

Fig.7. Work for moving the charge depends on method of movement and route.

the charge value during the transfer will be close to zero, and, consequently, the electrostatic force and the charge transfer and separation work will be close to zero too. For example, instead of selecting the route you can wait for the charge to be reduced to zero and then transfer it quickly, and when the charge increases, immediately stop the transfer and fix the charge. Or you can duly select the route and velocity. There are many options. This was evidently realized by Paul Baumann, who is *so far* practically unknown to the official science, and who can find consolation in the idea that the inventor of the wheel will never be known at all. The problem of simple arrangement of all this is just a matter of technique.

You cannot help, thinking that all these might be just tricks. The history of *perpetual mobile* abounds in evidence of downright swindling and frauds, and not a single positive result before, and who can guarantee that the information given above will not prove to be another swindle?

First of all, if all the people always piously believe in the unquestionable stability of the energy conservation law, there will never be any progress in this sphere, and it is then unexplainable how man got down from the palm at all. Secondly, to justify the proposed rebellious position, the following idea comes in mind: if 30 years ago somebody had told the authors (who were then already professors) that at the beginning of the next millennium they would deal in such research, it would have seemed not only a silly joke, but an absolutely impossible thing as well. But, as Voltaire said, "He is silly who does not change".

In conclusion we wish to express with certainty that the time of theoretical recognition and of practical universal using of overunity devices will come soon and become the epoch of new energetics. The people of our planet will regret that so much oil, coal and gas was burned causing terrible ecological losses.

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KOZYREV-DIRAC EMANATION.

INTERACTION WITH MATTER and METHODS OF DETECTING

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In this paper the authors show the possibility of creation of a new kind of emanation. The magnetic monopole beam can be made in space as a result of focusing of some natural substance. Special devices based on the Moebius band elements make the given focusing. This emanation is able to magnetize graphite and organics, decrease the radioactivity, and influence the oncology diseases .The time reverse technology is realized in such devices.

Experimental data, which allow making a conclusion about existence of previously unknown emanation, are presented in this report. Here are descriptions of experiments and methods of measurement. The effects of interaction between new type of emanation and matter have been obtained.

Till the present moment theoretical physics didn't pay attention to the nonoriented configurations and spaces. The reason of this situation is the fact, that from the philosophic point of view it is not possible to determine and locate the area of the nonoriented topological structures in our world. We (eight scientific teams) joined our forces and we needed more than 30 years to solve this problem by an experimental approach.

The fundamental tenet of the casual mechanics developed by Kozyrev can be formulated as follows. There are two types of energy in the Universe. The positive or «right» energy acts as a factor of the entropy increase. The negative, or «left» energy tends to decrease the entropy, i.e. it acts as a factor, which regulates the entropy increase. The «right» energy is transformed to the «left» one and this fact may be interpreted as a course of time from the past to the future. When the energy is transformed from the «left» to the «right» form, time is reversed. Kozyrev supposed [1] that through revolving of a body together with a

6. Activation by nuclear magnetic resonance;
7. Activation by electronic paramagnetic resonance;
8. Activation by electrochemical force.

All these methods can be used as possible way to high efficient energy systems. Gerlovin wrote: "Usually 1, 6 and 7-th methods of structural activation are realized in catalysis simultaneously. Besides, catalysis differs from macroscopic methods because it has the most minimal distances from the sources of activator fields to the activated molecules. And finally, an active participation of force fields created by nuclei of atoms and significantly more active participation of disturbed EPV is possible in catalysis. That's why catalysis is the most effective method of structural activation. The detailed account of this method exceeds the limits of this article and we can only annotate it." [1, p.333]

Information stated above is only a small part of the questions appeared under consideration in Gerlovin's theory of fundamental field (TFF). Other important questions should be considered with a new experimental data.

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Antigravitation Force and Antigravitation of Matter. Methods of its Creation

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Part I

For a long time there is an opinion in physics about antimatter as a possible source of antigravitation, but the researches on this subject came into a dead end. The existent presentations and formulas forbade the conclusion about antigravitation, but our conducted investigations brought us to the possibility to get antigravitation of substance and to the paradoxical conclusions concerning the next:

1. Two types of space exist:
   a) The Absolute space
   b) The Relative space

2.a The Gravitation Field is the relative space, which has accelerated motion, directed to the center of a planet.

2.b The Antigravitation Field is the relative space, which has accelerated motion, directed from the center of a planet.

3. Gravity force does not depend on mass of a body! The mass can be presented in three versions:

a) m_k –mass as amount of atoms.

b) $W_{m_A^e}$ - electronic-atomic energy in mass.

c) $W_{m_G^m}$ – mechano-gravitational energy in mass.

On the basis of the stated notions we offer to revise the essence of force not only in Coulomb's formula, but in Newton's formula too.

$$F = K\frac{q_1 \cdot q_2}{R^2} \qquad F = P\frac{m_1 \cdot m_2}{R^2}$$

It is well known, that mechanical energy can be bringing in electrostatic charge, where mechanical energy runs (turns) into energy of electric field, where

(mechanical energy) $F \cdot R \rightarrow \frac{E_2 \cdot V_{m^3}}{2}$ (electrical energy)

Similarly it is also possible to insert mechanical energy into mass of a body. As the result, the mechanical energy will turn into energy of gravitational field, where

(mechanical energy) $V \cdot F \cdot t \rightarrow \frac{g^2 \cdot V_{m^3}}{2}$ (gravitational energy)

Since the volume of the Earth is constant, the acceleration of gravitational field will be increased.

It should be logical to expect, that when removing the mechanical energy from mass the inverse process will occur, that is to say acceleration reduction of gravitation field will occur.

In his works I. Newton affirmed about existence of two spaces:

The Absolute space - is an immovable non-rotatable space, which represents a limited cube, with our planet in the center.

The Relative space – is a movable space. It can move with acceleration in the absolute space.

Editor's note: In aether conception this means two parts of aether: some part is involved into the motion with the mass, but another part of aether is immovable.

The main mistake in search of aether consisted in the following: Maikelson's experiments were aimed on search of relative velocity between bodies and space. However, it was the **relative acceleration** between bodies and space that was necessary to search for.

To quote the conclusions of I. Newton: “Body can keep the quiescent mode or mode of rectilinear uniform motion …” By this, he postulates, that the relative linear velocity between solids and space does not exist. But we know that for rotation it exists (the famous experiments with revolving pail of water).

The gravitational field is the accelerated “falling” relative space, which represents a spherical form. If relative space moves, thus the question appears: where does it move? There is only answer: it moves in the absolute cubic space.

In Einstein’s theory there is notion of unified and curved space in gravitational field, but the contradictions appear here, and on concerning that N. Tesla writes: “Only by presence of force field it is possible to explain the observed motion of celestial bodies, but thus the hypothesis of curvature of space is not necessary. The whole scientific literature on this subject is futile and doomed on oblivion”. [1]

The fact that gravitation is the accelerated moving relative space can be proved by observation of accelerated moving rocket, where the acceleration in rocket is equivalent to the acceleration in gravitational field. Accelerated movement of rocket is relatively, that allows speaking about either acceleration of rocket motion in immovable space, or accelerated motion of space in immovable rocket!

The anti-gravitational field is the relative space, which has accelerated motion from the center of a body (for example: rotating cylinder, Earth satellite and etc.) But it is possible to create the model of anti-gravitation without rotations. On the basis of analogy between mechanical and electric energy comes to conclusion that gravity between bodies does not depend on mass of the body, but on mechanical-gravitation energy, contained in this mass, which is possible to contribute or to extract from. **Therefore, this is the internal gravitation energy.**

Part II

The “Mass” can be considered as a measure of three different conditions of matter:

m_k - as a measure of amount of atoms, representing a “framework” or “container”, in which two types of independent energies are concentrated.

$W_{m_A^e}$ - as a measure of electric energy, which can be either accumulated or extracted, and it have a “compressed” form.

An example of accumulation of electric energy in mass is a big cylinder, rotating with linear velocity, close to velocity of light, in this cylinder the mass of electric and magnetic fields of atoms increases. There are another possible ways to contribute and to extract the said energy from mass.

And finally $W_m M_G$ is the mass, which can be a measure of mechanical energy, or it can be either inserted or extracted from the matter (it can be identified as the gravitational mass). This gravitational mass is what we put our attention on, because it affects upon gravitation and it is able to create antigravitation.

“In his time N. Tesla worked on more general problem, which is the problem of matter and energy. And he has found, as he believed, the new physical principle, on the ground of which he brought forth his gravitational theory that was named dynamic gravitation. But he did not tell about it until almost the end of his life”. [2] **Really, dynamic gravitation is the energy of motion.**

Let’s take the following indications:

V – mechanical velocity
F – force
t – time.
In this case the product $W = V \cdot F \cdot t$ has the dimension of energy. Hereinafter, let’s take

I – strength of electric current
U – difference of potentials
t – time.

Then $W' = I \cdot U \cdot T$ **has the dimensional of energy.** Thereby, $W \sim W'$ that is to say, the following products are accepted as equivalent:

1. $V \cdot F \cdot t \sim I \cdot U \cdot T$

2. In previous materials it was reported about untraditional way for accumulation of energy, under the condition, in which at constant current I the product $q = U \cdot t$ will depend on amount of inserted energy in unchangeable circuit L = const, in which the energy can be accumulated by untraditional way not only in electric capacity, but also in inductance.

Similarly the energy can be accumulated by untraditional way in a moving body, under the condition V=const and m_k=const (the product $qr = F \cdot t$ will depend on inserted energy and have unlimited value). **Exactly this charge will create the powerful gravitational fields.**

3. Let’s take: F is mechanical force, R is distance. Then the product $F \cdot R$ has the dimensionality of energy. For the uniform electric field the product $E_a \cdot \frac{E^2 \cdot V}{2}$ also has the dimensionality of energy. In this case E_a is constant, E is intensity of electric field, V is volume. Thereby, $F \cdot R \sim E^2 \cdot V$. Similarly, $V \cdot R \cdot t \sim g^2 \cdot V$

We have received the correlations of resemblance for heterogeneous physical values, on the ground of which the following physical experiments can be offered:

On the grounds of the above-mentioned analogies it can be assumed that the accumulation of "compressed" energy is possible in mechanics, as well as in electricity. Since the velocity is relative, that the mass can have zero velocity relatively a observer, who moves with this mass, but the force field will remain unchangeable, since it depends on already invected mechanical energy.

Let's note that:
When the "compressed" electric energy is accumulated, the power field does not change.

When the "compressed" mechanic energy is accumulated, the power field increases.

Now we have come to the amazing conclusion that the gravitational force does not depend on mass of matter, but it depends on mechanic energy, which is included in this mass. This energy is unstable and at contact with land it is disappearing, and at zero gravity it can be saved for a long time.

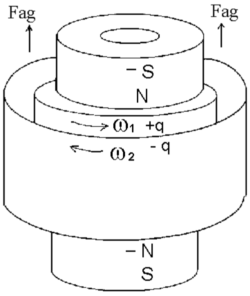

Fig. 1 The first way to obtain the antigravitational force.

1. The magnets are not revolved.
2. The cylinders of charged capacitor are revolving in different directions.

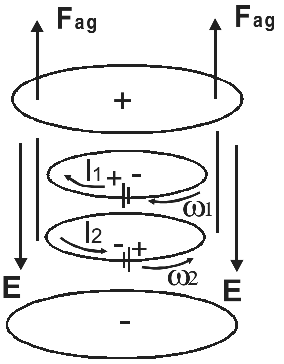

Fig. 2 The second way to obtain the antigravitational force.

1. The capacitor plates are charged and not revolving.
2. The current circuits are revolving in different directions.

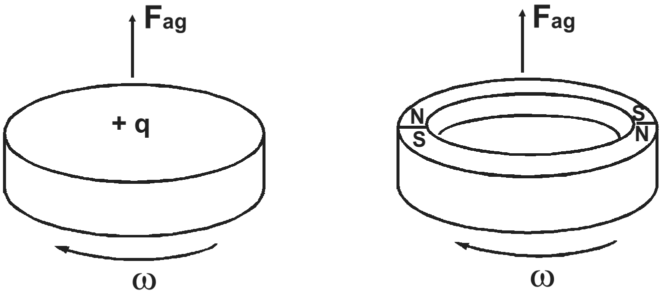

Fig. 3. The third way to obtain the antigravitational force

a) electric
b) magnetic

1. The disk and the ring are made from electrical current conductive material.

2. When these disks rotate, the currents, which emit the mechanic-antigravitational energy in the manner of heat, are formed there.

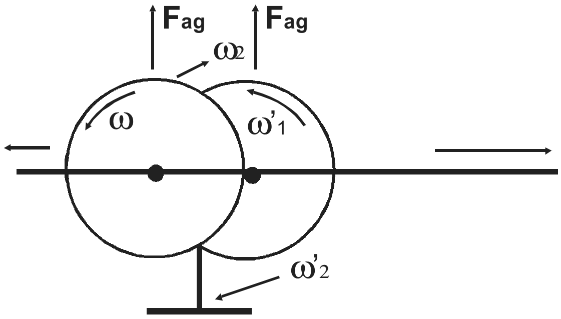

Fig. 4. The fourth way to obtain the antigravitational force.
Mechanical method.

1. This is an extraction of energy from matter. It was reported in details on the 10 international symposium in Volgo-Donsk, Russia.

2. The difference with electric circuits is that it is possible not only to extract the mechanical energy, but also to insert additional energy in the system.

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1. Magazine Inventor and Rationalizator, Russia, #9, 1979.

2. Magazine Inventor and Rationalizator, Russia, #9, 1979, p.28

The Capacitor, which has the Energy of an Atomic Bomb

(Review of Anatoly K. Gaponov's research by Eugenie and Marina Golomolzins)

Is it possible to place a pail of water into a one-liter jar? At the first look the answer is obvious: certainly not! However, the inventor from Novosibirsk, Anatoly Gaponov thinks differently. He does not "press" water, but electrical energy, placing an energy equivalent of atomic bomb into ordinary electrical capacitor.

Everybody using ordinary batteries knows its defect: they need frequent recharging. Gaponov's capacitor is slightly smaller than a matchbox. Just come home by electrical automobile, take out the capacitor from engine, and then put it into the pocket. For home needs you can just insert the capacitor into plughole to power the light, boiler, and TV system. In general, each electronic device can have its own capacitor, then an electrical wiring is not necessary. After one

On the grounds of the above-mentioned analogies it can be assumed that the accumulation of "compressed" energy is possible in mechanics, as well as in electricity. Since the velocity is relative, that the mass can have zero velocity relatively a observer, who moves with this mass, but the force field will remain unchangeable, since it depends on already invected mechanical energy.

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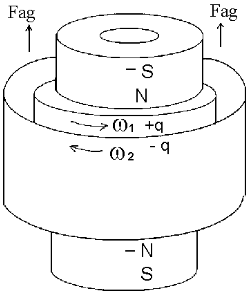

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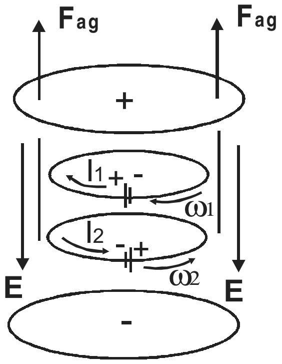

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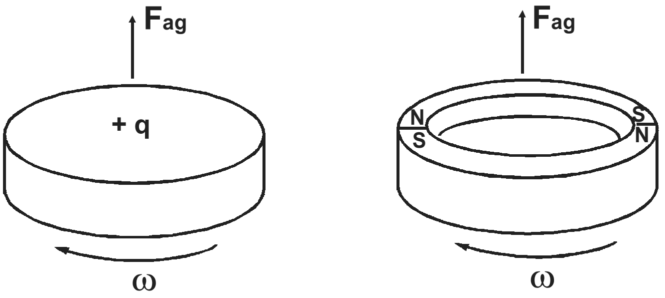

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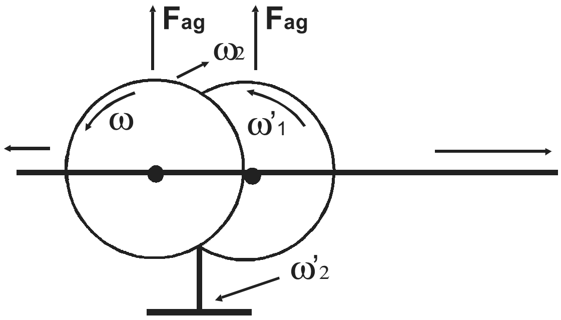

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or two years you will just have to come into electric service station and charge your magic capacitor like a gas balloon. Meantime, this research work began from hypnosis.

Anatoly Konstantinovich Gaponov (by birth from Kaluzhskaya region) is Ziolkovsky' countryman. In his youth Gaponov was brought by fate into Sakhalin, where he showed hypnotic abilities. As an inquisitive person Gaponov had organized a research group, started experiments and soon he understood that human brain had incredible possibilities.

A mental prick was made distantly to the hypnotized man, and he uttered a cry of pain. The ability to see people through, to define and to avoid organism's faults, was revealed in a hypnotic trance. It was possible to inspire pleasant emotions, to force "watching" a film on the given subject, as if on the screen. An uneducated person became an erudite, as if being connected to a certain global information database. Thus an idea to make an amazing experiment was appeared.

In one of the experiments Gaponov hypnotized the person with four classes education, and asked, if it was possible to transmit the electric current without wires? The hypnotized person gave the answer, that it was possible. For that it is required to convert the electric energy in x-ray radiation. And what afterwards? Afterwards it is required to focus that rays. By what? By the lens made from quartz glass, gold coated. It was a miracle! The person told about things that in usual condition he had no idea of! The information was received from somewhere outside.

Further quite an amazing thing has occurred. Gaponov asked the hypnotized person, if it was possible to intensify the abilities of hypnotist's brain?

He answered, that he could. "He turned me round and stared at the back of my head, - recalls Anatoly. - And suddenly the smile began to tear my mouth. I could not do anything with myself. When my mouth was sprawled literally from ear to ear, the hypnotized person in some inhuman voice declared that experience could not be continue since the cerebral hemorrhage would occur. I was hardly able to give the order to stop the experiment".

Thereby, the experiments with hypnosis gave the beginning to the thirty-years period of inventions in the field of accumulation and transmission of energy. After the return to native Kaluzhskaya region, Gaponov was occupied with physics, development of logical thinking and became the town champion in chess.

The necessary books fell into his hands by themselves: some time a certain acquaintance gave it to read; another time he found the last copy in a bookstore. As a majority of self-taught inventors, Anatoly preferred practical experimentation. In quest of laboratory for realization of his own ideas, he moved to Novosibirsk. **As a result, in 1980 Gaponov has made experimental system for compression of energy.** From the school Physics we have known the notion of "electric arc" – it is a small blue lightning between two electrodes. Gaponov has tamed this lightning in such a way, that having drawn apart two wires, which executed the role of electrodes, by hands and got the arc by length up to half meter. Anatoly confirms that in principle, it is possible to create an arc of any desired length under any amperage.

One of the experiments found out one more enigmatic characteristic of electric discharge. During electric photography of arc a person happened to be between the camera and the system. On typing pictures, the researchers have found with surprise, that the electric arc was perfectly seen through the person. That is to say, it created the invisible field, for which material object was not an screening obstacle, and which was fixed on the film.

The further experiments with electric arc have allowed to get a new source of energy, as well as to open the possibility of setting light and sound on fire! Just imagine, you ring up a bell, it's sound waves spread at once in all directions, and then flash up with bright blaze.

(Editor's note: this experimental facts are rare modern evidences of possibility to create longitudinal electric waves. It is clear analogy here with sound waves in air since they are longitudinal waves also. Alexander V. Frolov)

When the problem of energy source was solved, Gaponov turned to the problem of energy accumulation. According to Gaponov, he has provedexperimentally the possibility of charging of an ordinary capacitor with any amount of energy. This statement sounds paradoxically: how it is possible to place the unlimited amount of contents in limited volume? However, this is not a simple way.

Gaponov believes that energy "placing" occurs not in space, but in time by means of his system! In what way? Imagine, that you fill one-liter jar with water. But already after an instant the water-filled jar is in past, and that present one is once again ready to be filled. And so ad infinitum. Water as if it fills a certain "time reservoir", and a jar is just a neck of this "time reservoir".

(Editor's note: This method is described in other articles also but usually it is pure mathematical discussion about Minkovsky space-time and theoretical proposals. Gaponov's experiments are realization of fantastical idea to take power from the time flow, i.e. from Past or from Future to get over-unity in Present space. Alexander V. Frolov)

"It is possible to demonstrate one more example, - Anatoly Gaponov adds. – Let's charge the capacitor with the expectation, that it will supply the light bulb

for one second. Thereby, on the Earth this light bulb will be on only for an instant. But if the same capacitor with light bulb is placed in rocket and dispersed around the Earth at the velocity, closed to velocity of light, time on the board of rocket will be so slowed that the light bulb on rocket will be glowing infinitely long for an observer from the Earth. It means, that in any case it is the same energy quantity, but in one case it's action is sprawling for a second, and in another one it is sprawling for eternity! It is possible to say, that in my system I have created the condition corresponding to this hypothetic rocket".

The system for accumulation of electric energy could be charged by ordinary wall plug 220 VAC. Time period of charging is different and depends on the certain scheme of the system. By the way, sea electric slopes are the certain natural analogues of such capacitor. Some elements of internal device of these sea creations reminds the "pump" elements for placing of electric energy into "temporal jar".

Finally, the third Gaponov's invention is the system for transmitting of energy without wires. As well as in two previous cases, there is an experimental device. Anatoly Gaponov speaks that he has succeeded in getting the essence of experiments for transmitting of energy, which were conducted by Tesla.

It is clear, that the main advantage of this method is an absence of wires and losses of electric energy. The electricity could be transmitted directly into any point, where receiving equipment placed, let say from Kaluga to Sahara. However, this is not so interesting for anybody, since for the present day Anatoly Gaponov's inventions don't have demand.

" The first system was created twenty years ago", - says Mr. Gaponov. – "Now I am fifty five, but things have not budged an inch". He adds dreamily: "Eh, if only I had a laboratory and some money...".

Gritskevitch's Hydro-Magnetic Dynamo

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Editorial: The article presents construction and operation of Oleg V. Gritskevitch's hydro-magnetic dynamo, which is an example of very powerful new energy system. The prototype in Armenia has been produced over 1500 KWtts power during several years.

The author was born on 14 August 1936 and grew up in Vladivostok, Russia. He is married and has a son Boris. Gritskevitch is a physicist by education. He worked in the Far - East branch of the USSR Academy of Sciences. Since 1985 he has been working independently as an inventor. He has more than 70 patents on inventions ranging from household engineering up to high technologies, which he has been trying to apply in our country and met big difficulties. After numerous attempts to receive the patents the author was convinced that outflow of the information occurred. Therefore he has received the state certificates as on know-how (on a French way of patenting), for all his inventions.

Introduction

During the Institute for New Energy 1999 Symposium, I lectured on my hydro-magnetic dynamo. This paper is my attempt to explain the construction and operation of my dynamo.

To fool investigators of my secrets, I have an occasion provided misleading information. For example, the drawing accompanying the Russian patent referenced below shows a cylinder across the toroid to fool readers. The real dynamo only has the toroid without the cylinder. Even its name "hydro-magnetic dynamo" is somewhat deliberately misleading.

I have some familiarity with the new energy field. Nearly all purported new energy devices are fairly small electrical generators. The dynamo may be the only new electrical generator which most nearly meets all the requirements of an ideal large-scaled electrical generator. My dynamo really is the single most valuable invention the world has ever known.

Alexander V. Frolov of St. Petersburg recommended me to contact with Dr. Patrick Bailey, Institute for New Energy since Pat has lots of contacts who could possibly help me with patenting my invention of a new source of energy in USA.

I conducted the work on the theory and creation of the electrostatic generator-converter «Hydro-magnetic dynamo» about 20 years. (See dynamo history below.) The first primitive equipment was created when I worked in Academy of Sciences. During that time various changes were introduced in the generator and in the theory of its work. It is now possible to manufacture, install, and apply it in industry.

For the first time I made the public report on this work in 1991 on a symposium in Volgodonsk city. The report received the positive replies and reviews of the experts of a nuclear industry in USSR. The same year I was accepted in International Nuclear Society. In these years I offered development of this technology to different state bodies and private enterprises. But there was the only answer: "It is very interesting and perspective project, but there is no money for it".

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Research on advanced space propulsion methods and new energy systems

History of invention: Poliakov's vortex drive

Patented by Research Institute of Space Systems named by Krunichev, Russia

Also in this issue:

- * New gravidynamic paradox
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Gravitonics is Electronics of the XXI Century

Hypothesizes, Conclusions, Speculations

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Today we can easily insist that ways to solve main gravitonics problems are already defined, at that the practical realization of any of them will mean the break through in engineering. So, what successes has the Russian science already achieved in the area of gravitonics, and what priorities can we lose here in the nearest future?

Introduction to Gravitonics

The electronics of the "past century" uses electron as a ball, which has weight, radius, electric charge and magnetic moment. These very parameters define electron behavior in the electrostatic, magnetostatic and electromagnetic fields. But electron abilities are not limited by it; electron spin and internal microstructure features remain unaccounted and unclaimed. Evenly speaking, General Theory of Relativity (GTR) of Einstein was a power impulse for mathematical physics development and gave birth to many productive ideas. But the main problem, that is the secret of gravitation, remains undisclosed… In works of K.P. Stanjukovich [1] and A.Z. Petrov [2], who carefully followed GTR, it was shown that this theory described neither energy, nor impulse of gravitational radiation, i.e. it can not explain gravitation. About 20 years ago V.B. Braginsky, today's RAS Corresponding Member, came up with an idea: "if the propagation speed of gravitational signal is higher than the velocity of light, there will be already another theory, not GTR!" Maybe, the reason is the postulation of equality of gravitational and electromagnetic radiation velocities?…

Today the approximate theory of gravitational radiation sources can be built on the basis of the following simple considerations: if during annihilation of "electron-positron" pair there creates the pair of gamma-quantums with energy about 0.511 MeV, then the pair of back gamma-quantums with the energy about 0.511 MeV, could create "electron-positron" pair. Is it possible to assume, that electron, positron and gamma-quantum with the energy about 0.511 MeV are just three stages of one and the same object?! If it is possible, then for the rational description of the given object we will have to suppose the existence of subparticles, named by us uniquantums [3], or named by other authors microleptons [4].

On the basis of Heisenberg uncertainty relation conformably to the energy and duration of quantum of electromagnetic radiation, measured by laboratory means, it is possible to calculate the minimal "electrical length" of photon (i.e. quantum geometrical extension in free space in wave-length units), which is equal to 137λ, and in the uniquantum theory it is equal to 137 uniquantum-antiuniquantum pairs. On the basis of these conceptions it is possible to construct the spatial microstructure model of electron. So, what kind is it?

We think, that electron can be represented as thin-walled spheroid, walls of which are two light (C) barriers, separating the "internal" part of electron from the "external" one. From the traditional physics point of view "over-barrier" space is an "imaginary" one. This very space can contain the gravitational mass of electron. The radius of the gravitational spheroid is equal to the half of the classic electron radius, and its imaginary weight is 137 times more than the rest mass of electron. Being "cut" off by the double light C-barrier, uniquantums of the spheroid internal part are as if non-existent for the outer world, and the rest mass of electron is formed by magnetic energy of three uniquantums on the external orbit with the classic electron radius. This very spheroid, rotating with the tangential velocity C, let us get the precise value of the electron spin.

The study of presented model shows, that:

- The "electromagnetic" rest mass of electron is "magnetostatic";
- The gravitational mass of electron is an imaginary value and it is 137 times more than the rest mass of electron;
- The gravitational radius of electron is two times less than the "classical" one;
- The "internal" gravitational radius of electron is 45.7 times more than the external one, i.e. the internal space is compressed per 45.7 times (!);
- The spin is equal to the classical one, but this value is imaginary one (!);
- The value of the "effective" electron charge is three times more than the classical tabulated value;
- The native magnetic field of electron is equal to $8{,}9 \cdot 10^{13}$ Oersted;
- The gravitational constant is equal to 10^{33} $cm^3/g.s^2$, i.e. it is about 10^{40} more than the "world" gravitational constant of the Earth;
- The gravitational energy of electron is equal to $137 \cdot 0.511$ MeV, i.e. 137 times more than the equivalent energy of the rest mass of electron.

The model is paradoxical. But it can be tested experimentally! Comparing "electromagnetic" rest mass of electron with the relation of electromagnetic energy to gravitational one, it is possible to determine the connection between magnetostatic and gravitational energy of electron, and, therefore, with energy of the magnetized ferromagnetic.

Gravitational constants of the Earth and of the electron differ in about 10^{40} and can be described by the same simple equation:

$$\gamma_{loc} = 2k\gamma_0 \cdot \omega^{3/2},$$

where k - is a parameter of the gyroscope shape, γ_0 - is absolute universal constant, equal to 1/137 and ω - is native rotation frequency of the gyroscope.

Let us assume, that gravitational constants of all objects should be described by this equation. By substitution of the new gravitational constant into the known equation of the gravitational energy $W = \gamma m^2 / r$ we will get the equation of the gravitational energy of rotating gyroscope with any size (from electron up to the Galaxy!). Thus, the main point of the "non-Einsteinian" theory of gravitational energy sources comes to the thing that any rotating object and any magnetized ferromagnetic have their own gravitational energy, and the sources of gravitational radiation can be only nonlinearly moved objects, or objects which are in the state of change of phase (for example, permanent magnet during its demagnetization). It is the gravitational theory and explanation of "strong" and "weak" interactions!

Laboratory test of the equations

Magnetostriction

J.P. Joule found the effect of change of ferromagnetic linear sizes and volume during magnetization as early as 1842. Magnetostriction is widely used in modern technique, but in the physical encyclopedia of 1963 there is the following honest acknowledgement: "For the most ferrites both longitudinal and transverse magnetostriction is negative; the reason of it is still unclear."

In the scientific literature magnetostriction is usually defined as $\lambda=\Delta L/L$. However, during the change of external field to some arbitrary and enough small value ΔH, it is advisable to define magnetostriction as $\lambda=1/L\cdot\Delta L/\Delta H$, since in magnetostriction experiments the value $\Delta L/\Delta H$ (or $\partial L / \partial H$) is changed. By means of the suggested equation $W=137(BHV)=BHV/\alpha$, which connects magnetic energy with the gravitational one, it is possible to get enough simple equation for the magnetostriction:

$$\lambda = 1/L \cdot \partial L/\partial H = \alpha \cdot k/(B \cdot H)_s \cdot H^2 \cdot \partial\mu/\partial H$$

where $(B\cdot H)_s/\alpha$ - is the density of gravitational energy in the point of magnetic saturation, k – is the parameter of share of gravitational field in the magnetostriction effect, H - is magnetic bias, $\partial\mu/\partial H$ - is differential magnetic conductivity.

The new equation qualitatively corresponds to four known features of magnetostriction [5], namely:

- The magnetostriction sign is defined by the sign of $\partial\mu/\partial H$, i.e. by the course of the magnetization curve, measured in the direction of calculated component of the linear magnetostriction;
- Graphical sum of three linear components of magnetostriction, calculated by three main axes of the anisotropy form of the model, is always negative and numerically close to the value of the volume magnetostriction;
- Magnetostriction is an even effect, since the equation includes squared value of the external magnetic field;
- Dependence of magnetic conductivity μ from the filed H and hence dependence $\partial\mu/\partial H$ has a hysteresis nature. Therefore, the magnetostriction is a hysteresis phenomenon too.

So we have the right to "close" the question of physical encyclopedia on the cause of magnetostriction. **Magnetostriction is the secondary gravitational effect of ferromagnetic "self-constriction" in its own gravitational field.**

Gravitational-optic effects of GTR

Distortion of the light beam, passing near the Sun and the photon frequency bias in the field of terrestrial gravity (the Nobel experiment of Paunda and Rebki) are the main arguments in favor of GTR canonization. It is very attractive to repeat these experiments in laboratory conditions, basing on our conception of the origin of gravitational field.

The acceleration of gravity, used in experiments with ferromagnetic, reached the value $4.72\cdot10^{15}$cm/s^2, i.e. about $4.8\cdot10^{12}$g. At such values of acceleration there is no necessity to introduce a definition "space masses". In these experiments there was used the optically transparent ferromagnetic, which was the saturated solution of manganese chloride in water at room temperature. The experiment on the beam distortion was made in 1975 [7]. It was shown, that this effect is the result of two simultaneous processes. The first is an intense drift of magnetic ions, which forms the gradient of index coefficient that causes the light beam distortion. Another process is a relatively weak gravitational beam distortion, for which, nevertheless, the relation of deviation angle to the track length (the length of the dish is about 100 mm) is turned out to be about 10^{10} more than in "Einsteinian" gravitational-optic experiments.

The experiment on bias of the optic radiation frequency [8] was made in 1978-1980 and was repeated in 1983. With use of heterodyne and interferometrical methods of measurement we were succeeded to observe effects of "red" and "blue" frequency biases in the non-uniformly magnetized ferromagnetic by means of simple displacement of the working dish (with the length about 40 mm) from one side of the magnet gap to another. The maximum displacement is about 10^{-5}, that is about 10^{10} more than in the experiment of Paunda and Rebki.

Problem of the propagation speed of gravitational radiation

There are still only few publications about such fundamental parameter as the propagation speed of gravitational radiation; it is able to speak only about pages, or even lines! Let us refer to major sources:

I. Newton: *"The propagation speed of gravitational interaction is equal to infinity."* It is an argument, because otherwise we would have to bring the "delay" parameter Δt into the Law of Gravity, what is not noticed in real conditions of star observations [9].

P.S. Laplace in 1787, taking into account observation errors of that time, showed, that gravitational interaction speed was about $50 \cdot 10^6$ times more than the light propagation speed, i.e. it was about $1{,}5 \cdot 10^{18}$ cm/s [10].

A. Einstein: *"The propagation speed (of gravitational interaction) is equal to the light velocity".* This statement is postulated.

Even during the change of propagation speed of gravitational radiation between the Earth and the Moon it is impossible to define the signal delay about 10^{-11} s, i.e. we cannot measure directly the propagation speed of gravitational radiation (supposing that we have both generators of the gravitational radiation and receivers of it). But this speed can be estimated by the reflection impulse, what exactly was made in 1987 [3]. And its value is about $9 \cdot 10^{20}$ cm/s!

On the basis of conservation law of impulse of unidirectional radiator with arbitrary energy type we can get a simple equation:

$$F/(dW/dt) \cong 10^4 \cdot V/C^2 \qquad \text{[g/Wt]}$$

where V – is the speed of radiation propagation, F – is tractive force in grams, dW/dt – is power of radiation in Watts and C – is velocity of light.

For making the experiment there were constructed, produced and adjusted: sensible scales with one degree of freedom (sensitivity of balance is about 1g at the oscillator mass together with the moving element of scales which is about 50kg); the indication system of small mass changes (phase-meter receiver); gyroscopic system, changing the mass in the dynamic mode (there are 16 possible operating modes – from the rotation with steady and variable angular speed up to the forced precession with the variable angle of precession, with the "right" and "left" rotation of all load-bearings elements at option); power sources and commutation automated system. The period from idea up to its realization took about two years (1985-1987) [3]. Taking into account the real parameters of the system, the program of calculation was drawn and propulsive burns were calculated. The results of machine computation can be compared with real impulses, demonstrated on the screen of the oscilloscope.

If strange speed value 177 C^2 is discarded, then the middle speed value is close to C^2, i.e. to $9 \cdot 10^{20}$ cm/s! Of course, we would like to think that this is the second fundamental matter speed of our world, which we has approached experimentally …

Gravitational receiver

During the creation of gravitational antennas and receivers there appear almost insuperable difficulties from the modern fundamental science point of view. That is why it is advisable to look at this problem from another side. At first, it is necessary to consider gravitational radiation interaction not with the mass, which it goes through without losses, but with the gravitational field of independently gravitating mass, when the interaction must be the most effective because of the principle of physical processes reversibility. At second, it is necessary to choose some critical parameter of auto-gravitating receiver as a value, which is directly measurable by gravitational detector. For example, angular velocity of free rotation of thin disk with big diameter, the frequency of magnetization precession during NMR (nuclear-magnetic resonance) or NFMR (non-linear ferromagnetic resonance) etc. can be chosen as such a value.

In 1987 there was the first successful attempt to receive the gravitational impulse. The source of external signal was gyroscopic precessing system with the variable angle of precession (the propagation speed of gravitational radiation was measured by it). Double gyroscope, setting in motion by one electric motor, but with the opposite directions of rotation, was used as a detector. Between disks there was placed the source of light, impulses of which, passing through disks openings, were registered by photodiodes. Their signal came into differential circuit of data processing. The memory oscilloscope reproduced impulses of gravitational radiation. At that radiating system and memory oscilloscope was started up simultaneously. During the work process there appeared a problem of exciting of slow auto-oscillations of gyroscope-detector. This problem together with the low frequency of auto-oscillations of mechanical system led to a conclusion that this research direction is not very promising. However, the fact of detection was proved!

Gravitational engine of continuous action

Only about nine years passed since the appearance of the idea about engine up to its realization! In 1997 the engine was produced and tested. The engine with weight about 28 kg was made "weightless" on the magnetic hanger, and longitudinal draft, appearing in accordance with the impulse conservation law, was measured by micrometer detector of longitudinal shifts (sensitivity is about 50g/point). Such engine could be built still in the beginning of the last century… However, it has a secret **that is a gyroscope with the variable radius, working in the continuous mode.**

The engine power is defined by the formula

$$\frac{dW}{dt} = 5k\gamma_0\omega^{3/2}\left(\frac{m^2}{r^2}\right)\cdot\frac{dr}{dt}$$

In June of 2000 there were made experiments with the model of gravitational engine, which represents a gyroscope with the variable radius (see photo on the 1st cover page). The mercury was used as rotating fluid. Tests were made in the Research Institute of Space Systems named by Krunichev. In three experiments, at a certain speed of rotating fluid there was fixed a decreasing of the engine weight (38,5 kg) up to 1.0-1.5 kg (2-3%). The specific impulse of the engine was equal to 2.5-3.0 kg per kilowatt of electric power. Analysis shows, that the increasing of propulsion force is possible at optimization of design and operating modes.

Some preliminary resume

In the magazine “Foreign Literature” #1, 1967 the article “For hundred years forward…” by Jack Marabini was published. There were made some conclusions about prognostic work of firm Rand Corp., including the area of gravitational technique. Namely:

- Development of communication facilities on gravitational waves in 2000;
- Creation of spaceships with antigravity engines in 2050;
- Transformation of gravitational energy into electric one in 2100.

In the article it was noted, that the most “fantastic” predictions of this firm, as a rule, come true passing ahead.

According to our crude estimations, the propagation speed of gravitational radiation is “C” times as much than the velocity of light, but we know neither laws of attenuation and propagation of gravitational waves, nor laws of their reflection and refraction, nor laws of their interaction with the substance… The large routine work is expected: making of measurements and investigations, tabulating of obtained data, publishing and society familiarization of the results, their “popularization”. It is necessary to learn to use gravitational radiation and to protect oneself from its accidental influences, to design standards and dosimeters, etc., i.e. to repeat the way of radio engineering and nuclear physics comprehension.

For that we need generators and receivers of gravitational radiation. It means that the financial support is necessary. And engineers are sure to be ready to pay the highest price for the chance to give to the Mankind spaceships, systems of instantaneous communication with them and real perspectives for the very long history.

Conclusion

We have already passed the long way, if not in space, then in time. We have made:

- Gravitational engines of continuous action with the specific impulse about 2.5 kg/kWt [11];
- Transformers of gravitational energy into thermal and electrical ones [12];
- Communication system based on gravitational waves [13];
- Receivers of gravitational (microlepton) radiation of biological and mineral objects [5];
- Devices for control of “laboratory time” flow (time machine) [14].

The main goals of the authors were to attract readers’ attention to the problems, which demand an urgent solution. Some questions were decided, and even seemed to be clear. It also seems to be clear what to do further. And what do you think about it?

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BEAMSHIP TECHNOLOGY

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Read in this issue a report by Russell Anderson, USA, on beamship Model Flying Craft

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Experimental Research on Gravitational Propulsion System

*Editor's: It is a review of the article by **V. A. Menchikov**, the Director of Research Institute of Space Systems, named by Krunichev, Russia. The article was published in"Polyet" magazine #10,2001, p.38-39, Russia. It scrutinizes the matters on development of propulsion systems based on the unconventional approach to the problem of gravity, i.e. gravitational engines. It also cites the results of the gravitational engine model research made by means of the experimental facility, created in the Khrunichev Research Institute of Space Systems.*

The device, transforming rotary motion into unidirectional motion, looks like S.M. Poliakov's one. It also operates with rotation of liquid, which causes the propulsive force. Truly speaking, Poliakov had an agreement with Research Institute of Space Systems named by Khrunichev in 2001. Some funds were assigned to develop the device, however the project, into which Poliakov had put a lot of work, still remains unrealized. Besides, the scientist's name is not even mentioned in the patent.

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Scientific and technological advance opens to mankind more and more wide abilities to use space for the solution of global problems. In many respects the complete realization of these abilities will be defined by the developement of means used for delivery of payloads into the space. In the XXI century the dominating use of reactive chemical and electrical propulsion systems in rocket-space technique as well as low application level of engines with other physical principles can be the factor of an "inhibitory" influence for the development of such techniques. It is caused by the fact that created rockets practically do not correspond to noticeably increased standards of safety, operating costs, costs for transport operations execution and ecological influence on the environment.

Thus, there becomes to be urgent the problem of development of alternative approaches towards the creation of propulsion systems, made for the rocket-space technique on the base of unconventional ideas and engineering solutions. A rather old-established idea of creation of gravitational engine should be concerned as one of such ideas. It is based on the unconventional approach to the problem of gravity. Nowadays many countries take part in solution of the gravitational problem, namely Russia, USA, Japan, etc., and if till recently only some scientists and inventors showed the interest to this problem, then now it arouses interest of research-and-production majors. Unfortunately, now it is not possible to speak about sufficient theoretical or practical development of this idea. However, the interest is so considerable, that practically separate experiments on this subject were made earlier and they are still made nowadays. After all, stakes are very high and are defined by applied nature of the problem (the ability to create qualitatively new engines for the rocket-space technique), as well as by its scientific significance.

One of the directions to solve the problem of the creation of gravitational propulsion systems is the realization of associated theoretical and experimental methods of the search of physical processes, leading to the antigravity effects appearance, which cannot be adequately described by existed theoretical conceptions. V. Shauberger's patent, based on the postulate of gravitational energy radiation by "disturbed rotating mass" can be considered as an example of such practical realization. Taking into account a number of known experimental results, a model of gravitational engine and experimental system for estimation of this model parameters were made in Research Institute of Space Systems named by Khrunichev to provide the practical realization of Shauberger idea (Fig.1). It is the metal construction, which provides the model displacement in upward direction with the ability of its rotation around vertical axis.

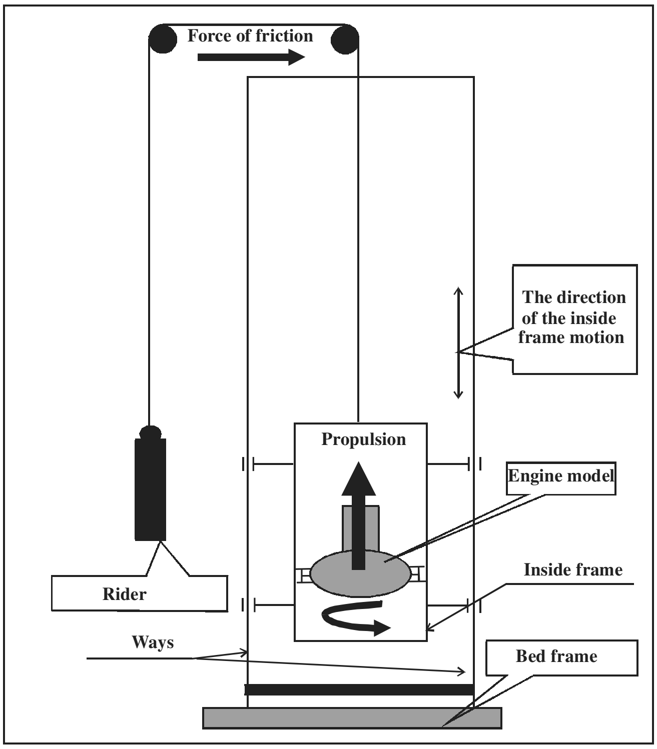

Fig.1
Schematic circuit of the experimental system

Later, to increase the system sensitivity it was improved and the block system of suspension was replaced by the lever frame.

Turning angle of the stand frame, where the model of gravitational engine is suspended, depends on the following: weight and geometry characteristics of the frame; weight characteristics of the engine (of counterweight); engine propulsion and frictional forces in bearings. Laser indicator of frame turning angle and vertical ruler let increase the gauge of lifting height of the gravitational engine model proportionally to the arm of light beam.

On using this system there was made a wide cycle of tests, which qualitatively confirmed the presence of propulsion force. Tests were recorded by video. The analysis of experimental results shows, that acting time of propulsion was about 12 s at each switching. During repeated switching of the gravitational engine model in different conditions it is able to create the propulsion, the value of which at 40…50 s of operation can be about 3 standard units of propulsion force (1 standard unit of thrust is about 10gs), and while using the powerful electromotor it can be about 80 standard units of propulsion at the intervals up to 4 s.

Research Institute of Space Systems named by Khrunichev, works on automation of experimental researches and on development of laboratory resources for factor analysis of appearance of the propulsion vector with the usage of the described model of gravitational engine.

Patent

The patent was published in the Bulletin of Patent Information in 2001.
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(24) 01.08.2001

Editorial: V.A. Menchikov together with A.F. Akimov, A.A. Kachegan and V.A. Svetlichnyi have got this patent. Dr. Spartak M. Poliakov, being the author of the principle, is not mentioned at all in the patent.

NEWS REVIEW

Boeing Tries to Defy Gravity

According to Jane's Defence Weekly (UK), http://www.janes.com, Boeing, the world's largest aircraft manufacturer, has admitted it is working on experimental antigravity projects. These projects are able to overturn a century of conventional aerospace propulsion technology and alter the entire aerospace business. Boeing uses researchers by Yevgeny Podkletnov, who claims to have developed a device, which can shield objects from the Earth's gravity. Many conventional scientists, who have not been able to reproduce Dr Podkletnov's results, view his project, named «GRASP» (Gravity Research for Advanced Space Propulsion) with suspicion.

Dr Podkletnov claims to have countered the effects of gravity in an experiment at the Tampere University of Technology in Finland in 1992. The scientist says he found that objects above a superconducting ceramic disc rotating over powerful electromagnets lost weight. The researches have shown that the reduction in gravity was small, about 2%, but the implications - for example, in terms of cutting the energy needed for a plane to fly - were immense.

His devise, named "impulse gravity generator" is capable to produce a beam of "gravity-like" energy that can exert an instantaneous force of 1,000g on any object – enough, in principle, to vaporize it, especially if the object is moving at high speed. Laboratory installation has already demonstrated the 4in (10cm) wide beam's ability to repel objects a kilometer away and that it exhibits negligible power loss at distances of up to 200km.

Applications of the device can include space launch systems, artificial gravity on spacecraft, aircraft propulsion and "fuel-less" electricity generation ("free energy"). However, observers say that Podkletnov's device could be engineered into a radical new weapon, for example, adapted for use as an anti-satellite weapon or a ballistic missile shield.

Documents, obtained by reliable sources, show that Boeing is taking Dr Podkletnov's research seriously. It is also possible, Boeing admits, that "classified activities in gravity modification may exist". The paper points out that Podkletnov is strongly antimilitary and will only provide assistance if the research is carried out in the "white world" of open development.

Boeing is the latest in a series of high-profile institutions trying to replicate Dr Podkletnov's experiment. The military wing of the UK hi-tech group BAE Systems is working on an anti-gravity programme, dubbed Project Greenglow. The US space agency, Nasa, is also attempting to reproduce Dr Podkletnov's findings, but a preliminary report indicates the effect does not exist.

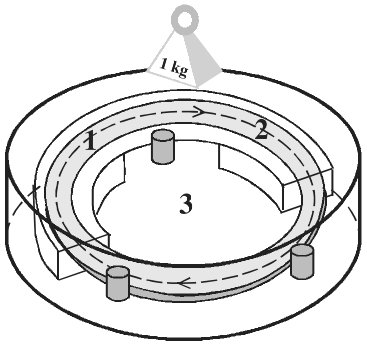

1. Solenoids create magnetic field
2. Spinning, super-conducting ceramic ring
3. Liquid Nitrogen acts as coolant

BEAMSHIP TECHNOLOGY

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Read in this issue a report by Russell Anderson, USA, on beamship Model Flying Craft

www.americanantigravity.com

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Beamship Technology: a Re-working of Early 20th century Discoveries

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Some Basic Background

The concept of an electric aero-spacecraft with no moving parts was initiated by the Yugoslavian electrical wizard **Nikola Tesla**, who lit the entire world 100 years ago, at the turn of another century, with his revolutionary AC electric current. In 1916-17, Dr. Francis Niepher performed meticulous mass-deflection experiments under rigorous scientific conditions with lead spheres suspended by wires with shielded and unshielded containers. An accounting of this important series of experiments is in TRANSACTIONS OF THE ACADEMY OF SCIENCE OF ST. LOUIS VOL.23, 1916 and 1917. Related article is in THE ELECTRICAL EXPERIMENTER, March 1918.

Before 1905, **George S. Piggot** was routinely suspending small silver balls to water globules, corks, wood, using the electrostatic field from a specially designed Wimshurst machine in a glass container under several atmospheres of pressure to raise the current level. Output voltage was typically 500KV. The field was propagated by a charged sphere. A small curved conducting plate on the floor acted as a ground. He observed unusual patterns of blue dots with filaments over the suspended objects, sometimes with an anomalous 1/2 cm "dark band" on the suspended objects. Piggot states, "It is my firm conviction that that somewhere on the outer confines of our planet there exists a similar contracting belt thru which naught but the gravitational vibrations of the sun penetrate, and these vibrations absolutely annihilate or absorb all other less powerful ones". If the force was Coulombic in nature, objects would be first attracted, and then strongly repelled by the charged metal sphere. After the objects were suspended, Piggot found he could remove the conducting ground plate, and the objects still floated, suspended. The phenomenon of levitation was accompanied by "luminous halos".

In 1925-27, **Albert Einstein** released his scientific "gem", his "zur Einheitlichten Feldtherie", or the Unified Field Theory for Gravitation and Electricity, to the press and the scientific community. It combines electricity, magnetism, and gravitation into a single mathematical expression, showing how High-Voltage/Low Current electricity (Electrogravity) -and conversely Low-Voltage/High-current (magnetogravity) "acceleration-fields" (G-field) could be produced using then-available relatively LOW-technology. Indeed, a very simple technology. The unifying field is the electrical field (because it can produce gravitation and repulsion fields, as well as magnetism). His Crowning work was released with much press write-ups and fanfare, then it was quickly forgotten as if the scientific community and the world had suffered some kind of collective amnesia!

All of the readers of this magazine need no introduction to the pioneering work of American Scientist **Thomas Townsend Brown**, who was playing around with an X-ray tube around the same year as Einstein's Unified Field Theory was released. He filed his first patent for this newly and accidentally discovered "electrogravitational-effect" which causes motion in a high-voltage condensor or capacitor configuration. He was only 17 at that time. The discovery that high-voltage/low amperage electrostatic potentials applied to an object causes motion in the direction of the positive pole, and electrical charges naturally move to the OUTER surface of an enclosed charge-conductor, held strong prospects for what Brown would later name the "space-car", and wrote an article "HOW I CONTROL GRAVITATION". His pioneering work, and demonstration of devices in Hawaii during World War II, drew attention from the department of Naval Intelligence. He was invited to work on "Project-Rainbow" (the Philadelphia Experiment for Electromagnetic Stealth) because of his pioneering work on what was starting to be understood very covertly as a true WARP DRIVE. Experiments with certain new and classified arc-welding apparatus at the Philadelphia Navy Yards to weld armor-plate for battleships was (by use of banks of primitive but powerful avalanche-discharge capacitors) producing anomalous and unexplained effects, such as disappearing tools and other apparatus in the heavily shielded welding chamber. These strange effects were accompanied by a strange "blackout -zone" which, like Piggot's early work, was not optical in nature. TT Brown's devices in his AH Bahnson Labs home movies lift more than their own weight and move inside vacuum chambers in these films. TT Brown later founded NICAP in 1956, which became the most respected UFO data gathering and hard scientific organization in the world, besides the US department of Naval Intelligence itself, and the Foreign Technology Division at Wright-Patterson Air Force base in Ohio.

My background and work

I primarily have a background and degree in computer programming, electronics, most fields of science, Flying Saucer Technology research (almost 30 years worth), Radio/Control fixed and rotary-wing aircraft since 1972. I have been experimenting and working with high-energy and electrogravitic devices and systems since 1987. I built my first small High-Voltage generators starting around this time. I built kits from Information unlimited and elsewhere.

In late January 1990 I built my first working 2-foot flying discs, which were a direct replication of Thomas Townsend Brown's most important representation of his electrogravity-propelled scale-model vehicular concept, from US Patent #2,949,550. In January 1992, I built a 120KV high-voltage/low-current electrostatic generator from an Information Unlimited kit, primarily for force-field propulsion research.

In June 1999, I built a tower and rotor apparatus to complete the experiment, and I powered it with the output from a 100KV generator I built from an Information Unlimited Kit. The results were spectacular, and taught me a great deal about what was involved in producing and maximizing the Biefeld-Brown Electro-gravitational effect. **I suspected from my research, and my experiments, that the basic effect was not due to current-flow and resulting ion-wind. When there was current-flow, the effect is attenuated, power consumption goes up, and thrust goes DOWN.** In late June of 2000, I presented this working TT Brown Electrokinetic Apparatus with larger 1-meter discs at the 2nd Antigravity Conference in Reno, NV, hosted by Jim Cox. A VHS videotape of this working and spectacular presentation at the first part of the conference is available from www.soundphotosynthesis.com

Now that I had mastered producing horizontal thrust, vertical thrust, or antigravity, was the next goal. About this same time, there was buzz all over the Internet about claims of two or three individuals who sounded credible at the time who had successfully replicated the many multi-layered "gravity-warp capacitor" or "electric rocket". Oddly, these claims could not be verified, and the individuals making the claims disappeared back into the woodwork. Such actions are bizarre and hinder the progress of true science, which is undergoing a shift in paradigms right now, if not a change in dogma.

I spent months die-cutting hundreds to thousands of tinfoil and aluminum-foil circular-notched conductor plates and wax paper and mylar rings. I did some initial testing with a Tin and wax-paper 400-layer gravity warp-capacitor heap, according to plans I had acquired from H & A Industries in 1992, and what was on Bill Beatty's amateur science site. No one else has come forward with positive results on this tedious and time-consuming device. So much work for so little effect! And, if you short out the stack with too much power, you must tediously and laboriously search thru hundreds of layers to find the dielectric layers with the telltale carbonized holes. The Electric rocket has been recently successfully replicated and tested in hard vacuum and patented recently by Hector Serrano. The Serrano effect is identical to the so-called Biefeld-Brown Electrogravitational effect. They are one in the same thing. I may dust off my completed 400-layer grav-cap, but I hardly find it worth the time and effort, because of my recent work starting in early October 2001.

The Lifter and The Evolution to Beamship Model Flying Craft

Although I had attempted a few small "Hagen" patent-type antigravity (VTOL) models in the early 90s, I found their performance poor at best and their power consumption high. In late summer, 2001, someone, I forget who, on the JLN's lab list of researchers and anomalous science-experiment and technology enthusiasts ran across a website owned by Transdimensional Technologies, of Huntsville, Alabama (famous for NASA research facilities, the late Dr. Rolf Schaffranke, author of the important ETHER TECHNOLOGY, under the pseudonym "Rho Sigma", and Dr. Tom Bearden) had produced a hovering device. From my previous work, I recognized it immediately as TT Brown's Electrokinetic Apparatus that I had successfully replicated and demonstrated before a live audience years earlier. I noticed the capacitors were made from Aluminum FOIL, not the thin-but-heavy Aluminum sheet stock from Home Depot that I had been using for years, (I had assumed that to make my 3-foot discs hover and ascend vertically, I would have to use voltages in the hundreds of kilovolt range, and generate high x-ray, UV, and possibly gamma-ray emissions as a by-product, in other words, a typical flying saucer with all the associated radiological effects that have been documented for over half a century) so they could lift their own weight. The result matches almost exactly the simplest graphical representations of TT Brown's patent from 1960, and De Seversky's Ionocraft patent from 1964, which was a thin foil cathode plate with a thin anode wire separated from the cathode by stand-off insulator posts. I was eager to reproduce these devices (I don't know how I overlooked this simple solution, it was all sitting in those old 1960s Brown and De Seversky patents I have studied for 15 years previously) and many people around the world, especially the webmaster of the JLN Lab's site French researcher Jean-Louis Naudin, who began replicating many different types of larger and more sophisticated devices, some of which resembled model spacecraft, and began amassing tables of very useful data, that researchers could use as basic guidelines to follow. I replicated the first hovering device, the "Lifter" (so-called by Transdimensional Technologies) as a 1-foot triangle, with 2-inch foil cathode and #42 enameled copper magnet wire. To energize it I used a commercial power supply from Gamma High-Voltage Research that I had acquired from Ebay some years ago. It was perfect for antigravity research, having full metering, and variable voltage from 0 to 40KV, and current limiting from 0 to 1.5 milli Amperes of current. The heavy 1-meter discs of the Electrokinetic Apparatus were too heavy and the rotor-friction to great for this low-powered device (60 Watts, maximum), but for the lifter, it proved ideal.

My first "lifter" antigravity device worked, but its performance was less than ideal. It had to be stripped of its lower balsa-wood frame and some of its foil before it would degravitate (counterbary), and it "maxed-out" the current-limited power supply at 33KV I 1.5mA, for a stable hover (actually this is an upward flight configuration, because the device is tethered to the lab table with 3 sewing threads). That is 49 Watts. The concept of a hovering TT Brown Electrokinetic Apparatus had been proven to my satisfaction, however, and I initiated more research into past works and patents to raise efficiency to workable levels. The performance was slightly better than my early 1990s "wire-grid" type devices. I found this slightly encouraging.

After a couple months reading and research (why re-invent the wheel, its all been done before), I started to replicate larger models in February and March 2002, but kept coming up against a size-barrier with the Multi-cellular (grid) approach that many researchers had assumed would raise thrust, and efficiency. This approach obviously did neither, as no one seemed to be able to produce hovering devices above a certain size, the current consumed (adding to total wattage consumed) was prohibitive with the low-powered (still high-voltage, low-current) devices that most of the mostly amateur researchers were using. Researchers around the world started to replicate different versions of the basic lifter 1 (an 6 to 12-inch equilateral triangle). The lifters are always tethered to the testing surface with 3 strings to keep them from going dangerously unstable and possibly short-circuit when they reach the limit of the umbilical supplying power to the device.

From my previous Biefeld-Brown effect replications years earlier, and from carefully reading Brown's EK Apparatus patent, I knew that increasing the diameter of the wire would reduce leakage current created by coronal discharge, mostly coming from the forward electrode, which in the 2 and 3-foot saucers consisted of an arc of copper tubing in the front quadrant of the saucer, or disc. Corona robs power (amperage) from the disc that otherwise would be used to "propel" the disc. Increasing the diameter of the copper tubing, as per Brown's patent if the effect was due primarily to ion-wind, more current and current flow between the electrodes would be desired to effect more air movement. But this is not what I saw in the saucers. **There was apparently another, far more powerful but subtle force effecting silent propulsion of the saucers that had nothing to do with charge-transfer and ion-momentum.**

In February of this year, I undertook an effort to replicate and improve performance and reduce power consumption of the lifter device, based on data from my electrogravitic work of years past. I started by using thicker diameter enameled copper magnet wire, #35 to #30 diameters. I first built a 1-foot equilateral triangular basic "Lifter-1", weighing only 3.5 grams. On March 16th, I built a lifter with the thicker #35 enameled copper wire.

I made the three sides 1-foot long and exactly 2-inches high. After experimentation, I found the optimum spark gap for my High-Voltage power supply (Gamma High Voltage Research 40KV with current limiting to 1.5mA). The small silver-colored device leapt off the test table and pulled violently against its anchor strings to a distance of about a foot. This seemed like a great deal of force for such low power. The large discs of my TT Brown EK apparatus required a good deal higher voltage to initiate motion in the direction of the anode. The device consumed 26KV I 0.56mA DC, which calculates out to 14.56 Watts. I was getting more excited, because this was the best efficiency seen of any result yet posted.

On March 19th, I tested 2 lifters glued together in a "diamond" shaped configuration.

This 2-foot device weighed 6.0 grams, with the same #35 wire and a 2 and 5/8" air gap. It took 25KV to nullify the weight of the device, and it achieved a stable hover at 35KV I 0.8mA. That is 28 Watts. This is about what I had initially expected, double the power for double the Watts. Still, this was far less overall power going into the device to achieve a stable hover than my first primitive and radically shorn and trimmed device. After lift off to the extent of the anchors, I found I could reduce power slightly and maintain a stable hover. On march 22nd at 3:49 pm I got the diamond lifter to achieve a stable hover with a 2 and 5/8" air gap at 29.5 KV I 0.32mA. This was only 9 Watts! This was unheard-of efficiency. I was further encouraged to build and test larger hovering devices to see how large I could get them with my low-powered commercial power supply.

I then built a "lifter-2", which consists of three 1-foot triangular capacitor cells taped together. It weighs 11.4 grams. March 30th at 3:22 pm, the device achieved a stable hover at 38KV I 0.57mA for 19.76 Watts total power. The larger device was more energy efficient than a device 1/3 the size. I wanted to see how far this could go, so I added three more lifter cells to make a 6-cell device, 3 feet on each of its three sides. I was eager to check the performance of this fairly large device. This was the diameter of my horizontally propelled TT Brown Discs.

This device weighed 21.6 grams. I kept the spark gap the same distance on this device. However this device failed to achieve counterbary (lift). It just sat on the test table, filling the air with the smell of ozone and making a sizzling sound (corona noise). I noticed that the current maxed-out on the power supply at a fairly low voltage and would not go any higher.

I concluded in my disappointment that all that wire from all the inter-connections to the cells was causing corona leakage and robbing current, which otherwise would be used by the device for propulsion.

The idea then hit me that perhaps I could make a device with the same outer diameter as the 3-foot device, but have greater efficiency because of a much shorter length of wire. I built basically a 3-foot (1-meter) version of the first 1-foot device. This device weighed 16 grams. It lifted off the table with amazing force and hovered stably with I 52mA 30KV which is 15.6 Watts. Not only had I achieved a larger-size device, but far better power efficiency for a much larger and heavier device. I was overjoyed! I saw that I had a great deal of lifting force to spare. I had not even come near the limit of my power supply. I added extra bracing at the corners and extra balsa and a triangular paper "payload -tray" in the center of the device, supported by three 1/16"x1/16-inch balsa stock. The extra bracing and payload area added approximately 2 more grams. With a 5 gram payload, the device consumed 39.9 KV I 0.99mA, for total power consumption of 39.5 Watts. I was really encouraged at that point, because I knew that these results were unheard-of, in terms of energy efficiency. I had solved the problem of decreasing efficiency by dispensing with a "grid-based" device. Increasing the area of the capacitor plate was one of the factors that increased performance and efficiency, lessening the input power requirements with increasing size. Now the Biefeld-Brown effect could be properly studied, now that most of the ion-flux had been eliminated, resulting conservation of energy by the device, and resulting in greatly increased propulsive force.

Since I now knew the limit of payload for the device at the power level I was using, I added a balsa framework that approximated a central cabin area, and three small styro-foam spheres on the center of the straight sides on short lengths of balsa. The device no longer looked like a test device, but now looked like a scale model spacecraft. I remembered the Edouard "Billy" Meier UFO contact case, and knew that all his original photographs and movie footage of extraterrestrial spaceships the extraterrestrials themselves called "beamships" (there are several styles and variations, all with different specific functions and capabilities, some manned, some remote-controlled "telemeter discs" that had a tri-hemispherical undercarriage that I knew from past research were propulsion condensors) and that the original un-tampered photos all passed rigorous analysis using the latest and most sophisticated computer and other equipment, case detractors not withstanding. Also the spiritual messages of these genetic brothers of Man and their accounting of humankind's history and origins from far across space rang true and struck a chord with me.

I decided to name this new 1-meter model spacecraft Beamship Variation I. The three sides of the device performed the same function on this device that the three spherical or hemispherical capacitors often seen on the underside of full-size "beamships" (Daylight-disc-type UFOs), which illustrates a similar if not identical propulsion methodology to full-size 3 to 7 meter and larger "off-Earth-built" aero-spacecraft. Clearly the propulsion methodologies were exactly the same in the model as in the full-size flight device.

I immediately built a 4-foot diameter model with a full cabin framework and internal payload area and achieved even greater performance and efficiency. I was ecstatic. This 4-foot device I dubbed Beamship Variation II. I received a suggestion from Mr. Tim Ventura of American Antigravity that performance could be increased by using small diameter stainless-steel wire. It seemed unlikely to me that smaller diameter wire would increase performance, it contradicted Brown's patent, and my own past research with large electrogravitic discs. But Stainless steel has a high number of free electrons in the outer valence atomic shells (electron orbits).

So I obtained some #40 stainless locally and the results confirmed Mr. Ventura's suggestion. Corona noise was heard at a much higher power level, and was greatly attenuated in volume. Leakage current was less, and the two Beamships now had more thrust with less power input. They even carried more payload at less power input. Variation II weighs 21 grams and loft a payload of 6 grams at 40KV I 1mA for 40 Watts total power. Again, this was unheard-of efficiency. The anode wires sang a strange harmony as the Beamships floated in the air, stably at any altitude, from floor to ceiling, without any fuel or visible means of support. This was very Beamship-like.

I thought that now since corona discharge on the anode wire was less, I could decrease the spark-gap distance without creating a spark (which kills lift). Thrust seemed initially to increase, but efficiency went down because there was current-flow now, and current consumption went way up. The supply would now max-out at 37KV I 1.5mA and would not increase because of the current limiting. The Beamships now were noisy, as the foils chattered loudly because of all the ion-wind that was now rushing downward along and past the foils. I used a concert fog machine to observe the ion-flux vector, and filmed it digitally with my Logitech web-cam, and with VHS analog video.

Analysis of the fog -tests showed a circular vortex of air surrounding the anode wire that flared out into a downwash of air below the Beamship. I was disappointed, because I thought then that the thrust action of the device was due to simple ion-transfer. A useful-enough effect, but of questionable use in the vacuum of space without an ionizing medium.

Beamship Variation III

I reasoned I had just about enough power in the supply to build and fly a 6-foot (2-meters) Beamship. Since the balsa came in 3-foot lengths, this was simple. As with all the lifter devices and the more evolved and efficient Beamship-series model aircraft, construction techniques are extremely simple and require little skill to assemble. Weight of the Beamship Variation III is 42 grams, with 6-feet of length on its 3 sides. Height of the foils was still 2". Full frame and cabin, with Searl "IGV"-type landing legs, to support the weight of this heavy and very large device. I set the spark gap at 2 and 1/2 inches. At 12:15pm EDT, May 12th, 2002 the Beamship was weightless at 32KV with current maxed-out at 1.5mA.

The device barely lifted off, and "hopped", across the floor once or twice at full power. It had the same loud rattling of the foils due to the terrific downwash of electrified air. I needed to raise the power level. I increased the distance of the spark gap to 2 and 3/4". Now the Beamship took off straight up with power to spare, as if it was one of the smaller craft. Beamship Variation III is weightless at 30KV I 0.85mA (25.5 Watts), and airborne into a stable hover at 35KV I 1.35mA. That is only 47.25 Watts. It can carry a payload of 5 grams, or 5 grams worth of additional framework and structure, to the limit of the power supply, which is 60 Watts (40KV I 1.5mA).

The 42-gram, six-foot model aero-spacecraft only consumes 47.25 Watts at hover, but my first small and trimmed device ate up 49 Watts! Clearly, using the single-cell Beamship methodology had a huge advantage over the "multi-cellular" design that other researchers had built and tested, seemingly reaching an impasse in terms of size and efficiency, which my large single-cell Beamship technique had seemingly solved. In early April my 1-meter Beamship, weighing 22 grams including 5-gram payload, consumed 39.6 Watts. So the 42-gram, 6-foot Beamship used only 7.65 Watts more total input power at stable hover that the 1-meter Beamship. Power-to-weight ratio for the 2-meter Beamship V. III works out to 1.125 Watts to lift 1 gram stably of scale model electric spacecraft. With little to no ion wind, the Beamship had plenty of upward force and achieved stable counterbary at greater efficiency than I had ever heard or read about. Also, I was not aware of any devices in scientific history that has achieved this type of counterbary for this little input power and this colossal size. I performed additional fog-tests with two red semiconductor-emitted laser beams in the plane of one side of the device, one above the wire, one below the foil. The Beamship without all the ion-wind was nearly silent again, except for "singing" and softly "thrumming" anode wires. These laser-beam tests further confirmed the marked absence of ion-wind with a larger spark gap.

At 1.125 Watts-per gram at 57KV I 1.4mA (78.8 Watts) would lift 89.775 grams worth of electric spacecraft. So not only is the larger size in a single cell far more efficient that the "grid" design, in thrust and power consumption, but the reduction in current from increasing the spark gap raised power level to the device, while dropping power consumption of the device. My initial suspicion of ion-wind producing most of the thrust in the Biefeld-Brown effect had been disproven also because of the great weight of the device. I never would have discovered this important fact if I had stayed with smaller devices, trying to raise their efficiency. And I never would have discovered the efficacy of the Biefeld-Brown effect if I had stayed with the multi-cellular "lifter" methodology. One of the factors that raises the level of propulsive force (if "propulsion" is the right word) is increasing the area of the plate, according to TT Brown's patents. So the larger size single-cell capacitor's ability to reduce power consumption and effect greater propulsive force and upward acceleration, was easily explained by the Biefeld-Brown Effect. Brown had been vindicated. My gut feeling had seemingly been confirmed: this was our first warp-drive (reaction-less drive).

My experiments had yielded greater efficiency, and greater size and weight of VTOL hovering models than any that I had ever heard or read about. I still am having difficulty taking in these facts; and it is very awe-inspiring to see such a large device de-gravitate and hover stably at any altitude, from floor to ceiling.

Next for me is a higher-powered supply (60KV), moving up to a three-meter Beamship Variation IV, improvements to the cathode such as a thin, symmetrical airfoil shape, as Brown suggests in his patents, tungsten wire, and then carbon-wire for the anode, and full heat-shrink coverings on the frames, running lights, onboard lasers, onboard digital/proportional Radio/Control, and now that we know the power requirements, and have a good handle on efficiency, onboard power generation. I have already begun designing with my associates our own custom-made outboard and inboard battery-powered power supplies, and finally will cut the power umbilical to the model electric spacecraft permanently, and Beamship technology advances further. If the on/off duty cycle is pulsed at a low frequency, power input can be reduced by two-thirds, at least. Experiments conducted by Jean-Louis Naudin last fall (2001) confirm this phenomenon, suggested by Brown and De Seversky in their patents. Clearly, onboard power can easily be effected, using modern miniaturization and circuitry. Pitch and roll vector control can be achieved by electrically isolating the anode wires on the three sides of the ship, and varying pulses to these three wires. Yaw control can be achieved by simply installing a horizontal-double sided capacitor inside the ship near one corner. Simple full 4-channel flight control is thus achieved.

The Beamship series aircraft are fascinating research and entertainment devices (see cover page), and are the vanguard of a whole new generation of radio/controlled antigravity model aircraft with no moving parts and dead silent propulsion. But they are more than that. The Beamships, if allowed, could probably rise up at any speed thru the atmosphere, right up to near-Earth-orbit, and probably keep on going out into limitless space. No need to achieve ballistic escape velocities of miles-per-second. This is non-ballistic flight. They even have a certain amount of wind resistance outdoors and indoors because the electrical field causes air to flow AROUND the model flying craft, not into it. This is such a safer, environmentally cleaner, vibration and nearly silent and more pleasant method of aero- space travel than carrying tons of explosive reaction mass, which can and does explode. No more use of heat energy to effect transportation.

The 21st century has begun in earnest!

Beamship series aircraft are available for sale for research and hobby/entertainment use right now through the American Antigravity website: www.americanantigravity.com. Look for the Applied Electrogravitics antigravity technology website late spring, 2002. You can contact me, Russell Anderson for details on pricing, and new and improved variations, and power supplies for outboard and onboard drive, which are currently in design stages.

Editor's note: More ideas on development of T.T. Brown's patents are on our web site: http://www.faraday.ru. Read about T-capacitor!

Data Table 1

Antigravity device	Weight of device	Wire type	Voltage/current	Total Watts	Payload	Payload/power
1-foot "Flyer-1"	3.2 grams	#42 enameled copper	33KV I 1.5mA	49	None	———
1-foot "lifter-1"	3.5 grams	#35 enameled copper	26KV I 0.56mA	14.56	None	———
2-foot "diamond-lifter"	6.0 grams	#35 enameled copper	29.5KV I 0.32mA	9	None	———
2-foot, 3-cell "lifter-2"	11.4 grams	#35 enameled copper	38KV I 0.57mA	19.76	None	———
3-foot, single-cell "Beamship Variation I"	16 grams	#35 enameled copper	30KV I 0.52mA	15.6	None	———
Beamship Variation I-fully-rigged	18.5 grams	#35 enameled copper	———	39.5	5 grams	39.9KV I 0.99mA
4-foot "Beamship Variation II"	21 grams	#40 stainless-steel	———	40	6 grams	40KV I 1mA
6-foot "Beamship Variation III"	42 grams	#40 stainless-steel	35KV I 1.35mA	47.25	None	———

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SmartPAK Technology™

invention by William Alek

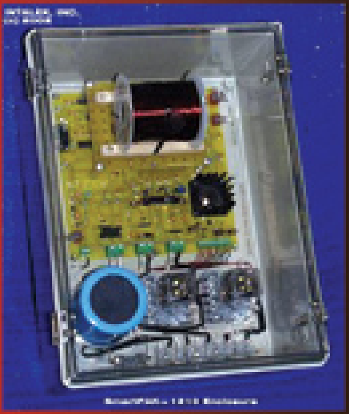

the world's first commercial all solid-state system that provides a "standard" platform for experimenters, researchers, and developers to do energy-related practical applications, experiments, and perform exploration of highly efficient alternate energy system

The theory of operation is based on the amount of energy that is required to magnetize and de-magnetize ferromagnetic materials utilizing a core/coil/magnet assembly. It has been discovered that it takes MORE energy to magnetize a suitable core assembly than to de-magnetize it. The SmartPAK system is designed to measure and collect the difference, and store the excess energy for later use.

The SmartPAK device is controlled by a 68HC908GP32 micrcontroller programmed to measure input/output voltages and currents, calculate COP, and contains software algorithms for a complete "turn-key" power management system. The device features a "standard" user interface, which allows the user to design their own custom core/coil/magnet "head assemblies", and immediately test and display in real-time its' performance.

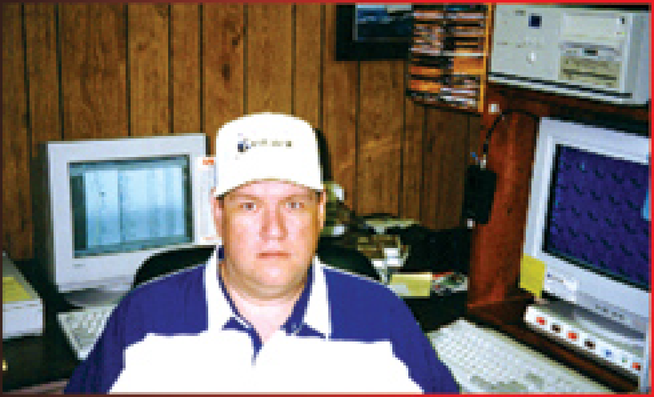

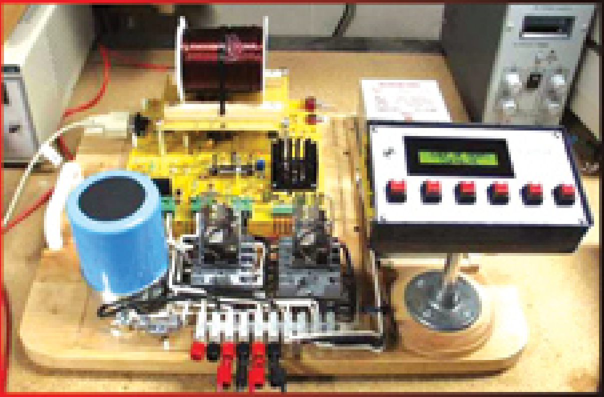

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Commercial Antigravity

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Introduction

Let me begin by posing a simple question that I would like the reader to keep in mind throughout this article: How far away is commercial antigravity? I'm not talking about a laboratory experiment where a giant magnet is used to levitate a frog, or secret UFO experiments that the government isn't sharing with the business world, but a real, viable antigravity solution to what I consider to be the most pressing issue facing the world today – transportation.

Who can answer a question like that? How far away is commercial antigravity? The author has read numerous scientific texts on the subject, and is familiar enough with contemporary theories of gravity, antigravity, and electromagnetism to suggest that most scientists believe that commercial antigravity is at least 100 years away from existence. But the author believes that most scientists are wrong.

Defining terms

Any article about antigravity would not be complete without properly defining the terms to be used. In this article, antigravity is not used in the strict sense of the word. The author's intent is to discuss a method of propulsion, which for all intents and purposes can be considered antigravity, and may include antigravity – but also may include several other forms of similar propulsion. The reasoning behind this is that experience has shown that the majority of people in the world don't care how something works – they care what it can do for them. This article is about the effect of Antigravity – not the cause.

Real Antigravity would consist of an apparatus used to either reduce the apparent mass of an object or reduce the effects of gravitational attraction between the Earth and an object. An example of an apparatus that may in fact do this is the Podkletnov superconductor apparatus currently being tested by NASA.

This Podkletnov device essentially consists of a spinning superconductor that self-levitates above a pool of liquid nitrogen and supposedly creates a "beam" or "shaft" of antigravity (or reduced gravity) directly above it as it operates. The levitation of the superconductor itself is not antigravity – it is a well-known side effect of ceramic-superconductors called the "Meissner Effect". The Meissner effect is simply a side effect of the superconductor's interaction with the Earth's magnetic field, and is easily explained by physics.

Podkletnov claims that when he worked with a team of researchers investigating superconductors in Russia around 1991, the smoke from the tobacco pipe of a fellow researcher began to climb steeply in a column directly above the superconductor. The researchers began to think that they were on to something, and Podkletnov subsequently performed several follow-up experiments that led him to the conclusion that the levitating superconductor produced a shielding effect between the Earth and anything positioned directly above the superconductor. He reasoned that gravitational shielding would provide a "column" of reduced gravity above the superconductor that should extend up and away from the Earth indefinitely. Podkletnov calculated that with a rapidly spinning levitating superconductor he had achieved a 2% loss in weight for anything directly over the superconductor.

Podkletnov's research is interesting and compelling, and it would fall into the category of "real" antigravity – but I am writing about Podklentov's type of research as well as enormous amount of research and theory available on electromagnetic propulsion systems. These can be considered "effective" antigravity.

The Harrier jet fighter can swivel its engine exhaust-nossels to create vertical lift, which resembles antigravity in that it is VTOL takeoff. However, the Harrier does not use effective antigravity because it has all of the functionality and side effects of an aircraft. A helium blimp would be a closer example to "effective" antigravity, but it too is not – because it works on basic aerodynamic principles.

Aerodynamics is not effectively antigravity – aerodynamics is instead expensive, difficult to manufacture, prone to explosive failure, and highly unreliable. This is not to suggest that a jet aircraft is unreliable, because it has a variety of backup systems, but that the technology itself is unreliable in that a jet is adversely effected by the medium that it uses to propel itself. Air pressure, humidity, temperature, and strong winds all cause a degree of unreliability. In addition, turbine engines stretch the limit of what mechanical engineering can achieve – which is why they are prone to break if even something as small as a bird gets sucked in during flight.

Antigravity is not about moving the air around — it is about a medium-agnostic means of air transportation that produces vertical and/or directional lift without relying on air-pressure like a wing or blimp. Antigravity is an electromagnetic or electrogravitic system for reducing the weight of an apparatus to allow it to lift more easily. Antigravity is pushing a button and having your vehicle take off without runways, noisy engines, minimum flight-speeds, propellers, or any of the other drawbacks that limit conventional aircraft from achieving popularity similar to what an automobile might have.

The author's definition of Antigravity for the purposes of this article is confined to electromagnetic or electrogravitic devices that reduce the weight of an object to enable it to take off without conventional thrust-producing apparatus. This definition might also fit many of the classical characteristics known at one time as "the electric spacecraft".

1. *Business Analysis versus Scientific Analysis*

The author disagrees with the majority of scientists as to when commercial antigravity will become possible for some very basic and obvious reasons. To begin with, the majority of credentialed physics-related scientists come from a theoretical school of thought, which tends to limit their world-view to only contain those things that are currently or potentially explained by theory. The author, however, comes from an experimental school of thought that seeks to capitalize on existing observational data without the rigorous need to explain every last detail of its functionality. The author is an engineer, not a scientist – and engineers don't need to totally understand how something works in order to make it better.

This difference between the engineering point of view and the physicists is also different in the manner in which they seek out observational data. A physicist looks towards naturally observable data, and in the event that none exists they look towards current theories to explain potential future observations. The engineer is more open to ideas that are less rigorously tested from the perspective of scientific method, but are currently observed as potential solutions to real-world problems.

2. *Potential Technologies Overivew*

Phycists currently tend to dismiss the entire concept of Electrogravity, and the reasoning behind their logic is very sound. To begin with, Electrogravity is not observable in nature. In addition, many of the claims by those persons who submit Electrogravity and antigravity devices for public review are faked, exaggerated, or just plain wrong.

Physicists are responsible for maintaining a working body of theoretical knowledge, and if they were to admit results such as Schnurer's without skeptical scrutiny it would undermine the very fabric of technology itself. If the Podekletnov results were to be accepted as fact at face value without rigorous prrof, imagine the amount of money that would be wasted in attempts to build enormous Antigravity vehicles based on this theory.

In the middle of the spectrum lies the concept of Maglev, which is mentioned here only for the purpose of specifying that Maglev is not commercial antigravity. It has been mistakenly thought of as antigravity by many because it utilizes a magnetically-levitated train to improve the velocity of the train and reduce transit time between stops. In reality, Maglev is not really a vehicle at all.

The definition of a vehicle would be a device that transports itself as well as its passengers and cargo between two points. This is why an automobile is considered a vehicle but an escalator or elevator is not – the automobile transports its entire propulsive apparatus to another location, but an escalator or elevator does not move – it merely repositions its cargo between points. The Maglev train is not really a vehicle at all – it is actually a very long electromagnetic armature that transports people and cargo between its ends at high speed. While it may serve a commercial need, it is not to be confused with Antigravity.

On the opposite end of the spectrum is the author of this article – who has built and successfully tested over 30 electromagnetic "Lifters" at the time of this writing. The Lifter is a device based on research by Transdimensional Technologies and related to research by Thomas Townsend Brown that demonstrates an antigravity effect when a High-voltage DC current is applied to it.

Currently, the exact method of propulsion for the Lifter is being debated. It is thought to be one of two things – either an effective form of "ion-wind" propulsion, or else a form of field-effect propulsion based on an as-yet unknown force. While the debate about the exact nature of this propulsion is important with regard to future research, in reality it does not change the observational data that demonstrate that this technology works perfectly, consistently, and reliably.

The Lifter design was demonstrated by the author in a continuous mode of operation for over 7 hours straight on Sunday, April 21st, 2002, at the Seattle Center "EarthDay and Renewable Energy Exhibition". During this seven hour period of time, the author's Lifter hovered at a tethered height of 12 inches from the surface of the table, powered by a 30 watt load from a simple computer monitor.

This article is not meant to get into the details of methods of antigravity, only to suggest that it already exists in the form of electromagnetic propulsion systems if nothing else. The author is confident that in time physicists will find a theoretical reason for why the Lifter operates as it does, but for the time being the fact of its operation overshadows the method of its operation.

3. *Market Needs*

Commercial Antigravity doesn't require a 2% loss in weight to operate – it will require something akin to a 200% loss in weight. A commercial antigravity device will have to demonstrate exceptional performance to gain market acceptance, but not for the reasons that might immediately come to mind.

One might believe that skepticism from the scientific community would prevent antigravity technology from gaining the scientific acceptance needed to become a commercially accepted engineering discipline. The long term view, however, shows that this is not the case – engineering and market forces drive innovation, and formal science plays a supporting role in explaining and quantifying the innovations that engineers have already commercially qualified as valid.

The real roadblock to success for commercial antigravity is market acceptance. The author's demonstration of the Lifter technology at the Renewable Energy Exhibition helped him to realize that the vast majority of consumers have no idea what antigravity technology could be used for, much less what they themselves could use it for. The same thinking was apparent at the dawn of the age of personal computing, when the idea of having a computer in the home was a completely foreign concept.

So in brief, a market does not exist for antigravity technology, which is why inventors working with this technology have been unable to find appreciable support for their work. Many inventors look at this technology and ask, "how could the public not understand how valuable a technology like this is?" – but that isn't the problem. The problem is that most innovators with an interest in antigravity are so closely tied to the science behind the technology that they fail to review and address the business needs that drive the market acceptance of a new technology. In other words, people don't buy antigravity – they buy solutions. People don't buy cars to simply have a car – they buy cars because people need transportation needs that they have to fulfill. People don't buy computers because they want to have a computer – they buy computers because they want to share and process information and communications.

Marketing Requirements

How will antigravity technology gain the market acceptance to become a commercially viable technology? There are a variety of ways in that antigravity technologies will become commercially viable, but only after antigravity is no longer sold as antigravity – it needs to be sold as a personal or business solution.

The solutions that antigravity technologies are best prepared to provide at the moment are in the realm of transportation technology. This includes moving people and cargo to destinations in a similar manner to conventional transportation technologies such as aircraft or automobiles.

With regard to providing transportation solutions, antigravity has the ability to incorporate the best features of both contemporary automotive and aerospace technologies into a single technology that will serve point-to-point transportation needs better than either of the two aforementioned technologies could by itself.

For a moment, assume that a person wants to travel from Los Angeles to New York in a short period of time. Currently, the most convenient method of transportation to accomplish this would require the person to take an automobile to the airport, and from there take an aircraft from the Los Angeles airport to the New York airport. After departing at the New York airport, the passenger must then take another vehicle to their intended destination.

Commercial antigravity technology could serve a dual-purpose short and long-range transportation role, taking on the aspects of both ground transport as well as air transport.

Product Delivery Requirements

In order to deliver commercial antigravity as a viable solution to business needs, a variety of work will need to be completed on the various component systems of this technology to turn it from what is currently a "proof of concept" into a commercial reality.

Let us assume for a moment that we have developed a working device based on Antigravity or some method of Field-Effect Propulsion. While this is the critical stepping stone to success, this is by no means the end al be all of the development cycle.

To begin with, the technology must be perfected to the point of being both economical and reliable. As it stands now, the market already has technologies in place that fulfill some or all of the requirements for the technology that Antigravity is being developed to replace. In order to serve as an effective replacement for these technologies, antigravity technology must then demonstrate that it both costs less in terms of operation and manufacture, as well as being more reliable than conventional air-transportation solutions.

I mention reliability in light of the recent negative media attention surrounding several recent commercial airline crashes. From a marketing perspective, air-travel disasters provide a great deal of negative publicity for the airline industry. Since the airline industry has a mostly successful track record of delivering passengers and cargo, people are for the most part willing to forgive the occasional air-disaster. However, with a new technology such as antigravity-based air-transport, there is not a long enough track record to permit public acceptance of air-disasters. One substantial disaster in the early days of antigravity could serve to forever damage the credibility of this new technology.

With regard to being economical, any type of antigravity system that intends to surpass existing methods of air-transport must be able to do so at a less-expensive rate to own and operate, and must have a vehicular lifespan at the very least similar to conventional air-transport devices. This would allow the total cost of ownership (TCO) to be less for an antigravity vehicle than it would otherwise be for a conventional craft.

There is one caveat to acceptance of antigravity technology as compared to conventional aircraft, which is simply that if antigravity vehicles are able to operate in an environment or manner that precludes conventional aircraft, then they should be able to gain a market niche without immediately having to surpass conventional aircraft in the area of TCO.

Assuming that we can develop a propulsion system that is both more reliable and less expensive to operate for the transportation of passengers and cargo, we then have to build up the skeleton of a vehicle compatible with this form of propulsion around the actual propulsion system.

For instance, a conventional aircraft has pitch, yaw, and several other flight controls, but for an antigravity vehicle there is a high likelihood that some or all of these controls will not be required, thereby changing the dynamic of flight associated with the craft. This will require new methods of pilot certification and flight-qualification, as well as requiring a control-philosophy to be created surrounding how the craft will operate.

I use the phrase "control-philosophy" instead of simply "control layout" because one of my assumptions about antigravity propulsion systems is that they will allow more flexibility in the design process for engineers to determine how the craft "should" fly, as opposed to an aircraft or helicopter, in which the components determining speed and handling are based primarily on an interaction between the design of the craft and the atmosphere.

In brief, an antigravity cargo-transport may have very different needs for flight than perhaps a lightweight passenger vehicle would, although there would also need to be a consistency between the control-systems of these devices to reduce the need for extra pilot training and competency testing.

Therefore, it should be apparent from the last few paragraphs that not only are there several propulsion-system related challenges involved with developing a commercial antigravity device, but there are also several challenges in the design, training, support aspects of this technology that also factor into the requirements to be complete before a complete product can be delivered.

Conclusion

At the beginning of this treatise, I posed the simple question of **"how far away is commercial antigravity"**. The reader, I expect, probably interpreted that question in terms of time, which is the usual measurement of questioning when new technologies will become part of our lives.

However, as I have attempted to demonstrate throughout this article, **the time component is much less important to the development process than is the distance component – that is, how far away from commercial antigravity we are.** When I use the word distance, I mean specifically what tasks must be completed in order for antigravity to go from being a proof-of-concept approach to a new form of propulsion-system to being a completed vehicle ready for manufacture.

I have attempted not to address the legal implications of antigravity technology with regard to certification for general or specific use – my thought on this is that the discussion of legal ramifications of antigravity is best left for another time. This is due primarily to the size and scope of that discussion, which is beyond what I am attempting to analyze in this article.

So, in finale, how far away from commercial antigravity we are depends not so much on time as on the rate at which we can perform the work required to provide the underpinnings on top of which the technology can be built. This seems important to me, as it underscores how close we appear to be to a working method of antigravity propulsion, and how we might consider focusing resources and goals to achieve the realization of this common dream that we share.

EDITORIAL: PERPETUAL MOBILE OF 1902

There is one more interesting example of perpetual mobile, which was described in the collected articles [1]. The motor shown in Fig.1 was invented in 1902. The vessels *b, c, d* and *e* are mounted on a shaft *a*, and have one side *f* tangential to the shaft, and the other side radial. Compressed air is forced into each vessel through the valves *p*. It is stated that under "the action of the internal pressure of the vessels, and after a slight impulse has been given to same, in the direction of the arrow, the whole apparatus will begin to move and continue to do so without ever stopping, the velocity corresponding to the pressure established within the vessels".

Really simple... Let's try to examine it.

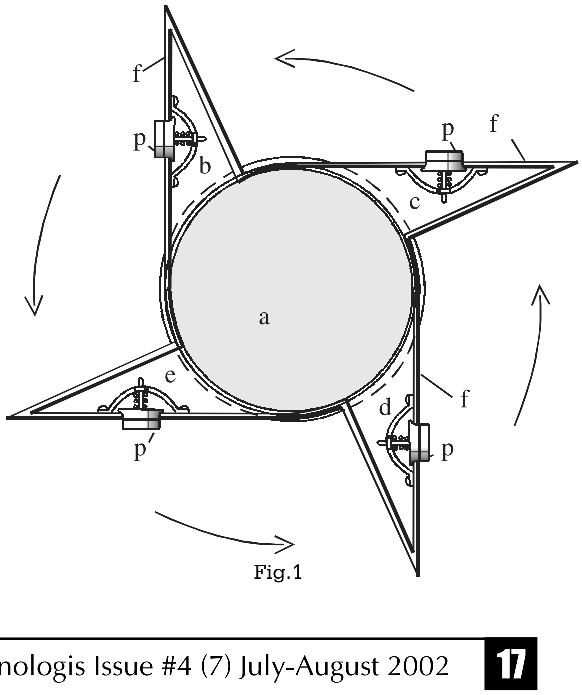

Fig.1

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Action without Reaction

New Gravidynamic Paradox

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Editorial: Yu.N. Ivanov discovered a new unusual physical phenomenon that is a gravidynamic paradox. The sense of the paradox is the existence of the situation, which is not forbidden by physical laws and which allows any man (even a child) easily hold suspended or carry things with 100kg or more weight by means of some simple device. This phenomenon is just a part of the significant applied topic and a demonstration of the possibility to cancel weight characteristics of any material object. Per se it is a work on the obtaining of the methods to eliminate aircrafts weight.

We can use only resistant things as a support!

Galilee-Newton's Laws are in the basis of classical mechanics. Thought concerned fundamental, these laws do not explain the main thing, i.e. the internal processual essence of the phenomena, described by them. There is another scientific line – the quantum mechanics, which tries to discover the essence of deep processes. There is no connection between these lines, therefore they as if exist independently. There are also long-time conversations about necessity to combine the quantum and the classical approaches. We suppose, that practically the combining has already happened, since thanks to rhythmodynamics, there appeared phase, frequency and velocity of light in formulae of classical mechanics (without these attributes the quantum mechanics is impossible). It was revealed, that phase-frequency method of late mechanics formulae presentation gives a real physical sense both to formulae themselves, and to concepts which seemed vague before *(namely: cause of motion, force, velocity, inertiality, gravitation)*. In this sense, the upcoming rhythmodynamics fills up the gap between the main physical lines and draws them together. But let's change the vector, since **the subject of the given article is to concern cases in which the third Newton law is not directly valid.**

Newton formulated the third law in the following way:

> ***"Action always has equal and opposite interaction, in other words, actions of two bodies on each other are equal and directed in opposite sides".***

This law represents the fact that one-way action of one body to another cannot exist in nature, but there is only an interaction between them, i.e. there is no action without reaction [1].

We must note, that the third Newton law is valid only for systems with 100% feedback, appeared in the interaction period. For example, during the magnet influence on the iron object it is revealed, that this object also starts to influence upon the magnet, i.e. to attract it with the same force. It happens because in the period of action of magnetic field the iron object itself becomes the source of magnetic field (Fig.1). Here the magnetic field, as an especial environmental condition, acts as a mediator, i.e. exists by itself in the interval between object and magnet .

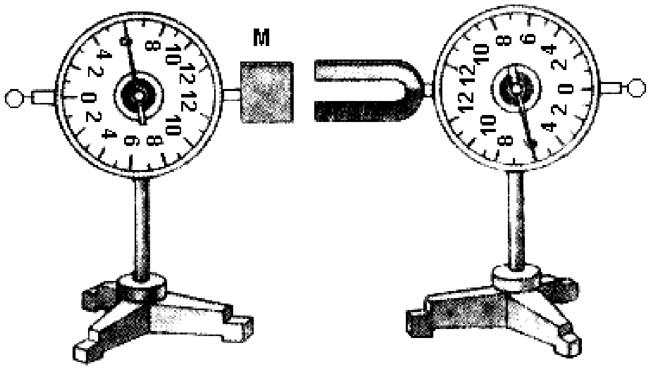

Fig. 1

Interaction of magnet and metal body M. Here the action is equal to reaction, i.e. the third Newton law is valid.

It is considered to be that magnetic field, created by electric current, spreads with the velocity of light. If current impulse is short, then the magnetic field spreads independently from the conductor and no matter if there is current in the conductor at present, or not. If the distance up to the object is big, then the magnetic field remains between source and object for some time, and has no influence upon the object. In this sense the portion of magnetic field, placed on the path between source and body, can be considered as moving independent "entity", i.e. the space by means of itself carries its changed state (magnetic properties) from one place to another. In this period magnetic properties in the form of quantum can influence neither on the source, from which the magnetic quantum is already detached, nor on the object, which the magnetic quantum still does not reach.

But having reached the object, magnetic field changes the state of this object. If as the result of influence the object becomes a source of magnetic field, then the part of the field is reradiated in the direction of source, i.e. the object itself becomes the source for some time, and by this it is able to influence on the first primary source. In this situation the principle of action and reaction works, because the feedback takes place.

If the feedback does not appear during the period of influence of one body to another, then the action and reaction law is not valid in the system. Let's demonstrate it by the example of the mechanical experiments, in which there is a feedback between objects.

Let there is a device (Fig. 2), which throws off two water (air) streams in the opposite directions in such a way, that reactive forces completely compensate each other. At that the thrown down stream compensates the gravity too. In this case the device will fly without falling, i.e. it will have zero weight.

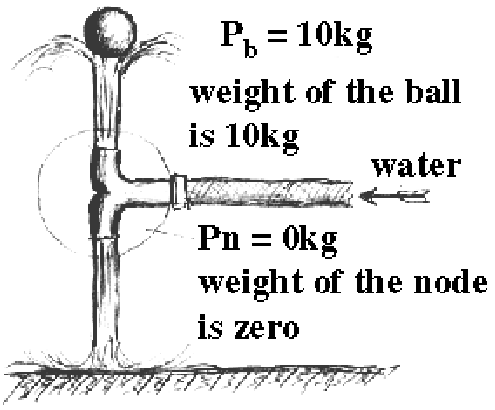

Fig. 2

The ball, suspended in the water stream, does not put pressure on the source. It happens because there is no feedback between the ball and the source. If you have such a device, then, lifting the ball by means of it, you will not feel the weight of the ball. The reason: the ball hangs due to the kinetic energy, which the stream passes to it and and this ball can not influence on the source through the water stream.

The appearance of the ball with the weight P_b does not influence on the weight P_n of the device. And even in the case if we press the ball down, i.e. essentially displace its location in the stream, the device will feel nothing.

The absence of device weight is evident for us; therefore we can easily move the device if its original (vertical) orientation remains unchanged.

Let's change the situation and place the ball (body with the shape, which is steady for hanging) in the upper stream. This ball with the weight about 10 kg is placed in a way to be kept by this stream at some distance, for example at 0.5 m. Will the device react on the changed situation, i.e. on the ball appearance? Will the weight of the ball, hanging in the stream, be added to zero weight of the device (0 + 10 kg)?

The calculation shows that it will not: $\Sigma P=0+10= 0$ [kg]. There is only an illusion that the ball is supported by the stream and that it is a part of the system. As a matter of fact, the ball is detached from the system and hangs due to the water kinetic energy. It is easy to check it by making an experiment in a bathroom: "Remove the douche sprayer, then direct the stream up and holding it by the one hand with the aim of weighting, try to influence on the source by the other hand through the stream. You will be surprised to feel that the hand, which is supported by the stream or any object, which is hanged in the stream, does not influence on the source".

At first sight the situation seems to be a paradox, however it very illustrates the possibility of the force action without reaction. So, the action can be one-way, i.e. calling no reply reaction in the form of pressure on the action source.

In such an unusual way it is possible to keep the ball of bigger weight (100 kg and more), at that to move it easily by means of the device and at the same time not to feel the presence of additional weight in the stream. **It is possible only in the case when there is no feedback between body and source,** i.e. the body, hanged in the stream, has no ability to act on the force source. Thus, we can both hold and move the heavy ball without additional efforts, and also lift it up to any height (for example, 100 m). As a matter of fact, we deal with the **new gravidynamic paradox**.

It is interesting then, how to solve the task of the following type: "Let the body with 100 kg weight is hanged in the water (air) stream in such a way, that it does not change the velocity and direction of liquid outflow from the source nozzle. How much energy the operator must spend to lift this body to the height about 10 m?" (Here it means that the operator must take the device, which supports the ball, and, moving upstairs, lift the body, which hangs in the stream, by means of this device to the height about 10 m). If to solve this problem correctly (the condition is that the operator lifts himself together with the device and the ball), we will find out, that operator's energy is spent only for lifting of the device, which creates water streams. The operator, lifting together with the device, will not even notice that in the stream there is a body with about 100 kg weight **(this is the sense of the paradox).**

The situation only seems to be absurd, and even paradoxical for theorists, but it is not a hopeless one.

We can also observe the effect of action without reaction in ultrasonic field of the source. If the source is fixed on scales (Fig.3) and body is hanged, as it was made in the stream, the scales will show only the precise weight of the source and will not react on the weight of the hanged body, no matter how heavy it is.

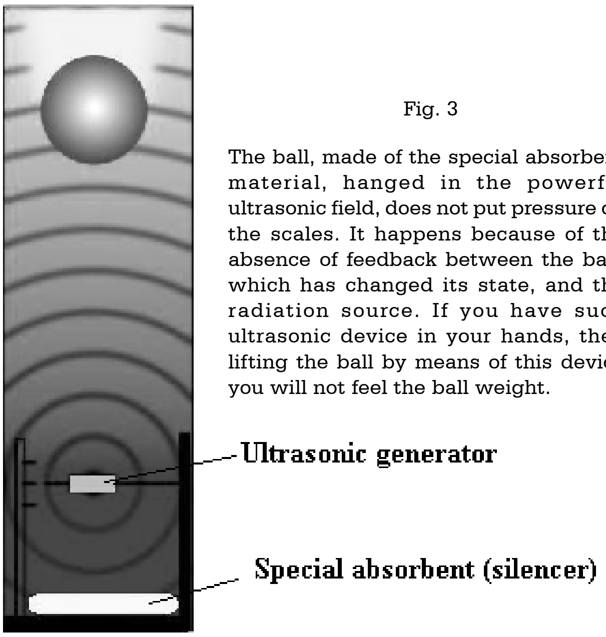

Fig. 3

The ball, made of the special absorbent material, hanged in the powerful ultrasonic field, does not put pressure on the scales. It happens because of the absence of feedback between the ball, which has changed its state, and the radiation source. If you have such ultrasonic device in your hands, then lifting the ball by means of this device you will not feel the ball weight.

The experiment of such type was made in one of the secret institutes. Water was used as an acoustic environment. The heavy ball easily floated up from the vessel bottom i.e. it behaved as if it had no weight.

The similar phenomena but such of the other organizational level, sometimes become apparent in nature. The phenomenon has its very name because the event happens unexpectedly and is not analyzable through laboratory research [3].

"A spherical ball lightning about the size of a football ball flew over a village Galtsovka of Altaisky Krai at a height of twenty to thirty meters. The first shed in its way, with ferroconcrete poles, was crushed and collapsed. Flying over a slated house, the ball lightning tore away the roofing slate together with nails, raised it into air and pulled it along, scattering its parts all over the village. Flying over a tractor station, the ball lightning crushed a frame, welded of metal angles and covered with tarpaulin. On the approaching of the ball lightning to another frame, it was at first dragged along the ground, and after the ball lightning had passed it, the frame was lifted and carried at a distance of 300 meters. The weight of the frame was no less than 100 kg".

Further the author analyzes the situation from point of view of the known physical laws: "The frame of hundreds kilograms weight was carried by fields of the flying ball lightning. However, for some reason the ball lightning kept on flying straight and did not note that some metal frame was caught to it. If the ball lightning, as it is usually considered, has a density of air and it is a weightless formation, then why the frame with the weight not less than 100 kg could not change its flight trajectory even in some extent?"

It draws attention that in some cases the ball lightning field pushed objects away, and in other cases it attracted them. It can be explained only by fact that in each case the ball lightning field specifically influenced on internal properties of objects, and then objects themselves somehow reacted on their new state (they changed their motion) . The feedback absence (in other way it happens between magnet and iron object) allows the ball lightning not react upon the things, which take place in its field. If these objects themselves became sources of similar field, i.e. reradiated it, they would influence on the ball lightning trajectory. **Most likely, in the given case, there was realized the situation when action caused no reaction.**

Conclusions

In the context of known physical laws the particular problem of direct action without feedback was formulated and solved. The solution of this problem provides deep understanding of how to control weight characteristics of material objects in open systems. As it was shown by the example with water (which is only an illustration of more fundamental processes) we can "deceive" the nature, but only through the deep understanding of the processual character of the concerned events.

By the example of ultrasound we show, that in principle there can exist such field flows, which are able to influence on bodies without the feedback effect. There were defined some conditions and criteria of bodies and methods of influence, at which the third Newton law is not directly valid (it is not published in this article).

The described type of influence can be called as pressure. But during consideration of processes at atomic or deeper level, i.e. from the position of rhythmodynamics, we find out something of another kind, that is phase-frequency one. It prompts to us, what kind of technologies will exist and how our aircrafts will look in nearest future. But not everyone is able to understand it at once.

Moscow 15.05.2002

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Comment

In the gravitation field we have a balanced open system, in which appearance of the new body at first sight must cause this system reaction such as weight increase. However, this is not the case.

The given problem is solved in two independent steps:

1) examination of interaction between water source and water (reactive effect, which is compensated by counter flow);

2) examination of interaction between water, detached from the source, and the body (unit time impulse per unit area).

It is impossible to examine the interaction between the source and the body because water has no rigidity. There are no means to influence on the source through the intermediate stream, therefore the principle of action and reaction is valid for each step individually, but not for both! But in this case the third Newton law must be developed as following: "If there is a 100% feedback between two bodies, their interactions are equal and inversely directed. And if there is no feedback, the action of one body to another causes no reaction, i.e. the action is not equal to reaction". And this is already another law!

New Possibilities of Vortex Electric Power Devices

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The earlier published article [1] was devoted to the explanation of the excess energy output at the rotation of flow medium in vortex tube (VT). The researches on VT demonstrated by the real examples that the excess energy output is a real fact, which is determined by natural physical processes. These processes take place in the fluid at its vortex (rotational) motion in the closed volume by means of phase transformations (skips) of the fluid state. However, the practice shows that for obtaining of patents and benefits for the real vortex devices, which are made for heat generation, it is necessary to write a little about their real technical characteristics, though technical and constructive possibilities of vortex devices can be much better. Temperature of water of these devices could not be higher than 120°C, and value of fluid pressure is confined within 5…6 kg/cm^2. Circulation pumps of pressure over 6 kg/cm^2 are used to increase thermal power output of vortex heat generators (VHG). It causes the discredit of VHG since at such a method their generative possibilities reduces to 100% value and less! We set a problem to discover the ways and engineering solutions for the essential increase of the coefficient of VHG energy conversion to not less than 200% value.

Our experience in development and exploitation of deep-sea physical devices has given some engineering solutions in this way. Actually, we have the opportunity to use the generally applicable circulation pumps, which have pressure not more than 4.0 kg/sm^2. At the same time we can raise the temperature of the heat carrier to 300°C and higher! and the pressure can be increased to 1000kg/sm^2! Such fluid parameters allow to use this fluid as a heat carrier in powerful hot-water generators of steam engines, turbines etc. By the way, this method allows to make the value of temperature of water enough to supply its PYROLESIS! The main point of the method is the following: all the closed system of water-filled VHG works at pressure with the value under 1000kg/sm^2. It is provided by means of the special device, the so-called automatic pneumohydraulic block (APHB). This lets to raise the temperature of working fluid to 1000°C with no change in its aggregative state. The practical functional scheme of such a device is shown in Fig.1.

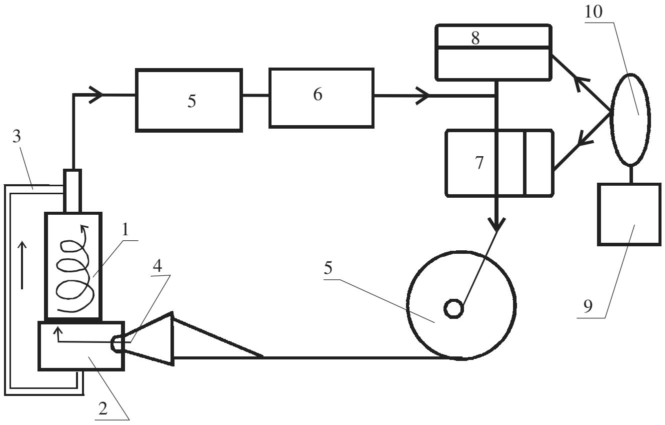

Fig. 1

1 – vortex tube; 2 – entry vortex chamber; 3 – by-pass; 4 – upstream end; 5 – circulation pump; 6 – heat-exchangers; 7 – APHB; 8 – volume of fluid leakage compensation; 9 - compressed-air flask; 10 - gas pressure regulator

The device works in the following way. The whole device is filled with working fluid without entrapped gas. At the operation of the circulation pump (5), fluid through the upstream end (4), placing in the entry vortex chamber (2), swirls, accelerates and gets into the vortex tube (1), where its “energy saturation” is realized. Then heated fluid gets into the heat-exchangers (6) for heating or for other purposes. After passing through the heat-exchangers, fluid gets into the pneumohydraulic device (7), where there is kept up the proper level of fluid pressure in the whole system. To prevent the system breakdown at the accidental fluid leakage, there is a device (8), which compensates such leakages. Compressed-air flask (9), with the volume under 1000kg/cm^2, and gas pressure regulator (10) keep up the selected level of the pressure in the system. The use of blocks (7,8,9,10) excludes evaporation in the system and prevents the breakdown of the circulation pump (5).

This VHG scheme allows to double the effectiveness of YUSMAR devices [2] only at the expense of rise in working fluid temperature in 2…3 times.

Observation of any fluid swirls and film documents of windspouts arrive to conclusion that all vortex structures are rotation bodies, created by the lines of the second order: $Y=aX^2$. In other words, as a result of the rotation in the swirl, air or fluid mass gets the acceleration of the second order. Taking into account the aforesaid, it is evident that in order to form the classical swirl in the VT, the very VT should be a tubular body of rotation. This body is created by the curve (see below Fig.2).

In YUSMAR and similar devices the vortex fluid motion take place in straight cylinder and 1/3 of this area is used for fluid deceleration that causes vortex flew disruption. This results in the impossibility to increase additional heat in the straight tube in more than 1.54 times. It is caused by the fact that the main vortex formation takes place only in the vortex chamber and the flows separation does in the tube itself. Then, this vortex formation is right away disrupted by different plate brakes! It suggests itself that output part of VT should be made in the spiral form, expanding at the flow passage.

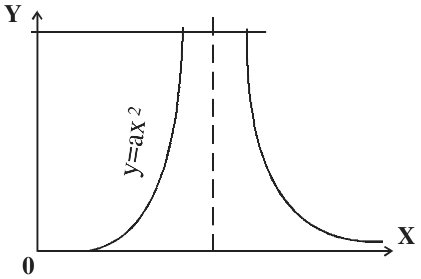

Fig. 2
Generatrix of the wall of vortex tube

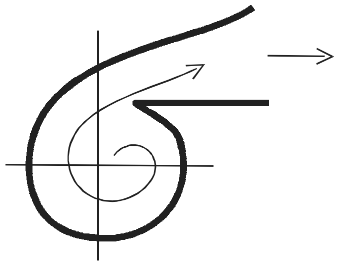

Fig. 3
Upper part of the tube

Such section, made on the outlet of the vortex tube, helps to slow down the flow avoiding its disruption, since axial-cold flow, placed along the tube axis, should stay intact. Two of such engineering solutions allow raising the level of the additional VHG energy up to 180…200%.

YSMAR devices are designed for one tube with the assigned heat output. However, if to take into consideration and to use the aforesaid conclusions, then we can raise energy conversion coefficient (ECC) above 200% at the series connection of two and more VT. The scheme of such a device is shown in Fig. 4.

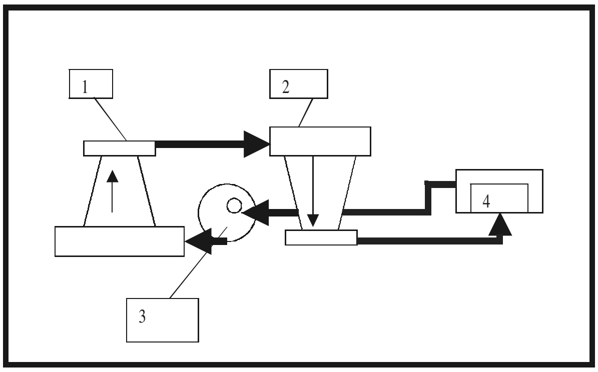

Fig. 4

Where: 1 – the first VT; 2 – the second VT; 3 – circulation pump; 4 – heat exchanger

According to Fig.4, the total energy output of the presented device is:

$$Q=K^2$$

Where: *Q* is the total output of the device; *K* is energy conversion coefficient of one VT; 2 – quantity of serially connected VT; *P* – the assigned power of the circulation pump.

In our earlier article [1], concerning VT application, we supposed that there is a straight transformation of vortex motion of ionized fluid into electric current. Under studying of many articles, devoted to the methods of water ionization, we discovered a significant one. It demonstrates that at the determined temperature, pure water increases its ionization capacity up to 3 orders without changing in the aggregative state [3]. The diagram in Fig.5 shows such dependence.

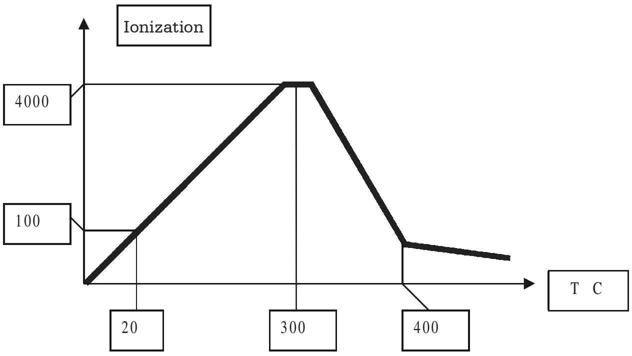

Fig.5
Diagram of the dependence of pure water ionization from temperature

The diagram demonstrates that water at 300°C temperature increase the quantity of ions in 4000 times as compared to 0°C and in 40 times as compared to 20°C. If to take into consideration that first experiments on VHG modernization help us to find the ways of fluid heating up to the practically any temperature without changing of its phase state, then on using the dependences (see Fig.5) it seems possible to create vortex fluid electric generators of the forward transformation. The aforesaid pneumohydraulic block, which is used for VHG functioning, allows to keep up water temperature at 300°C and pressure at about 90kg/cm^2 without threat of water evaporation! Presence of any rotation of fluid medium always causes appearance of two vortex flows. **These flows always move and rotate in opposite directions and if we do not put obstacles for their motion then they transform into each other and can exist without energy supply for an indefinite period of time.**

The presented VT form (see Fig.6) provides the producing of two fluid flows in the tube. These flows do not influence to each other and there is only their reciprocal overflow without disruption of the flows in the central part of VT. The tube presents a tubular body of rotation, which is created by hyperbola. There is positive angular acceleration of fluid in the lower part of the tube; maximum speed of rotation of the axial and peripheral flows is in the middle part and negative angular acceleration, i.e. deceleration and transfer of kinetic energy into heat energy, is in the upper part of VT.

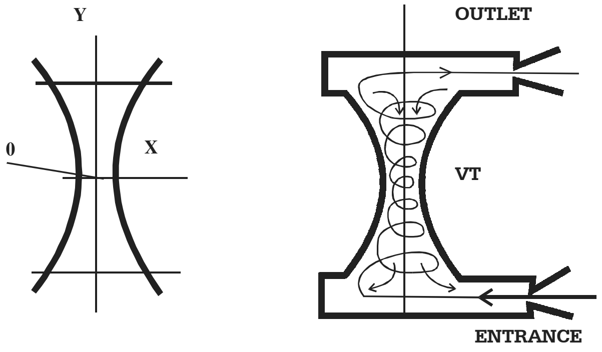

Fig.6

The maximum heating of fluid and its polarization is in the point Y=0. The polarization potential in the point can reach 10.000 V at 5m/sec flow speed for 10 cm diameter in the point. The cold flow, which comes along VT axis, is opposite to the peripheral hot flow. These flows close into one system in lower and upper chambers of VT. Thus, the presented VT classically modeled "rolling" and "unrolling" of water area.

There are no single vortexes in nature. Two vortexes, rotating in opposite directions, always appear while fluid mediums rotation! Science is not still able to describe energy overflows from one vortex center to the center of another one by means of mathematics. However we believe that this moment is close. There are maximum energy transformations of rotating water in the point Y=0.

The potential of the inner flow is equal to the outer flow by its value but is opposite by its sign. Potential difference is maximum in the point Y=0, in which removal of electric charges is the most effective.

It is appropriate mention here the name of Romanian engineer and researcher Henry Koanda, who in 20th of the last century discovered the so-called "Koanda effect" (attachment of fluid jet to the surface of usual kettle at pouring of it out the cups). Basing on this effect he suggested to make new type of aircrafts, which could have advanced bearing capacity and maneuverability. Unfortunately, money and conservatism of aircraft-industrialists did not allow realization of these engineering solutions.

At the same time, Koanda charged his disciple Patrick Flanagan with the job to research all **water properties**. The result was amazing! It was turned out that water actually has infinitely many phase states and when it is moving, then it can trap energy from the environment by some way. The publications on the point appeared in our press in the early eighties, late nineties of the last century. Most likely, they had become the basis of the invention, made by Potapov, i.e. vortex tubes for water!

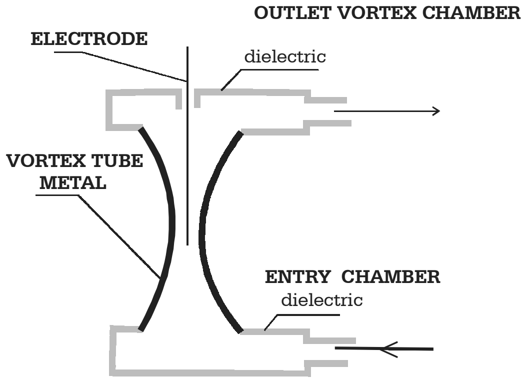

Fig.7
Scheme of vortex electric generator

In the presented scheme of electric generator the entry and outlet vortex chambers are made of dielectric material in the spiral form. This material certainly should withstand not less then 300°C of fluid temperature and about 100kg/sm^2 of pressure. Fluoroplastic or ceramic can be used as such a material.

From aforesaid it seems to be possible to submit the new scheme of electric generator for readers' consideration (see Fig.8).

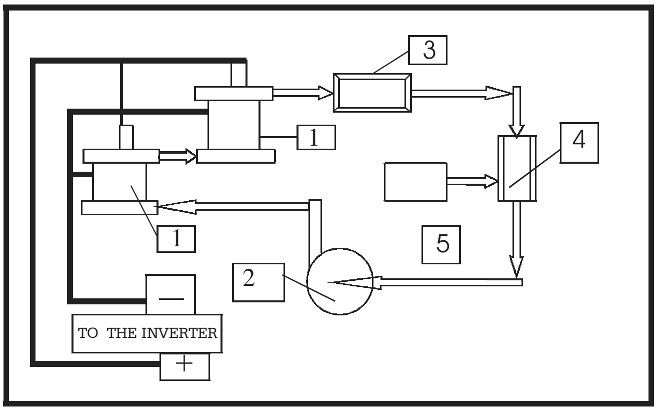

Fig.8
Generalized scheme of vortex electric generator
1 – vortex tubes; 2 – circulation pump; 3 – heat exchanger; 4 – automatic pneumohydraulic block; 5 - compressed-air flask

Actually we could finish the article if it were no disputes about excess energy, which is released at vortex motion of fluid in tubes. Having used a simple experiment, which any inquisitive person can repeat, we found the positive solution (see the scheme of the experiment in Fig. 9).

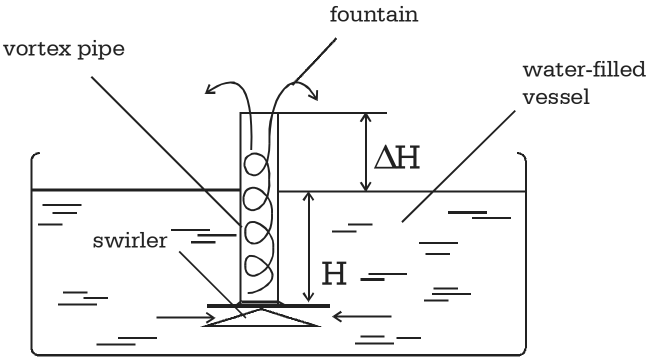

Fig.9
Demonstration of energy increase of fluid, rotating in vortex tube

A pipe with not less than 60 cm length and about 1-inch diameter is placed in a reservoir with not less than 50 cm depth. The lower part of the pipe is formed as an arm circular generator with about 15...17cm diameter. The gap width is about 2 cm. If we place the pipe with closed top end, which then will be open, into the reservoir, then water is splashed out above 20 cm of the reservoir level. Thus at the least 20% energy increase of energy mgH is observed.

By the way, we suggest orthodoxies of physics and other who have doubts to make one more simple experiment. Try to boil water in a can. When water starts to boil, swirl it with a spoon to the right or to the left. Then you will suddenly discover that all water surface is calm and only in the center of the can there is a water-steam mixture, which is about 20% higher than the level of water surface. You will also see that water is absolutely calm at walls of the can. This experiment can be reproduced anytime and anywhere, even in space, since it is a demonstration of **vortex** fluid motion and its actual influence on everything, which is around!

All presented engineering solutions are practically reproducible in any laboratory. The authors of the article would welcome the opportunity to co-operate with science and industry representatives for realization of the ideas in real serial production devices.

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2. Patent RF #2045715, 1993
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Investigation of Electric Energy Transmission Processes in non-Metallic Conducting Channels

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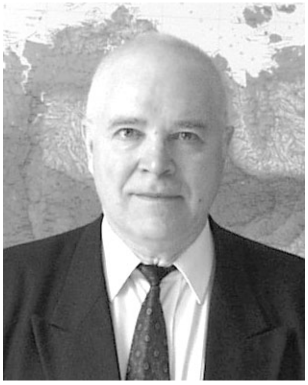

D.S. Strebkov

(Editor's notes by Alexander V. Frolov)

It has been found that at low frequency (1-25 kHz and higher) electric power can be transmitted with low losses from generator to receiver along single channel made of non-metallic conductive media such as water in plastic tube carbon thread, layer of damp soil, ITO films on glass substrate, laser and electronic beams. Transmitted power, as well as for traditional three phase lines, is limited by natural power of the transmission line and line capacity may reach at high voltage and pulse and operation modes the value 10^9 Wtt.

Introduction

The well-known methods of electric power transmission are based on transmission of active energy by means of conductivity currents in closed circuit. Electromagnetic energy spreads along power transmission lines (PTL) as progressing waves of electromagnetic field or field of charge [1]. Line wires made of aluminum or copper are conductive (guide) channels. Electromagnetic energy stream moves along these channels from generator to energy receiver and backwards to the generator. Maximum transmission possibility of 3-phase PTLs is limited by losses on the line resistance, by peak voltage (which is determined by electric strength of the insulation) and by electromagnetic stability of the line.

The modern approach to provide the electromagnetic stability consists in rigid regulation of line parameters by means of high-speed shunt reactor and consequence capacitive compensation for the purpose to except changes of electromagnetic power flows and to suppress resonant properties of a line [2].

In Tesla works [3] and in the researches of Russian scientists [4] a method of active power transfer was offered. This method supposes to transfer active power by means of electromagnetic capacitive current assisting with resonant properties of a single-wire line (SWL), made of a metal conductor. The purpose of the present work is a research of an opportunity to use non-metal conducting mediums for transmission of electric energy.

A pipe with not less than 60 cm length and about 1-inch diameter is placed in a reservoir with not less than 50 cm depth. The lower part of the pipe is formed as an arm circular generator with about 15...17cm diameter. The gap width is about 2 cm. If we place the pipe with closed top end, which then will be open, into the reservoir, then water is splashed out above 20 cm of the reservoir level. Thus at the least 20% energy increase of energy mgH is observed.

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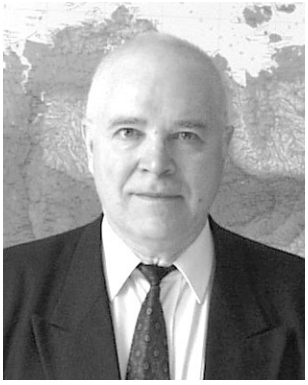

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Methods

For realization of the experiments a single-wire energy system (SWES) was used. Its electric circuit is shown in Fig. 1 a,b. SWES consists of the following parts: high-frequency generator (1) of 28V voltage AC and 1 kWtt power; transmitting (2) and receiving (3) Tesla transformer with conductive channel (4) between them; rectifier (5) and electric load (7) as an incandescent lamp or electric motor (220V, 1 kWtt power). High-voltage winding of Tesla transformer is made in the form of cylindrical winding on the ferrite core with 50-100mm in diameter, 4000-6000 turns. The internal end of a high-voltage winding is connected to the conducting channel, and the external end is not connected at all (free end). A low-voltage winding that consists of 40-60 turns provides power supply of Tesla transformer. At the submission of electric power from the high-frequency generator to the winding of power supply zero potential appears on the free end of the high-voltage winding, and voltage with corresponding to the generator 1-25 kHz frequency is formed on the conducting channel. Besides, Tesla transformer as the spiral antenna generates electromagnetic waves of 5-10 cm length , which corresponds to the turn length of a high-voltage winding. Current resonance mode is formed in a supply circuit of Tesla transformer. At the same time, voltage resonance mode (of frequency equal to the generator frequency) is formed both in the reception and transmitting circuit of high-voltage windings and in the conducting channel (1).

The following materials were used as the conducting channels: filled with water or sea water polythene tubes with 10 mm diameter and 1,5 m long; plastic tray with soil layer of 150×10×400mm; film of tin dioxide – indium oxide (ITO) on 0,3 micrometer thick and 300 Ohm resistant glass substrate; graphite thread of 0,1 mm diameter, 500 mm long and with 100 Ohm resistance. For comparison steel and copper wire of 0,1 mm diameter and 5 m long was used also.

The voltage on the conducting channel changed in limits 1-10 kV, generator frequency changed from 1 up to 25 kHz. Voltage, current and capacity were measured on SWES output and on the load by standard electric measurement equipment.

Results and discussion

The replacement of the metal conductive channel to the channel made of non-metallic conductive materials does not effect to any reduction of possibilities of transmitting SWES or heating of a material of conducting channels. The consecutive connection of the channels did not resulted in reduction of transmitted power. Circuits break in the conducting water channel by the creation of an air gap led to the occurrence of arc discharge of reactive capacitor current. However this discharge did not cause increase of water temperature at transmitted power 300 Wtt and voltage 4,5 kV within 1 hour, that confirms the absence of energy losses in the conducting channel. The increase of water temperature did not result in decrease of transmitted power. Water PH reduction from neutral value up to 4 was detected.

The increase of sea salt concentration in water up to the level of 5-7 g/l did not increase transmitted power in comparison with tap water. However the replacement of tap water to dionized water with 16 MOhm resistances resulted in 100 % decrease of transmitted power.

Thus, it is experimentally shown, that conducting channels, produced from non-metal materials, have quasisuper-conductive properties in SWES at resonant mode. Possible explanation of this effect is the absence of active conduction current in the channel and the dominant role in the process of energy transfer belongs to displacement current, for which Joule Lentz law is not valid [11]. In the supply circuit of Tesla transformer current is practically reactive, and in resonance conditions active values of inductive and capacitive currents are equal. Vectors of these currents are opposite in their phases. Current of the high-frequency converter is spent for losses (component less than 2 %) in supply circuit wires and in the core of Tesla transformer and also for creation of reactive current in the conducting channel. In the mode of voltage resonance we have measured voltage active values of high-voltage inductance windings and conducting channel, interturn capacitance of windings and the capacities of the conducting channel. **We have discovered that they were equal and their phases were opposite to each other.** Losses from transmission of capacitive current through active resistance of the conducting channel are insignificantly small. Corona discharged losses and leakage current could be decreased by isolation of conducting channel. In this case active current and magnetic field of the line are equal to zero. Electric field of the line has maximum value. As well as in usual PTLs, maximum transferred power is limited by charge power of the line. Angle between vectors of voltage is equal to zero in the beginning and at the end of a line. Quality factor of SWES at frequency 5 kHz is in 100 times above than usual PTLs at frequency 50 kHz. In the conditions of resonance it leads to the significant increase of voltage along the conducting channel and it also leads to transmission power.

In usual PTLs voltage changes along the line are insignificant. The angle between vectors of voltage in the beginning and in the end of PTL constitutes the value, which is proportional to the wavelength of line.

On the basis of the researches the methods and devices are offered for transmission of electrical energy through plastic water guide, electro-insulated from ground, through irrigational channels and through isolated pipelines, which are used for gas, oil, hot and cold water transportation. Also the energy can be transferred through fiber-optic cable with conducting film on the surface, through all-carbon composite cable and through electro-insulated part of a ground and water surface, including highway parts. There are also methods and devices, designed for the following transmissions. These methods can be applied for transfer of power to stationary and mobile units. There are also generated requirements to electrical safety and to restriction of use of drinking and hot water from pipelines, which are under electrical voltage. These requirements and restrictions are generally the grounding of pipeline parts, which are located on certain distance from the generator. This distance is equal to the whole number of half-waves and for it SWES voltage is equal to zero. In the case of a side pipeline it is necessary to ground the parts of the pipeline that are placed on the distance of odd number of quarter-wavelength from the main pipeline. For 5kHz frequency the quarter-wavelength is equal to 15000 m.

N. Tesla grounded one end of high-voltage windings of his transformer on the receiving and on the transmitting end of SWES. Tesla considered this condition as the necessary one for the transfer of power along the Earth. The results of our researchers demonstrate that it is not necessary to use metal self-closed conductor (and current lines in the Earth) for transmission of electric energy on low frequency (1-25 kHz).

For this frequency energy could be transferred from the generator to the receiver if we have single-wire guide system created as non-metal conducting channel. By the similar way electromagnetic energy is transferred by laser beam or microwave-beam. But in our case we can obtain high degree of efficiency that is caused by slight losses on energy absorption and energy emanation. Thus one of the ends of high-voltage winding at the energy generator will have zero potential and remain free. The symmetric end of a high-voltage winding on the reception end should be connected to some natural capacity 6 (Fig. a), which can represent the case of a balloon or frame of a tractor. In our experiments we used metallic safe-box as such natural capacity.

Editor's note: In 1887, October 11, the famous Russian scientist Pavel Yablotchkov got the France Patent #120684, which described the method to increase efficiency of electrical circuit by means of "atmosphere electricity". It was confirmed in many experiments that output power can be twice more than power provided for the circuit from primary electric generator. For that it is necessary to use a single-plate capacitor. The special feature by Yablotchkov, that provides maximum efficiency, is the high degree of air ionization. For this Yablotchkov proposed to use the special capacitor, which consists of a big number of metallic needles. By its view this construction reminds of a hedgehog. Thus we can assumed; that above described natural capacity (balloon or frame of a tractor) serves as a collector of free electrons. By Yablotchkov the efficiency of such systems can be increased by means of maximization of ionization process. It will not lead to the increase of losses if the second end of the high-voltage winding is not grounded.

In the other method of energy transfer, a condenser-diode block 8 was connected to the conducting channel on the receiver end. This block is one of the known circuit of voltage doubling, Fig.1 (b). On the condenser 8 electric energy is transferred through electronic switch 9 to load 7. In this case the entire length of conducting channel 4 and Tesla transformer winding 2 at generator must be equal to odd number of quarter wave-lengths.

Non-metal conducting channel (for instance, fiber-optic or coal-plastic cable) can be used for transfer of electric energy not only along but also as perpendicular to the Earth (for example, to relay aerostat or sounding balloon).

SWES conducting channel can be also created by ionization of air ions with laser beam [13]. Neodymium laser with double frequency and with energy 1 Joule in impulse is able to create 10^{15} cm^{-3} ion concentration in air. This concentration is sufficient for streamer initiation and for transfer of electric energy through the conducting channel. Ionization potential, time of ion existence and of excited molecule state, coefficient of multiquantum absorption, all these determine the limiting length of conducting channel in atmosphere that is equal to 300 km and its wave resistance at 200-400 Ohm. Voltage which is necessary for SWES comes to the quantity 0,5 MV – 15 MV, that depends on the length of a channel.

We suggest to use relativistic electron bunches of high energy as the conducting channel out of the atmosphere. As distinct from laser bunches they do not have divergency. In this connection the Moon or artificial conducting body, where the energy receiver is placed, can be used as natural capacity 6. Whereas energy generator can be installed on the Earth or on its satellite. Transmission range of electric energy is determined by the length of the generated conducting channel. The entire length of the conducting channel in the beginning and in the end must be equal to the whole number of half-waves. Here the length of high-voltage windings of two Tesla transformers must be taken in considerations. Electric energy, transmitting through the conducting channel, can exceed the energy of electron and laser beams generators in 10-100 thousand times. These generators play the role of a directing system (of usual SWEG wires), along which the transfer of electric energy proceeds.

It was offered to use colliding and crossing electron and laser beams with conducting transitional bodies as conducting channels for transfer of energy from the Space to the Earth and back. On the heights up to 30 km compositional coaly and fiber-optic cables can be used. To create the global energy system of the Earth it was also suggested to apply single-wire energy system and conducting layers of the Earth ionosphere as the conducting spherical channel [14].

Thus for electric energy transfer at the frequency 1-25 kHz and higher in the resonance mode a single-wire channel from the following non-metal conducting mediums can be used: water, damp soil, coal-plastic, oxide film, ionized air channels, that are created by laser beams in the atmosphere, ionosphere conducting layers, and also beams of relativistic electrons out of the atmosphere. These non-metal conducting channels in the resonance mode have negligibly small resistance losses especially if to be compared with metal conductors, which are used in the known non-resonance methods of energy transfer by means of active conduction currents in the closed circuit. Electric energy in the resonance mode can be transferred with small losses from the generator to the receiver along the single-wire channel, made of non-metal conducting materials. The transfer can be realized at the frequency 1-25 kHz and higher, to any distance and to any direction relatively to the Earth. The transmission capacity is limited by charge power of a line as well as in the usual PTL. At high voltage the transmission capacity can reach the quantity from 10 Wtt to 10^9 Wtt in the pulse and streaming modes.

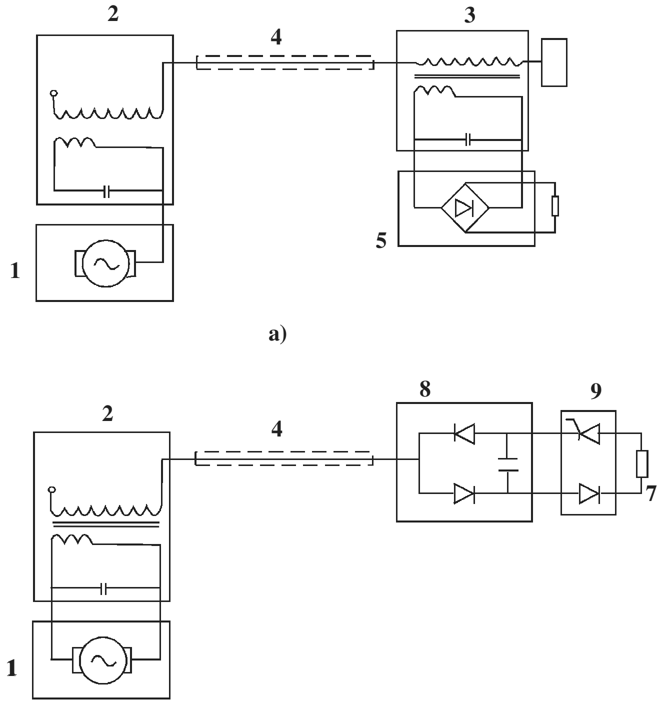

Fig. 1
Electric circuit of single-wire energetic system with non-metal conducting channel
a) SWES with symmetric array of Tesla generators

b) SWES with diode-capacitor block in the end of conducting channel

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Microcosm, Universe, Life

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The authors of this article have prepared the 3rd edition of the book "Microcosm, Universe, Life" and now they are looking for a publisher to edit Russian and English version. In particular, the mechanism of energy transformation in the Universe (Fig.1) is described in the book. Matter radiates energy in the form of photons (as well as neutrinos). In general this energy is observed in the form of Cosmic Microwave Background Radiation (CMBR). Photons and neutrinos transfer the most of energy to de Broglie longitudinal photons. Matter absorbs energy mainly in the form of longitudinal photons. Thus, a cycling process of energy transformation (as well as matter transformation) occurs in the Stable Universe.

The 3rd edition is devoted to the description of 6 World Systems (Table 1), at that the 6th System is based on Unified Field Theory, which is developed by the authors, and proceeds from the following:

(Editor's: The understanding of the energy transformation mechanism allows to develop new fuel-less energy sources based of mutual transformations: longitudinal photons⟷transverse photons).

Table 1

System	Principal Ideas
The 1st – Geocentric (Ptolemaic system)	Geocentrism and Anthropocentrism
The 2nd – Classic (Copernicus – Newton's system)	Description of the Universe on basis of Newton's Law of Gravity
The 3rd – Compromise (Tycho Brahe's system)	The compromises between two first systems
The 4th – Fractal (Charlie's system)	Non-heterogeneity of Large-Scale distribution of matter in the Universe
The 5th – Relativistic (Einsteinian system)	Description of the Universe on basis of gravitational field equations. Anthrop principle
The 6th – based on Unified Field Theory	Electromagnetic nature of all physical interactions. Irreversibility of all elementary micro-processes in combination with circular character of transformations in Large Scale of space ($c/H=R$ order) and time ($t_H=I/H$ order).

1. For theoretical results, which agree with the facts, it is necessary to use assigned inertial system (as Lorentz did), which, as we have known, is connected with CMBR. Obtained by this way decisions can be applied to the other systems, in particular, with use of Lorentz transformation for mass, energy, momentum, time and length.

2. Theory must agree with the whole known collection of facts, starting with such established empirical generalizations as basic principles of Natural science (Giordano Bruno, Lyell) and conservation laws (Mayer, Joule, Helmholtz, Faraday, Newton, Huygens, Vernadsky).

3. All physical objects could be presented as the systems, consisting of quanta of positive electric charge (protons), quanta of negative electric charge (electrons in fermions or boson states, which are part of neutrons

and atomic nuclei) and quanta of energy, impulse, moment of momentum (apeirons).

4. The leading role in the Universe energetic belongs to de Broglie longitudinal photons (of the first class, i.e. with the spin I=0), energy of which is twice as much as apeiron energy and is equal to *h H*, where *h* – is Plank's constant, *H* – is Hubble's constant.

5. Longitudinal photons, polarizable and depolarizable by matter particles, are the carriers of gravitational, magnetostatic and strong interaction. Electromagnetic interaction is carried by photons with spin I=±1 and weak interaction is carried by neutrinos and apeirons with spin I=±0.5.

6. All elementary microprocesses are irreversible, that correlates with circular character of transformations in Large Scale of space and time.

7. In particular, there is an irreversibility of the process of photons and neutrinos motion. At each segment, equal to the length of de Broglie wave, photons and neutrinos lose energy *h H*, which is equal to longitudinal photon energy. In such a way, Hubble's law can be presented as the following:

$$\lambda = \lambda_1 \exp\left(\frac{r}{R}\right) = \lambda_1 \exp(Ht),$$

$$Z = \frac{\lambda}{\lambda_1} - 1 = \exp\left(\frac{r}{R}\right) - 1 = \exp(Ht) - 1,$$

where λ, λ_1 – are observable and laboratory wave lengths, *r* – is distance, *R* – is radius of gravitation interaction, which is equal to the radius of Metagalaxy, *t* – is time, *Z* – is cosmological red shift.

8. As resulted upon this process, the excess of longitudinal photons is absorbed by matter. At that, mass is considered as measure of capacity, which is absorbed by matter in form of longitudinal photons. Thus, energy of the matter should be increased according to the law:

$$E(t) = m_\circ c^2 \exp\left(\frac{\varepsilon'}{c^2} t\right) \approx m_\circ c^2 + m_\circ \varepsilon' t,$$

at that,

$$\frac{\varepsilon'}{c^2} = \frac{H}{137^2},$$

where ε'- is the capacity, which is absorbed by unit mass in form of longitudinal photons, *c* – is velocity of light. In particular, electron of the 1st Bohr orbit in hydrogen atom (i.e. in this case at de Broglie wave length) absorbs energy *h H* at 1 period.

9. Being in ionization state, intergalactic matter is the general portion of average density of matter in the Universe ρ_{av}, besides, the average value of absolute velocity of baryon component is close to c/137. Let's consider this correlation to be exactly executed.

CMBR is the most powerful cosmic radiation. Its specter is close to that one of black body at temperature T_F=2.726K, i.e. its spectral density is maximal at frequency ν=160GHz. Cosmological red shift causes the increase of spectral density in radio-region (ν<160GHz) and the decrease of it in microwave region (ν>160GHz). Each of these processes is compensated by the inverse Compton effect, i.e. by the dispersion of radio-photons at matter corpuscle, first of all at protons. Calculations demonstrate, that average energy of absorbent radio-photons is equal to $0.45\cdot10^{-15}$erg (ν=68GHz) and average energy of radiated microwave photons is equal to $2.17\cdot10^{-15}$erg (ν=330GHz). There is one re-radiated microwave photon per one absorbed radio-photon. At that, the concentration of photons and CMBR spectrum remain unchangeable. Syunyaev and Zeldovich concerned the close inverse Compton-effect of CMBR dispersion on electrons in clusters of galaxies. Actually such an effect was discovered in 2 clusters of galaxies.

Thus, on transferring of energy to photons, matter corpuscles must fill the deficiency of energy by receiving it from longitudinal photons. In fact, there are observed demonstrations of longitudinal photons, they are "static fields". In this case it is a cosmic magnetic field, which accelerates charged particles of matter (Alfven). More detailed consideration let us to find a virial correlation between 4 main components of energy density:

$$\frac{\rho_{av} c^2}{137^2} = E_F = 2E_M = 2E_{kin},$$

where $r_{av}c^2$- is an energy equivalent of mass density of matter; E_F- is energy density of CMBR; E_M - is average energy density of magnetic field; E_{kin} - is average density of kinetic energy. Thus, some kinds of energy circularly transfer to another, which are interrelated (Fig. 1).

$$\frac{\varepsilon_{av}\rho_{av}V}{1.26} = E_F HV = 2E_M HV = 2E_{kin} HV = \\ = \frac{(\varepsilon_{av} - \varepsilon')\rho_{av}V}{0.26} = \varepsilon'\rho_{av}V,$$

where ε_{av} - is average capacity, radiated by unit mass in form of photons; *V* – is volume of 10^{81} cm^3 order, according to which the averaging is made.

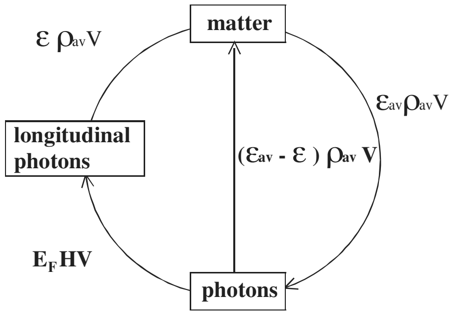
matter
$\varepsilon\,\rho_{av}V$
$\varepsilon_{av}\rho_{av}V$
longitudinal photons
$(\varepsilon_{av} - \varepsilon)\,\rho_{av}V$
$E_F HV$
photons

Fig.1
Energy transformation in Large Scale ε_{av}=0.0942 erg gr^{-1}sec^{-1} – is average energy, which matter unit radiates in unit time; ε'=0.07476 erg gr^{-1}sec^{-1} – is energy, which matter unit absorbs in form of de Broglie longitudinal photons in unit time; ρ_{av}=$0.8730\cdot10^{-29}$ gr cm^{-3} – is average matter density in the Universe; E_F=$4.18\cdot10^{-13}$ erg cm^{-3} – is energy density of cosmic microwave background radiation (CMBR); $V\approx10^{81}$cm^{-3} –is volume at which the averaging is made; *H*=$1.562\cdot10^{-18}$ Hertz.

10. These correlations include pressures, densities and temperature T_F, i.e. we have the equation of the state of intergalactic matter, and thus of Metagalaxy and the Universe. Let us present this equation in simple form:

$$E_F = \frac{\varepsilon' \rho_{av} R}{c} \approx \frac{\varepsilon_{av} \rho_{av} R}{c}$$

and let us compare it with correlation for density of radiant energy on surface of a star * or of star system

$$E_* = \frac{\varepsilon_* \rho_* R_*}{3c} \approx \frac{\varepsilon_* \rho_* R_*}{c}.$$

It is an especially amazing analogy between Metagalaxy (and the Universe) and large-scale cosmic system *g,* for which

$$E_g \approx \frac{\varepsilon_g \rho_g R_g}{c},$$

at that $E_g \approx E_F,\ \varepsilon_g \approx \varepsilon_{av} \approx \varepsilon'.$

This equation agrees with the whole observed data of globular clusters, galaxies, groups and clusters of galaxies, in particular, with empirical correlations, which are magnitude - angular diameter.

11. The stated approach lets to determine the values of many fundamental constants by different ways. As a case in point, the results of definite values ε_{av} and ε', erg g^{-1} c^{-1} are presented in the Table 2.

Table 2

#	Data	ε_{av}	ε'
1.	The boarder between two parts of the Main Sequence of stars	of 0.1 order	of 0.1 order
2.	The results of recalculation of observed star characteristics as respects to their centers	of 0.1 order	of 0.1 order
3.	The local minimum of star luminosity function near the Sun (according to G.A. Starikova's data)	of 0.1 order	of 0.1 order
4.	The correlation: mass - luminosity of white dwarf stars	of 0.1 order	of 0.1 order
5.	The correlation: mass - luminosity of neutron stars	of 0.1 order	of 0.1 order
6.	The correlation: mass - luminosity of globular clusters	less than 0.5	less than 0.5
7.	The correlation: mass - lumonosity of elliptic galaxies	more than 0.06	more than 0.06
8.	The correlation: mass - luminosity of spiral galaxies and irregular galaxies *Ir I*	less than 0.5	less than 0.5
9.	The correlation: mass - luminosity of galaxies as a whole	of 0.1 order	of 0.1 order
10.	The correlation: mass – luminosity of clusters of galaxies	of 0.1 order	of 0.1 order
11.	Empiric values of H, ρ_{av}, E_F constants	of 0.1 order	of 0.1 order
12.	The most exact values of h, e, G, E_F constants	0.0942	0.07476

12. Uncontradictory description of Microcosm and the Universe promotes the better understanding of Life, which is inseparably unified with them. The statistical data manipulation of more than 100 catalogues of microphysics and cosmic objects let us to get more than 1000 empirical correlations and diagrams, and to determine, that they agree with theoretical correlations, which were received according to the ideas on circular character of energy transformations (Fig. 1) and of matter in the Universe.

The Russian edition of the book is mailed out: the 1st edition (1995) at the cost of $3; the 2nd edition (1998) at the cost of $6.

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HYPOTHESIS OF A THEORY OF EVERYTHING

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This work grew out of an interest in curious occurrences, physical, mathematical and metaphysical. Many things just do not fit normal knowledge or are of unknown origin. Items such as gravity, time, mathematical equations of higher order, ghosts, e.s.p., etc. After a number of years, the problem began to appear to be not of this physical dimension but of a grander scale. A multi-dimensional space-time format seems to offer solutions to understanding most of the problems. In the following hypothesis all known physics and mathematics are considered to be valid. Metaphysical aspects, while not accounted for by physics and mathematics, are considered to be present in nature, either real or as a defect in physical processes, simply because they are experienced by so many people. The hypothesis will be kept simple because the details require the work of many specialists beyond my abilities and there is an endless list of speculative problems to which the hypothesis could be applied. To save time and distractions to the reader the following is stated as fact, knowing full well it may not be so, in order to present the most concise statement of the hypothesis.

The Universe, from the smallest to largest unit, is a quantum probability based fractal illusion. All matter exists in three-dimensional space, both internal and external. Any grouping can be considered a fractal space. It is both real and imaginary at the same time acting according to Eulers equation:

$$(e\,^\wedge(i*Pi))+1=0$$

more useful in this instance is the general form:

$$e\,^\wedge ix = -1=\cos x + i \sin x = -\tan 45 \text{ deg}$$

which allows use of a variable where Pi , a constant, is used in the original. The key to understanding of multi-dimensional space time is the realization that Pi is a variable! As we know Pi is the lock on three-dimensional space. Because of its mathematical nature it can neither grow nor diminish, thereby locking in the three dimensional form of the fractal unit under consideration. Such a fractal unit is considered to be at rest. But Einstein's equation $E=mc^2$ includes speed or movement. When objects are moving relative to a fixed point, the moving object is foreshortened in the direction of movement. A circle becomes an ellipse and Pi becomes indeterminate letting the circumference fluctuate, according to its relative speed, between two and Pi in a circle of unit diameter. If one goes beyond the value Pi the Universe grows out of bounds without limit becoming unstable. If the value goes below two then the Universe blinks out. I.e., one has exceeded the value of the constant c. Since all matter moves relative to a fixed fractal point and there are infinitely many points in the Universe of constantly changing velocities, the Universe is constantly adjusting its reality to the relative speeds of its components. Thus you get at times some weird things. Since not only time changes but the structure and observable mass also, one finds such things a matter appearing and disappearing as the small units of chaos move through the Universe. Changes in the local probability structure cause matter or reality to change in the image structure of the Universe.

To delve further into the aspects of what is happening, let us consider the following. Einstein's familiar formula gives the relationships for our three-dimensional fractal space. The inverse of the formula gives the speed with which any fractal space can change, including the Universe. There is both a positive and negative component to the change. If we consider our fractal space to be positive then we may consider any other point to be negative. There are an infinite number of such points and while the effect on our space may be small from any one point; the effect adds up. Any moving or changing of mass must effect the entire Universe. Mass and inertia are tied together in such a system. Measured mass is the attempt of the mass to return to zero relative speed in its associated fractal space according to the laws of physics, i.e. return to its lowest energy state. Inertia is the same effect of the changing state of the mass from one-dimensional state to another. Both are the result of efforts to change the dimensional state of mass. The positive aspect of the square root of the ratio of energy/mass is the view we behold from our position in space while the negative is the view from the opposite position.

In addition to the view of the Universe as being made up as fractal space, all moving at different relative speeds to any other fractal space, one must consider the make up of space having at the same time dimensional space, according to Euler's formula given above. There are at any moment an infinite number of spatial dimensions, defined by the relative speed of the fractal units involved, extending throughout the Universe. Each fractal unit is constantly changing its position in dimensional space. There are thus constantly changing energy states throughout the Universe both in relative position in real space and in dimensional space. While on one hand the distances across the Universe are immense in relative space, many points across the Universe are present in the same dimension at the same moment, possibly allowing for instance travel across space without the time penalty. This results in what might be considered a tuned circuit for the Universe or its components.

If we consider the structure of the relative Universe to be stored energy analogous to magnetic fields and the dimensional fields to be capacitive, then we can plot the results on a conventional two-dimensional chart where x is the horizontal axis and the vertical is the imaginary axis. A well-known construction in electrical physics and which is known to very often follow relativity closely. That throws the negative side of i into the second quadrant and the positive into the fourth quadrant, if we consider the Universe to be reflective and x to be negative when i is positive. Euler's equation does not reflect a totally positive or negative result. One wonders at this point as to other equations where unity is set to one or higher dimensional equations where the three dimensional components are factored out leaving another component. The fourth is considered to be time but how do the remaining fit into a Universe as this hypothesis describes? The line of thought can be followed further into electrical analogy, which I leave to the reader. The important result is that there should be a resultant Q, figure of merit, of the Universe resulting in nodes, or peaks, of probability. The resultant tuned frequencies of the Universe can be calculated from known factors of the Universe. Such an effect should show nodes of reality where matter occurs.

Properly applied the above hypothesis gives speculative answers to most of the problems facing science today. Questions such as:

Is the Universe open or closed?

Both. At each fractal component of the Universe there is a separate universe each reaching limits beyond which it cannot exist. At the same time there is somewhere a top Universe that must ever remain open.

What is the structure of time?

Time results from the ever changing fractal Universe and goes forward because all justification of the Universe causes a corresponding change in reality. Time moves slower at higher relative speeds and as all time is perceived to be slower in other fractal units, changes in our time are perceived to always go forward.

What are such phenomena as ghosts, spirits, apparitions, etc?

Events such as these are fragments of probability left behind due to sudden changes in the probability of the illusion we perceive to be reality. Having little energy they are perceived but are not able to interact with the more forceful real reality. They float free in probability space interacting at random intervals with the more forceful realities of the real world.

Where is the missing matter of the Universe?

There may be clouds of matter floating about in deep space, however, most of the approximately 90% of matter missing will be found in the layers of dimensions making up space and which, though interacting, do not appear in our reality. Calculations show only about ten dimensions are active in any one reality. The rest curl up in a ball or knot. While an essential part of space or reality they are not perceivable from the fractal Universe of which they are a part.

Parapsychology?

Events of this type can be attributed to interconnections on the dimensional, or imaginary, level where there can be interactions between fractal units though not directly associated with each other in relative space. The manifestation varies or is temporary due to the constantly changing and adjusting due to interactions of the probabilities of the Universe. Due to the innate probabilities of each individual, one may be more susceptible or sensitive than other individuals.

Bible, prophesies, angels, demons, aliens, etc.

If one takes the Bible at face value, with some leeway for it's age and many translations, it pretty well describes what it purports to describe. Historic predictions and conditions of today. If we assume this hypothesis has any value then the passage in which God says "Let us make man in our image." takes on new meaning. If we assume the probability basis of the Universe and the constant changing due to justification of reality and time then the miracles listed do not seem so in violation of the physical world. The miracles only require some ability to control reality. Certainly well within the providence of a creator. It speaks of heavenly beings capable of traveling through the Universe in real time and some who interfered with mankind on the Earth and that they are still doing so today. If this hypothesis is correct then it is readily seen how such events could occur. Creation events closely compare with the way todays computers are made and organized. If man can do it, why could not the original creator? If one ignores a creator, then one is hard pressed for an answer as to how the Universe was created.

UFOs

If one accepts any part of the above then the functioning of UFOs begins to be understandable. They move through space by making spatial jumps through fractal nodes. Their appearing around magnetic and electrical sources maybe due to some, on our part unrealized, easy entry and exit to other space at those points. They are able to make right angle turns at high speeds because the speed is only from our viewpoint. From the viewpoint of the craft it is simply changing locations in space. The turning on edge may be only a different orientation of space at that point.

Particles "Out of the Vacuum"

As we shoot atomic matter at higher and higher speeds into nuclei we are able to fracture the construction of the building blocks of matter. The high speed fractal construction of probabilities of the unit used smashes into the target with enough speed to mix the probabilities resulting in new nodes from the total probabilities present. Various probabilities are ejected resulting in short lived particles in unstable nodes. At times fragments of probabilities appear out of nowhere as they form up to combine into larger nodes. Travel distance and speed observed may give a clue to the basic frequency of the Universe.

Black Holes

The midpoint of the tuned circuit of the relative structure and dimensional structure of the Universe. As matter spirals in, from the relative structure, to be torn apart into its basic probabilities it passes through to the dimensional structure of space which holds 90% of the matter. There it is available for recollection and use by the relative space.

Probability. Basic structure of the energy of space.

Everything operates at random but within preferred patterns set by the frequencies involved. If you look long enough anything can be found. As a result we find odd bones of prehistoric creatures that may have never existed. Weird things can happen. Odd pieces of structure can occur such as metaphysical events. The Q of space is sometimes sharp and sometimes rounded, spreading out to include things not really meant to be in the overall scheme of the Universe. Christ said "If you had the faith of a mustard seed, you could say to the mountain move and the mountain would move". (For those not of the Christian faith, this may be considered not as any proof but as a representative statement of the meaning of this paragraph.) That is in keeping with the quantum statements that nothing exists until it is seen and that we have some control over the probabilities. If the structure of space is based on probability then the next important question is 'What is a probability'. We look to probability as a simple mathematical work. But, what makes probability work?

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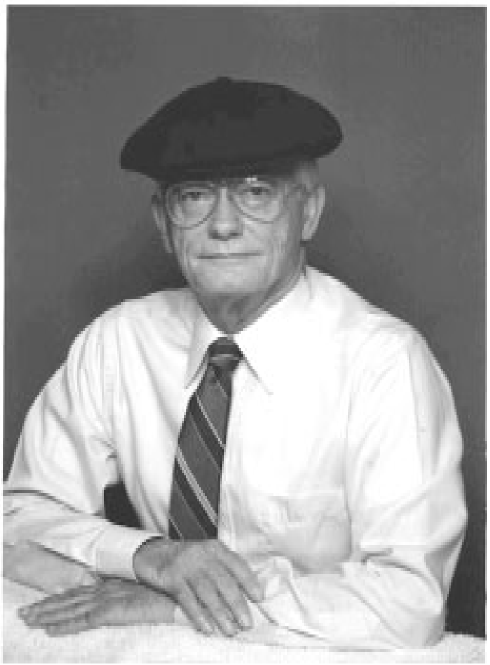

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The entire Universe is based on mathematics but we have no idea what is underneath the mathematics. Are dimensional planes perhaps better represented by other number bases? Are some of the unsolvable mathematical problems solvable in other number bases?

Gravity

All forces in the Universe are the same. Gravity happens to be the one that works on our fractal space. Others, molecular, atomic, and nuclear are the same but work in different fractal space. All are the result of matter trying to reach its lowest potential.

The above are only random questions chosen without any order. Most other problems can in some way be answered in line with the hypothesis, if not in detail. Too many questions can be fitted to the hypothesis not to take a serious look at it even though it may seem a little far out. The number of answers from one simple statement of the structure of the Universe defends the idea better than details.

One possible proof, and a relatively simple one, occurs to mind. Einstein's theory of relativity was proved when NASA flew a clock in space and then determined that time did slow down. To test the above hypothesis I would like to see four clocks used in the following manner.

Four atomic clocks in sets of two each. Two to be left on the Earth and two to be placed in space for an appropriate time. At the end of that time one of the clocks on the Earth to be taken into space and compared to the two already in space. Bring one of the clocks in space down to the Earth and compare to the clock left on the Earth.

The clock taken to space should read slower compared to the clocks in space because the ones in space were at rest compared to the one on the Earth.

The clock brought back from space should read slower, the same as the first one flown by NASA, because the clock on the Earth was at rest compared with the one in space.

The two clocks left in space should be returned after an appropriate time and compared to the ones on the Earth. The original in space should now be slower than the original on the Earth and its mate from space. The fourth clock is unpredictable.

The author apologizes for any errors in theory, mathematics, etc. There was no one to consult on the hypothesis which is an original work of my own and drawn on many references of others from the past If it has any value I am indebted to the work of all the others whose work I relied on. Any errors are entirely my own and not attributable to others. This work is freely published in the public domain to be used by any and all who wish to do so. It is not to be copyrighted or patented in any manner so as to restrict others rights to the hypothesis or it's use.

The Charge and Mass of a Photon

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Abstract

The discovery of true elementary particle named **electrino**, which has a constant mass and constant positive charge and which is a material carrier of magnetic field, electric current and all kinds of emanation, was firstly practically applied at the modernization of wireless telephone. In the review V. Anpilogov writes: "The question on the influence of low intensity microwave radiation on human health still remains open for discussion for more than 50 years" [3]. Discussion on this question has been already inappropriate still it was definitely proved in the patent application "Device, which is made to put away the charged particles flux from the head of the user of mobile wireless phone". During the talk on mobile wirelessphone $2{,}6\cdot10^{22}$ particle/sec pass through user's brain, whereas their energy is $7{,}65\cdot10^{-19}$ Joule, and the energy of binding of molecules in protein polymers ranges at $4{,}3\text{-}7{,}6\cdot10^{-19}$ Joule according to L. Poling. From that we can conclude that microwave radiation of the radiotelephone with top antenna leads to the destruction of user's brain tissue. The author of the patent application D. Baziev (#2001105456, 28.02.01. in Russia and #PCT/RU02/00054 of the international application) offers to fix the antenna on the low part of the radiotelephone and to produce radiotelephones with minimal length within 10 cm. In this case the diagram of the directional radiation pattern is on the level of the user's chin and the brain is out of the direct exposure area. This harmless of the microwave radiation could not be proved before the discovery of "electrino".

Introduction

A systems analysis of all experimental and observation material gathered in physics, astronomy, and astrophysics from the times of Galileo let us reveal the following:

1. Experimental materials do not agree with the existing physical theory.
2. There is a certain fundamental disadvantage of the experimental material, which prevents to build a consistent theory.
3. This fundamental disadvantage consists in the absence of a charge antipode of electron, which is in the form of a true elementary particle with a positive charge and finite mass.
4. The proton and positron are not true elementary particles and neither of them can be a charge antipode of the electron because they are subjected to splitting.
5. Discovery of the second true elementary particle with a positive charge could restore the charge symmetry in physics, thus leading to a radical revision of the existing theoretical physics and resolving its current crisis state.

Searching for this particle required to ascertain physical nature of Planck's constant. This became possible only after the structure of a light beam had been understood. Namely, it was the photon sector velocity, known as Millikan constant μ, rather than the speed of light *c*, that proved to be a constant, viz.:

$$\mu = \lambda_i^2 \nu_i = 119.916984\ \mathrm{m^2/s} = \text{constant}, \qquad (1)$$

where λ_i and ν_i are the wavelength and frequency of the *ion* monochromatic beam in the light beam.

This new quantity elucidated the physical nature of Planck's constant:

$$h = m_\varepsilon \mu \frac{\sqrt[3]{4\pi/3}}{2} = \\ = 6.6262681\cdot10^{-34}\ \mathrm{kg\,m^2/s} = \text{constant}, \qquad (2)$$

where m_ε is the mass of the second (after electron) true elementary particle to be called "electrino". From this expression we have

$$m_\varepsilon = \frac{2h}{\mu\sqrt[3]{4\pi/3}} = \\ = 6.85575729963\cdot10^{-36}\ \mathrm{kg} = \text{constant}. \qquad (3)$$

The electrino has a positive charge ε determined by

$$\varepsilon = \frac{m_\varepsilon n_\varepsilon e}{m_u - n_e m_e} = \frac{-3.229526609098\cdot10^{-54}}{1.6578584539\cdot10^{-27}} = \\ = 1.98764431671\cdot10^{-27}\ \mathrm{C}, \qquad (4)$$

where $m_u = 1.66057 \times 10^{-27}$ kg is the mass of an elementary atom accepted as a mass equivalent of one atomic unit; $n_e = 3$ is the number of electrons in one elementary atom; $e = 1.6021892 \times 10^{-19}$ C is the charge of an electron; $m_e = 9.038487 \times 10^{-31}$ kg is an improved value of electron mass; $n_\varepsilon = 2.418198867 \times 10^8$ is the number of electrinos in an elementary atom.

Thus, it is obvious that Planck's constant is the angular momentum of the electrino. Moreover, it was Planck's constant that concealed the second true elementary particle, which is the charge antipode of the electron discovered by J.J. Thompson as far back as in 1897.

The solution of Planck's constant has become a basis for the synthesis of the new theory of physics [1]. This theory in particular shows that the electrino is the carrier of the magnetic field and electrical current. It is a photon of radiation of all ranges, and serves as a universal carrier of energy and information. The electrino plays the role of a neutrino in moving along the first order trajectories.

The first experiment

An extraordinary importance and novelty of the new theory required **an experimental proof of the electrino**. For that several experiments were made in the Institute of General and Inorganic Chemistry, Moscow. The experiment was based on the following effects predicted by the theory.

1. If assume that electrino exists and that light beam is a flux of particles having positive charge and finite mass [1] we can conclude the following. At the discharge of the dc source through an incandescent lamp in which the current is converted to light and irreversibly emitted, the source weight in charged state must differ from its weight in discharged state. If we prove this difference experimentally we may say that light does consist of material particles of finite mass and a dc charge carried away by light is positive because an incandescent lamp (W=15 Wtt) does not emit electrons, which are the carriers of negative charge.
2. The second effect to prove was that the weight of a discharging dc source is *increasing* whereas its weight when charged is *decreasing*.

To prove the validity of these predictions, several sealed containers with different dc sources inside were fabricated. The electrodes were brought out through glass insulators. The batteries were discharged through an electric lamp radiating in the visual and infrared ranges. The weight of containers was measured before and after discharge process with accuracy $\Delta W=\pm 0{,}02$ mg; balance error was equal to $\Delta = \pm\ 0{,}05$ mg the standard deviation of the measurements was within $\sigma = \pm 0{,}03$ mg; the buoyancy was calculated for each measurement of weight. In this paper, we present test results of only one container with four generally marketed GP rechargeable cells connected in series. The total battery voltage reached 5400 mV at 6000 mA/h charge capacity. The discharge was interrupted when the voltage dropped to 4000 mV, the duration of the discharge was measured accurate to one second. Two series of experiments were run: one in air, the other, under argon. Each series had ten charge-discharge cycles (Table 1 and Fig. 1). The total amount of the experiments and detailed discussion of results have been summarized in a recently published brochure [2].

The results of the above tests allow us to make the following conclusions:

1. Both galvanic and rechargeable cells during a discharge through an electric lamp show sufficient changes in their weight and charge thus proving that photons have a finite mass and a positive electric charge.
2. A new elementary particle, named electrino, derived from Planck's constant in August 1982, and published in May 1994, thus gets a complete and absolute experimental confirmation.

The second experiment

One of the concepts of the new theory is that the speed of light in vacuum is a function of photon frequency along the beam axis, according to the proportions:

$$c_i = \sqrt{\mu \nu_i} \quad \text{[m/s]}, \tag{5}$$

$$\nu_i = \mu / \lambda_i^2 \quad [\text{s}^{-1}]. \tag{6}$$

According to the new theory, for the velocity of monochromatic light (solar light or mercury-discharge lamp, but not a laser) with a wavelength of λ_r=6.8×10^{-7} m (mid-point of the red spectral line), we have

$$\nu_\text{r} = \mu / \lambda_\text{r}^2 = 2.59336038 \cdot 10^{14}\ \text{s}^{-1}, \tag{7}$$

$$c_\text{r} = \sqrt{\mu \nu_\text{r}} = 1.76348505882 \cdot 10^{8}\ \text{m/s}, \tag{8}$$

which is 58.823% of the speed c_v = 2.9979246×10^8 m/s of a violet beam with a wavelength of 4 × 10^{-7} m.

We have to account that, according to this theory, the laser beam is not a true light beam though it is created of electrinos. The speed of laser beam is equal to the speed of beam plus the speed of current in the conductor, viz.,

$$v_0 = 2.8992629 \cdot 10^8\,\text{m/s} = \text{const} \tag{9}$$

If we select a monochromatic beam of ultra-violet light with a wavelength of λ_1 =4 · 10 $^{-8}$ m then its velocity will be c_1=10 C:

$$c_1 = \mu / \lambda_1 = \frac{119{,}916984 m^2/\text{sec}}{4 \cdot 10^{-8} m} = $$
$$= 2{,}9979246 \cdot 10^9\, m/\text{sec}$$

$$\nu_1 = \mu / \lambda_1^2 = \mu / 16 \cdot 10^{-16} m^2 = 7{,}4948115 \cdot 10^{16}\ \text{sec}^{-1}$$

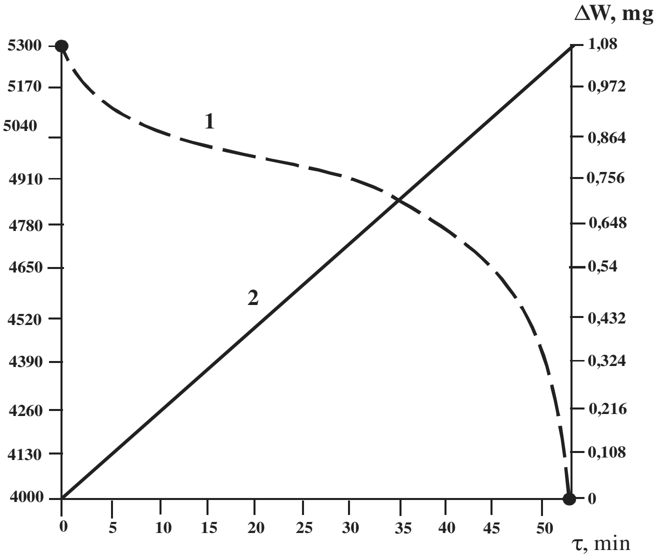

Fig. 1
Voltage drop [mV] of a battery and (2) weight increment [mg] of container #6 in an argon atmosphere during the second discharge cycle [minutes]. X-direction – is spark duration in minutes; Y-direction – is voltage of a battery; auxiliary Y-direction – is weight incensement (mg).

$$c_1 = \sqrt{\mu \cdot v_1} = \sqrt{8{,}987551907 \cdot 10^{18} m^2 / c^2} = 2{,}9979246 \cdot 10^9 m/\sec$$

This experiment has been run yet, and it is offered for experimental verification with further publication of experimental results.

Table 1

Weight of container #6 (under argon) in charge-discharge experiments

		Charged battery		Discharged battery			Charge
Run	Measured value $W \pm \sigma$, mg	Buoyancy Gmg	Real weight $W_0 = W + G$	Measured value $W \pm \sigma$, mg	Buoyancy Gmg	Real weight $W_1 = W + G$	weight $\Delta W_z = W_1 - W_0$, mg
1	126825.13±0,02	85.031	126910.166 ±.0.02	126825.901 ±0.01	85.002	12691.903 ±0.01	0.737
2	126825.107±0.02	86.572	126911.679 ±0.02	126826.221 ±0.01	86.538	126912.759 ±0.01	1.080
3	126825.21±0.01	86.782	126911.992 ±0.01	126826.279 ±0.01	86.560	126912.839 ±0.01	0.847
4	126825.187±0.01	86.563	126911.749 ±0.01	126826.493 ±0.02	86.385	126912.878 ±0.02	1.128
5	126825. 65±0,04	86.290	126911.941 ±0.04	126826.65 ±0.01	85.836	126912.941 ±0.04	0.770
6	126827.28±0.00	85.187	126912.467 ±0.00	126827.990 ±0.01	85.204	126913.194 ±0.01	0.727
7	---	---	---	---	---	---	---
8	126826.98±0.00	86.182	126913.162 ±0.00	12682 7.897 ±0.02	86.308	126914.205 ±0.02	1.042
9	126826.95±0.00	86.307	126913.257 ±0.00	126827.757 ±0.01	86.402	126914.159 ±0.01	0.902
10	126827.25±0.00	86.294	126913.544 ±0.00	126828.35 ±0.00	85.729	126914.079 ±0.00	0.535

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3. V.P. Anpilogov, "The century of quality", #3, 2001, p.60

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About the Author

When a child Dzabrail Kh. Baziev became a political exile along with all Balkarian people; in 1956 he was rehabilitated and in 1957 graduated from the secondary school with steady purpose to become an outstanding chemist. His first higher education is biological and chemical (two-profile department of Kabardino-Balkarian State University). In 1965 Baziev also completed his post-graduate study in Biological Department of Moscow State University.

At 1979 Dz.Kh. Baziev had published 25 scientific articles on ornithology and ecology, however, this period became a sudden turn in his scientific work. In order to elaborate the basis of theoretical biology, he came to the conclusion that biological process could not be described without understanding of its physical essence. On the other hand, it had become evident that there was no any solution for physical phenomenon, which is the basis of biological process.

In 1983 the scientist gave descriptions of his first fundamental discoveries. He found the solution of the physical essence of Plank's constant and pioneered the use of it in gases analysis. It was a revolutionary step in science since the synthesis of science was realized at the fundamental level for the first time.

As the result of this considerable work there was a new interdisciplinary theory of physics. The author created new thermodynamics of real gases and new electrodynamics, which differs from maxwellian one and it considers *electrino* as the carrier of magnetic field and electric current.

Dzabrail Kh. Baziev has succeeded in the systematic analysis of the vast experimental material and discovered that ***electrino,*** **as the true elementary particle with positive charge, is able to provide the connection of physics with biology, chemistry and other parts of the fundamental science. Thus it leads us to the radical reconsideration of all conceptions, existing in natural science.**

The Homopolar Motor: A True Relativistic Engine

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This article discusses experiments, which enable the identification of the seat of mechanical forces in homopolar-machines. Authors provide a suitable variation on a recent work "The Unipolar Dynamotor: A Genuine Relational Engine" [3], where "relational" implies "absolutely relativistic". The authors' view agrees with both Weber's recognition in the 19th century of the importance of relative motion in electromagnetic phenomena [4] and Einstein's 1905 statement concerning electromagnetism [5].

The Faraday disk: a reversible engine

The essential components of the homopolar machine, first conceived by Faraday in 1832, are shown in Figure 1. A conducting disk, free to rotate in the neighborhood of a permanent magnet, is attached to the end of a shaft. A closing wire provides a conducting path between two arbitrary points of the disk. Such a device exhibits *reversible* behavior.

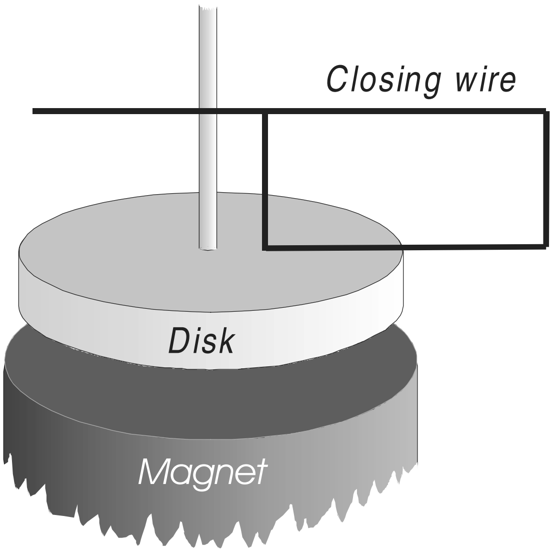

Fig.1
Faraday's setup magnet, disk and closing wire

A radial current path of length L takes place in a region of the disk when direct current (*dc*) from an external source is injected into the closing wire. The interaction of the current with the magnetic field produces a Laplace force [6]

$\boldsymbol{F} = \int_a^{a+L} I(d\boldsymbol{r}x\boldsymbol{B})$ causing the rotation of the disk. This set-up is the *motor configuration.*

When the disk is spun by an external source of mechanical energy, an *emf* appears in it. The displacement of free charges is produced in this case by the Lorentz force $\boldsymbol{f} = q(\boldsymbol{v}x\boldsymbol{B})$, converting the conducting disk into an *emf* source able to drive *dc* through the whole disk plus closing-wire circuit. This set-up is the *generator configuration*.

A seemingly curious fact occurs in the motor configuration, when *dc* is injected into the circuit with the disk attached to the magnet. Both disk and magnet turn together.

Two rival theories, a relativistic and an absolutistic one, have been applied to understand the observed facts:

In relativistic view, generator configuration makes sense only when there is relative motion of the magnet with respect to either the disk or the closing wire. Also, a motor configuration will only take place if the *possibility of relative motion* between magnet and either disk or closing wire is enabled.

Thus, in the relativistic framework, with the magnet attached to the disk, the closing wire becomes the "active" part for the production of mechanical forces or *emf*. In this case the disk itself behaves as a "passive" element providing a closing-circuit current path.

Conversely, in the eyes of an absolutist, a generator configuration is enabled only because of the disk or closing-wire *absolute* motion. Here, absolute means "relative to a frame where the preponderance of the mass of the universe is at rest" [7,8]. In our case, the lab frame acts as an acceptable absolute-motion reference. Thus, from an absolutistic view, the magnet's rotation with $\partial B/t = 0$ in each point of the surrounding space is unable to produce an *emf* on nearby conductors. When in a motor configuration, *dc* is injected in the circuit, and the absolutist assigns the observed rotation to the magnet "dragging" by the conductor. Here, the closing wire acts as a "passive" circuit element.

New experimental work, complementary to that currently known on the subject, introduces arguments in favour of the relativistic viewpoint. The related experiments, whose underlying physics rests upon a modified version of the original Faraday setup, are described in the following sections.

The asymmetrical rotor

Figure 2 shows the disk-shaped ceramic permanent magnet creating the axial magnetic field ***B***. The removal of a 12° sector introduces a field-reversion region. Outgoing and ingoing ***B*** field lines are represented by the and symbols, respectively.

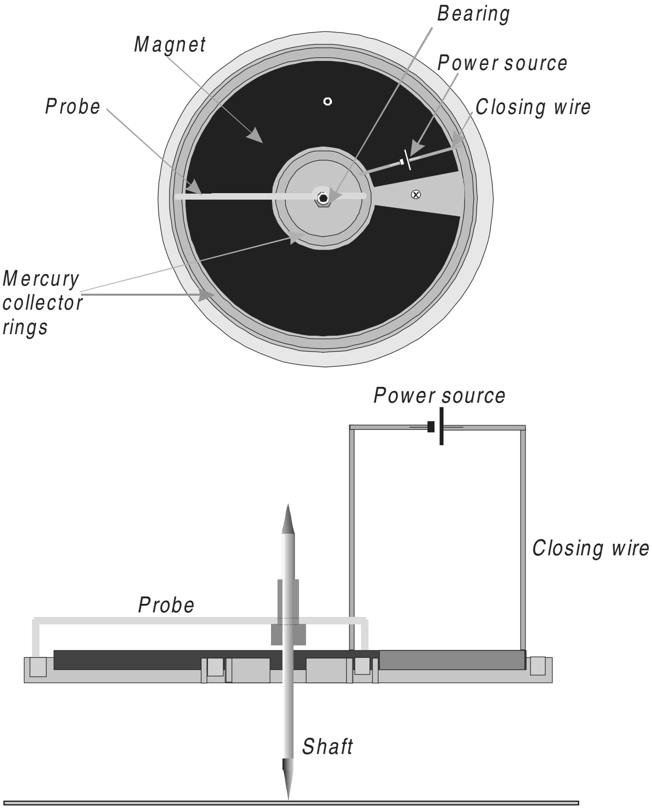

Fig.2
Layout of the Asymmetrical Rotor applied to the experiments

Two mercury collector rings are embedded in a wood cylinder. One is located close to the hollow-disk magnet inner rim and the other in the proximity of the outer rim. The magnet's inner and outer radii are 25 and 75 mm, respectively, and its height 25 mm. Its average flux density 2 mm above the magnet has been estimated to be 0.05 T based on a generator experiment with a rotating copper disk. The magnet-and-wood-cylinder body (the asymmetrical rotor from here on) is firmly anchored to a vertical shaft terminated in sharp points at both ends. While the lower one lays on a hard-polished surface, a conical bearing, enabling its almost frictionless rotation, centers the upper one.

Unlike the series-connected conductors diametrically anchored to the shaft in the Guala-Valverde case [3], only one radial conductor wire, a probe located 2 mm above the magnet's face, was considered. By mounting it on a bearing, its free rotation is permitted with its ends remaining in contact with both collector rings. A 12V lead-acid battery applied to the closing wire feeds the probe through the collector rings. In the first four experimental cases presented the closing wire remains firmly anchored to the lab. In two complementary experiments, rotation of the closing wire mounted on two shaft-centered bearings is allowed. Its behavior as a probe occurs by the injection of *dc* from an additional closing-circuit wire anchored to the lab.

Experimental

Six experiments performed are described below:

1. Rotor anchored to the lab, probe free to rotate above the magnet's upward magnetic-field region: A radially-ingoing injected *dc* in the 0.2 A range was enough to overcome conductor-bearing and mercury-wire contact friction. A net *counterclockwise rotation* of the probe took place.

2. Probe anchored to the rotor above the magnet's upward magnetic-field region, with both free to rotate: A radially-ingoing injected *dc* in the 5 A range was enough to overcome conductor-plus-rotor inertia and friction. A net *counterclockwise rotation* of the probe took place.

3. Rotor anchored to the lab, probe free to rotate above the magnet's downward magnetic-field region: A radially-ingoing injected *dc* in the 0.2 A range was enough to overcome conductor-bearing and mercury-wire contacts friction. A net *clockwise rotation* of the probe took place.

4. Probe anchored to the rotor above the magnet's downward magnetic-field region, both free to rotate: A radially-ingoing injected *dc* in the 5 A range was enough to overcome conductor-plus-rotor inertia and friction. A net *counterclockwise rotation* of the probe took place.

5. Rotor anchored to the lab, closing wire free to rotate above the magnet's upward magnetic-field region: A 0.4 A *dc* injected in the inner collector ring was enough to overcome conductor-bearing and mercury-wire contacts friction. A net *clockwise rotation* of the closing-wire took place.

6. Rotor anchored to the lab, closing wire free to rotate above the magnet's downward magnetic-field region: A 0.4 A *dc* injected in the inner collector ring was enough to overcome conductor-bearing and mercury-wire contacts friction. A net *clockwise rotation* of the closing-wire took place.

Discussion of results

Experiments (1) and (3) can be explained using either absolutist or relativistic viewpoints because of the coincidence of the probe motion relative to the lab with the probe motion relative to the magnet.

Experiment (2) can be explained by a trivial absolutist argument founded on a hypothetic probe "dragging effect" on the magnet. A relativistic viewpoint recognizes the "active" rotational torque on the closing wire rather than on the probe where, hinging on Newton's third law, the whole action may be split in two:

Magnet-probe. The magnet produces a counterclockwise torque on the probe, and the probe exerts an equal but opposite torque on the magnet.

Magnet-closing wire. The magnet exerts a clockwise torque on the closing wire, and the wire an equal but opposite torque on the magnet.

With the probe attached to the magnet, there is no chance for relative motion between them. Consequently, due to the action-reaction cancellation, rotation is forbidden. Conversely, with the closing wire mechanically decoupled from the magnet, relative motion of the latter is permitted. The torque exerted by the closing wire on the magnet is responsible for the observed rotation.

Experiment (4): Due to its similarity with (2) a trivial relativistic explanation is applicable to the counterclockwise torque exerted by the closing wire on the magnet. There is no known plausible absolutistic explanation for it. As quoted above, the hypothetical dragging effect would produce a clockwise rotation in this case. The consideration of the experiments (2) and (4) suffices to reject the dragging hypothesis.

Complementary experiments (5) and (6) confirm the short-range extension of the field-reversion region founded on the closing-wire *clockwise* rotation (6). Briefly speaking, the closing wire is not sensitive to the field reversion and the magnet's *counterclockwise* reaction explains at once the outcome of (4). Clearly, experiments (5) and (6) show that the torque on the closing wire is independent of its location on the magnet.

Figure 3 depicts the two rotational torques involved in (2) and (4).

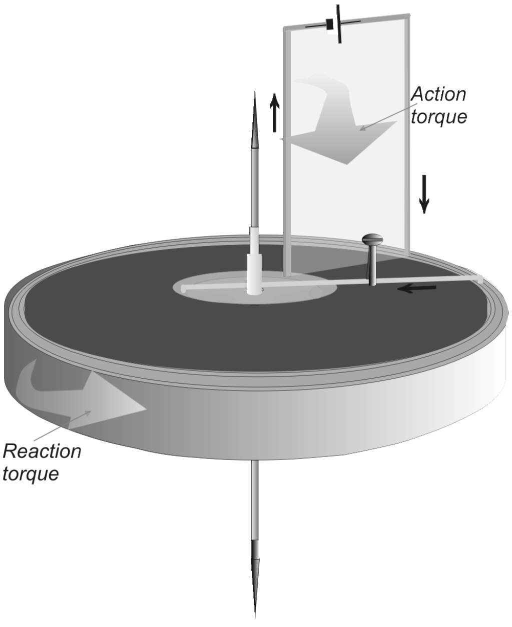

Fig.3
Rotational torques acting on the magnet and on the closing wire

Topological and miscellaneous considerations

One of the keys to the success of the above described experiments lies in the dynamotor's magnet design (see Fig.4). The short-range field reversion region allows the inversion of the Laplace force on the probe, making the force on the closing wire insensitive to that ***B**-field* reversion.

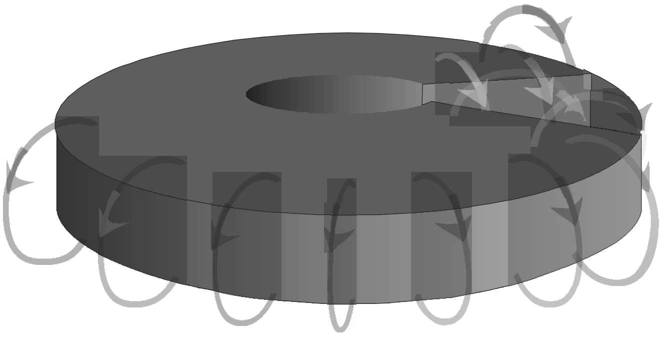

Fig. 4
The magnet's field-revision region

In all the above cases the electromagnetic forces between probe and closing wire were neglected because of its small magnitude compared to the predominant magnet-wire interaction forces.

The observed torques became, in all the experiments, independent of the location of the contact points between closing wire and collector rings. Also, the closing wire shape exhibited no noticeable influence on torques. These observations can be easily explained using the $div\mathbf{B} = 0$ fundamental law, Laplace force, and some elementary topological considerations.

Kennard [1], Bartlett [1]· Panosky [7,8], Muller [9], Wesley [10] and some of this article's authors took absolutistic viewpoints when dealing with homopolar phenomena [11,12]. On the contrary, Weber [4], Assis [13], and Kelly [14] adopted a relativistic framework on the issue from the beginning.

By attaching the magnet to the disk in the original Faraday setup, the relative rotation between disk and closing wire remains unchanged. Therefore, in a generator configuration, the disk plus magnet rotation at with the closing wire at rest in the lab is entirely equivalent to the closing-wire rotation at – with the disk plus magnet at rest. This fact introduced a correct but physically "colorless" weak relativism to the homopolar generator description: the "unipolar generator really has three components, the magnet, the cylinder and the meter (including the contacts). A relative motion of the last two, not the first two, is required" [1].

A growing interest in basic electromagnetism [15,27] can not be ignored, and from time to time some authors, attempting to catch "free energy" from the space, have claimed the design of homopolar engines with efficiency greater than unity, as can be checked by searching for *homopolar motor* on the Internet. The strict application of Newton's third law precludes the above non-physical possibility.

It is worthwhile to stress that the homopolar machine is a famous example where Faraday's flux rule fails. This fact worried Faraday himself and is clearly discussed by Feynman [28] who emphasized that the correct physics is always given by the Lorentz force law and the Maxwell fundamental equation *curl E = -B/t.* Homopolar induction is fully understood using only the Lorentz force. Our experiments enhance the relativistic structure of the Lorentz force because the only relevant velocity is the velocity of the conductor relative to the magnet.

Acknowledgments: To Profs. C.N. Gagliardo and A. Ipohorski-Lenkiewicz for the conceptual comments on this development.

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Weight Reductions Generated by Bucking-Field Permanent Magnets

LAB REPORT ON SmCo RING MAGNET EXPERIMENTS

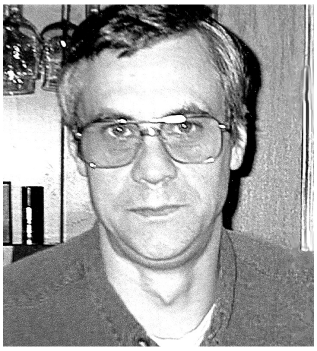

Experiments conducted by:
William C. Simpson

New Horizons Research 600 Meridian Street Extension,
#302 Groton, CT 06340
Tel. (860) 405-1157

The following experiments were conducted at the *Coastal Environmental Laboratory* (CEL) at Avery Point, Groton, Connecticut. (41° 19‘ 0.17" N. latitude x 72° 3‘ 50.27" W. longitude x 35 feet elevation above mean sea level) I wish to thank the personnelat the CEL for their generosity for providing the use of their *Mettler Toledo*® Model AG104 electronic scale for the measurements taken in the proceeding experiments. The AG104 electronic scale is an enclosed pan unit with a maximum mass range of 101-grams with 0.0001-gram readability.

The purpose of these experiments was to see if there is any detectable weight change when permanent magnets are forced together with their like-poles facing each other. The magnets were weighed individually, in both directions, with their field poles oriented vertically. The sums of the two individual magnet weights (magnet #1 and magnet #2) in each vertical orientation were compared to the weight measurements taken when they were assembled using the nylon bolt and wing nut depicted in **DIAGRAM 1**. The specifications for the two Samarium Cobalt magnets used in the following experiments are shown in **DIAGRAM 1**.

The first set of experiments with the SmCo Ring magnets were conducted January 14, 2002. An inverted paper cup was used to raise the test sample magnets 2.75" above the AG104 electronic scale pan in order to minimize possible magnetic interaction with the scale-sensing element, as depicted in **DIAGRAM 2**. The tare adjustment was used to set the scale readout to 0.0000-gram with the cup in place. The magnets were weighed individually. Magnet #1 weighed 9.9450-gram with the N pole facing up and 9.9397-gram with the S pole facing up. Magnet #2 weighed 9.9520-gram with the N pole facing up and 9.9443-gram with the S pole facing up.

The second set of experiments with the SmCo Ring magnets were conducted February 4, 2002. These experiments were shielded with Mu 80 magnetic

Editorial: This article is one more link between magnetizm and theory of aether, to my mind. It is possible to assume that in his experiments the author creates small but detectable changes in density of aether, that demonstrates itself as the weight changes.
Alexander V. Frolov.

DIAGRAM 1

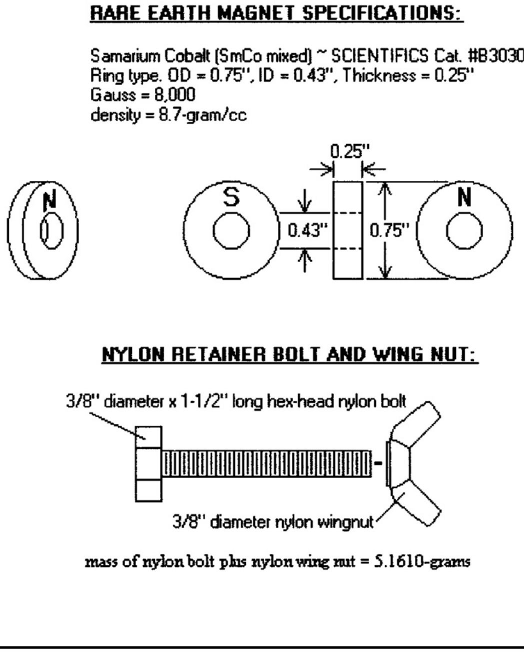

RARE EARTH MAGNET SPECIFICATIONS:

Samarium Cobalt (SmCo mixed) ~ SCIENTIFICS Cat. #B30307-30
Ring type. OD = 0.75", ID = 0.43", Thickness = 0.25"
Gauss = 8,000
density = 8.7-gram/cc

0.25"
N
S
0.43"
0.75"
N
NYLON RETAINER BOLT AND WING NUT:
3/8" diameter x 1-1/2" long hex-head nylon bolt
3/8" diameter nylon wingnut

mass of nylon bolt plus nylon wing nut = 5.1610-grams shielding material as depicted in **DIAGRAM 3**. The scale was tare adjusted to 0.0000-gram with the entire set of Mu 80 shield pieces in place. Then the magnets were weighed individually. Magnet #1 weighed 9.9483-gram with the N pole facing up and 9.9486-gram with the S pole facing up. Magnet #2 weighed 9.9527-gram with the N pole facing up and 9.9542-gram with the S pole facing up. The Nylon bolt and wing nut were placed in the Mu 80 shield can (without the magnets) and the scale was tare adjusted to 0.0000-gram. Therefore, the readouts would only be reading the weight of the bucking magnets.

The first column in **TABLE 1**, the vertical measurements, is the distance of separation d, or air gap, of the magnets. The second column shows the January 14, 2002 weight measurements of the two magnets, as shown in **DIAGRAM A**. The third column shows the January 14, 2002 weight measurements of the two magnets, as shown in **DIAGRAM B**. The fourth column shows the February 4, 2002 weight measurements of the two magnets, as shown in **DIAGRAM C**. The fifth column shows the February 4, 2002 weight measurements of the two magnets, as shown in **DIAGRAM D**.

The horizontal measurement, as depicted in **TABLE 2**, **TABLE 3**, **TABLE 4** and **TABLE 5**, are through the four basic magnetic compass headings; North, East, South, and West respectively. They are referenced to **DIAGRAM E** and **DIAGRAM F** for the January 14, 2002 experiments and **DIAGRAM G** and **DIAGRAM H** for the February 4, 2002 experiments. The corresponding graphs of the force change plots, **GRAPH 1**, **GRAPH 2**, **GRAPH 3**, **GRAPH 4**, and **GRAPH 5** accompany each table. The forces were converted from the mass readings, which are a scalar measurement, to dynes. The convention used for the force vector was chosen as plus (+) for up, or a weight reduction, and minus (-) for a weight increase.

DIAGRAM 2

01/14/2002 EXPERIMENNTS

CUP HEIGHT: 2.75" above scale pan. 1.75" upper diameter, 2.5" lower diameter

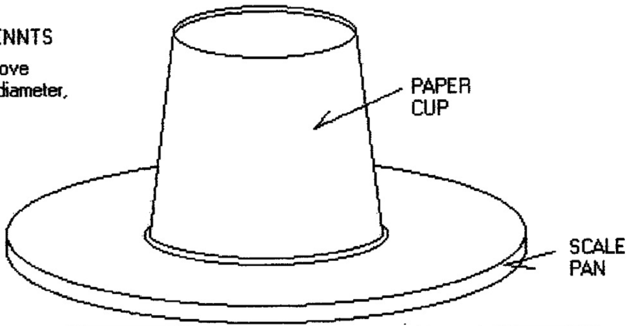

DIAGRAM 3

02/04/2002 EXPERIMENTS

MU METAL SPECIFICATIONS:

Source: NATIONAL ELECTRICAL ALLOYS
Oakland, NJ
SPECIFICATION: MIL N 14411C COMP 1
GRADE: HY MU 80 SHIELDING ALLOY
COLD ROLLED BRIGHT
DESCRIPTION: COIL
HEAT # 982011207
CHEMICAL ANALYSIS:
Ni: 80.16%
Mo: 4.6%
S: 0.0007%
C: 0.010%
P: 0.004%
Mn: 0.486%
Si: < 0.010%
Fe: BALANCE
MECHANICAL PROPERTIES:
HARDNESS: HV1 = 159
GRAIN SIZE: 8.5
COERCIVE STRENGTH:
HC = 0.0080 Oe
PERMEABILITY: MUMAX = 355000
SATURATION: 7900 Gauss
THICKNESS: 0.010"
DENSITY: 8.747-gram/cc

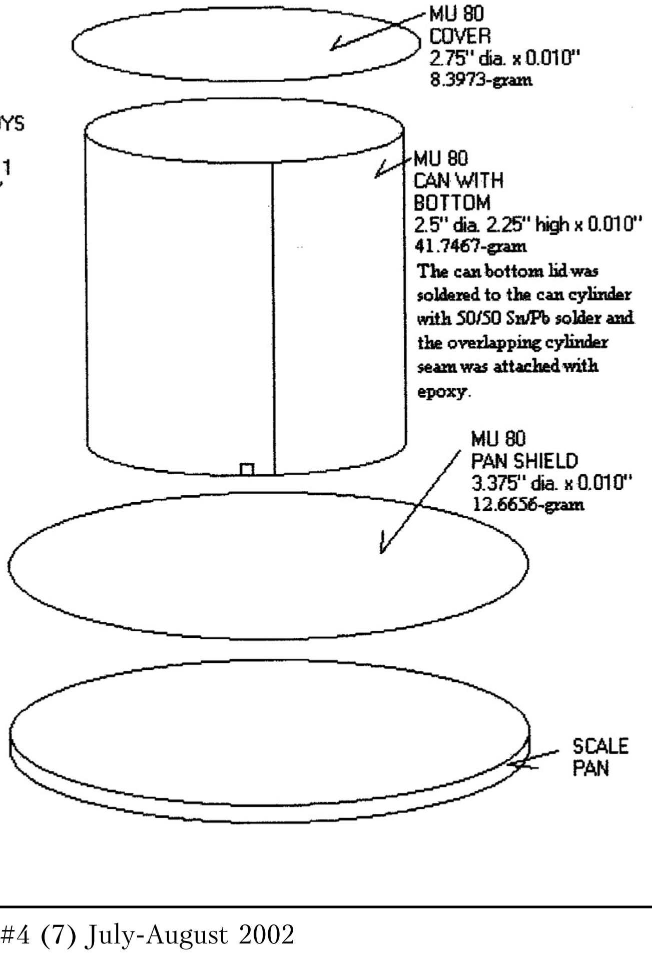

The can bottom lid was soldered to the can cylinder with 50/50 Sn/Pb solder and the overlapping cylinder seam was attached with epoxy.

ELEVATION VIEW OF THE VERTICAL EXPERIMENTS

DIAGRAM E

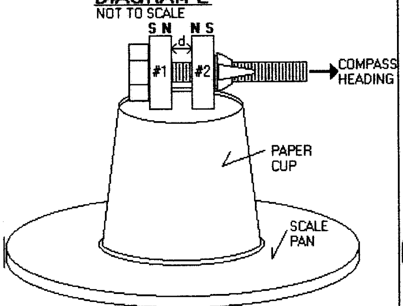
NOT TO SCALE
S N
N S
d
#1
#2
COMPASS HEADING
PAPER CUP
SCALE PAN

DIAGRAM F

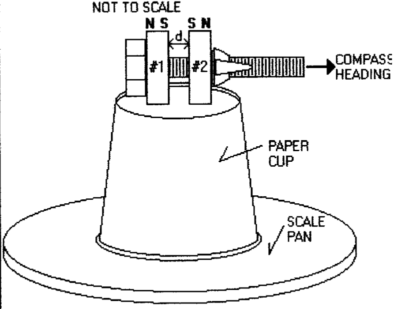
NOT TO SCALE
N S
S N
d
#1
#2
COMPASS HEADING
PAPER CUP
SCALE PAN

DIAGRAM G

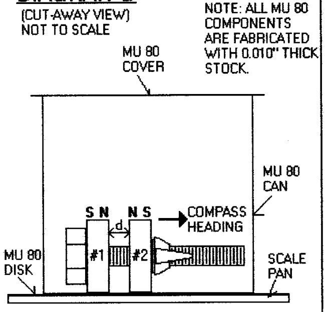
(CUT-AWAY VIEW)
NOT TO SCALE
NOTE: ALL MU 80 COMPONENTS ARE FABRICATED WITH 0.010" THICK STOCK.
MU 80 COVER
MU 80 CAN
S N
N S
d
COMPASS HEADING
#1
#2
MU 80 DISK
SCALE PAN

DIAGRAM H

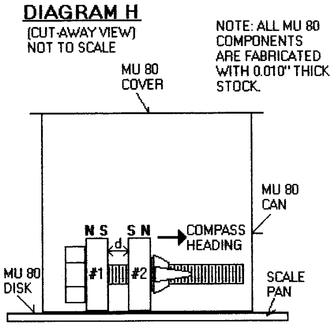
(CUT-AWAY VIEW)
NOT TO SCALE
NOTE: ALL MU 80 COMPONENTS ARE FABRICATED WITH 0.010" THICK STOCK.
MU 80 COVER
MU 80 CAN
N S
S N
d
COMPASS HEADING
#1
#2
MU 80 DISK
SCALE PAN

NOTE:

January 14, 2002 Experiments: Start time: 13:27 hours EST, End time: 15:40 hours EST.

February 4, 2002 Experiments: Start time: 13:18 hours EST, End time: 14:50 hours EST.

TABLE 1:

	01/14/2002 EXPERIMENTS OPEN, WITH PAPER CUP		02/04/2002 EXPERIMENTS WITH MU 80 SHIELDING	
Air gap d	**Diagram A** N to N vertical 19.8893-gram (Sum of 1 & 2)*	**Diagram B** S to S vertical 19.8917-gram (Sum of 1 & 2)*	**Diagram C** N to N vertical 19.9025-gram (Sum of 1 & 2)*	**Diagram D** S to S vertical 19.9013-gram (Sum of 1 & 2)*
0.0 Inch	19.8759-gram 0.0134-gram weight reduction (0.06737%)	19.8757-gram 0.0160-gram weight reduction(0.08045%)	19.8760-gram 0.0265-gram weight reduction(0.13324%)	19.8758-gram 0.0255-gram weight reduction(0.12821%)
1/8 Inch	19.8761-gram 0.0132-gram weight reduction(0.06637%)	19.8751-gram 0.0166-gram weight reduction(0.08346%)	19.8760-gram 0.0265-gram weight reduction(0.13324%)	19.8763-gram 0.0250-gram weight reduction(0.12570%)
1/4 Inch	19.8763-gram 0.0130-gram weight reduction(0.06536%)	19.8748-gram 0.0169-gram weight reduction(0.08497%)	19.8760-gram 0.0265-gram weight reduction(0.13324%)	19.8768-gram 0.0245-gram weight reduction(0.12318%)
3/8 Inch	19.8765-gram 0.0128-gram weight reduction(0.06436%)	19.8753-gram 0.0164-gram weight reduction(0.08246%)	19.8760-gram 0.0265-gram weight reduction(0.13324%)	19.8777-gram 0.0236-gram weight reduction(0.11866%)
1/2 Inch	19.8774-gram 0.0119-gram weight reduction(0.05983%)	19.8753-gram 0.0164-gram weight reduction(0.08246%)	19.8757-gram 0.0268-gram weight reduction(0.13475%)	19.8809-gram 0.0204-gram weight reduction(0.10257%)
5/8 Inch	19.8776-gram 0.0117-gram weight reduction(0.05883%)	19.8754-gram 0.0163-gram weight reduction(0.08195%)	19.8779-gram 0.0246-gram weight reduction(0.12368%)	19.8806-gram 0.0207-gram weight reduction(0.10408%)
11/16 Inch	19.8777-gram 0.0116-gram weight reduction(0.05832%)	19.8748-gram 0.0169-gram weight reduction(0.08497%)	19.8773-gram 0.0252-gram weight reduction(0.12670%)	19.8832-gram 0.0181-gram weight reduction(0.09100%)

* Magnets #1 and #2 were individually weighed in the orientation used in each experiment and their separate weights were added together.

The following equation was used to calculate the weight changes, in dynes, in the proceeding graphs.

$$\overrightarrow{\Delta F} = k \cdot \Delta mass \cdot g$$

where

$$k = 980.665 \cdot dyne \cdot gm^{-1}$$

and

$$g = 9.80665\ m \cdot sec^{-2}$$

which is the local rate of gravitational acceleration.

The product of the measured changes in mass, Δmass, and g is denoted as follows on the graphs:

$$NNopen_{n,1} = \Delta mass \cdot g$$

for N-to-N pole facings in the open (or unshielded).

$$SSopen_{n,1} = \Delta mass \cdot g$$

for S-to-S pole facings in the open (or unshielded).

$$NNshield_{p,1} = \Delta mass \cdot g$$

for N-to-N pole facings shielded with Mu 80 shielding.

$$SSshield_{p,1} = \Delta mass \cdot g$$

for S-to-S pole facings shielded with Mu 80 shielding. In the subscripts, $_n$ and $_p$ refers to the respective number of data points per plot. The subscript $_1$ refers to the vertical change in force (weight change) axis and $_0$ refers to the horizontal distance d axis. In **GRAPH 1**, $_n = _p$.

GRAPH 1:

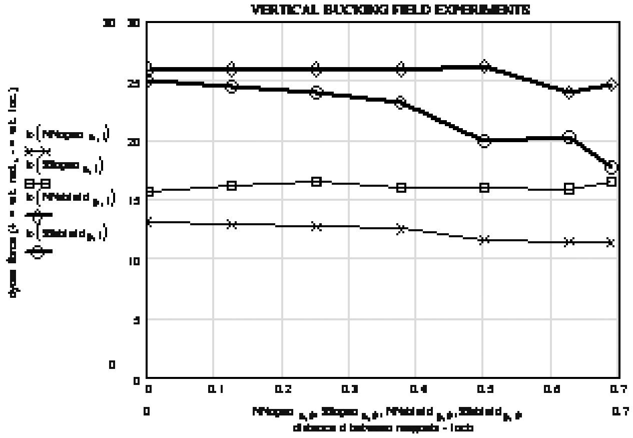

ISOMETRIC AND ELEVATION VIEW OF THE HORIZONTAL EXPERIMENTS

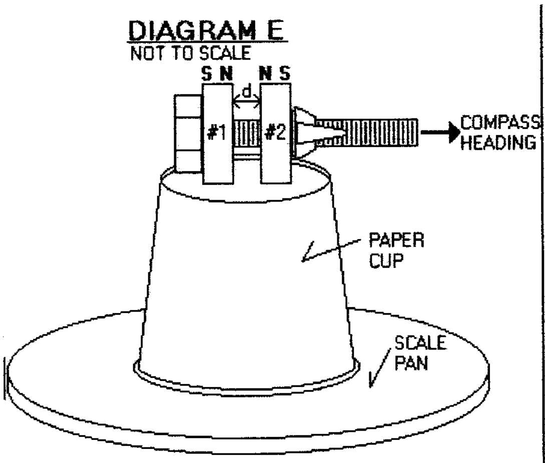
DIAGRAM E
NOT TO SCALE
S N
N S
d
#1
#2
COMPASS HEADING
PAPER CUP
SCALE PAN

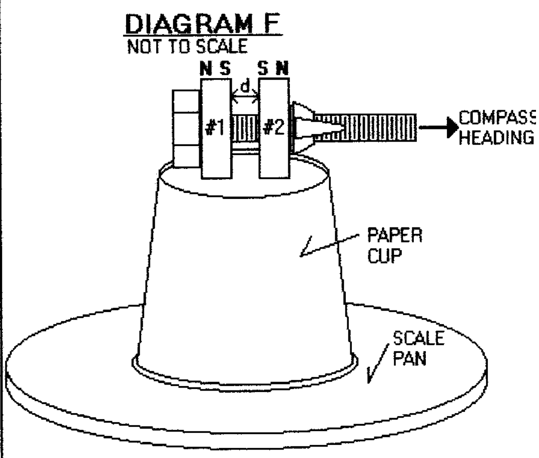
DIAGRAM F
NOT TO SCALE
N S
S N
d
#1
#2
COMPASS HEADING
PAPER CUP
SCALE PAN

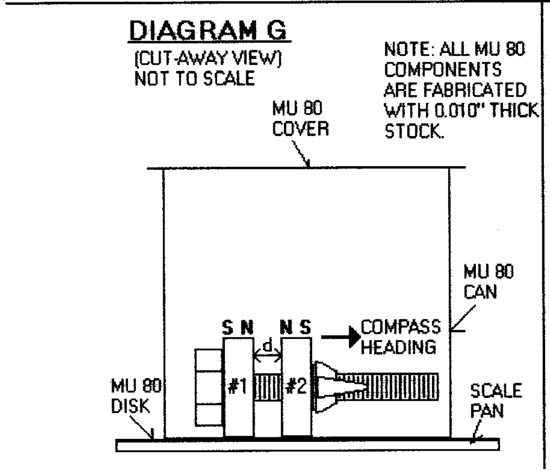
DIAGRAM G
(CUT-AWAY VIEW)
NOT TO SCALE
NOTE: ALL MU 80 COMPONENTS ARE FABRICATED WITH 0.010" THICK STOCK.
MU 80 COVER
MU 80 CAN
S N
N S
d
COMPASS HEADING
#1
#2
MU 80 DISK
SCALE PAN

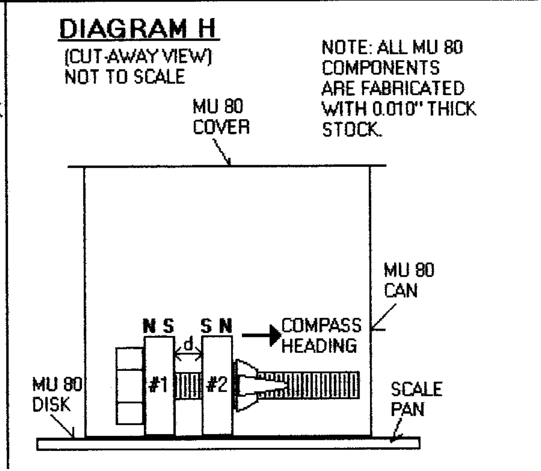
DIAGRAM H
(CUT-AWAY VIEW)
NOT TO SCALE
NOTE: ALL MU 80 COMPONENTS ARE FABRICATED WITH 0.010" THICK STOCK.
MU 80 COVER
MU 80 CAN
N S
S N
d
COMPASS HEADING
#1
#2
MU 80 DISK
SCALE PAN

MAGNETIC DECLINATION FROM THE LOCAL TOPOLOGICAL MAP:

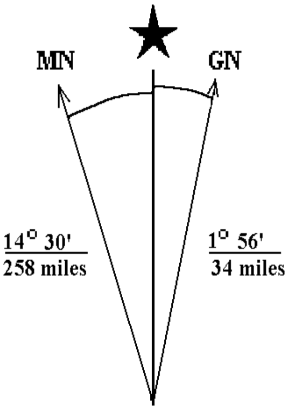

1984 Magnetic Declination~ U. S. Geological Survey
New London, Connecticut Quadrangle Topological Map

TABLE 2

North # **Heading**	01/14/2002 EXPERIMENTS OPEN, WITH PAPER CUP		02/04/2002 EXPERIMENTS WITH MU 80 SHIELDING	
Air gap d	**Diagram E** N to N horizontal 19.8905-gram (Sum of 1 & 2)*	**Diagram F** S to S horizontal 19.8905-gram (Sum of 1 & 2)*	**Diagram G** N to N horizontal 19.9019-gram (Sum of 1 & 2)*	**Diagram H** S to S horizontal 19.9019-gram (Sum of 1 & 2)*
0.0 Inch	19.8735-gram 0.0170-gram weight reduction (0.08547%)	19.8778-gram 0.0127-gram weight reduction(0.06385%)	19.8890-gram 0.0129-gram weight reduction(0.06479%)	19.8810-gram 0.0209-gram weight reduction(0.10497%)
1/8 Inch	19.8728-gram 0.0177-gram weight reduction(0.08899%)	19.8790-gram 0.0115-gram weight reduction(0.05782%)	N/A **	N/A **
1/4 Inch	19.8721-gram 0.0184-gram weight reduction(0.09251%)	19.8798-gram 0.0107-gram weight reduction(0.05379%)	N/A **	N/A **
3/8 Inch	19.8705-gram 0.0200-gram weight reduction(0.10055%)	19.8800-gram 0.0105-gram weight reduction(0.05279%)	N/A **	N/A **
1/2 Inch	19.8698-gram 0.0207-gram weight reduction(0.10407%)	19.8811-gram 0.0094-gram weight reduction(0.04726%)	N/A **	N/A **
5/8 Inch	19.8693-gram 0.0212-gram weight reduction(0.10658%)	19.8818-gram 0.0087-gram weigh t reduction(0.04374%)	N/A **	N/A **
11/16 Inch	19.8696-gram 0.0209-gram weight reduction(0.10508%)	19.8827-gram 0.0078-gram weight reduction(0.03921%)	19.9190-gram 0.0171-gram weight increase(0.08588%)	19.9029-gram 0.0010-gram weight increase(0.00502%)

Compass Heading is approximate
* Magnets #1 and #2 were individually weighed with pole faces oriented vertically, with N up then with S up, and the results were averaged and added.
** Due to time constraints, these measurements were not taken.

GRAPH 2:

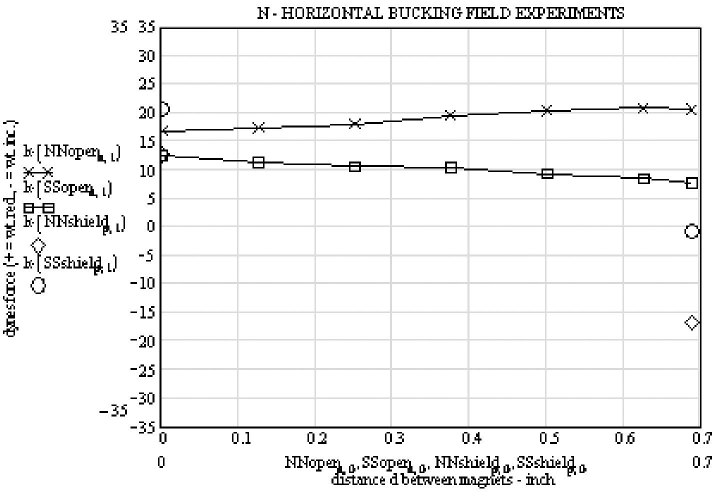

NOTE:
The calculated mass of each magnet was determined by the following formula based upon the manufacturer's dimensions and density value.

$$\text{volume} := \pi \cdot \left[\left(\frac{0.75 \cdot \text{in}}{2} \right)^2 - \left(\frac{0.43 \cdot \text{in}}{2} \right)^2 \right] \cdot \left(\frac{1}{4} \right) \cdot \text{in}$$

$$\text{volume} = 1.214963\ \text{cm}^3$$

$$\text{density} = 8.7 \cdot \text{gm} \cdot \text{cm}^{-3}$$

$$\text{mass} = \text{density} \cdot \text{volume}$$

$$\text{mass} = 10.570177\ \text{gm.}$$

This is higher than the magnetized mass of each magnet.

However, some tables give a lower density for the SmCo magnet, 0.300lb/in^3, which equals:

$$\text{density} = 8.303971 \cdot \text{gm} \cdot \text{cm}^{-3}$$

$$\text{mass} = 10.089017\ \text{gm.}\ .$$

This is still higher than the magnetized mass of each magnet. Does the SmCo material become slightly lighter in weight when it is magnetized?

TABLE 3

East # **Heading**	01/14/2002 EXPERIMENTS OPEN, WITH PAPER CUP		02/04/2002 EXPERIMENTS WITH MU 80 SHIELDING	
Air gap D	**Diagram E** N to N horizontal 19.8905-gram (Sum of 1 & 2)*	**Diagram F** S to S horizontal 19.8905-gram (Sum of 1 & 2)*	**Diagram G** N to N horizontal 19.9019-gram (Sum of 1 & 2)*	**Diagram H** S to S horizontal 19.9019-gram (Sum of 1 & 2)*
0.0 Inch	19.8763-gram 0.0142-gram weight reduction (0.07139%)	19.8755-gram 0.0150-gram weight reduction(0.07541%)	19.8928-gram 0.0091-gram weight reduction(0.04570%)	19.8731-gram 0.0288-gram weight reduction(0.14464%)
1/8 Inch	19.8777-gram 0.0128-gram weight reduction(0.06435%)	19.8750-gram 0.0155-gram weight reduction(0.07793%)	N/A **	N/A **
1/4 Inch	19.8782-gram 0.0123-gram weight reduction(0.06184%)	19.8743-gram 0.0162-gram weight reduction(0.08145%)	N/A **	N/A **
3/8 Inch	19.8779-gram 0.0126-gram weight reduction(0.06335%)	19.8722-gram 0.0183-gram weight reduction(0.09200%)	N/A **	N/A **
1/2 Inch	19.8792-gram 0.0113-gram weight reduction(0.05681%)	19.8715-gram 0.0190-gram weight reduction(0.09552%)	N/A **	N/A **
5/8 Inch	19.8814-gram 0.0091-gram weight reduction(0.04575%)	19.8712-gram 0.0193-gram weight reduction(0.09703%)	N/A **	N/A **
11/16 Inch	19.8815-gram 0.0090-gram weight reduction(0.04525%)	19.8720-gram 0.0185-gram weight reduction(0.09301%)	19.9338-gram 0.0319-gram weight increase(0.16021%)	19.9030-gram 0.0011-gram weight increase(0.00552%)

Compass Heading is approximate
* Magnets #1 and #2 were individually weighed with pole faces oriented vertically, with N up then with S up, and the results were averaged and added.
** Due to time constraints, these measurements were not taken.

GRAPH 3:

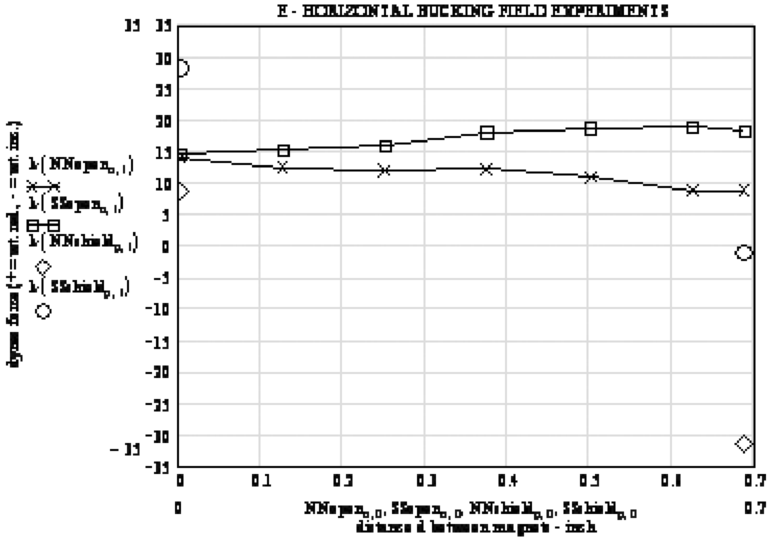

TABLE 4

East # **Heading**	01/14/2002 EXPERIMENTS OPEN, WITH PAPER CUP		02/04/2002 EXPERIMENTS WITH MU 80 SHIELDING	
Air gap D	**Diagram E** N to N horizontal 19.8905-gram (Sum of 1 & 2)*	**Diagram F** S to S horizontal 19.8905-gram (Sum of 1 & 2)*	**Diagram G** N to N horizontal 19.9019-gram (Sum of 1 & 2)*	**Diagram H** S to S horizontal 19.9019-gram (Sum of 1 & 2)*
0.0 Inch	19.8746-gram 0.0159-gram weight reduction (0.07994%)	19.8769-gram 0.0136-gram weight reduction(0.06837%)	19.8896-gram 0.0123-gram weight reduction(0.06178%)	19.8660-gram 0.0359-gram weight reduction(0.18030%)
1/8 Inch	19.8720-gram 0.0185-gram weight reduction(0.09301%)	19.8788-gram 0.0117-gram weight reduction(0.05882%)	N/A **	N/A **
1/4 Inch	19.8709-gram 0.0196-gram weight reduction(0.09854%)	19.8797-gram 0.0108-gram weight reduction(0.05430%)	N/A **	N/A **
3/8 Inch	19.8704-gram 0.0201-gram weight reduction(0.10105%)	19.8803-gram 0.0102-gram weight reduction(0.05128%)	N/A **	N/A **
1/2 Inch	19.8711-gram 0.0194-gram weight reduction(0.09753%)	19.8814-gram 0.0091-gram weight reduction(0.04575%)	N/A **	N/A **
5/8 Inch	19.8698-gram 0.0207-gram weight reduction(0.10407%)	19.8825-gram 0.0080-gram weight reduction(0.04022%)	N/A **	N/A **
11/16 Inch	19.8703-gram 0.0202-gram weight reduction(0.10156%)	19.8817-gram 0.0088-gram weight reduction(0.04424%)	19.9423-gram 0.0404-gram weight increase(0.20290%)	19.8810-gram 0.0209-gram weight reduction(0.10497%)

Compass Heading is approximate
* Magnets #1 and #2 were individually weighed with pole faces oriented vertically, with N up then with S up, and the results were averaged and added.
** Due to time constraints, these measurements were not taken.

GRAPH 4:

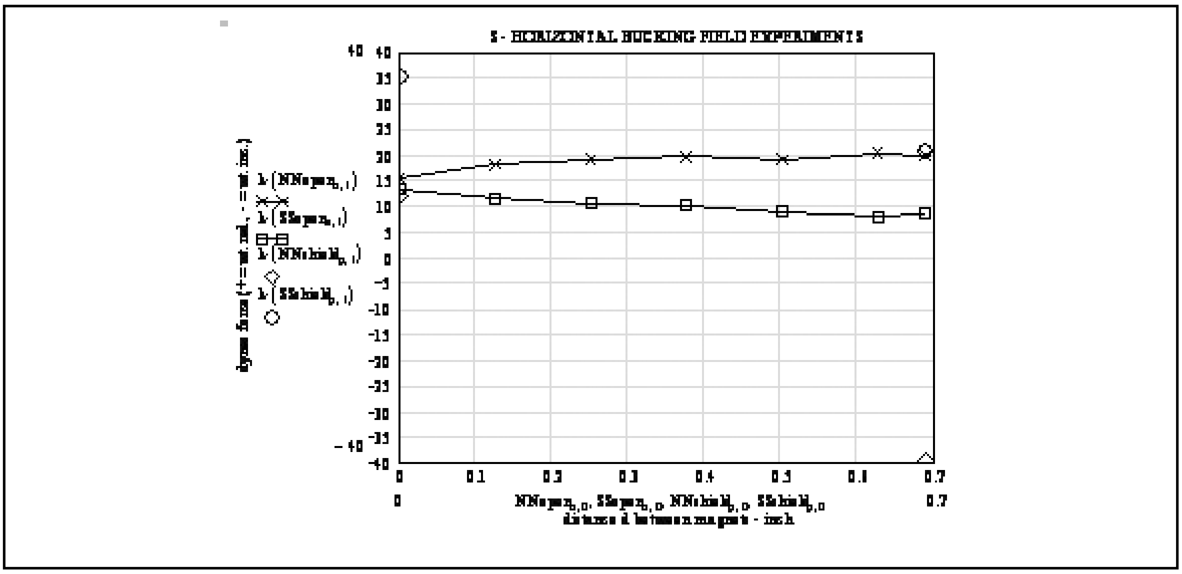

TABLE 5

West # **Heading**	01/14/2002 EXPERIMENTS OPEN, WITH PAPER CUP		02/04/2002 EXPERIMENTS WITH MU 80 SHIELDING	
Air gap D	**Diagram E** N to N horizontal 19.8905-gram (Sum of 1 & 2)*	**Diagram F** S to S horizontal 19.8905-gram (Sum of 1 & 2)*	**Diagram G** N to N horizontal 19.9019-gram (Sum of 1 & 2)*	**Diagram H** S to S horizontal 19.9019-gram (Sum of 1 & 2)*
0.0 Inch	19.8777-gram 0.0128-gram weight reduction (0.06787%)	19.8748-gram 0.0157-gram weight reduction(0.07893%)	19.8933-gram 0.0086-gram weight reduction(0.04319%)	19.8724-gram 0.0295-gram weight reduction(0.14816%)
1/8 Inch	19.8767-gram 0.0138-gram weight reduction(0.06938%)	19.8737-gram 0.0168-gram weight reduction(0.08446%)	N/A **	N/A **
1/4 Inch	19.8777-gram 0.0128-gram weight reduction(0.06435%)	19.8733-gram 0.0172-gram weight reduction(0.08647%)	N/A **	N/A **
3/8 Inch	19.8783-gram 0.0122-gram weight reduction(0.06134%)	19.8727-gram 0.0178-gram weight reduction(0.08949%)	N/A **	N/A **
1/2 Inch	19.8806-gram 0.0099-gram weight reduction(0.04977%)	19.8722-gram 0.0183-gram weight reduction(0.09200%)	N/A **	N/A **
5/8 Inch	19.8811-gram 0.0094-gram weight reduction(0.04726%)	19.8715-gram 0.0190-gram weight reduction(0.09552%)	N/A **	N/A **
11/16 Inch	19.8803-gram 0.0102-gram weight reduction(0.05128%)	19.8723-gram 0.0182-gram weight reduction(0.09150%)	19.9427-gram 0.0408-gram weight increase(0.20491%)	19.8976-gram 0.0043-gram weight reduction(0.02160%)

Compass Heading is approximate
* Magnets #1 and #2 were individually weighed with pole faces oriented vertically, with N up then with S up, and the results were averaged and added.
** Due to time constraints, these measurements were not taken.

GRAPH 5:

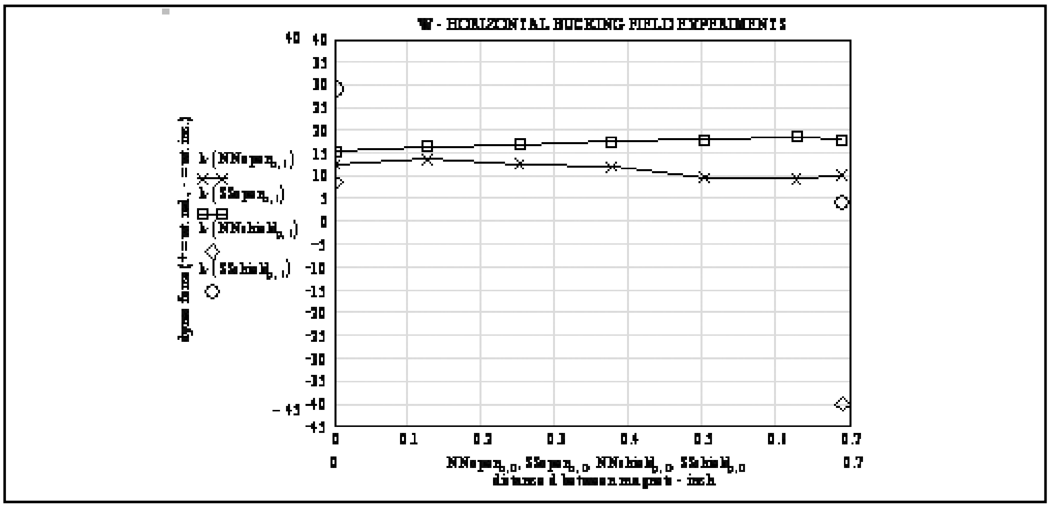

RING MAGNET #1, N UP: 9.9483-grams
RING MAGNET #2, N UP: +9.9527-grams
TOTAL WEIGHT: 19.9010-grams
WEIGHT INCREASE WITH OPPOSITE POLES ATTRACTING, AS DEPICTED IN **DIAGRAM I**, IN MU 80 SHIELD where 19.9861-grams was the measured value:
19.9861-grams – 19.9010-grams = 0.0851-gram weight increase.

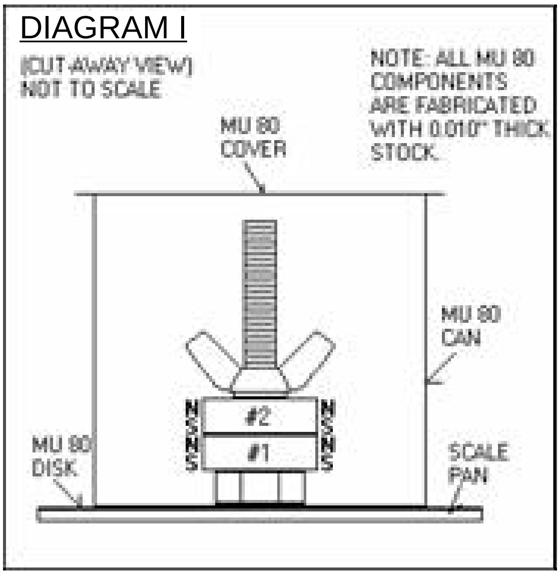

THREE RIVERS COMMUNITY COLLEGE, THAMES VALLEY CAMPUS LAB REPORT ON SmCo RING MAGNET EXPERIMENTS

The following experiments were conducted at the *Thames Valley Campus* (TVC) of the *Three Rivers Community College*, Room #207 Chemistry Laboratory, in Norwich, Connecticut on March 8, 2002. (41° 30' 34.62" N. latitude x 72° 6' 13.63" W. longitude x 115 feet elevation above mean sea level) I wish to thank the instructors at *Three Rivers* for their generosity for providing the use of their *Sartorius*® Model # 2442 analytical balance for the measurements taken in the proceeding experiments. The *Sartorius* Model # 2442 analytical balance is an enclosed pan unit with a maximum mass range of 200-grams with 0.0001-gram micrometer readability and a precision of 0.05-mg standard deviation.

The purpose of these experiments was to compare the Avery Point vertical measurements conducted on the *Mettler Toledo*® Model AG104 electronic scale, in **TABLE 1**, with the *Sartorius* Model # 2442 analytical balance measurements recorded in **TABLE 6**. The same two Samarium Cobalt magnets (magnet #1 and magnet #2) weighed individually in each vertical orientation were compared to the weight measurements taken when they were assembled using the nylon bolt and wing nut depicted in **DIAGRAM 1**. The specifications for the two Samarium Cobalt magnets used in the following experiments are shown in **DIAGRAM 1**.

The first column in **TABLE 6**, the vertical measurements, is the distance of separation d, or air gap, of the magnets. The second column shows the weight measurements of the two magnets, as shown in **DIAGRAM A**. The third column shows the weight measurements of the two magnets, as shown in **DIAGRAM B**. An inverted paper cup was used to raise the test sample magnets 2.75" above the *Sartorius* Model # 2442 balance scale pan in order to minimize possible magnetic interaction with the balance, as depicted in **DIAGRAM 2**. The fourth column shows the weight measurements of the two magnets, as shown in **DIAGRAM C**. The fifth column shows the weight measurements of the two magnets, as shown in **DIAGRAM D**. These experiments were shielded with

Mu 80 magnetic shielding material as depicted in **DIAGRAM 3**. The resultant data of **TABLE 6** is plotted on **GRAPH 6**. The results of the previous experiments at *Avery Point*, from **GRAPH 1**, and the recent *Thames Valley* experiments, from **GRAPH 6**, are plotted on **GRAPH 7** for comparison. The Mu 80 magnetically shielded experiments on the *Sartorius* Model # 2442 analytical balance at *Thames Valley* are in close agreement with the data collected with the AG104 electronic scale at Avery Point. However, the *Thames Valley* data collected for the unshielded experiments is somewhat smaller in weight reduction. I attribute this to external interference. The *Thames Valley* setup included a nonferrous tabletop, as did the Avery Point setup. However, the *Thames Valley* balance table consisted of a steel frame and legs, which may have altered the readings. The Mu 80 shielding provided a more intrinsic method for accurate data collection.

The horizontal measurements were not taken in this set of experiments due to time constraints. A final experiment was attempted to replicate the relative weight increase with the opposite poles of the ring magnets "stuck" together, as depicted in **DIAGRAM I**; however, the magnets shattered during assembly!

TABLE 6

	03/08/2002 TRCC EXPERIMENTS, @ TVC: OPEN, WITH PAPER CUP		03/08/2002 TRCC EXPERIMENTS, @ TVC: WITH MU 80 SHIELDING	
Air gap d	**Diagram A** N to N vertical 19.8734-gram (Sum of 1 & 2)*	**Diagram B** S to S vertical 19.8726-gram (Sum of 1 & 2)*	**Diagram C** N to N vertical 19.8912-gram (Sum of 1 & 2)*	**Diagram D** S to S vertical 19.8929-gram (Sum of 1 & 2)*
0.0 Inch	19.8699-gram 0.0035-gram weight reduction (0.01761%)	19.8696-gram 0.0030-gram weight reduction(0.01510%)	19.8691-gram 0.0221-gram weight reduction(0.11110%)	19.8706-gram 0.0223-gram weight reduction(0.11210%)
1/8 Inch	19.8699-gram 0.0035-gram weight reduction(0.01761%)	19.8699-gram 0.0027-gram weight reduction(0.01359%)	19.8688-gram 0.0224-gram weight reduction(0.11261%)	19.8707-gram 0.0222-gram weight reduction(0.11160%)
1/4 Inch	19.8695-gram 0.0039-gram weight reduction(0.01962%)	19.8695-gram 0.0031-gram weight reduction(0.01560%)	19.8687-gram 0.0225-gram weight reduction(0.11312%)	19.8712-gram 0.0217-gram weight reduction(0.10908%)
3/8 Inch	19.8695-gram 0.0039-gram weight reduction(0.01962%)	19.8699-gram 0.0027-gram weight reduction(0.01359%)	19.8692-gram 0.0220-gram weight reduction(0.11060%)	19.8730-gram 0.0199-gram weight reduction(0.10004%)
1/2 Inch	19.8689-gram 0.0045-gram weight reduction(0.02264%)	19.8699-gram 0.0027-gram weight reduction(0.01359%)	19.8695-gram 0.0217-gram weight reduction(0.10909%)	19.8738-gram 0.0191-gram weight reduction(0.09601%)
5/8 Inch	19.8686-gram 0.0048-gram weight reduction(0.02415%)	19.8699-gram 0.0027-gram weight reduction(0.01359%)	19.8702-gram 0.0210-gram weight reduction(0.10557%)	19.8746-gram 0.0183-gram weight reduction(0.09199%)
11/16 Inch	19.8680-gram 0.0054-gram weight reduction(0.02717%)	19.8699-gram 0.0027-gram weight reduction(0.01359%)	19.8707-gram 0.0205-gram weight reduction(0.10306%)	19.8756-gram 0.0173-gram weight reduction(0.08697%)

* Magnets #1 and #2 were individually weighed in the orientation used in each experiment and their separate weights were added together.

NOTE:
March 8, 2002 Experiments: Start time: 12:12 hours EST, End time: 13:47 hours EST.

GRAPH 6:

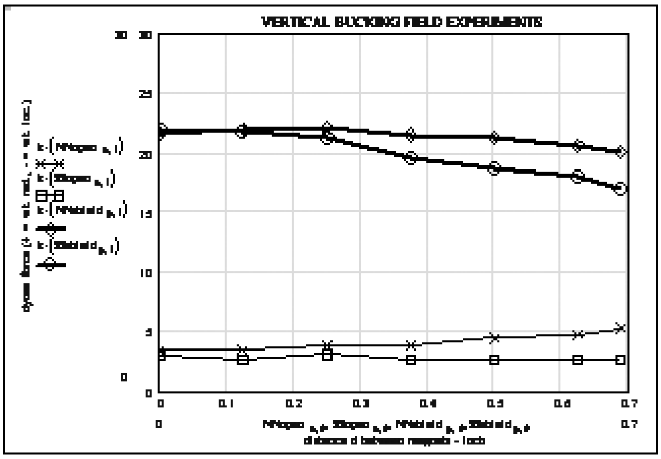

MAGNETIC DECLINATION FROM THE LOCAL TOPOLOGICAL MAP

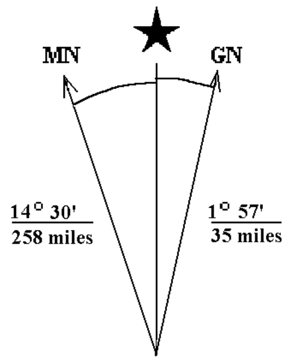

1983 Magnetic Declination~ U. S. Geological Survey Norwich, Connecticut Quadrangle Topological Map

GRAPH 7:

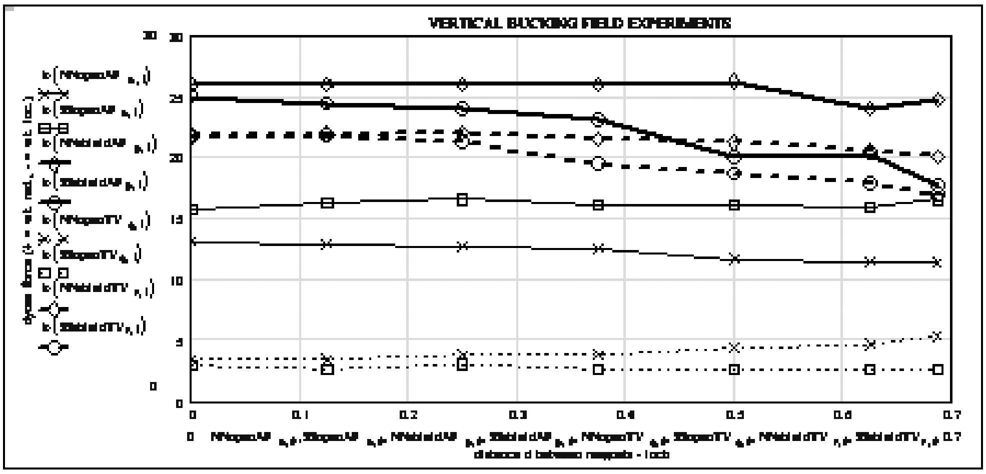

KEY TO **GRAPH 7**:

For N-to-N pole facings in the open (or unshielded) at Avery Point (AP):
NNopenAP
For S-to-S pole facings in the open (or unshielded) at Avery Point (AP):
SSopenAP
For N-to-N pole facings shielded with Mu 80 shielding at Avery Point (AP):
NNshieldAP
For S-to-S pole facings shielded with Mu 80 shielding at Avery Point (AP):
SSshieldAP
For N-to-N pole facings in the open (or unshielded) at Thames Valley (TV):
NNopenTV
For S-to-S pole facings in the open (or unshielded) at Thames Valley (TV):
SSopenTV
For N-to-N pole facings shielded with Mu 80 shielding at Thames Valley (TV):
NNshieldTV
For S-to-S pole facings shielded with Mu 80 shielding at Thames Valley (TV):
SSshieldTV

The subscripts for the data points $_{n} = {}_{p} = {}_{q} = {}_{r} = 7$ are all the same value in **GRAPH 7**.

Advanced Nuclear Waste Decontamination Technologies

Mark Porringa

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Deep River, Ontario K0J 1P0, Canada
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It is a review of nine alternative, peer-reviewed techniques as candidates for the global clean-up of nuclear waste.

The following is a reasonably comprehensive list of potentially effective nuclear waste treatment methods that might be employed to treat the entire range of radioactive wastes that have proven to be such a daunting and horrendously expensive problem for the nuclear industry (in all its forms) with major, long term implications for the environment.

A wide variety of methods will probably be required to accommodate the many different radioactive waste sources including high and low level, solids, liquids and gases. Process names used here are in some cases just convenient labels used to categorize and set them apart from each other.

Theories on several of these processes are still quite speculative and solid evidence that would pass conventional peer review is still lacking. This is after all a very new field of science.

Some of these technologies are already well protected by international or national patents, with additional US and international patents pending, and further patents may be obtained on new developments as they are made.

The Brown's Gas-Metal Matrix Process:

The BG-MMX process utilizes a patented electrolysis cell of the Australian Prof. **Yull Brown**'s design that is said to produce a stoichiometric mixture of monatomic hydrogen and oxygen or possibly a quasi-stable water molecule raised to a high-energy state. This gas has some very peculiar properties including the ability to sublimate tungsten (6000°C) with an implosive flame that burns cool in air with a temperature of only 130°C.

The gas is used to heat a proprietary mixture of metals and/or metal oxides including the radwaste to be neutralized. A highly exothermic radiant reaction appears to result in the immediate reduction of radioactivity approaching 95% of the original levels judging from preliminary tests, within seconds of treatment. The process is conjectured to be effective with high level solid wastes and possibly gasses, but probably not liquids. The high temperatures involved may also preclude the processing of more volatile wastes.

Since 1991, this technology has been successfully demonstrated, on a small scale, at least 50 times to US, Chinese, Japanese and United Kingdom officials on a variety of nuclear waste products including Americium, Cobalt, Uranium, and Plutonium. The technique can be applied for the immediate decontamination of stockpiles of nuclear waste materials being held near nuclear power plants. The process is very simple, safe, and inexpensive to develop further into robotics application for on-site treatment with no foreseen environmental effects.

Photoremediation

The *Photoremediation* process of the American Dr. **Paul Brown** is essentially conventional physics, *albeit* applied in a new and novel way. The process involves the use of a high-energy electron beam impinged on a target, which in turn produces a monochromatic gamma radiation that is tuned to induce *Photofission* and *Photoneutron* reactions in the target material causing rapid neutralization of radioactive isotopes. The efficiency claimed exceeds 500% due to the high cross-section reactions in the Giant Dipole Resonance region. The 10 MeV electron beam produces typical fission reactions in the 200MeV range effectively turning high level solid wastes such as spent fuel into an energy source. The process is apparently intended for on-site treatment with some waste-partitioning required, an aspect which may not be desirable in certain countries.

While this idea is similar in topology to a system being developed by **Los Alamos National Labs**, Dr. Paul Brown's approach offers several advantages: no need for extensive chemical pre-processing and the energy required to effect transmutation is greatly reduced. No new technology needs to be developed, yet the engineering of such a photon reactor must be completed and it could itself become a practical method for generating power.

ZIPP Fusion

The ZIPP fusion process, identified by **Mark Porringa**, induces a wide variety of fusion reactions, resulting from the radial compression of individual diatomic and other simple molecules dissolved or suspended in a light water, carbon arc electrolysis cell. A variety of other cell configurations are envisioned.

The process appears to produce only stable isotopes, which should therefore make it capable of stabilizing a wide variety of radioactive waste materials. The theory on the process draws from Condensed Charge phenomena, Brown's Gas implosion, cavitation bubble collapse and sonoluminesence - all variations of the Casimir effect - which is believed to cohere the Zero-point energy of Quantum Vacuum Fluctuations. Transmutations using variations of this basic process may be applicable to a wide variety of nuclear wastes and appears capable of operating with an efficiency exceeding 100%.

A major implication of this process is that the Strong force of the nucleus is understood as an ultra close range Casimir effect. **Oakridge** Nuclear Laboratories in the US in conjunction with several international collaborators have just (this month, in fact) announced a deuterium cold fusion process based on the essential elements of the ZIPP Fusion process first reported in 1998. The process is very simple and inexpensive to develop.

RIPPLE Fission

The RIPPLE Fission process is an adaptation of existing potential technology utilizing a supersonic ionized gas to aerosol a counter flow heat exchanger that envelopes the radioactive waste aerosol in a vacuum induced plasma vortex which appears to disrupt the matter stabilizing influence of the Quantum Vacuum fluctuations resulting in "gentle" low recoil fission reactions which produce only stable fission products, with excess neutrons being prompt converted to protons via quenched Beta emissions. The process is apparently proven with conventional non-radioactive wastes and is believed applicable to the entire spectrum of radwaste without the need for waste partitioning. This process is also conjectured to operate with over-unity efficiency.

The LENTEC Processes

The Low Energy Nuclear Transmutation Electrolytic Cells of the Cincinnati group produce a variety of transmutation reactions using a variety of exotic electrolysis cell designs that generally produce condensed charge clusters composed primarily of up to 10^{11} electrons each. These electron charge clusters produced with the use of special electrodes can penetrate the nuclei of larger atoms in solution and transmute these atoms into stable elements.

The range of design and operating protocols and potential applications are essentially limitless provided for the waste that is dispersed in the electrolyte. The reported transmutation of thorium to stable titanium and copper by the Cincinnati Group and by the Salt Lake City group is one of the most dramatic examples of this type of treatment process. Application to other high-level liquid transuranic fissionable wastes such as surplus Plutonium seems likely. The glaring absence of normal fission yield energies is perplexing but probably explicable as another form of low recoil fission reaction, similar to RIPPLE fission.

The Plasma Induced/Injected Transmutation - PIT Processes (also known as HDCC)

Plasma Induced/Injected Transmutation processes run include a gamut from recent achievements dating back to the **Oshawa-Kushi** cold plasma transmutations reported in 1964. The patented high-density charge cluster process (HDCC) was first discovered by **Kenneth Shoulders** and added on to by **Harold E. Puthoff**. Later, the late **Stan Gleeson** discovered HDCC in properly processed solutions. Still later, **Alexander Ilyanok** of Belarus discovered HDCC, followed by **Vasiliy Baraboskin** in Russia.

The production of Condensed Charge Clusters and various plasma glow discharge phenomena in a variety of gaseous atmospheres is again implicated as the underlying cause with what should be by now an obvious connection with the coherence of Zero-point energy from the Quantum or Stochastic vacuum.

Desk-top high energy particle accelerators have also been envisioned, based on the "piggy back" principle, in which the clusters permit acceleration of "piggy-backed" heaver +ions to extremely high energies capable of causing fusion and transmutations in target materials including those in solution and the materials of which the electrodes are composed. Brown's Gas implosion and cavitation bubble collapse reactions are also believed to be prevalent in these types of cells due to the prevalence of electrolysis.

A high-density charge cluster technology was discovered and used by Stan Gleeson to stabilize radioactive liquid wastes and has been developed further in the last 4 years by a group led by **S-X Jin** and **Hal Fox**. Best results for radioactive liquids have been demonstrated in the processing of thorium for a 30-minute period and achieving a reduction of radioactivity of about 90% from a liquid sample.

Kervran Reactions

The very compelling evidence compiled by French Nobel Candidate Dr. **Louis Kervran** has identified a wide range of nuclear transmutations in biological systems that have not been adequately explained. Coherence of Zero-point energy via Casimir effects within the *Somatid* particles identified by the Canadian **Gaston Naessens** is implicated as a possible cause. A wide variety of *in vitro* and *in vivo* reactions are believed to be possible as proven in nature and numerous experiments typically involving a reaction medium composed of a dielectric fluid such as water. Highly radiation resistant microorganisms have been found thriving in the core of nuclear reactors indicating the possibility of microorganisms being capable of transmuting some bioactive nuclear wastes in the course of the normal metabolism of such organisms.

The Monti Process

The Italian **Roberto A. Monti's** process involves confined explosions involving proprietary mixtures of materials that include radioactive waste. Ignition of such mixtures causes nuclear transmutations resulting in reduced radioactivity (to near-background levels) following combustion, gradually over 1 to 4 days.

This technique has been confirmed by the Italian **ENEA** and is supported by the French CEA scientists as a serious candidate for treatment of waste stockpiles. The system, as currently designed, required waste to be inserted into a chamber.

Higher group symmetry electrodynamics

Extremely weak, non-classical, higher group symmetry electromagnetic fields were found during a 1991 experiment made by **Glen Rein** to alter significantly the level of radioactivity in materials, even those in the environment. The experiments suggest that higher group symmetry electrodynamics modulate the quantitative and /or qualitative properties of radioactive species. If the non-classical fields directly affect the radioactive species, it is likely that the appropriate field parameters will be discovered to neutralize radioactive emissions. In 1999, a theoretical basis for the phenomenon was developed by the Welsh physicist, **M. W. Evans**, with the participation of Lt. Col. (retired) **Thomas E. Bearden**.

The technology is extremely simple and could be applied with minimum logistics for treating massive structures, *in-to* outdoors, such as the Chernobyl disaster site.

Psitronics Group Systems, International

Robert "Paul" LeBreton, 2901 Hwy. 6, HC 77 Box 42, Laguna, NM 87026 USA

E-mail: wizzard9@earthlink.net Phone:1-(505)-836-7534

Psi/Group's Magnetic Motor - Funding for New Prototype Sought:

As the engineer who designed the self-sustaining magnetic motor being advertised by Psitronics Group Systems, International. It perhaps falls upon me to explain (as well as I am able) the methods used by me in this motor's design:

The actual "picture" description is totally Intellectual Property; Protected as a Trade Secret.

However: This magnetic motor is a "perpetually imbalanced configuration" of permanent magnets; an unequal number of magnets on the rotor & stator; that revolves in a "self-sustaining" manner as the magnets seek balance... There are no electrical components in the design unless one wished to insert alternator windings in the stator to provide an electrical output...

We have discovered: through a prior unsuccessful prototype that using a para-magnetic material (we used aluminum) for the rotor & stator was self-defeating; as with the powerful rare earth magnets used in the design aluminum destroyed the magnetic fields... On further analysis of the failed prototype it was deduced that a "latch up" condition would occur between rotor & stator magnets; unless the rotor magnets were canted or skewed at an angle from the stator magnets... The plastic prototype contemplated corrects both of these problems....

We are seeking an investor willing to put up $4000 (DUS) for the prototype and who can offer $40,000 return on investment "if it proves successful" ...We have a Global Distribution 'ready to go" as well as a pledge of $ Millions towards Manufacturing & Marketing from EarthTech, International on submission of a running motor...

Very Respectfully Yours,
Paul LeBreton

http://home.earthlink.net/~wizzard9
(Psi/Group Website)

Inquiries should be emailed to:
wizzard9@earthlink.net

Experimental Investigations of the Radioactive Isotope Half-Value Period Changing in the Local Volume of Cause-Effect Relations

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Nuclear-design methods of the elemental analysis are based on the property of the radioactive isotope decay rate constant. Half period as a constant quantity is defined by the time feature (the time flow is uniform in the every space point). The given postulate is confirmed by the long-term results and raised no doubts. But in last years some researches, investigating enough fine effects by change of the registered radiation intensivity, came to the conclusion about influence of space cycles on the time flow [1]. In his turn, N. A. Kozyrev during the investigation of active physical properties of time came to the conclusion about violation of its uniform flow in the local volume of the cause-effect relations, created by the cyclic motion (rotation, oscillation) of bodies [2,3,4].

Thus, the author get an idea to use a radioactive isotope cezium-137 as a "sensor", measuring the changes of time flow uniformity in the certain local volume of cause-effect relations. In basis there are following arguments: owing to a conception of time uniformity and considerable cezium-137 half-value period, the source activity must be permanent during the experiment time. By the time flow (period) change, i.e. changes of uniformity in the local volume of cause-effect relations, the half-value period – T is changing in the direct proportion. Source activity, respectively, is changing in the inverse proportion according to the law exp (1/T) in relation to the external space volume. Hence, registered gamma-quantum intension (amplitude impulse distribution) in the absence of the cause-effect relations is proportional to the function $N_0 \sim \exp(\ln 2/T_0)$. Then the proportion $N_0/\Delta N$, where $\Delta N = N_0 - N$ is made, and by means of it a half-value period difference is defined by the formula

$$1/\Delta T = \left| 1/T_0 + \ln(\Delta N/N_0)/\ln 2 \right| \qquad (1)$$

N_0 – selective average amplitudes of impulses at the case of static liquid (in the absence of the cause-effect relations);
N - selective average amplitudes of impulses at the case of rotation of liquid.

In this case, there were investigations of the determination of the gamma-quantum intension change (i.e. change of a half-value period) dependence on the angular velocity of the activator rotation, and also on the coordinates location and amount of cause-effect relations (Fig. 1).

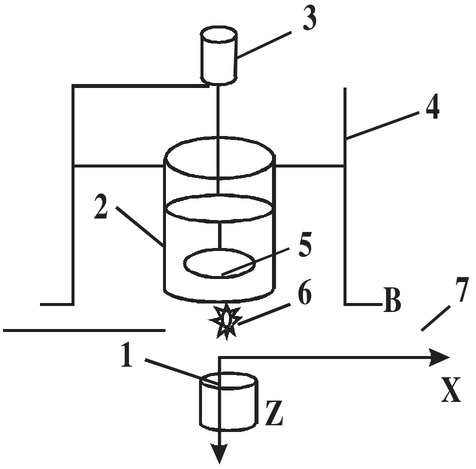

Fig.1

The following devices were used as measurement equipment: semi-conducting detector (SCD-63V) (1), preamplifier (PAG-2K), amplifier (BAI-3K) and analyzer (AMA-02F1). Energy gamma-line of 662 KeV was measured with the resolution 4 KeV. The gamma-quantum source was glued to the detector housing at the distance of 100 mm from its surface; so, any spatial change through coordinate axes was executed together with the detector to avoid even a tiny change of the source-detector geometry.

The vessel with a liquid (2) was placed above the source (6), vortex fluid motion was created by an activator (5), placed on the rod of electric motor (3). The glass with a liquid, connected with the motor and frame (4), was displaced regarding to the center of the revolved activator, what was the reason of the glass vibration in horizontal line, and, hence, one of frame sides vibration in vertical line (v). In its base, the frame was a square with the side of 200 mm. To assign the direction of the space cause-effect relations, one of frame sides was vibrating, and the opposite one (on the X axis) was fixed on the table (7). An experiment was made in such a way, that vibrating parts did not adjoin with the detector. The radius of glass is 50 mm, the distance from central axis up to the vibrating frame part is 100 mm. N-selection of the every value on the diagram (Fig. 2) corresponded to twenty measurements, roots from the average variance of numbers distribution $D \approx 160$ impulses.

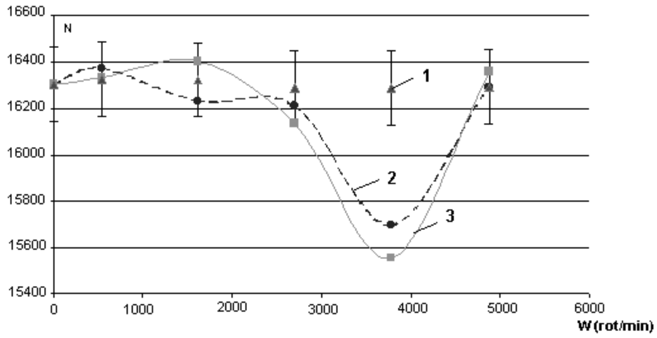

Fig. 2
Dependence of photopeak-N area from the angular velocity of rotation – W, where 1 – is photopeak area at static liquid, 2 – is photopeak area at clockwise rotation, 3 – is photopeak area at anticlockwise rotation

During two months eighteen experiments were made (at the one geometry) of the given effect fluctuation study, and there were no considerable deviation. An effect of the time deceleration always appeared at the angular speed of the activator rotation W=3780 r/min (during the vibration of the whole perimeter of the frame base). If there was a vibration on the only one side of the frame base (on the X axis), then this effect appeared at the higher speed of rotation. Unfortunately, the maximum motor speed of rotation W_{max}=4880 r/min did not let to define the precise position for the next rotation point. During the experimental results extrapolation $W_2 \approx 5930$ r/min ($W_2 \approx \pi W/2$) was obtained.

In the table there are selective middle amplitudes of impulses $-N=\sum N_n/n$ roots from the numbers distribution average variance D, dispersion of the simple average G at the different directions of the liquid rotation (for the rotation point W=3780 r/min). The half period is estimated by the equation (1) and formula $T=T_0+\Delta T$ where T_0=30.2 year (the cezium-137 half-value period).

Liquid motion	N, imp.	D	G	T, year
Static liquid	16304.0	160.7	35.9	30.200
Clockwise	15696.0	162.0	36.2	30.412
Anticlockwise	15553.0	165.0	36.9	30.423

During the investigation of the activator angular speed of rotation dependence on the registered gamma-quantum intension, **there was discovered the time deceleration effect in the fixed point of ambient space of the glass with the liquid.** The effect was versatile, during the further study of the reasons of the effect disappearance, the following regularities were found:

1. Intension change appeared only at the case of asymmetrically fixed glass, when there appeared horizontal oscillations, transmitted to the vertical oscillations of the frame;

2. An effect disappeared, if the gamma-quantum source was placed in the glass center (~ 2 ÷ 3 mm down from the glass bottom);

3. At the same speed of rotation but without liquid, with an eccentric activator, the time deceleration effect disappeared.

Will consider the system with liquid, its internal chain consisted of three cause-effect relations:

1. Activator-liquid;
2. Liquid-glass (frame);
3. Frame-table.

Glass oscillations were transmitted to the frame through the hard cohesion. There was only one cause-effect relation – an activator (a frame) – a table. Thus, amplitude of the time flow changing was, most likely, influenced on by the amount of cause-effect relation, and also, there was observed a quantum effect, dependent on the activator and liquid rotation frequency.

The time deceleration maximum amplitude appeared during the source displacement from the central axis of glass along the X coordinate to the distance ~ 5 mm. There appeared the necessity to check the given effect on space points along the all coordinate axes in the radius R ≈ 100 mm from the central point of the glass bottom (an extreme vibration point along the X axis was placed on this distance).

On this purpose there were made some experiments, results of which are shown on the (Fig. 3), (Fig. 4).

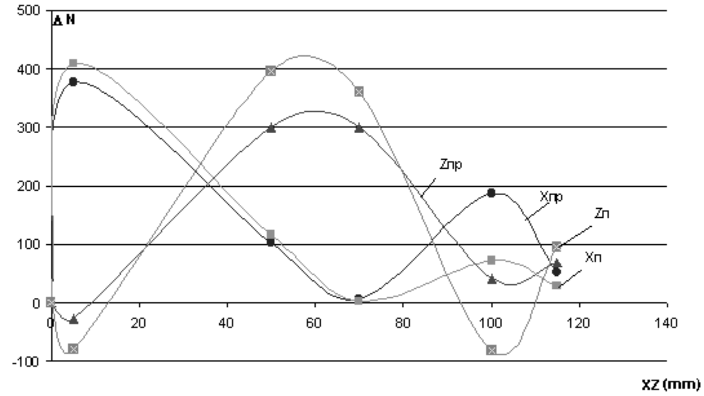

Fig. 3
Dependence of the increase of photopeak -ΔN area from the spatial interval in Cause-Effect Relations by X and Z coordinates, where X_cZ_c – is clockwise rotation, $X_{ac}Z_{ac}$ – is anticlockwise rotation

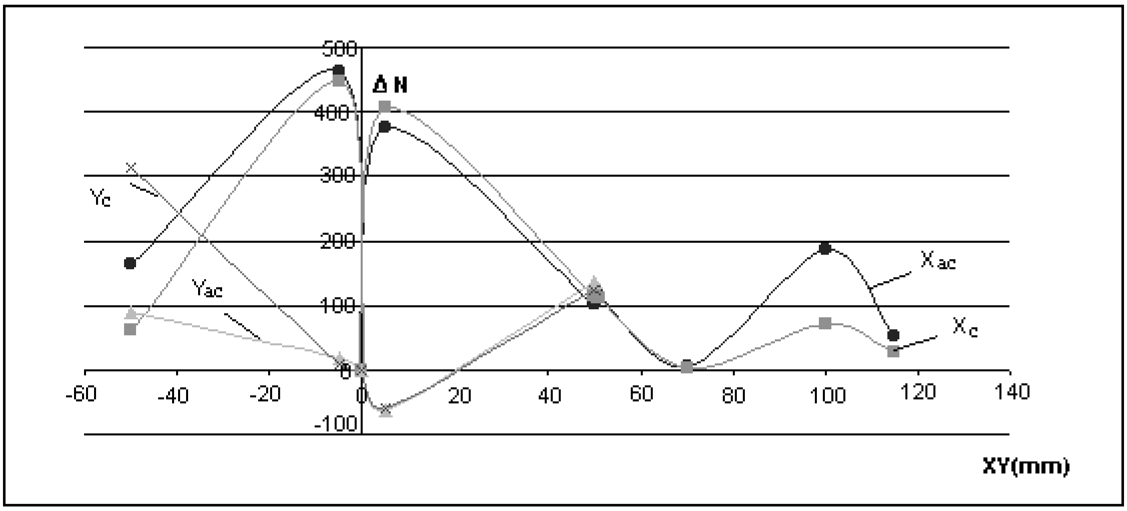

Fig. 4
Dependence of the increase of photopeak -ΔN area from the spatial interval in Cause-Effect Relations by X and Y coordinates, where X_cY_c – is clockwise rotation, $X_{ac}Y_{ac}$ – is anticlockwise rotation

Let us suppose that positive axis Z is directed from the glass bottom center to the ground and axis X – from the central axis of glass to the vibrated part of the frame (North-West), in this case Y is directed to the North-East. Along the all coordinates, in every adjusted space points on the distance R_i from the glass bottom center (R_i = 5; 50; 70; 100; 115 mm), there were forty measurements. At that in every point after ten measurements connected with the rotation there were measurements at the static liquid. It was made to avoid any systematic errors. The amplitude of the sample average impulses at the static liquid - $N_0=10550$ imp. In this case the root from the dispersion $\Delta=120$, dispersion of the simple average G=19. Amplitude increment was calculated by the formula $\Delta N=|N_0-N|$. Following regularities were found:

1. If considering the difference of impulse amplitude (in the positive coordinate space) in the first cause-effect relation evidence (activator-liquid), i.e., to put the difference between the initial (5 mm) and final (50 mm) points of amplitude registration (their middle evidence between "clockwise" and "anticlockwise") $\Delta N_5^{50}=|N_5-N_{50}|$ into the formula (1), then relations $\Delta T_Z/\Delta T_X=\Delta T_X/\Delta T_Y\approx1.11$ ($\pi/2\sqrt{2}\approx1.11$)

2. Change of impulse amplitude difference along X is the antiphase of changes along Z and Y;

3. At the rotation clockwise and anticlockwise there takes place a periodical inversion of amplitudes difference relation;

4. At the liquid rotation clockwise and anticlockwise, there appears an obvious distinction in evidences of the increment ΔN in negative region of coordinate axes;

5. Along Y and Z-axes in points (5; 100 mm) there is observed insignificant time acceleration.

The whole cause-effect relation system was defined as an internal (activator-table), as an external one (ground - system center of gravity). **In the internal space volume time at the certain conditions breaks its own uniformity, at that the time period change is nonlinear and is defined by its quantum nature.** Therefore, standard clocks in causal relations must be considered regarding to the center of gravity and location of the measurement point in the internal system space.

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TILLEY ELECTRIC VEHICLE

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Nowadays there stays urgent the development of technologies, which could possibly be combined into a reliable, commercially successful advanced self powered vehicle with additional desirable but currently commercially unavailable features.

The advantages of electric vehicles seem to be evident – they are clean, quiet, powerful, require much less maintenance than gasoline or diesel-fueled vehicles, and are inherently much simpler and easier to manufacture. Their drawbacks have been a short range, long battery recharging time, and a heavy, bulky battery pack.

After several years of personal accomplishments in the alternative energy industry, **Carl B. Tilley, the inventor from USA,** was convinced that it was possible to build an electric car that could be powered without the help of external power to keep the battery charged.

The concept to produce a useful electric performance car that would last more than a few hours and would be economical to run, safe to drive around town or across the United States and never use a drop of fuel challenges the future of transportation as we know it today.

With the establishment of the **Tilley Foundation, Inc.**, in the year 2001, Carl Tilley set out to prove it could be done. It was an ambitious project and it broke ground on the facility in Tennessee that would build the first self-generating electric car.

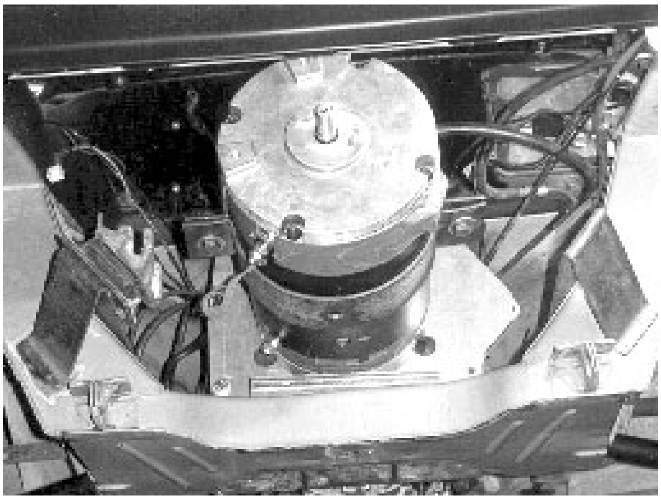

Construction of a 1,800 square foot building, that was powered with another recently developed electric device, began in the year 2002. Electricity for this car is provided from a different energy invention, which was void of any outside power supply. It is ironic that one alternative energy device actually built the invention to power and build the electric car.

The **Tilley Electric Vehicle** (**TEV**), converted from a 1981 DeLorean, energizes the imagination and defies what has been accepted as a standard in the area of transportation for years.

From the selection of the proper car to be converted, to the advanced technology, which is on board, the **TEV** performs comparably to gasoline-powered vehicles.The difference is you have no need for fuel and you do not have to stop the vehicle to charge it after driving. There is no pollution and you can cruise the highways at the same speed as any other vehicle.

There is a new car on the road today. A car built with technology that defies the concept of fossil fuel powered cars, and can run coast to coast without ever relying on the battery being charged from an outside source.

The long awaited transportation revolution and the end of our reliance on fossil fuel has now begun **....the Tilley Electric Vehicle.**

The demonstration of a DeLorean powered by an electric motor and 12-volt standard car batteries is supposed to be on September 7, 2002, at the Nashville Superspeedway, USA. The battery bank is kept in a charged condition by the “on board” charger which is the device invented by Carl B. Tilley. Racing legend Bobby Allison is one of the guest drivers for this demonstration.

Details and results of the demonstration read in our next issue

The Problem of Time: Force as the Cause of Change of the Course of Time

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Abstract

Material processes occurring in a physical system under the action of a force field necessarily influence the course of time along the trajectory of motion of particle. A general relationship is obtained which relates the course of time on one path section of a particle when moving in a force field to that on the other path section in the same inertial reference frame. According to the results obtained, the force in relativistic mechanics is not only the cause of acceleration of particle relative to an inertial frame of reference, but also the cause of change in the course of time along the particle's trajectory. ***Therein lies the physical content of the dynamical principle underlying the special theory of relativity (relativistic mechanics).*** *The applications of the theory developed to homogeneous fields - to the field of gravity and electromagnetic field, and to the gravitational field produced by a point mass particle are considered. Physical properties of the state of imponderability of particle in an external force field are investigated. It is noted that the change in the course of time in a force field is in no way connected with the change in space-time metric and is a direct consequence of the causality principle of relativistic mechanics.* ***The existence of dependence of the course of time on the state of motion of particle in a force field points to the feasibility of controlling the course of time using force fields.***

Time is among the most common concepts, which are used constantly both in everyday life and in science. This is because all the events and material processes in the world happen in space and develop in time and, hence, the laws that govern space-time connections are the most general and hold for all the forms of matter. Nevertheless, time remains one of the most mysterious concepts of physics; its physical essence is not adequately revealed up till now [1-4]. The concept of time with difficulty yields to logical analysis.

From the point of view of common sense the essence of time is that time characterizes the duration of events and processes, indicates their natural sequence, at which the present, going away to the past, gives place to the future.

Isaac Newton gave a clear-cut characteristic of the concept of time, to which the majority of physicists adheres: "The absolute, true, and mathematical time in itself and by virtue of its nature flows uniformly and regardless to any other object". Though, according to Newton, time flows equally and uniformly and does not depend on the processes, occurring in the world, the daily experience speaks in favour of the fact that the course of time is not uniform. Depending on circumstances in our history, it seems to us that time either flies swiftly or hangs heavy on our hands; sometimes it even changes suddenly, by leaps. In connection with these speculations the question arises of whether the subjective sensations of non-uniformity in the course of time familiar to everyone have an objective basis.

In Newtonian mechanics time is of an absolute character, it does not change as one passes from one inertial reference frame to another and represents merely a parameter, whose change at the will of explorer results in the change of state of a mechanical system in accordance with the equation of motion.

In relativistic mechanics time remains a parameter describing the development of system. But now time and space are intimately linked with each other to form a single system, i.e. the 4-dimensional space-time. In going from one inertial frame of reference to another time gets entangled with spatial coordinates, so that time in one reference frame represents a "mixture" of time and coordinates in the other. Time ceases to be universal, the same in all inertial reference frames; it takes on a relative character.

The indissoluble association of time and space takes on special importance in the light of the concept of physical field, which was called by Einstein the most important discovery in physics after Newton. According to this concept, the occurrence in space of a force field means that space turns into a physical environment, which is capable to interact directly with other bodies and gains, thus, physical properties, becoming an active participant of physical processes. In view of the fact that **space and time are indissolubly related to each other, the presence of a force field in some area of space must necessarily result in the appearance of physical properties of time caused by the motion of body in this area.**

Thus, from the synthesis of the notion of space-time and of the idea of physical field it follows with necessity that **the course of time in a given region of space should depend on physical processes in this region, i.e. time, as well as space, should have physical properties [5-8].**

It should be emphasized that in special theory of relativity (STR) time and spatial coordinates are independent and formally equal in rights quantities, which determine the position of elementary events in space-time. On the other hand, time stands out in relation to spatial coordinates. The special role of time is due, from the viewpoint of geometry, to the pseudoeuclidity of geometry of the 4-dimensional space. From the physical point of view, it is associated with the dynamical principle (causality principle), according to which the state of motion of a physical system at an instant of time t uniquely defines its behaviour at the next instant of time $t+0$. The significance of dynamical principle lies in the fact that it relates the temporal evolution of system to the physical processes caused by force fields and in doing so it allows one to determine the course of time in the system, its possible dependence upon the character of physical processes, and not just the sequence of events and their duration.

The idea about the existence of the physical properties of time belongs to N. Kozyrev [9]. By introducing into mechanics an additional parameter taking into account the directivity of the course of time, Kozyrev has formulated causal (asymmetrical) mechanics from which it follows that time has physical properties. According to the results of theoretical and experimental investigations conducted by Kozyrev and his followers [9-13], events can proceed not only in time, but also with the help of time, **information being transmitted not through force fields, but via a temporal channel, and the transfer of information happens instantaneously. The appearance of additional forces, associated with the physical properties of time and capable to fulfill work, testifies that time can serve as a power source.**

In the papers by I. Eganova [12] and M. Lavrent'ev and I. Eganova [13] it is stated the problem of direct experimental research of the physical properties of time to ascertain the relations of a new type between phenomena and to discover new methods to change the state of substance. In [14] O. Jefimenko investigated the dynamical effect of the slowing-down of time.

According to [6-8], the conclusion that physical properties of time exist follows strictly from relativistic mechanics, without introducing any additional hypotheses. The physical properties of time are of purely dynamical nature: their existence results from dynamical principle. **The availability of physical properties of time is manifested in that time has a local inhomogeneity: its course along the trajectory of motion of a point particle in a force field is continuously changed, and this change in the course of time is a result of the action upon the particle of a force field in the inertial reference frame, in which the motion is considered.**

Editor's note: The author gives a detailed consideration of the physical content of the local dynamical inhomogeneity of time. Considering the motion of a classical point particle under the action of a force field in the inertial reference frames, that moves relatively to each other, Valentin P. Oleinik derives 73 equations, that help him to obtain the following conclusion (mathematical details and physical reasoning may be found in http://temporology.bio.msu.ru/OLEINIK/oleinik.htm.*)*

The elucidation of the physical nature of time is one of the most important problems of theoretical physics. The purpose of research on the problem of time is to study the physical properties of time, i.e. to ascertain the possible interrelation between time and material processes. In particular, it is of interest to find out

- whether the flow of time depends upon physical processes and whether the back influence exists (i.e influence of the change of the time course on physical processes);
- what mechanisms of the change of the course of time are available;
- what factors are capable to speed up or to slow down the flow of time.

In papers [5-8] on the basis of Lorentz transformations relating to coordinates of points, lying on the trajectory of motion of particle in a force field, the phenomenon of local dynamical inhomogeneity of time is predicted. The main result consists in the proof that material processes occurring in a physical system under the action of a force field necessarily influence the course of time along the trajectory of motion of particle. The case in point is the change of the course of time along particle's trajectory in one inertial reference frame as compared with that in the other.

In this paper the next step is made: the relationship is obtained which relates the course of time on one path section of a particle when moving in a force field to that on the other path section in the same inertial reference frame. The main idea underlying the approach developed results from the analysis of Lorentz transformations and consists in that **the course of time of a particle moving by inertia, i.e. of a particle being not exposed to force, should be uniform.**

As is well known [17,18], the existence of dependence of the course of time upon the gravitational field potential is predicted with the general theory of relativity (GTR). According to GTR ([17], p.303), time flows differently at the different points of space in one and the same reference frame. Since "gravitational field is nothing more nor less than a change of the space-time metric" ([17], p.313), one can assert, apparently, that the change in the course of time is due, in the view of GTR, to the change of the 4-space metric. It should be emphasized that in the present paper gravitational field is considered as an ordinary force field, and the particle motion is supposed to occur in pseudo-Euclidian space-time. The main formulas of the article, (22) and (25), describe the change in the course of time in an arbitrary force field at different spatial points in one and the same inertial reference frame. As is seen from the results received, the change in the course of time in a force field is in no way connected with the change of space-time metric. It is conditioned by the force field action on particle in inertial reference frame and is a direct consequence of the dynamical principle underlying relativistic mechanics.

It should be emphasized that the existence of dependence of the course of time on the state of motion of particle in a force field points to the feasibility of controlling the course of time using force fields.

Note an important peculiarity of the non-inertial reference frame, in which the imponderability state of a particle is attained: **there is such a space-time region in which the reference frame at hand can be approximately considered as inertial.** In connection with the fact that such reference frames (it is natural to call them **quasiinertial** in contradistinction to the **true inertial** reference frames) are, generally speaking, not equivalent to each other (see previous section), the derivation of a rigorous criterion for inertial reference frame acquires especial significance. The dynamical criteria for defining the inertial and non-inertial states are considered in the papers by B. I. Peschevitsky [19]. The heliocentric reference frame seems to be among the quasiinertial reference frames, being inertial with adequate accuracy only in a restricted region of space (for example, within the limits of our Galaxy) [16].

The author is grateful to Yu.D. Arepjev for his interest to the paper and stimulating discussions.

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Time and its Physical Relationships

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> *Time cannot be absolutely defined, and there is*
> *no inseparable relation between time and signal velocity.*
> *Albert Einstein [1]*

Time does not exist by itself

The phenomenon of time emerges in relationships – as an expression of properties of physical bodies and changes that occur to them.

Time is a factor of energy. Time has to do with the *increase* and *decrease* of energy. For example, as energy is brought down to a "zero level", time is "eliminated", so in a sense, time cannot be "compressed" - only eliminated. In the zero-energy level, electrons occupying this level in unlimited numbers are available through state transitions for the building of matter and the vacuum [2]. So it is the extent and the nature of energy flow that determines the characteristics of time.

How do we know all this?

In his seminal foundations of physics work of the early 1900s, **Sir Edmund T. Whittaker** demonstrated by canonical quantization that there exist physical, time-like and longitudinal photons *in vacuo* [3,4,5]. The 2 scalar potential functions, F and G which completely characterize an electrodynamic field due to electrons in the ether are:

$$F\,(x, y, z, t) = \sum \frac{e}{4\pi} \sinh^{-1} \frac{\bar{z}'-z}{\left\{(\bar{x}'-x)^2 + (\bar{y}'-y)^2\right\}^{1/2}}$$

$$G\,(x, y, z, t) = \sum \frac{e}{4\pi}\, \tan^{-1} \frac{\bar{y}'-y}{\bar{x}'-x}$$

In these equations, for the fundamental case in which a field is due to any number of electrons moving in any way, we observe that time emerges only through the displacement of energy. Another way of putting it would be that time emerges through change in energy.

These photons have an independent physical existence. Whittaker himself observed, after computation that the "total disturbance at any point, due to this system of waves, is independent of the time, and is everywhere proportional to the gravitational potential due to the particle at the point" [6]. **A. D. Sakarov** admitted that the gravitational field is a "conglomerate of loose things and not a fundamental field of nature at all [7].

Everything electromagnetic, and probably gravitational, starts from these potentials, not fields, and under certain circumstances, there may exist photons without fields being present at all. In the *vacuo*, the longitudinal light photon travels in the direction of the beam, like an energy capsule, as a scalar four-potential-function energy standing-wave field, with many different frequencies, with an internal symmetry based on circular polarization [8,9], an energy field or nexus that "has an end, but no beginning". The time-like and space-like parts of the four potential are photons with spin –1, 0 and +1 that are longitudinally directed, and which are observed in the ***Compton*** and the photoelectric effect [10].

Movement of light affects time

Philip S. Callahan designed an elegant experiment that shows how variations in the movement of light affect time [11]. Changes in exposure settings of photographs of same objects, including coherent light laser spots results in shift of position of images. The more coherent the light, the less apparent is a shift in time. He suggested that time is neither absolute nor independent of photon activity of space.

We can also state, as a corollary, that the *movement* of light generates time. After all, the electrodynamics is associated with photons. This is particularly significant in time engineering, as will be seen later.

Time and life

Now, it is well known that the ability of cells to sense the presence of light is a primary function of life itself. If a cell can sense light, it is alive; if it cannot, it is dead [12]. Callahan was able to observe that time increments were detected on light-detecting surfaces of living organisms such as the cuticles of leaves.

The Russian time researcher, **Nikolay A. Kozyrev** considered that living systems "consume" time for their life-energy [13]. **Velimir Abramovich** suggests that living organisms are naturally-driven "time machines". They each have an inbuilt time that serves as a "code" to structure their own physical totality and to regulate their own functioning. Thus their "local time" acts as a "time operator" ("time condition") frequency [14]. The nature and level of electromagnetic fields in living systems could therefore be considered as indicators of their "energy level" and how it affects and adjusts the inherent rate of time-flow.

Time and consciousness

We append to these statements the notion that, yes, time is "consumed" by living organisms – but only if they are conscious. Essentially, time can be perceived by measurement, which always requires a conscious observer.

When we measure, we observe the differentials of energy flow. It is the measurement of these differentials - as we note from the Whittaker equations of scalar fluxes - that allows us to the measure the equivalence of time. When we measure differentials, we are effectively creating our notion of time.

It is difficult for humans to conceive that time does not exist when humans think about it. **Saint Augustine** speaks for all humans with his observation:

> *While I do not think about time, I know that time exists. When I begin to think about it, I stop understanding what it is.*

With such conditioning, humans cannot come to grips with the notion that the Universe has no beginning and no end. It is like the paradigm of absolute nothingness – people cannot deal with the concept of no time because, effectively, consciousness, like life, consumes time. One could advance the notion that thought itself is time in motion. When we think, we are creating time. Life is movement – and the brain registers energy differentials and their associated fluxes of scalar potentials.

Time and causal mechanics

Since time is the result of movement of energy (and accordingly, light), then time is associated with the cause-effect processes linked to a first position of energy to the next. In other words, time is innate to causal mechanics.

Variations in energy flow, logically, lead to variations in the characteristics of time. They also permit variations in causality.

Conversely, changes in time lead to changes in physical structure [15]. This phenomenon was proven by Kozyrev and has been labelled as the ***Kozyrev effect*** [16]. He demonstrated that changes in the course of time affect the performance of electronic components. Figuratively speaking, a transistor is like a corral in which light behaves in a certain way. By changing the way that light behaves, a transistor becomes valueless.

To create an extra-temporal causality (with linkages to another level/dimension) one must change the light movement. Changing the light patterns means changing the behaviour of a wave, and its concordant photonic reality. By altering the photons, we make them go to another dimension.

Changes in time can effect change in living systems [17]. The engineering of "time-polarized" waves has the promise to target and amplify natural healing procession in living organisms. It is these natural activities that would restore diseased cells to their original and healthy condition [18]. Such time engineering may also include the reversal of the effects of AIDS, smallpox, anthrax, and most bio warfare agents, with treatment times of only a few minutes per week, with no more than 3 treatments required in all. Eventually it may also be possible to reverse the effects of genetic disorders, effect limb regeneration, and cure spinal cord injuries [19].

Engineering causality

Variation in the density of energy determines variation in the "the course of time". By the "speed of course of time" is meant the rate of causal transformation and the input of additional forces into systems (including mechanical tensions). According to Russian scientists [20, 21,22] there are interesting possibilities in deploying engineering for causal mechanics.

In preventive time engineering, one could delay the approach of a known cause and to artificially close the consequence loop, and thereby annulling it from ever achieving an effect. In other words, one can make the effect "happen" before its normal time, disrupting space structure with its related "speed of the course of time". One can also make it "happen" after its expected deadline. This technology could have interesting implication in strategic situations (preventing a extra-planetary body from attaining a collision course).

According to the Russian experience, when the spatial structure is disrupted by time-engineered causal mechanics, the affected region undergoes relative greater entropy (or, less order). The volume of space is forced out to somewhere else, generating torsion fields, much like a balloon will drift away from denser air. A similar phenomenon occurs when the velocity of a mass increases, the force emerges against it, called "inertia" [23]. Now, to increase velocity, the energy of the mass increases. In the case of time, as the movement of energy increases, interaction or reaction with another dimension ensues to compensate for that primary change [24].

The boundary layer between the two states of space can then act as a mirror and the approaching agent may be reflected back to its source. For example, a light beam may be reflected back to its emitter, in full, or in part, depending on the engineering.

With space-time engineering, we could develop teleportation systems [25]. The course of time goes from the past to the future, in the direction of greater disorder. Going back to the past represents deceleration. The etheric continuum is perceived by Kozyrev is containing variations of "density" of structural elements. The "denser" the etheric region, the slower is the course of time. A zone of accelerated time course would be forced out into "rarefied" ether. A zone of slowed time would be forced into denser ether, hence the basis for a teleportation technique.

In vivo experiments with a Time Machine

For over 15 years, a Russian association of scientists has conducted experiments with acceleration and deceleration of time with 4 prototypes of time machines

[26]. Light-heartedly, the units are called "muskrat traps" since the experiments conducted in remote forest were disguised as a high-tech electromagnetic technology for trapping muskrats. The time machine units are spheres ranging in diameters of 30cm, 1 meter and 2.1-meter. The shells are encased with coils designed to produce convergent waves.

Team leader **Vadim A. Chernobrov** describes converging electromagnetic waves as moving from a periphery to a central point. They are observed when a hoop is thrown into the water and inside the hoop the waves converge. If a potential is applied to do work and to initiate the energy differential process, the other reverse direction scalar (the reverse-time energy flow) must react. Thus, compensation of time - in the form of the deceleration or acceleration of the rate of time - can take place [27].

The first trials involved mice, in which most (25 out of 31) died. Eventually, there were successful 2-hours runs of time travel. An experiment with a dog that was clearly frightened also showed no ill effects. This led to experiment with humans, the first being **Ivan Konov** who, on August 26, 2001 decelerated into the past by 3% of planetary time during a half-hour trial. Dozens of others have experienced the phenomenon and report such sensations as: quicker pulse, giddiness, itching skin, body twisting, numbness at extremities and a case of an out-of-body experience. Harmful effects on living systems do not appear to be linked to the change of the rate of time, but rather to the variations of the time rate value among regions of a living organism.

Some individuals reported visual experiences such as "starry sky", "luminous vortices" and colour spots. Individuals observing outside of the time travel machine noted headaches. The most interesting phenomena occurred just before the start-up: significant presence of ozone for several hundreds of meters around the machine, which was located in a forest. Also noted were strange lighting effects in the sky above the apparatus, accompanied by sounds that inexplicably appeared to generated from inside.

Factors affecting the rate of time

The experiments yielded interesting observations: the phenomenon of the rate of change of time varies according to the hour of the day and according to the lunar phase. The rate can be influenced by a variety of external inputs, including mechanical vibration.

The transition into the future differs from than into the past. It is like movement from any point in a tree – where downwards represents past time. There are many paths possible towards the future – upwards, along the branches, but only one towards the past – downwards to the trunk. The return from the past time is possible only if the time traveler does not interfere with occurring events – or the possibility of returning to another branch of the tree. However, a return move from any variant of future time is possible regardless of the behaviour of the traveller.

The Russian time-travel experiments point to a relationship between inertia and time. In changes of rates of time, the region adjacent to the spheres develops a boundary layer effect, appearing as an aura of "white mist". The greater the time differential, the denser is the mist.

A similar phenomenon has been observed, and captured on film, with some experiments conducted by **John Hutchison** involving remote-controlled lifting and disruption of objects [28,29]. It may be that the ***Hutchison effect*** involves causal mechanics.

Time and frequency

Time may be viewed as a process – or "change-of-space" in any direction that does not exist in our dimension [30,31,32]. In physics, new properties are commonly acquired as the result of change in some property: charge, current, induced magnetic field, etc. Here, the new property becomes a new dimension. For the frequency of oscillations, the formula is $f = 3/\lambda$ [l/s], where λ is wavelength in [m]. Here, the velocity of light is equal to 3 (the 10^8 mathematical degree is omitted since it is a question of scale of measurement only).

Therefore, the analogy between our dimension and frequency gives us a new notion, which is curvature ρ: $\rho=3/r$ [l/m] and $f = 3/\lambda$ [l/s]. The 3-dimensional radius is represented by $R=\lambda/\rho= r/3$ [m] and time as a period of oscillation has the relationship: $T = \lambda/f$ [s]. **Time can be considered to be equivalent to the radius of curvature ρ if the linear radius r and the wavelength λ are the same. This is a condition for the spatial resonance effect.** Note that in this analysis, *"m"* and *"s"* are unlike when length is measured in meters in our dimension. However, for a new dimension it is possible to use equal units for (m) of 4th dimension and conventional "second". Furthermore, light (photons) is possible in our dimension only as a process in such a spatial resonator.

Experiencing time dilation

Based on the above discussion, it is proposed that we experience changes in rate of time in our daily life. During sleep, as our energy level decreases, so it can be argued that time decreases and we "go" into another dimension. Aspects of what is observed during the dream-state do not obey the rules of our familiarity of physical existence, and conventional causality - because the rate of time is different. As we start our dreaming, and as we emerge from dreaming, the recalled experiences resemble more our regular experiences. Before and after sleep, our brain frequency tends to resemble the daytime's. In effect, understanding our dream state's sense of time may be a reference key to comprehending the physics and causality mechanics of time engineering.

Time and planetary gravity

The Earth's mass appears to be in continual growth. 250 to 350 million years ago, our globe may have been half size - with all of the continents as one landmass [33]. In ancient sediments, the natural angles of slope in sand beaches greatly exceeded those of today, indicating that gravity has on our planetary surface has increased 8-fold, several times, during the last 1.5 billion years. Yet the planet's average density may not have changed – only the acceleration of free fall [34,35].

There could also be another explanation possible for the change of slope of beaches. The pull of the moon may have been different in the past.

Also, the planetary magnetic fields could have increased over the millions of years, through interactions with the solar flux of hydrogen atoms. The sun is in constant explosion – production of energy differential. Earth and other planets could be responding with harmonics to compensate for the solar activity, leading to an overall increase in magnetic fields. Such a phenomenon may give the illusion that the physical body is growing larger. In other words, with time, the force of gravity would alter planetary mass and energy.

Assuming that the Earth's density has not increased, it is possible account for, mathematically, the relative increase – growth processes - of the nuclei of terrestrial atoms, including the doubling of mass of nucleons and of electrons [36]. Such calculation also accounts for the emission of 2 different photons by hydrogen atoms (also known as the "red shift" described by **E. Hubble**).

The phenomenon can be explained with the time-like and longitudinal photons described by the bi-directional 2 scalar potential functions [37,38]. Could it be suggested that matter is gravity minus time? In other words, gravity is related to accumulation of energy differential (time) in mass.

The value of gravity varies throughout the planet, in part because of the poles and in part due to local density of matter. **Kirill P. Butusov** has noted a correlation between places of civilization and regions of greater gravity. A faster rate of evolution may be associated with such gravity zones. In these zones there would be a greater influx of scalar potentials. Time would be more "authenticated" by these energy flows into conscious beings. Butusov reminds us that time has a "positive energy" and flowing into nuclei of atoms or a "negative energy" flowing out of the nuclei of atoms [39].

The outflow would be representative of gravitational energy. Longitudinal waves are known to be able to enter and to leave nuclei. Such flows of time must come from other dimensions. After all, the surface of any elementary particle separates our dimension from another. This leads to an interesting possibility in which all time-associated processes between dimensions are synchronized.

Time reconsidered

Arguments have been laid that suggest that time is equal to energy differential (including movement of light). Living systems "consume" time as part of their consciousness and measuring processes.

It is possible to engineer causality. An understanding of higher-order electrodynamics is required. Techniques exist for the generation of scalar potentials. Causality technology has many applications. They include: therapeutics, energy generation, consciousness technology, inter-dimensionality, defence systems, teleportation, and of course, "time travel".

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Time as Phenomenon of the Expanding Universe

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Preface

In 1992 the author of this words, having been stimulated by Kozyrev's book [1], started to reflect on Time meaning and Time and Space asymmetric roles during the Universe Expanding. The development of these ideas has led to the work [2], it is available now (the Russian version only) on the website of the Institute of time nature explorations (grant #00-07-90211 of the Russian fund of basic research).

I would like to thank the Chairman of the Russian Interdisciplinary Temporology Seminar Dr. A. Levich from Moscow State University for his constant support and friendly interest. Also I would like to thank A. Moskowsky for the 20-year discussion of the physics history and philosophy.

The said work [2] pretends to revise radically a number of basic physical concepts of the Space - Time, Motion and Energy nature. It includes a detail analysis and mathematical calculations. Only a brief account of the main part of this work is presented below.

Introduction

The nature of time is not yet enough clear for natural science. In Newton mechanics time was presented as some universal formal parameter. Its value rises steadily at every point of the Universe by unknown for us reason. Each physical process occurs in space in correspondence with the time course.

In the Special Relativity (SR) time and space are integrated to the common 4D-continuum. However, in this theory the time component having imaginary factor seems also to be "exotic". In this concept the increase of time is also implied in each reference frame.

The General Relativity (GR) allowed linking the time properties with gravitational fields and the space geometry. The time currency started to be associated with a spatial expansion of the Universe.

The theoretical physics traditional approach to the process description is based upon the considering of time course as primary (original) one. There are also in the modern physics [3] several attempts to deduce the time concept as secondary one from different fundamental (microscopic) concepts. However, the third way (inverse to the first one) is possible and forms the basis of this paper. A starting point of this way is the following question: "Does any universal process exist which could *generate* physical time?"

(Editor's note: The same question was formulated and the answer was proposed by Alexander V. Frolov in 1996, report "Matter as process", Scientific congress "New Ideas in Natural Sciences". It was assumed that similar process can be produced by special technical methods also.)

Such fundamental cosmic process really exists and it is well known in the modern science. **It presents the Universe expansion** and was opened at the first third of the 20th Century by the American astrophysicist E. Hubble and others [4]. It means the general increase of distances between all 3D-bodies. The same scattering of two-dimensional-figures happens on the surface of some spherical balloon during air incoming. The centre of this sphere does not belong to the surface; all points of the sphere (the Universe) are equivalent.

Some time earlier the theoretical physics had come to the same results. As it is well known, the Einstein's GR was published in the 1916. After that Friedmann (1922) proposed the concept of the expanding Universe. For example, in the book [5] a description of the basic cosmic model is given. Hereinafter this model is called "Einstein-Friedman model", or "EF-model". In this model the Universe is presented as 3D- hyper surface of a 4D- sphere with increasing radius. Of course, the curvature of the 3D-hyper surface increases with time too.

Basic hypothesis relative to time nature

Some simple and pictorial views consist a basis of the new concept. Hereinafter it is called briefly as "The Spherical Expanding Universe Theory (SEUT)".

In the SEUT, as well as in the EF-model, in every time the Universe represents the 3D-hyper surface of a 4D-sphere. However, there is one very important difference. In the Einstein's theory the spatial components of the metric tensor are opposite in sign to the time's one. For example, we may consider time as imaginary quantity, then spatial coordinate as a real one. On the contrary, in the SEUT the 4D-continuum is considered as purely

Euclidean, all the four coordinates are real quantities. The usual spherical geometry can be used on a surface of the 4D-sphere.

As it is well known, in the GR the Age of the Universe can be *calculated* using the EF-model or a similar one. Usually, the radius-age dependence is not a direct proportionality in such GR models. However this result may be deduced if to neglect the global pressure of matter that fills the Universe. In [2] it is demonstrated, that an account of the static pressure of matter follows to the Universe radius linear dependence on its age (see below).

On the contrary, in the SEUT the time universal course is *manifested*. The Universe age is *identified* with a current Universe radius divided by the velocity of light. Numerous important consequences may be deduced from this statement. On the other hand, it allows avoiding many other arbitrary postulates in the model.

Mechanical motion and maximum velocity in the SEUT

The SEUT states, there is no unlimited set of independent mechanical motions. Only world lines of moving bodies exist. Each of them has some inclination relative to the time line, which presents a normal to the hypersurface of the 4D-sphere. It is *an inclination angle that defines the spatial motion velocity*. At the increase of sphere radius the intersection point of word line and current hypersurface "moves" with exact correspondance with a modern physics prediction.

In particular, immovable objects (stars) have zero inclination, their world line are normal to the hypersurface. Hence they "scatter" according to the Hubble law, their mutual velocity is proportional to mutual distance. If a body world line has some inclination relative to normal, the angle is more than zero. But it can't exceed 90°, therefore *maximum* mechanical motion *velocity* appears *naturally*, it is equal to the velocity of light.

Let us consider three variants of motion (see Fig.1).

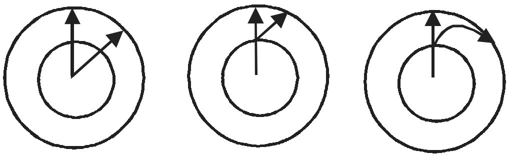

Fig. 1
Phenomenon of a "motion" of point on a sphere surface for immovable (at the left), uniformly moving (at the centre) and non-uniformly moving (at the right)

The left picture illustrates the Hubble effect. The right picture presents a general case of motion with acceleration. The central picture corresponds with an inertial motion; its world line is direct. In this case the moving body displacement increases proportionally to the Universe radius increment. So, *inertial* motion is not postulated in the SEUT, it appears as natural model consequence.

At a large 4-sphere radius values all the relationships of SR and usual mechanics laws are applicable approximately in the SEUT. A Special Relativity light cone transforms to all the hyper surface of the 4D-sphere. But the analogy is not complete, because an absolute remote SR area degenerates to this 3D- hyper surface in the SEUT (see Fig. 2).

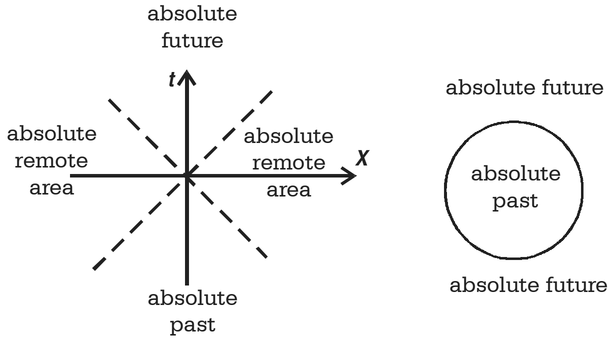

Fig. 2.
4D- continuum areas in the SR (at the left) and in the SEUT (at the right)

SEUT and Minkowski geometry

Let us consider small increments of time and space coordinates along body world lines during the Universe expanding. It is enough to consider a small area of the Universe, so we can neglect its curvature. Then it is acceptably to replace approximately concentric hyper surfaces ("isochrones") by parallel hyper planes. The space-hold corresponds with a representative point "drift" perpendicularly to isochrones, an inertial motion corresponds with displacement along inclined direct lines between isochrones.

At each time the Universe is represented by a certain isochrone that contains all the real spatial points. Let us accept that 4D-sphere radius increment divided by velocity of light presents invariant measure of (absolute) time increment. We will also state that this quantity has the same value in each *inertial* reference frame, i.e. at a motion along each *direct* world line.

Let the angles of world line inclinations from normal direction are enough *small*. Then metric relationships like Minkowski geometry ones appears in our purely Euclidean 4D-continuum. In particular, well known relationship

$$c^2 ds^2 = c^2 dt^2 - dr^2$$

can be deduced from the Pythagorean theorem. It connects a spatial component *dr* with a time component *dt* (at moving reference frame) through velocity of light *c*. Here *ds* is an absolute time interval (between two 4D-events at a immovable reference frame). **Hence, if velocities aren't very high, the Lorentz transform is correct in different inertial reference frames.**

On the Einstein's relativity principle

If the world lines inclinations from exact normal direction cannot be accepted as small, then Minkowski geometry relationships are correct approximately only. It means that Einstein's relativity principle is correct (in the SEUT) only for reference frames that move with velocities enough small relative to *selected* reference frame. Such reference frame is linked hardly with a body at (absolute) rest, i.e. drifting along radial world line.

The selected reference frame existing reminds of old ether theories that contradict to the Special Relativitiy views. It seems, these theories became a thing of the past irretrievably. In fact, the velocity of light in vacuum is constant everywhere and everywhen. However, the reference frame existing can be detected in principle as a light signal frequency bias, i.e. with the help of Doppler effect. Well, this phenomenon is really detected by the modern astrophysics!

The temperature diagram of the Cosmic Microwave Background Radiation (CMBR) coming to the Solar system from all the sides of the Universe is presented on Fig.3. The data was registrated during 4 years by the Cosmic Background Explorer (COBE) satellite (NASA Goddard Flight Centre, COBE Science Working Group).

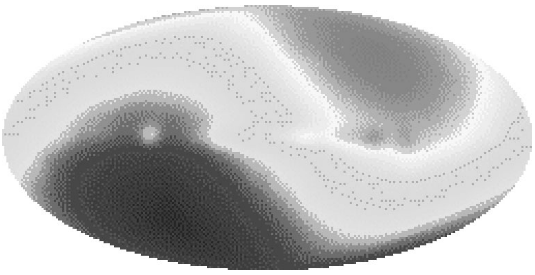

Fig. 3
The anisotropy of the Cosmic Microwave Background Radiation (CMBR)

The well-known Russian scientist J.B. Zeldovitch in the Editorial Addition to [6] in connection with earlier experiments notes that careful measurements **allowed to find out some anisotropy of CMBR.** An antenna oriented to the Lion constellation detects that the radiation temperature is 0.013% more, than mean temperature. The radiation temperature in the opposite direction is 0.013% less, than mean. **Generally, a temperature varies continuously between these two values.** The isotropy presents only for some imaginary observer. ***The Solar system, Earth move to the Lion constellation relative to this observer having velocity 390 ± 60 km/s.*** Hence, as a result of the Doppler effect, a incoming radiation seems to be more hot, and an overtaking radiation seems to be more cold. This example shows that for observer of any point of the Universe this CMBR is isotropic. We may consider this observer and the connected reference frame as selected one. The selected reference frame existence at the Universe every point looks like the physicists commonly held view preceding to Relativity. They thought that the light presented ether oscillations occupying whole the Universe. They thought also that a reference frame connected with ether was preferable, or selected. They tried to detect the Earth motion relative to ether. We know that these experiments gave the negative result: any ether doesn't exist. But the Universe evolution follows that when CMBR is observed (and only in this case!), the selected reference frame (called sometime "new ether") appears. ***The new ether or CMBR just realises the motion according to Hubble's law.***

The modern NASA's data allows to put the relation of the Solar system velocity to the velocity of light equal to 0,15%. It is enough small value justified Special Relativity and Minkowski geometry relationships application. But can we believe this phenomenon to be an exhaustive proof of the SEUT accuracy?

To test it we propose a not complicated observational experiment. If the CMBR anisotropy is due to the real selected frame existence, then it may be detected for any electromagnetic radiation. In particular, an anisotropy of solar radiation has to exist at the different year periods. It has to be detectable in August, when the both solar radiation and CMBR come to the Earth from the Lion costellation side (see Fig. 4). In February these sourses are opposite in disposition relative to the Earth, therefore the solar radiation anisotropy direction has to be opposite. The expected effect value (with account of the Lion constellation straight ascendancy and obliquity of the ecliptic) is approximately equal to 300 km/s, i.e. nearly 0,1% of the velocity of light. In November and May the anysotropy has to be practically absent.

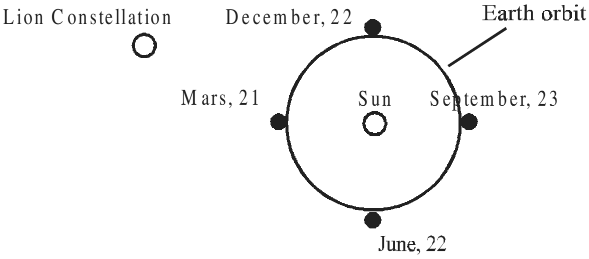

Fig. 4
The Sun and Lion constellation disposition relative to the Earth

Probably, an analogous SEUT test in a laboratry is realizable with help of artificial radiation sources.

Particle mass, energy and impulse

So, we consider the Universe as expanding 3D-hypersurface of a 4D-sphere. Mass localisation places in the Universe present the points of the hypersurface intersection by world lines. So, **these world lines have a real physical meaning, not abstract illustrative** this one. We may expect this physical meaning to be more essential than simple word expression.

Particularly, while the Universe global analysis is making, we may suppose that such fundamental particle feature as its mass at rest presents some *relative* value. Such relation (some kind of a quantum number) may include, for example, 4D-sphere (the Universe) diameter and some characteristic size like de Broglie wave period that is inversely proportional to the mass. This hypothesis may make clear *inertia* nature as two characteristic times *relation*. It may also explain the *rest-energy* notion.

Meanwhile, the Universe radius increases with time. Well, what happens to mass? If a de Broglie wave period increased proportionally to time, we couldn't generally detect the Universe expansion, including famous "red shift". But if particle wave periods are constant, then *matter mass has to rise proportionally to the Universe age and size*.

In the Relativity (like Minkowski geometry) we use vectors having imaginary projection to time axis and real projections to space ones. Particularly, it is true for velocity, acceleration, and energy-impulse 4-vectors. As against, vectors having all the real components are only used in the SEUT. At that, a 4-interval value (length in pseudo-Euclidean space) of some relativistic vector answers the absolute time axis projection of a corresponding SEUT-vector, and imaginary component of a relativistic vector (time of motion) answers the corresponding vector length in purely Euclidean continuum of the SEUT. For example, the energy-impulse vector module presents such quantity. Its projection to absolute time axis is energy at rest divided by velocity of light, and its projections to spatial axis are impulse components. This quantity is *constant* while the particle movement is *inertial* one.

A jump to *non-inertial* motion in the SEUT is connected with a corresponding state vector *changement* law. So, if particle motion velocity changes, its *energy at rest* doesn't change, therefore full acceleration at a time interval can be calculated using the difference between new and old impulse values. Thus, the non-uniform motion equation in the SEUT can be found like SR as time derivative of an impulse expression.

The force-acceleration relation depends on a mutual orientation of force and velocity vectors in the both SR and SEUT. But in Relativity a reference frame velocity can be choised arbitrary, for example it can be zero, then the relation will be equal to one.

On the contrary, in the SEUT an *absolute* velocity is presented, it is defined by the world line inclination relative to the normal. Let the Earth move with any velocity relative to the immovable (selected) reference frame. Then we will be able to detect the absolute velocity using two measurements, the first one along the world line, and the second one in a perpendicular direction.

If this absolute velocity is really defined by direction and value following from CMBR anisotropy effect, then we can expect a relative difference near $2{,}25 \cdot 10^{-6}$ between longitudinal acceleration and transversal one.

Local gravitational fields of particles

What does the SEUT talk about body gravitational fields? Let us imagine all the bodies as immovable and drifting exactly along the *radial* world lines. If there is a mutual gravity attraction effect between two bodies in such Universe, an observer will detect some curvature of their world lines. They will seem to be bending one to another instead of a radial divergence. In essence, in this case we may replace a world line by a gravitational field line. Then the analogy allows us to identify an Universe isochronous intersection with an equal potential surface that these field lines have to be *normal* to this surface. So, we arrive to a presentation that a Universe isochronous intersection is not strictly concentric hypersurface. It is perturbed by some kind of craters (see Fig.5), that centres correspond with gravitating bodies.

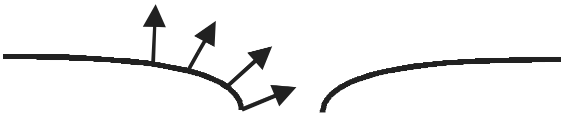

Fig. 5
Local body gravitation field

The inclination angle of a crater profile relative to non-perturbed sphere hypersurface is equal exactly to the inclination angle of a normal relative to strict radial direction. Hence, a local gravitation field intencity measure agrees practically in each point with body velocity measure that we used earlier. It authorizes energy concept using for both mechanical motion and gravitation phenomenon.

SEUT and General Relativity

Let us discuss some GR's aspects. Is it acceptable to neglect pressure of matter? When Einstein searched for his early cosmological static model solution, he had to introduce a cosmic constant in his equation. This constant answered a ***negative matter pressure***, that Einstein could not determine a meaning. In a non-stationary model a solution exists independently on cosmic constant presence, therefore it may be put often as zero. As rule, bodies' velocities may be put as zero too; therefore (*dynamic*) pressure is usually neglected.

However, we insist on necessity to account a *static* pressure of gravitating matter. Really, it can be ignored in the case when Einstein's relativity principle is applicable. Accordingly with it a gravitation field can be *always* replaced by reference accelerated frame. In this case a purely kinematical side is only accounted. However, *not every* field may be considered (even locally) as uniform one (see Fig. 6). Let the radius of a field source (or a *probe particle*) have the same order that the mutual distance. Then the Einstein's equation connecting space geometry with matter physical features seems to be incomplete. More precisely, it is incorrect to put exactly equal to zero a static pressure in the matter density tensor, it is necessary to introduce its (unknown, calculable) value accounting **the *continuum deformation energy*.**

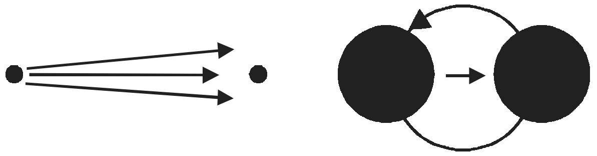

Fig. 6
At the left a locally uniform gravitation field is presented, the right field can't be considered as uniform one even locally

Are the proposed amendments important? Specialists know, that the Metagalaxy gravitation radius is *in fact* comparable with its real size. **In [2] we have showed that the Universe radius was *less* than its gravitation radius.**

It is shown also in the same work [2], that a resulting gravitational pressure in the Universe is *negative* and it is responsible for the Einstein's cosmic constant. This fact seems to be evident because a gravitation force aims to *gripe* any matter accumulation. **But it is possible to conclude it by a non-trivial way.** Let us consider a matter pressure as a reactive force operating within a uniform sphere of incompressible liquid. A pressure dependence on internal density is presented in [7]. We can see [2], **that if the sphere gravitation radius exceeds its geometric radius not more than approximately 1% (or it is still less), then a sudden negative change of the pressure appears at the internal abroad. This phenomenon may be explained as a volume "expansion" due to a metrics perturbation.**

The consideration of static pressure allows not only to find out a *new* (linear in time) cosmologic solution, but also to calculate a dependence of the Universe gravitational pressure on the radius of the Universe. This *negative* value has the representation like that one for a non-relativistic sphere (a star or a planet, for example). Also we would like to note, the formulation of density-Universe radius in the SEUT is exactly the same that the formulation of so-called *critical* density in the EF-model.

Two very important circumstances are clarified for all that. First, the **Universe mass was turned out as *linearly increasing* function of the 4D-sphere radius, and it is not a constant. A famous Einstein's programme is realized unexpectedly in the SEUT: a matter features (density) are reduced to a space features (curvature).** In other words, a necessity to introduce a mass distribution in the equations externally ("by hands") is eliminated in the SEUT. This operation is need in the GR to find out a spatial metrics changement law.

Secondly, the seeming paradoxicality of University mass (and energy!) non-conservation make us to reflect on conditions that the *accomplishment* allows to the energy conservation law correctness (see Fig.7).

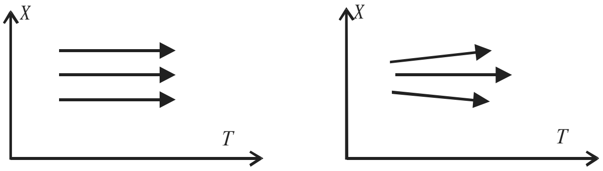

Fig. 7
If space features *do not depend* on time, then the closed system energy is *constant* (at the left). But if space features *evolve* in time, then the isolated system energy *have not to be constant*.

It is evident, we believe, that the energy can be exactly constant only in such physical system (or in whole the Universe) for which space features (in particular, a curvature) are strictly constant in time also. However, the both modern physics and SEUT issue from the opposite concept. Hence, this state can only be accomplished approximately, moderately of a bit of the modern rate of a relative space curvature evolution. This rate has order 10^{-10} per year for the modern Universe.

N.A.Kozyrev [1] basing on astrophysical observations stated the common star radiation origin that has to be due to the time-energy transformation. Accordinly with the SEUT, the relative increment of star mass (and its rest energy) is equal to the Universe age relative increment. It is interesting that the Sun mass relative lost due to the radiation consists in 10^{-15} per year, i.e. five orders less than mentioned above energy increment.

Universe origin and closed geometry

The cosmological EF-model could not say anything on the Universe origin. On the contrary, the work [2] approach allows an obvious way to study the problem.

As it is noted in [7], the metrics of any sphere area having a non-zero density is perturbed relative to Euclidean one, its geometry agrees with 4D-sphere hypersurface geometry. For non-collapsing sphere its gravitation potential relief is like a very small *"pit"* that gravitation radius is much less than its geometric size. However, when the density rises, the metrics perturbs more and more, and the pit transforms to some kind of *"crater"*. The crater is connected with the external surface by a narrow neck. Only this neck or its part is visible for an external observer, and the gravitation insurmountable barrier transmutes an object central area into "a lost world".

From the point of view of the external world, the central area presents a "black hole" absorbing irreversibly all the matter and radiation. On the other hand, for our Universe inhabitant the "navel-string" connecting with the external world has to seem a spherical "white hole", to which a matter and radiation are coming continuously (and, may be, carry out an information on the external world features). There is an old Russian fiction science book called "Sannikov Land", where an internal gigantic trench concerning central small star is described. Our model seems to be like this picture.

Is it possible that we live in such a black hole? The present hypothesis answers affirmatively this question. The negative sign of the matter pressure due to continuously increasing of our world size allows to such conclusion. And the University self-closing can be physically explained by the way.

On the other hand, as it is shown in [2], in spite of matter average density negligibly small, the Universe gravitation radius is more than its geometrical radius; hence, it presents a black hole. This condition accomplishment agrees the Universe self-closing, the boundary absence in spite of its finite volume. Also, this fact confirms our assumption that the Universe rest energy localisation area does not exceed the gravity operation area.

A specific model of star collapse is created in the modern General Relativity. In general, it can study in *three* different reference frames. As a rule, the "point mass" models are used. *The first* model is linked with an external observer; the *second* one accompanies a matter falling to the black hole. *The third* model presents an internal reference frame, i.e. an observer within collapsing object.

From an external observer's point of view the matter falling time to the black hole is infinitely large. However, in an accompanying reference frame it is finite. Since in the accompanying reference frame time and space coordinates are expressed through the both types of external reference frame coordinates. What is more, in the internal reference frame the time and space coordinates quite trade places, the metrics tensor components are depending on time. Further, any matter point history in this accompanying reference frame starts at the zero moment and finishes after same universal time period in a special (singular) point, after which nothing exists ("time barrier").

As we believe, another lacing between internal and external collapse pictures will be possible, if we consider a non-point collapsing object. Nobody wonders now at a situation, when a time period can be finite in one reference frame and infinite in another one. **Therefore, we can believe, unlimited black hole *collapse* in the external Super-Universe may seem to present unlimited *expansion* of our Universe observing inside.** This expansion seems to *start* from a singular point, and the same point is the history end of all the matter of the external Super-Universe that fall to the black hole. I would like to note especially, it does not mean that internal time pass in opposite to external one. **Rather, it is possible to state, time within a black hole passes ortogonally to external one.**

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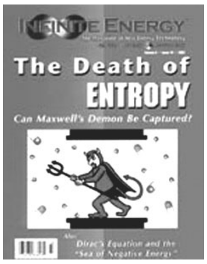

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The Experiments on Thermo-Gravitation

This review of the article by Alexander P. Schegolev, the scientist from Saint Petersburg, was received by NET editors from our reader vladrim@mail.ru and presents his own view about Schegolev's experiment [1]. The opinion of our editorial board is not fully in agreement with the author's conclusion. Also we have no information who is vladrim@mail.ru.

It is known from the science history that the very experiment gives a push to revising of old knowledge; it also checks the new designs and conclusions. The knowledge of physical theories is based on the experiment; the experiment confirms hypothesizes or refuses them. Making experiments, we ask questions to the nature. And it always answers us on the clear pointed question. However…

Michael Faraday was trying in vain to find out the relationship between gravitation and electricity. These experiments were repeated on the modern level. Further, there was made an attempt to screen gravity force, the influence of environment on gravity was also trying to be researched. Many efforts were spent on finding out of the gravitational radiation falling to the Earth from depths of the Universe, as well as artificial generation of gravitational waves.

The experimental studies of weight change must be under attention. In particular, the attempt to find the differences in weight after sharp turning of body from the quiescent state into the state of rotation around its own axis was undertaken. The experiments of the influence of strong magnetic field and temperature on the weight of a body were made.

But alas! No changes of weight were discovered in previous experiment *(Editorial: Perhaps, the author has no information about sucessful results. We reported about such results in our magazine)*. Analyzing these experiments and theoretical premises, the author of the given article has made an unusual experiment imitating the heat motion in the Earth from core to peripheries. For that experiment there was used the steel ball with 100 mm diameter. The cone hole was made in the ball up to its center. The ball was installed by the hole upwards on laboratory scales with 50 mg scale factor and laser beam was directed inside (into the hole). The directed heat flow outgoing from the center of the ball was created by this way. While the surface temperature increasing, the arrow of scales became to be rejected aside weight decrease. The temperature was measured by the contact thermocouple. After an hour and half, approximately, when the temperature was 300 degrees Celsius the laser was switched off. The difference (the decrease) in weight against initial value (in the cold state) was four grams per 4200 grams of the test body.

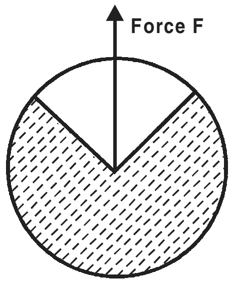

Fig. 1
The ball with cone hollow

Further, the ball was getting cold slowly on the scales and its arrow was creeping to the initial position. For acceleration of this process, the ball was periodically blown on by pressure air. It was the check, if the air (heated by the ball) influences on scales or not. The stability of its data independently on actions of pressure air stream excludes such suggestion. When the temperature of the ball became the same with room temperature, its weight return to the value nearly initial. However it is necessary to add, that this "nearly" is about 200 mg. This confirms that the change of the weight was not occurred because of the evaporations of metal from action of laser beam, and we were the witnesses of absolutely unusual phenomenon. *(Editorial: Perhaps, it is necessary to take into account the deformation).*

That is all concerning the question, which was given to nature by the author of the given article. However, one more doubt remains: did the heat radiation (coming from the ball) affect on mechanism of scales? To check this, the control experiment was made, under which the same ball was heated by usual way in the electrical furnace. In spite of its temperature was about 600 degrees Celsius and the ball was placed on scales for a long time (until full cooling down), the arrow did not move from the initial position. Thus, we have really turned out face to face with a phenomenon requiring an explanation.

If the weight change in this experiment has happened in consequence of gravitational interaction, then, therefore we must revise some fundamental concepts. Today it is difficult even to assume the consequences. The only thing, which is possible to say certainly, is **that divergent on radius uni-directional (single-vector) heat flow** is the object for observation, absolutely unknown to us or unnoticed before, which holds the ensemble of surprises. Up to now, we have dealt only with **chaotic** heat motion, which was researched by the thermodynamics and heat transmission.

For analogy, it is possible to give the example **of the electric current arising, which is possible to get only under directed electrons moving.** In general, more than ten experiments were made, and all of them have given the same result: the weight of the body was decreased. Who will solve this enigma?

Editor's note: The question is presented above. The answer is the aetherodynamics theory. Any directed (unidirectional) heat flow is also a flow of aether. The mass changes are the demonstration of natural mechanism of existence of this mass as aether vortex (Alexander V. Frolov).

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The RotoVerter from arkresearch

Editor's: The description of this invention was received from Hector D. Perez Torrez, designer of the "RV" Rotoverter and TV transverter OU "transformation" devices.

Here is the first prototype, used to test a 3PH generator. Light bulb was a 100W 120V, AC generator required 380W for excitation to 120VAC plus the light bulb load for a total of 480W. Input to rotoverter was 240W for a total of 200% efficiency from the prime mover. Friction loss and prime mover loss was not calculated, PF unity, 120VAC unto a purely resistive load excitation pure DC120VDC3.1666667A (380W) + 100W = 480W. -240W=240 excess.

It is a common 3PH dual winding 230/460V motor wired to 480V run at 120v as a ROTOPHASE converter. That's the beauty of it, OFF the shelve components preferably totally enclosed motors (so fan can be removed) low friction bearings, from 3HP to 7.5HP. Re-rating hp can be from 1/7 to 1/3 the original HP (some motors can run up to 1/2 HP capacity but will require extreme care and cooling.... and exact tuning to load).

System requires starting and running capacitance; the perfect starting capacitance is the one that gives same plate current value as 480V but running at 120V. The best running capacitance is the one that gives the lowest Amperage reading at programmed load. (ALL capacitors are AC 370V OIL "no electrolytic").

Some motors are better than others; also for generator use you must choose the over-unity generator and motor combination to obtain OU. It looks easy to gain it, but requires quite a good choice of items and common sense. In this Research we have found even a few turns or a run weld in stator can change drastically the results. Up to date best performance has being obtained from US (motors 7.5 HP, BALDOR 3,5, HP, GE 3HP totally enclosed, dual winding 230/460V). Higher HP will require professional expertise in industrial electricity and power eng. (not recommended for amateur experimenter). Anyone engaged in this experiments must be familiar with safety procedures and basic electric and mechanic knowledge. Voltages and rotating machinery must be handled with great care. SEE basic diagram and connection.

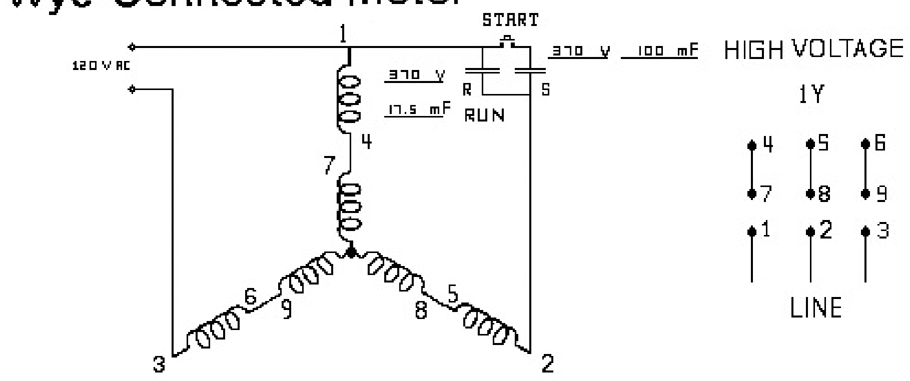

Fig. 1

Latest UPDATE BELOW 7-01-02

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EXPERIMENT ON MAGNETIC ROTO AMPLIFICATION

Starting current > 9.0 A
running voltage 120.0 V
running current 3.00 A
PT 360.0 w

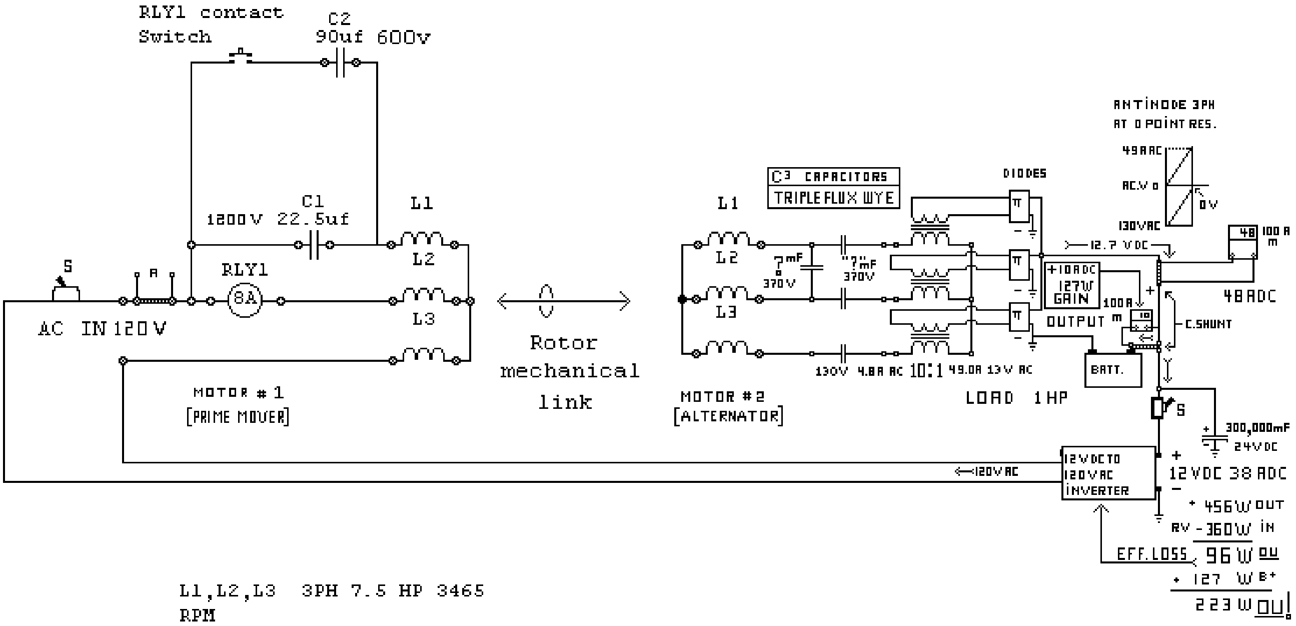
RLY1 contact
Switch
C2
90uf 600v
C1
1200V 22.5uf
L1
L2
L3
S
A
RLY1
8A
AC IN 120V
MOTOR # 1
[PRIME MOVER]
Rotor
mechanical
link
C3 CAPACITORS
TRIPLE FLUX WYE
L1
L2
L3
?mF
370V
"?"mF
370V
130V 4.8A AC 10:1 49.0A 13V AC
MOTOR # 2
[ALTERNATOR]
DIODES
ANTINODE 3PH
AT 0 POINT RES.
49AAC
AC.V 0
130VAC
0V
12.7 VDC
48
100 A
m
48ADC
+10ADC
127W
GAIN
OUTPUT
100A
m
10
C.SHUNT
BATT.
LOAD 1HP
S
300,000mF
24VDC
12VDC TO
120VAC
INVERTER
←120VAC
12VDC 38ADC
+ 456W OUT
RV - 360W IN
EFF.LOSS 96 W OU
+ 127 W B+
223 W OU!

L1,L2,L3 3PH 7.5 HP 3465
RPM
460 V MOTOR 184TCH

L1,L2,L3 SAME BUT WIRED
FOR 230 V

THERMAL & MECHANICAL LOSS WAS NOT CALCULATED

Fig.2

Subject: RV Basic level 1 Full MODEL Disclosure (Public domain)

This is the RV (Level 1) plan of a full looped RV system:

Battery provides primary power for 12VDC to 120VAC. As to run prime mover (Roto-converter), second motor acts as ansquirrel cage self-exited generator, a triple flux-capacitor LC tank tuned to best Standing wave condition as to create standing wave current node internally in battery at 0 voltage to battery “negative resistor”. At 0 volts “voltage” a negative current is created as to maintain a reverse flow (charge) to battery exceeding the forward drain of the inverter demand, detuning system with a forward charge at 10 amperes with a voltage rise of approximately 0.83333 V over the battery. Voltage charge produces OU transform from the 0 point standing wave component. System gains energy from stochastic resonance within the LC tank components draining energy from “thermal” signature of the Aether and K thermodynamic-thermoelectric ambient heat (Electron spin). This is a full disclosure of an operational and tested device. System is made of standard off shelve items. Tuning is made by changing capacitor values and the proper selection of standard items for its construction, 3PH motors, 10:1 12V or 5:1 24V transformers with the proper core and winding values (standard) off shelve, diode bridges capacitor (all standard).

Warning: System opens (NON standard) space-time anomaly as time is reversed due to aether energy transform....
Extreme warning: Do not exceed 10KW Nor use of trans-uranic elements near unit as they may reach critical mass by regressive “inversed” decay. PB 206, U235, U238 must be maintained as far as possible from unit.
Extreme Warning: Dangerous Toy, Eldridge, Event horizon and hell raiser effects may be created by protoplasmic fields at extreme potentials PK.
Use wisely. You Can create Paradise or open the gates to Armageddon.

The choice is yours now....

Hector D Perez Torrez

Lifter Project
by Jean-Louis Naudin
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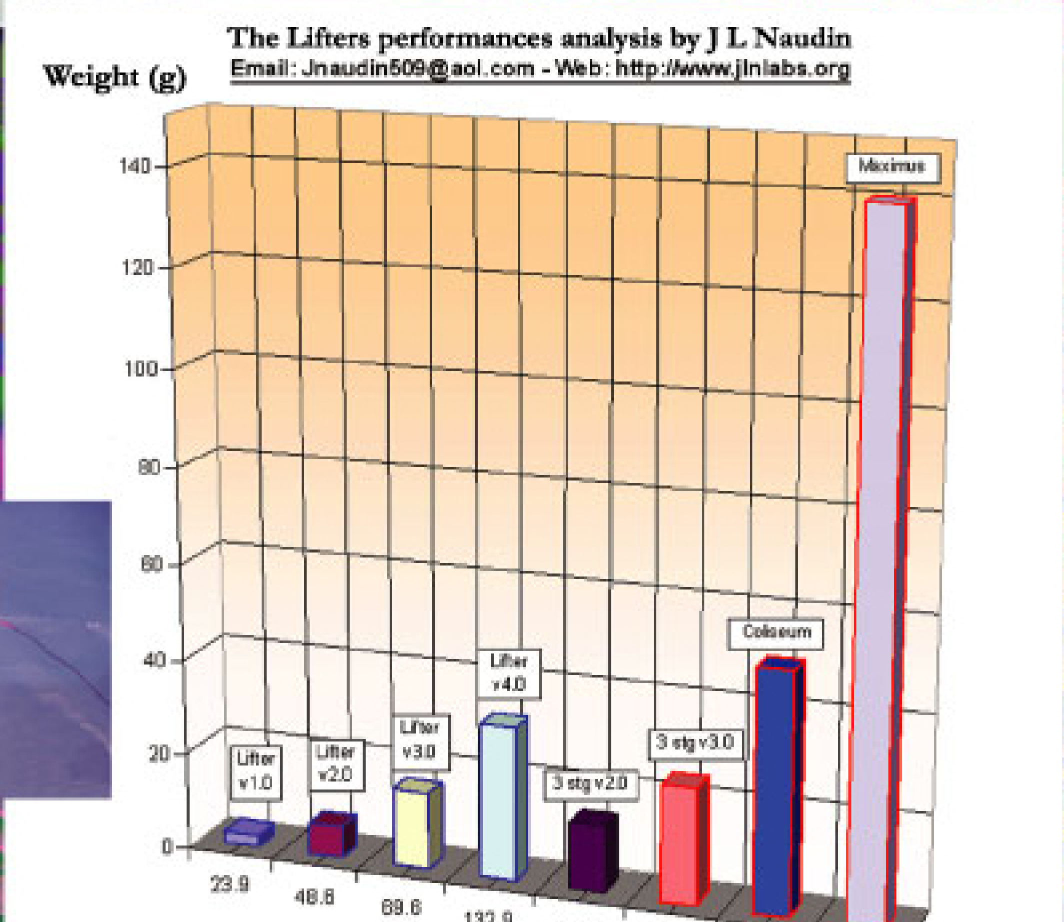

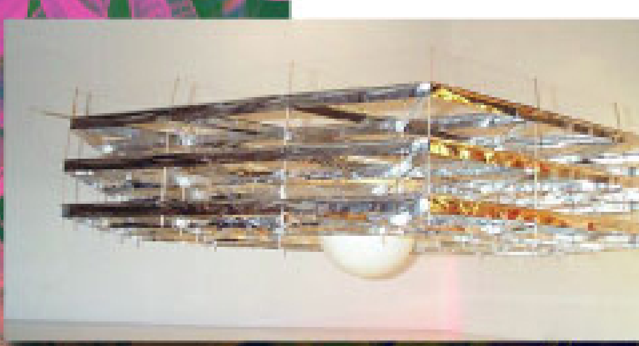

Mouse aboard!

The 1st Worldwide Electronaut Lifter Project

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New Energy Technologies

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20 kWt!

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- Cold Fusion by Plasma Electrolysis of Water
- News of Hydrogen Energetics
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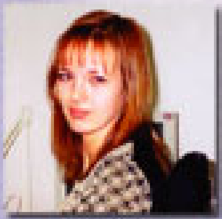

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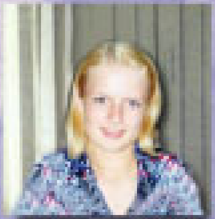

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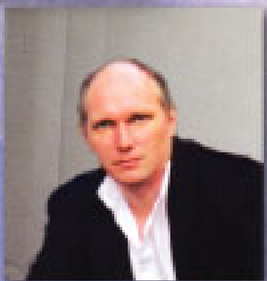

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Searl Effect Technology

http://www.sisrc.com

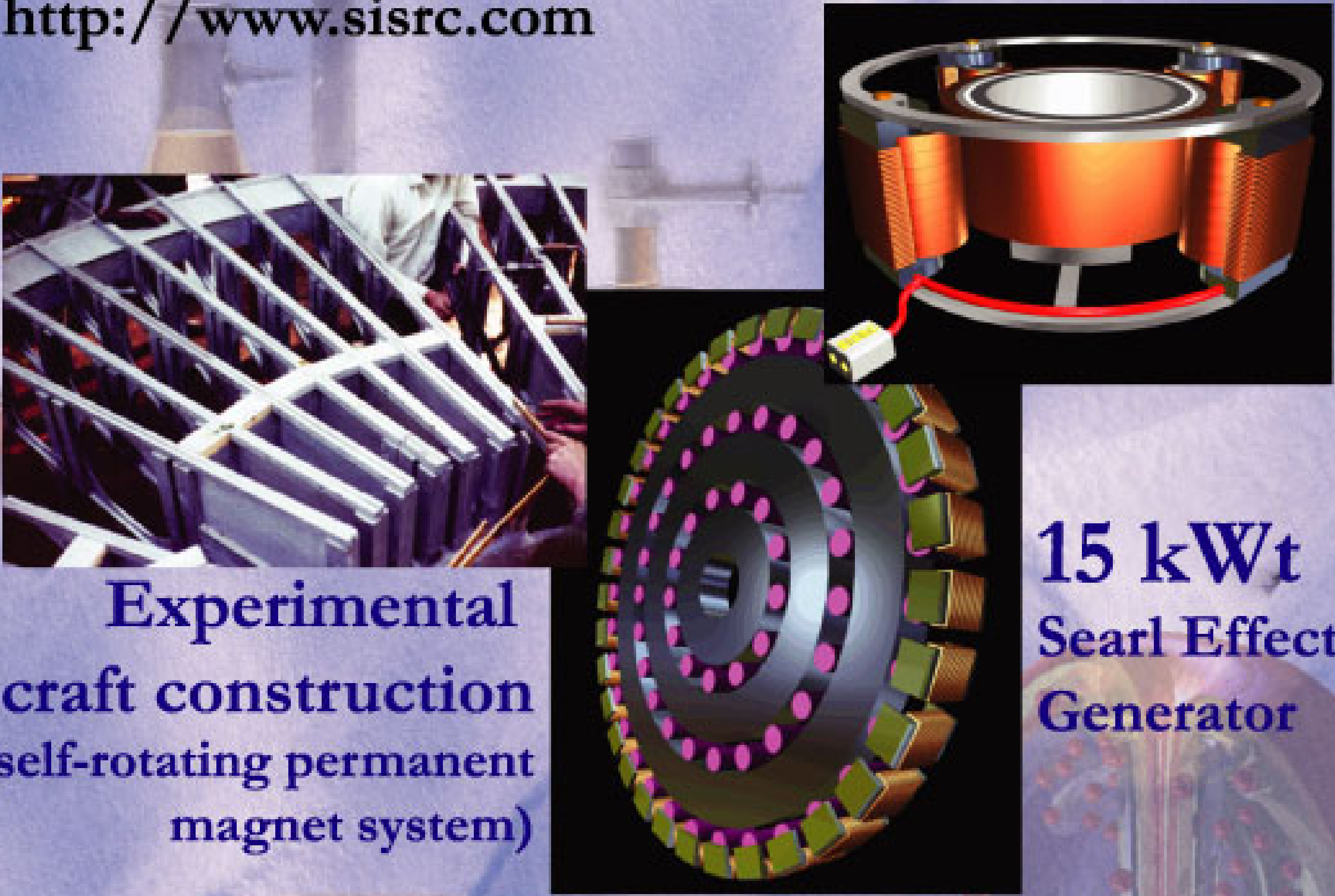

Experimental craft construction (self-rotating permanent magnet system)

15 kWt
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LENR Experiments
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NEW ENERGY TECHNOLOGIES #10

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TESTATIKA

Review of well-known electrostatic system

Editor comments by Alexander V. Frolov
General Director, Faraday Lab Ltd

A running "free energy" machine coming from Switzerland, Europe. It was developed over a 20 years Research period by a religious group called Methernitha. This group lives in Linden, Switzerland. The head engineer of this superb machine, Mr. Paul Baumann discovered its principles while observing nature. He claims its running principle was found by studying the lightning effects from nature. The documents being offered here shed light on this energy marvel.

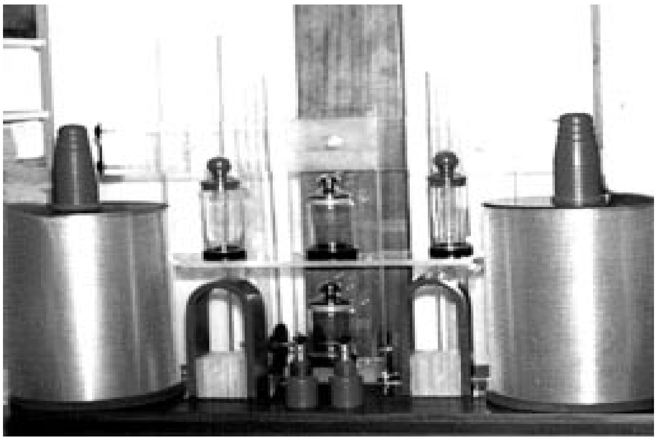

These documents are the result of work of people who have witnessed this wonder machine over the years... And here are the facts:

- The Testatika is a rotary-type machine that runs on it's own, once started by revolving it's two discs by hand!
- The machine not only runs on it's own energy, but produces also a huge amount of excess power, at least 3 KWtt of power! This is almost enough to supply a small house with one machine!
- The machine is about 70cm wide, by 40cm deep and is about 60cm in height!
- It delivers from 250 volts to about 320 volts direct current, depending on the humidity in the air! At this voltage it can supply at least 10 Amperes of pulsating direct current!
- Testatika is not a perpetual motion device, but an energy machine that collects it's huge amount of energy from the ions contained in air. However, there are some technological secrets implemented to overcome the normal drag-resistance of conventional generators. This is but one of it's secrets held by the Methernitha group.

There are many different sized Testatika machines, some of the smaller units deliver only about 200 to 300 watts, none of which are mass-produced. These devices are still laboratory prototype units.

Methernitha is a spiritual community (Christian Alliance) http://www.methernitha.com. They wrote: "We are fortunate in gaining the experience that paradoxically the most beautiful and useful results can be achieved by just using the most simple means. Never did we use any borrowed capital because we want to stay free Swiss citizens and do not want to be hindered or even bound in any way in the pursuance of our aims."

The two contrary-rotating discs generate an electrostatic charge. One disc represents the earth, the other the cloud. Using grid electrodes the charges are bound. After that they are collected by non-contacting so-called antenna keys and then sorted.

After being initially turned on by hand, the discs rotate by themselves according to the electrostatic laws about attraction and repulsion. A rectifying diode keeps the cycles in steady state. Otherwise the impulses of attraction and repulsion would accumulate and cause the discs to run faster and faster. The correct speed is of great importance and for optimal power generation the discs have to run quite steady and slow.

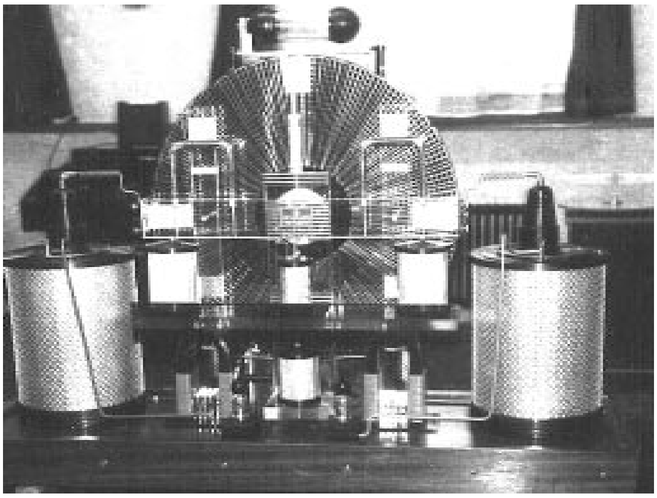

By means of grid condensers the energy is stored and then uniformly discharged, at the same time reducing the high voltage and building up power with additional devices. Finally the machine supplies a uniform direct current, which varies according to the size of the model. The machine furnishes about 3-4 kWt permanent output, depending on humidity, whereby the electric potential ranges from 270 to 320 Volt. High humidity of the atmosphere prevents the build-up of electric potential. The drier the air is, the better.

(Editor: It is necessary to note that the analogues method was used by Russian inventor Pavel N. Yablochkov who in 1877 take out a patent #120684 "The system of distribution and amplification of electrical currents by means of atmosphere electricity..." As it was shown by Yablochkov devices, power doubled in lamps, though current of consumption did not increse.)

No doubt, through the so far achieved results one main objective has been reached, namely to prove that it is possible to use Free Energy. Nevertheless the research work is not yet completed.

To the educated physicist many things of this machine may seem impossible, maybe even crazy. Maybe he is also offended by the conceptions used to explain the whole. Only partly we could use the concepts of conventional physical terminology to explain and define only approximately the functions and properties of the various parts of the machine.

After all it will be necessary to create some more new concepts like the one we have already used before, when we termed the non-contacting collectors of electric charges as antenna keys.

This machine puts experts, which are just trained in conventional physics to a very hard test, because its mode of action is not explainable with the state of the art of officially accepted physical knowledge, or at the most only partially explainable. However also a trained specialist should remain free and independent in his thinking, and should avoid to be limited by the temporal framework of publicly admitted knowledge in any science.

It has to be noted that the established science was already many times forced to change or give up some of its very fundamental concepts. Think about Galilee, to name only one example. Our human society almost condemned this man as a sorcerer and magician, just because he investigated and discovered a truth that seemed unacceptable by the established science of the days.

The book knowledge of any times is not wrong, but it is incomplete, and therefore allows to draw wrong conclusions.

There was used information from the official web site: http://www.methernitha.com

Official adress of Methernitha: Methernitha Genossenschaft Administration, Moosbuehlweg 2, 3517, Linden, SWITZERLAND

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COLD FUSION BY PLASMA ELECTROLYSIS OF WATER

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Abstract: It has been disclosed that transmutation of the atomic nuclei of alkaline metals and the atomic nuclei of the cathode material takes place during plasma electrolysis of water.

Key words: atom, nucleus, proton, neutron, electron, cathode, low-current.

INTRODUCTION

Cold nuclear fusion is the first hypothesis of a source of additional energy in heavy water electrolysis. Fleischmann and Pons, the American electrochemists, are the authors of this hypothesis [1]. They reported about it in 1989. Since that time a large number of experiments has been carried out in order to obtain additional energy from water [2], [3], [4], [5], [7], [8], [9], [10], [11], [12]. We continue to discuss this problem.

THE FIRST EXPERIMENTAL PART

In order to check this hypothesis, the following experiments were performed. Two cathodes were made of iron with mass of 18.10 g and 18.15 g. The first cathode operated during 10 hours in KOH solution; the second cathode operated during the same period in NaOH solution. Mass of the first cathode remained unchanged; mass of the second one was reduced by 0.02 g. The voltage by plasmaelectrolysis process was 220 V and the current (0.5-1.0) A (Fig.1). The indices of the consumption of the solution and the gases being generated were as follows (Table 1).

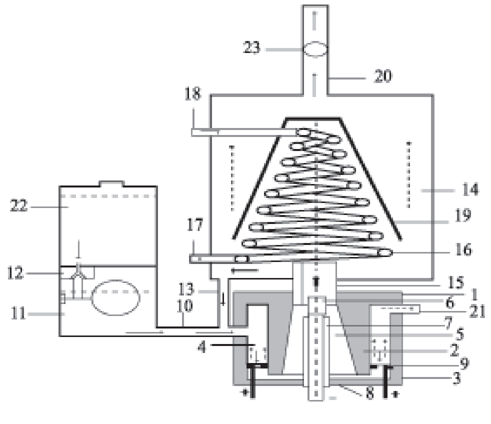

Fig. 1.
Diagram of gas generator. Patent # 2175027:
1 - lid of the reactor; 3 - body of the reactor; 6 - the cathode; 9 - the anode; 11 - solution dosing unit; 16 - cooler; 20 - pipe for gas release; 23 – anemometer

Table 1
Experimental results

Indices	Water consumption, kg	Volume of gases,m^3	Energy expenses, kWh/m^3
KOH	0.272	8.75	0.28
NaOH	0.445	12.66	0.21

In order to increase safety of experimental results, the volume of the gases introduced with the help of anemometer is reduced twofold.

It is known that from one litre of water it is possible to produce 1220 litres of hydrogen and 622 litres of oxygen. Quantity of the gases generated by the plasma electrolytic process is much greater than it is possible to get from consumed water (Table 1) [6]. It gives the reason to think that not only water molecules, but also the nuclei of alkaline metals and the atomic nuclei of the cathode material serve as a source of these gases. The analysing experiment has been performed in order to check this fact.

Tadahiko Mizuno, the famous Japanese scientist (the co-author of this article), who works at the Division of Quantum Energy Engineering Research group of Nuclear System Engineering, laboratory of Nuclear Material System, Faculty of Engineering, Hokkaido University, Japan, kindly agreed to perform chemical analysis of the cathode samples with the help of the nuclear spectroscopy method (EDX). Here are the results of his analysis. The content of chemical elements on the surface of non-operating cathode is as follows (Table 2).

Table 2
Chemical composition of the cathode surface prior its operation in the solution

Element	Fe
%	99.90

The new chemical elements have appeared on the working surface of the cathode, which works in KOH solution (Table 3).

Table 3
Chemical composition of the surface of the cathode, which operates in KOH solution

Element	Si	K	Cr	Fe	Cu
%	0.94	4.50	1.90	93.00	0.45

The chemical composition of the surface of the cathode, which operates in NaOH has proved to be different (Table 4).

Table 4
Chemical composition of the surface of the cathode, which operates in NaOH solution

Element	Al	Si	Cl	K	Ca	Cr	Fe	Cu
%	1.10	0.55	0.20	0.60	0.40	1.60	94.00	0.65

Thus, the hypothesis concerning the participation of the nuclei of alkaline metals and the atomic nuclei of the cathode material in the formation of gases during plasma electrolysis of water has experimental confirmation. Let us carry out the preliminary analysis of the data being obtained (Tables 2, 3, 4).

THE FIRST THEORETICAL PART

In any of these cases, the atoms and the molecules of hydrogen are formed. The part of it is burned and the other goes out with the steam. We have already shown that the processes of fusion of the atoms and the molecules of hydrogen and its isotopes result in occurrence of additional thermal energy [6]. Numerous experiments show that up to 50% of additional thermal energy are generated during the plasma electrolysis of water, it is less than the results of the calculations originating from the existing cold fusion theories [6]. That's why it is necessary to analyse energetics of the particle creation process during the atomic nucleus transmutation.

Having considered the model of the electron we have found out that it can exist in a free state only when it has a definite electromagnetic mass [6]. Being combined with the atomic nucleus it emits a part of energy in the form of the photons, and its electromagnetic mass is reduced. But stability of its condition does not become worse, because the energy carried away by the photons is compensated by binding energy of the electron in the atomic nucleus [6].

If the ambient temperature is increased, the electron begins to absorb the thermal photons and to pass to higher energy levels of the atom reducing binding with it. When the electron becomes free, it interacts with the atom only if the ambient temperature is reduced. As this temperature is reduced, it will emit the photons and sink to lower energy levels [6].

If the electron is in a free state due to an accidental external influence on the atom and the environment has no photons, which are necessary for it to restore its mass, **it begins to absorb the ether from the environment and to restore its constants in such a way**: mass, charge, magnetic moment, spin and radius of rotation. The electron acquires the stable free state only after it has restored its all constants [6].

Thus, if an interchange of the free state and binding state with the atom takes place due to the accidental influences on the atom, **the electron restores its electromagnetic mass every time due to absorbing the ether. It means that actually it plays the role of a converter of the ether energy into the thermal photon energy.**

The Japanese investigators Ohmori and Mizuno [4] registered neutron radiation during plasma electrolysis of water and reported that not only the nuclear process, but also the process of the electron capture by the free protons can be the source of this radiation.

As hydrogen plasma is generated during the plasma electrolytic process of water electrolysis, there exists a tendency of the capture of the free electrons by them.

It is known that rest mass of the electron is $m_e = 9.109534 \times 10^{-31}$ *kg*, rest mass of the proton is $m_p = 1.6726485 \times 10^{-27}$ *kg*, and rest mass of the neutron is $m_n = 1.6749543 \times 10^{-27}$ *kg*. The difference between the mass of the neutron and the mass of the proton is equal to $\Delta m_{np} = 23.058 \times 10^{-31}$ *kg*. It is $23.058 \times 10^{-31} / 9.109 \times 10^{-31} = 2.531$ of the mass of the electron. Thus, the proton should capture 2.531 electrons in order to become the neutron. The question arises at once: what will happen to the remained of electron mass $(3.0-2.531)m_e = 0.469m_e$? The disturbed balance of masses in this process is explained by modern physics in a simple way: a neutrino is created [6].

As the neutrino has no charge, it is very difficult to register it. If the neutrino takes the excess mass away or replenish the lacking one, can the elementary particles execute this process by themselves?

As the photons are emitted and absorbed only by the electrons, the proton, which absorbs the electrons, cannot convert the remainder of mass of the third electron into the photon. If the electron is absorbed by the third one and gives more than a half of its mass to the proton in order to convert it into the neutron, the remaining part of mass ($0.469m_e$) of the electron, which has no possibility to become the photon, is converted into a portion of the ether, which "is dissolved" and mixed with the ether in the space. The fact that plasma has no photons with the mass corresponding to the part of mass of the third electron, which has not been absorbed by the proton during its conversion into the neutron, can serve as a proof of such affirmation. Let us calculate energy of such photon [6].

The difference the mass of the neutron and the proton is equal to $\Delta m_{np} = 23.058 \times 10^{-31}$ *kg*. If we subtract this value from the mass of three electrons, we'll get mass m_F, from which the photon should be formed [6]

$$m_F = 3m_e - \Delta m_{np} = 3 \times 9.109534 \times 10^{-31} - 23.05810^{-31} = 4.270602 \times 10^{-31} \text{ kg} \qquad (1)$$

If the photon is formed from this remainder of mass m_F, its energy will be [6]:

$$E_{ph} = m_F \times C^2 = \frac{4.270602 \times 10^{-31} \times (2.997924 \times 10^{8})^2}{1.602189 \times 10^{-19}} = 23.956126 \times 10^{4} eV \qquad (2)$$

This value of energy corresponds to roentgen spectrum, that's why the creation of each free neutron should be accompanied by the creation of one roentgen photon. If it does not take place, we have two opportunities: the first one – we should think that in the case when the neutron is created, the neutrino was formed from mass $m_F=4.270602 \times 10_{-31}$ *kg* and flew away in the unknown direction; the second one – there were no conditions for the formation of the photons in the process being considered, and mass, which failed to be formed as a particle, "was dissolved" in the ether. Which variant is closer to the truth [6]? There is no exact answer, but it is known that the Japanese scientists registered only neutron radiation with intensity of 50,000 neutrons per second, and they failed to register roentgen radiation [4].

If in this process the roentgen photons were created, they would not exceed heat efficacy of the plasma electrolytic process, because they would not be the thermal photons. The thermal photons are radiated and absorbed when the electrons make the energy transitions to the energy levels, which are the most remote from the atomic nuclei, where the infrared photons and neighbouring ones from the optical range of the spectrum with energies of ≈(0.001-3.3) eV are generated (Table 5) [6].

Table 5
Electromagnetic spectrum bands

Bands	Wave-length, m	Energy, eV
1. Low- frequency band	$\lambda \approx (10^{7}...10^{4})$	$E \approx 10^{-15}...10^{-11}$
2. Broadcast band	$\lambda \approx (10^{4}...10^{-1})$	$E \approx 10^{-11}...10^{-6}$
3. Microwave band	$\lambda \approx (10^{-1}...10^{-4})$	$E \approx 10^{-6}...10^{-3}$
4. Relic band (maximum)	$\lambda \approx 1 \times 10^{-3}$	$E \approx 1.2 \times 10^{-3}$
5. Infrared band	$\lambda \approx (10^{-4}...7.7 \times 10^{-7})$	$E \approx 10^{-3}...1.6 \times 10^{-2}$
6. Light band	$\lambda \approx (7.7 \times 10^{-7}...3.8 \times 10^{-7})$	$E \approx 1.6 \times 10^{-2}...3.27$
7. Ultraviolet band	$\lambda \approx (3.8 \times 10^{-7}...10^{-9})$	$E \approx 3.27...1 \times 10^{2}$
8. Roentgen band	$\lambda \approx (10^{-9}...10^{-12})$	$E \approx 10^{2}...10^{5}$
9. Gamma band	$\lambda \approx (10^{-12}...10^{-18})$	$E \approx 10^{5}...10^{9}$

Thus, the neutron fusion processes in plasma electrolysis of water will not generate additional thermal energy. But the appearance of the neutrons in plasma will promote the formation of the nuclei of deuterium and, possibly, of tritium. As the balance of masses remains almost unchanged, we have no reason to expect that **additional energy will take place** when deuterium and tritium are formed. But it is sure to appear during **fusion of the atoms of deuterium and tritium, i.e. the hydrogen atoms [6].**

In order to become a proton, the neutron should radiate something, which mass is $\Delta m_{np}=23.058 \times 10^{-31}$ *kg*. Let us convert this mass into energy [6].

$$E_{ph}=\Delta m_{np} \times C^2 = \frac{23.058 \times 10^{-31} \times (2.998 \times 10^{8})^2}{1.602 \times 10^{-19}} = 1.294 \times 10^{6}\, eV \qquad (3)$$

This energy corresponds to the gamma range photons, i.e. not to the thermal photons, and this process does not give additional energy. Thus, if the process of the formation of the helium atoms takes place during plasma electrolysis of water, it should be accompanied by gamma radiation. If there is no such radiation, but the helium atoms are formed, the neutrino takes away the above-mentioned portion of mass Δm_{np} or this mass, which has no opportunity to be formed as the photon, "is dissolved" in the environment, i.e. it is transferred into the state of the ether [6]. As the roentgen photons and the gamma photons are not the thermal ones, this process gives no excessive thermal energy [6].

Another variant is possible. When the atoms of alkali metal bombard the cathode atoms, they are destroyed completely and destroy the atoms of the cathode materials. Under the notion "completely" we'll understand such state when both the atom and the nucleus are destroyed. In this case, the protons of the destroyed nuclei begin to form the hydrogen atoms. The process of fusion of the atoms and the molecules of hydrogen generate additional thermal energy [6]. But one should bear in mind that if plasma disintegrates water molecule into hydrogen and oxygen and if these gases contact plasma, hydrogen is combined with oxygen, and water is formed. Noise generated by plasma is hydrogen microexplosions. Taking into consideration the above-mentioned fact the larger the volume of hydrogen burnt in plasma, the smaller its volume in the gas-vapour mixture. It means that such reactor operation modes are required when quantity of burnt hydrogen is minimal one. Our theory allows us to have such results.

As iron is the cathode material, the nuclei of its atoms are the targets of the atomic nuclei of potassium, alkaline metal. During the transmutation of the iron nuclei (Fig. 2 b), the atomic nuclei of chromium (Fig. 2 a) and the atomic nuclei of copper (Fig. 2 c) are formed [6].

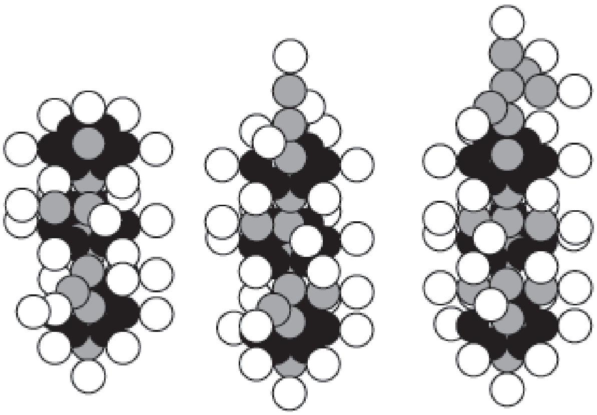

a) Cr (24,28) b) Fe (26,28) c) Cu (29,34)

Fig. 2.
Diagrams of the atomic nuclei of: a) chromium, b) iron, c) copper

When the atomic nucleus of iron (Fig. 2 b) pass into the atomic nucleus of chromium (Fig. 2 a), two protons and two neutrons are released; two atoms of deuterium or one atom of helium can be formed from them. If the neutrons pass into the protons, four atoms of hydrogen are formed.

It is easy to see (Fig. 2) that the atomic nucleus of iron (Fig. 2 b) should lose two upper protons and two neutrons in order to pass into the atomic nucleus of chromium (Fig. 2 a).

Three additional protons and six neutrons (total 9 nucleons) are required for the formation of the atomic nucleus of copper (Fig. 2 c) from the atomic nucleus of iron. As on the cathode surface (Table 3) the number of chromium atoms, which probably are formed from the atomic nuclei of iron, four times more than the number of atoms of copper, then the solution is sure to have superfluous protons and neutrons of the destroyed atomic nuclei of iron, and we can determined their approximate relative quantity.

Let us suppose that four nuclei of the iron atoms pass into the nuclei of the chromium atom. The total quantity of free protons and neutrons (nucleons) is equal to 16. As one atom of copper falls on each four atoms of chromium, 9 nucleons are spent for the formation of one nucleus of the copper atom, and 7 nucleons remain free.

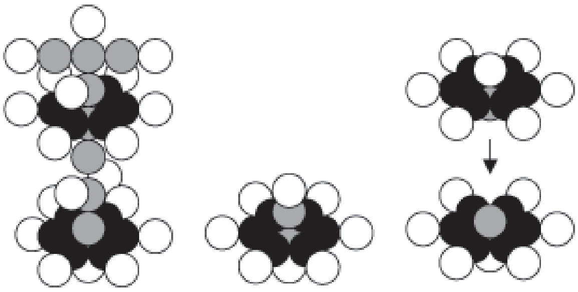

a) K (19,20) b) O (8,8) c) Si (14,14)

Fig. 3.
Diagrams of the atomic nuclei of:
a) potassium, b) oxygen, c) silicon

Let us see what is formed when the nucleus of the potassium atom is destroyed. Potassium is situated in the first group of the fourth period of the periodic law. Its nucleus contains 19 protons and 20 neutrons (Fig. 3 a) [6].

In Fig. 3 a, we can see a weak link of the nucleus of the potassium atom [6]. It is situated in the middle of its axis neutrons. When the transmutation of the nuclei of the potassium atoms takes place, the nuclei of the oxygen atoms can be formed (Fig. 3 b) as well as its isotopes and the nuclei of the silicon atoms (Fig. 3 c).

The analysis of the structure of the nuclei of the potassium atom (Fig. 3 a) shows that it is the most probable source of the nucleus of the silicon atom (Fig. 3 c), which atoms appear on the cathode (Table 3).

It is easy to count that during the destruction of one nucleus of the potassium atom and the creation of one nucleus of the silicon atom 5 free protons and 6 free neutrons, i.e. 11 nucleons, are formed.

Thus, the transmutation of the nuclei of the iron atoms and the potassium atoms results in the formation of free protons and neutrons. As the protons cannot exist in free state, the hydrogen atoms are created from them. If the protons are connected with the neutrons after the destruction of the nuclei of the iron atoms and the potassium atoms, the formation of deuterium, tritium and helium is possible.

Let us pay attention to the main fact – absence of the sodium atoms in the cathode material. It is natural that the potassium atoms have appeared on the cathode, which operated in KOH solution (Table 3). Why are no sodium atoms on the cathode, which operated in NaOH solution? The answer is as follows: the nuclei of the sodium (Fig. 4,a) atoms are completely destroyed during the plasma electrolytic process. The presence of potassium on the surface of the cathode, which operated in NaOH solution (Table 4), can be explained by insufficient ablution of the reactor after the operation with KOH solution.

As free protons and neutrons appear during the destruction of the nucleus of the sodium atom (Fig. 4,a), some nuclei of this element begin to form the atomic nuclei of aluminium (Fig. 4, b), chlorine (Fig. 4, c) and calcium (Fig. 5).

But not all free protons and neutrons are spent for the construction of the atomic nuclei of aluminium, chlorine and calcium. A part of them is spent for the hydrogen atom formation.

If we knew the total quantity of transmutating atomic nuclei of iron, potassium and sodium as well as the exact composition of the gases generated during the plasma electrolytic process, it would be possible to determine the atomic nuclei being formed from additional nucleons. Now we can only suppose that the majority of new nuclei are the protons, i.e. the nuclei of the hydrogen atoms. The increased volume of the gases generated during the plasma electrolytic process is explained by it [6].

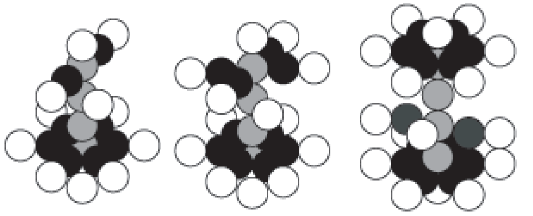

a) Na (11,12) b) Al (13,14) c) Cl (17,18)

Fig. 4.
Diagrams of the atomic nuclei of:
a) sodium, b) aluminium, c) chlorine

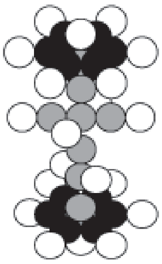

Ca (20,20)

Fig. 5.
Diagram of the nucleus of the calcium atom

The analysis of these Tables shows that transmutation of the nuclei of iron, of which the cathodes are made, results in the formation of chromium and copper in both cases. Apparently, aluminium, chlorine and calcium are formed from the destroyed sodium nuclei. In any case, free protons and neutrons are formed.

But not all free protons and neutrons are spent for the formation of the atomic nuclei of copper, aluminium, chlorine and calcium. A part of them is spent for the formation of the hydrogen atoms. In any case, the atoms and the molecules of hydrogen are formed. The analysis has shown that plasma electrolytic process extracts not more than 0.005 kg of alkaline metal from one litre of the solution. It appears from this that if all neutrons of the atomic nuclei of the molecules of water and alkali metals are transferred into the protons and the atoms and the molecules of hydrogen are formed, the formed volume of gas will be considerably less than the one registered during the experiment (Table 1). A question arises: where do additional gases come from? In order to get the answer on this question we made the next experiment.

THE SECOND EXPERIMENTAL PART

First of all we take into account, that high temperature of plasma forms the conditions when a set of various processes takes place at the cathode. First of all, water is boiled and evaporated. At the same time, one part of water molecules is disintegrated with a release of the atomic hydrogen; another part of the molecules forms the orthohydrogen molecules. A part of water molecules is disintegrated completely and is released at the cathode together with hydrogen and oxygen. A part of hydrogen is combined with oxygen again generating microexplosions (noise) and forming water.

During plasma electrolysis of water, water vapor, hydrogen and oxygen are released simultaneously. If vapor is condensed, gas mixture is released. In order to measure gas flow rate the electronic anemometer have been used. Diameter of the electronic anemometer was equal to internal diameter of the gas make tube (23, Fig. 1). Its readings were registered and processed by the computer. The experiment was performed dozen times, and each time its readings were reproduced with small deviations [11]. But we had no hydrogen analyzer, that's why the results being obtained cannot be considered as final ones. We admonished it in all editions of the book Water is a New Source of Energy with such a phrase: "We abstain from lending an official status to these results with the hope to get necessary financing and to repeat them with a complete set of the necessary devices" [12, page 176].

In the middle of the year of 2002 we received small financing, which allowed us to make a new reactor and to buy some measuring instruments, in particular the scales with the measurement limit up to 600 g and accuracy of 0.02 g. Careful preparation allowed us to increase duration of continuous operation of the reactor (to 10 and more hours) and to register solution consumption for gas production.

The main difficulty of operation with the hydrogen is in the fact that its mixture with air (4-74)% or oxygen (4-94)% is combustible, and the fact was emphasized more than once during the experiments that made the researches be very careful. The second difficulty during hydrogen quantity measurements generated by the plasma electrolytic reactor is in the fact that its molecule has the smallest dimensions, that's why it penetrates easily to the places where the molecules of other substances do not penetrate. Molecular hydrogen diffuses easily even into metals. For example, one volume of palladium absorbs up to 800 volumes of hydrogen.

Gas flow speed was measured with the help of various anemometers, its readings being registered with the help of the computer. Numerous measurements and numerous analysis of gas flow speed measurement accuracy with the help of the anemometers showed that error of a conventional anemometer can be 100%.

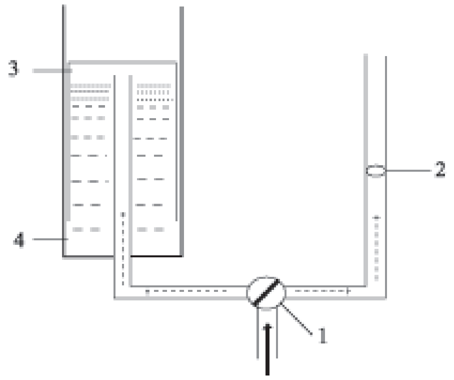

Fig. 6.
Diagram of measurement of flow rate of the gas and its volume:
1 - tap for gas flow movement direction switching,
2 – anemometer, 3 – graduated tank, 4 – water tank

It is known that it is possible to produce 1220 litres of hydrogen and 622 litres of oxygen from one litre of water. Quantity of the gases generated by the plasma electrolytic process is much greater than it is possible to get from consumed water (Table 1). It was a strong reason for a search of the measurement error. For this purpose, the diagram of measurement of flow rate of the gases and their quantity was used (Fig. 6).

The results of the measurements were as follows. The anemometer showed that 200 litres of gas mixture penetrated through it during 10 minutes. Nearly one litre of gases was in the graduated tank during this period.

Thus, the measurement of gas flow with the help of the anemometers distorted the result 200 fold. It should be mentioned that the reactor operated in the production mode of hydrogen and oxygen in the cathode zone. As a result, their mixture burst. The pulses of these explosions increased the readings of the anemometer.

It has become necessary to return to the reactor operation modes when no oxygen is released in the cathode zone. Our theory allows us to do this easy.

PROTOCOL

of tests of the first model of low-current Electrolyzers

It is known that it is possible to produce 1.22 l of H_2+ 0.622 O_2= 1.843 (H_2+O_2) from 1 ml of H_2O

Table 6
Experimental results

Indices	1	2	3	Average
1-duration of experiment, hour	1	1	1	1
2-voltage, V	70	70	70	70
3-current, A	0.038	0.080	0.098	0.072
4 – power, W	2.7	5.60	6.44	4.91
4-volume of consumed solution, ml	1.67	3.98	4.32	3.32
5-density of the solution, kg/l	1.04	1.04	1.04	1.04
6-volume of consumed water, ml	1.60	3.83	4.15	3.19
7-volume of the gas mixture being produced, l	2.95	7.06	7.85	5.95
6-volume of hydrogen being produced, l	1.95	4.67	5.07	3.80
7-energy consumption per 1 l of hydrogen, W·h/l	1.38	1.20	1.27	1.28
8-energy consumption per 1m^3 of hydrogen, kWh/m^3	1.38	1.20	1.27	1.28
9-existing energy consumption for production of 1 m^3 of hydrogen from water, kWh/m^3	4.00	4.00	4.00	4.00

CONCLUSION

Transmutation of the atomic nuclei of alkaline metals and the atomic nuclei of the cathode material during plasma electrolysis of water existed. Plasma electrolytic process opens new prospects in study of matter on the nuclear, atomic and molecular levels. The low-current electrolysis allows us to get the inexpensive hydrogen from water.

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LENR
(Low Energy Nuclear Reactions)

http://www.lenr-canr.org

Editorial: There is a collection of some papers on LENR (Low Energy Nuclear Reactions), also known as Cold Fusion. CANR, Chemically Assisted Nuclear Reactions, is another term for this phenomenon. These original scientific papers are reprinted with permission from the authors and publishers.

Website http://www.lenr-canr.org features a growing library of scientific papers about LENR and an extensive bibliography of journal papers, news articles and books about LENR.

COLD FUSION: What is it and what does it mean to science and society?

Edmund Storms

Cold fusion is important because it promises to be a new source of pollution-free, inexhaustible energy. In addition, it is important because it reveals the existence of a new way nuclei can interact that conventional scientific theory predicts is impossible. What then is this phenomenon that suffers such promise and rejection?

Energy can be obtained from the nucleus in two different ways. On the one hand, a large nucleus can be broken into smaller pieces, such as is experienced by uranium in a conventional nuclear reactor and by the material in an atom bomb. This is called fission. On the other hand, two very small nuclei can be joined together, such as occurs during fusion of deuterium and tritium in a Hot Fusion reactor and in a hydrogen bomb. This process, called fusion, also takes place in stars to produce much of the light we see.

The fission reaction is caused to happen by adding neutrons to the nucleus of uranium or plutonium to make it unstable. The unstable nucleus splits into two nearly equal pieces, thereby releasing more neutrons, which continue the process. As every one now knows, this process produces considerable waste that is highly radioactive. The uranium used as fuel also occurs in limited amounts in the earth's crust. As a result, this source of energy is not ideal, although widely used at the present time.

The normal hot fusion reaction requires two deuterium or tritium nuclei to be smashed together with great energy. This is accomplished by raising their temperature. However, this temperature is so high that the reactants cannot be held in a solid container, but must be retained by a magnetic field. This process has proven to be very difficult to accomplish for a time sufficient to generate useable energy. In spite of this difficulty, attempts have been under way for the last 40 years and with the expenditure of many billions of dollars. Success continues to be elusive while the effort continues.

Cold fusion, on the other hand, attempts to cause the same process, but by using solid materials as the container held at normal temperatures. The container consists of various metals, including palladium, with which the deuterium is reacted to form a chemical compound. While in this environment, the barrier between the deuterium nuclei is reduced so that two nuclei can fuse without having to be forced together. Because the process causing this to happen is not well understood, the possibility is rejected by many conventional scientists. Difficulty in producing the process on command has intensified the rejection.While this difficulty is real, it has not, as many skeptics have claimed, prevented the process from being reproduced hundreds of times in laboratories all over the world for the past 13 years. As you will see by reading the reviews and papers in our Library (see http://www.lenr-canr.org/LibFrame1.html), the process continues to be reproduced with increasing ease using a variety of methods and materials.

What is the nature of this process and why has it been so hard to understand? To answer this question, a person needs to understand the nature of the barrier that exists between all nuclei. Because all nuclei have a positive charge in proportion to their atomic number, all nuclei repeal each other. It is only the surrounding electrons that hold normal matter together, with the nuclei being at considerable distance from each other, at least on the scale of an atom. When attempts are made to push the nuclei closer, the required energy increases as the nuclei approach one another. However, when deuterium dissolves in a metal, it experiences several unique conditions. The surrounding metal atoms produce a regular array that is able to support waves of various kinds. These waves can be based on vibration of the atoms (phonons), vibration of the electrons, standing waves of electromagnetic energy, or a wave resulting from conversion of the deuterium nuclei to a wave. In addition, the high density of electrons can neutralize some of the positive charge on the deuterium nuclei allowing a process called tunneling, i.e.. allowing passage through the barrier rather than over it. The mechanism of this neutralization process is proposed to involve a novel coherent wave structure that can occur between electrons under certain conditions. All of these wave processes have been observed in the past under various conventional conditions, but applying them to the cold fusion phenomenon has been a subject of debate and general rejection.

While the debate based on wave action has been underway, people have proposed other mechanisms. These include the presence of neutrons within the lattice. Normally, neutrons are unstable outside of the nucleus, decomposing into a proton, an electron, and a neutrino. Presumably, this reaction can be reversed so that neutrons might be created in a lattice containing many free electrons and protons. Having no charge, the neutron could then interact with various atoms in the lattice to produce energy. These neutrons might also be hidden in the lattice by being attached to other nuclei in a stabilized form, to be released when conditions were right. Several particles normally not detected in nature also have been proposed to trigger fusion and other nuclear reactions.

While search for a suitable mechanism has been underway, an understanding of the environment that triggers the mechanism has been sought, the so-called nuclear-active-environment. Initially, this environment was thought to exist in the bulk of the palladium cathode used in the Pons-Fleischmann method to produce cold fusion. It is now agreed that the nuclear reactions only occur in the surface region. Recent arguments suggest that this surface layer does not even require palladium for it to be nuclear-active. Nuclear reactions have now been produced in a variety of materials using many methods. The only common feature found in all of these methods is the presence of nano-sized particles of material on the active surface. If this observation is correct, four conditions seem required to produce the nuclear reactions. First, the particle must have a critical small size; second, it must contain a critical concentration of deuterium or hydrogen; third, it must be constructed of certain atoms; and fourth, it must be exposed to a source of energy. This energy can take the form of a sufficiently high temperature, a significant high flux of hydrogen through the particle, application of energetic electrons or charged particles, or application of laser light of the proper frequency. Until, the importance of these factors is understood, the effect will continue to be difficult to replicate.

Technical Introduction to LENR-CANR

Edmund Storms

At low energies, the Coulomb barrier prevents nuclei from coming together and fusing to form a single nucleus. To initiate a nuclear reaction, several methods are used. Nuclear reactions are normally initiated by pushing two atoms together with enough force to overcome the Coulomb barrier by brute force, or by using neutrons which penetrate the nuclei without seeing a barrier. (Neutrons have no electrical charge, so the Coulomb barrier does not stop them.) These forces are normally provided by high-temperature plasma or by accelerating ions to high energies. In contrast, LENR describes the mechanism and conditions that cause a variety of nuclear reactions to take place with relatively low activation energy. These unique conditions reduce the need for excessive energy. The normal method forces the nuclei together, while the new method encourages them to come together. The challenge has been to understand the unique characteristics of the necessary solid structure such that this structure could be generated at will.

Because the proposed method is unique, at odds with current nuclear theory, and is still difficult to reproduce, support for studies in many countries, but not all, has been very limited. Nevertheless, considerable information has accumulated over the last 13 years since Profs. Stanley Pons and Martin Fleischmann showed the world the possibilities inherent in this phenomenon. Much understanding is buried in conference proceedings and reports that are not available to a serious student. This information will, as time permits, be made available on this site. Students of the subject are also encouraged to use this site to interact with other people in the field and provide objective critiques of the work published here.

PHENOMENA DISCUSSED IN SOME OF THE PAPERS

At least 10 ways have been demonstrated to produce anomalous heat and/or anomalous elemental synthesis. A few of these methods will be described here. For course, not all of the claims are worthy of belief nor are they accepted by many people. Nevertheless, the claims will be described without qualifications in order to provide the reader with the latest understanding.

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The most studied method involves the use of an electrolytic cell containing a LiOD electrolyte and a palladium cathode. Current passing through such a cell generates D+ ions at the cathode, with a very high effective pressure. These ions enter the palladium and, if all conditions are correct, join in a fusion reaction that produces He-4. Initially palladium wire and plate were used, but these were found to form microcracks, which allowed the required high concentration of deuterium to escape. Later work shows that the actual nuclear reaction occurs on the surface within a very thin layer of deposited impurities. Therefore, control of this impurity layer is very important, but rather difficult. The use of palladium is also not important because gold and platinum appear to be better metals on which to deposit the impurity layer. This method is found, on rare occasions, to generate tritium within the electrolyte and transmutation products on the cathode surface. Different nuclear reactions are seen when light water (H_2O) is used instead of D_2O, although the amount of anomalous energy is less when H_2O is used. These observations have been duplicated hundreds of times in dozens of laboratories.

Application of deuterium gas to finely divided palladium, and perhaps other metals, has been found to generate anomalous energy along with helium-4. Both palladium-black as well as palladium deposited as nanocrystals on carbon have shown similar anomalous behavior. In both cases the material must be suitably purified. Palladium deposited on carbon can and must be heated to above 200/260°C for the effect to be seen. When deuterium is caused to diffuse through a palladium membrane on which is deposited a thin layer of various compounds, isotopes that were not previously present are generated with isotopic ratios unlike those occurring naturally.

A plasma discharge under H_2O or D_2O between various materials generates many elements that were not previously present. When the electrodes are carbon and the plasma is formed in H_2O, the main anomalous element is iron. This experiment is relatively easy to duplicate.

Several complex oxides, including several superconductors, can dissolve D_2 when heated. When a potential is applied across a sheet of such material, the D+ ions are caused to move and anomalous heat is generated.

If deuterium ions, having a modest energy, are caused to bombard various metals, tritium as well as other elements not previously present are generated. These ions can be generated in a pulsed plasma or as a beam.

When water, either light or heavy, is subjected to intense acoustic waves, collapse of the generated bubbles on the surrounding solid walls can generate nuclear reactions. This process is different from the fusion reaction claimed to occur within a bubble just before it disappears within the liquid because neutrons are not produced in the former case, but are produced in the latter case. This method has been applied to various metals in heavy water using an acoustic transducer and in light water using a rotating vane which generates similar acoustic waves...

HOW TO EXPLAIN THE CLAIMS

A major problem in deciding which model might be correct is the absence of any direct information about the nature of the nuclear-active-environment. At this time, two important features seem to be important, the size of the nanodomain in which the reactions occur and the presence of a deuterium flux through this domain. The domain can apparently be made of any material in which hydrogen or deuterium can dissolve. Until the nature of the nuclear-active-state (NAS) is known, no theory will properly explain the effect and replication of the claims will remain difficult.

When fusion is initiated using conventional methods, significant tritium and neutrons are produced. In addition, when other elements are generated, they tend to be radioactive. This is in direct contrast to the experience using low energy methods. These products are almost completely absent and, instead, helium-4 is produced. When radiation is detected, it has a very low energy. This contrasting behavior, as well as the amount of anomalous energy, has made the claims hard to explain using conventional models. This difficulty has been amplified by a failure of many skeptics to recognize the contrasting effect of the environment, a plasma being used in the older studies and a solid lattice of periodic atoms being present as the new environment.

Over 500 models and their variations have been proposed, some of which are very novel and some are variations on conventional ideas. Most models attempt to explain the nuclear reaction once the required environment has been created, without addressing what that unique environment might be like. These models involve conversion of a proton (deuteron) to a neutron (dineutron), creation of an electron structure that is able to neutralize the barrier, conversion of deuterium to a wave which interacts without charge, and the presence of otherwise overlooked neutrons and/or novel particles. Many of the models will have to be abandoned or seriously modified once the nature of the nuclear active environment is understood.

It Started in 1989 . . .

Peter Hagelstein

Many of us recall the controversy surrounding the announcement of claims of observations of fusion reactions in a test tube that were made in 1989. At the time, these claims were greeted with considerable skepticism on the part of the physics community and the scientific community in general.

The principal claim of Pons and Fleischmann

The principal claim of Pons and Fleischmann in 1989 was that power was produced in palladium cathodes that were loaded electrochemically in a heavy water electrolyte. The evidence in support of this was a measured increase in the temperature in the electrochemical cell. There was no obvious evidence for nuclear reaction products commensurate with the claimed heat production. Fleischmann speculated that perhaps two deuterons were somehow fusing to He-4 through some kind of new mechanism.

Rejection by the physics community

This claim was not accepted by the physics community on theoretical grounds for several reasons:

First, there was no mechanism known by which two deuterons might approach one another close enough to fuse, since the Coulomb barrier prevents them from approaching at room temperature.

Second, if they did approach close enough to fuse, one would expect the conventional dd-fusion reaction products to be observed, since these happen very fast. Essentially, once two deuterons get close enough to touch, reactions occur with near unity probability, and the reaction products (p+t and n+He-3) leave immediately at high relative velocity consistent with the reaction energy released. To account for Fleischmann's claim, the proposed new reaction would seemingly somehow have to make He-4 quietly and cleanly, without any of the conventional reaction products showing up, and would somehow have to arrange for this to happen a billion times faster than the conventional reaction pathway. Most physicists bet against the existence of such a magical new effect.

Third, the normal pathway by which two deuterons fuse to make He-4 normally occurs with the emission of a gamma ray near 24 MeV. There was no evidence for the presence of any such high energy gamma emission from the sample, hence no reason to believe that any helium had been made.

Finally, if one rejects the possibility that any new mechanisms might be operative, then the claim that power was being produced by fusion must be supported by the detection of a commensurate amount of fusion reaction products. Pons and Fleischmann found no significant reaction products, which, given the rejection of new mechanisms, implied an absence of fusion reactions.

An alternate explanation is proposed

The physicists decided in 1989 that the most likely reason that Pons and Fleischmann observed a temperature increase was that they had made an error of some sort in their measurements. When many groups tried to observe the effect and failed, this led most of the physics community to conclude that there was nothing to it whatsoever other than some bad experiments.

The claim of Jones

A second very different claim was made at the same time in 1989 by Steve Jones. This work also involved electrochemistry in heavy water and the observation of reaction products corresponding to the conventional dd-fusion reactions. The initial publication showed a spectrum of neutron emission that Jones had detected from a titanium deuteride cathode loaded electrochemically. The response of the physics community was skeptical, as the signal to noise ratio was not particularly impressive. Given the polarization of the physics community in opposition to the claims of Pons and Fleischmann (which were announced essentially simultaneously), the physicists were not of a mood to accept much of any claims that fusion could happen in an electrochemical experiment at all. Jones went to great lengths to assure fellow scientists that his effect was completely unrelated to the claims of Pons and Fleischmann, and was much more reasonable.

Also rejected

Physicists had reason to be skeptical. Theoretical considerations indicated that the screening effects that Jones was relying on were not expected to be as strong as needed to account for the fusion rates claimed. As this experiment could not seem to be replicated by others at the time, it was easy for the physics community to reject this claim as well.

Cold fusion, weighed and rejected with prejudice

Cold fusion, as the two different claims were termed, was dismissed with prejudice in 1989. The initial claims were made near the end of March in Utah, and the public refutation of the claims was made at the beginning of May. It only took about 40 days for the physics community to consider the new claims, test them experimentally, and then announce loudly to the world that they had been carefully weighed and rejected.

Following this rejection, physicists have treated cold fusion rather badly. For example, Professor John Huizenga of Rochester University was selected to be co-chair of the DOE ERAB committee that met to review cold fusion and issue a report. Shortly afterward, he wrote a book entitled Cold Fusion, The Scientific Fiasco of the Century, in which he discusses the claims, the experiments, and the extreme skepticism with which the new claims were greeted. Robert Park discusses the subject in his book entitled Voodoo Science. You can find many places where physicists and other scientists happily place the cold fusion claims together with claims of psychic phenomena.

A Science Tutorial

Talbot Chubb

First it is important to recognize that there are four distinct types of energy production:
1) chemical energy, that powers our cars and most of our civilization;
2) nuclear fission energy, as used to generate about 15% or our electricity;
3) hot fusion nuclear energy, which powers the sun and most stars;
4) cold fusion nuclear energy, which appears as unexplained heat in a few experimenter's laboratory studies and which most scientists believe is impossible.

The three types of nuclear energy produce 10 million times as much heat per pound of fuel than occurs with chemical energy. How do these types of energy differ? To understand this question you need to know some chemistry and physics.

Lesson 1

Nature has provided us with two types of stable charged particles, the proton and the electron. The proton is heavy, normally tiny, and has a positive charge. The electron is light, normally large and fuzzy, and has a negative charge. The positive charge and the negative charge attract each other, just like the north pole of a magnet attracts the south pole of a magnet. When you bring two magnets together with the north pole of one facing the south pole of the other, they pull together, bang! When they bang into each other they release a little bit of energy in the form of heat, but it is too small an amount to easily measure. To pull the magnets apart you have to do work, which is another way of saying you have to use up energy. It's almost like pulling a rock back up a hill. Rolling the rock down a hill actually creates a little heat, and pulling the rock back up the hill takes energy. In the same way the positive charge of the proton pulls on the negative charge of the electron and they stick together releasing energy in the process. The result is a hydrogen atom, designated H. A hydrogen atom is nothing but a fuzzy electron hugging a compact proton. The proton is the nucleus of the hydrogen atom. If you knock the electron off the hydrogen atom you get a positive ion H+, which is nothing more than the original proton. An ion is the name applied to an atom or molecule that has lost or gained one or more electrons, hence is no longer electrically neutral.

Lesson 2

As you know, nature has provided us with more than one type of atom. We have oxygen atoms, nitrogen atoms, iron atoms, helium atoms, etc.. How do these atoms differ? The answer is that they all have different types of nuclei (plural of nucleus, from the Latin). And these different nuclei all have different numbers of protons inside them, which means they all have different plus charges. The nucleus of the helium atom has 2 protons inside it, hence has plus 2 charge, and requires 2 electrons to neutralize its charge. When 2 electrons stick to it, it becomes a helium atom. The oxygen nucleus has 8 protons and has charge 8. When 8 electrons stick to it, it becomes an oxygen atom. The nitrogen atom has 7 electrons, and the iron atoms something like 26. But all the atoms are built more or less the same way, with a compact positively charged nucleus embedded in a cloud of fuzzy electrons. The difference in size between the compact nucleus and the fuzzy electrons is enormous. The sun has a diameter only about 100 times that of the earth. The electron cloud on an atom has a diameter which is about 100,000 times that of the nucleus. Cube these numbers to get the difference in volumes.

Lesson 3

We now are in a position to understand what chemical energy is. The atoms, all electrically neutral, can actually join with each other and release more energy. This is another way of saying that they can join into more stable configurations. The electrons in an atom try to configure themselves so as to get as close as possible to their nucleus, but their fuzzy nature requires that they take up a certain volume of space. However, if they join together with the electrons of another atom they can usually find a tighter configuration that leaves them closer to their beloved beginning of May. It only took about 40 days for the physics community to consider the new claims, test them experimentally, and then announce loudly to the world that they had been carefully weighed and rejected.

Following this rejection, physicists have treated cold fusion rather badly. For example, Professor John Huizenga of Rochester University was selected to be co-chair of the DOE ERAB committee that met to review cold fusion and issue a report. Shortly afterward, he wrote a book entitled Cold Fusion, The Scientific Fiasco of the Century, in which he discusses the claims, the experiments, and the extreme skepticism with which the new claims were greeted. Robert Park discusses the subject in his book entitled Voodoo Science. You can find many places where physicists and other scientists happily place the cold fusion claims together with claims of psychic phenomena.

A Science Tutorial

Talbot Chubb

First it is important to recognize that there are four distinct types of energy production:
1) chemical energy, that powers our cars and most of our civilization;
2) nuclear fission energy, as used to generate about 15% or our electricity;
3) hot fusion nuclear energy, which powers the sun and most stars;
4) cold fusion nuclear energy, which appears as unexplained heat in a few experimenter's laboratory studies and which most scientists believe is impossible.

The three types of nuclear energy produce 10 million times as much heat per pound of fuel than occurs with chemical energy. How do these types of energy differ? To understand this question you need to know some chemistry and physics.

Lesson 1

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Lesson 4

We have slid over one point in the above discussion. How does Nature make a nucleus containing two or more protons in the first place. After all, each of the protons has a positive charge, and the positive charges repel each other very strongly when they are separated by a tiny distance, equal to the distance across a nucleus. The repulsion of like charges is just like the repulsion between the north poles of two magnets when they are pushed together the wrong way. Something must overcome this repulsion, or else the only kind of atoms we would have would be those of hydrogen. Fortunately, this is not what we observe. The answer is that there is a second kind of force which acts on protons. This is the nuclear force. The nuclear force is very strong but requires particles to almost sit on each other to have any effect. Also, there is a second kind of heavy particle, which is just like a proton, except that it has no positive or negative charge. It is not pushed away by the proton's plus charge. This other kind of particle is called the neutron, since it is electrically neutral. A peculiar fact of life is that it exists in stable form only inside a nucleus. When not in the nucleus it changes into a proton, an electron and a very light anti-neutrino in about 10 minutes. But it lasts forever inside a nucleus. Anyway, the neutron and the proton very strongly attract each other once they get close enough together, and then they combine to form a highly stable pair called a deuteron, which we designate D+. The single deuteron, when it combines with a single electron, forms the heavy hydrogen atom called deuterium, designated D. A second nuclear reaction occurs when two deuterons make contact. When they can be forced together so as to make contact, the 2 deuterons fuse, making a doubly charged particle. The grouping of 2 protons and 2 neutrons is even tighter than the proton-neutron grouping in the deuteron. The new particle, when neutralized by 2 electrons, is the nucleus of the helium atom, designated He. Larger groupings of neutrons and protons exist in nature and serve as the nuclei of carbon, nitrogen, oxygen, and iron, etc. atoms. All of these groupings are made possible by the very strong nuclear force, which is felt between particles only when they are in contact or share the same nucleus-size volume of space.

Lesson 5

We can now understand normal nuclear energy, which is really nuclear fission energy. During the early history of the universe massive stars were formed. In the explosion of these massive stars, lots of different types of nuclei were formed and exploded back into space. Second and later generation stars and planets were formed from this mix, including the sun. In the explosion process probably every possible stable configuration of protons and neutrons was produced, plus some almost-stable groupings, such as the nucleus of the uranium atom. There are actually 3 different types of uranium atom nuclei, called uranium-234, uranium-235, and uranium-238. These "isotopes" differ in their number of neutrons, but they all have 92 protons. The nuclei of all uranium atoms can go to a lower energy configuration by ejecting a helium nucleus, but this process occurs so rarely that the Earth's uranium has already lasted over 4 billion years. But the uranium nuclei are unstable in another way. In general, groupings of protons and neutrons are happiest if they have about 60 protons-plus-neutrons. The uranium nuclei contain more than three times this number. So they would like to split in two, which would release a lot of heat. But nature doesn't provide a way for them to split apart. They have to first go to a higher energy configuration before splitting in two. However, one of the three forms of uranium nucleus found in nature called uranium-235 and designated ^{235}U, gains the needed energy if it captures a neutron. The energized nucleus that results from neutron capture then splits apart with the release of an enormous amount of energy, and incidentally with release of additional neutrons. The additional neutrons can then split more uranium-235 nuclei, keeping the reaction going. This is what happens in nuclear power plants, where the heat, which is the end product of the nuclear splitting process, is used to boil water, generate steam, and turn electrical generators. (One also gets lots of radioactive products, which are a nuisance to dispose of safely.)

Lesson 6

We are now also in a position to understand hot fusion nuclear energy. As mentioned in lesson 5, the groupings of protons plus neutrons is most stable when the numbers of neutrons and protons approximate those found in the nucleus of an iron atom. Just as uranium has too many neutrons plus protons to be comfortable, so the light elements like hydrogen, helium, carbon, nitrogen and oxygen have too few. If the nuclei can be made to make contact under proper conditions, they can combine to create more stable groupings, plus heat. This is the process of fusion. Nature has found a way of doing this in stars like the sun. All Nature has to do is heat compressed hydrogen hot enough and wait long enough and hot fusion will occur. If Nature were to start with deuterium, which already has a paired proton and neutron, the task would be relatively easy in a star. Temperature is a measure of how much speed an atom of a given type has as it bangs around inside a cloud of such atoms. The higher the temperature, the higher the speed and the closer the atoms get to each other momentarily during a collision. In a star the temperatures are high enough that all the electrons quickly get knocked off the atoms, so one is really dealing with a mixed cloud of electrons and nuclei. At very high temperature the nuclei occasionally get close enough during collisions for the pulling-together short range nuclear force to turn on. Then the nuclei can stick together and go to a lower energy grouping of protons plus neutrons, releasing heat. Hot fusion nuclear energy is an attempt to carry out this process in the lab, using deuterium and mass-3 hydrogen (whose nucleus is a compact grouping of 1 proton and 2 neutrons) as the gas. Hot fusion requires that the gas be contained at temperatures of hundreds of millions of degrees, which can be done with the help of magnetic fields, but only for 1 or 2 seconds. The hope is to contain the gas for longer times. During the period of high temperature containment nuclear reactions occur during collisions. The main form of energy release is ejection of high energy neutrons and protons. The proton energy quickly converts to heat. The neutron energy can also be converted to heat but makes the equipment highly radioactive. It then becomes difficult to repair the equipment, which could make hot fusion a poor candidate for commercial power production. In any case hot fusion power is a dream that is still probably at least 50 years away. But most scientists view hot fusion as the only way to achieve fusion power. Hot fusion produces less radioactivity than fission power, is environmentally benign, and has a virtually limitless fuel supply on earth (many millions of years at present energy usage rates).

Lesson 7

So now we come to cold fusion. Cold fusion may provide an easier and non-radioactive way of releasing nuclear fusion energy. Cold fusion relies on a different way of letting the protons and neutrons in one nucleus make contact with those in another nucleus, so that the nuclear force can bring them into a more stable configuration. The requirement for any nuclear reaction to occur is that the reacting nuclei occupy the same volume of space. This condition is called particle overlap. In hot fusion particle overlap is brought about briefly by banging the nuclei together so as to overcome momentarily the repulsion of the two positive charges which try to keep the particles apart. In cold fusion particle overlap conditions are achieved by making deuterium nuclei act as fuzzy objects like electrons in atoms, instead of like tiny points. When either light or heavy hydrogen is added to a heavy metal, each hydrogen “atom” occupies a position inside the metal where it is surrounded by heavy metal atoms. This form of hydrogen is called interstitial hydrogen. With interstitial hydrogen the electrons of the hydrogen atom become part of the pool of electrons of the metal. Each hydrogen nucleus oscillates back and forth through a negatively charged electron cloud provided by the electrons of the metal. They can be thought of as moving back and forth like the pendulum in a grandfather clock. This vibration exists even at very low temperature, due to a peculiarity of a branch of physics called quantum mechanics. The vibration is called zero point motion. The nucleus then becomes a fuzzy object, like the electrons in an atom. But this amount of fuzziness is not enough to permit a hydrogen nucleus to make contact with another hydrogen nucleus. To get two or more hydrogen nuclei to share the same volume one must go one step further. In a metal electrical current is carried by electrons that act more like vibrating matter waves than like point particles. If electrons did not become wave-like inside solids, there would be no transistors and no present day computers. This wave-like kind of electron is called a Bloch function electron. The secret of cold fusion is that one needs Bloch function deuterons. One needs wave-like deuterons inside or on the surface of a solid in order that two or more deuterons share the same volume of space. But once the Bloch function deuterons are created, the nuclear force comes into play and the protons and neutrons making up the deuterons can rearrange themselves into the more nuclearly stable Bloch function helium configuration, with release of heat. To study cold fusion the experimenter has to force deuterons to assume the wave-like form and keep them in the wave-like state. Cold fusion experiments demonstrating release of excess heat show that this can be done. But at present no one knows how to do it reliably. Since cold fusion promises millions of years of energy without the problems of global warming or radioactivity, a real effort should be made to learn how.

For more tutorials go to www.hometown.aol.com/cffuture1 and www.hometown.aol.com/cffuture2

LENR (Low Energy Nuclear Reactions) Experiments

Review from
http://www.lenr-canr.org

Have you ever wondered what a physics laboratory looks like? They are seldom spacious or organized the way they are shown in movies. Most LENR researchers work at universities or home laboratories, with tight budgets in a crowded space. They keep old, broken equipment on shelves to scavenge parts for new experiments. In this section we present some photographs of equipment provided by researchers, and close up pictures of equipment. The actual cells, cathodes and other equipment used in electrolysis experiments often have an ad-hoc, home-made appearance, because they are made by hand. They have to be; they are unique, one-of-a kind prototypes. Nothing quite like them has ever been made before.

A visitor seeing a LENR experiment the first time may feel disappointed. It looks like any other electrochemical experiment. The heat or neutron flux produced by the experiment are so small they can only be detected with sensitive instruments. A null cathode that produces no effect looks exactly like an active cathode. The difference between one cathode and another is in the microscopic structure, or the traces of elements mixed in with the palladium. Only one kind of cold fusion looks dramatic i. e. the glow discharge reaction.

Here are a few photographs of cold fusion cells and devices (also see the cover page).

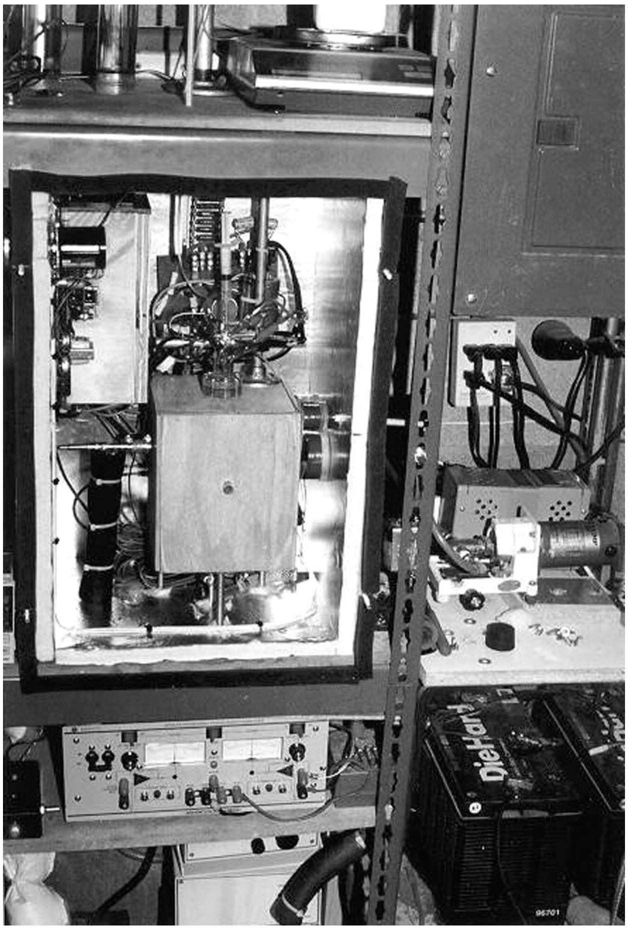

Fig.1
Box Calormeter

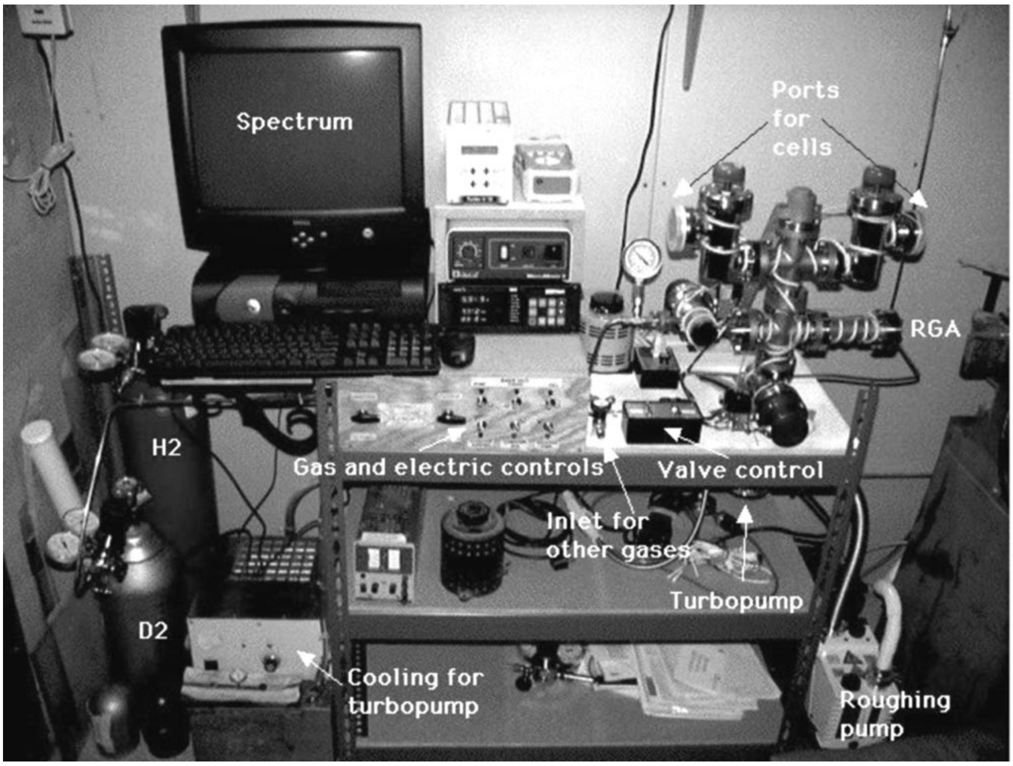

On Fig. 1 there is a calorimeter constructed by Edmund Storms. Note the DieHard® battery, lower right, that serves as an unninterruptable power supply. A power failure can ruin an experiment. Whenever possible, inexpensive, ordinary materials and instruments are used. However, experiments are never cheap, and they cannot be done on a shoestring. The equipment, arranged for another experiment (see Fig. 2), costs about $40,000.

Fig.2 (On the left)
Vacuum system to prepare particles for gas loaded cold fusion cells, courtesy E. Storms.

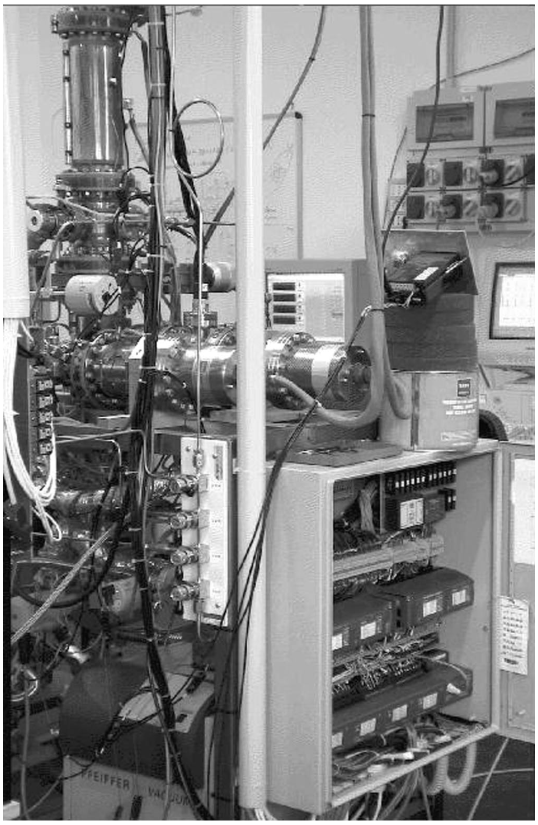

Fig.3

A high resolution mass spectrometer used for on-line helium detection during a cold fusion experiment at C. R. ENEA Frascati. (http://www.frascati.enea.it/nhe/)

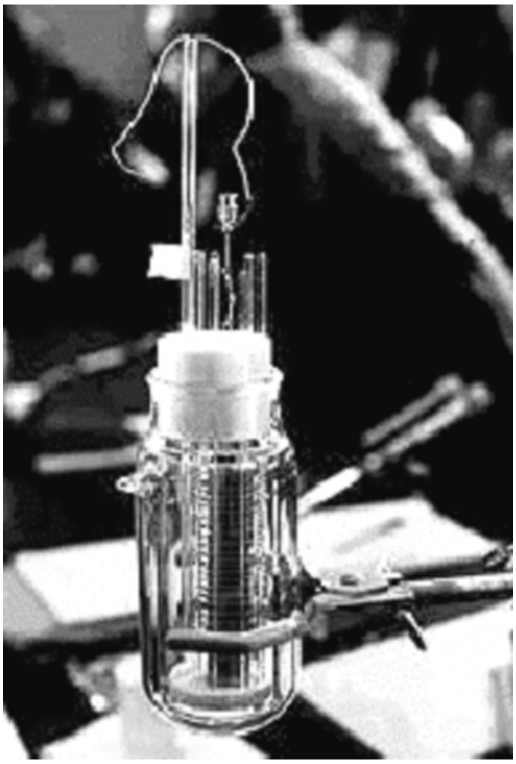

Fig.4

A cell at ENEA Frascati

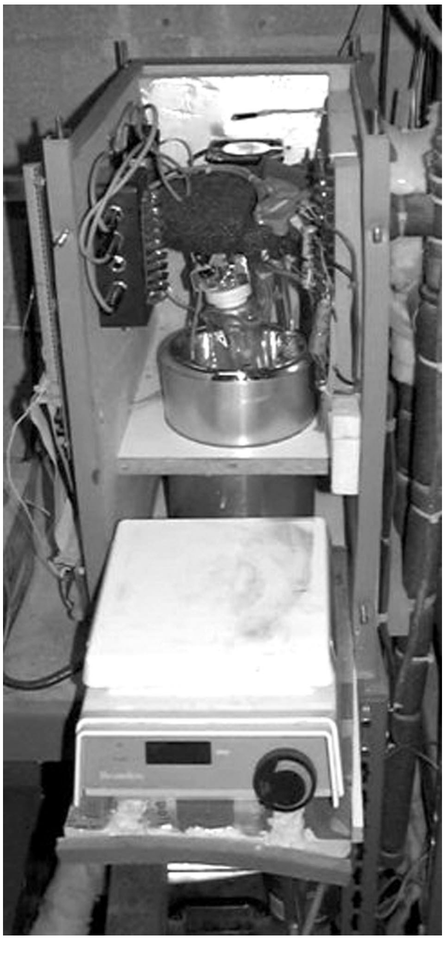

Fig.5

A flow-type cell, courtesy E. Storms

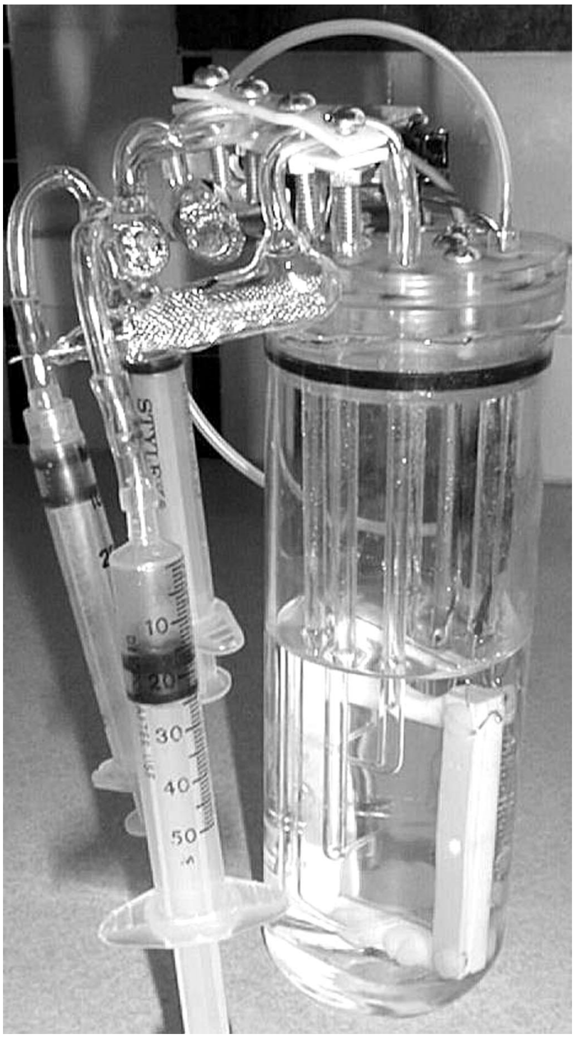

Fig.6

Close up of a Miley-style cell, courtesy E. Storms

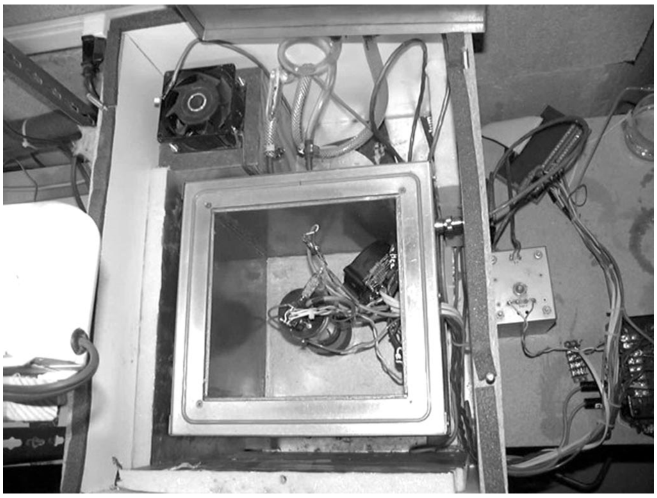

Fig.7

A cell installed inside a Thermonetics Seebeck calorimeter with the lid removed, courtesy E. Storms

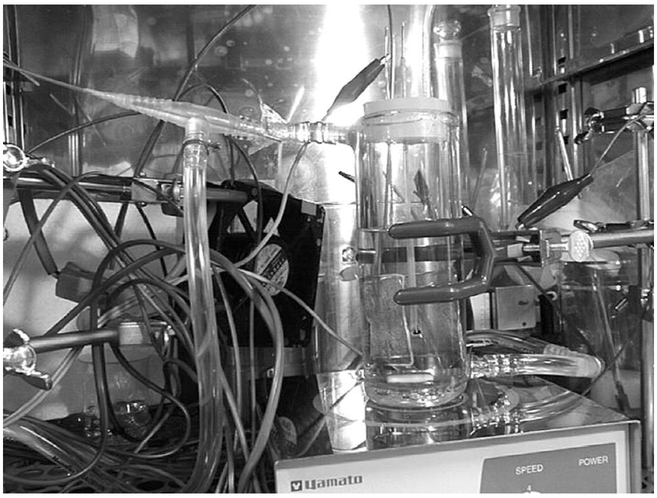

Fig.8

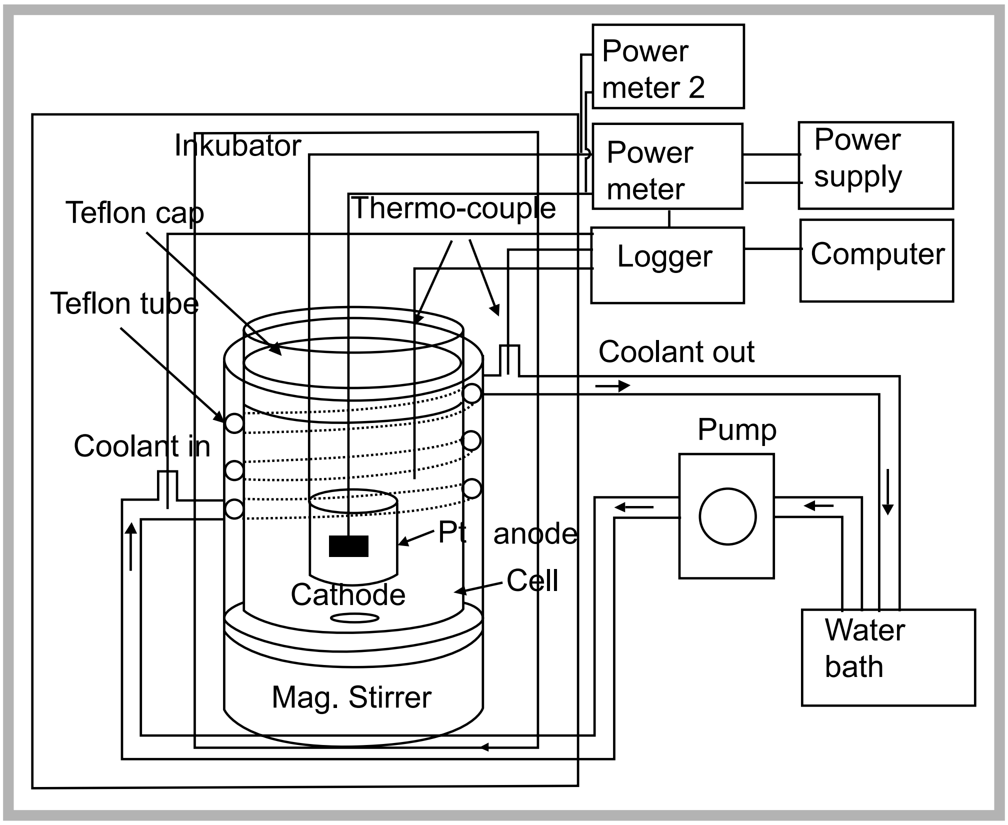
Power meter 2
Inkubator
Power meter
Power supply
Teflon cap
Thermo-couple
Logger
Computer
Teflon tube
Coolant out
Pump
Coolant in
Pt anode
Cathode
Cell
Water bath
Mag. Stirrer

On the Fig. 8 you can see a glow discharge electrochemical cell at Hokkaido University, courtesy T. Mizuno. The cell is installed inside a crowded constant temperature air-cooled chamber. It placed on a magnetic mixer. Cooling water is pumped through the plastic tubes attached to the top and bottom. The muffin fan at the back circulates the air in the chamber

Fig.9

A schematic of the calorimeter shown above.

Hydrogen power engineering

Faraday Laboratories Ltd, Moscow, and Spectrum Investments Ltd, London, started joint R&D project on hydrogen power engineering. Photo: Alexander V. Frolov, Faraday Laboratories Ltd and Nicholas Moller, Spectrum Investments Ltd. The project includes designing and building of prototype to use hydrogen recombination process for heat generation.

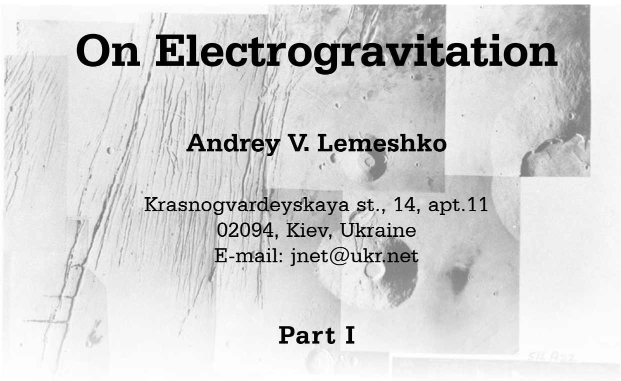

On Electrogravitation

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Part I

"let's go to the Mars!"

Nowadays it becomes evident that exploration of deep space by means of rocket equipment is impossible. Aircrafts, which run on jet thrust, are too expensive and unreliable. Besides, they are too slow-speed if were considered on a scale of solar system. For example, the flight to the remote areas of our planetary system can drag on tens years. But the main disadvantage of rockets is their low load-carrying capacity. Thus, the most powerful transport system "Progress" can deliver less than 100 ton of load to the orbit of the Earth, and only 1 ton to the orbit of the Mars. Rather natural question arises as to whether any alternative ways of space exploration exist? Are there any transport systems, which can compete with rocket equipment on the interplanetary routs of future? Actually, at present there is only one technology, which is alternative to rocket ones – it is the so-called light sailers, using light pressure for acceleration. Laser and maser can be also used for their acceleration from satellites. However, there are also some disadvantages here.

There is also one more transport system, which is undeservedly consigned to oblivion. It uses electricity in acceleration aggregate. This transport system or the electric propulsion system is a result of researches and investigations of two little-known, but extremely talented American physicians and inventors, Thomas Townsend Brown and Paul Alfred Biefeld (the last one was also a professor of Astronomy).

Thomas T. Brown was the first who discovered electric principle of this propulsion system. Thus, in twenties of the XX century Thomas T. Brown, being the student of secondary school, became interested in X-rays. He wanted to reveal if the rays, outgoing the X-ray unit, could take positive effect. For his researches the inventor had got Coolidge Tube, the device, which radiates X-rays and consists of a glass tube. Deep vacuum is created in this glass tube. Anode and cathode are placed in the tube. Cathode radiates electrons and anode brakes them. X-rays are created at striking of electrons against anode. Brown used Coolidge Tube in the way nobody had done before. For ease of handling the researcher suspended the device on wires, which run to anode and cathode parallel to the Earth. During the operation of the device he noticed that every time when current fed to the tube, the tube was moved aside and tended to make slight progressive motion. Subsequent experiments demonstrated that the deviation value depended only on the value of voltage, which is between anode and cathode. The higher voltage is, the more deviation. X-rays were neither here not there. Much later at participation of Paul A. Biefeld, the same tendency to move was revealed at plane disc capacitors. The reason, which causes this motion, is the same, i.e. voltage, which exists between plates and not between anode and cathode as in Coolidge Tube.

Having run series of experiments, the researchers proved that electric energy could be directly transformed to mechanical. They also devised the physical principle, which were included in the scientific annals as Biefeld-Brown effect.

Editor's: Let us note that earlier Ampere and Faraday have been working on Electrokinetic effects which are easily detected at strong current. Modern researches on this point are known as "Sigalov's effect" (force appears in electric conductor which is bent at angle and at current impulse).

The essence of this effect lied in the fact that charged disc electric capacitors tend to move in the direction of their positive pole. At formulating of the essence of this effect the scientists consciously did not mention Coolidge Tube in order to demonstrate that according to their experimental observations, electron streams were not involved in generation of electromotive force. This effect of the direct transfer of electric energy to mechanic one (Biefeld-Brown effect) is observed, when current is fed to the Coolidge Tube or to the plane disc capacitor.

However, all this was realized much later, when in 1923 Brown became a student of Dennis University in Greenville, Ohio, where he met his teacher and later on a coauthor, Paul A. Biefeld. In school time the inventor came to the conclusion that the reopened by him phenomenon has nothing in common with X-rays and that high voltage, used for rays generation, is the basis of this phenomenon. Besides, Brown designed a device named "Gravitor". It looked like a usual bakelite box and was made as a simple construction, which consisted of several flat aluminum plates. The plates were placed as coins in a rouleau and separated with dielectric. It had only to place the box on the scale and connect it to some energy source with 100 kV voltage as the device either lost or put on about one percent of its weight that depended on polarity. An outside observer, who was not familiar with the essence of this effect, could think that mass was really changed. *(Editor's: Weight but not the mass is changed here. Weight is the force. There is a possibility of partial compensation of the weight by another force.)* But this was not the case. For better understanding of the processes, which take place at gravitor operating, let us make a mental experiment. Let us take a weight, put it on the scale and then raise it a little. The scale will certainly show that the weight has become lighter. After that let us press the weight then the scale will show that it has become heavier. However, in fact mass does not change. In the same way motive force, caused by high voltage, slightly raises the gravitor and at changing of polarity presses it. At that it seems that there is some change in weight. Thus, as if by chance, the scientist has discovered effect of direct transition of electric energy into mechanical one. *(Editor's: Let us specify the author's terminology. In T.T. Brown's Patent of 1927 it was mentioned that there* *was generated a force which partially compensated weight. The matter was always about the generation of x-force while gravitational field remained unchangeable).*

Having graduated from the University, from 1926 up to 1952 Brown already by himself was being occupied with development of his electrical propulsion system. At the same time whether in chase of fame or in hope to obtain money for his researches, T.T. Brown began asserting that he had discovered something new in physics, viz "electrogravitation", i.e. some connecting effect between gravitation and electricity. *(Editor's: In my opinion, T.T. Brown has never posed a problem in such a way. The matter always concerned the fact that X-force appears while gravitational field does not change.)* As for the development of the invention, it came to the decrease of weight of the device and increase of DC voltage, which fed the plates of the "gravitor". As a result the devices could fly and lift weight which greatly exceeded their own. Thus in 1953 in his laboratory Brown demonstrated the flight of aircraft which had a disk form. The device made 51 m/c (180 km/h), flying at circular course of 6 m diameter. This device was nothing but very lightweight capacitor in which by means of the special construction electromotive force was redirected in two planes upward and sideward. It made the device rise in air and fly around the mast. Current of 50kWtt voltage was supplied to the central mast by the wire. Then speed of "flying disks" became higher, the payload capacity was increased but that was again resulted by decrease of weight and increase of the supplied voltage. T.T. Brown so succeeded in decreasing of the thickness of capacitor plates and in making his devices superlight, that the witnesses of these demonstrations called these devices as "air films".

Later on all works in this area were placed on secret list and then closed because of lack of prospects. Thus, accounts and experiments demonstrated that it was impossible to overcome terrestrial attraction entirely and go to outer space by means of the gravitor because there are no such natural materials which could take huge electric and heat loads. Besides, sufficiently massive electric power station would be needed to produce required currents. *(Editor's: Thereupon the following question appears: why the author looks for "currents" while the essence of the technology is in applying of high voltage but not of the currents?!)* Moreover some alternative was made, i.e. jet engines. Gravitor could not compete with them by above-mentioned and quite objective reasons. In time, since the mechanism of transition of electric energy into mechanical one was not disclosed and Brown's populist idea has received some publicity, this effect became surrounded with idle talks and guess-works. However the scientists who researched this very effect, has developed only three theory wh ich could explain its existence.

The first theory was suggested by T.T. Brown, the discoverer of this effect. To his dying day Brown asserted that he had discovered the effect which could connect gravitation and electricity, i.e. "electrogravitation". But this theory can be easily refuted by practice. It is enough to put Brown's bakelite box to the scale in such a way as to place the plates of the "gravitor" at right angle to the surface of the scales. Then poles of the "gravitor" will be placed at the same level and parallel to ground and as a consequence electromotive force will influence in no way on the scale, since this force is directed sideward but not upward or downward. The scale will accurately show that there are no changes in weight and hence there is no **electrogravitation**. *(Editor's: The author will obtain propulsive force and it is directed not upward and downward but sideward. However the effect exists in any case. The changing of weight appears only when propulsive force generated by the device is directed against the weight force, i.e. upright.)*

The second theory was suggested by T. Brown's opponents. They asserted that electromotive force appears as a result of the so called "electron wind", i.e. electron streams which exist between the plates of the "gravitor". In their argumentations Brown's opponents rest upon the following facts which are well-known to every physicist. Fast electrons, as well as photons, have dual properties, i.e. interacting with matter and environment, they behave both as a wave and as a material particle. Since light or photons carry energy, then they heat bodies which are in their way and put pressure on the illuminated surface etc. Similarly electron streams carry heat or kinetic energy and hence they can put pressure on the anode of Coolidge Tube and get it moving forward. This theory seems to be interesting, however it explains appearance of electromotive force only in Coolidge Tube, but there is no explanation why discoid capacitors tend to move. Point is that there are no free electron streams in the capacitors. Usually between the plates of capacitors there is a dielectric which brings electron streams to nothing. If there is no electron wind, then what makes capacitors move?

Editor's: There is always a surface charge and reactive outflows of ions. But it is just a partial explanation of Biefeld-Brown's effect.

The third theory is based on the following fact. It is well known that electrons can have heat or Brownian chaotic motion. Free electrons, placed in a conductor, are in the similar chaotic heat motion before voltage is applied to this conductor. The higher temperature of the environment is the higher speed of this heat motion. According to school course of physics, heat energy or energy of chaotic motion of molecules (electrons) can be entirely transferred into mechanical one. If all molecules (electrons) start to move simultaneously and in the same direction, and if they push some piston toward this direction then heat energy of molecules (electrons) will be entirely transferred into mechanical work. In other ways, this piston will move until molecules (electrons) calm down. It is considered that this process is unrealizable in practice.

However, it seems that this is not quite the case, i.e. it is possible to regulate chaotic heat motion of electrons. Obviously this process takes place in the capacitor and in Coolidge Tube. It is no secret that when negative electrons try to move to the neighbor positive charged electrode, then dielectric layer which is placed between the plates of the capacitor prevents it. Electrons rest upon this layer and start to heat. Their internal energy is also increasing. The higher voltage is the higher heating of electrons, i.e. their capacity to have chaotic heat motion increases. However, chaotic motion of electrons is not observed on the capacitor plates, since the directed force (voltage) influences electrons. Electrons tend to move upward, downward, to the right and to the left, but voltage prevents it. Thus they just are forced to move in space in one direction and with the same speed. Capacitor or gravitor has to move alongside with electrons because plates of the capacitor (gravitor) become a piston which is pushed by heated electrons. This piston is in progressive motion. It starts to move under the influence of electrons, or rather together with electrons. The higher voltage is, the higher temperature of electrons and hence the higher their speed. Therefore speed of capacitor (gravitor) increases at voltage increase. There is a usual chain, i.e. electric energy transfers into heat energy and heat energy transfers into mechanical one. Approximately the similar process takes place in Coolidge Tube, but there the heat of electrons is caused by thermoelectric emission on the cathode. Electrons evaporate from the cathode surface. Voltage, existing between anode and cathode, makes electrons move in one and the same direction. They move towards anode, which serves as piston and takes heat push upon itself, i.e. it transfers heat energy of electrons into mechanical work. It is clear that the higher voltage is the more intensively electrons are heated. Therefore electrons more intensively influence anode and the suspended tube is deviated to a greater extent. (*Editor's: Nowadays this very explanation is the most admitted one.)*

Resting upon Biefeld-Brown's theory and experimental results and at sufficient financing, already within the next few years it would be possible to create a unique electric engine which can operate on hot or quick electrons. Besides there will appear a possibility to orbit the first spaceship equipped with a propulsion system similar to gravitor one's. In near future scheduled cargo-and-passenger service could be organized within planetary system. First of all such transportations can be organized between the Mars, Moon and Venus orbits that will let to start active colonization of these planets.

Thus, more than 200 flights to the Moon and back and about 70 flights to the Mars are possible by means of the gravitor which is made of modern fusions and dielectric materials and which is placed on the Earth orbit. At that there is a minimum risk for its breakdown during the flight, because gravitor has no movable parts and no explosives are used. Negative consequences for the crew in an improbable emergency are insignificant. Even if high voltage causes disruption of dielectric layer between the electrodes and voltaic arc appears then the spaceship, equipped with such a propulsion system, will mechanically arrive its destination. The source of energy will be its only trouble spot and it will happen only if nuclear reactor instead of solar batteries is used. There is also an idea to attach dwelling capsules and cargo bays, equipped with such electric engine, one after another, like carriages are attached to a locomotive. It will let to equip this interplanetary vehicle in several stages by compactly packed modules which are delivered from the Earth. Unfortunately, this project exists only on paper and support of government or financial institutions is not expected in the near future. Faint hope is rested upon enthusiasts but there are too few of such people, besides almost all of them are rather hardly related to space flights and science. Most of scientists even hear nothing about Biefeld-Brown Effect, because it has never become widely known, since all works of this field, except the very first experiments from the USA, were run and then closed in secrecy.

Part II

"...it's time to go to the stars"

Due to the theory of relativity there is an ingrained belief of several generations that it is impossible to move with more than 300 000 m/c speed, i.e. to move faster than light, since the postulates of this theory read that mass is directly depended on speed. Calculations demonstrate that while speed of some accelerated body verges towards light speed its mass will increase and in the point of equilibrium (V=c) it will unrestrictedly increase. Hence acceleration will tend to zero and speed will not virtually increase, no matter how long acceleration speed acts on the object. In other words, the accelerating mass dissipates speed. In principle it is correct but another conclusion can be also drawn from the dependence of mass and speed, for example, the following one: to accelerate an object to the speed which exceeds light speed, mass of the accelerated body should decrease and its speed should increase. Any physicist will say that this statement is correct. At first sight it is practically impossible to realize this idea therefore it was wrongly give to writers of science fiction. They added this idea to their armory and the hypothetical device, which realizes it, was named as gravitational engine. Let us realize this idea from the practical point of view and basing only on facts and logic.

Thus let us apply to the facts and give the description of one experiment. Professor of Pulkovo Observatory N.A. Kozyrev is the author of this experiment, he was also the first to discover the phenomenon of lunar volcanism. Kozyrev used a gyroscope, i.e. the device consisting of two rings of different diameter. These rings are placed athwart one in another and movably jointed. Top is attached to the inner ring through the cardan. The scientist put usual thermos filled with hot water near the beam scale. The top of the gyroscope was preliminarily spun up counterclockwise. At that balance indicator showed that gyroscope top at 90 gram weight became 4 milligram lighter in weight. Then Kozyrev started to pour water of room temperature inside the device through the vinyl chloride tube fixed into the hole, which was made in the plug of the thermos. Seemingly it is impossible to influence upon the gyroscope operating and its weight by a balloon filled with hot water, which is being cooled. Besides the thermos consists of a double-walled container which practically entirely excludes heat exchange with the environment. However balance indicator moved at one or two points, i.e. such connection existed.

This experiment can be divided into two steps. At the first stage the thermos filled with hot water is placed near the gyroscope and we can register the decrease of the top weight. At the second stage water of room temperature is poured into the thermos and the scale again shows that the weight has been changed. Somehow Kozyrev explained the second stage of this experiment. He assumed that when we pour cold water in the thermos, then the equilibrium of the system is broken because some irreversible processes take place there. Cold water can not cause temperature increase of water in the thermos. Until the system come to equilibrium at a new level, i.e. until the same temperature is set in the whole volume of the thermos, this process will cause the condensation of time which "additionally" influences the top. However the scientist missed that the weight of the top had decreased long before the moment when cold water was poured into the thermos, i.e. before irreversible processes appeared there. *(Editor's: Evidently, the author of the article is not well familiar with Kozyrev's researches and with works of other experimenters who investigated this problem.)* In other words, at the first stage of the experiment there is nothing to condense time and that insignificant weight condensation, which was equal to 4 milligram, absolutely does not fallen into his theory. Some other process is presented there.

It is quite possible that at the first stage of the experiment we deal with nullification of the top weight, i.e. mass of the top tends to zero. Some conclusion arises from this assumption, i.e. hot water can influence the mass of the top in some still incomprehensible way. *(Editor's: The point is not in water temperature but in the process of changing of the entropy.)* Thus there is a simplest and primitive model of the gravitational engine, viz there are hot water along with gyroscope and the required decrease of mass at the "outlet". Certainly, it is very bold assumption but it can be easily checked. Near the gyroscope there should be placed thermos filled with not boiling water (of 100°C temperature) but with water of 50°C temperature. If the weight of the top decreased by one half (for example, by 2 milligram instead of 4 milligram), then we can surely ascertain that the hotter water in the thermos is the more decrease of mass. Besides, each 100°C of water heating will decrease mass of the top by 4 milligram. It is not very difficult to calculate the temperature at which mass of the top will verge toward zero and the top will start accumulating negative mass.

Let us now assume that our experiment was successful then water as well as any other matter cannot be heated to such high temperature. However it is possible to heat electrons. They are very compact and have insignificant mass and can be heated to very high temperature. It is necessary to take several plates then to place a dielectric between them and to apply voltage. Electrons rest on the dielectric and start heating. The top can be rotated anti-clockwise by means of electric engines, i.e. capacitor and gyroscope should be combined in one system with common center of gravity. It is not very difficult, as the saying goes, it is just an engineering problem. The higher temperature of electrons is the more decrease of the top mass. Finally there is a moment when mass of the capacitor-gyroscope system will reach zero and this electric machine will rise to the surface of the gravitational field of the Earth or any other planet. It will be Biefeld-Brown's force that will make our apparatus taking off the gravitational field of the Earth. This very force will start to accelerate our apparatus in the space vacuum and top of the gyroscope will lose its mass which appears at acceleration. Thus it is quite possible to reach speed, which is close to the light one, or even to overcome the threshold of light speed.

Part III

"...what is new?"

What is implied by gravitational waves? This question has been exciting the scientists from the half of the XX century. But still nowadays, in spite of all attempts of the scientists to dissolve the problem, these waves were not discovered. There is a standard way to discover them, which is based on general relativity. Basing on this theory, scientists assume that gravitational waves should change in some way the weight of material objects. According to this assumption the scientists suspend very heavy balls to very precision scale and then try to trace changes of their weight. There were only negative results. It seems that mass changes so quickly and to such short period of time that scale fails to react upon these changes. However there is another way which seems to be very promising.

Dependence of time and gravitation is a well-known fact. Thus speed of time course depends on force of the gravitational field of an object. Stars and planets can be considered as an example. The more intense attraction near them the more slowly time passes there. In other words, the greater mass of the planet the more slowly time passes near it. It is possible that oscillations of masses, which generate gravitational waves, in some way change speed of the time course along the whole way of the propagation of gravitational waves. In other words, gravitational waves are always attended with slight time fluctuations. Time starts to pass a little faster or a little more slowly as compared with its usual course. These changes can be traced by means of usual quartz plates. Let me remind of the fact that quartz plates are used at some models of clocks to keep time. Thus, oscillations of gravitational masses produce in space both gravitational waves and time fluctuations (chronowaves), which can be easily detected. Possibly these chronowaves are the part of gravitational waves. This assumption is already a scientific fact which is unfortunately ignored by more than one generation of researchers.

Professor N.A. Kozyrev was the first who surmised about the existence of time ways (chronowaves). He called them as "time flows". The scientist worked out and run a simple experiment to confirm his hypothesis. Telescope and quartz plates were used. Quartz plates were placed in focus of the telescope, which was pointed to some bright star. Its objective lens was covered with black paper or tin plate in order to exclude the influence of light beams. At that quartz plates reacted upon the presence of chronowaves. Thus there was changed the frequency of oscillations of plates which were placed in focus of the telescope.

Besides the scientist discovered that in focus of the telescope there were changed electroconductivity and volume of some matters. It is explainable since some parameters of space as well as speed of passing of some physical processes and phenomena depend on the speed of time course. Outwardly it appears in change of electroconductivity and volume. In spite of the fact that during the experiments tin plate (thick metal cover) was used some skeptics insisting that the point is in infrared radiation which is produced by the heated cover. However they was silenced by Kozyrev's researches. Basing on the fact that we usually see stars not where they really are, but at the place they were at the moment of emanation of light signal, the scientist calculated the location of Procyon star, which is the nearest to the Earth. Kozyrev pointed the telescope to this "clear" part of the sky zone that allowed to avoid the influence of infrared radiation and to fix the location of the star. Thus it is nothing but chronowaves generated by the star that can change oscillation frequency of quartz plates.

After Kozyrev's death this field of research is not considered by official science and the very existence of chronowaves is denied. Only some theorists warily impute the above-listed effects to the action of some torsion fields and waves the existence of which is rather questionable. However chronowaves exist and they can be used in practice, for example, to get information from any point of our galaxy in several seconds. **It is quite possible since chronowaves have no mass and thus they are propagated more quickly than light waves.** However it is still a question what will transmit this information to us because the transmitter of these waves yet has not been invented. *(Editor's: It is interesting what mass of light waves the author means. It is a pity that the author of the article did not read 9 previous issues of NET magazine! There was a detailed demonstration of the connection of Kozyrev's theory and experiments with the theory of longitudinal waves in aether. If to replace Kozyrev's notion of "waves of time density" by the notion of "waves of aether density" then we will get a real experimental approach which can help to solve the problem of antigravitation and time control.)*

Of course theoretically chronowaves can be also generated without participation of great gravitational waves (it seems that heat processes can also generate them). However no particular success was achieved in this field. Thus by means of chronowave transmitter it is possible just to "listen" to remote stars the light of which will reach the Earth in many years. This receiver is very simple and it can be made by anyone who knows a little about radio engineering. *Under home conditions it is better to use a miniature incandescent bulb (lamp with filament tungsten) as a receiver and usual ohmmeter as measuring instrument.*

If in usual receivers radio waves are excited by weak electric currents existing in antenna then chronowave antenna is constantly under tension. Chronowaves do not excite current there but change some characteristics of it, influencing on electroconductivity of the matter which was used for the antenna (let us remember Kozyrev's experiments). Later on these insignificant changes are transferred in audio signal or fixed by any other means. That is the principle of operation of the device.

Editor's: These experiments on the registration of flicker effect in more detail are described in A.M. Mishin works which were published in previous issues of our magazine. As the reader could notice, the editors' opinion in many respects does not coincide with the author's point of view. (Alexander V. Frolov)

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Time Machine

Alexander V. Frolov gave this interview to the Spain magazine "Mas Alla de la Ciencia" ("Science"). The interview concerns some questions about scientific-research work on investigation of active properties of time. Let us remind that in 2002 Faraday Lab Ltd and Vadim A. Chernobrov (Moscow) started the join Time Machine Project.

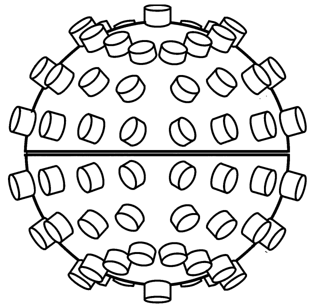

Miguel Segui: How does it value the results obtained by the prototype of time machine?
Alexander V. Frolov: Usually it is about 3% changes, i.e. 3 sec per 100 sec of experiments.

M.S.: How other devices are preparing inside the project Time Machine?
A.F.: Now we have project with special electromagnets, which are emitters of the longitudinal waves. So, other devices are electronics parts to provide impulse current. But it is not the only one version of the system. If the emitters of the longitudinal waves are based on other principles so all device has other design.

M.S.: Do you believe that some day the time trips will be possible?
A.F.: Yes, sure. We have the clear theory for it and it is based on understanding of physical sense of the aether, its relation with notion of time and with concept about existence of elements of matter in space-time. According to aether-vortex theory any element of matter is created from aether and its temporal parameters depend on density of aether.

M.S.: What practical applications can have the prototypes that are developing?
A.F.: Any change in the time course is the method of influence onto biological systems and the medical aspect is the main application. Also any physicist know relation between G (the gravity constant) and time course (rate of time). For example, time is slower on the surface of Earth than in space. So, local time changes (which are changes in density of aether or direction of aether wind) can be used to get propulsion force without reactive mass

flow. Also we can hope that some new materials can be produced in special area of slowed or accelerated time course.

M.S.: Which are the main difficulties of developing of these devices at the moment?
A.F.: For us now it is a part of the work that is related with designing of the powerful current electronics circuits. Also there are no known analogies for patent work, but we hope to complete our patent claim in March of 2003.

M.S.: Is it foreseen that they carry out experiments with human beings and the machine of modification of the time, just as V. Chernobrov carried out?
A.F.: We, i.e. Faraday Laboratories Ltd, are developing small unit for testing of the principles. In future we'll work with other design and with participation of the pilot (human passengers). But it will be the system of other kind. Let me explain: now we are working to get small local change of the aether density, so called "chronal charge". It is analogy with electric charge, which produces electric field in space. If the electric charge is moving then it will produce magnetic field. According to our plans after confirmation of the principles we are going to create design with moving "chronal charge" to generate "chronal field". There are suppositions that this field can be used practically for antigravitation propulsion transport.

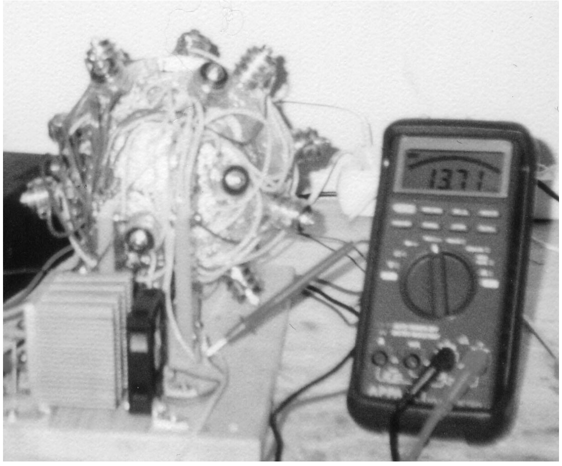

"FRCM" – Avalanchedrive

Fractioning and Replacement of a Constant Mass

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For the while, this project has only these two names, as above. There is still a lot to do upon this development that involves free energy and / or "over-unity". It is designated to be of free use and application by everybody and everywhere, without any royalties just like it was a very old idea, which is now opened for entire community use. The inventor has enough strong reasons for this will.

This is a kind of donation, a personal donation, for the very best future of the Earth. Pioneers are needed (late pioneers?) Any person may be involved in this development to make money since there are no barriers for that. This means that this is an open idea and in this way it must stay. The principles are new and original and the energy involved is quite huge. In the inventor's mind there is realized the possibility to create an expert hands-on group to finish the project. In this article there is a rough draw which seems to be enigmatic but in fact it can clear the understanding of the principle and show the situation at which body may offer controlled spatial variation of length for the same weight.

The short text and a schematic draw (see Fig.1) are the way to show the principles and a few possible construction solutions. The photo shows a part of the device which can clear the so called weight localized rarefaction. Possibly the understanding of capacity for an observer will be a little forced. If necessary author can send the full patent requirement text, which contains 54 pages and 32 figures, not in English but in Portuguese.

FRCM – "AVALANCHEDRIVE"

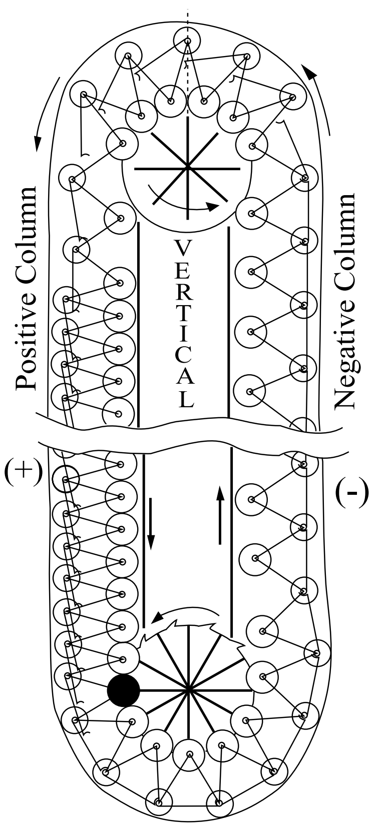

Fig. 1

Understanding of **FRCM / avalanchedrive** is a challenge in itself. When you start to learn about FRCM you will find complete original problems to deal. **Free your mind basing on some mechanical and physics knowledge and then avalanchedrive will come to make a part of your life. Feel free to work.**

PATENT REQUIREMENT RELEASE

This patent requirement is basically the application of a new physical principle which could be defined and found at least 400 years ago, so simple it is. Surely it is one of such things which was let behind by human mind and concern. FRCM is odd and amazing. The key for this project is a special body that can behave like a solid and like a fluid, at the same time, with combined characteristics just as designed and required.

The mass potential of a specially designed segmented body is hold and managed, and throughout proper means is sequentially fractured while suspension balance is kept. This causes, after start, a constant and cyclic movement, since arrangement goes, and the conducting and forcing form of the mass is not interrupted.

Also called "avalanchedrive", this principle work is based on just three main parts or components: 1st is the special segmented body – a chain; 2nd is the stationary and external assembling to hold and conduce the chain; 3rd is the straight vertical, in order to achieve the maximal weight storage position in the arrangement.

The chain is an endless repetitive zigzag construction with weights and defined angles that looks like an entire and elongated ellipse. Its design makes easy the change of its profile and form (mutant profile) that will be contracted or elongated, according to the way it is organized, supported and driven. When contracted or expanded, the chain assumes its maximal or minimal weight, in comparatively the same heights and level, but at different cross sections (tunneling?).

For distribution of the chain track the external assembling forms a kind of duct or rail, which is also elliptical. It allows to the chain to be contracted and expanded, to change direction, move, and pass away, as desired. The chain follows the way that the rail allows, in four different zones: mass-united zone, or positive column, or weight capacitor; the lower reversion input zone; the liberation zone, or negative column, with same height of the positive one; and the upper reversion zone, and its "zero point", or non-resistance top.

Both reversion zones are composed mainly of wheels. However, while the lower zone has to hang, open and bolt the chain, in order to change its profile and natural falling-down trajectory, the upper has a very passive function, that is just to let the chain cross over, and avoid any turn back possibility.

Fact is that in all circuit the chain follows with passivity the "voids" of trails, but assumes a very strong positive and pressure action in mass-united zone, especially in the button, where to the wheel there is applied all the active potential weight of the device, formed by the entire stack of the full contracted state, forcing movement.

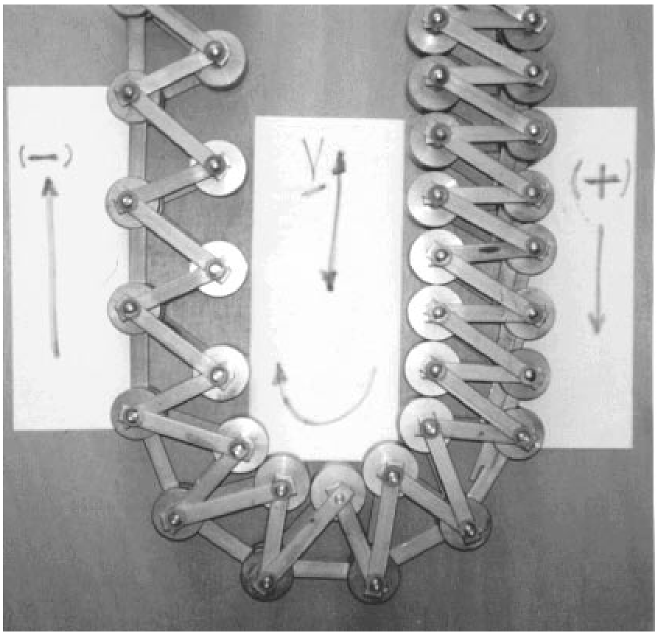

Photo of FRCM (Avalanchedrive)

It is easy to understand how and why FRCM works. Weight of the positive column is directly connected – as a compressed spring – against the relatively lighter negative column, through lower reversion wheel, where happens a kind of flux (the "solid flux") of the chain, that never can find a state of rest. Cycles of "breaking" of the chain can beconsidered as the instant of touch of each corner of the chain to the lower step wheel. To complete the circuitry, the chain excess, which is much lighter, passes over the upper wheel and turns back to the positive column top. It is impossible to turn the full subtracted potential to its source but mechanically the easier job to be done in FRCM.

FRCM manages and converts mass in energy...

The chain flows from the positive column, naturally finds changed profile and reverses to opposite way, and then it is pushed up to the negative column and to top. Finally it is collected, friendly, to restore the potential, at non-stop run! The only alternative to the chain is to move and move, and apply the positive surplus of weight to wrench under axle of the wheel.

This FRCM principle allows develop the equipment which is going to be able to take energy, work and force from gravity potential, so as it happens from wind and water at electrical generator machines, today. The potential is kept in such critical situation, that the only way for it is to escape and move. Besides in consequence of the suspending mass state the linear constant repetition of event will suffer. Water and other fluids do not offer "mutant profile" with fixed value of pressure, just as solid materials. There are many arguments for this view.

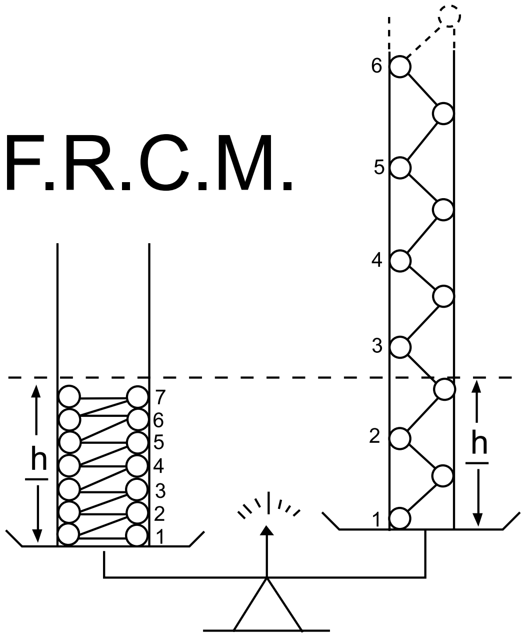

Fig. 2
Segment of a chain

Considering all mechanical losses, a part of the mass will be very active and applied in eccentric, or radial position to the wheel, even with the risk to cause too high speed. FRCM manages and converts mass in energy.

See a non-scale schematic draw (Fig. 2) and photo of a chain segment to compare densities between columns at right and at left.

A theoretical case can be calculated: at total chain weight - 100, general losses - 20, total negative resistance - 30, active or positive surplus is 50 – 30 = 20. This surplus that may be of 2kg, 200kg or 2,000kg, depending on scale, will force and free edge of the wheel, while the total weight keeps confined in the device. In the above case the difference of balance is 1.66. This means that the flowing velocity of the negative pile is 1.66 times higher than the falling of opposite positive pile. Just like a "solid venture", this change and relation is fixed, and in other cases may be varied or calculated to 3, 4 or even more! In all cases the speed must be hold that is not very easy job while one faces gravity acceleration.

The author of FRCM conceptions feels like these ideas have been around for many centuries, and that they are now discovered just like old draws. And this can be the bigger and the best moment to release this. Many thousands of different designs and solutions are coming in the future at looking for the better performance, costs and durability. Author thinks it to be strange that previous guesses could not reach this macro-physical concept. To build FRCM circuits, even re-applied or used old pieces, for example from ships and trains, will be useful.

This is only a start to a "new-old" development and clue to the sources of the modern mechanical engineering. Certainly some oppositions should be overcome. It is expected that other names are also going to be created and proposed to FRCM, but "avalanchedrive" seems to be a good one.

Author expects to get the invention and concept credits but not royalties and would also be glad to keep working on this concern. So, this message is a kind of invitation...

Editor: Unfortunately we have no photo or video documents of the operative device. We wait for readers' comments on this invention.

Complete text of the patent is avaible in Pourtuguese only.

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Hydrogen-Powered Vehicles at Least a Decade Away

Peter Behr
Greg Schneider

Washington Post
http://www.washingtonpost.com/wp-dyn/articles A635122003Jan29.html
Thursday, January 30, 2003; Page A09

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President Bush's vision of a hydrogen-powered, non-polluting "Freedom" car for the next generation of American motorists pulled out silently from a Newport Beach, Calif., garage with Gregg Kelly at the wheel, bound for his office 10 miles away.

Kelly, president of a California robotics company, happens to drive a Toyota prototype of a hydrogen-fueled car, one of a handful in the United States today.

It will take at least a decade before a host of technological, economic and political barriers are overcome, permitting a fleet of these revolutionary vehicles to appear on U.S. highways, industry experts said. But by including the goal of hydrogen fuels in his State of the Union message Tuesday, Bush has opened the door to a fledgling movement that has already attracted a surprising coalition of supporters.

Environmentalists, automakers, oil companies and coal producers, engineering labs and strategists have seized on hydrogen as an almost too-good-to-be-true power source. It is abundant in water and air, it burns cleanly and it could free the nation from its dependence on Middle Eastern oil.

"For President Bush to frame the goal as he did is significant," said Jeremy Rifkin, consultant and author of a book advocating a transition from oil and gas to hydrogen. "How much is made of this, time will tell."

The president said he hoped that Americans born today would learn to drive in hydrogen-powered cars, a schedule that auto experts said could technically be met. But whether these vehicles will be commercially available depends on a huge array of variables.

First, the technology is still incomplete and unaffordably expensive. The specially equipped Toyota Highlander that Kelly drives has no price tag. The Japanese manufacturer, after investing millions of dollars in research, lent the vehicle to a University of California research project that Kelly's company supports. "My checkbook isn't fat enough," Kelly said.

The car is powered by electricity generated in a fuel cell by chemically combining hydrogen and oxygen. The engine spits out water drops instead of the carbon dioxide and other pollutants generated by burning gasoline.

With foreign manufacturers committed to press ahead, Detroit's carmakers have had to accelerate their research programs. In June, Ford Motor Co. will unveil a prototype car that uses hydrogen to power an internal combustion engine – part of a "bridging strategy" to help ease hydrogen into the marketplace until fuel cells are fully developed.

General Motors Corp. has developed a fuel cell-powered, car-sized "skateboard" – four wheels attached to a platform less than a foot thick, to which any kind of car body could be buckled.

Rather than use fuel cells, BMW has refitted 10 of its $70,000 Model 745 sedans with hybrid engines that burn either gasoline or liquid hydrogen directly. It could be mass producing them by the end of the decade at a "reasonable" cost for its customers if there were enough hydrogen fueling stations to power them, said spokesman Gordon Keil. "We're trying to get [fuel suppliers] interested in hydrogen. We've not met with a lot of enthusiasm."

As daunting as the engineering challenge is the need for a national hydrogen fuel infrastructure – factories to produce the fuel, pipelines and trucks to distribute it and stations to store and sell it. Environmentalists dream of a totally "green" strategy in which solar or wind power is used to separate hydrogen from water – an approach whose costs now would be prohibitive. A nearer prospect is producing hydrogen from natural gas or coal, however in either case, the carbon dioxide byproduct would have to be injected underground to avoid a huge increase in greenhouse-gas emissions, experts say.

Rifkin argues that an eventual scarcity of oil and gas, decades ahead, will push prices of these fuels up to a point where hydrogen becomes cost-competitive. "It isn't a problem that will yield to technology alone," agreed David M. Nemtzow, president of the Alliance to Save Energy.

While all the major automakers are developing fuel-cell technology, most are cautious about hyping it. "We don't want to get too exuberant about it in that sense, overselling it," said Greg Dana, vice president for environmental affairs at the Alliance of Automobile Manufacturers.

Fresh in some minds is the experience of the Clinton administration, which launched a high-profile, $1.5 billion research venture with the

Detroit automakers a decade ago to produce an 80 miles-per-gallon family car. No cars emerged, and the Bush administration halted the venture in favor of its hydrogen strategy.

Some of the president's political opponents contend the hydrogen option is a way of deflecting criticism over administration policies favoring energy production over conservation. "The president seems content with the auto industry's approach: 'Don't make us do anything today'," said the Sierra Club's Daniel Becker. Others say it does not go nearly far enough. Sen. Byron L. Dorgan (D-N.D), chairman of the Democratic Policy Committee, said recently, "It's moving in the right direction. But his proposal is rather timid. I think we need a bolder plan."

Bush's spending plan for the hydrogen project, $1.5 billion over five years, represents a $500 million increase over his current budget. The administration proposes to earmark $273 million for the 2004 fiscal year, but did not offer many specifics yesterday. The funding would support research on fuel cells, vehicle technology and distribution issues.

The magnitude of the goal demands an effort on the scale of the Apollo Moon project, Dorgan said yesterday. "You have to set benchmarks for five, 10 years out."

UNUSUAL PERMANENT MAGNET MOTORS

Thomas Valone

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Abstract

Permanent magnet motors that try to achieve unusual overunity efficiencies with changes in wiring geometry, electronic switching schemes and magnetic configurations often are not successful. There are some designs that should be regarded as conventional and others as promising. Hopefully this article will help the reader to tell the difference before investing or accepting investment. Note: patents can be viewed for free at www.uspto.gov and also http://gb.espacenet.com/espacenet.

Introduction

An article about permanent magnet (PM) motors would not be complete without first reviewing the basic configurations that are present on the market today. Commercial PM motors are necessarily DC motors since their magnets are permanently polarized before assembly. Many PM motors which use brushes are switching to brushless motors that promise less friction and wear. Brushless motors include electronic commutation or step motors. A step motor, often used in the automotive industry, offers more continuous duty torque per unit of volume than any other electric motor but it is often a lower speed motor. The electronic commutation design is applicable to the switched reluctance (SR) motor. The SR motor substitutes soft iron in the place of higher cost permanent magnets for the outer stator and instead has an inner PM rotor. Brushless motors in general produce torque from current in the armature by the application of Faraday's Law. The ideal PM motor has a linear torque vs. speed curve. There are both outer rotor and inner rotor designs that are standard in PM motors.

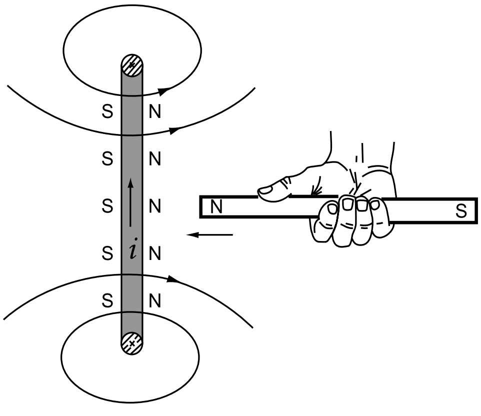

Fig.1

Lenz's Law
Induced B-field opposes motion.

To point out the focus of many of the problems with analyzing motors, the *Motion Control Handbook* (Designfax, May, 1989, p. 33) says that there is a "very important relationship between torque and back emf that is sometimes not understood." This relates to the electromotive force (emf) that is produced by the application of a changing magnetic field (dB/dt). In engineering terms, the "torque constant" (N-m/amp) equals the "back emf constant" (V/radian/sec). In physics, the motor terminal voltage

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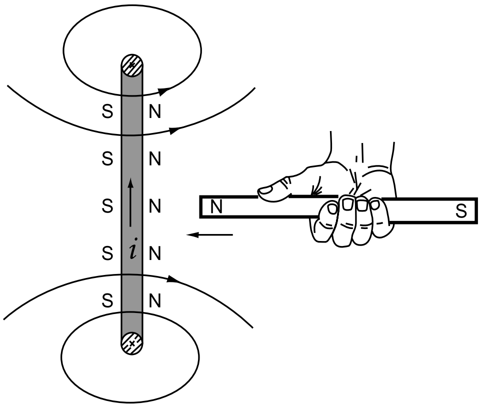

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Therefore, it is recommended that Faraday's Law be carefully reviewed first before proceeding. An article such as "Faraday's Law—Quantitative Experiments" (*Amer. Jour. Phys.*, V. 54, N. 5, May, 1986, p.422) will help convince the valiant new energy experimenter that the change in flux which causes a back electromotive force (emf) is INHERENTLY equal to the back emf. It cannot be avoided or circumvented for excess energy benefit, unless the amount of magnetic flux change per time is also altered. They are two sides of the same coin. The energy into an inductive coil style of motor will naturally equal the energy out. Also referred to as "electrical induction," the changing flux "induces" a back emf.

Switched Reluctance & Field Switching Motors

To explore an alternative method for inducing motion, the "Permanent Magnet Motion Conversion Device" by Ecklin, patent #3,879,622, uses rotatable shutters for alternately shielding the poles of a horseshoe magnet. Repeated again in the Ecklin #4,567,407 "Biased Unitized Motor Alternator with Stationary Armature and Field," the idea of switching the magnetic field with a "flux switch" is common to these types of motors. To illustrate the underlying principle, Ecklin states, "The rotors of most of today's generators are repelled as they approach a stator and are attracted back by the stator as soon as the rotor passes the stator in accordance with Lenz's law. Thus, most rotors face constant nonconservative work forces and therefore, present generators require constant input torque." However, "the steel rotor of the unitized flux switch alternator actually aids the input torque for half of each rotation as the rotor is always attracted and never repelled. This construction makes it possible for some of the current or power fed to the motor windings to magnetically feed through a solid magnetic path to the AC output windings ..." Unfortunately, Ecklin still to this day has not achieved a self-running machine.

Also related is the Richardson patent #4,077,001 which discloses a low-reluctance keeper physically moving in and out of engagement with the ends of a magnet (p.8, line 35). Lastly, the Monroe patent #3,670,189 uses a related principle but accomplishes gating with the passing of rotor poles between permanent magnet stator poles. Monroe's claim 1, seems by its length and detail, to have almost guaranteed its patentability but of course its utility remains questionable.

It seems unlikely that as a closed system the Field Switching Motor can become self-running. In many examples, a small electromagnet will be necessary to help push the keeper into a synchronized rhythm. The Magnetic Wankel from Popular Science (June, 1979) can be compared in a basic manner to this type of invention. Also, the Jaffe patent #3,567,979 can also be compared (see abstract). The Minato patent #5,594,289 is also of a similar type as the Magnetic Wankel and quite intriguing to many people.

It has been found with inventions such as the Newman motor (U.S. Patent Application Serial No. 06/179,474), a nonlinear effect such as an impulse voltage is advantageous for overcoming the Lorentz force conservation effect of Lenz's Law. Also similar is the mechanical analog of the Thornson inertial propulsion device which uses nonlinear impact to transfer momentum along an axis perpendicular to the plane of rotation. A magnetic field contains angular momentum which only becomes apparent under certain circumstances such as Feynman's Disk Paradox, where it is still conserved. The impulse technique may possibly be used to advantage in this Field Switching Motor if the field switching can be done fast enough, with a rapid rise time, but more research is needed.

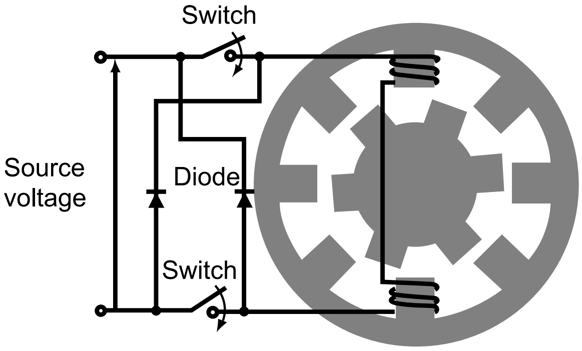

Fig. 2
Switched Reluctance Motor (*IEEE Spectrum* 1/97)

The best Switched Reluctance Motor that also has full accommutation is the Dr. Harold Aspden patent #4,975,608 which optimizes the performance of the coil input and operating above the knee of the B-H curve. Switched reluctance motors are also explained and praised in *IEEE Spectrum* (1/97).

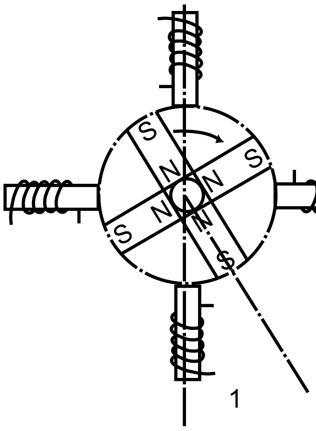

Fig. 3

Adams Motor

The Adams motor has attracted many followers including an endorsement from *Nexus* magazine as the best free energy motor they have seen. The performance of the machine, however, can be fully explained by Faraday's Law. The pulsing of adjacent coils which moves a magnetized rotor is actually following the same configuration as a standard switched reluctance motor. The delay that Adams speaks of in an Internet posting of his motor can be understood from the exponential voltage (L di/dt) of the back emf. The latest addition to this category, which gives credit to the Adams motor, comes from down under with PCT WO 00/28656 awarded to Brits and Christie in May, 2000. The simplicity of this motor is immediately obvious with the switchable coils and permanent magnet on the rotor. The patent also makes it clear that the "input DC current as supplied to the stator coil produces the magnetic repulsion force and is the only outside input to the overall system for total movement...." It is a well-known fact that all motors work on this principle. The key to their design is on p.21 of their patent where the inventors want to "maximize the influence of back EMF which tends to maintain rotation of the rotor/armature in a single direction." All of the motors in this field-switching category try to achieve this effect. Figure 4A of Brits and Christie disclose the voltage sources "VA, VB, and VC." Then, on page 10 it is stated, "At this time current is applied from the power source VA and continues to be applied until the brush 18 is no longer in contact with one of the contacts 14 to 17." There is nothing unusual about this design compared with the more sophisticated attempts listed previously in this section. All of these motors require an electrical power source and none of them are self-running.

When pulsing a coil with the passing of a permanent magnet, a suggestion that would help prove the claim for free energy is not to use battery power for the coil current. Instead, the amazing Weigand wires are recommended (*Pop. Sci.*, May, 1979) that exhibit a huge Barkhausen jump of magnetic domain alignment and a very well-defined pulse shape. Having a coil wrapped around a Weigand wire produces a substantial pulse of several volts with a changing external magnetic field passing a certain threshold. No electrical input power is required for this pulse generator.

Toroidal Motor

As compared to motors on the market today, the unusual design of the toroidal motor is similar to the Langley patent #4,547,713 with a two-pole armature in the center of the toroid. If a single-pole design is chosen, with for example North poles at each end of the armature, this would resemble the radial magnetic field for the armature which the VanGeel patent #5,600,189 uses. The Brown patent #4,438,362 assigned to the Rotron company, utilizes varying magnetization segments for a rotor in a toroidal air gap. The best example of a carousel toroidal motor is the Ewing patent #5,625,241, which also resembles the Langley patent mentioned above. Based upon magnetic repulsion, the Ewing invention uses a microprocessor-controlled carousel, basically to try and take advantage of Lenz's law and get a jump ahead of the back emf. The Ewing invention may be seen in operation, with co-inventor David Porter, in the commercial video, "Free Energy: The Race to Zero Point." Whether it may be more highly efficient than other motors on the market remains an open question. As the patent states, "it is also possible to operate the device as a motor using a pulsed direct-current power source" (col. 7, par. 30). It also contains a programmable logic controller and power control circuit which the inventors thought would send it over the top of 100% efficiency.

Unless a prototype proves to be successful in achieving a torque or force conversion linkage, the internally propelled magnet may be left without a practical application. Commercialization of these types of motors may not be favorable, since many competing designs are currently available on the market, with high flux linkage.

Linear Motors

The area of linear induction motors is well known in the literature. Schaum's Outline Series, *Theory and Problems of Electric Machines and Electromechanics* (McGraw Hill, 1981), explains that these are the same as cutting the rotor and stator of a standard induction motor and laying them out flat. The late Dr. Laithwaite, author of

Motion Without Wheels, was famous for monorail designs for trains in England based on linear induction motors.

The Hartman patent #4,215,330 is an example of one that achieves a linear motor transportation of a steel ball up a magnetized incline of approximately 10 degrees. Another invention in this category is the Johnson patent #5,402,021, which uses permanent arc magnets on a four-wheel cart, exposed to a parallel track of alternating permanent magnets which are in a fixed position. An even more amazing permanent magnet patent is the Johnson #4,877,983 which an eye witness has seen operating at the Johnson home in a closed loop for hours. It is reasonable to assume that a pickup coil could be positioned nearby so that each trip would result in a pulse of electricity to charge a battery. The Hartman patent could also be arranged in such a circular track so that perpetual motion of the first kind can finally be demonstrated.

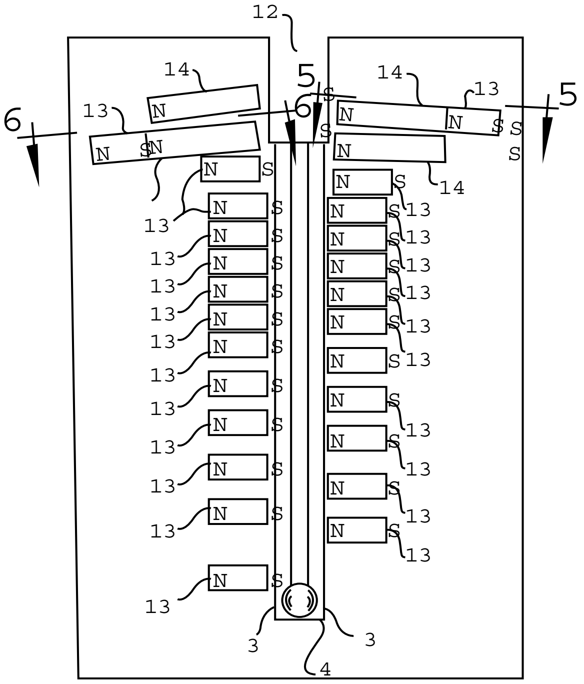

Fig. 4

Hartman patent #4,215,330

The Hartman patent is based upon the same principle as the famous electron spin experiment in physics called the Stern-Gerlach experiment. With an inhomogeneous magnetic field (one that is non-uniform) the force on an object with a magnetic moment is the gradient of the potential energy. Every physics textbook points out that this type of field, that is strong at one end and weak at the other end, will result in a unidirectional force on the magnetic object equal to dB/dx. That is exactly what the Hartman patent possesses (note spacing of magnets). Therefore, the resulting force propelling the ball up a ten degree incline, in the x direction, is in keeping with the laws of physics.

With state-of-the-art magnets, including ambient temperature superconducting magnets which are now finishing the development stage, a demonstration of impressive cargo weight will be shown to be transportable without maintenance electricity costs. Superconducting magnets have the unusual property of retaining the initial magnetized field for years, without the need for periodic energization to restore the initial field strength. Examples of the state of development of the superconducting magnet market can be found in the Ohnishi patent #5,350,958 (lack of cryogenics and lighting system output) as well as the reprinted article from *IEEE Spectrum*, July, 1997 on magnetic levitation.

Static Electromagnetic Angular Momentum

In a provocative experiment with a cylindrical capacitor, Graham and Lahoz (*Nature*, V.285, No.15, May, 1980) have expanded upon the proof published by Einstein and Laub in 1908 that the Lorentz force needs an additional term to preserve action and reaction. The article they cite has been translated and published in my book, *The Homopolar Handbook* (described below). Graham and Lahoz emphasize that there is a "real angular momentum density to r x (E x H)/c^2" and suggest how to see this energy effect in permanent magnets and electrets.

This is encouraging work, with an impressive source of Einstein and also Minkowski for its information. It is possible that it may have a direct application for the homopolar generator as well as the magnetic energy converter mentioned below since both have an axial magnetic field and a radial electric field like the cylindrical capacitor experiment of Graham and Lahoz.

Homopolar Motor

My book, *The Homopolar Handbook* (HH), covers experimental tests and history of the Faraday discovery, including Tesla's contribution to it. Recently however, there have been new developments into a multi-rotor design of a homopolar generator, similar to the invention of John R. R. Searl.

Recurring interest in the Searl device, as pictured on the cover of *Antigravity*, the biography of Searl by John Thomas, should also center on the homopolar generator (HG). Preliminary analysis reveals that there are actually two separate HG phenomena occurring simultaneously, one which can be called the "revolution" effect (#1) and the second that could be called the "rolling" effect (#2). The first effect can be visualized as magnetized segments of an imaginary solid ring revolving around a common center. As suggested by drawings in HH, p.141-2, there are precedent designs that allow for segmenting an HG rotor.

With this model in mind, the #1 effect can be calculated, for 1 Tesla strength magnets, magnetized axially, adjacent to a single ring 1 meter in diameter, to produce more than 2 volts emf across each roller, (E-field directed radially from outer diameter of rollers to outer diameter of the adjacent ring) with say, 500 RPM. Note that this #1 effect is independent of any rolling of the magnet. The magnetic field in an HPG is tied to space and not to the magnet so rolling will not affect this large scale homopolar generator's Lorentz force effect (HH, p.10).

The #2 effect, located within each roller magnet, is the one noted in *Electric Spacecraft Journal*, Issue 12, 1994, (HH, p.160) where each roller, is a small homopolar generator. This effect is found to be somewhat weaker as it generates electricity from the center of each roller to its periphery. This design is like Tesla's HG (HH, p.81) where a rolling belt is contacting the outer edge of a circular magnet. With rollers in the vicinity of a tenth of a meter in diameter rolling, without slipping, around a 1 meter ring, approximately a half of a volt will be generated. The Searl design of ring magnetic material will normally strengthen the roller's B field.

It is important to realize at this point that the principle of superposition applies to these two effects. The #1 effect is a uniform E field across the diameter of the roller. The #2 effect is a radial effect as stated above (see HH, p.6-8). However, only the emf in the section of a roller between the two contacts, say at the center of the roller and its edge which contacts the ring, will actually cause current flow in any external circuit. This realization means that the effective voltage from the #1 effect will be half of the available emf, or a little more than 1 volt, which is still about double of the #2 effect. Upon applying superposition in the limited region indicated, we also find that the two effects oppose each other and the two emfs must be subtracted. The result of this analysis is that approximately one half of a volt of regulated emf will be present to generate electricity from a single set of rollers and one ring about 1 meter in diameter. As current is drawn, a Ball Bearing Motor effect will also take place (HH, p.54) that actually pushes the rollers along, assuming the roller magnets have a reasonable conductivity *(Thanks to Dr. Paul La Violette for this reminder)*.

In a related work, (*Tech. Phys. Lett.*, V. 26, #12, 2000, p.1105-07), Roshchin and Godin have published experimental results of their one-ring device, called a "Magnetic Energy Converter," with rolling magnets on bearings. It was designed as an improvement to the Searl device. Though my above analysis does not depend upon the ring being made of magnetic material, Roshchin and Godin did so. Their findings are encouraging and detailed enough for researchers to find renewed interest in this type of magnetic motor.

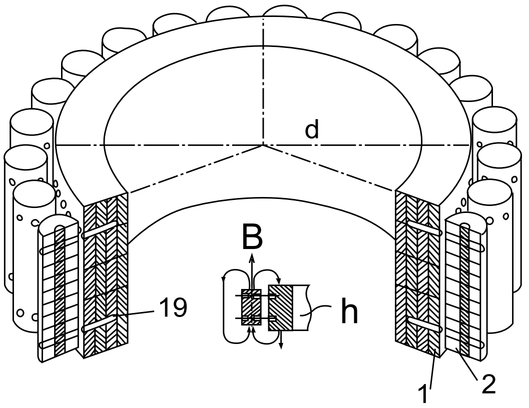

Fig.5

Magnetic Energy Converter in the experiment
by Roshchin and Godin (Russia)

Conclusion

So far, a couple of permanent magnet motors may have achieved perpetual motion, which exceeds 100% efficiency. Of course, conservation of energy concepts have to be considered and the source of the alleged extra energy examined. If permanent magnet field gradients do offer a unidirectional force, as the textbooks predict, then it is about time for its conversion toward useful work. The roller magnet geometry, now called a "magnetic energy converter" is also a unique style of magnetic motor. Exemplified in the Russian patent #2155435 by Roshchin and Godin, it is a magnetic motor-generator that shows potential for excess energy output. Since it relies upon the circulating cylindrical magnet rolling around a ring, the design is actually a generator rather than a motor. However, as they utilize the torque produced by the self-sustained motion of the magnets to run a separate electrical generator, it is working as a motor.

Reprint from Proceedings of Institute for New Energy Conference, 2001

Hydrogen Energetics

Review by Alla Pashova

A Russian writer Ludmila Ulitskaya, who is rather far from energy problems, says: "I'm quite sure that cheap electric energy sources have been already worked out and are hidden in oil king's safes. However such projects won't be taken out of the safes until the last oil drop is combusted. They don't want redistribution of money, world, power, and soon". Experts are sure to agree with the writer.

Now only ideas which can coexist together with the traditional oil power engineering and with a system of world oil distribution can escape the safes. Some expensive scientific toys promising future universal welfare are created to reassure ecologists, viz automobiles equipped with hydrogen engine. According to estimation of Japan representatives of motor car industry, installation of the hydrogen engine into such a car as a classical Sedan now comes to about $700 000. Approximate cost of a hydrogen bus named Kitaro achieves the astronomic amount of $1.25 million.

The hydrogen engine consists of several fuel elements, which are known as fuel cells. Hydrogen under pressure of 1.5-2.7 atmospheres comes to an anode. A cavernous catalyst splits the molecules into electrons and protons. The electrons set the electric engine in motion, and the protons come through a membrane acting to a cathode as an electrolyte. Here the catalyst combines them with the working electrons and with atmosphere oxygen into water molecules. It should be noted that the Europeans and the Americans are extremely charmed by this water streamlet which is exhausted instead of poisoning gases. Moreover, output of the fuel cell is 3-5 times more than output of the petrol engine.

The first hydrogen power station inaugurated in Las Vegas, Nevada, in 2002, (see Fig.1, 2) represents a system of the fuel cells with the proton penetrable membrane as an electrolyte (they are designed and produced by experts of Plug Power Inc.). The station produces hydrogen transforming and cleaning natural gas and generates electric power combining hydrogen stored in reservoirs with atmosphere oxygen. The USA Energy Department and Air Products Inc. together paid $ 10.8 million for this project.

It is necessary to note that the priority branch of the hydrogen engineering is providing new means of transport with fuel, and electric power production is just the second aim. The mentioned station produces electric power in addition to its main function. Nevertheless, if fuel market begins to decrease then the electric power payments will provide the "hydrogen magnates" with stable profit.

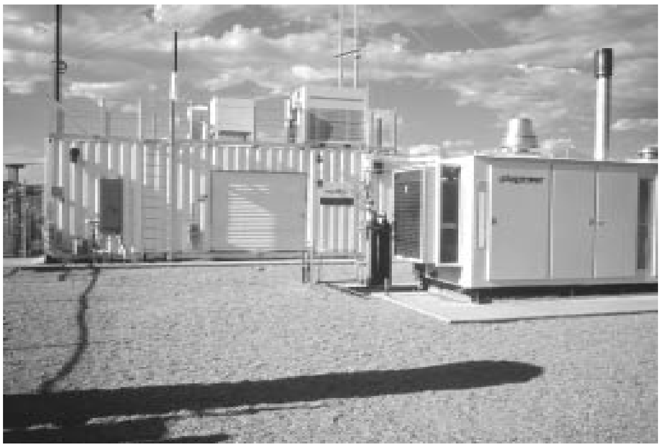

Fig. 1
Hydrogen power station

Nowadays the hydrogen automobiles allow oil kings keep the system of centralized fuel distribution and the infrastructure of service stations which will provide the means of transport with methanol, natural gas with hydrogen blend, and liquefied or gaseous hydrogen. Thus interested companies control the hydrogen engineering and scientific thought.

Moreover, oil can be applied as it is useful for board reforming (conversion), i.e. it can be used as a hydrogen source. The systems based on conversion have been known for a long time but there was need to work at them.

Russian experts improved the conversion system by replacement of the catalyst by plasma. Thus the conversion occurs in gas discharge of HVF appearing in the blend which needs to be converted. According to experts' opinion the Russian system is portable and has high output. In 2001 a group of experts of Russian Centre of Automobile Engine represented experimental prototype basing on Chevrolet Pickup S 10.

The ideal of modern hydrogen engineering is the following: "There should be minimal changes in the system of fuel distribution, non-polluted air, and thin streamlet of distil exhausted". However, evidently, the exhausted water is an ideal source for hydrogen fuel reproduction by means of high effective electrolyzing. If the closed system is worked out we would obtain an energy source powered by continuous chain of electrolyzing and recombination whose efficiency would be more than 100 %.

What are the known ways of hydrogen production? The greatest amount of the gas is produced on the base of catalytic conversion of hydrocarbon with water vapor. Temperature of the process depends on the catalyst composition. It is known that temperature of propane reaction can be decreased to 370° using bauxite as a catalyst. Approximately 95% of by-product carbon monoxide is further used in the reaction with water vapor.

A significant part of the total hydrogen production is given by a method of water gas. The essence of the method lies in reaction of water vapor with coke that is followed by the producing of carbon monoxide with hydrogen mix. The reaction is endothermal, it occurs at 1000°C. The heated coke is processed by the vapor; extracted purified mix of gases contains some hydrogen, some carbon dioxide, and great share of carbon monoxide. Further vapor processing of the carbon monoxide at 370°C increases the hydrogen extraction. The amount of carbon dioxide increases as well however it is easy to be removed by passing the gases mix through a scrubber sprayed by a water contraflow.

AIR PRODUCTS

Fig. 2

There is a well-known iron-vapor method according to which vapor is passed above iron at 500-1000°C. Hydrogen obtained by this method is usually applied to hydrogenise fats and oils. Composition of the iron oxide depends on the process temperature. Iron-3 oxide (Fe_3O_4) prevails at the temperature below 560° C. If the vapor is passed above the iron at the temperature above 560° C then iron-2 oxide (*FeO*) share increases. A slight admixture of carbon monoxide is removed when the heated mix passes above a catalyst. At this time the carbon monoxide is transformed into methane.

In the processes of oxidation and thermal cracking of hydrocarbons at soot production hydrogen is produced as a by-product.

The next effective method is methanol-vapor one. It is an endothermal reaction which is proceeds in common iron reactors at 260° C temperature and at 20 atmospheres pressure.

There should be also mentioned a catalytic reaction of ammonia decomposition at which nitrogen and hydrogen is produced. The reaction can be profitable if it is necessary to produce great amount of hydrogen. The method is useful if the obtained hydrogen is directly applied.

Electrolysis is the oldest method to produce hydrogen. Direct current comes to electrodes, the cathode collects hydrogen, and the anode accumulates oxygen. The technology makes hydrogen to be too expensive energy carrier. There is often used a technology of hot processing of water vapor at 700-900° C accompanied with light petrol and heavy liquid fuel which bleeds oxygen. This method is quite expensive as well.

As it is known, **wasteful power consumption of classical electrolysis** is caused by the fact that it is used to overcome forces of hydrate bound of ions with water molecules and to compensate endothermal effect of water decomposition. Therefore, ions reduction at corresponding electrodes requires more current intensity than in the case of absence of this physical phenomena. Hence production of 1 cubic meter of hydrogen requires 18-21.6 MJ, and total power consumption exceeds 50 MJ (taking into account the electric power production). Therefore hydrogen becomes too expensive.

In 1888 D.A. Lachinov patented a method of non-contact electrolysis. Improvement of this method promises huge amount of cheap hydrogen and appearance of high effective energy source operating as a closed cycle. The main problem of Lachinov's method is a gas layer covering the electrode in some time and impeding the reaction. It was proposed by I. A. Goryachev to prevent the gas layer using pulsating electric field. A.V. Frolov has proposed to increase electrolysis efficiency by means of rotation. Centrifugal force causes more swift detach of gas blebs from electrodes surfaces. Power consumption to overcome frictional force in the construction and to generate potential electric field is insignificant as compared with output. Hence efficiency of the system may exceed 100%.

There is also described the experimental device for production of hydrogen and oxygen from water where modulated voltage (not dc voltage) is applied to the electrodes. Modulation frequency is in connection with proper oscillation frequency of water molecules as well as with spatial structure. Possible efficiency of water electrolysis in spark discharge which removes oxygen admixture should be investigated . Water electrolysis at the radiation by electromagnetic waves of light range needs to be investigated as well.

Ikar Research Centre informs that plasma electrolysis can be the most probable source of cheap hydrogen. In 1987 a group of Russian scientists patented the first plasma-electrolytic reactor. Since the reactor had been worked out at a defense establishment then the patent was restricted and not covered by press. The patent contains a structural scheme of the reactor and some results of cleaning and disinfection of water by plasma. The patent does not represent any information of additional energy generated by plasma or hydrogen production.

In April of 1989 American scientists Pons and Fleishman published their experimental results on additional energy production at common water electrolysis. They claimed cold fusion to be source of this energy. However there is no reliable proof for this phenomenon.

In 1996 Yu. Beklyamishev, one of the co-authors of the first plasma-electrolytic reactor, published his experimental results. They demonstrated that there was additional energy in the plasma-electrolytic process. However he did not explain the energy source.

In 1998 there were published new experimental issues of appearance of additional energy in the plasma-electrolytic process. A group of Russian scientists tested one of the plasma-electrolytic reactors and officially fixed the additional energy. A report of the testing session was published in issue #22 of “Infinite Energy” magazine. In May of 1998 the third edition of a book named “Crisis of Theoretical Physics” was published by Prof. F. M. Kanarev. It contains data of additional energy production at plasma electrolysis of water defining the energy source. Soon Ohmori and Mizuno (Japan) published their results in works of Vancouver conference on cold fusion and in issue #20 of “Infinite Energy”. Ohmori and Mizuno observed neutron radiation occurring at a plasma process as well as iron, chrome, nickel, and carbon appearance on a wolfram cathode. That seemed to be a strong evidence of cold nuclear fusion at plasma electrolysis of water. Ohmori and Mizuno have explained neutron radiation as a result of electrons captured by protons. Nevertheless their conclusions raise doubts as cold fusion would have produced much more additional energy than it was fixed.

In 1996 there appeared the first publications where hydrogen atoms fusion instead of nuclear fusion was supposed as the additional energy source at usual electrolysis as well as at plasma source. In Russia first experimental results demonstrating energy consumption decrease for hydrogen production at plasma electrolysis of water were published in 1999 by Prof. F.M. Kanarev. (See F.M. Kanarev’s article in this issue of NET).

Fig. 3

Honda FCX-V3 uses hydrogen as a fuel. Hydrogen is fed under high pressure in the engine.

Nevertheless we have to note that high efficiency electrolysis is possible! O. Hvolson in his “Physics” (Berlin, 1923) explains a method of designing of a machine which can produce heat due to positive difference between energy of hydrogen combustion and energy consumed to hydrogen production by means of water electrolysis. In this case we do not consume energy to split the atoms. It occurs due to intermolecular forces at water dissociation by sulphuric acid ions. Energy is consumed only to neutralize charges of existent hydrogen ions and acid residue ions. Hydrogen combustion produces the energy which would have been consumed to split the atoms in the air. **Hence 67.54 Kcal of energy can be produced at 5 Kcal consumed. (F. Lepehin)**

High effective electrolysis application is clear future of energetics. Nowadays Stuart Energy Inc applies water electrolysis as a hydrogen source in a frame of hydrogen-fuel project. Experts of Stuart Energy Inc have designed a refueling unit which produces hydrogen and stores it in a 104-pound reservoir. Thus several auto are provided with fuel and it takes a couple of minutes to refuel.

It is quite simple to predict social and economical consequences of innovation of high effective energy source operating as a closed cycle energy system. Economic activity and private life of people will be independent of cities, of their industry and power engineering. People will move out of the cities and they will use compact and powerful energy sources there. Hence, decentralization of world economics will happen.

Regions of any country become more free from the central authority, the power of which nowadays is based on centralized fuel energetics.

On the Longitudinal Electromagnetic Waves

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Concerning acoustic waves, we deal with longitudinal oscillations of the medium, since degree of air (medium) compression and rarefication changes along the direction of the wave spreading. Notion of the medium of electromagnetic waves propagation, i.e. notion of "aether", as well as the very possibility of the existence of longitudinal electromagnetic waves is disputable for some scientists. Let's clarify the situation and demonstrate that usual photon is longitudinal wave of energy density, which can be described as Umov-Poynting vector.

The transverse character of electromagnetic waves means that vector of electric field and vector of magnetic field are directed across the wave line. However, these vectors are just our subjective way to describe the process. Notions of electric and magnetic fields can be replaced by the notion of **unified helical field**, since to describe the motion of the point along the helical line there should be concerned the linear transfer (it is detected as electric field) and the process of rotation (it is described with the magnetic field). Thus notions of electrodynamics are just one of the ways to describe reality. Energy density of the given point of space is the real (objective) parameter of the wave. This energy density is described by the known Umov-Poynting vector $\overline{S} = \overline{E} \times \overline{H}$.

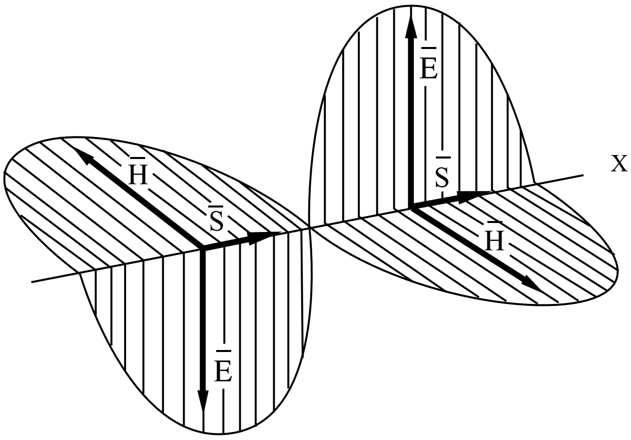

Fig.1

Let us consider electromagnetic wave in classical representation (Fig.1). Then we discover that direction of Umov- Poynting vector coincides with the wave line. The vector is unidirectional and "pulsating", because its quantity changes from zero to some maximal value and then it is reduced to zero, besides it takes place at half of the period of transverse wave. So, it is the explanation of the fact that frequency of longitudinal oscillations is twice as much than frequency of transverse oscillations (Fig. 2). **Previously it was known from the mechanism of energy interchange between longitudinal and transverse plasma oscillations and from the phenomenon of parametrical resonance. However the physical meaning of this phenomenon was not disclosed.**

From the presented here conception it follows that from the physical point of view, electromagnetic waves are **longitudinal oscillations of energy density**. In usual case these oscillations are unidirectional pulsations that determines the ability of the photon to be moving unidirectionally. Practically it is possible to create other types of photons, i.e. types of oscillations of energy density with qualitative new physical properties. It can be achieved by setting of definite functions and superposition of $\overline{E}$ and $\overline{H}$ vectors.

For example, in 1996 a conference "New Ideas in Natural Science" was organized by us in Saint-Petersburg, with the participation of 30 foreign guests and more than 100 Russian scientists. The report made by Academician Ignatyev, Krasnoyarsk, aroused great interest. During the experiments with rotating of crossed vectors $\overline{E}$ and $\overline{H}$ (see Fig. 3) there was created Poiting's vector, which corresponds to propulsion force of 60 N (about 6 kg).

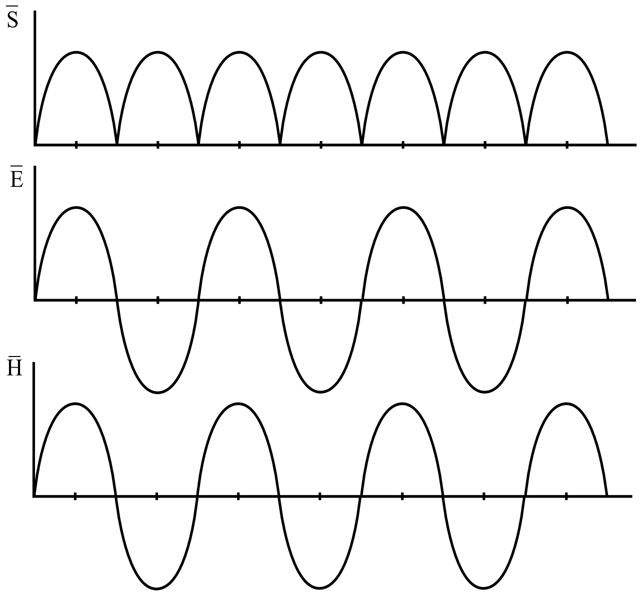

Fig. 2

The experiment is demonstrated on the photo (see Fig. 4), where the diameter of the device is equal to 4 meters and ends of the coils are to toroidal capacitors. This experiment was made in Krasnoyarsk.

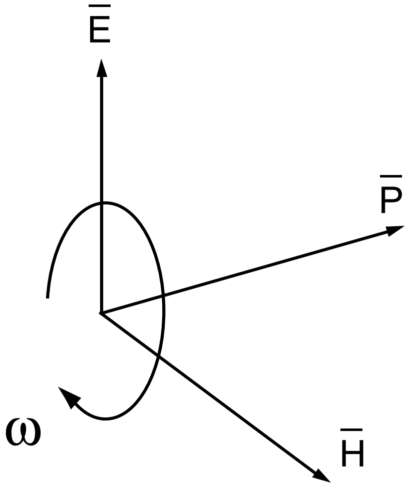

Fig. 3

Since it is impossible to consider vacuum, where some form of energy can exist, as "emptiness" then we can speak about vacuum as about some medium. Faraday and Maxwell, classics of electromagnetic theory, wrote exactly about deformations, stresses and expansion of aether. From this point of view electromagnetic waves are analogues of the waves of longitudinal deformation of elastic medium. More than 60 years ago Nicola Tesla wrote: "I showed that the universal medium is a gaseous body in which only longitudinal pulses can be propagated, involving alternating compressions and expansions similar to those produced by sound waves in the air. Thus, a wireless transmitter does not emit Hertz waves which are a myth, but sound waves in the ether, behaving in every respect like those in the air, except that, owing to the great elastic force and extremely small density of the medium, their speed is that of light." [1]

Nowadays, the development of engineering and the new views upon the phenomena of electromagnetism, impel us to consider physical **vacuum as material medium of the special type**, which has the well-known properties, in particular electrical and magnetic properties. Moreover, this medium has energy, and energy density can be changed in case of propagation of any photon. Thus, as Tesla stated in his article "The True Wireless": "The Hertz wave theory of wireless transmission may be kept up for a while, but I do not hesitate to say that in a short time it will be recognized as one of the most remarkable and inexplicable aberrations of the scientific mind which has ever been recorded in history".

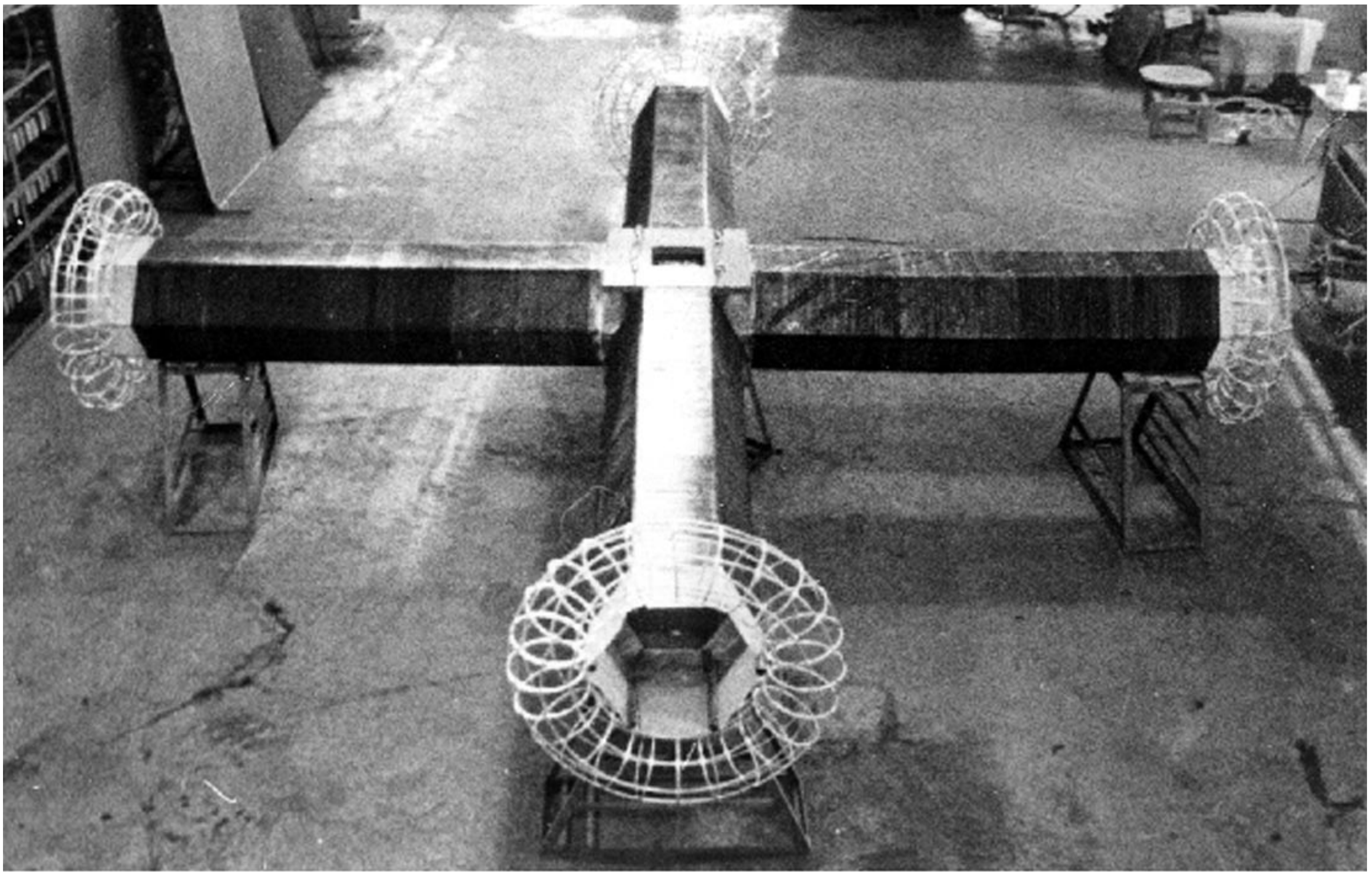

Fig. 4

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"OUTSIDE THE BOX"
SPACE AND TERRESTRIAL TRANSPORTATION AND ENERGY TECHNOLOGIES FOR THE 21ST CENTURY

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Abstract

This paper reviews the development of antigravity research in the US and notes how research activity seemed to disappear by the mid 1950s. It then addresses recently reported scientific findings and witness testimonies - that show us that this research and technology is alive and well and very advanced. The revelations of findings in this area will alter dramatically our 20th century view of physics and technology and must be considered in planning for both energy and transportation needs in the 21st century.

Historical Background

Townsend Brown's Technology of Electrogravitics [1]

In the mid 1920's Townsend Brown [2] discovered that electric charge and gravitational mass are coupled. He found that when a capacitor is charged to a high voltage, it has a tendency to move toward the positive pole. His findings, which became known as the Biefeld-Brown effect, were opposed by conventional minded physicists of his time.

The Pearl Harbor Demonstration. Around 1953, Brown conducted a demonstration for military top brass. He flew a pair of 3-foot diameter discs around a 50-foot course tethered to a central pole. Energized with 150,000 volts and emitting ions from their leading edge, they attained speeds of several hundred miles per hour. The subject was thereafter classified.

Project Winterhaven. Brown submitted a proposal to the Pentagon for the development of a Mach 3 disc shaped electrogravitic fighter craft. Drawings of its basic design are shown in one of his patents. They are essentially large-scale versions of his tethered test discs.

Review of Issues from the 1950s

In 1956, a British research company, Aviation Studies (International) Ltd. published a classified report on Electrogravitics Systems examining various aspects of gravity control. They summarized the pioneering work of Townsend Brown and then described the use of electrogravitic thrust as follows:

"The essence of electrogravitics thrust is the use of a very strong positive charge on one side of the vehicle and a negative on the other. The core of the motor is a condenser and the ability of the condenser to hold its charge (the K-number) is the yardstick of performance " [3].

In one of their conclusions, based on Brown's work, they suggested that: "Electrostatic energy sufficient to produce a Mach 3 fighter is possible with megavolt energies " [4].

In spite of Brown's solid research, they later stated that, "One of the difficulties in 1954 and 1955 was to get aviation to take electrogravitics seriously. The name alone was enough to put people off" [5]. It seems that is as true today as it was in the 1950s.

A report by another British company, Gravity Rand, Ltd. in 1956, agrees with this assessment and states: "To assert electrogravitics is nonsense is as unreal as to say it is practically extant. Management should be careful of men in their employ with a closed mind or even partially closed mind on the subject." [6]

However, a trade press magazine, The Aviation Report, made numerous references to antigravity projects and listed many of the companies pursuing research in this area. Quotes from The Aviation Report listed in the Aviation Studies (International) Ltd. Report [7] are suggestive of what was going on behind the scenes.

In 1954 they predicted that: "… progress has been slow. But indications are now that the Pentagon is ready to sponsor a range of devices to help further knowledge."… "Tentative targets now being set anticipate that the first disk should be complete before

1960 and it would take the whole of the 'sixties to develop it properly, even though some combat things might be available ten years from now." (Aviation Report, 12 October 1954) [8].

During this time period many of the major defense and technology companies were cited as either having research projects or activities in this new field. For example: "Companies studying the implications of gravitics are said, in a new statement, to include Glenn Martin, Convair, Sperry-Rand, and Sikorsky, Bell, Lear Inc. and Clark Electronics. Other companies who have previously evinced interest include Lockheed, Douglas and Hiller." (Aviation Report, 9 December 1955) [9].

Others of these reports mention: AT&T, General Electric, as well as Curtiss-Wright, Boeing and North American as having groups studying electrogravitics.

During the same time period, the Gravity Rand report notes that: "Already companies are specializing in evolution of particular components of an electogravitics disk." [10]

However, in the area of predictions, the Aviation Report stated the following based on an extrapolation of technology development: "Thus this century will be divided into two parts – almost to the day. The first half belonged to the Wright Brothers who foresaw nearly all the basic issues in which gravity was the bitter foe. In part of the second half, gravity will be the great provider. Electrical energy, rather irrelevant for propulsion in the first half becomes a kind of catalyst to motion in the second half of the century." (Aviation Report, 7 September 1954) [11].

Looking back it is easy to say that they missed the mark. Did they really miss it by a half a century? Reading through these reports it is quite obvious that there was much interest in antigravity among a number of very high profile companies, as well as in the Department of Defense. What happened to this interest and why was it all downplayed during the following four plus decades? After all, T. Brown had shown that there is a demonstrable connection between high voltage fields and gravity. Why has it taken until the 1990s for more than just a few scientists to look at these results and publish on them in the open literature? A review of recent statements by former military personnel and civilians connected to covert projects begins to shed light on research activity in these areas over the last half century. **And it appears that there had been significant breakthroughs during this time period, well shielded from both the scientific and public eye.**

Recent Scientific Developments

In this section we consider developments in the antigravity field since the late 1980s and why the confluence of scientific findings and the testimony of witnesses associated with the military and covert groups indicates that a gravity solution with technological implications has been found.

Although general relativity has not been able to explain Brown's electrogravitic observations, or any other antigravity phenomenon, the recent physics methodology of quantum electrodynamics (QED), appears to offer the theoretical framework to explain electrogravitic coupling. Recent papers by members of the Institute for Advanced Study Alpha Foundation are putting a solid theoretical foundation onto the antigravity effects within the theory of electrodynamics and include papers by Evans [12] and Anastasozki et al [13].

Earlier in a 1994 breakthrough paper, Alcubierre showed that superluminal space travel is, in principle, physically possible and will not violate the tenants of the theory of relativity [14]. Puthoff [15] later analyzed these findings in light of the present SETI (Search for Extraterrestrial Intelligence) paradigms that insist that we could not be visited by extraterrestrial civilizations because of the speed-of-light limitations dictated by the general relativity theory. He suggests that superluminal travel is indeed possible. This leads to reduced-time interstellar travel and the possibility of extraterrestrial visitation, which our limited understanding of physics and scientific arrogance has "forbidden" in some sectors for most of the 20th century.

The second aspect of these physics findings deals with the zero point or vacuum state energy shown by the Casimir effect [16], which predicts that two metal plates close together attract each other due to imbalance in the quantum fluctuations. The implications of this zero point or vacuum state energy are tremendous and are described in several papers by Puthoff [17] starting during the late 1980s. Bearden [18] and colleagues have also written extensively on the theoretical physics of zero point energy and additionally have described various technological means of extracting this energy (for example see the recent paper by Anastasozki et al [19].). A theoretical book on zero point energy (and antigravity) was published by Bearden in 2002 [20]. There is significant evidence that scientists since Tesla have known about this energy, but that its existence and potential use has been discouraged and indeed suppressed over the past half century or more [21].

The coupling of the electrogravitic phenomena observations and the zero point energy findings are leading to a new understanding of both the nature of matter and of gravity. This is just now being discussed in scientific journals (though some evidence suggests that it has been understood for decades within the black project covert community). The question that is being addressed is: what keeps the universe running? Or more specifically, where do electrons get their energy to keep spinning around atoms? As electrons change state they absorb or release energy, and where does it come from? The simplistic answer is that it is coming from the vacuum state. Puthoff [22] describes the process as follows: "I discovered that you can consider the electron as continually radiating away its energy as predicted by classical theory, but **simultaneously absorbing a compensating amount** of energy from the ever-present sea of zero-point energy in which the atom is immersed. An equilibrium between these two processes leads to the correct values for the parameters that define the lowest energy, or ground-state orbit (see "Why atoms don't collapse," NEW SCIENTIST, July 1987). Thus there is a DYNAMIC EQUILIBRIUM in which the zero-point energy stabilizes the electron in a set ground-state orbit. It seems that the very stability of matter itself appears to depend on an underlying sea of electromagnetic zero-point energy."

Furthermore, it appears that it is the spinning of electrons that provides inertia and mass to atoms. These theories, linking electron spin, zero point energy, mass, and inertia have been presented in a number of recent papers, such as those by Haisch [23] and colleagues and provide us with a possible explanation of the Biefield-Brown effect. It appears that an intense voltage field creates an electromagnetic barrier that blocks the atomic structure of an atom from interacting with the zero point field. This slows down the electrons, reducing their gyroscopic effect, and thus reducing atomic mass and inertia, making them easier to move around.

Evidence of Extensive Antigravity Technology

The B-2 Advanced Technology Bomber

In 1993, LaViolette wrote a paper [24] discussing the B-2 bomber and speculating on its probable antigravity propulsion system, based on a solid understanding of electrogravitics, [25] the aircraft's design and the materials used in its manufacture. It appears that the craft is using a sophisticated form of the antigravity principles first described by T. Brown. Support for this thesis came from the Aviation Week and Space Technology (March 9, 1992), which reported that the B-2 bomber electrostatically charges its leading edge and its exhaust stream. Their information had come from a small group of former black project research scientists and engineers suggesting the B-2 utilizes antigravity technology. This information was supported by Bob Oechsler, an ex-NASA mission specialist who had publicly made a similar claim in 1990. These findings support the contention that there have been major developments in the area of antigravity propulsion which are presently being applied in advanced aircraft.

LaViolette later states the obvious that "the commercial airline industry could dramatically benefit with this technology which would not only substantially increase the miles per gallon fuel efficiency of jet airliners, but would also permit high-speed flight that would dramatically cut flight time." [26]

The Hunt for Zero Point [27]

This recent book contains some of the strongest evidence yet for major efforts and success in the field of antigravity technology. The author, Nick Cook, who for the past 15 years has been the Aviation Editor and Aerospace Consultant for Jane's Defense Weekly, spent the last 10 years collecting information for the book. This included archival research on Nazi Germany's antigravity technology and interviews with top officials at NASA, the Pentagon and secret defense installations. He shows that America has cracked the gravity code and classified the information at the highest security levels. **Because antigravity and its allied zero point energy technologies potentially offer the world a future of unlimited, non-polluting energy it has been suppressed because of the "huge economic threat".** His findings support those reported by many of the Disclosure Project witnesses cited above.

Antigravity Technology Demonstrations

Although T. Brown reported many of his findings nearly a half century ago, other experimenters have just recently begun to reproduce his work and report on it in the open literature and on the WWWeb. For example, Davenport [28] published the results of his work in 1995 supporting the findings of T. Brown, while Bahder and Fazi [29] in 2002 described their assessment of the forces associated with an asymmetric capacitor. Transdimensional Technologies [30] in the USA and J. Naudin [31] labs in France have posted on the WWWeb: diagrams, web videos, and data on their versions of antigravity "Lifters" based on an extension of Brown's work. It is a sad commentary on this whole area of research to see that public science is requiring us to demonstrate principles that were demonstrated nearly fifty years ago.

There have also been a number of other demonstrations of "antigravity" phenomena by researchers throughout the world. This includes the work of Brazilian physics professor, Fran De Aquino, and such devices as: the Searl Electrogravity Disc, the Podkletnov Gravity Shield and Project Greenglow, the Zinsser Kineto-baric Field Propulsion and the Woodward Field Thrust Experiments on Piezoelectrics. All of these are described in more detail by Greer and Loder. [32]

Implications of This Research

Antigravity and zero point energy research and their applications are finally being addressed by some of the open scientific community. This means there will have to be a rewriting of textbooks in this area so our new generation of students can apply this "new knowledge." Its application will lead to major breakthroughs in transportation technologies both earthside and in outer space. The implications are that we have the potential for human exploration of our solar system and beyond, if we have the will, within our lifetimes. It also means that the majority of 20th century space technology will be obsolete and in fact may already be so.

The zero point or vacuum state energy source is seen as a totally non-polluting energy source, which has the potential to replace all the fossil fuels on this planet. It also will provide the energy needed for long range space flights. This means that fuel cells and solar cells in common use today for space flight energy applications will only be needed until we transition to these new energy technologies.

Based on an analysis of trends in antigravity research over the last half-century and the information provided by numerous witnesses, it appears that there is both good and bad news. The good news is that it appears that we (at least covert projects) have already developed the theories of antigravity, and additionally have developed working spacecraft based on these principles. The bad news is that these technologies have been developed for at least several decades, at the public's expense and that human kind has been deprived of these technologies, while continuing to waste energy using less efficient and pollution enhancing technologies.

Supporting this contention is the following quote from Ben Rich, former head of the Lockheed Skunkworks. Just prior to his death, he stated to a small group after a lecture [33] that: "We already have the means to travel among the stars, but these technologies are locked up in black projects and it would take an act of God to ever get them out to benefit humanity…" He further went on to say that, 'anything you can imagine we already know how to do.' Strong words from a knowledgeable deep insider and words that support what a number of the witnesses stated as well.

As the reality of this knowledge begins to be understood, there will be an outcry among space scientists not on the inside for release of these technologies to allow all of us to explore space. There will be major changes in the way that NASA does its business, though predicting these changes is difficult. Not only has space exploration in the public sector suffered, but our planet's environment has suffered as well. Thus as this knowledge begins to sink in there will be an outcry among all concerned citizens on this planet for release of these technologies to allow all of us to reduce and ultimately eliminate global warming and environmental pollution that so threatens our way of life. These technologies will not only affect space travel technologies, but will also have a profound effect on transportation and energy production on the earth's surface.

In conclusion, we might consider the observation made by Halton Arp [34]: "We are certainly not at the end of science. Most probably we are just at the beginning!"

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Congress "The Time Machine"

Faraday Labs Ltd invites to participate in scientific congress devoted to experiments on changing of space-time properties. It is planned April 12, 2003, Moscow. Main topics of the congress are time and gravitation in the context of eatherodynamics, experiments and applied aspects of these technologies. The main report is "Method to Control Temporal Parameters of Physical Processes" by Alexander V. Frolov.

Organizing committee: Vadim A. Chernobrov (KOSMOPOISK research center) and Alexander V. Frolov (Faraday Labs Ltd). The registration fees are not required.

Please, contact us http://www.faraday.ru or **email** congress@faraday.ru **Phone/fax 7-812-380-3844**

Please send this pre-registration form by post: P.O. Box 37, St. Petersburg, Russia 193024 **or e-mail:** congress@faraday.ru

PRE-REGISTRATION FORM **for participation in the congress "The Time Machine"**

Last name:
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☐ I would like to submit an oral presentation (report). (Please, enclose one-page abstract).

☐ I intend to participate as a guest

☐ I'm interested in further information.

Date Signature

COMMERCIALISING the "SEARL EFFECT" for ENERGY and PROPULSION SYSTEMS

Review from web site http://www.sisrc.com/
Email address: admin@sisrc.com

The "Searl Effect", discovered by J.J.R. Searl, is a method of extracting energy. Some current expressions for the source of this energy being The Space Fabric, Quantum Space Field, and Zero Point Energy.

SISRC Ltd has been formed to develop and license Searl Effect Technology (SET) on a global basis.

THE COMPANY

SISRC Ltd is the company formed to administer the implementation of the Searl Effect Technology, (SET) invented by J. R. R. Searl. SISRC Ltd designs, develops and implements Searl Effect Technology as it is initiated in various applications and territories. SISRC Ltd is the administrative hub of the group and will continue to be based in the UK. SISRC Ltd will grant production and marketing licenses for Searl Effect Technology applications to different companies in specific territories. Currently proposed related companies include:

* SISRC -Germany, SISRC -Iberia, SISRC - Sweden, SISRC - Australia, SISRC New Zealand.
* SISRC -AV (Audio Visual) provides computer graphics presentations of the SET.

BACKGROUND

The Searl Effect Generator (SEG) technology, as applied to the commercial market, had been previously developed to the point where a few prototype SEG generators were made, and used for electricity generation and motion. Commercial interest at that time focused on the SEG's transport potential and, under commercial pressure to deliver a fully functioning system, the original generators were used and lost in a series of vehicular propulsion experiments and demonstrations. Funding was insufficient to continue with the manufacture of the required larger-scale pressurized cabin machines - resulting in the termination of the project at that time.

Although all the operating principles, precise proportions and weights of the required materials are known for three of the four required operating materials, the precise data of the original magnetic layer is uncertain. The objective of the current R&D programme is to re-establish the original magnetic layer using modern and more efficient materials.

Originally, the layered materials were constructed and magnetized by the now-defunct Midlands Electricity Board under the direction of John Searl (see colored photo of the experimental craft construction on the cover page).

Modern magnetic materials have advanced considerably, and old ones discontinued, so a series of tests need to be conducted to establish the optimum materials and processes. These tests need to comply with the working criteria required and must lead to a cost-effective manufacturing process.

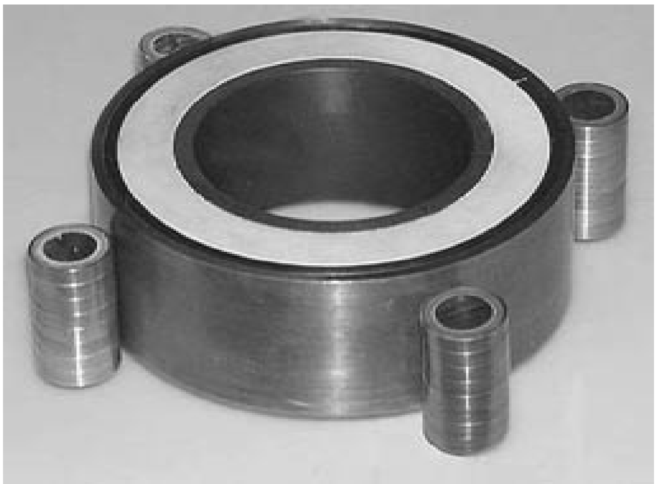

Fig.1
Experimental ring and rollers

In recent times SISRC has been re-establishing the original research. Due to the very limited funding that has been available, only a partially functioning demonstration prototype of the SEG principles has been possible. This prototype consists of the innermost of the three composite rings required and several rollers.

We would like to hear from anyone who worked on or was involved with Searl Technology prior to 1983. Also anyone who has any old technical data, photographs or films relating to the technology. Such information could greatly assist this technology to reach the marketplace for the benefit of all and would be dealt with in the strictest of confidence.

TECHNICAL DESCRIPTION

Physically the Searl Effect Generator (SEG) consists of three concentric rings each made of a composite of four different materials which are also concentrically attached to each other. The three rings are fixed to a base. Surrounding each of the rings, and free to rotate around them, are rollers - typically 10 on the first ring, 25 on the next and 35 on the outer ring. Surrounding the rollers on the outer ring are coils which are connected in various configurations to supply either AC or DC current at a variety of voltages.

Multiple magnetic poles are imprinted on the rings and rollers to form frictionless magnetic bearings. These also arrange the static charge into opposing charge clusters which cause the rollers to rotate around the circumference of the ring (as shown in Fig. 2).

Some expressions currently in use to describe the source of the energy for the SEG are The Space Fabric, Quantum Energy field of Space or Zero Point Energy. This is an unlimited and constant source of energy which can be made to flow when the correctly proportioned masses concerned are stimulated by the correct frequencies creating an 'open system'.

The idea of utilising this source of energy is currently the subject of various devices and experiments such as the 'Lamb shift', 'Casimir Effect' and the work of the Russian Nobel Prize winner Ilya Prigogine. However these devices and experiments tend to only prove the existence of the energy and not a method to create a coherent, ordered flow to produce useful power.

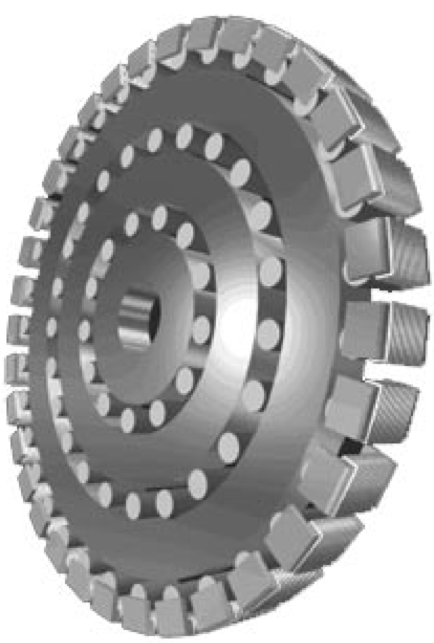

Fig. 2

15 KWt Searl Effect Generator (SEG)

In contrast, John Searl has discovered that, in order to create a steady and stable flow, all the masses of the device (and the stimulating frequencies) must conform to precise values determined mathematically by the 'Law of the Squares'. A machine constructed to these principles produces a stable and useful power output.

DEFINITION OF A SURFACE OPERATING S.E.G. (J. Searl) 15.09.00

A Linear motor operating on a magnetic bearing with the characteristics of an auto-transformer. The S.E.G. is defined as a device, which is constructed from 2,124 component parts, which make up 3 plates and 66 roller sets (see figures on the cover page). 12 of the 2,124 components create the 3 plates, which act as reaction components. 2,112 components are employed to create 66 roller sets, which act as active components. Each roller set consists of 8 segments constructed from 32 components. Each segment cannot be less than 34 grams in weight, as the law of the squares defines that value as the lowest value suitable for the reasonable generation of electricity. Therefore the smallest roller set must weigh 272 grams, making a grand total of 2,244 grams per roller set for the smallest surface bound SEG.

Tolerance should be about 0.05 gram per roller set. The larger the error the greater is the loss of power within the unit. Therefore the total tolerance for the smallest SEG roller set must not be greater than 3.30 grams - above this factor the SEG will not function. **For the best results, the tolerance across the total 66 roller sets should not exceed 0.05 grams!**

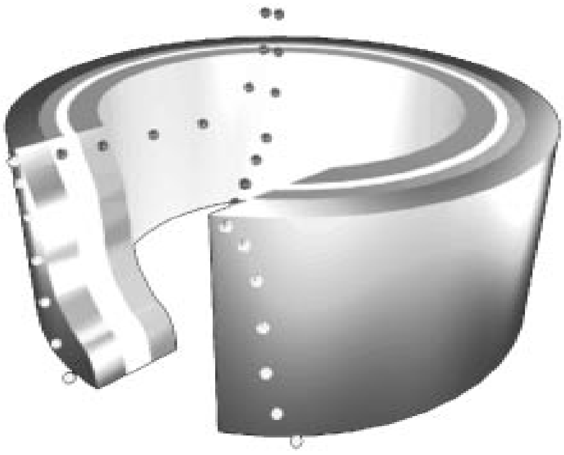

Fig.3

The S.E.G. is a step up rotary transformer. In fact it's a 'three rotary transformers' operational system, within a unit. The inner transformer output is fed in to the input of the second plate which increases the output of the second unit, which output feeds as an input to the final unit, thereby increasing its finaloutput to a very high voltage. Therefore the S.E.G. is just a prime mover for the production of clean electrical energy. The output windings must be designed to step down this output to 240 volts at 15KWt's.

During 1968 it being upon this issue, as development progress both here and in the USA, new findings are being created, and updates will be added to this page, as they are certified. When the SEG rollers are brought into close proximity to the SEG Ring, the Searl Effect resonant magnetic field causes negative ions and electrons to be drawn into and accelerated through the machine. This process is assisted by the highly electron-attracting rare earth metal Neodymium.

The unique mechanical and material arrangement of the SEG pulses the neodymium to continually release and replace the surplus electrons to provide electrical or mechanical power, or both.

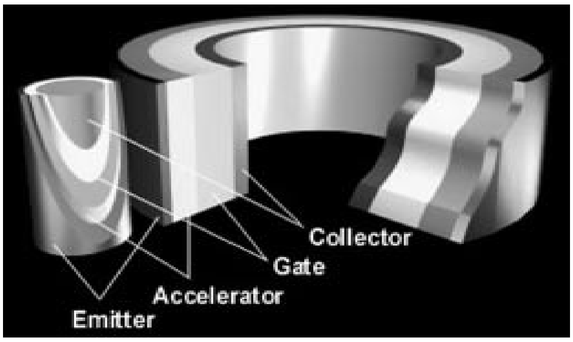

Fig.4

DEVELOPMENT

Prior to the production of complete 15KWt Searl Effect Generators (SEGs), a minimum of two demonstration Ring & Roller prototypes are to be produced.

The "Ring" is typical of the innermost of the three rings required to make a complete SEG. The 69-roller sets in a complete three ring SEG are identical. Six roller sets will be made for the prototype inner rings so that the Searl Effect can be demonstrated.

The production of a self-running Ring & Roller prototype will establish the precise sequence and parameters of electrical, magnetising and material processes required for the SEG and will demonstrate electrical power generation. An operating single inner ring with 1-8 rollers will also determine if a particular material will function correctly and at what level of power output.

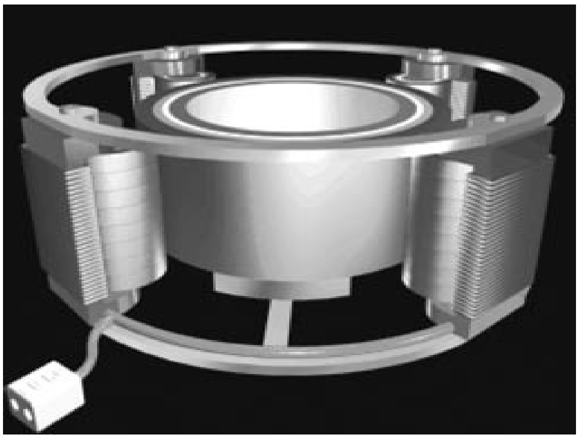

Fig. 5
Demonstration ring and rollers

The five phases of the development programme that commenced in October 1999 have been completed and the rollers successfully magnetised with 'Searl Effect' magnetic fields. A sixth phase is now required to apply the technology developed in Phase five to the "Ring". This sixth Phase resulting in a demonstration Ring & Roller prototype has duration of 6 months.

NEWS REVIEW

Scientific Breakthrough Liberates Energy Users from Fossil Fuel Dependence

Information from
http://www.genesisworldenergy.org/genesis_world_energy.htm

Story originally published by Diana Echeverria, USA

Director of Public Relations
Guy Rome & Associates, Inc.
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Technology breakthrough harnesses energy from the molecular structure of water

BOISE, ID - Dec. 5, 2002 - Genesis World Energy, a privately funded consortium created by a group of military and space program research and development specialists, today unveiled a scientific breakthrough that allows consumers to easily access the energy contained within the hydrogen and oxygen molecular structure of ordinary water. This scientific breakthrough provides a limitless, low cost and environmentally clean source of energy that can be implemented with minimal cost and effort. The viability of using water as an energy source, previously a theoretical concept, is now a reality. "Water has always been the source of life on this planet, now it will also transform the way we create energy" said Charles Shaw, corporate counsel and spokesperson for Genesis World Energy. "The implications for worldwide energy generation and consumption are nothing less than staggering."

The Edison Device

The first application of this technology is represented in the "Edison Device", a self-contained, self-sustaining energy generation unit. Roughly the size of an outdoor air conditioning system, the power source can be quickly and easily installed in any home or business to provide virtually unlimited energy from any available water source. The Edison Device utilizes the existing electrical wiring and natural gas plumbing in a home or business to replace the energy provided by utility companies. The home version of the Edison Device produces approximately 30 kWtt of combined gas and electrical energy per day. By comparison, the typical home uses between five to six kilowatts per day. The commercial model is capable of producing 100 kilowatts of energy per day. The energy generation portion of the devices has no moving parts. In fact, the only "mechanical" aspects of the equipment are small circulation pumps and micro-valves, making the Edison Device both silent and virtually maintenance-free. A minimum amount of water is used over an estimated 20+ years of service life.

Interesting Publications of the Last Year

Discovery by a Group of Scientists Headed by Valerian Sobolev

Some time ago mass media announced that a sensational discovery was made by a group of Russian scientists headed by Valerian Sobolev. This discovery aroused ambiguous attitude of physic community. We have written about this fundamental and, to a certain extent, revolution discovery. Let us revise the fact that Sobolev claimed 7 scientific discoveries which were made, i.e. the process of depletion (a special electrochemical process), magnetic discharge, a new energy source, a method of low temperature plasma generation and superconductor. A laboratory system of the experimentally disclosed process as well as its industrial prototype is easy to be realized in practice for creation of new energy sources and wide-ranging production of ultrastrong materials. In many cases these materials can replace existing constructional materials.

The materials produced as a result of the process are multielement chemical compounds which are new states of matter. This new state of matter has **a time-changing magnetic field that can be EMF source in a coil of a generator.** Ordered structures of matters which are in the new modified state are nothing but a magnet charge. Materials containing the magnet charge and representing a continuous matters are **new energy sources.** Due to the new state matters become able to produce electric power as well as to generate low temperature plasma. It is easy to be realized in the process of common technological procedures. That promises designing of propulsors for “unsupported” transportation systems in near future.

Basing on realization of the disclosed process and using new materials the group of Russian Scientists headed by Sobolev together with American businessmen has created superfine and flexible glass for packing. The glass was called as “strong glass”. It seems to demonstrate higher pressure stability than steel. A method of production of these materials was patented in 1999. In the patent the scientists of Valerian Sobolev’s group are represented as authors of this new method, and the owner of the patent is Dynelec Corp (Columbus, Ohio, USA). You can read about the patent at the Web-site of http://patft.uspto.gov/netahtml/srchnum.htm (patent #5,964,913, October 12, 1999).

Sobolev’s group has appeal to the Russian government for sponsorship; however only foreign investors have provided funds for new energy sources developing. According to Russian Information Agency “News”, Sobolev’s group has signed a $168 million contract with one of Canadian companies for developing industrial production of energy sources. Manufacturing of such energy sources **can change energy supply system all over the world**. According to the contract the Canadian company is going to finance building of at least two plants. One of the plants is going to be built in Russia, and the other one is planning to be established in Canada. Each plant is supposed to produce 70 thousand of the self-running energy sources a year. Power output of the sources will come to 3-10 kWt. In other words, in the nearest future every person will be able to buy such an energy source and to apply it in household.

Single-Wire Electric Power System

(see photo on the cover page)

Experimental Results of Russian Scientists

Scientists of the All-Russia scientific research institute of electrification of agriculture (VIESH) academician D.S. Strebkov, engineer S.V. Avramenko, dr., A.I. Nekrasov, post-graduate student O.A. Roshchin developed a new method and the equipment for transmission of electric energy on a single-wire line using resonant idle operation mode and reactive capacitive currents for transmission of active electric power. Tesla transformers and frequency converter were used at the experiments.

First there was created the experimental sample of single-wire electric power system (SWEPS) with **10 kW** electric capacity and 3000 V voltage. As a result, obtained SWEPS electric parameters a hundred times exceeded parameters of a usual two-wire or three-wire alternative and direct current line.

In the end of 2002 there was made an attempt to increase transmitted capacity by using of more powerful condensers, which were installed in resonant circuit. There was developed the electric technique of **20kW** single-wire electric power system (SWEPS) with two Tesla transformers. As a result parameters of a low-voltage winding of the step-down transformer were changed. They **exceeded parameters of a usual two-phase or three-phase ac line or dc line in two hundred times.** At room temperature effective specific transmitted electric power was 4 MW/mm^2 and specific current density was 600 A/mm^2. These parameters could be achieved for existing methods of electric energy only at use of special materials in a mode of low temperature superconductivity. The measurements which were made at wire with diameter of 1mm, 100 microns and 80 microns, demonstrated that parameters did not depend on diameter of a wire. There was also experimentally confirmed the property of a single-wire line to transfer active power without essential losses on line resistance. Irradiation losses at low frequency 3,4 kHz were small. In single-wire power system the 80 microns wire plays a role of directing system for an electromagnetic energy flow, which runs from the generator to the load.

"Lifter" Project

We present update information on the experiments with Lifters or asymmetrical capacitors, which use High Voltage to produce a thrust. ***By Jean-Louis Naudin it was demonstrated with "****Maximus****" experiment, that a Lifter can be scaled up and also that such a device is able to lift up to 60 g of payload (total weight: 194 g). According to Naudin, it is now possible to build a craft which will use the Biefeld-Brown effect to fly silently and without moving parts only powered by electrical energy.*** *It was also declared that on January 8th, 2003, there was successfully done two historical flights with a mouse as a test pilot of the Lifter "Maximus"* ***(propellantless electrokinetic craft)****. Below there is an analysis of electrogravitation experiments made by Jean-Louis Naudin and Tim Ventura. (See color photos on the cover page).*

Review of Electrogravitation Experiments made by Jean-Louis Naudin and Tim Ventura

Tim Ventura

Tim Ventura Website: http://www.americanantigravity.com
Email: TVentura@seattle.telecomsys.com, tventura6@atbi.com

There is a spreadsheet containing a jpeg-snapshot of data that I have assembled based upon Jean-Louis Naudin's published results (JLN Labs Website: http://jnaudin.free.fr. and http://www.jlnlabs.org). In the graphs that I've created, it seems to indicate that current plays more of a role in propulsion than voltage does — i.e.: for a given amount of power in watts, raising the current and decreasing the voltage seems to create a higher level of thrust.

In light of this, I have been increasing the thrust of my own Lifters by creating an electrical-bypass of the "load-resistor" on my power-supply's high-voltage output. This has an interesting result:

I use a current-driven power-supply, which means that if no load is connected to it the voltage will build up on the high-voltage output until arcing occurs. In my case the voltage will build up to around 65kV, at which point the power-supply will automatically shut down. Conversely, if a very light load (such as a short circuit) occurs, the opposite effect happens and the power-supply will deliver much higher current at a much lower voltage until the supply is overdrawn and once again shuts down.

Normally the output load-resistor constrains the current, and in doing so it maintains the voltage on the high-voltage output at the nominal 50kV output level. However, bypassing the output load-resistor allows the power-supply to deliver voltage and current that are based almost entirely on the type of load connected to it.

When I connect a normal Lifter to the bypassed power-supply, the voltage will build across the air-gap until ions begin to flow in a conduction-current across the air-gap. Although this begins to happen at approximately 15kV, it seems to have some type of "peak efficiency' at approximately 22.5 kV. The amount of current climbs to approximately 11mA at this voltage.

This method of experimental setup seems to allow the Lifter to "find its own sweet-spot" for operation, instead of using the output-resistor to "force" a specific voltage on it for operation. This appears to maximize the thrust output during operation.

Lifter Efficiency Spreadsheet

Description	Lift capacity (grams)	Length (cm)	Efficiency (g/m)	Lifter Weight (grams)	Voltage (kilovolts)	Corona Air-Gap (centimeters)	Current (mA)	Power (watts)
Lifter 1	3.3	60	5.5	2.3	41.9	3	0.57	23.9
Lifter 2	9.6	180	5.3	6.6	43.35	3	1.12	48.5
Lifter 3	20	360	5.6	16	27.5	3	2.53	69.5
Lifter 4	36	720	5	32	44	3	2.01	132.9
3-Stage Lifter 3	54	1080	5	24	30	4.5	8.06	240
Coliseum Lifter	90	2160	4.16	50	31.769	4.5	8.06	254.15

New Electric Fire Technology

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http://www.intrasoft.ru/nizot

Abstract

The article proves importance and prospects of development of combustion technologies. In particular there is considered application of a new electric fire technology for environmentally appropriate combustion of any matters and gases. The technology uses electric fields as combustion catalyst. There is observed application of technology in heat-and-power engineering, transport heat engines, disposal units etc. [1, 2]. It is demonstrated that the new technology allows intensify combustion processes and increase their controllability (i.e. the control of temperature, gases pressure, gradient of heat conductivity, and so on). There is made a conclusion about availability of the technology to solve critical energetic and ecological problems of the civilization.

We hope that this article will excite interest of a wide circle of readers, i.e. of professionals in the area of combustion and heat technologies, physicists, ecologists, and those people who are interested in new scientific ideas.

Global Ecological Problems are the Problems of Ineffective Combustion of Hydrocarbon Fuel

The ecological problems become more and more serious and threaten to grow into world ecological catastrophe. The main cause of the atmosphere pollution in megapolises is imperfection of combustion technologies (of heat-and-power engineering, heat machines, transport engines, waste combustion…). It has been proved that their share of pollution of the planet atmosphere comes to 70-80%. The combustion technologies mean any technologies of combustion of fuel, matters and gases. The combustion technologies are the most popular technologies in the world. The modern civilization without the combustion technologies is impossible. There are many industries, which apply these technologies, such as heat-and-power engineering, transport, metallurgy, food industry, oil-and-gas refining industry, chemical industry, waste combustion neutralization.

Therefore the global ecological problems will not be solved until the mankind develops the combustion technologies. The article describes and discloses the essence of the new technology of ecologically appropriate and effective combustion of fuel and wastes of any type.

Why is it difficult for ecologists to conserve nature?

Modern methods and technology used for solving of the ecological problems consist in **analysis** of extent and sources of the environment pollution (ecological monitoring), and, moreover, in **refinement of atmosphere, water and soil, which are used in different technologies or have been polluted due to the imperfection of the technologies** (it is refinement from such toxic components as drinking and run-off water, exhaust and waste gases etc.).

Unfortunately, methods of measuring of the huge spectrum of toxic matters, which are thrown into the atmosphere at matters combustion, as well as the methods of their utilization are impartially difficult, expensive and imperfect. Even using of an ideal technics for measuring of the atmosphere pollution is not effective since it is a struggle with **consequences** of the combustion and other technologies imperfection but not with **causes** of the atmosphere pollution.

Ecological and energetic effectiveness of the known combustion technologies

It is known that real effectiveness of transformation of chemical energy of fuel in the combustion process is low. For example, in heat engines it comes to 25%, effectiveness of transformation of heat energy into electric energy in thermoelectric power stations does not exceed 40%. If energy consumptions of mining, processing and delivery of the fuel to consumers are taken into account then the summary efficiency of the existent combustion technologies (of heat machines and devices) comes to no more than 10 – 15%! It means that more than the half of chemical energy of the fuel is transformed into heat and different toxic matters and waste gases, which pollute the planet atmosphere. They cause acid precipitation, a global “greenhouse” effect, which threaten to cause the climate warming, the world flood, and final poisoning of the living nature. Thus the share of imperfect power engineering in the nature pollution comes to 70 – 80%! How is it possible to cleanse the planet atmosphere, especially the environment of world megapolises, in the situation when the amount of toxic matters produced by transport and industries is comparable with the amount of rest pure air?

Until the mankind learns burn matters and gases by effective and ecologically appropriate way the planet atmosphere will remain polluted and in near future it can become uninhabitable. Thus we will not solve the ecological problems until we gain the understanding of the combustion processes and processes of combustion transformation of matter chemical energy into heat energy, and then into other useful types of energy (i.e. electric energy, mechanical energy, light energy).

Physical Essence and Problem of Classical Combustion of Matters

Combustion is one of the most difficult phenomena, which are known by the humankind. From the scientific point this phenomenon is a chain reaction of sequential fragmentation of fuel particles into smaller charged radicals; it is physical chemical processes of transformation of chemical energy of intermolecular connections as well as combustion also includes physical processes of transformation of energy into heat and light on molecular and atomic levels. Many other processes, which proceed simultaneously, are involved.

From school years we know that combustion is a process of interaction of fuel with an oxidant that is accompanied by heat and light energy generation. In higher school the words of "as well as by cryptic energy of chemical connection of waste gases" are added to the school definition. The combustion processes are studied and improved by scientists and experts of different areas (chemists, physicists, heat-and-power engineering specialists, thermalphysicists etc.). There are known fundamental investigations of combustion chain reactions made by such Russian scientists as N.N. Semenov, Ya.B. Zeldovich and their followers.

Until now intensiveness of fuel combustion is increased by air blowing into the combustion zone that increases the amount of waste toxic gases thrown into the atmosphere. **Let us arouse several questions, which seem naive at first sight. Why is an oxidant (air or oxygen) needed for matter combustion? Is it possible to do it without any oxidant?** How does the combustion process begin and proceed? There are a lot of vague questions in physics of combustion. For example, how can the temperature and the intensiveness of the combustion be regulated? Can the heat conductivity of the flame be controlled? How can heat motion of particles be regulated in the flame and in the waste gases, and what can it cause? There is another problem of combustion. It is the very hydrocarbon fuels, which are applied at modern heat processes. The great Russian scientist, D.I. Mendeleev stated that to use oil is the same thing as to stoke a stove with banknotes.

Since the hydrocarbon fuels are complicated chemical matters and the combustion processes are imperfect then in the process of their combustion a great amount of different by-product matters and toxic gases are produced. They waste unused self-energy of fuel into the atmosphere and pollute our planet.

Physical essence of the new electric combustion technology

How is it possible to burn the hydrocarbon fuel by environmentally appropriate way? How can this environmentally appropriate technology be realized in practice? A brief answer is following**: it is necessary to make such conditions of combustion of organic fuel, and to introduce such a combustion catalyst that the energy of intermolecular and intramolecular connections of the organic fuel becomes absolutely free. At that the chemical energy can be transformed into energy of electromagnetic radiation, for example, into light energy and heat energy without generation of by-product polluting matters and gases. Then a working body (for example, water) is effectively heated by this directed concentrated electromagnetic radiation. In this process effects of electromagnetic waves reflection and concentration are used, or the electromagnetic radiation is directly transformed into electric energy.** In this case there is a new opportunity to regulate flame temperature and to extremely decrease quantity of the oxidant, i.e. to create organics combustion with minimal quantity of waste gases.

Is it principally possible to burn organic matters and gases without the atmosphere pollution using electric field as a catalyst? It is possible if parameters of this field are correctly chosen. More precisely it is possible if huge Coulomb forces of the electric field are correctly regulated by interaction of electrically charged particles of the fuel and the oxidant with force lines of the electric field.

One variant of an experimental device is represented in Fig. 1.

Devices for approbation of the new electric combustion technology

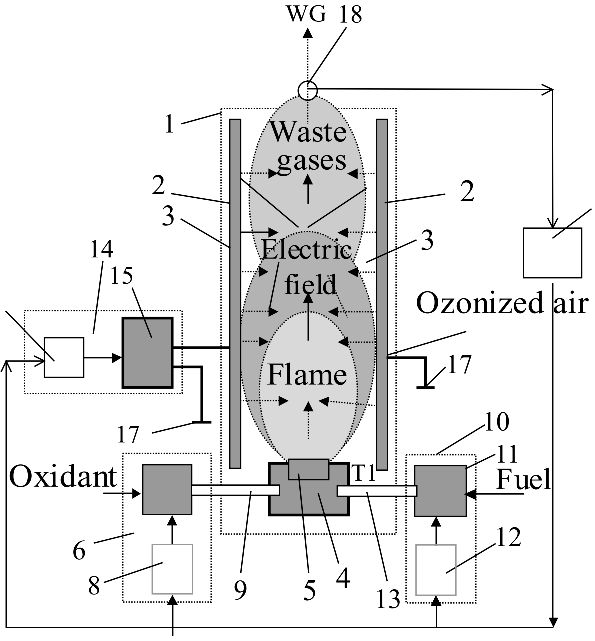

Fig.1 a
Plan of the experimental device

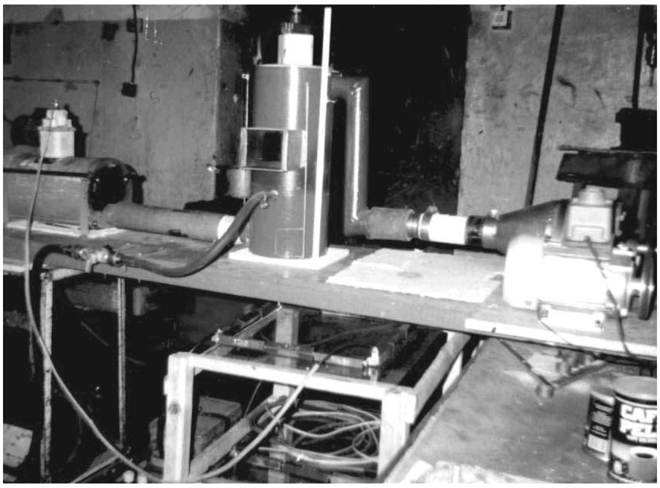

Fig. 1 b
Photo of the experimental system

A structure chart of the experimental device, which was designed to investigate the new electric combustion technology, is demonstrated in Fig.1a. The device contains a body (1) equipped with flat electrodes, which are insulated from the body (2), (they can be placed in either horizontal flat or vertical flat). The electrodes (2) are located on opposite inner walls of a combustion chamber (3). The device is equipped with a mixer (4) with a device for supplying of blended fuel to the zone of combustion. At the same time the device (5) is used for electrical combustion of the blend. The described device is equipped with an air track (6), which contains an oxidant activator (7) joined with a regulator (8) by a control circuit and with the mixer (4) by an air pipe (9). The regulator (8) serves for regulation of the oxidant activation extent. At the end of the air pipe it is possible to place a vortex device (it is not shown in the figure). Also the device is equipped with a fuel track (10) containing a fuel activator (11) and a regulator (12) of the activator and consumption of fuel. The block (11) is joined with the mixer (4) by a fuel pipe. The device is equipped with an electric combustion activator (14) containing a high-voltage transformer (15) of intensity and frequency joined to its regulator (16) by a control circuit. An electric outlet of the block (15) is joined to one of the electrodes (2), and the second outlet is safely electrically grounded by a grounding mat (17). The high-voltage wire of the outlet of the block (15) is connected with the electrode (2) through a bushing insulator (it is not demonstrated in Fig.1a). The device is equipped with a gas toxicity calculator (18) joined to the inlet of a mode optimizer (19), which is a control system for interacted regulating of all the parameters of combustion. For that the outlet of the mode optimizer (19) is joined to the inlets of control of the regulators (8), (12), (16).

The device operates in the following way. At first an activated oxidant of O1 is applied through the air track (6), activator (7) and air pipe (9) to the mixer (4). Then an activated fuel of F1 is applied through the fuel track (10) and the activator (11) to the same mixer (4). A blended fuel is prepared in the mixer (4) and then is atomized and combusted by a sparkle of the block (5). In the combustion chamber (3) flame and waste gases are processed by strong alternating electric field, which is generated by the block (14) in a gap between the electrodes (2). In the process of combustion waste gases toxicity is measured by the special toxicity sensor (18). Depending on current toxicity the parameters of flame combustion are regulated by the mode optimizer (19). More precisely the oxidant consumption and the extent of its activation are changed by the regulator (6), the fuel consumption and the extent of its activation are changed by the regulator (12), the intensity and frequency of the alternating electric field generated by the block (14) in the combustion chamber (3) is changed by the regulator (16). Let us note that the electric field in the combustion chamber (3), viz in the gap between the electrodes (2), catalytically influences on both the flame and the waste gases. The essence of the process lies in the fact that the processes of fragmentation and oxidation of fuel radicals and of toxic oxide molecules are accelerated. Intensiveness of combustion and of toxic gases refinement increases as well as the intensity of this field and its frequency do. As a result of the interconnected regulation of all the listed parameters fuel of any kind can be fully, intensively, “cleanly” combusted.

In Fig.1b there is a photo of the operating experimental device designed to investigate the processes of influence of electric field on the process of matters combustion and of cleaning of waste gases. The photo represents following things.

1. In the left side there is a furnace with a high-voltage electrode in a higher part of its body.
2. In the centre there is a vertical column of the electric combustion cleaning (after-burning) of toxic gases in the electric field; on the top of the column a high-voltage electrode can be seen. Gas pipes designed for toxic gases supply–withdrawal are connected with the column and located to the right and to the left from it.
3. A regulable blower is represented in the upper right side of the picture. It is designed for toxic gases withdrawal and connected with the gas pipe by the column.
4. At the foot of the picture there is a regulable high-voltage tension source (the electric field source), which is connected with the furnace and the column of toxic gases cleaning by high-voltage wires.

It is experimentally proved that combination of two stages of the combustion activation (i.e. in the furnace and the column) ensures ideal cleaning of toxic gases at combustion of any toxic matters.

Some Results of Experiments

Our experiments and investigations of many-sided influence of electric and high-voltage electromagnetic fields on the combustion process have proved that such practically ideal condition of fuel and matters combustion is possible to be realized in practice [1].

Low-powered static and alternating electric fields (i.e. the fields of constant sign and of variable sign) of more than 1kV/cm intensity were used as combustion catalysts as well as high-frequency electromagnetic fields of low power with some frequency of oscillations of molecules in the flame (flame power is 0.1 – 1% of heat power of the flame of the combusted organic fuel).

Peculiarities of Oxidants Application in the New Technology

It is known from the thermodynamics and combustion theory that optimal ratio of the oxidant mass, for example air, and the fuel is approximately 1:16 in an average combustion process. In our experiments with the electro-field catalyst the ecologically appropriate combustion of the hydrocarbon fuel (mazut, straw oil) was achieved at oxidant deficiency (for example, at the ratio of oxidant mass and the fuel of 1:1). For experts it means that there is a real possibility for 10 – 15 times decrease of amount of waste gases of any heat machines and to while their former power is the same. As the experiments demonstrate carbon and hydrocarbon are absolutely removed from the waste gases. In the experiments oxides of hydrogen and nitrogen were 4 – 8 times decreased and flame existence was 5 – 10 times increased.

The issues of the experiments prove the hypothesis about possibility of effective environmentally appropriate combustion as a process of direct transformation of chemical energy of organic fuel into electromagnetic radiation energy of the flame (including heat and optic diapasons). The transformation is accompanied by removal of polluting toxic components from the waste gases that occurs due to many times intensification of the combustion process under action of electromagnetic catalysts.

Operations of regulable activation of fuel oxidants (simultaneous or separate), which are introduced into the combustion technology, ensure additional improving of the combustion process. Especially it occurs at heavy oil fuel combustion and water-fuel emulsion combustion that was experimentally tested by us. The process becomes especially effective if the flame of the combusted activated blended fuel is additionally processed by alternating electric field. Due to introduction of the operation of all the combustion parameters regulation (of consumption of fuel, oxidant, of their activation extent, and of their combustion intensiveness extent), according to the information of the waste gases toxicity, it is possible to achieve effective combustion of fuel and waste products of practically all kinds.

Our experiments demonstrate that combination of the very flame procession with procession of the waste gases and air (i.e. an oxidant) by electric field is very effective for the waste gases cleaning. The essence of this additional cleaning of the waste gases lies in fragmentation of carbon particles and exhaust opacity by electric forces of an alternating field as well as in after-oxidation of some toxic oxides in the medium of an ozonized oxidant. Energy consumption for activation of the flame combustion by strong electric fields is small and does not exceed 1–3% of heat energy of the flame. Advantage of this invention is universality of the application for combustion of any inflammables. It is possible due to widening of the diapason of the electric field parameters regulation (of intensity and frequency), especially in the mode of their interconnected regulation.

The essence of catalytic action of the alternating electric field on the flame combustion process consists in effective breaking of dipole radicals of fuel by an activated (dipole) oxidant. Moreover, the essence lies in better mixing of layers of combusting flame with the oxidant that occurs due to removal of a doubled electric layer from the limit line of the flame. Thus this technical solution allows achieve new positive effects due to its significant peculiarities, i.e. extending of application area of the known electric combustion method over the combustion process of any inflammables as well as it allows significantly increase controllability of the flame combustion process.

Let us note that in the experiments on the combustion of organic fuel in strong electric fields the regulation of the flame temperature and of its existence was achieved at unchanged consumption of fuel and of oxidant. That was achieved by changing of the parameters of the combustion electric-field catalyst (intensity and frequency) of a longitudinal electric (electromagnetic) field. Rotation and stabilization of the flame was achieved by a rotating transversal electric field. Changing of the flame height was realized by the longitudinal electric field.

The investigation, which has been performed by us, proves that directly acting on the flame the very electric field which directly influences on the flame and emission of electrons flow (ideal type of oxidation) into the flame can most effectively intensify the combustion process and make it harmless for the humankind and for the environment!

It has already been experimentally proved that energy consumption required for generation and regulation of this electric field and of the electrons flow for intensification and environmental appropriateness of the combustion is quite small relatively the combustion energy and comes to fractions of a percent of the flame energy. Thus our experiments prove that the best **"oxidants" and combustion catalysts are** not superfluous air but **the electron and the electric field!**

Regulation of Heat Conductance of the Flame and the Heat Flow

As our experiments have demonstrated, the electric field can act as an effective combustion catalyst as well as a regulator of its intensiveness; moreover, it can control even a vector of heat conductance. It is proved by the experiments that the parameters of this field can be regulated as well as temperature of the flame and gradient of the flame heat conductance. Interesting experimental results were obtained measuring full heat of combustion of the same quantity of fuel at the usual method of fuel combustion and at the method, which uses combustion electric catalysts, even in the case of oxidant deficiency. In the last case the energy of fuel combustion almost 1.5 times increases that can be explained by fuller transformation of fuel chemical energy into electromagnetic radiation. At the usual combustion methods the chemical energy of the organic fuel was not completely used and remained as a cryptic summary chemical energy of intermolecular connections of many toxic waste gases, which were exhausted into the atmosphere by heat devices. Basing on the performed experiments it may be supposed that, evidently, specific heats of matters are 20-50% higher at this method than at their usual combustion method. The essence of the new electric combustion technologies consists in this new physics of combustion.

The author has already got patents for invention of Russian Federation [3 – 12] for the methods of regulation and intensification of matters combustion processes.

Some peculiarities of atomization, inflammation and combustion of organic fuel in electric fields

We have not discussed all the potential capabilities and advantages of the new electric combustion technology for different areas of technics. Let us demonstrate them in more details.

One of characters of the new electric combustion technology is **effects of oxidant ozonization, of electrostatic atomization and electrostatic injection of electrically charged particles of fuel and the oxidant that is followed by generation of the finest aerofuel opacity on a molecular level in a combustion chamber**. Naturally, such fine atomization of the fuel causes its easier evaporation, inflammation and combustion especially in the medium of the ozonized oxidant. **The mechanism of fuel electrostatic fragmentation is physically explained by Coulomb interaction of repulsion from each other of electrically likely charged fuel drops (particles) that is accompanied by their progressing fragmentation and corresponding decrease of their mass and electric charge**. As the experiments have shown the extent of the fuel drops (particles) fragmentation depends on initial electric potential of fuel charging and initial size of injected fuel drops (particles), which for their part depend on configuration and size of a fuel-injection nozzle as well as on pressure occurring in a fuel line of the heat machine.

Generated by dipolar high-voltage potentials catalyzing electric field can be introduced into the atomization zone or (and) the combustion zone of the combustion chamber of an engine. Its Coulomb forces accelerate motion of electrically charged particles of fuel and oxidant to an opposite electric potential, which is connected with, for example, a piston of an engine. Thus electric field acts as an electrostatic pump that allows decrease pressure in a fuel line as well as allows practically ideally atomize the fuel and mix it with the oxidant. Moreover, it lets simplify and improve the systems of injection and inflammation of the blended fuel in heat machines and devices, for example, in internal combustion engines or in boiler plants. Their application can cause additional improving of energetic and ecological characters of the combustion technologies. According to our information, such high-performance fuel-injection nozzles have yet been unknown in technics therefore they have not been applied in heat machines (injector internal combustion engine).

Is it possible to combust water? Water as a fuel!

More amazing experimental results were obtained at 40-80% dilution (emulsification) of liquid organic **fuel**, for example diesel oil, with **habitual water**. Summary energy as heat and light, which is generated in the process of such blend combustion, was not practically changed that can be explained by liberation of energy of chemical connections of water as well as of fuel. In the process of the experiments on combustion of the emulsion at first **it was transformed into the finest water vapor on the molecular level by means of capillary electroosmosis and of electrostatic atomization. Then dipolar water molecules, which had been electrified by field, were fragmented into hydrogen and oxygen, and then the hydrogen was effectively combusted in the medium of the ozonized oxygen.** Let us note that at this mechanism of water "evaporation" and of following splitting of water molecules into hydrogen and oxygen the electric field expends energy, and heat of organic fuel combustion just accelerates (catalyze) this process.

Editor: It is necessary to note that electric field can not expend energy. If there are no conduction currents then the field source does not decrease difference of potentials. Hence it can be concluded that effectiveness of such power systems is possible to be UNRESTRICTEDLY HIGH. The author writes about it below as about an "incomprehensible phenomenon".

The most amazing and incomprehensible fact is that the electric field transforms water into "vapor" and breaks the water molecule into hydrogen and oxygen practically **without any expenditure at minimum of energy consumption**. Electric power of the intensity high-voltage transformer, which is necessary for strong field generation, lies in the interval from several watts to tens of watts. As the experiments have demonstrated electric consumption of the high-voltage source practically is not changed at correct shunting of the flame by the electric field (i.e. through an air gap). Current consumption practically did not increase depending on mode of fuel atomization and its combustion (of flame height, of combustion intensiveness...).

There are only two conditions of effective work of static electric field as an electrostatic pump-atomizer of fuel and as a catalyst of blended fuel combustion. The first one is intensity of the field in the zone of fuel atomization and in the zone of flame combustion. The second one is enough emission of electrons into the blended fuel flow. In this mode Coulomb forces make work of electrostatic pressure generation and of electrostatic fragmentation of particles and molecules of fuel and water. The forces repulse likely charged drops of water. Heat motion of fuel radicals, which are combusted and fragmentized in the flame, impedes their chemical recompounding into water molecules in the zone of combustion. Moreover, it causes proceeding of a very physical chain reaction of hydrogen combustion in the flame.

Therefore additional light and heat energy, which is generated in the flame by combustion of hydrogen generated from water molecules that occurs in the ozonized oxygen, does not decrease summary energy of combustion of blend of fuel with water but increases it.

Thus using of electric and electromagnetic fields as the strongest catalysts of combustion of organic fuels and any matters clears great **prospects** of combustion technologies improving. Moreover it allows create ecologically appropriate heat machines and devices and 20-50% increase their effectiveness due to fuller transformation of chemical energy of inflammables into heat or light energy.

Ways of radical improvement of heat machines or about a new mechanism of transformation of heat energy into mechanical energy and into kinetic one

For clear realization of causes of extremely low output of modern heat machines that has generally lead the civilization to the ecological catastrophe it is necessary to understand their common principle of operation as well as a cause of heat energy non-effective using in them.

A mechanism of transformation of heat energy, which is generated by fuel combustion, is the same for all known heat machines. It consists in generation and transformation of superfluous pressure of a heated working body (i.e. gas, vapor etc.) into kinetic energy of a working element of the heat machine (i.e. a piston of an internal combustion engine, a turbine of an aviation engine, a reaction jet flowing out a rocket nozzle etc.) in special chambers of the machines.

It is also known that the higher the temperature of the heated working body, for example of a gas, the higher initial pressure in the working chamber of a heat machine. **Why output of heat machines is so low?** Any expert of thermal physics, thermodynamics, and heat machines can answer that efficiency (output) of heat energy transformation into mechanical one is defined by the second law of thermodynamics and is clearly illustrated by Carno heat cycle. According to these postulates, **output** of an ideal heat engine does not depend on a working matter and on the engine construction but is defined by temperatures of the working body in the starting point and in the final point of the cycle, i.e. by the temperatures of the heater and of the refrigerator of the **heat machine**. Real output of the heat machines is limited by heat stability of materials and by imperfection of engine constructions.

Nevertheless known thermodynamic processes and lows of heat motion of particles and molecules are significantly changed in strong electric fields and demonstrate new prospects for improving of heat machines.

A solution of the problem can be briefly formulated as: to increase output of heat machines it is necessary to use a new mechanism of redistribution of heat energy into energy of directed pressure of a compressed working body (i.e. gas, vapor, etc.) on the working element of the heat machine. At the minimal pressure it should be redistributed on sidewalls of the working chamber.

Can it be realized in practice? On the face of it the technical solution is unrealizable nevertheless it exists. It is possible to redistribute and to regulate heat motion (pressure) of heated gas inside a closed reservoir and, hence, its temperature in a certain direction. To achieve this aim **it is necessary to introduce static electric field into the combustion chamber of a heat machine and to orient heat motion of electrically charged and dipolar molecules of expanding working bodies (i.e. gas, vapor) along force lines of the electric field by electric Coulomb forces**. Something similar occurs, for example, in liquid crystal cells of electronic timer, in Kerr cells (electric optic effect) at periodical application of electric field to them that causes dipolar molecules turn along a field vector as well as change of light penetrability of these matters.

There is a difference between this known in electrooptics phenomenon and our case. The difference lies in the fact that polarized gas molecules remain movable along force lines of the electric field in contrast to liquid crystals, which do not. This fact causes redistribution of parameters of heat energy (i.e. pressure, temperature, and heat penetrability) of dipolar molecules of heated gas just along force lines of the field. The more the intensity of the field at the initial temperature of the working body is the more the difference of pressures on the sidewalls of the chamber and on the working element, for example, on an engine piston.

Heat motion of polarized particles of heated gas can be decelerated by combination of three electric fields of constant sign in accordance with all three coordinate axes; hence it is possible to significantly and quickly decrease temperature and pressure of the gas. In this case the heat energy of the heated gas makes jump transformation into electromagnetic radiation.

Editor: Historically this method, i.e. plasma retention by electric field, was proposed by Oleg Lavrentiev in 1948. He had 7-grade education and served as a sergeant in Armed Forces in Sakhalin. After he sent Stalin a letter containing a phrase, as "I know a secret of hydrogen bomb creation" he was invited to Moscow to set his ideas out to academicians. His ideas were not lost nevertheless the scheme of plasma electrostatic retention was not applied ("Expert" magazine #23, 18 of July of 2001). In 1950 Sakharov and Tamm proposed a scheme of a toroidal magnetic thermonuclear reactor which has been developed until now. Why is it so? It is difficult, expansive and practically unreal…

Thus introduction of strong electric fields into heat machines allows significantly increase effectiveness of transformation of heat energy of a working body into mechanical and kinetic energy of working elements of the machines by means of directed regulation of temperature and pressure of heated gas, for example, in the starting point and in the final point of a working stroke of a piston. In other words it allows increase output of the machines.

APPLICATION AREA OF NEW ELECTRIC COMBUSTION TECHNOLOGY

Practical application of the new combustion and thermal technologies

The new technology is universal and applicable in practically all spheres of technics. Therefore we believe that further development and application of this new technology of fuel and waste products combustion is very important for radical improving of all the heat machines and of all thermal technologies. As the civilization uses hydrocarbon fuel and matters in its life circle then just this new technology can solve critical ecological and energetic problems of the civilization.

It is impossible to view in details all proposed perspective technical solutions based on this technology [1-25] within one article. Therefore we give only one striking example.

Environmentally appropriate engine for motor transport

Since the transport, which uses thermal internal combustion engine (ICE), is most harmful for the environment then let us discuss ways of their ecological and energy improving. Several years ago the author patented "method of intensification of ICE operation" [7]. The essence of the invention consists in introduction of controllable electric field into combustion chambers during the whole operation period of an engine by special monoelectrode spark-plugs (Fig.2).

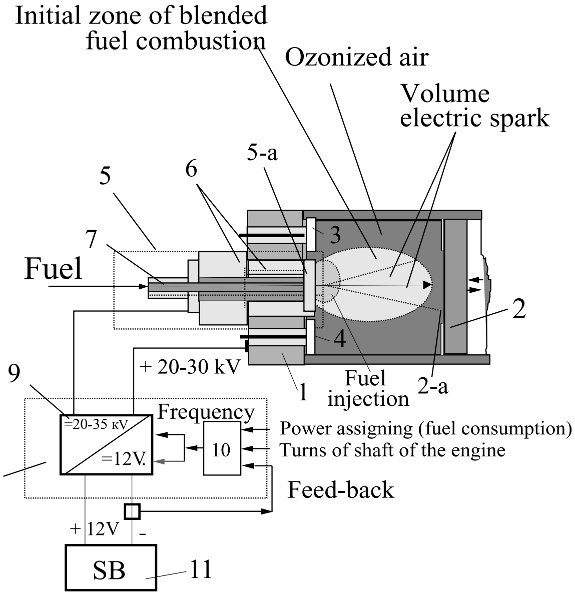

Fig.2a

Plan of an environmentally appropriate ICE
(for transport)

1. – combustion chamber;
2. – piston, 2a –heat-resistant surface of the piston (zone of electric-spark discharge)
3. – admission valve (its canal is not indicated)
4. – exhaust valve (its canal is not indicated)
5. – combined mono-electrode spark-plug; 5a – fuel nozzle with hollow central electrode and end disk electrode
6. – electric insulator of the spark-plug – fuel nozzle
7. – fuel pump (for example, an electrostatic one)
8. – high-voltage regulable transformer (electric field source)
9. – force block of tension high-voltage transformer (=12V/25kV)
10. – system of regulation of electric field source (9)
11. – board current network =12V (SB is a storage battery of an automobile).

This structure chart briefly demonstrates basic components of a new ICE, where there is directed pressure of gases on a piston. In particular, many inventions of the author are realized in practice here, i.e. semi-digital spark-plug, electrostatic fuel nozzle (5), electrostatic fuel pump (7). A new mode of volume inflammation of blended fuel has been realized in practice, i.e. "a spark coming from a disk electrode (5-a) to a piston (2-a)". Since it is possible to regulate the electric field intensity generated by a high-voltage source of tension then an advance angle of blended fuel inflammation can be regulated, gases pressure on the piston at explosion stroke of ICE operation can be regulated as well.

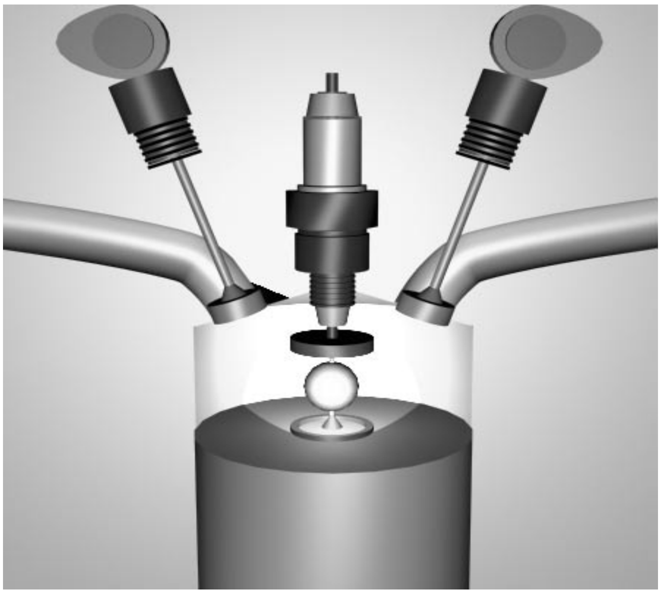

Fig.2b
Photo of a simplified construction of the new ICE

Fig.2b demonstrates simplified three-dimensional construction of the proposed energetically and ecologically perfect ICE. There are observable elements such as a combustion chamber, a piston, valves, a monoelectrode spark-plug, and an electrostatic fuel nozzle (in the centre on top), which is connected with the spark-plug. In the centre of the combustion chamber it can be seen volume inflammation of the blended fuel at spark appearance from end electrode to the piston.

As a result a summary positive effect of ecological, construction and energetic improving of ICE is achieved, i.e. effective cleaning of exhausted gases directly in the combustion chambers of the engine, significant simplification and perfection of a fuel injection system, improvement of system of distribution and electric inflammation of the blended fuel. In this engine a distributor (as well as its analogues) is removed at all since sparking and intensive inflammation of the blended fuel automatically appears between central electrode of the spark-plug and the piston which comes to the upper "dead" point. The central electrode of the spark-plug is constantly under high tension. The advance angle of ignition is regulated by change of the electric field intensity. Powerful multipoint ignition causes simultaneous intensive inflammation of the blended fuel that occurs throughout the whole chamber. The electric field as a powerful combustion catalyst intensifies the process of the blend combustion at the explosion stroke of the engine and at after-burning of waste gases directly in the combustion chambers at the following output stroke of the engine operation. Directed along the axis of the piston in the combustion chambers this electric field serves as a transformer of gases heat energy into mechanical energy of the thermal engine pistons. That is caused by the fact that the field orients heat motion of the expanding gases along the axis of the pistons in combustion chambers of the engine at explosion stroke of ICE just. It causes redistribution of heat energy and increase of the gases pressure on the very pistons that significantly improves effectiveness of transformation of heat energy of the fuel combustion into mechanical energy of the piston motion (theoretically the improvement is by two-three times), i.e. it two-three times increases output of a classical thermal engine making it come to 70-80%.

The electric field, which is introduced into the combustion chambers of an internal combustion engine, ensures significant economy of fuel (up to 30-40%) at saving of its working characteristics. It occurs due to fog electrostatic spray of fuel and to the fuel electrization as well as due to oxide ozonization. Moreover it occurs as a result of deep after-burning of hydrocarbon components of fuel, combusting blend and waste exhaust gases. This method allows effectively regulate temperature of the blend combustion in the chambers while required compression in cylinders is the same, for example, to minimize nitric oxide generation in the exhaust gases. As a result there is no necessity in external devices for cleaning of exhaust gases of internal combustion engines; ecological appropriateness improvement can be simultaneously achieved. Additional aerosol hydro-alkaline processing of these gases can allow totally clean **exhaust gases** of the transport, which operates on thermal engines.

Workability of such an environmentally appropriate engine in two-stroke and four-stroke variants is experimentally demonstrated. There are also experimentally shown decrease of all toxic components in exhaust gases, 20-30% increase of useful power of the engine, and simultaneous decrease of fuel consumption. Thus practical application of the new electric combustion technology can exert revolutionary influence upon propulsion engineering development and upon increasing of ecological compatibility and effectiveness of the transport, which operates on thermal engines.

Diagram of operations of technology of effective using of refinery wastes in heat-and-power engineering

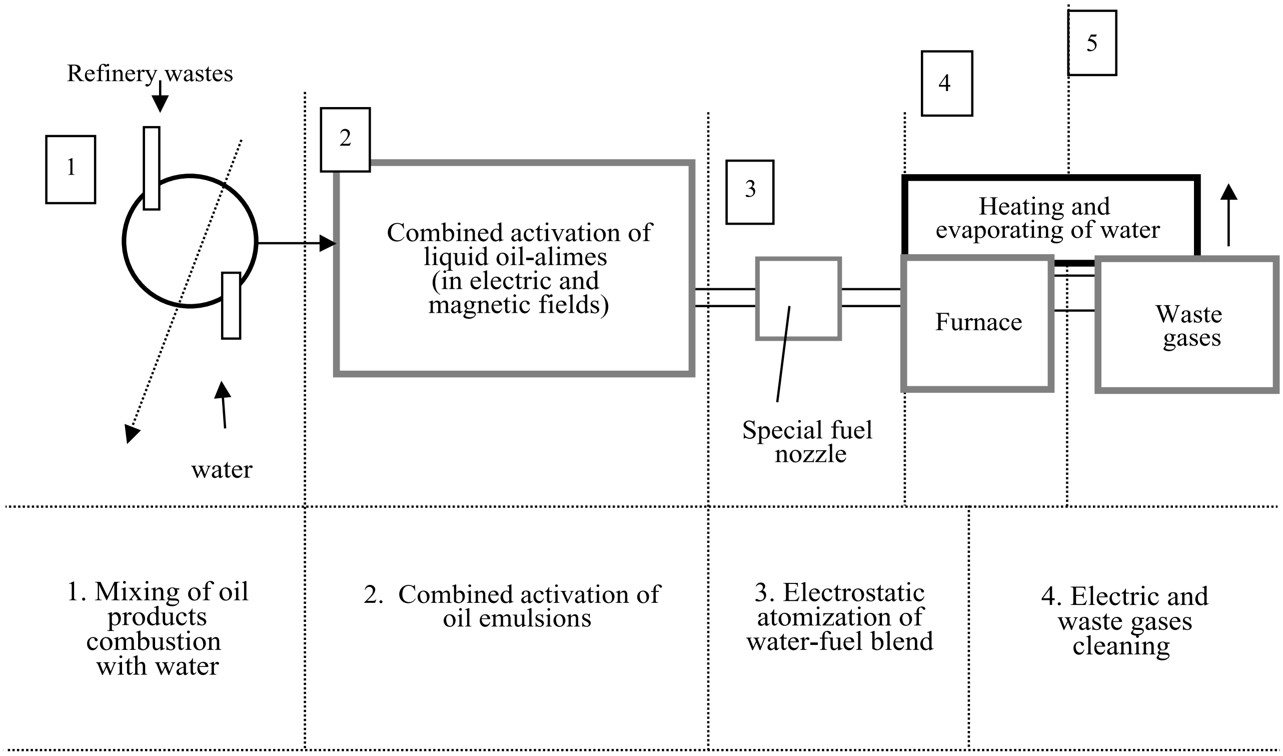
Refinery wastes
1
2
Combined activation of liquid oil-alimes (in electric and magnetic fields)
3
4
5
Heating and evaporating of water
Furnace
Waste gases
Special fuel nozzle
water
1. Mixing of oil products combustion with water
2. Combined activation of oil emulsions
3. Electrostatic atomization of water-fuel blend
4. Electric and waste gases cleaning

Fig.3

Technology of environmentally appropriate combustion of refinery wastes as fuel for boiler plants

The author has patented other technical solutions of improvement of different devices, which are based on these technologies. These solutions concerning boiler plants, gas turbine engines and jet engines and many other heat machines and devices allow increase their effectiveness and simultaneously significantly improve their ecological factors. As an example of application of this technology in heat-and-power engineering there is a diagram of operations of the technology of the environmentally appropriate combustion of refinery waste as a fuel for boiler plants (Fig.3). Unfortunately the limits of one article do not allow discuss these inventions in details nevertheless the author will realize it in practice in future works.

Conclusions:

1. The existent methods of solving of the ecological problems are ineffective as well as work of organizations, which deal with ecological and nature conservation activity. It is caused by the fact that they are oriented to search and remove consequences of ecological pollution of the nature instead of their causes.
2. The article demonstrates real causes of global ecological problems, which consist in imperfection of technologies of generation and transformation of energy.
3. Using of strong electric and electromagnetic fields of low power as combustion catalysts allow significantly improve ecological factors of combustion technologies and of devices, which realize the technologies in practice. In other words it allows realize in practice “clean combustion of fuels and wastes and possible existence of “clean” heat technics”.
4. Application of electric and electromagnetic fields in the combustion technologies allows significantly increase effectiveness of transformation of chemical and heat energies of fuel into mechanical and electric energies.
5. The electric combustion technology allows realize in practice principally new ways to control combustion process as well as to control many thermal and kinetic processes (i.e. processes of pressure, heat conductance, temperature, etc.), i.e. allows increase output of heat machines.

6. The new electric combustion technology is a universal method of solving of ecological and energetic problems of the civilization and a universal way of radical improvement of technics (i.e. of the transport, boiler plants, oil-and-gas processing plants, combustion wastes recycling plants, etc.).

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New Effect of “Cold” Evaporation and Dissociation of Liquids Based on Capillar Electroosmosis

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There is discovered new electric physical effect of intensive “cold” evaporation and dissociation of liquids and aqueous solutions into fuel gases **without any energy consumption** due to high-voltage capillar electroosmosis [1].

Prospects and problems of hydrogen engineering

Effective obtaining of hydrogen from water is a long-standing tempting dream of the civilization. That is connected with the fact that there is a huge amount of water on the planet, and hydrogen engineering promises the possibility to obtain unlimited quantity of “free” energy obtained from water. All the more, the very process of hydrogen combustion in oxygen medium, which is obtained from water as well, ensures ideal high-calorie and environmentally appropriate combustion.

Ecological and energetic problems are very actual nevertheless they have not been effectively solved. All known methods and devices of production of hydrogen and other fuel gases are ineffective since there is no a real high-performance technology of evaporation and splitting of liquid molecules. The main cause of ineffectiveness of the analogous consists in their difficulty and in energy consumption for breaking of intermolecular connections at dissociation of water liquid fractions.

Physical-chemical structure of even habitual tap water is quite complicated since there are numerous intermolecular connections, chains and other molecular structures in water. In particular, in habitual tap water there are different chains of oriented water molecules, which are peculiarly connected with admixture ions (cluster formations), its various colloidal compounds and isotopes, mineral matters as well as various dissolved gases and admixtures.

It is a paradox but in the living nature there is a long-standing effective way of electric capillar delivery and “cold” evaporation of liquid, which allows transform it into gaseous state without heat energy and electric energy supply line. This natural effect is realized in practice by plants, which deliver aqueous solution and make its “cold” evaporation by capillar electroosmosis. It is quite comprehensible that this natural energetically perfect technology is applicable in methods of liquids transformation into fuel gases. The author of this article has designed such experimental devices of cold electric capillar evaporation of liquids according to electric pumps of trees (Fig.1-3).

The simplest operating device, which experimentally realizes in practice the effect of high-voltage capillar electroosmosis of the “cold” evaporation and dissociation of water molecules, is demonstrated in Fig.1.

New Electroosmotic Capillar Method of Obtaining of Fuel Gas from Water

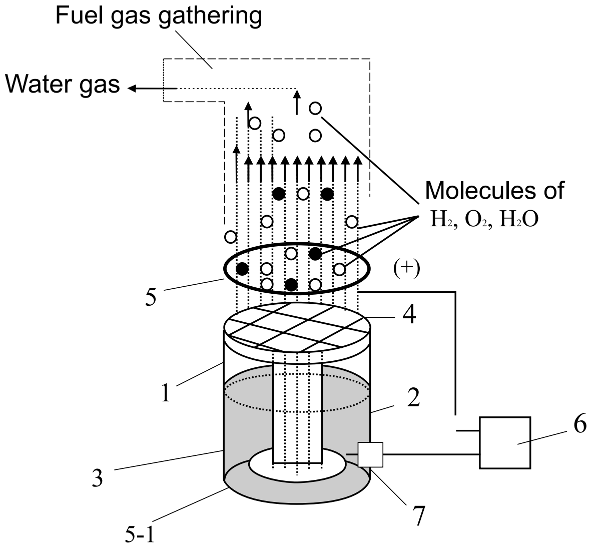

Fig.1
Simplest device of capillar electroosmosis of liquids

First experiments on the electric capillar dissociation of liquids were made with using of habitual water as well as its solutions and water-fuel emulsions of various concentrations as liquids. In all these cases fuel gases were successfully obtained in spite of the fact that these gases greatly varied due to their composition and heat capacity. The experiments on the electroosmotic evaporation and dissociation of liquids are realized in practice by the following way. First a wick (3) and a porous evaporator (4) are moisten with a water-fuel blend (emulsion) (2) then the blend (2) is poured into a reservoir (1). Then a high-voltage source of tension (6) is switched on and high-voltage difference of potentials (about 20 kV) is supplied to the liquid at some distance from the capillaries (i.e. from the wick (3) and the evaporator (4)). The source of electric field is joined to the device by electrodes (5-1) and (5). A plate perforated electrode (5) is placed above the evaporator (4) surface at a distance, which is enough to prevent an electric breakdown between the electrodes (5) and (5-1). Electrostatic forces of longitudinal electric field acts on the liquid. As a result dipolar polarized molecules of the liquid move along capillaries of the wick (3) and evaporator (4) from the reservoir to an opposite electric potential of the electrode (5) (i.e. electroosmosis occurred). Liquid molecules are detached from the evaporator (4) surface by these forces and transformed into a visual fog, i.e. the liquid is transformed into another aggregative state at minimal energy consumption of the electric field source (6). After that they provide electroosmotic elevation of this liquid. In the process of detaching and collision of evaporated liquid molecules with molecules of air and ozone as well as with electrons there is occurring partial dissociation between the evaporator (4) and the upper electrode (5) in an ionization zone. At the process a fuel gas is produced, which can come thorough a gas collector (7), for example, into combustion chambers of motor transport engine.

It has been experimentally shown that change of intensiveness of process of evaporation and dissociation of vapor molecules depends on change of distance from the electrode (5) to the evaporator (4). Moreover, this dependence is conditioned by the following factors, viz by changing of the evaporator area, kind of the liquid, quality of capillar material of the wick (3) and the evaporator (4), parameters of the electric field as well as the source of intensity (of power) (6).

The author's first experiments on this simplest device, which were organized in 1986, demonstrated that "cold" water fog (i.e. gas) appears in capillaries from liquid (i.e. water) at high-voltage electroosmosis without any observable energy consumption but just using potential energy of the electric field. This conclusion is evident since in the process of experimenting consumed electric current of the field source was the same and equal to the consumed current of the source idling. This current was not changed depending on the appearance of the liquid evaporation.

The experiments demonstrated that capillar electroosmosis evaporated quite significant quantity of water (1 liter) without any energy consumption for 10 minutes at a 10-centimeter-diameter capillar cylinder. That is to say that the consumed electric power (10 Watts) of the electric current source, i.e. of the tension high-voltage transformer (20 kV), was unchangeable and did not depend on mode of its operation. It has been experimentally stated that the whole consumed energy supplied by the current network is insignificantly small comparably with the energy of liquid evaporation. It can be explained by the fact that power was consumed only to generate the electric field and did not increase at liquid capillar evaporation that occurred due to work of an ionic pump and of a polarized pump. Hence the effect of cold electric-capillar evaporation of liquid is very economical in respect to the process energy consumption.

In spite of the fact that energetic essence of this process has not been disclosed it is evident that both "cold evaporation" and water dissociation are realized in practice by potential energy of the electric field. More precisely, the visual process of evaporation and water splitting into H_2 and O_2 at the capillar electroosmosis is realized by powerful Coulomb forces of this strong electric field.

Editor: It is not the most surprising fact. The most astonishment is aroused by school-day stereotypes that work of a field at a closed cycle is equal to zero. These stereotypes have been kept in mind of people for a long period of time. Everybody understands that a field can do work but if a body falling from some height is accelerated in a potential field and its kinetic energy increases then it requires energy consumption to relevate the body up to this height. Nevertheless, the analogy of a gravitation field with an electric one is not one-valued since the electric field may be generated only at a part of trajectory of the accelerated body motion. An electric field can be pulsating, it can be screened or it is possible to change its direction at the reverse part of the trajectory in such a way that the field constantly accelerates the body. Hence a principal conclusion can be made: summary work of a potential field may not be equal to zero. This conclusion has earlier been proposed by A.V. Frolov in his article published in the USA (Newsletter of the Institute for New Energy. May 1994. p. 1-4).

In principle this uncommon electroosmotic pump-evaporator-splitter is an example of the perpetual motion machine of the second type. Thus the high-voltage capillar electroosmosis of aqueous liquid provides really intensive and energetically free evaporation and splitting of water molecules into the fuel gas (H_2, O_2, H_2O) by means of using of potential energy of the electric field.

To produce more complete dissociation of water molecules into the fuel gas it is necessary to make the whole water molecules collide each other and be split into molecules of H_2 and O_2 in an additional transversal alternating field (Fig.2).

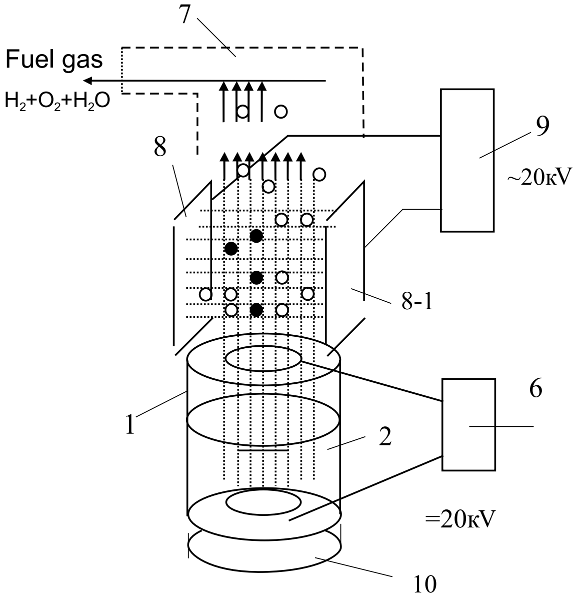

Fig.2
Device for production of fuel gas by electroosmosis. The device is equipped with an additional high - voltage splitting center of liquid molecules by electric alternating field.

At the second stage of water dissociation the energy of the second electric field is used, more precisely, powerful electrostatic forces are used to intensify oscillation resonant process of "collision-repulsion" of electrified water molecules represented as water gas. The result of this process is complete breaking of liquid molecules and generation of fuel gas molecules.

Conditions of optimal dissociation vary due to a kind of the liquid, to capillaries properties, and to the field parameters. These conditions are caused by required productivity of the process of dissociation of concrete liquid. Fig.2 demonstrates in details functional structure and composition of the device equipped with two sources of the electric field.

In the case of preliminary division of initially chemically neutral water into chemically active fractions (i.e. acid fraction and alkaline fraction) realization of the technology of production of fuel gas from water becomes possible at temperature below zero (up to –30°C). In winter it is quite important and useful for motor transport. This "fractional" electrically activated water does not freeze at degree of frost; hence the device designed for hydrogen production from such activated water can operate at environment temperature below zero and at degree of frost.

This principle of additional chemical activation of water (or liquid) is realized in practice in the device

(Fig.3). In contrast to the devices mentioned above (see Fig.1, 2) this device is supplied with an electrochemical activator of liquid (3) with evaporators (4).

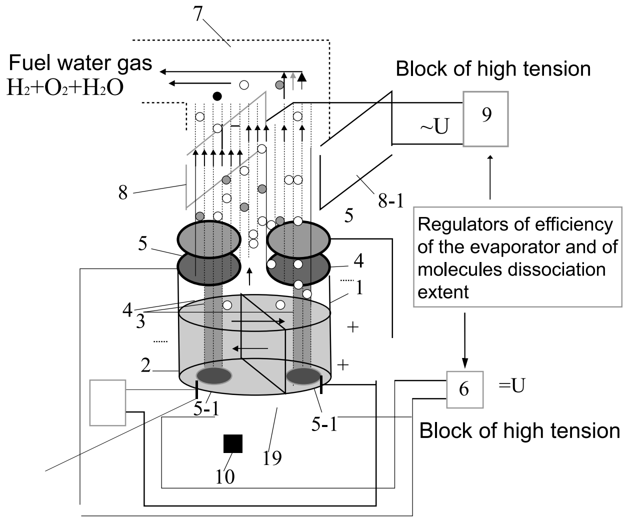

Fig.3

Hybrid device equipped with two sources of electric field and liquid electric activator

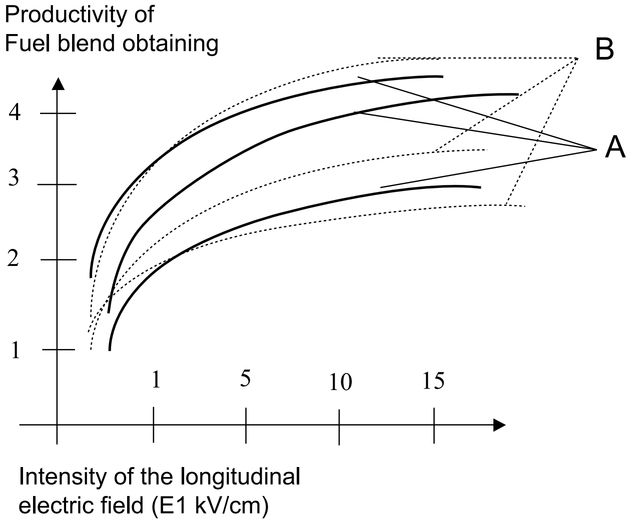

Fig.4

Productivity of the method increases as well as oscillation frequency of the second transversal electric field (A) and evaporating area (B) increase.

There is a known and low-expenditure progressive electric technology by Stanly Mayer, which has been worked out to obtain fuel gas from water (Mayer cells). Our technology is more progressive and ensures higher productivity than Stanly Mayer's technology does [3]. It can be explained by the fact that this electroosmotic effect of evaporation and liquid dissociation combined with a mechanism of the electrostatic pump and the ionic pump ensures intensive evaporation and dissociation of liquid as well as effective detachment of gas molecules from the dissociation zone. The process of gas molecules detachment is accompanied by acceleration from the upper end of the capillaries. Therefore in our case the effect of screening of the working zone of molecules electric dissociation is not produced. All these processes proceed at minimal energy consumption, which is similar to analogous energy consumption. Moreover, the process of fuel gas production does not slow down as the process in Mayer's technology does therefore gas productivity of our method is significantly higher than that of this progressive analogue at similar minimal energy consumption.

Some technical and economical aspects of the new technology realization

In the near future production run of these high-effective electroosmotic generators of fuel gas from practically any liquids (including tap water), which are based on the proposed new technology, can be established. At the first familiarization level it is especially easy and economically appropriate to realize in practice a variant of the device of transformation of water-fuel emulsion into fuel gas. A prime cost of the production-run device for generation of fuel gas from water of 1000 m^3/hour productivity comes to approximately 1 thousand of US dollars. Consumed power of such an electric generator should come to no more than 50-100 Watts. Therefore such compact and effective fuel electrolyzers can operate practically in any motor car. As a result heat engines can work on any hydrocarbon liquid or even on habitual water. Mass application of these devices for the motor transport can cause immediate energetic and ecological perfection of the motor transport as well as designing of an environmentally appropriate and economical heat engine. Approximate financial expenditures for working out and designing of the device for fuel gas obtaining from water, and for bringing the investigation of the first testing device of 100 m^3/sec productivity to an experimental-industrial model come to about 450-500 thousands of US dollars. That contains the expenditures for projecting and investigation, for designing of the very experimental device and of a testing bed, which is necessary for approbation and engineering development of the device. The author is interested in business and creative cooperation with those companies, which can provide this project with investments to bring the device to the experimental-industrial model and introduce the perspective technology into practice.

Conclusion

Electroosmotic "cold" evaporation and dissociation of water and aqueous solutions through capillaries is a perspective way of highly productive fuel gas production at minimum of energy consumption.

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Conceptual Hurdles to New Millennium Physics

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Abstract

Time, space, energy and mass form the four-fold conceptual basis for gauging physical reality. The following paper, as a follow-up to a previous exposition [1] which focused on the necessity to change the current paradigm for time, continues in this same vein, but will also consider in greater depth the interrelations of this phenomenon with the other three yardsticks cited above. Again, information garnered from a wide variety of sources will be considered. We hope to provide, through just such a unique eclectic format, the beginnings of a possible fresh understanding of the workings of nature and perhaps ultimately furnish a conceptual basis for extending the structure of current physical theory to compatibly encompass the elements of a unified framework of physics and metaphysics.

Introduction

In the former article cited above, by investigating the following varied sources and research [2-17], we came to the inescapable conclusion that the phenomena of time and space are considerably more intimately related than is currently suspected by modern science, and will require a drastic re-working to fit the conclusions of the various evidence cited. Towards this end, the adoption of a more expansive paradigm for these yardsticks was suggested, which incorporates a fluid-field nature for time and space where both are derivatives of the fundamental ground-form of energy in flux or oscillation. These new approaches involve the inclusion of a Kozyrev-type of "substantial"(active) time-flow as opposed to the conventional "relational"(passive) concept of time, where it is used as a static parameter signifying duration. The substantial aspect of time presupposes that it is an essence which can and does affect physical processes, and that those same physical systems can cause a reverse action on time [8]. Such active fluctuating (deformable) types of time or space, implies the establishment of a revolutionary notion: positing completely *non-scalable* metrics for both time and space. This is in direct contrast to all contemporary orthodox models for physical reality, either in Einsteinean relativity (Special or General theory), quantum field theory, or even superstring/supersymmetric theory, all of which continue to consider both of these yardsticks from their relational (length or durational) standpoints. Consequently, all these formalisms require scalable metrics of some sort for their proper description (for refreshing viewpoints on this matter, see [7]). For instance, in the standard equations of quantum theory, time is regarded merely as an unchangeable static parameter. When we later consider applying these novel substantial aspects of time to the edifice of quantum theory, we will see that time must then become a "hidden variable". It will be seen that by considering time in this manner, a clearer and more tractable explanation of the inevitable probabilistic aspects of quantum theory, evidenced in the signature Uncertainty Principle, complementarity and non-locality will arise, without having to invoke the counter-productive and ill-conceived Copenhagen Interpretation.

Oscillatory Models for Time and Space

Upon accepting non-scalable metrics for time and space, we observe that a similar field nature for **energy** and **mass** must in turn also be postulated. Moreover, from the Killick description of how (sub-atomic) tachion-pairs operate [6], shuttling their energy back-and-forth in a free-wheeling but purposeful manner and creating oscillatory features of time and space by their action, we should consider the possibility of another unprecedented concept: a "value-motivated" energy might be at the foundation of the structural integrity of physical matter. This is conceivable when considering Killick's description of the tachion-pair dynamic/evolutionary cycle as necessarily including the 3-step process of observation – reflection – action (**trinitivity** of motion). Along the same lines, from the Smith book **The New Science** [5], we learn that a so-called "tempic field" energy exists, which could be described as the parent structure out of which our standard conception of "clock-time" (entropy changes) results. The tempic field is essentially a scalar (but not static) function which has vectorial nature only in terms of its distribution or *gradient* in space. Because of the nature of the tempic field, its derivatives – the electric and magnetic fields can operate on each other in a specific geometric/topological manner, to produce a local change in the *time-frame* of matter, to use a term coined by the entity Kryon [4]. This theoretical description of the alteration of inertial/gravitational mass and time-frame has possibly seen recent actual demonstration in the dramatic experiments of John Hutchison [10] and Rudolf Zinsser's "kinetobaric" effect [11], as well as unpublished research of both Wilbert Smith and Ken Killick with electric caduceus-wound coils [5,6].

New Models for Relativistic-Fluidic Vacuum-Structure and Possibility of its Manipulation

All of this evidence allows us to conclude that measurable changes in relativistic parameters of time, space, mass and energy might not only be a feature accompanying rapid uniform movement of physical objects (Special Relativity), or representative of large gravitating astrophysical objects (General Relativity). Indeed, by relying on current limited paradigms, contemporary physics may have missed ascertaining the possibility of being able to alter these same relativistic parameters by the artificial technological manipulation of the tempic (vacuum) fields of sub-atomic particles in stationary matter, by use of specific electromagnetic fields. Tom Bearden, for one, has articulated on these various "futuristic"-type technologies in his many writings over the years [15]. We have recently seen that some of the novel theoretical conceptions of the more visionary physicists such as David Hestenes on the zitterbewegung (vacuum "jitter") phenomenon exhibited by the electron [12-14], has finally caught up with some of these advanced ideas by presenting new mathematical demonstrations (using geometric Clifford-algebraic) manipulations of the Dirac equation. In summary, the Hestenes' study concludes that the Dirac wave function and its properties, including the Dirac equation and relations to physical observables such as energy-momentum, spin and position probability current, all possess heretofore obscured important geometric relations. These results imply that probabilistic features of the quantum theory of the electron/positron arise principally from the electromagnetic interaction of the accompanying zitterbewegung-spin field of these particles with the ambient dynamic vacuum. This is, of course, in direct contrast to the conventional received view that ascribes wave-particle duality as a property of matter that is completely independent of the nature of its interactions. This revolutionary geometric interpretation of electron dynamics incorporates in its model an electron spin which arises from a helical or spiral world-line in space-time. The essential unprecedented feature of the Hestenes' zitterbewegung idea is the association of the spin with the local circulatory-helical motion characterized by the *phase* of the electron wave function. Thus, we reach the conclusion that the complex phase factor of the electron wave function can be directly associated with an objective helical motion of the electron which is, in turn, a derivative of the zitterbewegung. One intriguing feature of this structure is a frequency of oscillation that is inversely proportional to the scalar radius of curvature of the particles' helical world-line. Moreover, the Clifford-algebraic analysis reveals that this oscillation frequency is identical to electron/positron *mass*, revealing a possible key variable particle mass-energy (*frequency measure*), which is in inverse relationship to particle size. It is clear that this new model has important classical implications not yet considered by established physics which nevertheless directly correspond to some of the key features of sub-atomic behavior enumerated above and previously. Here, we refer to the tachion-pair dynamics [1,6], and also to the microscopic dynamics of elementary particles revealed by the selected esoteric sources previously considered [1-5].

Another researcher who echoes many of these conclusions is C. Sano [21]. Sano built on the work of A.P. Smirnov [22] who postulated that Newton's Third Law of action/reaction actually modeled "screw" structures, implying that elementary particles (specifically electrons/positrons) possess chiral-spiral field configurations. Accordingly, Sano posited that all actions/reactions are transmitted between actors and reactors by parallel or perpendicular clutching of the rotating chains of electromagnetic spirals of the hidden electrons and positron-pairs of the vacuum. Also, similar to the Hestenes' development cited above, Sano postulated that the radius of the outer electromagnetic spiral surrounding the electron/positron pair can change, oscillating in size around either particle, and thus producing the particles' electric or magnetic character. Supporting his theory, Sano cites the key research of I.M. Shakhporanov [23] whose experiments claimed that magnetic monopoles were generated, by employing an electrical circuit based upon Moebius band topology. Some of the unusual phenomena demonstrated by this apparatus, tending to support the magnetic monopole hypothesis, was transformation of diamagnetic substances into paramagnetic, the ferromagnetization of normally non-magnetizable materials (graphite, etc.), acceleration of chemical reactions, acceleration or deceleration of the decay of radioactive materials, etc. Sano also claimed that extraction of energy from the vacuum was possible using rotational action/reaction using magnetic monopoles.

Referencing this research to the current exposition, we recall that the key element of Killick's hypothetical tachion-pair operation was the similar non-linear/non-orientable Moebius-type dynamic cycle which results in the corresponding deformation (compression or rarefaction) of time/space/energy parameters [1,6]. In this regard, the remarkable similarity of this model to the research of Sano and Shakhporanov may be much more than mere coincidence. In fact, later we shall examine new research outlining an apparatus (yet untested), which claims to overcome the Coulomb barrier in low energy nuclear reactions (LENR), and achieves nuclear fusion by producing local time-dilation of soft photons in proximity of the deuteron reactants.

Additional Key Russian Research

To motivate the reader's sensibilities towards consideration of some of these unorthodox ideas, we defer to the previous article [1] in which many of these notions and mentioned research are explored in greater depth, as well as consider the following corroborative research.

One intriguing example of such experiments is the work of V. Chernobrov, from which he has claimed to demonstrate both acceleration and deceleration of local time-rate, within a small spherical enclosed volume conducted since 1988 [18]. The experimental system to produce these effects, was a set of electromagnets, connected in series and parallel and installed inside the globe-shaped surface in several layers. In various arrangements including up to 3 to 5 of such layers, these electromagnetic working surfaces (EWS) of various diameters were installed inside each other (similar to the Russian toy doll "matrioshka") with the maximum EWS diameter was about 1 meter, and the minimum (internal) diameter of 115 mm. With this configuration, Chernobrov claimed to measure small but detectable deceleration (-30 sec/hr.) and acceleration (+30 sec/hr.) of time within the sphere to time monitored outside its field of influence. One interesting difference was noted between the slowing down vs. the speeding up of time. The deceleration occurred considerably more smoothly and steadily whereas with acceleration, sharp discontinuous jumps were observed. These instabilities accompanying time-acceleration was observed in connection with cycles of the moon, diurnal fluctuations, and also operator presence. Chernobrov also noticed another phenomenon that also was reported in connection with the alleged legendary Philadelphia experiment, where matter in different time-frames apparently exhibited strange relative optical phenomena [see 1,4]. Specifically, the human eye in the time-frame exterior to the experiment perceives matter within the time-frame created by the apparatus as either transparent or surrounded by a vague white mist. We note with interest that transparent "shimmering" effects of substances in the target area were also occasionally a feature of Hutchison effect [10].

Academician A. Chernetsky produced what he termed a self-generating discharge (SGD) in a plasma that exhibited longitudinal energy density waves from a structured vacuum. Some unusual effects noted were over-unity energy generation (C.O.P. > 1), as well as change of the electrical conductivity of matter (reduction of the resistance of resistor) placed between the capacitor plates of the SGD. A local structured vacuum was definitely produced since the resistance value remained unchanged even when the generator was turned off. Here reference must be made to the Kozyrev experiments [1,8], in which a type of similar *memory* process was activated ostensibly within the vacuum. Specifically, it turned out that in experiments with a vibrating torsion balance (or pendulum), at points of support the emerging additional forces did not disappear when the irreversible process (vibration) was stopped, but remained in the system for an appreciable time. The SGD plasma device may have also produced a detectable change in local time-flow rate as evidenced by decrease in frequency of a quartz oscillator placed in the discharge of the generator. The Chernetsky generator thus possibly caused anomalies in time-rate at a local space position. There were also basically anecdotal phenomena where psychic ability of personnel in proximity to the SGD was apparently enhanced [19]. The latter effects are not inconceivable once the intimate connection of consciousness to space and time is ascertained, from consideration of not only hypothetical "value-motivated" tachion-pair dynamics, but from the more prosaic studies as we shall see next.

Pathological Studies in Time-Perception

We can motivate further understanding for the claimed intimate connection of time to space by considering the results of a recent study of patients possessing a disjointed sense of time by Metod Saniga of the Slovak Academy of Sciences [20]. Saniga discovered the brain is hard-wired to perceive space and time as interconnected. Specifically, time pathology is apparently always accompanied by space pathology, in a sense that space either loses dimensions or acquires other dimensions. To quote Saniga "When time seems to stop, people often feel as if space becomes 2-dimensional. On the other hand, when the subject feels they perceive the past, present and future all at once, they simultaneously have the impression that space has infinite dimensions". This phenomenon is apparently not culturally endemic since Saniga illustrates that both pathologies cross cultural lines, evidencing similar studies cited from Italian, German and English psychological journals. In his report, Saniga combined mathematical models ("pencil-conics") and pathology reports of schizophrenic, drug-induced and other abnormal perceptions of time. His current work also encompasses studies of near-death experiences. He found that most of those who claim to have allegedly crossed over to the "other side" and back, tell similar tales. For that brief moment of near-death, the universal subjective experience of all individuals in this state of consciousness is that time loses its meaning. Although such evidence can at best be considered as anecdotal, since subjective conscious experience transcends the possibility of scientific proof, nevertheless perhaps these results from pathological and near-death studies also give us a hint towards new conceptions of time and space that necessitate both phenomena to be inextricably linked.

Investigation of the Possible Internal Properties of Time

One inescapable conclusion that results from all the above varied studies, either scientifically or psychologically based, and which cries out for future experimental verification, is the possible existence of an internal structure for time. Such a structure also implies the necessity for constructing a new edifice for physical reality that incorporates non-scalable metrics for the four fundamental yardsticks. We shall first investigate supporting evidence for internal time structure and subsequently the various implications of space, time, energy or mass that is non-scalable.

First, accepting an internal time structure, we are led to conclude that in quantum theory, time must then attain "hidden variable" status. One recent study that brilliantly articulates this notion, is the thought-provoking paper by X. Chen [24]. By positing 3 time variables as quantum hidden variables, Chen derives the Dirac equation classically. Moreover, he demonstrates that the non-intuitive property of "spin" of an electron or positron , arises naturally as a topological property of 3-dimensional time + 3-dimensional space. By extrapolating from this model, Chen then concludes that the inherent probabilistic aspects of quantum theory itself, as evidenced in wave-particle duality, Uncertainty Principle, quantum non-locality ("entangled" particles), etc., can be interpreted as the behavior of a single particle in 3 + 3 time-space. Chen postulates that the three dimensions of time geometrically form a "time sphere", with a generic point on the sphere possessing the following 3 coordinates: time radius, and two "time angles". The mathematical formalism arising from the process of stereographic projection from the north pole of this sphere, having radius of one-half, to any point on the spherical surface, incorporates both the positive-energy (north hemisphere) and negative-energy (south hemisphere) solutions to the Dirac equation (see Fig. 1 for clarification; note Z is a four-component spinor wave function). Also, by considering the evolution of a single particle, from the standpoint of this model of internal time-space, we can derive a picture of different paths on the time sphere of different weights, and on each path causality is satisfied. Through this process, Chen derives a purely classical explanation of the originally quantum-mechanically canonized Feynman Path Integral concept. This result emerges since each path from the time-sphere center to the surface corresponds to each Feynman path, and the surface of the sphere corresponds to the "surface" of the wave function. Chen also classically explains the processes inherent to Bose-Einstein-condensation (BEC) and superconductivity with this model. In such phenomena, two particles with the same spatial coordinates, cannot possess the same time angle, and thus will not have any interaction with each other and occupy the same quantum state as evidenced in BEC and superconductivity. Finally, Chen's solutions of the Dirac equation for a free particle correspond to Hopf bundles in monopole theory, and each Hopf fiber corresponds to each plane wave with different momentum states. This picture corresponds to wave packet diffusion in quantum theory. When a particle is in a fixed momentum state, each space point can contain only one Hopf bundle (one time angle), and various different time angles will be distributed in the whole space but with the same Hopf bundle. Consequently, that particle can be found everywhere. This picture appears to describe the Uncertainty Principle classically using 3 + 3 dimensional time-space. Along similar lines R. Kiehn [25] has also recently underscored the important but overlooked classical connection between spinors, minimal surfaces and the Hopf map.

Recently, Chen's work has been further developed by H. Kitada [26] who, by introducing both 3-dimensional time and energy operators, sheds new classical light on the uncertainty relation that holds between these two parameters as well. Moreover, Chen is not the only reseracher to derive the Dirac equation classically. R.A. Close has published a paper which presents a classical mathematical description of circularly-polarized waves in 3-dimensions [27]. It turns out that these chiral space waves are satisfied by a four-component wave function which satisfies a Dirac equation. Furthermore, much like the Hestenes' zitterbewegung interpretation of quantum theory, the term normally associated with electron mass in the Close equation, introduces a rotation or oscillation frequency of the propagation direction.

Classical models for nuclear processes have also recently been proposed which incidentally also imply internal time structure. Notable among these, C. Cagle claims to have developed a fusion energy device employing LENR based upon such a classical theory [28]. Normally, Deuterium nuclei are diffuse in momentum space (having high relative velocities). The process Cagle outlines produces a compactification of their momentum space (low relative velocities), so that the deuterons develop a common de Broglie wavelength that is greater than or equal to the inter-particle distance. This is claimed to be accomplished by passing soft x-ray photons near the region of two deuterons in a lattice structure of Lithium Deuteride. **The soft x-ray, when absorbed , produces a region of total *time-dilation*, causing two effects: first, ionization of atoms by strongly repelling any associated electrons in the area, and secondly and most importantly, the physical extent of the time-dilation causes two adjacent normally repelling Deuterium nuclei to overlap in a common momentum space; that is, their relative velocities achieve very low values.** Consequently, due to the time dilation, for a very short time their common de Broglie wavelength exceeds their inter-particle distance. Thus, they become strongly attractive and undergo nuclear fusion.

Cagle also claims to clarify misconceptions about the fusion process in a thermonuclear bomb. He maintains that it is not due to extreme kinetic energies (high temperatures) of particles as supposed in current paradigms, but due to nuclear processes caused by absorption of a time-dilated soft photon flux, produced by Compton scattering of hard x-rays from a fission igniter, passing through a foil of depleted Uranium. Again, just like the controlled nuclear fusion process, this causes overlapping of deuterons in momentum space (low kinetic energies) for a few pico seconds, and subsequent fusion with normal exothermal processes ensuing.

Furthermore, as a fundamental component of his LENR fusion device, which ostensibly produces time dilation and controls energy production from the fusion process, Cagle incorporates a topological field structure termed an electromagnetotoroid. The toroidal field current oscillates between toroidal and poloidal modes in a dynamic cycle which is amazingly virtually identical to Killick's description of the oscillation dynamics of a single unit toroidal tachion [1,6](also see Cagle's website for animated simulation).

Regarding dynamics of astrophysical structures, Cagle further claims that the stellar jet core star of HH30 is also a gigantic electromagnetotoroid. During the poloidal current mode, vast quantities of matter are produced and ejected along the poloidal axis when the mode changes from poloidal to toroidal. This leads one to consider the possibility that the source of superluminal gamma ray bursters, which have heretofore mystified astrophysicists and defied explanation in terms of current paradigms, might be the result of large- scale abrupt changes in the time-frame of celestial vacuum regions, subsequently causing a boost in light velocity.

Implications of Non-scalable Metrics

When postulating fluid-field natures for the four yardsticks of physical reality: time, space, energy and mass, we must assume the existence of a *non-scalable* metric for our vacuum structure. Such a non-scalable vacuum, absent of a defined reference frame, must of necessity possess a *dual* nature. That is, the primary feature of a dual vacuum structure implies that infinitely small quantities must be treated on an equal footing with those that are infinitely large. In other words, information encoded into infinitesimal elements, is also instantly present in the unbounded infinite extents as well. This is tantamount to the existence of a holographic information encoding and transmitting vacuum field, which would structure events in space and time as a non-Markovian chain. In a non-Markovian chain of events, the prediction about the next link in the chain, requires a knowledge of **all** links, not just the one preceding it.

Metod Saniga's research into mystical perceptions of superconscious reality appears to support such a primordial non-Markovian holographic mapping of time and space. To quote from a transcript of such a vision: "I wake up in a whole different world…a different space…This space was distinct from the one we all know. It had different dimensions, everything contained everything else. One was situated in a state of being in which the 'will be' (future) and the 'vanishing' (past) were already included, and this being was my consciousness. It contained it all. The 'being contained' was present very vividly in a geometric way in the form of circles of different sizes which again were all part of a unity since all of the circles formed exactly one circle. The biggest circle was a part of the smallest and vice versa."[20].

Such a structure of time and space can best be topologically encoded in a non-orientable structure such as the Moebius band or Klein bottle. Similar to the data presented in the above mystical revelations and in the previously treated Killick tachion-pair dynamics [1,5], in such configurations "inside" and "outside" lose their meanings and meld into one another; ordinary dichotomic relations distinguishing thesis from antithesis are sublated and supplanted by a higher unity defining the evolutionary process of the system. In the mathematical edifice abstracted from such a vacuum structure, duality rather than exclusivity of field structures holds sway. This in turn, presupposes a static-dynamic triality of fundamental field structures, characterized by the three magnitudes: zero, infinity and the mediating factor of unity, the latter being an indication that each of the other two field extremes are in perfect balance. Accordingly, we will assume that the stability (coherency) of non-scalable fields results whenever more than half their reality is in common.

Further development pertaining to a specific algebraic-geometric structure that would inherently incorporate this field model, will be carried out in a future paper. Nevertheless, the interested reader can skirmish on this frontier by consulting the relevant recent references to a Clifford-algebraic structure which encodes the projective duality of "space" and "counterspace" into a model for mechanics on the quantum level [29]. This promising model accounts classically for the phenomenon of quantum non-locality. It also heralds a new version of quantum field theory which, by treating electron-positron pairs as topologically non-orientable, is free of the detrimental divergences in self energy and charge, thus obviating the necessity for the ad hoc prescription of renormalization so endemic to current theory [30].

However, due to the limited scope of the current treatment, here we shall only make general comments on the significance of the above-mentioned concept of field triality. Although this model may appear foreign to current physical theory, we underscore that exactly such a system was delineated by W. Smith in the book, The New Science [5]. Observing, as we have [1], that this book in some parts of its exposition can cause confusion, we carefully choose the following selected passages that are most instructive in clarifying the notion of non-scalable metrics and in pointing the way to new paradigms (my comments in parentheses). General comment on non-scalable metrics: "Unity is half way between zero and infinity and always remains the fulcrum about which all other values regardless of scale pivot". On the electric field: "Between the two limits of zero and infinity and through unity there is divergence which we recognize as the electric field, but with the exception that there is no point charge at zero. Our awareness establishes the charge at radius unity with exactly half of it being 'inside' and the other half being 'outside'". On tempic field dynamics: "The tempic field being purely scalar in nature merely contributes to the manner in which changes can occur in the system. If, however, through some characteristic of configuration, the tempic field within a composite particle displays some irregularity, this will manifest as a 'vibration', and if the magnitude of the vibration is sufficient as to cause the interpenetrating fields to exceed the half-and-half point , the whole system will come apart: radioactivity. When a system does come apart, those field which were coherent and interpenetrating in the correct proportion will remain so and take off down the tempic field gradient and become radiated energy". On velocity of light/Planck's constant: "Within the universe we perceive, we are reasonably satisfied that the maximum value of all the coherent fields involved in our particles and radiated energy have the same value. Planck's constant is the numerical expression of this value, and the velocity of light is the expression of the numerical value of the (local) tempic field intensity". On nuclear fusion: "If a region is selected in which there are two fields of the same kind, same magnitude, same direction, such that very nearly half the reality of each is within the region, then the two fields are just on the verge of becoming coherent. If the fields are not coherent, the total energy in the region is the sum of the energies of the two fields; i.e., twice the square of the field intensity of each integrated over the region, or twice the energy of the two fields incoherent. This represents the 'packing energy' of bits and pieces of atomic nuclei, and also points the way to the precipitation of energy out of the cosmic background (vacuum engineering)". Notice how this description, written 45 years ago, of how a tempic field gradient (time-stress) operates between atomic nuclei to produce coherency (half-in half-out condition), perfectly parallels the recent Cagle view, which claims the fusion process takes place only as a function of time-dilation [28]. Finally, on gravitation: "With the exception of skew electric fields (electric field possessing tempic field gradient) all the other fields of an aggregate mass may be considered as static because they have no component of the tempic field at right angles to them. The skew fields (spiral-helical?) on the other hand, are dynamic because they do have a quadrature tempic field component. Furthermore, skew fields are largely incoherent (gravitation cannot normally be shielded) simply because the usual almost random orientation precludes their meeting the half-in requirement of form to become coherent. Since the gravitational field is due to the skew electric field, or stated differently, to the induction from the 'motional magnetic field' (longitudinally moved magnetic field), this is the logical region to explore for the mechanism by which fields may be produced to combine with the gravitational field (of Earth) to produce a resultant more to our liking (alteration of local gravitational potential)".

This last quote describes the gravitational field of a mass as a residual field phenomenon, similarly to the Sakharov and Puthoff conclusions which attribute gravitational and inertial mass to the interaction of accelerated or gravitating matter with the zero-point-vacuum-fluctuations (ZPF) causing a vacuum reaction force [31]. Moreover, similar to the Hestenes' claims, in their recent papers [32], Haisch/Rueda/Dobyns propose that, via this new interpretation of inertial mass as an acceleration-dependent electromagnetic (Lorentz) force, that a former postulate of quantum mechanics appears to be derivable classically via the interpretation of rest mass as the energy of the ZPF driven zitterbewegung; that is, the de Broglie wavelength of a moving particle, may be derived from Doppler shifts of the Compton frequency oscillations associated with zitterbewegung that occurs when a particle is placed in motion.

For further studies of physical theories with non-scalable metrics, the reader is directed to the excellent work of A.A. Nassikas [16]. Like few theories hitherto postulated, Nassikas posits a fundamental probability density function for vacuum energy, out of which oscillatory-deformable sub-atomic level physical aspects of time and space then emerge. This is the reverse to most contemporary paradigms, which view energy as a derivative of matter, time and space, even at the quantum level. Finally, A. Frolov has used Nassikas' theory to explain over-unity energy generation that has been demonstrated in some LENR electrolytic cells of the Pons-Fleischmann variety [17].

Editor: Actually Prof. Nassikas wrote in this patent that the idea which is described in the patent was proposed by Alexander Frolov. In 1996 these questions were discussed by us in Saint-Petersburg. Specifically, a Palladium cathode over-saturated with protons produces an imbalance of the vacuum engine in this area, with an accompanying change in the local time-rate and subsequent breakdown in the Coulomb barrier of the nuclei as per schemes articulated by C. Cagle [28] and T. Bearden [15].

Conclusions

In this journey through the latest research and speculations involving new interpretations of the four physical yardsticks: time, space, energy and mass, we hope the reader and technical specialists/theorists have been inspired to continue research along the lines suggested in the above dissertation. In this regard, certain open-ended questions present themselves that focus squarely on the viability of technological future developments in the new energy field. First, could the missing element in our eventual understanding of all devices featuring documented over-unity energy generation, change in mass (gravitational potential), LENR-based transmutation of elements and the amelioration of radioactivity, etc., be due the alteration of local time-flow in sub-atomic vacuum fields within the apparatus? Secondly, could the frustrating feature of the capriciousness of over-unity power and the like to yield to testable replication in many cases, be due to currently unperceived uncontrollable aspects of time and the vacuum which must be addressed in order to solve these problems? Thirdly, could incorporation of non-orientable topological structures such as the Moebius band, Klein bottle, etc. in new models of electrodynamic field structure, be instrumental in finding the answers to both of the previous questions? With sufficient probing for possible answers to such questions, the present author has the firm belief that new paradigms are certain to soon result that will crystallize these thoughts into viable scientific hypotheses subject to experimental testable verification. As an offshoot and definite bonus of this process, possibly a new more expansive understanding of the role of the vacuum in both nature and consciousness will be in the offing.

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Resonant Phenomena Occurring in Alternating Current Circuit

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There is a classical (according to manuals) notion that resonant phenomena can not influence on efficiency of a transformer or a motor as in a capacitive circuit or in an inductive circuit power produced at minimal power at the input of an oscillation circuit is reactive (let us remind that active power is measured at active resistance).

At the beginning of the last century this aspect was viewed differently. Advantages of a resonant case in alternating current circuits were used in practice. Let us appeal to a rare book by J. Claude-V. Ostwald named "Electricity and its applications by popular language" (I.N. Kushnerev Press, Moscow, 1914, p. 463).

"The phenomenon proceeds in a corresponding electric circuit as well as it occurs in hydraulic model: if self-induction and capacity parallel connected with each other are under influence of an alternating electric propulsion force then the total current coming through the system is equal to the difference of currents which pass two certain paths.

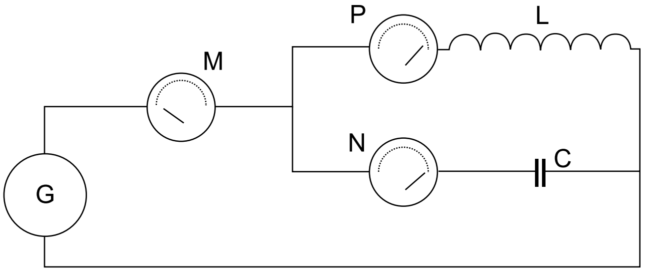

Fig.1

… join ammeters to the general circuit (M) and to either path (P and N). If P demonstrates 100 Amperes and N demonstrates 80 Amperes then the total current will be equal to 20 Amperes instead of 180 Amperes. Thus alternating current has its own "summary" so we should consider its condition. …capacity introduction compensates self-induction action in some way… let us begin to change the self-induction by moving a core into. What will happen if the current coming through the coil achieves 80 Amperes, i.e. is equal to the current observed in the path with a capacitor?

As you guess, since the total current is equal to difference between currents passing the paths then now it will be equal zero. It is an incredible case:the device produces zero current dividing into two paths and in each of these paths current is equal to 80 Amperes. It is a good example for the first acquaintance with alternating current, isn't it?"

Andrey A. Melnichenko (Moscow) is one of modern investigators who research this phenomenon. Any motor of alternating current can be considered as inductance. A circuit consists of motor coils and some capacitor connected in series with the motor winding. Thus if we take the circuit, consisting of motor coils and a capacitor which is connected in series to motor winding and adjust it in resonance, then mechanical power occurring on the motor shaft is produced at zero (minimal) power consumption of an alternating current source.

Melnichenko applied a simple method of voltage increase by meanse of resonance: he succeeded in obtaining of normal voltage for operation of standard motors of 50 Hz 220 V from a source of 50 Hz 110 V and 70 V. The circuit consumption for overcoming of its active resistance (of coils) can be considered as insignificant. Low frequency currents require a large capacitor. Nevertheless even at higher frequency, for example at 400 Hz, the system can be compact and effective. This method is worth to be applied in a scheme consisting of an alternating current motor in resonance mode and an electric generator which has a stable load. Change of load causes change of rotation speed therefore the system requires to be readjusted for resonance.

Experiments with powerful alternating current motors (about 100 Amperes as J.C. Ostwald wrote) working in resonance mode should demonstrate all advantages of the resonance mode application.

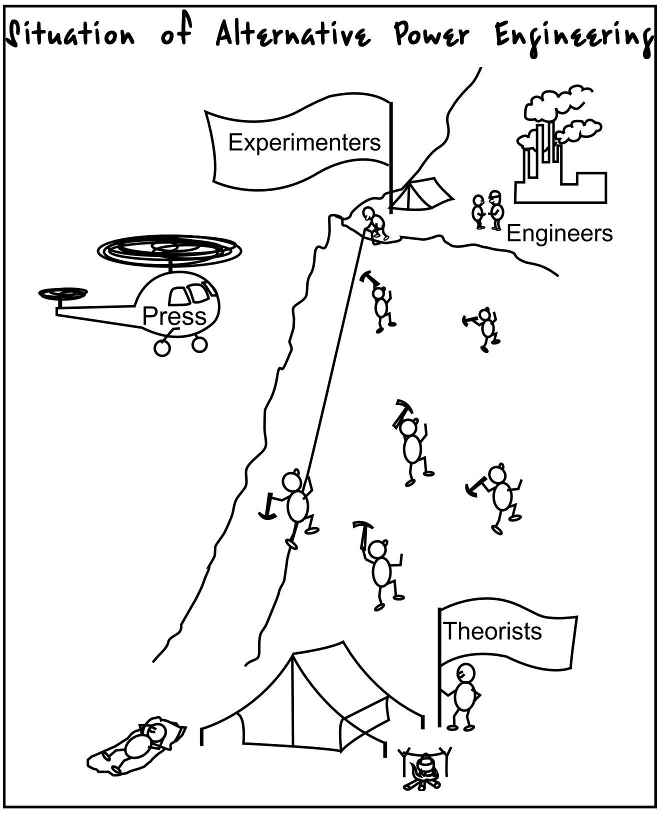
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Space Power Generator and Paramahamsa Tewari Update

Submitted by Toby Grotz, USA

http://www.tewari.org

A new generation of Space Power Generators is being built by Paramahamsa Tewari. The new design is expected to achieve substantial gains over previous models which has been measured over unity by experts in the utility industry as well as by independent consultants. Details are presented on the web site http://www.tewari.org.

From the Electron to a Perpetual System of Motion

Paramahamsa Tewari, B.Sc. Engg

As is well known, an electron, despite high-speed interactions with electric and magnetic fields and other particles of matter, remains unaffected structurally—maintaining its mass, charge, inertia, and locality after the interactions. This single fact itself is sufficient to postulate on the existence of some unique universal entity constituting the electron, such that the structure explains the known properties and behavior of the electron – as to how it sustains the collisions with the other particles and, yet, remains permanently indestructible without any reduction in the quantities of its basic properties. A theory that explains this enigmatic fact is framed and described in detail elsewhere. It reveals that the electron is a perpetually rotating system, a space-vortex (vortex of absolute vacuum) that through the process of motion in electric current, and interaction with external magnetic field can also lead to the development of a system partially violating Lenz's law and, thereby, capable of achieving perpetual motion in a machine. Such a conclusion has a new theoretical basis, as well as experimental confirmation – briefly outlined in this paper.

The basic understanding of the interaction of electric current with magnetic fields requires deeper knowledge of the fundamental nature of the electric current as well the magnetic field; this, in turn, leads to an inquiry on the nature of "electric charge" and its distribution in the electron structure. The origin of electron mass and charge, electrostatic and electrodynamic forces are described below with the vortex structure of electron, which further facilitates explanation of atomic structure and, thereafter, an over-unity efficiency generator. Due to brevity, predominantly qualitative-descriptions of the physical processes involved have been presented.

The full theory and diagrams are presented in From the Electron to a Perpetual System of Motion at http://www.tewari.org.

Universal Principles of Space and Matter (A Call for Conceptual Reorientation)

A new book, *Universal Principles of Space and Matter* has just been published by Paramahamsa Tewari. Arangements are being made with the publisher to provide these books outside of India. The price is expected to be about $30 depending on shipping costs from India.

A new theory of matter, that confronts with the existing concepts of space in the contemporary physics.

The basic phenomena dealt with are:

* Structural interrelationship between space and matter
* Origin of mass, inertia, and electric charge
* Creation of the electron from space

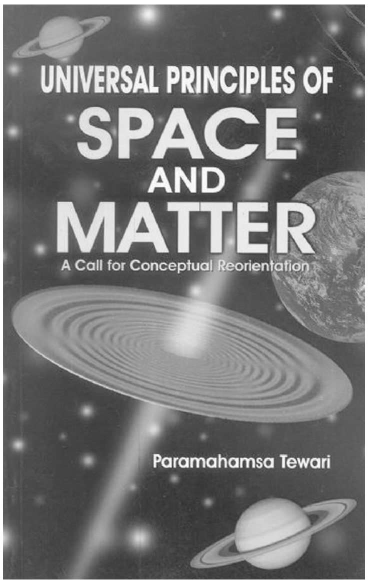

* Discovery of new fundamental equations on mass and charge
* Derivation of the presently known universal constants (gravitational, Coulomb's constant, dielectric, magnetic permeability, electron charge, electron mass, Planck's constant etc.) with the postulate of a single universal costant – the speed of light in the absolute vacuum
* Discovery of an inward force in nuclear structure against the Coulomb repulsive forces, hitherto unknown
* Relationship between light and gravity
* Theoretical derivation of the surface gravity of the Earth, Sun and the planets
* Discovery of electrical repulsive forces between the Sun and the planets, unknown in celestial mechanics
* Derivation of the planetary orbits
* Prediction of the continuous creation of universal matter at glactic centers and existence of electrical forces of interaction btween the stars and galaxies, so far least suspected
* Identifying the fundamental particle of matter
* Revelation of conceptual errors in the modern understanding of the basic nature of light
* Vindication of Einstein's conclusion of the speed of light as the limiting speed
* Vindication of Descartes' principle of property-less ether.

New Reviews of P. Tewari's work

New reviews of P. Tewari's work have been received from Dr. John A. Wheeler and Prof. Umberto Bartocci. A copy of Universal Principles of Space and Matter was forwarded this summer to Dr. John A. Wheeler at his summer residence in Maine.

Dr. Wheeler saw the development of modern physics while working with Neils Bhor at age 27 and was a colleague of Albert Einstein's at Princeton. Credited with being the "father of the Black Hole Theory", Dr. Wheeler is well schooled in quantum mechanics and relativity.

After receiving his copy of Universal Principle of Space and Matter Dr. Wheeler called the book "a unique gift". Further reviews of P. Tewari's work by Dr. Wheeler can be found at: http://www.tewari.org/Critical_Reviews/critical_reviews.html.

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This is a very singular book, in front of the current paradigm of contemporary Physics, a "cartesian-inspired" work which calls for reorientation in the foundations, by wisely warning that:

The conclusion of the modern physics that absolute space, time, simultaneity, and space filling media are discredited ideas is certainly premature (p. 178).

The books deals with arguments such as: Discovery of Charge and Mass Equations; Fundamental States of Cosmic Energy, Fields and Forces; Gravitation; Universal Constants; Motion of Electron; Atomic Structure; Light; Creation of Cosmic Matter (about Tewari's physical conceptions see also the second section of this Episteme's special issue http://www.dipmat.unipg.it/~bartocci).

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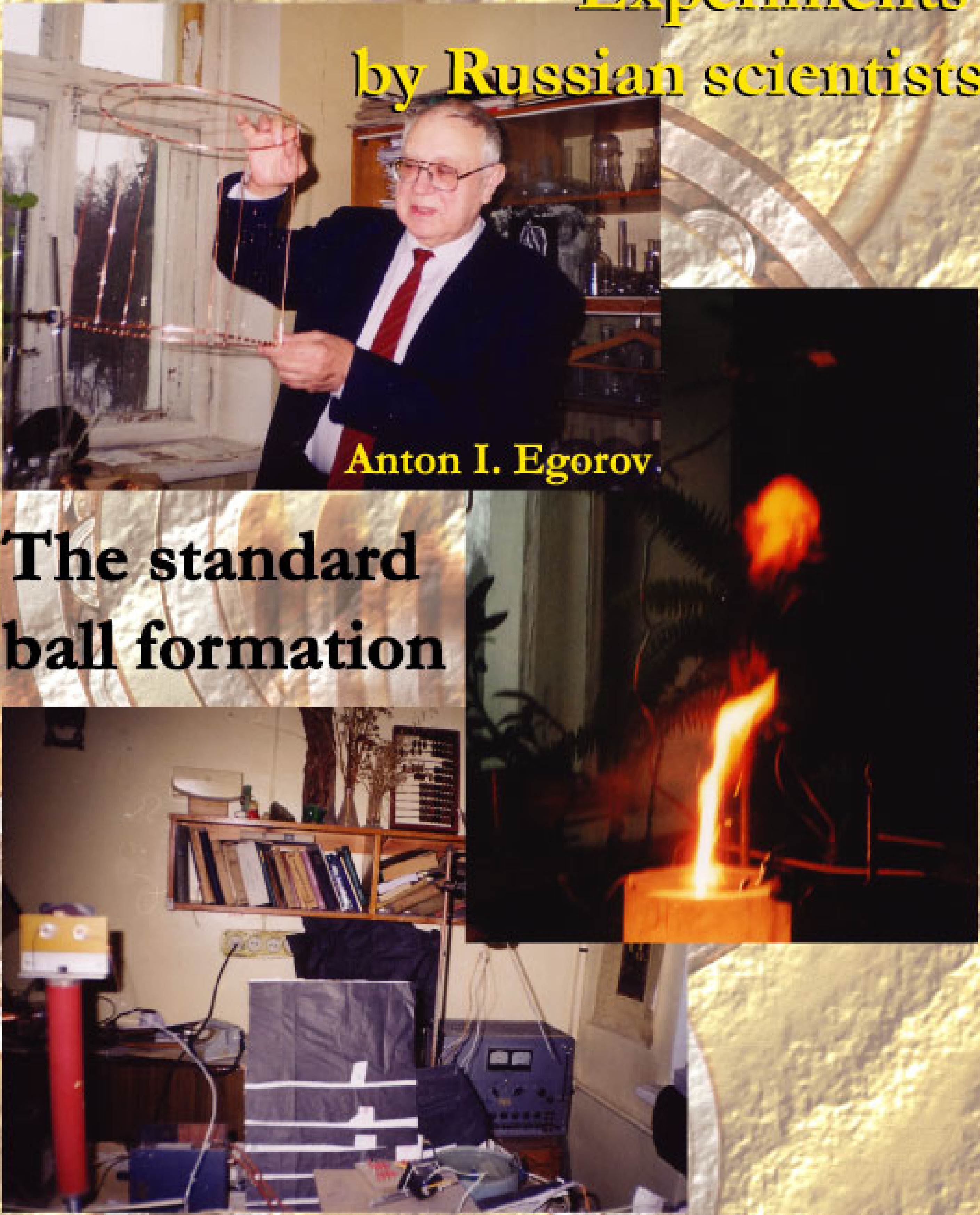

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15. Electric Vehicle in Russia. Review by A. Pashova (Russia)
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17. Spontaneous Flow Heat Pump. J.-L. Brochet (France)
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20. To the Question of Work Made by Electrostatic Field. A.V. Frolov (Russia)
21. Comments to Electro-Reactive LIFTER News.
22. Letters from Readers.
23. Advertisements (books)

Perfect Energy Source

Minato wheel. Experiments in Sweden

Eric Vogels, Sweden

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http://fdp.hemsida.net

The self-running bicycle wheel was shown to the public at the First International New Science Symposium in 1997, held in Korea. The inventor of the wheel, Mr. Kohei Minato, was a speaker during the symposium. On www.keelynet.com you can find the quote of an eye-witness:

"The motor is actuated by moving the N pole of a large permanent magnet (the drive magnet) toward the wheel. As this magnet is moved toward the wheel, the wheel starts to spin. As the magnet is moved closer to the wheel it spins faster.

The acceleration of the wheel is rapid. So rapid in fact, as to be startling. To put it another way I was very impressed. The motor works. And it works very well. In the film clip (see http://fdp.hemsida.net) a slight pumping action of Minato's hand holding the magnet is apparent. When I braced my hand so that there was no pumping action, the motor still ran. In fact it seemed to run better.

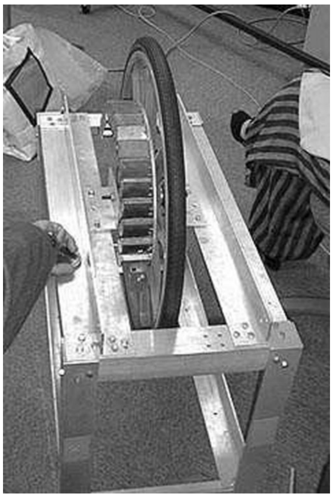

Fig. 1

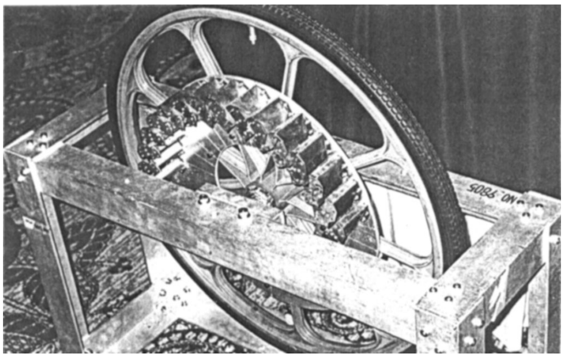

Fig. 2

Pumping action by the hand held magnet **is not** the power that drives the motor. When the drive magnet is moved away from the wheel it coasts rather quickly to a stop and comes to rest in a manner typical of any spinning bicycle wheel. Again when the wheel is at rest and a large magnet is moved up to the wheel it starts to spin. At no time it is necessary to touch the wheel to get it rotating."

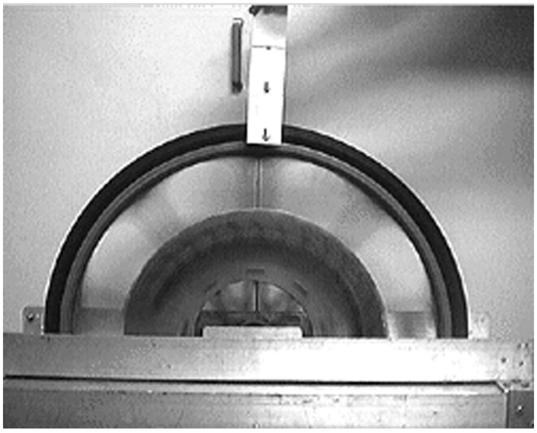

Fig. 3

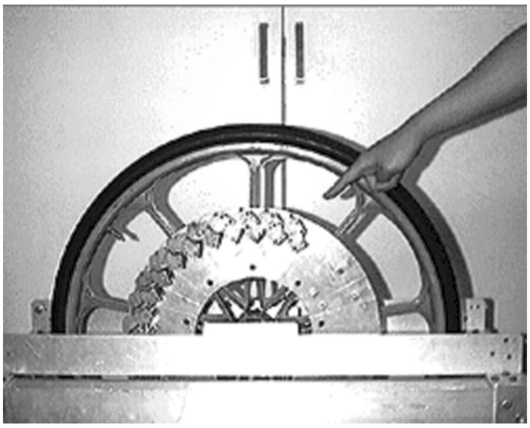

Fig. 4

Since the symposium in 1997 and the first publications in the Internet several people have tried to replicate the wheel, as it seemed to be a **perfect energy source for the future**. Some claims are made that replication was successful but no proof in the form of pictures or video clips are given.

Because I have a great interest in magnets and free energy and the fact that I did a lot of experiments to find a device that could be rotated only by means of permanent magnets, I decided to try to replicate the wheel by myself.

This journey started by searching on the Internet and collecting all the material that was available. A good way to sort all the found material was building my own website at http://fdp.hemsida.net where all my findings are presented.

One of the devices I build was made from a ‘how to build a Minato wheel’-manual that I found on the Internet.

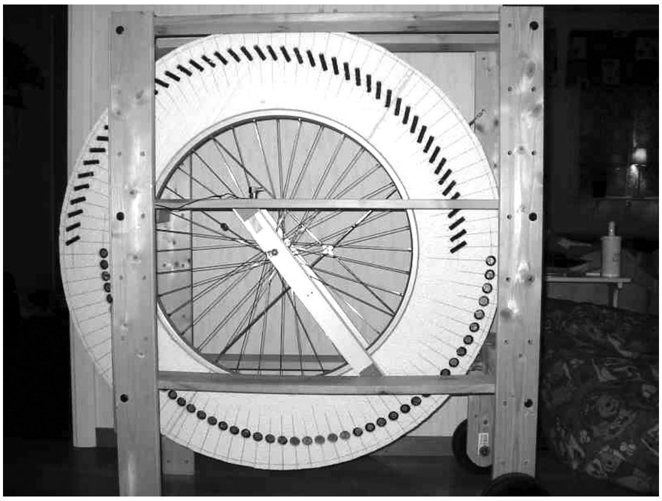

Fig. 5

Unfortunately this wheel did not show any movement at all. I mounted the magnets at several angles and distances from the rim without achieving any positive results. Since the size of the wheel (1 meter diameter) was not very practical to handle and since the results were negative I searched for an easier way for testing. I found that the use of Styrofoam, an old turntable and Neodymium disc magnets kept the whole project within the edges of my kitchen table. I developed a computer program to help me design wheels, since I want to be able to replicate my own wheel, in case I find a model that works. I do not believe in an engine that works after several weeks of tuning and that fails to function as soon as one magnet is replaced. Individual tuning is okay to optimise a working design but if a design does not show the potential to rotate by itself it’s a flawed design.

After optimising the way to build the small wheels, I could design and make a wheel in 30 minutes. I made a test scenario and the results for every test were posted on the web site.

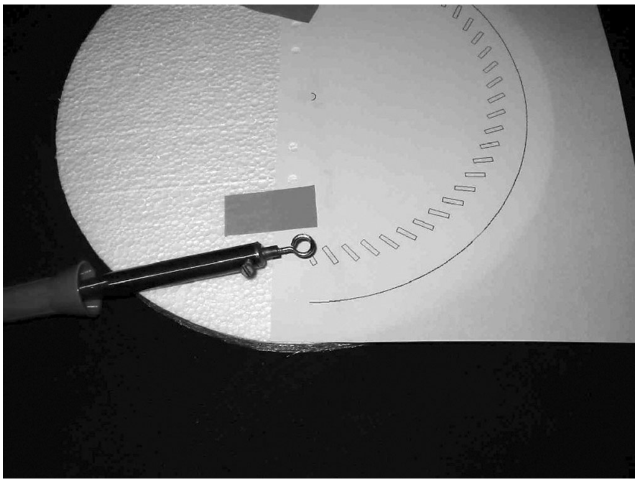

Fig. 6

I searched for the ‘perfect’ angle, number of magnets and position. The set-up with the strongest thrust was used as the base for the other experiment. By this time I realized that I was not really trying to rebuild the Minato wheel but that I wanted **a rotating device, powered by permanent magnets.**

When for the first time I decided to split a track of magnets that covered 180 degrees of the wheel in a number of smaller tracks, **the results became much better**.

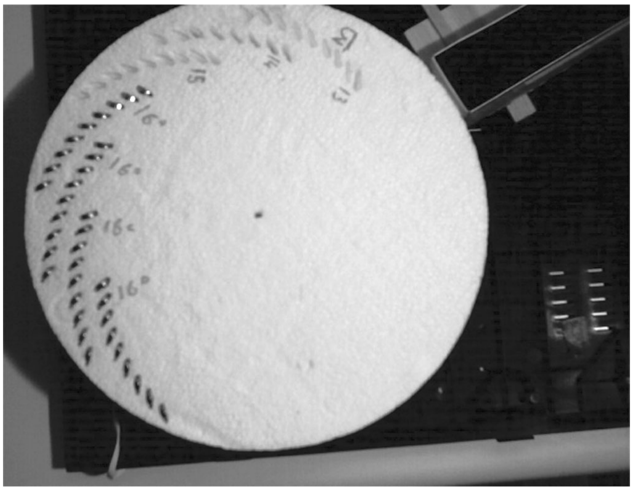

Fig. 7

By using this way of placing the magnets, every track differs a little bit from the next track, depending on its place on the wheel. The angle of the magnets influences on the thrust that is given by the stator magnet, depending on the speed that the track is entering the magnetic field of the stator. In other words: the track at the beginning of the wheel, with magnets covered side of the wheel, gives less thrust than the track at the end. This is important since a track with a lot of thrust has a big ‘sticky spot’ that should pass the stator. This ‘sticky spot’ stops the wheel during its rotation just before the first track enters the magnetic field of the stator.

During the last experiments the stator magnet changed place and pushed against the magnetic fields of the tracks from above. Simply because more thrust was developed by this way. The next wheel will have the tracks mounted on a different level. It means that the first track will have a bigger distance to the stator magnet than the last track. This should make the sticky spot weaker and the final 'kick off' stronger. The final wheel will be mounted vertically, like the Minato Wheel.

Thanks to the invention of the Neodymium magnet in 1983, magnets became much more powerful while the size and length decreased. Before 1983 a lot of the experiments could not be done since the size of the magnets made the positioning of several magnets in tracks like this was impossible. It is my personal believes that the strength of these magnets will lead to results that are impossible according to the physical law books, because these magnets did not exist when those books were written.

Until the moment I write this I have not found the perfect energy source yet but by exploitation all the material and findings on my web site I hope that more people get interested and will help searching for a great energy device that will not pollute the air which our children and grand children have to breath.

Mechanism of Drive-Free Motion

Sergey A. Gerasimov, Russia

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The article presents results of the experimental study of the motion created by vibrations of an internal mass of the system of bodies accompanied by impacts of the unbalanced load with the external body. This type of propulsion drive is known by a number of names. Among these are the ***vibrational propulsion device*** *and* ***reactionless machine****. Sometimes it is called the* ***inertioid*** *[1, 2]. The vibrational transposition is proved to go on by means of internal forces of a system of bodies [3-5]. The Tolchin's inertioid [6] is considered to be the first device that used the forces of inertia to create the reactionless infinite motion in space. We are not in a position to be a judge of this. There exist a number of projects of such machines but experimental results concerning such kind of motion are very limited. Below there are the experimental results on average velocities of such a motion and the description of a propulsion device a main particularity of which is absence of wheel-drive.*

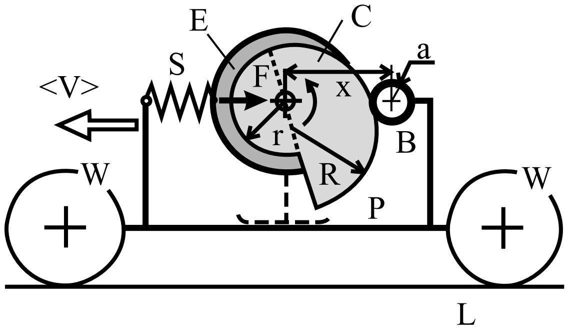

Fig. 1

Scematic representation of a vibratory-impact self-transposition

The unbalanced load in this device is an electric motor *E* of mass *m* that executes undumped vibrations relative to a platform *P* of mass *M* with four wheels *W* which can roll on a horizontal surface *L* with rolling friction the coefficient of which is *k*. The frictional force is determined to be a force which adjusts to keep the cart from motion across a surface. A disk cam *C* at one end of the axle of the motor ensures a prescribed character of the vibrations and elastic impacts between the load *m* and the follower *B* of radius *a*. In present experimental device, the cam *C* consists of two semicircles of different radii *r* and *R* as it is shown in Fig.1. In this experiment r=0.03m, R=0.05m and a=0.01m. The electric motor and the platform are coupled by a connecting spring *S*. The force *F* by means of which the electric motor is pressed to the follower varies linearly from F=4N at x=0.04m to F=4.8N at x=0.08m. The compressed spring *S* is necessary not only for creating close contact between the cam and the follower. The restoring force of the spring produces the transposition of the cart in a direction opposite to **F** when the follower moves without contact from x=2R-r+a up to an impact at $x=r+a$. The impact suppresses the transposition. Another mode of transposition is also possible when the impact of the cam on the follower is a reason of the transposition of the cart in the direction of the force **F**. In this case the frictional force extinguishes the transposition of the cart.

Friction between the load of mass *m* and the cart is negligible since the corresponding effective coefficient is less than 0.001. The same is for the friction between the cam and the follower. The mass of the spring is m_S=0.007 kg , and the mass of the cam is m_C=0.019 kg. The total mass of the wheels is m_W=0.082 kg. This value can be useful for a theoretical

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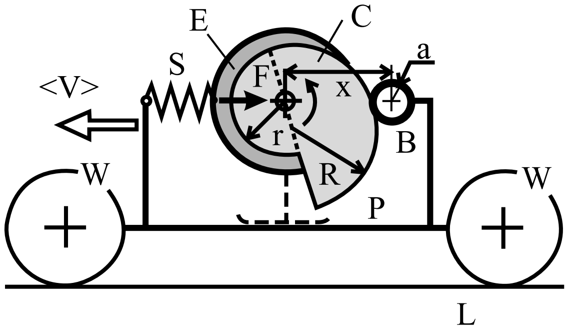

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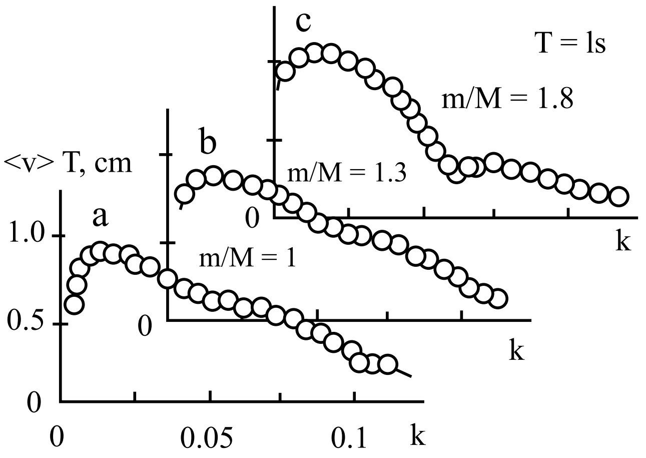

Fig. 2

Frictional coefficient dependence of average velocity of the platform at the period of vibrations *T*=1s for various mass ratios *m/M*:
(*a*) *M*=0.9 kg , (*b*) *m*=1.2 kg , (*c*) *m*=1.6 kg

At least in the case of irreversible mode, one could expect that the value of average velocity of transposition <*v*> must be proportional to the number of impacts per unit of time. In the other words the path traveled by the cart per one impact must not depend on frequency of vibrations. This is a reason why the dependence of the product <*v*>*T* versus the value of the friction coefficient *k* and ratio of masses d = *m/M* is investigated in this work. Measurements were carried out for two magnitudes of rotation period *T*= 1s and *T*=6s of the cam. The obtained results are presented in Fig. 2 and Fig. 3. First of all, the assumption mentioned above is not confirmed.

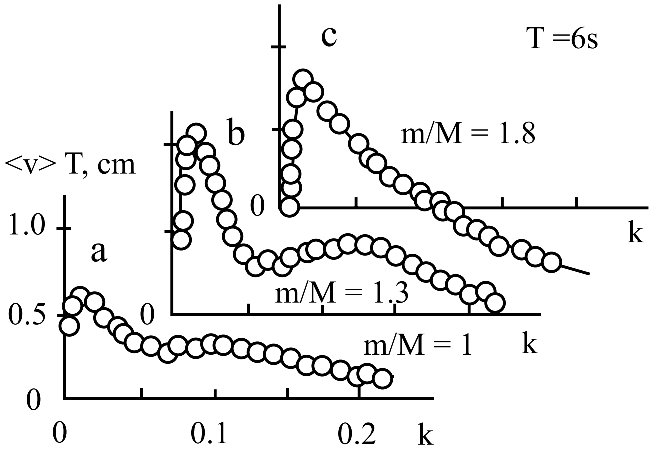

Fig. 3

Average velocity of the platform <*v*> as a function of frictional coefficient *k* at *T*=6s for various mass ratios *m/M*: (*a*) *M*=0.9 kg , (*b*) *m*=1.2 kg , (*c*) *m*=1.6 kg

The value <*v*>*T* for the period of the rotation *T*=1s sufficiently differs from that for *T*=6s measured at the same conditions. Besides, when the mass ratio is large the cart can change its direction of transposition. The reason of these results is not clear but this device provides a challenge to explain and investigate this kind of motion that enables us to discover the reactionless motion if it is probable. One should pay attention to a fact that the infinite transposition of the platform takes place even if the friction coefficient *k* is small.

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About the Author

Sergey A. Gerasimov graduated from Faculty of Experimental and Theoretical Physics of Moscow Physical Engineering Institute in 1976. Received Degree of PhD in Physics and Mathematics in 1987. Author of about 70 articles on Astrophysics, Atomic and Radiation Physics, Classical Electrodynamics and Mechanics. In present - Associate Professor of Department of General Physics of Rostov-on-Don State University. The fields of scientific interests are questionable problems in physics: self-interaction, self-transposition, unipolar induction.

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Production of Ball Lightning in Laboratory Environment

Report by our correspondent Alla Pashova

Three years ago a working device producing a ball lightning in laboratory environment was designed in Saint-Petersburg Institute for Nuclear Physics (SPINP). The produced ball lightning is accessible for detail investigation and quite stable. The lifetime of the ball lightning comes to about one second that is rather significant for alike artificial formations. The experiments on the device made by scientists of SPINP, i.e. A. E. Egorov, G. D. Shabanov, S. Stepanov, are not supported or financed. Let us note that every scientist of the group searches proofs for his own hypothesis of nature and structure of the ball lightning at all.

A leading expert of SPINP, Anton I. Egorov, pays attention to dethronement of scientific myths:

— There is a myth of ball lightning that is created by mass media. The mythical ball lightning is a concentrate of mysterious energy which is extremely dangerous for a human. It destroys houses, kills animals, pursues people. After meeting it a human can lose his hair or teeth and different misfortunes begin to happen. Supposing a simple story of a farmer-eyewitness: “It thundered, and a fist-sized fire ball rolled down along a drainpipe. It fell into a barrel of water, the water gurgled. I came up to it and put my hand into the water. The water seemed to become warmer…”. After republishing of the story by several newspapers a dramatic story about a ball lightning which has evaporated a barrel of water appears. No wonder that such familiar attitude to facts causes hundreds of hypotheses of ball lightning nature.

— **What is your hypothesis about ball lightning structure?**

— At the beginning of 90th I. D. Stakhanov, a member of Institute of Magnetism (IZMIRAN), developed a special method to interview eye-witnesses that resulted a right notion on ball lightning phenomenon. According to Stakhanov, ball lightning is a clot of hydrated plasma which is generated in wet air at electrical discharge.

Water as a chemical compound is remarkable for its anomalous properties: combining of two lightest elements does not generate gas but produces a high-boiling liquid. This is caused by extremely irregular distribution of electrons in a water molecule. Due to this property it acquires properties of an electric dipole. Water molecules interact with charged ions, aerosol particles, and with each other in a special way.

If a positive ion and a negative ion are introduced simultaneously into a puff of warm wet air then water dipoles immediately produce hydrate shells around the ions. When the hydrated positive ion approaches the hydrated negative ion additional water molecules are drown into gaps between them. As a result, there is a stable cluster in which the charged ions are conserved. The cluster consists of two ions of opposite charges and the hydrate shell. Water molecules prevent the ions’ approaching and recombination, hence, lifetime of the ions in the cluster increases up to tens of minutes, i.e. in 12-13 orders. Interaction of clusters causes open-chain structures followed by space structures. That is to say, there is appeared a clot of cold hydrated plasma that accumulates great energy (up to 1 kylojoule per liter). The clot of plasma loses this energy at recombination of ions.

— **Could you, please, tell about the design of the device? What processes proceed when the device is operating?**

— Our task is to introduce an abundant population of ions into a puff of warm air saturated with water vapors. A base of the device for laboratory reproduction of ball lightning is a capacitor bank which is able to be charged up to 5.5 kV. The positive pole of the capacitor bank is connected to a ring electrode by means of a copper bar. The ring electrode is placed on a bottom of a polyethylene reservoir filled with water. The negative pole of the capacitor bank is connected to a carbonic electrode which is placed in the centre of the reservoir near water surface. A quartz pipe encloses the electrode in such a way that it is possible to drop water or to put some natural matter on it.

To generate a ball lightning 2-3 drops of water are put on the electrode. When impulse discharge occurs a bright plasma spout escapes the centre of the electrode that is accompanied by a quiet plop. A glowing plasmoid which is an artificial ball lightning parts from the plasma spout. It comes up slowly in the air and then disappears falling to pieces in 0.2-0.3 seconds.

We have made thousands of experiments for investigation of ball lightning properties, i.e. defining size, lifetime, colour, average temperature, excessive charge, content of a dust component.

It was ascertained that the artificial ball lightning is generated in a narrow interval of breakdown tensions. The average size of such a ball lightning is 12-20 cm, and its lifetime comes to 1 second. Temperature of the ball lightning is not very high, i.e. 50° C. This can be defined if to take into account speed of rising of the ball lightning. If the plasmoid is accepted as a puff of warm wet air of 14-centimeter diameter which in atmosphere comes up at 293 K at speed of 1-1.2 m/sec then, consequently, its temperature should not exceed 330 K.

Colour of the lightning varies greatly and depends on presence of aerosol of matter trapped in the moment of discharge. Usually the lilac central part of the plasmoid is surrounded by a diffusive yellowish layer. Some admixture of natrium salt and calcium makes the core of the plasmoid yellow or orange.

If the central carbonic electrode is replaced by an iron or copper or aluminum one then the fundamental character of the phenomenon does not change. However, colour of the plasmoid depends on a radiation spectrum of excited atoms of the electrode, i.e. iron plasmoids are whitish, copper plasmoids are greenish, aluminum ones are white with reddish shimmer.

— **A generated ball lightning exists for about 1 second. How can it be made more stable?**

— Lifetime of an artificial ball lightning depends on many conditions, i.e. size and geometrical form of the central electrode, voltage between the electrodes, value and duration of a current impulse, temperature and electroconductivity of water which is put on the central electrode. Besides, lifetime of the plasmoid can be changed by introducing an additional dispersive phase into it. We have tested tens of matters and begun to investigate suspensions of colloidal graphite and fine-dyspersated ferric oxide.

A suspension of 3 g of colloidal graphite, 8-10 ml of acetone (which played role of penetrating agent), and 90 ml of water is put on the central carbonic electrode. When an electrical discharge occurs a layer of the suspension forms a flying spherical plasmoid. It comes up slowly and disappears in 0.3-0.8 seconds. The core of the plasmoid has a colour of flame, i.e. colour of burning carbon.

To prolong the existence of the generated ball lightning without application of aerosols it will be possible to use the so-called “Faraday’s cylinder” whose production has been already begun. For the same purpose G.D. Shabanov proposes to put a stopping potential on a probe of detention.

— **There is an opinion that physical nature of ball lightning is similar to the process of controlled thermonuclear fusion. In this case, if your work on generation of a stable ball lightning is successful then you will be a competitor of the expensive project of controlled thermonuclear fusion**.

— I think that it is totally incorrect. Hydrated plasma is the first enemy of the thermo-nuclear fusion as water molecules do not allow neutrons approach each other. Effective cold fusion should be realized in organic liquids, for example, in heavy acetone or in a water-free medium. Somehow, it should be an absolutely “dry” process. No experiments on real “dry” cold fusion have been realized in practice. It has not been also examined the surfaces on which the combination of heavy hydrogen atoms produces maximal heating.

Scientists should pay attention to two most effective cold fusion processes. The first one expects association of two atoms of deuterium occurring on a totally dry deuterated surface which consists of, for example, zirconium deuteride. In the moment of fusion of a deuterium molecule local heating appears, and neutrons depart. The other perspective method of realization of the cold fusion process requires an absolutely “dry” organic liquid, i.e. liquid acetone in which hydrogen atoms are replaced by deuterium atoms (C_3D_6O) or by atoms of cyclic compound of $C_6(D_2)_6$. A tellurium or zirconium tip of an ultra-sonic dispersant is placed into a reservoir of this liquid. Cavitation blebs are formed on the surface of the dispersant. Neutron output comes to 10^4 particles. Maximal neutron output, which was achieved by Lipson, an American experimenter, consists of 10^8 neutrons at a desired result of 10^{13}. Certain quantity of neutrons can be obtained during ultrasonic cavitation which is accompanied by a phenomenon of sonoluminescence. Due to sound resonance the only cavitation bleb is generated in acetone. When the bleb collapses weak glowing is observed. The cause of this phenomenon consists in gas heating occurring in the bleb that is the result of high pressure produced by its collapse. The burst can last from 1/20 up to 1/1000 sec. Light intensiveness depends on quantity of gas in the bleb. If gas is absent in the bleb then the glowing does not occur. Light emission of the bleb is very weak, it becomes visible if it is strengthen or in absolute darkness.

— Is it rightful that cold fusion is the future of world power engineering?

To my mind another direction seems to be more perspective, i.e. extraction of uranium from sea water and then its burning in heavy hydrogen reactors like one which exists in Canada. Photo voltaic accumulators can also become a successful approach of the alternative traditional fuel engineering. By the way, a working model of such a device to utilize free solar energy has recently been created in our Institute (official web site: http://www.pnpi.spb.ru).

Editor: Read the publications on this theme in following issues of our magazine. Below there is a description of other attempts to generate a ball lightning in laboratory environment or at home. Besides, we publish an article dedicated to the problem of laser control of ball lightning. In the article there are photos (also see the cover page) and a scheme of the working device designed by this scientific group.

Ball Lightning Experiments

Information from
http://www-personal.umich.edu/~reginald/ball_l.html

Ball Lightning in the Microwave

This is a great experiment to try at home. It requires a microwave oven, a candle, a toothpick and a lighter. First you put the candle (~1-2 inches in height) in the microwave (remove glass plate from bottom so candle sits on metal). Put the toothpick in the candle sticking straight up. Light the toothpick on fire so that flames are leaping off the tip. Shut the door quickly and turn on oven full blast. There will be loud popping noises and then balls of fire will leap from the toothpick and fly around inside the microwave while making a buzzing sound like a bee. If it doesn't work at first try to move the position of the candle in order to find the "hot spot" in the oven for it to work.

Real Ball Lightning Generated by Pulsed Power Inductor

This experiment is very DANGEROUS. The author did this one a few years ago. The Idea was got from an article about a guy generating ball lightning using a high current transformer (TBA). The author had an idea of using an inductor to store large amounts of electrical energy. The conductor on the end of the stick touches the metal ring. This completes the circuit, and start the inductor. Then there was used the air compressor nozzle to blow out the arc as the wire was pulled away. The copper wire explodes and creates rapidly rotating and burning molten balls of copper. These 'Balls of Fire' exhibit many of the properties of real ball lightning.

Electric Discharge Produced into Air Half-Space

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In the article a possibility of streak lightning control by means of low intensive laser emission is observed.

During investigation of an electric discharge into air half-space [1] it was noticed that this discharge can be controlled by a low intensive laser beam. Now there is a problem of laser control of lightning discharge [2]. However, numerous works on this approach demonstrate that "the hope to get a quick solution of the problem of lightning control by laser emission has not been confirmed" [3].

Careful observation of this problem in [2] has shown ways out the situation. The authors of [2] consider plasma channel produced (by means of laser) in free atmosphere at a possible greatest height to be of doubtless interest of the science of lightning. Finally, creation of the plasma channel should be of benefit for lightning protection. The authors of [2] give notice that "there are many difficulties of fundamental and practical importance on this path".

Weak theoretical understanding of lightning generation causes pessimistic estimations of solution of the problem. The article [2] notes particularly that "there are neither adequate theory, nor numerical calculations and qualitative understanding of the phenomena defining the speed of a leader... The situation of a theory of the leader channel is little better (from quantitative point of view)...".

Realistically the following statement can refer to the lightning discharge: "The electric discharge appeared to be very "unhandy" for theoretical description but the most interesting phenomenon in the experimental aspect" [4].

Experimental Part

In this work a capacitor bank with 0.6 mF capacity, which can be fed up to ~5 kV, was used to produce impulse discharge into air half-space. A scheme of the device is presented in Fig.1. At connection/disconnection of a discharger 5 a "spout" is let out of an electrode 3. The spout carries the potential of the cathode (virtual cathode) at a significant height into air half-space. A probe placed at the height of ~15 cm fixes a potential which is similar to the potential occurring at the cathode. The researches have demonstrated that the produced formation continues to glow for several hundreds of milliseconds (the glow is fixed from a zone located at 15-45 cm above the cathode). Typical time of the discharge comes to 100±20 msec and depends on the cathode material. Electric field generated in the spout comes to less than 8 V cm^{-1}.

Ball Lightning Experiments

Information from
http://www-personal.umich.edu/~reginald/ball_l.html

Ball Lightning in the Microwave

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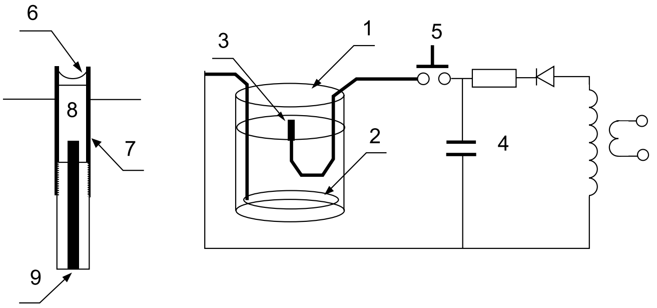

Fig 1
A scheme of a device made for producing of long-living plasmoids

1 – a polyethylene reservoir, 2 – a ring electrode, 3 – a central electrode, 4 – a capacitor bank of 0.6 mF capacity, 5 – a discharger, 6 –water or aqueous suspension drop, 7 – a quartz pipe, 8 – a carbonic or metal electrode, 9 – a copper bar.

The spout was acted by weak laser emission of less than 1 mW at 22-centimeter height. The laser beam was directed perpendicular to the discharge axis, the spout achieving the laser beam moved along the beam towards the laser.

In Fig.2 the spout has moved ~8.5 cm along the laser beam, and a usual sphere formation was generated. Due to the horizontal motion it was distorted if to be compared with usual sphere formation. The usual sphere formation is represented in Fig.3 (also see the cover).

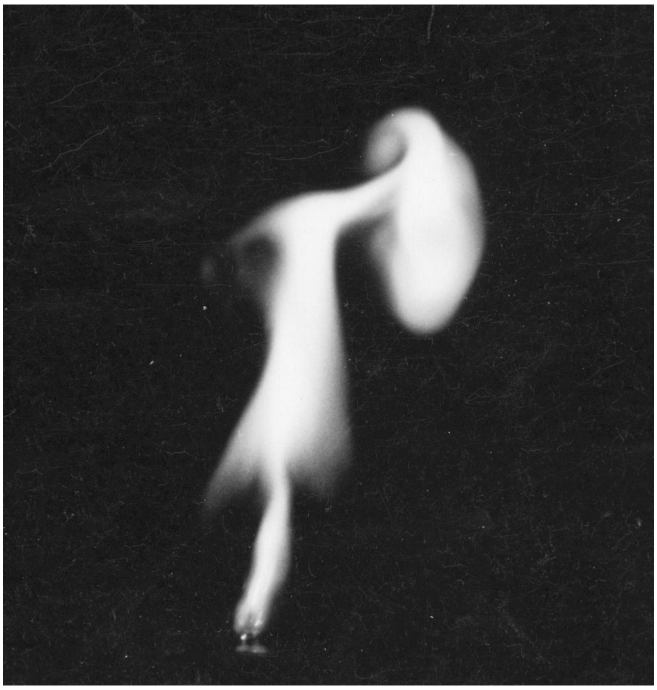

Fig. 2
Motion of the leader channel (spout) along the laser accompanied with the sphere formation

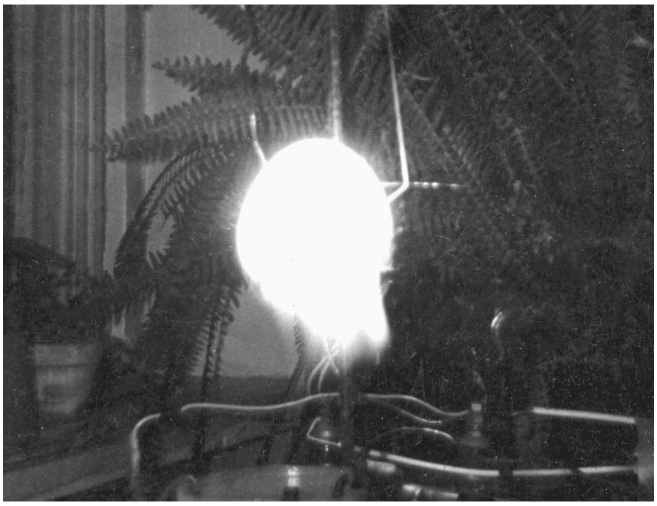

Fig.3
The standard ball formation

Discussion

As it is evenly mentioned in [5], results of model experiments are difficult to be applied directly to laser control of lightning because in short intervals characteristics of the discharge differ from characteristics of lightning discharges. Actually, at comparing considered current and the field existing in a lightning (i~100 A, ~3 V cm^{-1}) with these phenomena occurring in a laboratory spark (~1 A, ~300 V cm^{-1}) incorrectness of modeling of this process becomes obvious. From the other hand the authors of [2] note that "the leader channel is like a channel of electric arc… At current strength of ~100 A plasma of the channel of the arc is supported by fields the densities of which come to several volts by a centimeter. The lightning has such leader currents".

Even an air arc of atmosphere pressure has a field of about 100 V cm^{-1} at currents of about 1 A. The generated discharges (spout) accompanied by the field of less than 8 V cm^{-1} (maximal current appearing in the discharge gap is 50-60 A) are more appropriate for modeling the leader channel of the streak lightning than typical discharges used for investigation of these processes, for example, like [6].

At first approximation the leader channel is considered as an ideal conductor in the article [2]. We make research to define the field in the discharge (spout) more exactly. The article [2] makes the following consideration about a cause of occasional generation of new leader heads: "the surface of *equipotential* plasma conductor (channel) *has* a property of *instability*. There is an occasionally generated sharp jut. An intensified field appears at the jut along the edge. Under the influence of the field the jut becomes to grow in any direction including at the significant angle to the weak outer field". The aforesaid seems to explain why our leader channel changes its direction and runs at right angle to its initial motion. (Fig.2). Weak harmonic action of the laser beam to the leader channel causes generation of a new head which continues motion "on the significant angle".

The effect of plasma motion towards a light beam is a demonstration of a general tendency of propagation of the discharges to an incident electromagnetic field [7]. “Area occupied by plasma usually increases towards the laser emission” [8]. Leading character of motion of this formation is confirmed in [9] as well as the interaction with the laser beam is confirmed in [10]. It should be taken into account that in the works [9-10] experiments were performed at devices which generated such a discharge. However, that discharge was by 2 orders weaker than the discharge generated by the device represented in this work. Naturally, the results were less defined. Comparison of the discharges is presented in [11].

According to our data, the leader channel (spout) has a very abrupt bound (less than 1 mm). In this layer the field can come to ~30 kV cm^{-1} (at height of 15 cm).

Conclusions

Due to the assumption [2] about *instability* of the surface of the *equipotential* leader channel there has been successfully performed the “control” action on an electric discharge which models a streak lightning. It has been achieved by means of weak harmonic oscillations made by the laser. This mechanism is supposed to be applied for streak lightning control.

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In general the conception was formulated in 1995 and today we can say that the concept of physical vacuum, which is a new source of energy, finds more and more supporters. The fundamental works about nature of "zero point energy" are published, for example, Andrew D. Sakharov [1], Hal T. Puthoff [2] and many other interesting works. It is clear now that space or "physical vacuum" has its internal structure, therefore it can be used as a new source of energy if we organize the process of changing of this structure. Moreover, according to some theories, the existence of reality (i.e. the World of some certain parameters of space and time) is defined by the function of probability of energy density. For example, Dr. Nassikas, Greece [3], proves that it is not possible to consider the space without its energy, and there is no space without energy. The internal structure of reality is coexistence of two forms: gravitational energy and electromagnetic energy. Any local increase of the first one should produce decrease of the second one, so the sum amount of the change is zero.

In some other articles about energy transformation processes (gravitational form of energy into electromagnetic heat radiation of mass, for example) we can find that both increase of entropy and the inverse processes (decrease of entropy) are possible and in this case the electromagnetic energy can be converted into the gravitational form, that is shown in details in the works of Nobel laureate I. Prigozhin, Order and Haos. Man's new dialog with Nature, London, 1984. Since **the direction of time** (the time course) **and direction of the entropy change** (increase or decrease) are related notions then free energy technologies are considered by Kozyrev as methods of practical application of natural time course [4] that is presented in aether-dynamics by Frolov as aether flow of some density and this aether density determines the time rate as hardness of cause-effect connections for any process, and also for the process of existence of matter in space-time of this aether density.

According to this theory, in any point of space it is possible to get power by means of energy transformations without any consumption of mass-fuel. We can say also that in this case some change of the energy density of space should be detected.

Let's clarify some determinations:
1. The Potential (lat. Potentia that means "force"). In physics this is scalar parameter, it's gradient expresses the intensity of field of a certain force. In common sense, the potential is possibilities, which exist for execution of some task, for completion of some work.
2. The Work is a quantitative parameter of energy transformations. The transformation means here change of form.
3. The Energy (Greek "Energie" means "action, activity") is a quantitative characteristic for different forms of motion.
4. The Power is amount of work per unit of time.

According to the given determinations by The Soviet Encyclopedic Dictionary, edition of 1988, Moscow, **the fact of presence of potential (scalar) field, for example, electrical or gravitational filed, is real possibility to produce some work if we can organize change of energy forms. Let's note that power source is not required to keep the potential field in force. It is free.**

...the potential (scalar) field can produce real work!

The example of this work, which is produced by the field: body falls in gravitational field and when it strikes on the ground then some part of its potential energy is transformed to heat, that is the work as transformation of energy forms. So, there is a conclusion: the potential (scalar) field can produce real work! But we have considered only a half of cycle and in classical case in the second half of the cycle it will be necessary to produce the same work against the field to raise the body to the initial point.

Let's formulate the task to produce the work periodically and to get the power in load from this process. Usual mistake is to accept the particular case (the same body returns back in the same field) as a single possible case. But in special case changes of the system are possible, for example, the field intensity is not a constant but some variable value (alternating or pulsing), or the body changes its own parameters. In this case in each of half-cycle of the process the field can produce real positive work to accelerate the body.

The main technological solutions are obvious: **it is necessary to create gradient of field in space** (full or partial screening of trajectory of the body, which is moving in the field) **or gradient of field in time** (pulsing mode of field). This is quite easy for electric and magnetic fields, but for system, which uses gravitational field to produce the work, we can assume changes of parameters of the body only.

It is possible to understand why professional physicists dislike the question about possibility to use scalar (potential) fields to produce useful work in a load since they think about The Law of Energy Conservation. To find mutual understanding it is necessary "to upgrade" this Law for 4-dimentsional case of real physical system. It is necessary to introduce **the notion of the structure of space-time** where the considered process is created. In other words, for real practical engineering tasks it is necessary to consider **space-time of the real process** but not an abstract space-time. Usually the energy density of technical processes is small in comparison with natural energy density of space (aether density), which is a result of real astrophysical processes, i.e. motion of planet, star, galaxy. If we discover structure of this real rhythm of the space-time of our planet then we'll be able to design it in our technical devices to use aether-dynamics as theoretical basis.

So, in orthodox physics there is the unchallengeable formulation: the work of potential field on closed trajectory of motion is equal to zero. Yes, it is right for only case: if one part of work is positive (the acceleration) and another part is negative (the deceleration). But one part of the trajectory or a part of periodic process with the negative work can be excluded by different methods: by means of spatial superposition, pulsing mode and change of interaction polarity or by the screening of electromagnetic interaction.

For example, minor changes in vacuum tube design (the grid is located under cathode) allows increasing the kinetic energy of electrons and to increase emission current by means of the potential on the grid only. Also vector potential of magnetic field or gravitational potential can be used by similar way.

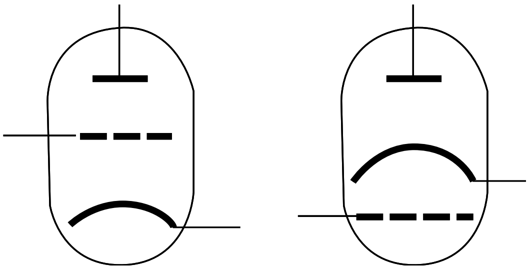

Fig. 1

Besides this way it is possible to use pulsed mode and switch-off the primary energy source before the emission electrons will reach the anode, Fig.2. In this case there is not the conductivity current between anode and cathode and the primary source is not discharging during its work.

Therefore, it is not a news that potential field can produce real work. In any textbook there are examples of positive and negative half-cycles that result to zero net work. But for the case of consequent execution of two processes the parameters of one of the processes can be changed, that **the work, which is produced on the closed trajectory can be formed as two or more parts of positive work.** Important aspect is following: it is necessary to determine the point (moment) of change the sign of the interaction and at that point (moment) to change the parameters of the process accordingly.

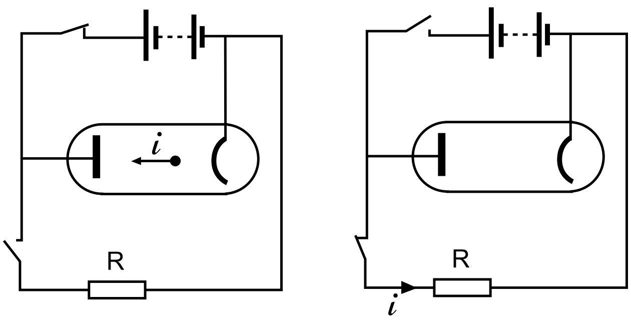

Fig. 2

The good sense requires the answer: what is the source of the power to produce this work if this proposed concept is right? Let's notice that before the considered examples, the existence **of power interactions of potential fields** must make the same question. For example, how the ordinary permanent magnet (i.e. its vector potential) holds a piece of metal making work against force of gravity without any fuel? How the potential field can move and accelerate ions, i.e. kinetic energy of ions can be increased without any fuel? What provides the forces of elasticity? Let's try to find answers from consideration of inner structure of electric and magnetic field, especially let's develop **our understanding of the notion of gradient, which describe properties of space-time design in area of this field.**

The concept of potential as bi-directional flow of photons and anti-photons was proposed by English mathematician E. Whittaker, and then it was developed by Dr. Thomas E. Bearden [5]. In this concept, the generalization of the Third Newton's law looks as the requirement of complementary pair to the process of the electromagnetic radiation. Since "process" means a change of information in time, this paired anti-process is reversed in time. Of course, it is development of process to its own future, but from our point of view, it goes from future to past. According to generalized Third Newton's law the radiation of photon is paired with anti-photon. In this case, the internal space-time structure of electric potential field is formed by two contrary flows of energy: photons spread from charge source and the anti-photons "inflow" into the charged mass. Let's notice that this concept defines the relationship of charge and mass. The charge without mass does not have any sense.

The flow of energy outgoing from charged mass is responsible for all phenomena of radiation. Incoming flow of energy is responsible for the gravitational interaction. Therefore, the notions "radiation" and "gravitation" can be considered as complementary pair; that is considered in details in concept of Josef Hasslberger [6].

...it is impossible to get "something" from "nothing"

There is a quite correct question: since "something" can not be created from "nothing" then what and where will be changing if we create the process of free power dissipations in local area of our space-time by means of asymmetrical potential interaction?

Let's try to present a "process" as some change of "information" in time and from this point we'll get the conclusion about results of this energy disbalance of the natural internal structure of potential field: in this case the entropy process in direct time (heat dissipation in load) should be balanced with equal anti-entropy process in reversed time. In other words, the disbalance is change of the space-time curvature and changes in the time rate.

So, it is impossible to get "something" from "nothing" but if we have understanding of the balance (process in time and anti-process in reversed time) then in the Universe the 4-dimentsional balance is not violated. It is assumed here that it is impossible to create one process but it is possible to create two opposite balanced processes, and each of them produce real work in the load. In astrophysical consideration it was stated in 1964 by Academician Gustav Naan, Estonia, Tartu. He wrote [7]:

> ***"In our real world we could extract any amount of energy from vacuum if some technology provides at the same time the extracting of the same amount of energy for anti-world. Total sum value of energy is equal to zero."***

Let's note also that similar conception of "dynamical zero" was applied in ancient India mathematics, i.e. "zero" is not "nothing" but it is hidden possibilities (balance of forces).

One more interesting question appears: what is about reality of the particle of matter after we have claimed that its mass-parameters are parameters of certain process? With this idea the material world as a whole is certain process and "stability" is not a property of some object but a parameter of its existence, which is a process in space-time of some certain energy density and some certain structure. By analogy the vortex in liquid is a process but it is not a liquid.

Thereafter, as electron was presented by Shredinger as wave packet and by Whittaker as function of two scalar potentials, the old idea of instability or **dynamic structure of matter** has the possibility of experimental testing and development as a teleportation technology. This idea is technology of space-time engineering, i.e. creation of the space-time with some certain parameters where curvature (or rate of time) determined rate of existence of the matter in space. It is related with some energy density, which can be increased or decreased. Since by this way it is possible to consider any material particle of substance as certain process, which is balanced by corresponding time-reversed process, so there is no theoretical difficulties to develop technologies of chemical transmutation, materialization, dematerialization, teleportation etc.

So, the using of potential energy to create a process of dissipation of power in load does not violates the Law of Conservation, and this Law can be generalized: the total energy of four dimensional system is amount of energy of processes in time and energy of processes in reversed time, it is constant and it is equal to zero.

Now let's try to review some free energy projects (the systems to produce work without consumption of fuel). Russian Peter the Great had intention to visit Germany in 1725 to test the Orferius' device. There is a very old description of "perpetually rotating wheel", which was made in India by inventor Bhaskar in 1150! From that times the mind of inventors is developed to other modern systems but due to the efforts of scientific groups, which are interested to keep in force the ideas of primitive materialism, the great idea of free energy transformation is distorted to such extent that any person, who began to speak about free energy, had a chance to get the name of "mad". Why? The reason is common understanding of the "power", which is "some work per unit of time" and generally it can be presented only as result of some transformation of matter structure, i.e. disintegration, chemical reaction, nuclear decay, nuclear synthesis or any change of structure of a matter. In any case, a material (the firewood, oil products or nuclear fuel) is considered as the fuel, regardless of its transformation method.

Some concepts did not consider the fields (electromagnetic, gravitational and others) as a kind of matter. So hypotheses, and even successful experiments on transformation of "non-material" type of energy in energy of material object (into the work) were not taken into consideration. The physics is a study about measurable and tangible quantities. New measurement methods let us work with a new physical phenomenon. So, we can see that **real situation in alternative energy is changing due to experimenters efforts** but not from the great theoretical team.

Some time ago the electric energy was not considered as a material object, but gradually people have been able to refuse the gas pipes, which were real material source of power for the gas light lamp, in favor of electric wires for electrical illumination. In a short time, I think, it will be possible to refuse the wires and we'll consider the aether (physical vacuum) as unlimited energy source if we organize **the process of transformation of space-time parameters.** It will be necessary to drop the old conception of "primary source of power", which should be connected with the consumer by some method and to develop conception of free energy source in any place "on-demand".

Let's consider, what the term "free energy" means today. The energy in general sense means the "ability of body to produce some work". The energy of closed system is constant. Certain device can look like "perpetual mobile", but nobody will be shocked because the way of energy "inflow" is known. For example, solar panel battery is obtaining its power from external source of light. But in general case, 3-dimensional observer can see nothing similar to the inflow of energy into the system if multi-dimensional energy balance is not analyzed. In other words, "perpetual mobile" is a right name since for its description it is necessary to use notions of "Time", "Eternity", "Causality" and other categories, which are more related with philosophy and religion but not with modern physics.

The "perpetual mobile idea" is really value to be the purpose of serious scientific work. In the book "Great experiments in physics" published by "World", 1973, Professor G. Lipson wrote: "Joule was the person of a very practical kind of mind and he was enthusiast of the perpetual mobile idea". I hope that it is not necessary to explain here who was Joule. However, "practicality" of free energy generators is obvious only for energy customers, but not for energy producers, who created the centralized system of energy distribution. This is the main reason of absence of alternative fuel-less energy systems in the modern market.

Let's consider the existing classification of "perpetual mobiles":

1. "Perpetual mobile" of the first kind is a design, which can "create energy". It is disputable aspect and all patent offices refuse to consider the patent claim of such type. They answer that "energy can not be created or destroyed" but energy can be transformed from one type into another type.

2. "Perpetual mobile" of the second kind is the collector of environmental heat. It is not a "thermo-pair" which uses temperature difference to produce electricity, but it is the "heat pump". This type of devices works with negative entropy, or more exactly, with sintropy. The terminology still is not defined but we can say that in entropy systems the produced work is equivalent to the dissipated heat and the work, which is produced by sintropy systems is equivalent to some absorbed environment heat.

3. The "perpetual mobile" of the third kind is a demonstration of perpetual motion without friction. The analogue is electric current in superconductors. Development of this idea is creation of systems with negative friction. In electromagnetic systems it corresponds to the known cases of the "negative conductivity", i.e. some electrical circuits in this mode can generate output power.

Additionally, let's show that "creation of energy" is possible in theory, for example: two processes of equal power compensate each other $A + B = 0$. Let's assume that some technology creates another (inverse) process as: $0 = A + B$ i.e. two processes of some power in sum create zero result. In general principle, also there is possibility to use many processes balanced situation as $A + B + C + \dots = 0$ and this interesting conception is known as theory of multipolarity.

Let's consider some quite real (to my mind) examples from the history of development of free energy technologies. Nikola Tesla's investigations are not well known to modern scientists and engineers. In his works on development of wire-less telecommunication Tesla used flat spiral coils as a secondary winding of transformer. The magnetic field of such coil is radial and it is placed in the plane of the coil. In 1995 the author of this article experimented with similar flat spiral coils. I have to claim that when such coil is operating as secondary winding and the solenoid is the primary winding of the transformer then we can measure asymmetrical mutual induction, i.e. connection of active load (lamp) to output circuit of the transformer is free from input power in the primary winding. It is the simplest example of technical realization of the asymmetrical cause-effect connection, described by Kozyrev in his theory of active properties of time.

... "creation of energy" is possible in theory...

Another Tesla's invention is his resonance transformer. Modern electrical engineering describes transformer with forced electrical oscillations and radio engineering considers operation of resonance systems mainly. Tesla put the question on transformation of power in resonance transformer and by this way the efficiency can be more than 100%. With high frequency currents and high power level Tesla used single-wire terminals as loads, i.e. the lamps and other single-wire receivers of power (motors) were powered from high frequency changing electric field. Such single-wire terminal does not consume any power from primary source because it uses the change of potential in point of connection to conductor (let's note also that for maximum efficiency this point of connection should be one of the maximums of standing wave).

The notion about "free vibrations" belongs to Tesla and this term describes sinusoidal oscillations in electric circuit that is created after short non-sinusoidal impulse due to real vibrations of the free electrons. Resonance mode of the free vibrations can be the real way to excess power output.

Original Tesla’s approach to electrodynamics allowed him to build in 1934 fuel-less car with electromotor, which was powered from some 12 vacuum tubes generator of unknown design.

The standing waves of electric field that were observed by Tesla during thunderstorm brought him to conclusion about possibility of the system to power remote energy consumers from energy generator without any transmission lines and without radiation methods. He assumed that it is necessary to create special standing wave of electric potential (or variable in time electric potential field) around the generator, then the unlimited number of loads (lamps, motors) in area of this potential field can be powered if they are tuned in resonance with oscillations of the generator. Let’s notice that in each receiver the power can’t be more than power of this generator but it is possible to install many independent “receivers” without mutual interference.

The modern investigations on these problems sound as sensation, because Tesla’s works are unknown for the modern generation of scientists. Of course, modern electronics components and the tools facilities allow to create real “miracles” in comparison with the past age experiments. For example, engineer Avramenko described his work on single-wire power transmission in Journal of Russian Physical Ideas, 1991, No.2, and in journal “Inventor and rationalizator” 1992, No. 5, 6. The light bulb (or ventilator) was used as load of the single-wire power transmission line. This line can be made of high resistance material, for example, tungsten, but the power can be transmitted without heating of wire! It is possible to say that in this experiment a wire does not transmit power from the generator to the load, but the wire is the conductor of information signal, which is created by polarizational current opened and described by M. Faraday.

It is not difficult to repeat the experiments with single-wire line: it is necessary to place two diodes on the end of a line, which is connected to secondary windings of high voltage transformer (I used television set high voltage unit) by such a way that different poles of the diodes are connected to the line, Fig.3.

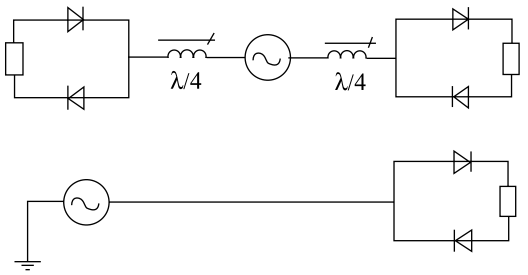

Fig.3

Two other poles of diodes create the source of potential difference (voltage), from what it is possible to charge the capacitor or to power the load (luminescent bulb). This diodes scheme is named as “Avramenko’s diodes plug”. In my experiments it was determined that high efficiency mode is resonance mode in real line and in this case the maximum change of potential is created in the point of connection of the “Avramenko’s diodes plug”. There is well known formulas to calculate this resonance as quarter-wave antenna vibrator system. Of course, high frequency and high potential allow creating high power in the load. In 2001-2003 New Energy Technologies magazine have published new experimental results on single-wire power transmission reported by research team from Moscow (Prof. Strebkov, Avramenko, Nekrasov and others). For example, they built and tested lines from 20 to 100 Kwtt power level!

... the electric potential field can create non-compensated force in the system and to produce a work without any power input.

One more well known researcher on the subject of free energy was Thomas Townsend Brown. He considered creation of reactionless propulsion force by means of electric forces only. Ionization is not considered here! According to his works, the electric potential field can create non-compensated force in the system and to produce a work without any power input. English patent by T. T. Brown #300,311 of August 15, 1927 describes the method to create propulsion force and power from electric energy source only. In this first patent it was claimed that in ordinary flat electric capacitor (two flat plates and dielectric between them), which is charged up to 50 kilovolts and more, Brown discovered propulsion force. This force moves the capacitor to positively charged plate direction. It is only one of his ideas and in his other patents of 1930 - 1965 Brown has described many new methods to create propulsion force and free power in load by means of electric field only (scalar potential field as a source!).

... the efficiency of “electric system can be million to one”

We have to exclude ideas on electrokinetic apparatus since it is just a reactive method and propulsion force is result of ionization flow. Especial case is Brown’s **idea to create the asymmetry of electrostatic forces** by means of some special form of surface, USA patent #3187206 of June 1, 1965, application of May 9, 1956 (Fig 4).

The schemes and descriptions by the Brown’s patents are undoubtedly the work of great practical value. As was mentioned by Brown, the efficiency of “electric system can be million to one” because the potential field can produce real work, for example, rotate some electro generator, but it does not change the primary source of field.

In 1927 T. Brown demonstrated the devices in Ohio, later he worked in France. His works in France were stopped and he returned in the USA. Detailed information on his works can be received from descriptions of patents http://www.soteria.com/brown and from the book “Electrograviticis Systems” by Thomas Valone, Integrity Research Institute, USA.

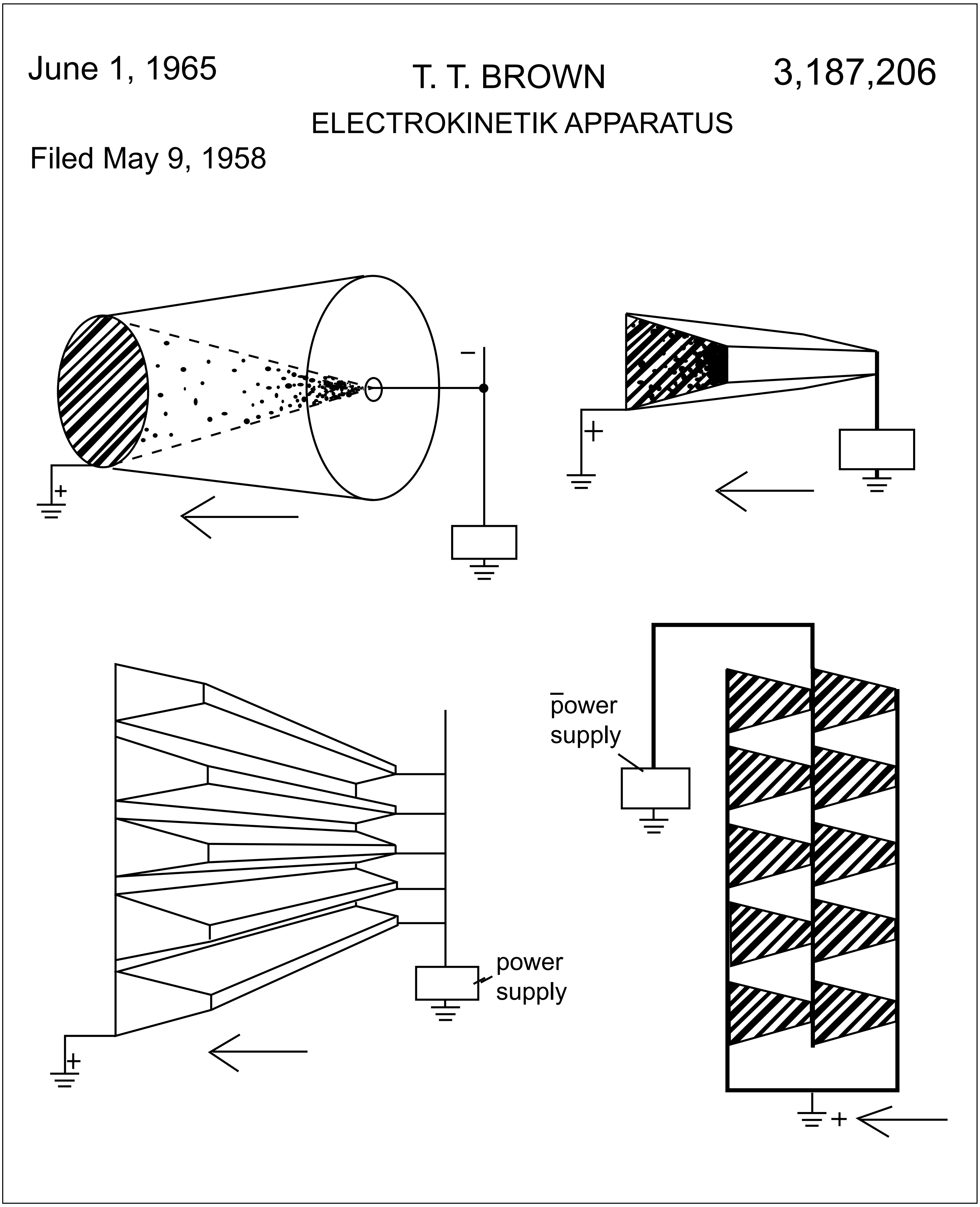
June 1, 1965
T. T. BROWN
3,187,206
ELECTROKINETIK APPARATUS
Filed May 9, 1958
−
+
+
+
power supply
power supply
+

Fig. 4

Electrokinetic apparatus by T.T. Brown

Besides, there is the simplest example of creation of real work by means of potential field that is also resulting from the Brown's works. Usually two plates of electric capacitor are equal to each other. However, if one of the plates is small and another one is large then the electric field between them is not isotropy field and in this case there is some **gradient of intensity of the field**. In such field any dielectrical object, for example a ball, will be polarized unevenly and due to this fact some force should make it to be moving aside, where the field has the greater intensity. I have to note for mathematicians that since the intensity is "gradient of potential" then gradient of intensity is the **gradient of the gradient**, i.e. it is the second derivative of potential. This idea is an example of the well-known rule: the change gives the new quality.

The example of creation of the propulsion force by means of potential field is also connected with "perpetuum mobile" task, since conductivity currents in the capacitor are very small and it almost does not require power consumption (after being charged once time) and the system can produce mechanical work permanently, in this case it is the work against the gravity force. In general case, if the design allows asymmetrical energy transformations, then the surplus output power and reactionless propulsion force can be created in this system.

Most likely future aerospace systems, which are based on the electrogravity, are the most perspective direction of free energy technologies. Why not for the power engineering? It is clear that now there are some existing fuel heating systems, heat stations and power industry to provide by some traditional way all current needs of the society and due to this fact the innovation of any free energy technology is related with hard competition. However, for commercial programs for cosmos the reactive rockets principles are not acceptable more. Each satellite during its operation should produce profit to compensate large expenses for the rocket-carrier. Only fuel-less propulsion systems can allow developing space commercial programs that are new infinite market. Let's note that the gravitational (reactionless propulsion) technologies are not related with cosmodrome and their cost can be quite acceptable to realize the project with private funds.

... future aerospace systems, which are based on the electrogravity, are the most perspective direction of free energy technologies.

There are some known examples of free energy systems.

In 1921 The Seattle Times, as well as Denver Post of August 8, 1921 published the articles about inventions of Alfred Earl Hubbard. His device included the central core with coil and eight remote coils placed around the central core. After primary impulse, the impulses in all coils were powered and rotating magnetic field was created in central coil. The power produced in the central coil was quite sufficient for self-excitation of the system and for producing of useful work in the load (motor). The boat and the car with electromotor, which was powered from the Hubbard's generator, were demonstrated.

In 1928, Lester Hendershot invented the electric generator of 300-Watts power. This device was designed of details used in radio-receiver to get oscillator (500 kilohertz) and non-inductive coil. Later, in 1970, William Cooper experimented with non-inductive bifilar coils. He used induction phenomenon in the case of zero magnetic component (two-wire winding or flat spire coil).

The Cooper's USA patent 3610971 of 1971 describes **the principle and the device to create power in secondary circuit without reaction on primary circuit**, as well as method to get reactionless propulsion force for aerospace application. Cooper also has found that specially designed coils can produce the field, which can not be screened and this field has some common parameters with the gravitational field.

The gravitation is considered by Cooper as a polarization of atoms in gravity field of planet. So he declares in description of his patent: "the electronic generator... of super high frequency creating the pulsing electric field of single polarity... acting in opposite direction to the Earth gravitational field... that to depolarized the atoms and to release them from the gravitation".

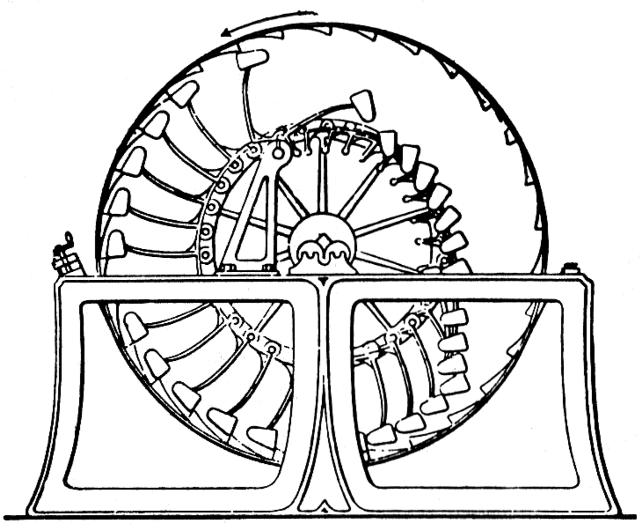

Fig.5

By the way, the gravitational field itself can be used to get a power. "Unbalanced wheel" is a well known design. The weights on the one side of the wheel, which is rotating in vertical plane, can be organized to be moving to axis, but on the another side the same weights can be organized to be shifted from the axis to the periphery of the wheel. By this way there is some constant shifted center of gravity in the system and it can be permanently rotating system. One of the inventors who built such wheel is Hugo R. Fraga, Havana, Cuba (The Perpetual Motion Mystery. R.A. Ford, Lindsay Publications Inc., Bradley, IL 60915, USA, 1987, see Fig. 5).

The earliest information about such systems is dated of 1150 and the name of inventor is Bhaskar, India. He used the tangential disposed pipes, which were half-filled with water. In France (1235-1240) William de Onnecure demonstrated self-rotation wheel with seven weights. In Italy (1438) Mariano de Jacopo has built the system made of eight bars disposed in the plane of rotation, and the bar can be fold up in the middle like elbow joint to provide rotation. One of the well-known and documented events of real demonstration of perpetual rotation wheel was mentioned in 1620. Edward Somerset (Second Marquis of Worcester), author of the book "Century of Inventions", 1963, has built and tested the wheel of about 4 meters in diameter, 14 weights of 25 kilograms each. The test of this machine was organized in London, in witness of King Karl, Grand Duke Hamilton and Grand Duke Richmond, and there are files in royal archives about this test. The descriptions of these and other systems are published in the book "Perpetual mobiles: past and present time" by Brodiansky, Moscow, Energoatomisdat, 1989.

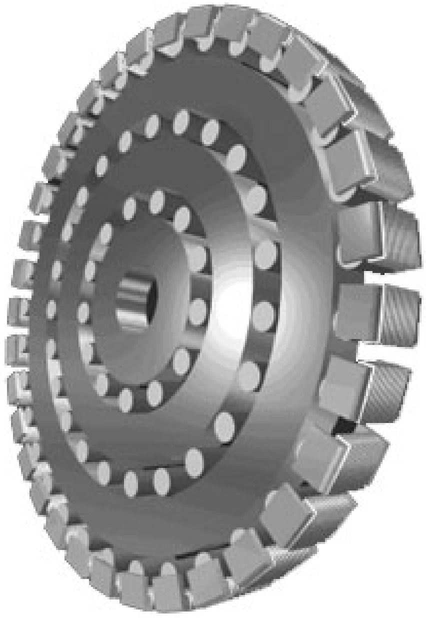

Fig.6

In different idea, which is known from Leonardo Da Vinchi drawings, lifting of water is produced by the helical "Archimedes' screw" of small diameter with large centrifugal acceleration, which reduces weight, but lowering of water was organized with the screw of other (large) diameter, so the force of weight is working to rotate this screw by the weight of the falling water. The paradox of these systems will be removed if to consider them as systems of variable topology, as it was done at the beginning of the present article. Practically, the **cycle is separated here into two processes** (the lifting and falling of mass) in the system with different parameters (the topology) for the first stage and the second stage of the cycle, but herewith **it is necessary to consider two different physical systems, not one and the same.** In that case, the classical theory can explain the work created by potential gravitational field of our planet as energy exchange between two different systems.

Other well known topic is research projects by John Searle, i.e. the "Searle's disks" (Fig. 6). It is necessary to note that the inventor mentioned in his articles anti-gravitational effect and free energy output also. The address is: John Searle, 13 Blackburn Lower Strand, Graham Park Estate, London MW9 5 NG, United Kingdom.

In several words we can say that rotor makes free electrons to be displaced to the peripheries of the system. With sufficient velocity it was mentioned that there is phosphorescence and ionization around the disk. It is possible to assume that main effect is based on well known Lorenz forces and understanding of the Poynting vector, which is circulating in this system. The ionization currents are closed through the space from periphery to the center, and self-rotation of the disk is provided by the classical Lorenz force, since the current interacts with magnetic field of the rollers.

In Russian experiments of 1992 Roshin and Godin built similar system of 7KWtt power output and they claimed that 100 kg axial force and areas of decreased temperature in environmental also were detected. Fig.7 demonstrates main parts of the system by Godin and Roshin.

It is necessary to note that similar anti-gravitational effects appearing for the case of over-unity operation were observed by different inventors independently. For example, in 1990 Floyd Sweet demonstrated his invention named as "vacuum triode amplifier" VTA. The barium magnets were pre-conditioned by special method to be used in special "trigger mode". This "bi-stable condition of magnet" provides possibility of transition from one direction of field to another direction due to the weak control signal, which was provided from external generator. It is known that if the material was pre-conditioned by the magnetic switching of 60 Hz frequency then its control signal must have the same 60 Hz frequency. A part of output power was closed to provide feedback and additionally some power can be used in output coil for the load. Tom Bearden studied the scheme of vacuum triode amplifier and confirmed that it demonstrates the work with negative energy. It means that the work in the load is connected with use of negative time. In this negative time, according to Bearden, the gravity is repulsing force. The experiments on VTA demonstrated that VTA decreased its weight according to level of the power, which is extracted from vacuum. Additionally we can

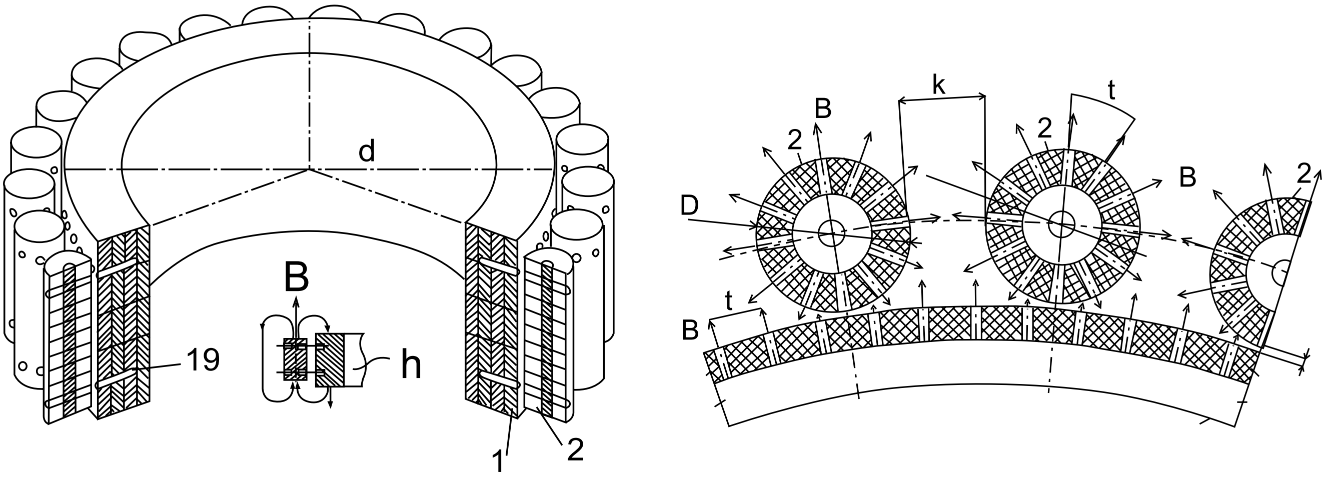

Fig.7

say that permanent magnets and coils of VTA were self-cooling during operation and the temperature difference was about 20 degrees in contrast with the environmental temperature.

One of VTA schemes includes two sets of magnets 4 x 6 x 1 inch, placed on two walls of frame. The attraction is created between them. Output and controlling coils are located between them. The axes of output coils are parallel to the magnetic field lines, but the axis of control coils are placed under 90 degrees angle. The secret of system is the "conditioning process", which "brings the magnets to the special condition". It is necessary to create great number of micro-cracks in the magnet due to re-orientations of magnetic domains. In such "half-magnet" the domains get the ability to be orientated in the same direction in a weak "control" magnetic field. In fact, they are not domains but large parts of magnet's material, separated by micro-cracks, that is to say acoustic domains. Many researchers repeat Floyd's works. Let's note that arc discharge of alternating current through magnet barium ceramics directly can provide the best results of the "conditioning" process. The coil of "conditioning" is not necessary in this case. The frequency of alternating current must be corresponded to the frequency of the control signal. Thereby, Sweet was creating **the bi-stable solid-state condition of magnetic substance.** The acoustic resonance is the reason of oscillations with the frequency according to the control weak magnetic field. Floyd Sweet died on July 5, 1995 at age of 83 years old. It is known, that his widow sent the archives to some great Automobile Corporation.

... the extraction of space energy is result of transformation of vacuum energy but from the other hand the energy density in this case determines so called "time rate"

It is interesting to note again that the magnets of VTA demonstrated self-cooling during operation, up to 20 degrees difference in comparison with the environmental temperature. It is one more example of relation between notion "density of time" and "energy". We can say that the extraction of space energy is result of transformation of vacuum energy but from the other hand the energy density in this case determines so called "time rate".

Kozyrev's articles [4] on causal mechanics theory and experiments describe possibility to use "time course for producing of useful work". Kozyrev introduced notion "density of time" and he demonstrated experimentally several methods how to change the density of time, which depends on irreversible processes intensity. Powerful "generator" of such processes is biosphere of our plane and it creates **season and daily changes of the density of time**. It is known that VTA power output also was variable in different time of day and night. It can be explained by Kozyrev. Next step in logical development of this idea is **to change notions from the "density of time" to "density of aether"** [10].

Relation between magnet phenomena and aether circulations was known from the beginning of the electrodynamics and now we can assume that VTA was real example of asymmetrical cause-effect connection, where the hardness of this connection depends on the density of aether. In this case the season and daily variation of the aether density are reason of VTA output power variations. So, we can make a conclusion: conception of **asymmetrical cause-effect connections** should be used as theoretical basis of all over-unity systems.

Generation of extra power in nonlinear materials (ferrites and dielectrics) was considered by Nikolay E. Zayev, Journal of Russian Physical Ideas, #1, 1991. Discovery was claimed as "Cooling of some dielectrics by changing electric field with generation of energy", Russia discovery #32-OT-10159, November 14, 1979; the inventions were also claimed as "Method of transformation of heat energy of dielectrics into electric energy", Russian patent claim #3601725/07 (084905), of June 4, 1983 and "Method of transformation of heat energy of ferrites into electric energy", Russian patent claim #3601726/25 (084904), of April 3, 1983. This theory is not about some transformation of space-time structure but in any case the practical application of conversion of environmental heat is very important because this work is real basis of free energy systems.

In one of Zaev's articles, which were published in Journal of Russian Physical Ideas, he quoted from K. Zialkovsky: "If the heat can be transmitted from cold body to hot body, then it must have enormous importance, and not only philosophical or scientific, but also practical importance. The Clausius postulate is not confirmed in this case. The gravitational force, as well as other reasons (number of the reasons is unknown) break this postulate... heat can be transmitted from cold body to hot body but only as the result of some exclusive conditions", published in Russian, "The Second beginning of thermodynamics", Kaluga, Russia, 1914. So, the inventor of free energy system should provide this "exclusive conditions" to organize collection and transformation of environmental heat in his free energy system.

Another well-known free energy system is Swiss electrostatic machine. In spiritual commune Methernitha, Linden in Switzerland, since 1980 several free energy devices have been generating total power of 750 kilowatts. From the technical point of view, these devices are modernized electrophore generator. Permanent magnets also included into design of these devices. The machine of 20 cm diameter produces about 200 watts, and a big machine has the disk of 3 meters and it produces about 30 kilowatts, Fig. 8.

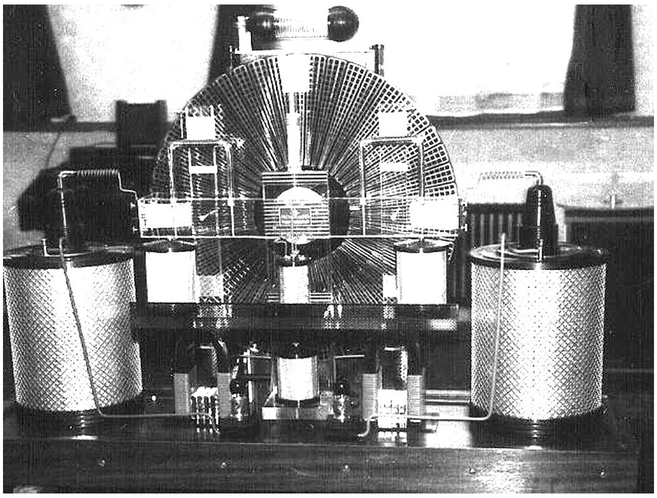

Fig.8

One of the modern technical decisions, which are very close to this Swiss machine is patent USA No. 4897592 by William Hide, January 30, 1990. This device is "system to generate power from electric field". It is one more example of work, which can be produced by potential field, in particularly by means of electric field that can be used as free source of power. The energy (the potential energy) is the possibility to produce work and the power is a work per unit of time, i.e. it is a process. The properly organized process, for example acceleration of rotor in Hide's machine, uses the potential field on the part of positive work (acceleration) and the author of the patent provides meta screen on the part of the trajectory, where the field decelerates the rotor.

... it is "perpetuum mobile" and it can not be patented even if it really works!

One more example is Reed's motor, which uses energy of permanent magnets. By the description of 1991 it is made of four disks (two immovable discs and two rotating discs), and eight magnets are placed on them. Howard Johnson used similar method, USA patent #4151431, Fig.9

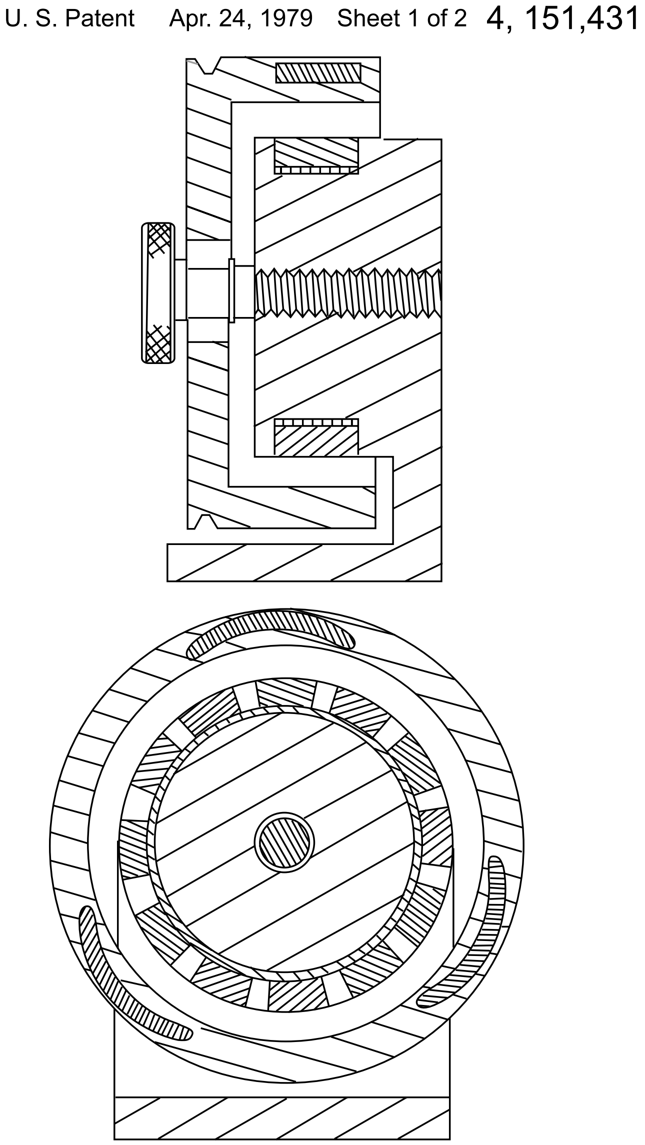

Fig.9

Journal "Science & Mechanics" of 1980 describes this invention. Hovard filled the application in 1973 but he has got the confirmation only in 1979! The reason of delay is very clear: it is "perpetuum mobile" and it can not be patented even if it really works! Johnson found clear and simple description of generation of power in his device and explained it as "extraction of power from inner energy of electron spin in ferromagnetic material".

From text of his description it follows that USA patent #4,151,431 of April 24, 1979, "Permanent magnet motor", author Howard R. Johnson, application #422,306 December 6, 1973 was developed from the prototype that is USA patent #4,074,153 of 1978, class of international classification H02K 41/00E:

"The invention is directed to the method of utilizing the unpaired electron spins in ferromagnetic and other materials as a source of magnetic fields for producing power without any electron flow as occurs in normal conductors, and to permanent magnet motors for utilizing this method to produce a power source. In the practice of the invention the unpaired electron spins occurring within permanent magnets are utilized to produce a motive power source solely through the superconducting characteristics of a permanent magnet and the magnetic flux created by the magnets are controlled and concentrated to orient the magnetic forces generated in such a manner to useful continuous work, such as the displacement of a rotor with respect to a stator. The timing and orientation of magnetic forces at the rotor and stator components produced by the permanent magnets to produce a motor is accomplished with the proper geometrical relationship of these components."

...conception of asymmetrical cause-effect connections should be used as theoretical basis of all over-unity systems.

It is reported that functioning Johnson's model produced about 5 kilowatts power free of any primary source of energy. Let's note that Johnson writes in his patent about permanent magnet as about system with "super conductive parameters". The currents of electrons in permanent magnet are manifestation of real superconductivity and for this case it is not necessary to provide the cooling for zero ohmic resistance. Moreover, the "resistance" must be negative since the magnet could save and renew its magnetized condition. Thereby, any permanent magnet is the example of perpetuum mobile of the third kind on the micro level. Also we can say the same about each atom.

Also, let's note that in general case motion (rotation) can be created due to the discussed above gradient of field, which in Johnson's device is result of asymmetry in "rotor-stator" system. By the similar way the gradient of velocity of airflow above and below wing creates the gradient of pressure and this fact produces great lifting power in airplanes.

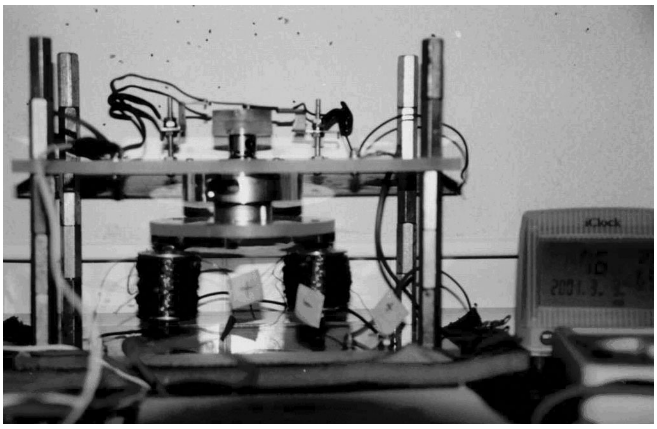

Fig.10

Well-known variant of permanent motor-generator is Adams motor, Fig.10. The rotor with radial orientated (the same pole outward) permanent magnets is rotating and creating inducted currents in stator coils, which are placed around rotor in the plane of rotation. From the point of traditional electrical engineering, any motor-generator without closed magnet flux is not high efficient device. However, exactly open magnetic flux of the Adams motor allows to take off power without deceleration of the rotor. We can assume that in this case phenomenon of electromagnetic induction is not important but in this design there is magnetic induction only, i.e. magnetization and demagnetization of cores in the field of the moving magnet. It is a perfect analogy with phenomena of electric induction that is "electrization by influence". Similar "magnetization by influence" differs from electromagnetic induction and secondary magnetic field in winding of generator is not related with deceleration of the rotor. Robert Adams works with Harold Aspden under patenting of their system. Adams is more than 70 years old but from our correspondence with him we can say that he is going to build demonstration version of 10 Kwtt generator.

...any permanent magnet is the example of perpetuum mobile of the third kind on the micro level.

There is also special name "alternators" for this class of devices, which use interruption of magnetic flux, for example it is the device by USA patent of John Echlin #4567407.

The experiments to investigate the alternator principles were organized also by the author of this article and it was demonstrated that ferrite core of the generator coil is self-cooling. The simplest experiment is based on electro motor, which rotates iron plate and it periodically appears in the gap between magnet and coil. But it is necessary to note that change of the flux in the coil area should be organized by such a way to decrease the flux of the field in the rapprochement half-cycle and to increase the flux for the moving off half-cycle. In this case the rotor is accelerated by the secondary field (back-EMF). From 1994 to 2003 several experiments were produced and main principles were claimed in the patent description, Fig.11.

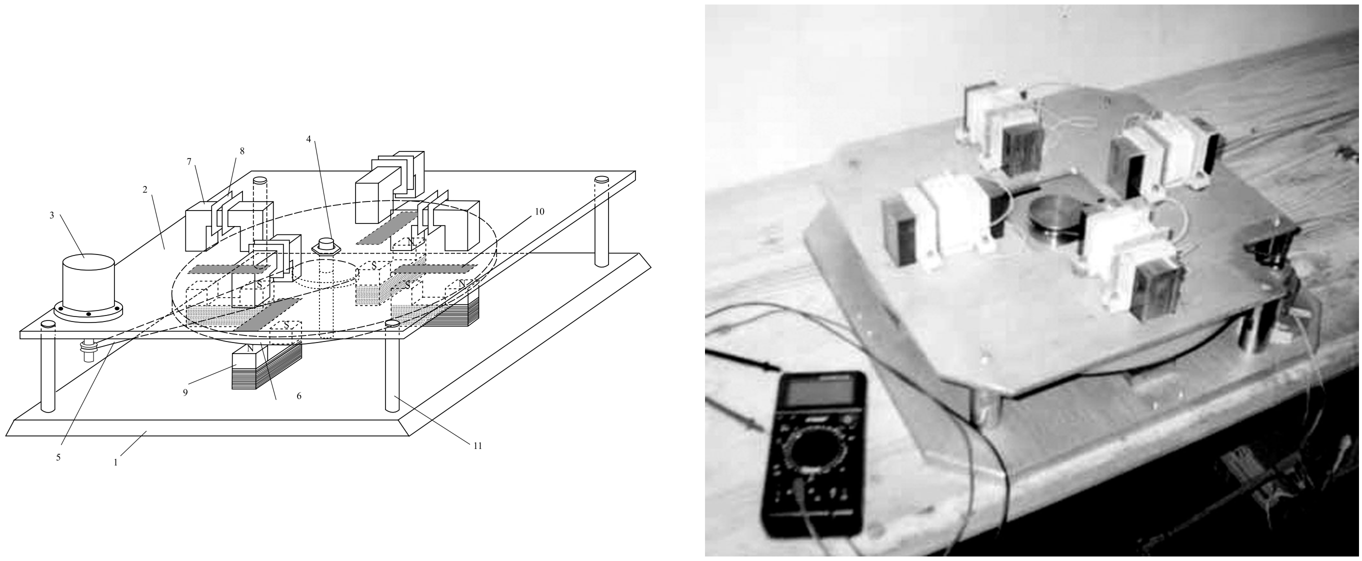

Fig.11

One more topic is “extraction of power from air” and Josef Swenson has conducted the series of simple experiments to develop it. The frequency of natural pulsations of electric field of planet is about 7.5 Hz and it is well known from Tesla’s age. Swenson works with frequency 375 kilohertz and antenna of 10 meters. Please, contact for more details: Josef Swenson 423 North 15th Street, Moorhead, Minnesota 56560, USA. However, everybody remembers from the school story about simplest electrical experiments by Lomonosov and Rihman, who investigated arc discharge in gap between iron wire from a roof (“antenna”) and ground wire. Let’s include the resonance circuit “inductance-capacity” and diode rectifier to get some useful work in the load “from atmospheric electricity”, Fig.12.

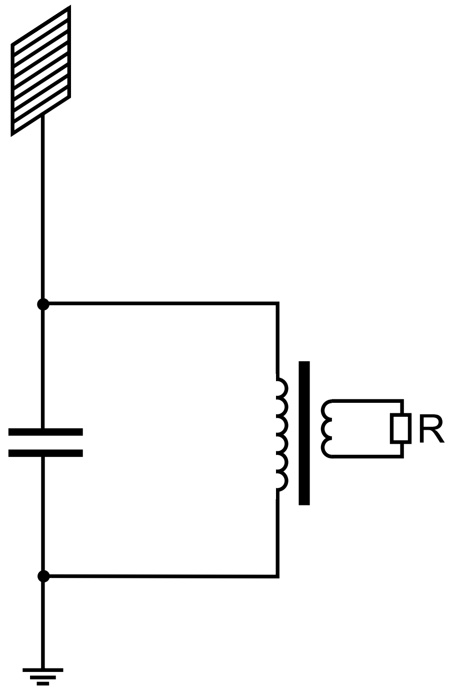

Fig.12

In 1900-1930 a lot of articles were published in technical press about Henry Moray. His demonstration systems produced more than 50 kilowatts free power output. It is known that Mr. Yakovlev (from USSR Foreign Department headed by Mr. Molotov) visited Morey in November of 1929 in New York to test his devices. The devices consist of capacitors, coils and special electronic-vacuum lamps.

In 1990 journal “Magnets”, 2 (3) published article, which describe analogy between Moray’s devices and Hubbard’s coils, which can extract power by means of inner energy of nucleuses of materials if special resonance is created. In 1978 Cospray Research Institute has published the well-known book “The Sea of Energy” by T. N. Moray, in which theory of Moray is presented most completely.

RQM Raum-Quanten-Motoren Corporation (Schmiedgasse 48, CH-8640 Rapperswil, Switzerland, fax 41-55-2125209) offers for free energy devices of different power level: RQM 25 kilowatt and RQM 200 kilowatt. The principle of work is based on an invention by Oliver Crane and his theory. Web site http://www.rqm.ch. But I have to note that in present time they are developing capitalization of the company mainly (actives are above 650 million dollars) than innovation of the new technology.

One more historical example: in 1925-1945, Hans Koler demonstrated his free energy devices. The system was built in Germany and it produced 60 kilowatts of free power. The description includes six permanent magnets and coils, which were superposed in plane of hexagon form. Each magnet is core of the coil.

Another interesting topic is unipolar induction effect, which is well-known from Faraday. This effect creates electro motive force (EMF) in rotating disk if axial magnetic field is applied to the disk. One of the well-known practical developments in this area is device by Bruce de Palma. In 1991 he has published the results of his tests, from which it follows that deceleration of the rotor due to back EMF in the case of unipolar induction is less than in traditional electro generators. So output power of system can exceed the power, which is necessary to rotate the rotor.

Really, motion of electrons in magnetic field, which is perpendicular to plane of rotation, is the reason of the Lorenz force and this force acts in radial direction that can not be the reason of deceleration. Indian research on this topic is developing by P. Tewari. In New Zealand there is research group headed by Dr. Ashley Gray. In 1994 the leader of Japanese market MITI published report about progress in 40 KWtt unipolar generator, which uses superconductors for its electromagnets. The interest of Japan to alternative energy projects can be explained by the position of Japan on fuel market.

There is a well known rule: Demand is related with Proposals. It is easy to imagine the prospects of local introducing of free energy systems in one or several countries, if some producers of product will be able to exclude expenses on electricity and fuel from cost sales. Other countries of their own rich natural resources (for example, oil) will be in problematic position on the new international market, mainly due to the fact that their industry and transport are oriented to conversion and consumption of oil fuel that increase the cost of all products.

... increase of the spark gap produces more surplus power in the load of the circuit.

One more modern free device was invented by Wingate Lambertson, USA. In his device free electrons get the additional energy passing through the number of thin metal-ceramic composed layers. The units were designed by the authors and each unit can generate 1600 watts, and it is possible to connect them in parallel. The address of author: Dr. Wingate Lambertson, 216 83rd Street, Holmes Beach, Florida 34217, USA.

Especially the researches on free energy with plasma processes should be noted here. In 1980-1990 Alexander Chernetsky, Yury Galkin and others have published the results of experiments on creation of “self generated discharge” SGD. The electric arc was placed consecutively into secondary circuit of electromagnetic transformer and it produces real increase of power in load and reduction of consumption power in primary circuit of transformer. The author of the present article produced simplest experiments to investigate the arc (electric discharge) in electric circuits and possibility to create the mode of “negative resistance” in this circuit was confirmed. One of the effects was demonstrated in 1996 during the conferences “New Ideas in Natural Science”, St.-Petersburg.

Adjusting parameters of arc (distance between two electrodes) it is possible to see that consumption current is decreasing until zero and then it can change its direction i.e. this system begins to generate the power. During similar experiment of 1971 by Dr. Chernetsky substation transformer in Moscow Aviation Institute was destroyed in result of strong “reversed current” impulse, which exceeded consumed power in 10 times more. According to Chernetsky’s concept, the reason of this mode is well known phenomenon of plasma instability and **pinch-effect for great currents.** However, the author of this article tested device, which demonstrated similar effect (switching on the load in secondary circuit of transformer and in the presence of arc in this circuit, consumption power does not increase, but reduces) for small currents about 300 mA.

Since for pinch-effect it is necessary hundreds Amperes then it was offered another explanation: the surplus power in this circuit appears due to the acceleration of electrons in the gap between electrodes, i.e. particles of plasma are **accelerated by means of electric potential field between two electrodes**. It is noted during the experiments that increase of the spark gap produces more **surplus power in the load of the circuit.** To avoid mistakes the measurements of the consumed power were organized in DC (direct current) battery circuit and therefore there is no any reason to speak of phase shifts mistakes to try to explain skeptically this effect.

... waves of density of time are used by organisms for their vital activity.

Today theory and experiments on self-generating discharge are quite well developed to build free energy systems of any power scale. The reason of delay in its practical development is a complex problem: this work leaves the frames of classical physics. In his book “About physical nature of bio-energy and its simulation”, Moscow, Publ. VZPI, 1989, Dr. Chernetsky considered the structure of biological fields and bio-energy processes in living organisms from the point of **longitudinal waves conception.** Self-generating discharge in the mode of negative resistance produces such longitudinal waves and they are self-sustaining (self-powered energetically) and it is considered as field of living object.

Really experimentators of the Chernetsky's group, who worked with SGD device detected influence of biologically active radiations and fields, which can be not screened by usual methods. It was reported by Chernetsky that parameters of this radiation can be selected to accelerate the development of plants and biomass or to suppress it. So, we should speak about artificial living biological system or biological form of energy for this class of free energy devices. Perhaps by the same plasma oscillation way all living organisms provide its vital activity, since long time ago it was known that metabolism and food can not provide enough energy for vital processes.

Nikolay A. Kozyrev also wrote about "reason of life" and he confirmed that waves of density of time are used by organisms for their vital activity. Between "waves of density of time" and "waves with longitudal component" there is a clear analogy. Kozyrev and Chernetsky experimentally demonstrated methods of creation of such waves.

...any free energy system should change the causality in surrounding space-time.

New Energy News magazine, March 1996, wrote about attempts to innovate for American aerospace stations special power source, which uses similar plasma technology: anomalous electric discharge. The USA patents #5416391 and #5449989 belong to Dr. Paulo Correa and Dr. Alexandra Correa, Canada. In their report on free energy Denver conference it was claimed that efficiency is about 483% .

Let's note one more free energy topic: high efficient electrolysis. Classical electrolysis as decomposition of electrolyte in electric field is a wonderful example of work, which is produced by field and it can be organized by such a way to be free from the primary energy source (battery). The traditional scheme uses closed circuit of current through electrolyte and the battery, so the battery is discharged during the operation with electrolytic cell. However any physics textbook confirms that **ions in electrolyte are moving due to electric field only, i.e. work to organize the displacement of ions and heat power, which is connected with this work, are produced by the potential field and expenses of the primary power are not required.**

The current through the battery, which is created in usual closed electric circuit destroys the primary difference of potentials in the battery but it is not some necessary condition. For correct organization of the experiment the products of electrolysis (gases) can be created almost free and their utilization (burning) can provide more heat power than input electric power.

Prof. Latchinov, the real member of Russian Physic-Chemical Society, who patented his method of electrolysis in 1888, mentioned that in some cases the electrolytic cell is freezing during its operation. This is an effect of the law of Conservation, which forces to return the surplus power by means of heat environmental energy. In the experiment by Latchinov the electrolytic cell can create gases of high pressure and consumed power is the same as for the case of low pressure gases. However, it is clear that high pressure gases can produce more work than low pressure gases do. This question was sensational problem in scientific societies of 1888 and it is not solved yet completely.

One of other variants of high efficient electrolysis was investigated by Igor Goriatchev, Russia. Instead of usual 3 Volts level of electrolysis, Goriatchev uses 0.2 Volt pulsing mode. He claimed ratio output/input as 1500% efficiency and he hopes to increase this value twice in more perfect design.

Professor Kanarev from Krasnodar wrote about his experiments on plasma electrolysis and has proved that in electrolysis of water output power can be more than input power.

Real example of "perpetuum mobile of the second kind" is invention by Russian engineer Albert Serogodsky (Moscow) and German engineer Bernard Sheffer (Berlin). They have patented new system for direct transformation of environmental heat into electricity, Germany patent #4244016. Retro-condensation of mixture of benzine and water is organized in closed system under temperature of 154 ^{0}C degrees. You can try to get more info from: Werkstatt fur Dezentrale Energleforschung, Pasewaldtstrasse 7, 14169 Berlin, Germany.

The fundamental theoretical researches on direct transformation of environmental heat to useful work were provided by Real Member of The Russian Physical Society Mr. Gennady N. Buynov, St.-Petersburg. The description of his project on "The Mono-thermal device" was published in journal "Russian Ideas" #2, 1992.

In 1995 the scientific journal of Russian Physical Society #1-6 published article "Perpetuum mobile of the second kind (paired gas-chemical cycle)". The author Gennady N. Buynov proposed to consider that **entropy function can be abortive**, i.e. it can be undetermined in some place if reversible chemical reactions are presented in the system.

Herewith, the circular integral of entropy is not a zero and in this case the heat function but not entropy function (according to the Gess law) becomes the function of condition.

Buynov offers to use four–oxide of nitrogen as working matter for this cycle. His works are excellent example of scientific enthusiasm, which (in combination with financial interest of the customers) could produce real results for Russia many years ago. Let's note that priority of this discovery belongs to Russia in spite of attempts of other scientists to claim and develop this idea now as their own work.

We can make a very interesting conclusion if we analyze history of so called "cold fusion" discovery. According to de-classified materials of 1960, priorities of Russia in this topic are obvious. In 1989 Pons and Fleshman have reported about results of their experiment. In 1995 Russian Journal "Inventor and Rationalizator", #1 has published article about invention made by Ivan S. Filimonenko that was named in 1957 as "warm nuclear syntheses". In 1957 he detected **extra power output in process of heavy water electrolysis** and he mentioned several applied aspects, for example, propulsion force and possibility to reduce radioactivity by means of this process. In 1960 Kurchatov, Korolev and Zhukov have supported the ideas of the author. Russian Government adopted secret resolution on this work:

1. Investigation of energy generation.
2. Development of propulsion without reactive mass flow.
3. Research on protection from radioactivity.

But in next several years this work was suppressed by people of nuclear power plant team. The only system of such type named as TOPAZ was innovated for Russian aerospace systems. World-wide innovation of this technology is a real way to introduce "warm reactors of syntheses" and it is not necessary to wait for results of high-cost "Tokomak" project and other thermonuclear researches. Let's note that secondary effects (propulsion force and influence on radioactivity) are possible due to using of "free energy" aspect if output power is result of change of space-time parameters.

In 1994 Journal "Russian Ideas", #1-6, it was published an interesting document "Conclusion of The Moscow City Council Commission on the question about Ivan Filimonenko's discovery and its development". In this document it was recognized that it is vitally necessary to renew this works. But in 2003 we still have nothing new on this topic. Why? It can be assumed that the Problem of innovation for this technology is possible military application of the methods since influence on radioactivity (for example, remote reduction of radioactivity of some object) is area of interests of the Defense Department. The fact that energy generators by Filimonenko can be used for quick restoration of the present ecological balance is not so important in this case. The same conclusion is about propulsion method, which was proposed by Filimonenko. Mr. Korolev knew about this method; however present space programs are still based on rockets and reactive principles, and anti-gravity flying machines we can see only in fantastic movies.

At the same time, development of commercial cold fusion projects was started in some countries, for example: Patterson Power Cell is introduced in Texas, USA (Clean Energy Technologies Inc., Dallas, Texas, fax 214-458-7690). More than thirty patents were owned by ENECO Corporation, which is collecting the main technological solutions in this area. The production of electrolytic thermal cells was started by Nova Resources Group., Inc., Colorado.

In August of 1995 Atomic Energy of Canada, Ltd. Company, which is member of The Planetary Association for Clean Energy, has published the review on modern methods of conversion of nucleus wastes and deactivation. Two new technologies were offered for introduction: contact processing by "Brown's gas" and remote processing by scalar (torsion) fields. Let's note that the technology proposed by Canadians and Filimonenko's technology demonstrate the effect of influence on the rates of radioactive decay.

These examples are only small part of real situation. Main references on publications are foreign and it can lead to wrong conclusion that Russia is delayed in this direction of new technologies development. In fact, Russia has more talented inventors and researchers than any other country. However, condition for work, patenting and publications of ideas are not the same, and usually Russian technologies cannot reach the level of international market. This problem depends only on real and official state policy with respect to inventors and scientists. In real life financial support of scientific institutes is mainly subsidy for management of the institutes, but not for science. The inventions and discoveries always were made by a certain real person, but not by Institute or some scientific team.

In Russia of last age and in the other world on the whole the institutes and laboratories have been creating for a new scientific problems, discoveries or new directions in science. It was necessary to claim about discovery and provide priority for own country to get official support. Main schools of thought appear by this natural way. By the same natural way the necessary in existing of some scientific institute can be removed when the idea grows up to serial production stage. If there are no any fresh ideas in this school then the institute should be transformed in design office of the production plant on this topic. It is almost impossible to create a new research institute in modern Russia, so really new ideas (if they are not ranged in frames of some existing scientific directions) can not be developed and they can not create a new school of thought in Russia.

... it is possible to make a conclusion about grandiose misinformation of society...

People (carriers of the new ideas) have to leave Russia to realize their sensational ideas on free energy and antigravitation topics. Why they do not work with Russian Academy of Sciences? It is the rhetorical question. Usually after many years of correspondence with patent office or with official science bodies the authors can find that their ideas are published in "serious scientific magazines" but without any respect to their names...

Attachment 1 presents some information about patented technologies. When we study old and modern patent documents, it is possible to make a conclusion about **grandiose misinformation of society**, which leads to appearance of two different Worlds, separated by the level of knowledge: evident and hidden knowledge. The achievements of the second hidden world could change our planet, give a chance to remove all energy and ecological problems. Besides, we have discussed that some free energy systems (for example, self generated plasma discharge) have also the medical-biological aspects. This "influence" from free energy system is related with negative entropy processes in area of the operation of the system so some components of biological systems can be changed to less entropy. The design of free energy system defines the type of this influence. It was noted before that operation of any free energy system should be considered in high topology space-time as multidimensional system to see what the reason of the effect is.

So, since the rate of time course is determined by Nikolay A. Kozyrev as rate of cause-effect transformations, then any free energy system should change the causality in surrounding space-time. In this case we can assume that it creates quantum physics effects on the macro level. It is interesting to assume Heisenberg's uncertainty, tunnel effect and manifestation of wave characteristics (up to diffraction of objects) for macro level.

Some experimental data by Kozyrev is related with quantum effects, which were detected in his experiments with rotating and vibrating gyroscopes. This technology is the basis to design real teleportation systems, which will change parameters of space-time to allow changes of position of some material object from one point of space to another point of space (without transference on the distance between these points) by means of combining these points in the same place of space for some time.

The process of study of new technologies in alternative power industry and gravitation is developing actively in the world. Besides secret programs and institutes, it is possible to make a conclusion that activity of this work in countries of limited fuel resources is more efficient. Now Russia has rich **natural materials and oil resources but in the short time this advantage will not play any role in development of economy.**

Industrial and defense power of any country will depend on free energy technologies, knowledge on the biologically active energy and reactionless propulsion methods.

The new technology creates not only a new technical systems but also **new economical systems**. It is not physics but policy... Development of great Russian territories with industry of free energy technologies for home and commercial application is the way to change world economical balance in favor of Russia. It is difficult to say now what financial-economical group of modern Russia is most interested in development of this direction of science. The purpose of any financial-economical group is power on the market of energy resources, but when the free energy technologies are developing, then people and industrial or agricultural producers will be more independent from centralized system of energy and oil distribution, therefore, they will be more independent from influences of central authorities.

From the point of view of serious business, there is only one real argument in favor of developments of any really new technology: it should lead to increase of profit and expansion of the market. In this sense, it is possible to compare the new energy technologies with beginning of the steam machine age or with appearance of electric machines and illumination. This means the super profits and serious fight with competitors. To develop this way any efforts of scientists are not sufficient work. It is necessary to join them with the efforts of large business structures, which are interested to create new market of energy and power engineering in parallel to present monopoly fuel-energy market or to develop commercial exploration of space by means of new propulsion principles. In particular, telecommunication space satellites and projects on colonization of space could be the nearest commercial directions of the new market.

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Attachment 1

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Attachment 2

Organizations

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- The Russian Physics Society, 141002, Moscow reg., Mytishy, B. Sharapovskaya str. 3. Fax 095-2926511
- Academy for Future Sciences, P.O. Box FE, Los Gatos, CA 95031, USA.
- AERI, Advanced Energy Research Institute, 14 Devonshire Mews West, London W1N 1Fp, Great Britain.
- ADAS, Association of Distinguished American Scientists, P.O. Box 1472, Huntsville, AL 35807, USA.
- Borderland Sciences Research Foundation, P.O. Box 429, Garberville, CA 95440-0429, USA.
- Center for Action, P.O. Box 472, HCR 31, Sandy Valley, NT 89019, USA.
- Electrodynamics Gravity, Inc., 35 W. Tallmadge Ave., Akron, Ohio 44310, USA.
- Fusion Information Center, P.O. Box 58639, Salt Lake City, Utah 84158-0369, USA
- Gravity Power Research Association, 36 Mountain Road, Burlington, MA 01803, USA.
- GRI, Group Research Institute, P.O. Box 438, Nelson, New Zealand. Dr. Ashley Gray.
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- INE, Institute for New Energy, 1304 South College Avenue, Fort Collins, CO 80524, USA.
- Integrity Institute, 1377 K Street, NW, Suite 16, Washington DC, USA. Fax 202-543-3069.
- Orgone Biophysical Research Laboratory, Inc., P.O. Box 1395, E1 Cerrito, CA 94530, USA.
- Quantum Biology Research Laboratory, P.O. Box 60653, Palo Alto, CA 94306, USA.
- SEA, Space Energy Association, P.O. Box 11422, Clearwater, FL 34616, USA.
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- Methernitha, 3517 Linden, Switzeland. Manager Francis Bosshard.
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Some General Properties of Matter and Energy Sources

Devoted to memory of Academician A.A. Harkevich

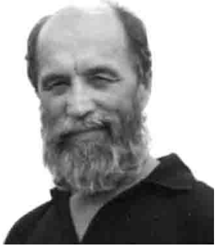

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Introduction

Nowadays there are appear more and more attempts to disclose new methods of obtaining energy from the ambient space, i.e. from heat, electromagnetic, gravitational fields, physical vacuum, aether, etc. (See, for example, publications in New Energy Technologies [1-3]). The publications demonstrate that researchers meet various incompletely investigated physical processes. These scientific areas are difficult to be investigated. All this makes obstacles for development of works on creation of new energy sources. **In this work there is made an attempt to demonstrate general properties of energy sources of any physical nature. This attempt is based on a general analysis of properties of matter.** A theory of transformers is used to investigate general properties of matter.

Action of all physical, technical and biological systems is expressed in energy transformation. Numerous theories based on particular (specific for some system) methods are applied for description of these systems. However, if the number of degrees of freedom and of elements inside a system increases then many theories are not able to describe operation of the systems. First these problems appeared in electrical engineering, radio engineering, automation and acoustics. The theory of transformers is applied to these fields of science. The theory represents a complicated system as a “black box” having several inputs and outputs. Operation of the numerous elements occurring inside the box is represented as some equivalent functions reduced to the inputs and outputs.

In the last decades methods of solution of mechanical dynamic tasks by the method of complex resistances are developed as well as representation of elements as linear transformers [11] and finite elements in liquid [14]. This tendency can be applied to the mechanics of liquids and gases. Now there are successfully developed those concepts which assume observation of models having very few degrees of freedom to be enough for analyzing processes in hydrodynamic systems [10]. However, a mathematical apparatus for description of transformers operation which is well-developed in these areas of science and engineering has a special view and is applicable only for these scientific areas.

Academician A.A. Harkevich developed a theory of a linear transformer up to the level of the general theory of transformers which is applicable for transformation of any types of energy [24]. The general theory of transformers proposed by A. A. Harkevich is applicable for description of various energy sources, flying and swimming objects, functioning of different animals’ organs, and technological processes. In this work some general properties of matter and energy sources are investigated, according to the general theory of transformers.

General theory of energy transformer

The whole ambient space, from the microworld to the macroworld, is filled with energy. According to different theories, space is represented as a compact medium (i.e. having distributed parameters) or a medium consisting of a limited number of discrete elements (i.e. having concentrated parameters). On the analogy of hydrodynamics [10, 14] the compact medium can be represented as an equivalent system with a limited number of degrees of freedom. Hence, the whole space can be represented as some system consisting of elements and communications between the elements with a limited number of degrees of freedom. Energy exchange occurs due to the degrees of freedom. Energy transmission occurs if energy gradient is presented in the ambient space. Due to the energy gradient a force tends to realize transmission in the space [4]. The elements can be systems as well.

Hence, the more we observe dividing the elements on the systems and the systems on the elements the more we will penetrate into the microworld (i.e. atoms, elementary particles, physical vacuum, aether, etc.). The more we combine the elements in the systems, and the systems in the new larger systems the more we observe the macroworld (the Solar System, galaxies etc.). All the systems and the elements are interconnected. The systems and their elements are transformers of energy. Energy motion occurs in the smallest part of space. Consequently, the whole space can be represented as a system consisting of the energy transformers. In the general case due to every type of energy limits of a transformer consist of outer limits (i.e. communications with the macroworld) and inner limits (i.e. communications with the microworld). Dividing into the macroworld and the microworld occurs in relation to the size of a transformer for every type of energy. Types of energy coming through communications of a transformer and inside it may differ, i.e. mechanical, heating, electromagnetic, chemical and other known and unknown types of energy.

The processes in which a great number of interacting elements and different types of energy participate are very complicated and do not allow describe the processes accurately by modern mathematical methods. Hence, there is a problem to find such methods of solution of the tasks which without disclosing all the communications inside the element can give the understanding of the way an element moves in the system. The following premises can be made for the method of solution of the task of a system and its elements' motion:

1. Motion of all the elements in the space is characterized by energy exchange occurring among them;
2. We are interested in a certain limited area for every individual type of energy. The chosen limited area will be called as **a transformer**;
3. The transformer has degrees of freedom both on its limits (sides) and inside it (inner degrees of freedom);
4. Further this limited area (the transformer) which has or is able to have a limited number of degrees of freedom (sides) at its limit will be observed;
5. Interaction between this transformer and the ambient space occurs only through these degrees of freedom (sides) by means of energy exchange;
6. Motion of energy between the elements of the transformer occurs according to its degrees of freedom inside the transformer. There can be a limited or unlimited number of degrees of freedom.
7. All the space is full of the transformers. All the transformers adjoin each other without gaps. Energy exchange between the transformers occurs through their sides which do not have a size but reflect general kinematical and dynamic characteristics of the energy transferred through these sides.

Editor: The full variant of the article includes mathematical description of operation of energy transformers which is followed by these conclusions:

- There can be any number of different types of elements having a corresponding number of degrees of freedom and any type of energy inside the transformer. However, on every side of the transformer a generalized force has the same value and depends only on change of energy according to this degree of freedom. Therefore, two transformers are considered to be equal if the generalized forces (energy changes) on all the sides are equal. In this case it is not necessary for the inner structure of the transformer, number of inner degrees of freedom, and energy types of these two transformers to be equal. This is **a principle of equivalency of transformers at the equivalency of the forces acting at the sides of transformers**.

- In the general case the generalized force at any side depends not only on energy exchange occurring at this side but on energy exchange occurring among the sides or at other sides of the transformer. The generalized forces are produced by energy distribution in the space.
- A transformer is characterized by the fact that there are different types of energy at its different input sides (or the energy can be of the same type but having other characteristics of motion).

Resistances of the interaction provide information about physical properties of the transformer, in particular, about physical interaction between the sides. At that a number of inner degrees of freedom in this transformer as well as the reactions at the other sides do not play any role. Proper resistances of the sides and resistances of the interaction provide information about inner physical characteristics of the transformer reduced to equivalent values at the sides. Hence, it is possible to have two transformers having equal equivalent resistances of interaction for all the sides. However, according to their geometrical and constructional characteristics and types of energy, the transformers will be different. The resistances may be a function of kinematical characteristics **(a nonlinear transformer)** or of time **(a parametrical transformer)**. Moreover, it can have constant values **(a linear transformer)**.

It is appropriate to consider physical properties of matter included in the volume of a transformer only due to resistances at the sides of the transformer.

Structure of the transformer

Every inner degree of freedom can be represented as a series circuit. By analogy with electric circuits [6, 7, 11, 16-18] the transformer can consist of various circuits. An unlimited number of degrees of freedom allows represent a transformer consisting of an unlimited number of chains. The circuits have series, parallel, or mixed junctions. A part of a circuit whose elements have the same generalized displacement is called as a branch. The branch can consist of one or several elements. A place where three or more branches are joined is called as a multiple junction. A circuit is considered to be a closed path including several branches and multiple junctions. All the elements of a chain connected in series have equal generalized displacement (as well as equal speed and acceleration). The generalized force acting on the whole circuit is equal to the sum of forces acting on the elements of the series circuit.

The elements connected in series can be replaced by one element in such a way that the generalized displacement and the summary generalized force would not change. In the case of a parallel connection all the branches of the circuit are joined to the same pare of multiple junctions and are under influence of the same generalized force. Parallel circuits can be replaced by series equivalent circuit and vice versa [6, 7, 11, 17, 18]. Hence, a number of inner degrees of freedom and a quantity of chains may be decreased as well as increased. In this case resistances occurring on all the sides will be constant.

Structure of the linear transformer

The simplest transformer is a one-side transformer having one inner degree of freedom…

If to the input of the transformer we deliver generalized displacement (or force) which depends on time as a pure sinusoidal signal then the linear transformer will have sinusoidal reaction of the same frequency. For the sinusoidal signal with fixed frequency the linear transformer (including a transformer having an unlimited number of inner degrees of freedom) can be represented as an equivalent transformer reduced to this input as one chain. An equivalent transformer placing at this input at other fixed frequency of sinusoidal disturbance will be represented as a chain having one degree of freedom but different values of chain elements.

If the signal at the input of the transformer is of complicated time-periodical form then it can be decomposed to Fourier series. Every harmonics of the Fourier series will produce its own chain. The general complicated signal will produce the complex chain consisting of compound sum of elementary series chains. This complicated chain consists of elementary chains interconnected in series or in parallel and combined in multiple junctions and circuits. The construction principles of this complicated chain can be based on methods of identification and synthesis which are well developed in electrical engineering, automation for linear and non-linear transformers [9, 12, 13]. These principles are formally useful for transformers which transform energy of any physical nature. Identification produces so much elementary chains as the number of inner degrees of freedom. Every elementary chain reflects motion by one inner degree of freedom. Physical analogy occurring among motions of different nature is actual here [11, 16, 18]. Values of the generalized masses, elasticities, dissipative and active elements can depend on kinematical variables (non-linear chains), on time (parametrical chains), or they can be constant (linear chains).

If a series circuit includes mass and elasticity then it will have resonant frequency. At this frequency reaction of mass and elasticity will be absent in the summary reaction. It is equal to the fact that we will know nothing about the value of mass (and elasticity) and, moreover, about its presence at all. The mass can have huge value, but it will be absent for us. Hence, if we assume a transformer as an atom then the atom may include elementary chains having huge masses (much more than the mass of the Earth), but we will not know about it until we apply such frequency to the input which explicates this mass.

Any energy transformer including a transformer with distributed parameters can be represented as a system of elementary series and parallel chains connected in a certain way. A concrete transformer can have various types of these connections. All of them can be included into another combination of connections that is accompanied by change of values of masses, elasticities, dissipative and active elements. However, in this case equivalency of reaction should be fulfilled at a certain diapason of frequencies on all the sides of the transformer.

There is a special spectrum of resonant frequencies for every combination of connections of the transformer. There will be an unlimited number of degrees of freedom and, hence, an unlimited number of resonances for the transformer with distributed parameters (for example, an elastic nail, a compressible fluid having a limited size). Our influence on the transformer usually has a certain diapason of frequencies. As the result of a limited diapason of excitation frequency the transformer will represent a system having a limited number of inner freedom, even if the transformer has distributed parameters.

Values of equivalent elements depend on oscillation frequency. Moreover, according to known laws, several parallel circuits can be transformed into a series one and vice versa. Taking it into account the following conclusions can be made:

1. The generalized mass, elasticity and dissipative elements do not have constant values in nature. Their value depends on frequency of the process, i.e. they depend on the character of time-change of the disturbance acting on the transformer.
2. The generalized mass, elasticity and dissipative elements are products of time-space change of energy.

Types of energy transformers

Transformers can be nonlinear, parametrical and linear. The transformer can be **active** (having an internal source) and **passive** (having an external source). The passive transformer can never be an energy source (by definition). A transformer can accept or transform one type of energy (monoenergetic transformers) or several types of energy (polyenergetic transformers). The polyenergetic transformer includes a mechanism and corresponding elements and chains which allow transform one type of energy into another one. Fundamentally, all the transformers are polyenergetic transformers of energy, however many of them can be represented as monoenergetic ones since other types of energy participate weakly in them. Designing a transformer it is more convenient to put the energy source out the transformer. Let us further classify the passive transformers.

The passive transformers can belong to the following types:

1. Simple transformers

In this case energy is produced at the output due to transformation of energy coming to the inputs into energy of another type or having other characteristics. The following transformation can serve as the example.

An electric transformer: resistance of one value comes to the input, and the resistance of another value comes from the output (a type of energy is the same).

A furnace for combustion of fuel: energy of chemical connections comes to the input and heating energy comes from the output (energy of radiation may be neglected).

A Wind Generator, Hydroelectric Power Station: kinetic energy of moving air or water comes to the input, and electric energy comes from the output.

2. Energy intensifiers

In this case a transformer intensifies energy coming to one of the inputs due to energy coming to the other inputs (or to the other input). Below there is an example for a *monoenergetic transformer*. Energy (an electric signal having certain parameters) comes to the input of a transformer, and the output energy has the same characteristics but it is more intensive. It can occur due to electric energy coming to the other input of the transformer.

A heat pump represents an example for a *polyenergetic transformer*. Low potential heat energy of the ambient space (air, water, ground) comes to the input of the heat pump, and electric energy from a power network comes to the other input. The output heat energy has value which is equal to the sum of the coming heat energy of the ambient space and electric energy coming from the power network through the electric engine of the compressor. The output heat energy excesses energy coming from the power network by several times. The output energy is always lower than the sum of the low potential heat energy and the electric energy coming to the input. Hence, the output of a heat pump is always less than unit.

Efficiency of the heat pump consists in the fact that a consumer pays for electric power produced by power network only (use of the low potential heat of the ambient space is free). However, the output heat energy is several times more than the energy which can be produced by the electric power coming to the input.

3. Active oscillator

An active oscillator is a device of a certain type. Energy of time-constant characteristics comes to its input, and at output there is energy of time-periodical characteristics. Energy with time-periodical characteristics can come to the input as well since these characteristics are not connected with the time-periodical characteristics of the output energy. The transformer can operate in a mode of an active oscillator if it has the following features:

1. Indirect connection as a series circuit: one of the outputs is connected to an additional transformer whose output is connected to one of the inputs of the transformer. The additional transformer provides certain changes of the input signal (time delay).
2. Energy comes to the input (it can be time-constant or time-periodical).
3. The transformer must have a certain type of non-linearity.

Examples of the active oscillator

Internal combustion engine: the indirect connection is the system of combustion, the non-linear element is the system of admission and exhaust valves, and the energy source is energy of chemical connections of fuel.

Various electric generators: all of them have the indirect connection, the non-linear element, and the energy source.

The active oscillators differ from the electrical intensifiers qualitatively. The difference consists in the fact that the active oscillator can operate and receive energy from the ambient space without additional energy coming to it (from a power network, for example).

Theorists and experimenters try to create a self-supporting self-organizing system in their works on creation of alternative sources. This fundamentally correct tendency requires using theory of active oscillators. There is the developed theory in electrical engineering, automation, and other scientific fields [25]. To simplify application of these theories it is necessary to use analogy between equal processes which take place in different physical fields.

4. Rectifiers

Time-periodical energy comes to the input of the transformer. The output energy has time-constant or practically time-constant characteristics. If the transformer has a non-linear element or elements of a certain type (a diode or a one-sided valve) then it can operate in the mode of a rectifier. The examples are electrical rectifiers and pumps of a valve type.

Properties of energy transformers

General properties:

1. A transformer can transform energy of one type as well as transform one type of energy into another type.
2. The generalized kinetic, potential and dissipative energies are specific peculiarities of energy change in the space and time.
3. The generalized masses, elasticities and dissipative elements are products of energy change in space and time.
4. Values of the generalized masses, elasticities and dissipative elements (existing inside the transformer as well as reduced to the equivalent values on the sides of it) depend on a temporal character of changes of kinematical or dynamic disturbances. Values of the generalized masses and elasticities at the sides of the transformer are lower than the corresponding values inside the transformer.
5. Energy interchange between macrostructures and microstructures can occur through a transformer.
6. One area of space can "know" about another area of space through energy exchange only, i.e. through generalized dynamic and kinematical interactions. In the light of the fact that chains of different transformers can have similar physical properties (for example, an equal resonant structure) interference of these transformers seems to be possible including interference occurring at a great distance.

Properties of the passive monoenergetic transformer:

1. Transformation of characteristics of the same energy type.
2. The output energy can be both equal or lower than the sum of energies coming to all the inputs. The sum of the output energies decreases due to dissipative losses occurring inside the transformer.

Properties of the passive polyenergetic transformer:

1. One energy type coming to an input can be transformed into another energy type coming from the output.
2. The sum of energies of all the outputs can be equal to the sum of energies of all the inputs or less than it. The sum of the output energies decreases due to dissipative losses occurring inside the transformer. The output will always be lower than unit. If the energy coming from certain of the outputs (within the limits of one output) is considered as a positive effect then the output will be less than the mentioned value.
3. Energy of one and the same type comes to the input and from the output while other energy types can come from other outputs. This property can allow increase one type of energy coming from an output at the expense of the other types of energy coming to the inputs.

Analysis

This article is aimed to provide general properties of the energy transformers and to analyze some problems of creation of renewed energy sources, according to these properties. There are made various attempts to design a renewed energy source which would produce energy without fuel consumption. In the light of the above mentioned results, the researches on creation of the renewed energy source may be represented by the following way. Energy can be produced from the macrostructures and the microstructures.

In the case of the macrostructure, energy can be produced by a simple transformer, an electric intensifier or an active oscillator. Methods of production of energy from the ambient space by means of simple transformers (thermoelectric and hydroelectric power stations, wind generators, etc.) are developed sufficiently by the humankind. Works on producing energy from the ambient space by means of energy intensifiers are on its initial stage. Heat pumps, which utilize low potential heat energy by means of Freon-compressor heat pumps, are successfully introduced. One of the perspective approaches is replacing such a heat pump by a vortex oscillating heat pump which does not contain Freon and a compressor [3, 5, 19, 22]. In future it will be possible to replace the energetic pump by a new energy transformer of the type of an active oscillator. In this case the energy source will always obtain energy from the ambient space without using additional energy from a power network. Energy sources of the type of the active oscillator are internal and external combustion engines, stream engines, etc.

In the general case a transformer can contain different energy types and has communications with **outer microstructures**. It should be noted that the outer microstructures can be included in the geometrical size of the transformer. Energy of this microstructure can be huge; hence, this energy can be obtained from them for a very long period of time. Atomic reactors can serve as an example for this fact. The types of energy in these microstructures can be represented by known types (electromagnetic energy, nuclear energy) and unknown types (whose numerous quantity can be considered). These energy types exist in the ambient space. However, almost all the transformers of energy produced by a human (except the nuclear reactors) do not interact with the energies, and we do not obtain energy from these microstructures.

The task of creation of a new energy source consists in designing such an energy transformer which could obtain energy from the microstructures and transform it into the type of energy which is needed to a consumer. In this case all the designed transformers will not have over unit output. Efficiency of these transformers will be defined by the cost of the energy produced by them. This energy depends on a ratio of energy coming to one of the inputs (electric power) (for example, in heat pumps) to the output energy. If the output energy is much more than the artificial energy which comes to one of the inputs then this transformer can be very useful for a consumer.

New high effective energy sources are often claimed to be created. According to the observed facts, existence of such sources is practically possible. Nevertheless, realization of this source will depend on our knowledge of physics of the microstructures and methods of transformation of energy of the microstructures into such type of energy which can be used by a consumer. Physics of microstructures is investigated badly, and many types of energy are totally unknown. Therefore, modern scientists try to create the new energy sources at random. In this case the following results can be achieved:

1. The high effectiveness of an energy source (over unit output) does not correspond to reality.
2. The output energy of the energy source is actually higher than the input energy (the source of the energy intensifier type).
3. The energy source actually produces energy without artificial input energy (the source of the active oscillator type). It can occur if an inventor failed to recognize the source of energy coming from the microstructures. It can be connected with particular or total lack of exploration of physics of the microstructures. Moreover, the fact is caused by transcendent difficulty of disclosing energy sources from the macrostructures.

Conclusions

It is principally possible to create an energy source whose output energy would be higher than its input energy (an energy intensifier) or an energy source which would produce energy without additional input energy (an active oscillator).

1. Various energy sources or transformers of energy of the macrostructures and microstructures can be designed.
2. Practical value of the energy source is defined according to cost of its output energy instead of the output value.
3. Designing new energy sources it is useful to consider them from the point of view of transformers. It is worth to define all the communications of the transformer and to state experimentally energy at all the accessible communications of the transformer.
4. Developing theories of sources it is expedient to use physical analogy and to take into account ready results of works on theories of transformers, chains, etc. of electrical engineering, radio engineering, automation and other scientific fields.
5. In the light of the fact that it is planned to obtain energy from the microstructures it is necessary to pay attention to new probable types of radiation and to their influence on a human.

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Commercial Exploration of Space

Review
by Olga Leontyeva, Editor
http://www.faraday.ru

Of late years the mankind has greatly advanced in space exploration. New spaceships are created, automatic apparatus are launched to the planets of solar system, space stations are orbited. A man has passed to outer space and begun exploring the planets of solar system. More and more specialists and people of different professions are involved in the development of space industry. However to present day only a few of them has succeeded flying into space.

At the present state of affairs space flight is very expensive and a serious reason should exist to forward a man into space if he or she does not relate to the aims of professional cosmonautics. However in last years there has appeared a certain breakthrough in the solving of the problem. Nowadays space technologies gradually turn from the sphere of experimental and scientific researches to the area of practical application. The time has come for a man to realize the real space flight without being the professional cosmonaut.

What are the ways to solve the problem? No doubt that special attention should be paid to the development of new space technologies, search of new types of fuel and attraction of investments to the sphere of space tourism.

April 28, 2001 can be considered as official date of birth of space tourism, when there was launched the space ship "Soyuz TM-32" with the first space tourist aboard. Almost in a year, on April 25, 2002 the space tourist #2 South African Republic person Mark Shattlword started on his space journey.

Today many companies give the opportunity to make a real space flight for all comers who have enough money and health. It is promised the providing of the most modern space technologies and the most perfect space equipment. It can be created a furor by the "Minimum program" of the Russian company "Atlas Aerospace" which is made by the members of Yu.A. Gagarin Center of training of cosmonauts.

In recent years at the international market there appear more and more companies which deal with search and encouragement of inventors who work on creation of alternative propulsion systems. Activity of "X Prize Foundation" company can be considered as an example.

The X PRIZE Foundation

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http://www.xprize.org
E-mail: press@xprize.org

The X PRIZE is a $10,000,000 prize to jumpstart the space tourism industry through competition between the most talented entrepreneurs and rocket experts in the world. The $10 Million cash prize will be awarded to the first team that:

- Privately finances, builds & launches a spaceship, able to carry three people to 100 kilometers (62.5 miles)
- Returns safely to Earth
- Repeats the launch with the same ship within 2 weeks

The X PRIZE competition follows in the footsteps of more than 100 aviation incentive prizes offered between 1905 and 1935 which created today's multibillion dollar air transport industry.

For more than 30 years, the general public has waited for an opportunity to enjoy the space frontier on a first-hand basis. The X PRIZE Foundation is working to make space travel possible for all. The spaceships that compete for the X PRIZE are designed to carry passengers.

Since its inception in May 1996, the X PRIZE Foundation has registered more than 20 teams from seven countries to compete for the prize. The X PRIZE is fully funded through January 1, 2005, through private donations and backed by an insurance policy to guarantee that the $10 million is in place on the day that the prize is won. Additional funds are still being raised by the X PRIZE Foundation to implement the competition (judging, media, event management, etc.) and continue the Foundation's education mission.

The X PRIZE was inspired by the early aviation prizes of the 20th Century, primarily the spectacular trans-Atlantic flight of Charles Lindbergh in The Spirit of St. Louis which captured the US $25,000 (US$) Orteig prize in 1927. Through a smaller, faster, better approach to aviation, Lindbergh and his financial supporters, The Spirit of St. Louis Organization, demonstrated that a small professional team could outperform a large, government-style effort.

The Societal Benefits of the X PRIZE include:

* Creation of a new generation of heroes
* Inspiring and educating students
* Focusing public attention and investment capital on this new business frontier
* Challenging explorers and rocket scientists around the world; and,
* Vehicles built for the X PRIZE will eventually serve four different industries:
- Space Tourism
- Low-cost satellite launching
- Same-day package delivery
- Rapid point-to-point passenger travel.

In Fig. 1 it is demonstrated the typical X Prize trajectory.

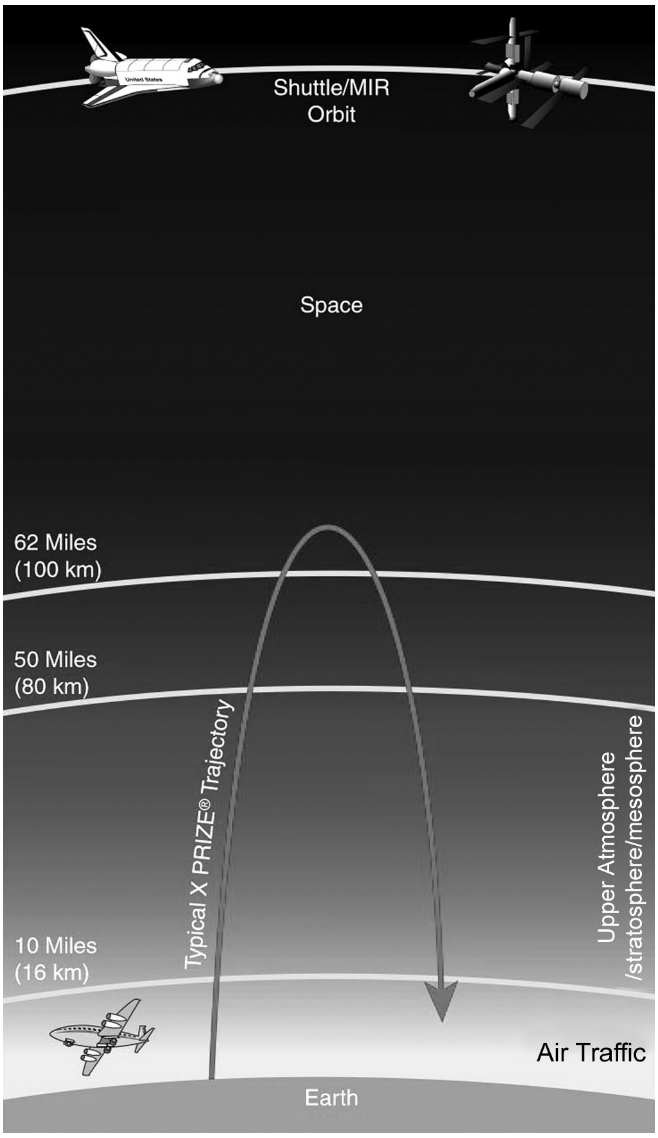

Fig. 1

Editor: Below we publish photos and brief comments about some official X PRIZE registrant teams. More detailed information you can find at http://www.xprize.org/imagefacts/photo1.html.

The Da Vinci Progect

http://www.davinciproject.com

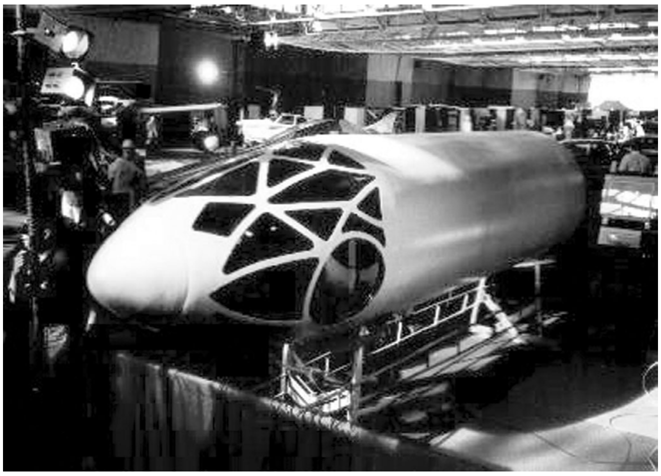

Fig. 2
“Wild fire”

The **da Vinci Project** will launch its spacecraft (“Wild Fire”) from the world’s largest helium balloon. The 3,270 kg (7,200 pound) rocket will be tethered 720 meters (2,400 feet) below the balloon and lifted over the course of an hour to an altitude of 80,000 feet. The 10,000 pound thrust, liquid oxygen, kerosene engines will fire the first stage and the rocket will fly an initial angular trajectory to clear the balloon. The spacecraft then will transition to vertical flight to its apogee of 120 km in space. The rocket will reach a maximum speed on both its ascent and re-entry of Mach 4, or 4,250 kph (2,650 mph).

An innovative ballute will protect and stabilize the rocket on re-entry. A flyable parachute will be deployed at 25,000 feet and the rocket will descend under control, guided by GPS, to a predetermined landing zone. The da Vinci Project has already successfully conducted full-scale rocket motor test and has built a full-scale mockup of their vehicle.

“Discraft” corporation

http://www.xprize.org/teams/teams.html

John Bloomer, the team leader, is an aerospace engineer and he has worked on many aerospace progects, including Apollo and holds more than 60 patents on a disc plattorm aircraft. Bloomer’s ship utilizes “Blastwave” Pulsejets.

Flight Sequence

Fixed, 7850-ft^2-area, laminar-flow wing take-off at about 60 mph within about 150 ft, featuring climb with gradual air-breathing acceleration (according to a fixed program) at fixed angles, to exit the atmosphere at Mach 10 on an unpowered ballistic arc to reach 75-mi. altitude: return on down-leg of same unpowered arc to gradual power-on flare-out re-entry of the atmosphere in simple reverse sequence of the take-off velocity profile. Range above 100,000 ft is about 480 mi. which is covered in about 5 minutes.

"Kelly Space & Technology"

http://www.kellyspace.com

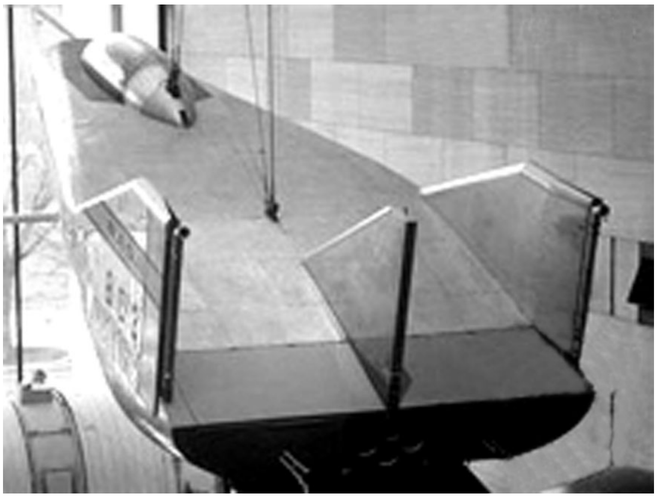

Fig. 3
"LB-X"

The vehicle is a rocket-powered delta wing glider with a liquid oxygen and kerosene liquid rocket engine. The spacecraft is prepared and fueled at the takeoff airport. The spacecraft is towed to release altitude behind a conventional jet powered aircraft such as Boeing 747 aircraft. Upon release from the tow aircraft, the main engine is throttled up for boost phase. The vehicle nominally coasts to an apogee altitude of 100 kilometers. The vehicle then glides to a landing at the takeoff airport for checkout and refueling prior to the next flight.

Flight Sequence

The lifting body will be towed to launch altitude behind another aircraft, and the rockets will be ignited. The craft will return to the landing site and make an unpowered, horizontal landing.

"Lone Star Space Access"

http://www.dynamicar.com

The Cosmos Mariner employs air-breathing jet propulsion for take-off and landing from conventional airports and rocket propulsion for ascent from cruise flight in the stratosphere to 30 or 40 nautical miles altitude. From there, the vehicle coasts to a target altitude of around 65 nautical miles. The air frame is designed to interface with two jet engines (turbofan or turbojet) each with 20,000-lbs static thrust or less. For rocket propulsion, the Cosmos Mariner will use the Aerojet AJ26-NK31A, a staged-combustion kerosene engine. The vehicle is designed to take off and land from conventional runways.

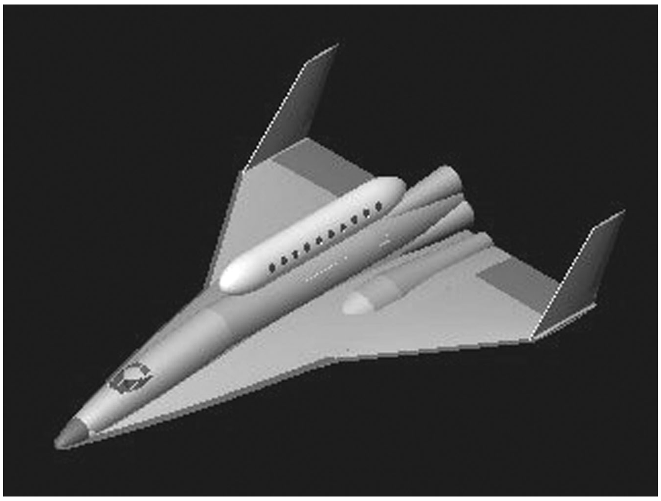

Fig. 4
"Cosmos Mariner"

*Along with X Prize Foundation it should be mentioned **ALLTRA** Company (Germany). ALLTRA consists of a small group of space experts. The main objective of ALLTRA is to 'sell' the space idea to a broad public and to identify future commercial opportunities in the space sector.*

On the official ALLTRA website http://www.alltra.de you can find collection of artist's views of the projects which are aimed at decrease in space ships value by means of using of new types of engines. Besides the Company deals with the development of space hotel projects.

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collection of articles
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Alternative Aircrafts and Space Propulsion Systems

Editor: Nowadays all over the world there are made numerous attempts to create new types of aircrafts and alternative space propulsion systems. Below we publish the review of some interesting devices which are presented in the modern market.

"Arbortech Pty.Ltd"

http://www.airboard.com.au

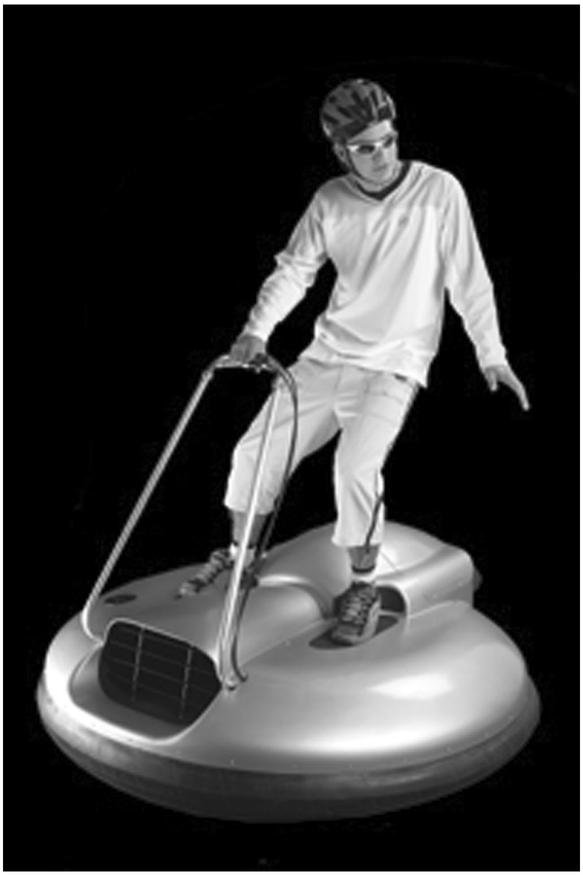

Fig. 1
Airboard 2000

General Technical Specifications

Total payload, including rider — 100 kg (220 lb)
Operating time — 1 hour on full tank of fuel
Construction — Fiber glass/High-impact plastic shell, Aluminum frame, Rubber skirt
Starting — Electric key-start, Battery included
Engine — Briggs & Stratton 4-stroke
Fuel tank capacity — 5 litre (1.3 US gal)
Fuel type — 85 Octane unleaded

How does it work?

Airboard uses Hovercraft air cushion principles to glide just above the ground. The air cushion is generated from a purpose designed engine and fan which are suspended below the Airboard shell. In addition to providing an air cushion for the Airboard to ride on the fan also provides a fast stream of air exiting from the rear of the craft to provide forward thrust – just like a hovercraft. To help provide better acceleration the Airboard also includes a unique friction drive wheel at the rear. When the rider wishes to accelerate forward, weight transfer is used to bring the friction drive into contact with the ground. By engaging the friction drive clutch the Airboard can be accelerated forward without losing the feel of hovering above the ground. The control of the Airboard is provided by weight transfer of the rider, similar to surfboards, skate boards and snow boards. In operation the Airboard can be started, stopped and steered in a controlled manner and this means that riders can perform stunts, trick maneuvers and race around tight tracks against each other. In this unique way the Airboard is the first ever vehicle to deliver the advantages of hovercraft vehicle without the disadvantages of proof acceleration and handling.

"Trek Aerospace, Inc."

http://www.solotrek.com

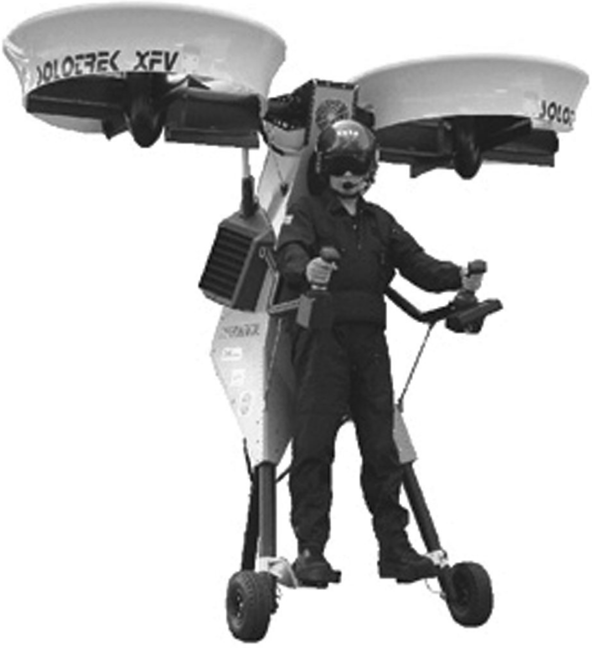

Fig. 2

Trek Aerospace

Preliminary Specifications and Predicted Performance

Normal Gross Take Off Weight	800 Lbs.
Fuel (15 U.S. Gallons)	98 Lbs.
Mission Payload, net of fuel	352 Lbs.
Takeoff/Landing Distance	0 (VTOL)
Maximum Speed	70 Mph
Range	120+ Miles
Hover/Loiter Endurance	2+ Hours
Engine Type	Advanced Int. Combustion
Fuel Requirements	Heavy-Fuel or Gasoline

Special Features: 100% fly-by-wire control system with electronic stability augmentation; Intuitive, easy to fly safely; Minimal field service requirements; Rugged, efficient power train.

DM AeroSafe

http://dmaerosafe.freeservers.com

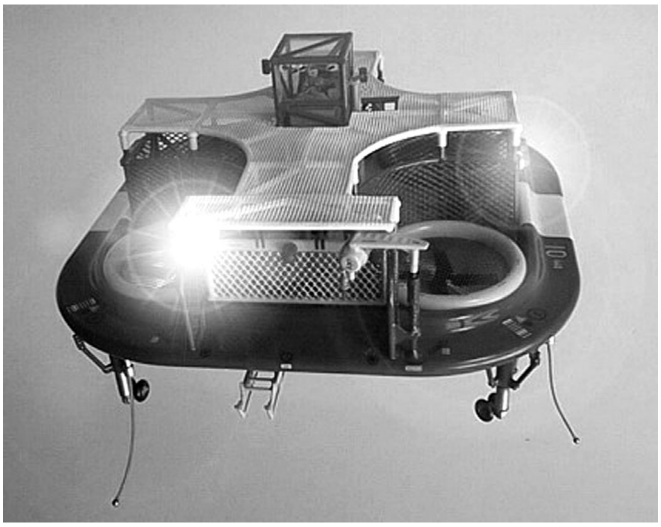

Fig. 3

EAGLE vertical take-off and landing aerial rescue platform

DM AeroSafe is a small research and development team, which has developed a totally new high-rise rescue technology to retrieve trapped people from areas which cannot be reached by conventional aerial ladder, conventional helicopter or a helicopter equipped with a Heli-Basket.

This technology could give rise to a new class of air transportation means, used for safe close-in maneuvering around tall structures, even inside the highly populated areas.

Eagle Aerial Rescue Platform's Performance Summary

Dimensions:

Length - 42 feet (12.8 m)
Width - 42 feet (12.8 m)
Height - 16 feet (4.8 m)

Weights:

Max. Gross weight - 5000 pounds (2268 kg)
Payload (Crew of two plus 10 rescued people) - about 2000 pounds (about 900 kg).

Propulsion System:

Four (4) variable collective pitch Ducted Propellers
Propeller Diameter - 7.8 feet (2.4 m)
Engines - four (4) four-cylinder radial piston aero engines with forced air cooling system 250 hp each (1000 hp total)

Performance:

Max. Duration - about 5 hours without refueling
Max. Airspeed - 40 knots (75 km/h)
Max. operating altitude - about 7000 feet (about 2200 m).

"LTAS/CAMBOT, Inc."

http://www.lvcm.com

Passenger Craft "Ltas 30-Xb"

The ships have rigid monocoque hulls, hybrid powered vectored thrust control and full active buoyancy control. (LTAS US Patent Pending).

This small 2-3 person craft at 70 to 80 feet in diameter will demonstrate ALL production systems and is designed for the LTAS FAA Type Certification program.

NASA's Langley Research Center

http://science.nasa.gov

NASA researchers are studying insects and birds, and using "smart" materials with uncanny properties to develop new and mind-boggling aircraft designs.

The "personal aircraft" that replaces the beloved automobile in people's garages may still lie in the realm of science fiction or Saturday-morning cartoons, but researchers at NASA's Langley Research Center (LaRC) are developing exotic technologies that could bring a personal "air-car" closer to reality.

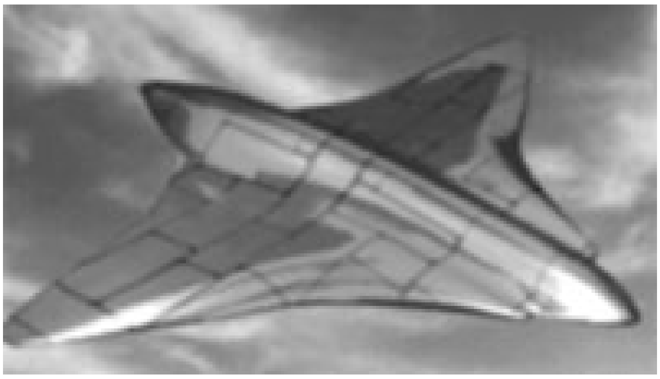

Fig. 4

And air-cars are just the beginning! Self-healing wings that flex and react like living organisms, versatile bombers that double as agile jet fighters, and swarms of tiny unmanned aircraft are just a few of the science-fiction-like possibilities that these next-generation technologies could make feasible in the decades ahead.

Laser Beam Flight

Lightcraft Technologies, Inc. (LTI)

http://www.lightcrafttechnologies.com

Lightcraft Technologies, Inc. is a new company committed to providing low-cost access to space through the use of beamed energy propulsion. (See color photos on the cover page).

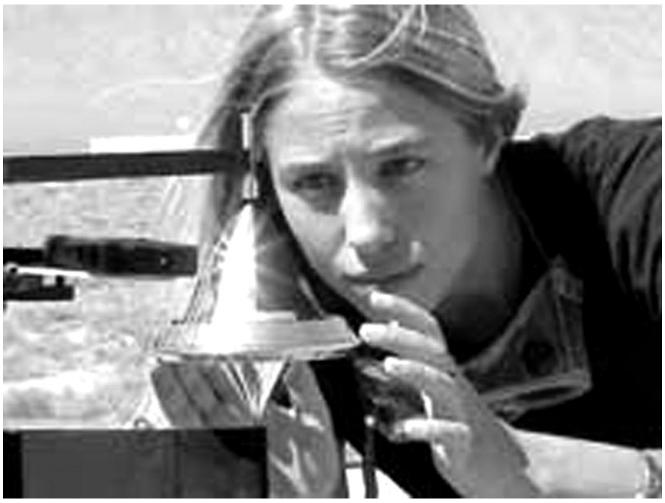

Fig. 1

In 2000 at the High Energy Laser Systems Test Facility (HELSTF), Lightcraft Technologies, Inc. (LTI) set a new world's altitude record of 233 feet (71 meters) for its 4.8 inch (12.2 cm) diameter laser boosted rocket - in a flight lasting 12.7 seconds. Although much of the flight was spent hovering at 230+ feet, the Lightcraft sustained no damage and will fly again. Besides setting the new altitude record, the craft demonstrated the longest ever laser-powered free flight and the greatest "air time" (i.e., launch-to-landing/recovery). LTI launched a total of seven vertical flights between 8:30 am and 11:30 am with three Lightcraft weighing less than 1.8 ounces (51 grams). Two of the flights by Lightcraft #3 reached 159 and 184 feet with the same propellant load!

...set a new world's altitude record of 233 feet!

The record flights were powered by the 10 kW pulsed carbon dioxide laser named "PLVTS" by the organization that owns it: the Directorate for Applied Technology, Test and Simulation (DATTS). Even though PLVTS was suffering from an arcing or grounding problem that caused it to run erratically, the laser power was still adequate to propel the craft to record altitudes.

What is a Lightcraft?

A Lightcraft is a 1kg launch vehicle, made from high temperature ceramic materials, that flies into space on a megawatt laser beam.

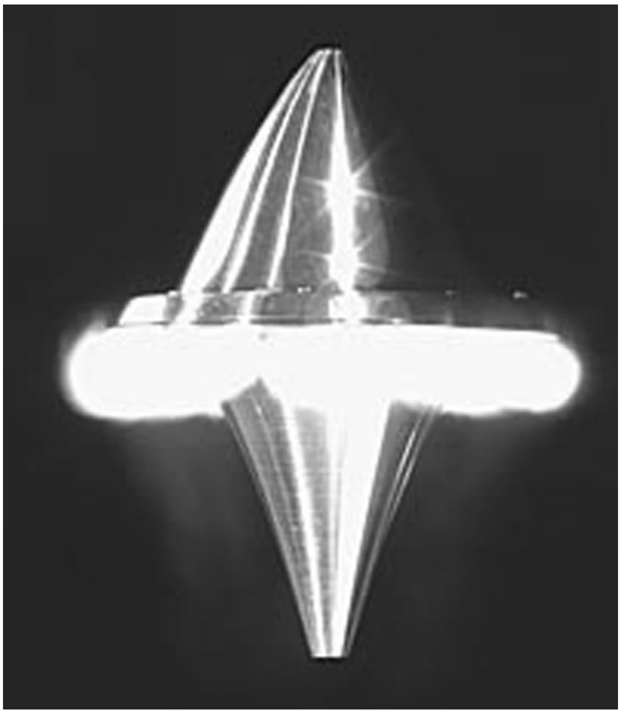

Fig. 2

The Lightcraft is both a single-stage-to-orbit launch vehicle and a satellite. If you have any further questions or comments, write or call LTI headquarters in Bennington, VT. The company representatives would be delighted to send you more information, or answer any inquiries over the phone.

How does it work?

A ground based laser is the power source that propels the Lightcraft into orbit. Lightcraft can deliver payloads into space for a fraction of the cost of traditional rockets because most of the engine stays on the ground, thereby unburdening the craft from having to lift the energy source for its propulsion system.

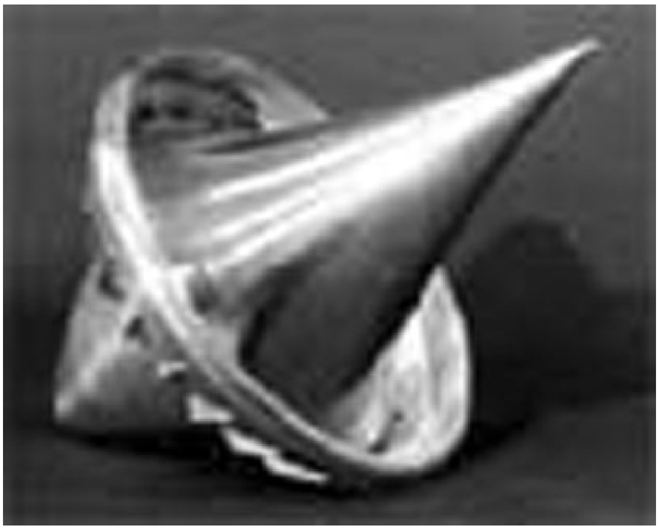

Fig. 3

The back side of the craft is a large, highly polished parabolic mirror that is designed to capture the laser beam projected at it from the ground. The mirror focuses the beam, rapidly heating the air to 5 TIMES the temperature of the sun, creating a blast wave out the back that pushes the vehicle upward. As the beam is rapidly pulsed, the vehicle is continuously propelled forward, on its way to orbit.

History of Lightcraft

1987 — Prof. Leik Myrabo invents Lightcraft for SDIO.

1997 — First successful wire-guided tests at WSMR. Solved flight stability difficulties, much like the Wright brothers did with the airplane.

1997 — Lightcraft broke Goddard's 41 ft., 1926 first successful rocket flight - but this time with no on-board fuel.

1998 — Record flight of 99 ft. with air breathing Lightcraft engine.

1999 — Record flight of 128 ft. with first rocket Lightcraft engine.

2000 — LTI sets new world record for highest flight (233 ft), longest flight time, and heaviest vehicle.

How can LTI reduce launch costs?

Conventional Launch — $175,000,000
The Lightcraft — $46,000

Chemical Rockets:

- carry massive propulsion source on board
- are expendable
- extremely costly
- prone to explosion due to fuel on board

Laser Propulsion:

- propulsion energy source remains on the ground!
- Lightcraft are inexpensive to manufacture and extremely light weight
- highly reusable power source is never subjected to the risks of flight

Lightcraft Technologies, Inc.

1914 Walloomsac Rd.
Bennington, VT 05201
Office: 802-447-6275
FAX: 802-447-8216
E-mail: tmyrabo@lightcrafttechnologies.com

Alternative space propulsion systems Star Drive

Mark R. Tomion, USA
http://www.stardrivedevice.com

Re: U.S. Patent **6,404,089** for the **Electrodynamic Field Generator**, **(EDF),**
issued June 11, 2002 to Mark R. Tomion.

The 'official' name of the "StarDrive device", per the U.S. Patent and international PCT Applications, is **Electrodynamic Field Generator.** The EDF Generator uses banks of permanent magnets and rotating Field Coils to produce a very-high DC rotor voltage, and plane-parallel ring electrode arrays to electrostatically expand and control that voltage *as applied to the hull*, so that huge quantities of external Field electrons may be accelerated to energy levels that are usually reached only with a particle accelerator! It's somewhat like a glorified arc welder whose output is deliberately shorted to its own housing, and the DC voltage and current across the emitter and collector housing sections can be thermionically increased to values that are generally observed only in lightning: but the Field's *current density* is limited to a value which falls short of damaging the hull!

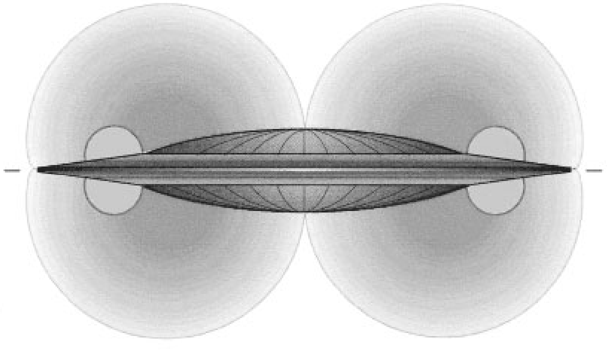

Fig. 1
StarDrive device hull & electrodynamic
Field configuration

As depicted above (Fig. 1), electrons circulating in the external Field envelope can achieve an impact velocity at the central collector sections which is very nearly that of light, and applied magnetic fields allow broad modulation of the Drive Field current's properties. The *Primary Arrays* shown in the generalized schematic diagram below (Fig. 2) have control grids which allow an arc resistance imbalance to be imparted to the otherwise symmetrical Field current, so that they *render the two relativistic current impulses variably non-isometric:* thereby yielding thrust that is essentially **reactionless**! And the simple DC *Primary Power System*, like the early Faraday disk dynamo, *is wholly rotor-based* **. . .**

Note: It can be seen that the propulsive thrust developed by a StarDrive vessel is essentially brute-force in nature – it's produced simply by means of a controlled variable imbalance in the continuous *physical impact* of the two external hemitoroidal electron current streams with the collectors! If these two Field currents were of equal magnitude, no net force would be developed. However, if the "lower" current stream is stronger than the "upper", the vessel will be propelled away from the stronger current – in the "upward" direction. Since there's no 'backward' exhaust produced in the process, this type of thrust is truly and demonstrably reactionless in nature.

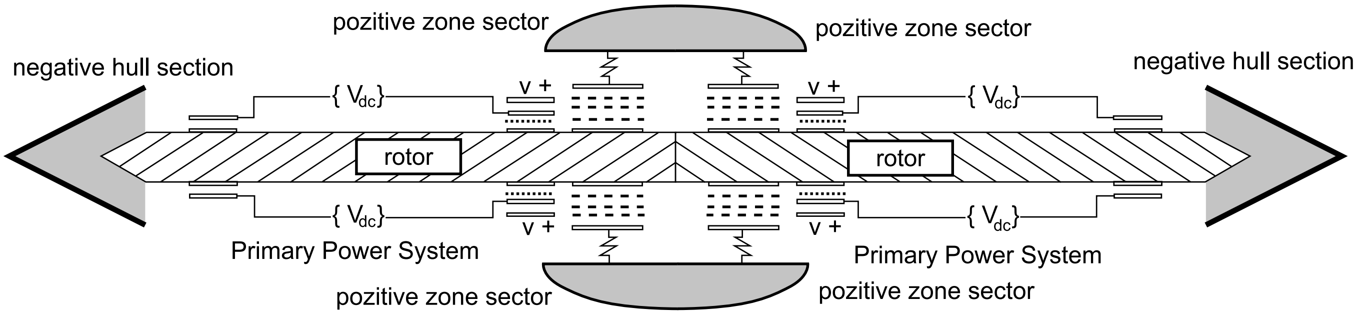

Fig. 2
Generalized schematic of rotor & dual induction ring assemblies

Needless to say, tremendous quantities of heat are produced in the StarDrive device's electron "targets" or collector housing sections, and liquid sodium must be pumped through each Primary Array's ceramic resistor network as a coolant. However, this excess heat in ground-based units may be used in the *commercial generation of electric power and desalinization of seawater*.

In fact, because an intense arc discharge field has the unique capacity to absorb vast quantities of quantum background energy, the EDF Generator is so efficient that the latter task may become truly cost-effective for the first time! And not only will large ***over-unity*** StarDrive Dynamo units be able to produce electric power at 60 to 720 MW output levels, they'll be able to do so for many years before the permanent magnet banks must be remagnetized!! *The only truly external input energy required* in the interim *is that necessary to initially bring the rotor up to speed . . .*

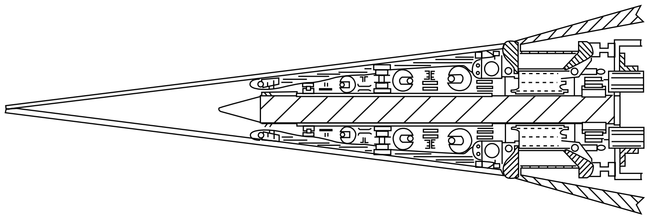

Fig. 3
A denumbered version of Fig. 1
from the EDF Generator Patent

Those of you who find this advanced technological prospect for the 21st century as exciting and fascinating as we do should consider making the inventor's book *StarDrive Engineering* a valuable addition to your personal or reference library.

A Layman's Description of the StarDrive Device

Nearly anyone who endeavors to gain an initial understanding of the *Electrodynamic Field Generator*, even a scientist or engineer, is likely to ask for a concise layman's explanation of "how it works". This isn't easily accomplished, for this device represents an unorthodox and multidisciplinary technology. However, the overview provided below will discuss the operative characteristics of the machine's simplified *electric power generation variant* in what is hoped to be the most direct manner possible. In this case, when people ask the question above, what they generally mean is: "By what means is *over-unity* operation achieved in a 'StarDrive' Dynamo?". It is assumed here that the reader has not only already become acquainted with certain basic aspects of the design, but also understands that over-unity operation is an absolute prerequisite for any viable system of light-speed interstellar propulsion.

By way of further background, the formative mechanical design basis of the EDF Generator is of course the original Faraday disk dynamo. For whatever reason, no one seems to have bothered trying to develop this simple machine into a more sophisticated *and patentable* form before now. The principal limitation of Faraday's disk dynamo in its original form was that, when one or more permanent magnets were used to pass flux directly through the plane of a solid conductive rotor, a rather high-loss heavy current at very low voltage was produced. The first design improvement was therefore to use rotor-mounted toroid field coils in order to generate a much higher-voltage primary current, and to segment the rotor to reduce "eddy current" losses. Also, the toroid coil configuration absolutely minimizes Lenz losses, or the magnetic "drag" that is experienced by any conventional generator's rotor.

To eliminate the use of brushes, it was necessary to apply traditional vacuum tube design and operating principles. Fortunately, most of the original patent work in this field has passed into the public domain, so incorporating certain aspects of that work into the EDF Generator presented no impediment to its patentability. By using plane-parallel electrode arrays instead of brushes to charge the rotor, it is possible to limit that portion of the induced rotor current which passes through the field coils to a very low level – effectively isolating them from the actual output circuit. More importantly, however, it then becomes possible to thermoelectrically charge the Generator's housing itself in such a way that *it* carries the device's full output circuit current instead!

The reason for this unorthodox design parameter is that it was desired to actually incorporate a standing electric arc field into the output circuit, to take advantage of the electron's inherent ability to absorb quantum background energy [including *zero point energy*, if and as necessary]. As a result of a thorough study of lightning, the inventor of the StarDrive device reasoned that the electrons comprising any naturally-occurring bolt of lightning had to *recover* (or absorb) an amount of ambient photonic energy equal to that which they expended in transit – in order to satisfy the conservation of energy principle. In such a case, it is not necessary that "we" do the *work* of moving charge *against* a potential gradient; the work may be done by the charge itself in being attracted *along* the potential gradient (or voltage level).

And since it is known from the field of welding that it takes less energy to sustain an arc than it does to initiate it, it therefore becomes possible to create an electrical circuit that outputs more energy than it requires as input. This is exactly what the EDF Generator does – by incorporating a standing arc field in its output circuit. Using the StarDrive device as our mechanism, "we" only provide the work-energy required to establish and maintain the external field's potential gradient, by initiating rotor rotation and bringing the thermoelectric elements up to temperature. The electrons in the electrodynamic field do all the rest . . .

Further Notes from the Inventor

In conjunction with one of our *StarDrive Generator* prototype project funding proposals, we are presently working on an interim proof-of-concept experiment for our proposed 24 kW air-cooled EDF Generator prototype. This full-scale mock-up of the 30"-dia. Generator's rotor and dual induction ring assemblies is intended to demonstrate the fundamental design principal discussed at the close of the Technical Overview (linked to our website's Method of Operation Summary page), whereby the voltage electrostatically induced on the rotor anode rings which power each Primary Array should be roughly one-third (1/3) of the Field Coil voltage (because of the capacitive dual induction ring geometry of the Primary Power System). For safety reasons, the Field voltage in all *air-cooled* StarDrive *Generators* will be limited by design to 850 VDC, and to 1,400 VDC in the larger *liquid-cooled* StarDrive *Dynamos*.

The experiment will also assist greatly in the derivation of remaining production model specifications, and will in fact incorporate production-quality rotor segments and electrode rings. Should this proof-of-concept experiment be successful, not only will the ability of our over-unity 24 kW Generator prototype to deliver large-scale DC output that's compatible with standard AC inverters (for utility grid distribution or off-grid conventional use) be virtually assured, but a major milestone incentive in our existing funding proposals will have been fulfilled as well. Further updates like those below will be forthcoming on the *News* page of http://www.stardrivedevice.com.

01/28/03 - International Patent Filings Secured!: We are very pleased to report that we were successful in our efforts to secure numerous international (PCT) Patent Application filings for the *Electrodynamic Field Generator* by the final deadline of January 21, 2003! These important filings were effected in Australia, Canada, the People's Republic of China, the European Union (including France, Germany, Italy, Spain, and the United Kingdom), India, Japan, Mexico, the Russian Federation, and South Africa.

The securing of these key Patent Application filings adds immeasurable value to our StarDrive Engineering Project overall, as it will greatly protect and enhance our investors' upside global market potential (assuming, of course, that our *24 kW StarDrive Generator prototype* is successful)! Be sure to check back from time to time for further updates as we proceed into the development phase of the Project.

11/07/02 - Academic Reference: Those of you kind visitors to our website who would like to have the benefit of an informed and unbiased academic opinion regarding the Electrodynamic Field Generator are welcome to contact John J. Tulip, Ph.D., Exec. Vice-Pres. of *American International University*. This consideration also applies of course to those parties who may be interested in securing a direct participation in our forthcoming EDF Generator Prototype Project. Dr. Tulip has not only expressed much-appreciated support of our efforts to introduce this important new technology, but has also had the opportunity to review our technical manual *StarDrive Engineering*. You may contact Dr. Tulip via e-mail at TulipJJ@aiuniversity.edu although we ask that you expect him to field serious and respectful inquiries only. Should you desire to speak with him by telephone, please be assured that he will endeavor to return your call whenever circumstances permit if you provide him with the proper phone number.

10/07/02 - Joint Venture Agreement Announced!: Mark Tomion, founder and president of Archer Enterprises and inventor of the recently-patented *Electrodynamic Field Generator*, is very pleased to announce that he has signed a Joint Venture Agreement with Affirm Technology Partners of Carlsbad, California to build a working prototype of his over-unity 'StarDrive' device's electric power output variant. The co-developers are planning to commence construction of a small air-cooled **StarDrive Generator** unit with a projected output rating of 24 kW and a housing diameter of only 30 inches, at a total weight of under 50 lbs., before the end of November 2002.

Should this exciting project be successful, it would represent an historic milestone in the development of over-unity electric power generation technology. Not only is this small prototype EDF Generator expected to demonstrate *a minimum Coefficient of Performance in excess of 20:1*, but the design employed is completely linearly-scalable in a very broad range of sizes that would include liquid-cooled ***StarDrive Dynamo*** units with output ratings of up to 1 gigawatt! The most remarkable feature of these large Dynamo units is that an amount of recoverable thermal energy comparable to their respective electrical outputs will be made available for desalinating seawater, or for use in centralized municipal and industrial hydronic heating systems. And this capability would make the large-scale desalinization or distillation of water truly cost-effective for perhaps the first time ever.

Interested parties are welcome to contact Mr. Tomion at office@stardrivedevice.com (585-526-6817) for further information.

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Prospects of Hydrogen Energetics

Ph.M. Kanarev, Russia

E-mail: kanphil@mail.kuban.ru

Hydrogen is the only pollution free and inexhaustible energy carrier. But the implementation of such attractive properties of hydrogen is restrained by large expenses of energy for its production from water. Modern level of knowledge gives the opportunity to reduce these expenses [1], [2], [3].

It is known that a gram-atom is equal numerically to atomic mass of the substance, and a gram-molecule is equal numerically to molecular mass of the substance. For example, the hydrogen gram-molecule in the water molecule is equal to 2 grams, and the oxygen gram-atom is equal to 16 grams. The gram-molecule of water is equal to 18 grams. As the mass of hydrogen in the water molecule is 2x100/18=11.11% and the mass of oxygen atom is 16x100/18=88.89%, the ratio between quantity of hydrogen and oxygen is preserved in one litre of water as well. It means that 1000 grams of one litre of water contain 111.11 grams of hydrogen and 888.89 grams of oxygen.

One litre of hydrogen has mass of 0.09 grams, one litre of molecular oxygen has mass of 1.47 grams. It means that from one litre of water it possible to produce 111.11/0.09=1234.44 litres of hydrogen and 888.89/1.47=604.69 litres of oxygen. Thus, one gram of water contains 1.23 litres of hydrogen [1].

Now energy consumption for production of 1000 litres of hydrogen from water is 4 kWh and of one litre – 4 Wh. As it is possible to produce 1.234 litres of hydrogen, then 1.234x4=4.94 Wh are spent for production of one gram of water now.

Instruments and Equipment Used for the Experiment

A special experimental low current electrolyzer, a voltmeter of the highest accuracy (accuracy class 0.2, GOST 8711-78), an ammeter of the highest class of accuracy (accuracy class 0.2, GOST 871160), a balance with value of a division of 0.10 grams and 0.010 grams, and a stopwatch with value of a division of 0.1s.

Experimental Results

Indices	**Sum**
1 – duration of electrolyzer operation connected to the supply line, in 6 cycles t, min	6x5=30.0
2 – readings of voltmeter V, volts	13.6
3 – ammeter readings I, amperes	0.02
4 – power consumption (P=VxIxτ/60), Wh	0.136
5 – duration of electrolyzer operation disconnected from the supply line, in 6 cycles t, min	6x55=330.0
6 – solution mass change m, grams	0.44
7 – mass of evaporated water m', grams	0.02x6=0.12
8 – mass of water converted into gases m''=m-m', gram	0.320
9 – power consumption per gram of water converted into gases P'=P/m'', Wh/grams of water	0.425
10 – existing power consumption per gram of water converted into gases P'', Wh/grams of water	4.94
11 – reduction of power consumption for hydrogen production from water, K=P''/P', times	11.62
12– quantity of released hydrogen, ΔM =0.320x1.23x0.09=0.035, grams	0.035
13 – power content of hydrogen being produced (E=0.035x142/3,6)=1.397, Wh	1.397
14 – energy efficacy of water electrolysis process (Ex100/P), %	**1027**

Note: Gas output is clearly observed during many hours after the electrolyzer is disconnected from the electricity supply.

Conclusion

Low ampere water electrolysis is a way for production of inexpensive hydrogen from water and hydrogen energetics.

References

1. Ph.M. Kanarev. The Foundation of Physchemistry of the Micro World. Krasnodar, 2002. 320 pages
2. http://book.Kanarev.innoplaza.net
3. hppt://www.n-t.org/tp/ns/if.htm.

Heater Producing Healthy Effect

The First Device of Healthy Life Support in Fuel-Energy Industry

A. Belyaeva, L. Savelyeva, O. Bondarenko, Kirghizia

http://www.leteco.h1.ru
Email: leteco@mail.ru

Nowadays problems of rational use of resources including energy resources are very important. Lack of energy-efficient technologies causes consumption of great amount of electric power, coal, and mineral oil. From another hand, in the XXI century one of the main approaches of human society development is turned to healthy life-style and development of ecologically appropriate technologies. Hence, basic direction of heating systems development should correspond to, at the least, two requirements, i.e. effectiveness (energy-saving) and ecological appropriation (ecological functioning). Moreover, it is necessary to take into account additional requirements for modern works:

- Relatively low prime cost of the systems;
- Minimal operating costs;
- Availability of a system of temperature mode control;
- Use of domestically produced materials for the systems.

The aim of the work is creation of a universal electric device of natural ecologically appropriate materials. The device should maintain relative air humidity of natural atmosphere in a quarter, make its ecology healthier, meet all the listed requirements, and represent new generation energy-saving system designed for heating of industrial and domestic areas according to features of technical solution.

A.L. Belyaeva is the author of this work. The invention of this heating device was acknowledged as the best invention of Kirghiz Republic of the last two years. A.L. Belyaeva was called as a laureate of a competition of “The Best Inventing in Kirghiz Republic in 2001-2002”.

Solving this problem the author based on work experience existing in the area of semi-conductors production. Actually, the model was worked out in the common area of electric engineering and industrial crystals growing. Using of knowledge and skills of the both areas made creation of this device possible.

It should be noted that initially the invention of the heating device, which is discussed here, was connected with necessity to improve microclimate and air atmosphere in a semi-conductor shop since the industrial process required optimal conditions. Hence, the device was observed as an element of the industrial process. However, soon other positive characteristics of the device were disclosed, i.e. when it was installed in a quarter all visible mould disappeared. Laboratory investigations stated that the operating device annihilated all pathogenic microflora. This rediscovered feature allowed using the device both in domestic and industrial area. After series of following laboratory investigations and bench tests construction of the device was changed and improved that allowed prepare it for line production.

Ceramic electroconvector: general characteristics

The working name of the final version of the model is *Ceramic Electroconvector TY 2971-006-22997241-2002.* Ceramic Electroconvector is an industrial and domestic electric heater of direct stationary action. It has high effective heat emission and satisfies ecological, sanitary, medical, and fire-prevention requirements.

At the same time it should be mentioned that by several characteristics this electroconvector differs from other known models of electroconvectors as well as from other existent heaters. It may be observed as a representative of an independent, specially created group of heating devices.

One of the main characteristics of the electroconvector is presence of constructive heating carbonic elements made of ecologically appropriate natural *non-metal* materials. Essentially, the electroconvector construction does not contain metal (the only metal part of the device is its supporting construction).

Production of heat of physiologically comfort zone requires 0.3 kW/h energy consumption which is 3-10 times less than energy consumption of known models of heating engineering. The Ceramic Electroconvector influences positively on ecology of a room. Room heating occurs better and more softly as conducting carbonic elements can be heated maximally up to 100° C. As a result oxygen is not burnt, and air is not overdried in a room. Achieved minimization of metal content in the constructive elements of the device increases the level of ecological compatibility both of electroconvector constructions and operation.

The device accumulates no static electricity, neutralizes harmful magnetic field generated by alternating current in the conducting element (it is typical for all the other electrical household appliances). Therefore, **the additional positive effect** is produced and higher ecological characteristics of functioning of this electroconvector are confirmed.

Insulating strength of ceramics prevents electrical shock accidents. Ecological compatibility of the electroconvector is provided by materials of the construction. The base of the device is a studied natural silicate fiber which has quantitative and qualitative content of useful chemical elements which are the closest ones to the group of medical adsorbents listed in a medical encyclopedia. The ceramics is adjusted to emit electromagnetic waves only in infra-red spectrum.

The electroconvector produces heat waves in the average IR spectrum (8.4-8.6 mkm) which is maximally approximated to the diapason of heat waves generated by a human (9.37 mkm). It annihilates humidity of buildings independently of outer space humidity. At the same time it neither burns oxygen nor overdries air.

Healthy effect is produced by all the constructive elements made of ecologically appropriate natural materials. Electric power is transformed into heat emission by conducting elements. This process causes a mode of generation of a continuous heat spectrum of radiation. The heat radiation is similar to heat spectrum of radiation generated by a human. At the same time, this feature together with resonant oscillations of the crystal lattice of the ceramic cylinders produces a destroying effect on pathogenic and conditionally pathogenic microorganisms.

From the point of view of room ecology the proved healthy effect of the operating electroconvector becomes very significant. The effect considers continuous presence of a human in the room, i.e. risk of pathogen infection through respiration objectively decreases.

Application of the ceramic electroconvector is especially actual in patient care institutions and children's institutions, in special precision industries and space technologies. It can also be used in saunas with dry vapor.

The ceramic electroconvector is designed for unsupervised continuous work.

Structure of the electroconvector producing the healthy effect

Shortcomings of known electric heaters are: great electric power consumption (0.75-3.0 kW/h), big number of metal details, complex technical performance, and use of a necessary additional blower as a ventilator. Big number of metal details decreases ecological compatibility and productivity of the heaters. The listed devices have to use high temperatures on heat-release surfaces for warming up rooms up to the level of physiological comfort. This causes increase of energy consumption. Moreover, using of metal heating elements influences on air and relative humidity in the room. According to available data, no existent electroconvectors have healthy influence on ecology of a room.

The represented ceramic electroconvector contains a carrying frame with horizontal boards which have convective gaps. The carrying frame has heat-release monolithic hollow ceramic cylinders whose walls contain longitudinal through holes. Heating carbonic conducting elements and de-energized carbonic rods are built in the through holes. The heating conducting elements are connected in parallel-series circuit at the output of the cylinders with it's ends placed into insulating supports of the carrying frame.

Constructive heating elements are the main differences of the device. All the heat generating constructive elements, i.e. conducting and de-energized heating elements, as well as heat-release surfaces of ceramic cylinders have contiguous spectra of infra-red radiation.

Energy-efficient effect

The electric scheme of connection of the conducting elements provides different modes of work of the device. According to these modes, energy consumption is in the interval of 0.05-0.3 kW/h. The mode of 0.05 kW/h is calculated on a supporting level of warming-up of a room. Maximal energy consumption (0.3 kW/h) corresponds to the superior limit of the temperature mode of heating of working heat-release surfaces of the ceramic cylinders. In this case temperature of the heat generating elements, i.e. de-energized carbonic rods and conducting carbonic elements) lies in the limit of max 100°C. This produces a significant potential resource of electric strength and of durability of the used elements. The de-energized carbonic rods function as heat accumulators at switching on and switching off the device. Heating the conductors the de-energized rods accumulate heat through the ceramic walls of the cylinder till their temperature becomes equal to the temperature of the conducting elements. Appearing electromagnetic resonance between the conductors and the de-energized carbonic rods intensifies infra-red radiation of the ceramic wall. Accumulative heat potential of the de-energized carbonic rods allows maintain uniform radial heating of the heat-release ceramic surface of the cylinder without decreasing energy consumption. In this case additional conducting elements of infra-red radiation become unnecessary.

The heating efficiency of the ceramic electroconvector was estimated by independent experts. Surface density of the radiation flow was calculated by formula of Stefan-Boizmann distribution law. Taking into account heating of the cylinders' surfaces up to 70° C this value came to 727 W/m^2. **Total heat generated by the electroconvector per hour comes to 600 kcal or 698 W** at the total area of the radiation surfaces of 0.96 m^2 (on the basis of 1 kcal=1.163 W/h according to [1]). The electroconvector consumes 300 W/h and produces 698 W/h. That is to say that it effectively transforms electric energy into heat energy. Operational modes of the electroconvector are based on analysis of the heating effect produced by different devices, i.e. a tube metal heater (TMH) having a conducting metal element of Nichrom, a ceramic cylinder having a Nichrom conducting element, and a ceramic cylinder having a conducting element of carbonic ribbon. The carbonic ribbon produces high heating efficiency. Temperature on the surface of the ceramic frame is up to 80° C and temperature on the conducting element is 100° C. Hence, the device equipped with the conducting element of the carbonic ribbon does not produce excessive heat radiation.

The electroconvector consumes 300 W/h and produces 698 W/h.

After one-year operation of the preproduction models in a private school it was noticed that number of respiratory illnesses and influenza among the pupils slumped, condition of skin became better, attacks of bronchial asthma among the teachers stopped, and allergic itch left the patients who suffered from allergy. A side effect was that flowers began to grow better, and those which had not blossomed began to blossom at least. Obviously, a combination takes place there: air cleaning of microorganisms, humidity normalization, warming comfort, and influence of pyramidal ceramic structures on water vapors which are transported by warm blasts.

Applied Know How

Ambient air in rooms is a complex substance including various chemical compounds, ions, dust parts, water vapors, infectious and potentially infectious microflora, etc. The electroconvector is represented by a ceramic hardphase crystal structure. Cold air blast moves close to the ceramic surface. It meets combined oscillation of crystal microlevel structures of ceramics. *Filtering electromagnetic screen* appears that breaks shell of pathogens and potential pathogens. It is a performance of **sanitation properties**. Atmospheric water contacts with structures of ceramics, then it is cleaned and structured. After that water cleans air which is breathed in by a human. Hence, the organism becomes healthier. It is a performance of the **healthy effect**. A clean room warmed uniformly improves human's health.

Main Performance Attributes of the Ceramic Electroconvector Producing Healthy Effect

Nominal required power	0.05-0.3 kWt/h
Voltage of the feeding network	220 ± 22 V
Frequency of alternating current	50 Hz
Temperature of the conducting element in operation mode	50…110° C
Temperature of the heat-release surface of the cylinder	39…90° C
Surface density of radiation flow	727 Wt/m^2
Quantity of radiated heat	600 kcal/h
Class of protection	1
General area of heat-release surfaces of the cylinders	9600 cm^2
Sizes	410 x 400 x 75 mm
Weight	18-21 kg
Durability	30 years

The ceramic electroconvector is designed as a floor construction for repetition work.

References

1. Heat Engineering Reference-book, Moscow, Energy (Energia), 1975, V. 1, p. 12.

About the author

After graduating from Polytechnic University of Frunze city Alexandra L. Belyaeva (1953) participated in launching of semiconductor production. She was given a rank of Perfect Inventor and Rationalyzer for invention and rationalization action. In 1987 her invention named Method of Production of Monosilicon Seed Crystals was introduced into manufacture, according to close copyright of USSR. Since that year this introduction has allowed grow monosilicon having better semiconductor properties. She was given a rank of Inventor of USSR for the invention.

Alexandra L. Belyaeva has acknowledged and given a rank of Inventor of Kirghiz Republic. Since 1994 in collaboration with Russian specialists of ceramics she has been dealing with organization of ceramic productions in Kirghizstan. Here are the inventions by Belyaeva: Method of Production of Seed Crystals and Its Variants (Patent #42 KG), Ceramic Mass for Insulators' Production (Patent #43 KG), Ceramic Mass Having Heat-Radiating Properties (Patent #464 KG).

In 1992 Belyaeva was rewarded with a Silver medal of VDNH (Exhibition of Achievements of National Economy, Moscow) for development of technologies for production of constructive nitride-cadmium items of semiconductor wastes.

Her Method of Production of Nonexpendable Seed Crystals is at introduction stage. The seed monocrystals produced by the new method will allow grow ribbon monocrystals having certain properties. It will be possible to produce items made of the monocrystals which will meet requirements of energy-saving and ecological appropriation. These devices represent non-aging powerful energy sources, various semiconductive devices with no inner microdeffects and with unlimited durability, structural water filters.

Since 2002 she has been dealing with organization of production of ecologically appropriate industrial-domestic appliances causing healthy effect. The invention of Ceramic Electroconvector Producing Healthy Effect is now introduced. Energy-saving of the new ecologically appropriate electroconvector exceeds energy-saving of all the existent heating systems.

Belyaeva is a laureate of competition of The Best Inventing in Kirghiz Republic in 2001-2002.

Inertial Propulsion Device

Vitaly E. Senkevich, Russia

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A body is at rest or moves linearly and uniformly until it is not influenced by an external force.
(School course of physics)

Forget everything that you were taught at school.
(Arkady Raykin)

This propulsion device consists of an engine and a body. The engine (see Fig.1) is remarkable for its movable stator (S) which can make free rotation as well as a rotor (R). When the engine starts the stator and the rotor begin to rotate in opposite directions. Thus the engine has two ends and one of them is connected to a flywheel (F). This flywheel begins accelerated rotation.

A cross-beam (CB) is connected to the second end of the engine where a rotating momentum appears. Under the influence of this momentum the cross-beam presses down one of the supports placed on the body (for example, Sup.1). As a result a force which is compensated by acceleration of the flywheel (F) appears on the support. When the flywheel is accelerated up to certain speed a control system (CS) switches the windings of the engine to change the direction into the opposite one (reverse). At that the cross-beam also tends to turn to the other side and presses down the second support (Sup.2). Thus the cycle repeats. It should be noted that forces acting at the supports are **codirected** and they move the whole device.

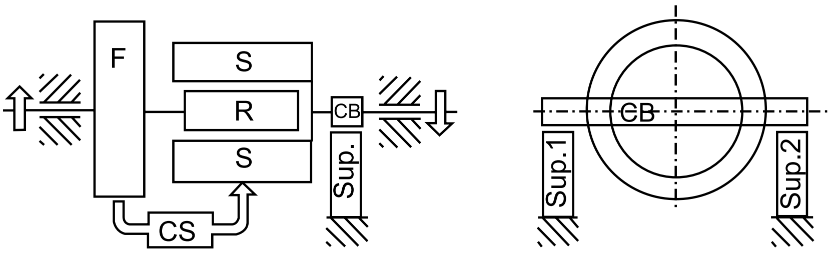

Fig.1

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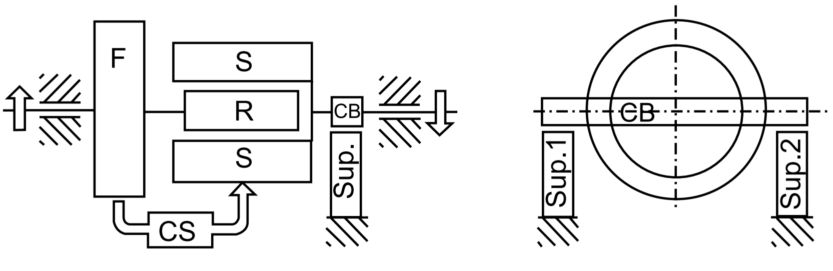

Fig.1

Unlimited Accelerated Nonreactive Motion

by G.P. Ivanov

Information from http://tts.lt/~nara/ruspopul.htm

Bias of centre of inertia of the closed system is a phenomenon exceeding the bounds of modern scientific conceptions. At the same time it is a way to the new marvelous world of earlier unknown laws and phenomena of nature. Researches made by G.P. Ivanov, Russia, have allowed him come to the following conclusion: it is a quite realizable task to create technical devices which can move under the action of nonreactive forces. However a purposeful scientific-research spade-work is required for the reliable registration of them by modern experimental facilities. According to the author during the whole XX century the known idea of latent impulse were misleading the scientists from the serious research of impulse-energy processes existing in systems at the presence of quasi-stationary electric and magnetic fields. According to G.P. Ivanov, it is related with the fact that the notion of “latent impulse” has nothing in common with the real momentum, since the very existence of “latent impulse” and “latent energy” which attends it, would make it impossible, for example, to adjust radio equipment since all effective capacitances change their value a hundred and thousand times as much (it depends on their orientation with respect to the magnetic field of the Earth).

Fig. 1, 2 demonstrate the patented by G.P. Ivanov method of realization of nonreactive motion (G.P. Ivanov, Yu.G. Ivanov. Method for production of propulsion. Patent #2172865, M., 2001). Fig. 1 demonstrates a device which consists of magnetized core with the attached metal electrodes.

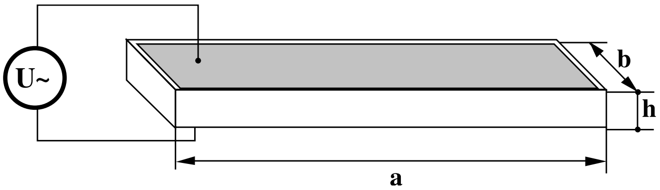

Fig. 1
The simplest “nonreactive” element

When alternating voltage is applied the device together with the center of inertia of the whole system (including power source and lead) will oscillate under the action of nonreactive force. It will move along the direction which is perpendicular to the vectors of electric and magnetic fields inside the core.

On Fig. 2 there is an analogous device supplied with a cylinder core. Magnetization of the core is defined by current of the coil which is wound around it (see Fig.2).

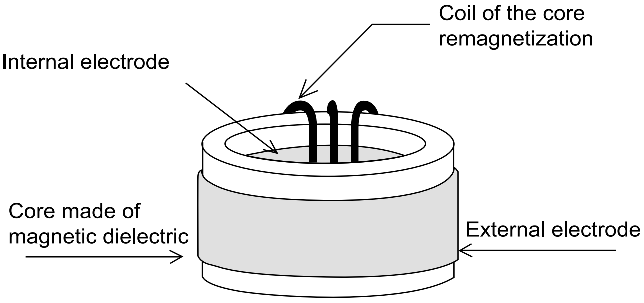
Coil of the core remagnetization
Internal electrode
Core made of magnetic dielectric
External electrode

Fig. 2
Diagram of the device which can be in unlimited accelerated nonreactive motion

Let us supply the electrodes of the device with such voltage which is enough to change field density in the core (for example, according to the law $E = E_0 \sin\omega t$), and the coil with voltage enough to change the magnetization (according to the law $M = M_0 \cos\omega t$). Then nonreactive force which is constant in its direction will act on the device along the axis of the cylinder. The average of the force is $F_{cp} = \pi f E_0 M_0 V / c^2$, where E_0, M_0 are the amplitudes of density values of the electric field and amplitudes of the core magnetization, **f** is frequency, **V** is core capacity. As a result the device can either move with acceleration or act against external forces. The researches allow the author to prove the validity of the following theorem: **At motion of the open-loop system (device) the work made by nonreactive force could not be realized by means of decrease of energy of the proper (appurtenant to the system) power source.** Where this energy comes from if there are no artificial power sources outside the device? However everywhere there is such form of matter as electrovacuum. It allows us come to a conclusion that nonreactive forces make work by means of decrease of electrovacuum energy.

Existence of electrovacuum does not contradict to the modern physical picture of the world. On the contrary providing the realization of laws of momentum and energy conservation, this idea originates from and organically supplements it. The theory of electrovacuum opens quite realizable prospects in different fields of human activity which seem to be fantastic and impossible. It also proposes unusual ways to solve many problems which are considered as insoluble. For example, it becomes possible to create nonreactive cosmonautics and private aircrafts. Energetics will be changed beyond recognition since power sources which require no material fuel will occupy the place of big and small modern electric power stations. The analogous list could be continued. There are presented quite realizable prospects related to inexhaustible reserves which are hidden in the ambient space.

Revolutionary Current

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*Electricity is one of the most wonderful inventions of the 18th century. It can be produced by various methods in which different types of energy are used such as mechanical or chemical energy. In this article we discuss a new type of methods in which **electrostatic energy** is used.*

In this method we use **electrets** as an energy source. Electrets are permanent polarized dielectric material which is made by cooling dielectric material in a high intensity electric field. When we place an electron in the electric field of a point charge, it is influenced by a force. If the direction of the force is such that the electron moves in a closed path then it represents a current in the opposite direction along the closed path. Here closed path means a metal wire loop in which the electron movement is responsible for the current.

The charge of the electrets remains constant for many years (100) and there is no loss of energy because we use only the property of electrets that they apply force when a charge is placed in its electric field. Since here we create energy in the form of electric current then it violates the Law of conservation of energy.

Let us discuss the method in three steps:

1) Fundamental
2) Equivalent circuit
3) How we can use it as a potential source of electricity.

1. When we put a metal rod in the electric field of a point negative charge then the electron is influenced by repulsion force which moves in arrow direction and the electric field is cut by putting an earthed metal plate from any direction. When we place four charges on the corner of the metal frame and shield the electric field in particular direction as shown in Fig.1 then the force on the electron which is placed in metal frame will be in the direction of arrow and this makes a loop. The force influencing on the electron will be continuous, so the current which moves in direction opposite to the electron movement will induced in the metal frame.

2. The equivalent circuit of Fig.1 is shown in Fig2. It demonstrates that a 'V' volt battery and a resistance 'R' can be replaced by an arm of the metal frame. The polarity of the battery is shown in Fig. 1. A current of magnitude (V/R) will be induced in the circuit by this method.

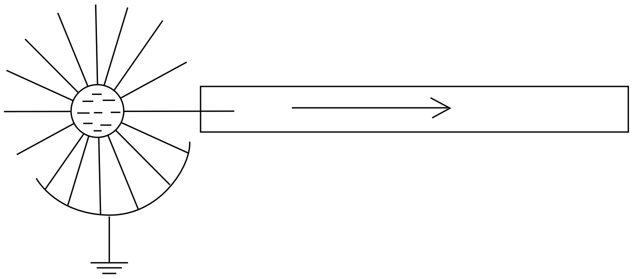

Fig. 1a

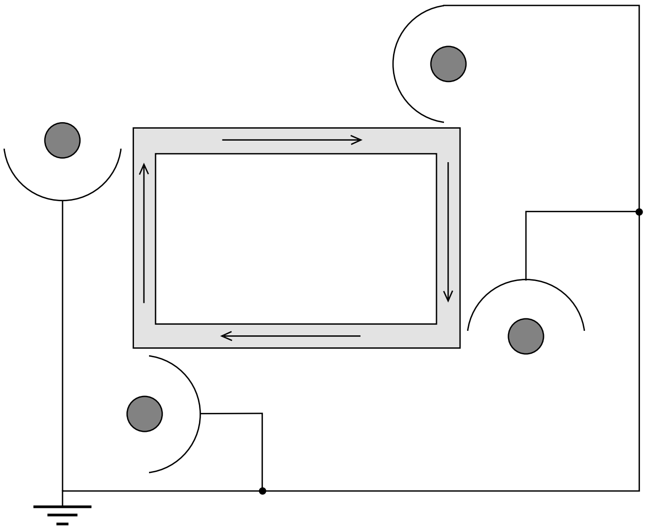

Fig. 1b

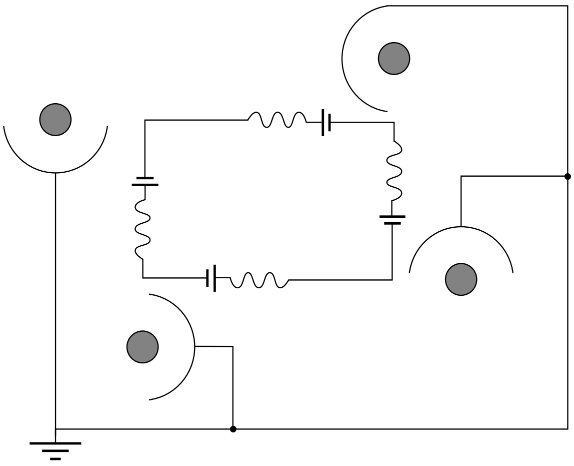

Fig. 2

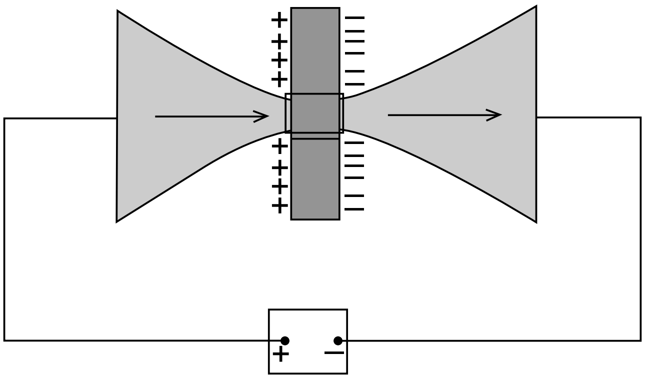

Fig. 3

3. We can use another device as a potential source (see Fig3.). Let us take an electret and make a hole at the centre. A hollow thin walled metal cylinder is fitted in the hole and a metal frame is taken as shown in the Fig. 3. We can use this metal cylinder as an electric field shield which may affect the direction of the force influencing on the electron. We may use this device as a potential source of electricity which will give electricity until the charges on the electrets vanish. The charge on the electrets remains constant for many years. Thus we can create energy and the problem of energy shortage can be solved by this method forever. We are trying to make a prototype of this but due to lack of equipment facility we are not able to demonstrate a working model. However we are trying to modify it.

NEWS REVIEW

Russian scientists are preparing new application of energy of geothermal waters

http://www.sciteclibrary.ru

A way for economical use and utilization of energy of geothermal waters was found in the Institute of Geothermal Problems (Russian Academy of Sciences). The new technology can be applied for heating in different purposes, and can compete with the power engineering, which uses the conventional energy carriers.

Geothermal springs are ideal for generating electricity by means of using of their permanent heat. This is especially important for Kamchatka, which is rich in these springs; however they are almost never used in mass power engineering, but only serve as an attraction for tourists, who admire beauty of Kamchatka geysers. At the same time the region itself freezes every year because of shortage of fuel for electric power stations.

What prevents us from using the geothermal springs?

The problem is that the storages of most of geothermal water fields have low and medium temperatures. This does not allow providing their competitiveness as regards conventional energy carriers. During tens of years this fact was an obstacle to the development of geothermal energy.

A solution was found in the Institute of Geothermal Problems. It was brought out that at many exploited geothermal fields wellhead overpressure exceeds 5-10 MPa and more. These waters contain fair quantity of dissolved organic gases. The scientists have found out that methane content of these waters exceeds 90 %. And until now at exploitation of the fields these types of energy have not been properly utilized.

The scientists of the Institute of Geothermal Problems have developed a technology of the optimum utilization of energy of geothermal waters and have increased the thermodynamic effect of the process.

This aim was fulfilled by means of transmission of thermal energy of geothermal water through the intermediate heat exchangers to the secondary heat carrier. Chemical energy of dissolved gases was used as an additional source of energy. The transmission was held by the use of primary and secondary separators. The distinctive feature of their technology is that associated potential energy of geothermal water is used as an additional source of energy. Expander and compressor placed on the same shaft are used as potential energy converters. Gas-holder and gas control point are used for utilization of energy of dissolved gases.

Thus on the bases of this technology geothermal energy can be effectively developed that will be competitive with fuel hydrocarbon energy.

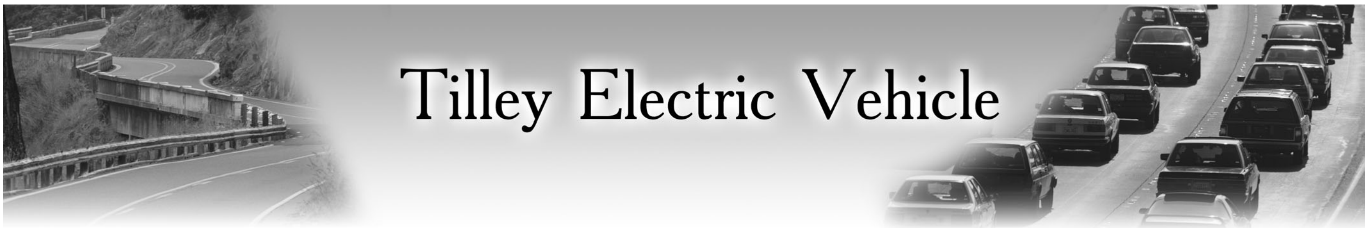

Tilley Electric Vehicle

Tilley Foundation, Inc.

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Editor: The advantages of electric vehicles were proved more than once. No fuel is required to set them in motion. Along with evident advantages of electric vehicles, such as their powerful characteristics and harmlessness for environment there is a side benefit, i.e. much less maintenance as compared with gasoline or diesel-fueled vehicles is required. Moreover it is easier to manufacture such vehicles.

In the previous issues of New Energy Technologies magazine we have already acquainted our readers with Tilley Electric Vehicle designed by Carl B. Tilley (USA). Below there is some up-to-date information and photos from the inventor. Besides we also publish an article devoted to the similar types of fuel-less motors.

After several years of personal accomplishments in the alternative energy industry, Carl B. Tilley was convinced that it was possible to build an electric car that could be powered without the help of external power to keep the battery charged.

The concept to produce a useful electric performance car that would last more than a few hours and would be economical to run, safe to drive around town or across the United States and never use a drop of fuel challenges the future of transportation as we know it today.

With the establishment of the Tilley Foundation, Inc., in the year 2001, Carl Tilley set out to prove it could be done. It was an ambitious project and it broke ground on the facility in Tennessee that would build the first self generating electric car.

...you have no need for fuel and you do not have to stop the vehicle to charge it after driving.

Construction of a 1,800 square foot building, that was powered with another recently developed electric device, began in the year 2002. Electricity from the building built the car from a different energy invention, that was void of any outside power supply. It is ironic that one alternative energy device actually built the invention to power and build the electric car.

From the selection of the proper car to be converted, to the advanced technology which is on board , the **Tilley Electric Vehicle TEV** performs comparably to gasoline powered vehicles. The difference is you have no need for fuel and you do not have to stop the vehicle to charge it after driving. There is no pollution and you can cruise the highways at the same speed as any other vehicle.

The rear mounted electric motor provides over 130 SAE net horsepower at 5,500 rpm. It offers a 3 speed automatic transmission that is smooth shifting and totally silent running. All this is combined with rack and pinion steering and a 35/65 rear weight bias that enables fast, sensitive handling and needs no power assistance.

...battery system will be fully charged at all times while in use.

It has 4 wheel disc braking for fast progressive, fade-free stopping. Counterbalanced gull-wing doors need only 14 inches of clearance. The rear sporty louvers are aerodynamic designed so that it almost eliminates any drag effect. All this with a stainless steel body makes for a great car.

Control center for the battery bank only allows what is needed to keep the batteries charged while in operation no matter what the speed or discharge from the battery bank. Your battery system will be fully charged at all times while in use. Simply get in, start the car and drive like any other vehicle.

A 1981 DeLorean was converted as the Tilley Electric Vehicle.Conversion of the car began in late June of 2002. State of the art metal fabrication to construct support for the electric motor, battery bank, control center and the TEV device was completed in July of 2002.

Several tests were made to validate the TEV technology. One of the last tests was made on September 7th, 2002. It has been demonstrated that after 17.3 miles driven on the Superspeedway at speeds ranging from 80MPH to 96MPH independent engineer certified batteries were full.

Assembly Pictures (see also the cover page)

Photos by Robert Gaither

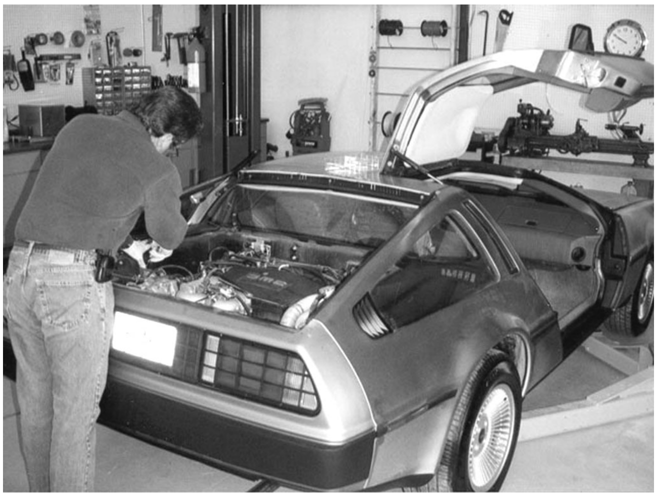

Fig. 1
Removing Gas Motor

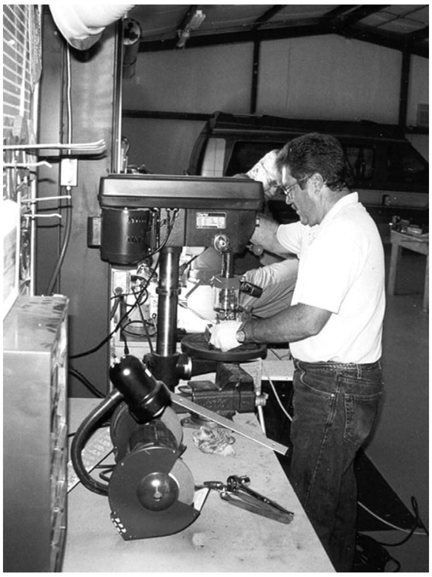

Fig. 2
Fabrication

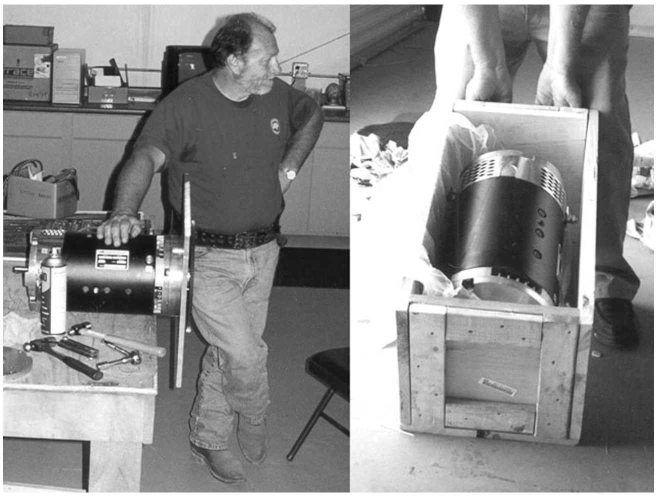

Fig. 3
Drive Motor

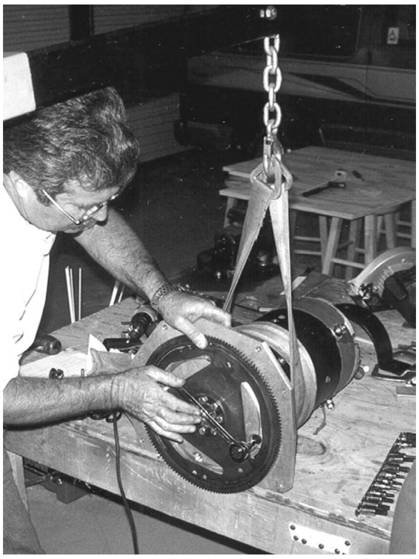

Fig. 4
Fitting Parts

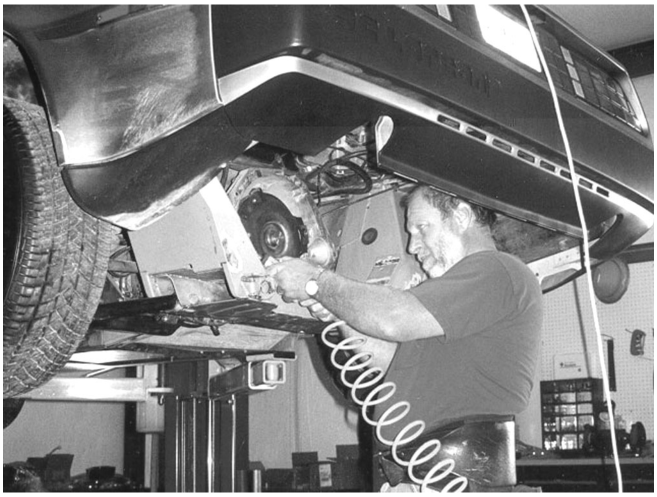

Fig. 5
Transmission Work

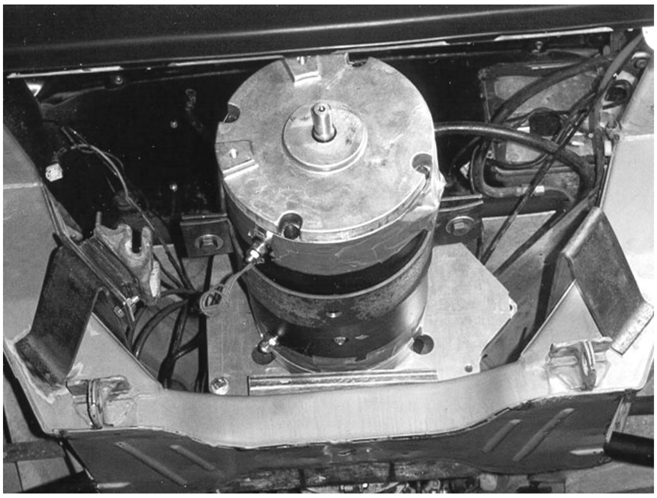

Fig. 6
Motor Mounted

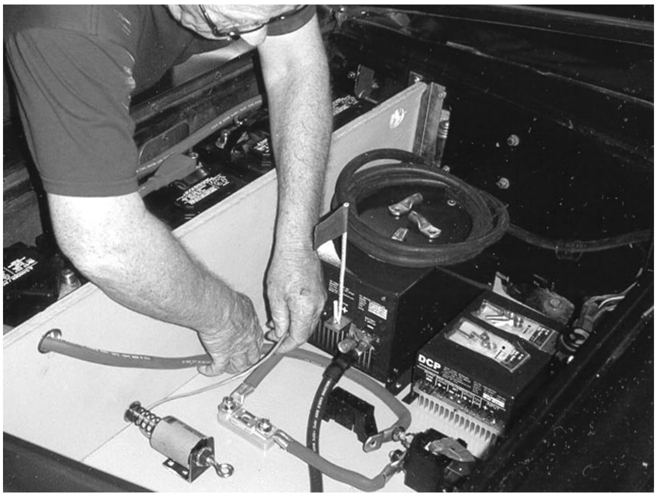

Fig. 7
Making Connections

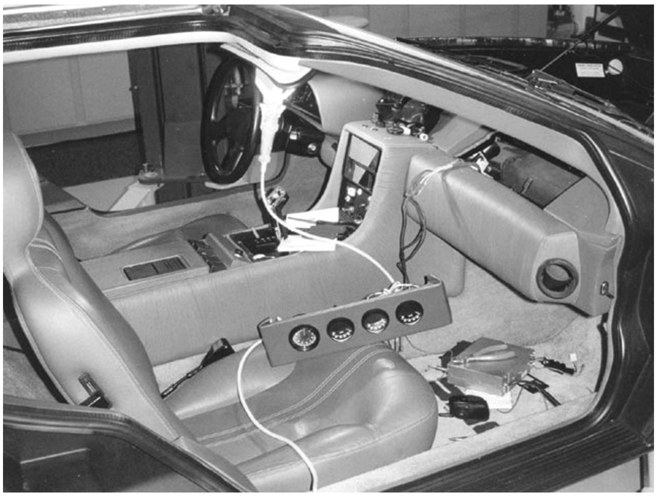

Fig. 9
Special Wiring &Guages

Fig. 8
About Ready

Fig. 10
Car Unveiling

Trends in the Application of Motor-Generators

Adrian Akau, USA

E-mail: adrianakau@aol.com

If the Tilley generator-motor should enter into the world market, some curious consequences may result, the most important being the transition of the Honda and Toyota hybrid cars into full fledged electrics.

First of all, a comparison should be drawn between the Tilley and the two hybrid cars presently being sold, the Honda Civic and the Toyota Pirus should be made.

The Honda Civic and the Toyota Pirus both use charging systems with a gasoline motor for better milage. The Tilley motor-generator is a stand-alone electric vehicle. The Honda motor-generator is just 60mm thick and provides (10kW or 13hp). The Toyota Pirus has a 44hp unit (American Version) which feeds power into electric motors at the wheels. Both Honda and Toyota gasoline motors are off at 0 mph. Only the electric system is used until the power demand reaches 10 kW; then the gasoline motor automatically kicks in. The Pirus is able to get higher milage in city driving than in country driving from the fact that the ratio of the power from the electric part to power to the gasoline part of the motor is greater at lower than at higher speeds, that is, less power is needed to run the car in city driving than in country driving because of the lower speeds and air resistance.

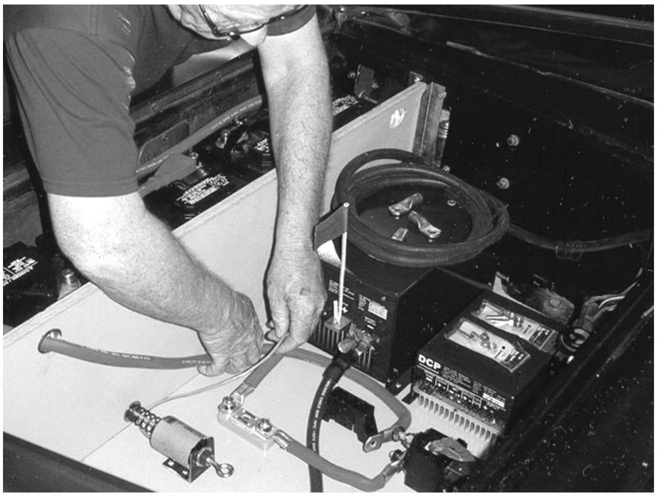

Fig. 7
Making Connections

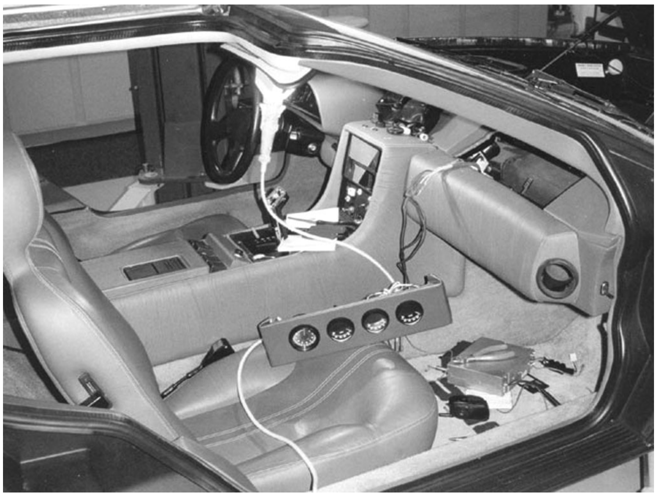

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American car companies are beginning to develop their own starter-generators to “save an extra 10% on the gas milage”. Are they doing this because they don’t want to be left behind in the milage competition or because they really understand the nature of the starter-generator motors used by the companies producing the hybrids?

With the advent of the Tilley motor-generator, a new factor enters into the situation. If the system proves valid, does this mean that Honda and Toyota are out of the running? Hardly not! It is likely that these companies have allowed or even planned for this contingency with larger capacity motor generators which would do a similar job. With their fine cars and superb engineering, the transition from a hybrid to a pure electric might be costly but not too difficult to engineer. Each of the two hybrid companies may already have been built, tested vehicles of this nature. However, since the primary purpose of the car companies is to make money it is doubtful if this full-fledged fossil fuel-less type will be placed on the market unless competition so requires. A car using the Tilley motor-generator might certainly push them in this direction.

Should the Tilley remains undeveloped, one might expect the second level hybrid car to arrive in a few years from Honda and Toyota. These cars should have greater electric generator-motor capacities and smaller gasoline engines. These systems could give small cars much higher gas milage and could also be placed in larger, more elegant vehicles such as the Honda Accord and the Toyota Camrey.

The transition to fuel-less motors should hopefully be slow and painless for both the pocket book as well as the human psych. If scientists cannot be convinced by studying conventional scientific laws on how these motors work, perhaps they will better see the need for the promulgation of new laws in this area.

We know that at the present time, both Honda and Toyota motor generators (M.G.) have a powers assist function while the Tilley stands alone. Let us look at the present situation (we will use the Toyota U.S. M.G. because it is the more powerful version):

Honda and Toyota classify their M.G.’s as permanent magnet types; Carl Tilley says his is and advanced D.C. motor.

Power output:

Honda is given at 10 kW at 3,000 rpm or 13 hp
Toyota is 33 kW at 1,040-5,600 rpm or 44 hp
Tilley is up to 135 hp depending on rpm’s

Voltage/Battery (Ni-MH=Nickle Metal Hydride, AH=amp hours)

Honda: 144V, 120 Ni-MH cells@1.2V ea., 6.5 AH
Toyota: 274V, 228 Ni-MH cells@1.2V ea.
Tilley: 144V,12-12V lead acid (Wal-mart), 1200AH

Physical Characteristics of each M.G.

Honda: 60 mm wide
Toyota: unknown
Tilley: 9" dia., 146 pounds

The main effort should be to implement the transition away from the use of fossil fuels. We know this can be done but it takes proper attitude. Proper attitude takes knowledge and knowledge takes willingness to learn. Willingness to learn takes desire to learn and desire to learn takes humility. Unfortunately, humility is a characteristic that many people, especially learned ones lack. *Editor’s: Carl Tilley’s comments are also given below.*

Very Good…you seem to know what we already were aware of…before we could mass produce our Tilley car I am sure some auto company would come out with basically the same thing…I do believe they already have it and they are just waiting for the right time. The good news is that at least the Tilley car lighted their fire to get them started.

Carl Tilley

Read in the next issue!

In April 12 of 2003 scientific conference “The Time Machine” was organized by Faraday Laboratories Ltd in Moscow. There were presented the reports by V.A. Chernobrov, A.V. Frolov, A.V. Rykov, E.D. Sorokodum, V.J. Kosyev, A.N. Solonyi, V.A. Atsukovsky. There was discussed design of the device made by Faraday Laboratories Ltd. as well as main principles of control on temporal characteristics of physical processes by changing of density of space energy, i.e. aether density according to patent claim.

Details are in the next issue!

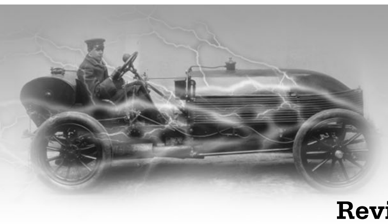

Electric Vehicle in Russia

Review by Correspondent Alla Pashova, Russia

The director of *EV* (*Electric Vehicles*) company located in Tolyatti (Russia), Alexander Mukhanov states: "If during 2 centuries intellectual efforts of a scientific thought were concentrated on an electric engine instead of the internal combustion engine then now we would have driven electric vehicles, and the greenhouse effect would not have exist".

The electric vehicle has driving-wheels which are set in motion by an electric engine, and it is powered by an electric battery. The electric vehicle appeared in Great Britain and France in 1880 and it is significantly older than the automobile equipped with the internal combustion engine.

At the beginning the speed and the fuel distance of the electric and gasoline vehicles were approximately the same. The main disadvantage of electric vehicles was a complicated system of recharge since there were no usual transformers of alternating current into direct one. Hence, the electric vehicle was recharged in a quite difficult way. An electric engine operated on alternating current was used to recharge it. The electric motor rotated a shaft of the generator which was connected to batteries of the electric vehicle. However in 1906 a rectifier which was simple to operate was invented. Despite its principle of operation was quite complicated (mercury vapor was used for transformation of alternating current into direct one) it has given a great stimulus for development of automobile industry.

There were no essential proves of advantage of gasoline vehicles as compared with electric vehicles. Nevertheless, even at that time there was an opinion that electric vehicles run more slowly and to shorter distances. However "gasoline" records were also insignificant and comparable with results produced by the electric vehicles. At the same time producers of electric vehicles did their best to demonstrate the advantages of these vehicles. If you remember, Walter Baker, one of the most famous American constructors and producer of the electric vehicles, achieved the speed of 130 km/h driving his car. An electric vehicle produced by Borland Electric company run from Chicago to Milwaukee (the distance of 167 km/h along non-asphalted road) without recharge. Next day after recharging the electric vehicle returned to Chicago by its own power without meeting any incidents. During the journey its speed came to 55 km/h.

In 1899-1900 a hereditary Russian nobleman Ippolit Romanov made an experiment on designing of the first Russian electric vehicle. Since these vehicles had been designed to run in Saint Petersburg then the city council required to produce them in the same place. In 1899 Romanov's first electric vehicle was made. Its general design was borrowed from English cabs in which a cabman sat on a high dickey placed behind passengers. Romanov's electric cab had two passenger seats situated in front of the dickey in a half-cabin having side and back windows. The cabin was equipped with a hood. The seat of a driver was placed behind and above the cabin; a box containing an accumulator was located under the driver's seat. The vehicle was four-wheeled. Diameter of the front wheels was smaller than those of the rear wheels. The front wheels were fixed by elliptical springs and were driving ones. They were connected to two independent electric motors by a roller chain drive. The regulated rear wheels had a smaller diameter and were fixed by spiral springs.

This first electric vehicle was equipped with lead accumulator which had 36 banks. It required recharging every 60 versts (1 verst – 3500 feet). The total power of both the electric motors was equal to 4 hp. Design of the vehicular part of Romanov's electric vehicle was borrowed from the models produced by an American company named *Morris-Salom*. This company had produced electric vehicles since 1898; however those models had wheels of greater diameter as they were equipped with pneumatic tires, while Romanov's vehicle had wheels with light rubber rims. Both the electric vehicles had two electric motors, but the distinction of Romanov's electric vehicle consisted in the presence of 6-row ball bearings in the wheels.

Romanov's second cab was built in 1900. This model had entirely closed and glazed cabin for passengers. The chain drive was replaced by a gear; however the basic sizes remained the same. This model was equipped with an accumulator designed by Romanov. The general weight of the electric vehicle was 45 poods (750 kg), and the weight of the accumulator came to 22 poods (362 kg). It should be noted that weight of American and French electric vehicles exceeded these figures. The speed of both Romanov's models of the electric vehicles came to 15 km/h.

Romanov's first electric bus was built in the same 1900. The electric bus weighted 100 poods (1600 kg) could make speed up to 10 km/h. For reasons beyond Romanov's control, traffic of the electric vehicles in Saint Petersburg was not organized.

A vehicular company named *"Frezer and Co."* participated directly in production of Romanov's electric vehicles, i.e. a running gear of these vehicles was created by this company. In January 1900 *The Cyclist* magazine reported that this company had built an electric vehicle which had already been tested. A picture of this first electric vehicle by *"Frezer and Co."* can be found in advertising publications of those years. Various firms proposed the innovation for sale and described its technical characteristics.

Frezer electric vehicle was four-seated, had two engines whose total power came to 7 hp. The advertisement booklets reported as following: "The accepted system of accumulator is remarkable for its solidity and life-time. Capacity of the elements is about 15 Amperes/ hour per a kilogram of electrodes. The size of the battery is defined according to calculation of 120 W/h per one ton and per one-kilometer of the distance; its weight is equal to 30-40% of the total weight of the vehicle including a payload". Weight of Frezer electric vehicle came to 70 poods (1120 kg). It made the speed of 15-18 km/h and required recharging every 35-50 versts of the path. The second variant of Frezer electric vehicle differed from the first one for less weight of the accumulator which was located above the rear axle.

In addition to the four-seated vehicles, *Frezer* Company produced two-seated electric vehicles equipped with engines of 3.5-hp power. The two-seated electric vehicle was remarkable for its more perfect steering tube. There is known one specimen of this model purchased by somebody from Riga (Latvia). Moreover, on the territory of *"Frezer and Co."* there was a station for recharging accumulators of the electric vehicles.

In the period of the Soviet Union pilot batches of electric vehicles began to be produced only after the II World War. In general there were small lorries applied for transportation inside great buildings, for example, in a main post office or an airport.

Now there is a great probability that Moscow will be the first Russian city where the electric vehicles can find mass application. Russian capital suffers from gas pollution which is especially heavy in the center of the city. At the same time the budget of the city allows acquire own ecologically appropriate transport. Now financing of production of the electric vehicles is realized through the Fund of Ecologization of Moscow Transport. The means are assigned due to income taxes coming to the budget of the city.

To tell the truth, citizens of big cities know electric vehicles very well, i.e. usual trolleybuses and trams are electric vehicles despite they are not autonomous. An autonomous public electric transport has one advantage which is especially valuable in the conditions of the cities overcrowded by cars. This advantage is their mobility. Trolleybuses are inseparable with their wires that causes decrease of their maneuverability. For example, they cannot pass several cars which have been parked wrongly. In this case a maneuverable and autonomous electric vehicle will run to the center of the road and pass the obstacle with ease.

A Moscow company named *Eltran* which deals with exploitation of electric transport has developed a model of EV which runs the distance of 60 kilometers without recharging. Total recharging of this electric vehicle takes about 5 hours, however a half of required energy they can obtain for 1 hour. Hence, if the accumulators are recharged before their full discharge then this vehicle can operate constantly. However, a developed infrastructure of charging stations is necessary for this aim.

From the economical point of view, EV does not yield to trolleybuses and trams which house more passengers but run twice more slowly than the autonomous and compact EV. Therefore EV does not experience difficulties in jams in the conditions of the traffic of the city. It maneuvers easily in thick traffic current.

Unfortunately, now EV cannot replace automobiles equipped with internal combustion engines. Imperfection of its accumulator batteries does not allow it to become a public vehicle. The battery imperfection causes a small run on one recharging, long cycle of recharging, and high price of the electric vehicle.

To tell the truth, EV has important advantages. Maintenance charges of EV are lower than the charges of the standard automobile requiring expenditures for support of cooling systems, powering systems and exhausting systems. The lifetime of the electric engine comes to 10 thousands hours. Quantity of operations for maintenance of the engine is minimal. For example, it is necessary to change brushes in the dc motor from time to time. As for a modern three-phase electric motor and synchronous ac motor they are practically maintenance-free.

EV is easy to drive. To start the car you should only insert the key, turn it and press the accelerator pedal. You do not need to make any manipulations with adherence or gearshift.

Use of EV is justified in so called zones of higher environmental requirements that are cities, parks, vacation resorts. Electric buses, developed by *Eltran* run in the public green space of All-Russia Exhibition Center. There are about ten compact commercial EV operating in Moscow.

Taking care of environmental sanitation the management of AZLK (big automobile plant) has developed EV on the basis of two production automobile models "Moskvich-2141" and "Moskvich-pikup-2335". "Moskvich-Elektro" (Fig. 1-2) at fully loaded mass of 2060 kg accelerates up to 60 km/h at 15 seconds. Maximum speed of the load-free vehicle is 110 km/hour. Cruising range at one battery charging is 100 km, and it comes to 80 km with 400 kg of load. At present Electrical Vehicle “Moskvich” is filled with imported component parts, which are cheaper but functional. In time it will be supplied with Russian equipment that will make it cheaper.

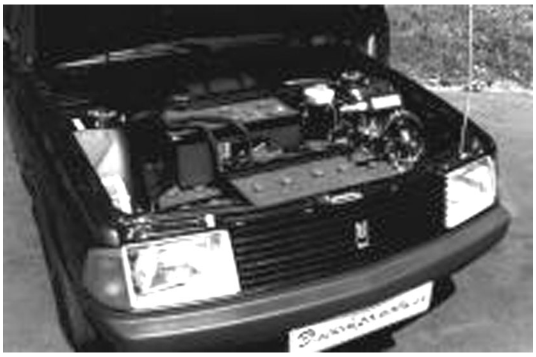

Fig. 1

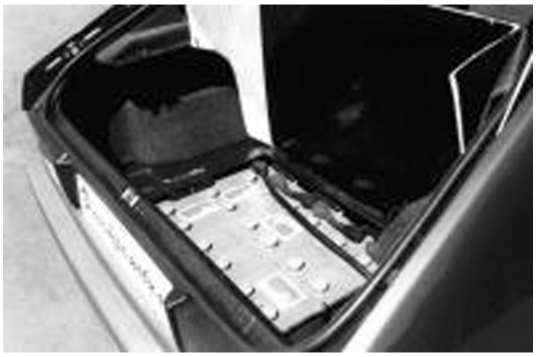

Fig. 2

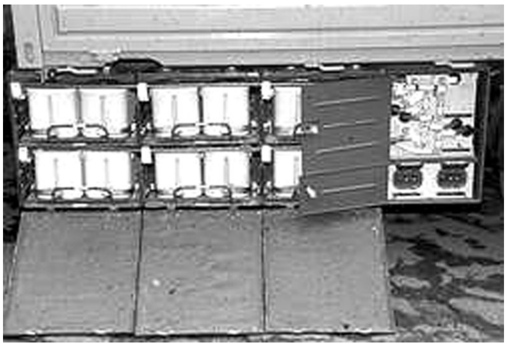

Fig. 3

The model of truck equipped with electric motor “ZIL-Electro”, the authors of which being called “AVEKS” and “Optimum-electro”, also enjoys the support of the Fund of Ecologization of Moscow Transport. Various privileges and free passage to any location in public green zones are promised to the future owners of “ZIL-Electro”.

Forty-eight lead-acid traction batteries of roll type (Optima battery) are hanged in pairs along the ramps of the truck. They are united into 4 sections (Fig.3). Capacity of these batteries is enough for 70 km running. Probable charging station for these machines is the loading/unloading point. Charging time varies from 30 to 60 minutes. Substantial disadvantage of the model is that batteries take away a great percentage of carrying capacity. Among the advantages of the model there are small internal resistance, fast recovery (to 400 A), discharging to zero level without serious consequences.

A traction induction unit “ATAD-Optimum 50/120” serves as the engine for “ZIL-Electro”. Its weight is only 100 kg and it doesn’t require any diesel generator or transmission that compensates a little the loss of carrying capacity.

The engine is very simple. It is a non-contact rotor of a “squirrel cage” type rotating on the bearings. No brushes are used. Thus expensive maintenance is postponed for uncertain date. On the other hand there is asynchronism. It means that some equipment is needed for converting into three-phase current and further frequency and amplitude adjustment. However it is expensive and complicated.

In spite of all existing disadvantages, Electric Truck is considered to have a bright future ahead of it. There several reasons for that:

1 The vehicle is manufactured from cheap production component parts.
2 The system of optimum vector control of the drive is introduced. (The torque and shaft speed of rotation is regulated precisely, energy of the batteries is used rather efficiently.)
3 Microprocessor system with feedback coupling and great number of sensors (current sensor, heat sensor, velocity sensor, voltage sensor) minimizes losses, prevents the motor and batteries from overheating, protects mains from short circuit in case of an accident.
4 The vehicle is reasonably priced (for such an exotic object) – about $26 000 USD subject to serial production.

Volzhsky automobile plant has already been engaged in research of EV for a quarter of a century. Over 10 original models have been designed and produced for these years. They have been appreciated abroad as well as in Russia. These are electric vehicles “Poni”, “Oka”, “Elf”, “Gnom”, “Niva”, “Rapan” “Lada-golf”, etc.

The models manufactured on the basis of VAZ-1111 “Oka” became the most popular among them. These EV received many different rewards, and became world-renowned. For example, VAZ-111E “Oka”, manufactured in 1993, kept all merits of a production midget car. Use of electric motor makes it a non-toxic and noiseless vehicle. Efficient fast-acting short circuit protection eliminates current rush, providing absolute car operating safety.

In EV of VAZ manufacture two direct-current motors are commonly used as a power-generating set. The first is a 25kW capacity motor with torque of 110 Nm.

Another one has 40 kW capacity and torque of 190 Nm. Motors of the first type are usually mounted on light vehicles, such as "Golf", "Oka-Electro", "Elf", while high-power motors are usually used for VAZ-2108, VAZ-2109, "Niva".

The first models of electric vehicles used to be equipped with nickel-zinc batteries. But as life time of these batteries is not long, it was decided to start using nickel-cadmium batteries, manufactured at Saint-Petersburg plants "Rigel" and "Istochnik". Nickel-cadmium batteries are power-consuming, they withstand temperature of –40°C. The only drawback of these batteries is their cost, and as a consequence a high cost of the vehicle itself. Because of that the final choice has been made in favor of lead-acid storage batteries, which were mounted at "Gamma Golf" in particular, thus reducing its price by several times. The batteries are located under the driver and passenger seats. They allow discharge of 80-85% and provide cruising range without recharge of up to 100 km within city area and several times more on a highway. Power current is transmitted from the electric motor to the front wheels through single-reduction gear unit, which substitutes the transmission.

For the present time electric vehicles are not developed to take the place of automobiles with internal-combustion engine in all industries and spheres of application, but only as a specific vehicle for highly specialized utilization. They are utilized when use of internal-combustion engine is objectionable or impossible.

It is considered that so-called hybrid models of EV would be able to replace automobiles with internal-combustion engines. These are vehicles with two motors, an electric motor and an internal-combustion engine usually running on diesel oil. In this case the combustion engine works constantly, but under the operation modes of little air pollution. Besides, fuel consumption is also much reduced.

In this direction real commercial success is possible. For example, "Toyota-Pirus" has already been chosen as a personal vehicle by tens of thousands of customers, this being a good result for such an original construction.

Nowadays three circuits of hybrid propulsion system are generally known. The simplest one is a series circuit, in which combustion engine operates together with a generator, and battery or generator powers electric motor providing propulsion. Actually this is the same circuit of electric transmission that is used at quarry trucks. Its main disadvantage is great losses of energy at transmitting the torque to the wheels. In parallel circuit the output shafts of the motor-generator and combustion engine are rigidly bound, and it doesn't allow working in steady-state mode (i.e. with permanent rotations and load).

In the third circuit, which is also the most commonly used there are an electric motor, combustion engine and a generator. The output shafts of all these units are bound by planetary differential. This allows almost lossless distribution of power between the units, and provides sustained performance of the combustion engine. The disadvantage of this circuit is the extreme complexity of coordination of units operating.

A hybrid EV was produced in Russia by automobile plant "Izhmash" though it has not been put in mass production yet. At the developing of the propulsion system instead of unique components there were used units of Russian mass automobile production that is one of the fundamental design solutions. "Orbit" Izh-21261 was used as a base for the device. It was equipped with gasoline engine (of 30 hp power and 650 cm^3 capacity), drive dc motor ПТ-125-12 (of 120V voltage and 49 H/m torque) and eight accumulators 6CE-55. Twin-engined propulsion system works according to the parallel circuit of engine joint. Electromotor serves as starter and at the acceleration it operates simultaneously with internal-combustion engine. On reaching some definite speed the electromotor changes its operation mode to the mode of generator and charges the accumulators. When the loads at gasoline engine increase then the electromotor begins to operate together with it. Operation of the hybrid propulsion system is controlled by starting regulation electronic equipment. Control unit, speed transducer of crankshaft of the internal combustion engine, detector of the accelerator pedal etc. are responsible for coordinated work of the engines.

During the tests fuel consumption of the hybrid vehicle "Orbit" was less by 20% than that of the usual model. For Russian prototype it is a good qualitative characteristic, however foreign designers reach better results, for example, "Crysler ESX3", which was presented in 1998 at Geneva auto show, consumes 3.3 liter of diesel oil per 100 km of path.

Representatives of specialized Moscow companies producing EV assert unanimously that these are hybrid electric vehicles which should change public transport with internal combustion engine. To encourage the automakers it is useful to create the proper laws drawing on foreign experience. For example, in California, USA, automakers whishing to present their production in the state market should put out 2% of automobiles with null blast. Legal system also supports an automobile user who is provided for free parking and free or cheap recharge. The user is granted with maximum of discounts to encourage him buying EV which is still twice as expensive. However it is said that in one of the villages situated near Moscow where the so called new Russians live, everybody drive electric vehicles leaving their cars with gasoline engine outside the gates. It would be quite good if EV turns to the real vehicle from the extravagancy of nouveau riches and beloved creation of ecologists.

The Richard Clem Motor and the Conical Pump

An Investigation of the Clem Motor

Robert Koontz, USA
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In December of 1992 Jerry Decker posted an article on the KeelyNet BBS, about a self-running motor that developed excess useable power. The information, gathered from newspaper and individual sources, gave an anecdotal account of the motor invented in 1972 by Richard Clem of Flower Mound, Texas. New information has since been added and can be found on http://www.keelynet.com/energy/clem1.htm.

Richard Clem worked with heavy machinery for the city of Dallas. He used asphalt-spraying equipment, which pumped liquid asphalt. He noticed the asphalt pump would continue to run for up to 30 minutes after the power was turned off. It was this discovery that led to the development of the motor. Modifications he made eventually resulted in a substantial 350 horsepower output from a 200-pound motor. Clem is said to have often driven a car, powered by this motor, up and down Central Expressway in Dallas. He claimed it didn't use any fuel, and only needed a change of oil every 150,000 miles.

The motor had only one moving part, a cone shaped rotor mounted vertically on a hollow shaft. Spiral channels cut into the cone wound around its length and feed into peripheral nozzles at its large end. When fluid flowed through the spiral channels it was ejected out the nozzles and caused the cone to spin. At a certain velocity, the rotating cone became independent of the starter pump and began to operate by itself. At an operating speed of 1800 to 2300 RPM the fluid heated up to 300 F, requiring a heat exchanger. Vegetable oil was used because at 300 F water boils and conventional engine oil breaks down. A 12-volt battery was the only other power source. Clem never applied for a patent because his motor design was derived from the asphalt pump that was already patented. Fifteen companies turned him down before a large coal company offered to back him and signed contracts to sell the motor. Soon after the deal was signed, Richard Clem died of a heart attack

The above account contains only what I considered to be relevant for analysis of the Clem motor. Visit http://www.keelynet.com/ for the original material.

The gear pumps, typically used for asphalt spraying, do not match the description of the pump used by the city of Dallas back in 1972. There should be public records showing what equipment manufacture the asphalt sprayer was purchased from. Since the asphalt pump was patented, I searched for a pump patent that met the following criteria:

1) Patent issued on or before 1972.
2) Delivered pressure equivalent to a positive displacement gear pump.
3) Cone shaped rotor with spiral channels.
4) Self-propelling action.
5) Capable of pumping a viscous fluid like asphalt.
6) Large heat transfer to pumped fluids.

The following illustration (Fig.1) is from US Patent 3,697,190 (Truncated Conical Drag Pump). The patent was issued October 10, 1972 (criteria 1) and appears to match the description of the asphalt pump that Clem converted into his motor.

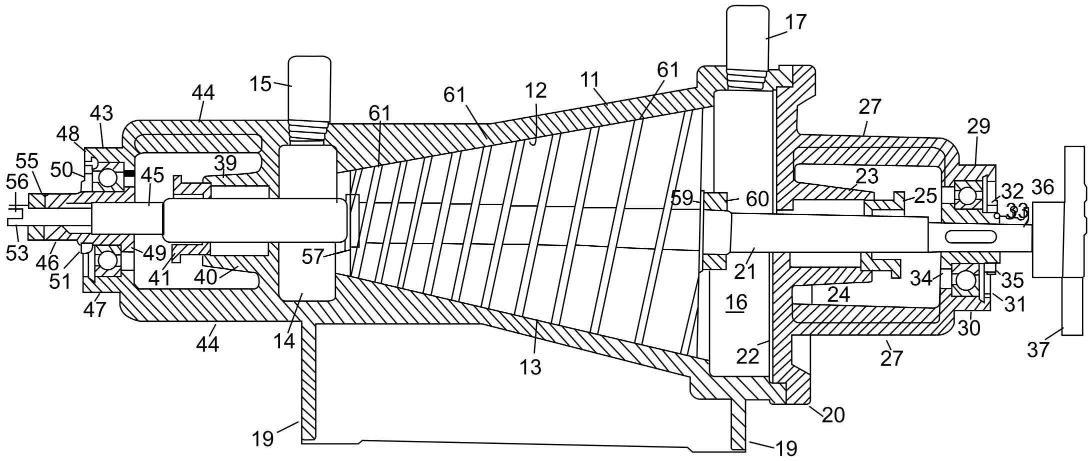

Fig.1

Housing 11, Conical interior wall 12, Conical rotor 13, Inlet chamber 14, Inlet pipe 15, Outlet chamber 16, Outlet pipe 17, Support feet 19, Detachable end cap 20, Rotor shaft 21, End cap wall 22, Boss 23, Packing 24, Adjustable gland nut 25, Bracket arms 27, Bearing boss 29, Bearing 30, Snap ring 31, Inner race 32, Sleeve 33, Shoulder 34, Retainer nut 35, Reduced diameter outer end 36, Coupling 37, Packing 39, Retainer 40, Gland nut 41, Bearing boss 43, Integrally formed bracket 44, Shaft reduced diameter 45, Bearing sleeve 46, Bearing 47, Snap ring 48, Inner flanged 49, Inner race 50, Nut 51,Shaft reduced diameter 53, Lock nut 55, Flat faces 56, Snap ring 57, Washer 59, Nut 60, Helical channel 61, Channel base 63, Channel sidewalls 64.

This is a high-pressure, low volume drag pump that can be used in place of conventional positive displacement pumps (criteria 2). It has a conical rotor that has a close fit clearance with the stationary housing wall. Delivered pressure is limited by back flow across the radial clearance and is inversely proportional to the square of the clearance. As a result, even a small increase in radial clearance would rapidly reduce pressure. The rotor is cone shaped so that the clearance can be controlled by axial adjustment of the rotor relative to the housing wall.

The conical rotor has two helical channels (criteria 3), in the form of square threads, spaced 180 apart for balance. The channel depth decreases as the rotor diameter increases. Fluid enters the channels at the small end of the rotor. The fluid is induced to rotate with the channel by boundary layer drag. The boundary layer is the thin layer of fluid adhering to the channel surface. Molecular cohesion tends to drag the adjacent fluid with the boundary layer. The fluid is also in contact with the housing wall. The boundary layer drag against this stationary wall slows the rotation of the fluid in the channels. Because the fluid rotates slower than the rotor, it is forced through the channels towards the large end of the rotor. In addition the fluid is forced towards the large end by centrifugal force.

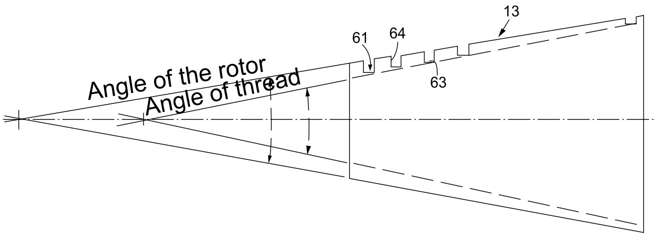

Fig.2

The above drawing illustrates the proportional decrease in channel depth as the rotor diameter increases. Why was this done? Note that as the diameter doubles so does the circumference. This means the fluid has to travel twice as far in the same time to maintain a constant slip velocity. By reducing the channel depth in half (cross-section area = depth x width) the fluid velocity is doubled thereby keeping the slip constant.

The spiral channels could be thought of as very long convergent nozzles. The increase in fluid velocity is in the opposite direction of the rotor spin. We should expect a reaction force from the acceleration of the fluid. This thrust would be directed tangent to the circumference and would increase the spin torque on the rotor. Even without the peripheral nozzles, that Clem later added, the pump rotor experiences a thrust force in a direction that would self-propel it (criteria 4).

Because fluid drag is the primary pumping force, it is well suited for viscous fluids like asphalt (criteria 5). The long channels also represent a large sliding surface area with frictional losses that would transfer heat to the pumped fluid (criteria 6).

All six of the patent search criteria have now been met. Of course this doesn't prove that it is the asphalt pump Richard Clem worked with.

A peculiar condition indicated by the patent is that as the velocity increases in the channels the pressure also increases. Bernoulli's Law requires the pressure to drop proportionally as the velocity increases. Assuming an ideal fluid without losses, when the channel depth is reduced in half, the cross section area is also half and this doubles the fluid velocity and the fluid pressure should drop in half. So what is going on here? There is a centrifugal component that would add to the fluid pressure.

My guess is it's too small to overcome the predicted pressure drop. Here is what I think may be going on. As the diameter and velocity increases the drag force propelling the fluid through the channel is proportionally greater. Energy is being added all along the length of the channel. Whatever the reason, if this high-velocity, high-pressure fluid is feed into tangent peripheral nozzles at the rotor large end, the energy will be converted to shaft horsepower.

The Clem motor is producing 350 shaft-horsepower and a large heat energy component. Where is this huge amount of energy coming from? Recent quantum mechanics zero-point field (ZPF) theories may point to the answer. From an article available at "BEYOND $E=mc^2$" Bernhard Haisch, Alfonso Rueda & H.E. Puthoff [1]:

"Our work suggests inertia is a property arising out of the vast, all-pervasive electromagnetic field we mentioned earlier, which is called the zero-point field (ZPF). The name comes from the fact that the field is held to exist in a vacuum-what is commonly thought of as "empty" space-even at the temperature of absolute zero, at which all thermal radiation is absent."

ZPF researchers theorize that mass, inertia and gravity are not intrinsic properties of matter but the interaction of matter with the zero-point field. By all pervasive it is meant that the ZPF exists not only in empty space but it is passing through your body right now and everywhere else. When you throw a stone you are interacting with this field since the ZPF resists change in motion. In essence the ZPF is the modern day aether.

The amount of energy making up the ZPF is thought to be enormous. Is the fluid acceleration in the Clem motor interacting with the ZPF in such a way as to rectify it and draw energy from it? Is it a hydraulic aether-diode? The fluid, in the Conical Drag Pump, flows through long convergent channels. Disregarding the boundary layer, is this accelerated flow laminar? Would such a long orderly flow entrain the aether energy?

From the perspective of the rotating channels the fluid appears as the discharge from a long nozzle. To exaggerate, if the fluid was held fast to the housing wall, the rotating channel would travel through the stationary fluid. This would be equivalent to achieving 100% efficiency. In reality the fluid is slipping against the stationary housing wall so that the rotating channel (nozzle) is moving faster than the fluid discharge velocity. Assuming the reaction thrust as the only propelling force, this would give efficiency greater than 100%. So, as the slip increases the reaction thrust decreases, but the efficiency increases.

Assuming the Conical Drag Pump is the pump Clem used, can it answer the following?

1) Why was a hollow shaft used?
2) Why was the cone mounted vertically?
3) Why was a starter pump needed?
4) How were the peripheral nozzles added?
5) How was the motor RPM regulated?
6) How did a large coal company get involved?
7) Was this kind of pump ever used in asphalt sprayers?

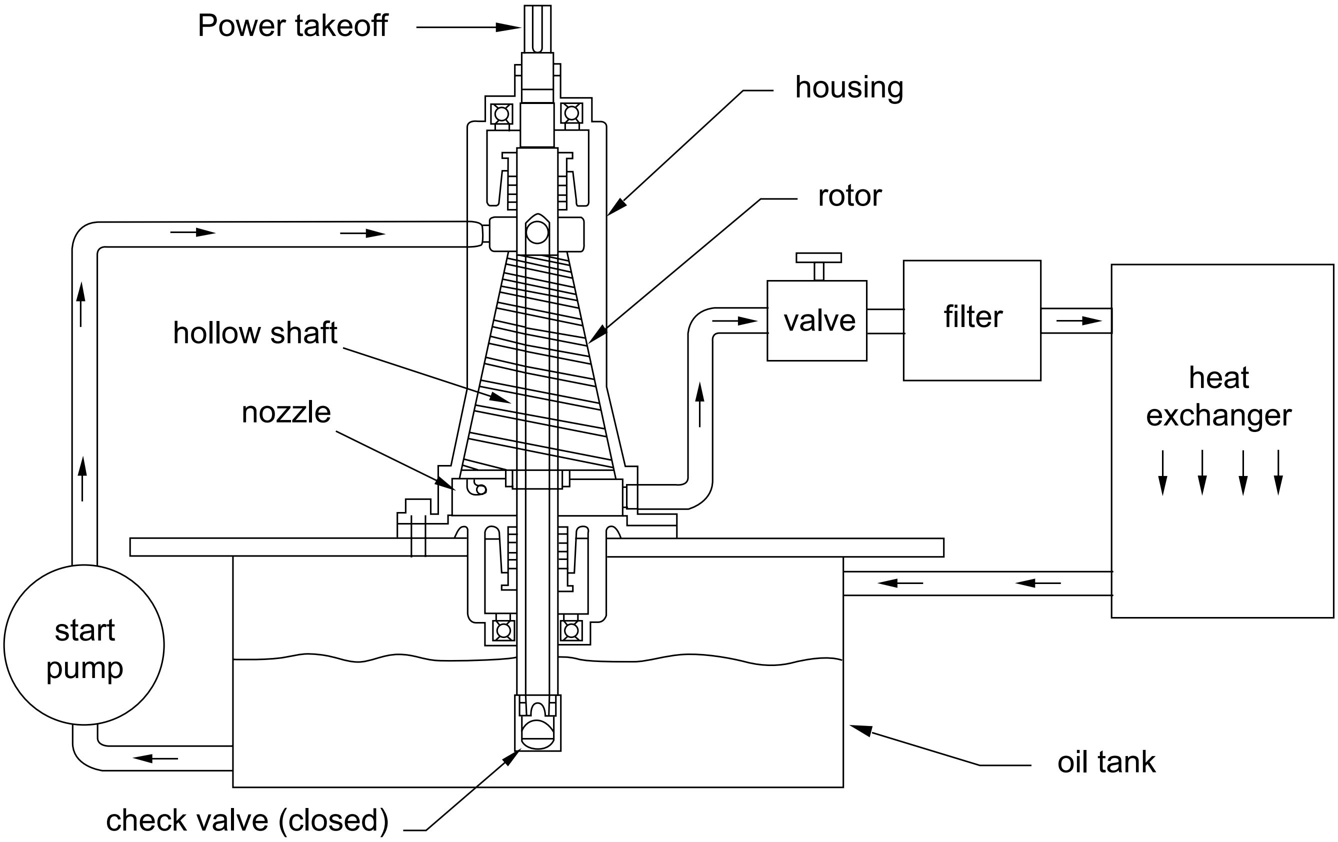

Fig.3

Clem motor shown in start mode
The arrows show oil flow

The above drawing shows a hypothetical Clem motor based on the Conical Drag Pump. The motor is mounted vertically so that the check valve on the hollow shaft is submerged down in the oil tank. The hollow shaft extends from the oil tank through the rotor into the inlet chamber. The start pump draws oil from the tank and forces it up the external feed line connected to the inlet chamber at the small end of the rotor. This fills the hollow shaft and forces the check valve closed. The oil flows into the spiral channels and out the peripheral nozzles. The reaction thrust of the nozzles spins the rotor. The oil flows through the return line, through the valve, filter, and heat exchanger and back into the tank. The start pump is most likely a standard hydraulic gear pump. It continues to pump until the rotor spins up to its operating speed. The combinations of a start pump and check valve would be a simple way to both prime the motor and spin up the rotor.

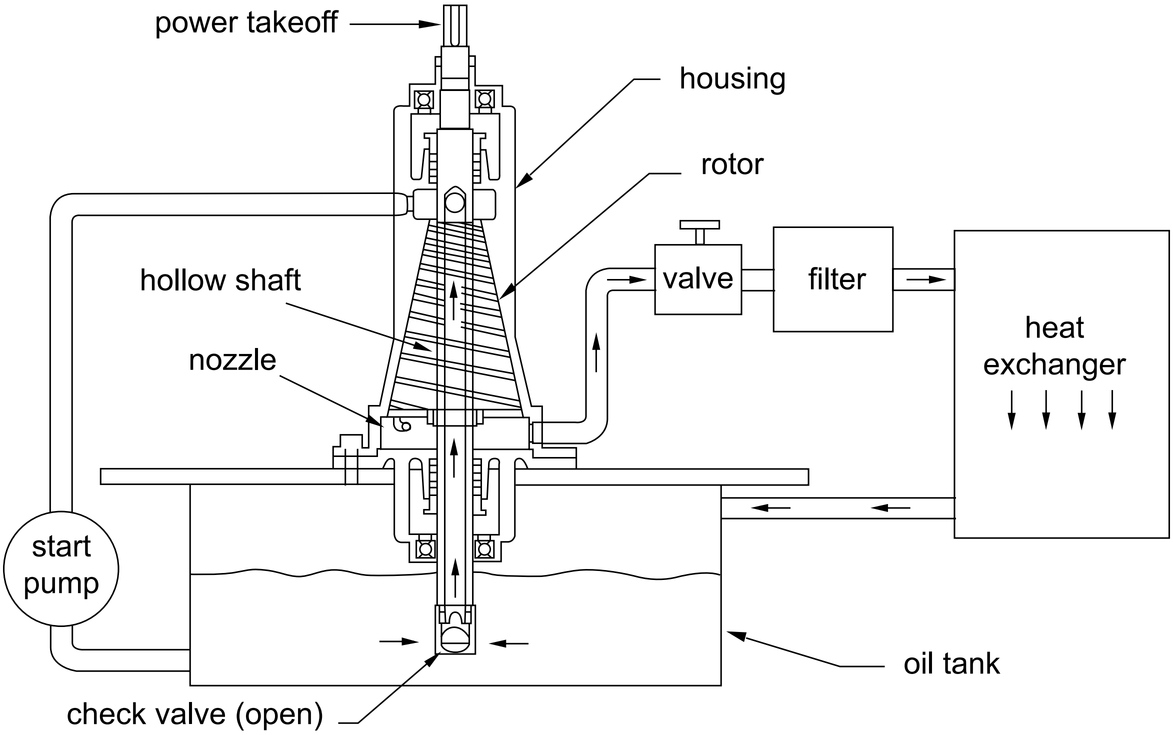

Fig.4

Clem motor shown in operation mode
The arrows show oil flow

Once the start pump is shut off the check valve is free to open. Oil is drawn up into the hollow shaft to the inlet chamber at the small end of the rotor. The spiral channels pump the oil down towards the large end of the rotor. A plate is attached to the large end of the rotor and fits with a close clearance with the housing wall. Nozzles attached to the outer edge receive high-pressure oil from the spiral channels. The jet reaction thrust from the nozzles delivers shaft horsepower to the power takeoff at the shaft top. Adjusting the valve to create hydraulic backpressure regulates the motor RPM. Closing the valve stops the motor.

When I first read about the Clem Motor I found it odd that a deal had been made with a coal company. Was there a connection with the pump? After finding the Conical Drag Pump patent, I wanted to contact the inventor Walter D. Haentjens of Barrett, Haentjens & Co., Hazleton, Pennsylvania. Otto Haentjens founded Barrett Haentjens & Co., in 1916. The business began in the coalmines of Pennsylvania with Otto Haentjens original patent on the balanced opposed impeller multi-stage volute pump. The company still supplies pumps to the coal industry. They have expanded to other markets and their pumps are installed in many industries worldwide. It is now known as Hazleton Pumps Inc., after its acquisition by The Weir Group.

I contacted Peter Haentjens, the VP/General Manager of Hazleton Pumps, by e-mail to find out if this pump had ever been put into production. He replied that they had not done anything with the patent.

An unusual pump design would have a tough time competing in the market with an industry standard like gear pumps. The Dallas asphalt sprayer may have been a one of a kind field test of the pump design. Or the pump manufacturer offered it for testing to an asphalt equipment company in the hopes of generating interest in it.

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Bernhard Haisch, Alfonso Rueda & H.E. Puthoff, “BEYOND E=mc^2” //The Sciences, Vol. 34, No. 6, November / December 1994, pp. 26-31 copyright 1994, New York Academy of Sciences.

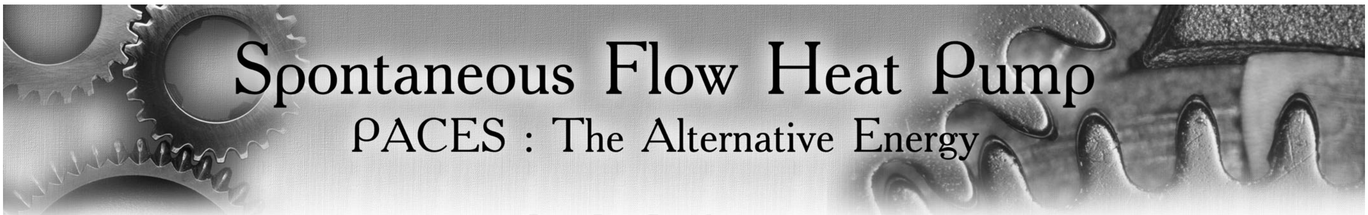

Spontaneous Flow Heat Pump

PACES : The Alternative Energy

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"Paces" is a new high performance electronic process. It is not a traditional heat pump fitted with some electronic gadgets to improve its output, but a truly revolutionary process totally unused up to now. There are no moving parts, not even a moving fluid in it. "Paces" is an electronic process because for its development the pump's fundamental element uses micro-electronic techniques.

...an average of 9000MW could be produced, that is to say the equivalent of several nuclear power stations.

The principle consists in attracting the gas neutral molecules onto a so-called "electrostatic" plate, to accelerate them and heat the plate. An intense electric field is applied in a capacitor with micro-pores covering the plate. The neutral molecules are polarized and accelerated when they penetrate these micro-pores where the intense electric field exists. Each molecule accelerates and absorbs electrical energy when it enters into a pore. But in turn it decelerates and gives off an equal amount of energy upon its exit from the pore.

The molecules, by going back and forth between the plates, continually give off and take energy, thus resulting in a total consumption equal to zero.

The gas fluid does not undergo any change of thermodynamic state, contrary to all other heat pump processes. A thermodynamic cycle remains at the level of each gas molecule, but not at the level of the entire set of molecules.

There is more to this new process, it is not just heat pump process added to an already long list: **these new characteristics also enable some new applications.** Besides the traditional heat pump applications, due to its excellent coefficient of performance this process makes it possible **to produce electricity by cooling the environment.**

For instance, if the Rhine was equipped with heat exchangers into which diverted water could flow, thus cooling its temperature by just one degree, an average of 9000MW could be produced, that is to say the equivalent of several nuclear power stations. Please note that this process would also enable **both electricity and fresh water to be produced from seawater,** an interesting application for areas of the world where water is a scarce resource.

Thus we have at our disposal an ecological process for producing electricity, it would become conceivable to produce hydrogen in great quantities; vehicles would be hydrogen powered. Ozone, CO2 or any other type of pollution would become a thing of the past.

It will most probably be the energy source of future generations, ecological and excellent, inexhaustible, powerful yet completely harmless, stable and steady (contrary to the sun and wind); an invention capable of re-launching the world economy, in particular giving impetus to the currently depressed new technology sector.

However, you have probably noticed that this invention requires advanced technology, and the few French laboratories capable to develop this process have proven inaccessibility to do it for independent researchers such as the author of the article. Besides, the invention's claimed qualities, the revolutionary aspect was very often interpreted by examiners as 'utopian', even before they read the document! Having tired of battling against concept fixed for the past two centuries, the author of the article **has now decided to place this project within the hands of the international scientific and technological community,** in order to give the best chance of success to the invention.

It will most probably be the energy source of future generations!

Initial development requires the construction of a prototype; three possibilities are described on the website (http://www.new-energy-paces.com). As there is no longer legal protection abroad, anyone is free to experiment and to market, as he or she wishes, in all other countries outside of France.

Please help me to spread the word about this project, for example through scientific forums on the Internet. This will allow you to receive feedback and gather other opinions. Your participation, even the most modest, will be of use. To those of you who help this project to see the light of day, all of humanity will be indebted.

Registration of Gravitational Waves

Vladimir N. Petrov, Russia

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Registration of gravitational waves is one of fundamental problems of physics. At the beginning of the last century A. Einstein's works predicted existence of these waves. Nevertheless, despite numerous attempts are made in different countries of the world these waves have not been fixed up today. Josef Veber, an American physicist working in 60th of the XX century, is sure to be called as the first experimenter who disclosed gravitational waves. Nowadays lots of many-million projects on registration of gravitation waves are developed and realized (LIGO (USA), GEO-600 (Germany-England), VIRGO (Italia), and TAMA (Japan)). However no positive results were achieved.

Failures in registration of gravitational waves can be explained by the fact that researchers have erroneous notion of the essence of these waves. This erroneous notion is laid in an experimental project that causes negative results.

Many researchers believe that influence of gravitational waves on the bodies should be resulted in deformation of these bodies (i.e. in change of mutual place of particles of a material body). All the attempts to disclose the gravitational waves are based on this notion. Now two types of ground gravitational antennas are supposed as priority.

The first type supposes the registration of mechanical oscillations of a massive test body that is initiated by influence of gravitational waves on it.

The second can register changes of a distance between space-apart free masses when gravitational waves act upon them. Great attention is paid to the second type of antennas in the developed projects. Failure attempts of registration of gravitational waves can be explained by their low intensiveness and insufficient accuracy of existing measuring equipments. Therefore, now there are made various attempts to register gravitational waves produced by such great cosmic phenomena as confluence of black holes. More accurate instruments and measuring equipments, for example, a laser interferometer, are developed. Nevertheless, positive results are hardly to be obtained.

Here is one of the fallacious explanations of action of gravitational waves on a body: *"Passing of gravitational waves changes an interval between objects transferring them one from another like two boats sometimes are approached sometimes moved from each other by sea waves".*

Following this example to explain influence of the gravitational waves on bodies placing on the Earth, it can be said that all bodies are in one boat and raising or sinking of the boat on sea waves does not cause change of the distance between the bodies. However, this example seems to be very simplified for explanation of influence of the gravitational waves on bodies. In fact, the case is much more difficult.

According to A. Einstein's theory, bodies moving with variable acceleration will radiate gravitational waves. **Gravitational waves represent the essence of changes of gravitational field occurring at light speed.** Since the gravitational field is a deformed space-time then the gravitational waves cause change of deformation of the space-time. Change of deformation of the space-time is accompanied with change of deformation of geodesic lines (i.e. lines by which all the bodies move).

A body moving by a geodesic line whose deformation is changed changes its acceleration. Change of acceleration of the body will change gravity applied to the body in this area of space. Hence, influence of gravitational waves on the body occurs through gravity which influences on it.

It is known that a fundamental difference between gravity and other forces appearing at a direct contact with a body consists in the fact that gravity provides all the elements of the body (all its points) with equal acceleration (deformation can not occur), and other forces influence on certain parts of the surface of a body and so cause its deformation.

Hence it is senseless to try to measure deformation of a body or change of a distance between test bodies occurring under influence of gravitational waves. It is necessary to note that, in particular, when a body is placed on an unmovable support relatively to the Earth, value and the direction of gravity coincides with weight of the body. Therefore, in this case gravitational waves can be registered at measuring of changes of the body weight.

An experiment on registration of the gravitational field of the Earth by measuring change of weight of a test body was made. Before the beginning of the experiment there was set a problem to register gravitational waves produced by the Mercury and the Venus at approaching to the Earth. The gravitational field in which the Earth moves changes due to superposition of gravitational waves of other planets on it. These changes were necessary to be registered.

The experiment was as follows: a test body (a 100 grams weight) was weighted on an electronic balance in equal time intervals of 14 days. The experiment was lasting for 12 months. In the experiment it appeared that change of a distance between the Earth and the mentioned planets causes change of weight of the test body. The change of weight of the body occurred in proportion to the distance between the planets. The test body was weighted in the same conditions and in the same place. The performance of the experiment is so easy that every person can made it.

It is known that weight of a body changes (decreases) at moving along the Earth surface from its pole to the equator. Change of weight of a body locating in the same place has not been fixed until now.

The fixed change of weight of the test body proves change of gravity applied to it and, consequently, change of the gravitational field in which the test body moves as well as the Earth does. **These changes of the gravitational field were caused by motion (superposition) of the gravitational waves produced by the mentioned planets at their approaching towards the Earth at the distance of the existent gravitational field.**

Hence, the Earth and all the bodies locating on it move in the constantly changing gravitational field, therefore, constantly change their weight. Nevertheless, as it is known, change of the gravitational field is the influence of gravitational waves on it. Hence, measuring changing of weight of bodies we can speak about registration of gravitational waves.

In search of the 4th dimension

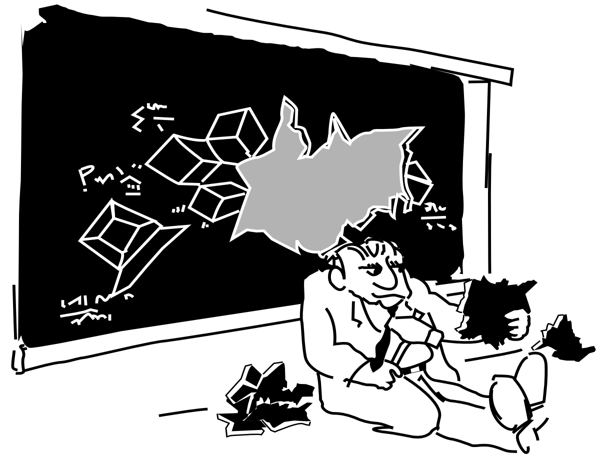

From http://home.ural.ru/~meop/index.html

High-Energy Hyper-Low-Frequency Electric Field

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E-mail: ux01w@hotmail.com

The article represents a practical and theoretical research on possibility of existence of a high-energy hyper-low-frequency electric field which is interpreted by modern measuring instruments and subjective perception as a static field. Besides there are observed a problem of the field registration, a hypothesis of relic origin of the registered field and a hypothesis of wave nature of the Universe.

A passenger on board a ship sailing in the ocean will never notice action of waves of high and low tide. At the same time, weathering waves of several numbers produce a dangerous storm. However, an ocean liner is designed for such a storm therefore the passenger would just experience some discomfort. It is another case if tide wave hides reefs… I wish our ship, i.e. the Earth, the Solar System, the Galaxy, and the Universe, not to be lead to such a place by any ignorant "navigator"!

One of the most mysterious persons in the history of electricity physics was an outstanding inventor Nicola Tesla (1856-1943). When the majority of scientists developed researches of microworld particles he followed the opposite scientific path. He was interested in the electrical potential of the whole Earth. He researched ways to influence on it, control its state and methods of its regulation. Therefore many of his patents, experiments as well as a purpose of constructions and devices built according to his ideas arouse perplexity and misunderstanding of modern scientists.

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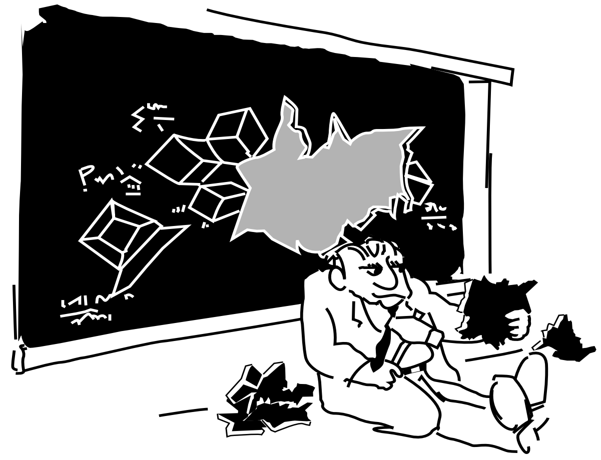

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Having formulated my own hypotheses I often think why such a Great Genius as Nicola Tesla took his invention away with him.

Danger of this invention lies in simplicity of production of devices for generating (detecting) energy.

Practical Prerequisites

Prerequisites of this and other hypotheses were some undeclared effects occurring in practical wireless communication as well as investigation of devices for distant transmission of electric power.

Distant energy transmission was demonstrated by Nicola Tesla in 1892 in London and in 1893 in Philadelphia. However, even now the way he did it remains unknown.

In 1977-1985 I had to work a lot with radio transmitting equipment of different power of middle-wave (MW) and short-wave (SW) diapasons. According to fundamentals of physics, intensive electromagnetic field is produced around antenna curtain connected to a radio-frequency transmitter. There are brightly glowing gas-discharge electrovacuum devices at the distance up to several meters in this field. Attention was paid to the fact that more than ten daylight lamps of 80 W were successfully "glowed" at 40 W power of a transmitter. In this case a distant correspondent did not note significant decrease of a level of a received signal at the indicator of the receiver. It had to return to this fact in many years. The data of this experiment are represented in a particular document.

There is one more interesting effect which is disclosed when transmitting equipment (TX) and antennas (ANT) are adjusted. An incandescent lamp, which is connected to a certain place of a break of the antenna curtain or of a power feeder (L), glows brightly. The antenna circuit is not closed as galvanic element. (See Fig. 1).

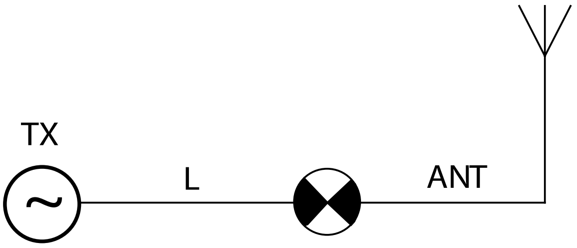

Fig. 1

Hence, the power line of the incandescent lamp is as if it is single-wire. It also had to return to investigation of this effect in many years. The data of this experiment are represented in a particular document. As in the case of the incandescent lamps, the correspondent did not note significant decrease of the level of the received signal at the indicator of the distant receiver.

S. V. Avramenko designed a plug of semiconductor diodes. Connecting this plug to a generator of alternating voltage of 10-10000 V by means of a single-wire line in the load of the plug he discovered current, which was continuous by the direction but pulsating by the value. Electric current measured in the single-wire line is very little, hence, the impression of superconductivity is produced, i.e. it is possible almost to avoid energy losses in the wires.

My experiments also represent a visual demonstration of the effect. For example, several links of light-emitting diodes connected inverse-parallel glow in the single-wire line. Garlands of light-emitting diodes and lamps having a single-wire power line can be produced. It is interesting that in this case power consumed by the generator do not increase practically (See Fig. 2, 3, 4). It was noted that if a standing wave is created around the generator "then an unlimited number of consumers would be able to apply a change of a value of this field to produce power in a load in their place" *(Editor: This phrase is in inverted commas since it is a part of the well-known article "Free Energy" by Alexander V. Frolov (Read in this issue, p. 15)).*

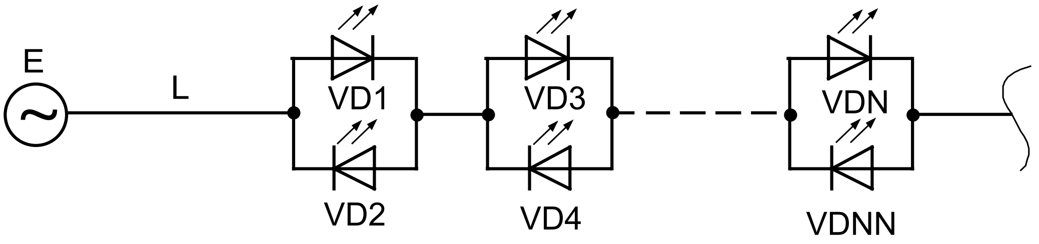

Fig. 2

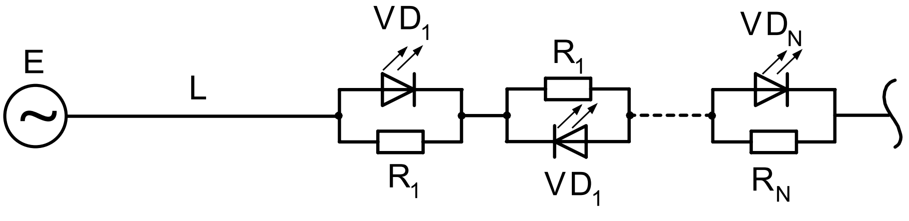

Fig. 3

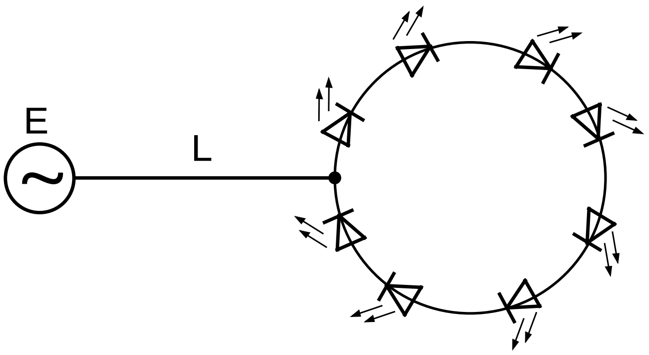

Fig. 4

Russian scientists investigated this phenomenon and proposed an explanation of producing active power in the load by means of reactive capacitive current. This was made applying resonant properties of the single-wire line made of a metallic conductor. Further, possibilities of application of nonmetallic conducting mediums for transmitting electric power were investigated. However, the researchers pay attention for the fact that this explanation is insufficient.

A task group named "Analysis" from Voronezh city (Russia) made a qualitatively new explanation of results of S. V. Avramenko's experiment. The works of this group from Voronezh are devoted to the comparison of properties and characteristics of so-called inertial and inertialess currents occurring in circuits at low frequencies. Their general and particular features have been disclosed. In the works there are demonstrated conditions at which conductivity caused by inertialess discharges predominates in conductors and conditions at which currents caused by conduction electrons predominate. There are demonstrated a description of S. V. Avramenko's experiments and the conclusions made by the researchers. The authors cite data of their test experiments which prove a part of conclusions made by S. V. Avramenko and his colleagues.

However this explanation does not have a right to exist as it does not have variants for practical application.

Results of my theoretical and experimental researches allow provide a **fundamentally new (!)** explanation of energy "transmission" having occurred in the experiments performed by S. V. Avramenko, investigations by D. S. Strebkov, V.A. Kuligin and other investigators. *(Editor: See publications of these works in previous issues of our magazine*). Moreover, they allow explain origin of many physical phenomena and processes including the origin of non-inertial charges and currents and their visualization.

First Hypothesis

Recently a number of scientists all over the world have declared a thought that surplus power is produced in the systems having overunit output due to inability to identify correctly all the existent energy sources. And a so-called phenomenology is observed due to the inability to deal with different types of energy (or fields).

In physics a negation of an overunit device follows a well known state which is considered to be true in other fields of knowledge, i.e. energy conservation law. It should be noted that it is formulated for isolated (closed) systems. I have devoted some time to the investigation of this state and to practical experiments and come to the following conclusion: there are **no isolated (closed)** systems in the nearest cosmos which can be observed by us!

Particular physical, chemical and other processes may actually be observed in closed circuits for making calculations with sufficient approximation.

Show me an isolated system, and I will prove that it is open.

Hence, according to fundamental physical laws, energy does not appear from nothing and not disappear to nowhere. However, the source of oscillations, i.e. our generator, does not provide a load with energy; nevertheless, power is produced in the load. Energy conservation law must be fulfilled! The classical formulation of the energy conservation law is as following: total energy of an isolated system is not changed in the course of time. According to this, the only fact remains valid, i.e. the single-wire system is not isolated from outer influence, hence, energy is consumed from some other source which is outer in relation to the system?! In this case our generator is one of sources of information about an amplitude, frequency, and phase.

Calculations and experiments have allowed made a following supposition. Avramenko's diode plug is a particular case of a device known in radio engineering for a long time, i.e. AM detector (a peak-detector, a limiter, a frequency mixer). I have examined the other known circuits of AM detectors and frequency mixers. The investigations are continued and by this time the supposition has been confirmed.

Let us accept an artificial generator (Tesla's transformer or any other one) as a main generator (or a main oscillator) and a hyper-low-frequency (HLF) oscillation of a huge amplitude as an envelope curve. Let us name it as RW ("relic wave") without placing emphasis on the sense of the name.

Let us suppose that the field can be of:
- local origin (artificial radio transmitters);
- atmospheric origin;
- geomagnetic Earth origin;
- the Moon – the Earth;
- the Sun – the Earth (the Sun as a nuclear reactor producing electromagnetic radiation, the Solar System);
- galactic origin;
- Universal origin – the Relic Wave; in contrast to the relic radiation occurring in the diapason of SHF (i.e. in

contrast to the convenient notion) it is the diapason of HLF.
- Etc.

The researches have demonstrated that the field of local and atmospheric origin may be excluded. The other variants require to be developed. Nevertheless, the variant of the Universal scale seemed to be the most probable. There is some reason for this supposition: the modern notion of the birth and the state of the Universe, i.e. the Big Bang and the expanding Universe. The known variants of scenarios of the Big Bang are based on a nuclear explosion of enormous power. The nuclear explosion is accompanied by an electromagnetic impulse (disturbance). It can be supposed that the Big Bang caused forming of a field having enormous amplitude values and long (great) period of oscillations. Probably, we deal with this field.

The second hypothesis about inconstancy, i.e. about wave nature of the Universe

A Russian proverb says: “Everything passes, everything changes”. Constant electric voltage does not exist (!). That, what is considered as the constant voltage, really is a constant component (occurring at a certain time interval). This component is formed by combining of variable sinusoidal oscillations and/or is a quite low frequency fundamental. Hence, it is a non-sinusoidal “changing” having amplitude linear part at the time interval of the observer.

For example, in reality a usual storage battery of “direct current” can not support invariable voltage, i.e. when a discharge appears the voltage decreases (changes in time, oscillates with a non-sinusoidal oscillation and a quite low frequency fundamental), when a charge appears the voltage increases.

It is necessary to observe the constant voltage occurring after a rectifier and even a stabilizer as a constant component existing in the time interval from switching on to switching off. This will correspond to that is proposed by Fourier!

Show me a device producing constant voltage, and I will prove that the voltage is not constant.

Conclusions

If the supposition is totally confirmed then the statement that an electric field plays a fundamental role in the Universe will be valid.

We live in an electric field of a huge potential but we do not notice it. Since **our reference point is the amplitude value of RW field in our point of space** then the potential is equal to zero for our perception and for measuring instruments. Besides, **RW has an amplitude linear part at the time interval of the observer**. Hence, we consider RW field existing as unrevealed or as weak interactions in natural processes. Nevertheless, this influences directly on the whole surrounding material world.

Artificial production of heterogeneities in the RW field can cause its significant visualization.

According to the concept of the physical field, which was called by Einstein as the most important discovery in physics since Newton’s time, every body generates a force field in the ambient space (for example, the electric field occurring if the body has an electric charge). This force field becomes apparent when a test body located in a certain point is influenced by a force.

Discovery of the fields of this scale allows define this concept more accurately. I would like to restate the information mentioned above in the following way: every non-homogeneity of physical vacuum (aether), which is registered by our perception or by measuring instruments as a physical object or a physical field, interferes with RW (according to other interpretations, it absorbs or rereflects RW, or becomes excited) producing new wave fields. This perceived physical field has frequency which is higher than RW frequencies. It is perceived as static in the time interval of observation. Hence, the field generates a charge and not the reverse. Any linear or non-linear transmission (motion) of a material or field object changes non-homogeneity which is generated by this object.

A question about measuring of parameters of the Universe remains open. Can an oscillation of the period of $T=14$ billions years and of the amplitude of $A \sim T$ be seen, perceived, registered or measured?

The used literature and references are not cited in the article due to its great volume. The reader can familiarize with them at the web-site of http://www.efir.com.ua. The complete text of the article and other materials can be received from the author.

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To the Question of Work Made by Electrostatic Field

Alexander V. Frolov, Russia

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We know some simple examples of work making due to the forces, which appear in electrostatic field. Since the field itself does not require energy consumption from the source (not taking into account the charge leakage), then free energy can be received with these forces. The first phenomenon that we are going to consider is a phenomenon of **electrostriction**. Mechanical forces appearing in dielectric under the influence of electrical field tend to deform it. Sometimes these forces are small, but they can be huge in special dielectrics. The character of deformation also depends on non-linearity of electrical field. Suffice it to remember that heating of a body takes place during deformation, and we can make a conclusion on possible using of the given effect in practice. Periodical deformation can be created due to the rotor or any other methods to change the field.

The second effect is not so popular. It was found by Hertz in 1881 that there is a rotation of dielectrical cylinder (or ball) in permanent electric field if it is created in some liquid or in gas (see Fig.1).

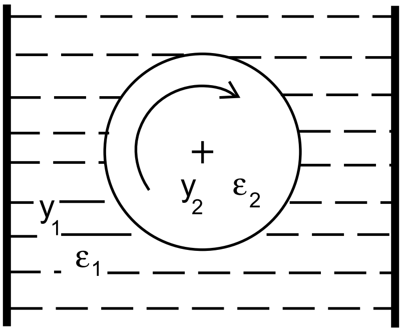

Fig.1

Here $\varepsilon1$ is a dielectrical permittivity of the liquid, $\varepsilon2$ is a dielectrical permittivity of the rotor, $\gamma1$ is a conductivity of the liquid and $\gamma2$ is a conductivity of the rotor. This effect was discovered by Hertz, then it was described by G. Quincke, Germany. Also Japan scientist I. Sumoto studied the effect in 1955. Modern research work was made by K.M. Polivanov, Moscow. There is the so called equation by Polivanov describing special conditions, which are necessary to begin rotation ($\varepsilon1/\ \varepsilon2=\gamma2/\gamma1$ is the Polivanov's condition). Forces of electrostatic field produce this rotation and it is a real free energy system that can trap energy from inner structure of potential field. Let's try to describe the mechanism of this effect and then we'll be able to increase the power of the system up to the level of industrial application. So, why does it work? To my mind, there are some differences in conditions for polarization of the rotor and molecules of liquid or gas those are surrounding the rotor since there is a difference in permittivity and conductivity.

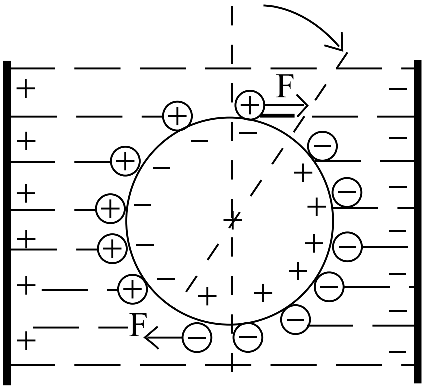

Fig.2

Due to this reason the molecules are polarized both by the field of electrodes and by the field of rotor. The rotor is polarized in the electrical field of electrodes, and molecules of liquid on its surface are polarized by the electric charge of the rotor, but not according to direction of the field. So, the rotor is surrounded by "screen" of molecules on its surface. The electric charge of this screen partially compensates the field of electrodes.

When some angle is created by the first initial turn, there is some part of the rotor surface, where molecules of liquid on the surface of the rotor are attracted to electrodes and it is the reason for future rotation. After some angle of the turn the polarization in this point of the rotor surface is changed but new molecules are incoming in the so called "sector of attraction" and the rotation is always accelerated. This well-known effect of 1881 is a very good example of possibility to produce useful work in load by means of electrostatic field only.

One more interesting effect is known as Faraday effect. In 1836 Faraday noted that raising of liquid upwards takes place in condenser with liquid dielectric (plates are installed vertically). During this process electrostatic field makes the work against gravity. A. Gyemant in 1926 established that value of this force is proportional to the square of voltage on condenser. Later in 1955 this phenomenon was studied in details by I. Sumoto, Japan. That's why in physical encyclopedias this effect is called "Faraday-Sumoto effect". In Tareev's book [1] it is pointed: "Under high voltage this phenomenon leads to flowing and turbulent boiling of liquid". I should remember for those, who see nothing unusual here, that it does not necessary to consume the power from initial source. Creating an initial field in electric capacitor, then we can use the received mechanical work. It is evident that the gradient of electrical field creates the conditions for movement of liquid dielectric. A task to create conditions for liquid circulation is more complex, but it has solution, if we take into account the presence of one more static field, i.e. gravitational field. Joint action of electrostatic and gravitational fields stipulates the circulation of liquid dielectric even in the simplest constructions. Besides, electrostatic filed can be partially screened.

The analyzed examples should draw attention of experimenters to these obvious ways of how to create useful work by means of electrostatic field.

References

1. Tareev B.M. Physics of dielectrical materials, Moscow, Energoisdat, 1982, p.199 – 200.

Editor: Below we publish the comments of our reader.

Letter On
Hertz-Quincke-Sumoto Effect

from Doug Marett
Email: doug.marett@sympatico.ca

…As far as I can tell, the original reference by Hertz is "On the Distribution of Electricity over the Surface of Moving Conductors", Wiedemann's Annalen, 13, pp.266-275,1881. Hertz's discussion of this phenomenon is cursory at best, having very little experimental work included. The real phenomenon appears to have been discovered by W. Weiler in 1893 (Zeitschrift fur den Physikalischen und Chemischen Unterricht, Vol.6, pp194-195). Weiler observed that a glass cylinder placed in a poorly conducting liquid between two spherical electrodes began to rotate when the electrodes were connected to an electrostatic generator. In 1896, George Quincke reported the same phenomenon and published a comprehensive report on it. This was in Annalen der Physik, Ser.3, Vol. 59, pp.417-486. Subsequent investigators have tended to attribute the discovery to Quincke, when in fact Weiler was the first to pioneer the work.

I do know that P.E. Secker et al. performed work on this field, references of which are available in the English language. These are:

P.E. Secker, et al., (1968) Journal of Applied Physics, Vol. 39, pp.2957-2961, and
P.E. Secker, et al., (1970) Journal of Physics D: Applied Physics Vol.3, pp 216-220.

I hope that this information might be of use to you.

BOOKS REVIEW

The Foundations of Physchemistry of Micro World

Ph. M. Kanarev

The Second Edition

The book was published in Russian and English; you can also read it at http://book.Kanarev.innoplaza.net

The new axiomatic of natural sciences is given in the book; on its basis, quantum physics and quantum chemistry have been returned to the classical way of development. The first steps are made on this way, which have led to discovery of the structure of the photon, the electron, and the principle of the formation of the atomic nuclei, the atoms and the molecules.

The Planck's Law of radiation of perfect blackbody is given on the basis of classical concepts, and the connection of quantum phenomena with the laws of classical physics is proved.

The application of the new theoretical results to the solution of practical energy tasks on the basis of plasma electrolysis of water is shown. Due to this electrolysis, additional heat energy and the energy containing gases (hydrogen and oxygen) are generated. Cold Nuclear Transmutation of the atomic nuclei of alkaline metals and the atomic nuclei of the cathode material takes place during plasma electrolysis of water.

The book is intended for physicists, chemists and other specialists who are seeking the new directions for understanding the foundations of the micro world and the new energy sources.

Comments to Electro-Reactive LIFTER News

Alexander V. Frolov, Russia

General Director, Faraday Laboratories Ltd
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http://www.faraday.ru

March 21, 2003 we got news from France about electro-reactive propulsion system.

Blaze Labs reached 100g PAYLOAD level.

You will find all the details of the Saviour's experiment at: http://blazelabs.com/exp14.htm.

This electro-reactive ionization-flying model requires 46 kVolt, 4 mA, i.e. about 200 watts to fly with 100 g useful load.

It is interesting to note that Jean-Louis Naudin's previous opinion of 1997 – 1999 about priority of the Frolov's asymmetrical capacitor now is changed. Sometimes people wish to re-write the history. It is possible and it is easy. Naudin's web page about http://jnaudin.free.fr/lifters/story.htm (see Fig. 1) is not started from the real beginning of the story. He forgot our discussion of 1997 and also photos and MPEG video I have send to him when he has started his way in electrograviticis.

If you remember the name of Naudin's first asymmetrical capacitor "Frolov's Hat" (see Fig.2) then you know why there is this name of this technology. But really it is not important to try for some serious reply from Jean since he has no personal post address, phone, or his photo on the web site...

Also it can be useful to visit this page http://www.faraday.ru/t-cap.html to know about something **more important than electric ionization flying models (Lifters),** since it is just a reactive ionization way, which is similar to rockets.

Ideas now developing by us are not aimed to increase the power level (from 1 gram to 100 gram propulsive force). It is **a qualitatively new idea**; it is really electrograviticis instead of "electro-reactive Lifter".

So**, what is about real "history of the question" instead of the French version?** The question here is not about a priority, it is nonsense after T.T. Brown's patents. As an example the NASA patents on asymmetrical capacitors can be mentioned since the ideas were opened before the NASA patent and there is nothing new in it. The problem is that people who develop reactive ionization Lifters develop only primitive reactive technology. **It is not essence of T.T. Brown research but it is the distortion of his ideas.**

So, the team in France is working to develop and support ideas of secondary and wrong method. Why? Perhaps they either do not see the real way or have payment for the wrong way **to mask a real work.**

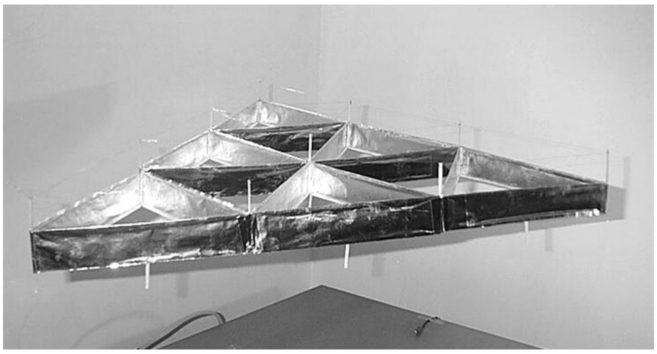

Fig. 1

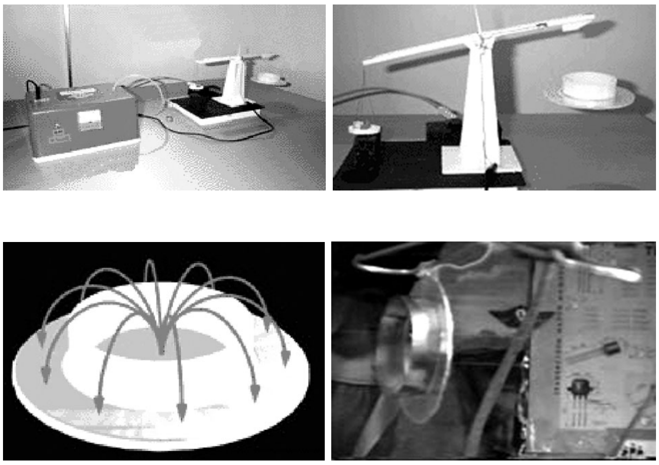

Fig. 2

Questions & Answeres

Josh Werrmann (Email: jsh111@yahoo.com): I wanted to ask you a few questions about an article titled “Highly Efficiency Electrolysis” by A.V. Frolov. In this article it is stated that Dmitry A. Latchinov patented a method for electrolysis, where one of the electrodes is insulated completely from the water. It is also stated that another scientist, Igor Goryachev, used a method of pulsed electric fields. I don’t know if you know, but inventor Stanley Meyer has a patent that covers both of these processes together, in a way. His patent is U.S. patent number: 4936961. Take a look at this. In the patent it states EXPLICITLY that there is a pulsed electric field, where a condition of NO CURRENT is preferred. This is very similar to the above to Russian scientists, except that the patent states a condition of resonance is necessary. I am wondering do the two scientists that are described require resonance in their devices? Or just plain pulsed electric fields, where one electrode is insulated from water.

Another patent I would like to refer you to is Archie Blue’s electrolyser, U.S. patent number: 4124463. This device is similar to A.V. Frolov’s idea, to get the oxygen and hydrogen bubbles off the electrodes, except he uses a blower to blow air in the cell, instead of rotating the cell like A.V. Frolov does. His invention also uses the conductivity current to work.

Alexander V. Frolov: As far as I know resonance is not created in this case. The main idea is the removal of gaseous film which appears on the surface of electrodes by rotation or some other methods.

NEWS REVIEW

Giant magnets lead the world to the new source of energy

http:// www.sciteclibrary.ru

The system of 150-tons magnets which have been developed by scientists of the USA, Japan and Russia opens a new era of safe and unlimited energy. In this system nuclear fusions serve as a source of energy. They accumulate heavy chemical elements not by means of nuclear reactions but by ultrahigh plasma pressure.

After supplementary research is held which aims to reduce manufacturing costs of the giant magnet weighing 925 tons, this magnet will be produced and demonstrated at the opening of the International Thermonuclear Experimental Reactor (ITER). This magnet in its turn will become a part of a bigger system, that is combined into a magnet weighing approximately 10 000 tons. The task of ITER is the demonstration of the process of nuclear fusion, as an energy source. During the process of nuclear fusion the light elements are combined by immense pressure, thus producing heavier elements. During this production process a lot of energy is emitted. The task of giant high-power magnets is to create magnetic fields, which must hold and control plasma, or to charge electrically the gas, in which the fusion is being held.

In Japan the system of 150-tons magnets serves as adjustment system of 925-tons magnets, which will be finally put into operation and heat up the ITER plasma. Two additional giant magnet systems will confine the plasma and will control its form. The model for one of them is presently being examined in Germany; the model of the other is in project.

Cylindrical 150-tons magnets have three main parts: external module, built by the Japanese team, internal module, built by the American team and a thin rod in the core which is equipped with process control equipment. Three different rods were separately checked, two of them were built in Japan, another in Russia.

Harnessing the Wheelwork of Nature

(340 pgs. Adventures Unlimited Publishers, 2002)

Thomas Valone
Email: iri@erols.com

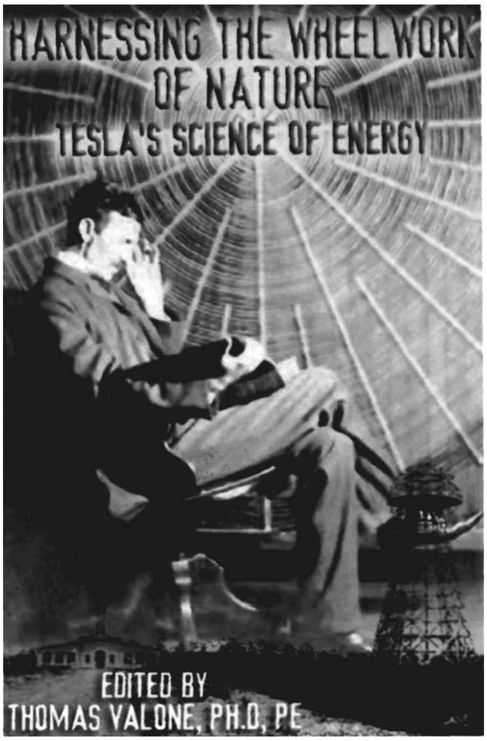

It is a new book by **Thomas Valone**, who edited this anthology in time for the **Wardenclyffe Tower Centennial (1903-2003)**. This book presents for the first time, the feasibility argument for Tesla's most ambitious dream, the wireless transmission of power. Pictured on the book's cover near his feet, the 187-foot Wardenclyffe Tower was Tesla's means to deliver natural 8 Hz electricity anywhere in the world, by longitudinal waves.

Unknown to most electrical engineers, Nikola Tesla's dream answers the energy crisis worldwide, saves electrical conversion losses, and provides a real alternative to transmission lines. In Dr. Corum's contributed papers, he explains Tesla's magnifying transmitter, which Tesla compared to a telescope. Corum points out that "the tuned circuit of his magnifying transmitter was the whole earth-ionosphere cavity resonator." This fact helps explain why Tesla stated, "When there is no receiver there is no energy consumption anywhere. When the receiver is put on, it draws power. That is the exact opposite of the Hertz-wave system...radiating all the time whether the energy is received or not." Thus, with Tesla's futuristic transmission of power, source dissipation will only be experienced when a load is engaged in a tuned receiver somewhere on the earth. This fact alone represents **a major leap forward** in electrical transmission efficiency, even one hundred years later.

Why wasn't the prototype of Wardenclyffe finished in 1903? Tesla offered this visionary conclusion: "The world was not prepared for it. It was too far ahead of time. But the same laws will prevail in the end and make it a triumphal success... Let the future tell the truth and evaluate each one according to their work and accomplishments. The present is theirs; the future, for which I really worked, is mine."

Up until now, there has been a general malaise regarding the lack of scientific comprehension of Tesla's greatest dream. For example, the Serb National Federation notes, "With the exception of the first biography of Tesla by John J. O'Neill, science editor of the *New York Herald Tribune*, and published in 1944, unfortunately no biographer since has had the necessary scientific/engineering academic credentials to discuss Tesla's work in the various fields." Contributors to ***Harnessing the Wheelwork of Nature*** are primarily physicists and engineers who are experts in Tesla technology. Their wealth of knowledge demonstrates their mastery of this extraordinarily progressive and technical subject. Finally, the best academic credentials have been brought to bear on the world's greatest electrical futurist.

This is a very readable and profusely illustrated reference volume on wireless transmission of power, besides being an excellent biographical gold mine of Tesla history. Nick Cook, editor of *Jane's Defence Weekly* and author of *The Hunt for Zero Point* says, "Tesla is one of the great overlooked geniuses of science and electricity. His full story deserves to be told. Tom Valone sheds important new light on his life and work."

Integrity Research Institute will hold a Tesla Energy Conference & Expo on November 8-9, 2003 to celebrate the Wardenclyffe Tower Centennial (1903-2003) in conjunction with the Tesla Wardenclyffe Project, Inc. (www.teslascience.org).

See www.IntegrityResearchInstitute.org for more details.

Experiment on the generation of gravitational field

by Dmitry Yu. Tsipenuk

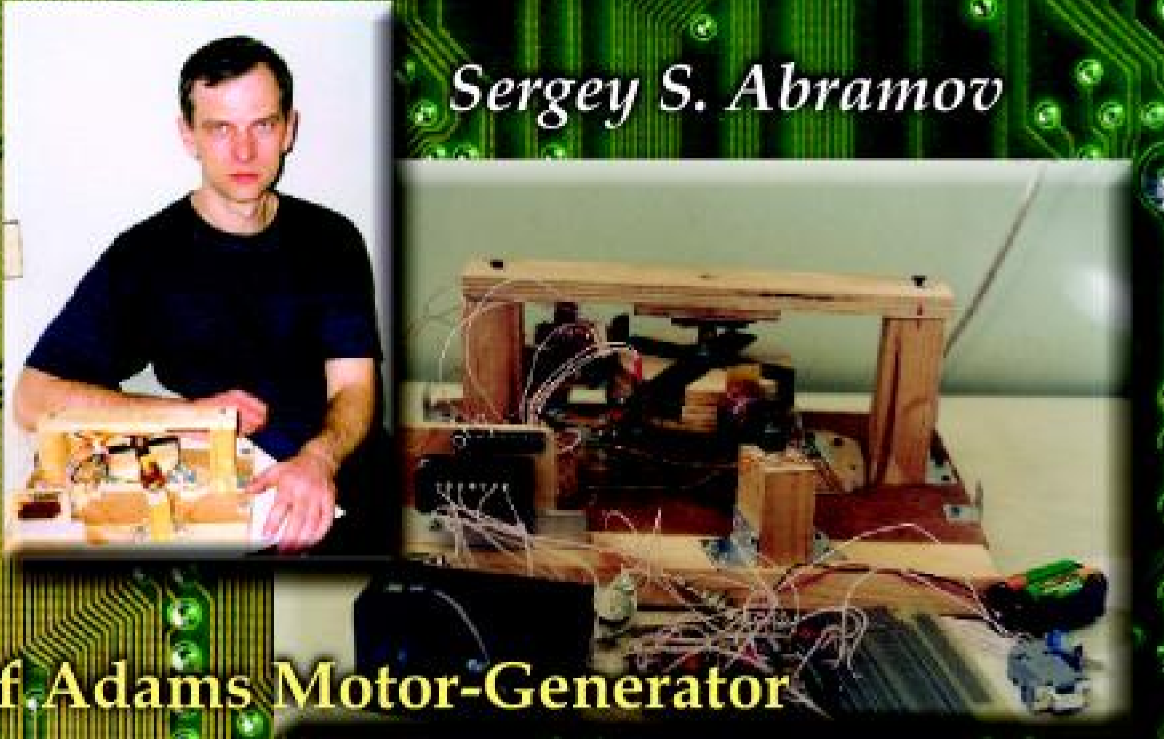

Sergey S. Abramov

Model of Adams Motor-Generator

Новая Энергетика

Electrolytic photoaccumulator for the XXI century energy systems

Read the new article by Anton I. Egorov

Flynn Generator

Original version of photomaterials is presented at http://www.flynnresearch.net

Joe Flynn Laboratory, USA

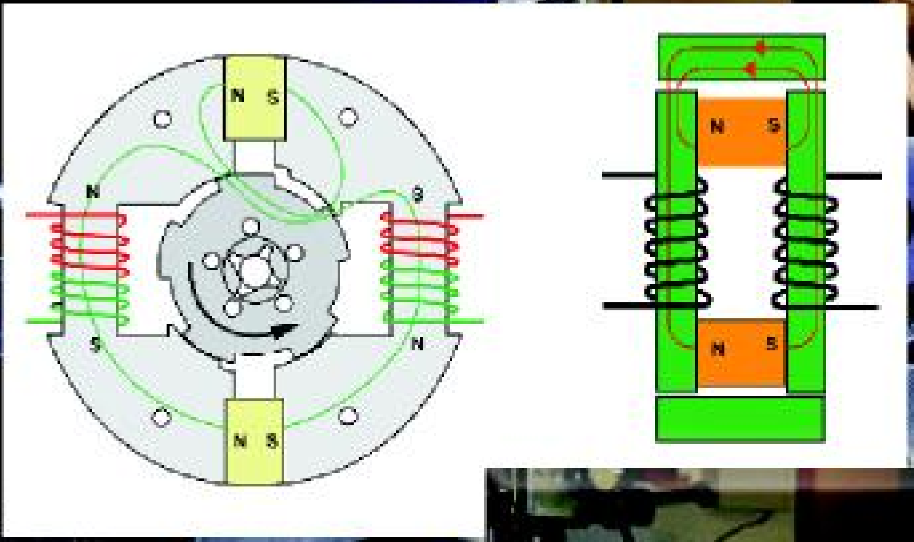

Electric generator by Joe Flynn

More than 350% efficiency generator operating on permanent magnets

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Read the article by Tim Harwood in this issue

New Energy Technologies

Printed version ISSN 1684-7288
Online version ISSN 1684-9698

Published by Faraday Laboratories Ltd. **Issue #3 (12), 2003**
Research on advanced aerospace systems and new energy sources

Time Machine

Conference in Moscow: discussion of the patent application on the method and device to control temporal parameters of matter

Time Machine

Experiments by research
group "KOSMOPOISK"
Summer, 2001

Device designed
by Faraday Lab Ltd, 2002

Alexander V. Frolov
Vadim A. Chernobrov
April 12, 2003, Conference hall
Hotel "Cosmos", Moscow

NEW ENERGY TECHNOLOGIES #12

1. Works on the Designing of Time Machines. Vadim A. Chernobrov (Russia)
2. Control of Temporal Parameters of Physical Processes. Alexander V. Frolov (Russia)
3. Etherodynamics as a New Field of Physics. Vladimir A. Atsukovsky (Russia)
4. Electromagnetic Gravitational Interaction Vadim Ya. Kosyev (Russia)
5. Medium For Existing of Matter in Nature. Anatoly V. Rykov (Russia)
6. Adams Motor. Sergey S. Abramov (Russia)
7. Field Transformation in the Model of Extended Space. Dmitry Yu. Tsipenyuk (Russia)
8. Joe Flynn’s Parallel Path Magnetic Technology. Tim Harwood (USA)
9. Flynn Laboratory Photos
10. Flux-machine and Its Analogies. Review
11. Russian Patents on Alternative Energetics.
12. Gravitational Spaceships. Gregory R. Uspensky (Russia)
13. On Velocity Of Drive-Free Motion. S.A. Gerasimov , V.V. Stashenko (Russia)
14. Electromagnetic Self-Action. S.A. Gerasimov, A.V. Volos (Russia)
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17. Teleportation. Alla V. Pashova (Russia)
18. “Mass Defect” in Home Conditions. Prokofy V. Sherbak (Russia)
19. Aether as Unified Field. Alexander M. Mishin (Russia)
20. Global Energy. Philip M. Kanarev (Russia)
21. Fusion Processes Of Molecules Of Oxygen, Hydrogen And Water. Philip M. Kanarev (Russia)
22. Plasma Energy Power Generation. Bruce A. Perreault (USA)
23. News
24. The Marcus Device Controversy. Tim Ventura (USA)
25. Systems of conversion of thermal energy to mechanical one. Review
26. I. Prigozin
27. Letters

CONFERENCE "THE TIME MACHINE"

Editorial: On April 12 of 2003 a scientific conference "The Time Machine" was organized by Faraday Laboratories Ltd in Moscow, Russia. It was devoted to the experiments on control of space-time physical properties. At the conference there were discussed problems of time and gravitation in the context of etherodynamics, experiments and applied aspects of these technologies. Below we publish a review of the main reports presented at the conference.

The First Results of the Works on the Designing of Devices to Control Parameters of Physical Processes (of Time)

Further Plans on Designing of the Time Machine

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To conduct the experiments on the influence upon physical Time (density of space energy) some special devices were used as a general method of such influence. These devices can create converging waves which can cause the appearance of quasi-monopole in the confined space. *Quasi-monopole* is a part of space which has some parameters of hypothetical unitary monopole or bunch of such particles (in particular, it allows registering one magnetic pole by means of measuring equipment from the outside at some distance from this pole).

The pilot experiments have shown that it is very difficult (if not impossible) to create long-living quasi-monopole by means of permanent magnets or electromagnets operating on direct currents (in this case quasi-monopole represents a space with one outer and one inner magnetic pole). It can be explained by the fact that lines of force of the "inner pole" invariably find a weak spot in the heterogeneous surface of magnets and break out. As a result, at the device along with one "outer" magnetic pole there is a local output of magnetic lines of the "inner" pole.

During the designing of new devices there was a task to create a quasi-monopole situation in the confined space. This situation should be created not uniformly but transiently by pulsation method. Frequency of work of electromagnetic oscillators first of all was selected depending on linear dimensions of the devices. Selection of the frequency was made in such a way that one period of pulsation does not exceed the period of time which is necessary for electromagnetic waves to reach the center and opposite waves of the device.

At the designing of laboratory devices, which generate converging longitudinal waves, several different principles to obtain required parameters were considered in the multi-layer quasi-monopole, which works in high-frequency mode. Several types of the devices were realized at different degrees of development and with different success. It was shown that the simplest devices were that ones which used electromagnetic (solenoid) oscillators connected in series and in parallel. In different experiments between 3 and 5 such surfaces were used. These surfaces were called electromagnetic work surfaces (EWS). All layers of EWS of different diameters were mounted in series in each other (like matreshka). The outer layer was either mounted at force shell or simultaneously represented such a shell by itself.

The size of the maximal EWS was about 0.9 m, the diameter of the minimal (inner) EWS was equal to 115 mm that was enough to place laboratory animals inside the control detection devices. Laboratory animals were used to determine the consequences of the influence of converging spherical electromagnetic waves. Payload, (i.e. that which was directly used for transfer in Time-Space), included the afore-mentioned detection devices and (occasionaly) laboratory animals. The term "payload" was coined by analogy with the term which is used in cosmonautics. Volume of payload section was placed in the center of symmetry of the Time Machine (TM). In all the earliest Machines (except the 7th model) this volume still has not exceeded the volume of a football. The device with an outer diameter of 2.1 m and inner payload section of 1 m has the maximum size. It allows making human-aided experiments.

At different stages of the experiments the calculations were made by all available known modern methods to fix time. All types of electronic, quartz, mechanical and several specially made doubled quartz generators were used (there were compared frequency readings of measuring and etalon heat-insulated generators which were placed at a distance). Certain experiments used lightguiding diodes and some other methods. Before and after the experiment (more rarely during the experiment) readings of measurement clocks were periodically compared with those of an etalon clock and with signals of exact time which were transmitting by radio. Other physical factors causes side effects upon some types of measuring devices, for example, upon quartz-crystal clocks. However, doubling of measurement methods allowed essentially decreasing inaccuracy of measurements.

At some operating modes (which were not always predicted) the change of Time speed was attained (Prof. Nikolay A. Kozyrev called it density of Time t/t_0). This change came to about a fraction of a second per an etalon hour. Let us take usual "etalon" earth time as $t_0=+1$ then it becomes clear that it is speed range of $+0.99<t/t_0<+1.01$ which is researched in the experiments. Thus being placed inside the device, the inanimate objects and animals were transferred in the Future (with "above-zero" speed) more slowly or faster than those around them. It occurred at all operational modes of the device (deceleration or acceleration).

Difference of Time (gradient of Time speed or curvature of Space-Time field) was observed not only inside the TM, though there is no doubt that a maximal value of changed Time was registered inside the smallest "matreshka". As was expected, during the experiments Time change was also registered outside the device. However such change which had an opposite sign was smaller than the change inside the device approximately by an order of magnitude. It entirely corresponds to geometric laws, i.e. in proportion to the cube of the distance).

In other words, TM influences not only its inner part and payload but also the environment. It bears a strong resemblance to jet propulsion but in Time and not in Space. It is a flight which is realized by rejection of Time instead of mass.

Thus it was determined that the processes of deceleration and acceleration of Time distinctly differ in their nature and consequences. In such a way the deceleration was considerably smoother and more stable. During acceleration there were observed sudden changes in readings and this operational mode was characterized by general instability and dependence on any (or many) external factors. Particularly, acceleration instability also consisted in the following: at fixed power the value speed of Time depended on the time of day and situation of the Moon. Possibly it also depended on some other factors including the presence of an operator or other people near the device. Even insignificant external influence, for example, mechanical shaking, caused the change of speed value which sometimes was rather significant.

Inside the laboratory devices there was also registered that **Time can change with some sluggishness**. After the changed Time speed influenced some physical object (for example, soil) then residual effects were observed at it for some period of time. These effects can be eliminated only by the influence of another speed of Time.

Preliminary general conclusions

The Present is the transfer or transformation of the polyvariant easily changeable Future into the univariant unchangeable Past. Thus flights in the Past (at "negative" density-speed t/t_0) and in the Future will happen in different ways. They can be compared with the motion of an ant along the tree: from any point of the tree (i.e. from the Present) there is only one way downwards open to the ant (i.e. in the Past) and many different ways upwards (i.e. in the Future). However among all the ways to the Future undoubtedly there are most probable, low-probable and almost improbable variants for development of the Future. The less probable this variant of the Future the more unstable and energy-intensive the motion to the Future will be. According to the "law of the crown of tree", return to the Present is possible only if when being in the Past the traveler does not interfere in the course of events and does not change the course of the past History. Otherwise the chronotraveler will return to the parallel Present from the Past by another branch of History. Penetration to the Future from the Present is hampered by the choice of the branch for transference. However return from any variant of the Future into the Present is possible at any scenario if there are no fusions of different variants of History…

In other words, we have a circumstantial evidence of the assumption that Time has more than one dimension. Thus there is an affirmation of the theoretical inferences of R. Bartini who believed that Time has 3 dimensions. Hence we can consider our terrestrial globe as 6-dimensional where the dimensions are: length; width; height; age or date of Time; variant of History or blur of Time; density or speed of Time. Thus the notion of "Arrows of Time" is completely absent in the fourth dimension (date of Time) but it is a special case of the notion of the sixth dimension i.e. speed of Time. At the same time the notion of speed of Time also relates to the physical notions of gravitation and energy. Thus the notion of "Einstein-Rosen bridge", which was introduced in 1916, or notion of "worm course", which was introduced by John Willer in the end of the fifties, are connected with transference in the 5th and 6th dimensions.

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Method and Device to Control Temporal Parameters of Physical Processes by Means of Changing of Energy Density of Space

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This invention belongs to the methods and devices to provide control on rate of physical processes (that includes the process of the existence of matter in space-time) by means of increasing or decreasing of energy density of space (i.e. energy density of physical vacuum or density of the aether).

Let us consider the history of the invention:

Earlier there were proposed some methods and devices to influence the rate of physical and chemical reactions, biological processes or period of oscillation of the system. In the works by N.A. Kozyrev [1] there is a description of the experiments on the influence of some process (for example, process of evaporation or crystallization of matter) upon the period of another process, which serves as a detector and can be compared with reference oscillation process. In one case, the rate of oscillations of the detector decreases in the surrounding area near the process of matter evaporation. In another case, the rate of detector oscillations increases in the surrounding area near the process of matter crystallization. If we use a term of "entropy" then it is possible to say that the processes which are accompanied with entropy increasing (for example, conversion of matter from solid state into liquid one) influence on the matter (surrounding processes) in such a way that entropy of systems decreases. In another case, for example, near the process of crystallization, entropy of systems increases in the surrounding area near this process. Kozyrev used the term "wave of density of time" and he made a conclusion that in addition to "directivity" of time (time course) there are active properties of time, for example, "density of time".

To develop this approach for applied purposes it is necessary to use in-depth analysis of the physical sense the "law of the crown of tree", return to the Present is possible only if when being in the Past the traveler does not interfere in the course of events and does not change the course of the past History. Otherwise the chronotraveler will return to the parallel Present from the Past by another branch of History. Penetration to the Future from the Present is hampered by the choice of the branch for transference. However return from any variant of the Future into the Present is possible at any scenario if there are no fusions of different variants of History…

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To develop this approach for applied purposes it is necessary to use in-depth analysis of the physical sense of the "time density" notion. Connection of notions about "time directivity" and "entropy of the system" was demonstrated in the work "Introduction into thermodynamic of irreversible processes", 1964 by Ilya Prigozhin [2]. In the work "Quantum fluctuations of vacuum in curved space and theory of gravitation" by A.D. Sakharov [3] the conception of vacuum structure was suggested. In the USA the work "Can the vacuum be engineered for space flight applications?" by H.E. Puthoff [4] is well-known. The author considered the applied aspects for study of vacuum structure and described the method and device to obtain propulsive force by means of changes in vacuum properties.

A substantive conception of time and methods for creation of waves of energy density were also considered by Prof. K.P. Butusov in the work "Time is a physical substance", 1991 [5]. In the book "What is The Time?" by Yu. G. Belostotsky [6] the connection between the notions of time and aether was demonstrated. This connection was considered from the point of view of astrophysics there.

We can also say that the modern conception of aether is successfully developed by V.A. Atsukovsky in his works [7].

In my articles, for example, "Physical principles of the Time Machine" [8], it was demonstrated that to develop experimental works on the topic it is useful to clarify the terminology and to consider **"waves of time density" as longitudinal waves of energy density in space.** In this case the notion of "time density" has a physical sense of energy density (aether density).

This approach can be realized practically by means of classical electro-technical and radio engineering methods and it is a development of aether-dynamical conception on the nature of electricity and magnetism by M. Faraday, "Experimental researches on electricity", volume 3, [9].

Let us consider a usual bipolar magnet from the point of view of aether-dynamics. Then it is possible to say that it is inflow and outflow of aether, i.e. it is a balanced energy system which does not change energy density in space. In this case it is evident that creation of magnetic monopole or modeling of quazi-monopole by means of electro-dynamical methods is a technical basis to create some local change of energy density in space.

Electric processes could also be used alongside with the magnetic phenomena. For example, in another book "Symmetrization of Maxwell-Lorenz equation" by Prof. Butusov [10] the creation of longitudinal wave was also considered. It was demonstrated that an electrically charged sphere can radiate longitudinal wave when the sphere radius is changing, i.e. when its surface is changing while the value of electric charge is constant.

One more well-known method is described in the book "Experimental gravitonics" by Polyakov [11]. There is a consideration of the generation of gravitational waves at the high-frequency magnetization and demagnetization of ferromagnetic material, i.e. at the powerful volume magnetostriction. Since at this phenomenon there are changes of matter density (i.e. changes of energy density in space, which is occupied by matter), then volume magnetostriction is a special case of changes of energy density.

Earlier Vadim A. Chernobrov had described a method and device to control temporal characteristics of physical and chemical processes by means of creation of the magnetic monopole (quasi-monopole). In this magnetic mono-pole there is a convergent wave, which is created by several sources situated in the spherical frame. According to this method in the multilayer spherical structure where every layer (the so called "electromagnetic work surface") is an assembly of electromagnets, by means of series connection of the layers the wave is created, which converges to the center of the device. The device has the same outside magnetic poles of the electromagnets (and the same inner poles) and thus a model of macroscopic magnetic monopole is created.

We assume that at in-phase operation of all sources of waves, interference of longitudinal waves provides some change of value of energy density of space in the focus of the system.

Experimental facts prove that detectors installed in the center of the device (for example, mechanical or electromagnetic oscillators) show change of period in their own oscillations. We have protected them by shielding them from heat radiation as well as from other kinds of electromagnetic influence. Thus it is possible to assert that the detectors decelerate or accelerate their oscillation period depending on the energy density, which is generated in the center of the device.

However for the experiments made by means of such a device, accurate adjustments of all wave sources are required to provide their in-phase operation. At the same time, operational stability of the system depends on the operational stability of each of the wave sources. Increase of the impulse frequency causes increase of the effect; however, it is limited by the parameters of electromagnets and generator of impulses. Besides, to increase the effect it is necessary to use more powerful energy sources since the current in the windings of electromagnets determines the value of the magnetic field of the created quasi-monopole.

Since the efficiency of such systems directly depends on the frequency and the value of changes of energy density in space, then in the next version of realization of this technology we suggest using of plasma shells instead of electromagnetic working surfaces. This will allow significant improvment in the specific parameters of the device.

Thus let us consider general engineering principles of operation and outline the ways to develop this method. Fig. 1 represents a three-layered electromagnetic emitter. This electromagnetic emitter is designed according to the invention in which the directed radiation of wave of energy density is created along the axis of the device.

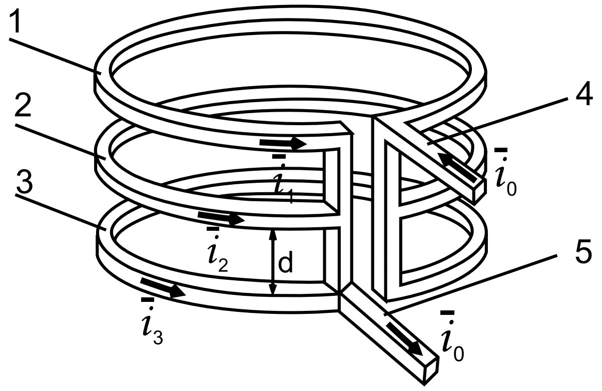

Fig. 1
Three-layered electromagnet

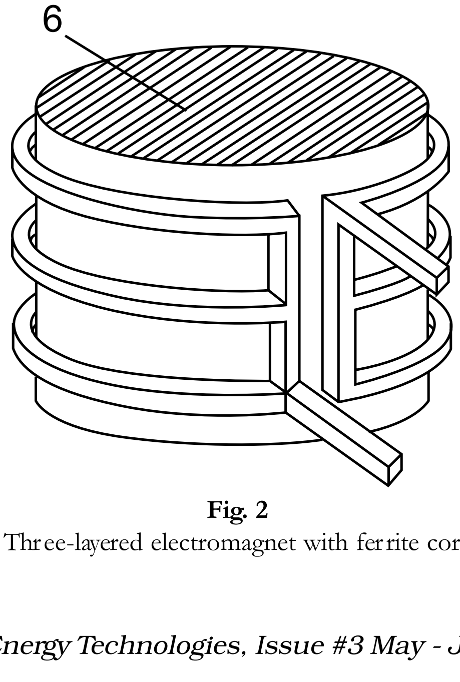

Fig. 2
Three-layered electromagnet with ferrite core

The device is designed according to the idea by Vadim A. Chernobrov for creation of the directed wave of energy density by means of phase shift in propagation of impulse front in three current branches, namely i_1, i_2, i_3. These branches are displaced along the electromagnet axis at some distance d.

The device works in the following way. When the pulsed generator is activated, front of current pulse i_0 appears at the output 4. Impulse front at branch 1 advances impulse front at branch 2 that is caused by spatial shift of current branches 1, 2, 3 relatively to each other along the electromagnet axis at the distance d. Impulse front at branch 2 in its turn advances impulse front at branch 3 for a certain time T. The second output of the electromagnet 5 is placed in such a way that impulse front at branch 1 will phase lag behind the impulse front at branch 2 (which in its turn will phase lag behind the impulse front at branch 3) for the same period of time T. Therefore at branch 5 the united impulse front is generated again.

Time T can be calculated in the following way:

$$T=d/c \text{ (seconds)} \qquad (1)$$

where c is a constant of propagation of impulse front. This constant is known as velocity of light.

At each impulse the T (i.e. the value of relative lag of impulse front) is a constant value. Thus high-frequency consequent excitation of layers of the electromagnet appears at each impulse. The frequency of the excitation is calculated in the following way:

$$f=1/T \qquad (2)$$

where T is relative lag of impulse front in seconds.

There is an example of frequency calculation: for the shift distance d=7 mm we can calculate a lag $T = (7/2.997924)\text{x}10^{-11}=2.335\text{x}10^{-11}$ (seconds) and frequency $f=1/T$ approximately comes to $4.28\text{x}10^{10}$ (Hertz).

Thus this design of three-layered electromagnetic emitter allows creating the waves of super-high-frequency band (for example of millimeter range) without the use of a semiconductor or other radio components.

It is very expedient to use the electromagnets designed with magnetostrictive material cores, that will significantly increase energy density of the longitudinal wave, which is generated by the multilayer electromagnet. In Fig. 2 there is an emitter with the core. In the case of high-frequency ferromagnetic magnetostrictive materials 6 the efficiency of emitter operation significantly increases.

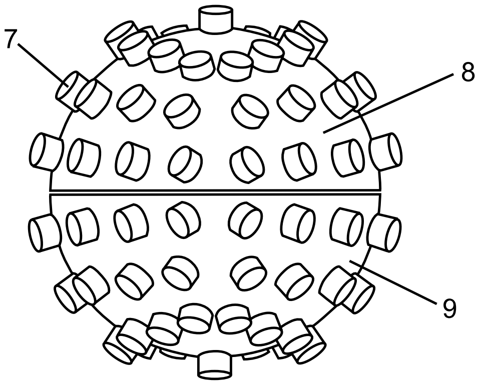

Fig. 3
Spherical design

Fig. 3 represents the spherical distribution of emitters 7 at the upper 8 and lower 9 hemisphere of the frame which could be opened in order to place detectors and different objects inside. It can also allow to establish in what way the changes of density of space energy influence the properties of different materials, velocity of physical and biological processes as well as chemical reactions. The installation of detectors 10 inside the device is shown on Fig. 4.

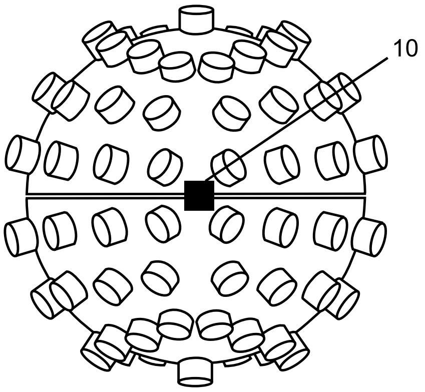

Fig. 4
Detectors inside the system

Another version of design is represented in Fig. 5, where the suggested method is realized by means of a spherical electric capacitor with three coats 11, 12, 13. Each capacitor coat is connected to the outlet of three-phase pulsed generator 14.

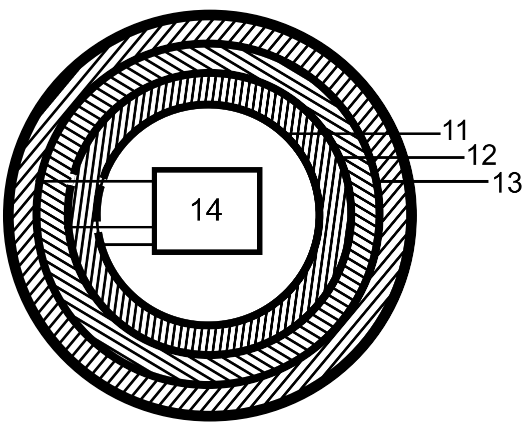

Fig. 5
Three-layered spherical capacitor

In this case the wave of energy density is created without electromagnetic emitters and this principle is not related to the modelling of magnetic quasi-monopole. The device operates due to the control unit, which provides the high-frequency changes of electric potential at each coat in such a way that the mode of high-frequency converging or diverging wave of energy density is created. In fact it is a standard three-phase generator but it produces not the rotation of the rotor of some electromotor but **"compression" or "decompression" of aether.** Aether is "pumped" in the center of the device or "pumped out" of the center.

In this case there is no need to tune separate sources of waves to make the device work in in-phased mode. It ensures reliability of the device operation if to be compared to the quasi-monopole. Besides, much less energy is necessary for the processes of charging and discharging of multi-layer spherical electric capacitor than for creation of magnetic field by means of conductivity currents.

Since the efficiency of such systems directly depends on the frequency and value of changes of energy density in space, we suggest the use of plasma shells instead of electromagnetic work surfaces for the next version of the device. It will allow significantly improvment in the specific parameters of the device. For that it is enough to place the electrodes of the multi-layers capacitor in a low-pressure gas area and these electrodes should be made as gauze electrodes. At that the wave is created in plasma, which is excited layerwise by several gauze electrodes placed in a spherical space between the inner and outer spherical bodies of the device. Therefore this version of design of the device can be considered as **the manipulation of the plasma method**.

Fig. 6 is a plan of one more design version. It is made as an inner frame 15 and outer frame 16, the space between them is filled with some gas 17. Three electrodes 18, 19 and 20 are connected to the three-phase pulsed generator 21. **Consequent excitation of plasma layers by electrodes 18, 19 and 20 creates the wave of energy density.** Propagation of this wave can be directed both to center of the device and from the center of the device.

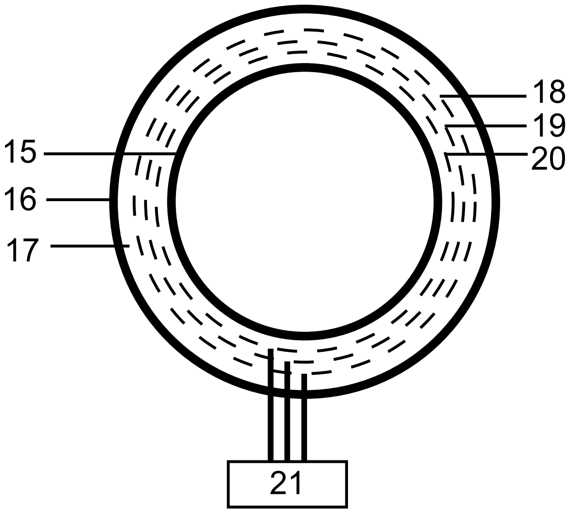

Fig. 6
Wave in plasma

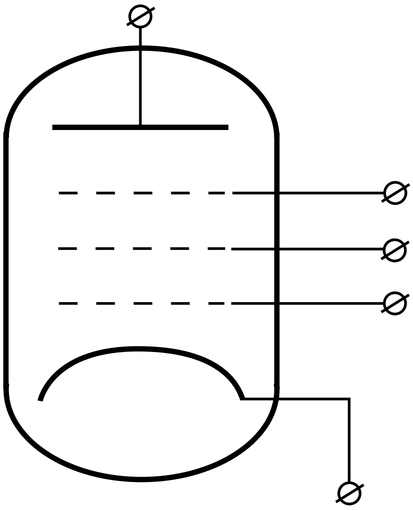

Fig. 7
Schematic electric circuit

In Fig. 7 there is a schematic electric diagram of the design.

To conclude. The work on time control has just started. We have clearly determined the main physical principles of operation of such devices, which can change the aether density in some given volume of space and thus influence temporal parameters of any physical process. The small experimental results today allow us to make real positive conclusion on availability of this method and on the possibility of its practical application in applied aspects. The first aspect is antigravitation propulsion technology and we are developing the methods to detect mass (weight) changes in the time control experiments to prove this applied possibility. Another area is medical applications of the changes in the aether density.

Russian Federation patent claim #2003110067 was filled April 9, 2003. At present time we are interested in marketing for this technology as well as in search of additional investment and partners.

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Aetherodynamics as a New Field of Physics

Theory and Experiments

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A crisis exists these days both in Natural science on the whole, and, in its basis, i.e. physics. This situation is caused by fundamental errors in the methodology of its theory. The postulate method and predominance of mathematics above physical sense can be also considered as the reasons for this. Crisis situation has also taken place in the past and the way out was always to use a deeper level of matter organization than the accepted one.

A large amount of material on elementary particles of matter is collected in physics. It was discovered that all these particles can be transformed in each other. Besides that, there was discovered the ability of vacuum to create such particles at strong electromagnetic fields. In this connection it becomes clear that all these particles and vacuum have a common building material, i.e. a physical medium which fills all the world space. This medium was renamed **aether** and the element of the medium was renamed **amer**.

The worked out methodology of aetherodynamics allowed determining that aether is a usual viscous coercible gas for which all laws of usual dynamics of gases are valid. It has allowed to determine its characteristics for near-Earth space and then to describe the structures of primary stable elementary particles (i.e. proton, neutron, electron, photon, atomic nuclei, atoms and some molecules) as well as physical essence of general fundamental interactions (i.e. strong and weak nuclear interactions, electromagnetic and gravitational interactions) and some physical phenomena.

Also developed was the model of aether circulation in the Universe within the limits of perpetually existent matter, usual Euclidean space, and evenly flowing time. Formation and decay of matter, formation and decay of celestial bodies and galaxies as well as functional classification of galaxies are also included there.

To confirm some theses the author and his research team conducted several experiments mainly on electromagnetism that gave positive results. The research was conducted on testing of the presence of aether wind. These research works have confirmed the results obtained by D. Miller in 1925.

Report by Vladimir A. Atsukovsky

Electromagnetic Gravitational Interaction

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In the article some mechanisms of electromagnetic gravitational interaction will be considered in the view of the Unified Theory of Field, Space and Time. See the complete description of The Unified Theory of Field, Space and Time at http://uic.nnov.ru/~kovy2; http://uft.h1.ru or in the book [1] which has the same title.

First of all, let us consider the structure of Space-Time where the radiation propagates. In our World gravitation is the unique substance which exists everywhere and gets over any obstacles. There are no known methods of insulation of gravitational field in modern science. It is impossible to imagine space and gravitation separately. Gravitation exists everywhere where there is some space. The gravitational field created by all masses of our metagalaxy is the aether in which cosmic objects moves and electromagnetic oscillations are propagated. The space surrounds us since the whole matter carries gravitational charge of only one sign. From astronomical research of cosmic space it follows that radius of metagalaxy is equal to the critical (gravitational radius) and hence gravitational potential is equal to $c^2 \sim 10^{17}$ $[m^2/c^2]$ in each point of space.

In our space the sum potential of the electric field is equal to zero. All bodies and space-time as a whole are electrically neutral. This assertion follows from two unique properties of gravitational space-time:

1. Values of electric charges of different signs of elementary particles are exactly equal.
2. There is an equal number of elementary particles which carry electric charges of different signs.

If electric potential is equal to zero in the given point of space then energy of alternating magnetic field passes entirely to the electric field and radiation gains the parameters of electromagnetic oscillations. However electric potential of positive and negative signs can prove its properties at the simultaneous charging of different local spatial regions. In the electric field the character of radiation differs from that one which is observed in ideal gravitational space-time (without electric potential).

In the presence of electric potential some part of magnetic energy is spent to create gravitational alternating field. Radiant energy is absorbed. Electrically charged spatial regions are perceived by us as filled with a strong absorbing substance. At the same time if the potential of the electric field can be compared to the potential of the gravitational field then spreading of radiation becomes impossible.

Change of both electric and gravitational field results in the creation of a magnetic field in the region of space-time which has a dual electrogravitational nature. Change in the magnetic field results in the creation of both electric and gravitational fields. The amplitude of electromagnetic and magnetogravitational constituents of the unified electromagnetic gravitational oscillations depends on field potential of opposite nature. The electromagnetic constituent is determined by gravitational potential and the magnetogravitational one is determined by electric potential. Transference of gravitational masses of matter in electrogravitational field-aether causes the creation of the proper magnetic field. Coming from the direction of magnetic field some force influences upon the moving electrically neutral masses. This force is similar to Laurence force.

Electromagnetic gravitational converter designed according to the Searl Effect (Fig. 1) visually demonstrates the mechanisms of electromagnetic gravitational interaction. A detailed description of the experiment is presented in the article [2] by Vladimir Roshschin and Sergey Godin (see http://www.n-t.org/tp/ts/dms.htm).

The device consists of a cylindrical stator of about 1 meter in diameter which is surrounded by 24 cylindrical rollers. Stator and rollers are made of magnetic material and they are magnetically linked (there is no contact between them). Vector of the magnetic field of the stator and rollers is vertically oriented along the axis of the cylinder but it has opposite direction. Rollers are mounted on the movable separator which circles round the stator. Each roller rotates on its axis in the same direction. The weight of the device is 350 kg. During rest, the device is electrically neutral and has proper gravitational charge, inertial mass, magnetostatic field of the stator and rollers.

On rotating of the magnetic system the following effects were observed:

- Depending on the frequency (up to 35%) the weight of the device was decreased.
- At a frequency of 550 rpm there is a spontaneous acceleration of the system and turns of the rotor abruptly increase (in quadratic dependence). To stabilize the mode it had to take off the excess energy to active load (up to 7 kWtt) by means of electromagnetic transducers.
- Magnetic field was distributed in a room as concentric surfaces of 5-8 cm thickness and 50-60 cm period. Depending on speed of rotation of the magnetic system there was a fixed temperature decrease from 0 to 8° within the regions of space which were curved by magnetic field.
- The glowing (corona discharge) appeared around the working converter.

Appearance of all mentioned effects is caused by the simultaneous presence of electric, magnetic and gravitational fields in the area of the converter.

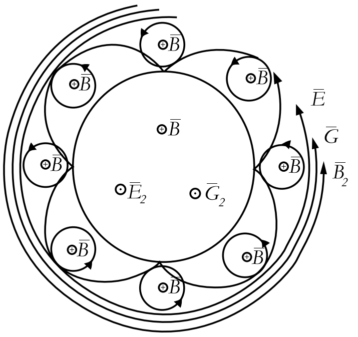

Fig. 1
Electromagnetic gravitational converter

Because of the Searl Effect a very complicated configuration of electric, magnetic and gravitational fields appears in the device. Rollers having their own field $\boldsymbol{B}$ rotate around the stator which has its field $\boldsymbol{B}$. Cycloidal motion of numerous magnets which are built in the rollers causes change in the magnetic flux. EMF $\boldsymbol{E}$ appears in the area of rotation of the rollers. EMF is directed along the perimeter around the device. The electric field creates stationary waves which are registered around the device as concentric electromagnetic gravitational walls. Magnetic rollers should be made non-conducting in such a way as to allow electric field penetrating inside. In the presence of the electric potential change of the magnetic flux causes appearance of gravitational field $\boldsymbol{G}$. This field is directed along the perimeter around the device. In the presence of electric potential the Lorenz force influences the gravitational masses of the rollers. These gravitational masses move in the external magnetic field of the stator. The Lorenz force is directed transversely to the velocity along the cycloid and in the direction of the field $\boldsymbol{B}$. The value of the Lorenz force depends on the electrical potential, magnetic intensity, mass of the rollers and their traverse speed. The electric potential in its turn depends on speed of rotation of rotor of the magnetic system. As a result the Lorenz force depends on speed according to square law. Rotating gravitational masses of the rollers generate magnetic field $\boldsymbol{B}_2$. Field $\boldsymbol{B}_2$ generates derived fields $\boldsymbol{E}_2$ and $\boldsymbol{G}_2$ etc.

Spontaneous acceleration of the system does not depend on the direction of rotation. Directions of fields and forces change at change of the direction of rotation that corresponds to acceleration in the opposite direction. When the direction of rotation is changed the weight of the device changes. When rotation is in one direction the field $\boldsymbol{G}_2$ is directed upwards (decrease of weight), when rotation is in another direction, it is directed downwards (increase of weight). In the presence of electrical potential many other interesting but still unstudied phenomena are observed (for example, curve of space, change of speed of time-flow, changes of ambient temperature…). Magnetogravitational converter transforms gravitational energy of space-time into energy of electric field which in its turn is transformed into mechanical energy of the rotating magnetic system and electric energy of the load. Energy resources of the future are not coal and gas reserves or nuclear power. They are in the inexhaustible energy of gravitational aether of our space-time.

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Medium For Existing of Matter in Nature

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By medium for existing of matter in Nature we understand physical vacuum which is a category determining all spheres of matter “life” (from particles of microworld to gravitational interactions in the Universe). Matter can not exist without this medium. Thus a question emerges, viz: how physical science can be developed without taking this fundamental aspect into consideration?

According to the Einstein postulate, in a void light always propagates with limited speed, which does not depend on the motion mode of a radiating body. It is a statement of deep physical sense which lies in the fact that only some physical medium can possess such a property. Indeed, if velocity of light, which was radiated by a body, further does not depend on speed of this body then it is possible only in a certain medium. For example, in air sound propagates with a certain speed which does not depend on the speed of the source and is determined only by density and volume elasticity of air. Thus, according to the Einstein postulate, there is a physical medium instead of void and velocity of light depends on the parameters of this medium (as is well known, velocity of light is equal to the square root from the product of inverse values of electrical and magnetic conductivity of vacuum).

The author of this article made an attempt to research this physical medium [1]. The author used a well-known experimental fact that at interaction of a photon with a charged real particle this photon transforms to electron-positron pair. Besides, it was taken into consideration that photon is an electromagnetic phenomenon. The research allows the following conclusion: the medium named in physics as vacuum (before the XX century it was called aether) is created by electric dipoles from (+) and (-) elementary charges. These dipoles are surrounded by magnetic (mass) continuum. There were determined dipole intervals, elasticity of decompression and ultimate strength of this interval. What does this model of medium mean?

1. This model is a physical validating for the “birth” of electron-positron pair at energy which is necessary to break dipole and create the “clot” of mass of these two particles. A certain model for the “birth” of mass must exist. It is not clear as yet but can be represented as a vortex of magnetic continuum inside the charge shell of electron and positron.

2. Let us suggest that values of (+) and (-) charges differ at $7.848981x10^{41}$ Coulomb, then this difference is sufficient for the medium to be a source of gravitation and inertia. According to Newton’s law of gravity, a weak electric charge of medium (all material bodies exist in this medium) causes all bodies to attract one another (under Coulomb’s law). On the other hand, weak medium charge of a like sign creates repulsive forces which manifest themselves in the form of the expanding Universe. Thus it becomes clear the amazing uniformity of gravity and forces of negative pressure for the Universe. The mentioned difference of values of (+) and (-) charges of medium dipoles is not used as arbitrary parameter but it logically follows from its electrical structure [2].

3. Hypothesis of nature of gravitation is confirmed by calculations of the deflection angle of electric waves by the Sun. Calculated angle differs from the experimental value only in the fifth sign, which depends on the accuracy of several physical values used in calculation formula. There is practically an absolute coincidence with Einstein’s theory. The difference is that it is a concept of space and time (i.e. geometry) which prevails in the general theory of relativity while in the nature of gravitation physical basing is used. Velocity of light is unstable and determined by medium state which depends on electric, magnetic and gravitational potentials.

4. The existence of “black holes” relates to medium structure and nature of gravitation. At the edge of “black holes” the ultimate acceleration from gravity is realized. It causes breakdown of connections in electric dipoles of medium, creation of matter and antimatter (the so called “evaporation” of black holes which was theoretically predicted by E. Hoking, England). However at the border of a black hole the velocity of light is equal to zero since its propagation

medium disappears. According to Einstein's theory it is such a deceleration of time that electromagnetic oscillations gain zero frequency.

5. Naturally the medium is a carrier of all types of electromagnetic radiation, beginning at stationary electric voltage and ending with super-high-frequency "photons", which can be determined not as electromagnetic but as magnetoelectric phenomenon. In the latter case magnetic continuum of medium has a crucial importance since it determines very small degrees of magnetoelectric disturbance. These degrees are thousands of times less than those of a hydrogen atom. It is reasonable that such small degrees creates illusion that a photon possesses properties of particles.

6. Medium structure directly leads to the notions of Quantum Mechanics, beginning at quantification of electronic "orbits" in atoms. This medium determines the "allowed" spots for electrons to be placed around a nucleus. Thus medium is a necessary place for the existence of all matter or matter of the Universe. The so called Compton length of electron wave is one of the validations of this statement. It is directly calculated to a high accuracy according to electric structure of vacuum.

7. Thus Plank's constant is not a mysterious "quantum of action", on the contrary it is entirely determined by medium parameters. Thereby the crisis (which conventional physics is accused of) can be logically overcame by the introduction of medium which is capable to take radiation in electromagnetic region only by quanta. Plank's constant is always presented at all quantum approaches. It is additional evidence in favor of the necessity to take into account the medium as natural place for existence of all the matter in Nature.

8. It is still a question what processes take place in the centers of galaxies. The observations show that the centers of galaxies create star matter. They often flow out the centers and settle themselves at approximately the same plane. It is an evidence of the fact that centers of galaxies quickly rotate and the favorable conditions for stars to reject matter are created. Similarly planetary systems are created around the rotating stars. It is thought that centers of galaxies are gigantic black holes. In the context of the concept of medium for matter existence it can be set up a hypothesis that being at some special state the medium creates stellar systems, i.e. galaxies.

9. Astrophysicists more and more trend to accept the existence of unknown "dark" matter, which occupies approximately 70% of all matter. It is said that due to antigravitation property this dark matter is responsible for the expansion of the Universe. Hypothesis on the nature of gravitation gives the affirmative replies to such suggestions as: expansion of the Universe is caused by weak electric charge of the medium and distributed mass of magnetic continuum is the very dark matter.

10. All elementary particles (electrons, positrons, mesons, protons, neutrons etc.) are in the medium and interact with it. In the case of electrons and positrons this interaction causes the great extension of dipoles of medium which directly adjoins to borders of particles. This extension helps photons to break the particles. In case of protons, there is such a breakdown of the medium at their borders that protons turn to be dressed in "coats" of virtual electrons and positrons. And medium is shown to be in entire state only when reaching the first Bohr orbit. This interaction of the medium and particles leads to the factors which determine the life time of some of them. Thus life time of a neutron is up to 30 minutes depending on the state which it has while leaving the nucleus. For mesons "the tearing" Coulomb forces, which exist between the medium and particles, are very powerful that makes the life time of mesons very short. However if the particles moves with a high speed relatively to the medium, then these forces noticeably decrease and if the speeds of motion is close to velocity of light then these forces become very small. The life time of such particles noticeably increases. In Einstein's theory it is said about "deceleration" of time. Finally the life time of particles is determined by the inner steadiness and outer influence of the medium. Protons have fantastic binding energy and they cause such great external destructive effect that their life time becomes immense.

11. When particles move in medium with high speeds, there is a concentration of magnetic continuum which is recognized as increase of mass of particles at increase of their speed. Evidently, we can continue the list of physical phenomena which relate to the presence of medium for existing of matter in Nature. However it seems to be enough to admit that medium (physical vacuum, aether) is of a great importance for the very existence of the Universe and for the processes which take place there. "Mechanism" of gravitation and inertia has a special importance since

it is the only thing which can make clear the real mechanism of Nature. It is possible that the methodology, which is accepted in physics, is necessary for more accurate description of phenomena but it is not enough for understanding of the nature of "space" and matter. Research of the medium for existing of matter will be able to meet the conditions sufficiency.

The understanding of vacuum structure, which is created by electric lattice from charge dipoles, surrounded with magnetic continuum, gives an opportunity to control the forces of gravitation and inertia. The medium of vacuum can be influenced by:

1. The radiation which has frequencies coming to the frequency from point #11 of the list of parameters.
2. Electric voltages which exist in vacuum (it is not very promising because of real matter breakdown).
3. Magnetic intensities (magnetic flux density). It is the most promising influence method (1-10 Tesla is enough to compensate terrestrial gravity).
4. Transformations of low accelerations to high accelerations of impact type.

Potential electric and magnetic energy is immense in vacuum medium. Reasoning from energy of one dipole, which is equal to 1.6x10 (-13) Joule, we will derive the value of electric energy equal to about 10 (+31) Joule per one cubic meter of the medium that is equivalent to mass annihilation of 10 (+15) kg!

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◆

Spartak M. Polyakov

(09 January, 1931 – 04 June, 2003)

Spartak M. Polyakov, a legendary physicist-experimentalist, known for his research in the field of gravitation, has died. Polyakov was the author of more than 50 research works, among them "Introduction into experimental gravitonics». Polyakov was the creator of the new model of photon. He also conducted numerous research in the field of electrodynamics, gravitational phenomena and superlight connection.

Spartak M. Polyakov graduated from Kishinev State University with degree in "General Physics". For many years he worked at the top secret military engineering department "Istok" (Russia).

Plyakov's alternative physical theory allows explaining such phenomena as magnetostriction and optical magnetization. The basic postulate of this theory states that the speed of propagation of gravitational waves is dozens of times faster than velocity of light regarded by the traditional science as the limit. In his experiments Polyakov demonstrated such methods of generation of gravitational waves as precession of gyroscope and remagnetization of ferromagnetic.

While working for "Istok", Polyakov designed on his own a device which is possibly the first gravitational motor in history. Total specific thrust produced by rotation of gravitating mass comes to 2.5 kg/kWt. This index is close to that produced by the engines of modern helicopters, which is equal to 8 kg/kWt. Practical application and further development of Polyakov's ideas can provide humanity with new kinds of communication, gravitational engines and free energy devices.

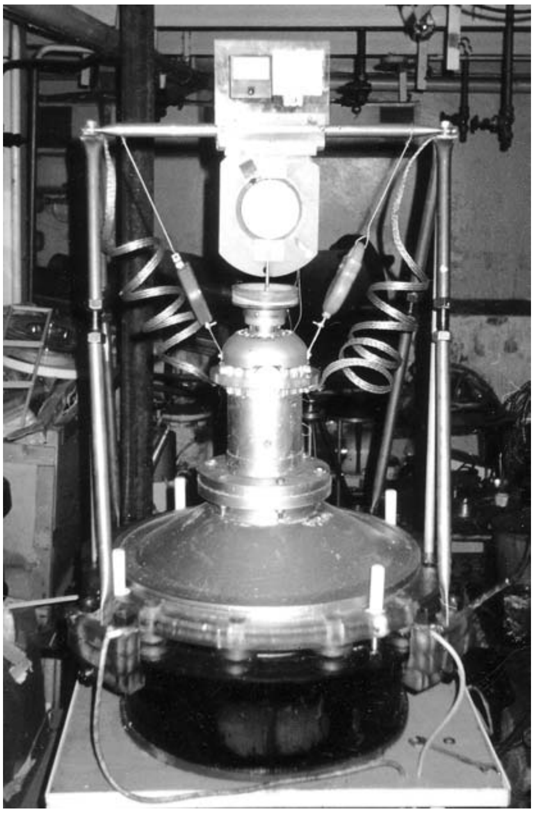

Adams Motor

Principle of Operation and Experimental Data

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Adams' motor-generator represents the type of devices which use, as their creators claim, so-called "free energy". The term "Zero point energy" is also used in some sources [1, 2]. Due to quanta-mechanical fluctuations, this energy exists even at zero temperature. Adams' motor-generator belongs to the group of Switch reluctance motors [3]. Robert Adams, **former Chairman of the Institute of Electrical Electronics Engineers, USA (New Zealand section)**, designed this machine in the late sixties of 20th century. Similarly to all the devices utilizing free energy (referred to in come sources as "overunity devices"), Adams' device remains practically unknown to the general public. **The device is rather simple to assembled even at home, which I experimentally proved. However, it is necessary to be very careful while choosing the model parameters. As to the latter I have managed to collect quite a big number of instructions from existing sources; the summary of these instructions is presented below in this article. Based on these instructions, a low-power model can be assembled even without a mathematical analysis and modeling of electromagnetic field. Such model would certainly facilitate optimization of the device.**

Adams' motor is most frequently a DC machine; however, it can also use an AC source through a rectifier. In the latter case only the adjustment of the device and its control system can be provided.

Editorial: We disagree with some assertions of the author; however this article is of great interest.

My experiments on my own model do not yet allow me to make an unambiguously positive conclusion concerning the possibility to generate excessive energy. Experiments with my new control system designed on the base of AVR controller AT90s2313-10PI (it is produced by Atmel company (http://www.atmel.com) will allow to be more specific. Below there is a general analysis of the motor principle of operation and a number of recommendations concerning the construction and technology. I do not propose to take this as compulsory rules to follow; other technical solutions are possible.

Basing on the principle described in this article, R. Adams (the link to his articles is available at: http://www.aethmogen.com/wri/intro.shtml) created a few DC motor-generators which operate on permanent magnets. Some of them, according to information found on the Internet, have manifested 690% electrical efficiency and 620% mechanical efficiency. These devices operate at room temperature without overheating. My device has shown between 1 and 3 degrees overheating after an hour of functioning. However, it is easy to prove that such overheating is predictable for an average current of 0.15 A in coils of 35 mm long and 25 mm in cross sectional diameter. I have not been able to prove the data published on the Internet concerning the Adams motor capability to operate when the stator temperature is a few degrees lower than that of the environment. The temperature of the coil and of the power transistor is a good indicator of correctness of the circuit set-up and of functioning of the control circuit. There were cases when transistor and coil were noticeably heated after adjustment. Usually this was explained by a bad choice of points of transistor switching or by too extensive current impulses in the stator (which must amount to approximately 25% of period length). After the required adjustment the motor continued to operate almost without overheating.

Adams' motor was first mentioned in Australian Nexus Magazine in 1992. Later, Harold Aspden (Britain) proposed a slightly improved version of the motor and received Great Britain patent No. 282708 [4], which strongly reminds of the original version published by the above magazine. **Adams' device** represents an electrical motor and/or generator consisting of a rotor with radially directed permanent magnets and of a stator also constructed with a few radially directed and periodically magnetized cores with winding. (Fig. 1). In some models axial orientation of magnets and coils are also used.

Permanently magnetized poles of rotor can include any number of poles, even an odd number. Analogous poles of the magnets (all N poles or all S poles) are directed outside. A version with alternating poles is also possible; such model allows the torque to increase. In this case, after passing a rotor pole the stator is demagnetized by the current impulse and begins to be attracted by the magnet of different polarity. This circuit requires a more complicated control; on the other hand, it manifested rather good results in certain models.

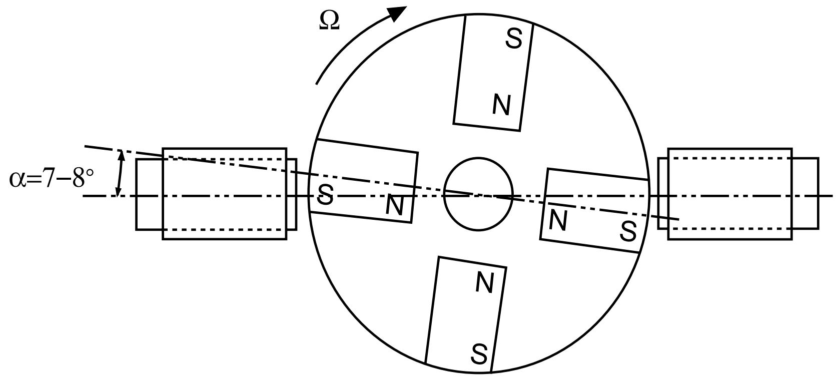

Fig. 1

Poles with winding placed on the rotor are radially oriented in order to obtain a supply of energy emerging as a result of the influence of counter emf from the rotor poles. Steel or iron cores are used for the poles of the stator with winding. It is also possible to use other materials, at that the core must have high magnetic inductivity and low level of magnetization reversal losses. The stator winding consists of a few hundred turns. The current inducted by the magnet in this winding will have the polarity which will cause repulsion of the magnet. Since the electromagnetic state of stator changes quite significantly and quite fast, then the stator core can be considered to be the most crucial element of the device. Ignoring this fact was one of the most frequent mistakes made by those who tried to reproduce Adams motor.

The current inducted in the stator is the function of:

- field size,
- number of winding turns,
- speed of flux changes.

Resultant parameters of this device cause each pole to be attracted or repulsed by stator poles when the rotor is in certain position in case when the rotor is unbalanced. To achieve this effect it is required to switch the input current in control coils after the signal from sensor of rotor position. R. Adams used a mechanical switch as a sensor. My device and a number of other devices use the signal from two Hall sensors. However, according to experimenters' information, better results are achieved if a position optical sensor is used.

Time of switching of impulses is determined by the size of the motor itself, i.e. the speed of motor rotation, location of rotor magnets towards the stator windings and the distance the rotor magnets pass while moving by the poles with stator winding.

It is necessary to take into account that any part of this motor can be modeled based on the existing electromagnetic theory and no part of the motor is in conflict with any laws of electromagnetism. There are so many ways to construct Adams' motor that any version may be considered to be correct.

One can say that the frequently pulsating electromagnetic process in the stator core is what allows Adams' device to function as a kind of diode which borrows energy from the field of permanent magnet but then does not return that energy in full.

5 stages can be defined in the periodical process which takes place in stator:

1. The magnet is attracted to the stator core. The permanent magnet is attracted to the iron core of the stator with winding. While doing so no consumption of electrical current takes place. It is as if kinetic energy is borrowed from an internal ferrite magnetic source and is supposed to be returned into the stator.
2. Stator core is magnetized. During the period when the magnet is positioned in front of stator core they both comprise a single magnetic conductor with an air gap and the stator core becomes an extension of the magnet side it faces. It is usually supposed that the energy "borrowed" on the first stage is getting back now.
3. Stator core is demagnetized. When the stator core becomes rotor magnet extension, the circuit closes and current impulse gets to stator windings. I have seen the instructions saying that the angle between

stator axles and rotor magnet must amount to 7-8 degrees as shown in Fig. 1. However, my model made it clear that at increase of speed of rotation it is necessary to start the coil a little earlier, when the magnet axle has not reached the stator axle. Probably this applies to the circuit with a Hall sensor only and if an optical switching is used the making angle will be different.

Magnetic field of this current acts to compensate magnetization of the stator, which is caused by the field of rotor magnet. Consequently, the summed current significantly compensates attractive force between rotor and stator and the rotor can freely rotate by using the inertia obtained at stage 1. This process is characterized by the fact that this current impulse is amplified by the current inducted in the stator winding by rotor magnet which, in accordance with Lentz law (1834), counteracts the power which induced it. Consequently, kinetic energy obtained as a result of attraction of the rotor to the stator at stage 1 is transformed into electrical demagnetizing impulse in stator winding during the period when the rotor and stator directions are congruent. This is the unique overunity characteristic of this model. However it is obvious that instead of returning this energy the motor transforms it into electromagnetic demagnetizing field.

4. Restoration: when the rotor is removed from the stator attraction zone the latter looses energy and returns to its initial demagnetized state. Decreasing electromagnetic field creates a current wave of reverse polarity which can be stored in the capacitor.
5. Reiteration of the process: This periodical process is renewed as described in stage 1 during the next magnetization of the stator, excluding the fact that emf preliminarily stored in the capacitor, on term of presence of suitable electrical circuit, can be used for facilitating stator demagnetization or even used to supply the load.

It may be briefly summarized that the frequently pulsating electromagnetic process in the stator core is what allows Adams device to function as a kind of diode which borrows energy from the field of the permanent magnet but does not return that energy in full. The important characteristic of such motors is that the stator windings are used for demagnetizing and not for magnetizing as it could seem from the first sight.

It is noteworthy that there is a small pause between attraction to the stator and repulsion from the stator. The effect of attraction to the core takes place a split second before the repulsion effect manifests clearly. This pause being the reason of electromagnetic asymmetry creates conditions necessary for achieving overunity effect. If the attraction to the core and repulsion by means of Lentz currents were taking place simultaneously and with the same power there would not be any overunity characteristics. That is why the rotor must be as lightweight as possible. From this point of view, T. Harwood's model is the most lightweight of the known models. In Harwood's device the magnets are mounted between two CD disks fixed on the shaft by means of plastic washers and glue. My model is heavier, which can be considered as one of its disadvantages.

The principle of operation of Adams' motor is based on the balance, which creates the electromagnetic asymmetry. To get the motor to operate the magnet must be attracted to the stator core which must have a smaller cross-section area in order to create attraction without any significant repulsion effect from the stator windings mentioned above. When stator and rotor axles are congruent the Lentz induced current must be sufficient for compensating the natural attraction of the magnet to the stator core. Consequently, stator windings must have enough turns for demagnetizing effect, but not to the extent that this effect fully manifests before the rotor reaches the stator axle when Lentz current has its maximal value.

During my experiments at 12 V voltage and on using two independently controlled stator coils the speed of rotation reached 3400 rpm. Please note that while reproducing such device it is necessary to take certain measures in order to ensure safety in case of possible breakdown. **The magnet disconnected from the rotor may be dangerous!**

Technological recommendations are as follows:

1. The device must be low power. It is better not to try to begin with a motor functioning in kilowatt range. This is feasible only on condition of having all necessary technological documentation which is not available at the moment.
2. The preferable voltage for the first model is 12 V. If the voltage is less the speed of rotation is too slow for indicating the expected characteristics of the device.
3. The best magnets are ferrite ones with dimensions 4x4x5 (where 5 is the magnet length). The practice has shown that at 12 V voltage neodymium-iron-boric (NdFeB) magnets cause a jerky rotation of the rotor.
4. The side of the stator core facing the rotor must

Control circuit with hall sensors

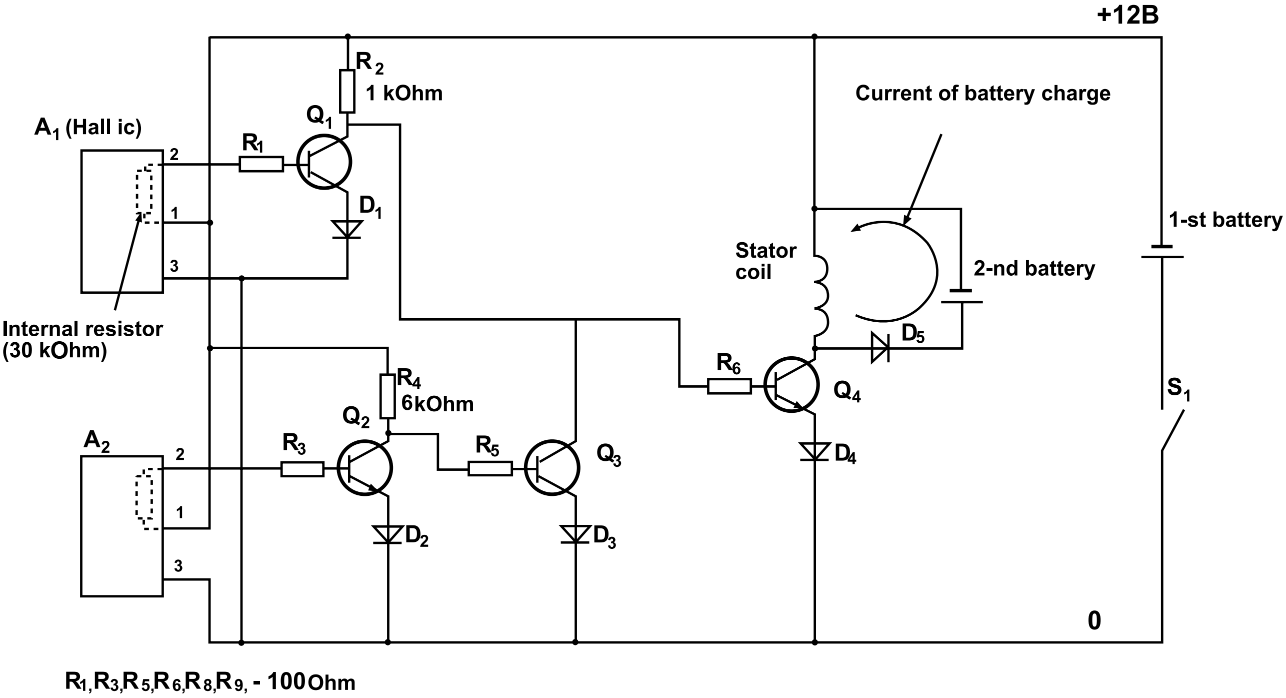

Fig. 2

have the size which is 4 times smaller than the corresponding side of the magnet. If cross-section area of the stator is larger, a bigger part of magnet field comes to the stator core when their axles coincide and thus there is nothing to induce Lentz' currents in the stator windings. It is a common point of view that it is necessary to try to minimize the volume of a device and to obtain the maximum efficiency at minimal material expense. In practice, it has always been the goal while designing electrical machines to decrease losses in stator I²R. As for the Adams motor, it requires not only the use of disproportionate magnets but also stator windings with disproportionate number of turns specially designed to obtain maximum Lentz' currents that is achieved by hundred of turns of winding.

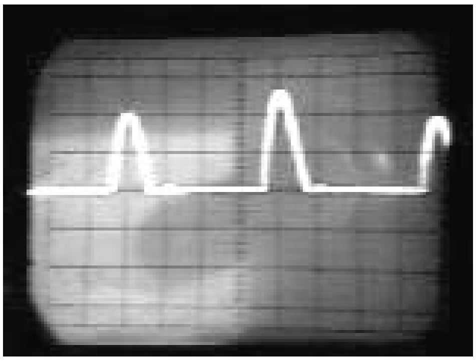

5. It is necessary to define approximately the effective zone of the magnet field. If practically applicable magnet field is equal to, for example, 8 cm, and the stator has a 10 cm long winding, then more than 20% of turns will not be efficiently crossed by magnetic force lines and will only create an excessive mass of the device. To define the degree of effective action of the magnet we can put a paperclip on the table and move it gradually in direction of the magnet until the paperclip is attracted to it. Actually if we take into account friction losses then the magnet influence zone will be a little larger. That is why the stator winding in the axle direction can be 10% larger than that in this experiment. The description of this test has been found on Tim Harwood's website (http://www.geocities.com/theadamsmotor/cdmotor.html).

6. The air gap clearance between the stator and the rotor must not exceed 1 1.5 mm.

7. Use as little metal in the device as possible. It is preferable that the metal is used in the core and stator windings only.

In order to increase the efficiency of this motor, it is necessary to build it in a manner, which allows removing the counter emf from the stator windings. To do that, this emf may be taken off and stored in the capacitor. The article published by Nexus magazine and Great Britain patent No. 282708 consider special generator windings; however, no sufficiently detailed data on operating rules are provided. Michael Smith (Australia, http://www.Fortunecity.com/greenfield/bp/16/content1.htm) has unequivocally informed me in one of his letters that

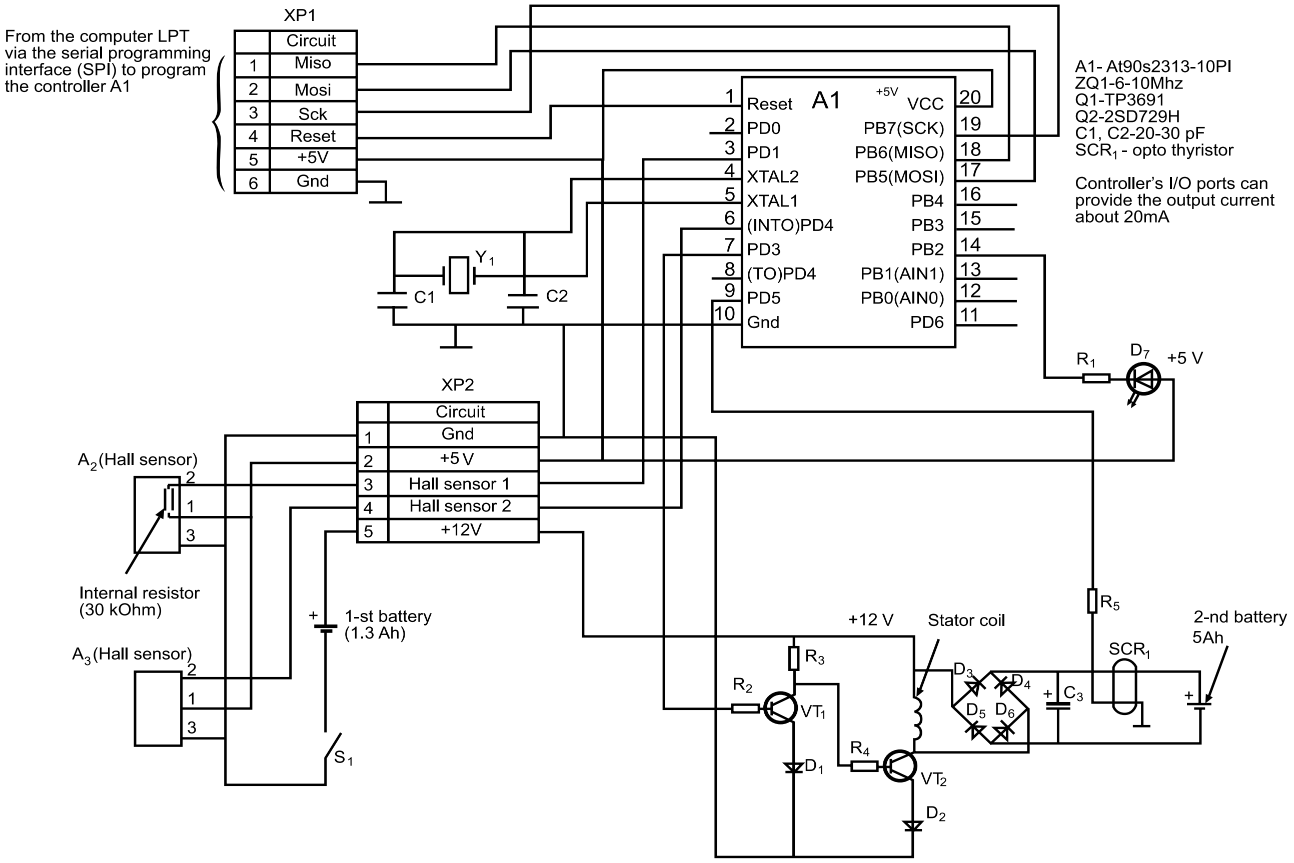
XP1
From the computer LPT via the serial programming interface (SPI) to program the controller A1
Circuit
1 Miso
2 Mosi
3 Sck
4 Reset
5 +5V
6 Gnd
A1
+5V
1 Reset
2 PD0
3 PD1
4 XTAL2
5 XTAL1
6 (INTO)PD4
7 PD3
8 (TO)PD4
9 PD5
10 Gnd
20 VCC
19 PB7(SCK)
18 PB6(MISO)
17 PB5(MOSI)
16 PB4
15 PB3
14 PB2
13 PB1(AIN1)
12 PB0(AIN0)
11 PD6
A1- At90s2313-10PI
ZQ1-6-10Mhz
Q1-TP3691
Q2-2SD729H
C1, C2-20-30 pF
SCR1 - opto thyristor
Controller's I/O ports can provide the output current about 20mA
Y1
C1
C2
R1
D7
+5 V
XP2
Circuit
1 Gnd
2 +5 V
3 Hall sensor 1
4 Hall sensor 2
5 +12V
A2(Hall sensor)
Internal resistor (30 kOhm)
A3(Hall sensor)
1-st battery (1.3 Ah)
S1
+12 V
Stator coil
R5
2-nd battery 5Ah
SCR1
R3
R2
VT1
D1
R4
VT2
D2
D3
D4
D5
D6
C3

Fig. 3

he has not achieved generation of excessive energy in such a system. During his experiments a two-battery circuit proved to be more effective. In this circuit, during a part of periodical process the energy is stored in the capacitor and then a command is transferred to a thyristor, which discharges it into the second battery. At that capacity, the second battery must be no less than 4 times more than the capacity of the first one. Otherwise the excessive energy does not have enough time to be stored during the discharge. I have also managed to provide the charge of the second battery, but the control circuit has not been assembled fully yet, as it is shown below in Fig. 4. Better results are expected when its final adjustments together with AT90s2313 controller program have been made.

In order to increase the efficiency of this motor, it is necessary to build it in a manner, which allows removing the counter emf from the stator windings.

I managed to start my first model of the motor in April, 2002. Afterwards, I spent approximately six months increasing its rotational speed from 750 to 3200-3400 rpm, decreasing vibrations and improving control circuit. In order to achieve a better rotor balance I had to re-construct it twice. It is very important to align the axles of the bearings with maximum precision; otherwise a considerable decelerating torque will manifest. The shaft penetrates the lower moving base. It is possible to rotate the base at a small angle for the precise alignment of axles and then to fix it with screws and nuts.

In order to decrease aerodynamic losses, two veneer parts are mounted between the magnets. Thus I managed to increase the speed, although the rotor weight has also been increased.

Stator cores are made of plates taken from a disassembled radio transformer. Tim Harwood used nails with winding, however, my own results with such core proved to be poor. Dimensions of the core are 10x11x50 mm.

The type of power source is also important. First, I connected a 9 Volt accumulator of "Krona" type in series with three metal-hydride 1.2 V accumulators. The speed of rotation did not exceed 1500 rpm. But when I used a lead/acid accumulator with 1.3 Ah capacity, the speed increased to 2600 rpm if there was one coil on the stator.

Four magnets mounted on the rotor have the dimensions of 20x20x35 mm and are fixed on a 105 mm glass fiber laminate disk. The current impulses proved to be too wide, by up to 40%. In order to make them shorter (down to 25-30%), I had to use the control circuit (Fig. 2) with two Hall sensors. At the signal from the first sensor the stator current is started, the second sensor switches it off. Many experimenters used a timer to control the impulse length while working with Adams' motor that is more practical since impulses are supposed to be wider during the start. I took this factor into account while designing the controller circuit. Current impulses are shown in Fig. 3. Their fronts are supposed to be shorter; it is probable that the coil has more inductivity than necessary. The impulses amplitudes are slightly different which is explained both by the difference in volume of induction of the magnets and by difficulty in achieving similar air gaps while working at home.

I have provided the charge mode of the 2-nd battery at my two-battery design. After 75 minutes of operation of the device the source lost 0.17 Volt whereas the second battery was charged at 0.36 Volt. The capacity of both batteries in this experiment was equal. Besides after such charging the second battery started to discharge quickly. The circuit where stator current charges the battery directly has to be considered ineffectual (see Fig. 1). To evaluate the charge, which is gained in non-hermetic accumulators, the density of electrolyte can be measured.

To obtain a more uniform torque I added the second stator which is controlled independently. This required installing two more Hall sensors and an additional power transistor. The angle between axles of the coils amounts to 135 (180-90.2=135) degrees. When the current is present in one part of the stator it is absent in another and vice versa. The speed has increased up to 3200-3400 rpm, and I deemed the further increasing of this characteristic unnecessary.

Increasing the number of circuit elements does not seem a good idea. Futhermore the adjustment process becomes more complicated. In order to improve the circuit of battery charge adding a timer circuit is required. Thus, I decided to use a controller circuit. A simple Basic program has been developed for AVR controllers. This program operates in mode similar to transistor circuit, but its capability can be significantly increased due to the built-in processor timers. Today program improvement is the most efficient way to solve the task of generation of excess energy in this circuit.

This article is meant to elucidate the principles of operation of one of the simplest devices which pretend to become an "overunity device", "free energy machine", "perpetual motion machine", whatever you call it. Probably someone will try to create such motor-generators on their own. I hope that my article will serve as a guide and will help to avoid the mistakes made by many experimenters (including myself) before they managed to build their own model.

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Prediction and Experiment on Field Transformation in the Model of Extended Space

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A series of preliminary experiments on checking the possibility of generation of gravitational field at deceleration of charged massive particles in matter was carried out.

Introduction

In previous works [1-3] generalization of the special theory of relativity (STR) for the five-dimensional extended space with metric (+;-,-,-,-) was offered.

The model of extended space (ESM), combining electromagnetic and gravitational interactions, was made. For this, there was made (1+3)-dimensional space extension $M(T;\vec{X})$ of Minkovsky to (1+4)-dimensional space $G(T;\vec{X},S)$. Let us call it extended space. As the 5-th additional coordinate the value already existing in Minkovsky space, i.e, S interval

$$s^2 = (ct)^2 - x^2 - y^2 - z^2 \quad (1),$$

is used.

Let us note that attempts to combine gravitation and electromagnetism have a substantial background.

Modern approaches to this problem trace back to the work of F. Klein [10] in which he proved that classical Hamiltonian mechanics can be represented as optics in the space of a great number of dimensions.

Then T. Kaluza tried to generalize Einstein's theory of gravitation to include electromagnetism in this theory as well [11]. He proposed to consider (1+4)-dimensional space with metric depending on potentials of the electromagnetic field. Kaluza's idea was evolved by O. Klein [12], G. Mandel [13] and V. Fock, and the model they had created got the name of the Kaluza-Klein theory. They proved that the trajectory of a charged particle has the form of a geodesic line with zero-length in 5-dimensional space.

In his works on 5-optics Y. Rummer [15] proposed to assign action dimensionality to the new dimension and to consider it periodical with the period equal to Plank's constant. Note that rest mass of particles in all these constructions unlike the model of extended space evolved in the works [1-7] was considered a fixed value. Subsequent development of multidimensional theories is given in the monograph [16].

A separate approach is represented by multidimensional constructions in the theory of strings and superstrings [17].

Approach to construction of (1+4) dimensional space evolved in [18] is close to the proposed model of extended space. Here it is proposed to use mass (matter) as the 5-th coordinate. However, in this model, as its originators admit, it is impossible, for example, to create the energy-pulse tensor. There is no such disadvantage in the extended space model [8].

Mechanics of a material point [1, 2, 7] and electrodynamics [1, 8] were made in the introduced extended space. Besides Lienar-Vihert potentials [6, 19] corresponding to such a model were also considered and properties of solutions of Maxwell augmented system of equations which are in conformity with these potentials were analyzed there.

Gravitational effects in extended space, such as the second orbital velocity, red shift and light deflection [4, 20, 21] were considered. It is proved that the formulas received in the general theory of relativity for calculation of values of these effects can be received by an absolutely different method within the framework of the extended space model as well.

It was proved [6, 19] that the fields in the model of extended space can change their signs. Such change of field-intensity sign and, consequently, change of sign of Lorenz force can be associated with radiation reaction of these fields which occurs when charged particles move with acceleration.

Thus, on the one hand, it was proved in the model of extended space that it is possible to get certain formulas describing gravitational effects of the general theory of relativity [4,20] using the technique of turns in extended space. On the other hand, it was proved that the electromagnetic field can be a source of gravitational field [6, 19].

Besides, a moving massively charged particle under deceleration can create a variable gravitational field around itself [9, 6, 19]. The following experiment was offered for experimental check of the latter assumption. In this experiment probable occurrence of gravitational field at deceleration of relativistic electrons was determined by change of oscillations of a massive torsion pendulum.

Experimental device

A narrow bunch of relativistic electrons from a microtron 1 (average power of the bunch is 450 Wt, electrons energy is 30 MeV) was directed to a brake target (position 2 or 3) made of wolfram exactly where deceleration of accelerated electrons took place.

A special torsion pendulum suspended on a vertical suspender 5 made of a springy metallic string with 1,8 mm diameter was placed near the brake target to register gravitational field which could probably appear at electrons deceleration. The length of the suspender made is 85 cm. The pendulum could rotate freely on the suspender only in horizontal plane.

The pendulum consisted of a light aluminum rod 4 (with a length of 120 cm) on the ends of which massive loads 6 and 7 made of non-magnetic material were fixed. The weight of each load was equal to 4kg. In the center a pendulum was fastened to a vertical suspender 5 by a special mounting preventing slippage during turns. To reduce the influence of magnetic inducings the pendulum was grounded and additionally screened by metallic grid from all sides. The period of free oscillations of the pendulum made were about 40 s.

Rigidity of the pendulum vertical suspender could be changed by means of limiting the length of effectively operating part of the suspender. As a result, the period of oscillations could be continuously changed within the limits of 40 to 27 s.

To reduce the influence of mechanical noise and to introduce additional attenuation in pendulum oscillations two liquid dampers 10 and 11 located near the pendulum massive loads were used.

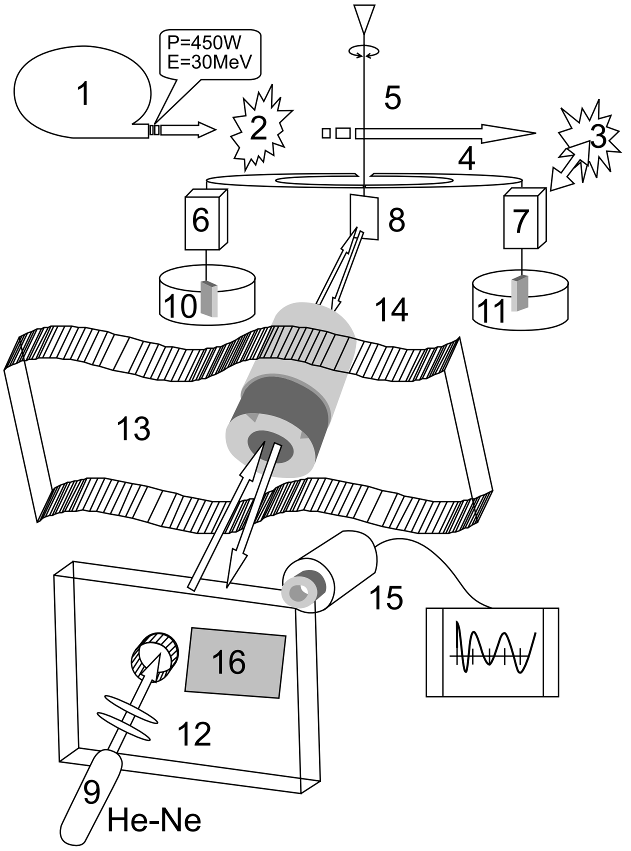

Fig. 1
Experimental device
1 – microtron, brake target made of wolfram – positions 2 or 3, 4 – rod, 5 – vertical suspender, 6 and 7 – massive loads, 8 – mirror, 9 – He-Ne laser, 10 and 11 – liquid dampers, 12 – optical system, 13 – concrete protection, 14 – observation channel, 15 – video system, 16 – screen.

Pendulum deflections were observed on a graduated screen by deflection of a laser beam reflected from a flat mirror 8. For this, the beam from a continuous He-Ne laser 9 through the optical system 12, which constricts the divergence angle of the laser beam, was directed to the mirror through a special narrow channel 14, located in concrete protection 13 around the microtron. By means of a video system 15 the beam reflected by the mirror was registered on the screen 16 located at a distance of 500 cm from the mirror. The video system allowed remote checking of vibrations of the laser spot and additionally enlarged the visual angle up to 12 times. The diameter of a focused laser beam on the screen was made 0.15 mm. The maximum turn angle of pendulum for the reflected beam to remain within the receiving channel was approximately 2 degrees. The accuracy of turn angle registration of the whole system was 5x10^{-4} degrees.

The pendulum was placed in such a way that one of the massive loads were close to the brake target at a distance of about 20 cm. There was also an opportunity to move the brake target from one end of the pendulum (position 2) to the other (position 3). This allowed changing the place of deceleration of electron bunch at constant parameters of all unaccounted mechanical noise and magnetic inducing. Thus, direction of pendulum torsion was changed under probable exposure of occurring gravitational radiation.

Below there is a photo of the experimental plant (see also the colored photo on the cover page).

Calibration Measurements

To make measurements it was necessary to select optimal parameters of the pendulum (masses of loads, suspender rigidity and the value of oscillations attenuation). On the one hand, while carrying out the measurement it is desirable that the amplitude of pendulum oscillations should be as maximal as possible. On the other hand, the beam reflected from the mirror should not go outside the limits of observation, restricted by the diameter of the narrow observation channel in radiation protection around the accelerator. Besides, the typical operating time of the loaded accelerator usually is 10-15 minutes. Necessity to accumulate the minimum of sufficient statistical data within this time limited oscillations period and the time of setting of the pendulum in a new equilibrium position at outside influence. All these requirements were as far as possible taken into account during selection of the final setting parameters.

An example of free oscillations of the pendulum in the presence of minor mechanical vibrations caused by the operating of vacuum pumps is given in Fig. 2, series I (the experiment took place on 31 May, 2001). The diagram shows the amplitude of laser beam oscillations on the screen 16 (upper and lower rows of values) depending on the number of oscillation. The laser beam is reflected from the mirror 8 which was fixed to the pendulum. The diagram also shows the current central equilibrium position (the central row) calculated by these amplitudes. Series I represents oscillations at influence of the background mechanical noise. Series II represents the response of the pendulum to minor permanent outside force. Accuracy in determination of position of the center of a light spot was 0.1 mm.

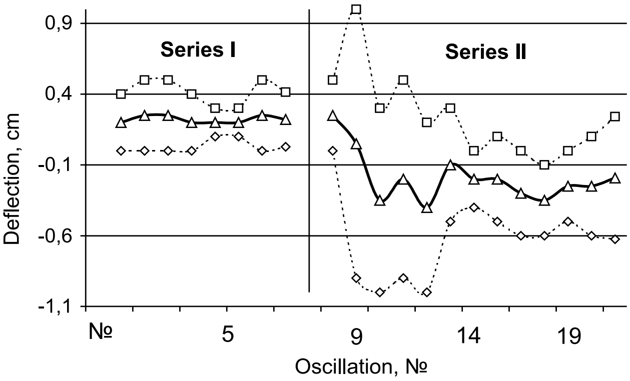

Fig. 2

Calibration Measurement 31 May, 2001

Measurement was carried out with one liquid damper in service and with increased rigidity of suspender (it was made by means of limiting the effectively operating suspender length). The period of free oscillations in these series was 29 sec. In this case there were set continuous oscillations of the pendulum around the average value of balance of 2.2 mm with the average amplitude of values fluctuation of about 0.2 mm.

Air cooling of one of the massive loads by a very light continuous air flow was carried out to study response of the pendulum to a minor constant external force. In this case (Fig. 2 Series II) noticeable change of pendulum oscillations already took place after 3-4 periods. Absolute setting of a new balance took place after 7-8 oscillations.

In the case of another series of calibration measurement (held on 7 June, 2001) both liquid dampers were used and rigidity of suspender was decreased. The period of free oscillations of pendulum was about 40 sec.

Addition of the second damper and decrease of suspender rigidity caused, on the one hand, increase amplitude of pendulum oscillations at influence of the external force and, on the other hand, in that case noticeable change of the equilibrium position of the pendulum took place after 1-2 oscillations.

Periodical checking of the invariability of initial central position of pendulum balance in time was also carried out. Thus, for example, in the series of measurement of 7 June 2001 measurement of equilibrium position was checked not only before the start of the main series of measurement, but also 2 hours after completion of the main works.

Experimental Results and Their Analysis

Within the period from 17 May, 2001 to 7 June, 2001 7 measurement series were carried out at various operation modes of the accelerator and at various pendulum parameters.

A record of check of equilibrium position of the pendulum was carried out before and after switching off the electron bunch (as well as during calibration measurement). At the same time, all electric inducing and mechanical noise remained stable within the whole measurement period. This was achieved by means of additional switching on all the devices which were used during measurement (water and vacuum pumps, magnetron, deflecting magnets, etc.) and their switching off only on completion of the measurements.

In Fig. 3 there are results on measuring the central position of the pendulum when brake target is in position 3 (see Fig. 1). Series I and III on the diagram correspond to check measurement directly before switching on and several minutes after switching off the electron bunch. Series II-A and II-B totally reflect pendulum oscillations at the time when the accelerator is operating (for about 10 minutes) and for some time after the bunch is off. Additionally, a trend line is drawn (averaging by 3 points).

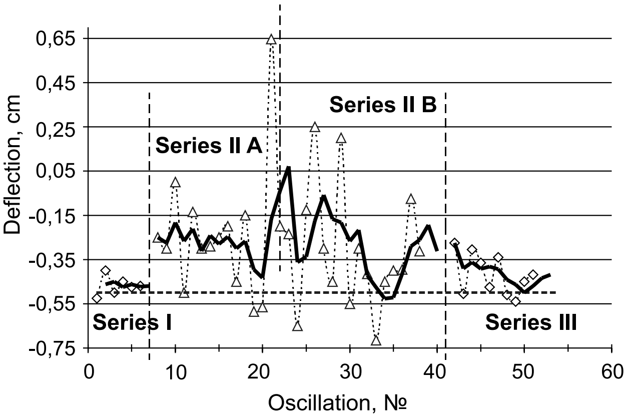

Fig. 3
Measurement of central position of pendulum equilibrium when brake target is in position 3.

Results of a similar experiment are given in Fig.4. The only difference in this experiment is that the brake target is in position 2. Also a trend line is added (averaging by 3 points). Series I and III are check measurements made directly before switching on and after switching off the electron bunch. Series II are pendulum oscillations at the time when accelerator is operating.

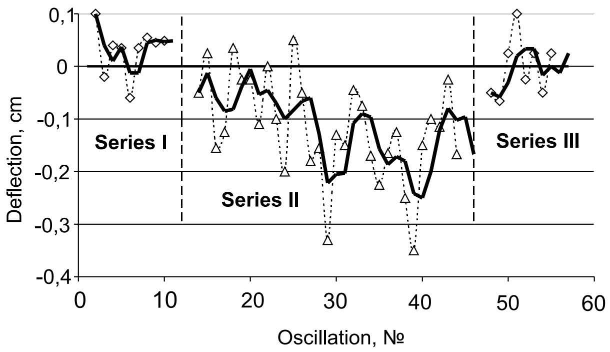

Fig. 4
Brake target in position 2

From qualitative comparison of trend lines (Fig. 3 and Fig. 4) it can be derived **that there is a correlation between switching on the electron bunch and the average deflection of the pendulum from equilibrium position if compared to checked series before and after switching on. At that, direction of deflection changes depending on what pendulum load the brake target is close to.**

Unfortunately, due to circumstances beyond the control of the author it seems to be difficult to improve experiments accuracy or to accumulate much of statistical data by now. Estimate of the value of the force which may cause such a shift of position of pendulum equilibrium was carried out. In the experiments this deflection did not exceed 1-2 mm (in the units of registering scale). Calibration of a rigid suspender (if it applies to a massive load at a pendulum end) gives the upper boundary of this force of not more than 10^{-6} N.

Conclusion

A series of experiments were made on checking the possibility to generate a field at deceleration of charged massive particles in matter.

Electrons accelerator was used as a source of charged particles. A narrow bunch of relativistic electrons (average beam power is 450Wt, electrons energy is about 30 MeV) was directed at a brake target made of wolfram where deceleration of accelerated electrons took place.

Measurement proved appearance of statistically reliable deflection of a torsion pendulum, one of massive loads of which was located close to a brake target by the time of deceleration of relativistic electrons.

Change of direction of pendulum torsion at shift of a brake target from one end of the pendulum to the other was also registered. The value of the force which causes pendulum deflection has the upper boundary of N.

Of course, these first experimental results on checking the predictions made on the basis of development of the model of extended space are of preliminary nature and need more thorough checking. That will be the basis of future experiments.

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Joe Flynn's Parallel Path Magnetic Technology

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There is a widespread opinion common to the mainstream academic community and also to various alternative scientific forums, that some kind of exotic new physics will be required to design and implement over-unity technologies. That is to say electrical motors, electrical generators, or other apparatus, which produce an excess of magnetic force or energy above the value actually inputted.

However, this has recently been experimentally demonstrated not to be the case, as I have validated myself in simple $20 experiments undertaken at home with parts bought from the local hardware store. It is the purpose of this article to educate readers that with care, thought, and a little work, it can be demonstrated that existing textbook physical law, freely allows for the extraction of excess electrical energy from magnetic systems.

The Flynn Research Project

Joe Flynn has been engaged in magnetic flux research for over 25 years now. His work is long standing, comprehensive, and in later years, well funded. It is reported $7m has been spent to date, with over $1m alone developing a revolutionary high performance magnetic motor. His equipment is validated, and apparently already in mass production for select customers. Yet few researchers have heard of Joe Flynn. This surprising situation will hopefully shortly be changed, and Joe Flynn awarded the scientific accolades he deserves, for being the genius master mind behind one of scientific history's most outstanding research projects. Since many lines of research have been formulated and explored by Joe Flynn, the following article presents only a brief summary of some of his best art apparatus, but is nonetheless sufficient to convey the basic ideas.

The first illustration (Fig. 1) is taken from Joe Flynn's US patent 6,246,561, and explains a simple magnetic force multiplication experiment, which forms the basis for the Flynn magnetic art. If the windings on either side of the central magnet, which are normally connected in series, are properly pulsed, the field of the permanent magnet in the center will be diverted to the opposite side of the core flux path provided. Or in alternative language, the side of the core that is pulsed is demagnetized, relative to the field of the permanent magnet used in the apparatus. This is elementary textbook physics anyone can understand.

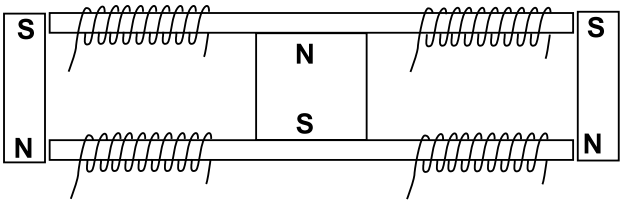

Fig. 1

1.75 times more force is delivered to the legs of the core than is provided by the electrical input to the control coils

So what is surprising about this apparently simple apparatus is that the armature on the side of the flux core will contain 1.75 times more units of magnetic force, that could be manifested by the electrical input to the apparatus alone. Since the ability to arbitrarily move the force from one point to another is the basis for motion or work, however simplistic, we therefore have a basis for a system that can be developed for practical technological purposes. Expressed in alternative language, we also have the capability to engineer a time varying magnetic field, without the need for moving parts, which will allow development of systems that output electrical energy. Both capabilities are highly desirable, and offer substantial opportunity for technical development.

Following on from this basic experiment, there is a second simple and logical improvement in layout illustrated in Fig. 2, which should be obvious, but has been shown not to be the case. In this instance, the pulse is centrally located, and a dual flux field layout employed, which both demagnetizes the core relative to one magnet, and magnetizes it relative to the other. Since the two actions are complementary, the input required to manifest the flux switching effect is halved, therefore doubling 'efficiency.'

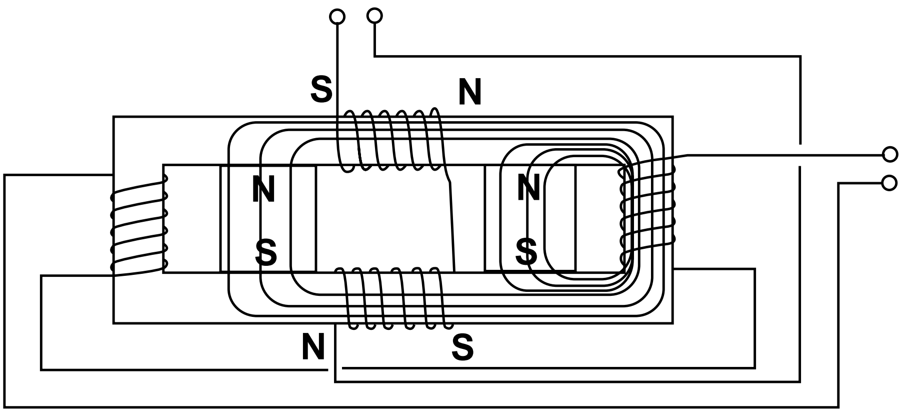

Fig. 2

3.47 times more force is delivered to the legs of the core than is provided by the electrical input to the control coils

It should be noted that while the efficiency is doubled, the absolute output may not be significantly improved. This is because the major weakness of this effect and technology is flux saturation of the core, with values depending upon the specific properties of the B-H curve of the core material employed, limiting the absolute output of both layouts the same.

The previous statements are not required to be taken on trust, and simple experiments have been proposed by Joe Flynn, such that anyone can validate this effect for themselves. Figure 3 is a simple experiment taken from the Flynn website (http://www.flynnresearch.net), that can be used to validate the principals put forth in this article.

Simple Magnetic Force Multiplication Experiments

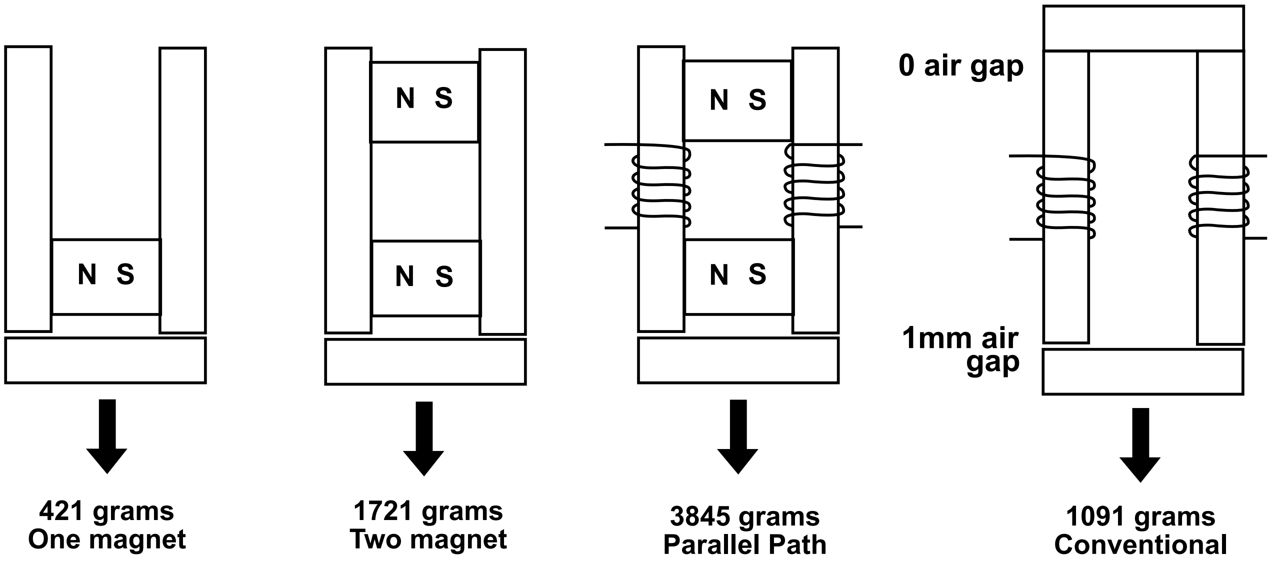

Fig. 3

Parallel Path can deliver 3.47 times more force to the legs of cores than any competing conventional technology

An even simpler non electrical flux experiment was proposed by GM in the Parallel Path Egroup. My apparatus is illustrated below in Figure 4. It is no more than magnets and steel staple strips, bought from a local hardware store for a total of under $10. The Parallel Path effect can be replicated with identical apparatus, at only a slight increase in cost and complexity, with the addition of a simple 12V polarity reversible power supply, such as those commonly sold to power computer speakers, among other applications.

Simple Magnetic Force Experiments

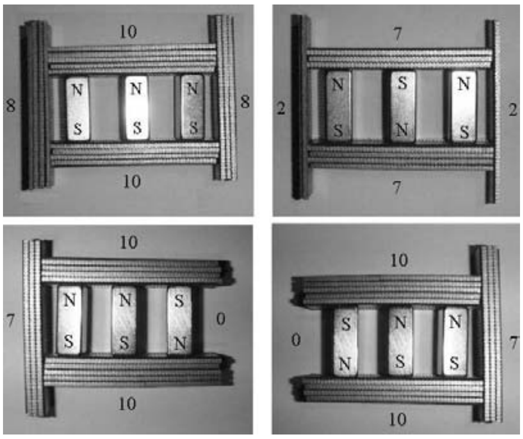

Fig. 4

Relatively small changes in layout produce large changes in force

Conservation of Energy / Field Potential

One of the aspects of the Flynn technology people find most difficult to understand, is how you can have a device that delivers 3.47 times more magnetic force than is electrically inputted, yet not violate accepted principals of text book physics, as stated in the introduction. The key point here is conservation of energy. Magnetic fields do not gain energy – they are conservative. You can only ever obtain less energy from a magnetic field minus losses, than is in fact present. I feel this apparent puzzle can not be better explained, than by reference to Joe Flynn's own words:

"Since the Parallel Path System produced 3.47 times more force than the conventional system, with the same electrical input, it appears to violate conservation, this is only true when observed from a traditional view point. The system contains three flux producing sources (2 magnets and an electromagnet) which together are capable of producing a far greater force than is actually produced. All of the flux sources together can produce a force of 13.11 units, therefore in the physical sense a loss of 1 - (9.01 / 13.11) = 31% is realized."

So the system is 350 % efficient, in terms of delivered magnetic force compared to net electrical input, yet still conforms to the accepted physical principals of energy conversation, by being only 69 % efficient, in terms of the fields present in the system. However surprising this result may appear, the analysis presented is in outline correct, with the difference between fields present in the system, and net electrical input, being the important concept presented.

Losses in the System and Optimisation

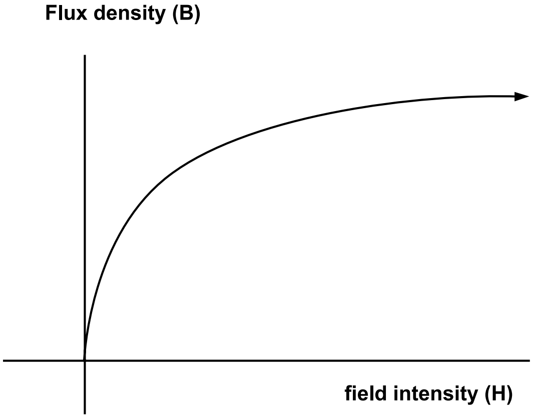

Fig. 5

In order to properly optimise flux cores, an appreciation of the physics that underlies the transfer of flux within a core is required. The normal magnetization curve, or B-H curve, is a mathematical relationship between applied field intensity H, and resultant flux density manifested in the core B. It varies according to core material, and the curve will shift, if there is a starting magnetism within the core, such as that provided by the field of a permanent magnet. If the start magnetism is excessive, the core is saturated, and will not properly respond to the applied force H. A simple B-H curves is illustrated in Fig. 5.

Hysteresis is a delay between applied magnetic force H, and resultant flux density B, that again varies according to material type. It also manifests as a delay between the termination of force H, and the manifestation of flux density B. So, the system will not turn on instantly, and will not turn off instantly, in simple terms. This is because the magnetic memory of the core, means a flux vector remains within it, even when the application of magnetic force H has been terminated. If we apply a reversed force H to the core, the basic B-H curve is now expanded as in Fig. 6, with the memory effect also illustrated.

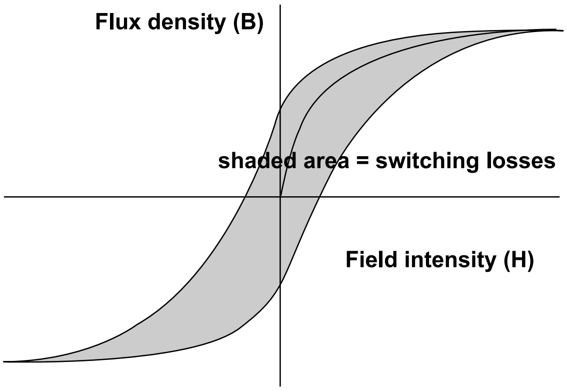

Fig. 6

Thus as can be seen, to return to the initial switched state, the remnance magnetism must now be overcome, hence input once in operation, will be greater than that required for the very first pulse. The area within the hysteresis curve gives a rough estimate for the amount of wasted energy, and along with other conventional sources of losses resultant in flux transfer within a core, is what reduces the efficiency of flux cores from maximum values of 2, or 4, down to values such as 1.75 or 3.47, typically.

Motor Apparatus

Simple Parallel Path Technology Demonstrator Motor

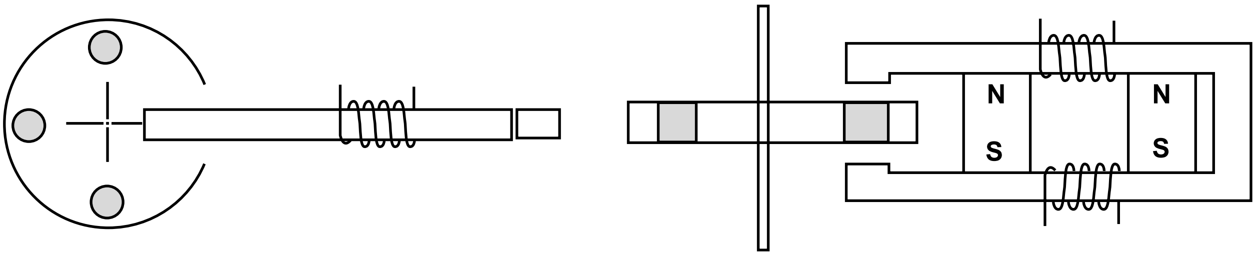

Fig. 7

Designed to demonstrate core principals, not provide over-unity

Although numerous practical applications abound for this effect, electric motor design remains the most outstanding opportunity. To this extent, again a few simple images, should be sufficient to explain how the basic flux switching apparatus, can be turned into a highly efficient electrical motor.

The first motor shown in Fig. 7 is one I have proposed to validate the flux switching effect at a most basic level. It illustrates the point made in the Flynn patent, that the armature of the core can be removed, and replaced with a motor flux path. This first motor is not claimed to be highly efficient, but it helps one to understand how the transition from simple flux core to motor takes place.

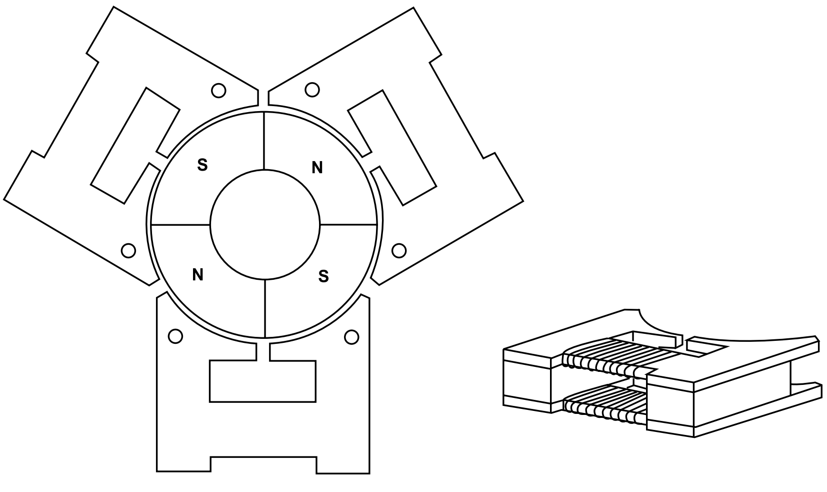

Fig. 8
Magnetic force is alternately switched from one leg to the other, imparting motion to the rotor sections

The next motor shown in Fig. 8 is again taken directly from the Flynn patent, and illustrates the next intermediate step to motor design. The fields of the permanent magnets are alternatively switched from one side of the surrounding flux cores to the other, alternately interacting with N and S poles on the rotor, imparting motion to the central rotor shaft.

With proper financial support, and the facilities to have metglas cores custom moulded, Joe Flynn was able to develop his final best art, shown in Fig. 9. No detailed performance numbers have been released for this motor, whose precise performance characteristics remain proprietary to Joe Flynn at this time. But the optimisation is so expert, it is stated to posses certain exotic properties, such as cool ambient operation, even during prolonged periods of continuous load. This 'cold running' is said to be of great interest to the American military, as it offers excellent stealth performance characteristics.

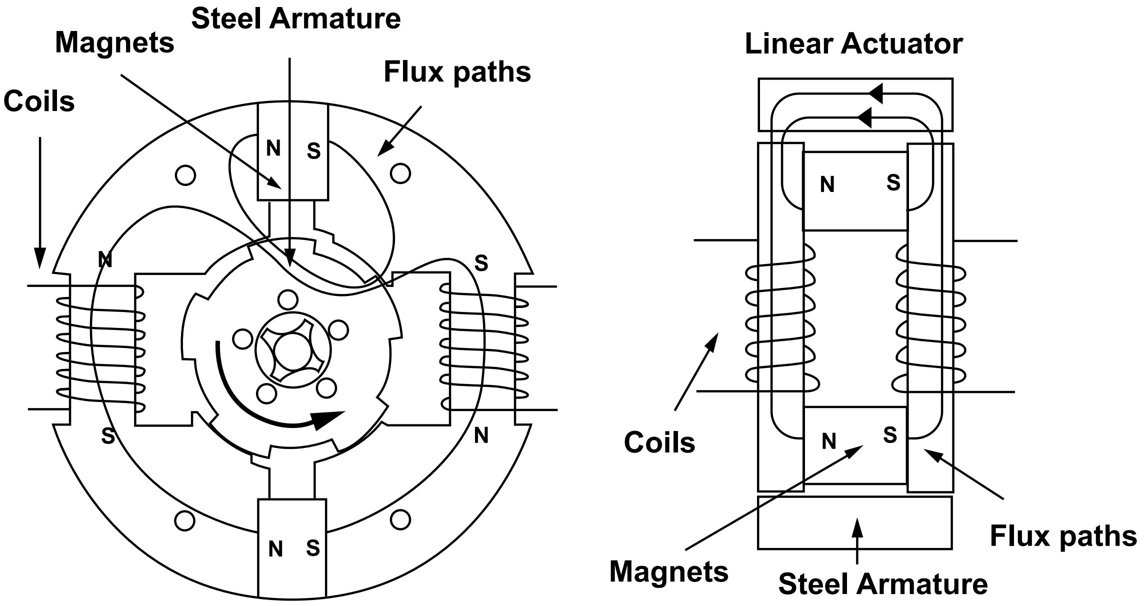

Fig. 9
Optimal Flux Core Motor Construction

Electrical Apparatus

Many readers will no doubt have noticed the similarity of the first illustration presented in this document, to the so called 'Tom Bearden MEG.' This is fair comment, and Joe Flynn has always highlighted this issue. However, it has been commonly stated Joe Flynn has simply developed mechanical apparatus, and the MEG with its electrical functionality, is distinct art, more advanced than the mechanical Flynn apparatus. However, this is shown not to be the case by a careful examination of the Flynn patent, in which the following is stated in the 'Power Conversion' section:

'The construction (shown in Fig.10 A) utilizes four control coils and a single permanent magnet and the construction (shown in 10 B) uses two control coils and two permanent magnets. The flux that would normally be supplied by a primary winding is supplied by the static flux of the permanent magnet or magnets and the control coils convert this static flux into a time varying flux in a novel way. Both arrangements use two secondary coils, the secondary coils are placed in the region of the continuous flux path that would be occupied by an armature or rotor in the linear or rotary arrangements. The regions of the flux paths that perform work are the same in all cases.'

'By alternating the polarity of the control coils during one cycle, one working region experiences an increasing flux and the opposite region experiences a decreasing flux and during the next cycle the opposite occurs. This results in the induction of a voltage in the secondary coils that is decided by the magnitude of the change in flux in the working region and the time in which this change occurs. The novelty of this discovery is that the primary flux inducing the voltage in the secondary coils is supplied by the permanent magnet or magnets and is far greater than the flux supplied by the control coils.'

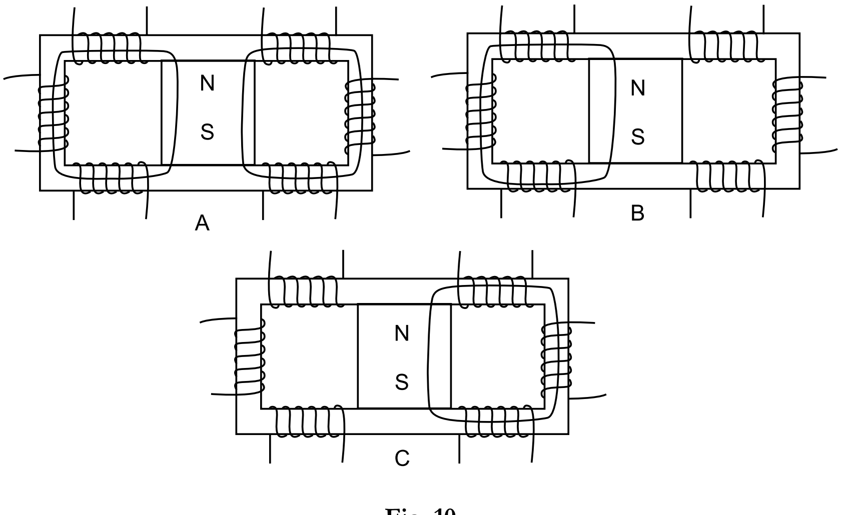

Fig. 10

Fig.10 taken directly from the Flynn patent makes the point even clearer. As can be seen, the device illustrated is in all functional respects absolutely identical to the so called 'Tom Bearden MEG.' This identical prior art, therefore calls into question the intellectual property rights of Magnetic Energy LTD, as the same invention can not be patented more than once. Joe Flynn has also stated that his intellectual property rights will be robustly defended, by legal action if necessary, and he regards himself and his company as being in possession of exclusive rights to the so called 'MEG' unit.

As regards replication of electrical output orientated flux core devices, certain important details need to be stated. For example grade 8 ceramic magnets should be used, so as to avoid flux saturation of the core. A basic error, many early experimenters wasted time on. The requirement for strong magnets to obtain over-unity results, is as much of a myth, as the idea new physics is required.

But perhaps the greatest trade secret of the electrical devices, one which several lengthy non disclosure agreements are required to be signed before it can be disclosed, is that the input and output circuits must be closed in series. The disclosure of this technique amounts to putting the basic MEG methodology fully into the public domain.

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The reason for this circuitry requirement is obvious enough, with only a little analysis. If the output circuit is closed when the input circuit is activated, then the input energy simply leaks into the output circuit, as in an ordinary transformer. So no flux switching effect is manifested, and the field of the permanent magnet is static in time. Thus you have an ordinary transformer, with reduced efficiency, because of the core flux saturation effect provided by the permanent magnet.

This is one of the most important point to make about the Flynn apparatus. If you approach it as if it is a normal piece of scientific equipment, then proper optimisation is not greatly problematic. For example more turns on the output coils, simply means more voltage and less current, exactly as standard textbook equations predict. Generally, problems only occur, if you imagine the effect is based upon exotic scalar type or vacuum energy physics, when in fact it is ordinary flux manipulation within a core.

Present Status of the Flynn Project

Initially Joe Flynn was remarkably open about his work and research. However, since performing a working demonstration of various advanced hardware samples for the American Department of Defence, little has been heard.

I want to clearly emphasize I do not speak for Flynn research, nor am I in any way connected with Flynn research, and by consequence, have no inside information whatsoever as to the present status of the project. But we all sincerely hope, that the project has not been swallowed whole by the American deep black military industrial research complex.

However, even if this is the case, it does not mean the technology is lost. Extensive and generous details have been provided by Joe Flynn of his research, both in his patent deposition, website, and other comments, such as to enable persons of scientific training and skill, to replicate the effects stated.

While replication of the electrical effect remains extremely demanding, the mechanical apparatus is very easy both to understand and replicate. There is no reason why scientists and home tinkers together, can not build Flynn type flux core motors, and explore over-unity flux manipulation for themselves. The future has arrived, and it is simpler and cheaper than anyone imagined to be possible.

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Flynn Research Company

http://www.flynnresearch.net

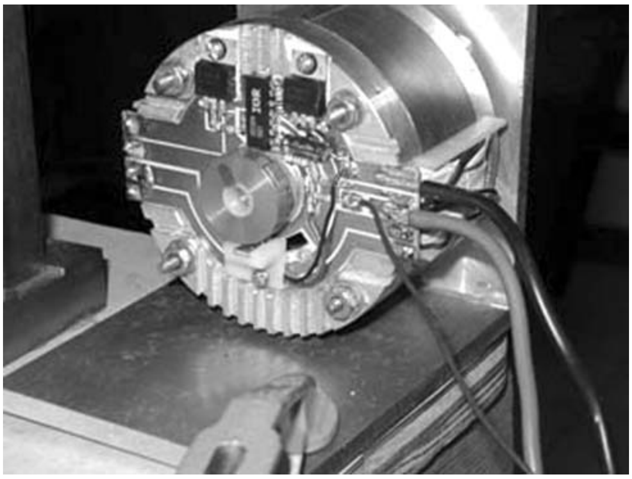

Photo 1

3.3" 1.2" stack height 1/2 hp weight 59 oz

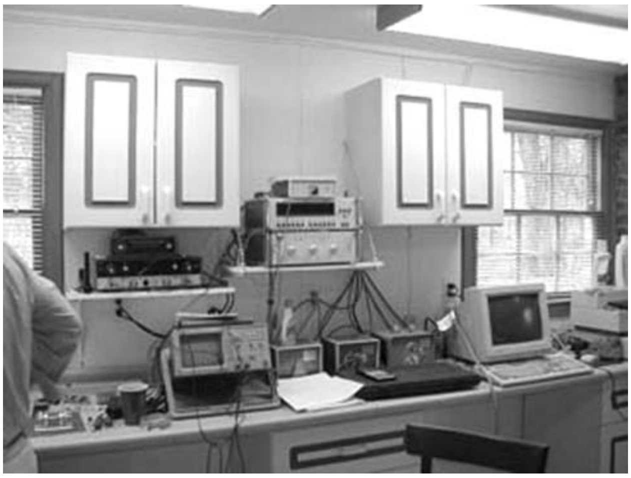

Photo 2

Dynamometers, Power Analyzer etc.

Editor: Below we publish information and photos, represented on Flynn Research Company website (http://www.flynnresearch.net), and a description of the patent on methods for controlling the path of magnetic flux.

Flynn Research is dedicated to research focused on the novel application of permanent magnet and electromagnetic technology. Magnetism is a field that has potential for tremendous growth from both a science and application perspective. The researchers of Flynn Research Company believe that magnetism is one of the least understood and most misinterpreted of the natural forces, with the exception of gravity.

Even though much work has occurred in the advancement of magnetic materials, little advancement has occurred in the basic understanding of magnetism. The field of magnetism is based on both theory and 'myth' and is generally described as a 'phenomenon'.

We still do not know what a line of flux is and how it travels through space. We know flux "appears" to originate within a permanent magnetic material, forms a loop from one end to the opposite end of the magnetic material, appears to occur without a time constant, produces a force (attractive and repulsive) between other permanent magnets and "magnetically permeable materials and has a relationship to current flow. Everything known about magnetism is based on "effect and relationships" without a clear understanding or provable definition of what is a line of magnetic flux.

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The research is based on the "magnetic force of attraction effect" that is related to magnetic flux by the number of lines of flux occupying a given area or flux density squared. The simple fact that if the number of lines of flux occupying a given area "doubles" the force of attraction becomes four

Photo 3

8" dia x 8" height motor presentation

Photo 5

Technology Discussion

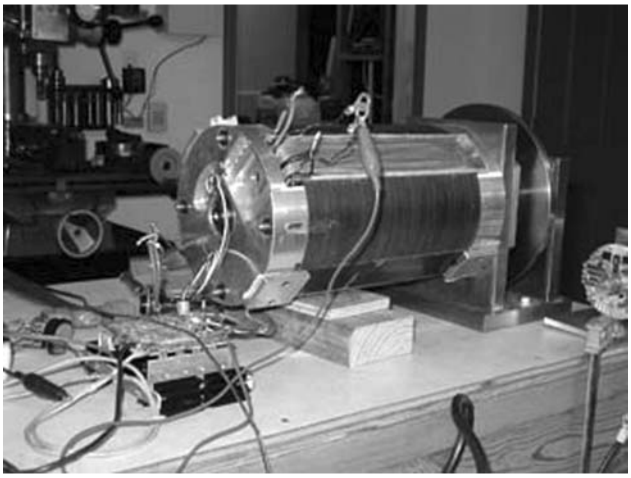

Photo 4

8" X 8" motor testing

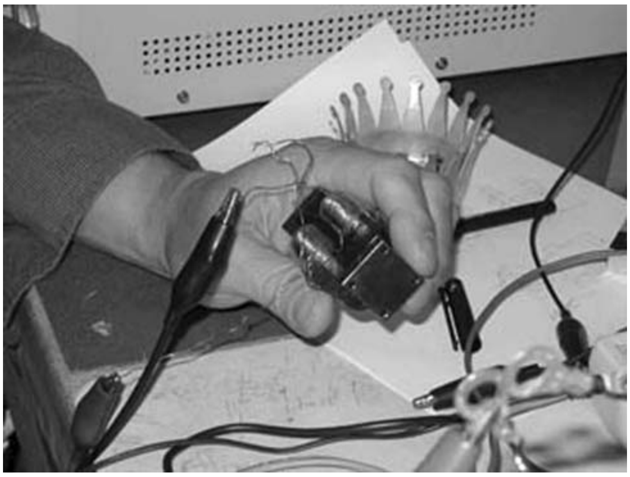

Photo 6

Parallel Path Test Apparatus

times greater. The basic model shows that with specific structures electromagnetism acting with permanent magnet materials can divide and multiply force in a manner that cannot be explained with conventional physics.

Rotary devices, linear devices, reciprocating devices and power conversion devices are now a patented product of this research. The goal of the Company is to commercialize their devices for use in an energy dependent world. Flynn Research is a research & development company and in cooperation with Magnetic Revolutions LLC licenses their technologies for use in the electric motor and power conversion industries.

The researchers do not construct their own test equipment nor write capture and data evaluation programs but use industry / scientific accepted products. Close to $1.5 million has been expended developing, protecting and evaluating the technology. Many fine minds have been involved in the development and evaluation of the technology. Many presentations have been given both to motor companies and academic groups. The prototypes have all been professionally built, which include a 1/2 hp 3.3" dia 1.2" stack height, the assembled motor weighs 59 oz and a motor 8" dia with a stack height of 8" currently undergoing testing.

United States Patent No. 6,246,561
June 12, 2001

Methods for controlling the path of magnetic flux from a permanent magnet and devices incorporating the same

Inventors: **Flynn; Charles J.** (Greenwood, MO)
Assignee: **Magnetic Revolutions Limited, L.L.C** (St. Louis, MO)
Appl. No.: **127056**
Filed: **July 31, 1998**

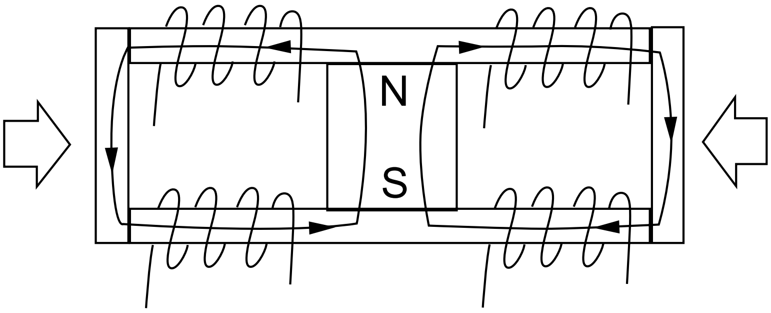

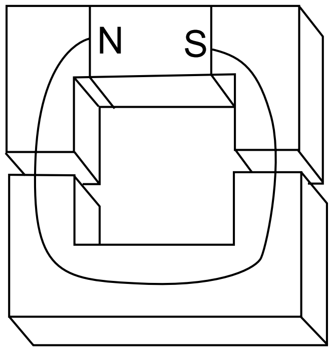

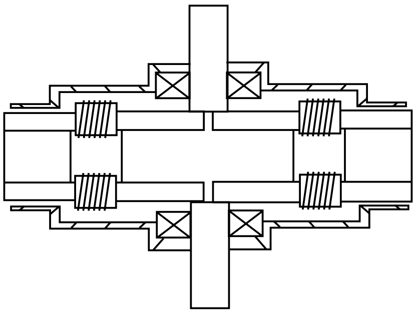

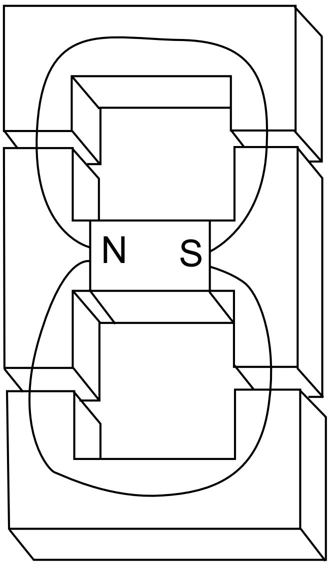

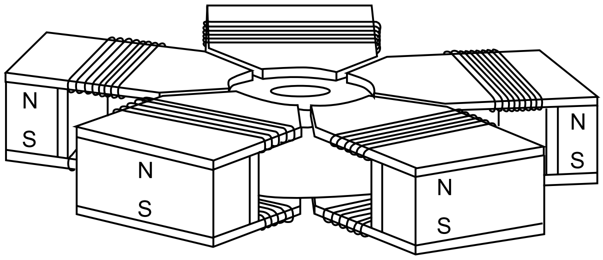

A permanent magnet device includes a permanent magnet having north and south pole faces with a first pole piece positioned adjacent one pole face thereof and a second pole piece positioned adjacent the other pole face thereof so as to create at least two potential magnetic flux paths. A first control coil is positioned along one flux path and a second control coil is positioned along the other flux path, each coil being connected to a control circuit for controlling the energization thereof. The control coils may be energized in a variety of ways to achieved desirable motive and static devices, including linear reciprocating devices, linear motion devices, rotary motion devices and power conversion.

Editorial: The principle of designing of the device (two counter parts of the flux are used) resembles Φ-machine or Gramm's generator. Read in this issue more details on these devices.

Flux-machine And Its Analogues

Review prepared by correspondent Alla Pashova, Russia

Flux-machine (or Φ-machine, since configuration of its field resembles the Russian letter "Φ") was designed by Alexander V. Frolov during the first half of 1990s. Φ-machine description was published more than once on the pages of scientific periodicals (1994, Institute of New Energy, Newsletter, June 1994, p.9.; 2002, New Energy Technologies, 2002, p.3), and it is well known to many researchers concerning themselves with such kinds of engineering.

Let us consider the arrangement of Φ-machine; see Fig. 1 (first published in 1994). A report was presented at the conference «New ideas in natural science», 1996 in Saint Petersburg (see photo in Fig. 1). The primary coil is mounted in the center of generator; two secondary ones are diametrically wound on a ring core. An air gap between ring and central magnetic circuits are of particular importance. **Two magnetic fluxes from two coils are balanced, and, thereby, there is no reaction in the primary circuit.**

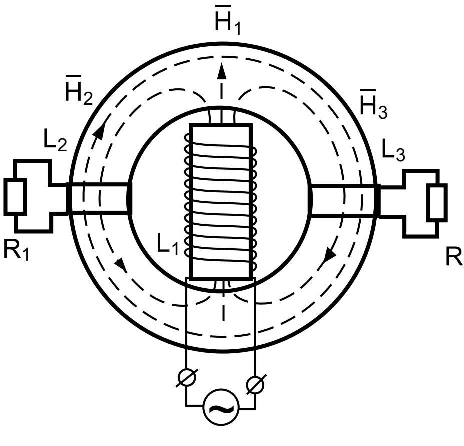

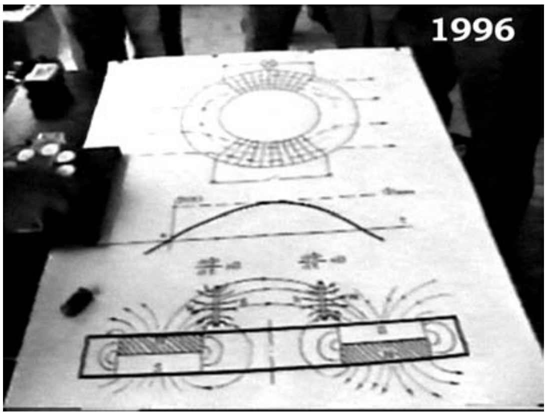

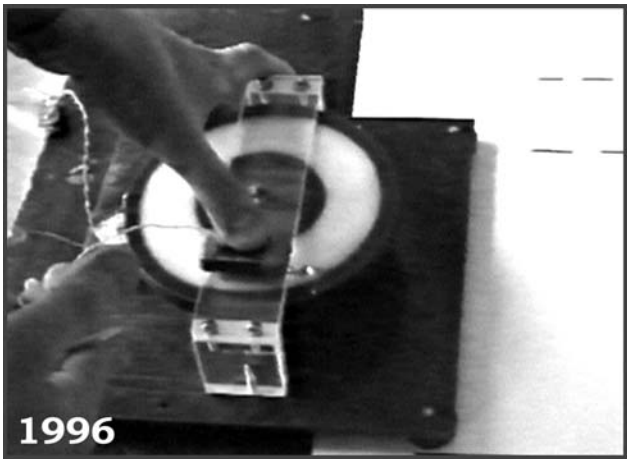

Fig.1
See also Fig. 7, p.29 – the analogy is evident

The device bears some similarity to the Gramm's generator (Zenob Theophyl Gramm, 1826-1901, Belgium-France, took out a patent for an electric ring-rotor generator in 1869). In Gramm's generator (Fig. 2) the ring rotor with a toroidal winding rotates. The toroidal winding touches two diametrically located conducting brushes. It turns out that in the ring of the rotor all winds of one rotor half create a field which is directed towards a field created by the other rotor half.

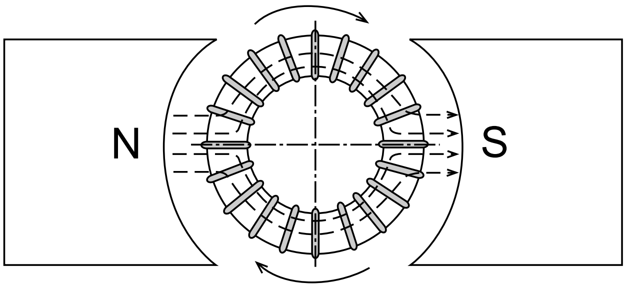

Fig. 2

An example of analogous device is represented in Fig. 3 (information is from the website: http://www.skif.biz/energy/arhiv1-6.shtml), and also in Fig. 4 (we have written about this invention in New Energy Technologies, Issue #5 (8), 2002, article by V.I. Boryak, Email: spin@i.com.ua).

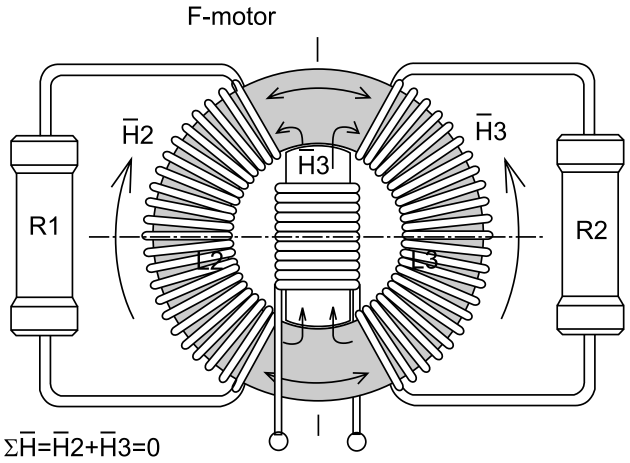

Fig. 3

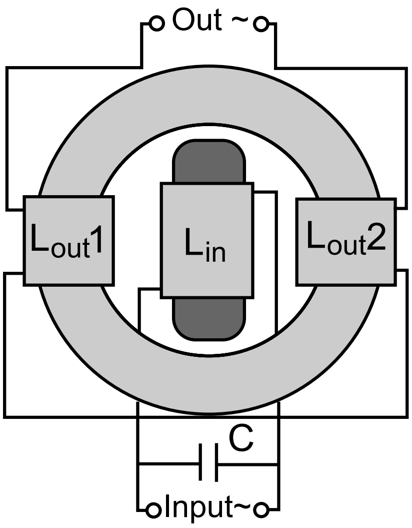

Fig. 4

In August 1999, according to Stephen Hartman (Hartman Multimedia Service, Email: hart@harti.com, info@ccard.net), a German research team designed a toroidal generator. As stated by the researchers, it obtained more than 1.200 W by load while efficiency exceeded 100%!

This subject has become very popular among different researchers. Fig. 5 illustrates a design with a magnet rotating in the center (designer - Olaf Berens, Email: olaf.berens@prognost.com).

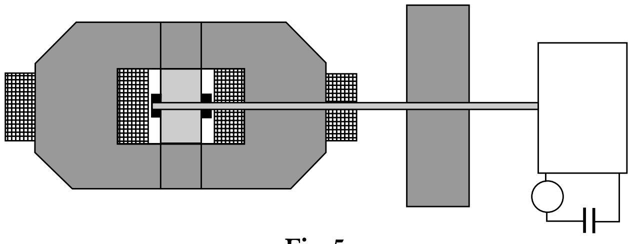

Fig. 5

One more example from the USA: in February, 2003 Donald Hofmann (USA) filed an application for patenting “Generators and transformers with toroidally wound stator winding». Below we publish the description of the patent.

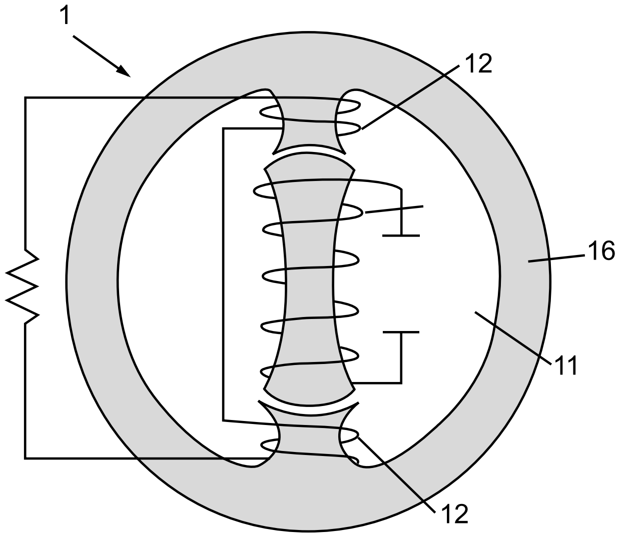

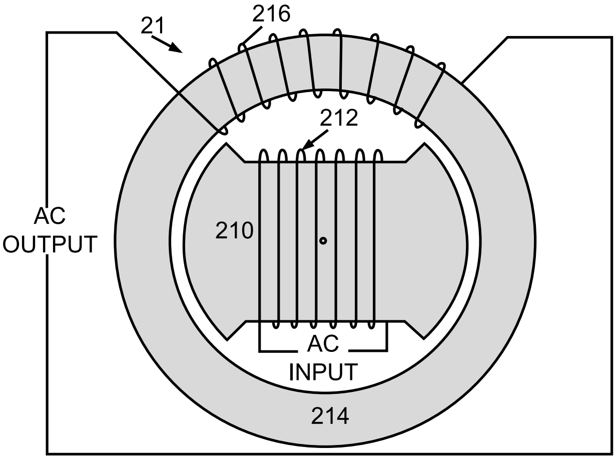

Fig. 6

Inventors: **Steven L. Sullivan, USA; David L. Goulet, USA; Donald Hofmann ,USA.**

Electrical generators are provided with toroidally wound stator windings electrically connected in series; a high permeability stator core, preferably an amorphous magnetic alloy material, glassy metal or HYPERCO™ 50 laminations; and a rotor. The toroidally wound stator coils and the stator core trap essentially all of the flux fields generated by the stator coils within the stator core. Since there is essentially no magnetic field leaving the stator, there is essentially no flux field interaction with the field generated by the rotor. The reduction of flux field interaction also reduces counter torque.

According to another embodiment of the invention, open positions of a rotor may be filled with magnetic material, preferably iron. Filling open portions of the rotor may assist in reducing undesirable flux leakage from the rotor. By trapping substantially all of the flux within the rotor, interaction between rotor and stator flux is reduced. In this manner, counter torque is reduced thereby increasing the overall efficiency of the device.

A prototype of this embodiment was constructed using a standard 10 kWtt gas-powered generator. The stator was removed from the generator and its housing. The stator windings were removed from the stator and rewound by hand using a No. 10 size copper wire with 180 winds wrapped in a toroidal fashion around approximately 180 degrees of the stator. The stator was then reinstalled in the modified housing and re-attached to the gas-powered generator. A standard 12 volt car battery was attached to the input of the rotor. A 12.92 volt input with 0.8 Amps was measured as the input to the rotor. The output was measured as 6.5 volts with a 40 Amp output. A series of input and output measurements were taken for various inputs.

Editor: Thus input power is 10 Wt, and output power is 260 Wt.

So, the old well-known ideas have found new ways of embodiment, though their essence remains unchanged. Let us note that Faraday Labs Ltd has been working on creating a prototype of ▯-machine with a toroid of 200 mm in diameter.

Please, read more about this in the next issue!

◆

Editorial: We publish the specification of several interesting patents, which were taken out by Russian inventors for recent years.

Russian patents on alternative energetics

- №93001754, 1996.06.27, Converter of gravitational forces into energy, V.V. Mironov and others
- №92008720, 1995.02.10, Slavic method to produce energy by conversion of gravitational forces, V.V. Mironov
- №93006696, 1995.04.30, Supporting converter of gravitational forces into energy, V.V. Mironov
- №2001121071, 2003.04.10, Method to create energy in liquid, heat-generator and heat-and-power device, A.Yu. Baurov and others
- №2132109, 1999.06.20, Generator of mechanical energy, A.Yu. Baurov and others
- №2001125794, 2003.05.10, Generator of static electricity, S.I. Danilov
- №2001120796, 2003.04.10, Electric power device, D.M. Beliy
- №98116077, 2000.05.10, Heat engine (monotherm, "perpetual mobile of second-type"), V.I. Likhachov and others
- №93048971, 1996.04.20, Float engine, I.P. Tchinarev
- №94023174, 1996.03.27, Gravitational-hydrostatic engine, I.P. Tchinarev
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- №95107181, 1997.02.20, Method to convert energy of physical vacuum into energy of physical space, O.K. Polev and others
- №92008695, 1995.04.20, Method to get overunity efficiency, Yu.V. Karasev and others
- №93006851, 1995.04.30, Principle, method and device for circulation of mass by force of gravitation and inertia, G.S. Kirichenko
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- №2143170, 1999.12.20, Method to convert energy of mechanical loading into energy of repeated transference, V.I. Rahovsky and others
- №2000119415, 2002.06.20, Method to convert energy of fields of permanent magnets into mechanical work, Yu.S. Pilipkov
- №2001109811, 2003.02.27, Method to capture and convert energy of physical vacuum into electric energy, S.N. Kovalev
- №99121374, 2001.11.10, Perpetual mobile, E.M. Volodin
- №94026259, 1996.05.20, Device to convert magnetic field energy into kinetic energy, P. Imrish

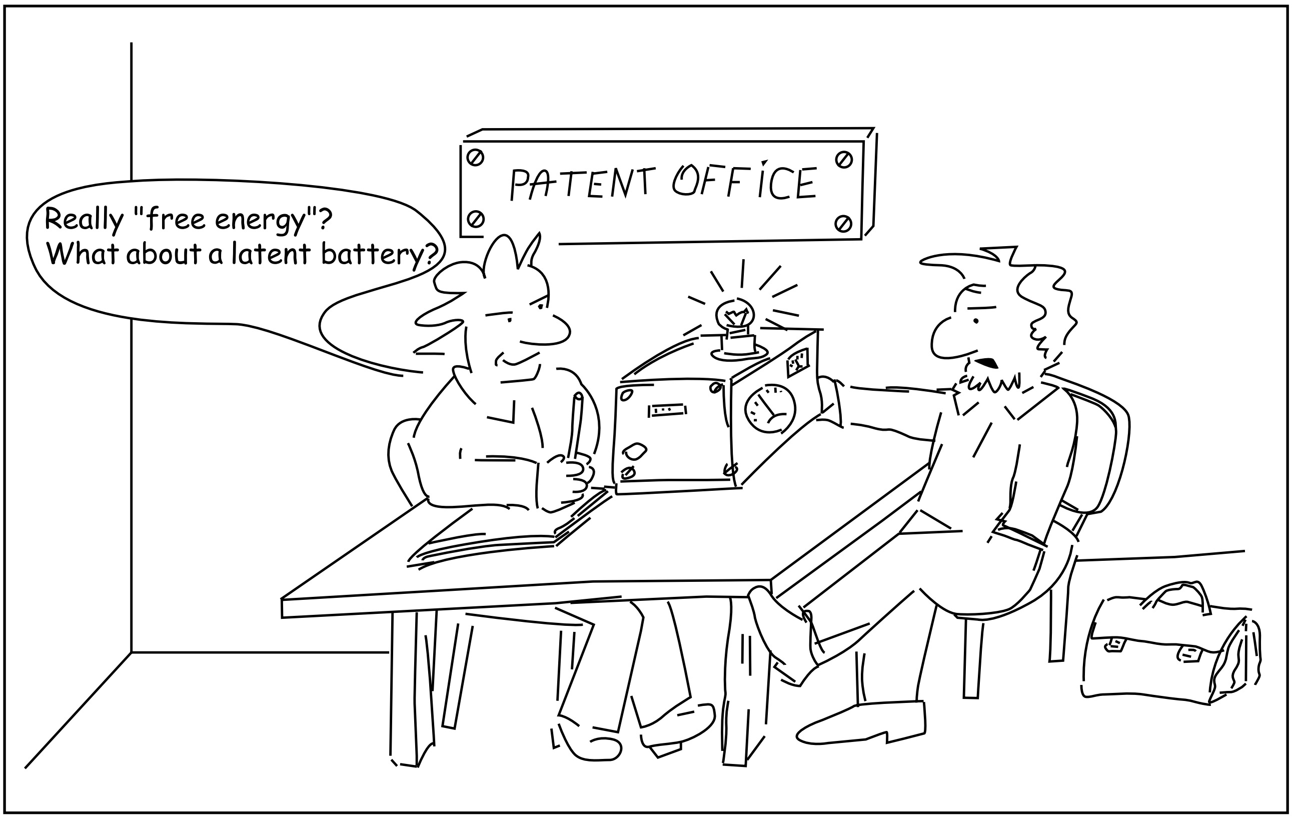
PATENT OFFICE
Really "free energy"?
What about a latent battery?

Device for conversion of magnetic field energy into kinetic energy

No. 94026259, 1996.05.20

Author: Pavel Imrish

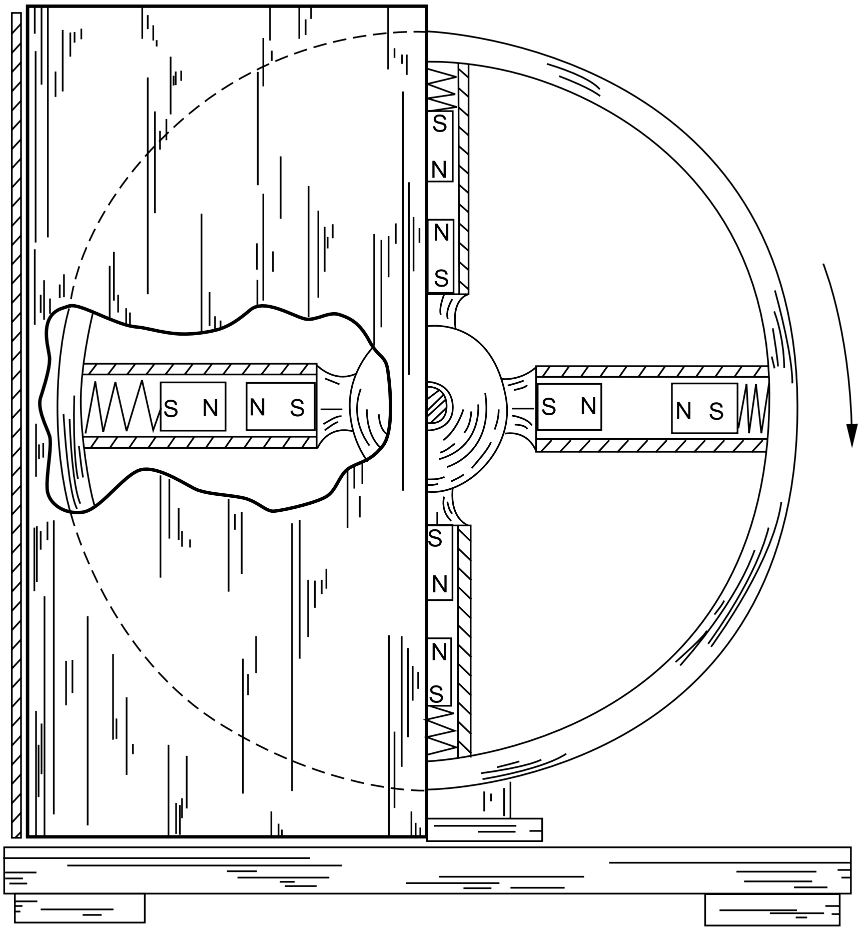

Fig. 1

The invention refers to a device for conversion of magnetic field energy into kinetic energy. The device has a rotating wheel with at least two radially opposing non-magnet holders used as guide ways for at least two permanent magnets, respectively. The permanent magnets are mounted in the holders so that there is a possibility to remove them. From the both sides of the wheel plates made of magnetic material are mounted axially; the plates surround the wheel partially. Depending on direction of the both poles, namely on location of the similar and opposite poles towards each other, compression element is situated on the holders, or between the wheel and the outer end of the permanent magnet located at the furthest radial distance from the axle of the wheel, or between two permanent magnets. (The device operation principle is obvious from Fig. 1).

Editor: We have found an example of a similar device whose description is presented in the book by R. Ford The Perpetual Motion mystery [1].

In this case, there is an analogous process, during which half of the cycle is screened and the rotor is supposed to rotate permanently (see Fig. 2).

1. RA. Ford, The Perpetual Motion mystery. Lost Technology Series, p.23.

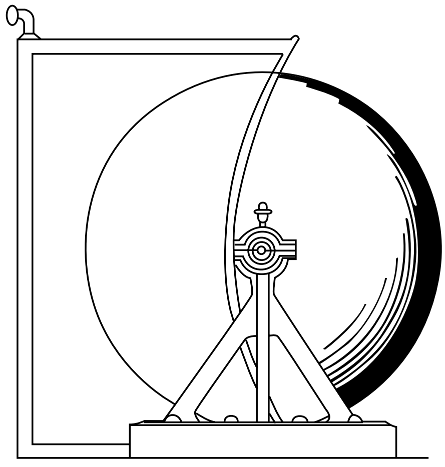

Fig. 2

Gravity spaceships

Review on Grigory R. Uspenskiy's works, Russia

http://space21.boom.ru/gravity.htm

The level of development of modern astronautics is primarily determined by the energy capabilities of space carriers. So, nowadays, the single-mission carrier rockets equipped with chemical engines allow space exploration within the solar system. These carriers have delimited the near-earth space in the form of a geostationary orbit, where the practical-purpose space complexes operate.

Newer and higher levels of quality will be reached by cosmonautics upon its mastering gravity power engineering. Flights towards the nearest stars will become possible and by the end of the next century this will be followed by travels throughout Galaxy.

Gravity engines are structurally simple (**two bodies of different density are rigidly connected**). To form some practicably significant value of thrust it is required to use absolutely new technology regarding creation and retaining of matter of high density which can be compared to that of atomic nuclei. For instance, at an engine mass of about 2 t, it is possible to attain 10 N thrust using bunches of aluminum and lead nuclei. The nuclei are approached to each other at a distance comparable with sizes of these bunches.

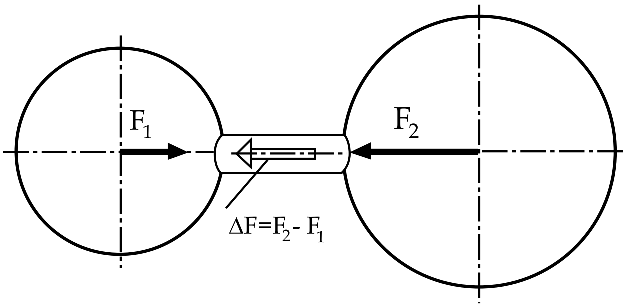

Fig. 1

Use of matter which is denser than nuclei bunch, increase of mass of the gravitating bodies, and reduction of the distance between the bodies causes increase of thrust. So, for a level of density of gravity holes (i.e. for extremely dense state of matter in which it is not attracted by other bodies) limit value of acceleration of the gravity engine reaches the order of 10^{100} ms^{-2}.

In engineering, we usually use units of distance as meters, centimeters, millimeters, and microns. Let us consider one of them – millimeters. With such a size of the gravitating bodies and distance between them, it is possible to obtain substantial thrust forces of the gravity engine and, accordingly, accelerations of its motion.

So, using an engine of 20 ton mass we will get the thrust of $2x10^4$ N, with mass of 200 ton we will get the thrust of $2x10^6$ N, and so on. Thus, by increasing the engine mass by one order of magnitude, we obtain increase of thrust by two orders, while sizes of the bodies remain unchanged. But acceleration, in this occasion, remains constant and equal to approximately 1 m/s^2.

Decrease in size of gravitating bodies of the engine leads to the corresponding increase of thrust by an order. Decrease of size is realized by increase of density of these bodies by 3 times up to 0.3 mm at the same masses. The acceleration they produce is increased by an order as well, i.e. up to 10 m/s^2. Decrease of sizes of the gravitating bodies and the distance between them down to 0.1 mm results in further increase of engine thrust by one more order and also increase of acceleration up to 100 m/s^2. If size of the bodies is 1 micron then acceleration increases up to 10^6 m/s^2.

It is apparent that even with up-to-date technological possibilities of miniaturization the gravity engine with masses of dozens and hundreds of tons is capable to create great thrust forces and form accelerations considerable enough to fly across the Galaxy. Therefore, the problem of creating a gravity engine is, mainly, the problem of producing and retaining the high-density matter. It will be possible after studying the mechanism of interaction between matter & gravitational substance followed by developing techniques for synthesizing of high-density, large-mass, and small-size substance from this matter.

It is possible to control the value of thrust of the gravity engine changing the distance between gravitating bodies. Thrust direction can be changed by turning the rigid connection of the gravitating bodies. The engine can be activated by bringing the gravitating masses together, and switching-off by moving them apart.

In a 24-hour period, such a ship can reach a speed of 10^6 m/s and cover a distance of about 10^{10} m. In a month, with a top speed of 3x 10^7 m/s the ship will cover the distance of 10^{13} m; in a year, with a speed of 4x 10^8 m/s the ship will cover a distance of 10^{15} m; in 10 years - 4x 10^9 m/s and 10^{17} m, respectively. Apparently, the ship with sufficient over-load can be used for flights within the solar system and for manned flights towards the nearest stars.

When transporting unbreakable and non-urgent cargoes, the acceleration can be increased up to a few dozens of unities. The flight duration might be also increased by several tens of years. This extends the area of utilizing the gravity ships with over-loads of several unities. Besides these ships can be used for transporting operations within near vicinities of the Galaxy.

The high-speed flight will demand protection against approach flow of matter. So, per second (with a ship speed of 10^{10} m/s) 10^{-12}kg of matter will approach the ship. At that density of interstellar material is 10^{-24} kg/m^3 and midship area is 10^2 m^2.

The great speed of approaching matter will create a substantial resisting force. At a speed of 10^{10} m/s, this force will come to the order of 10^{-2} N, whereas with a speed of 10^{18} m/s it will come to 10^{14} N. This is a great value, but as compared to thrust of such a ship which is to equal to 10^{17} N, the former value is a small one. That is why it is possible to overcome such resisting force.

Intercommunication with these ships might be, most likely, realizable by means of distortion of gravitational field. It is possible that the gravitational field distortion will be formed, on the contrary, by generating the matter from the gravitational field, and, most probably, by a method as yet unknown.

New books and DVD

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On Velocity of Drive-Free Motion

S.A. Gerasimov , V.V. Stashenko, Russia

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***Editorial:** We publish a summary of the article. The original text you can receive from the authors.*

A drive-free system made on the basis of a planar mechanism is described. The experimental results on average velocities of the drive-free propulsive system are presented in a scaled view.

During usual motion, a system is repealed from the surface in the case of its motion on a plane or from the medium when it moves in a resistance medium. This kind of motion is achieved by using a drive mechanism. In contrast to the usual motion, the drive-free propulsive system moves due to interaction of a body of a system with another body of the same system. Sometimes such machines are called inertioids [1] or vibration propulsive devices [2]. To produce such kind of motion it is sufficient to provide anisotropy of the resistance force [3-5] or asymmetry of the internal force [6]. One of the simplest ways to do it is to use a simple two-link planar mechanism. A device for such a motion is shown in Fig. 1.

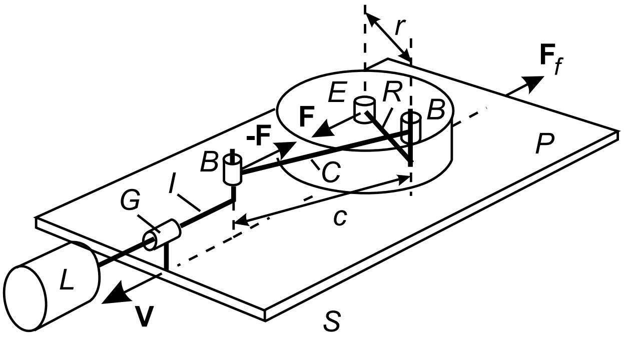

Fig. 1

Experimental device

This device with a total mass of M+m consists of a platform P on which an electric motor E rotating a drive rod R of length r is mounted. This is only one part of the planar mechanism. Another link is the connecting rod C of length c which connects the unbalanced load L and the drive rod R by means of two bell bearings B. The unbalanced load L of mass m on the rod I slides in guide G. The basic distinction of this mechanism is in that this variant of drive-free machine allows us to analyze the experimental data on average velocities of motion. Actually the only forces, which act on the platform and are collinear to the moving direction, are the force **F** caused by vibrations of the load L and the frictional force $\mathbf{F}_f$. The platform starts to move when the force acting on the platform becomes greater than the frictional force.

Let us discuss possibilities of the real propulsive system shown in Fig. 1. Measurements were made at $r=0.01$ m and at three mass ratios m/M. The values of frictional coefficients were measured for each parameter of the system and vary from $k=0.25$ to $k=0.4$. The system starts moving when theoretically the drift does not take place. When motion becomes reversible, the velocity of drive-free drift does not decrease.

Thus drive-free motion is possible even if the frictional coefficients are very small. When increasing the frequency of vibrations velocity does not decrease. We can not discuss the existence of some third force acting on the platform (we can suggest the existence of frictional force $\mathbf{F}_f$ and the internal force **F** caused by vibrations). Let somebody else take the liberty of making such a conclusion!

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ELECTROMAGNETIC SELF-ACTION

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The torque of a self-action exerting on the mobile part of the reactionless engine is measured. It is shown that there exists a value of the height of the mobile electrode at which the torque of self-action is maximal.

There is an opinion that a body can not act on itself [1]. The existence of the so-called force of self-action is believed to contradict to the law of conservation of momentum. This is nothing but prejudice. Though the experimental confirmations of existence of self-action [2-4], conventional science is ready to refuse modern electrodynamics and make up a new theory of electromagnetism [1, 5] in order to save Newton's third law in use. It is comprehensible. First of all, these are the theoretical [5] and experimental [3] errors. The equivalence [5] of the Biot-Savart force is mathematically coarse since in this case the highest terms of expansion of force of self-action are cast out. This equivalence violates law of action and reaction and Ampere force law for which the principle of equality and collinearity of action and reaction forces is valid. Non-linearity of dependence of the torque of self-action on the current intensity [3] makes us doubt in the validity of these results. Moreover, typical values of force [2, 4] and torque [3, 6] are too small even if direct current in the circuit is significant. It is required to pass through the direct current of hundred amperes to produce the considerable displacement or turn of a body. As a result, small values of the effect caused ambiguity in the explanation of the phenomenon [1].

In fact, searching the reactionless propulsive devices we usually forget about the magnetic self-action which arises when a body consisting of a magnet and incomplete electric circuit can move violating law of action and reaction [7]. This violation is proved theoretically [8] but peculiarities of this motion are not well discussed. The principle of such a motion is shown in Fig. 1. This is the magnetic interaction between two current elements one of which is a part of a closed circular loop ***L*** and another is perpendicular to the first one. Since the force $d\mathbf{F}_{jm}$ acting on any current element of the loop ***L*** is perpendicular to the density of current $\mathbf{j}_m$ then the **Z**-component of the torque $d\mathbf{N}_m=[\mathbf{r}_m x d\mathbf{F}_{jm}]$ is equal to zero while torque which exerted on the second current element by the magnetic field of the loop, does not.

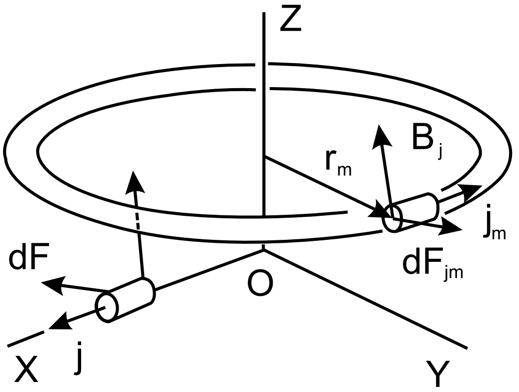

Fig. 1

Violation of law of action and reaction.
The force $d\mathbf{F}_{jm}$ with which the magnetic field $\mathbf{B}_j$ of another current element acts on the current of density $\mathbf{j}_m$, is not equal nor opposite to the force $d\mathbf{F}$ with which the magnetic field **B** of the first current element acts on the current of density **j**.

An experimental device is shown in Fig. 2. A commercially available ring-shaped carbon-steel magnet ***M*** (inner radius – 20 mm; outer radius – 55 mm, height – 25 mm) of $2.2x10^5$ A/m magnetization is located on the cover of a cylindrical electrode ***E*** suspended by thread ***T***. The electrode ***E*** is furnished with a central electrode ***C*** of the same height ***h*** and 5 mm diameter. The radius of the electrode ***E*** is 130 mm. The open end of electrode ***E*** and the central electrode ***C*** are submersed in a conducting liquid L_+ and L_- placed in two volumes of a vessel ***V*** so that the depth of submergence of these parts is about 5 mm. In this experiment the conducting fluid is 10% solution of copper sulfate ($CuSO_45H_2O$). The vessel ***V*** consists of two thin coaxial plastic cylinders of 2 mm thickness. The radii of the plastic cylinders having the common bottom are equal to 10.5 cm and 18 cm. The height of the vessel is 12.5 cm. A disk and a ring-shaped electrodes S_+ and S_- of 1.5 mm thickness are placed on the bottom of the vessel to supply the direct electric current of intensity *I*. All conducting parts of the device are made of copper. The thickness of the electrode ***E*** is 1.5 mm.

When the direct current *I* of density **j** flows through the electric circuit, the magnet and the electrode *E* rotate in the direction of the magnetic force *d***F** which is proportional to the vector product [**j**x**B**] as shown in Fig. 2. This is a force of self-action by means of which the mobile part of this device consisting of the magnet *M* and the electrode *E* acts on itself. However there is no force of reaction which could cause such a rotation. This is really true since a ring-shaped magnet is equivalent to two cylindrical surfaces with the surface current of density $\mathbf{j}_m$. The force of self-action *d***F** acting on the cover of the electrode is compensated by the force of self-action $d\mathbf{F}_*$ acting on the cylindrical part of the electrode *E*. Magnetic induction field $\mathbf{B}_*$ "does its part" as shown in Fig. 2. Therefore, it would be appropriate to find out how the height of the electrode *E* influences the value of the torque **N**. Such an influence is demonstrated in Fig. 3.

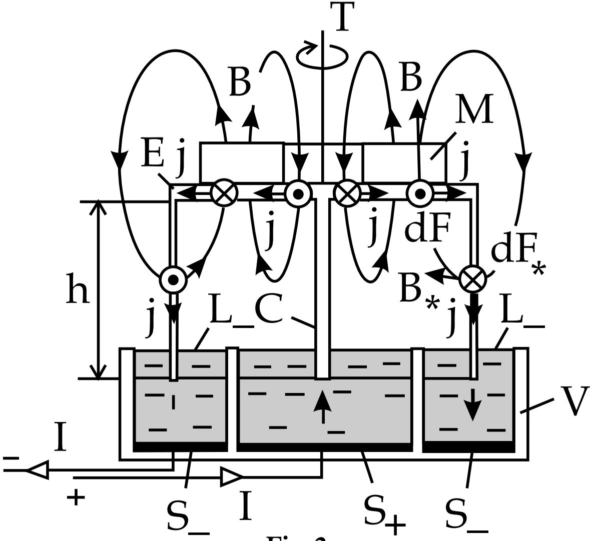

Fig. 2
Experimental device
(•) and (x) – directions of magnetic forces acting on various parts of the mobile electrode *E*

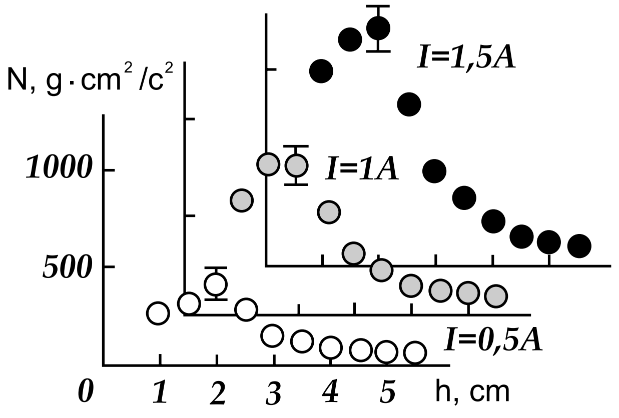

Fig. 3
Dependence of the torque *N* on the height of the electrode *h* at various values of the direct current *I* in the circuit

Thus there exists the value of the height *h* at which torque of self-action is maximal. This is the first result of the present work. At *I*= 1 A and *h*= 2 cm the electrode *E* turns at angle of 2.2 radian (126 °) with respect to the equilibrium position. Such a turn corresponds to 3.4x10^2 gxcm^2/s^{2}rad, i.e to the constant of torsion of the thread. The second result is that the maximum value of the torque of self-action *N* at the current *I*= 1 A is even larger than the value of the torque produced by the traditional unipolar device [3] at the current 50 A.

In fact, this work represents an attempt to draw attention to a more effective and simple practical application of the self-action. It remains only to transfer electric current in an unclosed electrical conductor and such a possibility really exists.

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Uranium Photoaccumulator

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Photoaccumulators are galvanic elements consisting of two communicating vessels, one of which is exposed to light and another is kept in darkness. Ionic composition of electrolyte, which fills these vessels, depends on intensity of illumination. If an inexpensive electrode is placed in each vessel, then a potential difference will appear. If the electrodes are closed at external working resistance the electron stream will begin to equalize ionic composition and the difference in illumination intensity will tend to disbalance it. As a result, a certain working mode will be established which will allow to utilize the photoaccumulator for production of industrial electrical energy. As distinct from the solar battery, which works while exposed to the light, the photoaccumulator stores some part of solar energy in its electrolyte which is supplied with electrical energy after sunset too.

The idea of photoaccumulator is not a new one. It was established in the end of 19th century that it is feasible to create a photoaccumulator containing electrolyte made of the following mixture: $Fe^{2+} + Hg^{2+} = Fe^{3+} + Hg^{+}$.

This photoaccumulator was not adopted in practice because of high toxicity of the electrolyte and very low EMF (approximately 0.018). Development of technology is accompanied by a widening range of materials and matters which can be used in large scale production and power industry. Among such materials are, in particular, titanium, depleted uranium and rare-earth elements. Nuclear power industry uses U235 isotope only. Naturally occurring compound contains only 0.72% of U235. Hundreds of thousands of U238 from which U235 has been extracted are kept as useless stock.

In the end of sixties in one of radiochemical laboratories of LINP (Leningrad Institute of Nuclear Physics) P.N. Moskalyov repeated the same experiment over a long period of time. In the morning he placed a tightly closed retort filled with uranylchloride soluted in compound of water, spirit and hydrochloric acid on the window-sill. The solution in the retort changed its color from yellow to emerald-green. Before leaving the laboratory Moskalyov removed the retort with green solution from the windowsill to a closed chest. In the morning Moskalyov retrieved the retort with the solution (which was already yellow) from the chest and placed it on the sill. The solution became green again and the whole process repeated daily.

Chemical processes in uranium electrolyte are rather complicated: first, under the light influence the uranyl ion oxidizes ethyl alcohol, which is then transformed to aldehyde: $UO_2^{+2} + C_2H_5OH^{+} = U^{iv}(OH)_2 + C_2H_4O$.

In the dark ions of urany-4 interact with aldehyde and are transformed to UO_2 uranyl ion and spirit again. Thus, **this cyclic process can take place over a significant period of time being supported by the energy provided by light quanta of visible light which are transformed into the heat.**

The idea of utilizing this process in order to obtain electrical energy emerged in the late nineties. The mechanism of uranium photoaccumulator is very simple (Fig. 1): two glass vessels, one made of transparent glass and another of non-transparent glass, are connected with a black acid-proof rubber tube. The communicating vessels are filled with aqueous electrolyte containing 40% of spirit, 80-100 g/l UO_2Cl_2 and 0.2 m HCL. The electrolyte is previously activated by multiple cycles of exposing it to light and then placing it in darkness in order to obtain a significant volume of aldehydic fraction. The major difficulty of designing uranium photoaccumulator is connected with the choice of the material for electrodes. In galvanic elements carbonized platinum electrodes are usually used. For practical use platinized titanium gives the best fit. Titanium foil covered with superfine layer of platinum is currently widely used in electrochemical industry and is procurable.

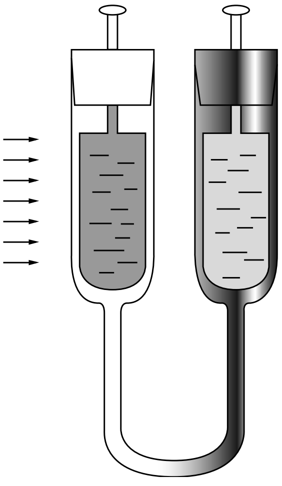

In the transparent vessel the titanium petal-shaped electrodes are parallel the light flow, so the light quanta move freely through the solution.

In working condition each photoaccumulator produces 10 mA of current at 0.3 volt voltage, so they are to be connected in large batteries, both in series and in parallel.

It is also necessary to consider the aspect of safety. Until now, the depleted uranium has been used for one purpose only, namely, for manufacturing of cores for armor-piercing shells. When used in this manner, the uranium is pulverized, which leads to environmental damage. The battery of photoaccumulators is placed in hermetic metal chest; the front panel of the latter must be made of solid safety glass. Such a system will protect the photoaccumulator battery from malicious intent and the security staff from weak uranium radioactivity.

International Prize on Power Engineering “GLOBAL ENERGY”

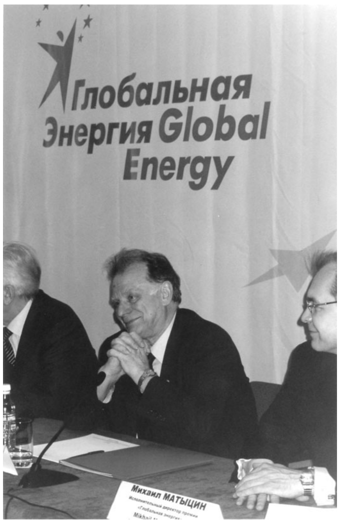

Zhores I. Alferov

International Prize “Global Energy” was first presented in St. Petersburg on June 15, 2003. The bonus fund of $900,000 was shared between three scientists “whose work has been and is still important both to the last century and future research”, said Zhores Alferov, Chairman of the Global Energy Prize Award International Committee.

Nick Holonyak, Professor at the University of Illinois (USA), was awarded for “fundamental contributions to the development of power silicon electronics and invention of the first semi-conducting light-emitting diodes in a visible part of the spectrum”. Thyristor invented by Holonyak allows the transformation of direct current into alternating and vice versa, to direct this process, to store and accumulate energy. This device is used for every electric locomotive, for frequency transformation. Such devices help to save significant amounts of energy, thus, about 30 percent of all energy produced in the world is processed through thyristors.

Nick Holonyak’s other invention, i.e. semi-conducting light-emitting diodes in a visible part of the spectrum, has led to development of a new field of the modern power engineering. Supposedly, efficient and safe light-emitting diodes will replace daylight lamps in the next ten years.

“Although Nick Holonyak’s invention dates back to the end of the 50ies of the last century, it remains current” said the Chairman of Expert Commission, Academician Vladimir Fortov. “This is one of the key inventions leading to the search of new ways of sustainable energy saving”.

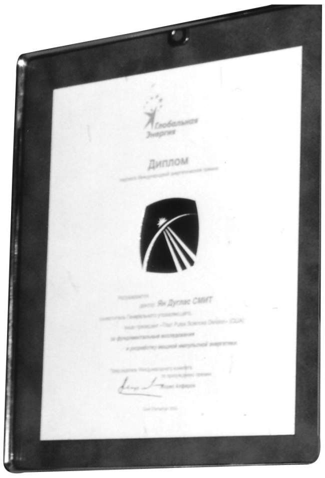

Diploma of Global Energy Prize laureate

Gennady Mesyats, Academician of Russian Academy of Sciences, and **Ian Douglas Smith**, Senior Scientist at The Titan Pulse Science Division, were awarded for giving birth to a new direction in the field of power engineering, i.e. power pulse energy. Due to their research, commutation of high-level currents at megavatt levels of voltage has become possible; a number of powerful current choppers have been created, futhermore, there have been developed transformer constructions which allow avoiding energy loss in power transmission lines. These research and innovations resulted in the creation of a number of unique pulse power machines and devices widely used in Russia and abroad (“Aurora”, “Helia” (USA), “Sinus”, “Gamma”, “Maus”, “Pik” (Russia) and others).

Глобальная
Энергия Global
Energy
Геннадий МЕСЯЦ
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Жорес АЛФЕРОВ
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Михаил МАТЫЦИН
Mikhail MATYTSIN

Teleportation

Review prepared by correspondent Alla Pashova, Russia

For conventional science, the term "teleportation" is not worthy of serious consideration unless ascertained by compulsory "quantum" teleportation. Thus, teleportation is unconditionally referred to microworld phenomena and, in fact, comes to distant information transfer. Spatial transference of a macroobject of definite mass has been excluded.

Teleportation of states

What does **quantum teleportation** mean? During active development of quantum theory, in 1935, the so-called EPR-paradox (Einstein-Podolskiy-Rozen paradox) was formulated in the well-known work "Can quantum-mechanical description of reality be full?" written by Albert Einstein, Boris Podolskiy, and Natan Rozen.

The gist of the paradox is as follows. There are two particles interacting for some time, thereby forming a common system. From the position of quantum mechanics, this coupled system can be described with a certain wave function. When interaction is over and particles scatter within arbitrarily large distances, they still will be described by the same function as before. At that, state of each separate particle cannot be known in principle that is apparent from uncertainty relation. Only when one of the particles enters a receiver, which records its parameters, the relevant characteristics of the other one emerge (exactly emerge, but not become known!). Thus instant unlimitedly distant "transmission" of quantum state of the particle is possible. Therewith, teleportation of the particle itself and transference of mass do not take place.

Einstein and his colleagues believed that existence of such particles predicted by quantum mechanics prove theory incompleteness. Thereof, the scientists inferred the necessity of other parameters (besides wave function) to describe quantum states. Otherwise, from the local viewpoint, correlations between elements of such a system could not be understood. It was far much later, when Bell showed that some of measurements could define these correlations and exclude any local hidden parameters. It was not until early 1980-s that famous experiments were performed finally eliminating a possibility of local hidden parameters.

In 1980, Alan Aspect experimentally proved that EPR-paradox in quantum world takes place indeed. Special measurements of state of EPR-particles indicated that EPR-pair not only has a common origin, but in addition, that one of the photons somehow "get to know" the way the second one was changed. In further experiments, existence of EPR-paradox was affirmed, even if particles of EPR-pair were removed from each other over a distance of 10 kilometers or so.

In 1993, Charles H. Bennett and his colleagues worked out a method to transfer the quantum state of some object of the microworld to another quantum object by means of EPR-pair and called this method "quantum teleportation". In 1997 a group of experimentalists under the direction of Anton Zeilinger for the first time implemented quantum teleportation of the photon state in the University of Innsbruck.

In such a way, researchers keep on improving the process of quantum teleportation. In 2001 Danish scientists managed to link gas particles spaced at a substantial interval from each other, by transmitting information about quantum state from one particle to another by means of laser. The quantum teleportation between two gaseous clouds were attained by Eugene Polzik and his colleagues in Orkhus University. They succeeded in coupling about million of cesium atoms, whereas the previous record was only four atoms.

Scientists of Australian National University destroyed a laser beam and nearly instantly recreated it in another point in space; in other words, they teleported photons of the laser beam. In contrast to previous similar experiments, the physicists managed to obtain the required result in 100 percents of cases. Ping Koy Lam, the head of the task group of Australian University, claimed that the first atom of solid substance was likely to be teleported within near three to five years. However, as most scientists admit, a task to teleport a human remains almost impracticable. Even teleportation of atoms, as compared to that of photons, is much more complicated process. It is even harder when dealing with molecules. It is basically possible (though practically very difficult) first to transfer a molecule to a minimum-energy state (ground state) causing it to radiate a certain sequence of photons. These photons will find themselves in a certain superposition containing all the "quantum" information, which was available in the molecule. Thereafter, it is possible to teleport photon states by means of EPR-pairs. Moreover, it is also required that the classically measured information about a molecule. If molecule of minimum-energy state is present in the receiver, then this molecule, by interacting with teleported photons in a required order, will transform to the quantum state identical to that of the initial one. Consequently, the quantum state of molecule of a certain material will be transmitted, actually with velocity of light. When that happens, the quantum state at the transmitting side will be destroyed.

The human organism comprises about 10^{27} atoms. To save and transmit information on properties of that number of particles seems to be practically unachievable. "Theoretically, nothing prevents us from doing that, but complexity of the problem is such that now no one seriously thinks about the solution" – states Ping Koy Lam.

Being a method of information transmission, quantum teleportation has found its application in quantum computers, whose information is stored in the form of a set of quantum states. Impossibility to wiretap and copy transmitted information is considered to be an advantage of such computers. Those researchers, who, nevertheless, wish to answer the question of "How to teleport matter, but not its state?" have to seek for more perspective theories and techniques.

Teleportation of material objects

Those people, who really want to realize instant spatial transportation of objects, i.e. teleportation, should refer to studying properties of Space and Time. Quantum teleportation has a certain finite velocity that cannot exceed that of light. The genuine teleportation assumes that an object should set off from a starting point to a finishing point (these points differ by a certain distance X), at that the transference time comes to zero. The object to be teleported is not changed or taken to atoms to be gathered later at a distant point of space according to information transferred to this point. (Fig.1).

The object disappears from one place and simultaneously appears in another place. How is that possible? A body will disappear from point A and appear in point B if to bend space in such a way as to let point A and point B coincide. Then the object will instantly appear in point B since there is no interval between points A and B. Teleportation could be realized by a device, which would make it possible to superpose points A and B.

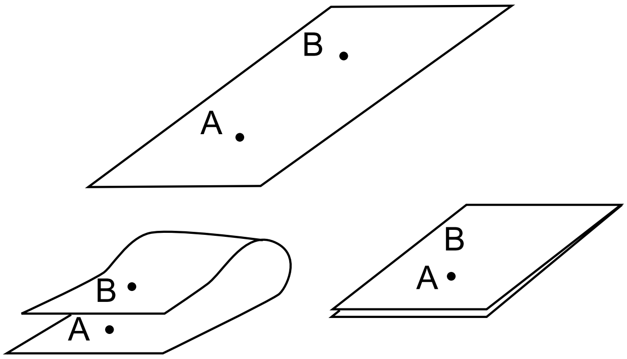

Fig. 1

Space is supposed to be unbendable without enormous energy consumption. However, Alexander V. Frolov points out that this issue is not so unambiguous: "Normally we consider space in connection with "natural" course of time existing in it. That is some degree of space curvature. Let us assume that it can be changed. The space curvature can be considered as acceleration or deceleration of time. Acceleration always demands, for instance in mechanics, some energy consumption. But if we "decelerate" time, energy is liberated and it can be accumulated for subsequent use".

K.Z. Leshan suggests surrounding a transferred object with a closed surface consisting of vacuum holes. Inside such a "hole sphere" there is geometry similar to that of a black hole. This place is absolutely isolated from the external Universe. No radiation is able to penetrate through the hole in space and time. For an observer, who is inside the hole sphere, the distance between sphere center and its border is infinitely large, since spatial metrics is ever-varying from the center to the border. Distances between the points is continuously shortened so that the distance between any couple of points comes to zero at the very hole surface. A matter transmitter can have inner or outer hole surface. In the first case a teleportation station has a spherical chamber to place the object. Equipment to produce holes should be located upon the outer side of the sphere. Such a station is capable to provide hundreds of launches a day by instantly expulsing spaceships to deep space over distances of millions of light years.

From microcosm towards macrocosm

Simeon Bocharov (member of Chemistry and Biochemistry Department, University of Delaver, Newark, USA) considers teleportation phenomenon using microobjects as an example and applying an interesting conception of protomatter.

In S. Bocharov's opinion, many paradoxes of the present-day science could be solved under condition of considering the whole existing matter to be a single continuum, i.e. protomatter. At this approach, the microcosm objects are not independent ones, being represented in the form of distortions of the very continuum and its manifestations here and now. Protomatter, whose distortion degree is beyond modern possibilities of detection, corresponds to vacuum. In the present-day paradigm redistribution of protomatter distortion corresponds to motion of particles. The important peculiarity is a refusal of such concepts as structure, dimensions, mass and other macroscopic characteristics with respect to microcosm objects, since here they are not considered as separate entities.

For experimental justification of his theory, S. Bocharov suggests to consider teleportation of microobjects incorporated in fullerens under low temperatures and pressure.

As a basis for reasoning he takes the fact that identical or similar conditions, whereon distortions are located, bring them to the state of identical or similar by lability/diffuseness. And vice versa, distortions, which are similar by lability/diffuseness, influence their near surroundings, creating, as a result, similar macroscopic states. In such a case protomatter distortion (in some spatial domains and under similar conditions) will cause appearance of similar distortions in another domain, whose degree of removal depends on presence of other distortions and their characteristics. In other words matter will be teleported from one spatial domain to another.

Possibility to realize teleportation of microobject causes the well-known phenomenon, which is nowadays described as embedding of particles into inner hollows of spheroid fulleren molecules without reacting with them. As object of teleportation there can be used distortions classified as elementary ones, such as hydrogen, helium or stable matters (noble gases). In both cases the influence of objects upon surroundings is minimized.

The researcher believes that in case of successful experiment, new pattern of matter structure will be confirmed, and valuable teleportation of microobjects (with prospects of such possibility for macrocosm objects) will be demonstrated.

One more approach to teleportation of physical macroobjects was considered in the work "Practical application of time rate control" (New Energy Technologies No. 3, 2001) by Alexander V. Frolov. It is assumed that density of space (aether) energy determines rate of passing of any processes including the very process of matter existence. Changes of aether density (increase or decrease) must result in the emergence of a force analogous to that of buoyancy, though acting towards the fourth dimension. This "chrono-motive force" (CMF) is also an analogue of electromotive force (EMF) and can be generated by analogy with electrodynamics. According to Alexander V. Frolov, laws of quantum mechanics as to discretization of levels of energy of material system, which exist in the domain of increased or decreased aether density, are valid in the macrocosm as well. Teleportation (as a transition from one state of the system to another one) can be studied with electron transference from one orbit to another as an example with the only difference that for the teleported object not only its location, but also the very spatial properties are changed. In aether of different density (after discrete transition) the same object will have different space around it, wherein time is decelerated or accelerated. Experiments of this field have already been in development stage.

Therefore, modern theoretical physics has handed the problem of teleportation to researchers-experimentalists, who possess sufficient breadth of mind. Perhaps, using teleportation technologies, they will manage to fundamentally alter the process of space exploration and raise our civilization up to radically new development level.

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“Mass defect” in Home Conditions

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The idea to conduct experiments on “mass defect” demonstration appeared after a cycle of seminars, which took place in1993-1996 at the Moscow Aviation Institute under the direction of V. I. Patrushev, Doctor of Technical Sciences, Professor of “Designing of aerohydrodynamic systems” Department (the author of the article is also a graduate of the Department). At the seminars, an enterprising group studied and developed an applied theory of “Displacing fields” by Alexis V. Murlikin and an associate “Theory of energy exchange processes”. Later the group was called **“Group studying non-inertial transference”** (non-inertial natural processes).

The experiment was aimed to test some theoretical suppositions, namely, that it is possible to influence on existent energy flows which input and output to the matter. At that the simplest way to influence indirectly is to change the medium the flows come through. In general, optic experiments on luminous flux refraction show the same. But light refraction and change of speed of light propagation at passing through different mediums is one thing; and change of mass of a material body is something new that has not ever been dealt with. Moreover you can consider light (i.e. electromagnetic radiation) to be the secondary manifestation of output energy flow. Besides mass defect is very important for nuclear physics because it “helps” to develop this branch and stimulates drawing “energy dividends” in splitting reactions, decay reactions and nuclear fusion reactions. But unfortunately we can not touch element nucleus and even million nuclei while we can easily touch metallic balls of 1 gram weight.

Let us note that a concept of mass is one of the most uncertain in physics. We can not measure mass directly. It is possible to do it only indirectly, by gravity, using scales (it does not matter what kind of scales are used), or by kinetic momentum (in this case mass is a measure of inertia) by means of dynamometers.

Thus it is evident that change of WEIGHT shown by scales is not MASS change as measure of matter quantity. Since one of the most important points of the theory of “Displacing fields” is creation of a vehicle of new generation, then one of the major tasks is to overcome gravity (to decrease weight). And this “home experiment” shows the way to solve it. However we can call it “home” only in part, because for weighing there were used electronic scales (mass-comparator with measurement accuracy of 0.1 microgram. (See Fig. 1).

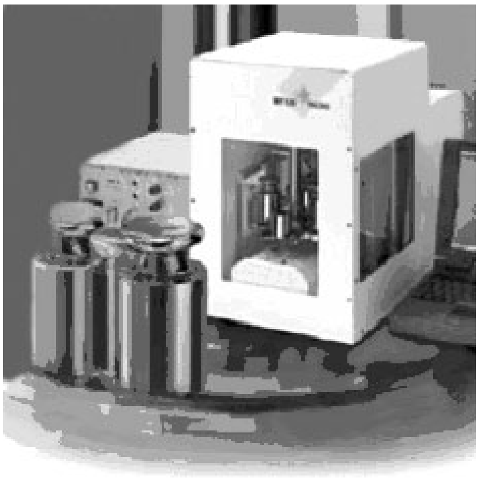

Fig. 1

Precision scales METTLER TOLEDO allows making:
High-accuracy weighing in the range
from 0.1 microgram to several tones
Measurement with resolution up to milliard points

Two sets were designed for weighing. The first one had an aluminum (Al) ball-kernel which weighed 1 gram and a lead (Pb) casing-shell consisted of two parts (half-spheres) which also has weight of 1 gram. The second set had on the contrary a lead kernel and an aluminum casing. The sets were disassembled and then hermetically assembled to make a single device with no gaps (See Fig. 2).

Since it had to be done with great accuracy and it was a piece article, not a Moscow product company undertook to produce it. And only one of the students, Nicholas Sorokin, a young boy with skilful fingers, had helped. He invented a technology which allowed making balls of the necessary size at home conditions. He was literally pickling every micron of metal with acid and finally got the necessary size and weight.

So, the weight of a non-assembled set was: 1 gram (weight of kernel) and 1 gramm (weight of shell). Weight of an assembled set, according to the "Theory of energy exchange processes" by Murlikin, is not equal to the simple sum of the non-assembled components, and mass defect would be different for various sets right up to the change of sign.

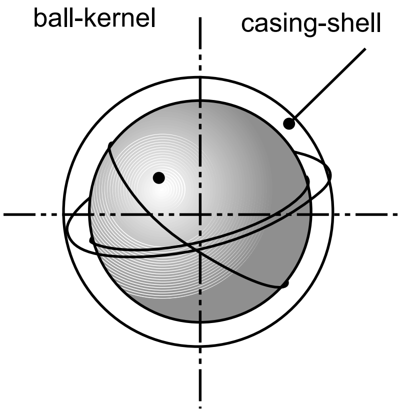

Fig. 2

Set of experimental balls

More than 50 experiments was carried out on weighing for every set. Assembled sets as well as non-assembled sets were weighed. **It was confirmed that there was an interaction between input and output flows for MATTER MAINTENANCE. It became apparent in the form of mass defect. Defect appeared in the sixth sign, i.e. it comes to the range from 0.0002% to 0.0007% of "kernel" mass (or "shell" mass). At that the lesser mass defect corresponds to aluminum shell, while the greater one corresponds to lead shell. Accuracy of weight measuring by the mass comparator exceeded the acquired result by 10 times. So we could not tell about inaccuracy of measurements.** So we had to apply to the "Russian center of testing and certification" which was very famous all over the world (Rostest-Moscow).

In general that is all, we have got an answer for ourselves, and the period of testing is behind. We have to advance; very much is still to be done. In addition let us mention one more surprise we got during the experiments. The matter concerns some time delay in receiving final results of every weighing. A qualitative picture of it is represented in Fig. 3. We did not expect that this effect would appear at such a rough level of measurement of energy exchange processes.

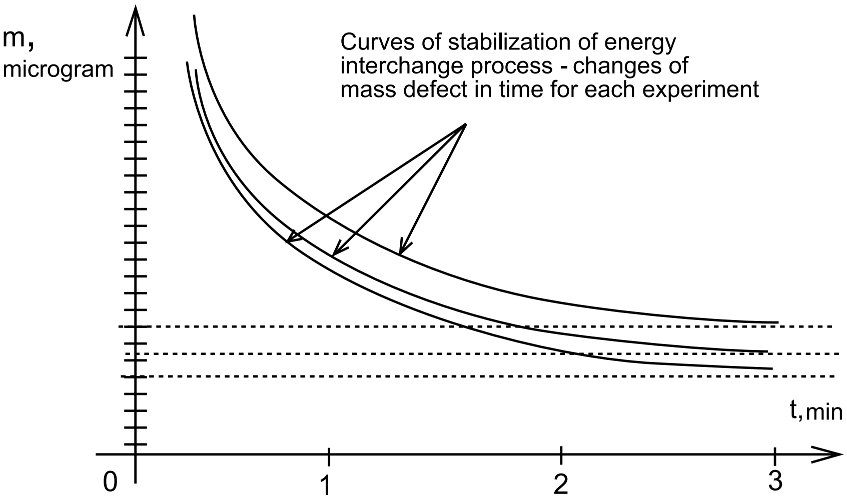

Fig. 3

Time stabilization of the process for receiving final weight

The subsequent report and detailed discussion of the experimental results by specialists (including physicists of various specializations) resulted in an unexpected non-recognition of facts and distrust. The main argument was a demand to increase the number of experiments up to 5-10 hundreds. And only then scientists would be ready to accept facts. It was quite a predictable reaction for the orthodox science in the middle of 90s. It remains to hope that if the discussion took place today it would have a paved way. However it is not a fact.

In conclusion let us note that this experiment on revealing mass defect ranks with famous experiments, in which rotating gyroscopes also demonstrate mass defect (decrease of weight) and even one of higher order than in our experiment. But in return we have no rotation, no chemical and nuclear reactions, while mass defect is presented.

Let us add that it is possible to complicate the task: to make a double casing and to choose other materials for "kernel" and "shell". (See Fig. 2). In our case low prices and availability made us use Al and Pb. The results will be more interesting, for example, with Li and Os (and with other supertransuranic elements).

Aether as Unified Field

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Based on the original observations and experiments, the article gives more precise definitions of aether model, than which was previously elaborated. General laws of the Universe aetherodynamic are considered. There is described a new physical reality in the form of quasi-real aetherodynamic structures ("topological harmonics") generated by dynamics of the substantial world.

At the present-day stage of physics development words of Maugham, an English philosopher, take on particular topicality: "The great verities are too important to be new". Indeed, we are increasingly making certain that our remote ancestors were familiar with fundamental laws of the Universe; furthermore, they knew these better than we do. But which methodology of cognition of Nature and what kind of information sources did the ancient scientists have? Today, we can openly say: they had not ordinary experience only, but also esoteric, pretersensual one, without feeling any necessity to be divided into materialists and idealists. For more details on evolution of physical ideas, refer to work [1].

In discovering all over again, I also had to elaborate a "cellular taction" strategy, which enables the most important characteristics of aetherodynamic processes to be sensually perceived and evaluated. The main thing is that all my sensory observations are definitely reproduced at laboratory experiments while the simplest physical equipment is used.

We may get reliable knowledge about Nature from Nature itself only. Thus foundation of classical physics describing usual substantial world is also based on empirical facts studied by Galilei, Newton, Faraday and many other physicists-natural philosophers. I also would like to defend great Newton against attacks on his adherence to inductive methods which really brought imperishable values into science.

A new convolution of cognition is possible on condition of introduction into science of new concepts based on empirical study of physical entities previously unknown. Thereupon, I share the thought of Elena Ventzel, professional mathematician: "Mathematical methods are not useful, but harmful until phenomenon is not studied at a pre-mathematical, humanitarian level". It is ideological and logical language that may be used today to discuss the aether problem, whose solution calls for comprehension of natural-science facts, which are beyond traditional notions settled over centuries.

The long-term investigations have confirmed that exhaustive definition of a fundamental natural entity was given by Rene Descartes: "Universe does not contain anything but aether and its vortexes". This is not merely a postulate; this is an objective summary of empirical observations of Nature phenomena. In any academical model of microcosm there is no answer to the question: what kind of substance are electrons, quarks, strings made of? That is the very substance our forefathers called aether. Aether is unified field indeed; and it appears that for nearly his whole life Einstein had been searching for something that was under his foot.

It must be recognized that there is no undistorted, quiescent aether in Nature; as well as no zero-size vortexes exist. Therefore, in a customary sense, the aether concept is pushed behind transcendental horizon and turned into an inconceivable entity whose mystique is tantamount to religious ideas. However, all quantum vortex-wave distortions of the superfluid three-dimensional aether, which have an appearance of tori, threads, solitons and occupy spatio-temporal spectrum from zero to inter-universe scale, are material and contain energy under scientific interpretation. Any spaces such as turbulent fields, physical vacuum, gravitational fields and, of course, matter are material. All of them are etherodynamic structures of the real world. Spatial hierarchy of aether vortices is referred to as quantum stairs, fractal structure or "matreshka" [2-5].

To understand basic laws of aetherodynamics it is necessary to give a general definition for classical matter and other aether states. As a first approximation, let us give the name of matter to aether microscopic **left-screw** self-oscillating vortex-wave systems (elementary particles), whose existence and parameters are conditioned by higher hierarchical systems. This is our displayed world, with its electromagnetic fields and fundamental constants. Let us refer to vortex-wave structures of any vortex size, which in the considered space domain are **balanced** by a number of left- and right-screw vortices corresponding to matter and antimatter with prefix "quasi" to a free aether. Stable vortex lattices with alternating direction of helicity can be also considered in this case. Under natural conditions everything but classical matter or electromagnetic and gravitational fields can be related to the free aether. In the first place, these are the so-called physical vacuum and vortex fields, which attend gravitation. They represent anisotropic nonlinear subspaces and occupy definite places on spatio-temporal spectrum of the world aether. Particular free subspace creates an aggregate of topological harmonics [5] attending all the physical processes. Satellite of the gravitational field is distinguished because it belongs to specific class of stable vortex lattices.

Apparently, in general case, energy of free aether is virtual for our world due to its helical symmetry and quasi-matter, from the view of difference in sizes of typical vortices which correspond to protomatter. But this is not the entire point. There is also superfluidity of aether, whose vortex viscosity has marvellous properties. As a result, there are created phenomena of inertia and energy-information barrier separating material world from constant influence of quasi-real structures or turbulated space.

Classical inertia, as vortex viscosity, arises in the microscopic and more fine-structure free aether (in Newtonian space) and ever regularly reveals itself during acceleration of material bodies. However everything is different at stage of macrovortex aether, where inertia has properties of adaptation. Here it is affirmed that inertia phenomenon is "spread" throughout the spatial-temporal spectrum of vortex distortions of aether field. At that nature of inertia is changed. Within topoharmonic subspace in laboratory scales, the inertia law "diminishes" in time according to exponential dependence, whose time constant is determined by specific conditions and varied over wide limits (from seconds to many days). On the expiry of this time, inertial intercoupling transforms to the law of flicker effect. It may be said that flicker effect specify penetrability of energy and information barrier after expiry of time of paraphysical regular phenomenon [6]. Consequently, most of time the interaction with free macroaether is of random character and should be evaluated by mean observation.

To extend conceptual scope of our investigation it may be added that in classical hydrodynamics a liquid, along with ordinary inertia, has determined vortex macroinertia, which is created by vortices of the liquid itself. Therefore, it is necessary to keep on comparing processes at all levels of the unified field of aether. For instance, electric inductance is a kind of specific inertia, and topological harmonics of electromagnetic and other phenomena are subjected to the energy-information barrier (under laboratory conditions).

In the above arguments, the principle of relativity is latently and unconsciously presented. However, this complicated question needs to be separately considered. Physical nature of the energy-information barrier and reason for dependence of the inertia properties upon the size of vortices of free aether remain unclear, too. However, it can be supposed that classical elementary particles, as distinct from protomatter, have self-oscillating properties and are commensurable with vortices of the surrounding free world; and that the above-mentioned energy-information barrier does not exist for them on microscopic section of the spectrum. The gist of the barrier itself comes to "memorizing" topoharmonic processes by Earth's gravitational fields and laboratory equipment. Turbulent fields (physical vacuum) do not have such a "memory".

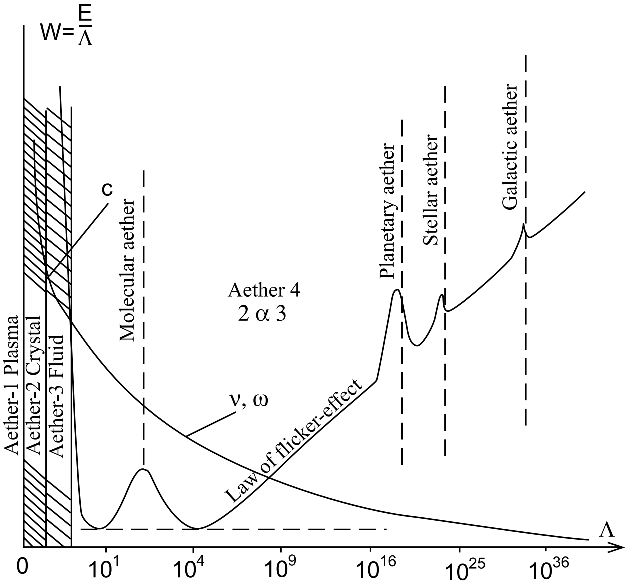

Fig.1

Fig.1 depicts diagrams of spectral density of vortices' energy; diagrams of rate of interaction transfer v and circular frequency ω depending on sizes of vortices of the world aether Λ (in picometers). As we can see, velocity of distortions propagation v is equal to velocity of light C in the physical vacuum, i.e. in electron sizes, exceeds C in nanocosm and tends to zero toward megacosms. Circular frequency of vortices rotation and course of physical time have the analogous qualitative dependence. However, vortices energy W has a feature and grows toward both ways from the lab scales; the aether numbers have been assigned conditionally, but all the specified phase states reflect some physical reality.

One of the most complicated questions is a definition of vortex matter in each particular case. The diagram demonstrates energy of free aether in the form of protomatter (simplest elementary particles – vortexes), and energy of classical elementary particles as helically definite self-oscillating emissions of aether field is localized in the most nonlinear subspace (physical or substantial vacuum). Unification of the elementary particles into atoms and macrobody does not denote direct transition to parallel world with different fundamental constants, whereas change of vortex size in the diagram exactly implies such a transition, though at a level of protomatter. This is a very intricate and crucial point. For example, a star is, unconditionally, an elementary particle of the relevant level of the Universe, even though comprising the ordinary matter.

Left wing of energy spectrum reflects property of the turbulent field of aether to gravitate, to sink down to the "bottom" transferring energy to the vortices of lesser scales. This phenomenon of distributed "gravitation" is available in every space point and explains a least-action principle. An illustrative analogue of this regularity is represented by the Earth's gravitational field and structure. Dense plasma assumed as iron core is situated in the center, and higher - there are magma, solid crust, water and air. These phase states exist in free aether within universe scales as well. Consequently, in femtocosm, and maybe at an even deeper energetic "bottom", there must be a plasmic subspace; evidently, it is assignable that aether translated from Greek means "fire".

Increase of energy to the right is connected with extending a dynamic band of the vortices spectrum, as the scale increases. In our world, this increase follows the flicker effect law, but this is only what we perceive across the energy-information barrier. Actually, at this section the vortex energy must increase well more strongly, because **our observation capabilities are limited** by accessible matter processes. Turning back to stars, one may affirm that modern science is unable to evaluate their real energy (evaluations are considerably underrated). The Galaxy vortex entrains such deep levels of multidimensional space-aether to its rotation that this causes violation of the Newton's law of inertia. Notion of "hidden mass" is unnecessary for explaining dynamics of galaxies. It is quite enough to take into account that differential rotation entrains the fine-structure aether (inertial subspace), and this process results in decreasing the inertia and external centrifugal forces. Unfortunately, Fig. 1 reflects only a characteristic size of the galactic vortex and does not visually demonstrate its active band of the spectrum. The finer is the space structure, the more inertial and closer to the absolute reference frame is the space. Obviously, the non-homogeneous, stereodynamically multidimensional and multiphase aether requires a perfectly new theory of random fields, which would also make allowance for the phenomenon of the material world.

Energy motion processes or spectral energy-cascades along abscissa axis are of decisive importance for existence of our world and the Universe. These processes have unusual properties. The "violet" cascade is attended with reduction of vortices size, absorption of matter energy and tends to increase energy concentration at the "bottom" of the world aether (near ordinate axis on Fig.1). This regularity experimentally confirmed in both spatial and temporal domains is a direct consequence of the above-mentioned phenomenon of distributed gravitation and clarifies an existence of the left wing of the spectrum. In classical physics "the violet" cascade effect is reflected in the least-action principle as well as in the thermodynamics laws.

The "red" energy cascade (right wing of the spectrum) corresponds to increase of vortices size and is accompanied with energy liberation. To start it up under earthy conditions special technologies are called for [7]. This has been confirmed with laboratory experiments and underlies the "perpetual motion" theory, where energy is pumped from nanocosm to the classical material world. Conception of artificial biofield [6], I have developed, considers methods of creating the aether vortex-wave macroscopic-scale distortions in physical systems. As a matter of fact, we deal with **ways of extending of natural spatio-temporal spectrum of aether (which settled into itself) by creation of a subspace of the topological subharmonics of the classical elementary particles, atoms and molecules**

(physical bodies), within the context of the etherodynamics fundamental law [5].

Even within action of fluctuating energy-information barrier, the spectrum right wing exhibits existence of natural processes in Nature that, supposedly, violate the known laws of thermodynamics [8]. But, as far as Nature cannot conflict with itself, we have to recognize that there is another physics, which "works" in geographic and greater scales, where role of the energy-information barrier demands to be reappraised. To all appearance, the universe vortex partialyl entrains plasmic subspace of aether into its rotation, and conditions for realizing "red" energy-cascade and generating matter are created on the sections of the maximum density gradient ("spectral" non-linearity). But the same way as a fish in ocean does not know reasons for storms and currents, we will never learn which force untwists the Universe handwheel, whose energy feeds our substantial world.

There are two components of free aether field that are the most essential for the present-day physics. The first one (left wing) is positioned on the spectrum beside the "bottom" in the form of dense liquid-crystalline "plasmatic" medium transforming to the Newtonian inertial subspace (physical vacuum). Since inertia is as regular as electric inductance is, the first subspace proves to be especially material and not such free, because it has properties which were imposed by the Universe rotation and distributed "gravitation". Let us conventionally limit the spatial spectrum of the first component with a nucleon size. The second component of aether space (right wing of the spectrum) stretches towards larger scales.

Except for known cosmic objects, this is an unknown ocean of the macrovortex and really free aether, or topoharmonics, which are born by dynamics of the substantial world. It is an experimentally proven fact that topoharmonics are generated by photons, electrons, and all the moving bodies [5, 9].

The second component has an ability to conversely affect the matter it was generated by as well as other material objects via "flickering" forces [10, 11]. This special subspace turns out to be doubly virtual, a genuine phantom. That is why, it has been winning the status of a real physical entity with such a difficulty, while Chinese philosophers were familiar with the same thousands years ago, separating entities "yang" and "yin".

The laboratory experiments indicate that topoharmonics have not only properties described in [5], but also an ability to interact with the space, creating a static domain of the excited aether in the course of propagation of the vortices-waves. At that physical bodies placing within this space volume are "charged" [2, 9]. The mentioned active domain (horizontal route) is "separated" by the Earth's gravitational field as follows: quasi-substantial constituent rapidly settles down creating vertical flow, but some phase structures are disintegrated very slowly (days, months, years).

The surprising thing is that biosystems equally belong to both aether components, not experiencing any constraint from the side of the energy-information barrier. The so-called human biofield is a topoharmonic part of physical body. It occupies its place on the spatio-temporal spectrum (Fig. 1). Quasi-substantial constituent (yang) and antiquasi-substantial one (yin) are strictly balanced, and acupuncture points and chakras are an analogue of Hartmann's geophysical grid, which is well-known to paraphysicists.

Conceptual generalization of physical ideas in the context of unified field of aether gives a constructive, cognitive impulse in solving of different problems, such as Nature's choice of exclusive laws for existence of "left-screw" material world as well as the problem of flicker-effect. At that, researching into the physical processes responsible for proton positive charge is of fundamental importance.

In conclusion, let us take note of conventional character of dividing the aether field into two components by the form of energetic spectrum. As a matter of fact, topoharmonics are generated by matter towards both larger spatial frequencies (subharmonics) and smaller ones (harmonics) and fill all levels of the Universe. The aforesaid is aimed at making perception of the most studied aspect of the **new physical entity** (vague due to diversity of hypothetical descriptions which exist in publications on this subject) more accessible.

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GLOBAL ENERGY

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Lately, the notion "Global energy" has become widely spread as a prize corresponding to this notion has been instituted in Russia. Since the Euclidean times, an unwritten law exists in science: to give definition to the notions, which are involved in scientific analysis. It is done for the purpose that everybody who uses this notion can understand the sense implied in it.

The Global energy problems have been discussed for a long time; they are well known. Depletion of natural energy carriers (oil, gas and coal) is the first problem. Environmental safety of energy carriers is the second problem. It is generally recognized that the solution of the issues connected with the aggregate of these two problems is of a global character. The results of scientific research, which should deal with global energy, originate from it. First and foremost, they are such scientific investigations, which result in the possibility to use an inexhaustible and environmental friendly energy carrier. It has been known for a long time. It is hydrogen produced from water.

Why hydrogen and why from water? At combustion of hydrogen, water is regenerated; thus, the energy carrier is inexhaustible. As far as inexhaustibility and environmental safety are concerned, hydrogen has no competitors. However implementation of these qualities is restricted by large energy expenses for hydrogen production from water. For hydrogen production, modern electrolyzers use from 10 to 20% more energy than it is produced at combustion of hydrogen.

It is easy to imagine what financial and intellectual resources of the world are included in the search of the ways to reduce energy expenses for hydrogen production from water. In Russia many scientific institutions of applied research and educational institutions deal with this problem. There is a Research Hydrogen Institute.

The associations of scientists on hydrogen energetics have been established in USA and Europe. This year, they carry out their regular scientific conferences, to which the author of this article has been invited.

Editorial: Let us note that it is not necessary to coin new scientific term "global energy", since quite for a long time the notion of "free energy" is used. This term represents the idea of the possibility to freely use energy by a consumer.

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Energy problem is global not due to depletion of oil and gas, but due to their environmental unsafeness. However the confirmations exist that the world owners of energy resources do not bother about the problem of environmental unsafeness of modern energy carriers.

In history of science, the facts of annihilation of the scientists who have won success in reduction of energy expenses for production of hydrogen from water have already been registered. The requesters of these actions think that they will lose their profits with the coming of hydrogen energetics. They do not understand that this process cannot be abrupt. It is impossible to replace the infrastructure of the existing energy carriers by infrastructure of hydrogen energetics within one or even ten years. Besides, infrastructure of hydrogen energetics will not be created on a blank place. It will be integrated into the existing infrastructure of energetics gradually; and its owners will automatically become the owners of hydrogen energetics. The first step has already been made in this direction. In the USA, a decision has been taken to equip all filling stations with pumps to fill the cars with hydrogen.

It is known that a priority of results of theoretical investigations is their publication in press. Usually, such priority is a personal one. Generally a patent is a priority of the results of experimental investigations. As a rule, this patent belongs to a group of authors. A published patent is a genie released from a bottle. No finesse of the authors to hamper a reproduction of experimental data given in a patent without the participation of the authors can stop the process of their implementation. Thus, the authors or a group of the authors who have filed an application for a patent are deprived automatically of the opportunity to influence the process of practical realization of their ideas.

In Russia, the state is a main patent holder of the global patents. Due to the well-known reasons, it has proved to be unable to control the course of scientific investigations and to forecast significance of their results.

It is known that if it becomes possible to reduce energy expenses for hydrogen production of water fivefold, it will be the cheapest energy carrier. Russia has already got technology, which reduces these expenses tenfold and more. However another way of looking is more perspective. Is there any use to decompose water into hydrogen and oxygen and to use hydrogen as fuel for heating, for example, of water in heating systems? Is it possible to make water generate heat? It turned out that, it is possible.

In Russia, three firms ("Yusmar", "Termovikhr" and "Noteka") sell cavitation heating equipment with energy performance index up to 150%. Official science looks awry at this activity, since such results conflict with one of the main laws of physics: law of conservation of energy. But market profit is stronger than this law.

Meanwhile, engineering practice has already proved that additional energy in the form of heat is generated in the ventilation systems and in the systems of water cavitation. Thorough scientific analysis of this problem shows that physical vacuum is the most probable source of additional energy in the systems of ventilation and water cavitation. Valence electrons of destroyed molecules of water take energy from physical vacuum and release it during repeated fusion of these molecules.

Why is additional energy generated in the air systems of ventilation and in systems of water cavitation? Because they are mechanical systems and mechanical destruction of chemical links requires half energy as compared with thermal destruction of these links. This is the main reason why one fails to increase energy performance index of cavitation processes over 200%.

Certainly, an increase of efficiency of any process by 30 or 50% is a good result; if it is obtained, it is possible to get even better one. But what if a water molecule is destroyed not mechanically, but electrodynamically? In this case, it becomes possible to find resonance frequencies of influence on the molecules and therefore to reduce considerably expenses of electrical energy for their destruction. Subsequent fusion of destroyed molecules will release determined quantity of energy unavoidably. It is a simple idea, and it has already been implemented. At electrodynamic influence on water molecules, electrical energy is converted into thermal energy with tenfold energy performance index. It means that if we spend 1 kWh of electric energy, we will get 10 kWh of thermal energy. To obtain such results, it is necessary to have knowledge of physchemistry of the microworld, which corresponds to knowledge of the 21st century, and it has already been published. Every month more than 1000 foreign scientists become familiarized with this knowledge at
http://Kanarev.innoplaza.net and
http://book.physchemistry.innoplaza.net.
The Russian speaking readers get this information from:
http://www.n-t.org/tp/ns/if.htm,
http://www.ikar.udm.ru/sb28-2.htm and
http://www.n-t.org/tp/ts/eb.htm.

I hope that now the readers will know the essence of the notion "global energy" and will understand those results of scientific researches which can really solve the related problems.

Energy Balance of Fusion Processes of Oxygen, Hydrogen and Water Molecules

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There is revealed the cause of appearance of additional energy during formation of covalent bonds in the fusion processes of oxygen, hydrogen and water molecules, besides the source of this energy is described.

Introduction

Engineering practice connected with servicing of ventilation systems allows revealing appearance of excessive thermal energy in circulated air. Similar phenomenon has been registered in systems of water circulation with the devices for its active cavitation. The results of our investigations explain not only a cause of these phenomena, but they give an opportunity to perform quantitative calculations for energy processes, which generate additional thermal energy [1], [2], [3], [4], [5].

Theoretical part

An oxygen atom is the eighth element of the periodic table. It is situated in the sixth group. The structure of its nucleus is given in Fig. 1 [1], [2], [3].

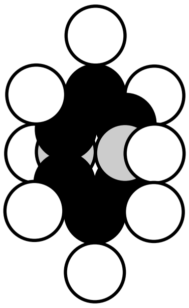

Fig. 1
Diagram of nucleus of oxygen atom: light – the protons, dark and grey – the neutrons

In Fig. 2 a diagram of the oxygen atom originating from the structure of its nucleus is given (Fig. 1). It has eight electrons. The electrons situated on the axis of symmetry are the most active ones (1, 2). Other six electrons situated in the plane, which is perpendicular to the axis line (a line of symmetry), by means of their total electric field remove electrons 1 and 2 from the nucleus at a large distance at that forming conditions for their large activity during the interaction with the electrons of the neighbouring atoms [1], [2], [3].

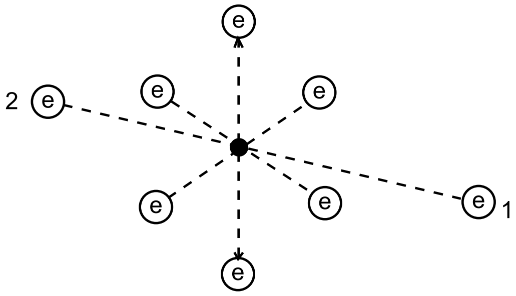

Fig. 2
Diagram of the oxygen atom

The least ionization energy of the electron of oxygen atom is equal to E_i =13.618 eV. Binding energy of this electron with the atomic nucleus corresponding to the first energy level is equal to E_1 =13.752 eV. Let us call this electron the first one. The calculation of energy indices of this electron, including its binding energies E_b with the atomic nucleus, according to the formulas (1) and (2), gives the following results (Table 1) [1], [2], [3].

$$E_{ph} = E_i - \frac{E_i}{n^2} = E_i - \frac{E_1}{n^2} \tag{1}$$

$$E_b = \frac{E_1}{n^2} \tag{2}$$

Table 1
Spectrum of the first electron of the oxygen atom

Values	n	2	3	4	5	6
E_{ph} (exp.)	eV	10.18	12.09	12.76	13.07	13.24
E_{ph} (theor.)	eV	10.16	12.09	12.76	13.07	13.24
E_b (theor.)	eV	3.44	1.53	0.86	0.55	0.38

The oxygen molecule structure is given in Fig. 3, a. It is formed by means of a connection of unlike magnetic poles of axis electrons of two oxygen atoms [1], [2], [3]. It is known that the fusion process of the oxygen molecules is accompanied with a release of 495 kJ/mole of energy, or in calculation for one molecule

$$E_b = \frac{495 \cdot 1000}{6{,}02 \cdot 10^{23} \cdot 1.602 \cdot 10^{-19}} = 5.13eV. \quad (3)$$

What principle does the Nature follow by distributing energy of 5.13 eV between the electrons of oxygen molecule (Fig. 3, a)? Energy of 5.13 eV is a thermal binding energy between the electrons 1 and 2' of two oxygen atoms (Fig. 3, a). When the oxygen molecule is formed, it is emitted in the form of the photons by the electrons, which enter into the bond. Hence it is equal to an amount of energies of two photons emitted by these electrons. Consequently, each contacting electron emits a photon with energies of 5.13/2=2.565 eV=E_b (Fig. 3). According to Table 1, in this case the valence electrons are situated between the second energy level and the third one [1].

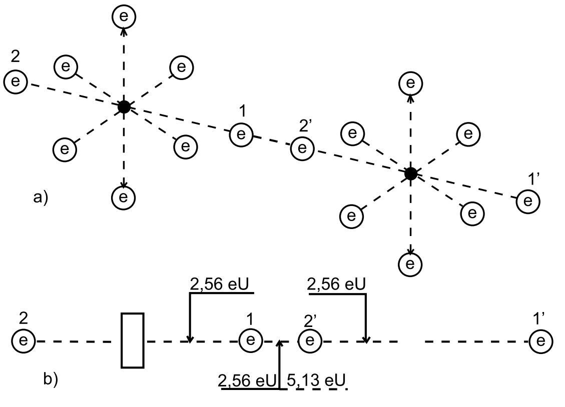

Fig. 3
Diagram of binding energy distribution between the electrons in the oxygen molecule

Two oxygen atoms are combined into a molecule in an excitation state. The excitation state is the state of an atom when its valence electrons are situated at such distances from the nuclei when the binding energy E_b between them is reduced to the thousandth of fractions of an electron-volt. In such state the atom can loose an electron and become an ion. Otherwise, without loosing electrons it is combined with an electron of the neighbouring atom by the valence electron, and a process of formation of oxygen molecule begins. It is an exothermic process when the axis valence electrons 1 and 2' emit photons, descend on lower energy levels and release 2.565x2=5.13 eV.

Let us pay attention to the fact that energy 5.13 eV is released by two electrons, which form a bond with energy of E_b=2.56 eV. In modern chemistry this bond is called a covalent bond. In order to break this bond it is necessary to use 2.56 eV of mechanical energy. For thermal cleavage of this bond, double quantity of energy is required, i.e. 5.13 eV. It is explained by the fact that the photon energy of 5.13 eV is absorbed by two electrons simultaneously. Only in this case, both electrons will be transferred to the highest energy levels with minimal binding energy E_b when they are disconnected, and each oxygen atom becomes a free one.

Thus, energy expenses for destruction of oxygen molecule depend on the method of influence upon the bond. During thermal action upon the bond it is destroyed when energy is 5.13 eV. During mechanical effect upon the bond, it is necessary to spend 2.56 eV of energy in order to destroy this bond. Therefore energetic of fusion process of the oxygen molecule depends on method of its destruction.

After thermal destruction of the oxygen molecule process of its formation begins from emission of the photons with energies of 2.56 eV by both valence electrons, and the previous electrodynamics binding energy (E_b=2.56 eV) is restored between the electrons of both atoms.

Thus during thermal destruction of the oxygen molecule the same amount of thermal energy is spent than that which is released during its further formation. No additional energy appears during thermal dissociation of oxygen molecule and at its further fusion.

If oxygen molecule is destroyed by a mechanical method, then it is necessary to spend 2.56 eV of mechanical energy for this purpose. Valence electrons of oxygen atoms are in a free state at lack of energy, which corresponds to such state, as there is no process of absorption of 2.56 eV of energy by each of them. The electrons cannot remain in such state; they should replenish immediately the energy, which they have failed to receive during a mechanical break of the bond between them. Where should they take it from? There is only one source: the environment, i.e. the physical vacuum filled with aether. They convert aether into energy of 2.56 eV immediately. The next stage is a connection of two oxygen atoms, whose valence electrons have replenished the reserves of their energy by means of aether. This process is accompanied by emission of the photons with energies of 2.56 eV by two electrons. Thus energy of absorbed aether is converted into thermal energy of the photons. If we spend 2.56 eV of mechanical energy for destruction of oxygen molecule, we will get double quantity of energy (2.56x2=5.13) eV during further fusion of this molecule. Additional energy is equal to 2.56 eV.

Much experimental data show that in ventilation systems thermal energy of circulated air exceeds electric energy spent for a fan drive. Now we know that this energy is generated at mechanical destruction of covalent bonds in the molecules of gases, which the air consists of.

Using the above-mentioned method, let us analyse energetic of water molecule, which sometimes generates additional thermal energy. A water molecule consists of one oxygen atom and two hydrogen atoms. Binding energies E_b of the hydrogen atoms with its nucleus are given in Table 2 [1], [2], [3].

Table 2

Spectrum of hydrogen atom

Values	n	2	3	4	5	6
E_{ph} (exp.)	eV	10.20	12.09	12.75	13.05	13.22
E_{ph} (theor)	eV	10.198	12.087	12.748	13.054	13.220
E_b (theor.)	eV	3.40	1.51	0.85	0.54	0.38

It is known that combination of hydrogen and oxygen is accompanied by an explosion, but its cause remains unknown. Let us try to find it.

Energy of fusion of hydrogen molecule is equal to 436kJ/mole, or 4.53 eV per a molecule. As the molecule consists of two atoms, then the above-mentioned energy is distributed between them. Thus energy of one bond E_b between the hydrogen atoms is equal to 2.26 eV (Fig. 4). At mechanical destruction of this bond 2.26 eV is enough. At thermal destruction of this bond double quantity is required (2.26x2=4.53 eV) [1].

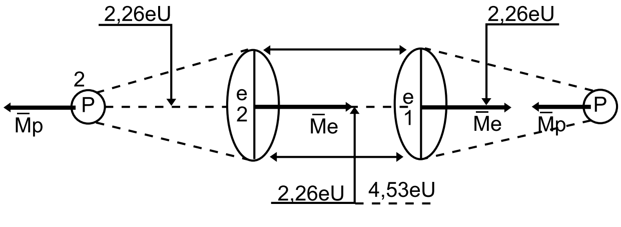

Fig. 4
Hydrogen molecule

In order to form two water molecules, it is necessary to break two hydrogen molecules and one oxygen molecule into atoms. At mechanical destruction of covalent bonds 2.26x2=4.53 eV is required to break two hydrogen molecules and 2.56 eV to break an oxygen molecule. Sum of these energies is equal to 7.13 eV. If the destruction processes of the above-mentioned molecules are carried out with a thermal method, then 4.53+4.53=9.06 eV is required for the destruction of two hydrogen molecules, and 5.13 eV is required for the destruction of one oxygen molecule. In total, it is equal to 14.19 eV. The difference between the energy spent for mechanical and thermal destruction of covalent bond of hydrogen and oxygen molecules is almost double.

It is known that during fusion of one mole of water 285.8 kJ or $285.8x1000/6.02x10^{23}x1.6x10^{-19}$=2.96 eV per a molecule are released. As a water molecule consists of one oxygen atom and two hydrogen atoms, 2.96/2=1.48 eV falls per the bond (Fig. 5). Hence the electrons of hydrogen and oxygen atoms in water molecule are between the forth energy level and the fifth one at the usual temperature (1.48/2=0.74 eV = E_b), Table 1,2 [1].

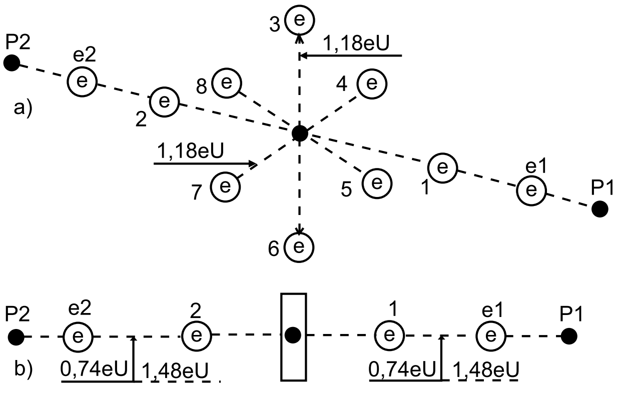

Fig. 5
Diagram of water molecule:
1, 2, 3, 4, 5, 6, 7, 8 are the numbers of the electrons of oxygen atom; P_1, P_2 are the nuclei of the hydrogen atoms (the protons); e_1 and e_2 are the numbers of the electrons of hydrogen atoms

Thus when two hydrogen molecules $2H_2$ and one oxygen molecule O_2 are destroyed by the thermal method, 14.19 eV are spent. As a result of fusion of two water molecules ($2H_2O$), 2.96x2=5.98 eV is released. There is some disbalance here since fusion process of water molecule is an exothermic one and 2.96 eV is released by one molecule. The given calculation shows that (14.19-5.98)/2=4.10 eV is absorbed during fusion of one water molecule. What is the cause of this contradiction?

The oxygen atom in the water molecule should reduce its volume when the transition from gaseous state into liquid state takes place. It will happen when the ring electrons of oxygen atom descend on lower energy levels (nearer to the nucleus). They will emit the photons and their total energy will be equal to energy spent to destruction of two hydrogen molecules and one oxygen molecule, i.e. 14.19 eV. Since two water molecules have 12 ring electrons, each of them will emit 14.19/12=1.18 eV= E_b (Fig. 5). It is more than energy (E_b=0.74 eV) of binding of axis electron with the nucleus, and it shows that the ring electrons are situated nearer to the nucleus than the axis ones.

In this case quantity of energy produced due to fusion of two water molecules (14.19+5.98) eV exceeds energy, which was spent for the destruction of two hydrogen molecules (9.06 eV) and one oxygen molecule (5.13 eV). Energy difference of 5.98 eV is divided between two water molecules. It means that 5.98/2=2.99 eV or 285.8 kJ/mole fall per a molecule. It corresponds to the existing experimental data completely [1].

The above-mentioned facts clarify a cause of the explosion, which takes place when hydrogen is combined with oxygen. Simultaneous transition of six ring electrons of each oxygen atom in the nascent water molecules to lower energy levels is accompanied by simultaneous emission of the photons, which generate explosion phenomenon.

Let us pay attention to the fact that two binding energies E_b between valence electrons e2 and 2 and between 1 and e1 are shown in Fig. 5, b. Energy of one electrodynamics bond is equal to E_b= 0.74 eV. If this bond is destroyed by the thermal method, 0.74x2=1.48 eV is required. This energy will be released during further fusion of the water molecule from hydrogen atom H and hydroxyl ion OH^-. In this case, no additional energy is generated.

Therefore the given bond is destroyed by the mechanical method spending 0.74 eV per a bond, each electron will have energy deficit equal to 0.74 eV after bond destruction. This energy will be immediately absorbed from the environment and will be emitted during the repeated fusion of the water molecule from the hydrogen atom H and the hydroxyl ion OH^-. At mechanical destruction of one bond of water molecule, the covalent chemical bond forms E_b= 0.74 eV of additional thermal energy, which is registered in systems of water cavitation constantly (as we have already noted) [1], [2], [3].

It is known that water molecules combine and form clusters. If the bonds between the molecules in the clusters are covalent ones, mechanical destruction of these bonds should be accompanied by a release of additional thermal energy as well [1], [2], [3].

Experimental Part

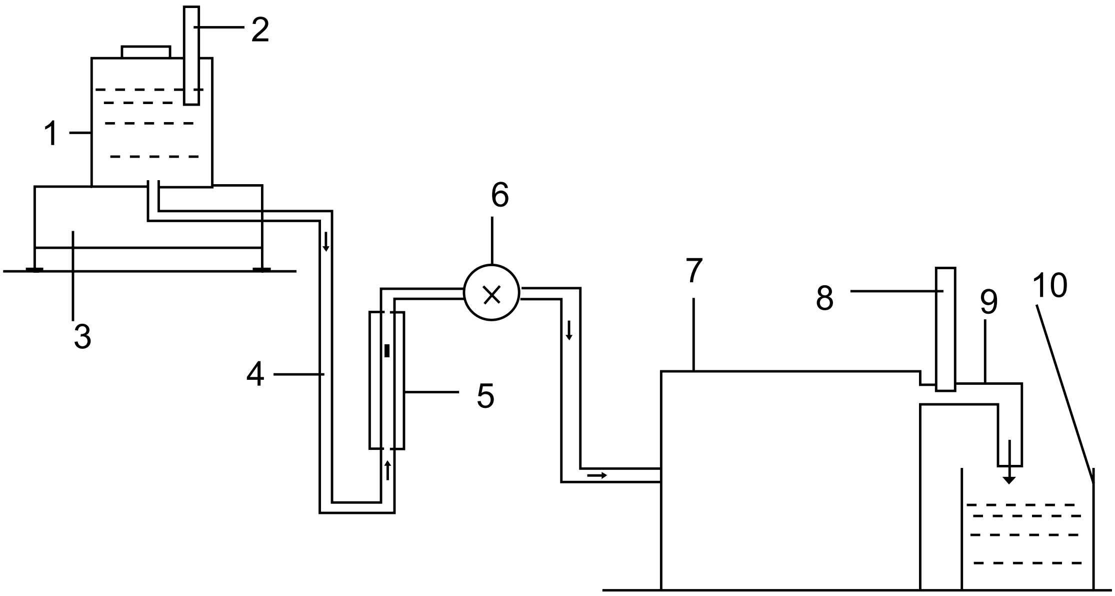

Fig. 6

Diagram of the experimental device: 1 - reservoir for solution; 2 - thermometer; 3 - electronic scales; 4 - solution supply duct; 5 - rotameter; 6 - feed solution regulator; 7 - a special thin plasma reactor is in the process of patenting; 8 - thermometer; 9 - discharge of heated solution; 10 - inlet reservoir

Thus, chemical bonds between the atoms in the molecules and the molecules in the clusters can be destroyed mechanically, by electrodynamic and thermal influence. We have already shown that the mechanical way of destruction of such bonds requires half energy as compared with thermal energy. It appears from this that energy expenses for electrodynamic destruction of these bonds should be less than thermal expenses as well. Electrodynamic impact on the bond gives the opportunity to form the resonance modes where energy expense for the destruction of these bonds is reduced to greater degree. In order to check this hypothesis a special experiment was carried out. It was connected with electrodynamic destruction of chemical bonds of water molecules with a changing frequency of impact. To test this hypothesis the check experiment was prepared and carried out by (besides the author of this article) A.I. Tlishev, G.P. Perekotiy, D.A. Bebko, D.V. Korneev. A diagram of the experimental device is given in Fig. 6. The results of this experiment are given in Table 3.

Table 3

Protocol of control test

Indices	1	2	3	Mean
1 – mass of the solution, which has passed through the reactor m, kg.	2.112	2.153	2.118	2.128
2 – temperature of solution at the input of the reactor t_1, degrees	24	24	24	24
3 – temperature of the solution at the output of the reactor t_2, degrees	33.5	33.5	33.5	33.5
4 – differential temperature of the solution $\Delta t = t_2 - t_1$, degrees	9.5	9.5	9.5	9.5
5 – durability of the experiment $\Delta\tau$, s	300	300	300	300
6 – reading of voltmeter V, B	25.0	25.0	25.0	25.0
7 – reading of ammeter I, A	1.40	1.40	1.40	1.40
8 – electric power consumption according to indices of voltmeter and ammeters, $E_2 = I x V x \Delta\tau$, kJ	10.50	10.50	10.50	10.50
9 – power spent for heating of the solution, $E_3 = 4.19 x m x \Delta t$, kJ	84.10	85.70	84.31	84.70
10 – reactor efficiency index according to the reading of voltmeter and ammeter K= E_3/ E_2	**8.00**	**8.16**	**8.03**	**8.06**

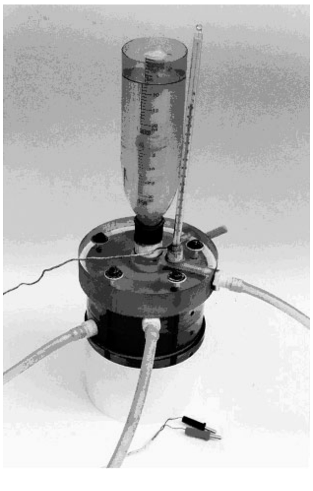

Fig. 7

Photo of heat reactor

In the Russian market three firms (Yusmar, Termovikhr and Noteka) sell cavitation water heating equipment with energy efficiency index of 150%. Soon, an air heating devices with the same efficiency will be produced. The processes of mechanical destruction of covalent bonds of the air gas molecules, molecules and clusters of water and their further fusion serve as a source of additional energy generated by these devices [1], [2], [3].

Conclusion

Analysis of energy balance of the molecules with covalent bonds shows the possibility of additional thermal energy formation during mechanical and electrodynamics destruction of these bonds.

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The Fourth State Of Matter (Plasma Energy) Power Generation

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Under the proper configurations and in the correct pre glow discharge environment more electrons can be released than what is required to trigger the release. This release of energy attains a high frequency oscillation that is indicative of the metal or metals involved in its release.

The release of high frequency energy from metals and semi metals (semi conductors) through the mechanism in the pre-glow discharge leads to the generation of radiant energy. This correlation has been identified through my findings. The release of high frequency energy from the atoms of electrical conductors is credited to my identification of the mechanism in the pre-glow discharge, or fourth state of matter. This has lead to extremely efficient alternative energy circuits.

The release of high frequency energy from the atoms of electrical conductors is credited to my identification of the mechanism in the pre-glow discharge, or fourth state of matter. This has lead to extremely efficient alternative energy circuits.

The pre-glow discharge condition occurs when a sufficient amount of charge difference is applied across the gap of two electrical conductors. It makes a hissing sound if the electrodes are surrounded by air. The electrical properties between this gap change: electrons become "stripped" from their respective atoms and are liberated. In this state, air is **ionized** and is transformed into a **plasma** and is no longer a gas. It is now in the fourth state of matter, the other three being solid, liquid, and vapor (gas). The fourth state of matter is a good conductor of electricity, its average resistance being much lower than that of the same substance in its gaseous state.

A good readily available spark gap combination is lead and iron. This combination generates plenty of radiant energy and causes noise to be heard on a radio in its vicinity. As a general rule, the better the thermoelectric difference between the dissimilar couple the more radiant energy that will be generated when it is exposed to a plasma field.

Early in the summer of 1981, the pre glow had first caught my attention. This is where I had observed it between two plastic insulated hook-up wires from radio shack. The plasma between the two wires was called into existence because of a high voltage power supply that I had obtained for my electrogravitic experiments. The two wires were twisted together and given a charge of around ninety kilovolts.

It was not until 1989 when I observed a high frequency signal on my oscilloscope coming from the pre-glow discharge phenomenon. These signals were coming from across the room and originated from a crude component that I had built. This crude component consisted of a guitar wire that was centered through a section of PVC tubing. Around this tube was wrapped a coil of insulated transformer wire. This was my first ion-valve. It was excited with the same power supply where I had observed the plasma effect several years previous.

I knew that my ion valve was generating high frequency oscillations using air ions but did not find any practical applications for it until six years later. It was in this year (1995) when I realized the importance of the ion valve and its associated high frequency ion field, known as radiant energy to Moray, it being the essential principle behind his energy receiver.

In one experimental set-up, it was confirmed that when a charged capacitor is discharged through a spark gap that the stored energy is transferred by way of high frequency electrical oscillations. It was found that these oscillations occur directly before the discharge of the capacitor, thus the term, pre-glow discharge. It was found that during the pre-glow discharge plateau, energy is transferred from a primary to a secondary electrical coil. Directly after pre-glow discharge, a surge of current is measured. At the point of current surge is where most of the stored energy in the capacitor is released as wasted heat. It was apparent that by maintaining the pre-glow discharge plateau a very efficient mode of energy transfer and conversion can be obtained. Logically what is required is a control mechanism. This is where my ion valve finds its niche. Upon further investigation, it is found that it keeps pre-glow discharge oscillations at their plateau, and suppresses current surge in a spark gap. It is a self-regulating quenching device. When it is placed in series with an air-core transformer and arc gap, its plasma hisses smoothly, the arc in the spark gap is almost silent and is very small. Continuous oscillations can be seen on an oscilloscope. A light bulb connected to the secondary will glow brightly. This result is not possible without the ion valve included in the circuit. The ion valve has the added feature of preventing back electromotive force, generated from inductive loads, from being discharged back through the circuit. Without the ion valve, energy is normally lost when it is discharged and is transformed into heat. Using the ion valve therefore has the effect of conserving energy.

Fundamental Radiant Energy Device

"Standard" scientific principles are not being violated. There is no fringe science involved with radiant energy power generation. This is a very old source of energy being extracted and harnessed in a unique way through my discoveries. What I have discovered is practically a limitless source of energy. Radiant energy has existed since the beginning of time. What I hold claim to is an improved method to generate and to convert radiant energy, kinetically active ions, cosmic energy, call it what you will, into useful electrical power. Think of the radiant energy power generator as a type of energy detonator that liberates great quantities of energy with only a small exciting spark. No laws of physics are being violated. No new laws are being implied. They are being expanded. The concept is not that much different from how a lighted matchstick is able to start a bonfire.

The power generated from my circuits comes from the transformation of matter into radiant electricity. It does not come from the splitting of atoms. To obtain high wattage from a spontaneously radioactive substance would require unsafe amounts of radioactive material.

Under the right conditions, ordinary matter can be made to generate intense surges of radiant energy that can be heard on a radio receiver as static noise. Build a device that can efficiently capture this energy and convert it into useful electrical currents and you will have yourself a powerful source of electrical power. This device will be powered by artificially disintegrating matter as described by Gustave Le Bon in his book "The Evolution of Matter" and in his book "The Evolution of Forces".

Energy and matter are two distinct entities of the same manifestation. Matter represents a stable condensed form of energy. Heat, light, electricity, etc., are uncondensed vibrations of matter oscillating at differing rates. "Cosmic Energy" is the term that Le Bon used to define matter and energy as being one and the same manifestation. He theorized that when stable matter is disintegrated it is transformed into energy that we recognize as heat, light, electricity, radioactivity, etc.

Semiconductors will generate intense surges of electron oscillations that become powerful sources of radiant energy. A simple **ion valve**, or call it what you will, can be used to generate and convert this form of radiant energy into useful electromagnetic oscillations. A tuned transformer can be used to directly convert these oscillations into to a practical voltage and amperage. This unique valve is shown in Fig. 1. Before it can function it must be connected to a suitable voltage source. The circuit in Fig. 2 demonstrates the full working concept. Other embodiments are also possible. The proof of concept circuit reveals how radiant energy can be generated and converted into useful electrical currents. Many additional stages can be added for more power. Many other circuit and component configurations can also be used but the fundamental conversion principle remains the same. The circuit and components shown should give you a very clear idea of how the technology works. The actual mechanics and electronics of building and validating a radiant energy prototype are relatively simple. Contrary to what some people might think, dangerous levels of radioactivity are never used in my devices.

Ion-valve Converter Technology Explained

The ion-valve converter (ion-valve) shown in Fig.1 has an axial negatively charged tungsten cathode wire that extends the length its cylinder and is capable of emitting secondary electrons. The anode cylinder is positively charged and is made from a semiconductive material that will readily capture electrons.

Within a few milliseconds the accumulated negative ions are attracted to the positively charged onrushing atomic ions. When the negative and positive charges collide they neutralize each other generating high frequency electrical oscillations.

There appears to be a common thread shared between several alternative energy devices. It is the pre-glow discharge. The report on the **Hans Coler** device released by the British Government indicates that there is excess energy released when electrical contacts are opened and closed. The **Lester Hendershot** device utilized a buzzer circuit that opened and closed its electrical contacts. In the **Alfred Hubbard** coil pre-glow discharge flowed through electrical contacts, a distributor cap and radium soaked spark plug. The **Joseph Newman** motor used a sparking commutator. **Thomas Moray** invented a glowing, cold cathode discharge tube that was the heart of his radiant energy device. **Hermann Plauson** was granted U.S. Patent No. 1,540,998 that used spark gaps to convert atmospheric energy. **Frank Wyatt Prentice** was granted Canadian Patent No. 253,765 that detailed his invention, which lighted 50 sixty-watt carbon lamps with an input of only 500 watts. His invention utilized a spark gap driven high frequency tuned resonant system. **Chancy Britten** used ion-valves constructed with a central wire that was surrounded by a coil of wire which is described in his US Patent No. 1,826,727. Britten's valve was said to have lit up his home in the 1930's according to a local newspaper article of that time period. **Alexander Chernetski** experimented with what appears to have been a type of ion-valve that was filled with hydrogen gas. It is said that he got up to five times more energy out of his device than what he put into it. **Edwin Gray** was granted U.S. Patent No. 3,890,548 for his efficient spark gap driven capacitive-discharge motor. He improved on this patent by replacing the spark gaps with a pre-glow discharge switching tube. His U.S. Patents No. 4,595,975 and No. 4,661,747 describes this tube in detail. Gray's patents claim to conserve battery power by sending unused energy back to the supply batteries. On close examination, we also find that his switching tube is actually a quenching device.

Radiant energy was generated during the pre-glow discharge cycle that also contributed to recharging the batteries. **Paulo N. Correa** and **Alexander N. Correa** obtained patents to a pulsed pre-glow discharge system that recovers energy and recharges a battery.

I have found that radiant energy is generated when a plasma field is in contact with the atoms of an electrical conductor. Most importantly, the quantity of radiant energy is greatly increased when the plasma field occurs between the inter-electrode couple of two differing electrical conductors. That, the wattage produced will depend largely on the type of electrode materials that are used. I do not suspect that the above referenced inventors were aware of this amplifying mechanism.

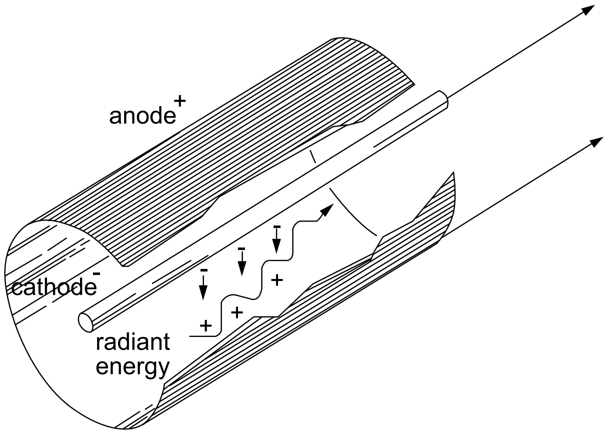

Fig. 1

Ion Valve

In the embodiment in Fig. 1 the negative charge on the wire in the ion-valve negatively ionizes any gas that contacts it. These ions rush towards the positively charged cylinder. When a metal ion that carries an excess electron hits head-on with an elementary differing positively charged onrushing metal ion a violent union of the two metals occurs. This causes the newly formed bimetallic alloy to violently oscillate, break up (dissociate) and to liberate a burst of electrons. The **"sea electron model"** helps to explain this effect. According to the sea electron model metals are bonded to each other through electron sharing. The model suggests that metal atoms be bathed in a sea of valence electrons. If this model is taken one step further it can be seen that when metallic atoms are dissociated from each other excess electrons are released in the form of electrical oscillations of high frequency (radiant energy). This occurs because the electrons no longer take part in the inter-atomic binding force that existed before the dissociation took place. It becomes clear that the freed electrons will add amperage to the output circuit to which it is connected. Henceforth, the equation **I x E = P** holds true in this system. Where, "I" represents the electrons (amperage), "E" electromotive force (ionic voltage), and "P" the power generated.

Obtaining Electrical Energy from the Transformation of Cosmic Energy

Matter is cosmic energy in a condensed state according to Le Bon and Moray. What this means is that matter can be excited its plasma state and caused to rapidly disintegrate transforming itself into electricity.

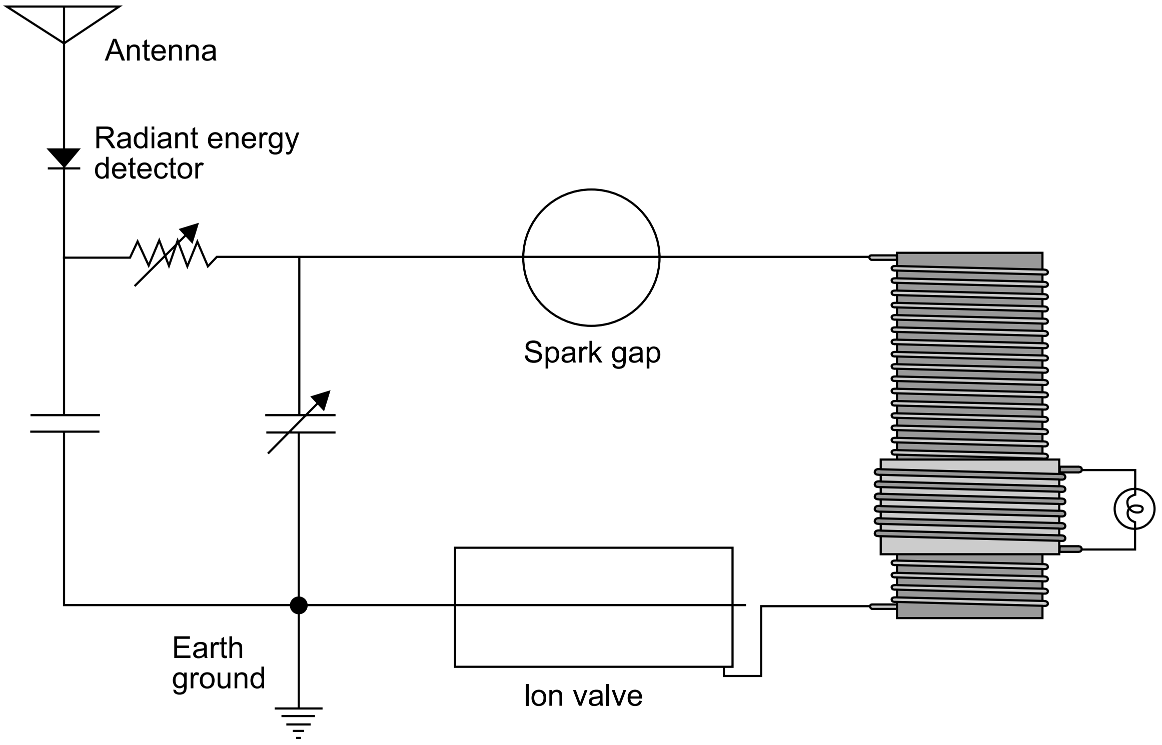

Fig. 2

Proof of Concept

The proof of concept shown will obtain energy from the dissociation of matter bringing the circuit to life. It does this by creating a plasma field between differing electrical conductors. Electrons are unleashed and feedback to the circuit where they are converted into useful power.

Plasma oscillating on the correct wavelength will act like a spark on a mass of explosive material but releasing electrical particles instead of heat. This is to say that the excited fourth state of matter (plasma) causes condensed energy (solid matter) to become uncondensed (radiant energy). The reaction will be far superior to the force that invoked it in the first place because the energy stored in matter is released. The energy that is condensed in the elements of matter is immense. The result is that an enormous amount of energy is released with only a slight loss of matter. Gustave Le Bon proved this when he demonstrated that the action of solar light and from electric arcs on bodies produced electric particles similar to those of uranium. He showed that it caused all bodies to disintegrate to different degrees.

the excited fourth state of matter (plasma) causes condensed energy (solid matter) to become uncondensed (radiant energy). The reaction will be far superior to the force that invoked it in the first place because the energy stored in matter is released

According to the law of conservation, when we give to a material body a determined quantity of energy, this energy might be transformed, but the body will never give back a quantity in excess of what it received. This principle is considered too self-evident to be disputed. It makes sense that matter can only give up energy that is given to it and is unable to create excess energy. Without violating this law, matter can be excited into giving up its stored inter-atomic energy. Condensed matter can become uncondensed if its oscillations become violent enough and henceforth transforming itself into radiant energy. No laws have been violated. They have been expanded. The first law of thermodynamics describes the principle of the conservation of energy. It states that "energy is not created or destroyed; it merely changes form". The fact is that the creation or destruction of energy is a result of matter being broken down or built up. They both go hand in hand.

Naturally occurring radioisotopes were created through the billions of years of **cosmic ray** bombardment of ordinary matter. Their matrixes became unbalanced. The correct trigger will cause these isotopes to seek their original balanced state. Enormous amounts of electrical energy can be obtained from the transformation of stored cosmic energy. These isotopes contain a very old energy reserve that can be released in a unique way with my discoveries.

Have you ever wondered about spontaneous radioactive decay? Is it really a super charged state of matter? If an atom can become ionized by either gaining or by losing electrons then why can there not be a nuclear ionization too? I hypothesize that atoms do become ionized on the nuclear level by gaining or losing neutrons. This may appear incidental but could be at the very heart of an ultra-chemistry. It is highly probable that this hypothesized phenomenon is behind natural spontaneous radioactive decay and explains many unanswered questions about nuclear science.

Liberated Energy

With a slight excitement from a pre-glow discharge in a spark gap, or even with no excitement at all, as we observe in spontaneously disintegrating radioactive bodies, such as U235, we can obtain large quantities of energy. Clearly, we did not create this liberated energy, since it already exists in matter, but we release it under the right conditions. This is being done without violating the law of energy conservation. The idea that matter could be transformed into energy was absurd before the acknowledgement of nuclear transformations.

A Nu Science is on the horizon. It involves the means of transforming matter into energy without splitting atoms. This science recognizes several isotopes of matter that spontaneously liberate energy as observed in naturally occurring radioisotopes. My research indicates that it is also possible to artificially speed up the natural decay process of condensed energy (matter) using a minute plasma field, as from a pre-glow discharge, etc… With a very small quantity of energy, we will be able to produce a very large quantity of energy without splitting the atoms.

Capture Capacitor

Nature offers us cosmic energy that manifests itself in many different forms. Electricity is only one of its manifestations. From this knowledge, we can obtain electrical power with no moving parts. The natural world contains many storehouses of this cosmic energy. Energy is all around us just waiting to be transformed. The capture capacitor is one such example. It is called a capture capacitor because it captures and transforms electrical charge into electrical current. It does this with the aid of naturally occurring radioactive matter (N.O.R.M.). Put a pair of dissimilar metal electrodes together with a porous ceramic dielectric material sandwiched between them, along with a weak electrolyte and you have built a capture capacitor. In a low power capture component there exists a minute impurity of N.O.R.M. It is always present in clays and is usually present in ceramic materials.

If you want a capture capacitor to generate more power all you have to do is to add additional amounts of radioactive material to the dielectric. Lead–210 is the optimum choice because it has a half-life of around 22.3 years and is a pure beta (electron) emitter. Its half-life is almost twice as long as tritium. This means that it is feasible to build a component that will put out power for several years with little maintenance. Lead-210 is a decay product of radon gas. The parent source of radon is uranium. Therefore, uranium ore can be powdered and mixed into the ceramic material.

The atomic ions emitted from naturally occurring or artificially induced radioactive transformations can be directly converted to electrical power. The circuit shown can be used to convert radiant energy into useful electrical currents. Additional stages can be added for more power. The circuit shown gives a general idea of how such an energy conversion device functions. By no means is this technology limited to this one circuit, configuration, or source of radiant energy.

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NEWS REVIEW

◆ A new type of high field superconducting magnet from Oxford Instruments has enabled physicists at the University of Nottingham to balance the force of gravity and levitate heavy and dense materials such as lead, gold and diamonds. The patented Minimum Condensed Volume™ (MCV™) Cryofree™ superconducting magnet, developed and manufactured by Oxford Instruments in collaboration with the University of Nottingham, is the first of its kind in the world. Unlike conventional superconducting magnets, the MCV magnet never needs to be refilled with liquid helium and yet can generate a field over 300,000 times stronger than the Earth's magnetic field. MCV has a very small footprint and, operating at 4.2 K with a room temperature bore, can generate highly stable magnetic fields up to 16 Tesla.

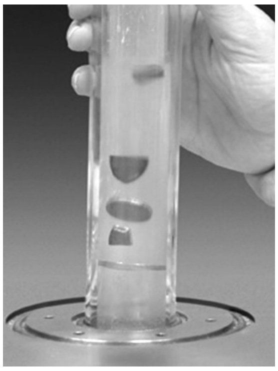

http://www.oxford-instruments.co.uk

◆ Polish inventor Zygmunt Orlowski called attention of the scientific society to his perpetual motion machine **METOZ**, which according to the author after further improvement will be able to extract energy from the earth's gravitation.

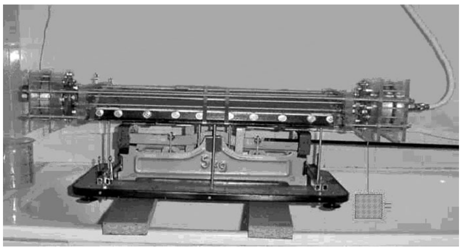

http://www.nets.pl/~metozor/perpetual_motion_machine.htm

◆ It is necessary to change behavior of people in order to decrease environmental damage. This was the message of **"Green Week 2003"** which took place since June 2 through June 5 in Brussels.

The conference's key issues were three aspects of United Europe environmental policy: sustainable production and consumption, renewable energy and water supply.

Green Week is the first environmental forum of such a scale. Three thousand participants from all over the world represented governments and funds, industry and mass media. The exhibition organized in the framework of Green Week included 62 displays from 14 European countries and were dedicated to the newest environmental technologies and projects. During the Green Week 26 conferences and seminars took place, as well as a great number of press conferences and actions for young people.

◆ **British researchers (**Gardner Watts company) **believe that they have made a groundbreaking scientific discovery after apparently managing to "create" energy from hydrogen atoms.**

The device represents "thermal energy cell" which appears to produce hundreds of times more energy than that put into it. If the findings are correct and can be reproduced on a commercial scale, the thermal energy cell could become a feature of every home, heating water for a fraction of the cost and cutting fuel bills by at least 90 per cent.

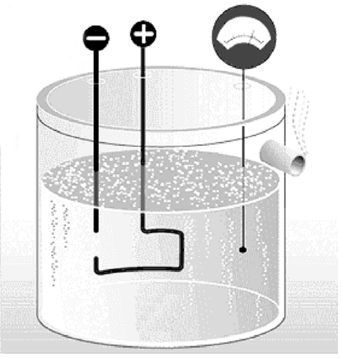

http://www.telegraph.co.uk

◆ **Gravity Conversion Rotary Device**

The below figure is from
http://www.theverylastpageoftheinternet.com/newclaims/GravityMotor/gravity_motor.htm

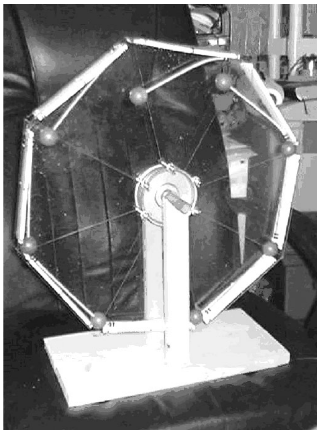

Does it really work?

THE MARCUS DEVICE CONTROVERSY

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http://www.americanantigravity.com
http://www.americanantigravity.com/marcus.html

Editorial: This overview is devoted to the fantastical device created by inventor Marcus Hollingshead that encountered more than its share of publicity and controversy between November 2002 and March 2003. You can participate in discussion on aggroup@yahoogroups.com.

The problem with Marcus has been that he was pressured by too many people to produce too fast results. I started talking to him in November, and he is always sounded like an honest, rational man with a good heart. The problem is that once people started to hear his private claims that he could lift something like 2 tons of weight, things kind of went south.

While people in general have been very well-meaning, they are desperate to solve many of our current energy-problems, and when Marcus appeared with a potential solution it got out of control. Pretty soon film crews were showing up at his house unannounced, and he was getting unwanted phone calls from people who had looked up his number online.

In my opinion, it is really a problem of a "social dynamic" at work here – too many people, with too much access, all at once. This also correlates to the type of person that different people are. For instance, I am a very open person, and I really do not value my privacy a heck of a lot — therefore, when TV crews drop by with 5 minutes notice (and they have), I tend to just let them in for a demo. However, Marcus, who is much more of a private person, seems to have become a bit overwhelmed at this proposition.

Also, keep in mind that I had initiated working with the media because I felt that it was time for the excellent work in the Lifters groups to see the light of day. There was some debate about this, but the Lifters group as a whole has greatly benefited from being about to tell people about this new technology.

Marcus had not actually "gone public" about his work. He had leaked information about his research to a few people, and from there it was leaked to several others, who in turn told their friends about it. Unlike the Lifter technology, which has hundreds of people that can talk about how it works and where it came from, Marcus technology was represented solely by himself. That means that everything surrounding his device came back ultimately to him alone. Without any real group ownership of the expertise behind the device

As I said before, Marcus was new to the publicity, and did not have time to prepare the resources that the rest of us have had to answer questions, provide demo materials, etc. Naudin and Saviour have a masterful manner with regard to teaching people about Lifter technology, but they have had years to prepare this information and perfect a method of presenting it to people.

Most of us in the AG groups tend to proselytize for the technologies that we believe in. I know that I do, and if you haunt the newsgroups much you will notice that everybody there believes in something and can go on for months non-stop telling the world about it (again, I do this). Marcus, however, does not really have this personality — he is more of a "take it or leave it" type of person.

For me, this was another indicator that he was the "real deal". You have to understand that I have never seen working prototype pictures of the Marcus device, and all that I had to go on was the feeling that I got from interacting with him on the phone and online. The fact that he did not try to "sell me" on the idea was a big plus. He told me about the device, and his story was always consistent. The other people that he talked to also had a consistent story – I have not talked to anybody and heard a different version than I heard from Marcus himself. That is a big plus from the credibility perspective.

Marcus initial goal (from when I started talking to him in November) was to gradually ease into working with the public to tell them about the technologies he was working on. Unfortunately, I probably aggravated the issue a great deal, because his early descriptions of the technology might have gone unnoticed if it had not been for some of the things he had mentioned about his research.

When I read Marcus' firsts posts on the device, my very first thought about his claims was that they were bogus. Judging from the reaction of the Antigravity newsgroup, I gathered that a few other people also had the same initial reaction. The reason might be a little selfish – after you hear claims but do not see results for a long enough period of time, you tend to protect yourself emotionally by becoming skeptical to the idea that somebody can be lifting hundreds of pounds of weight using a completely new and revolutionary technology.

Nonetheless, something that Marcus had said resonated with me. I remember that he was talking about his results being based on a study of the Earth's fields, which is something that I had read about myself during the college years. Telsa had done a lot of work involving the Earth's electrical and magnetic-fields, and I had always felt that this research might come in handy later as a potential basis for Antigravity research. However, I did not have any specific ideas, and began asking Marcus questions offline to find out more about his research.

In reality, I am nobody special, so I think that perhaps this would have happened in any event no matter what my reaction would have been. Certainly I am not the only person that took an early interest in his work, and from what I learned later he had already been a little bit too honest in the BBC online newsgroup before he ever became involved with the Antigravity newsgroups.

From January to mid-February Marcus became like somewhat of an addiction in the newsgroups. This was a strange phenomenon to watch, but if he did not answer questions in the newsgroups for even a day people started asking whether he had been kidnapped or the government had assassinated him.

You have to understand that most inventors tend to segregate their time into "public" and "private". I do, Naudin does, and everybody does this. When you talk to the public about what you have built, you really get into it — but when you are actually working on it, you tend to hole up in the garage and put the entire world on "ignore" until you have finished with whatever it is that you are doing.

Marcus really started to get publicity in late November 2002, and it built up over a few week period of time. By mid-December, he had a healthy following in the Antigravity newsgroup and people in the 5 or 10 other AG newsgroups were developing more than just a passing interest. Great stuff for Marcus – he had thought that he was the only person doing this research, and it turned out that lots of people shared this common interest with him. We had lots of really valuable and productive exchanges.

Marcus bided his time working on the projects – he had initially stated that he could lift around 200 pounds of weight with his November version (prototype #161, if I remember correctly). He did not have a digital camera, and he did not want to publish photos until he had a better prototype anyways. That was OK with me – I am used to work with a variety of inventors and came to realize a long time ago that everybody has their own style. I was content to wait until Marcus had additional data, and the only thing that I insisted upon was that sooner or later he ante-up and provide some photographic evidence.

Despite lacking photos or video evidence, Marcus did have documentation. In fact, he wrote more documentation about his device than I had ever hoped to receive. He cranked out about the equivalent of 30-pages of "real" documentation in a very detailed form within 1-month, and had the email equivalent of many more pages in postings about how the device worked online. Marcus had already been publishing details online for about 2.5 months.

Despite the incredible amount of published data that Marcus was able to complete, in some ways it made things worse for him than not having anything at all. The reason was the nature of his research. My work, currently focused on Lifters, was in a technology that is easy to explain – the device is built like this, it works like that, and it can be described in a manner similar to some other thing ....basic, easy to explain, and easy to compare.

After all, Lifters have been accused by science of being ion-wind devices. If nothing else, rebutting this claim gives us someplace to start – something to compare against to provide people with an idea about how the device works. Additionally, we had tons of video and photographic evidence to back up our claims. In Marcus case, the documentation that he provided made things worse because his technology is so utterly different. It is not ion-wind, nor the Biefeld-Brown effect, nor apparently the Searle effect. In fact, the more than you tried to pin down exactly what it was, the harder it became to describe it.

Also, its not like he could simply fall back onto describing the construction of the device **– reason being that it contained a series of interrelated coils with a unique configuration that were intrinsically tied to the operation of the device.** Every time he wrote a detailed summary of the construction of the device, we had come away with more questions than we had started out with. After a time I gave up trying to understand how it was constructed, because I only had bits and pieces.

Marcus was using an arrangement of 6-coils, and what are described as "bifilar windings". Essentially, this means that you wind two wires together around a coil and then tie one of the ends to another, making the two wires essentially one long wire wound "against itself" down the length of the armature its on. There are 6 of these armatures on the device, mounted around a central RP (or reference point).

Marcus created all of the terminology for these parts – this lends additional credibility to the idea that he had had 7 years of experience with it. These are ideas that you just do not "make up" for publicity. For instance, the bifilar windings on the armature-coils are self-cancelling fields, and even a basic-electronics education will tell you that. However, the interesting thing is that once you really start to get into the advanced "post-scientific" research on magnetic fields you start to see self-cancelling magnetic coils all over the place. The reason is apparently that while the "B-field" *(Editor: i.e. magnetic field)* of the coils cancels, the "A-field" *(Editor: i.e. vector potential)* that Tom Bearden keeps talking about does not, which means that you can isolate the really interesting effects from the coil without having to deal with the high field-intensity effects from normal electromagnetism.

Marcus had described these six armatures as being activated in a series, or order, to obtain results. Each of the coils was spun by an electric motor mounted on the armature, and when the coil was spun up to a certain speed and "stubs" mounted a periodic intervals on the side of the armature were fired in sequence the antigravity effect was created.

Marcus Antigravity effect was a directional force that was applied in a unique manner depending on which coils were activated. This means that by activating (for instance) coils 1 and 3, he could create an antigravity effect and move the device left – or something to that effect. Turning on and off each set of coils gave him movement on one axis of thrust, which corresponded to X, Y, or Z in a standard 3-D geometric graph. Since you can move in either direction down any given axis of thrust, this means that you have 6 axis of movement height (up and down), width (left or right), and depth (forward or backward). His device provided movement on any axis by either one coil or an arrangement of coils.

For a while Marcus did not want to talk about side effects, but I pressured him into it. The reason was that I have seen side-effects that were pretty darned strange in a number of different experiments, and I was willing to bet that if I pressured him a bit he would talk about what he had seen but did not want to reveal (for fear that people would not take him seriously). It turns out that I was right.....

Marcus had talked about the RP, or "Reference Point" upon several occassions. This is a multi-layered device that acts somewhat like a capactive element. It sits in the direct center of the Marcus device, and it is the reference-point for the entire device. The RP is manufactured from cast-iron, and Marcus says that he has a local company build them for a few bucks each by pouring iron into a mold based on one of his designs.

You can active the RP at the same time that you activate the coils. You have coils rotating around the RP, with "stubs" on the coils firing periodically at points corresponding to spots on the surface of the RP. Meanwhile, you also have an electrical charge on the RP itself, which means that there are a lot of elements interacting at once to create a very complex dynamic.

One of the interesting side effects was a darkening and "blurring" effect of the RP, as if light was being reflected off it. Another was a Star-Trek like "force shield" around the RP. These only occurred when all of the coils were activated at once. Also note that since the coils are opposing in nature (one for each direction on each axis), that when you are creating the force field effect the device cannot be levitating. However, the device is operational, and you have a force-field that you can apparently bounce a heavy hammer off without being able to penetrate it (Marcus description).

Another interesting note is that the force-field effect can be modified to create a vacuum. I am not sure how

Marcus noticed this, but he had said that it appeared to create a vacuum inside of the field's boundaries during operation. Interestingly, it also ran very cold – apparently down to a hundred degrees below zero, but only within the localized boundaries of the field.

I am not a professional physicist, but this is something that has been reported with the Searl effect and several other experiments, and the reason that I believe it occurs is because you are taking the kinetic energy of the device as well as some of the kinetic energy of its molecules (i.e.: heat energy), and injecting it into another dimension. After all, anytime we directly modify a gravitational field we are creating a dimensional effect, but in normal life we do not notice it because the boundaries between gravitational fields are very gradual.

Well, in the Marcus device the boundary between gravitational fields is not a several thousand mile-long gradient like the Earth's field is – instead of you have a gradient perhaps 10-times more intense focused within a 3 to 4 inch area. That means that you are creating essentially a rift in time and space (self-healing) that is kept open by the energy that you are pumping into the device.

the energy input is used only in putting the device into another frame of reference, but that any interaction between us and our "normal" frame would have to be modified for any interactions with the "modified" frame.

To the best of my knowledge, this is the most accurate description that I have seen yet for why his device does this. Marcus himself could not explain why these effects occurred, and to be honest I scared him more than a little when I told him my theory.

In the hypothesis that I just put forth on the origin and functionality of the Marcus device effect, the interesting this is that there really is not a direct correlation between input energy and the effect itself. That is because you are not using the input energy to actually cause an effect – you are essentially using the input energy to translate the device into another dimension (although it is still partially within ours).

Einstein called these "frames of reference". The idea is that the energy input is used only in putting the device into another frame of reference, but that any interaction between us and our "normal" frame would have to be modified for any interactions with the "modified" frame.

Again, this takes place in normal physics – but usually it involves motion, and normally it takes place over a vastly larger gradient of time/space/whatever. The difference between two frames is the difference between two locomotives moving at different speeds – the energy input goes into accelerating each locomotive up to that speed, but the actual work is performed if those two trains interact is solely a product of the frame of inertial reference (mass & velocity = energy).

Another excellent example is a helium-balloon. You put the energy into condensing the helium and pumping it into the balloon, but it is not the helium that creates lift – it is the surrounding atmosphere. In a very real sense a helium balloon gets its energy from the surrounding environment. The energy that you put into "maintaining flight" in a helium balloon is only the strain on the fabric used in holding the helium into the confines of the bag that encloses it. With the Marcus device, I would bet money that it is not the input energy creating these effects – it is instead the difference in frames of dimensional/inertial reference between "our" environment and the "device's" environment, whatever that difference may be.

You see, even though this sounds like a load of BS, magnetism is not real. This is not an idea that I am making up – in fact, it is an entire chapter in the physics 101 textbook kicking around downstairs in my house. Take two magnetic fields, and project them in the same direction at the same speed. Field A can not interact with Field B, because neither of the fields really exists – they are merely ripples on a pond, and that pond is the background of the time-space continuum. People that believe in relativistic gravitational effects take for granted that things like this happen – after all, gravity is not a force per se in relativity – only a modification of the dimensions of time-space. Well, most people do not realize that Einstein based his theory of gravitational force on his study of magnetism. Magnetism is the same thing – it is a modification of the fabric of time-space.

Take two magnetic fields that did not interact from a moment ago, and now change the direction that one of them is traveling in. Suddenly, the two fields that could not even see each other a moment ago now create an incredible "torque" – this is the same thing that we see in bar-magnets and electric motors. This is the "torsion field" research.

Bar magnets are different than pure fields because they are composed of the discrete fields of thousands of tiny magnetic "domains". That is why the fields from bar-magnets are never "invisible" to each other – it is because that the fields in bar magnets are too jumbled to ever really "line up" to the point of being invisible. Pure fields can do this, however, reinforcing the supremacy of Einstein's relativistic effects with relation to electromagnetism.

Anyhow, that is about it for now – I will try to come up with a more detailed picture for you on this if you like, but I expect that you will probably have more questions about Marcus theory and device in near future. It is a very complex idea underlying his research, but the basis of it is the idea of "rotating magnetic fields".

If you want to do additional research on your own into related fields of study, I would definitely look up "relativity and magnetism" – it provides an excellent example of how to visualize relativity theory in the study of magnetic field interactions. This is something that electronics engineers are not taught, which is why you have never heard of this in an engineering sense before. However, in physics is a well-known concept, although most physicists prefer to work with quantum mechanics rather than relativity these days.

In terms of rotating magnetic fields, you can look up "torsion fields" – again, the Russians have the best understanding of advanced torsion field physics, although their best material probably has not been translated yet. Additionally, rotating magnetic fields are the basis for the Searle Effect and the Hamel device.

Marcus was intrigued by Searle's claims, because they appear to have matched many of his own results. Interestingly, Marcus had developed his work within an "intellectual vacuum" and had never heard of Searle before I told him about the similarities. Nevertheless, force-fields, ice-cold operating temperatures, and antigravity seem to be a pervasive similarity between all manners of experiments that have been reported using rotating magnetic fields. I had assumed that Searle's claims were bunk, but after hearing about similar effects from Marcus research it led to reconsider some of the criticism surrounding Searle lately.

One a final note – one group that may lend additional credibility to this research is Godin and Roshchin in Russia. They obviously benefit from the years of knowledge that the Russians accrued in magnetic field systems theory, and they attempted a replication of the Searle effect device some years back (and claimed to get some results). I hear that they have been working on a revised version of their experimental setup recently and hope to have even better results in the very near future.

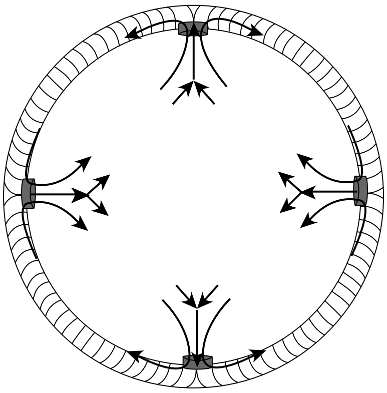

Fig. 1

Magnetic flow for a bifilar-wound toroid that is split at four points on the toroid. This configuration occurs when the coils in the nubs are charged to match the charge on the toroidal coil. The configuration is a quadra pole with a minimum magnetic field at the center

Fig. 2

Marcus recommends the Kikusui 6000L and 18000L multipurpose AC power-supplies

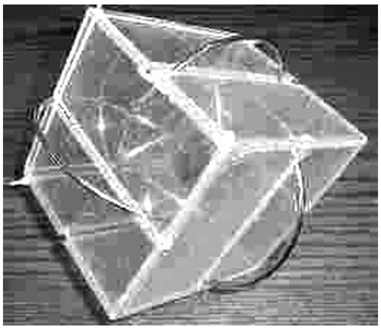

Fig.3

A scale-model mockup of the ring-arrangement within the Marcus device, showing the interlinking coils

History pages

Systems of conversion of thermal energy to mechanical one

Review prepared by correspondent Alla Pashova, **Russia**

There is a wide class of closed-cycle heat engines using differential temperature of water and ambient air. This kind of systems enables thermal energy to be directly converted to mechanical one so as to perform a useful work. We publish patent specifications of two analogous devices of this kind.

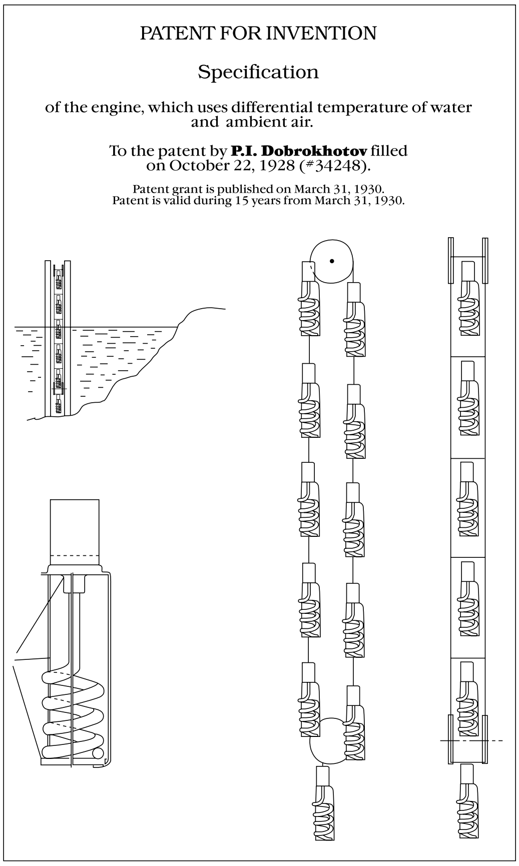

PATENT FOR INVENTION

Specification

of the engine, which uses differential temperature of water and ambient air.

To the patent by **P.I. Dobrokhotov** filled on October 22, 1928 (#34248).

Patent grant is published on March 31, 1930.
Patent is valid during 15 years from March 31, 1930.

In 1928 **P.I. Dobrokhotov** proposed a design of such an engine. It represents an endless chain thrown over a pair of blocks and partly immersed into water. The chain consists of coiled pipes filled with a volatile liquid (such as sulfurous anhydride or ammonia). One end of each coil is fastened to a frame, while another end is fastened to a cylinder piston mounted on the same frame. When overwater elements are heated by means of ambient air, the liquid inside the coil evaporate. Vapor put pressure upon the pistons which being in motion compress air in the cylinder, and thereby reduce volume of each element. When submerging, the element gradually cools down, thereupon causing a decrease in pressure of vapor of the liquid, which is enclosed within coils. The pistons move in backward direction, and the volume of air available inside the cylinder increases. Increase of volume results in increase of water buoyancy force that sets the device in motion.

In 1980, **Y.S. Grigoriev** developed his forerunner's idea by improving the system described above. The inventor aspired to enhance the effectiveness of this method of conversion of heat energy to mechanical one. He suggested fixing the volume of chambers filled with a heat-sensitive actuating medium at its minimal magnitude before immersing of those chambers into warm water. In water the actuating medium heats and partially evaporates. At a maximum depth of submersion, the chambers are released from fixation to be expanded during emersion. Thus one may avoid expansion of the chambers during their submersion. Futhermore, there is a possibility to activate the device and get the useful work without preliminary spinup from an external drive.

INVENTION SU1404681 A1

23.06.88
Yu.S. Grigoryev
Prototype: USSR patent #13534
F 03 G 7/06, 1928

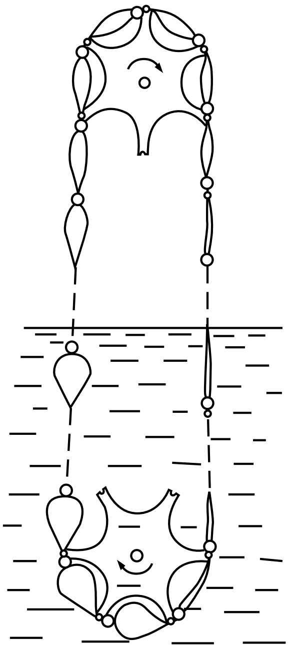

Iliya R. Prigozhin

(25 January, 1917 – 28 May, 2003)

Iliya R. Prigozhin, aged 86, Nobel Prize Winner, Belgian scientist of the Russian origin, died on 28 May in Brussels. Prigozhin made a number of prominent discoveries in the field of thermodynamics and statistical mechanics of nonequilibrium processes. In particular, he developed a concept of irreversibility as applied to thermodynamics. Prigozhin was studying time as a physical phenomenon. In 1977, he was awarded the Nobel Prize for chemistry "for works on thermodynamics of nonequilibrium processes".

The scientist formulated one of the major theorems of the theory of nonequilibrium processes. This theory was later named after him. According to Prigozhin's theorem, stationary state of the system corresponds to minimal entropy generation. The outstanding physicist was also an initiator of applying methods of theory of nonequilibrium processes in biology.

Thermodynamics principles were enunciated in the middle of the XIX century after the invention of a steam-engine, when interaction of heat, electrical, and mechanical work aroused a higher interest. In accordance with the first law of thermodynamics representing an energy conservation principle, energy neither disappears nor appears in any closed system, but transforms from one form to another.

The Prigozhin's theorem sounds as follows: stationary state of the system (under conditions impeding attainment of equilibrium state) corresponds to the minimal generation of entropies. If there are no such impediments, then production of entropy reaches its bare minimum, i.e. zero. The theorem was proved by Prigozhin in 1947.
In thermodynamics the nonequilibrium specifically open systems were of most interest for Prigozhin. In such systems either or both (matter and energy) interchange in reactions with an environment. At that, quantity of matter and/or energy increases or decreases in the course of time.

It is obvious that human society as well as the biological environment is an example of dissipative and nondissipative structures. In the 60s and 70s, Prigozhin developed his theory of dissipative structures and described the formation and development of embryos. Critical points of bifurcation in his mathematical model are correlated with a point, where a biological system becomes consecutive and stabilized.

For his scientific career time, the physicist was awarded over 40 scientific rewards and admitted as an honorary member into national academies of many countries all over the world.

New Energy Technologies

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The 11th Russian Conference on Cold Nuclear Transmutation of Chemical Elements and Ball-Lightning (RCCNT&BL-11) is to be held during September 28- October 5, 2003. The place of the Conference is in Dagomys near the city of Sochi.

The program of the Conference includes the following subjects:

- Experimental research in cold nuclear transmutation (fusion) and ball lightning;
- Theoretical models with respect to cold nuclear transmutation (fusion) and ball-lightning effects;
- Applied to these problems technologies and devices.

The Organizing Committee of the Conference is pleased to invite you to attend the Conference. The terms of your participation are as follows:

The full cast is $900, which will include the registration fee, hotel reservation and living, three daily buffet meals, conference proceedings, transportation from the Sochi airport and back, social dinner and special excursion or entertainment.

The languages of the Conference are Russian and English.

The total cost can be reduced to $800 if transferred before August 10 to the account of the Organizing Committee, which is to be announced on having received from you a confirmation about your decision to attend the Conference.

If you make a decision to take part in the Conference, please, let us know before July 1 about the title and abstract of your report.

Contact telephone: (7) (095) 196-9476 (ask Mr. Igor Goryachev), Fax: (7) (095) 196-6108
Email: gnedenko@kiae.ru; Bazhutov@erzion.madi.ru; bazhutov@izmiran.rssi.ru; bychvl@orc.ru
Address: I. Goryachev, Russia, 123182 Moscow, 1 Kurchatov Sq.,
Research Institute of High Technologies at RC "Kurchatov Institute"

Letters from our readers

Thank you for publication of my article. Your magazine becomes more and more popular.

My special thanks to Editor-in-Chief Alexander V. Frolov. Whatever they say or write in the press, he has done a great work and it is not only my own opinion. He has managed to do that everybody had been waiting for a long time. My colleagues (not only from Rostov-on-Don State University but also from other Rostov Institutes of higher education) ask me personally send the best regards to the editorial staff of your magazine.

Sergey A. Gerasimov

Free energy?

The scientific community says that it cannot exist. Where did we hear that before? Academician Valery Sobolev from the Academy of Sciences, the head of the research group working on the experiment says: "This is not some new physics, but just experiments that have been performed very seriously. Make surge of electrons from the environment, remove them, deplete the fused electrolyte with basic typical metals; what you derive from it is what cannot be produced by chemical methods. This is a new state of substance." As the researchers say, first they discovered a particular electrochemical process where high-temperature materials in a new state are the product. This in its turn allowed to discover a new state of substance, new class of materials, a new source of energy, a new method of cold plasma generation, a new superconductor. See whole article at: http://english.pravda.ru/science/19/94/379/9675_energy.html

Josef Hasslberger

Personal home page on physics, energy technology, social and economic issues: http://www.hasslberger.com

Interference disc generator with permanent magnets

inventor Alan Francoeur, Canada

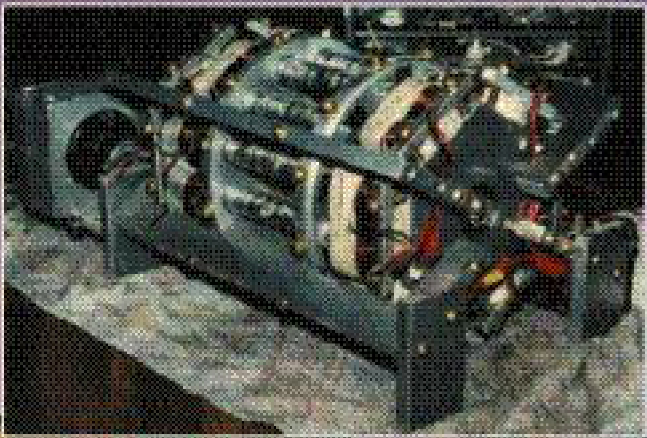

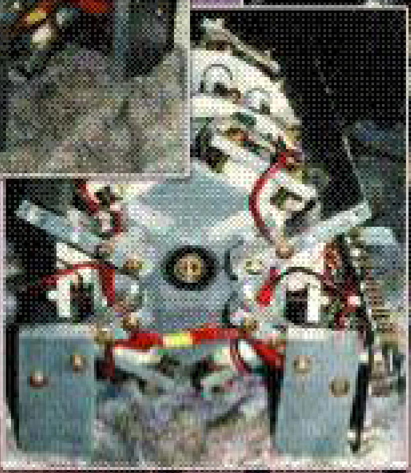

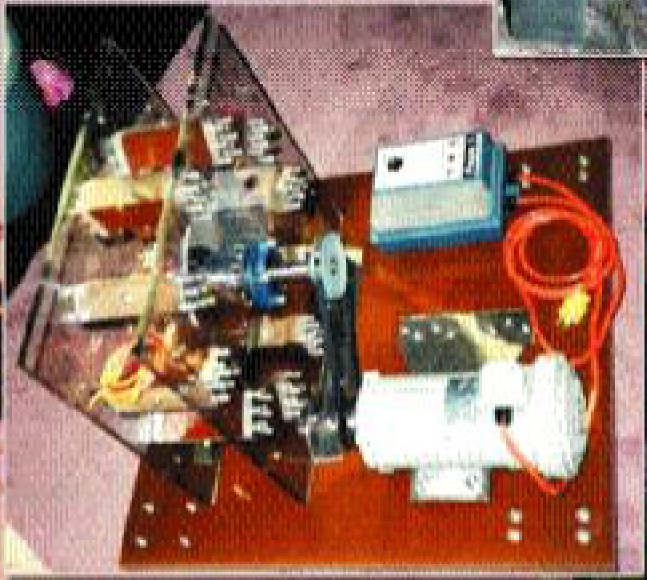

Carl Reich

Bud Johnson

Vortex heat pump

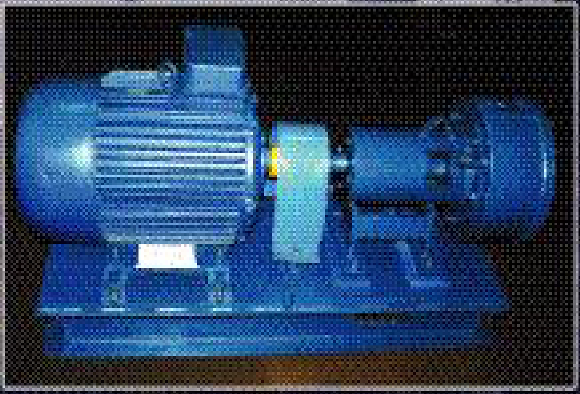

Efficiency 200% and more!

Inventor: Vladimir Susorov
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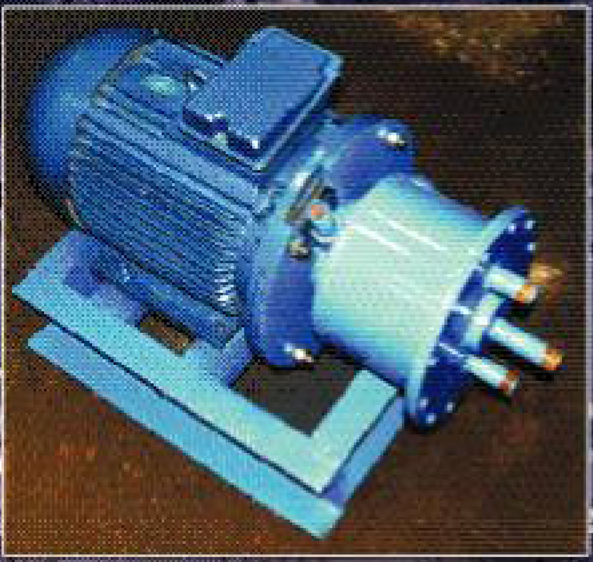

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Gravity-heat power system

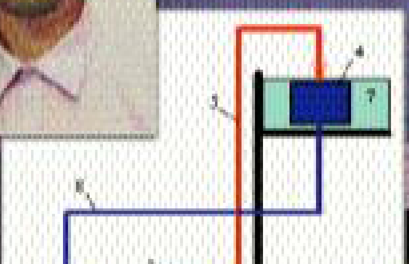

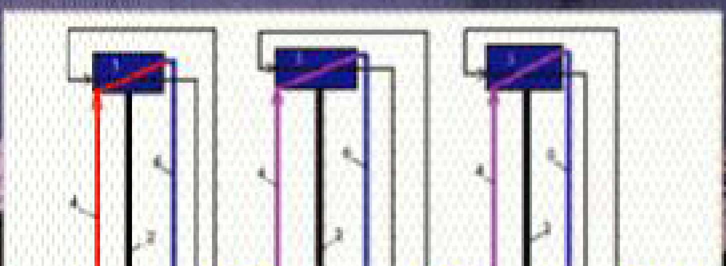

Author: Vladimir Sukhanov Wladimir.Sukhanov@soros.ksu.ru

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New Energy Technologies

Published by Faraday Lab. *Special Christmas Issue #5-6, 2003*

Research on advanced aerospace systems and new energy sources

In this issue:

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- *magnetic generators*
- *capillary perpetuum mobile*
- *Hutchison effect*

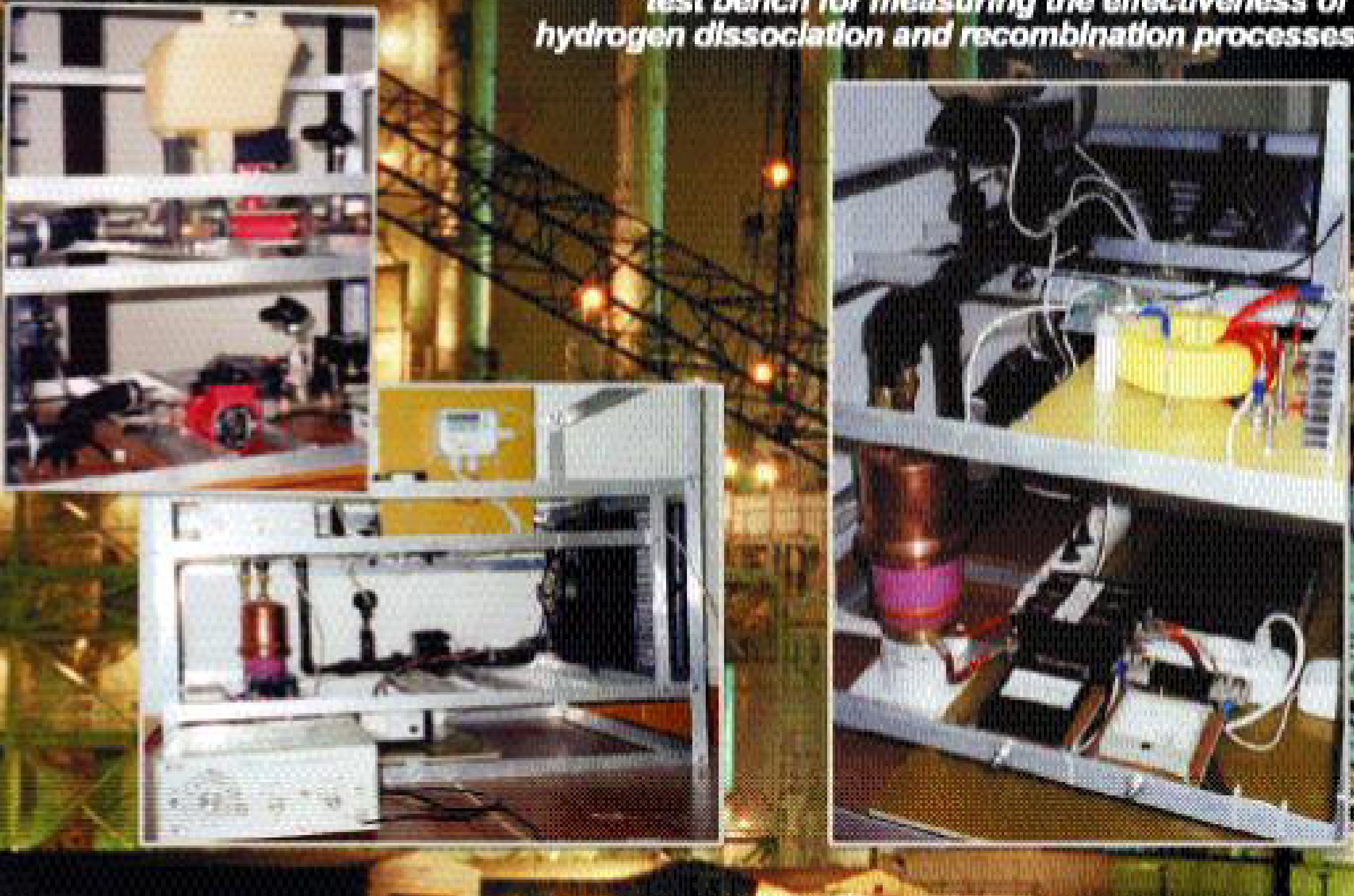

Photos from Faraday Laboratory: test bench for measuring the effectiveness of hydrogen dissociation and recombination processes

Bogomolov's Invention

Over-unity from elastic forces of spring, compressed by rotation.

Read in this issue!

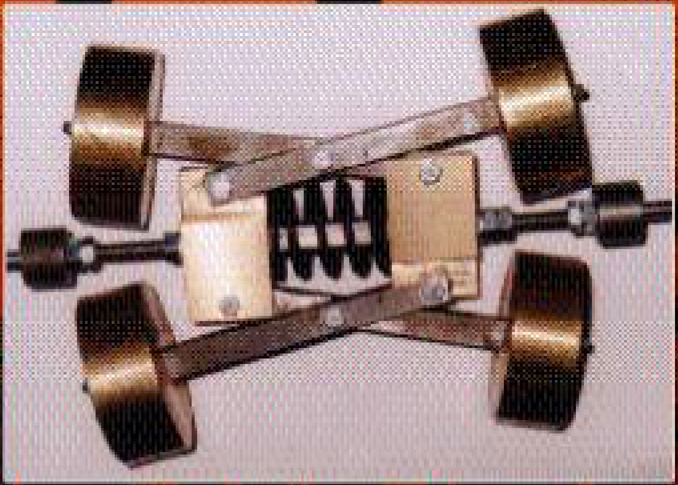

Spin Wave Laser of Ines Espinoza, USA

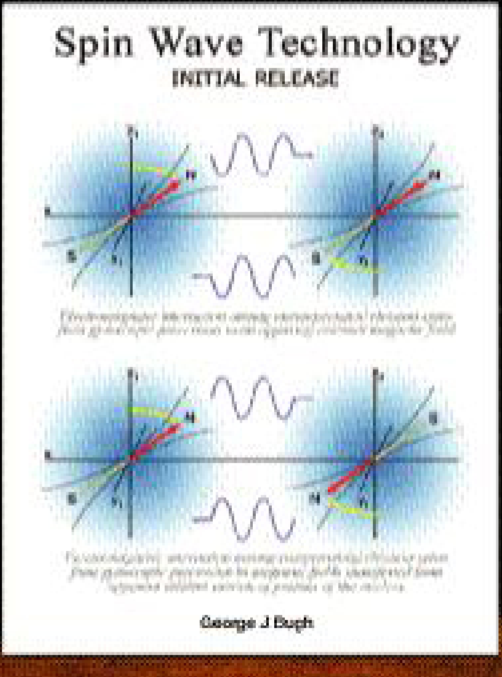

Spin Wave Technology
INITIAL RELEASE

George J Bugh

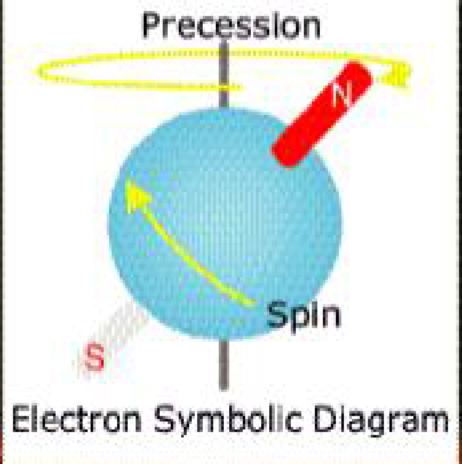

Electron Symbolic Diagram

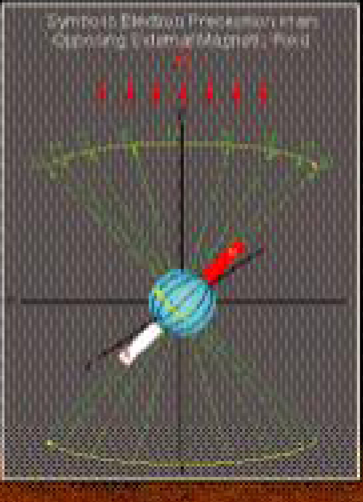

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Faraday Lab News

One of the most interesting research projects of our company in the year 2003 has been the research on hydrogen dissociation and recombination processes. It has taken us about half a year to build a special vacuum tube and in October, 2003 we obtained some experimental results on the heat output and efficiency of the system. The system we designed in our laboratory is shown in Fig.1 and also on the cover. The water-cooling system and the heat measurement system make it possible to measure the heat output within the range of 100 W to 5 kW with pinpoint accuracy. In the year 2004 we are planning to go on with our research work.

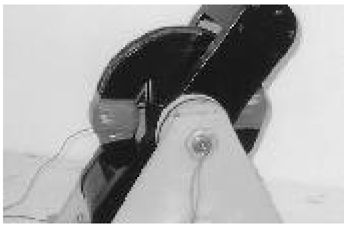

Fig.2

We have completed the second stage of designing and developing a high-efficiency magnetic generator with the neodymium permanent magnets of 1.25 Tesla. We confirmed the possibility of double output increase from the usage of two magnetic induction counter fluxes produced by the two coils wound on the generator core (Fig.2).

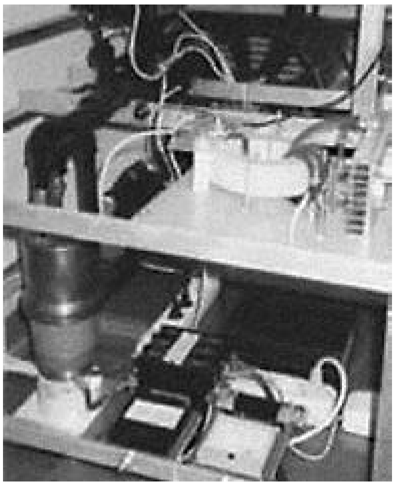

Fig.1

Our laboratory continues designing and perfecting a powerful "alternator"-type generator with permanent magnets and a drum-type rotor. We will give our readers more detailed information after we are aware of the patent examining result.

Our research on "The Control of Temporal Characteristics of Physical Processes by means of Ether Energy Density Change" is also awaiting the results of the patent examining group. This research on time and the construction of the "time machine" is not a pure theory but it has quite real prospects of being applied to the aerospace industry as a propulsion method.

It is worthy to note that now the alternative energy prospects in Russia do not entirely depend on financial factors. The cooperation is important between researchers, investors and organizations interested in the innovative development of Russian industry rather than in the development of Russia as the world primary natural resource is also important. Progressive political and public organizations should develop and introduce alternative energy programmes as well as render support to local researchers. The successful innovation of new technologies is impossible without this support and lobbying government. Let us hope that the year 2004 will bring along new opportunities and promising contacts.

Alexander V. Frolov
General Director Faraday Laboratory Ltd
http://www.faraday.ru

Novozhilov's Motor

Yury N. Novozhilov, Russia
Bratislavskaya Str., 25-6, 390035, Ryazan,
Tel.: (80912) 72-12-72

An interesting but a very simple motor has been designed. It operates on the basis of heating differences of its components due to temperature variations of contacting environments or due to variable radiation intensity.

Motor structure

The motor structure (see Fig.1) includes a metal or plastic wheel (1). In the center of the wheel there is an axis (2), on which spoke ends are fixed (3). Other spoke ends come through a hole in the wheel rim. On the spoke end there are weights, for example, in the form of small balls (4).

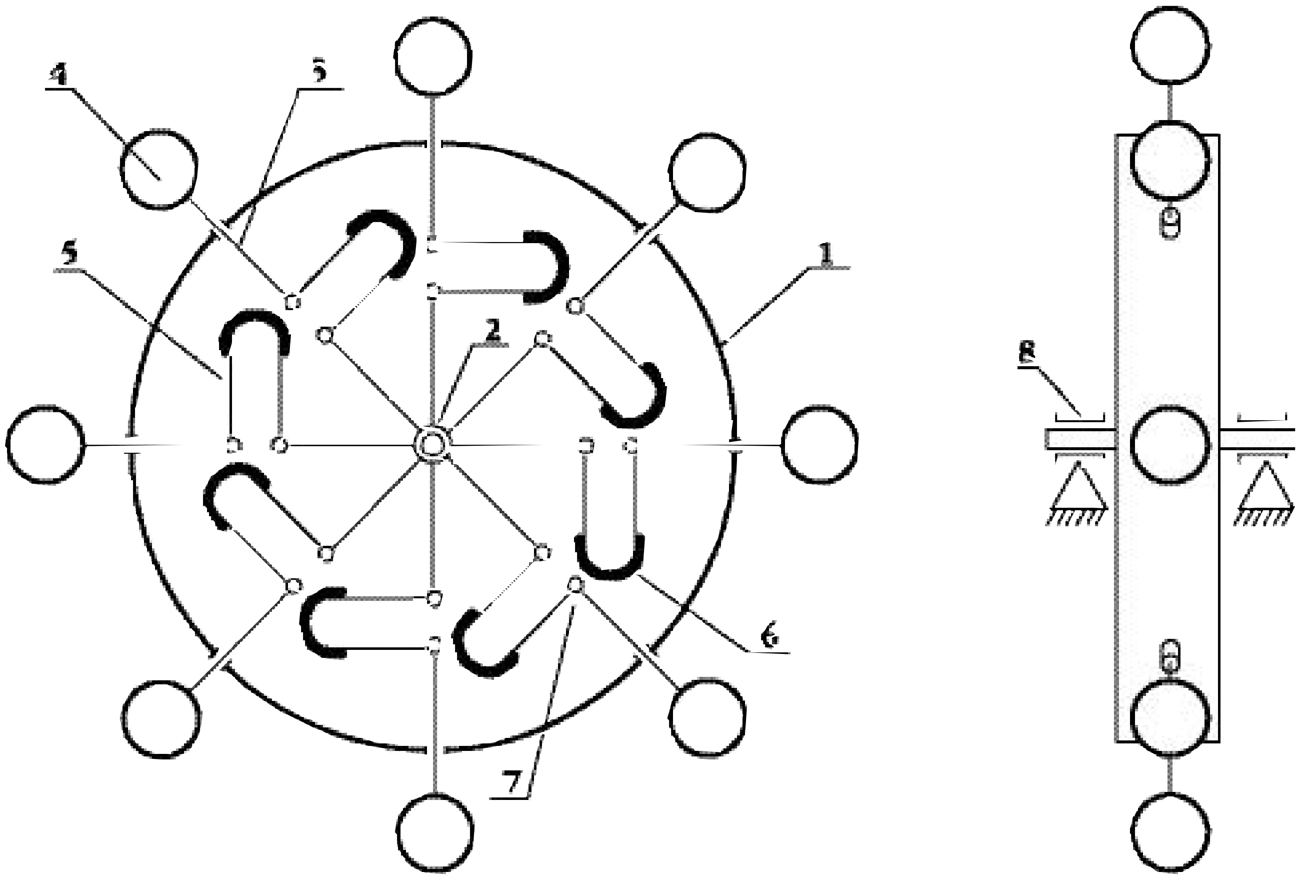

Fig.1
Motor

The structure peculiarity is preconditioned by a loop-shaped part placed on each spoke (5), which has a form of a metal strip or core. An arched bimetal component is built in the center of each loop-shaped part (6). Joints can be fixed at the joining point of loop-shaped parts and spokes to simplify the motor movement (7).

In the motor structure described arched bimetal components become straight when heated. The motor axis ends are placed in bearings (8).

To initiate the motor movement the loop-shaped parts need to be in mediums (zones) with different temperature. For instance, the lower part of the wheel may be placed into hot water (9) and the upper part will stay in the air (10).

Motor operation

When the motor is in a medium with identical temperature, for example, in the air, the temperature of all bimetal components will also be the same; therefore, they have identical form. In this case all spokes will similarly project over the wheel rim and all weights have similar distance from the wheel axis.

This state makes the whole system balanced and immovable. But if the motor wheel is partly placed into water with the temperature exceeding that of the ambient air **the bimetal components in water will become straight and shift the axis weights from the wheel axis.** This phenomenon initiates motor operation.

Let us consider this process in more detail.

On touching water, the bimetal component in the loop-shaped part becomes straight and shifts a weight from the wheel axis. The wheel becomes unbalanced, obtains torque and turns clockwise. This rotation makes the following bimetal component on the next loop-shaped part of the following spoke touch water. This bimetal component also becomes straight and shifts a weight from the wheel axis, generating an increased torque that turns the wheel clockwise.

At the same time a bimetal component comes from hot water on the left side of the wheel in zone “A”. The component cools and restores its initial form, i.e. it curves more and pulls the weight on the spoke to the rotation axis. This leads to a decrease of its counterclockwise torque that affects the wheel.

The loop-shaped parts on the left side (A) and the right side (B) of the motor wheel will cause asymmetry in the number of weights projected by the spokes. On the motor left side (A) the weights will be projected from the wheel axis when the spokes are located in corner “C”. On the right side (B) the weights on the spoke axes will be shifted from the axis when the spokes are located in corner “D”. Fig.2 shows that corner “D” is far larger than corner “C”. This means that more weights will be shifted on the right side of the wheel in zone “B” than on the left side in zone “A”.

Fig.2 shows that the wheel weights generating a clockwise torque are projected on the right side. On the left side in zone “A” only one weight is projected and it generates a counterclockwise torque. More weights shifted from the wheel axis on the right side will generate a greater clockwise torque than the weights shifted from the wheel axis on the left side. This is the cause of the wheel clockwise rotation.

This interesting effect is achieved due to the loop-shaped parts on the wheel spokes with bimetal components placed on them. When the next wheel spoke reaches corner “D”, the bimetal component connected with it touches hot water, becomes straight and shifts the corresponding weight further from the wheel rotation axis. The motor wheel continues rotation, making the next bimetal component touch water. It is also heated, becomes straight and shifts the corresponding weight from the wheel rotation axis. The wheel continues rotation. Bimetal components are touching water in succession. On the left side, in zone “A”, the bimetal components successively come out of hot water, cool in comparatively colder air, return to the initial sharply curved form and pull the weights on spokes to the wheel rotation axis. This is the reason for the wheel torque to decrease.

Mass movement from the axis in a rotating object commonly causes reduction of rotation speed. And, on the contrary, the rotation speed increases when the mass comes close to the axis. In motor zone “A” the weights come close to the rotation axis after the corresponding bimetal components come out of hot water, and the same number of weights move from the center in zone “B”, i.e. these effects on the rotation wheel compensate each other.

In essence this is a heat machine. The heat transfer from a warmer medium – water – to the cold medium – air – is achieved owing to the heat capacity of the band-form bimetal component. This is the reason for fast heating and cooling processes. Due to the fact that bimetal components are not large, not so much heat is needed for their heating.

The motor will operate when the air temperature exceeds that of water but in this case it rotates counterclockwise.

There is another model of this motor when nitanol components are used instead of bimetal ones. Nitanol is a memory metal alloy that changes shape when reaching certain temperature. In this instance, the nitanol component is normally curved but becomes straight when heated (for example, up to 50^0 C), and the weight on the spoke end moves from the wheel rotation axis initiating rotation of the wheel. That means similar operation of a nitanol-based and bimetal-based motor.

The motor structure is very simple and its operation does not require power or fuel supply: it is enough to place its wheel into the water the temperature of which is different from that of the air.

The motor structure may be further developed: for example, a focused sun ray can be used for the heating purposes; the bimetal component can be heated with a common electric lamp on one side of the wheel, the required heat may come from a heating radiator, stove or burning gas-jet. Such motor may be heated when installed on a mantelpiece, etc.

This article describes the motor model that can be used as a toy. Being supplied with looking-glass units it may be applied to get various luminous effects or may be installed in the shop showcases, or else at exhibitions. This motor is also able to operate in a gravity force environment, even on the Moon. There direct sun rays may heat bimetal components to 200^0 C, and the temperature of the components located in the shadow almost reaches absolute zero, i.e. the temperature difference in this instance is over 400^0 C, which enables constant efficient motor operation.

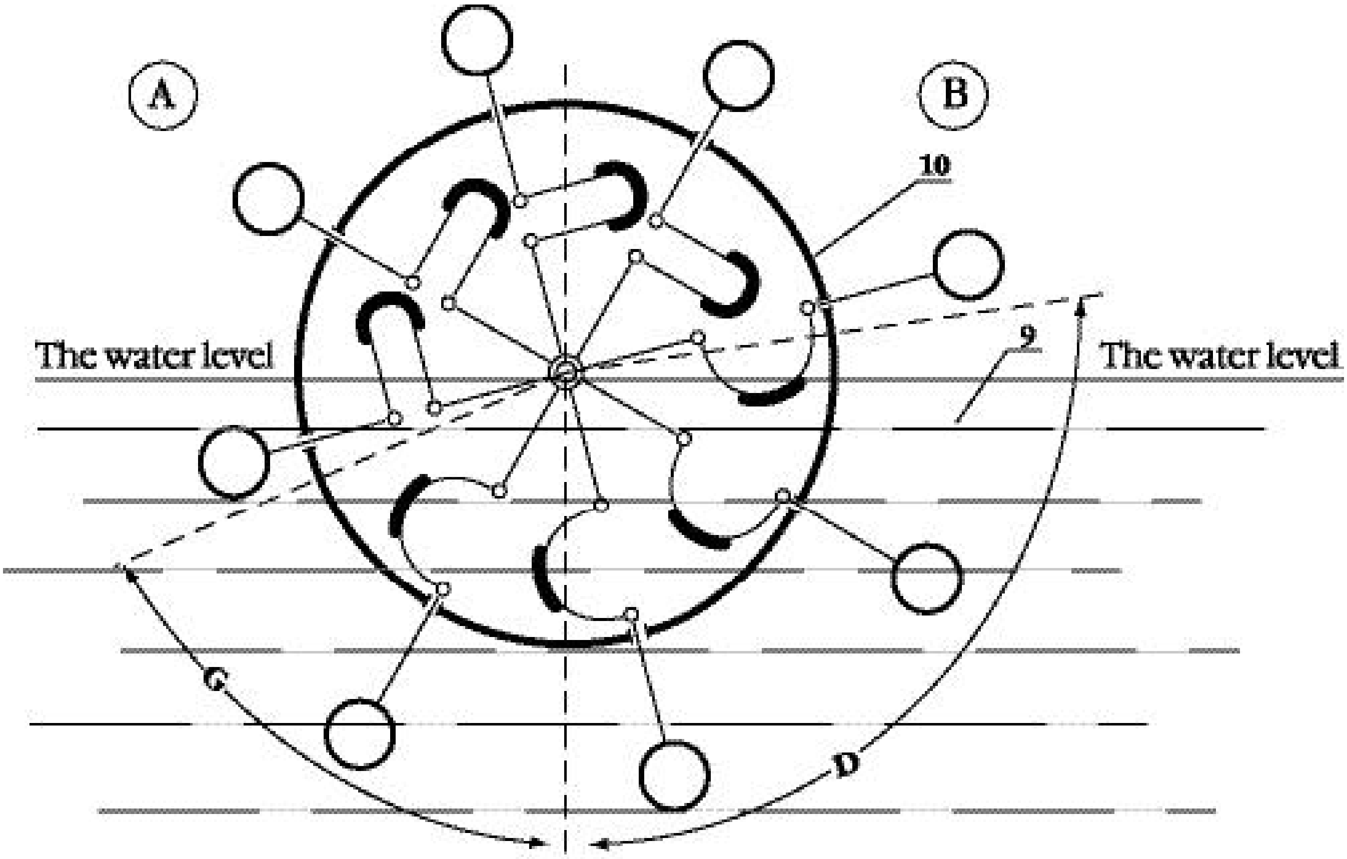

Fig.2
The motor in operation

Self-Interaction in Electromagnetic Rotation

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Introduction

The electromagnetic rotation is the motion of a magnetized body ina direction perpendicular to both the vector of magnetization J_m and the direction of the electric current j in a liquid inside which the magnet is located (Fig. 1).

Editor: Readers can compare this vector composition and the device scheme of Godin and Roschin with the Searl experiments. The similarity is evident. *A. V. Frolov*

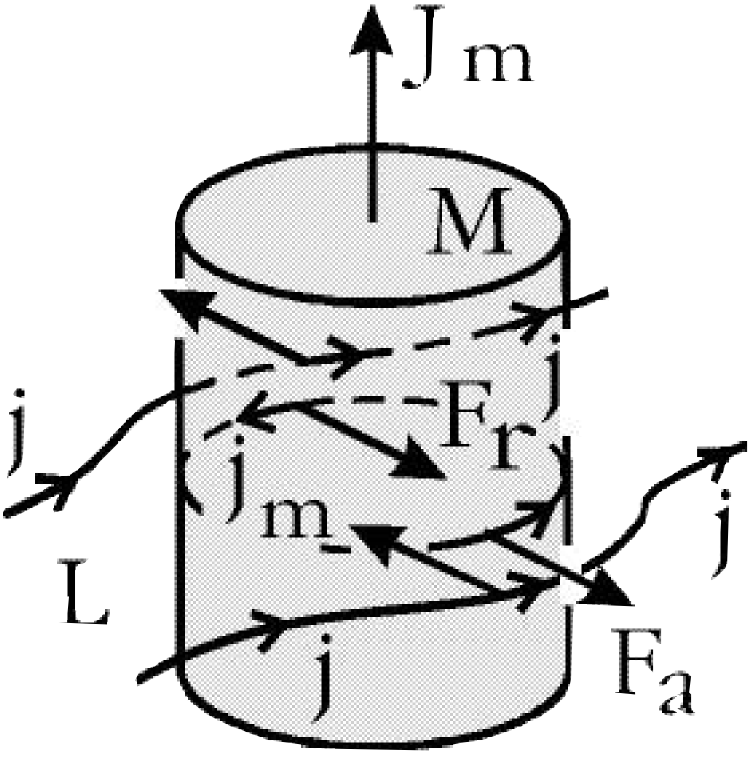

Fig.1
Electromagnetic rotation. A magnet M of magnetization J_m that is partly or entirely submerged in a conductive liquid L with a direct current of density j is moving in the direction of the force F_a+F_r

The force producing such a motion is sufficiently weak and, normally, the phenomenon is observed at rotation. Although, this is quite a well-explored phenomenon [1-6], nobody knows what makes the magnet rotate [4]. There is an opinion [2,3] that the motion of the magnet in the conductive liquid is caused by the forces of attraction $\mathbf{F}_a$ and repulsion $\mathbf{F}_r$ between currents of density $\mathbf{j}$ flowing in the liquid and surface magnetization currents $\mathbf{j}_m$ of the magnet, often called the Ampere currents as shown in Fig. 1.

The external magnetic field of a long cylindrical magnet originating far from either pole is zero. Therefore, no force is exerted on charges moving in the liquid far from the ends of the magnet. Nevertheless, the magnet still moves in the liquid with the direct current even if it is only a thin magnetized needle [5]. Thus, the deeper the magnet is immersed in the conductive liquid, the more liquid gathers around it. The deeper the immersion is, the higher the total force must be. That should be so.

In reality, it is quite different. During intermediate immersions when the magnet is partly submerged in the liquid, the torque N does not depend on the depth of immersion, in the other words, currents flowing round the cylindrical magnet do not influence the exerting force acting [6]. Moreover, during shallow immersions, the magnet moves together with the liquid. **This is none other than *the self-interaction* [7].** The conductive liquid under the magnet experiences the magnetic action. The direction of this force coincides with the direction of the magnet motion. **Thus, the part of the conductive liquid moving in this direction under the action of the magnetic field B, affected by the frictional forces in the liquid causes the motion of the magnet in the same direction.** The only way to find out the role of the self-interaction in this phenomenon is experimental investigation. It would be appropriate to exclude the currents flowing under the magnet. In this case the magnet must rotate in the opposite direction.

Experimental system

A commercially available cylindrical magnet M of magnetization J_m=1,95•10^5 A/m and a balanced load *P* connected by a rocker R are suspended by a thread *T* as shown in Fig. 2.

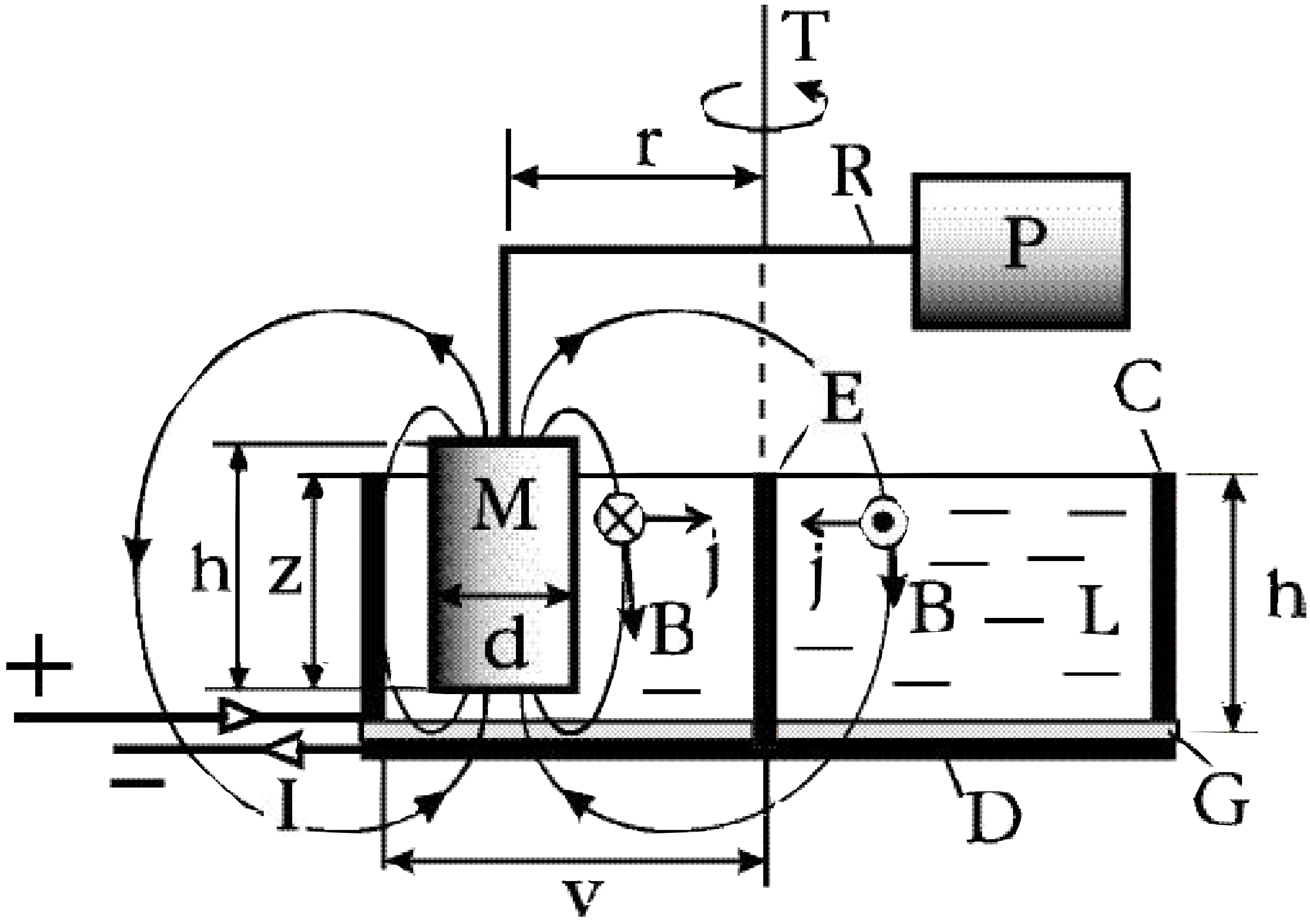

Fig.2
The experimental set and its parameters: h=50 mm, r=35 mm, d=25 mm, v=70 mm, the diameter of the central electrode E is 5 mm, the thickness of the bottom G is 2 mm. (×) and (•) are directions of the force acting on current elements of current density j in the magnetic field of inductance B

The magnet is immersed in the 5% copper sulfate solution ($CuSO_4$) so that the depth *z* of immersion can vary. A vessel containing the conductive liquid *L* is large enough for the magnet to be almost entirely immersed. The cylindrical surface *C* of the vessel and the central electrode *E* of the system are made of non-magnetic materials. The bottom of the vessel *G* is, of course, insulator. The magnet is coated with an insulating moisture-proof varnish. The length of the electrode *E* equals the height h of the vessel. A direct current of strength *I* passing through the cylindrical electrode *C*, the conductive liquid *L*, the central electrode *E* and the disk electrode *D* generate a torque of electromagnetic origin which results to the rotation of the magnet. The disk electrode *D* is intended to provide the system with the symmetrical supply of the current.

Experimental results

The size of this experimental device differs from that described previously [6]. **As a result we have obtained the torque N, which is about ten times more intensive than the former one.** But the main result is that the torque does not change its sign when the magnet is being immersed in the conductive liquid (Fig. 3).

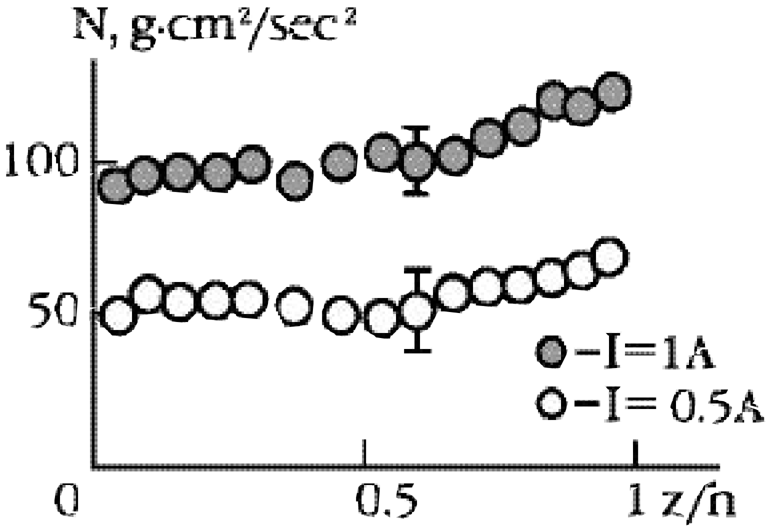

Fig.3
A typical experimental dependencies of the torque *N*
acting on the magnet depending on the depth of immersion *z*

When the magnet is almost entirely submerged in the liquid the depth of which equals the height of the magnet, no currents are flowing under and above it. In this case the rotation of the magnet is expected to be the result of drag action of the rotating liquid located in the intermediate field relative to the magnet. This part of the conductive liquid is rotating in the direction opposite to that of the motion of the magnetized body. It seems to be the right way. The magnet pushes the liquid away and, therefore, is moving in the opposite direction. No, this is wrong. If it was correct, this effect would also occur during the shallow immersion. At small *z* the magnet and the liquid rotate together. So far we still do not know what makes the magnet rotate.

S.A. Gerasimov

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Capillary Motor

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For several decades the author has been organizing a contest for young inventors on the radio, television, in mass media and the Internet. There have been accumulated thousands of engineering solutions that belong to schoolchildren and youth. There are many original ones, including perpetual mobile. Though unfeasible in principle, they have interesting structure and competent engineering solutions.

For example, a child's dream to create an oblique roof over a city or field and direct the rain flow to a turbine to obtain mechanical work is of little use. But it's quite another matter if this child takes a pencil, a sheet of paper and tries to make a sketch or a drawing of such construction. Even if the construction is primitive and unfeasible, the child will get his first engineering experience and self-reliance.

I can still remember one peculiar case. Once the editors were instructed (it was in the times of the USSR) to assist an honored inventor of new machines. It was a Stalin Prize laureate, creator of a special type of lime that was widely applied in construction (I will not disclose his name). The inventor was given (that was not common practice) a large room in a shared apartment situated in a prestigious block of apartments in Moscow. It turned out that all room space, except for narrow passages at the walls, was occupied by a huge table. On the table up to the ceiling there were some pipelines, glass and metal vessels, retorts and other laboratory ware. The most impressive thing was retorts heated by gas coming through a hose from the shared kitchen. All that staff was bubbling, hissing and steaming. The inventor was creating a perpetual mobile!

I will give one more example of a situation common for the editors of the "Inventor and Rationalizer". Once we had a respectable-looking visitor who made an odd request to get the President of the French Academy of Sciences to respond to his letters about a perpetual mobile plan. The essence of Alexander Rodionov's (Maloyaroslavets, Russia) invention was that "in accordance with Newton's and Guerin's laws fluid flows up through capillaries and turns a wheel when flowing down (see Fig.1).

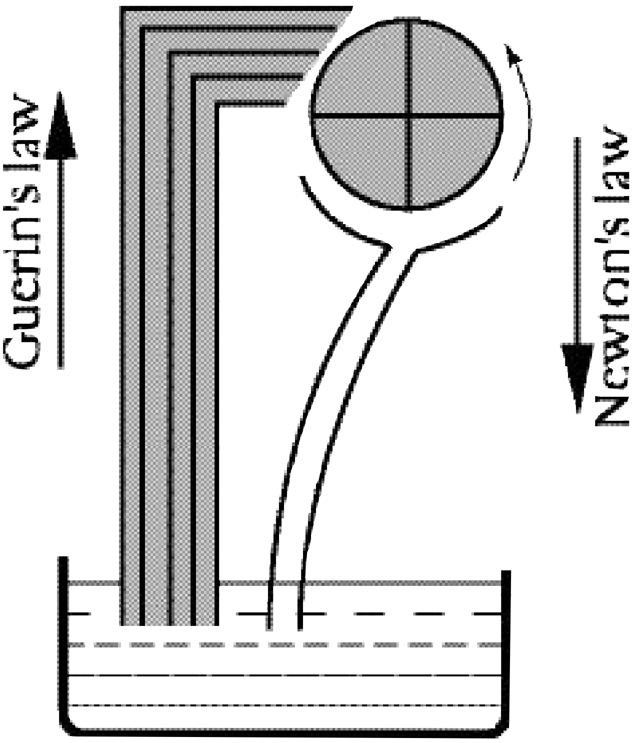

Fig. 1
Perpetuum-mobile

There are many similar projects in the history of engineering. Hence, this case may be considered as typical. We all know that the molecular adhesion forces (moistening) that push the fluid upwards will stick to it and the capillary motor will never work. But is the idea totally unfeasible? Since false modesty is inappropriate when it comes to perpetual mobile, I will present my ideas on this not so honorable subject for the reader's judgment.

It seems that all perpetual mobile inventors start not with a pencil and a sheet of paper but with experimenting on magnets, oblique plane, wicks, wheels, springs and other materials at hand. My first heat (perpetual) motor was also the result of an experiment.

The "Capillary" idea of Alexander Rodionov haunted me. I recalled that the great Lomonosov devoted lots of time to studying molecular adhesion and capillarity. They are present in everyday life, let alone the nature, especially in plants that would not be able to exist without them. How else would moisture flow up the trunks and stems? But, on the other hand, according to Mikhail V. Lomonosov's data, water flows up only for the maximum of several dozens of millimeters even through the thinnest capillary. But trees may have the height of several dozens of meters! If, as it is customarily considered, moisture flows from one capillary to another of its own accord, why not suppose that a capillary perpetual mobile is feasible? Explanations that moisture in plants flows up due to root pressure do not sound plausible. So where is the truth?

Years have passed since that visit of A. Rodionov. Now, just like I used to sympathize with, as it then seemed, a rather odd inventor, now my relatives sympathize with me. One can not blame them: for weeks and months there have been flowerpots all around the apartment - on the tables, window-sills and bookstands. With bottles, tubes and self-made water manometers to follow.

Once, when I was assembling a device, I could not find two similar glass tubes and had to put in the tube of thin polyethylene. But no matter how hard I worked the water in the communicating vessels was at different levels. In the glass tube the water level was always higher. It could not be otherwise, if you come to think of it, but isn't it the right time the words "made of equally wettable material" were inserted into the communicating vessels law?

Here is a primitive experiment: make a hole in the bottom of a plastic flowerpot containing soil and a plant, and insert there one end of an elastic tube. The other end is inserted into the bottom of a plastic bottle containing water (see Fig. 3). In accordance with the communicating vessels law, the water will flow from the bottle into the flowerpot. When we see that the soil has been made wet, the experiment shall get more complicated: elevate the flowerpot so that its bottom is higher than the liquid level in the bottle. In some days we shall notice that the soil has not dried up and the water level in the bottle has lowered. One should not be a Solomon to guess that the soil or the roots of the plant transfer the water from the lower to the higher level. Here is a typical natural perpetual mobile!

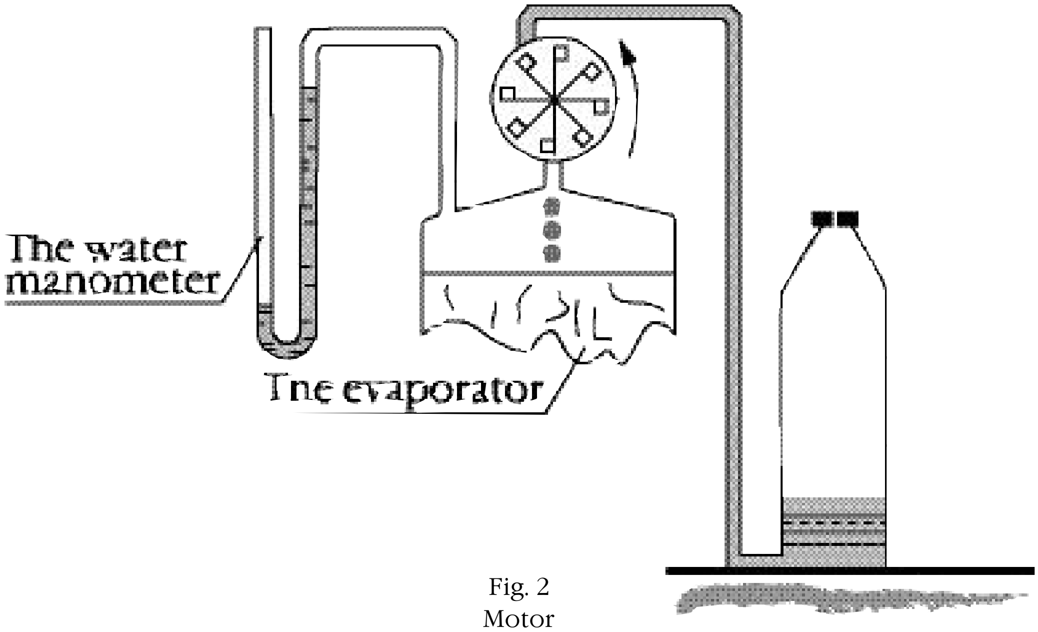

Fig. 2
Motor

It is no use referring to the molecular adhesion forces since they can not be applied at such height differences. What is it then? A molecular collision as in a boiling kettle? But a leaf has neither high temperature nor much space. Nevertheless, water evaporates both from the soil and leaf surfaces. At the same time there is rarefaction under the evaporating surface. Can it be the rarefaction that pulls up new portions of water?

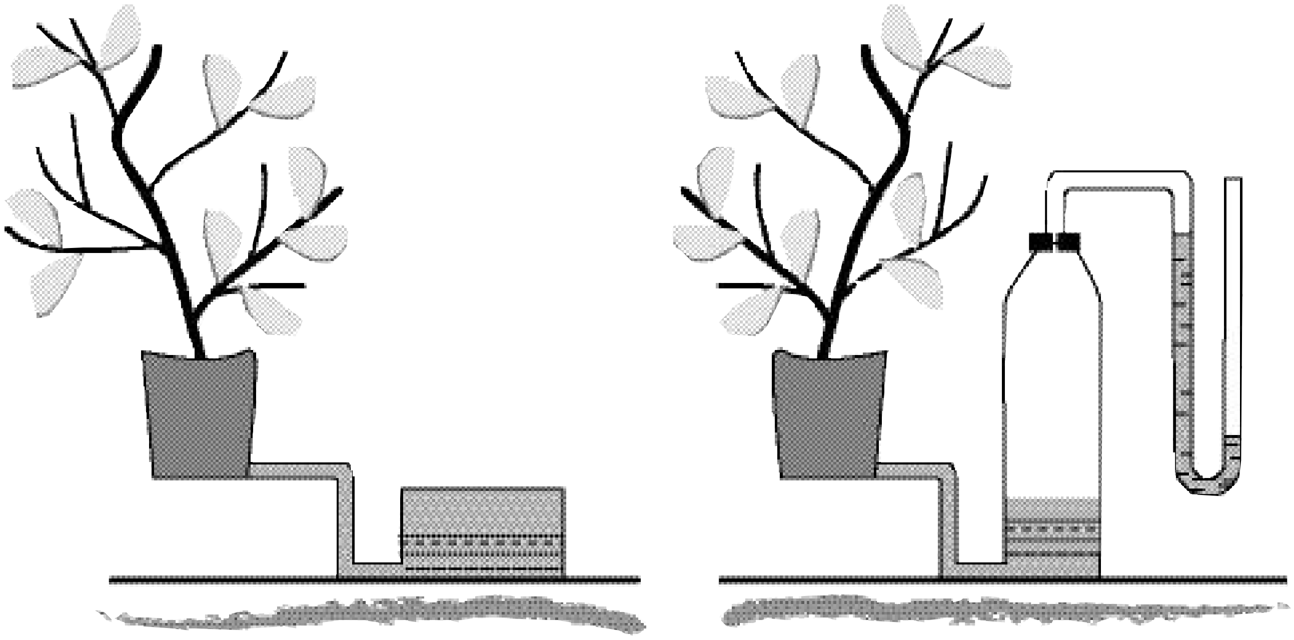

Fig. 3
Rarefaction

Let us make the experiment still more complicated. Put the leg pipe of a liquid manometer into the bottle cork. (Fig. 3) Almost immediately the water level in the closest leg to the bottle will start rising. It means that there is rarefaction in the bottle. Can it be the rarefaction that "rules" the plants?

Most likely, the essence of the mistake made by Rodionov and other authors of capillary motors consisted in attempts to get the water outflow from the capillary. **If it is not flowing out but evaporating, as it is common for the soil or plants, then, probably, vacuum will manifest itself and the capillary perpetual mobile will start working.**

I made my first capillary perpetual mobile many years ago (see Fig. 4). And it worked: though slowly, the wheel was steadily turning. No doubt, it was due to the heat inflow from the air. Therefore, such motor will work if there is a temperature difference and relative humidity of surrounding air is below 100%.

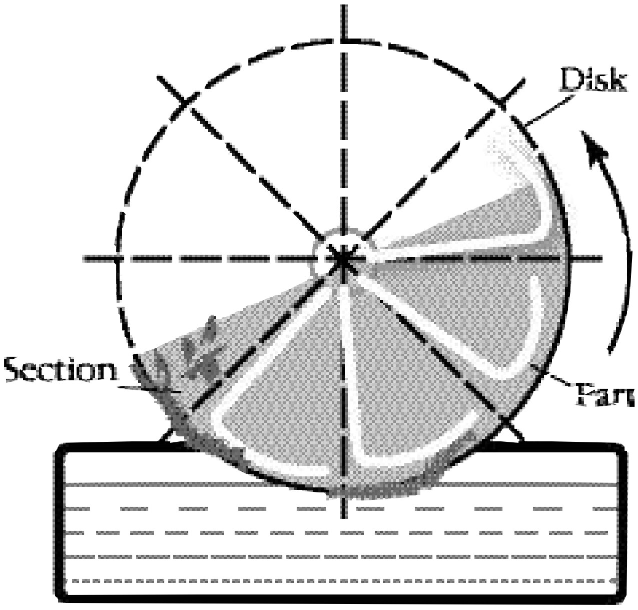

Fig. 4
Capillary Motor

The heat motor operating principle is clear from this figure. The disk (many disks on the common axis) is divided into isolated sections. Their surface is covered with a moisture-proof piece of material (filtered paper, cloth, etc.). The part of each section somewhat gets under the base of the next one. Hence, a small part of the base of one section and a part of the part following the section can get into water simultaneously. Due to the capillary moistening the section and the part will start to absorb water. Since the section is shifted about the center of gravity, the turning moment is bound to appear. The section that is out of water starts to dry up, the moment will increase and the wheel will start turning.

Having determined that, though slowly, the motor is turning, the author applied to a patent authority for a patent on the invention of the "Perpetual mobile", meaning it as a joke. I hoped that the experts (I knew some of them personally) will understand this joke. But, unexpectedly, the device was considered an invention, though under the name of the "Heat motor" (certificate of authorship USSR # 1455040).

Basically, the motor is similar to the project of A. Rodionov. I would not be surprised if he protested. The same capillaries and the spontaneous rise of liquid on the moisture-proof material. The only difference is that the liquid does not flow out but evaporates from the capillaries.

Almost without any reason - one can not predict his eccentricities - I have recently made one more capillary motor (see Fig. 3). Perhaps, it resulted from my experiments with plants. This motor directly and spontaneously lifts water to a higher level, which is more convincing. Moreover, water flows in the form of drops (or a stream) and turns the propeller! The motor is quite operable and has even been shown on TV. But do not try to verify it on your own - such work is useless without certain know-how. The author would not like to disclose the "secret" yet. I could still make a patent application.

NEWS

The Continuous Rotation Device

The essence of this invention is that in a closed circle the rotation of the object occurs without any outer influence or any power sources (electric energy, oil, diesel oil, etc.), which results in the rotation of the rotating part of the device. The torque can be easily enhanced by means of transmitting it to the reduction system. At that rate, the necessary rotation speed and rotation power can be acquired.

The device is small, easy to transport, mobile (both, in operation and switch-off), simple and inexpensive to make and assemble. It is economical, ecological and weather independent.

The device can be used in any industrial or household appliance field where the continuous rotation is required. It is especially important to note that this device can be used to generate energy on a large industrial scale as well as in small laboratories, in mountains and remote districts, in tunnels, at sea, etc. for it does not require any power lines.

Patent Claim Priority:
#20030059, April 19th 2003

For more information
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Gravity-heat Power System

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Natural hydrologic cycle is a widely recognized phenomenon. Water evaporates from the ground and water reservoir surfaces, generally, due to the Sun heat, then moves to the superstructure atmospheric layers where it is condensed, and precipitates onto the ground surface, but on higher levels compared with evaporation surfaces. In this process water is also purified and desalted. From the higher levels water flows to its main evaporation points, forming streams like brooks and rivers where water power plants could be established. Flowing to the lower surface layers with lower potential energy, water in the Earth's gravitational field performs work that can be utilized.

Natural hydrologic cycle principle is used in the gravity-heat power system (USA patent No. 3953971, International class. F03G7/04 of May 4, 1976).

In this system the temperature difference between ground surface layers (the mountain foot and its top) is used to produce electric power and obtain fresh water. The temperature difference does not change much with change of height, and the system effectiveness is quite moderate, which can be named as its drawback.

The system utilizes free environmental energy. Its efficiency (converted to the process maintaining energy) tends to infinity.

The author proposes a new gravity-heat power system that can substitute modern heat power plants. It contains all installation components as per USA patent No. 3953971 except for the heat exchanger on the ground surface whose functions are performed by a conventional steam boiler.

Gravity energy component **G** in the proposed system:

$$G = X_m \cdot T\, g\, H\,,$$

where

- X_m – fluid flow,
- **T** – time of operation,
- **g** – acceleration of gravity,
- **H** – tower height between the steam boiler and the freezer (condenser).

This formula does not allow for vapor density of operating fluid.

The vapor density is insignificant as compared with the operating fluid density.

Energy **P**, required to maintain operation:

$$P = X_m \cdot T\, q\,,$$

where **q** – specific fluid vaporization energy

Efficiency **K** – of the system should not be lower than 80%

To obtain efficiency that equals 120% the following is required:

$$H = 2{,}2q/g$$

Or **H** = 25,4 kilometers.

Construction of such towers is too complicated for modern technology. Therefore, a stratospheric balloon that is linked to the ground surface by a flexible twin-core hose rope may be used. One core is designed to send down fluid and the other to send up vapor. Flowing down to the ground surface through the hose, the fluid will generate fluid column pressure. The fluid will cross water-turbine generator cascades, after each of which the fluid pressure will decrease and the fluid will continue its way down.

There is an alternative. To make the tower several times lower the evaporation (at the tower foot) and condensation (at the tower/mountain top) should be phased (in the form of cascade) at various pressure values and with utilization of the same heat energy. For this purpose a heat carrier is used that will transfer heat from the tower (mountain) top to its foot. This operation will enable the tower height segmentation into **H/n** sections where **n** is the number of grades in a cascade.

Cascade structure is shown in Fig. 1

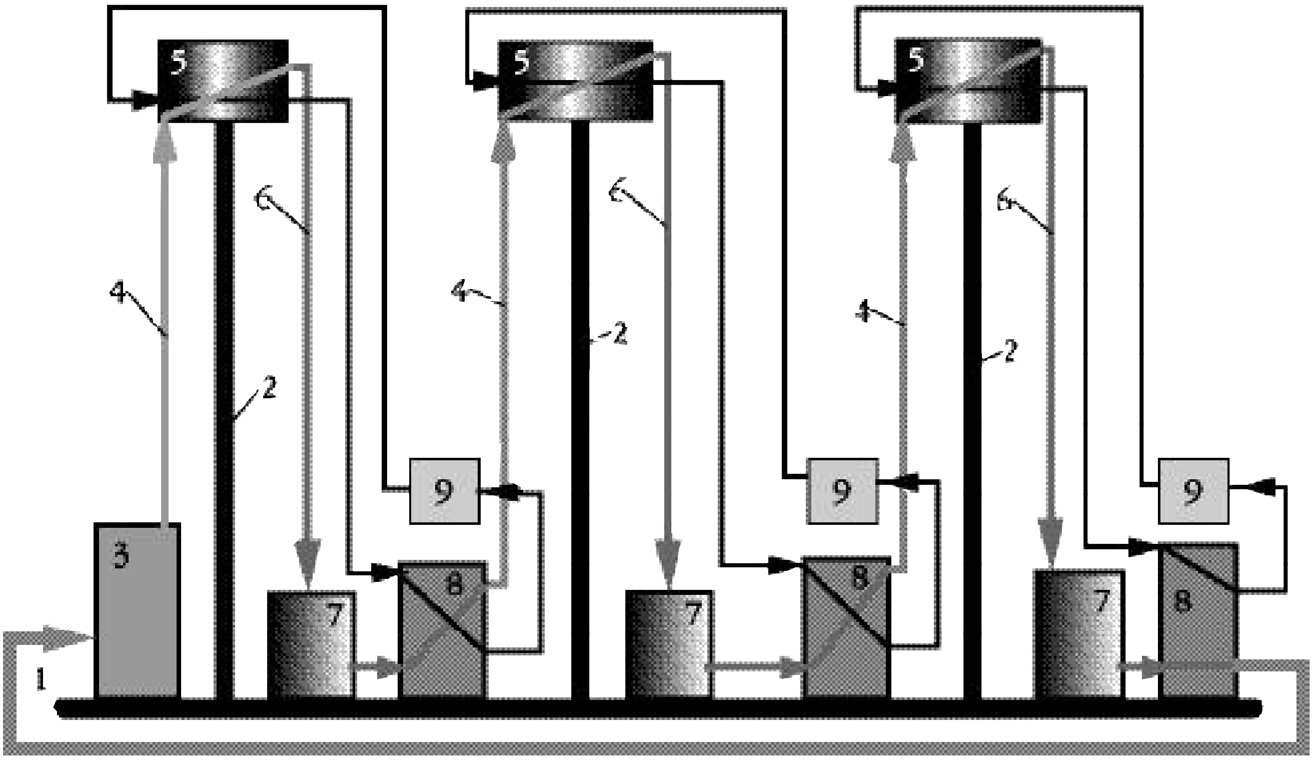

Fig. 1
Cascade

where

1 – ground surface,
2 – tower component or the smoke-stack of the steam boiler,
3 – steam boiler,
4 – steam pipe,
5 – heat exchanger and condenser,
6 – pressure pipeline,
7 – water-turbine generator,
8 – heat exchanger and evaporator,
9 – circulation pump,
10 – pipeline of the heat carrier circulation.

Cascade (operating fluid, water) with 500 meters of height can contain several dozens of grades (50 and more). **In this case the cascade efficiency may approach 120%.**

Decreasing the tower height to 500 meters (for water) will allow for utilization of conventional water-turbine generators and standard equipment.

In the proposed cascade the heat energy is required to maintain the cascade working capacity when Earth's gravitational field energy is utilized. In the author's opinion there are still other ways to use gravitation.

The system scale is its main drawback. Therefore, partial utilization of the proposed principle may seem more attractive. The proposed engineering solution was simple.

In a thermal power station the condenser is installed on the top of the tower (mountain). After the condenser the water lift in the water tower finished at the steam boiler pressure pipe (omitting the pump that was no longer necessary). Energy required for pressure pipe operation was saved. In other words, the water tower was utilizing the Earth's gravitation at the conventional juncture of vapor condensation in the steam plant.

Such proposal was made on June 17, 1982 in the patent application USSR N3453603/06, (101161) expert code 060701KH. However, the utilization of free and environmentally friendly gravity energy did not arouse interest even on the part of patent experts.

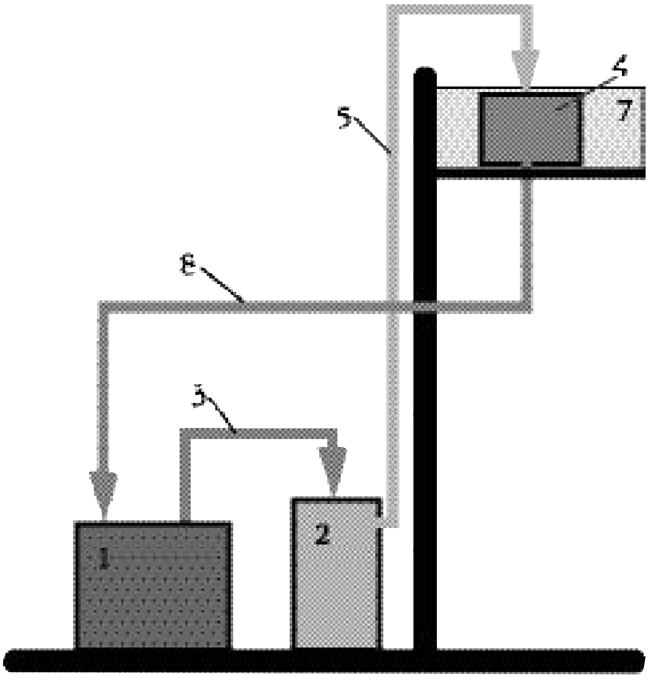

Fig. 2
System

The author is looking for serious partners.

The Alternative Energy Potential in Russia

According to the International Energy Agency (IEA) calculations, total investments into the energy industry constitute approximately 330 billion dollars annually. Almost half of this sum (150 billion annually) is allotted to the development of the electric power industry. This information only partially reflects the potential of the alternative energy development and does not include the market growth factor upon the introduction of autonomous power system technologies. Vast territories of the planet have not been sufficiently developed yet due to the absence of local energy resources and power lines. From this point of view, Russia is the country with an enormous consumer demand potential provided that the mass production of autonomous fuel-less energy systems guarantees low production prices.

Alexander V. Frolov
Editor-in-Chief

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Modern Perpetual Mobile

Review prepared by correspondent Alla Pashova, Russia.
Based on the Internet pages and other information sources

It is common knowledge that any experimental information, which is against a conventional scientific paradigm, is considered to be false, extracted from the society and finally is turned into something **classified and elite.**

Politics-oriented science as a whole and natural science in particular often result in misrepresentation and falsehood of **popular knowledge** that turns it into the fighting weapon of socio-political organizations, states and their groups.

World-outlook and political contradictions of any society often determine science development strategies. In 1885 Nicola Tesla presented his transformer in action by means of which he lit carbon lamps in a 25 miles circle without any cords, conductors or switches using the 5000-HP turbine of the Niagara hydroelectric power station. Afterward, he obtained financial support for one of his energy projects.

On a special testing ground Nicola Tesla built vacuum-energy systems. However, in 1885 the systems, as well as the testing ground, were destroyed as it became evident that if they went on the mankind would never need organic fuel again. But the destruction of the systems and testing ground does not at all mean the destruction of papers and documents...Ever since that moment people have been trying to find "free energy".

The experiment of distant lighting of carbon lamps without using any cords was repeated only once by the physicist Filippov. He managed to light the lamps in Tsarskoe Selo employing the electric generating systems in St. Petersburg. Filippov died in 1914 under mysterious circumstances.

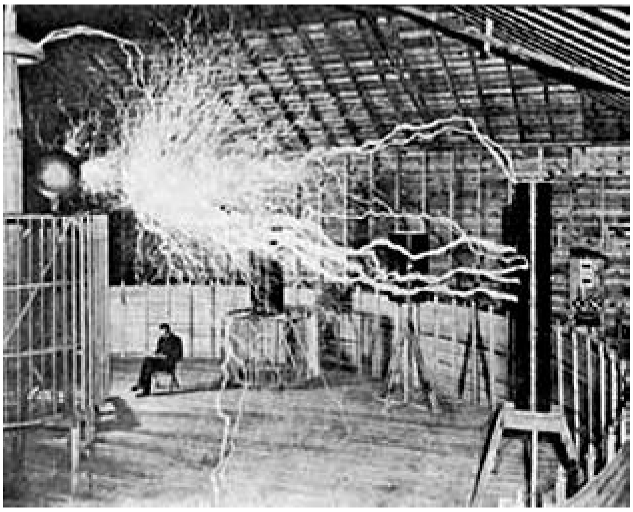

In 1917 the Portuguese American Andres invented non-convetional fuel for an internal combustion engine. The essence of his invention was in some inexpensive chemicals, which he dissolved in water (some drops of chemicals per pail of water). A special state committee tested the new fuel during the New York - Washington - New York automobile races. After the races one of the largest oil monopolies in the U.S. offered Andres 2 million dollars in cash for the documents and all rights for his invention and later locked all the information in their safes. Two days later after getting the money Andres disappeared. (The information was disclosed by V. Vasilevsky, the former chief of the scientific and technical intelligence department of the KGB of the USSR, who had been in charge of the department since 1930).

The above-mentioned examples show that there were a lot of attempts to develop revolutionary energy technologies. But what then are the grounds for the 'energy crisis' complaints? The answer is simple: the desire of a group of financial and energy multinational corporations for an economic, political and, finally, for a total control of the world. That is why there is no room for "free-energy" hunters in our science, not even as laboratory assistants, not to mention some higher positions.

Practice often negates scientific dogmas, especially when it comes to the efficiency of different devices. In general, the traditional understanding of efficiency is quite limited and should be forgotten. Instead of the traditional notion "efficiency" we should consider the notion "energy-conversion efficiency" (ECE), which has no limits. In 1974 in the USA a six-stroke internal combustion engine was designed which had a double ECE. The fifth stroke of the engine operation included water injection; the sixth was characterized by the water vapor introduction. Firstly, the engine had a higher ECE than that of the Carnot cycle. Secondly, taking the 55 % ECE of the contemporary internal combustion engine, the ECE of a six-stroke engine exceeds 1.

> *Practice often negates scientific dogmas, especially when it comes to the efficiency of different devices.In general, the traditional understanding of efficiency is quite limited and should be forgotten. Instead of the traditional notion"efficiency" we should consider the notion "energy-conversion efficiency"...*

Before the war there appeared "studebekkers" with the fuel consumption of 5.5 l per 100 km. But the fuel-economy record was set by the Japanese. In 1986 they built up an automobile, which used only 0.055 l of fuel per 100 km (about 44 g). Unfortunately, now we do not have plants, which could manufacture automobiles of the kind.

In 1832 Tomson came up with the idea of **a heat-pump unit**. Stating the unity and interconvertibility of substance movements, he proved that the mechanical energy consumption can restore stray heat. At that time cross-Atlantic ships had low-temperature steam engines, which employed exhaust steam and ether vapors. The efficiency of those engines was already higher than the Carnot cycle efficiency.

Now with the help of the facts acquired during the last century we will prove the scientific inconsistency of the orthodox model of the second stage of thermodynamics. In 1941 the English physicists O. Hougen and K. Watson published their work featuring the experimental fact that the ammonia-saturated vapor pressure in liquids was higher than the general pressure. For example, with the general pressure of 50 atm and the temperature of 0^0 C, such pressure was 17 % higher. This means that having placed a semitransparent partition and a turbine between two containers it could have been possible to build up a natural-heat vapor-converter. This method was used by **von Platen, the Nobel prizewinner from Sweden, who constructed a self-rotating centrifugal machine, which provided a 1000 atm pressure when ammonia interacted with water. The heat emitted was enough to compensate friction losses**. It is also known that the Carnot principle cannot be applied to closed cycles. W. Vielstich, 'Combustion Cells', 1968: **"If an entropy change of a reaction is negative, it can exceed 1**. It means that a certain amount of energy can be obtained from the natural heat. Such an effect is possible in electrochemical generators, which employ a direct oxidation process before oxidation and dioxidation".

A demonstrative example of scientific experiments withdrawn from science is discovery # 13 "The knock power-transfer regularity" made on December, 18th, 1962, which makes it possible to create a mechanical "perpetual mobile". The experiment shows that the conventional "knock theory" does not work in practice: **the bouncing energy of a body after it has been knocked can be higher than its energy before it has been knocked**.

Trying to get some recognition, **E. Aleksandrov, Doctor of Engineering Science, made his demonstrative experiment in front of many different commissions: a chilled-steel ball when falling from a 10 m height onto a firmly-fixed chilled-steel plate made a 14-15 m-high bounce**. That was the notorious 'perpetual mobile' as it is. It went on like this until somebody decided to explain the result of the experiment by a metal lattice internal energy. At once, everything was clear. Since that moment the above-mentioned principle has been successfully employed in percussion-action machines. This principle can also be used in simple electric-power systems.

Now we can see that electro-technicians had already constructed demonstrative 'perpetual mobile' machines 10 years before politicians and economists started to speak about the 'energy crisis'.

In 1921 the mass media wrote about A. Hubbard who invented an electromagnetic generator without any external energy supply. The Hubbard generator was used as a boat motor.

...now we can see that electrotechnicians had already constructed demonstrative 'perpetual mobile' machines 10 years before politicians and economists started to speak about the 'energy crisis'...

In 1928 L. Nidershot invented a 300 W electric generator, which did not require any external energy supply. The device consisted of a radio-technical oscillation generator (500 kHz) and a coil. After 68 years there appeared publications about A. Melnichenko who repeated the experiment.

In 1927 T. Brown (England) obtained a patent on the ways of originating a moving power and energy using an electric field. Later, in 1955 while working in France, he presented a system with the speed-capability of several miles per hour using a 2000 eV field. After that he had to stop his experiments and was sent to the USA.

In 1943 N. Tesla presented an electric-motor automobile. The energy was generated by a previously-unknown generator.

In 1960 Stovbunenko (whose research work results were subject to a special verdict of the Military-Industrial Complex) presented his motor, which made it possible to move in his old automobile 'Moskvich' around the city for the whole day utilizing the power of a standard automobile battery.

In 1980 there was a qualitative break through in electro-technical "perpetual mobiles". Baumann's electrostatic machines of the total capacity of 750 kW started functioning in the religious community of Liden (Switzerland), serving all daily needs of the village. (See the photos below)

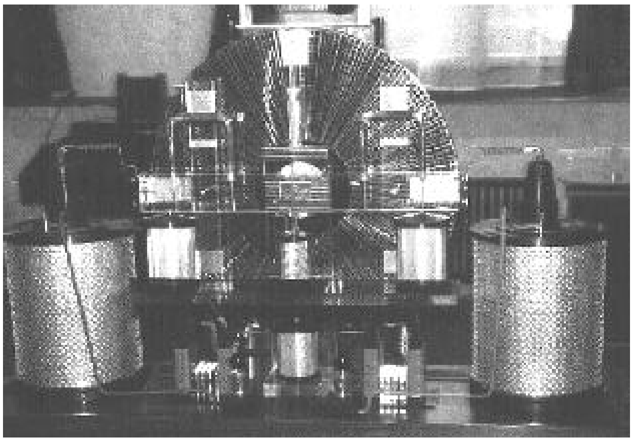

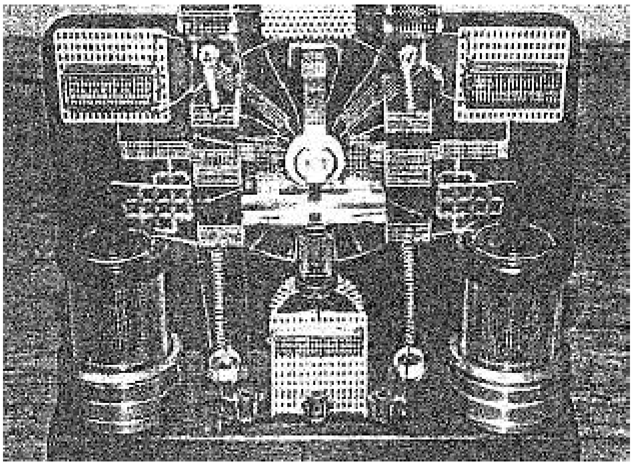

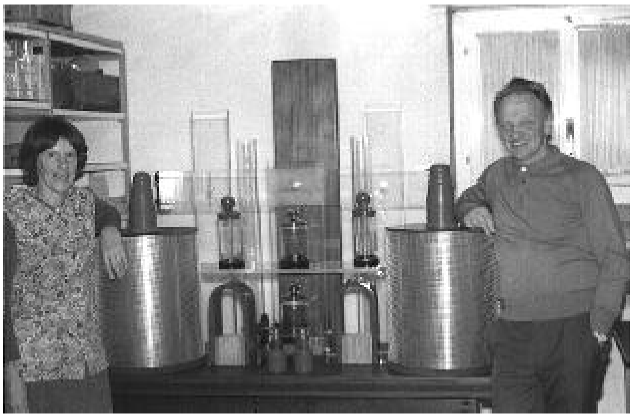

The photos are taken from www.free-energy.cc

Thus, in 1980 there appeared a community with no energy problems, no need for organic fuel and no fear for the 'energy crisis'.

In 1881 N. Sluginov discovered an energy imbalance that occurred in the water electrolysis process. In his experiments he got that the output energy was 30 % higher than the input energy. In 1980 American scientists recreated this energy imbalance and proved that while employing the steam turbine rejected heat, the water electrolysis efficiency reaches 120%.

This information introduces a story about an energy system invented in 1957 under the guidance of I. Filimonenko. The system did not simply generate energy in the form of a high-pressure vapor and output hydrogen and oxygen but also absorbed radiation. In 1960 the USSR Central Committee and Cabinet Council gave a special secret ruling, known as “The Three 'K’s'” (Keldysh, Kurchatov, Korolyov) to go on with the research in this system. However, after Kurchatov's death the project was "oppressed" and later on after the death of Korolyov the project was completely cancelled. The special committee of the USSR Academy of Sciences stated that the system was functioning against "the Law of Nature". I. Filimonenko was dismissed and expelled from the party. Later, in 1980-1991 the experiments were partially renewed. Several testing systems were constructed in the Chelyabinsk region but the construction was never finished and the use of a mobile system for eliminating the damage caused by the Chernobyl accident was refused. This story is a demonstrative example of the traditional rejection of promising projects by science, which could be very beneficial for Russia.

Theoretical Background of 'Perpetual Mobile'

Originally, the term 'entropy' was used only in connection with the reasoning about limited or eternal nature of the Universe. Later it came to be used to describe the functioning principles of thermal machines. Now there exist more than 600 contradictory definitions for 'entropy', which are actually the results of a long and unfinished discussion between the supporters of Dekart and Leibnitz, who defined 'motion' in different ways. It is these permanent contradictions in the theoretical fundamentals of physics that make it impossible to explain the existence of a 'perpetual mobile'. However, standard physics has never denied the possibility of creating energy technologies allowing the ECE higher than 1.

We should remember that the basis of the so-called variational calculation is the mathematical apparatus technique of the conventional mechanics. It seems that if system behavior equations directly depend on time, this system cannot fall under any conservation laws. **This is the proof of a complete failure of the conventional energy conservation law!**

> *It is these permanent contradictions in the theoretical fundamentals of physics that make it impossible to explain the existence of a 'perpetual mobile'*

In time-independent thermodynamics the existence of 'perpetual mobile' can be explained by the system internal energy usage. There exist two kinds of thermodynamic systems. Some of them when being heated or affected in some other way start increasing their internal energy while other systems show the internal energy decrease. The latter are called negative absorption systems. The standard version of the first law of thermodynamics does not cover all the processes occurring in such systems. The output of a negative absorption system can be higher than its energy. The additional output is acquired by the gradual internal energy loss.

To cap it all, there are more than a hundred experimental facts that show the limited nature of the Maxwell theory. They were obtained by scientists from different research institutes and construction bureaus, were tested and registered. Thus, for example, in 1973 in the USSR the acoustic magnetoelectricity effect was discovered. The author of the discovery proved the interaction of electrons with ultrasonic waves with a 1000-times energy increase. This is against the Maxwell theory, which absolutely denies effects of the kind. But the limited nature of the theory was never accepted.

However, the examples of the machines in action prove that since 1834 when the first refrigerator was invented, when the cross-Atlantic ships were equipped with low-temperature ether-vapor steam-engines, the contemporary science had no right to introduce 'the second holy principle', especially in the orthodox form of 'the Carnot cycle efficiency'. The modern theoretical physics cannot provide grounds for the negation of creating over-unity devices. That is why we should rely on the physicists-experimentalists who develop the science in a practical rather than theoretical way.

Alekseenko's Fuel-less Motor

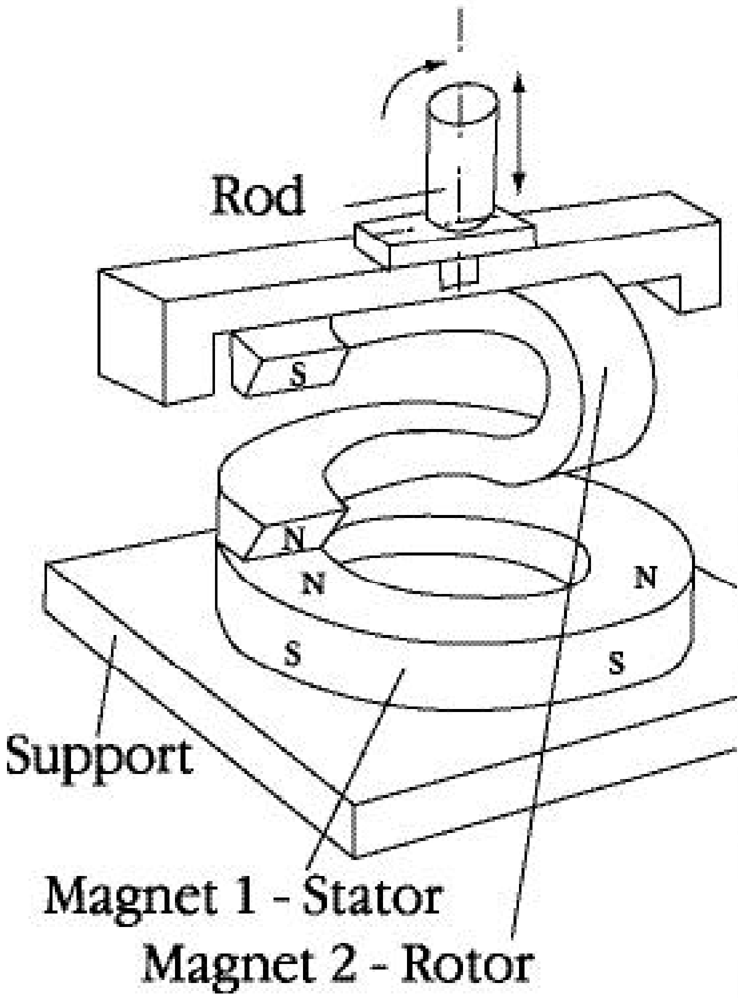

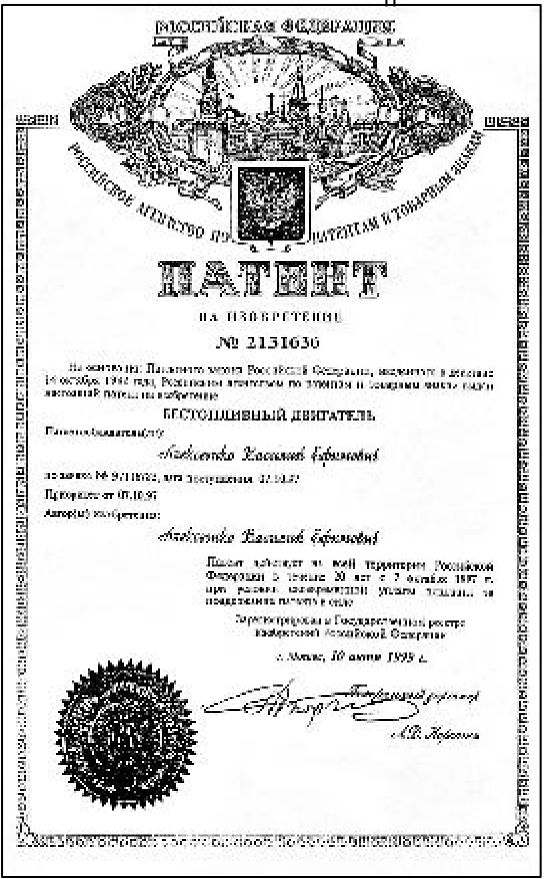
РОССИЙСКАЯ ФЕДЕРАЦИЯ

ПАТЕНТ

НА ИЗОБРЕТЕНИЕ

№ 2131636

БЕСТОПЛИВНЫЙ ДВИГАТЕЛЬ

Алексеенко Василий Ефимович

Алексеенко Василий Ефимович

Patent # 2131636
Vasiliy E. Alekseenko

Aerospace Defense Research Finds Free Energy and Antigravity Possible

Dr. Ines Espinoza, USA
email: dr.ines@vasantcorporation.com

Editor: it is worth mentioning that the first gravitational-wave physical mechanism and the mechanism of spin-effect "grazer" (gravitational lasers) designing were described by S. M. Polyakov and O.S. Polyakov in the book "An Introduction to the Experimental Gravitational Studies", Moscow, 1991.

After a 7-year research study, a senior staff aerospace defense engineer, George J. Bugh, concludes economically free energy and even antigravity are possible.

A 7-year study of "free energy" devices, sometimes called "over unity" devices, was done to determine if any of these devices generated power by transferring energy from unknown sources and if so to determine where the energy was coming from. Included in the study is research of related devices with claimed antigravity effects. The study attempted to determine validity of claims, commonalities of device characteristics and to determine how these devices could work. **The results conclude that some devices can generate economically free energy. This study also concludes there is a possible link between gravity and electromagnetism that can be exploited to generate antigravity or electrogravity effects.**

The majority of the study was to come up with a theory to explain how the devices could work. In his research, Mr. Bugh used mostly classical electrodynamics rather than quantum electrodynamics. In Quantum theory, the wave-like characteristics of matter are described using abstract probability waves. However, Bugh proposes that the wave characteristics of matter may also be described as coming from a very real sea of unseen electromagnetic standing waves among all matter. There is a slide show presentation at the website that explains the differences between the Quantum and Classical way of explaining particle interactions.

According to classical electrodynamics, all electrically charged particles, like quarks of protons and neutrons as well as orbital electrons for example, **should radiate away energy from precessional and precessional plus orbital motion**.

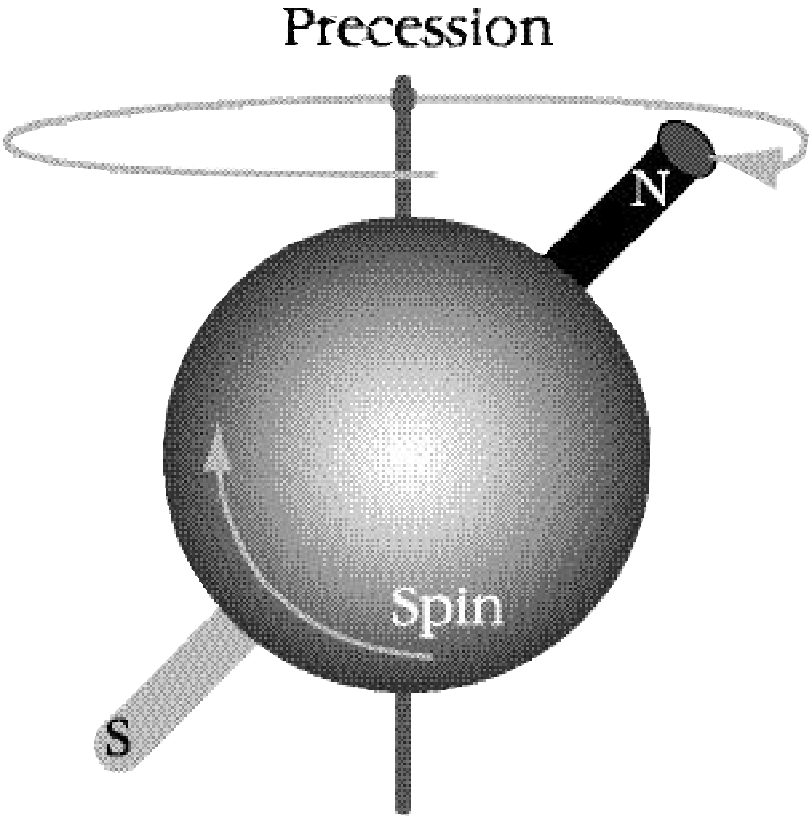

Fig.1
Electron motion

If in fact this really happens then all electrically charged particles can be radiating away energy all the time. However, all particles can also absorb just as much energy from all other radiating particles. The absorbed energy applies electromagnetic forces that naturally move all similar type particles into harmonious precessional motions with all other particles. This results in a vast sea of electromagnetic standing waves among all matter. Even free particles would move into precessional motions that are in sync with the established sea of standing waves.

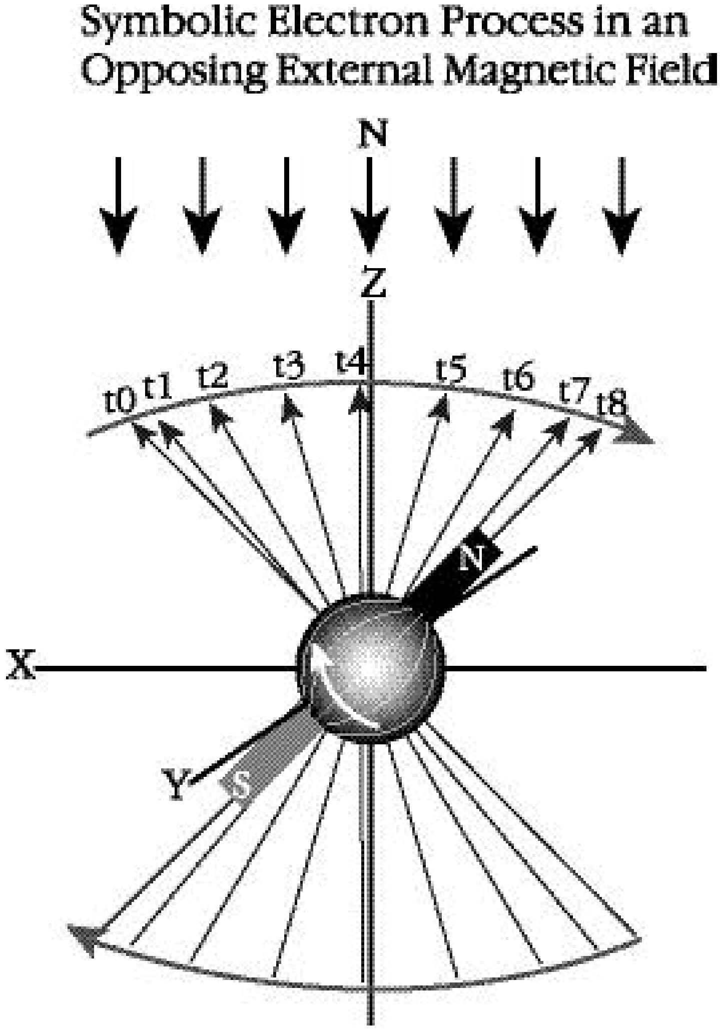
Symbolic Electron Process in an Opposing External Magnetic Field
N
Z
t0
t1
t2
t3
t4
t5
t6
t7
t8
N
X
Y
S

Fig. 2
Electron precession

There can be a hidden yet strong tendency towards harmony among all matter in the universe due to these unseen standing waves and spin interactions among all matter. This tendency can overcome to a great extent the tendency towards chaos and heat death of the universe. This tendency can also be exploited to perform work.

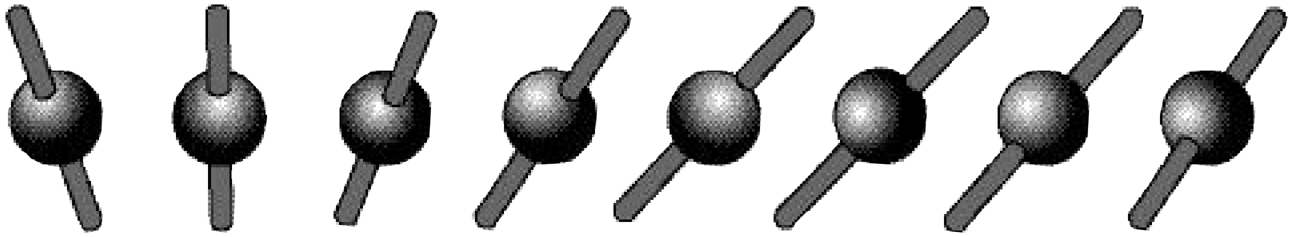

Fig. 3
Spin wave

This is an interaction among all matter that Ernst Mach alluded to as necessary to cause matter's characteristic of inertia. Einstein later called this Mach's Principle. Einstein studied Mach's ideas while developing his theory of General Relativity.

Bugh describes inertial resistance to acceleration as caused by electromagnetic forces. Changes in position of a mass will cause phase differences to develop between the precessional motions of the particles of that mass relative to the sea of standing waves. This in turn causes electromagnetic force that resists a mass from changing its position.

The research papers are published in a book and a CD titled "Spin Wave Technology Initial Release".

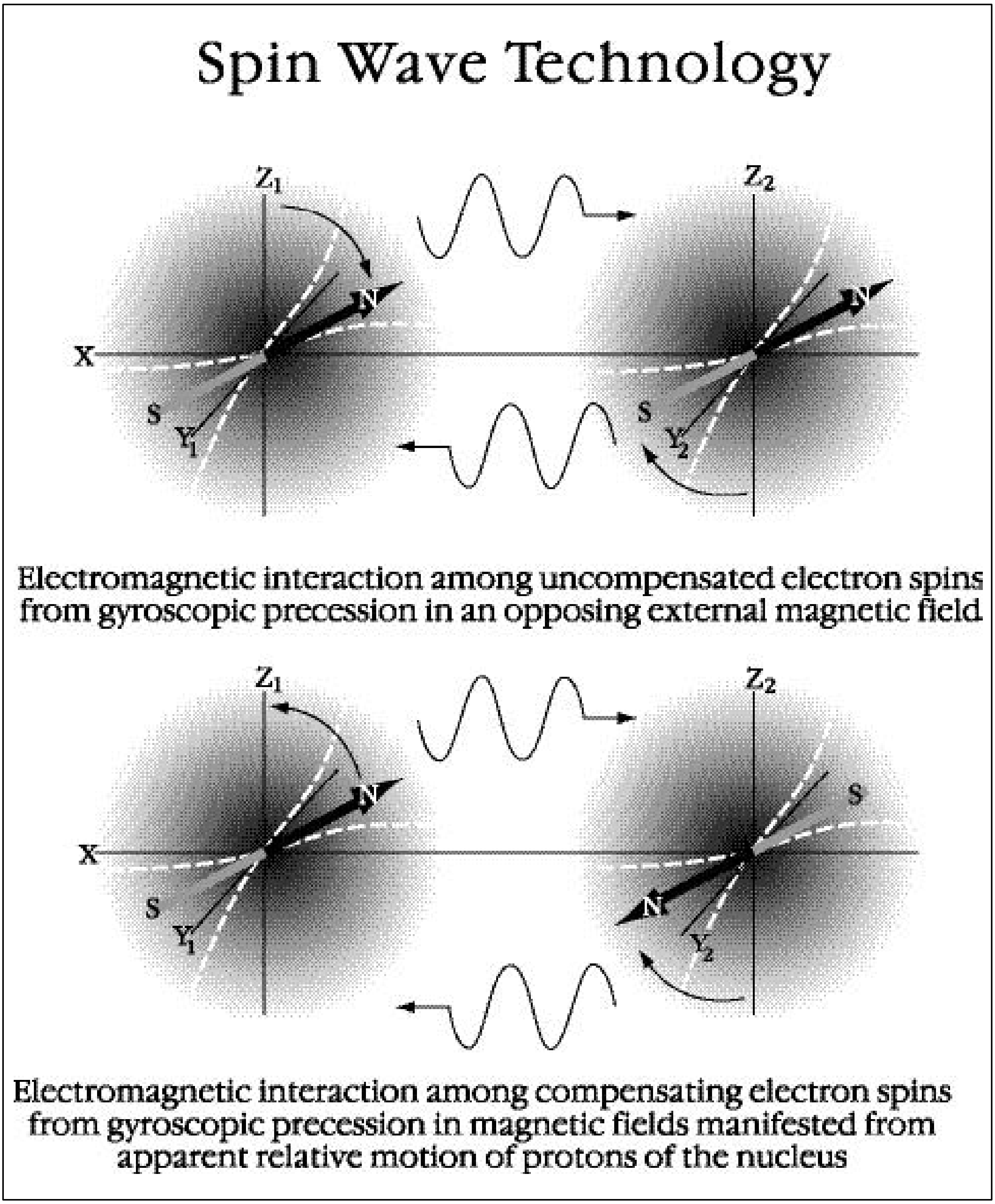
Spin Wave Technology
Z1
Z2
X
N
S
Y1
Y2
Electromagnetic interaction among uncompensated electron spins from gyroscopic precession in an opposing external magnetic field
Z1
Z2
X
N
S
Y1
Y2
Electromagnetic interaction among compensating electron spins from gyroscopic precession in magnetic fields manifested from apparent relative motion of protons of the nucleus

Fig. 4.
Spin wave technology

At the end of the book it suggests that it should be possible to create computer simulations of particle interactions using classical electrodynamics to demonstrate both inertial resistance and gravitational attraction and it should be possible to simulate devices that manipulate these particle interactions to demonstrate antigravity effects.

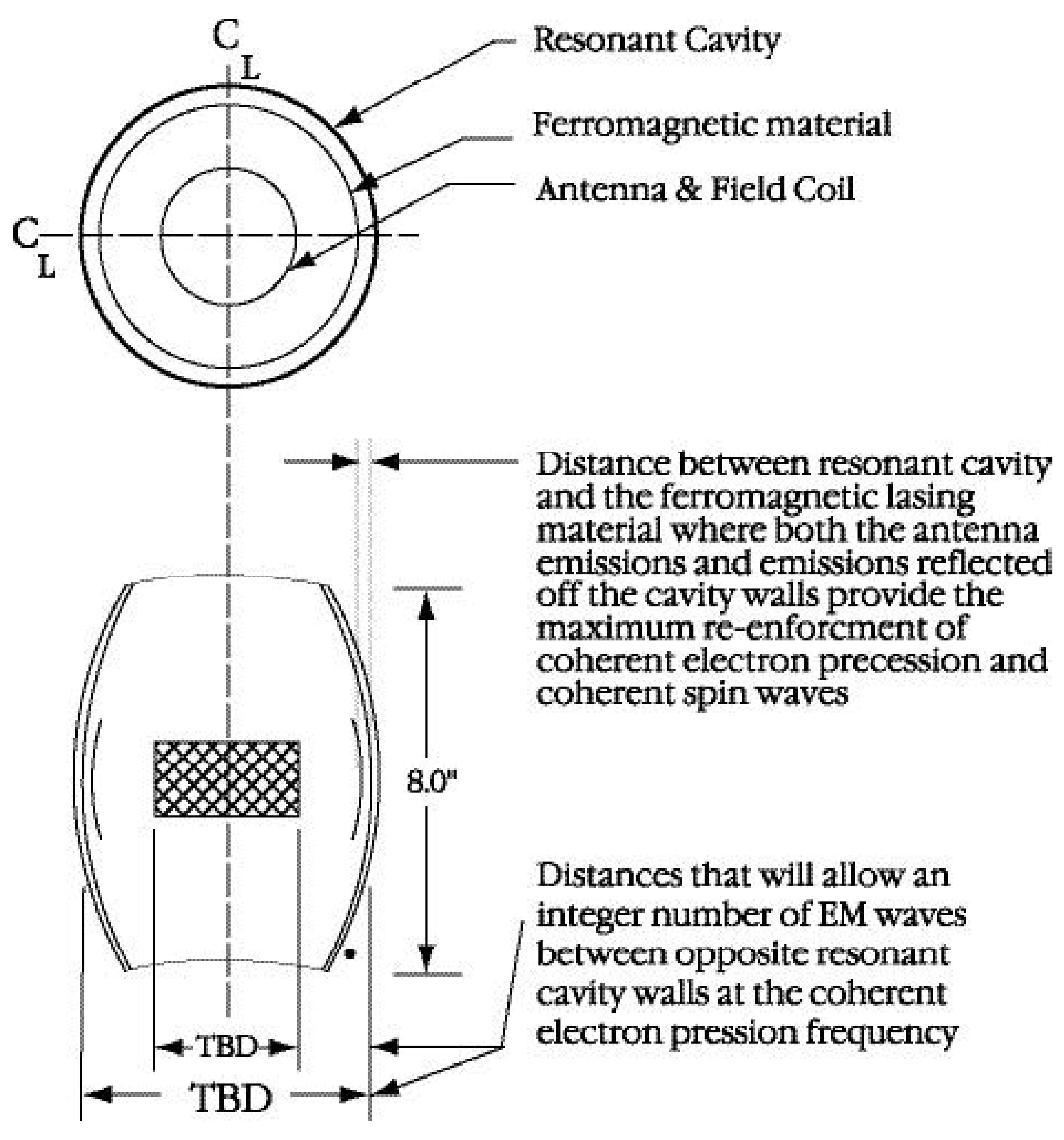
C L
Resonant Cavity
Ferromagnetic material
Antenna & Field Coil
C L
Distance between resonant cavity and the ferromagnetic lasing material where both the antenna emissions and emissions reflected off the cavity walls provide the maximum re-enforcment of coherent electron precession and coherent spin waves
8.0"
Distances that will allow an integer number of EM waves between opposite resonant cavity walls at the coherent electron pression frequency
TBD
TBD

Fig. 5
Spin wave laser

More information is available about the research results at the website: www.vasantcorporation.com.

On Physics of Electromagnetism
Mechanical Analogue or Pure Mechanics?

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After publication of the article "Study of possibility of a high-energy hyper-low-frequency electric field" in the "New Energy Technologies" magazine, Issue #2, 2003 I am often asked why I have mentioned the Big Bang in my hypothesis.

I would like to reassure atheists since I do not back the Big Bang hypothesis. But I had to base myself on something. At present the origin of the Universe as a result of the Big Bang has priority and is recognized by the academic science.

Both theorists and experts have long noticed a deep analogue between vortex motion of air currents and electromagnetism. My vision of the physics of electricity and electromagnetism is fully based on existence of a vortex capable physical environment. What is considered to be and is measured **as electric voltage, electric current, magnetic or gravitational interactions is nothing but similar-originating phenomena - the result of vortex flow environment affecting our detectors - dissimilar formations for these vortex flows**.

For instance, let us consider three vectors for the flow along the skin-layer of the line conductor - aerial emitter, together with alternating voltage attached to it (Fig.1):

1) longitudinal - showing as electric voltage, the gradient of potentials between the emitter feeding point and the emitter cold end, U;

2) tangential - showing as amperage - electric current, I;

3) radial - showing as the interacting force of two flows - magnetic field (attraction/repulsion), H (not to be mixed with the commonly used term of magnetic intensity).

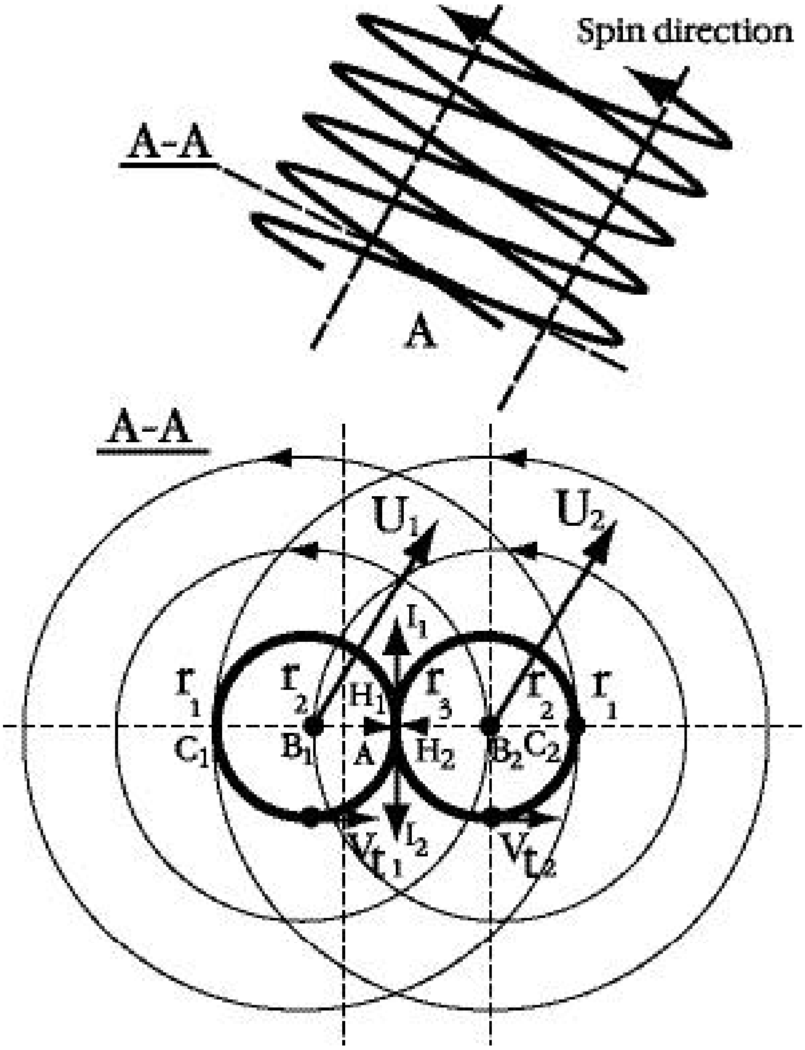

Fig.1
Interaction of two left-handed homogeneous parallel flows.

Let us consider it step by step:

Consider line conductor AB with length L in free space (Fig. 2).

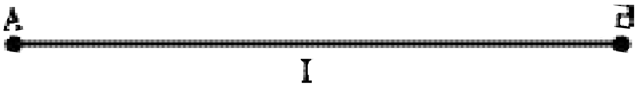

Fig.2
Line conductor in free space.

Let us assume that he is not affected by and fields. Then the gradient of potentials between A and B equals zero. Let us apply sinusoidal voltage from the generator output to point A (Fig. 3).

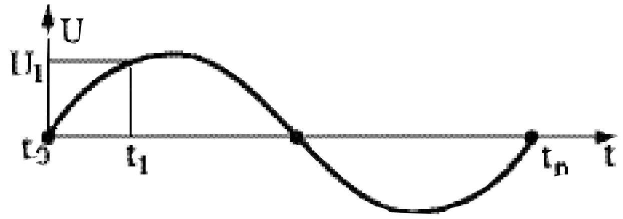

Fig.3
Sinusoidal voltage at the generator output.

Let us consider the initial time point t_0. The generator output voltage is U=0. At time point t_1 the generator output voltage has changed and took on value U_1.

It is necessary to note that (See Fig. 2) the propagation speed is finite: c=300000 km/sec. Point B will "learn" about the voltage alteration only in time $t_B=t_1+L/c$. Therefore, at time point t_1 between points A and B appears gradient of potentials $\Delta\varphi = U_1$. So what is the direction of vector U_1? Right, along conductor AB.

What practice says

One should not be a physicist or radio mechanic to notice small electro-shock of ungrounded metal objects close to aerials of powerful transmitters. Specialists term them as "electromagnetic inducers". Has an expert ever measured the actual characteristic of the field intensity distribution along a line conductor? Why should he? Everyone knows from school lessons how alternating voltage is distributed along the conductor, the length of which is comparable with the wave length (Fig. 4).

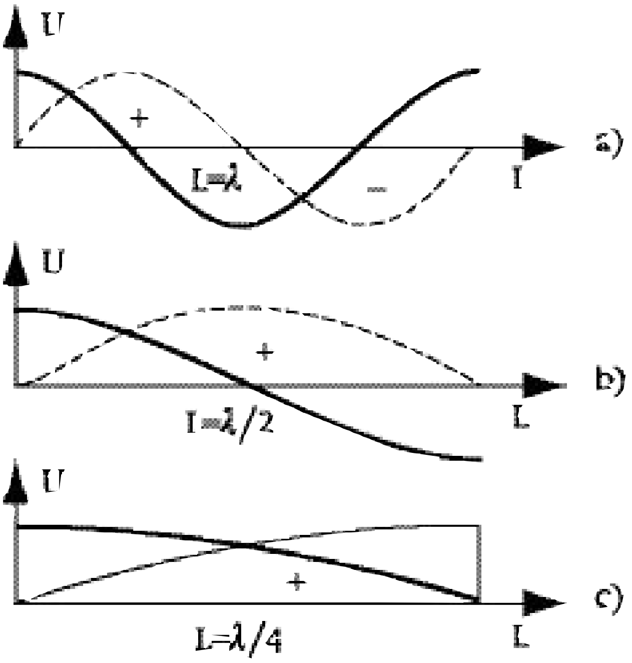

Fig.4
Classical representation of voltage distribution along a linear vibrator a) for λ, b) for $\lambda/2$, c) for $\lambda/4$.

Now let us consider what experimental measurements suggest.

An experiment of measuring the field intensity distribution along the line conductor is shown below. A classic field indicator (FI), assembled as per scheme in Fig.5, was used as an intensity measuring instrument.

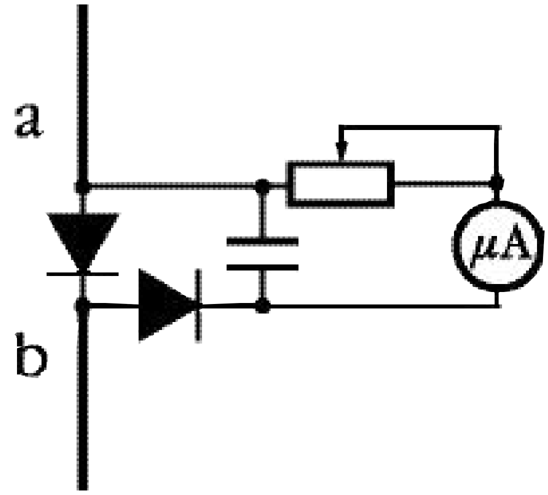

Fig.5
Field indicator principle diagram.

FI was located in immediate proximity to the vibrator but had no galvanic contact with it. Experimental frequencies were selected in accordance with the standing wave coefficient minimum (SWC) for λ, $\lambda/2$, $\lambda/4$. Sinusoidal signal generator was connected to one end of the vibrator (Fig. 6a).

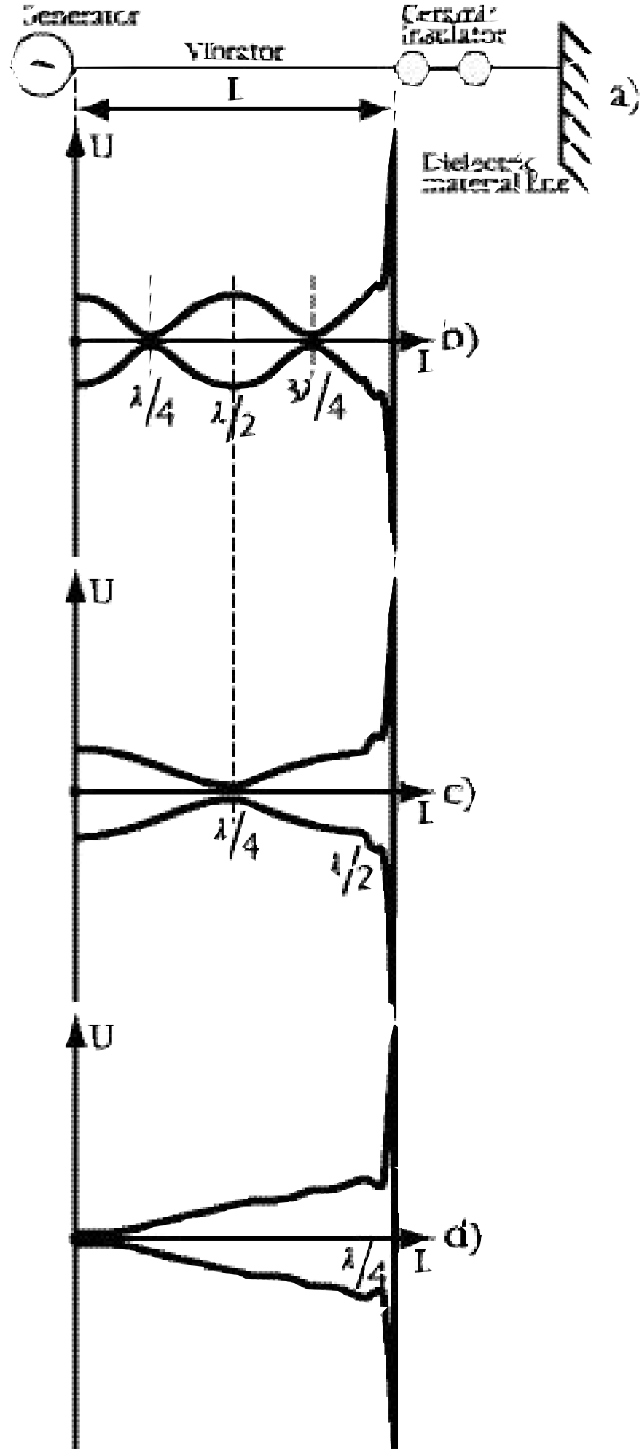

Fig.6
Measured field intensity
along a linear vibrator.

To better understand diagrams in Fig. 6 curves are drawn at the upper and lower ends of each axis L that corresponds to the vibrator location. The curves were run with FI horizontally located on both sides of the vibrator.

From Fig. 6d it is clear that the diagram is axisymmetric and looks like a conic funnel.

Meanwhile, the vibrator directional diagram measured by the monitor receiver far more distant than λ, shows the characteristic that coincides with the simulated one through the Matlab-6 system (See Fig.7). As you can see from this figure, the spatial characteristic of the directional diagram is in the form of a toroid.

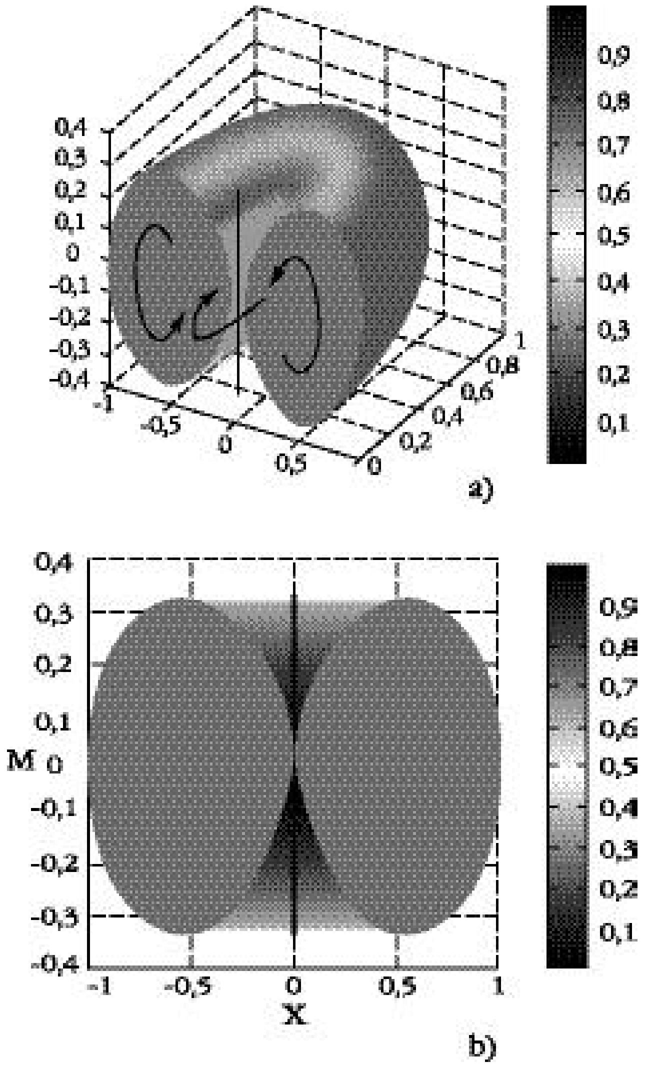

Fig.7
Matlab-6-simulated directional diagram of the semi-wave vibrator

A series of alterations was made to explore vortex ether dynamic processes with variable wave length and frequency in line conductors, solenoidal and flat coils, etc.

For certain purposes the solenoidal coil may be considered as a shortcut linear vibrator. On respective frequencies the field intensity distribution along the solenoid corresponds to the linear vibrator. This data may prove useful to many modern engineers of the Tesla transformers and generators. To increase voltage on the cold end a toroid capacitor is set in the Tesla transformers. Nuclear physicists use the hemisphere capacity for the particle accelerators. Thus, a voltage of millions of volts may be achieved.

Flat coils are best explored in terms of field intensity distribution (See Fig. 8)

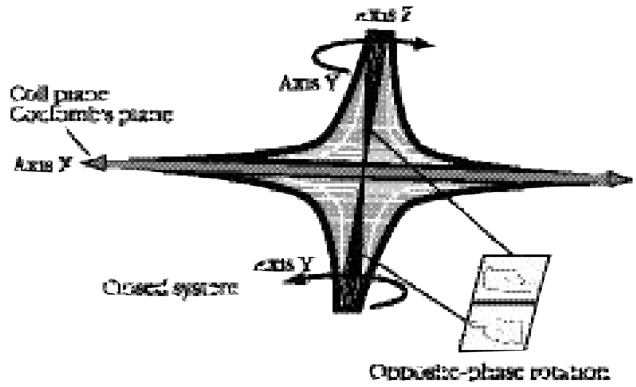

Fig.8
Field intensity distribution for a flat coil in a closed resonance circuit.

Field intensity distribution on a resonance frequency is correct.

The practical experiment for the case in fig. 6d has shown that the neon lamp that is connected with the vibrator end will be off. And this is with a 100 W generator! It is a paradox, one would say. The measurement diagram shows a "splash" of the field intensity at the vibrator end but we feel nothing. Indeed, when the FI is located as shown in Fig.9 for $\lambda/4$, the "electrodynamic vacuum" will generate. The device showed "0" intensity, which conforms neither with the diagram in Fig.6 nor with the diagram in Fig.7.

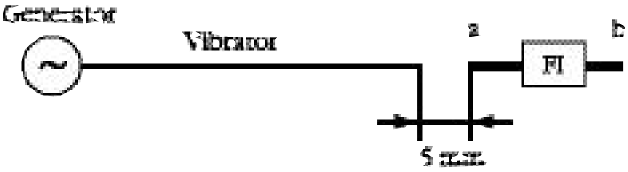

Fig.9
Field indicator shows "0" - "electrodynamic vacuum".

The same "vacuum" in the center of tornado was observed by people in the epicenter.

Remember what is measured with the field indicator (an ampere meter) along the linear vibrator. The Ampere force!

So, both people and their environment are in rotation process. The Earth rotates around its axis and around the Sun. The Sun rotates around the Galaxy center. The Galaxy rotates around the center of the Universe. The Universe rotates...

Every space point has an inceptive rotation impulse (torque). Let us remember the analogy. Water flowing out of the tub rotates counterclockwise in the northern hemisphere and clockwise in the southern hemisphere. If you set a right-handed torque in the northern hemisphere, the water will continue to flow counterclockwise.

The electromagnetism is the same. It has a natural left-handed rotation. Nevertheless, practical radiotechnology is familiar with right-handed fields artificially generated by transmitters.

The commonly used term of magnetic interactions is easier to understand if we consider the electromagnetic field as a vortex flow. Two left-handed homogeneous parallel flows are shown in Fig.1. At the point of interaction A of vector projection, the speeds of flow propagation on section plane **A-A** have opposite direction and compensate each other. The actual flow density is $\rho_1 < \rho_2 < \rho_3$. Reduced pressure occurs at point A. The flows are attracted. The resulting attraction vector for the whole flow is radially directed. The counter parallel flows will have composition, i.e. overpressure, and will repel.

One should note that graphic presentation in Fig.1 for vectors H and I for the etherdynamic systems is possible only in special cases. In dynamic vortex flows the current intensity vector is actually directed towards the flow movement and coincides with the vector direction of its propagation speed (V). The resulting vector H remains a radius-vector only for the considered point of interaction of two flows. The flow energy parameters are defined by its propagation speed V (Fig.1).

I am convinced of existence of ether vortex flows in the Universe. Modern astronomic and cosmological surveys confirm my hypotheses of aether Hyper-fields existence on a Universal scale.

The commonly used term of magnetic interactions is easier to understand if we consider the electromagnetic field as a vortex flow.

Even an amateur in aerodynamics and dynamic of gas vortex may make cosmological conclusions:

♦ vortex initiation implies the initial gradient flow of at least two counter flows;

♦ energy parameters of the emerging vortex flow can not exceed those of the parent flows

♦ there exist ether flows with energy exceeding that of our Universe

♦ our Universe has not originated from a point and is not finite. It is the spiral (vortex) structure of our Universe that testifies against the Big Bang hypothesis.

Conclusions:

Practical radiotechnology is familiar with the key difference between the field intensity distribution diagrams of aerial emitters in near and far zones. After combining diagrams 6d and 7b (Fig.10) it is possible to draw certain conclusions.

When transverse waves (radio waves) are formed around the aerial vibrator, the double transformation of the initial flow geometry starts:

♦ **the first flow is a homogeneous spiral flow on the conductor skin-layer;**

¨ **the second flow is a non-homogeneous vortex flow of the near zone;**

¨ **the third flow is a toroidal flow of the far zone.**

The toroid volume alteration in the far zone (as per the transmitter vibration frequency) forms volumetric planar transverse vibrations (spherical waves) that are called electromagnetic or radio waves. The gradient of potentials alterations (as per the transmitter vibration frequency) provoke changes of the Coulomb plane, which form longitudinal vibrations with a narrow directional diagram.

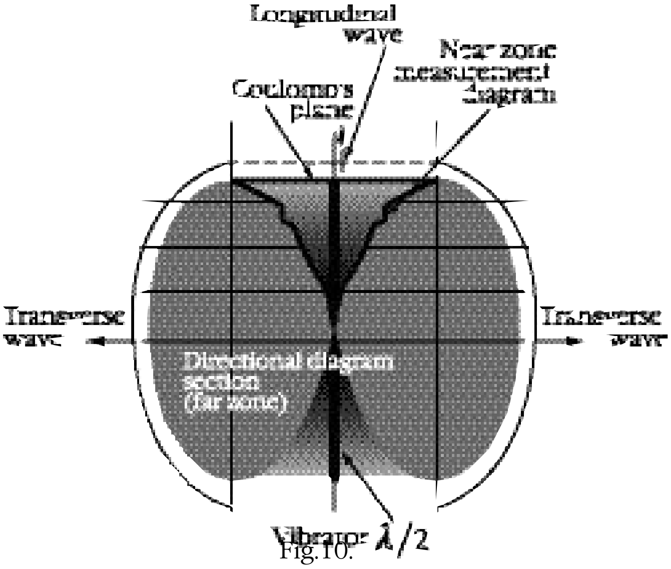

Fig.10.

The longitudinal flow is assumed to be formed as a chain of toroids (like smoke rings)

Ether-dynamic approach provides grounds for more substantial conclusions and assumptions. A new approach to energy and communication systems is made real. Further results of the experiments with transmitters and aerials, assembled on ether-dynamic principles, enabled to draw the following conclusions:

- all reasons, preventing transformation of the transmitter power into the power of transverse radio waves, are evident;
- all reasons for the transverse wave phase lagging with the increase of distance from the emitter, are also evident;
- besides the toroid that forms the transverse wave, the second flow generates a crucially new radiation that has a very narrow directional diagram along its longitudinal axis;
- the aerial ignores wave geometry for the second flow and its longitudinal derivative;
- the radiation along the second flow axis has a very high penetrating power;
- the radiation along the second flow axis has no signs of polarization.

The list of references is not shown in this article due to its size. It can be looked up at **www.efir.com.ua.**

NEWS

In October 2003 the second stage of the research on the "time control" was completed. In the photo below you can see Chernobrov V. A. and Frolov A. V. in the laboratory, October 31st 2003.

The second stage conclusions are quite interesting, however the usage of timers (chronometers) as detectors is proven to be inappropriate for they are subject to magnetization and their indication variations cannot be reliable in this case.

The next stage will feature the following method of detection of the time rate changes (the rate of the matter existence) that is the radiation wave-length measurement. If it is possible to achieve significant results then we will be able to detect the change of the laser ray colour in the area of the effect and its linear path deviations. The experiments will be held to register the weight changes of the detector at the expected influence of the produced effect on the ether density.

Our company looks for cooperation with corporations, which are interested in the application aspects of these technologies.

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CELL OF THE THIN PLASMAELECTRIC HEAT GENERATOR

Ph. M. Kanarev, A.I. Tlishev, Russia
E-mail: kanphil@mail.kuban.ru

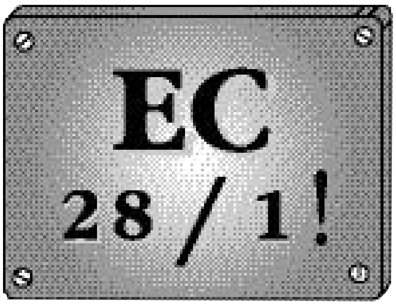

The main task of the experiment was to check the hypothesis: "Electrodynamic influence on the water molecules gives the possibility to significantly reduce energy expenses on destruction of their chemical bonds; further fu-sion of these molecules considerably increases the output of additional energy in the form of heat".

In order to solve this task, special experiments were carried out as regards the electrodynamic destruction of chemical bonds of water molecules by electric pulses of various frequencies.

Photo of the Thin Plasmaelectric Heat Generator

CHECK TEST RECORD FOR PLASMAELECTRIC HEAT GENERATOR

Table 1

	Indices	1	2	3	Avg.
1	mass of the solution, which has passed through the reactor m, kg.	0.470	0.432	0.448	0.450
2	temperature of solution at the input of the reactor t_1, degrees	22	22	22	22
3	temperature of the solution at the output of the reactor t_2, degrees	66	66	65	65.67
4	temperature difference of the solution $\Delta t = t_2 - t_1$, degrees 44	44	43	43.67	
5	durability of the experiment $\Delta\tau$, s	300	300	300	300
6	reading of voltmeter V, V	4.50	4.50	4.50	4.50
6’	**Reading of oscillograph , U', V**	**4.47**	**4.47**	**4.47**	**4.47**
7	reading of ammeter I, A	2.1	2.1	2.1	2.1
7’	**Reading of oscillograph , I'**, A	**2.2**	**2.2**	**2.2**	**2.2**
8	electric power consumption according to indices of voltmeter and ammeters, $E_2 = I \cdot V \cdot \Delta\tau$, kJ	2.84	2.84	2.84	2.84
9	power the heated solution, $E_3 = 4.19 \cdot m \cdot \Delta\tau$, kJ	79.64	80.01	80.72	80.46
10	**reactor efficiency index K = E_3 / E_2**	**28.04**	**28.17**	**28.42**	**28.21**

Supply voltage and current were measured with the help of a voltmeter, an ammeter and an oscillograph (Fig. 1-4)

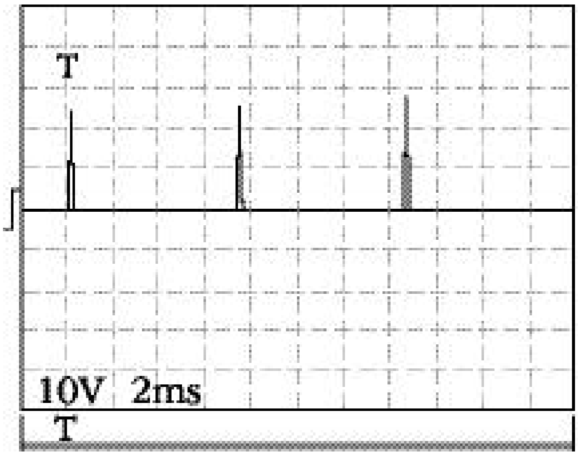

Fig. 1
Voltage

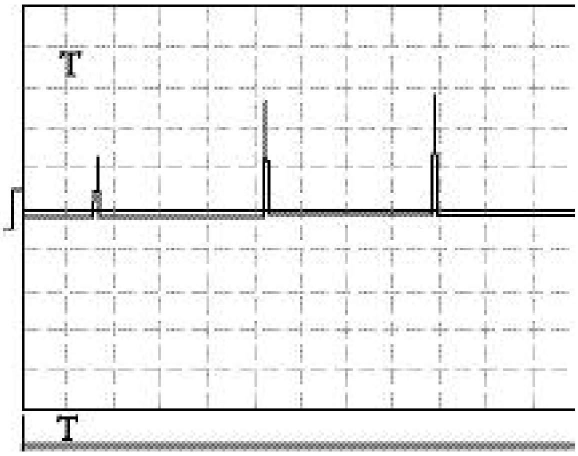

Fig. 2
Voltage

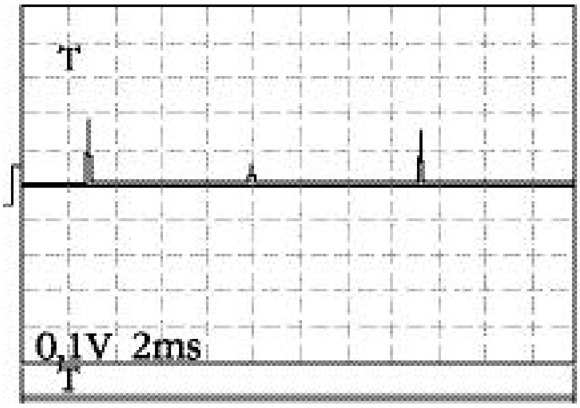

Fig. 3
Current

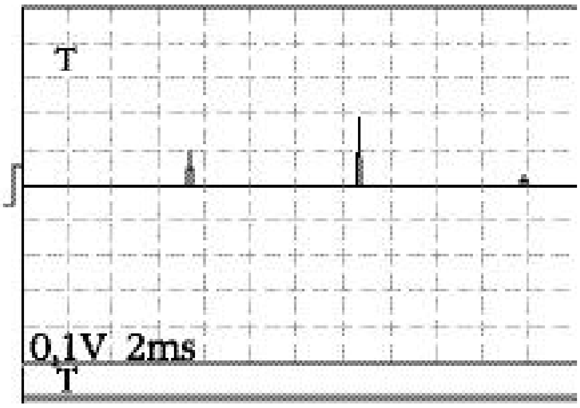

Fig. 4
Current

Process parameter calculation according to the oscillograms (Fig. 1-4) to the check test record (Table 1) gave the following results:

- Pulse scale 10.

- Average voltage amplitude according to Fig.1 and Fig. 2: $Ua_{av} = (23+25+28+10+26+29) \times 10/6 = 235$ V.

- Average current amplitude according to Fig. 3 and Fig. 4: $Ia_{av} = (20+6+17+7+10+19+3) \times 10/7 = 117$ A.

- Pulse repetition period T = 7.4 ms. Pulse duration $t_p = 0.28$ ms.

- Pulse frequency f = 1000/7.4 = 135.1 Hz. Relative pulse duration S = 7.4/0.28 = 26.32.

- Space factor Z = 0.5/26.32 = 0.019.

- Average pulse voltage $U_{av} = 0.019 \times 235 = 4.47$ V.

- Average current in pulses $I_{av} = 0.019 \times 117 = 2.22$ A.

Thus, it is possible to consider that the experimental test of energy efficiency of the water electric heat generator with the help of two methods gives practically identical results and confirms the above-mentioned hypothesis concerning the possibility to generate additional energy in the processes under consideration. It should be noted that as during measurements the pointer instruments of high class of accuracy of 0.2 have been used (relative conventional gauging error does not exceed 0.2%), and oscillographic measurement accuracy is much lower (usually, about 5%), the readings of the voltmeter and the ammeter should be considered more accurate.

Commercial efficiency of the water electric heat generator will depend on pulse generator economy. Since efficiency of powerful pulse generators can be near one unit, energy efficiency in industrial plants that use the considered heat generators should not differ greatly from the data obtained during laboratory research.

Simplicity and one hundred per cent reproducibility of the described experiments open a prospect for quick commercialization of the water electric heat generator.

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2. Kanarev Ph.M. The Foundation of Physchemistry of Microworld. The second edition. (In English). http://book.physchemistry.innoplaza.net
3. Kanarev Ph.M. Water Electric Generator of Heat. http://Kanarev.innoplaza.net

Professor Kanarev looks for co-projects with prospective investors.

• Fantastic Projects •

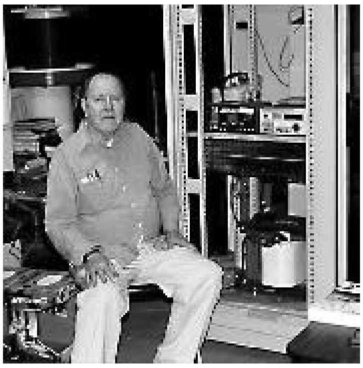

Smith's Generator

Review

TransWorld Energy,
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Don Smith is a University degreed professional in science & engineering. Served in three wars; WWII, Korea and Vietnam. He has enjoyed a long and successful profession as an executive in the petroleum industry. His life long outside interests include electronics and engineering. A popular walk on substitute for University Professors in physics, chemistry, biology and computer assisted drafting. Teaching style similar to Richard Feynman. He enjoys celebrity status in Japan and Saudi Arabia.

About 20 years ago, the book "Inventions, Researches and Writings of Nicola Tesla", resulted in his reconstructing, as a way of understanding the many theories and devices shown in the book. From this encounter, a very strong bonding resulted. The object then became putting his thinking inside that of Tesla, such that expanding upon and extrapolating areas not yet reached by Tesla. Technological advances in materials provide sourcing for devices not possible at earlier periods. For example, magnetic permeability which is the counter part of negative resistance is an open field for experimentation today.

Don does not sell his inventions, but trades licenses for shares in companies which then incorporate the new technology into their marketing systems. As such, he is on the Board of directors of several well established ventures located in Japan, Brazil, Mexico and Saudi Arabia.

Successful reproductions of Don's technology are present in Finland, Saint Petersburg - Russia, Yugoslavia, Romania, Japan, Hong Kong, and numerous other Countries. His book "Resonance Energy Methods" has a circulation of 40,000 copies in worldwide in many languages.

generators can be near one unit, energy efficiency in industrial plants that use the considered heat generators should not differ greatly from the data obtained during laboratory research.

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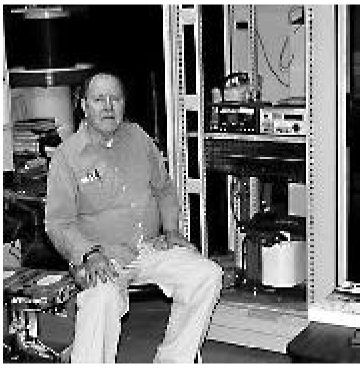

Smith's Generator

Review

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Email: donsm1@earthlink.net
http://altenergy-pro.com

Don Smith is a University degreed professional in science & engineering. Served in three wars; WWII, Korea and Vietnam. He has enjoyed a long and successful profession as an executive in the petroleum industry. His life long outside interests include electronics and engineering. A popular walk on substitute for University Professors in physics, chemistry, biology and computer assisted drafting. Teaching style similar to Richard Feynman. He enjoys celebrity status in Japan and Saudi Arabia.

About 20 years ago, the book "Inventions, Researches and Writings of Nicola Tesla", resulted in his reconstructing, as a way of understanding the many theories and devices shown in the book. From this encounter, a very strong bonding resulted. The object then became putting his thinking inside that of Tesla, such that expanding upon and extrapolating areas not yet reached by Tesla. Technological advances in materials provide sourcing for devices not possible at earlier periods. For example, magnetic permeability which is the counter part of negative resistance is an open field for experimentation today.

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Abstract

Mr. Don Smith has discovered that Ohm's Law of Resistance does not apply to Magnetic Resonance that travels unrestricted for great distances. Therefore, multitudes of electrons are disturbed. The Magnetic moments are translated into usable electric energy. The Magnetic Dipole provides an unlimited source of electrical current. Mr. Smith's "Dipole Transformer" has been pending since last September.

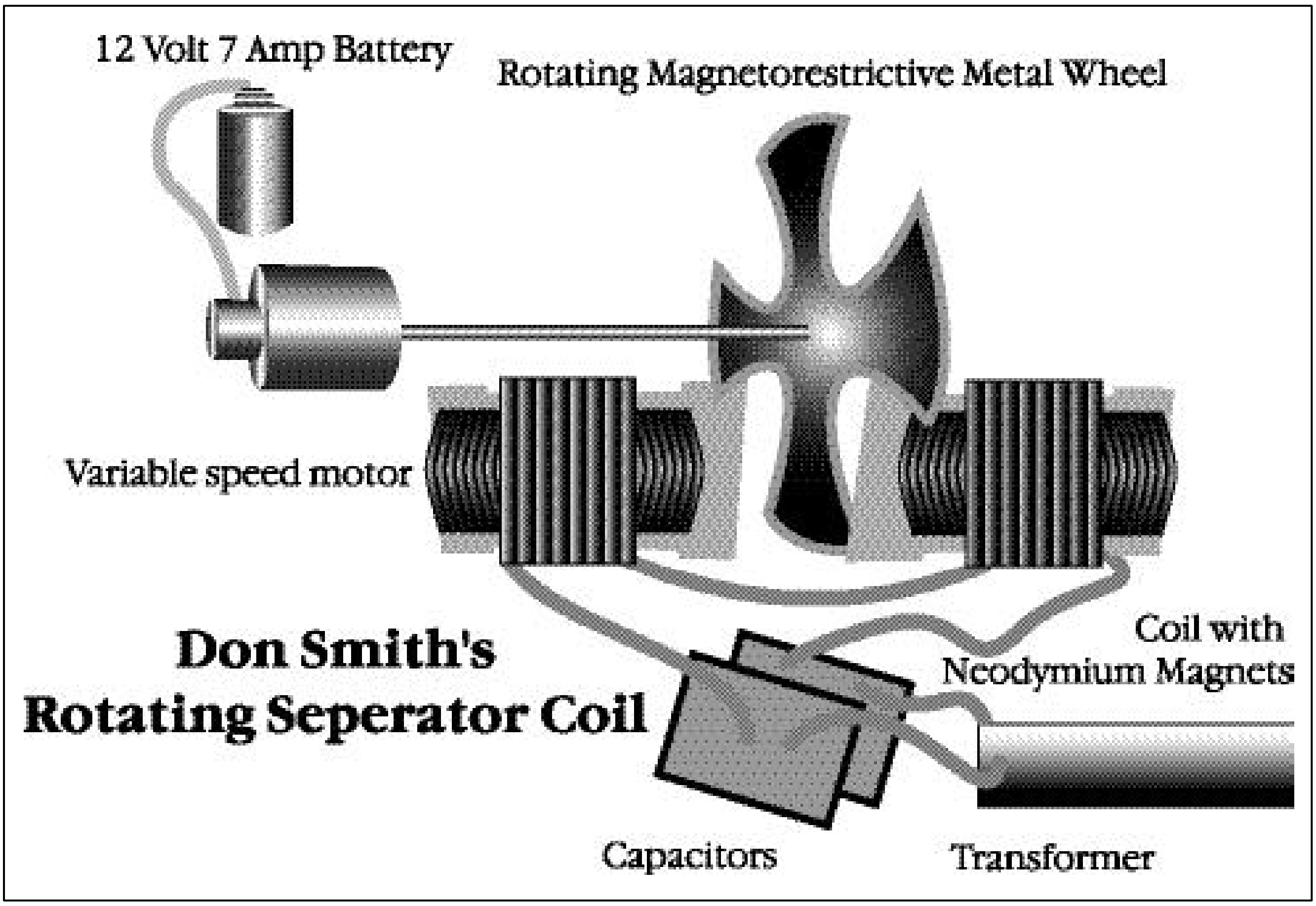

Fig.1
Smith's Energy Receiver

Useful energy occurs as the result of imbalances of ambient background energy and it is a transient phenomenon. In conventional circuits, the electrical field is in a closed system that is damped out with heat loss, which severely limits its utility. **The flip side of the electron generates magnetic waves, which is an open system, not subjected to heat loss. These being unrestricted are the universal source of energy. Universally present electrons are flipped to their electrical position, resulting in useful energy.** When properly constructed an electrical circuit can become self sustainable once started. An obvious corollary would be that the number of radio or television receivers in operation does not deplete the magnetic wave source providing the service. The key source of unlimited energy is Magnetic Resonance. To understand this requires putting a stake through outdated physics. An obvious example is the piano where the key impacts the one note giving one sound, which resonates with its two side keys providing a much higher level. Magnetic Resonant Energy clearly amplifies demonstrating more energy out than in. **Excess energy consequent to a reaction is called Free Energy and can be very large as is in the case of Magnetic Resonance.** The intentionally ignorant physicist makes a habit of ignoring this fact.

Useful electricity is obtained from disturbed electrons, which radiate magnetic fields and waves. The generator disturbs and collects this

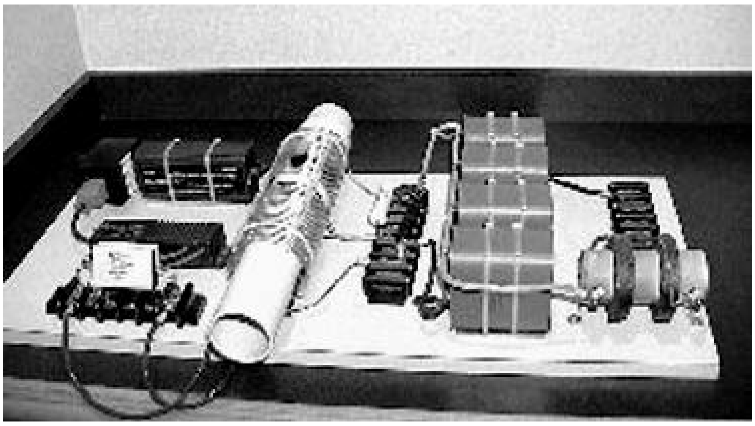

Fig.2
D. Smith's Energy Receiver

emitted electron energy. These electrons remain fully in tact and undiminished until the end of time. This Energy is free and the cost of accessing it depends on the ignorance of the collector. With an appropriate collector system an unending source of environmentally benign, inexpensive, available energy everywhere, is provided.

Editor: in September 2003 Donald Smith took part in the annual "Inventor's Week-end" Conference where he presented the report on his invention. In this issue you can find more details on the conference.

It is worth of a note that we have received ***a number of negative comments on this inventor's work****. However, we thought his articles to be quite interesting and decided to publish them. We would be glad to get readers' comments, who are familiar with the work and inventions of Donald Smith.*

NEWS

News from Farady Lab

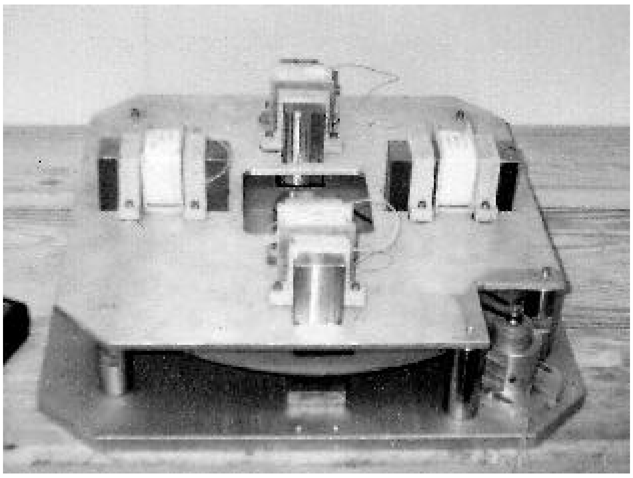

Disk permanent-magnet generator
Faraday Lab Ltd

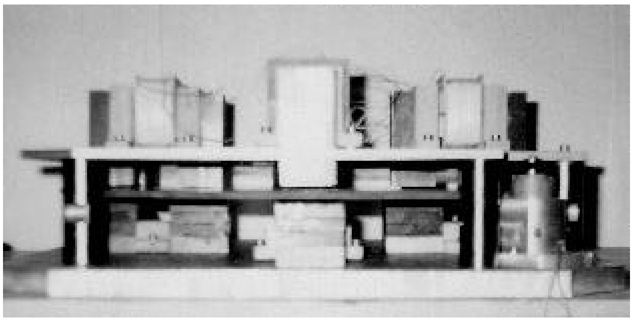

In our lab we are still working at the optimization of the alternator design (electromagnetic generator with the permanent magnets). We have introduced the drum rotor instead of the disk rotor into the new design of the alternator. The operation mechanism is the same, namely, the alternation of the magnetic flux near the generator coils occurs as a result of the rotating elements operation of the rotor, which "shunt" the magnetic flux.

Frolov A.V.

Strategies for Launching a New Over-Unity Device

Ryan S. Wood, USA
14004 Quali Ridge Drive, Broomfield, CO 80020

Problem description: With any singly successful over-unity energy device comes a host of business, technical and financial problems and opportunities. A public announcement permanently will lead to a "Pons & Fleishman" effect that at best delays public success and at worst derails the entire technological effort. Careful attention needs to be applied to the marketing launch, replication, patents, legal defense and finances.

Potential Solution: With a few working devices that generate100-500 horsepower it is relatively easy to hook these units to the electrical gird and generate monthly checks from the utilities. The law states that major utilities must purchase electricity from any supplier at "cost avoidance" rate now typically, between 6 and 10 cents per kilowatt-hour. This law, California Public Utilities Commission - Rule 21, for example, is designed to help small hydro-electric producers and solar or wind farms. There is a safety requirement of grid transfer switches, but they are not terribly complicated or expensive. The entire equipment set-up must be approved by the utility, however, if you start with a diesel electric generator or small hydro plant it can be approved, operating and stable before the clandestine switch or hybrid operation with an over-unity machine. The law is strongly supportive of the energy producer and disconnection for non-safety or maintenance reasons is exceeding rare.

A key benefit of this approach is that you have established repeatability by having multiple working sites, you have established that it can generate money and the technology does real work and you have created several independent locations where press and scientists can visit to validate the over-unity effectiveness in-situ.

Typical revenues would be as follows:

Generator Horse Power	**100**	**200**	**300**	**400**	**500**
Annual $, 90% uptime @ 6 c/kWh	$ 35,100	$ 70,199	$ 105,299	$ 140, 398	$ 175, 498
Monthly payment @ 6 c/kWh	$ 2,92	$ 5,850	$ 8,775	$ 11,700	$ 14, 625
Annual $, 90% uptime @ 10 c/kWh	$ 58,499	$ 116, 999	$ 175, 498	$ 233,997	$ 292, 496
Monthly payment @ 10 c/kWh	$ 4,875	$ 9,750	$14, 625	$ 19,500	$ 24, 375

It will take money without the strings of investors to champion and defend a new breakthrough technology into the energy marketplace and this strategy offers a quiet way to prepare for the ultimate launch and resulting scientific and media frenzy that will ensue. It will take years for the business to form, products to be built and marketing and acceptance and industry confidence to be established. All during those years this strategy can generate cash to support engineering and operations.

Please call if there are questions at 303-941-9663 (cell),
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Ryan S. Wood

The Hutchison Effect – An Explanation

Mark A. Solis, USA
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People often ask, "What exactly is the Hutchison Effect?" This brief essay is an attempt to answer that question to the satisfaction of the majority. First of all, the Hutchison Effect is a collection of phenomena which were discovered accidentally by John Hutchison during attempts to study the longitudinal waves of Tesla back in 1979. In other words, the Hutchison Effect is not simply a singular effect. It is many.

The Hutchison Effect occurs as the result of radio wave interferences in a zone of spatial volume encompassed by high voltage sources, usually a Van de Graff generator, and two or more Tesla coils.

Editor: We can call this effect "The H. Wells Effect" because he was first to describe it in his book "The Invisible man". The main character of the book used two sources of electromagnetic vibrations and Wells said that they were not Hertz waves but something else. "But the essential phase was to place the transparent object whose refractive index was to be lowered between two radiating centers of a sort of ethereal vibration..."("The Invisible Man", chapter 20).

A. V. Frolov

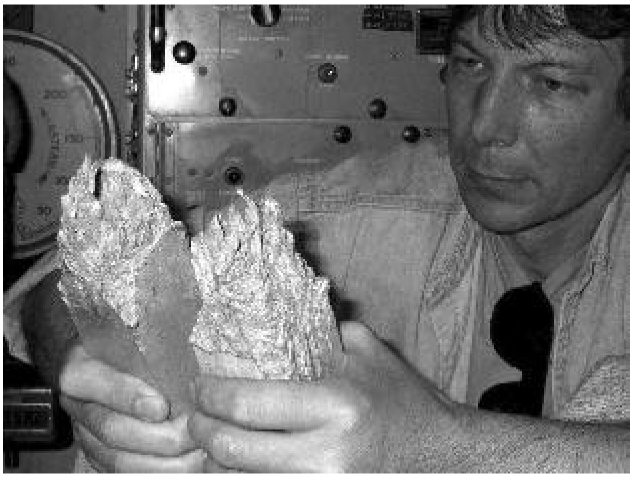

The effects produced include levitation of heavy objects, fusion of dissimilar materials such as metal and wood, the anomalous heating of metals without burning adjacent material, spontaneous fracturing of metals (which separate by sliding in a sideways fashion), and both temporary and permanent changes in the crystalline structure and physical properties of metals.

Fig.1 represents the proof of Hutchison Effect based on metal blocks. Deformation occurred at room temperature as a result of complex interaction of electromagnetic fields.

The levitation of heavy objects by the Hutchison Effect is not - repeat not - the result of simple electrostatic or electromagnetic levitation. Claims that these forces alone can explain the phenomenon are patently ridiculous, and easily disproved by merely trying to use such methods to duplicate what

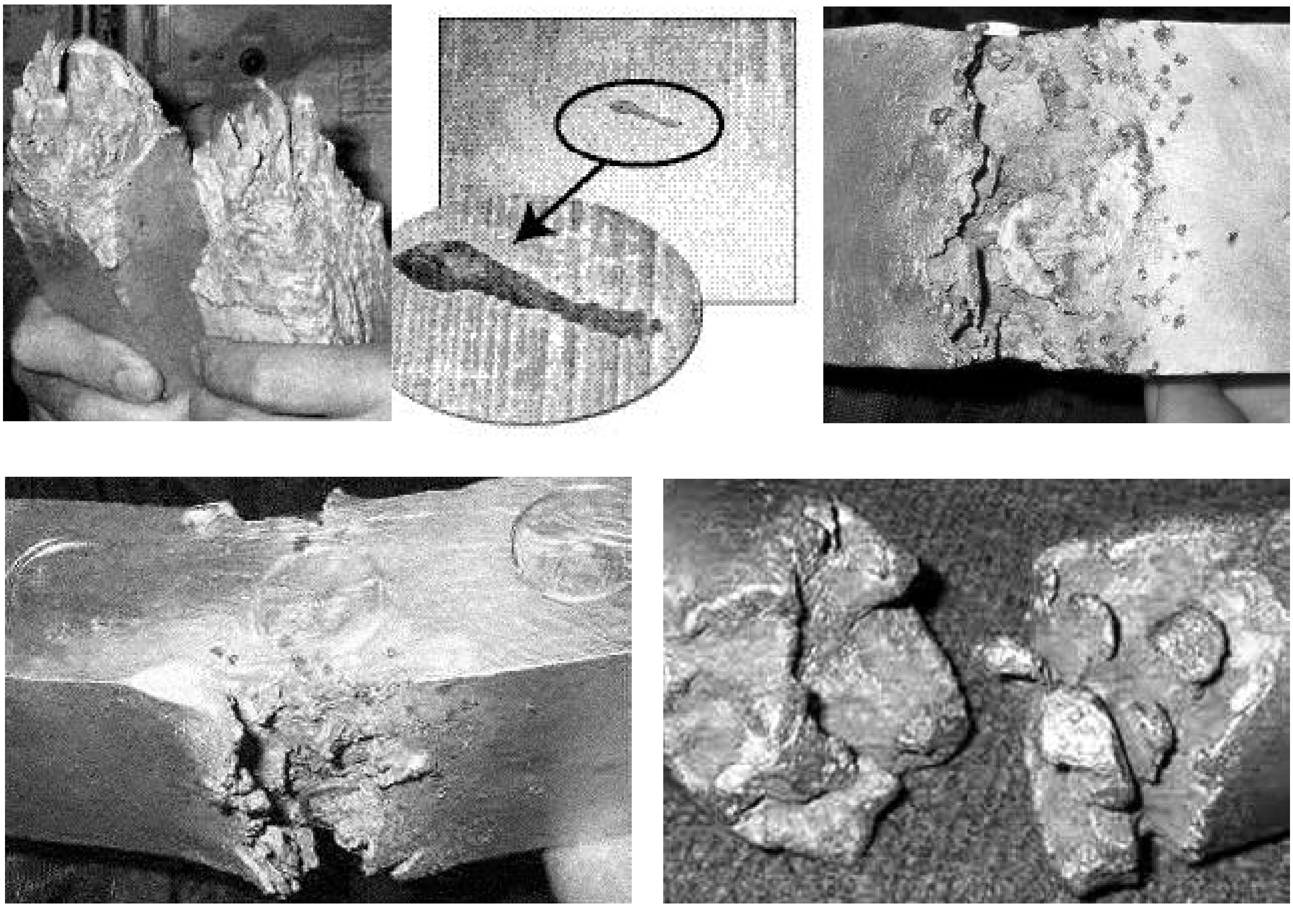

Fig.1

Cold melting of metals

The upper left: steel, The lower left: aluminium with coin prints and with a coin inserted in a partially open split; The lower right: fully torn aluminium bar; The middle upper and right: a section part of the aluminium block, into which a wood block is fused (brown matter)

http://www.rumormillnews.com/JOHN-HUTSHISON2.htm

the Hutchison Effect has achieved, which has been well documented both on film and videotape, and has been witnessed many times by numerous credentialed scientists and engineers. Challengers should note that their apparatus must be limited to the use of 75 Watts of power from a 120 Volt AC outlet, as that is all that is used by Hutchison's apparatus to levitate a 60-pound cannon ball.

The fusion of dissimilar materials, which is exceedingly remarkable, indicates clearly that the Hutchison Effect has a powerful influence on Van der Waals forces. In a striking and baffling contradiction, dissimilar substances can simply "come together," yet the individual substances do not dissociate. A block of wood can simply "sink into" a metal bar, yet neither the metal bar nor the block of wood come apart. Also, there is no evidence of displacement, such as would occur if, for example, one were to sink a stone into a bowl of water.

The anomalous heating of metal without any evidence of burning or scorching of the adjacent materials (usually wood) is a clear indication that possibly the nature of heat may not be completely understood. This has far-reaching implications for thermodynamics, which hinges entirely on the presumption of such knowledge. It should be noted that the entirety of thermodynamics is represented by the infrared portion of the electromagnetic spectrum, which is insignificant in a context of 0 Hz to infinite Hz. The anomalous heating exhibited by the Hutchison Effect shows plainly that we have much to learn, especially where thermodynamics and electromagnetism meet.

The spontaneous fracturing of metals, as occurs with the Hutchison Effect, is unique for two reasons: (1) there is no evidence of an "external force" causing the fracturing, and (2) the method by which the metal separates involves a sliding motion in a sideways direction, horizontally. The metal simply comes apart.

Doctor John Hutchison

Some temporary changes in the crystalline structure and physical properties of metals are somewhat reminiscent of the "spoon bending" of Uri Geller, except that there is no one near the metal samples when the changes take place. One video shows a spoon flapping up and down like a limp rag in a stiff breeze. In the case of permanent changes, a metal bar will be hard at one end, like steel, and soft at the other end, like powdered lead. Again, this is evidence of strong influence on Van der Waals forces.

The radio wave interferences involved in producing these effects are produced from as many as four and five different radio sources, all operating at low power. However, the zone in which the interferences take place is stressed by hundreds of kilovolts.

It is surmised by some researchers that what Hutchison has done is tap into the Zero Point Energy. This energy gets its name from the fact that it is evidenced by oscillations at zero degrees Kelvin, where supposedly all activity in an atom ceases. The energy is associated with the spontaneous emission and annihilation of electrons and positrons coming from what is called "the quantum vacuum." The density of the energy contained in the quantum vacuum is estimated by some at ten to the thirteenth Joules per cubic centimeter, which is reportedly sufficient to boil off the Earth's oceans in a matter of moments.

Given access to such energies, it is small wonder that the Hutchison Effect produces such bizarre phenomena. At the present time, the phenomena are difficult to reproduce with any regularity. The focus for the future, then, is first to increase the frequency of occurrence of the effects, then to achieve some degree of precision in their control.

> *The spontaneous fracturing of metals, as occurs with the Hutchison Effect, is unique for two reasons: there is no evidence of an "external force" causing the fracturing, and the method by which the metal separates involves a sliding motion in a sideways direction, horizontally. The metal simply comes apart.*

Editor: On November 17th 2003 we got to know that the inventor John Hutchison can eventually lose his home laboratory. The property can be confiscated upon court order due to neighbours' complaints. Apparently, it is dangerous to conduct experiments of the kind at home and even within a town. We wish him success!

A. V. Frolov

A SIMPLE DEVICE FOR HEAT TO ELECTRICAL ENERGY CONVERSION BY MEANS OF FERROELECTRICS

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Introduction

A few years ago, Zaev [1, 2] demonstrated experimentally the possibility of heat to electrical energy conversion by means of ferroelectrics. A capacitor filled with a ferroelectric material was charged and discharged periodically at a temperature just a little lower than the Curie point. According to Zaev, the capacitor must have a nonlinear capacitance dC/dV > 0, which means the capacitance increases with rising voltage. Besides these experimental results, it was proven by a theoretical calculation that the electrical energy obtained during discharging can reach up to 1.35 of the energy introduced to charge the capacitor. The present paper presents an inexpensive and simple electric circuit which can be used to prove heat to electricity conversion experimentally. Moreover, the physical mechanism of heat to electricity conversion is explained in the form of a thermodynamic cycle.

Thermodynamic cycle for energy conversion

The following thermodynamic cycle is composed of four reversible steps. It works only at a temperature just a little lower than the Curie point, where the dielectric constant is highly temperature dependent. Fig. 1 shows the relative dielectric constant of a representative ferroelectric ceramic as a function of temperature.

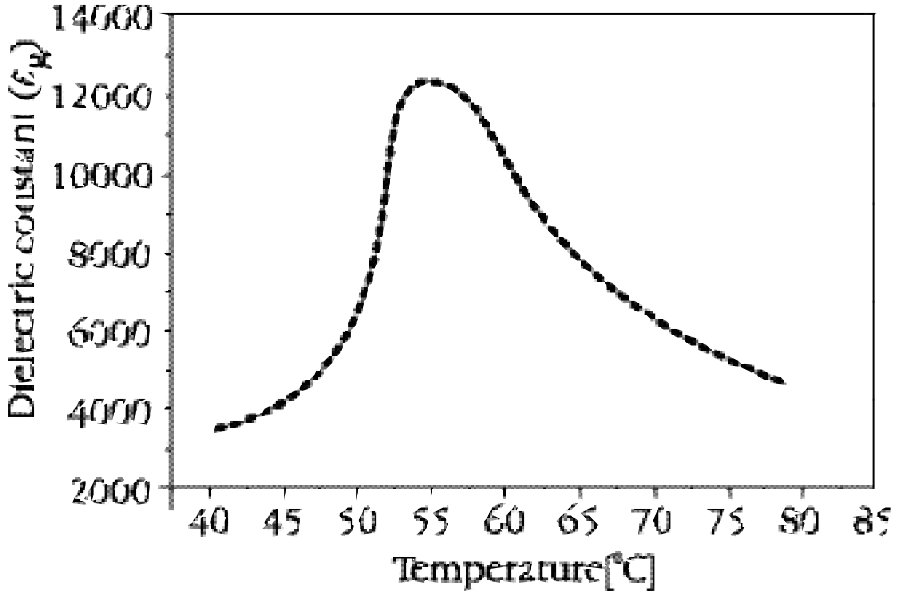

Fig. 1
Relative dielectric constant versus temperature for a barium strontium titanate ceramic (80% Ba, 20% Sr) prepared by the author. Curie point = 55° C.

As it can be seen, just below the Curie point in the range from 50 to 55^{0}C, small changes of the temperature cause high changes of the dielectric constant.

Furthermore, to understand the conversion mechanism, it is necessary to understand the electrocaloric effect. When an electric field is applied to a dielectric medium, the latter is polarized. For ferroelectric materials, the parallel domain alignment is the most important part of the total polarization. During the successive alignment of the domains, some material parameters in particular entropy, heat capacity and temperature change. Since the material possesses less degrees of freedom in the polarized state, its entropy and heat capacity are reduced. As a consequence, provided that no heat exchange with the environment is possible (adiabatic conditions), the temperature increases. It is very important to understand that the energy for warming of the dielectric is not taken from the polarizing electric field. The increase in temperature is a result of the decreased heat capacity only.

From this, it can be derived easily what means "nonlinear capacitance".

When a capacitor is charged adiabatically which means its voltage increases faster than any heat exchange with the environment is possible, due to the electrocaloric effect, the temperature of the dielectric must also increase. As it can be seen from Fig.1, below the Curie point, an increasing temperature leads to a higher dielectric constant. Assuming that both temperatures, the one before charging and the other after charging are still below the Curie point, one can say that the dielectric constant increases with an increase in voltage.

Since the capacitance is proportional to the dielectric constant, the capacitor has a nonlinear characteristic $dC/dV > 0$. In the same way it can be concluded that adiabatic charging just a little above the Curie point reveals a nonlinear capacitor characteristic with $dC/dV < 0$.

Quantitative experimental measurements on the electrocaloric effect in some representative ferroelectric and antiferroelectric materials were published by Thacher [3].

STEP 1: Adiabatic charging of the capacitor

We consider a capacitor filled with a ferroelectric medium at an environmental temperature a little lower than the Curie point.

An adiabatic charging of a capacitor (no heat exchange) effects an increase in temperature and capacitance due to the electrocaloric effect. We assume that this increase in temperature is so small that the temperature remains below the Curie point. Finally, the capacitor is completely charged while the dielectric medium has a higher dielectric constant and therefore a higher capacitance than it posseses at the environmental temperature.

To go further to step 2, the capacitor is hold under conditions where no discharge is possible, e.g. it is disconnected from the power supply.

STEP 2: Thermal equilibration

After a short time, the charged capacitor has cooled down to the environmental temperature. While cooling down, the dielectric constant and capacitance decrease. But the charges of the capacitor plates remain constant. As a consequence, the voltage and the electrical energy increase. This can be readily recognized from the general capacitor equation $q = C V$ (q = charge, C = capacitance, V = voltage):

$$q = \text{constant} = C_1 V_1 = C_2 V_2$$

STEP 3: Adiabatic discharging of the capacitor

While discharging the capacitor the temperature and capacitance decrease (again heat capacity changes) due to the electrocaloric effect, leading to a further increase in the available electrical energy. The ferroelectric medium posseses now a final temperature below the temperature of the environment.

STEP 4: Thermal equilibration

In order to proceed with step 1, it is necessary to reach the environmental temperature. An inflow of heat from the environment to the dielectric material is required.

Electric circuit to observe energy conversion

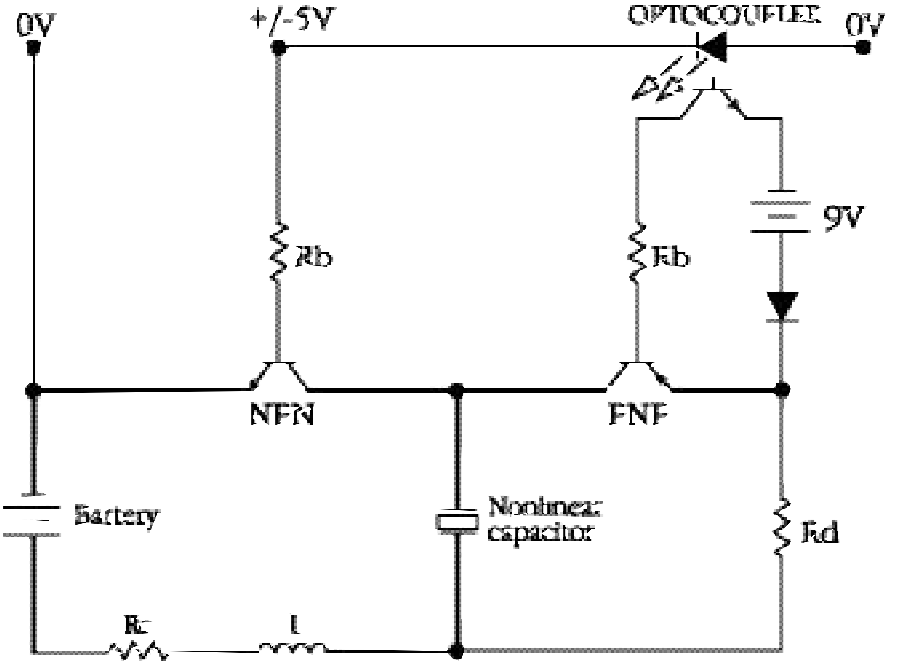

Fig. 2
Electric circuit for testing the energy conversion effect. The connections to the square wave generator are labeled with 0V and +/- 5V, the resistors Rb are to adjust the maximum base current of the transistors.

Assuming the experimenter has a nonlinear capacitor, the set-up shown schematically in Fig. 2 is proposed as a possible conversion device. The circuit contains two different types of transistors (NPN and PNP) which fulfill here the function of a switch.

The NPN junction transistor consists of two n-type semiconductors (called the emitter and collector) separated by a thin layer of p-type semiconductor (called the base). On the other hand the PNP junction transistor consists of a thin layer of n-type semiconductor lying between two p-type semiconductors. The base is the ON/OFF switch for the transistors. If a current flows to the base, there is a path from the collector to the emitter, where a current can flow (switch is ON). If there is no current flowing to the base, then no current can flow from the collector to the emitter (switch is OFF).

The charging-discharging process is controlled by a square wave generator which produces an output signal switching from +5V to -5V. The switching frequency is adjustable from 0.1 Hz up to at least 10 kHz. This output signal is applied to the bases of both transistors.

During the time the square wave generator output signal is +5V, a base current flows through the base-emitter junction of the NPN transistor which creates a low resistance path between the collector and the emitter. As a consequence, the capacitor is charged by the battery. The collector-emitter junction of the PNP transistor has a very high resistance, because here no base current flows. Therefore the capacitor is not discharged at the same time. When the output signal switches to -5V, a current flows to the base of the PNP transistor and not to the base of the

NPN transistor. Now the capacitor is discharged.

In order to understand the function of the inductance in Fig. 2, we analyze the thermodynamics of the charging process.

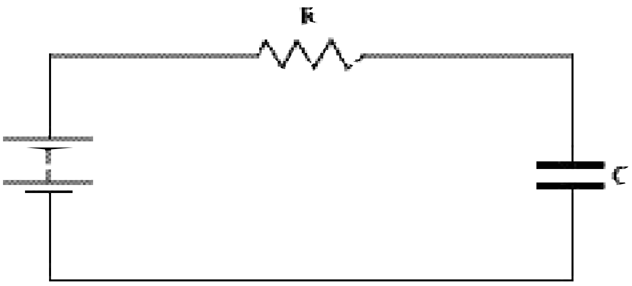

Fig. 3
Simple circuit for charging a capacitor

If a linear capacitor of capacitance C is charged to a voltage V through the load R according to Fig. 3, the energy $W = 0.5\ C V^2$ is stored in the capacitor. During the charging process, a time-dependent current I(t) flows:

$$I(t) = V/R \exp(-t/RC)$$

This current develops the heat Q in the load:

$$2Q = R \int I^2(t)dt = 0{,}5CV^2$$

Here the integration limits are from zero to infinity. This calculation shows, that the energy taken from the battery is the energy stored in the capacitor after charging plus the heat produced in the load, also 2•C V2. One can see that the heat Q is not dependent on the resistance value R.

The above used equations are only valid in case of a one-step charging process.

If the capacitor is charged stepwise to the final voltage V, e.g. using a ramp generator, and each voltage step effects a voltage increase , the total heat produced in the load is (N = number of voltage steps):

$$Q = N\ 0{,}5\ C\ (V/N)^2 = 0{,}5\ C/N\ V^2$$

Now the energy taken from the source is:

$$W = 0{,}5\cdot(1 + 1/N)1/2\ CV^2$$

If the number of steps N tends to infinity, the heat Q tends to zero.

This energy loss in the load dramatically influences the efficiency of any conversion device and must be taken into account, otherwise all experimental attempts to observe energy conversion would fail.

A more detailed discussion on charging a capacitor and the unavoidable energy losses was given by Heinrich [4] and Gupta et al. [5].

The inductance in the circuit (Fig. 2) effects a slower rising of the current during the charging process (due to self induction) and can reduce the heat generated in the load dramatically.

Acknowledgments

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• Fantastic Projects •

The Gates Motor

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The Gates motor company has produced a motor that does not run on fossil fuel or on electricity. It comes in a 28 HP and a 5,000 HP version. When linked to an electric generator, the larger motor will produce 2,200 kW.

My name is Adrian Akau. I am a recently retired school teacher, having taught science and math in the public school system, state of Hawaii for the past 36 years. One of the classes I taught was on energy.

Our world should be reaching the half-way mark in easily accessible oil by about the year 2016. Since the rate of oil usage is becoming higher each year, it is unlikely that the oil supply will last as long as the 140 years since the first well was drilled in Pennsylvania. We will become more dependent upon OPEC with all the political pressures and problems that accompany this type of dependency. As the easy oil is consumed, we must look for ways to extract less accessible oil such as from shale. The added expense will be passed on to the consumer.

The burning of coal is not the answer either because coal cannot supply convenient energy as does oil. An oil-based economy cannot transfer over readily to natural gas; there is not enough natural gas available and it is again, not a convenient and concentrated source as is oil. We also have serious pollution problems with the burning of fossil fuels (natural gas being the exception) but the burning of all fossil fuels have contributed to the serious problem of global warming.

It may take all of 50-80 years to transfer to a non-fossil fuel economy. The transfer must be made slowly so as not to disturb the infrastructure of our economy which is presently based upon fossil fuels. We must gradually create a new infrastructure that is non-fossil fuel dependent.

> *The motor incorporates a unique spring configuration to provide rotation*

The production model of the motor is 24 inches high by 48 inches in length. Connected to a generator it will provide sufficient power for about eight hundred US homes. It is designed to be tough and to last a long time. It uses a high grade airplane synthetic engine oil to prevent friction and the build up of heat. Only the oil filter needs to be changed. The motor has special needle bearings and portions of the motor are made of high quality steel.

The Gates motor is designed to run 24 hours/day, 365 days/year without incurring any fuel costs. The larger size motor would come in pairs; the spare motor being used as a back-up unit should the regular motor be turned off for maintenance such as to change the oil or in case there should be any problems with the first motor. The company is willing to enter into a contract for maintaining the motor after installation.

The Gates motor represents a major breakthrough in motor design technology and provides practical solutions to environmental and fuel conservation concerns. **Finally, a completely mechanical motor has been developed.** It can deliver the power needed in a wide variety of service applications without any waste products or emissions to adversely affect the environment. This revolutionary new motor utilizes spring power technology. Unlike conventional motors which must reach a maximum rpm level before the desired horsepower, the Gates motor provides maximum horsepower instantly by virtue of the torque stored in the springs.

The basic operating principle of the Gates motor involves a series of springs configured to provide the required motor rotation and power delivery. Consider, if you will, the operating principle of a grandfather clock. Once the clock is wound, it continues to operate until it runs down and stops. The springs must then be rewound so it will operate again. Suppose the clock is continually being rewound as it operates. Then the clock would run continuously. This condition is what forms the basis for the operating principle of the Gates motor. The motor incorporates a unique spring configuration to provide rotation. The springs inside the motor are wound and preset at the factory at the time the motor is assembled. The amount of torque wound into the springs at the factory determines the horsepower of the motor. Inside the motor are a multiple of springs positioned horizontally in a circular arrangement. As the motor operates, the springs are unwound a set number of degrees. A double ratchet system at one end of the motor rewinds the degrees used back into the springs. As the springs are unwinding, **the power generated from all the springs reset each spring (one at a time) during each revolution of the motor**. It is this reset action that produces and delivers power from the springs to the flywheel located at the opposite end of the motor. The flywheel serves to ensure the smooth operation of the motor and to convert the springs into useable horsepower. The smaller motor has 50 foot pounds of torque at a shaft speed of 3000 RPM and will produce 28 HP. The HP can be altered by factory adjustment. The speed of the engine is controlled by a hydraulic pump which provides pressure upon the power shaft.

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Editor: We tried to get the video of this device operation from Gates Motor Co., but after a long consideration it was not provided since the authors are competitor-conscious.

Alexander V. Frolov

Longitudinal Waves

Cold Electricity

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Dr. Peter Lindemann in his book "The Free Energy Secrets of Cold Electricity" presents the story of this type of electricity which really is not electricity as electricity is normally meant to be understood. Cold electricity behaves differently than normal electricity. Regular electricity may be used in the process to generate this cold form but this transformation is not the type of change in voltage and current that occurs in a transformer. Rather, it is the extraction of a form of current from "normal" electricity by a process that uses high voltage.

In discussing the Edwin Gray motor, Dr. Lindemann relates a demonstration by Gray. Gray used a 6 volt car battery with lead wires running to a system he had devised using a voltage booster and a series of capacitors which raised the voltage to 3,000 volts. He then closed a switch that ran the high voltage into two electromagnets which caused a loud popping sound and cause the top electromagnet weighing a pound and a quarter to be propelled over two feet into the air. Gray claimed that only 1% of the system's energy was used with 99% going back to the battery. He said that he had 'split the positive' with his system.

Other evidence of using this fractionated electricity was Gray's use of a small motorcycle battery (15 amps which would normally produce W=V x A = 6 V x 15 A= 90 watts) to run concurrently six 15-watt electrical light bulbs, a portable 110 volt T.V. set and two radios. A glowing 40 watt light bulb running off the system was dropped into water without the glass breaking; the bulb gave off light but not the heat that accompanied a bulb run by regular electricity. This would mean that tungsten in the filament of the light bulb was not resisting the flow of this fractionated electricity and that this "cold electricity" was causing the luminous glow by some other means.

According to Gray's Patent #4,595,975, low voltage was chopped into pulsating DC by passing it through a multi-vibrator (buzzer like a door bell). Then the pulsed DC was sent through the low voltage winding (primary) of a transformer which changed it to pulsating high voltage DC current at the secondary side. The pulsating high voltage DC was rectified by a full wave bridge and changed into high voltage DC.

The high voltage DC was used to repeatedly charge a capacitor as the current was sent to briefly discharge across a spark gap (rated at 3000 volts). The discharge of the spark across the gap had to be in one direction only and its duration was controlled by the size of the capacitor and by the strength of a magnetic field encompassing the gap. This magnetic field had a quenching effect because it caused a back EMF each time the discharge occurred. The current from the discharge across the gap was then sent through a resistor and then to a vacuum tube (the conversion switching element tube).

Another of Edward Gray's patents "Efficient Electrical Conversion Switching Tube Suitable for Inductive Loads" (April 1987, patent 4,661,747) described the switching tube. It utilizes a low voltage anode (positive plate), a low voltage anode (positive plate) and one or more electro-static or charge receiving grids (located between the positive plates and the cathode or negative plate supplying the electrons). This tube's function was to 'split the positive'. A normal vacuum tube usually uses only a single anode at a particular voltage to control the voltage flow within the tube. The function of the charge-receiving grids was to collect the "cold electricity".

The most unusual part of this Power Supply circuit consisted of devices specifically designed to remove excess energy when the Switching Tube was functioning. A spark-gap protection device, served to "protect the inductive load and the rectifier elements from unduly large discharge currents". As stated, the rectifier elements are the two anodes and the grids in the Switching Tube. In a normal vacuum tube, no protection would be necessary because the maximum power of the tube would be based upon the electricity provided to heat the tube filament and to charge the anode (voltage x amps). Therefore, the excess energy comes from the process occurring as the spark gap affected electrical pulses pass through the Switching Tube. The process of extracting the "cold electricity" places danger of overload upon the system. (Please take note that the "electricity" from the Switching Tube is no longer the normal type of electricity we have from our batteries or from an electrical outlet but rather a completely new form with entirely different characteristics.)

The description continues, "Should the potentials (voltages) within the circuit exceed the predetermined values fixed by the mechanical size and spacing of the elements within the switching tube, the energy is dissipated (bypassed) by the protective device to the circuit common (electrical ground)" by two strategically placed diodes (devices that permit the passage of electricity in one direction only). The question now arises "What is the cause of this large amount of excess energy which must be dumped to ground through device acting like a lightning rod in order to prevent the circuit from burning out?"

To examine the cause of the excess energy source, we must go back over a hundred years to 1889. Heinrich Hertz had just announced in 1887 that he had discovered electromagnetic waves and Nicola Tesla was attempting to duplicate Hertz's experiments. Tesla used abrupt and powerful electric discharges produced with banks of capacitors charged to very high potentials and was able to explode thin wire (copper bus bars). He came to the conclusion that Hertz had mistakenly associated electrostatic inductions (electrified shockwaves in air) for true electromagnetic waves.

The explosion of the copper bars by means of the "disruptive discharges" from the capacitor bank produced sharp shockwaves which struck Tesla with great force across the entire front of his body. Tesla said they felt more like powerful gunshots rather than electrical sparks. They produced effects similar to lightning or to those produced by high voltage DC generators previously discussed; the simple closing of a high voltage DC generator caused a stinging shock. AC generators were not in use in this pre-AC era and it was shown, later on, that AC generators did not produce these effects.

This shock was first assumed to be the result of residual static charging. It stood straight out of highly electrified conductors, seeking ground paths which included workmen and switchboard operators. In long cables, Tesla estimated that this electrostatic concentration was several orders in magnitude greater than any voltage the DC generator could actually produce. It caused a hedge or crown of bluish needles or spicules to point at right angles to the cable or straight from the electrical cable line into the surrounding space. The bluish needles appeared the very instant the switch was closed and disappeared a few milliseconds later, after which the system functioned normally. However, anyone through whom the blue needles passed, especially in large regional power systems which used high exceptionally high voltages, usually did not survive. Generators rated at a few thousand volts produced hundreds of thousands or even millions of electrostatic volts during the start-up pulse. Highly insulated, heavily grounded relay switches had to be installed to protect workers from certain death.

Engineers at this time assumed **the effect to be caused by a "bunching" action which occurred when a powerful force was not able to move charge sufficiently quickly through a system.** (A similar "choking effect" also happened with large steam engines; if steam was introduced too rapidly, the steam engine could explode.) The metal of which the wire was composed somehow offered resistance to the charge carriers before they were able to move away from the generator terminals. It seemed that the wire acted as a blocking force to the electrons or to some unknown part of the electrons for the first few milliseconds, rather than as a conductor. The powerful, deadly bluish spikes sprang from the line until the current charges actually "caught up" with the applied electrical field. It was as if the spicules were a form of relieving pressure on the system by converting the voltage impulse into some other form.

Tesla began wondering why the electrostatic field moved faster than the actual charges. He believed that this effect could help him find electric waves better than his capacitors because the line resistance caused the electrostatic charges to bunch together into a density much greater that obtainable with his capacitors.

Tesla understood that ordinary capacitor discharges were oscillating currents or spark currents which "bounced" between each capacitor plate until their stored energy was dissipated. The high surge voltage of the DC generator exerted such a high one way pressure on the dense line charges, due to the millisecond resistance of the metal, that possible voltage "bounces" were also oscillations of current as was true with the capacitors. Tesla used every means possible to block the "back-rush" (bouncing) of the oscillating current in order to prevent the supercharge to prematurely decline; he wanted to maintain this powerful "bunching" effect as long as possible in order to study it and to make use of it.

His face and hands experienced a penetrating shockwave; a sharp pressure and an electrical irritation were brought on at the sudden closing of the switch. His face and hands were especially sensitive to these shockwaves which caused a "stinging" effect at close range. Tesla believed that he was being struck by material particles approaching the vapor state as they were thrust from bluish crowned wire.

Later on, he was to discover they were not gas particles. **He placed himself behind a glass shield but to his amazement, he still felt the shockwaves and stinging effects; the glass shield did not protect him.** These stinging rays could be felt at great distances from their sources and, to his amazement, would penetrate shields of both glass and copper. Tesla knew that normal electrostatic charges spread over the surface of a metal (copper, for example) shield so that the stinging effect could not have an electrostatic origin and therefore was not electrostatic in nature but was from some other yet unknown source.

Joseph Henry in 1842 had noticed the magnetization of steel needles by the discharge of a Leyden Jar (type of primitive condenser made with a glass bottle). The Leyden Jar was at the top floor of a building while the needles were in the basement. Dr. Henry, noting the passage of these magnetizing rays through brick walls, oak doors, stone and iron flooring and tin ceilings believed that the spark given off by the discharge released "light-like rays" that passed through the material obstacles with ease before magnetizing the needles.

Elihu Thomson, a physics instructor in 1872 had been attempting to make sparks from a Ruhmkorff Spark Coil more clearly visible for his physics students. He attached one pole of the coil to a cold water pipe and noted that the previously blue spark changed to white. He then attached the other pole to a large metal table top and produced a silver-white spark that would be clearly visible to all attending his lecture. He went to the door of the room to notify his colleague but received a strong shock from the door knob. Turning off the Ruhmkorff coil prevented the brass knob on the oak door to stop shocking. He returned with his friend, again turned on the coil and discovered that all metal objects in the entire building, no matter how distant from the coil or insulated from the floor, produced long and continuous white sparks upon the touch of a penknife or screwdriver.

The device Tesla perfected was far superior to the Ruhmkorff Spark Coil. The effect of his disrupter device was so strong that a single wire placed in an oil bath produced what he had originally but mistakenly thought to be gaseous streams so powerful that they visibly depressed the oil into a depth of about two inches. Tesla concluded that "besides the air, another medium is present".

> *...he placed himself behind a glass shield but to his amazement, he still felt the shockwaves and stinging effects; the glass shield did not protect him. These stinging rays could be felt at great distances from their sources and, to his amazement, would penetrate shields of both glass and copper...*

Tesla had been able to perfect his device by placing a capacitor between the switch and the D.C. generator thus increasing the power and protecting the generator windings in much the same manner as the diodes Edwin Gray's Switching Tube protected Gray's circuit. Tesla also raised the voltage and quickened the "make-break" rate of the switch to increase the power level by placing a powerful permanent magnet crosswise to the discharge path of the high voltage output of the DC generator wires. The magnetic field caused the discharge arc to automatically "blow out"; the charge passing through the wires in the presence of the magnetic field built up reverse emf (electromotive force or voltage).

Tesla believed he had discovered a new type of electricity with special characteristics. This form of electricity did not consist of alternating waves. **They were longitudinal waves** composed of successive shocking waves with effects that could be seen and felt at a distance. **Vector components of these shock waves were unidirectional. They were able to force charges in the direction of their propagation.** In his patent #787,412, "Art Of Transmitting Electrical Energy Through The Natural Mediums" (April 18, 1905), Tesla calculated the mean velocity of the waves propagated by his device to be 471,240 Km/sec. Knowing that the velocity of light is 300,000 Km/sec would indicate that the type of transmission to which Tesla is referring is different than standard electromagnetic radiation; these special longitudinal "Radiant Energy" waves moved faster than the speed of light.

After conducting hundreds of experiments, Tesla found that "Radiant Energy" longitudinal waves **could penetrate all materials and cause "electronic responses" in metals such as copper and silver.** Impulses exceeding 0.1 millisecond duration produced effects such as pain, mechanical pressures, explosion of thin wires and vibration of objects. Impulses of 1.0 microseconds caused the sensation of physiological heat; at still shorter lengths white light would fill the room. Impulses less than 100 microseconds were safe to work with and Tesla planned to use them for his power broadcast system since they could pass through all matter.

In 1890, Tesla discovered that placing a long single turn copper helix near his magnetic disrupter became covered with an envelope of white sparks. Effects were strongest when the helical coil was placed within the disrupter wire circle. In this "shockzone", the coil was surrounded by a blast of long, fluid like silvery streamers which clung to the surface of the coil, flowing over the coil at right angles to the windings. Tesla hypothesized the electrostatic-like effect was due to radiant transformation rules requiring measurements of discharge lengths and attributes of the helix used (number of turns, diameter, etc.). (Editor: resonance)

The new induction law he discovered showed that radiant shockwaves became much stronger when encountering segmented objects. The radiant shockwaves "flashed over" the outer skin of the helix from end to end without passing through the windings of the coil; shockwaves of 10,000 volts introduced to a 24 inch coil rise to 240,000 volts. The greater the resistance in the helix turns, the higher the maximum voltage. This was completely different from magneto-induction. Remember that he was not working with electricity but with radiant shockwaves.

> *Aether particles were incompressible and could easily pass through space and matter with a speed much greater than the speed of light. This was pure radiant matter but, at the same time, pure Radiant Energy. Cold electricity is one of the forms of this Radiant Energy*

This transformer he invented used radiant shockwaves to produce pure voltage without current. Each transformer had to be "tuned" by adjusting the disrupter to a specific impulse duration. At that point, voltage impulses could flow smoothly, flowing over the copper surface much like a stream of water in a pipe. No amperage could be detected but if the stream was aimed at a distant metal plates, "current" was produced which reached several hundred or even thousands of amperes. Tesla then began to wonder what made up this white, currentless stream.

Tesla determined that normal charge carriers (electrons) could not travel as quickly as the radiant pulse; no current moved the coil because the electrons were choked in the metal lattice of the coil. **The radiant pulse moving over the surface of the coil was not electronic in nature.** He placed the legs of a heavy U-shaped copper bus bar directly to the disrupter primary and then connected the short-circuited system to several incandescent lamps. These lamps glowed with a brilliant cold white light as with Gray's light bulb, proving that the power for the light was not electrical in nature. Tesla believed that the electrons were blocked from flowing through the wire while the radiant pulse was released over the coil surface as a "gaseous" pulse (splitting the positive, according to Gray).

Tesla came to believe that voltage could be viewed as streams of aether under various states of pressure and that his transformers affected the aether as to produce the luminous effects he observed. In his patents, he describes his "light-like rays" as tightly constricted aether streams propelled from his transformers along infinitesimal ray lines along which an incompressible movement occurs instantly through space on all points along its path. Aether streams were being drawn in through his transformer at higher natural pressure and then accelerated in the electrical discharge. The voltage in his transformer could control the brilliance of light in a room but this type of light was almost impossible to register on film. He could heat up a room or cause cool breezes by controlling the voltage in impulse duration in his transformer.

Tesla saw electrical current was really a complex combination of aether and electrons. Through the application of a disrupter, the electrons were removed from the gap by the magnetic field while the aether steams continued to flow through the circuit. He considered aether particles highly mobile with infinitesimally small mass and cross-section as compared to electrons. They were incompressible and could easily pass through space and matter with a speed much greater than the speed of light. This was pure radiant matter but, at the same time, pure Radiant Energy. Cold electricity is one of the forms of this Radiant Energy.

Edwin Gray, Dr. Nicola Tesla and Dr. Thomas Henry Moray all used radiant energy technologies. It is important to understand that the Laws of Thermodynamics and Maxwell's equations do not pertain to "Radiant Energy" technologies.

• Fantastic Projects •

Gravity Conversion Rotary Device

Review is prepared by editor Tatiana Ezhova

Here another fuelless perpetuum mobile is presented.

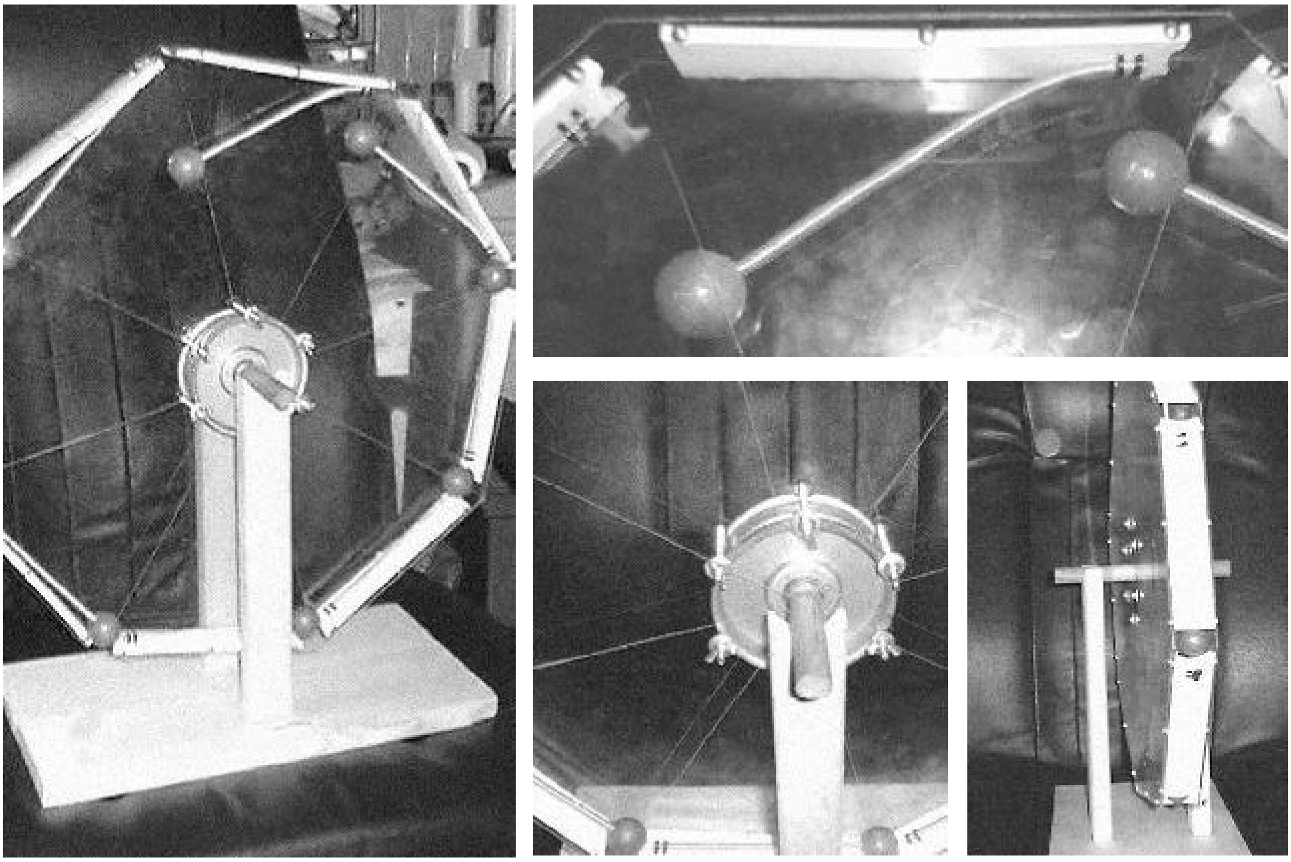

The system design

The design includes a wheel with spring spokes. Pegs may be fixed inside the wheel to balance movement of weights on springs. All parts should be homogenized as to dimension and weight. The author used 4 oz. lead balls and the 3/16" springs. The wheel measures 9" in radius as measured from hub center to center of each lead ball at outer periphery. This device is actuated and stopped by the hand. Its speed is self governing, it ramps up to speed quickly and simply stays there.

Note: you can find more detailed information about the device at http://www.greaterthings.com/News/FreeEnergy/Directory/GravityMotors/photos/. Also read in this issue article "Novozhilov's motor" that describes another wheel motor that does not require any fuel for its operation.

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ABSTRACT

Highly localized nuclear activation in electrochemical systems and other electrical discharge processes have been observed by many laboratories in the world. This report is an attempt to explain such anomalous phenomena by using torsion field theory and axion model. Anisotopic behaviours of radiation products, burst character, "heat after death" of excess energy release in electrical discharge systems are considered to be interpreted by the torsion coherence of vortex dynamics with the zero-point energy induced by localized intense field emission of micro-protrusion of the cathode, and the dynamic Casimir effect of transient evolution of triple region of gas, liquid solution, and electrode protrusion. Axion model and Primakoff's effect are proposed for explanation of nuclear transmutation without noticeable gamma radiation.

Nuclear products with high concentration, unidentified tracks with highly collimated lines of low energy nuclear reactions in the electrochemical systems were recorded by CR-39 solid detectors and photo-films, and localized spots with chemical alterations were observed at our laboratory. It is suggested to carry out intensive study of vortex dynamic for explaining the anomalous phenomena in wide area of nature and laboratories. Analysis of vortex dynamics with wide range from pitting corrosion of electrochemical system, laboratory plasma, tornado, to quasar spiral model with extremely high energy cosmic rays in the center region, leads to a conclusion for that vortex dynamics creates torsion fields responding to the anomalous effects.

I. INTRODUCTION

Many laboratories in the world have observed nuclear reactions and **excess heat** in electrochemical systems. The mechanism of such anomalous phenomena is not being well understood according to normally accepted physics.

Nuclear products with high concentration and tracks with highly collimated lines of low energy nuclear reactions in the electrochemical systems were recorded by CR-39 solid detectors and films at our laboratory [1,2]. These facts suggest that quasar model with spiral structure and extremely high enrage cosmic rays in the center could be used to explain the mechanism. It is supposed to use the concept of torsion field to interpret the observed phenomena, typically, the properties of axion acceleration, memory effect, and the polarized nuclear reactions with torsion effect [3].

II. PHENOMENA IN NATURE AND AT LABORLATORIES

The vortex and spiral structures are the archetype that appears at all levels of nature and laboratories, for example, atom structure, vortex lattice in superconductors, dense plasma focus, lightning, quasar etc.

Recent report of dark matter annihilation at the galactic center describes that the cold dark matter near the galactic center is accreted by the central black hole into a dense spike [4]. Particle dark matter annihilation makes the spike to be a compact source of photons, electrons, positrons, protons, antiprotons and neutrinos. It reminds us for that there is a similarity among pitting corrosion with electrochemical noise, laboratory plasma pinching (dense plasma focus, for example), fast laser induced ion beams [5] and quasar spiral model with high-energy cosmic rays in spiral center in spite of large dimension difference. Comparing the experimental results of electrochemical cells with excess heat and nuclear transmutation to astrophysics phenomena, it is supposed that the investigation of vortex dynamics of torsion coherence with the zero-point energy is essential for tapping the zero-point energy.

As it is predicted by quantum mechanics that the vacuum is seething with active energy, even at temperature of zero point Kelvin. This zero-point energy (ZPE) can be thought as an infinite number of virtual photons that are popping out of the vacuum and going back in, but should be a measurable effect en masse. To exam the origin of ZPE background, the interaction of matter with the ZPE can be treated on the basis of charged point particles interaction with a background of electromagnetic zero-point radiation with spectral-energy density.

Based on observation in the experiments, the following features are considered in order to understand the experimental results with electrical discharge systems.

A. ELECTROCHEMICAL DOUBLE LAYER

In an electrolytic cell, the electrolysis with high conductivity and the electrochemical double layer with large layer-capacitance lead to a typical structure of the cathode potential distribution similar to the cathode drop of glow discharge in low gas pressure. For a compact layer the thickness of the double layer is equal to one ionic layer, across which there is a linear fall of potential. Thus, high electric field exists in some regions on the surface of the cathode. The local enhancement of the electric field on the cathode surface with the double layer is related to the protrusions and cracks similar to the tip discharge in air or in a vacuum. The current distribution depends strongly on the surface roughness and the work function of the electron emission. A high transient current density ($> 10^8 A/cm^2$) could be expected due to enhanced field.

B. ENERGY CONCENTRATION

On the cathode surface, the high persistent electrical fields ($>10^7 V/cm$) and large equivalent capacitance ($>25 \mu F/cm^2$) lead to a high energy concentration in the double layer [6]. The concentrated field on the tips of the protrusions or cracks after a long-loading period with deuterium on the palladium cathode surface creates a high transient electron flux because of the large distributed capacitance and the negligible inductance in a localized discharge mini-network. The experimental data show that the reactions take place only in some restricted areas that have specific properties. The idea of micro fusion due to the results of energy concentration and the high deuteron flux could be used to explain the nuclear transmutation.

C.TORSION FIELD AND THEIR EXPERIMENTAL MANIFESTATIONS

Elementary particles have the moment of quantity of motion, i.e. spin. If in any substance the spins of particle have a preferable direction, then it is interpreted as spin polarization of the substance. Every substance creates a torsion-field (or called spin-field or axial field) in the space surrounding it when polarized by spins [7]. The superposition of torsion field, generated by the atomic and nuclear spins of each molecule, determines the intensity of torsion field in the space surrounding each molecule. Torsion field has strong penetration ability and does not interact with the crystal lattice of substances. The torsion field created by rotation of some sort of matter is concentrated in two opposite beams propagating along the rotation axis. The intensity of torsion-field with some lower constant value can be retained for several weeks after the rotation is stopped. Such property of vortex mater has been recently observed in type II superconductors with magnetic flux line lattice [8]. The studies of vortex matter of type II superconductors have shown a number of puzzling phenomena associated with vortex motion, including: low-frequency noise and slow voltage oscillations; a history-dependent dynamic response, and memory of the direction, amplitude duration and frequency of the previously applied current.

Some behaviors of the torsion-field effect have been observed in the experiments of electrolysis regarding the so-called cold fusion, such as when the gas bubble chains come out from the protrusions of the cathode surface a long time after switching off the electrolysis potential. The more surprising thing is the heat after death, which has been recorded by many labs. This phenomenon could be explained by the persistence effect of the torsion-field produced by vortex dynamics of tip effect.

D. EXPERIMENTAL RESULTS IN THE ELECTROCHEMICAL CELL

CR-39 plastic films possessing with a high degree of optical clarity and isotope in track response, and are sensitive to neutron, proton, tritium, alpha, and other charged particles, were used to detect the products of nuclear reactions. The films of CR-39 were immersed in the NaOH electrolyte of heavy water and placed adjacent to the tips of the cathode [9]. After 110 hours, electrolysis experiment with the applied voltage 1 V and current 2 ma, the solid detector was etched by 6.25 N NaOH solution in 70^0C for 11 hours. The photomicrograph shows the cluster of tracks with a cycle crater of 100 μm in diameter and 25 μm in depth. According to the etching condition, the energies of the most of the particles, P, T, α are estimated roughly to be in the range of 1-4 MeV. On the backside of same region of the CR-39 film detector, one can clearly see a few of tracks in the circle area or nearby. Such tracks are believed to be created by recoil-protons of forward incident neutrons. High concentration of the cluster of nuclear tracks could be explained by the quasar spiral model and by the crystal channeling effect [Fig.1]. The experimental results of the generation of tritium with single crystal metal of Pd show that none of the generation of tritium has been revealed by using non-single crystal electrodes [10]. The importance of the crystal channeling effect for nuclear reactions in the electrochemical systems can be inferred.

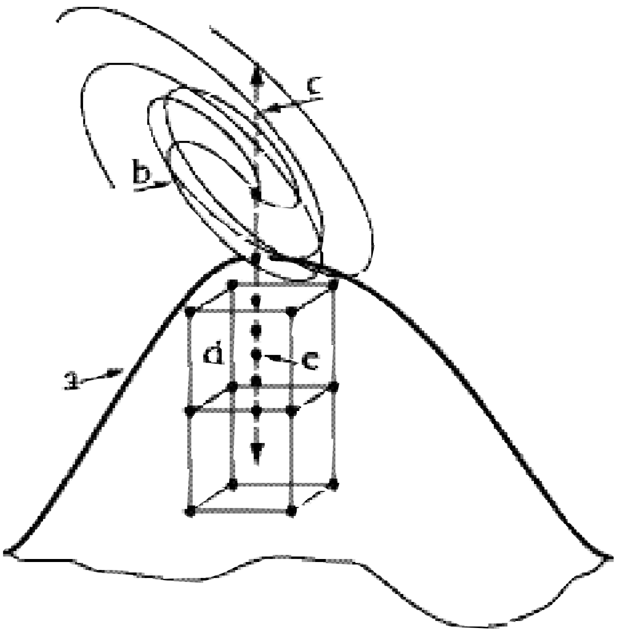

Fig.1
Schematic presentation of a micropinch spiral by tip effect in the electrolysis cell:
a) tip of the electrode; b) spiral structure of micropinch; c) electron beam; d) crystal channel; e) ion beam

To determine the spatial distribution of radiation active sites (RAS), Black-white 135 films of 27 DIN have been used to image the position of the RAS. After a 1,5 year of deposition in glass tube of finishing electrolysis experiments with light water electrolyte for more than 200 hours running, the patterns of RSA were clearly formed on the films after exposure of 100 hours [2]. The bright spots corresponding to the tips of palladium cathode edges can be seen due to the tip effect. The effect of magnetic field on the traces of the charged particles has been observed while the Pd samples exposing to the films, which were folding and wrapping up the sample, were inserted between couple magnets. The tracks stretching along the film surfaces confirm that the tracks were created by charged particles, electrons for example, with low energy about some keVs. Highly oriented tracks can be observed by autoradiography by using normal films locally[Fig.2].

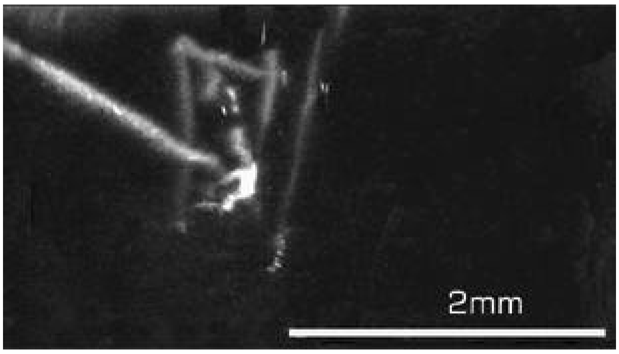

Fig.2
Autoradiography of charged particle tracks of beta delay isotopes on the surface palladium cathode. Some tracks of beta particles are paralleling the cathode surface.

E. SONOLUMINESCENCE AND “BUBBLE NUCLEAR FUSION”

Some scientists of Oak Ridge National Laboratory in America reported their articles of bubbles experiments in Science. Experimental results show that the radiation lights of sonoluminescence possess three characters: short duration with picoseconds; wide continual spectrum; highly oriented thin beams. **Based on those characters, vortex dynamics with axial acceleration of bubble collapse could be inferred.** Nuclear reaction with abnormal gamma radiation was observed [11]. Dr.Claudia Eberlein describes her conclusion on sonoluminescence that only the ZPE spectrum matches the light emission spectrum, which must be a ZPE phenomena [12]. The effect of torsion field on nuclear reactions along the axis of vortex should be taken into consideration for the low ratio of the nuclear products of n/T due to spin polarization of reaction particles.

Axion model and the Primakoff effect are proposed for explanation of nuclear transmutation without noticeable gamma radiation. Many laboratories in the world have been engaged in several experiments to search for axions, light neutral pseudoscalar particles yet to be discovered. The axion would be produced in the solar core through the Primakoff effect if its mass is a few electronvolts and could be detected in the laboratory.

III. CONCLUSION

Researchers of new energy study of "cold fusion" type should pay great attention to the general processes of electrolysis to find the key points, which could play a major role in the transit from the electrochemical processes to processes of torsion and the nuclear processes. From the authors' point of view, the evolution of double layers is of importance to understand the anomalous effect, typically on the protrusions of cathode. The change of space-time near the tips due to torsion field generated is expected to delivery the zero-point energy, and dynamic Casimir effect for the evolution of gas bubbles on the tips are expected to generate photons and excess heat [1]. The yields of transmutation products are related to the current distribution on the cathode surface. The cathodes of thin wire were benefit to the generation of nuclear reactions and excess heat for electrochemical systems. Careful examination of the evolution of electrochemical double layer will lead to a good understanding of pitting corrosion with electrochemical noise, and further to recognize the anomalous excess heat and nuclear reactions.

Heat after death was observed at many laboratories. It is believed that the persistence behaviors of torsion field can be used to explain such anomalous phenomena.

The contact between beads coated with a thin metallic layer or multilayered film and palladium black particles could be regarded as point-contact similar to the tip-effect [13].

We may say that it is expected to reveal the puzzles of the mechanisms of high-Tc superconductivity with pinning vortices by the torsion field theory [14,15].

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Fantastic Projects

The Invention of Roman Solomyanny

Our previous issue featured an article about Roman Solomyanny who came to our office and told us amazing things. He said that during his army years (according to his words, he was in the military intelligence) he made a radio technology invention and later on built a free energy generator. The inventor claimed that his device had been working for a certain period of time without any fuel and had been producing power enough for heating and lighting his countryside house. We could not ignore such an intriguing piece of information. Moreover, Roman promised to build and present his device in 2003. We paid him for this interesting story to be published in the issue and prepared for the continuation... Alas, to no avail... His mobile phone was silent and we started to worry about the inventor's health. Fortunately, we managed to contact his parents on his home telephone (Roman lives in St. Petersburg) and they told us that the chap was OK. It seems he's lost his interest in us. But we still hope that Roman did invent something really exciting and not only polished up his talent for writing science fiction articles. Those people, who want to know the details about this invention or discuss it with the inventor himself, can get in touch with us for his contact information. Anyway, we will be very pleased to see him again full of new exciting stories. We have already introduced the 'Humour' section into the magazine and are planning to start the 'It Just Can't Be So' section.

Editor

Physicists are Joking

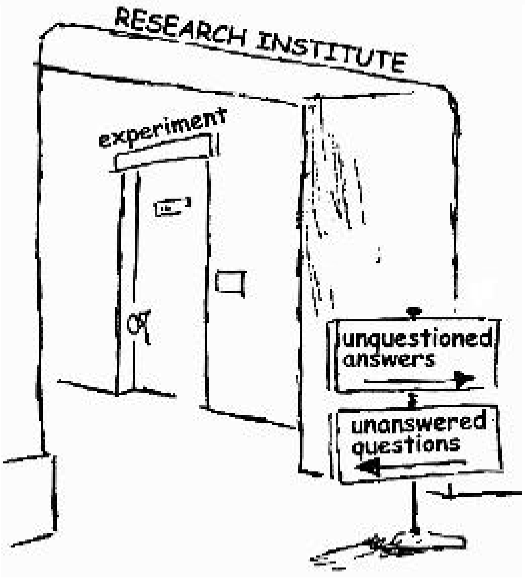

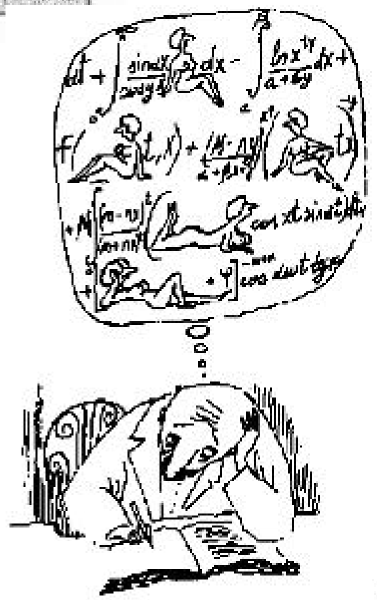

Anti-Gravity: The Holy Grail of the 21st Century

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A Primer on the Role of Electromagnetic, Electrostatic, and Torsion Fields in Anti-Gravity and Field-Effect Propulsion

Before visiting a University of Washington physics professor to talk about electrostatic propulsion, and hopefully anti-gravity, I realized: *Birds defy gravity. So do 747's for that matter. They apply the laws of physics and lift off the ground. That's anti-gravity, isn't it?* Yes, that's true, I suppose, in a metaphorical sense. But seagulls, jumbo jets and space crafts manifest anti-gravitation effects strictly speaking. What I want to address here is not the overcoming of gravity but the neutralizing of it.

Dr. Eugene Podkletnov, one of the foremost researchers in anti-gravity, and whose work is sought by NASA, Boeing and British Aerospace (now known as BAE Systems) describes the hunt for anti-gravity the greatest scientific quest of this century. He calls for an international effort, akin to the Manhattan Project that developed the atomic bomb, to conquer the secrets of anti-gravity, and usher in a new era of scientific understanding whose technological development will be at a scale so vast that the potential outcomes are merely hinted at by our previous achievements.

Just getting such a project off the ground will require unprecedented international cooperation, and public disclosure as well; the potentials are that vast, that scary, and that dangerous. Dr. Dan Marckus, noted British avionics expert, states in The Hunt for Zero Point, the seminal work-to-date on anti-gravity written by Jane's Defence Weekly aviation editor Nick Cook, that the secrets of anti-gravity in the wrong hands will make thermonuclear weapons look like firecrackers.

The secrecy surrounding anti-gravity research is phenomenal. Boeing refuses to publicly acknowledge any activity in anti-gravity development despite the fact that its competitor and sometime sub-contractor, British Aerospace (BAE Systems) is, the latter providing funds for four university research efforts as part of its Project Greenglow, one of which was a Podkletnov replication experiment headed by Dr. Clive Woods at the University of Sheffield,. Further, Nick Cook publicly, and privately to me in an email, states quite directly that George Muellner, former director of Boeing's ultra secret Phantom Works, claims Boeing sought the services of Dr. Podkletnov to unlock the secretes of his gravity-shielding research. Cook says that Muellner states Boeing was denied Podkletnov's services due to the objections of Russian officialdom, which the Russian-born Podkletnov must pay attention to, apparently, despite the fact that he works in Tempere, Finland. Dr. Podkletnov, wisely perhaps, chooses not to clarify these particulars despite our several emails.

Perhaps Boeing can deny any activity on anti-gravity because NASA is doing its own research, and as a prime contractor to NASA, such as by running the Space Shuttle Program, Boeing probably knows what NASA knows. NASA spent $600,000 recently in its Breakthrough Propulsion Physics program (BPP) to purchase Podkletnov replication equipment. Inexplicably, that equipment sits in boxes in NASA's Marshall Research Center in Huntsville, AL, awaiting more funding; according to an email I received from NASA propulsion researcher, Ron Koczor.

But enough with this business; what do we know about anti-gravity?

The search for that answer has taken me to some exciting and obscure places in this world, like the Aeronautics and Astrophysics lab at the Seattle campus of the University of Washington. I called those folks because Nick Cook in The Hunt for Zero Point, mentions that UW received a NASA contract to study theories of inertia as part of its BPP program. *That's a good place to start,* I thought, but it took backtracking to BPP Project Director Marc Millis at NASA's Glenn Research Center in Cleveland to find Dr. John Cramer at the UW Physics Department. His mission was to confirm with Dr. James Woodward the latter's 1996 preliminary research into the loss of gravitational mass in a targeted piece of metal from oscillating capacitors. Although Woodward's initial data appeared encouraging, NASA's Millis told me that their funding dried up before completing their research. Furthermore, the entire BPP became unfunded in 2002 and now in 2003 has become a hazy, privatized version of its former NASA subset self.

However, UW is continuing related research, such as magnetically confined fusion energy generators and that, for me, by using electromagnetism to contain an inner field makes it a close cousin of anti-gravity and field-effect propulsion. I spoke with Professor Uri Shumlak who told me that he and other UW staff from the Department of Aeronautics and Astronautics, along with a bevy of their grad students, are building a prototype of a fusion generator called HIT, which stands for Helicity Injected Torus.

This donut ring-shaped torus encloses a roundish chamber. Within that chamber a vacuum is first created, and then a volume of hydrogen gas is introduced and heated to a few million degrees Celsius, which separates the electrons and protons from their atoms turning the whole stew into a quasi-neutral foam of plasma. Then the torus envelopes the plasma with a magnetic field to keep it away from the sides of the chamber enabling the plasma mass to stay hot, and keep the rest of Seattle cool. (While I was standing next to his little eight foot long gizmo, Prof. Shumlak assured me there was no danger of a couple million degrees of heat escaping. The heat density of the plasma was "too low" for me to, well, break a sweat over. His quote was, "There's no more heat mass inside that chamber than what's contained in a cup of coffee." I sure hope you're right, Doc.)

Then, once the plasma field is contained, the magnetic field squeezes the plasma, fusing the nuclei of one hydrogen atom into another. As the hydrogen couples combine, a helium atom is created and a neutron is released, along with lots of energy in the form of heat. One day, such a generator will give us unlimited amounts of electricity, as the heat can produce electric voltage.

Lots of electrical power on the cheap the UW predicts; and the Department of Energy agrees, once the details of building reliable magnetic field generators are solved. What does magnetic fusion have to do with anti-gravity? Two things: first, magnets. Electromagnetism seems to be one of the major players in anti-gravity, particularly the use of electromagnetic fields to contain other fields, such as plasma fields in the HIT, or torsion fields, but more about that later. Secondly, the HIT works, or is about to. It's real and mainstream science embraces it, while anti-gravity is, well, a little more out there and reliable data is harder to obtain. So the technology of HIT lays a base that other research can build upon, such as not only containing other fields, but also building field effect propulsion systems, the most elementary of which is electrostatic propulsion, and aspects of that are already being applied by NASA.

Electrostatic propulsion uses electrical fields differently than electromagnetism does. In EM a current flows and creates a field, while in electrostatic systems the current is static and a charge builds up a field, such as in a capacitor.

These theories are utilized on NASA's Deep Space I, a probe bound for the outer reaches of our solar system. On Deep Space I, the propellant, a tankful of xenon gas, is excited electrostatically into positive ions. The engine has a negative charge at the exit end, so the charged xenon rushes out the tail pipe with a greater thrust than if it was just using conventional chemical propellants. In fact, the electrostatic propulsion system on Deep Space I allows it to fly at 60,000 mph, or 10,000 mph faster than it would with a conventional rocket. In addition, only 82 kg of xenon is needed for its entire mission, so with its smaller mass and weight Deep Space I will fly along side its intended target, a comet, and drag race on equal footing while filming and conducting studies. Again, not anti-gravity per se, but electrically charging Deep Space I's fuel-field sets the stage for a closer look at electrostatic propulsion.

Taking that closer look is Tim Ventura and his fellow researchers at American Antigravity, an organization based in Kirkland, WA. Ventura and his crew use electrostatic asymmetrical capacitors to create a field that levitates objects, such as their small, kite-like "lifters." These lifters are very light, weighing only a few ounces, and have balsa wood struts that support the capacitors. When two capacitors of different size receive their share of a 30,000 volt charge, the lifter lifts- no motors or wings.

How, no one really knows in my judgment; and the phenomenon is replete with controversy and mystery. But as one who has seen a lifter fly, let me tell you what one looks like and what I saw when Tim Ventura's took off.

Tim has been building lifters since he was a kid and has perfected a four-foot, by-four-foot, by four foot triangular lifter which has flown so many missions in his garage that the silver aluminum foil has turned white. The thin, chopstick-like balsa wood ribs that hold the aluminum foil in place are joined every few inches by a vertical strut (much like a telephone pole on a HO model railroad set) which sticks up and secures the copper or stainless steel wire of the upper capacitor. The ribs are intersected every ten inches or so by the strut of an interior triangle, since the whole lifter is composed of interconnected isosceles triangles which give the necessary strength to the balsa wood frame. All told there is about 30 linear feet of aluminum foil and a similar run of wire.

The lower and larger capacitor is a strip of aluminum foil stretched between the horizontal balsa wood struts. The second capacitor is a thin strip of 50 gauge wire mounted about one inch above the aluminum foil. As capacitors they store electrical charge but don't pass it on in a current.

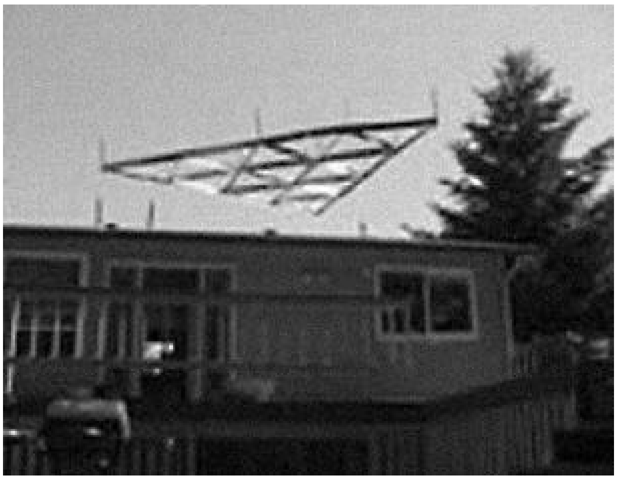

Fig.1
Lifter

The negative lead goes to the lower aluminum foil and the positive lead is attached to the upper wire. The three corners of the lifter are tethered to the work table so that the electrical leads from the power source are not broken off in flight.

The power source kicks out 15,000 volts at 250 watts. Tim uses a voltage generator made by Information Unlimited, Inc, but before the current reaches the capacitors, the voltage is stepped up to 30,000 volts by Tim's homemade voltage multiplier stack. At full throttle the lifter is straining at the tethers, bending the balsa wood frame near the point of fracture.

Throw the switch and at around 17,500 volts the lifter begins to quiver in take-off. At the full power of 30,000 volts the lifter is roaring and a noticeable downward breeze is observed. Many physicists call it "ion wind," and say that it is how the lifters fly. But what exactly is ion wind, and can it be the cause of flight?

"Ion wind is the movement of ionized air particles," according to Ventura, "which flow downward according to electrical charge." Here's his theory:

The positively charged wire on the top part of the lifter steals elections from the surrounding air, leaving the effected air molecules positively charged. These positively charged air molecules, or ions, then head downward toward the large source of negatively charged electrons generated by the aluminum foil. These air molecule ions are bigger and heavier than the electrons seeking them, so there is a net thrust downward pushing the whole lifter up. That's the theory, and frankly all I can do to verify the theory is to tell you what others tell me. Before I do that, though, let me tell you what I experienced standing next to a levitating lifter.

In flight the lifter emits a high whining, hissing buzz, and I could feel a good breeze coming up at me from the work table underneath the lifter. Also, standing next to the lifter but not touching it, the hair on the back of my head started to rise up in electrostatic-like fashion.

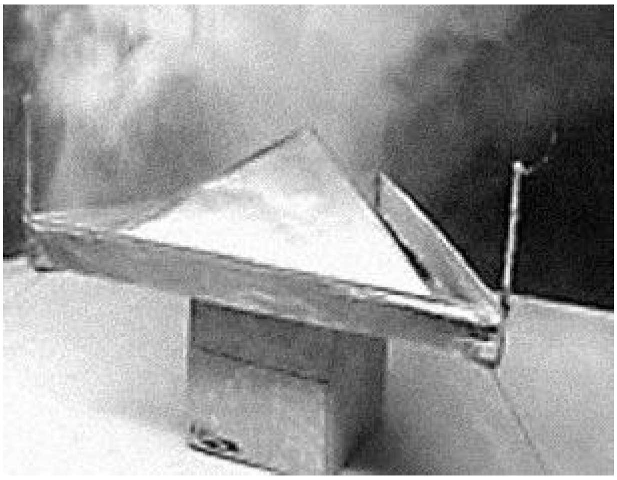

Fig.2
Lifter

To analyze the air currents Tim blew baby powder at the top of the lifter. The majority of the particulate cloud was drawn into the middle area of the lifter and then sucked downward. A kind of vortex was created at times, for intermittently I could see a cloud forming into an organized column beneath the lifter and then spreading out in 360 degrees once it hit the work table surface.

Electrostatic propulsion uses electrical fields differently than electromagnetism does. In EM a current flows and creates a field, while in electrostatic systems the current is static and a charge builds up a field, such as in a capacitor

Is that ion wind? Well, there certainly was a breeze, and it sure felt like air, but how would I know if it was ionized? Something definitely sucked the baby powder down, but was it more than just regular air blowing past me? Again, I don't know.

Is the movement of wind why lifters fly, regardless of whether it is ionic or not, or is the wind just a by-product and not the propulsion? Could the capacitors be creating a field that neutralizes gravity, allowing the craft to levitate? Or are they creating some kind of new field that is localized and the surrounding ambient field pushes this "field-bubble" up, much like a helium balloon is pushed up by the surrounding heavier air trying to fill the emptier "field" of the lighter helium?

Ventura thinks at least two phenomena are at work. Ion wind is definitely one he feels, for the breeze is self-evident. However, he thinks a second effect is at work, too, and many agree with him. Most speculation concerns what is called the Biefeld-Brown effect, the "Brown" being T. Townsend Brown, whose name is well known in early quantum research and whose work is prominently discussed in Nick Cook's The Hunt for Zero Point.

The Biefeld-Brown effect, according to Ventura, is the theory that high voltage, air-gapped capacitors with different or asymmetrical capacities generate a net directional force upwards from the larger element to the smaller element, which on the lifter is from the aluminum foil to the wire. This force then pushes against the ambient energy field of the surrounding area, perhaps pushing against a more rigid energy field of the zero point energy field.

Brown apparently made his case for these electromagnetic effects, receiving patents in the 1960's for his research. NASA's Dr. Jonathan Campbell at Marshall Research Center in Huntsville confirmed to me that he also, has received a patent recently for his research into the thrust effects of asymmetrical capacitors.

Editor: By the way, this patent is meaningless from the point of view of a prime claim. Before that there had been many publications on the subject.

A.V. Frolov.

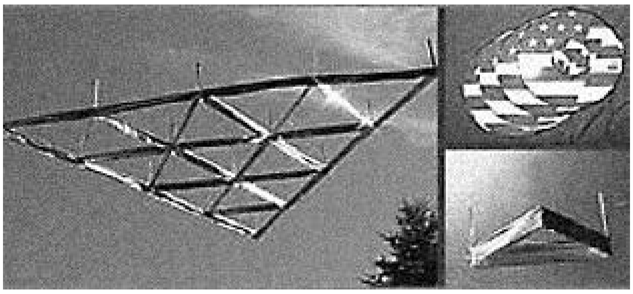

Fig.3
Lifter

However, prominent physicist Hal Puthoff, whose research is a broad swath across the fields of the 'new physics', featured in both The Field and The Hunt for Zero Point, and who was also the military's "Top Psychic" as the twelve-year director of the CIA's remote viewing squadron, has a different perspective: "I'm quite certain at this point that the so-called 'lifter' phenomena is just an electrostatic ion wind phenomena, not 'antigravity.'"

But Dr. John J. Rusek, Adjunct Professor of Aeronautics and Astronautics at both Purdue University and the United States Air Force Academy, says that "Initial findings of 'classroom' experiments with lifters show ionic wind to be way too small a factor, by three orders of magnitude." Dr. Rusek has formed a technological company, Swift Enterprises, to continue this research and bring it to the level that is "presentable to the mainstream physics community."

Along these lines, Jean-Louis Naudin shows on his extensive web site, not only how to build a lifter, but also several photos of research into the ion wind issue. Naudin's team has wrapped test lifters in plastic yet they still produce anti-gravitational effects.

Others may have a clue to the second or even a third force at work. Researcher Fran De Aquino, professor of physics at Maranhao State University in Sao Luis, Brazil, is described in the literature as showing that "bubbles of localized space-time" can exist in variance to the surrounding fields. Anecdotal experience suggests that the lifters may be undergoing such space-time anomalies.

Editor: At this point we need to interrupt the author as he has already completely confused the reader. I would recommend referring to Thomas T. Brown's patent: USA patent #3,187,206, 1965.

Alexander V. Frolov

The Hunt for Zero Point states that NASA sought the services of Dr. Eugene Podkletnov, and although their replication research languishes, The Hunt claims that researcher Ning Li, of Huntsville, AL is pursuing this line of research as a private contractor to NASA.

Another Huntsville operation, Transdimensional Technologies, is exploring these multi-faceted phenomena as well, and its extensive web site shows it to be a frequent contractor to NASA, including research into "asymmetrical capacitive propulsion," and capacitor-based devices to test "ion wind" forces. Jeff Cameron, of Transdimensional, is said by Ventura to be "the father of the lifter," having developed them while exploring anomalous torsional effects of high energy lasers. The lasers twisted and at the time it was considered a nuisance. But the unknown forces at work later led Cameron to found Transdimensional, develop lifter technology to a commercial level, and subsequently patent many pieces of related technology. Unfortunately, I have been unable to reach Jeff

Cameron or anyone at Transdimensional for any kind of confirmation.

Nevertheless, how would gravitons be blocked, or gravity shielded?

Dr. Hal Puthoff says there are two ways of looking at it. First, one can look at the issue from a quantum point of view, that there is a particle exchange between the gravitons and something else, and the net effect is anti-gravity. The how's and why's of that are speculative, so Puthoff turns to a classical approach for answers. He prefers looking at "engineering the vacuum." To do that one must first look at the vacuum.

As I understand it we are all in the vacuum, everything is. The "vacuum" is the matrix that contains all matter and all energy. It is the engineering perspective of the zero point energy field, or the *"Field"* as popularized by Lynn McTaggart in her masterpiece The Field. Puthoff shared with me statements from fellow researcher Dr. T. D. Lee that state: "The vacuum is the seat of energetic particle and field fluctuations, and ... is the seat of space-time structure ... that encodes the distribution of matter and energy.... The vacuum is energetic in its own right."

Thus energy can be drawn from the field; and spacecraft can have "vacuum propulsion systems, or propellant-less propulsion," in other words, field effect propulsion.

At any rate, more and more physicists are thinking that the vacuum can give them a whole lotta oomph, enough to propel spacecraft; and when they learn how to corral it, a whole bevy of new phenomena may be encountered, including anti-gravity. This new potpourri of research is being called by many the "new physics." And although his approach is classical, Dr. Hal Puthoff seems to be sensing what's out there waiting to be discovered.

Puthoff's current research as been to explore "the perturbation of atomic or molecular ground states, hypothesized to be equilibrium states involving dynamic radiation/ absorption exchange with the vacuum fluctuations. In this model atoms or molecules ... are expected to undergo energy shifts that would alter the spectroscopic signatures of excitations involving the ground state." Puthoff says he's had no success so far with this approach, but his words remind me of De Aquino's speculation that objects lose mass as they absorb energy. Pull energy from the field around you and you lose weight. Bingo, lift-off. **But how does one pull energy from the field?**

Editor: Some solve this problem by means of the ether density changes, which are performed with the help of vortex longitudinal-wave technologies.

A.V. Frolov

Torsion fields might play a role here according to many, and the literature on anti-gravity is filled with the phrase, "torsional effects." But what exactly is a torsion field? "It has something to do with spin," Nick Cook told me on the phone. "You have a torsion field when you spin something. Add a little electromagnetism and you might have anti-gravity." That's the short-hand version of it and here's a deeper look.

Mike Wright, resident physics expert at BeyondTheOrdinary.Net web stream radio, told me this: "When forces create curvature (such as rotation) in more than two planes, a torsion field results. Not only does the object go around, but it goes around and 'down' or 'up', and the up/down movement is an additional acceleration in that dimension. EM and gravitational fields differ by having a magnitude of force and only one direction of movement.

"A tornado is a structure of air in air. A whirlpool is a structure of water in water. So, because more than two planes are involved, objects can be created from 'nothing'; that is to say that objects can be created from the medium of the environment, such as a tornado from two air masses of differing temperature."

So spin plus movement is the key. Again, Tim Ventura is on the hunt. He demonstrated to me **that spinning magnets will cancel out their magnetic fields sufficiently so that two magnets facing each other with like poles will not push each other away if one of the magnets is rotating**

perpendicular to the force of opposition. It's not anti-gravity, but it gets us closer to the heart of the matter.

Further, Russian physicists have been researching the torsional effects of both subatomic particle spin, and the loss of gravitational mass in planets from the angular momentum of their orbits. Spinning makes something happen, but what? Tornadoes and Mother Nature might have a few clues.

Tornadoes spin, in a sense, although no one is Oklahoma who has spent a night in a storm shelter during an F5 event would describe the tornadoes in the night sky as *spinning*. Nevertheless, tornadoes have anomalous effects that are legendary: blades of grass stuck into mirrors, a piece of straw embedded flawlessly into a tree trunk. How? It seems as if the laws of mass, gravity and inertia are melted as winds swirl at speeds up to 300 mph in an organized vortex pattern. Is this a clue to melting the pull of gravity?

Getting information to this question has not been easy. Many scientists claim not to have even heard of torsion fields, including particle physicists at major US universities. So, again I turn to Nick Cook and The Hunt for Zero Point

Dr. Dan Marckus says that if "you generate a torsion field of sufficient magnitude the theory says you can bend the four dimensions of space around the generator. The more torsion you generate the more space you perturb. When you bend space you also bend time."

Marckus continues, "If you dipped ...one of these whirlpools ... into the zero point energy field, the seething mass of latent energy that existed on an almost undetectable level all around us [in the field would] ... react in an almost magical way by directing that energy."

The torsion field, in effect, is "a pump, a 'coupling' device that could dip into, and then direct, energy out of the zero point energy field." "But," Marckus continues, "the vortex wasn't a three-dimensional phenomena or even a four-dimensional one. It couldn't be. For a torsion field to be able to interact with gravity and electromagnetism it had to be endowed with attributes that went beyond the three dimensions of left, right, up and down, and the fourth-dimensional time field they inhabited; something that the theorists for convenience sake labeled a fifth dimension-hyperspace."

Cook concluded that the torsion fields "bind with gravity ... to produce a levitation effect -- an antigravity effect," but "it wasn't doing so in the four dimensions of this world, but somewhere else." That somewhere else is hyperspace. **So how do we activate torsion fields and enter hyperspace?**

Dr. Eugene Podkletnov may have a clue.

Podkletnov, the Russian researcher working in Finland, has studied the gravity shielding effects of superconductors. Again, Nick Cook in The Hunt, relays vital information. Cook says Podkletnov claims, "If the superconductors are rotated considerably faster than 5,000 rpm ... the disc experiences so much weight loss that it actually takes off." Thus, torsion field creates levitation. I emailed Dr. Podkletnov to find out more about this issue. He replied: "[A] fast rotating object can, under certain conditions, cause the polarization of the volume that it occupies in space and around it. This polarization causes the gravitational effect as it modifies [the] local gravity field. The vortex of the polarized particles will create a vertical thrust with a certain force and spatial momentum. Some scientists call these polarized particles gravitons. The term graviton is an artificial one and at present we are not sure if it is a wave or a particle and what type of particle. Maybe it is a usual tachyon or a superluminal neutrino (a faster-than-light-particle). Polarization of the media means that the spins of electrons, protons, neutrons and of small subatomic particles that constitute the fabric of space or vacuum would be parallel. Then a kind of gravity well is formed and the objects tend to fall into this well. We observe this picture as an object rising to the sky. Polarization of the media (of space) causes some glow around the object as it acquires additional energy and because of it, the glow around some objects is observed."

What I understand from Dr. Podkletnov is that gravity is the effect of spin -- the spin of all subjected particles, from the sub-atomic level and up being parallel; thus they are all aligned to fall into the gravity well of earth. And spinning objects, such as his superconducting discs, when influenced additionally by an electromagnetic field, will experience a shift in the spin of the sub-atomic and atomic elements. They will be turned and not be aligned in parallel. Thus, they are able to levitate.

But how to polarize the media and get things spinning? Enter Dr. Marcus Hollingshed, an enigmatic figure allegedly from Cambridge University. Dr. Hollingshed claims to have built a six-ringed toroidal coil antigravity device, which achieved great effect using rotating magnetic fields. In January 2003 he announced on the Internet that he has developed a 160kg vehicle able to lift in excess of 2000kg and that it has both horizontal and vertical drive features. His device cannot only go up and down and sideways, but it can push things away and pull objects to it.

In addition, the field that the device purportedly generates is capable of being broadened and weakened, or narrowed and amplified in a lensing effect, with the field producing an absolute vacuum of 2.2m spherical diameter. Best of all, when it's cranked up the core of it goes invisible, although the term Dr. Hollingshed uses is that there is a "loss of reflected light." There are no reports of independent confirmation, and Nick Cook says he hasn't been invited to see it, so, he's skeptical.

Where does this leave us? Perhaps Dr. Podkletnov's words sum up our current situation."Modern theoretical physics cannot give you the direct answer to your questions (levitation, torsion fields, etc.,) and a scientist who would agree to give you the answer cannot be regarded seriously, softly speaking. If you had asked Dr. Einstein if he were an expert on gravity, the answer would be NO. I can repeat his words: No, I am not a magician, yet; I am still learning."

ELECTRICAL LEVITATION

Wayne Macleod, USA
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Gravity is the incremental slowing of time as we move closer to its source. If we imagine panes of glass stacked on top each other, one pane slightly denser than the one immediately above, a ray of light coming from above will constantly refract in a curved beam downward as it enters the stack. The same is true of a ray of light entering a gravity field. The analogy is not too far fetched because refraction is caused by a slowing of light in the denser medium. Of course, gravity affects material objects as well as light, but this is explained by every object traveling on a 'world line' in spacetime. We can use light as in the glass example because light is its own world line.

Why the world lines of objects take the paths they do can best be understood by compressing our normal 3 dimensional space into 2 dimensions, length and height only. When we throw a stone into the air it rises and falls in a parabolic arc in these two space dimensions. That path in space is a complete mystery until we consider another dimension, time, a dimension we can imagine measured at a right angle to the plane of the 2 space

energy and because of it, the glow around some objects is observed."

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Why the world lines of objects take the paths they do can best be understood by compressing our normal 3 dimensional space into 2 dimensions, length and height only. When we throw a stone into the air it rises and falls in a parabolic arc in these two space dimensions. That path in space is a complete mystery until we consider another dimension, time, a dimension we can imagine measured at a right angle to the plane of the 2 space dimensions. By multiplying the time of the object in flight by the speed of light, we have a three-dimensional coordinate system, not of space but of spacetime. We can then graph the world line of the object. So why does the object fall? It is because spacetime near massive bodies is curved. A remarkable fact is that the curved world lines of all objects in the same gravity field, whether of a thrown ball or fired bullet, have the same radius of curvature. Hence all objects fall with the same acceleration.

To neutralize gravity we must somehow 'straighten' the world lines of objects traveling in curved spacetime. It would be as if we had in our stack of glass panes a bubble, around which the density of glass became less on approach to the bubble. Then the ray of light, when close to the bubble, would refract opposite to the path it would normally take when traveling thought the rest of the glass. Similarly, if we could manufacture a 'time bubble' in a gravity field opposite to the time slowing known as gravity, we would have any object embedded in the time bubble isolated from that gravity field.

The Electrical Levitation theory can best be understood by first considering an analogy. Let us imagine a wheel spinning on an arm like a child's propeller toy. The arm also rotates, in a direction opposite to the spinning wheel. We consider the rate of spinning of the wheel from the point-of-view of two observers, one observer stationary on the ground, the other observer rotating with the arm. Obviously the two observers will not see the same rate of spinning on the wheel. Because the arm is rotating opposite the spin of the wheel, its rotation must be subtracted from the rate of wheel spin as seen by the stationary ground observer. This is not true of the observer rotating with the arm, who will see the spin of the wheel as if there were no arm rotation.

The concept is easier to envision with linear motion, such as of a man throwing a ball on a moving train. The velocity of the ball seen by the pitcher on the train will not be the same as its velocity seen by a stationary observer on the ground. As the stationary observer sees it, that velocity will have the train's velocity subtracted from it if thrown against the train's velocity. It is the same with rotary motion: the velocity of the wheel for the stationary observer is slower because the arm's rotation is subtracted from it.

But suppose the wheel rotation is *the same* for the two observers! Something must be different between them, and that is time. As explained by Special Relativity for linear motion, time is not a universal constant; it differs between observers depending on their relative motion. The property of nature that *is* constant, that produces this relative time difference, is the speed of light. So we must look for a similar constant in nature for a relative time difference between observers in our rotary example. We have one in electron angular momentum, known as electron "spin," $h/4\pi = 5.28 \times 10^{-35}$ kg-m^2/sec, where h is Planck's constant. Like the speed of light, this quantity is constant for all observers, whether the observer is on a rotating system or stationary on the ground. Here is the tool for producing our time 'bubble'.

Let us now imagine a series of concentric rings, all rotating in the same plane and in the same direction. Electric current is pushed through these rings in the same direction as the ring rotation. (Current here is considered the flow of electrons, not conventional positive current.) The rotating rings are sandwiched between two magnetic plates, the function of which is to maintain the angular momentum of the current electrons oriented properly with ring rotation.

Analogous to the above example, each electron takes the place of the spinning wheel and the rotating arm is replaced by the rings. Thus, because electron angular momentum is a universal constant, an observer of the electrons in this rotating system will not have the same time as a stationary observer outside it. If each current electron has its "spin" oriented opposite the rotation of the rings, time on the rotating system would run faster than for a stationary ground observer, the same as in empty space relative to the Earth. The rotating system would therefore have the world line of empty space, not that of the gravity field. Its spacetime would not be curved. Since gravity is a time phenomenon, such a system in a gravity field could not have the behavior of a normal object. This conclusion may seem erroneous considering that ring rotation could never reach relativistically significant velocities, but we have an analogy with magnetism that is caused by a Lorentz contraction of the distance between moving electrons. If we considered the diminutive drift velocity of electrons alone we would never conclude that magnetism was possible, but the effect is *accumulative* over trillions of electrons. The hypothesis here is that the same is possible with the trillions of free electrons oriented with a spinning ring, to produce an accumulative time effect.

We now come to the controversial part of this theory because the above treats electron angular momentum the same as angular momentum of a normal physical object, whereas the electron is a quantum particle and quantum particles have their own realities with bizarre consequences when analogized with our macro universe. For instance, the electron has quantum spin number 1/2, and such a particle would have 720 degrees in one rotation, not 360. Nevertheless, the electron *does possess* di-pole magnetism. It *does behave* as a spinning ball with negative charge. Electrical Levitation is therefore an empirical theory. The property of the electron that gives electron di-pole magnetism cannot be an actual physical rotation, but whatever that quantum property, if it produces di-pole magnetism there is reason to expect it to produce other macro physical phenomena as if it were.

The theoretical finding of General Relativity that time runs slower in a gravitational field was confirmed by the Pound-Rebka experiment in 1959. **It is not that gravity causes time slowing, gravity *is* time slowing.** Since time and energy are reciprocal, more time on our rotating ring system would mean less energy seen by an observer in that frame of reference than seen by a stationary observer on the ground, the opposite of the red shift of a gravity field. This energy difference must equal the energy of the mass in a gravity field that is to be levitated, its energy of weight, and lost. Experimenters should therefore be aware that their device might radiate. But this is not a free energy machine. The energy of levitation comes from its magnetic field, and the electron magnetic moment energy turns out to be $V_e = mc^2$ divided by the electrical current, *m* is the mass to be levitated and *c* is the speed of light. This is an enormous amount, but becomes practical if enough electrical current can be sent through the rings. That means the electrical resistance of the ring material must be very low. For copper it is not. No material currently exists with sufficiently low electrical resistance at room temperatures, but **superconducting materials** exist that at cryogenic temperatures experience a dramatic loss of electrical resistance.

An experimental device can therefore be envisioned using a superconducting disc substituting for the electric rings. The disc would serve as a conductor for an electric current and would therefore need to be sliced along one radius with an insulator placed in the notch. Both edges of the notch would be connected to a power source by brushes rotating with the disc. With a counterclockwise disc rotation as seen from the top, to have clockwise electron "spin" the magnetic field between the plates would have to be up. Only the moving free electrons of the current will be available for any time alteration effect. These will also **produce a magnetic field, which it is reasonable to assume would be of the same time alteration effect as the electrons, thus producing the required alternate time "bubble".**

The resources required for an experiment using superconducting material at cryogenic temperatures are beyond this writer's means and an experiment has not been attempted, but an experiment at the Tampere University, Finland, 1992, using a superconducting disc suggests that gravity shielding is possible. Owing to the immense advantages gravitational shielding would give to the present interest in space exploration, effort toward its development would be logical. This essay may offer clues on how to begin.

Editor: I find the article by Wane McLeod quite interesting as his approach is very similar to the idea I first presented in my report at the "Space, Time and Gravitation" Conference which took place in St. Petersburg in 1998. The report was included into The Proceedings of the Conference, Part I, 1999. Before that the brief version of the article was published in English in the 'ELECTRIC SPACECRAFT' magazine, Leicester, North Carolina 28748 USA, Issue 27, 1997 p.30-31.

I managed to demonstrate that the ideas of Thomas T. Brown, especially his USA patent # 3,187,206 of 1965, are something more than just the force asymmetry in the electric capacitor. According to the concept presented in my report, by creating a matter property gradient (in particular, the dielectric permittivity gradient) we actually change the curvature of the electric force line in space. Normally, the natural space curvature accounts for the electric field potential decrease with the distance increase from the surface of the charged object. By creating the dielectric permittivity gradient (described by T.T. Brown in his patent of 1965) we change the natural distance potential gradient law. We can both increase and decrease this change and even reverse it. With the dielectric permittivity change square function, the natural space curvature is completely compensated and with more extent it is reversed and can be turned to negative. At that rate, the potential is not decreased but increased with the increase of the distance from the surface of the charged object. This is the essence of my concept that has never been considered before by any author. By creating the gradient described by the quartic function we get the same distance potential gradient law as in the natural conditions only with a different sign!

T.T. Brown, who discovered a force in capacitors with a special dielectric, offered the practical application of this concept. However, he did not find the source of this force, which, according to my concept, is conditioned by two factors: the corresponding dielectric property gradient function and the elastic properties of the dielectric material, which is of no less significance. Normally, dielectric particles are attracted to the charged surface but when the reversion of the curvature of electric field force lines occurs, they are repulsed from it and we can use this propulsion force. Elastic deformations (including those occurring during the pulsating operation of the field) account for the reaction forces equivalent to the generated propulsion force. Thus, the momentum conservation law is in action, however, the device is still moving.

T.T. Brown also considered other ways of generating a force, such as the material magnetic property gradient. Logically, by analogy with the electric field we can consider the gravity field, which can be "designed" and "reversed" by means of creating a matter with the density gradient. At that rate, the gravity potential must change in accordance with a certain law when the distance from the gravity field source being increased.

We should also note that the local space volume levitation effect with the accelerated or decelerated time rate was first described in my articles "Physical Principles of the Time Machine", NET #3 (6), May-June 2002 and "Practical Application of the Time Rate Control (TRC) Theory", NET #3, November-December 2001.

Our company conducts experimental researches on creating new materials that possess the properties described. We are interested in serious business contacts with companies in the aerospace industry to further discuss eventual cooperation projects in this field, including *co-patenting*.

Alexander V. Frolov

Perpetuum Mobile Not in the Past but at the Present

Vladimir I. Likhachev, Russia
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In several issues of the "Nature and man. Light" magazine in 1995-97 my colleague E.Oparin and I wrote on the unscientific character of absolutizing the law of degradation of energy, on the important issue of creating the perpetuum mobile of the second kind utilizing infinitely available *environmental heat energy*. We even send a letter to Yury S. Osipov, the Russian Science academy President, but received no reply. Notwithstanding many official discussions, there are no well-reasoned objections to our arguments or proof on the part of "high" official science, because, in fact, we are right.

I have recently received one more confirmation: bright and feasible data on the negentropy cycle (the cycle with spontaneous reduction of entropy) with a chemically active working substance that will be described later.

After the publication of Victor M. Brodyansky's book "Perpetuum Mobile in the Past and at Present. From Utopia to Science and from Science to Utopia", Second Edition, one can not but return to these issues. More so because the foreword of V.A. Fabricant, member of the USSR Academy of Pedagogical Sciences, claims the law of degradation of energy to be the "law of nature" and supports shamefully the deformation of the monothermists, especially P.K.Oschepkov, by academicians P.Kapitsa, L.Artsimovich and I.Tamm ("Pravda" of November 22, 1959), followed by E. Velikhov, A.Prokhorov and V.Sagdeyev ("Pravda" of June 22, 1987).

After the publication of Brodyansky's book I met the author several times (notably at a special seminar in The Moscow Energy Institute) and expressed my opinion about his book: the book avoids serious discussion of the monothermists, stresses their failures which are quite normal in the initial development of perpetuum mobiles of the second kind.

For example, Brodyansky knew about Tsiolkovsky's discovery. Guay's book "On the Little-Known Hypothesis of Tsiolkovsky" is listed among the First Edition references. But Vladimir Brodyansky avoided analyzing this discovery both "in the past" and "at present". The Second Edition references even list the "Physical Thought in Russia" magazine, issue #1 of 1991, that contained for the fist and only time the modern edition of the "Law of Degrading of Energy" by Tsiolkovsky. "At present" V. Brodyansky knows my analysis of Boltsman's mistakes but he paid no scientific attention to my analysis either.

In Brodyansky's book the description level of chemical reaction cycles is even lower than that of Schpilrine. Schpilrine at least tried to present his arguments but here we see unsupported statements "justified" by the phrase "the detailed discussion would take too much space". Vladimir Brodyansky's analysis of anti-Stokes luminescence (pp.216-219) is also superficial. Dissipative and entropy processes prevail in it. But if there is evidence supporting higher frequency quanta than the frequency of radiating flux, **it is the evidence of negative entropy**. Vladimir Brodyansky not only is familiar with it and also shows it by the example of investigating the Sun and the Earth (p.247).

Vladimir Brodyansky's analysis of Rank's tube (pp.235-237) displays the same tendency. In the Rank's tube the dissipative processes also prevail. Its effectiveness as a refrigerator is lower than in the traditional schemes.

But one can not deny the existence of negentropy processes in it. It is these processes that "originate" the cold gas flow. And Brodyansky's "origination" on p.236 "The vortex tube in fact divides the coming gas into two fluxes: heated and refrigerated" - is totally false. That can be performed only by "Maxwell's demon" that does not exist in substance.

The refrigerated flux in the Rank's tube is formed by the "Tsiolkovsky's flux" by way of heat transfer "from cold to hot", from the tube center to its circumference by **centrifugal accelerations**. On its basis (to be more exact, on the basis of Finko's tube) the perpetuum mobile of the second kind can be created. And we have this engineering solution. E.Oparin and I made the corresponding patent application for an invention but the Federal Institute of Industrial Property again refused to consider such applications. Here one can see similarity with the causes of re-edition of Vladimir Brodyansky's book. And one need not be a big politician to admit the reality and understand the sources.

Environmental and, especially, anti-nuclear movement is invincibly expanding. Danger to human life and threat of ecological catastrophe are quite real. The Second Edition of Brodyansky's book protects behind scientific arguments those who use Russia as a source of easy money and then flee.

But we like our country - vast and austere. This austerity and space form REAL PEOPLE and support humanity and materialistic humanism of the energetic and talented, not just the rich.

In modern Russia the powerfully spread alcoholism, debauchery and drugs are the instruments of slavery. But the monothermy and development of alternative power engineering will become basis for Russia's revival and unprecedented prosperity.

Russians learn slowly, sometimes, very slowly, even disgracefully slowly. But we will learn. And then no one will stop us. The following tips are meant for those who are ready to risk their efforts and facilities in order to build alternative energy knowledge base: dissipative and negentropy processes are inseparable and very often their mechanism is the same. In our environment the dissipative processes are more effective and hide the negentropy ones. No dissipative process combination can generate the negentropy cycle. Look for examples in Brodyansky's book. To create the negentropy cycle and use the environmental energy at least one negentropy process is required that has effectiveness and negentropy exceeding entropy growth at all levels of the cycle.

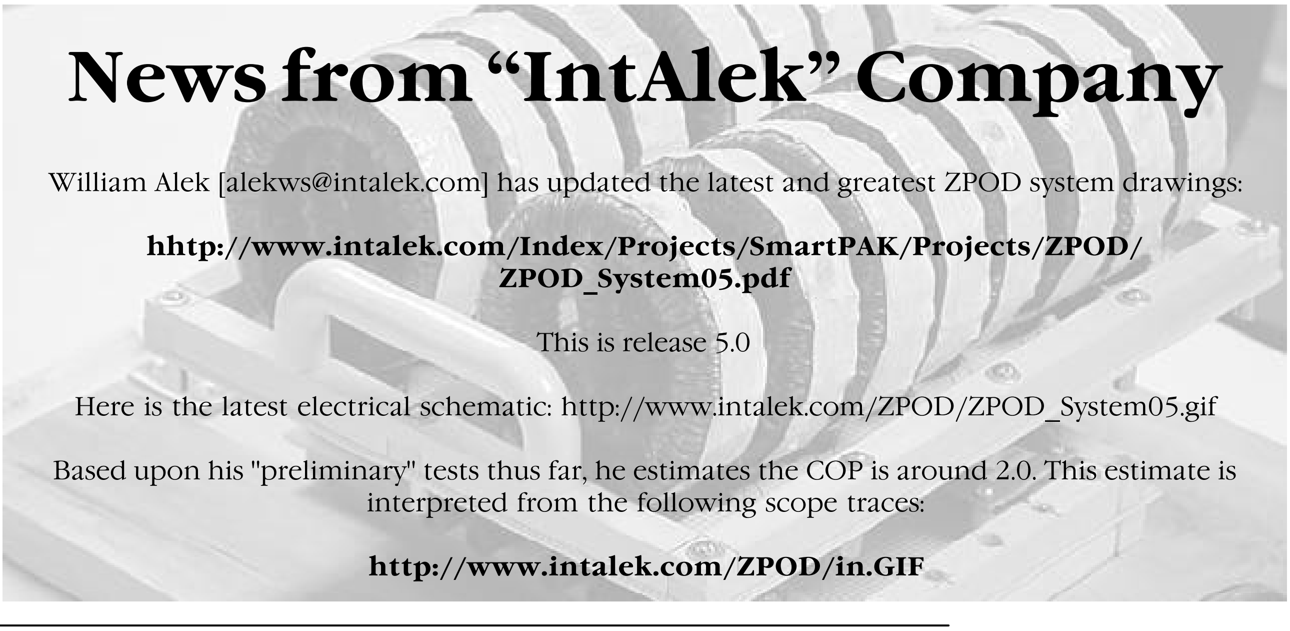

News from "IntAlek" Company

William Alek [alekws@intalek.com] has updated the latest and greatest ZPOD system drawings:

hhttp://www.intalek.com/Index/Projects/SmartPAK/Projects/ZPOD/ZPOD_System05.pdf

This is release 5.0

Here is the latest electrical schematic: http://www.intalek.com/ZPOD/ZPOD_System05.gif

Based upon his "preliminary" tests thus far, he estimates the COP is around 2.0. This estimate is interpreted from the following scope traces:

http://www.intalek.com/ZPOD/in.GIF

Alan Francoeur's Generator
Canada

Alan L Francoeur, Canada
Email: al.f@shaw.ca

This is my writing and development about the Interference disc generator, and the permanent magnet dynamo machine, and other related inventions. I have always been intrigued with electricity and magnetism and aetheric energies starting at a young age. Back in 1980 I wanted to do something to help get my large vehicles better fuel economy. With this goal in mind, I experimented and designed my first heat exchanger vaporizer system to do my part to clean up our cars and trucks, fig. 1, 2, and 3 are two earlier vaporizer units under construction. For more information about this fuel system, please refer to my vaporizer fuel system report. The main body of this writing is referring the permanent magnet dynamo system that has been in the making since 1987, starting after the development of the interference disc generator.

Fig. 1

Fig. 2

Fig. 3

I invented the Interference Disc generator concept while I was employed at Giant Yellowknife Mines NWT from 1983 to early 1986. The idea of using metal blocking plates to shield magnetic fields stirred in my mind while working around heavy electrical mining equipment, and 1000hp and other electric motors with exposed coils that have heavy metal around the outer casing. I did a search at the time and found John Ecklin's work very interesting with his application of the shielding effect. During my off time in Yellowknife, I was experimenting with the interesting effect of producing induction with a stationary coil mounted beside a stationary magnet with a small air gap maintained between the magnet and the coil. During the construction of my first disc machine, I called it the Interference Shielding effect because of the interference the blocking disc does to cause induction, thus the Interference Disc Generator fits the description. The first transformer coils I used to test the interference shielding effect were used from old radios, and the magnets were alnico types. Back in 1986 in Calgary Alberta, a friend Bud Johnson and I constructed the first test disc generator model using alnico magnets, fig. 4, and later ceramic magnets were installed. Months later I designed and began construction of another larger Interference Disc machine with horseshoe shape neodymium 35 grade magnets mounted on the outside, and with the N and S magnetic poles facing toward the coils in the center portion of the machine. The coils and magnets in this larger machine are mounted in reverse of the first Interference Disc generator, fig. 5, 6.

Fig. 4

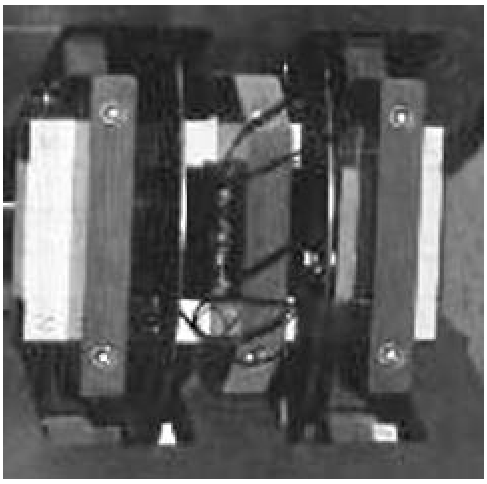

Fig. 5

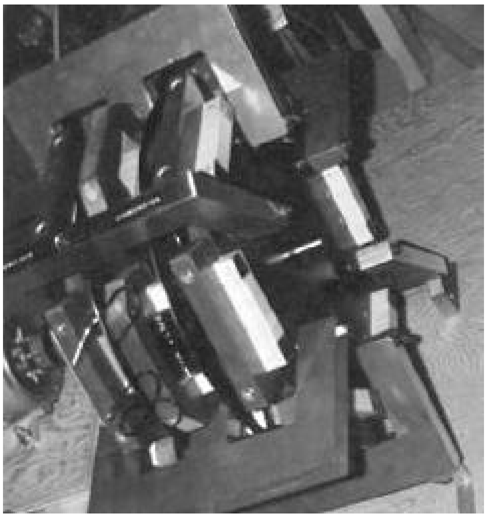

Fig. 6

General description of the interference disc generator

The Interference Disc electrical generator is made of a stator (114) consisting of an array of even number parallel mounted bar magnets (112) arranged and supported (114) in a circular fashion equidistant from each other, where the polarity of the magnets (112) are alternating when viewed at either end. Fig. 7

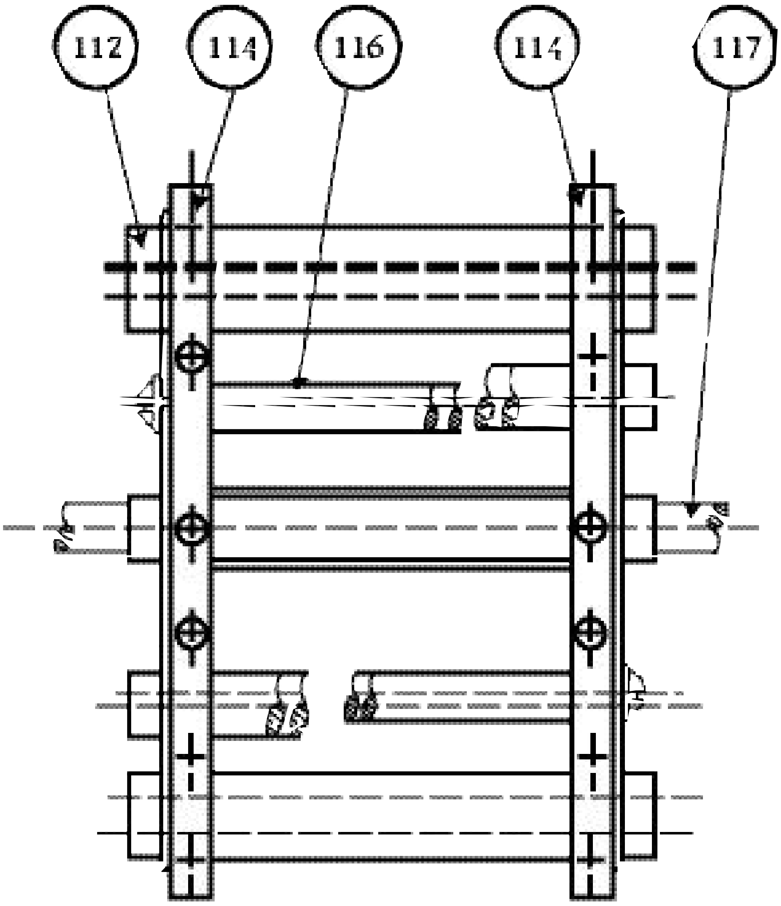

Fig. 7
Magnetic bars assembly (rotor)

Also in the stator fig. 8, (102) there are twice the number of coils (111) as bar magnets (112) wound in pairs on U-shaped cores (110). One half of the coil pairs mounted at one end of the bar magnets (112) in the same circular fashion, each corresponding to and aligned opposite to a pair of bar magnets (112) and separated from it by an air gap. On the other end of this pair of bar magnets (112) there are another set of coils (111) aligned likewise.

The rotor is made of two magnetically susceptible circular plates (109A or 109B) (such as iron or steel) Fig. 9, centrally mounted on an axle (107) fig. 7, which is in respect to the array of magnets and coils Fig. 9a.

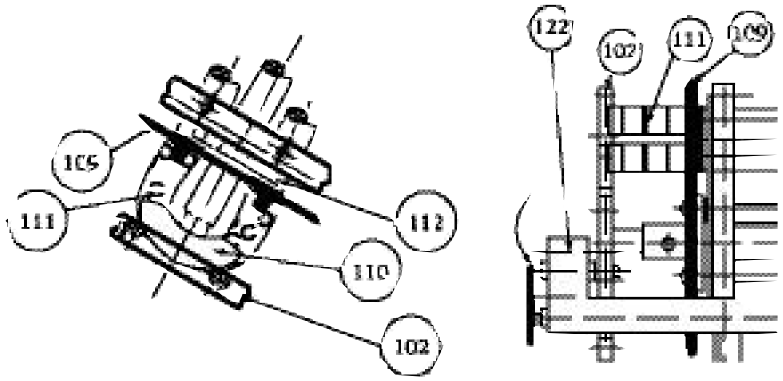

Fig. 8

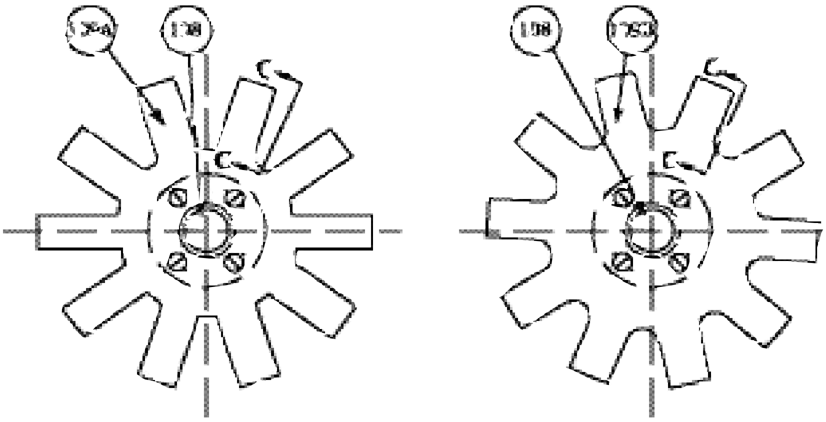

Fig. 9

The interference discs (109A or 109B) are separated from each other so that they can rotate in the air gaps between the magnets (112) and the coils (111). The interference discs (109A or 109B) have a number of **equidistant opening, either more or less in number than the number of the bar magnets (112)**.

The arrangement and size of the openings are such that when the discs (109A or 109B) are rotated by an outside motive force, they open the magnetic field between adjacent bar magnets (112), and the opposing coils (111) at both ends of the stator (114) simultaneously. Hence inducing an alternating electric current in the stationary coils (111) fig. 10.

By opening and closing the magnetic influx to the core (110) of the coils (111), an alternating current will be generated in the coils

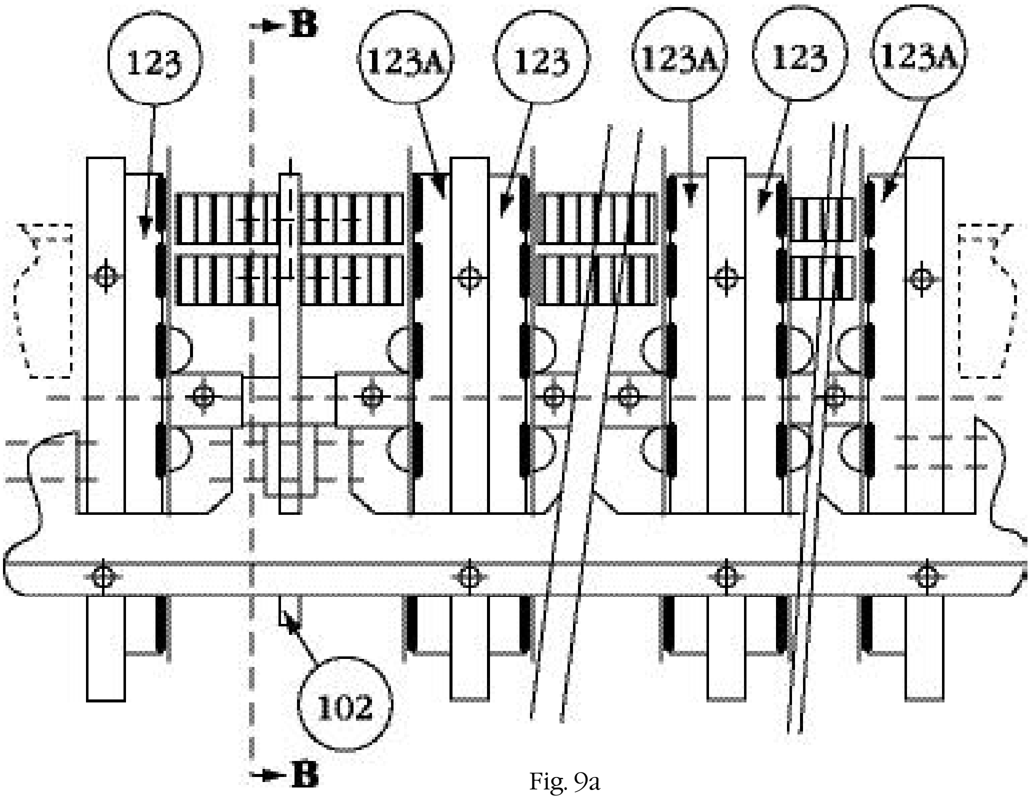

Fig. 9a
Magnetic bars assembly (stator)
Option II: multable magnetic coil-disk assembly

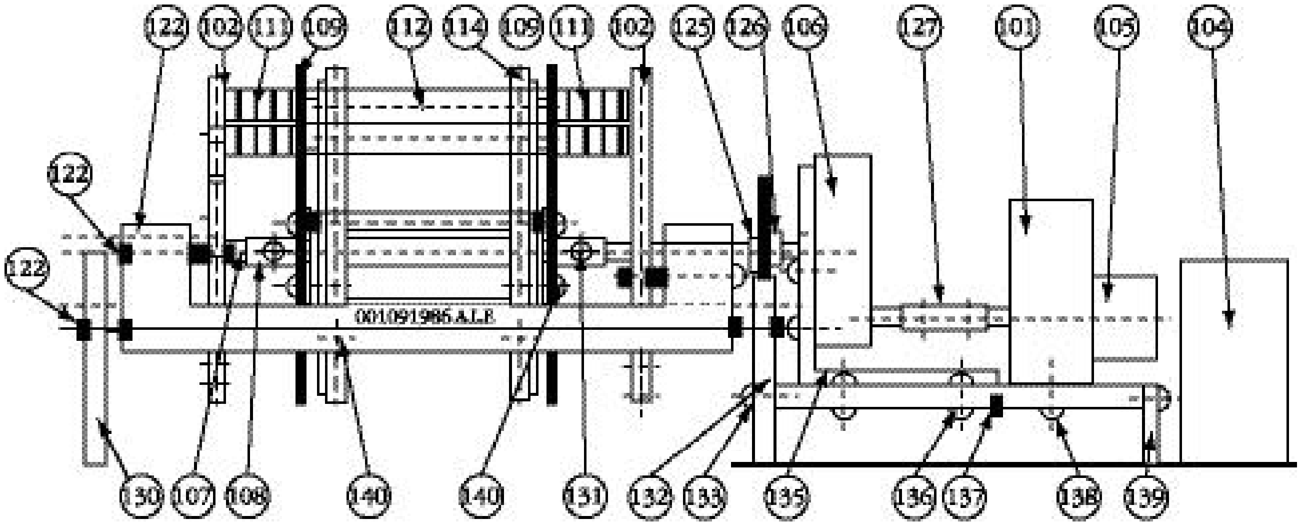

Fig. 10

(111) in a retro-order to the rotational direction of the interference discs (109A or 109B). Depending on the number of magnet-coil assemblies three phase AC current can be obtained. The regulation and attenuation of these currents can be achieved by known electric engineering methods (Fig. 10).

The efficiency of the unit would vary greatly depending on the speed of rotation, the width of the air gap, the strength of the magnets, and the materials used to construct the coils. I used nickel base amorphous metglass in the coils in both the smaller and larger machines, which as a result, shows greater efficiency as compared to conventional core laminates. Less energy is needed to spin the balanced disc rotor while causing a larger moving magnetic field to cause induction in the stationary coils. With this effect, it is easy to visualize the advantages this design has over conventional generators and motors. New testing of the coils will be conducted after the machine goes through all the upgrades to eliminate the problems with the warping interference discs.

The Interference Discs Generator described in this document **has the potential to produce more than unity effects** by easy turning of a magnetically balanced (non-warping) interference disc. Optimizing the device with closer tolerances and correctly selected materials and incorporating internal magnetic balancing, will add to the success and improved performance of this unique generator design.

Improvements can be made with this design while the operating principal remains the same. Looking at the photographs included you will see the 1st proof of concept generator frame is constructed mainly from aluminum, this metal was used only because it was inexpensive material and easy to work with fig. 11. Non magnetic and non-conductive materials should be used to construct the generator frame supports to eliminate the eddy current losses. All of the nuts and bolts used to hold the disc generators together worked well for making the test machines capable to have adjustable air gaps, however, they can all be eliminated with design changes that preset the gaps and tolerances to optimize the conditions of the interference disc effect.

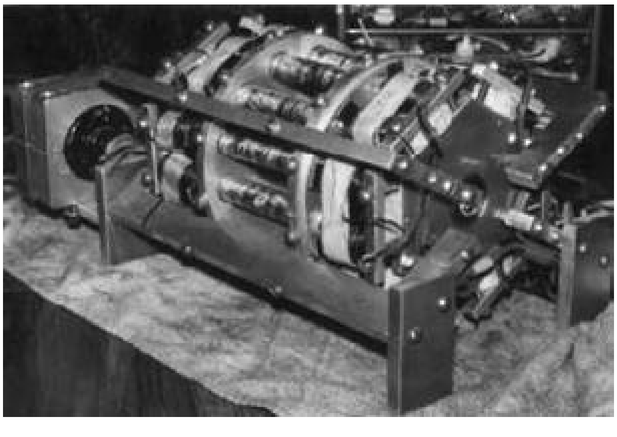

Fig. 11

Many improvements were adopted in the next larger #2 version of the Interference Disc generator fig. 12. Phanolic materials (non conductive and non magnetic) were used in the frame supporting the magnets and the coils, thus eliminating eddy current losses within the frame support. Large aluminum E bars were used to support the magnet frame support and the coil frame support with no noticeable eddy current losses. The aluminum used is positioned further away from the coils and magnets in the larger generator so as not to be affected by the magnets. Larger more powerful neodymium magnets and I shaped transformer coils were installed and tested in the larger machine which showed an increase in output power over the 1st machine fig. 13. Using more powerful neodymium magnets in this larger disc machine created some problems with the interference discs. Not only did they warp the discs they caused them to vibrate and chatter causing the fins to hit the magnets and the coils. I increased the air gap to over half an inch and moved the disc further away from the magnets to prevent damage. The effect was a reduction of magnetic flux reaching the coils that reduced the power output. The discs must be constructed much stronger and rigid if using neodymium magnet grade 35 or greater, then the air gap can be closed so more magnetic flux will reach the coils allowing for a greater electrical output.

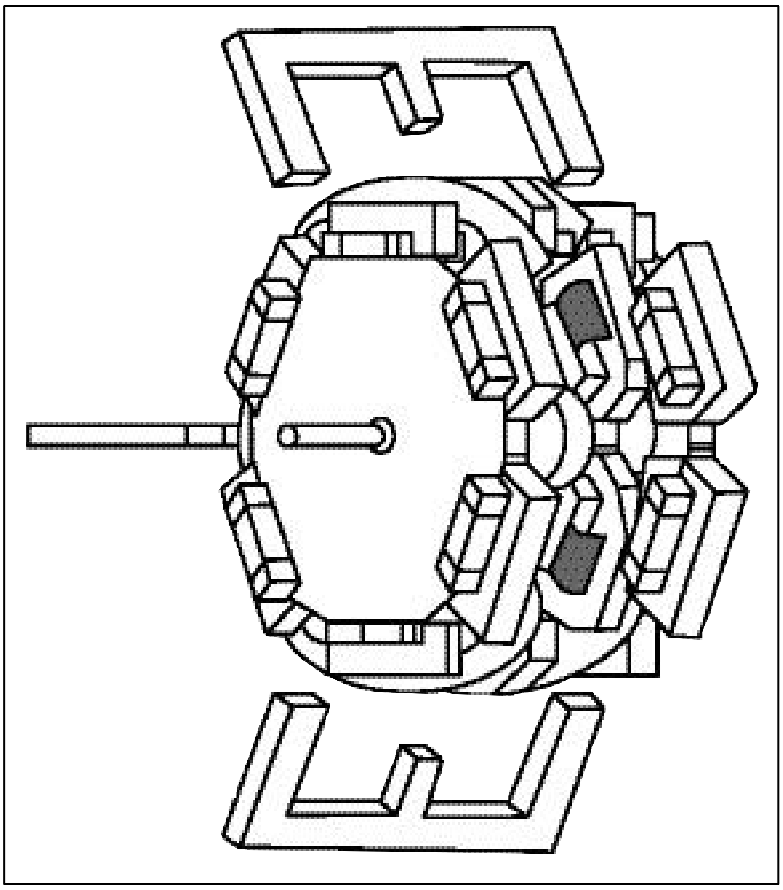

Fig. 12

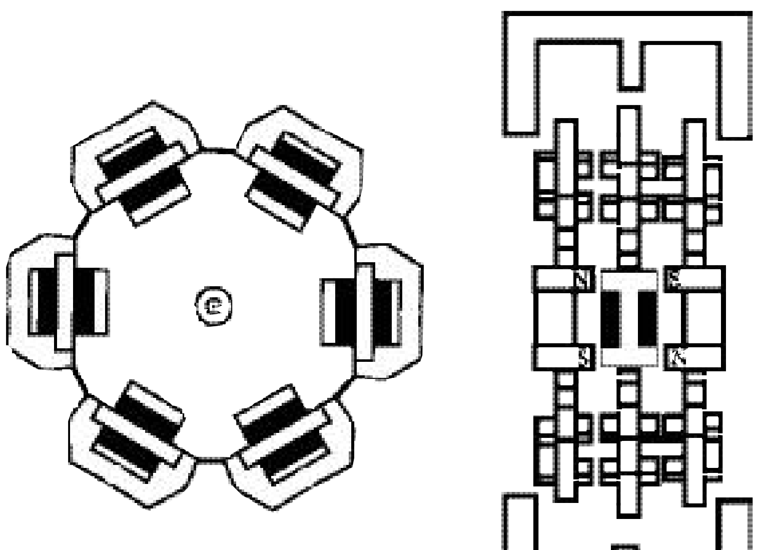

Fig. 13

The wiring of the coils circuit can be constructed by known engineering methods to achieve AC or DC power, and like any conventional transformer, wind the coils with heavy wire for more amps and more turns for more volts. The coils are stationary in this machine which makes it easy to harness AC power directly from the coils without brushes. All coils that are in phase can be wired in series or parallel, the number of the blocking plates on the interference disc determines the phasing of the coils.

The diagram in fig. 14, 14a shows the path of the magnetic flux movement in relation to the position of the blocking plates of the interference disc. The magnetic field in the core/coil is switching polarity as the interference disc fins alternately moves in and out of the air gaps on each side of the coil. As you can see, depending on the position of the disc, positive and negative induction takes place for AC output of the coils. John Ecklin has achieved this effect using rotating blocking plates. I have achieved the same effect using balanced rotating interference discs with multiple stacks of isolated coils and poles mounted in a circle equal distance from each other.

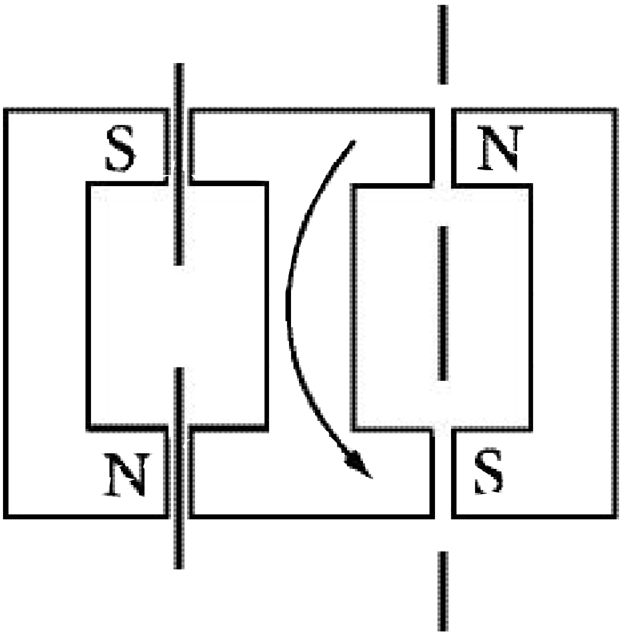

Fig. 14

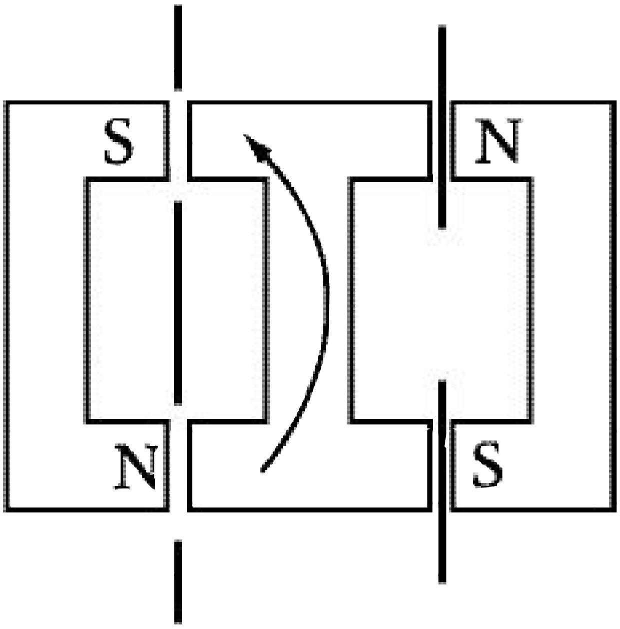

Fig.14a

The effect I reproduced with Gary Wesley's permanent magnet motor is related to the Interference Disc generator in the fact that blocking plates are used to shield the magnetic field, only we differ on methods to balance the blocking shields. Gary Wesley used springs to carefully balance the blocking plate, and I used a different number of interference fins working with the magnets to balance the blocking plates. The magnets in my Interference Disc machine become the springs.

More photos of both Interference Disc machines are shown in fig.15, 15a and 15b below.

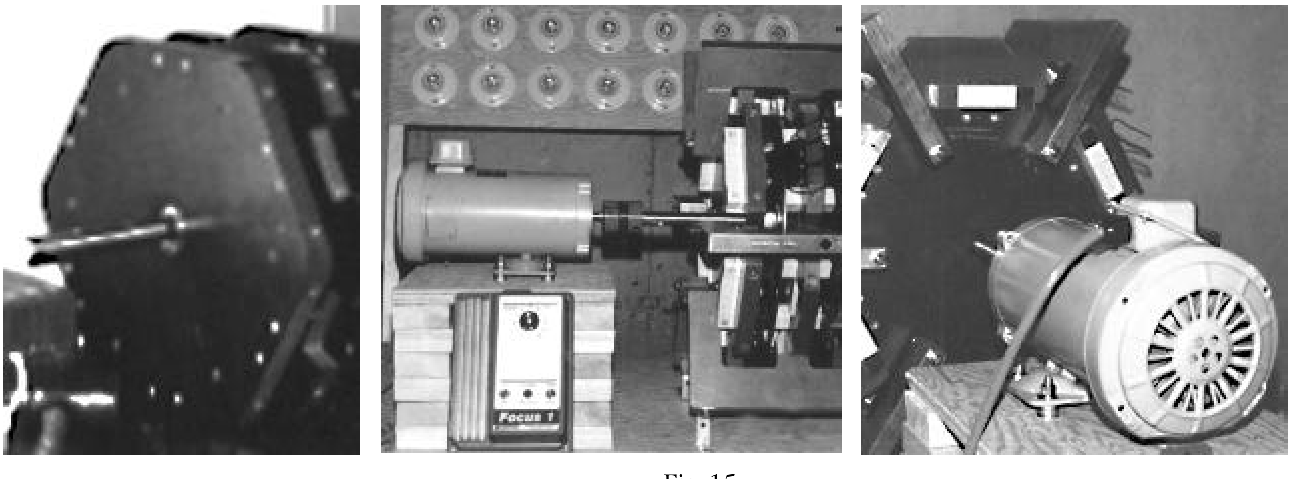

Fig. 15

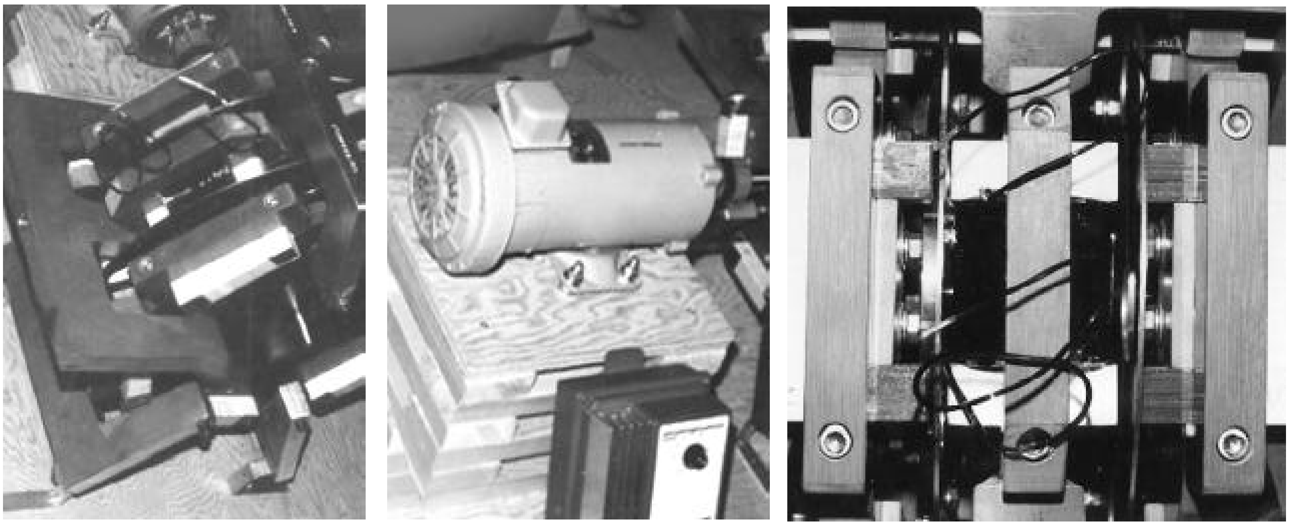

Fig. 15a

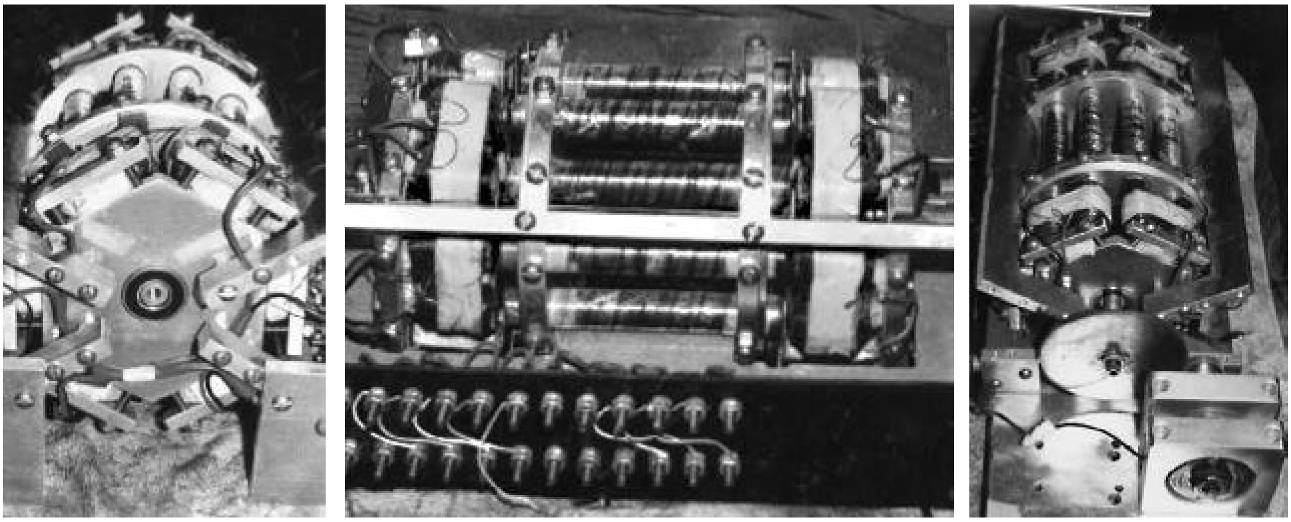

Fig. 15b

Closing comments on the disc generator

In closing this discussion of the Interference disc generator, I would like to go over and point out some of the concepts that I incorporated into the design of my permanent magnet dynamo.

As I made further progress and completed the later stages of the Interference disc generator, it became clear to me to use certain concepts of the machine and incorporate them into the design of my multiphase permanent magnet dynamo. Some of these concepts are explained here.

I have constructed several interference discs that have a different number of blocking shields, some with 10 blocking fins and some with 11 blocking fins and others with 12 blocking fins. They are all interchangeable on the machine to change the phase relations between all the isolated coils. The 12 finned disc will produce a single-phase dynamo with all the coils in phase, and the 10 finned disc on the machine will produce a three phase dynamo. One phase represents four groups of isolated coils, and the second phase represent the other four coils, and the four coils left are the third phase, for a total of twelve coils. All just by changing the number of fins on the interference disc and or adding more layers. Using 12 magnet poles and the 10 or 11 interference fins on the disc, the rotor discs becomes magnetically balanced and easy to rotate in spite of the load on the coils. The 12 finned disc has a larger holding force because of the same number of fins as magnetic poles. However, it can be reduced to almost nil by adding more layers of interference disc and balance them against each other. Many in phase coils can then be added in series or in parallel to build your power levels to any desired potential.

Both machines have stationary coils, and the disc generator has 12 magnetic poles (6N and 6S), and the permanent magnet dynamo also has 12 magnetic poles (6N and 6S). The disc generator uses 10 or more fins on the interference shielding plate per rotor, and the permanent magnet dynamo has 10 or more coils around each rotor. There is the same number of interference blocking plates as there are induction coils on each of the two difference machines and the number of blocking fins and or coils are interchangeable. The back emf effects are different on both machines, the Interference disc generator demonstrates easy turning of the discs while the stationary coils are loaded, and when producing alternating current the permanent magnet dynamo rotor slows down when a load is placed on the stationary coils. Both machines produce AC power out of the coils and the Interference Disc generator has a closed magnetic circuit through the coils, and the permanent magnet dynamo has open magnetic circuit through the coils.

The Permanent Magnet Dynamo

I would like to begin this topic at this point by describing my permanent magnet dynamo machine.

I designed this machine to be completely interchangeable into many different motor generator combinations. These combinations involve different number of magnetic poles and different number of interchangeable coil poles in the same machine, two versions are possible, one with isolated coils and another with the coils that share a common core fig. 16.

We can change the magnetically balancing effect (*holding force*) by changing the number of coil poles or (*interference disc fins*) in relation to the magnetic poles. This turns the machine into a multipurpose, multiphase, variable output, and variable frequency ac dc permanent magnet motor generator system. I first designed this unique multi purpose dynamo in 1987 after I built my third Interference Disc generator.

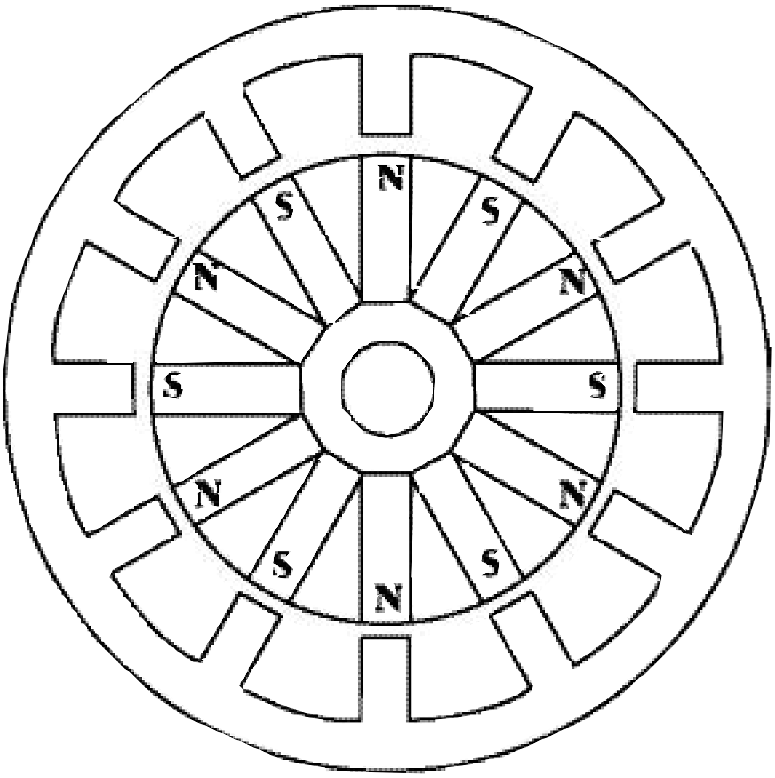

Fig. 16

Dynamo description:

Rotor:

It is well known that a bar magnet has its magnetic field concentrated at the N and S pole ends, and the half way line between the poles of a magnet is the neutral zone, this is the region where the magnetic field is canceled or neutralized. The *ferrous* keeper ring I designed for this rotor is mounted near the axle and it has machined flat decks so the magnets attach flush to the deck of the

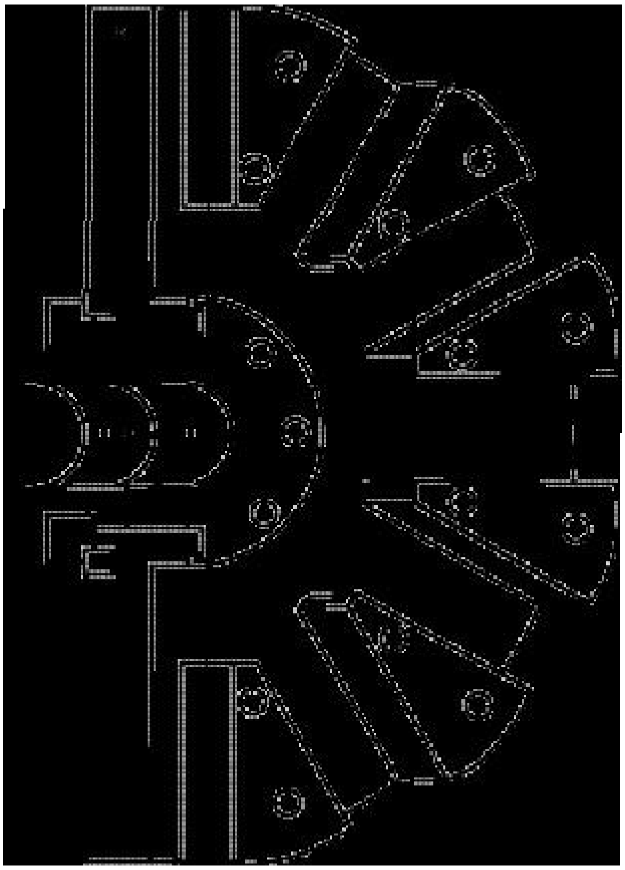

Fig. 17

keeper ring. Because of this feature, flux leakage is reduced at the keeper ring and the magnetic field concentrates at the rotor poles. With the poles of the magnet positioned near the axle and attached to the keeper ring in the rotor, the magnetic field that was there is now forced to add magnetic field density to the outer magnetic poles on the rotor rim. The density of the magnetic field at the poles is now greatly increased which makes a very powerful small size rotor. The *ferrous* inner keeper ring (*active iron*) that is installed inside this rotor design, is also the *neutral zone* of the magnetic field when viewing all the combined permanent magnets in the rotor. Shown is a cut away view diagram of the rotor, fig. 17.

I utilize rare earth rectangular shape neodymium grade 35 bar magnets with the dimensions of 3" long and 1"x1" on the end poles. There are 12 bar magnets mounted 30 degrees apart in NSNS configuration, and the bar magnets are attached to a precision machined inner keeper ring which makes the active iron the region of the middle of the magnetic field (the neutral zone). Another way to view this is to imagine two 3" long bar magnets attached together, you now have a 6" long magnet. Bend this magnet in half and install iron at the U and it now becomes a horseshoe magnet with two 3" long pole ends. It's a powerful rotor design in the fact that each of the 3" long bar magnetic poles has the field strength of a 6" long bar magnet. More poles on the rotor will allow for higher frequency ac generation at lower rpms, twelve magnetic poles on each rotor is shown in fig. 18, 19.

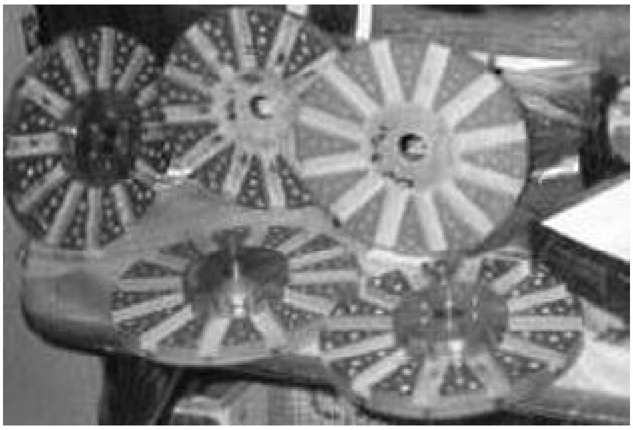

Fig. 18

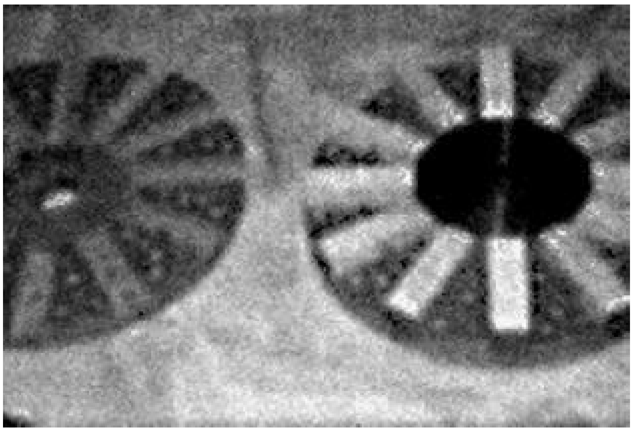

Fig. 19

The drawing in fig. 20 and picture in fig. 21, shows twelve magnet poles in each rotor in relation to the position of the coils. Ten *amorphous* cores are shown mounted around each of three rotors before they were wound with magnet wire fig. 21. The machine I have constructed houses a total of three rotors side by side that are mounted 10 degrees apart in relation to their *magnetic poles*, each rotor has twelve magnets installed for a total of 36 magnetic poles shown infig. 20. This dynamo concept can be constructed to any size with unlimited numbers of rotors and coil combinations to fit any power requirements.

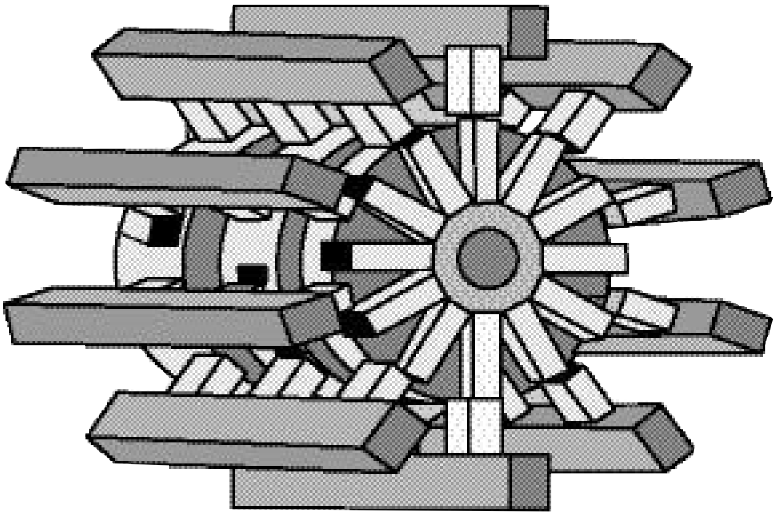

Fig. 20

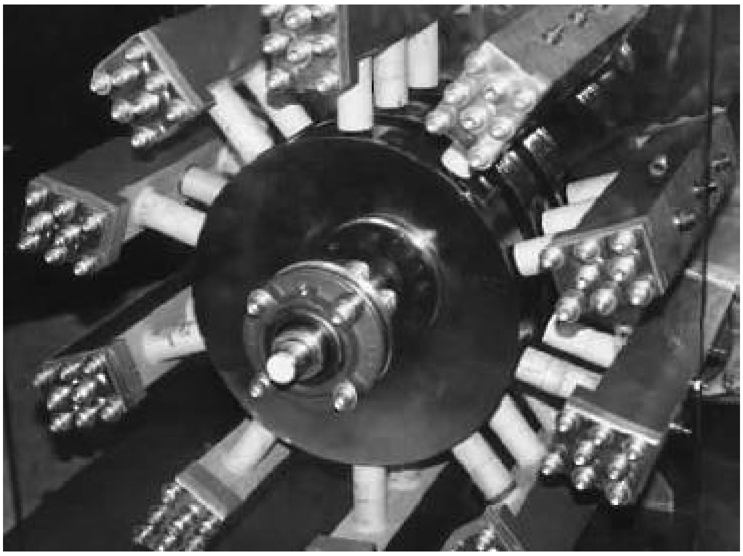

Fig. 21

It is well known that a magnet exerts a force of attraction to iron bringing them closer together, after they have come together, they are in their **static position**. A force must be exerted to either the magnet or the iron in order to pull the magnet and the iron apart, removing them from their static position. The term **static position** is used to describe the point when the magnet and the iron bar are at their nearest point.

As in the Interference Disc Generator, this Permanent Magnet Dynamo I am describing also uses an internal magnetic balancing effect which reduces startup torque on the rotor.

In this system, one set of magnets is in their static position in relation to the coils, such as the impulse coils. Another set of magnets on one side of the rotor is not in the static position, and there is another set of magnets that is not in its static position on the opposite side. One side is half in to the coils, and the other side is half out the coils, allowing the rotor to have minimal start up torque in turning the rotor. The magnets function in two jobs, the first with its velocity is to cause induction into the transformer coils producing ac power.

The second function, is the opposite pair magnetic fields on the rotor balancing each magnet out of their static position in relation to the coil positions at any given time, they cancel their holding force which puts the rotor at equilibrium. This reduces the amount of start up energy required to rotate the rotor resulting in higher efficiency. It allows the rotor and or multiple rotors to turn easily and efficiently despite the inherent powerful holding force of the rare earth neodymium magnets. With the three rotor machine configuration, I have connected 6 impulse coils in three phase to function as the motor impulse circuits with a hall effect brushless motor controller fig. 22.

Star wound three phase motor impulse coils.

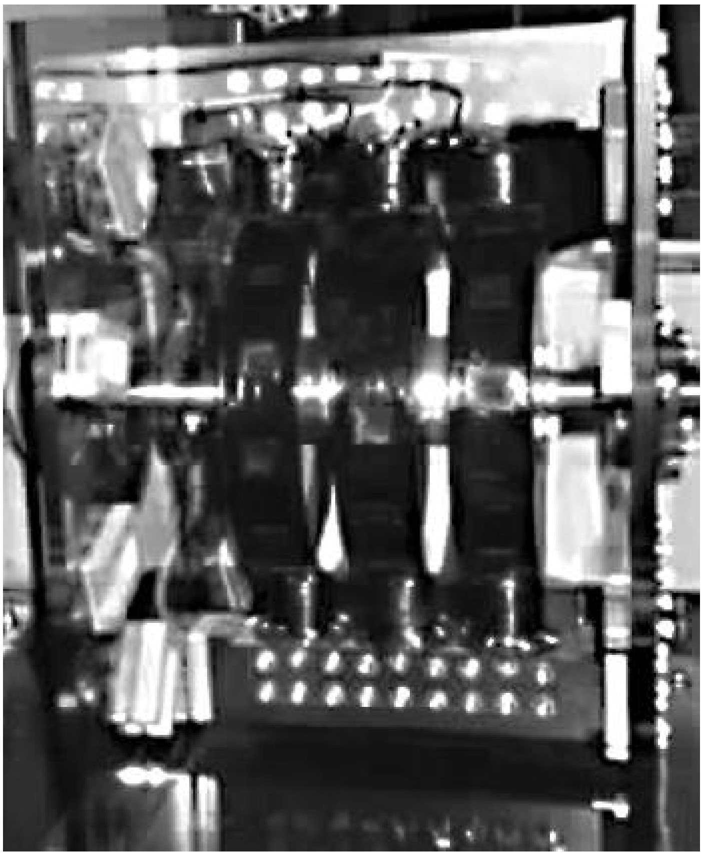

Fig. 22
Star wound
three phase motor impulse coils

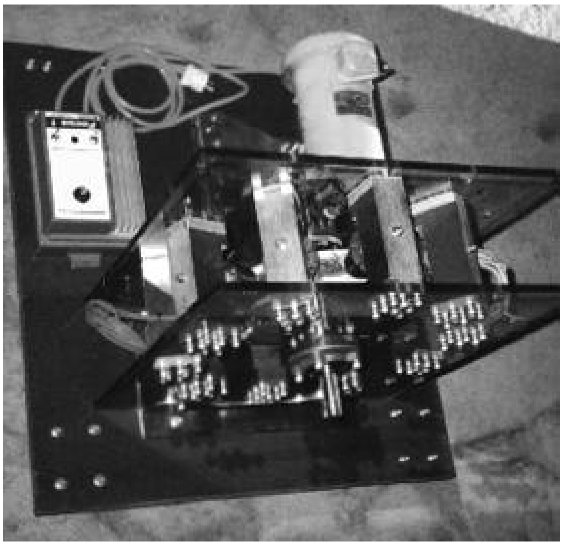

Fig. 23

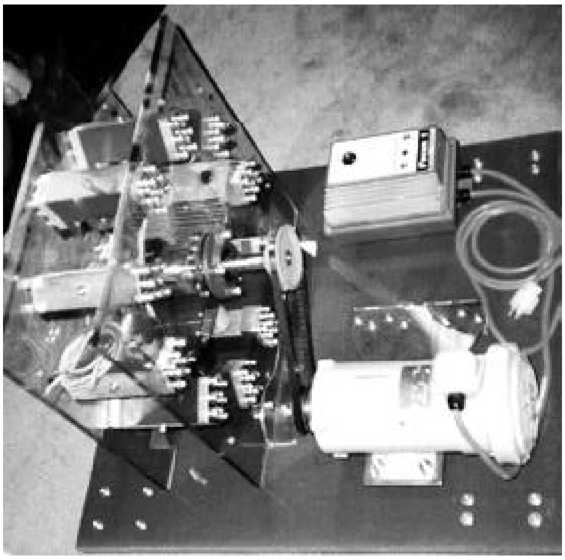

Fig. 24

Two more pictures of the one rotor dynamo option are shown with a 1hp dc motor turning the rotor with an 800 watt load on the coils, six 100 watt AC light bulbs, and two 100 watt 12 volt DC light bulbs, Fig. 25, 25a.

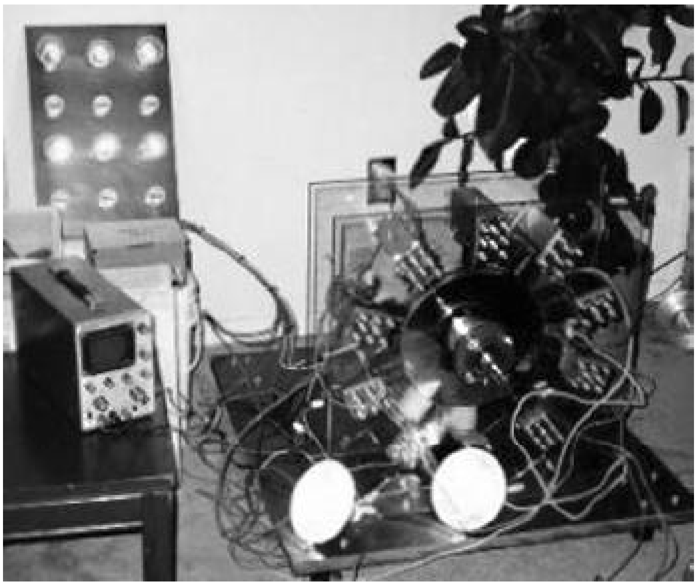

Fig. 25

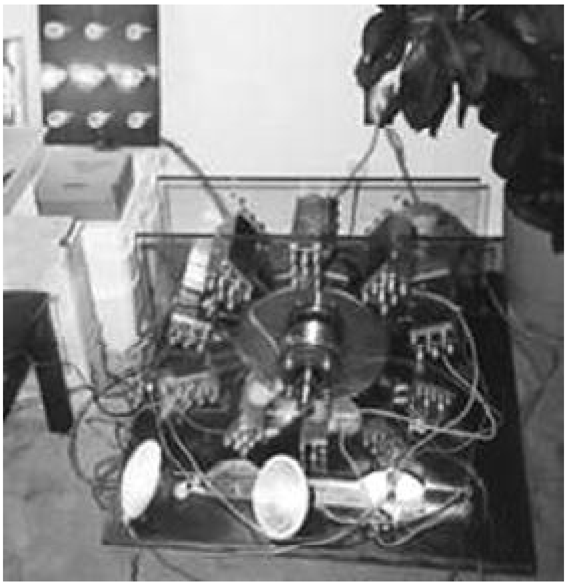

Fig. 25a

The efficiencies of this dynamo are so far inconclusive with regards to producing an endless self running machine. Our research is continuing to improve the efficiency by eliminating all conventional type ac and dc motors from this dynamo, and incorporating high voltage dc impulses of very short time duration's as Ed Gray did with his technology years ago. However, a description of my early self running attempts is included near the end of this dynamo report. These tests have manifested an abundance of heat in the 24 volt dc drive motor.

Another picture of the three-rotor dynamo configuration is shown with 12 regenerating ac to dc coils, and with the motor impulse coils removed fig. 26.

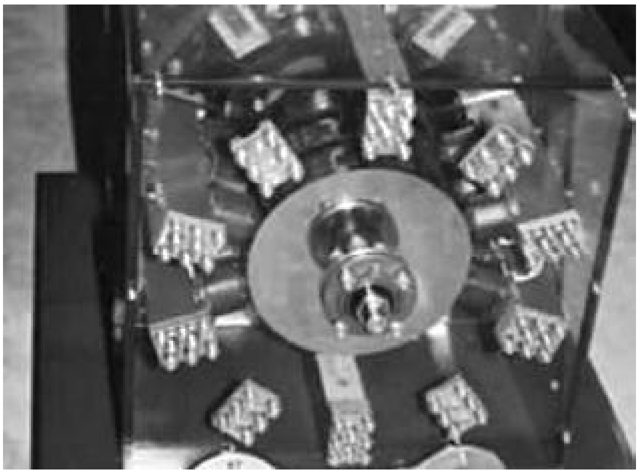

Fig. 26

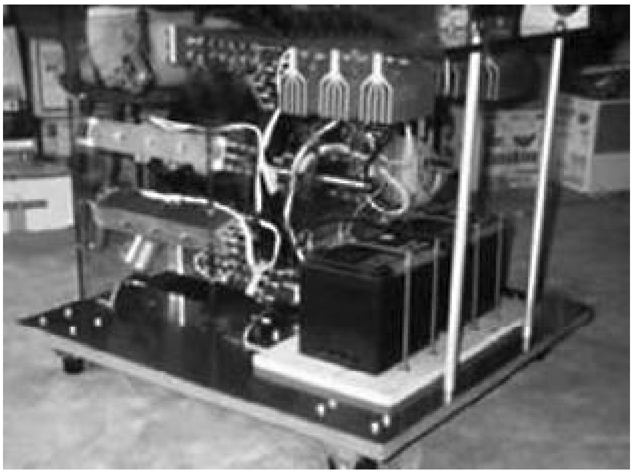

Fig. 26a

Another close up of the regenerating coils and three phase motor impulse coils is shown on the dynamo fig. 27.

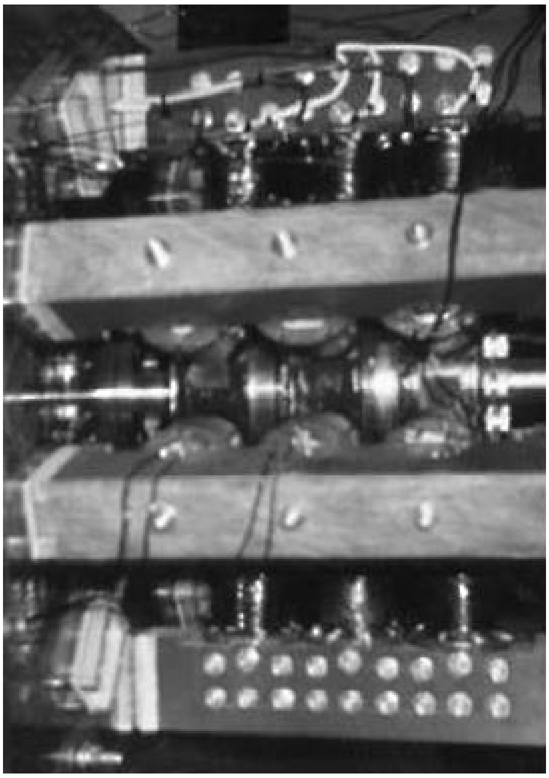

Fig. 27

Tests to produce an abundance of heat

I have testing the machine so as the output coils are connected to regenerate a 12 volt battery as the motor is turning the rotors. I used a bran new conventional permanent magnet 1/4 hp 24 volt dc motor that is running on 12 volts to turn the 110 pound 3 balanced rotors, and or the 35 pound 1 balanced rotor version.

The regenerating output coils produce AC to DC power with no noticeable ripple on the scope. The generated direct current from the coils is connected to go back into the battery, in which the motor uses to produce the torque needed to rotate the rotor. As this happens, the regenerated dc power from the coils is again going back into the battery first, and then to the motor. The result is that the battery supplies less power to the motor when the regenerating DC current is going into the battery. The motor takes on a load from two sources, one is from free wheeling the rotor with out loading or drawing current from the coils, and the other is the load induced on the motor when the coils are loaded to produce current.

The dc permanent magnet motor has shown that during one of many switch mode tests, it consumes 15 amps at 12 volts from the battery while a chosen number of regenerating coils supply ? the amount of current going back to the battery. The battery supplies 50% of the amps and the regenerating coils supply the other 50% amps. This effect can be changed depending on how many open isolated regenerating banks of coils are activated and loaded.

This test shows a 15 amp draw the motor while it is turning the rotors under load while regenerating current from the coils. It may be they balance each other and both battery and coils supply 7.5 amps each that make the total 15 amps draw on the motor. This accounts for the 15 amps total load that is shown on the dc drive motor. It produces an excessively large amount of heat in the dc motor that is useable output energy. On a larger scale the heat generated in a given motor can be enormous. More accurate measurements are needed to determine the true energy in verses energy out.

However, this electric heat pump effect can be altered to produce more or less heat depending on the size and type of the drive motor, and the amount of regenerating coils that are placed under load. Cooling tubes wound around the motor with water flowing through them is a way to pull the heat out for useful applications. Hot water from the drive motor and electric power from the coils at the same time.

After running the machine, the amorphous regenerating coils remain cool to the touch where as the conventional dc motor gets very hot with higher amps going through it. The machine also has a longer running time when the coils are regenerating the battery, as compared to running an outside equal load with the same amp draw, in that case the battery drains much faster.

This sheds light with the observation of high heat build up in the motor side (less efficient side) of the circuit while being cooler on the generator side (amorphous side) of the circuit. After hours of run time the battery begins to drain, when this happens, the battery begins to show tangible temperature changes from one side of the battery to the other. The whole negative side of the battery remains cool to the touch (temperature drop), while the whole positive side of the battery gets warmer to the touch (temperature rise). The effect is repeatable and only happens when the regenerating coils are connected to charge the battery as it is running. It may be approximately 20 degrees difference in temperature, depending on how many regenerating coils are activated sending its current to the battery. There must be exothermic reactions and endothermic reactions going on inside the battery motor generator combination that is causing this temperature difference. The load and heat generated can be changed the on the motor from the flick of a switch that activates and loads the output coils, which in turn dumps it's energy back into the battery pack or outside load. The efficiency ratio of the machine changes depending on how many and which banks of regenerating coils are activated, which again also effects the temperature difference manifesting on each side of the battery, motor, and amorphous coils.

Other tests

An Automotion dc brushless 3 phase motor controller with hall sensors was used to test the machine in fig. 26a. Tests have shown the 1hp dc motor and the three phase brushless dc motor controller will not be the answer to closing the loop on this motor generator machine. The brushless controller has a 50% duty cycle which will not manifest the electro radiant effect, and it also has a constant draw on the battery as a regular dc motor does. It is much less efficient than using very fast and short unidirectional dc impulses in the motor impulse coils to kick the rotor around. This brings the subject of Nikola Tesla's magnifying transmitter and Ed Gray's radiant energy impulse motors to light, and a possibly answer to closing the loop for a real auto-rotating machine.

Before I go further with this, I want to point out the many phase possibilities this dynamo has. If you look at the coil arrangements in the 10 coil machine, you can clearly see the coils that are in phase with each other. When a second and third rotor is installed with all the coils attached, one pair of coils on the first rotor is in phase with another pair of coils on the second rotor, and another pair of coils is in phase on the third rotor. With the ten coil to twelve magnet pole rotor assembly, the machine has five phases of isolated banks of coils. If twelve coil mounting bars are attached around the three rotors, and the three rotors are spiraled off set by 10 degrees, you will have a powerful three phase dynamo. If the rotors are not off set by 10 degrees and are lined up in phase with each other, all the coils on the machine will be in phase for a powerful single phase dynamo. The volts and or amperage can be tailored for an application by the winding of the transformer coils, and the machine produces 60hz at 600 rpm. This dynamo machine concept is also interchangeable into many other motor generator combinations, and sizes, and any volts or amps requirements, it all depends on the needs of the end user.

> *Cooling tubes wound around the motor with water flowing through them is a way to pull the heat out for useful applications. Hot water from the drive motor and electric power from the coils at the same time.*

It is possible to have super efficiencies with this system using unidirectional hv dc impulses of very short duration's at the make brake contact at the closure of the switch.

I have acquired two of Ed Gray's radiant energy impulse motors #4 and #5 to revive an almost lost technology. I am proposing to combine a special permanent magnet dynamo with less back EMF that is tailored to produce 5kv dc under 2000rpm. This dynamo will energize a 5kv dc capacitor bank and replace Gray's 12 volt to 5kv dc converter. The energized capacitor bank will discharge through the conversion tubes in the very same manner as in Gray's original circuit, only the capacitors will get energized from the high voltage dc dynamo instead of from a battery through an inverter. This version of a high voltage dc dynamo will be connected to and turned by Ed Gray's EMA motor, a starter motor will disengage after it begins running.

There are three banks of high voltage coils that are connected 120 degrees out of phase from each other, each bank represents 12 - 100 watt coils for a total of 1200 watts per phase. All isolated coils in each phase are wired in series to produce the high voltage dc potential to energize the capacitor bank. The isolated capacitor bank will discharge their potential through its conversion tubes in 120 degree increments each time the impulse coils are at their closes point toward each other. One isolated capacitor bank will discharge through the conversion tube with it disconnected from the dc dynamo circuit. The second isolated capacitor is at this point beginning to receive its charge from the dc dynamo, while the third capacitor phase is fully energized just before the switching circuit disconnects it from the dc dynamo for it discharge phase. This fully aligns all the isolated 3 coil phases in this permanent magnet dynamo system to the 120 degree three phase radiant energy impulse system of Ed Gray's EMA motor #5.

The plan is to eliminate all the batteries and converter and use a rotating high voltage dc dynamo in its place. Nikola Tesla used high voltage dc dynamos with capacitors as part of his magnifying transmitter to produce radiant electricity. So it seems logical to do the same thing, merging Ed Gray's radiant energy motor and our version of a high voltage dc permanent magnet dynamo. Could it regenerate a car, or power a home, and or a factory?

Shown below are pictures of Ed Gray's motors in fig 28, 29.

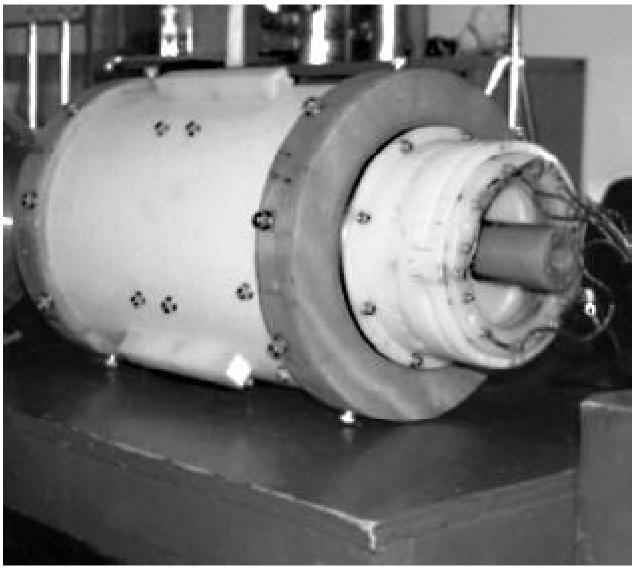

Fig. 28

Fig. 30
Bud Johnson

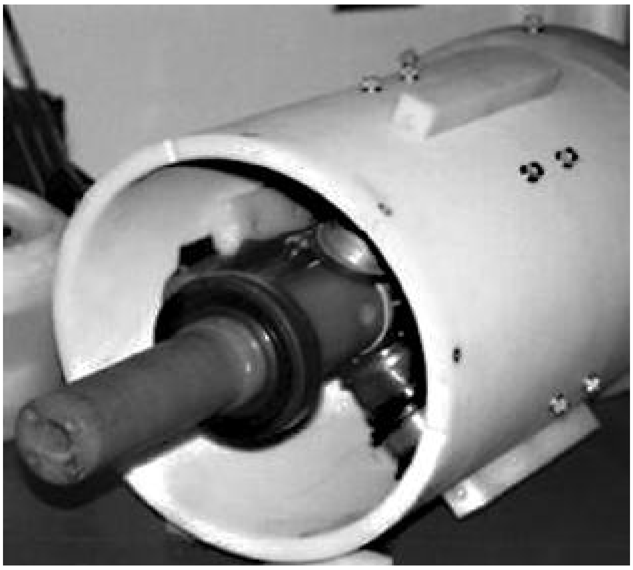

Fig. 29

Fig.31
Dr. Carl Reich

I would like to acknowledge two friends of mine who have helped make the Interference Disc machine possible, Bud Johnson 1986 shown in fig. 30 and the late Dr. Carl Reich shown 1987 in fig. 31. I would also like to acknowledge Wilbert Griffith and Brian & Rose Langan for their contribution in helping us make these projects possible, and there are others who wish to remain anonymous. Bud Johnson also an inventor, was one of the first people who I met after relocating to Alberta from the NWT, he made arrangements for us to construct the first disc machine in a machine shop.

Dr. Carl Reich was a pioneer in the alternate medical field and he published a book along with Robert R. Barefoot called "The Calcium Factor", copyright 1992. Through Carl's dedication and hard work with alternate health and energy, Dr. Carl Reich contributions have also helped made the Interference Disc machine and our Permanent Magnet Dynamo possible.

I also would like to thank my wife Jan Francoeur for being part of making this research possible, she has spent countless hours to prepare this report and assist in the reconstruction of these machines.

The test results and hypothesis I have written are not complete, and the research and development of the described magnetic energy machines is on going, and as such, the potential and performance and true efficiencies of these machines are still yet to be determined. This author knows that the aether is real and free energy systems are possible, and I will continue to work until I have completed the integration of Ed Gray's radiant energy motors with our larger version dc dynamo machine. When this happens, a new round of testing will begin with our attempts to run the two machines together in closed loop regenerating mode.

I hope I explained these energy machines in a way that you all can understand, and more information will be released as progress is made. ***You may find this information useful with your quest to be energy independent. However, if you profit from any of my ideas I have described in this writing, then in all fairness, please remember to reward the inventor so research and development can continue.***

This is my gift to humanity.

Interesting Information

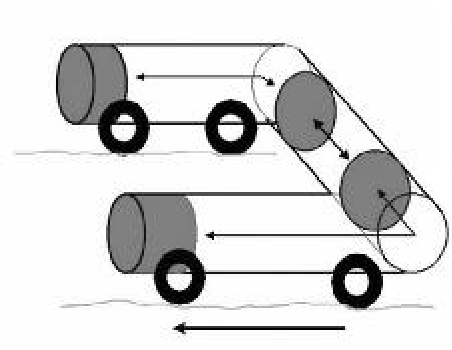

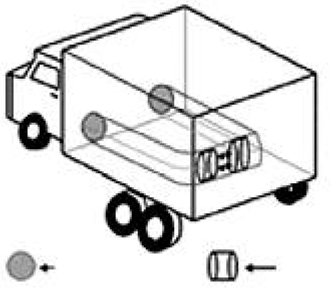

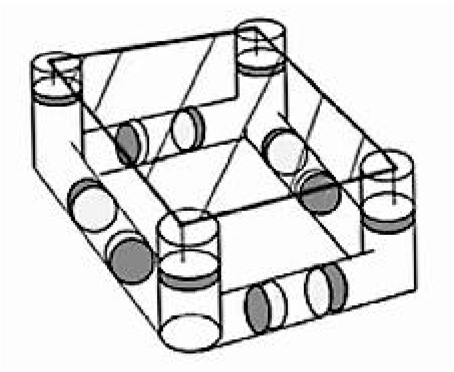

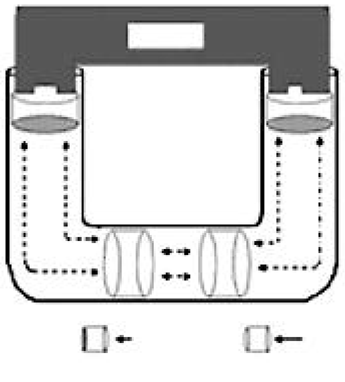

New Propulsion Letter
from Paul Toomer <jorjencar@leeds322.fsnet.co.uk>

Please take a look at this new web site on how to challenge Newton's third law of motion at

http://magnetic.propulsion.mysite.freeserve.com

A NEW PARADIGM FOR TIME

EVIDENCE FROM EMPIRICAL AND ESOTERIC SOURCES

Donald Reed, USA
1032 Borden Road, Depew, NY 14043
Email: torsionpower@yahoo.com

The author of this article
presents an experimental approach
to the teleportation problem
and time pace control
and
space regularity questions.

Part I of II

ABSTRACT

The following essay seeks to establish awareness, through a far-ranging careful examination of various empirically documented anomalous research results in the field of new energy, the long-suspected evidence provided by associated key legendary secret government project work in the USA and former USSR, maverick new theoretical models in foundational physics for elementary particles/fundamental electromagnetic wave-field structures, as well as remarkably corroborative related information from esoteric (psychically channeled) sources, of the necessity for the development of a new paradigm for mass, energy and especially time. After having been guided through this process, the reader will hopefully be motivated to acknowledge the importance of this imperative for a new understanding of the workings of nature, as well as gain hints for the associated future development of new viable sustainable energy sources and related technologies.

Introduction

When we come to examine the annals of physics over the past century, we find them replete with several competing core theories of the physical world, each attempting to demonstrate a unified conception of space, time, energy and matter. Notable among these, the most successful and formally canonized in academia, are special and general relativity, and quantum theory, the latter of which includes quantum electrodynamics and quantum chromodynamics as recent offshoots.

However, even these fundamental theories have fallen short in achieving this coveted goal, due to many reasons, not the least of which is their failure to account for the anomalous but substantial documented evidence continually presented over the years by new energy research and other related empirical evidence considered outside mainstream science. In this author's opinion, these weaknesses in current physics and its relative ignorance and/or selective omission of the findings of non-orthodox scientific research, stem primarily from an ill-conceived institutionalized conception of **time**, as an immutable linear flow against which everything involving **change** can be measured. This "relational" concept of time treats it as a specific passive property of physical systems and changes happening to them. It is a one-dimensional continuous and homogeneous entity geometrically describing the property of duration. This antiquated relational view of time is abstracted from our unique prejudiced viewpoint as sentient beings whose particular point of waking conscious focus is this camouflage physical reality, which is apprehended through the limitations circumscribed by the physical senses.

Accordingly, modern physics is built on the basis of this relational conception of time. However, the use of this conception has not so far resulted in resolving all the problems associated with time. Moreover, so far even an essential definition of time has not been formulated in physics, there are only operational definitions indicating different methods of measuring time intervals.

In contrast, the "substantial" conception of time, advanced in this paper, implies that time is an independent phenomenon of nature existing side by side with matter and physical fields, whose active essence can and does affect objects and processes occurring in the universe. Moreover, the following dissertation argues, by positing that active substantial **change** is the basic concept and relational **time** is its derivative, that those objects and processes can also have a reverse action on time.

Accordingly, we will attempt to show, through a wide-ranging examination of new energy research and other information, the necessity for the establishment of a fluidic, elastic, field nature for true active time which is malleable; one in which even the local pace of time, and mass and energy content can be influenced artificially by intelligent technological control, or naturally by conscious intent, or by a combination of these two methods. To help motivate the reader's awareness for this imperative, we will also examine several esoterically-based sources from key selected psychically channeled transcripts. These will be taken from the following sources: unpublished comments by Jane Roberts on an altered state of consciousness[1] (indicated in this manuscript by J.R.), or published transcripts from **The Seth Material** and The **"Unknown" Reality** (indicated in the manuscript by UR)[2], published chronicles from the entity Kryon, channeled by Lee Carroll [3], and concepts from Wilbert Smith's legendary discourse: **The New Science** (NS) [4]. For easier reference, all psychically channeled transcripts will appear in italics, with my additional explanatory comments in regular type within parentheses.

Granted, our unique investigative foray, ranging as it does from the concrete arena of knowledge represented by the cutting edge of visionary science to the intangible arcane realms bordering on the spiritual, will of necessity lack the exacting logic of scientific rigor.

Nevertheless, we hope to provide, through just such a unique eclectic format, the beginnings of a possible fresh understanding of the workings of nature and perhaps ultimately furnish a conceptual basis for extending the structure of current physical theory to compatibly encompass the elements of a unified framework of physics and metaphysics.

As "unscientific" as this proposed venture may appear, especially to the contemporary physicist or theoretician, we unabashedly press on, secure in the belief that the currently perceived "mutually exclusive" bodies of knowledge defined through psychic means and that of orthodox physics are more closely linked than is currently suspected. Indeed, it will be demonstrated that that some of the psychically defined data bears a striking resemblance to the tenets of present empirical knowledge.

New Research

Theories Indicate Necessity for Novel Time Concept

A body of work which postulates a fluid-field substantial nature for time, is the esoterically-based book written by Wilbert Smith in the early sixties, **The New Science**. Here, Smith outlined a unified theory of all physical interaction by positing that an active mass-free field energy he termed the *tempic field* exists, and is the parent field structure out of which our passive relational linear clock time emerges. To be sure, this book and its specific format of exposition has its weaknesses, not the least of which is a writing style which taxes one's comprehension to the limit. All researchers who have attempted to connect Smith's knowledge with the frontiers of current scientific knowledge, new energy research, etc., have been frustrated by his introduction of terms which may or not have the same meaning as the corresponding terms in mathematical science. This practice causes many passages to appear so vague as to cause total bewilderment on the part of the reader.

> *...the establishment of a fluidic, elastic, field nature for true active time which is malleable; one in which even the local pace of time, and mass and energy content can be influenced artificially by intelligent technological control, or naturally by conscious intent...*

In coming to investigate the source of Smith's theory 25 years ago, I came into contact with Kenneth Killick of Canada. Killick was the individual who served as the original mentor and for a time a colleague of Smith in the mid-1950's. Smith, whose background was in electrical engineering, found it very difficult to accept or understand the philosophical overtones of Killick's thought. Consequently, he resorted to the use of psychic mediums to try to verify the information provided to him by Killick. This is the origin of Smith's association with discarnate entities known to those familiar with his work as "the boys topside". Thus Smith's subsequent writings promote such confusion perhaps because he only obtained a partial understanding of these cosmic ideas, and he opted to writing in a kind of code basically to try to hide his own confusion. Through my own association with Ken, I discovered that The New Science is able to be put into reference with known facts once the spiritual-philosophical elements of Killick's teachings are duly integrated. When this is done, "Wib" Smith's book can teach much and can become a cornerstone to new energy science. Otherwise, it remains at best, a fragmentary enigma.

The work by Smith and Killick is pertinent to the theme of the present paper, since they both showed through experimentation with a special caduceus-wound coil, that so-called relativistic parameters of mass and gravity, energy, and time-flow, can be altered through intelligent artificial control. Adequate delving into some of the elements of these theories will enable us to glean new insight for transforming the current paradigm of time. Further details on Ken's so-called tachion energy theory can be found in this author's earlier expositions on this subject in issues of **Energy Unlimited** (1978-1982)[5].

Smith's main error is in postulating a fundamental "spin" dynamics based upon conventional continuous rotation. As Killick points out, such a concept of spin on the microscopic level, precludes any possibility of true evolutionary change, in the cosmic sense.

Also, as we shall see presently, the continuous spin concept obviates expression by anything in the universe, of its personal moral responsibility. However, with tachion energy theory intact and untrammeled, the impersonal dualistic concept of interaction between two polar entities, such as is expressed not only in ordinary classical Newtonian physics, but its 20th century successors, relativity and quantum theory, is supplanted with the omnipresent workings of a **trinity** at all levels and manifestations of reality.

Indeed, the fundamental tachion field (mass-free) energy has **three** components: two polar opposite entities (a positive "charge" and a negative "charge"), and the ability for these two to be in what is called "static-dynamic balance". The static-dynamic balance completes the trinity.

A simple physical macroscopic manifestation of static-dynamic balance can be seen in two people arm wrestling. As the energy of one participant is brought to bear against that of the other, we will see a vibration or oscillation once a balance of their energies is obtained. As more effort is expended, the vibrations will increase in frequency and decrease in amplitude. At this point we will see a static state relative to the two arms; neither causes loss of arm position of the other. But simultaneously we also have a dynamic situation in the rapid oscillation which maintains, and is in turn sustained by the muscular energy which produces the static state of the arms. Both states mutually support each other's existence. The two component entities (the arms) resonate together, but without losing their own identity.

The implications of this last statement, missing in current physical theory, is unique to the system of tachion energy. We will see in the following that the dynamic functioning of these sub-atomic tachions is such that by their inherent ability to manipulate space and the time-frame of matter through static-dynamic balance, they do not harm anything else in their environment, nor are they affected (forced to lose their own identity) by the ambient environment. Accordingly, inertial mass is not an inherent component of tachion energy, but is a derivative of certain tachion field modes.

We spoke earlier of tachion "charge". We keep the word in quotes to underscore that this is not to be equated to electrical charge, but merely signifies two polar energy states of the primordial ground-form, out of which all known physical forces come to be manifest. These tachion energy states can be defined in terms of "rotational" motion. Again "rotation" must also be placed in quotes as it does not signify the common idea of continuous spinning. Such a concept was suggested above in connection with evolutionary progress in its cosmic interpretation.

The tachion-pair could be described as executing a "back-and-forth" ratcheting movement. The tachion-pairs are analogous to the ends of a drum majorette's baton. But unlike the twirling motion of the baton, the tachion-pairs do not demonstrate the classic macroscopic continuous spin motion, but oscillate in a 3-component "clocking" action.

In Fig. 1 we have drawn a circle and have divided it into three 120 degree arcs. The first motion in the tachion cycle is an arc from the 0^0 -360^0 location, to the 240 degree position. This movement is stated philosophically as the question, "Can I go?" In the second phase it swings back from the 240 degree position to the 120 degree point, and then returns to the 240 degree position. This graphically represents an analysis of the first question, and can be phrased as the "Let me think" component. Finally, then it proceeds forward another 240 degrees taking it past the 360 degree point to 120 degrees. This last stage is the action motivated from the analysis in stage two, and is entitled, "Yes I can". In this activity it will be observed that all path lengths are 240 degrees.

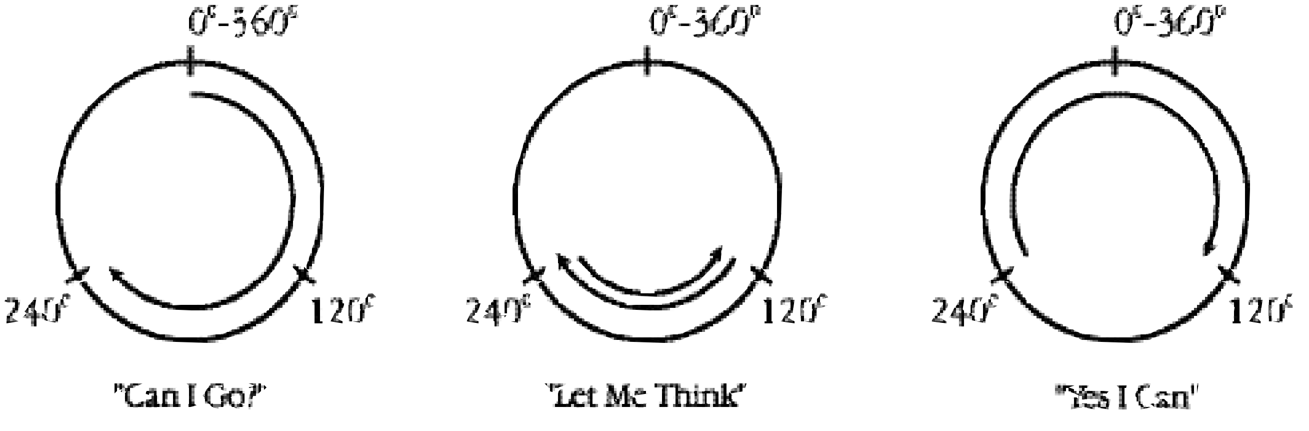

"Can I Go?" "Let Me Think" "Yes I Can"

Fig.1
The 3-Component Tachion Movement

However, as representative of true evolutionary progress, the tachion-pair does not remain confined to the plane in its 3-phase cycle. After each "Let me think" stage, the entire pair unit could be considered to advance "upward", perpendicular to its plane of "rotation". The combined motions can be viewed as an elevation up an inclined ramp, screw-fashion (Fig. 2).

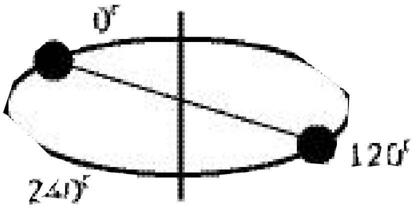

d) 240° Rotation, "Yes, I Can"

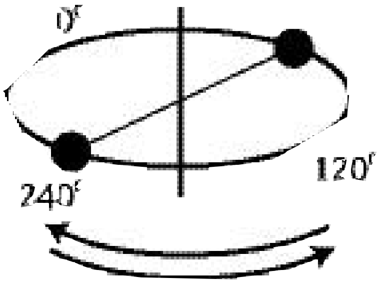

c) 120° & 120° Forward. "Let Me Think"

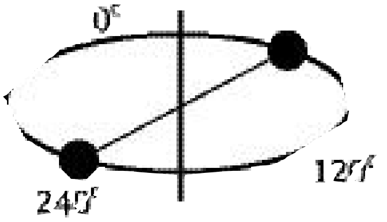

b) 240° Rotation, "Can I Go?"

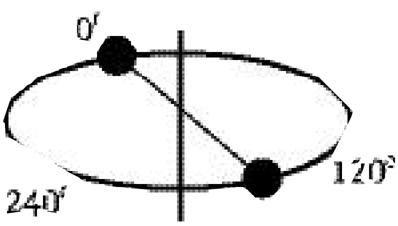

a) Initial Position

Fig.2
Tachion "Ratcheting"

Thus, while they clock themselves backwards in the plane, they never go back to where they were originally but only seem to do so from the point of view of an observer in the plane. This entire activity can be visualized as a diametrically opposed pair "rotating" in a plane, but there must still be considered an upward ratcheting movement. They execute the clocking motion simply because they adhere to the three principles of observation, analysis and motivation. A meaningful application of this idea to the structure of physics would eliminate the necessity for a totally impersonal type of interaction governed solely by force. Unlike all current theories of elementary particles, the tachion-pair, by its unique activity, thus expresses a personal moral responsibility. So this elemental energy of the universe never goes where it is not wanted, but only where it will not disturb its immediate environment.

The topological structure of each tachion in the pair is also significant in regards to this "ethical" modus operandi. First, tachions in their primordial state are massless, toroidal shaped fields which always occur in pairs. Like toroids, tachions will singly exhibit three motional degrees of freedom, to wit;

1. rotation around its major axis.
2. inner (P), or outer (N) rotation about its cross-sectional (poloidal) axis.
3. expansion and contraction of the field (each toroid pulsates radially about its cross-sectional axis).

As a pair-unit, the combined motions will give rise to the following possible orientations: two identical (N) rotations; (N) rotation - (P) rotation; two identical (P) rotations (Fig. 3).

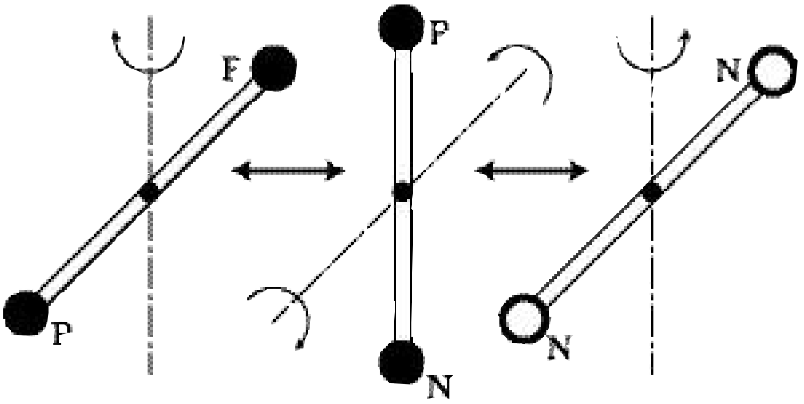

Fig.3
The Three Tachion Modes

The dual (P) or (N) rotations will always lie in the same plane, whereas in the "mixed" rotation mode, the orientations of the tachions will be mutually perpendicular. In the pair unit, the energy will shuttle back and forth between the tachions by virtue of their harmonious expansion and contraction. The contraction of one pair partner is immediately compensated for by an equal amount of expansion in the other. When one is fully expanded and the other completely contracted, they will reverse roles executing the second portion of the cycle. There will be two points in the clocking cycle where the tachions will share an equal amount of energy ("field equity") stage. In each cycle of a tachion-pair the field equity stage is passed twice, a fact which is significant when topology of the field dynamics is considered (see [5]). Now, looking at the field geometry for the tachion-pair unit at the two field equity stages of the cycle, we observe that the two geometries are not identical but are *mirror images* of one another via a non-orientable field structure. See Fig. 5, which shows the isomorphism between the dynamics on a Moebius band (a non-orientable topological structure) and the tachion pair clocking cycle.

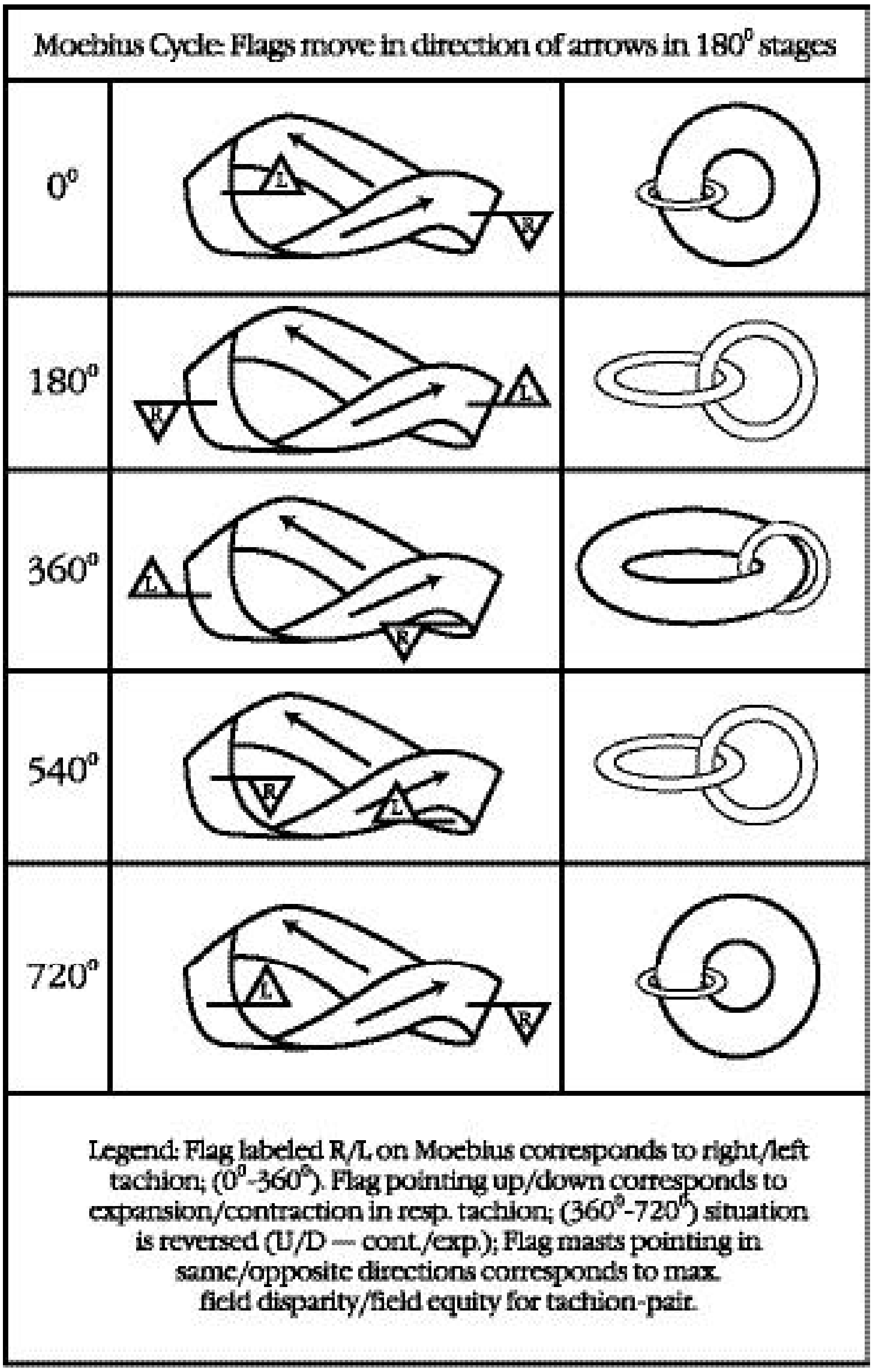
Moebius Cycle: Flags move in direction of arrows in 180° stages

Legend: Flag labeled R/L on Moebius corresponds to right/left tachion; (0°-360°). Flag pointing up/down corresponds to expansion/contraction in resp. tachion; (360°-720°) situation is reversed (U/D — cont./exp.); Flag masts pointing in same/opposite directions corresponds to max. field disparity/field equity for tachion-pair.

Fig.5

This suggests the remarkable idea that the space time points that the pairs generate are not, as commonly assumed, identical, static, and bereft of intrinsic character, but exhibit *enantiomorphic* topologies, which by virtue of their mirrored relationship exert upon one another a potential for dynamic interaction. For now we present a second diagram to illustrate the three pair energy modes: N-N, N-P, P-P, as well as one sequence of oscillation of the N-P pair (Fig. 4).

a) Three types of pairs:

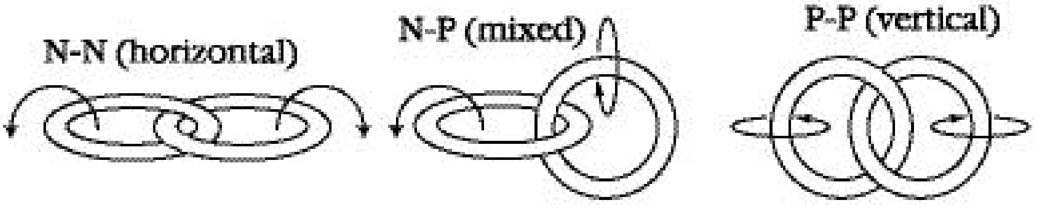

b) Stages in clocking cycle of N - P pair (I thry V)

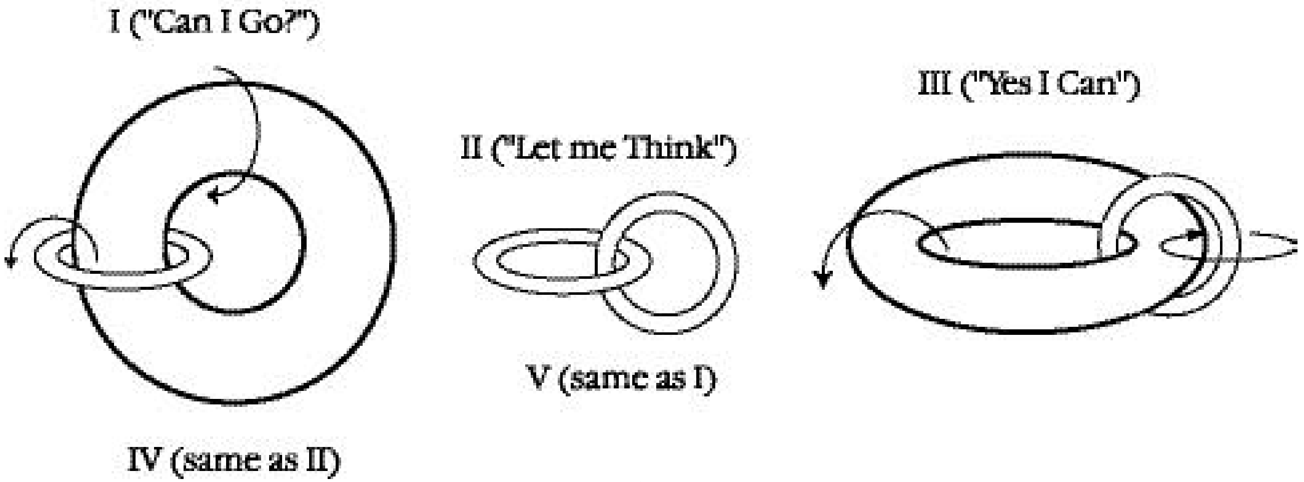

Fig.4

In this figure we note a unique trinity of field operation: two stages of maximum field disparity (I and III) connected by the intermediate condition of field equity (II). Upon postulating the additional requirement that the pair will create a new space-time location every time the field equity state is reached, we see that with each cycle the unit will not return to its original state with respect to the environment, but will advance to new evolutionary states with each pulsation. In accordance with the above comments, the tachion-pair unit "ascends" the evolutionary spiral via this unique action we have termed "clocking" motion. In acccordance with the description in Fig. 4A, in Fig. 4B, stage I represents "Can I go?", stage II represents "Let me think", and stage III represents "Yes I can".

Now, in this regard, the previous analogy of the tachion-pair as likened to the ends of a baton, where the baton rises and falls as it rotates, is quite apt. However, unlike the ends of the baton tachions are not rigidly connected but possess much freedom of movement outlined above. On the other hand, much like the baton ends, they are mutually supportive of each other's activity and requirements, never seeking to overpower, or to be eclipsed by the identity of their partner. In this manner they exhibit personal moral responsibility, as we have previously stated. By their mutual harmonious action tachion-pairs will progress in a true evolutionary fashion, while never harming anything else in the universe by their action.

> *...the dynamic functioning of these sub-atomic tachions is such that by their inherent ability to manipulate space and the time-frame of matter through static-dynamic balance, they do not harm anything else in their environment...*

Now, the above is an inherent characteristic of tachion-pairs as long as they go about their business individually- that is, in their pre-physical state. Now, when the three fundamental tachion-pair energy modes described above exhibit a slow clocking frequency, there is opportunity for them to join together whereupon we begin to see matter being formed. The element of mass, or inertia is provided by the binding activity of the (N-P) mode, which is a function of the slow oscillation of the pair unit. Besides the clocking frequency, the factor of inertial mass or density of physical substance is also dependent upon the amount of separation between the two pair components in each individual sub-atomic tachion-pair unit. In general, the denser or more massive an object is, the slower its microscopic tachions will clock, and the farther apart will be the individual toroid components. This is a classic push-pull situation, i.e., there is a key inverse static-dynamic balance relationship between tachion-pair pulsation frequency and their area of operation (density of field). The rest mass that any physical substance displays to macroscopic observation, is thus a direct function of the amount of energy supplied by the master field to sustain the oscillation of the pair-unit. Thus, a primary feature of tachion dynamics is the following: if we change the energy, we must expect to observe a corresponding change in the manifestation of the mass, and vice versa. Consequently, in tachion dynamics there is a built-in interchangeability of energy and mass, an idea which concurs with similar conclusions in Einsteinean relativity (notably, $E = mc^2$).

But here is where tachion theory and relativity part company. We have seen that our postulated "clocking" pulsation of the pair is the factor, which determines both space and time. Both **space** (area of pair operation), and **time** (frequency of pulsation) are mutually dependent on what **we shall call the master field of thought and intention, which determines the clocking frequency**. From the dynamic influence of the master field arises subsidiary conditions of time and space which are truly "fluid" qualities of tachion operation. This is indeed consonant with the assumptions of a proper unified field theory in which all the factors of our objective world as apprehended by the physical senses, are subsumed under the relative state of a guiding master field. Moreover, under the geometrical constructs of such a theory neither space nor time should be subservient to the other but should retain their unique qualities in a mutually supportive relationship. This is guaranteed in tachion theory under the fluid give-and-take of the pair operation. Relativity, on the other hand, despite its logical consistency, does not meet the above requirements. To his great credit Einstein recognized the need to integrate time with space in a synthesis that would retain the distinctive qualities of both. The result was a theory, which extended the classical Euclidean concept of 3-dimensional space as a kind of "cosmic container" of matter, to embrace a structure of space, which arises from the laws interrelating its material content. Thus, for instance, in his General Relativity theory gravitation became interpreted as a distortion of the spatial fabric by sources of mass-energy in a non-Euclidean framework. Unfortunately, as a foundation of his theory, Einstein mistakenly assumed a subservient role of time to space. He tried to "freeze" time down into spatial-like dimensions utilizing metric equations, which were variants of a basic form. Before a true understanding of gravitation is developed, the rationale for applying such metrics to this end should be seriously re-appraised. In short, instead of freezing time down into a spatial dimension in order to make it fit a world ruled by nothing but gravity, we must develop a conception of space sufficiently fluid to let true time have its proper place therein.

These and other similar ideas are articulated by Andrea and Paulo Correa in their recent insightful essay on the various serious shortcomings of relativity theory. They write: "Time is not treated by relativity as distinct in nature or in quality from the set of topological locations or lengths between points. Whether in the SR (Special Relativity) form of a flat Minkowski spacetime or in the GR (General Relativity) form of a curved Riemannian spacetime, the essence in relativity lies in its treatment of time as the fourth length of a 4-dimensional space. As the actual metric of a length of time is not fixed, only the intervals being invariant, one can no longer speak of the reality of timelines or of synchronicity" [6].

In their second installment, the Correas even imply the existence of a mass-free energy, which is an integral element of the Killick tachion energy theory: "From a strict physical viewpoint, only an energeticist position can make sense. While space and time may be considered to exist outside the function of matter, independently from it, *they cannot be conceived outside the function of energy*...the field remains conceptualizable (in Einsteinean relativity) only by the pseudo-Riemannian manifold, which, on its own, fails to analytically treat the difference in dimensionality between Space and Time, fails to differentiate between them as distinct manifolds, and fails to account for them as the intrinsic properties of energy in flux".

The tachion theory is such a model that delineates the functions of time and space in terms of a basic mass-free energy substratum. Now as we have seen, since tachion dynamics pre-supposes a static-dynamic balance feature connecting frequency of the pairs (fundamental time elements) with their area of operation ("fluid" space configurations), it represents such a foundation upon which to construct such a theory which will harmoniously treat time and space on an equal footing without neutralizing the unique structural features of each. Since the decrease/increase in the clocking frequency of the tachion-pairs will result in a corresponding increase/decrease of area of operation, the local *pace of time* will also decrease/increase at that space-time location. This is due to the push-pull relationship between energy and time. The intrinsic energy of a tachion-pair will be defined to be its energy of "motion" (energy in the "convergent", pre-physical state). Thus we see that an increase/decrease in the clocking frequency also implies that the intrinsic energy of the pair will also follow suit. Consequently, the intrinsic energy available for a manifestation will increase/decrease as time pace allotted for this purpose decreases/increases. Moreover, the product of intrinsic energy and time interval will always be constant due to the perfect trade-off between both factors in the tachion clocking action. This relationship is remarkably similar to the quantitative statement of the Uncertainty Principle in quantum mechanics in the form: $E \cdot t = h$. This formula states that the product of the energy exchange of a quantum mechanical particle and the time interval required for that exchange to take place, is equal to the so-called "quantum of action", or Planck's constant.

Thus, as a concomitant of tachion dynamics, which is argued could also be the basis of electron spin geometry among other things (see [5]), *time* is made malleable; no longer continuous, or rigidly uniform as in Newtonian conceptions, or subservient to space as in Einsteinean relativity, time "flow" can go to zero, and can even reverse under the application of certain electrodynamic field configurations such as provided by the caduceus coil and other devices [5]. With tachion dynamics even the laws of causality will no longer hold. This is due to the fact that tachions have a much broader field of operation than the purely physical realm. Thus, many unusual demonstrated features relative to quantum theory, such as the principle of Indeterminacy, quantum non-locality (EPR experiment), "entangled particles" as well as hypothesized qualities of an *aether* of space, can find their source in this microscopic non-linear electrodynamic clocking oscillation attributed to the tachions. In fact, the ultimate expression of time as well as space to our sensory perception, could be a direct function of these substratum pulsations. From this consideration there emerges a new dynamic model for **fundamental time** as a "fluid-elastic" field effect arising from the unique ratcheting oscillatory motion of tachion-pair entities. Ultimately, it will be seen that tachions may even form the structural essence of consciousness itself, thus providing the long sought-for unifying link between physics and metaphysics.

N. Kozyrev

Other Recent Russian Research Implying New Dimensions for Time

Another key researcher who postulated an active substantial role for time was the Russian astrophysicist Nikolai Kozyrev [7]. He argued that the gap between the exact (physical) sciences and the natural sciences will not vanish until the principle of causality differentiating cause and effect is placed at the basis of the exact sciences. This implies the objective directionality of time or its flow. We encounter numerous manifestations of this principle in our life and in natural science. Yet this principle is new in both mechanics and physics as a whole. The natural scientist's time is not Minkowski's geometrical time, nor is it the time of mechanics, theoretical physics, etc.

> *Nikolai Kozyrev argued that the gap between the exact (physical) sciences and the natural sciences will not vanish until the principle of causality differentiating cause and effect is placed at the basis of the exact sciences*

As Kozyrev argued, mechanics has been using only the "geometrical" property of time, its duration size, i.e., the intervals between the events under study. Timed, these intervals acquire the same passive properties as the interval measured between two points in space. It is only this property of time that the objective sciences assumed to be existing objectively, postulating that all other time properties are subjective. However, if we want to differentiate causes and effects, in reality the *flow of time* must be a physical quantity, duly expressed mathematically and entering the equations of mechanics. The physical meaning and mathematical expression of the flow of time can be obtained from the space-time properties of causality. Thus, processes in the world occur not only in time, but also *with the aid* of time. Time flow is an active property owing to which time may act on a material system. Consequently, it is in the properties of time that the source maintaining the vital processes of the world must be sought.

From these arguments, we can also derive a fundamental property of time. Let us assume that we have changed by a certain technique the flow of time in a material system. In this process we have perhaps changed the stresses within the system and hence its energy.

However, it is impossible to change the total amount of motion of the system, i.e., to obtain a momentum equivalent to an external action. In other words, time may carry energy but no momentum. Time is a non-momentum material reality. From the above property of the flow of time, Kozyrev concluded that it follows directly that the rotation of a body may be used as a device for changing the flow of time in a system. Time flows into the system in the cause-effect direction, the rotation increases the flow, and hence the system obtains additional energy.

In attempt to verify his theories, in the 1950s, Kozyrev thus performed experiments with spinning gyroscopes and discovered, in agreement with his predictions, that the weight of the spinning system changes slightly depending upon the magnitude of the angular velocity and the direction of rotation. Although the effect detected was not large, the nature of the arising forces could not be explained by existing theories. By applying a vibrating framework to the gyroscope, Kozyrev also found that not only does time deliver an energy, but that near the cause-effect system *time density* changes. Time is rarefied near the generator and becomes denser near the receiver. In other words, time becomes stretched by cause and compressed by effect. In addition, the variation in time intensity is in inverse ratio to the first degree of the distance. This can be seen by the following consideration: Time is expressed by rotation and hence involves planes passing through a pole of the rotating system with any orientation in space. **In the case of lines of force issuing from a pole, their density decreases in inverse ratio to the square of the distance, while the density of planes can readily be shown to decrease with the first degree of the distance.**

Kozyrev discovered another property of time when investigating irreversible processes such as crystallization of a substance, condensation, or evaporation. This influence can be effected by any irreversible process and is registered by a measuring system without any preliminary excitation, i.e., when the cause and effect positions are not separated. In other words, apart from flow and density, time seems to have another property, causal orientation, resembling in a way the polarization of light [8]. This property proves to be so variable that even the sign of the observed influences may change and hence the reciprocal cause and effect positions become reversed.

Continuing his studies on the properties of time, Kozyrev (with V.V. Nasonov) conducted astronomical observations using a receiving system of a new type. When the telescope was directed at a certain star, the special detector positioned within the telescope registered the incoming signal even if the main mirror was shielded by metal screens. This fact implied that electromagnetic waves (light) had some component that could not be shielded by metal screens. When the telescope was directed, not at the visible but at the true position of the star, the detector registered a signal that was much stronger. The registration of the true position of different stars could only be interpreted as the detection of star radiation that had velocities billions of times the velocity of light. It was concluded that the radiation from stellar bodies hence had a component, which was non-electromagnetic. Kozyrev also found that the detector measured an incoming signal when the telescope was directed at a position symmetrical to the visible portion of the star relative to its true position. This fact was interpreted as a detection of the future positions of stars [9].

From the 1960's onward, additional Russian research groups continued and expanded upon the work began by Kozyrev on the unique non-electromagnetic radiation that was apparently a concomitant of all rotating bodies, whether accompanying macroscopic spinning objects of great mass (cosmological or terrestrial), or at the quantum level exhibited by elementary particles possessing recorded anomalous spin features which were not accountable by standard theories. This emanation which was exhibited by rotating bodies was termed torsion radiation [10]. Subsequently it was learned that this unique radiation was a part of all living or inert substances. This so-called "torsion field" research was carried on mainly in secret in the former Soviet Union, and only became known to the Western nations after the fall of the Iron Curtain. Many effects attributable to alterations in time and gravity have been reported through this research. For more information on this topic the reader is directed to this author's review in reference 10 and references therein.

Part II of II

Summary of Part I

It is the intention of this multi-part dissertation to motivate an imperative for considering the eventual establishment of a more expansive paradigm for the phenomenon of time, one which views time from the "substantial" as opposed to the orthodox "relational" standpoint. The substantial concept of time implies the existence of an **active** essence which can and does affect objects and processes occurring in the universe. Furthermore, approaching time from such a fundamental basis implies that by positing active substantial change as the ground form **prime mover** and relational time (**passive** "clock-time", or entropy changes) as its derivative, that those objects and processes can also have a **reverse** action on time.

Towards this end in Part I (hereinafter referred to as I), we considered the key research of the late astrophysicist N.A. Kozyrev who, in carefully controlled experiments which were subsequently successfully replicated, recorded phenomena which have hitherto been unexplainable by standard contemporary received knowledge- whether from the standpoints of Newtonian, Relativistic or Quantum physics. Kozyrev pointed out that only by considering time as an active essence, could these cited "anomalous" phenomena, which are virtual conundrums from the viewpoints of a relational (passive) concept of time, be duly formulated on a logical basis. Accordingly Kozyrev's associated "causal mechanics" incorporates an objective directionality of time flow, implying differentiation between "cause" and "effect". **Consequently, by applying a thermodynamically irreversible process to a physical system (example: vibration to a spinning gyroscope), the rotor in this instance would be observed to lose (or gain) a small but detectable percentage of its weight, depending upon the direction of rotation.** Moreover, in this process **linear momentum** (linear speed of rotation) is not changed, but energy is nevertheless delivered to the system by additional forces directed along the axis causing a change in **angular momentum**, and that near the cause-effect system of the irreversible process, **time density** is altered - rarefied near the generator and concentrated in proximity to the receiver. Kozyrev concluded that time is a non-momentum material reality.

Other experiments of an astrophysical nature showed that registration of the true position or future position (as opposed to visual-present-position) of different stars via the non-electromagnetic component of star radiation, demonstrated the existence of an energy essence, which was apparently instantaneous, or had a propagation velocity of at least a billion times the velocity of light. In this regard, Kozyrev opposed the conventional astrophysical paradigm, which posits energy generated/emitted by stars is a physical consequence of thermonuclear conversion. Instead he maintained that via rotation, stars converted time essence into non-physical (or pre-physical) energy. The latter was nevertheless detectable on Earth by transduction through reflecting telescopes shielded by metal screens, of stellar radiation by a Wheatstone bridge. Hence the "impact" of time was detected by resistor electric conductivity changes (see I and references therein).

Leaving no stone unturned in our investigation, we also took up a discussion of the related Killick-Smith tachion energy model for fundamental (pre-physical) reality. Here we coined a new term- a **trinitivity** of action, which was underscored as a key feature of the operation of tachion-pair entities. Accordingly, we posit the existence of two polar topologically orthogonal toroidal fields, with the unique ability, by the mutual shuttling back-and-forth of their energies, to exist in a third auto-generated state called "static-dynamic balance". Now, since tachions are hypothesized to transfer energy instantaneously, inertial/gravitational mass is not a primordial component of tachion operation (see I). Here we see a striking similarity to the Kozyrev conception of the operation of time in interaction with a physical system - where energy changes are manifested without linear momentum alterations delivered. Likewise, the Smith book, **The New Science** (see I) treats **the hypothetical tempic field as a scalar quantity, which only has direction in relation to its distribution (or "density" change). Only through establishing what Smith termed a *tempic field* gradient does the tempic field possess vectorial nature.** Similarly, Kozyrev viewed time like space as possessing both geometrical and physical properties. The geometric property of time is duration (its scalar component), while physically the course of time is similar to vectorial field propagation and the density of time to field intensity. Although Smith and Kozyrev apparently never were aware of each other's research, the following quote from Kozyrev reveals that they both made key profound discoveries about nature which indeed bear more than a superficial similarity: "Time density is a scalar quantity, just the one observed in the above experiments. Time density decreases with increasing separation from the process creating it. Therefore, a vector property corresponding to density gradient and tractable as time obtaining, should also be observed"[7]. However, in I we also enjoined the reader to observe caution and selectivity when attempting to separate the wheat from the chaff in Smith's book.

Accordingly, the previous ideas are substantially correct, whereas his concept of "continuous spin" of tempic field energy is basically flawed. Killick replaces this outmoded counter-productive notion with a key ratcheting motion, like the escapement of a watch, which is performed by the tachion entities composing a pair-unit. Through this unique "clocking-motion", a cycle of tachion-pair operation exhibits what could only be described as an **ethical modus operandi**, passing through the three stages of observation - reflection - action. By virtue of this 3-stage process, tachion-pairs demonstrate in their individual activity and in interaction with their environment - *personal moral responsibility*.

This is indeed an unprecedented notion which implies that a type of conscious thought process can be ascribed to tachion operation. This can be related to current notions from quantum physics, relative to quantum coherence of states - such as wave-function collapse, Indeterminacy, quantum non-locality (EPR experiment), "entangled" particles, etc. This may be an indication that in such cases, whenever the Principle of Causality is breached or at least compromised, we may be witnessing the unique effects of the inherent conscious microscopic non-linear clocking oscillation of the tachions.

Along these lines, although Kozyrev did not report observing any effects of time energy, which could be considered as "value-motivated", he did report on an equally mysterious "after-effect" in many experiments, which could only be construed as signifying a **memory** process. For instance, it turned out that in experiments with a vibrating torsion balance (or pendulum), at points of support the emerging additional forces did not disappear when the vibration was stopped, but remained in the system for an appreciable time. Interestingly, **their relaxation times were found to be independent of the mass of a body but were dependent on its density**. The largest effects with maximum preservation times were observed on porous materials like brick or volcano tuff. In enumerating on this unusual preservation action Kozyrev observed: "...a body placed for a certain time near an (irreversible) process and then brought to a torsion balance, produced the same effect on it as the process itself...aluminum showed no memory. The largest memorizing effect for processes of both signs has been shown by sugar"[7]. Also, his colleague Danchakov later observed in conjunction with biological experiments that water with decreased viscosity due to having been subject to the action of a process, exerted a distant action on water that had not been under such an action, causing its viscosity to decrease as well.

In this second part of the current dissertation, we will examine other important related information gleaned principally from esoteric sources, referenced in I. These have been obtained from books by Jane Roberts: **The Seth Material**, **The "Unknown" Reality** (UR) [2], unpublished transcripts (J.R.)[1], and transcripts from the entity Kryon channeled by Lee Carroll [3]. This information is remarkably corroborative with that from Kozyrev research and the tachion energy theory. Finally, we will cap off our exposition with a brief examination of a bold new maverick physical theory of subatomic electron structure, featuring variable time/mass attributes, which could be the catalyst for bringing the cited elements from esoteric knowledge and empirical physics research (Kozyrev, etc.) out from their hitherto relative obscurity, to the forefront in our ongoing mainstream investigations in probing the cutting edge frontiers of not only physics, but those of the natural sciences as well.

Other evidence

When one compares the transcripts from various esoteric sources it's remarkable how similar is their description of nature's fundamental operations at the pre-physical level. For instance, a careful reading of the Jane Roberts' channeled transcripts from the entity Seth, reveals a remarkable close connection with the particles termed EE (electromagnetic energy) units and the above Killick teachings on tachion pair dynamics. But first a word of caution to the reader. We should resist the tendency to put into the frame of reference of our sentient physical experience, structures whose essence is fundamentally non-physical. The customary physical characteristics of duality and dichotomy of fields, and the related yardsticks of mass, length and time, for the most part, may not apply in this situation.

It would be impossible, however, to formulate a comprehensive model for the EE unit dynamics were none of the factors for gauging physical reality to be able to be applied to higher dimensional realms. Fortunately, one characteristic does survive the transition to the non-physical framework- the element of **pulsation**. Seth reports in [2] how EE units, much like tachion-pairs are built up and dynamically pulsate in response to thought patterns. First, depending upon the relative intensity of the emotional energy, they will instantly be drawn together in clumps or may just as quickly disperse. Furthermore, being of a pulsating nature, these units can expand and contract. Theoretically, there is no limit to their size or frequency of pulsation. Seth describes their operation in the following manner: **Now, there are electromagnetic structures, so to speak, that are presently beyond your instruments, units that are the basic carriers of perception. Their size varies. Several units may combine, for example. To put this as simply as possible, it is not so much that they move through space, as that they use space to move through. There is a difference**.

On this point, if our conceptions remain "earthbound" we will not perceive any difference between these actions, but once we cast our mental gaze beyond physical experience, an important distinction becomes apparent. To understand this, we need only reflect on the similar non-classical logic that is the basis for the non-orientable Moebius topology that we have seen governs the dynamics of the tachion-pair unit [5]. Tachions, whose translational movement is governed by the relative pulsation frequency, apparently enter and leave our level of reality at two times (field equity stages) during each pulsation cycle. Before leaving our plane, the tachion-pair constitute what we call a space-time point.

Upon returning to our level, due to the Moebius topology of the clocking cycle, their essence creates a new space-time point with enantiomorphic (mirror image) characteristics to the first. The resulting progress of the units in physical reality is thus manifested by a "jerkily discontinuous" movement. Summing up, since the units **are** the point they create, it can now be understood that the units **use** space (or the nature of the space-time points) to move through, rather than the case of macroscopic matter which moves continuously (or appears to) through space.

Seth continues his description of the EE unit dynamics: *Laws of attraction and repulsion are used and, in a manner of speaking, thermal qualities are involved, and this is the only hint that your scientists have received of them so far. The units charge the air through which they pass, and* *draw to them other units. The units are not stationary in the way that, say, a cell is stationary. These units have no "home". They are built up in response to emotional intensity. They are one form that emotional energy takes. They follow their own rules of attraction and repulsion. As a magnet will attract with its filaments, so these units attract their own kind and form patterns which appear to you as perception. They are electromagnetic, in your terms, following their own patterns of positive and negative charge. In this instance, like definitely attracts like. The units are just beneath the range of matter. None are identical. However, there is a structure to them. The structure is beyond the range of electromagnetic qualities as your scientists think of them. Consciousness actually produces these emanations, and they are the basis for any kind of perception, both sensory and extrasensory. These emanations can also appear as sounds and you will be able to translate them into sounds long before your scientists discover their basic meaning. One of the reasons they have not been discovered is precisely because they are so cleverly camouflaged within* ***all*** *structures.*

Being just beyond the range of matter, having a structure, but a non-physical one, and being of a pulsating nature, they can expand and contract. They combine qualities of a unit and a field, in other words. Since they are beyond the range of matter, upon which matter is formed, they will not follow the laws of matter, although at times they may ***mimic*** *the laws of matter. It is almost impossible to detect an individual unit, for in its dance of activity it constantly becomes a part of other such units, expanding and contracting, pulsating and changing in intensity, in force, and changing* ***polarity****. It would be as if the positions of your north and south poles changed constantly while maintaining the same relative distance from one another, and by their change in polarity upsetting the stablility of the planet- except that because of the greater comparative strength at the poles of the units, a newer stability is almost immediately achieved after each shifting.* Even the altruistic motives of the tachion-pair as cited by Killick parallels similar behavior of these EE units.

Again from J.R.: *The behavior of these units changes in the following manner. When a unit is in the act of combining with another, it aligns its components in a characteristic way. When it is separating itself from other units, it will align its components in a different way. The polarities change in each case, within the units. The unit will alter its polarities within itself, adapting the polarity-design of the unit to which it is being attracted; and it will change its polarity away from that design on breaking contact.*

Ken Killick has described the mutual action of several tachion-pairs bonding, as the origin of standard sub-atomic particles possessing features known to modern science such as mass, charge, spin angular momentum, magnetic moment, etc. Thus, according to tachion energy theory, the electron attains its validity, and maintains its structural integrity, by virtue of relations between the component pair dynamics [see [5]). Since for the bulk of their independent existence, tachion pairs are in the pre-physical state, we can speculate that they may actually be superluminal entities. Remarkably, J.R. echoes this view with similar notions: *...the electron achieves its validity because of these* (possibly superluminal) *orbital units* (tachions?). *What we see as an electron is not made of the same things as the orbital units, however; it is an* ***effect****... when you change the structure of the electron, you are changing the relationships between the orbital units. This change will require an application of energy. It may be possible to construct a chamber that would give the electron more freedom.*

Whatever we do now in the handling of electrons is not giving them enough freedom and we are structuring the way in which they can appear. The next observation made by Seth could prove to be essential in clarifying the true nature of time: ... *If electrons were given more freedom they would affect* **our notion of time in perceiving them. The way the measurements (on electrons) are made forces the electron to appear**

in a particular way, but actually it's flitting around, seemingly in many places in rapid succession (pulsing in and out of physical reality). Turning to the structure of elementary particles in [2], Seth offers a similar observation in which he describes the electron as commonly perceived by scientific measurement apparatus, as merely a shadow or facade of the actual electron entity which constitutes a multi-dimensional structure.

In terms of a structural model for the electron, Seth says it would be more appropriate to view these units as composed of *interrelated fields* rather than as the current conception of a particle or a wave. Correspondingly, both of these criteria are key elements of the tachion theory, which posits the electron as composed of two-pair tachion fields. The electron achieves its stability-integrity from the interaction of these free-wheeling units.

Electron Spin and Structure of Fundamental Time

The electron "spin" feature is also claimed to be integral to the exhibit of "time's arrow" in UR [2]: *The electron spin determines time "sequences" from your viewpoint. In those terms, then, a reversed spin is a reversed time motion... electrons, however, spin in many directions at once, an effect impossible for you to perceive. You can only theorize about it. There are "electromagnetic momentums" thus achieved and maintained- certain stabilities that operate and maintain their own integrity, though these may not be "equal" at all portions of the spin. There are equalities set up "between" the inequalities... time, in your terms, then, is spinning newly backward as surely as it is spinning newly into the future. And it is spinning outward and inward* (pulsing inward and outward of physical reality) *into all probabilities simultaneously.*

It is vital that you understand this inward and outward "thrust" of time, however, and realize that from this flows the consecutive appearance of the moment. The thrusting gives dimension to time that so far you have not even begun to realize... This inward and outward thrusting allows for several important conditions that are necessary for the establishment of " relatively" separate, stable universe systems. Such a system may seem like a closed one from any viewpoint within itself. Yet this inward and outward thrusting condition effectively sets up the boundaries and uniqueness of each universal system, while allowing for a constant give-and-take of energy among them. By their unique operation , the EE-units, which form the elementary particles such as the electron, serve as the conduit for this energy flow once it is transduced by elements of thought that Seth terms "consciousness units"(CUs). Continuing in UR on this subject Seth **describes how time can be alternately created or "broken down"**: *The consciousness units serve as source points or "holes"* (Black holes or White holes?) *through which energy falls into your system or is attracted to it- and in so doing, forms it. The experience of forward time and the appearance of physical matter in space and time and all the phenomenal world, results. As CUs leave your system, time is broken down. Its effects are no longer experienced as consecutive, and matter becomes more and more plastic until its mental elements become apparent.* These observations are corroborated by Kryon in his dissertations to follow.

Specifically, in the Kryon channelings, further insight on this electron "freedom" is given in the context of change of frequency: *...There is something we call the electron haze which is around the nucleus of the atom. The space between the energy haze and the nucleus (which is great), varies more than you think in matter. As the space varies, the speed (*frequency*) of the haze must change. It is in the physics where the speed of the haze is strong and fast that you have a different time-frame than your own... you have not yet accepted that an object can seem to be stationary- yet traveling (*vibrating*) very fast. Not in a linear time from point A to point B, but in the electron haze of its vibrating parts.*

J.R. corroborates these comments in this dissertation: *Einstein considered relationships of this sort that hold in the far universe as one increases velocity towards the speed of light,* *but there are also "inner" situations (*altered **stationary** states*) that relate these quantities, and that are much easier to get into.* In regards to atomic structure to allow for frequency changes, Kryon adds: *What is it that makes the distance between the parts change? This is the puzzle for the scientists. For the area between the nucleus and the energy haze although vast, is not void. It is a patterned soup of energy (*the so-called "vacuum"*), and it is within the pattern of this null that changes the distance, and therefore the speed* (frequency*) of the haze.*

Mass, gravity and time are intimately related to this frequency change in the atom. Witness the comments from J.R.: ***Time exists as an invisible drag on matter and this is interpreted as gravity. Time exerts a definite force like gravity, and this is connected with the behavior of the electron.*** *However, since we always look at electrons in a certain way and gravity in a certain way, we miss the connection.* And this related comment as well: *There is another equation to be discovered that expresses the relation between time, mass and gravity.* Kryon reiterates this sentiment, along with relatively detailed scientific information: *Gravity is an absolute product of the characteristics of mass and time... one of which you may change.*

*What has been missing so far in your thoughts is how gravity is related to time, and that the entire issue of gravity, mass and time is non-linear. You have yet to develop the formula of physics. It is not here yet, and we are going to give you three attributes of the formula, but without the formula. These attributes are understood but the way they relate are misunderstood. Your science is just now beginning to see the shadows of them, however. The first attribute of the formula is the ability to understand the **density** of mass. Why is the electron haze so far from the nucleus? We have told you that you can change this distance, and in doing so, the density will change in the mass that is defined by the atoms being shifted. The electron haze will have to vibrate faster (this is possibly the "freedom" referred to earlier by J.R.), the closer it is to the nucleus; when the electron haze vibrates faster, its **time-frame** will shift. Therefore, the second attribute of the formula is a time-shift, and they go together. Also, be aware that you make an erroneous assumption that the actual speed (frequency?) of the electron haze must always be the same no matter what the distance. This is not understood yet either. There is a difference between speed (velocity/ translatory rate) and vibratory rate, and it has to do with the actual physical definition of the **electron haze**.*

Mass discrimination is the ability to control the density of mass. With a density shift will come a time-shift, and with a time-shift will come a third attribute...we will call the **reality of location**, or where the matter is... in which dimensional reality it goes to when shifted. Here is an axiom: **shifts in dimensionality when matter is changed in this fashion create a reality where the matter has to be to exist in its new form**. It might be inches from where you changed it or miles. That depends on how much it got changed. The difficult thing to explain to you is a concept that has not been recognized... that matter has a **reality index**, and that its core attributes are linked to where it exists in time and space. Therefore, the three attributes that must work together are **density, time-frame and location**.

Electromagnetic Field Manipulation of Cosmic Lattice and Time-Space-Matter

In regards to tapping this (mass-free) energy-haze-soup, between the atomic nucleus and electron shells, Kryon speaks thusly: *There's something we are going to call APD (atomic phasic displacement). This is a term that is going to refer to the ability to tap the (Cosmic) Lattice for unlimited energy. The Cosmic Lattice is balanced, but it is not quiet. The Lattice has astounding power. It has a flow of energy that I cannot explain to you, for there is no paradigm model for it yet in your thinking. Therefore, you would not easily understand. The Lattice has vents that we can best describe as necessary for the flow of energy. It balances the slight inequity of the* *polarity. The vents also have to do with time...you will always find two vents together. One will be prominent, the other will be secondary. You might graphically and clearly see one, but you will have to look carefully to see its partner. There are always two. This is an axiom or physical rule of the Lattice energy, and of the universe:* This information remarkably parallels Killick's teachings on tachion energy pairs.

Witness this Kryon pronouncement:*Hiding within common atomic structure is a marvelous peek at something that will totally and completely mystify you, for it will seem to break all the laws of time and space. The" twins" are a pair of atomic parts that always relate to each other, and are always found in pairs. You will discover that when stimulated correctly, they will always move together as a pair. When you start separating them by distance to experiment, they will continue to move exactly together. If one's energy is converted, then the other will do the same. This will cause you to totally reexamine your ideas of time and space, for this condition will not follow the "ultimate speed" of transmission that you thought was correct... that of the speed of light. You will have discovered something that travels faster than you can ever measure*. Compare this statement with the torsion energy claimed by the Russians to travel at a billion times light speed [10].

In returning to the discussion on how to tap the Cosmic Lattice for energy, Kryon continues: *The vents are very necessary for the balance of your universal energy. The vents are also energy portals, (drains, to you), and are where the front of each Lattice cell touches the back...Like so many other physical processes, however, its going to take a tremendous amount of energy in order to unbalance even one cell's null attribute... Once you understand how to" prod" the null to unbalance itself, you will be rewarded with a steady flow of energy, far beyond what you put into it. This is accomplished since you create your own tiny "vent". An unbalanced cell creates a situation where the other cells around it will try to" feed" energy to the one that is unbalanced. This creates a tap that will pull upon the Lattice indefinitely, as long as your work matches the properties the Lattice expects to see.* Kryon further expands on the specific method to accomplish this...*Here's how it works. Two magnetic fields together, postured in the correct way- a way that is very three-dimensional in your thinking process- will create a "designed magnetic field" that is very specific. It's one you have never seen, and does not exist naturally. Start with trying several magnetic fields postured against one another- of unequal force and pattern, and at right angles. Don't make any assumptions. Think freely. Done in the right fashion, these two fields will create a third pattern which is unique and is the product of the original two. This third custom-created pattern is the one that you want to deal with, and is the one that has the potential of manipulating the Lattice. Once you have created it, you will know of its special qualities by how dramatically it changes the physics around it. And this important admonishment is given:* Here is a caution. *Keep this experiment away from your body. Keep the experiment in check with your scientific methods. Go slowly. Understand what you're seeing before you go on to the next step. Do not expose yourself to any magnetic fields. Remotely conduct all energy experiments. Remember that magnetics also plays an important part within your body (DNA components).*

> *...your math told you that there might be a possibility of invisibility and that was your goal. This was again because you did not understand that because the distance between the parts change, it doesn't necessarily mean that the overall size will dramatically change or that it might vanish...*

Here is another. Understand that if you unbalance the Lattice too grandly and too greatly, you will have a ***time displacement****,* *for the process also involves the property of* ***time****... One of the actual physical players in the creative process of unbalancing the Lattice is the manipulation of the time-frame of matter.* ***This is not time travel, but time displacement.*** *It is where you are actually addressing tiny parts of matter, and changing the time-frame they are in. When the inequity of time-frames meet one another (*matter mixed up with differing time attributes*), the result is a displacement of distance (*reality of location*). Although there is no horrendous danger for Earth within this time displacement, it can and will affect the local situation within the experiment. In other words, it can create a matter-distorting effect, completely stopping the experiment, and actually dislocating the parts. We are not going to say any more about this at the moment, but the more astute scientific minds reading this will go to the next obvious step... and the answer is "yes", the Lattice is also the key to quick travel of large physical objects... even of very short distances.*

Possible Documented Demonstrations of Time-Space Warping

Such fantastic transformations were possibly evident in the Hutchison experiments [11], in which metal samples were catastrophically fractured when exposed to radiation from the unique electromagnetic field effect. It was also noticed that many physical objects of different composition which were separate in space before the electromagnetic field was applied, became inexplicably embedded in each other once these objects were radiated by the field effect. For instance, **pieces of wood contained metal knives**, etc. Other metal samples were catastrophically fractured in their molecular-atomic crystal arrangement, producing a substance which was uniform and geometrically symmetrical at one end but appeared to have the resemblance of corrugated cardboard at the other.

Also, similar to Kryon's assertion of the inevitability of time-shift with mass altering phenomena, in Hutchison's work anomalous inertial impulses were recorded on film, sometimes resulting in the complete lift/levitation of various substances of different mass. We notice also anomalous inertial impulses were a feature of the Zinsser "kinetobaric" effect [12], in which due to excitation by **sawtooth microwave impulses with very fast rise time**, a sample attached to a torsion balance, deflected the balance for days and weeks after the original excitation was extinguished. Notice the similarity between these results and those of the Kozyrev experiments, some of which reportedly featured a memorizing preservation effect on a torsion balance, etc.

We also find additional confirmation from the basically anecdotal evidence from the alleged legendary Philadelphia Experiment in 1943, which apparently caused either large time- or space (teleportation) shifts in a Navy ship. In fact, in another piece Kryon himself possibly speaks directly about the Philadelphia Experiment, providing us with further insight into important possible new paradigms for time, mass and energy: *In all your questions regarding magnetics and the massless condition, you have never asked about what happened in your year 1943. You tried to create a massless condition with coarse equipment and little understanding of what you were doing. In the process you actually did create an unstable massless condition for a moment. Its instability created a situation where, instead of a true massless condition, you received one where the time-frame changed but the parts within the sphere of the time change did not have the fine-tuned synchronicity needed for a massless object. The result was an actual distance displacement of the object instead of a true massless condition. Indeed, humans were involved on the large object and their biology was damaged greatly. Your experiment was done in an atmosphere of desperation, and your goal was flawed. For your math told you that there might be a possibility of invisibility and that was your goal. This was again because you did not understand that because the distance between the parts change, it doesn't necessarily mean that the overall size will dramatically change (or that it mightvanish).*

Although this may seem like a paradox to you, the internal mechanics of small particle behavior supports this. The change is measurable but very small, much like what happens with heat and chill...Many of you have guessed correctly that ***magnetics and electricity play a critical role in the determination of the real attributes of mass****... and the magnetic variables that determine the mass product, are often working within very small particles to create the density of an object and also its time-frame. The time frame of a massless object is slightly different than your own, making you to appear slightly slower than the massless object. Its reaction to more traditional mass molecules around it is also predictable: because of the very slight time displacement, it tends to change the number of electrons within the atoms directly in contact with it. This is a clue on how to detect a massless object even if you can't see it.*

*The reason you felt the object (*ship*) would vanish was that you were able to simulate a "vanishing" in the laboratory with smaller objects. This observation was not consistent however, so you again were in desperation to try this experiment on a larger object. The "vanishing" was an illusion and was due to a distance displacement rather than an "in place" vanishing... does this give you a clue to long distance travel using magnetics and the vibratory rate of matter?... Only one human on the planet has ever captured a true massless condition, and even this was a coarse one and lasted for only for a few moments that were uncontrollable in scope. This massless condition was created in the primitive workshop of a great electrical scientist in your culture on the American continent not too long ago. If you were able to visit his workshop, you would note the holes in the ceiling and the patched glass-covered light port where his massless objects took off and wildly flew everywhere. If he had been born 50 years later he would have been able to control the attributes of the experiment. As it was, he did not have the precision tools you have now to direct and control such an experiment. It was his great passion to understand this phenomena, but because it was so uncontrollable and sporadic, he was never able to bring others to see it work, for he could not accurately create it consistently. This depressed him in his later years, for his was a great three-dimensional mind...* When asked the identity of this scientist Kryon replied*: The inventor of your multi-phase current, born in the land you now call Yugoslavia.*

From the above information, there emerges a remarkably consistent picture suggesting that atomic structure may not be as rigid or immutable as formerly thought. Changing the fundamental frequency of vibration of atomic structure can perhaps apparently not only change the density of matter by altering the distance of electron shells from the nucleus, but in so doing alter the time-frame of that object, its mass and also the reality of location of that substance. Certainly, the implications of the Kozyrev research, among others, can possibly form the basis for the eventual technological implementation of these futuristic principles. Perhaps those experimenting with the relatively detailed data provided by Kryon on APD can actually realize this coveted goal.

Maverick New Theories in Physics Suggest Fluid Nature for Time, Space, Energy

The Dirac theory is to be understood as a theory of the electron with electromagnetic interactions. It consists of the Dirac wave function and its properties, including the Dirac equation and relations to physical variables such as energy-momentum, spin and position probability current. In spite of its indisputable mathematical successes, the Dirac theory is still without a completely satisfactory physical interpretation. In particular, the so-called *zitterbewegung* ("jitter motion") is a distinctive feature of the Dirac theory which continues to be the subject of conflicting interpretations in the standard scientific literature. The concept of zitterbewegung was introduced by Schrodinger to interpret high frequency oscillations in free-particle wave packets of the Dirac theory. These oscillations with angular frequency $2mc^2/h$ arise from interference between positive and negative energy components of a wave packet. Schrodinger interpreted the oscillations as fluctuations in position of the electron about an average motion. However, this concept has not been interpreted in the bulk of the literature as having an objective significance, but has erroneously been viewed by standard theory as a mathematical artifact of the one-particle Dirac theory which does not appear in a correctly formulated quantum field theory.

However, as noted theoretical physicist David Hestenes suggests in the first of his recent article series in the journal, **Foundations of Physics** [13], it is only by interpreting the zitterbewegung literally and objectively as point particle motion, that a complete and coherent interpretation of the Dirac theory can be achieved. Moreover, this model has implications that have not yet been previously considered by established physics that relate directly to some of the key features of sub-atomic behavior enumerated in the tachion energy theory and also in the microscopic dynamics of elementary particles revealed by the selected esoteric channelings that we have previously considered in the present exposition.

In particular, it implies that the electron is the seat of a fluctuating electromagnetic field which oscillates with the DeBroglie frequency of the electron (1.6×10^{21}cycles/sec).

Thus, it tells us that a kind of electromagnetic wave-particle duality is implicit in the Dirac theory. Of course, this contradicts the conventional view that wave-particle duality is a property of matter which is completely independent of the nature of its interactions. If the zitterbewegung is an objective phenomenon, then it originates from electron self-interaction, since it persists in the absence of external fields. In this new theory which considers the zitterbewegung as an objective physical phenomenon, the electron mass and spin can be identified with the energy and angular momentum of electromagnetic interaction. It suggests that the self-interaction is such that there exist certain stable, non-radiating but accelerated states of motion; in particular, for a free particle, this implies motion in a circle with the radius of a Compton wavelength- the zitterbewegung. The zitterbewegung implies that some of the mass, at least, is kinetic self-energy associated with a spin, and it reconciles the mass with a zero mass of the bare electron. Thus, according to this bold new theory, the electron spin arises from a helical world-line in spacetime. To be sure, some researchers have previously postulated such a helical electron dynamics. Unfortunately, such models have failed to explain why a helical motion for spin should depend on interference between positive and negative energy states or why the zitterbewegung should depend on the way a wave packet is constructed, or even how the zitterbewegung can be the origin for electron spin despite the fact that it vanishes for plane wave states that certainly describe a particle with spin.

The Hestenes model does offer an explanation for such effects and accounts for the ubiquitous feature of spin angular momentum as a function of the zitterbewegung. The essential unprecedented feature of the Hestenes' zitterbewegung idea is the association of the spin with a local circulatory-helical motion characterized by the phase factor of the electron wave function.

Thus, we reach the conclusion that the complex phase factor of the electron wave function can be associated directly with an objective helical motion of the electron, which is, in turn, a derivative of the zitterbewegung. Although the idea of helical motion connected with the electron has been considered before, it has not previously been related to electron phase to produce a complete interpretation of the Dirac theory.

Moreover, in the next installment of his dissertation [14], Hestenes argues that the zitterbewegung is not only an objective dynamical phenomenon associated with the electron, but is a ubiquitous phenomenon, with manifestation in every area of quantum mechanics, even in the non-relativistic domain. For instance, by showing that spin angular momentum can be regarded as angular momentum of the zitterbewegung fluctuations, the zitterbewegung interpretation of the Dirac theory begun by Hestenes in reference 13 provides an explanation for the electron spin and magnetic moment in the physical circulation of momentum and charge. It also explains the mass as the energy of this circulation. Thus, the origin of the zitterbewegung is attributed to self-interaction of the electron with its own electromagnetic field. The relations derived by Hestenes in this article suggests that the interaction is of magnetic origin, since it has the form of a Larmor precession energy if spin angular momentum is proportional to a self-generated magnetic field. The so-called "rest mass" of the electron is thus a kinetic energy of self-interaction. It is this that gives the electron its inertial properties, and the flywheel-like nature of this inertia may be the ultimate origin of spin dependence in electron scattering. And the Heisenberg Uncertainty relations can now be attributed to the "zitterbewegung fact" that an electron cannot be confined to a region smaller than a Compton wavelength. Also, the stationary states of a bound electron exhibit a resonance of the orbital frequency with harmonics of the zitterbewegung frequency, which is imposed formally in the standard theory by requiring single-valuedness of the wave-function. Evidently, such resonances, so prominent in quantum mechanics, can be interpreted as zitterbewegung resonances. This leads to a new explanation of penetration of a potential barrier by sub-atomic particles as due to zitterbewegung fluctuations in momentum, and the Aharonov-Bohm effect as a shift in zitterbewegung phase. The zitterbewegung phase factor literally represents a physical rotation. The rotation rates of this phase in time and space directions are the source of the electron's energy, mass and momentum.

In his third paper [15], Hestenes draws a closer relation of the zitterbewegung dynamics to the Dirac theory by suggesting that the latter actually describes a statistical ensemble of possible electron motions, which are actually governed by the zitterbewegung sub-structure. Since the energy-momentum of the electron can now be interpreted in terms of a rotation rate in the spin-plane, Hestenes then derives a corresponding relation which defines a variable mass for the electron-another unprecedented idea which is in agreement with the information given by Kryon in his dissertations and Ken Killick's tachion theory. The mass m, the scalar radius of curvature r and the zitterbewegung frequency all covary with changes in the rotation rate in the electron spin-plane. Hestenes obtains a relation demonstrating that the electron mass is inversely proportional to the zitterbewegung frequency. This conforms to the relativistic concept of mass as a measure of energy content. But here, mass is concluded to be primarily a **frequency** measure. This also conforms to DeBroglie's original idea that the electron contains an internal clock with frequency determined by its mass, though for a free particle, the zitterbewegung frequency differs from the DeBroglie frequency by a factor of 2. Moreover, the new key relation derived by Hestenes: $m \cdot r = 1/2h$ (h, Planck's constant), says that this frequency measures the radius of curvature of the electron world-line, so it is a thoroughly geometrical quantity. Thus, as mass increases the radius of curvature decreases, in concert with the tachion dynamics as well. All this suggests that the electron mass relates our externally imposed time scale to a time scale intrinsic to the electron.

The reader can see that the information transmitted by J.R. is also remarkably similar in this connection. It should be evident that there is introduced a new concept of mass here, though, to a certain extent, it was already implicit in the Dirac theory. The formerly vague concept of mass as some kind of material stuff is completely gone. Also, no longer is vanishing mass a distinguishing feature of particles moving with the speed of light.

Corroborating Research on Oscillatory-Fluid Nature for Time

In his recent thought-provoking dissertation [16], Tom Bearden relates of the dynamic influence of time on a material system: "But we can also legitimately state that 'time is energy' and be rigorously accurate...Time is extremely compressed EM spatial energy...Without further elaboration, we speak of a 'mass' in which a small portion exists as 'masstime' rather than mass, as having been 'time-charged' or 'time-excited'.

The t-polarization wave in the time dimension is quite unique: The *spatial* energy of the wave is in equilibrium and not vibrating at all; instead, the photons comprising the wave are vibrating in their **time**-components... In short, mass m is changed into masstime mt by photon absorption... Rigorously, a mass does not really 'travel through time' continuously, per se, but proceeds with an overall serial change mechanism, driven by its total virtual and observable photon interactions, as m→ mt→ m→ mt→...We propose that this may account for the duality of particle and wave...The particle actually oscillates at a high rate between the m and mt states... Mass 'travels through time' by an extremely high oscillation between corpuscle-like state and wave-like state". Notice how Bearden's description of the macroscopic operation of time on a physical system closely parallels Hestenes' proposed model for of the zitterbewegung dynamics at the sub-atomic level which provides the electron (and possibly photons, etc.), with a time-substructure (its internal "clock").

We can see many other places in Bearden's treatise where the unique terminology chosen can now be put into direct reference with equivalent concepts and unique phraseology employed by many of the researchers examined in the current exposition. This cross-referencing certainly provides much needed clarification about key ideas for researchers currently involved with the development of this fledgling discipline that we shall term causal mechanics, after Kozyrev's designation.

All such efforts will help to place investigative endeavors currently scoffed at by establishment science on a firm rational foundation, as well as assist in synthesizing seemingly disparate but surprisingly related "anomalous" phenomena. For instance, to implement the science he has termed "vacuum engineering", Bearden often speaks of the necessity of establishing a "local time-stress of the **vacuum potential**". This process, which as we hope to have shown here is completely legitimate, is identical to what Smith calls creating a "tempic field gradient", Kozyrev's "alteration of time-density", or Alexander Frolov's "change in the local time-rate".

It can clearly be seen that such ideas can only be perceived as science fiction fantasy, if we observe strict adherence to all current received paradigms (even in superstring theory), which consider space and time purely from their relational standpoints. These theories must of necessity involve models employing scalable metrics for their proper description. However, once we embrace the novel view posited here that vacuum energy is primary and both local space and time are derivatives of this mass-free non-scalable dynamic non-local oscillating substratum, then we can conceive of space and time properly as complementary aspects of non-local conscious reality, neither fixed in a scalable manner or subservient to the other, but fluid and mutually interdependent features of energy in constant flux (see the related ideas voiced by A. Correa and P. Correa in I).

With this approach we will then come to acknowledge the technological feasibility of many of the "futuristic" claims made in the channeled transcripts. For instance, we can see that it will no longer be necessary to propel elementary particles to relativistic velocities, or to probe astrophysical systems possessing large gravitational fields, to recognize alterations in space, time and mass parameters, since these phenomena can equally as well be accomplished in the laboratory by modifying atomic structure of stationary matter through electromagnetic means. Once again, peruse the Kryon dissertations on this process, for it may be key to future technology.

For those who wish to further investigate these theoretical possibilities, the papers of **A. A. Nassikas** are recommended. Nassikas has postulated what very few researchers before him have theorized: the existence of a ground-form probability density function for energy, as a necessary precursor to the malleable (deformable) characteristics of time and space [18]. One of Nassikas' conclusions is significant in light of ideas articulated in the present exposition concerning the hypothetical tachion-pair model for reality (see I). Here we refer to the key push-pull oscillatory ("breathing") operation between space and time, which may be responsible for the structural integrity of matter as we know it (again re-read the Hestenes zitterbewegung model).

Researcher **Alexander Frolov** has taken Nassikas' theory even further to suggest an explanation for the **anomalous over-unity effect** that has continually been demonstrated in low-energy nuclear reactions (LENR) over the past decade [19]. In such so-called "cold fusion" cells the Palladium cathode is over-saturated with protons, producing a local imbalance in the vacuum engine, causing a local alteration in the time-frame of the experiment to compensate the local change in energy density. **Subsequently, as Frolov claims, this time-frame change converts non-local time-energy directly into heat energy, similar to Kozyrev's description of energy production by stars.** Perhaps this observation might provide the hitherto missing key in our understanding of fusion by electrolytic action.

Conclusions and Prospects

In the preceding paper it is sincerely hoped that the author has demonstrated ample evidence that will spur on researchers of a kindred spirit towards the development of new paradigms for space, energy, mass and especially time. All these concepts, as well as the foundations of current classical electromagnetic theory, are in need of a drastic overhaul before we can fully appreciate and understand the operations of nature as it interrelates the metaphysical-mental realms with the physical level of reality.

At any rate, the continual appearance of research results, such as the Kozyrev effect, which up to present apparently resists explication in terms of conventional scientific paradigms, certainly offers clear evidence of the incompleteness of our knowledge of nature, even in this enlightened era since the dawn of the new millennium.

Accordingly, hints as to how the Kozyrev effect arises in association with the postulated active properties of time, and how the latter interacts with known physical forces, can assist us towards the development of a more comprehensive paradigm which embraces a wider spectrum of human knowledge - one in which the current conundrums rampant in the foundations of theoretical physics, and biological science disciplines as well, which have hitherto prevented the establishment of a unified model of all physical interaction, can find satisfactory solution. Also, such empirical evidence which generally flies in the face of current scientific wisdom, presents the greatest challenge to our ongoing search for new sustainable energy sources which will be of absolute necessity in the future.

In this light, if formally integrated into scientific thought, the tenets of tachion energy theory, which is based on an altruistic modus operandi, also may hold profound implications for the status of our very social, political and religious structures as well. Indeed, unlike the impersonally motivated interactions believed to be the basis for force interactions in modern sub-atomic physics, which help sustain our illusory belief in the supremacy of the ego, the philosophical basis of tachion dynamics is an able reminder of the humility of purpose which should be the guiding force whatever our walk of life. Like tachion-pairs, in the ideal social structure individuals will work side-by-side, yet achieving a common accord. United in the circle of their activity they will work together joyfully in freedom, each with his own task, yet always conscious of the common bond.

With the full import of these simple truths appreciated, tachions may afford a rational justification of the formerly "unprovable" mystical doctrine of the omnipresent intelligent plan behind the working of the universe at all levels of conscious reality. We will come to realize the profound truth of Einstein's vision of ultimate reality couched in his heretofore cryptic statement, *"God is subtle, never malicious"*.

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On the Rotating Permanent Magnet System

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In one of our issues we published an article about the results of the experiment conducted by S.M. Godin and V.V. Roschin. They started in 1990 at Moscow Aviation Institute (MAI) when a technical physics laboratory was created in Machine Industry Projects Institute at the "Aeropromservice" Association. Their research work was financed by private investors and was continued in close cooperation with Chair 310 of MAI, especially with Prof. PhD. L.K. Kovalev, Prof. PhD. V.V. Rybakov and PhD. K.V. Ilyushin. By 1991 "a device for inner energy of matter conversion" had been designed and tested (according to the Technical Design Assignment). The prototype was finished in the middle of 1993 (Fig.1).

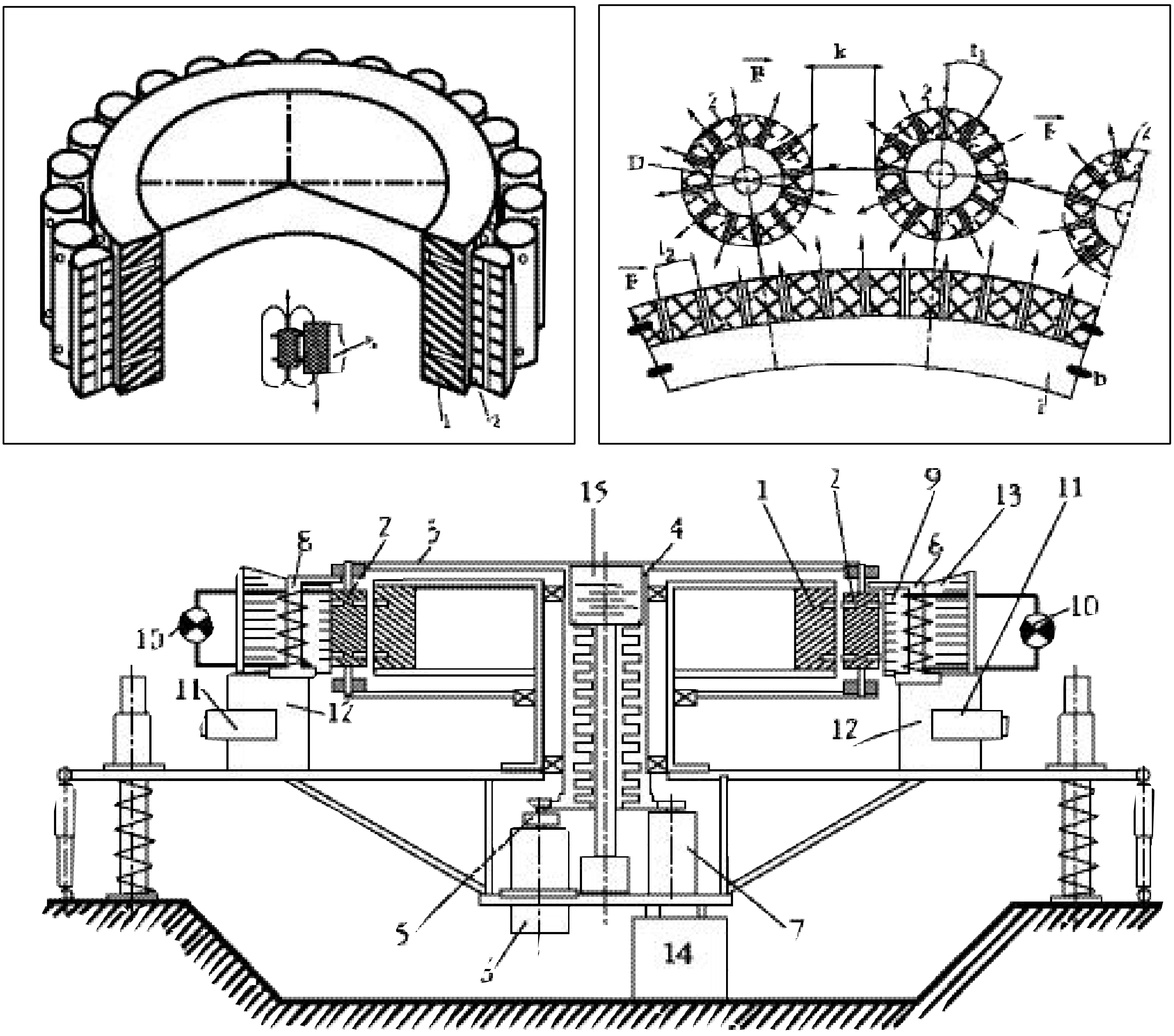

Fig.1

The experiments resulted in the possibility of creating a 7 kW output power in load after the rotor was sped up to 10 rps, but in the autumn of 1993 the laboratory was closed due to the investors' financial problems. Now their research work is continuing in Moscow and we hope the scientists will obtain new experimental results.

You can email S.M. Godin for more information at: smgodin@online.ru

Considering the theoretical basis of the functioning of these systems I should suggest a number of interesting details for prospective researchers.

S.M. Godin, V.V. Roschin et. al. (Physics of Negative Viscosity Phenomena. Prof. Victor P. Starr. Massachusetts Institute of Technology) spoke of vacuum (quantum medium) as **a physical medium possessing negative viscosity.** At that rate, it is worth making assumptions that can be useful to the developers of this topic. I think that standard (positive) viscosity of matter, from the physical point of view presupposes the presence of positive friction and a "work-to-heat" entropy transformation. Consequently, **negative viscosity** should correspond to the **negentropy cycle** "heat is converted to work". This is exactly the stray heat conversion once described by Tsyolkovsky in 1914. Apparently, **the medium of the kind supports self-sustained vortices** characterized by the surrounding medium heat absorption, which was mentioned yet not explained by S.M. Godin and V.V. Roschin.

It is possible that all the elements of matter are the self-sustainable vortex structures. To mathematically describe these physical mechanisms, the notions "heat-work-heat" transformation and "time" or "gravitation" should be interrelated. Russian philosopher Pavel D. Uspenskiy had been making related research since the year 1910.

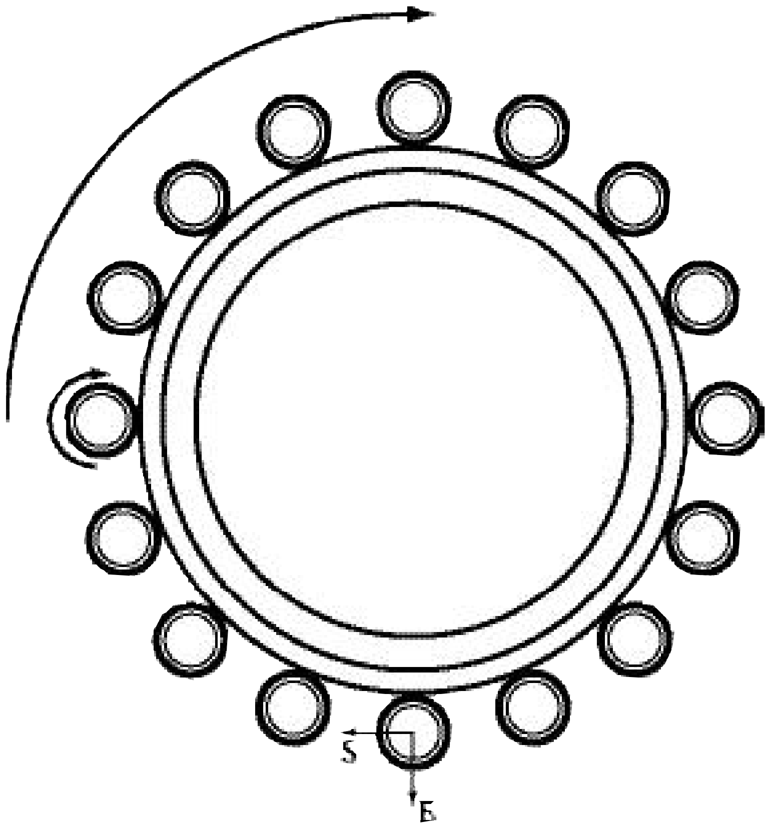

Fig.2

From the conventional point of view, this device (Fig.1) creates a circulating energy flux described by the Umov-Pointing vector (toroidal vortex) as the roller magnet field vector is vertical and the electric field is radial.

S.M.Godin (on the left) and A.V.Frolov (on the right), St. Petersburg, June 2001.

Inventor's Week Conference 2003, USA

Review is prepared by Editor Tatiana Ezhova

This year the annual Inventor's Week-end Conference was held on September 19-20 in Seattle, Washington. The conference featured several interesting inventions, including MEG.

Bill Alek demonstrated a device that he believed could let him detect Vortex-Energy. It was attached to a meter, and his belief was that if he walked into a naturally-occurring energy vortex carrying the device it would show him changes in gravitational and other energies. He cited the Vortices in Santa Cruz and Oregon as examples that might be good for experimentation.

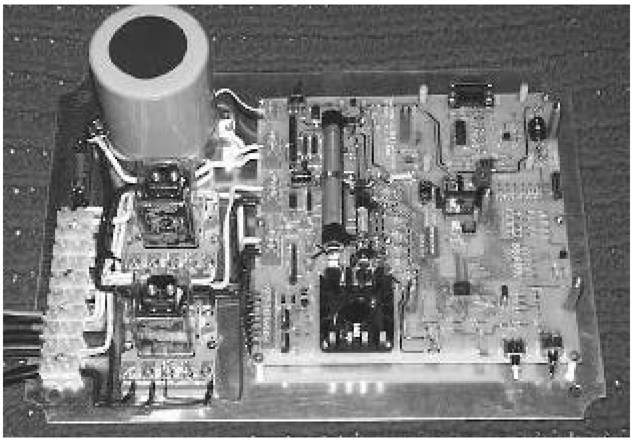

Bill Alek

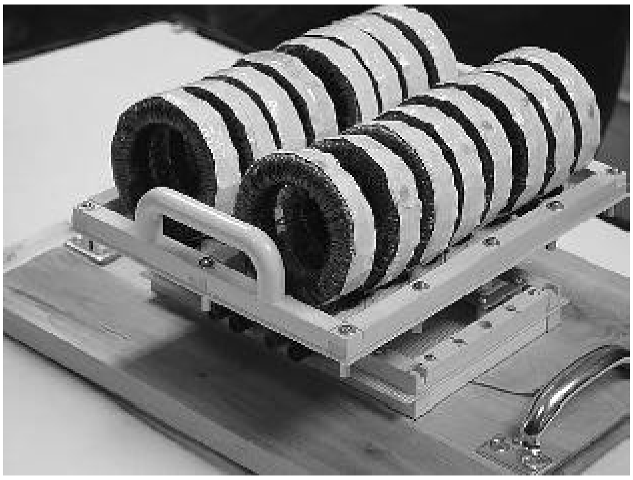

Z-Pod, Bill Alek

In his report "Introduction to Parametric Mass Fluctuation - a breakthrough in Energy and Inertialess Field Propulsion" Bill Alek presented the Z-Pod, developed to test a theory of solid-state parametric mass fluctuation. Here is the URL for a good overview of the device that he published online at www.intalek.com:

http://www.intalek.com/Index/Projects/SmartPAK/Projects/ZPOD/ZPOD_System03.pdf

Rio Von Sternberg

Rio Von Sternberg was presented as the original inventor of the MEG. He apparently has a patent on the device; however, from his presentation I understand that his configuration is somewhat different than the model that J.L.Naudin and T.E.Bearden have been experimenting with.

Alexander Peterson had a very interesting presentation on optical-mirror magnetic field systems. The crux of his presentation involved cutting precise notches into magnetic coils to separate them into identical optical-isomeric shapes. Apparently, by cutting a thin line directly down the center of the transformer-core is believed by Peterson to increase the efficiency of electric motors by up to 50%.

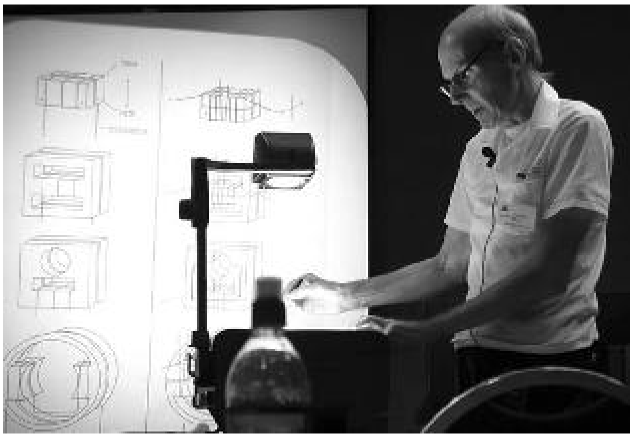

Alexander Peterson

Mark Plotkin, a well-known Washington DC attorney also took part in the conference. He is interested in new energy technologies and works with new technologies in collaboration with Mark Whitford at www.awetec.info. The photo of Mark shows him rotating a steel coil apparatus that was passed around the conference by Slim Spurling.

Mark Plotkin

Slim Spurling is an inventor from the Southwest, shown holding a helical-wound coil that he claims provides health benefits through an interface with zero-point energy. Spurling's belief is that this specific circumference of the coils provides a "Casimir-like Effect" that concentrates the energy.

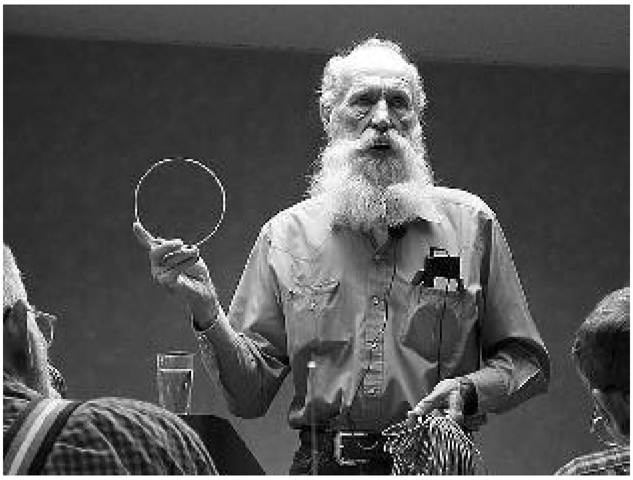

Slim Spurling

Donald Smith

Note: Donald Smith, a well-known inventor, also took part in this year's conference. His work is described in more detail in a separate article of this issue.

Full information on the conference and reports is presented at http://ionvalve.com/iw/2003/conference2003.htm.

USA "Inertia" Patents

Information from www.rexresearch.com/inertial/

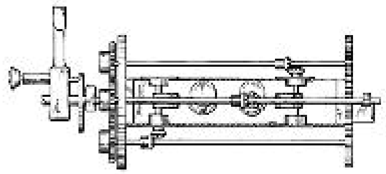

№ 6,290,622 (7/18/01)
Mechanical Force Generator
Murray, Lawrence D.

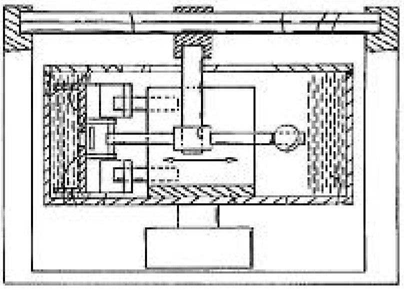

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Motion Imparting System
Deschamplain, Daviv

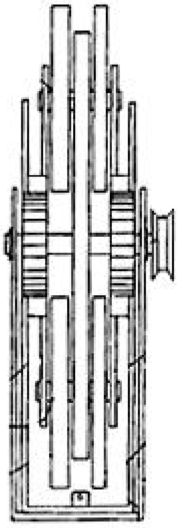

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Apparatus for Generating
a Propulsion Force
Oades, Ross A.

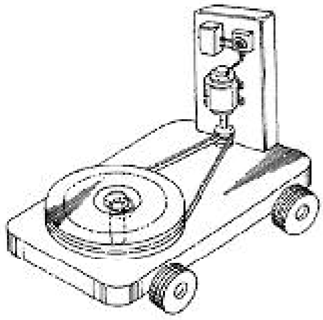

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Centrifugal Propulsi
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Kunz, William T.

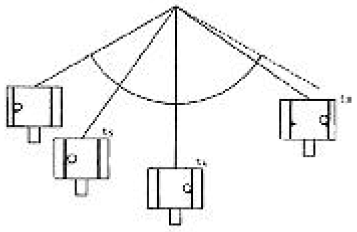

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Method & Apparatus
for Propulsion
Rasmussen, James K.

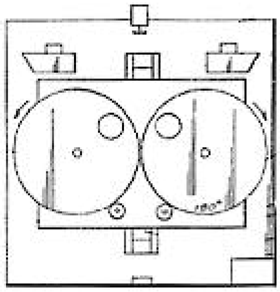

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Propulsion System
Laul, Virgil R.

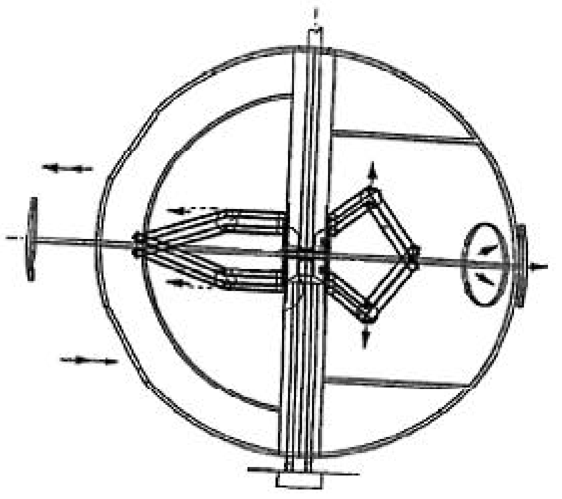

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Apparatus for Energy Transformation & Conservation
Shimshi, Ezra.

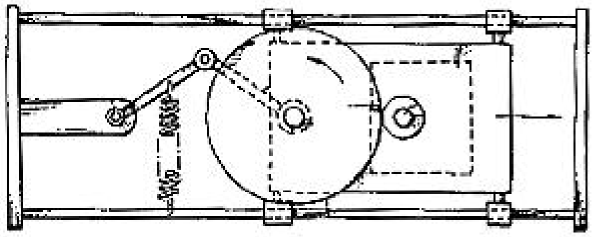

№ 3,492,881 (2/3/70)
Prime Mover
Auweele, Albert J. v.

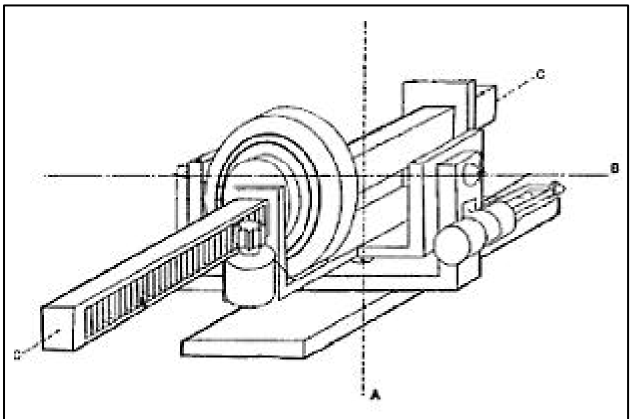

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Gyroscopic Propulsion System
Laithwaite, Eric R. & Dawson, Wm.

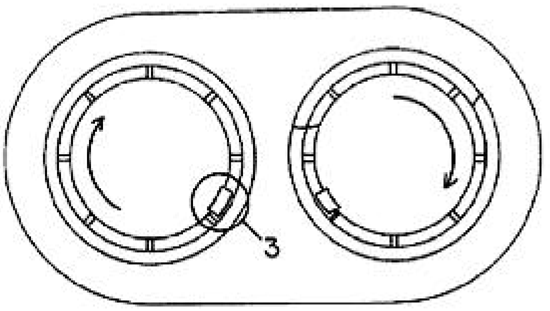

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Bootstrap Propulsion System
Stopplecamp, Timothy J.

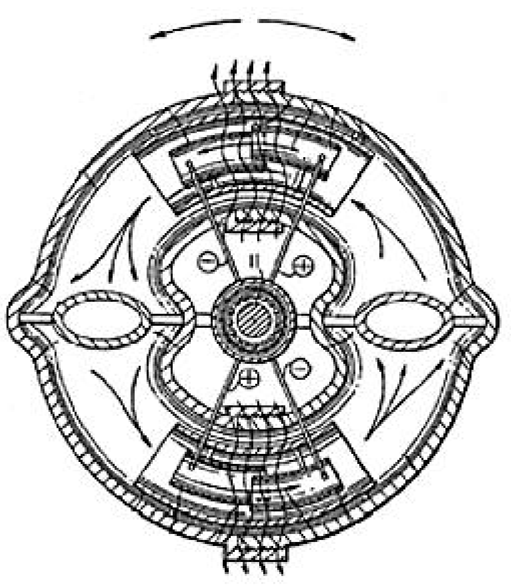

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Propulsion System
Butka, Kemal

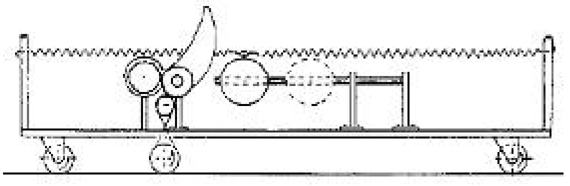

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Inertial Propulsion Plus Device & Engine
Foster, Richard E.

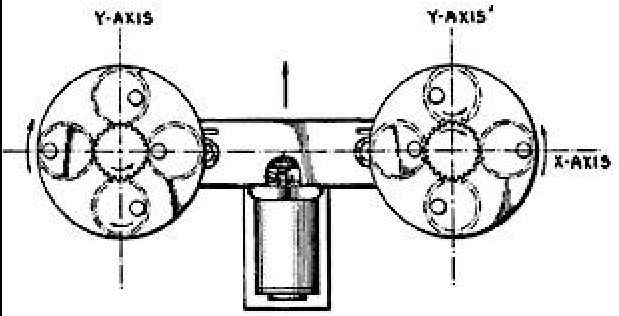

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Energy Transfer Device
McMahon, John C.**

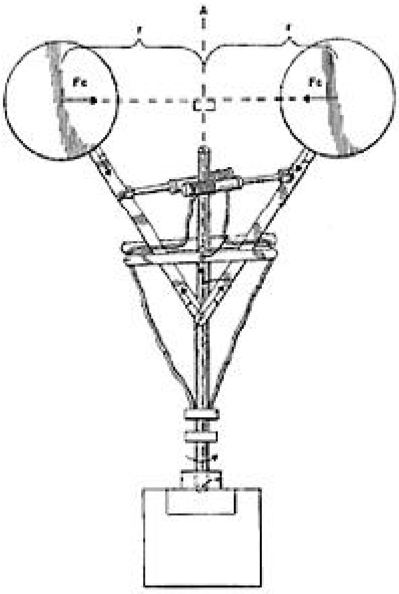

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Centripetally Impelled
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Claxton, John C.**

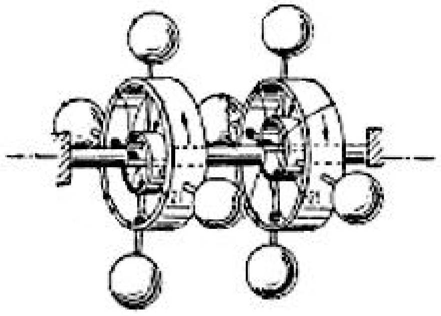

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Converting Rotary Motion
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Bristow, Theodore R., Jr.**

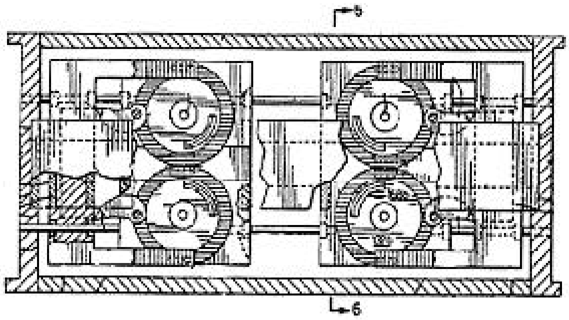

**№ 5,182,958 (2/2/93)
Non-Linear Propulsion &
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Conversion System
Black, James W.**

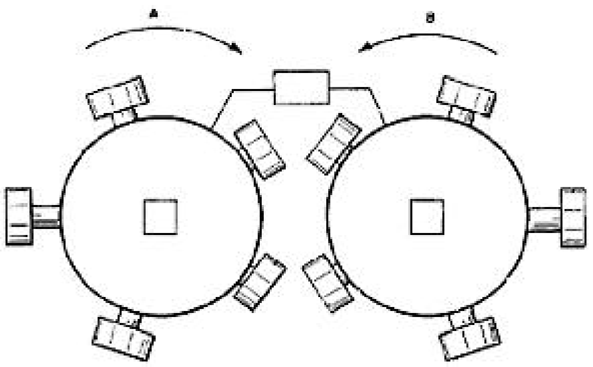

**№ 5,782,134 (7/21/98)
Electromagnetically Actuated
Thrust Generator
Bouden, James D.**

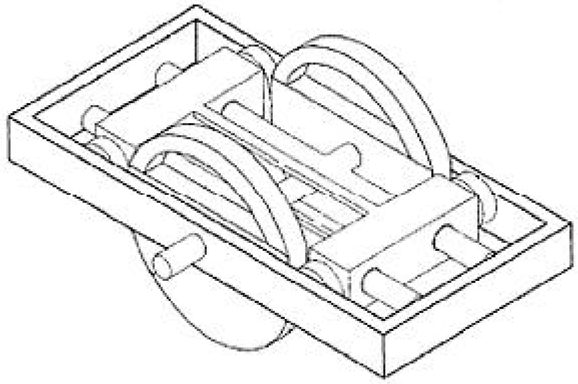

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Centrifugal
Inertia Drive
Lieurance, Richard L.**

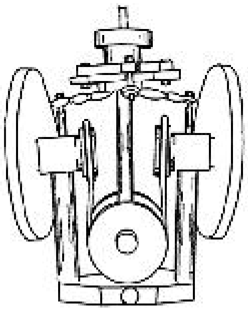

№ 5,024,112(6/18/91)
Gyroscopic Apparatus
Kidd, Alexander D.

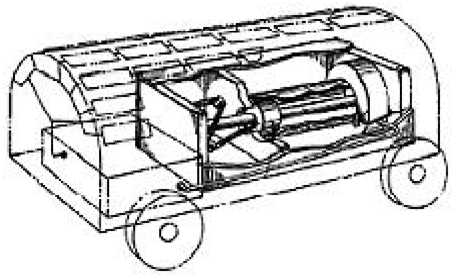

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System for Propulsion &
Positioning
Rogers, Charles E., et al.

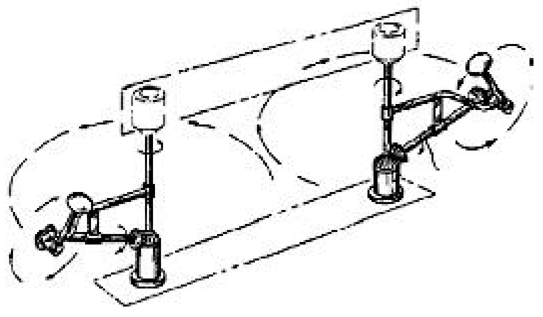

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Centripedal Device for
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Centrifugal Force
Mason, Lyle M.

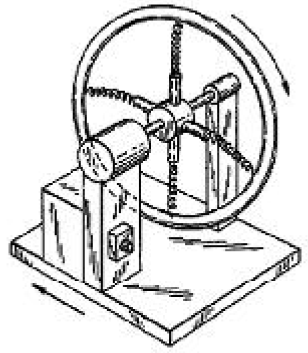

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Gyroscopic Propulsion
Device
Kethley, Lancelot I.

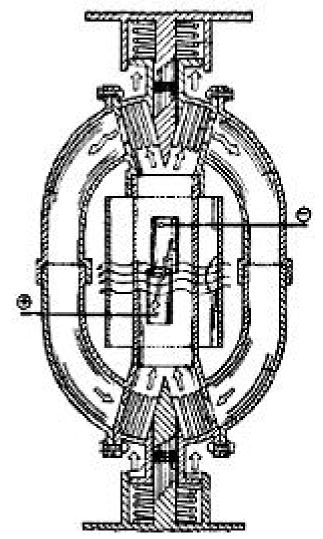

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Propulsion System
Butka, Kemal.

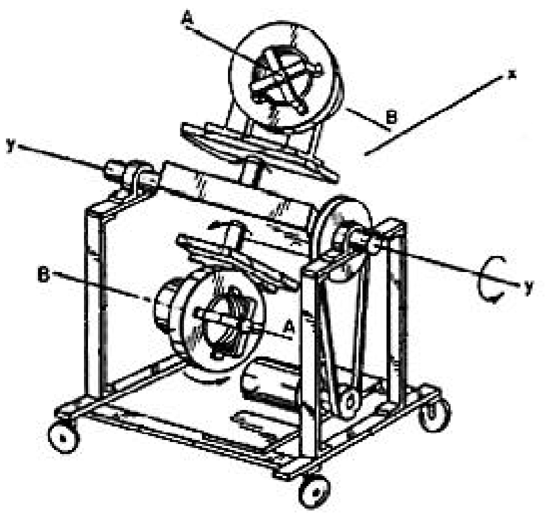

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Gyrostat Propulsion
System
Derloy, M.S.& Derloy M.

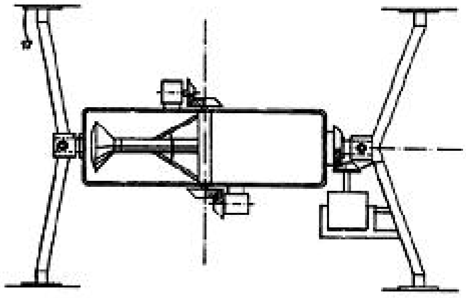

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Centripedal Device for
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Zachystal, George J.

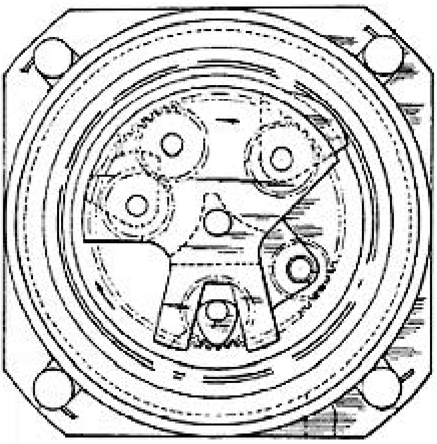

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Conversion of
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Montalbano, Paul J.

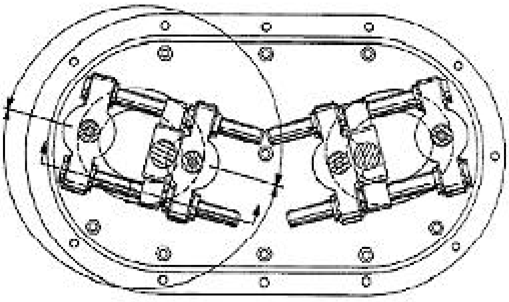

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Universal Propulsion Powerplant &
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Mundo, James D.

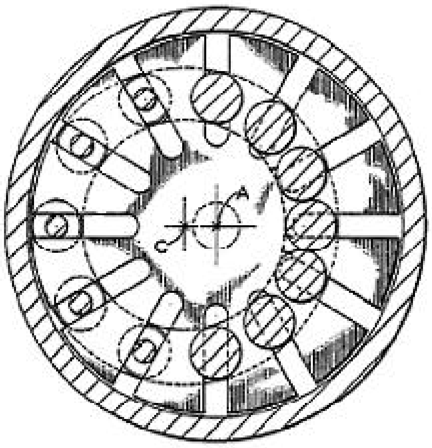

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Flywheel
Fulop, Charles.

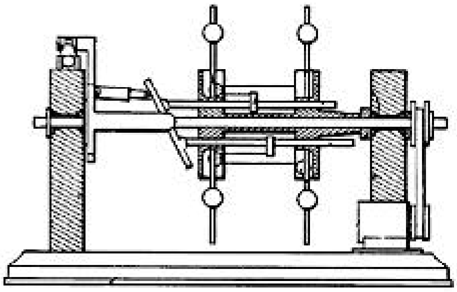

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Controllable
Gyroscopic Propulsion
Apparatus
Rodgers, A.T.

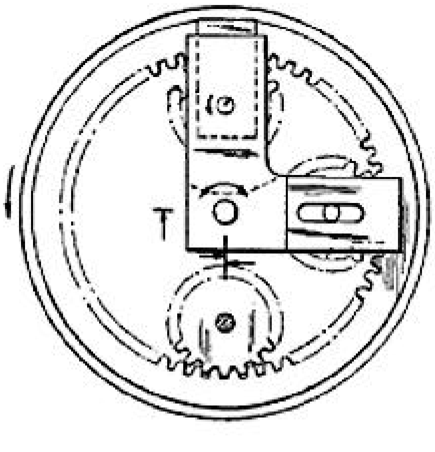

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Conversion of
Rotational Output
to Linear Force
Montalbano, Paul J.

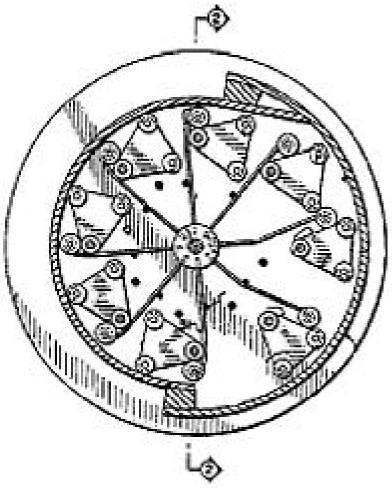

№4,744,259(7/17/88)
Apparatus for
Producing a Directional
Unit Force
Peterson, Oscar F.A.

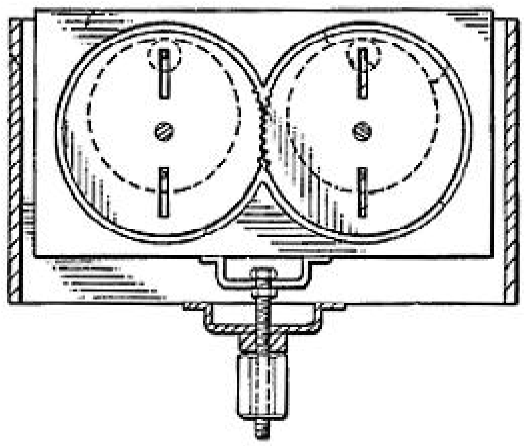

№4,712,439(12/15/87)
Apparatus for Producing a Force
North, Henry.

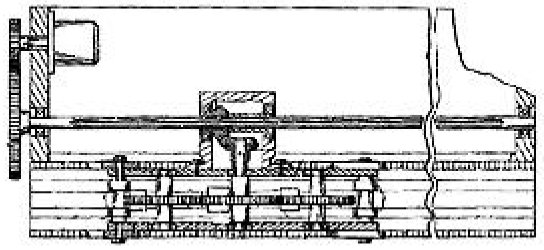

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Mechanical Propulsion System
Srogi, Ladislaw G.

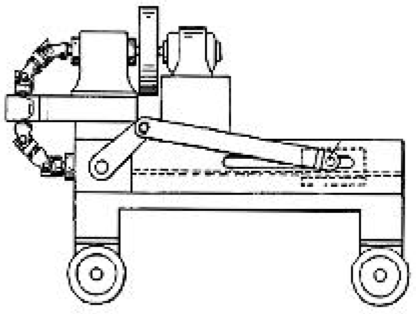

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Impulse Drive
Peppiatt, Alvin C., et al

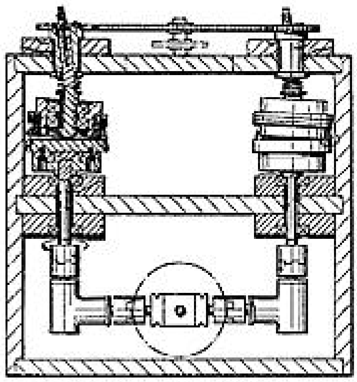

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Propulsion System
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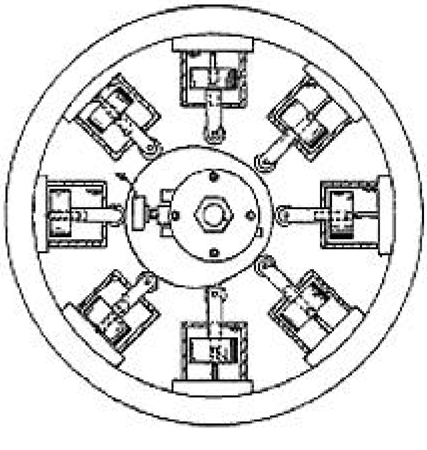

№4,579,011(3/1/86)
Propulsion Apparatus
Dobos, Elmer M.

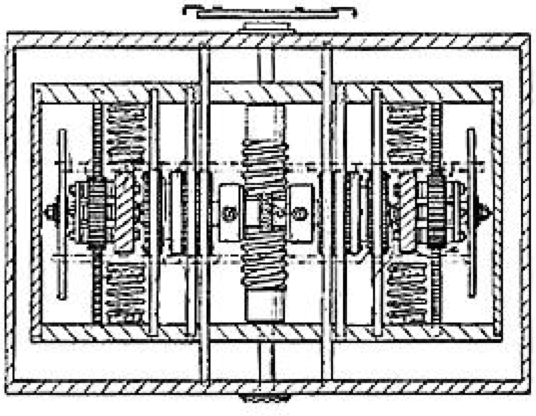

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Mechanical Propulsion System
Colla, Joseph.

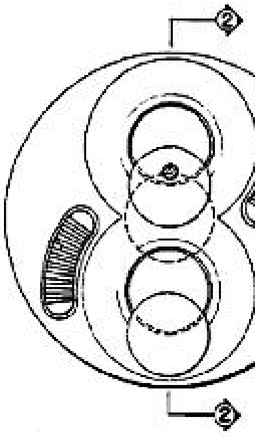

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Apparatus for
Developing a Propulsive
Force
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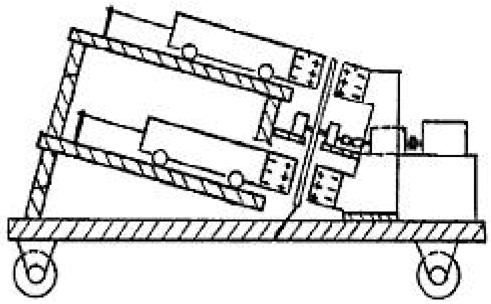

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Propulsion System
Mast, Oscar.

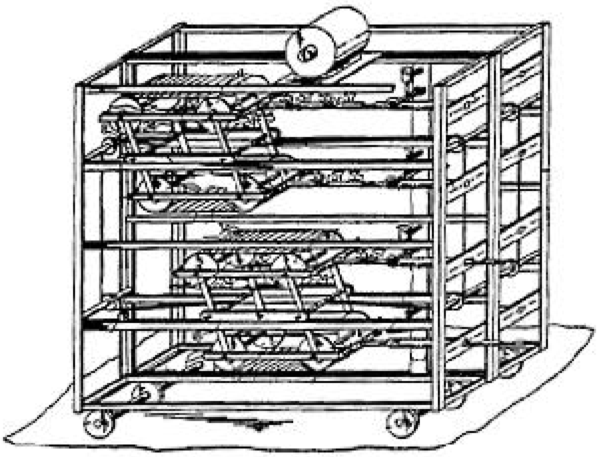

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Continuous Force & Impact
Generator
Melnick, Harry S.

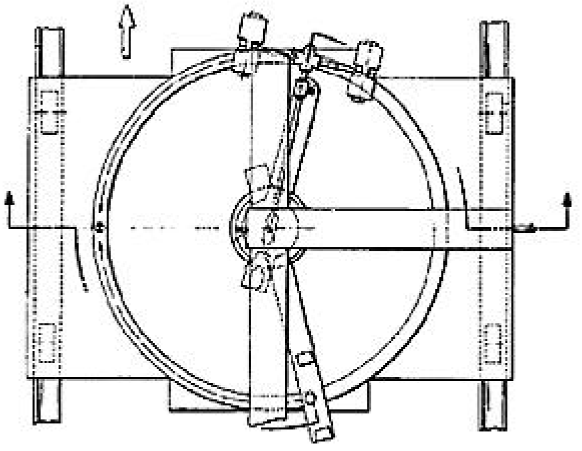

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Conversion of Centrifugal Force
to Linear Force &
Motion
Cook, Robert L.

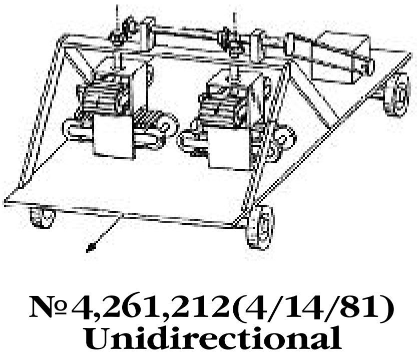

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Unidirectional
Force Generator
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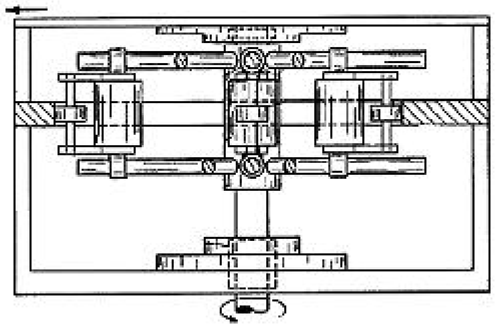

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Converting Rotary Motion
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Unidirectional Linear Motion
Cuff, Calvin I.

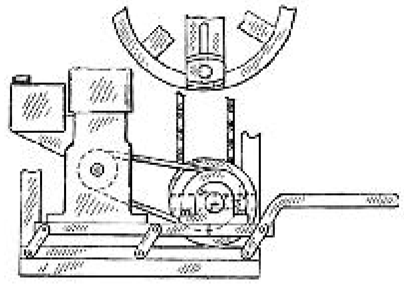

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Converting Rotary Motion
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a Rectilinear Force
Dehen, Frederick L.

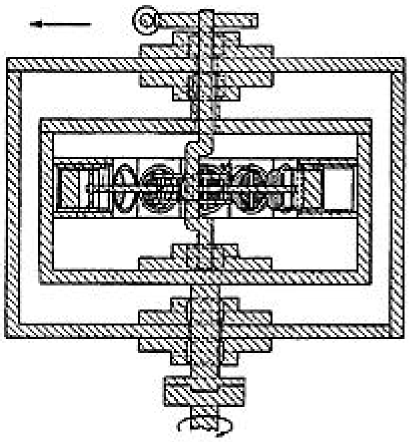

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Motion
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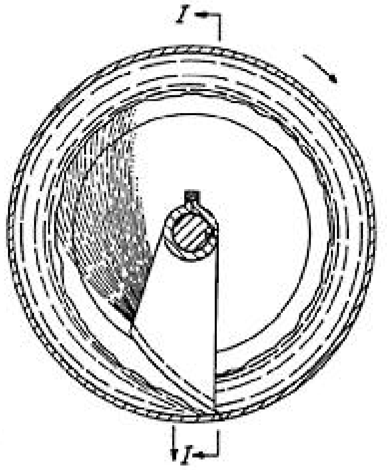

№ 3,979,961(9/14/76)
Propelling an Object by an
Unbalanced Centrifugal
Force...
Schnur, Nicolas J.

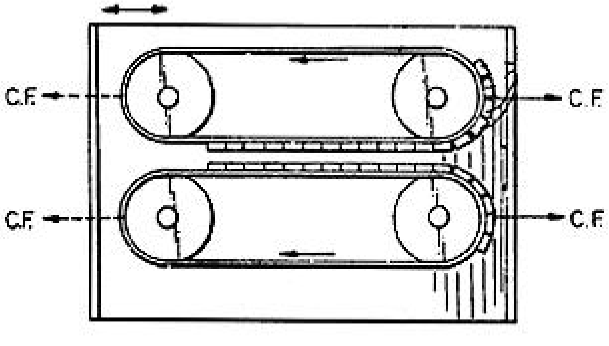

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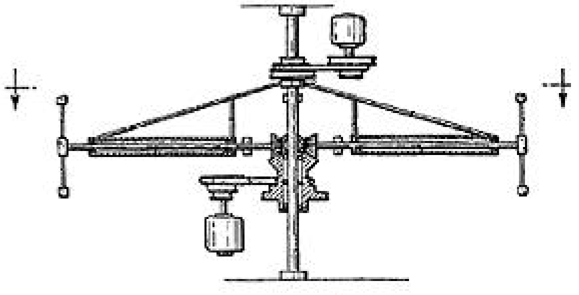

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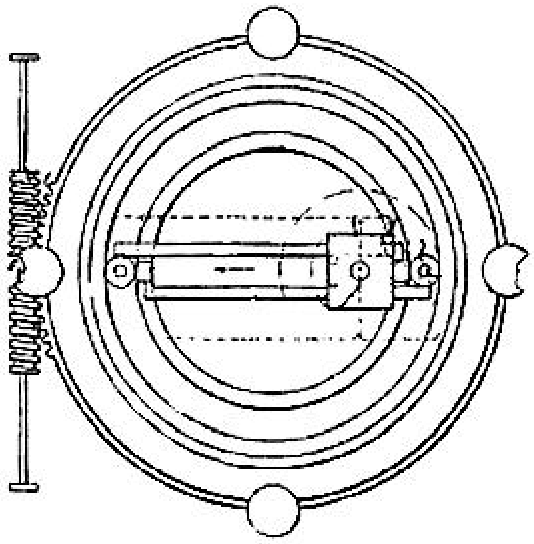

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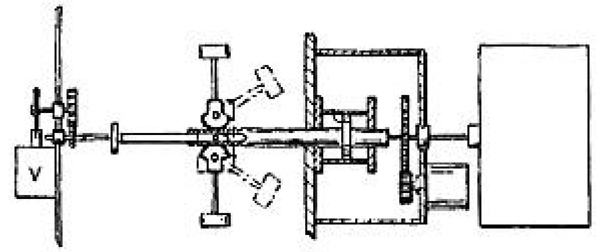

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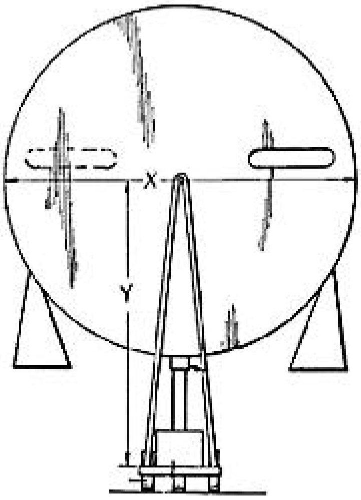

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Propulsion System
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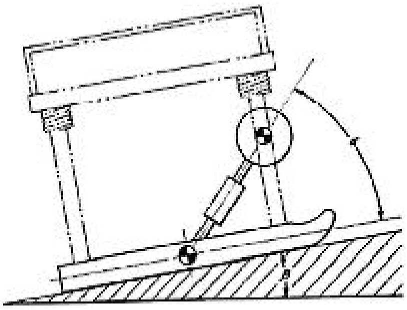

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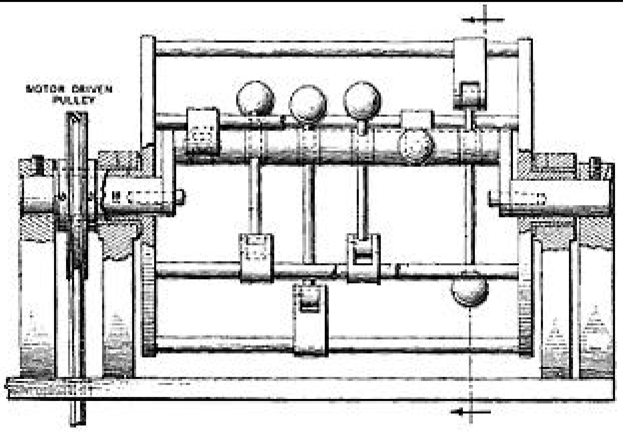

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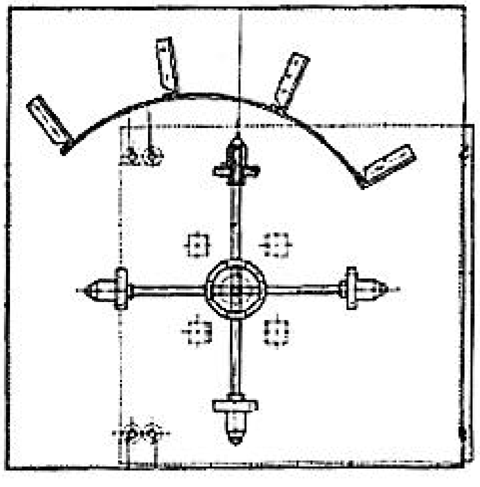

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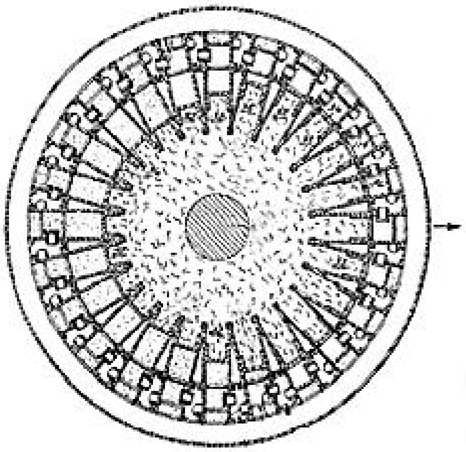

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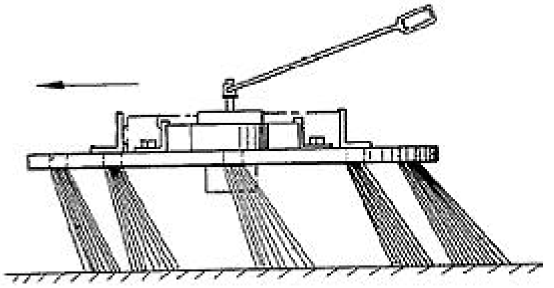

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Toy Vehicle Having...Self-Contained
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Rakestraw, Robert G.

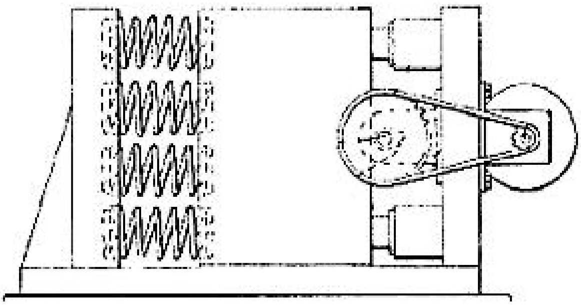

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Device
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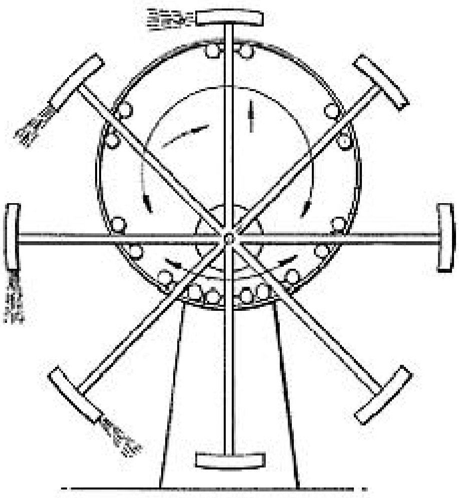

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Apparatus
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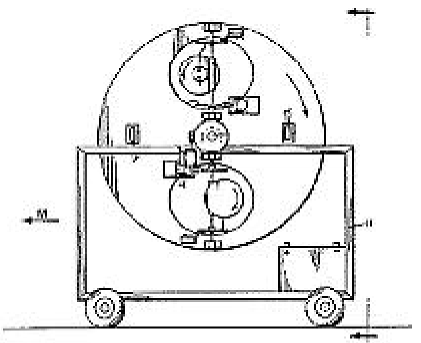

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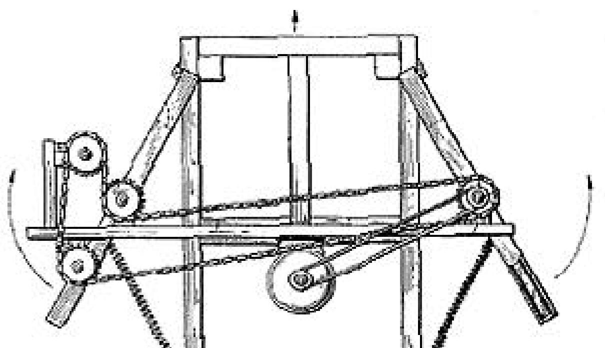

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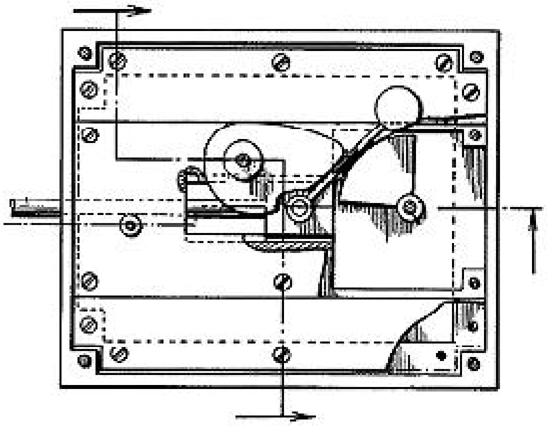

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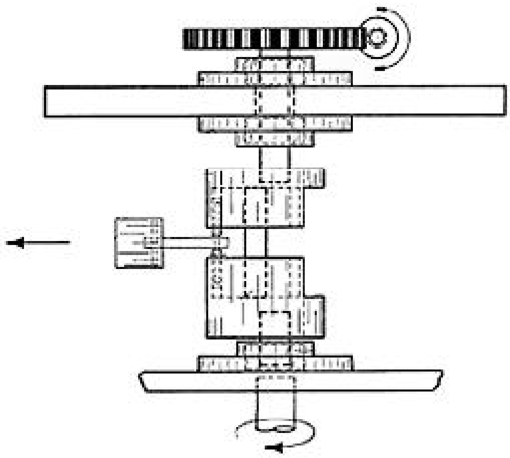

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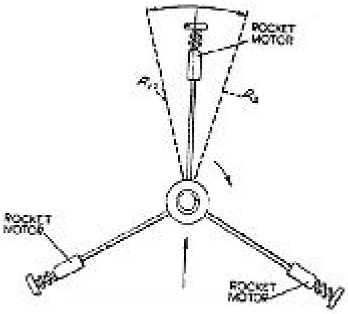

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Orbital
Propulsion
Apparatus
Knap, George.

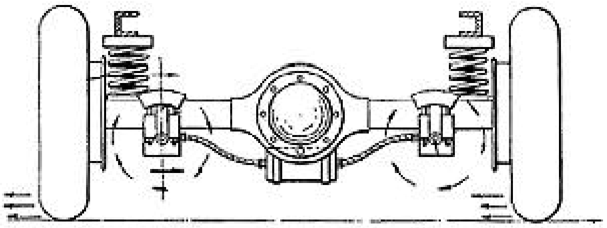

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Method & Device for Imparting
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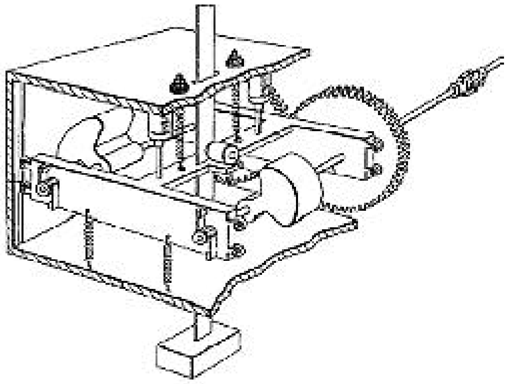

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System for
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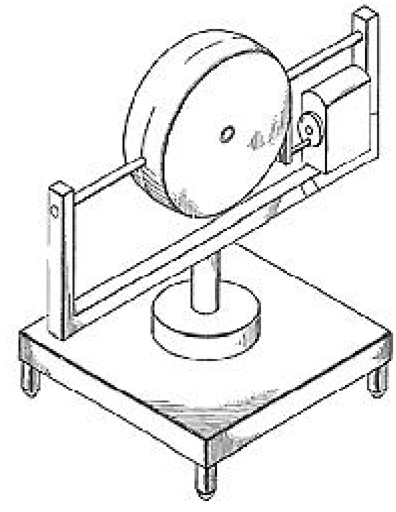

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Gyroscopic
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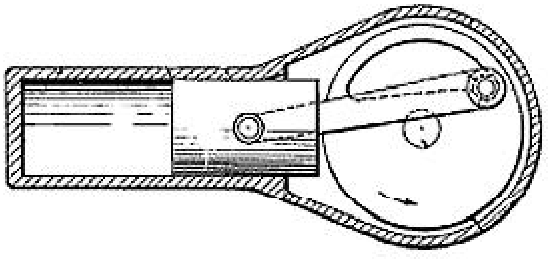

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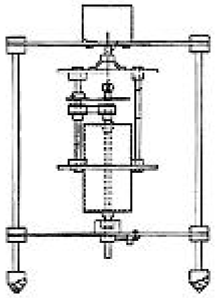

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Translational Force Generator
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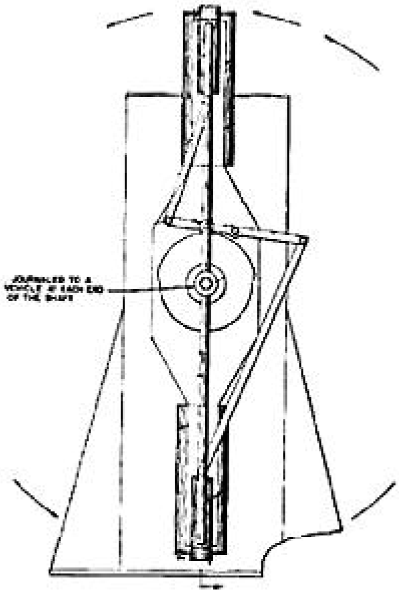
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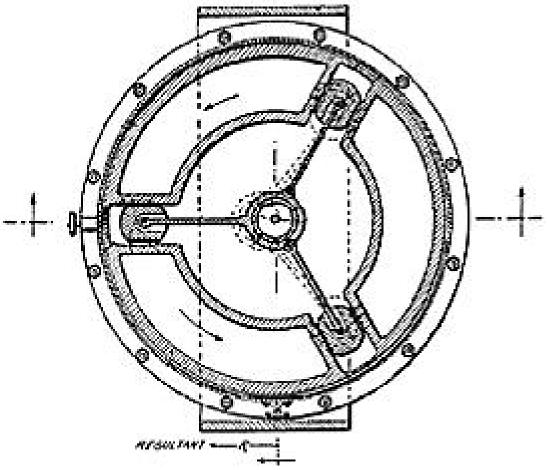

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Centrifugal Variable Thrust Mechanism
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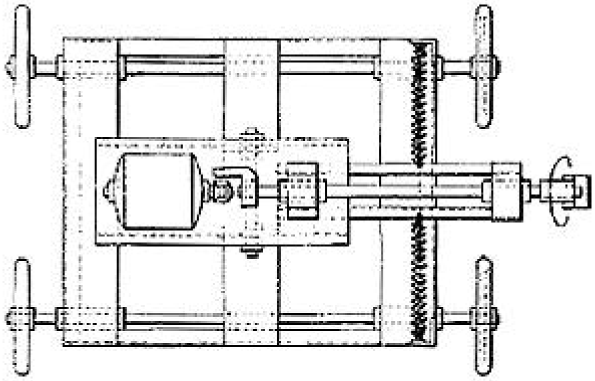

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Reaction Motor
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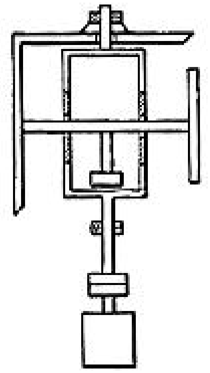

№ 3,404,854(10/8/68)
Apparatus for Imparting Motion to a Body
di Bella, Alfio.

The Free Energy Centrifugal Force Experiment

This experiment is conducted by Faraday Lab Ltd
in cooperation with V. I. Bogomolov

In the previous issue we wrote about the invention of Bogomolov V. I. The device shown in Fig.1 (and also on the cover) was constructed and tested in our laboratory.

Fig. 1
The Device

The simplified diagram is known as "Maxwell's Pendulum" (Fig.2). This is a disk set onto the horizontal axis with two attached strings. The upper ends of the strings are fixed to the crossbar.

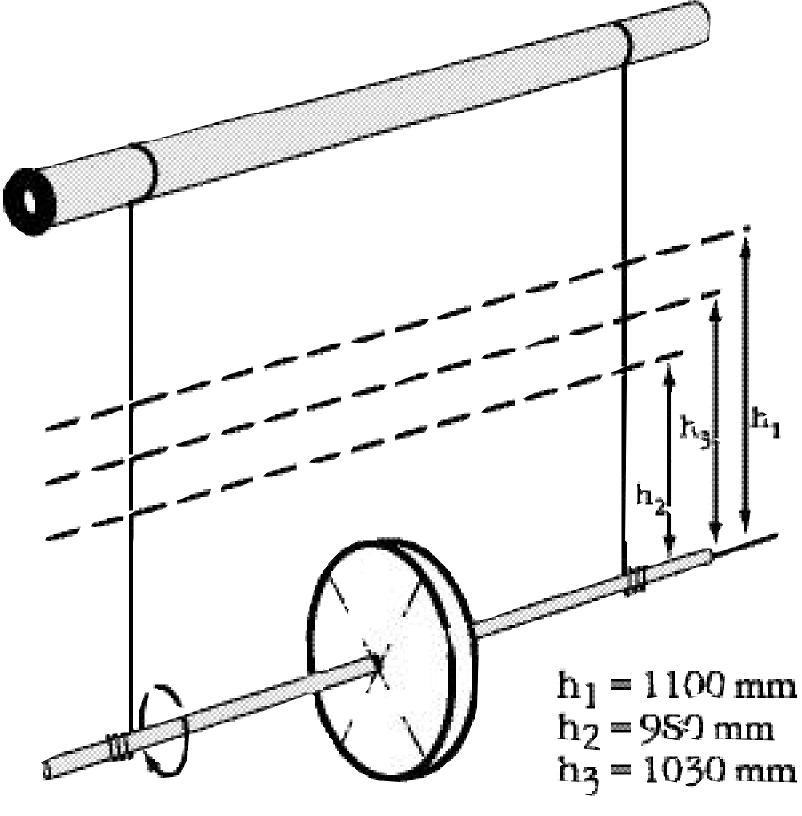

Fig. 2

If we wind the strings about the axis, the disk will lift (the height h) and store the potential energy of the Earth's gravitational field E = mgh (m - mass of the flywheel; g - free fall acceleration; h - the height of the mass fall). If we let the pendulum go, we can observe periodic "up-and-down" damped oscillations: first, the string spins and potential energy converts into rotation kinetic energy; upon reaching the lowest point the disk, still rotating, goes up using rotation kinetic energy and then converts it again into potential energy. This device is interesting: due to the energy conservation law we can observe the usage of rotation kinetic energy of the flywheel, measuring only the h-parameter, the lift height of the flywheel strings in the second semi-oscillation compared to the height with which the pendulum started falling in the first semi-oscillation, the difference h1 - h2 of the two semi-oscillations is directly proportional to the losses of rotation kinetic energy for air resistance work and friction.

We have made "Maxwell's Pendulum" more complicated by substituting the flywheel disk for the Watt centrifugal governor in accordance with its description in the article (1). The main difference of the device from Maxwell's flywheel is that the flywheel inertia momentum changes by the centrifugal force operation at the lever transferring of weights (the total weight - 1200 g) from the minimum radius position (40 mm) to the maximum radius position

(90 mm). At that, the levers compress the string with the force of about 16 N.

There have been three stages of the experiments. During the first stage we define the necessary lift height of 1100 mm at moment when the string winds around the axle. When the flywheel falls from this height, the rotation speed and centrifugal force are achieved, which move apart the loads to the maximum radius (90 mm) and which **completely compress the string**. During the second stage the loads are fixed at the minimum radius position (40 mm), thus the compress string centrifugal forces are not involved any more and we can measure the air resistance and friction **losses of kinetic energy**. At this stage the flywheel lifts up to 980 mm losing 120 mm. During the third final stage the load fixing rods are taken away and ***centrifugal forces are applied***. Just like during the second stage the Watt governor starts spin-falling from the height of 1100 mm. It compresses the string and lifts up to the height of 1030 mm thus **exceeding the second stage height by 50 mm**!

The experiment conclusions of the author:

1. At the third stage the flywheel exceeds the "loss height" h=980 mm. This means that the compression of the string was performed "for free".

2. At the third stage the flywheel converted kinetic energy into potential energy and lifted up 50 mm more. This means that in accordance with the principle of conservation of moment of momentum, the **outer compressed string energy force** has caused the moment of momentum change of the rotating masses, thus giving the additional acceleration to the flywheel and **increasing its kinetic energy "for free"**!

3. For the practical application of the Bogomolov generator in order to generate free energy it is necessary to achieve a high rotation speed (more than 10 000 rpm) and involve centrifugal forces to transfer the rotating mass to the less possible inertia radius difference.

The described centrifugal regulator diagram is not sufficient for larger experiments. For the industrial generator the author has a hydraulic-principle pneumatic string device drawing (know-how).

Editor: Also in this issue: the article on "Glen Gates Motor" by A. Akau. The principle is almost the same. The further implementation of this ideamay soon design purely mechanical power-generating systems, which use inertia and centrifugal forces.

References:

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Magnetic Power Inc. (MPI) is developing Self-Powered Generators. Together with its subsidiary, Room Temperature Superconductors Inc., (see the website www.ultraconductors.com), MPI has raised a total of more than $7 million from Angel investors to date.

Due to a pleasant surprise, solid-state electric power generators might be fabricated by modifying off-the-shelf utility hardware. If confirmed in coming weeks, this could result in serial fabrication by this time next year, since large devices of the type needed for conversion are presently manufactured worldwide.

Multiple modules may prove able to replace power plants. Smaller units appear practical for powering homes. Later, optimized designs might replace engines in every variety of vehicle. These generators may make possible very rapid utilization of fuel and pollution free electric power --a revolutionary, new, renewable energy alternative.

Accredited Angel investors can help speed the work needed to bridge into major capital, and accelerate this remarkable alternative. Multi-million dollar funding is on the horizon. Additional information is available privately. We welcome due diligence by qualified parties.

History of Perpetual Motion and Free Energy Machines

Web site http://www.phact.org/e/dennis4.html

Hundreds of people for centuries have attempted to solve the holy grail of energy production - **Perpetual Motion Machines**. Still to this day Eric Kreig gets weekly emails from people who feel they are about to get one working. Eric is very skeptical about free energy. But his collection of information is very interesting. Eric offered a special prize for those who will agree to publicly test their over-unity devices.

♦ **Villand de Honnecourt** 13th century had a drawing of one.

♦ **Leonardo da vinci** made a number of drawings of things he hoped would make energy for free.

♦ Jesuit priest, **Johanes Taisnerius** worked on a magnetic based perpetual motion machine.

♦ **Mimara** in 1518 designed a "self-blowing windmill".

♦ **John Dee** of 16th century reported seeing one - but wasn't allowed a closer look.

♦ **Cornelis Drebbel**, 1610, was an alchemist and magician supposedly made one.

♦ **Robert Fludd** 1630 proposed many machines -people were trying to patent variations of Fludd's device in the 1870's.

♦ **Edward Somerset** 1638 demonstrated many free energy water wheels to the king of France.

♦ **1635** - first of many English perpetual motion machine patents granted. - By 1903, 600 such patents had been granted. Free energy claimants love impressing people with patents.

♦ **Ulrich von Carnach** in 1664 in Germany designed a perpetual ball-moving machine.

♦ Scientist **Jean Bernoulli** (1667 - 1748) proposed a fluid energy machine.

♦ **Bockler** in 1686 made designs for self powered water mills.

♦ In 1712 **Johann Bessler aka Orffyreus** investigated 300 different perpetual motion models and claimed he had the secret of perpetual motion and got much investment money.

♦ **Dr Conradus Schiviers** in 1790 made a belt driven wheel.

♦ **Sir William Congreve** in 1827 tried a machine running on capillary action.

♦ Britisher **Henry Prince** 1866 described the first partially submerged perpetual motion machine.

♦ **Mark Zimara** of Italy had a huge air powered machine that never worked.

♦ **Horace Wickmam** of the USA got a patent to a machine with many balls that just rotate around.

♦ Austrian, **Alois Drasch** patented a machine in the US in 1868.

♦ German, **George Andreas Bockler** proposed 'self operating mills' using variants of Archimedes screws.

♦ **E. P. Willis** of Connecticut made money off a perpetual motion machine in 1870 - people eventually found out a secret source of power to it.

♦ **Charles Redheffer** in 1812 in **Philadelphia** made much money on a perpetual motion machine, tried to restrict scientific evaluation, but was eventually debunked.

♦ Scottish shoemaker **Spence** designed a magnetic based machine, which was debunked.

♦ **John Worrel Keely** of Philadelphia in 1872 (he also had a traveling show of exhibitions). He fooled many scientists with a machine, which appeared to run on water.

♦ **John Gamgee** in 1881 got considerable support for a machine very similar to Dennis Lee's, which used liquid ammonia - it got vaporized from heat readily available, thus expanding it would drive a piston. Gamgee thought the vapor would condense to liquid to start the cycle over again. The Navy appeared to have been fooled and showed it to president Garfield - it never went anywhere Tom Napier agrees that Dennis Lee may have resurrected Gamgee's engine.

♦ **J. M. Aldrich** was arrested for getting investors for his free energy machine in 1899 - he some how was able to avoid conviction and conned many investors. One of whom was finally able to inspect the machine found a hidden spring.

♦ **T.H. Moray** in the 20's demonstrated a "radiant energy device" to many people who were unable to find a hidden power source. Some how, the secret was said to have been forgotten.

♦ **Lester Hendershot** in 1928 got an Army commandant to endorse his free energy machine - but it was later found to have a hidden power source in the motor. His sons believe Lester lost his notes and that maybe they can rediscover how to get it to work.

♦ **Viktor Schauberger** claimed to have discovered some special vortex energy in water. Since he died in 1958, I don't know if his claims have been replicated, but people are still studying his works.

♦ **Mr Papf** in 1966 was a conspiracy believer alternative car engine got a few investors but killed someone during a demo. He tried to blame the problem on an investigating skeptic. He disappeared and became part of urban legend of scores of people, which the big conspiracy has been silencing for generations.

♦ **Guido Franch** was convicted of fraud in 1954 and 1973 of selling rights to distribute little green pills that would convert water into gas. He hid behind conspiracy theory and secrecy to avoid fair testing. A number of people have run this scam and many people still believe there are pill repressed by the oil companies.

♦ **Garabed T.K. Giragossian** in 1917 claimed to have a free energy machine. He was one of the early frauds to hide behind conspiracy theory. Woodrow Wilson signed a resolution offering him protection from some kind of conspiracy. After much fanfare, and delaying tactics his machine turned out to be a giant flywheel, which was charged up with energy slowly and put out a lot of energy for just a second. In spite of lack of proof of anything significant his followers still bothered the US congress for recognition.

♦ **Otis Carr** in 1958 sold stock for a company to manufacture UFO's and free energy machines from Oklahoma. He claimed inspiration from Tesla.

♦ **Edgar Cayce** even babbles about "Motor's with no Fuel".

♦ **McClintock** was claimed to use air as a fuel and had a patent.

♦ The **Evgray** machine scammed many investors (who didn't know how to test 'depleted' batteries).

♦ **Arnold Burke** in 1977 collected $800,000 of investor money (again, mostly from bible believing farmers) for a 'self acting pump'. He tried to hide behind religion. He called his device Jeremiah 33:3' Finally, an open test was done in 1979 and found a hidden source of electricity. His believers (with an infinite supply of denial) still raised $250,000 to get out of a fraud conviction. He still went on making lots of claims with no evidence.

♦ **Robert Adams** in 1977 made all kinds of conspiracy and OU claims in New Zealand. Many still believe in the Adams Motor. - He had the obligatory battles over patents, debates over theory, debates over power measurement and dabbling in other areas of alt physics. He's 80 years old and said to have a scientific education. He has a lot of theories about Aether. Skeptical information.

♦ **Robert Stewart** in 1978 got over $3,000,000 of investment money (much from farmers) for a closed cycle engine using freon rather than water. This 'engine' used the same scheme John Gamgee tried to sell the navy in 1882. -Eric Krieg thinks this is the same approach Dennis Lee's free energy machine works on. I think he just faded away (people claim he was silenced).

♦ **Rory Johnson** of Elgin Illinois, claimed to have invented a cold fusion, laser activated, magnetic motor that produced 525 HP, weighed 475 lbs, and would propel a large truck or bus 100,000 miles. After signing a number of dealers, he moved all his equipment out of his labs, moved to CA and died. (To this day, folks say he was silenced by OPEC).

♦ **RJeseph Maglich** was a physicist and claimed to have a device in 1978, which harnessed fusion power from seawater. They say they put power in and get more power out. I've never heard of them since.

♦ **Howard Johnson** got a patent for a device that claimed to make free energy from a motor like device. As of 11/02, Stephen was claiming he would soon mail out samples of working ones. By 12/12/02, Stephen dropped out of contact.

♦ **Keith Kenyon** had a device claimed to produce more energy than consumed. Calculations seemed to not take power factor (also known as phase angle) into account. It never openly had its output hooked up to its input. Even Dennis Lee tells his followers that all the *over unity motors* (claim to make more electricity than consumed) usually just fool people who can't measure power factor.

♦ **Muller:** Bill Muller and Carmen Muller of Germany raised money on an over unity motor and got a few followers, but never actually demonstrated one working.

♦ **Dennis Lee** Since 1988 has been promising to demonstrate free electricity "in a month or two". He is much like Newman in his mixture of religion & extremist politics, evasion of qualified investigators, endless promises, threatening detractors, etc. He had a Fischer engine, a CRD device and now, and OU motor device. Dennis has invested in Searle and Stanley Meyer and joined Pantone in 2001 in a 50 state tour.

♦ **Stanley Meyer** 1996 claimed to have a water powered car and was also big on mixing Christianity and patriot politics in with fringe science. Meyer was found guilty of fraud after his Water Fuel Cell was tested before an Ohio judge. It is rare for an inventor to be prosecuted for an invention that does not work, but Meyer's problem was that he had been selling "dealerships", offering investors the "right to do business" in Water Fuel Cell technology. Meyer refused to allow anyone else to measure his device. Dennis Lee invested in him. He died in early 1998.

♦ **Joseph Newman** in 1984 claimed to have a free energy machine based on alternative physics. Like many perpetual motion inventors, he sued the US patent office. Many people wrongly measured the true power output of this machine, (they didn't realize you must specially calculate power for non sinusoidal current consumption). He now refuses to ship a unit for testing. Ten years ago, inventor Joseph Newman gave an open week-long demonstration in the Super dome in New Orleans. Over 9,000 people attended from across the country (including Dennis Lee who reportedly wanted to join his ideas with Newman). Newman is suing some former investors he claims are trying to steal his invention. I give more information. Evan Soule of Newman's organization offers a rebuttal.

♦ **Bruce De Palma** had a machine in 1986, which appeared to one Electrical Engineering professor to put out 4 times more power than consumed. Turned out it was just a measurement error. (We could go on and on with such examples).

♦ **Dr. Potapov** sold a device that was claimed to produce more energy than consumed.

Editor: Eric's skeptical remarks can be tolerated but sometimes he writes about the things he does not know. Potapov and his team have created a technology, which have been replicated and sold by dozens of companies in Russia (see the cover picture of the Susorov heat generator). There are several devices in St. Petersburg to be tested. The efficiency is 200 % and more. The operation principle: electric motor rotates in water and causes the heating of water. We have also received the information about another Russian invention, namely the close cycle vortex generator: "water rotation – vapour – turbine – electric power " (the power is from 100 kW).

Alexander V. Frolov

♦ **John Bedini** claims to have a free energy device.

♦ **Mr. Finsrud** is a Norwegian artist who made a sculpture where a metal ball moves for weeks apparently with no outside influence.

♦ **Don Watts** of Las Vegas in around 1990 had a patented **CEACU**, which stands for Centrifugal Energy Amplification and Conversion Unit - it turned out to be one more investment fraud.

♦ **Stephan Marinov** claimed to have proven much alternative physics and to have contacted a Methernitha that claims to have a Free Energy Machine. He committed suicide on July 15, 1997 but he left behind some intense rants.

♦ **Greg Watson** sold kits for a rolling ball and track that were thought to have over unity in 1997. Attempts of replication I know of have failed.

♦ **CETI** These people have claimed to have a device that puts out anomalous yet small amounts of heat - maybe cold fusion. They raised millions. As of 10/97, they have not been willing to have me come over and see for myself. They have said, *we want people to think it doesn't work so we won't have competition.* I've wondered if the energy may have come from not accounting for friction effects from the cooling flow through the pellets. (**Jed Rothwell**, a rational editor of Infinite Energy Magazine says "*however, tests with CETI cells at Motorola, SRI and the French Atomic Energy Commission show no measurable friction*"). Milton Rothman has a response: "I openly admit that I have not followed all the history of cold fusion claims and am generally ignorant on the subject".

♦ In January 1998 **Barbara Hickox** allegedly has a patent dating from 1981 for a fusion powered free energy system.

♦ **Paramahamsa Tewari** of India claims to have a device that is 200% efficient.

♦ **RQM** is a Swiss company selling FE machines found at www.rqm.ch.

♦ **Ted King** is looking for people to buy stock for a car he plans to drive across the country using just 2 12-volt batteries. You can contact Ted if you want to buy shares.

♦ **Bruce Perreault** has claimed to have discovered a new element, the plasmatron, ion pump, radiant energy device, etc.

♦ **Daniel Pomerleau** of Canada claims to have something that works, but he isn't interested in releasing it (as 12/97).

♦ **Entropy Systems** of Ohio 1999 Sanjay Amin got 1.6 million investment dollars for a device that would violate the 2nd law of thermodynamics. I've asked them to apply for my prize for proof. - They seem to have folded. See a rational review of Amin's claims.

♦ **Brian Collin** of Australia claims revelation from God *(like most of these people)* to make a free energy device. A Stephen Mark claimed he invented it.

♦ **Kawai** and **Takahashi** - both of Japan claimed in the 90's to have overunity devices.

♦ **Carl Cella** claimed to have one of the many cars said to run on water.

♦ **Robert LeBreton** in 1999 claimed to be making a 600 hp free energy machine.

♦ **Renzo Boscolio** in 1999 in Italy claimed to have low-energy nuclear reactions but refused to supply real proof that he promised to people who came out from Infinite Energy Magazine.

♦ **Doug Konzen** of Seattle says he has an overunity motor in Jan of 2000 that anyone can see.

♦ **Troy Reed** of Oklahoma was ready to issue licenses for manufacturing his permanent magnet motor etc. He's taking investment money for a device he claims puts out more heat energy than input energy. He says he's dumped a few million into his designs over the last 10 years and had little interest in my prize offer when I contacted him in 2001.

♦ **Kipper Motor.** In 10/00, Steve Elswick thought it was overunity. But David Sligar who paid $175 for plans could not get it working.

♦ **Ludwig Brits and Victor Christie** in 2001, claim the **Lutec** free electricity over unity motor/generator will soon be in Australia.

♦ **Jasker** in 2002, an Irish company has claimed to have free electricity. (Some have said it is just a joke).

♦ **Confidential Technology -Wayne Cochran** died 12/29/02 Crazy Jack Carey took over. They have been promising FE soon for about 20 years now.

♦ **Tom Bearden's MEG device:** many articles on the Internet.

♦ **Gurbakhsh Singh Mann of India** claims to have invented gravity and buoyancy perpetual motion machines.

♦ **Michael J. Marshall** in Las Vegas has a device called QSFG , which stands for quick start fuel-less generator he says 64 nations have asked him to build factories.

♦ **Carl Tilley and Robert Kibbey** in 6/2001 in Tennessee have claimed some over unity device and other stuff. Their demonstration failed in 9/02 and as of 11/02, they have been evading proper demonstrations.

♦ **Stephen Walker** in 9/2002 promised to send me and several others a free energy machine in mail.

♦ **PerEnDev** promised to make some kind of free energy by means of magnets.

♦ **Bill Muller** of Canada in 2003 claimed to have some kind of OU device. Independent tests found it under unity.

♦ **Energie:** In 2003 this Greek company promised a homopolar magnet (De Palma design) FE design by June of 2003. They actively seek investors.

♦ **GWE Genesis World Energy** In 2002 this group claimed to have 400 people who developed some device that sounds like it separates water into H2 and O2 using less energy than mainstream science says is possible. As of 2003, they have evaded independent confirmation. More information is available.

♦ **Steven Greer (Disclosure Project)** In 02.2003, Steven announced he had discovered some real sources of Free energy, which he promised to make sure get proven to the general public.

Tesla Energy Science Conference and Exposition

1220 L Street NW, Suite 100-232 Washington DC 20005
Tel: 800-295-7674
Fax: 301-513-5728
www.IntegrityResearchInstitute.org
Email: iri@erols.com

Saturday, November 8, 2003

Wireless Electricity Seminar

9:30 AM 10:15 AM

Opening Address: “Space Solar Power” – Dr. **Paul Werbos** Program Director, National Science Foundation

10:15 AM 12:15 PM

Special 2-Hour Presentation: “Nicola Tesla and the development of RF Power Systems” - Dr. **James Corum**, Physics Professor, research Scientist and Inventor and **Kenneth Corum**, Physicist, teacher, consultant.

2:00 Pm 3:00 PM

“Power Engineering Scalar Field Theory: Faraday vs. Maxwell and Longitudinal Wave Demonstration” – Professor **Konstantin Meyl**, Engineer, Author, Inventor of the Demo-Set, Professor at the University of Berlin

3:15 PM 4:15 PM

“Wireless Energy Through the Earth-lonosphere Cavity” – Dr. **Elizabeth Rauscher,** Nuclear and Astrophysicist, Inventor of the ELF Earthquake Predictor and Triangulator.

4:15 PM 5:15 PM

“Masters of the lonosphere HAARP Modifies the Polar Electrojet” – **BBC Video on Tesla Technology**, with Wiliam Terbo, demonstrating ionospheric excitation by radio waves.

6:30 PM 7:15 PM

Masters of the Ionosphere – BBC Video Presentation **repeated** for the Special Tesla Evening Event attendees

7:30 PM 8:30 PM

“The Wardenclyffe Dream: Tesla’s Plan for Wireless Worldwide Distribution” – **Dr. Marc Seifer** Professor, Author of the best-selling book *Wizard, The Life and Times of Nikola Tesla*, presents an illustrated historical account.

8:30 PM 9:00 PM

High Voltage Tesla Coil Demo – **High Voltage Device** with **Music**: The Tesla Tower wind ensemble composition by Prof. **Holland**, Skidmore College

Sunday November 9, 2003

Electrotherapeutic and Tesla History Day

9:30 AM – 10:30 AM

“A Family Perspective on the Personality of Nikola Tesla. Review of the Popular Interest in this Scientific Icon” with Q and A Session – **William Terbo**, Engineer, Closest living relative of Tesla (Grand-nephew). Founder and Director of the Tesla Memorial Society.

10:30 AM 11:30 AM

“The Search for Free Energy: Genius, Vision and Psychology of Invention” – **Keith Tutt**, British Writer and Author of the book *The Scientist, The Madman, The Thief and their Lightbulb* that includes Tesla.

11:30 AM 12:15 PM

“Electrotherapy with Tesla Coil Design: Intorduction to Bioelectromagnetics” – Dr. **Thomas Valone** Physicist, Professional Engineer, Author of the new book, Bioeletromagnetic Healing: A rational for its Use.

12:15 PM 1:00 PM

Exhibitors Presentations – **Brief Presentations by exhibitors** (5-10 minutes each)

2:00 PM-3:00 PM

“Emerging Opportunity: cancer Electromagnetic Frequency Therapy” – Dr. **Mark Neveu** President, the National Foundation for Alternative medicine.

3:00 PM 4:00 PM

“Turn of the Century Electrotherapy Discoveries” – **Jefrey Behay** Director, The Turn of the Century Electrotherapy Museum.

4:00 PM 5:00 PM

“How a Crushed Leg Helped Me Discover High Voltage Electromagnetic Healing Device” – **Ralph Suddath**, Third generation Tesla Electrotheraphy Inventor, radio Host, Entrepreneur.

5:00 PM 5:15 PM

Closing Remarks – **Thomas Valone** Program Coordinator

The Conference Report Compilation can be purchased from T. Valone, Integrity Research Institute.

“Nornikel” and Alternative Energy

“Norilsky Nikel”, the largest Russian non-ferrous metal producing company has announced the beginning of the cooperation with the Russian Academy of Science. Metallurgists are planning to invest into the development of the hydrogen energy and fuel cell R&D projects of the Russian Academy of Sciences. Accordingly, last week an agreement was signed. **Mikhail Prohorov**, the General Director of “Nornikel” said that they are ready to invest 20-40 million dollars annually into R&D projects of the Academy in this field.

“Expert” magazine, # 43, November 17-23, 2003

PERENDEV Magnetic Motor

Review

www.perendev.co.za/products/magnetic_motor/index.html

Shown below is a Magnetic Motor with Alternator (Patent Pending):

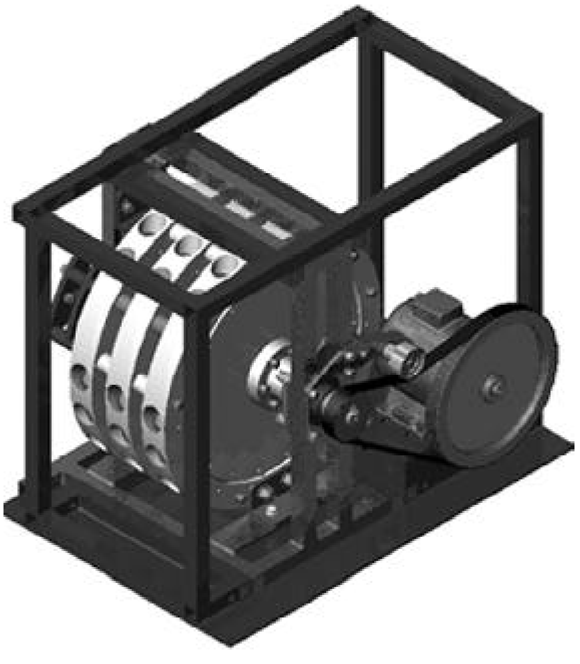

Fig.1

This is the "PerEnDev" (Perpetuum Energy Devices) company latest motor predicted to deliver some 60 kW. Motors can be built up to 4 mW.

Background of the Magnetic Motor

The Company started in 1969 with the development of a magnetic motor to drive an alternator to produce electricity. The concept was sound but the problem they faced was that the magnets that were available at the time (ferrite magnets) were not very powerful. The unit ran but had very little power and the project was abandoned.

In 1996 the "Perendev" company started to investigate the possibility of reviving the original idea, magnets had now come a long way and were very powerful (rare earth).

Fig. 2
Rare earth magnets

After the engineers successfully designed a new model, the company developed a 3 rotor system producing 6 kW, coupling this to an alternator through an 11:1 gearbox to produce electricity in 220volt and 380volt, single or 3 phase.

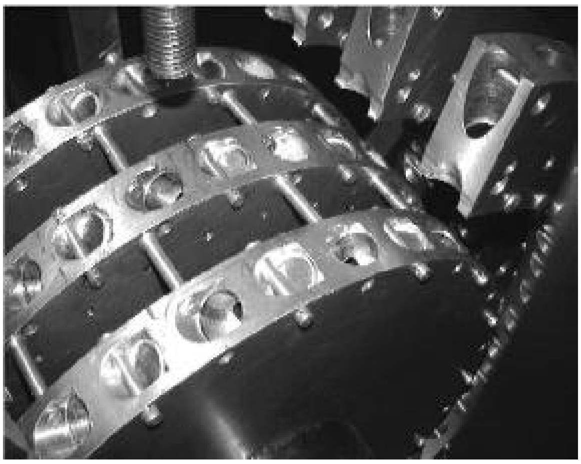

Fig.3

The units will be ideal for the small and large user, such as emergency, military, farms, plots, industrial and large users... in fact any application requiring power.

Key Benefits Foreseen:

- No fuel costs
- Constant running
- Reliable
- Cost Effective
- Portable (6kw-120Kw)

Editor: In 2002 "Faraday Lab" got an offer from the company to buy their 6 kW generator for testing at the price of about $6,000. However, no contract was signed. The company is currently engaged in redesign of their motors and is looking for regional partners but they are not yet ready to produce on the line. In our issues we will try to inform the readers on their activities. Alexander V. Frolov

Internet Pages

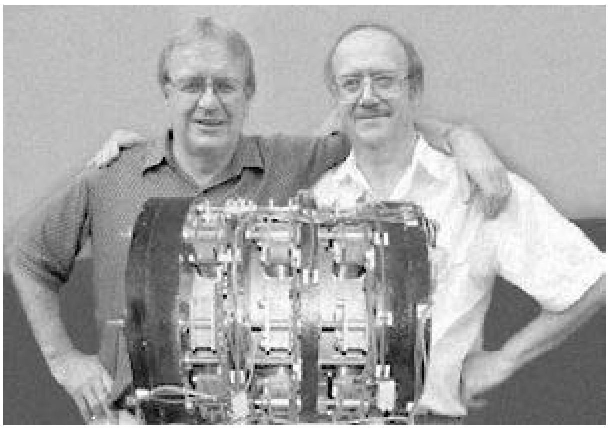

Lutec 1000

Jasker Power System

Electric Radial Motor

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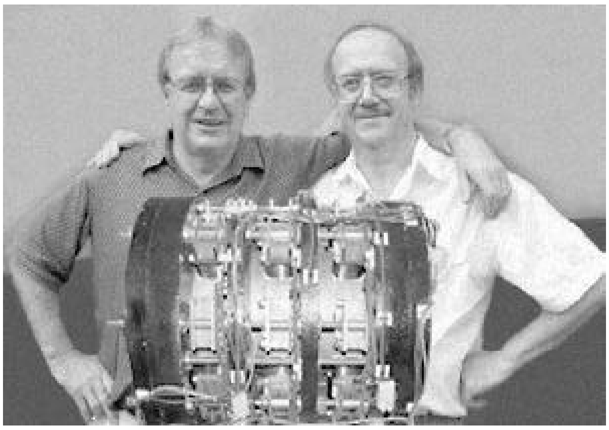

Lutec 1000

Electric Radial Motor

18 Meter Perpetual Wheel

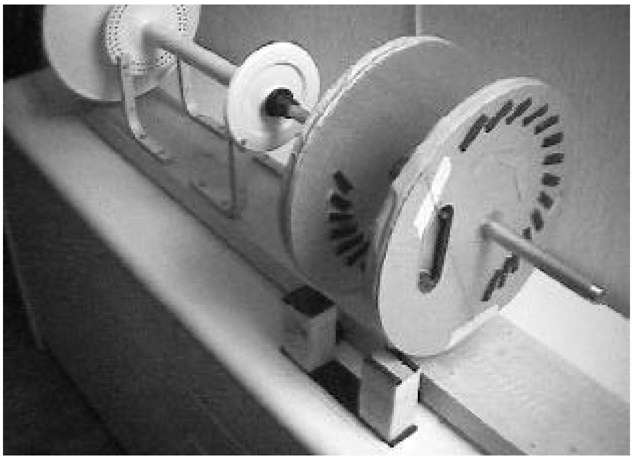

Minato Wheel, E. Vogel, Sweden

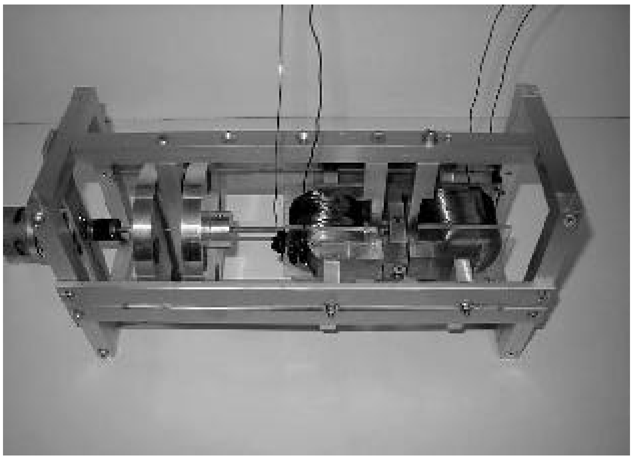

Generator from James W. German

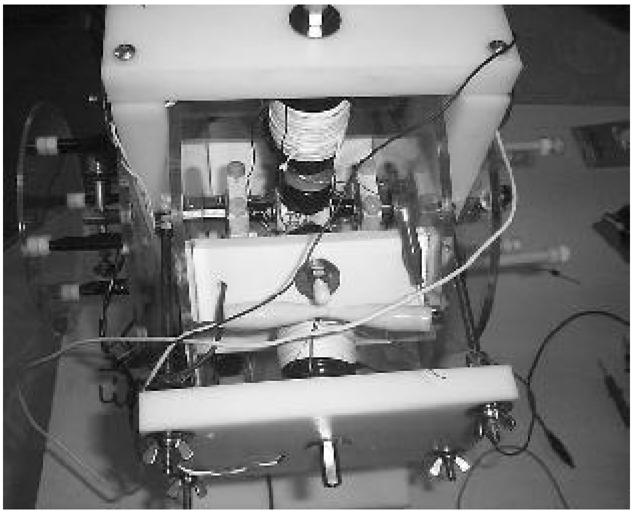

Konzen
Pluse Motor

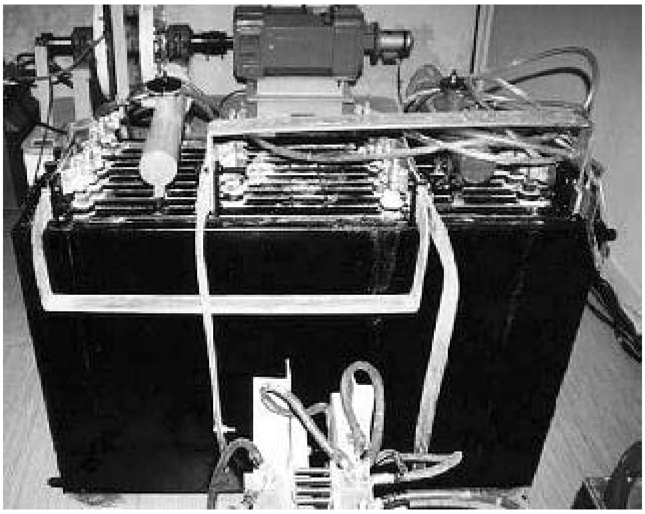

200-300 percent over-unity energy Space
Power Generator

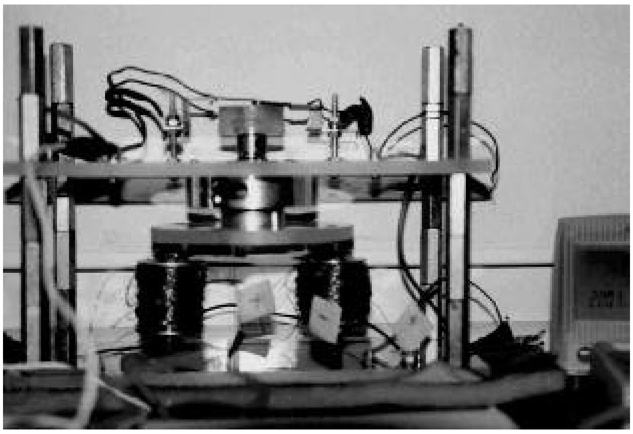

Adams Motor, Robert Adams

The RotoVerter

Bendini Pulse Motor

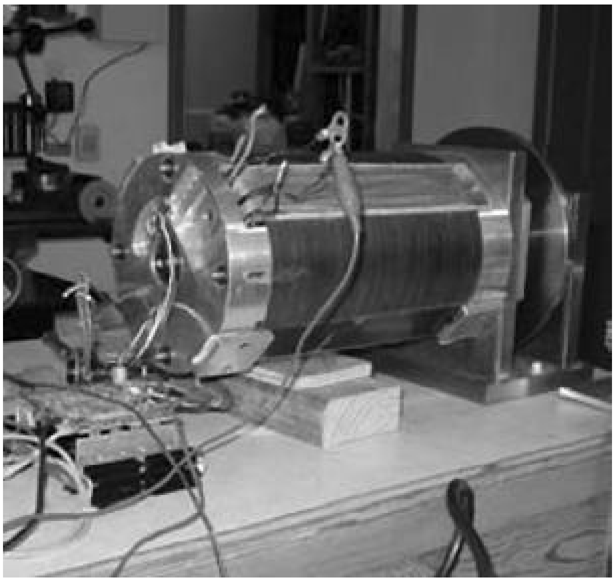

Motor based on Flynn Technology

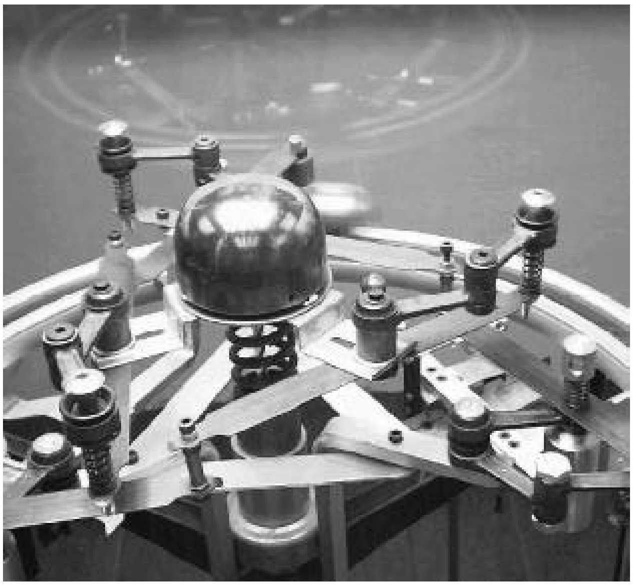

Finsrud Device

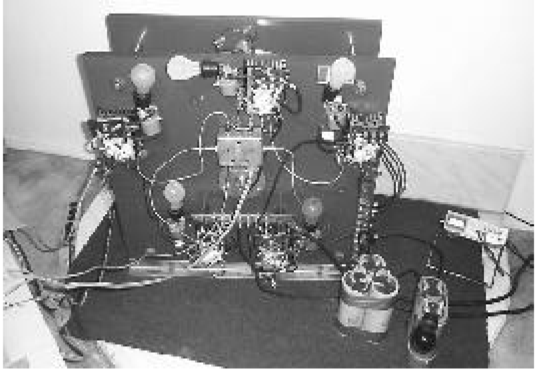

The Muller Unit

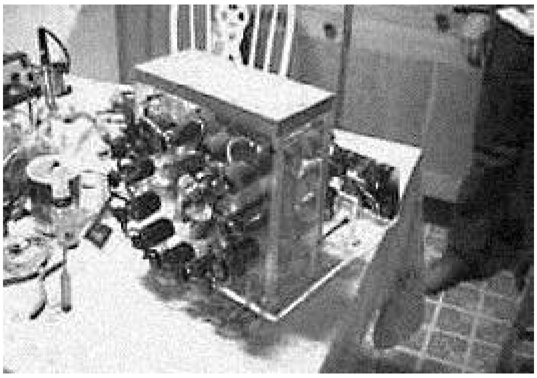

Alte Olsen Generator

Vladimir Matveev's Electrical Generator

Entirely New Kind Of Generator Invented!

(1-26-2003) TASHKENT, Uzbekistan (UPI) – An Uzbek inventor said he has created a type of electrical generator that does not rely on the principle of electromagnetic induction – on which all existing generators are based.

The new generator employs a concept called **magnetic conductivity modulation** and it has potential applications in industry, communications, households and even the military, explained Vladimir Matveev, the inventor, a specialist in electronics.

Matveev said he is convinced he has created a fundamentally different machine.

"All electrical machines I know are based on the principle of interaction between the magnetic fluxes (lines of force) of their rotor (rotating member) and stator (portion that remains fixed)," he explained.

Such machines, Matveev said, are based on electromagnetic induction, a property of energy discovered by Michael Faraday, an English physicist and chemist, in the 19th century. The machines produce electrical current either by moving a conductor across a magnetic field or by regulating the flux of that field.

"My machine has a principal difference," Matveev told United Press International. "The magnetic field of its stator does not interact with the magnetic field of the rotor (because) its rotor is not a magnet – the rotor only changes the magnetic resistance of the stator," he said.

The stator in Matveev's generator contains a magnetic core with a permanent magnet and a detachable winding. A rotor with changeable magnetic resistance is placed at a cutoff point in the core's magnetic field. It is composed of alternating magnetic and air parts and can operate in either linear or rotary form.

When the rotor is set in motion, its alternating components pass through the magnetic core's cutoff point. When the magnetic part passes through the cutoff point its magnetic resistance decreases. When the air part passes through, its resistance increases.

This pulsing of resistance results in changing the magnetic conductivity of the magnetic core, which in turn produces an alternating electrical current in the core's winding. The frequency of the winding's current can be controlled by regulating the rotor's speed or by changing certain qualities of its magnetic or air parts. Also, the generator's electrical

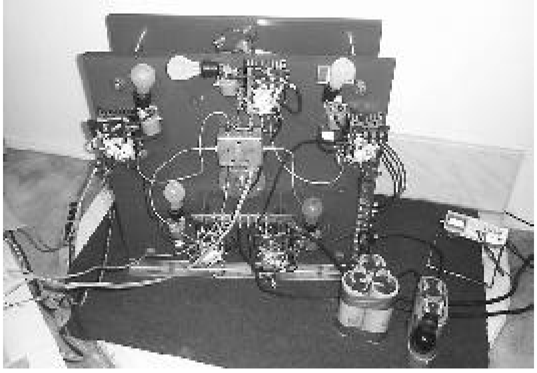

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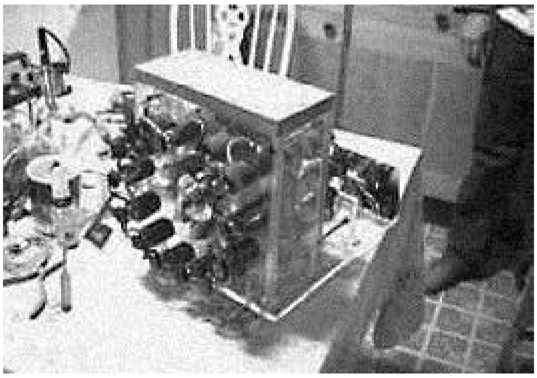

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This pulsing of resistance results in changing the magnetic conductivity of the magnetic core, which in turn produces an alternating electrical current in the core's winding. The frequency of the winding's current can be controlled by regulating the rotor's speed or by changing certain qualities of its magnetic or air parts. Also, the generator's electrical output – its voltage – can be controlled by changing the configuration of the rotor's components, Matveev explained.

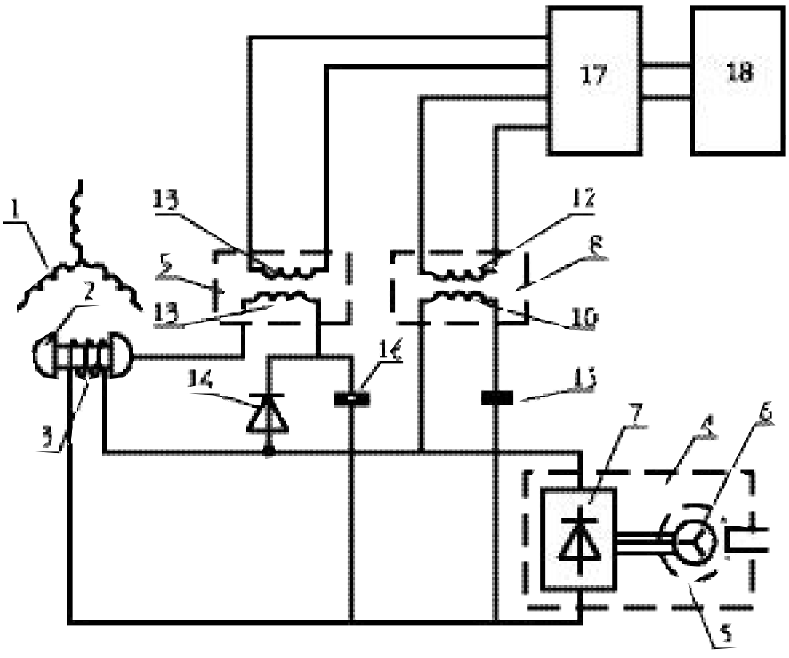

Electrical machine assembly -
FEDORO V F 1996.10.10 1996RU-119822
(1998.09.27) G01R 31/34, 31/02

Addnl.Data: VOROBEI V K MATVEEV V A

NOVELTY - Device has electrical machine, non-brush field exciter with diode rectifier, two dynamics double-winding transformers, which primary windings are located on rotor and secondary windings on stator. One end of primary winding of second transformer is connected to rotor housing; another end is connected to common point of conductor which is connected between capacitor and cathode of semiconductor diode, which other terminals are connected to direct current terminals of diode rectifier. Semiconductor diode is connected to cathode group of rectifier; capacitor is connected to anode group. Secondary windings of transformers are connected to actuating member through generator of signal, which is proportional to resistance of insulation in excitation winding circuit.

USE - Electric power production

Matveev said his generator is different from an invention by Howard Johnson of the United States. Johnson discovered how to build motors that can run without input of electricity or any other kind of external energy. He obtained a patent in 1973 for describing electrical generation using only the energy contained in the atoms of permanent magnets.

Matveev also said some Russian inventors have experimented with a generator similar to his. Their generator changes its magnetic conductivity by changing temperature. However, the machine requires a lot of time to be heated and cooled alternately and results in a current frequency much lower than what generally is used in industry. Moreover, the Russian generator requires high steel density and greater mass.

Matveev's machine generates electric energy of industrial frequency. Furthermore, he said his machine is simple, reliable and requires less steel and mass than conventional generators. It also can be adapted to flows of low speeds, such as weak water or wind streams. Matveev tested the generator in his former household in Kazakhstan before he patented it in Uzbekistan.

"I want to pass the invention on to all mankind," he said.

Boris Abdurakhmanov, director of the Uzbek Koinot (Cosmos) design office and head of the laboratory of semiconductors and photoelectricity of the Institute of Electronics of the Uzbek Academy of Sciences, told UPI: "Matveev has offered a fundamentally new approach to a problem of the creation of electric power generators."

Utilization of the Gravity Force in Power Engineering

Editor: In the previous issue we made a review of Mikhail Smeretchanski's invention "Perpetual motor with magnetic control elements" (# 4, 2003). This invention was patented; shown below are some pages from the patent itself. You can contact the author by e-mail: smeretchanski.mikhail@wanadoo.fr, or the postal address: 13 av. Rochambeau 3800 GRENOBLE FRANCE

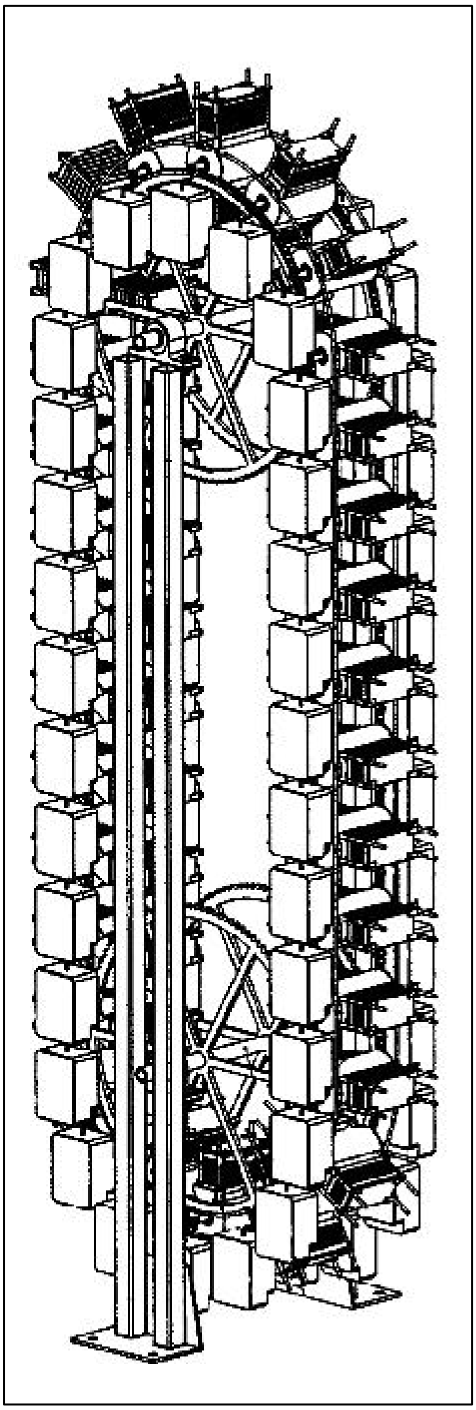

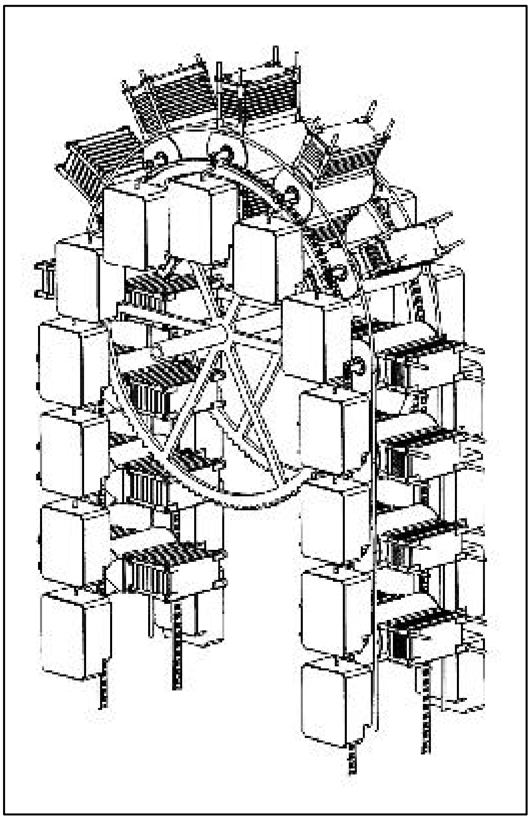

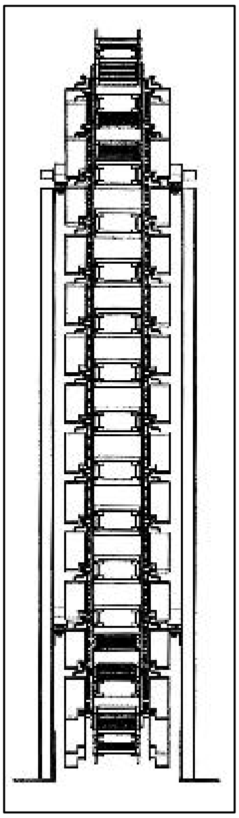

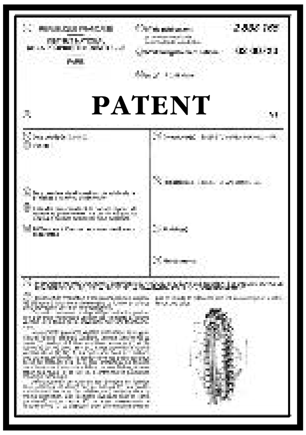

PATENT

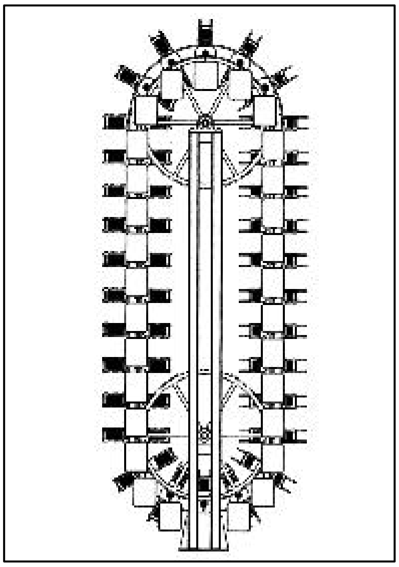

The Most Interesting Articles - 2003

In the year 2003 we have published more than 120 articles, mainly on the alternative energy, new propulsion principles and the development of ether dynamics.

"Cold fusion", low energy nuclear reactions (LENR) and highly-efficient electrolysis were represented by the works of Professor Kanarev, E. Storms, P. Hagelstein, T. Chubb and E. Cartlidge.

Almost every "New Energy" issue features articles on highly-efficient permanent magnet motor or generator experiments or patents of the kind. The articles by T. Valone, E. Vogel, A. Akau, T. Hardwood, A. Francouer and S. Abramov are of great value for engineers and researchers in this field.

The interesting articles by M. Filo, R. Koontz and V. Bogomolov reveal several principles of designing and building purely mechanical energy generating systems. All these systems possess one common feature: namely, the fact that a substance (a solid or fluid working mass) is accelerated in the gravitational field or in the centrifugal force field. The design characteristics of the system make it possible to obtain free energy.

We have published several articles by S. Gerasimov and his colleagues on the reaction-less propulsion device experiments. We hope that in the future we will keep in touch with these researchers.

The article by D. Reed on the new physics development concepts is worth mentioning too. The article by E. Sorokodum on new energy sources and the article by V. Chernobrov on the research into the active properties of time are of no less importance.

A. Egorov's article on the ball lightning makes it possible to form a number of experimental approaches to the problem of creation multi-purpose stable plasma objects.

Electrogravity questions, water-powered vehicles, longitudinal electromagnetic wave technologies, the Searl effect commercialization, capillary engines, resonance high-efficiency power-engineering, single-wire power lines, heat pumps and other similar research works were presented to our readers in the year 2003. We have minimized theoretical articles and we hope that the magazine has become more interesting and useful for the new energy practice development.

Alexander Frolov
St. Petersburg, Russia

There is interesting newsgroup of the site: http://www.overunity.com, Stefan Hartmann, email: harti@harti.com

Stefan Hartmann writes: This is the answer I got from Finsrud; it seems that the film they have done about him will be shown [on Discovery Channel] in 2004 when [if] I interpret this norwegian text right...

Subject: Documentary Film
Reidar Finsrud,

Dear Sir,

The Australian Broadcasting Company together with The Discovery Channel, have funded my company to make a documentary film entitled 'A Machine To Die For', the story of Perpetual Motion and the search for 'Free Energy'.
I have read extensively about your Perpetual Motion sculpture and we would be interested in traveling from Australia to Norway in order to film this now famous piece of work. At the same time we would request an interview with yourself.
If you are in agreement with this it is our intention to be in Norway on the 10th and 11th of July 2003. This documentary will be released worldwide and should produce considerable interest in your Gallery.

Mark Eliot
Catherine Jarvis and Mark Eliot
Romany Mill Studios

Hydrogenics Secures $3 Million from Japan Auto Makers

Letter from RemyC remyc@prodigy.net
Contacts: investors@ hydrogenics.com

Hydrogenics Secures $3 Million in Test Equipment Orders Japanese Auto Makers Select Greenlight Power for Fuel Cell Testing Equipment

TORONTO, Sept. 30 – Hydrogenics Corporation (Nasdaq: HYGS; TSX: HYG), a developer and manufacturer of fuel cell products, announced today that its wholly owned subsidiary, Greenlight Power Technologies (Greenlight) has received orders totaling US $3 million for fuel cell test stations from two leading Asian automotive customers. Both are repeat orders for multiple machines.

Cumulatively, Greenlight is providing seven Fuel Cell Advanced Test Stations (FCATS) to two major customers. The first order is for three 3 kW PEM FCATS L-Series test systems. The second is for three 12 kW PEM FCATS H-Series test systems and one 60 kW PEM FCATS HX-Series testing station. The stations are expected to be delivered over the next two quarters.

"Our decision to open an office in Tokyo, Japan over three years ago continues to pay dividends," said Pierre Rivard, President and CEO of Hydrogenics. "The Japanese market is advancing quite aggressively towards the commercialization of fuel cell technology, as evidenced by our growth in test equipment sales to the region over the past three years. We are delighted to secure these major contracts with customers who are clearly setting the pace in fuel cell development."

Greenlight fuel cell testing systems provide high precision instrumentation, combined with full-featured software. They deliver fuel cell testing results that prove the reliability, repeatability and versatility required for world-leading fuel cell development programs.

About Hydrogenics Corporation

Hydrogenics Corporation (Nasdaq: HYGS; TSX: HYG) is a leading clean power generation company, engaged in the commercialization of fuel cell technology and test stations for fuel cells. The company is building a sustainable business, in a potentially "game changing technology" for transportation, stationary and portable power. Hydrogenics, based in Mississauga, Ontario, Canada, has operations in British Columbia, Canada, Japan, the United States and Germany. For more information, please visit www.hydrogenics.com .

About Greenlight Power Technologies, Inc.

Greenlight Power Technologies Inc. (http://www.greenlightpower.com), a wholly-owned subsidiary of Hydrogenics Corporation, is a leading global supplier of testing and diagnostic equipment to the fuel cell industry. It has supplied fuel cell test equipment to the world's premier fuel cell stack manufacturers, component manufacturers, system integrators and research organizations. Greenlight provides a full suite of test equipment for fuel cell stack, stack component, reformer and system testing for companies focused on portable, stationary, and transportation fuel cell applications.

Hydrogen Fuel Cells

Anuvu Incorporated

3980 Research Drive
Sacramento, CA 95838
USA
Tel: (916) 921-7040
Fax: (916) 921-7044
Email: anuvu@anuvu.com

www.anuvu.com/home.html

Now our readers can get familiar with some hydrogen fuel cell development photos. It is worth of a note that the prices are high for the majority of people. For example, a hydrogen fuel cell car costs 100 000 dollars FOB Sacramento, CA. The next picture features a fuel cell van, which costs 150 000 dollars.

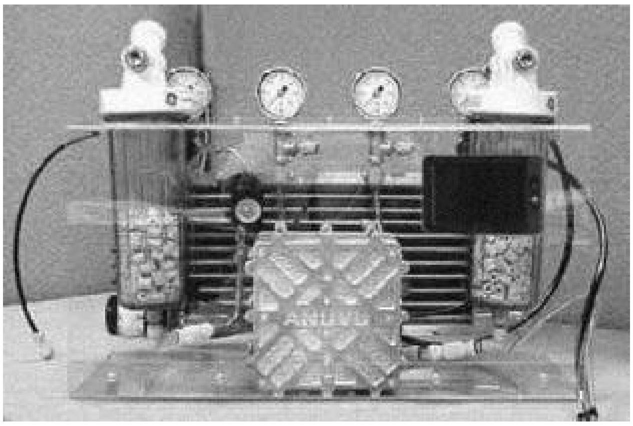

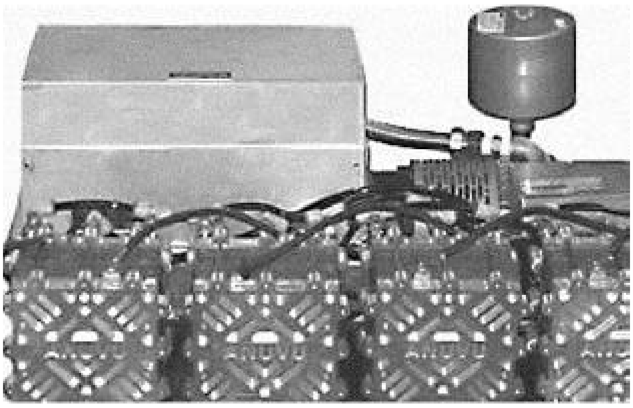

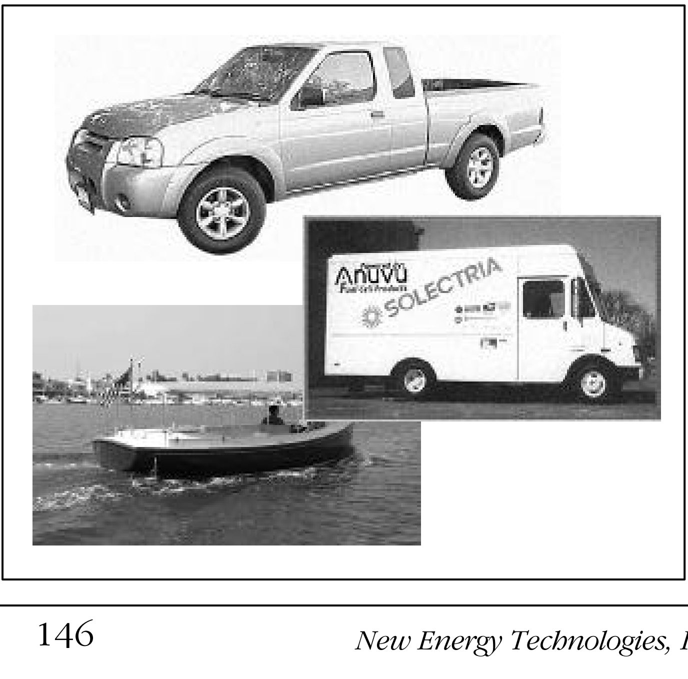

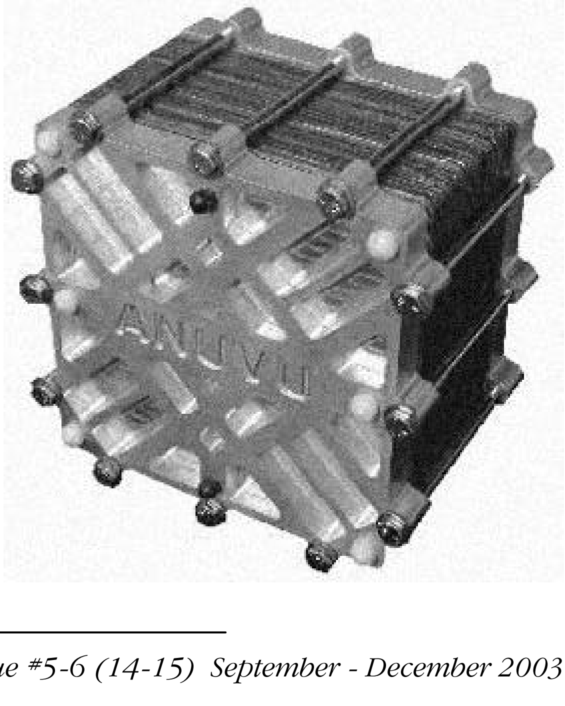

EXCESSIVE OUTPUT
BY MEANS OF AIR IONIZATION

We have received an interesting article from California. Here is the short version of the article.

The Mechanism of The Electric Spark

Review of the research
by Leonard B. Loeb
Professor of Physics, University of California at Berkeley
and
John M. Meek, Research Engineer
Stanford University Press, Stanford University, California

Dedicated to Professor J. S. Townsend whose pioneer research and theory laid the whole foundation for the study of the mechanism of the electrical spark discharge.

Although the electric spark has been known to mankind in its various manifestations from time immemorial, its mechanism has to date been little understood. The initial clarification of the mechanisms involved is due to J.S. Townsend as a result of his brilliant researches in the early nineteen hundreds. On the basis of his theory of ionization by collision by electrons and positive ions, the fundamental mechanisms active and especially the coefficients required in their application were made available.

In 1936 the present senior author was forced to describe the mechanism of spark discharge in terms of a modified but distinctly unsatisfactory Townsend theory. In 1935 the discovery of photo-ionization in air by corona discharge indicated a solution was not far off. The turning point of a more successful theory came in the discovery of streamers in positive point to plane corona in 1936. The quantitative analysis of the self-propagating positive streamer in all breakdown phenomena became clearly evident as a result of the data concerning electron avalanches. As a result a qualitative mechanism of sparking by streamer propagation from anode to cathode functioning by means of photo-ionization in the gas was established.

The Townsend Sparking Criteria

It will not be necessary here to derive the famous equation of Townsend for the current [i] in a gap between electrodes as a function of the photoelectric current [io] from the cathode, the gap length [x] and the coefficients [a] and [B]. For this the reader can go to any standard text. *(Editor: the equation is omitted)*

In this equation the first Townsend coefficient [a] represents the number of new electrons created in the gas by an initial electron in its advance of 1 cm along the field axis from the cathode.

The second Townsend coefficient [B] in Townsend's original theory was the number of new electrons created by a single positive ion in its advance of 1 cm along the field from the anode.

The quantity [a] has been extensively studied in various gases. It varies with the ratio of field strength to pressure, X/p, where [X] is in volts per centimeter and [p] is in millimeters of Hg.

Note: the reason we are going through this is to determine the actual increase in current provided by the spark gap, and thus be able to design the circuit to avoid blowing out semiconductor components. It also provides a sound and already proven scientific theory to work from giving us a good foundation and the confidence to proceed with technical design work.

The quantity [B] has been evaluated, albeit rather inaccurately, from the variations of [i] with [x] at various higher values of X/p, by many observers in different gases. Inasmuch as it has now been shown that there are numerous other mechanisms other than impact with positive ions, which can liberate the secondary electron, needed in discharge.

There has been an inclination to give up the mechanism of impact ionizations by positive ions in gas. The discovery of measurable photoelectric ionization in gas has now made it possible to explain such cases. The exact way in which photo-ionization in the gas could operate to cause a spark, was not clear until the development of the present **streamer theory**.

The Streamer Theory of Spark Discharge Anode Space-Charge Field Due to an Avalanche

Assume a spark gap of 1 cm in length. Assume that in air at atmospheric pressure the potential across the plates is 31,600 volts, which is the conventionally observed sparking potential [Vs].

Let us then calculate what happens in the field to one of those electrons. It starts across the gap, quickly acquiring an average random energy of some $E=1/2mC^2= 3.6$ electron volts and a drift velocity [v] in the field direction of about 1.5 to 2 times 10^7 centimeters per second. As it moves it creates new electrons at a rate of [a] per centimeters in the field direction so that in a distance [x] it and its progeny amount to e(ax) electrons, forming what is called an **electron avalanche**.

Therefore, e(ax) positive ions have been left behind by the electron group, virtually where they were formed in the 10^{-7} second of advance for the electrons in the distance x=q across the plates. As the electron avalanche advances, its tip is spreading laterally by the random diffusive movement of the electrons.From these data it is possible to compute the density of positive-ion space charge left behind at any point [x]. The value of [a] under these conditions is about 17, making e(aq)=e(17). The first ion pair is created at 0.0407 cm from the cathode. At 0.5 cm from the cathode there are 4914 ions, at 0.75 cm there are 3.66 times 10^5 ions, and within 0.0407 cm from the anode there are 1.2 times 10^7 ions. **Most electrons will be drawn to the anode except for some few that are bound by the positive ions, making a sort of a conducting discharge plasma in the avalanche.**

Such a distribution of ions does not make a conducting filament of charges across the gap, and hence in itself an avalanche that has crossed does not constitute a breakdown of the gap. Thus one must look further for the mechanism of the spark.

If Loeb and Meek are correct then if we assume a spark gap of 3 mm and a voltage of 5,000 voltsthere are roughly 2,000 electrons created by avalanche for every one electron leaving the cathode. They state that most of these 'free electrons' are absorbed by the anode. [This would certainly explain why the semiconductor components cannot handle the current gain.]

NOTE: Loeb and Meek make little reference to initial amperage. There are only two values they refer to 10^{-5} ampere and 10^{-12} ampere.

In conclusion: Sparks and Arcs are two different beasts. My initial research into the amperage necessary to form an arc does not apply to spark and the process of avalanche where this huge gain mechanism is possible.

Photoelectric Ionization in Gas as a Secondary Mechanism

Accompanying the cumulative ionization there is produced by electrons from four to ten times as many excited atoms and molecules. Some are excited to an energy exceeding the ionizing potential of some of the atoms and molecules present, either by excitation of an inner shell, by ionization and excitation, or in a **mixed gas like air by the excitation of molecules of higher ionizating potential, e.g., N2**. These excited atoms or molecules emit radiations of very short wave length in some 10^{-8} second. This short ultraviolet radiation is **highly absorbed** in the gas and leads to ionization of the gas. In fact, the whole gas and the cathode as well are subjected to a shower of photons of all energies traveling from the region of dense ionization with the velocity of light. Thus nearly instantaneously in the whole gap and from the cathode new photoelectrons are liberated which almost at once begin to ionize cumulatively.

The Mechanism of Positive Streamer Formation

The photoelectrons created at points in the gas and at the cathode at any great radial distance from the avalanche axis will merely create other avalanches. Those in the gas will be short and those coming from the cathode region will be long and like that of the initial avalanche. Being smaller and, in any case, later in creation than the parent avalanche, such avalanches will be of no interest in breakdown. However, those photoelectrons created near the space-charge channel of positive ions, and especially near the anode, will be in an enhanced field, which exerts a directive action drawing them into itself. If the space-charge field [X1] is in the order of magnitude of the imposed field [X], this action will be very effective. In addition the values of [a] will be much enhanced.

The electrons from the intense cumulative ionization of such photoelectron avalanches in the combined fields [X] and [X1] which are drawn into the positive space charge feed into it, making it a conducting PLASMA which starts at the anode. The added fields will be most effective along [X] and so will the ionization. The positive ions they leave behind will therefore extend the space charge towards the cathode. These electrons also create photons, which produce electrons to continue this process. **In this fashion the positive space charge develops toward the cathode from the anode as a self-propagating positive space-charge streamer.**

As the streamer advances towards the cathode it produces a filamentary region of intense space-charge distortion along a line parallel to the field. The conducting streamer of a plasma consisting of electrons and ions extending to the anode thus makes a very steep gradient at the cathode end of the streamer tip. As this advances toward the cathode the photoelectron avalanches produced by radiation at the cathode, especially at the intercept of the extended streamer axis at the cathode, it begins to produce an intense ionization near the cathode. Hence the positive ions created there may increase the secondary emission. Thus, as the space-charge streamer approaches the cathode a cathode spot is forming which may become a source of visible light.

When the streamer reaches the cathode there is a conducting filament bridging the gap. As the streamer tip reaches the cathode the high field produces a rush of electrons towards the end of the streamer. This if followed by a current of electrons, gives a high-potential wave, which passes up the preionized conducting channel to the anode, **multiplying the electrons present by a large factor**. The channel is thus rendered highly conducting. If the metal can emit a copious supply of electrons because of the formation of an efficient cathode spot, the current of electrons continues the channel maintaining its high conductivity and **ever increasing in it**. This current, unless limited by external resistance, will then develop into **an arc**. It is, however, the intense increase in ionization by the potential wave, which gives the highly conducting channel characterizing the spark.

Conclusion: According to Loeb and Meek there are three means by which a spark in open air will provide a very large current gain. If this is true, it should be fairly easy to prove with inexpensive and unsophisticated equipment. Once the actual amount of current gain has been determined for the design parameters of the spark gap, then the rest of the circuit can be designed for the increased current value.

Editor: It is worth of a note that the current gain by means of ionization was patented by Pavel N. Yablotchkov (the patent of France # 120684, October 11th 1887). Some two years ago one of our issues featured an article about him. We think it is worth being published again.

PATENT of 1877 by Pavel N. Yablotchkov

Alexander V. Frolov
Faraday Lab Ltd,
Lev Tolstoy St., 7 St. Petersburg, 197376 Russia
Tel: 7-812-380-3844

Pavel N. Yablotchkov was born in 1847 near Saratov, Russia. He graduated as a Military Engineer in 1866 and spent several years in the Russian Army.

In 1872 he came to Moscow and started his activities in electrotechnical field. Since 1875 he had been working in Paris with the famous Louis Breget and his first French patent # 110479 of November 29th, 1875 was dedicated to an electromagnetic transformer. Then he developed and patented a lighting system (the well-known Yablotchkov electrical candle). In 1876 he patented a new electromagnetic transformer for industrial purposes, France # 115793 of November 30th, 1876.

The most interesting patent claim on over-unity devices by Pavel N. Yablotchkov is known as France patent # 120684, October 11th, 1877, "The system of distribution and amplification of electrical currents by means of atmosphere electricity..." The patent describes special capacitors connected in series with the load to increase the output current by means of ionization. Experiments were conducted together with the well-known physicists such as Dr. Maskar, Dr. Varren-Delaru and others and **they confirmed the 200 % efficiency of the circuit**. Now we will try to explain the method.

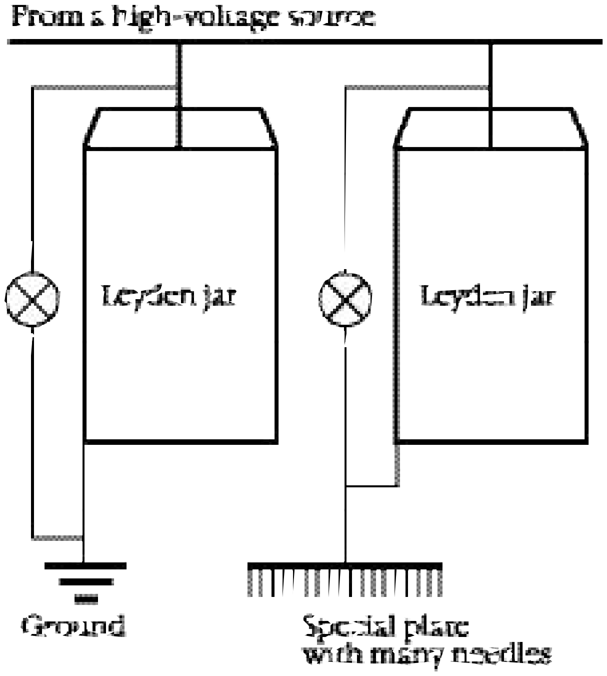

Fig.1 features a schematic drawing taken from Yablotchkov's patent. The Leyden jar is an asymmetrical capacitor, i.e. it is different in principle from a two-plate flat capacitor. The inner electrode of the jar should be connected to a high-voltage source and in this case the changes of the potential have an effect on the potential changes on the external electrode. It does not work in the opposite case and if you connect a high-voltage source to the external electrode no potential changes will be detected on the inner electrode. Connection to the ground or to a special plate (which is covered with many needles to increase air ionization) is necessary to attract the maximum number of electrons to the plate surface or to return the maximum electrons from the plate surface when potential changes on the external electrode are produced by means of electrical induction in the Leyden jar.

In conclusion I should mention one more supposition of the secrets of the well-known Swiss M-L converter (Methernitha). The main elements of the design are Leyden jar capacitors, which have the external surface made of perforated metal.

The other known fact is that great ionization of air is observed when the converter is in operation. So, the electrostatic machine can produce pulses of a very high voltage (potential difference) but it cannot be used as a source of a powerful current. In order to increase the current in the circuit we should apply a certain method and Yablotchkov's technology seems to be appropriate. A large surface of the external electrode of the Leyden jar can be a good solution to the problem. Maximum strong ionization allows us to obtain the output current several times stronger than the weak current generated by the electrostatic machine.

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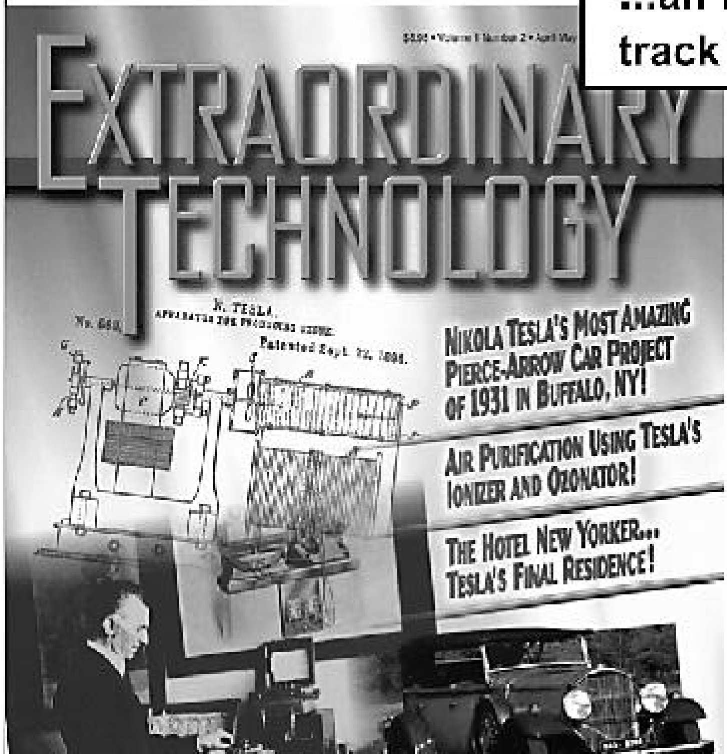
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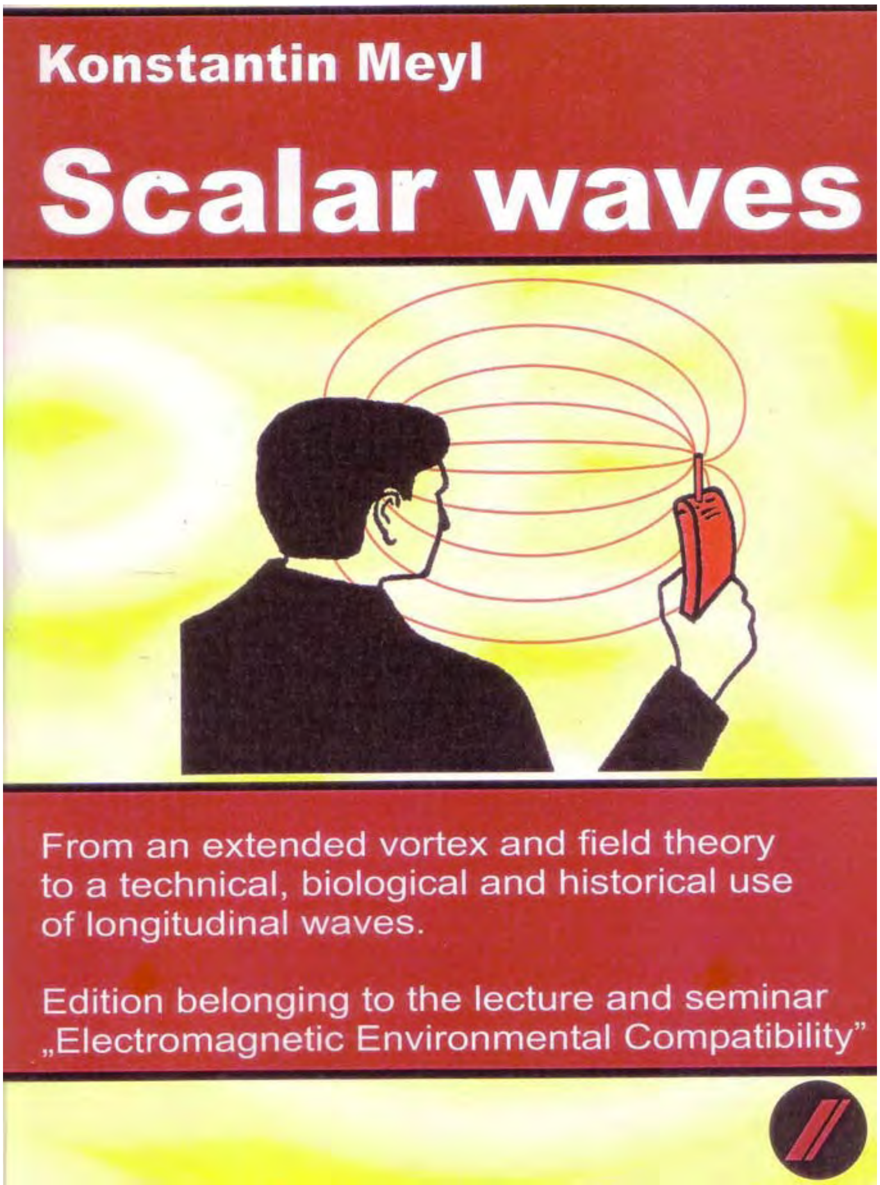

Konstantin Meyl

Scalar waves

From an extended vortex and field theory
to a technical, biological and historical use
of longitudinal waves.

Edition belonging to the lecture and seminar
„Electromagnetic Environmental Compatibility"

Preface to the lecture, 1st Edition 1996

The theme encloses the electromagnetic compatibility of both technical and biological systems. Only part of the electromagnetic wave can be considered for function troubles, namely the part that was absorbed and has rolled up to a vortex. The activity depends on the number of created vortices and of their lifetime, their decay.
The eddy current only manifests in conducting materials. In the air and in dielectric materials on the other hand the vortex of the electric field will form, also called the potential vortex. To calculate and to measure this vortex is our goal.

First we'll carry out a survey of the problems and the usual methods. From the analysis of unsolved problems the need for the introduction of the new vortex phenomena is deducted and an adequate field-theoretical approach will be chosen. Afterwards the potential vortices are calculated and their properties are discussed and interpreted. For the purpose of proving their existence, on the one hand the Schrodinger equation will be derived and on the other hand the quantum properties of the most important elementary particles will be calculated and compared with the well-known measured values. Measurement and calculation are in excellent agreement for weight, charge, magnetic moment and spin. So the theory not only proofs it's correctness, in addition it demonstrates it can achieve much more. The theory takes us to the unification of the well-known interactions and physical phenomena and shows itself as an unified theory. In the practical conversion and usage of the theory there will not only be informed but by all means also be provoked as an entrance in a fruitfully discussion. Fundamental questions will be taken up like: What is information, energy, temperature or smell? The connection to the theme of the electromagnetic environmental compatibility is formed by the technical and the biological usage of the potential vortices, the energy transmission of Nikola Tesla exactly like the in a similar way functioning nerve conduction. Here we already can expect biological reactions.

This lecture, held for the first time in the winter semester of 1995/96, is available in book form, as an edition belonging to the lecture. This lecture will not deliver ready recipes or instructions. The goal is reached when the critical sense of the listeners and readers has been inspired and discussions have been set going. Everybody has to draw the consequences out of such a theory by him- or herself.
In addition to this lecture a seminar is offered, wherein several themes are supplemented or deepened, different theories are compared and possible consequences are discussed. The appearance of an edition belonging to the seminar has started in 1998<i>. Regarding the conversion of consequences both politicians and scientists are equally addressed, because the electromagnetic environmental compatibility has developed to one of the most urgent problems of today's world. But in last consequence all of us bury the worldwide responsibility for our environment.

<i>: K. Meyl: Electromagnetic environmental compatibility, Part 2 and 3 of this book, Edition belonging to the seminar.

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1. Introduction

Here the extremely controversially discussed question of the environmental compatibility of electromagnetic fields will be persuaded. Limits should inform what is incompatible and what is compatible. But there are as many limits as there are commissions and specialists. And besides that differ the results from each other for several powers of ten. In course of time the legitimate doubts become unmistakable and the representatives of science slowly get to feel the burden of proof.

For the sake of efficiency, the actual discussion concerning the theme of electro-smog is analysed and the necessity to involve an until now unnoticed field phenomenon in the discussion about limits is derived: It concerns vortices of the electric field. These potential vortices, as they are called, have the corresponding properties to show biological effects even at the lowest field strengths. In any case it is not possible to exclude that at present the wrong physical phenomena are measured and made responsible.

A parable should bring clarity.

Lets imagine that the to us well-known and over our sense of touch understandable physical phenomenon of the temperature is unknown to us, neither measurable nor perceptible. Our weather station only exists of a barometer that could show us the air pressure and deliver us indications if good or bad weather is to be feared. We ready realize that there exists a connection between the air pressure and our health and make the to us well-known phenomenon responsible. When the pointer points to good weather we can go out lightly dressed. With bad weather we should take a coat, so we know from experience.

"Now we imagine the realistic situation that in winter we have a weather situation of high pressure but it's stone-cold outside. The weather station will display high temperatures with the result that some people will walk around with short-sleeved and open shirt, only to lie in bed with a cold in the evening. Of course the air pressure was to blame! Logically the "pressure sensitive", as they are called mocking, demand the limits for the allowed pressure to be reduced so far that no consequences for health are to be feared. Concerning the theme of allowed limits, science is asked and science proceeds in a systematic way: the pressure is investigated in the laboratory, isolated from all other parameters and so it is discovered that man catches no cold even at a substantially higher air pressure, so there is no reason to alter the limits.

Actually we would expect these at any time reproducible results to have a calming effect on the minds of the participants of the discussion and on the population. Instead the pressure sensitives time and again cite new knowledge that won't fit in the scheme. So is for instance stated that draught causes the same health problems although this pseudo effect has nothing at all to do with the air pressure. So owing to incomprehensibility and emotions the discussion about limits becomes a farce.

The fact that sensitive people react to effects of air electricity and possibly get ill without proof that some today measurable physical quantities are responsible should make us think. It is little calming watching our scientists poking at the dense fog whereas at the same time among the runners of the new telecommunication networks there spreads something like a gold-digger mood.

To introduce a new technology is not difficult, but to abolish it for reasons of the electromagnetic environmental compatibility is almost impossible!

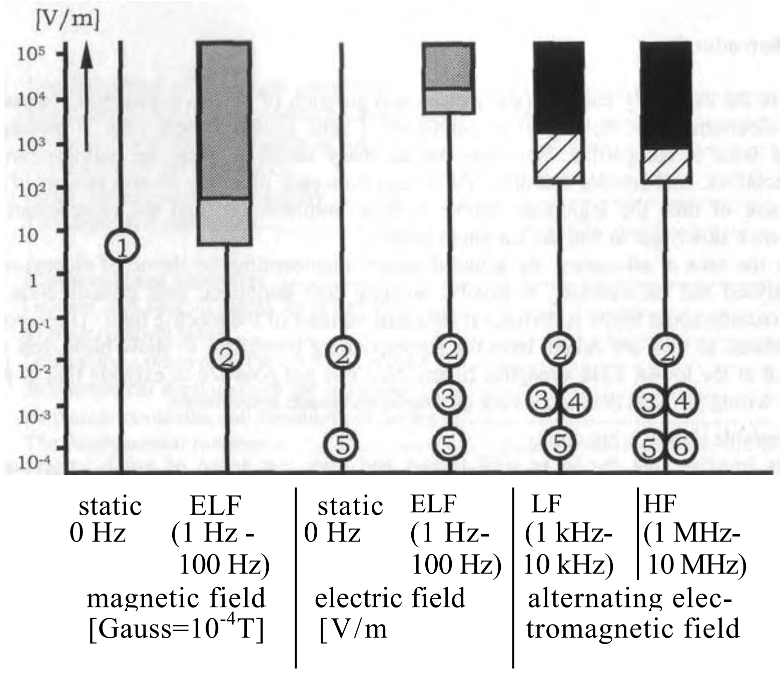

Fig. 1.1: Discussion about limits

■ Limits for professional exposition (electronics engineers) and
▨ Limits for non-professional exposition (population in general) according to the Recommendation of IRPA/INIRC<ii>.
▒ Limits according to VDE 0848 / 1989
▓ Limits according to VDE 0848 / 1992
⊛ experimentally determined threshold values of reactions of biological systems <i>:

1 Increase of the activity of movement of birds
2 deflection of divining-rods
3 influence on the time of reaction of men
4 conditional reflexes of fish without electrical organs
5 conditional reflexes of fish with electrical organs
6 conditional muscular reflexes of men

taken from:
<i>: H.L. Konig: Unsichtbare Umwelt (Wetterfuhligk.), 5. Aufl., Bild 111, S. 123 Verlag Moos & Partner Munchen, ISBN 3-89164-O58-7
<ii>: Habiger u.a., EMV, Verlag Technik, Berlin 1992, S. 152

1.1 Discussion about limits

Whoever follows the public discussions concerning electro smog always sees two arguing parties, whose standpoints lie so far apart that they inevitably talk at cross purposes and there can be found no consensus.

On one side the "affected" find together who maintain to have found the electromagnetic radiation as the damaging cause for their problems. They are to be taken serious, even when only their personal sensitivity serves as means of measurement and proof and a more or less distinct sensitivity against electromagnetic phenomena. This group occasionally finds support of homeopaths who can base on reproducible laboratory results that fit as few into the view of life of science as the empirical statements of affected and possibly hurt people.
On the other side stand the representatives of the energy-supply companies and the runners of radio networks who argue with the needs of our modern industrial society and give "limits" prescribed to them by scientists. These, for their part, proceed according to strictly scientific methods. Their presented results are reproducible and there's no doubt about them.
The limits after all are fixed far below those that are recommended from a scientific viewpoint. Nevertheless both groups are separated from consensus by powers of ten. When we want to know how deep the ditch is we want to bridge, we should take a look at the determined limits (Fig. 1.1).

The limits stem from the 1RPA (International Radiation Protection Association) an organ of the World Health Organization that in turn has appointed the INIRC (International Non Ionizing Radiation Committee). These now state to have used all available scientific research results as basis for the given guidelines.
Moreover a safety range was worked into them. So the limits were fixed at substantially lower levels to guarantee that no health damage arises. In this way first the limits were determined for the people who for reasons of profession are exposed to electromagnetic fields.
For the population in general the limits for the so called non-professional exposition were reduced further to one half till one fifth for reasons of caution and care. In Fig. 1.1 these limits are registered. Thereby is distinguished between magnetic fields and electric fields that appear stationary or at extremely low frequencies (ELF describes frequencies between 1 Hz and 100 Hz). Moreover limits for low-frequency (1-10 kHz) and high-frequency (1-10 MHz) alternating electromagnetic fields are given.
The graph should serve as a rough orientation and show us the proportion of scale. As further information some thresholds of measured reactions of biological systems are registered (after Konig*[1]*). Because a logarithmic scale was chosen to fit all the values on one graph it becomes clear that between the first reactions and the recommended limits there lie up to five powers often. The ditch seems to be insurmountable.

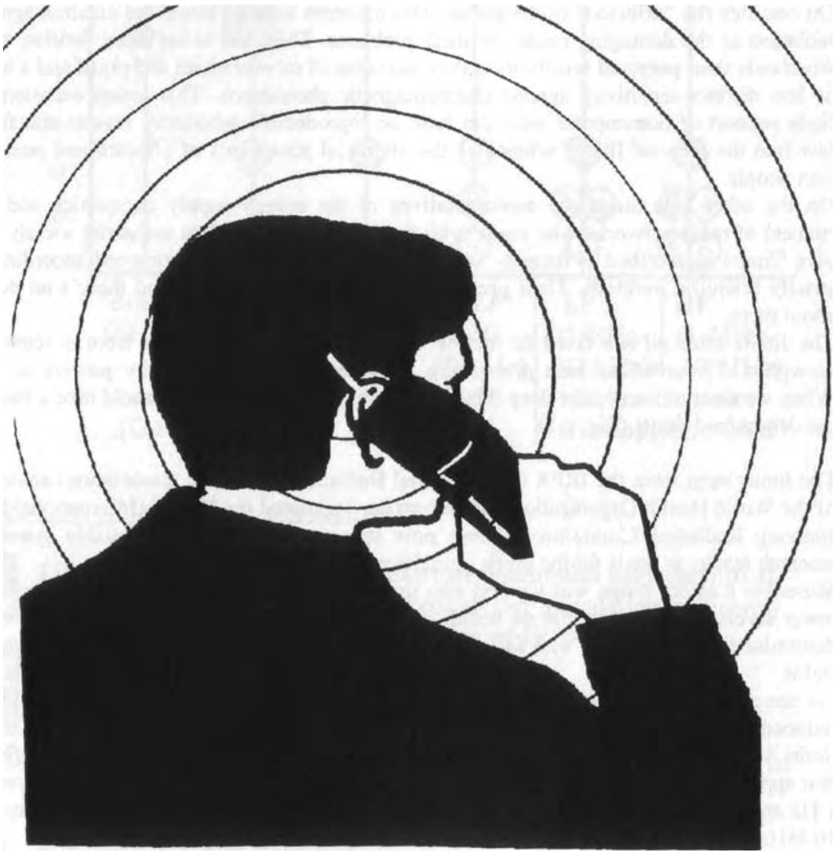

Fig. 1.2: Set of problems of environmental compatibility by means of the example of the handheld wireless telephones (handy).

<i>: L.v.Klitzing: Neurophysiologische Einflusse durch elektromagnetische Felder wahrend und nach der Exposition, Med. Universitat zu Lubeck

1.2 Wireless telephones

Measuring technical surveys with regard to the influence of brain currents by digital radio signals by the university hospital in Lubeck have startled handy manufacturers and users equally <i>. Although in this case measurement errors could be detected, the „bugaboo on the wall" remains that we are sitting unsuspecting in a restaurant and a neighbour draws his handy out of his pocket to make a digital telephone call. Thereby synchronizing the brain currents within a radius of 100 meters on the broadcasting signal and occupying our brain useless with technical signals. The derivation will show that from the start this can't happen to all visitors, because as a prerequisite conditions of resonance must be fulfilled. But would there be an affected, he or she for sure would have considerable problems, because informations that are not picked up over the sense organs can neither be classified timely nor as regards content.

An affected whose brain has picked up technical signals not even is able to register by itself that it was fed with incorrect informations. It would be reasonable when the visitors of the restaurant would defend themselves and put the radio operator on the doorstep. The number of restaurants where apart from cats and dogs also handy's have to stay outside is increasing. How should we keep out of the way of electromagnetic fields? Should we walk around permanently with a steel helmet or even better in a knight's armour and even go to bed with them? It would be worse than in the dark middle ages.

Summarizing: it should be guaranteed that the operation of electro technical apparatus causes neither health damage nor unintentional influence or irritation. A systematic and scientific procedure should investigate in the laboratory all relevant physical phenomena individually for their interaction. Electro physics bases on two phenomena in connexion with electro-smog: on the one hand the radiation and on the other hand the thermal effect, but at a close look both factors prove to be of only little importance!

In radiation measurements the intensity of the electromagnetic wave at a certain place is determined. In laboratory experiments the field strength is increased so long till biological reactions are observed. Thermal limits are determined in a similar way. As said, the values lie about powers of ten above those that possibly bother you when you hold a handy to your ear. It is true that the microwave radiation penetrates into your head but we also know that it marches out again on the other side and this visit in your head happens with the speed of light.

Exactly like this are guest in your body constantly your local radio station, your local television station the satellites with hundreds of programs and anyway the whole radio technical world even when you did not invite them.

For an electromagnetic wave to become receivable, the field strength must lie clearly above the common noise signal and this can only be achieved by a permanent overlap, by standing waves, like in a cavity tuned to a specific frequency or an antenna. As long as people don't let themselves grow antennas on their heads they hardly have to fear direct biological effects of electromagnetic waves.

That leaves as the second phenomenon the thermal effect. With a handy held to your cheek there comes into being a local fever in your head. But that is not at all unusual or unnatural for the human body. Something like that happens to a far greater degree when you take a hot foot bath or let yourself be irradiated at one side from the sun at a tourist grill.

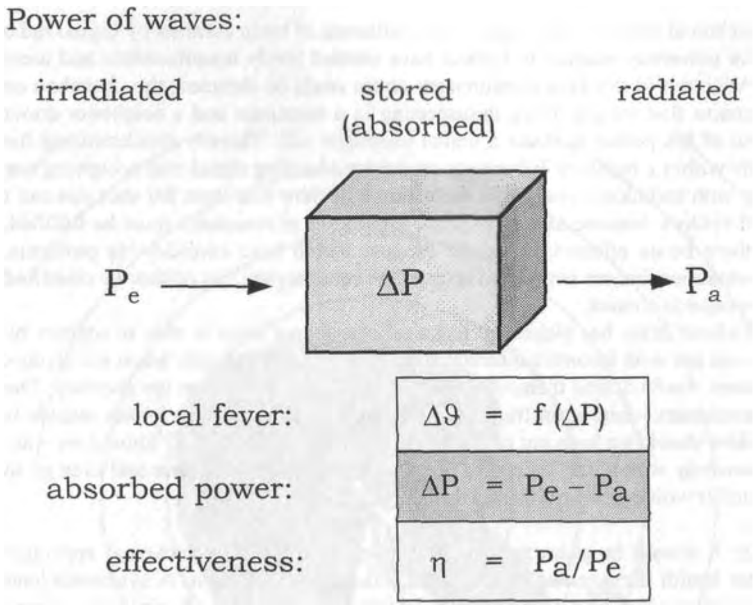
Power of waves:
irradiated
stored (absorbed)
radiated
P_e
ΔP
P_a
local fever:
$\Delta\vartheta = f(\Delta P)$
absorbed power:
$\Delta P = P_e - P_a$
effectiveness:
$\eta = P_a/P_e$

Fig. 1.3: Damping of waves and ability to absorb of a body (our head) if we are making a phone call with a handy.

a contribution to the theme dielectric losses

- capacitor
- high-frequency welding
- microwave oven

<i>: K. Meyl: Potentialwirbel Band 1 [Al] (only in German), INDEL Verlag, Villingen-Schwenningen 1990, ISBN 3-9802 542-1-6

<ii>: K. Meyl: Potentialwirbel Band 2 [A2] (out of print), INDEL Verlag, Villingen-Schwenningen 1992, ISBN 3-9802 542-2-4

1.3 Absorption of waves

The with the theme dealing physicians logically have to put up with criticism that they work only with two phenomena that not at all can be involved authoritative in the causes for biological effects. A third factor can be considered, a field phenomenon until now stayed unnoticed by science: the vortex of the electric field, the so called potential vortex. A vortex is to be considered as an oscillation around a fixed point. Through that a permanent overlap is caused, like what happens at an antenna only that the vortex is not bound to the dimension of an antenna. The potential vortex is contracting and in this way reaches extremely high energy densities at very little spatial measurement, densities that lie far above those that field strength measurements are pretending to us [Al]<i:>.

When again you take the handy at hand with which you ,,blow" the pulsed microwaves into your head. Don't worry, because with the speed of light and without provable damage almost everything comes out again on the other side, but only almost everything. A little damping of the wave has taken place and your head has absorbed this part of the irradiated wave (Fig. 1.3). Who claims this is already the thermal factor actually should realize that there exists no corresponding term in the wave equation. Here there are found merely two dual vortex phenomena as a possible damping term: the eddy current and the potential vortex. An eddy current damping is ruled out because of the bad conductivity of the head. But this favours his dual anti-vortex, the potential vortex [A1]<i>.

Seen physically the following is taking place in your head: the absorbed waves roll themselves up to vortices and through that become localized and overlap themselves permanently (Fig. 1.4b). In the course of time the vortices decay and produce the well-known eddy losses that lead to the measurable increase in temperature. When reactions or biological effects arise, simply and solely the vortex can be considered as the possible cause. Thereby play two points an important role: the number of the generated vortices and their lifetime that is determined by the time of decay.

In anticipation of the mathematical calculation of the potential vortices it is pointed out here that these are favoured not only by a low conductivity, but also by a high dielectricity. Because water has an unusual high dielectricity (ε_r = 80) and our head consists predominantly of water doubts in dealing with handy's are reasonable.

Also the relaxation time constant representative for the lifetime can be calculated [A2]<ii>. We must proceed from the assumption that both the number of the vortices and their lifetime, that is all the at a fixed point in time in our head existing and effective vortices, can be a cause and therefore have to be considered and investigated scientifically.

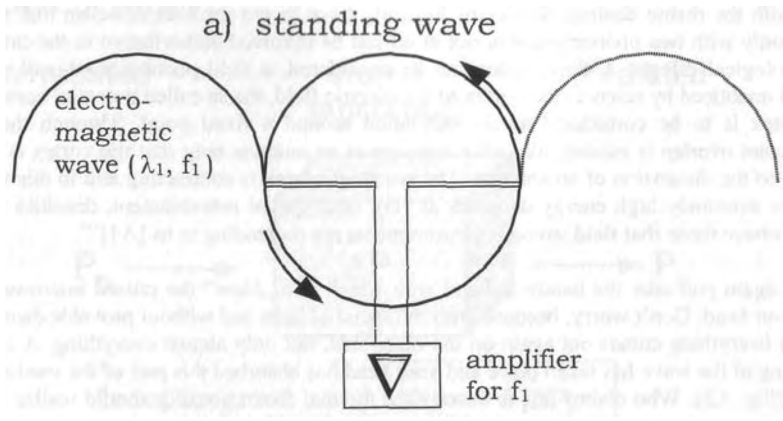
a) standing wave
electro-
magnetic
wave (λ_1, f_1)
amplifier
for f_1

b) localized vortex = noise

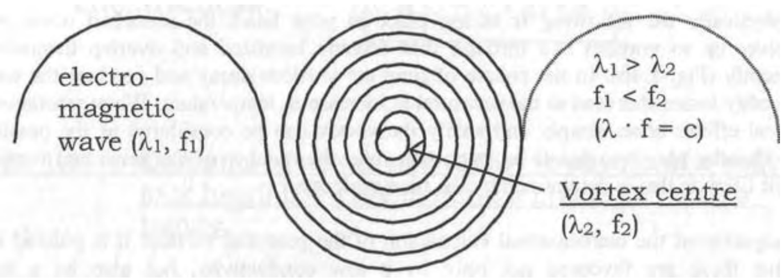
electro-
magnetic
wave (λ_1, f_1)
$\lambda_1 > \lambda_2$
$f_1 < f_2$
($\lambda \cdot f = c$)
Vortex centre
(λ_2, f_2)

c) broadband antenna for EMC-measurements

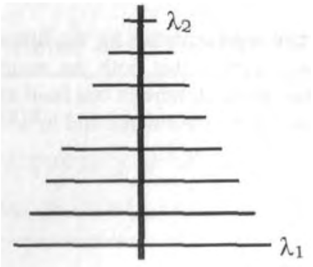
λ_2
λ_1

Fig. 1.4: Measurement of localized waves and vortices

1.4 Overlap effect

The graph at the left (Fig. 1.4) should clarify once more that only the in space localized and permanently overlapping field appearances can be considered as a cause for biological effects. This can concern an over an antenna standing wave (a) or a vortex (b) which is to be taken as localized by nature.

It would be allowed to in general speak only of a vortex because the standing wave can by all means be understood as a special case of the vortex. The essential difference is that the vortex is not bound to the size of a fixed antenna and can contract itself at any time to achieve in this way a substantial higher energy density. As a result this than will lead to an increased biological effectiveness.

It should be pointed at a further omission. In the discussion about limits, without exception, the absolute field strength of the broadcasting signal is valued and not the type of modulation. The last mentioned should actually not at all play a role according to the prevailing scientific opinion.

Totally different is the case with a vortex that acts damping. Such a vortex shows near it's centre a considerable smaller wavelength than more to the outside and through that it has a big frequency bandwidth [A5]<i>. It is to be expected that in the extremely broadband pulsed signals of the digital networks the creation of vortices (or eddies) will be favoured considerably stronger than in amplitude- or frequency-modulated signals (AM/FM/C-network). In connexion with analog modulated radio- or handy-signals until now there never has been reported of any synchronization of the brain currents with handy-signals from a comparison of the EEG with the broadcasting signal.

Interestingly the for EMC-measurements usual stepped broadband antennas have exactly the construction that certainly would be favourable to the measuring technical registration of vortex phenomena (Fig. 1.4c).

With the dipole antennas of different lengths for different wavelengths there still are measured waves and not vortices but these measuring techniques is certainly accommodating to the until now unnoticed and stayed undiscovered vortex phenomenon. So there are some good reasons that the vortex is a dominating influential factor for EMC-problems.

By means of the example of the handheld wireless telephones can be studied and discussed with which set of problems the very young discipline of science of the environmental compatibility has to fight in the future. And in which ways there can be found approaches towards a solution of the problem. When the comfortable and trodden out ways of textbook physics do not lead to the goal than we will have to force our own way through the jungle of science.

At first we'll have to obtain a short overview of the actual level of research and knowledge. From the criticism to this we than can derive the tasks of the electromagnetic environmental compatibility and in particular the unsolved tasks.

<i>: K. Meyl: Wirbel des elektrischen Feldes, eine neue Storquelle? EMC Journal 1/95, 6. J, S. 56-59.

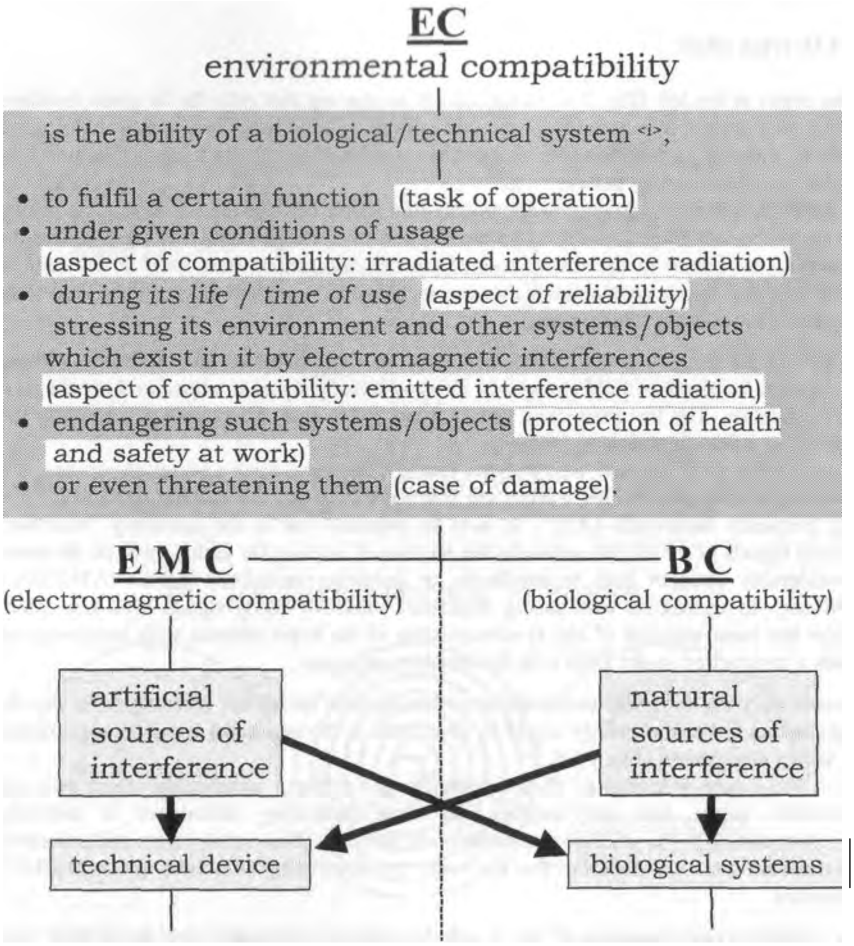

EC

environmental compatibility

is the ability of a biological/technical system <i>,

- to fulfil a certain function (task of operation)
- under given conditions of usage (aspect of compatibility: irradiated interference radiation)
- *during its life / time of use (aspect of reliability)* stressing its environment and other systems/objects which exist in it by electromagnetic interferences (aspect of compatibility: emitted interference radiation)
- endangering such systems/objects (protection of health and safety at work)
- or even threatening them (case of damage).

EMC
(electromagnetic compatibility)
BC
(biological compatibility)
artificial sources of interference
natural sources of interference
technical device
biological systems

Regulations of	called EMEC	know how of
the German Post	thirties: radio	druids
Office since 1992:	operator disease	magic
EMC-law<ii>	today, E-Smog,	esoteric
from 1996:	HF-, SW-therapy	medicine
EU -regulation	diathermy, etc.	biology

Fig. 2.1: Overview concerning environmental compatibility

<i>: E. Habiger: EMV-ubergreifende Aspekte zu benachbarten Problemfeldern, Elektrie 48 (1994), Heft 5/6, Seite 163-161

<ii>: EMVG: Gesetz uber die elektromagnetische Vertraglichkeit von Geraten, Bundesgesetzblatt Teil I vom 9.11.1992, S. 1864

2. Tasks

2.1 Tasks of the electromagnetic environmental compatibility

The environmental compatibility (EC) forms the generalization that includes both the electromagnetic compatibility (EMC) and the biological compatibility (BC). Besides the technical and functional goals of an undisturbed functional course it also pursues ethical and moral goals.
Technology should benefit to humanity and at the same time be in accord with nature. This goal will not be reached when this technology directly or indirectly is endangering humanity.
A direct attack on the health of people poses for instance the military usage of technical apparatus or the negligent usage, by pretended ignorance and unsuspicion.
Is a technology posing a danger to the environment so humanity endangers itself indirectly with this technology. After all are human beings a product of their environment. We always should reckon on the environmental sins taking revenge on us sooner or later.

In fig. 2.1 a formal definition is given that in particular concerns the claims for an undisturbed functional course: it concerns the compatibility aspects of unallowed emitted and irradiated interference radiations, the reliability and quality safety with which a function and task is fulfilled and finally the questions of the protection of health and the safety at work.

Moreover fig. 2.1 provides an overview and the structure of the 2nd chapter. First we'll treat the electromagnetic compatibility (EMC) that first of all deals with the influence of artificial but also natural interference sources on technical apparatus.
After that we'll throw a glance at the appearing fields in nature. The biological compatibility (BC) deals with the influence on biological systems.
An especially sensitive area of the environmental compatibility (EC) than describes the with a cross-link hinted influence of artificial interference sources on biological systems that is popularly described as „electro smog".

The numerous aspects of the environmental compatibility for instance in the areas of chemistry and biology that certainly are important, but do not fall in the area of electromagnetism, can't be treated in the here marked framework.

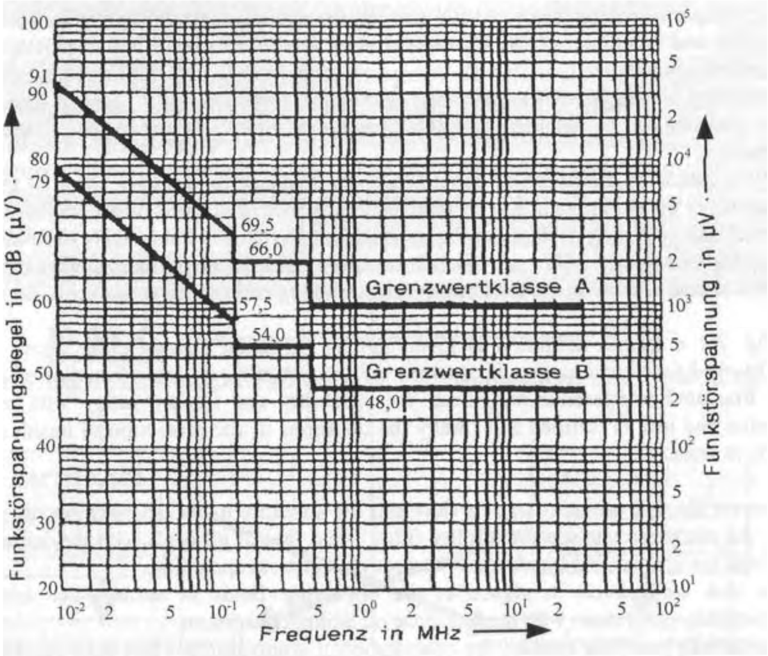

Fig. 2.2: Classes of limits according to VDE 0871 (since 1-1-96: VDE 0875)<i>

<i>: Anton Kohling: Grundlagen der Funkentstorung in der Bundesrepublik Deutschland, etz Bd. 108 (1987), Heft 10.

2.2 Tasks of the electromagnetic compatibility (EMC)

First of all the EMC (electromagnetic compatibility) is concerned with the function of technical apparatus. Correspondingly rational and dry sounds the official definition: "electromagnetic compatibility (EMC) describes the ability of an electrical setting-up (i.e. of a construction element, of a construction group, of an apparatus or of an installation) to function in an electromagnetic environment without stressing this environment by electromagnetic effects in an unallowed fashion ".

Actually it concerns an old need for protection that should be as old as the usage of electro technical apparatus. But in the beginning no one cared about it. The spark gaps with which Heinrich Hertz 1888 in Karlsruhe has carried out the first radio technical experiments were genuine „polluters", that would have been detectible at several hundreds of kilometres distance with modern receivers. For these installations that he had assembled in the lecture room with his students, today he would hardly get a permission of operation and the since 1996 required declaration of conformity he would get not at all.

1925, as in Germany the number of radio listeners had exceeded the limit of one million, for the first time a need for protection appears in the certificate of approval for radio receivers: "The public telegraphs and telephone installations must not be disturbed by the radio receiver".
Later on every backside of the good old steam radios there was found the following hint (translated): "This apparatus meets the interference radiation regulations of the German Post Office". So the manufacturers were urged to measure the emission of their apparatus and in particular to screen the HF-oscillators in the superhet-receivers.

Since the fifties, in the VDE-institute EMC-examinations in the present day sense are taken. The main point of the measurements and the by the VDE recommended limits, however is about interferences bound to a circuit. On the supply lines of the network the prevailing conditions are reproducible so that standards can be put through (Fig. 2.2).

For measurements of interference radiation maybe the time was not ripe enough or the necessity was not big enough. The usual argumentation was: what we can't measure reproducibly, can not be forbidden and certainly not be put under punishment. Therefore merely recommendations were issued or impositions weak as wax were made like: "the interference field strength ... must be so small that an undisturbed reception is guaranteed as soon as the minimum field strength for utilization exists at the place where the antenna is mounted"[i].

In common parlance that means something like: "as long as no one bleats, everything is allowed". Within a connected industrial area there even existed an officially legitimized fools freedom. Merely at the fence of the industrial area limits had to be fulfilled.

Specially for the line-frequency of the screen one has decided to build a loophole in the law so that one didn't have to throw the TV sets, that so successfully had conquered the living rooms, out of the window. Of course the flickering screens did interfere exactly as before but this EMC-interference now was officially approved.

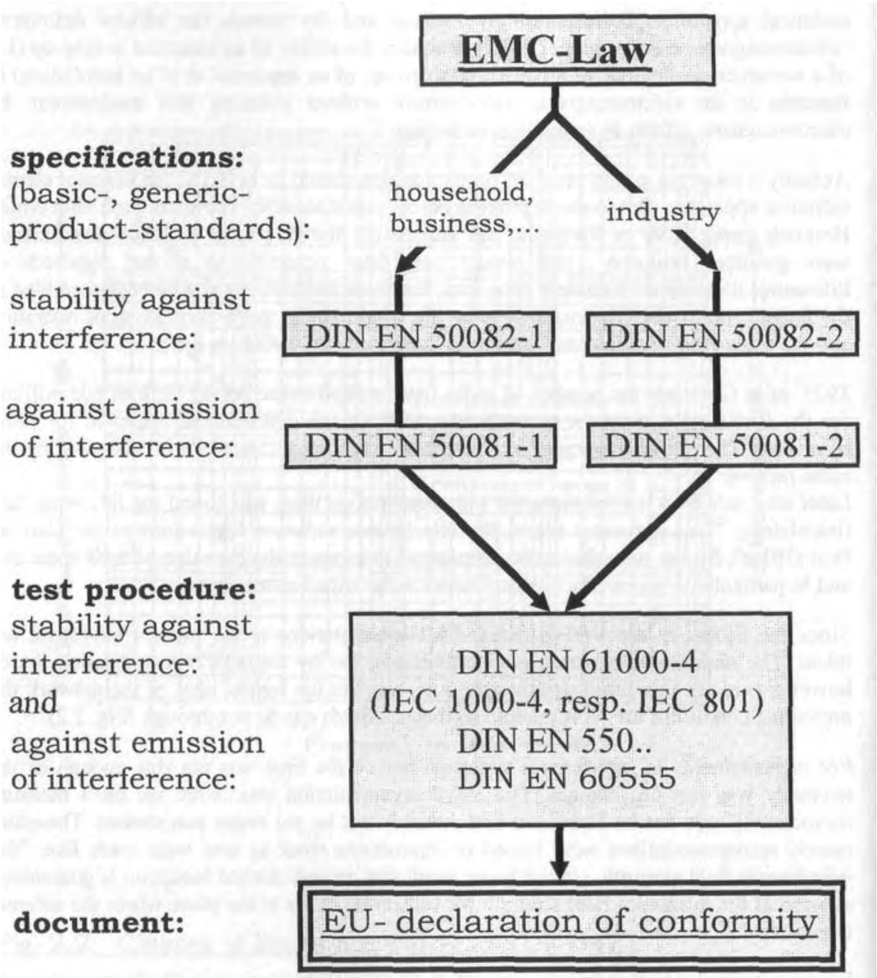
EMC-Law
specifications:
(basic-, generic-
product-standards):
household,
business,...
industry
stability against
interference:
DIN EN 50082-1
DIN EN 50082-2
against emission
of interference:
DIN EN 50081-1
DIN EN 50081-2
test procedure:
stability against
interference:
and
against emission
of interference:
DIN EN 61000-4
(IEC 1000-4, resp. IEC 801)
DIN EN 550..
DIN EN 60555
document:
EU- declaration of conformity

Fig. 2.3: The way to EU conformity

2.3 Declaration of conformity

In the EMC times seem to have gone as the standardizers had to fit in with the insufficiencies of technology. Meanwhile the conditions have turned up. We owe this circumstance first of all the EMC-law of 1992 that doesn't name any limits but it states the political intention to demand from technical apparatus and installations an appropriate stability against interference and at the same time limit the sent out interference. As a consequence of this law the measurement facilities and measurement processes had to be standardized to get reproducible measurement results that are not influenced by the electromagnetic environment. That goes so far that even the floor covering of a measurement hall is dictated because the conductivity of the floor influences the degree of reflexion. Normally the examinee is situated on a revolving plate that is turned around for 360° during the measurement of the radio interference field strength. Is it however not possible to turn the examinee than the antenna has to be led around it, thereby again increasing the dimensions of the measurement hall. The distance to the antenna should be up to 10 meters. Moreover it must be possible to move the antenna, up till a height of 4 meters to register the influence of the reflexions on the floor.

Moreover there is to plan a reflexion free zone around the measurement track (in elliptical form) that depends on the reachable damping of reflexions of the used absorber. Used are pyramids of foam material soaked with carbon and increasingly tiles of ferrite or shieldings of wallpaper.

Taken all together for a measurement hall doing justice to standards there result considerable measurements of for instance 18 m length x 10 m width x 7 m height. Let's again come to talk about the EMC-law with which only the intention but not the way is fixed. To form the claims catalogue in a way that is fulfillable in general, some concrete prescriptions, the so called standards, have to be worked out. This task was transferred to the European committee for electro technical standardization CENELEC, which has established the workgroup TC 110 to at first work out some standards: The basic standards deal independent of product with general questions of the EMC, of the testing process and of the measurement environment.

The generic standards likewise deal independent of product with the so called fundamental technical standards for apparatus in their dependence of the respective electromagnetic environment (protected computer room or medical room, environment of the house, office or industry).

The product standards concern the EMC-standards referring to products (7 product families / approx. 50 products).

In Fig. 2.3 the arduous way through the jungle of paragraphs for a technical apparatus is outlined. Corresponding to the requirements of use, first the relating ES-standards for the apparatus have to be determined and than have to be measured according to own test standards based on the fundamental technical standards. When the allowed limits for stability against interference and for sending out interferences are not exceeded, the EC-declaration of conformity is handed out. Since 1.1.96 that declaration is needed when apparatus are commercialized or - stated more exactly - "put in circulation" and operated. When still further EC-guidelines are met in the end the CE-hallmark is awarded. Since 1.1.96 only with this hallmark the access to the common market of the EC is possible. Violations can be punished with fines and if need be with imprisonment. But there are great national differences in the EC. The Federal Republic of Germany with fines of up to 50.000 Euro counts as expensive for criminals.

Simulation of network for the measurement of the interference voltages U_{st1} and U_{st2}.

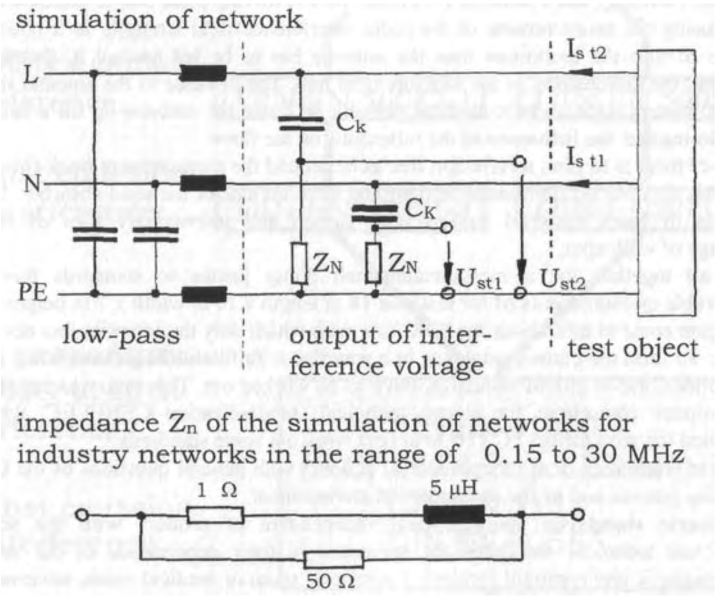
simulation of network
L
N
PE
C_k
C_K
Z_N
Z_N
$I_{s\,t2}$
$I_{s\,t1}$
U_{st1}
U_{st2}
low-pass
output of interference voltage
test object
impedance Z_n of the simulation of networks for industry networks in the range of 0.15 to 30 MHz
1 Ω
5 µH
50 Ω

Fig. 2.4: Simulation of network for the measurement of interference voltages.<i>

<i>: acc. to Ernst Habiger: EMV, Huthig Buch Verlag Heidelberg (1992), ISBN 3-7785-2092-X

2.4 EMC-techniques to measure the emission of interference

Actually we already can be glad that it came to an europe-wide agreement for the regulation of the EMC-set of problems. But the question if we can be satisfied with what we have reached is still outstanding. All too often the lowest common denominator of the measurable and checkable was sought and not so much the technical possible was taken into consideration.

The main emphasis is put on the measurement of the emission of interferences. Traditionally the interferences bound to a circuit are registered in a frequency range up to 30 MHz. The corresponding wavelengths thereby can correspond with the length of the supply lines and form standing interference waves. Primarily the spectrum of the interference currents is measured e.g. over a HF-current converter. These currents produce a voltage drop over the internal resistance of the feeding network. Because the properties of the networks can vary very strong, a standardized end-resistor is required for the measurement of the interference voltage. For this purpose an imitation of the network is switched between the network and the examinee. This imitation in addition has the task to keep away the interference signals that come from the supplying network with the help of filter-elements (Fig. 2.4).

The measurement of the interference radiation, the field-bound interference emission, lakes place between 30 MHz and 1 GHz. For that a free field or an absorber-hall with little or no reflexions is required. The standardized distances of measurement are 3, 10 and 30 meters. The electric field strength is determined with dipole broadband antennas, the magnetic field strength with frame antennas. It must be possible to both vary the receiving antenna between horizontal and vertical polarization and to adjust the receiving antenna in the height and the position to the test object.

Typical measurement set up to measure the emission of interferences bound to a conductor<i>

A: shielded link conductor
B: bundle of conductors folded like a meander
C: connection to the reference mass
ME: receiver of interference signal
NNB: Simulation of network
PO: test object

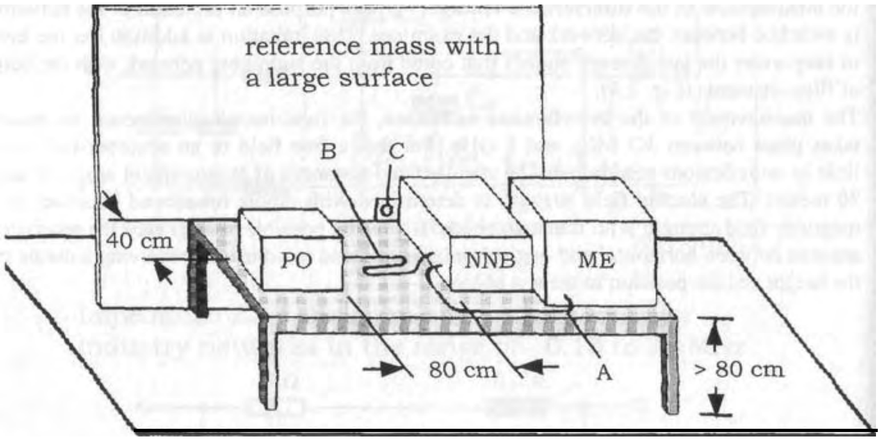
reference mass with
a large surface
B
C
40 cm
PO
NNB
ME
80 cm
A
> 80 cm

Fig. 2.5: Measurement set up to measure the emission of interferences bound to a conductor,<i>

<i>: Ernst Habiger: EMV, Huthig Buch Verlag Heidelberg (1992), ISBN 3-7785-2092-X

2.5 Electro-Smog

There is almost no end to the possibilities of variation and one needs already a lot of overview and experience to determine the field strength maximum. Nevertheless we have to ask ourselves if in this way really all emissions of interference are understandable, that popularly are described as „electro smog".

Smog is the combination of the terms Smoke and Fog. It therefore describes a pressure on the environment with fog like smoke. When for instance in the case of smog alarm all interference sources are switched off, which means all kilns are brought to a stop and all automobiles are stopped, than the fog like smoke therefore still is not vanished from the air. It just distributes itself and dissolves only very slowly.

The transfer of the smog idea on the electromagnetic interference radiation is bound to fail because, when the test object is switched off no emission of interference at all is detectable with the usual measurement means. Nevertheless the rainbow-press is trying to enumerate almost all electromagnetic field phenomena under the term „electro smog" without consideration of the fact that this term is not at all a collection term. From the sight of an expert one can only speak of smog when something like smog remains and stays active further after the switching off of an electro technical apparatus. It should be a phenomenon that is not understandable by the standardized measurements of interference radiation. Such a phenomenon would be e.g. the vortex of the electric field. However vortices are virtually not measurable in a direct way because they have the unpleasant property to whirl about around the measurement probe. But they will be detectable by their eddy losses and in the case of the electric field vortex appear as noise. Until now the standardizer however haven't planned to investigate the influence of an apparatus on the noise in the environment. Here we still grope in the dark.

At least the vortex shows a storing property that would justify the use of the idea "smog". We'll have to investigate the phenomenon.

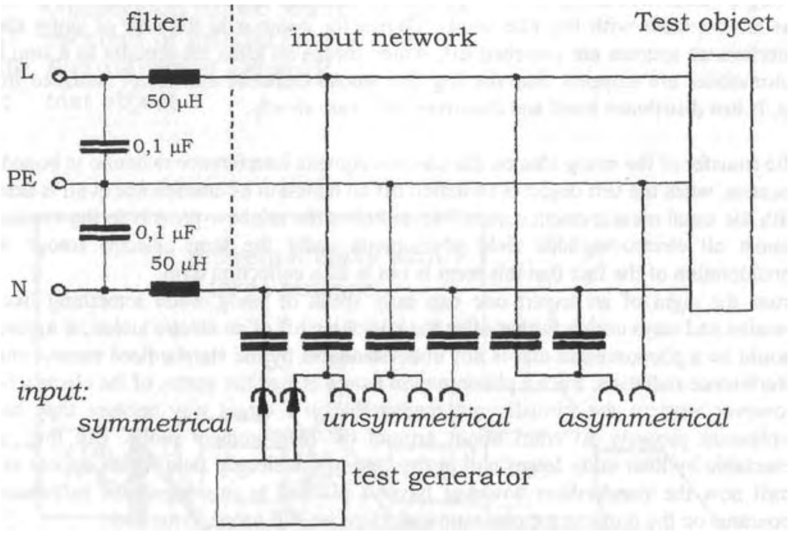
filter
input network
Test object
L
50 µH
0,1 µF
PE
0,1 µF
50 µH
N
input:
symmetrical
unsymmetrical
asymmetrical
test generator

Fig. 2.6: Picking up of interference voltages in network lines.<i>

<i>: Ernst Habiger: EMV, Huthig Buch Verlag Heidelberg (1992), ISBN 3-7785-2092-X

2.6 EMC-techniques to measure the stability against interference

The question is: what kind and what intensity of an electromagnetic interference can an apparatus cope with without limiting it regarding its technical function. For that test generators are used and with their help interference signals are produced in the test object. Fig. 2.6 shows the possibilities of a symmetrical, of an unsymmetrical and of an asymmetrical production of interference voltage signals in the power supply lines of an examinee. Over and above that the testing possibilities and testing methods are numerous. In principle the following processes are used:

1. The simulation and production of interference factors typical for the network like harmonic waves on network voltages, overlapping signal voltages, changes of network voltage, decrease of network voltage, network interruptions, network unsymmetries and network frequency changes.
2. The production of both energy-poorer and energy-richer interference impulses like they can form in energy-networks by switching acts or by the effect of lightning (burst).
3. The simulation of the course of events when static electricity discharges.
4. Low-frequency magnetic fields like those that can form by network frequency operating and loading currents or by short-circuit and lightning currents in the form of a pulse.
5. The stability against interference against the influence of an electromagnetic field also called radio interference firmness. For this purpose high-frequency generators and broadband antennas are used to expose the examinee to electromagnetic fields in a frequency range between 10 kHz and 18 GHz. At the moment tests are only performed between 27 and 500 MHz. The modulation of the carrier wave should be possible to be able to imitate the interferences by radio technology as realistic as possible. Thereby the field strength values can by all means reach up to several 100 V/m.

In accordance with expectation the result of this irradiation with an outside field is that every conduction path and every wire can act as an antenna and therefore can produce high-frequency currents and measurable potentials. Building parts of the analog technology as a consequence battle with problems of drift whereas with digital logic parts and computer parts the danger exists that switching states change unintentionally. Let us remember again the overlap effect of fig. 1.4. The electromagnetic wave itself marches with the speed of light through the examinee. When a small part of the wave finds an object that it can use as an antenna than the localized overlap comes into play. This than as a cause is responsible for the effective and measurable antenna currents. Until here the text books help us to explain the problems that happen and to remove them logically.

However time and again cases are reported where textbook physics can't help us any further. Spectacular cases even came to court like e.g. the ABS (Antilock Braking System) of a truck that had failed due to EMC-interference radiation. As a consequence the brakes had failed. When after that the local radiation pollution is measured no anomaly at all can be discovered. The measurable field strength is not higher as is usual in the whole area. Maybe you also have made the experience that often the causes can't be found when your computer suddenly "crashes" out of the blue.

Here the mentioned vortex of the electric field is capable to deliver plausible explanations because it is not bound to the geometry of an antenna and in addition is highly active without being detectable with the usual EMC measurement methods of the interference radiation measurement!

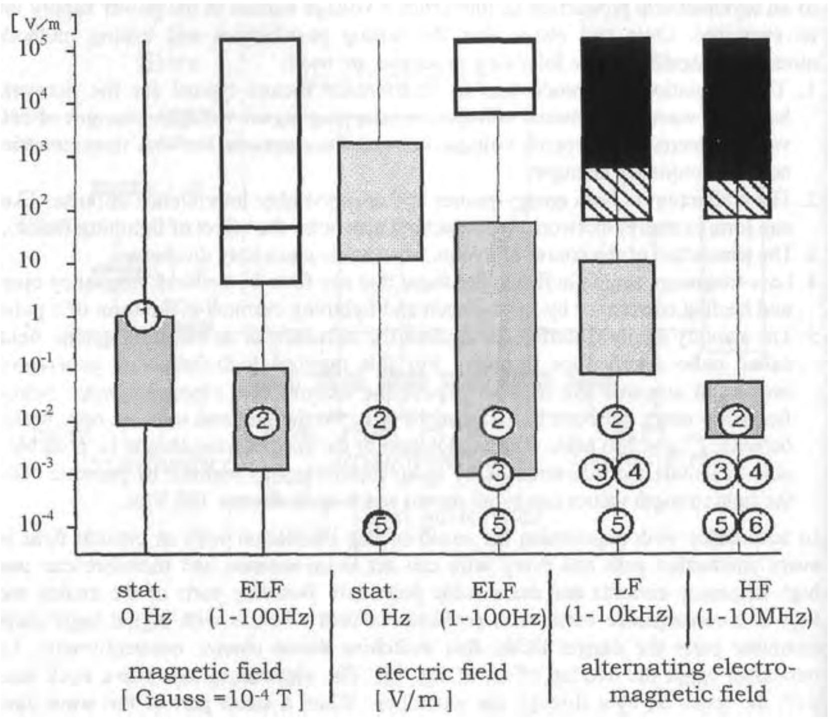

Fig. 2.7: Intensities of natural electromagnetic fields
(electric, magnetic and electromagnetic fields) ▒

In addition to fig. 1.1, page 3,
magnetic field in Gauss (= 10^{-4} T),
electric field in V/m.

<i>: A.S. Presman: Electromagnetic Fields and Life. Plenum Press, New York - London, 1970

2.7 Tasks of the biological compatibility

The second leg of the environmental compatibility (EC) forms the biological compatibility (BC) besides the electromagnetic environmental compatibility. Whereas the interests of the EMC are looked after by electrotechnical engineers and electrophysicists, with the BC also doctors, biologists and architects are addressed.
Moreover this leg is already very old and already existed long before artificial interference sources could be created by mankind. The interaction between the arising interference sources in nature and the biological systems in general and specially men always interested the doctors, the priests, the druids and geomants, that not seldom looked after several functions in personal union equally. Unfortunately they as a rule have kept their knowledge and capabilities as secret knowledge, didn't make any recordings and merely initiated and trained their respective successors. Through that a great deal got lost and today non-medical practitioners, homeopaths and esoterics trouble themselves to take up to the far-reaching buried knowledge.
Because this concerns pure knowledge by experience, often the with the topic occupied persons themselves are not capable to say anything about the physical backgrounds and causes. One concentrates entirely on the under certain circumstances reachable results and only in rare cases on reproducable effects. In some areas the scientific assignment already has succeeded, have parascientific phenomena managed their admission in the so called "exact sciences", but in most experience disciplines the assignment is still due. There still is a lot to do here.

In the time as there not yet were operated any artificial interference sources on our planet, the senses of man naturally were a whole lot sharper for his electromagnetic environment as today. Today, where there scarcely is a place on earth where we are not irradiated by terrestrial transmitters, by satellites or by the netfrequency that is measurable everywhere. In the bluntness of our senses perhaps the hybris of modern man is founded, with which he wants to rise himself above esotericism, geomancy and other sciences of experience and thereby dispute the electric and magnetic fields their biological effectiveness.

The fields of natural origin form an electromagnetic environment for men, that they have adapted to and that they probably need for a life in accord with nature. The evolution has taken care for a corresponding adaptation.
In fig. 2.7 in addition to the limits from fig. 1.1 the intensities of natural electromagnetic fields are registered<i>. They lie clearly lower as the recommended limits but exactly in the area wherein the first reactions of living beings are observable.

When we ask us how much electromagnetism is good for us and how much harms us so the obvious answer is: exactly as much radiation as nature dictates in the fluctuations between day and night, between the months, years and in the end between the cycles of sunspots of 11 years. Here the guide value is found that man and nature have adapted themselves to. In fig. 2.7 the corresponding area between the natural minimum and maximum values is given.

Irradiation strengths of the field radiation in the biosphere and how the optical windows are situated in the atmosphere[<i>].

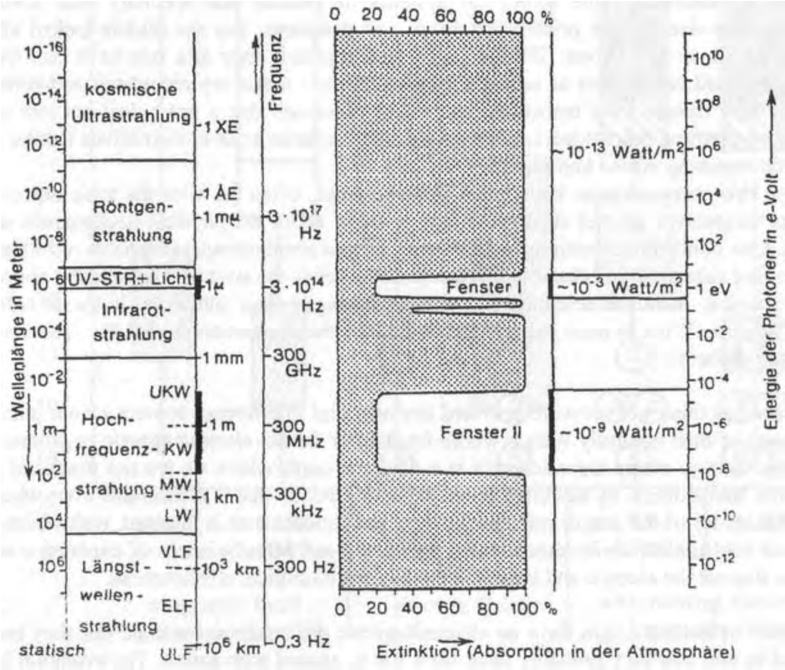

Fig. 2.8: Absorption dependent on frequency in the atmosphere

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<i>: entnommen aus: H.L. Konig: Unsichtbare Umwelt (Wetterfuhligk.), 5. Aufl., Bild 8, Seite 14, Verl. Moos & Partner Milnchen, ISBN 3-89164-058-7

2.8 Natural fields

Our electromagnetic environment has something to offer:
From the magnetic north pole to the magnetic south pole of the earth run the field lines of the earth's magnetic field that we are exposed to. With a compass we use the vector character of the magnetic field to fix our position. The induction averaged over time is approx. 50 uT. But it is overlapped by short-time fluctuations caused by geomagnetic storms in the ionosphere.

These storms again are caused by the eddy currents and the currents of charged particles that come from the sun. At the same time these eddy currents in the ionosphere together with the earth's magnetic field form a protective shield with a excellent screening effect for us inhabitants of earth.
In several layers like for instance the ozone and Heaviside layers a filtering and damping until the complete suppression of the very broad cosmic spectrum is caused. This extraterrestrial spectrum of radiation doesn't leave a single frequency out and has a lethal intensity for us.

Only for a little window in the frequency spectrum, radiation can pass almost undamped, as can be seen in fig. 2.8: the light with the spectrum of the colors. For this nature has donated man a sense organ so that man can protect himself against too high dose values. After all, who will look voluntarily into the sun? We only get into trouble when our sense organ doesn't function any more (for instance in the fringe range of the visible spectrum, the UV-range).

For other frequencies of electromagnetic radiation man neither has a sense organ but that doesn't mean that he is not influenced by these. Here, as in the UV-range he only indirectly notices that he has got too high a dose when he has to discover some influences on his well-being and his health. Without the help of neutral measurement apparatus he himself by no means is in a position to make a connection between an excessive exposition to radiation and his health problems.

When natural field strengths should be used as a measure for technical limits, so there should be paid attention to the fact that nature doesn't know intense continuous irradiation. The values are subject to powerful fluctuations that leave men and nature the chance to regenerate.
The television stations not even think it is necessary to reduce their broadcasting power after the end of broadcasts and further sprinkle the sleeping population with test signals, with senseless pictures of going by underground or nonstop program advertisements. People need the intermissions. That again shows how good nature means it with us.

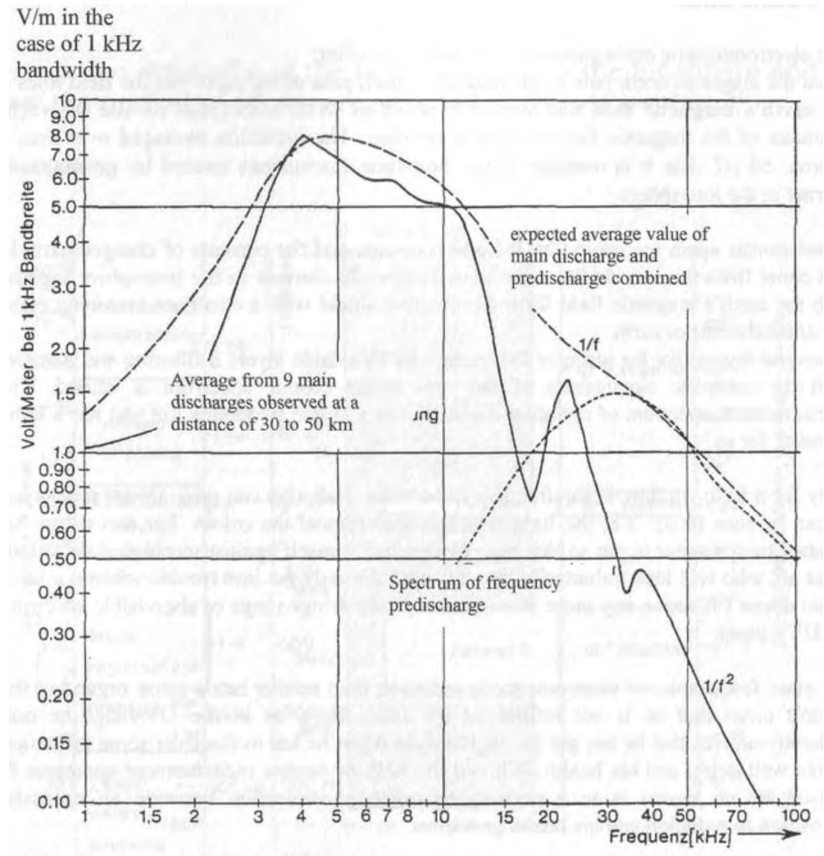

Fig. 2.9: Spectrum of frequency of one lightning, measured
field strength at a distance of 1.6 km from the place of origin. See Watt and Maxwell:<i,ii>

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from:
<i>: H.L. Konig: Unsichtbare Umwelt (Wetterfuhligk.), 5.Aufl., Bild 38, Seite 27, Verl. Moos & Partner Munchen, ISBN 3-89164-058-7, see <ii>.

2.9 Electricity of the air

The electrostatic field strength of the earth lies between 50 and 500 V/m. That is a whole lot considering that voltages off 60 Volts can be lethal for man. But a living person distorts the terrestrial E-field for reason of his own field and his electric conductivity, so that there exists no danger for him as long as he doesn't grow into the sky.

Maybe the dinosaurs had to become extinct because they were to big and for instance the E-field near the ground had risen with a jump by a meteorite that brought a high charge from the cosmos. That would explain why the smaller living beings could survive the natural disaster.

Also the thunderstorm electricity can become life-threatening. Burns, heart and brain failures are the most common consequences. After all the probability to be struck by lightning is four times higher as to have six right ones in the lottery.
Over the lightning channel of approx. 1 meter in diameter charges between 10 and 200 C are transported what results in current strengths of 2000 up to 200,000 A. The main discharge lasts between 10 and 50 usec. With the preceding and all the following discharges it lasts over a second.
Field strengths on the scale of 4,000 V/m are typical but in a distance of 5 km these wear off to 8 V/m. The frequency spectrum of a lightning reaches 4 powers of ten into the range of the radio waves. In fig. 2.9 is shown the field strength measured in a distance of 1.6 km from the place of origin[i,ii].

The origin of lightnings is still an unsolved problem after the well-known models (Wilson) arc not in a position to explain the reason for the origin of the potential difference of more than 100 million Volts required for the ionization of the air. Also the lightnings that struck in the direction of the ionosphere still are mysterious.
We'll have to come back to this[iii].

<i>: H.L. Konig: Unsichtbare Umwelt (Wetterfuhligkeit), 5. Aufl., Bild 38, Seite 27, Verlag Moos & Partner Munchen, ISBN 3-89164-058-7, according to <ii>.

<ii>: A. D. Watt and E. L. Maxwell: Characterisic of Atmospheric Noise from 1 to 100 Kc/s. Symposium on the Propagation of VLF Waves, Boulder, Col., Paper 35, Jan. 1957.

<iii>: see Part 1, chapter 5.4 and part 2, chapter 14.11.

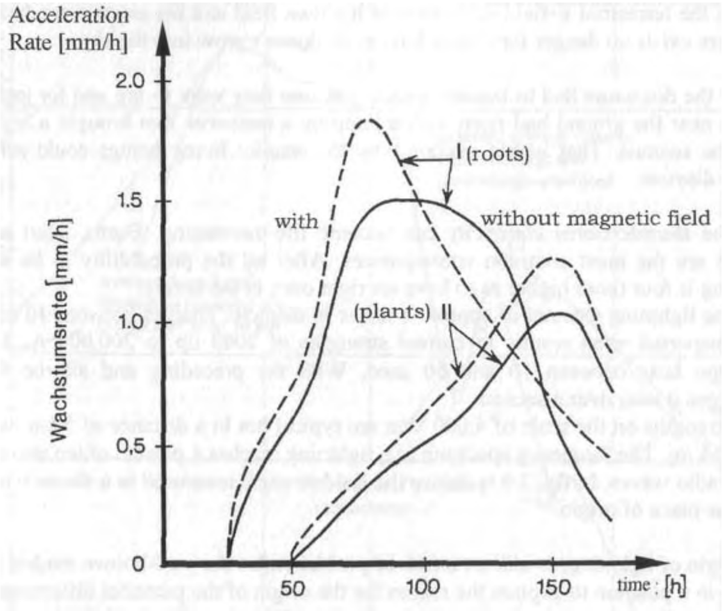

Fig. 2.10 A: Effect of a static magnetic field of 100 kA/m (0,12 Tesla) on the root (I) and on the plant (II) of barley seeds.
plants in the magnetic field: dotted line
plants for checking: drawn line
according to Novitskii[iii]

<iii>: Novitskii, Yu.I.: Effects of a magnetic field on the dry seeds of some cereals. Proceedings of Conference on the Effect of Magnetic Fields on Biological Objects, Moscow, p. 52, 1966.
Taken from: H.L. Konig: Unsichtbare Umwelt (Wetterfuhligkeit), 5. Aufl., Bild 72, S. 73, Verlag Moos & Partner Munchen, ISBN 3-89164-058-7

2.10 Biological effects

The in fig. 2.1 indicated connection between the EMC and the BC, by some authors inofficially described as EMC-environment (EMCE), describes the effect of artificial fields on biological systems. This concerns the sensitive range of tasks that is discussed extremely controversially in the public. The problem thereby is that the artificially produced field strengths lie above the natural field strengths for several scales. In the thirties first reports about troubles were provided by navy radio operators that complained about headache, dizzyness, concentration failure and indisposition. Besides these negative reports concerning the so called "radio operator disease" at the same time medical usages concerning high-frequency therapy were tested. In the beginning this diathermy called healing method still was a short wave irradiation. Today it is extended into the microwave range and uses the thermal effect of electromagnetic rays. The increased temperature of the tissue causes an increased local blood flow. This supports healing processes, loosens cramped muscles and can help in case of rheumatic fever. The advantage of the HF-irradiation compared to contact heat by a hot-water bottle or by infrared rays is the higher penetration depth. Herein short waves are superior to microwaves. But microwaves can be better focussed on a certain part of the body. Is the temperature further increased, so the tissue is damaged. This is used for the treatment of cancer and is called hyperthermy. Because cancer cells as a rule are flowed with blood worse than healthy cells, they are more sensitive to heat and therefore are faster destroyed than healthy cells at a correspondingly increased temperature. In this way for Instance in the USA cattle with a so called cancer eye are treated. For that the spot suffering from cancer is irradiated with 2MHz-waves for 30 seconds with a handheld apparatus of 10 Watts broadcasting power. The rate of succes is given to be 90%! The method of hyperthermy has not yet been able to establish in the area of the medicine for humans. Also at our college corresponding research work is carried out in co-operation with the radiological clinic of the university of Freiburg (Germany)<i>.

The thermal effects of high-frequency fields are therefore well-known and subject of scientific research. On the other hand and in spite of numerous publications, non-thermal effects even today are denied by some scientists as non-existent<ii>. Here only a few counter-examples will be listed.

Fig. 2.10 A shows the effect of a static magnetic field of 0.12 Tesla on the root (1) and on thc plant (II) of barley seeds. The readable effect is an acceleration of the growth of the treated seeds (dotted line) compared to the plants for checking (drawn line)<iii>.

<i>: H. Schulz, W. Oppitz: Lokale Hyperthermie durch hochfrequente Wirbelstrome, Medizin Technik 1, 1987.

<ii>: G. Nimtz: Mikrowellen, Einfuhrung in Theorie und Anwendung. 2. Aufl., BI-Wissenschaftsverlag 1990, ISBN 3-411-03203-0

<iii>: Novitskii, Yu.I.: Effects of a magnetic field on the dry seeds of some cereals. Proceedings of Conference on the Effect of Magnetic Fields on Biological Objects, Moscow, p. 52, 1966; taken from: H.L. Konig: Unsichtbare Umwelt, fig.72, p. 73, Verlag Moos & Partner Munchen, ISBN 3-89164-058-7

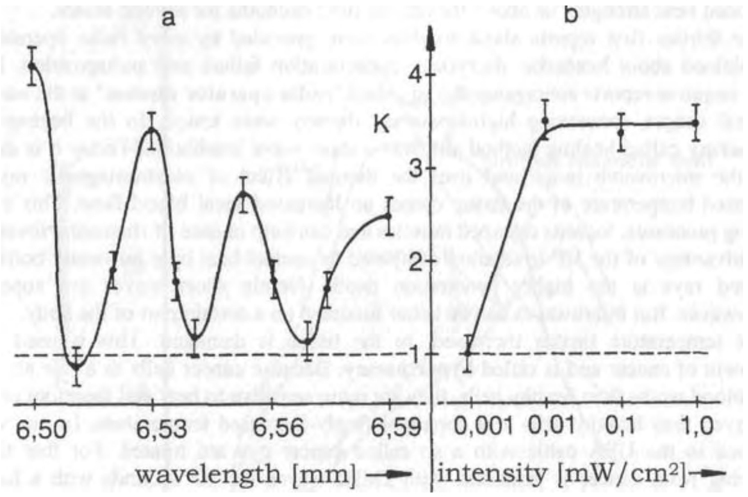

Fig. 2.10 B: Measured increase in the production (K) of colicin by colibacteria as a microwave effect

a) as a function of the wavelength,
b) as a function of the intensity of the microwaves,

according to Keilmann<i>.

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taken from:
<i>: H. L. Konig: Unsichtbare Umwelt (Wetterfuhligkeit), 5. Aufl., Bild 106, S. 111. Verlag Moos & Partner Munchen, ISBN 3-89164-058-7

A static field naturally produces no induction and hence no heating will arise. In the case of alternating fields the thermal effect in experiments is excluded by working with cxtremly low stimulations. The example after fig. 2.10 B shows the measured increase in the production (K) of colicin by colibacteria at only 0.01 mW/cm^2 microwave power<i>.

In addition the example provides the interesting information that obviously only a certain frequency and it's harmonic waves increase the production, other frequencies on the other hand remain inactive. Because only minimal field strengths are used it more likely concerns an information-technical as an energetic effect (curve a). This statement is supported by the observation that an increase of the intensity not at all necessarily as a consequence also increases the production (curve b). What the colibakteria need is obviously neither energy nor heat but only a certain frequency that stimulates the colicin production or the growth.

Should it really be confirmed that biological effects of electric and magnetic fields can be produced by certain frequencies and can't happen by an energy transition so the discussions about limits must seem ample meaningless.

Maybe the one or the other in thought already draws a connection to the acceleration, the acclerated growth of kids, which is observed world-wide and stronger in cities than in the country. It started for approx. 100 years simultaneous with the electrification of the homes in the towns. In Asia the acceleration and also the electrification have started later. Other growth stimulating effects like radio waves, X-ray examinations, atomic tests and provable also the nourishment with vitamin B6 happened only until much later and at the most could support the actual effect.

But how should a proof be offered when anyway the field strength not at all can have a decisive influence on the growth of man after the statement of fig. 2.10 B? Which information is authorative? Where lies the responsible frequency window? Does the information actually manifest as frequency? Is the authorative influential factor also in this case not at all noticed and measured?

A lot of pressing questions are still outstanding. But in any case the numerous influential factors detected in experiments do not at all let themselves reduce to a sole factor, for instance the nourishment. For a family doctor it may be comfortable to be able to give an easy explanation: „Cause is the nourishment!" With such a reductionism on the other hand the actual cause stays in the dark and the asked questions in this way won't let themselves be answered.

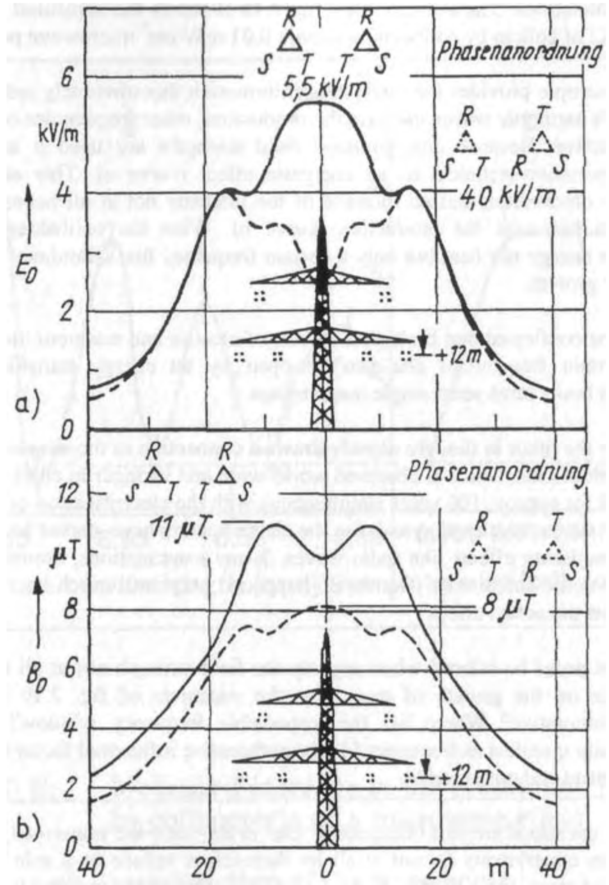

Fig. 2. 11: ____ profile of the 50-Hz-field on the ground at 380kV/1kA in each circuit.<i>
a) electric field,
b) magnetic field.

____ taken from:

<i>: E. Habiger u. a.: Elektromagnetische Vertraglichkeit, fig. 7.3, page 147 and Fig. 7.1, page 146, 2nd Ed., 1992. Berlin, Miinchen: Verlag Technik.

2.11 Artificial fields

The scepticism of people feeling close to nature is especially directed against artificial fields that man can't see nor hear nor smell. Objects of doubt are first of all the installations for the creation, distribution and conversion of electric energy.

An essential role plays the fact how close the supplying and the draining conductors are to each other, so that the respective fields can compensate each other. The worst solution one can think of is realized at the electrified railway. Here the rails and the earth are used as the draining conductor for the current while there exists an ample large distance to the supplying conductor. A compensation is almost impossible thus causing gigantic interference fields that are detectable even at a distance of 10 kilometers. The increased putting on of railway engines feeded by rectified current is likely to aggravate the set of problems because the non-sinusoidal absorption of current is strongly afflicted with harmonic waves.
With high tension transmission lines (fig. 2.11) the interference field strength is reduced when the three cables are suspended with only little distance between them. But even the selected phase order can play a role. Of course the optimal compensation effect is guaranteed with cables in the earth. But these are expensive and technically not realizable for such high voltage levels.

In the eighties also the computer screens got in the headlines. The terminals are furnished with a cathode ray tube and have a very broad radiation spectrum that already starts at 0 Hz. Here already static maximum values of 64 kV/m are measured[i]!

I'requency range	Measured maximum values E_{max} resp. H_{max}	30 cm in front of the screen
static field (0 Hz)	64 kV/m	
30 Hz. 60 Hz	10 V/m and	
	0.2 - 1 A/m	
5 Hz - 1 kHz	1800 V/m and	10 V/m and
	4 A/m	0,6 A/m
50 Hz - 0,5 MHz	1 A/m	
15 kHz-220 kHz	50 V/m and	15 V/m and
	1.1 A/m	0,17 A/m
3 MHz -300 MHz	< 0,2 V/m	

Fig. 2.11: Electromagnetic fields from screens[i]

system about	used frequency	measured value
radio broadcasting station (MW 2O kW)	6OO kHz	2...17 V/m
radio broadcasting station (SW 1OO kW)	15 MHz	1...25 V/m
SOS-transmitter on a ship (1OO W)	41O kHz	1...3 V/m
Epitaxiedevice (induction oven)	45O kHz	37...4OO V/m
HF-welting press (welding of plastic foils)	27,12 MHz	70...85 V/m
radar on a ship (TRN 311)	9,3 GHz	1...3O uW/cm^2
radar of an airplane	9,2 GHz	45O... 28OO uW/cm^2
domestic appliances measured in a distance		of 3O cm:
hand mixer	5O Hz	5O V/m
refrigerator	5O Hz	6O V/m

Fig. 2.12: ____the electric field strength resp. Power density in our environment.<i>

____ taken from:

<i>: E. Habiger u. a. : Elektromagnetische Vertraglichkeit, Fig. 7.2, page 146, 2. Ed., 1992, Berlin, Munchen: Verlag Technik, ISBN 3-341-00993-0

2.12 Protection against artificial fields

Artificial fields more or less always occur in the neighbourhood of electric apparatus and installations. Especially problematic are those that work with the free radiation of electromagnetic fields, that is all the radio broadcasting stations, handheld and radar transmitters.
Herewith it is important that not needed parts of the antennas are shielded, that antennas with little close by field pollution are used and that the stand should be situated at least 3 km remote from inhabited areas. For instance at radar installations damping values of 10 dB and more can be obtained only by using a corresponding tree growth.
This obviously concerns a damping of the waves in a dielectric manner. We'll have to come back to this because textbook physics does not know a corresponding damping term in the wave equation.

The radiation leaking out in case of the high-frequency welding of plastic foils and of the microwave oven should be minimized.
In the case of induction ovens or of motors an active shielding often causes problems so that for simple domestic appliances like a hand mixer and especially for the electric hair-dryer non proportionally high field strength values are measured. Fig. 2.12 informs about it.
Protective measures for the operator are hardly possible. To protect uninvolved people not only the apparatus but also the rooms and eventually whole parts of buildings had to be shielded and grounded.

Sometimes also fairly simple possibilities are helpful like e.g. the usage of a remote control. By clearing away the cable salat at the workplace and at the sleeping place induction loops can be removed. Alarm-clocks operated by batteries should have preference over those operated by the network. Mattresses with metal in them and spring-beds which clearly act as an antenna should be avoided. In extreme cases even so called "current-free switches" and shielded network lines are recommended (fig. 2.13).

In the area of the network supply lines a choking coil can help decrease the spreading of high-frequency interference radiation. It is especially important that all the conducting metallic objects like e.g. water pipes, heatings, steel racks, machines, switching racks, steel armaments and metallic windows should be grounded properly, because otherwise extremly high static charges could result instead of a shielding. Construction biologists recommend to when possible do without metals when building houses and furnishing, what of course is only realizable with limitation.

In any case numerous measures are known that to a lesser extent find their legitimation in classical physics, but more likely in precaution. As long as we do not know which phenomenon causes the electrosmog and we don't have a measuring-instrument at our disposal, precaution is really the only thing we can do irrespective of the effectiveness of the measures and of the arising costs!

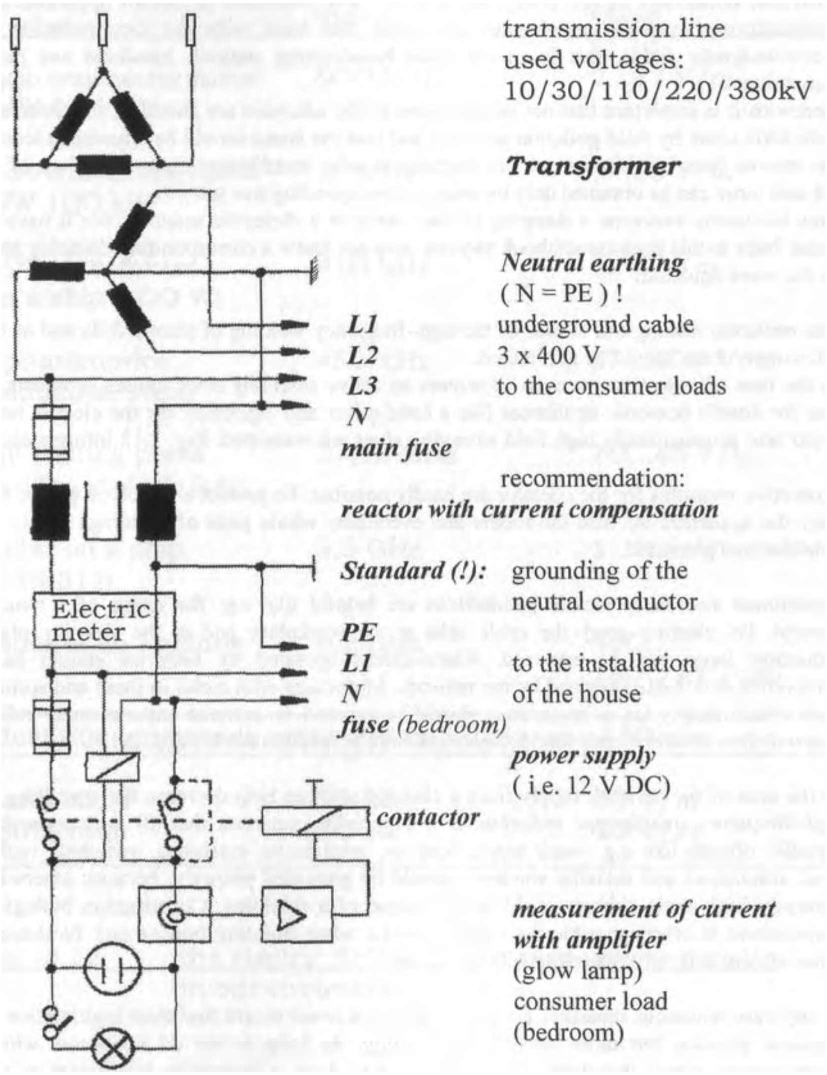
transmission line
used voltages:
10/30/110/220/380kV
Transformer
Neutral earthing
(N = PE) !
L1
L2
L3
N
underground cable
3 x 400 V
to the consumer loads
main fuse
recommendation:
reactor with current compensation
Standard (!):
grounding of the
neutral conductor
Electric meter
PE
L1
N
to the installation
of the house
fuse (bedroom)
power supply
(i.e. 12 V DC)
contactor
measurement of current
with amplifier
(glow lamp)
consumer load
(bedroom)

Fig. 2.13: About the circuitry and the problems involved with a "current-free switches" installation

2.13 Unsolved tasks

The report concerning the actual state of research could be continued at will. But the expositions should suffice, to understand what are the tasks of the electromagnetic environmental compatibility (fig. 2.1) and which questions still have to be supplied with a solution. One can get deeper into every of the addressed points and then discover that some questions can be expressed sharper and maybe conceivable answers can be found, but at the same time and unavoidable the number of new questions increases faster.

Let us again take up the example of the handheld wireless telephones (chapter 1.2). At least it now is clear to us that the usage of the built-in microwave antenna of a handy is problematic. In the interior of an automobile it never should be used. If, however, one uses the antenna installed on the outside on the sheet metal then the damping and screening effect of the sheet metal chassis is advantageous at least for the handy user.

With that of course the central question is not answered. The question of what the cause is for the interfering and at worst health endangering effect of the HF-radiation. Field freedom we can't find anywhere on this world. Possibly we even need the fields. But then the question is how much is necessary, how much is healthy and how much makes us ill.

The gap of explanation especially gets clear in the case of the static or of the low-frequency magnetic field: away from technical interference sources normally fields on the scale of 10 nT are measurable. Construction biologists say that 20 nT, so twice that value, should not be exceeded at the sleeping place and maybe 50 nT at the desk. These values however are determined purely empirical.

When a person is examined in a nuclear magnetic resonance tomograph that person is exposed to a field that lies between 0.2 and 1.5 Tesla. that is a value 7 till 8 powers often higher than before mentioned without this leading to the death of that person. Entirely on the contrary this method is regarded as especially caring and safe compared to the X-ray examination.

Here again the legitimation of the thesis put forward is entirely comfirmed. The thesis that the well-known physically measurable and controllable phenomena can not be considered as a cause and that possibly a until now undiscovered field phenomenon should be called to account.

Should such a phenomenon exist it should be derived, calculated and proved. We must go to endless troubles and try everything. The actual difficulties wherein the electromagnetic environmental compatibility is stuck are a challenge.

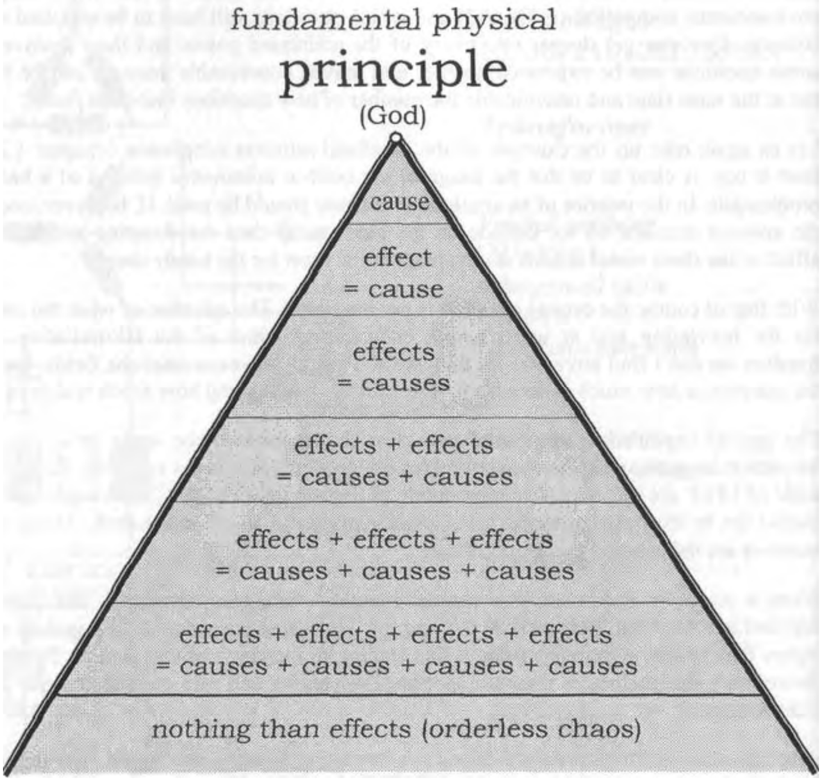
fundamental physical
principle
(God)
cause
effect
= cause
effects
= causes
effects + effects
= causes + causes
effects + effects + effects
= causes + causes + causes
effects + effects + effects + effects
= causes + causes + causes + causes
nothing than effects (orderless chaos)

Fig. 3.0: pyramid of causality

vortices are a consequence of the principle of causality

3. Approach

In the question, if there exists a still unknown phenomenon that influences the electromagnetic environmental compatibility, we must fall back far until upon the roots of our physical understanding. Here we find a fundamental principle that until today is not doubted and that is regarded as elementary, the principle of causality. Every result of a measurement, every interpretation is checked for causality and only after passing this examination it is accepted and published.

This principle of cause and effect has established, not only in physics but also in many other disciplines of science. Is an effect observed, so there immediately is asked for the cause. This principle encounters us in daily life<i>.

When all observable and measurable effects ever can be assigned to a cause without force and without exceptional regulations then the logical result is a pyramid of causality. On top a fundamental physical principle is found, that is regarded as given by nature or as given by god and that with its properties is responsible as the cause for different effects. These effects again appear as the cause for new effects and so on (Fig. 3.0). Sometime we have removed us so far from the top of the pyramid that a direct reference to the describable effects can't be made anymore, so the impression could arise that it concerns an isolated and independent discipline. We should take care not to think in such a monocausal way, because both delimitation and avoidance of interdisciplinary working methods will inevitably steer us into a dead end!

This pyramid of causality stands for the vision of a "unified theory", like it is demanded and sought-after by numerous research scientists. But as long as it is not found, we'll have to do with unsolved problems of causality. About this any number of examples can be given.

A physical principle based on the principle of causality is the vortex. This the eddy current demonstrates us clearly. The cause for its origin is an alternating field. According to Faraday's law of induction this induces a voltage that in a conducting medium results in a current according to Ohm's law. Around this current according to Ampere's law an alternating field forms, that points perpendicular to the current and overlaps the original alternafing field. This induced field first of all is an effect that overlaps the cause and itself becomes the cause. The effect that follows from that further overlaps and forms a new cause etc. In this way vortices form.

Vortices quasi represent the principle of causality.

<i>: When for instance a woman complains: "Doctor, my left knee hurts" (effect). The doctor diagnoses the cause: "Yes, that comes with age!" With that causality is established. "But doctor", says the woman, "my right knee is exactly as old as my left knee!" And already the doctor has a new problem of causality.

Principle of Causality:

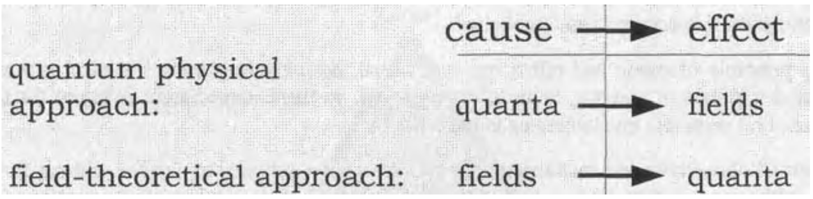

	cause	→	effect
quantum physical approach:	quanta	→	fields
field-theoretical approach:	fields	→	quanta

---

violations of the principle of causality:

1. monopoles exist
2. starting point for the strong interaction
3. fields and quanta are a cause at the same time
4. hypothetical particles (gluons, quarks, etc.)
5. transmission of information with speeds faster than light
    - with photons (University of Berkeley)
    - with microwaves (University of Cologne)
    - with laser beams (Technical Univ. of Vienna)
6. transmission of energy with speeds faster than light
    - with scalar waves (Nicola Tesla)

Fig. 3.1: Causality or the principle of cause and effect

3.1 Principle of causality

Our physical view of life strictly obeys the rules of causality, the principle of cause and effect. But there are numerous cases, where causality at first could not be fulfilled anymore. Here alternate solutions had to be found to not endanger this very successful principle. A few examples should clarify this:

1. Technically it is impossible to produce a magnetic monopole. When a north pole is produced then the accompanying south pole is also formed. In the same way only the positive and negative pole can be assembled as the so called dipole. In the microcosm however we find monopoles. Electrons are such particles. To restore causality we must grant the microcosm its own laws that are not valid in the macrocosm! But this monocausal hypothesis contradicts the observation that the microcosm represents an image of the macrocosm and vice versa. Doubts if this assertion is allowed are reasonable.
2. Like charges repel each other and that the more the smaller the distance gets. In an atomic nucleus positively like charged protons are together at the smallest possible room without any repulsion happening. Arithmetically seen all atomic nuclei would have to explosively fly to pieces. But because this doesn't happen, shortly a new and supposedly fundamental interaction, the strong interaction, was introduced to save causality. Nevertheless this interaction now holds the like particles in a not explained manner together. Causality could be obtained only by the introduction of a new fundamental phenomenon.
3. When causality should hold as the supreme principle, it should be demanded with priority for the fundamental phenomena of physics. Instead, in quantum electrodynamics the particle is attributed the same physical reality as the field. With the wave-particle duality Heisenberg has given out the corresponding formula of compromise. This slaps the face of the principle of cause and effect.

Causality on principle allows only two approaches for a solution: the quantum physical approach. which holds the quanta as the cause for the fields, and the field-theoretical ašproach. wherein only the fields act as the cause. For both approaches there are good arguments. The field theorists cite that fields can exist also in the vacuum, so that there exist fields without particles but never particles without fields. Against that the quantum physicists hold that somewhere, even when quite far away, there exist particles and that the measurable fields merely are their action at a distance.

Both approaches first arouse the impression to be fully equal. In the course of the discoveries in the area of quantum physics, the corresponding approach has been able to establish. But it demands that all phenomena have to be understood as a consequence of particles. So should gravitons make gravitation possible, should gluons hold everything together and the quarks form the basic building parts. Meanwhile there is only worked with hypotheses. Out of poverty quantum physics meanwhile has said goodbye to strict causality, after the number of the violations of causality has risen that much and in every respect there is a lack of models of explanation. It seems as if the end is reached, as if the quantum physical approach to a large extend is exhausted.

Field-theoretical approach:

3rd Maxwell equation

$$\boxed{\text{Div}\,\mathbf{B} = 0} \quad (3.3)$$

4th Maxwell equation

$$\boxed{\text{Div}\,\mathbf{D} = \rho_{el}} \quad (3.4)$$

With the relations of material:

$$\boxed{\mathbf{B} = \mu \cdot \mathbf{H}} \quad (3.5)$$

$$\boxed{\mathbf{D} = \varepsilon \cdot \mathbf{E}} \quad (3.6)$$

$$\mu \cdot \text{Div}\,\mathbf{H} = 0 \quad (3.3^*)$$

$$\varepsilon \cdot \text{Div}\,\mathbf{E} = \rho_{el} \quad (3.4^*)$$

H: source free vortex field

E: non-vortical source field

New field-theoretical approach: $\boxed{\text{Div}\,\mathbf{D} = 0}$ (3.7)

thus: $\text{Div}\,\mathbf{H} = 0$ (3.3**) and $\boxed{\text{Div}\,\mathbf{E} = 0}$ (3.7*)

H and **E**: source free vortex fields!

Einstein:

> "Is it conceivable, that a field theory permits us to understand the atomistic and quantum structure of reality? This question by almost all is answered with No. But I believe that at the moment nobody knows anything reliable about it"<i>.

Pauli:

> "The electric elementary quantum e is a stranger in Maxwell-Lorentz' electrodynamics"<ii>.

Fig. 3.2: The field-theoretical approach

<i>: A. Einstein: Grundzuge der Relativitatstheorie, S 162, Anhang II; 5. Aufl., Vieweg, Braunschweig 1974.

<ii>: W. Pauli: Aufsatze und Vortrage uber Physik und Erkenntnistheorie. Vieweg, Braunschweig 1961, entnommen aus:
H. G. Kussner: Grundlagen einer einheitlichen Theorie der physikalischen Teilchen und Felder. Musterschmidt-Verlag Gottingen 1976, S. 161.

3.2 Field-theoretical approach

The field-theoretical approach is the very much older one. Until the last turn of the century the world in this respect still was in order. Max Planck, by the discovery of quanta, has plunged physics into a crisis.
Albert Einstein, who, apart from his lightquanta hypothesis, in his soul actually was a field theorist, writes: „Is it feasible that a field theory allows us to understand the atomistic and quantum structure of reality?". This question by almost all is answered with No. But I believe that at present nobody knows anything reliable about it[i]".

By the way the "No" can be justified by the fact that the field description after Maxwell is by no means able to the formation of structure so that it is not possible for quanta to appear as a consequence. The field-theoretical approach could, obstructed by Maxwell's field theory, not further be pursued and to this until today nothing has changed.
Nevertheless it would be an omission to not at least have tried this approach and have it examined for its efficiency. Maybe the above mentioned problems of causality let themselves be solved much more elegantly. For this however the Maxwell theory must be reworked to a pure field theory. With the well-known formulation it offends against the claim of causality, since it is field theory and quantum theory at the same time. To Maxwell himself the quanta were still unknown, but today we know that the fourth Maxwell equation is a quantum equation:

$$\mathrm{div}\, \mathbf{D} = \rho_{el} \quad (3.4)$$

After this the electric field is a source field whereby the individual charge carriers, like e.g. electrons, act as sources to form in their sum the space charge density p_{el}. The other three Maxwell equations are pure wave equations. In this way the third equation identifies the magnetic field as source free:

$$\mathrm{div}\, B = O \quad . \qquad (3.3)$$

This for Pauli probably was the reason to call, "the electric elementary quantum e^- a stranger in Maxwell-Lorentz' electrodynamics"[ii].

Let's return to the principle of causality according to which in the field-theoretical approach the fields should act as a cause and not the particles. In a corresponding field description quanta logically have not lost anything. It is only consistent to likewise demand freedom of sources of the electric field:

$$\mathrm{Div}\, D = O \quad . \qquad (3.7)$$

When the electric field is not a source field, then what is it? The magnetic field is a vortex field. Hence it would be obvious to also conceive the electric field as a vortex field. Numerous reasons speak for it:

1. A non-vortical gradient field, like it is formed by charge carriers, merely represents a special case of the general vortex field. Only by the generation of quanta a source field can form as a special case.
2. The electromagnetic wave teaches us the duality between the E- and the H-field that are directed perpendicular to each other and are in a fixed relation to each other. If one of them is a vortex field then also the dual field must be a vortex field.

Duality:

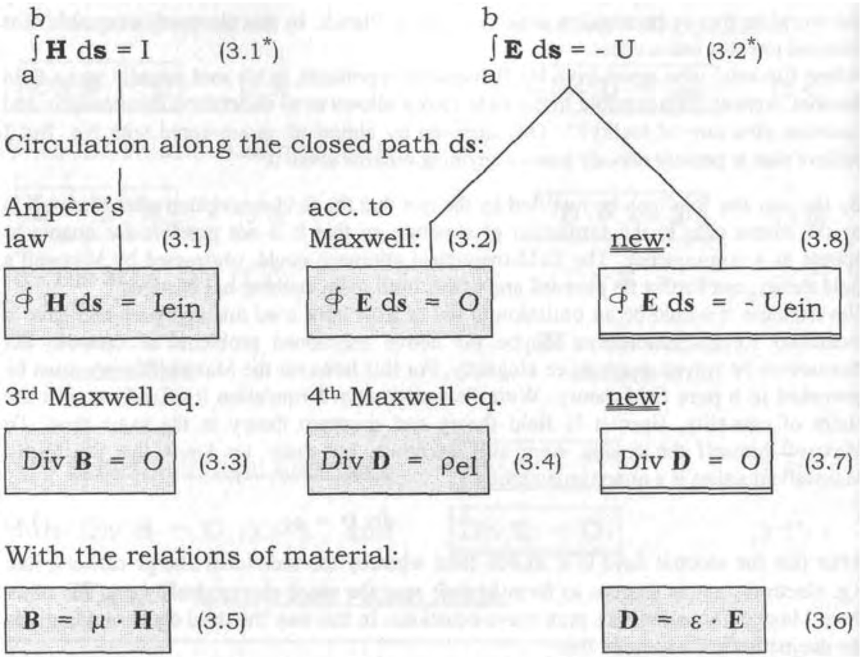
$\int_a^b \mathbf{H}\, ds = I$ (3.1*)
$\int_a^b \mathbf{E}\, ds = -U$ (3.2*)
Circulation along the closed path ds:
Ampère's law (3.1)
acc. to Maxwell: (3.2)
new: (3.8)
$\oint \mathbf{H}\, ds = I_{ein}$
$\oint \mathbf{E}\, ds = 0$
$\oint \mathbf{E}\, ds = -U_{ein}$
3rd Maxwell eq.
4th Maxwell eq.
new:
$\mathrm{Div}\,\mathbf{B} = 0$ (3.3)
$\mathrm{Div}\,\mathbf{D} = \rho_{el}$ (3.4)
$\mathrm{Div}\,\mathbf{D} = 0$ (3.7)
With the relations of material:
$\mathbf{B} = \mu \cdot \mathbf{H}$ (3.5)
$\mathbf{D} = \varepsilon \cdot \mathbf{E}$ (3.6)

Fig. 3.3: The dual field description

Dual approach according to Jackson[i] or Lehner[ii]:

$\mathrm{Div}\,B = \rho_{magn}$ because of the 4th Maxwell equation: $\mathrm{Div}\ D = \rho_{el}$ (3.4)

$\rho_{magn} =$ magnetic monopoles should exist,
otherwise dual extension (3.8) not allowed!

Caution: closed loop conclusion!
Maxwell theory proves the correctness of the Maxwell theory.
Result: search for magnetic monopoles unsuccessful.

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[i] J. D. Jackson, Classical Electrodynamics, 2nd Ed. , John Wiley, New York, 1975, S. 251 - 253

[ii] G. Lehner, Elektromagnetische Feldtheorie, Springer-Verlag Berlin, Heidelberg 1990, S. 35 - 36 und S. 533 ff.

3.3 Duality

Duality is a fundamental physical principle. Opposite, but one another complementing phenomena can be assigned to each other in pairs, like e.g. (see fig. 8.8):

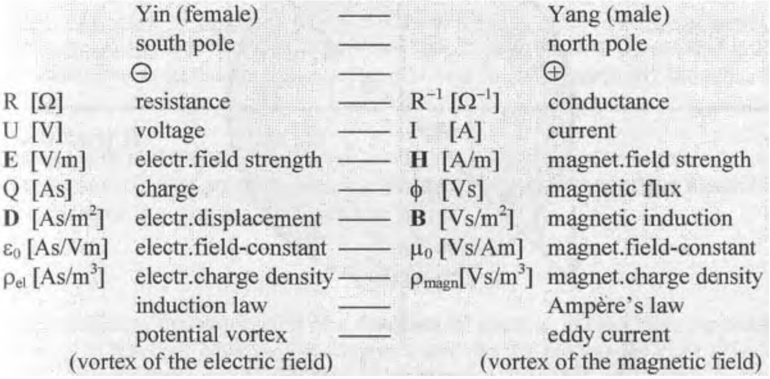

	Yin (female)	——		Yang (male)
	south pole	——		north pole
	⊖	——		⊕
R [Ω]	resistance	——	R^{-1} [Ω^{-1}]	conductance
U [V]	voltage	——	I [A]	current
E [V/m]	electr.field strength	——	**H** [A/m]	magnet.field strength
Q [As]	charge	——	ϕ [Vs]	magnetic flux
D [As/m^2]	electr.displacement	——	**B** [Vs/m^2]	magnetic induction
ε_0 [As/Vm]	electr.field-constant	——	μ_0 [Vs/Am]	magnet.field-constant
ρ_{el} [As/m^3]	electr.charge density	——	ρ_{magn}[Vs/m^3]	magnet.charge density
	induction law	——		Ampère's law
	potential vortex	——		eddy current
	(vortex of the electric field)			(vortex of the magnetic field)

First of all we find the duality confirmed in the case of the electromagnetic wave spreading in a homogeneous medium. Here the field pointers of E and H are directed perpendicular to each other and are in a fixed relation to each other. But if the wave is damped in the presence of matter, for instance by eddy currents, then by basing on Maxwell's field theory the duality will vanish.

A good example for perfect duality provides the integral of a field strength vector along the path from a to b:

$$\int_a^b \mathbf{H}\, ds = I \qquad (3.1^*) \qquad \text{and} \qquad \int_b^a \mathbf{E}\, ds = U \quad . \qquad (3.2^*)$$

Urn if the integration takes place along a closed path then the circulation yields:

$$\oint \mathbf{H}\, ds = I_{eing} \qquad (3.1) \qquad \text{and} \qquad \oint \mathbf{E}\, ds = 0 \quad . \qquad (3.2)$$

According to Ampere's law (3.1) the magnetic field can thus form enclosed currents and spatially spreading eddy currents. The electric field on the other hand should be irrotational (3.2).

Let's take the case that the electromagnetic wave is damped by eddy currents and the magnetic field in this way becomes a vortex field. The electric field itself that, as said, is in a fixed relation and perpendicular to the vortex field H, will show all the vortex-typical properties. Hence nothing would be more obvious as to also grant the electric field a formation of vortices:

$$\oint \mathbf{E}\, ds = -U_{eing} \quad . \qquad (3.8)$$

Critics of this dual approach, like for instance Jackson[i] or Lehner[ii], point out that with reference to the fourth Maxwell equation the electric field should be understood as a source field:

$$\operatorname{div} \mathbf{D} = \rho_{el} \quad . \qquad (3.4)$$

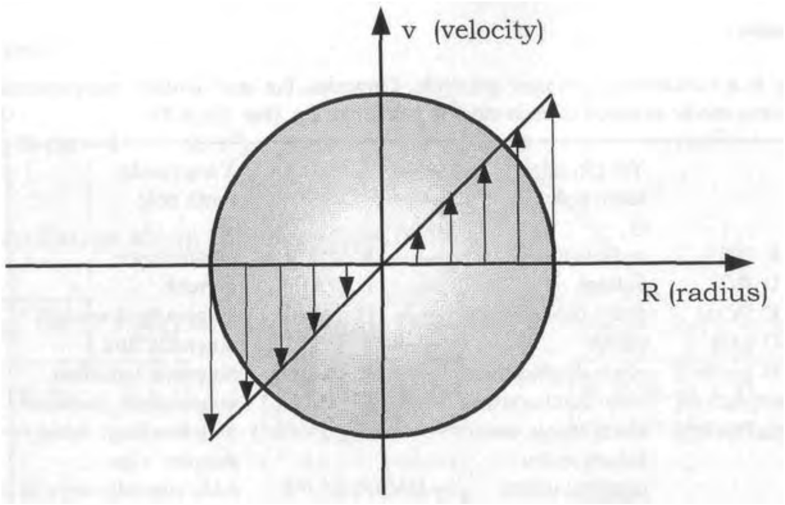
v (velocity)
R (radius)

Fig. 3.4a: Velocity distribution v(R) for a vortex with rigid-body rotation

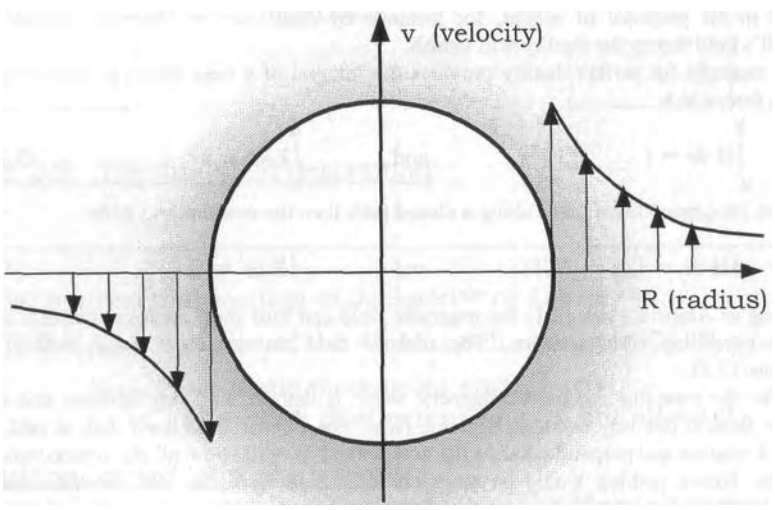
v (velocity)
R (radius)

Fig. 3.4b: Velocity distribution v(R) in a potential vortex (see Lugt[i]).

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[i] Lugt, Hans J.: Vortex flow in nature and technology. Krieger publishing company, Florida 1995; page 30 and 31, ISBN 0-89464-916-7

For a complete duality from the existence of electric monopoles, individual in the space charge density ρ_{el} contained charge carriers, the claim for magnetic monopoles is derived.
In spite of intensive search such north or south pole particles however until now could not be found. Herein from the sight of criticism is seen a confirmation for the assumption that Maxwell's field theory is self-contained and hence in principle may not be extended. The critics have a problem of causality: They postulate source fields that at the same time should be vortex fields. But if one asks how one should imagine such a field that is scalar and at the same time vectorial, then it looks as if no one has ever made any thoughts about it.

The from causality derived solution of the problem of lacking duality requires to extend the Maxwell theory in one point, by introducing the potential vortex of the electric field here and at the same time make a cut in another place:

$$\operatorname{div} D = O \tag{3.7}$$

With this formulation, the assumption of a freedom of sources in principle, the complete duality already is reached: Now neither magnetic nor electric monopoles exist (Fig. 3.3)!
At first we have to accept the loss of the electron hoping that the calculation in the end works out: the "exchange" vortices against particles, by which the quanta can be banned from the field theory, suggests that the elementary particles themselves are nothing else as spherical vortices that have found to an own physical reality.

3.4 Flow vortices

In fluid engineering convincing and strong indications for the correctness of the chosen approach can be found. It benefits us that hydrodynamic vortices are visible or can be the injection of smoke, e.g. in a wind-tunnel.
Already Leonardo da Vinci had observed at liquids that there exist two dual basic types of plane vortices: "Among the vortices one is slower at the centre than at the sides, another is faster at the centre than at the sides."
A vortex of the first type, also called "vortex with rigid-body rotation", is formed for instance by a liquid in a centrifuge that due to its inertia of mass is pressed to the edge because there the largest velocity exists. In an analogous way the electromagnetic vortex in electrically conductive material shows the well-known "skin effect" (Fig. 3.4a).
To explain the other vortex Newton describes the experiment where a rod is dipped into a liquid as viscous as possible and then is turned. In this potential vortex the velocity of the particle increases the closer to the rod it is (Fig. 3.4b).
The duality of both vortex phenomena becomes obvious when we make ourselves clear that in the experiment with the centrifuge the more liquid presses to the edge the less viscous the medium is. And that on the other hand the potential vortex forms the stronger the more viscous the medium is. As conclusion we read in text books that the viscosity of the liquid decides whether a vortex with rigid-body rotation or a potential vortex is formed.

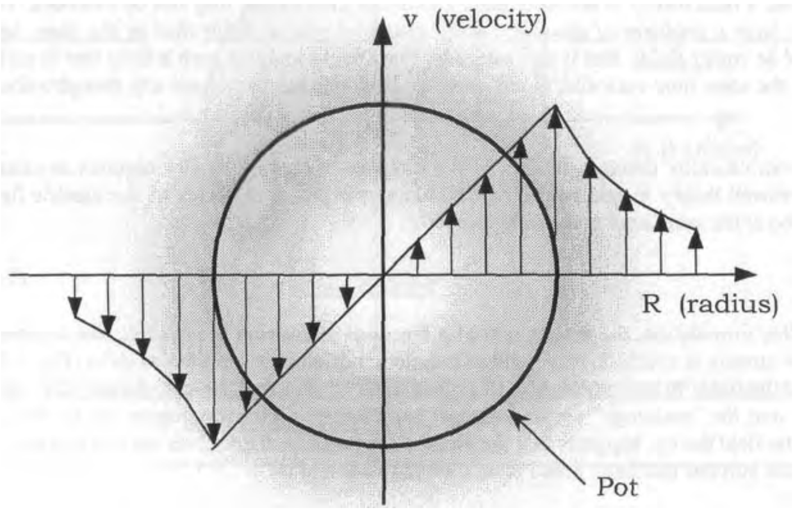

Fig. 3.5: Combination of a vortex with rigid-body rotation and a potential vortex (Lugt[i]).

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[i] Lugt, Hans J.: Vortex flow in nature and technology. Krieger publishing company, Florida 1995; ISBN 0-89464-916-7

3.5 Rankine vortex

When we, in a third experiment, immerse the centrifuge filled with water into a tough medium and let the centrifuge rotate, then inside the centrifuge a vortex with rigid-body rotation forms and outside the centrifuge a potential vortex forms (Fig. 3.5).

It is obvious that one vortex always causes the other vortex with the opposite properties and so the existence of one causes that of the other. So in the first case, that of the vortex with rigid-body rotation, outside the centrifuge potential vortices will form in the surrounding air, whereas in the second case, that of the potential vortices, the turning rod itself can be interpreted as a special case of a vortex with rigid-body rotation. Hence in all conceivable experiments the condition always is fulfilled that in the centre of the vortex the same state of "peace", that we can fix as "zero", prevails as in infinity.

When we take a tornado as an example, thus a whirlwind. In the "eye of the cyclone" there's no wind at all. But when I go away from this spot, then I'm blown to the outside. I can really feel the vortex with rigid-body rotation in the inside. If. however, I am standing on the outside, then the potential vortex tries to pull me into the vortex. This potential vortex is responsible for the structure and in the end also for the size of the tornado.

At the radius of the vortex, the place with the largest speed of the wind, an equilibrium prevails. The vortex with rigid-body rotation and the potential vortex at this point are equally powerful. Their power again is determined by the viscosity, which thereby fixes the radius of the vortex!

Therefore meteorologists pursue with interest whether a tornado forms over land or over water. Over the ocean for instance it sucks itself full with water. In that way the potential vortex increases in power, the radius of the vortex gets smaller and the energy density increases dangerously.

If the knowledge from hydrodynamics is transferred to the area of electromagnetism, then the role of the viscosity is taken over by the electric conductivity. The well-known current eddy occurs in the conductor, whereas its counterpart, the postulated potential vortex, forms in the bad-conducting medium, with preference in the dielectric. The duality of both vortices is expressed by the fact that the electric conductivity of the medium decides whether current eddies or potential vortices can form and how fast they decay, i.e. convert their energy into heat.

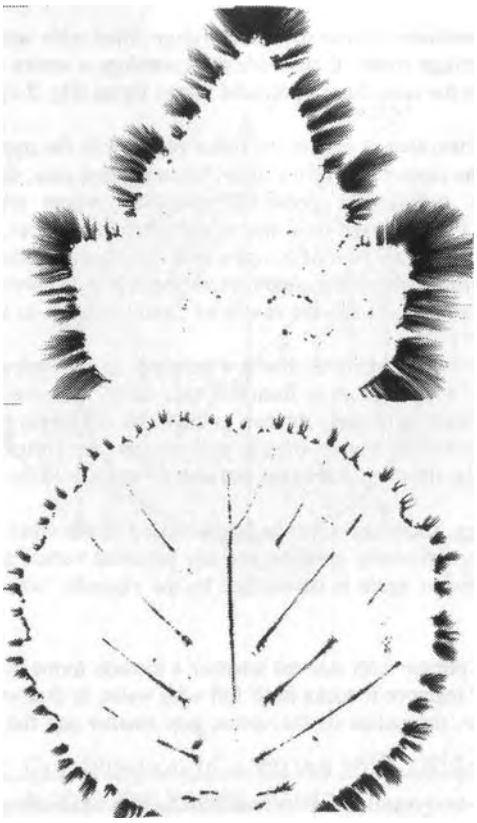

Fig. 3.6: Kirlian photograph of leaves[i] structured corona discharges

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<i>: (produced by students of electronics in the laboratory for power electronics of the Author, University of Applied Sciences Furtwangen 1991)

<ii>: Kupfmuller, Karl: Einfuhrung in die theoretische Elektrotechnik, Springer-Verlag Berlin, 12. Auflage 1988, page 453

<iii>: Kupfmuller, Karl: Einfuhrung in die theoretische Elektrotechnik, Springer-Verlag Berlin, 12. Auflage 1988, page 208

3.6 Vortex and anti-vortex

Fig. 3.5 shows that vortex and dual anti-vortex mutually cause each other. In high tension transmission lines we find a striking example for the combination of current eddy and potential vortex. Within the conductor current eddies are formed. Thus the current density increases towards the surface of the conductor (skin effect). Outside of the conductor, in the air, the alternating fields find a very bad conducting medium. If one follows the text book opinion, then the field outside the conductor should be an irrotational gradient field! But this statement causes unsolvable problems.

When vortices occur inside the conductor, then for reasons of a detachment of the vortices without jumps at the interface to the dielectric, also the fields in the air surrounding the conductor must have the form and the properties of vortices. Nothing would be more obvious as to also mathematically describe and interpret these so-called gradient fields as vortex fields. When looking exact this argument even is mandatory!

The as laws of field refraction known boundary conditions<ii> in addition demand steadiness at the interface of the conductor to the dielectric and don't leave us any other choice. If there is a vortex field on one side, then also the field on the other side is a vortex field, otherwise we offend against the law! Here an obvious failure of the Maxwell theory is present.
Outside the conductor, in the air, where the alternating fields find a very bad conducting medium the potential vortex not only exists theoretical; it even shows itself. Dependent among others on the frequency and the composition of the surface of the conductor, the potenial vortices form around the conductor. When the thereby induced potentials exceed the initial voltage, then impact ionisation takes place and the well-known corona discharge is produced. Everyone of us can hear this as crackling and see the sparkling skin with which high tension transmission lines cover themselves.
In accordance with the text books also a gradient field increases towards the surface of the conductor, but an even shining would be expected and not a crackling. Without potential vortices the observable structure of the corona would remain an unsolved phenomenon of physics (Fig. 3.6).

But even without knowing the structure-shaping property of the potential vortices, that in addition acts supporting and that we'll have to derive, it can be observed well that especially roughness on the surface of the conductor stimulate the formation of vortices and can produce vortices. If one is looking for a reason why with large frequency the very short impulses of discharge always emerge from roughness<iii>, then very probable potential vortices are responsible for it. By means of a Kirlian photograph it can be shown that the corona consists of structured separate discharges (Fig. 3.6).

With this the approach is motivated, formulated and given reasons for. The expositions can't replace a proof, but they should stand a critical examination. Mathematical and physical evidence will be furnished later.

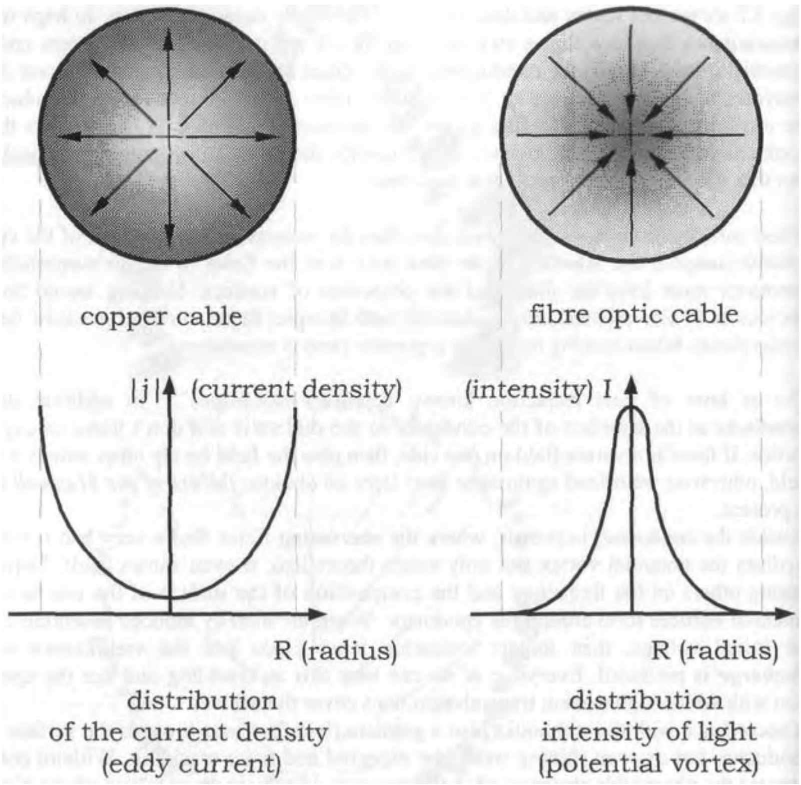
copper cable
fibre optic cable
|j| (current density)
(intensity) I
R (radius)
R (radius)
distribution
of the current density
(eddy current)
distribution
intensity of light
(potential vortex)

Fig. 4.1: The distribution in principle of the intensity of light within a fibre optic cable<i> compared to the distribution of the current density in a copper cable

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<i> Meyl, Konstantin: Potentialwirbel, Band 1: Diskussionsbeitrage zur naturwissenschaftlichen Deutung und zur physikalisch-technischen Nutzung, basierend auf einer mathematischen Berechnung neu entdeckter hydrotischer Wirbel, INDEL GmbH, Verlagsabteilung, Villingen-Schwenningen 1990, ISBN 3-9802-542-1-6

4. Properties

4.1 Concentration effect

It can be assumed that until now there does not yet exist a technical application for the here presented potential vortex theory unless the phenomenon was used by chance and unconsciously. About this the transmission of optical light signals over fibre optic cable can be given as a typical example.
Compared to a transmission of energy impulses over a copper cable fibre optic cables show a considerable better degree of effectiveness. The derived potential vortex theory provides a conclusive explanation for this phenomenon and therefore is put here to discussion: If we cut through a fibre optic cable and look at the distribution of a light impulse over the cross-section, then we observe a concentration in the centre of the conductor (fig. 4.1).

Herc the duality between the vortices of the magnetic and of the electric field comes to light. Whereas the current eddies in a copper conductor cause the "skin effect" as is well-known, potential vortices show a "concentration effect" and align themselves with the vortex centre. The measurable and in fig. 4.1 shown distribution of the light intensity in a fibre optic cable may confirm this phenomenon, the orientation of the potential vortex on the vortex centre.

For instance the calculation of the resistance of a copper cable provides as an important result an apparent decrease of the resistance directed towards the conductor surface. There the associated better conductivity as a consequence causes an increased current density. In the reversed direction, towards the centre of the conductor, consequently a decrease of the effective conductivity would be present, and this result is independent of the used material. According to the rules of duality this is a condition for the formation of potential vortices. As already said the conductivity is responsible for it, if the expanding eddy current with its skin effect or the contracting potential vortex with its concentration effect is predominant.

Usual fibre optic materials possess not only a small conductivity, but in addition a high dieletricity. This additionally favours the formation of vortices of the electric field. If one consciously or unconsciously supports the potential vortices, then there is a possibility that the life of the fibre optic cable is negatively influenced because of the concentration effect. Of course it can not be excluded that other effects, like e.g. reflections or the modes of the light are involved in the concentration effect. But it should be guaranteed that this actually concerns is causal phenomena and doesn't concern only alternative explanations out of ignorance of the active vortex phenomenon.

The formal mathematical reason for the concentration effect provides the reverse sign in Faraday's law of induction compared to Ampere's law (see also equation 3.1 and equation 3.8 in fig. 3.3).

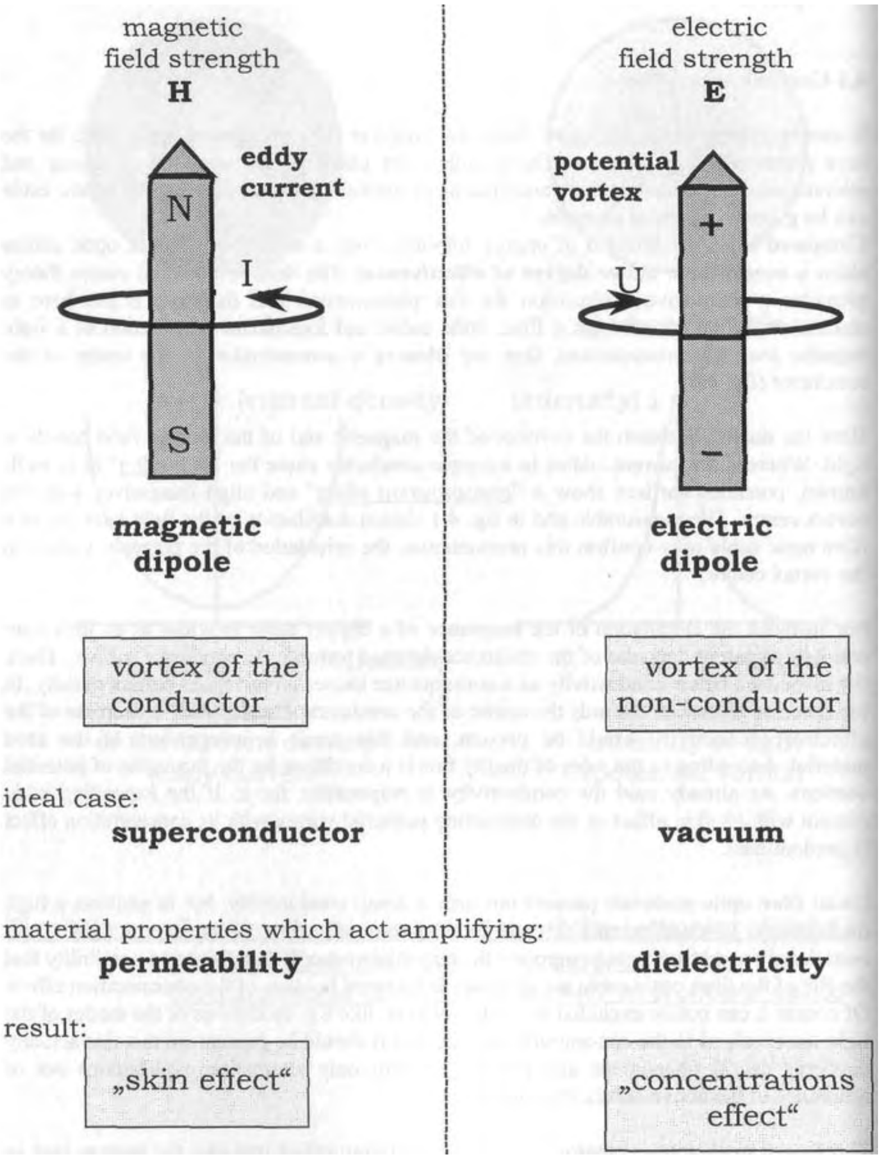
magnetic
field strength
H
eddy
current
N
I
S
magnetic
dipole
electric
field strength
E
potential
vortex
+
U
–
electric
dipole
vortex of the
conductor
vortex of the
non-conductor
ideal case:
superconductor
vacuum
material properties which act amplifying:
permeability
dielectricity
result:
„skin effect“
„concentrations
effect“

Fig. 4.2: The acting as a dipole of
current eddies and potential vortices

4.2 Duality of the vortex properties

The rules of duality dictate for the vortex of the electric and of the magnetic field the following characteristics:

1. Whereas currents and eddy currents demand a good conductivity, potentials and potential vortices can only form with bad conductivity, thus in a dielectric and best in the vacuum.

2. Eddy currents run apart, strive towards infinity and thus show the well-known "skin effect" with a spatially limited arrangement of the conductor. According to the rules of duality the potential vortex will strive towards the vortex centre and in this way will show a "concentration effect".

3. Another property of vortices is shown in fig. 4.2.
On the left side a plane eddy current is indicated. Since the discovery of Ampere's law it is well-known to us that such a circular current (I) forms a magnetic dipole standing perpendicular to the vortex plane.
On the right hand side the dual phenomenon is sketched. Here charges are piled up circularly to a planar potential vortex (U). Thereby an electric dipole forms, standing perpendicular to the vortex plane. This relation directly follows from the equations of the field-theoretical approach.
Whereas circular currents and current eddies produce magnetic dipoles, the postulated potential vortices will form electric dipoles.

With these three interesting properties some key questions of quantum physics, that until now have stayed a mystery to science (fig. 4.4), can be answered conclusively and without compulsion e.g.:

I.Why are there no magnetically charged particles?
The better the conductivity of a medium is, the higher as a consequence the number of free charge carriers is. the more strongly eddy currents are formed. The answer to question I is inferred from the opposite case:
In the ideal vacuum no charge carriers at all are present, why no currents, no current eddies and consequently no magnetic poles can exist.
With this well-known fact the first question already is answered. The question why in the microcosm there can not exist magnetically charged elementary particles, why the search for magnetic monopoles doesn't make any sense. Let's ask further:

II. Why are there only electrically charged particles?
Let us for that consider the dual conditions. The worse the conductivity of a medium is, the more the potential vortex -will be favoured that because of this property also can be understood as the vortex of the dielectric.
In the mentioned extreme case of the ideal vacuum, no electric conductivity is present for reason of the missing charge carriers. But this circumstance favours the potential vortex and that, according to fig. 4.2, forms electric poles and with this also the second question would be answered clearly.
It can be traced back to the boundary conditions of the microcosm that without exception electricallv charged particles are entitled to exist; a realization derived from the field-theoretical approach, that covers all experiences.

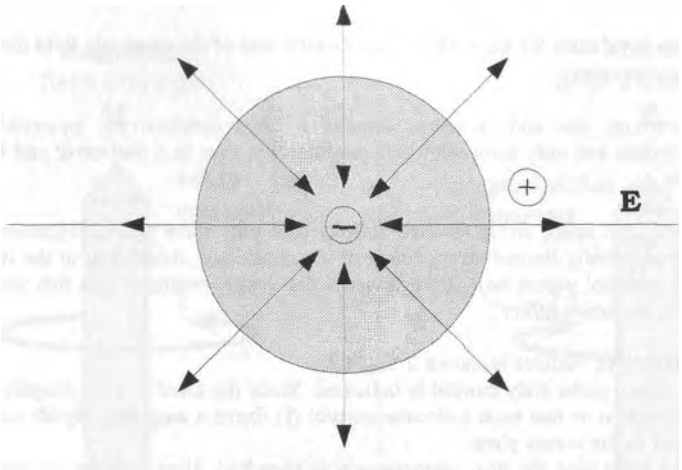

the positron e^+

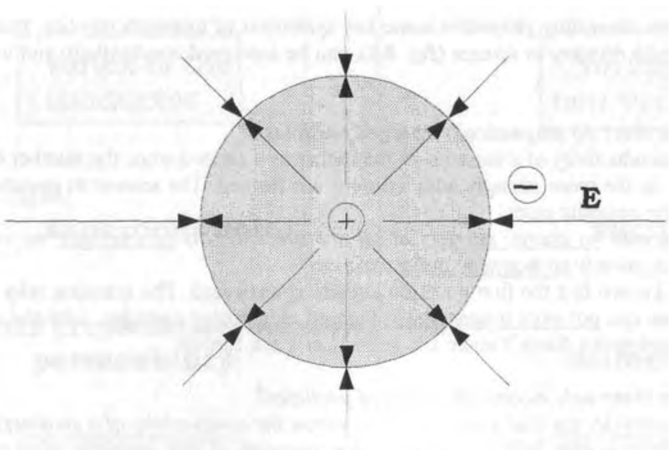

the elektron e^-

Fig. 4.3: Elementary particles as configurations of potential vortices

4.3 Derivation of the electron as an elementary vortex

The next key question necessarily has to be brought to a conclusive answer to save the principle of causality, so that we no longer have to postulate an own physics with its own laws for the microcosm:

III. Why do these particles show as monopoles?

More concrete the question has to read:
Where is the positive pole in a negatively charged electron, if it should be an electric dipole?
The only possible answer is:
In the centre of the particle!

Thus in the centre of the electron its positive pole is hidden and in the centre of the positron its negative pole is hidden. But we only observe these particles from the outside and for reason of the field conditions of the electron we measure a negative charge and for its antiparticle, the positron, a positive charge. If in each case we wanted to measure the electric fields included in the inside, we had to destroy the particle. Then a proof would not be possible anymore.

Here also a persistent mistake is eliminated by the for a long time known axiom that monopoles can not exist at all if one considers continuity! By means of technical-physical experiments this axiom is sufficiently secured.
The quantum physical approach is standing on uncertain ground if it is postulated that other laws of nature should apply to particle physics, if a second approach, the field-theoretical approach, is conceivable that does not know these problems!

The discussed concentration effect gives the potential vortex a structure shaping property. With that also the fourth key question can be answered:

IV. Why do the particles have the form of spheres?

The potential vortex is favoured in the particle-free vacuum of the microcosm because of the missing conductivity. In connection with the concentration effect the following conclusion can be drawn:
The extremely mighty potential vortex exerts a high pressure on the microcosm and on each particle.

With that also the fourth key question, why stable elementary particles are spherical, can be answered by the potential vortex theory:
Only the sphere is able to withstand a high outside pressure.
All other forms, like e.g. dipoles formed like a rod or a club would be instable in the presence of the extremely concentrating potential vortex. They would be immediately destroyed by the pressure of the potential vortex.

I. Why are there no magnetically charged particles?
(the vacuum has no conductivity!)

II. Why are there only electrically charged particles?
(in the vacuum only potential vortices can exist!)

III. Why do these particles show as monopoles?

(the other pole is locked up in the inside of the vortex oscillation!)

IV. Why do the particles have the form of spheres?

(for reason of the outside pressure by the concentration effect!)

V. Why is the elementary quantum stable?

(without conductivity no decay of vortices takes place!)

VI. Why does for every particle of matter exist an antiparticle?

(there are two swirl directions with equal rights!)

VII. Why are particles and antiparticles incompatible?
(contrary swirl directions!)

Fig. 4.4: Key questions of quantum physics

4.4 Quanta as field vortices

The fied-theoretical approach demands removing the electron from the field equations (eq. 3.7) and at the same time introducing the potential vortex of the electric field. With this vortex phenomenon there now is a possibility that the electromagnetic wave spontaneously rolls up to a vortex in case it is disturbed from the outside. The vortex particle that is formed in such a way owes its physical reality on the one hand the concentration effect of the potential vortex, that compresses this particle to the dimension of a tiny sphere and on the other hand its localization for reason of the oscillation around a fixed point.
The spherical elementary particles are being compressed to inconceivably small dimensions. Therefore they are capable to bind a comparatively high energy in their inside. This is confirmed by the mass-energy relation $E = mc^2$. (4.1)

The fact that the energy is dependent on the speed of light can be judged to be a clear indication that quanta actually are nothing but oscillating electromagnetic packages, vortical oscillations of empty space!
The next question reads:

V. Why is the elementary quantum stable?
The worse the conductivity is, the more the potential vortex will be favoured, the more strongly the concentration effect will form, the smaller the spherical phenomena will get - the larger the authoritative relaxation time will be, i.e. the slower the decay of vortices and with that the more stable the vortex phenomenon will be.
In the microcosm, that comes the ideal case of a particle-free vacuum very close, the spherical vortices because of the missing conductivity have an absolute stability.

VI. Why does for every particle of matter exist an antiparticle?
Since every vortex can also oscillate in the opposite direction, there always exist two forms of formation of spherical vortices with equal rights, one of them is assigned to the world of matter and the other to the world of anti-matter.

VII. Why are particles and antiparticles incompatible?
For reason of the contrary swirl direction they are incompatible to each other. They have the tendency to destroy each other mutually, like two trains that want in the opposite direction on a single-tracked distance.

The quantum physical approach does not have an answer to these key questions. Until now scientists have merely thought about to what the observable contraction in the microcosm and the macrocosm can be traced back. Because the approach was not able to furnish an answer, without further ado some new matter was introduced: the sluons. These binding particles should be able to exert the necessary pressure. But until now no one has been able to observe or detect this fabulous matter. Nobody knows its structure and its composition. Despite missing evidence it is stated that this matter is mass less and at the same time lumped; it is invisible because it can't interact with any other matter, not even with the supposed building parts of the atomic nuclei, the quarks. But at the same time there should be exerted a pressure on the quarks, for which reason quarks again should be able to interact with gluons!

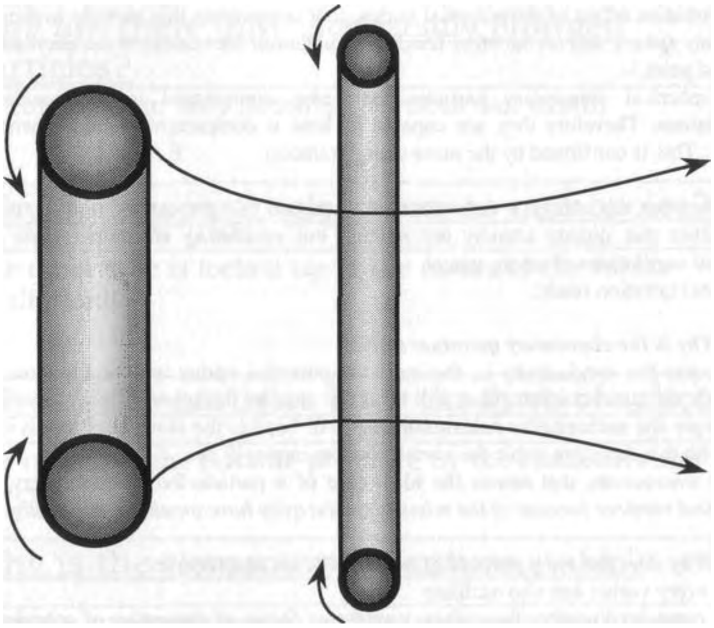

Fig. 4.5: Two coaxial oscillating vortex rings (Lugt<i>).

<i> Lugt, Hans J.: Vortex flow in nature and technology. Krieger publishing company, Florida 1995; page 42, ISBN 0-89464-916-7

4.5 The photon

The ability to form structures as a consequence of the concentration effect gives the potential vortex a number of highly interesting properties. To derive these properties we can make work easier when we fall back upon the observations and experiences of flow dynamics.

Here the vortex ring takes a special place. Its vortex centre is not closed, for which reason it is not stationary and propagates in space with a constant speed. It can be observed that the velocity of propagation increases with the ring diameter becoming smaller. By means of the vortex rings, that skilful smokers can produce with pointed lips, these properties can be made visible.

Now if two vortex rings run into each other with the same axis and direction of rotation then both oscillate around each other, by one vortex attracting the other vortex, thereby accelerating and thus contracting it. The second vortex then slips through the core opening and gets again slower and larger. Now the first vortex accelerates and plays the same game (fig. 4.5).

It would be obvious for the vortex of the electric field to have a corresponding property. The electron e- and with the opposite swirl direction the positron e+ will form such a potential vortex corresponding to the derivation. Two electrons, as like charged particles, would repel each other and surely will be out of the question for such a configuration. An electron and a positron however will attract each other and because of their incompatibility they will mutually destroy unless they open their vortex centres to form a vortex ring. Now the e- shows its positively charged centre that shows the same swirl direction as the e+ seen from the outside. Therefore the vortices don't hurt each other, when the positron slips through the opened vortex centre of the electron and vice versa.

This oscillating electron-positron pair has strange properties: seen from the outside one moment it is negatively charged and the next moment it is positively charged. Therefore over time on the average no charge will be measurable and no electromagnetic interaction will take place.

One moment the particle is matter and the next moment it is anti-matter. Hence no mass at all can be attributed to the particle. Interactions primarily takes place between both dual vortices. We can predict, the particle has neither mass nor charge. The environment merely sees a fast oscillating particle that only within every half cycle is capable of an interaction.

The centre of the oscillating particle is open, for which reason it is not stationary anymore. Instead it propagates in z-direction with the swirl velocity, which is the speed of light, in this way preventing a rotation around the x- or y- axis (fig. 4.6). In this way a polarizability is present.

The only possible and, as we will see, necessarily taking place rotation around the z-axis gives the particle a spin of the magnitude of a quantum of angular momentum. After all the rotation for e^- and e^+ is of the same magnitude with a spin of each time $\frac{1}{2} \cdot \hbar$.There should be paid attention to the fact that for the case of an opposite sense of direction of the respective rotation around the common z-axis the spin on the average will be zero.

In addition the particle is characterized by an outstanding property: a periodically taking place oscillation with any frequency, but that frequency has to be constant. We now only have to take a table of particles to hand. Actually we will find a corresponding particle that has all these properties: the γ-quanta,also called photon.

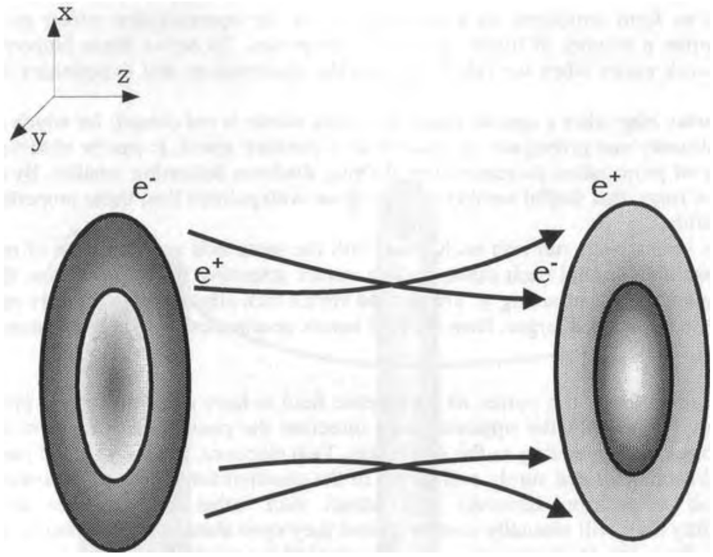

Fig. 4.6: The photon as oscillating electron-positron pair

The decay of the γ- quanta (photon)[i]
(= pair creation = Bethe-Heitler-process 1934):

$$\gamma \longrightarrow e^- + e^+$$

(4.2)

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[i] Nachtmann, Otto: Phanomene und Konzepte der Elementarteilchenphysik, Vieweg, Braunschweig 1986, S. 135, ISBN 3-528-08926-1

4.6 Pair creation

Proof for the correctness of the model concept provides the decay of the photon in an electron and a positron in the presence of a strong field, as for instance in an atomic nucleus. This observable decay is called pair creation or Bethe-Heitler process<i>:

$\gamma \longrightarrow e^- + e^+$ (4.2)

In this process the elementary vortices for a short time get back their localization and are therefore detectable. Otherwise the electron and positron have the form of a sphere, the photon however rather has the form of two oscillating discs.

The photon doesn't participate in the electromagnetic interaction, because the electric field lines run from one disc to the other (from + to -). The field lines are not open as they are for e^- or e^+ (fig. 4.3). To open up the field lines an energy is necessary that corresponds to the sum of the two formed particles. But from this it by no means follows that this amount of energy will be released in the reversed and much better known process, where matter and anti-matter annihilate under emission of γ-quanta. At the end of the derivation the vortex model will provide us the desired answers on questions of the energy of photons.

Here first of all only the properties will be concerned. Experiments, in which light shows as a particle, are the photoelectric effect, the Compton effect and a lot more. According to the by Maxwell developed classical theory of light however is light an electromagnetic wave that is not quantized in any way, neither as sphere nor as disc, the wave nature of light as well has a physical reality and is secured by experiment. This is witnessed by the interference patterns of overlapping coherent light beams.

A concept in which light could exist at the same place and the same time both as wave and as corpuscle could never be brought into accord with the principle of causality. Formulas of compromise, like the uncertainty principle of Heisenberg that refers to the point of view of the observer, can't change anything about this dilemma. The dual nature of light, that in this context is gladly spoken of, rather consists of the fact that dependent on the local field conditions, any time and spontaneously the wave can roll up to a vortex.

As an example of a violation of the principle of causality it has been indicated under point 3 (fig. 3.1) that both fields and quanta at the same time should be the cause of something. This concept was formulated by Maxwell and written down in modern quantum electrodynamics by Dirac but in the field-theoretical approach we have dropped this concept because it violates all rules of causality in an elementary manner. Therefore it only is consistent, if we hold the view that the light is either wave or particle but never is both at the same time!

In the spontaneous transition of the wave to the particle all the important properties are conserved: the propagation with the speed of light, the characteristic frequency of the oscillation and the mentioned polarizability.

The process of rolling up possibly takes place already in the laboratory, in a bubble chamber and at the latest in our eyes. To receive the electromagnetic wave, we had to have antennas. We actually see the photons. It therefore would be obvious if our cells to see only could perceive vortices, in this case photons. We don't possess a sense organ for fields and waves.

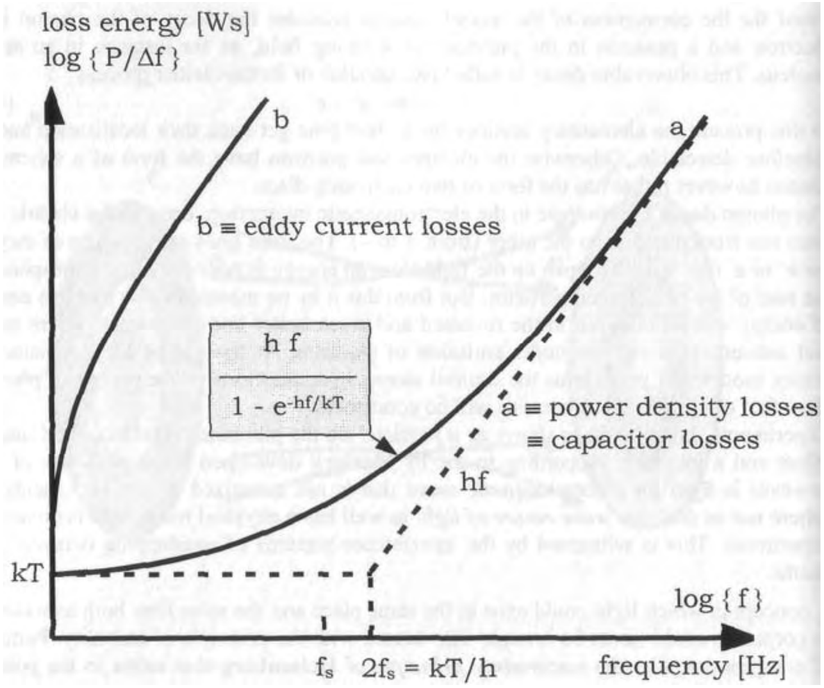

Fig. 4.7: The power density shown against frequency for noise
(a) according to Kupfmuller<i>,
as well as for dielectric losses of a capacitor (also a) and for eddy current losses (b) according to Mevl<ii>
(b in visible duality to a).

<i> Kupfmuller, Karl: Einfuhrung in die theoretische Elektrotechnik, Springer-Verlag Berlin, 12. Auflage 1988, ISBN 3-540-18403-1

<ii> Meyl, Konstantin: Dreidimensionale nichtlineare Berechnung von Wirbelstromkupplungen, Dissertation Universitat Stuttgart 1984

4.7 Noise

If, according to the field-theoretical approach, there exist electric field vortices then they will not only form the elementary particles in the vacuum, but will also macroscopically form and have an effect in larger dimensions.

Assuming a wave that rolls up to a plane vortex it would be obvious if polarization and velocity of propagation are conserved in the process. But how does it stand about the frequency?
The wave now will walk round a stationary point, the vortex centre. The propagation with the speed of light c will remain existent as the swirl velocity. For a plane circular vortex, where the path for a revolution on the outside is very much longer than near the vortex centre, there arises a longer wave length and as a consequence a lower frequency on the outside as more to the inside. With this property the vortex proves to be a changer of frequency: the vortex transforms the frequency of the causing wave in an evenly spectrum, that starts at low frequencies and stretches to very high frequencies (fig. 1.4). Exactly this property we observe in "white noise". The consistent conclusion would be that this concerns the vortex of the electric field. Anyone can, without big expenses, convince himself or herself of the localization, of the property to change the frequency and of the circumstance that vortices can be very easily influenced, that they avoid or again whirl about a place of disturbance, for instance an antenna. For that one only needs to tune a radio receiver to a weak and noisy station and move oneself or some objects around, then one is able to directly study the influences from the manipulation of the receiving signal.
But already the fact that the using and measurability of signals is limited by noise makes clear. which attention the potential vortex should be given.

Within a limited frequency range the power of the Nyquist or resistance noise is independent of frequency (fig. 4.7). This should be clarified particularly by the term "white noise" analogous to white light, where all visible spectral ranges independent of frequency have the same energy density.

But this relation doesn't hold for high frequencies of any magnitude. Here another noise-effect appears, that is said to have its cause in the quantum structure of energy<i>. Untouched by possible interpretations an increasing power of the noise is measured, that more and more turns into a being proportional to frequency (fig. 4.7, curve a). Interestingly this curve shows a remarkable duality to the power curve of eddy currents, likewise shown against the frequency, that for instance can be measured at eddy current couplings<ii> (fig. 4.7, curve b). This circumstance suggests a dual relation of the potential vortex of the electric field in bad conducting media on the one hand and the eddy current in inductive materials on the other hand <iii>.

<iii>: Meyl, Konstantin: Wirbel des elektrischen Feldes,
EMC Journal 1/95, 6. J, ISSN 0945-3857, S. 56 - 59.

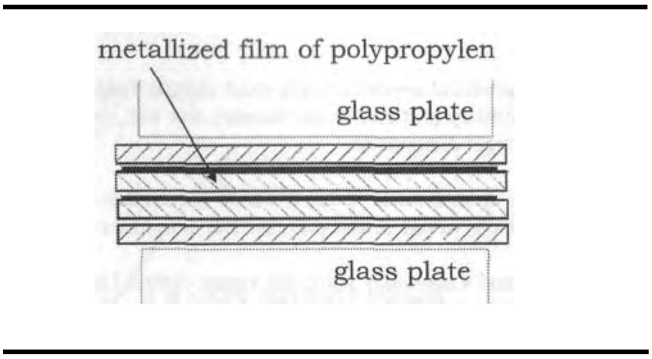
metallized film of polypropylen
glass plate
glass plate

a) measurement set up according to Yializis and others[i]

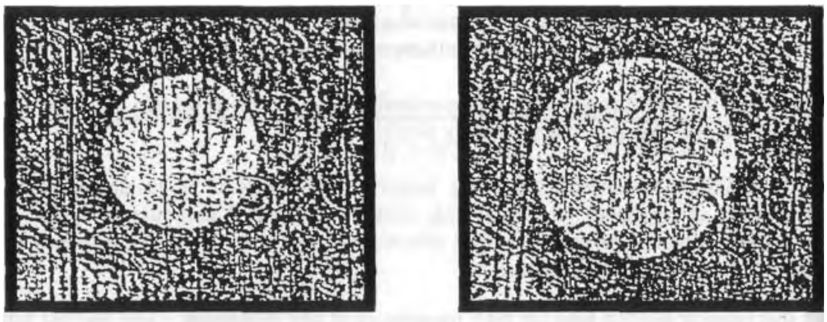

b) after 40 hours c) after 52 hours

Fig. 4.8: Measurement set up (a) and photo of vortex structure in a metallized polypropylen layer capacitor (at 450 V/ 60 Hz/ 100°C)
Observation of the formation of a vortex (b) and (c). (110 fold magnification), according to Yializis et al.[i]

<i>: A. Yializis, S. W. Cichanowski, D. G. Shaw: Electrode Corrosion in Metallized Polypropylene Capacitors, Proceedings of IEEE, International Symposium on Electrical Insulation, Bosten, Mass., June 1980;

4.8 Capacitor losses

Next the dielectric losses in a capacitor fed with an alternating voltage are measured and likewise put on against the frequency. At first the course is independent of the frequency, but towards higher frequencies it increases and shows the same characteristic course of the curve as the before mentioned power of the noise (fig. 4.7, curve a).

This excellent agreement suggests the assumption that the dielectric losses are nothing but eddy losses.
These vortex phenomena, caused by time-varying fields, are not only found in ferromagnetic and conductive materials, but equally as dual phenomena in dielectrics and non-conductors.

As examples of practical applications the induction welding or the microwave oven can be mentioned. The process can be described in other words as follows: in both examples the cause is posed by high-frequency alternating fields that are irradiated into a dielectric as an electromagnetic wave, there roll up to potential vortices and eventually decay in the vortex centre. The desired and used thermal effect arises during this diffusion process.

The striving in the direction of the vortex centre gives the potential vortex of the electric field a structure shaping property. As a consequence of this "concentration effect" circular vortex structures are to be expected, comparable to the visible vortices in flow dynamics (e.g. tornados and whirlwinds). At the same time the dual anti-vortex arises, the diverging eddy current. It takes, as is well-known, the given structure of the conductor, so in the technical literature one correspondingly talks of a "skin effect". Now if conductor and non-conductor meet as they do in a capacitor, then at the boundary area visible structures will form. Circles would be expected, if the eddy current in the inside and striving to the outside is equally powerful as the potential vortex that comes from the outside and concentrates.

Actually such circular structures are observed on the aluminium of high tension capacitors, when they were in operation for a longer period of time. The formation of these circles, the cause of which until now is considered to be unsolved, is already experimentally investigated and discussed on an international level by scientists (fig. 4.8) [<i, ii>].

These circular vortex structures can be seen as a visible proof [<iii>] for the existence of potential vortices of the electric field.

<ii>: D. F. Taylor, On the Mechanism of Aluminium Corrosion in Metallized Film Capacitors, IEEE Transactions on EI-19,August 1984,No.4,pp.288-293.

<iii>: Meyl, Konstantin: Wirbel des elektrischen Feldes, EMC Journal 1/95, 6.J, ISSN 0945-3857, S. 56-59.

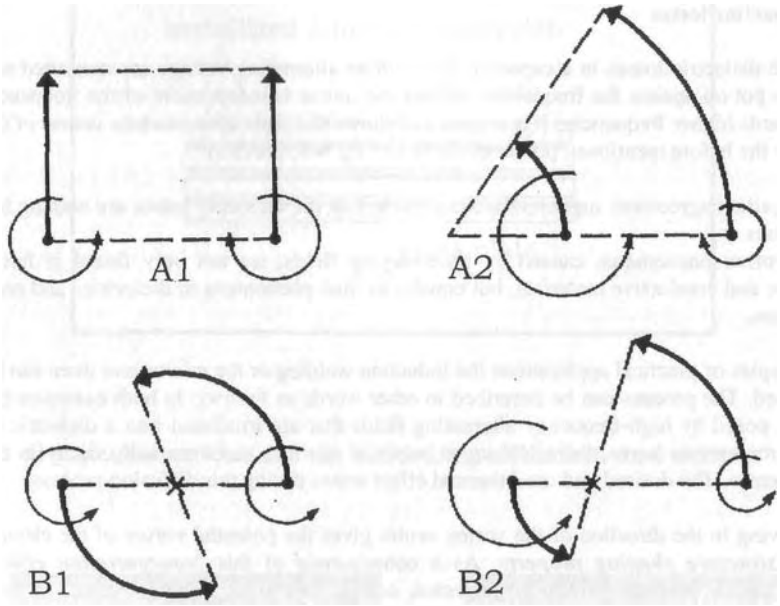

Fig, 4.9: Motion of two point vortices. (Lugt<i>)
A. with opposite direction of rotation
B. with the same direction of rotation
1. for equal vortex strength
2. for unequal vortex strength

Example from practice for case A1:
vortex pair behind an airplane

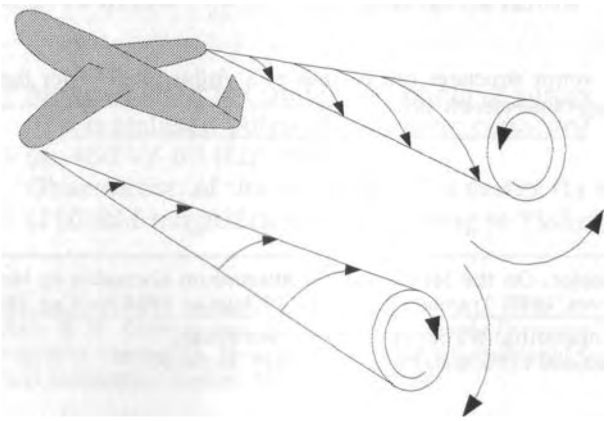

4.9 Vortex lines and vortex streets

It can be assumed that the vortex of the electric field is relevant with regard to the electromagnetic environmental compatibility. This then holds not only for microcosmic and microscopic vortices, but also for macroscopic and larger dimensions. The individual vortices can join together to balls and lines. For the study of this process it is useful to again fall back upon experiences of flow dynamics.

The co-operation of individual point vortices has been investigated thoroughly in flow dyamics. Without any outside manipulation an individual vortex rotates on the spot. That changes in the case of two neighbouring vortices. Now it depends on their mutual strength and sense of rotation. If they have the opposite sense of rotation and equal strength then their centres of rotation move straight forward in the same direction. If however the direction of rotation is the same then both vortices rotate around each other (fig. 4.9).

In this way a multitude of point vortices is capable, to form in the first case whole vortex streets and in the second case spherical vortex balls. In principle a vortex string can also consist of a multitude of potential vortices pointing in the same direction; but it has the tendency to roll up to a vortex ball in case it is disturbed from the outside, as can be shown very clear by means of computer simulations<i>.

As a starting-point for a discussion the thesis can be put forward that also electric field vortices, in nature usually consisting of a multitude of individual point vortices, appear as vortex strings and vortex balls.

Perhaps historians see in this property an answer to the question, how it was possible for the Romans to build streets straight as a die in the wilderness. Their land surveyors, the Augures, had at their disposal neither laser, nor any other suitable gauges. Their most important tool was the Lituus, the crook, that at its upper end was rolled up like a vortex in the sense of a flat coil shaped like a spiral.
The question poses what this strange object was used for. Perhaps the roman land surveors tracked down any vortex lines with this crook and then used them to orientate themselves?
History still holds a lot of secrets, but for now only this indication is given. The following seminar will give enough opportunities for speculations and discussions<ii>.

<i>: Lugt, Hans J.: Vortex flow in nature and technology. Krieger publishing company, Florida 1995; p.38, fig. 3.25, 3.26 and 3.27, ISBN 0-89464-916-7

<ii>: K. Meyl: Elektromagnetische Umweltvertraglichkeit Teil 2 und 3 Seminar-umdrucke, INDEL Verlag VS; see part 2 and 3 of this book.

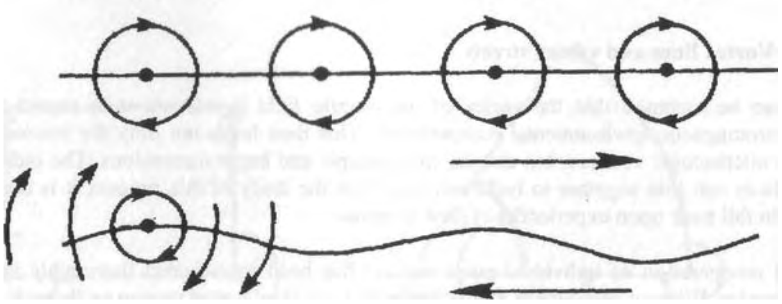

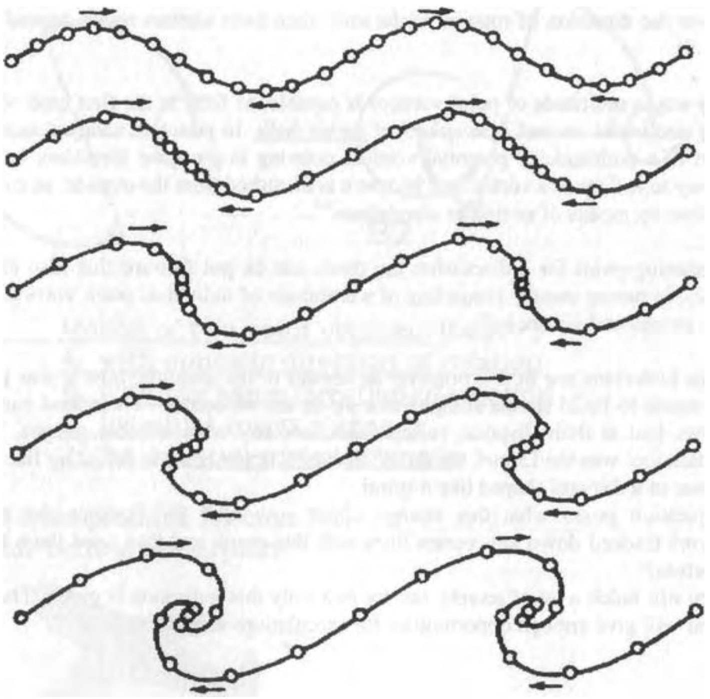

Fig. 4.10: The rolling up of a vortex chain to a vortex ball for the smallest disturbance (case Bl in fig. 4.9) (Rosenhead[i]).

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[i]: L. Rosenhead: Formation of vortices from a surface of discontinuity. Proc. Roy. Soc. A 134, 1931, 170. taken from:

Lugt, Hans J.: Vortex flow in nature and technology. Krieger publishing company, Florida 1995; page 39, figure 3.29, ISBN 0-89464-916-7

4.10 Water colloids as vortex balls

We have to realize that in the biosphere we are staying in a relatively ideal dielectric. The two "capacitor plates" are being formed by the ionosphere and the earth. The potential vortex will, as said, be favoured by a bad conductivity and by a high dielectricity. Consequently it will dominate and take effect in the biosphere. In which way it takes effect is the central theme of the electromagnetic environmental compatibility.

Life in this world consists predominantly of water and water has a very high dielectricity! With that the effectiveness and the long life of the potential vortex increases. The human head for instance contains 7O% and plants contain over 90% water! But it does not simply concern H_2O, but structured water in a colloidal form. These water colloids could be vortex balls because they consist of a large number of water molecules in a spherical arrangement They form independent and insoluble particles with a negative electric charge (fig. 4.11). Water is not equal water thanks to this structure. One can buy healing water and corresponding sources are well-known and famous. Many an effect can be explained by means of a chemical analysis but not everything.

The highest age in this world is reached by the inhabitants of Hunza, in the mountains of norhern India at the foothill of the Hindu Kush, at an altitude of 2500 meters. They drink some muddy glacial water that is strongly colloidal. Hence it would be obvious that plants and also we ourselves need such water for our physique. Processes are known with which the advantageous vortex balls, say colloids, are produced artificially by mechanic or chemical treatment<i>. Levitated water, as it is called and as it is for sale nowadays, is said to be more healthy. Unfortunately people predominantly work empiric in this area, because science occupies itself with this topic only little or not at all.

Another problem is the fact that the colloids again fall apart quickly. The like negative charge favours this process. The liquid crystals have to be stabilized from the outside. In the case of the Hunza-water the colloids are surrounded by a vegetable layer of fatty acid and are protected in this way <ii>. It possibly is very obliging to nature, if the water colloids also in biological systems are stabilized in that way.

Everyone of us knows that fresh spring water tastes much better than stale, bottled water, even if the chemical analysis turns out of be absolutely identical. For this fact classical science is not able to give a cause - a further problem of causality. In any case should potential vortices with their structure shaping property be considered as a cause for the formation of water colloids. It surely causes no difficulties at all to interpret the colloids as vortcx bulls.

<i>: V. Schauberger: Die Entdeckung der Levitationskraft, Implosion 1995 Nr. 112 und:
N. Harthun: NaturgemaSe Technik - Wege fur die Forschung nach Viktor Schauberger, Verlag Delta Design, Berlin 1996.

<ii>: Flanagan: Elexier der Jugendlichkeit, Waldthausen Verlag Ritterhude 1992, orig.: Elixir of Ageless

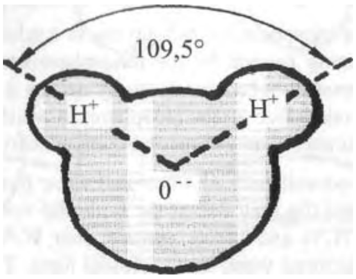

H_2O: the angle of the bond between 2 H molecules = 104,5°
angle of the bond in excited state = 109,5°

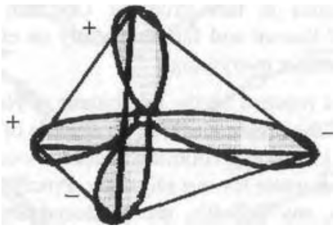

electron orbital diagram of energy (excited H_2O) = tetraeder
most stable liquid crystal = 8 tetraeder = star of octaeder

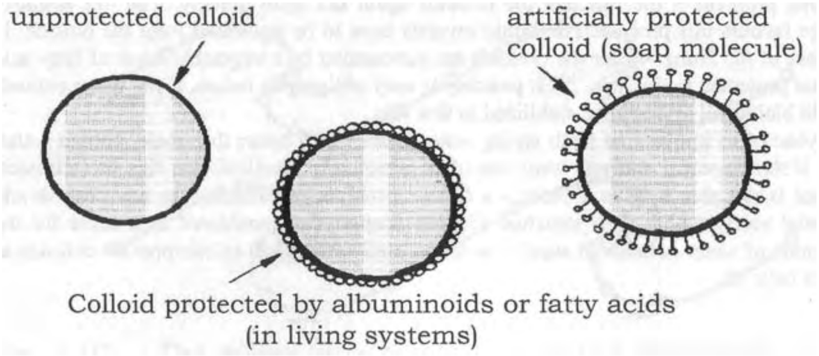
unprotected colloid
artificially protected colloid (soap molecule)
Colloid protected by albuminoids or fatty acids (in living systems)

Fig. 4.11: Water molecules and water colloids

4.11 Phenomenon of transport

The vortex principle is self-similar. This means that the properties of an individual vortex also for the collection of numerous vortices again appear and can he observed in a similar manner. That's why a vortex ball behaves entirely similar as an individual isolated vortex. The same concentration effect, that keeps the vortex together, shows its effect for the vortex ball and keeps it together also.

Something corresponding holds for a basic property of potential vortices, being of a completely different nature. It is the property to bind matter in the vortex and carry it away with the vortex. Well-known are the vortex rings that skilful cigarette smokers can blow in the air. Of course also non-smokers can produce these air eddies with their mouth but these remain invisible. Solely by the property of the vortex ring to bind the smoke it becomes visible to the human eye.

If out potential vortex transports something then it rather should be a dielectric material, so preferably water. Therefore if in the environmental air we are surrounded by potential vortices that we can detect for instance as noise, then they are capable with their "phenomenon of transport", to pick up water and to keep it in the vortex. In this way the atmospheric humidity is explicable as the ability of the air particles to bind comparatively heavy water molecules. If the vortex falls apart then it inevitably releases the water particles and it rains. This is merely a charming alternative for the classical representation without claim to completeness.

Already the Romans have made use of this phenomenon to find water and sources. About this Vitruv<i> (from 23 BC) in his 8th book about architecture writes: "Before sunrise one has to lie down on the earth at the places, where to search for water,... and one has to look at the area... Then one has to dig at the place where there appears curling and in the air rising moist steam. Because this characteristic can not occur at a place where there is no water". The at a certain time of day and in certain seasons occasional in meadows and corn fields observable streaks or circular mostly moist places with differing vegetation, have to be judged as an infallible sign for the existence of this phenomenon.

This phenomenon of transport again appears for the discussed water colloids. The involved water molecules form a spherical object with a negative charge. They turn their negatively charged side to the outside and point with the positively charged end in the direction of the middle of the sphere. There, no longer discernible from the outside, a negatively charged ion can be, that is stuck, that no longer can escape and that gives the whole colloid a characteristic property. In this way nature knows various water colloids that constitute plants and animals. But starting at a temperature of 41°C the liquid crystals fall apart. This not by chance is the temperature at which a person dies. Already 10 millivolts per liquid crystal suffice for the electrically induced death.

The to a colloid identical structure we find in the structure of the atoms. Here the atomic nucleus is held in the inside of a vortex-like cloud of electrons, the atomic hull. We'll hit the phenomenon of transport a last time, when we derive the elementary particles. For the photon is already discernible the tendency of an elementary vortex, to take another vortex in its inside. Merely because the electron and positron are evenly matched a stable configuration is prevented for the photon.

<i>: Vitruvius Pollio, Marcus: Ten Books about architecture, WBG 1987

In chapter vortex calculation used differential operations:

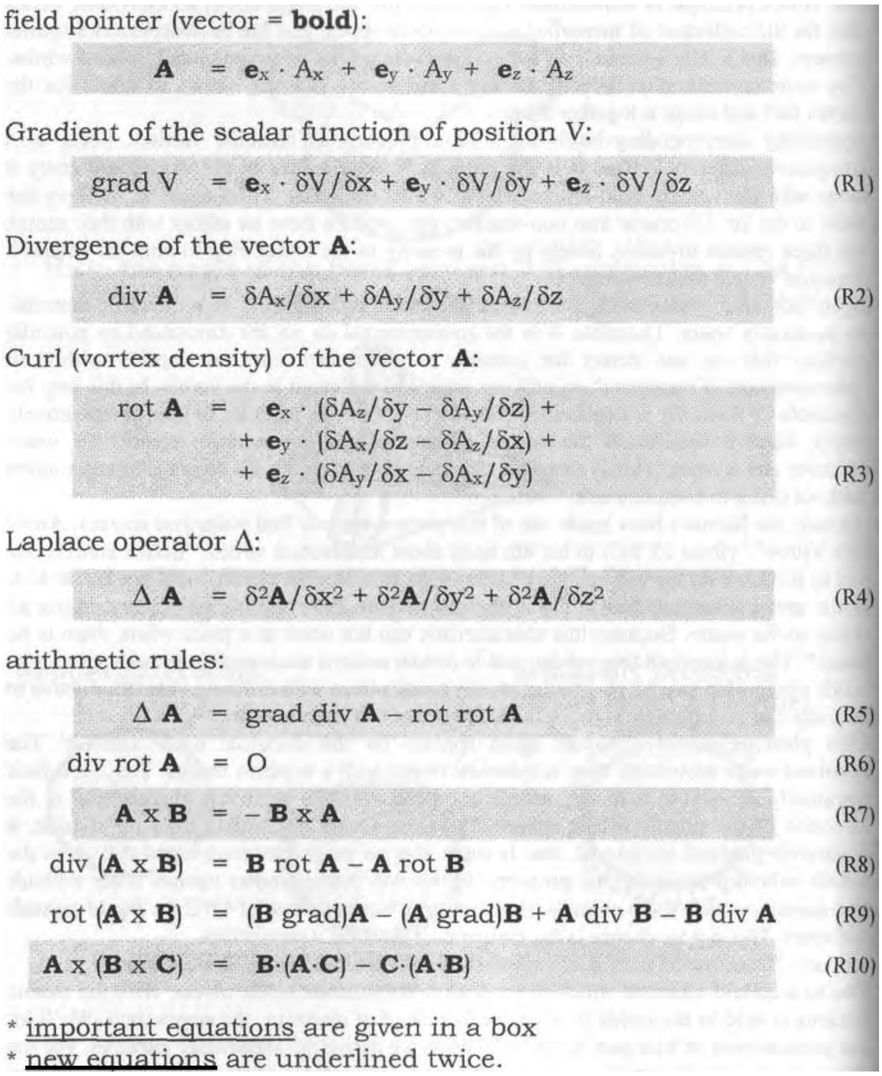

field pointer (vector = **bold**):

$$\mathbf{A} = \mathbf{e}_x \cdot A_x + \mathbf{e}_y \cdot A_y + \mathbf{e}_z \cdot A_z$$

Gradient of the scalar function of position V:

$$\text{grad } V = \mathbf{e}_x \cdot \delta V/\delta x + \mathbf{e}_y \cdot \delta V/\delta y + \mathbf{e}_z \cdot \delta V/\delta z \quad \text{(R1)}$$

Divergence of the vector **A**:

$$\text{div } \mathbf{A} = \delta A_x/\delta x + \delta A_y/\delta y + \delta A_z/\delta z \quad \text{(R2)}$$

Curl (vortex density) of the vector **A**:

$$\begin{aligned} \text{rot } \mathbf{A} = \; & \mathbf{e}_x \cdot (\delta A_z/\delta y - \delta A_y/\delta z) + \\ & + \mathbf{e}_y \cdot (\delta A_x/\delta z - \delta A_z/\delta x) + \\ & + \mathbf{e}_z \cdot (\delta A_y/\delta x - \delta A_x/\delta y) \end{aligned} \quad \text{(R3)}$$

Laplace operator Δ:

$$\Delta \mathbf{A} = \delta^2 \mathbf{A}/\delta x^2 + \delta^2 \mathbf{A}/\delta y^2 + \delta^2 \mathbf{A}/\delta z^2 \quad \text{(R4)}$$

arithmetic rules:

$$\Delta \mathbf{A} = \text{grad div } \mathbf{A} - \text{rot rot } \mathbf{A} \quad \text{(R5)}$$

$$\text{div rot } \mathbf{A} = 0 \quad \text{(R6)}$$

$$\mathbf{A} \times \mathbf{B} = -\mathbf{B} \times \mathbf{A} \quad \text{(R7)}$$

$$\text{div } (\mathbf{A} \times \mathbf{B}) = \mathbf{B} \text{ rot } \mathbf{A} - \mathbf{A} \text{ rot } \mathbf{B} \quad \text{(R8)}$$

$$\text{rot } (\mathbf{A} \times \mathbf{B}) = (\mathbf{B} \text{ grad})\mathbf{A} - (\mathbf{A} \text{ grad})\mathbf{B} + \mathbf{A} \text{ div } \mathbf{B} - \mathbf{B} \text{ div } \mathbf{A} \quad \text{(R9)}$$

$$\mathbf{A} \times (\mathbf{B} \times \mathbf{C}) = \mathbf{B} \cdot (\mathbf{A} \cdot \mathbf{C}) - \mathbf{C} \cdot (\mathbf{A} \cdot \mathbf{B}) \quad \text{(R10)}$$

* important equations are given in a box
* new equations are underlined twice.

Fig. 5.0: Collection of formulas for vector analysis

5. Derivation and interpretation

Vortices cause big problems to every measuring technician. They have the unpleasant property to whirl around the sensor even if it is as small as possible. Vortices avoid the smallest disturbance and then can hardly be detected reproducibly.

From the well-known eddy current we know of this problematic. Instead of the vortex, we are forced to measure and analyse any effects that arise from the vortex. These can be measurements of the eddy losses or effects back on the stimulating field. But only provided that the effect actually occurs.
The prerequisite for an increase in temperature by eddy losses is that the vortex falls apart. In an ideal medium it unfortunately will not do us this pleasure.

As vrtex of the dielectric the potential vortex will find fairly ideal conditions in air or in water. How should a vortex be detected, if it does not produce any effect? The classical measuring technique is here at its wits' end.

From the duality to the well-known eddy current and by means of observation in the previous chapters numerous properties of the potential vortex have been derived. But these are not all the properties. The mathematical calculation of the electric vortex field, that we want to turn to now, will reveal still further meaningful and highly interesting properties.

The observation is important, but it can't replace an exact calculation. A strictly mathematical derived result has occasionally more expressiveness than a whole book full of explanations. It will be a big help to derive and to discuss the field equation that all considerations are based on.

We facilitate the mathematical work by vector analysis. Therefore it is useful that we choose the differential form (equation 5.1 and 5.4) instead of the integral form (equations 3.1 and 3.2 resp. 3.8).

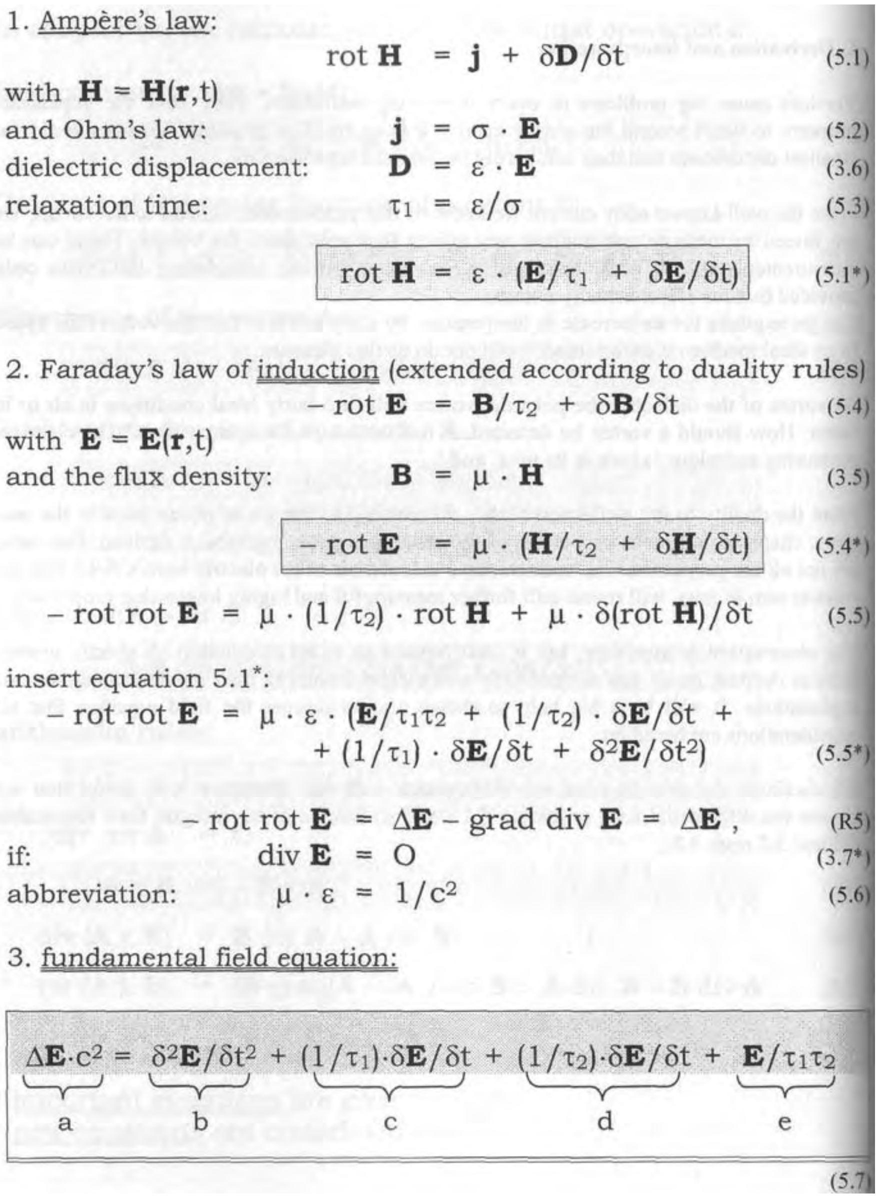

1. Ampère's law:

$$\text{rot}\,\mathbf{H} = \mathbf{j} + \delta\mathbf{D}/\delta t \qquad (5.1)$$

with $\mathbf{H} = \mathbf{H}(\mathbf{r},t)$

and Ohm's law: $\mathbf{j} = \sigma \cdot \mathbf{E}$ (5.2)

dielectric displacement: $\mathbf{D} = \varepsilon \cdot \mathbf{E}$ (3.6)

relaxation time: $\tau_1 = \varepsilon/\sigma$ (5.3)

$$\boxed{\text{rot}\,\mathbf{H} = \varepsilon \cdot (\mathbf{E}/\tau_1 + \delta\mathbf{E}/\delta t)} \qquad (5.1^*)$$

2. Faraday's law of induction (extended according to duality rules)

$$-\,\text{rot}\,\mathbf{E} = \mathbf{B}/\tau_2 + \delta\mathbf{B}/\delta t \qquad (5.4)$$

with $\mathbf{E} = \mathbf{E}(\mathbf{r},t)$

and the flux density: $\mathbf{B} = \mu \cdot \mathbf{H}$ (3.5)

$$\boxed{-\,\text{rot}\,\mathbf{E} = \mu \cdot (\mathbf{H}/\tau_2 + \delta\mathbf{H}/\delta t)} \qquad (5.4^*)$$

$$-\,\text{rot}\,\text{rot}\,\mathbf{E} = \mu \cdot (1/\tau_2) \cdot \text{rot}\,\mathbf{H} + \mu \cdot \delta(\text{rot}\,\mathbf{H})/\delta t \qquad (5.5)$$

insert equation 5.1*:

$$-\,\text{rot}\,\text{rot}\,\mathbf{E} = \mu \cdot \varepsilon \cdot (\mathbf{E}/\tau_1\tau_2 + (1/\tau_2) \cdot \delta\mathbf{E}/\delta t + {} \\ + (1/\tau_1) \cdot \delta\mathbf{E}/\delta t + \delta^2\mathbf{E}/\delta t^2) \qquad (5.5^*)$$

$$-\,\text{rot}\,\text{rot}\,\mathbf{E} = \Delta\mathbf{E} - \text{grad}\,\text{div}\,\mathbf{E} = \Delta\mathbf{E}, \qquad (\text{R5})$$

if: $\text{div}\,\mathbf{E} = 0$ (3.7*)

abbreviation: $\mu \cdot \varepsilon = 1/c^2$ (5.6)

3. fundamental field equation:

$$\boxed{\underbrace{\Delta\mathbf{E}\cdot c^2}_{a} = \underbrace{\delta^2\mathbf{E}/\delta t^2}_{b} + \underbrace{(1/\tau_1)\cdot\delta\mathbf{E}/\delta t}_{c} + \underbrace{(1/\tau_2)\cdot\delta\mathbf{E}/\delta t}_{d} + \underbrace{\mathbf{E}/\tau_1\tau_2}_{e}} \qquad (5.7)$$

Fig. 5.1: Derivation of the fundamental field equation.

5.1 Fundamental field equation

We'll start from Ampere's law which provides a value for the current density at any point pace and this value corresponds to the vortex density of the magnetic field strength

$$\mathrm{rot}\,\mathbf{H} = \mathbf{j} + \delta\mathbf{D}/\delta t \qquad (5.1)$$

We'll use Ohm's law: $\mathbf{j} = \sigma \cdot \mathbf{E}\,,$ (5.2)

the dielectric displacement: $\mathbf{D} = \varepsilon \cdot \mathbf{E}$ (3.6)

and the relaxation time: $\tau_1 = \varepsilon/\sigma\,,$ (5.3)

that indicates how fast the current eddies decay. So far we can fall back upon well-known relations.

The result is: $\boxed{\mathrm{rot}\,\mathbf{H} = \varepsilon \cdot (\mathbf{E}/\tau_1 + \delta\mathbf{E}/\delta t)}$ (5.1*)

The new electric field vortices demand the introduction of a corresponding time constant tau$_2$ that should describe the decay of the potential vortices, as an extension. The extended Faraday law of induction now provides a potential density, that at any point of space corresponds to the vortex density of the electric field strength:

$$-\mathrm{rot}\,\mathbf{E} = \mathbf{B}/\tau_2 + \delta\mathbf{B}/\delta t \qquad (5.4)$$

with the flux density $\mathbf{B} = \mu \cdot \mathbf{H}\,.$ (3.5)

The result fulfils the required duality to equation 5.1*: $\boxed{-\mathrm{rot}\,\mathbf{E} = \mu \cdot (\mathbf{H}/\tau_2 + \delta\mathbf{H}/\delta t)}$ (5.4*)

If we again apply the curl to equation 5.4*

$$-\mathrm{rot}\,\mathrm{rot}\,\mathbf{E} = \mu \cdot (1/\tau_2) \cdot \mathrm{rot}\,\mathbf{H} + \mu \cdot \delta(\mathrm{rot}\,\mathbf{H})/\delta t \qquad (5.5)$$

and insert equation 5.1*, we obtain:

$$-\mathrm{rot}\,\mathrm{rot}\,\mathbf{E} = \mu \cdot \varepsilon \cdot (\mathbf{E}/\tau_1\tau_2 + (1/\tau_2) \cdot \delta\mathbf{E}/\delta t + (1/\tau_1) \cdot \delta\mathbf{E}/\delta t + \delta^2\mathbf{E}/\delta t^2) \qquad (5.5^*)$$

which according to the rules of vector analysis can still be further simplified: = rot rot E = $\Delta\mathbf{E}$ - grad div E , where we should remember that the divergence has to vanish (div E = O. fig. 3.2, equation 3.7), should the corresponding field vortex be inserted!

Furthermore the following well-known abbreviation can be inserted: $\mu \cdot \varepsilon = 1/c^2$ (5.6)

With that the relation with the speed of light c simplifies to the sought-for field equation:

$$\boxed{\underbrace{\Delta\mathbf{E} \cdot c^2}_{a} = \underbrace{\delta^2\mathbf{E}/\delta t^2}_{b} + \underbrace{(1/\tau_1) \cdot \delta\mathbf{E}/\delta t}_{c} + \underbrace{(1/\tau_2) \cdot \delta\mathbf{E}/\delta t}_{d} + \underbrace{\mathbf{E}/\tau_1\tau_2}_{e}} \qquad (5.7)$$

This equation describes the spatial (a) and temporal (b, c, d) distribution of a field vector. It describes the electromagnetic wave (a, b) with the influences that act damping. As dumping terms the well-known eddy current (c) and in addition the newly introduced potential vortex (d) appear.

Field vector: ψ = E, H, j, B or D

1. elliptic potential equation:
(stationary: $t \longrightarrow \infty$ resp. $\delta/\delta t = 0$)

$$\boxed{\underbrace{\Delta\psi \cdot c^2}_{a} = \underbrace{\psi/\tau_1\tau_2}_{e}}$$

(5.8)

2. hyperbolic equation:
(undamped wave equation)

$$\boxed{\underbrace{\Delta\psi \cdot c^2}_{a} = \underbrace{\delta^2\psi/\delta t^2}_{b}}$$

(5.9)

3. parabolic equation:
(vortex equation)

$$\boxed{\underbrace{\Delta\psi \cdot c^2}_{a} = \underbrace{(1/\tau) \cdot \delta\psi/\delta t}_{c/d}}$$

(5.10)

decay time of the eddy currents =
relaxation time: $\tau_1 = \varepsilon/\sigma$ (5.3)

decay time of the potential vortices =
relaxation time: $\tau_2 \sim \mu \cdot \sigma$ (5.11)

Fig. 5.2: mathematically divisible individual cases.

5.2 Mathematical interpretation of the fundamental field equation

Every specialist will be surprised to find the Poisson equation (a, e) again as a term in the wave equation. This circumstance forces a completely new interpretation of stationary fields upon us. The new damping term, that is formed by the potential vortices (d), is standing in between.

Let us start with a mathematical analysis. We have applied the curl to equation 5.4*, then inserted equation 5.1* and obtained a determining equation for the electric field strength E. Of course we could as well have applied the curl to equation 5.1* and inserted equation 5.4*. This would have resulted in the determining equation for the magnetic field strength H.

If we insert Ohm's law (5.2) and cancel down the specific conductivity, or we put in the relations of material (3.5) or (3.6) and cancel down by u respectively ε, then the field equation can likewise be written down for the current density j, for the induction B or for the dielectric displacement D.

It just is phenomenal that at all events equation 5.7 doesn't change its form at all. The field vector is thus arbitrarily interchangeable! This circumstance is the foundation for the claim of this field equation to be called fundamental.

It does make sense to introduce a neutral descriptive vector ψ as a substitute for the possible field factors E, H, j, B or D.

The fundamental field equation 5.7 consists of three different types of partial differential equations: a hyperbolic (b), a parabolic (c and d) and an elliptic (e) type. On the left-hand side each time the Laplace operator (a) is found which describes the spatial distribution of the field factor.

The potential equation of the elliptic type (e) is known as Poisson equation. It describes the stationary borderline case of a worn off temporal process ($t \rightarrow \infty$, resp. $\delta/\delta t$= O).

With this equation potentials and voltages can be calculated exactly like stationary electric currents (5.8).

The hyperbolic equation (b). known as wave equation, shows a second derivative to time. which expresses an invariance with regard to time reversal; or stated otherwise: the direction of the time axis can be reversed by a change of sign of t, without this having an influence on the course of frequency. Wave processes hence are reversible. Equation 5.7 makes clear that a wave without damping by no means can exist in nature. For that both time constants (τ_1 and τ_2) would have to have an infinite value, which is not realizable in practice. Seen purely theoretical, undamped waves could withdraw themselves from our measuring technique (5.9).

Both vortex equations of the parabolic type (c and d) only show a first derivative to time. With that they are no longer invariant with regard to time reversal. The processes of the formation and the decay of vortices, the so-called diffusion, are as a consequence irreversible. Seen this way it is understandable that the process of falling apart of the vortex, where the vortex releases its stored energy as heat e.g. in form of eddy losses, can not take place in reverse. This irreversible process of diffusion in the strict thermodynamic sense increases the entropy of the system (5.10).

Because it poses an useful simplification for mathematical calculations, often the different types of equations are treated isolated from each other. But the physical reality looks different.

field vector: ψ = E, H, j, B or D

1. Borderline case: no conductivity (vacuum)
($\sigma = 0$; $1/\tau_1 = \sigma/\varepsilon = 0$):

$$\boxed{\underbrace{\Delta\psi \cdot c^2}_{a} = \underbrace{\delta^2\psi/\delta t^2}_{b} + \underbrace{(1/\tau_2)\cdot \delta\psi/\delta t}_{d}}$$

(5.12)

(damping by potential vortices)

2. Borderline case: ideal conductivity (superconductor)
($1/\sigma = 0$; $1/\tau_2 = 0$):

$$\boxed{\underbrace{\Delta\psi \cdot c^2}_{a} = \underbrace{\delta^2\psi/\delta t^2}_{b} + \underbrace{(1/\tau_1) \cdot \delta\psi/\delta t}_{c}}$$

(5.12*)

(damping by eddy currents)

3. Diffusion equation

$$\boxed{\underbrace{\Delta\psi \cdot c^2}_{a} = \underbrace{(1/\tau) \cdot \delta\psi/\delta t}_{c/d} + \underbrace{\psi/\tau_1\tau_2}_{e}}$$

(5.12**)

(vortex)

Fig. 5.3: Two borderline cases of the damping of waves and
the diffusion equation for the decay of vortices

5.3 Physical interpretation of the fundamental field equation

In nature the different types of equations always occur in a combined manner.

1. Let's take the concrete case of the particle-free vacuum. Here the specific conductivity is zero. The relaxation time constant $\tau_1 = \varepsilon/\sigma$ responsible for the decay of vortices tends towards infinity according to equation 5.3 and the terms (c) and (e) are cancelled from the field equation 5.7. What remains is the by potential vortices (d) damped wave equation (b) (equation 5.12).

2. The reversed case (with $\tau_2 \longrightarrow \infty$) will consequently occur in materials without resistance, super conducting materials. We now are dealing with the well-known case of the wave damped by eddy currents (equation 5.12*).

Virtually all in nature existing materials however don't fulfil these boundary conditions, from which it follows that both damping terms always occur together and in addition the stationary term (e) becomes active.

It is true that every antenna demonstrates that the electromagnetic wave is convertible in high-frequency alternating currents and voltages, which then are amplified in the receiver. But until this fundamental equation was written down it however was not understood that this transition takes place by means of a vortex. Used are either antennas from well conducting material, or wave guides and horn radiators, which only have a minimal conductivity, because they are filled with air. Actually the wave can be converted in two dual ways; by means of the rolling up to current eddies or to potential vortices (fig. 1.4). Now we finally are capable to explain, why wave guides make possible a better degree of effectiveness: Owing to the concentration effect of the potential vortex the HF-power is bound in the inside and not emitted until the antenna is reached as happens for a wire for reason of the skin effect.

Therefore, physically, one has to imagine this relation, which describes the transition of an electromagnetic wave into a vortex, in the way that the wave spontaneously can roll up to a vortex in case it is disturbed from the outside. The more vortices are generated, the larger consequently is the damping of the wave (equations 5.12 and 5.12*).

3. The life span of the vortices is limited and is determined by the electric conductivity. The at first stored vortices decay with their respective time constant τ. This process is described by the diffusion equation 5.12**. The final stage of the decaying vortices finally is described by the Poisson equation (a, e: equation 5.8).

If the vortex falls apart, it converts the in the vortex stored energy in heat. These processes are known from the eddy current. We speak of heating losses, that the stationary currents cause in the conductor material.

But new is the concept that such vortex phenomena can occur as dielectric losses in capacitors or in the air. The microwave oven or induction welding are good examples of this.

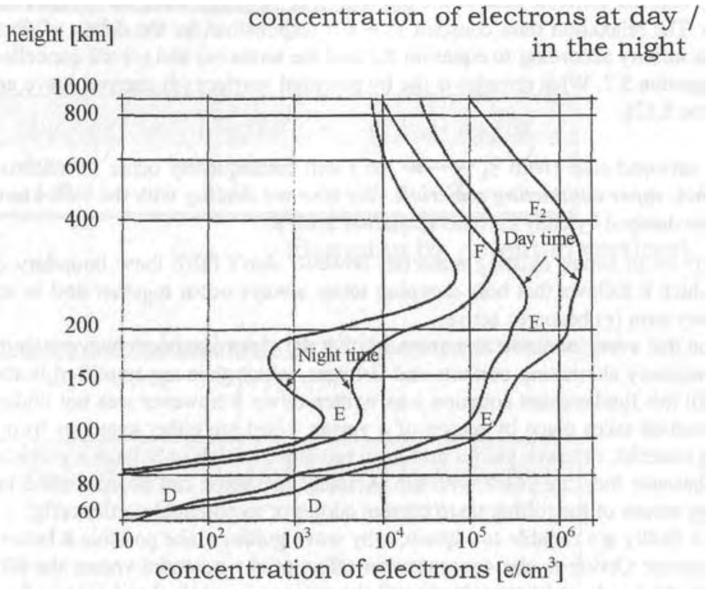

Fig. 5.4: The dependency on height of the ionisation in the ionosphere for medium latitudes .<i>

left curve: for a minimum of sun spots

right curve: for a maximum of sun spots

<i>: H.L. Konig: Unsichtbare Umwelt (Wetterfuhligkeit), 5. Aufl., Bild 6, Seite 11, Verlag Moos & Partner Milnchen, ISBN 3-89164-058-7

5.4 Phenomenological interpretation of the fundamental field equation

How does a damping by vortices take effect in practice? First of all we notice that the reception of broadcastings gets worse. "The information signal is neglectable regarding the noise" explains the radio engineer and means, the number of vortices increases at the expense of the wave intensity.

Why, does the pupil ask, is it so cold in space? There the sun shines day and night and in addition much more intensely than on earth! The correct answer would have to read that because of the extremely small conductivity no diffusion process can take place. We owe the warmth on our earth solely the here taking place decay of vortices. Responsible is the conductivity of the atmosphere.

In 60 km to 500 km height over the earth's surface, the region which is called the ionosphere, the gases predominantly exist in ionized form. There a very good conductivity prevails and eddy current losses are the result. Correspondingly high are the measurable temperatures. Besides the diffusion process the eddy currents carry out a damping of the cosmic radiation. We say the sunlight is filtered and reduced to a for nature bearable intensity.

But not all frequencies are damped in the same way (fig. 2.8). We observe a blue shift, if we look into the actually black sky. The blue sky doesn't show any spots or clouds. The reason is to be sought in the skin effect of the eddy currents, which strive outwards. Since no edge of a conductor is present here, no skin can form. The vortices spread evenly over the ionosphere.

The potential vortex however is able to structure. It merely needs a bad conductivity and this it finds in lower heights between 1 km and 10 km. It damps the wave and with that also the light, for which reason we say it becomes darker, the sun disappears behind clouds.

The clouds well visibly form the discussed vortex balls and vortex strings. Clouds can form virtually from the nowhere during intense solar irradiation, i.e. the waves can roll up to vortices. But as a rule this takes place above the oceans. Here also the phenomenon of transport has an effect. Because of the high dielectricity the water surface favours the formation of potential vortices. So the vortices bind individual water molecules and carry them away. If a diffusion process takes place, in which the vortex decays, then it rains. This can happen in two different ways:

1. Either the conductivity increases. If for instance during intense solar irradiation air ions form, the sun is able to break up clouds and fog. Or when the air is raised in higher layers with better conductivity, because a mountain forces this, then it rains at the mountain edge.
2. For potential vortices the electric field is standing perpendicular to them. If at one point an exceptionally lot of vortices join together, which let the cloud appear particularly dark to black, then the danger exists that the ionization field strength for air is reached, in which case a conductive air channel forms along which the stored up charges discharge. Also lightning is a diffusion process, in which potential vortices decay and rain can form.

In connection with the electromagnetic environmental compatibility great importance is attributed in particular to the storage and the decay of electric vortices. There not only is an academic-scientific interest in the question, how many potential vortices are generated, how many are stored and how many decay, if we make a telephone call with a handy, if we are staying under a high-tension line or if we are eating food, which has been heated up in a microwave oven. The necessary mathematical description is provided by the fundamental field equation 5.7.

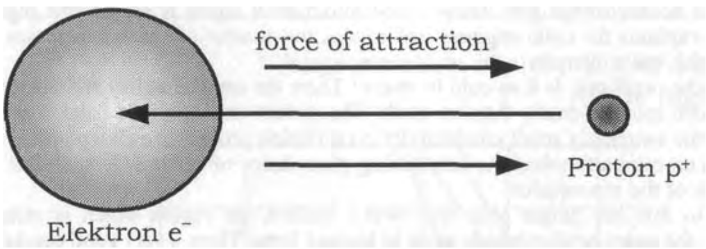
force of attraction
Proton p⁺
Elektron e⁻

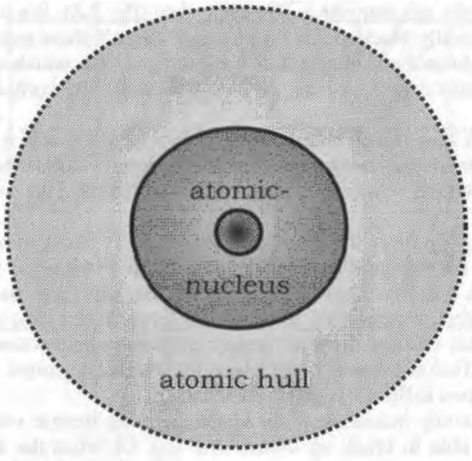
atomic-
nucleus
atomic hull

Fig. 5.5: The structure of atoms in the view of the fundamental field equation

condition for equilibrium: $$\boxed{\tau_1 = \tau_2} \tag{5.13}$$

5.5 Atomistic interpretation of the fundamental field equation

Let's again turn to the smaller, the atomistic dimensions. Here positively charged protons and negatively charged electrons are found. Both are matter particles and that means that seen from the outside both have the identical swirl direction. For reason of the unequal charge conditions they attract each other mutually and according to fig. 4.9 rotate around a common centre of mass as differently heavy pair. Chemists say: "the light electron orbits the heavy atomic nucleus". With small balls they try to explain the atomic structure.
But the model is no good: it contradicts causality in the most elementary manner. We are dealing with the problem that according to the laws of electrodynamics a centripetally accelerated electron should emit electromagnetic waves and continuously lose energy, to eventually plunge into the nucleus.
Our experience teaches that this fortunately is not true - and Niels Bohr in order to save his model of the atom was forced to annul the laws of physics with a postulate founded in arbitrariness.
Actually this state only exists for a very short time and then something unbelievable happens: the electron can't be distinguished as an individual particle anymore. "It is smeared over the electron orbit" do certain people say; "it possesses a dual nature" says Heisenberg. Besides the corpuscular nature the electron should in case of its "second nature" form a matter wave, "the position of the electron is to be looked at as a resonance which is the maximum of a probability density", do explain us de Broglie and Schrodinger.

These explanations can hardly convince. If the electron loses its particle nature in its second nature, then it also will lose its typical properties, like for instance its mass and its charge. but this is not the case.
THE vortex theory provides clear and causal answers: if the electron were a ball it continuosly would lose energy, therefore another configuration forms that does not know this problem. Here the phenomenon of transport takes an effect. The electron opens its vortex centre and takes the tiny protons and neutrons as atomic nucleus up into itself. The Bohr electron orbit with that is not a path anymore, but is occupied by the whole particle as spherical shell. This is confirmed by the not understood measurements exactly like the photos of individual atoms with the scanning electron microscope.
But now an electron does in its inside have the opposite swirl direction as the proton seen from the outside. As a consequence a force of repulsion will occur, which can be interpreted as the to the outside directed current eddy, the force of attraction for reason of the opposite charge works in the opposite direction and can be interpreted as the potential vortex effect.
If both vortices are equally powerful: $\tau_1 = \tau_2$ (5.13)
or if both forces are balanced, as one usually would say, then the object which we call an atom is in a stable state.
It probably will be a result of the incompatible swirl direction, why a very big distance results, if the electron becomes an enveloping electron. On such a shell not too many electrons have room. Because of the rotation of their own, the electron spin, they form a magnetic dipole moment, which leads to a magnetic attraction of two electrons if they put their spin axis antiparallelly.
As a "frictionless" against one another rotating pair they form two half-shells of a sphere and with that occupy the innermost shell in the hull of an atom. If the positive charge of the nucleus is still not balanced with that, then other electrons is left only the possibility to form another shell. Now this next electron takes the whole object up into itself. The new shell lies further on the outside and naturally offers room to more as only two vortices.

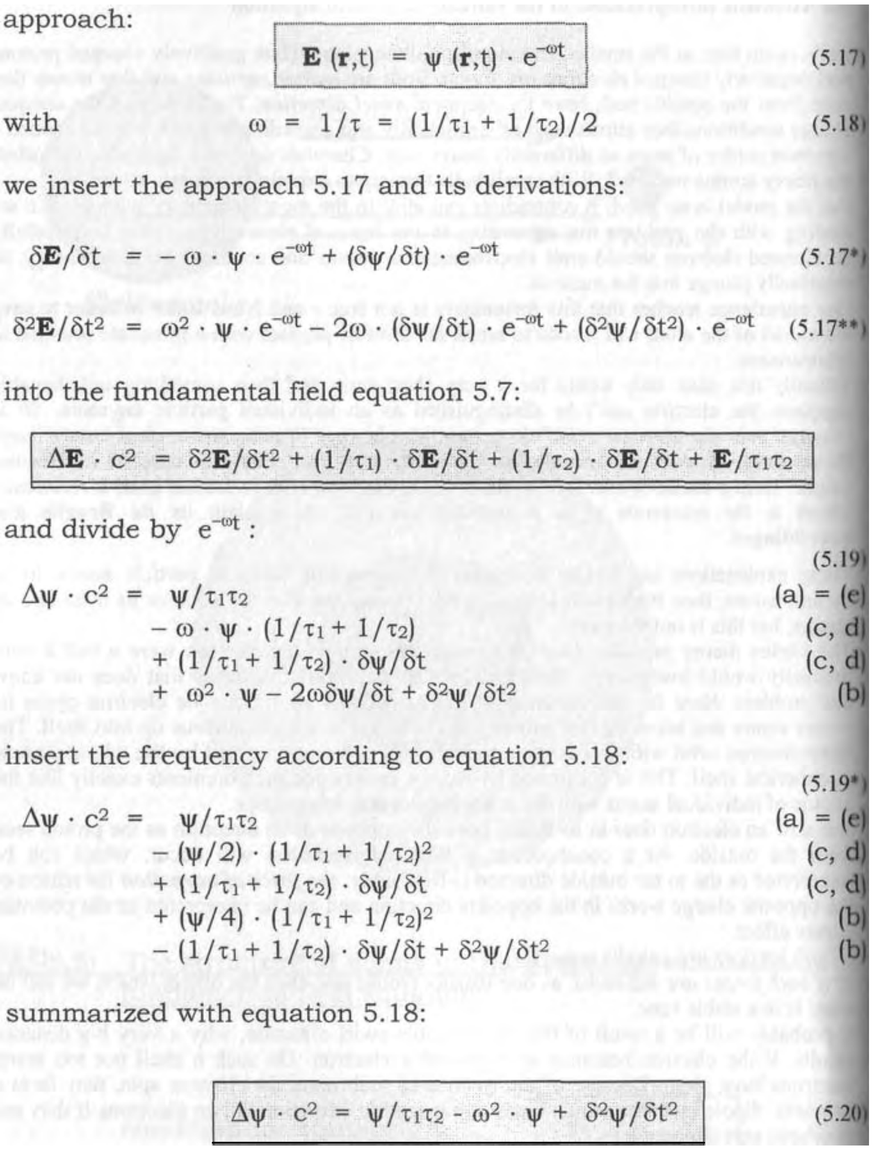

approach:

$$\boxed{\mathbf{E}(\mathbf{r},t) = \psi(\mathbf{r},t) \cdot e^{-\omega t}} \qquad (5.17)$$

with $\omega = 1/\tau = (1/\tau_1 + 1/\tau_2)/2$ (5.18)

we insert the approach 5.17 and its derivations:

$$\delta\mathbf{E}/\delta t = -\omega \cdot \psi \cdot e^{-\omega t} + (\delta\psi/\delta t) \cdot e^{-\omega t} \qquad (5.17^*)$$

$$\delta^2\mathbf{E}/\delta t^2 = \omega^2 \cdot \psi \cdot e^{-\omega t} - 2\omega \cdot (\delta\psi/\delta t) \cdot e^{-\omega t} + (\delta^2\psi/\delta t^2) \cdot e^{-\omega t} \qquad (5.17^{**})$$

into the fundamental field equation 5.7:

$$\boxed{\Delta\mathbf{E} \cdot c^2 = \delta^2\mathbf{E}/\delta t^2 + (1/\tau_1) \cdot \delta\mathbf{E}/\delta t + (1/\tau_2) \cdot \delta\mathbf{E}/\delta t + \mathbf{E}/\tau_1\tau_2}$$

and divide by $e^{-\omega t}$:

$$\begin{aligned} \Delta\psi \cdot c^2 = \; & \psi/\tau_1\tau_2 && (a) = (e) \\ & - \omega \cdot \psi \cdot (1/\tau_1 + 1/\tau_2) && (c,\ d) \\ & + (1/\tau_1 + 1/\tau_2) \cdot \delta\psi/\delta t && (c,\ d) \\ & + \omega^2 \cdot \psi - 2\omega\delta\psi/\delta t + \delta^2\psi/\delta t^2 && (b) \end{aligned} \qquad (5.19)$$

insert the frequency according to equation 5.18:

$$\begin{aligned} \Delta\psi \cdot c^2 = \; & \psi/\tau_1\tau_2 && (a) = (e) \\ & - (\psi/2) \cdot (1/\tau_1 + 1/\tau_2)^2 && (c,\ d) \\ & + (1/\tau_1 + 1/\tau_2) \cdot \delta\psi/\delta t && (c,\ d) \\ & + (\psi/4) \cdot (1/\tau_1 + 1/\tau_2)^2 && (b) \\ & - (1/\tau_1 + 1/\tau_2) \cdot \delta\psi/\delta t + \delta^2\psi/\delta t^2 && (b) \end{aligned} \qquad (5.19^*)$$

summarized with equation 5.18:

$$\boxed{\Delta\psi \cdot c^2 = \psi/\tau_1\tau_2 - \omega^2 \cdot \psi + \delta^2\psi/\delta t^2} \qquad (5.20)$$

Fig. 5.6: Derivation of the Klein-Gordon equation (5.20) from the fundamental field equation (5.7)

5.6 Derivation of the Klein-Gordon equation

The valid model of the atom today still raises problems of causality, as has been explained. An improvement was provided by an equation, which was proposed by the mathematician Schrodinger 1926 as a model description. This equation in this way missed the physical root, but it nevertheless got international acknowledgment, because it could be confirmed experimentally. Looking backwards from the result then the physical interpretation of the probability density of the resonance of the waves could be pushed afterwards.

$$i \cdot \hbar \cdot \delta\psi/\delta t = U \cdot \psi - (\hbar^2/2m) \cdot \Delta\psi \quad (5.14)$$

The Schrodinger equation is valid for matter fields (of mass m), while the interaction with a outside force field the energy U indicates. It can be won from a wave equation by conversion, which possibly is the reason why it usually is called a wave equation, although in reality it is a diffusion equation, so a vortex equation!
For the derivation Schrodinger gives the approach of a harmonic oscillation for the complex wave function ψ:

$$\boxed{\psi(\mathbf{r},t) = \phi(\mathbf{r}) \cdot e^{-i\omega t}} \quad (5.15)$$

if the entire time dependency can be described by one frequency f = W/h (de-Broglie relation): $\omega = 2\pi f = W \cdot 2\pi/h = W/\hbar$ (5.16)

The high-put goal is: if the structure of the atom is determined by the fundamental field equation 5.7 then one should be able to derive the experimentally secured Schrodinger equation and to mathematically describe the discussed special case. Also we select at first an approach periodic in time:

$$\boxed{\mathbf{E}(\mathbf{r},t) = \psi(\mathbf{r},t) \cdot e^{-\omega t}} \quad (5.17)$$

with $\omega = 1/\tau = (1/\tau_1 + 1/\tau_2)/2$. (5.18)

We insert the approach 5.17 and its derivations into the field equation 5.7 and divide by the damping term e^{-wt}:

$$\Delta\psi \cdot c^2 = \psi/\tau_1\tau_2 - \omega \cdot \psi \cdot (1/\tau_1 + 1/\tau_2) + (1/\tau_1 + 1/\tau_2) \cdot (\delta\psi/\delta t) + \\ + \omega^2 \cdot \psi - 2\omega\,\delta\psi/\delta t + \delta^2\psi/\delta t^2 \quad (5.19)$$

If as the next step the angular frequency according to equation 5.18 is inserted, then summarized the provisional intermediate result results:

$$\boxed{\Delta\psi \cdot c^2 = \psi/\tau_1\tau_2 - \omega^2 \cdot \psi + \delta^2\psi/\delta t^2} \quad (5.20)$$

The derived equation 5.20 represents formally seen the Klein-Gordon equation, which is used for the description of matter waves in quantum mechanics and which particularly in the quantum field theory (e.g. mesons) plays an important role. Even if it often is regarded as the relativistic invariant generalization of the Schrodinger equation, it at a closer look is incompatible with this equation and as "genuine" wave equation it is not capable of treating vortex problems correctly, like e.g. the with the Schrodinger equation calculable quantization of our microcosm.

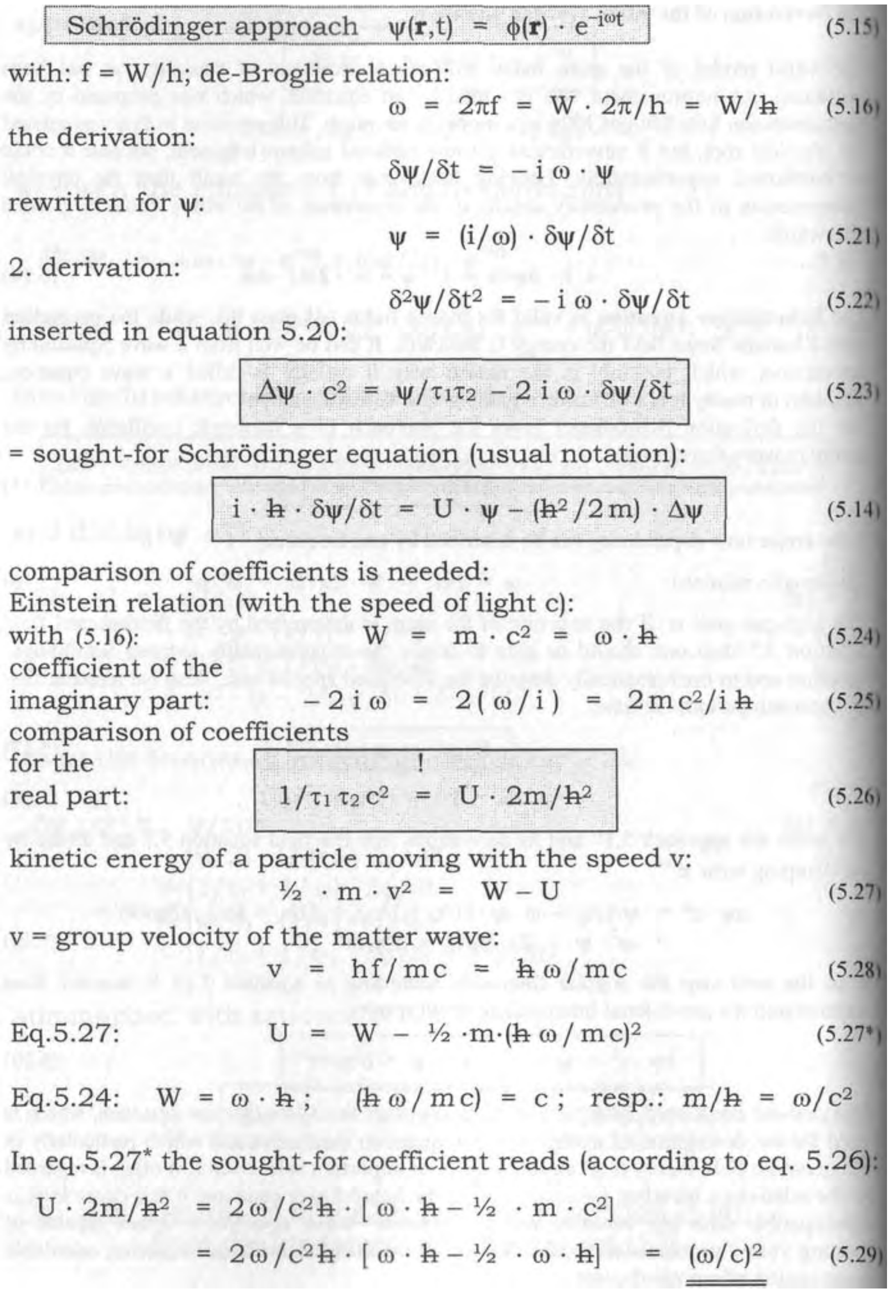

Schrödinger approach $\boxed{\psi(\mathbf{r},t) = \phi(\mathbf{r}) \cdot e^{-i\omega t}}$ (5.15)

with: f = W/h; de-Broglie relation:

$$\omega = 2\pi f = W \cdot 2\pi/h = W/\hbar \qquad (5.16)$$

the derivation:

$$\delta\psi/\delta t = -i\,\omega \cdot \psi$$

rewritten for ψ:

$$\psi = (i/\omega) \cdot \delta\psi/\delta t \qquad (5.21)$$

2. derivation:

$$\delta^2\psi/\delta t^2 = -i\,\omega \cdot \delta\psi/\delta t \qquad (5.22)$$

inserted in equation 5.20:

$$\boxed{\Delta\psi \cdot c^2 = \psi/\tau_1\tau_2 - 2\,i\,\omega \cdot \delta\psi/\delta t} \qquad (5.23)$$

= sought-for Schrödinger equation (usual notation):

$$\boxed{i \cdot \hbar \cdot \delta\psi/\delta t = U \cdot \psi - (\hbar^2/2m) \cdot \Delta\psi} \qquad (5.14)$$

comparison of coefficients is needed:
Einstein relation (with the speed of light c):

with (5.16): $W = m \cdot c^2 = \omega \cdot \hbar$ (5.24)

coefficient of the
imaginary part: $-2\,i\,\omega = 2(\omega/i) = 2mc^2/i\hbar$ (5.25)

comparison of coefficients
for the
real part: $\boxed{1/\tau_1\tau_2 c^2 \overset{!}{=} U \cdot 2m/\hbar^2}$ (5.26)

kinetic energy of a particle moving with the speed v:

$$\tfrac{1}{2} \cdot m \cdot v^2 = W - U \qquad (5.27)$$

v = group velocity of the matter wave:

$$v = hf/mc = \hbar\omega/mc \qquad (5.28)$$

Eq.5.27: $U = W - \tfrac{1}{2} \cdot m \cdot (\hbar\omega/mc)^2$ (5.27*)

Eq.5.24: $W = \omega \cdot \hbar$; $(\hbar\omega/mc) = c$; resp.: $m/\hbar = \omega/c^2$

In eq.5.27* the sought-for coefficient reads (according to eq. 5.26):

$$U \cdot 2m/\hbar^2 = 2\omega/c^2\hbar \cdot [\omega \cdot \hbar - \tfrac{1}{2} \cdot m \cdot c^2]$$

$$= 2\omega/c^2\hbar \cdot [\omega \cdot \hbar - \tfrac{1}{2} \cdot \omega \cdot \hbar] = \underline{\underline{(\omega/c)^2}} \qquad (5.29)$$

Fig. 5.7: Derivation of the time dependent Schrodinger equation

5.7 Derivation of the time dependent Schrodinger equation

With the Schrodinger approach 5.15 and its derivations the derivation is continued:

$$\boxed{\psi(\mathbf{r},t) = \phi(\mathbf{r}) \cdot e^{-i\omega t}}\ , \qquad (5.15)$$

$$\delta\psi/\delta t = -i\omega \cdot \psi\ , \quad \text{bzw.} \quad \psi = (i/\omega) \cdot \delta\psi/\delta t \qquad (5.21)$$

$$\delta^2\psi/\delta t^2 = -i\omega \cdot \delta\psi/\delta t \qquad (5.22)$$

The for a harmonic oscillation won relations according to equation 5.21 and 5.22 are now inserted into equation 5.20:

$$\boxed{\Delta\psi \cdot c^2 = \psi/\tau_1\tau_2 - 2i\omega \cdot \delta\psi/\delta t}$$

This is already the sought-for Schrodinger equation, as we will see in a moment, when we have analysed the coefficients. Because, besides equation 5.16 for the total energy W, also the Einstein relation is valid (with the speed of light c):

$W = m \cdot c^2 = \omega \cdot \hbar$, (5.24)

we can replace the coefficients of the imaginary part by:

$2(\omega/i) = 2mc^2/i\hbar$ (5.25)

To achieve that equation 5.23, as required, follows from the Schrodinger equation 5.14, a comparison of coefficients is carried out for the real part:

$\boxed{1/\tau_1\tau_2 c^2 \overset{!}{=} U \cdot 2m/\hbar^2}$ (5.26)

If thc kinetic energy of a particle moving with the speed v is:
$\frac{1}{2} \cdot m \cdot v^2 = W - U$, (5.27)

then acccording to De Broglie this particle has the wavelength h/mv. The consideration of the particle as matter wave demands an agreement with the wave length c/f of an electromagnetic wave (with the phase velocity c). The particle hence has the speed v, which corresponds with the group velocity of the matter wave:

$$v = hf/mc = \hbar\omega/mc\ , \qquad (5.28)$$

if we insert v into equation 5.27 :
$U = W - \frac{1}{2} \cdot m \cdot (\hbar\omega/mc)^2$ (5.27*)

According to equation 5.24 on the one hand the total energy is W = w • h and on the other hand the relation 5.28 gives $(\hbar\omega/mc) = c$ resp.: $m/\hbar = \omega/c^2$

Inserted into equation 5.27* the sought-for coefficient reads (according to eq. 5.26):

$$U \cdot 2m/\hbar^2 = 2\omega/c^2\hbar \cdot [\omega \cdot \hbar - \tfrac{1}{2} \cdot m \cdot c^2]$$
$$= 2\omega/c^2\hbar \cdot [\omega \cdot \hbar - \tfrac{1}{2} \cdot \omega \cdot \hbar] = \underline{(\omega/c)^2} \qquad (5.29)$$

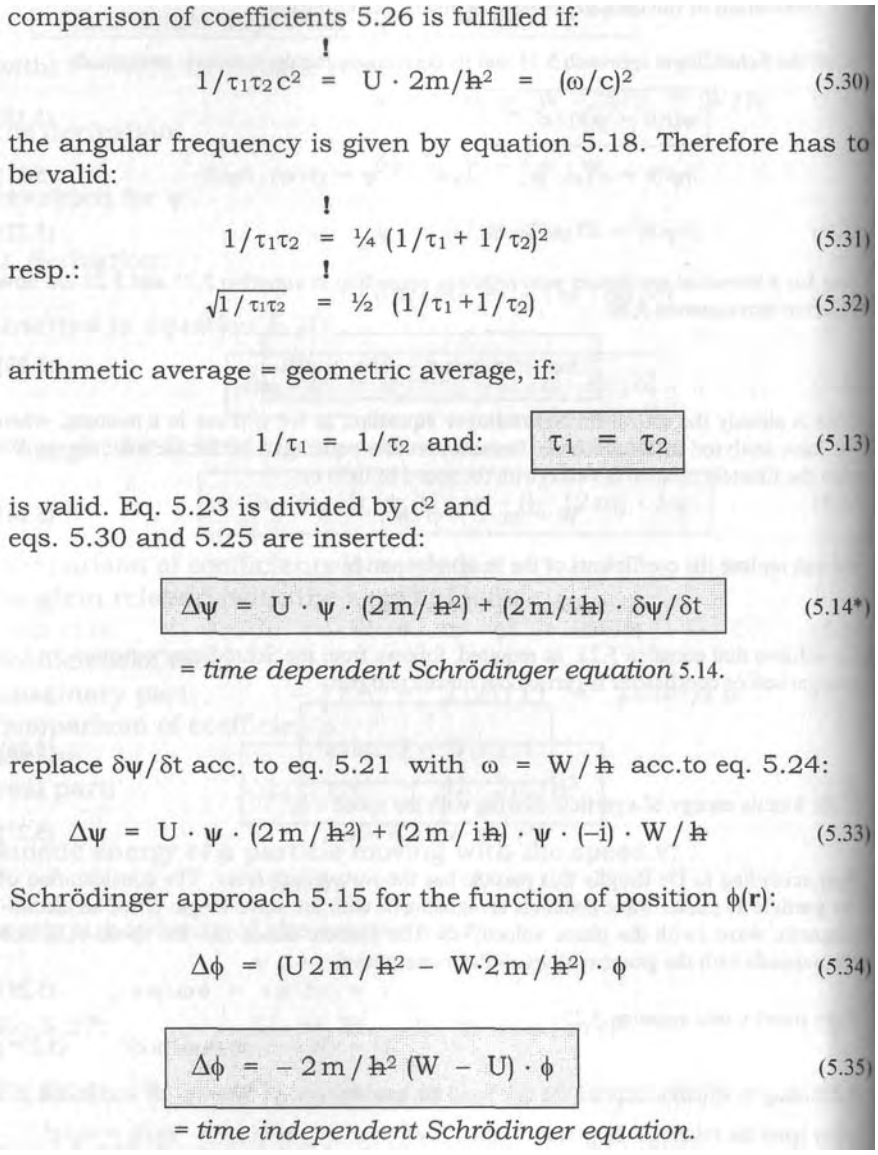

comparison of coefficients 5.26 is fulfilled if:

$$1/\tau_1\tau_2 c^2 \overset{!}{=} U \cdot 2m/\hbar^2 = (\omega/c)^2 \qquad (5.30)$$

the angular frequency is given by equation 5.18. Therefore has to be valid:

$$1/\tau_1\tau_2 \overset{!}{=} \tfrac{1}{4}\,(1/\tau_1 + 1/\tau_2)^2 \qquad (5.31)$$

resp.:

$$\sqrt{1/\tau_1\tau_2} \overset{!}{=} \tfrac{1}{2}\,(1/\tau_1 + 1/\tau_2) \qquad (5.32)$$

arithmetic average = geometric average, if:

$$1/\tau_1 = 1/\tau_2 \text{ and: } \boxed{\tau_1 = \tau_2} \qquad (5.13)$$

is valid. Eq. 5.23 is divided by c^2 and eqs. 5.30 and 5.25 are inserted:

$$\boxed{\Delta\psi = U \cdot \psi \cdot (2m/\hbar^2) + (2m/i\hbar) \cdot \delta\psi/\delta t} \qquad (5.14^*)$$

= time dependent Schrödinger equation 5.14.

replace $\delta\psi/\delta t$ acc. to eq. 5.21 with $\omega = W/\hbar$ acc.to eq. 5.24:

$$\Delta\psi = U \cdot \psi \cdot (2m/\hbar^2) + (2m/i\hbar) \cdot \psi \cdot (-i) \cdot W/\hbar \qquad (5.33)$$

Schrödinger approach 5.15 for the function of position $\phi(\mathbf{r})$:

$$\Delta\phi = (U 2m/\hbar^2 - W \cdot 2m/\hbar^2) \cdot \phi \qquad (5.34)$$

$$\boxed{\Delta\phi = -2m/\hbar^2\,(W - U) \cdot \phi} \qquad (5.35)$$

= time independent Schrödinger equation.

Fig. 5.8: Derivation of the time independent Schrodinger equation

5.8 Derivation of the time independent Schrodinger equation

The goal is reached if we are capable to fulfil the comparison of coefficients 5.26:

$$U \cdot 2\,m/\hbar^2 \overset{!}{=} (\omega/c)^2 = 1/\tau_1\tau_2 c^2 \tag{5.30}$$

The angular frequency w is given by equation 5.18. Therefore has to be valid:

$$\tfrac{1}{4}\,(1/\tau_1 + 1/\tau_2)^2 \overset{!}{=} 1/\tau_1\tau_2 \tag{5.31}$$

$$\tfrac{1}{2} \cdot (1/\tau_1 + 1/\tau_1) \overset{!}{=} \sqrt{1/\tau_1\tau_2} \tag{5.32}$$

As is well-known the arithmetic and the geometric average only correspond in case the variables are identical. In this case, as already required in equation 5.13:

$$\tau_1 = \tau_2\,. \tag{5.13}$$

has to hold.

From this we can draw the conclusion that the Schrodinger equation is just applicable to the described special case (according to eq. 5.13), in which the eddy current, which tries to increase the particle or its circular path and the potential vortex, which keeps the atoms together and also is responsible for the stability of the elementary particles, are of identical order of magnitude.

As a check equation 5.23 is divided by c^2 and equations 5.30 and 5.25 are inserted:

$$\boxed{\Delta\psi = U \cdot \psi \cdot (2\,m/\hbar^2) + (2\,m/i\hbar) \cdot \delta\psi/\delta t} \tag{5.14*}$$

This is the time dependent Schrodinger equation 5.14 resolved for $\Delta\psi$.

Next we replace $\delta\psi/\delta t$ according to equation 5.21 with $\omega = W/\hbar$ acc. to equation 5.24:

$$\Delta\psi = U \cdot \psi \cdot (2\,m/\hbar^2) + (2\,m/i\hbar) \cdot \psi \cdot (-\,i) \cdot W/\hbar \tag{5.33}$$

If we separate the space variables $\phi(\mathbf{r})$ from time by the Schrodinger approach 5.15 we obtain:

$$\Delta\phi = (U\,2\,m/\hbar^2 - W \cdot 2\,m/\hbar^2) \cdot \phi \tag{5.34}$$

This quation 5.34 for the function of space coordinates $\phi(\mathbf{r})$ is the time independent Schrodinger equation:

$$\boxed{\Delta\phi = -\,2\,m/\hbar^2\,(W - U) \cdot \phi} \tag{5.35}$$

The solutions of this equation which fulfil all the conditions that can be asked of them (of finiteness, steadiness, uniqueness etc.), are called eigenfunctions. The existence of corresponding discrete values of the energy W, also called eigenvalues of the Schrodinger equation, are the mathematical reason for the different quantum postulates.

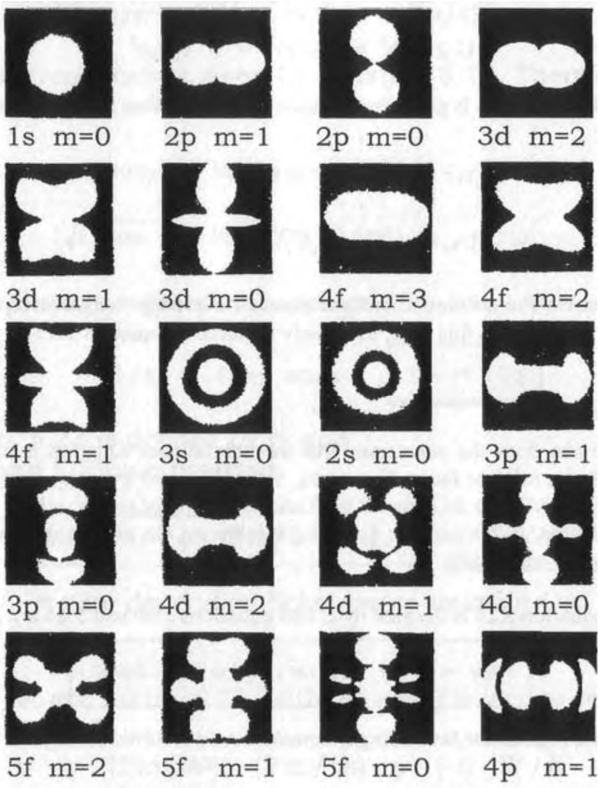

1s m=0 2p m=1 2p m=0 3d m=2
3d m=1 3d m=0 4f m=3 4f m=2
4f m=1 3s m=0 2s m=0 3p m=1
3p m=0 4d m=2 4d m=1 4d m=0
5f m=2 5f m=1 5f m=0 4p m=1

Fig. 5.9: Photographs of models of the probability densities for different states of the hydrogen atom. The densities are symmetrical if rotated around the vertical axis<i>

taken from:

<i>: U. Gradmann/H. Wolter: Grundlagen der Atomphysik, AVG, Frankfurt a. M. 1971, P. 190.

5.9 Interpretation of the Schrodinger equation

The interpretation of the Schrodinger equation is still disputed among physicists, because the concept of wave packets contradicts the corpuscular nature of the elementary particles. Further the difficulty is added that wave packets at a closer look never are connected, run apart more or less fast, and really nothing can hinder them doing that. But for a particle the connection represents a physical fact. Then there can be no talk of causality anymore. The monocausal division into two different levels of reality, in a space-timely localization and in an energetic description, does not represent a solution but rather the opposite, the abolition of the so-called dual nature. As has been shown, the potential vortex is able to achieve this with the help of its concentration effect.
But from the introduction of this new field phenomenon arises the necessity to interpret the causes for the calculable and with measuring techniques testable solutions of the Schrodinger equation in a new way. Laws of nature do not know a possibility to choose! If they have been accepted as correct, they necessarily have to be applied.

Three hundred years ago the scholars had an argument, whether a division of physical pheomena, like Newton had proposed it, would be allowed to afterwards investigate them in the laboratory individually and isolated from other influences or if one better should proceed in an integrated manner, like for instance Descartes with his cartesian vortex theory. He imagined the celestial bodies floating in ethereal vortices. One absolutely was aware that the whole had to be more than the sum of every single realizaton, but the since Demokrit discussed vortex idea had to make room for the overwhelming successes of the method of Newton. And this idea after 2100 years was stamped, to in the meantime almost have fallen into oblivion.
Today, where this recipe for success in many areas already hits the limits of the physical possibilities, we should remember the teachings of the ancients and take up again the vortex idea It of course is true that only details are calculable mathematically and that nature, the big whole, stays incalculable, wherein problems can be seen.
If we consider the fundamental field equation 5.7, we find confirmed that actually no mathematician is capable to give a generally valid solution for this four-dimensional partial differential equation. Only restrictive special cases for a harmonic excitation or for certain spatial boundary conditions are calculable. The derived Schrodinger equation is such a case and for us particularly interesting, because it is an eigenvalue equation. The eigenvalues describe in a mathematical manner the with measuring techniques testable structures of the potential vortex .
Other eigenvalue equations are also derivable, like the Klein-Gordon equation or the Lionville equation, which is applied successfully in chaos theories. So our view opens, if chaotic systems like turbulences can be calculated as special cases of the same field equation and should be derivable from this equation.
The in pictures recorded and published structures, which at night should have come into being in corn fields, often look like the eigenvalues of a corresponding equation. The ripe ears thereby lie in clean vortex structures flat on the soil. Possibly potential vortices have charged the ears to such high field strength values that they have been pulled to the soil by the Coulomb forces.

Consequences resulting from the derivation of the Schrodinger equation from the fundamental field equation 5.7:

1. *Any experiment which confirms the Schrödinger equation is with that able to confirm at the same time the existence of the newly discovered potential vortex and the correctness of the field-theoretical approach.*

2. *Properties of the atomic hull and of the atomic nucleus, which can be described with the Schrödinger equation, can as of now be interpreted as an electromagnetic phenomenon.*

3. *There exist no particles or wave packets from matter waves, but only configurations consisting of potential vortices and current eddies.*

4. *There exists no matter! What we call matter is nothing but an electromagnetic state of oscillation of empty space.*

The relation between the energy of oscillation and the mass is described by the relation named after Albert Einstein

$$\boxed{E = mc^2} \quad . \qquad (6.1 = 5.24)$$

Fig. 6.1: Derivation of the Schrodinger equation, power of proof and consequences

6. Theory of objectivity

6.1 Proof

A new theory only has chances on acknowledgment if it is provable. For that physical phenomena in the sense of the new theory are calculated and independently of this experiments are being carried out. If the calculations are confirmed by reproducible measurement results, then with that the correctness of the approach is proven.
In the here presented case we have chosen the field-theoretical approach instead of the usual quantum physical approach. As a consequence of this we had found as a new phenomenon the vortex of the electric field. With regard to the normally used Maxwell theory this resulted in changed field equations in a dual formulation. If both equations, each of which describes a source-free vortex field, are inserted into each other the result is an only in time and space formulated, generally valid and hence fundamental field equation (5.7, fig. 5.1).
This equation has many special cases; one of them, the Schrodinger equation, could be derived by using an approach which was harmonic in time. We renounced to give special solutions of the Schrodinger equation, because these are printed in numerous text books. On the other hand experiments are known, which are capable to confirm the theoretical solutions and thus to prove the Schrodinger equation. The eigenvalues of the equation describe for instance the shell-shaped structure of the atoms with the by Niels Bohr given radii.
Now this already proven equation was derived from the new field-theoretical approach. Thus for the special case, the area where the Schrodinger equation is valid, the new theory can be said to be proven (fig. 6.1).
We still are not content with that and put another stone on top: we will calculate the quantum properties of the elementary particles for ourselves. These until now have only been measured. Today is merely sought for symmetries and for models of explanation, like e.g. the quark-hypothesis. From a calculation science is miles and miles away. We will compare the calculation results with the measurement values. Then everyone can check and compare for him or herself.
The conditions in an elementary particle are completely different. Here it concerns the vortex itself, whereas the model of the atom merely describes vortex properties, so-called actions at a distance. The differences in size and distances for an atom lie more than five powers of ten over those of a particle!
Here a new problem of causality comes to light, at which we now must have a critical look: the question of the by Einstein postulated constancy and universality of the speed of light. Seen from a relativistic and subjective point of view of an observer, Einstein by all means may be right. But may such a theory be generalized? How are the measurements concerning the speed of light and the relativity of space and time to be judged when looking at them objectively?
The current measurements of speeds faster than light speak a clear language and represent a challenge (fig. 3.1, violation of the principle of causality no. 5).

The electron as a spherical capacitor (see fig. 4.3):

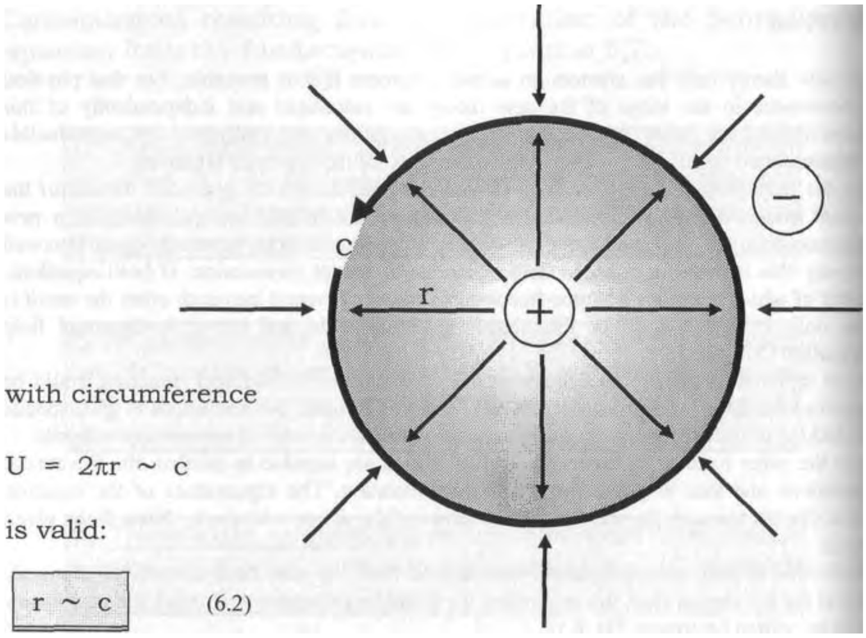

with circumference

$U = 2\pi r \sim c$

is valid:

$$\boxed{r \sim c} \quad (6.2)$$

field theoretical approach (vortex particles):
The amount of energy bound in the inside of the particle is identical with the free and measurable amount of energy on the outside of the particle.

(If the number of particles is left unchanged):
In an isolated system the sum of the energy is constant

(particle = electromagnetic vortex)
Energy is a state description of electromagnetism.

Fig. 6.2: Derivation of the law of conservation of energy

6.2 Law of conservation of energy

Let the starting-point for our considerations be the electromagnetic wave in a particle-free vacuum. Here no vortices appear, so that the plane wave can propagate undamped with the speed of light, and in this way a transport of energy takes place. Electric and magnetic energy each are the same magnitude.

Let's now imagine the symmetry is disturbed as the wave is "slowed down" on one side. As a possible result the wave rolls up to a spherical vortex.

As we will see such a process is possible, for instance at impact on a strong field. Thus part of the energy is bound in the inside. This part from now on withdraws itself from every possibility to measure it. We can only measure the second part of the field energy, with which the particle interacts with its neighbourhood.

We can assume that:

The amount of energy bound in the inside of the particle is identical with the free and measurable amount of energy on the outside of the particle.

The same energy W_e = 0,51 MeV, we attribute to the electron for reason of its mass with the help of the Einstein relation (6.1), is also bound in its inside. This conclusion is also applicable to other elementary particles and with that to all matter.

We here again recognize the principle of the duality between the to the outside striving eddy current in the inside of the elementary vortex and the concentrating potential vortex on the outside. Thus also seen energetically both are of the same magnitude. Whereas in the case of the electromagnetic wave it concerns a symmetrical oscillation around "zero", by the process of quantization, by the rolling up to a spherical vortex, there forms an energetic state of space different from zero. The order of magnitude is determined by the number of elementary vortices, of which the particles and all matter consist.

Anti-matter forms the opposite energetic state and this again is for the particles of matter available in their inside in a bound form.

As long as we do not artificially produce new elementary vortices and thus keep the number of available vortices constant, the energetic state will not change, or as it is formulated in text books:

In an isolated system the sum of the energy is constant.

THE law of conservation of energy is not an axiom, but follows without compulsion from the vortex theory. It is not elementary, but a consistently derivable consequence of the field-theoretical approach, according to which solely the field acts as cause for all other physical phenomena, also for the conservation of energy! Because the cause of it is the electromagnetic field, the following has to hold:

Energy is a state description of electromagnetism.

Now we finally can explain why energy can be converted. Different forms of energy only are different forms of formation of the same phenomenon!

Of course this statement of the field-theoretical approach does not yet explain what, for instance, the temperature has to do with electromagnetism. I ask for some patience; no question will be left unanswered.

From

$$\boxed{c \sim r} \qquad (6.2)$$

follows:

The speed of light determines the size of the elementary particles.

Energy of a capacitor:

$$W = Q^2/C, \qquad (6.3)$$

written down for the electron (with the Einstein relation):

$$W_e = e^2/C_e = m_e c^2 = 0{,}51\ \mathrm{MeV} \qquad (6.1)$$

Capacity of a spherical capacitor:

$$C_e = \varepsilon_0 \cdot 4\pi r_e \qquad (6.4)$$

"classical" radius of the electron[i] is:

$$r_e = e^2/\varepsilon_0 \cdot 4\pi \cdot W_e \qquad (6.5)$$

$$r_e = 2{,}82 \cdot 10^{-15}\ \mathrm{m} \qquad (6.6)$$

in the case of Kuchling[ii] the radius of the electron is:

$$r_e = 1{,}41 \cdot 10^{-15}\ \mathrm{m}\ . \qquad (6.7)$$

Fig. 6.3: Calculation of the radius of the electron.

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[i]: Mende, Simon: Physik, Gl. 10.39, VEB-Leipzig, 4. Aufl.

[ii]: Kuchling: Physik, Gl. At4, VEB-Leipzig, bis einschl. 11. Auflage 1974

6.3 Radius of the electron

For the crucial process, in which the electromagnetic wave rolls up to a vortex, it is for reasons of continuity to be expected that the velocity of propagation remains equal that thus for the vortex oscillation exactly like for the electromagnetic wave the speed of light is determining. The direction of propagation in the case of the vortex takes place perpendicular to the in fig. 6.2 shown field direction of the electric field strength. Not even in that both field-phenomena differ.
Summarizing: the propagation takes place with the speed of light c along a circular path with the perimeter $U = 2\pi r$. Therefore holds:

$$\boxed{c \sim r} \quad (6.2)$$

According to this equation the radius and with that the size of the electron is determined by the speed of light. Therefore the question of the size of the electron is raised.

The energy interpretation predicts that for the theoretical case of a change of size the energy density in the inside of the particle is influenced that however the quantity of the included energy remains unchanged. We therefore can further proceed from the assumption that the bound amount of energy is independent of the size of the particle!

Consequently for the elementary quantum the energy W_e = 0,51 MeV is assumed, which it has acccording to the Einstein relation $W_e = m_e c^2$. For the electron of mass m_e the with measuring techniques determined value is inserted.
The spherical electrode of a spherical capacitor with the above given energy W_e (according to eq. 6.1) and the capacity C_e (according to equation 6.4, fig. 6.3) represents a very realistic model of the negatively charged particle.
In this manner the classical radius of the electron is calculated to be<i>: $r_e = 2{,}82 * 10^{-15}$ m.

But in the case of Kuchling it only is half this size<ii>, what according to equation 6.2 would mean that in the case of Kuchling the light would be on the way only half this fast <iii>. Therefore if one is careful, one prefers to be silent concerning this delicate theme and if one is honest, one admits not to know anything exact.
Not only the electron but also all the other elementary particles are according to the field-theoretical approach formed from concentrated potential vortices. For these equation 6.2 hence has to hold in the same manner, so that more generalized we can conclude:

The speed of light determines the size of the elementary particles.

This statement is incompatible with the assumption of a constant speed of light! Because then all elementary particles would have identical size. As is known, however, are the building parts of the atomic nucleus, the protons and neutrons very much smaller than individual electrons. The constancy of the speed of light is to be questioned. This question is of such an elementary importance that we are not content with these considerations and in addition undertake a mathematical derivation in the sense of the field approach.

<iii>: Difference = Thomas factor

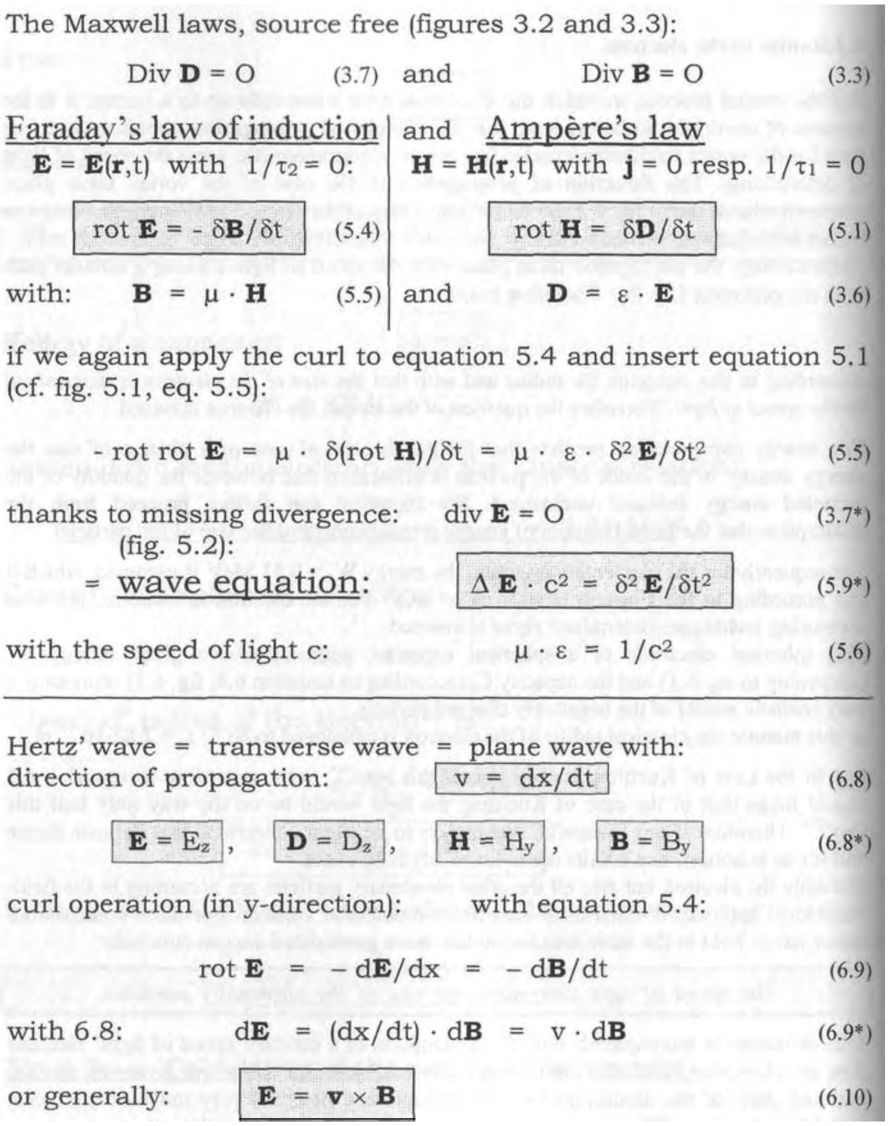

The Maxwell laws, source free (figures 3.2 and 3.3):

$\mathrm{Div}\,\mathbf{D} = O$ (3.7) and $\mathrm{Div}\,\mathbf{B} = O$ (3.3)

<u>Faraday's law of induction</u> and <u>Ampère's law</u>

$\mathbf{E} = \mathbf{E}(\mathbf{r},t)$ with $1/\tau_2 = 0$: | $\mathbf{H} = \mathbf{H}(\mathbf{r},t)$ with $\mathbf{j} = 0$ resp. $1/\tau_1 = 0$

$\boxed{\mathrm{rot}\,\mathbf{E} = -\,\delta\mathbf{B}/\delta t}$ (5.4) | $\boxed{\mathrm{rot}\,\mathbf{H} = \delta\mathbf{D}/\delta t}$ (5.1)

with: $\mathbf{B} = \mu \cdot \mathbf{H}$ (5.5) and $\mathbf{D} = \varepsilon \cdot \mathbf{E}$ (3.6)

if we again apply the curl to equation 5.4 and insert equation 5.1 (cf. fig. 5.1, eq. 5.5):

$$-\,\mathrm{rot}\,\mathrm{rot}\,\mathbf{E} = \mu \cdot \delta(\mathrm{rot}\,\mathbf{H})/\delta t = \mu \cdot \varepsilon \cdot \delta^2\mathbf{E}/\delta t^2 \quad (5.5)$$

thanks to missing divergence: $\mathrm{div}\,\mathbf{E} = O$ (3.7*)
(fig. 5.2):

= <u>wave equation:</u> $\boxed{\Delta\mathbf{E} \cdot c^2 = \delta^2\mathbf{E}/\delta t^2}$ (5.9*)

with the speed of light c: $\mu \cdot \varepsilon = 1/c^2$ (5.6)

Hertz' wave = transverse wave = plane wave with:
direction of propagation: $\boxed{v = dx/dt}$ (6.8)

$\boxed{\mathbf{E} = E_z}$, $\boxed{\mathbf{D} = D_z}$, $\boxed{\mathbf{H} = H_y}$, $\boxed{\mathbf{B} = B_y}$ (6.8*)

curl operation (in y-direction): with equation 5.4:

$$\mathrm{rot}\,\mathbf{E} = -\,d\mathbf{E}/dx = -\,d\mathbf{B}/dt \quad (6.9)$$

with 6.8: $d\mathbf{E} = (dx/dt) \cdot d\mathbf{B} = v \cdot d\mathbf{B}$ (6.9*)

or generally: $\boxed{\mathbf{E} = \mathbf{v} \times \mathbf{B}}$ (6.10)

Fig. 6.4: Derivation of the laws of transformation

<i>: Prof. G. Bosse in his text book in reversed direction derives the Faraday law of induction from the law of transformation 6.10, which he again derives from considerations about the Lorentz force. G. Bosse, Grundlagen der Elektrotechnik II, BI 183, Hochschultaschenbucher-Verlag, Mannheim 1967

6.4 The Maxwell field equations

The laws of transformation of the electromagnetic field shall form the starting-point for the coming up considerations. To exclude any doubts with regard to the interpretation, the equations will be derived from the Maxwell laws under the assumption that no sources or charge carriers are present (fig. 3.2 and 3.3) and as a consequence no current density (j = 0) is to be expected.
This corresponds to the vanishing of the time independent terms, which consequently are responsible for the occurring of force effects like e.g. the Lorentz force. Only at the end of this derivation we can understand the sense of this assumption (with $1/\tau_1 = 0$ and $1/\tau_2 = 0$). The procedure at first corresponds to that of fig. 5.1. Here the fundamental field equation had been derived from Faraday's law of induction and Ampere's law. With the assumptions made this time the in fig. 5.2 treated undamped wave equation is left (5.9, here 5.9*). Whom the derivation is still present can go in at this point.
In a sufficiently great distance from the source we are dealing with a plane wave, in which the field factors only depend on the direction of propagation x. The Hertz' wave is a transverse wave, in which the field pointers oscillate perpendicular to the direction of propagation and in addition stand perpendicular to each other:

$$\boxed{v = dx/dt} \quad (6.8), \qquad \boxed{\mathbf{E} = E_z, \quad \mathbf{D} = D_z, \quad \mathbf{H} = H_y, \quad \mathbf{B} = B_y} \quad (6.8^*)$$

The curl, applied to the electric field pointer, itself points in the y-direction:
rot E = - dE/dx . This for the transverse wave carried out curl operation is now compared with Faraday's law of induction (5.4):

$$\text{rot } E = -dE/dx = -dB/dt \qquad (6.9)$$

The relation won in a mathematical way, with the speed fixed by (6.8), reads:

$$dE = (dx/dt) \cdot dB = v * dB \qquad (6.9^*)$$

The result of this derivation at first only is valid for the introduced simplification, for instance for the case of the transverse electromagnetic wave. Better known is apart from that the generalized formulation, which among others by G. Bosse<i> is called law of transformation.

$$\boxed{\mathbf{E} = \mathbf{v} \times \mathbf{B}} \qquad (6.10)$$

With Ampere's law (5.1) we now should proceed in an analogous manner. The result is:

$$\boxed{\mathbf{H} = -\mathbf{v} \times \mathbf{D}} \quad (6.10^*)$$

This equation 6.10* is given among others by Simonyi<ii>. Now that we know, under which circumstances these equations of transformation can be derived from the Maxwell equations, the actual work can start.

<ii>: K. Simonyi, Theoretische Elektrotechnik, 7. Auflage VEB Verlag Berlin 1979. pp. 921 - 924; In addition see chapter 27.8 in part 3 of this book.

Laws of transformation:

$$\mathbf{E} = \mathbf{v} \times \mathbf{B} = \mathbf{v} \times \mu \cdot \mathbf{H} \qquad (6.10)$$

$$\mathbf{H} = -\mathbf{v} \times \mathbf{D} = -\mathbf{v} \times \varepsilon \cdot \mathbf{E} \qquad (6.10^*)$$

and

We experience the magnetic field as an electric field and the electric field as a magnetic field simply and solely for reason of the same relative motion!

The component of the direction of motion perpendicular to the area defined by the field pointers:

$$E = v \cdot \mu \cdot H \qquad (6.11)$$

and

$$H = -v \cdot \varepsilon \cdot E \qquad (6.11^*)$$

with the relations of material:

$$B = \mu \cdot H \qquad (3.5)$$

$$D = \varepsilon \cdot E \qquad (3.6)$$

with the speed of light:

$$c = 1/\sqrt{\mu \cdot \varepsilon} \qquad (5.6)$$

additional field:

$$E_z = -v^2 \cdot \mu \cdot \varepsilon \cdot E = -(v^2/c^2) \cdot E \qquad (6.12)$$

resp.

$$H_z = -v^2 \cdot \varepsilon \cdot \mu \cdot H = -(v^2/c^2) \cdot H \qquad (6.12^*)$$

basic field: E resp. H (at $v = O$)

measurable overall field: (if $v \neq O$)

$$E_o = E + E_z \qquad (6.13)$$

resp.

$$Ho = H + H_z \qquad (6.13^*)$$

Fig. 6.5: Properties of transformation of the electromagnetic field.

6.5 Equations of transformation

As a consequence of the in fig. 6.5 again written down laws of transformation of the electromagnetic field (6.10 and 6.10*) magnetic phenomena can be traced back to electric phenomena and vice versa. The mathematical formulation reveals us the two sides of the same medal and points to a perfect duality between both fields and their factors of description.

Because a way exists, as is shown here, in which the equations of transformation can be derived from the Maxwell field equations, the same generally valid and extensive importance should be attributed to them. They can with the same right be called the foundation of electromagnetism. Wherein does lie its message for physics, the always curious researcher will ask? For that the relations of material 3.5 and 3.6 are completed:

$$\boxed{\mathbf{E} = \mathbf{v} \times \mu \cdot \mathbf{H}} \quad (6.10) \qquad \text{und} \qquad \boxed{\mathbf{H} = -\mathbf{v} \times \varepsilon \cdot \mathbf{E}} \,. \quad (6.10^*)$$

The here presented equations state, that we measure an electric field strength E, if we are moving with regard to a magnetic field H with the speed v and vice versa. The electric and the magnetic field therefore prove to be an experience of the observing person and we can say:

We experience the magnetic field as electric field and the electric field as magnetic field simply and solely for reason of the relative motion!

Let's assume, v is the component of the relative velocity (6.8), which stands perpendicular to the area defined by the field pointers (6.8*), then the equations of transformation (6.9* with 3.5) now read:

$$\mathrm{E} = \mathrm{v} \cdot \mu \cdot \mathrm{H} \quad (6.11) \qquad \text{and} \qquad \mathrm{H} = -\mathrm{v} \cdot \varepsilon \cdot \mathrm{E} \,. \quad (6.11^*)$$

If we are moving with the velocity v in a basic field which is present with the field strength E, then according to equation 6.11* we observe a magnetic field, which again according to equation 6.11 is to be interpreted as an additional electric field E_z:

$$\mathrm{E}_z = -\mathrm{v}^2 \cdot \mu \cdot \varepsilon \cdot \mathrm{E} = -(\mathrm{v}^2/c^2) \cdot \mathrm{E} \quad (6.12)$$

In duality equation 6.11 inserted into equation 6.11* provides for the magnetic field strength a corresponding additional field H_z:

$$\mathrm{H}_z = -\mathrm{v}^2 \cdot \mu \cdot \varepsilon \cdot \mathrm{H} = -(\mathrm{v}^2/c^2) \cdot \mathrm{H} \quad (6.12^*)$$

We obviously owe the measurable overlap fields in a laboratory simply and solely to the relative velocity v with which the laboratory is moving. But now we must pay attention to the fact that a terrestrial laboratory rotates along with the earth, that the earth orbits the sun and the sun again rotates around the centre of the milky way. Eventually the whole milky way is on the way in the cosmos with a galactic, for us hardly understandable speed. If we further take into consideration that for every subsystem an additional field occurs as a consequence of the relative motion with regard to the super ordinate system, then one additonal field follows after the next and overlaps this one.

Let's imagine, the relative velocity could be reduced towards zero - and maybe we are moving around such a cosmic point - then here no overlapping field would be measurable.

<*>: A derivation using vectors is written in chapter 28 (part 3).

Additional field (from fig. 6.5):

(6.12)
(6.12*)

$$\boxed{\begin{aligned} E_z &= -(v^2/c^2)\cdot E \\ H_z &= -(v^2/c^2)\cdot H \end{aligned}}$$

and

Superposition of the fields:
The additional field (E_z resp. H_z) overlaps the basic field (E resp. H) to produce the measurable overall field (E_0 resp. H_0):

(6.13)

$$\boxed{\begin{aligned} E_0 &= E + E_z = E\cdot(1 - v^2/c^2) \\ H_0 &= H + H_z = H\cdot(1 - v^2/c^2) \end{aligned}}$$

(6.13*)

transformed:

$$\left(1 - \frac{v^2}{c^2}\right) = \frac{E_0}{E} = \frac{H_0}{H}$$

(6.14)

for the Lorentz contraction holds apart from that:

(6.14*)

$$\left(1 - \frac{v^2}{c^2}\right) = \left(\frac{1}{l_0}\right)^2$$

From the comparison
Follows

(6.14**)

$$\frac{E_0}{E} = \frac{H_0}{H} = \left(\frac{1}{l_0}\right)^2$$

the proportionality:

$$\boxed{E, H \sim 1/l^2} \quad \text{and} \quad E_0, H_0 \sim 1/l_0^2 \qquad (6.15)$$

Fig. 6.6: The field dependency of the Lorentz contraction

6.6 Field overlap

Field vectors can be superpositioned. In this manner the additional field E_z resp. H_z which depends on the velocity, according to equation 6.10, overlaps the respective basic field (E resp. H) to produce the measurable overall field (E_0 resp. H_o):

$$\boxed{E_0 = E + E_z = E \cdot (1 - v^2/c^2)} \qquad (6.13)$$

$$\boxed{H_0 = H + H_z = H \cdot (1 - v^2/c^2)} \qquad (6.13^*)$$

In the result something surprising the factor $(l-v^2/c^2)$ appears, which is well-known from the special theory of relativity and for instance appears in the Lorentz contraction.
If we rewrite both equations for the characteristic factor and compare with the in a purely mathematical way, over the Lorentz transformation, won length contraction $(1 - v^2/c^2) = (l/l_0)^2$, then it becomes clear that the Lorentz contraction physically seen should have its cause in the changed field conditions which a with relativistic speed moving body finds with regard to a resting body.

$$1 - \frac{v^2}{c^2} = \frac{E_0}{E} = \frac{H_0}{H} \overset{!}{=} \left(\frac{l}{l_0}\right)^2 \qquad (6.14)$$

The equation is a compulsionless consequence of known physical laws. In this derivation actually no new factor was introduced and nevertheless a completely new picture for the natural scientific reality results<i>.

In our observer system, where the field E_o exists, a rule has its proper length l_0. In another system, which is moving with the speed v relative to the observer, as a consequence of the here prevailing field E the corresponding rule has a length 1. In which relation the factors stand to each other, is described by equation 6.14. Accordingly the following proportionality holds:

$$\boxed{E, H \sim 1/l^2} \text{ and } \boxed{E_0, H_0 \sim 1/l_0^2} \qquad (6.15)$$

If we are exterior to a very fast moving body with velocity v, we immediately can observe how this body for reason of its relative velocity experiences the calculated additional field and in this way experiences a length contraction. If the observer is moving along with the body, then he purely subjective seen doesn't detect a length contraction, because he himself and his entire measuring technique is subjected to the same length contraction. From the axiomatic approach what would be, if the field, which itself only represents an experience, would determine perceptible space and its dimensions, quickly a fundamental realization can develop if the described experiences should coincide with real observations.

<i> : Because in this point of view the subjective status of the observer is determining, it is not completely impossible that there is an error in the interpretation of the equations of transformation (6.10 and 6.10*). But because we started from the same point of view of the observer for the derivation of the length contraction from the Lorentz transformation, here the same error is to be expected. In putting both results equal (6.14), a like constituted error on both sides will cancel out in any case and the result stays above all doubts!

$$\boxed{E, H \sim 1/l^2} \quad \text{and} \quad \boxed{E_0, H_0 \sim 1/l_0^2} \qquad (6.15)$$

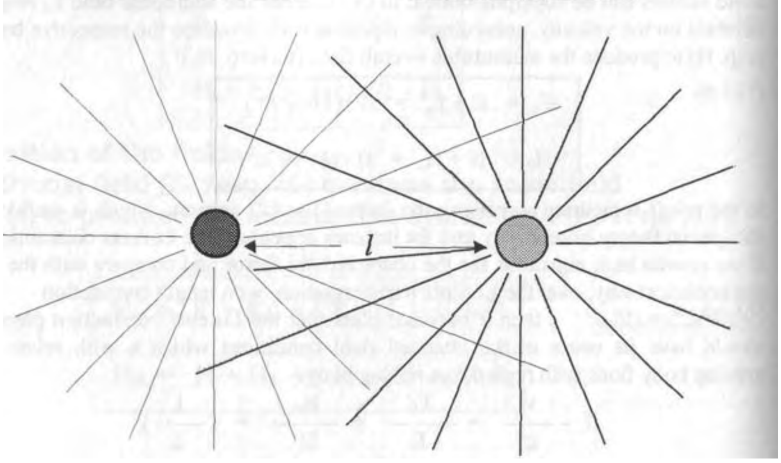

(Model):
Two particles of matter each in the field of the other particle.

Two elementary particles or two accumulations of matter consisting of these are able to reduce the distance to each other for reason of their fields, which we interpret as a force of attraction.

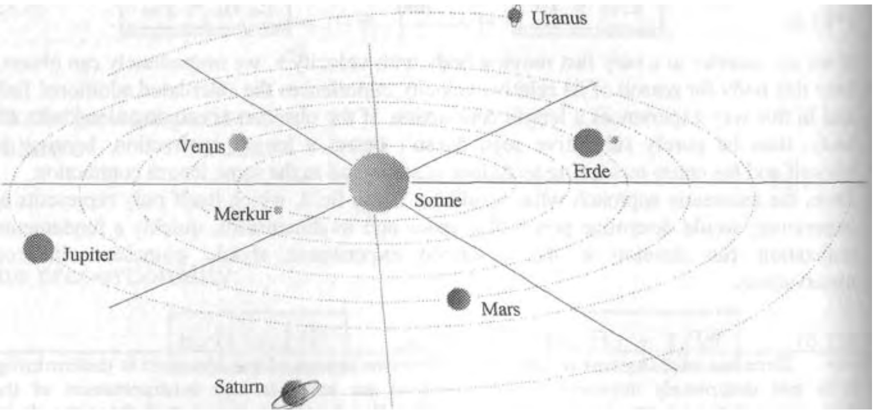
Uranus
Venus
Erde
Sonne
Merkur
Jupiter
Mars
Saturn

B: (Example): The orbits of the planets in the field of the sun.

Fig. 6.7: The influence of the field on interactions.

6.7 Field dependent curvature of space

Let's assume, an accumulation of matter, as big as our earth, wanted to fly past the sun in the distance earth-sun. But it would not succeed. Because the fields arising from the sun decreases with increasing distance and according to equation 6.15 as a consequence the size of the particles of matter increases. The planet hence is more strongly contracted on its side turned towards the sun, as on the turned away "night side". It bends towards the sun and its flight path becomes a circular path around the sun. That is the interaction known as gravitation!

To an earth inhabitant this curvature reveals itself merely in the observation that the duration of sunshine at daytime is longer, than it would be expected to be under the assumption of the earth as a homogeneous sphere. In this context one willingly speaks of a curvature of space. Actually it is a curvature of matter under the influence of the field dependent length contraction.
Exactly this contraction the planets owe their circular orbits around the sun and by no means the equilibrium of forces between the force of attraction and the centrifugal force (fig. 6.7 B). It obviously is a fundamental mistake to think that gravitation would causally be connected with a force effect!
If, in this context, we speak of a force of attraction for the sake of our subjective observation, then we must realize that it merely can concern an auxiliary term founded in usefulness.

A thought experiment should bring us clarity (fig. 6.7 A). The field, which surrounds every particle of matter, reaches till infinity but becomes less effective with increasing distance. If the distance between two particles is 1, then one particle is in the field of the other particle. As a consequence of the field the length 1 reduces and in this way the size determining field increases, which again leads to a further reduction of length etc. As a consequence it can be observed that both particles are moving towards each other. We speak of a force of attraction, because we can't register the influence of the field with our senses.
In this way the consistent result that we and our environment at daytime must be smaller than in the night will as well remain hidden. We experience the effect only indirectly as gravitational pull of the earth.

Because we don't see the cause of a subjectively observed force effect, for the electromagnetic interaction, just as for the gravitation, the field dependency of the length contraction will be responsible. Hence the following conclusion holds for both interactions equally way.

Two elementary particles or two accumulations of matter consisting of these are able to reduce the distance to each other for reason of their fields, which we interpret as a force of attraction.

Now the question still is open, why gravitation only knows forces of attraction, whereas the electromagnetic interaction also permits forces of repulsion and which are the causal fields for each.

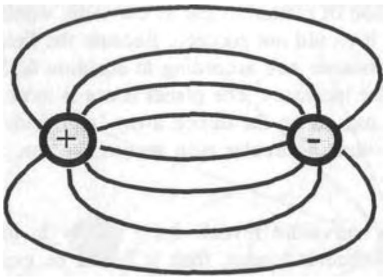

A: The field lines of the E-field for unlike charged particles

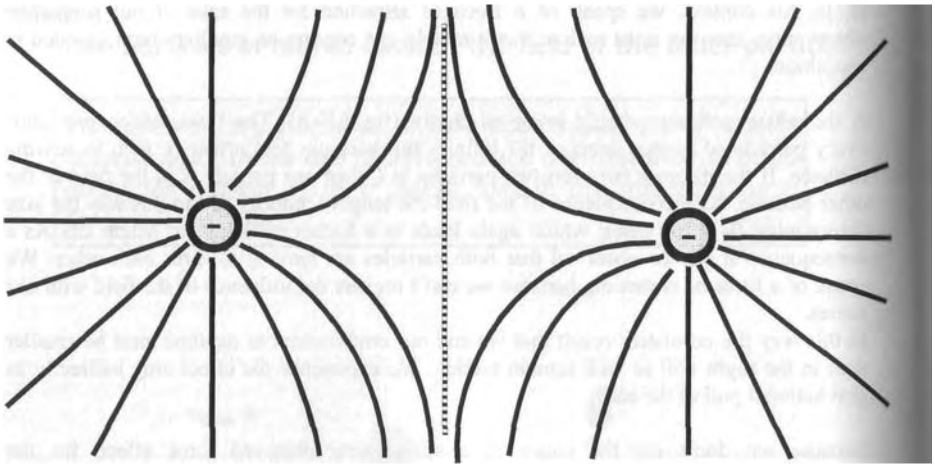

B: The field lines of the E-field for equal charged particles

The electromagnetic interaction of a particle is a result of the influence of the open field lines arising from it on the dimensions of space.

Fig. 6.8: The influence of the open field lines of the E-field

6.8 Electromagnetic interaction

A convincing answer to the open question provides us the analysis of the course of the field lines, on the one hand for charged particles and on the other hand for uncharged particles, which do not participate in the electromagnetic interaction. If at first we consider electrically charged particles, like e.g. electrons, protons or ions.
Then all in common is that the towards infinity running field lines of the electric field are open. With this field the particle is able to interact with its environment. We measure a charge and an electromagnetic force effect. In the case of unequal charges, as is well-known, a field amplification and attractive acting forces are observed whereas for equal charges a field reduction results and repulsion is observed.

If we make a connection between the field conditions and the electromagnetic interaction in the sense of the proportionality (6.15), then the particle in reality is able to influence the distance to other particles merely with the help of its electric field. For unequal charges a compression of field lines arises, in which one particle stays in the focussed field of the other and vice versa. In this way a contraction of all lengths occurs and the observable attraction happens (fig. 6.8 A).
For equal charges the opposite case is present, in which even a local field freedom can occur (fig. 6.8 B). If the field tends towards zero on the dashed line, then the distance will go to infinity (according to eq. 6.15). Consequently, the observable effect that both bodies go away from each other, will reach to infinity.

Actually the electromagnetic interaction proves to be a result of the field dependent length contraction.

The electromagnetic interaction of a particle is a result of the influence of the open field lines arising from it on the dimensions of the space, in which it is.

It is important that the field lines are open, for which reason they are bent away from like charges and are directed towards unlike charges. Subjectively seen we find out that as a consequence of the field reduction repulsive force effects and as a consequence of the field compression attractive acting force effects are observed (fig. 6.8).
The consequence of is every electric field is, as is well-known, a magnetic field standing perpendicular on it. The field lines of the magnetic field run parallel to the surface of the particle and have a closed course (fig. 6.9 A)!
Therefore no magnetic poles form, which would be measurable. Seen from the outside the particle behaves neutral magnetically seen, because of the closed course of the field lines. An artificial field reduction and as a consequence observable forces of repulsion, like in the case of the electromagnetic interaction, hence in principle are impossible.

The effect of the magnetic field thus is limited to a geometrical manipulation of the environment, namely the curvature of space, with which we have founded the phenomenon of the attraction of masses and of the gravitation.

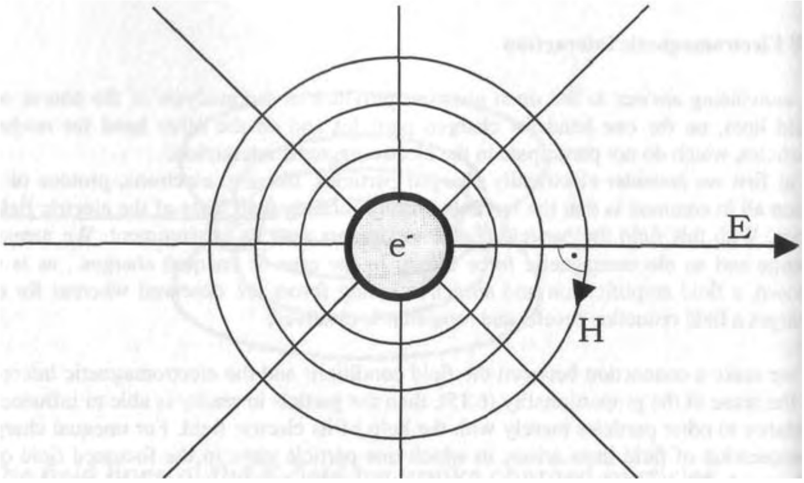

A: The open field lines of the E-field and the closed field lines of the H-field of an electrically charged particle (e.g. e-)

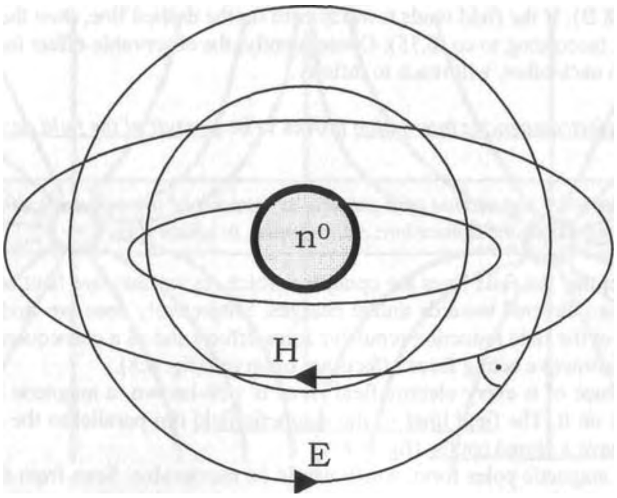

B: The closed field lines of the E-field and H-field of an electrically uncharged particle (e.g. of the neutron n°).

Gravitation is a result of the influence of the field lines with a closed course running parallel to the surface of the particles on the dimensions of the space, in which they are.

Fig. 6.9: The influence of the closed field lines of the H-field.

6.9 Gravitation

For uncharged, neutral particles (neutron, atom, molecule etc.) both the magnetic and the perpendicular on them standing electric field lines have a closed course. Now both run parallel to the surface of the particle (fig. 6.9 B).
As is said, the density of field lines with a closed course can't be influenced from the outside. If we approach a particle, the consequence of an increase of the density without exception is a decrease of the linear measures and thus a larger force of attraction. For this case of field lines with a closed course, for which in general it doesn't give a field attenuation and no forces of repulsion, there holds:

Gravitation is a result of the influence of the field lines with a closed course running parallel to the surface of the particles on the dimensions of the space, in which they are.

Both interactions logically have an infinite range. Both form a whole in the influence of the fields on the size conditions.
It surely is of the greatest importance that for this derivation of the field dependency of the Lorentz contraction from the known equations of transformation of the electromagnetic field we could do completely without the introduction of new factors of description or neglects.
Solely by consistent derivation and interpretation of the result the unification already has suceeded and the electromagnetic interaction and the gravitation could, with the derived field dependent Lorentz contraction, be traced back to a single basic phenomenon. Doing so we have to pay attention to the fact that the observer is subjected to the same Lorentz contraction as his measuring technique and therefore he can't see the field dependency at all. Merely as being an exterior observer it in rare cases will be possible to him to see the curvature of space in the presence of strong fields.

From this for an astronaut practical consequences result. If he namely would land on Jupiter, he would think flat hills to be gigantic mountains, that small he would be! Vice versa if he landed on the moon, high mountains would appear to be insignificant hills, not because of wrong altitude readings of the terrestrial mission control and measurement centre, but only because of his own body size. The astronauts of the Apollo missions were not prepared for this circumstance and after their landing on the moon were completely surprised, how little validity learned textbook physics has, hardly has one left the earth. They have brought photographs with them which prove the Lorentz contraction to depend on the field and therefore on gravitation.

The fact that force effects should arise from the interactions is an auxiliary concept and auxiliary description of the observing person founded in pure usefulness. The Lorentz force therefore shouldn't be regarded as cause anymore. It actually appears only as property of the field factors. Seen this way it only would be consistent to do without space charges and currents as a result of moving charges and to assume a source-free and quanta-free field description (fig. 6.4: $j = 0$).
From an unified theory it is demanded that it besides the electromagnetic interaction and the gravitation also is able to integrate the strong and the weak interaction. We will also solve this problem.

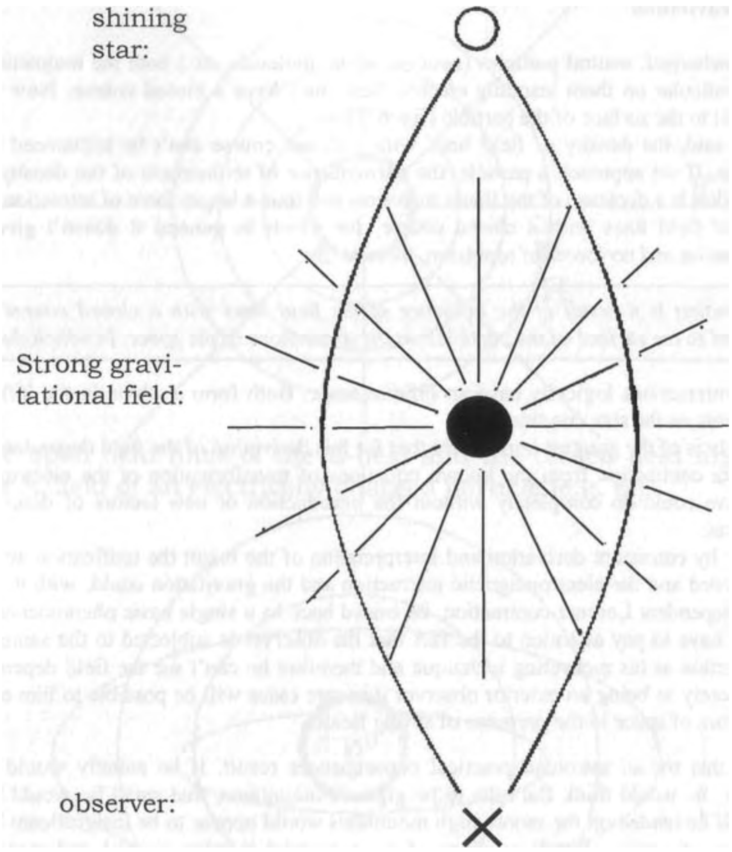
shining star:
Strong gravitational field:
observer:

Fig. 6.10: Diversion of the light by a strong gravitational field.

Speed of light of the wave: $c = \lambda * f$ (6.16)

For the wavelength λ holds (because of eq. 6.15): $E, H \sim 1/\lambda^2$

From equation (6.16) follows (with f = constant):

$$E \sim 1/c^2 \quad , \quad H \sim 1/c^2 \tag{6.17}$$

The speed of light depends on the field!

6.10 Field dependent speed of light

But not only matter is bent towards a gravitational field. If we only think of the much cited phenomenon that the ray of light of a star is diverted towards the sun, if it passes very close to the sun on its way to us, like this has been observed for the first time during an eclipse of the sun in 1919 (fig. 6.10).

Quite obviously the field of the sun also slows down the speed of light. On the side of the ray of light which is turned towards the sun, the field is somewhat larger and the speed of light correspondingly is slower than on the side which is turned away, and with that the ray of light changes its direction in the observable manner. Exactly this relation willingly is interpreted as a consequence of a curvature of space.

The extremely strong field of a black hole can divert the light down to a circular path, in order to in this way catch and bind it. The light now orbits the black hole like planets the sun.

At this point the open-minded reader already might have tapped the confirmation of the proportionality 6.2 ($c \sim r$), which has been derived from the vortex model (fig. 6.2).

The sceptic is offered still another derivation: for the borderline case that the relative velocity v tends towards the speed of light c (fig. 6.6), according to equation 6.13 the measurable overall field E_o (and also H_o) will go to zero and equation 6.12, with E_z. = - E (and H_z = - H), will again turn into the wave equation (5.9*) after double differentiation (fig. 6.4).

The speed v = c so to speak forms the escape velocity, with which the electromagnetic wave runs away from the cosmic field. Under these circumstances of course neither an attraction of masses nor an electromagnetic interaction can be exerted on the wave.

If E_0 goes to zero at the same time l_0 tends to infinity (equation 6.15, fig. 6.6): i.e. the wave spreads all through space. This result entirely corresponds to the observations and experiences.

For the wave length λ and in the end for the velocity of propagation c only the self-field of the wave E resp. H is responsible. Because of

$$\boxed{c = \lambda \cdot f} \quad (6.16)$$

and the proportionality from equation 6.15: $E, H \sim 1/\lambda^2$ (6.17*)

obtain the new relation: $\boxed{E, H \sim 1/c^2}$ (6.17)

If the speed of light in the presence of matter decreases, then we now also know why. It is the field, which surrounds matter, that slows down the speed of light. Therefore a gravitational field is able to divert a ray of light in the same manner as matter which flies past. Finally moves the speed of light in the proportionality 6.17 to the place of the linear measure (in 6.15).

But if the rule fails one will try to replace by an optical measurement arrangement. In this manner the field dependency of the Lorentz contraction should be measurable; but it isn't!

From the comparison of the derived proportionalities:

$$\overset{(6.15):}{E, H \sim \frac{1}{l^2}} \sim \overset{(6.17)}{\frac{1}{c^2}}$$

follows:

$$\underline{l \sim c} \qquad (6.18)$$

The speed of light is proportional to the measurement path.

The variable speed of light is being measured with itself.

The result at all events is a constant value.

The constancy of the speed of light is based on a measurement which is faulty from the principle!

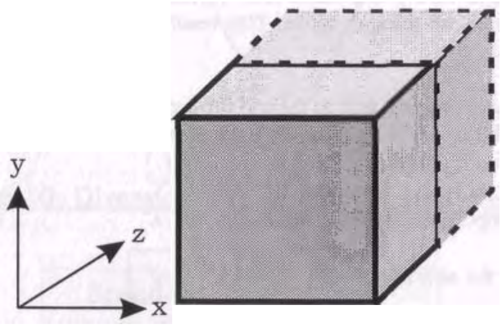

Because of c ~ r: physical length contraction

Fig. 6.11: Derivation of the length contraction (field dependent Lorentz contraction)

6.11 Universality

Why can't the rule be replaced by an optical measurement arrangement? The crucial indication provides the comparison of both derived proportionalities 6.15 and 6.17. According to them holds the same field dependency for both the Lorentz contraction and the speed of light:

$1/l^2 \sim 1/c^2$ or $\quad 1 \sim c \quad (6.18)$

If the rule has proved to be useless, then we will experience the same disaster if we measure optically, i.e. with the speed of light.
Obviously both, the length 1 and the speed of light c as a length per unit of time, depend in the same manner on the respective local field strength. On the one hand do both measuring methods lead to the same result; but on the other hand will anything which can't be measured with one method, neither be measured with the other method.
If now the speed of light is being measured optically, then the measurement path will be proportional to the speed of light and as a result will the unknown factor be measured with itself. The result of this measurement, which is faulty from the principle, at all events is a constant value, because here two variables which stand in direct proportionality to each other are related to each other.
Was the famous experiment of Michelson and Morley unnecessary, the result trivial? And how does it stand about the postulate of the universality of the speed of light?
If we for that consider a cube (fig. 6.11). And we assume that the speed of light is a vectorial quantity, which in our experiment is for instance in one direction twice as large, as in the direction of the other two space axes. By means of the mentioned influence of the speed of light on the spatial length is, as a consistent consequence, the cube along this edge pulled apart to a cuboid. We however register this spatial body with our eyes, which is with the speed of light and that has increased proportionally to the length of the edges, for which reason we as subjective observer still see a cube in front of us and not a cuboid.
If we trust an apparent objective measurement more than our sense organ and measure the three lengths of the edges of the cuboid again with a rule then we get three times the same length, which is a cube.
We probably are dealing with an optical deception using the true meaning of the word.

If the by Einstein postulated universality and constancy of the speed of light in reality doesn't exist at all, we in no way would be capable to register this; neither to observe nor to measure it!
The Galilean theorem of the addition of speeds objectively seen still is valid, even if the fact that the speed of light apparently is independent of the speed of the source pretends us the opposite.
If for instance a light source is moved towards a receiving device or away from it, then the speeds will overlap, like for the passenger, who marches in a driving train against or in the driving direction through the corridor. For the ray of light also the fields, which influence the speed of light and the measurement equipment, overlap. As a consequence will a measuring technician, who himself is exposed to this overlapping field, always observe and "measure" the identical speed of light. The observer as a result imagines, there is an universality of the speed of light.

The field takes over the function of the aether.

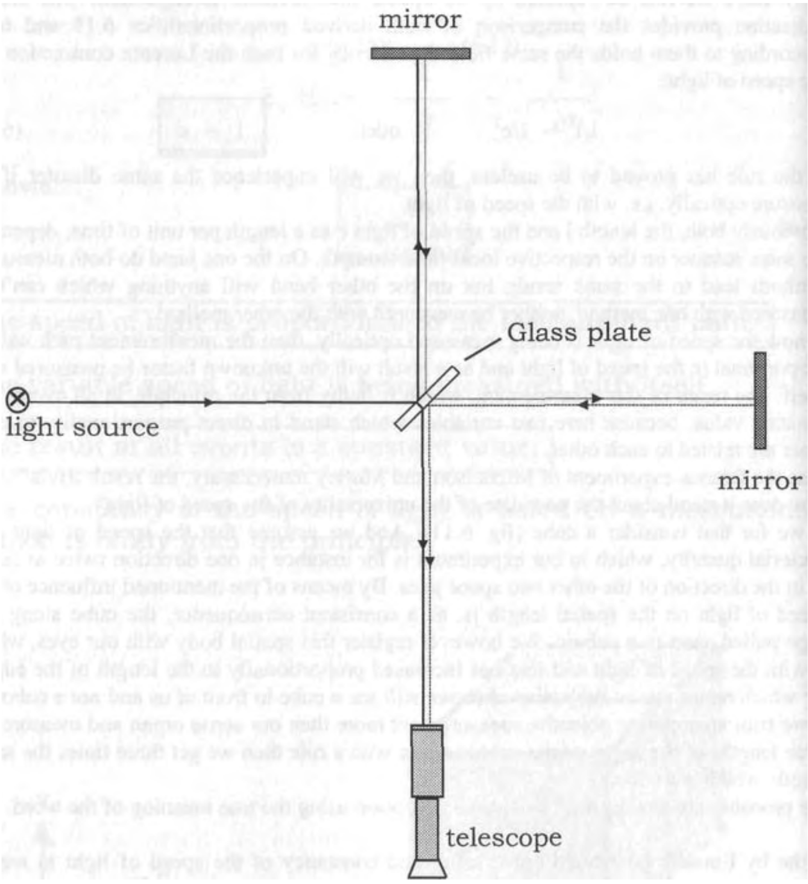

Fig. 6.12: Experiment of Michelson and Morley to detect an aetherwind[i]

<i>: A.P.French: Special Relativity, Massachusetts Institute of Technology, 1966.

<ii>: Nikola Tesla: "This is the same as writing a business letter and forgetting the subject you wish to write about". To Einstein's Theories, Rare Book and Manuscript Library, Columbia University, 15.4.1932.

<iii>: Einstein proceeds in the same manner with the time dilatation, by assuming a time constant by definition for the derivation to present at the end of his derivation a variable time. And with that he presents a result which contradicts his approach completely.

6.12 Aether

Important experiments like the one of Doppler concerning the redshift or the one of Bradley concerning the aberration of the stars show only to clear, where the influence of the speed of light subjectively still is perceptible, or for laboratory experiments like the one of Michelson and Morley, where the influence isn't perceptible anymore, because the length of the interferometers always changes proportionally to the speed of light. The look in the stars at the same time is a look in cosmic areas, where completely other field conditions prevail and as a consequence completely other values for the speed of light and for the dimensions of space are present. The mentioned observations suggest that we together with our measuring station are moving through the cosmos and therefore a relative velocity has to be present with regard to an aether which determines the respective speed of light.

If we however constrict our range of vision and retire in a laboratory, then we no longer are capable to observe the influence of the field on the speed of light. The experiments of Michelson which Maxwell had prompted to and which Morley with a higher precision had repeated with the goal, to detect the aether, inevitably had to turn out negatively. The laboratory experiments resulted in the misleading picture, as if the earth was resting in the aether.

The not understood measurements will suggest any observer, he forms the centre of the universe and everything rotates around him, entirely in the sense of the Ptolemean view of life, which, although long ago abolished, here belated has experienced support. With a Swabia caper Albert Einstein has prevented a relapse into the dark Middle Ages and removed the open contradiction in the question of the aether, which once is measured as moving and another time as resting, by without further ado abolishing the aether. With that he undoubtedly has solved a central problem of physics and at the same time created a new one. As is known does the speed of light have a certain value, and therefore the question is raised, what determines is size. Exactly for this purpose a luminiferous aether had been introduced, however it is constituted.

Scientifically it does make little sense, to make an assumption, if at the end of the derivation the prerequisite is deleted without substitute. In such a case either in the approach or in the derivation is a principal error*[1]"*. Nikola Tesla comments on the working method of Einstein with the applicable comparison, as if Einstein had, while he was writing a business letter, forgotten completely the subject he wanted to write about (fig. 6.12[<ii>]).

The answer, which removes all contradictions and is entirely in accord with all observations and measurements, is obvious. Naturally a luminiferous aether exists, which determines the velocity of propagation and of course it by no means is bound to the observer.

As has been derived in figures 6.5 and 6.6, will for a relative velocity v arise a field, which according to proportionality 6.17 determines the speed of light. With that we have derived completely.

The field takes over the function of the aether.

The equations 6.10 also answer the question, why no aetherwind is being observed, although such a wind actually is present: we experience, as we have discovered, an E-field with „head wind" as a resting H-field and vice versa and therefore we aren't capable to detect the head wind in the aether!

Key questions of quantum physics (fig. 4.4 + continuation):

IV. Why do the particles have the form of spheres?
(with increasing E-field decreases c)

VIII. Why is the elementary quantum localized?
(in the vortex centre: c = 0, see figures 4.3 and 6.2)

IX. Why do the elementary particles have a spin?
(spherical form demands field compensation)

X. Why is the magnitude of the spin quantized?
(cosmic basic field determines the need of E_z)

XI. Why can speeds faster than light occur in a tunnel?
(a reduction of the cosmic basic field can only be realized locally in a tunnel)

to XI:

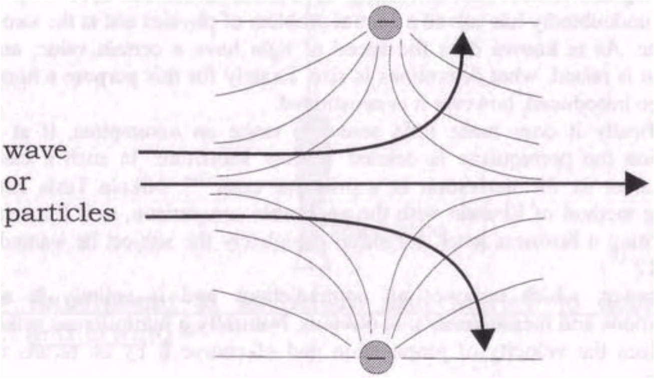

Fig. 6.13: Consequences concerning the field dependency of the speed of light: spin effect and tunnel effect <i,ii>

<i>: Nimtz,G.: Instantanes Tunneln, Tunnelexperimente mit elektromagnetischen Wellen, Phys.B1.49, VCH Weinheim (1993) Nr.12, S. 1119-1120<*>
<ii>: Thoma, P., Weiland.T.: Wie real ist das Instantane Tunneln? Phys.Bl.50, VCH Weinheim (1994) Nr.4, S. 359-361<*>
<*>: The measurement results are in accord with the theory of objectivity, not however the contradictory attempts to interpret them <i> and <ii> et al.

6.13 Spin and tunnel effect

Only with the field dependency of the speed of light (6.17) we can understand, why the elementary quanta can form as spheres, like is drawn in the figs 4.3 and 6.2. In the centre the field lines run together, i.e. the field increases and the speed of light decreases. Only in this way it will be possible for the vortex oscillation to everywhere occur with the speed of light, even in the inside of the particle! In the centre of the vortex particle the field in theory will become infinitely large and the speed of light zero. This circumstance again is the foundation why the elementary particles are localized and it answers key question VIII of quantum physics. The absence of a speed after all is the characteristic of an immobile thing.

The field dependency of the speed of light answers also further basic and up to today unanswered key questions of quantum physics, like why the elementary particles have a spin (IX) and why the magnitude of the spin is quantized (X).

A vortex particle after all does not exist alone in the world, but it is in the field of other particles. We can call this the cosmic basic field (E resp. H). This basic field overlaps the self-field and takes effect the strongest in the area of the spherical shell, where the self-field is correspondingly small. In order to keep the form of a sphere, this influence of the basic field has to be compensated. The additional field (E_z resp. H_z according to eq. 6.12) necessary for the compensation is produced by the particle, by rotating in a spiral around itself with a speed v which increases towards the outside of the spherical shell. Therefore does the elementary particles have a spin. The electron spin is therefore determined by the cosmic basic field.

Another effect of the field dependent speed of light is the tunnel effect. As an example we consider the two differently charged particles shown in fig. 6.8 A. The open, outside of the particles running, field lines of the electric field are predominantly bent towards the each time oppositely charged particle. If another particle wants to pass between the two, then it gets into an area of increased field strength. As a consequence it will be slowed down, because here a smaller speed of light is present.

Water molecules show with their polar nature exactly this property. Water has a remarkably high dielectricity e and slows down the speed of light correspondingly according to equation 5.6 ($\varepsilon \cdot \mu = 1/c^2$). The refraction of light at the water surface is an observable result of the reduced speed of light in the presence of matter.

If we now examine the case in which the two particles have the same charge as is shown in fig. 6.8 B (and fig. 6.13 belonging to XI). The field lines repel each other, so that exactly in between the two particles a field free area forms, in which the speed of light goes to infinity! This area acts like a tunnel. If we send through a particle exactly here, then purely theoretically seen it won't need any time to run through the tunnel, and for a short time the signal becomes infinitely fast.

If a particle hits only slightly besides the tunnel, then it will one-sidedly be slowed down and diverted by the respective field. We call this process reflection or scattering. Only the few particles, which exactly hit the tunnel, arrive behind the hurdle and in the ideal case even almost without loss of time!

The current measurements of speeds faster than light demonstrate in a convincing manner the superiority of the field-theoretical approach with regard to the nowadays normally used quantum physical approach.

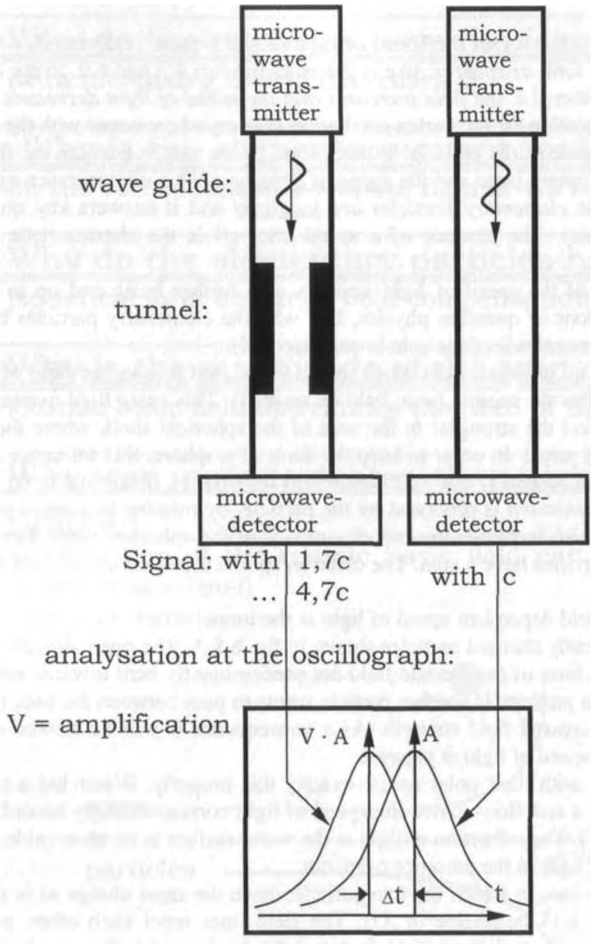
micro-
wave
trans-
mitter
micro-
wave
trans-
mitter
wave guide:
tunnel:
microwave-
detector
microwave-
detector
Signal: with 1,7c
... 4,7c
with c
analysation at the oscillograph:
V = amplification
V · A
A
Δt
t

Fig. 6.14: The microwave experiment at the II. Physical Institute of the University of Cologne to measure speeds faster than light.[i]

[i] Nimtz, G. : New Knowledge of Tunneling from Photonic Experiments, Proc. of the Adriatico Research Conference, 1996, World Scientific Publishing Company

6.14 Interpretation of the measured speed faster than light

Now the attempt can be undertaken, to interpret the spectacular experiments, in which a speed faster than light has been measured. It is reported<i> that in experiments with photons at the University of California in Berkeley on an average a speed of 1.7 times the speed of light has been measured by Prof. Raymond Chiao and his co-workers. At the Technical University of Vienna Prof. Dr. Ferenc Krausz already has obtained 2.4 times the, according to Einstein at maximum obtainable, speed of light with tunnelling laser light.

The first measurements of speeds faster than light have been carried out with microwaves at the University of Cologne<ii> by Prof. Dr. Gunter Nimtz and co-workers. They at first had published the measurement of a speed 2.5 times the speed of light. In the meantime they even have transmitted a symphony of Mozart with a speed almost 10 times the speed of light and with that have contradicted Einstein's hypothesis, according to which the speed of light in vacuum would be the highest possible speed for the transmission of signals. The different experiments only resemble each other in the point that the particles have to tunnel, because one has put a barrier in their way. This "tunnelling" apparently is the cause for obtaining speeds faster than light. With the prevailing physical view of life these measurement results are incompatible.

In the measurement set up in Cologne the microwaves are sent through a wave guide, which they pass with the speed of light. If a parts with narrowed cross-section is inserted, where the microwaves actually don't fit through at all, then the signal gets damped strongly. Now however arrives nevertheless a small part of the signal at the other end of the wire, but much faster than allowed, namely with the measurable speed faster than light.

The answer of the here presented potential vortex theory reads as follows: the waves picked up by the wave guide run up to the entry of the tunnel, in order to find out that they don't fit through. They are reflected or absorbed. A small part however rolls up to potential vortices and these fit through the tunnel. They however have to be compressed additionally. In the derivation of the photon (fig. 4.5 and 4.6) we had seen that the inner vortex always is faster than the bigger one, through which it slips through. The compression therefore causes an increase in speed. In flow dynamics is known an analogy: the Venturi-tube. The flow-technical potential vortices also confirm exactly this property. One can as well start with the Lorentz contraction (fig. 6.6, eq. 6.14*). This states that a particle moving with a higher speed actually becomes smaller and not only appears to be smaller as an optical deception of the observer. Because only smaller particles fit through the tunnel, the particles, measurable at the other end, must be correspondingly faster: quod erat demonstrandum. In the same manner also the experiments of Berkeley can be explained physically, because here is worked with photons from the start<i>. With that the process of rolling up the wave can be left out. The tunnel lets pass only compressed and therefore faster light particles.

<i>: R.Y.Chiao, P.G.Kwiat, A.M.Steinberg: Schneller als Licht? Spektrum der Wiss. 10/93

<ii>: B. Schuh, Gespenstisch fixe Wellen, DIE ZEIT Nr. 45, 5.11.93, S. 43.

<ii>: Enders, A., Nimtz, G.: Photonic-tunneling experiments, Physical Review B, Vol. 47, No. 15 (1993), pp. 96O5-96O9.

<ii>: Enders, A., Nimtz, G.: Evanescent-mode propagation and quantum tunneling, Physical Review E, Vol. 48, No.l (1993), pp. 632-633.

"The theory of relativity is not a physical theory... it is a mathematical poetic idea, a deduction from impossible premises."<i>
Oskar Kraus

"The theory of relativity is a mathematical masquerade, behind which is hidden an inextricable ball of a mixing up of ideas, contradictions, fallacies, arbitrary assumptions and ignoring of healthy logic."<i>
Erich Ruckhaber

"The theory of relativity not only is fantastic, but also of an inconsistency which in the history of science not yet has been present."<i>
Harald Nordenson

"A physics of hybrids, of contradictions and fantastic confusions, nonsense!"<ii>
Johann Marinsek

"This is absurd."<iii> (regarding mass-energy interpretation) ________
Nikola Tesla

"In my experiments I have destroyed billions of atoms, without having observed any emissions of energy. "<4i>
Nikola Tesla

Fig. 6.15: Some statements regarding the theory of relativity.

<i>: Walter Theimer: Die Relativitatstheorie, Seite 7, Francke Verlag, Bern, 1977, ISBN 3-772O-126O-4

<ii>: Johann Marinsek: Rationale Physik, S. 163, dbv-Verlag TU Graz, 1989, ISBN 3-7O41-O176-1

<iii>: Nikola Tesla, To Einstein's Theories, Rare Book and Manuscript Library, Columbia University, 15.4.1932. Entnommen aus J.T.Ratzlaff: Tesla Said, Tesla Book Company, pp. 238, ISBN O-914119-OO-1

<4i>: Nikola Tesla, Franz Ferzak World and Space Publications 1985.

6.15 Definition of the speed of light

If a light signal propagates in space, then as a consequence of the velocity of propagation c, it at a certain point in time t is in a distance r of the light source:

$r = c * t$ (6.19)

Should the speed of light become smaller for instance by Δc, then the light signal obviously has covered a distance less by Ar or the time interval has changed by Δt:

$r + \Delta r = (c + \Delta c) \cdot (t + \Delta t)$ (6.20)

This equation describes purely mathematically the most general case which can be assumed. By writing out the multiplication and subtraction of equation 6.18 the change in distance considered for itself is:

$\Delta r = c \cdot \Delta t + t \cdot \Delta c + \Delta c \cdot \Delta t$ (6.21)

The answer of mathematics is that the change in distance can have its cause in a change in time, in a change of speed or in both. We now want to turn to the physical interpretation and have a closer look at the two possibilities, in which either c or t is to be taken constant (see fig. 6.16).

In the first case the speed of light c is constant and as a consequence the change Δc = zero. The mathematical formulation (according to eq. 6.21) therefore reads:

case 1: $\boxed{c = \frac{\Delta r}{\Delta t}}$ (relativity) (6.22)

If in this conception world a change in distance is observed, for instance the Lorentz contraction, then in order to save this relation inevitably a change in time, for instance a time dilatation, has to make the compensation. Einstein in an applicable manner speaks of relativity, because according to his opinion in the case of both variables, the length contraction and the time dilatation, it only concerns observed changes.

For the time dilatation experiments are given. But for the measurement of time always only atomic clocks are available and their speed of running of course could also be influenced by the Lorentz contraction. In any case it can't be claimed the time dilatation is proven experimentally as long as we do not know the mechanisms of decay of atoms. Otherwise the statements of the theory of relativity are familiar to us, for which reason further remarks seem unnecessary.

In the second case the time t is constant and consequently the change At = zero. At a closer look this case is much more obvious, since why should time change. After all time has been stipulated by definition.

After all, we are the ones who tell, what simultaneity is!

The mathematical formulation for this case reads (eq. 6.21 with Δt= 0):

case 2: $\boxed{\Delta c = \frac{\Delta r}{t}}$ (objectivity) (6.23)

This equation does open up for us an until now completely unknown and fundamentally other way of looking at the physical reality.

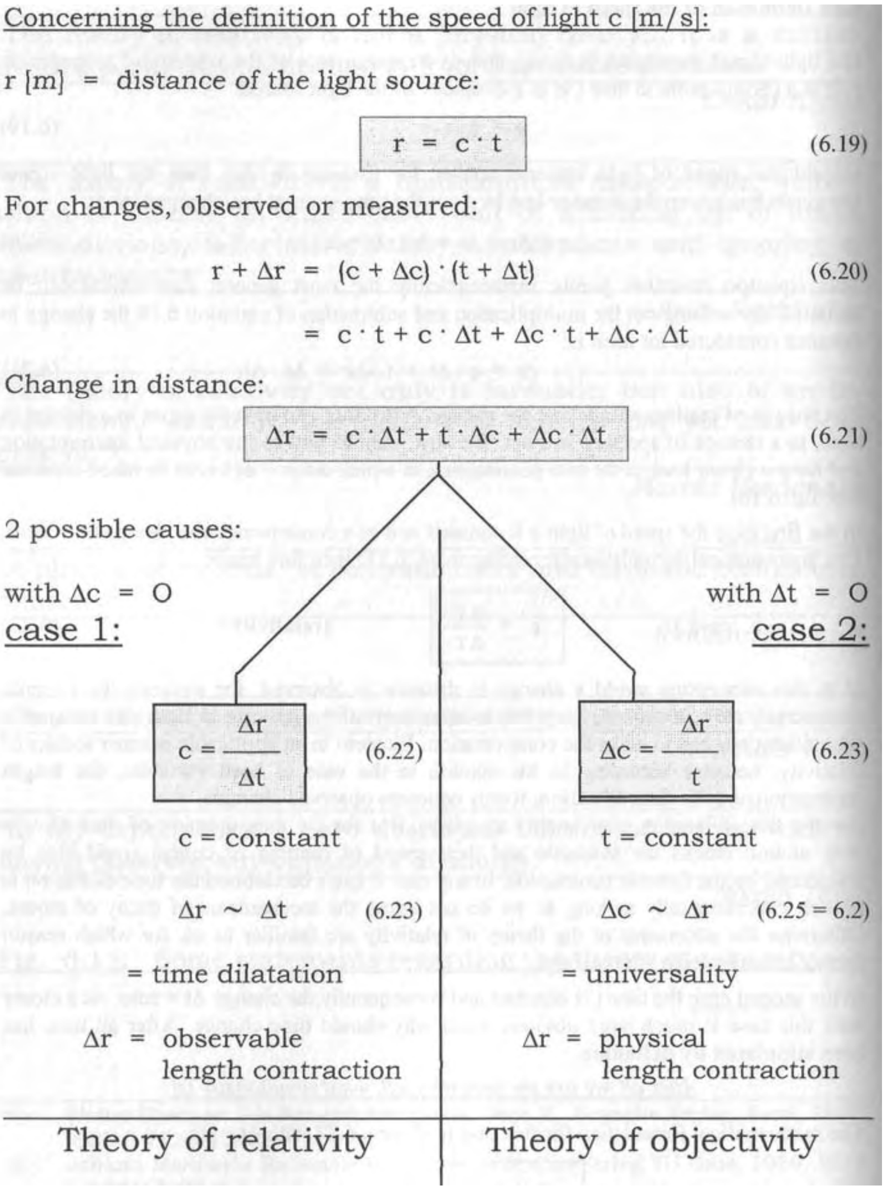

Concerning the definition of the speed of light c [m/s]:

r [m] = distance of the light source:

$$\boxed{r = c \cdot t} \qquad (6.19)$$

For changes, observed or measured:

$$r + \Delta r = (c + \Delta c) \cdot (t + \Delta t) \qquad (6.20)$$

$$= c \cdot t + c \cdot \Delta t + \Delta c \cdot t + \Delta c \cdot \Delta t$$

Change in distance:

$$\boxed{\Delta r = c \cdot \Delta t + t \cdot \Delta c + \Delta c \cdot \Delta t} \qquad (6.21)$$

2 possible causes:

with $\Delta c = 0$

case 1:

$$\boxed{c = \frac{\Delta r}{\Delta t}} \qquad (6.22)$$

c = constant

$$\Delta r \sim \Delta t \qquad (6.23)$$

= time dilatation

Δr = observable length contraction

Theory of relativity

with $\Delta t = 0$

case 2:

$$\boxed{\Delta c = \frac{\Delta r}{t}} \qquad (6.23)$$

t = constant

$$\Delta c \sim \Delta r \qquad (6.25 = 6.2$$

= universality

Δr = physical length contraction

Theory of objectivity

Fig. 6.16: Theory of relativity and theory of objectivity, derivation and comparison.

6.16 Relativity and objectivity

New to the second case (equation 6.23) is particularly the proportionality contained in it:

$$\boxed{\Delta c \sim \Delta r} \quad (6.25 = 6.2)$$

But to us it is not new, because we have derived the same proportionality from the model conept (equation 6.2, fig. 6.2), in which the elementary particles are understood as spherical vortices. Equantion 6.25 unconcealed brings to knowledge that any change of the speed of light c [m/s] in the same way leads to a change of the radius r [m], the distance between two points in space or even the length of an object, e.g. a rule. Such a rule after all consists of nothing but spherical atoms and elementary particles and for their radius r again the proportionality 6.25 holds. Therefore it is to be set:

$$r \sim 1 \quad (6.26)$$

and taken both together we already had derived as equation 6.18 (fig. 6.11) from the field dependency. Here the vortex model as well finds a confirmation of its correctness, as in the derivation from the equations of transformation of the electromagnetic field. Because all three, the derivation according to the model, the physical and the mathematical derivation, lead to the same result, this second case should be called "objective".

With that the first case, which describes the subjective perception of an observer, is not supposed to be devaluated. It contains the definition of reality, according to which only is real what also is perceptible. The theory of relativity of Poincare and Einstein is based on this definition.

With the second case, the case with a variable speed of light, we however get serious problems, since we observe with our eyes, and that works with the speed of light. If that changes, we can't see it, as already said. If we could see it, then "reality" would have a completely different face and we surely would have great difficulties, to find our way around. In this "objective world" neither electromagnetic interactions nor gravitation would exist, so no force effects at all. Because all distances and linear measures depend on the speed of light, everything would look like in a distortion mirror.
The concept of an "objective world" at first has not a practical, but rather a theoretical and mathematical sense. The distinction between an observation domain and a model domain is founded in pure usefulness.

The observation domain should correspond to case 1 and the model domain to case 2. The mathematical derivation tells us, how we can mediate between both domains (equation 6.21): This mediation amounts to a transformation, which provides us the instruction, how a transition from the observation into a not perceptible model concept, from the relativity into an objectivity has to.

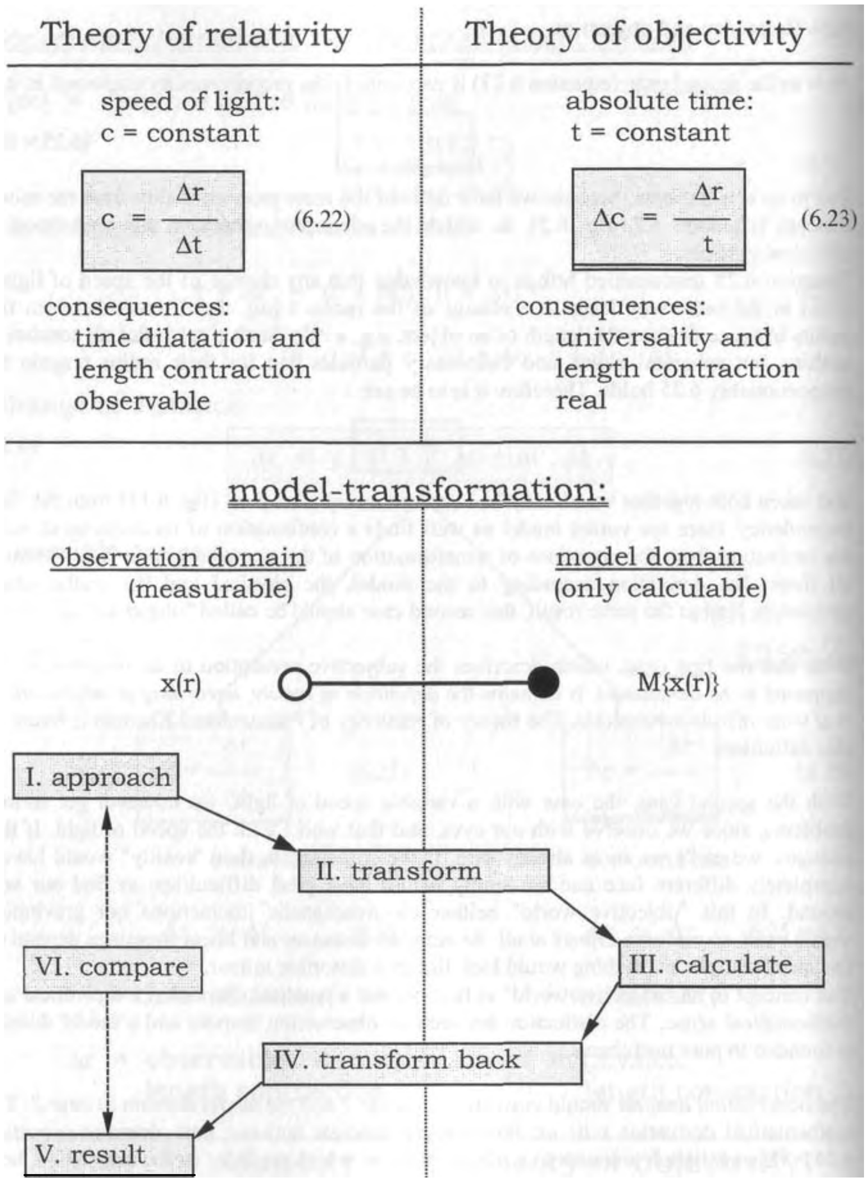
Theory of relativity
Theory of objectivity
speed of light:
c = constant
absolute time:
t = constant
$c = \frac{\Delta r}{\Delta t}$ (6.22)
$\Delta c = \frac{\Delta r}{t}$ (6.23)
consequences:
time dilatation and
length contraction
observable
consequences:
universality and
length contraction
real
model-transformation:
observation domain
(measurable)
model domain
(only calculable)
x(r)
M{x(r)}
I. approach
II. transform
III. calculate
IV. transform back
V. result
VI. compare

Fig. 6.17: Model-transformation between
theory of relativity and theory of objectivity.

6. 17 Transformation

The observation domain is, as the name already expresses, perceptible (observable) with the help of our sense organs and measurable with corresponding apparatus. The special theory of relativity for the most part provides us the mathematics needed for that. And in that is assumed a constant speed of light. Because a length contraction is being observed and can be measured, a time dilatation must arise as a consequence. Such is the consistent statement of this theory. Because we already could make us clear that it concerns a subjective theory, of course caution is advisable if generalizations are being made, like the one of the inductive conclusion of the length contraction on the time dilatation. We'll come to speak about that in this chapter (fig. 6.20).

The model domain however is not observable to us and only accessible in a mathematical manner. Here the time is a constant. On the other hand do the radii of the particles and all other distances and linear measures stand in direct proportionality to the speed of light. If that changes, then does that lead to a change in length. The length contraction occurs physically, which means actually. We propose the name "theory of objectivity" for the valid theory which is derivable with this prerequisite and independent of the point of view of the observer.

The importance of this model domain and of the possible model calculations is founded in the circumstance that many physical relations within our observation domain aren't recognized by us and can't be mathematically derived. Besides is only all to often worked with unallowed generalizations and with pure hypotheses. Such a thing does not even exist in the model domain.

The model domain can be tapped over a transformation. For that we select an approach x(r) in the to us accessible observation domain. This then is transformed into the model domain by a calculation instruction M{x(r)}. Here we can calculate the sought-for relation In the usual manner and transform back again the result according to the same calculation instruction M^{-1}\{x(r)} but in the reversed direction. After being returned in our familiar observation domain, the result can be compared and checked with measurement results (fig. 6.17).
In this way we will derive, calculate and compare the quantum properties of the elementary particles with the known measurement values. Here we remind you of the fact that all attempts to calculate the quantum properties conventionally, without transformation, until now have failed. Not even a systematization may succeed, if it concerns for instance explanations for the order of magnitude of the mass of a particle.

A transformation at first is nothing more than an in usefulness founded mathematical measure. But if a constant of nature, and as such the quantum properties of elementary particles until now have to be seen, for the first time can be derived and calculated with a transformation then this measure with that also gains its physical authorization. We now stand for the question: how does the instruction of transformation M{x(r)} read, with which we should transform the approach and all equations from the observation domain into the model domain?

general relations:	special theory of relativity	theory of objectivity
domain of validity:	observation domain	model domain
speed of light c [m/s]:	$c = c_o$ $= \text{constant}$	$c \sim r$ (6.25)
field strengths (6.15)	(6.15) + (6.18)	
H [A/m] :	$H \sim 1/r^2$	$H \sim 1/r$ (6.27*)
E [V/m] :	$E \sim 1/r^2$	$E \sim 1/r$ (6.27)
because of eq. (5.6) $\varepsilon \cdot \mu = 1/c^2$ is valid:		
μ [Vs/Am] :	$\mu_0 = \text{const.}$	$\mu \sim 1/r$ (6.28*)
ε [As/Vm] :	$\varepsilon_0 = \text{const.}$	$\varepsilon \sim 1/r$ (6.28)
relations of material:		
$B = \mu \cdot H$ (3.5): B [Vs/m^2]	$B \sim 1/r^2$	$B \sim 1/r^2$ (6.29*)
$D = \varepsilon \cdot E$ (3.6): D [As/m^2]	$D \sim 1/r^2$	$D \sim 1/r^2$ (6.29)
e.g. spherical capacitor		
capacity: C [As/V]	$= \varepsilon 4 \pi r$ (6.4)	$C = \text{const.}$ (6.30)
charge: Q [As]	$= C \cdot U$ (6.31)	$Q = \text{const.}$ (6.32)
energy: W [VAs]	$= Q^2/C$ (6.1)	$W = \text{const.}$ (6.33)
with energy-mass relation: (5.24) and (6.1)	$W = mc^2$	
mass	m [kg = VAs^3/m^2]	$m \sim 1/r^2$ (6.34)
relaxation time	τ_1 [s]:	$\tau_1 = \text{const.}$ (6.35)
with	$\tau_1 = \varepsilon/\sigma$ (5.3)	
specific conductivity	σ [A/Vm]:	$\sigma \sim 1/r$ (6.36)

Fig. 6.18: Transformation of the dependencies on radius

6.18 Transformation table

The attempt to write down at this point already a closed mathematical relation as instruction of transformation, would be pure speculation. Such an instruction first must be verified by means of numerous practical cases, i.e. be tested for its efficiency and correctness. But we not even know the practical examples necessary for this purpose, if we apply the transformation for the first time!
For his reason it unfortunately is not yet possible, to calculate absolute values in a direct
We have to be content to work with proportionalities and to carry out comparisons.
In fig. 6.18 the proportionalities are compared in the way, how they would have to be transformed: on the left side, how they appear and can be observed in the view of the special theory of relativity, and on the right side, how they can be represented and calculated in the theory of objectivity.
The change, which here would have to be transformed, is the physical length contraction, which is the change in length as it depends on the speed of light. For spherical symmetry the length 1 becomes the radius r (eq. 6.26), of which is to be investigated the influence. In the observation domain we had derived the proportionality (6.15 + 6.18):

$E \sim 1/r^2$ and $H \sim 1/r^2$.

The field of a point charge or of a spherical capacitor confirms this relation:

$$E = Q/\varepsilon 4\pi r^2 .$$

Because the speed of light in our observation is constant, also both constants of material which are related to it (eq.5.6: $\varepsilon \cdot \mu = 1/c^2$), the dielectricity ε and the permeability μ, are to be taken constant.
With that the same proportionality as for the field strengths also holds for the induction B and the dielectric displacement D:

$$B \sim 1/r^2 \quad \text{and} \quad D \sim 1/r^2.$$

In the model domain everything looks completely different. Here the radius and any length stands in direct proportionality to the speed of light. In this way we get problems with our usual system of units, the M-K-S-A-system (Meter-Kilogram-Second-Ampere). The basic unit Meter [m] and as a consequence also the unit of mass Kilogram [$kg = VAs^3/m^2$] appear here as variable. It would be advantageous, to introduce instead the Volt [V] as basic unit.
But in any case does the dimension of a quantity show us, in which proportionality it stands to the unit of length. This in the model domain then is authoritative! As an example does the speed of light have the dimension Meter per Second. In the model domain there consequently has to exist a proportionality to the length r [m].
The speed of light determines with equation 5.6 again the constants of material:

$$\mu\,[Vs/Am] \sim 1/r \quad \text{and} \quad \varepsilon[As/Vm] \sim 1/r \tag{6.28}$$

According to the model holds unchanged:

$$B\,[Vs/m^2] \sim 1/r^2 \quad \text{and} \quad D\,[As/m^2] \sim 1/r^2. \tag{6.29}$$

But if we insert the proportionalities 6.28 and 6.29 into the equations of material 3.5 and 3.6, then holds for the field strengths:

$$H\,[A/m] \sim 1/r \quad \text{and} \quad E\,[V/m] \sim 1/r. \tag{6.27}$$

Further dependencies of the radius can be read in the same manner either by inserting into well-known laws or immediately from the dimension.

In the observation domain:

energy density of a field:

$$w = (\varepsilon \cdot E^2 + \mu \cdot H^2)/2 \quad \sim \quad 1/r^4 \qquad (6.37)$$

energy: $W \sim 1/r$ (6.38)

with c = constant and $W = m \cdot c^2$: $\boxed{m \sim 1/r}$ (6.39)

e^- is bigger and lighter than p^+ or n^0!

$$\boxed{\frac{m}{m_0} \overset{(6.39)}{=} \frac{r_0}{r} \overset{(6.26)}{=} \frac{l_0}{l} \overset{(6.24^*)}{=} \frac{1}{\sqrt{1 - (v/c)^2}}} \qquad (6.40)$$

In the model domain:

e.g. spherical capacitor

capacity: $C\ [\mathrm{As/V}] = \varepsilon 4\pi r$ (6.4) | $C = \text{const.}$ (6.30)

charge: $Q\ [\mathrm{As}] = C \cdot U$ (6.31) | $Q = \text{const.}$ (6.32)

energy: $W\ [\mathrm{VAs}] = Q^2/C$ (6.1) | $\boxed{W = \text{const.}}$ (6.33)

(6.33) means: law of conservation of energy!

relaxation time τ_1 [s]: | $\tau_1 = \text{const.}$ (6.35)

with $\tau_1 = \varepsilon/\sigma$ (5.3)

specific conductivity σ [A/Vm]: | $\boxed{\sigma \sim 1/r}$ (6.36)

(6.36) means: elementary vortices are indestructible!

Fig. 6.19: Interpretation of the dependencies on radius

6.19 Interpretation of the transformation table

The transformation should tell us, what we would see if the variable speed of light would be observable to us. Doing so highly interesting results come out.
The energy density of a field is as is known $w = (\varepsilon \cdot E^2 + \mu \cdot H^2)/2$. (6.37)
In the observation domain will, according to fig. 6.19, decrease the energy density w proportional to $1/r^4$. Multiplied with the respective volume we obtain for the energy itself the proportionality: $W \sim 1/r$. (6.38)
If we make use of the Einstein relation $W = m \cdot c^2$
with c = constant holds also for the mass m: $m \sim 1/r$. (6.39)
In this manner we finally find out, why the small nucleons (protons and neutrons) subjectively seen are heavier than the very much larger electrons. As a consequence does a relativistic particle experience the increase of mass (with the length contraction according to equation 6.24*):

$$\boxed{\frac{m}{m_0} \overset{(6.39)}{=} \frac{r_0}{r} \overset{(6.26)}{=} \frac{l_0}{l} \overset{(6.24*)}{=} \frac{1}{\sqrt{1-(v/c)^2}}} \quad (6.40)$$

This result is experimentally secured. Our considerations therefore are entirely in accord with the Lorentz-transformation. There at least is no reason to doubt the correctness.
In the model domain we with advantage assume a spherical symmetry. As easily can be shown with equations 6.4 and 6.31, are the capacity and charge of a spherical capacitor independent of the radius (6.30 and 6.32). In that case also the from both values calculable energy (6.1) must be constant. We come to the same conclusion, if take we the above equation 6.37 for the energy density of a field or if we carry out a verification of dimensions:

W [VAs] = konst. . (6.33)

This simple result is the physical basis for the law of conservation of energy! With that we have eliminated an axiom.
The result states that the energy stays the same, even if the radius, the distance or the speed of an object should change. To the subjectively observing person it shows itself merely in various forms of expression. Consequently is the energy, as is dictated by the here presented field theory, formed by binding in the inside of the quanta the same amount of energy but of the opposite sign. The amount of energy therefore is bound to the number of the present particles, as we already had derived.
Under the assumption of a constant time (6.35) there results for the electric conductivity σ, by calculating backwards over the equation of the relaxation time (5.3), the proportionality: (6.36)

$$\boxed{\sigma\,[\mathrm{A/Vm}] \sim 1/r} \quad (6.36)$$

Maybe the result surprises, because it can't be observed. Actually we know that the (microscopically observed conductivity in reality only represents an approximated averaged measure for the mobility of free charge carriers. In a particle-free vacuum however this well-known interpretation doesn't make sense anymore. Hence it is recommended, to only work with the relaxation time constants. Who nevertheless wants to continue to work with σ as a pure factor of description, can do this. But he mustn't be surprised, if in the model domain with decreasing radius the conductivity suddenly increases. But this is necessary, because otherwise the elementary particles would collapse. Only by the increase of the conductivity, which is produced by the spherical vortex itself, will the expanding eddy current build up in the inside of the particles, which counteract the from the outside concentrating potential vortex.

Approach:

a.The particles don't decay by themselves, but only by a corresponding disturbance from the outside.

b.The decay time is the statistical average in which such a disturbance can occur and take effect.

c.The elementary particles consist of an integral and finite number of elementary vortices, which can't decay anymore for their part.

d.If the compound particles get into the disturbing range of influence of high-frequency alternating fields, then they are stimulated to violent oscillations and in that way can be torn apart into individual parts.

e.As disturbing factor the high-frequency fields of flying past neutrinos are considered primarily.

f. Authoritative for the threshold of decay and with that also for the rate of decay is the distance, in which the neutrinos fly past the particle.

g.The distance becomes the larger, the smaller the particle is. If the particle thus experiences a relativistic length contraction, then it will, statistically seen, to the same extent become more stable!

That has nothing to do at all with time dilatationl

We are entitled to demand a simultaneity, after all we are the ones, who tell what that is!

Fig. 6.20: Proposal for an interpretation of the particle decay

<i>: Walter Theimer: Die Relativitatstheorie, Seite 106, Francke Verlag, Bern, 1977, ISBN 3-772O-126O-4

6.20 Particle decay

We still have to get rid of a fundamental misunderstanding. It concerns the problem of the time dilatation. Here the model domain doesn't give us any difficulty, because it dictates a constant and therefore by us definable time. In the relativistic view however should in moving systems clocks go wrong! But how does one want to explain a time dilatation physically, if it merely represents a purely mathematical result of the actually taking place length contraction on the one hand and the postulate of a constant speed of light on the other hand?

Nobody has troubled more about the physical interpretation than Einstein himself. But he had as less as we nowadays the possibility to verify the so-called phenomenon experimentally, by accelerating a laboratory clock to values close to the speed of light. Only atomic particles can, e.g. in accelerator systems, be brought on such high speeds and then be observed for their properties. But also these experiments don't have any power of proof, as long as we don't know the atomistic structure of the particles and there exists the danger of misinterpretations.

So the slowing down of the rate of decay of instable. particles at high speeds willingly is cited as "proof for time dilatation[i]. "The most cited example for the time dilatation is the "long-living" meson. The μ-meson is a charged particle, which exists only $2,2 * 10^{-6}$ seconds if it is observed in rest. Then it decays ... About 10 % of the mesons reach the earth's surface. Even if they fly with approximately the speed of light, they at least must have used $30 \bullet 2,2 * 10^{-6}$ seconds, in order to reach the earth. Their "life" therefore by the movement has been extended for a multiple... to the supporters of the theory of relativity here the time dilatation is revealed..."

This "proof however is worthless, as long as "the structure and the mechanism of decay of the particle are not known", like W. Theimer[i] expresses himself.

On the basis of the new field theory the approach standing on the left page is dared (fig. 6.20). Accordingly the particles don't decay by themselves, but only by a corresponding disturbance from the outside, which for instance is triggered by the high-frequency fields of flying past neutrinos. The closer the neutrinos fly past the particle, the sooner it will decay. But the distance becomes the larger, the smaller the particle is. If the particle thus experiences a relativistic length contraction, then it will, statistically seen, to the same extent become more stable!

That has nothing to do at all with time dilatation, as this proposal for an interpretation shows (fig. 6.20). The same effect of course also occurs, if atomic clocks are taken for a fly in a plane and compared to identically constructed clocks on earth.

The time was stipulated by us and therefore should be able to keep its universal validity. We are entitled to demand a simultaneity, after all we are the ones, who tell what simultaneity is!

An interesting technical use would be the acceleration of the rate of decay in order to dispose of radioactively contaminated waste. For that the waste has to be irradiated by collecting and focussing free neutrinos or with the help of a neutrino transmitter, like one which will be discussed in chapter 9. After such a neutrino shower dangerous radioactive waste would be reusable or at most be harmless domestic refuse.

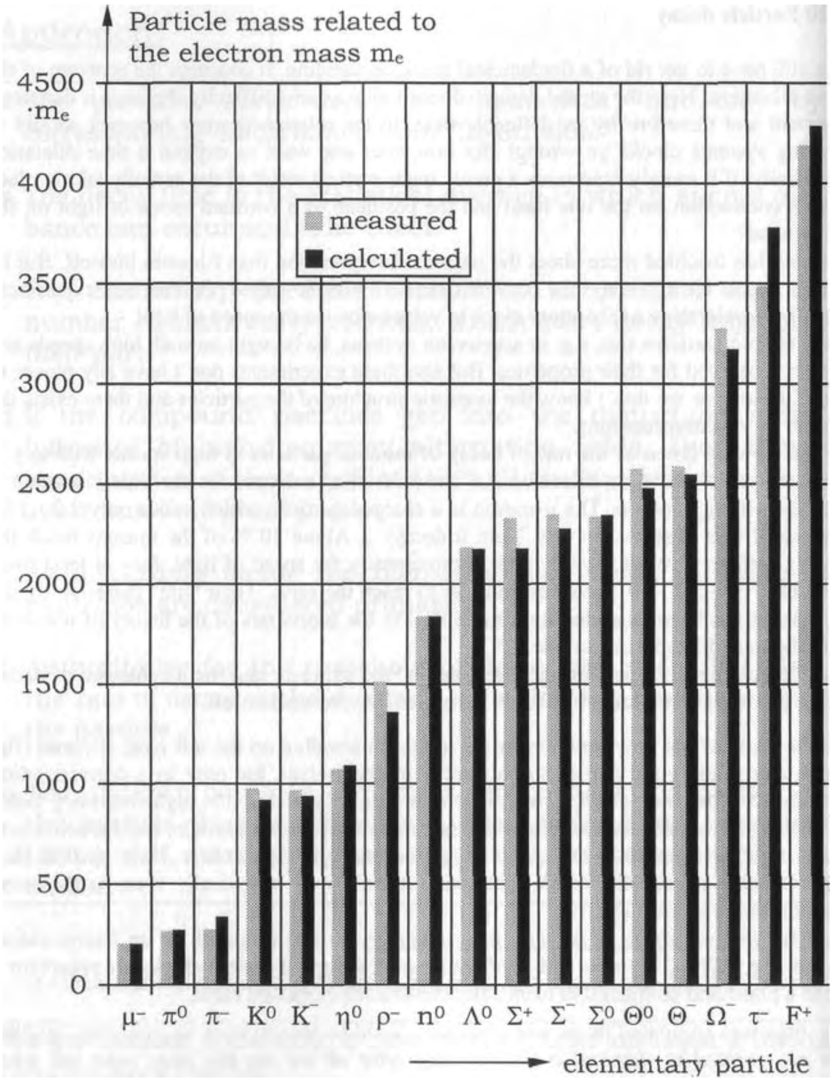

Fig. 7.0: The comparison with power of proof:
▨ the measured particle mass
■ the calculated particle mass

7. Proof

Ample evidence is available for the correctness of the theory of objectivity. The field dependent change in length is observed and used as magnetostriction or electrostriction. If a ferromagnetic material, e.g. a nickel rod, is brought into an alternating magnetic field, then field dependent longitudinal length oscillations are observed. In the same manner barium titanate or quartz crystal oscillates in the electric field if a high-frequency alternating voltage is applied.
A practical application forms the production of ultrasound.

In this chapter are, as already announced, the quantum properties of the elementary particles calculated and in this way is furnished perhaps the most convincing proof for the existence of potential vortices and for the correctness of the field-theoretical approach and the theory which is based on it.
A special challenge represents the calculation of the particle mass. This mass stretches from 207 electron masses of the myon over 1839 of the neutron into the order of magnitude of 18513 electron masses (Y°). Doing so not only can be tested, if the calculated values correspond with the measured ones. Also the gaps have to correspond, i.e. where there doesn't exist a discrete mathematical solution also no particle should exist. The fig. 7.0 standing on the left page anticipates the result and shows that even this strict condition is fulfilled! The agreement of the calculated with the measured results is excellent. If in individual cases small deviations become visible, we always have to bear in mind that the measurements as a rule are analysed statistically and the results are falsified if small particles creep in unrecognized. Particle physics nowadays has at its disposal extremely precise gauges, but even here remaining errors can't be excluded.

Quantum physics is occupied with further taking apart the elementary particles into hypothetic particles, the quarks, and to sort these according to properties and symmetries. Seen strictly causal this procedure thus corresponds to the quantum physical approach. We however have taken the field-theoretical approach, and this excludes the introduction of hypothetic particles from the start. It should be our goal to derive and to explain the quantum structure as a field property. Yes, we even want to calculate it, with which we would have overtaken quantum physics in the scientific competition with one leap!

Strong support our approach has experienced by current experiments, in which matter was transformed in electromagnetic waves - practically the reversal of the rolling up of waves to vortices. To do so at the Massachusetts Institute of Technology (David Pritchard and others) sodium atoms were dematerialized in waves by lattice scattering<i>. According to Einstein one surely could have blown the whole M.I.T. in the air with the occurring mass defect; but don't worry, no emission of energy whatsoever has been observed, entirely as predicted by the vortex theory.

<i>: J. Teuber: Materie und Energie, Ganze Atome wurden zu Energiewellen,
Illustrierte Wissenschaft Nr. 7 (1996), S. 56

With the classical radius of the electron $r_e = 2,82 * 10^{-15}$ m:

$$C_e = \varepsilon_o \cdot 4\pi r_e = 3,135 \cdot 10^{-25} F \quad (6.4^*)$$

$$U_e = e/C_e = 511 kV \quad (6.31^*)$$

(constant independent of r_e)

Formation forms (vortex properties):

I. Amassing (formation of vortex balls):

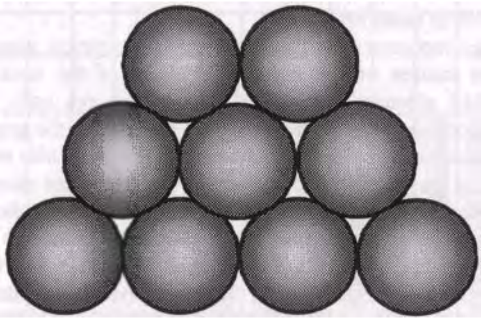

II. Overlapping (phenomenon of transport)

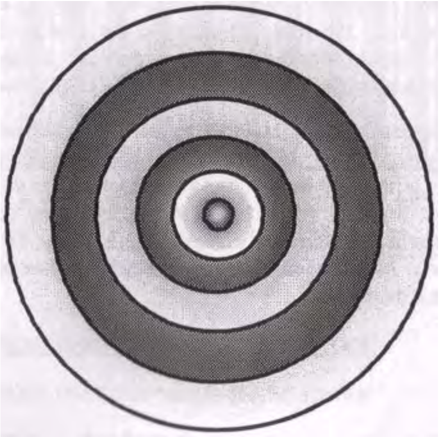

Fig. 7.1: The amassing and overlapping of elementary vortices

7.1 Elementary vortices

We had derived the electron and the positron as elementary vortices (fig. 4.3). Before we can go in the calculation, we must gain a clear picture of the possible configurations of vortices, which for reason of the derived properties are possible. For that we start with the elementary vortex and afterwards we predict the behaviour of interaction which can be expected.

Actually only one single particle is really elementary. According to the realizations of the new theory it is an elementary vortex in the form of a sphere. Its size is determined by the speed of light and this again by the local field strength; its stability is founded in the concentration effect of the potential vortex. The whirling takes place everywhere with the speed of light, even in the vortex centre, where all field lines run together, where the field increases infinitely and the speed of light goes to zero. This last circumstance owes the elementary vortex its localization.

We can attribute a charge to this vortex for reason of the field lines which on the outside run towards infinity and which we can measure (fig. 4.3). This is the smallest indivisible unit, the elementary charge e. Structure and course of the field lines suggest to understand and to calculate the elementary vortex as a spherical capacitor. By basing on the classical radius of the electron r_e given in fig. 6.3 the capacity according to equation 6.4 is calculated to be:

$$C_e = \varepsilon_0 \cdot 4\pi r_e = 3{,}135 \cdot 10^{-25}\ \mathrm{F} \quad (6.4^*)$$

Here the theory of objectivity has provided us the realization that even for a change of the radius of the electron the capacity remains unchanged constant (6.30), and this entirely corresponds to our observation.

Between the hull of the elementary vortex, measured at the radius r_e, and its centre, respectively also with regard to infinity, there exists according to equation 6.31 the tension voltage of:

$$U_e = e/C_e = 511\ \mathrm{kV} \quad (6.31^*)$$

It as well is constant and independent of the size of the elementary vortex.

Since a different solution is refused, we'll have to assume that all elementary particles consist of an integer multiple of elementary vortices. For that the amassing, like closely packed tennis balls, or the overlapping of individual vortices in the form of shells, like in the case of an onion (phenomenon of transport) can be considered.

The among each other occurring forces of attraction can be traced back to the fact that every elementary vortex is compressed by the field of its neighbour as a consequence of the field dependent speed of light. This field as a rule is for the small distances considerably larger than the field on the outside. Therefore do compound elementary particles not have the twofold or triple mass, but at once the 207-fold (myon) or the 1836-fold (proton) mass. After all there is no other explanation for the fact that there don't exist lighter particles (with a mass less than 207 electron masses)!

a. The electron-positron pair

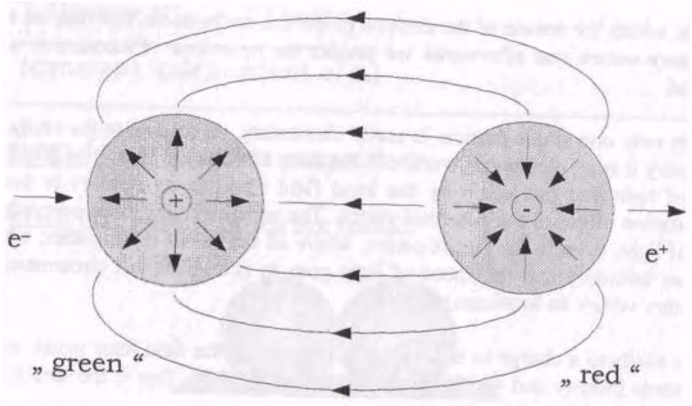
e⁻
e⁺
„ green “
„ red “

b. . The e^- - e+ pair for a small distance:

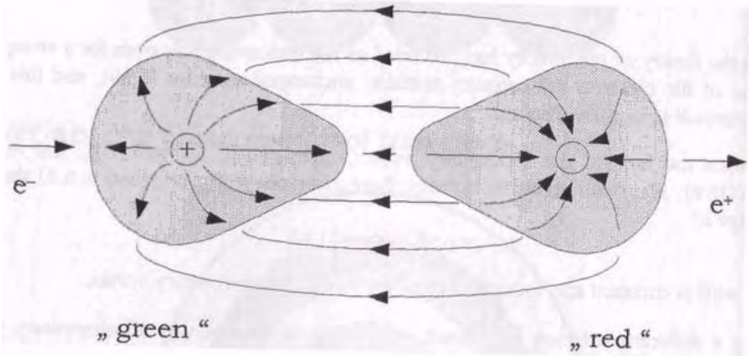
e⁻
e⁺
„ green “
„ red “

Fig. 7.2: The electron-positron pair annihilation

7.2 Matter and anti-matter

For the amassing or overlapping of elementary vortices several cases must be distinguished, because two inverse forms of formation are possible for the elementary vortex: the negatively charged electron and the positively charged positron. Whereas in the case of the electron the vortex produces a component of the electric field which points from the inside to the outside, has the field in the case of the positron the opposite direction for reason of a reversed swirl direction.

This statement can be generalized: if we consider the elementary particles from the outside, then we assign the particles with a swirl direction identical to that of the electron to the world of matter and call the particles with the opposite swirl direction anti-matter. It now is strongly recommended, to take colours to hand, in order to optically clarify the properties of vortices. The electron will be marked as a green sphere and the antiparticle, the positron, as a red sphere.

If we now look into the world of matter, then appears our world of matter to us "green", the world of anti-matter however "red". The uniform green colour of all the in our world existing elementary particles however doesn't exclude that red anti-vortices can exist hidden in the inside of the green vortices, where we can't discover them. But they must be completely covered, otherwise a disastrous reaction occurs, the pair annihilation, as a consequence of the oppositely directed property of the vortices which cancel out. By means of the pair annihilation a dematerialization can occur, because every elementary vortex keeps in its inside the same amount of energy with opposite sign and the fusion of two inverse particles can result in a zero sum of the energy. The best known example is the annihilation of an electron-positron pair under emission of radiation discovered by Klemperer in 1934. In the upper representation (fig. 7.2a) the elementary vortices still are symmetrical, but the outside field lines already are "bent" and linked together in such a way that, with the exception of the ones in the direction of the axis, no interaction takes place which can be measured.

The two particles for reason of the different charge approach each other quickly, and the closer they are, the larger the mutual force of attraction becomes; a vicious circle, which leads to the asymmetry shown in the lower sketch (fig. 7.2b) and only comes to rest, if both particles have destroyed themselves mutually.

The electron and the positron had the same amount of, but oppositely directed swirl activity, so that purely arithmetically seen a zero sum of the rest energy results. But it should be paid attention to both particles having some kinetic energy on the occasion of the relative motion to each other and if they rotate around their own axis also rotational energy. An emission of annihilation radiation occurs, is the explanation of particle physics.

With the knowledge of the photon (fig. 4.6) we can interpret the annihilation radiation as a consequence of the phenomenon of transport. The faster and consequently smaller vortex, for instance the green one, slips into the red one and sees the green inside, which is compatible for it. Unfortunately it only can remain there, as long as it is smaller, thus is faster, and therefore it shoots out on the other side again. Now the electromagnetic force of attraction fully takes effect. It is slowed down and the red vortex correspondingly accelerates. The process is reversed.

These around each other oscillating vortices, so we had derived, have a characteristic frequency (colour), are polarizable and are moving forward with the speed of light as a consequence of the open vortex centre. It therefore concerns the photon.

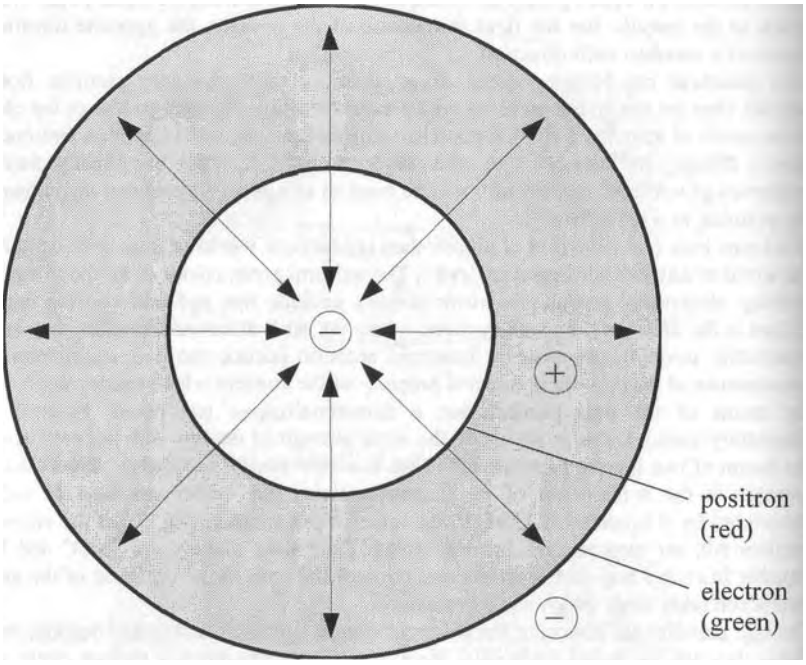
+
−
−
positron
(red)
electron
(green)

Fig. 7.3: Theoretical final state of the positronium = static γ-quant (photon).

7.3 Positronium

But before the two elementary vortices, the electron and the positron, are annihilated under emission of radiation, they will for a short time take a shell-shaped, a bound state, in which one vortex overlaps the other.
Its formation we can imagine as follows: an electron, flying past a resting positron, is cached by this for reason of the electromagnetic attraction and spirals on an elliptic path towards the positron. In doing so its angular velocity increases considerably. It will be pulled apart to a flat disc for reason of the high centrifugal forces, to eventually lay itself around the positron as a closed shell.
Now the red positron sees the electron vortex so to speak "from the inside" and doing so it sees as well red; because the green vortex has a red centre and vice versa! The result is the in fig. 7.3 given configuration.

The number of field lines, which run from the red border of the positron in the direction of the centre, is identical to the number, which point towards the green border of the electron. Here already the same state has been reached as in the centre, which corresponds to the state at infinity. That means that no field lines point from the green border to the outside; seen from the outside the particle behaves electrically neutral. It doesn't show any electromagnetic interaction with its surroundings.

If the particle were long-living, then it undoubtedly would be the lightest elementary particle besides the electron; but without stabilizing influence from the outside the positronium can't take the in fig. 7.3 shown state at all. The positron takes up the kinetic energy which is released if the electron becomes a shell around it. But before the bound state can arise, which would identify the positronium as an elementary particle, the equal rights of both vortices comes to light. With the same right, with which the electron wants to overlap the positron, it itself vice versa could also be overlapped.
If the stabilization of the one or the other state from the outside doesn't occur, then the stated annihilation under emission of y-quanta is the unavoidable consequence (fig. 4.6).

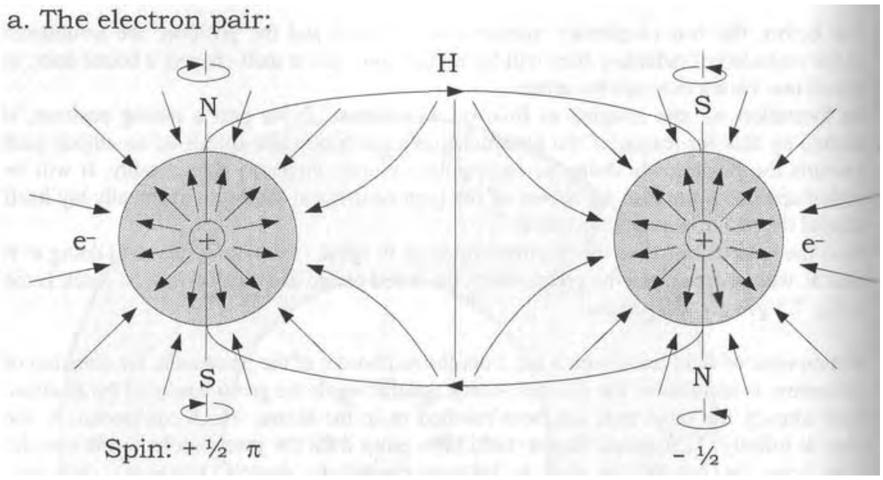

a. The electron pair:

H
N
S
S
N
e⁻
e⁻
+
+
Spin: + ½ π
- ½

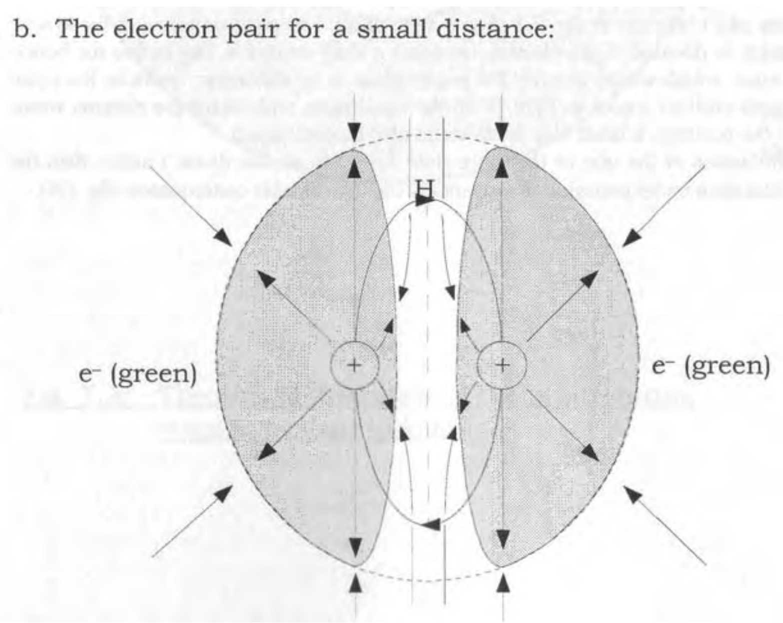

b. The electron pair for a small distance:

H
+
+
e⁻ (green)
e⁻ (green)

Fig. 7.4: Two electrons with oppositely directed spin

7.4 Dipole moment

As electrically charged spheres elementary vortices have a magnetic dipole moment along their axis of rotation as a consequence of the rotation of their own (fig. 7.4). This is measurable very precisely and for the most important elementary particles also known quantitatively. In contrast to the angular momentum the magnetic moment can't be constant according to the here presented theory. It should slightly change, if we increase the field strength in the laboratory.

In a particle consisting of several elementary vortices the vortices mutually increase the local field strength. Therefore we measure at the proton, which consists of three vortices, not the triple, but only the 2,793-fold of the nuclear magneton which can be expected for reason of its mass. Also the neutron has instead of the double only the 1,913-fold nuclear magneton. The deviations therefore are explicable as a consequence of the surrounding fields.

Prerequisite for this point are two other, still unanswered, key questions of quantum physics:

> XII: Why is measured for the proton approximately the triple of the magnetic dipole moment which can be expected for reason of the charge?
>
> XIII: Why does the neutron, as an uncharged particle, actually have a magnetic moment?

These questions can only be brought to a conclusive answer, if we have derived the vortex structures of the respective particles.

The elementary vortex, as a consequence of the spin along its axis, forms a magnetic north pole and a south pole. Another possibility to interact with an external field or with other particles is founded on this property. This shall be studied by means of two electrons. which form an electron pair.

For reason of the equal charge the two electrons at first will repel each other. If they rotate of their own they however will mutually contract, which, seen from the outside, is interpreted as a force of attraction. And in addition will they align their axes of rotation antiparallelly. While they now rotate in the opposite direction, a magnetic force of attraction occurs.

As is shown in fig. 7.4, the magnetic dipole field in this way is compensated towards the outside, as is clarified by the field line (H) with a closed course. Between both electrons a space free of E-field stretches. If both vortices are a small distance apart they lay themselves around this space like two half-shells of a sphere. A particle forms which seen from the outside is magnetically neutral, but it carries the double elementary charge (fig. 7.4b).

The exceptional affinity is always restricted to two vortices of equal charge with an opposite direction of rotation. Further vortices can't be integrated anymore and are repelled. This property of vortices covers the quantum condition (Pauli's exclusion principle) for the spin quantum number perfectly.

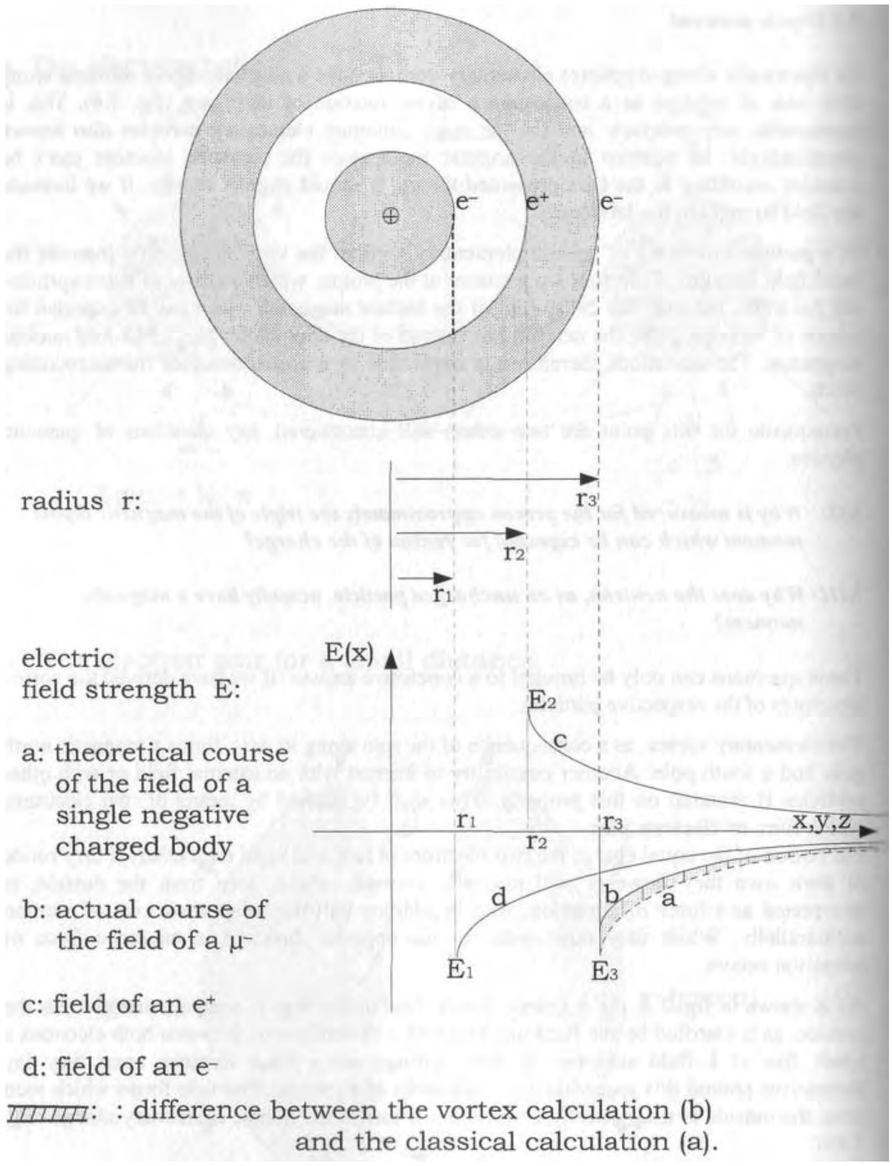
e⁻
e⁺
e⁻
⊕
radius r:
r₃
r₂
r₁
electric
field strength E:
E(x)
E₂
c
r₁
r₃
x,y,z
r₂
d
b
a
E₁
E₃
a: theoretical course
of the field of a
single negative
charged body
b: actual course of
the field of a μ⁻
c: field of an e⁺
d: field of an e⁻
▨: : difference between the vortex calculation (b)
and the classical calculation (a).

Fig. 7.5: The mvon and the electric field E(x) of the three elementary vortices

7.5 Myon

We now have discussed all conceivable possibilities, which two elementary vortices can form: the creation of a pair for like charge and the annihilation under emission of photons via the formation of the positronium as an intermediate result for unequal charge. Next another elementary vortex shall be added and all different possibilities and configurations will be derived, which can be formed by amassing or overlapping.

The positronium can, as said, only take the in fig. 7.3 shown bound structure, if it is stabilized from the outside. This task now a further electron shall take over. According to the shell model the innermost elementary vortex an electron (e^-), is overlapped by a positron (e^+) and that again overlapped by an electron (e^-).
With an in the sum single negative charge, a completely symmetric structure as well as a half-integer spin this particle will show a behaviour corresponding to a large extent to that of the electron. Merely the mass will be considerably larger, because every vortex each time compresses the other two.

It therefore concerns the myon (μ^-), which also is called "heavy electron". The myon was discovered 1937 in the cosmic radiation (Anderson and others).
In fig. 7.5 are drawn above each other the shell-shaped structure of the myon and the electric field E(x) of the three elementary vortices.
It is visible that merely in the proximity of the particle the actual course of the field deviates from and is smaller, than the course which theoretically can be expected for a single negatively charged body. The difference is marked by a hatching.

We now can tackle the calculation of the myon. For that the following considerations to begin with are useful:
Mass is an auxiliary term founded in usefulness, which describes the influence of the electromagnetic field on the speed of light and with that on the spatial extension of the "point mass".
Without exception the local cosmic field E_o has an effect on a free and unbound elementary vortex, thus on an individual e^- or e^+, and determines so its size and its mass. But as long as we haven't determined this field strength, the calculation of its quantum properties won't succeed.
Instead the masses of compound particles will be compared to each other, which are so heavy that the field strength of the neighbouring vortices is predominant over the basic field E_0, so that a neglect of E_o seems to be allowed. The course of the calculation is made for all elementary particles in the same manner, which is explained hereafter.

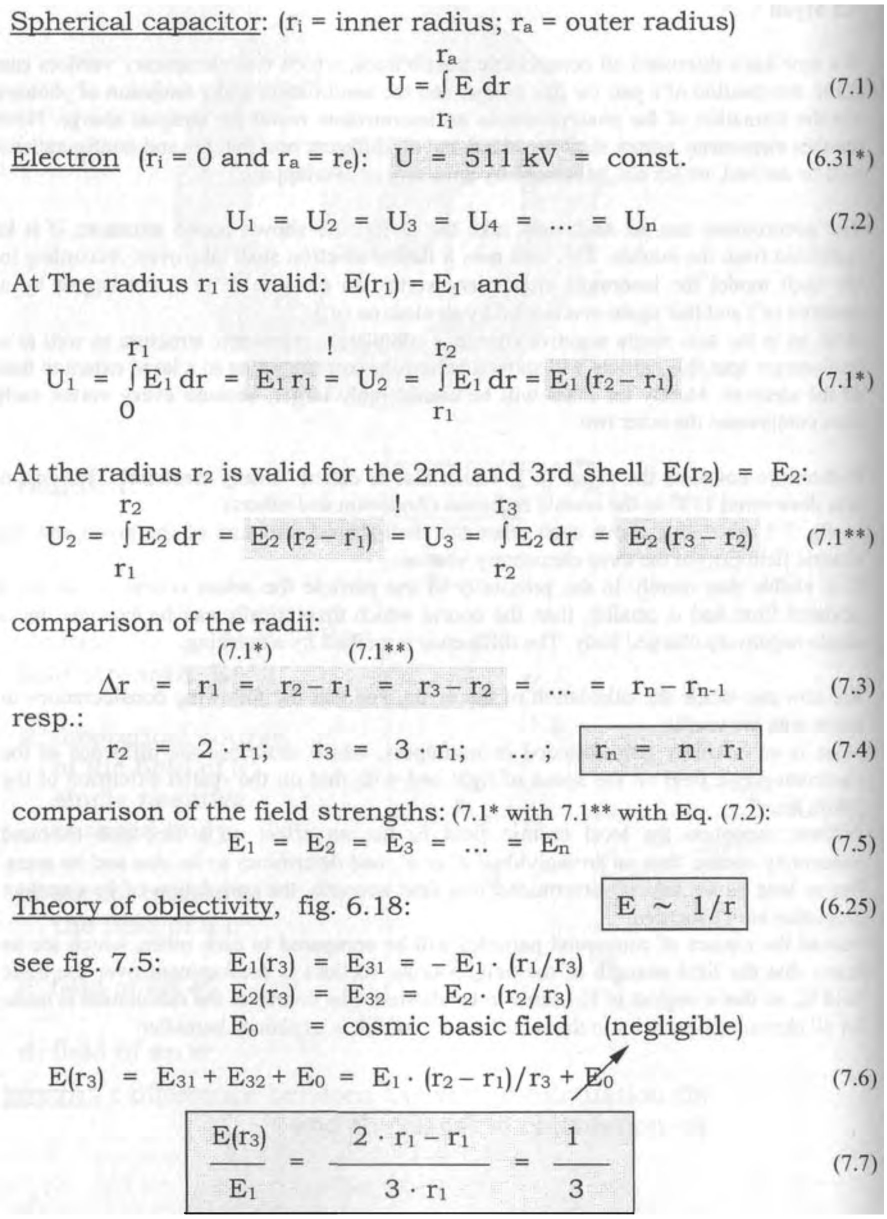

Spherical capacitor: (r_i = inner radius; r_a = outer radius)

$$U = \int_{r_i}^{r_a} E\,dr \qquad (7.1)$$

Electron ($r_i = 0$ and $r_a = r_e$): $U = 511\,\text{kV} = \text{const.}$ (6.31*)

$$U_1 = U_2 = U_3 = U_4 = \ldots = U_n \qquad (7.2)$$

At The radius r_1 is valid: $E(r_1) = E_1$ and

$$U_1 = \int_0^{r_1} E_1\,dr = E_1 r_1 \overset{!}{=} U_2 = \int_{r_1}^{r_2} E_1\,dr = E_1 (r_2 - r_1) \qquad (7.1^*)$$

At the radius r_2 is valid for the 2nd and 3rd shell $E(r_2) = E_2$:

$$U_2 = \int_{r_1}^{r_2} E_2\,dr = E_2 (r_2 - r_1) \overset{!}{=} U_3 = \int_{r_2}^{r_3} E_2\,dr = E_2 (r_3 - r_2) \qquad (7.1^{**})$$

comparison of the radii:

$$\Delta r = \overset{(7.1^*)}{r_1} = \overset{(7.1^{**})}{r_2 - r_1} = r_3 - r_2 = \ldots = r_n - r_{n-1} \qquad (7.3)$$

resp.:

$$r_2 = 2 \cdot r_1; \quad r_3 = 3 \cdot r_1; \quad \ldots; \quad \boxed{r_n = n \cdot r_1} \qquad (7.4)$$

comparison of the field strengths: (7.1* with 7.1** with Eq. (7.2):

$$E_1 = E_2 = E_3 = \ldots = E_n \qquad (7.5)$$

Theory of objectivity, fig. 6.18: $\boxed{E \sim 1/r}$ (6.25)

see fig. 7.5:
$$E_1(r_3) = E_{31} = -E_1 \cdot (r_1/r_3)$$
$$E_2(r_3) = E_{32} = E_2 \cdot (r_2/r_3)$$
E_0 = cosmic basic field (negligible)

$$E(r_3) = E_{31} + E_{32} + E_0 = E_1 \cdot (r_2 - r_1)/r_3 + E_0 \qquad (7.6)$$

$$\boxed{\frac{E(r_3)}{E_1} = \frac{2 \cdot r_1 - r_1}{3 \cdot r_1} = \frac{1}{3}} \qquad (7.7)$$

Fig. 7.6: Calculation of the electric field strength E(r) of the myon from its dependency on radius

7.6 Calculation of the vortex fields

The tension voltage of an elementary vortex, like for a spherical capacitor, is determined by integrating over the electric field strength from the inner radius r_i up to the outer radius r_a:

$$U = \int_{r_i}^{r_a} E \, dr \quad (7.1)$$

For the electron ($r_i = 0$ und $r_a = r_e$) we already have carried out the integration and determined the tension voltage to be 511 kV (equation 6.31 *).
Doing so we further had discovered that it won't change, if the radius r varies. Even for a shell configuration, in which electrons and positrons alternately overlap, the approach is valid:

$$U_1 = U_2 = U_3 = U_4 = \ldots = U_n \qquad (7.2)$$

At a certain radius all elementary vortices show the same density of field lines and with that also the identical field strength, so that we can solve the integral (7.1) for the each time neighbouring vortex shells and can compare the results:
At the radius r_1 with $E(r_1) = E_1$ the agreement, according to equation 7.1* (fig. 7.6), is valid for the innermost and the overlapped vortex shell.
At the radius r_2 with $E(r_2) = E_2$ the agreement according to equation 7.1** (fig. 7.6) is valid analogously for the 2nd and 3rd shell.
If still more shells are present, then we can arbitrarily repeat this procedure. For the radius of each shell we always obtain relation 7.3, which, related to the innermost radius, provides the following simple expression for the individual radii:

$$r_2 = 2 * r_1; \quad r_3 = 3 \bullet r_1; \quad \ldots; \quad r_n = n * r_1 \qquad (7.4)$$

From the comparison of the integration results 7.1* and 7.1** follows further that all elementary vortices produce the same field strength:

$$E_1 = E_2 = E_3 = \ldots = E_n \qquad (7.5)$$

We infer from the transformation table (fig. 6.18, eq. 6.27) that the field strengths E and H decrease with 1/r. In fig. 7.5 the decrease of the fields with 1/r is shown. Up to the radius r, the field of the innermost vortex E_1 has worn off to the value $E_{31} = - E_1 \bullet (r_1/r_3)$. This field is overlapped by $E_{32} = E_2 * (r_2/r_3)$ as well as the cosmic basic field E_o:

$$E(r_3) = E_{31} + E_{32} + E_0 = E_1 \bullet (r_2 - r_1)/r_3 + E_o \qquad (7.6)$$

The local basic field E_o is not known, but it is very small with regard to the field of the neighbouring vortex shells, so that a neglect seems to be allowed. From equation (7.6) in this way follows with the radius relation (7.4):

$$\frac{E(r_3)}{E_1} = \frac{2 \cdot r_1 - r_1}{3 \cdot r_1} = \frac{1}{3} \quad (7.7)$$

For the shell-shaped configuration of the myon (fig. 7.5) relation (7.7) indicates, which field the outside vortex shell is exposed to. From this can already be seen, how much it is compressed thanks to the field dependent speed of light and how much its mass as a consequence is increased.

Structure of the proton p^+:

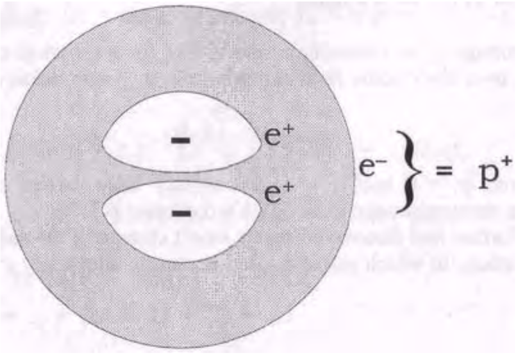

Calculation:
structure consisting of two shells, inner vortices with $2 \cdot E_1$,
field strength at the outer radius r_2:

$$E(r_2) = 2 * E_{21} = 2 * E_1 (r_1 / r_2) = E_1 \qquad (7.8)$$

Comparison of p^+ (7.8) with u^- (7.7) (z_e = number of the elementary vortices being involved with) in building up the structure, here each time $z_e = 3$):

Comparison of the radii with $E \sim 1 / r$ (6.27)

$$\frac{r_p}{r_\mu} = \frac{z_{e\mu}}{z_{ep}} \cdot \frac{E_\mu(r_3)}{E_p(r_2)} = \frac{3}{3} \cdot \frac{1/3}{1} = \frac{1}{3} \qquad (7.9)$$

Theory of objectivity (fig. 6.18): $m \sim 1/r^2$ (6.34)

$$\frac{m_p}{m_\mu} = \frac{z_{ep}}{z_{e\mu}} \cdot \left(\frac{r_\mu}{r_p}\right)^2 = \frac{3}{3} \cdot \left(\frac{3}{1}\right)^2 = 9 \qquad (7.10)$$

$$m_p/m_e = 9 * (m_u/m_e) = 9 * 207 = 1863 \qquad (7.11)$$

Measurement value, proton mass: $m_p = 1836 \cdot m_e$
Resp.:
measurement value myon mass $m_u = 207 * m_e$
myon calculated value: $m_p = 204 * m_e$. (error = 1,5%)

Since we, by using this calculation method, for the first time succeeded in deriving the mass of an elementary particle from that of another particle, the particle mass isn't a constant of nature anymore!

Fig. 7.7: Calculation of the proton

7.7 Calculation of the proton

If we again remember the affinity of two elementary vortices, which rotate with opposite spin. They align their axis of rotation antiparallel and form a very probable, but not particularly tight bound pair (fig. 7.4).

If we this time start with a positron pair, then does this pair have a double positive elementary charge. The two e^+ hence exert a particularly big force of attraction on electrons flying past them. If they have cached one and put it round as a shell, like a coat, then they will never again give it back! To again remove the electron, a triple positive charge would be necessary. But such a particle can't exist at all. The new particle therefore has an absolute stability and a very big mass, because the positron pair is considerably compressed by its outer shell. The total charge is single positive. With these properties it actually only can concern the proton. Its structure is shown in fig. 7.7. We can start from the assumption that both positrons are very close together in the inside and thus each forms the half of a sphere. For the calculation of the proton mass we then can assume as an approximation a structure of two shells, in which the inner vortex will have the double charge and the double field ($2 * E_1$). With equation 7.4 the field strength at the outer radius r_2 is:

$$E(r_2) = 2*E_{21} = 2*E_1*(r_1/r_2) = E_1 \qquad (7.8)$$

If we want to compare the results of the p^+ (7.8) and the μ^- (7.7), then it should be considered that the field of the innermost elementary vortex E_1 only is equal, if the number z_e of the elementary vortices involved in building up the particle is identical. Here with each time $z_e = 3$ this is the case. Because of equation 6.27 (E, H ~ 1/r) now also the radii are comparable:

$$\frac{r_p}{r_\mu} = \frac{z_{e\mu}}{z_{ep}} \cdot \frac{E_\mu(r_3)}{E_p(r_2)} = \frac{3}{3} \cdot \frac{1/3}{1} = \frac{1}{3} \qquad (7.9)$$

The mass of a particle first is determined by the number of the elementary vortices z_e. According to the theory of objectivity (fig. 6.18) however also the radius has an influence on the mass:

$$m \sim 1/r^2 \qquad (6.34)$$

This proportionality should be applied to the p^+-μ^-- comparison.

$$\frac{m_p}{m_\mu} = \frac{z_{ep}}{z_{e\mu}} \cdot \left(\frac{r_\mu}{r_p}\right)^2 = \frac{3}{3} \cdot \left(\frac{3}{1}\right)^2 = 9 \qquad (7.10)$$

The calculation provides a nine times bigger mass for the proton with regard to the mass of the myon. Therefore the mass of the proton related to the mass of the electron is:

$$m_p/m_e = 9*(m_\mu/m_e) = 9*207 = 1863 \qquad (7.11)$$

It would be favourable, to start from the with measuring techniques determined value for the mass of the proton $m_p/m_e = 1836$ and calculate backwards the related mass of the myon.

Then we obtain 204 as the calculated value instead of the measurement value $m_\mu/m_e = 207$.

The reason for the deviation of 1.5 percent is caused by the neglect of the cosmic field E_o with regard to the field of the neighbouring elementary vortex. This neglect takes very much less effect for the relatively heavy proton than for the light myon.

The cosmic field therefore will compress the myon more strongly and increase the mass more strongly as is calculated here, in agreement with the measurement results.

Summarizing: since we, by using this calculation method, for the first time succeeded in deriving the mass of an elementary particle from that of another particle, the particle mass isn't a constant of nature anymore!

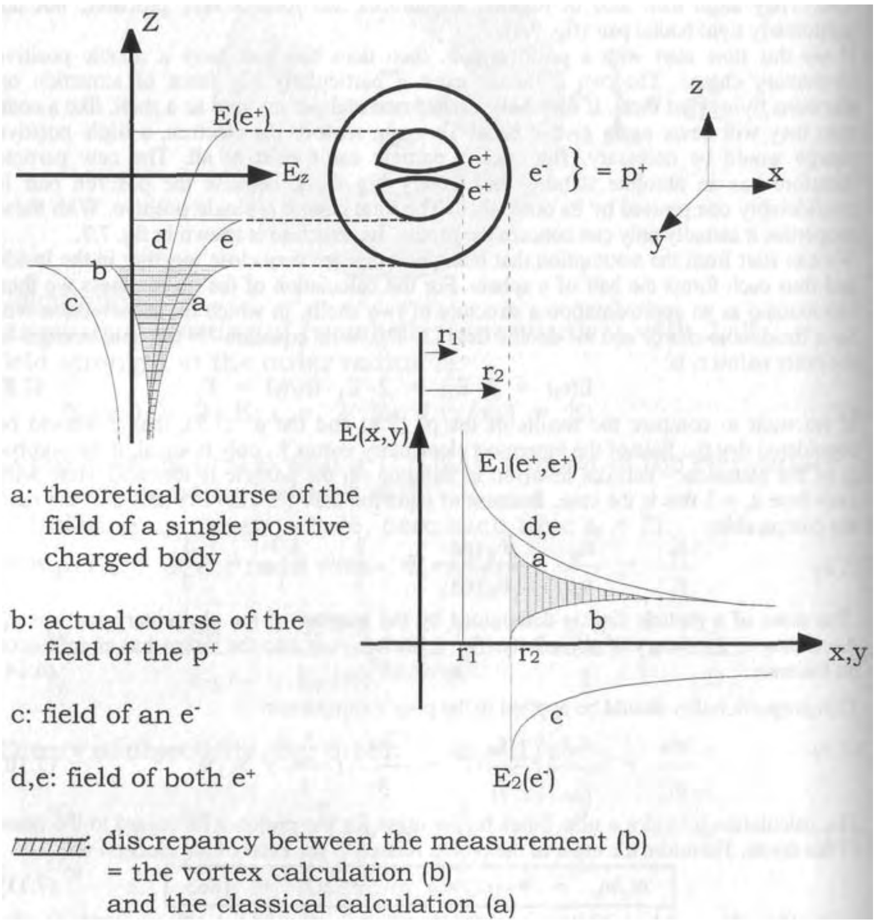
Z
E(e⁺)
E_z
e⁺
e⁺
e⁻
} = p⁺
z
x
y
d
e
b
c
a
r₁
r₂
E(x,y)
E₁(e⁺,e⁺)
d,e
a
b
x,y
r₁
r₂
c
E₂(e⁻)
a: theoretical course of the field of a single positive charged body
b: actual course of the field of the p⁺
c: field of an e⁻
d,e: field of both e⁺
▨: discrepancy between the measurement (b) = the vortex calculation (b) and the classical calculation (a)

Fig. 7.8: The proton and the electric field of the three elementary vortices in x-, y- and z-direction

7.8 "Strong interaction"

A central question of nuclear physics concerns the forces which keep the atomic nucleus, which consists of many neutrons and protons, together and give it its very good stability in spite of the like positive charge (key question XIV fig. 7.13).

According to today's textbook opinion (course of the field indicated with a in fig. 7.8) the forces of repulsion between the individual protons increase further as the distance gets smaller, to obtain immense values within the nucleus. They theoretically had to be overcome by new and unknown nuclear forces. Therefore physicists assume the hypothesis of a "strong interaction". But they are mistaken. The answer to this open question is provided by the course of the field (b) for the proton, sketched in fig. 7.8. We see that the electric field at first indeed still increases if we approach the proton, but in the proximity it contrary to all expectations decreases again until it is zero. With that then also any force of repulsion has vanished! But the course of the field follows without compulsion from the overlap of the three individual elementary vortex fields.

The field direction in the z-direction even is reversed! In this topsy-turvy world, in theory, an electromagnetic force of attraction between two like charged protons can occur. We conclude:

A strong interaction doesn't exist at all. The usually given values for "range" and "strength" just represent a misinterpretation. The hatched drawn area marks the difference which is misinterpreted by quantum physics. The model concept over and above that answers another mysterious property of the proton. As an electrically charged particle with a spin it first of all should form a magnetic moment for reason of the rotating charge. But until now the measurable order of magnitude couldn't be explained.

7.9 Magnetic moment of the proton

If the inner positrons rotate around each other with oppositely pointing spin, then the magnetic field line is already closed within the particle and no effect in x- or y-direction is observable from the outside.

As pair they however still can rotate together around the z-axis and they'll do that. The overlapping electron for reason of its rotation of its own will likewise build up a magnetic dipole moment along its axis of rotation. It also will align its axis in the z-direction, so that now all three elementary vortices have one field axis. Being comparable to individually "elementary magnets" aligned in the same direction they produce a triple magnetic moment (key question XII fig. 7.13).

If we namely would start with a single positively charged body according to the theory of quantum mechanics, then we would have expected the value of the nuclear magneton<i> p_m as the magnetic moment for the proton $p_m = e \cdot \hbar/2m$. Opposite to that provide experiments with protons the approx. threefold value as already predictable by the new vortex theory. In addition does the direction of the vector p_{mp} correspond with the spin-axis, so as if the proton were negatively charged. The reason for that is that only the outermost elementary vortex determines the spin of the particle, and that is actually a negatively charged electron! Also this excellent agreement in the case of the proton can be judged as proof for the correctness of the vortex model.

<i>: The nuclear magneton has the value of: $p_{mk} = 5{,}0508 \cdot 10^{-27}$ Am^2

a. n^0 if the e^- amasses to a p^+.

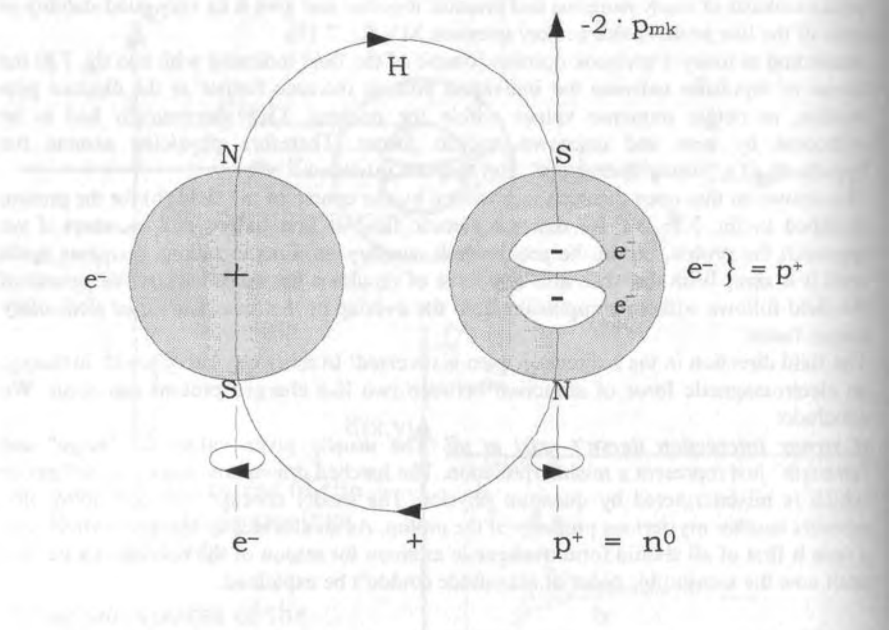
-2 · pmk
H
N
S
e⁻
+
-
e⁻
-
e⁻
e⁻ } = p⁺
S
N
e⁻
+
p⁺ = n⁰

b. n^0 if the e^- is overlapped by an e^+ of the p^+

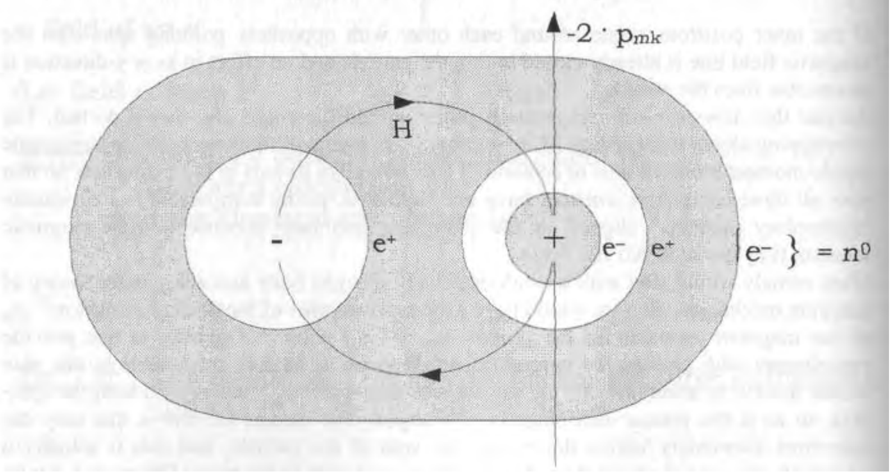
-2 · pmk
H
-
e⁺
+
e⁻
e⁺
e⁻ } = n⁰

Fig. 7.10: The neutron with magnetic dipole field H

7.10 Structure of the neutron

Until now could not be solved, why despite its missing charge also the neutron n° has a magnetic moment. The experimentally determined value is approx. the double of the nuclear magneton. Further was with measuring techniques an only 0,14% bigger mass with regard to the proton determined. The difference is approximately two and a half electron masses. And how reads the answer in the view of the potential vortex theory? It is obvious that a positively charged proton and a negatively charged electron mutually attract and amass together (fig. 7.10a). A pair annihilation can't occur, because the electron, which jackets both positrons, prevents this. The formation of an outer shell is not permitted by the high stability of the proton. It would have to be a positron shell, which instead of neutrality would produce a double positive charge. Conceivable is however the configuration, in which one of the two e^+ of the proton takes up the e^- in its inside and overlaps it (fig. 7.10b).

At first appears the amassing of p^+ and e^- to be the obvious answer to the structure of the neutron also in view of the small increase in mass. Since both elementary particles (p^+ and e^-) have a spin, will they align their axes of rotation antiparallelly and rotate against one another, exactly like an electron pair. But we now have unequal conditions: the proton brings the triple magnetic moment, the electron however only the single, and its field line will be closed by the proton. The difference which remains is the measurable double nuclear magneton, with which key question XIII (fig. 7.13) would be answered exhaustively.

This structure is shown in fig. 7.10a and has as rest mass the by only one electron mass increased proton mass, but it will deviate from this value, when the unequal partner come closer. Doing so the electron will be more strongly compressed by the heavier proton as vice versa.

Mass, magnetic moment and charge thus correspond to a large extent with the measurement values. Problems are seen concerning the spin and the stability.

Set of problems concerning spin: both the e^- and the p^+ have a half-integer spin, for which reason this configuration should have an integer spin.

Set of problems concerning stability: the neutron decays as is well-known in a p^+ and an e^- , but this object should be shorter-lived as determined by experiments. If namely the partner come each other very close, then the field strength of the p^+, contrary to expectation, doesn't increase but decreases, as is shown in fig. 7.8. The e^- therefore can only be bound very, very loosely; in z-direction it even will be repelled!

For these reasons is the open structure, which is shown in fig. 7.10a, not feasible as an isolated elementary particle, but only in a spatially extended network, like it is present in an atomic nucleus. In this case the neutron is, as is well-known, lighter by the mass defect, which is interpreted as binding energy.

Possibly it only concerns an intermediate stage. The heavier final product of the n° then could look like is shown in fig. 7.10b. For this version the line of the magnetic field already is closed partly within the particle, so that also here the approx. double nuclear magneton remains as a rest with a sense of orientation, as if the neutron were negatively charged.

Without charge and with the 1/2 spin it in this configuration fulfils all important quantum properties of the neutron, even that of the stability.

the field of the e^-: $E_{31}(-) = - E_1\,(r_1/r_3)$,

the field of the e^+: $E_{32} = E_2\,(r_2/r_3) = E_1\,(r_2/r_3)$

and in addition the e^+: $E_{3\,1} = E_1\,(r_1/r_3)$.

$$E(r_3) = E_{31}^{(-)} + E_{32} + E_{31} + \underset{\searrow\,\text{negligible}}{E_0}$$

With the radius relation (eq. 7.4): $r_2 = 2*r_1$ und $r_3 = 3*r_1$
The total field is:

$$\frac{E(r_3)}{E_1} = -\frac{r_1}{r_3} + \frac{r_2}{r_3} + \frac{r_1}{r_3} = -\frac{1}{3} + \frac{2}{3} + \frac{1}{3} = \frac{2}{3} \quad (7.12)$$

With $z_{en} = 4$ elementary vortices

$$\boxed{\frac{r_n}{r_p} = \frac{z_{ep}}{z_{en}} \cdot \frac{E_p(r_2)}{E_n(r_3)} = \frac{3}{4} \cdot \frac{1}{2/3} = \frac{9}{8} = 1{,}125} \quad (7.13)$$

n_0 is 12,5% bigger than p±

$$\boxed{\frac{m_n}{m_p} = \frac{z_{en}}{z_{ep}} \cdot \left(\frac{r_p}{r_n}\right)^2 = \frac{4}{3} \cdot \left(\frac{8}{9}\right)^2 = 1{,}05} \quad (7.14)$$

n^0 is 5% heavier than p±

Fig. 7.11: Calculation of the mass of the neutron

7.11 Calculation of the neutron

The calculation of the mass for the structure of the neutron according to fig. 7.10b has still remained open.

Because in this book for the first time has been shown, how the mass can be calculated, if the particles are understood as potential vortices, we also in this case again want to make use of this possibility.
We have, like for the μ^-,a structure of three shells with the radii r_1, r_2 and r_3. At the outer radius r_3 the fields of the elementary vortices on the inside have an effect on the electron On the outside: like is the case for the μ^-

the field of the e^-: $E_{31}^{(-)} = -E_1(r_1/r_3)$,

the field of the e^+: $E_{32} = E_2\,(r_2/r_3) = E_1\,(r_2/r_3)$

and in addition the e^+: $E_{31} = E_1\,(r_1/r_3)$.

The total field is, with the radius relation equation 7.4:

$$\frac{E(r_3)}{E_1} = -\frac{r_1}{r_3} + \frac{r_2}{r_3} + \frac{r_1}{r_3} = -\frac{1}{3} + \frac{2}{3} + \frac{1}{3} = \frac{2}{3} \quad (7.12)$$

If we compare the neutron, in which now $z_e = 4$ elementary vortices are involved, with the proton:

$$\frac{r_n}{r_p} = \frac{z_{ep}}{z_{en}} \cdot \frac{E_p(r_2)}{E_n(r_3)} = \frac{3}{4} \cdot \frac{1}{2/3} = \frac{9}{8} = 1{,}125 \quad (7.13)$$

then we infer from the arithmetically determined result that the neutron according to the radius is 12,5% bigger than the proton. The mass is calculated to:

$$\frac{m_n}{m_p} = \frac{z_{en}}{z_{ep}} \cdot \left(\frac{r_p}{r_n}\right)^2 = \frac{4}{3} \cdot \left(\frac{8}{9}\right)^2 = 1{,}05 \quad (7.14)$$

The particle therefore has a mass which is 5% larger than for the proton, slightly more as has been measured for the neutron. The difference is acceptable. The particle after all is structured very asymmetrically, in which the reason is to be seen, why the uncharged particle, looked at from close up, nevertheless shows an observable charge distribution.

Decay equations if neutrinos are involved:

$$n^0 \longrightarrow p^+ + e^- + \bar{\nu}_e \qquad (7.15)$$

$$n^0 + \nu_e \longrightarrow p^+ + e^- \qquad (7.15^*)$$

$$\mu^- \longrightarrow e^- + \bar{\nu}_e + \nu_\mu \qquad (7.16)$$

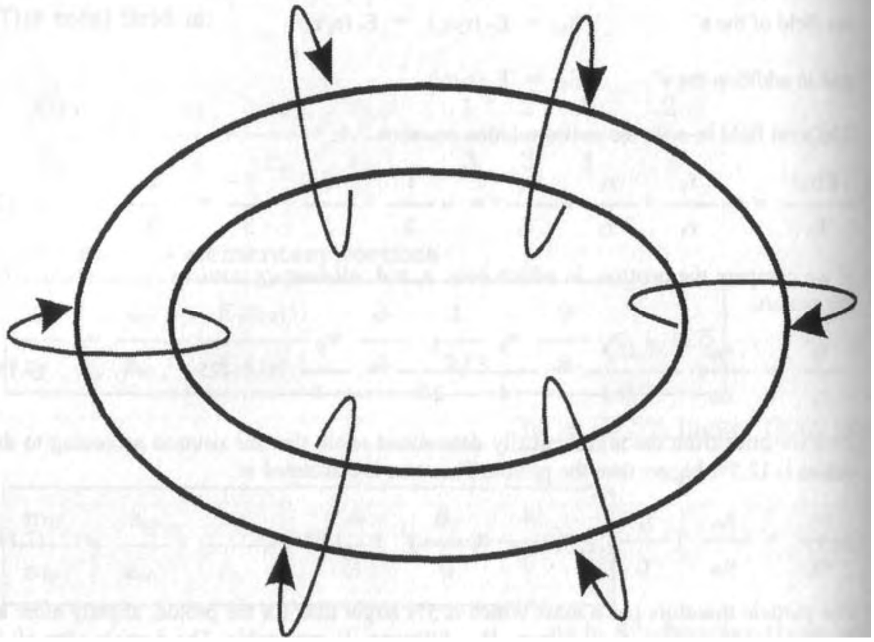

Fig. 7.12: The electron-neutrino as a ring-like vortex

7.12 ß-decay

In the case of the calculated quasistable particles, the μ^- and the n°, the verification by means of the well-known decay processes is still due. Also free neutrons, those which are not bound in an atomic nucleus, decay. But with an average life of 918 seconds they are by far the longest living among the quasistable elementary particles. Should the neutron decay be triggered by neutrinos, then obviously a distant flying past does not suffice. For that the electron is bound in the proton too tight. There probably has to occur a direct "crash", in which a neutrino is used, since the decay equation reads:

$$n^0 \longrightarrow p^+ + e^- + \overline{\nu}_e \quad (7.15)$$

As could be expected a proton p^+, an electron e^- and the mentioned electron-antineutrino ν_e are formed. What here is written down as the emission of an antiparticle, is equivalent in the absorption of the particle<i>, in this case of the neutrino. The reaction equation 7.15 can be reformulated accordingly<i>:

$$\boxed{n^0 + \nu_e \longrightarrow p^+ + e^-} \quad (7.15^*)$$

Also for the decay of the myon an electron-neutrino is used. In both cases it provides the energy necessary for the decay. But we can really understand the β-decay only, after we have got to know these particles better.

Without charge and without mass neutrinos show hardly any interactions with matter and as a consequence they possess the enormous ability of penetration - as is well-known. They are said to participate in the „weak interaction", which should trigger a conversion of the concerned particles, which is their decay. Pauli already has postulated the neutrino 1930 theoretically, because the transition from a half-integer spin to an integer spin for the n^0 -decay otherwise wouldn't have been explicable.

If we imagine an elementary vortex is being born, but the local field strength and energy isn't sufficient for obtaining a quantized state. The result is an incomplete potential vortex, which has an open vortex centre and as a consequence shows no localization at all. In the form of a vortex ring it oscillates around itself, while it continually turns its inside to the outside and then again to the inside.

One moment the vortex ring is green, then it is red again, one moment matter, then anti-matter, one moment positively charged and the next moment negatively charged. In contrast to the photon the number of the involved elementary vortices z_e for the neutrino is odd (for the ν_e z_e= 1). Perpendicular to the direction of propagation the neutrino has a spin $(s/\hbar = 1/2)$ for reason of a rotation, which overlaps the pulsating oscillation. This vortex ring is, as said, not a member of stationary matter, because it doesn't form a "black hole" in its centre, where the speed of light becomes zero. But it has an absolute stability like every elementary vortex, even if it only occurs incomplete and hence not in any quantized form,. This concept of the electron-neutrino as an open oscillating elementary vortex in the form of a ring-like vortex covers the experimentally determined realizations unexpectedly well.

<i>: Kussner, H.G.: Grundlagen einer einheitlichen Theorie der physikalischen Teilchen und Felder, Musterschmidt, Gottingen 1976, S.155

A strong interaction doesn't exist. The electric field in the proximity of the proton goes to zero within the range which is determined with measuring techniques.

A weak interaction doesn't exist. That interaction only is a special case of the electromagnetic interaction which appears in a weakened form. ______________

XII: Why does the proton have approximately 3 times the magnetic moment which can be expected for reason of the only single charge?
(3 elementary vortices)

XIII: Why does the neutron as an uncharged particle anyway have a magnetic moment?
(Structure of the n°)

XIV: What owes the atomic nucleus, which consists of like charges, its stability?
(Course of the field of the p^+, instead of "strong interaction")

XV: Why does the free neutron decay, although it is stable as a particle of the nucleus? ________
(Interaction with neutrinos)

XVI: Why do neutrinos nevertheless participate in the "weak interaction", although they have no mass and no charge? ______________________
(Oscillating charge)

XVII: How can be given reasons for the finite range ____of the "weak interaction"?
(Reaction cross-section for particle decay)

Fig. 7.13: Further key questions of quantum physics (Continuation of figures 4.4 and 6.13)

7.13 "Weak interaction"

Let's now look again at the β-decay of the neutron, in which a neutrino ν_e is used. But this by no means will be a process of the weak interaction. Instead will neutrinos, contrary to the textbook opinion, participate in the electromagnetic interaction. They after all are one moment positively charged and the next moment negatively charged. With slow-acting gauges this it is true can't be proven, because the interaction is zero on the average. But this charged oscillating vortex ring can exert a considerable effect while approaching a neutron, which is based solely on the electromagnetic interaction.

The neutron is stimulated to synchronous oscillations of its own by the high-frequency alternating field of the neutrino, until it in the case of the collision releases the bound electron, which takes up the energy provided by the neutrino and transports it away. The interaction obviously is only very weak due to the oscillation. But a physical independency of it has to be disputed.

The finite range, which is given in this context, indicates the reaction cross-section around the n°-particle, within which the "crash" and as a consequence the β-decay occurs. This range is considerable larger as the particle itself. The electromagnetic interaction for such small distances after all is so violent, even if it only occurs in pulses, that the neutrino is thrown out of its path and can fly directly towards the neutron.

Perhaps we now understand also the β-decay of the myon. It actually were to be expected that without outside disturbance an absolute stability could exist because of the ideal symmetry of the μ^-. On our planet we however are in every second bombarded with approx. 66 milliard (billion) neutrinos per cm^2 <i>. Obviously it takes 2,2 μs on the average till a neutrino ν_e flies past a myon so close that it decays. In doing so it stimulates the outside elementary vortex to violent oscillations by trying to synchronize it. In this case the electron-neutrino ν_e carries away with it the two outer, and therefore weaker bound, elementary vortices of the myon, which meanwhile are oscillating synchronously. The innermost vortex, an electron e^-, is left behind. The decay of the myon which takes place with a probability of almost 100 % reads:

$$\mu^- \longrightarrow e^- + \overline{\nu}_e + \nu_\mu \qquad \text{resp.} \qquad \mu^- + \nu_e \longrightarrow e^- + \nu_\mu \quad (7.16)$$

Thus a different neutrino ν_μ, is formed which can be distinguished from the ν_e and is called myon-neutrino since it forms from the μ^-. Actually it even has a similar structure of three shells, as is shown in fig. 7.5. But the vortex centre is open and the particle isn't stationary anymore. In the picture now only a momentarily state is shown, in which the ν_μ appears green on the outside and red in its open centre. As already for the ν_e oscillates also here the inside to the outside and vice versa, this time merely as a packet of three shells, so that also this particle shows all the typical neutrino properties discussed for the example of the ν_e.

The for potential vortices typical and already discussed phenomenon of transport here has an effect. In particular in connexion with vortex rings this property is known from hydrodynamics. It thus can be observed, how vortex rings bind matter and carry away with them. Because the neutrino is not quantized, it neither is restricted with regard to its ability to transport elementary vortices. Consequently even bigger configurations are conceivable, like configurations of 5 shells, 7 shells etc..

<i>: "Zeugen aus der Sonne", VDI-Nachrichten Nr. 45 vom 9.11.90, Seite 26

a: the structure of the tau-neutrino with 5 shells

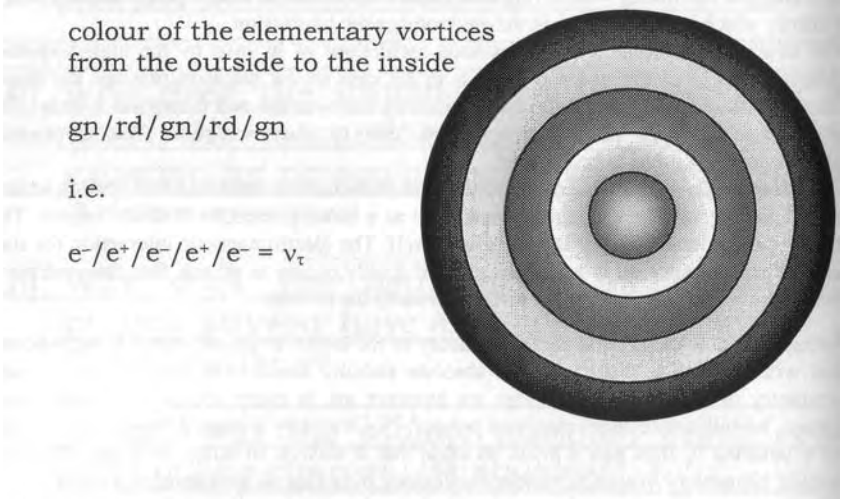
colour of the elementary vortices
from the outside to the inside
gn/rd/gn/rd/gn
i.e.
$e^-/e^+/e^-/e^+/e^- = \nu_\tau$

b: the heavy and stable variant of the tau particle

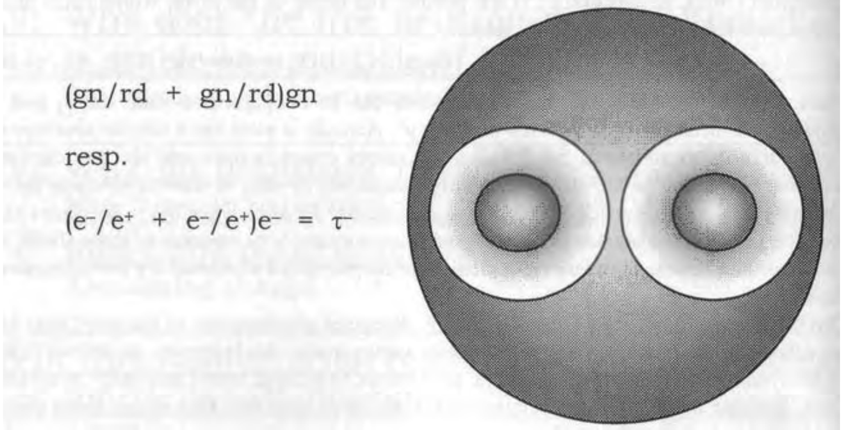
(gn/rd + gn/rd)gn
resp.
$(e^-/e^+ + e^-/e^+)e^- = \tau^-$

Fig. 7.14: Tau-neutrino and tau particle

7.14 Tau particle

In the table of the leptons after the e^- and the μ^- as the next particle the tau particle τ^- is found with its accompanying neutrino ν_τ. The obvious solution for the tau particle is the structure of five shells, as is shown in fig. 7.14a. With that the electron would have another particularly heavy relative with otherwise very similar properties.
For the myon the neutrino was stable, the particle itself however instable. We after all huve explained the particle decay as a consequence of an outside disturbance, and disturbances always are based on interactions. Correspondingly should, with the small possibility for an interaction, also the neutrino ν_τ of the tau particle have a better stability than the particle τ^- itself.
Without doubt this structure of 5 shells fulfils all known quantum properties like spin, charge etc. Merely the check of the mass is still due. This we now want to calculate for the structure shown in fig. 7.14a.

$$m_5 = m_p \cdot (\frac{Z_{e\tau}}{Z_{ep}})^3 \cdot (-\frac{r_1}{r_5} + \frac{r_2}{r_5} - \frac{r_3}{r_5} + \frac{r_4}{r_5})^2 \quad (7.17)$$

$$m_5 = 1836 \cdot (\frac{5}{3})^3 \cdot (\frac{2}{5})^2 \cdot m_e = \underline{\underline{1360 \cdot m_e}} \quad (7.17^*)$$

But the for the tau particle measured value is considerable higher!
Even if this structure is the only possible in the case of the neutrino ν_τ for reason of the complete symmetry, will the tau particle however change its structure by itself if another structure exists, which is more stable, thus in which the particle can take a bigger mass. Such a maximum provides the structure shown in fig. 7.14b after checking all possible configurations with five elementary vortices:

$$m_\tau = m_p \cdot (\frac{Z_{e\tau}}{Z_{ep}})^3 \cdot ((-\frac{r_1}{r_3} + \frac{r_2}{r_3}) \cdot 2)^2 \quad (7.18)$$

$$m_\tau = 1836 \cdot (\frac{5}{3})^3 \cdot (\frac{2}{3})^2 \cdot m_e = \underline{\underline{3778 \cdot m_e}} \quad (7.18^*)$$

This value now lies 8% above the measurement values. It would be obvious, if unbound tau particles predominantly would take the structure shown in fig. 7.14b. The remaining error becomes explicable, if a very small number of tau particles in the lighter structure according to fig. 7.14a are involved with a correspondingly smaller probability.

The enormous variety of kinds of decay, and not a single one of the dominating ones has a probability of over 50%, makes it more difficult for us, to be able to directly infer the inner structure of a particle from the decay products. It nevertheless should be mentioned that after all 35% of all decays take place by taking up and using a neutrino ν_e or ν_τ, entirely in accordance with the model of the myon decay (equation 7.16).

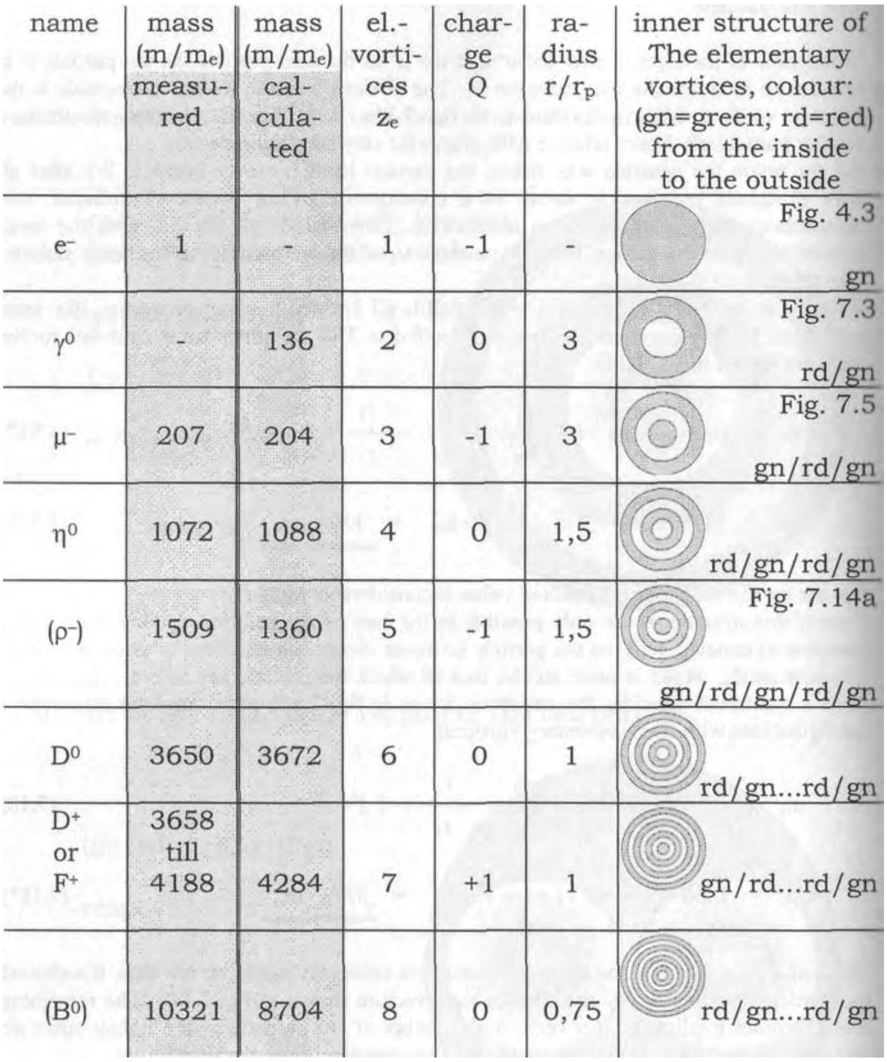

name	mass (m/m_e) measured	mass (m/m_e) calculated	el.-vortices z_e	charge Q	radius r/r_p	inner structure of The elementary vortices, colour: (gn=green; rd=red) from the inside to the outside
e⁻	1	-	1	-1	-	Fig. 4.3 gn
γ^0	-	136	2	0	3	Fig. 7.3 rd/gn
μ^-	207	204	3	-1	3	Fig. 7.5 gn/rd/gn
η^0	1072	1088	4	0	1,5	rd/gn/rd/gn
(ρ^-)	1509	1360	5	-1	1,5	Fig. 7.14a gn/rd/gn/rd/gn
D^0	3650	3672	6	0	1	rd/gn...rd/gn
D^+ or F^+	3658 till 4188	4284	7	+1	1	gn/rd...rd/gn
(B^0)	10321	8704	8	0	0,75	rd/gn...rd/gn

7.15 Table of vortices of the calculated leptons and mesons compared with measurement values (Part 1).

7.15 Pions

Unlike the leptons, which we could derive and calculate fairly completely, the mesons don't have a half-integer spin. With this characteristic property they therefore can't represent an individually overlapped elementary particle and they probably will consist of the amassing in pairs of individual configurations of potential vortices. This kind of bond can't be particularly tight. Consequently we don't know any stable mesons.

The most important basic building part of the mesons we have got to know over the positronium in fig. 7.3. It necessarily has to amass to another particle, otherwise it annihilates under emission of a γ-quanta, as already mentioned. This γ^0-particle, as it will be named here, has the mass of:

$$m_{\gamma 0} = (2/3)^3 \cdot (1/2)^2 \cdot 1836 \cdot m_e = 136 \cdot m_e \quad (7.19)$$

which only can be determined arithmetically. As a partner, to which the γ^0-particle can amass, first of all another γ^0-particle should be considered. Because both partner will rotate against one another, this new particle would not have a spin and moreover would be uncharged. The mass now would be twice as big with:

$$m_{\pi 0} = 2 \cdot m_{\gamma 0} = 272 \cdot m_e \, . \quad (7.19^*)$$

But the two γ^0-particles will come very close together and mutually feel the local, in the same direction orientated, distribution of the field, which will lead to a weakening of the field and as a consequence to a slight reduction of the mass.
With these properties it probably concerns the uncharged pion π^0. This model concept finds an excellent confirmation in the two possible kinds of decay, which can be regarded as equivalent:

$\pi^0 \longrightarrow \gamma + \gamma$ with a probability of 99%
and
$\pi^0 \longrightarrow \gamma + e^- + e^+$ with a probability of 1%

Also in the case of the charged pion $\pi^\pm$ the observable decay offers a big help, which will take place with a frequency of almost 100 %:

$$\pi^\pm \longrightarrow \mu^\pm + \nu_\mu$$

The equation doesn't state anything about the fact, if a neutrino v_e is used in the process. But it points at the circumstance that the partner of the γ^0-particle for the $\pi^\pm$ most likely is a myon $\mu^\pm$. The mass will be smaller than the sum of both building parts:

$$(204+136) * m_e = 340 * m_e.$$

name	mass (m/m_e) measured	masse (m/m_e) calculated	elem.-vortices z_e	charge Q	inner structure of The elementary vortices, colour: (gn=green; rd=red) from the inside to the outside
B^-	11194	9793 +?	9 +?	-1	$r/r_p = 0{,}75$ 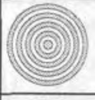 gn/rt...rt/gn
(Y^0)	18513	17001 +?	10 +?	0	$r/r_p = 0{,}6$ 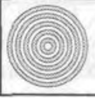 rt/gn...rt/gn

Some compound configurations

π^0	264	272	4	0	2 x fig. 7.3 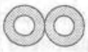 $\gamma^0 + \gamma^0 = \pi^0$
π^-	273	340	5	-1	fig. 7.3 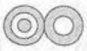 + fig. 7.5 $\mu^- + \gamma^0 = \pi^-$
τ^-	3487	3778	5	-1	fig. 7.14b 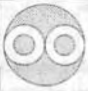 (2x gn/rd)/gn
(K^0)	974	918 +?	6 +?	0	$r/r_p = 2$ 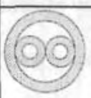 (2x rd/gn)/ rd/gn
(K^-)	967	939 +?	11 +?	-1	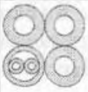 (rd/gn + gn)/ rd/gn + 3 γ^0

Fig. 7.16: Table of vortices of the calculated leptons and mesons compared with measurement values (Part 2).

7.16 Table of vortices of the mesons

The numerous kinds of decay for K-mesons suggest that these strange particles will consist of various combinations of amassed together and in pairs rotating γ^0- and $\mu^\pm$-particles. The possibilities of combination now already have increased in such a way that for every kaon and other mesons several solutions can be proposed. To avoid unfounded speculations, only a few clues will be given.

Besides the γ^0-particles also heavier arrangements should be considered as partner for the spin and as a building part for kaons and other mesons.
If for instance a π^0 is overlapped by a γ^0, then this particle has an arithmetically determined mass of 918 m_e. It therefore can concern a building part of the uncharged kaon K^0.

The likewise with three γ^0 formed configuration of 6 shells however, if it actually would staystable for the duration of a measurement, would have the mass of 3672 electron masses<i>.

A very much better detectability must be attributed to the configuration of 4 shells which consists of two γ^0, so to speak a heavy relative of the γ^0 and the π^0. It among others should be able to decay like a π^0.With this property and with an arithmetically determined mass of 1088 m_e it actually only can concern the η^0-meson. Solely according to the numeric value the η^0-meson could also consist of four π^0-mesons; but the decay in only two light quants speaks against it.

The kaon-puzzle in addition is made more difficult by the spontaneously possible ability to change of the involved γ^0-particles during a process of decay, as is made clear by the numerous kinds of decay. These dependent pion halves can be "swallowed" or "spit out" by neutrinos in the process, they can form from incident light or be emitted as photons and eventually they even can break up in their individual parts.

In fig. 7.16 the possible configurations of potential vortices are sketched and the respective, according to the new theory calculated, mass is given. If above that the other decay products and quantum properties, which can be given for the vortex structures, are added, like e.g. charge, spin and if need be magnetic moment, then an assignment without doubts to the until now only from measurements known elementary particles is possible. In order to better be able to assess the efficiency of the potential vortex theory, the measurement values are compared to the calculated values.

Some terms are put in brackets, because it can be assumed that the calculated part only concerns the dominating part, to which further γ^0 or other small configurations of vortices will amass for reason of its high mass. Correspondingly should the mass in that case be corrected slightly.

<i>: It could e.g. concern the D°-meson.

name	way of decay	mass (m/m_e) measured	mass (m/m_e) calculated	elem.-vortices z_e	charge Q	Inner structure of the baryon vortices
p^+	stable	1836	- (reference value)	3	+1	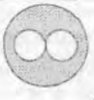 fig. 7.8 $r/r_p = 1$ $(2x\ e^+)/e^-$
n^0	$p^+ + e^- + \overline{\nu}_e$ (100%)	1839	1837	4	0	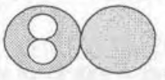 figure 7.10a $p^+ + e^-$
			1934	4	0	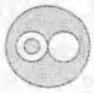 figure 7.10b n^0 $r/r_p = 1{,}13$
	$p^+ + \pi^-$ (64%)		(2176)	8	0	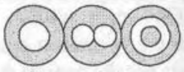 $\gamma^0 + p^+ + \mu^-$ (64%)
Λ^0		2183	2187			
	$n^0 + \pi^0$ (36%)		(2206)	8	0	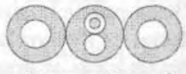 $\gamma^0 + n^0 + \gamma^0$ (36%)
	$p^+ + \pi^0$ (51%)		(2108+?)	7 + ?	+1	$\gamma^0 + p^+ + \gamma^0$ (+?) (51%)
Σ^+		2328	2142+?			
	$n^0 + \pi^+$ (49%)		2177	9	+1	$\gamma^0 + e^+ + p^- + \mu^0$ (49%)
Σ^-	$p^+ + \pi^-$ (100%)	2343	2274	9	-1	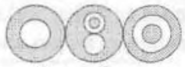 $\gamma^0 + n^0 + \mu^-$ (100%)

Fig. 7.17: Table of vortices used for the calculation of the most important barvons with suggestions for the structure (Part 3).

7.17 Table of vortices of the baryons

The number of possibilities of combination quickly increases, if only a few elementary vortices extend the structure of a particle. This probably is the reason for the large number of observable hyperons, which recently have been produced artificially and observed with the help of particle accelerators.

Both the neutron and the lambda particle can exist in a lighter and a heavier variant. At the moment of the decay, as it for instance is observed in a bubble chamber, according to expectation the state with the smaller mass takes the bigger probability. But in the amassing with further particles as building part of bigger and heavier hyperons the heavier structure is more likely. This circumstance should be considered in calculating the mass of the hyperons.

In figures 7.17 and 7.18 the most important baryons are listed, which are characterised in the way that one of the amassed together packets of vortices is a nucleon, thus a proton or a neutron.

The given, from measurements known, kinds of decay are able to confirm the inner structure pretty good. Of course an infinitely lot of combinations are conceivable and numerous predictions are possible. But speculations are unnecessary from the time on where we are able to calculate the particles!
The restriction to the few in the table listed particles seeming to be important hence doesn't limit the universal importance of the theory of objectivity in any way!

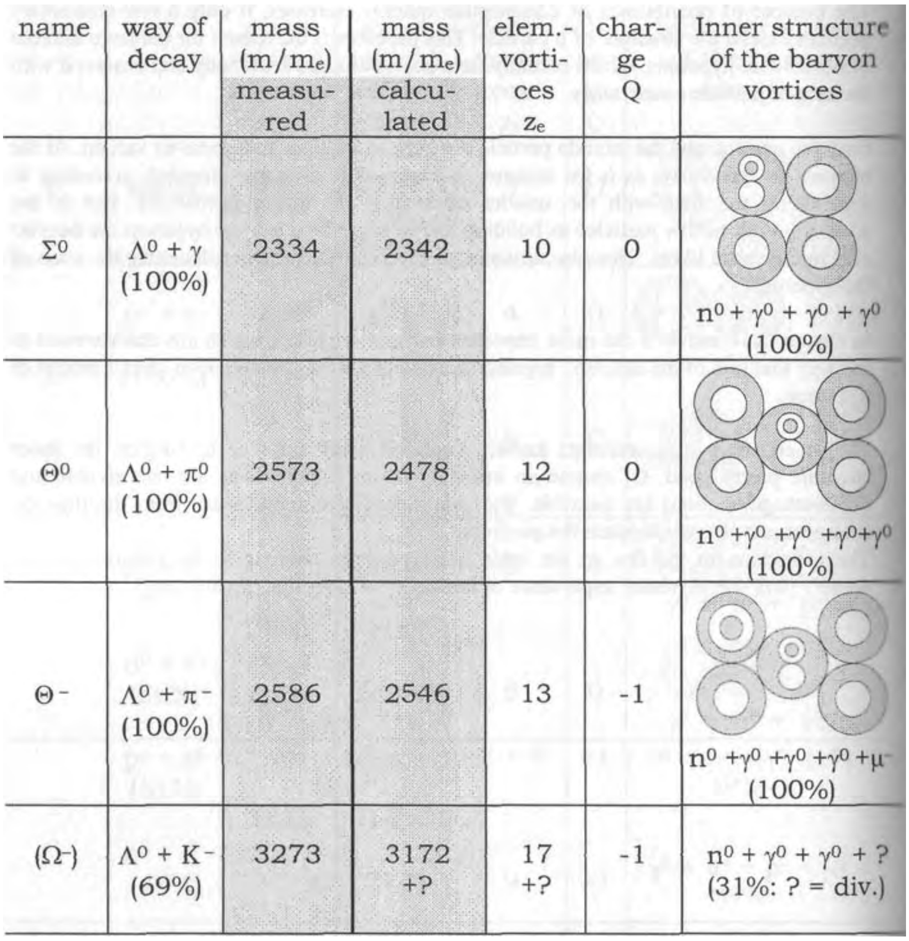

name	way of decay	mass (m/m$_e$) measu-red	mass (m/m$_e$) calcu-lated	elem.-vorti-ces z_e	char-ge Q	Inner structure of the baryon vortices
Σ^0	$\Lambda^0 + \gamma$ (100%)	2334	2342	10	0	$n^0 + \gamma^0 + \gamma^0 + \gamma^0$ (100%)
Θ^0	$\Lambda^0 + \pi^0$ (100%)	2573	2478	12	0	$n^0 + \gamma^0 + \gamma^0 + \gamma^0 + \gamma^0$ (100%)
Θ^-	$\Lambda^0 + \pi^-$ (100%)	2586	2546	13	-1	$n^0 + \gamma^0 + \gamma^0 + \gamma^0 + \mu^-$ (100%)
(Ω^-)	$\Lambda^0 + K^-$ (69%)	3273	3172 +?	17 +?	-1	$n^0 + \gamma^0 + \gamma^0$ + ? (31%: ? = div.)

Fig. 7.18: Table of vortices used for the calculation of the most important baryons with suggestions for the structure (Part 4).

8. Unified theory

With the theory of objectivity the longed for goal of a "theory of everything" (TOE), of an universal theory, seems to have moved within reach. If in the nineteenth century still promising field theories and approaches were being discussed, then has at the latest Einstein's theory of relativity destroyed all hopes in such a theory. Science as a consequence has become very much more modest and understands a TOE only as the unification of all known interactions.

Einstein has stated the minimum demand so: "a theory should be favoured by far, in which the gravitational field and the electromagnetic field together would appear as a whole" <i>. It is evident that a subjective or relativistic observer theory never is able to achieve this.

The presented theory of objectivity made it possible that the unification here for the first time actually has succeeded. This undoubtedly brings science a whole lot further, but it still is not sufficient to lie one's hands in one's lap being content with oneself. After all we still know very much more phenomena, which likewise should be unified. After all it is no accident that both Maxwell and Einstein, to name only two prominent representatives, after completion of their well-known works have struggled for the question, what sort of phenomenon it concerns in the case of the temperature and how this could be integrated in their theory.

The requirement reads: We must be able to derive all basic factors, which influence our system of units with their basic units, as a compulsionless result from the new theory. Besides the dimensions of space and time which determine our continuum, the explanation and unification of the basic factors mass and charge has to be tackled. If we have succeeded in doing so, we'll also tackle the problem of the fifth and last basic factor, which until now has put itself in the way of any unified theory as the question of fate, the problem of the temperature!

<i>: Einstein, A.: Grundziige der Relativitatstheorie, Vieweg+Sohn, Braunschweig 1973, 5. Aufl., WTB 58. Seite 97.

"A theory should be favoured by far, in which the gravitational field and the electromagnetic field together would appear as a whole"<i>.

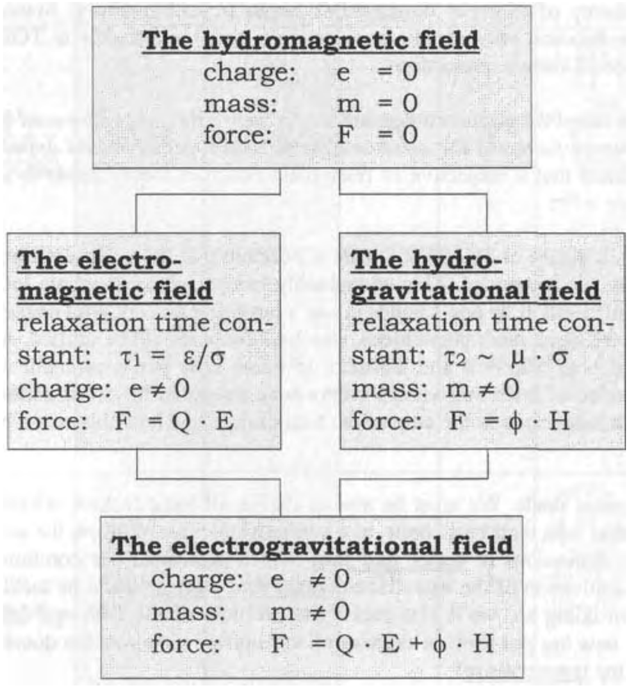
The hydromagnetic field
charge: e = 0
mass: m = 0
force: F = 0
The electro-magnetic field
relaxation time con-stant: τ1 = ε/σ
charge: e ≠ 0
force: F = Q · E
The hydro-gravitational field
relaxation time con-stant: τ2 ~ μ · σ
mass: m ≠ 0
force: F = ϕ · H
The electrogravitational field
charge: e ≠ 0
mass: m ≠ 0
force: F = Q · E + ϕ · H

Fig. 8.1: Structuring of the fields and definition of terms

<i>: Einstein, A. : Grundziige der Relativitatstheorie, Vieweg + Sohn, Braunschweig 1973, 5. Aufl. , WTB 58.

<ii>: derived from the Greek hydro (= water).

8.1 Structure of the field theory

In contrast to Maxwell's theory the new field theory, which we derived from duality, is also able to describe fields, in which no particles and no quanta exist. It probably is justified and useful in the sense of a clearer communication, to give the new field a name of its own.
The author recommends the introduction of the term "hydrotic field". In it should be expressed, which importance water has for both the like named potential vortex and this field<ii>.
As we already have worked out, the hydrotic field is favoured particularly by polar materials and by a high dielectricity. Water is a corresponding and in the biosphere of our planet dominating material.

Whereas we had to correct the concept of a vortex free electric field, we had until now, considerable, we can take over the description of the magnetic field unchanged. This then should also be valid for its name. The new field which consists of both correspondingly is called hydromagnetic field.

In fig. 8.1 we recognize the structure. At the top stands the "hydromagnetic field", which is described mathematically by the equations of dual electrodynamics in fig. 3.3. It does not know quanta and as logical consequence neither charge nor mass! If we insert these equations, Ampere's law and the dual formulated Faraday law of induction, into each other, then there results as a mathematical description of our space-time-continuum the fundamental field equation (5.7, fig. 5.1). As a new physical phenomenon the potential vortex appears, which gives the hydromagnetic field a new and important property: this field can be quantized!

Starting-point is the wave, which for corresponding interference effects can spontaneously roll up to a vortex, which as highly concentrated spherical vortex finds a new right to exist and finds to a new physical reality.

The in the described manner formed particles show specific properties of their own. We now are able to attribute them for instance a charge or a mass. And these properties also can be investigated and described individually and isolated from each other. Thus are formed the two special cases, strange by nature, on the one hand the well-known, with the help of the Maxwell equations describable "electromagnetic field" and on the other hand the new "hydrogravitational field".

If we overlap the results of the two special cases, e.g. by adding the force effects of electric charges and accelerated masses, then we summarized obtain a field, which we accordingly should call "electrogravitational". This case is not at all unknown. Already Niels Bohr in this way has calculated the radii of the electron orbits in the hull of his model of the atom, to mention only one example. We can summarize:

The hydromagnetic field is the all encompassing and with that most important field. Apart from that the electromagnetic field of the currents and the eddy currents and the hydro-gravitational field of the potentials and the potential vortices merely describe the two possible and important special cases. For reasons of pure usefulness for every special case a characteristic factor of description is introduced, the charge and the mass!

Auxiliary terms (description of quantum properties):
* mass * charge * temperature * Planck's quantum of action

The hydromagnetic field does not know any quanta!

Structure of the fundamental field equation 5.7 (fig. 5.1):

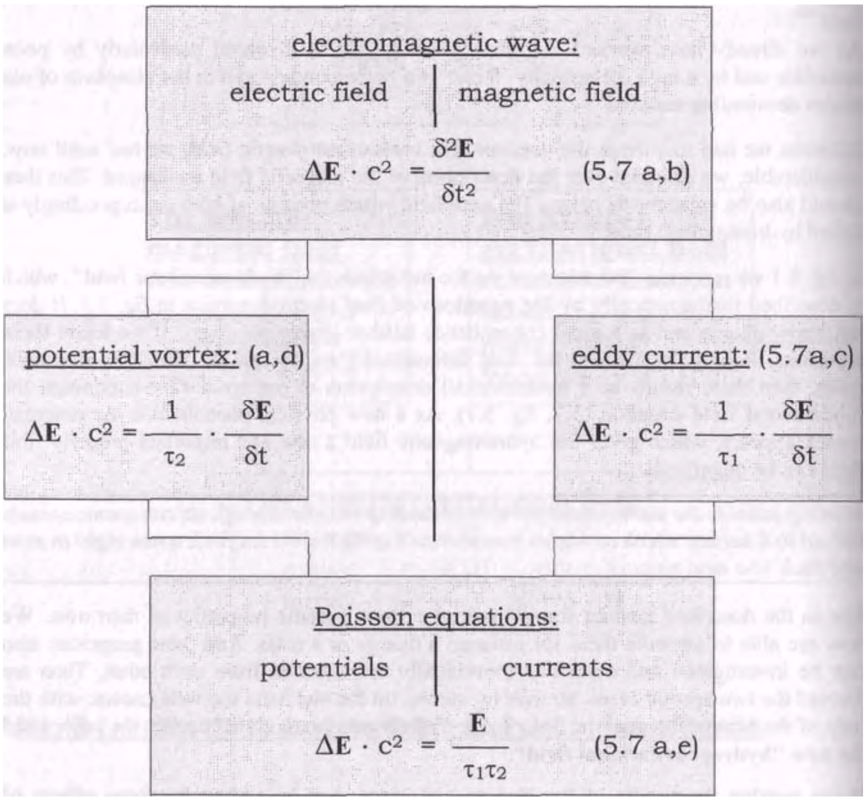
electromagnetic wave:
electric field
magnetic field
$\Delta\mathbf{E} \cdot c^2 = \frac{\delta^2\mathbf{E}}{\delta t^2}$ (5.7 a,b)
potential vortex: (a,d)
$\Delta\mathbf{E} \cdot c^2 = \frac{1}{\tau_2} \cdot \frac{\delta\mathbf{E}}{\delta t}$
eddy current: (5.7a,c)
$\Delta\mathbf{E} \cdot c^2 = \frac{1}{\tau_1} \cdot \frac{\delta\mathbf{E}}{\delta t}$
Poisson equations:
potentials
currents
$\Delta\mathbf{E} \cdot c^2 = \frac{\mathbf{E}}{\tau_1\tau_2}$ (5.7 a,e)

Fig. 8.2: Unified theory

*electromagnetic interaction (open field lines)
*gravitation (closed field lines)
*strong interaction (does not exist)
*weak interaction (only special aspect)

The interactions are a result of the
field dependent speed of light!

8.2 Unification of the interactions

The discovery and introduction of the hydromagnetic field makes the desired unification possible, because the electromagnetic resp. Maxwell field, which describes the electromagnetic interaction, and the hydrogravitational field of the gravitation can be derived from this field as a consequence of the formation of quanta.
The kind of the interaction is caused by the course of the field lines of the field quanta which form as spherical vortices: the open field lines make the electromagnetic interaction possible. And the field, lines with a closed course lead to gravitation. Both are a direct result of the field dependent speed of light. A more perfect unification seems hardly possible.

As the next step the unification with the strong and the weak interaction is required, but it could be shown that those don't exist at all. It just concerns misinterpretations with much fantasy, which should help explain the difference between a wrong theory and the physical reality.

Numerous auxiliary terms for the description of the quantum properties exist, like for instance mass, charge or Planck's quantum of action. The prerequisite for their usability naturally is the existence of the quanta. But until these have found to a physical reality, the auxiliary terms are unnecessary. The hydromagnetic field does not know quanta, quantum properties or auxiliary descriptions. It will be shown that, according to expectation, also the temperature is a typical quantum property, which comes within the group of the auxiliary terms. In this way also the temperature is fitted into the unified theory without compulsion.

Without the by us for reasons of usefulness introduced auxiliary terms the fundamental field equation is left with its description of a spatial-temporal principle. If a world equation should exist, then this field equation 5.7 has the best prerequisites. For the fundamental field equation the division in four parts is repeated like already for the hydromagnetic field (fig. 8.1). It likewise consists of four individual parts, the wave (b), the two vortex phenomena (c and d) and the time independent term (e) (fig. 8.2). Whereas the duality still is combined in the wave, it comes to light clearly for the vortices to again be combined in the fourth case. Here arise however potentials and currents, which again can react and oscillate with each other, for instance as L-C-resonant circuit in an electronic circuit, with which the principle is repeated.
This principle is shown clearer for the phenomenon of the temperature as in all other cases. If we start at the top in the picture in fig. 8.2 we have an electromagnetic wave, which is absorbed and thus becomes a vortex. If the vortex falls apart, then eddy losses are formed. We observe that the temperature rises and propagates in the well-known manner. We have arrived in the bottom box, but this again can be taken as the top box for the now following process, because the equation of heat conduction is a vortex equation of type c or d! We discover a self-similarity:

The spatial-temporal principle formulated mathematically by the fundamental field equation can be carried over into itself time and again.

Temperature is the oscillation of contraction of the elementary vortices resulting from the speed of light depending on field strength.

a. at absolute zero temperature:

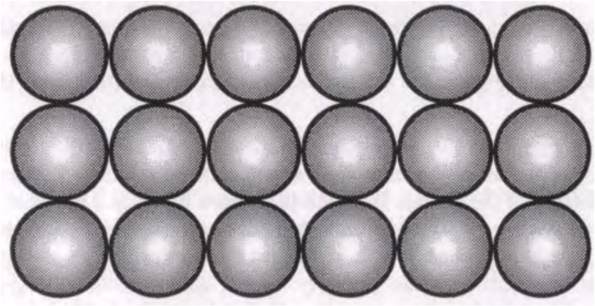

b. if thermally excited:

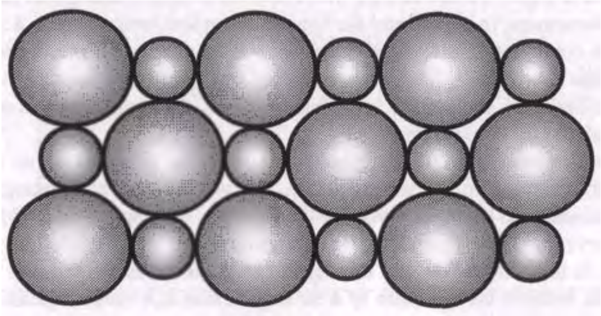

Fig. 8.3: Temperature as an oscillation of size for the speed of light depending on field strength

8.3 Temperature

Following the atomic view, in the case of heat it concerns kinetic energy of the molecules, which carry out more or less violent oscillations. In the case of gaseous materials with this concept, basing on mechanical models, actually successful calculations are possible, like for instance the speed distribution of gases won by Maxwell from theoretical considerations concerning probability.

But the attempt to apply the formulas of the kinetic theory of gases to solids and liquids only succeeds, if additional supplements and improvements are introduced. Since at all events it concerns temperature, thus the same physical quantity, of course also an uniform interpretation should be demanded, which in addition should stand in full accord to the presented design of an integrated theory (TOE).

Against the background of the new theory of objectivity we consider, what happens, if for instance the local field strength is increased by a flying past particle. The matter located at this point is contracted for a short time. By coming closer to each other, the individual elementary vortices mutually reinforce their field and are further compressed. Sometime this process comes to a standstill, is reversed and swings back.

At the same time every single particle, which in this way carries out an oscillation of size, has an effect on its neighbours with its field, to also stimulate these to the same oscillation, but delayed by some time. This phenomenon spreads in all directions. The propagation only will become stationary, if all neighbouring elementary vortices pulsate with the same amplitude. It now should be recorded:

The oscillation of contraction of the elementary vortices we call temperature.

Also this thermodynamic state variable therefore is a result of the variable speed of light. At the absolute zero of temperature no oscillation takes place anymore, whereas the upper limit lies in infinity. Since the cause for temperature represents an oscillation of the local electromagnetic field strength around the cosmic field strength, the following phenomena must be considered as excitation and cause, as dictated by the fundamental field equation 5.7:

1. Electromagnetic waves (b) are able to stimulate matter particles to synchronous oscillations of contraction by their alternating field. In doing so energy in form of heat is transferred to the particles, with the result that their temperature is increased. The wave is absorbed completely, if the thermal oscillation corresponds with the frequency of the wave.

We speak of thermal radiation.

2. But also the two dual vortices, the eddy current (c) and the potential vortex (d) can cause oscillations of contraction. This immediately becomes clear, if we consider a vortex as the special case of the wave, in which the oscillation takes place around a more or less stationary vortex centre. In the case of the decay of vortices, of the transition of energy from vortices to matter, the increase in temperature is measurable.

In the case of this process of diffusion we speak of eddy losses and of loss heat.

Answers to open questions of thermodynamics:

1. Temperature occurs independent of the state in which the matter is (unified theory).

2. Temperature even occurs in solids, where a purely kinetic interpretation fails (unification).

3. Each elementary particle is carrier of a temperature.

4. Expansion with increasing temperature because of the increasing need for room for larger amplitude of oscillation (principle: bi-metal-thermometer).

5. For solids the thermal oscillation of size is primarily passed on by the electrons in the atomic hull. Good electric conductors therefore at the same time also have a high thermal conductivity. (principle: electrical resistance thermometer).

6. For gases the entire atoms carry out this task, for which reason a kinetic auxiliary description becomes applicable.

7. For extreme amplitudes of oscillation the atoms partly or entirely lose their enveloping electrons, when they change into the plasma state.

8. The second law of thermodynamics loses its claim to be absolute and at best reads: with today's technology we are not capable, to design a cyclic working machine, which does nothing else, as to withdraw heat from a heat container and to convert it into mechanical work.

Fig. 8.4: Questions concerning thermodynamics

3. Flying past particles, in particular unbound and free movable charge carriers (e) produce an alternating field for other fixed particles. Doing so kinetic energy can be transformed in temperature, thus in energy of pulsation. A good example is the inelastic collision. But it can also be pointed to numerous chemical reactions. Whoever searches for a concrete example, takes two objects in his hands and rubs them against one another. In that case the particles which are at the frictional surfaces are being moved past each other in very small distance, in this way causing oscillations of pulsation, which propagate into the inside of the objects according to the thermal conductivity. We speak of friction heat.

This model concept provides sound explanations for a whole number of open questions (fig. 8.4), i.e. why the temperature occurs independent of the state (1) and even in solids, where a purely kinetic interpretation fails (2). Every single elementary particle after all is carrier of a temperature (3).
With increasing temperature most materials expand, because the need for room, purely geometrically seen, increases for larger amplitude of oscillation (4). This principle is used in the case of a bi-metal thermometer.
In the case of solids the thermal oscillation of size is passed on primarily by the electrons in the atomic hull (5). Good electric conductors therefore at the same time also have a high thermal conductivity. An example of an application is the electric resistance thermometer.
In the case of gases the entire atoms carry out this task, for which reason a kinetic theory becomes applicable as an auxiliary description (6).
For extreme amplitudes of oscillation the atoms partly or entirely lose their enveloping electrons, when they change into the plasma state (7).
Finally the model concept even limits the second law of thermodynamics, which contains the postulate that it is impossible to design a cyclic working machine, which does nothing else, as to withdraw heat from a heat container and to convert it into mechanical work (8).

8.4 Heat energy

The discussed oscillation of contraction shows two characteristic properties, which must be looked at separately: the amplitude and the frequency.

Temperature describes solely the amplitude of the oscillation of size.

The heat energy however is determined by both,
by the amplitude as well as by the frequency.

Consequently the ideas of temperature and heat energy should be kept strictly apart. It therefore isn't allowed to set this oscillation equal to the electromagnetic wave in tables of frequency.
To be correct two tables should be given, one for the wave, characterized by a propagation with the speed of light, and another one for oscillations of contraction, thus for stationary phenomena and phenomena bound to matter. The latter indeed can likewise propagate relatively fast by fluctuations of pressure in the case of acoustical sound frequencies or by free movable charge carriers in the case of heat conduction, but the velocity of propagation for sound or heat is as is well-known still considerably smaller than the speed of light. Thus an assignment without doubts can be made as to which kind of oscillation it concerns.

***Temperature** describes the amplitude of the oscillation of size of all spherical vortices.*

*The **heat energy** however is determined by both, the amplitude and the frequency.*

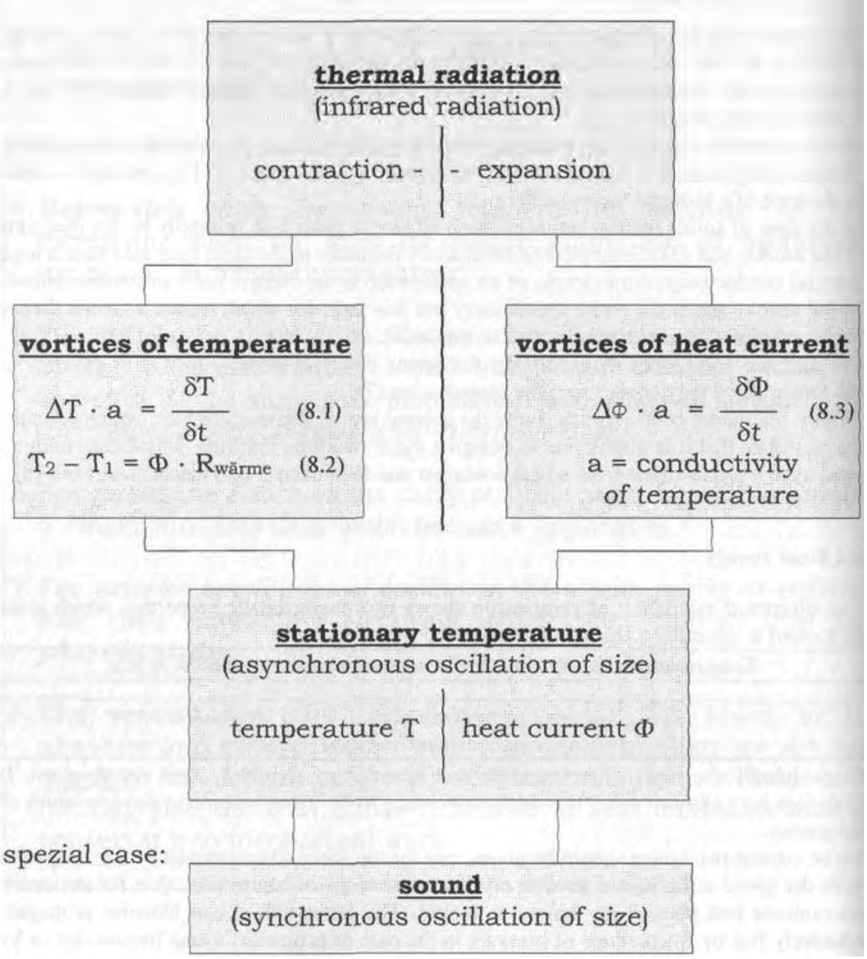
thermal radiation
(infrared radiation)
contraction -
- expansion
vortices of temperature
$\Delta T \cdot a = \frac{\delta T}{\delta t}$ (8.1)
$T_2 - T_1 = \Phi \cdot R_{wärme}$ (8.2)
vortices of heat current
$\Delta\Phi \cdot a = \frac{\delta\Phi}{\delta t}$ (8.3)
a = conductivity of temperature
stationary temperature
(asynchronous oscillation of size)
temperature T
heat current Φ
spezial case:
sound
(synchronous oscillation of size)

Fig. 8.5: Heat conduction resp. sound

8.5 Sound

The close relationship of longitudinal sound waves with the oscillations of contraction of thermally heated matter becomes particularly clear for ultrasound, where the arising heat in the inside of the body which is exposed to sound can be measured directly. The fundamental difference consists of the fact that the produced sound waves not only have the same frequency, but also the same phase, what needs not be the case for the temperature. The apparently uncoordinated occurring oscillations of size of the temperature, which as a rule occupy more space if the intensity increases, form a "thermal noise".

The oscillation of size with the same phase is not realizable at all in a spatial formation of particles, with one exception, the case that all particles expand and afterwards again contract simultaneously and in the same time. We can observe such a synchronization of the pulsation oscillations of all elementary vortices in the case of a pulsar. For us a pulsar looks like a "lighthouse" in space which shines with a fixed frequency. In reality it as well can concern a constantly shining sun, which carries out a synchronized, thermal oscillation of size, like a gigantic low-frequency loudspeaker. During the phase of contraction of the star its emitted light stays back. To us the pulsar looks dark. In addition the field strength is extremely increased and the light becomes correspondingly slow. During the phase of expansion the conditions are reversed and we observe a light flash. Exactly the pulsar unambiguously confirms the here presented theory of the variable, field dependent speed of light.

The well-known fact that the microcosm represents a copy of the macrocosm, already suggests that each atom is capable of the same oscillation of size as a pulsar: if next to the oscillating atom a resting one is placed, then does this one see a smaller field during the phase of contraction because of the increasing distance. It hence becomes bigger itself. If the pulsating neighbouring atom afterwards expands, it however becomes smaller. The at first resting atom in this way becomes a "pulsar" oscillating with opposite phase. The oscillating atom has stimulated the neighbouring atom as well to an oscillation of size, and this process will be repeated with the closest neighbouring atom. We speak of heat conduction.

To which extent the average distance between neighbouring atoms is influenced while a material is heated, solely depends on the structure of the atomic lattice. For matter with a fixed lattice according to expectation a smaller heat expansion will occur, as for the unordered structure of gases, in which we find confirmed well-known relations.

In a for potential vortices characteristic property sound waves and thermal waves of contraction correspond:

The propagation of potential vortex fields takes place as a longitudinal wave.

In this point vortex fields clearly differ from the transverse propagating electromagnetic waves!

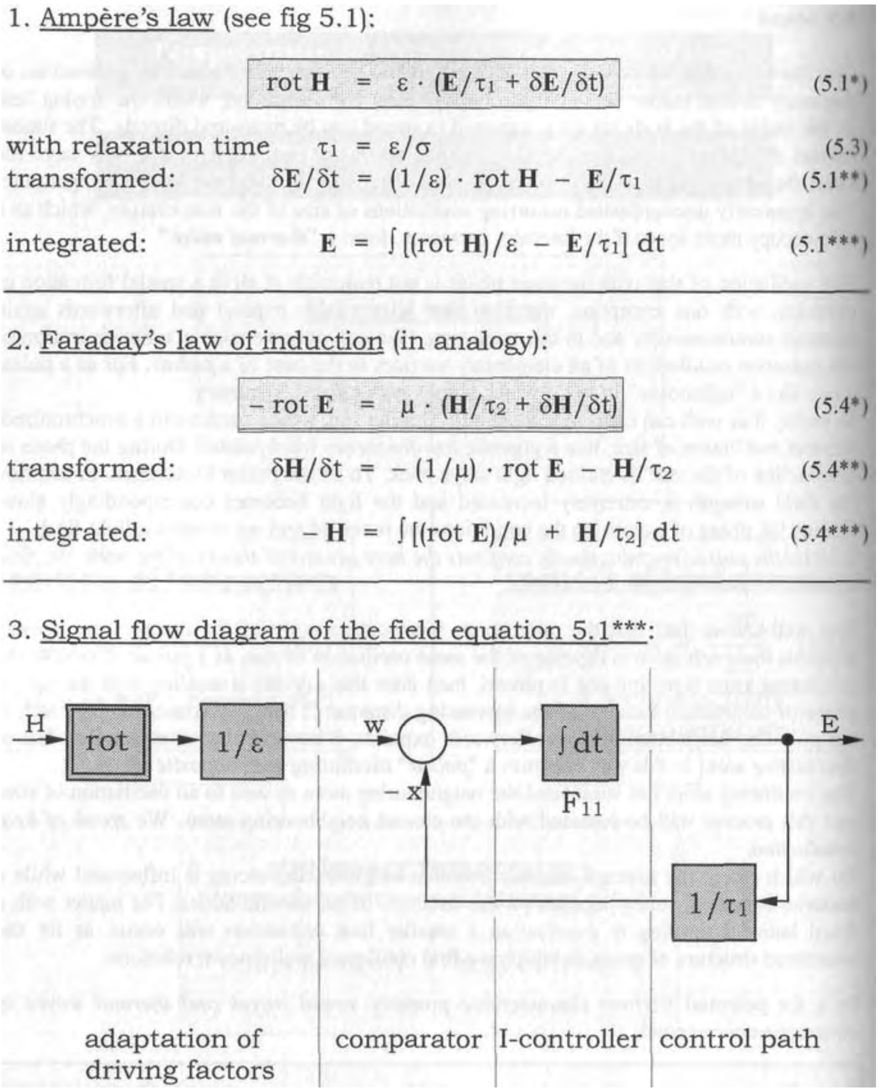

1. Ampère's law (see fig 5.1):

$$\boxed{\text{rot}\,\mathbf{H} = \varepsilon \cdot (\mathbf{E}/\tau_1 + \delta\mathbf{E}/\delta t)} \qquad (5.1^*)$$

with relaxation time $\tau_1 = \varepsilon/\sigma$ (5.3)

transformed: $\delta\mathbf{E}/\delta t = (1/\varepsilon) \cdot \text{rot}\,\mathbf{H} - \mathbf{E}/\tau_1$ (5.1**)

integrated: $\mathbf{E} = \int [(\text{rot}\,\mathbf{H})/\varepsilon - \mathbf{E}/\tau_1]\, dt$ (5.1***)

2. Faraday's law of induction (in analogy):

$$\boxed{-\,\text{rot}\,\mathbf{E} = \mu \cdot (\mathbf{H}/\tau_2 + \delta\mathbf{H}/\delta t)} \qquad (5.4^*)$$

transformed: $\delta\mathbf{H}/\delta t = -(1/\mu) \cdot \text{rot}\,\mathbf{E} - \mathbf{H}/\tau_2$ (5.4**)

integrated: $-\,\mathbf{H} = \int [(\text{rot}\,\mathbf{E})/\mu + \mathbf{H}/\tau_2]\, dt$ (5.4***)

3. Signal flow diagram of the field equation 5.1***:

H
rot
1/ε
w
x
∫dt
F11
E
1/τ1
adaptation of driving factors
comparator
I-controller
control path

Fig. 8.6: Control technical analysis of the dual equations of the hydromagnetic field.

8.6 Basic principle of cybernetics

Surely can be attributed also information to the potential vortex. But how should information be formed? Is information a form of energy? Energy occurs as a consequence of the formation of potential vortices. Without this phenomenon there wouldn't be any energy!

Can information be described by means of a mathematical equation?

To be able to answer these questions, we subject the fundamental field equation to a control technical analysis. If it actually concerns a world equation, then an answers should be possible.

We again take up Ampere's law 5.1* from fig. 5.1 and remodel it according to the time derivative (5.1**). If the equation now is integrated over the time (5.1***), a signal flow diagram can be drawn (fig. 8.6).

The structure of a regulatory circuit is clearly visible. The individual paragraphs are described in an analogous way as for a technical control system. The execution of the curl operation on the field pointer of the magnetic field strength H and the multiplication with $1/\varepsilon$ accordingly form an adaptation of driving factors. In the comparator the difference for control from driving factor w and controlling factor x is formed and supplied to an integral controller. The control path has a purely proportional behaviour and consists of the processing of the measurement value of the electric field strength E with $1/\tau_1$, in which τ_1 describes the relaxation time of the eddy currents.

In technical control systems such a structure is found remarkably seldom, although it has an invaluable advantage: it possesses a stability in principle. Not a single adjustment of the controller exists, in which the closed regulatory circuit could become unstable, because it shows a proportionally delaying behaviour of first order. Possible changes of the adjustment of the controller or of the control path merely take effect on the speed, with which the regulatory circuit is able to follow changes of the driving factor.

This control technical basic principle convinces by its simplicity and efficiency. It meets us again in identical form in the second field equation 5.4*, the extended Faraday's law of induction. In dual formulation the electric field strength now appears as input factor and the magnetic field strength as output factor. Both regulatory circuits are coupled and connected with each other, by deriving their driving factor each time from the controlling factor of their dual partner. Is this structure actually efficient and meaningful?

Every regulatory circuit needs a target value, which is dictated from the outside. Let us think of the numerous control systems in nature. At all events a higher intelligence would be necessary for all the target values. This problematic is comparable to the question, what existed first: the egg from which a hen hatches or the hen without which no eggs can exist. Without a given target, evolution would not exist.

The connected regulatory circuit structure provides the matching answer: cybernetic systems, which usually and as is well-known strive to a state of balance, get their target value from their dual "partner". It is crucial that correspondingly dual systems are self-sufficient and can form and develop independently out of themselves without target values of a third side. This basic principle of cybernetics undoubtedly is brilliant.

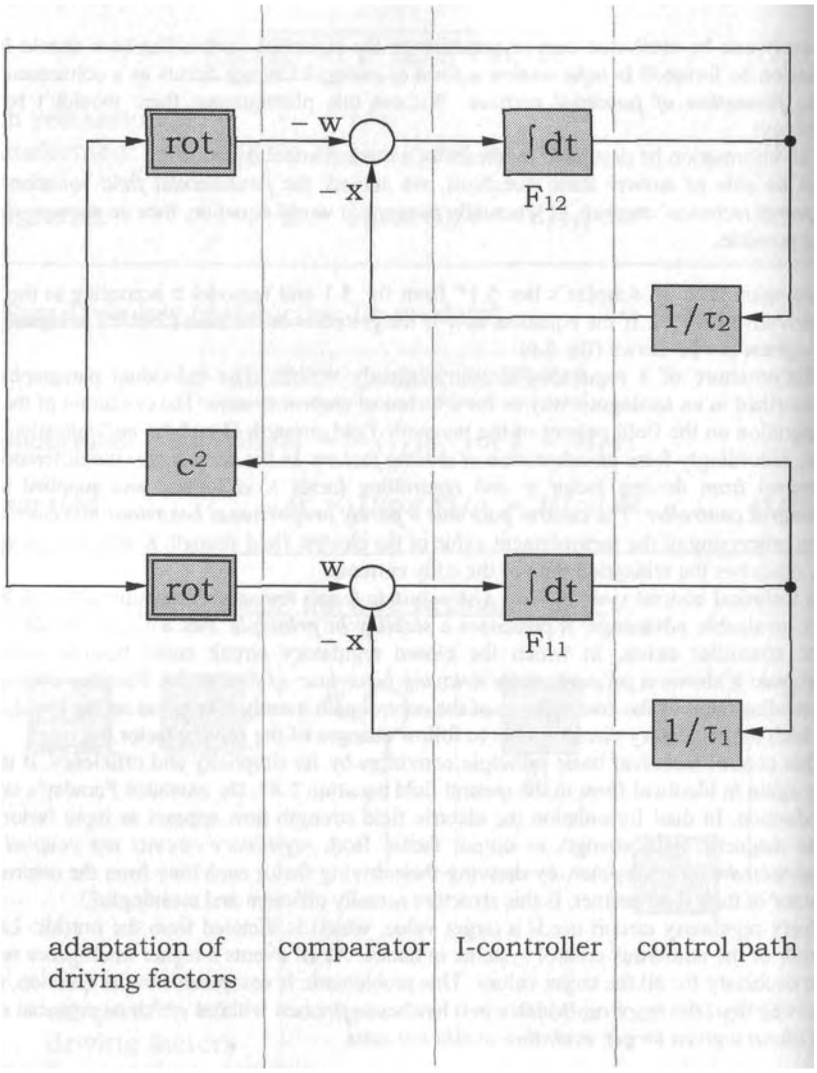
rot
– w
∫dt
– x
F12
1/τ2
c2
rot
w
∫dt
– x
F11
1/τ1
adaptation of driving factors
comparator
I-controller
control path

Fig. 8.7: Signal flow diagram of the fundamental field equation
with adaptive structure.

8.7 Adaptive regulatory circuit structure

If out of the nowhere something like the cosmos or like life on earth should form, then the connected regulatory circuit structure basing on duality probably is the only possible and conceivable. Thus it merely concerns the control technical representation of the fundamental field equation.

The question for the efficiency not only concerns the stability, but equally the possibility of both systems, to oscillate and to communicate with each other by the coupling and the associated exchange of information.

Fig. 8.7 shows the signal flow diagram of both regulatory circuits. These are switched in line and form a coupled circuit, which itself can be interpreted as a third regulatory circuit. Also this one shows a change of sign in the circuit like the other two circuits.

The information technical interpretation could turn out as follows: information about a regulatory process in the lower regulatory circuit F_{11} caused for instance by a disturbance is communicated over the coupled circuit to the upper regulatory circuit F_{J2}. In this case F_{11} acts as transmitter and F_{12} as receiver of the information. Afterwards both exchange their places, because F_{12} for its part reacts by a regulatory process and reports to F_{11}. The regulatory circuits adapt to each other. Obviously it concerns the basic structure of an adaptive regulatory circuit.

To analyse the coupled circuit the examination of individual special cases is recommended. If the regulatory circuits F_{11} and F_{12} are opened up in the way that the time constants tau$_1$ and tau$_2$ go towards infinity, then the double integral effect is left. Analyses of technical regulatory circuit teach us that such systems always tend to instability. Because in addition the target value is zero, an oscillation around zero will arise, which we call electromagnetic wave.
If one of both time constants becomes finite, e.g. τ_2, then damping of the waves will occur. The "subordinate" cascade regulatory circuit F_{12} will adjust itself and now has a proportional delaying behaviour of first order. Together with the integral controller of the open F_{11}- circuit the coupled circuit will show the typical and more or less optimal regulatory behaviour of a damped oscillation.

These special cases correspond with the mathematical (fig. 5.2) and the physical (fig. 5.3) interpretation of the fundamental field equation. In addition a spatial rotation, a swirling will occur because of the double execution of the curl operation.

If interpreted control technically then vortices are the temporally stable, spatial swing of a field pointer around a centre, the vortex centre.

Without potential vortices no stability, no matter, no energy nor information would exist!

As can be looked up in Goethe's Faust, it always has been a desire of humanity, to find out, "what keeps the world together in the heart of hearts".

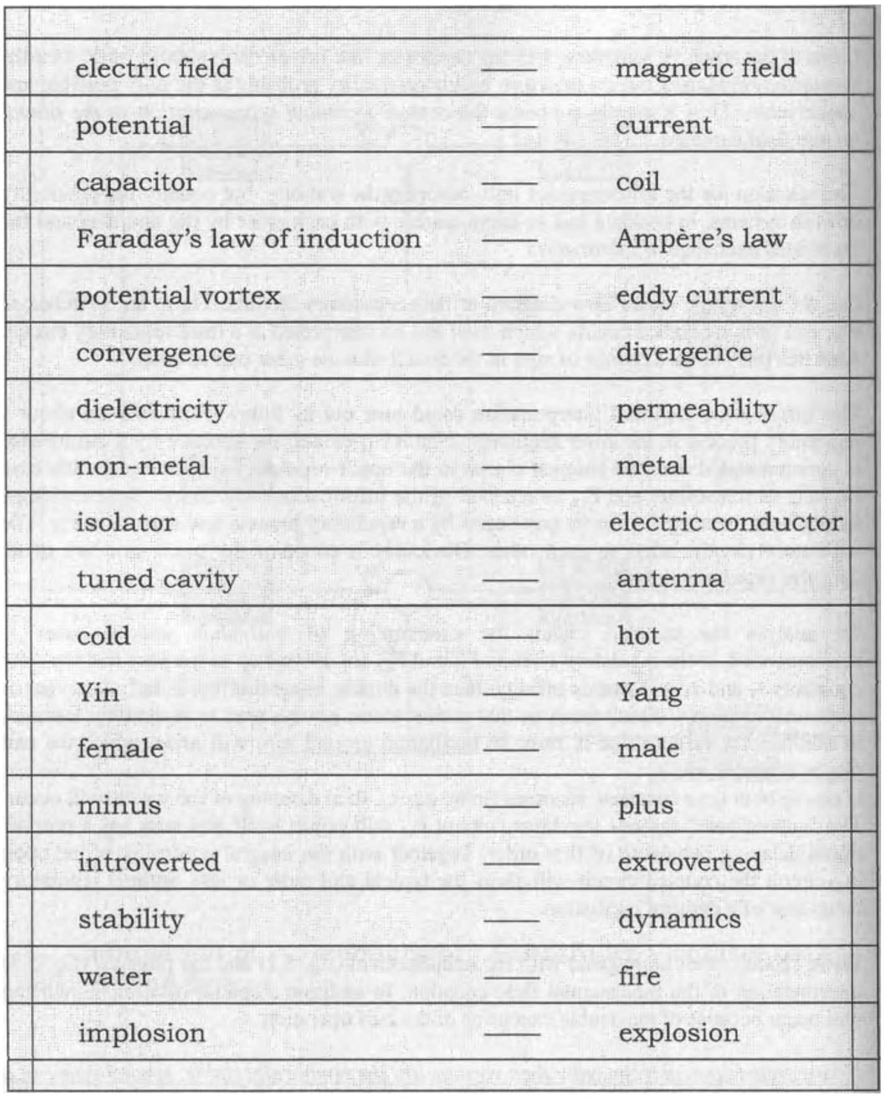

electric field	—	magnetic field
potential	—	current
capacitor	—	coil
Faraday's law of induction	—	Ampère's law
potential vortex	—	eddy current
convergence	—	divergence
dielectricity	—	permeability
non-metal	—	metal
isolator	—	electric conductor
tuned cavity	—	antenna
cold	—	hot
Yin	—	Yang
female	—	male
minus	—	plus
introverted	—	extroverted
stability	—	dynamics
water	—	fire
implosion	—	explosion

Fig. 8.8: Table of dual correspondences
(as a supplement to chapter 3.3 and fig. 4.2).

8.8 Information

The search for an answer for numerous philosophers and physicists was tantamount to the search for a world formula. Of course mustn't be forgotten that a formula only is a mathematical description and never the physical reality itself. It is a mathematical tool in the hand of a person and not the world or the cosmos itself, which he tries to understand. What keeps the world together in the heart of hearts, has to be more than only a pure apparatus of formulas. Actually the fundamental field equation tells us more. It reveals us a basic principle basing on duality in which the dual partners mutually dictate target values and goals. This principle convinces by its simplicity and efficiency. Apart from the "self regulation" it obviously also has the fundamental possibility of a "self organization" and the "generation of information". The field equations of the hydromagnetic field thus are the starting-point for the formation not only of matter and energy, but also of information. Accordingly holds:

Information is nothing but a structure of electromagnetic vortex fields!

This statement is new and to a large extent incompatible with the conception world of Norbert Wiener, who goes as the founder of cybernetics. From N. Wiener stems the sentence: "information is information, not matter and not energy".

We hold against it that obviously a fairly direct connection exists. We have worked out that only the vortex can show a stable adaptive regulatory circuit structure. Only the vortex and not the wave exists in two forms of formation dual to each other, and the principle of duality again is the prerequisite for the formation of information, of self organization and finally for the evolution. In fig. 8.8 well-known dual partnerships are listed. From it follows in a consistent way that for the production of information without exception the electromagnetic vortices should be considered.

But how can this so important duality occur, how can it form? This question is closely associated with the question of the formation of vortices. The signal flow diagram (fig. 8.7) to that says that the dual regulatory circuits F_1 and F_2 can only exist by the coupled circuit, which provides them the necessary target values and at the same time forwards the respective information. In this way of the oscillations and the more or less damped wave F_1 and F_2 communicate with each other.

The electromagnetic wave serves solely the mediation of information and energy.

With that falls a central role upon the wave, so that vice versa is valid:

Without wave no vortices, no duality and
consequently no evolution can exist.

According to the to date state of knowledge the basic principle of cybernetics forms the basis for matter and energy as well as for information. Since the wave can only serve the transmission of information, the principle of duality and the vortex will function as carriers of information. We are entitled, to speak of vortex information, this by no means is characterized by special frequencies or modulations of frequencies. This is prevented by the property of the vortices which allows them to change the frequency. On the other hand various configurations of vortices are possible and numerous combinations and modulations are conceivable.

If technical apparatus generate vortices, then they produce information. Here a serious danger with regard to the environmental compatibility can not be excluded!

Equivalent things:

- elements of the fundamental field equation 5.7
- elements of the Greek philosophy of nature
- temperaments
- (impulses of growth)

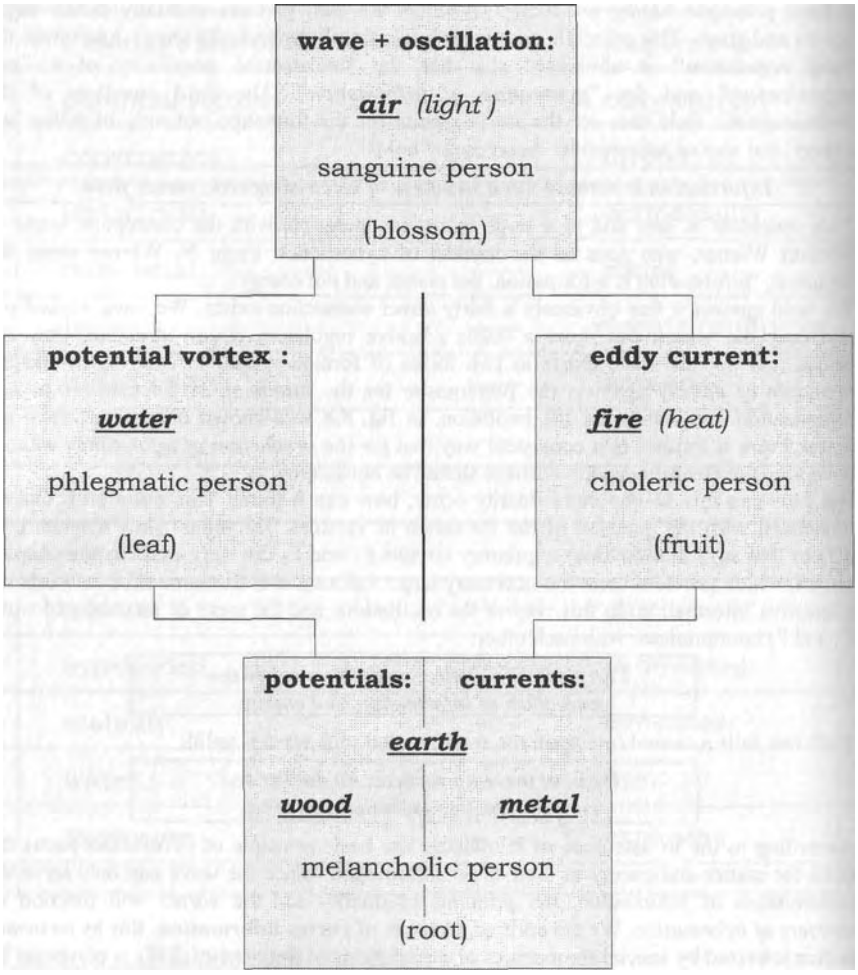
wave + oscillation:
air (light)
sanguine person
(blossom)
potential vortex :
water
phlegmatic person
(leaf)
eddy current:
fire (heat)
choleric person
(fruit)
potentials:
currents:
earth
wood
metal
melancholic person
(root)

Fig. 8.9: The theory of four elements of the old Greek philosophy of nature (Aristotle and others)

8.9 Philosophy of nature

Seen in the view of the philosophy of nature now two dual points of view are possible.
The optimistic one would be:
We and our environment on the one hand are a result of the cybernetic principle and on the other hand of our observation point of view which should be valued relativistically.
If really everything should be electromagnetism, a phenomenon which can't be grasped directly by humans, then the pessimist would come to the conclusion: everythins is nothing. What we observe is nothins but a deception of the senses. Perhaps therefore famous philosophers of antiquity, like Empedokles or Demokritos have ended their life in the crater of the Etna. According to the theory of the atom of Demokritos (470 to 380 B.C.) the formation of matter, earth and celestial bodies will occur by means of formation of vortices!
Empedokles (482 to 420 B.C.) was the first to develop a theory basing on four elements, which was continued and improved by Plato (428 to 348 B.C.) and Aristotle (384 to 322 B.C.). Accordingly these elements are changeable into each other and mixable with each other. From them all bodies are build up.
The terms "air, water, fire and earth", with which the philosophers have described the four elements, are of course not identical with the ones in our translation and conception world, but they were used in a philosophical sense as a substitute for the description of the respective basic principle.
There also have been different approaches, to translate these terms differently, e.g. by an assignment to the four states of matter (solid, liquid, gaseous, plasma). But the ancient texts don't get easier to read in that way.

Fig. 8.9 shows the obvious assignment to the four building parts of the fundamental field equation 5.7. It would be worth an attempt, to exchange the terms in the translations of ancient texts and to translate air with wave, water with potential vortex and fire with eddy current. The term earth has two sides, which should be translated with potential instead of wood and current instead of metal.

Let's try the translation this way with the theory of Plato<i>, by correspondingly translating anew the talk of Timaios about the formation of the world. The perception of smell then is described as follows: "...as the potential vortex turns into waves (or) the wave into potential vortices, the smells are formed during this transition, and smells are smoke or fog. But fog is the transition of waves into vortices, the transition of the vortex into waves however smoke".
Plato here provides an indisputable and conclusive interpretation of the fundamental field equation. In this equation the potential vortex acts as damping term in the wave equation, what in the case of waves rolling up to vortices will show to the observer in the way that the electromagnetic waves and therefore also the light will be damped. We say, the visibility gets worse and speak of fog. If the damping phenomenon disappears again, as the potential vortices break up, then Plato speaks of smoke.
Numerous ancient texts, which until now only could be "interpreted" philosophically, in this way turn out to be a rational textbook description of natural scientific phenomena. They anyway only get readable and understandable for the general public with the modern technical terms.

<i>: Platon: Samtliche Werke 5, Rowohlts Klassiker Nr. 47, S. 188, 66e

Optimist:

We and our environment on the one hand are a result of the cybenetic principle and on the other hand of our observation point of view which should be valued relativistically.

Pessimist:

Everything is nothing. What we observe is nothing but a deception of the senses.

Plato<i> (talk of Timaios about the formation of the world) description concerning the perception of smell:

"...as water (the potential vortex) turns into air (waves) or air (the wave) into water (potential vortices), the smells are formed during this transition, and smells are smoke or fog. But fog is the transition of air (waves) into water (vortices), the transition of water (vortex) into air (waves) however smoke"

changed translation with the technical terms:

air______ = ____wave
water = ___ potential vortex
fire______ = ____ eddy current

As a consequence:

smell is vortex information

Fig. 9.0: The explanation of Plato concerning the formation of smell, smoke and fog<i>

<i>: Platon: Samtliche Werke 5, Rohwohlts Klassiker Nr. 47, S. 188, 66e

9. Usage

If the newly discovered vortex phenomenon of the vortex of the electric field exists, then it will be possible to practically use it. Whereas we still think about possibilities for technical usage, there by all means exists the possibility, that nature already is successfully using the vortex for a long time. We should look precise at things. We can only learn of nature!

Remarkable about the passage of Plato (fig. 9.0) is not only the fact, that the potential vortex already was known for two and a half thousand years and was taken into consideration for an interpretation, but also the realization of Plato, that during the described transition the smells form. Smell thus would be a vortex property!

After all vortices are able to bind information as can be inferred from the basic principle of cybernetics. With this vortex property and the statement of Plato smell obviously would be nothing else than pure information which by potential vortices is stored, distributed and eventually is caught by the hair cells for smell of the nose. If now a dog takes up a track, does it then run after vortices which remained behind or does it analyse, according to the encyclopaedia, the chemistry left behind, or does it combine both? Does the bloodhound for instance interpret the vortical oscillations of chemical substances like lattice oscillations or the movements of the electrons in the atomic hull? A lot of work awaits the research scientist of vortices here. The seminar will offer opportunity, to deepen this topic<i>.

Only if technicians exist, who put an electronic box on the table with a button, at which they adjust the wanted scent of rotten eggs to lavender, we honestly can claim to have understood the phenomenon of the smell.

For the majority of the people a theory only wins its sense by the practical applicability, and therefore we'll have to develop and present a technical usage on the basis of the vortex theory.

<i>: Suggestions for appropriate seminar themes: the meaning of smell, taste, the aroma therapy, the homeopathy or the effect of aetheric oils. (To that in part 3, INDEL Verlagsabt. 2003)

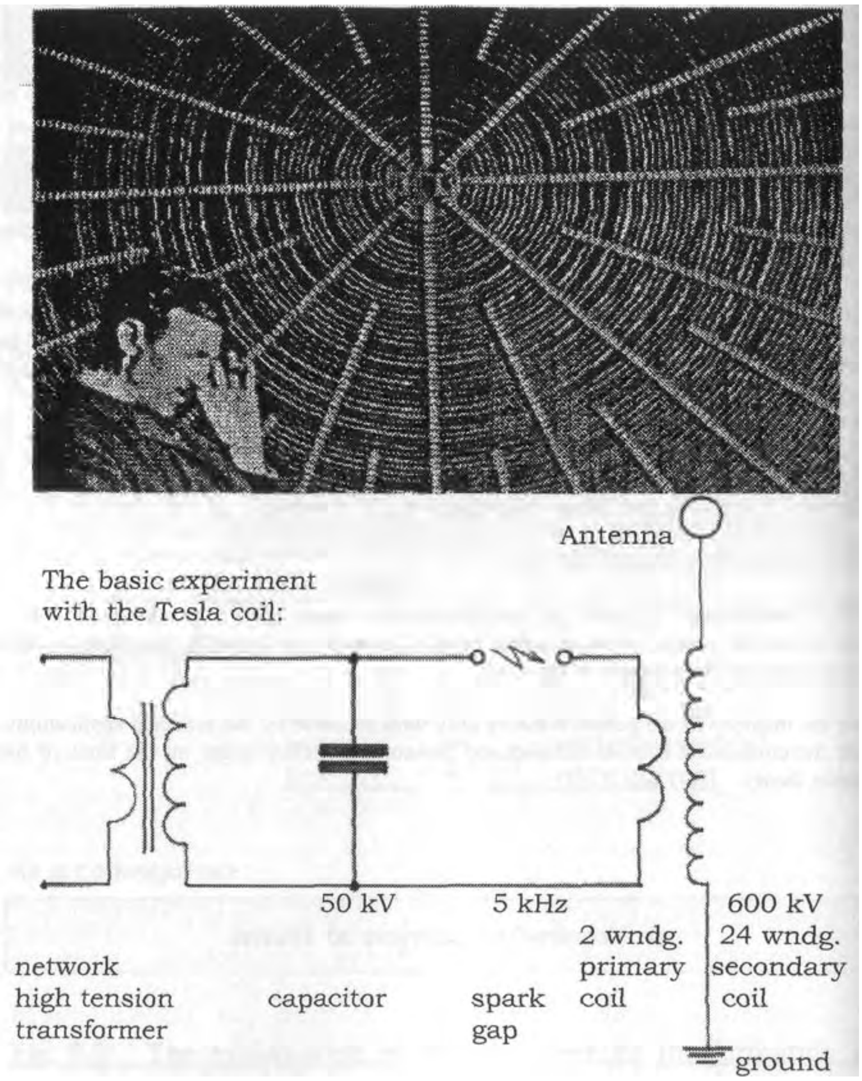
Antenna
The basic experiment
with the Tesla coil:
50 kV
5 kHz
2 wndg.
primary
coil
600 kV
24 wndg.
secondary
coil
network
high tension
transformer
capacitor
spark
gap
ground

Fig. 9.1: High tension transmitter of Nikola Tesla

9.1 Longitudinal electric waves

It is important, that experts struggle for problem solutions. Only if the discussion about limits doesn't come to a result which can be grasped and verified, then also in the environmental compatibility the willingness will grow, to accept a not yet known phenomenon as a further and possibly crucial influential factor.

Already for a hundred years there has been a dispute of experts. At that time scientists all over the world were trying to verify the experiments of Heinrich Hertz. Then from America the message came, Hertz had been mistaken and the electromagnetic wave would have completely other properties. The scientists in Europe were indignant, but they had to take the message seriously, because it after all came from the important experimental physicist Nikola Tesla (1856-1943), who with his inventions of the rotary field and of the asynchronous motor has stamped today's electric energy technology as no other.

As a result Lord Kelvin boarded a steamship as a mediator and sailed 1897 to New York to convince Tesla from the opposite. But the experiments, which Tesla presented his Lordship, didn't give rise to any doubts<i>, and thus Kelvin returned to Europe with the message: "Both are right, Tesla as well as Hertz! Whereas the electromagnetic wave which Hertz has detected, is a transverse wave, does Tesla work with a longitudinal wave"!

Lord Kelvin as a result started to draw most different vortex models, because it was clear to him, that a propagation as a longitudinal standing wave analogous to the sound wave only is conceivable, if quantized structures exist, which knock each other mutually. Kelvin therefore assumed vortex structures of the electromagnetic field. His vortex models were published and landed in the curiosity box of orthodox science.

Heinrich Hertz did have a big advantage. He could refer to Maxwell and calculate his wave with the field equations. For modern technology the mathematical calculability is almost an indispensable prerequisite!

For Tesla wave there however neither was a mathematical nor a physical theory. The only thing Tesla had, were presentable experiments.

In Colorado Springs he had build a 10 kW transmitting installation and lighted 200 fluorescent lamps of 50 Watt each on a mountain in the Rocky Mountains in a distance of 25 miles. With that he had completely transmitted the transmission power of 10 kW, as can be inferred from the press reports at that time. With Hertzian waves, which propagate spatially, this experiment even today, after over 100 years, wouldn't be realizable technologically. According to the law of the square of the distance one isn't even able to let glow a tiny little lamp in such a distance.

For sure his rotary field theory was a big help for Tesla in all experiments. Actually a rotary field can be seen as the special case of a planar vortex.

Thus Tesla obviously was able, to use the potential vortex without even knowing it. Tesla has stimulated a loosely coupled high tension coil wound like a spiral to self-resonant oscillations and emitted the produced vortices over an antenna (fig. 9.1). On the receiver side the process was then reversed.

<i>: N. Tesla: III. The Singular Misconception of the Wireless (Famos Scientific Illusions), Electrical Experimenter, Feb. 1919, p. 732.

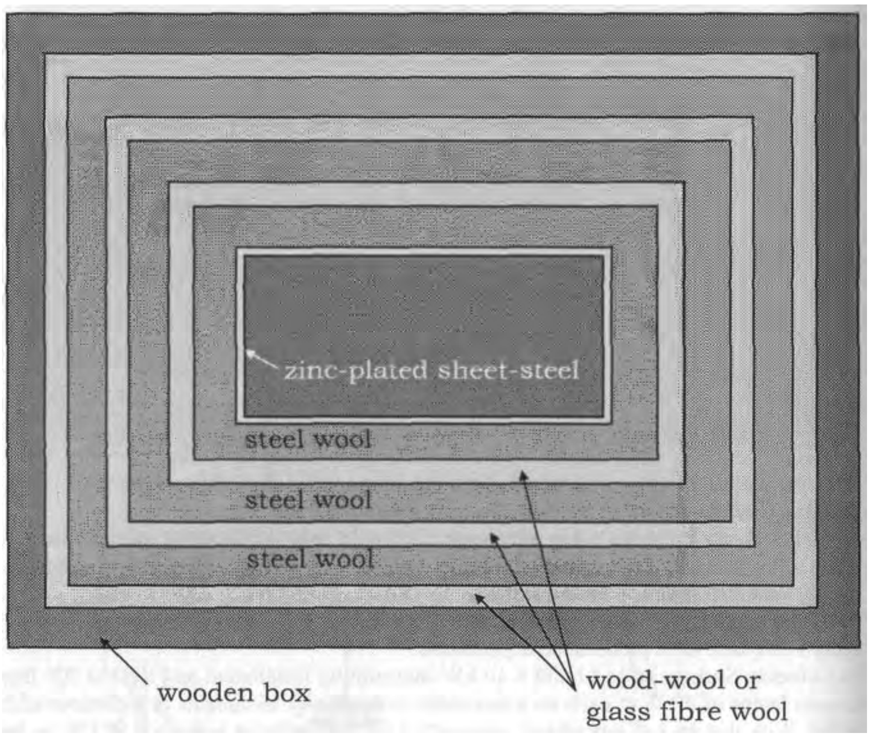
zinc-plated sheet-steel
steel wool
steel wool
steel wool
wooden box
wood-wool or
glass fibre wool

Fig. 9.2: Orgone accumulator according to Wilhelm Reich.<i>

<i>: Dr. James DeMeo: The Orgone Accumulator Handbook, ISBN 0-9261855-0-7

9.2 Medical technical usage

Nikola Tesla at his time was extremely popular in the area of medicine. With his inventions injuries were cured and pain eased. Modern diathermy goes back to his work. But Tesla at that time has treated the patients with vortices, whereas today, possibly out of ignorance, electromagnetic waves are used. These however have in contrast to potential vortices only a small penetration depth. Today in addition only the effect of heat is considered and in no way the information technical effect of electric vortices. Here we are missing the comparison, to be able to say. if the treatment with a Tesla apparatus was more successful than with modem microwave radiators.

The experiments of Wilhelm Reich (1897-1957) aimed in the same direction. Exactly as Tesla 55 years before also Reich emigrated to America in 1939. He had specialized in catching and collecting vortices, which he called "orgone", from the air. In this way he could store up high energies over time and then use them purposeful. With his "orgone accumulator" he was able to cure wounds faster and to ease pain. He also treated cancer and a lot of forms of anaemia. Technically Reich could demonstrate, that charged capacitor plates discharge faster under the influence of his apparatus. His orgone accumulator for instance is a wooden box, filled with wool of steel and wood, which alternate in layers. He said that the reason for this construction is, that metals repel the orgone energy, whereas organic materials become charged and accumulate it. That holds in his opinion to a particularly high degree for water.

Reich concludes that no material and no device are known, with which the orgone energy could be shielded. This with regard to the environmental compatibility of the vortex phenomenon should make us thoughtful.

As a supplement it should be mentioned, that Reich already at the end of the forties has pointed to the dying of the forests and he has made a direct connection to the orgone energy. Reich was slandered and mocked and died in the prison of Connecticut, while his writings were burned publicly.

Not much better fared the Austrian forester Viktor Schauberger (1885-1958), who also can be described as visionary. He was able to produce water with a particularly good conductivity. His water in addition goes for medicinal and healthy. Also to him travelled cancer patients of far away to get this water.

Schauberger spoke of the natural treatment of the water, whatever he meant with that. In any case he build with great success installations to transport wood by floating it and even installations to mine ore with so-called double twist pipes, which made possible a transport without friction even of materials, which are heavier than the "means of transport" water. It could be proven that no contact with the pipe took place. This was scientifically investigated and confirmed at the university of Stuttgart 1952 by Prof. Popel. Quite obviously in the double twist pipe vortices have formed, which have bound the material to be transported (see phenomenon of transport).

Today you can buy levitated water at over 100 selling points in Europe, of which is claimed, that it is prepared according to instructions of Schauberger. Unfortunately we aren't able to ask him anymore, if he agrees with such a "centrifuged" water. Thus the test of the effectiveness has to be left to everyone himself or herself.

A: Concerning the functioning of the Faraday generator $(E = v \times B)$:

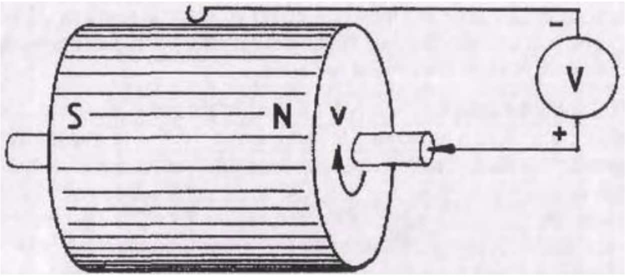

B: Construction of the flying disc:

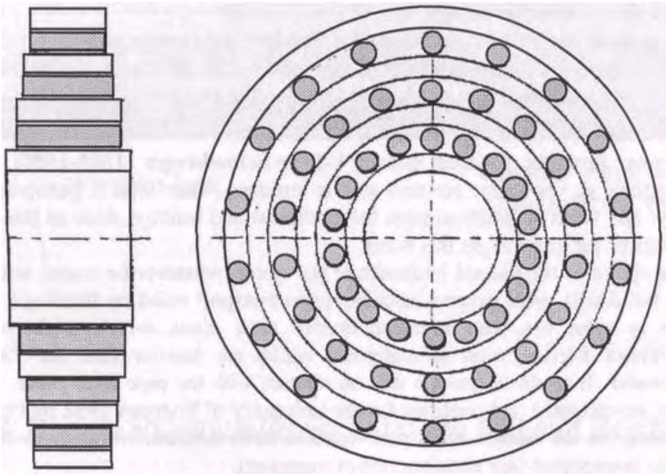

Fig. 9.3: Applications of the Faraday generator[i] in the flying disc of Prof. John Searl

9.3 Flying objects

The medium of Viktor Schauberger always was the water. He could produce light effects and very high temperatures with it with only minimal excitation in the form of impulses. An installation, which had been built according to his plans at the company of Siemens, eventually melted at 4000°C by improper operation, as he himself stated. According to that the machine would have released more energy than used, thus a perpetuum mobile. The authorities of the state in the Third Reich were impressed and put Schauberger in a concentration camp, where he was instructed to build a "flying saucer" under permanent supervision together with fellow prisoners. For him it's all about the concentration effect and the usage of the as a result occurring implosion in contrast to our today's " technology of explosion and fire" as Schauberger was accustomed to express himself. It is not known, if Schaubergers "repulsine" ever has took off.

A disc, which has proven its suitability to fly, was constructed and built by the english technician John R. R. Searl, although he said he can't explain the effect. He also had big difficulties, to get the apparatus under control. A disc broke through the ceiling and the roof of his laboratory and disappeared to never be seen again. Five other flying discs, which he after this experience started in the open, went lost in the same manner. Without knowing the effect, he of course neither could assess the dangers. His experiments have claimed serious injuries and a casualty. While he 1985 was put in prison under a pretext, his laboratory and his house were burned down and all documents destroyed. Now he works on a technical usage. According to the principle it concerns a Faraday machine. Thereby a permanent magnet, magnetized in axial direction, is turned. Now the magnetic induction B for a relative velocity v is measured as an electric field strength E according to equation 6.10: $E = v \times B$. (6.10)

Because the vectors are arranged as standing perpendicular to each other, will arise a tension voltage in radial direction (direction of E-field) which can be taken off. Apart from the friction no further force of reaction occurs in the case of the Faraday generator. Because of the small gain of energy until today no application ready for the market exists. But this principle, to convert magnetic field energy into electric, already has moved the nature of many inventors. Professor Searl has reversed this old principle. Whereas normally the component of the velocity towards the centre of rotation decreases, it increases in Searls case. For that he works with roller pivoted concentric rings, which he drives by a small electric motor (fig. 9.3). Doing so something inexplicable for him happens: After switching off the motor the revolutions per minute don't decrease again, but increase audibly and increase further, until the produced electric field shows the well-known high tension phenomena: corona discharges, formation of ozone, ionisation of the air and production of a vacuum in the inside of the disc.

The rings and rollers consist of several layers, which are built up similar to a bi-metal. The only explanation I can think of is that a change in structure would occur as a result of the physical length contraction which is caused by the increase of the E-field in the direction of the centre of rotation. The bi-metals try to withdraw themselves from this change by an increase of their rotation of their own (fig. 6.5). To compensate the field the disc builds up a spin, as also the elementary particles do (fig. 6.13). While the formation of vacuum prevents sparking in the inside of the flying disc, and the revolutions per minute further increase because there is no air friction whatsoever, the disc weighing 5 tons all of a sudden lakes off the ground and according to reports of eyewitnesses shoots vertically upwards.

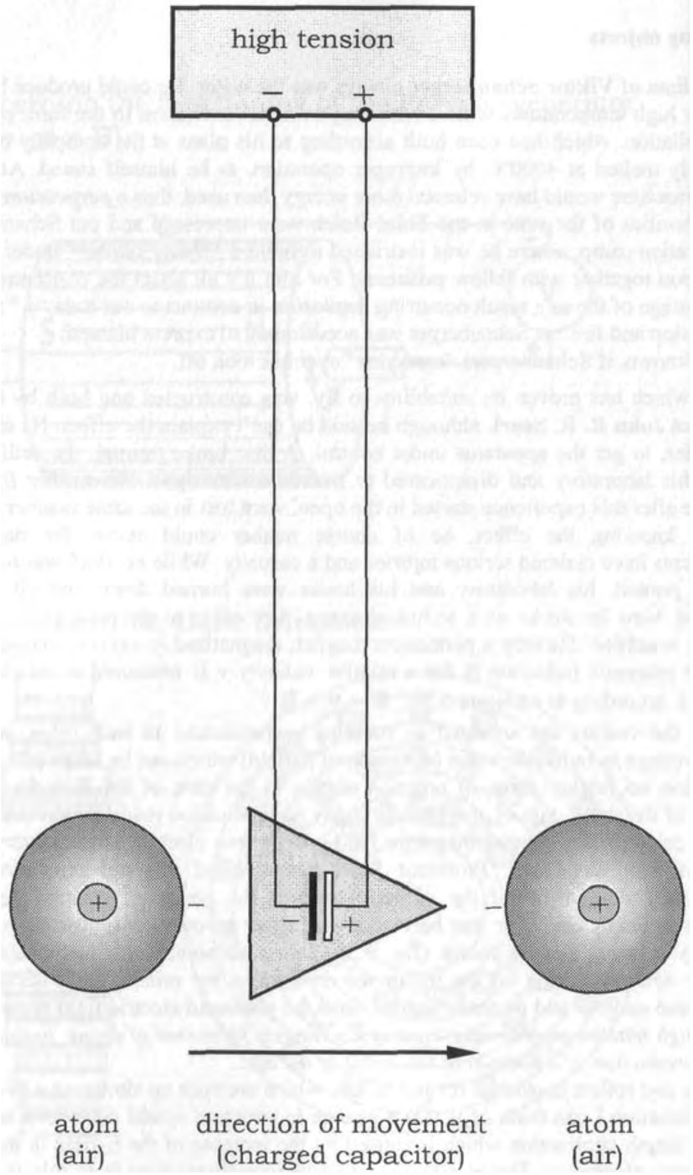
high tension
−
+
+
−
−
+
+
−
atom
(air)
direction of movement
(charged capacitor)
atom
(air)

Fig. 9.4: Capacitor experiment concerning the so-called electro-gravitation according to Prof. Biefeld / Dr. Brown

9.4 Electro gravitation?

Wild speculations circulate about the mechanism of the flight of a "flying saucer", which should function without sound and without combustion, and for which no sound barrier exists, as pilots have observed. The talk is about cancelling gravitation or about an "electro gravitation".

Reproducible in any case is an experiment, which has been systematically investigated by the american professor Biefeld and his pupil T. Brown from 1925. Accordingly does a body charged to high tension show a force effect in the direction of its positively charged note. As a check for oneself a capacitor can be suspended on its connection wires and it can be observed, how it moves visibly in the direction of the positive pole in case it is charged (fig. 9.4).

Because the Biefeld-Brown effect depends on direction, it actually can't concern gravitation at all but merely a not understood electromagnetic interaction. In the neighbourhood of the capacitor pole air molecules are found, and their negatively charged atomic hull is attracted by the positive pole. At the same time the atomic nucleus is repelled. By that the air atoms in the presence of the high tension capacitor become unsymmetrical, causing the force of attraction due to the smaller distance to exceed the force of repulsion. At the negatively charged end the conditions are exactly reversed. There a repulsion occurs. Because the polarized air atoms and molecules are sucked in, no pressure can build up and as a result no sound barrier can occur. Experiments with charged and uncharged rockets have brought the interesting result, that the electrically charged rockets flew many times as far as the uncharged ones (5-6 times as high)<i>.

Many a person now perhaps starts to dream of the flying carpet but, as said, it isn't an "effect of antigravitation". Does "free energy" actually exist, we have to ask ourselves? From the gravitation the soviet physicist Landau calculates an energy density of 16 megawatt hours per cubic meter for the earth's surface. Immediately inventors are found, who want to use this gravitational energy.

Nikola Tesla in his laboratory in Manhattan has incidentally built resonators, of which he could bring all electric, magnetic and mechanic factors in resonance. On an evening stroll he fastened a battery operated vibrator to the tubular steel scaffolding of a new building and let everything shake and wobble. In his laboratory such a device once got out of control by inattentiveness and triggered an earthquake. In that way the road surfacing and pipes were burst and window panes got broken. The police penetrating his laboratory only could see, how Tesla forcible finished the experiment with a sledge-hammer.

The experiments which got out of control of Tesla, Searl and Schauberger have one thing in common: it concerns constructions with an unipolar arrangement of the field.

Tesla had arranged the magnetic field in a unipolar way, as he has reported himself, Searl had realized electric unipolar fields in a construction similar to the electron, and Viktor Schauberger had specialized in producing unipolar structures with water vortices.

In the case of the corresponding technical usage, which can be interpreted as making use of the occurring "spin coupling", therefore in principle utmost caution is imperative.

<i>: Rho Sigma (Dr. Rolf Schaffranke): Forschung in Fesseln, das Ratsel der Elektro-Gravitation, Ventla-Verlag, Wiesbaden, 1972, Page 67.

Nikola Tesla: „Ere many generations pass our machinery will be driven by power obtainable at any point in the Universe This idea is not new, we find it in the marvellous myths of Antheus, who derives energy from the earth... Everywhere in the universe there is energy. Is this energy static or kinetic? If static, our hopes are in vain; if kinetic, and this we know it is for certain, then it is a more question of time when men will succeed in attaching their machinery to the very wheel work of nature". New York, the 20th may 1891, American Institute of Electrical Engineers.

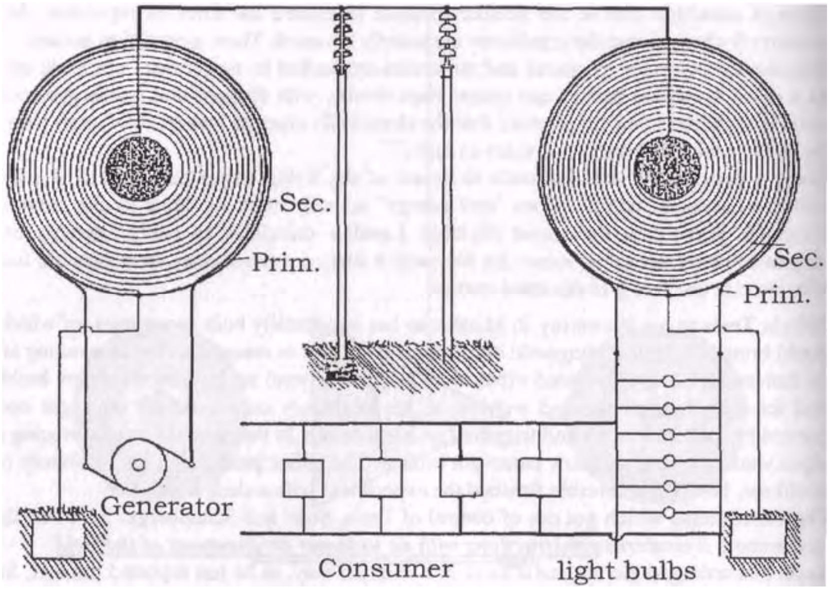

Fig. 9.5: Energy transmission bound to a wire, Patent No. 593,138 (1897) of Tesla.

<i>: Philadelphia Public Ledger, Nov. 2, 1933

<ii>: Dr. Nikola Tesla: Complete Patents, Tesla Book Company, New Edition 1983, Compiled by J. T. Ratzlaff, ISBN 0-960356-8-2, page 301-304.

9.5 Free energy?

Furthermore is reported of Tesla, he would have developed a "converter for space energy" and 1931 have built it in a luxury car (Pierce Arrow)[i]. The car was a 145 km/h fast, doing so the asynchronous motor (presumably built by Westinghouse) furnished 80 HP at 1800 Rpm. The "free energy" the converter, build by Tesla himself, got from a 1.8 m long antenna. Because the motor ran without adaptation of frequency in slipping operation, it had to be cooled correspondingly. It was on the way in trial run for over a week. Now we of course want to know, of what this "free energy" consists, which Tesla will have used and of which he already 1891 had spoken in the American Institute of Electrical Engineers.

For the electron as a spherical vortex we have calculated an electric tension voltage of 511 kV between its surface and its centre respectively infinity (equation 6.31*, fig. 7.1). The highest level of tension voltage normally used for the high tension transmission lies at 380 kV (effective value); for a direct current transmission it is 500 kV. Although still higher tension voltages would be desirable, they are avoided. This is no accident. Experiments with higher tension voltages namely have resulted in inexplicable high losses. We have an explanation: the electrons are taken apart on the way! Their inner energy amounts with the outer energy to zero. The charge carrier, which in the power station as result of an energy conversion has been sent on a journey, is in danger to vanish into thin air (e.g. corona) for tension voltages above 511 kV. The transmitter of Nikola Tesla however (fig. 9.1 and 9.5) worked with 600 kV and more. He said, with his experiments he had destroyed billions of particles without being able to observe an emission of energy and made fun of the misinterpretation of Einstein of the already at that time well-known mass-energy relation $E = mc^2$.

For the purpose of a one wire or a wireless energy transmission the tension voltage therefore has to be higher than 511 kV. With Teslas equipment however the electrons shouldn't be destroyed, but merely be pulled apart to plane circular vortices with help of the today is Tesla coil known winding. These then could be sent on a journey over the antenna, to again be caught and formed back in spherical electrons by the receiver antenna. As long as the electrons don't fall apart, they keep their structure and quantum property. Quanta pass on an excitation, for instance a bump, in form of a longitudinal standing wave, by one particle bumping the neighbouring particle, analogous to sound waves, where one gas molecule passes the bump on to the neighbour. The transmission hence takes place as longitudinal scalar wave.

Electrons pulled apart to planar vortices in addition haven't got a closed vortex centre anymore on their journey. For the by Tesla in his laboratory used and publicly presented one wire energy transmission (1897, Patent Nr. 593,138) the transmission hence doesn't take place in the wire, but as vortices around the -wire. That explains, why only a relatively thin conductor, which normally should have melted, was necessary for a demonstrated power transmission of 10 kW. Tesla however could show, that the wire stayed cold and virtually no heating losses were measurable<ii> (fig. 9.5). He himself said, that this one wire transmission technology is much better than the alternating current technology full of losses, which stems from him as well. Tesla must have known the limit of 511 kV very exactly, because on several photographs one can see, that he changed the coiling technique off this value!

<i>: Philadelphia Public Ledger, Nov. 2, 1933

<ii>: resp. Tesla's lost inventions, VAP, page 36 and page 48, 49.

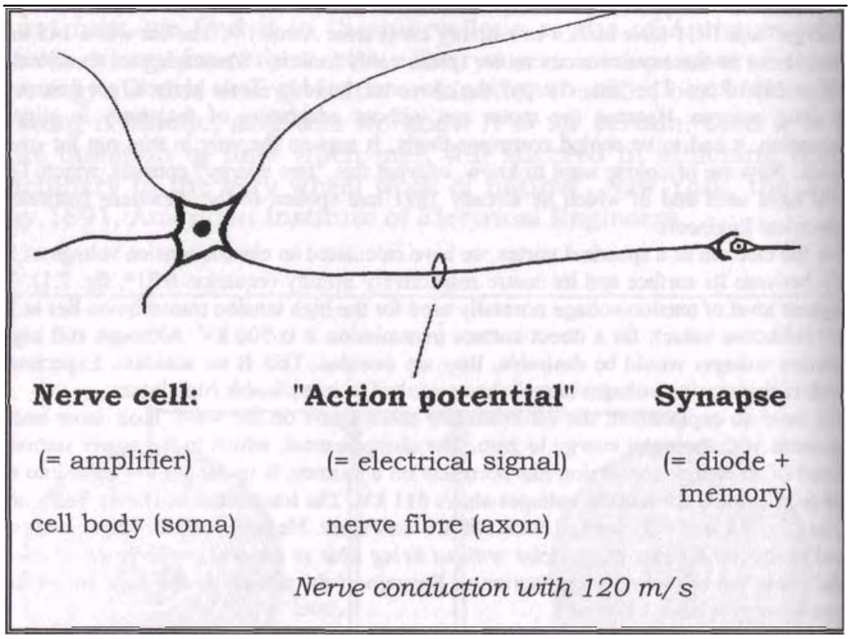
Nerve cell:
(= amplifier)
cell body (soma)
"Action potential"
(= electrical signal)
nerve fibre (axon)
Synapse
(= diode + memory)
Nerve conduction with 120 m/s

Fig. 9.6: Nerve cell and message processing (neurons)

- Material information conduction: at plants
- Information conduction with hormones: at simple animals
- Electrical information conduction: at higher developed creatures
- Analog transmission: from 10% and more difference in potential, and
- Digital transmission: number of the action potentials
- Modulated information: i.e. complex modulation of the action potential (the potential vortices)

9.6 Nerve conduction and action potential

Technical solutions often are only a suboptimum and many times they are anything but an optimum. In many cases the feasibility stands in the foreground. In the question of the current distribution at that time the decision was made for the worse system, the full of losses three phase system, because no current meters were available for the free of losses one wire technology. Without being able to collect money from the consumer, it wouldn't have been possible for the energy distribution installations to pay for themselves. Compared to that is nature with its selection principle merciless and without compromises. Only the most efficient system has a chance to survive and to spread. If it's about transmittining information in an electric way and two different principles present themselves, then in nature only the better one will be brought into action.

Let's take a look at the nerve conduction in the human body. In the synapses ion concentrations and electric potentials of 70 to 90 mV arise. Here with conventional gauges the activity of a nerve can be detected. From a measurement of the transmission time of synapse to synapse the velocity of the signal is determined. If we however want to measure between the switch points on the line, then we have to find out, that for instance with an ammeter actually nothing is measurable. In addition the nerve fibre has a miserable conductivity.

The biologist calls the electric signal just "action potential" and draws a vortex-like ring around the nerve fibre and speaks of a mixed digital and analogue information transmission.

The doctor on the other hand knows two different types, fast and slow nerves. In the inside both are built up virtually identical. A characteristic difference consists of the fact, that the fast nerves are jacketed with a thick fat layer.

The technician would say, they are better isolated, but why they therefore should be faster, he hardly would be able to answer. If we however assume, that the action potentials or OUT potential vortices oscillate around the conductor, thus exactly in the isolation layer and are forwarded there, then possibly an explanation would have been found.

The nerve conduction moreover has much in common with the one wire system of Tesla:

1. Charges and electric potentials are transmitted
2. Doing so a transport of charge carriers, thus an electric current on the line, isn 't detectable.
3. Consequently no losses worth mentioning occur.
4. Decisive for the functioning is the dielectric insulator material which surrounds the conductor and not the electric resistance of the conductor.
5. In contrast to electric circuits a draining conductor is unnecessary.

It looks as if the one wire system is not new at all, as would nature use it already for ages in the highest perfection. We realize immediately, why our head does without a ventilator and how the high of signal processing density can be explained. Compared with our brain modern personal computer (PC) with their backward cable technology are far less than a suboptimum.

With regard to the pressure on the environment by interference radiation we had derived, that currents and eddy currents with the skin effect direct their radiation to the outside, whereas potential vortices with their concentration effect direct it to the inside. Probably for this reason the radiation field of a person is environmentally better compatible than that of a PC.

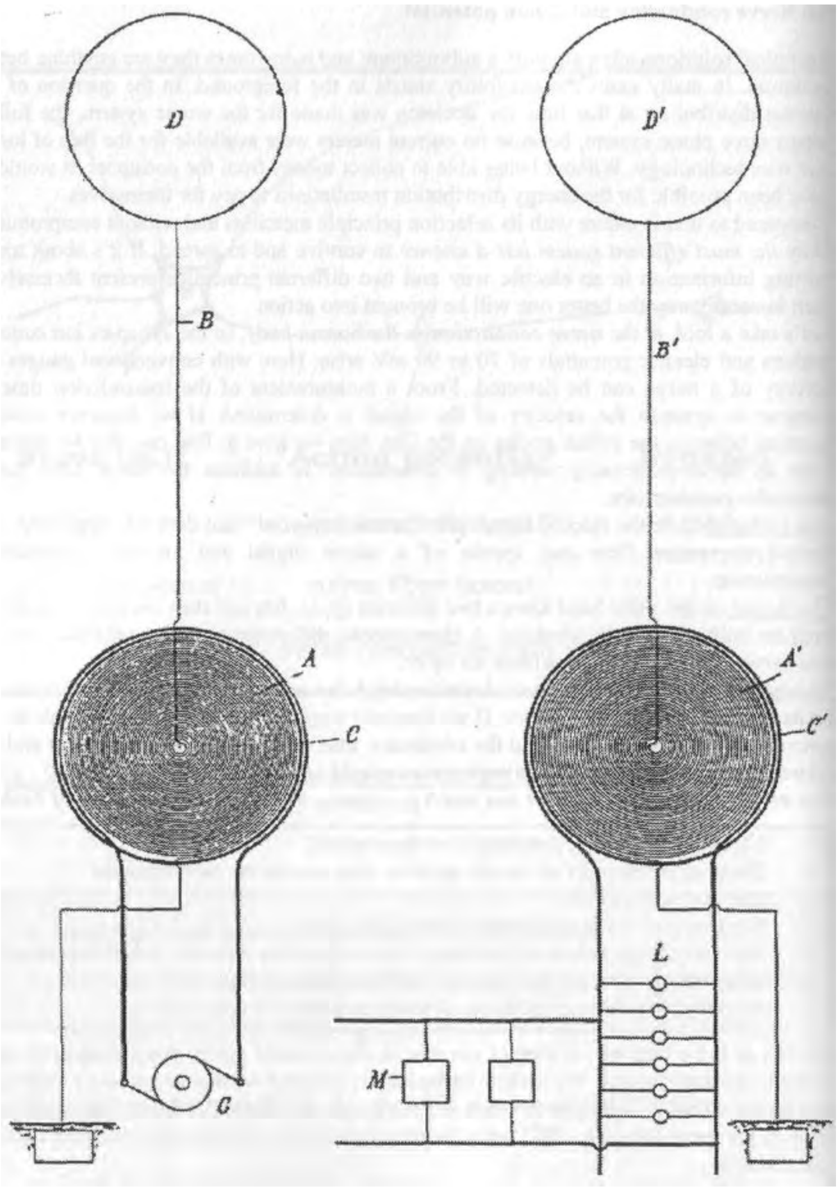

Fig. 9.7: Wireless energy transmission, Patent No. 645,576 (1900) of Testa.<i>

<i>: Dr. Nikola Tesla: Complete Patents, Tesla Book Company, page 311-321.

9.7 Wireless energy transmission technology

Tesla still went a step further. He has cut the wire connection between transmitter and receiver (fig. 9.5) and instead has installed each time a spherical electrode (fig. 9.7). With this facility he now was able, to transmit energy completely wireless (1900, Patent No. 645,576). Building on this principle Tesla already 1890 had built a radio remote control for a battery operated submarine and had presented his patented system the navy. But they weren't able, to recognize the strategic importance of the radio technology and rejected with the words: "It's too advanced!" (fig. 9.8).

Tesla further had proven with this technology the mentioned proof concerning the existence of longitudinal electromagnetic waves. There exist descriptions, partly of Tesla himself, how he, inside or also outside his laboratory, goes in search of oscillation nodes of the standing wave with a measuring receiver<i>. He names several conditions for the wireless energy transmission:

1. "perfect resonance" (same frequency) of transmitter and receiver
2. Installation of the receiver on an "oscillation node" (maximum).

Important is also the measurement of the velocity of propagation, and that isn't constant from the start for a wave, which oscillates in the direction of propagation. From the research of earthquakes we know, that the longitudinal waves are faster than the as well occurring transverse waves. Usually the distance to the epicentre is determined from the difference in transmission time.

In the patent specification the measurement is described<i>. Tesla has sent longitudinal radio signals from his transmitter in Colorado Springs once around the earth along the earth's surface and determined a transmission time of 0,08484 seconds. This corresponds to a frequency of approx. 6 Hz. He saw his result confirmed, as he could find the oscillation node of the standing wave again (according to $\lambda/2$) in his laboratory (on the ground plate).

For the full wave length λ the Schumann resonance, which describes a standing wave of an around the earth running Hertzian wave, lies as is well-known at 7.8 Hz! Tesla calculates for his wave a speed 1.6 times the speed of light assuming the polar radius of the earth to be 6363 km.

Also this measurement result confirms, that Tesla didn't use the Hertzian wave. Tesla found the off-beat concept of Einstein, the speed of light would be the fastest possible velocity of signal transmission, only funny. If however today is claimed, 1993 in tunnelling experiments for the first time a speed faster than light has been measured, then this just isn't true. Possibly also the Tesla wave tunnelled, as the vortices for a small conductivity of the air contract and as a result of the length contraction become correspondingly fast.

Later Tesla after several goes in vain even succeeded in building a high tension tube as a tunnel, with which the velocity of the signal could be increased arbitrarily. Tesla with that pursued the goal to be able to make radio contact with other worlds<ii>.

<i>: N.Tesla: Art of Transmitting Electrical Energy Through the Natural Mediums, US-Patent No. 787,412, 18.4.1905, Complete Patents pp. 397-402.

<ii>: M. Cheney: Tesla, Man out of Time, Barnes & Noble Books, New York, 1993, und S. 309, Omega-Verlag, 1996, ISBN 3-930243-01-6

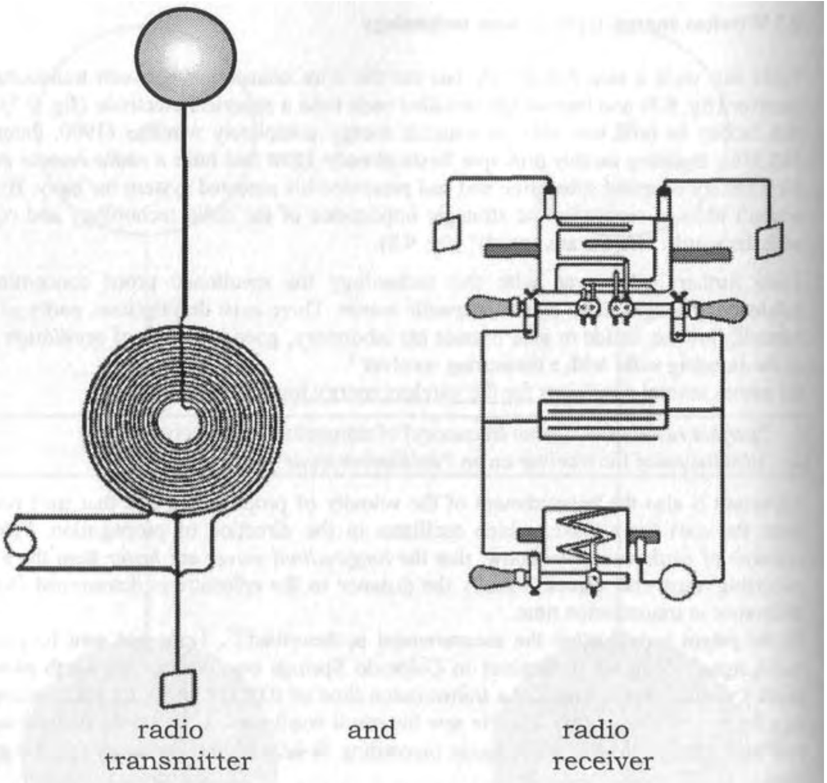
radio transmitter
and
radio receiver

Fig. 9.8: Energy wave broadcasting system, Patent No. 787, 412 (1900) of Tesla.

In today's switching technical notation:

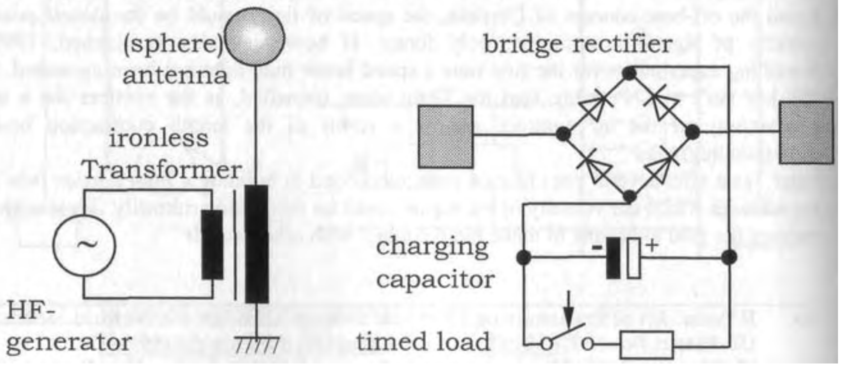
(sphere) antenna
bridge rectifier
ironless Transformer
~
charging capacitor
-
+
HF-generator
timed load

9.8 Measuring and switching technique of Nikola Tesla

As an important and accepted experimental physicist with 14 doctor titles and carrier of the Edison medal Tesla always has held on to his measurement results. Not a theoretical interpretation but exclusively correct carried out measurements have shown him the physical reality. But the by Tesla won measurement results were already for 100 years hard to digest and couldn't be brought into accord with any theory. Therefore a switching technical analysis of the by Tesla described and carried out experiments should give us now information over the nature of the free energy, the tachyon energy, the orgone, or however fantastic the terms may read.

The Tesla coil, according to the instructions of the inventor, is a flat coil wound like a spiral in contrast to the copies today on sale which, surely out of ignorance, are mostly cylindrical. Its peculiarity probably is to be seen in the circumstance, that charges moved through the wire of the coil inevitably increase their angular velocity towards the centre, In this way the electrons, which at first are spherical elementary vortices, are pulled apart to vortex rings like planar discs.

Tesla switches the "secondary" called flat coil between two "terminals". Following he sends, stimulated by his "primary", charge carriers from one terminal to the other and back again and produces a standing resonant oscillation.

Mostly replaces Tesla one of both terminals by the earth. He thus assumes, that now the earth as a spherical electrode takes over the function of one terminal. That he again infers from the observation, that a by the transmitter wireless fed little lamp goes out, if he cuts the connection to the ground. Doing so the oscillation collapses. Radio sets on the other hand can also be operated without grounding, as we know!

The degree of effectiveness of today's distribution technology of current due to the heating losses lies clearly beneath 100 per cent. Without the losses of the wiring it lies close to 100 per cent for the discussed one wire energy transmission. There the vortex rings are guided nicely one after another along the line like beads drawn over a string. This result even is to be expected, as far as no vortex "jumps off the wire or "falls apart". For the wireless version Tesla however to his own surprise had to find out that more energy could be received, than his transmitter produced. The measured degree of effectiveness lay above 100 per cent! He therefore called his transmitter a "Magnifying Transmitter" (fig. 9.10). The further transmitter and receiver were away of each other, the further the received energy increased. Tesla inferred from this, that there had to exist free energy and that he had caught that too.

Consequently he had built a receiver for free energy and registered for patent (1901, Patent No. 685,957, fig. 9.9). Tesla states that the amount of energy depends on the size of the "terminal". Of today's sight we could be willing, to describe this receiver plate as a solar panel, but we should know, that the apparatus produced energy even at night! In addition the energy gain was considerable higher than for today's solar panels. Tesla spoke of "radiations ", of an unknown radiation and he in his lifetime has in vain sought-for help of explanation.

The vortex model will also in this question be a valuable help to us.

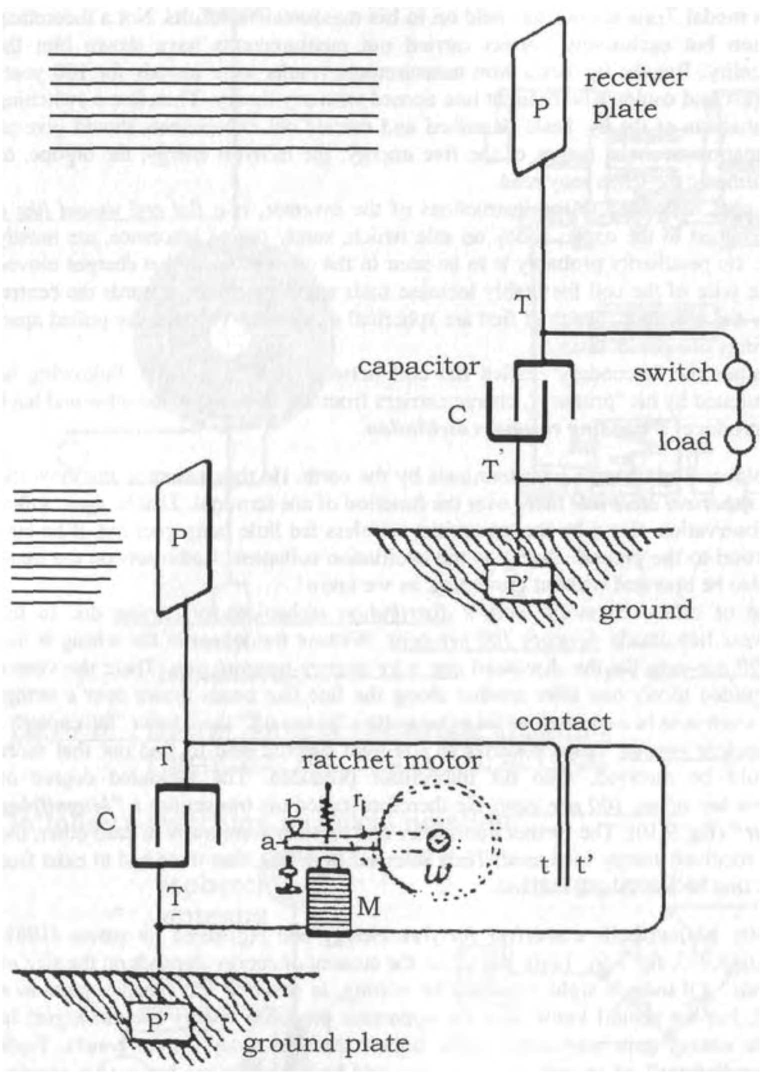
receiver plate
P
T
capacitor
switch
C
load
T'
P'
ground
P
contact
T
ratchet motor
C
b
a
ω
t
t'
M
T
P'
ground plate

Fig. 9.9: Receiver for "free energy", Patent No. 685,957 (1901) of Tesla

9.9 Energy technical usage

The answer of the potential vortex theory could turn out as follows:
If at the transition of the one wire to the wireless transmission the ring-like vortices is purloined the guiding wire the vortices immediately begin to turn around each other, as is observable for flow-technical ring-like vortices,. In this way the ring-like vortex the next moment shows its inside. If it before was an electron vortex (fig. 4.3), then it now shows as positron, if it was negatively charged, then it now is positively charged. Following it oscillates back again, etc. Wit that the ring-like vortex on the average has no measurable charge and no mass, because it alternately forms matter and anti-matter. Without interaction it has an enormous ability of penetration . In physics such particles are called neutrinos.
Tesla thus had, apart from his transmitted energy wave, which turned out to be neutrino radiation, by chance also caught neutrinos which oscillated synchronously.

According to the actual level of knowledge do neutrinos penetrate the earth and appear also on the night side. The order of magnitude in every second amounts to approx. 66 billion neutrinos per square centimetre. It is a true bombardment. If we would be able, to collect and convert all neutrinos, the won energy would be entirely sufficient, to cover the need for energy of the world population (approx. 27 W/m^2). We merely have to materialize them, thus give them mass, charge and the necessary localization. Tesla was able to do that experimentally! Let's record:
The ring-like vortices, which Tesla with his transmitter has sent on a journey as electrons with an open vortex centre, are neutrinos (fig. 7.12). Tesla requests that transmitter and receiver operate in resonance, thus with the same frequency. Under this condition the receiver collects in all oscillating vortices, so that no one is lost.
If the neutrinos for instance are just positively charged when leaving the transmitter electrode, then an electromagnetic force of attraction takes place, if the receiver electrode at the same time is negatively charged. The required operation with the same frequency and opposite phase guarantees that also the next moment, if both, the neutrino and the receiver, have changed their polarity, the electromagnetic attraction is preserved.
It is obvious, that strange neutrinos which fly past and by chance oscillate synchronously are as well attracted. In that way the power collected in the receiver capacitor will increase further and degrees of effectiveness of over 100% are obtainable. Tesla discharges the receiver capacitor timed with the frequency of resonance (fig. 9.9) and points to the difficulty of an exact keeping of the condition of synchronisation.
Tesla indeed did work on a theory of his own, but never published it. The patent office and his lawyers had to proceed from the Maxwell theory, although Tesla knew only too good, that his apparatus in no way could be described with this theory. It therefore can't be excluded, that important facts in his patent specifications haven't been mentioned at all - or even worse - consciously or unconsciously in an inapplicable manner have been explained with the Maxwell theory.
Perhaps this is the more profound reason, why the numerous Tesla imitations don't want to function quite so well. With the new theory there should be some changes, and we should accept the challenge for the sake of humanity.

The transmitter tower of Tesla (57 m high with a spherical electrode of 21 m) for the transmission in multiplex mode of operation (according the inventor) of:

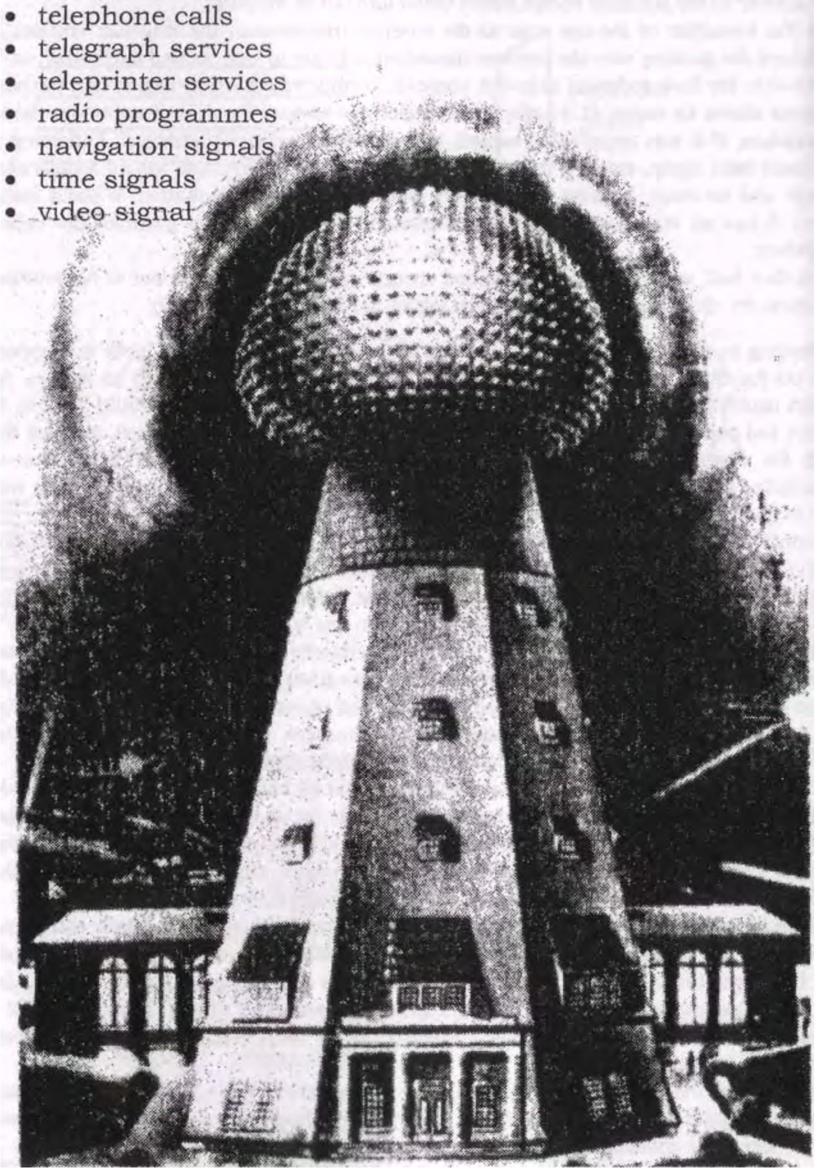

- telephone calls
- telegraph services
- teleprinter services
- radio programmes
- navigation signals
- time signals
- video signal

Fig. 9.10: The planned transmitter Wardencliff of Tesla on Long Island, 7.5 MW (1902).

9.10 Environmental compatibility

We now can summarize the different observations and try to find answers for the in the first chapter raised questions concerning the electromagnetic environmental compatibility.
The by Tesla used longitudinal energy wave is a potential vortex wave in the sense of the vortex model of Kelvin, which we again could identify as neutrino radiation (Dirac).
Also other, partly quite fantastic terms, are known like "radiations" (Tesla), "orgone radiation" (Reich), "tachyons" (Feinberg), "grid radiation" (Hartmann), "bioradiation" or "water veins".
Actually these rays have nothing to do with water as a cause. Water with its high dielectricity however favours and influences the course and the local distribution of the radiation. The maximums of the standing wave considered for themselves result lines in straight as a die in the landscape. Of Tesla is known, that he measuring technically could detect the cross points of the lines, which he called oscillation nodes. There exist so-called dowsers, who can make these standing waves out even without technical aids. For that they hold a fork in their hands, which suddenly moves over such lines.
Let's remember that the same potential vortices are used at the nerve conduction as reaction potentials to conduct stimuli. If ring-like vortices arrive at a muscle, it contracts without knowing, if the signal was sent from the brain over the spinal cord or picked up from the environment over the fork and the hand.

Thus if the same signals, which we use for the tasks of controlling and thinking, are also produced by technical apparatus, then this touches the question of the environmental compatibility in a direct way. Above extremely strong points of resonance, which are called "geopathic zones", now and then even is warned about "psychotronics", a function trouble of the brain, which can show in a disturbance of the waking consciousness.
A possible explanation would be that the brain is occupied with so much vortices picked up from the outside, that it isn't able anymore to accomplish its actual tasks. For muscle cramps or an inexplicable crash of a PC an correspondingly interpretation would be obvious.
As long as no gauges are available, the highest caution is imperative!

If Tesla had been able to put into operation his transmitter tower for longitudinal waves ("World Telegraphy", Wardenclyffe, Long Island, s. fig. 9.10) with the estimated power of 7.5 Megawatt and thus had been able to realize his dream of a world-wide wireless communication, then this could have had hardly estimable consequences for the health of the world population.
Shortly before the completion of the project, in the year 1905, Tesla without notice let stop all work. He to that never made an explanation to anyone. Officially it was said, his financial backer J. P. Morgan would have withdrawn his financial means. In any case was Tesla financially ruined with this step.
Perhaps also T. A. Edison was behind it, who was his opponent at that time. Edison committed himself engaged for the use of direct current. Against the alternating current, preferred by Tesla, Edison argued with unhealthy risks, and with that he perhaps wasn't so wrong at all.

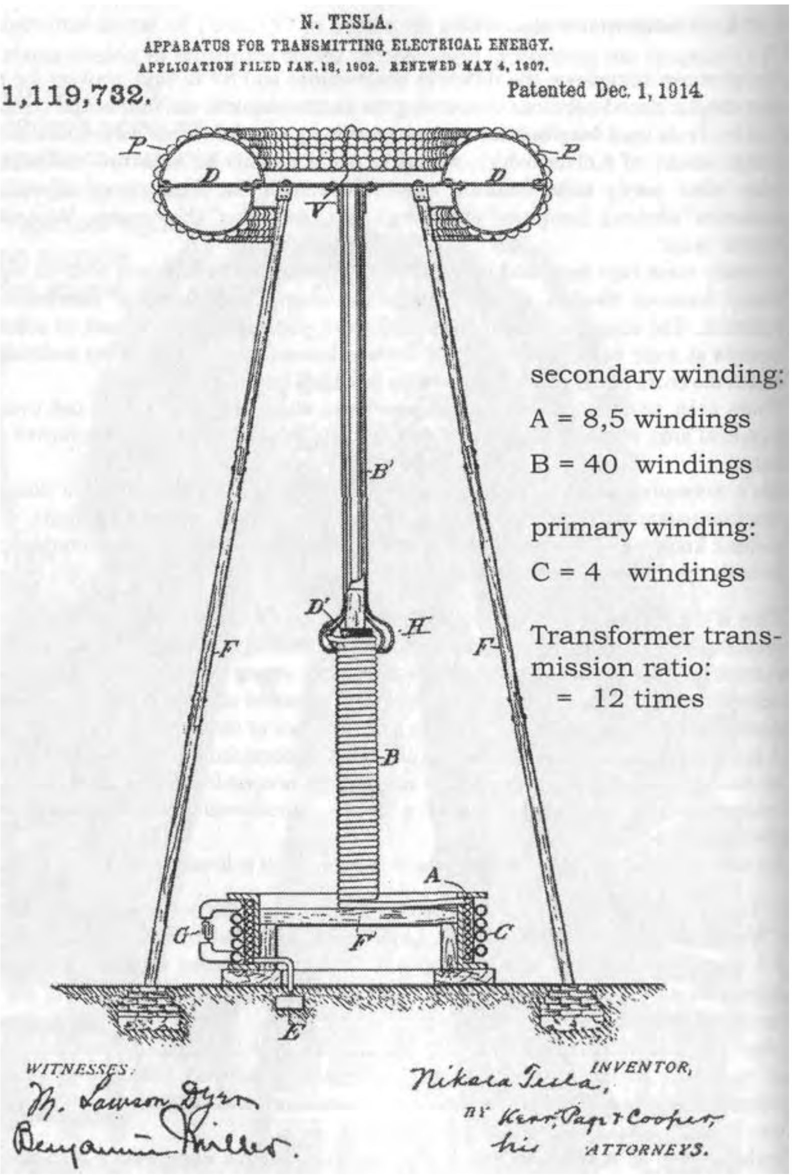
N. TESLA.
APPARATUS FOR TRANSMITTING ELECTRICAL ENERGY.
APPLICATION FILED JAN. 18, 1902. RENEWED MAY 4, 1907.
1,119,732.
Patented Dec. 1, 1914.
P
P
D
D
V
B'
D'
H
F
F
B
A
C
C
F'
E
secondary winding:
A = 8,5 windings
B = 40 windings
primary winding:
C = 4 windings
Transformer transmission ratio:
= 12 times
WITNESSES:
M. Lawson Dyer
Benjamin Miller.
Nikola Tesla, INVENTOR,
BY Kerr, Page & Cooper, his ATTORNEYS.

Fig. 9.11: Concerning the technology of the Wardencliff transmitter (fig. 9.10).<i>

<i>: Dr. Nikola Tesla: Complete Patents, (J.T.Ratzlaff), Tesla Book Company (1983), ISBN 0-960356-8-2, P. 435.

9.11 Ecologically fair usage

Tesla not only has stimulated ecologically fair usages of the energy radiation. To that can be counted the use of a Tesla transmitter as a radiation weapon<i> as well as the mentioned building of a Tesla interferometer, the low-frequency interferences of which can lead to mighty gravitational waves and with help of which it should be possible, to produce earthquakes, to sink ships or to shoot down planes from the sky<i>. Against the background of two world wars it can be understood, why Tesla has drawn attention to the possibilities of a use of his system for the purpose of defence.

In today's sight a technology like Tesla's wireless energy transmission (fig. 9.11) hardly would have any chance of a large technical use, because it should be reckoned with enormous problems of environmental compatibility. After all had come out in our considerations, that entirely in contrast to the Hertzian wave just of the Tesla energy wave direct biological effects are to be expected. A purposeful medical use of the Tesla rays however can be imagined.

The collecting of "free" energy waves with a neutrino receiver at first undoubtedly would be a clean and ecologically fair alternative to the present energy technology, with which we heat or nuclearly contaminate our environment. But even the use of free energy converters has limits. Should it turn out that the Photosynthesis uses such a materialization, in which the necessary free electron for the chemical reaction actually is produced from a caught neutrino in the so-called reaction centre and thus the reaction energy is won, then for an as usual excessive use by men it can't be excluded anymore, that the plants on earth die and nothing grows anymore!

I in contrast attribute big chances to the one wire transmission technology. Because for an use of alternative and regenerative energy sources, like the sun in the desert or the geothermal energy in Iceland, the transport of energy has to be made over large distances through the oceans the small losses and the possibility to be able to use sea cables, play a big role. In the residential areas and conurbations on the other hand it has a positively effect, that by the concentration effect of the potential vortices the interference radiation is directed inward. Laid on the bottom of a sea or of a river, such a line in addition is protected against the effects of lightning and sabotage, and it neither spoils the countryside, as the old-fashioned high tension pylons do.

For transportation tasks the mentioned making use of the spin coupling would surely be the most suitable drive. The denser the medium, the more efficient would be the driving effect, for which reason not only flying objects, but quite particularly also ships and submarines could be operated non-polluting in this way without combustion and without exhaust fumes. Build up effects by the water pressure or the sound barrier don't occur. But control might not be entirely unproblematic. If for the reason of a unipolar arrangement of the field a relative velocity to compensate the field becomes necessary, then a correspondingly build up arrangement will do so without considering losses. It is no accident that most apparatus which got well-known have flown the builder sooner or later "past his ears" (note of the translator: broke into pieces). Till a commercially utilizable flying saucer has been built, many technological hurdles have to be taken.

Claims to an up-to date environmental policy
in view of longitudinal electromagnetic energy waves
= Tesla waves = neutrino radiation = scalar waves
= potential vortex waves:

---

1. Gauges must be developed and built, with which the energy waves can be measured.

2. All technical apparatus should be tested regarding the emission of energy waves. Harmful radiation should be avoided.

3. Only such transmitter antennas may be brought into action, which emit a minimum of energy waves.

4. The ability of biological systems to absorb energy waves should be determined. To that also belongs the question, how many vortices collect locally and how fast they fall apart.

5. Limits for allowed pressure produced by artificially energy waves should be fixed, regulations and laws enacted.

6. The in nature available energy waves should be brought to a technical use, with the goal of a natural energy production.

Fig. 9.12: Catalogue of claims concerning the environmental compatibility in the view of the new field theory.

9.12 Claims concerning the environmental compatibility

Now we still not know, if the using of a handy or another electronic device poses a danger to the user. Now, we surely can't exclude a danger, and the statement of the manufacturer, it is safe because all limits have been met, is worth nothing, as long as the part of longitudinal waves isn't measured. Therefore stands at the very top of the list of the catalogue of claims (fig. 9.12) the development and the building of gauges to measure Tesla radiation. More than half the 700 patents of Nikola Tesla concern the building of transmitter and receiver installations for energy waves. Here a lot of valuable clues are found, especially as he himself has built and used some of the switching circuit designs. In the seminar a rebuild is discussed, with which 1995 the existence of longitudinal waves could be proven [A7].

For an earthquake always both, the transverse and the longitudinal wave, occur simultaneously and, taken exact the same is valid for the sound wave, even if the transverse part doesn't get too far in the air. The emission of both parts in analogy is almost to be expected of an electromagnetic wave generator or transmitter. Actually both waves are detectable at the receiving point: The useful transverse wave and the longitudinally propagating vortices, which show as noise (fig. 4.7). If the vortices are predominant and the useful signal goes under in the noise, then a interruption of the radio operation occurs. Also small gardeners immediately near a radio station have made experiences as e.g. in a distance of one kilometre from the transmitter of RIAS-Berlin. They were able to light their allotments day and night with a neon tube, to which they merely had tied a free wire. The radio station immediately insinuated, that they in an illegal manner had tapped their useful wave and damped it. But it can't be excluded, that the transmitter has sent a longitudinal part in the ether too, which was responsible for the energy transport. But that suggests, that also at other transmitter antennas, thus for the mobile phones, the unwelcome parts is transmitted even than, if we don't use it at all.

Still another problem is added. If in a modern receiver radio waves arrive, then they roll up to a standing wave and according to fig. 1.4 to a vortex over the antenna. According to that we aren't able anymore to distinguish, if the transmission took place as Hertzian wave or as Tesla wave. The separation of both sorts of waves has to take place before the antenna is reached.

An up-to date measurement arrangement would look as follows: In front of the receiver antenna a path with a tunnel, which represents an insurmountable obstacle for the transverse waves (fig. 6.14), is placed. Then only the longitudinal waves pass the tunnel, and these at the end of the tunnel can be recorded and analysed with conventional technology. The tunnel is an elegant possibility, to make use of the part of Tesla waves. After all only this part is relevant with regard to the electromagnetic environmental compatibility. Concerning the above asked question we can take home at least one important realization. The probability is quite high, that you actually notice nothing of the handy radiation, because not every system react in the same manner to certain vortices. The resonance conditions regarding frequency, phase and position always have to be fulfilled, if an absorption of energy waves should occur. (fig. 2.10 B, E. coli bacteria). On the other hand it however can't be excluded, that just you or me synchronize according to frequency and collect 100 % of the transmitted energy radiation. In contrast to the Hertzian wave plays for that the distance to the source of interference only a secondary role! Seen that way worries would by all means be entitled ...

From Indian mysticism:

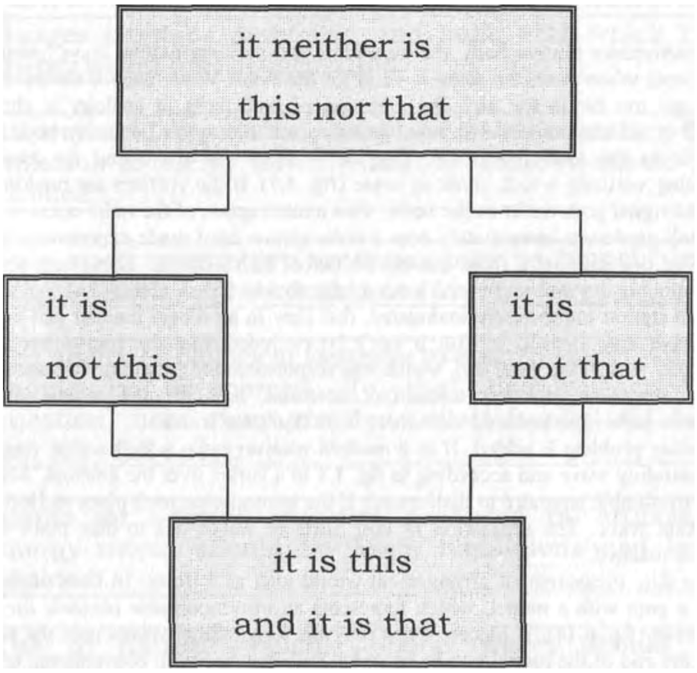
it neither is
this nor that
it is
not this
it is
not that
it is this
and it is that

Fig. 9.13: The structure of the world equation, an example from Indian mysticism

9. 13 Epilogue belonging to part 1

The correctness of a new theory not by all means guarantees, that it also is accepted! A new theory must be used. Only if a concrete need exists then an acknowledgement is to be expected if at first only by the direct beneficiaries.

In november 1994 in Munich the trade fair "Electronica" took place. Here invited by the Deutschen Gesellschaft fur EMV-Technologie (German association for EMC-technology, note of the translator) the books about potential vortices [Al, A2] were honoured with a prize by an internationally renowned EMC-scientist. The number of people, who the potential vortex theory helps further to find answers to problems, which until now aren't explicable, grows further.

Nevertheless, nobody should believe that something will be changed to the content of the text books in the shelves that fast. Habit and laziness encourage to further use the to date interpretation, even if a new theory has ready a better and convincing answer. It will take some time, to give an example, till the heating of water in a microwave oven is explained as eddy losses, as is described sound by the potential vortex theory already today. The discovery of a physical phenomenon may happen in a fright second. Its acknowledgement on the other hand as a rule is a lengthy procedure. If we look back in history we find out that even in the past it hasn't been otherwise.

Of the four fundamental phenomena in fig. 8.2 at first the tension voltages and the charges have been discovered by Coulomb (5.7e).

(5.7c): An effect of the eddy currents was observed already 1825 by the French physicist Arago. He discovered that a magnetic needle suspended above a rotating disc tends to rotate along. Out of ignorance he named the effect "rotational magnetism".

But the eddy currents could only be mathematically described with the help of two laws, the law of Ampere (1820) and the law of induction of Faraday (1831). Because the effect due to the eddy current losses rather was regarded as disturbing, technical applications or patents at first have stayed out. At first Riidenberg has carried out fundamental calculations for eddy current brakes in 1906. The discovery and usage of the "skin effect" is to be attributed to Tesla.

(5.7b): The electromagnetic wave for the first time was mathematically described by Maxwell (1864). He had aimed to calculate the light and he could show, that his theory actually could correctly describe all properties of the light. With that he was able to prove the correctness of his theory. But he had to deal with many sceptics, because he had postulated the dielectric displacement, without however in his lifetime being able to measure it because of its smallness.

This may be the reason, why the discovery is attributed to Heinrich Hertz and was and is spoken of the Hertzian wave. Neutrally seen Hertz at first was nothing more than a enthusiastic pupil, who had worked through the "Treatise"<i>, Maxwells books. All results, which Hertz could observe experimentally, already were contained in the Maxwell-theory and published.

<i>: James Clerk Maxwell: A Treatise on Electricity & Magnetism, vol. 2, Chapter XX: Electromagnetic Theory of Light. Dover Publ. New York

But the great mathematical description of Maxwell at first had a purely academic importance. The interest of the general public on the other hand concentrates on the practical applicability. Hertz had experimented with antennas and has laid the foundations of the building of a gauge for electromagnetic waves (1888). The wireless transmission of invisible waves was convincing. It was an entirely new technology, which stimulated fantasy in view of a technical usage. A practical man, who was stimulated by the theoretical realizations, was Marconi. He goes for the inventor of the radio (1895, Nobel prize: 1909).

Between the three summits, first the calculation and at the same time discovery, second the measurement and third the usage of the wave phenomenon lay 31 years, and the radio technology is developing still further, even today. In the area of the cellular phone network and the telecommunication even a kind of gold mining mood prevails, which can't be impressed much even by hints of an electromagnetic environmental compatibility.

In the euphoria of the past 100 years is fallen into oblivion completely, that besides the by Hertz detected transverse wave in the wave equation according to Laplace and according to the original version of Maxwell also a longitudinal wave was described mathematically. This one was discovered and detected by Tesla in numerous experiments. With reference to his discovery Tesla initially had asserted publicly, Hertz had been at fault, with which he undoubtedly was wrong and had incurred the wrath and the scorn of the scientific community. As a result of this development his experiments haven't been reproduced and the discovery of the scalar wave could fall into oblivion.

Not enough with such sanctions against the inconvenient freethinker Tesla a series of professors like Gibbs and Heaviside have made cuts and discarded all parts from the original version of the Maxwell equations, which by that time weren't considered to be experimentally proven by experiments of Ampere, of Faraday, of Ohm and Hertz. With that the scalar waves fell victim to the axe, what, though it had encountered severe criticism, finally entered as textbook opinion into all textbooks, after Hertz also had sanctioned this measure.

If the field equations according to Maxwell in today's revised version don't describe scalar waves anymore, then all orthodox scientists, who want to bear reference to that, have to bear one thing in mind: discarding a term of an equation is the same as neglecting it. But the term only may be neglected if it is sufficiently small. The first thing every student learns in the physical practical training is that this first has to be tested. For that the term has to be measured and its order of magnitude must be determined. Then it is little helpful and extremely unscientific, if at first is neglected and on the basis of the revised field equations, which have put all scalar waves to zero, is demonstrated that the neglect was allowed or even necessary.

A practical example are the longitudinal wave parts, like they occur and are proven in the near-field of a transmitter antenna. Considering the order of magnitude a neglect is out of the question. On the other hand they should not exist at all according to textbook physics, because they had fallen victim to the axe. Since most scientists in present time do not know about the cutting action anymore, they are postulating field vortices anew in the proximity of an antenna. Field vortices, which are propagating longitudinally in the direction of a field pointer as a scalar wave.

With that they calculate their own arbitrary assumption<i>.
If in the practical training of physics a student unevaluated neglects an essential factor of influence, then his experiment goes as not passed. The experiment must be repeated so long until according to the approved methods of scientific soundness all used neglects have been tested individually and have undergone an error consideration.
Do we now have to deny the cutting action, which had been plotted by Gibbs, Heaviside and others, having the necessary scientific soundness? Do we have to review and rework all textbooks concerning the illegal neglect? Since the cutting action a gap gapes in the field theory!

(5.7d): The potential vortex fills the remaining gap in fig. 8.2. Several research scientists and scientists can be named, who already could observe this phenomenon: in front of all goes Nikola Tesla for discoverer of the Tesla currents, very weak currents which are said to cause extremely high potentials. Here presumably cause and effect have been mixed up, because weak currents never can produce high potentials. Actually the potentials prove to be a result of the potential vortices, whereas the currents aren't more than a result, nothing but leak currents. At least Tesla could use the vortex, but without a usable theory he neither could calculate nor adequately explain it. Besides Tesla Wilhelm Reich should be mentioned, who has collected the vortices in his orgone accumulator.
Mostly only certain aspects were observed and investigated: by Tesla the planar vortex, by Reich the influence on the weather, by Schauberger the water vortices and by all three the medical and biological aspect. The list of names is incomplete and could arbitrarily be continued.

With the discovery of the potential vortex (1990) the basis for the building of a gauge and the technical usage of the physical phenomenon is laid [Al]. It not only concerns the search for water, but also the detecting of the vortex balls and vortex streets, of the standing waves of the energy radiation in the air, at the workplace, at the bedroom, in clinics, in recreational areas and hotels. As explained at the start, neither the field strength of a Hertzian wave nor the arising heat development can be made responsible for biological or technical harm.
It primarily are the newly discovered vortices of the electric field, which take effect. The effects can, as we have seen, as well be good for health as bad for health. Intensity, plane of polarization, vortex configurations and many other characteristics play a role here. To research these influential factors gauges for vortices will be needed as well.
We have to realize that in the technical domain the electromagnetic compatibility of an apparatus is determined by its sensitiveness to vortices, thus by the fact how many and which vortices can cause a function trouble. To determine the environmental compatibility of a product the emitted vortices, the energy radiation, have to be measured. Limits for high tension lines, for screens or handheld phones must be given in units of the potential vortices. The potential vortex has shown us the way to a unified theory and has brought along a new picture and understanding of our environment. It with that wants to show us the correct way for an ecologically compatible dealing with nature.

<i>: Zinke, Brunswig: Lehrbuch der Hochfrequenztechnik, 1. Bd., 3.Aufl. 1986 Springer-Verlag Berlin, Seite 335

Part 1: Edition belonging to the lecture:
"Electromagnetic Environmental Compatibility"

Prof. Dr.-Ing. Konstantin Meyl

Scalar waves

Abstract:

1. Auflage 1996, 4. Auflage and 1st English Edition 2003

Both technical and biological systems can be influenced by electromagnetic fields, whereby numerous questions still are open, like e.g. concerning limits and the nature of physical interference fields. The book shall do justice to the circumstance, that a fact oriented discussion about „electrosmog" implies an analysis of possible reasons, a mathematical derivation and a physical argumentation.

We proceed from the assumption, that only that part of the electromagnetic wave should be considered for malfunctions, which has been absorbed and which has rolled up to a field vortex. The effectiveness depends on the amount of the produced vortices and on the life span, the decay of vortices.

Analogous to the sound wave vortices in space are propagating as longitudinal waves. In this context is pointed to numerous effects. Examples for the technical and biological use of these standing waves are the energy transmission of Nikola Tesla as well as the nerve conduction, which functions in a corresponding manner. If the same vortices, which man uses for conduction of information, are emitted by technical devices, then biological reactions can't be excluded anymore and worries with regard to „electrosmog" seem to be justified.

Causes, phenomena and natural scientific consequences

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Scalar Waves

From an extended vortex and field theory to a technical, biological
and historical use of longitudinal waves.

Part 2

by

Professor Dr.-Ing. Konstantin Meyl

Edition belonging to the lecture and seminar "Electromagnetic environmental compatibility"

(Original title: "Elektromagnetische Umweltvertraglichkeit")

Translated out of the German language
by Ben Jansen
(2000-2003)

* * *

Part 2: Edition belonging to the energy technical seminar

Free energy and the interaction of the neutrino radiation

***

INDEL GmbH, Verlagsabteilung

Villingen-Schwenningen 1996-2003

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Preface to the seminar

The point of a seminar is, to deepen, to practise and, as far as possible, to practically appy the material of a lecture. The knowledge of the content of the lecture hence is a prerequisite for the participation.
For the reader of this book that's tantamount to the recommendation, to have read the first part, the edition belonging to the lecture, before*¹*. Here the questions concerning the „electromagnetic environmental compatibility" are asked and the necessary bases for their answering is laid. Also practical consequences for various areas of science are indicated. The deepening most suitable should be made in form of a seminar, subdivided into the here presented part 2 to the energy technical seminar and a part 3 to the information technical seminar. Part 2 correspondingly concerns the energy technical aspect of electric or magnetic longitudinal waves, whereas part 3 is dedicated to the information technical aspect<ii>. Because it concerns a book which merely for reasons of usefulness is published in three parts, the chapters are consecutively paginated. References to chapter 1 to 9 hence automatically relate to part 1. The numbers of the figures and tables as a rule are identical with those of the chapters, in which they are discussed.

The seminar should lead on over the pure reading, consuming or listening and should stimulate to join in. All involved persons may and should give ideas and ask questions, even if these may sound little orthodox. The scientific working method takes, that is struggled for answers and even is argued, if necessary. To reach this goal, it mustn't exist any obligation or censorship, neither for the leader of the discussion nor for the participants of the seminar.

The seminar is being carried out since the summer semester 1997. The works of the seminar written by students treat the knowledge of text books of the respective theme. Following the lecture the answers are discussed and compared to those of the theory of objectivity<i> and other models of explanation. This procedure in this edition belonging to the seminar is reflected at some points, if for instance a chapter is completed with a „discussion".

The first edition of this 2nd part still was incomplete and has been handed out to the participants of a congress in Switzerland instead of a manuscript belonging to the lecture the 17th of Nov 1998. The here presented second edition in the meantime to a large extent is complete, but surely not yet perfect. In accordance with the experience made with the first part of the book also for this 2nd part a third and revised edition, in which the ideas of the participants of the seminar and of the readers find consideration, will be due to be dealt with after a year. The reader of the second edition has to console himself with the fact that a lively seminar constantly is changing and developing further. And that has to be so!

Villingen-Schwenningen, January 1999

<i>: Electromagnetic environmental compatibility, Part 1, Edition belonging to the lecture, INDEL Verlagsabteilung, 1996, see page 1-218 of this issue.

<ii>: Electromagnetic environmental compatibility, Part 3, Edition belonging to the information technical seminar, 2002, see page 443 - 625 of this issue.

10. Oscillating interaction

A theory is not an end in itself, even if it sounds very convincing. It has to be measured by its applicability. As an entry into the practical consequences, which result from the theoretical part[i], the question about the validity of Kepler's laws is raised.

10.1 Kepler's laws

The "radius vector", a line drawn from the sun to a planet, sweeps out equal areas in equal periods of time. At least has teached us Johannes Kepler it that way (fig. 10.1). The balance of forces, the gravitation on the one and the centrifugal force on the other hand results in the innermost planets of our solar system orbiting the sun very much faster than the outer planets (Mercury in 88 days, the Earth in 365 days, Jupiter in 4333 days and Pluto in 90465 days!).

For the inner planets as well as the big planets Jupiter and Saturn Kepler's laws are still found confirmed. But that shouldn't apply anymore for the outermost planets of the solar system. Beyond Saturn should prevail changed rules as is said, based on observations of the Voyager spacecrafts[ii].

If we direct our view to an unknown galaxy, then does it rotate around its centre and in doing so to a large extent keeps its form. Despite rotation of its own an elliptic, a barred or even a spiral galaxy virtually doesn't change its characteristic form. From this follows, that the inner stars of a galaxy are considerably slower on their way than the outer stars! But we expected exactly the opposite.

According to Kepler's regularity the outermost stars would have to orbit extremely slow, In order not to be hurled into space as a result of the centrifugal force. But then a galaxy wouldn't keep its structure. The spiral form, as it already has been observed and classified by Hubble (fig. 10.2), merely would be an accidental exception as a momentary picture, but by no means the rule.

We have to take note, that the structure and in particular the cohesion of a galaxy can't be explained with Kepler's laws[iii].

<i>: Konstantin Meyl: Electromagnetic environmental compatibility, Part 1 of this book: Causes, phenomena and natural scientific consequences.

<ii>: Kendrick Frazier: Das Sonnensystem, Time-Life Bucher, Amsterdam (1991)

<iii>: The basic laws of the universe start to rock: ,,What is the matter with the galaxies? They rotate in their fringe ranges much faster, as is allowed by the laws of physics. Or is something wrong with these venerable laws? The astronomers and physicists stand for the dilemma to have to decide between the two alternatives: feign the observations us an other world or do we calculate wrong since centuries?" (translated), Bild der Wissenschaft Nr. 2, 1989

Kepler's 1st law:

The planets move in elliptical orbits, with the sun at one focus.

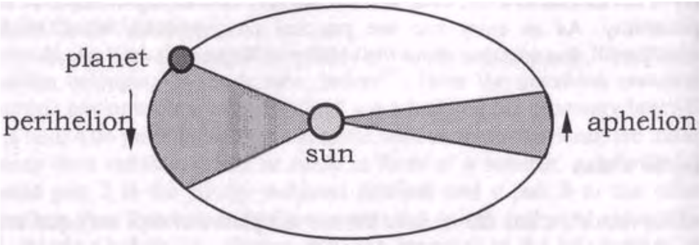
planet
perihelion
sun
aphelion

Fig, 10.1: Kepler's 2nd law (concerning the conservation of angular momentum):

The line drawn from the sun to the planet sweeps out equal areas in equal periods of time.

Kepler's 3rd law:

The ratio of the squares of the revolutionary periods of two planets is equal to the cube of their average distance to the sun:

$$\frac{t_1^2}{t_2^2} = \frac{r_1^3}{r_2^3} \qquad (10.1)$$

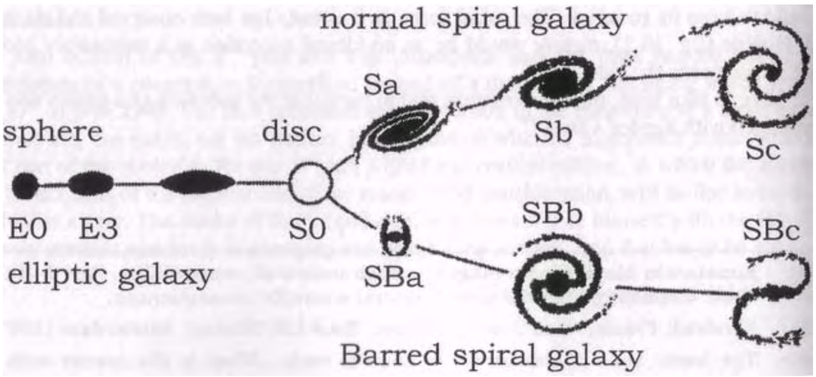
normal spiral galaxy
Sa
sphere
disc
Sb
Sc
E0
E3
S0
SBb
SBc
elliptic galaxy
SBa
Barred spiral galaxy

Fig. 10.2 The classification of the galaxies according to Hubble<i>

<i>: according to H. J. Lugt: Vortex Flow in Nature and Technology, page 223

10.2 Unknown interaction

So which interaction keeps a galaxy together? We today believe to know four different sorts.

I. The gravitation<i>: But since Kepler's law isn't valid in this case anymore, the gravitation is ruled out from the start. Obviously for the distances in a galaxy it hardly is effective.

II. The electromagnetic interaction: It is responsible for the structure of the atoms. Looked at from the outside atoms carry no charge, i.e. the charge conditions are balanced. A binding of our sun to the centre of the Milky Way by an electromagnetic interaction thus is ruled out as well.

III. The strong interaction: Since for the proton another charge distribution is measured, as a single positively charged particle should have according to the normally used theory, the strong interaction was introduced as a nuclear force, to explain the big error, the grave difference between measurement and calculation. The good advice hence reads: instead of giving birth to postulates at random, first of all the fault should be searched for in the normally used theory<ii>!

IV. The weak interaction: It quite obviously is involved in the particle decay<ii>. Both, the weak and the strong interaction, only have an extremely short range. With this property they consequently won't be able to keep a galaxy together.

Conclusion: In a galaxy a still unknown interaction takes effect, and science is requested to search it.

Both interactions with infinite range, the electromagnetic interaction and the gravitation occur as a result of static fields, therefore assume a constant charge or a constant mass. Considered more exactly in that case it merely can concern special cases. Gravitational waves, which reach our earth and which are detected in very costly experiments<iii:>, already show that the existence of alternating fields can't be excluded and oscillating interactions by all means are conceivable! The physical research at present probably is on the right track. The researchers however don't have ready an usable explanation yet. We accept the challenge!

<i>: Derivation of Kepler's 3rd law in fig. 11.10

<ii>: Konstantin Meyl: Potentialwirbel, Band 2
INDEL-Verlag, Villingen-Schwenningen 1992, ISBN 3-98O2542-2-4

<iii>: Gero v. Randow: Wenn kosmische Katastrophen Raum und Zeit verbiegen, zum Thema Gravitationswellen-Detektor, VDI Nachrichten Nr.9, 1.3.91, S.32

Analogy:

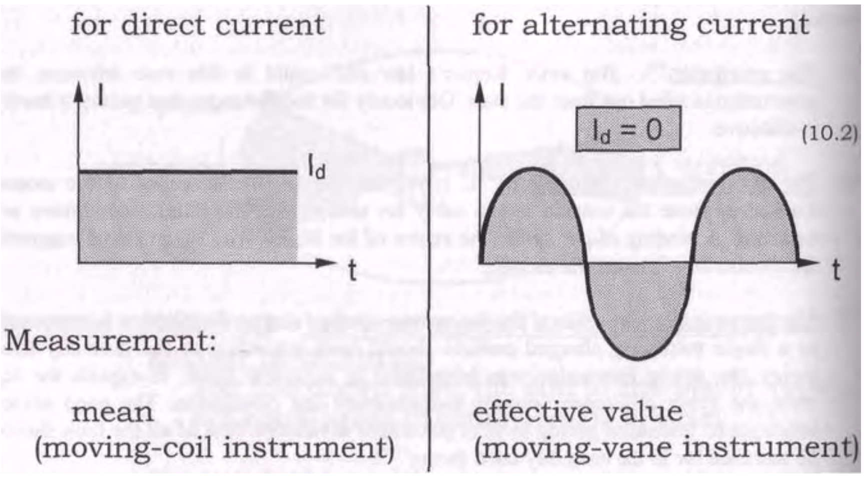
for direct current
I
I_d
t
Measurement:
mean
(moving-coil instrument)
for alternating current
I
$I_d = 0$
(10.2)
t
effective value
(moving-vane instrument)

Fig. 10.3: Direct current and alternating current

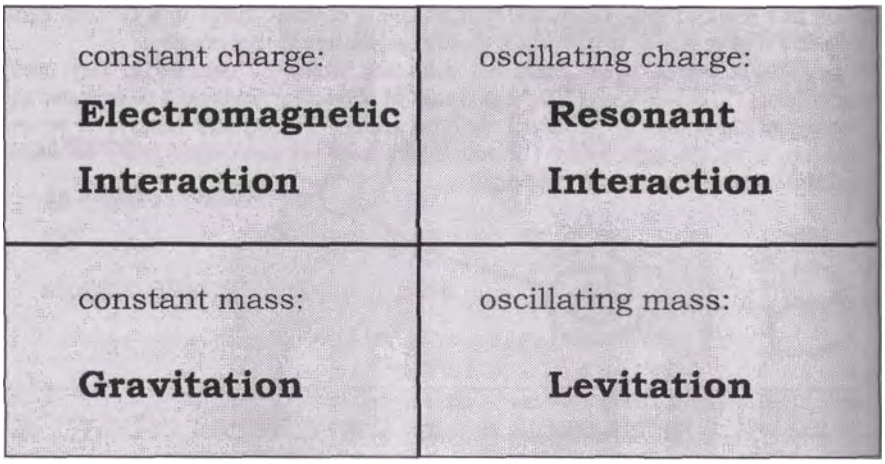

constant charge: **Electromagnetic Interaction**	oscillating charge: **Resonant Interaction**
constant mass: **Gravitation**	oscillating mass: **Levitation**

Fig. 10.4, a: The four fundamental interactions

10.3 Harmony of the alternating current engineers

Today's situation can be clarified by the following picture: you engage a "direct current engineer" to measure the tension voltage in the socket of our power supply system. The „dyed-in-the-wool direct current engineer", who never has heard anything of alternating current, reports: „No tension voltage is measurable". If he for reason of your doubtful expression looks still more exact he will realize: ,,The pointer of my moving-coil instrument strangely fidgets around zero, but the swing is so small that one confidently can touch it", (fig. 10.3)
Modern science is accustomed to say, without a valid theory and without technical measurability nothing can exist, what mustn 't exist. If you drop dead after the experiment, then you probably had a weak heart or other afflictions. In such cases as a rule the victim himself is to blame and by no means theoretical physics!

In the case of our power supply system the answer is known: The mean of the alternating voltage of the network is approximately zero. The pointer of a moving-coil instrument for reason of its inertia can't follow the fast changing anymore and only fidgets on the spot. The effective value however amounts to around 230 Volts. But to measure it you need another device, for instance a moving-vane instrument. Seen so, direct current describes the special case of alternating current with frequency zero.

The properties of alternating current can be depicted best by an extraterrestrial observer. He will tell us: Seen from a distance at least at night a great harmony seems to prevail on earth. All lights in the streets and cities twinkle completely synchronously. All generators are in resonance among each other and with all consumers. There are two big races: The 50 Hertz race and the 60 Hertz race, which appear if the earth turns further and the 50 Hertz race is switching off again its twinkling lamps.

The synchronization necessary for an exploitation of alternating fields is so obvious for us, that hardly anybody realizes, that a consumer operated with only one Hertz difference to the frequency of the network can't be supplied with power anymore. Apart from the correspondence in frequency it even depends on the correct phase. The phase angle must be between 0 and +90°. This corresponds to an efficiency factor $\cos\varphi$ between 1 and 0. The cable connections serve both the transport of current and the synchronization of all the generators and consumers connected to the network. The frequency is kept so constant that simple clocks, switching stations and even old record-players can be operated synchronously with the frequency of the network.
The synchronization of the feeding in power stations is supervised by a station of its own, which dictates the time. It is true that we aren't capable of seeing the twinkling of the lamps anymore for reason of the inertia of our eyes, but it can be detected and filmed with high-resolution cameras. Even if we can't perceive the harmony of the alternating current engineers, it nevertheless exists.

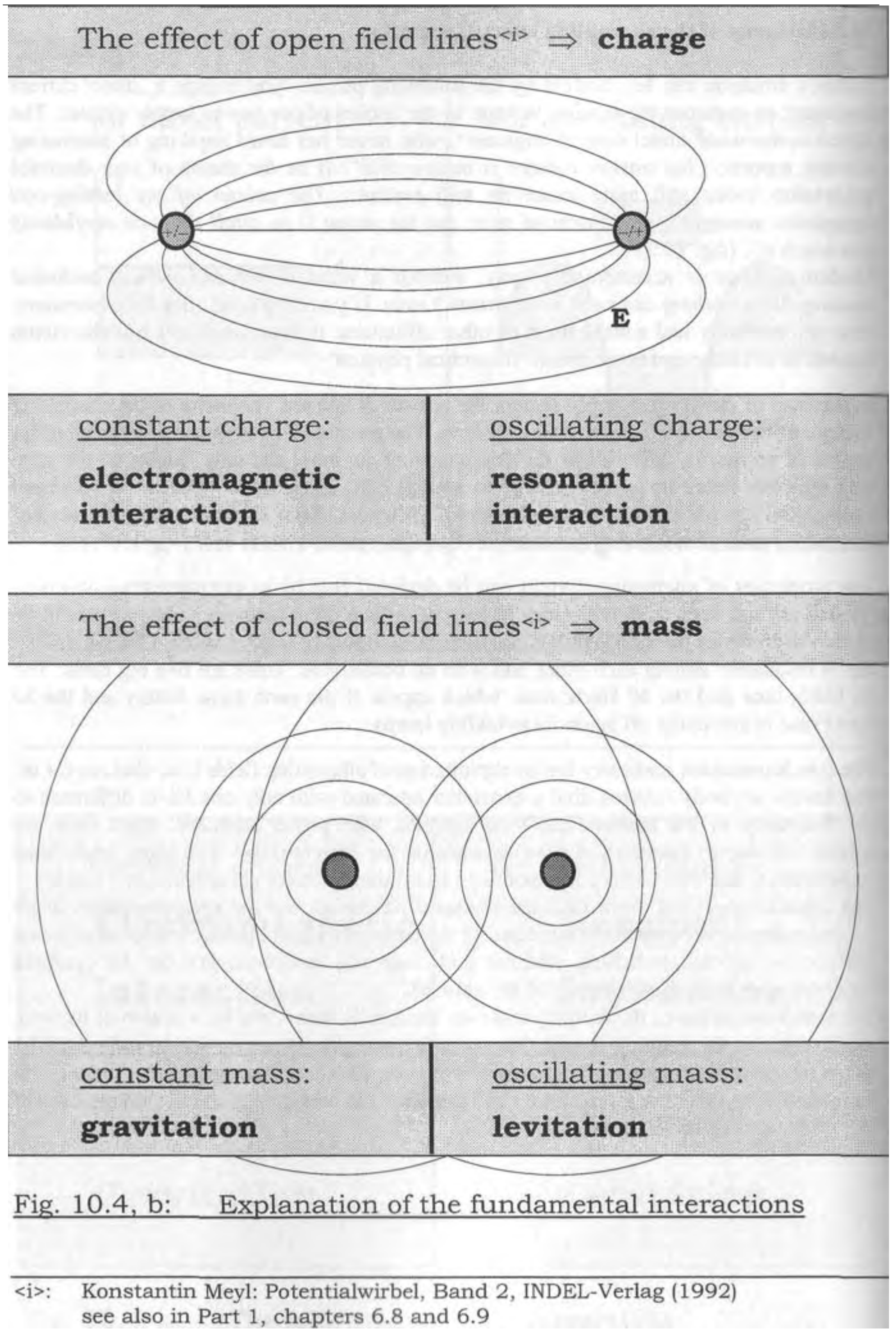

The effect of open field lines<i> ⇒ **charge**

constant charge: **electromagnetic interaction**	oscillating charge: **resonant interaction**

The effect of closed field lines<i> ⇒ **mass**

constant mass: **gravitation**	oscillating mass: **levitation**

Fig. 10.4, b: Explanation of the fundamental interactions

<i>: Konstantin Meyl: Potentialwirbel, Band 2, INDEL-Verlag (1992)
see also in Part 1, chapters 6.8 and 6.9

10.4 Four fundamental interactions

These considerations suggest, that also gravitation and electromagnetic interaction merely describe the special case of oscillating interactions with frequency zero. To avoid confusions, we'll have to think of new names.

The electromagnetic interaction can be clarified by means of open field lines, which start at a charged body and end again at another body of unequal charge. In physics classes it is normal to make the field lines of a magnet visible with iron filing. Between the unlike poles a force of attraction is observed[i].

If we this time assume that both magnetic poles change their polarity at the same time, then the force will decrease for a short time during the changing of polarity, to afterwards be active again in full magnitude and in the same direction. Therefore a force of attraction is observed again even for a reversed polarity.

The generalization hence reads: The electromagnetic interaction will occur also in the oscillating case, but in weakened form, if both bodies involved in the interaction change their polarity synchronously and if they are in resonance. A name by analogy would be "resonating interaction" (table 10.4).

It is known of the electromagnetic interaction, that its effect is larger than that of the gravitation by powers often. This presumably has to do with the described and observable bundling up of the open field lines, whereas closed field lines can't be bundled up. The gravitation hence is linked with the closed field lines, which surround all elementary particles, every atom and every body[i].

The opposite of the bundling up is the repulsion of open field lines, for which reason here also forces of repulsion can occur. For the gravitation however no repulsion is observed, because closed field lines virtually can't be influenced.

Apart from the circumstance that the effect generally will be smaller in the oscillating case, similar properties are to be expected. Also its range will be infinite as well. It is recommended to call the case of oscillating charges, as already said, "resonating interaction" and the case of oscillating masses, the oscillating gravitation, ,,levitation" (table 10.4).

The term ,,levitation" is very appropriate, but not new. Unfortunately until now no generally binding definition existed, what should be understood by that, for which reason misinterpretations and irritations can't be excluded. Mostly levitation is linked to a cancellation of gravity, up to a state of free floating, but we will see that quite other phenomena become describable with this term.

10.5 Resonating interaction

The question, what keeps a galaxy together, now can be answered unambiguously. The well-known interactions already have been excluded. If for the enormous distances the gravitation can't keep the outer stars anymore in accordance with the Kepler rule, then the levitation won't be able at all.

Example: central star S_z with 3 planets P_1-P_3
and with 4 neighbouring stars S_1-S_4

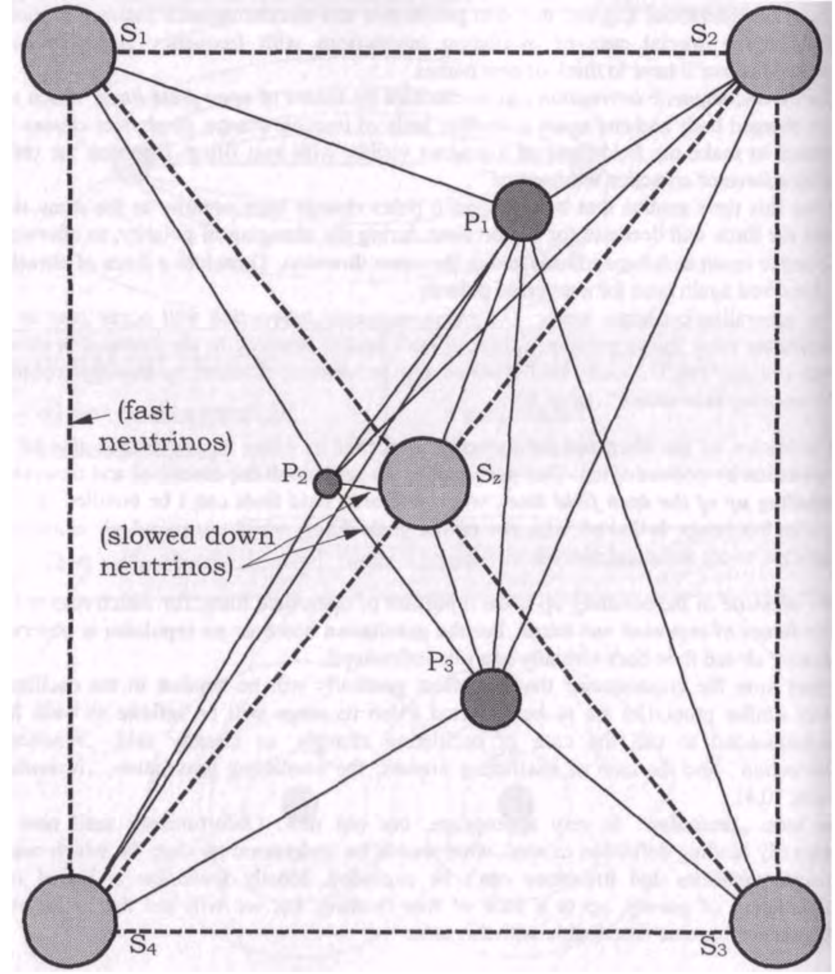
S₁
S₂
P₁
(fast neutrinos)
P₂
S_z
(slowed down neutrinos)
P₃
S₄
S₃

Fig. 10.5: The invisible threads of a resonant interaction

milky way-radius: $15000\text{pc}*3*10^9 = 45*10^{16}$ km
sun system-radius: $50\ \text{a}*15*10^7 = 7,5*10^9$ km

$$\frac{45\cdot 10^{16}}{7,5\cdot 10^{9}} = 1,27\cdot 10^{8}$$

the resonant interaction is more than eight decimal powers bigger than the gravitation!

Therefore the oscillating charge is left. Actually the resonating interaction will reach to the outermost areas of a galaxy. The bundling up of the field lines results in the centre of the galaxy and one of its stars to stand in an exclusive resonance to each other, what looked at from the outside looks like, as if the star hangs at an invisible string or a "rubber band" and thus turns around the centre.

Because quite a few stars hang at the centre of a galaxy, it can be assumed that it provides correspondingly many resonance. The centre perhaps is comparable with an extremely broad banded transmitter, which operates on all channels simultaneously. The stars then pick as a receiver the for them suitable channels and hang themselves by „rubber band" at the heap (fig. 10.5).

Should there exist any particles with an oscillating charge, which synchronize between centre and star with the resonating interaction, then they will mediate between both partners. If we assume that the centre at one channel just is positively charged, then all at the same time negatively charged particles will be attracted, the positively charged particles however repelled. Whereas the unlike particles in the centre participate directly in the production and maintaining of the oscillation, the like positively charged particles will be hurled into space.

But at the same time does a star, which clings to the centre, have to be negatively charged. It hence attracts the repelled particle. The particle thus drifts from the centre to the star, even then if all three, the centre, the star and the particle, change in polarity. The result is, that the stars grow in diameter by collecting the particles. Only because our sun actually grows, it has the chance, to sometime become a red giant!

Since the sun radiates, as is well-known, in every second a radiation equivalent of 5 million tons, it permanently has to be supplied with a substantially greater amount of matter. If a resonating interaction should occur, then our sun will get its „material" supplied from the centre of the Milky Way and that is a black hole!
But no particle with a mass comes out of such a hole, yes not even light. For a particle to be able to leave the black hole, it should have neither charge nor mass. At most an oscillating charge and mass would be allowed. Such a particle would have an enormous ability of penetration as a result of the missing static interaction. It would be able to rush through the earth unhindered.

According to actual knowledge only neutrinos have the described properties. One also knows that the centre of our Milky Way represents a mighty source of neutrinos. From this derivation follows:

1. As mediators of the resonating interaction serve synchronously oscillating neutrinos.
2. Starting with the proof of the neutrinos it should be able to backwards also prove the existence of the resonating interaction.
3. If, as a practical consequence, we imagine that the centre of the Milky Way wouldn't supply neutrinos anymore. Then the whole galaxy would fall apart and not one of its stars would shine anymore.

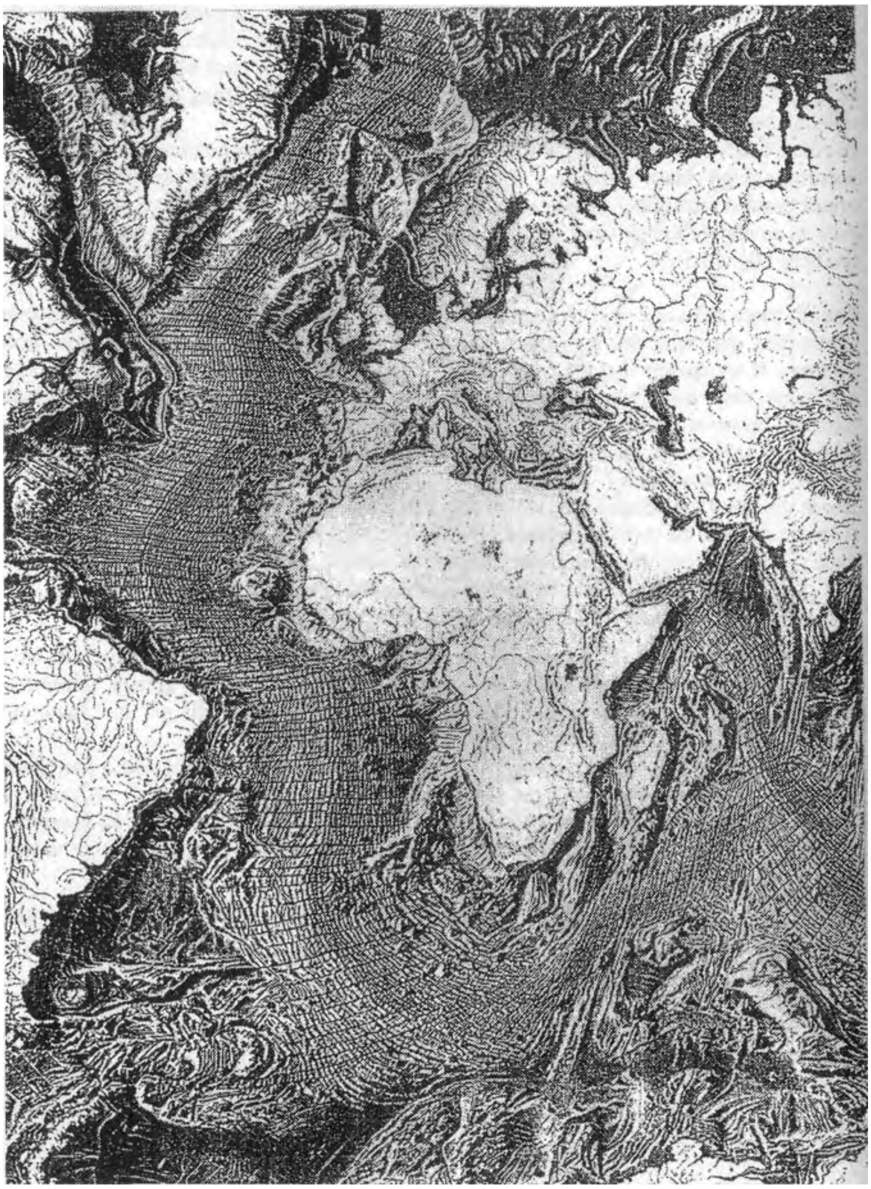

Fig. 11.1: The Atlantic ocean floor<i>

<i>: Miller, R.: Driftende Kontinente, Time-Life, Amsterdam 1991, S. 79

11. The growing globe

11.1 Long-distance effect of the neutrinos

The long-distance effect thus lies in the circumstance that the neutrinos, in the case of a resonance of the source of neutrinos and the receiver, span an invisible „rubber band" between both, which is called resonating interaction and keeps the two together.

As a transmitter of neutrinos functions for instance a supernova, the death of a star, in which 98% of the mass annihilates under emission of neutrinos or a black hole, which continually swallows light and matter and spits them out again as neutrinos after a still unexplored „process of digestion". The process, which in the case of a supernova takes place as a singular occurrence, in a black hole possibly takes place permanently. The hurled out neutrinos on the other hand serve the sun as a source of energy. A receiver of neutrinos then for instance is our sun. So that the hard and very fast cosmic neutrinos become utilizable for the sun, they at first have to be slowed down. But that is only partly successful:

1. Some very fast ones manage to pass through the sun and fly out again on the other side of the sun. The compared to the cosmic neutrinos strongly slowed down neutrinos then are called solar neutrinos.
2. Another part can be further slowed down and materialized. As a result of the oscillating mass of the neutrinos as well particles of matter as also some particles of anti-matter are formed. The particles of matter make the sun grow.
i. The with matter incompatible anti-matter annihilates under emission of light as is well-known. For this and for no other reason our sun shines!

Also the planets have such a neutrino reactor at their disposal. Only so the heat in the inside of the earth is explicable! It can be assumed that the planets materialize less the fast and hard cosmic neutrinos and that they are served more by the slowed down solar neutrinos, which our sun releases again unused.
As is well-known radiates the planet Jupiter already today twice as much radiation energy, as it from the sun receive. In this typical encyclopaedia type balance the involved neutrinos of course are not considered. But it shows that Jupiter is on the best way to become a sun itself. Its moons then will become planets.
From this the example we also see that with increasing mass the crust of the planet becomes thinner and thinner at the expense of the neutrino reactor in the inside, until it finally is eaten up and the celestial body openly starts to shine. Astronomers report for reason of their observations of the formation of more and more new stars.

One part of the collected neutrinos thus is materialized by the planet. In the case of our earth it contributes to its growth.
Who doesn't want to believe that the earth becomes bigger, should look at modern maps of the oceans, on which the topography of the ocean floor is shown. According to the theory of Alfred Wegener concerning the continental drift North and South America on the one hand and Europe with Africa on the other hand steadily drift apart since 200 million years. The result can be read at the atlantic ocean floor. The gaping, chequered rift zones to the right and left of the Mid-Atlantic Ridge show how the earth is torn apart (fig. (11.1).

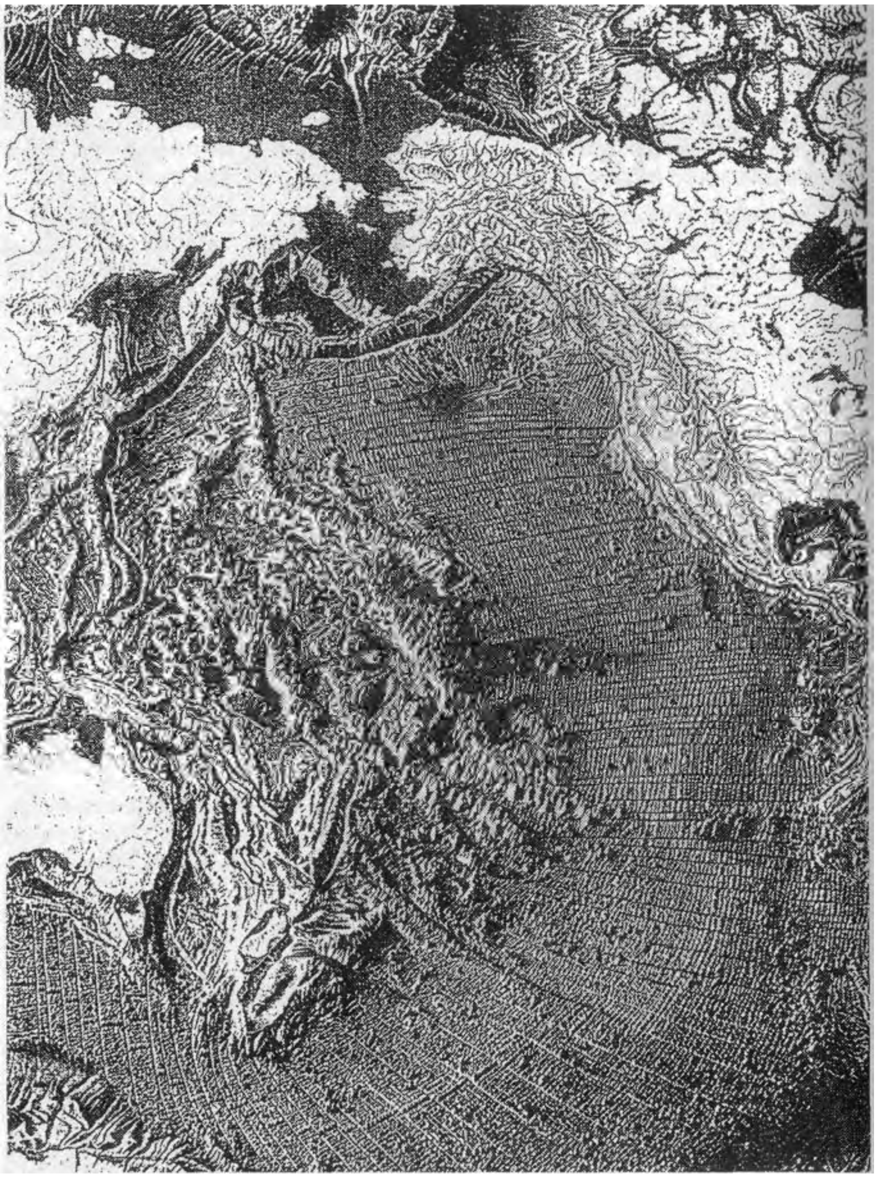

Fig. 11.2: The pacific ocean floor<i>

<i>: Miller, R.: Driftende Kontinente, Time-Life, Amsterdam 1991, S. 78

11.2 Model of expansion

Geographers assume that at another point to the same extent continental plates are subduced and molten. That thus has to happen in the Pacific Ocean. But the sea maps tell one just the opposite (fig. 11.2). At the ocean floor of the Pacific Ocean the same rift formations are found as in the Atlantic Ocean (fig. 11.1). That means that America drifts away from Australia and Asia exactly as from Europe, without being crushed or molten in doing so!
The only possible answer thus is: the earth grows.
The characteristic rift zones in addition are found around the Antarctic. From this the conclusion can be drawn that the 7th continent slowly is moving away, while the biggest habitable mass of land predominantly stays behind on the northern hemisphere, by Eurasia and North America forming a clip around the North Pole.

Concerning the evolution of the earth there are and were numerous approaches in various directions. Paul Dirac<i> at his time postulated, the brightness of the sun should decrease as a result of a decrease of the gravitational constant as well. In contrast to that Astrophysicists today observe just the opposite (Ingersoll 1987). According to the hypothesis of Carey<ii> energy will transform in matter in the universe. According to the idea of Oesterle<iii> aether particles are absorbed, which make our globe grow. Also other research scientists share the idea of the growth of the earth with him in their reports<i4,5,6>. As a geologist Oesterle<iii> cites his colleague Herzig: „The at the Mid-Oceanic Ridge newly produced oceanic crust has to be consumed again at other points, because otherwise the earth would expand" and criticizes the „plate tectonicians" that they would postulate their model without physical grounds.
He gives some arguments for the correctness of the model of expansion <iii>:

a) Subduction: The already discussed missing of zones of subduction and of melting of continental plates to the assumed extent.

b) Paleomagnetism: errors and mistakes in the hypothesis of the migration of the poles.

c) Continental depth drillings: They brought much higher temperatures in depths from 4000 meters, as expected and calculated according to models.

d) Stand of the sea water: Only if the water can spread in newly forming oceanic basins it can be explained, why the covering with water on earth continually is going back. This argument we want to investigate with a derivation of our own.

<i>: Dirac, P. A. M. Nature 139, p. 323 (1937)
<ii>: Carey, S. W.: Theories of the Earth and Universe. Stanford University Press: 1-413, Stanford, California
<iii>: Oesterle, O.: Goldene Mitte: Unser einziger Ausweg, Universal Experten Verlag, Rapperswil (1997), ISBN 3-9520261-9-0
<i4>: Hilgenberg, O. C: Vom wachsenden Erdball, S. 1-56, Eigenverlag, Berlin (1933) und Neues Jahrb. Geol. Palaont. Abh. 116, 1, Berlin (1962)
<i5>: Jordan, P.: Die Expansion der Erde. Vieweg 1-180, Braunschweig (1966)
<i6>: Giancarlo Scalera, K.-H. Jacob: Why expanding earth? Institute Nationale di Geofisica e Vulcanogia, Roma and Technical University of Berlin 2003

Today's earth:

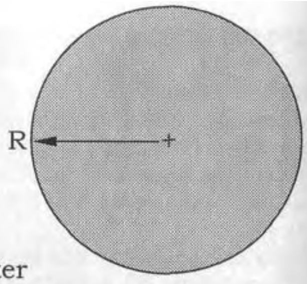

equatorial radius: $R = 6378$ [km]

earth's surface: $O_E = 4 \cdot \pi \cdot R^2$
(sphere) $= \underline{\underline{5{,}112 \cdot 10^8}}$ [km²]

29% of this area is land and 71% is water
for an average water depth of $t_w = 3.8$ [km] results a

water volume of: $V_w = 0{,}71 \cdot O_E \cdot t_w = \underline{\underline{1{,}38 \cdot 10^9}}$ [km³] (11.1)

The earth **200 million years ago** (super continent: **Pangaea**):

today's land area (29%) was 100% of the earth's surface!

Pangaea surface area: $O_p = 0.29 \cdot O_E$
$= \underline{\underline{1{,}48 \cdot 10^8}}$ [km²]
$= 4 \cdot \pi \cdot r_p^2$ (11.2)

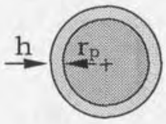

Pangaea radius: $r_p = \sqrt{O_p/(4 \cdot \pi)}$
(corresponds to $= \underline{3435}$ [km]
the radius
of the sphere of shelf): $= 54\%$ of today's radius

Pangaea volume: $V_p = \frac{4}{3} \cdot \pi \cdot r_p^3 = \underline{\underline{1{,}697 \cdot 10^{11}}}$ [km³] (11.3)

Pangaea was covered with water h [km] high:

volume: $V = V_p + V_w = \frac{4}{3} \cdot \pi \cdot (r_p + h)^3 = \underline{\underline{1{,}71 \cdot 10^{11}}}$ [km³] (11.4)

$= 15{,}7\%$ of today's volume of the earth

$r_p + h = (3 \cdot V/4 \cdot \pi)^{1/3} = 3443{,}8$ [km] (11.5)

Pangaea water-level h above the NN (sea-level) at that time:

$$\boxed{h = \underline{\underline{8{,}78}} \text{ [km]}} \quad (11.6)$$

Fig. 11.3: The calculation of the covering with water on earth 200 million years ago

11.3 Ancient Egyptian legend of Genesis

We don't have to search long for evidence. If we go back 200 million years in the history of the earth, as all continents still were united and formed the super continent Pangaea, as the 29% landmass of today thus constituted 100% of the earth's surface. At that time the diameter of the earth was almost half of today's diameter (exactly 54%). But if one distributes the amount of water of our oceans of today over the smaller earth, then possibly the water stood the young earth up to its ears in a first rough estimate. We now want to calculate how high the water stood.
For that we determine at first the water volume of today's oceans, by multiplying 71% of the earth's surface O_E with the average water depth. In doing so it is supposed that the water volume has not changed in the course of time. As an approximation this assumption could be correct if the factors, which influence the water volume, mutually compensate. On the one hand it has to be taken into account that in the process of fusion in the inside of the earth apart from other materials also juvenile water is formed, but on the other hand the water volume is reduced by photosynthesis and by the splitting of water molecules. In the case of the newly formed water it should concern roughly one cubic kilometre per year<i>. The photosynthesis however possibly can be estimated by means of the formed oxygen of the air just as the splitted water by the content of oxygen of the waters and the seas. Since the processes are subject to temporary fluctuations, the exact estimate is difficult. At least should an effect of compensation more or less be taken into account.

Next we calculate the surface of the earth 200 million years ago, the super continent, which Alfred Wegener called Pangaea. If the 29% continental land mass of today at that time constituted the whole surface, then the diameter of the earth at that time was determined at 54% of today's diameter, then the volume together with the water volume would amount to only 15.7% of today's volume and the water stood 8.78 kilometres high above the level NN at that time (fig. 11.3). With that even the highest peaks were under water.

Consequentially stands in the legend of Genesis of the ancient Egyptians:

„ They tell us that the earth was completely covered with water and that the earth rose from the water. It is talked about a primeval hill, of which creation took its start, on which the first sunrise and sunset was observed<ii>.

If at that time life only existed in the water, of which we today still can detect the remains in excavations in mountains and plateaus, then it surely wasn't because the evolution had forbidden living on the land. There existed no land! All land was lying under water. But if, looked into the future, the land area increases further at the expense of the surface of the sea, then our earth sometime will dry up, as already other planets before us, e.g. our neighbouring planet Mars.

<i>: Oesterle, O.: Goldene Mitte: Unser einziger Ausweg, Universal Experten Verlag, Rapperswil (1997), ISBN 3-9520261-9-0

<ii>: Robert Bauval und Graham Hancock: Der Schlussel zur Sphinx, List Verlag (1996), S. 253 and in der Sendung: Die grossen Ratsel VII am 25.5.97 in S 3

a. **Today's earth**:

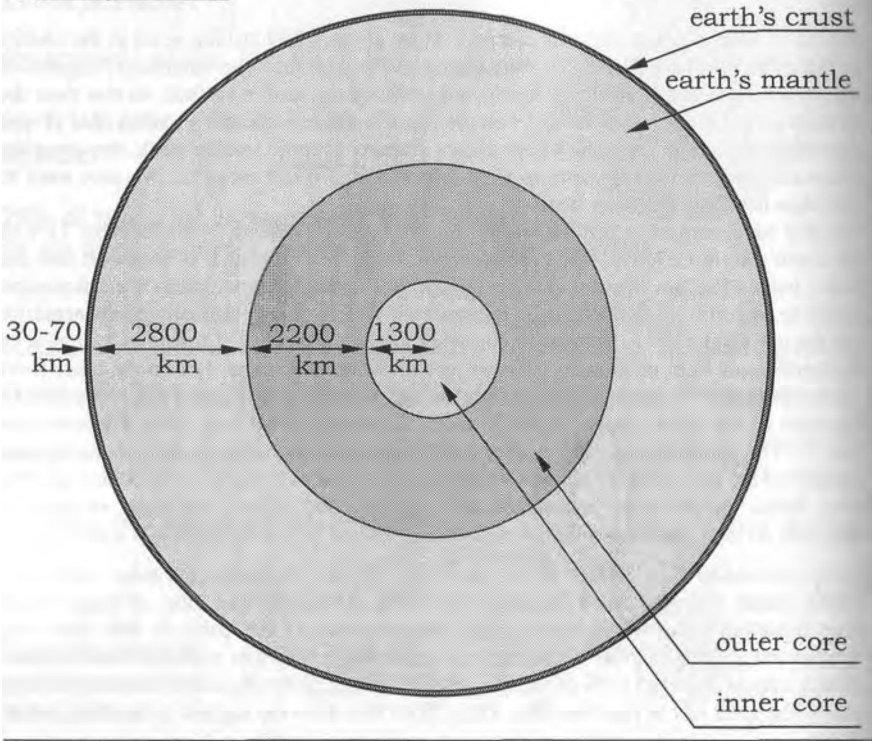
earth's crust
earth's mantle
30-70 km
2800 km
2200 km
1300 km
outer core
inner core

b. The earth **200 million years ago** (super continent: **Pangaea**):

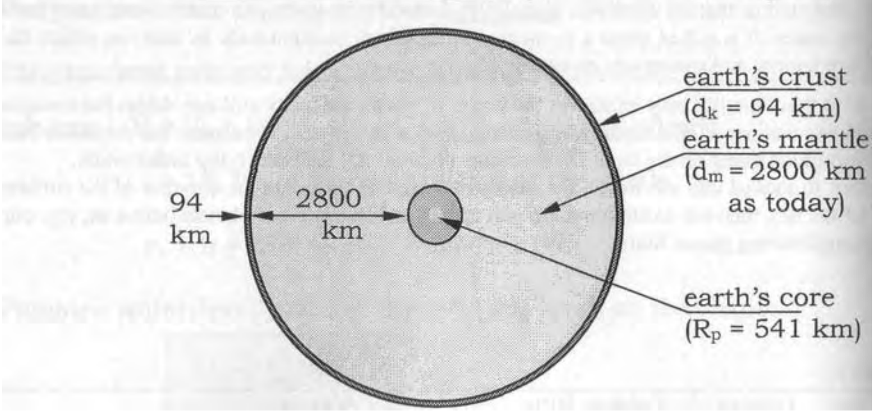
earth's crust (d_k = 94 km)
earth's mantle (d_m = 2800 km as today)
94 km
2800 km
earth's core (R_p = 541 km)

Fig. 11.4: The inner structure of the earth on an average

11.4 Inner structure of the earth

Next the question is raised: How fast does our earth actually grow? The calculated growth, distributed over the 200 million years, results in a yearly increase in the diameter of the earth of less than 0.1 mm. Carey[i] assumes 0.04 mm per year and Owen[ii] only 0.01 mm per year.

Actually the young earth must have been somewhat bigger than calculated, because as a result of the smaller gravitational acceleration the density of the matter must have been smaller. But this changes nothing to the relations, because the less dense earth was surrounded by likewise less dense water, the water-level nevertheless reached the peaks, as already calculated.

For indicating absolute linear measures and the calculation of the gravitational accleration the respective density should be considered. In most calculations the density is cancelled out, so that as well can be calculated with an unchanged density.

A grave error however lies in the assumption of a linear growth. Hilgenberg assumes an exponential growth[iii] and gives as a reason for the empirical approach of the e-function the „law of organic growth". In order to now not to speculate or to postulate in the same manner, we will derive and found our approach.

If namely the earth grows, then its core of fusion also grows, which causes the growth to take place accelerated, etc. A customer of a bank, who sees his amount of money grow according to such a regularity, will be given information immediately about the growth rate with a compound interest calculation.

But how big is the growing fusion reactor of our planet? According to today's level of knowledge about the structure of the earth the inner core is surrounded by the outer core and that again by the earth's mantle. On top floats the thin, but firm earth's crust, on which we live. The inner core has a radius of nearly 1390 km, the outer core stretches to a radius of 3500 km, whereas the crust is only between 10 and 78 km thick, dependent on the geographical latitude[i4] (fig. 11.4).

<i>: Carey, S. W.: Theories of the Earth and Universe. Stanford University Press: 1-413, Stanford, California

<ii>: Owen, H. G.: Has the Earth increased in size? - In: New Concepts in Global Tectonics, Texas etc. University Press (1992), p. 289-295, Lubbock

<iii>: Hilgenberg, O. C: Vom wachsenden Erdball, Berlin 1933, Eigenverlag, Seite 31 und 32

<i4>: Mitton, S. (Herausg.): Cambridge Enzyklopadie der Astronomie (The Cambridge Encyclopaedia of Astronomy), Orbis Verlag (1989)

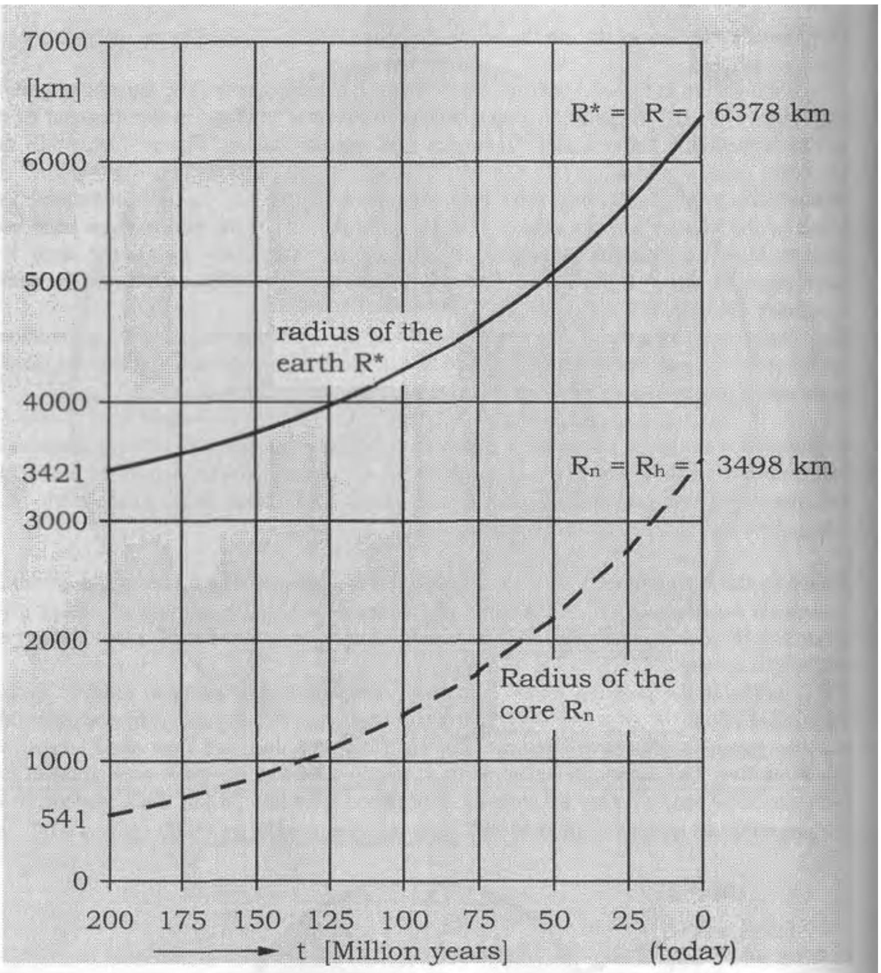

Fig. 11.5: The change in the radius of the earth and of the core in the course of millions of years until today.

calculation: (see fig.11.6) $\boxed{R^* = 2879{,}5 + 541 \cdot q^{n/3} \text{ [km]}}$ (11.7)

t years ago: with: $\boxed{t = 2 \cdot 10^8 - n \text{ [a]}}$ and: $\boxed{q = 1 + 28 \cdot 10^{-9}}$

correspondents to the approximation: $\boxed{R^* = 2880 + (6378 - 2880) \cdot e^{-t/\tau} \text{ [km]}}$ (11.8)

with the time constant: $\tau = 107{,}1$ Mio. Jahre

11.5 Earth's core as a converter of neutrinos

I proceed from the assumption that the conversion of neutrinos and materialization in elementary particles takes place in the inner core. For the conversion no energy at all is used, because the inner energy together with the outer energy of the particle amounts to zero. The neutrinos merely have to be remodelled into another structure and for that they at first have to be slowed down with the help of the oscillating interaction.

During this process of slowing down, as said, no heat is formed because in the case of a mass less particle no energy can be set free in the domain where the classical law of conservation of energy is valid. Only after completion of the process of materialization we are able to detect mass and energy of neutrinos.

But if the oscillating interaction is taken as a basis, the oscillation with opposite phase between particle and earth's core, then contrary to all expectations a cooling down takes place. If the particle has reached its region of destination in the core, then the oscillations are overlapping. Mathematically seen they are added with reversed sign; they thus are subtracted. The result of the mutual compensation is the decrease of the thermal oscillation and the cooling down of the region which was expected.

In addition the formed particles with a mass mutually contract (see part I, chapter 8.3 and 8.4) and in doing so are further cooling down, as we will derive (chapter 12.7 with fig. 12.8). The physical limit of the process of contraction and cooling down is formed by absolute zero, at which no thermal oscillation at all occurs anymore, so that superconduction becomes possible with the result of giant electric currents and magnetic fields, which can be detected even at the earth's surface in damped form, for instance with a compass.

The necessary heat energy is flowing towards the quick-frozen inner core from the outside, principally from the outer core. Here, in the core, from the neutrinos slowed down to the speed of light various elementary particles are formed. Most of them immediately fall apart, to form other configurations. In the end only electrons and protons are preserved, which, as the only stable particles, can't fall apart anymore. These again are trying hard to take the state of an atom, which however needs very much space with the large distance between atomic nucleus and hull. Under the high pressure the enveloping electrons therefore will time and again fall into the nucleus to form neutrons together with the protons.

The neutrons need no atomic hull and can, as is well-known of neutron stars, take an extremely high density. In the case of the earth's core the neutrons however cannot be stabilized. The contraction to a neutron is accompanied by a corresponding drop in pressure, so that the neutron falls apart again. A continual oscillation of size is formed, with which the neutrinos again interact. With that also the high density of the earth's core would be explicable simultaneously.

In earth's outer core the various atoms and isotopes are formed, which in the sum release more energy than they absorb in their fusion processes. Here the fusion oven rages, which supplies the inner core with heat energy.

The formed matter is pushed further to the outside, rolls as a viscous mass through the earth's mantle and collects the surplus radiation and heat from the fusion oven.

With this model of explanation we now can tackle the calculation of the growth of the earth (fig. 11.6).

Growth in volume in analogy to the compound interest calculation:

duration: $n = 200$ million years

starting capital: $V_p =$ Pangaea volume $V_p = (4/3)\cdot\pi\cdot r^3$

final value: $V_h =$ today's volume $V_h = (4/3)\cdot\pi\cdot R^3$

savings bank formula: $V_h = V_p * q^n$ (compound interest) (11.9)

with „interest rate": $q = (V_h/V_p)^{1/n}$ (11.10)

---

radius of the core of the Pangaea sphere:

$R_p = r - d_m - d_k = 541$ [km] (11.11)

with

Pangaea radius: $r = 3435$ [km]

earth's mantle: $d_m = 2800$ [km]

earth's crust: $dk = 94$ [km] (incl. covering with water).

core radius today: $Rh = R - d_m - d_k = 3500$ [km] (11.12)

earth's crust today: $d_k^* = 34\text{-}78$ [km].

From $V \sim r^3$ the growth factor q is calculated to be

$$\underline{\underline{q}} = \left(\frac{V_h}{V_p}\right)^{\frac{1}{n}} = \left(\frac{R_h}{R_p}\right)^{\frac{3}{n}} = \left(\frac{3500\text{ km}}{541\text{ km}}\right)^{\left(\frac{3}{2\cdot 10^8}\right)} = \underline{\underline{1 + 28\cdot 10^{-9}}} \quad (11.13)$$

core radius after n years: $R_n = R_p * q^{n/3}$ (11.14)

radius of the earth after n years: $R^* = R_n + d_m + d_k^*$ (11.15)

Fig. 11.6: The calculation of the growth rate of the earth

11.6 Speed of growth

200 million years ago in the centre of the globe a core of fusion has formed and taken up its operation, probably under the influence of a cosmic occurrence connected with a high neutrino radiation. As a result the thin crust of the earth was torn apart and the oceanic basins were formed.

If we assume that the might of earth's mantle (with d_m = 2800 km) and crust (with less than 100 km) haven't fundamentally changed, then earth's core at that time had a radius of only 541 km. The „savings bank formula" now only may be applied for the core and only for its volume. On the condition of a constant neutrino density the volume of the core in every year will grow for one order of magnitude, which again depends on the respective volume itself. There results the in fig. 11.5 presented course of the radius of the core and of the earth.

According to our calculation the earth at present grows every year for $915*10^{11}$ tons, which corresponds to an increase in volume of 16500 cubic kilometres and an increase of area of 5.2 square kilometres. The earth momentarily grows for 6.5 cm per year in diameter, from which follows that the perimeter increases pi-fold and a continental drift of 10.2 cm per year is to be expected across both the Atlantic Ocean and the Pacific Ocean. Geologists today actually measure a plate movement of typically 10 cm, at individual points of up to 12 cm per year<i>!

Whoever likes to do handicrafts, can build together a globe of shells by himself. Hilgenberg for that gives a handicraft instruction<ii>. He draws the continents of a globe of today and cuts them out. Doing so, not the coast line of today is authoritative, but that of the edge of the shells, at which the mainland plates are breaking off into the deep sea. He hence also speaks of a sphere of shells and helps the handcrafters with the words: ..Because the paper shells of the sphere of shells owing to their strong curvature are difficult to nestle, we cut slits in the paper, which suitably lie there, where mountain ranges stretch and now can start with the gluing". Doing so it shows that the slits in particular in the case of the Ural and the Himalayan gape far apart, that in reversed direction in the case of the enlargement of the sphere of shells the lifting out of the mountains necessarily had to occur at these points by means of upsetting. Under these circumstances our model concept should be further rendered more precisely, If the change of the curvature of the growing surface of the earth is the cause for the lifting out of the mountains, then the surface of the earth 200 million years ago was structured merely by impact craters and by volcanic cones, then the amount of water may have been correspondingly smaller. The additional water of the oceans of today was collected by the earth either from the cosmos, by crossing the flight path of a comet with a water tail, or by the here discussed idea of a core of fusion in the inside of the earth it has produced the water itself!

How ever such detail aspects may have had an effect, it therefore nevertheless changes nothing to the model concept on the whole. Hilgenberg's globe of shells<ii> in my opinion to still makes more sense as all the models of explanation, as they are spread in today's text books.

<i>: Miller, R.: Driftende Kontinente, Time-Life, Amsterdam 1991, S. 78

<ii>: Hilgenberg, O.C.: Vom wachsenden Erdball, Berlin 1933, Eigenverlag

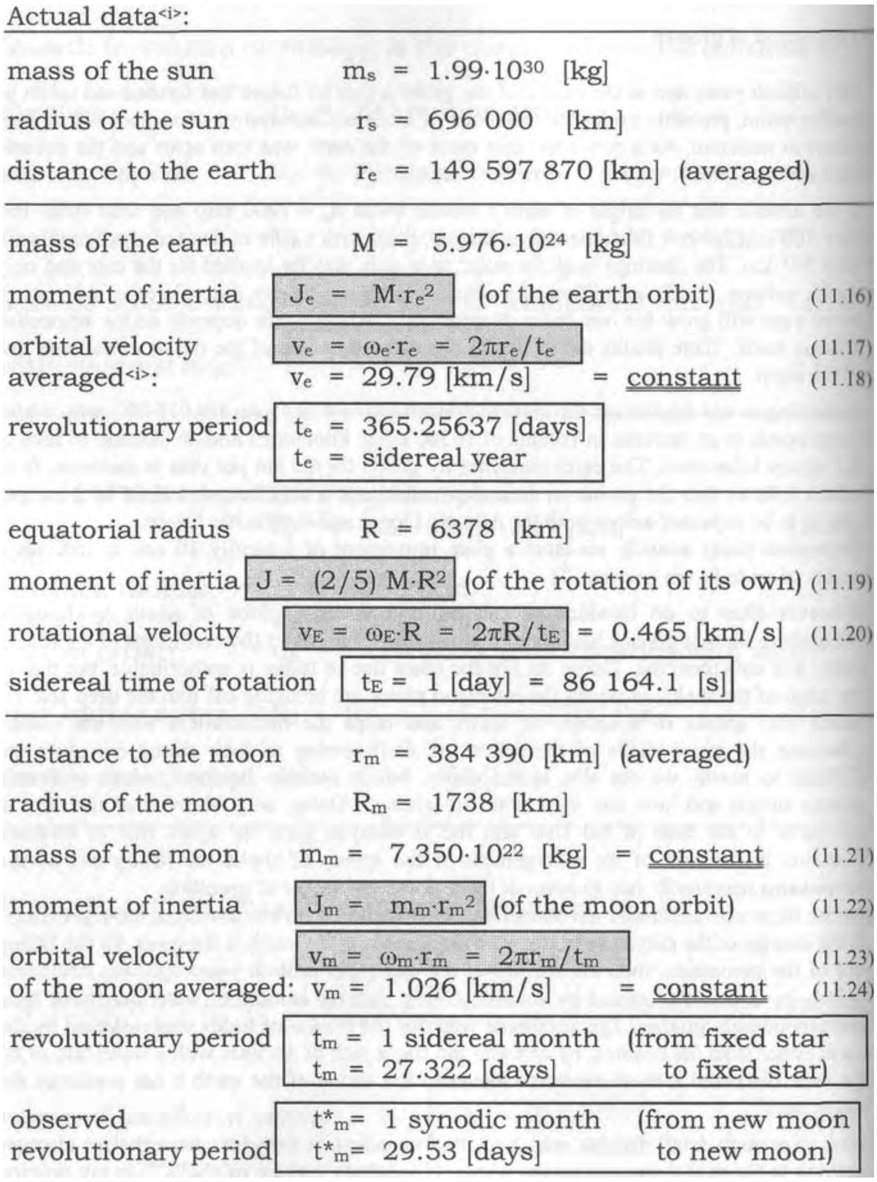

Actual data[i]:

mass of the sun $m_s = 1.99\cdot10^{30}$ [kg]

radius of the sun $r_s = 696\,000$ [km]

distance to the earth $r_e = 149\,597\,870$ [km] (averaged)

mass of the earth $M = 5.976\cdot10^{24}$ [kg]

moment of inertia $\boxed{J_e = M\cdot r_e^2}$ (of the earth orbit) (11.16)

orbital velocity $\boxed{v_e = \omega_e\cdot r_e = 2\pi r_e/t_e}$ (11.17)

averaged[i]: $v_e = 29.79$ [km/s] = constant (11.18)

revolutionary period $\boxed{\begin{array}{l} t_e = 365.25637 \text{ [days]} \\ t_e = \text{sidereal year} \end{array}}$

equatorial radius $R = 6378$ [km]

moment of inertia $\boxed{J = (2/5)\, M\cdot R^2}$ (of the rotation of its own) (11.19)

rotational velocity $\boxed{v_E = \omega_E\cdot R = 2\pi R/t_E}$ = 0.465 [km/s] (11.20)

sidereal time of rotation $\boxed{t_E = 1 \text{ [day]} = 86\,164.1 \text{ [s]}}$

distance to the moon $r_m = 384\,390$ [km] (averaged)

radius of the moon $R_m = 1738$ [km]

mass of the moon $m_m = 7.350\cdot10^{22}$ [kg] = constant (11.21)

moment of inertia $\boxed{J_m = m_m\cdot r_m^2}$ (of the moon orbit) (11.22)

orbital velocity $\boxed{v_m = \omega_m\cdot r_m = 2\pi r_m/t_m}$ (11.23)

of the moon averaged: $v_m = 1.026$ [km/s] = constant (11.24)

revolutionary period $\boxed{\begin{array}{ll} t_m = 1 \text{ sidereal month} & \text{(from fixed star} \\ t_m = 27.322 \text{ [days]} & \text{to fixed star)} \end{array}}$

observed revolutionary period $\boxed{\begin{array}{ll} t^*_m = 1 \text{ synodic month} & \text{(from new moon} \\ t^*_m = 29.53 \text{ [days]} & \text{to new moon)} \end{array}}$

Fig. 11.7: The data of sun, earth and moon of today[i]

[i]: Mitton, S. (Herausg.): Cambridge Enzyklopadie der Astronomie (The Cambridge Encyclopaedia of Astronomy), Orbis Verlag (1989)

It is an exciting matter, if one can experience for oneself, how the pieces of the puzzle fit together, how the southern end of America is wound around the Cape of Good Hope and the Falkland islands surface for the east coast of South Africa, in the vicinity of Australia how the Antarctic occupies the Pacific basin as a neighbour of Australia, von South, Middle and North America, run through by the equator, etc.
The corrections to the view of life of Alfred Wegener and the geographical evidence, which Hilgenberg gives, are sound, well founded and even after 65 years still highly actual. The physical statements of the geologists however, for instance the earth in the course of time would rotate faster and faster, cannot be followed.

11.7 Conservation of angular momentum

The question about the rotation of the earth is raised. Is it not changing at all, is it getting faster or slower? In the case of a with time growing earth there is only one possibility: The rotation of its own will decrease and not increase, as Hilgenberg supposes. For that you only need to place yourself on a turntable, to turn and if possible with weights in your hands stretch out your arms sideways, to feel, how the rotation of the table is decreasing. It surely would have done the geologist Hilgenberg good, to leave his desk for a short time for a stroll to the most nearby playground, for the purpose of the described physical experiment with himself.

In this case the law of conservation of momentum authoritatively has an effect in the formulation of the law of conservation of angular momentum for the rotating motion. According to that all angular momenta in the solar system should amount to zero. If we look at the planets which have no moon, then is remarkable that these need an eternity for a revolution around their own axis (Venus for instance needs 243 days). According to the law of conservation of angular momentum our earth owes its rotation of its own primarily the moon.

For reason of this relation we can assume a proportionality between the angular momentum of the moon J_m*w_m and that of the rotation of its own of the earth $J*w_E$ (eq. 11.39, fig. 11.10). They even have to be identical, if the partner of rotation earth and moon are seen as a closed system.
If the earth would be approached as a homogeneous, spinning sphere, the angular momentum at first would be too small for a factor 4.1 (eq. 11.29, fig. 11.9). The law of conservation of angular momentum dictates as a necessary result, that the dense core of the earth must rotate faster than the earth's crust! From the correspondence of orbital angular momentum of the moon on the one hand and the sum of the angular momenta of their own of earth's mantle and earth's core on the other hand results a 31 fold higher angular velocity of the earth's core compared to the rotation of the earth's surface (eq. 11.38, fig. 11.9).

Does our earth owe its geomagnetism this rotation of the core? At least the possibility exists that there exists a causal relation between the rotation of the earth's core and the geomagnetism. We'll further collect arguments and put the question concerning the formation of the geomagnetism under consideration.

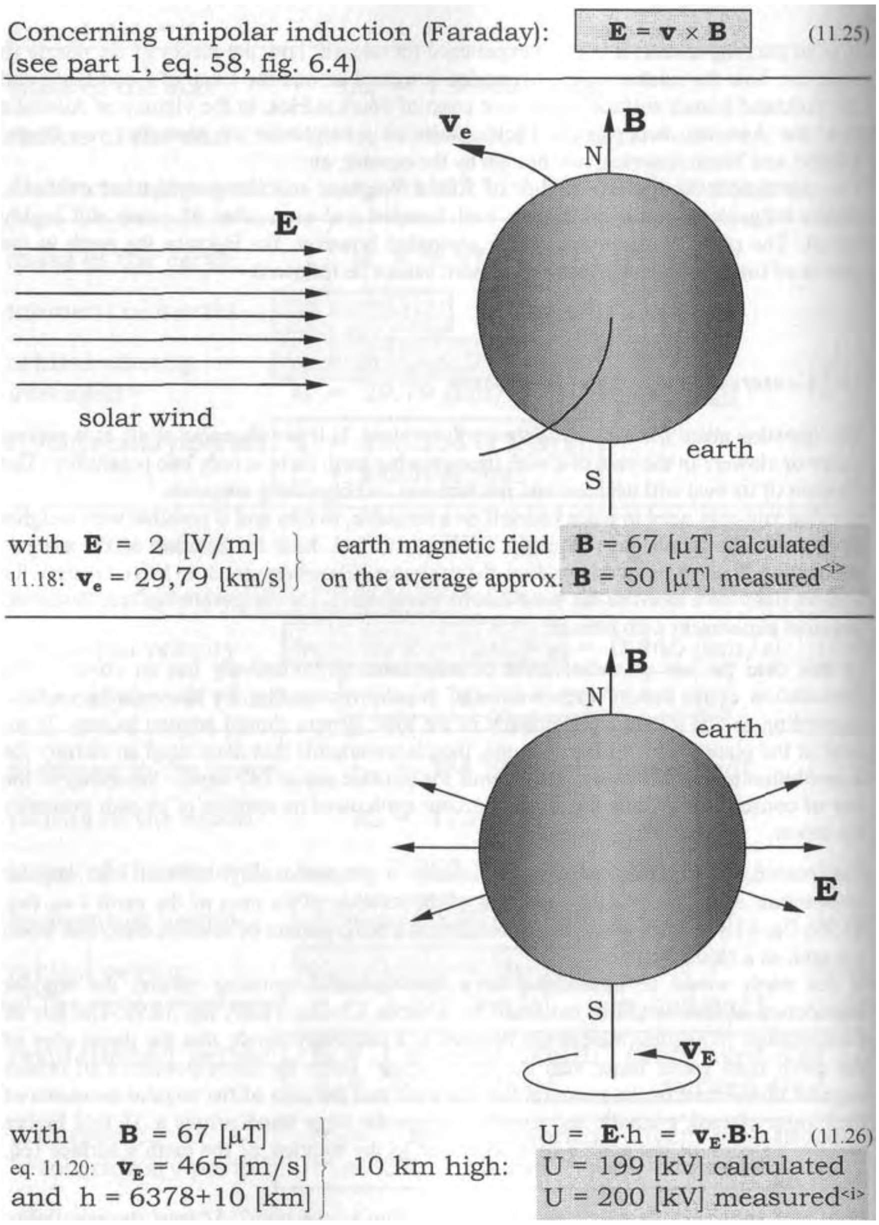

Concerning unipolar induction (Faraday): $\boxed{\mathbf{E} = \mathbf{v} \times \mathbf{B}}$ (11.25)
(see part 1, eq. 58, fig. 6.4)

with $\mathbf{E} = 2$ [V/m], 11.18: $\mathbf{v_e} = 29{,}79$ [km/s] } earth magnetic field $\mathbf{B} = 67$ [μT] calculated
on the average approx. $\mathbf{B} = 50$ [μT] measured<i>

with $\mathbf{B} = 67$ [μT]
eq. 11.20: $\mathbf{v_E} = 465$ [m/s]
and h = 6378+10 [km] } 10 km high:

$U = \mathbf{E} \cdot h = \mathbf{v_E} \cdot \mathbf{B} \cdot h$ (11.26)
U = 199 [kV] calculated
U = 200 [kV] measured<i>

Fig. 11.8: The magnetic and the electrostatic field of the earth
as a result of an unipolar induction

<i>: Measurement values in chap. 2.8, e.g. reference entry <i> (Prof. Dr. L. Konig)

11.8 Set of difficulties concerning the change of magnetization

Now investigations of the polarity of the magnetization of rocks have resulted in the fact that in irregular intervals, on an average every 500,000 years, a change of polarity of the geomagnetism has occurred and no one knows why.

If the rotation of the core should produce the magnetism, then it in any case also is responsible for the process of change of magnetization. That purely theoretically is possible in two ways: Either the core tilts out of its plane of rotation for 180° and rotates suddenly in the opposite direction or earth's mantle together with earth's crust, on which we live, is turned upside down.

It surely isn't my intention to produce any panic, but from a physical point of view only the second case is possible. Usually not the tail wags with the dog, but vice versa, the dog with the tail. The high rotational velocity of the earth's core exerts an extremely stabilizing influence. After all its angular momentum is 4.85 times larger than that of the mantle (eq. 11.33, fig. 11.9). Therefore the rotation of the core and the direction of earth's magnetic field always are preserved seen from the sun.

I further proceed from the assumption, that an electrostatic field arises from the sun accompanied by a particle flux, the solar wind, through which the earth flies through in a perpendicular direction. According to the Faraday law of induction $E = v \times B$ (eq. 11.25)

it experiences, as a result of the unipolar induction, a magnetic field which stands perpendicular on the ecliptic and thus dictates the orientation of earth's magnetic field. With that also the direction of rotation would be determined. The core thus by no means can tilt!

On the condition that the core doesn't rotate completely frictionless, the earth's mantle will in the case of the same direction of rotation be accelerated, in the case of unequal direction, after a changing of polarity, it will be slowed down again. If the process, for reasons of conservation of angular momentum, takes place alternatingly with a certain regularity, then the inhabitants of the earth for every changing of polarity might experience, how the North Pole in the shortest time turns over the equator to the South Pole, how the sun sets at the point, where it before had risen. As said, after a changing of polarity our earth is standing on its head! In the Bible corresponding clues are found[ii]. It can be taken from the media that one reckons with such a changing of polarity in the foreseeable future. When and if it actually takes place, stands however in the stars.

If magnetism thus is produced by the rotation of the core, or by electric currents in the earth's core as a result of the superconduction or by both, then the earth is aligned in the field of the sun like the magnetic needle in a compass. If we take as a cause a solar wind with an electric field strength of just 2 V/m, then this would not only determine the direction of earth's magnetic field, but also the order of magnitude, and that at present lies at 50 uT averaged over time (chap. 2.8).

With the same mathematical relation an electrostatic field around the earth of 199 V/m results as a result of the rotation of the earth. That fairly exact corresponds to the measured values![i] Quite obviously all is related to each other. In the question for the „how" at this point consciously no definite answer is strived for. It rather should be discussed and worked to together in the seminar.

<ii>: The Bible, OT, The 2nd book of kings 20,9-11 (king Hezekiah) and Joshua 10,12-14, literally cited on the page after the next page (chap. 11.9), note<ii>

Angular momentum $J_m \cdot \omega_m$ of the orbiting moon (with eq. 11.22 + 11.23):

$$J_m \cdot \omega_m = m_m \cdot r_m^2 \cdot \omega_m = 29*10^{33} \ [kgm^2/s] \qquad (11.27)$$

Angular momentum $J \cdot \omega_E$ of the rotation of the earth (eq. 11.19 + 11.20, same direction of turning):

(theoretically) $J \cdot \omega_E = (2/5)\ M \cdot R^2 \cdot \omega_E = 7*10^{33} \ [kgm^2/s] \qquad (11.28)$

$$\frac{\text{Orbital momentum moon}}{\text{Angular momentum earth}} = \frac{J_m \cdot \omega_m}{J \cdot \omega_E} = \frac{29}{7} = 4,1 \qquad (11.29)$$

Angular momentum $J_M \cdot \omega_E$ of earth's mantle and crust (R_h = core radius)

$$J_M \cdot \omega_E = (J - J_K) \cdot \omega_E = (2/5) \cdot (MR^2 - M_K R_h^2) \cdot \omega_E = 6*10^{33} \ [kgm^2/s] \qquad (11.30)$$

$$\text{conservation of angular momentum:} \quad J_m \cdot \omega_m = J_K \cdot \omega_K - J_M \cdot \omega_E \qquad (11.31)$$

Angular momentum $J_K \cdot \omega_K$ of the earth's core

$$J_K \cdot \omega_K = J_m \cdot \omega_m + J_M \cdot \omega_E = 35*10^{33} \ [kgm^2/s] \qquad (11.32)$$

$$\frac{\text{Angular momentum core}}{\text{Angular momentum mantle}} = \frac{J_K \cdot \omega_K}{J_M \cdot \omega_E} = \frac{35}{5} = 7 \qquad (11.33)$$

$$J_K \cdot \omega_K = (2/5)\ M_K \cdot R_h^2 \cdot \omega_K \qquad (11.34)$$

With the mass of earth's core $M_K = \rho_K \cdot V_K = \rho_K \cdot (4/3) \cdot \pi \cdot R_h^3$ (11.35)

and the averaged core density $ro_k = 12000 \ kg/m^3$

the angular velocity

of earth's core amounts to: $\omega_K = 3,3*10^3 \ [s^{-1}]$ (11.36)

and that at the earth's surface: $\omega_E = v_E/R = 0,073*10^{-3} \ [s^{-1}]$. (11.37)

$$\frac{\omega_K}{\omega_E} = \frac{3,3}{0,073} = 45 \qquad (11.38)$$

Fig. 11.9: Calculations concerning the conservation of angular momentum and the rotation of earth's core (One turn of the earth's core lasts 32 min. It results contrary to the earth rotation. Of the surface of the earth a period duration of 31 min should be observable.)

11.9 The weakly damped moon

The increasing angular velocity in the direction of the centre of the earth surely has something to do with the set of difficulties concerning the conservation of the spherical structure, comparable to the reason for the particle spin (chapter 6.13). The increasingly missing radial component of the gravitational field has to be compensated by an additional field produced by the rotation (according to part 1, equation 62, fig. 6.5).

The moon apparently doesn't know this set of difficulties. We can assume a constant mass for it (eq. 11.21). On the one hand is the moon smaller than the earth 200 million years ago, as it started to grow. On the other hand are doubts concerning the existence of an active core of the moon legitimate. In the Apollo-15 mission seismic gauges had been installed at the ground of the moon and at the start from the moon the produced seismic waves had been recorded<i>. The surprisingly small damping as the lunar module fell back onto the ground of the moon more likely allow the conclusion that the moon is hollow inside!
Also the small density of the moon points in the same direction, and finally no clues at all can be seen on the surface of the moon, which would point to a growth of the moon.

Apart from the mass also the orbital velocity of the moon is taken constant, what surely is true, as long as nobody and nothing drives the moon extra (eq. 11.24). The analysis of the law of conservation of angular momentum provides the in fig. 11.10 derived provisional result (eq. 11.41).

<i>: Moonquakes ever more mysteriously: „The by Apollo 12 triggered moonquake by „bombardment" of the surface of the moon with the clapped-out Lunar Module „Intrepid" at thursday evening puts scientists for bigger and bigger mysteries. An exact analysis of the measurement data now resulted in the by the astronauts Conrad and Bean installed „seismic station" on the moon ... to have recorded and to have sent to the earth 55 minutes long. ... The seismologist Dr. Gary Latham spoke of „important information about the structure of the moon" and meant, one now can „throw away the text book". One had reckoned that the impact of the Lunar Module on the moon would trigger a quake of at best some minutes", (translated) Frankfurter Rundschau vom 22.11.1969

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concerning reference entry <ii>, chap. 11.8:

<ii>: The Bible, OT, Joshua 10,12-14: There stands in the „book of Jasher ": So the sun stood still in the midst of heaven, and hasted not to go down about a whole day. And there was no day like that before it or after it, ...

The 2nd book of kings 20,9-11: king Hezekiah: This sign thou ... let the shadow return backward ten degrees. And Isaiah the prophet cried unto the LORD: and he brought the shadow ten degrees backward, by which it had gone down in the dial of Ahaz.

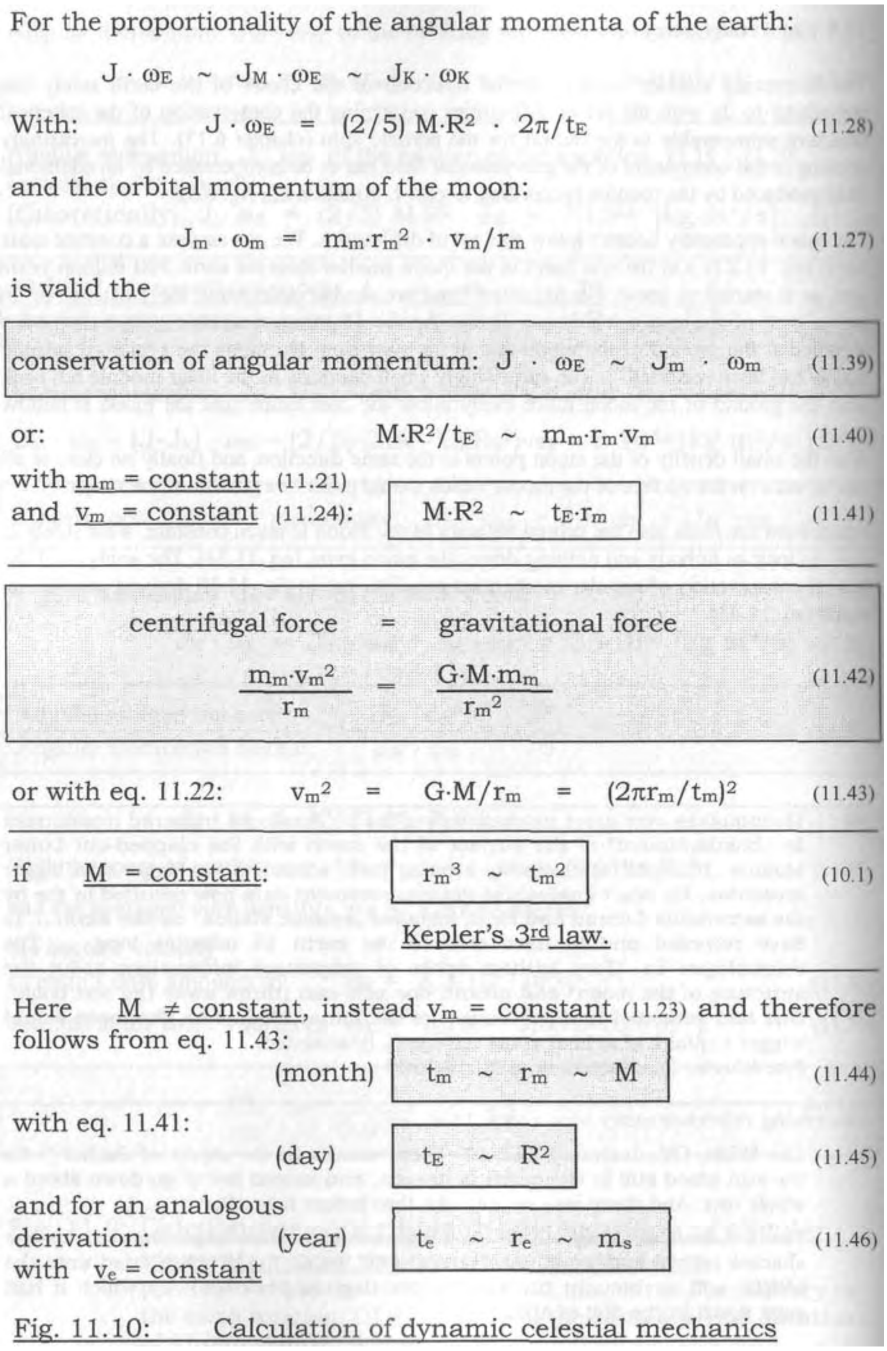

For the proportionality of the angular momenta of the earth:

$$J \cdot \omega_E \sim J_M \cdot \omega_E \sim J_K \cdot \omega_K$$

With: $$J \cdot \omega_E = (2/5)\, M{\cdot}R^2 \cdot 2\pi/t_E \quad (11.28)$$

and the orbital momentum of the moon:

$$J_m \cdot \omega_m = m_m{\cdot}r_m^2 \cdot v_m/r_m \quad (11.27)$$

is valid the

$$\boxed{\text{conservation of angular momentum: } J \cdot \omega_E \sim J_m \cdot \omega_m \quad (11.39)}$$

or: $$M{\cdot}R^2/t_E \sim m_m{\cdot}r_m{\cdot}v_m \quad (11.40)$$

with m_m = constant (11.21)

and v_m = constant (11.24): $$\boxed{M{\cdot}R^2 \sim t_E{\cdot}r_m} \quad (11.41)$$

centrifugal force = gravitational force

$$\boxed{\frac{m_m{\cdot}v_m^2}{r_m} = \frac{G{\cdot}M{\cdot}m_m}{r_m^2}} \quad (11.42)$$

or with eq. 11.22: $$v_m^2 = G{\cdot}M/r_m = (2\pi r_m/t_m)^2 \quad (11.43)$$

if M = constant: $$\boxed{r_m^3 \sim t_m^2} \quad (10.1)$$

Kepler's 3rd law.

Here M ≠ constant, instead v_m = constant (11.23) and therefore follows from eq. 11.43:

(month) $$\boxed{t_m \sim r_m \sim M} \quad (11.44)$$

with eq. 11.41:

(day) $$\boxed{t_E \sim R^2} \quad (11.45)$$

and for an analogous derivation: with v_e = constant

(year) $$\boxed{t_e \sim r_e \sim m_s} \quad (11.46)$$

Fig. 11.10: Calculation of dynamic celestial mechanics

11.10 Calculation of celestial mechanics

We still need a further relation and try the balance of forces between the centrifugal force and the gravitational force. Both the to the outside directed centrifugal force and the to the inside directed gravitational force depend on the mass of the moving body, here the mass of the moon m_m, so that it is cancelled from equation 11.42.
As determining mass only that of the earth is left and that is taken constant in accordance with the knowledge of text books. The result of this assumption is Kepler's 3rd law (eq. 10.1). But beware, it here merely concerns a momentary picture! In the course of time, according to the derivation, the mass of the earth increases so that this assumption is untenable.

Instead, as already said, the average orbital velocity of the moon, one kilometre per second, can be taken constant (eq. 11.24). Since the orbital velocity is calculated from the proportion of the perimeter of the circular orbit $2\cdot\pi\cdot r_m$ with regard to the revolutionary period of a month (11.43, left page), and at the same time from the balance of forces a dependency of the mass of the earth M and the radius of the orbit of the moon follows (11.43, right page), the interesting relation (11.44) results:
Here the mass M, the radius r_m and the revolutionary period t_m stand in a direct proportionality to each other, and that means: if the mass of the earth increases in the course of time, then the moon will go away from us to the same extent, then also every month will get correspondingly longer.

Clarified with numeric values follows from a growth of the earth for $915*10^{14}$ kg per year a going away of the moon for yearly 5.88 meters (fig. 11.11). The going away of our satellite could be confirmed by means of measurements with laser reflectors, which had been put up on the moon by Apollo astronauts, according to dpa message<i>.

In addition every month lengthens for 3 milli seconds. That is valid for the sidereal month (= 27.322 days), for which a fixed star serves as a reference point for the measurement of a revolution, as well as for the synodic month, as it is observed from the earth from new moon till new moon (= 29.53 days). The synodic month today is longer than four weeks. But 3.7 million years ago it once actually lasted exactly 28 days, as we can calculate easily (fig. 11.11).

But now also the length of a day is changing. If we insert the proportionality (11.44) from the balance of forces in that of the conservation of angular momentum (11.41), then it is shown that a day depends quadratic on the radius of the earth (11.45), that a lengthening of every day for $4.5*10^{-9}$ s can be determined with the help of the growth curve of the earth (fig. 11.5). This is really very small, but 200 million years ago the day had just 19 hours, if extrapolated to 900 million years only 18.04 hours! The result of the american geologists around Dr. Charles Philip Sonett of the University of Arizona in Tucson also is 18 hours in their analysis of correspondingly old sediment formations, as the US science magazine Science has reported<i>. The correspondence of this measurement with our calculation without doubt has force of evidence!

<i>: 900 million years ago a day had 18 hours, Washington (dpa) 1997

Going away of the moon per year with $\boxed{M \sim r_m}$ (according to eq. 11.44): for
$\Delta r_m = r_m \cdot \Delta M/M = 384390[\mathrm{km}] \cdot 9.15 \cdot 10^{16}[\mathrm{kg/a}] / 5.976 \cdot 10^{24}[\mathrm{kg}] = 5.886\ [\mathrm{m/a}]$

lengthening of month per year with $\boxed{M \sim t_m}$ (11.44) (sidereal): for
$\Delta t_m = t_m \cdot \Delta M/M = 27.322\ [\mathrm{days}] \cdot 86164\ [\mathrm{s/day}] \cdot \Delta M/M = 36\ [\mathrm{ms/a}]$

synodic month (from new moon till new moon) of 28 days:
$\Delta t_m = 29.53\ [\mathrm{days}] - 28\ [\mathrm{days}] = 1.53\ [\mathrm{days}] \equiv 132 \cdot 10^6\ [\mathrm{ms}]$
linearly calculated $132 \cdot 10^6\ [\mathrm{ms}]/36\ [\mathrm{ms/a}]$ = 3.6674 mio. years ago.

Day length 200 mio. years ago, with $\boxed{t_E \sim R^2}$ (11.45) amounted to t* hours
shortening: $\Delta t_E/t_E = \Delta R^2/R^2 = (R-R^*)^2/R^2 = (6378-3420)^2/6378^2 = 21.5\%$
$\Delta t_E = 0.215 \cdot 24\ [\mathrm{h}] = 5.16\ [\mathrm{h}]$ and $t^* = 24\ [\mathrm{h}] - \Delta t_E = 18.84\ [\mathrm{h}]$

Day length 900 mio. years ago, (R^*=3200 km) amounts to 18.04 hours

present lengthening per day amounts to: $\Delta t_E/t_E = 4.5 \cdot 10^{-9}\ [\mathrm{s/day}]$

but: the year increases 130,000 times faster than the individual day!
according to the measurement of Aristarchos 2300 years<ii> ago
is $\Delta t_e = 365.25637\ [\mathrm{days}] - 365.25062\ [\mathrm{days}] = 0.00575\ [\mathrm{days}]$
and $\Delta t_e/t_e = 0.00575 \cdot 24 \cdot 60 \cdot 60 \cdot 1000 / 365.25637 \cdot 2300 = 0.59\ [\mathrm{ms/day}]$

going away of the earth from the sun per year, with $\boxed{t_e \sim r_e}$ (acc. to eq. 11.46)
for: $\Delta r_e/t = r_e \cdot \Delta t_e/t_e \cdot t = 149.6 \cdot 10^6\ [\mathrm{km}] \cdot \Delta t_e/t_e \cdot t = 1.024\ [\mathrm{km/a}]$

growth of the sun per year/second, with $\boxed{t_e \sim m_s}$ (according to eq. 11.46)
for:
$\Delta m_s/t = m_s \cdot \Delta t_e/t_e \cdot t = 1{,}99 \cdot 10^{27}\ \mathrm{t} \cdot \Delta t_e/t_e \cdot t = 1.36 \cdot 10^{19}\ [\mathrm{t/year}]$
resp. in a second for: $= 4.3 \cdot 10^{11}\ [\mathrm{t/s}]$
and at the same time a loss due to radiation of: $5 \cdot 10^6\ [\mathrm{t/s}]$

Fig. 11.11: Figures according to analysis of some examples concerning dynamic celestial mechanics

11.11 The biblical age

We therefore owe the growing diameter of the earth that every day gets longer and longer (eq. 11.45) and from the going away of the moon a lengthening of the month results (eq. 11.44). Not only the months and the length of the days increase, but also the whole year. A corresponding derivation for the revolution of the earth around the sun, as it has been carried out for the revolution of the moon around the earth (eq. 11.44), delivers analogous results (eq. 11.46): The sun determines the length of the year and the distances to the planets. To the extent, to which the sun grows, the solar system increases in extension. Also the distance to the earth increases proportionally with the mass of the sun. By the going away from the sun the temperature on the planets however not necessarily decreases, because at the same time the radiation intensity of the growing central star increases. According to measurements it has increased for 30% since the formation of the solar system<i>.

If both the rotation of the earth and the revolution around the sun get slower, then by all means is conceivable, that the number of days per year approximately stays the same and mankind nevertheless gets less old. If we take the 2300 years old writing of the Greek Aristarchos about the sizes and distances of the sun and the moon<ii>. He determined, assuming a heliocentric view of life, the year to be 365.25062 days. Because the correction taken by Aristarchos concerned even the fifth place after the comma, we must assume that correspondingly precise gauges were available in Alexandria already 310 BC.
The today measured sidereal year with 365.25637 days has lengthened for whole 0.00575 days. From this follows that the year increases considerably faster than the individual day.
It of course would be nice, if we could calculate the lengthening of the year, but unfortunately no data about the growth of the sun are available.
If we proceed from the measurement of Aristarchos, without being able to verify or reproduce its reliability, then from that would result a going away of the earth from the sun for yearly one kilometre, then the sun should grow for $4.3*10^{11}$ tons per second. In any case the sun materializes mass considerably faster, as it loses mass in the same period as radiation equivalent, and that surely is correct (fig. 11.11). Today one generally assumes that „since its formation the earth has gone away from the sun for in total 30,000 km"<i>.

But if in the past the year consisted of less days and every day moreover was shorter, if therefore the biological life time was divided in shorter periods, then mankind could get older, then obtaining a biblical age possibly by no means was unrealistic. If Adam still should have got 930 years old, according to the 1st book of Moses, then his lifetime already must have been quite long ago. While Abraham still did get 175 years old, no successor of him has reached his age anymore. In the Bible it is said: „And the LORD said, My spirit shall not always strive with man, for that he also is flesh: yet his days shall he an hundred and twenty years "<iii>. Today even the limit given by the LORD isn't reached anymore!

<i>: Is the sun loosing her Gravitation? Illustrierte Wissenschaft, Nr.l, 1995
<ii>: Hermann Wild: Technologien von gestern, Chancen fur morgen, Jupiter-Verlag Bern (1996), ISBN 3-906571-13-0, Seite 22
<iii>: The Bible, King James Version, Genesis 6.3

The balance of forces (equation 11.42 generalized):

$$\boxed{\begin{array}{ccc} \text{centrifugal force} & = & \text{gravitational force} \\ \frac{M \cdot v_k^2}{r} & = & \frac{G \cdot M \cdot m}{r^2} \end{array}} \quad (12.1)$$

results in the cosmic velocity v_k:

$$\boxed{v_k^2 = G \cdot m / r} \quad (12.2)$$

independent of the mass M of the satellite or planet!

For	$v < v_k$	falling back into the central mass m
For	$v > v_k$	taking the leave into space
For	$v = v_k$	stationary orbit

written down for the nth planet in the solar system:

with $r(n) = r_n$ average orbital radius of the planet

and $v(n) = v_n$ average orbital velocity

as well as: m_s mass of the sun

$$\boxed{v_n = \sqrt{G \cdot m_s / r_n}} \quad (12.3)$$

or:

$$\boxed{v_n = G \cdot m_s / v_n \cdot r_n} \quad (12.4)$$

Fig. 12.1: The first cosmic velocity v_k

12. New cosmology

Astronomy still hasn't satisfactorily solved the question of the formation of the solar system. It thereby however concerns a central problem, because it includes the origin of the earth. But as long as we not yet have understood the relations in our nearest environment, the processes, which we observe with giant telescopes in the depths of pace, will remain a book with seven seals, will lose models of explanation concerning the Big Bang and concerning the so-called unavoidable heat exitus every reliability.

12.1 Concerning the formation of our solar system

2-8-1972 the observatories of the sun reported an unusual high solar activity and 6 days later a slowing down of the rotation of the earth occurred, which was recorded as the lengthening of a day for more than 10 milliseconds. This effect hardly can be explained by the tidal friction alone already just concerning the energy balance. Instead this observation makes clear two things to mankind. On the one hand, how much our earth depends on the solar processes and on the other hand, that the changes by all means can occur not continuously, but periodically and if need be even sporadic.

If, as a result of the conservation of angular momentum, the sun determines the orbital velocity of the earth, if it dictates the rotation of the earth by its neutrino activity and the growth of the earth and if the earth in the same manner determines the orbit of the moon, then it would be obvious that the moon originally has been a part of the earth and this in turn sometime a part of the sun. As it came off, the necessary angular momentum then has been passed on proportionately to the celestial companions, with which the cause for evolution and rotation of their own would be clarified. In addition the moon goes away from the earth and the earth again from the sun, so that looking back it by all means would be obvious, if they once had belonged together.

If we assume that cosmic dust particles meet and accumulate, then all collected rubble contributes to the rotation of its own of the forming celestial body. The more matter finds together, the larger its force of attraction gets, the faster it will grow like a celestial vacuum cleaner. In the course of time this process however is slowed down again and eventually comes to a standstill, because as matter condenses, volume and spherical radius decrease and the rotation of its own increases to the corresponding extent. The celestial body rotates faster and faster and reaches at its surface the cosmic velocity vk, which is given by the mass m and the radius r of the star (eq. 12.2). Now the centrifugal force has reached an order of magnitude, for which the celestial body hurls exactly as much matter into space, as it on the other hand collects by its gravitational effect.

Our sun was lucky to have been supplied with neutrinos in the range of influence of our galaxy. It went in resonance and started to grow, this time from out of the inside. It however could not yet shine, because a crust had formed on its surface around its core of fusion and its mantle, a crust on which permanently was falling cosmic matter from the outside. The increasing viscosity of the sun becoming compressed caused a slowing down of the core of the sun and the corresponding acceleration of the mantle and crust.

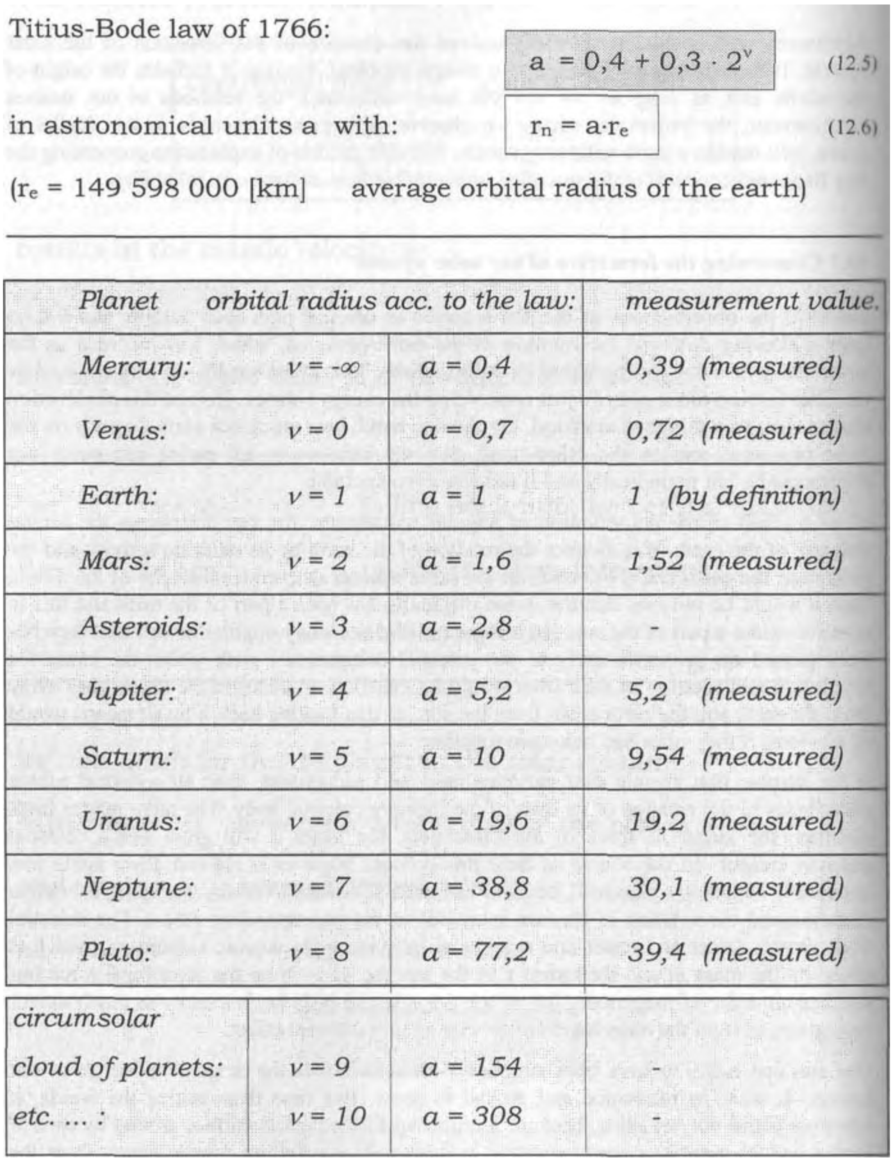

Titius-Bode law of 1766:

$$\boxed{a = 0{,}4 + 0{,}3 \cdot 2^{\nu}} \quad (12.5)$$

in astronomical units a with:

$$\boxed{r_n = a \cdot r_e} \quad (12.6)$$

(r_e = 149 598 000 [km] average orbital radius of the earth)

Planet	orbital radius acc. to the law:		measurement value
Mercury:	$\nu = -\infty$	$a = 0{,}4$	0,39 (measured)
Venus:	$\nu = 0$	$a = 0{,}7$	0,72 (measured)
Earth:	$\nu = 1$	$a = 1$	1 (by definition)
Mars:	$\nu = 2$	$a = 1{,}6$	1,52 (measured)
Asteroids:	$\nu = 3$	$a = 2{,}8$	-
Jupiter:	$\nu = 4$	$a = 5{,}2$	5,2 (measured)
Saturn:	$\nu = 5$	$a = 10$	9,54 (measured)
Uranus:	$\nu = 6$	$a = 19{,}6$	19,2 (measured)
Neptune:	$\nu = 7$	$a = 38{,}8$	30,1 (measured)
Pluto:	$\nu = 8$	$a = 77{,}2$	39,4 (measured)
circumsolar cloud of planets:	$\nu = 9$	$a = 154$	-
etc. ... :	$\nu = 10$	$a = 308$	-

Table 12.2: The Titius-Bode series of the planets (the theoretical values compared to the measurement values)

Sometime our like mad spinning sun had increased that much, that the crust came off like the „tread of an old car tyre" and was catapulted into space. The repulsion was achieved by the centrifugal force exceeding the gravitation for the force of cohesion, which at the moment of the separation of crust regions suddenly tears off. Like snowballs the planets lulled off the sun's surface in this process and were hurled away. Their velocity of rotation at this time was identical to the cosmic velocity of the sun v_k and with that for many a planet large enough to produce its own satellites out of its own surface, which perhaps was not yet completely ideally spherical.
With every planet, which the sun gave birth to, it gave away a part of its own angular momentum to its child as orbital momentum. Only from this time on the sun reduced its angular velocity steadily until this very day. By losing the crust it also started to shine openly. Thus at least could our solar system have been formed.

12.2 The birth of the planets

From this observation various consequences result. If stars are observed, which are rotating very fast, then they either are very young, or they have no planets. Stars, which compared to our sun are rotating less fast, have given away the angular momentum to their planets and such, which hardly are rotating, have their planets already sent away into space. But if the last planet leaves its solar system and the sun stops to rotate, then the sun, which meanwhile has grown to a red giant, without a, the spherical form stabilizing centrifugal force, will collapse. The supernova is the death of a star and thereby neutrinos are set free, the material for new life.

After the coming off of the planets these first clear free their flight paths, by together with the sun collecting the flying around matter. Even whole planets thus can collide, are slowed down and form bigger units. Finally only some few planets in very particular orbits are left. Their average distance to the sun obeys in an until now completely inexplicable manner the Titius-Bode series (equation 12.5, table 12.2).
In the case of the by the german scientist Titius 1766 formulated regularity it concerns a rule of thumb founded purely on experience. But it is remarkable, that the planet Uranus could be predicted (Bode 1772) and after systematic searching also be found (Herschel 1781) with it.

The most distant planets Neptune and Pluto however don't obey the law. Their distance should be very much larger. But this circumstance we already had given reasons for with the fact, that for them the resonating interaction already overlaps and exceeds the gravitation in its effect (chap. 10.1 note[ii] and chap. 10.5).

The arbitrary seeming series of numbers 0, 3, 6, 12, 24, 48, 96, 192, 384, ... with a respective doubling of the value, starting with the 3, the addition of 4 and the following division by 10 at first are nothing but pure acrobatics of numbers, which now really has nothing to do with physics (table 12.2). A physical background can be supposed however because of the tried and tested applicability and that should be fathomed.

Orbital angular momenta J·ω of the n^th planet
with: $J = m \cdot r_n^2$ and $\omega = v_n / r_n$: $\boxed{J \cdot \omega = m \cdot r_n \cdot v_n}$ (12.7)

By using	equation 12.3:	equation 12.4:	
amounts the orbital angular momentum to: $J \cdot \omega$	$= m \cdot \sqrt{G \cdot m_s \cdot r_n}$	$= G \cdot m \cdot m_s / v_n$	(12.8)
dependent	on r_n	on v_n	

change of the angular momentum (1st derivation) with the ordinal number n

$\frac{d(J \cdot \omega)}{dn}$	$= m \cdot \sqrt{G \cdot m_s} \frac{d(\sqrt{r_n})}{dn}$	$= G \cdot m \cdot m_s \frac{d(v_n^{-1})}{dn}$	(12.9)
$\frac{d(J \cdot \omega)}{dn}$	$= \frac{m \cdot \sqrt{G \cdot m_s}}{2 \cdot \sqrt{r_n}} \cdot \frac{dr_n}{dn}$	$= - \frac{G \cdot m \cdot m_s}{v_n^2} \cdot \frac{dv_n}{dn}$	(12.10)
with eq. 12.8: $\frac{d(J \cdot \omega)}{dn}$	$= \frac{J \cdot \omega}{2 \cdot r_n} \cdot \frac{dr_n}{dn}$	$= - \frac{J \cdot \omega}{v_n} \cdot \frac{dv_n}{dn}$	(12.11)

By comparison of the left and the right solution (of eq. 12.11),

after introduction of the constant: $\frac{1}{N}$	$= \frac{1}{r_n} \cdot \frac{dr_n}{dn}$	$= - \frac{2}{v_n} \cdot \frac{dv_n}{dn}$	(12.12)
the differential equations read:	$\boxed{\frac{r_n}{N} = \frac{dr_n}{dn}}$	$\boxed{\frac{v_n}{2 \cdot N} = - \frac{dv_n}{dn}}$	(12.13)
and the general solutions:	$r(n) = r_n = r_o \cdot e^{\lambda \cdot n}$	$v(n) = v_n = v_o \cdot e^{\lambda \cdot n}$.	(12.14)
The 1st derivation:	$\frac{dr_n}{dn} = r_o \cdot \lambda \cdot e^{\lambda \cdot n}$	$\frac{dv_n}{dn} = v_o \cdot \lambda \cdot e^{\lambda \cdot n}$	(12.15)
and the comparison with eq. 12.13 and eq. 12.14:	$\frac{dr_n}{dn} = \frac{r_o}{N} e^{\lambda \cdot n}$	$\frac{dv_n}{dn} = \frac{-v_o}{2N} e^{\lambda \cdot n}$	(12.16)
determine the coefficient λ:	$\lambda = 1/N$	$\lambda = - 1/2N$.	(12.17)
The result is for a planet in the n^th orbit:	for the average orbital radius $r(n) = r_n$ $r(n) = r_o \cdot e^{n/N}$ (12.18)	for the average orbital velocity $v(n) = v_n$ $v(n) = v_o \cdot e^{-n/2N}$ (12.19)	

Fig. 12.3: Calculation of the distances and orbital velocities of the planets

12.3 The derivation of the Titius-Bode law

Even if Bohr's atomic model should be wrong, it gladly is compared to the system of the planets. The radii of the electron orbits mathematically result as eigenvalue solutions of the Schrodinger equation, and that we have derived from the fundamental field equation (chap. 5.1, eq. 15) (chap. 5.5 - 5.9). The orbital radii are calculated in increasing order in accordance with the sequence of whole numbers with n = 1, 2, 3, 4, ...

From the same sequential regularity of the planetary orbits can be derived, that they also obey the eigenvalues of the same fundamental field equation, which isn't called a world equation in vain. The quantitative distances from the sun are determined by the size of the sun: if the sun increases, then also all distances increase to the same extent.

Now result identical distances between the orbits from Bohr's model, whereas this distance in the case of the planets with increasing distance from the sun gets larger. The reason for this unevenly grading can be calculated just like that (fig. 12.3).

We arbitrarily pick a planet, which occupies the orbit n, where n again represents the sequence of whole numbers (n = 0, 1, 2, 3, ...). If the orbit of this n^{th} planet changes, then also its distance to the sun $r_n = r(n)$, its orbital velocity $v_n = v(n)$ and the orbital momentum $J\cdot\omega$ (12.7) are changed.
We try (as in equation 11.42, fig. 11.10) the balance of forces between centrifugal force and gravitational force (eq. 12.1, fig. 12.1) and solve equation 12.2 for the orbital velocity. The orbital angular momentum of the planet written down once in its dependency on r_n and in the right column next to it on v_n (eq. 12.8, fig. 12.3), is derived for the orbital ordinal number n, to record the change in angular momentum (equations 12.9 to 12.11).

In fig. 12.3 the paths to the solution for both cases are given. For the average orbital radius r(n) as well as for the average orbital velocity v(n) of the planet an exponential course (eq. 12.18 and 12.19) and in logarithmic representation a straight line (fig. 12.4) results.

Even the orbits of the distant planets Neptune and Pluto, for which the Titius-Bode series fails, now are correctly recorded, so that with good cause can be claimed, to correctly have derived the regularity of the distances of the planets physically and mathematically.

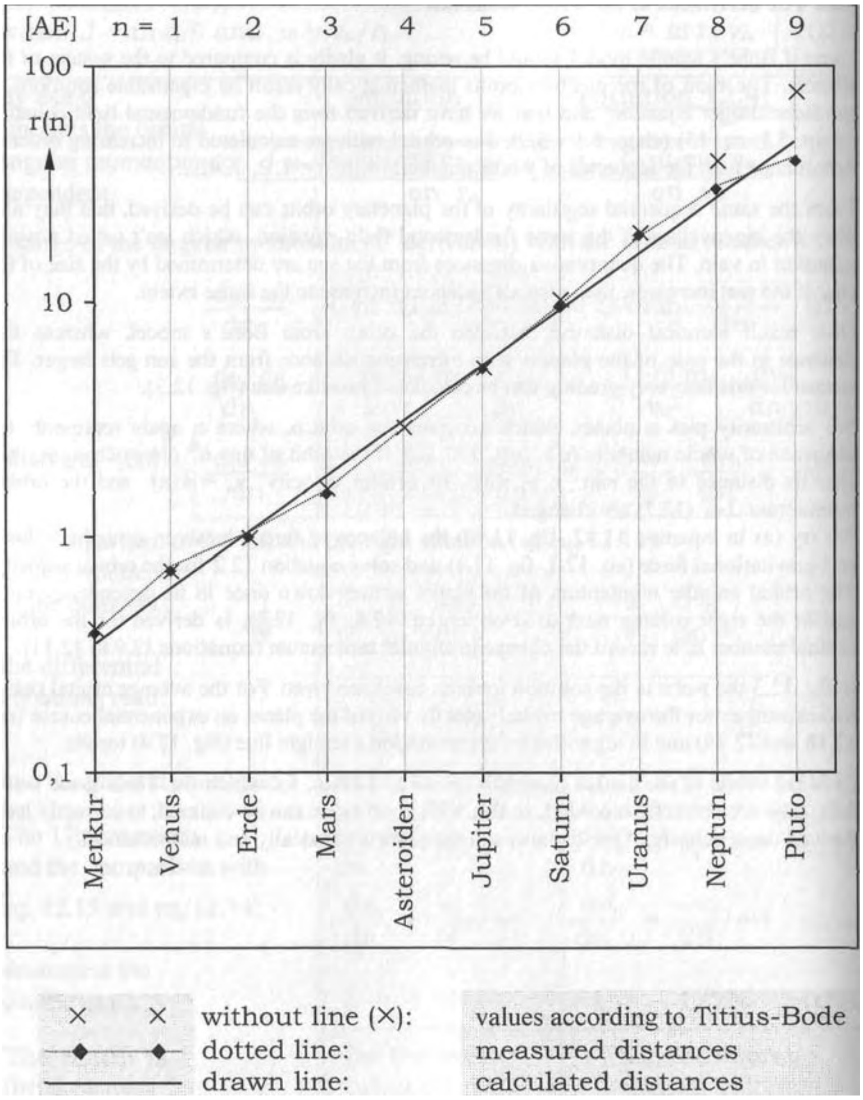

Fig. 12.4: Representation of the distances of the planets

result of the calculation: $\boxed{r(n) = 0,3332\cdot e^{\left(\frac{n}{1,82}\right)} \quad [AE]}$ (12.20)

12.4 The hollow planet

The numerous accompanying moons of the big planets obey in the same manner as the planets this regularity, so that for the found result every coincidence is excluded. The orbits of the moons of Jupiter (fig. 12.5), of the moons of Saturn (fig. 12.6) and of the moons of Uranus (fig. 12.7) in logarithmic representation lie almost on a straight line. Some orbits certainly are occupied several times, while many an orbit has remained unoccupied. Other orbits again are occupied by a ring of countless chunks of rock, so-called planetoids. Best known representative is the asteroid belt (n = 4) between the orbit of Mars (n = 3) and that of Jupiter (n = 5). The Titius law requested the planet "Aster", but what one found (Piazzi, 1801), at first only was Ceres, the biggest representative of the small planets.

As a second asteroid, as they are called, was found (Olbers 1802) its discoverer proposed the explanation that both, Ceres and Pallas, could have formed in a cosmic catastrophe, which a bigger celestial body had suffered.

Perhaps the sought-for planet Aster actually had imploded after a collision and had been torn apart in countless fragments, of which today still more than half a million pieces are flying around. Most of the fragments however have been collected by the neighbouring planets Jupiter and Mars. Also in the case of the moons of Mars and the outer moons of Jupiter it could concern scrap of Aster. Some presumably fell on the young earth and triggered natural disasters and left deep scars.

It can be imagined that the planet Aster was hollow from the inside and thus was built up similar to the moon. Such a hollow sphere could have formed, if the sun, or in the case of the moon, the earth still was rotating with the cosmic velocity and as a result of the centrifugal force at the perimeter parts of the crust came off as connected sheets and rolled up to a tube.

The fast spinning tube then remodels into a hollow sphere with openings at the poles. In the inside of the sphere, near the equator, protected conditions and the best prerequisites for an undisturbed development, for instance of intelligent living beings, are found by the way. Apart from the advantages the hollow sphere however has as a fundamental disadvantage, that the normally protecting shell in the case of a collision with a bigger celestial body can becomes instable and can implode.

In the case of the moon the pole openings in the meantime are closed and a presumed gas pressure in the inside in addition provides stability. The wall of the spherical shell however is not evenly thick, so that the moon all the time turns the same, namely the heavier, side towards the earth. In view of the seismic measurements of the Apollo-missions, which revealed an extremely small damping of the ground of the moon (chap. 11.9, note <i>), we should look after our moon well, because a comet, which lets the moon implode, would be able to bring about more damage on earth, than if it would hit the earth directly.

Should there exist a hollow and possibly even on the inside habitable planet in our solar system, then surely Saturn should be considered. Its density is smaller than that of water, so that water would be distributed over the inside area of the hollow sphere, if it would be existent. One should examine more detailed the extremely flat pole regions of Saturn for possible openings! Also Uranus and Neptune are possible candidates. This only is thought as an idea.

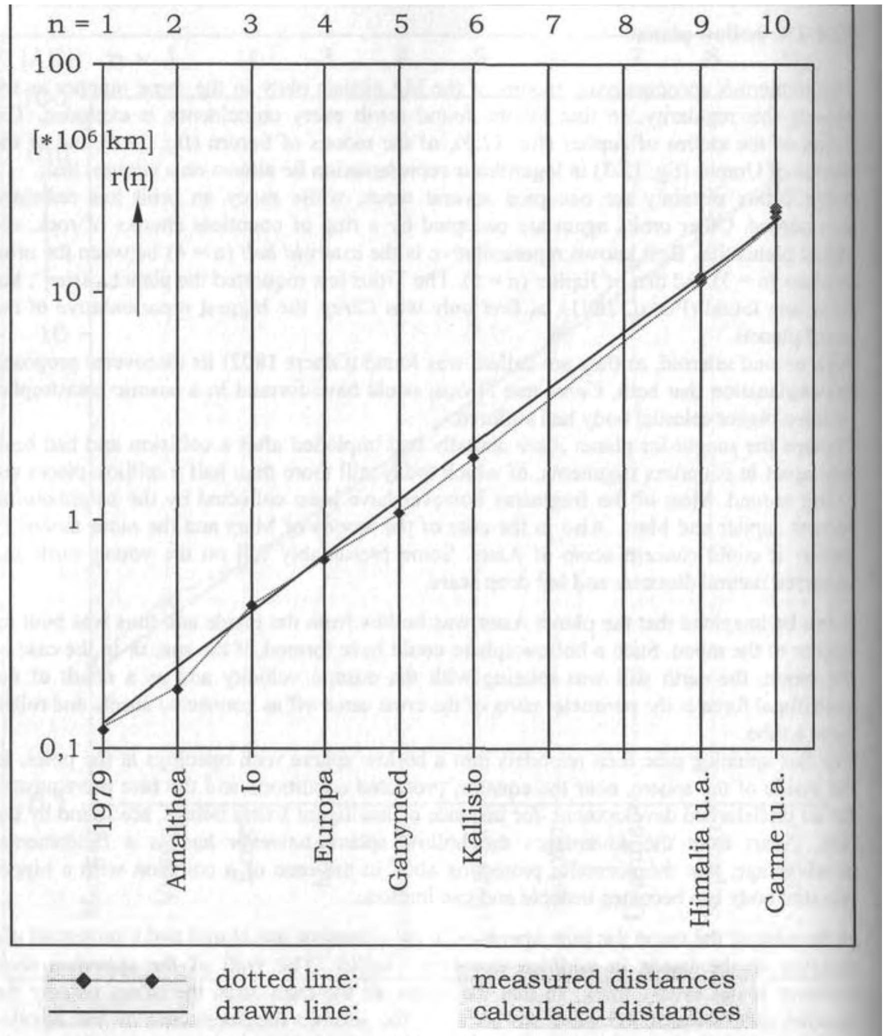

in position n = 9 stand: Leda, Himalia, Lysithea and Elara

in position n = 10 stand: Ananke, Carme, Pasiphae and Sinope

Fig. 12.5: The distances of the moons of Jupiter

Result of the calculation: $$r(n) = 67608 \cdot e^{\left(\frac{n}{1{,}743}\right)} \quad [\mathrm{km}] \tag{12.21}$$

<i>: Note to chapter 12.5:

What we observe as and call cosmos, is nothing but a structured state of space.

12.5 Concerning the formation of the universe

The widespread concept of an expanding universe bases on the observation of a red shift of the spectral lines of galaxies, which increases with their distance. As the physical explanation for the discovery of Hubble, the Doppler shift for a light source, which is moving away from us, is used. But this concept of an against the attraction of the gravitation taking place expansion is nothing more than a work hypothesis.

The by Christian Doppler in acoustics investigated effect treats the observable shift in frequency, if the source of sound or the receiver is moved with regard to the medium of propagation. But according to today's version there doesn't exist such a medium at all for light, because Einstein has abolished the concept of the aether. According to that the Doppler effect neither can be applied to changes in light frequency. In the case of the expanding universe, for a decrease of the density and the tracing back to a Big Bang, it therefore should concern a misinterpretation!

Here another effect has to take effect, which one is not yet clarified. Perhaps the changing field relations of the observer environment play a role, after the earth moves away from the sun. But perhaps the galaxies only influence the propagation of their own light, or the light ray on its millions of years lasting way through space slightly loses energy, what is expressed by gradually increasing its wavelength and shifting its spectrum towards the red frequencies.
The hypothesis of the Big Bang moreover contradicts every causality. It is not able to give an answer concerning the origin and the future of the universe and on the question of the origin of the energy and the particles. With that its physical value of explanation goes towards zero.

If we again hold the theory of objectivity against the theory of relativity (part 1), we come to quite other answers. Here apart from the waves also vortices are found. Specially in the case of the spherical vortex a part of the wave power is enclosed in the inside, so that looked at from the outside a from zero differing energetic state results, which even is accessible measuring technically (chapter 6.2).
Wave and vortex are two possible forms of state, so that for the conversion of one state in the other state at first no energy is necessary. The change of state depends on the local field relations.
If we assume that in the beginning the cosmos was free of energy and particles. Then the first vortex was a possible product of chance with an infinite extension. This first spherical vortex, which was contracted under the potential vortex pressure, gave structure to space, gave it energy and field and took care for the rolling up and formation of new vortices<i>.
It can be assumed, that even today new particles continually are being formed in the fringe areas of the infinitely extended cosmos, which fly towards us and in doing so contract. They are attracted and at the same time shrunk by the fields of the celestial bodies. They form the source of all matter and energy for our observable universe, which permanently is changing its structure. Because the same oscillation with reversed sign is enclosed in the inside of the spherical vortex, the sum of the energy present in the cosmos is exactly equal to zero. With that the question concerning the causality is superfluous.

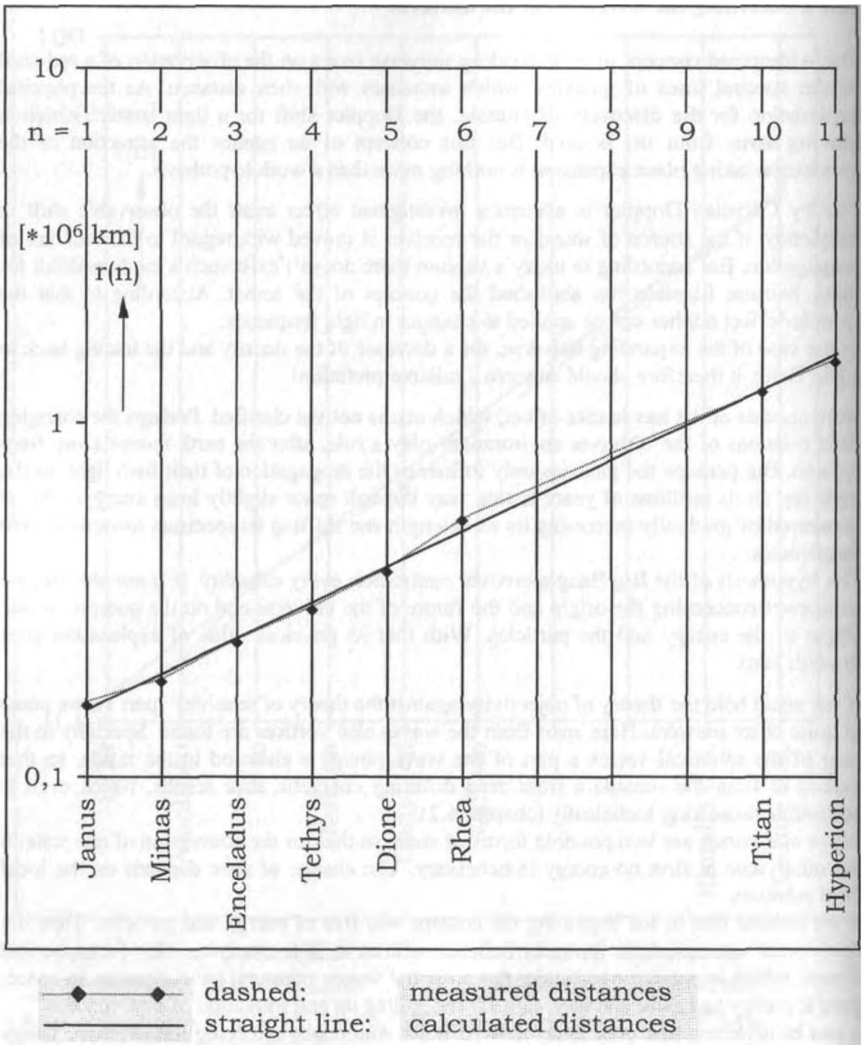

Fig. 12.6: The distances of the moons of Saturn

Note to chapter 12.6 (2nd law of thermodynamics<i>):

Heat cannot completely be transformed into mechanic or electric energy.

<i>: see Electromagnetic environmental compatibility, Part 1, fig. 8.4

The formation of the universe also can be explained causal and completely without a hot Big Bang, even if a supernova surely represents something like a "local Big Bang" for the concerned celestial bodies. According to the observations of the sky expansion and contraction, explosion and implosion occur everywhere in form of oscillations.

On the whole the expanding universe, which once was in thermodynamic equilibrium with matter, should cool down further and further. But stop, the 2nd law of thermodynamics teaches one just the opposite. If the entropy only increases, as the law dictates, then the whole universe should end in a heat death, just as mysteriously and inexplicable, as it should have been formed with the Big Bang. Perhaps something is wrong with the law (fig. 8.4)?

12.6 Counter examples concerning the 2nd law of thermodynamics

Most likely a small experiment convinces us. We heat two spheres, one somewhat less, the other somewhat more. Then we focus the heat radiation of the less hot sphere with help of a parabolic mirror and point it to the hotter one of both. That as a result becomes hotter, whereas the colder is cooled down. The heat thus has flown from the colder to the hotter sphere. Is it allowed to do that?
According to the 2nd law of thermodynamics it of course isn't. There the heat always can only flow from the hot to the cold sphere. But in this primitive experiment it measurable and verifiable flows in the wrong direction. Here the entropy, which is said to always only increase, actually decreases. Here entropy is being destroyed!
Shall we now let the carrying out of the experiment be forbidden under threat of penalty or shall we secretly put the law of entropy to sleep? It can't be denied that this law until now has quite well helped us along, at least for terrestrial processes, at least if one dispenses with the poor inventors, whose inventions offend against the since 100 years tried and tested 2nd law of thermodynamics. They haven't really arrived at the patent office at all, then they already are outside at the door again. Such inventors with their illegal behaviour even today must feel like criminals.

Just what that observed experiment can, each refrigerator and each warmth pump is using as well. And it is not an isolated case: also our sun clearly functions and operates illegally! The surface temperature amounts to only 5800 degrees Kelvin and supplies the atmosphere of the sun with energy. The energy thus flows from the sun to the corona, and that is with values above 1,000,000 degrees Kelvin for some powers of ten hotter!

Only the vortex concept resolves the many question marks without compulsion. In the case of the sun certainly vortices are at work. Here the high temperature in the corona arises as a result of vortices falling apart. We also speak of eddy losses. The transport takes place by heat radiation, exactly as in the experiment with the two spheres.
The possibility exists therefore in vortex processes as well as in technical circle processes that heat could flow from the colder to the hotter sphere. Whether this is an offence against the 2nd law of thermodynamics, is in the end a question of interpretation of the law and up to the opinions of the scholars.

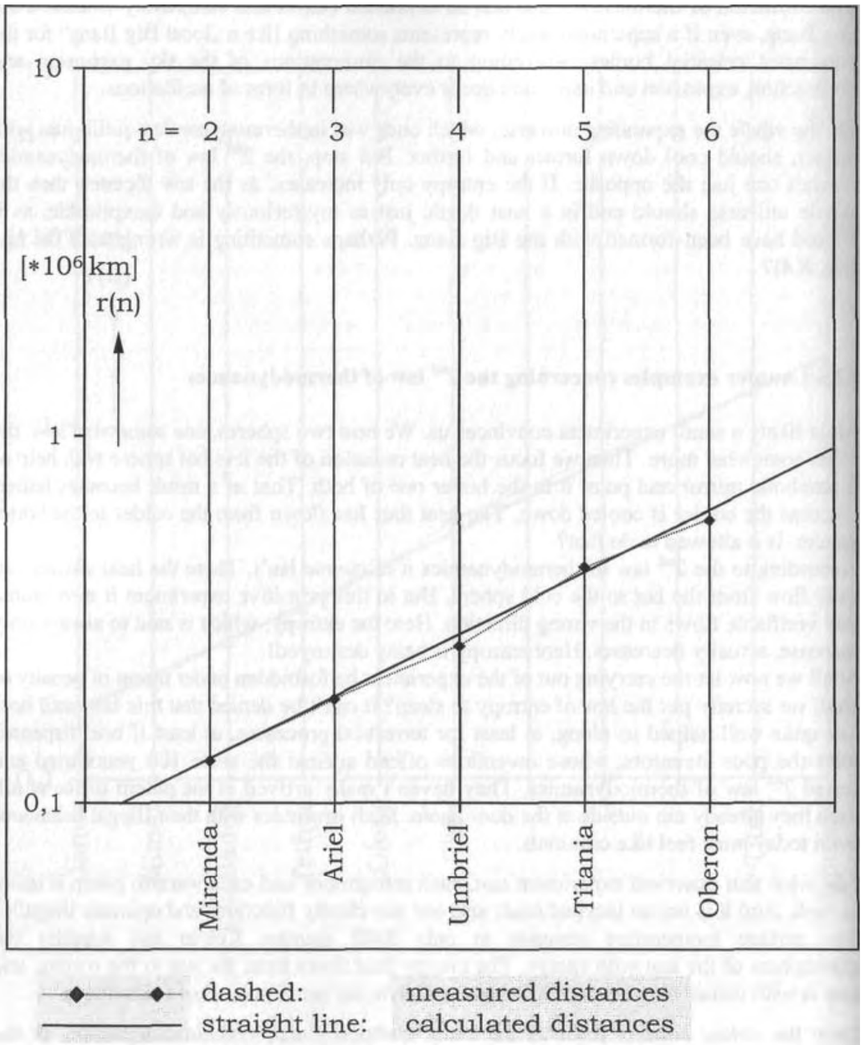

Fig. 12.7: The distances of the moons of Uranus

Note to chapter 12.7 (law of entropy):

The entropy of a closed system never can decrease. It is increased in the case of all irreversible processes. In the case of reversible processes it remains constant.

12.7 Entropy destroying potential vortices

Vortices in addition can amalgamate to balls and to planar vortex systems (4.9 and 4.10). In that case similar consequences, as they can be observed in flow-technical potential vortices in hydrodynamics, can be expected. As a result of the concentration effect (4.1) and because of the conservation of angular momentum an increase of the velocity of rotation of the vortex occurs. Like in the case of the pirouette in figure skating a spontaneous acceleration of its own is observed. In that way the kinetic energy of the system is increased, and that has to come from somewhere.
If we don't supply the contracting vortex with any additional energy for the increase of its rotation of its own, then as a source of energy only the heat energy is left. For this reason every contracting vortex generally converts heat in kinetic energy, it therefore cools down its environment! It moreover destroys entropy and offends against the 2nd law of thermodynamics (fig. 12.8).

It isn't an accident, if in the inside of a tornado it starts to hail. The whirlwinds really furnish visual instruction of the contraction and acceleration of their own of ring-like vortices. If then, even in tropical regions, hail stones are formed, the cooling effect has to come from somewhere, and it can be assumed that the vortex withdraws the heat energy from its environment (calculation in fig. 12.8).

If in specialist books is talked about matter or stars condensing, then vortex physics teaches us that they in reality are contracting and by doing that cooling down. That also is valid for whole galaxies. We owe solely the vortex laws that the continual heating by absorption of radiation is prevented and our sky in the night is dark and doesn't shine as light as day.

The cosmic background radiation, which as a result of vortices lies at almost 3° Kelvin, actually can only be given account for with a contracting of vortices of the Milky Way galaxy. If the cooling down in a compression resp. condensation process has arrived at absolute zero, the vortex becomes stationary, the contraction becomes dependent on the irradiated energy or it wholly comes to a standstill without supply of energy. An example for that is earth's inner core, which at zero Kelvin can't contract further.

From the point of view of causality it is suggested that we galactic and perhaps even cosmic to a large extent are in thermodynamic equilibrium, completely without Big Bang and heat death<i>.

Numerous inventions, as mentioned, are based on the principle of converting environmental heat in useable energy by contraction of vortices. If however the inventors don't know the vortex laws and if they have developed their concept empirically and less physically, then it very often happens that erroneously gravity is made responsible, then is talked of gravitational converters, of the use of a gravitational field energy. But the inventors don't do themselves a favour with that.

<i>: In the seminar it is desired to think about this. Doing so the philosophical faculty may feel as well addressed, as the sandpit of physics, in which completely unsuspecting is played and juggled with Big Bang hypotheses by ignoring all physical regularities and every common sense.

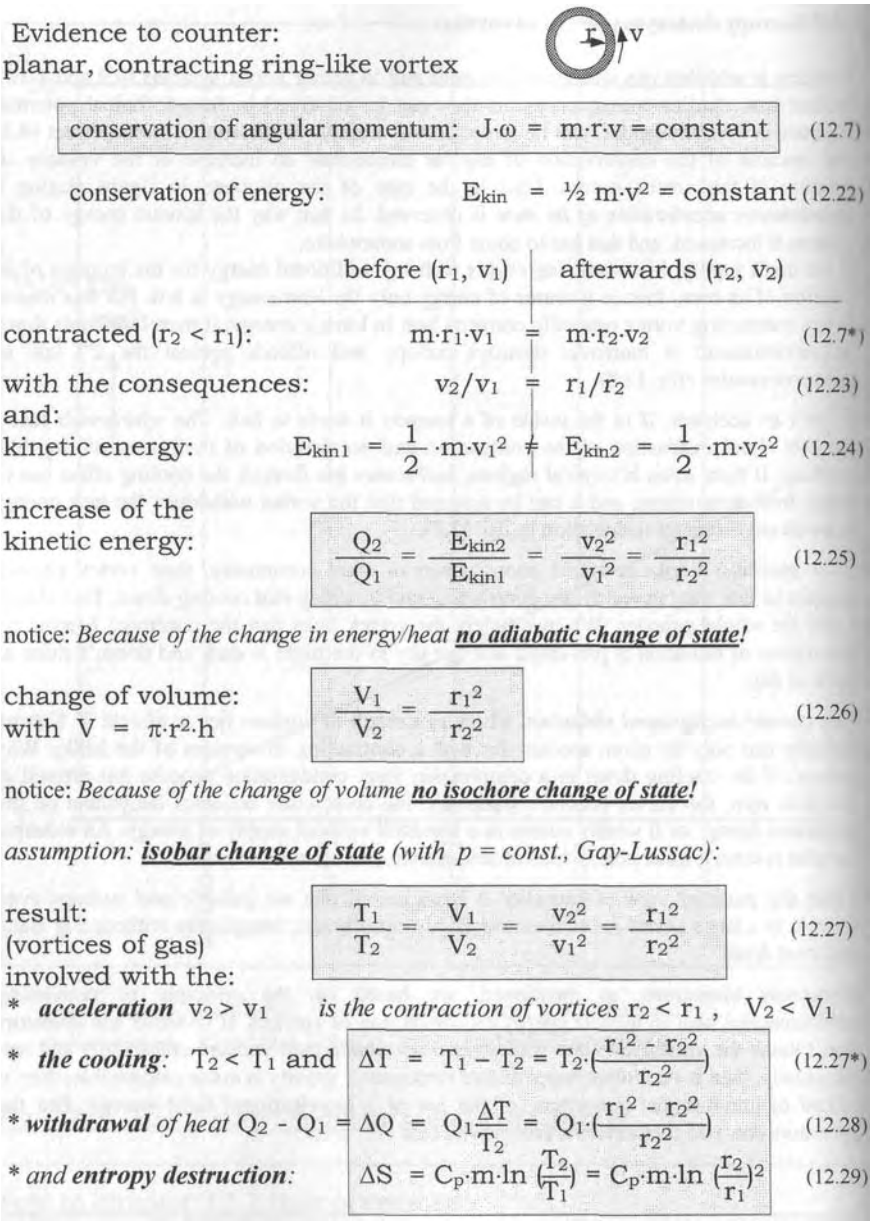

Evidence to counter:
planar, contracting ring-like vortex

$$\boxed{\text{conservation of angular momentum: } J\cdot\omega = m\cdot r\cdot v = \text{constant}} \quad (12.7)$$

$$\text{conservation of energy: } \quad E_{kin} = \tfrac{1}{2}\, m\cdot v^2 = \text{constant} \quad (12.22)$$

	before (r_1, v_1)		afterwards (r_2, v_2)	
contracted $(r_2 < r_1)$:	$m\cdot r_1\cdot v_1$	$=$	$m\cdot r_2\cdot v_2$	(12.7*)
with the consequences:	v_2/v_1	$=$	r_1/r_2	(12.23)
and: kinetic energy:	$E_{kin1} = \frac{1}{2}\cdot m\cdot v_1^2$	$\neq$	$E_{kin2} = \frac{1}{2}\cdot m\cdot v_2^2$	(12.24)

increase of the
kinetic energy:

$$\boxed{\frac{Q_2}{Q_1} = \frac{E_{kin2}}{E_{kin1}} = \frac{v_2^2}{v_1^2} = \frac{r_1^2}{r_2^2}} \quad (12.25)$$

notice: *Because of the change in energy/heat* ***no adiabatic change of state!***

change of volume:
with $V = \pi\cdot r^2\cdot h$

$$\boxed{\frac{V_1}{V_2} = \frac{r_1^2}{r_2^2}} \quad (12.26)$$

notice: *Because of the change of volume* ***no isochore change of state!***

assumption: ***isobar change of state*** *(with $p = const.$, Gay-Lussac):*

result:
(vortices of gas)

$$\boxed{\frac{T_1}{T_2} = \frac{V_1}{V_2} = \frac{v_2^2}{v_1^2} = \frac{r_1^2}{r_2^2}} \quad (12.27)$$

involved with the:

* ***acceleration*** $v_2 > v_1$ *is the contraction of vortices* $r_2 < r_1$, $V_2 < V_1$

* ***the cooling****:* $T_2 < T_1$ and $\Delta T = T_1 - T_2 = T_2\cdot\left(\frac{r_1^2 - r_2^2}{r_2^2}\right)$ (12.27*)

* ***withdrawal*** *of heat* $Q_2 - Q_1 = \Delta Q = Q_1\frac{\Delta T}{T_2} = Q_1\cdot\left(\frac{r_1^2 - r_2^2}{r_2^2}\right)$ (12.28)

* *and* ***entropy destruction****:* $\Delta S = C_p\cdot m\cdot \ln\left(\frac{T_2}{T_1}\right) = C_p\cdot m\cdot \ln\left(\frac{r_2}{r_1}\right)^2$ (12.29)

Fig. 12.8: The cooling and entropy destroying effect of contracting potential vortices (calculations concerning chapter 12.7)

13. Recording of space and time

If observations should force us to touch the sacred physical laws, then we should first of all judge our measuring technique critically of all sides and bring it in an usable state. I suggest, we start completely from the beginning with the devices, with which the dimensions of space and time are recorded, with the tape measures for the measurement of length and the chronometers, our clocks.

We must find out, why comets are slowed down if they approach the sun like by the hand of a ghost and in going away again are accelerated, although no forces at all act on the celestial bodies from the outside.

We must find out, why in mines deep under the earth another value for the gravitational constant is being measured as on the surface of the earth<i>. The results hardly can be imagined, if an universal constant should lose its constancy.
Thereby can Newtonian mechanics and the well-known laws be used very successfully from today's point of view, as the derivations in the last chapters have shown. We even could verifiably and mathematically correct calculate the growth of the earth and the solar system with them. The physical laws in the normally used formulation in spite of that seem to be bound to certain limits. Some observations contradict all experience<ii>.

<i>: H. Schuh: Eine Konstante verliert ihre Konstanz; neue Experimente nahren Zweifel an Newtons Gravitationsgesetz, Die Zeit Nr. 40 vom 25.09.97. From it the following quotation (translated):
„It already is suspected for several years, that a fifth force could exist, this suspicion goes back to exact measurements of the gravitational constant G in Australian mines and shafts. Physicists of the University of Queensland in Brisbane had determined, that G for measurements underneath the earth is about one percent larger than the corresponding, since centuries in laboratories determined size. Their proposal for explanation, namely a fifth repelling force, at first met with sharp disapproval. But an at 21 august in the journal Science (Bd. 237/87, P. 881) published work, which bases on measurements in a drilling hole in Michigan, confirms the Australian data".

<ii>: Already the nobel prize winner of physics, Lenard, pointed to the circumstance, that the relativistic representation of the astronomical aberration is incorrect, after no distinguishable aberration could be observed at binary stars, as it had been expected. With that Lenard by the way also has confirmed the existence of an aether.
P. Lenard, Annalen der Physik, Bd. 73, S. 89 (1924)

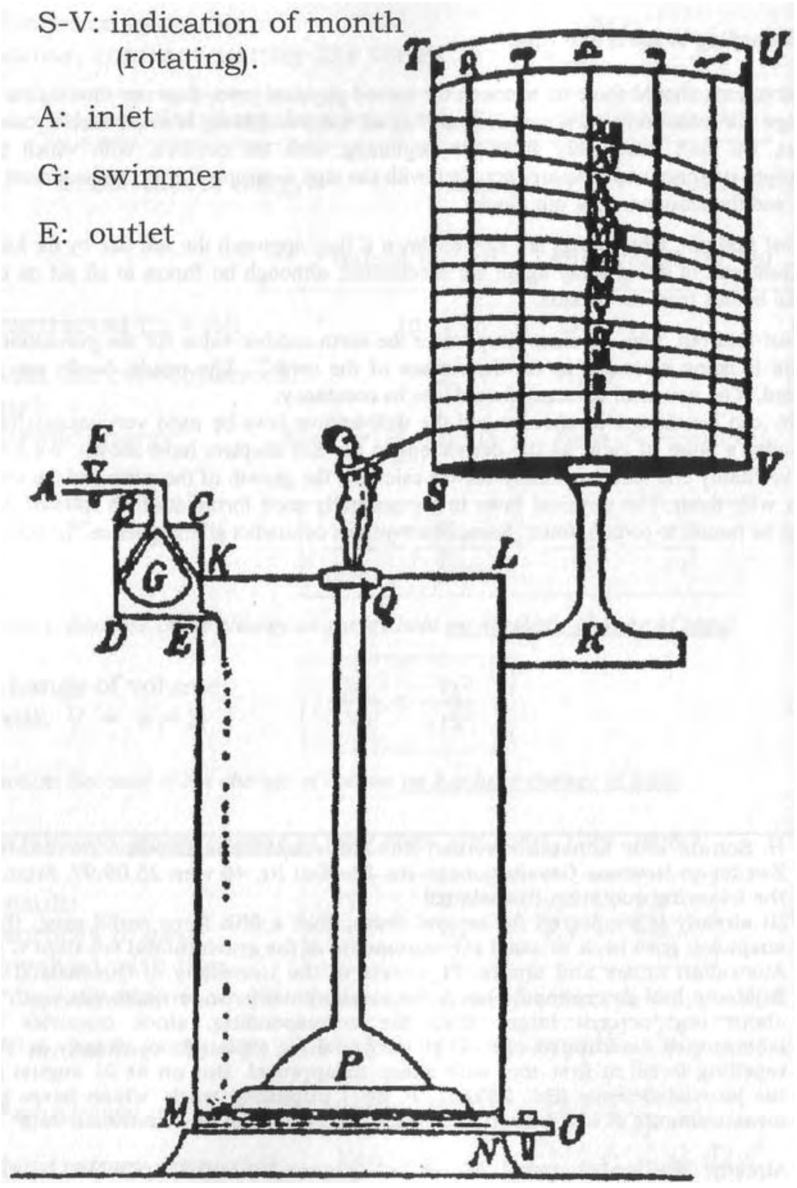
S-V: indication of month (rotating).
A: inlet
G: swimmer
E: outlet
T
U
V
S
F
A
B
C
G
K
L
D
E
Q
R
P
M
N
O

Fig. 13.1: The water meter of the Ktesibios (approx. 250 BC)
(with regulation of the water-level)

13.1 The measuring technical debacle

We are standing for a measuring technical debacle, because we have fixed our calendar to the rotation of its own of the earth. We call a 360° turn a day, divide it in 24 hours of 60 minutes each and every minute in 60 seconds. With that we determine the duration of a second.
A clock according to this definition only then is exact, if it follows the changes of the earth to the same extent. Obviously this in particular is the case for atomic clocks. An objectively seen precise going clock however would land at the waste disposal site as completely unusable.
Alter all nobody wants to know, how late it really is. Everyone only wants to find confirmed his subjective feeling, and our experience of time simply is directed after the course of the sun, thus after the rotation of the earth!

For the moment and as an approximation also for the life time of a person, this determination of time may be sufficiently exact, but seen over larger periods of time, one doesn't get around a conversion. Actually the 200 million years since the beginning of the Creation on the mentioned primeval hill are considerably less long ago. The earth and the whole solar system are very much younger, than was assumed until now!

If we as an example again take the cited research group of the University of Arizona (chap. 11.10<i>), which by means of an analysis of sediment formations have found out, in accordance with our calculation, that 900 million years ago a day only had 18 hours<i>. Such traces in geological deposit layers can be very informative, if they are analysed correctly, since here the measurement technician himself is not subject to the process. He stands outside and hence can exactly measure the time difference.
If a geologist of that time had looked at his watch during the formation of the layers, then a day obviously would have had 24 hours, and he wouldn't have been able to understand the whole excitement at all. The accusation, he would suffer from chronic blindness caused by his job, he of course would repel resolutely. Can you now imagine, from which disease our science of today suffers?

Our chronometers are nothing but the improved model of a sundial<ii>.

We live in the dimensions of space and time, but we quite obviously have the biggest possible difficulties with the dimensioning of both. Possibly we already aren't capable of that at all by principle. Most suitably we clarify the situation by means of examples concerning the two problem spheres.

Let us at first stay at the dimension of time. It may have become clear, how problematic the chosen determination of the time scale in seconds is and which contradictions can result if larger periods of time are considered. More and more often science fiction authors romp about on the playground of time, fantasize about some time travel, or they occasionally make jokes about it<iii>.

<i>: 900 million years ago a day had 18 hours, Washington (dpa) 1997.

<ii>: There also exist models, of which is asserted, they go according to the moon.

<iii>: A passenger, who got on the 10 o'clock bus, passes by the church steeple clock, which only reads 5 to 10 and curses: Damn, I took the bus in the wrong direction!

Centrifugal force $\boxed{F_{1,2} = (m/R)\cdot(v_E \pm v_f)^2 = m\cdot R\cdot(\omega_E \pm \omega_f)^2}$ (13.1)

with: $R = 6378$ [km] (radius of the earth),

$v_E = \omega_E\cdot R = 0{,}465$ [km/s] (rotational speed of the earth), (11.20)

$v_f = \omega_f\cdot R = \pi\cdot R/t_o$ (speed of the plane) (13.2)

and: t_o [s] (duration of journey)

energy of the moving steering quanta:

$$E_{1,2} = \int_O^R F_{1,2}\, dR = m \int_O^R R\cdot(\omega_E \pm \omega_f)^2\, dR = \tag{13.3}$$

$$E_{1,2} = \frac{1}{2}\cdot m\cdot R^2\cdot(\omega_E \pm \omega_f)^2 = \frac{1}{2}\cdot m\cdot(v_E \pm v_f)^2 \tag{13.4}$$

energy balance (generally of a quantum of radiation):

$\boxed{E_{1,2} + E_q = E_{ges}}$ resp. $\boxed{E_{ges} - E_q = E_{1,2} = \Delta E}$ (13.5)

in general: $E = h\cdot f = m\cdot c^2$ resp. $m = h\cdot f/c^2$ (13.6)

(Gl. 13.4 mit 13.6):

and specifically: $\boxed{\Delta E = h\cdot\Delta f} = \boxed{E_{1,2} = h\cdot f\cdot(v_E \pm v_f)^2/(2c^2)}$ (13.7)

$\Delta f/f = \Delta t_{1,2}/t_o$ resp. $\Delta t_{1,2} = t_o\cdot\Delta f/f$ (13.8)

(eq. 13.7 inserted into eq. 13.8)

resulting in: $\boxed{\Delta t_{1,2} = t_o\cdot(v_E \pm v_f)^2/(2\cdot c^2)}$ (13.9)

time of travel around half the earth: $t_o = \pi\cdot R/v_f$ (13.2)

results in a difference in going of: $\Delta t = \Delta t_1 - \Delta t_2$ (13.10)

$$\Delta t = [(v_E + v_f)^2 - (v_E - v_f)^2]\cdot\pi\cdot R/(v_f\cdot 2\cdot c^2) \tag{13.11}$$

result calculated: $\boxed{\Delta t = 2\cdot v_E\cdot\pi\cdot R/c^2 = \underline{207}\text{ [ns]}}$ (13.12)

measured by Hafele and Keating<i>: 214 [ns]! (13.13)

Fig. 13.2: The difference in going of two atomic clocks
(caesium resonant clocks)

<i>: Hafele-Keating-Experiment, Oktober 1971; s. a. W. Bauer: Klassische Physik, Graphia Druck, Salzburg (1975), Eigenverlag

13.2 The clock paradox

The theme „time dilatation" in connexion with the particle decay already has been treated (part 1, chapter 6.20). It has been shown, that a fast moving and with that length contracted particle to exactly the same extent (Lorentz's square root) becomes more stable and longer-living. If relativists pack an atomic clock based on radioactive decay in a plane and detect a difference in going between the one, which has been flown around and a second identically constructed clock, which has stayed at the ground, then they have with that detected experimentally a very small length contraction, which really occurred, and by no means a time dilatation, as they claim.

Now we in addition owe Einstein, that the aether has been abolished and from that follows, that it can't play a role in which direction the plane flies. If therefore both clocks are taken along each in a separate plane, one plane flying to the west and the other to the cast, both planes meeting again for the first time on the other side of the globe, then according to Einstein's theory it shouldn't be possible to determine a difference in going, if both planes constructed identically were on the way with the same velocity. But this is not the case!

Actually a difference in going is measured, which however can't be calculated with the theory of relativity, yes, which is completely incompatible with this theory and clearly brings anyone to the eye, that the effect actually can't have to do anything with a time dilatation, that the moving clocks merely go wrong and we have to ask us, why<1>.

These experiments were carried out with atomic clocks, which are constructed as caesium resonators and work with an exactness of one second in 300000 years. As a resonator serves a quartz crystal, which is controlled by an ion current of caesium atoms, which have lost their outermost enveloping electron. The system is fed back, because the oscillating quartz controlled by the caesium ions again adjusts the caesium vapour by radio wave and finally its own atomic controlling current (fig. 13.7).

The reason for the measured difference in going is seen in the field and here specially in the different gravitational field. The centrifugal force directed opposite to the gravitational force at least is not the same, because for a westward flight along the equator the speed of the plane v_f should be subtracted from the velocity of rotation of the earth v_E, whereas in eastward direction it should be added (eq. 13.1).

For the steering quanta supplied by the caesium resonator now the energy balance is put up (13.5 with 13.4) and the change of the reference frequency is calculated (13.7). With the change in frequency is connected directly a change of the at the two clocks readable times $t_{1,2}$ (13.8). For a journey around half the earth, where one clock is flown westwards and the other one eastwards, the difference in going should, according to the calculation, amount to 207 ns. Interesting of the result (13.11) undoubtedly is, that the velocity of the planes doesn"t play a role. It is cancelled out.

October 1971 caesium atomic clocks were sent around the world in scheduled planes in the Hafele-Keating experiment. To be able to estimate the inaccuracy in going of the clocks and with that the measurement error, four clocks were used. Between the westward journey (273 ±7 ns) and the eastward journey (59 ±10 ns) a difference in time of 214 nanoseconds was determined. This under strict scientific conditions determined result once more proves the correctness of the theory of objectivity by confirmation of the calculated value. That however is not valid for the special theory of relativity, because that doesn't appear in the calculation at all!

Who now believes, we would have less problems with the dimension of space, I must disappoint. The determination of the linear measures equally ends in a fiasco.

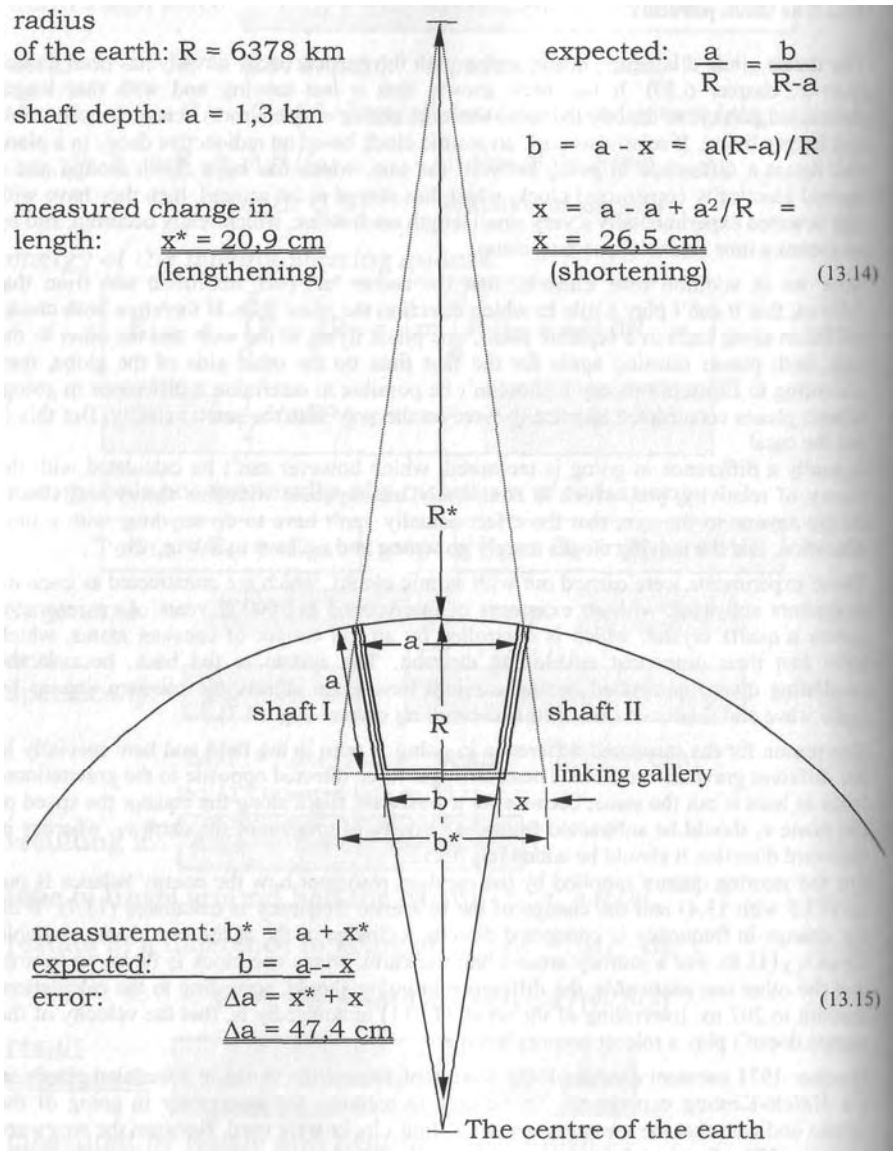

radius of the earth: $R = 6378$ km

shaft depth: $a = 1{,}3$ km

measured change in length: $\underline{x^* = 20{,}9\text{ cm}}$ (lengthening)

expected: $\frac{a}{R} = \frac{b}{R-a}$

$$b = a - x = a(R-a)/R$$

$$x = a - a + a^2/R = \underline{x = 26{,}5\text{ cm}} \quad \text{(shortening)} \tag{13.14}$$

measurement: $b^* = a + x^*$

expected: $b = a - x$

error: $\Delta a = x^* + x$

$$\underline{\Delta a = 47{,}4\text{ cm}} \tag{13.15}$$

R*
a
a
shaft I
R
shaft II
linking gallery
b
x
b*
The centre of the earth

Fig. 13.3: Expectation and measurement in the Tamarack mines

(The curvature of the earth and the length of the shaft a are drawn strongly exaggerated for clarification)

13.3 The Tamarack mines experiment

As long as the „foot measure" depended on the shoe size and the „cubit" on the forearm of the tailor, the world still was OK. The sciences however request a reproducible quantity for comparison, and that can be fetched at the Bureau International des Poids et Mesures in Sevres near Paris. The original meter is a Platinum alloy. Because the length of the metal always depends on temperature, it is stored at a constant kept temperature of 0° Celsius. Now there in addition still exists a field dependency, an electrostriction resp. magnetostriction. And how is the measurement bar behaving, if the earth grows and the density increases? Is it then shrinking just like other objects in its environment? At this point already chaos is proliferating.

The newest definition of the length measure meter acts as a blow for liberty and thus marks the abyss, at which we are standing: The length is determined by means of a measurement of transmission time of an electromagnetic wave, e.g. of a light signal. It is said that with this determination a higher reproducibility should be obtained. Actually a photo optical facility to measure length is as exact as the built-in facility to measure time, and there we use it again, our sundial. In addition a constancy of the speed of light is taken as a prerequisite, and that is given in meters per second. From a change of the speed of light for forinstance 10% a change in length for 10% as well would result<i>. Because we see this process with the help of our eyes as well with the speed of light, we never can see the change. We neither can technically measure it, because all gauges we construct are built up corresponding to our sensory impression. We ourselves have shovelled the hole, in which we fall.

Only if we succeed in taking a neutral standpoint outside of the events, the true relations will become visible to us. For the field dependency of the space measures a very clear experiment has been carried out, of which I now want to report<ii>.

1901 the French government was offered the possibility to carry out an experiment in the shut down Tamarack mines near Calumet (Michigan) with the goal to determine the diameter of the earth more exact. For that the geophysicists let down two plumb-lines of 27.2 kg each in two perpendicular winding shafts, which were at a distance of 1.3 km from each other. The plumb-lines were tied to hardly expandable piano wires of as well 1.3 km length. It now was expected, since the plumb-lines hung in direction of the centre of the earth, that in a linking gallery between the two shafts a length of (1.3 - x) km should be measurable. From the shortening x one wanted to infer the diameter of the earth (fig. 13.3). But it came completely different.
Instead of a shortening a lengthening for x* = 20.9 cm was measured in the gallery! The point of intersection of the lines through the two shafts had to be not in the inside of the earth, but in space! Immediately „hollow earthers" appear, who claim we would live on the inside of a hollow world<ii>. Perhaps one should shoot them to the moon, because from there the earth without doubt is seen as a sphere. Obviously we aren't dealing with a surprise of a fair, but with a fundamental measuring technical problem.

<i>: for that see also part I, chapter 6.11 and 6.12
<ii>: http:/www.t0.or.at/subrise/hollow.htm

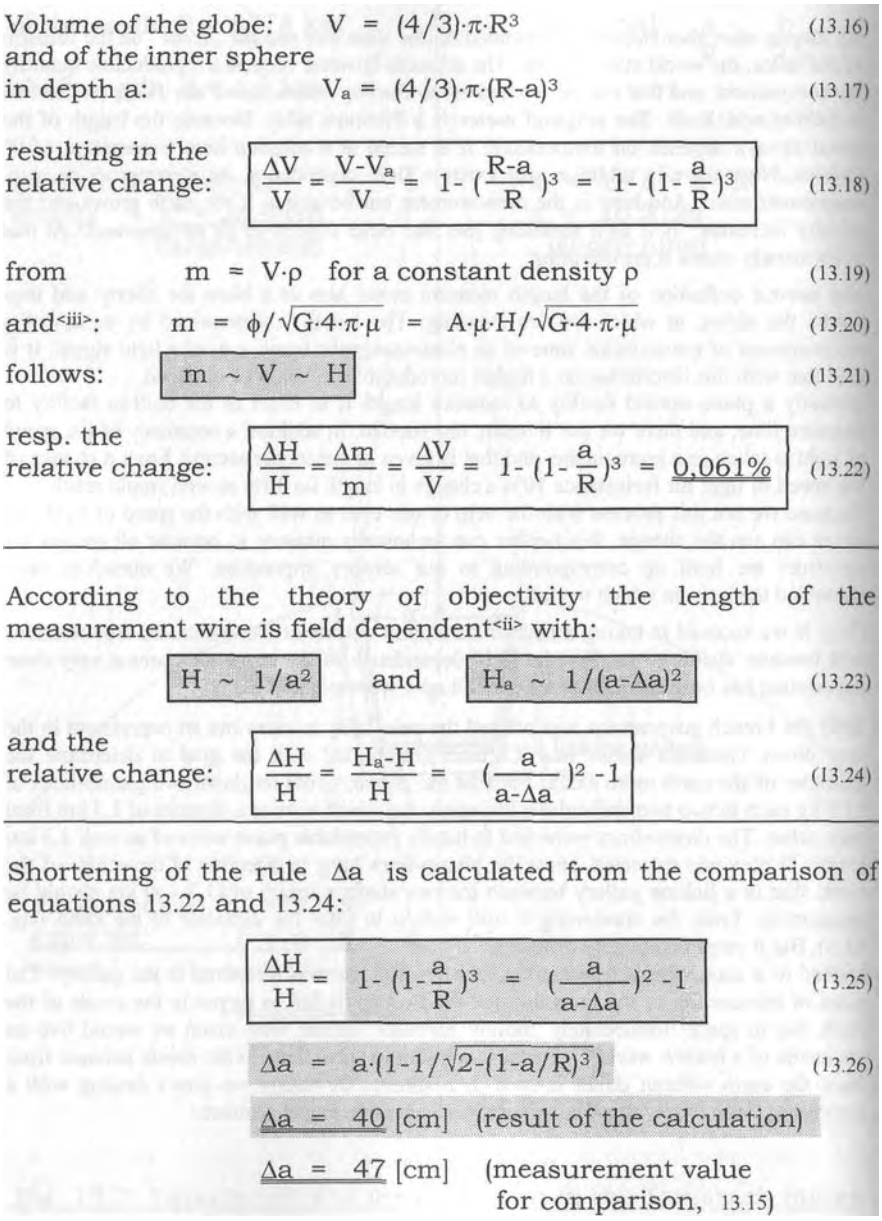

Volume of the globe: $V = (4/3)\cdot\pi\cdot R^3$ (13.16)

and of the inner sphere in depth a: $V_a = (4/3)\cdot\pi\cdot(R-a)^3$ (13.17)

resulting in the relative change:
$$\boxed{\frac{\Delta V}{V} = \frac{V-V_a}{V} = 1-\left(\frac{R-a}{R}\right)^3 = 1-\left(1-\frac{a}{R}\right)^3} \quad (13.18)$$

from $m = V\cdot\rho$ for a constant density ρ (13.19)

and<iii>: $m = \phi/\sqrt{G\cdot 4\cdot\pi\cdot\mu} = A\cdot\mu\cdot H/\sqrt{G\cdot 4\cdot\pi\cdot\mu}$ (13.20)

follows: $\boxed{m \sim V \sim H}$ (13.21)

resp. the relative change:
$$\boxed{\frac{\Delta H}{H} = \frac{\Delta m}{m} = \frac{\Delta V}{V} = 1-\left(1-\frac{a}{R}\right)^3 = \underline{0{,}061\%}} \quad (13.22)$$

According to the theory of objectivity the length of the measurement wire is field dependent<ii> with:

$$\boxed{H \sim 1/a^2} \quad \text{and} \quad \boxed{H_a \sim 1/(a-\Delta a)^2} \quad (13.23)$$

and the relative change:
$$\boxed{\frac{\Delta H}{H} = \frac{H_a-H}{H} = \left(\frac{a}{a-\Delta a}\right)^2-1} \quad (13.24)$$

Shortening of the rule Δa is calculated from the comparison of equations 13.22 and 13.24:

$$\boxed{\frac{\Delta H}{H} = 1-\left(1-\frac{a}{R}\right)^3 = \left(\frac{a}{a-\Delta a}\right)^2-1} \quad (13.25)$$

$$\Delta a = a\cdot(1-1/\sqrt{2-(1-a/R)^3}) \quad (13.26)$$

$\underline{\Delta a = 40}$ [cm] (result of the calculation)

$\underline{\Delta a = 47}$ [cm] (measurement value for comparison, 13.15)

Fig. 13.4: Calculational verification of the measured shortening

13.4 Field dependent linear measure

If a measurement result delivers just the opposite, as was expected by the experimentators, then the layman is amazed and the expert is surprised, at least at first. But then, out of a feeling of panic, the whole view of life could collapse, as many as possible scientists and renowned professors are being informed and integrated, if they want it (Prof. Mc.Nair) or not (Prof. Hallock, Columbia University) and eventually the matter is buried third class and a guise of silence is spread over it. The censorship of the scientific making of opinion in advance doesn't permit publications, which are not in accord with our view of life, out of the animal survival instinct<i>.

A science, which deserves this name, should look different. There it must be permitted, to ask questions and to publicly discuss about it.

I proceed from the assumption, that the earth is a sphere, which we inhabit from the outside; I have no doubts about that. With this as a prerequisite there is only one possible answer to the Tamarack mines experiment: The 1.3 kilometres long measurement wire, which in the gallery in a depth of 1.3 km had to jut out for 26.5 cm, instead is too short for 20.9 cm, from which immediately follows that it, howsoever, is shrunk for 47.4 cm in the depth.

At first of course the experiment was checked for possible measurement errors. The shafts were covered to exclude any draught. The measurement path was optically checked, but the result remained unchanged. But if the cause for the unexpected result doesn't lie in the experiment, then theoretical physics is addressed, after all it is still the experiment which shows us the physical reality and not some theoretical model concept.

In the 1st part of the book already the derivation of a useful explanation is found: The speed of light and with that also the linear measure depends on the field<ii>. The measurement wire accordingly gets shorter, if it is exposed to a larger field strength (eq. 13.23). We can verify the measured shortening calculative (fig. 13.4).

For that we at first determine the change of the field strength, as it is to be expected in a depth of 1.3 km. We here are dealing with the closed H field lines, which are responsible for the gravitation. In a past derivation it has been shown, that a gravitating mass can be converted into a magnetic field<iii>. Between a mass m and a field strength H hence exists a proportionality (13.21), in the same way as between the same mass and its volume, if a constant density is present (13.19).

The result accordingly is a relative decrease of the volume of the earth and the corresponding mass being under the measurement place, as well as a relative decrease of the radial component of the field strength, but a corresponding relative increase of the tangential component of the field for 0.061% (13.22 with 13.18).

In the gallery the measurement wire however is spread out in the direction of the tangential component of the field lines, and that shortens the measurement wire as a result of the field dependency of the linear measures<ii> (13.23). From the above increase in field the calculational shortening of the rule for 40 cm results, which compared to the measurement result also should be rated as a confirmation of the theory of objectivity which was taken as a basis<ii>!

<i>: Example: K. Meyl: Potentialwirbel, Bd. 1, reference entry /5/

<ii>: for that see also part 1, chapter 6.6, equation 65 and chapter 6.10

<iii>: K. Meyl, Potentialwirbel Band 2 (1992), page 27, equation 20

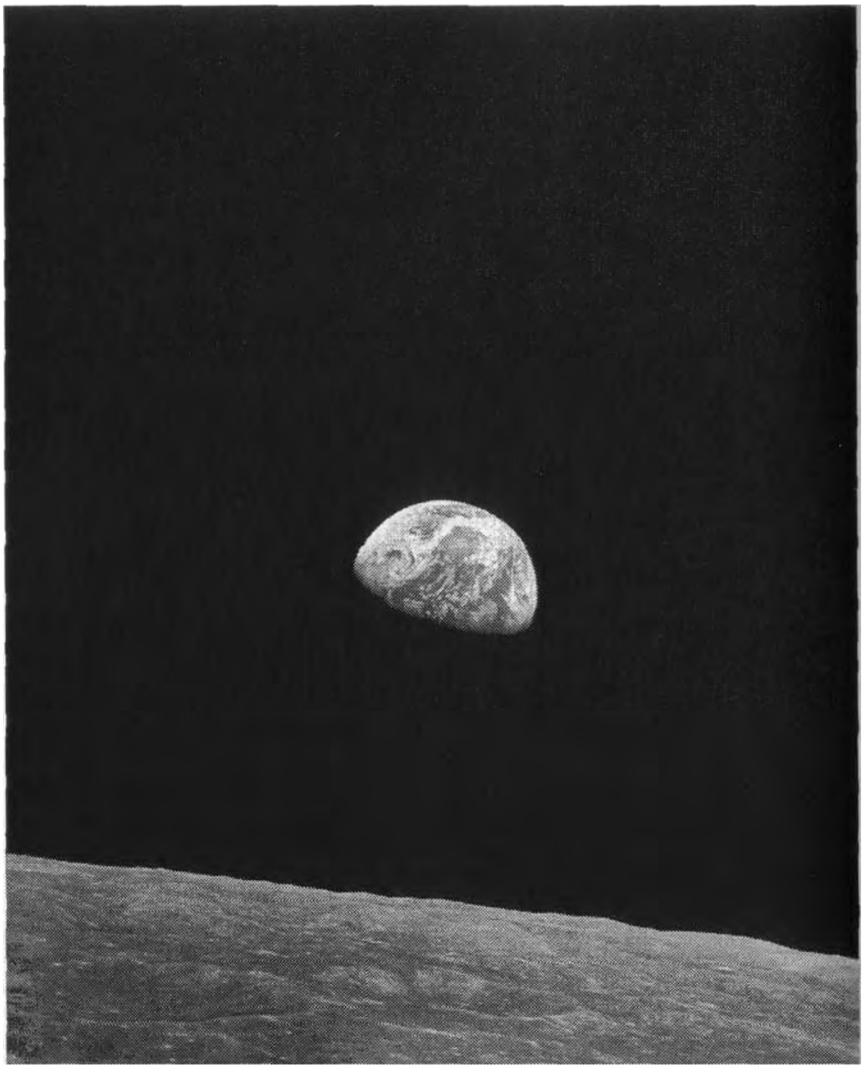

Fig. 13.5: Rise of the earth over the horizon of the moon""

<i>: Mitton, S. (Herausg.): Cambridge Enzyklopadie der Astronomie, Orbis Verlag (1989), note: No star is seen!

<ii>: see also the references in part 1, chapter 6.9

13.5 Experiences from space travel

The good correspondence of the calculated shortening of the measurement wire and the until now not understood measurement in the Tamarack mines shows both qualitatively, and quantitatively the correctness and useful applicability of the theory of objectivity of the field dependency of the linear measures. Our measurement laboratories normally are situated on the earth's surface and there everywhere are found approximately identical field relations. But if we leave the usual measurement environment and move the laboratory for instance in the sky, then we experience a complete mystery. Here however prevail the reversed conditions as in the mines experiment, in which in the inside of the earth. for an increase of the field strength, a length shortening was measured. In the sky the field strengths decrease and the linear measures correspondingly increase.

This experience astronaut Roosa made in the Apollo 14 mission. While he alone in his capsule orbited the moon, he depicted mission control, he could see the lunar module and observe his two colleagues at their work on the moon. Nobody wanted to believe the astronaut, since he was flying in a height of 180 km!

Commander Armstrong (Apollo 11) at the first landing on the moon indicated, the target crater Mackensen, 4.6 km in diameter measured from the earth, just has the size of a soccer field! Astronaut Scott (Apollo 15) called Mount Hardley, which is said to be 4.8 km high, a practice hill for skiing. Perhaps they somewhat have exaggerated, but a true core in the statements always is present!

Actually the gravitational field of our satellite is very much smaller than that of the earth. On the surface of the moon there is only one sixth of the gravitational pull of the earth. If we, to be able to compare, stick to the details of size, as they are measured by our laboratory on earth, then the astronauts on the way to the moon together with the lunar module and their rover had grown for a factor $\sqrt{6}$, then the first footprint is 2.5 times as large as on earth, then the astronauts were moving like giants in the scenery of a model of the railroad (eq. 13.23 and note[ii] at fig. 13.4).

On the moon there exists almost no atmosphere, for which reason the astronauts had imagined a wonderful view of the star-spangled sky, at least before they started. After the landing they were bitterly disappointed. The sky was black and not one single star could be seen! They have brought many photographs, but nowhere stars have been photographed, they apparently have moved outside the range of vision (fig. 13.5 and 13.6).

Many will still remember that the first pictures, which the space telescope Hubble supplied 1990, were completely blurred. The problem obviously was, that the mirrors had been adjusted on earth and not in space. Only after the optics had been given glasses in 1994, sharp pictures could be radioed to earth. Somehow the distance to the stars had changed. The telescope had become short-sighted, resp. the distance to the star-spangled sky appeared to be gotten larger. We already know why. If we remove us from the gravitational field of the earth, the field strength decreases and the observable distances increase! The highly sensitive telescope already sufficed the 5% deviation, with which should have been reckoned for the near earth orbit, to be fatal.

One should have familiarized the astronauts before with the laws of physics. Then this disappointment would have been spared to them, and in the case of the Hubble telescope the NASA and the european ESA could have saved a lot of money for the sake of the tax-paying population[ii].

Warum sieht man am Himmel keine Sterne?

Fig. 13.6 a: Illustrierte Wissenschaft Nr. 11 (1997) Page 62

1st example: landing on the moon gravitational ...

$$\frac{\text{...pull of the earth}}{\text{...pull of the moon}} = \frac{g_E}{g_m} = \frac{M / R^2}{m_m / R_m^2} = \frac{M}{m_m} \cdot \frac{R_m^2}{R^2} = 6{,}0375 \qquad (13.27)$$

in space everywhere on the surface of a sphere is valid: $A = 4\pi R^2$

eq. 13.20 (fig. 13.4<iii>): $m \sim \phi = A \cdot B = 4\pi R^2 \cdot \mu H \sim R^2 \cdot H$

as well as eq. 13.23 (fig. 13.4<ii>) for the field dependency: $H \sim 1/l^2$

and further:

$$6{,}0375 = \frac{g_E}{g_m} = \frac{H_E}{H_m} = \frac{l_m^2}{l_E^2} \qquad (13.28)$$

resulting in the length dilatation (expansion) on the moon:

$$\boxed{l_{m\,(\text{Mond})} : l_{E\,(\text{Erde})} = \sqrt{6{,}0375} = \underline{2{,}457}} \qquad (13.29)$$

2nd example: communications satellite in a geostationary orbit (at h = 36000 km above the equator, R = 6378 km).

$$\boxed{\frac{l_h}{l_E} = \sqrt{\frac{H_E}{H_h}} = \frac{R+h}{R} = \underline{6{,}64}} \qquad (13.30)$$

Fig. 13.6 b: Examples of calculation for length dilatation<i>

<i>: If the theoretical value of 6.64 could be quantitatively confirmed by observations from off the earth with a telescope at a corresponding magnification, then with that would have been proved, that in the case of the spherical aberration it actually concerns the calculated influence of the field.

<ii>: U. Seiler-Spielmann: Das Marchen vom toten Mond, Zeiten Schrift 5/94,S.39

13.6 Spherical aberration

It is true that the problem of the changed length relations is known to the experts under the term of a "spherical aberration". But with that it is neither qualitatively nor quantitatively understood. Only the theory of objectivity soundly gives reasons for, why the astronaut Roosa has seen his colleagues almost 3 times as large, why weather satellites in a height of 1500 km are approx. 25% larger and why communications satellites in a 36000 km high geostationary orbit even increase to the 6.64 fold of their original size[i]. It also explains, why the neutral point between earth and moon, at which the attraction of masses of both celestial bodies mutually cancel, wasn't reached at the point where it had been expected by the moon rockets[ii].

We, the inhabitants of the earth, are adapted completely to the conditions on the earth's surface. If we find our way well in the dimensions of space and time, as we observe them, then that must not be valid by all means for science, because that has made it its business to find out the secrets of nature.

If it wants to deserve the name science, then it on the one hand has to consider, that we, the organic materials, as well as all inorganic materials are assembled from the same atoms and molecules and with that are exposed to the same length relations. If changes in length between day and night (as a result of the gravitational field of the sun (see chap. 6.7), between summer and winter or as a result of changes in field occur, then we aren't able to register this at all. That even today the „foot" is used as a measure, for instance in the air traffic, shows only too clearly, how man raises itself to the measure of all things. Science asks for modesty!

On the other hand it should be paid attention to the fact, that man eyes everything with speed of light with the optics of his eyes, and that speed by no means has to be constant. Solely the definition of the speed of light c as a linear measure per unit of time points to the direct proportionality between c and a length 1 (see chapter 6.3):

$$c \sim 1 \qquad (13.31)$$

If a rule has proven to be unusable for measuring a distance, then we'll experience the same disaster, if we measure optically, i.e. with the speed of light. Obviously both, the length 1 and the speed of light c depend in the same manner on the respective local field strength. On the one hand both measurement techniques lead to the same result, but on the other hand what can't be measured with one method, neither can be measured with the other.

To prove the constancy, it is normal to measure the speed of light optically. But since there exists a proportionality between measurement variable and measurement path (53), the unknown variable is being measured with itself. This measurement faulty by principle in all cases delivers a constant value. In contrast to the textbook opinion of today by no means a constancy of the speed of light can be assumed. In the case of the in a vacuum measurable 300,000 km/s it concerns a capital measurement error, at best a constant of measurement, but never ever a constant of nature!

With the postulate and the misinterpretation of a constancy of the speed of light as a universal constant of nature Einstein already let several generations of physicists run into the same dead end, in which they today are stuck altogether. It surely is no accident, that the big time of discoveries abrupt came to an end with Einstein.

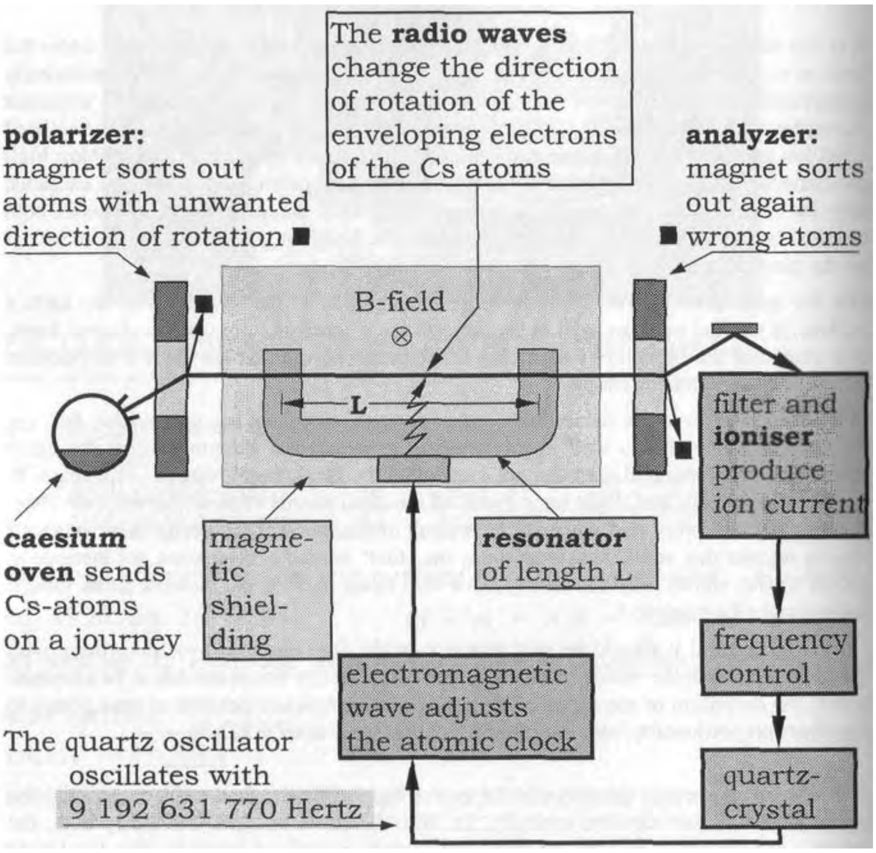
The **radio waves** change the direction of rotation of the enveloping electrons of the Cs atoms
polarizer: magnet sorts out atoms with unwanted direction of rotation ■
analyzer: magnet sorts out again ■ wrong atoms
B-field
⊗
L
filter and **ioniser** produce ion current
caesium oven sends Cs-atoms on a journey
magne-tic shiel-ding
resonator of length L
frequency control
electromagnetic wave adjusts the atomic clock
The quartz oscillator oscillates with
9 192 631 770 Hertz
quartz-crystal

Schematic representation concerning principle of functioning
L = length of resonator determining the exactness
The B-field is a weak magnetic field, which eliminates the influence of magnetic stray fields.
The arrangement in addition is situated in a vacuum tank.

Fig. 13.7: Set-up of a caesium atomic clock

13.7 Irony of the measuring technique

Let's record: The linear measure is determined and defined by a measurement of transmission time. As a reason is given, that with today's clock technology a higher precision and reproducibility can be obtained, as with a rule or original meter. The exactness of going of the atomic clocks again depends on the free flying path (L in fig. 13.7) of the atoms. For the caesium clocks of the Physikalisch Technischen Bundesanstalt in Braunschweig the resonator length amounts to several meters! The clock is used world-wide as a standard.

The irony thus lies in the fact, that a geometric length dictates the measurement of time and the measurement of time again determines the measurement of length - poor science!

How does one free oneself from a capital closed loop conclusion? Why and how do signal transmission times or clocks actually depend on the gravitation? Who once got stuck in a dead end, knows that he only can get out in the reverse gear.

A possible way goes back to the roots of classical physics and to the theory of objectivity in the 1st part of the book, which is free from the limits of a subjective and relativistic observer standpoint. That isn't a dead end and in addition explains, why all atomic clocks react sensitive to magnetic fields (magnetostriction) and what these fields have to do with gravity (see chap. 6.9)!

Today's clocks are so exact, that even differences between a clock stationed on a mountain and one at sea-level can be recorded. Even more clearly was the depending on gravitation determined at an atomic clock, which was shot in a rocket 10000 kilometres high into space. The result of the analysis without doubt was, that the clock in that case doesn't „tick" correctly anymore.

But what does theoretical physics say about it? It claims, here the ,,red shift" has been measured; it thus concerns a confirmation of the special theory of relativity. But since it concerns a clock experiment and not a light signal, it clearly contradicts this theory, which isn't able to describe any gravitational effect at all, as is well-known. For this case in the spheres of theoretical physics one helps oneself with the general theory of relativity, with which actually only would be proven, that the two theories from the legacy of Einstein completely incompatible contradict each other. We come to the following conclusion:

Whoever gives details about length or time, is obliged to also indicate the reference system.

He also has to inform where his laboratory is situated and with which devices he measures!

With the conclusion also the discussion would be opened. Throughout the last four chapters a main idea can be found. It should be worth, to again think about the brought forward arguments and to dare a comparison with text books.

In the text books there doesn't exist such a thing as an oscillating interaction. Here no answer is found to the question, why the solar system isn't hurled out of the galaxy as a result of the high velocity, why the inside of the earth is hot, how the geomagnetism is formed, why the continents drift and why the ocean floor nowhere is older than 200 million years, as samples from the ocean floor prove<i>. How would you answer these central questions?

<i>: Kendrick Frazier: Das Sonnensystem, Time-Life Bucher, Amsterdam (1991).

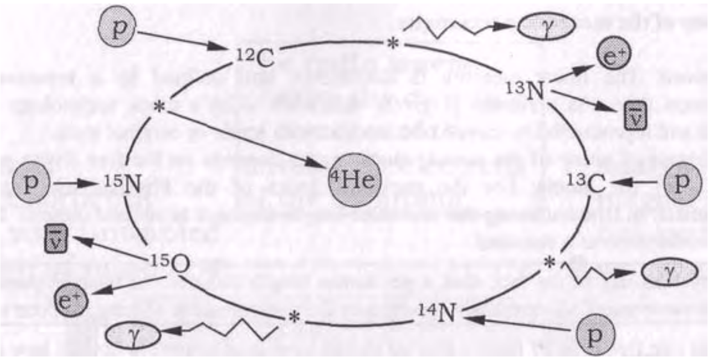
p
^{12}C
*
γ
e$^+$
^{13}N
$\bar{\nu}$
*
^{4}He
p
^{15}N
^{13}C
p
$\bar{\nu}$
^{15}O
*
γ
e$^+$
^{14}N
γ
*
p

Fig. 13.8: The Bethe-Weizsacker cycle (concerning the sun's fire)
(meaning of: ^{12}C = carbon nucleus, ^{4}He = helium nucl., γ = gamma quant, ^{14}N = nitrogen nucleus, p = proton, e^{+} = positron, ν= anti neutrino, ^{16}O = oxygen nucleus

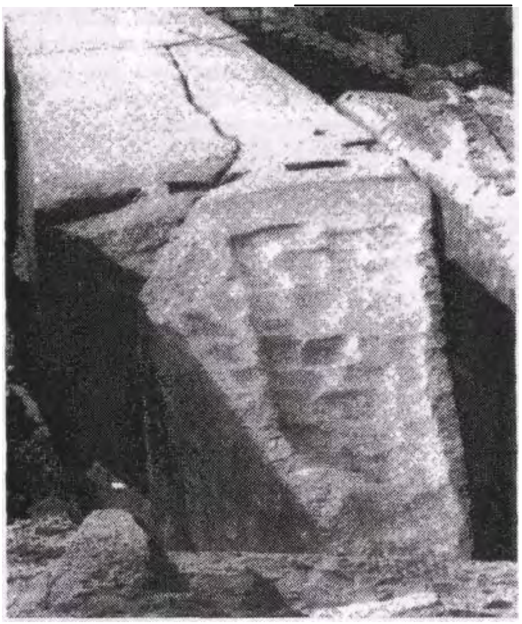

Fig. 13.9: The top of the unfinished obelisk in Assuan<i>

<i>: Hermann Wild: Technologien von gestern, Chancen fur morgen, Jupiter-Verlag Bern (1996), ISBN 3-906571-13-0

13.8 Discussion of the cosmological insights

The numerous models which are offered, of a geodynamo, an iron core, of assumed zones of subduction and of plate tectonics may be helpful for the explanation of individual isolated phenomena. But they physically don't give a uniform picture and partly contradict each other.

Lord Kelvin had calculated a period of shining of 5000 years on the basis of a sun consisting of coal<i>. The german physicist Hermann von Helmholtz landed at 15 million years, in which case the sun yearly should shrink for 100 meters. He already assumed a temperature of 15 million degrees centigrade, as also the Bethe-Weizsacker cycle has as a prerequisite, which according to today's concept should describe the process of nuclear fusion taking place in the inside of the sun (fig. 13.8). The only thing is that this extreme temperature is completely incompatible with the high density in the core of the sun! There are more than good reasons to assume the opposite of the widespread textbook opinion and assume that the core of the sun is cooled by the collected neutrinos in the same manner as the inner core of the earth and that superconducting areas are formed, which powerful fields even cause the protuberances on the surface of the sun. Since in the sun no measurement is possible, with which a model could be verified or disproved, terrestrial arguments naturally suggest themselves. Here the pieces of evidence for the growth of the earth can be taken in the hand and photographed. We already have discussed some facts. But there are found a multitude of other ones, for instance from the domain of archaeology, for which text books of today until now as well provide no explanation.

Possibly the stones and monoliths weighing several tons, as they were used for prehistoric buildings, should be linked with the growth of the earth. If the earth was smaller at the time they were build, then they perhaps by no means were as heavy as today!
Then the stones for reason of the smaller density in addition were softer and with that easier to work on. Dr. Wild points to the building technical peculiarity, that the stones formed like cushions originally must have been soft. He proves with the photograph of the top of the unfinished obelisk in Assuan (fig. 13.9), that the traces of working stem from a spatula in a plastic mass.
Also the perfect fitting of the stones used for the building of the pyramids can only be explained in this way. In the joints not even a knife point can be inserted!

If even stones in the course of time increase in density and hardness, then it is easier for us to comprehend, how small rivers in past time could dig large deep valleys in the earth's crust, then we perhaps also understand, why very old bones today are petrified<ii>. It is obvious, that also bones in the course of time increase in density and hardness. Even if science should succeed in breeding living dinosaurs, then their chance to survive in spite of that would be equal to zero, because the dinos would collapse under their weight of their own of several tons. Their bones would be much too thin and brittle for their weight of today!

<i>: Kendrick Frazier: Das Sonnensystem, Time-Life Bucher, Amsterdam (1991)
<ii>: The indication to petrified bones stems from a participant of the seminar.

25-07-1996:	Assistant head of government department Acceptance of the common standpoint.
11-12-1996:	European parliament Resolution of the guideline.
	commission Statement concerning proposals of change of the european parliament.
19-12-1996:	Assistant head of government department Resolution of the guideline.
19-02-1997:	Coming into effect of the guideline Publication in the official paper of the EC.
19-02-1999:	Period of translation of two years
	Reduction of the threshold values for current consumers:
19-02-1997:	to 40 million kWh (opening of the market 23%)
19-02-2000:	to 20 million kWh (opening of the market 28%)
19-02-2003:	to 9 million kWh (opening of the market 33%)
until 2006:	„Anti imbalance clause" A nine years period of transition to preserve equal opportunities in the competition. Report of the commission.
19-02-2006:	Further stage of the liberalization European commission tests by means of the made experiences, if the current market should be opened further.

Fig. 14.1: ____ Timetable of the EC single market guideline electricity<i>

<i>: Grawe, S. Thiele: Vorbereitung der Stromversorger auf den Wettbewerbsmarkt, ATW Atomwirtschaft-Atomtechnik 43. Jg. 1998, Heft 1, S. 10 - 13

14. The way towards free energy

Can energy actually be produced? No energy supply enterprise is capable to do that. Fact is, that energy only is converted and not produced. For that the available resources on earth are tapped and brought into a utilizable form of energy. As different the conversion processes may be, finally always heat is formed. We thus gradually burn the globe, on which we live. How long can something like that go right?

Science gives all-clear: „stock of energy is sufficient for the next 100 years. Newest calculations disprove the fear of a scarcity of energy on earth. There exist large stocks of coal and oil"<i>.

But what are 100 years compared to the age of the earth? How will our descendants judge our thinking and acting? They will condemn it and curse us, that much is clear already today.

We have an obligation to preserve the environment, and we only will be able to fulfil it, if we look to nature, how it covers its need of energy, if we finally understand and meaningfully copy nature.

We still are miles away of the goal.

14.1 The liberalization of the energy markets

It is important in the interest of a member of the executive that the stock of energy doesn't draw to an end, as long as he carries the responsibility for the enterprise of the economy of energy. The interest in the environment and the environmentalists for obvious reasons is less distinct. The problems are more of a commercial kind. Concerning that an actual example is given.

A special kind of problem is the meanwhile Europe wide valid decree of the EU concerning the liberalization of the energy markets (fig. 14.1). The list of the consequences starts with the fact, that the concluded licence contracts for power supply between energy supply enterprises and the communities, which are valid till 1997, are only wastepaper. Every customer of electricity as of now can conclude an individual contract with every "producer of electricity".

So an environmentally aware Black Forest person decides to obtain his power from a wind power station, which is situated in Denmark. That truly sounds very liberal. But how should that function, if there is no wind at all in Denmark for a week, or the connection is interrupted by a flash of lightning? The windmill further delivers power and the runner writes its bill truly believing, its power has arrived. The consumer then reads the bill at candlelight and puts with understandable anger his claim for compensation together. Pointing to the fact that such difficulties can be solved by book-keeping, the consumer again is calmed down; but that the not by contract obtained power will cost him dear, is another story.

<i>: Illustrierte Wissenschaft Nr. 6, Juni 1996, page 48-51.

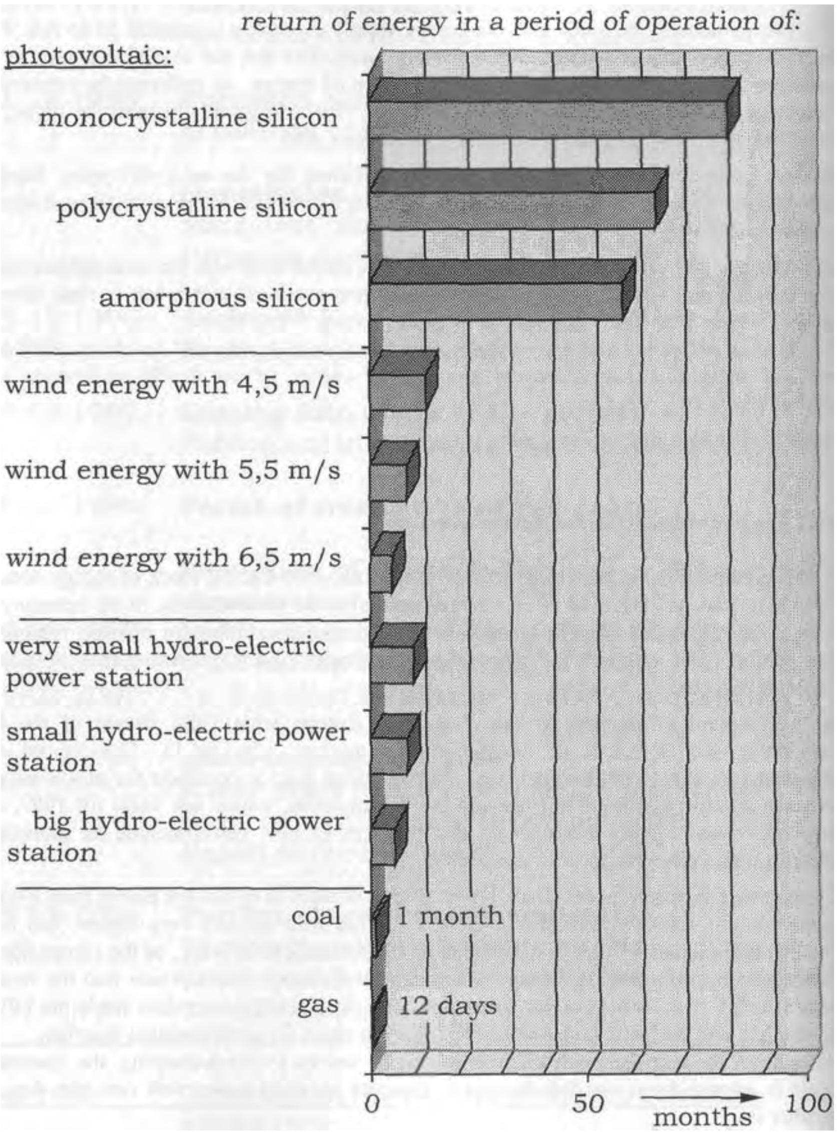

Fig. 14.2: Average time of paying for itself for the spent energy (return of energy)

14.2 The consequences of the liberalization

With the EU decree the monopoly only has shifted towards the runners of the distribution nets, after all only one net is present. Competition however would require at least two nets, thus a doubling of all house connections and all high-tension pylons, but that fortunately is unrealistic.

To prevent fleecing of the consumers by means of the net monopoly, politics introduces in the place of the free market economy dirigisme and plan economy with the well-known concomitants: no-one will look after the existing nets, no-one feels responsible anymore, because after all they have become public good by decree. One thus lets the pylons rot slowly and repairs only in emergencies. This possible development really can't have been the good intention of the EU.

In the next few years we however will be able to observe for the producers of energy exactly the development, which the EU-commissioners have imagined: Total competition contest, price war and a struggle for power to survive economically. A chance only has the nuclear power station, which gets rid of its refuse cheaper and if need be even illegally or which lives of indirect state subsidies, or the brown coal power station, which increases its efficiency at night, when no-one watches, by switching off the expensive filters.

The first power stations, which are selected out by the liberalized energy market, are the hydro-electric power stations which stand closest to nature. They simply are too small and too intensive of personnel, to be able to survive.

Gas turbine power stations, which deliver the power for half the price, than are ranking first. Then there is no place for regenerative systems anymore.

Solar energy, how many roofs a supporting program may have, stays a toy supported by the state. For a photovoltaic installation the „Return of Invest" still lies at more than 80 years, whereas is reckoned with a theoretical life of 20 years. In practical use on the other hand photovoltaic installations occasionally already have failed after seven years, after the photocells had gone blind. In this case not even can be talked of an ecologic energy, because the return of energy lies still above that. The supposed Idealist who spoils his roof with photovoltaic to reassure his ecologic conscience, would have spared the environment more, if he had covered his need of power from the socket, because already the production of the photovoltaic installation gobbles up more energy than can be produced with it. With regard to the environmental compatibility the ecologic balance sheet of a power station is attached a central importance (fig. 14.2).

With the law of feeding in power the state intervenes dirigiste, supposedly to protest the consumers. With this law the state orders, that not it, but the energy supply enterprises have to take the subsidizing of the regenerative energy, that they have to take over the power delivered at the inappropriate time in exactly so less suitable amounts at a price, which exceeds the market value by a factor of two and for falling prices of power even by a factor of four. With the law the politicians very fast and without agreement of the effected enterprises have shifted the „black Peter" further to these, which will get problems to preserve their competitiveness in the international comparison with the subsidy duty. It can't have been the intention of the EU-commissioners, that on a national level the price of power increases to finance some energy technical playground.

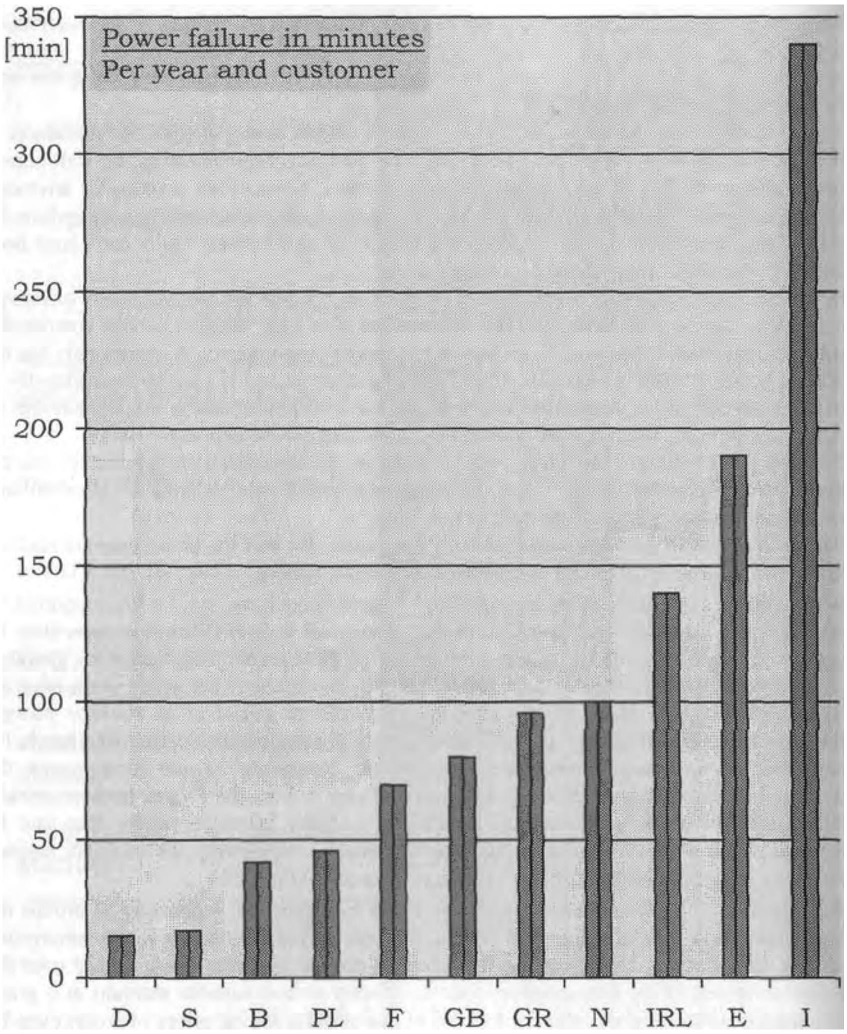

Fig. 14.3: Power interruption and not being at disposal

<i>: ETG, Energietechnische Gesellschaft im VDE: Qualitat der Stromversorgung, Dialog Nr. 1, Jan./Feb. 1998, S. 21

14.3 The chances of the wind energy

Meanwhile, as a result of the law of feeding in power, no longer the politicians but the energy suppliers are the ones, who around the North Sea look out of the window every day with the worry, some wind could blow and the mills could turn, because every kilowatt hour of a windmill must be subsidized strongly. Every windless day however reduces the power bill, with that helps the consumer and raises the chances of competition of our economy.

If it should be neglected, to tip over the law of feeding in power in due time with help of the EU, then the consumers will get their power in future abroad, then at the Preussen Elektra, damaged most by wind energy, as the first the lights will go out, then economic power and prosperity in Germany in future are dictated from abroad.

But if the law is dropped, then with that the duty to subsidize the regenerative energy carriers drops back to the state. Now all tax payers may foot the bill, even those, who don't use any power at all. The well-known Justice of subsidy" comes into effect.

Without support by the state only few types of power stations will be left behind. In addition are overcapacities being reduced, because they only cost money. But both is at the expense of the reliability of the delivering of energy and of the safety of the consumer. We owe the high stability of our network of today the large number of most different providers of power, which cover the basic load up to the peak load according to their suitability (fig. 14.3). But let us not talk of the golden past. The network after all isn't able to store power. From that follows, that without redundancy and without free power station capacities which can be activated at any time a short overload is sufficient, to let the network collapse.

Once the EU guideline concerning the liberalization of the energy markets is in effect, when persons selling power wend their way from front door to front door, to convince the housewives to obtain the power from them and not from other hawkers, when the power stations only live of stock and the depreciated overhead power lines only are entered in the hooks with the scrap value, then we should be dressed warmly and always have ready sufficient candles <i>.

14.4 The chances of being self-sufficient concerning energy

The only way out is the decentralized energy supply, the getting out of the large energy union and the way towards being self-sufficient. The argument sounds convincing in view of missing alternatives. But now it no longer is possible to plug the plug in the socket and then switch on whenever it pleases us. First it has to be calculated, if the windmill or the installation for solar energy supplies sufficient power or if a cold meal should be made. In contrast to today's consumer habits the runners of such installations will have to adapt their need of energy to the prevailing weather conditions.

<i>: A baby-Boom, like after the big power failure in New York, would be the smaller evil. The inhabitants and shopkeepers in the New Zealand metropolis Auckland will long and frightened remember the power failure in february 1998, which lasted weeks and was a result of not carried out maintenance works of high-tension pylons.

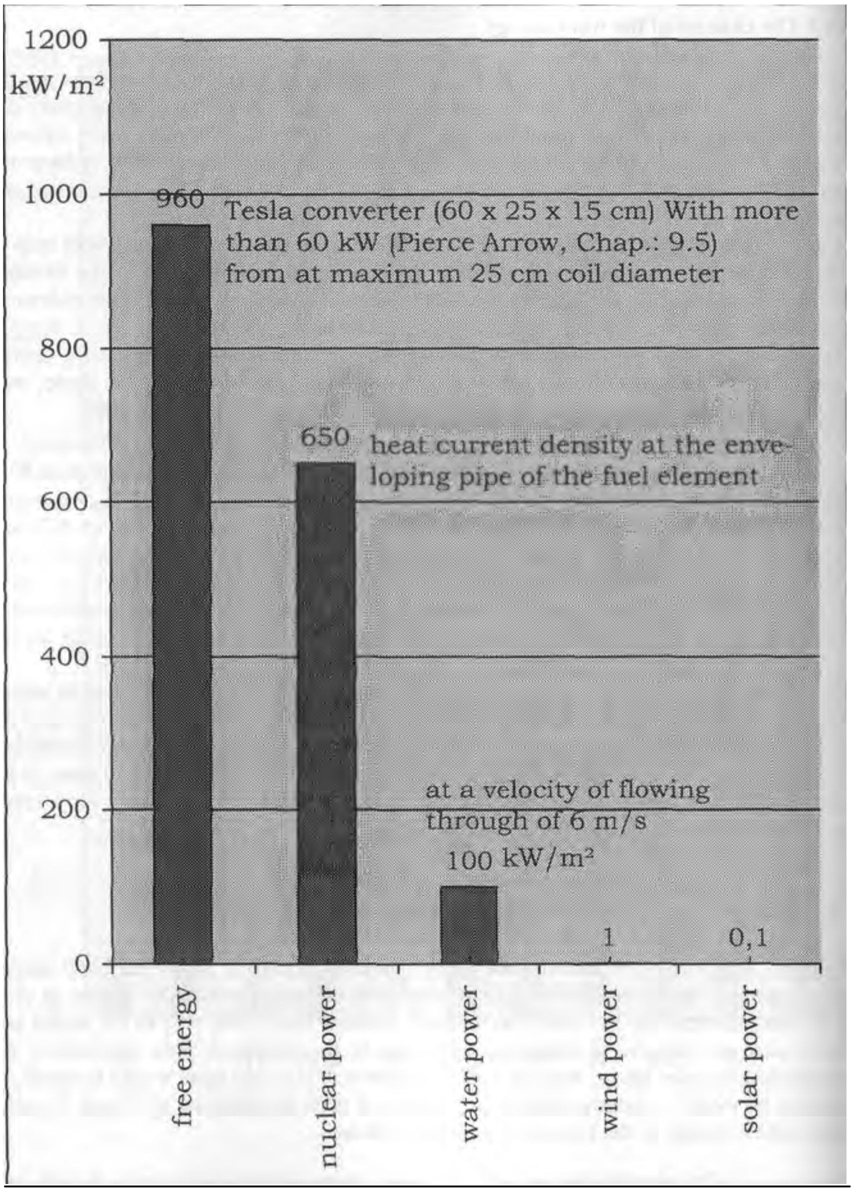

Fig. 14.4: At maximum obtainable power density of different carriers of energy

<i>: ETZ, Heft 19/1995, S. 40

Block heating power stations, propagated as stand-alone solution for people being self-sufficient, deliver power and heat at the same time. But if I don't need any heat on a hot summer day, then also no power is available or I uselessly heat into the open. For that one may leave all electric consumers switched on in winter, even if they aren't used at all, only to get the hut warm. Does a stand-alone solution look like that?

The situation truly is demotivating. Even the energy suppliers meanwhile may have realized that the energy politic way is a dead end. But for real alternatives in energy technology the pressure by suffering still doesn't seem to be big enough.
The intention to learn of nature is present in principle. The solar fire one wants to kindle on earth in a fusion oven, but the oven does not as it should.
Obviously the sun functions completely different, as physics imagines today (see fig. 13.8).
Before copying stands understanding, and in there seems to be a hitch!

14.5 The space energy technology of nature

Also nature needs energy, even very much. But it hasn't got any connecting pieces for tanking and no oven lid to fill in the fuel, it doesn't know our ecologically harmful combustion technology and environment destroying explosion technology at all. Nature rather works with the opposite, with implosion and fusion.
The sun, we have derived, materializes the matter which it needs for growing and shining from the neutrino field. The earth and other planets imitate the sun.
The concept is simple and convincing. The source of energy lies in the air and mustn't be dragged about in tanks. Collected and materialized is just as much, as is needed at the moment. In that way the resource energy is spared. In addition there can be done without any sort of storing. In addition it can show a substantially higher power density, than all today known and used energy carriers (fig. 14.4).
Such a source of energy solves all described energy problems at once. Nature wouldn't be as we know it, if it wouldn't have this ideal energy, also called „free energy". The balance sheet of energy alone brings it to light, because as a rule it doesn't work out for biological systems. Often more energy is released than is taken up by the food.
In that case some migratory birds materially seen should have completely used themselves up before reaching their destination, if the energy necessary for the flight would be of purely material nature. From a concrete example the following is reported<i>: „migratory birds have - depending on kind - a maximum range velocity between 24 and 83 km/h and at their Atlantic flights no opportunity for an intermediate landing. They are thousands of kilometres on the way and hardly lose weight. For instance an Albatross with a body length of up to 1.20 meters and a wing span of up to 3.50 meters uses per kilometre only 8.5 grams of weight at a non-stop flight. How is that possible without additional supply of energy?"

<i>: K. E. Rathgeb: Wie man die freie Energie anzapft: Vogel machen es uns vor, Raum & Zeit 79/96, S. 74

Fig. 14.6: Freiherr von Reichenbach (76 years old)

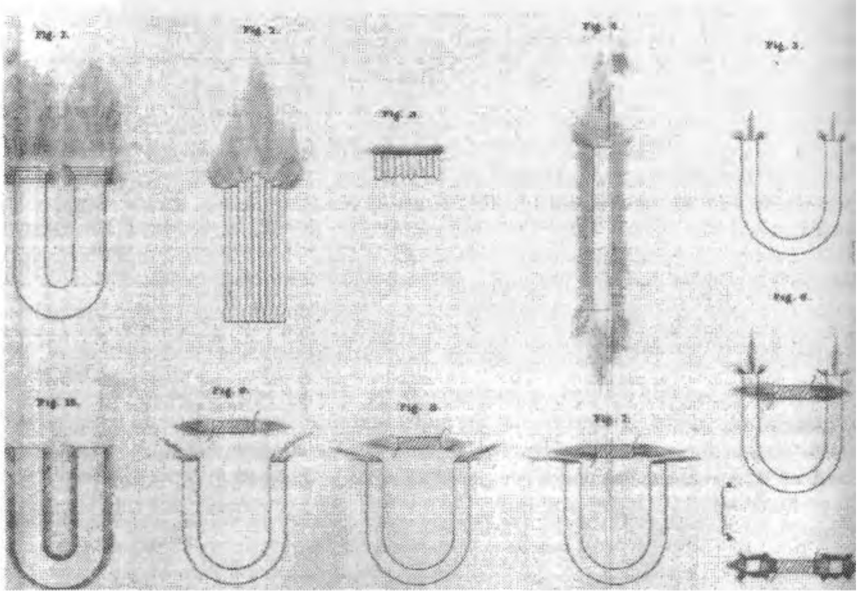

Fig. 14.7: Odic emanations of magnets according to pictures of sensitives.[i]

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[i] H.-P. Thietz: Tatort Erde, VAP (1996), ISBN 3-922367-62-3, Seite 13 und 15

14.6 The gap in the energy balance of man

Even man appears to tap an additional source of energy, because for reason of scientific tests with recruits these over longer periods of time are able to physically release more than twice the amount of energy they take of calories with the food. Obviously living beings don't rely on one source of energy alone. Possibly the taking up of food predominantly serves the metabolism, and the energy aspect plays only a secondary role.

This interpretation at least would be obvious, since we scoff several times a day, sort the necessary and useful building-materials out and hand over the rest to the purifying plant and nature, where some bacteria and organisms search the sorted out again for useful things. "Food chain" we call this kind of building-material trade.

If the whole had anything to do with energy or with a „ combustion process without fire ", then no animal nor any human being could do without the taking up of food for longer periods of time. But Franciscus of Assisi could fast 90 days, as is handed down to us [ii]. There exist numerous examples, which reach into the time of today.

The mitochondria, the energy centres of each cell, by no means are capable of the "combustion process", which man ascribes to them. Here in all probability a taking up of space energy independent of food takes place.

A research scientist only has to look at nature with open eyes, what unfortunately happens rarer and rarer, because the laboratory scientist always is troubled, to keep the disturbing factor ,,nature " away from the experiments.

14.7 Carl Freiherr von Reichenbach

In this context no-one can go past two natural scientists: Carl Freiherr von Reichenbach (1780-1869) and Dr. Wilhelm Reich (1897-1957).

Reichenbach called the by him investigated life energy „ Od-energy " in the style of the Teutonic God Odin. He worked with test persons, who could perceive actually invisible light phenomena and worked out the special properties of this Od-energy field with the "sensitives", as he called them.

A quotation from his work shows however that the knowledge about the life energy must be a lot older[iii] than his own discoveries: „On paintings saints often are shown with a ring-like aureole around their head, something I before this would have dismissed as a pure figment of imagination. But it was shown that this glowing ring actually can be perceived by the sensitives as an Od-phenomenon and so the aureole obviously can be traced back to real impressions of particularly sensitive persons."

Reichenbach also found out that water has a big endeavour to take up this Od-energy or in the language of the present day, to absorb the field energy. This circumstance we find confirmed in technology, since water absorbs high-frequency waves, whereas an insulator or a vacuum lets them pass through. But without vortex physics it however remains entirely unclarified, why!

<ii>: H.-P. Thietz: Tatort Erde, VAP (1996), ISBN 3-922367-62-3, page 110
<iii>: H.-P. Thietz: Tatort Erde, VAP (1996), ISBN 3-922367-62-3, page 16

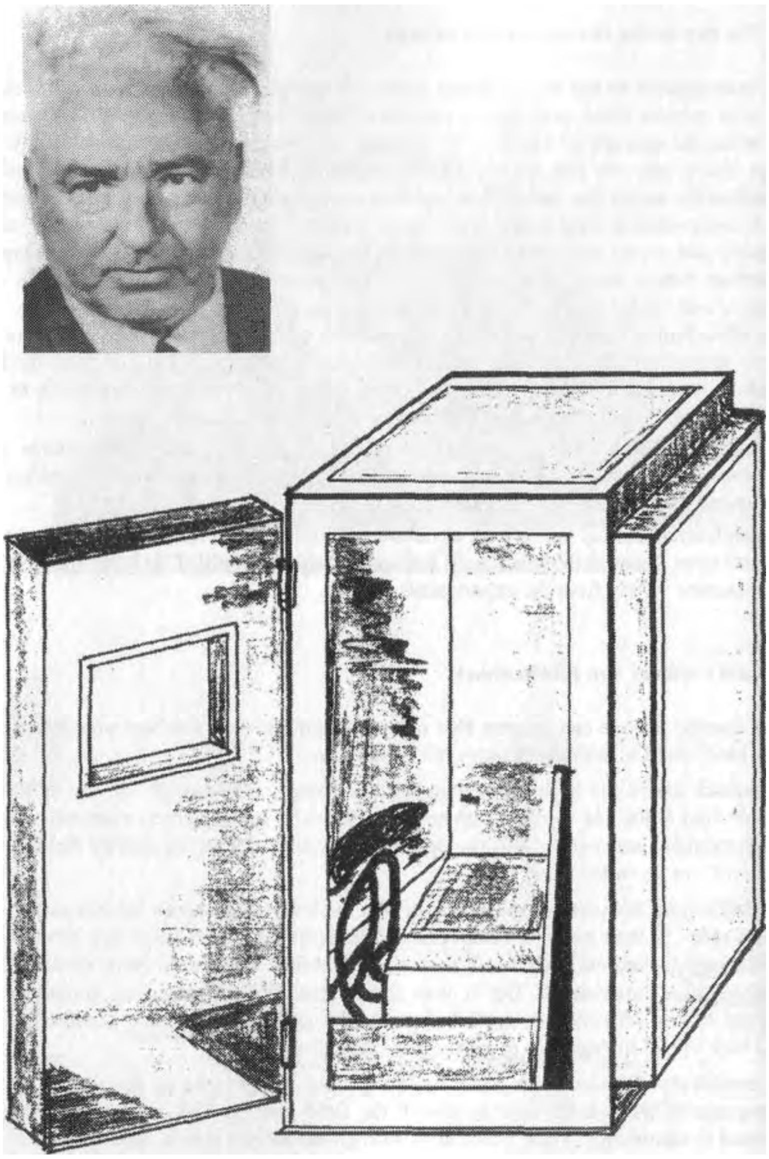

Fig. 14.8: Wilhelm Reich and the model of an Orgon accumulator for applications of the whole body.<i>

<i>: taken from: H.-P. Thietz: Tatort Erde, VAP (1996), ISBN 3-922367-62-3, pages 38 and 89.

14.8 Cold fusion and Genesis

Chronologically the doctor and psychologist Wilhelm Reich followed in the footprints of Reichenbach. He merely altered the name for Od and spoke of Orgon. His speciality was the accumulation of Orgon radiation, I would say the focussing of neutrino radiation. Actually the properties like e.g. the missing possibility to shield Od, Orgon and the neutrinos are identical, so that we can proceed from assumption, that it also concerns the same physically.

We already talked about Wilhelm Reich (part 1, chapter 9.2). He could show that the measurable temperature in a closed box, constructed like an „Orgon accumulator", is increased in a mysterious manner without supply of energy from the outside. He even could prove, that this energy actually concerns the sought-for life energy, as he observed the creation of life in the laboratory under the microscope. For that he cooked muscle fibres, vegetables or other cells so long until the cell structure had been destroyed entirely. But from the educts entirely by itself new living beings, like protozoa or algae, were formed<i>.

Reich at his microscope actually followed the transition of dead to living matter. What is of interest here, at first only is the energy technical aspect of this conversion. Later we will occupy us with the at the same time occurring information technical aspect.

Worth mentioning seems to me the experiment with the „silly" chickens, which have at their disposal astonishing abilities besides the laying of eggs<ii>.

The test chickens were handed chicken food, from which to a large extent all calcium had been extracted. But the chickens showed themselves unimpressed and further laid keenly their eggs. The experimenters were surprised, where the chickens actually got the lime for the egg shells. How solves such a chicken the problem of raw materials? For that further materials were extracted from the food and look, at the removing of silicon the laying of eggs was over. The experiment actually only allows the conclusion, that the "stupid" chicken is capable of a cold fusion, that it itself „produces" the necessary calcium from silicon presumably by using carbon. Every alchemist here has to go pale with envy. But what says the research scientist of fusion to that, who actually should know, how fusion functions? After all he is paid for it by the tax payer! The chicken uses the fusion already today and the other living beings presumably also, but for that energy is needed and the balance sheet should work out!

The neutrino radiation therefore has to be factored into the balance sheet of energy. If the balance sheet then works out, it could be proven with that, that here neutrino energy is put to use. In addition the process of the conversion of neutrinos has to be investigated, which surely has something to do with the frequency and the wavelength of the radiation. After all a child has cells exactly as big as an adult. It only has less cells! So that an interaction can occur, the cell size has to fit in with the wavelength, which obviously is very small, presumably in the range of the radioactive radiation, with which circumstance the biological incompatibility with this electromagnetic wave would be explicable.

<i>: H.-P. Thietz: Tatort Erde, VAP (1996), ISBN 3-922367-62-3, S. 39

<ii>: Louis Kervran: Biological Transmutations, s.a. J. Heinzerling: Energie, S.278

1. Primary reaction
   (light reaction in the centre of reaction):

   ring-like vortices/neutrinos are being collected
   electrons are formed
   energy is produced
   e^- is attracted by the water dipole
   water molecule is being splitted (photolysis):

2. Secondary reaction (dark reaction):

   carbon dioxide is reduced with the hydrogen splitted off from the water to carbohydrate

Reaction equation of photosynthesis:

	6 mol CO_2	(carbon dioxide)
+	12 mol H_2O	(water)
+	675 Kcal	(vortex energy, light)
	1 mol $C_6H_{12}O_6$	(glucose)
+	6 mol O_2	(oxygen)
+	6 mol H_2O	(water)

Fig. 14.9: Concerning photosynthesis

14.9 Photosynthesis

The materialization of free electrons is a prerequisite to start the photosynthesis. The normally used explanation, the free electron necessary for the splitting of the water molecule was knocked out an atom by light, doesn't seem to be correct, after until now all attempts of a technical realization according to this model concept have failed. At the photosynthesis the plants obviously help themselves with the neutrino radiation, which according to an estimation of today with 66 billion particles per second and per square centimetre might be more than sufficient for a green earth.

If we put a seed in a water glass, then a plant grows from it and forms small leaves, which get bigger and bigger. A wonder of nature, we say. Where does it actually get its building-materials? From the water or from the air? Necessarily the plant obviously produces a part of the matter itself!

Experts think they have understood the process of photosynthesis: Take light and water and carbon dioxide and handicraft from that sugar and oxygen. But from where does the plant take the necessary energy for the rebuilding and the splitting of the water molecule, the photolyse? The taken up solar energy hardly is sufficient for that, especially since the plants only absorb about 1% of the photosynthetic utilizable sunlight incident on earth<i>. By means of reception molecules, which look like small antennas, pigments less than 30 nm in diameter, such is the level of knowledge, the sunlight is collected and led into a photochemical centre of reaction. Here the reaction should take place, provided that an electron set free by the light jumps into the middle of the centre of reaction. But exactly this favour the electron doesn't make the research scientists, who want to imitate the process. Copying nature still doesn't succeed.

The mistake presumably lies in the circumstance that the light doesn't set free any electron at all. The electron actually first of all is produced in the centre of reaction. By means of the antennas a neutrino vortex is collected, which at first occupies the entire space, to afterwards contract to an electron, which as a result automatically is centred in the centre of reaction.

In the process of materialization at the same time the necessary energy of the process is formed. The reaction equation after all also has to work out energetically, because the plants doing so get neither hot nor cold (fig. 14.9).

Because curiously the light reaction even can be observed in the dark<ii>, one could be inclined to in principle call into question the influence of light on the photosynthesis. But such an influence nevertheless seems to be present, after all does a plant react on the irradiation of light and changes its spectrum of absorption through its colour. But it for sure is another influence and not the one, which one attributes the green plants today! It would be important to finally understand the way of functioning. The plants and particularly the algae are the ones, which actually first have made possible life on this planet with the photosynthesis, the most original form of a production of matter and energy.

<i>: Luttge, U. u.a.: Botanik, VCH, Weinheim (1994) ISBN 3-527-30031-7, S. 136

<ii>: Luttge, U. u.a.: Botanik, VCH, Weinheim (1994) ISBN 3-527-30031-7, S. 126

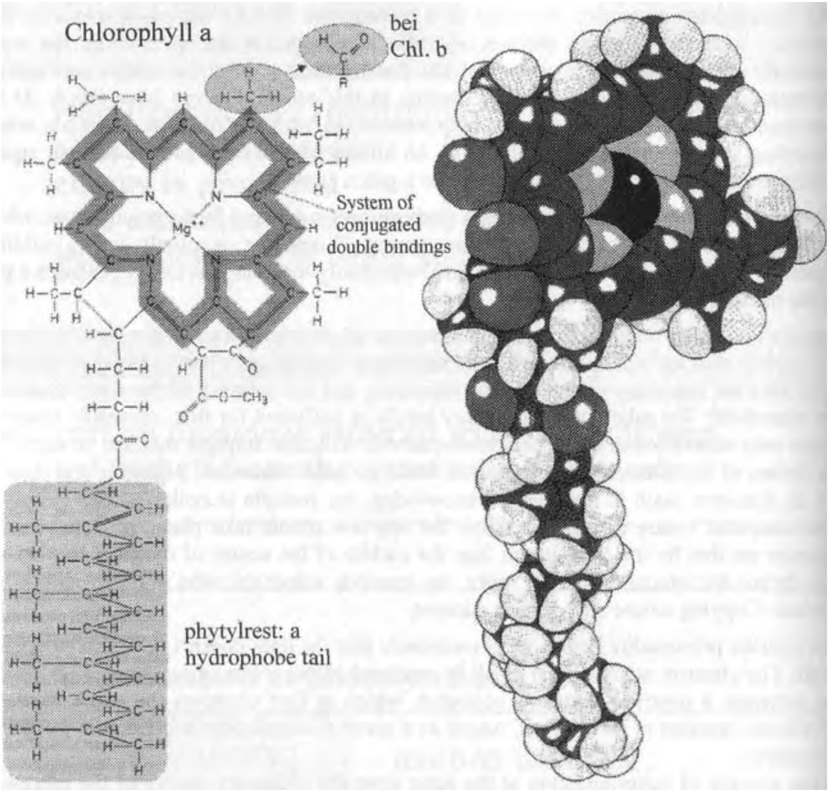
Chlorophyll a
bei
Chl. b
Mg^{++}
System of
conjugated
double bindings
phytylrest: a
hydrophobe tail

Fig. 14.10: Formula of structure and spatial model of the photosynthesis pigment chlorophyll.[i]

[i] Luttge, U.et al.: Botanik, VCH, Weinheim (1994) ISBN 3-527-30031-7, p. 118

14.10 How nature materializes

The structure of the receiver antenna allows us a deeper insight into the manner, how free energy is tapped during the photosynthesis. For the dimensions determining the frequency of the photosynthesis pigments, as the antennas are called, we have to go down to the molecular structure. Fig. 14.10 shows the formula of structure and next to it also the spatial model of the pigment chlorophyll[i].

Two points point at the function for free energy conversion. On the one hand is situated in the centre of the molecule a double positive ionised Mg atom, surrounded by four nitrogen atoms and a carbon ring consisting of 20 atoms, from which arises a polarization of the entire molecule. This in addition is oscillating because the electron cloud of the enveloping electrons, which hold the molecule together, perform swirl oscillations depending on the temperature. With that chlorophyll is able to go into resonance with oscillating neutrinos.
A role play the unipolar field configuration and the effect of resonance of the molecular oscillation of its own forming as a result of the polarization. A further role in addition seems to play the spatial structure.

The model of the „receiver antenna" chlorophyll taken out of a textbook[i] and shown in fig. 14.10, consists of a stalk and a spirally wound head, which resembles a Lituus or crook, which Etruscan and Roman Augurs have taken in the hands for land surveying, a precursor of the crosier (see fig. 16.10). This again has the form of a Tesla coil and that, as already derived, is able to withdraw rotational energy from the collected neutrinos (chapter 9.8). Doing so free electrons are materialized, and these then start the process of photosynthesis. An explanation concerning the way of functioning of the antenna pigments here for the first time is getting available.
By the way also the mitochondria, which form the energy centres in every cell, have as well the form of a Tesla coil. Whoever wants to understand the energy economy of a cell or the photosynthesis first should occupy himself with the Tesla coil (chapter 9.8).

The open question, how land surveying should be possible with a Tesla coil, we at first still have to shelve, because in this chapter it concerns the way towards free energy and the chance to learn of nature. Examples to be looked at are on the one hand the core of fusion in the inside of the earth and on the other hand the humus layer on the surface of the earth, which has been materialized in the course of time with the help of photosynthesis.

The goal seems to be worth striving for. If we in the first place have learned to produce energy exactly like nature, then we'll further try to produce matter purposeful, with which ageold alchemist dreams could be fulfilled. We wouldn't need to scrape and to search in some mines any longer. We would materialize the products without refuse, naturally and just for the environment, direct in the final form. I admit that at present it sounds pretty futuristic.

With another example, the lightning and particularly the ball-lightning, the collection concerning the use of free energy in nature shall be completed.

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[i] U. Luttge, M. Kluge, G. Bauer: Botanik, 2. Aufl.- Weinheim, VCH (1994) ISBN 3-527-30031-7, S. 118

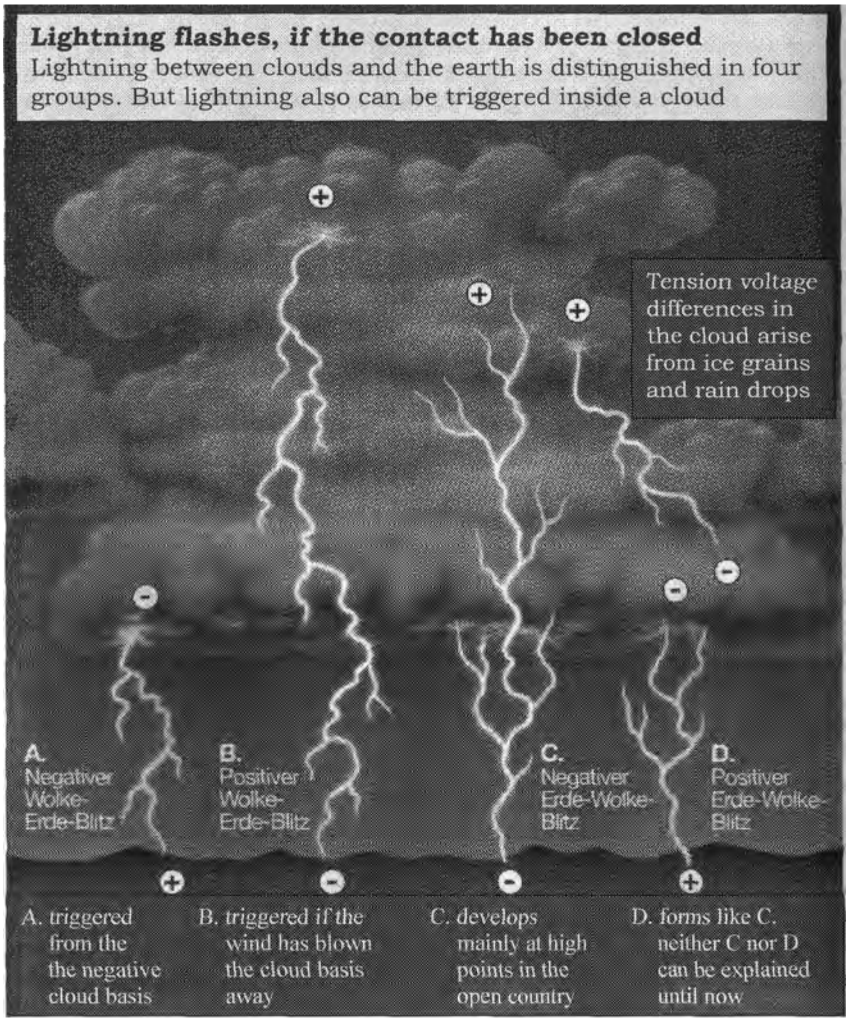
Lightning flashes, if the contact has been closed
Lightning between clouds and the earth is distinguished in four groups. But lightning also can be triggered inside a cloud
Tension voltage differences in the cloud arise from ice grains and rain drops
A. Negativer Wolke-Erde-Blitz
B. Positiver Wolke-Erde-Blitz
C. Negativer Erde-Wolke-Blitz
D. Positiver Erde-Wolke-Blitz
A. triggered from the the negative cloud basis
B. triggered if the wind has blown the cloud basis away
C. develops mainly at high points in the open country
D. forms like C. neither C nor D can be explained until now

Fig. 14.11: Concerning lightning.<i>

<i>: taken out of: Illustrierte Wissenschaft Nr. 8, August 1995, Das unverstandene Phanomen der Blitze, S. 13

14.11 Lightning

Lightning is a spectacle of nature just as imposing as unsolved. It concerns an electric process of discharge, in which to the amazement of all experts arrive for several powers of ten more charge carriers at the surface of the earth, than hefore were contained in the cloud! Furthermore unsolved is, why lightning glows. Let us start with the open question for the difference of potential necessary so that the air is ionised and a lightning channel is formed.

If at first the electric tension voltage of 200,000 volts between the surface of the earth and a height of 10 kilometres is available, which according to our calculations results from the rotation of the earth and the magnetism of the earth (fig. 11.8). Another source of tension voltage is not known. By air movement and supposed processes inside a cloud locally an additional accumulation of charge carriers may occur, so that in the case of a thunderstorm the by Tesla assumed, twice as big value doesn't seem unrealistic<i>.
On the other hand a tension voltage between 4,000 and 10,000 volts is necessary so that a blow can occur for an air gap of one centimetre depending on the atmospheric humidity<ii>. Linearly projected the thunderstorm cloud theoretically should hover just one meter above the earth if there is lightning.
Here somehow a huge gap gapes between theory and practice!

At the latest at the spikes, the mysterious lightning, which strike out of a thunderstorm cloud upwards in the direction of the ionosphere and the still more mysterious ball-lightning it has to get clear, that the actual source of tension voltage of a lightning by no means is known. Without knowledge about the cause we'll never understand lightning.

The potential vortex theory offers an useful approach, according to which the necessary difference of potential is formed from a formation of vortices<iii>. The vortex again, as damping term in the wave equation, occurs as a result of intense sun irradiation. That explains why lightning always strike from the part of a cloud, which is the darkest, where the most sunlight is absorbed and the damping is the largest.

The possible formation of ice in a lightning channel is a further confirmation for the correctness of the vortex explanation. After all it has been derived that contracting potential vortices withdraw heat in principle (fig. 12.8).

But now we also want to know from this efficient theory, why photons and electrons are formed during the lightning and where they come from. Here obviously energy is formed by means of materializing of vortex particles.

<i>: R. L. Clark: Tesla Scalar Wave Systems, The Earth as a Capacitor, The Fantastic Inventions of Nikola Tesla, ISBN 0-932813-19-4, S. 265

<ii>: Karl Kupfmuller: Einfuhrung in die theoretische Elektrotechnik, Springer-Verlag Berlin, 12. Auflage 1988, ISBN 3-540-18403-1, S. 221

<iii>: K. Meyl: Potential vortices, Part 1: Discussion contributions to the natural scientific interpretation and concerning the physical-technical usage, basing on a mathematical calculation of newly discovered hydrotic vortices, (only in german) INDEL GmbH, Verlagsabteilung, Villingen-Schwenningen 1990.

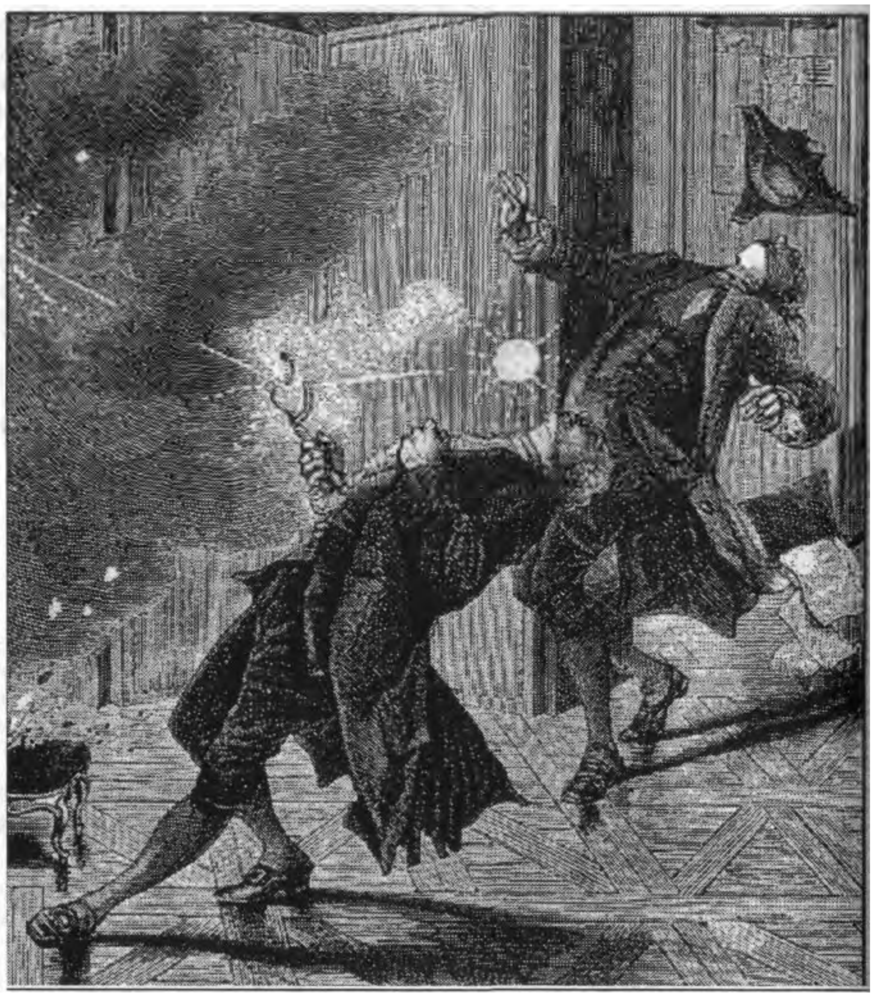

Fig. 14.12: Contemporary representation, how 1753 lightning research scientist Prof. Richmann is struck deadly by ball-lightning in his laboratory.<i>

<i>: Illustrierte Wissenschaft Nr. 8, August 1995: Das unverstandene Phanomen der Blitze, page 13

I proceed from the assumption that lightning collects and converts neutrinos. The process corresponds to the one at the sun, but on a smaller scale and only for a very short time. The lightning channel is polarized by the charge carriers. Change of temperature and field lead to a spatial oscillation, which by the way also functions as a source of sound, as anyone can hear. Taken both together lightning, seen from the outside, becomes an unipolar resonator, which is capable to attract neutrinos and to go into resonance with them. Now the predominant part is converted into electrons, because also the air molecules and air ions in the lightning channel belong to the world of matter. But it can't be avoided that a small part of antiparticles is formed, which then annihilate with particles of matter under emission of radiation. Doing so photons are emitted and lightning glows, as anyone can see!

14.12 Ball-lightning

If in the case of lightning there still exist excuses, the difference of potential preferably is traced back to neither understandable nor measurable processes inside a cloud, then at the latest in the case of ball-lightning most experts are at their wits end. Only for very simple natures explanations circulate in the direction that here for instance the organic remnants of a bird struck by lightning are burnt off.

Actually ball-lightning is observed very seldom. It is a ball flashing with reddish till blue-white colour. Its diameter lies between 10 and 50 centimetres. The glowing phenomenon can last several seconds to minutes. Doing so ball-lightning rolls over a street, temporary floats in the air, goes apparently unhindered through every wall and disappears from time to time without a trace or discharges with loud moise and formation of sparks. Some stink of poisonous gases and some also cause noise.

Famous has gotten the ball-lightning, which 1753 of all people should have struck the lightning research scientist Professor Georg Wilhelm Richmann in St. Petersburg. In his laboratory during a thunderstorm a ball of fire as big as a fist should have jumped from a iron tube to his head and should have hunted him down, so eye witnesses have reported (fig. 14.12).

Since ball-lightning has a closed structure, it has to drag about its source of energy with it. If this however consists of organic or other matter, the ball wouldn't be able to float, after all the brightness of a spherical vortex and with that the need of energy is enormous! We have to proceed from the assumption that just ball-lightning covers its need of energy from free energy and serves itself from the neutrino field.

The spherical form is a consequence of the structure shaping property of the potential vortex<ii>. Scientists are increasingly interested in this not understood phenomenon. In their experiments they try to artificially produce ball-lightning with more or less great success in the laboratory. By means of the experiment they then want to learn to understand, what the textbooks don't give away.

If we want to learn of nature something about free energy, lightning in the laboratory offers us in the form of a blow or of a spark gap relatively good possibilities. It surely is no coincidence that the father of free energy, Nikola Tesla, in his experiments almost all the time has worked with spark gaps!

<ii>: for that see in the 1st part the chapters 4.8 till 4.10

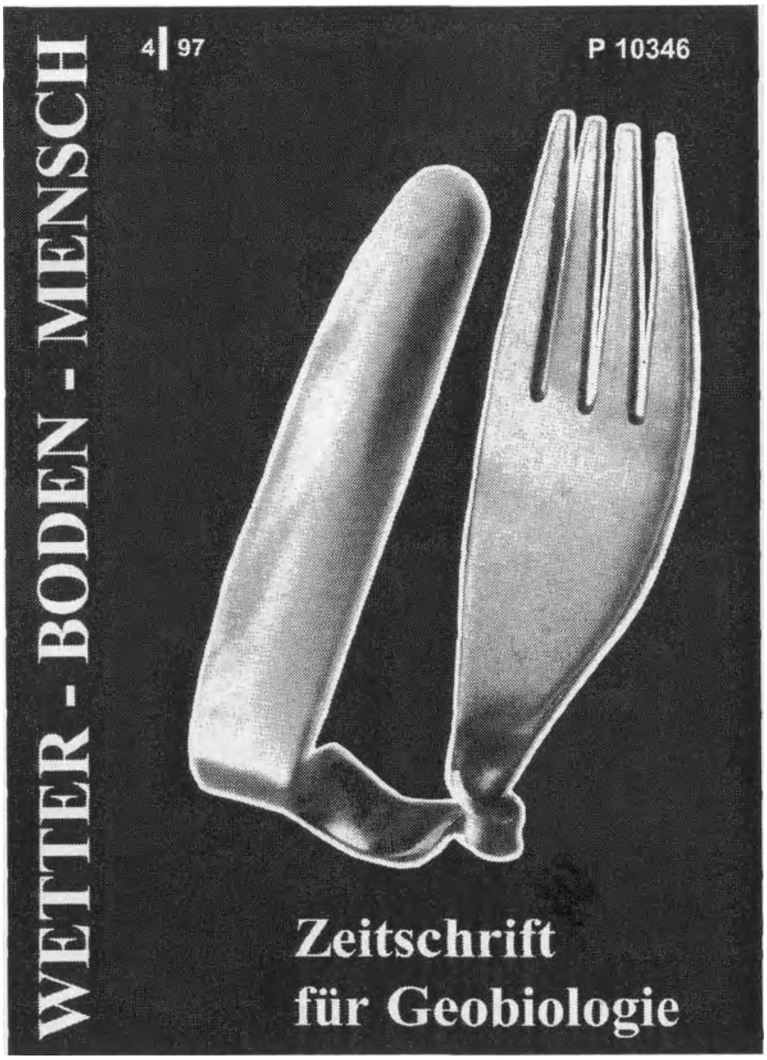

Fig. 14.13: Fork bent by „pure manual work".<i>

<i>: Whoever has to eat with bent flatware in the Hotel Adler in Waldkatzenbach (Odenwald, Germany), mustn't believe that the food didn't taste well to some rude fellow here. It is the host himself, who in a sociable round shows his guests from time to time that he not only can cook well. I could personally convince myself from the fact that Robert Hartmann doesn't use any aids. The picture shows the title page of the magazine „Wetter Boden Mensch" 4/97. A comment concerning this on page 3: Robert's 50ieth birthday.

14.13 Discussion concerning the neutrino conversion

In nature two different principles for the use of the neutrino radiation can be observed. In one case of use a glowing phenomenon occurs, in the other cases not.

The glowing lightning should be assigned to the first case. Here not only the neutrinos crossing the lightning channel are used, but also neutrinos from the environment oscillating in resonance are collected. Around the lightning channel a kind of reaction radius is formed, inside of which all synchronously oscillating neutrinos are attracted under the resonant interaction. During the discharge process the radius can increase like an avalanche, to collapse again with the transition into the stationary discharge current. A corresponding technical concept, which is discussed in the next chapter (15.5), is very efficient, but almost uncontrollable. A characteristic is the formation of antiparticles, of positrons, in the course of the materialization, which then annihilate under emission of radiation and cause a shining. Also spark gaps and fluorescent lamps possibly help themselves from the neutrino field, as still has to be to worked out.

In the second case nature works without any avalanche effect and without any glowing phenomenon. To this counts for instance the photosynthesis or the mode of operation of the mitochondria, the energy centres of a cell. All cells, whether vegetable, animal or human, only use the neutrinos which just that moment pass by them and only in those amounts, as they just are needed. They thus handle their energy very caring. Without exception electrons are materialized and no positrons.

If nevertheless unwantedly an avalanche effect occurs, something which happens fortunately only very seldom, then a self-inflammation and self-burning occurs, then it should happen, that a person burns off himself<ii>. This risk also is known of hay.

There also exist rare talented persons, who can control and regulate the process of materialization by concentration. These people can bend spoons or other metallic objects<i>. For that they concentrate themselves some time and send the materialized charge carriers into the object, which they hold in their hands. Since the metal lattice solely is kept together by the enveloping electrons of the individual atoms, the additional electrons make the metal structure sodden. Now for a short moment the metal can be bent and distorted at will. Doing so neither heat is produced nor is the colour changed. The result of the process can be produced neither by cold working with raw force nor under a flue. Also here nature shows us a technology for an ecologically compatible metal processing (fig. 14.13).

The way from the conventional over the regenerative towards free energy is predrawn. It only has to be gone! After the existence of the neutrino radiation goes as proven and 1998 for the first time concrete amounts have been determined measuring technical and published by a Japanese team of research scientists, with that also the question for an energy technical use of the particle radiation has been answered clearly. Now only the question of the mechanics is open. The Japanese research scientists by the way have found out that at night only half as much solar neutrinos can be detected than at daytime. The other half according to that is absorbed in the inside of the earth. This in the meantime published measurement result in brilliant manner confirms the working hypothesis of a growing globe (chapter 11).

<ii>: Zu Asche pulverisiert, Illustrierte Wissenschaft 6/ 1997, S. 61 acc. to an examination of the American SCI-COP in 1984.

cause/ field lines	interaction	F = force effect *mediation:*	**see chapter:** effect/ *application*
1. open **H**-field lines	magnetic (static)	F_{M0} = magnetic force (permanent magnet)	**chapter 15.4** *E.-engine, solenoid*
2. open **H**-field lines	resonant (oscillating)	F_{MS} = magnetic force (AC-magnet)	**15.4 + 15.5 - 15.7** lightning, *railgun*
3. open **E**-field lines	electric (static)	F_{E0} = Coulomb force *by charge carriers*	**15.9 + 15.10** atomic bond, *Testatika*
4. open **E**-field lines	resonant (oscillating)	F_{ES} = Coulomb force *by neutrinos*	**chapter 16 + 17** weak interact. galaxy bond *Tesla converter*
5. closed **H**-field lines	gravitation (static)	F_{MG} = gravity *by particles with mass*	**chapter 6.9 + 7** elementary particle mass
6. closed **H**-field lines	levitation (dynamic)	F_{ML} = reduced gravity	**chapter 18.3** gravit. waves *Casimir effect*
7. closed **E**-field lines	gravitation (static)	F_{EG} (force hardly detectable)	**chapter 18.7** *superconducting ring*
8. closed **E**-field lines	levitation (dynamic)	F_{EL} (no longer detectable)	**18.5 + 18.6** *Keely-/Searl-flying devices*

electromagnetic and resonant interaction		gravitation and levitation
$F_{M0} = 1{,}4 \cdot F_{MS} > F_{E0} = 1{,}4 \cdot F_{ES}$	»	$F_{MG} = 1{,}4 \cdot F_{ML} > F_{EG} = 1{,}4 \cdot F_{EL}$
for reason of open field lines		resp. closed field lines

Table 15.1: The force effect of interactions, ordered according to size, with examples

15. Principle of functioning of space energy

In this chapter we want to turn us towards the technical concepts and techniques concerning "space energy", which occasionally here and there already should have existed or have been operated with quite different success. After Nikola Tesla having pointed the direction more than 100 years ago, the way towards free energy appears to be predrawn. Never before the public interest in the topic of space energy was as big as today. Unfortunately this concerns more the collecting and gathering of rumours and speculations. As in every branch of science also here hunters and collectors can be found. But obviously the hunters, the inventors and theorists have bigger problems, to put something useful on the table. They are fighting against their own not knowing, unuseful textbooks, general ignorance, intolerance and an all-powerful energy lobby. What the collectors on the other hand come up with does make appetite but not full.

An useful and efficient theory might be the most important prerequisite just with regard to the reproducibility of an effect and the product liability of a SET-device. That's why one mustn't expect a complete list of devices of that kind in this chapter, because in the foreground stand the physical and technical explanations concerning the way of functioning, the understanding for constructive and guiding details and the learning from the mistakes and errors of the inventor.

For a better survey the possible courses of the field lines according to the theory of objectivity are listed in detail (table 15.1) and discussed from the top one after another, starting with the strongest known interaction. To complete examples and concepts are presented.

As is well-known there exist electric (E-) and magnetic (H-) field lines. Further exist open and closed field lines and finally is distinguished between the oscillating and the static case. The results are two to the third power, thus eight possibilities of combination in total. In table 15.1 all eight versions are given, even if one or another case is of more theoretical nature. For the objective of a systematizing of different concepts concerning space energy technology the taking apart in any case is helpful. The figure opposite is survey and structure at the same time for the following chapters.

15.1 The course of the field lines

In chapter 6 a relation between the course of the field of a body and its observable interaction has been made (part 1, chapter 6.7 till 6.9). Here a point of approach is offered. For instance to maximize the force effect a magnet or to optimise an electric motor, the engineers nowadays help themselves with costly programs working according to the method of finite elements. In this way they obtain a picture of the field lines, the course of which makes possible conclusions concerning the production of force or torque. The relation without doubt is given, the only question is in which order of magnitude.

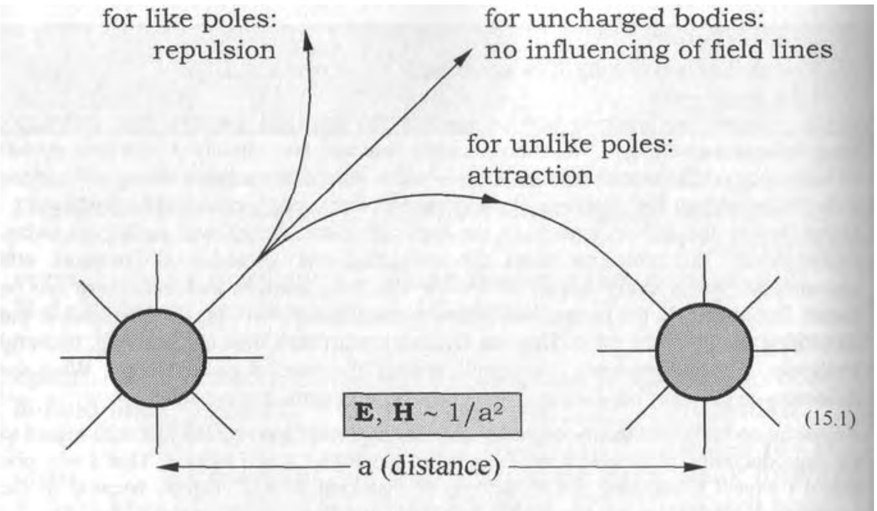
for like poles:
repulsion
for uncharged bodies:
no influencing of field lines
for unlike poles:
attraction
E, H ~ 1/a²
a (distance)

$$\mathbf{E}, \mathbf{H} \sim 1/a^2 \qquad (15.1)$$

Fig. 15.2 A: The course of the field lines leads to a force effect (repulsion or attraction)

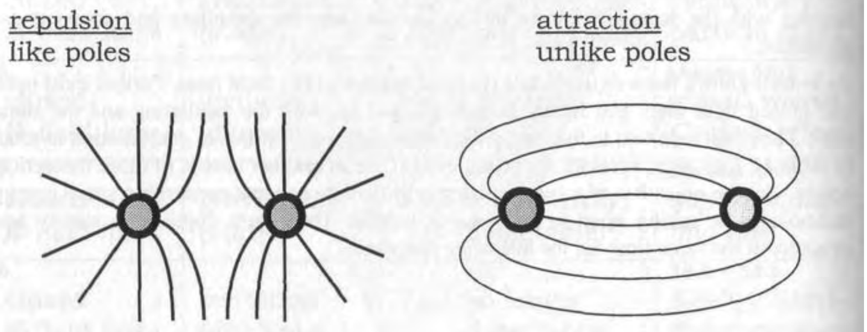
repulsion
like poles
attraction
unlike poles

Fig. 15.2 B: The course of open field lines

$$\boxed{\frac{F_{\text{Coulomb force}}}{F_{\text{magnetic force}}} = \frac{Q\cdot E}{\phi\cdot H} = \frac{\mu\cdot Q^2}{\varepsilon\cdot\phi^2}} \quad \text{with} \quad E = Q/\varepsilon\cdot A \quad \text{and} \quad H = \phi/\mu\cdot A \qquad (15.2)$$

i.e. e^-: where $\phi^2 = m^2\cdot G\cdot 4\pi\cdot\mu$ (Gl.13.20)

$$\boxed{\frac{F_{el}}{F_{magn}} = \frac{e^2}{\varepsilon\cdot m_e^2\cdot G\cdot 4\cdot\pi} = \underline{4{,}2\cdot 10^{42}}} \qquad (15.3)$$

Fig. 15.2 C: The proportion of forces at the example of the electron.

The theory of objectivity answers the question from the equations of transformation with the proportion 13.23 (fig. 13.4). According to that the electric or the magnetic field strength stand in inverse proportion to the square of a length or of a distance:

$$E, H \sim 1/a^2 \qquad (13.23) \text{ bzw. } (15.1)$$

Less mathematically expressed this, for two bodies in the distance a, where one body is situated in the field of the other, means nothing else as that the distance is reduced. Nearer to the body the density of the field lines again increases, in that way the distance further decreases and we observe an approximation.

Usually the idea of force is introduced as a factor of description and there is spoken of a force of attraction. But that not necessarily is required, because the force only represents an auxiliary description. The cause for the observed attraction rather is the spatial distribution of the field strength.

In this case the two bodies come closer and the mutually active fields get bigger and bigger, until the parts eventually run into each other (fig. 6.7 A). There one comes the thought to increase the force of attraction by an artificial compression of the field lines. In the case of the electromagnetic interaction such a compression actually takes place, since the field lines arise from one pole and end at an unlikely charged pole, which so to speak collects and bundles up the field lines (fig. 6.8 A).

At last we find out the reason, why electromagnetic forces of attraction are bigger than gravitational forces for many powers of ten (between 10^{30} and $4.2\text{-}10^{42}$ for the electron, derivation see fig. 15.2 C)! For table 15.1 this means, at the top have to stand the open field lines, which bundle up at the poles. Then very long nothing comes and after that the effects of closed field lines are being found.

For open field lines however also the opposite of a bundling up is possible. In the case of like poles the fields run away of the other pole (fig. 6.8 B). Between both a space is formed, which is free of field lines, where thus the field tends towards zero, whereas the distance between the poles according to the proportion 15.1 grows towards infinity. In this case we observe, how the bodies are going away from each other. We speak of a force of repulsion, which actually reaches until infinity. This gives reasons for the occurring of both forces of attraction and forces of repulsion in the case of the electromagnetic interaction.

15.2 Gravitation

In the case of closed field lines in principle no repulsion can occur, since no pole, neither north pole nor south pole, neither positive pole nor negative pole is able to influence the position of such a field line. This circumstance as well as the order of magnitude of a possible force of attraction suggest, to settle gravitation here.

It gladly is forgotten, that the field pointers of E- and H-field normally occur together and like in the case of the electromagnetic wave stand perpendicular to each other. It is normal to calculate only the electric field pointers for a charge carrier, without paying attention to the circumstance that the H-field is present as well. The textbooks as a rule remain silent about this dark chapter or they lapidary remark, the dual field lines are closed in themselves and hence inactive anyhow, which however is incorrect.

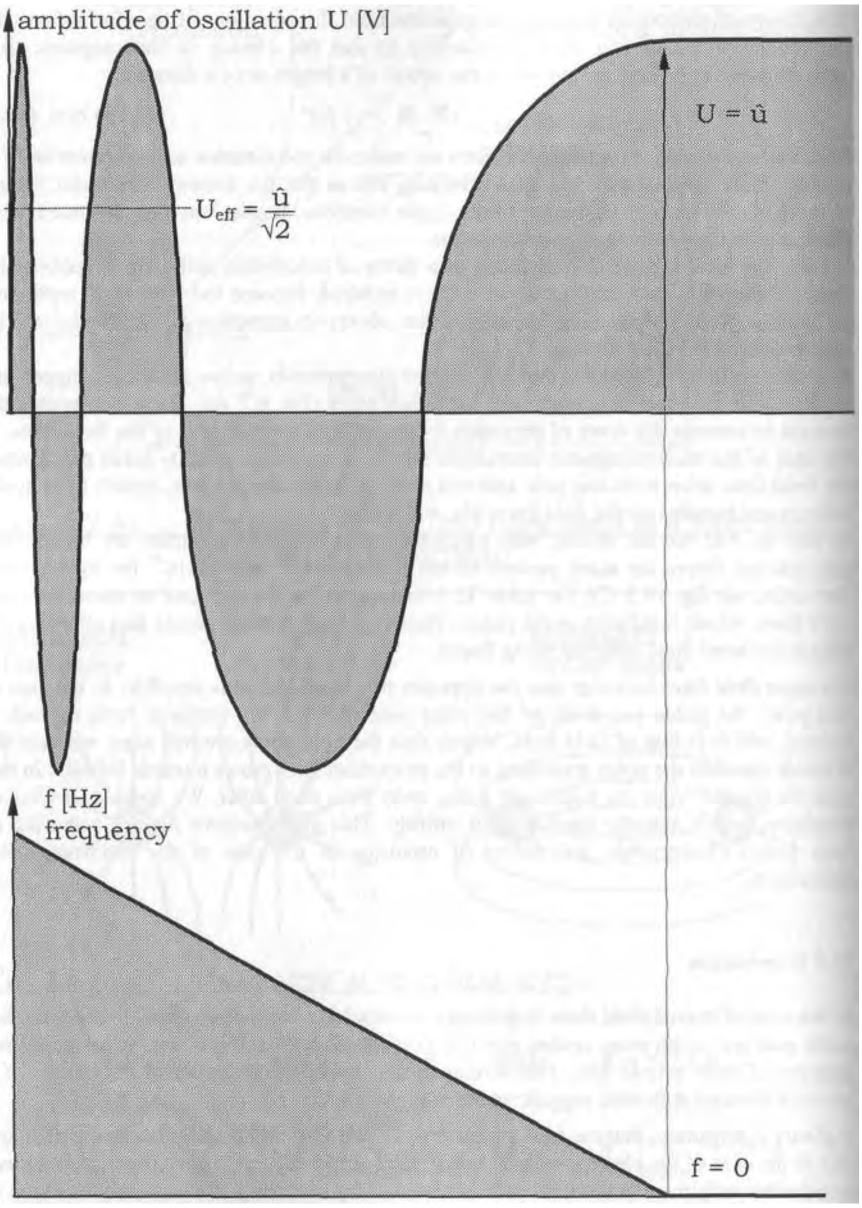
amplitude of oscillation U [V]
U = û
$U_{eff} = \frac{\hat{u}}{\sqrt{2}}$
f [Hz]
frequency
f = 0

Fig. 15.3: The transition of an oscillating into a static interaction

But, according to the proportion 15.1, they actually develop a force of attraction, even if this is relatively small. No one really needs to be surprised that gravitation is not understood until today, if a whole group of fields simply is overlooked by science! We now also can explain, why there don't exist any massless charge carriers. Namely only the E-field or the H-field can form open field lines and never both at the same time. Otherwise they wouldn't be able to stand perpendicular to each other anymore. The each time other field, in the case of electrically charged bodies it is the H-field, then is wrapped perpendicularly around the E-field lines, independent of the circumstance if electrically an attraction or a repulsion occurs and without exception it forms a weak force of attraction, the gravitation.

15.3 Systematizing the interactions

Next we should know, from which field is to be expected a larger force effect: from the E or from the H-field? At the example of an electromechanical converter this question can be answered concretely.

The forces which occur and form the torque in an electric motor customary in trade are produced by magnetic poles in stator and rotor, which repel each other in the case of like charge and attract each other in the case of unlike charge. Now there in principle exists the possibility to build a motor which works with Coulomb forces, thus with positive and negative poles, instead of the magnetic forces. About such designs numerous patent specifications exist, but no customary version on the market.

The reason very simple is that a magnetic motor for the same torque is many times smaller and better priced. From this the conclusion can be drawn that for the same construction volume a magnetic force F_M is considerably larger than a Coulomb force F_E, which for instance binds together atomic nucleus and atomic hull.

Thus in table 15.1 the magnetic forces are ranked before the Coulomb forces.

Finally we have to distinguish between the static and the oscillating case, which are distinguished in the frequency. In fig. 15.3 an oscillation is shown, which by chance just at the moment of the vertex value changes into the steady state, thus takes the frequency zero. In this case the effective values between a static and a sinusoidal oscillating interaction are distinguished by the factor $\sqrt{2}$ = 1.4.

If we operate an universal motor with direct current, then it releases more power, than for a corresponding feeding with alternating current. Even a high-tension line, which stands at maximum 511 kV, is operated with alternating current up to 380 kV, with direct current on the other hand up to 500 kV. Consequently in table 15.1 the static interactions stand before the oscillating interactions.

The strong interaction naturally isn't found in the list, after it has been derived that it doesn't exist at all (see chapter 7.8), whereas the weak interaction is hiding behind the oscillating interaction. It shakes other particles so long till they fall apart (see chapter 7.13).

We now would be as far, to discuss the 8 cases listed in table 15.1 one after another by means of practical examples.

The principle of the side-pole machine

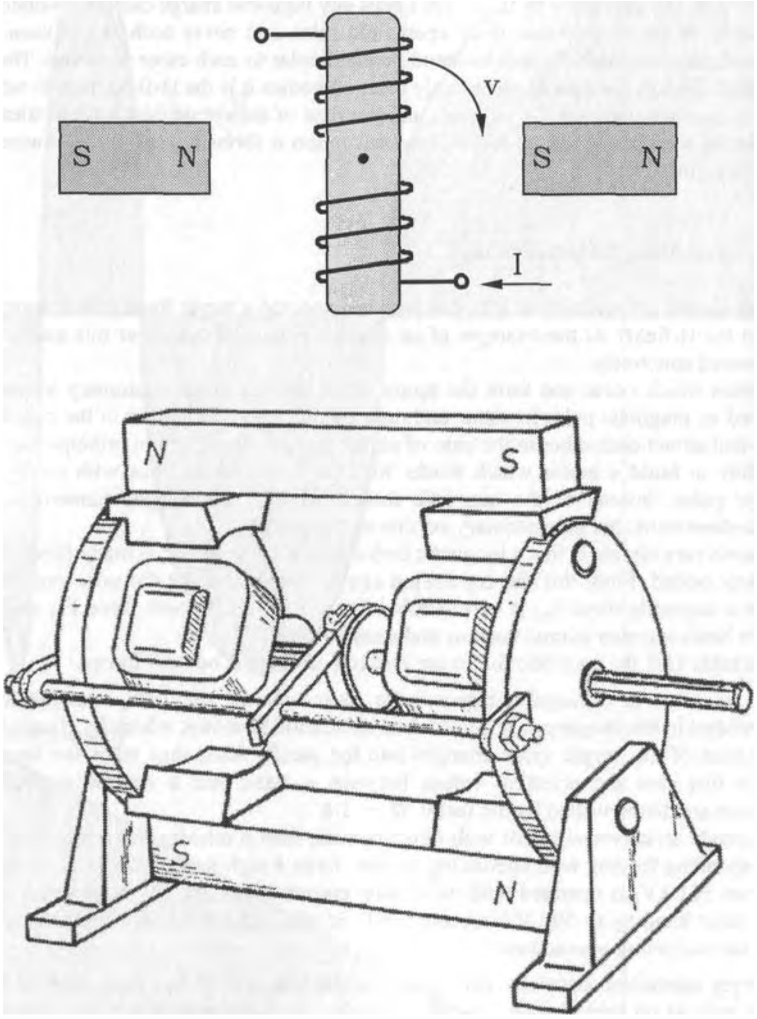

Fig. 15.4: Alternating current dynamo, according to the inventor (Kromrey) a magnetic converter for free energy with a degree of effectiveness of more than 100 %.<i>

<i>: Raymond Kromreys Molekularstromrichter, NET-Journal 6/98, S. 5

15.4 Magnetic force converter

As a result of the systematizing of all eight possible interactions, the largest force effects are to be expected as a result of static and of open magnetic field lines. It is questionable, if this statement is generally valid and is true everywhere in space. But it is valid at least for a terrestrial laboratory and only here, on earth, a solution for the energy problem is strived for. No wonder therefore, if the electric energy technology nearly without exception is using these force effects. We find them at a solenoid, at a relay coil, at a magnetic tuning cylinder and equally between the stator field and rotor field of an electric motor.

The motor however takes a special position, because its rotor is turning. In that way a switching of the winding and commutating of the currents is necessary or the field of the stator winding is being turned, for instance in the case of an alternating current motor. This is necessary, so that in the air split of the motor the fields from the stator and rotor always are standing opposite like for the solenoid and a driving force can be formed. For the operation therefore oscillating currents are necessary, so-called alternating currents, which are fed in into the winding with the right frequency and phase. There can be spoken of an operation in resonance. It surely is no coincidence, that Nikola Tesla, the founder of the rotary field theory and inventor of the alternating current motors at the same time is the discoverer of the neutrino radiation!

The electric motor slides already into the second column from the top in table 15.1, as we see, and should be assigned to the case of the oscillating interaction of open magnetic fields. The frequency for motors usually is very small.

But also at high frequencies there can't be reckoned on some free energy which would show or even be utilizable, as can be heard from the inventors who tinker with magnets, mostly with permanent magnets (Fig. 15.4). The reason very simple is that there exist no physical particles, which could mediate this interaction. Magnetic monopoles would be necessary, thus north pole or south pole particles, so that an interaction with the open H-field lines can occur.
Such particles could form as a result of currents and eddy currents, but for that a good conductivity would be necessary and that isn't present in the vacuum. Therefore magnetic monopoles can't exist at all! This point we already had worked out (fig. 4.4, question I). The same statement then also applies to the oscillating case.

If nevertheless something like free energy should show in the case of some magnetic field converters, then unnoticed by the inventor still other physical effects are added. By means of concrete concepts this circumstance can be studied and discussed. The meanwhile well-known railgun is a corresponding example, for which besides the used magnetic force unintentionally a further principle is used. A more detailed occupation with this device is worthwhile, because here some fundamental concepts of space energy get clear.

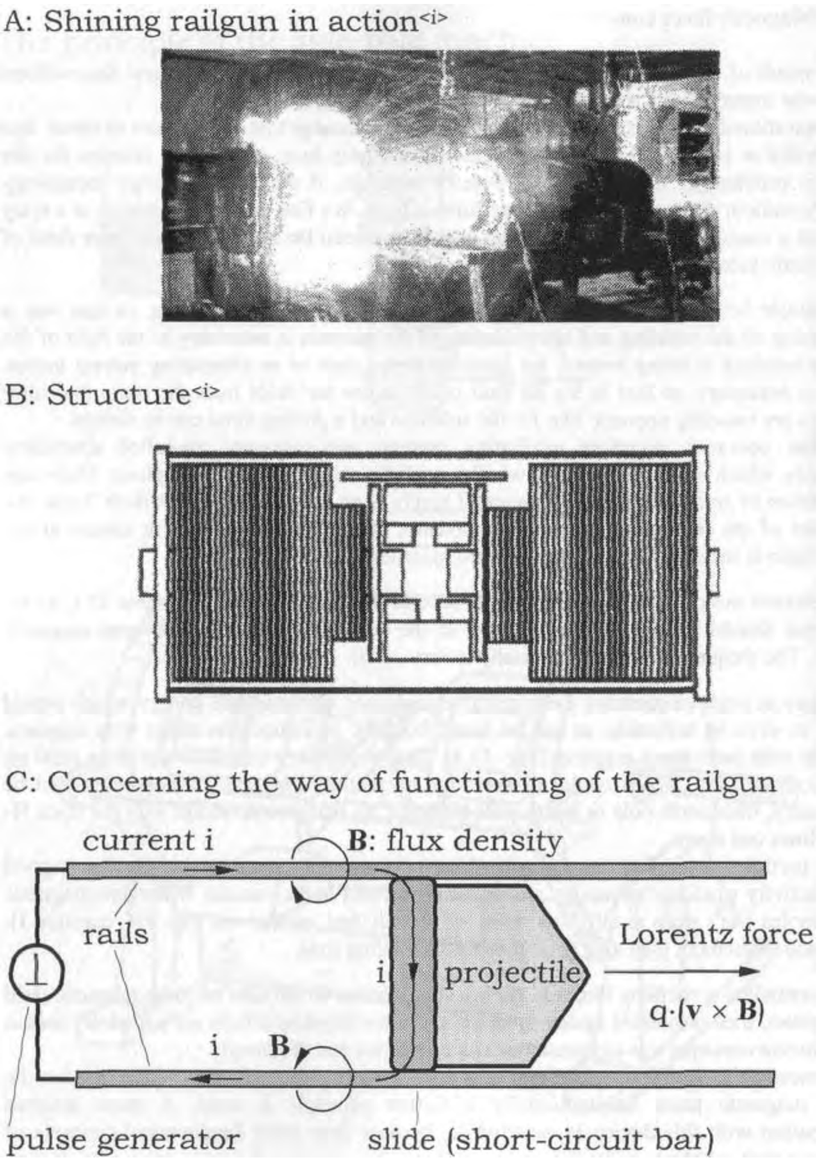
A: Shining railgun in action<i>
B: Structure<i>
C: Concerning the way of functioning of the railgun
current i
B: flux density
rails
i
projectile
Lorentz force
q·(v × B)
i
B
pulse generator
slide (short-circuit bar)

Fig. 15.5: Structure and way of functioning of the railgun

<i>: in the internet under: www.glubco.com/weaponry/railgun.htm

15.5 The railgun

The engineers and physicists involved in the SDI-project were quite astonished, as they had a close look at the bent rails of their gun. During the test operation the equipment was really flying around their heads.

They were very sure to only have fed in 16.7 MJ of energy, from the rotation of a homopolar generator, because more was not available for the experiment by any means. The projectile with mass m_0 = 0.317 kg lying on the rails thereby should have been accelerated to the velocity of 4200 m/s. Instead huge forces were at work here, which the construction couldn't counteract at all. There is talk about the released energy having amounted to 399 GJ, what corresponds to an over-unity effect of 24000<ii>. This factor describes the proportion of the released to the taken up power or energy. If these details should be correct then this would be the most efficient converter for free energy, which has been developed until now.

Behind the project name SDI (Strategic Defence Initiative) is hiding the by the United Slates prepared "Star wars". But how one fares a war, which nobody can pay anymore and no-one wants, entirely according to the motto: There is a war and no-one goes there? This war undoubtedly the strategists and initiators themselves have lost, who even had to watch, how their space gun appears in the internet with design drawings and rich visual material to be called by anyone<i>.

Today, where we are surrounded by nothing but friends, where in Russia and at other potential opponents is fought more against internal problems and one lets the expensive space toy rot for lack of money, the coat of the military secrecy obviously no longer can be held over such an explosive project as the railgun.

Thus informative details have reached the public. In the pictures a bright lightning can be seen at the moment of launching (fig. 15.5 A). Here presumably is being materialized, in which the part of anti-matter annihilates with the particles of matter under emission of light. There thus takes place the same process as in the case of lightning or the shining of the sun.

In addition is being reported that heat energy is withdrawn from the environment, a circumstance, which is typical for all functioning converters for space energy. We thereby are reminded of the possible formation of ice in a lightning channel.

Like for a lightning also the railgun is stimulated with a very high excitation voltage and with extreme speeds of change of the tension voltage (high du/dt) (fig. 15.5 C). From the setup it concerns a bridge of Ampere, which in various respects appears to be superior to the rocket engines, after the costly transport of the propellant into space isn't necessary, since the capacitor batteries can be recharged by solar power.

<i>: e.g.: www.glubco.com/weaponry/railgun.htm

<ii>: Galeczki, G., P. Marquardt: Requiem fur die Relativitat, Verlag Haag + Herchen (1997), S. 139

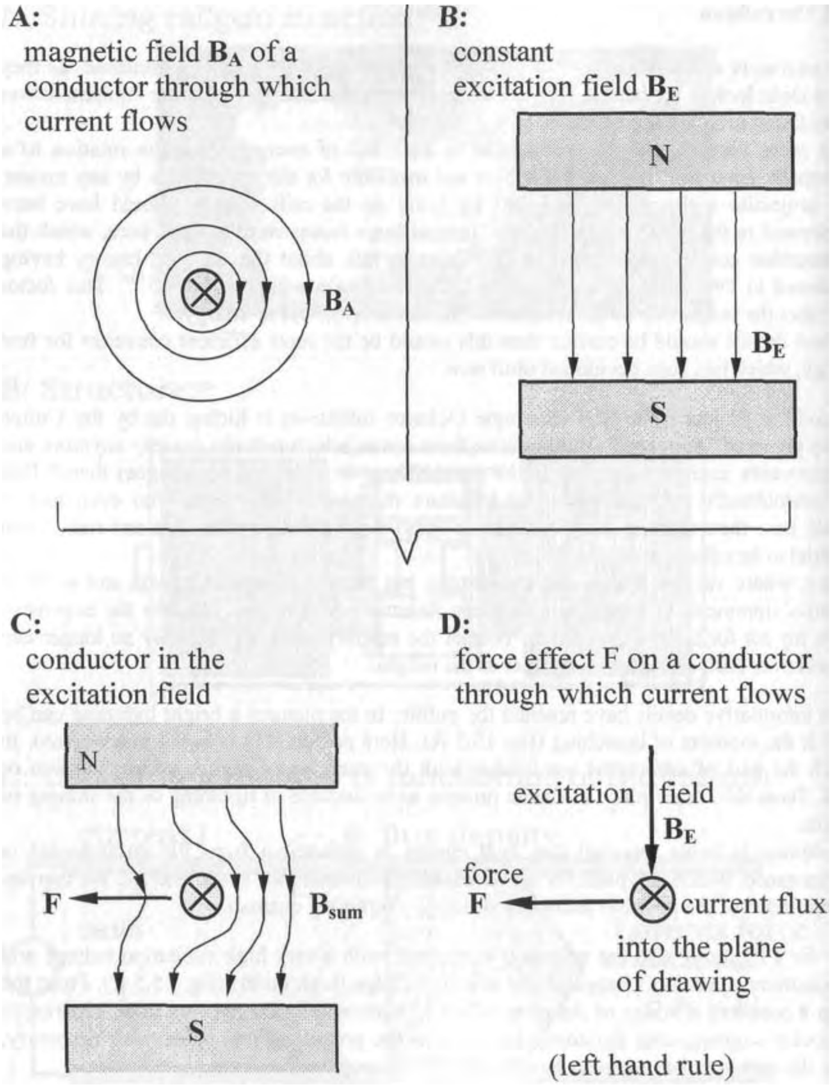
A:
magnetic field B_A of a conductor through which current flows
B_A
B:
constant excitation field B_E
N
B_E
S
C:
conductor in the excitation field
N
F
B_{sum}
S
D:
force effect F on a conductor through which current flows
excitation field
B_E
force
F
current flux into the plane of drawing
(left hand rule)

Fig. 15.6: ____ The distribution of field lines and force effect on the slider of the railgun through which current flows in a permanent magnetic field

The projectile has the form and the function of a short-circuit bar and is guided slidable between both rails of the railgun. The high-tension capacitors are switched on both rails at the moment of launching, so that in a very short time an extremely high short-circuit current of several thousands of Ampere flows through the bar.
Since the bar in addition is situated in a static magnetic field, there acts an accelerating force on it (fig. 15.6 D). It is the force effect of a conductor through which flows a current in a magnetic field, like it is active in every electric motor. If we overlap the fields of the conductor (fig. 15.6 A) and of the magnetic field (15.6 B), then we observe a bending and lengthening of the field lines (15.6 C). There exists the effort to re-establish the original state, which represents the smallest magnetic resistance, and for that the conductor is shifted out by means of the arising force. In the sketch it is accelerated to the left. That far the explanation concerning the bridge of Ampere. That has nothing to do with free energy. For the enormous degree of effectiveness, as it has been determined, further effects have to be added.

15.6 Unipolar induction

The projectile, or from the function let us rather speak of the short-circuit bar or the slider, at first is entirely conventionally accelerated and experiences, mathematically expressed, a dv/dt. The magnetic field B stretching perpendicular to the movement is constant, so that according to the Faraday relation<i> E = v x B from the velocity v an electric field strength E results and from the acceleration dv/dt a field change dE/dt. These open field lines along the length of the slider, in particular the oscillating part, appears to interact with oscillating particles and to collect these particles<ii>. It concerns presumably neutrinos, which primarily materialize in charge carriers. These contribute to the current flux in the slider and to the acceleration, whereupon still more neutrinos are collected.
A hardly controllable avalanche effect is formed. Only if the change in tension voltage has worn off and the capacitor is completely discharged, also the resonant interaction will again collapse.

The inventors, who want to construct a civil version of the railgun, is given a warning on the way which should be taken seriously. At first it doesn't take particularly much imagination to imagine a rotating arrangement of the gun, a construction with one axis, whit which a generator driven, which produces power. A small part is supplied the system again as supply for itself. The rest would be available free to the consumers as non-polluting, regenerative energy.
That really sounds good, if there wouldn't be this one obstacle.

<i>: The equation of transformation concerning the unipolar induction already was treated more detailed in chapters 6.4 and 9.3

<ii>: It is the resonant interaction according to table 15.1, line four

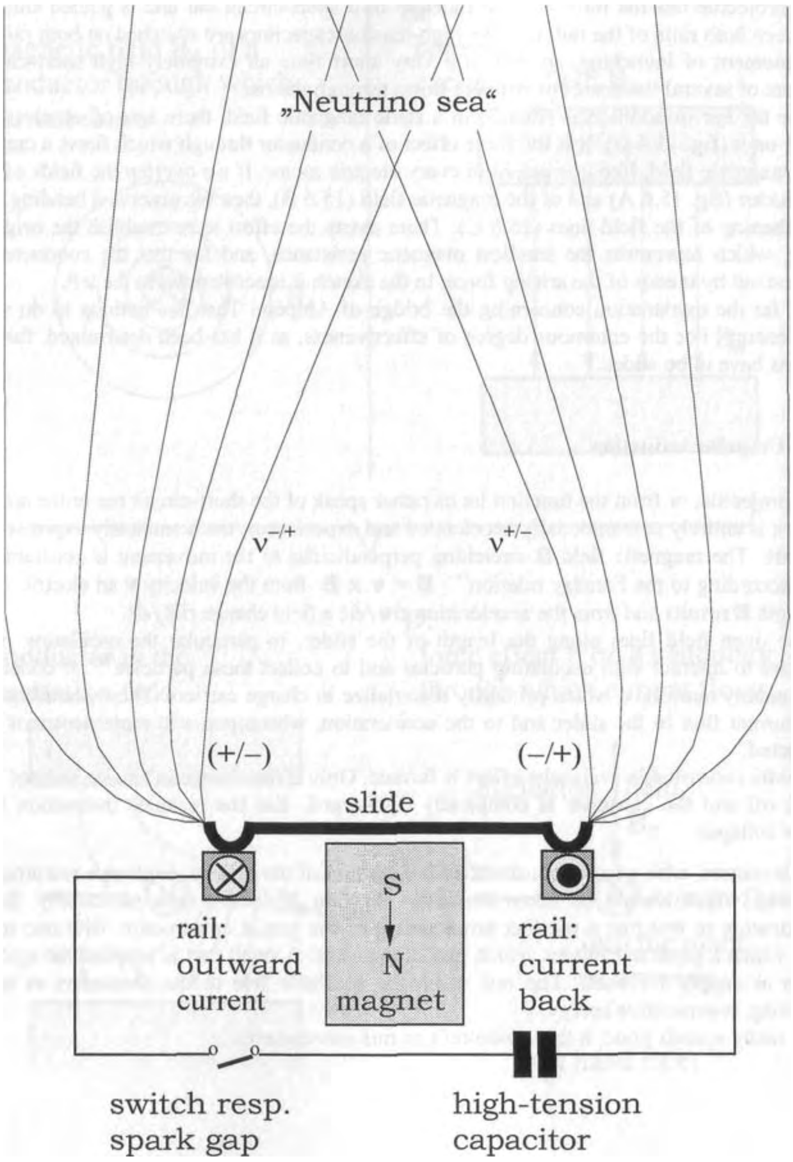
„Neutrino sea“
ν−/+
ν+/−
(+/–)
(–/+)
slide
S
N
magnet
rail: outward current
rail: current back
switch resp. spark gap
high-tension capacitor

Fig. 15.7: The collecting of neutrinos by oscillating open field lines

15.7 Tendency to instability

In a continuously working machine the discharging of the capacitor cannot remain a single event as in the case of the gun. The discharging and the recharging has to take place cyclic depending on the revolutions per minute. To obtain a rotating movement even to a certain extent ignition has to follow ignition. But if the new ignition takes place, although the avalanche effect of the last one still hasn't worn off, then inevitable a catastrophe will occur, then the work of wonder is taken apart under the eyes of its creator. Numerous inventors already have had to collect such painful experiences. It is assumed that not even Nikola Tesla had escaped, as he had to put away again his stately luxury car with electric motor and energy converter in a barn near Buffalo already after one week of test operation in the year 1931<i>.

Of course also for this problem solutions in accordance with engineering are offered. Meaningful would be a restriction of the revolutions per minute and a power regulation. Only most inventors don't think that far. On the one hand, because they handicraft without an useful physical model and on the other hand they think they already have reached the goal, if they observe something like free energy for the first time. Just as fast as the joy then the disillusionment comes, because a converter which doesn't work, is not able to convince anyone.

Tesla already was aware of this set of difficulties. He fastened his converter to the dashboard and not in the engine compartment, presumably to adjust the coupling of the coils from the drivers seat during the drive by means of two metallic rods, which he pushed into the case. But sometime even this regulation by hand has to go wrong, because the collected neutrinos on their part collect further neutrinos (fig. 15.7), so that in the case of an unfavourable order of ignition an additional amplification is possible. For a reliable operation according to that directly or indirectly the phase of the ignitions to each other should be checked.

At the example of the railgun space energy technologists and inventors can study the relations and the way of functioning very concretely and even calculate these relatively simple. It is a big relief, that all three vectors stand perpendicular to each other: the E-field, the B-field and the velocity v. Ideal conditions both with regard to a maximizing of the wanted accelerating force and for the resonant interaction, increase at the same time the collecting of space quanta, which probably may be set equal to the neutrinos. This is made possible by the Faraday's law of unipolar induction. In that way at the right and left end of the slider a positive a negative pole each are formed. The further the two poles are away of each other, the more the field lines are opened and the more neutrinos can go into resonance. In this place still considerable improvements and optimisations are possible.

In addition to the two discussed the phenomenon of the electrostriction is added as a third phenomenon, which authoritatively contributes to the conversion of neutrinos into electrons. It is a field dependent change of length, which in the case of lightning takes care of the thunder and in both cases, therefore also here, is active as a charge carrier producer.

<i>: see also chapter 9.5 Free energy,
A. Schneider: Energien aus dem Kosmos, Jupiter-Verlag 1989, Kap.ll, S. 20 and H. Nieper: Revolution, MIT-Verlag 1981, S. 194

A: electric dipole (e.g. electrostatics, see also fig. 6.8)

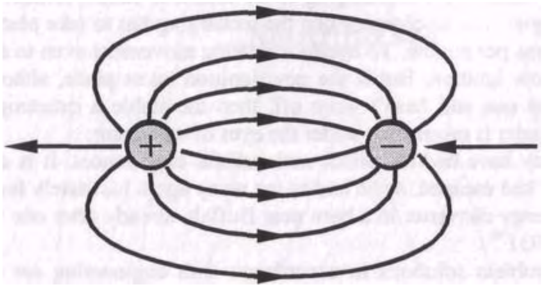

B: electric monopole (e.g. electron e~, see also fig. 4.3)

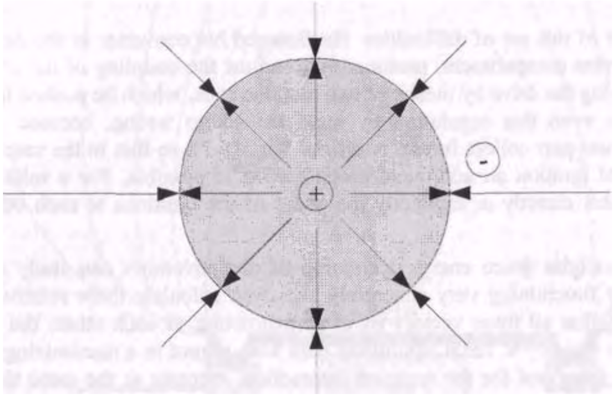

C: Mixed form in the case of cylindrical symmetry

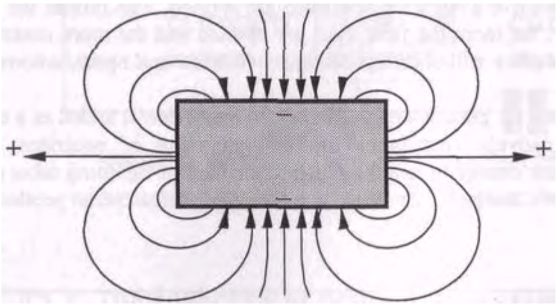

Fig. 15.8: Dipole fields with unipolar parts

15.8 Unipolar field configuration

If we again go back to fig. 5.1 and continue our considerations with examples concerning line 3. The obtainable force effect of open electric fields indeed is for powers of ten smaller than that of magnetic fields, but then particles are mediated, an invaluable advantage and an indispensable prerequisite with regard to the generation of space energy. As long as the particles are considered in the balance sheet of energy then in addition by no means can be claimed, space energy converter are perpetuum mobiles.

In the question, why only electric particles can be mediated, has to be pointed to the repeatedly mentioned circumstance that only electric particles can be formed as a result of the concentration effect of potential vortices. Magnetic particles however plain and simple cannot exist, since for missing conductivity in the vacuum no eddy currents are possible (see fig. 4.4).

In the case of the arising Coulomb forces again is distinguished between the static and the oscillating case. We want to start with electrostatics.

The range of technical applications of static electricity is large. It stretches from varnishing technologies and filter technologies till the fly grill in the arbour. In all cases the field is built up by charge separation. By means of a high-tension generator a positive pole and a negative pole are produced, between which the field is stretching. The field lines now start at one pole and end at the other, unlike pole (fig. 15.8 A).

In this manner almost no open field lines are available, which point to the outside and could interrelate with free particles. If one for instance intends to attract and collect charged particles from the solar wind, from the cosmic radiation or from the electricity of the air, then the design in one point has to be changed fundamentally.

A unipolar field configuration is necessary. What is meant with that, answers a glance at the spherical vortex model of the electron (fig. 15.8 B resp. fig. 6.2). Here it as well concerns a formation of dipoles as a result of the charge separation, but one pole is hiding in the inside of the other pole . In that way its field lines are captured and don't have a chance anymore to come out, to reach the other pole.

But if the pole lying on the outside for its part can't close its field lines any longer, then these point helpless into space and search in their neighbourhood, in the distant world and if need be even in the infinity of the universe an unlike anti-pole, which as a result interacts and is attracted.

The measuring technician analyses these open field lines and falsely calls the construction then a monopole, only because he isn't able to reach the locked up pole. To blame is the unipolar field configuration, which with that probably would be explained to a certain extent.

The designer and inventor as well might have realized how he has to construct his device, with which he generates open field lines to collect space quanta. He has to lock in one of the two poles as good as possible. Optimal would be of course a spherical symmetric construction like in the case of the elementary vortex. Compared with that a cylindrical symmetry indeed is suited far less good, but it offers constructive advantages (fig. 15.8 C).

We now will report of such a functioning device.

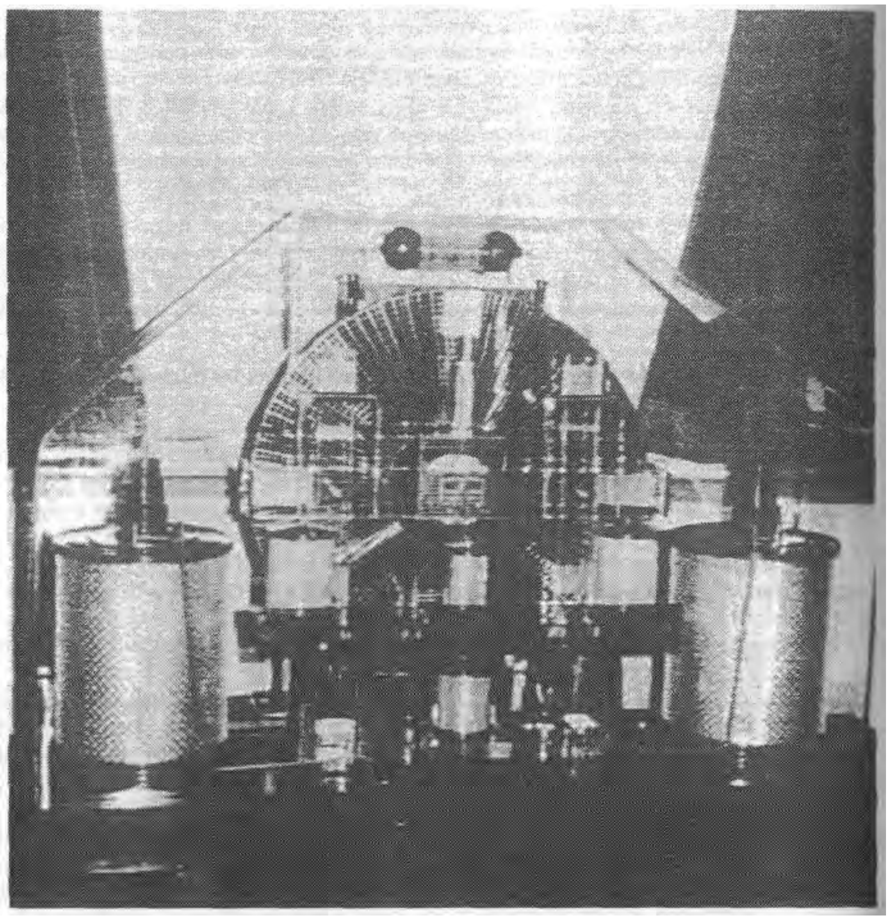

Fig. 15.9: Demonstration converter "Testatika".[i]

<i>: A. Schneider: Energien aus dem Kosmos, Jupiter-Verlag 1989, S. 29,
I. Schneider: Neue Technologien zur Freien Energie, Jupiter-Verl. 1994, p. 13 and in the NET-Journal, Heft 8/9, 1997, S. 16 as well as iss. 12, 1997, p. 6.
D. Kelly. Der Schweizer ML-Konverter, Raum & Zeit Special 7, S. 164

15.9 The Testatika

An electrostatic device, which produces open electric field lines, is situated in Linden in Switzerland. It optically is very imposing and belongs to a religious community, which has called it Testatika and is of the opinion that it is a free energy converter. Inexplicably the Testatika does not serve the community, which generates their electric power conventionally and to a large extent by itself, as a source of energy. Instead the 2 kW device only very seldom is demonstrated for special occasions or to select groups of visitors. The religious community after that explains the astonished observers humanity not yet is mature for the technology.

Perhaps just the opposite is correct and the technology not yet is mature. According to my personal assessment such an electrostatic device in principle is entirely unsuitable for the continuous operation.

It can be expected that the open field lines sooner or later will interrelate with the electricity of the air and thunderstorms are being attracted by the infernal machine so long until lightning strikes and the demonstration with that has finished. That's why the Testatika may be switched on only for a short time, only at sure weather situation and not too humid air, and many a registered visitor has been sent away without having seen the "thunderstorm machine".

As an object of demonstration and study the Testatika however is well suited. Alone the circumstance that no cable leads to the device and it nevertheless releases energy in the order of magnitude of 1 till 2 kW, surprises all visitors. At least the impression is mediated as if the machine would violate the law of conservation of energy, which is not correct. The Testatika is similar to an induction machine, which works with friction electricity. Thereby the unlikely charged bodies do not have to unconditionally touch and rub at each other, it already is sufficient, if they are brought in the immediate vicinity of each other. In the case of the Testatika the electrostatics of two against one another rotating discs is taken off by brushes.

The excitation energy presumably is taken out of the natural E-field, which just like that can amount to 200 Volts per meter (see chapter 2.9). The large diameter of 80 cm of the discs and their bad conductivity (acrylic glass) permit this conclusion. The charge taken off by the brushes afterwards is temporarily stored in two capacitors of 2 Farad at 300 Volt, so-called Leyden jars. This far one actually is reminded of a Wimhurst generator, in which the energy is supplied the system by turning the disc. Large powers cannot be drawn by that. Plans to build such an induction machine by yourself have been published<i>.

In the case of the Testatika however two discs are used and by hand stimulate to rotate oppositely. This rotational energy in this case isn't used to produce power, otherwise the discs quickly would stand still again, but that doesn't happen.

Until now apparently no-one has discovered the secret, which is kept strict by the members of the community. In my opinion the energy situation on our earth however is too serious, as that we would be able to afford playing hide-and-seek and egoistical secretiveness.

<i>: I. Schneider: Neue Technologien zur Freien Energie, Jupiter-Verl. 1994, S.14

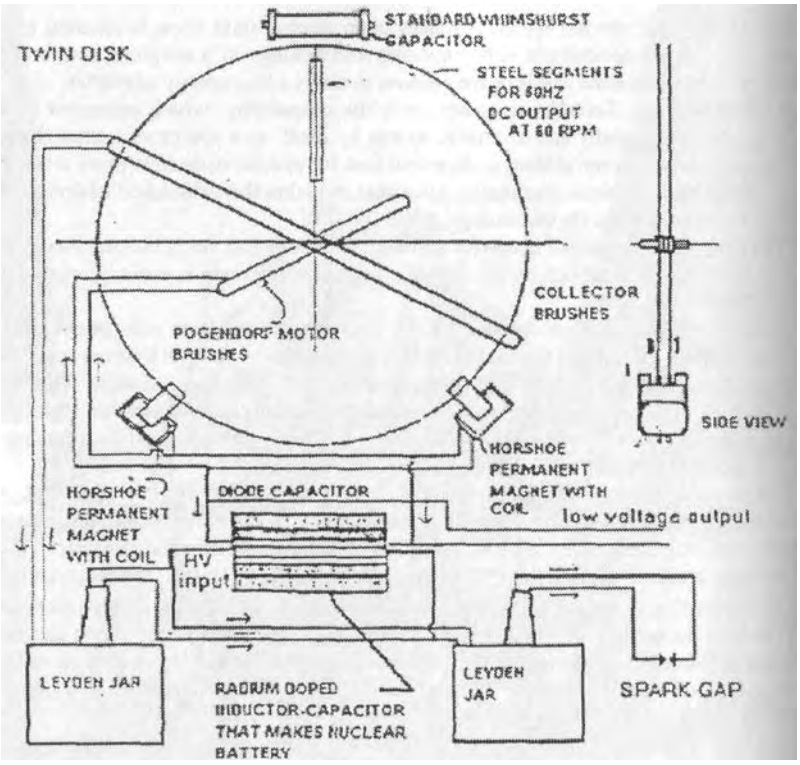
STANDARD WHIMSHURST CAPACITOR
TWIN DISK
STEEL SEGMENTS FOR 60HZ DC OUTPUT AT 60 RPM
COLLECTOR BRUSHES
POGENDORF MOTOR BRUSHES
SIDE VIEW
HORSHOE PERMANENT MAGNET WITH COIL
HORSHOE PERMANENT MAGNET WITH COIL
DIODE CAPACITOR
low voltage output
HV input
LEYDEN JAR
LEYDEN JAR
SPARK GAP
RADIUM DOPED INDUCTOR-CAPACITOR THAT MAKES NUCLEAR BATTERY

Fig. 15.10: Sectional drawing of the Testatika according to Don Kelly, (Clearwater, Florida, USA)

<i>: Der Testatika generator, NET-Journal, Dezember 1997, page 6 similar picture is found in Raum & Zeit Spezial 7, page 164

15.10 The secret of the Testatika

The crucial point is the opposite direction of rotation of both discs. If we assume the static earth electric field is the cause and serves as an excitation field, then as an effect a field arises, which stands perpendicular to that. The axial component now points out of the centre of the disc.
In the case of only one disc the field lines in front and behind the disc again are closed, so that no open lines can form. With one disc or with two discs rotating in the same direction hence no unknown charges can be attracted.
In the case of two oppositely rotating discs however shows one component along the axis of rotation to the observer, that of the other disc exactly in the opposite direction. In that way between both discs a pole is „pinned", which no longer is able to close all field lines on the outside around the machine. Thus open field lines and a, however incomplete, unipolar arrangement are formed.
The charge carriers sucked from the electricity of the air as a result support the natural electrostatics and speedy recharge the capacitors, even if up to 10 Amperes are taken out by the consumers.

The ingenious thing of the machine is its extremely simple construction and the simple concept.
If one includes the collected particles also in the balance sheet of energy, then it thus will turn out that the law of conservation of energy is not violated at all. There thus can't be talked of free energy. In this context the Testatika may rather be given as a counterexample. Air ions are the carriers of the electricity of the air and not carriers of free energy.

Negative air ions are indispensable for our welfare. One should only remember the first men in space, who after the landing were pulled out of their capsule more dead than alive, after they had to stay in the unhealthy atmosphere of the capsule for a longer period of time. Only the installation of ionising devices for negative air ions made possible longer staying in space.
The taking out of the air of negative ions hence is not unproblematic and not particularly ecologically compatible. An atmosphere harmful to life is formed which Dr. Wilhelm Reich has called DOR-state. He by the way has designed a Cloud-Buster, with which he could take static electricity, forming above the desert sand, out of the air. In that way the negatively charged rain clouds no longer are repelled and driven away. Reich has tested his weather machine 1954 in the desert of Arizona. After he had freed the atmosphere of the „DOR-strain", as he expressed himself, in the desert area the atmospheric humidity steadily increased from 15% up to 95%, there grew prairie grass and everything started to turn green, and eventually after many years for the first time rain fell again.

Static electricity, as far as the right polarity is chosen, may conditionally be used for the mechanics of rain making. For free energy concepts it however isn't suitable. Already Nikola Tesla has pointed to the circumstance that our hopes will be in vain if the free energy would be of static nature (see fig. 9.5). He in his speech, which he gave 1891 before the AIEE, has left no doubt that free energy exists, which is kinetic and with that energy technically usable for us,. Chapter 16 will be occupied solely with this case[i].

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[i]: according to point 4 in table 15.1

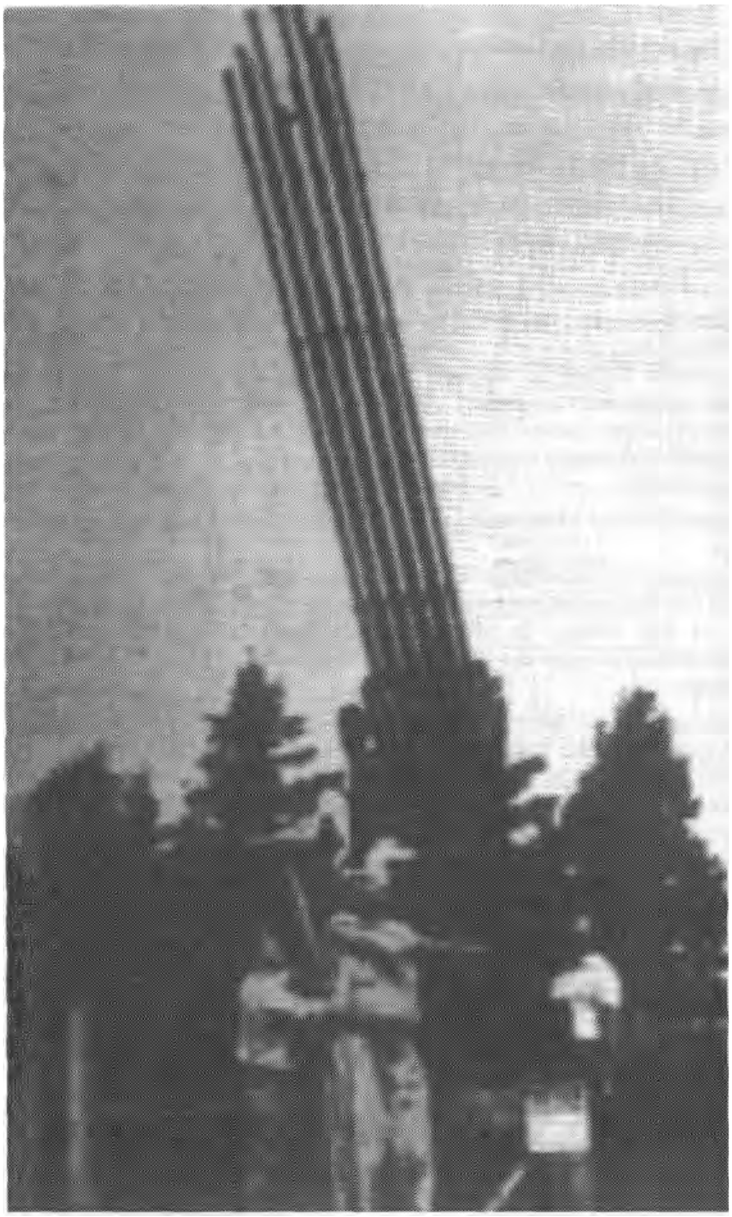

Fig. 15.11: The Cloud-Buster of Dr. Wilhelm Reich 1954.<i>

<i>: H.-P. Thietz: Tatort Erde, VAP (1996), ISBN 3-922367-62-3, page 122

<ii>: Part 1, fig. 9.3; concerning the unipolar induction see also fig. 6.5 and 11.8

Fig. 15.11 shows the weather machine of Reich, the Cloud-Buster. It can be understood only hard, why Reich directs a 3-4 m long metallic pipe with a diameter of 4 cm to the sky and connects the rear end with a deep well or with flowing waters. The effect should have been increased considerably with a few milligrams of radium. An indication that he must have worked with static electricity, delivers however a tragic accident, in which one of his collaborators was lamed on one side. He carelessly had touched the charged apparatus and suffered an electric shock[i].

15.11 The key to free energy

As a contribution to the discussion the individual principles of functioning of space energy again are collected and the attempt is undertook to value them.
In the case of an oscillating dipole configuration, for instance the railgun, open field lines are present only along the mutual line of connection (fig. 15.8 A). With that not particularly many space quanta can be reached. It hence has to be operated with gigantic excitation powers in the range of many thousands of Ampere, so that further field lines fling open and interact. The wanted over-unity effect therefore can only be reached at an enormous expense of technical apparatus.
An unipolar arrangement here is considerably more advantageous, where holds: the more unipolar, the fewer excitation power is required. But in that way it can take longer until the collecting of neutrinos like an avalanche again has worn off. In the case of an ideal spherical arrangement (fig. 15.8 B), as the ball-lightning takes, the process can even last for minutes. This explains why unipolar systems can be kept under control only very hard. If the neutrino avalanche is rolling then it purely theoretical only can be stopped with a still larger excitation power, for instance by phase shifting, what can hardly be realized in practice. The rolling avalanche can't be stopped anymore by normal means. A synchronous operation between the neutrino oscillation and the converter can, apart from the technologically hardly realizable high frequency, by no means really be recommended. As a rule one single steep flank of the change of the excitation voltage is sufficient to start the avalanche. By means of the repetition frequency or by means of the duty cycle of the excitation voltage then resonances to the neutrino field can be made or avoided. On the other hand can't be done without the avalanche effect. The utilizable power of the neutrino converter otherwise would be much too small. This case should be pursued further in the design of a longitudinal wave gauge.

All converter systems at first work based on a well-known and tried and tested physical principle of functioning. In the case of the railgun it is the bridge of Ampere. The thus used force effect on a conductor through which flows current is advantageous due to the obtainable order of magnitude and as a basic concept extremely recommendable. But also Coulomb forces or other physical principles can be used.
Despite that a further relation still must be added, which produces the interaction with the neutrinos. Closely associated with the unipolar arrangement it is the unipolar induction, which in virtually all space energy concepts is put to use. It already could be shown that the railgun uses the effect as well as John Searl in the case of his flying disc[ii]. The Faraday law of induction turns out to be the key to free energy.

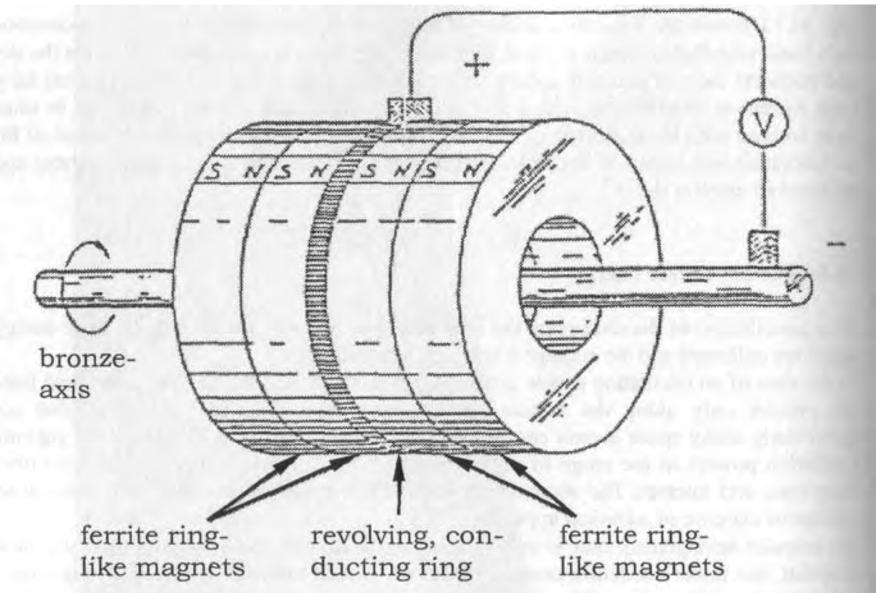
+
V
–
S N/S N/S N/S N/
bronze-axis
ferrite ring-like magnets
revolving, conducting ring
ferrite ring-like magnets

Fig. 16.1: The Faraday generator, which with rotating magnets is called N-machine.<i>

According to chap. 6.5, eq.60 the equations of transformation are:

$$\boxed{\mathbf{E} = \mathbf{v} \times \mathbf{B}} \quad \text{and} \quad \boxed{\mathbf{H} = -\mathbf{v} \times \mathbf{D}} \qquad (16.1)$$

where: $\mathbf{v} = dx/dt = v \cdot \mathbf{e}_x$ = component of the direction of motion perpendicular to the area being stretched by the field pointers $\mathbf{H} = H \cdot \mathbf{e}_y$ and $\mathbf{E} = E \cdot \mathbf{e}_z$.

Thus in addition to the basic fields E and H (at v = 0) additional fields E_z and H_z, depending on motion, occur and the overall fields E_o and H_o are measured (which corresponds to eq. 63 in chapter 6.5):

$$\boxed{E_o = E + E_z} \quad \text{and} \quad \boxed{H_o = H + H_z} \qquad (16.2)$$

(which corresponds to eq. 62 in chapter 6.5):

with: $$\boxed{E_z = v \cdot B} \quad \text{and} \quad \boxed{H_z = -v \cdot D} \qquad (16.3)$$

Table 16.2 A: The equations of transformation of the electromagnetic field.<ii>

16. Space energy technology (SET)

It quite concretely concerns the question for a technology concerning the use of the resonant interaction (according to line 4 in fig. 15.1). For that open and at the same time oscillating electric field lines are needed, which mediate neutrinos and pass them on to a receiver working in resonance. The sun, some planets and other celestial bodies, as we already have worked out, use the effect. Even an entire galaxy is kept together in this way. This interaction plays the crucial role for the theme of space energy and the question is asked, with which technology it can be produced artificially.

16.1 The unipolar generator

The most direct way obviously leads over the Faraday relation concerning the unipolar induction. With the classic Faraday generator, where a permanent magnet is turned along its axis, at first a static electric field can be produced. By rotating in opposite direction or magnets rotating in the same direction but oppositely poled, relatively simple one pole can be „pinned" between the magnets and an unipolar construction can be built. Numerous research scientists already have worked in the area of the Faraday machine more or less successfully (fig. 16.1)<i>. There is reported of instabilities and of the picking up of unknown energy at high revolutions per minute. In the majority of the cases it in a sense of the Testatika will concern collected electricity of the air.

The Faraday relation in addition also appears to be hardly understood correct physically by anyone. A scientific magazine in this context takes the opinion: "Faraday proves Einstein wrong", and the production of electricity with Faraday's unipolar inductor violates the laws of physics !<ii>

<i>: A. Schneider: Energien aus dem Kosmos, Jupiter-Verlag 1989, S. 44

<ii>: „Faraday in his experiment did let rotate a copper disc above a resting cylinder magnet; as expected in a loop of wire a tension voltage was created (F-machine). Than he let the magnets rotate, and the disc stood still; now again a tension voltage should have resulted - but there was no voltage. In the third experiment the magnet rotated with the disc in the same direction and with the same speed. Because there was no relative motion between both, an induced tension voltage wouldn't have been expected - but it was measurable! (N-machine, see fig. 16.1).
What does that mean? If the relative movement between magnet and disc is not always crucial for the formation of an induced tension voltage, then also the absolute movement has to play a role - because something has to move, for a current being formed. But an absolute movement according to the theory of relativity can't be detected - thus Faraday's experiment proves Einstein wrong! Therefore you won't find anything about this experiment in the textbooks".

Taken out of the article: Faraday widerlegt Einstein, PM-Magazin 11/ 1998, P. 133

from table 16.2 A:

$$\boxed{H - H_o \overset{(16.2)}{=} - H_z \overset{(16.3)}{=} v\cdot D} \qquad (16.4)$$

with the velocity $v = dx/dt$,
not accelerated $dv/dx = 0$ (inertial system) and derived for x:

$$\boxed{\frac{dH}{dx} - \frac{dH_o}{dx} = \frac{dx}{dt}\cdot\frac{dD}{dx} = \frac{dD}{dt}} \qquad (16.5)$$

The curl of the H-field pointer points in the z-direction:

$$\boxed{\text{rot }\mathbf{H} = \frac{dH}{dx} \overset{(16.5)}{=} \frac{dH_o}{dx} + \frac{dD}{dt} \overset{!}{=} \mathbf{j} + \frac{d\mathbf{D}}{dt}} \qquad (16.6)$$

comparison of coefficients with Ampère's law:

$$dH_o/dx = \mathbf{j} \,, \qquad (16.7)$$

integrated over dx and ds and formulated generally valid:

$$\boxed{\oint \mathbf{H_o}\, \mathbf{ds} = I_{ein}} \qquad (16.8)$$

thus follows from that: magnetic field = vortex field!

Faraday's law of induction (analogous derivation):

$$\boxed{\text{rot }\mathbf{E} = \frac{dE}{dx} = \frac{dE_o}{dx} - \frac{dB}{dt} \overset{!}{=} - \frac{d\mathbf{B}}{dt}} \qquad (16.9)$$

cause for measurable electric field E_o is missing:

$$dE_o/dx = 0 \,, \qquad (16.10)$$

integrated over dx and ds and formulated generally valid:

$$\boxed{\oint \mathbf{E_o}\, \mathbf{ds} = 0} \qquad (16.11)$$

thus follows from that: the electric field = irrotational (according to Maxwell)!

Table 16.2 B: The derivation of Maxwell's field equations (Ampère's law and Faraday's law of induction) from the equations of transformation of the electromagnetic field

The author of the article proceeds from Maxwell's formulation of Faraday's law of induction, according to which arises a tension voltage in a wire if the wire cuts magnetic force lines, thus is moved relative to a magnet.
If he had read my books, then he would know that Faraday not only has found the older, but also the more comprehensive law, whereas Maxwell only describes a special case. Starting-point for the by me developed theory of objectivity are on the one hand Faraday's law of induction and on the other hand the regularity dual to that, which both together are called equations of transformation of electromagnetism (fig. 6.5, eq. 60 and fig. 16.2 A, eq. 16.1).

16.2 Derivation of Maxwell's field equations

For the derivation we assume, as already in fig. 6.5 for sake of simplicity, that the movement $v = v_x$ takes place perpendicular to the area stretched by the field pointers $H = H_y$ and $E = E_z$. If we derive the equation of transformation, written down for a field component depending on motion, for the coordinate x by using the equations of material and compare the result with Ampere's law resp. Faraday's law of induction, then it becomes clear that the comparison is successful only under certain prerequisites. This circumstance proves that the Maxwell equations only describe a special case and that the equations of transformation are more general valid and causal (table 16.2 A and B).

But in this place is crucial that Faraday's law of induction according to Maxwell only is able to describe a formation of dipoles. For the formation of unipolar field structures however must be fallen back upon Faraday's law concerning the unipolar induction. Whoever wants to understand or even develop by himself concepts concerning space energy, first must have understood Faraday's law in its whole range.

Usually the Faraday generator is, like in the original building shape, equipped with permanent magnets and operated in a steady operating state. Doing so consequently only static electricity is formed. We however need oscillating fields, and for that either the rotation, or the magnet should be changed in polarity with high frequency. Expressed with the precision of mathematics, the first case is described by: $E(t) = v(t) \times B$ and the second case by $E(t) = v \times B(t)$. Both cases have to be investigated and discussed, because both $v(t)$ and $B(t)$ are possible in principle. It is added that in both cases mechanically moving, as a rule rotating, designs but just as well resting designs are conceivable, in which only the moving charge carriers themselves realize the component of velocity v.

This time the crucial point is, that in both cases equally a change of the electric field strength E(t) is produced, with the help of which neutrinos should be collected. Because of the extremely high oscillation frequency of the neutrinos large field changes dE(t)/dt and associated with that large changes of tension voltage dU/dt seem to be the optimal solution, which can be handled with today's technology. Apart from that further difficulties are added, which require a managing in accordance with engineering. If we namely work with a large acceleration dv(t)/dt, then the inertia of the accelerated masses should be overcome, then only very small and light projectiles can be launched like in the case of the railgun. If we however work with fast changes of the magnetic field dB(t)/dt, then the inductance acts slowing down.

A: Suggestion from the patent specification of John W. Ecklin

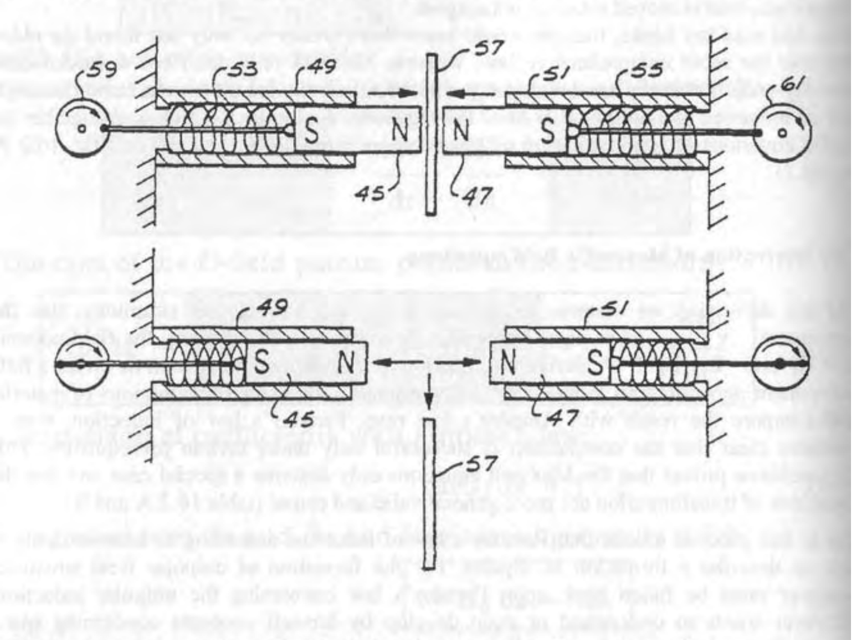
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B: For instance the „Stationary Armature Generator"

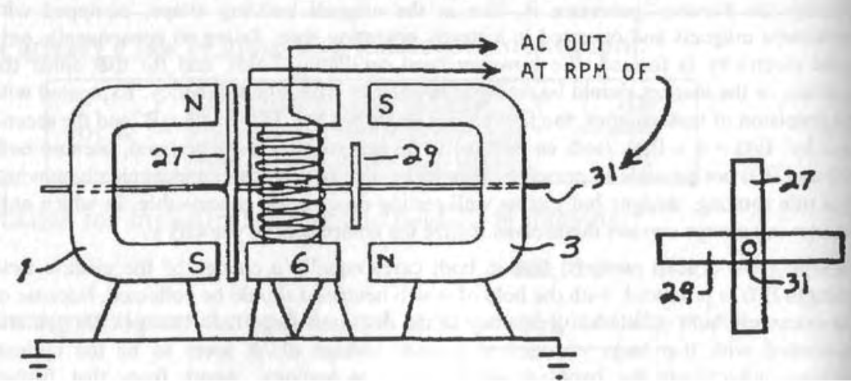
AC OUT
AT RPM OF
N
S
27
29
31
3
1
S
6
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27
29
31

Fig. 16.3: Principle of the Ecklin generator.<i>

<i>: A. Schneider: Generatoren mit Ferritkernumpolung, NET-Journal 6/98, S. 9
Ecklin: Permanent Magnet Motion Conversion Device, U.S.Pat. 3'879,622

16.3 SET-devices with rotating magnetic fields

If we again come to speak of the Faraday generator, which can be built up in two variants. In the case of the F-machine the magnets rest and only the disc rotates, whereas in the case of the N-machine the magnets rotate along. In this case can't be avoided that some of the induced charge carriers roam about in the magnets and sensitively disturb the structure of the material. One only thinks of the bending spoon effect!
The consequences stretch from a loss of the permanent magnetism, over a shattering and bursting up to a pulverizing of the magnets. Adventurous rumours and alarming reports in this direction are sufficiently available.
An improvement could be obtained by an isolation layer between the conductive disc and the magnets, but against induced charge carriers inside the rotating magnets this measure is not able to achieve anything.
Anyhow the best thing to do will be to completely do without permanent magnets in neutrino converters! If we replace them at least in our minds by electromagnets, then a feeding with alternating voltage is possible. That also is necessary if oscillating neutrinos and not air ions should be collected.
As a result of the alternating voltage at first large eddy currents occur in the disc. The losses can be reduced by radial slits in the disc. The induced currents then only can, as wanted. flow radially to the outside.
Bigger headaches causes us on the other hand the inductive and with that current storing effect of the excitation coils. If a too large excitation inductance should prevent a fast increase in current, then also the induced electric field will increase correspondingly comfortable and hardly be able to persuade a single neutrino to stay. A coil core of iron or dynamo sheet metal with that is ruled out from the start. Even ferrite would be suitable at most conditionally. Usable are air coils with as possible as few turns. In an advantageous design the slit copper disc rotates between two air coils, if need be flat coils built in the way Tesla did, which are fed with pulsed tension voltage. The highest speed of change in current surely is obtainable by means of a spark gap, like already Tesla has used (fig. 9.1). But also other techniques are thinkable as pulse driving. For instance semiconductor power amplifiers with MOS transistors not only can be switched fast and hard, but in addition frequency and duty cycle can be adjusted freely with reproducible exactness. These are niceties, which will gain importance in connection with the control and regulation of a converter.

Und the heading "generators with magnetic flux variation" Mr Adolf Schneider has collected and commented on some concepts[i]. The generator of the american research scientist John W. Ecklin registered for patent at 22-4-1975 thus stands as an example of a whole group of inventions, in which the magnetic conductivity in the magnetic circuit and with that the flux is changed with a jump.
Fig. 16.3 B shows a building form consisting of two horseshoe magnets (1, 3) with a likewise resting coil in between (6). In rest the magnetic circuit experiences no change and consequently no tension voltage is induced in the coil. The trick is that an axis (31) is pinned right through the arrangement which is turned with two soft iron anchors, which magnetically short-circuit alternating the left (27) and the right (29) horseshoe magnets.

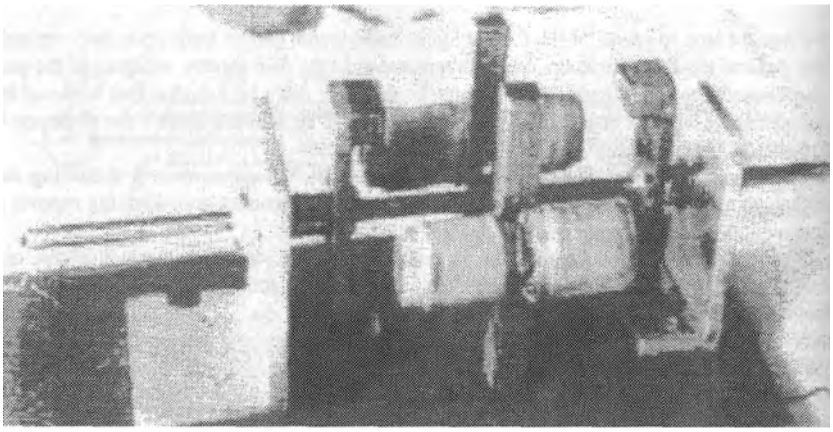

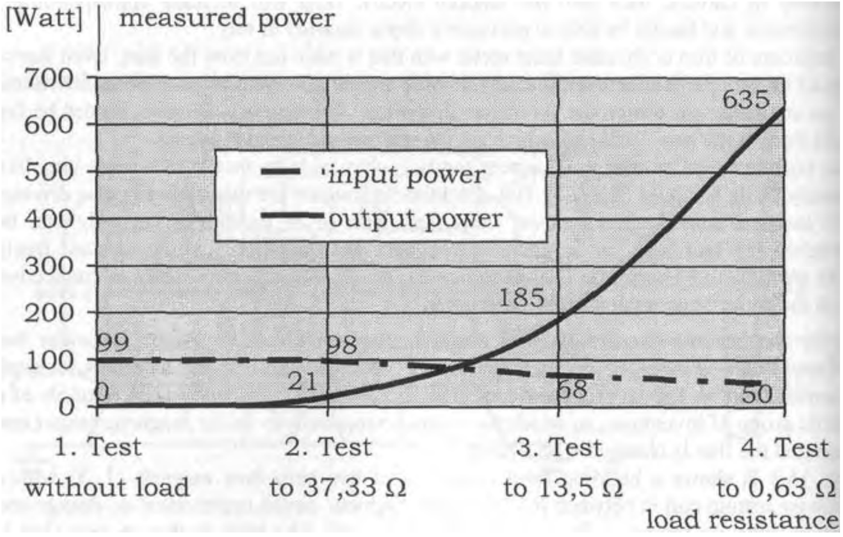

Fig. 16.4: Bedini magnetic converter.<i>

<i>: A. Schneider: Generatoren mit Ferritkernumpolung, NET-Journal 6/98, S.10

Besides the moment of reluctance, which should be compensated by the physical principle, and the friction of the bearing actually no further moment of reaction can occur which would have to be gotten over, not even then if current is taken out of the coil. If the flux change is large enough, purely arithmetically it should be possible to take off an electric power which is considerably larger than the friction power. John Bedini has 1985 measured an over-unity effect of up to 12.6 at a similar constructed generator, where with increasing strain also the factor could be increased (fig. 16.4).

16.4 Commentary concerning magnetic SET-devices

I judge these measurements rather sceptical, after I already in three cases had to break the message gently to the inventors, that their device unfortunately was nothing but an energy destroying machine and they merely had measured wrong, where admittedly the measuring of pulsed tension voltages and currents is not quite simple. So that you don't become a victim of wrong hopes and self-deception, I recommend all SET inventors to realize the closed-loop. If in the continuous operation power can be taken out of such an arrangement without supply of energy from the outside, and be it as small as possible, then that convinces everyone even any journalist and any non-expert.
Unfortunately in the case of numerous concepts at this place already the end is reached. As charming the variation of the magnetic circuit may be, in most cases I miss the unipolar arrangement of the fields. Perhaps here no neutrinos are needed at all and energy merely is withdrawn from the environment heat? I'm not able to answer this question and I surely don't need to, as long as no magnetic converter is demonstrated to me as closed-loop. such a converter, if it can be realized, presumably will at least partly hide one of its poles and produce some open field lines; that at least would be expected.

a still bigger measuring technical problem represent the neutrinos bound to a line, which oscillate around the conductor in the form of ring-like vortices. We have become acquainted with these in the case of the single-wire transmission technique of Tesla (fig. 9.5). They are formed, if neutrinos are slowed down and collected, but not yet have materialized to charge carriers. Tesla did use them for his loss-free energy transmission technology, but he couldn't supersede the alternating current technology full of losses, which also stemmed from him but which he called the worse technology, from the market because there were no power meters available for the single-wire-technology.

Today we still aren't one step further. The energy supply enterprises still decline this technology, as I had to learn myself, although this would be the only way to transport solar energy from the desert or energy from the geothermal energy of Iceland by a sea cable to Central Europe, where it is needed.
Today still no gauges exist for such neutrinos bound to a line. Therefore will every measuring technician experience his Waterloo at SET-devices, in which they occur! I now will report of such a converter and the odd measuring problems.

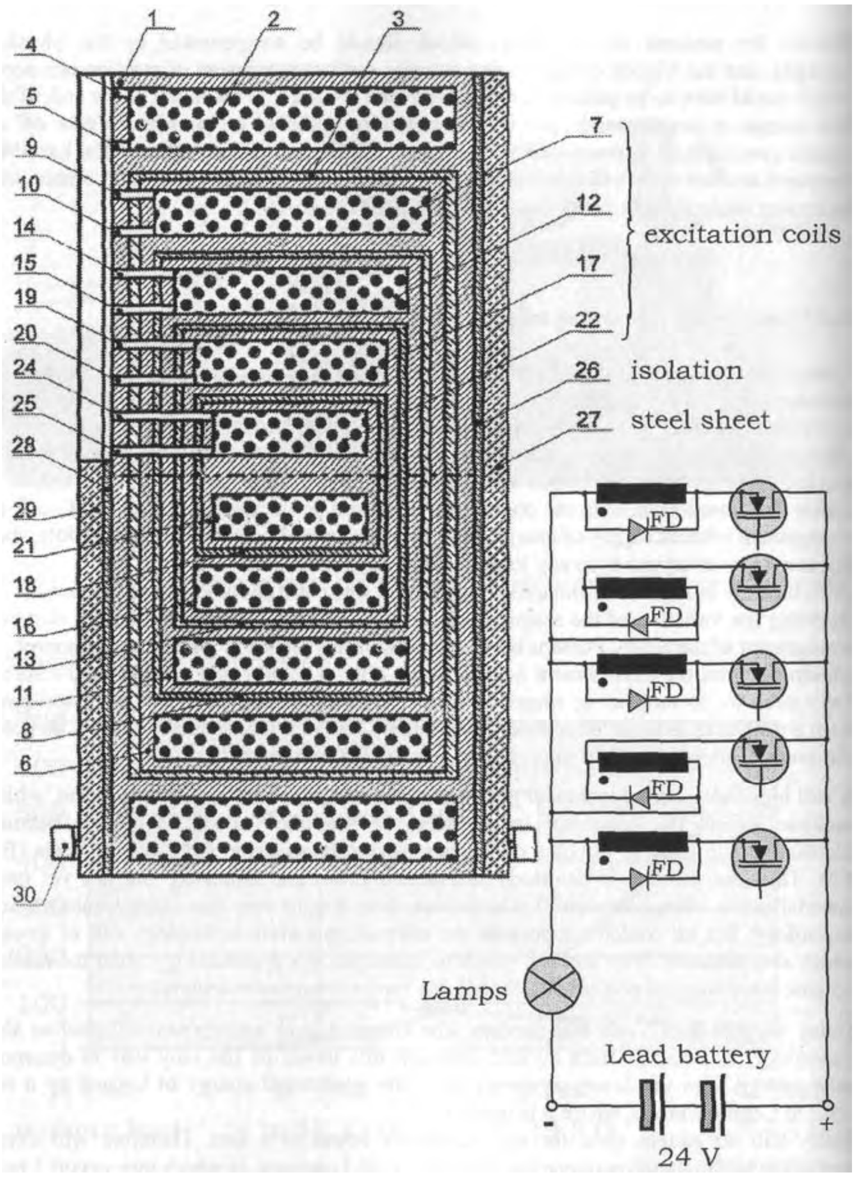
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8
6
30
7
12
17
22
excitation coils
26 isolation
27 steel sheet
FD
FD
FD
FD
FD
Lamps
Lead battery
-
+
24 V

Fig. 16.5: Space quanta manipulator of the Firma ROM AG<i>

<i>: Gibas, Greilinger, Lehner, Rusterholz: Strom aus dem All, Mega Link, Fachzeitschrift fur Elektronik, Nr. 6, Marz 1998, S. 18-23 resp. Bau: Glaube kann Berge versetzen, Bulletin SEV/VSE 25/97, S. 31

16.5 RQM and the space quanta manipulator

If an employee or one of the numerous shareholders of the Swiss Firma RQM AG in Rapperswil speaks of space quanta, then he with that presumably means the neutrinos. An oscillating source of neutrinos is called central Space Oscillator and an operation in resonance of the energy receiver, the so-called space quanta manipulator, is required. Mr Ludwig Sigrist, the creator of this world of imagination, was not a physicist but crane operator (pseudonym Crane O.) and inventor, whom textbook physics couldn't help further in his considerations anyhow. His concept, if it can be translated into a scientific comprehensible language or not, at least helped him personally and gave him the position to create the space quanta manipulator (fig. 16.5).

It consists of several pot coil systems, which are build up and boxed into each other according to the Matrjoschka principle of scaling down. The ferromagnetic core material of the pot spheres (1, 6, 11, 16, 21) should show magnetostrictive properties as distinct as possible. As we will see, this measure gains its actual importance first in connexion with the interaction with neutrinos!

Each pot sphere carries an excitation winding (2, 7, 12, 17, 22), through which alternatively flows a current in opposite direction. By means of this measure, which seems useless according to classic design concepts, one of both field poles is pinned in the centre, in which way the necessary open field lines are produced.

The individual pot spheres are insulated from each other, where the isolation layers (3, 8, 13, 18, 26, 28) should have a high dielectricity. The pot spheres thus in addition form capacitors with each other; even the ending plates at both sides (27, 29) function as capacitor plates. This construction, the core piece of the planned RQM converter, is driven by a transistorised power amplifier with excitation impulses as steeply flanked as possible. According to patent specification<i> the pulse widths are freely eligible in steps of 5 ns betweeen 200 nanoseconds and one second. Besides the frequency also the polarity and DC voltage offset are adjustable.

Every visit of the laboratory leaves a lasting impression: Carefully the engineers grope forward, turn at the frequency and the duty cycle, until the effect suddenly occurs and neutrinos, the space quanta, are being collected. One realizes that tuning parameters with still stronger reactions would be possible, but entirely without any regulation and limitation of power that can't be controlled anymore. The avalanche effect would destroy everything, and so one is further dangling along the brink of the abyss in the development laboratory of the RQM, all the time trying hard to gain control of the hardly understood effect. Concerning the setup and the mode of operation of the pot system the inventor did let his posterity have explanations, but why a diode in free operation FD suddenly loses its rectifying function, for that neither the employees nor specialist visitors of as high as possible scientific rank in the laboratory until now had ready an answer.

<i>: Gibas, Lehner, Greilinger: Vorrichtung und Verfahren zur Erzeugung elektromagnetischer Pulse, Patentschrift CH 687 428 A5 vom 7.5.1996

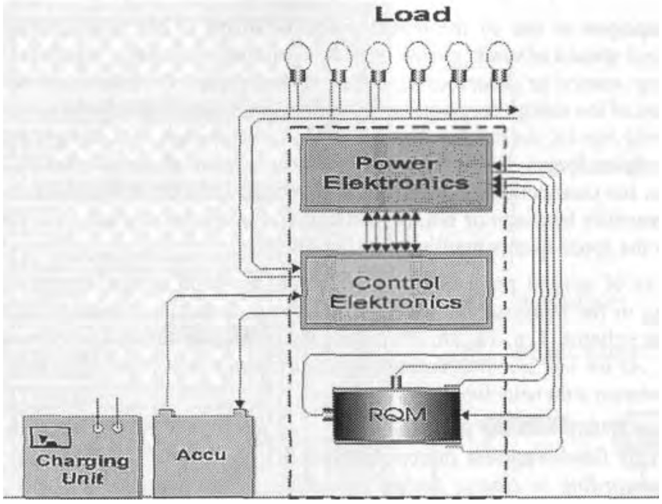
Load
Power Elektronics
Control Elektronics
RQM
Charging Unit
Accu

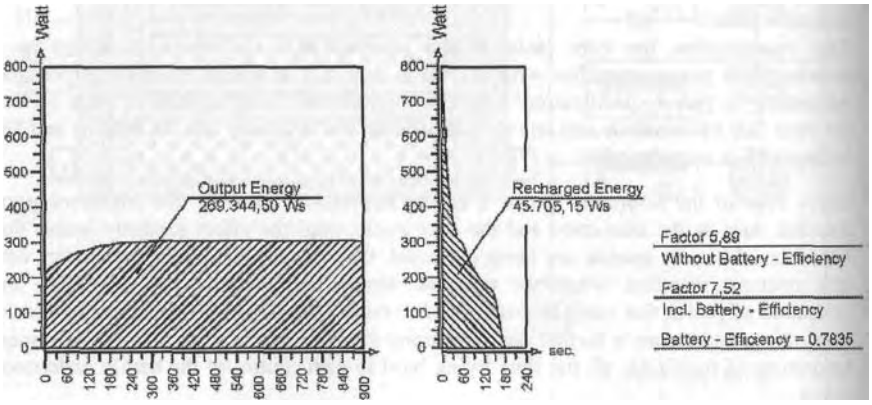

Fig. 16.6: The RQM test installation of 23-9-1996<i>

<i>: F. Greilinger: Der Weg zur erfolgreichen, stabilen Energieauskopplung, RQF Magnetik, Sonderausgabe 1996, page 10

As said, the neutrinos no longer are free but bound to a line, if they leave the pot system. They oscillate around the wire, even around every semiconductor and rove through the entire switchboard. Doing so they can cause quite something, also bring about quite some disaster.

Lead batteries are being recharged, which without doubt is desirable, but in the continuous operation they are destroyed by the same vagabonds. In normal light bulbs for instance some of them materialize to charge carriers, so that according to a gauge more current leaves the light bulb, as on the other side flows in to it. It indeed glows completely normal, but measuring technical for the installation nothing is normal anymore.

The visitor can be shown by means of a high precision measuring facility of vibrations that the pot coils oscillate not only electrically and magnetically, but also mechanically. But the effects alone don't make a converter, which can be produced and which await already numerous buyers of options and licenses.

On the one hand measures for the purposeful conversion of the roving space quanta in utilizable charge carriers here still are missing. On the other hand any controlling facility is missing, to adapt the power taken up from the neutrino field to the momentary need of the consumers. The brave engineers of the RQM still have quite some way in front of them. but the line of approach is right and the reached can be looked at.

16.6 SET-devices with pulsed magnetic fields

In the case of the space quanta manipulator mechanically nothing is moving. In the copper coils the charge carriers merely are on the way with the velocity v. We here have present a typical example of a SET-system with pulsed magnetic field. Compared to the before discussed SET-devices with rotating magnets, for instance the N-machine, the space quanta manipulator clearly has its nose in front. Without brushes, without friction and wear and tear it theoretically has a unlimited life.

In addition it is simpler to produce the necessary large steepness of the flanks in an electronic way as by a mechanical variation of the magnetic field. By means of electronically driving the process it also can be checked, controlled and regulated easier.

The question for an optimisation of the concept still remains. At present one already can be satisfied with a study of possibility, but sometimes one will question the design. There as an example the eddy current losses in the iron pots will be at discussion. About sheeted or sintered materials could be thought, if not at the same time the inductance of the coil would increase in that way, which slows down the increase in current. Ferrite materials again are very brittle and would crumble to dust under the mechanical oscillations of size. I proceed from the assumption, that also here an arrangement with air coils could turn out to be an optimum. It does make sense, if Tesla at higher frequencies always did experiment with air coils.

Now it still depends on the coiling technique. One single conductor loop doesn't provide any open field line. For this purpose if need be two loops have to be supplied with current in opposite direction, like it is the case for a so-called Mobius winding. In this way possibly just as many neutrinos interact as in the case of the pot coils of the space quanta manipulator, which are alternatively supplied with oppositely phased current. To clarify the situation we now should occupy us with the coiling technique.

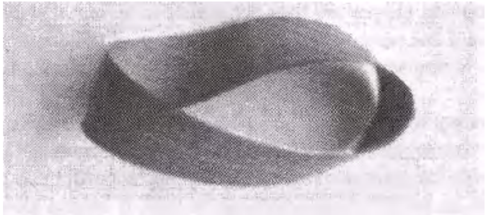

Fig. 16.7 A: The Mobius band

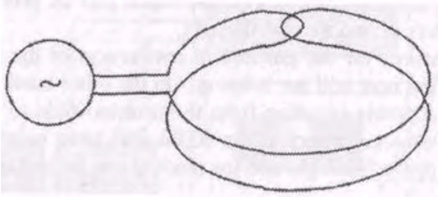

Fig. 16.7 B: The Mobius strip

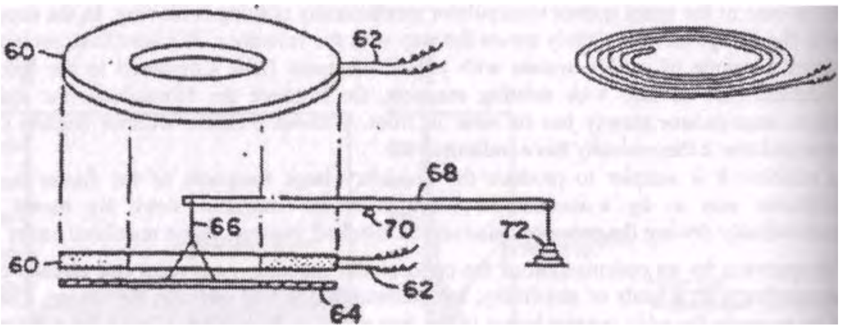
60
62
68
66
70
72
60
62
64

Fig. 16.7 C: Bifilar wound flat coil

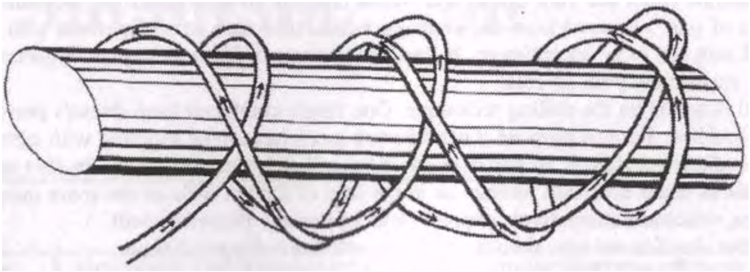

Fig. 16.7 D: Mobius winding arranged like a cross

16.7 SET-devices with Mobius winding

In connection with space energy devices often is talked about the use of a Mobius winding. That is traced back to the Mobius band, which one obtains, if one for example one end of a long paper strip after a half turn glues together with the other end. The result is a strip, which has neither top side nor underside and neither right nor left border. This object with only one side and only one border is a creation of the German mathematician August Ferdinand Mobius (1790 - 1868), fig. 16.7 A.

A distant relative of the Mobius band is the strip with the same name, where the magnetic field lines mutually cancel out. It is the same compensation, as we know of a two core electric cable, where the supply and return cable are run close together. For that the sense of winiding of a conductor loop simply is reversed (fig. 16.7 B).
If the magnetic field vector is wrapped right-handed around the supply cable and left-handed around the return cable, then both amount to zero, so that measuring technical no rest field can be detected anymore at some distance.
THE pointer of the electric field stands perpendicular to the magnetic field vector and points in the direction of the conductor and the movement of the charge carriers. From the coupling of magnetic and electric field follows, that the compensation of one of them also leads to the compensation of the other one. But if the electric field actually is compensated, then there may not flow any current in the winding!
There however flows a current if an electric tension voltage is supplied to the Mobius winding. As a result of this forced current flow both electric and magnetic fields have to occur, which are not compensated! Some field lines will fold outward the expected direction and stand in space as open field lines. These we, in the oscillating case, owe the interaction with the neutrinos.

A perfect compensation would be expected for a two core, bifilar winding. The American physicist William Hooper was able to obtain interesting effects with a bifilar wound flat coil. With help of a balance he could detect attracting or repelling force effects on different, electrically or magnetically neutral discs (fig. 16.7 C)[i].
But he feeds the flat coil with direct current, so that a contribution of neutrinos can't be expected. Such effects only will occur, if one works with pulsed signals, because the bifilar wound flat coil quite obviously is able to form wanted, open field lines.

<i>: Schneider, Adolf: Energien aus dem Kosmos, Jupiter-Verlag 1994, page 28, taken out of:

Mielordt, Sven: Tachyonenenergie, Hyperenergie, Antigravitation, kaum & Zeit Verlag 1984

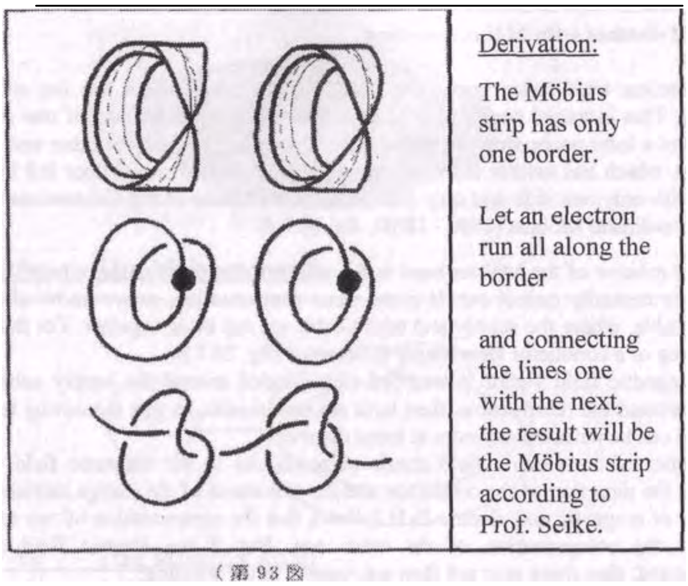

Derivation:

The Möbius strip has only one border.

Let an electron run all along the border

and connecting the lines one with the next, the result will be the Möbius strip according to Prof. Seike.

Fig. 16.8 A: Derivation of the Mobius strip acc. to Seike<i>

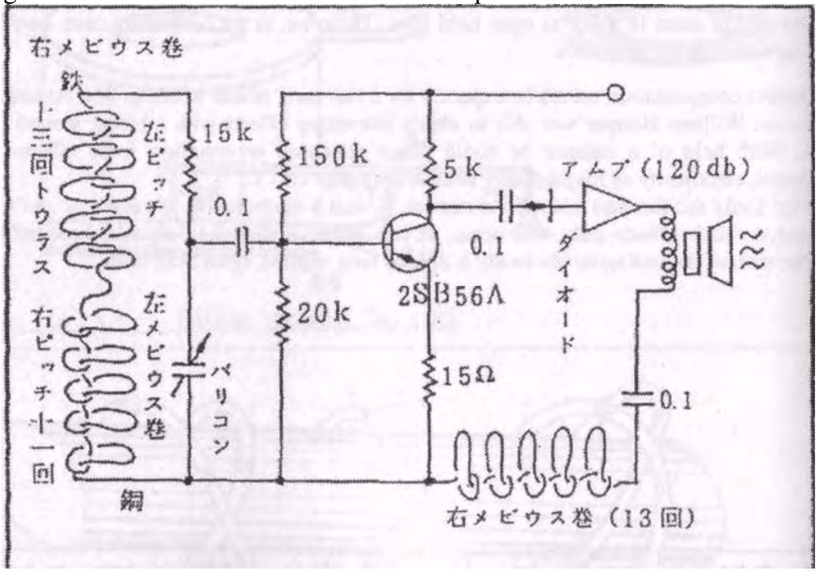
右メビウス巻
鉄
十三回トウラス
右ピッチ十一回
銅
左ピッチ
左メビウス巻
バリコン
15k
0.1
150k
20k
5k
2SB56A
15Ω
0.1
ダイオード
アムプ（120db）
0.1
右メビウス巻（13回）

Fig. 16.8 B: Scalar wave radio according to Prof. Seike<i>

<i>: Seike, Shinchi: The Principles of Ultra Relativity, Space Research Institute 1990, ISBN 915517-1

16.8 Mobius converter of Seike and Coler

Concerning construction it can be an advantage to wind a Mobius coil not purely bifilar and in that way to do without a perfect compensation. It often already is sufficient, if two conductors cross and only individual components of the field vectors partly cancel out. In the case of the coil, which is pulled apart and wound like a cross, drawn in fig. 16.7 D the conductor current and the fields of supply and return cable belonging to it stand under an angle of almost 90°. This in individual cases should already be able to cause the formation of open field lines.

Similar field conditions are formed, if after every turn the wire is looped under the last winding. At the knots again the angle conditions of approx. 90° occur. The Japanese professor Shinichi Seike preferably works with this kind of winding, which he directly derives from the Mobius band (fig. 16.8 A)<i>. He has designed an electro-gravitation motor basing on this principle. He also speaks of weight reduction and of an artificial anti-gravity field. It could be confirmed experimentally, that his setup cooled down slowly during the operational tests, despite the expected heating up by the copper losses of the current<ii, S.29>. Unfortunately I don't known anything more exact.
In his book further is found the wiring diagram of a radio for the reception of scalar waves (fig. 16.8 B). He thereby quite simply replaces all coils in the high-frequency part with his Mobius coils. If longitudinal waves already are measurable and receivable with this simple measure, first has to be checked.

The German captain Coler more than 50 years ago has developed another Mobius converter. His "Magnetstromapparat", with approximately 6 kW power and an at least four-fold over-unity effect uses six coils with permanent magnetic core. As a peculiarity he in addition runs the coil current through the core under an angle of 90° with regard to the coil current (fig. 16.8 C).

More detailed details can be seen in the footnote<ii, S. 22>.

<ii>: Adolf Schneider: Energien aus dem Kosmos, Jupiter-Verlag 1994

S.22: "Scientists of the Technical University Charlottenburg in Berlin and Munich confirmed that the device functioned without objections, but they didn't find a theoretical explanation for the production of energy. The professors Kloss and Franke of the Technical University of Berlin found a degree of effectiveness of 450%. Prof. Schumann confirmed that 4.8 to 6.7 times more energy came out, than was put into the device. Prof. Schumann excluded a deception entirely as the records prove.
But it wasn't simple to set the device going and the stability for longer periods of time wasn't guaranteed. The war confusion set an end to further research. After the end of the war the British secret service confiscated all available documents and apparatus. Part of the report was declassified in 1962".

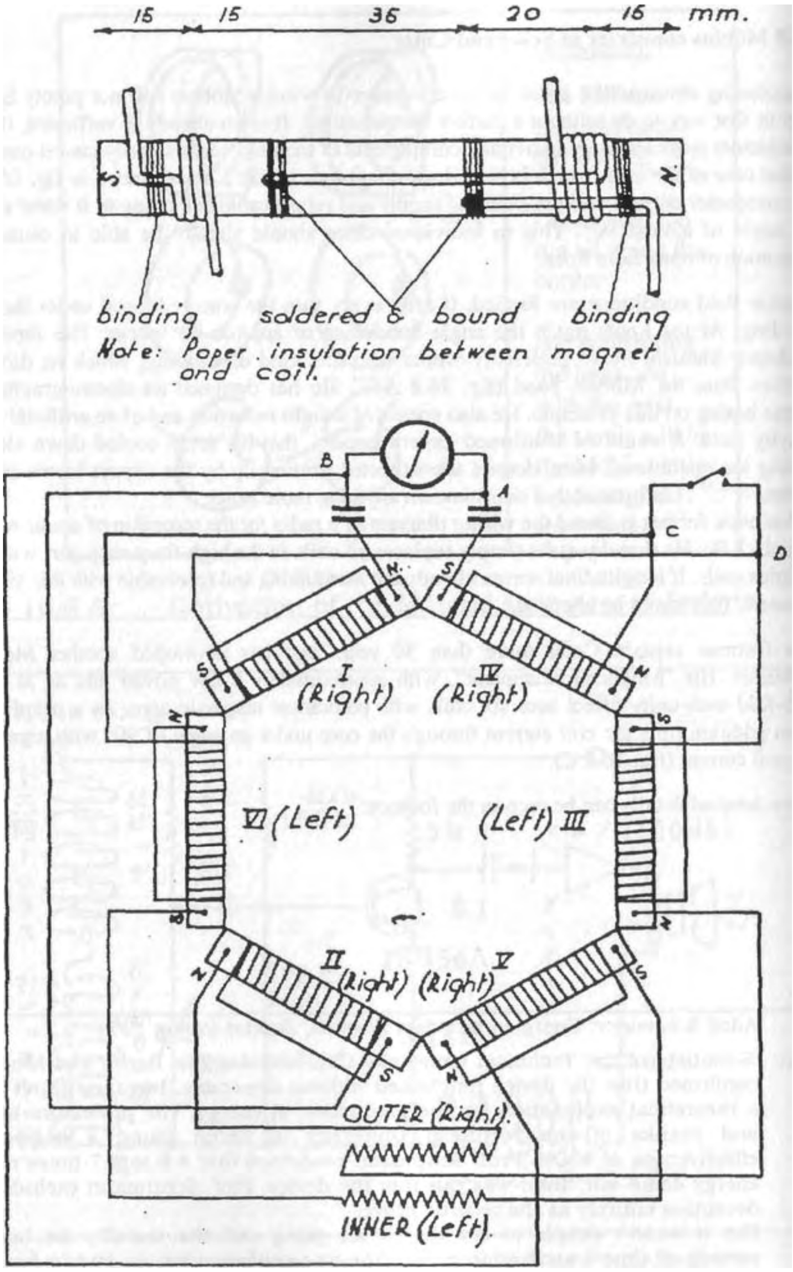
15
15
35
20
15 mm.
N
N
binding
soldered & bound
binding
Note: Paper insulation between magnet and coil.
B
A
C
D
N
S
S
N
I
IV
(Right)
(Right)
N
S
VI (Left)
(Left) III
S
N
N
S
II
V
(Right)
(Right)
S
N
OUTER (Right)
INNER (Left)

Fig. 16.8 C: The Coler converter

16.9 Tesla's flat coil

In the category of the unconventional coiling techniques without doubt the Tesla coil may not be missing. If in schools and high schools such coils were standing in the laboratory for teaching purposes, then as a rule it are cylindrical coils. In reality Tesla worked with flat coils but that, so is said, isn't necessary anymore today, since we have at our disposal better isolating materials than 100 years ago. Actually Tesla contended with problems of osilation, which he could solve with the help of the flat coil, but it should turn out that the coil geometry is attached a crucial importance.

Everything had started with Tesla having to leave the Technical Highschool in Graz without diploma. He ran out of money and he had dared to criticize the venerable Professor Poeschel and his sparking Gramm dynamo. With that he had put himself under compulsion to succeed. Two years later he had ready the solution. In the year 1882 he discovered the rotary field in Budapest.
In the time to come he designs and builds an alternating current motor, but no-one wants to have it and surely Thomas Alva Edison not. Tesla after this disagreement very fast gives up his job at the Edison Company again and again stands under pressure to succeed. With that the eternal bachelor Tesla urges himself to ever higher efforts. He wants to prove himself and the rest of the world that his alternating current system is superior to the direct current system.
Direct current, as is well-known, can't be transformed, and thus the advantage of Teslas alternating current lies in the possibility of power transport by high-tension cable over large distances. But for that the high-tension transformers first had to be developed and thereby the said problems of isolation occurred.
With each turn the tension voltage at the transformer winding increases. The distance to the grounding point lying on the outside has to be chosen bigger with each turn, so that no blow inside of the high-tension winding occurs. A consistent solution of the problem in accordance with engineering is the flat coil used by Tesla, wound spirally from the inside to the outside (fig. 16.9 A)[i].

It thus is correct that isolation technical reasons led to the flat coil, since Tesla himself was completely surprised as he had to find out that this coil can lose its self-induction, that scalar waves can be detected with it and that it is cooled down during operation in an inexplicable manner.

This cooling effect Tesla has investigated more detailed and after all even used. In his patent specification concerning the superconductivity he describes, that the flat coil also loses its Ohmic resistance, if he in addition previously cools it with liquid air. The remaining cooling down to absolute zero his flat coil obviously has carried out entirely by itself with help of the neutrinos (fig. 16.9 B)[ii].

<i>: Nikola Tesla: Coil for Electro-Magnets, Patent No. 512,340 (1894)

<ii>: Nikola Tesla: Means for Increasing the Intensity of Electrical Oscillations, Patent No. 685,012 (1901)

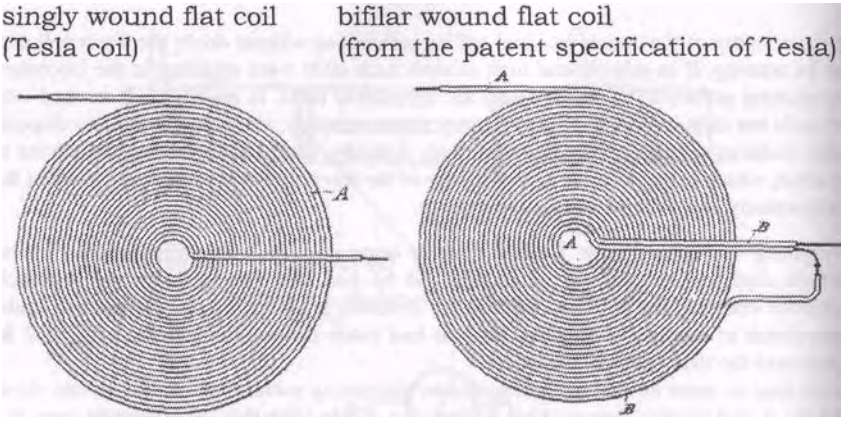
singly wound flat coil (Tesla coil)

bifilar wound flat coil (from the patent specification of Tesla)

Fig. 16.9 A: Coiling techniques of Tesla's flat coil.<i>

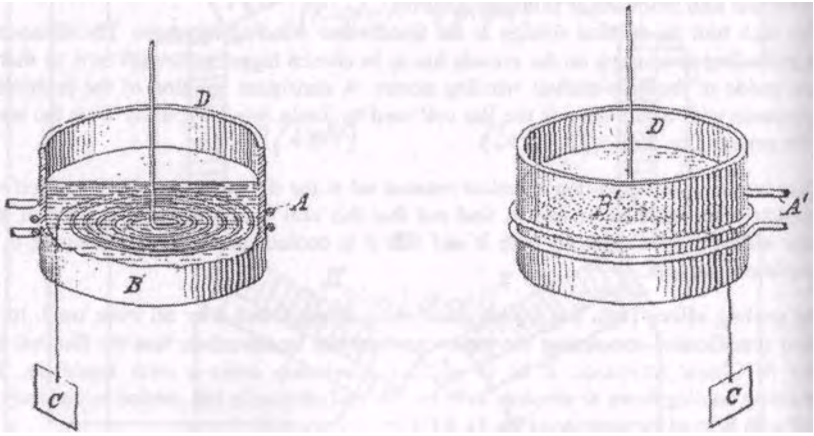

Fig. 16.9 B: Patent specification of Tesla concerning Superconductivity.<ii>

<i>: Nikola Tesla: Coil for Electro-Magnets, Patent No. 512,340 (1894)

<ii>: Nikola Tesla: Means for Increasing the Intensity of Electrical Oscillations, Patent No. 685,012 (1901)

16.10 The secret of the flat coil

The technical function could be explained in the way that the charge carriers of a flat coil by induction are set into motion for excitation from the outside. The transmitted energy shows in form of kinetic energy. The spiral flat coil becomes narrower and narrower towards the inside, the length of each winding shorter and shorter, so that the kinetic energy inevitable has to decrease in favour of a rotational energy. The faster and faster rotating spherical vortices are pulled apart to flat discs and eventually to ring-like vortices by the centrifugal force. The electrons at first become neutrinos bound to a line and finally free neutrinos. Tesla has technically used the first ones in the single-wire-transmission technique (fig. 9.5) and the last ones in his wireless energy transmission (fig. 9.7).

Like many other inventors, Tesla owes also the inventions, which he counts his greatest, like the radio technique and the Magnifying Transmitter, first of all his industriousness. his persistence and a great deal of inventor luck. A magician, as he is called in his most important biography, he by no means was<i>. The flat coil, to which led him chance and which plays a central role in all these inventions, gave him the lucky position, to collect neutrinos and materialize them to charge carriers or in reversed direction to dematerialise electrons to neutrinos.

The technology however is everything else but new. Already the Lituus of the Etruscan and Roman Augurs and the crook of the priests had the same spiral structure (fig. 16.10). In the case of the devices, which the Augurs for instance served at land surveying, it clearly concerns flat coils according to Tesla. We will go into this strange „gauge" more in detail in part 3 of the book<ii>.

The trick probably is, that one component of the electric field pointer is directed towards the centre of the coil and as a result some open field lines are generated, which then collect neutrinos from space.
In this process the neutrinos thanks to the resonant interaction are slowed down to the speed of light and following, as discussed, materialized by means of the flat coil, as in addition rotational energy is withdrawn from the neutrinos. Since the receiver oscillates resonant with opposite phase, in addition the thermal oscillations are reduced and the receiver becomes cold!

If one compares the Mobius coil with the Tesla coil, then besides numerous properties in common the strength of the first coil lies in the production of open field lines and the collection of neutrinos, whereas the special and additional property of the flat coil lies in the materialization, in the conversion of neutrinos into charge carriers. But the advantages of the flat coil have to be bought at the expense of having to work with very high tension voltages (above 511 kV) and with large changes in tension voltage (du/dt). With this set of difficulties we will have to deal in more detail.

<i>: Margaret Cheney. Nikola Tesla, Erfinder, Magier, Prophet (Orig.: Man Out Of Time, 1981), Omega-Verlag Diisseldorf 1995

<ii>: K. Meyl: Electromagnetic environmental compatibility, part 3, edition belonging to the information technical seminar, INDEL Verlagsabteilung 2003.

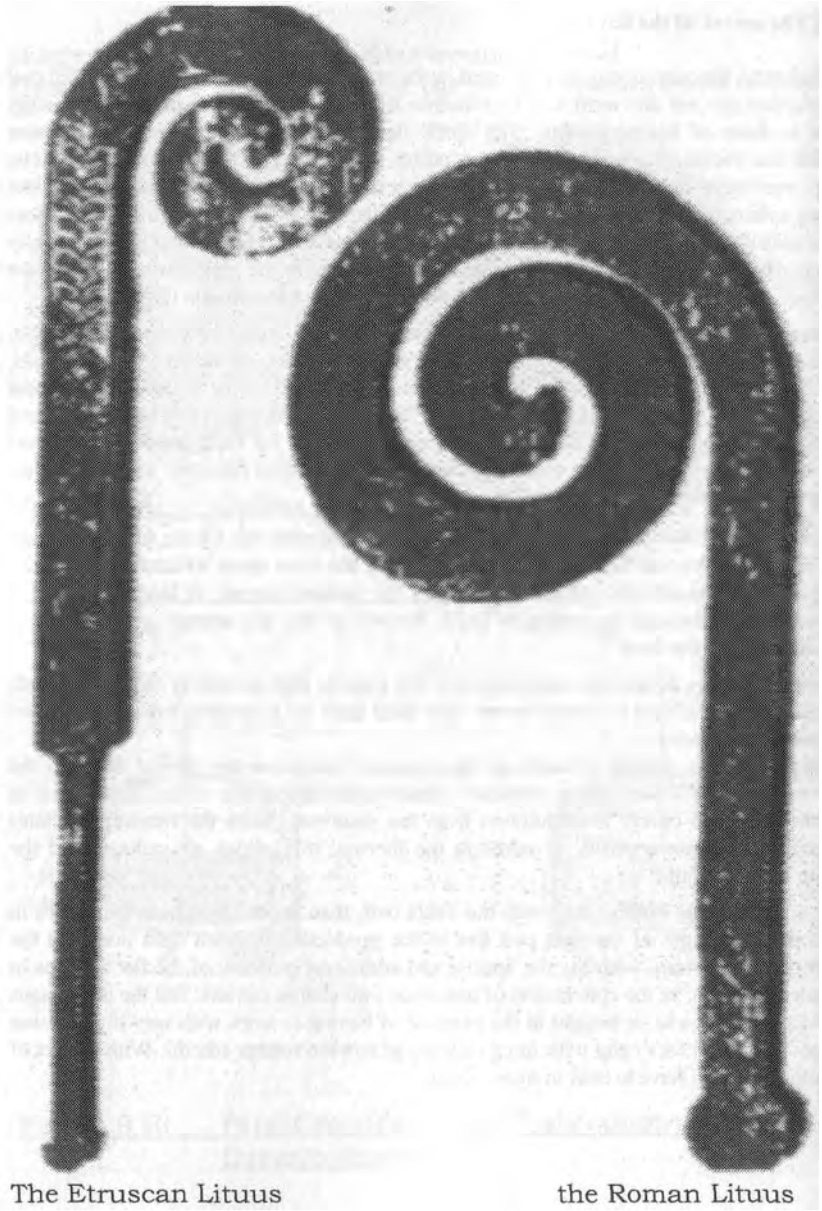
The Etruscan Lituus
the Roman Lituus

Fig. 16.10: The Lituus or crook of the Augurs in ancient Rome

16.11 Discussion concerning the technology of the neutrino collectors

Let us again collect the facts for the discussion: A SET-device is distinguished by a more or less unipolar design and open field lines, with which interact neutrinos, which are oscillating in resonance. These then are slowed down and collected. For the transient process a large change in tension voltage (dE/dt) is required, which can be obtained directly, for instance by means of a spark gap, or indirectly by means of Faraday's law concerning the unipolar induction (E = v x B).
The discussed possibilities concern the acceleration of a machine part (dv/dt), the variation of the magnetic field (dB/dt) by pulse-like excitation signals (16.5) or by magnetic flux variation (16.3) and the railgun. which even can be operated without foreign magnetic field (fig. 15.5 C) and for which in that case occur both a dv/dt and at the same time a dB/dt.
For resting arrangements the velocity v is that of the charge carriers moving in the conductor. So that Faraday's law thereby doesn't lose its influence, the pointers of E and v mustn't point in the same direction, as in the case of "normal" coils. Unconventional windings, which for instance can be knotted like Mobius strips (16.7), take remedial action. Also the ancient crook, rediscovered as flat coil of Tesla (fig. 16.10), proves to be suitable in principle. Here one component of the electric field pointer points in the direction of the centre so that the wanted, at least partly, unipolar arrangement can be formed.

The first step, the collecting of space quanta, shouldn't pose an insurmountable obstacle anymore in view of the numerous possibilities and the detailed explanations. A real difficulty we still have before us, because in most cases some ring-like vortices bound to a line are formed, for which no electronic construction element exists and for which functioning converters hardly are known.
There spoons are bending, some lumps are flying through space, radioactivity is disappearing without a trace, light phenomena are formed and the device suddenly is becoming cold. Almost all inventors, who have arrived in this place, are enthusiastic about the not understood effects or with that are wanting to get attention, but hardly anyone really starts something with that. Until now the necessary system and an useful theory were missing.

Only too often isn't considered, that only an indirect conversion into charge carriers is possible, that during the materialization of neutrinos a intermediate product is formed, which can be described with the model concept of a neutrino bound to a line or of an oscillating ring-like vortex. The technologies collected in this chapter concerning the collecting of neutrinos only form the first step from the free to the bound ring-like vortex. The coming chapter is dedicated to the second step. Here we should try to understand the properties of space quanta bound to a line and loudly think about for which purpose we could use them in practice<i>.

<i>: Reference: Both chapter 16 and chapter 17 treat point 4 according to table 15.1 concerning the resonant interaction (page 86).

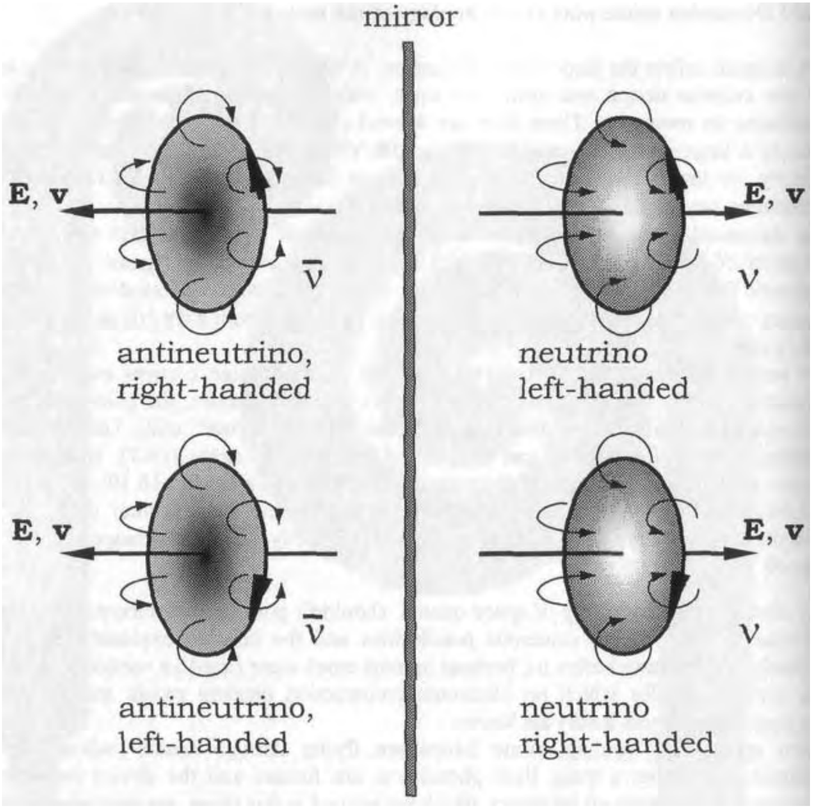
mirror
E, v
$\bar{\nu}$
antineutrino, right-handed
E, v
ν
neutrino left-handed
E, v
$\bar{\nu}$
antineutrino, left-handed
E, v
ν
neutrino right-handed

Fig. 17.1: Application of the mirror transformation to the neutrinos

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<i>: Kleine Enzyklopadie Atom, Verlag Chemie GmbH, Weinheim 1970, S. 119:

„For the neutrinos the quantum number parity isn't defined, because they have a fixed association of the direction of momentum and spin; the sense of rotation of the spin and the direction of momentum in their case form a left-hand wound screw, in the case of antineutrinos a right-hand wound screw. By the shown mirroring the direction of momentum is reversed, but the sense of rotation remains unchanged; i.e. reactions, in which neutrinos occur, are not mirror invariant, they violate the law of conservation of parity". (translated)

Note of the author:, an antineutrino by no means can be assigned to the anti-matter, since it exactly like every neutrino alternatingly takes the matter state and the anti-matter state, by oscillating around itself (see fig. 7.12). The description merely follows a definition founded in usefulness.

17. Technical use of the weak interaction

17.1 Radioactivity caused by neutrinos

Neutrinos are standing in a weak interaction with other elementary particles. This circumstance is known in general. According to the considerations and derivations expressed in the book the neutrinos mediate the resonant interaction, what leads to the conclusion, that the weak interaction represents a partial aspect of the resonant interaction, in which case it merely concerns the proximity.

Efforts are further being undertaken, to combine the weak interaction with the electromagnetic to an electroweak interaction, after it was remarked that a certain coupling constant corresponds in both cases. We of course aren't surprised, because the electromagnetic interaction anyhow describes only the special case of the resonant interaction with the frequency zero.

The weak interaction concerns with the very small range of just 10^{-16} meters only the proximity of the neutrinos, for instance the ß-decay, where the neutrinos for the reason of their oscillating charge a free neutron rattle and shake so long, until it eventually decays. on the average after approximately a quarter of an hour.

The Austrian physicist Wolfgang Pauli had remarked, that half the decay energy after a beta-decay is missing and the balance sheet of energy isn't working out. In addition also the balance sheet of angular momentum isn't working out, because the nuclear spin is being changed for a whole unit. Pauli as a result 1930 has introduced a hypothetical particle without mass and without charge, which he called neutrino.

With that Pauli and his co-working Italian colleague Fermi it is true are the givers of the name of the neutrinos, but not by all means the discoverer. If Cowan and Reines 1956 have detected these particles with large expenditure of devices, then also that by no means was a premiere, as falsely can be read in textbooks and encyclopaedias. After all Nikola Tesla already decades ago had demonstrated, that the neutrino radiation not only exists, but even can be used energy technically.

Now the radioactive decay a ß-radiation occurs, triggered by the conversion of neutrons in protons or vice versa. This obviously takes place under the influence and participation of neutrinos in the atomic nucleus. The ß-radiation to a special extent consisting of electrons and positrons, as it occurs in the case of nuclear fission, is quite unhealthy and by no means ecologically compatible. Under the influence of free charge carriers not only metal lattices become soft and spoons can be bent, but also an electrolysis takes place, where the water molecules are splitted into their parts. That isn't a good prerequisite for the flora and fauna on our planet, which predominantly is built up of water structures.

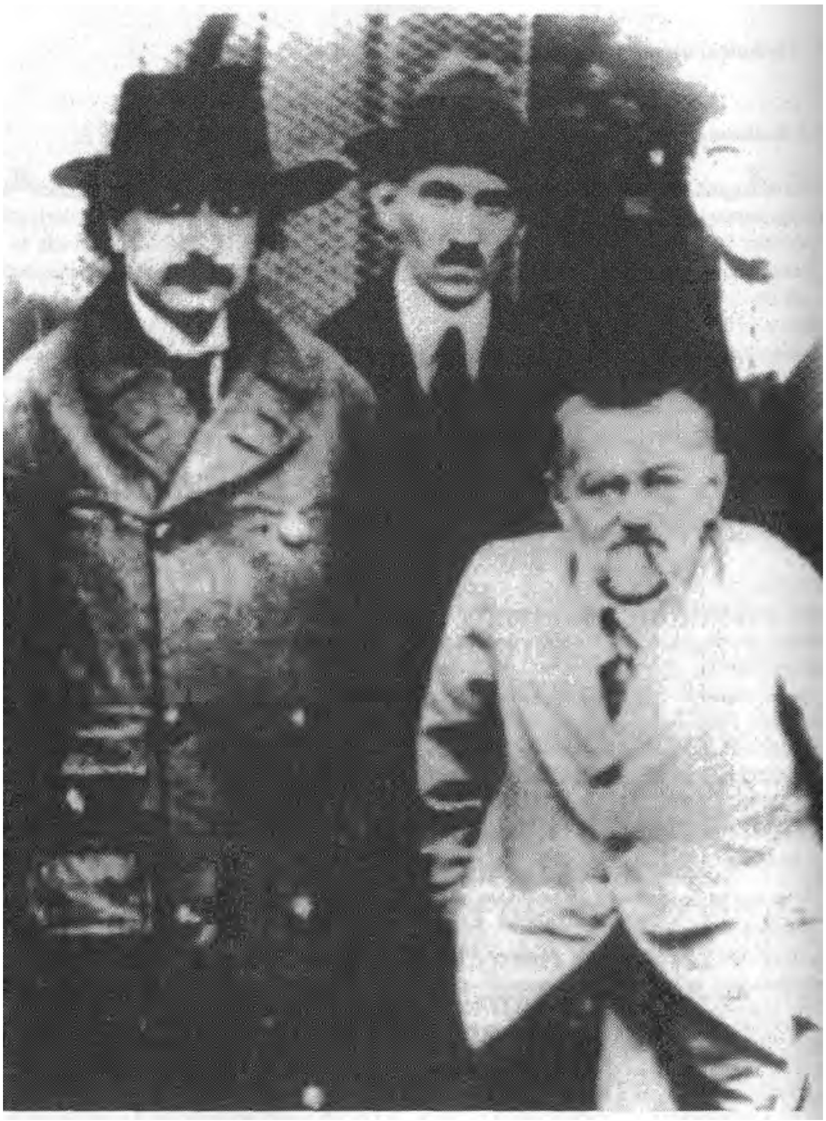

Fig. 17.2: Einstein, Tesla and Steinmetz[i] (from left to right)

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[i] Franz Ferzak: Nikola Tesla, Eigenverlag, S. 103

17.2 Nikola Tesla, the discoverer of the neutrino radiation

The discoverer of the neutrino radiation himself will best be able to explain the connexion. In the New York Times Tesla writes, that he has discovered and investigated the phenomenon of the cosmic radiation, long before others started their researches<i>:
"According to my theory a radioactive body is only a target, which constantly is being bombarded by infinitely small balls (neutrinos), which are projected from all parts of the universe. If this, at present unknown, cosmic radiation could be interrupted completely, then no radioactivity would exist any longer.
I made some progress regarding the solution of the mystery, until I in the year 1898 attained mathematical and experimental evidence, that the sun and similar celestial bodies emit energy-rich radiation, which consist of inconceivable small particles and have velocities, which are considerable faster than the speed of light. The ability of penetration of this radiation is so large, that it penetrates thousands of kilometres of solid matter, without their velocity being reduced noticeably. "
It must be admired how Tesla guided by experimental observations and a reliable instinct comes to the correct result. He merely with the conclusion, because of the missing interaction the neutrinos have to be inconceivably small, isn't quite right. Their size rather depends on the velocity, because the overfast neutrinos are being length contracted stronger. Tesla however hits the nail exactly on the head, if he on the occasion of the press conference for his 81st birthday declares, the radioactivity is a clear proof of the existing of an outer radiation of cosmic origin<ii>. „ If Radium could be shielded against this radiation in an effective way", Tesla writes in an essay of 1934, „then it wouldn't be radioactive anymore". At this occasion he contradicts Albert Einstein, without thereby pronouncing the name and is indignant at the wrong working method of the scientists<iii>.

Me personally fascinates, how here until now ignored results have been presented, which I first had to work out theoretically myself with difficulty. Tesla, to the best of my knowledge, hasn't taken theoretical derivations, at least none have been handed down. As a brilliant experimental physicist he must have reached his conception world by means of the measuring technique. The perfect correspondence of his experimentally determined and the by me theoretically won insights should be judged as evidence for the correctness of this view.

<i>: Dr. Tesla Writes of Various Phases of his Discovery, New York Times, Feb. 6, 1932, P. 16, col. 8

<ii>: Tesla Said (J.T. Ratzlaff), Tesla Book Company, ISBN 0-914119-00-1, P. 272

<iii>: "The scientists of today think profound instead of clear. One has to be mentally sane, to be able to think clear, but one can think profound and nevertheless be completely insane. The scientists of today have substituted experiments by mathematics, and they travel from one equation to another and eventually build up a construct, which has absolutely no relation to reality"...

taken from N. Tesla: Radio Power will Revolutionize the World, Modern Mechanics and Inventions, 7/1934, (Tesla Said, P. 264)

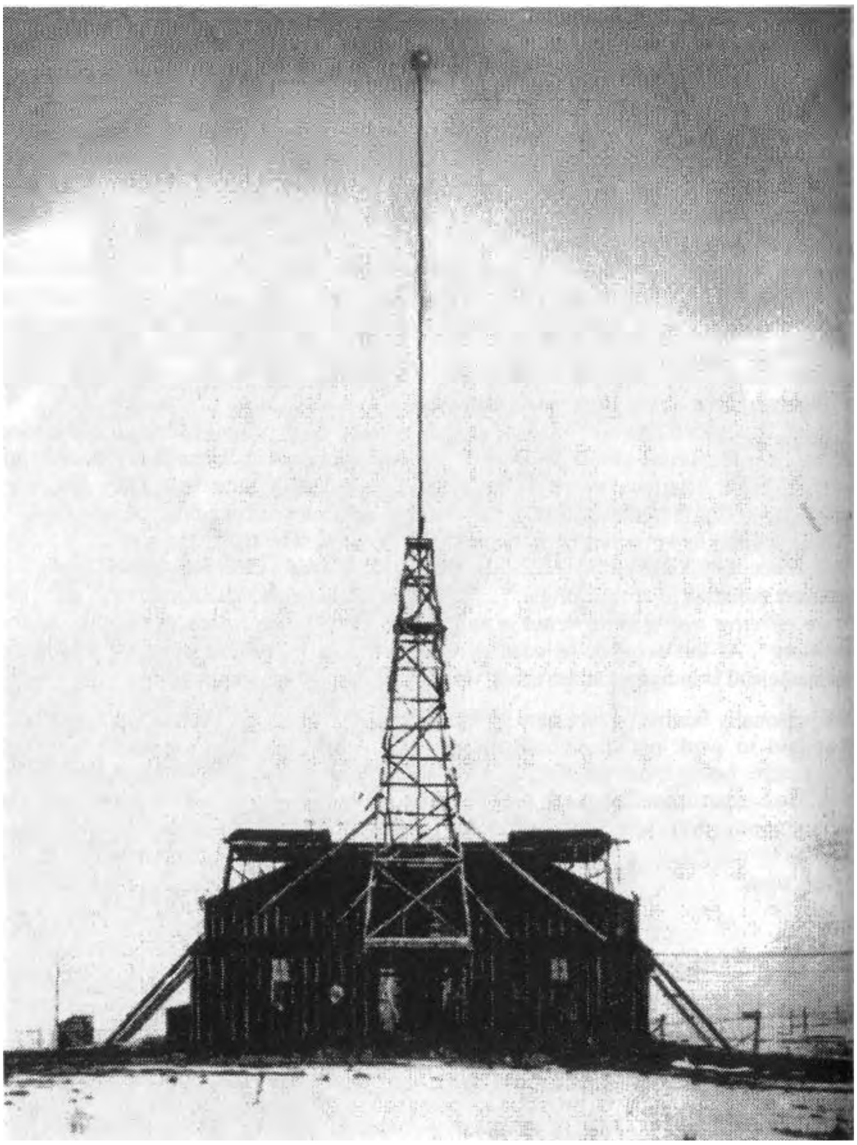

Fig. 17.3: The Magnifying Transmitter of Nikola Tesla
Would the research station in Colorado Springs (1899 - 1900) have been suitable for transmutation?

17.3 Transmutation and reduction of radioactivity

If we are capable to collect and bundle up neutrinos, then should with that an influencing of the radioactive decay become possible, then also a decontamination of radioactively contaminated material and a so-called transmutation should be possible. We here have a concrete possibility before us, to use the produced ring-like vortices directly for the benefit of humanity. Dangerous transports with Castor containers, permanent and temporary storage and the contamination of whole areas by radiation, like around the nuclear power station Tschernobyl, which got out of control, wouldn't be necessary at all. If namely burned out fuel rods and objects contaminated by radiation have undergone a concentrated neutrino shower, then the radioactive decay takes place accelerated, so that the half-life can be drastically reduced. After the treatment the dangerous special waste would have been changed to harmless domestic rubbish. Even recycling or reuse are feasible.

The topic is at least as explosive as the energy question and as well completely unsolved. That's at different places and in some companies is already feverish researched about technologies concerning transmutation. Often it are the same people, who also work at the theme of space energy. The reason quite simple is that in both cases neutrinos have to be collected and bundled up. In the case of transmutation however the necessity of materialization can be dropped, so that the goal can be obtained faster and simpler. Consequentially is reported of more cases of a successful decontamination and of transmutation, than of functioning energy converters. Until now most techniques however still hardly are suitable for bringing into action technically on a large scale, but they carry clues of a solution of the problem already in them.
At the congress "New Energy technologies from USA" 6.12.1997 in Zurich I have lectured concerning the theme<i>: ,,Presumably as the first one the doctor Dr. Wilhelm Reich has carried out corresponding experiments with his ,,Orgon accumulator" (fig. 9.2). From him also stem warnings about biological effects, which should be taken serious, if radioactive material is put under his Orgon accumulator and the process of decay takes place accelerated".
If one dares an interpretation of his experiments with only 1 mg radium, then numerous charge carriers materialized at hitting upon his sample of the bundled up neutrino radiation with the consequence of high electrostatics in the environment, which Reich has called DOR-state (Deadly ORgone) (chap.15.11).

Another way would be the rebuilding of a neutrino transmitter according to the plans and patent specifications of the experimental physicist Nikola Tesla (fig. 9.11). He 100 years ago had realized a real neutrino-broadcasting and for that developed an unconventional switching technique. Tesla called his transmitter a „Magnifying Transmitter" (fig. 17.3). He choose the name „Magnifying Transmitter", after he had received more energy than he had transmitted in experiments and this effect moreover was increased with increasing distance to the transmitter. He obviously also had collected free and synchronously oscillating neutrinos, and that would be the best prerequisite for a successful transmutation and decontamination of radioactive material!

<i>: Konstantin Meyl: Die Wechselwirkung der Neutrinos; uber Massnahmen, die Halbwertszeit beim radioaktiven Zerfall herabzusetzen. NET-Journal Jg. Nr. 3, Jan./Feb. 1998, S. 14-20

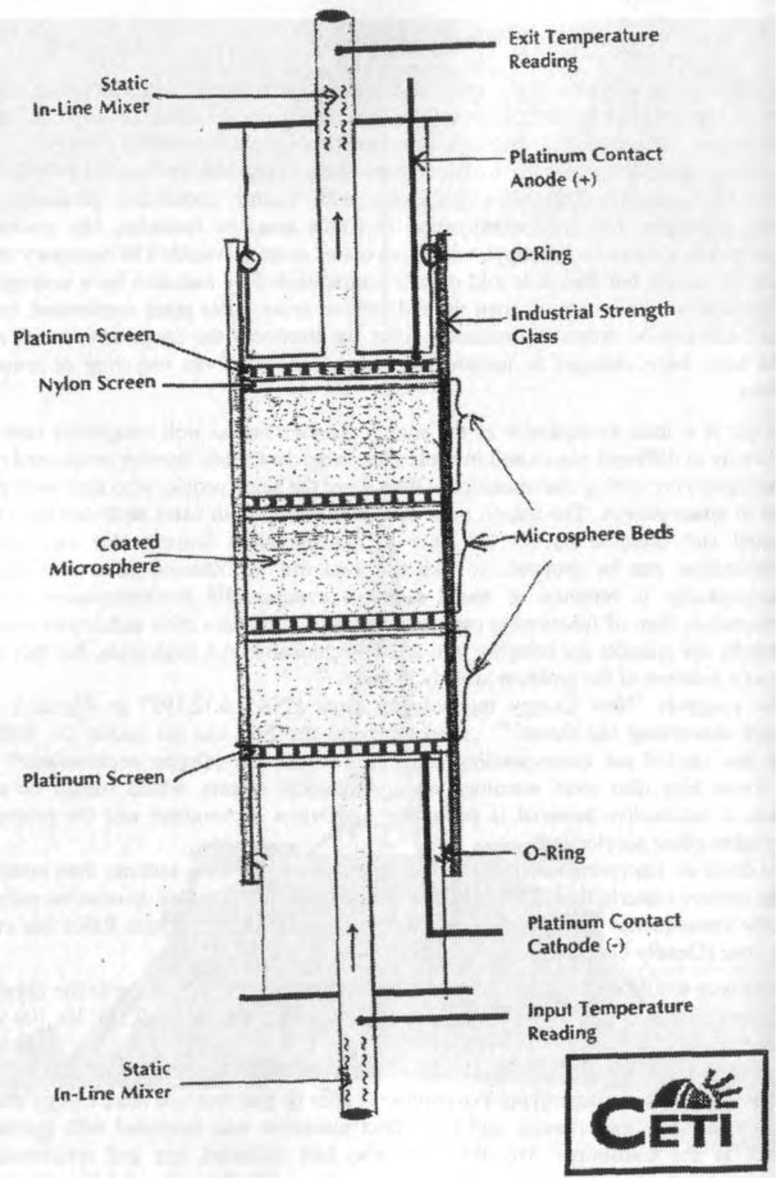
Exit Temperature Reading
Static In-Line Mixer
Platinum Contact Anode (+)
O-Ring
Industrial Strength Glass
Platinum Screen
Nylon Screen
Microsphere Beds
Coated Microsphere
Platinum Screen
O-Ring
Platinum Contact Cathode (-)
Input Temperature Reading
Static In-Line Mixer
CETI

Fig. 17.4: 1 kW Patterson Power Cell.<i>

<i>: Patterson, J. A.: System with electrolytic cell and method for producing heat and reducing radioactivity of a radioactive material by electrolysis. US Patent No. 5.672.259 of Sept. 30, 1997, as reprinted in Infinite Energy, July-Nov.1997, pp. 13-16

17.4 The Patterson Power Cell

As an example worth paying attention to, the Patterson Power Cell should be mentioned, which not only can be used for generation of energy but, how could it be otherwise, also for reduction of radioactivity and for transmutation. The energy cell invented by the chemist Dr. James A. Patterson is researched and developed further by the company CETI (Clean Energy Technologies Inc.) in Sarasota (Florida, USA). According to latest reports such a device supplies at most one kilowatt of heat energy at an over-unity of up to 4000; thus 4000 times the energy is released than is taken up as required for the operation!
In fig. 17.4 one single cell of the energy converter is shown. The glass container consists of three chambers of approx. 4 cm height each time and about 1.9 cm in diameter and works like a continuous-flow water heater. From the bottom tapwater or distilled water is supplied and at the top connection again taken away in heated form. The excitation takes place electrostatically by means of two platinum electrodes. The anode situated at the top is connected with the positive pole and the cathode with the negative pole of the source of direct current.
In the three chambers are situated tiny, filmy coated small balls, which form the real principal item of the cell. Production method and structure of the beads are oriented to the task to be mastered. In the case of a variant conceived for the generation of energy the barely one millimetre in diameter small synthetic beads carry after each other a thin layer of palladium, a layer of nickel and once again one with palladium<i>.

The small balls remind with their layered structure at first of the Orgon accumulator of Reich. They also seem to function as collectors of neutrinos, but for smaller wavelengths and much higher frequencies. In addition is chosen a concentric arrangement with the spherical form, which with the electrically conductive surface and the dielectric core fulfil the function of a cavity resonator. Resonance actually is possible with flying past neutrinos, which have a wavelength which amounts to an integer multiple (1,2,3,..) of twice the diameter of the sphere.
The arising resonant oscillation however concerns not only the electric and magnetic fields, but by means of electrostriction and magnetostriction also a mechanic oscillation of size. The oscillation of size in reverse causes again oscillating electric and magnetic field pointers, which are partly open along the spherical structure and can interact resonant with further neutrinos. In this repercussion field the actual secret of the functioning of a Patterson-cell is hidden.

The president of the German association of space energy, Prof. Dr. Dr. Josef Gruber on the occasion of his visit at the company CETI and of a conference about „cold fusion" in Vancouver has published a report<ii>:

<ii>: Gruber, J.: Kalte Fusion und Raumenergie, report concerning the 7th international conference about "cold fusion" of 19.-24.4.1998 in Vanvouver, B.C., Canada (Infinite Energy, Issue 19, 1998) and report concerning "International Symposium on New Energy" of 23.-26.5.1997 in Denver, Colorado, USA (Denver-report of the remote University Hagen)

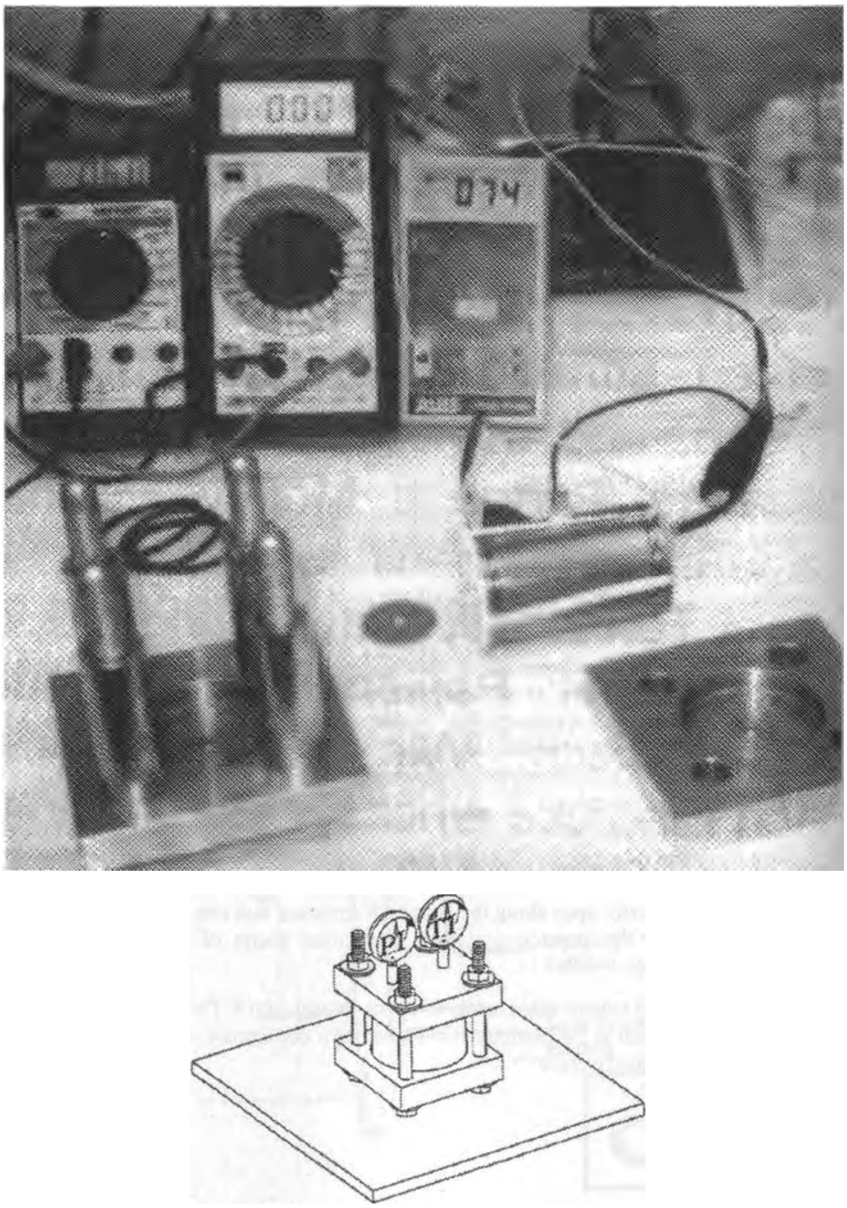

Fig. 17.5: _____ Low Energy Nuclear Transmutation Cell,<i>
the kit for experiments LENT-1
(Showing Temperature and Pressure Gags)

<i>: taken from the NET-Journal, 10/11 1997, S. 7

17.5 Report concerning the cold fusion

"In the case of the Patterson transmutation cell it concerns a special electrolysis cell, in which the radio nuclides are charged. During the electrolysis the decay activity measured by means of a Geiger-Muller counter decreases drastically. Within a few hours reductions of up to 80% are obtained. In such an electrolysis system with electrodes consisting of specially coated beads low-energetic nuclear reactions can be observed. In this case elements are detected in the metallic layers of the beads, which before were not contained in these. Further are measured changed (unnatural) proportions of isotopes. From these transmutation can be inferred, which is used in the cell for the conversion of radioactive elements.

Until now natural uranium and thorium were used as radioactive material. The reproducibility already now is very good. The applicability for commercial purposes, for the reduction of the radioactivity of burnt up fuel elements and for the conversion of plutonium is easy to see".

At his visit in the laboratory of CETI in Sarasota 28.5.97 Prof. Gruber has witnessed an experiment to annihilate radioactivity with the Patterson transmutation cell. He reported about it: "In the presence of N. J. Olson from Pacific Northwest Laboratory (operated by Batelle for the U.S. Department of Energy) a team of the television station ABC conducted by the science journalist Dr. M. Guillen made recordings for a television program, which meanwhile has been broadcasted all over the country. The original tension voltage - among others a Geiger counter rattled - subsided as the expected success became apparent in the experiment: After one hour 50% of the radioactivity stemming of uranium nitrate were removed, in another half an hour further 13%. Doing so also a considerable lot of surplus heat was produced.

New techniques of this kind to reduce radioactivity have an important advantage: One brings the SET-device there where the radioactive material is situated and reduces the radioactivity on the spot. For the conventional technique, still being in research, in contrast to that the radioactive material first is wrapped in a complicated manner and then transported to a special factory, where radioactivity is reduced at great technological expenditure and use of energy - altogether a procedure which is relatively costly and politically only hard to carry through".

Patterson cells already can be obtained commercially for research purposes. The same goes for a demo-kit<i> of the company Trenergy, Inc. of Hal Fox, who has built up the biggest database of the world concerning the theme "Low Energy Fusion" in the "Fusion Information Center" at the university of Salt Lake City. He is editor-in-chief of the "Journal of New Energy".

If one believes the statements on their web-site<ii>, then one is capable of converting 10 g of radioactive thorium in 900 mg titanium and some copper in less than an hour with the kit for experiments LENT-1. Under a pressure of 3200 psi sodium already is said to have fusioned to gold, something of which alchemists dream, as an unintentional side effect, as researchers in Cincinnati/Ohio say<iii>.

<i>: NET-Journal, Jan. 1997, S. 24

<ii>: see Internet: http://www.hal-fox@slkc.uswest.net

<iii> : NET-Journal, 10/11 1997, S. 7

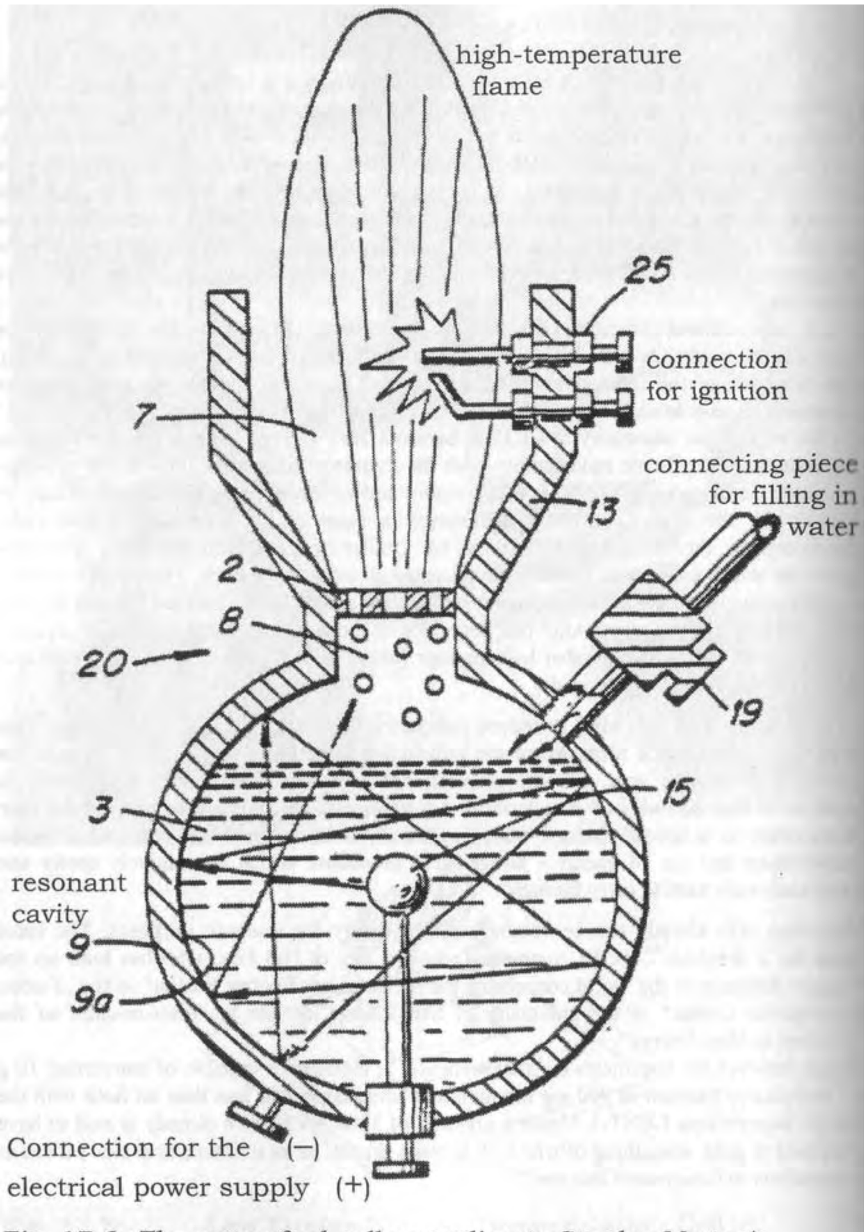
high-temperature flame
25
connection for ignition
7
connecting piece for filling in water
13
2
8
20
19
15
3
resonant cavity
9
9a
Connection for the electrical power supply
(−)
(+)

Fig. 17.6: The water-fuel-cell according to Stanley Meyer<i>

<i>: H.-J. Ehlers: Stan Meyers Wasser-Zellen-Technik, Raum & Zeit special 7, p. 201, taken from the Canadian patent specification 1234 773 of 5-4-1988

17.6 Water-Fuel-Cell technology

The United States are, just what concerns spectacular techniques like the removal of radioactivity or the transmutation of new materials, obviously still the land of unlimited possibilities. Nowhere the list of researchers of cold fusion is as long as in North America.
But there also in many places only is tried and tinkered without visible system or usable theory. Then in many cases unfortunately only a show-effect is to the fore, while construction plans and details concerning the way of functioning, as far as they actually exist, are kept secret. In total there, besides a lot of hot air and wrong hopes, is left behind little to be used and cited.
By the way, in my opinion cold fusion has to do very much more with space energy and neutrinos than with hot fusion. How much disaster a wrong referring to and an unusable theory can bring about, has become clear at the example of the "cold fusion researchers" Fleischmann and Pons. They have placed themselves into the scientific offside with their misinterpretation concerning cold fusion.
Moreover are both primarily scientists and theorists. Practice however is, according to general definition, "if in spite of all it functions!" The American Stanley Meyer is such a practical man and his water-cell-technology actually seems to function, although he in his 18 patent specifications gives theoretical explanations, which he just as well could have saved himself. With that his effect isn't explained.
An usable interpretation would be that this device, comparable to a cell of a plant during photosynthesis, splits water molecules into its parts by putting on neutrinos. Even without knowledge about space quanta the buggy of Stanley Meyer already runs with a air-cooled 1500 cc VW-engine, and it consumes no gasoline at all. The tank is filled with water; it even may be sea water. The consumption of water lies at 2.8 litres at 100 kilometres and thereby is formed predominantly hot steam again as a combustion product.
If thus cold water is converted into hot water and at the same time mechanical energy is available. then inevitably another source of energy must be involved. According to my interprelation it must concern the neutrino field. If the here presented details are correct then the over-unity effect lies at approx. 100, the degree of effectiveness thus at 10000 percent.

American companies, with which Stanley Meyer had concluded contracts, should make the "Water-Fuel-Cell technology" mature for series. Also the financing seemed secured. But then per internet the message came, he 21.3.1998 was having supper in a restaurant in Grove-City, as he suddenly jumped to his feet from the table and called out, he had been poisoned. He died on the spot<i>.

Alarge number of inventors is known, who tap space energy with the help of water. It concerns an increase of the content of oxygen or of the content of colloids, thus an improvement of the water quality. Or it concerns formation of vortices as already in the case of Walter Schauberger, glowing phenomena or also the generation of free energy from the neutrino field. In this concert the concept of Stanley Meyer takes an outstanding place, as particularly efficient, instructive and clearly understandable for us, for which reason we cast our eyes over the design (fig. 17.6 and 17.7).

<i>: Zum Hinschied von Stanley Meyer", NET-Journal April/Mai 1998, S. 25; see: obituary in Infinite Energy Magazine

A. The pattern of the pulses of the excitation voltage:

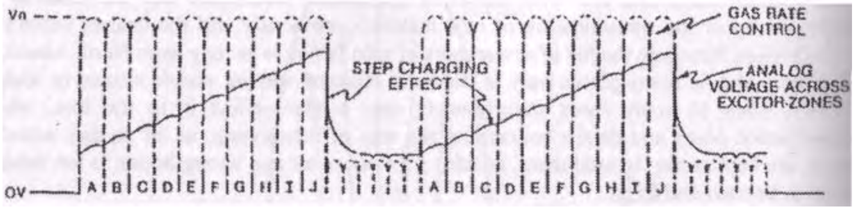

B. The wiring diagram:

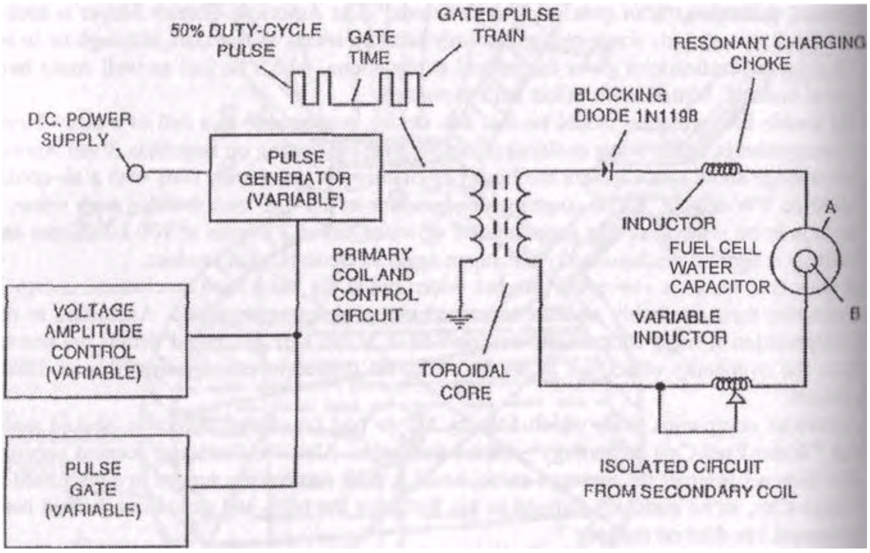
50% DUTY-CYCLE PULSE
GATE TIME
GATED PULSE TRAIN
RESONANT CHARGING CHOKE
BLOCKING DIODE 1N1198
D.C. POWER SUPPLY
PULSE GENERATOR (VARIABLE)
INDUCTOR
A
FUEL CELL WATER CAPACITOR
B
PRIMARY COIL AND CONTROL CIRCUIT
VOLTAGE AMPLITUDE CONTROL (VARIABLE)
VARIABLE INDUCTOR
TOROIDAL CORE
ISOLATED CIRCUIT FROM SECONDARY COIL
PULSE GATE (VARIABLE)

Fig. 17.7: Wiring diagram for the driving of the water-cell<i>

<i>: Stanley, A. Meyer: Process and Apparatus for the Production of Fuel Gas and the Enhanced Release of Thermal Energy from such Gas, 15.06.89, US-Pat. 207,730; International Publ. WO 89/12704; Int.Appl. PCT/US89/02622

17.7 Unconventional electrolysis

Numerous of the by Stanley Meyer used construction principles already have been treated, be it the excitation with pulses of electric tension voltage or the spherical structure of the resonant cavity (fig. 17.6). As a spherical capacitor with the positive pole in the centre and the negative pole at the outside edge it corresponds to the model of the electron and fulfils in an almost ideal way the conditions of an unipolar arrangement according to fig. 15.8 B. The use of certain patterns of the pulses and steep flanks of the pulses (large dU/dt) make possible effects of resonance at frequencies starting at ten kilohertz, in which neutrinos participate increasingly. First the series resonant circuit, consisting of the adjustable, external inductance and the spherical capacitor, is stimulated by means of the current rectifying wiring (fig. 17.7). In the case of resonance, which is carried out by comparison of the inductance, the excitation current drops, whereas the tension voltage at the same time teaches values of more than 1000 Volts. If in addition a neutrino resonance occurs, then the known avalanche effect will occur. The equipment then takes up virtually no current.

As a dielectric serves water, with which the container is filled permanently. The dimensions are oriented after the velocity of movement of the water molecules according to details of the inventor. Also the oscillating water molecules should go into resonance. Then they can help to materialize the neutrinos. Their rotational energy partly passes to the water molecules and as soon as the neutrinos have been converted to charge carriers, they will take the water molecule from the oppositely charged side and split it without further ado. The oxygen and hydrogen gases leave the capacitor through fine openings at the upper edge of the spherical chamber, which are so small, that no ignition back can occur, and in the simplest case reach a combustion chamber, where they burn again to water as a high-temperature flame (fig. 17.6).
The gases of course also can be guided into the cylinder of a Otto engine and be ignited there, as in the case of the experimental buggy. In the sectional drawing can be seen a filler by means of which, according to the consumption, water is refilled. The round resonant cavity not necessarily has to be spherical. Stanley Meyer more frequently differs from the ideal form and works with a cylindrical symmetry (fig. 17.8), with which obviously in spite of that the goal can be obtained, if perhaps not quite so good. To this compromise the explanations of fig. 15.8 C apply.
If we, to conclude, cast our eyes over the wiring diagram which Stanley Meyer discloses in his patent specification (fig. 17.7 and 17.8)<i>. In the centre is a transformer, which should produce an if possible high tension voltage. A rectifying diode, which takes care that only positive tension voltage pulses serve the excitation, is switched in series with the reaction capacitor, which is filled with water, a fixed and a variable inductance. In that way the positive pole is always situated in the centre of the reaction chamber. If both connections would be exchanged or the diode be turned over, then the neutrinos presumably would materialize in positrons and not in the wanted electrons. But if one leaves out the diode entirely and one has a tension voltage changing both in positive and in negative direction, then maybe electrons and positrons are equally generated, which annihilate each other under emission of gamma quanta. Doing so no gas is formed, but at most light, as long as the effect of collecting neutrinos isn't lost also. The concept should be worth to be examined more detailed already of pure scientific interest.

A: The high-tension transformer:

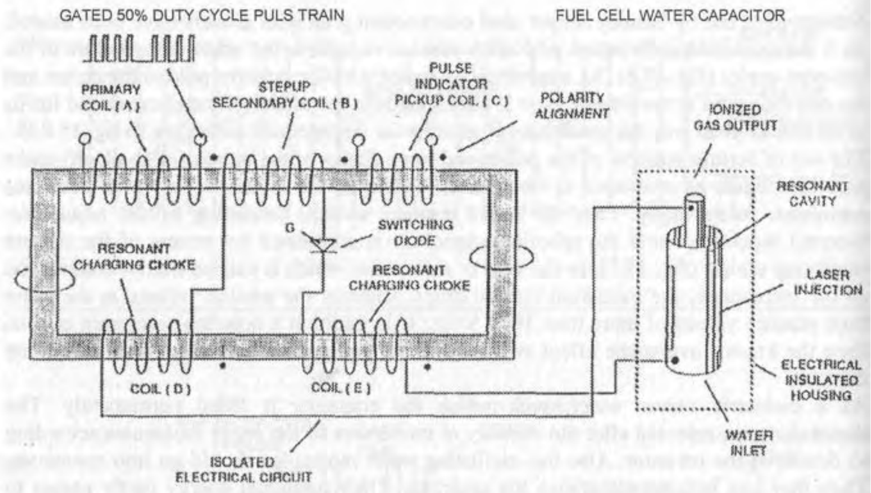
GATED 50% DUTY CYCLE PULS TRAIN
FUEL CELL WATER CAPACITOR
PRIMARY COIL (A)
STEPUP SECONDARY COIL (B)
PULSE INDICATOR PICKUP COIL (C)
POLARITY ALIGNMENT
IONIZED GAS OUTPUT
RESONANT CAVITY
G
SWITCHING DIODE
RESONANT CHARGING CHOKE
RESONANT CHARGING CHOKE
LASER INJECTION
ELECTRICAL INSULATED HOUSING
COIL (D)
COIL (E)
WATER INLET
ISOLATED ELECTRICAL CIRCUIT

B: The driving:

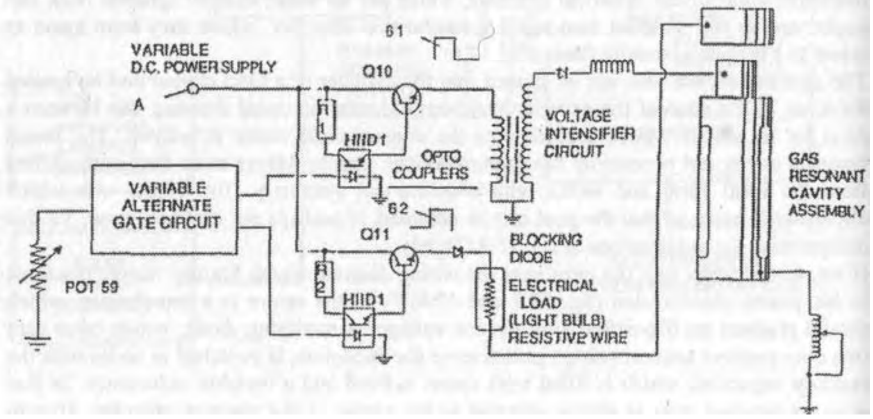
61
VARIABLE D.C. POWER SUPPLY
A
Q10
R1
HIID1
VOLTAGE INTENSIFIER CIRCUIT
OPTO COUPLERS
VARIABLE ALTERNATE GATE CIRCUIT
62
Q11
GAS RESONANT CAVITY ASSEMBLY
BLOCKING DIODE
R2
POT 59
HIID1
ELECTRICAL LOAD (LIGHT BULB) RESISTIVE WIRE

Fig. 17.8: High-tension transformer and driving of the cylindrical water-cell<i>

<i>: Stanley A. Meyer: Process and Apparatus for the Production of Fuel Gas and the Enhanced Release of Thermal Energy from such Gas, 15.06.89, US-Pat. 207,730; International Publ. WO 89/12704; Int.Appl. PCT/US89/02622

17.8 Materialization of neutrinos

In the centre of attention of the water-fuel-cell of Stanley Meyer is on the one hand the unipolar arrangement (according to fig. 15.5 B or C) to collect the neutrinos and on the other hand the water for slowing down and materializing. Over and above that a lot was tinkered and tried, as can be inferred from the patent specifications (fig. 17.8). That starts at the. coiling technique of the transformer and concerns the experiments with laser stimulation as well as the top part, which according to the inventor should extract the electrons (Electron Extractor Grid). The measures may bring an improvement, but are insignificant for our considerations.

At this place it primarily concerns the question of the materialization of neutrinos. But if such a materialization has to be made complete, if water molecules must be splitted, depends on how long the process lasts. If everything goes very fast, then perhaps it is sufficient that a neutrino for a short time is showing as an electron, before it again oscillates back. In this short time the splitting process already could have taken place. The used neutrinos for that had to be very low-frequent and very slow. They after that could again leave the reaction chamber and fly on as neutrino.

Possibly the fishes, which live in stagnant waters or in the deep sea, owe the slow neutrinos the content of oxygen in the water. Because here no bundling up takes place, the splitting of water takes place rather by chance. The volatile hydrogen atoms escape very swiftly, whereas the big oxygen atoms are left behind in the water.

Now we still don't know how charge carriers can be won. At the RQM unit resonant oscillations of size had been measured and that can be judged as an important clue. If namely a space quantum is slowed down then it becomes bigger. The inverse case we already had made us clear: If a particle is correspondingly fast then it is sufficient length contracted to fit through the tunnel (fig. 6.14).

To slow down neutrinos according to that the target area should carry out an oscillation of size with opposite phase. Organic material and biological systems are excellently suited for that. Every contraction of a muscle brings that to mind. Inorganic matter and our technology however normally don't know this phenomenon. Technical energy converters simply are built up fundamentally else than biological muscle machines.
In historical sources at certain places is pointed to the fact that priests had experimented with quartzes and miraculous phenomena were observed. Of course the question is asked, if such experiments today still can be reproduced. Because the density of the earth slowly increases due to the growth in volume, also the wavelength of these oscillation quartzes is changed. The same neutrino radiation therefore today can't be active anymore. It thus would be completely inappropriate wanting to reject a historical source only because a described effect today doesn't want to function anymore.

Magnetostrictive or electrostrictive material could be a solution. For instance a piezocrystal, which contracts under the influence of an outside field. As an ultrasound converter an applied alternating voltage leads to the emission of a sound wave. If we reverse the function, then a received longitudinal wave should lead to an electric tension voltage and then at last the materialized charge carriers could be taken off,!

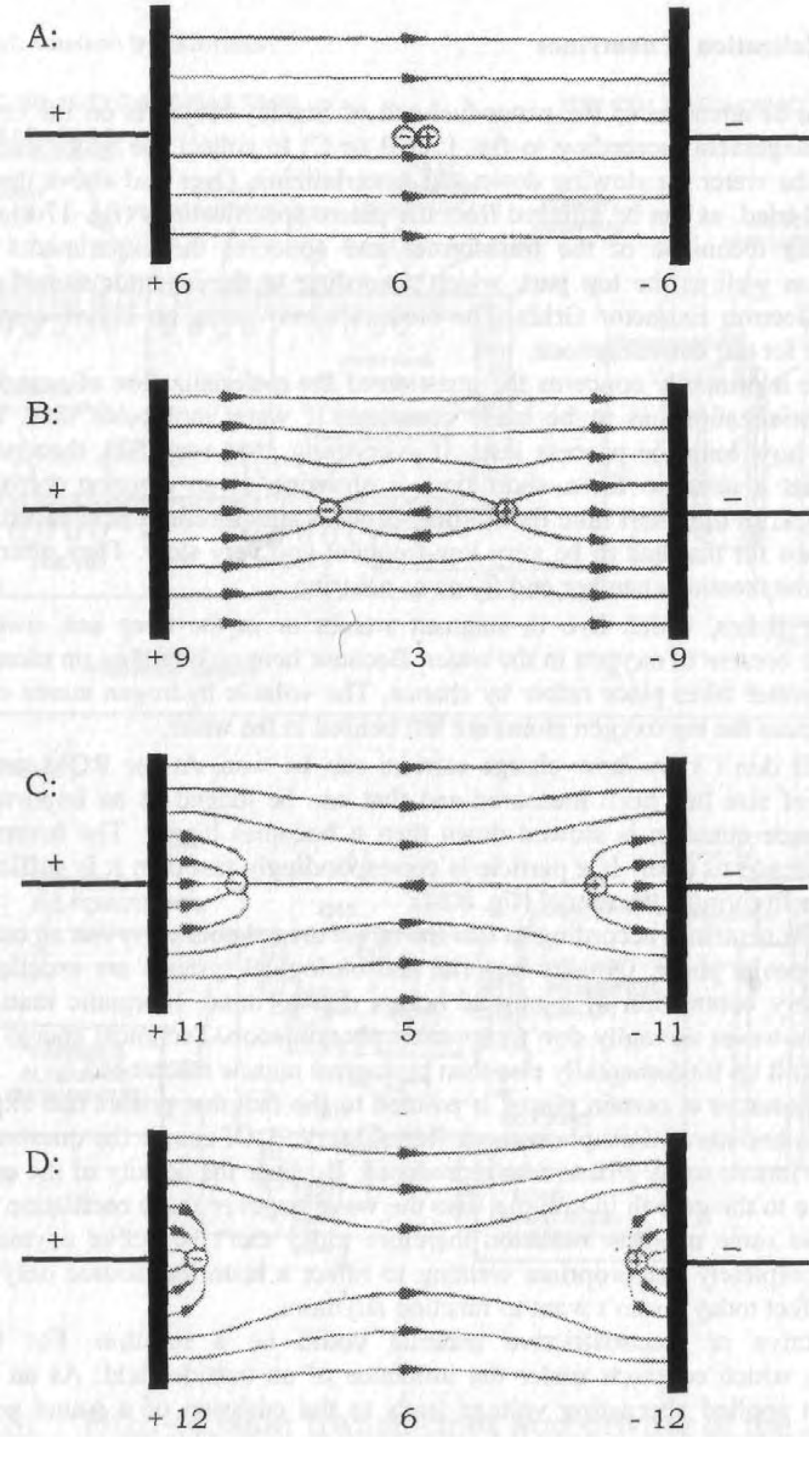

Fig. 17.9: The course of the field in the case of a glow-discharge<i>
(The numeric values indicate the active field lines, as they can be read from the representation).

<i>: K. Kupfmuller: Einfuhrung in die theoretische Elektrotechnik, 12. Aufl. Springer-Verlag (1988), S. 197

17.9 Oscillation of size and luminescence

There exist substances, which at high temperatures start to glow. In the sense of the theory of objectivity presented in the first part of the book in the case of temperature it actually concerns an oscillation of size of the involved elementary particles (fig. 8.3). If this oscillation of size lies in the visible frequency range, then we can directly perceive it and it can be used for instance in a light bulb for the purpose of lighting.
In the case of an arc. fluorescent tubes or glow-discharge lamps light is formed as well even without a thermal effect. These glowing phenomena are called luminescence. They can be caused by chemical processes, by friction, by crystallization or by electric fields. As can be shown speedily, in these cases it also concerns an oscillation of size.

If we for that consider the model on the left (fig. 17.9). Between two electrodes there is a non-conducting gas, e.g. air. If now a tension voltage is applied then, under the influence of the electric field, some gas atoms are splitted into positively charged ions and negative electrons (case A) and pulled apart (case B). This process of enlargement of the glow-discharge fast as lightning comes close to that of the thermal oscillation of size and obviously in the same way is perceived as light.
The ionised gas parts are attracted by the unlike poled electrodes and move towards these (case C, D). Whoever takes the effort to count the number of the field lines, will find out that between both electrodes the electric field drops, whereas it at the same time increases at the electrodes. The first thing causes that the process of ionisation is stabilized by itself and a state of equilibrium will result; the resulting current takes a constant value.
The increase of the tension voltage at the electrodes on their behalf causes that an arc remains standing or the glow-discharge lamp glows on, even if the feeding voltage is reduced. For this reason a fluorescent lamp needs a starter, since the network voltage is too small to start the effect of luminescence.

We indeed know, that the gain of light of a fluorescent lamp is at least three times better than that of a light bulb. As a rule a degree of effectiveness in spite of that can't be given, since it merely concerns a comparison measurement in the case of the measurement of the lighting intensity with a luxmeter. It hence can't be excluded, that we already are dealing with an over-unity effect in individual cases and neutrinos are involved in the effect of glowing.
A necessary oscillation of size would be present, as the perceivable noises of open spark gaps prove. Also in the case of lightning the thunder occurs as a consequence of a longitudinal oscillation of size and at the same time a glowing phenomenon occurs as a consequence of materialized neutrinos (fig. 14.11). It almost is obtruding a scientist that here the same principles are at work.

One however hardly can prove that neutrinos are involved in the luminescence, because the configuration is symmetrical with regard to the resonance of neutrinos and just as much particles materialize as anti-particles, which afterwards again annihilate completely as an impulse of light. They hence can't be measured directly. It gets interesting if an asymmetrical arrangement with unipolar character is chosen.

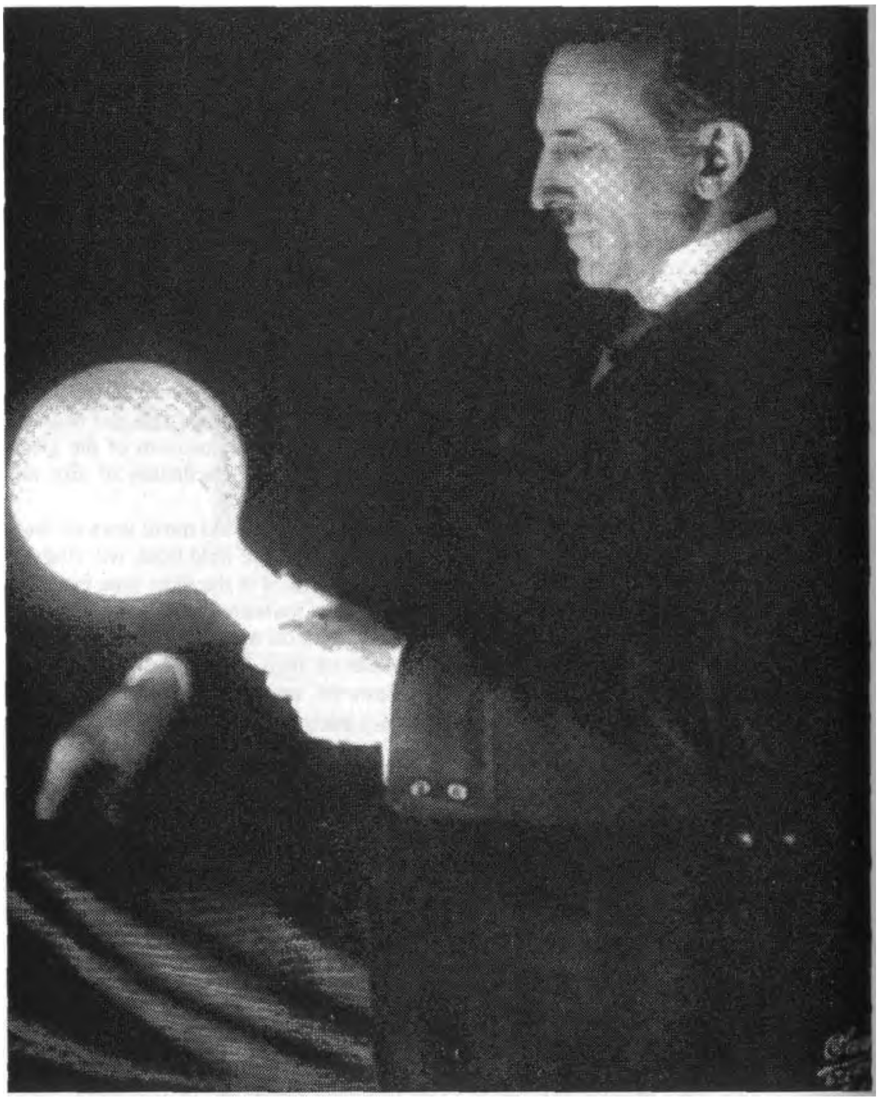

Fig. 17.10: Tesla with a wireless light bulb[i]

[i]: A Sarony-Portrait from 1894, Tesla-Museum, Belgrad

[ii]: R. Hiller, K. Weninger, S. J. Puttermann, B. P. Barber: Effect of Noble Gas Doping in Single-Bubble Sonoluminescence, University of California, Los Angeles, USA, Science, Vol. 266, 14.10.1994, P. 248-250

and: D. Lohse: Wenn sich der Schall in Licht verwandelt, Mechanismus liegt noch im dunkeln; (University of Twente, NL) Mitteilungen der DFG 4/98, S. 19-21

17.10 Phosphorescence and sonoluminescence

Let us first look at the observable after-glowing at fluorescent lamps or at a screen, the phosphorescence. It presupposes a storing effect, and that in accordance with prevailing textbook opinion can be traced back to the excited state of some atoms. Doing so electrons in the atomic hull change from one level of resonance, an instable state of energy, to another orbit, which represents the ground state. Doing so the difference in energy is emitted in the form of light. The process obviously not only takes place as luminescence during the switching on of the excitation voltage, but also as phosphorescence after the switchng off.

An enveloping electron now doesn't fly as a tiny planet around the nucleus, but occupies the entire orbit as an inflated spherical vortex (fig. 5.5). Seen from the outside it is a matter vortex. It however sees the enveloping electrons on the further on the outside lying orbit from the inside and there they are showing as anti-matter vortices. As long as the distance of respect is kept, nothing happens. If however an inner spherical vortex presses to the outside or the outside one to the inside, then the incompatibility of the vortices takes effect and both annihilate under emission of a photon. In this respect the explanations of the vortex model are very helpful.

But now, after this flash of light, two electrons are missing in the atomic hull. The positively charged atomic nucleus never would allow this loss. Replacement has to be fetched and that actually only can stem from the neutrino field. Therefore the enveloping electron doesn't change the orbit immediately, but instead has to wait, until a suitable neutrino passes by, with help of which the game of changing places can be executed. This explains the time delay and gives reasons for the observable after-glowing.

The form of the unipolarly charged sphere (according to fig. 15.8 B) forms almost ideal prerequisites for an interaction with neutrinos and the step-like change of size from one orbit to the next ideal prerequisites for their materialization. The longitudinal wave connected with the change of orbit without doubt can be called a high-frequency sound wave. It however can't be detected because of missing gauges for such high frequencies.

But if we take the frequency down into the range of the ultrasound, which can be handled technically, then effects arise which brilliantly prove this interpretation and the participation of neutrinos in the luminescence.

The not understood phenomenon is called sonoluminescence and at present is researched at numerous high schools primarily for academic interest. The structure is conceivably simple. One takes a ball of glass filled with water and positions at the edge one piezocrystal next to another. Then one with the piezo loudspeakers, operated with the same phase, sounds the whole with ultrasound and see there, the water glows mysteriously! The sound waves change the pressure. Inferring from the observations, during the phase of low pressure small bubbles are formed, which at the following rise of pressure collapse and emit a ultrashort flash of light. There thus takes place an oscillation of size, which leads to the luminescence phenomenon!

So far so good; but such a flash of light is much shorter than the collapsing of the gas bubble lasts. With less than 50 picoseconds it is faster than the otherwise usual atomic transitions of electrons. The whole thing obviously has nothing to do with this kind of luminescence. Also the spectrum doesn't fit and finally the over-unity effect lies at one trillion, the light energy thus is 10^{12} times larger than the energy part which is taken up from the sound wave by every atom<ii>!

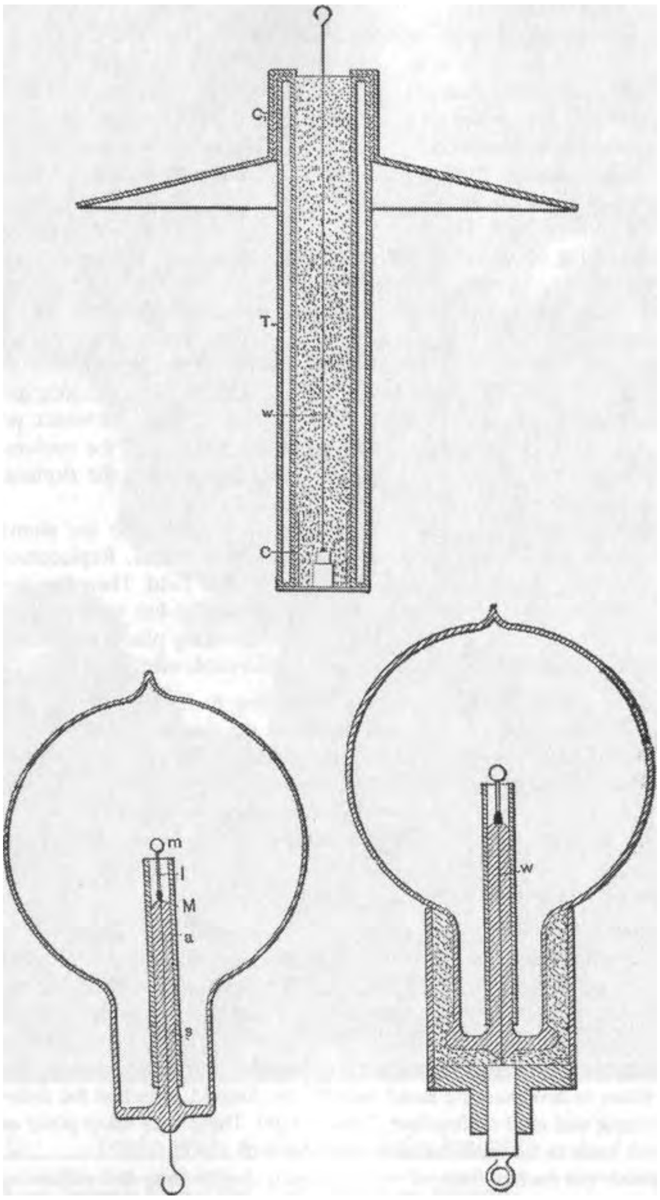

Fig. 17.11: Light bulbs according to plans of Tesla<i>

<i>: N. Tesla: Experiments with Alternate Currents of High Potential and High Frequency, Lindsay Publications Inc, ISBN 0-917914-39-2, Fig 18, P. 70+103

17.11 Discussion concerning the use of the weak interaction

In the case of the luminescence the conditions lie similar like those for lightning. The science of today it is true has some problems of explanation at detail aspects, but again and again manages to protect the ivory tower of physics from collapsing, with supporting auxiliary explanations. But at the latest in the case of an unipolar arrangement, in the case of a ball-lightning or the sonoluminescence, the participation of the neutrinos clearly comes to light, the auxiliary concepts prove to be unusable.

It surely is no accident that the discoverer of the neutrino radiation also was the first, who has experimentally investigated the luminescence. The lamps of Tesla (fig. 17.11) all were without wear and didn't have filaments like those of Edison. They however had to be operated with high tension voltage and relatively high frequency. Both a single-wire and a wireless transmission technique were possible (fig. 9.5 and 9.7). In his laboratory Tesla only needed to hang a fluorescent lamp without any return cable on a wire, then he had light. Famous also are the pictures on which he holds a lamp in his hand, which glows entirely without any connection, but only if he takes it in his hand! (fig. 17.10).

If we again turn through the chapter, then it is remarkable that in most cases, from the transmutation to the luminescence, neutrinos can be used for reason of their resonant interaction which in the proximity can be put equal to the weak interaction. A real materialization however poses an enormous difficulty. If namely the translatoric motion of the space quanta is slowed down, then the risk exists that for balance the rotation increases. But that as well has to be slowed down for a materialization! Only if both processes of slowing down take place, the goal can be reached. In that case the described cooling down effect occurs.

For a measurement technical check it therefore offers to record the slowing down of the translatoric motion and the collecting of the neutrinos by means of the measurement of the radioactive decay of a sample. And to read the materialization as the slowing down of the rotation from a measurement of temperature. In addition are helpful proofs about oscillations of size, glowing phenomena and deviations in the balance sheet of energy. With that it should be able to obtain a system for the exploration of these phenomena with the goal of a practical exploitation of the neutrino radiation for the benefit of humanity.

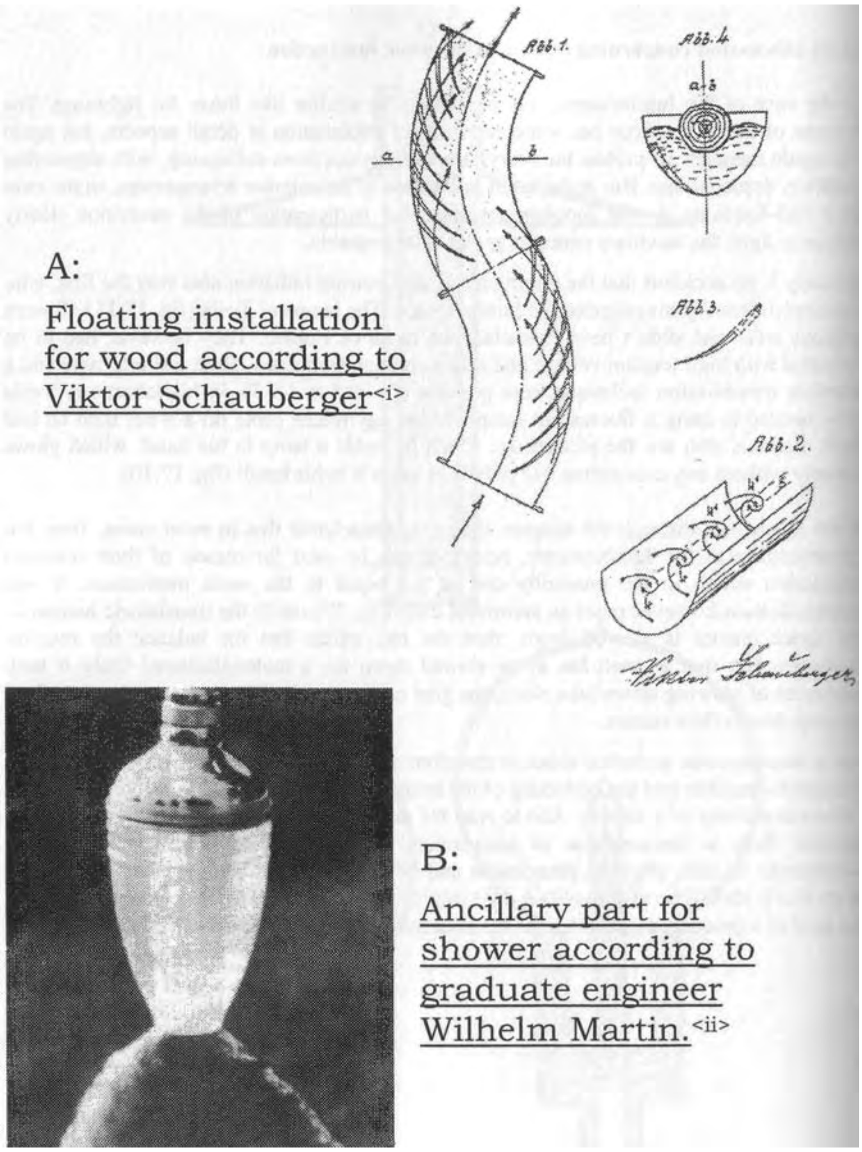
Abb. 1
Abb. 4
Abb. 3
Abb. 2
A:
Floating installation for wood according to Viktor Schauberger<i>
B:
Ancillary part for shower according to graduate engineer Wilhelm Martin.<ii>

Fig. 18.1: Mechanical whirling of water

<i>: N. Harthun: Naturgemasse Stromungsfuhrung nach Viktor Schauberger Analyse einiger seiner Patente und Zitate; MuT Nr. 4, 1980; s.a. Kap. 9.2

<ii>: O.Alexandersson: Lebendes Wasser; W.Ennsthaler Verlag Steyr, 1993, S.156

<iii>: V. Schauberger: Die Entdeckung der Levitationskraft, Implosion 112, S. 39.

<i4>: Do we owe the taste of bubbling spring water to neutrinos?

18. Physical phenomena

In this chapter it on the one hand concerns indirect effects of the resonant interaction and on the other hand effects of gravitation and levitation.

18.1 Water as a catalytic converter for neutrinos

Already the Austrian forester Viktor Schauberger has pointed to glowing phenomena at whirled water. He first had observed such in nature at torrents and waterfalls in the Alps. Later he was capable, to produce and to demonstrate this effect even artificially[iii]. One could speak of hydroluminescence, where still the question would be left open, how it actually functions.

Already in chapters 4.10 and 4.11 has been talked about the special properties of water. It here at first concerned the property of transport of a vortex, which even is capable to bind particles in the vortex, which are heavier than the whirling medium itself. Schauberger had become famous by letting build floating installations, in which not only tree-trunks, but also gravel could be transported down to the valley, without the sides of the channel actually having been touched by the rubble. This phenomenon has been examined and confirmed on the scientific side [i].

Basing on this principle today different devices for processing water are offered and sold, which bind lime, mineral materials and suspended matter in the vortex and in this way prevent deposits in the pipes. The methods, to whirl the water, are however very different. Some whirl the water mechanical, others magnetically and again others electrically.

Here the dipole nature of the H_2O-molecules has an effect. If I turn a water molecule with its electric charge distribution, then from the moving charge a magnetic field results. If thus in the pipe a hydrodynamic flow vortex is produced, then an electric and a magnetic vortex, the potential vortex and the eddy current, are the result (see fig. 4.2). The wanted flow vortices vice versa also can be obtained, by guiding bubbling whirled water past permanent magnets, or by feeding in alternating magnetic fields with the help of coils, or finally by working with pulsed electric potentials. Each of these systems, operated passively or actively, has its specific advantages and disadvantages (fig. 18.1 B and C).

It can be assumed that with the vortices also the water quality is changed. As a rule the content of colloids increases, due to which the surface tension falls. In the colloids negative ions are bound, for which reason also the electric conductivity decreases. Finally the content of oxygen increases and that actually only can come from an electrolysis. The neutrinos thereby are suspected [i4].

As an extreme dielectric medium water favours the formation of potential vortices, which immediately after their formation contract swiftly. This oscillation of size of the electrically charged potential vortices makes possible actually an interaction with neutrinos, and that on the one hand has as a consequence the water splitting and the increase of the content of oxygen in the water and on the other hand the above depicted, observable glowing phenomenon, the hydroluminescence.

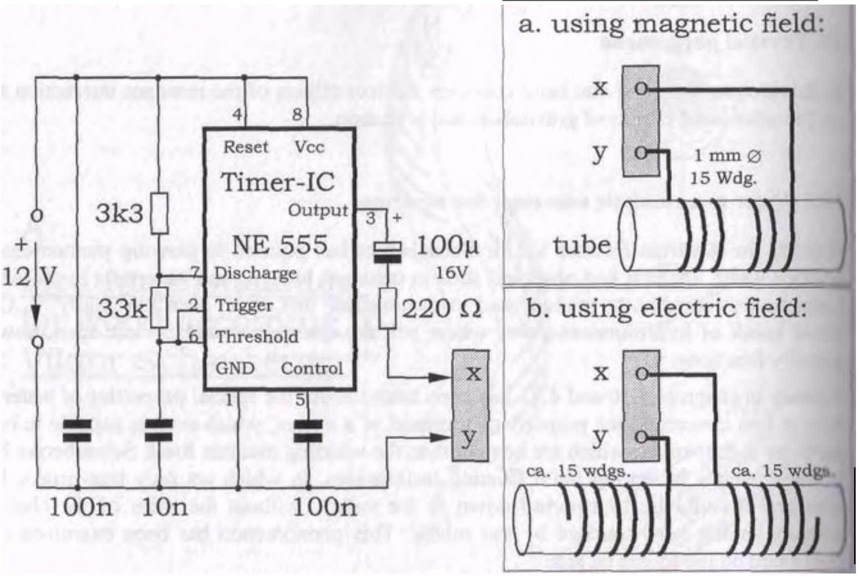
+
12 V
3k3
33k
4
8
Reset
Vcc
Timer-IC
Output
NE 555
7 Discharge
2 Trigger
6 Threshold
GND
Control
1
5
3
+
100µ
16V
220 Ω
x
y
100n
10n
100n
a. using magnetic field:
x
y
1 mm Ø
15 Wdg.
tube
b. using electric field:
x
y
ca. 15 wdgs.
ca. 15 wdgs.

Fig. 18.1 C: Wiring diagram for a simple water processor
with pulsed field (2 kHz rectangular signal)
a: for magnetic field excitation
b: for electric field excitation

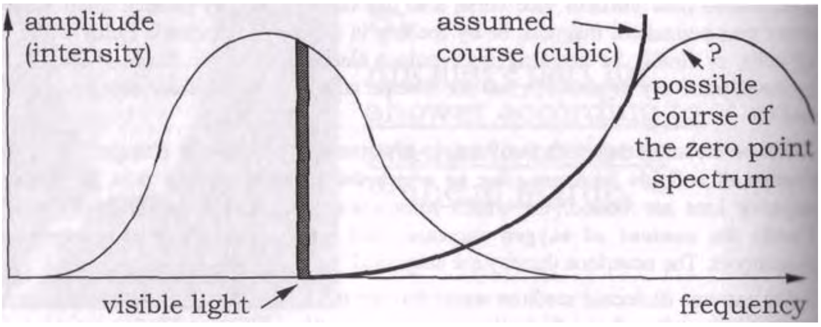

Fig. 18.2: The spectrum of frequencies of light and of the zero point radiation.<i>

<i>: A. Waser: The Puzzling Nature, AWVerlag Luzern 1996, p. 88

To complete in fig. 18.1 C the wiring diagram of a simple water processor is shown, which works with pulsed electric (b) or magnetic (a) fields.

If we temporarily again leave the theme water and take along the notion, that it must be attributed a great importance in connexion with the interaction and the materialization of neutrinos

18.2 Background and zero point radiation

Whathappens really, if cold matter or interstellar gas molecules are hit or touched by the everywhere present neutrinos? Then it can be expected that oscillations are being stimulated and as a result the temperature slightly increases. If we thus at a space flight hold a thermometer out of the shuttle window, then we will measure everywhere such a remaining temperature of a few degrees Kelvin, which is called cosmic background radiation.

By popular scientific small talkers the background radiation is called remnant of a so-called Big Bang. It even is misinterpreted as evidence for the Big Bang. Even if a certain value of entertainment can't be denied, the Big Bang from a physical view until now only has raised questions and contradictions.

If we stay at the fact that oscillating neutrinos depending on their radiation density and velocity of propagation produce a thermal oscillation, which can be detected as a slightly increased lemperature. To measure that we don't need immediately to undertake a space flight. We also can install the thermometer in an artificially produced vacuum. In vacuum physics out of ignorance of the relations the neutrino radiation then is called zero point radiation.

In the case of the neutrinos it of course concerns an oscillation around a mean value, which for a symmetrical form of oscillation has the value zero. The term nevertheless is misleading and chosen very unfortunate. After all we don't speak of zero point current in the case of alternating current!

Since every supernova and every black hole emits neutrinos and correspondingly in physical experiments until now no preferred direction could be determined for the zero point radiation, it is taken as homogeneous and isotropic in space. From the Lorenz invariance again is inferred a cubic course of the zero point spectrum, an increase of the radiation intensity with the third power of the frequency. With this assumption the radiation density of the vacuum however strives with increasing frequency towards infinity. Here an error has to be present in the considerations!

I proceed from the assumption that in the case of the spectrum of the neutrino radiation it rather concerns a spectrum of resonance, the maximum value of which lies above the frequency range measurable with devices of today. It of course would be very important to find out, where the radiation maximum lies, but without being able to measure it that lies unfortunately in the range of pure speculations (fig. 18.2).

Half the wave length in any case should be tuned to the length of the antennas of the energy centres of the cells, the mitochondria and the chloroplasts which are capable of photosynthesis. In both cases the head diameter of the ATPhases amounts to approx. 5 nanometer. It would be obvious, if the resonance point would lie here. But it could as well lie at still smaller wave lengths in the domain of molecular dimensions.

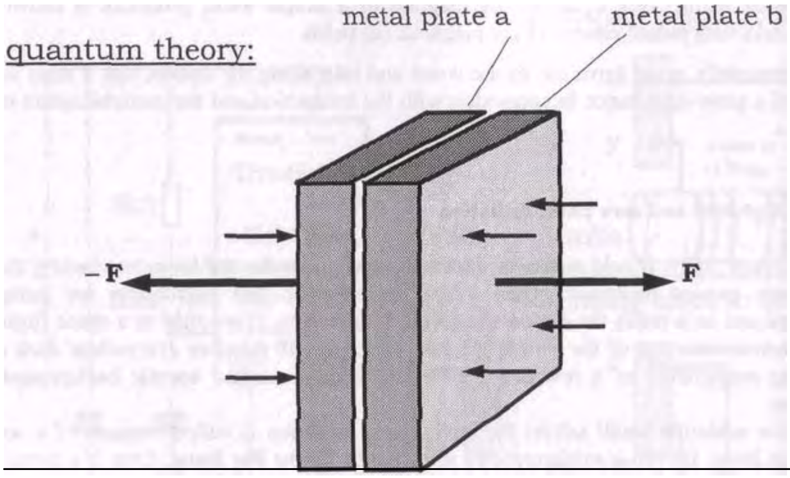
quantum theory:
metal plate a
metal plate b
– F
F

outside cause<i:>: pressure force by bombardment of quanta?

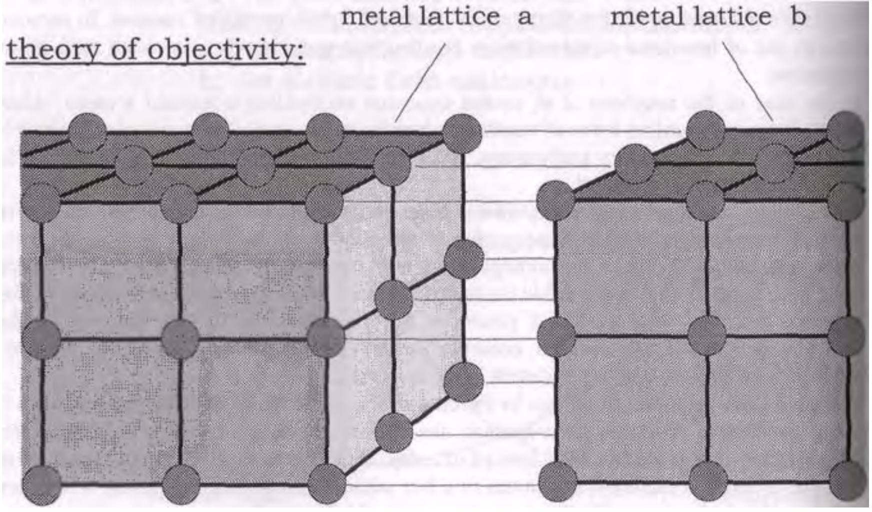
theory of objectivity:
metal lattice a
metal lattice b

inside cause<i>: levitational force by resonance effects?

Fig. 18.3: The Casimir effect

18.3 The Casimir effect

If this zero point radiation actually would be the cause of the Casimir effect, which is generally assumed today, then neutrinos would have to be involved, if the zero point raditation would be to put equal to the neutrino radiation. The effect even is quoted as evidence, but I have my doubts.

The experiment is relatively simple and functions also in a vacuum. Two absolutely plane and smooth polished metal plates are placed very close to each other. Doing so the distance should only amount to one thousandth till one millionth of a millimetre. If the force, with which both plates are attracting mutually, is measured then it exceeds by far the gravitational force. We are dealing with an unknown force, neither electric nor magnetic.
Because the force of attraction still arises near the absolute zero of temperature, some make the zero point radiation responsible. In our translation that would be tantamount to the neutrinos exerting a pressure from the outside on the metal plates, if need be with their small rest mass, as far as this should not be based on an offset-error of the detecting devices. For that the plates would have to damp the neutrino radiation effectively and by mutual shielding reduce the radiation pressure from the split. The question is asked, if the from the outside hitting bombardment of quanta, as it is called, actually can exert a pressure which would be compatible with the nature of the neutrino radiation.

If we now try an entirely other interpretation, which does without the postulating and designing of new force effects. Now the from the unified theory won interactions according to table 15.1 form the basis. In the Casimir effect, as said, neither magnetic nor electric forces are involved, so that open field lines and the corresponding force effects (1 till 4) are ruled out. It has to be the work of closed field lines and that in the static case we know as gravitation (5). Now the mass of the metal plates is too small, as that an acceptable force of attraction of masses could result.
The measurable force is much larger, even if it according to its nature could be a gravitational force. Here oscillations, as they actually take place in the hull of the metal atoms, seem to play a role. If between the oscillations of the two plates standing opposite occurs resonance, then a levitation is possible (6), which describes an oscillating interaction, produced by closed magnetic field lines<i>.
At extremely low-frequency signals this interaction is known as gravitational wave and object extravagant and costly physical experiments.

<i>: The question, which interpretation is correct and which one should be rejected, could be verified as follows: at first the force between two plates of a certain metal and afterwards that of another metal has to be measured. If in a third experiment a plate from the first and one from the second experiment are brought together and the force effect goes back measurably, then the quantum physical interpretation would be wrong clearly. With that would have been shown that here resonance effects are used, which presuppose an identical metal lattice structure of both plates.
If the force effect however doesn't go back, then both statements are possible, then one has to think up another experiment.

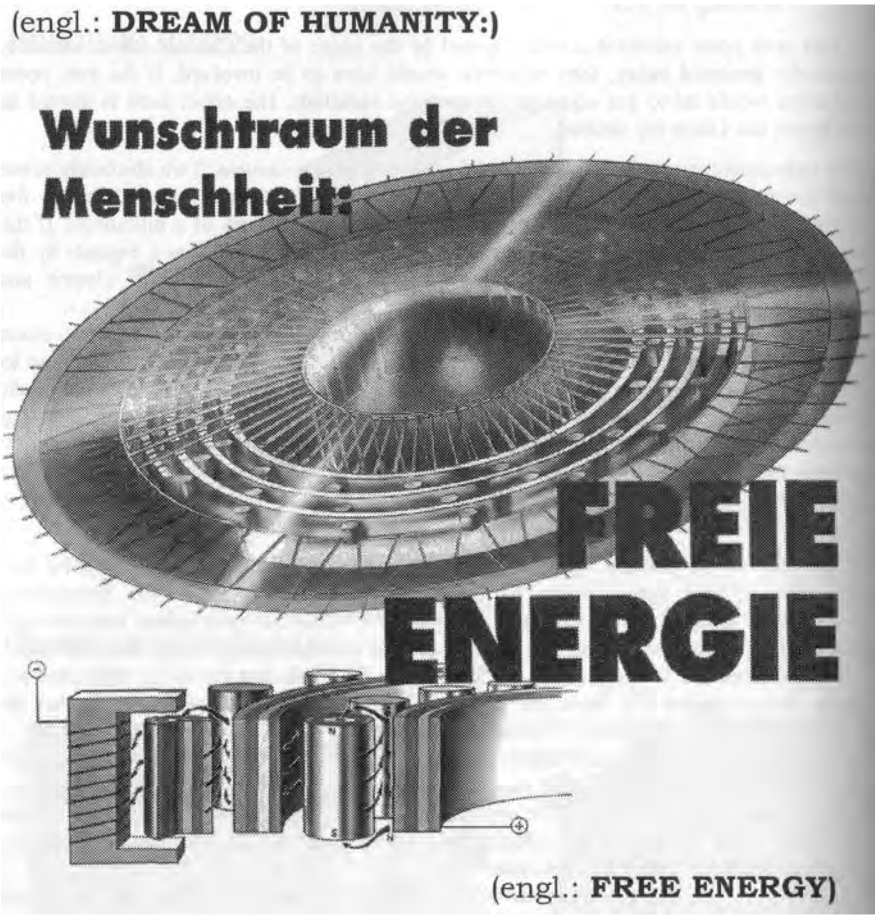
(engl.: DREAM OF HUMANITY:)
Wunschtraum der Menschheit:
FREIE ENERGIE
(engl.: FREE ENERGY)

Fig. 18.4: The flying disc of Searl on a german title page.<i>

<i>: Special 7, Raum 8s Zeit Dokumentation aus dem EHLERS Verlag

18.4 Effects under high tension

It crackles in the laboratory of high-tension. The air smells electrically charged. Only in a corner someone sits and waits with much perseverance and patience, until something happens. Then he lets thunder down lightnings of several millions of Volts on a small sample. It flashes and crashes and still nothing happens.
No, it doesn't concern Tesla! Tesla has worked purposeful. In addition has Tesla only called himself inventor. But the man in the corner feels himself a discoverer and as it is proper for a discoverer, he has immediately named the effect after himself. As a real American he lets market himself and his discovery by the media and a video tape.
Doing so he obviously doesn't know at all, what he wants to have discovered, of what this Hutchison effect actually consists. It perhaps is an event of pure chance, for which he sometimes has to wait hours. If it very suddenly would occur, then it is a real potpourri of all already discussed effects: metal spoons are bending (fig. 14.13), massif steel rods are breaking, light effects are being observed (chapter 17.9 PP), water starts to dance and to cook (chapter 18.1), without getting hot and finally do some samples take off and fly crosswise through the room. He then speaks of anti-gravitation.
In the video tape can be seen, how he brings about a physical length contraction as a result of a locally produced field concentration with two as an interferometer configured Tesla coils. In a bottle for instance the air volume is changed. This confirms the correctness of the here presented theory of objectivity (chapter 6.6 PP).
In any case no-one is amazed more about the results of chance than John Hutchison himself. Overwhelmed by the magic, the charm of the effects and the feeling to be able to move freely outside the trodden out ways of physics, he still sits in his corner with the video camera and waits, until finally something happens again.

There is worked with tension voltages, which are considerably higher than 511 kV, the calculated tension voltage of their own of the charge carriers (fig. 7.1). One thus by no means has to be amazed, if under the influence of several millions of Volt electrons are taken apart and metallic objects are breaking or bending.
The extreme tension voltage and field change we owe an oscillation of length and of size, which spontaneously can lead to an interaction with neutrinos. Materialized neutrinos again are responsible for glowing phenomena and for the electrolysis of water, which under the impression of the rising gas bubbles seems to dance and to cook. For my readers and participants of the energy technical seminar therefore models of explanation are available.

One effect we still haven't discussed and analysed more in detail: the antigravitation resp. the levitation. As long as no reproducible field conditions are present and the chunks are accelerated in any arbitrary direction, it will be difficult to understand the physical course of a levitation.
In chapter 9.3 we already had become acquainted with and discussed a levitation device with the flying disc of John Searl. for which the field conditions are comprehensible. This time we should have a somewhat closer look at the flying device (fig. 18.4)<i>.

<i>: Some reports can be found in Special 7 ,,Freie Energie", Raum & Zeit Dokumentation aus dem EHLERS Verlag, Seite: 141 bis 157 und 174 bis 185

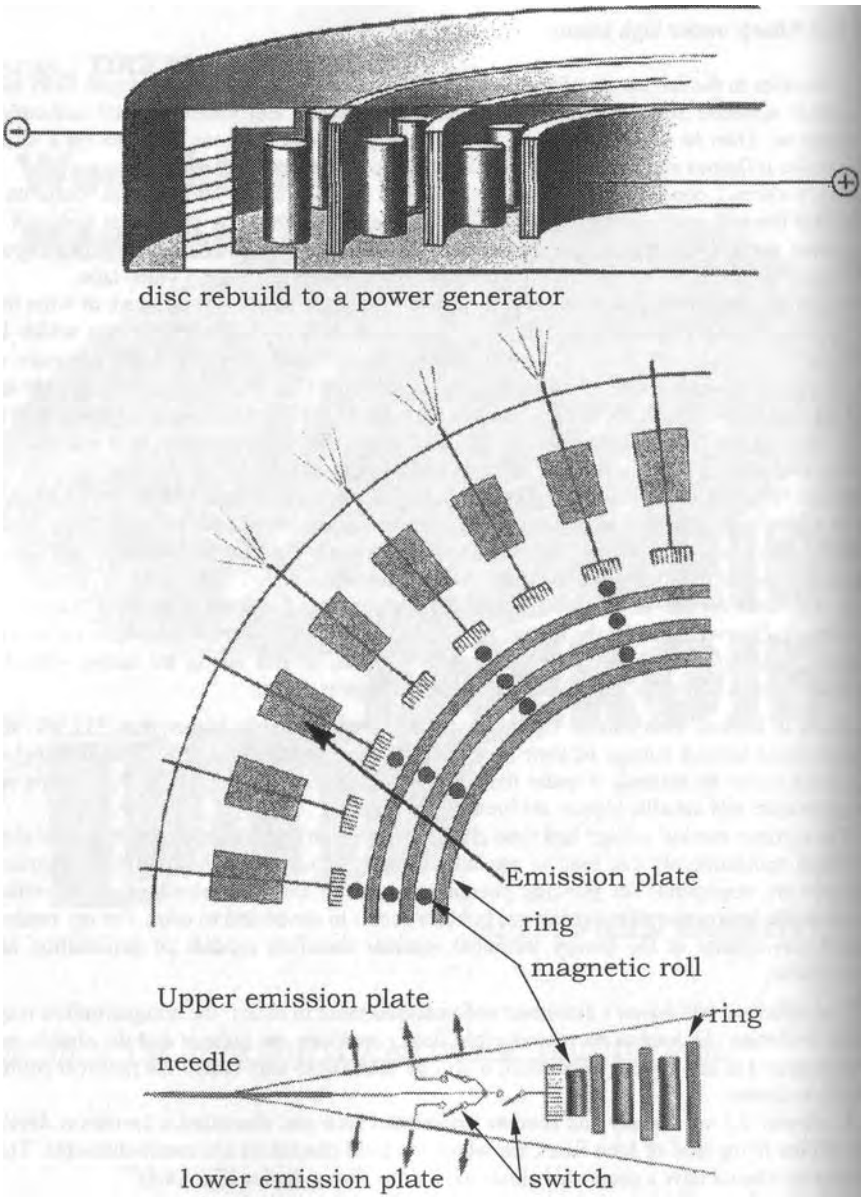
−
+
disc rebuild to a power generator
Emission plate
ring
magnetic roll
Upper emission plate
ring
needle
lower emission plate
switch

Fig. 18.5: Concerning the controlling of the flying discs according to Searl.<i>

<i>: H.Schneider, H.Watt: Dem Searl-Effekt auf der Spur, Special 7, Raum & Zeit Dokumentation aus dem EHLERS Verlag, Sauerlach, 1. Aufl. (1994), S. 183

18.5 Flying discs

The Searl-disc can be calculated relatively good with the Faraday equation concerning unipolar induction. To estimate the order of magnitude, we just suppose the roller magnets produce an induction of one Tesla and the radius is one meter, then between the centre of the flying disc and its edge 511 kV is applied, if the revolutions per minute has reached the value of 80000 revolutions per second. As soon as the revolutions per minute is reached, the neutrino conversion can start.
The at the edge of the disc arising corona, which consists of individual electrostatic discharge flashes, takes care for the necessary dU/dt, by every blow and every spark is drawing the potential for a short time towards ground. The tension voltage jumps in swift order between values of above 511 kV and zero Volt to and fro. In connection with the already discussed unipolar field configuration neutrinos are being collected in this way.

A technological challenge represents the layered construction of the roller magnets and the rings, which have to withstand extreme centrifugal forces (fig. 18.5). Friction however is not a theme, since on the one hand the air inside the disc ionises and a vacuum is formed and on the other hand the air split between rollers and discs increases by the field dependent contraction of the metal parts.

Actually one in this case by no means can speak of antigravitation, because the gravitation isn't really vanishing. The disc even in flight still is heavy tons. Here merely a resonant interaction is built up which is larger than the gravitational pull of the earth. The disc is attracted by the cosmic source of neutrinos, with which it has built up the resonance.
Exactly there it will fly!

The by Searl designed controlling<i> in my opinion actually can't have functioned satisfactorily. He uses emission plates, as he calls them, which alternatively are switched on by means of switches and are able to form electrostatic forces with some air charge carriers. In reality the drive probably is comparable to that of a sailing ship, for which the wind always blows from one direction. The ship isn't pushed by the wind, as one erroneously could think, but rather by the under pressure behind the sail pulled forward. Without steering facility the object always is driven in direction of the drain. The sailor would say, the ship without helmsman drifts towards lee.
Searl in this way has lost all flying discs which were started. By using solar neutrinos they presumably have fallen into the sun and burnt. The controlling should function analogous to a sail, then one would stand a chance, by "traversing" against the "wind", to sometime again come back to the starting-point.

<i>: H. Schneider, H. Watt: Dem Searl-Effekt auf der Spur, Special 7, Raum & Zeit Dokumentation aus dem EHLERS Verlag, 1. Aufl., Seite: 183

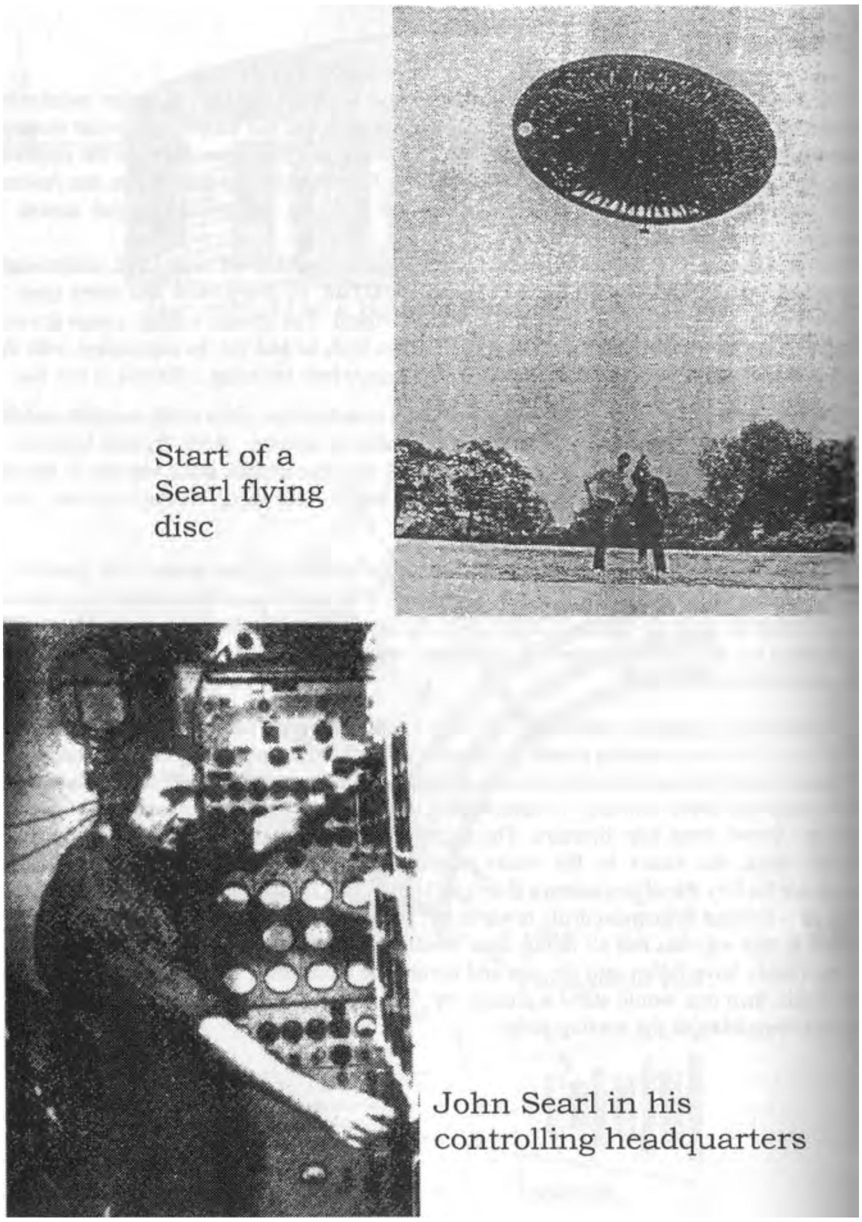
Start of a
Searl flying
disc
John Searl in his
controlling headquarters

Fig. 18.6: The remote controlled flying discs of John Searl.[i]

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[i]: Special 7, Raum & Zeit Dokumentation aus dem EHLERS Verlag, S. 152

18.6 Propulsion with neutrinos

In search for an ideal propulsion system for spacecrafts the flying discs of John Searl still have demonstrated a further possibility. After the start occasionally were left strange particles on the ground, which hadn't be there before. The flying device obviously had materialized them and dropped them at the start.

With this materialization of neutrinos the chance is showing of a very efficiently working recoil propulsion. If namely the neutrinos are converted into matter then they by that gain back their rest mass. If this takes place in flight then the materialized particles also bring along kinetic energy. It then works as ajet engine for which the direction of the jet can be directed and in that way the vehicle can be controlled comfortable.

In the case of the Searl-disc the materialization of neutrinos rather happens as a not understood side effect. In the case of a systematic use however the principle will show a characteristic property. Instead of a vapour trail a beam of light will shine out of the flying object in the direction of the emitted particles, but it will break off abruptly after a cartain distance.

To blame is the part, which has become anti-matter, which it is true as well contributes to the recoil, but simultaneously annihilates with incompatible particles of matter under emission of particles of light. If in some distance all antiparticles are used up then also the beam of light comes to an end.

It here concerns necessary properties of a corresponding propulsion technology for spacecrafts, which don't have to drag their propelling energy along with them. Our space technicians finally could handle another than the "hammer throwing method", in which case the "hammer" by means of terrible fuel consumption after a phase of acceleration only staggers uncontrollable through space under the influence of its inertia.

With a neutrino propulsion on the other hand one at any time can accelerate or brake. It will strongly influence the field around itself, so that can be reckoned that for every acceleration a field dependent change of size should be perceptible by an outside observer.

If therefore a corresponding flying device is accelerating then it will suddenly become smaller and that then looks so as if it would have moved away with a jump without temporal delay, but that isn't the case at all.

The jerky movements only would be a result of the perception with our eyes by means of the propagation of the light. Since the passengers are exposed to the same field, they change their body size along with that of the vehicle. They actually notice nothing of an apparently infinite acceleration, which only observers on the outside would observe and which indeed no living being could stand.

Nowhere the explanation crisis is larger than in space travel! The theory of objectivity represents a real help, because it perhaps as the only one puts us in a position to conceive and understand not understood observations as necessary technological consequences.

Only by uncovering parascientific as purely physical phenomena man of today will be able to free himself from the constraints of magic and his own illusions.

Is the until now discussed cases resonant or other force effects are being used, whereas the gravitation remains unchanged. Closed field lines after all cannot be influenced, normally at least. Perhaps an indirect possibility exists to have an effect on the gravitation?

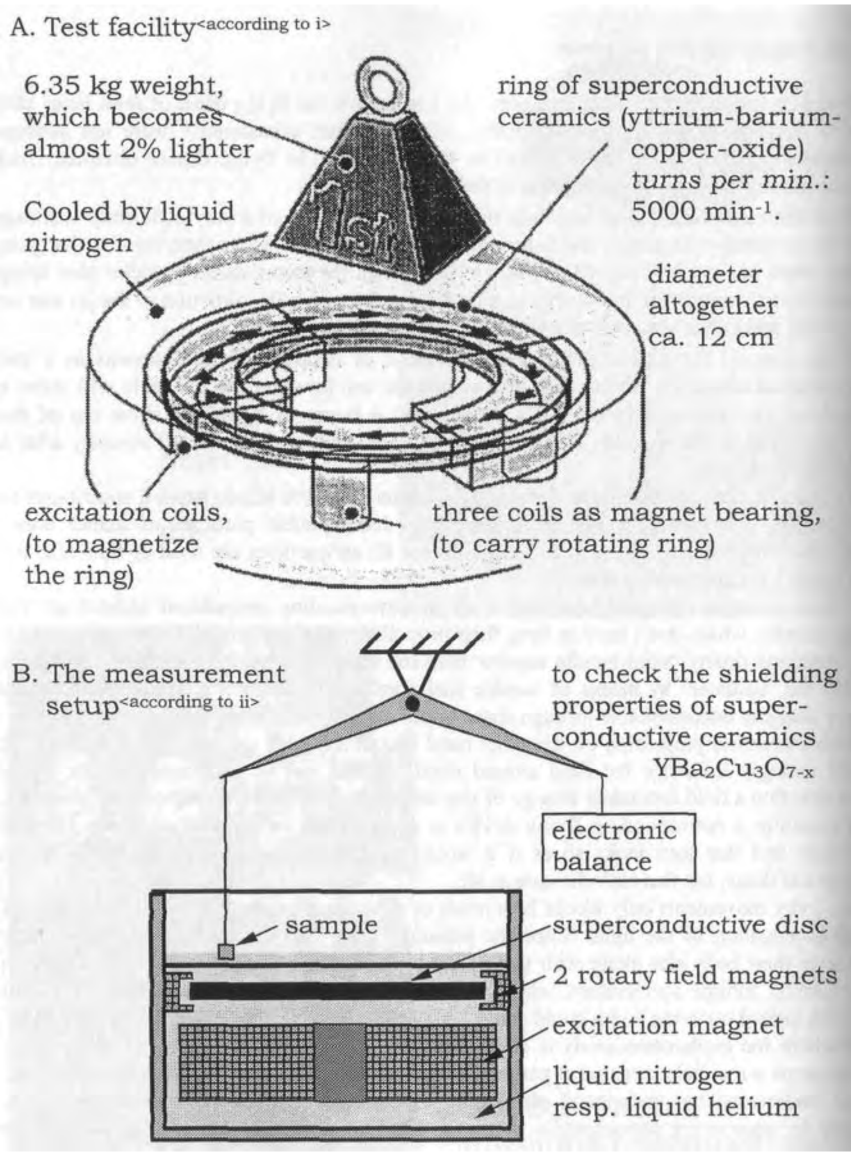
A. Test facility<according to i>
6.35 kg weight, which becomes almost 2% lighter
Cooled by liquid nitrogen
ring of superconductive ceramics (yttrium-barium-copper-oxide) *turns per min.:* 5000 min^{-1}.
1st
diameter altogether ca. 12 cm
excitation coils, (to magnetize the ring)
three coils as magnet bearing, (to carry rotating ring)
B. The measurement setup<according to ii>
to check the shielding properties of superconductive ceramics $YBa_2Cu_3O_{7-x}$
electronic balance
sample
superconductive disc
2 rotary field magnets
excitation magnet
liquid nitrogen resp. liquid helium

Fig. 18.7: Experiment for the manipulation of the gravitational pull of the earth.

<i>: Schneider: Anti-Gravitation im Labor nachgewiesen?, NET-Journal Januar 1997, S. 14,15; s.a. Internet: http://www.keelynet.com/gravity/fingrav.htm

<ii>: E. Podkletnov, R. Nieminen: A possibility of gravitational force shielding by bulk $YBa_2Cu_3O_7$-x Superconductor, Physika C 203 (1992), P. 441-444

<iii>: Force field Implications of Anti-Gravity, The Journal of Ideas, Art.191, 7.9.95

18.7 Antigravitation or levitation

The night already had fallen over Finland, but at the University of Tampere the light still was on. Then a scientist put his beardy head through laboratory door and with a "hello folks" blew the smoke of his pipe over the cryostat for the examination of superconductive materials. The scientists were speechless, because the smoke seemed to hit an invisible wall and was drawn upwards in direction ceiling almost at a right angle.
After having aroused the curiosity, Dr. Eugene Podkletnov also has held other materials above his rotating disc and had to discover that these as well lose weight, and that he actually influences the gravitation with his experiment. Even the air pressure at the corresponding place in a lying above floor was smaller<i>.
With a superconductive disc of 30 cm diameter cooled by liquid nitrogen a reduction of gravity for 2% to 4% can be obtained, if the disc rotates with more than 5000 revolutions per minute. With the revolutions per minute also the effect increases, but it is independent from the excitating field<ii>. Finally the fields of the superconductive currents in the ring remain existing unchanged even after switching off the excitation and it only depends on these fields.

The shielding effect of the arrangement on electromagnetic fields already had been known before and should be examined closer in the laboratory. One only was surprised that the gravitation could be shielded as well, that obviously both interactions are related. According to the prediction of the theory of objectivity the closed magnetic field lines gravitate and the field components directed towards the centre of the earth cause the measurable force of weight. By the very strong superconductive fields obviously field overlaps and possibly a local driving out of field occurs, like one has long known for eddy currents (Meissner effect).
With that the earth gravitational field of course is not cancelled, but merely spatially moved, or it partly has changed its direction. If only a small part of field pointers turns out of their orientation towards the centre of the earth, then at that point the force of weight is reduced to a corresponding extent. The theory of objectivity requires that!

By the way reports exist, according to which even without rotation a weight reduction can occur for superconductive rings, and others, where is worked even entirely without superconduction. As core material for the ring ferrite or a strong permanent magnet is used. In that case depends on the circumstance that the ring-like coil is operated in self-resonance and always in the right moment again is excited anew by induction. The ring core then stores the fields up over time, exactly as the superconductor.
Stricktly speaking it are the atomic nuclei and in the end all elementary particles, which are aligning in the high field. Dr. Ning Li wants to artificially produce gravity, by directly influencing the quanta. With that she comes the phenomenon very close<iii>. The possibilities of this effect nevertheless are very limited, since two percent more or less are not exactly much, and the dream of the complete cancelling of gravity or even inertia possibly stays just a dream. It stricktly speaking just concerns influencing the gravitation and not antigravitation!

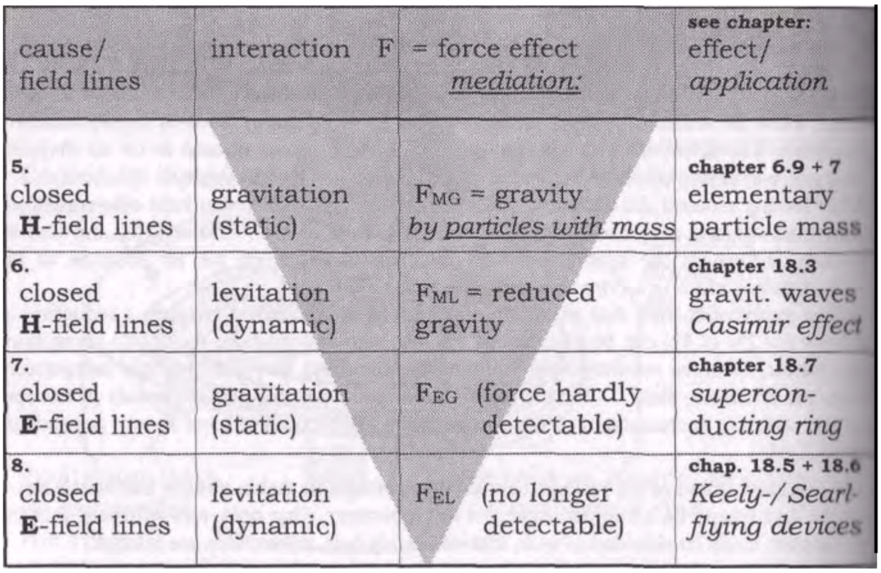

cause/ field lines	interaction F	= force effect *mediation:*	**see chapter:** effect/ *application*
5. closed **H**-field lines	gravitation (static)	F_{MG} = gravity *by particles with mass*	**chapter 6.9 + 7** elementary particle mass
6. closed **H**-field lines	levitation (dynamic)	F_{ML} = reduced gravity	**chapter 18.3** gravit. waves *Casimir effect*
7. closed **E**-field lines	gravitation (static)	F_{EG} (force hardly detectable)	**chapter 18.7** *supercon- ducting ring*
8. closed **E**-field lines	levitation (dynamic)	F_{EL} (no longer detectable)	**chap. 18.5 + 18.6** *Keely-/Searl- flying devices*

Table 18.8 A: The interactions of closed field lines.<i>

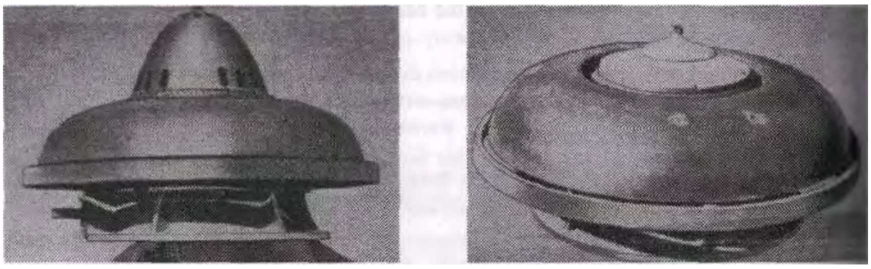

Fig. 18.8 B: Test models of the "flying saucer" according to Viktor Schauberger.<ii>

<i>: according to fig. 15.5, cases 5 to 8

<ii>: O.Alexandersson: Lebendes Wasser; W.Ennsthaler Verlag Steyr, 1993, S.103

18.8 Discussion concerning the effect of closed field lines

If we now direct our eyes exclusively to the lower half of fig. 15.5, in which the consequences of closed field lines are listed. Without the possibility of a direct focussing like for open field lines, the caused force effects turn out extremely small. With that they are less suitable for an use of free energy. The considerations in that context rather aim at technologies to reduce weight, like they would be worth striving for for flying devices.
If we allege that here in the same way the force effects of magnetic H-fields exceed those of electric E-fields for three to four powers of ten. Then it will hardly play a role for the force of weight of a body with or without additional electric charge, if its E-field lines are closed as well or are open. The increase in weight of an uncharged body only will have an effect in the third till fourth place after the decimal point. Seen so in the case of the gravitation it primarily concerns an effect of the magnetic field, more strictly speaking the effect of closed magnetic field lines (chapter 6.9).
If one succeeds in influencing these magnetic fields for instance by the influence of extremely strong fields of a superconductor, then also the gravitation will change, as has been shown (chapter 18.7). Let's imagine, in the case of a systematic procedure we would succeed in a perfect influencing, for which no component of the H-field lines points into the direction of the centre of the earth anymore, then an uncharged body would only have one tenthousandth of its original weight, whereas a charged body actually would weigh nothing anymore. This state of the weightlessness supposes that all E-field pointers point into the direction of the centre of the earth or diametrically in the opposite direction, since E- and H-field are standing perpendicular to each other. Unfortunately such a field distribution technically hardly can be realized and so the ,,flying carpet" furthermore remains reserved to the fairytales.
An effective reduction of weight of planes and other flying objects however seems by all means feasible, and so slowly the number of research facilities increases, which more or less officialy have a critical look at the cancelling of gravity and the levitation. The theories on which they are basing, however often sound very bizarre and moreover are completely unphysical. Maybe a look at the distribution of field lines, as proposed here, helps to get further.

In the case of the levitation, which occurs strictly speaking only in the case of oscillation for closed field lines, resonance again plays the crucial role for the coming about of the interaction. In connection with neutrinos the resonance can serve less the collecting; we rather need it for the materializing, for the production of mass, charge and energy.
For the artificial production of a levitation either a mechanical oscillation in the atomic or molecular domain is needed, like for instance is produced by a rotating water molecule, or a resonant oscillation of size takes place by use of electrostrictive or magnetostrictive materials, like piezocrystals or oscillating quartzes.
In this context surely is of great importance that also the temperature could be identified as a particle immanent oscillation of size (chapter 8.3). That's why besides a cold materialization or cold fusion also exists, at least theoretically, the possibility of a hot materializatin or hot fusion.

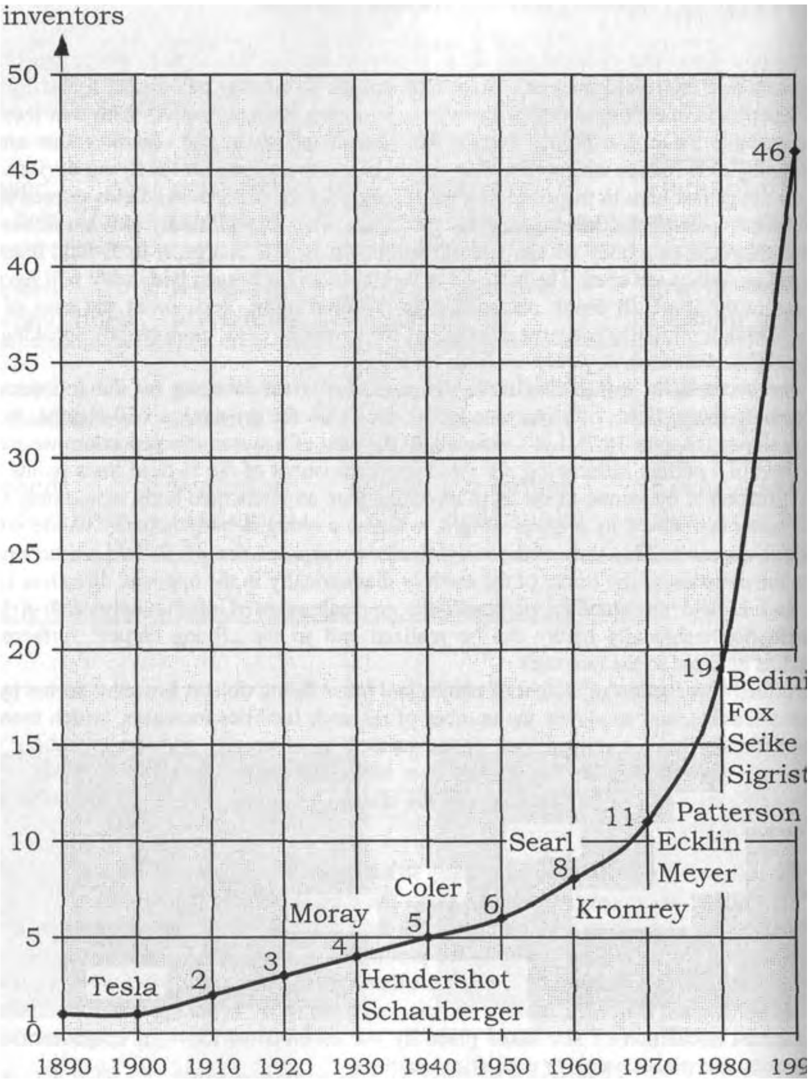

Fig. 18.9: The increasing number of free energy inventors.<i>

<i>: only the inventors mentioned in the text are entered. Literature for that: A. Schneider: Energien aus dem Kosmos, Jupiter-Verlag (1994), S. 77

18.9 Concerning the determination of the stand of today's energy technique

An analogy to the production of matter forms the production of light. At high temperatures as is well-known is formed thermal light and at low temperatures cold light, the discussed luminescence. An oscillation of size of the light source in all cases of the formation of light is the cause, be it as an electromagnetic wave or as photon vortex, be it in whirled water or as sonoluminescence. We at last see ourselves put in a position to understand the various light phenomena as something which is related.

The call for new energy carriers and an ecologically compatible energy technology can't be ignored anymore. The number of inventors at present increases fast (fig. 18.9). It is legitimate and worth recommending, to observe for this purpose first of all nature, how it solves its energy problem. Doing so we should realize that in contrast to the technology of today no combustion and no explosion takes place, but rather principles of a cold fusion and of an implosion as a result of contracting potential vortices are being used. Actually nature may point the way out of the energy technical dead end. We only have to accept the offer, be open and show being ready, to invest in the development of methods in accordance with nature.

Directed at the address of the distributors of supporting funds for energy research the claim in plain English reads: to grant no money anymore for ecologically harmful concepts, like nuclear fission or for not understood and not realizable developments like hot fusion. to immediately stop the fruitless works and to provide the money for an ecologically compatible energy research.

Immense saving potentials moreover are found in all domains of physics, where instead of costly experiments just as well the things could be calculated with an usable theory. To check the theory then only few experiments would be necessary. After all all important discoveries have come about in this manner. Nobody should think, he had understood a matter, once he has filled himself up with sufficiently much measurement data.

The root of the evil lies already in the education, where students of physics want to understand everything and therefore are trying hard to grasp with their view and hands for everything. Abstract thinking or mathematical derivations however are too uncomfortable for most; they have the erroneous opinion, understanding (German: begreifen) would have to do more with grasping (German: greifen), and for that the head after all can't be used.

One reason for this development can be seen in the relativistic point of view of Albert Einstein, who proceeds from the assumption of a subjective observability and has raised the relativity between a physical principle and the observation to the basis of physical thinking. The arrogant motto prevails: what I can't observe with my sense organs or register with corresponding gauges also isn't physics, but esoterics or parascience.

But if we want an ecologically compatible technology, then this can't be reached with this point of view. Then we only hinder ourselves with our own arrogance and intolerance. We have to leave the erroneous quantum physical way and again learn to think abstractly by taking up tried and tested principles of classical physics. An objective point of view forces us to register the phenomena, which lie outside the observable range, with mathematical MEANS (see chapter 13). Only if we have learned that, we will understand and realize the true relations in physics!

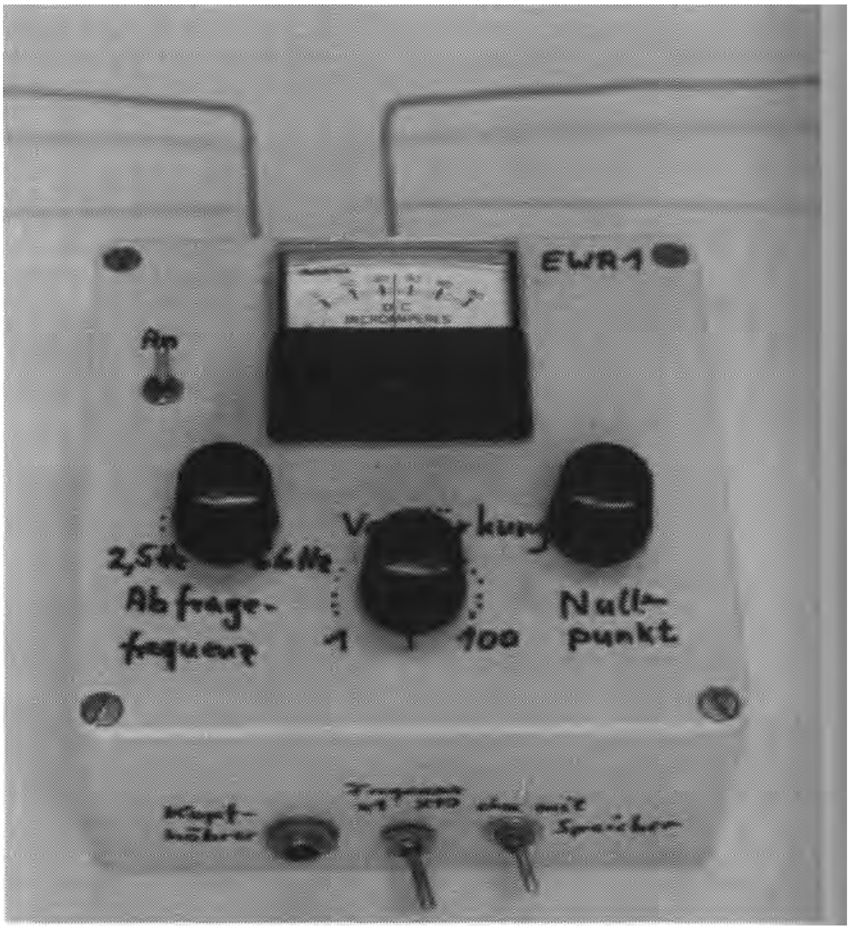
EWR1
An
MICROAMPERES
2,5Hz
Verstärkung
Abfrage-
frequenz
1
100
Null-
punkt
Kopf-
hörer
ohne mit
Speicher

Fig. 19.1: A self-built charge amplifier.

19. Own experiments

The opposite of the theoretical considerations form practical experiments. If we want to register and understand physical and natural scientific phenomena, then we shouldn't entirely forget the aspect of handicraft. Doing so it can't be avoided that it goes on very personally, if about the laboratory work is being reported, not even then, if the experimenter is at pains to exclude every influencing of the carrying out of the experiment and the result. After all does anyone have to execute the experiments himself, since a good sceptic anyhow only believes, what he has observed with his own eyes.

19.1 Concerning the rating of experimental physics

There already have been scientists, who have requested to reject a measuring technical determined result for the case that textbook physics doesn't produce it. This attitude even today still is taken by an uncounted community of believers of science, entirely after the motto: "Nature kindly has to fit in with the dogmas of theoretical physics!"

This wrong thinking is reflected in the scientific journals, which reject to print discussions. Controlled by a tester board, which only has the task to prevent dissenters from the publication of their ideas, they are the sad proof, how widespread this erroneous attitude today is in the university scene.

Actually solely the scientific experiment shows us the physical reality! The theoretical models, like the here presented vortex model merely should help to understand nature and its laws. The representatives of theoretical physics are in the role of a helper and that requires modesty and openness.

For the case that a professor of theoretical physics imposes a pledge of secrecy on an experimenting colleague, if this one wants to report publicly about his amazing tunnelling experiments, then the public nevertheless should have the right to find out, if a tunnelling experiment reveals speeds faster than light, even if it doesn't suit the theorist and he in inappropriate arrogance only should consider the experimental physicist as his assistant.

If universities only are occupied with preservation of property and the industry only with the increase of its productivity, if future research consists of hiding public research funds internally in such a way that nobody realizes the fraud of support and in reality nobody thinks of the future anymore or wants to work for it, then we will be able to observe how discoveries and inventions migrate from the industry and the universities with their controlled central organs and increasingly will take place again in garage, cellar, solitary study room or in privately organized circles.

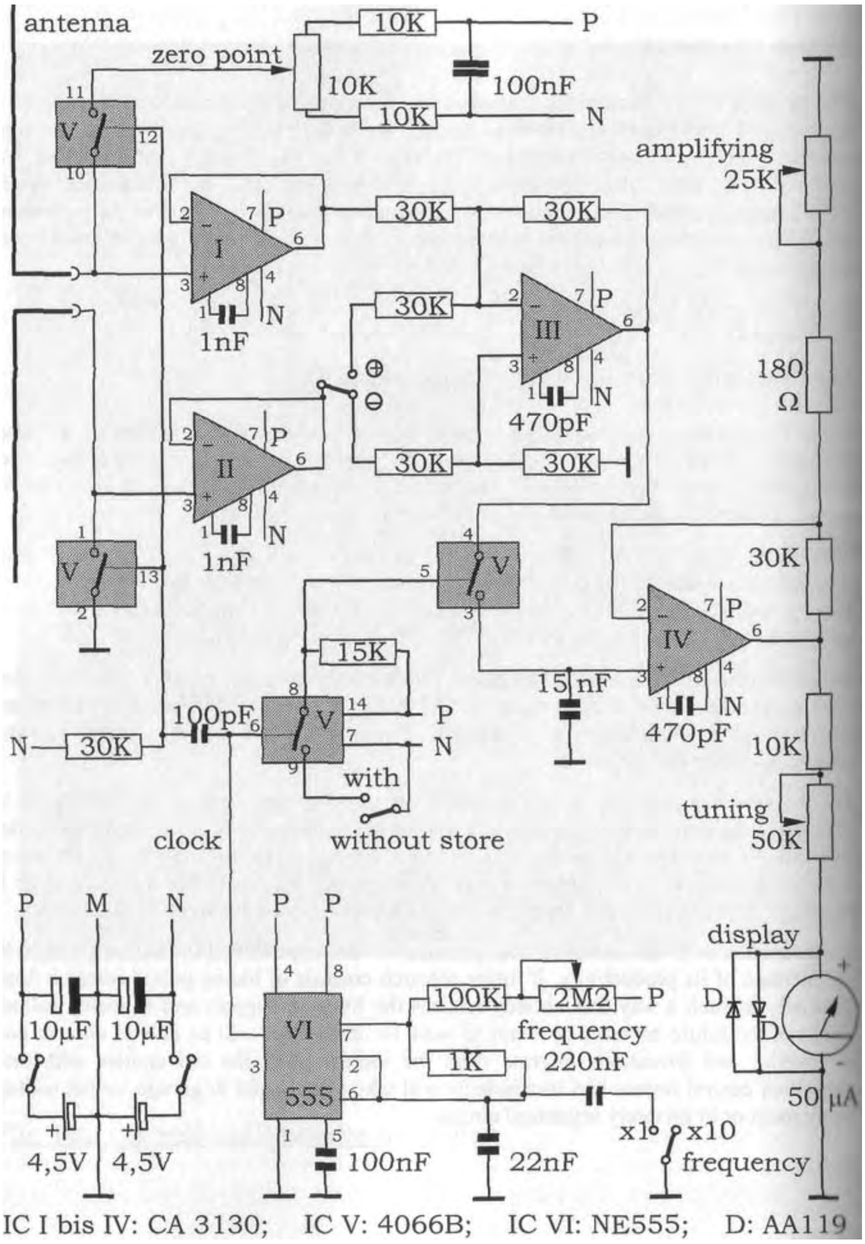
antenna
zero point
10K
10K
10K
100nF
P
N
V
11
12
10
amplifying
25K
I
II
III
IV
30K
30K
30K
30K
30K
P
N
1nF
1nF
470pF
470pF
⊕
⊖
180
Ω
30K
15K
15 nF
100pF
30K
with
without store
clock
10K
tuning
50K
display
D
D
50 µA
P
M
N
10µF
10µF
4,5V
4,5V
VI
555
100K
2M2
frequency
1K
220nF
100nF
22nF
x1
x10
frequency
IC I bis IV: CA 3130; IC V: 4066B; IC VI: NE555; D: AA119

Fig. 19.2: Wiring diagram of the self-built charge amplifier

19.2 The charge amplifier from the workshop of handicrafts

Is connection with my vortex theory in this book time and again clues to experiments can be found. I am aware of their importance and I always, to verify my theoretical working out, have accompanied it with practical experiments. Doing so not the proof, which can be published and reproduced by anyone at any time, stood in the foreground. With the experiments in my workshop of handicrafts I only wanted to check for myself, if my derivations still can be verified.

Consequently was at first done without a publication in the first and second edition of the second part concerning the "electromagnetic environmental compatibility". For the addition of the here presented chapter about own experiments from the third edition there are several reasons: first; I have been asked for it by several readers, second; from every experiment is coming a piece of physical reality to meet one and third are here latent some useful ideas and approaches which get us somewhere.
Of course can't be read much from a handicrafts self experiment, but perhaps one or another reader, who has better laboratory technical possibilities at his disposal than me, is stimulated to carry out own experiments.

To chase after the potential vortices in the air, I 1989 at first have built together a charge amplifier. I connected differently formed antennas at the particularly high-ohmic difference input. Corresponding the in nature arising static electric field a tension voltage should arise between both antennas, which my gauge should amplify and indicate on a moving-coil instrument.
To be able to register local changes, a measurement cycle is gone through, which periodically is repeated: It starts with the measurement time, during which entirely by itself between both antenna a charge is building up. The value afterwards is stored analogue in a Sample-And-Hold link and displayed by means of a moving-coil instrument. Then the input clamps are short-circuited, the antennas again discharged and the game starts from the beginning.

Measurement time, zero and amplification can be adjusted at the device (fig. 19.1). Whoever has fun to rebuild it, finds the by me realized wiring diagram in fig. 19.2.

It is true I did realize other designs, but technically the here shown design proved to be the most useful solution.

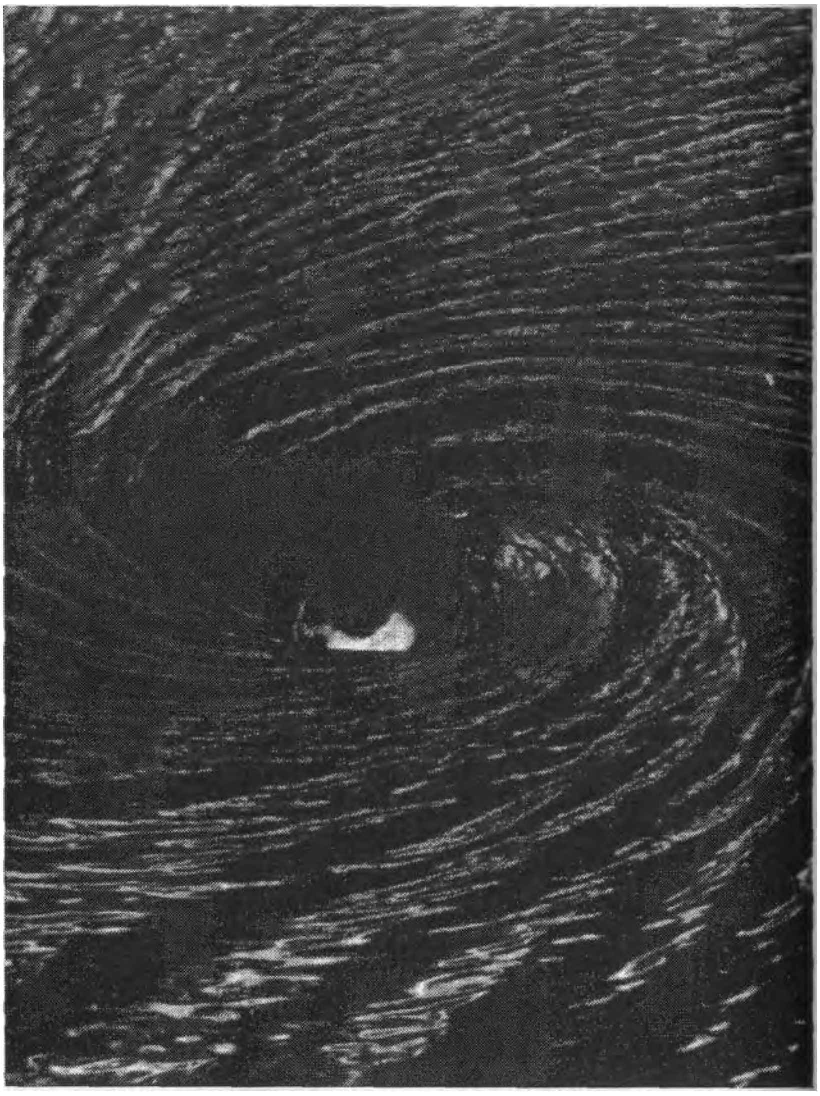

Fig. 19.3: The bath tub drain vortex;
shown is a tidal vortex near St. Malo.<i>

<i>: Photograph from the magazine „Life" of 4.7.1969, resp. from: H. J. Lugt: Wirbelstromung in Natur und Technik, Seite 371

19.3 Interpretation of the observations with the charge amplifier

The practical use of the device at first proved to be extremely difficult, because the pointer seemed to perform a wild dance. At a more close look I however could make exactly those observations, which I had sought-for as proof for the existence of potential vortices.

First I did find confirmed the known high field strength. We after all live between the ionosphere and earth's surface right in the middle of the dielectric of a "spherical capacitor". Because the values of the electric field reach very much closer to the maximum value, which is lethal for living beings, than the value of earth's magnetism, I did draw from that the conclusion that biological effects primarily can be expected from the E-field.

If the E-field, as Maxwell's field theory specifies, actually would be irrotational, then we would be dealing with a gradient field. My device would have to display everywhere to a large extent the same value. But that was not the case.

Maybe the building is responsible for the chaotic display and the wild swings of the pointer, so I thought. Doing so I had thought of the auxiliary explanations of the high-frequency engineer about so-called reflections in closed rooms. Therefore I stormed with the gauge, which had gone wild, into the open air and walked different ways, which should have been reflection free, but the picture stayed the same. In any case the E-field is not a gradient field. I had to find out.

Following I could, what required much patience, find certain places, at which for the same movement from the same direction could be seen a reproducibility of the swing of the pointer, it even could be arbitrarily often repeated. 1 marked the point exactly. Then I tried to move the device from another direction towards the marking and had to find out that the point had moved away.

If I sit in the bath tub in the evening and pull the plug, then I each time am enthusiastic about how sensitive the drain vortex reacts, how I can send it from one corner into the other by the snipping of a finger without it falling apart (fig. 19.3). Doing so one easily can imagine with a bit of phantasy how difficult, yes, almost impossible it would be to measuring technically register the vortex for the case that we could not see it. The gauge it is true would display violent wave movements. But a reproducibility we would not be able to obtain, exactly as for my self-built charge amplifier.

Now I knew that the by me at 2.1.1990 at first purely theoretical derived potential vortex actually exists as vortex of the electric field!

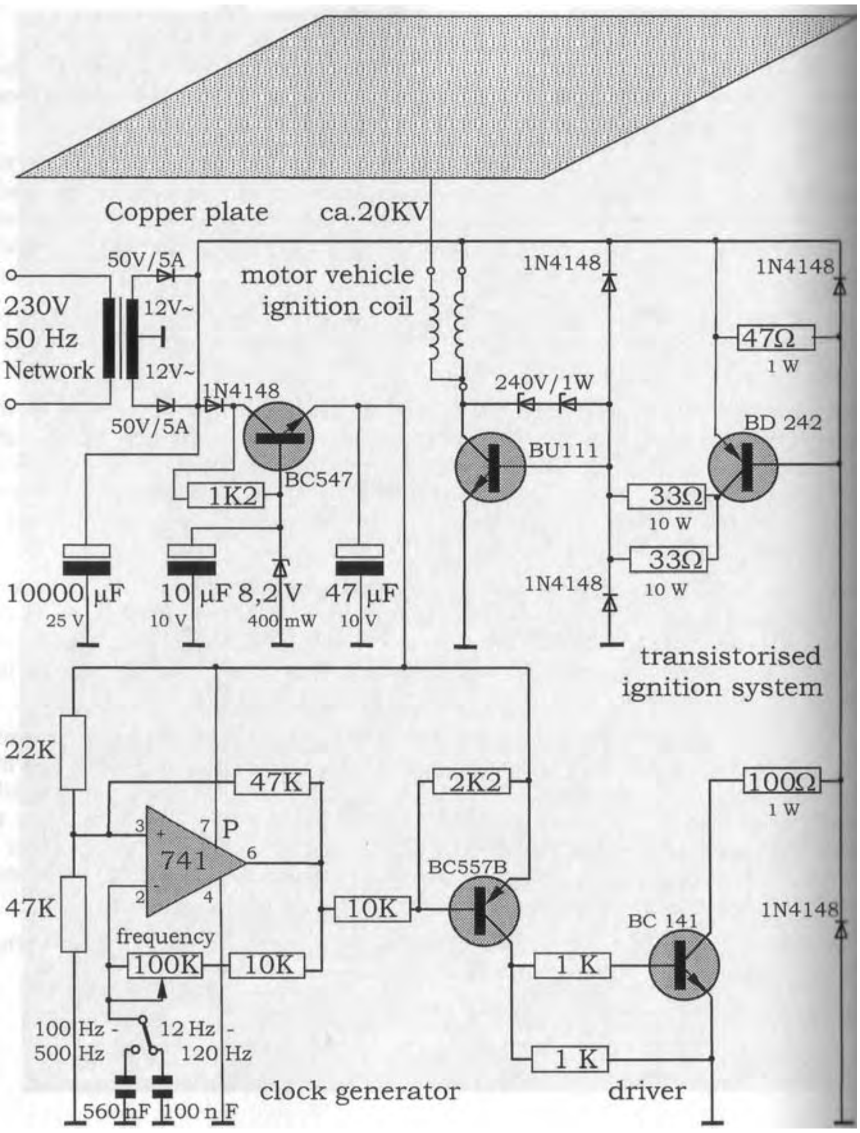
Copper plate
ca.20KV
50V/5A
230V
50 Hz
Network
12V~
12V~
50V/5A
motor vehicle
ignition coil
1N4148
BC547
1K2
10000 µF
25 V
10 µF
10 V
8,2 V
400 mW
47 µF
10 V
1N4148
240V/1W
BU111
1N4148
1N4148
47Ω
1 W
BD 242
33Ω
10 W
33Ω
10 W
1N4148
transistorised
ignition system
22K
47K
47K
3
7
P
+
741
6
-
2
4
2K2
BC557B
10K
frequency
100K
10K
100 Hz -
500 Hz
12 Hz -
120 Hz
560 nF
100 nF
clock generator
1 K
BC 141
1 K
driver
100Ω
1 W
1N4148

Fig. 19.4: Wiring diagram concerning the Kirlian device.<i>

<i>: Elektor, Fachzeitschrift fur Elektronik, Mai 1977, S. 22-25: KirlianfotogralV

19.4 High-tension experiments in the laboratory for performance electronics

At first the students of electronics, with which I had to do daily, were infected by my discovery. With true enthusiasm they soldered together one circuit after another. In my laboratory something like a mood of setting out could be felt. One student brought along and old ignition coil of a motor vehicle, then the control circuit for it was built, plexiglas organized, an aluminium plate glued under it and the whole box dragged into the photographical laboratory<i>. Three students made a detour along the outside grounds of the polytechnic and picked the necessary visual aids of trees and bushes.
Following the leafs were laid on photographical paper and by means of the self-built high-tension generator charged to 20000 Volt. Doing so at all edges and particularly at the tips of a leaf corona discharges arise, which expose the photographical paper. We then developed the photographs ourselves and discussed the results <ii>.

The indication, for a second photograph the whole leaf would appear even if half the leaf is torn apart after the first experiment and only one half is put on, occupied us in particular. Eventually we didn't put on a leaf at all in the second experiment and found out that nevertheless the leaf put on last became apparent on the photograph. Now only one physical interpretation was possible: The potential vortices of the leaf stimulated by high-tension still were in the plexiglas disc in weakened form! Here they swirl further and under high-tension furthermore produce corona discharge impulses.

Now also the students were convinced of the existence of the potential vortices.

This experiment stimulated the brain cells of the entire team: If potential vortices under high-tension cause electric blows, since the corona discharge is nothing else, then in this way the local vortex distribution in space should be measurable? One student immediately got down to work and build from the horizontal diversion unit of an old television a high-tension generator with an adjustable spark gap. Following he walked with his flashing and crashing device all through my laboratory and others walked with him and dragged the gauges behind them. But to their big disappointment they were not able to see an influence dependent on place.

Then it suddenly was clear for me: It would have done the students well, if they before would have had a bath and observed the drain vortex, "it suffices the famous wing stroke of a butterfly", I explained my team, "and instead come up with this infernal machine and chase away all the vortices, which we actually want to register ". We had to realize that as a rule phase of disillusionment follows the euphoria.

<i>: Klektor, Fachzeitschrift fur Elektronik, Mai 1977, S. 22-25: Kirlianfotografie; fig. 19.4 shows the wiring diagram and fig. 19.5 A the self-built device.

<ii>: The Kirlian photographs from the darkroom of the polytechnic are shown in fig. 3.6.

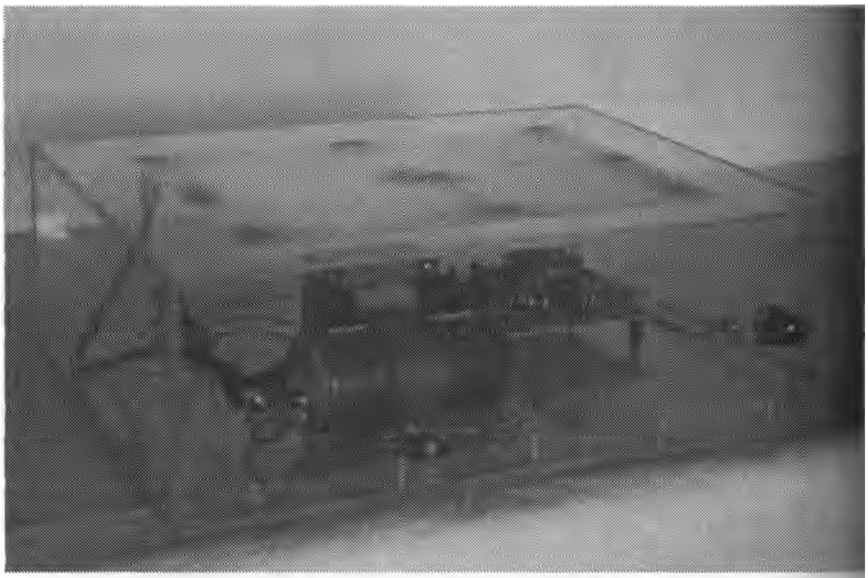

Fig. 19.5 A: A self-built high-tension device for Kirlian photography

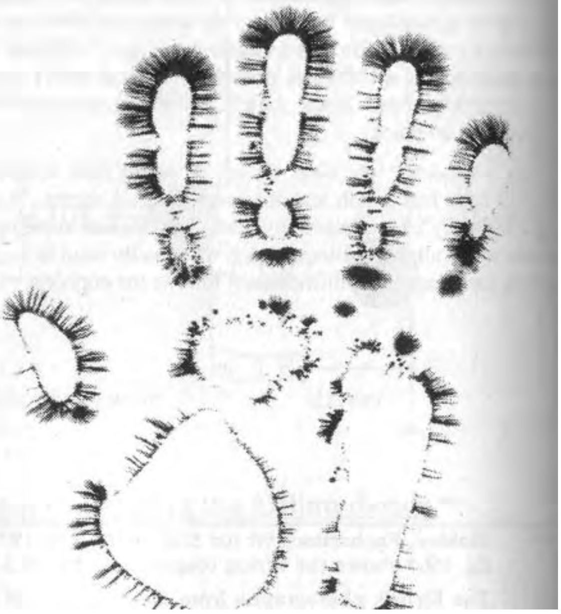

Fig. 19.5 B: Kirlian photograph of the right hand

19.5 Measurement of dielectric capacitor losses in the HF laboratory

My convincing work clearly was shaped more complicated with my professor colleagues. Most pretended to understand nothing about it and kept themselves out. But there also are exceptions. „something like that has never been there at our polytechnic, that a colleague puts forward an own field theory ",a physicist colleague remarked after my lecture public to the polytechnic<i> at 3.7.1990 and meant, that must be celebrated. He festively let me cast my eyes in his store room, got out a few bottles of wine, which then some of my colleagues of physics emptied with me in their official room. Doing so we small talked about the sense or nonsense to fix on the education of physics to the Coulomb charges.

The head of the high-frequency laboratory showed likewise impressed. At last he now knew, why capacitors at microwave frequencies can become so hot that they solder themselves out of the circuit by themselves and can fall out, why PVC-films can be welded with HF, etc. „We have to prove that not the dielectric is to blame, as stands in the textbooks" he came towards me.

At least following my idea potential vortices are the ones, as I expressed myself, which are behaving dual to the eddy currents. It concerns vortex losses, thus a physical phenomenon. Eddy currents now can be damped as is well-known, by for instance sheeting the iron circuit for engines and transformers. The insulation between the sheets prevents the formation of eddy currents in that direction and the degree of effectiveness increases.

"I would suggest", I told my colleagues, „to "sheet" a capacitor in a dual manner and to measure the losses". Because eddy current losses increase with the square of the frequancy, we picked microwave frequencies. In the HF-laboratory a card with an L-C resonant circuit was made, we should be able to quite precisely determine the losses by means of its quality. The inductance was formed as a microstrip line and for the capacitor a socket was planned.

The carrying out of the experiment consisted of using single layered ceramic capacitors, so called trapezium capacitors, with a vapour deposited silver coating on both sides as a package and to measure the quality of the resonant circuit as a measure for the dielectric losses. According to the rules of duality the dielectric (as nonconductor) thus corresponds to the permeable transformer sheet (conductor) and the silver coating (conductor) to the sheet insulation (nonconductor). In a second experiment the silver coating now was removed and the same capacitor material measured at identical conditions this time uncoated. Will the losses increase or isn't changing anything?

Tension and nervousness suddenly could be felt, even among the students, who followed the experiment from the second row. All looks were pointed at the monitor of the network analyser, on which slowly the bell-shaped curve of the measured resonant circuit quality became apparent. The result was surprisingly clear. I first looked at my colleagues and then at the students and had to realize that all eyes were pointed at me. The first measurement was a bull's eye! The vortex losses "uncoated" were considerably larger.

<i>: K. Meyl: Die mangelnde Dualitat der Maxwellschen Gleichungen with contributions concerning the theme of magnetic space poles, the mathematical calculation and the technical-physical interpretation of newly discovered potential vortices. Invited by the rector of the FH Furtwangen at 3.7.1990

- experiment 1: quality of resonant circuit with coated capacitors

from a series of 5 separate experiments averaged: Q = 48

- experiment 2: silver coating removed with diluted nitric acid

possibly the acid has damaged the dielectric: Q = 9

- experiment 3: silver coating polished off mechanically.

low quality means high dielectric losses! averaged: Q = 28

- resonance sharpness (quality number): $\boxed{Q = \frac{f_0}{\Delta f}}$ $\frac{\text{(Resonance frequency)}}{\text{(Resonance frequency rang}}$

at a resonance frequency f0 of approx. 400 MHz.

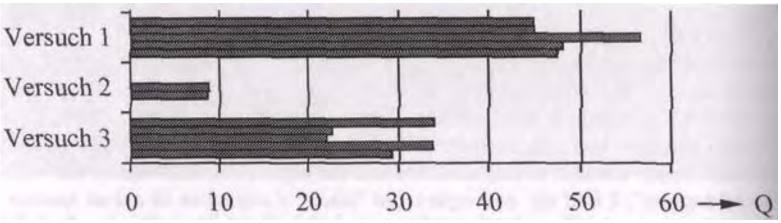

Quality number Q of the L-C resonant circuit

the dual ,,sheeted" capacitor has the lowest losses,
the resonant circuit with that the highest quality (experiment 1).

Fig. 19.6: Measurement of the dielectric capacitor losses over the quality of a resonant circuit in the HF laboratory at 11.06.1990.

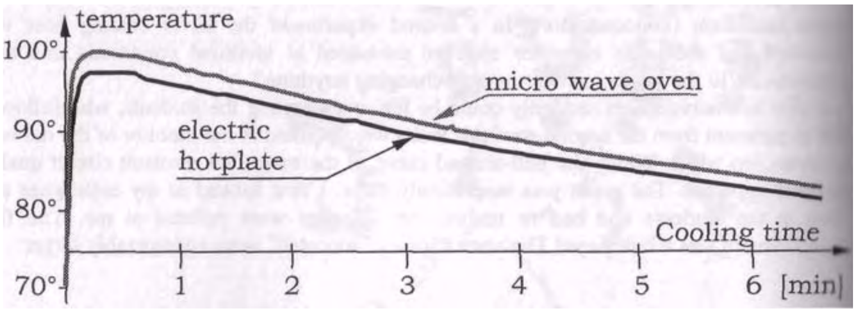

Fig. 19.7: Measurement curve of the water temperature over time
at 22.10.1996 in the electrical engineering training

Observation: for the microwave oven the container despite the "after cooking-effect"
remains colder than in the case of a hotplate. Sensor: PT 100.

19.6 Analysis of the measured capacitor losses

First of all the colleague spontaneously prompted a common publication.

But a certain disillusionment had to await us. For the next measurement hardly a differemce could be detected. We varied the contacting and removed the silver coating. once with hydrochloric acid, once with fine sandpaper. Every measurement we repeated umpteen times and in the end had to draw the conclusion that the results for our somewhat unprecise construction fluctuated extremely.

Averaged over all measurements and methods, indeed a reduction of the dielectric losses for alayered capacitor resulted, but at a critical consideration of the errors the results seemed to "drown" in the mean variation. In the opinion of my colleague the visible trend wasn't sufficient to convince dyed-in-the-wool sceptics, whereupon he withdrew with the indication, I should try at the people of microelectronics, they more likely would be capable to reproducibly gain control of a layered construction.

The experiment at least let a legitimate chance open that the vortices of the electric field actually exist, and in the case of the delectric losses of a capacitor it concerns vortex losses<i>.

19.7 Microwave oven for testing in the laboratory of electrical engineering

"Volunteers first" was said at 22.10.1996 in the electrical engineering practical training and two students got down to work. I had brought along from our kitchen the microwave oven, a portable immersion heater, a kitchen stove plate and different containers. In the laboratory of the polytechnic I in addition had got hold of a Bunsen burner. In the sense of the "Stiftung Warentest" (institution to protect consumers in Germany, note of the translator) it concerned the question for differences in heating water; or following the public discussion, is cooking with gas more healthy than cooking with the microwave oven?

We wanted to know. So we cooked water, filtered by inversion osmosis, once with the gas burner. once with the hotplate and finally with the microwave oven. Switched off always was at the same moment at the same temperature, and the cooling down curve was recorded with an x-t-time recorder (fig. 19.7).

Between gas and electric cooker virtually no difference could be detected, but the microwave oven at switching off still showed an odd temperature increase. I already had remarked this earlier. If one takes a water glass out of the microwave oven, then the water again really bubbled off, although the container itself had remained relatively cold. If one on the other hand takes a water pot off the gas cooker, the water suddenly stops cooking. From where comes this difference, which also the experiment could confirm?

<i>: A result of my dual way of looking at the vortex losses is the representation in fig. 4.7.

A: damped wave equation:

$$\Delta \mathbf{E}\, c^2 = \delta^2\mathbf{E}/\delta t^2 + (1/\tau)\cdot\delta\,\mathbf{E}/\delta t$$
$$(\text{wave}) + (\text{vortex})$$

B: open chain of reasoning in the physics of electromagnetism:

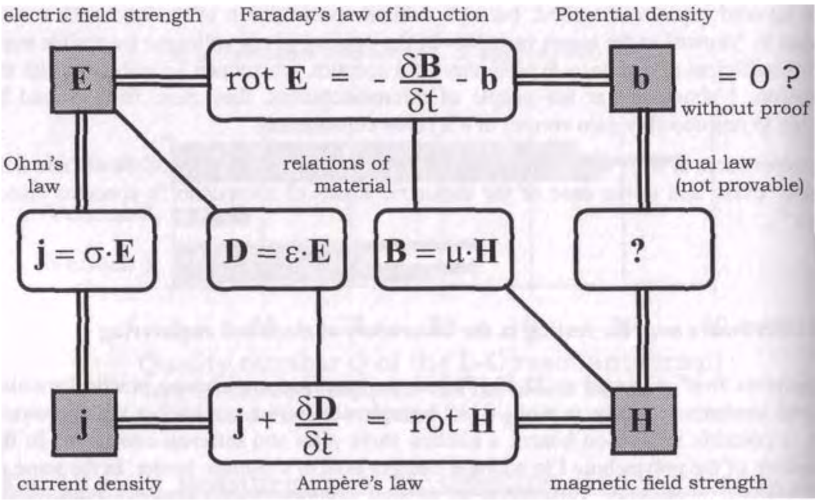
electric field strength
Faraday's law of induction
Potential density
E
rot E = - δB/δt - b
b
= 0 ?
without proof
Ohm's law
relations of material
dual law (not provable)
j = σ·E
D = ε·E
B = μ·H
?
j
j + δD/δt = rot H
H
current density
Ampère's law
magnetic field strength

C: for the stationary case $(\delta/\delta t = 0)$ in general representation:

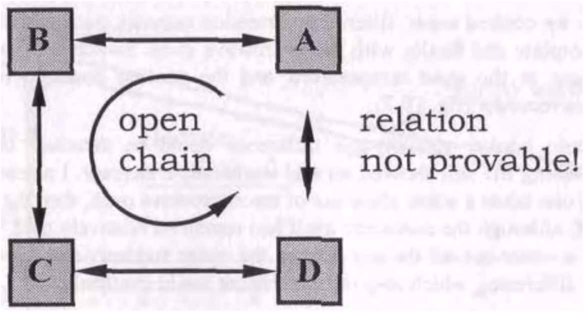
B
A
open chain
relation not provable!
C
D

Fig. 19.8: Contribution to the discussion about the impossibility, to prove, according to scientific methods, in a chain of reasoning (A-B-C-D) the last link (D-A), which closes the chain.

19.8 Microwave heating by decay of vortices

It has to concern a storing effect. In the case of an normal cooker the heat transfer takes place by convection. In the case of a microwave oven we however are dealing with an electromagnetic wave.

But in the wave equation nothing can be read about heat; here merely vortices can be found as a damping term (fig. 19.8 A)<i>! Therefore as the only possible interpretation is left that the microwaves roll up to vortices to fall apart themselves after a certain time.

Only at the vortex decay heat is formed.

The irradiated microwave power according to that is stored over a longer period of time as vortex in the water and the food. The vortex decay takes place according to an e-function with the calculated relaxation time constant tau<ii>.

From the circumstance that particularly water is heated up in the microwave oven despite the small electric conductivity but with high dielectricity, I infer that it has to concern mainly potential vortices, from which a biological effectiveness can be expected. The question if this should be valued positively or negatively, I have to leave up to the doctors and therapists. At least physically seen a difference is measurable. Thus a vortex decay will occur for a meal prepared in the microwave oven even if we already have consumed it.

Conclusion: I wish all: your health!

But what do I write about vortex losses, if every sceptic knows half a dozen alternative interpretations. Inevitably I have to bear in mind that also the eddy current heating owes its acknowledgement only the circumstance of the discovery of the corresponding laws. If Othm hadn't discovered his law and formulated it in the known form and instead the dual formulation would have been discovered, then we today would attribute the dielectric losses in a capacitor and in the microwave oven to the potential vortices, in the case of the transformer however the material would be responsible for the heating and not eddy currents, for which there then also wouldn't be a theory (fig. 19.8 B).

It actually is pure coincidence that at first Ohm's law and not the dual formulation had been discovered and acknowledged. But because both are equivalent, we also have to assume the correctness of both, even if the last link of a chain of reasoning A-B-C-D back from D to A in principle can't be proven anymore, since it already is explained by the chain A-B-C-D (fig. 19.8 C).

There I thus had discovered a potential vortex, without a possibility for a direct proof of existence. For that the textbooks are full with auxiliary explanations, with which physics successfully cheats past this important field phenomenon. I was frustrated. There had to be a way to measuring technically register the vortex in some way.

<i>: Fundamental field equation 15 in fig. 5.1 or equation 21, fig. 5.3

<ii>: Relaxation time constant: see equation 10 in fig. 5.1 or fig. 8.1

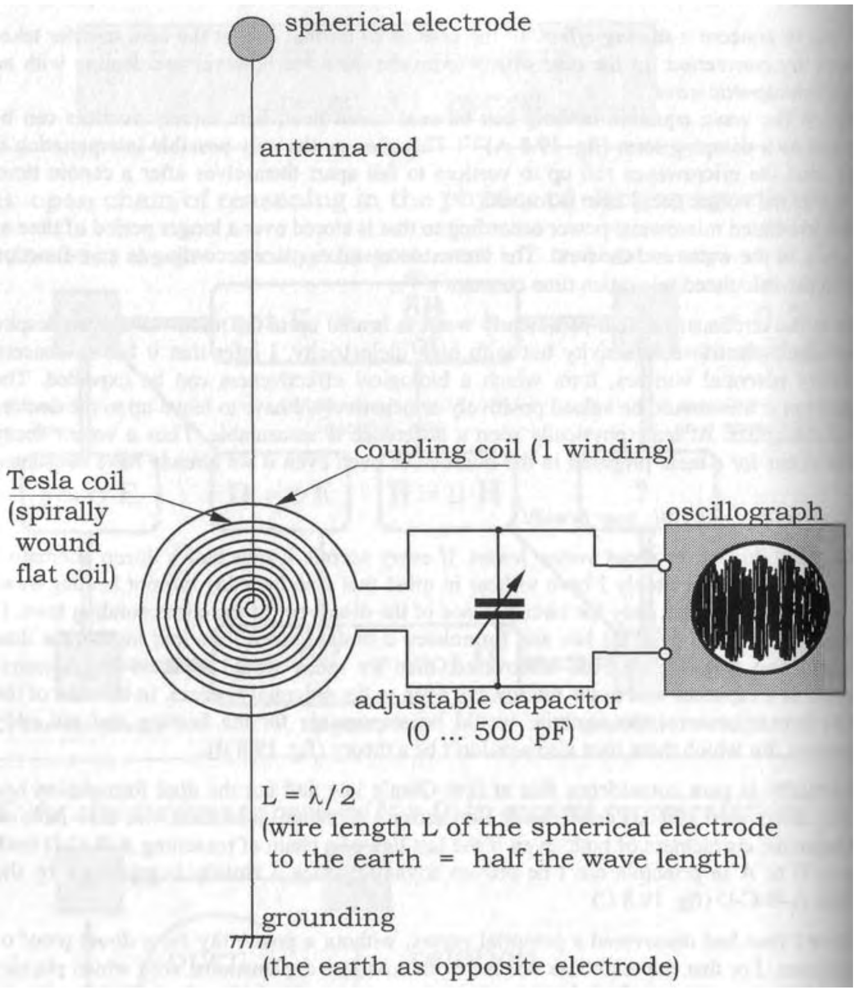
spherical electrode
antenna rod
coupling coil (1 winding)
Tesla coil
(spirally
wound
flat coil)
oscillograph
adjustable capacitor
(0 ... 500 pF)
L = λ/2
(wire length L of the spherical electrode
to the earth = half the wave length)
grounding
(the earth as opposite electrode)

Fig. 19.9: Proof of scalar waves with the Tesla coil.<i>

<i>: The inverse use for a high-tension transmitter according to fig. 9.1

19.9 The Tesla coil from the workshop of handicrafts

I again retired in my workshop of handicrafts and wound flat coils or I pondered in my study over Tesla books. 1995 from several sides my attention had been drawn to the circumstance that the inventions of Nikola Tesla can be organized in three categories:

The first third has made him world-famous. It concerns the rotary field theory, the asynchronous engine and the today normally used alternating current technology, which we owe him.

The second third concerns technologies and inventions, which were rediscovered by other people partly only years later or even were only pinched and distributed as novelty under another name. Electron microscope, superconduction, electrolyte capacitor, fluorescent lamp, fuse. coaxial cable and a lot more count among that.

The last third however concerns inventions, which until the day of today still aren't understood and await their scientific explanation and technological use. Tesla himself called these achievements his most important inventions, but still owes us a scientific explanation. The scientific world also hasn't got a theory ready and doesn't know to do anything with it. Public research doesn't take place or is prevented by lobbyists.

What remains, are tinkerers of various educational background and qualification, who are trying hurd to comprehend the buried experiments of Nikola Tesla off their own bat in the garage or in the hobby cellar.

I felt like one of these, by winding one winding after the next from the inside to the outside. Then I soldered an antenna wire at the inner end of the flat coil, which I in Tesla manner connected electrically with a spherical electrode hung up under the ceiling. The opposite electrode should be connected to the outer end of the winding, it is said, and the distance between both should be as big as possible. If namely an electrode just is collecting, then the opposite electrode is repelling the same space quanta. According to Tesla's recommendation I did use the earth as opposite electrode and for that tapped the central heating or the grounding of the foundations.

To take signals only one to two windings as secondary winding were necessary. I connected them with an adjustable air capacitor from an old steam radio to a frequency determining parallel resonant circuit and looked at the taken tension voltage at the oscillograph (fig. 19.9),

I still had problems with the statement of Tesla, the coupling had to be made loose. Thus the question is asked, how loose? I after that organized two toilet paper rolls of different size, (after the toilet paper had been used, naturally) and pushed them into each other. The smaller toilet paper roll carried on the gable-end the flat coil as primary winding of the air transformer and the bigger one the coupling coil. Now by shifting any wanted degree of coupling could be adjusted to (fig. 19.10).

I was astonished myself. Tesla actually was right with his discovery of the scalar waves. With my arrangement they can be clearly distinguished from the Hertzian waves.

The following procedure is recommended:

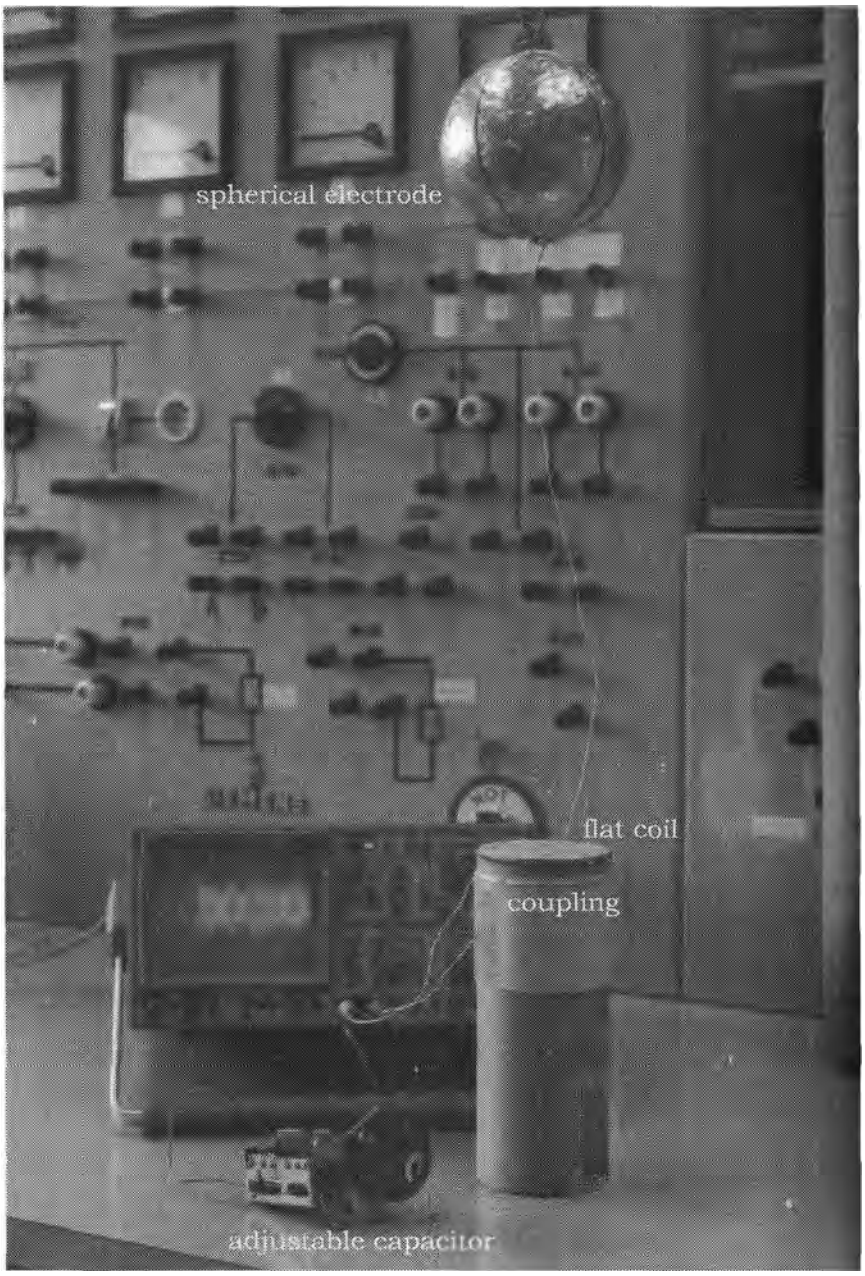
spherical electrode
flat coil
coupling
adjustable capacitor

Fig. 19.10: The experimental configuration

First of all I seek a source of interference with the adjustable capacitor and tune to maximum amplitude. Then I change the coupling and further optimise in this way. If now the amplitude again decreases from a certain point while approaching the coupling coil, then it concerns the sought-for longitudinal waves. If namely the coupling is too tight, then the received vortices again are driven away by the effect back on the fiat coil. They make way.
At last I had found a method to catch the vortices in such a way that they not immediately "ran away" from me again. At once I presented them in the technology centre in St. Georgen. In the time following I improved the technology further and further, used bigger toilet paper rolls and eventually even turn up garbage cans, I varied wire length, wire diameter and the sense of winding (fig. 19.10).

I had very different success. Sometimes, if at the same time in my workshop of handicrafts the radio worked, it would look as if the received signal would synchronize with the sound waves. Both are longitudinal waves after all. With transverse waves something like that would be unthinkable.
One moreover could observe, how a resonance builds up: first slowly and then faster and faster, so that I sometimes got terribly afraid. Several times we had to repair our oscillograph, after the protective diode at the input amplifier had blown, and that for signals of 50 to 100 millivolt!
That was entirely impossible. Only individual spikes, which were too fast to be seen at the screen, could be to blame. In the case of distant thunderstorm activity I obtained maximum values of more than half a Volt. After that I undamped the grounding as fast as possible, so that no lightning would be caught, since I didn't have the intention to burn off my workshop.

19.10 Biological effectiveness of the Tesla coil

Also the biogical effectiveness of the Tesla radiation I could impressively prove with this device. 14.06.1997 a woman, who called herself extremely electrosensitive, participated in the weekend seminar about electrobiology, which I took over from Prof. H.K. Konig (TU Munich) after his death. That I wanted to test.
I hung up my device in the lecture auditorium and installed the oscillograph in such a way that all could see it. The voluntary test subject however could see neither the public nor the screen. One person every 5 seconds said "now" and the female candidate should say, if I had clamped or undamped the grounding, if therefore scalar waves were received or not. After a training round her proportion of hits was lying at 100 percent!

According to her statement she could feel it. A further test subject achieved even at the back of the room with a pendulum the correct answer. I myself was surprised by this and I already have repeated this experiment several times with different success. It without doubt depends on the sensitiveness of the test subjects. Every person after all reacts to other signals.

What however has astonished all participants and can't be emphasized enough at all, is the circumstance that it in this case concerns a receiver and not a transmitter!

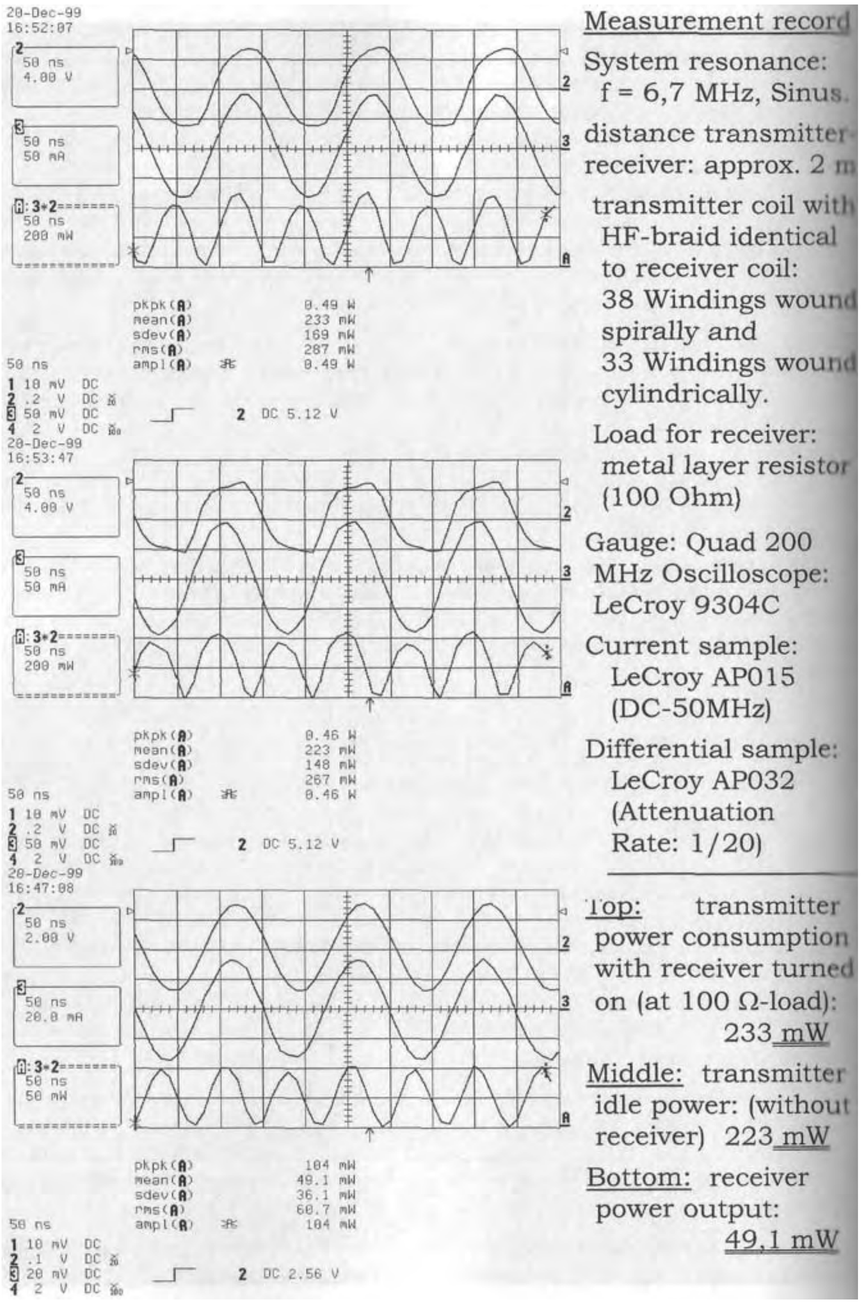

```
20-Dec-99
16:52:07
2  50 ns  4.00 V
3  50 ns  50 mA
A: 3*2  50 ns  200 mW

pkpk(A)          0.49 W
mean(A)          233 mW
sdev(A)          169 mW
rms(A)           287 mW
ampl(A)          0.49 W
50 ns
1 10 mV  DC
2 .2  V  DC
3 50 mV  DC
4  2  V  DC          2 DC 5.12 V

20-Dec-99
16:53:47
2  50 ns  4.00 V
3  50 ns  50 mA
A: 3*2  50 ns  200 mW

pkpk(A)          0.46 W
mean(A)          223 mW
sdev(A)          148 mW
rms(A)           267 mW
ampl(A)          0.46 W
50 ns
1 10 mV  DC
2 .2  V  DC
3 50 mV  DC
4  2  V  DC          2 DC 5.12 V

20-Dec-99
16:47:08
2  50 ns  2.00 V
3  50 ns  20.0 mA
A: 3*2  50 ns  50 mW

pkpk(A)          104 mW
mean(A)          49.1 mW
sdev(A)          36.1 mW
rms(A)           60.7 mW
ampl(A)          104 mW
50 ns
1 10 mV  DC
2 .1  V  DC
3 20 mV  DC
4  2  V  DC          2 DC 2.56 V
```

<u>Measurement record</u>

System resonance: f = 6,7 MHz, Sinus.

distance transmitter-receiver: approx. 2 m

transmitter coil with HF-braid identical to receiver coil: 38 Windings wound spirally and 33 Windings wound cylindrically.

Load for receiver: metal layer resistor (100 Ohm)

Gauge: Quad 200 MHz Oscilloscope: LeCroy 9304C

Current sample: LeCroy AP015 (DC-50MHz)

Differential sample: LeCroy AP032 (Attenuation Rate: 1/20)

<u>Top:</u> transmitter power consumption with receiver turned on (at 100 Ω-load): 233 <u>mW</u>

<u>Middle:</u> transmitter idle power: (without receiver) 223 <u>mW</u>

<u>Bottom:</u> receiver power output: <u>49,1 mW</u>

Fig. 19.11 A: Measurement record for scalar wave transmission line

19.11 Wrestling for measuring technical insight in the Transfer centre

In the central question who should be believed more, the famous experimental physicist Nikola Tesla or his critics, my experiments with the Tesla coil were the visible proof that we have to take Tesla's statements seriously. Now not only at myself, but also at the students of the polytechnic and the colleagues of my Transfer centre a true Tesla euphoria broke out.

In every free minute the patents and original writings were studied, which I had myself send from the Tesla Society in Colorado Springs in the USA. In particular my trainees and diplomands developed a incredible ambition in making a historical Tesla concept work. They built a whole series of various high-tension generators. In the laboratory one could hear crashing and there was a smell of ozone.

22.1.1998 at a presentation of the works for a degree the candidate looked after by me very proudly held a fluorescent lamp in his hand, which in the field of his self-built high-tension generator glowed even without any wire connected, entirely according to the great mode (fig. 17.10). At all efforts we however laboratory technical weren't able to reach tension voltages of above 511 000 Volt. But at this tension voltage the actual Tesla effects actually start!

Perhaps it was tough luck, but possibly also a chance that we in the laboratories, which I had at my disposal, were forced to work with lower tension voltages and that meant that we gradually had to beak away from the Tesla designs.

Moreover we hadn't at our disposal the precisely controllable spark gaps, which Tesla had developed and used. If one wants to obtain an if possible high tension voltage change (du/dt) for an interaction with neutrinos, then according to today's technology considerably more favourable concepts are offered, for instance with hard switching Power-MOS-Transistors. 50 Kilovolt per microsecond were to meet.

Therefore we changed the technology and worked from now on with fast semiconductor switches. From the laboratory radio now only a hissing and crashing came out of the loudspeaker, if our experiments were running.

At 12.10.1999 we for the first time succeeded to build up a transmission line for Tesla radiation. Doing so the transmitter and receiver were situated in different rooms of my transfer centre. The transmitter coil was operated in self-resonance and fed only from a small function generator with 10 Volt. But if the diplomand held a fluorescent lamp near the spherical electrode, then it started to glow!

Following I observed at the oscillograph the signal of the receiver coil, which as well was operated in resonance. If the diplomand switched off the transmitter, also no receiver singnal was present anymore. But if it concerned radio waves according to Hertz or Tesla radiation, with that still wasn't answered.

Therefore I prompted still another experiment. This time the colleagues observed at the transmitter the signal at the function generator, while I undamped and again clamped the receiver. The shouting with joy from the adjoining room indicated that it had been observed, how the receiver reacted upon the transmitter and both are in resonance with each other. Such an effect characteristic for scalar waves, is a radio technical impossibility! In the case of radio with Hertzian waves an effect back from the receiver on the transmitter is unthinkable by principle.

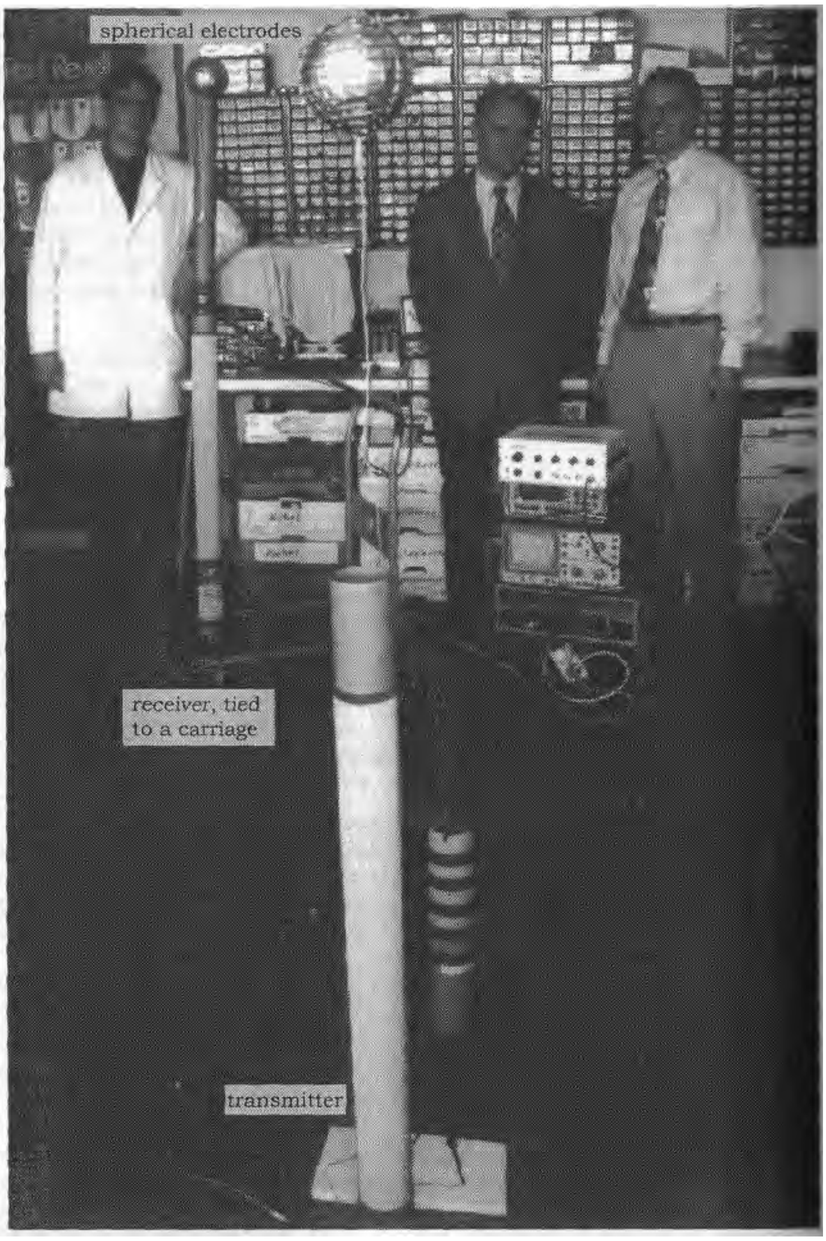
spherical electrodes
receiver, tied to a carriage
transmitter

Fig. 19.11 B: Scalar wave transmission line according to Tesla
f.l.tr.: M.Andresen (diplomand), author (TZ-head), Dipl.Ing.M.Rehm (project leader)

In the next step we let glow the famous little lamp on the side of the receiver. As a consumer served a small light-emitting diode, of which the light intensity remained unchanged in the case of resonance. To prove this, we placed the receiver on a carriage and rolled the corridor in the TZ up and down with it. If the receiver was only slightly out of tune, then from the then arising fluctuation the standing wave nature could be observed perfectly.

With the setup it can be demonstrated well, how the law of the square of the distance, of the decrease of the field strength with the square of the distance, known from radio technology hasn't got validity anymore for scalar waves. Very clear also was the energy transmission of scalar waves out of a closed Faraday cage.
In the end we have determined the degree of effectiveness of the scalar wave transmission line. An output power of 49 mW resulted from the measurements of the current and tension voltage for a loading of the receiver with a 100 Ohm resistance. Simultaneously the power taken up by the transmitter amounted to 233 mW. If we however subtract the idle power consumed by the transmitter from this, and that was determined to be 223 mW for switched off receiver, then actually only 10 mW are available for the wireless energy transmission. The degree of effectiveness according to that would be 490%!
If we here really have obtained an over-unity of 4.9 then the receiver must have collected along free space energy, or did some parts evade our power measurement? The sceptics I recommend an own rebuild, since alone the proof of the scalar wave properties inevitably has to lead to every Maxwell burdened HF technician breaking with the old belief.

19.12 Neutrinolysis, the alternative splitting of water

Free after the plans of Stan Meyer we filled diverse containers with water and let it "crash". If then bubbles raised and it got exciting, we changed the frequency and exactly paid attention to the effect remaining the same or if it increased as well with increasing frequency, thus if we only watched a classical electrolysis, or already the wanted "neutrinolyse", as we were accustomed to term the splitting of water in its parts under the influence of neutrinos in the laboratory. Typical for that is a bubbling and "cooking" of the actually cold water produced by the rising gas bubbles (fig. 19.12).

We also have reversed the principle. Doing so we have switched the container as neutrino receiver and measured the forming charge carriers. The passive system proved to be really moody. On the one hand tension voltages of several hundred millivolts at a load resistance of 10 megaohm can be realized, on the other hand the charged gas particles and the as secondary reaction in the water set free ions continually change the electric conductivity, so that the cause to be measured, the neutrino radiation, hardly can be reproduced on the displayed result. The water hence has to be changed more often and also the developers found themselves between jubilation and disillusionment subject to continually changing feelings.

<i>: A. und I. Schneider: Neutrino-Power - Energie aus dem Kosmos, Bericht zu Vortrag und Demonstration des Autors am 25.11.99 in Villingen, NET-Journal 12/99, S. 4-6; Interview mit Prof. Dr.-Ing. Konstantin Meyl: Durchbruch in der Freien-Energie-Forschung, NET-Journal 12/99, S. 7-9

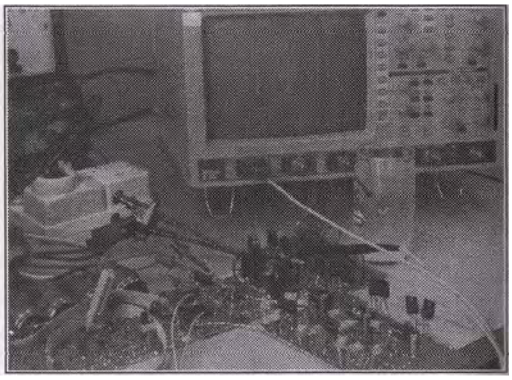

Fig. 19.12: Experimental constructions for the „neutrinolyse“.

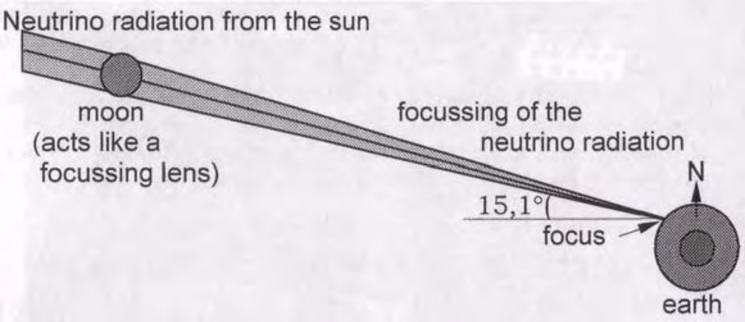
Neutrino radiation from the sun
moon
(acts like a
focussing lens)
focussing of the
neutrino radiation
N
15,1°
focus
earth

Fig. 20.1: Course of the neutrino radiation focussed by the moon on the occasion of the eclipse of the sun at the 11th August 1999.[i]

concerning the calculation of the position of the sun at 11.8.99:

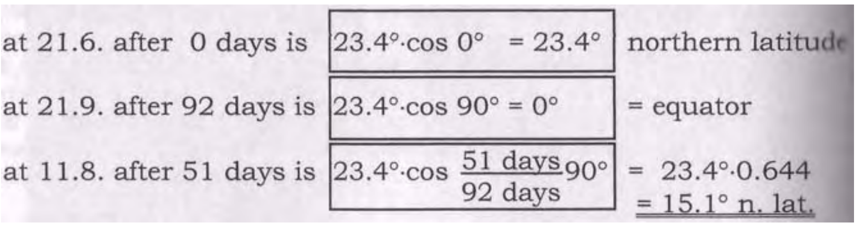

at 21.6. after 0 days is	23.4°·cos 0° = 23.4°	northern latitud
at 21.9. after 92 days is	23.4°·cos 90° = 0°	= equator
at 11.8. after 51 days is	$23.4°\cdot\cos \frac{51\ \text{days}}{92\ \text{days}} 90°$	= 23.4°·0.644 = 15.1° n. lat.

At 11.8.1999 the sun at noon stands above latitude 15.1.

---

[i] Konstantin Meyl: Zur Brennglaswirkung des Mondes bei einer Sonnen-

20. Cosmic experiments

As long as no usable technical gauges are available, we should observe and study nature and all celestial phenomena. Here the scalar waves with all their properties are presented to us. That is valid in particular for the case that the cosmos makes an experiment with us and with the entire earth. Such a situation offered the eclipse of the sun of August 11 1999 as an unique "bulk experiment" to which travelled millions of spectators, to participate in the cosmic experiment as voluntary test subjects.
My warning for possible influences proved to be absolutely justified afterwards, even if only comparatively few took note<i>. In view of strong changes in the EEG of individual test subjects and a proven temporary acceleration of the rotation of the earth science once more stands before insoluble problems.
To answer the open questions I want to start with my indications, which 1 have published in anticipation of the cosmic event of August 11<i>. Afterwards a revision and the attempt of an interpretation from the scalar wave view follows. Perhaps this way leads to a reliable prediction of of earthquakes and other cosmic events. After that we perhaps know more about origin, availability and further important parameters of the sought-for space energy.

20.1 Millions of voluntary test subjects at 11 August 1999

Astronomically seen, it concerns a harmless natural spectacle as it already was observed more often, if the moon glides between sun and earth and its shadow in broad daylight immerses parts of the earth in a dark night. The special thing about the eclipse of the sun of August 11 1999 however was, that the sun activity just strived for its maximum value in its eleven year cycle, and the orbital distance to the moon simultaneously reached a minimum value. In addition we must pay attention to the special situation of the angles (fig. 20.1). Due to the extremely rare constellation the area of complete shadow at first was larger and darker than normal. On August 11 it had a width of 110 kilometres.

The sun besides the light also sends us solar neutrinos and for those the moon is transparent. It with regard to them acts like a glass ball, which lets the light it is true pass through, but in doing so refracts it. The glass ball acts like a convex focussing lens, which focuses the arriving rays behind the ball in a focus.
To slow down and collect neutrinos the moon it is true is too small, but it will be able to influence the flying direction. Very fast neutrinos, which run through the moon, hardly will be diverted. The slow and biologically active ones however will be bent stronger.

At this point it would be of utmost importance to know, in which distance from the moon the rays run together and combine into a focus.

<i>: Konstantin Meyl: Zur Brennglaswirkung des Mondes bei einer Sonnenfinsternis, NET-Journal, Jg. 4, Heft Juli/August 1999, Seite 13-17

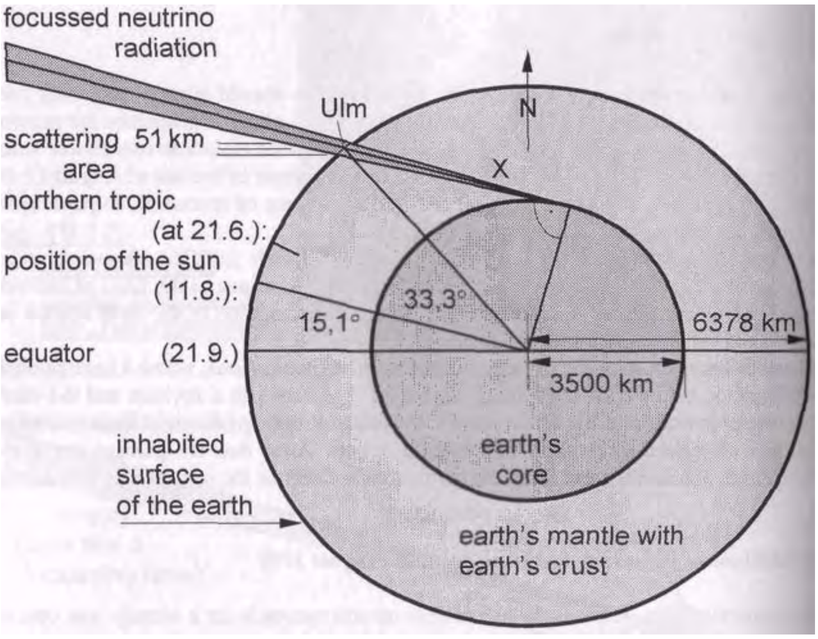
focussed neutrino radiation
Ulm
N
scattering 51 km area
X
northern tropic (at 21.6.):
position of the sun (11.8.):
33,3°
15,1°
6378 km
equator (21.9.)
3500 km
inhabited surface of the earth
earth's core
earth's mantle with earth's crust

Fig. 20.2:_____The course of the focussed neutrino radiation at 11.08.1999 for 48.4° northern latitude. (this corresponds to the line Ulm-Augsburg-Freising)

calculation of the critical latitude:

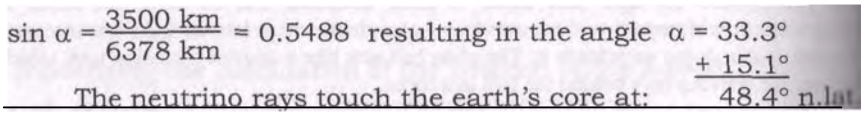

$\sin \alpha = \frac{3500 \text{ km}}{6378 \text{ km}} = 0.5488$ resulting in the angle $\alpha = 33.3°$

$+\ 15.1°$

The neutrino rays touch the earth's core at: 48.4° n.lat

minimum distance to the moon: $r_m^* = 358000$ km
radius of the moon: $R_m = 1738$ km
radius of the earth: $R = 6378$ km (at the equator)
length of the Tangente: $X = 3500 \text{ km}/\tan 33° = 5332$ km

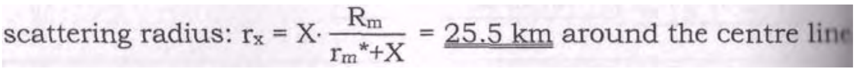

scattering radius: $r_x = X \cdot \frac{R_m}{r_m^* + X}$ = 25.5 km around the centre line

Focussing without scattering on earth's surface increase to
$R_m / r_x =$ 68 times , resp. with scattering to
68 * 0.5* 0.8 = 27 times the natural neutrino radiation!

For that we again bear in mind that neutrinos as particle radiation propagate in space in the sense of a plasma wave. Since the oscillation of such a longitudinal wave takes place in the direction of propagation, it neither knows a distinct velocity of propagation nor an upper limit.

The sea of neutrinos in which we swim, is a combination of differently fast particles. The slow ones are bent stronger by the moon, with the property of a convex focussing lens, so that the focus should be looked for near the moon, whereas the fast ones hardly are diverted. Their focus lies further distant from the moon than the earth, up to the extremely fast cosmic neutrinos, which experience almost no diversion, because they, as a result of the Lorentz contraktion, are small enough to tunnel through any kind of matter.

If neutrinos, depending on their velocity of propagation, have their focus partly before and partly behind the earth at an eclipse of the sun, then it comes up to a conclusive logic that there actually exist such, of which the focus lies exactly in the centre of the complete shadow on earth's surface. But thereby the question is asked, which biological effectiveness these neutrinos have or which damage they bring about.

20.2 Model of calculation for the cosmic experiment

More than a year ago the results of an international neutrino experiment have been made public. Thereby for the first time the order of magnitude of the natural radiation density was recorded. after the detector before having been calibrated at an artificial source of neutrinos. As the perhaps most important result at night only half as much solar neutrinos could be detected as during the day with the immense Super-Kamiokande detector in a Japanese mine. With that the here taken interpretation, that earth's core collects neutrinos, meanwhile even is proven experimentally! For that it has to interact with the particles and that means, it has to exert a force of attraction on them. Thus the earth's core during an eclipse of the sun will further amplify the effect of focussing if the konzentrierte neutrino ray is directed on earth's core. This critical point we have to calculate (fig. 20.2).

The proportion of the radii of earth's core (3500 km) and the entire earth (6378 km) results in the sine of the sought-for angle and that amounts to 33.3 degrees northern latitude. At August 11 moreover is added that at noon the sun with regard to the equator is standing at 15.1 degrees. so that a first extreme focussing should be expected, if the centre of the complete shadow intersects latitude 48.4. This would be the case for the latitude of Ulm in direction Augsburg and Freising.

Now we would like to know more about the amplitude of the focussed radiation, about the spatial extension and the period of time. Without concrete data material we have to proceed from several simplifying assumptions. If we therefore assume, 50% of the at earth arriving and biologically relevant neutrino radiation stems from the sun, which in the case of an eclipse of the sun is focussed to 80% and scattered to 20% by the moon. If we further assume the focus just touches earth's core, then between Ulm and Augsburg a sphere of action of 50 km can be expected, within which the neutrino radiation on the average reaches 28 times the value of the natural radiation. The intense irradiation under these assumptions will last one minute.

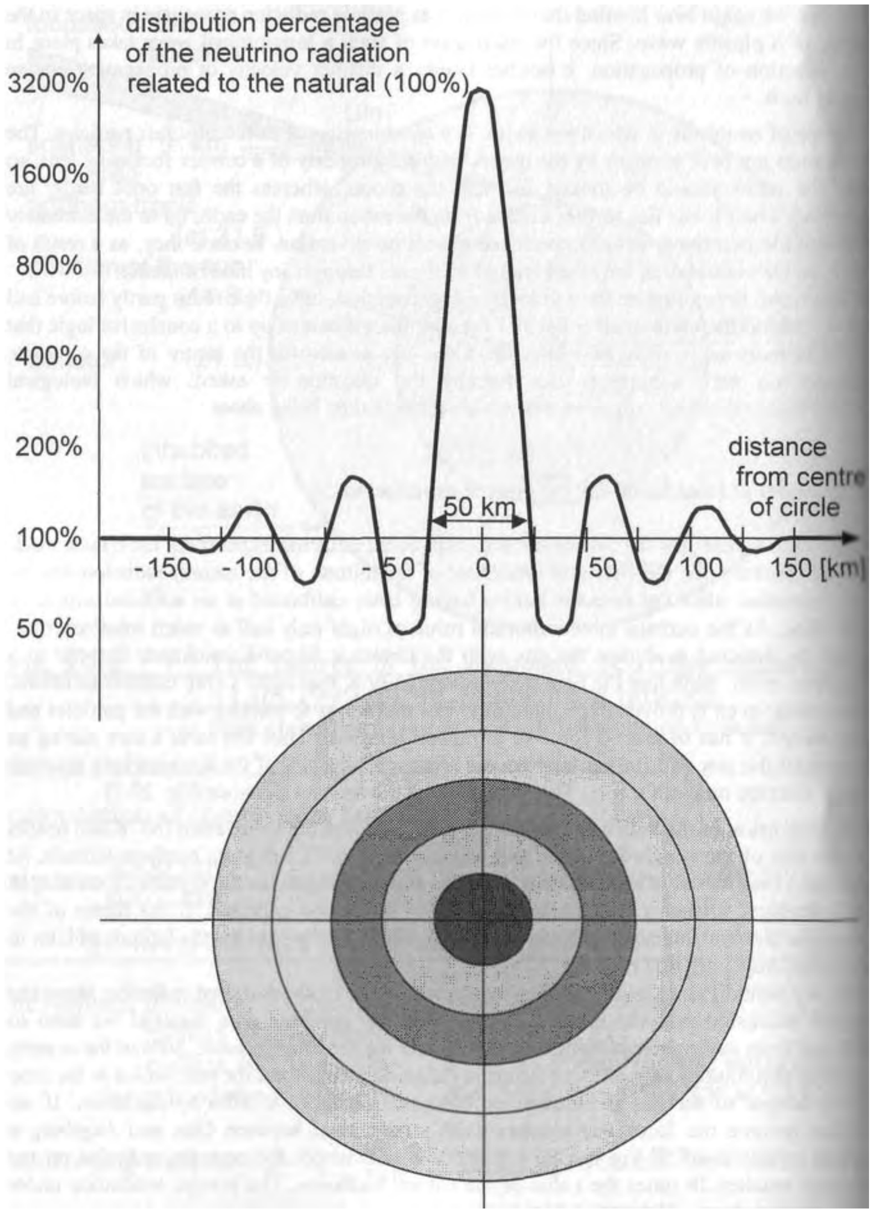

Fig. 20.3: ____ The spatial distribution in the case of focussing of the neutrino radiation by means of the burning glass effect of the moon on earth's surface.

Of course the calculated values only are valid to the extent, as also the assumed boundary values apply. After August 11 we know more about this cosmic experiment, about the spatial distribution and indirectly about the interaction with earth's core, about the physical properties and the biological effectiveness of the at present available neutrino radiation.

20.3 Physical technical consequences

The neutrino radiation is a scalar wave radiation which, as mentioned, can be perceived by sensitive people even without aids. Who hasn't at his disposal this sensitiveness, is recommended a simple setup.

For that one hangs up a fluorescent lamp, connects the one end with a piece of wire, as it were as antenna, and the other end is grounded. For a scalar wave radiation which increases fast, the lamp should start to glow by itself. Under big transmitting installations this method already has been successfully applied by many allotment gardeners thousandfold. I hence recommend all research scientists of eclipses to test themselves the possible field fluctuations in this simple way.

From a technical viewpoint first of all the atomic reactors and their nuclearly contaminated waste will be concerned by a fluctuation of the neutrino radiation. In view of present eclipses of the sun an accident can be expected less, since the neutrino radiation it is true for a short time reaches an extreme maximum, which averaged temporally and spatially over the whole event again is relativized somewhat. The relations shall be clarified with an example (fig. 20.3).

Whoever places himself in the centre line of the complete shadow on August 11, at first will detect a decrease of the neutrino radiation to 50 to 60 percent, then a steep increase to 2800 percent and from the summit again the whole backwards, while standing on the earth he turns by under the moving moon shadow. The ring with half the radiation, which reaches us first, doesn't pose a problem since, as said, we only have half the radiation in every night. Some animals and plants as aresult erroneously will set out for sleep.

The wave distribution one can imagine like that in the case of a pool, in which was thrown a stone. But we still don't know the resonance frequency, for which reason the length of the cycle depicted in fig. 20.3 is chosen arbitrary. The actual deviation from the distribution given by nature is the peak in the focussed ray centre. Living nature must stand large fluctuations of the solar radiation, since every supernova sends us a relatively short batch of fresh neutrinos. Where we have difficulties is the question, how much fluctuation still can be tolerated by mankind.

The question for possible biological consequences is due to be dealt with in view of the announcement of a complete shadow tourism causing concern, as it is awaited for August 11. At the incomplete state of knowledge about the properties of neutrinos, every trip to the complete shadow remains a journey into the unknown.

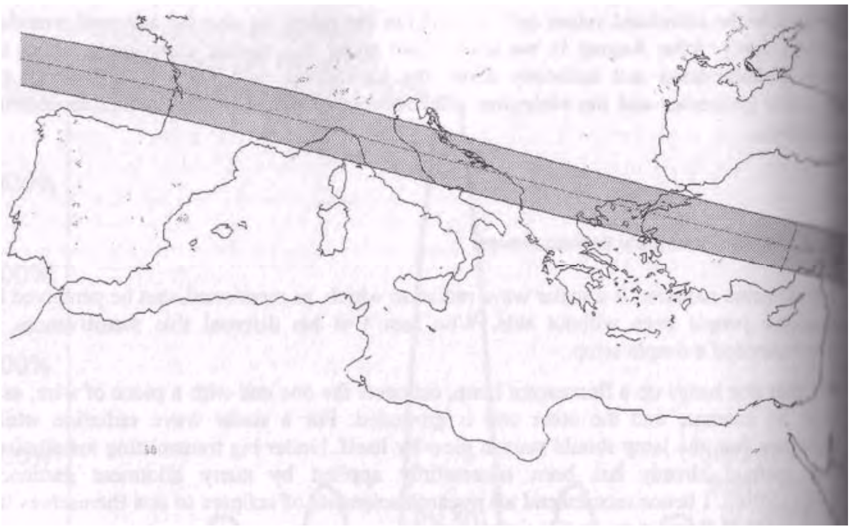

Fig. 20.4 A: The course of the complete shadow for the ancient eclipse of the sun at 28.5.585 B.C.

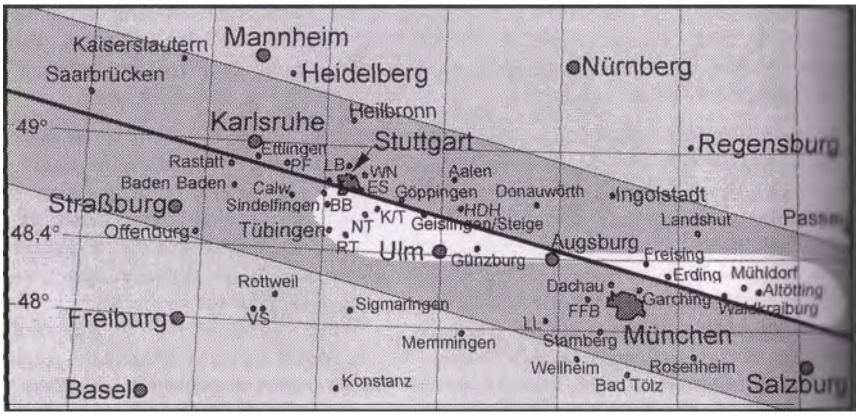
Kaiserslautern
Mannheim
Saarbrücken
Heidelberg
Nürnberg
Heilbronn
Karlsruhe
Stuttgart
49°
Regensburg
Ettlingen
Rastatt
PF
LB
WN
Aalen
Baden Baden
Calw
ES
Göppingen
Donauwörth
Ingolstadt
Straßburg
Sindelfingen
BB
HDH
Landshut
48,4°
Offenburg
Tübingen
NT
K/T
Geislingen/Steige
Augsburg
RT
Ulm
Günzburg
Freising
Erding
Mühldorf
Rottweil
Dachau
Altötting
48°
Garching
Waldkraiburg
Freiburg
VS
Sigmaringen
FFB
LL
München
Memmingen
Starnberg
Weilheim
Rosenheim
Bad Tölz
Basel
Konstanz
Salzburg

Fig. 20.4 B: The course of the complete shadow over south Germany at August 11 1999 (grey) and the possible course of the focussed neutrino radiation (white).

20.4 Biological consequences

In the case of an eclipse of the sun effects on the biology, like problems with the heart among affected, at least can't be excluded. If the scalar wave density increases above the density which is normal, then this has a positive effect on the economy of energy, as long as the body is capable to regulate the amount taken up. If the regulatory process however should fail. then the risk of a self-inflammation exists. Also straw bales and other organic and inflammable materials could thus go up in flames.

But before that happens, first the information technical influence of the scalar waves will show. Here we have to expect a psychotronic influencing, which is showing in a limited ability of perception. History teaches us as an example<i> that a by Thales of Milet predicted total eclipse of the sun at 28.5.585 B.C. compulsorily has ended a battle in Asia Minor between the Medes and the Lydians, because the soldiers apparently most literally had gone out of their mind (fig. 20.4 A).

Actually all in connexion with the free energy addressed phenomena are conceivable. from the "neutrinolyse" up to the acceleration of the radioactive decay. It would be understandable, if in a water glass bubbles should rise, even if no carbonic acid is contained in the water at all. After man not having at his disposal a sense organ for his own energy source, the brave in the complete shadow of an eclipse of the sun are recommended smaller technical experiments and observations. The cautious however will avoid the area from the start.

As counter movement to the complete shadow tourists there will also be refugees, who believe in the predictions of Nostradamus, who in his quatrains has predicted a messenger of fright over Europe for 11.8.1999. He mentions Lyon, Ulm and Moskau, which actually lie on one line<ii>.
The line of the complete shadow however will run under another angle from Plymouth in South England over Ulm to Bukarest and further into Turkey. Maybe Nostradamus wasn't a clairvoyant at all, but merely a good calculator, or he knew someone who could calculate excellently, after all he has indicated the time and even Ulm as the centre correctly. Apart from the small angle error, in addition the direction is correct (fig. 20.4 B).

Worth paying attention to also is, that he contrary to his habit here gives a concrete date which astronomically can be calculated unambiguously, that he simply skips the numerous eclipses of the sun of the past and only points to the one of 11.8.1999, which runs crossways through South Germany. Extremely sinister are his forecasts, which mustn't commented on further, since he speaks of "Mort et Tombe", of death and grave<ii>.

<i>: Merodot: Historien, Kroners Taschenausgabe 224, S. 33 (cf. page 586 and the modern misinterpretation note 9 on page 754); further sources: dtv-Atlas zur Weltgeschichte S. 45; resp. Propylaen-Weltgeschichte I, S. 168.

<ii>: Michel de Notredame (1503 bis 1566), Mathematiker, Astrologe, Leibarzt von Konig Karl IX: Centuries (1558) X, Vers 72.

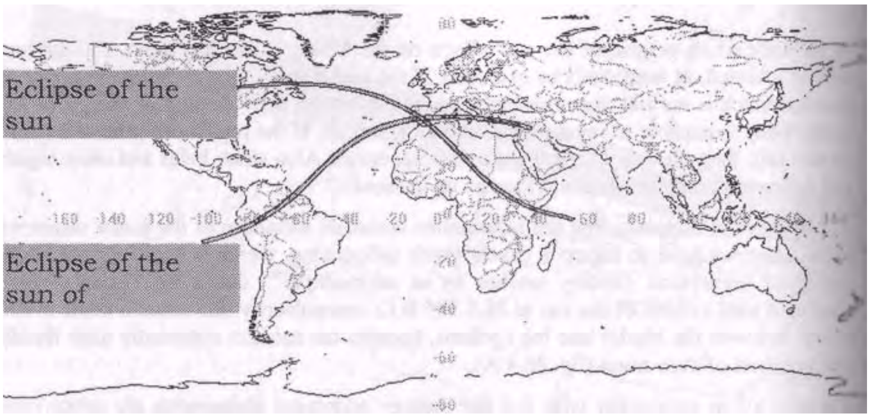

Fig. 20.5 A: The total eclipses of the sun of 18.4.1539 and
21.8.1560

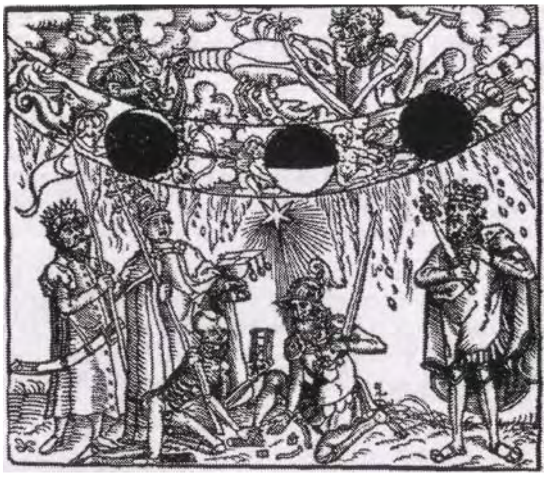

Fig. 20.5 B: Under the impression of the last two eclipses of the
sun over Europe death and war play dice about the fate of mankind during the eclipse of the sun of 1562.<i>

<i>: Werner Raffetseder: Sonnenfinsternis, Hugendubel Verlag, Munchen 1999, ISBN 3-89631-302-9, Seite 156.

20.5 Epilogue to August 11th 1999

My indications have been published two weeks before the cosmic event in the NET-Journal[i]. The public interest was immense. Now, after the spectacle is over, it is time for an analysis[ii].

Besides numerous very subjective descriptions of eyewitnesses, which scientifically hardly can be analysed, at numerous polytechnics over the world has been observed, how Foucault pendulums suddenly and completely unexpected have deviated from their normal swinging direction. With this device 150 years ago the rotation of the earth had been detected in Paris.
Since according to prevailing textbook opinion an eclipse of the sun is a purely optical phenomenon, the scientists world-wide are having a big problem. Which force here has teared at our earth and caused relative accelerations of the kind that the pendulums could turn out of their usual plane and changed into an elliptic orbit, while the shadow of the moon ran over us? The gravitational force isn't even roughly capable to that. That merely has brought a 50 cm higher flood. The enormous force effect, which even puts the gravitation in the shade, actually only can come from the interaction of the neutrinos.

Different reports are present concerning the influencing of the radioactivity. In the cases, in which measurement samples have been used, almost no change could be observed. This is confirmed by a video tape, which northeast of Munich directly in the centre of the complete shadow documents an experiment, in which during the whole time the radioactivity of 1 kg crude granite is monitored with a professional dosimeter. The background might be that calibrating samples are chosen in principle under the aspect of being influenced the least by outside interference sources. It therefore would have been better, if we instead had put a lettuce as a biological and broadband sample in front of the device. Because there, where one anyway hadn't expected deviations and thus neither were measured calibrating samples nor unfortunately were made recordings, is said to temporarily have occurred a visible increase.
Even in the case that somewhere accidentily should exist recordings, the increase is too small, to help explain traditions from the Middle Ages, according to which is talked about "stinking log" and about "aggressive damps, which fall from the sky". Other sources speak of harmful radiations, which one regarded as the trigger of plagues.
It is said: "They poison the drinking water and the crops and make people sick"[iii]. Crops after an eclipse of the sun either should not be harvested at all or only after a violent shower. The warnings for a poisoning "without adding poison", which reach back into the 19th century, suggest the assumption that it concerns results of a radioactive contamination.

<i>: Konstantin Meyl: Zur Brennglaswirkung des Mondes bei einer Sonnenfinsternis, NET-Journal, Jg.4, Heft Juli/August 1999, Seite 13-17

<ii>: From the third and extended edition of this second part concerning Electromagnetic Environmental Compatibility the following chapters are completed.

<iii>: Mark Littmann/Ken Willcox: Totality - Eclipses of the Sun, Honolulu 1991, Kapitel 4: Eclipses in Mythology; nachzulesen bei Werner Raffetseder: Sonnenfinsternis, Hugendubel Verlag, Munchen 1999, Seite 130/131.

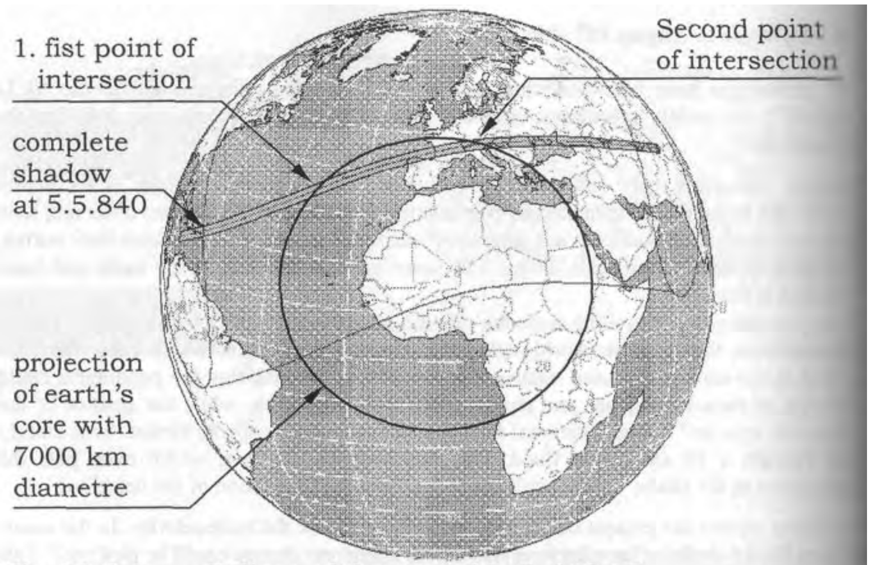
1. fist point of intersection
Second point of intersection
complete shadow at 5.5.840
projection of earth's core with 7000 km diametre

Fig. 20.6 A: Eclipse of the sun of 5. 5. 840 AD.

Fig. 20.6 B: Nostradamus announces catastrophes for 1999 in the Centuries of 1558.<i>

<i>: Bryan Brewer: Eclipse, Chapter 1: Eclipses Throughout the Ages, Seattle WA 1991, S. 20, cited in Werner Raffetseder: Sonnenfinsternis, Hugendubel Verlag, Munchen 1999, ISBN 3-89631-302-9, Seite 130, Bild Seite 159.

20.6 Dropping of the neutrino radiation

Plagues of that kind, which in the Middle Ages have claimed lives as a result of an eclipse of the sun, hardly are verifiable, unless a prominent victim was among them, like e.g. the son and successor of Charlemagne, emperor Ludwig I. He 5.5.840 witnessed an eclipse of the sun with a totality of five minutes. Further it is said: „The fright which this experience gave him, little later shall have torn him to death"<i>.

According to that there must have existed times, in which the radioactivity present in the countryside and stored in the body of a person during an eclipse of the sun could be set free and be the undoing of the affected. At the same time such a decontamination of radiation acts cleaning for nature.

In this case only the interpretation of Nikola Tesla provides us an explanation, which states that the neutrino radiation causes the radioactivity<ii>. Textbook physics however doesn't know this causality. For that the primeval fears of humanity are pure superstition. The prophesies of Nostradamus even are referred to as counter evidence.

But the question remains open, why his predictions concerning August 11 didn't happen, Obviously, so has shown us the cosmic experiment, the neutrino radiation relevant for the setting free of radioactive radiation drastically has decreased since the Middle Ages.

Nostradamus personally has occupied himself with the translation and interpretation of hieroglyphs and has written down his insights - surely out of fear of the inquisition - in the form of encoded quatrains. According to that he has based his considerations on considerably older sources, which presumably stemmed from a time, in which a considerably higher radiation prevailed.

We have to proceed from the assumption that the scientists of the Semitic- Aramean people of the Chaldeans, which ruled Babylon from 626 B.C., were just as capable as astronomers of today, to exactly calculate an eclipse of the sun even centuries and millenia in advance.

After all the Saros-cycle to determine eclipses of the sun is a discovery of the Chaldeans. What they however couldn't know and we ourselves still can't indicate today, is the prevailing density of the cosmic radiation at a future time. But that obviously has changed considerably.

The natural magnetic field strength for instance is recorded at the baking of earthenware jugs and vases, by strengthening along the parts containing magnetite. From the measurement of ancient earthenware goods we know that in antiquity a field strength must have prevailed which was 3 to 4 powers of ten higher.

According to the here presented theory the earth owes its magnetism its core and that again draws its energy from the neutrino field. According to that also the neutrino radiation should be subject to the same decrease.

If therefore the Babylonians out of the radiation situation at that time in the interpretation of Nostradamus and other fortune-tellers, who presumably all more or less have written each other off, have predicted a catastrophe for 11.8.99, then this scientifically is just as untenable, as the today widespread hubris, with which the knowledge and the reports of experience from ancient times are dismissed as superstition.

<ii>: cf. chapter 17.2 Nikola Tesla, the discoverer of the neutrino radiation, p. 133

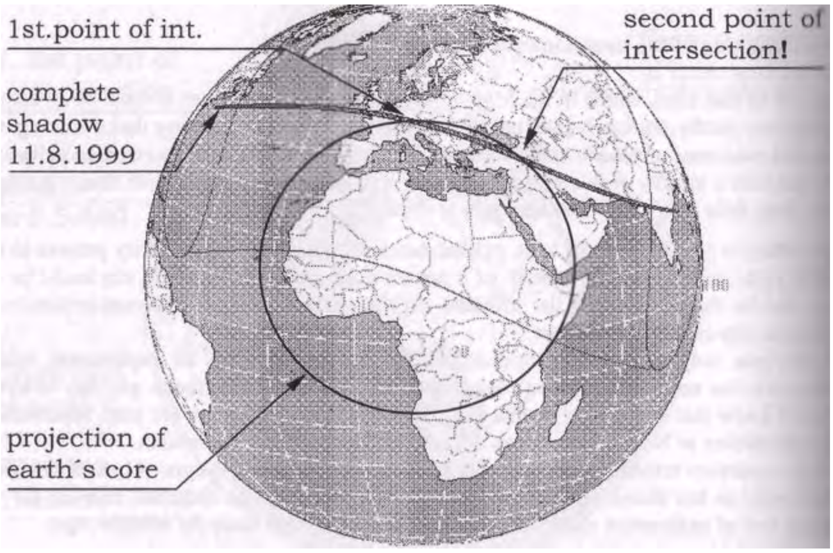
1st.point of int.
second point of intersection!
complete shadow 11.8.1999
projection of earth´s core

Fig. 20.7 A: Eclipse of the sun of 11.8.99 (declination: 15°)

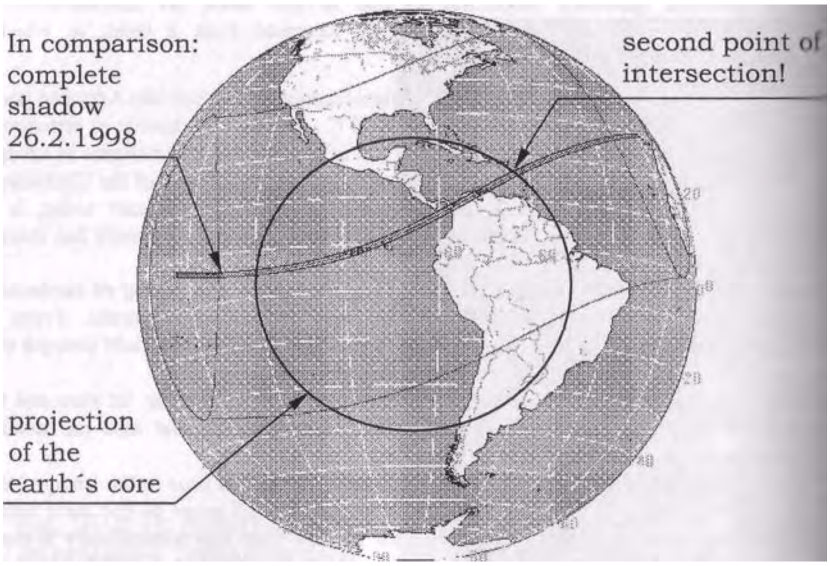
In comparison: complete shadow 26.2.1998
second point of intersection!
projection of the earth´s core

Fig. 20.7 B: Eclipse of the sun of 26.2.98 (declination: - 9°)

<ii>: Particularly violent earthquakes since 11.8.1999 (excerpt):
Turkey 17.8. (strength 7.8) till 19.8. (5,0), 31.8. (5.2), Greece 7.9. (5.8). Turkey 13.09. (5.8) and finally Taiwan 20.9.99 (strength 7.6) in a rythm of 6 to 7 days! Complete list in the internet under:
http://www-seismo.hannover.bgr.de/ermos_listing.html

This "superstition" mentions tremendous natural disasters like floods like the Flood or destructive earthquakes often as a direct result of an eclipse of the sun, and as the worst consequence the end of the world<i>.

Almost all reporters and newsreaders in the evening of August 11 full of irony pointed at the non-occurrence of the end of the world and spread the conviction that according to prevailing physical ideas something like that isn't possible at all. They at that time couldn't know that the anatolic plate, which the complete shadow had crossed, had gotten into motion. The relatively weak earthquakes, which 11.8. shook Cyprus and at the same time Iran, only were spontaneous harbringers.

In the following weeks the staggering core of the earth made us clear that there had been done force to it. Severe earthquakes with thousands of aftershocks followed each other and one message of terror chased the next<ii>. Public authorities however take care not to of decline to make a reference to the eclipse of the sun.

20.7 Analysis and comparison of the occurrences

If we for comparison consult the total eclipse of the sun of 26.2.1998, for which the complete shadow of the moon coming from the Pacific Ocean had run over the Caribbean into the Atlantic Ocean. Exactly the moment it crossed the Caribbean island Montserrat, the volcano Soufriere erupted.

Pure coincidence says science, which hasn't got an explanation model at all for a relation with the supposedly purely optical phenomenon. But this argumentation is relativized, if according to fig. 20.2 the tangential collecting of solar neutrinos by earth's core is considered. This process best can be compared with photon radiation, which is tangentially collected and directed into an orbit by a black hole inside the radius of Schwarzschild.

Since the shadow of the moon always draws a straight line on the earth, two points of intersection are present with the circle of the projection of earth's core on earth's surface, for which the radiation focussed by the moon just touches earth's core and in that way experiences an additional concentration. The first point of intersection at that time was situated in the Pacific Ocean; but the second one was situated exactly at the Caribbean island Montserrat (fig. 20.7 B).

This time, at August 11 1999 the first point of intersection was situated in South Germany, the second in Iran, and again the focussing at the second point of intersection has shown a devastating effect. The entire continental plate has gotten in motion (fig. 20.7 A).

Another strange phenomenon has occurred in the USA at the same time as the eclipse of the sun. A tornado swept with its destructive force right through Salt Lake City. It is remarkable that no meteorologic indications were showing before and hence official observation authorities had no possibility of warning for the tornado. Had here part of the focussed neutrino radiation been redirected at earth's core and given a rotation, to again screw out into the sky on the other side of the earth at Salt Lake City?

<i>: Werner Raffetseder: Sonnenfinsternis, Hugendubel Verlag, Miinchen 1999, ISBN 3-89631-302-9, Seite 120.

<ii>: Collection of particular violent earthquakes since 11.8.1999: see fig. 20.7.

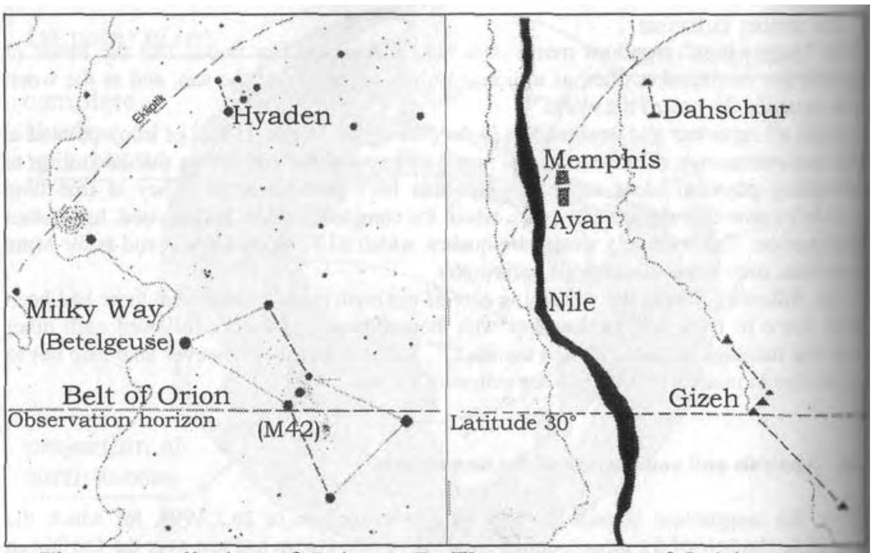
Ekliptik
Hyaden
Milky Way
(Betelgeuse)
Belt of Orion
Observation horizon
(M42)
Dahschur
Memphis
Ayan
Nile
Gizeh
Latitude 30°

A: The constellation of Orion B: The sanctuary of Osiris

Fig. 20.8 A and B: The ancient Egypt pyramids, a terrestria model and copy of the starry sky?<i>

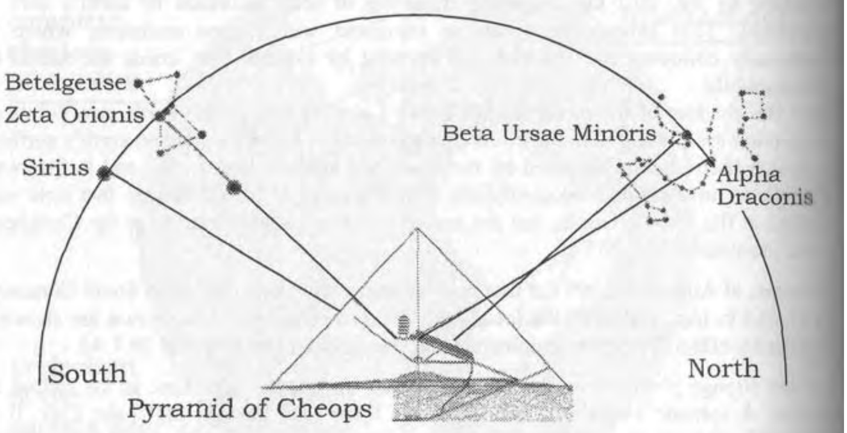
Betelgeuse
Zeta Orionis
Sirius
Beta Ursae Minoris
Alpha
Draconis
South
North
Pyramid of Cheops

Fig. 20.8 C: The orientation of the four shafts of the Pyramid o Cheops to four different stars around the yea 2500 B.C.<ii>

<i>: Robert Bauval, Graham Hancock: Der Schlussel zur Sphinx (Keeper of Genesis), List Verlag Munchen 1996, ISBN 3-471-77188-3, S. 286 und 287.

<ii>: dito page 86.

20.8 Radioactive decontamination with the help of a supernova

A mighty source of neutrinos forms the black hole in the centre of the Milky Way. For us, on an outer spiral arm of the galaxy, the distance to the centre is gigantic as well, so that a relatively equally distributed spectrum of differently fast neutrinos arrives at our world, which represents a kind of basic energy technical supply for the solar system and our world. For the fluctuations between day and night, or the focussing by the moon or other planets the "participants" in the solar system are responsible themselves.

In contrast to that a supernova, the explosion of a star, is a considerably smaller source of neutrinos, which however also is possible less distant to the earth. In addition it is a singular event, in which all neutrinos are set free simultaneously within a fraction of a second. They arrive at us one after another. First the fast and hard radiation reaches us as it were as harbringer. In the course of time the arriving neutrinos then become slower and shower, until they sometime become biologically relevant. If in the end everything is over, we can see the cause, only now the supernova is showing in the telescope.

If we assume such an event takes place, with perceptible might and in a distance of 500 light years. then this neutrino radiation overlaps with the general background radiation and a characteristic over-intensification of neutrinos of a certain velocity of propagation occurs. This problem then occupies us for 500 years, where the respective radiation situation permanently is changing depending on the time after the explosion.

If we in this way of looking dare a judgement of the cosmic events in historical time, so makes believe much the assumption that the radiation in the last hundred years has worn of completely. Edgar Cayce treats in the book "Our Ancestors" different cultural circles from the old Indian up to the Hopi, in which still is talked about an energy technical use of quartzes and other materials<i>.

We indeed can theoretically comprehend that the neutrino radiation can let an oscillating quartz glow, if it is stimulated in its resonance frequency, but technically the technology foday can't be realized anymore. Possibly the chance for technological use only existed for a few years or decades.

Presumably also the pyramids originally have been built as resonators, to slow down fast neutrinos to a technically utilizable speed. But in the course of time the original function was unnecessary and the neutrinos had gotten so slow that in antiquity alternatively an use as electrostatic lightning generator or as Nekropolis took place. Today they only stand in the countryside as unusable monuments of a gone epoch.

Many ancient techniques, to which I will come to speak in the third part, in this way just as unexpected become plausible as the radioactive decontamination described in the Middle Ages.

<i>: Hermann Wild: Technologien von gestern, Chancen fur morgen; Jupiter-Verlag Bern 1996, ISBN 3-906571-13-0, (z.B. S. 77 und 145 bis 163).

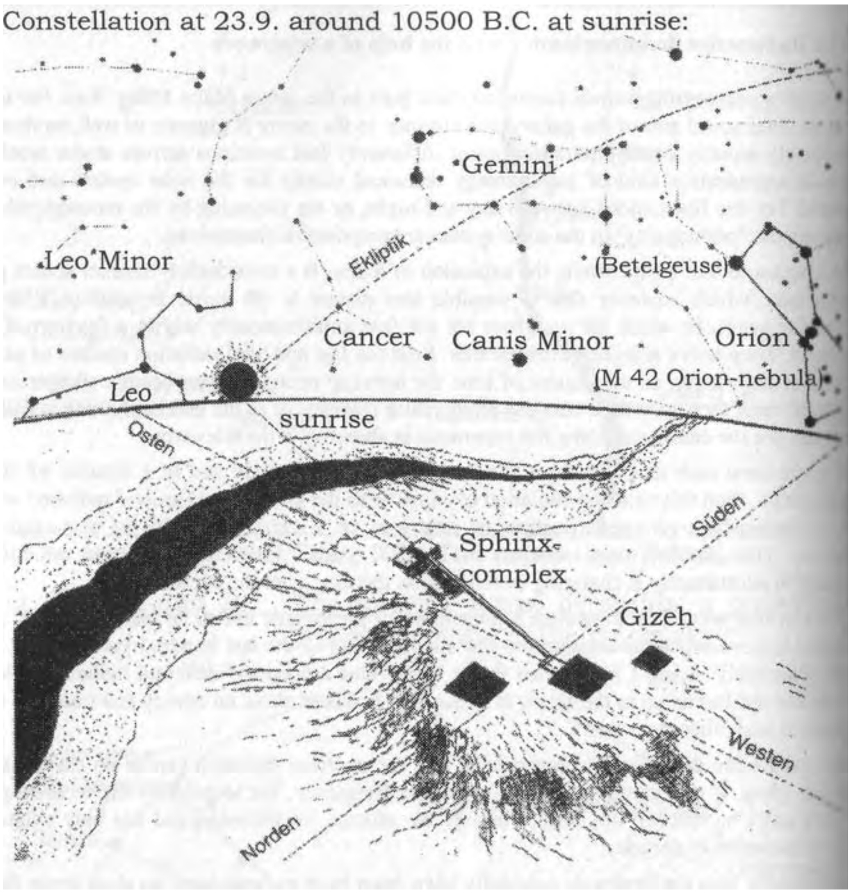
Constellation at 23.9. around 10500 B.C. at sunrise:
Gemini
Leo Minor
Ekliptik
(Betelgeuse)
Cancer
Canis Minor
Orion
(M 42 Orion-nebula)
Leo
sunrise
Osten
Süden
Sphinx-complex
Gizeh
Westen
Norden

Fig. 20.9: The orientation of the pyramids of Giza makes believe
an operation of the installation around 10500 B.C.<i>

<i>: Robert Bauval, Graham Hancock: Der Schlussel zur Sphinx (Keeper of Genesis), List Verlag Munchen 1996, ISBN 3-471-77188-3, S. 324.

The two research scientists take the hypothesis of an orientation of the ancient Egypt pyramids after the starry sky around 10500 B.C. This however is not compatible with their thesis of the aligning of the shafts to individual stars around 2500 B.C. (fig. 20.8 C). How should the precise worked shafts later have been integrated? It would correspond a certain logic, if an orientation of the buildings to the energy source at that time would have taken place; but doing so it should be taken into consideration that the stars are exploded as supernovae and today hardly might be observable.

Despite several good ideas more questions are raised by the book, than are answered. Have the technicians 2500 B.C., after making restorations, experimented with the buildings and sought-for alternatives of use?

20.9 Fre energy from the Orion constellation

After all hundred years ago still the last unreliable rests of the wearing off neutrino radiation were available to Tesla, Moray, Keely and other inventors for the experimental proof of free energy, of which we today aren't able to rebuild and show in function one single model. And that, although the technical aids have gotten better for many times. But for the free energy inventors that isn't a reason, to immediately stop their efforts, because the next supernova already is announced by the actual swings of the Foucault pendulum. It could concern the explosion of the giant red star Betelgeuse in the constellation of Orion in a distance of 500 light years[i]. It well may be possible that it already shortly has exploded and that it will supply us with fresh and free energy for scarcely the next 500 years and at the same time will give the earth a good shake, thanks to its might and a not too great distance.
The reaction, which happened after August 11, of earth's core, which is the first to interact with the fast particles, should make every astrophysicist clear that here something is coming towards us!
It would be obvious, if the reactions of earth's core still increase. Every year particularly around 21.6., if the sun is standing in the Orion constellation, deviations can be expected. But then the supposed source of neutrinos, Betelgeuse, the sun and the earth don't exactly form a line, because the giant red star lies 7.4° below the ecliptic. Because of that the rays slowed down and focussed by the sun run away over the earth. At the earth then rather would be expected a dropping of the radiation.
If the phase of shakes of the earth sometime should be over, a decontamination due to an increased radioactive decay and various biological effects should be expected. Then, perhaps in 200 years, also many concepts concerning free energy, today still dismissed as hopeless, suddenly will function entirely by themselves.

The relatively free possibility of development of the human mind and the present sciences we possibly owe the special circumstance to be able to live in a time of minimized field strengths. Strong fields however can lead to psychotronic influencing of the consciousness and to an outside determining of mankind. This circumstance seems to have caused Tesla to compare man with a robot, and to call him an independent machine controlled from outside[ii].

<i>: Freek Reijmerink: Sternenatlas Deutschland, Weltbild Verlag 1990, S.12 (ein sterbender Riese) und Illustrierte Wissenschaft, Nr. 9, 1999, S. 7, Brennen die grossen Sterne in den Sternbildern je aus? Die Entfernungsangaben schwanken zwischen 270 Lichtjahren (Meyers Lexikon), 310 (Sternenatlas), 500 (Ill.Wiss.) und 652 Lichtjahren (Cambridge Enzyklopadie d. Astronomie).

In the observable domain of the starry sky one statistically seen has the chance, to experience every second a supernova.

<ii>: Nikola Tesla: How cosmic forces shape our destinies, New York American, 7.2.1917, and Edition Tesla (1997), Bd. 6, ISBN 3-89539-245-6 der Mensch als machine, S. 65.

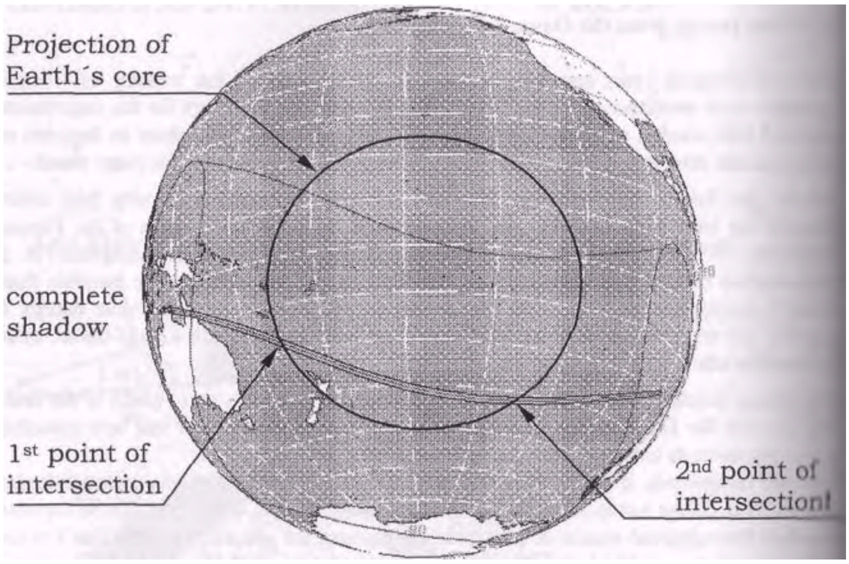
Projection of
Earth´s core
complete
shadow
1st point of
intersection
2nd point of
intersection

Fig. 20.10 A: Eclipse of the sun of 13.11.2012 (decl.: 18.1°)

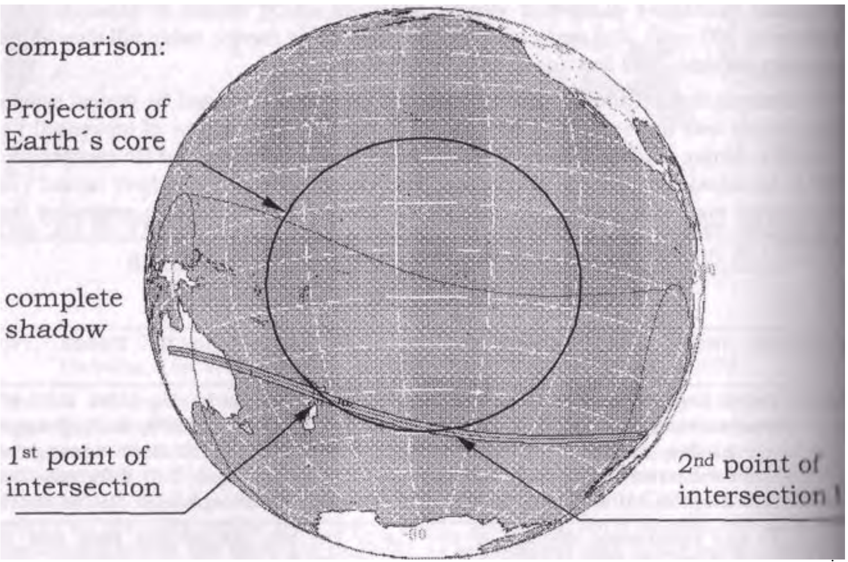
comparison:
Projection of
Earth´s core
complete
shadow
1st point of
intersection
2nd point of
intersection

Fig. 20.10 B: Eclipse of the sun of 11.11.3799 (decl.: -17.3°).<i>

<i>: The eclipse of the sun of 7.7.3797 is harmless compared to that of 11.11.3799. Have they been mixed up or is a calculation error present?

20.10 Interaction of the neutrinos with earth's core

A strong neutrino field still doesn't make a catastrophe. Only in connection with one of the regularly happening eclipses of the sun should one be expected under certain circumstances. Only, which eclipses of the sun can get dangerous, we have to ask us, and why warns e.g. Nostradamus only for very particular dates?
The check of the respective eclipses of the sun results in a critical constellation every time for the cases, where the line of the complete shadow and the circle of the projection of earth's core intersect under a very flat angle and both points of intersection lie very close together. In the extreme case finally the lines only are touching and the points of intersection fuse to a line of intersection.
A corresponding constellation the next time is expected at 13.11.2012. For 7.7.3797, at similar conditions Nostradamus foretells the end of the world; but why?

From the interaction of the neutrinos arises as from every other interaction a force effect.
If the points of intersection lie far apart, then earth's core is pulled once to the East and a short time later again to the West by the focussed neutrino radiation. On the average this will hardly influence earth's mantle and earth's crust because of the immense moment of interia. The possible earthquakes will remain regionally restricted to the area around the two points of intersection.
But if a line of intersection forms, then no compensation of the force effects takes place anymore, then during the whole time one-sided is pulled at earth's core and that can have fatal results. It is the same as for a spinning top, which is given a blow from the side: it staggers several times, until the gyroscopic forces have stabilized it again.

But if earth's axis staggers, then the sun describes strange orbits in the sky, it goes backwards again, for a longer time doesn't set or it doesn't show for the same period of time for the people living on the other side of the globe.
Such an event already is described in the Bible<i>. For the twenty hours, in which in Europe the sun didn't set for a day, again describe the chroniclers of the inhabitants in the South American Andes, how at their place the sun didn't show for twenty hours<ii>.

As a further example from the Greek mythology is mentioned the description of the poet Apollodoros. according to whom Hercules for the solution of his 10th task let the chariot of the sun bring to a standstill. "He turned his vehicle round and raced the way back, dragging along the Pleiaden and all stars, so that the sun set in the East"<iii>. But if all stars take part in the same backwards motion, then this example proves the assumption of the staggering earth's axis.

<i>: Josua 10.13-14 and the in chapter 11.8 cited passages.

<ii>: nach Montesinos, zitiert in Zecharia Sitchin: The Lost Realms (Versunkene Reiche), Knaur Verlag Miinchen 1992, ISBN 3-426-04827-2, S. 203

<iii>: Werner Raffetseder: Sonnenfinsternis, Hugendubel Verlag, Milnchen 1999, ISBN 3-89631-302-9, Seite 18.

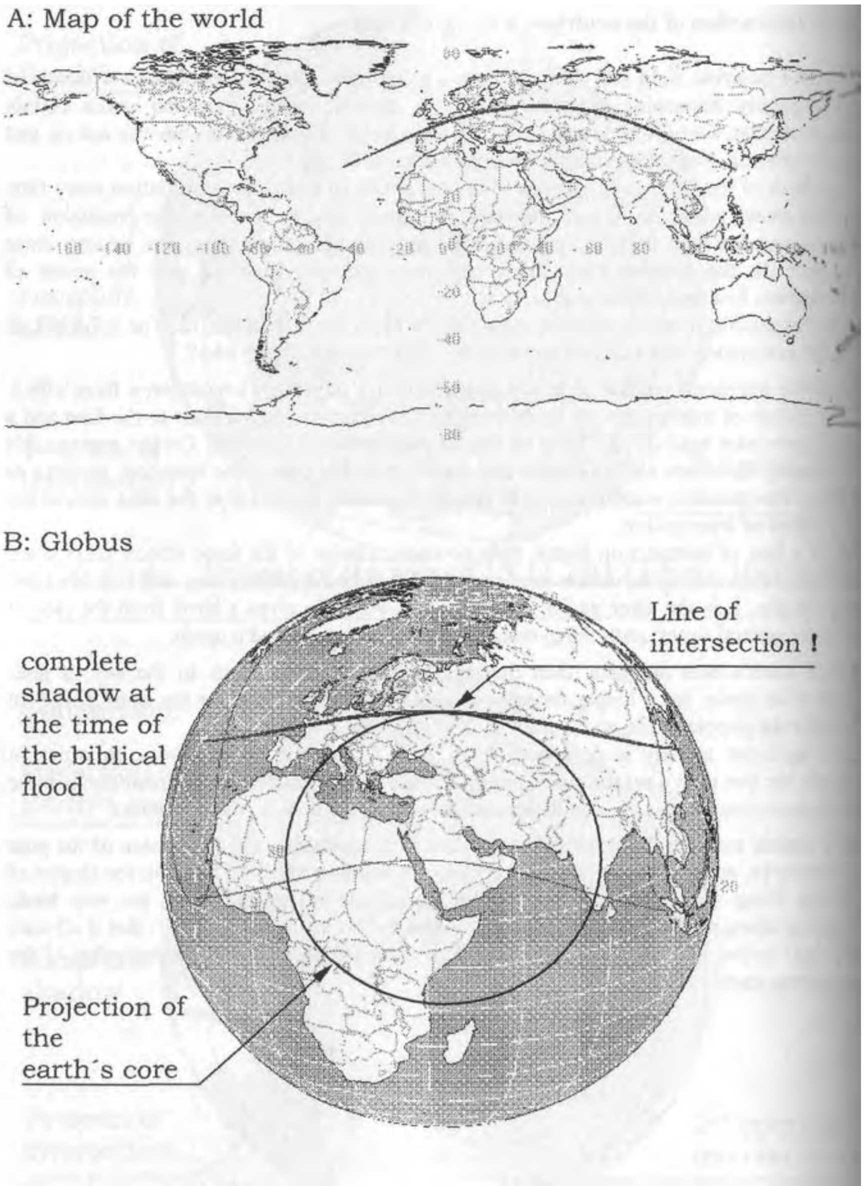

A: Map of the world

B: Globus

complete shadow at the time of the biblical flood

Line of intersection !

Projection of the earth´s core

60
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
-20
-40
-60
-80
20

Fig. 20.11: Eclipse of the sun of 27.07.2281 B.C.
(angle of the sun = declination: 19.3°)
The trigger of the biblical Flood?

20.11 Changing of polarity and apocalypse

The pulling at earth's core, which shows as a wobbling of the magnetic axis and in damped form can lead to a tilting of the axis of rotation of the earth, still doesn't make an apocalypse, no end of the world. This only can be expected, if after a tilting of the axis of rotation of earth's core a change of polarity on the surface of the earth occurs. Doing so the new magnetic poles, like a compass needle in the field of the solar wind, again align in such a that the North Pole will be lying "up" in the ecliptic. Because earth's surface will keep it direction of rotation, the sun will, after the process having stabilized, as usual again rise in the East and set in the West. But the inhabitants of the earth, which before still were having midsummer, find themselves again in the midst of midwinter and vice versa.

Truly apocalyptic processes can be expected during the phase of a change of polarity of the earth. Thereby occur unusual relative accelerations and violent earthquakes. The largest destructive potential however is present in the waters of the oceans, which are set in motion.

As is well-known the earth at the equator is measuring a radius which is 21 kilometres larger than at its poles. If only a part of the waters temporarily flows in the direction of the poles of the earth, then the biggest part of the habitable land in Middle and North Europe sinks in the floods; then indeed also the statement of Noah makes sense, who as the first thing saw the mountain of Ararat rise from the floods, after the water again flowed back into its usual ocean basins. The mountain of Ararat after all measures a height of 5137 meters above sealevel!

At comparing historical events with details from the Bible the Flood should have taken place in the year 2245 B.C.<i>. According to the description of the position of the stars Dr. Wild calculates July 2281 B.C. as time for the Flood. The Arabic historical writer al-Makrizi again shifts the event into the year 3094 B.C.<i>. Who is right? We must verify the eclipses of the sun in this time and determine the position of the points of intersection, then we perhaps find the correct answer. Possibly earth's axis has wobbled more than once, have occurred several catastrophes in different regions. At 27.7.2281 B.C. in any case there actually has occurred an extremely critical constellation, whereas the other two years are ruled out. Here no total eclipse of the sun took place (fig. 20.11).

According to the calendar of the Ugha Mongulala 6110 years before this Flood a still much more devastating one should have occurred. That therefore would have been 8391 B.C., while Scott-Elliot dates the catastrophe in the year 9564 B.C.<ii>. According to Plato it would have been about 9500 B.C. For such long periods of time a check however isn't quite easy anymore, because the meantime changes of the earth sum up considerably.

<i>: Wild S. 231, 229 and 225.

<ii>: Wild S, 219, 218 and 210, among others cited from Scott-Elliot: Atlantis und das untergegangene Lemuria, Bauer Verlag Freiburg 1977.

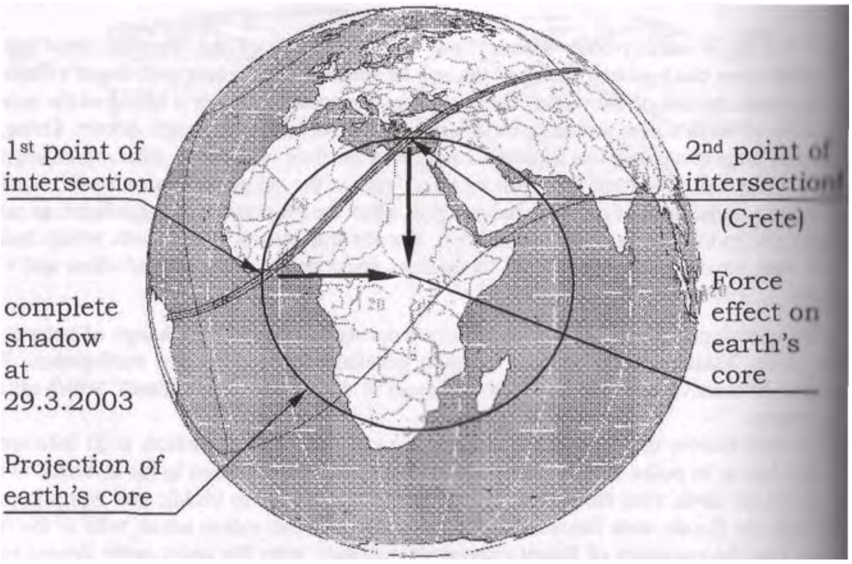
1st point of intersection
2nd point of intersection (Crete)
Force effect on earth's core
complete shadow at 29.3.2003
Projection of earth's core

Fig. 20.12 A: Eclipse of the sun of 29.03.2006 (decl.: 3.2°)

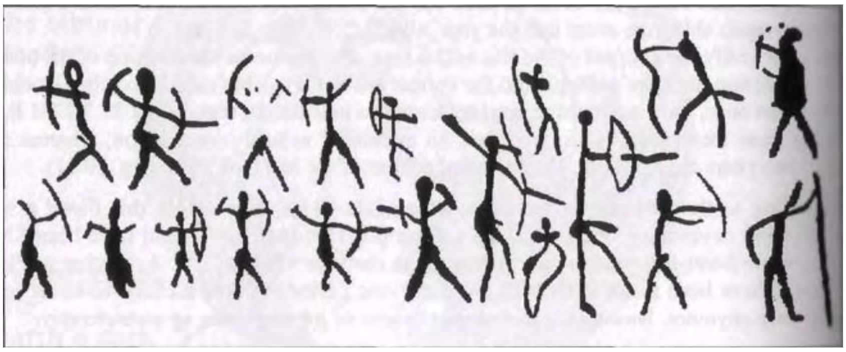

Fig. 20.12 B: Cave painting from Minateda (Spain).<i>

<i>: Laviosa-Zambotti: Origini e Diffusione della Civilta, Marzorati, Milano 1950,

Besides the constellation of sun and moon is crucial the occurring of a relevant neutrino radiation and the question if both is sufficient to tilt the earth and change its polarity. Some experts expect a change of polarity for the time coming, since it takes place with a certain regularity and measured in earth historical periods of time in addition fairly often!
This circumstance the earth presumably owes the river valleys cut deep in the countryside and other topographic phenomena. One presumably can only survive such a catastrophe in an ark (Noah), in the air bubbles of large caves (the walls of which painted children and artists out of pure boredom, see fig. 20.12 B) or in the highland, preferably in the area of the equator (Central Africa, highland of Mexico, Andes, Himalaya).

20.12 Scalar wave gauges for the prediction of earthquakes

We urgently need gauges, to be able to judge the neutrino situation. At first we with that pursue the same goal, as with the building of a free energy converter, however with the difference that the converter should maximize the collected amount of energy, whereas the gauge should minimize the taken up energy, to not too much load the source and not to change the local radiation situation.
In addition the neutrino radiation should be registered distinguishable in its velocity of propagation, what means that the building of a gauge will be very much more costly than that of an energy collector. That's why it can be expected that an usable measurement instrument might be available only many years later and we that long only can base on our own power of observation.

We for instance can statistically analyse, how the earth after an eclipse of the sun reacts to the neutrino radiation focussed by the moon. At August 11 the second focal point was situated in the East, and from that an acceleration of the rotation of earth's core can be predicted. Corresponding observations actually have been made on the surface of the earth with the help of the Foucault pendulum.
The relation the next time can be checked at the eclipse of the sun at 29.3.2006. This time the inverse case is present. A first focussing takes place in the West, so that pendelum swings in the reversed direction would be expected, which indicate a slowing down of the rotation (fig. 20.12 A).

But if the rotation of the earth should change, then the balance sheet of angular momentum of moon, earth's mantle and earth's core isn't correct anymore. As a result a force of difference occurs, which lets the spinning top stagger. But if earth's core staggers inside of earth's mantle, then it powerfully stirs the liquid magma, and in this way releases its surplus energy again. As a result earth's mantle is heated up somewhat. We, on our wafer-thin earth's crust, then time delayed feel the effects of the staggering of the core as an earthquake. The period seems to lie at approximately 6.5 days, as far as this can be read from reactions to the last two eclipses of the sun.

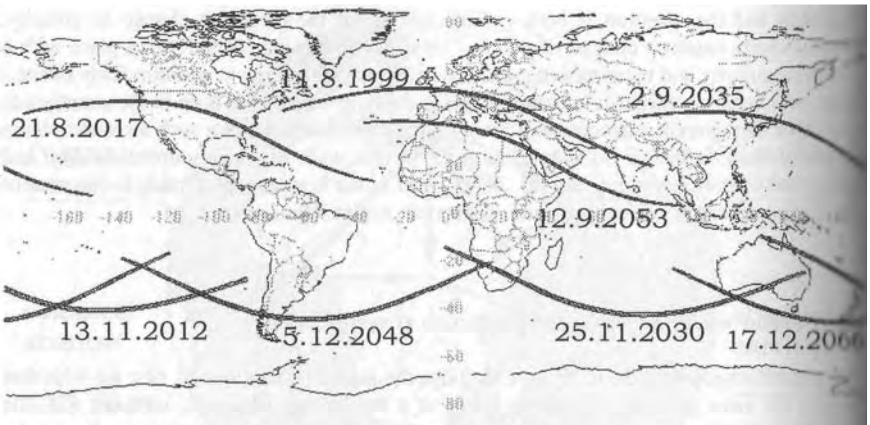
11.8.1999
2.9.2035
21.8.2017
12.9.2053
13.11.2012
5.12.2048
25.11.2030
17.12.206

Tafel 20.13 A: Eclipses of the sun of 2 Saros cycles.

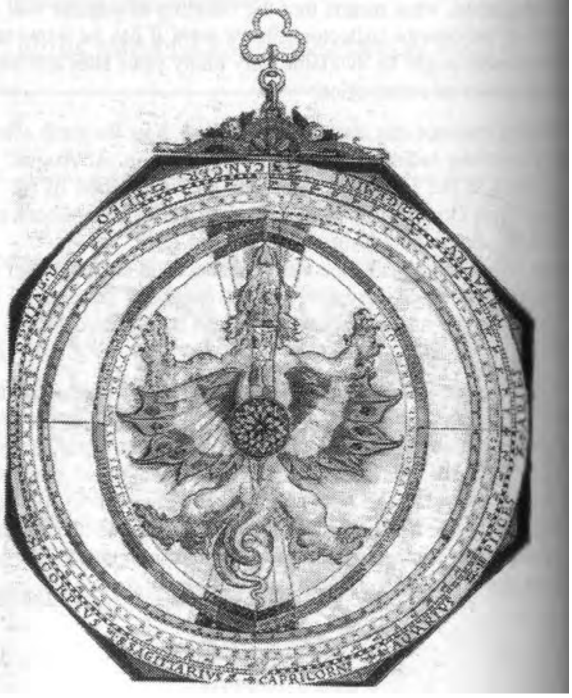

Fig. 20.13 B: The „Astronomicum Caesareum“ served around 1540 the determination of the positions of the moon nodes.<i>

<i>: Werner Raffetseder: Sonnenfinsternis, Hugendubel Verlag, Munchen 1999, ISBN 3-89631-302-9, Seite 134.

20.13 Calculation of future occurrences

From the analysis of past and present cosmic events with a strict scientific procedure can be predicted to a certain extent also future events. It thereby by no means concerns prediction, but exclusively the result of an analysis.

After the mentioned eclipse of the sun of 29.03.2006 there once more exists danger of earthquakes (approx. 4.4.2006) for the Island of Crete and Asia Minor. From the eclipse of the sun of 13.11.2012 as well no good can be expected, even if the points of intersection, situated close together, lie far away from populated land in the south-west Pacific basin. The Maya calendar by the way ends to this time. At 21.8.2017, 18 years or a Saros cycle after the eclipse of the sun at 11.8.1999 and correspondingly 120° further to the west, the corresponding complete shadow runs crossways through the USA. The thankless role of Turkey at the second point of intersection this time takes over South Carolina. One only can hope that the houses in Columbia are built more stable than in Izmit.
In fig. 2013 A the two eclipses of the sun of 11.8.1999 and of 13.11.2012 with their respective Saros cycles until 2066 are shown. The as critically to value tendency of the course of the complete shadow is visible, which wants to nestle against the circle of the projection of earth's core to form a line of intersection.

I here break off, since anyone with my indications and an eclipse of the sun-CD can analyse at home all further events personally. I value that if possible many analyses are made and controversially discussed, because possible cosmic catastrophes concern us all somewhat.

What good is the building of gigantic fusion ovens, if the runners by no means have understood the process of the fusion themselves? Why build ring accelerators for billions of dollars, if elementary particles can be calculated at the desk? How is the expenditure for gravitational wave detectors justified, if the actual music plays at entirely other velocities of propagation? Why is half the annual production of the world of Gallium used for an indirect proof of neutrinos, if every self-wound Tesla coil is able to collect more neutrinos?

Our scientists, for whom I as a colleague quite often must be ashamed, have the primary task to draw attention to cosmic and other risks and to calculate them in advance. In any case it is extremely unpardonable to leave this core duty up to some fortune-tellers and self-appointed prophets.
One should more often remind them that the Chinese Kaiser Tschung-Khang let sentence his court astronomers Hi and Ho to death, after the two not having predicted an eclipse of the sun. It thus certainly didn't concern a missed spectacle or a missed tourism business, but presumably the need for safety of the Kaiser and his subordinates, for which the two astrophysicists in ancient China had to take responsibility!

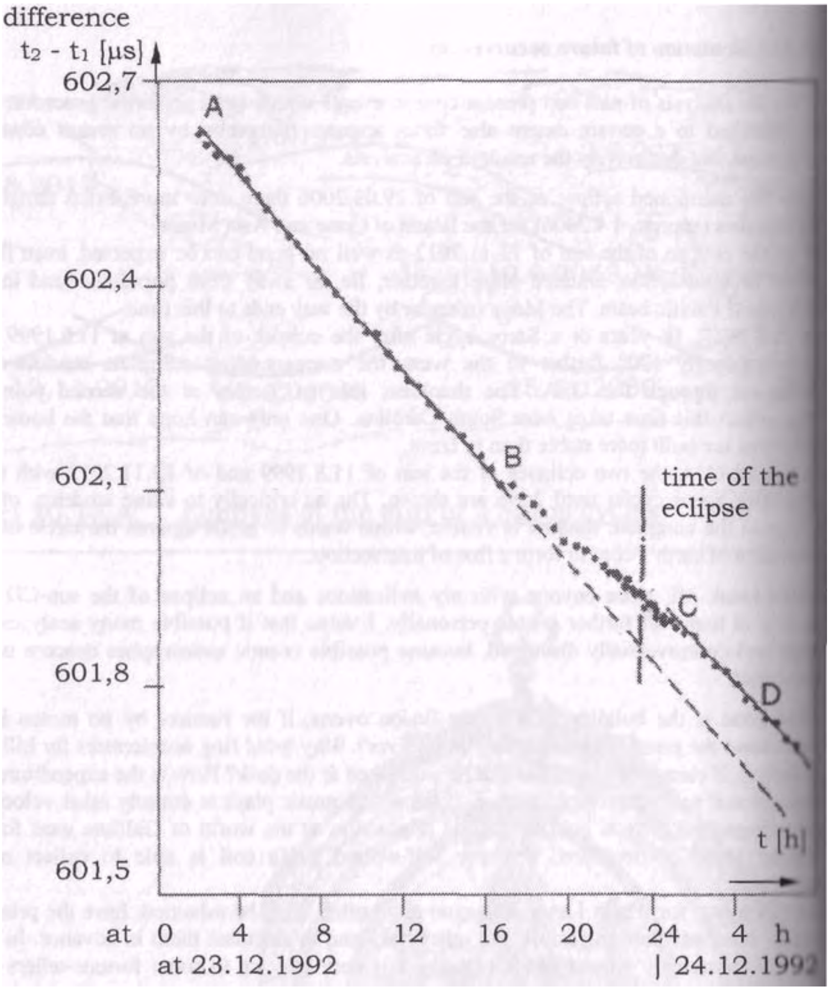

Fig. 20.14: The difference in going of two caesium atomic clocks positioned in different directions, but in the same laboratory in Harbin, China, during the partial eclipse of the sun of 24.12.1992.[i]

[i]: Shu-wen Zhou: Abnormal Physical Phenomena Observed When the Sun, Moon, and Earth are Aligned, 21st Century Science & Technology, Fall 1999, Vol. 12, No. 3, pp. 54-61. Comments concerning Figure 9: Straight lines AB and CD show that the rate of change of the time difference between the two clocks is constant in non-eclipse periods, but becomes irregular around the time of the eclipse.

20.14 Epilogue to the energy technical seminar

Very slowly the word goes round that the energy source of the future has got a name: "Neutrinopower". Unfortunately fundamental physics, which is financed with public money, still does know almost nothing about the nature of the neutrino radiation. In addition hinder useless model concepts any progress in this direction and so the responsible fundamental research steps on the spot.

Considerably more extensive were already 100 years ago the insights of the experimental physicist Nikola Tesla, the discoverer of the neutrino radiation and father of the free energy. The space energy however is showing most clearly in nature, which only uses this advantageous form of energy. In particular during eclipses of the sun and other cosmic experiments it openly comes to light and can be detected by us for a short time.

The physicist Prof. Shu-wen Zhou of the University of Huazhong in Wuhan, China, systematically has investigated the effects, if sun, moon and earth are aligned<i>. Doing so he has proven inexplicable physical anomalies in experiments. Stimulated by the discoveries of Maurice Allais with the Foucault pendulum he built an arrangement specially flor proving horizontal forces of acceleration, and actually he with that could measure face effects during the total eclipse of the sun of 24.10.1995. He even speaks of an oscillating force!

Further he could determine changes in the spectral wave length of various elements, which under normal conditions go as constant and even as characteristic for the respective element. The relative change of size of the wave length during the ring-like eclipse of the sun over China of 23.9.1987 resulted in the 100-fold value compared to the difference in the spectrum analysis between surface of the earth and surface of the sun! This comparison reveals an immense discrepancy between theory and practice and puts us for a solid problem.

For that six different models of spectrometers were installed in several laboratories of different polytechnics and a photograph was taken of the emission spectra of H, D, Ca, CN, Ni, Ti, etc. Also other reasons than that of an eclipse of the sun could be excluded unambiguosly. In the results of these, at artificial light carried out conventional measurements, in any case abysses yawn. The from spectrum analyses won "insights" about the composition of strange celestial bodies now for sure can be done away with without knowledge about the respective prevailing neutrino radiation.

Spectacular also is the proof of differences in going of atomic clocks of various constructions. During the partial eclipse of the sun of 24.12.1992 seven caesium clocks in four cities of China and in three planes were used. The analysis of the differences in going resulted in, as is shown exemplary in fig. 20.14, changes of the gradient during the eclipse. The results for the atomic clocks in the planes and for two further time measurements turned out with similar clarity<i>.

<i>: Shou-wen Zhou: Abnormal Physical Phenomena Observed When the Sun, Moon, and Earth are Aligned, 21st Century Science 6s Technology, Fall 1999, Vol. 12, No. 3, pp. 54 - 61.

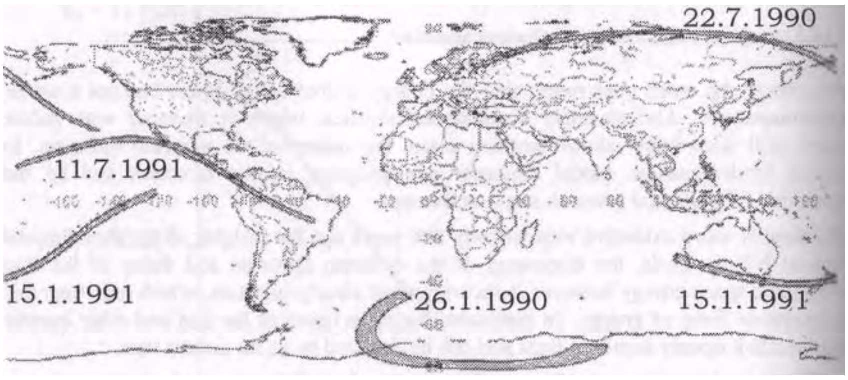

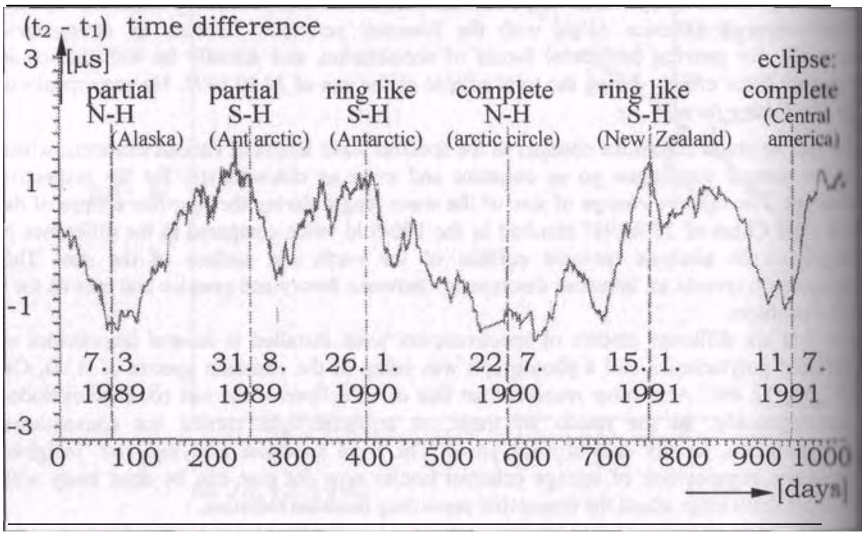

Fig. 20.15: Long-term measurement between 1989 and 991 of the difference in going of two atomic clocks at the U.S. Naval Astronomical Observatory.<i>

The in the 1000 days occurred eclipses of the sun have been entered later. In addition is recorded, if the northern hemisphere (N-H) or the southern hemisphere (S-H) of the earth was involved.

<i>:Shu-wen Zhou: Abnormal Physical Phenomena Observed When the Sun, Moon, and Earth are Aligned, 21st Century Science & Technology, Fall 1999, Vol. 12, No. 3, pp. 54 - 61. Figure 8.

A connection to the neutrino radiation Prof. Zhon doesn't draw, but it almost is obvious.

From the U.S. Naval Astronomical Observatory (LC/7970) long-term measurements over 1000 days between 1989 and 1991 are present (fig. 20.15). The difference in going between the two atomic clocks positioned at different places shows a permanent up and down. The reason goes as completely unknown.
But if the eclipses, which took place in this time, are entered then one immediately sees the assignment to a maximum or a minimum value. If an eclipse of the sun namely concerned the southern hemisphere of the earth, then the difference in going each time reached a maximum, but if the shadow of the moon run over the northern hemisphere, then each time a minimum occurred. Chance here probably is out of the question!

Let us record: The effect of an eclipse of the sun, to which for instance a Foucault pendulum reacts, can equally be traced back to the interaction of the neutrinos as the free energy. That's why the here presented book carries the title "Free energy and the interaction of the neutrinos". It has appeared in the series concerning the "Electromagnetic environmental compatibility", and also for that there are good reasons. Our energy technology must become more ecologically compatible and we come the goal closer, if we emulate nature, understand and copy it.

That it further concerns electromagnetism, likewise is explained from the interaction of the neutrinos, which concerns the oscillating and resonant case of the electromagnetic interaction. In this respect the reference to the series of books therefore would be given.

It only indirectly has to do with "electrosmog", or what otherwise is understood under environmental compatibility in general. It however could be shown that also the earth radiation is a form of neutrino radiation, and that it poses a biological effectiveness, after it turned out that it serves nature as an energy source. With that the conflict with space energy devices already is predetermined if the same scalar wave radiation should be used. Then one system takes away the other system the energy basis and the existence basis.
This environmental compatibility problem can be solved, if care is taken that both don't get in each others way with regard to the frequency and the wave length. We for that need a deep understanding concerning the topic of the space quanta and the neutrinos, their physical properties and the corresponding device technology. The book should make a contribution to that.

The other side of the medal is the information technical aspect of the scalar wave radiation and the environmental compatibility problem connected with that. The third and last part of the series of books is dedicated to this theme.

Part 2: Edition belonging to the energy technical seminar: "Electromagnetic Environmental Compatibility"

Prof. Dr.-Ing. Konstantin Meyl

Scalar waves

Abstract:

1. Auflage 1998, 4. Auflage and 1st English Edition

With regard to the environmental compatibility a decentralized electrical energy technology should be required, which manages without overhead power lines, without combustion and without radioactive waste. The liberalization of the energy markets won't on any account solve our energy problem, but only accelerate the way into the dead end. New, ecologically compatible concepts are collected and discussed in the book.

A useful energy source could be represented by space quanta, which hit upon the Earth from the sun or from space. They however only are revealed to the measurement technician, if they interact. It will be shown that the particles oscillate and an interaction or collection with the goal of the energy technical use only is possible in the case of resonance.

Since these space quanta as oscillating particles have almost no charge and mass averaged over time, they have the ability of penetration proven for neutrinos.
In the case of the particle radiation discovered 100 years ago by Tesla, it obviously concerns neutrinos. We proceed from the assumption that in the future decentral neutrino converters will solve the current energy problem. Numerous concepts from nature and engineering, like on the one hand lightning or photosynthesis and on the other hand the railgun or the Tesla converter are instanced and discussed.

Free energy and the interaction of the neutrino radiation

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Scalar Waves

From an extended vortex and field theory to a technical, biological
and historical use of longitudinal waves.

Part 3

by

Professor Dr.-Ing. Konstantin Meyl

Edition belonging to the lecture and seminar "Electromagnetic environmental compatibility"

(Original title: "Elektromagnetische Umweltvertraglichkeit")

Translated out of the German language
by Ben Jansen
(2003)

* * *

Part 3: Edition belonging to the information technical seminar

Scalar waves and the technical use of longitudinal waves and vortices

* * *

INDEL GmbH, Verlagsabteilung

Villingen-Schwenningen 2003

ISBN 3-9802 542-4-0

Preface to the seminar, part 3

With the appearing in print of the 3^{rd} part of the series of lecture notes of the electromagnetic environmental compatibility, the collection of material can be considered to be completed for the time being. By now almost all aspects concerning the theme of the potential vortices of the electromagnetic field and their propagation as a scalar wave should have been addressed or at least indicated.

And that's what it is about in the case of the editions belonging to the seminars: In the seminars, taking place inside and outside the university, questions about the phenomena and the biological effectiveness of the fields, which surround us, are discussed. The scientifically correct procedure asks as a preparation for the seminar a voluminous collection of material and a compilation of theses with the pros and contras to them. The argumentation, which is denoted as „textbook physics" and is generally accepted, the participant of the seminar can work out himself by means of the available journals and books. The potential vortex, which completed the field equations, however makes possible a counterstatement, which for most participants at first will be unusual. The old dispute between quantum and field physics rekindles. What is missing is a voluminous collection of material concerning the refined field physics, and this gap the editions belonging to the seminars should close.

In the case of this book the primary concern is to make sure, that all facets, properties and physical consequences of the new and unified field physics are addressed. The question, if all points can bear a strict verification, remains reserved to the seminar and its participants, of whom each should form its own judgement. The series of books should be understood as a stimulation, to make own thoughts about the various points. Who has no opportunity to participate in a seminar, by means of the lecture at least gets an idea of what is discussed here and how is struggled for scientific insights.

The herewith completed collection of material by no means may be compared or confused with a basic work about the theory of objectivity. That the editions cannot and want not afford at all. They together with the discussions at best form the basis for a scientifically basic work, at which I am working.

In the case of the collection of material concerning the electromagnetic environmental compatibility consisting of three parts, again and again new aspects have emerged, which found entrance into the book, at which I was working at that particular time, whereas the rough structure has been controlled precisely: part 1 with the chapters 1 to 9 treats the basics, part 2 with chapters 10 to 20 the energy technical aspect and part 3 with the chapters 21 to 30 the information technical aspect of scalar waves.

The here presented 3^{rd} part starts with the wave equation and the two comprised parts of a transverse and a longitudinal wave. The historic dispute between Heinrich Hertz and Nikola Tesla with the experimental evidence of the each time used wave part is continued over the wave-particle uncertainty compromise up to the dispute about the right field description: that of Maxwell or the new dual and at the same time unified description, which builds upon Boscovich and Faraday. The aspects, which seem so irreconcilably thereby only are two parts of a single equation, which is much older and can be traced back to Laplace: the wave equation.

Until now no derivations of this equation, which contains both wave parts, are known This for the first time succeeds from the new and extended field approach in the summary from chapter 26. At first however is attempted to make the world of the scalar waves plausible with models, calculations and observations. For that are used examples from high-frequency engineering, like the ground wave or the near-field area of an antenna, and from nature and medicine, which are granted two chapters. The comparison of the nerve conduction with Tesla's one wire technology is bringing it to light that scalar waves equally are used in both cases. In a frequency diagram the insights are entered concisely and is shown that considerably more unexplored domains occur than already is known, that in most cases not even gauges are available. With the design for building a scalar wave gauge the scientific verification of until now only empirically won results is stimulated, like for instance the results the radiesthesia wants to have determined with the help of the sensitivity of man as a biosensor.

Many relations will be revealed to the reader only, if he has worked through the summary, which follows. From Maxwell's field equations only the well-known (transverse) Hertzian waves can be derived. (Longitudinal) scalar waves however in the result are zero. This is a flaw of normally used field theory, since scalar waves exist for all particle waves, like e.g. as plasma wave, as photon- or neutrino radiation. Because the field pointer, in the direction of which longitudinal waves are propagating, is oscillating, the frequency will oscillate like the velocity of propagation, which again is measured as a noise signal. Any antenna noise proves the emission of scalar waves in space. But scalar waves, or whatever should be subsumed under the by mathematics minted generic term free of any value judgement, surely are more than only noise.

Starting from Faraday's discovery - instead of the formulation of the law of induction according to Maxwell - an extended field theory is derived, which goes beyond the Maxwell theory with the description of potential vortices (noise vortices) and their propagation as a scalar wave, but contains the Maxwell theory as a special case. The new field theory with that doesn't collide with the textbook opinion, but extends it in an essential point with the discovery and addition of the potential vortices.
Also the theory of objectivity, which follows from the discovery, is compared in the form of a summary with the subjective and the relativistic point of view and the consequences for variable velocity of propagation of the scalar waves, formed from potential vortices, are discussed. Like already in part 1 the unification of the electromagnetic interaction with the gravitation succeeds impressively.

Besides the mathematical calculations this book contains a voluminous material collection concerning the information technical use of scalar waves, if e.g. the useful signal and the usually interfering noise signal change their places, if a separate modulation of frequency and wavelength makes a parallel image transmission possible, if it concerns questions of the environmental compatibility for the sake of humanity (bioresonance, among others) or to harm humanity (electrosmog). With that the book again finds back to the starting point, to the open task, which made necessary an excursion through all domains of physics to answer it. I hope, the long march was worthwhile.

Villingen-Schwenningen december 2002

Preface to the 2nd edition of part 3

In favour of chapter 30 as a complement, an introduction into the ancient broadcasting technology of the gods, the 1st edition wasn't printed anymore in the year 2002 as originally planned. Instead the individual chapters have been prepublished in different places. The chapters 21 to 25 are found among others in the book "scalar wave technology", which has been published as an instruction for an experiment to demonstrate scalar waves in 2001. Excerpts from it, as also from the chapters 26 to 28 have appeared in form of individual essays in different journals.

Again experimental successes had been intervening, which caused a renewed deferring of the date of appearance of the 3rd part of the series of books. In my laboratory the bi-directional transmission of music and of data by scalar wave was successful. We thus also can transmit information backwards from a receiver to the transmitter or to a second receiver, whereby the receivers work purely passive, thus without own power supply. The operating energy is as well supplied to them by the transmitter by scalar wave. The demonstrated technology opens completely new possibilities of a technical application. Conceivable are telemetry installations where measurement signals have to be transmitted from rotating or otherwise inaccessible places of a machine. The energy for the measurement electronics can be transmitted wirelessly by scalar waves and the signal can be sent back along at the same time, by modulating it onto the energy carrier. In this way dozens of measurement stations can be connected wireless with a single central transmitter, which supplies them all with energy.

The question was asked: Is the technology really entirely new? The answer is amazing: No, it here concerns the oldest technology of humanity, which had developed to a peak in antiquity, to send receive engineering of the gods. For this claim even a mathematical proof is available. For that the authoritative transition, the unrolling of a vortex to a wave (the transition from the near-field to the far-field) or in the reversed case the rolling up at a receiver antenna (usually denoted as standing wave) is calculated with help of the extended field theory. The result is, that at this transition the velocities of propagation resp. the wavelengths of the transverse and the longitudinal wave stand to each other in the ratio of the Golden Proportion.
With regard to the optimization of a transmitter or receiver antenna the Golden Proportion has an effect on the construction resp. the architecture of corresponding buildings . Which ones, with that deals the complementing chapter 30. But it mustn't be missing either, since after all it concerns a grandiose practical information technical use of scalar waves, from which we technologically can learn a lot<i,ii>.

Villingen-Schwenningen march 2003

<i>: Note: chapter 30 provides an introduction into ancient broadcasting technology of the gods. The working off of history with respect to the use of scalar waves is so voluminous, that for that a book of its own is published with the title:

<ii>: K. Meyl: Sendetechnik der Gotter, historischer Sciencefictionroman (2003), Villingen-Schwenningen, INDEL Verlagsabteilung, ISBN 3-98O2 542-5 9

21. Derivation of the scalar wave

WilliamThomson, who called himself Lord Kelvin, after he had been knighted, already in his lifetime was a recognized and famous theoretical physicist. The airship seemed him too unsafe and so he went aboard a steam liner for a journey from England to America in the summer of 1897. He was on the way in a delicate mission.

Eight years before his German colleague Heinrich Hertz had detected the electromagnetic wave in experiments in Karlsruhe and scientists all over the world had rebuilt his antenna arrangements. They all not only found confirmed the wave as such, they even could show the characteristic properties.
It was a transverse wave, for which the electric and the magnetic field pointers oscillate perpendicular to the direction of propagation. This can be seen as the reason, that the velocity of propagation is showing itself field independent and constant. It is the speed of light c.

With that Hertz had experimentally proven the properties of this wave, previously calculated in a theoretical way by Maxwell, and at the same time proven the correctness of the Maxwellian field theory. The scientists in Europe were just saying to each other: "well done!" as completely other words came across from a private research laboratory in New York: "Heinrich Hertz is mistaken, it by no means is a transverse wave but a longitudinal wave!"

Such a screwball most said and did as if they hadn't heard the criticism at all. But then one couldn't ignore it completely, because on the one hand claimed the private research scientist to have experimental proof and on the other hand it wasn't just anybody, who here reported. It was nobody but Nikola Tesla, the Croat experimental physicist who emigrated to America
Him we owe the modern alternating current technology from the high-tension network for energy transmission over the alternating current transformer to the asynchronous machine.
With his magnificent inventions he had earned enough money, to be able to afford a private laboratory, in which he could research and invent uncensored and free. The key to his success was lying in his purposeful, concentrated and efficient working method.
He was fast! Whereas in Europe still was being discussed about properties and theoretical possibilities of application of the wave, Tesla already presented the armed forces a remote controlled scaled-down submarine in Madison Square Garden (fig. 21.1 A). To convince such a man, who only holds valid what his experiments reveal, from the opposite, should be a hopeless enterprise.
Lord Kelvin was aware of that, as he made the decision to go on the journey. He could not and did not want to put his head into the ground, as many of his colleagues, because on the one hand scientists are curious by principle and on the other hand he travelled as an official representative of science. He had been instructed to free, as Mr. Clean, the undamaged world of sciences from erroneous teachings. But it came completely different.

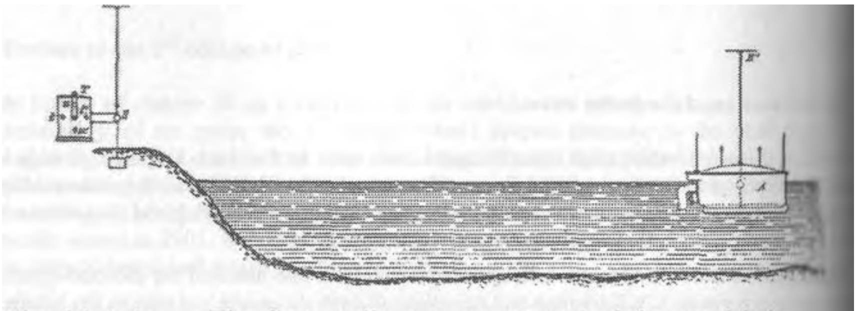

Fig. 21.1 A: The first radio remote control of the world.[i]

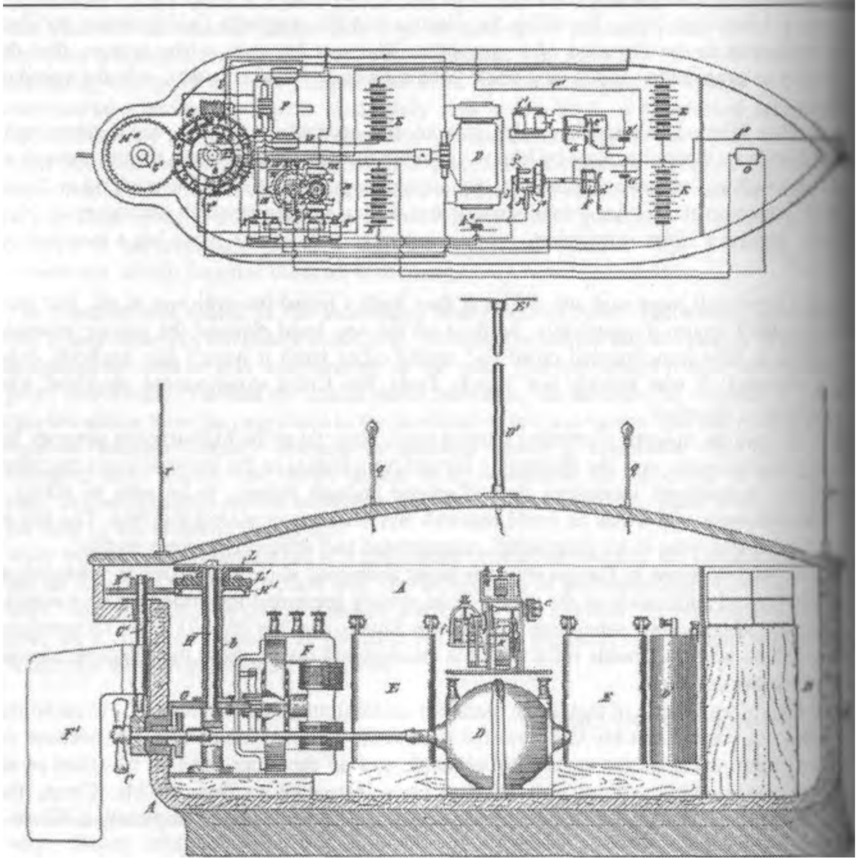

Fig. 21.1 B: Patent specification concerning the remote
controlled submarine.[i]

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[i]: Nikola Tesla: Method of and Apparatus for Controlling Mechanism of Moving Vessels or Vehicles, US-Pat. 1898, Nr. 613,809. Complete Patents: P. 351

21.1 Lord Kelvin in a delicate mission

The first day of his visit at Tesla Kelvin spoke the admonishing words he had been instructed to speak. He recommended Tesla warmly to publicly retract the remarks concerning the Hertzian mistake and to contribute himself to the settlement of the dispute. Seen from a specialist viewpoint they talked at cross-purposes.

But at night in his hotel room the Lord again thought about the experiments, which had been shown to him. The standing wave nature had been visible unambiguously: the oscillation nodes, the effect back on the transmitter, the high degree of effectiveness and many other things more. Such properties the Hertzian wave indeed doesn't know. Also Tesla didn't work with dipole antennas, but with flat coils, with spark gap oscillators and with a very unconventional switching technique, set up different in principle.

The next morning Lord Kelvin appeared in the laboratory again and greeted Tesla with the words: "Then you don't use Hertzian waves?" "Certainly not", Tesla answered," it are radiations. By waves no energy could be economically transmitted over a larger distance. My system works with true conduction, which theoretically seen can take place over a larger distance, without bigger losses occurring."
In the article of the "Electrical Experimenter" is noted further, that the doubting critic Kelvin suddenly turned into one of the biggest followers<i>.

Kelvin deduced very fast: according to that there exist two different sorts of wave propagation. So Hertz with his transverse wave is just as right, as Tesla with the longitudinal wave.
As a represantative of theoretical physics he however could pull out Tesla a decayed tooth. Maxwell had based his field description on an aether concept, which at that time in the world of sciences triggered violent discussions. Since Tesla saw such an aether as a prerequisite for longitudinal waves, he thought he and not Hertz had proven the Maxwell wave in experiment for the first time. By stating this the magnificent experimental physicist however revealed weaknesses in the area of theory. Maybe he had not read exact enough or understood the books of Maxwell, which without doubt were formulated mathematically only arduously comprehensible in the original version.
In this point Tesla had to learn otherwise by Kelvin. Maxwell's field theory provides without exception a mathematical description for the Hertzian wave. For the Tesla radiation however no field description exists! This by the way is the circumstance, why this wave could disappear from the textbooks and again fall into oblivion. Tesla himself had problems to theoretically imagine, what happens at his wave. His models in some points perhaps were even better than the official textbook opinion, but not without contradiction to accepted regularities. That's why Tesla did without a publication of his ideas, although he in his lifetime had filed away at an own theory.

<i>: Nikola Tesla: Famous Scientific Illusions, III. The Singular Misconception of the Wireless, Electrical Experimenter, Feb. 1919, printed in Tesla Said, p. 197

Figure 21.2 A:

William Thomson, 1846 becoming Professor at Glasgow University with the age of 22 years. From 1892. on he was called Lord Kelvin.<i>

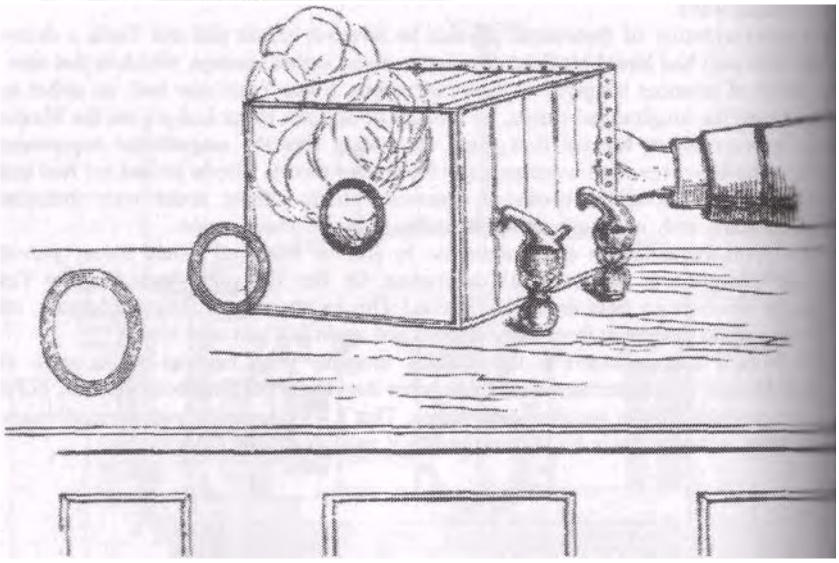

Fig. 21.2 B: Vortex rings from a smoke vortex gun.<i>

<i>: David Ash, Peter Hewitt: Science of the gods, Gateway Books, Bath, 1990

21.2 Helmholtzian ring-like vortices in the aether

Tesla told Kelvin at his visit from the meeting with the German Professor Hermann von Helmholtz on the occasion of the World's Fair in Chicago 1893. Kelvin knew him very well and had cooperated with him in the past. Now the vortex concept of his colleague and his model of stable vortex rings were very obliging.
In the case of a standing wave the impulse is passed on from one particle to the next. In the case of acoustics for instance we are dealing with a shock wave, where one air molecule knocks the next. In this way sound propagates as a longitudinal wave. Correspondingly the question is raised: What sort of quanta are the ones, which in the case of the Tesla radiation carry the impulse?

Lord Kelvin was already on the way back to Europe on the steamship and he deduced: The Tesla experiments prove the existence of longitudinal standing waves in space. In the question, what passes on the impulse, Kelvin comes to the conclusion: it are vortices in the aether! With that he had found an answer in experience. With his students he built boxes, with which he could produce smoke rings, to be able to study and demonstrate in experiments the special properties of ring-like vortices in their flow technical analogy (fig. 21.2<i>). But he didn't have ready a suitable field theory.

The from Germany to the Isles exported vortex physics for a short time could establish in England, before it was slaughtered and buried by the German quantum physicists. A main advocate has been James Clerk Maxwell, who held the vortex theory for the best and most convincing description of matter<ii>. As his successor at the Cavendish laboratory in Cambridge J. J. Thomson was appointed, who already as a young man had got a price for a mathematical treatise about vortices<iii>. He discovered the electron and imagined it, how could it be otherwise, as a field vortex.

The crucial weakness of vortex physics, the lacking of an usable field theory, was of benefit to the emerging quantum physics. This could change fundamentally with the discovery of the potential vortex, the vortex of the electric field<i4>!
In addition is the experimental proof of a vortex transmission as a longitudinal wave in air or in a vacuum, as it has been furnished by Tesla already 100 years ago, neither with Maxwell's theory nor with the today normally used quantum theory explicable or compatible. An urgent need is present for a new field theory!

<i>: David Ash, Peter Hewitt: Science of the gods, Gateway Books, Bath, England 1990.

<ii>: James Clerk Maxwell: "...the vortex rings of Helmholtz, which Thomson imagines as the true form of the atom, fulfil more conditions than any other previous concept of the atom."

<iii>: J.J. Thomson: "the vortex theory is of much more fundamental nature than the usual theory of solid particles."

<i4>: Konstantin Meyl: Potentialwirbel Band 1 (1990) and Band 2 (1992), INDEL-Verlag, Villingen-Schwenningen.

Scalar waves, a mathematical reasoning (I)

1. prerequisite: wave equation (textbook-formulation)

$$\boxed{\Delta \mathbf{E} = \frac{1}{c^2} \cdot \frac{\delta^2 \mathbf{E}}{\delta t^2}}$$

taking apart of the delta operator mathematically (Laplace operator) according to the rules of vector analysis (fig. 5.0):

$$\boxed{\begin{array}{lclcl} \Delta \mathbf{E} & = & \text{grad div } \mathbf{E} & - & \text{rot rot } \mathbf{E} \\ \text{wave} & = & \text{longitudinal} & + & \text{transverse} \end{array}} \quad (21.1)$$

---

2. State of the art of technology: Hertzian wave = transverse wave
special case: = solution of Maxwell's field equations
no sources:

$$\boxed{\text{div } \mathbf{E} = 0} \quad \text{and} \quad \boxed{-\text{rot rot } \mathbf{E} = \frac{1}{c^2} \cdot \frac{\delta^2 \mathbf{E}}{\delta t^2}} \quad (21.3)$$

transverse wave:
field pointers oscillate crosswise to the direction of propagation
The propagation occurs with the speed of light c.

---

3. claim: Tesla radiation = longitudinal wave
special case:
irrotationality:

$$\boxed{\text{rot } \mathbf{E} = 0} \quad \text{and} \quad \boxed{\text{grad div } \mathbf{E} = \frac{1}{c^2} \cdot \frac{\delta^2 \mathbf{E}}{\delta t^2}} \quad (21.4)$$

longitudinal wave, shock wave, standing wave:
field pointer oscillates in the direction of propagation.
Velocity of propagation is variable!

Fig. 21.3: The special cases of the wave equation

21.3 Taking apart of the wave equation

Before one plunges into the adventure of an entirely new field theory, it first of all should be traced and analysed, what the latest textbooks say about scalar waves.

There some scalar or vector potentials are introduced; there the constant of dielectricity e is written down as a complex variable, although it physically seen concerns a material constant, only to be able to calculate with this trick artificially a loss angle, which should indicate the losses occurring in a dielectric, where in reality it concerns vortex losses. Of course one can explain the dielectric losses of a capacitor or the heating in a microwave oven entirely without vortex physics with such a label fraud, but it should be clear to anyone, that in a complex constant lies buried an inner contradiction, which is incompatible with physical concepts.
We are used to such auxiliary descriptions so much, that the majority of today's physicists tend to attribute physical reality to this mathematical nonsense. As pragmatists they put themselves on the standpoint if with that experimental results can be described, then such an auxiliary description can't be so wrong after all. Doing so the circumstance is forgotten that here the ground of pure science is abandoned and is replaced by creeds.

We find everything already in the wave equation, as it can be found in all textbooks.

$$\boxed{\Delta \mathbf{E} = \frac{1}{c^2} \cdot \frac{\delta^2 \mathbf{E}}{\delta t^2}} \quad (21.1)$$

Behind this formulation two completely different kinds of waves are hiding, because the used delta operator consists of two parts according to the rules of vector analysis:

$$\boxed{\begin{array}{lll} \text{grad div } \mathbf{E} & - \text{ rot rot } \mathbf{E} & = \Delta \mathbf{E} \\ \text{longitudinal} & / \text{ transverse} & \text{wave} \end{array}} \quad (21.2)$$

We want to discuss two special cases.
If we put the left part (in eq. 21.2) to zero (div E = 0) which is tantamount to no sources of the field then the well-known radio wave remains, which also is called Hertzian wave, after Heinrich Hertz, as said, had experimentally detected it in Karlsruhe 1888:

$$\text{div } E = 0 \qquad \text{and} \qquad \boxed{- \text{rot rot } \mathbf{E} = \frac{1}{c^2} \cdot \frac{\delta^2 \mathbf{E}}{\delta t^2}} \quad \text{(special case)} \qquad (21.3)$$

It concerns the transverse wave, described by Maxwell, for which the field pointers oscillate crosswise to the direction of propagation. The propagation again occurs with the speed of light c. So much concerning the state of the art of technology.
But as we see, in the mathematical formulation of the wave equation is hiding, yes, even more than only the generally known electromagnetic wave. The no sources approach is a neglect, which only is valid under certain prerequisites!

Scalar waves, a mathematical reasoning (II)

3. claim: Tesla radiation = longitudinal wave

$$\boxed{\operatorname{rot} \mathbf{E} = 0} \quad \text{and} \quad \boxed{\operatorname{grad} \operatorname{div} \mathbf{E} = \frac{1}{c^2} \cdot \frac{\delta^2 \mathbf{E}}{\delta t^2}} \quad (21.4)$$

special case:
source field, because div E $\neq$ 0

=> sources = charge carriers (plasma waves)
=> sources = vortex structures

---

4. approach: (div E $\neq$ 0) is a scalar! => scalar wave
=> E-field vector can be derived from a scalar potential φ:

$$\boxed{\mathbf{E} = -\operatorname{grad} \varphi} \quad (21.5)$$

and $\operatorname{div} \mathbf{E} = -\operatorname{div} \operatorname{grad} \varphi \equiv -\Delta \varphi$ (21.6)

inserted in eq. 21.4: homogeneous scalar wave equation

$$\boxed{\Delta \varphi = \frac{1}{c^2} \cdot \frac{\delta^2 \varphi}{\delta t^2}} \quad (21.7)$$

---

5. proof: For the case of an additional space charge density ρ_{el} should be considered: div D $= \rho_{el}$
and div E $= \rho_{el}/\varepsilon$ (21.8)

inhomogeneous scalar wave equation = plasma wave!

$$\boxed{\Delta \varphi = \frac{1}{c^2} \cdot \frac{\delta^2 \varphi}{\delta t^2} - \frac{\rho_{el}}{\varepsilon}} \quad (21.9)$$

Fig. 21.4: Derivation of the plasma wave as an example of a scalar wave

21.4 Derivation of the scalar wave equation

Making neglects by all means is normal and legal in science. But it may not be carried out at will and untested. In any case an error consideration is necessary, the result of which should be, that the neglect indeed is sufficiently small.
In the here presented case of the wave equation I haven't found one single textbook, in which this error consideration has been carried out. As a result of this inexcusable negligence there is the danger that exactly the aspect is neglected, which it actually concerns. This could lead to catastrophical results, e.g. that the causes for electrosmog, for numerous EMC-problems, for biological and technical effects aren't seen and understood anymore, that pure science once more dilapidates to a creed!

In the case of the wave equation the assumption of no sources describes only one side of the medal. The other side, which for the electromagnetic wave occurs as an error term, we get if we this time put the right part in equation 21.2 to zero (rot E = 0).
In this case a divergence of the field is present, which requires a source field. As sources some charge carriers, quanta or at least particle structures, e.g. vortex structures have to exist. Their propagation occurs, as we know it from the sound propagation, as shock wave in longitudinal manner. The air molecules, the quanta or particle structures thereby oscillate in the direction of propagation. Also the field pointer has a component in this direction

$$\mathrm{rot}\,\mathbf{E} = 0 \quad \text{and} \quad \boxed{\mathrm{grad}\,\mathrm{div}\,\mathbf{E} = \frac{1}{c^2}\cdot\frac{\delta^2\mathbf{E}}{\delta t^2}} \quad \text{(special case)} \qquad (21.4)$$

The occurring divergence of the field pointer (div E) is a scalar, for which reason this wave preferably is called scalar wave.

In the special case of a scalar wave (rot E = 0) the E-field vector can be derived from a scalar potential φ:

$$\boxed{\mathbf{E} = -\,\mathrm{grad}\,\varphi} \quad (21.5)$$

On the one hand this term is used in the wave equation 21.4 on the right-hand side without forming the gradient on both sides of the equation. On the other hand the divergence of the approach 21.5:

$$\mathrm{div}\,\mathbf{E} = -\,\mathrm{div}\,\mathrm{grad}\,\varphi \equiv -\Delta\varphi \qquad (21.6)$$

is applied in equation 21.4. The result is the homogeneous scalar wave equation:

$$\boxed{\Delta\varphi = \frac{1}{c^2}\cdot\frac{\delta^2\varphi}{\delta t^2}} \quad (21.7)$$

Scalar waves, a mathematical reasoning (III)

Proof: plasma wave =
inhomogeneous scalar wave equation

$$\boxed{\Delta \varphi = \frac{1}{c^2} \cdot \frac{\delta^2 \varphi}{\delta t^2} - \frac{\rho_{el}}{\varepsilon}} \quad (21.9)$$

one solution<i>: $\omega^2 = c^2 \cdot k^2 + \omega_p^2$ (= Langmuir waves).

Fig. 21.5 A: Derivation of the plasma wave as an example of the existence of scalar waves in the wave equation

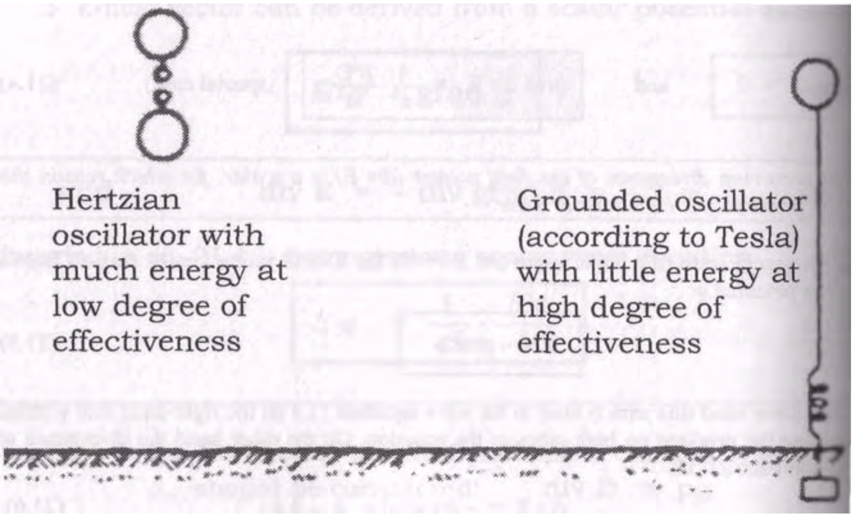
Hertzian oscillator with much energy at low degree of effectiveness
Grounded oscillator (according to Tesla) with little energy at high degree of effectiveness

Fig. 21.5 B: Nikola Tesla explains the difference between his radiation and the Hertzian wave.<ii>

<i>: The solution describes dispersion relations of plasma waves; longitudinal wave movements + Langmuir oscillations of the electron density.

<ii>: Nikola Tesla: The Problem of Increasing Human Energy, The Century Monthly Magazine, June 1900, ISBN 1-882137-00-0, Page i-15

21.5 Derivation of a plasma wave

Doing without formation of the gradient for the derivation of the homogeneous wave equation is tantamount to an integration of the equation. We hence under certain conditions must expect the occurring of an integration constant.

This is the case, if in addition a space charge density ρ_{el} occurs as source of the field, which according to Maxwell equation 4 can be considered as the divergence of a dielectric displacement D (fig. 21.4): $\operatorname{div} \mathbf{D} = \rho_{el}$,

resp. with the relation of material $\mathbf{D} = \varepsilon \cdot \mathbf{E}$: $\operatorname{div} \mathbf{E} = \rho_{el}/\varepsilon \equiv -\Delta\varphi.$ (21.8)

If we complete this contribution with possible present field sources, then the inhomogeneous scalar wave equation results:

$$\boxed{\Delta\varphi = \frac{1}{c^2}\cdot\frac{\delta^2\varphi}{\delta t^2} - \frac{\rho_{el}}{\varepsilon}} \quad (21.9)$$

For these equations solutions have been published[i]. They have the same form, as the well-known dispersion relations of Langmuir waves. That is electron plasma waves, thus longitudinal wave movements associated with Langmuir oscillations of the electron density.

With that it has been proven that scalar waves and longitudinally propagating standing waves are described by the wave equation and are contained in it. This in any case is valid in general just as in the special case of a plasma wave, as mathematically could be derived here.

From the example of the derivation of plasma waves from the wave equation 21.1, we see that scalar waves by all means are known and their existence isn't casted doubt on at all. After all the mathematically won solution is secured by numerous experiments. Why do textbooks concerning high-frequency engineering then ignore the scalar wave parts in the wave equation?

Our specialists seem to concentrate so much on their branch, that they are losing the view on the Big Whole. They practice one-eyed physics, where the plasma physicist keeps one eye shut and the radio technician the other eye. What the other one does and researches, they don't understand anymore for ages. It is necessary to point them to their common root.

The perhaps most important statement of the wave equation is that every emitted wave contains both longitudinal and transverse parts! Both parts in addition occur jointly, so that for corresponding boundary conditions it can be expected that one part is transforming into the other part. The HF technician then suddenly measures less field strength and comes to the conclusion that his radio wave has been damped or partly absorbed. Doing so heat is created, he says, although the wave equation by no means contains a corresponding term for the necessary thermodynamic description. He simply hasn't understood the wave equation!

Absorption means nothing but transverse waves in the case of a disturbance rolling up to vortices, to become a scalar wave in this way (fig. 1.4 and 5.3). With that they are evading every field strength measurement and what can't be measured doesn't exist in one-eyed physics! Therefore can't exist, what shouldn't exist.

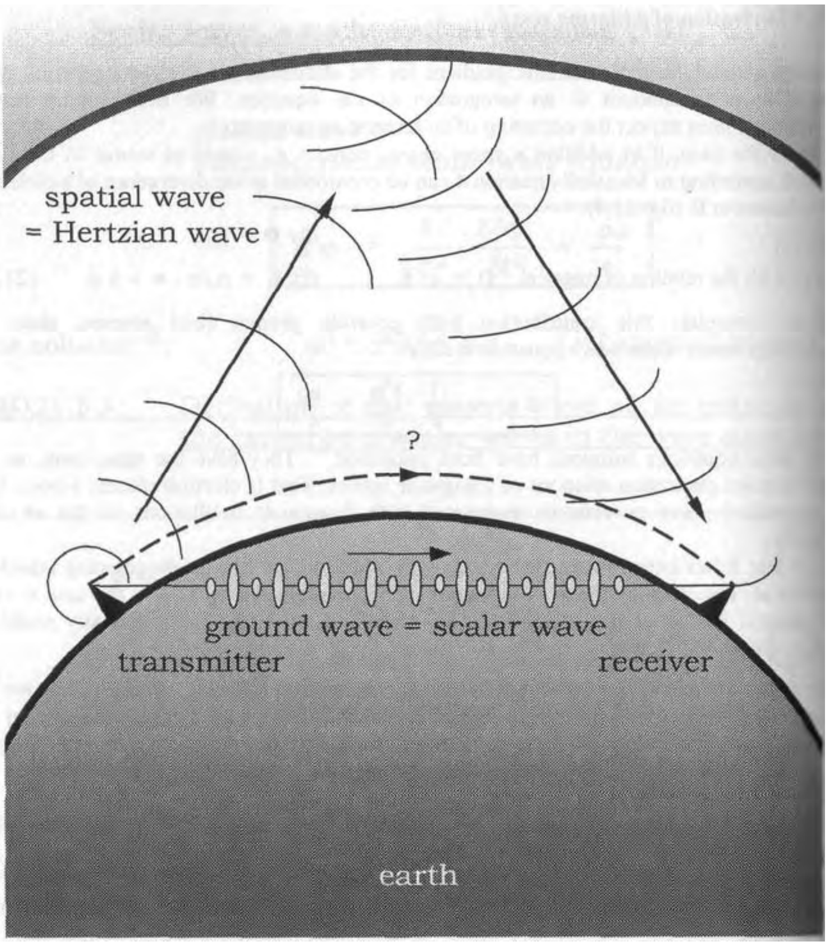
spatial wave
= Hertzian wave
?
ground wave = scalar wave
transmitter
receiver
earth

Fig. 21.6: Ground waves, which follow the curvature of the earth and radio waves reflected at the ionosphere.<i>

<i>: Meinke, Gundlach: Hochfrequenztechnik, 4.Aufl. Springer-Verlag Berlin 1986, Seite R 18: „Lang-, Mittel- and Kurzwelle breiten sich einerseits entlang der Erdoberflache als Bodenwellen, andererseits unter Mitwirkung der Ionosphare als Raumwellen aus."

21.6 Mistakes of the HF technology

The devastating judgement of Tesla, Hertz was mistaken, was rash. His claim of having detected the Maxwell wave himself, proved to be untenable. With this claim in particular Tesla hud the scientific world against him. If one opens encyclopedias or textbooks then one gets the impression, until the day of today science still hasn't forgiven Tesla, what once more shows how persistent prejudices are kept.

Just as little does a verdict of the American Supreme Court justice to the true circumstances, with the decision of the highest judges that Tesla and not Marconi is entitled the right to be the inventor of the radio. As we see, have both inventors in reality used completely other kinds of waves. The available transmitters of 100 years ago we would from today's viewpoint call „broadband dirt slingers". These spark flying monster have blown both parts of the wave equation, the transverse as well as the longitudinal part, into the air to ample extent. What distinguished the wave pioneers was their receiver technique, was eventually the question, which wave part they have filtered and utilized.

Marconi worked with dipole antennas, as already Heinrich Hertz. With that both could preferably track down and detect the radio wave. So they also should be entitled the right to be pioneers of radio technology. The verdict of the highest judges doesn't justice to this circumstance and should rather be judged as a nationalistically coloured political issue. Tesla however worked with two spherical electrodes, in which he preferably replaced one electrode by the globe, by grounding his devices. In this way he could receive the scalar wave parts. But that are not radio waves! Scalar waves have completely other properties, one even could be inclined to call them opposite properties.

To improve the degree of effectiveness of the transmission stretch one naturally was trying to also optimise the transmitting installation with regard to the respectively used wave part. Tesla optimised the scalar wave part and could record reactions of biological beings. His part represents a set of difficulties of the environmental compatibility, which should be taken serious. In the beginning the Marconists on the ships, as the radio operators were called, suffered from the so-called radio operator disease, which is unsolved until today. This phenomenon only disappeared after the radio devices on board had been optimised in favour of the used radio wave. The reached and measuring technically verifiable increase of the degree of effectiveness, primarily obtained by an improved antenna adjustment, simultaneously means a reduction of the scalar wave part, which endangers health.

But a received signal hides the receiver technician, if it has been on the way as a transverse or as a longitudinal wave. The coupling in one and the same equation leaves open both possibilities. Every radio amateur knows the so-called ground waves, which arrive faster at the receiver, than the Hertzian waves mirrored at the ionosphere, which propagate in a straight line. Allegedly the ground waves follow the curvature of the earth<1>, so it is written in expert books. This explanation hurts, since who can see along the curvature of the earth with a pair of field glasses. He would see the back of his head! No, the explanation the ground waves would run along the earth's surface is pure nonsense. The interference and the fading with which the radio amateur is fighting, are a result of the differently fast arriving wave parts, and doing so the scalar wave part tunnels as a straight line right through the earth (fig. 21.6)!

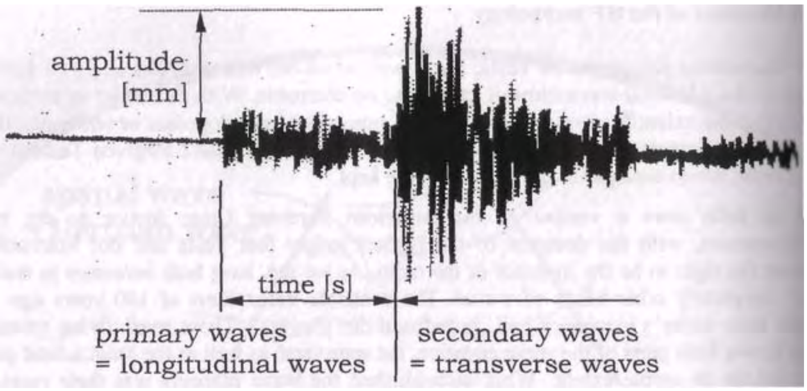

Fig. 21.7 A: Longitudinal and transverse earth quake waves.

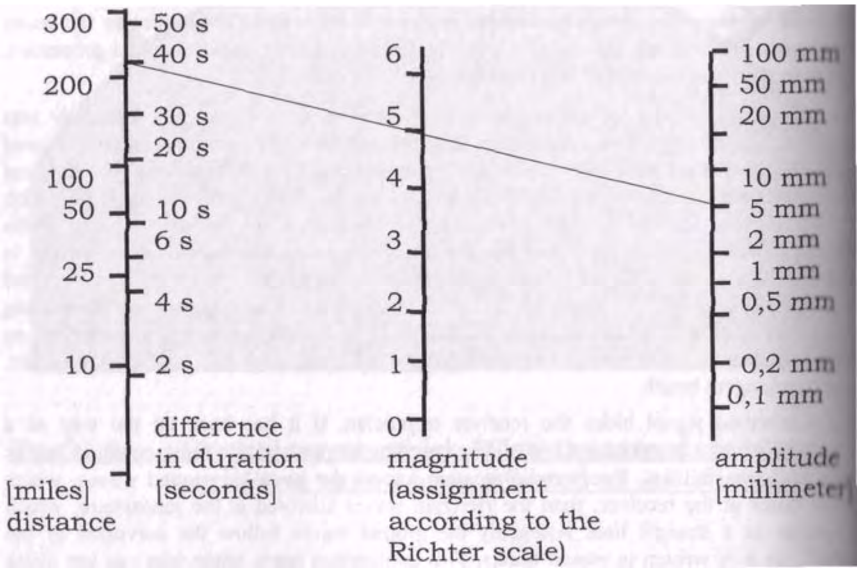
300
200
100
50
25
10
0
[miles]
distance
50 s
40 s
30 s
20 s
10 s
6 s
4 s
2 s
difference
in duration
[seconds]
6
5
4
3
2
1
0
magnitude
(assignment
according to the
Richter scale)
100 mm
50 mm
20 mm
10 mm
5 mm
2 mm
1 mm
0,5 mm
0,2 mm
0,1 mm
amplitude
[millimeter]

Fig. 21.7 B: Analysis according to the Richter scale.
(e.g.: 40 s duration between S- and P-waves for 5 mm amplitude means an earthquake of strength 5 in a distance of 220 miles.)

21.7 Coupling of the wave parts

The set of difficulties of ground waves makes clear the coupling of longitudinal and transverse waves as two aspects or parts of a wave. As the corresponding equation 21,1 mathematically taken apart into 21.2 dictates, does every transmitter emit both parts.

Exactly this circumstance the owners of allotments have used, which directly near a transmitter had illuminated their estate with freely hung up fluorescent lamps. The transmitter runners after that wanted to present them the power bill.and they could obtain, that this kind of illumination technique was prohibited.
Nowadays anyone may operate a high-frequency technical installation, even if he hasn't understood at all the wave equation used by that. Actually one should have been grateful to the allotment owners, if they withdraw the scalar wave radiation, which is incompatible with the environment and biologically harmful, with their fluorescent lamps. Taken exact it even is the task of the transmitting technician to pay attention to it. that only radio waves are sent into the air, since only those should be used. The time has come to reverse the burden of proof to protect the environment, nature, the consumer and the unasked and not involved persons, which are irradiated.

From other areas, for instance from flow dynamics or for body sound is generally known that both wave parts exist and in addition occur jointly. In the case of a propagation through the earth, like for an earthquake, both parts are received and utilized. Because their propagation is differently fast, the faster oscillations arrive first and that are the longitudinal ones. From the time delay with which the transverse waves arrive at the measurement station, the distance to the epicentre of the quake is determined by means of the different velocity of propagation. For geophysicists this tool is part of everyday knowledge (fig. 21.7).

Only who keeps one eye shut, could mean that the electromagnetic wave is purely transverse and sound purely longitudinal. It is true that a transverse sound wave doesn't get too far in air, for which reason sound as a rule is considered as a purely longitudinal wave by neglecting this part, but such a neglect may not be carried out in general, it must be checked if it is legitimate from case to case and an error consideration should be carried out.

Further examples for the coupling of the wave parts are furnished by the latest tunnel experiments. Here so-called pure transverse waves are sent into a tunnel, through which they don't fit through at all. The Maxwell-theory then dictates that behind the tunnel no signal should be measurable.
But a signal is being measured, which in the tunnel in addition was faster than allowed.

In conferences again is being discussed about the wave equation. The imagination of the specialists reaches from phase velocities of an electromagnetic wave, which isn't present at all up to instantaneous tunnelling, during which the clocks should stop<i>.
The wave equation however supplies the only possible answer: The tunnel filters out the scalar wave parts and lets pass from them only those, which are sufficiently small and correspondingly fast!

<i>: see Part 1, Chapter 6.14

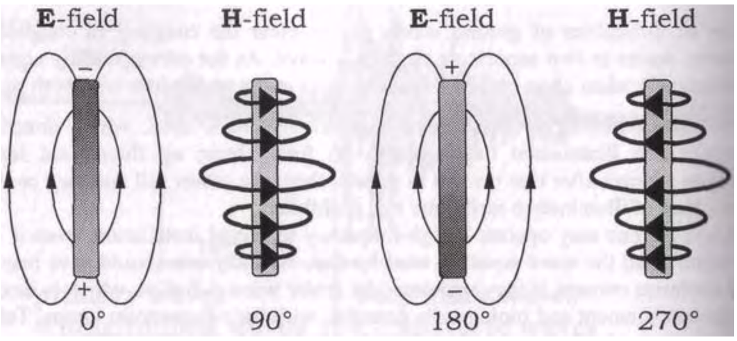

Fig. 21.8 A: The fields of the oscillating dipole antenna

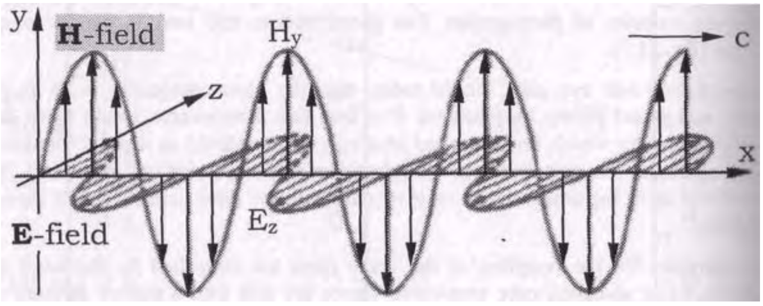

Fig. 21.8 B: The planar electromagnetic wave in the proximity

<i>: Zinke, Brunswig: Lehrbuch der Hochfrequenztechnik, 1. Bd., 3. Aufl. Springer-Verlag Berlin 1986, Seite 335

<ii>: dpa-message in the Sudkurier of 25.11.2000: „Gefahr furs Herz" (Translated:) Patients with a cardiac pacemaker produced in the Netherlands have been warned by the producer of the device (Vitatron) to be careful when passing anti-theft installations in stores. For devices, which were implanted between 1992 and 1998, there is the danger of the implant failing.

21.8 Set of difficulties of the near-field

In high-frequency technology is distinguished between the near-field and the far-field. Both have fundamentally other properties.

Heinrich Hertz did experiment in the short wave range at wavelengths of some meters. From today's viewpoint his work would rather be assigned the far-field. As a professor in Karlsruhe he had shown that his, the electromagnetic, wave propagates like a light wave and can be refracted and reflected in the same way. It is a transverse wave for which the field pointers of the electric and the magnetic field oscillate perpendicular to each other and both again perpendicular to the direction of propagation. It hence would be obvious, if in the case of the Hertzian wave it would concern the far-field. Besides the propagation with the speed of light also is characteristic that there occurs no phase shift between E-field and H-field.

In the proximity it looks completely different. The proximity concerns distances to the transmitter of less than the wavelength divided by 2*pi. Nikola Tesla has broadcasted in the range of long waves, around 100 Kilohertz, in which case the wavelength already is several metres. For the experiments concerning the resonance of the earth he has operated his transmitter in Colorado Springs at frequencies down to 6 Hertz. Doing so the whole earth moves into the proximity of his transmitter. We probably have to proceed from assumption that the Tesla radiation primarily concerns the proximity, which also is called the radiant range of the transmitting antenna.
For the approach of vortical and closed-loop field structures derivations for the near-field are known<i>. Doing so it must be emphasized that the structures don't follow from the field equations according to Maxwell, but the calculations are based on assumed rotation symmetrical structures. The Maxwell theory by no means is capable of such a structure shaping by principle. The calculation provides as an important result<i> that in the proximity of the emitting antenna a phase shift exists between the pointers of the E- and the H-field. The antenna current and the H-field coupled with it lag the E-field of the oscillating dipole charges for 90° (fig. 21.8). These charges form a longitudinal standing wave the antenna rod or antenna dipole. For this reason also the fields produced by high-frequency currents at first have the properties of a longitudinal wave in the proximity of the antenna.

The near-field already is used in practice in anti-theft devices, as they are installed in the entrance area of stores. The customer walks through the scalar wave transmitters. If the coupling coil has not been removed at the cash point, then a signal from the alarm system sounds. The coils work purely passive, i.e. they are supplied with electric energy per scalar wave and stimulated 'to oscillate for their part. Then the effect back on the transmitter is being utilized. Even if the principle is functioning, people still should be warned not to use a technology, which has not been understood completely. Then not explained catastrophes are inevitable <ii>.

<i>: Zinke, Brunswig: Lehrbuch der Hochfrequenztechnik, 1. Bd., 3.Aufl. Springer-Verlag Berlin 1986, Seite 335

<ii>: dpa-message in the Sudkurier of 25.11.2000: ,,Gefahr furs Herz". (quoted at the left, fig. 21.8)

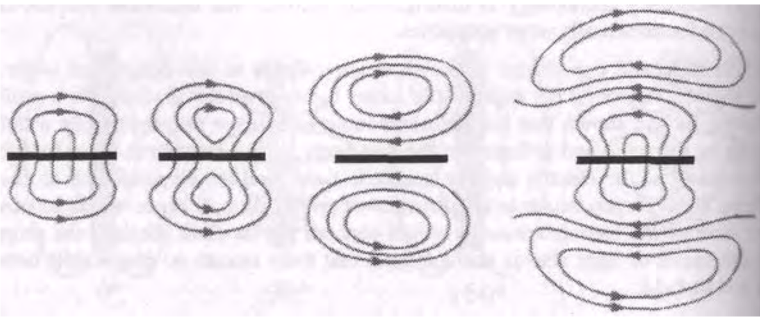

Fig. 21.9 A: The coming off of the electric field lines from a dipole
The forming vortex structures found a longitudinal electric wave carrying impulse!

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electromagnetic wave (transverse)

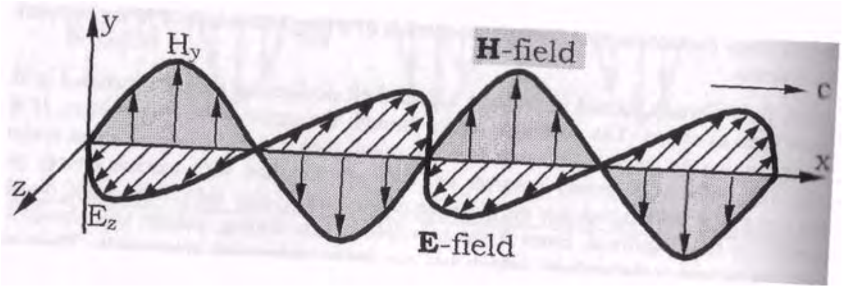

Fig. 21.9 B: The planar electromagnetic wave in the far zone

21.9 Transition to the far-field

In sufficient distance to the transmitting antenna as far-field the transverse electromagnetic wave results (fig. 21.9 B). It is distinguished by not occurring a phase shift between E- and H-field anymore. Every change of the electric alternating field is followed immediately and at the same time by a change of the magnetic alternating field and vice versa.
In the proximity however the phase shift amounts to 90°. Somewhere and somehow between the causing antenna current and the far-field a conversion from a longitudinal into a transverse wave occurs. How should one imagine the transition?

In the books the coming off of a wave from a dipole is represented according to fig. 21.9 A. The fields come off the antenna, the explanation reads. If we consider the structure of the fields coming off then we see field vortices, which run around a point, which we can call the vortex centre. Such field structures naturally are capable of forming standing waves and to carry an impulse. The scalar wave field in general and the near-field in special we only will understand with suitable vortex physics and with a field theory extended for corresponding vortices we also will be able to calculate it. Postulates cannot replace field physics!

Be that as it may, the vortex, after having left the antenna, for bigger getting distance at some time seems to unroll to propagate further as an electromagnetic wave. There takes place a transition from longitudinal to transverse, or spoken figuratively, from vortex to wave. How complete this conversion takes place, how big the respective wave parts are afterwards, on the one hand depends on the structure and the dimensions of the antenna. Information is given by the measurable degree of effectiveness of the antenna.
The vortex structures on the other hand are the stabler, the smaller and faster they are. If they are as fast as the light or even faster, then they become stable elementary particles, for instance neutrinos. Slower vortex structures however are predominantly instable. They preferably unwind to waves. Vortex and wave prove to be two possible and under certain conditions even stable field configurations.

Let's emphasize: A Hertzian dipole doesn't emit Hertzian waves! An antenna as near-field without exception emits vortices, which only at the transition to the far-field unwind to electromagnetic waves. A Hertzian wave just as little can be received with a dipole antenna! At the receiver the conditions are reversed. Here the wave is rolling up to a vortex, which usually is called and conceived as a ,.standing wave". Only this field vortex causes an antenna current in the rod, which the receiver afterwards amplifies and utilizes.
The mostly unknown or not understood near-field properties prove to be the key to the understanding of the wave equation and of the method of functioning of transmitting and receiving antenna. The question is asked, how one should imagine the rolling up of waves to vortices and vice versa the unrolling? How could an useful vortex mode) look like?

Circularly polarized wave (transverse)

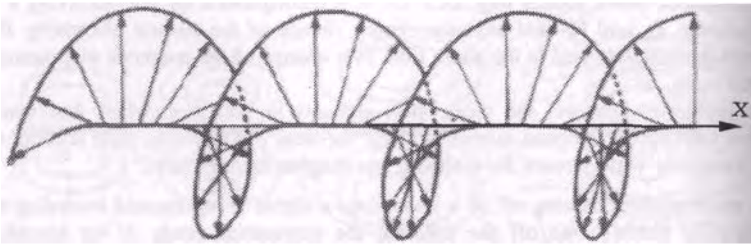

Fig. 21.10 A: Left-circular polarized wave
(as explanation for the transition to a vortex and to a scalar wave)

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electric wave (longitudinal)

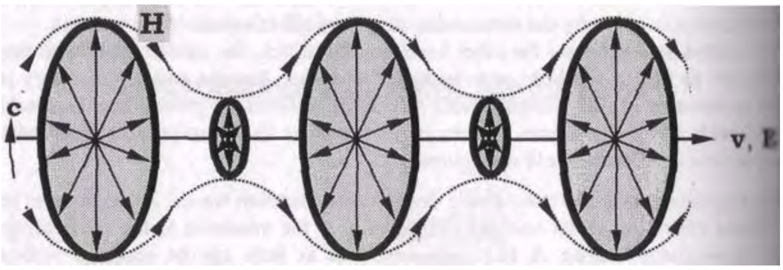

Fig. 21.10 B: Magnetic ring-vortices form an electric scalar wave.

vortex and wave = two stable field configurations
electromagnetic wave = transverse wave propagating in a straight line
ring-like vortex = transverse wave running in circles
vortex velocity = speed of light c
change of structure = if the field is disturbed without expense of energy

22.10 Scalar wave model

The light, as electromagnetic wave, in the presence of a heavy mass or of strong fields is bent towards the field source (fig. 6.10). The wave normally propagating in a straight line thus can be diverted. The square of the speed of light further is inversely proportional to the permeability and dielectricity, short, in presence of matter it is more or less strongly slowed down. If this slowing down of the wave occurs one-sidedly, then a bending of the path can be expected as well. At the end of the antenna a reflection and a going back of the wave can occur, which at the other end again hits itself. Now the wave has found a closed-loop structure, which can be called vortex. The figures 21.10 B and 21.11 A show the two possible structures.

In technical books this vortex with the properties of a „standing wave" is explained gistly. Near-field and standing wave are two examples, how the textbooks succeed in describing mathematically right a small part of the scalar wave properties, without having to have a good look at vortex physics. With such auxiliary descriptions however the end is reached fast, if for instance it concerns understanding a pure scalar wave transmission according to Nikola Tesla (fig. 19.11) and the special properties of this wave type. With the vortex concept of an extended field physics new horizons are opening.

If we direct our look again to the sketches (fig. 21.10 B and 21.11 A). In both cases electromagnetic waves are represented which propagate with the speed of light, only that the wave doesn't go forward in a straight line but instead runs around in circles. It also furthermore is transverse, because the field pointers of the E-field and the H-field oscillate perpendicular to c. By means of the orbit the speed of light c now has become the vortex velocity. Wave and vortex turn out to be two possible and stable field configurations. For the transition from one into the other no energy is used; it only is a question of structure. The vortex structure thus stabilizes itself by means of the field dependency of the speed of light.

By the circumstance that the vortex direction of the ring-like vortex is determined and the field pointers further are standing perpendicular to it, as well as perpendicular to each other, there result two theoretical formation forms for the scalar wave. In the first case (fig 21.10 B) the vector of the H-field points into the direction of the vortex centre and that of the E-field axially to the outside. The vortex however will propagate in this direction in space and appear as a scalar wave, so that the propagation of the wave takes place in the direction of the electric field. I call this an electric wave.

In the second case the field vectors exchange their place. The direction of propagation this time coincides with the oscillating magnetic field pointer (fig. 21.11 A), for which reason I speak of a magnetic wave.

The vortex picture of the rolled up wave already fits very well, because the propagation of a wave direction of its field pointer characterizes a longitudinal wave, because all measurement results are perfectly covered by the vortex model. It even is clear that no energy has to be spended for the conversion, since merely the structure has changed. If it becomes a vortex the wave just doesn't run in a straight line anymore but in circles, to either wrap around the magnetic field vector (fig. 21.10 B). or the electric field vector (fig. 21.11 A).

magnetic wave (longitudinal)

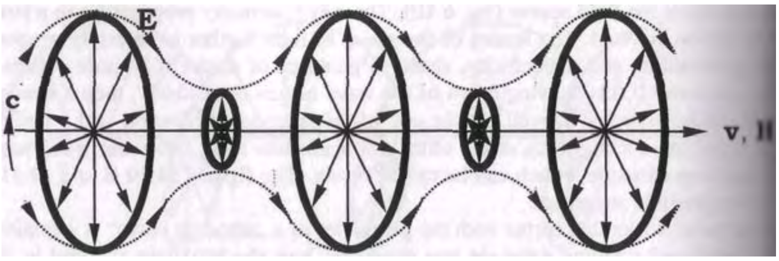

Fig. 21.11 A: The magnetic scalar wave

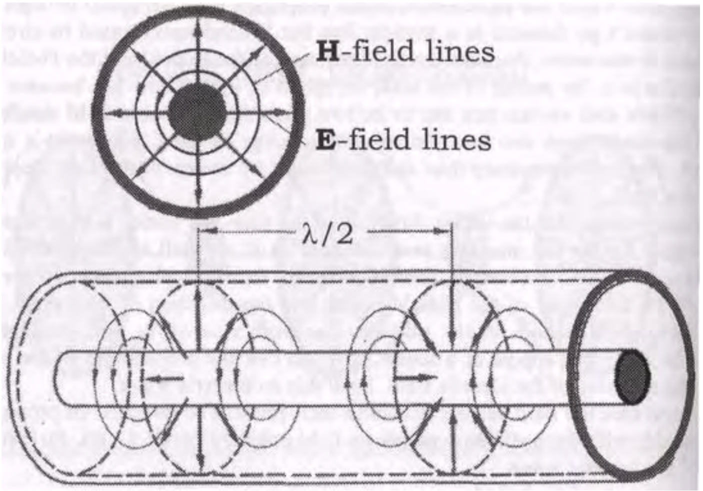

Figure 21.11 B: Wave propagation in a coaxial cable,
(Example for waveguide, horn radiator, etc.)<i>
Cross-section of coaxial conductor and field distribution in the direction of propagation.

<i>: H. Armbruster, G. Grunberger: Elektromagnetische Wellen im Hochfrequenz-

21.11 Double-frequent oscillation of size

Because a longitudinal wave propagates in the direction of the field, the field pointer also will oscillate with the velocity of propagation v. This hence isn't constant at all, it can significantly differ from that of the light and can take arbitrary values. According to the theory of objectivity the field oscillating with it determines its momentary size:

$$E, H \sim 1/v^2 \qquad (21.10).$$

The velocity of propagation v of the scalar wave thus oscillates double-frequently and with opposite phase to the corresponding field. A detailed description would mean, if the field strives for its maximum value, the velocity v of the wave reaches its smallest value. In the field minimum the scalar wave vice versa accelerates to its maximum value. For longitudinal waves therefore only an averaged velocity of propagation is given and measured, as this for instance is usual for the sound wave, and this can vary very strong as is well-known (body sound compared to air sound, etc.).
The two dual field vectors of E and H, the one in the direction of propagation and the one standing perpendicular to it, occur jointly. Both oscillate with the same frequency and both form the ring-like vortex in the respective direction. As a result the ring-like vortex also oscillates in its diameter double-frequently and with opposite phase to the corresponding field (fig. 21.10 Band 21.11 A).
This circumstance owes the ring-like vortex its property, to tunnel. No Faraday cage is able to stop it, as could be demonstrated in experiments<i>. Only therefore the ground wave runs through the earth and not along the curvature of the earth. A further example is the coaxial cable (fig. 21.11 B). Also this acts as a long tunnel and so it isn't further astonishing, that the electric field lines have the same orientation, as for a magnetic scalar wave. As a practical consequence in this place there should be warned of open cable ends, wave guides or horn radiators with regard to uncontrolled emitted scalar waves!

At present in the press is being discussed, if the cable network runners for some channels the mission to operate again should be withdrawn, because the airline radio traffic is being disturbed. The original opening for cable frequencies, which actually are reserved for the airline radio traffic, based on the erroneous assumption, that conflicts are unthinkable. But then the planes were disturbed in their communication. As the cause TV-cables made out, which hadn't been closed according to the rules with a resistor, as it by all means can occur on building sites and during renovation works.
On the other hand is being argued with the small current, which flows through the coaxial cable, and the large distance to the planes also is cited. According to that it actually can't concern Hertzian waves. It presumably are scalar waves, which escape from the open cable ends and which are collected by a receiver in the plane. It indeed is very little field energy, but because it again is being collected and bundled, the scalar wave is able to exceed the part of the radio wave by far just at large distances and to cause problems.
For such examples from practice the scalar wave theory is fully taking effect.

<i>: Adolf und Inge Schneider im Interview mit Prof. Dr.-Ing. Konstantin Meyl: Durchbruch in der Freien-Energie-Forschung, NET-Journal 12/1999, S. 7-9.

1. H. Hertz: electromagnetic wave (transverse)

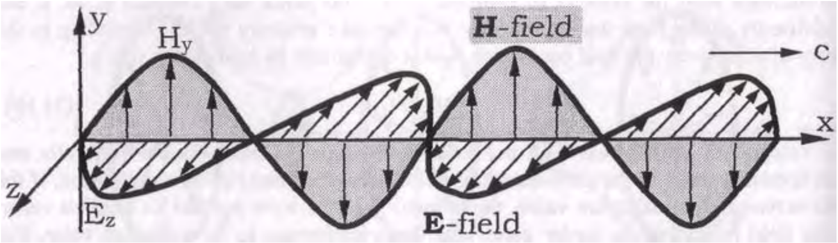
y
Hy
H-field
c
x
z
Ez
E-field

2. Nikola Tesla: electric wave (longitudinal)

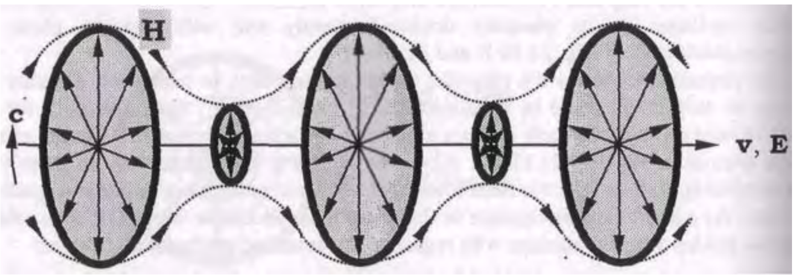

3. magnetic wave (longitudinal)

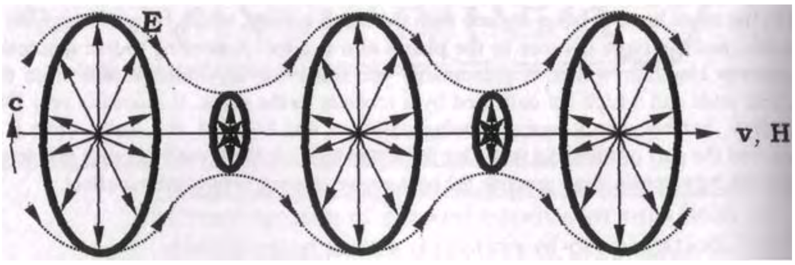

Fig. 21.12: The three basic types according to the wave equation
(21.1), (electric, magnetic and electromagnetic wave).

21.12 Electric and magnetic scalar wave

Let us record: For the wave propagation there thus are three possible and stable states (fig. 21.12): the transverse electromagnetic wave according to Heinrich Hertz (fig. 1), the longitudinal electric wave according to Nikola Tesla (fig. 2), and a longitudinal magnetic wave (fig. 3), which isn't connected yet with a name of a discoverer. The last one is a pure product of my theoretical derivation. The question is asked, which practical meaning the magnetic wave could have.
It is formed by individual electric field vortices, which I have discovered and called potential vortices 1990. I proceed from the assumption that the youngest of the three waves will play the by far biggest role in the future, because its properties are unattainable, both with regard to the energy technical and to the information technical use. One example for each should support this thesis.

The experiments concerning the electric wave according to Nikola Tesla, where is being worked with electrically charged spheres, don't show a particularly high power. Magnetic converters, so the experiences of my laboratory activities, are superior to an electrostatic converter as a collector for free energy by far. That even can be expected, because a magnetic engine is much smaller than an electrostatic engine of the same power as is well-known.

At a congress of medicines was given a talk on the basic regulation of the cells, on the communication of the cells with each other. Professor Heine in his decades of research work has found out that the cells for the purpose of communication build up channels for instance in the connective tissue, which after having conducted the information again collapse. Interestingly the channels have a hyperboloid structure, for which no conclusive explanation exists.
The structure of the data channels however is identical with the one of a magnetic scalar wave, as shown in fig. 3. Through a channel formed such, which functions like a tunnel or a dissimilarly formed waveguide, only one very particular scalar wave can run through. Waves with different frequencies or wavelengths don't fit through the hyperboloid formed tunnel at all in the first place. Through that the information transmission obtains an extremely high degree of safety for interference.
To the biologist here a completely new view at the function of a cell and the basic regulation of the whole organism is opening. The information tunnel temporarily forms more or less a vacuum, through which only potential vortices can be conducted, and that without any losses - simply perfect! From this example is becoming clear that nature is working with scalar waves namely with magnetic waves.

One other point should be recorded: The mentioned tunnel experiments, in which speed faster than light is being measured with most different devices, impressively confirm the presence of scalar waves. But if scalar waves exist which are faster than light and other ones, which are slower, then it almost is obvious that also such ones will exist, which propagate exactly with the speed of light. These then will have all the properties of the light and won't differ from the corresponding electromagnetic wave in the observable result. As scalar wave it however is formed by vortex configurations, which unambiguously have particle nature. Nothing would be more obvious than to equate these quantum structures with the photons.

Question: Is the light wave or particle?

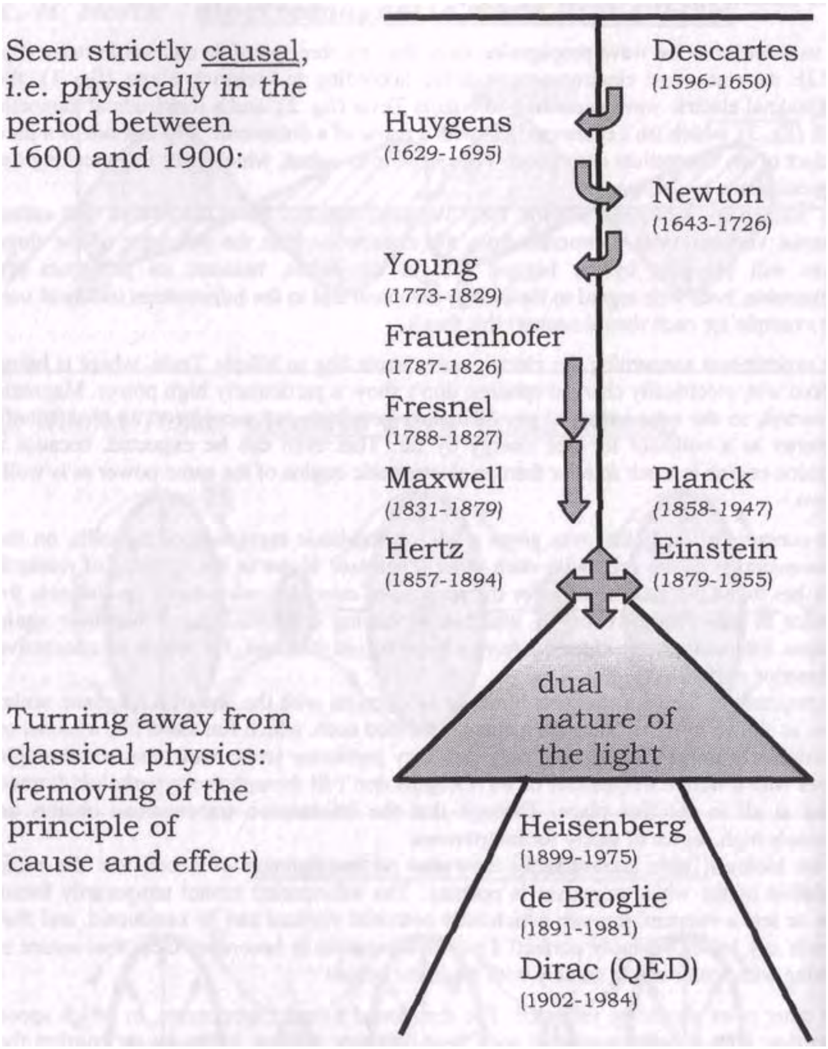
Seen strictly causal, i.e. physically in the period between 1600 and 1900:
Descartes (1596-1650)
Huygens (1629-1695)
Newton (1643-1726)
Young (1773-1829)
Frauenhofer (1787-1826)
Fresnel (1788-1827)
Maxwell (1831-1879)
Planck (1858-1947)
Hertz (1857-1894)
Einstein (1879-1955)
dual nature of the light
Turning away from classical physics: (removing of the principle of cause and effect)
Heisenberg (1899-1975)
de Broglie (1891-1981)
Dirac (QED) (1902-1984)

Fig. 22.1: The view of some physicists concerning the nature of the light as wave or as particle.

According to the wave equation the light is a mixture of wave and photon radiation!

22 Properties of scalar waves

For the light quanta hypothesis the Nobel Prize for physics was awarded 1921. But it only was a hypothesis, an idee fixe, which was honoured here. It is quite odd, if such an important prize is awarded to a research scientist, who hasn't got the slightest idea what light quanta are anyway, of what they consist and how they are built up. Albert Einstein cleverly used the embarrassing situation, by in his celebration speech on the occasion of the awarding of the Nobel Prize giving a talk on the theory of relativity. After the speech a member of the committee found it necessary, to point to it, that this wasn't object of the awarding of the prize and that the theory of relativity concerns a pure theory, which can't be proven by principle. A theory hence neither could be awarded the Nobel Prize.

Such words on the occasion of awarding a prize for a daredevil hypothesis give the whole event really grotesque characteristics. But it came still worse.

22.1 Wave-particle compromise

Physicists of name and rank had come together. It concerned the question if the light is wave, or particle or even both at the same time? For both variants experimental proof was present, the discussion became inflamed and the things boiled over. Finally they were as smart as before, as Werner Heisenberg presented his ideas concerning the uncertainty principle. This compromise, on which one eventually came to an agreement, with good cause may be called the worst in the history of physics. It dictates me, what I shell see and how exact I may look. With it the contradiction should be overcome that the light contrary to every causality should be wave and particle at the same time.

Such fixings not only have a funny, but also a tragic side. Since it were authorities, which have approved the compromise and the whole community of science has confidence in the statements of its authorities, which immediately and unfiltered is entered in all textbooks. At the meeting it simply and solely concerned the wave equation and only that could have supplied the correct and only possible answer: It falls apart into two parts and this explains, why the light one time appears as an electromagnetic wave and the next time as a vortex particle, which is called photon. The conversion can take place at any time spontaneously and without putting on energy, so that depending on the used measuring technique the particle appears as wave or as particle, but of course never as both at the same time!

Looking back one can say that the funny thing about the situation was that all discussed about the wave and its properties known at that time, that all should know the wave equation. An equation as is well-known says more than a thousand words and one look would have sufficed entirely, to answer the controversial question once and for all. It would have saved us a lot.

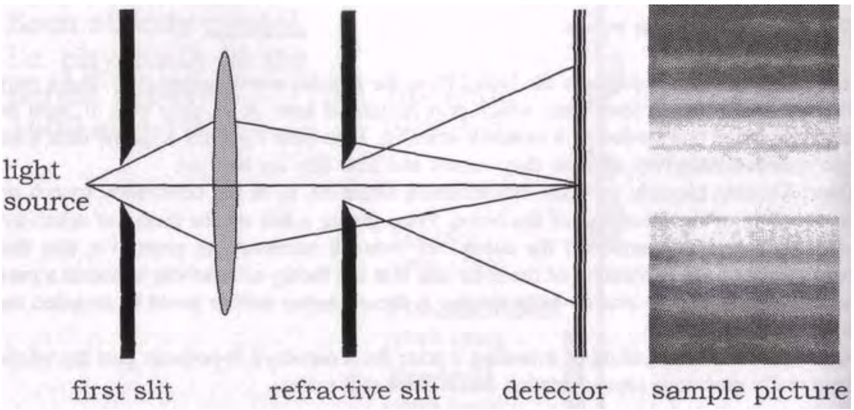
light
source
first slit
refractive slit
detector
sample picture

Fig. 22.2 A: Light forms interference patterns at the slit (light stripes are formed, where the waves oscillate in phase, dark stripes, where they oscillate out of phase).

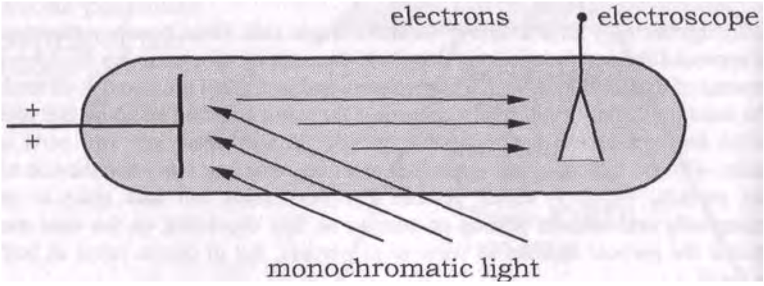
electrons
electroscope
+
+
monochromatic light

Fig. 22.2 B: The photo-electric effect

<i>: Atome als Energiewellen. Physiker wandelten einen Strom von Natrium atomen in Wellen um. III. Wissenschaft 7/1996, Seite 56 + 57

22.2 Concerning the measurement of light

The uncertainty principle with the interpretation of Heisenberg, the light is wave and particle at the same time, is incompatible with the wave equation. Heisenberg puts an equal sign, where in the wave equation in reality is present an addition of both wave parts. Fortunately in mathematics there is no need of speculating, there a derivation is right or wrong. Nothing is changed to that even if all physicists of the world should go in the wrong direction following the prevailing opinion. The wave equation exert an influence on the interpretation of the light experiments, on the one hand the ones concerning the interference and refraction of the light, where electromagnetic waves are becoming visible (fig. 22.2 A) and on the other hand the photo-electric effect, as proof of light quanta (fig. 22.2 B).

Already the wave theory of Huygens requires interference patterns of light rays, as they for instance are observed behind a slit, and demonstrates with that the wave nature. If on that occasion the particle nature is lost, if thus the photons present before the slit can't be detected behind the slit anymore, then plain and simple the measuring method, thus the slit is to blame for that. The vortices have unrolled themselves at the slit to waves. Corresponding experiments also have been carried out with matter. At the Massachusetts Institute of Technology whole sodium atoms were converted into waves. At the detector pure interference patterns were observed, which go as evidence for the successful dematerialization[i]. But the vortex physicist they show still more: they reveal, that atoms merely are waves rolled up to spherical vortices, which at any time and spontaneously can again unroll to waves at a lattice (chapter 5 and 7).
The common interpretation, the wave nature detectable behind a slit must have been present in the same form already before the slit, is untenable and in the end wrong, as makes clear the experiment with the sodium atoms.

The photo-electric effect, which on the other hand shows the quantum nature of the light, has been discovered by Heinrich Hertz, further investigated by Lenard and finally rendered more precisely by Millikan 1916 (fig. 22.2 B). It bases on the circumstance that light of higher frequency, thus blue light, has more energy than red light of lower frequency. But if electrons are knocked out a metal plate by light, then that occurs, by the waves rolling up to vortices. Now indeed photons are at work, which are detected with an electroscope indirectly.
In the same way a photon ray in a bubble chamber can be photographed. But also here the measuring method is responsible for what is being observed.

A good example is the human eye, the rods and cones of which merely can pick up potential vortices and pass them on to the nerves as so-called reaction potentials. Incident waves can only be detected, if they first have rolled up to vortices in the corpus vitreum of the eye. For us seeing, it doesn't play a role of how many percent vortices and waves the light is consisting.
Behind a sheet of glass for instance a larger vortex part can be expected and still the light has the same brightness as without sheet; the sheet of glass is perceived as transparent. We nevertheless must assume that light with a large wave part has another quality, than such light behind glass or artificial light with a large part of photons.

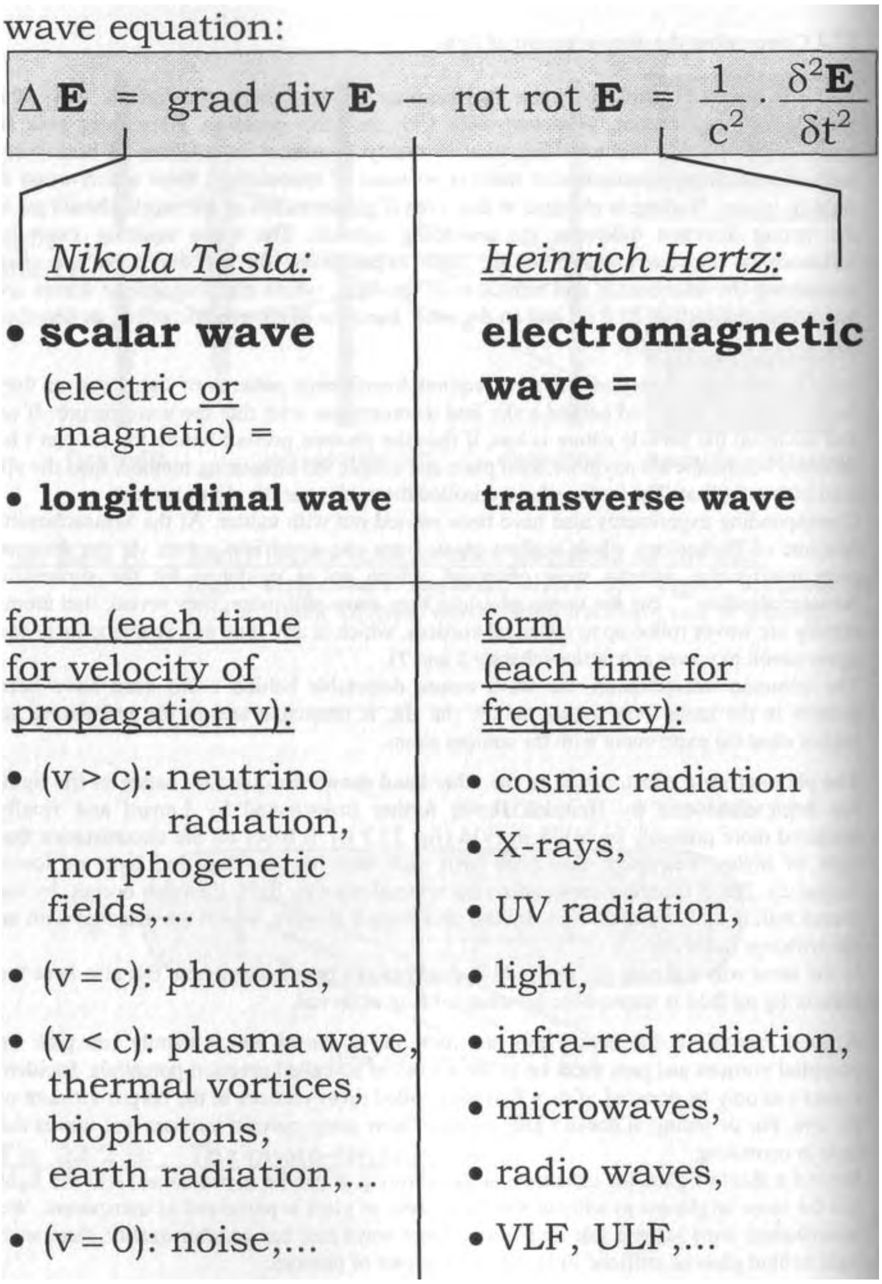

wave equation:

$$\Delta \mathbf{E} = \text{grad div } \mathbf{E} - \text{rot rot } \mathbf{E} = \frac{1}{c^2} \cdot \frac{\delta^2 \mathbf{E}}{\delta t^2}$$

Nikola Tesla:	*Heinrich Hertz:*
• **scalar wave** (electric or magnetic) =	**electromagnetic wave =**
• **longitudinal wave**	**transverse wave**
form (each time for velocity of propagation v):	form (each time for frequency):
• (v > c): neutrino radiation, morphogenetic fields,...	• cosmic radiation • X-rays, • UV radiation,
• (v = c): photons,	• light,
• (v < c): plasma wave, thermal vortices, biophotons, earth radiation,...	• infra-red radiation, • microwaves, • radio waves,
• (v = 0): noise,...	• VLF, ULF,...

Fig. 22.3:____ The two parts of the wave equation

22.3 Comparison of the parts of Tesla and Hertz

Light as a rule always is formed as photon radiation, even on the sun. If in the end only waves arrive on earth, then the vortices sometime on the way to us must have unrolled to waves. Photon radiation after all is a scalar wave radiation, which generally is predominant in the near-field of the source of radiation. There is no reason, why the light should act in another way than the wave radiated by a radio transmitter, which as well forms vortices in the near-field area, as we already have discussed. For different interpretations of wave properties of one and the same physical phenomenon there is no place in a unified theory.

If we stay at the comparison then it is not an individual case that an experimental setup is responsible for what is being measured and observed. A parallel case to the experiments concerning the nature of the light is the one concerning the wave propagation. Hertz has received and utilized the transverse part and Tesla the longitudinal part and either one claimed, only he is right. There doesn' t exist an other equation, which has been and is being ignored and misunderstood so thoroughly, as the wave equation.

Fig. 22.3 shows in a survey the two parts of the wave equation in the assignment to the terms and forms: Right hand side the electromagnetic wave according to Heinrich Hertz and left hand side the scalar wave according to Nikola Tesla. The terms, like on the one hand transverse wave and on the other hand longitudinal wave relate to the kind of wave propagation.

If the field pointers oscillate crossways to the direction of propagation, then as a consequence the velocity of propagation is decoupled from the oscillating fields. The result in all cases is the speed of light, and that in our observation is constant. It is usual to make a list for increasing frequency, starting at the longest waves (ELF and VLF) over the radio waves (LW, MW, SW, UHF), the TV channels (VHF, UHF), the microwaves, the infra-red radiation, the light, the X-rays up to the cosmic radiation.
It really is interesting that it concerns one and the same phenomenon despite the different forms! As long as Maxwell only had published a theory for the light, in the world of science 24 years long at first nothing at all happened. Only Heinrich Hertz with his short wave experiments opened the eyes. Now all suddenly started at the same time to research into various phenomena on the frequency scale, from Madame Curie over Konrad Rontgen up to Nikola Tesla, who primarily researched the area of long waves.

With regard to the scalar waves until now a corresponding booster detonation has failed to appear. The immense area is new ground scientifically, which is awaiting to be explored systematically. I try to make a contribution with my historic rebuild of a scalar wave transmission line according to the plans of Tesla<i>.

<i>: Im Gesprach mit dem Fernsehmoderator und Buchautor Johannes von Buttlar weise ich auf die Chancen und technischen Moglichkeiten hin: Johannes von Buttlar im Gesprach mit Prof. Dr. Konstantin Meyl: Neutrinopower, Argo-Verlag Marktoberdorf, 1. Aufl. (2000).

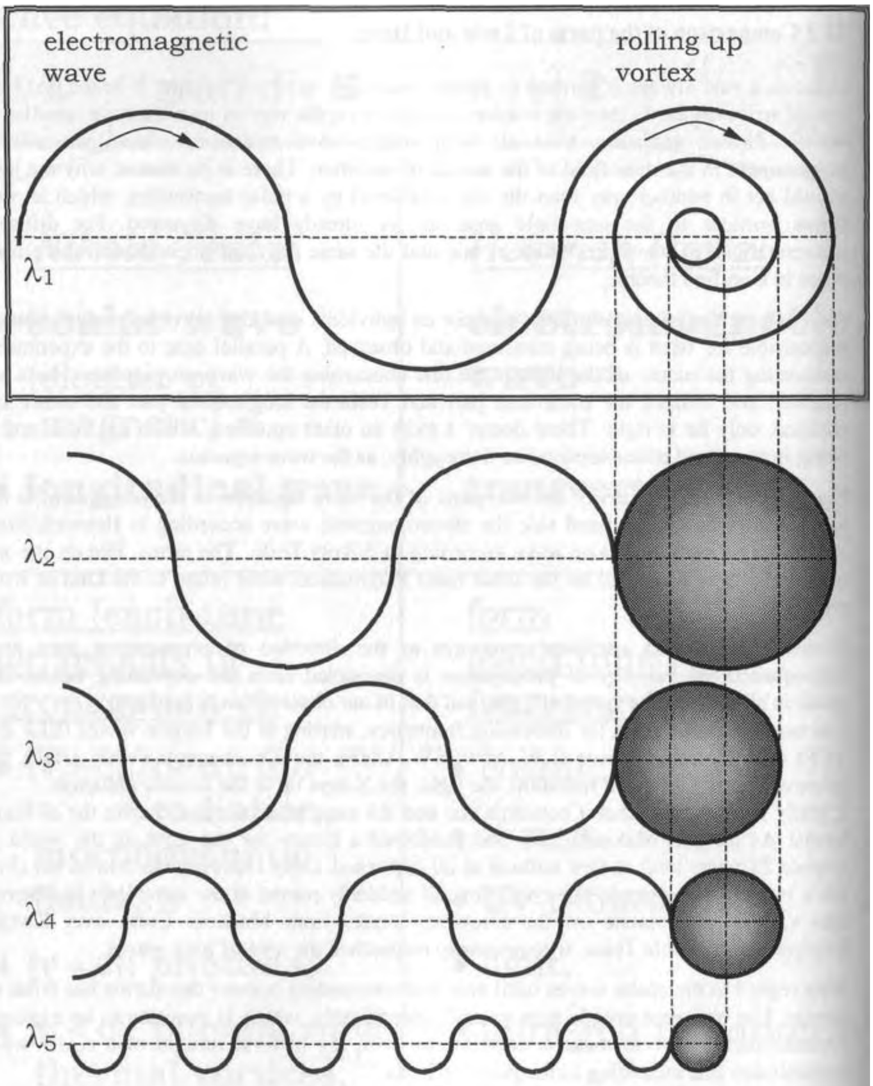
electromagnetic wave
rolling up vortex
λ1
λ2
λ3
λ4
λ5

Fig. 22.4: The wave rolling up to a vortex.

wavelength of the wave: $\lambda_1 = c/f_1$

wavelength of the vortex: λ_n (n = 1,2,3,4,5) $\leq \lambda_1$

$f_5 > f_4 > f_3 > f_2 > f_1$ $\lambda_5 < \lambda_4 < \lambda_3 < \lambda_2 < \lambda_1$

22.4 Noise, a scalar wave phenomenon

Longitudinal waves can take arbitrary velocities between zero and infinity, because they propagate in the direction of an oscillating field pointer and as a consequence of that their velocity of propagation oscillates as well and by no means is constant. It does make sense to llist the forms of scalar waves according to their respective velocity of propagation (fig. 22.3, left column).

If we start with a localized vortex, a wave rolling up, which further is contracting. Doing so the wavelength gets smaller and smaller, whereas the frequency increases. An evenly frequency mixture distributed over a broad frequency band is observed. This phenomenon is called noise (fig. 1.4). But besides the localized noise, noise vortices can also be on the way with a certain velocity as a scalar wave, e.g. for the radio noise. In this case they show the typical properties of a standing wave with nodes and antinodes.

Also the earth radiation is said to have standing wave nature, which can be interpreted as slowed down neutrino radiation. If it is slowed down on the way through the earth, then the neutrino properties are changing, as this was measured in the Kamiokande detector in Japan recently. Unfortunately the proof occurs only indirect, because there still don't exist measuring devices for scalar waves. We'll talk about this problem area later and are content with the clue that already within living memory the standing wave property has been used to find water and deposits of ores and still is used today (fig. 22.4).

If we continue our considerations concerning the forms of scalar waves, as they are listed in fig. 22.3. The scalar waves, which are slower on the way than the light, are joined by the plasma waves. This is confirmed by measurements and calculations.

For thermal vortices, as they have been investigated by Max Planck and for biophotons, as they can be detected in living cells by colleague Popp, the velocity of propagation however is unknown. It was not and still is not measured at all, now more than ever. The research scientists have confidence in the assumption that all waves go with the speed of light, but that is a big mistake.

For all wave kinds there at least exists also one vortex variant, for radio waves for instance it is the radio noise, which propagates with a velocity different from c. The velocity is the product of frequency and wavelength:

$$\boxed{v = f \cdot \lambda} \quad (22.1)$$

From the three variables v, f and λ at least two must be measured, if one has a suspicion that it could concern scalar waves. At this place most errors are made in the laboratories. Countless experiments concerning the biological compatibility, concerning medical therapy methods and similar experiments must be repeated, because as a rule only the frequency is being measured and it has been omitted to at least check the wavelength or the velocity of the wave. Countless research scientists must put up with this accusation. Much too blind the scientists, who now again may start from the very beginning with their work, have had confidence in the predominance of the speed of light.

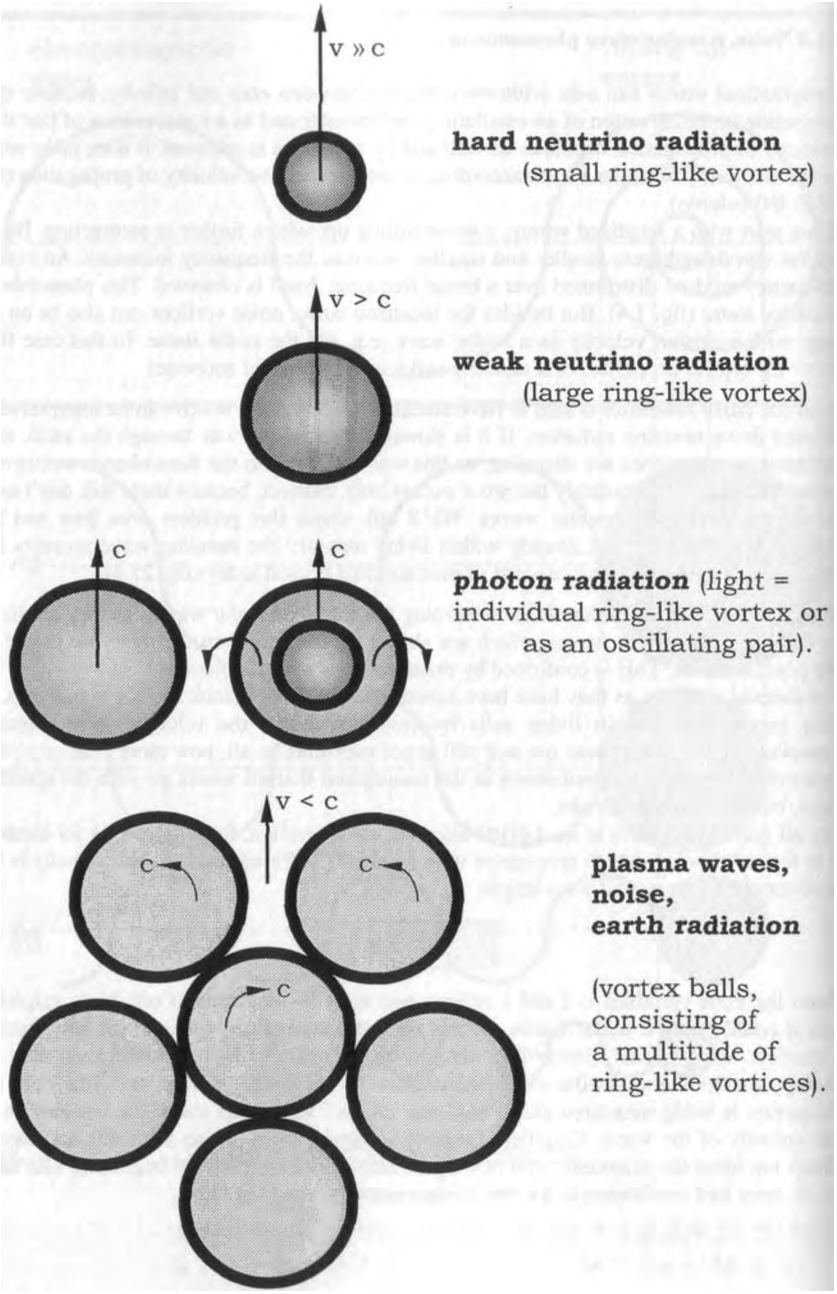
v » c
hard neutrino radiation
(small ring-like vortex)
v > c
weak neutrino radiation
(large ring-like vortex)
c
c
photon radiation (light = individual ring-like vortex or as an oscillating pair).
v < c
c
c
c
plasma waves,
noise,
earth radiation
(vortex balls, consisting of a multitude of ring-like vortices).

Fig. 22.5: ____The ring-like vortex model of scalar waves.

22.5 Neutrino radiation

The neutrino physicists make the same error. They proceed from the assumption that their particles are on the way with a speed somewhat less than the speed of light c. This contradicts the observation according to which black holes should represent strong sources of neutrinos, which are black only for the reason that no particle radiation is able to escape them, which is on the way with c or even slower. If a black hole does hurl neutrino radiation into space, than that must be considerably faster than c, as normal neutrino physicists still by no means can imagine it today.

But the neutrino radiation only can be detected after it has been slowed down to a value, which is smaller than c. If the slowing down occurs slightly assymmetrical, then as a consequence a mean of the mass different from zero appears. The ,,measurement" of such a rest mass, as it at present is propagated and celebrated, is a classical measurement error! As long as a neutrino on the way to us still is faster than the light, the mean of its mass is generally zero. The effective value of the mass of a neutrino is however considerable. Only it is able to give account for the sought-for dark matter, as far as it must exist in the today supposed form anyway.

The Tesla radiation, that the discoverer Nikola Tesla already in own experiments had found out, is faster than light (chapter 9.7 and 17.2). Since this Tesla radiation according to the description is identical with the neutrino radiation, since it so to say forms a subset, I will call neutrino radiation all the scalar waves, which are faster than the light. This stretches from the weak radiation at low frequencies up to the hard neutrino radiation of cosmic origin. But the hardness of the radiation does not only increase with the frequency, it in particular increases with the velocity.

The neutrino radiation first of all is carrying energy. On top of this basic wave radiation in addition information can be modulated. Doing so extremely complex modulation variants are offering. Of this kind we must imagine thoughts, as being complex modulated vortices, which can propagate as scalar wave in space. Rupert Sheldrake calls this vortex field a morphogenetic field. At this place merely is pointed at his very interesting research results[i].

Thoughts can be standing in space, in the form of localized noise, but they also can move with speeds faster than light. According to that a communication with intelligent beings from other star systems by all means wouldn't be an Utopia anymore.

Every fast neutrino forms an individual ring-like vortex (fig. 7.12). The slower the scalar wave is, the more dependent the vortices become. The photon already can consist of two ring-like vortices (fig. 4.6), whereas plasma waves and other slow scalar waves can form from a multitude of individual vortices, which are rotating around each other, to form vortex balls and vortex streets (chapter 4.9 - 4.11). From this circumstance already results very different scalar wave behaviour in the different areas of the velocity of propagation. This trend for small velocities can as well be observed towards lower frequencies. For a certain wavelength the frequency after all (according to eq. 22.1) is proportional to the velocity of propagation.

<i>: R. Sheldrake: Seven experiments that could change the world. New York: Riverhead 1995

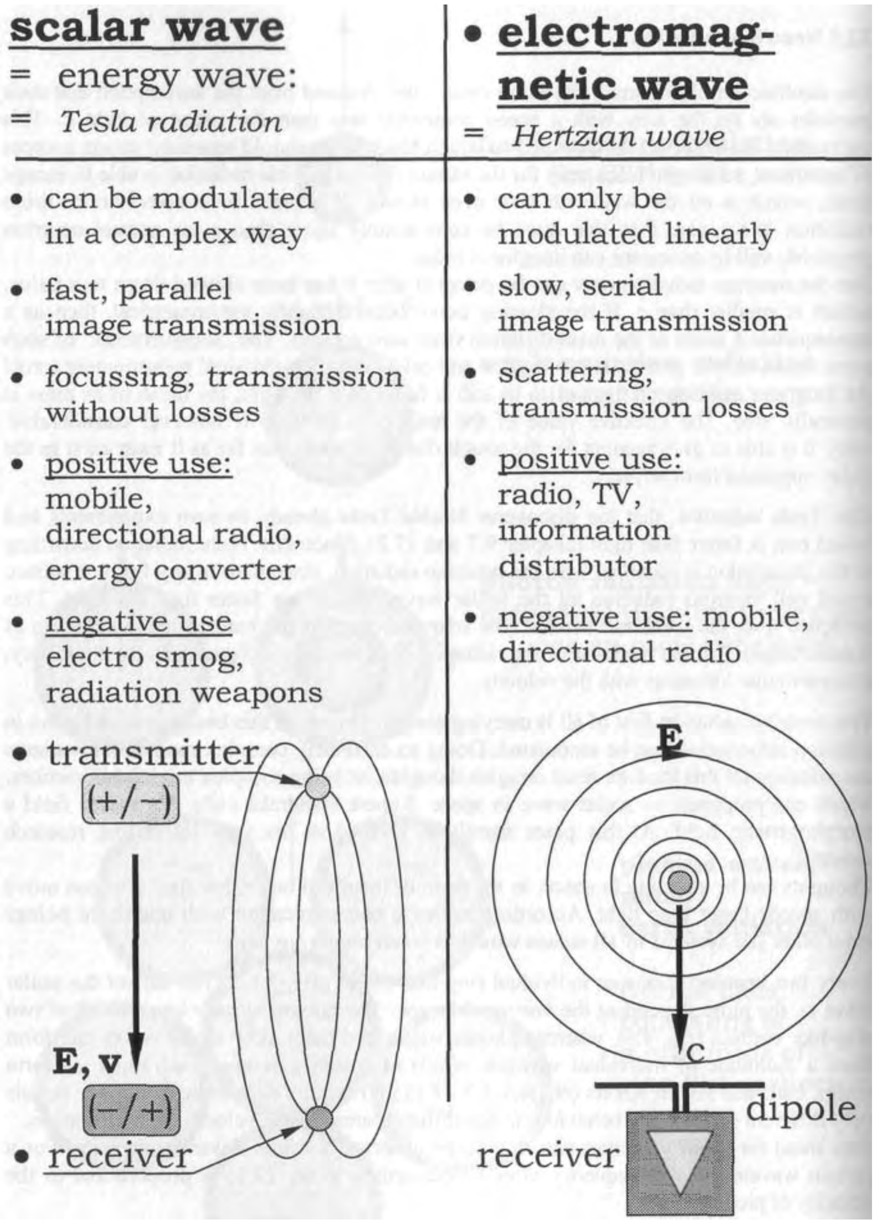

scalar wave = energy wave: = *Tesla radiation*	• **electromagnetic wave** = *Hertzian wave*
• can be modulated in a complex way	• can only be modulated linearly
• fast, parallel image transmission	• slow, serial image transmission
• focussing, transmission without losses	• scattering, transmission losses
• positive use: mobile, directional radio, energy converter	• positive use: radio, TV, information distributor
• negative use electro smog, radiation weapons	• negative use: mobile, directional radio

Fig. 22.6: Scalar waves and radio waves, comparison of the properties.

22.6 Parallel instead of serial image transmission

We continue with our considerations concerning the special properties of scalar waves, represented in the left column, and compare these with the well-known behaviour of electromagnetic waves in the right column (fig. 22.3 is now followed by fig. 22.6). If we again take up the possibilities for modulation and the transmission of information, then it becomes very clear from the comparison that we today work with a technology, which we it is true master more or less, but which is everything else but optimum. For the Hertzian wave the velocity of propagation is constant. With the frequency therefore at the same time also the wavelength is being modulated. But that strongly limits the information transmission. An image for instance must be transmitted serially point after point and line after line. The serial image transmission takes place very slowly, for which reason the velocity of the PCs permanently must be increased, so that the amount of data can be managed.

With the clock frequency on the other hand also the losses increase, so that in the end the CPU-cooler limits the efficiency of modern PCs. Something our engineers obviously do wrong, as a comparison with the human brain clarifies. Our brain works without a fan. For it a clock frequency of 10 Hertz is sufficient. It needs neither Megahertz nor Gigahertz frequencies and despite that is considerably more efficient.

Nature only works with the best technology. The second best technology, as it is put to use in our machines, in the evolution wouldn't have had the slightest chance of surviving. The strategies to optimize of nature are merciless. In a free economy that goes completely different. There the „bunglers" are joining together to companies dominating the market, buying up the innovative ideas without further ado, to let them disappear in the drawer, so that they can bungle further in the way they did until now. It after all have been the lousy products, which have made them to the companies they are today. The ego of power is incompatible with the interests of nature.

Nature works with scalar waves and their velocity of propagation is arbitrary. Wavelength and frequency now can be modulated and information can be recorded separately. In this manner a whole dimension is gained to modulate, the image transmission can take place in parallel, which means considerably faster, safer and more reliable. As anyone of us knows by own experience, assembling the image takes place all at once, the memory of past images takes place ad hoc. Nature is indescribable more efficient than technology with the scalar wave technique.

If we again take the right-hand side of fig. 22.6 with the properties of the Hertzian wave. In the opinion of Nikola Tesla it is a gigantic waste of energy. The broadcasting power is scattered in all directions and the transmission losses are enormous. At the receiver virtually no power arrives anymore. To receive a radio signal the antenna power has to be amplified immensely. It is a wave, which actually only can be used as radio wave, thus as a wave with which arbitrary many participants should be reached.

This wave however is completely useless, if it concerns a point-to-point connection. If I want to call someone, to talk only with him, a radio wave is the entirely wrong method, because I with that bother hunderds and thousands of people that I don't want to call at all!

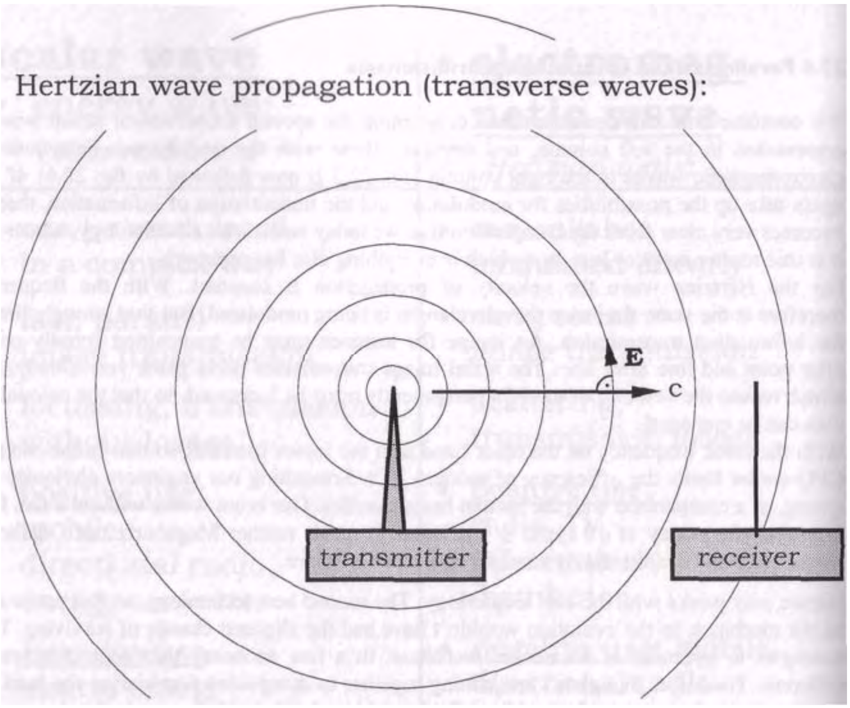
Hertzian wave propagation (transverse waves):
E
c
transmitter
receiver

Tesla radiation (radiations) = scalar wave, longitudinal wave propagation:

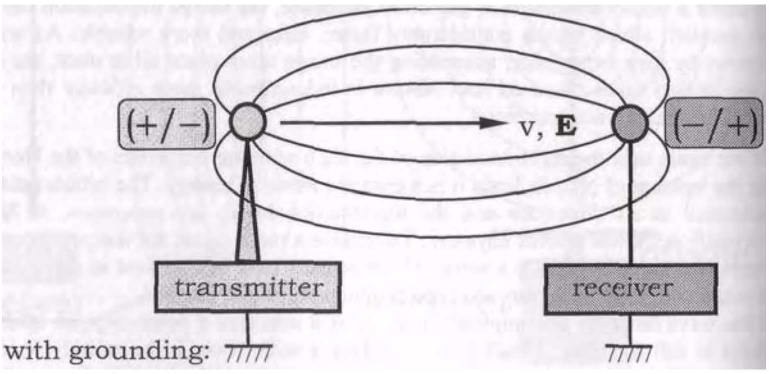
(+/−)
v, E
(−/+)
transmitter
receiver
with grounding:

Fig. 22.7: Comparison of radio waves according to H. Hertz and electric scalar waves according to Nikola Tesla.

22.7 Comparison of the properties

The course of the field lines clarifies the difference. For the scalar wave all field lines going away from the transmitter run together again. As long as no scattering field occurs, there also won't be any transmission losses. It is an energy wave, for which the full broadcasting power is transmitted wirelessly and which arrives at the receiver, by that focussing the field lines again.

Here one at once numerous technical applications come to mind, if energy should be transmitted wirelessly. A TV, which supplies its remote control with energy itself, lelemetric installations, which are fixed at difficult accessible or rotating machine parts and which can't work without energy supply.

For a mobile with 3 Watts of broadcasting power only a few microwatt arrive at the ground station. If I would have a scalar wave mobile, which functions with resonance, then a broadcasting power of some microwatt will be completely sufficient, to carry out a telephone call right through the earth. This minimum broadcasting power suffices, because everything, what is being transmitted, arrives at the receiver - crucial is that the conditions of resonance are fulfilled. That means, both must have the same frequency and the opposite phase. In addition the modulation has to fit, so that on the one hand not several participants in the conversation are getting in each other's way. For a purely carrier wave transmission on the other hand there would be the risk of natural fields being collected also and the power at the receiver taking inadmissibly high values. This is prevented effectively by a correspondingly complex modulation. Nature solves the problem in exactly this manner.
Mobile phone technology with scalar waves of course still is a pie in the sky. A big challenge for the engineers poses the adjustment condition of opposite phase and the fitting modulation, which Tesla called .,individualisation"<i>. Entirely by the way the network runners and the telephone companies are getting quite superfluous.

Telephone charges, so one perhaps can read in the history books in a hunderd years, were the indication of a century of rigorous exploitation of man and nature. With scalar waves a direct, more dimensionally modulated information transmission directly with the partner of conversation is possible and sufficient energy is available to humanity any time and any place, without being dependent on any companies! This notion is not new, but it is inconvenient for the rules; already Nikola Tesla has written about it, but obviously no-one wanted to listen to him<ii>.

Scalar waves are able, that is made clear by the properties, to revolutionize both the energy technology and the information technology fundamentally. It is more than only a technology for the new century. Scalar waves are a chance for the whole millennium!

<i>: N. Tesla: Transmission of electrical energy without wires, Electrical World and Engineer 7.1.1905; Edition Tesla Vol. 4, P. 131.

<ii>: N. Tesla, New York Times of 15.9.1908; Edition Tesla Vol. 6, P. 241.

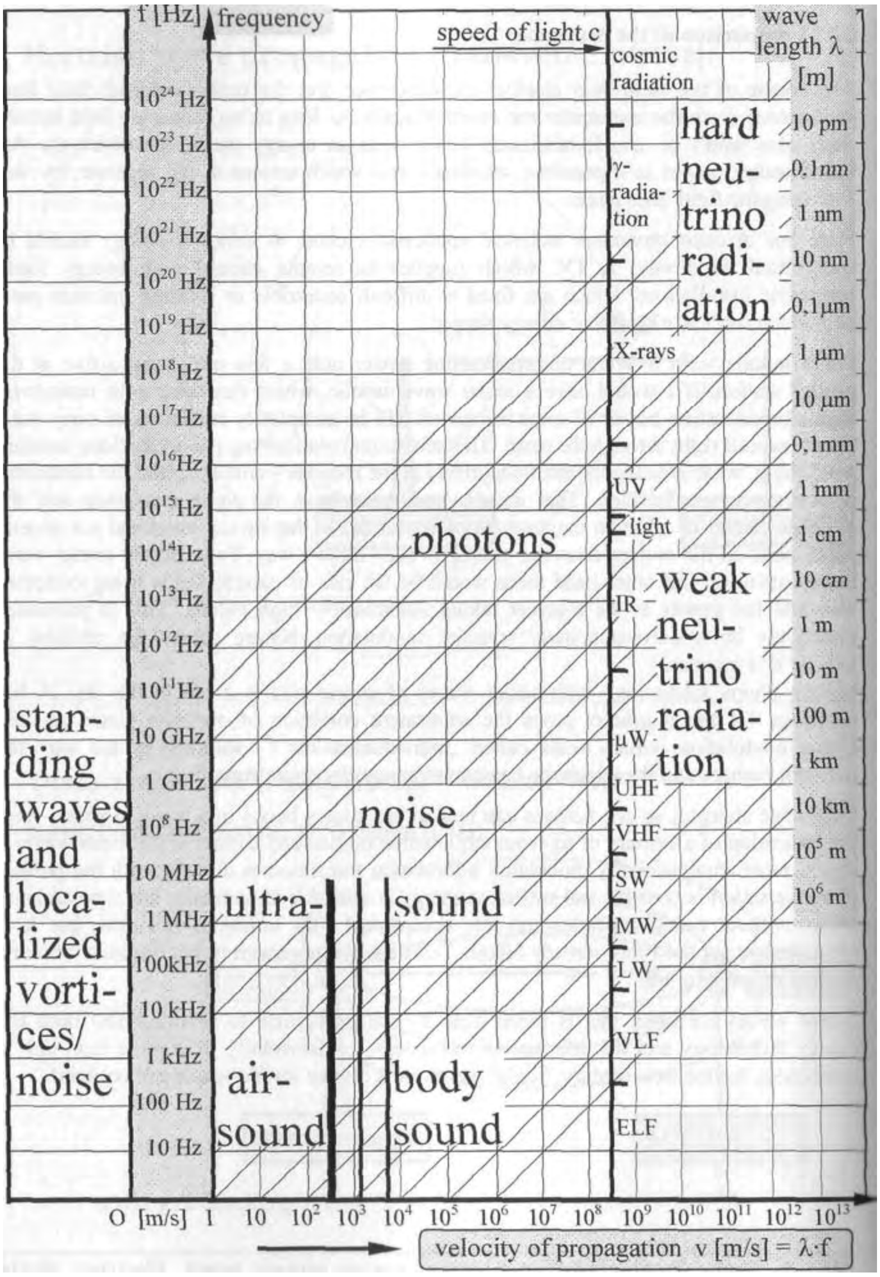
f [Hz]
frequency
speed of light c
wave length λ [m]
cosmic radiation
10^{24} Hz
10^{23} Hz
10^{22} Hz
10^{21} Hz
10^{20} Hz
10^{19} Hz
10^{18}Hz
10^{17}Hz
10^{16}Hz
10^{15}Hz
10^{14}Hz
10^{13}Hz
10^{12}Hz
10^{11}Hz
10 GHz
1 GHz
10^8 Hz
10 MHz
1 MHz
100kHz
10 kHz
1 kHz
100 Hz
10 Hz
hard neu-trino radi-ation
γ-radia-tion
X-rays
UV
light
IR
μW
UHF
VHF
SW
MW
LW
VLF
ELF
photons
weak neu-trino radia-tion
10 pm
0,1nm
1 nm
10 nm
0,1μm
1 μm
10 μm
0,1mm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
10 km
10^5 m
10^6 m
stan-ding waves and loca-lized vorti-ces/ noise
noise
ultra- sound
air- sound
body sound
O [m/s] 1 10 10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13}
velocity of propagation v [m/s] = λ·f

Fig. 23.1: Frequency diagram of longitudinal and transverse waves as they depend on the velocity v.

23. Research of scalar waves

Scalar waves are still unexplored area, scientific new ground as it were. Individual research scientists already have selectively ventured forward in this area and have described properties of the scalar wave investigated by them in their special research area mostly in measurement technical manner. But as a rule they lack the physical relation, as it is derived in this book for the first time. If we don't proceed from individual measurements, but from the wave equation and the mathematical physical derivation of scalar waves, then we have the great chance to understand as something belonging together on the one hand noise, photons, neutrinos and lots of other known phenomena as well as on the other hand still unknown phenomena, which are called parascientific. We should remember that we without theory of Maxwell and the representation in a frequency band today still wouldn't know that the radio waves (LW, MW, KW, UHF), the microwaves (μW), the infrared thermal radiation (IR), the light and the X-rays concern just the same phenomenon. The graphic representation of both waves in one diagram in this place is extremely helpful.

23.1 Frequency diagram

In fig. 23.1 the frequency f is shown against the velocity of propagation v with the wavelength λ as parameter. The broad line at $3*10^8$ m/s represents the speed of light c. Here the frequency band of the transverse waves can be found again in the well-known one-dimensional representation.

Crosswise to that, somewhat unusual, the longitudinal waves run. These start at the left at localized noise, over the sound as it propagates in air, in water and in metal, over a large, to a large extent still unexplored, range of the bio photons, the heat vortices and of the dowsing rod effects and end on the other side of the speed of light at the neutrinos. Between that the special case is settled that the particles, or said better vortices, propagating as a scalar wave have exactly the speed of light. It gives reasons for the circumstance, as already mentioned, that light can appear as wave or as photon radiation. It. according to the wave equation, after all always consists of a combination of both forms. At very high frequencies, e.g. the cosmic radiation, this combination is shifted in the direction of vortices and their distribution as a scalar wave, at low frequencies the tendency inversely goes in the direction of the normal wave.

If we assume that for the transverse wave over all frequencies a dozen of specialized gauges is necessary, each of them also can be switched over in range several times, then we can project that to record a scalar wave of a certain frequency over all velocities of propagation likewise 12 devices and for the whole field shown in fig. 23.1 approximately 12x12 = 144 devices will be necessary. Of these 144 gauges today just 12 are available. There thus still are missing 132 pieces, which should be developed. With these gauges, so I am convinced, the many white spots in the diagram can be tapped scientifically little by little if a systematic procedure is used. My vortex theory thus will be attached a central importance.

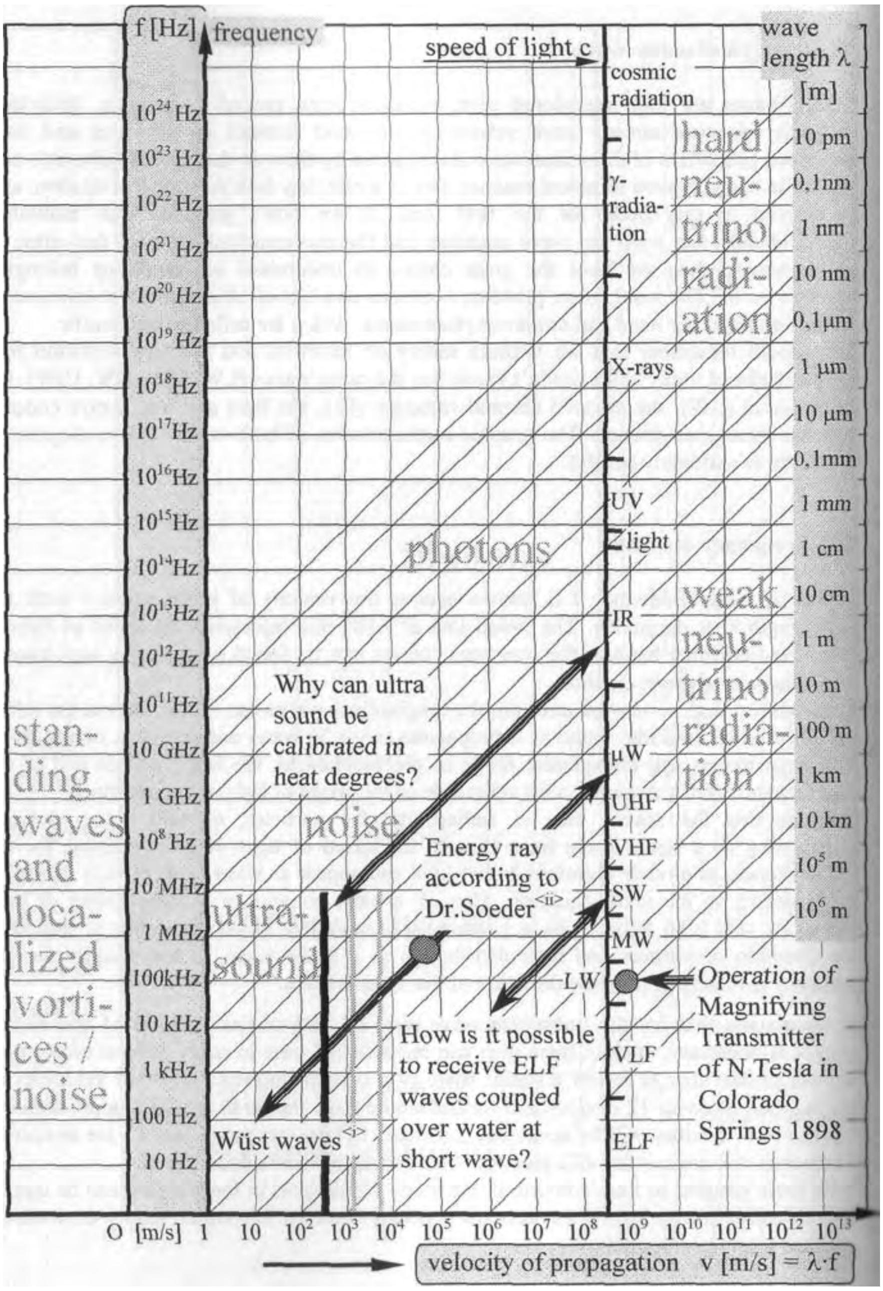

Fig.23.2: Frequency diagram with entries concerning Wust waves,
Tesla transmitter and various not understood effects.

23.2 The reverse of the HF medal

The diagram possibly may settle disputes, like the ones between the „Wustlingen" (note of the translator: the author here is playing with words, Wustlingen literally means lechers) and the „high-frequency engineers".
Professor Wust of Munich already 1934 had proven, that the Wust waves named after him in air have a velocity of propagation of approximately 10 m/s<i>. He investigated them in the frequency range between 16 Hz (λ= 60 cm) and 500 Hz (λ= 2 cm). The high-frequency technicians immediately have converted to the speed of light, since they don't know anything else, and on the spot have shifted the phenomenon into the range of the microwaves between 0.5 GHz (λ=60 cm) and 15 GHz (λ= 2 cm). In the diagram now can be found, at which place this phenomenon belongs actually. It presumably concerns the same „energy ray", which Dr. Soeder has observed and proven already at velocities of propagation of 55.2 km/s and wavelengths around 10 cm<ii>.

Furthermore follows from the diagram (23.2), why ultra sound can be calibrated in heat degrees, and why radio reception of signals from a completely other frequency range is possible by principle, if for identical wavelength a velocity of propagation different from c occurs. Further the range of operation used by Tesla at approx. 1.6 times the speed of light is depicted.

Also the noise is such a book with seven seals. It concerns, it is true, a fixed chapter of high-frequency engineering, but without visible connection to the other chapters. That might be based on the circumstance that the relation, as it is dictated by the wave equation, isn't recognized.
Every high-frequency signal is accompanied by a noise signal; every antenna produces more or less noise. HF engineering dictates the measures, how the noise can be suppressed resp. the signal-noise distance be increased. The goal is to make the electromagnetic wave stand out in such a way from the noise that it can be received. For that the measurement setup must be choosen correspondingly, are the measurement cables dictated, and must be paid attention to power adaptation and corresponding termination resistors. For measuring HF correctly all interference influences should more or less disappear.

But what are the interference influences, which the HF-technician suppresses? According to the wave equation it are the scalar wave parts, and to that also is counted the noise. Every HF-technician thus knows the scalar parts as interfering noise signal, but doing so he completely fails to notice the technical advantages and chances, which e.g. are present in the noise.
If by means of an autocorrelation function a noise signal is compared to itself then often a hidden message comes to light. According to that, informations can be hidden in the noise and of course transmitted wirelessly. This important circumstance is known, but it is hardly used. The noise vortices thus can be modulated in an extremely complex way. There can be transmitted a lot more information in the noise as scalar wave, than with the radio wave.

<i>: J. Wust: Physikalische und chemische Untersuchungen mit einem Rutenganger als Indikator. Further references in W-B-M 3/ 1991, S. 57.

ii>: A. Soeder: Ohne Strom lauft neuer Energiestrahl rund urn den Erdball. Raum & Zeit 59/92 Seite 62-67.

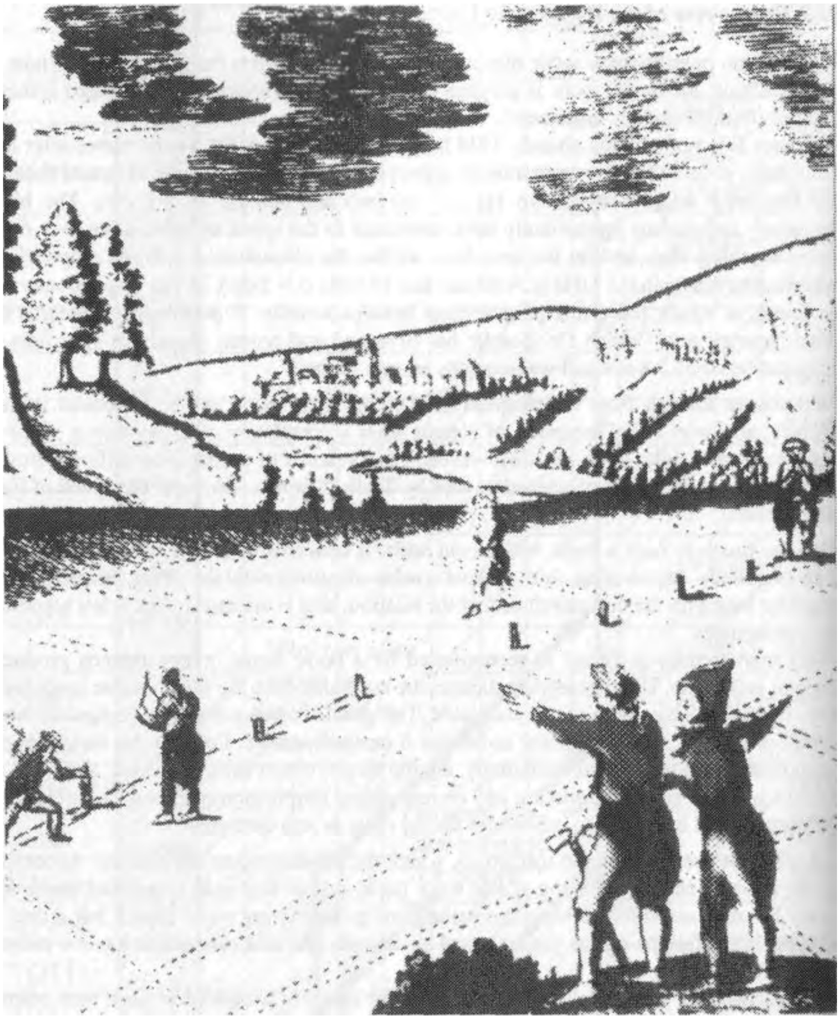

Fig. 23.3: ___ Dowsers dowse an ore vein.[<i>]
From: Speculum metallurgiae politissimum, Rossler, Dresden 1700.

[<i>] Ludeling, Hartmut: Handbuch der Radiaesthesie, Verlag Eike Hensch 1994, S. 145, ISBN 3-927407-09-7.

The possibility of more dimensionally modulating and parallel image transmission make scalar waves superior to the radio waves in such a way that one should seriously think about the reversed procedure, in which the noise is conceived as useful signal and the radio wave as interference signal.

In the frequency diagram (23.1 and 23.2) can be read like in a diary, in which most pages it is true still are empty, but in which some very informative marginal notes can be found for different points of difficulty. It mostly are parascientific phenomena, which, not understood and excluded by textbook physics, are waiting to be taken up in the building of physics. As an example we'll pick out an extensive area of alternative research.

23.3 Radiesthesia

A particularly broad spectrum of scalar waves is provided by the already several times mentioned earth radiation. An ancient science of experience, which troubles the exploration of the earth radiation, is the geomancy. The Roman land surveyors, the Augures, used as an aid a flat coil like also Tesla did to receive scalar waves. The Lituus, as the device was called, resembles so much that of the Etrusks that we must proceed from the assumption that the method is much older (fig. 16.10).

This part of the scalar wave research, also called radiesthesia, is derived of „radiare", which can be translated with "send out rays" resp. „perceive". It describes the doctrine of the sensitivity to radiation of man. Doing so the radiation sensitive uses his own nerve framework as a biosensor.

The nerve conduction could be derived as a biological variant of the Tesla one wire transmission, for which ring-like potential vortices are passed on as action potentials in form of standing waves (fig. 9.6). Of this kind are also the control commands, which cause a muscle to contract. If now corresponding vortices are picked up by means of a dowsing rod or similar aids in our nerves, then the contract addressed muscles contract, because they can't distinguish, from where the command comes. This unconscious nerve twitch leads to a swing of the dowsing rod and to the well-known dowsing rod phenomenon. But man can't replace a technical gauge. Hence one speaks of dowsing and not of measuring. To this should be added the condition of resonance, which must be fulfilled. Since every person however builds up other resonances, dowsed results of others often can't be reproduced. But from this particular difficulty one cannot draw the conclusion that the phenomenon does not exist and radiesthesia is not a science. Series surveys and statistical analyses here in any case don't lead any further. It always only are individual talented dowsers, who have at their disposal really fantastic abilities and find with great certainty water, ores and even oil.

With the perception of a physical phenomenon it mostly starts. Cultural man looks after his discovery as cult, whereas modern man, guided by the wish for reproducibility and more objectivity, is troubled to design and to build a technical measurement work. With regard to the scalar wave in general and the radiesthesia in special we still are at the stage of the Stone Age.

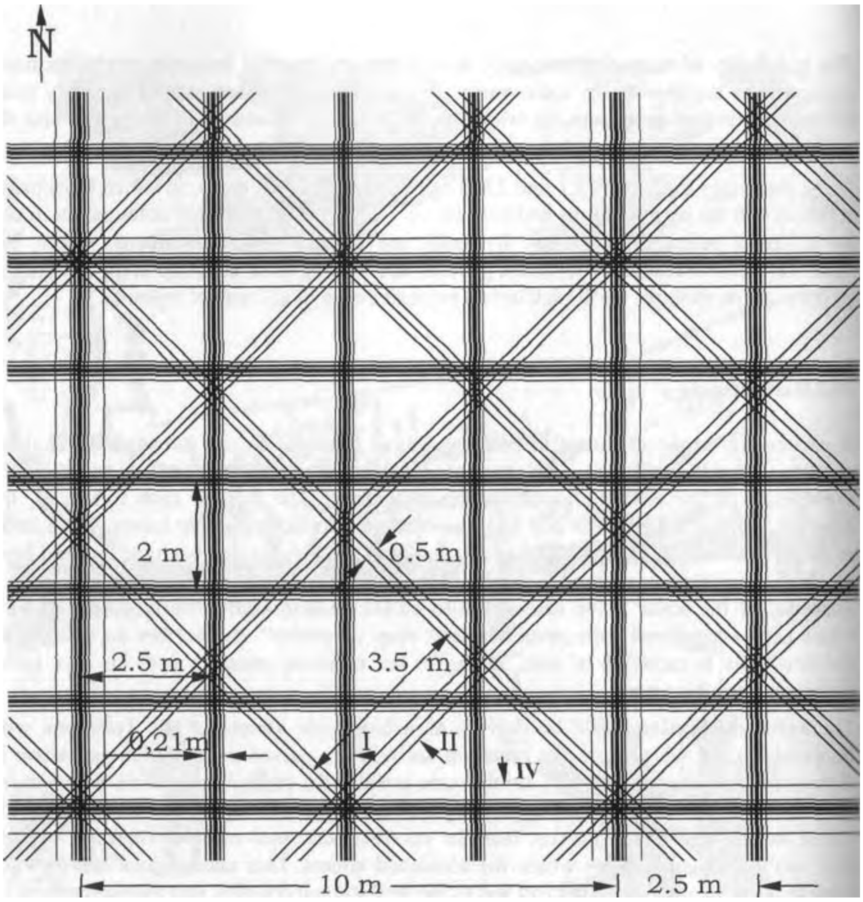

Fig. 23.4: Nets dowsed at latitude 49.<i>

I. net: ,,global net" according to Dr. E. Hartmann;
orientation: N - S: 2 m distance and E - W: 2.5 m distance

II. net: ,,diagonal net" according to Dr. M. Curry;
orientation: NE - SW and NW - SE: 3.54 m = 2.5 m * sqrt(2)

[III. ,,lightning net" according to R. Schneider; orientation like I.]

[IV. net acc. to Benker; like I. but: N - S: 10 m and E - W: 10 m]

[V. sun/planet net acc. to W. Auer; with 3.66 m orientation S./P.]

According to Prof. E.G.Hensch et al.:

<i>: Hensch: Radiaesthesie im landlichen Bauen und Siedeln, Arbeitskreis zuf Landentwicklung in Hessen, W4, Wiesbaden 1987; resp.: W. Auer: Erdstrahlen?... AWGEO 199, Eigenverlag 1998; resp.: Mayer/Winklbaur: Biostrahlen, 5. Aufl. ORAC Verlag, Wien 1989, Seite 168

23.4 Prediction of earthquakes with the help of scalar waves

The standing wave character of the earth radiation is a help. There are dowsed points and lines of maximum radiation intensity, which form nets, which encompass the whole world. On the one hand we are dealing with a net oriented in direction north-south and east-west (Hartmann net) and on the other hand with a net standing diagonally to that under 45° (Curry net). Because the angle of 45° can be derived as borderline angle from a vortex field calculation[ii], I already early have pointed to the circumstance that it here presumably concerns a vortex phenomenon[iii].
Because the nets in addition are dowsed in air, it must be vortices of the electric field, so-called potential vortices[iii], which here form regular structures. The formation of vortex lines and complete vortex streets (chapter 4.9), which consist of countless individual vortices, can be explained as follows:
Electric scalar waves propagate in the direction of the electric field strength and mediate field vortices, e.g. neutrinos. If at a certain moment the transmitter carries a positive and the receiver a negative charge, then all the particles which are positively charged are repelled by the transmitter and attracted by the receiver. All run at the same time towards the same goal, although all mediated particles carry the same charge and repel each other! This incompatibility can be compensated partly, by the vortices rotating around each other. In this circumstance can be seen the reason for the structure shaping, the formation of some lines in the countryside (fig. 23.3). The distances between the lines have characteristic values, which allow conclusions about the wavelength of the standing waves. We must assume that they dictate the structure shaping and that the spatial vortex distribution aligns with the nodes and antinodes of the respective standing wave. The distance between the lines, which corresponds to half the wavelength, becomes smaller and smaller towards the North Pole and the South Pole of the earth, the net thus narrower and narrower. Also is the net said to change strongly before an earthquake. This all are clues for the circumstance that the structure shaping radiation comes from the earth, that the cause must be sought in the earth radiation.
It should be noted marginally that with scalar wave detectors, which permanently scan the nets, a just as effective as inexpensive earthquake prediction should be possible. Such a facility would be an enormous relief and help for all earthquake warning services. It even should be possible to determine in advance the future epicentre, if there is measured at the same time at if possible many stations and the respective deviations are compared.

A further influential factor is the composition of the subsoil; e.g. ores and metals influence the earth radiation. Water shows a special affinity for the earth radiation. It does collect the radiation and after bundling it up releases it again. To blame is the high dielectricity of water ($\varepsilon \cong 80$), which again favours the formation of potential vortices .
A technical use of this effect would be the neutrinolyse (see fig. 17.6-17.8 and 18.1), the splitting of water molecules by neutrinos if these take the state of an electron, hydrogen escapes and the oxygen content in the water increases. If a neutrino however shows as a positron, then it annihilates and there is formed a light flash, which serves the „experts" in neutrino detectors as proof.

<ii>: Meyl, K.: Wirbelstrome, Dissertation Universitat Stuttgart 1984

<iii>: Meyl, K.: Potentialwirbel Band 1, INDEL Verlagsabt. 1990

Spectroid of the radiation field of a subterranean flowing water veign (according to P. Schweizer)[i]:

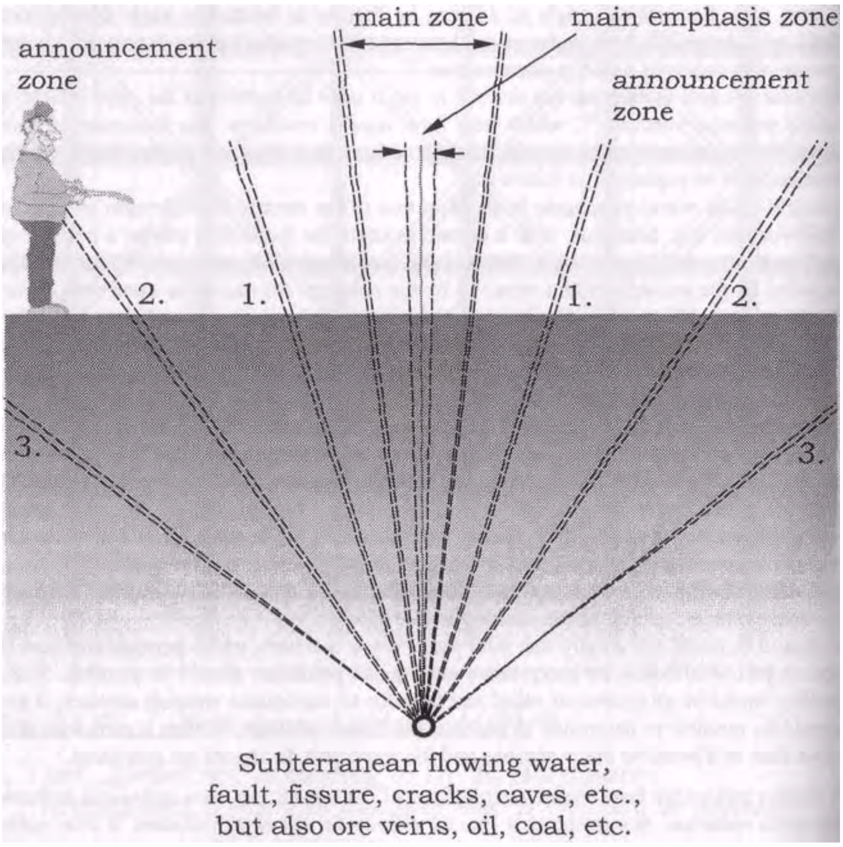
main zone
main emphasis zone
announcement zone
announcement zone
2.
1.
1.
2.
3.
3.
Subterranean flowing water, fault, fissure, cracks, caves, etc., but also ore veins, oil, coal, etc.

Fig. 23.5: Radiaesthetic search for water[i], (dowsing of the earth radiation)

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[i]: Ludeling, Hartmut: Handbuch der Radiaesthesie, Verlag Eike Hensch 1994 S. 145, ISBN 3-927407-09-7.

23.5 Searching water with the help of scalar waves

Faults of earth's crust lead to fissures and cracks in the rock, which often fill up with standing or flowing water. Potential vortices of the earth radiation are attracted by the high dielectricity of water and are radiated again in slowed down and focussed form. On the surface of the earth the mixture of various scalar waves arriving there can be dowsed as main emphasis zone. For reason of the broad radiation spectrum the results of proficient dowsers in the main emphasis zone more often coincide.

At both sides in addition spectroids are forming, which are dowsed as parallel running vortex lines. Because every harmonic wave produces other lines and every dowser reacts to other resonances, a profound ability is required, if from the distance of the so-called announcement zones the water depth should be inferred (fig. 23.5). Some specialists indicate besides the place and the depth also the amount of deposit and if need be the water quality. For that they analyse the radiation intensity, but unfortunately many all too often overrate their abilities.

Already the Augures, the land surveyors in the age of the Romans have aligned their streets and the castles with the nets and the lines in the countryside. Even today new evidence about the central importance of the standing wave character of scalar waves can be found at excavations (fig. 16.10). Since every scalar wave also occurs coupled with a radio wave by means of the wave equation, earth rays originally could be detected conventionally with field strength gauges. But the intensive use by radio stations has made it necessary to change from the short wave range to the VHF-range and further to the UHF-range. It were indirect measurements, which could be interfered easily. Today geologists work with ELF scanners in a range between 15 and 30 KHz if they search for water. They analyse the emitted signals of submarine transmitters, because these are attracted and amplified by water carrying layers.

Experiments also are carried out with noise receivers or unused broadband TV channels. Others analyse influences of the earth radiation on the magnetic field of the earth, but for this method the expressiveness is controversial.

Again others walk along a path with a scintillation counter measuring the inverse profile. At the places of maximum earth radiation a minimum of gamma radiation is measured. This stunning relation only can be interpreted as follows: the natural radioactive decay at these places takes place accelerated and that proves:

1.. that earth radiation sets radioactivity free and causes it in the first place (chap. 17.1 pp).
2. that in the case of earth radiation it actually concerns slowed down neutrino radiation.

But also this method works indirectly. It only functions in the open air and then only in the case of unspoiled nature, which sometime was covered with an even layer of radioactive dust. By cultivation or plantation the „radioactive layer" very often is changed and mixed up, whereupon the measurable profile hardly allows conclusions.

For indirect measurement methods of that kind, for which the measurement variable stands in a relation, which isn't known in more detail, to the scalar wave of interest, generally caaution is advisable. Too often a message is seen in a wonderful 3-D diagram of the magnetic field strength or the radioactivity distribution, which has much more mundane causes.

Lecher air antenna according to W. Busscher<iii>:

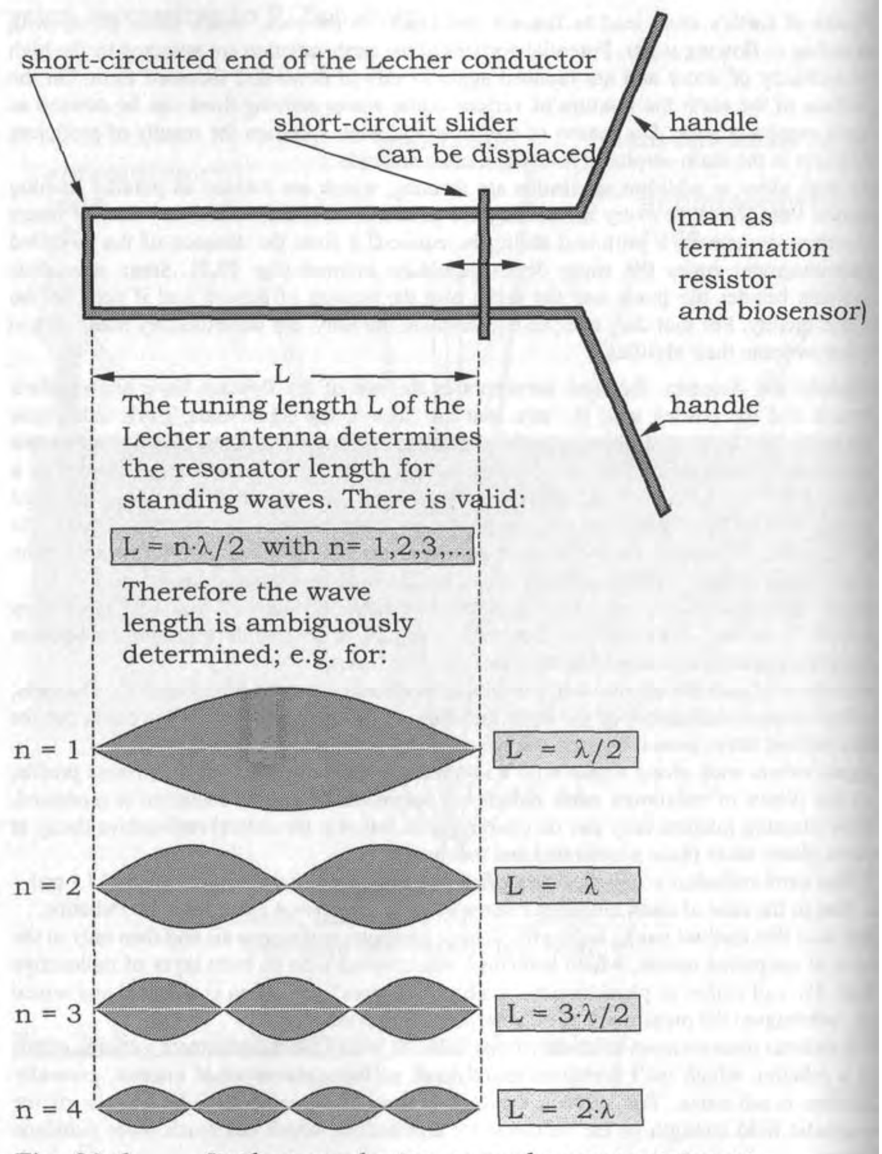
short-circuited end of the Lecher conductor
short-circuit slider
can be displaced
handle
(man as
termination
resistor
and biosensor)
L
handle
The tuning length L of the
Lecher antenna determines
the resonator length for
standing waves. There is valid:
L = n·λ/2 with n= 1,2,3,...
Therefore the wave
length is ambiguously
determined; e.g. for:
n = 1
L = λ/2
n = 2
L = λ
n = 3
L = 3·λ/2
n = 4
L = 2·λ

Fig. 23.6: Lecher conductor as scalar wave antenna.

Can be read at Prof. Dr. Ing. Christof Rohrbach:

<iii>: Rohrbach: Radiasthesie, Physikalische Grundlagen und Anwendung in Geobiologie und Medizin, Haug Verlag Heidelberg 1996, Seite 100.

23.6 Receiving scalar waves with the Lecher antenna

In the case of technical gauges it is normal to change the frequency tuning. For that the capacity of a capacitor is being varied, which is part of a resonant circuit. This method can simply be realized with the today available construction elements. Biological systems on the other hand, for instance a person, work primarily with a variation of the wavelength. In this case (according to eq. 22.1) the frequency is directly proportional to the velocity of propagation.

So provide for instance radiaesthetic dowsings clues for the wavelength. The frequency however can't be given, because that oscillates along with the velocity of propagation and at present the forming noise signal still can't be analysed. There can't be bought electronic construction elements, which like a body cell would be able of oscillations of length. Oscillation quartzes and piezo elements, on the basis of which scalar wave detectors could be constructed, form an exception.

Similar to the Lecher conductor different forms of tunable Lecher antennas have been developed. which are used for dowsing. Such a frame antenna, developed strictly according to the rules of high-frequency technology stems from W. Busscher (fig. 23.6)<i>. With the short-circuit slider a closed-loop antenna circuit in the upper part is tuned to half the wavelength or an integer multiple of it ($L = n \cdot \lambda/2$ with n = 1,2,3...). The person, who holds the Lecher antenna with both hands, forms the termination resistor for the attached antenna circuit. At the same time he prevents the occurring of an effect back on the tuned resonant circuit by means of damping of the Lecher conductor. The sense of this arrangement is lying in the circumstance that man as a „biosensor" should feel if standing waves, which I call vortices, are formed in the Lecher antenna.

A modification of the Lecher air antenna is the Lecher dowsing rod according to R. Schneider<ii>. It is produced as an etched board, which has a dielectricity of approx. 4. As a result the velocity of propagation and the wavelength are only half their normal value. In addition a shortening factor V is introduced, which depends on the construction of the Lecher dowsing rod<iii> ($L = V \cdot n \cdot \lambda/4$ with V = 0.952 and n = 1,2,3...).

In fig. 23.7 some published tuning values have been drawn up. The values for want of corresponding technical gauges it is true still haven't been confirmed, but they allow a certain insight into the world of the scalar waves, as they are influenced and radiated by water, by metals, by oil or even by other planets, the sun and the moon. Doing so some questions remain open: We for instance don't know, if the corresponding wavelength concerns the basic wave or only an m^{th} harmonic wave. The details not only are unreliable, they moreover also are ambiguous. If however several tuning values L' are present for which resonance occurs, then if need be an integer divisor can be sought and the wavelength can be determined. But that doesn't function always.

<i>: Will Busscher: Die Luft-Lecher-Leitung als Wunschelrute. Eine Methode um die Wellenlangen zu bestimmen. Wetter-Boden-Mensch 3/ 1991, Seite 46-57.

<ii>: R. Schneider: Einfuhrung in die Radiasthesie Teil II: Leitfaden und Lehrkurs ..., Oktogon-Verlag, Wertheim, 2. Aufl. (1984) S. 136.

<iii>: Rohrbach: Radiasthesie, Physikalische Grundlagen und Anwendung in Geobiologie und Medizin, Haug Verlag Heidelberg 1996, Seite 100.

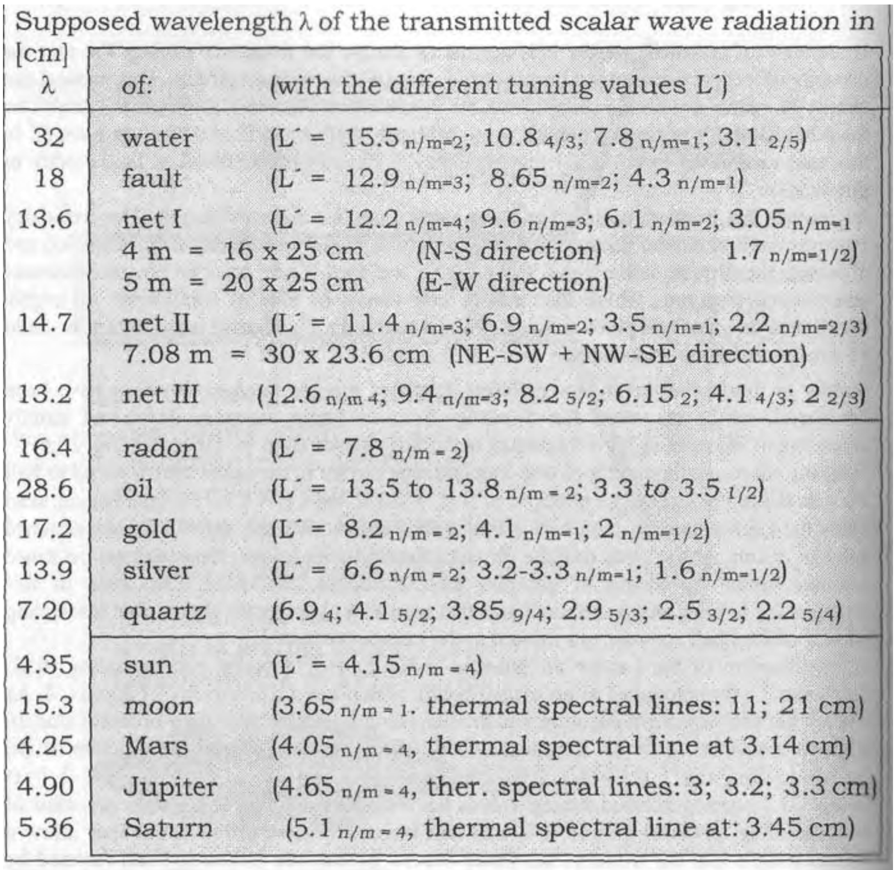

Supposed wavelength λ of the transmitted scalar wave radiation in [cm] λ	of:	(with the different tuning values L´)
32	water	(L´ = $15.5_{n/m=2}$; $10.8_{4/3}$; $7.8_{n/m=1}$; $3.1_{2/5}$)
18	fault	(L´ = $12.9_{n/m=3}$; $8.65_{n/m=2}$; $4.3_{n/m=1}$)
13.6	net I 4 m = 16 x 25 cm (N-S direction) 5 m = 20 x 25 cm (E-W direction)	(L´ = $12.2_{n/m=4}$; $9.6_{n/m=3}$; $6.1_{n/m=2}$; $3.05_{n/m=1}$ $1.7_{n/m=1/2}$)
14.7	net II 7.08 m = 30 x 23.6 cm (NE-SW + NW-SE direction)	(L´ = $11.4_{n/m=3}$; $6.9_{n/m=2}$; $3.5_{n/m=1}$; $2.2_{n/m=2/3}$)
13.2	net III	($12.6_{n/m\ 4}$; $9.4_{n/m=3}$; $8.2_{5/2}$; 6.15_{2}; $4.1_{4/3}$; $2_{2/3}$)
16.4	radon	(L´ = $7.8_{n/m=2}$)
28.6	oil	(L´ = 13.5 to $13.8_{n/m=2}$; 3.3 *to* $3.5_{1/2}$)
17.2	gold	(L´ = $8.2_{n/m=2}$; $4.1_{n/m=1}$; $2_{n/m=1/2}$)
13.9	silver	(L´ = $6.6_{n/m=2}$; $3.2\text{-}3.3_{n/m=1}$; $1.6_{n/m=1/2}$)
7.20	quartz	(6.9_{4}; $4.1_{5/2}$; $3.85_{9/4}$; $2.9_{5/3}$; $2.5_{3/2}$; $2.2_{5/4}$)
4.35	sun	(L´ = $4.15_{n/m=4}$)
15.3	moon	($3.65_{n/m=1}$. thermal spectral lines: 11; 21 cm)
4.25	Mars	($4.05_{n/m=4}$, thermal spectral line at 3.14 cm)
4.90	Jupiter	($4.65_{n/m=4}$, ther. spectral lines: 3; 3.2; 3.3 cm)
5.36	Saturn	($5.1_{n/m=4}$, thermal spectral line at: 3.45 cm)

Fig. 23.7: Details of not confirmed wavelengths.<i>
(derived from tuning values of a Lecher antenna
$L' = .\ V \cdot \lambda \cdot n\ /4 \cdot m$ with $V = 0.952$
and $n = 1,2,3...$ for $\lambda/4$, $\lambda/2$, $3\lambda/4$, λ, ...
and $m = 1,2,3...$ for 1 the basic wave
and the 2nd, 3rd, ... harmonic wave

---

according to:
<i>: Ludeling, Hartmut: Handbuch der Radiaesthesie, Verlag Eike Hensch 1994, S. 161 ff. The author gives the clue: ,,The values have been determined empirically by different persons and predominantly could be confirmed by the author and his co-workers. There however always can occur deviations caused by different dowsing methods. Every value therefore always should be checked with own measurements."

23.7 Assignment according to wavelength

As said, the methods to determine the wavelength by means of the Lecher antenna are ambiguous and unreliable. So water should have a wavelength twice as long as a fault. But since water often is collecting or subterranean flowing in faults, one is entitled the suspicion that here $\lambda/2$ was taken, where in reality the full wavelength λ acts. The rest of the table after that should be looked at with the same scepticism. The table nevertheless is not wholely uninteresting, because it points to certain trends and is able to furnish clues, which if need be can represent a help of orientation in the systematic research of scalar waves.

At the planets is remarkable that the Lecher conductor reacts to values, which correlate with the respective thermal spectral lines. If these spectral lines propagate with c and it actually should concern the same cause, the frequency thus should be identical, then the planets would emit scalar waves, which are faster than the light. In the case of Mars 1.35 times the speed of light c would be present, in the case of Saturn 1.55 times and in the case of Jupiter the values would lie between 1.46c and 1.63c. In the case of the moon two thermal spectral lines are being measured, which on the one hand have as a result 1.39c and on the other hand 0.73c. At this place still ample research tasks should be solved.

In the case of scalar waves the wavelength is the most important factor to refer to. The frequency however varies continually, which in electrical engineering is called noise. That again is connected to the circumstance that frequency and velocity of propagation oscillate, so that merely an average value can be given at a time. But that hardly can be measured, which again makes the assignment more difficult. We thus still aren't capable to enter the table values from fig. 23.7 into the frequency diagram of fig. 23.1.

A technical gauge for scalar waves is necessary. A practical solution could look as follows: A noise transmitter tunable in frequency and wavelength operates on top of a carried along noise receiver. The arrangement with that comes the Tesla transmission path for scalar waves very close. If the transmitted noise signal hits upon a likewise one in the surroundings then overlapping occurs, which at the receiver causes a change of the displayed value. If doing so a subtraction (extinction) or an addition (amplification) of the signals occurs is unimportant.

With this arrangement in any case statements are possible about frequency, wavelength, velocity of propagation and about the amplitude of the scanned signal, without withdrawing energy and strain the signal in doing so<i>. With such a gauge radiation conditions depending on location could be measured as well as technical devices checked lor the emitted scalar wave parts (fig. 24.1).

An important use over and above that would be given in medical diagnostics. Every living being „produces noise" the technician would say, it „emits scalar waves" I would say, whereas following general usage is talked about the „aura of man". The value of an aura diagnosis still is completely unknown to most doctors and therapists, especially as the scanning of the aura at present only is possible by dowsing. But the patient expects that a doctor works with a technical gauge and not with a dowsing rod!

<i>: First experiments, which I carried out with students in the laboratory, look very promising. Unfortunately the works at present rest for reason of lack of money.

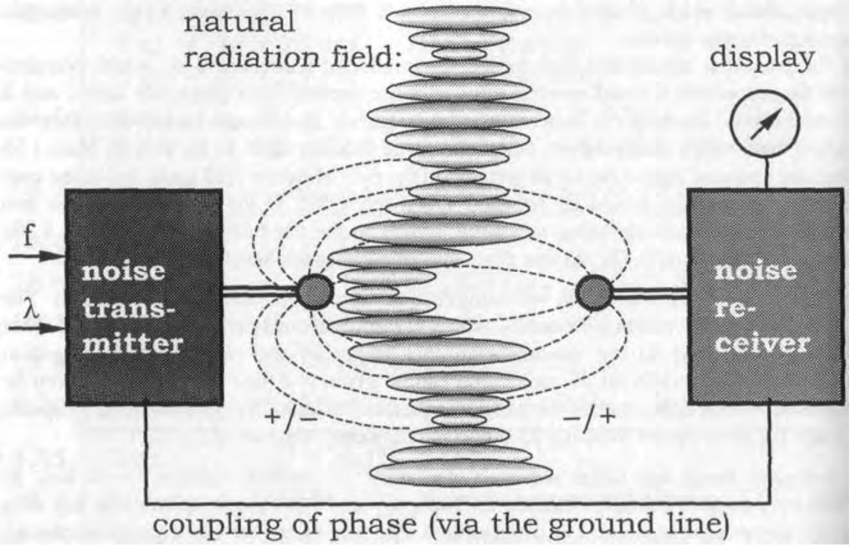
natural
radiation field:
display
f
λ
noise
trans-
mitter
noise
re-
ceiver
+/−
−/+
coupling of phase (via the ground line)

Fig. 24.1:____ Concept for a device to detect scalar waves

24. Medicine of oscillation

24.1 Mediation of information with the help of scalar waves

If for the discussed scalar wave gauge the transmitted comparison signal in addition deviates from the form of a sinus, if the signal is modulated in some way, then even the transmission of information by means of the noise as scalar wave can be realized. If we as an example again take the aura of man, which is more than only a radiation field, it carries information for instance about the state of health of man. Kirlian photography is one form of making it visible (Fig. 3.6).

Not only the nerve conduction and the brain work with scalar waves. Man in this way also corresponds with his fellow people, some more, others less. There are people who „beam" and that should be interpreted in the true meaning of the word. Others opposite to that are more „receiver characters", who pick up more scalar wave radiation than they give away. But because they not only pick up positive radiation energy, they are susceptible to information, which makes sick. That's why a healthy equilibrium in the exchange of thoughts, feelings and the different forms of scalar waves is very important. All that is reflected in the aura of man. If we technically are capable to scan the aura of man, than this can be a blessing for humanity and for the public health.

The possible abuse however must not be overlooked. Unbiased research results, which can be used for the benefit of humanity, in many cases just as well can be used to harm humanity.

A connector of both these worlds is the Russian psychologist Prof. Smirnov, who has shown publicly in television, how a spoken sentence can be transformed in a noise signal, which is taken up directly by the brain as information, with the help of a computer program [<i>]. He with that is capable to "sodden" individuals, as he says, he in this way can take the fear away from soldiers before a combat mission and can operate the disease out of drug addicts without bloodshed. In the television film such an „operation at the open subconscious"' is shown life. The patient hears the noise signal over headphones and is cured already after few minutes treatment time.

We here are getting in the domain of ethical and moral problems of scalar wave research, which aren't solved by us looking away and leaving the field up to others. According to the words of Prof. Smirnov the only thing, which can stop the research scientist, is his own moral. He doesn't say any more and that isn't exactly reassuring! One here is working with „signals resembling sound", is said in the report of the Zweite Deutsche Fernsehen[<i>], thus with longitudinal waves and that shows, that already more knowledge about scalar waves is present than is generally known by the masses.

Another way is leading over the bioresonance. Also here at first the possibility and chance to cure diseases is to the fore. The bioresonance is a central aid in the area of the medicine of oscillation, which is increasing in importance permanently.

<i>: Die Zombies der roten Zaren (Besta Film Warschau im Auftrag d. ZDF 1998)

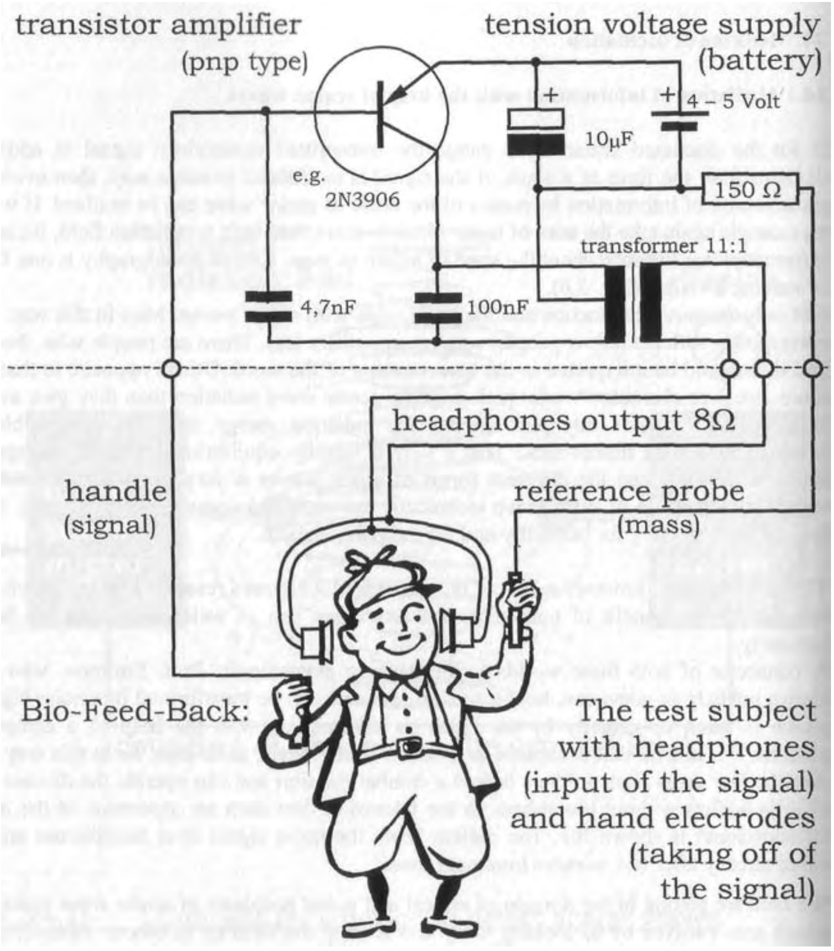
transistor amplifier
(pnp type)
tension voltage supply
(battery)
+
+
4 - 5 Volt
10µF
e.g.
2N3906
150 Ω
transformer 11:1
4,7nF
100nF
headphones output 8Ω
handle
(signal)
reference probe
(mass)
Bio-Feed-Back:
The test subject
with headphones
(input of the signal)
and hand electrodes
(taking off of
the signal)

Fig. 24.2 A: Wiring diagram of the Syncrometer.<i>

<i>: Wiring diagram taken from: H. Clark: The Cure for All Cancers (1993) New Century Press, USA, Page 434

<ii>: Flanagan: Horen mit der Haut anstatt mit den Ohren, Sonnenwind 1/97, S.13-17.
s.a.: N.Begich: Towards A New Alchemy, The Millenium Science, Earthpulse Press 1996

<iii>: Dr. Bodo Kohler: Biophysikalische Informations-Therapie, Gustav Fischer Verlag (1997), Kap. 11.6 Der individuelle Grundton, S. 239 ff.
s.a.: Dr. Bodo Kohler: Die bipolare Farb-Ton-Therapie, CO'Med 2/2000, S.10 - 15

24.2 Systems with positive feedback

The field of oscillation of man easily can be influenced, because it concerns a vortex field. A technical measurement with the gauges available at present is almost impossible and highly inaccurate. There however exists the possibility, to apply electrodes to a person and to integrate him in the circuit of a technical device. The two of them form a feedback system with man in the return loop. The operation can take place in two different ways, depending on the sign of the feedback (Fig. 24.3):
For positive sign it concerns positive coupling. In this case the signals released by a person sum up, for which reason already minimum amplitudes are sufficient to produce violent reactions in the case of resonance. For resonance to occur, the system must either search independently the suitable frequency and phase, or the therapist searches the points of resonance.

24.2.1 The Syncrometer.

An independently working system is e.g. the Syncrometer. By means of two electrodes, which are held with the hands or are attached directly to the head, the noise signal emitted by a person is called off and supplied to a broadband amplifier. The test subject again hears the amplified signal via headphones, so that the circuit is closed.
Apparently unspecific and still reproducible during operation certain signals capable of resonance are emerging stronger by amplifying and swinging themselves up. The aura starts to extend or expressed in the words of a radiation sensitive, the so-called reaction distance is increasing, with which he means the distance in which he detects a dowsing rod reaction.
The test subject now increases his radiation, so this method can be valued. By strengthening his own radiation power, he works more as a transmitter and less as a receiver for scalar waves. In the last point the therapeutic use seems to iie, because by that the patient can get rid of resonances to any unpleasant persons or to technical transmitters, which are burdening him. The device consequently also is sold as aid or protection against electrosmog.
The amplified signal also can be picked up directly by the skin instead of by the headphones and still being „heard". The reports stretch from a harmonizing and balancing effect up to "electronic telepathy" and states similar to ecstasy of the test subject<i>.

24.2.2 The sound therapy.

The controlled variant of this method for instance is the sound therapy. Now the sounds, which the patient picks up by means of headphones, do not stem from him but from a sound generator. The therapist goes through the scale and tries to find out at which sound the aura swings up. If the eigenfrequency is found, then the patient can therapize himself, by again and again playing or humming his eigentone<iii>.
It concerns here only a physical statement on the used methods of alternative medicine and not therefore, whether healing successes are actually possible.

sound frequency equally tempered [Hz]		wavelength [cm]	colour	wavelength [run]
F sharp"	740	46,4	(purple)	-
F"	698	49,1	(crimson)	-
E"	659	52,0	(violet)	-
D sharp"	622	55,1	indigo	421
D"	587	58,4	bleu	446
C sharp"	554	61,9	turquoise	472
C"	523	65,6	green	500
H'	494	69,5	yellowgreen	530
A sharp'	466	73,6	yellow	562
A'	440	78,0	orange	595
G sharp'	415	82,6	orangered	630
G'	392	87,5	red	668

Table 24.2 B: Scale of the colour range.<i>

colour		chakra	sense organ	planet type
purple	7.	(crown chakra)	epiphysis	Jupiter
indigo	6.	(brow chakra)	hypophysis	Saturn
bleu	5.	(throat chakra)	hearing	Mars
green	4.	(heart chakra)	feeling	Sun
yellow	3.	(solar plexus)	seeing	
orange	2.	(sacral chakra)	taste	Venus
red	1.	(root chakra)	smell	Moon

Table 24.2 C: Assignment of colours to chakras and planets.<i>

colour		metals	gems (selection):
purple	7.	tin	amethyst, fluorite
indigo	6.	lead	indigo-sapphire, azurite
bleu	5.	iron	sapphire, lapis lazuli
green	4.	gold	emerald, malachite, jade, gr. tourmalin
yellow	3.		topaz, amber, citrine
orange	2.	copper	carnelian, fire opal
Rot	1.	silver	ruby, coral, garnet, red jasper

Table 24.2 D: Assignment to a selection of gems.<i>

<i>: Dr. Bodo Kohler: Biophysikalische Informations-Therapie, Gustav Fischer Verlag (1997), Kap. 11.6 Der individuelle Grundton, S. 190 - 194

24.2.3 The colour therapy.

Analogous to acoustics also colours each time can be assigned a wavelength and also here can be detected that every person responds to certain colours, thus wavelengths, in particular which can stimulate his aura to resonant oscillations. In practice sound and colour therapy often are used coupled[i], even succeeds more or less an assignment to each other. That in last consequence leads to a "scale of the colour range" (table 24.2 B)[ii]. According to statement of the treating doctors does a patient, who responds to a certain colour, also react to the corresponding sounds and vice versa.

24.2.4 The aroma therapy.

If according to that it depends less on the circumstance if sounds or colours are used, but the wavelength of an oscillation is crucial, then a stimulation also should be possible by means of the remaining sense organs, e.g. the nose, the tongue or the skin. The smell after all already could be identified as vortex information (fig. 9.0). Fragrances of natural essences can significantly influence the frame of mind. But as long, as we still haven't understood the physics behind it, we technically hardly are capable to generate equivalent vortex modulations artificially.

24.2.5 The gem therapy.

Already the holy Hildegard von Bingen (1098-1179) knew and used the beneficial effect of gems. Physical background of this at first purely empirical form of therapy is the characteristic eigenfrequencies of the gems, which are picked up as stimulation over the skin. Because gems represent a mixture of various molecules, the oscillations in the atomic hull will overlap, so that overlapping and beat frequencies can form with wavelengths in biological relevant areas. There even can form modulations, which are carrying information. The effectiveness again is linked with the resonance condition, which must be fulfilled between the gem and his carrier.

24.2.6 Meditation and self-therapy.

There even exist people, who don't need any technical aid at all to get rid of unpleasant resonances. Some meditate and go into resonance with themselves, whereas others prefer to love a person, to whom they feel „attracted" or with whom they are „on the same wavelength", which means as much that they go into resonance with this person. In the Catholic Church for instance the priests are not allowed to get married, because they should be in a resonance with the church and with God.

<i>:: Dr. Bodo Kohler: Die Coloroma-Therapie, Der aussergewohnliche Einsatz von Aromen, Co'Med 4/2000, S. 48-52

<ii>: Cousto: Die kosmische Oktave, Synthesis Verlag Essen 1984

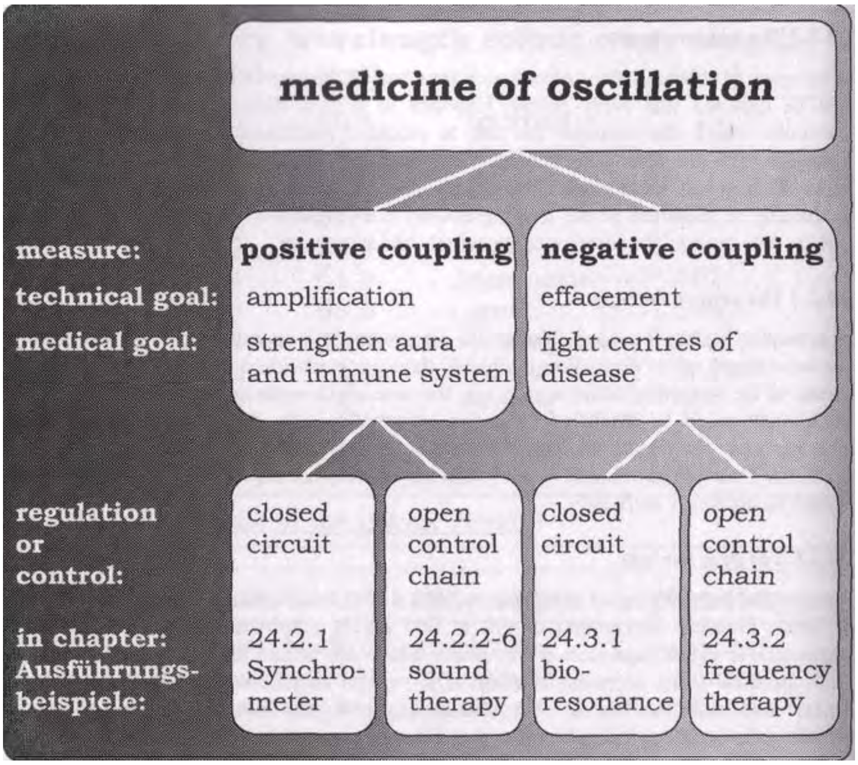
medicine of oscillation
measure:
technical goal:
medical goal:
positive coupling
amplification
strengthen aura and immune system
negative coupling
effacement
fight centres of disease
regulation or control:
in chapter: Ausführungs-beispiele:
closed circuit
24.2.1 Synchro-meter
open control chain
24.2.2-6 sound therapy
closed circuit
24.3.1 bio-resonance
open control chain
24.3.2 frequency therapy

Fig. 24.3 A: Structure concerning the medicine of oscillation

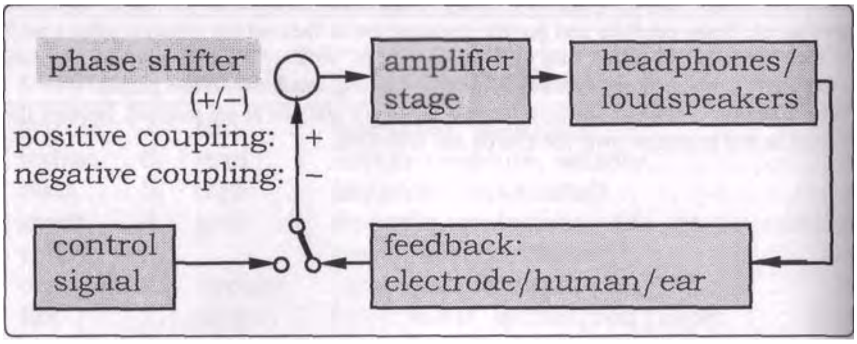
phase shifter
(+/–)
positive coupling: +
negative coupling: –
amplifier stage
headphones/ loudspeakers
control signal
feedback: electrode/human/ear

Fig. 24.3 B: Regulation or control?
Positive or negative coupling?

24.3 Systems with negative feedback

For negative sign it concerns negative coupling. In this case the signals are subtracted. The signals released by a person are played back to him with opposite phase. This method lies in the domain of the bioresonance.

24.3.1 The homeopathy

The concept, which is pursued by the medicine of oscillation in the case of the bioresonance, is that harmful or ill making oscillations should be effaced. Not the direct, but rather the indirect strengthening of the immune system is to the fore, which should be reached by relieving it. The approach with that pursues the same goal as the pill medicine, where oscillations, which should produce a wanted effect and which are bound by means of substances are supplied to the body.

The disadvantage of the administration of pills is the often toxic effect of the carrier substance. The German doctor Samuel Hahnemann (1755-1843) has demonstrated a way, in which to make the helpful and important information for the body to go over from the carrier substance to the water by diluting with water and by shaking. The water molecules now oscillate in time of the carrier molecules. Interestingly in doing so not even the information gets lost, the modulation thus is preserved. By constantly shaking there even occurs an amplification or a „potentiation", as Hahnemann expressed himself, because now every carrier molecule reaches and modulates countless water molecules. Thus the amount of water informed is bigger than the amount of the original chemical substrate. In the case of homeopathy like is treated with like. If for instance a poison causes certain complaints at a healthy person, then in "homeopathic" administration this information helps a sick person with similar complaints. There thus occurs a disturbance activation with opposite phase, as the engineer uses to express himself. Despite a widespread scepticism the method of homeopathy indeed seems to function, and it has stood the test in countless cases.

24.3.2 The bioresonance

A technical realization is represented by the bioresonance. For that endogenous oscillations are called off by means of an ECG (electrocardiogram), an EEG (electroencephalogram) or a MEG (magnetoencephalogram) at the surface of the skin. The technical device then shifts the phase for 180 degrees and amplifies the signal to the extent that pathological frequencies are extinguished for reversely directed input. This very reasonable theoretical concept in practice of course only is as efficient, as the empirical determined pathological frequencies are the cause of a disease and not only represent an unimportant symptom as side effect.

To that technical problems are joining. Prof. Heine blames the constantly changing reaction diversity and the thermal noise for the circumstance that the „frequency spectrum permanently is fluctuating", as he writes if*. That hardly can realize the necessary phase inversion. We meanwhile know that vortices have a fluctuating frequency spectrum, that in the case of biosignals it concerns such field vortices, which result in a noise signal unspecific in frequency.

With this knowledge we should be able to significantly improve bioresonance procedures, and even the inversion of phase shouldn't represent an insurmountable difficulty anymore.

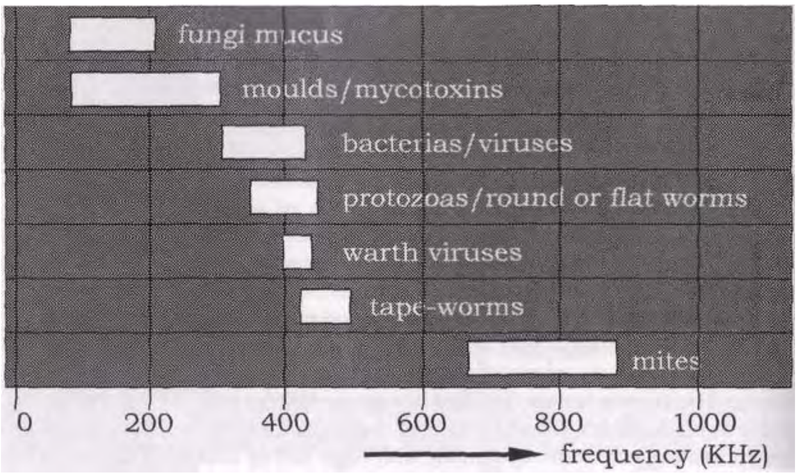

Fig. 24.3 B: Frequency spectrum of parasites according to Clark.<i>

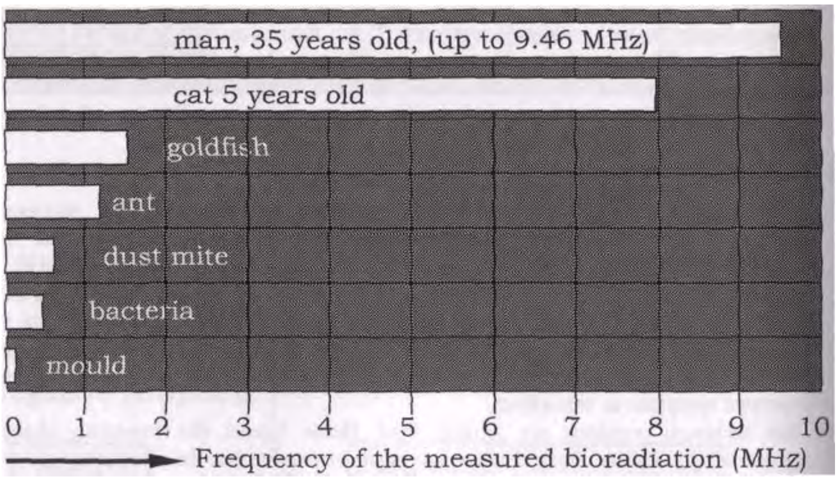

Fig. 24.3 C: Diagram of frequency ranges for some living beings.<i>

<i>: Dr. Hulda Clark: The Cure For All Diseases (1995), Page 604-643

A further problem, which Heine addresses, can't be denied<ii>: „For communicative molecule oscillations the microwave range of 1 GHz up to above 10000 GHz is crucial. A calling off of endogenous interference oscillations in this range with the help of normally used electrodes is not possible"<iii>. It thus could happen that essential frequencies, which are directly related to a disease, aren't recorded at all and as a consequence also not treated. There even is the risk of informations being brought in, which additionally stress the immune system instead of relieving it, that the patients after a treatment are worse off than before. The doctor or therapist is burdening himself with a big responsibility, when, how and at whom he applies methods of bioresonance or if he better does without them. For the mentioned reasons the method in the therapy only plays a secondary role. The bioresonance on the other hand is quite often and with great success used in the diagnosis (Nosoden), if it for instance concerns the determination of an incompatibility or an allergy - but that is a completely different theme. For the bioresonance the transition of diagnosis to therapy is however floating.

24.3.3 The frequency therapy

If using a frequency therapy the problems are standing similarly. If we separate the closed and negatively fed back circuit of a bioresonance and form an open control chain consisting of a technical control device and the patient, then we get the structure, as it is put to use in a frequency therapy. The goal still is the same: parasites or pathogenes, which stress and burden the immune system should be fought.

But a disadvantage of every open control chain is that the treatment at first occurs blind due to the missing feedback.

The natural healer Dr. Hulda Clark has examined as support various pathogenes and parasites under the microscope, while she has varied the frequency and at the same time applied a low-tension voltage. Doing so she could observe the dying of bacterias and parasites at certain frequencies. Correspondingly she publishes tables, in which the in each case „mortal" frequencies are listed<i>.

Hut without being able to verify the success of a treatment in the living organism, she proceeds from the assumption that by applying a low tension voltage (5-10 Volt), as it is produced at the output of a commercially available frequency generator, if a sinusoidal signal is set with the appropriate frequency exactly the associated parasites and leeches will be destroyed. Doing so a fixed rhythm of pauses and treatment times must be adhered to (7 min on, 20 min off, 7 min on, 20 min off and 7 min on).

The doctors and therapists treating with this particularly inexpensive method report amazing results, inexplicable spontaneous cancer cures, like of HIV-positive patients, who after the treatment were tested HIV-negative. But also the inverse case already should have occurred, that a HIV-negative patient afterwards was HIV-positive! Here too clear the limits of this method appear, which in practice unfortunately turns out to be relatively unspecific.

<ii>: Prof. Dr. H. Heine: Grundregulation und Extrazellulare Matrix - Grundlagen und Systematik, Lehrbuch der biologischen Medizin, (1991) 2.Aufl. Hippokrates Verlag Stuttgart, Seite 63

<iii>: U. Warnke: Bioresonanztherapie - Wunsch und Wirklichkeit. Medizin transparent Nr.2 (1996) S. 36-37

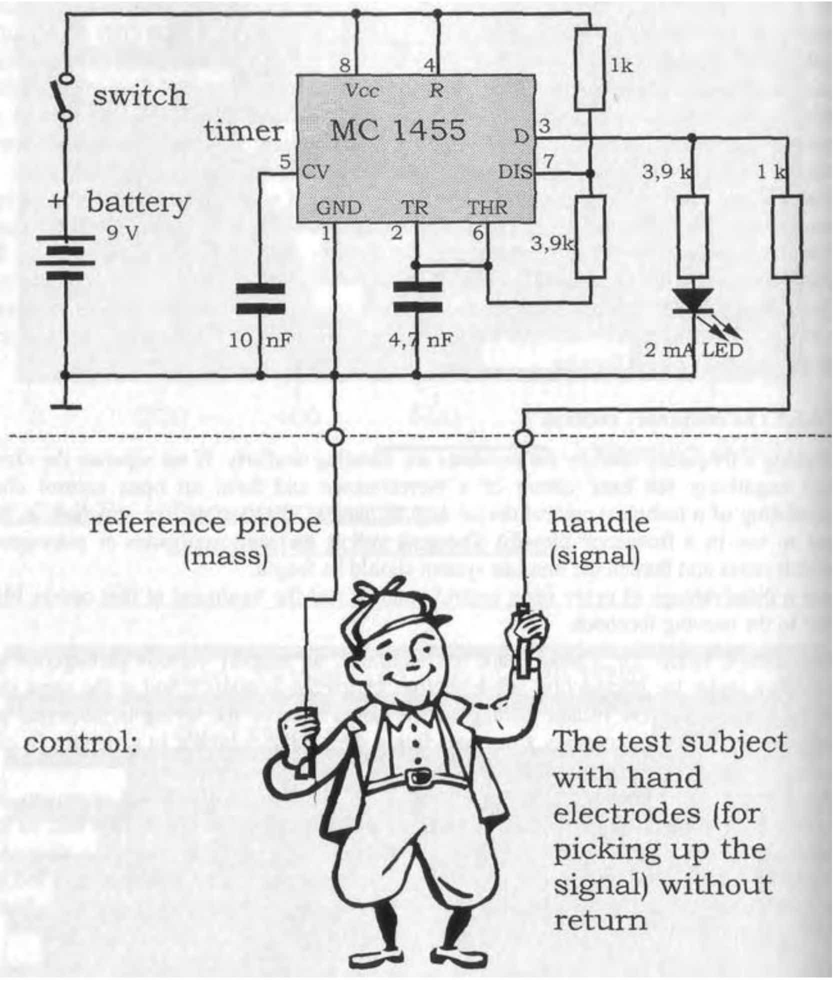
8
4
Vcc
R
1k
switch
timer
MC 1455
D
3
5
CV
DIS
7
+ battery
9 V
GND
TR
THR
1
2
6
3,9k
3,9 k
1 k
10 nF
4,7 nF
2 mA LED
reference probe
(mass)
handle
(signal)
control:
The test subject
with hand
electrodes (for
picking up the
signal) without
return

Fig. 24.4: Wiring diagram of the Zapper.<i>

Wiring diagram taken from:

<i>: H. Clark: The Cure for All Cancers (1993) New Century Press, USA, Page 507, resp.:

Dr. Hulda Clark: The Cure For All Diseases (1995), Page 48

24.4 The Zapper

From the point of view of physics of today the frequency therapy actually shouldn't be able to function at all. The electromagnetic waves penetrate only few millimeters into the skin at the used frequencies and wouldn't have the slightest chance, to reach a parasite, which is staying somewhere in the body. But it is said that it is possible to cure athlete's foot, by the patient taking the electrodes in his hands. How, we ask the question, does the signal of the function generator know where it should go?

It quite obviously concerns a resonance phenomenon. The likewise emitted scalar wave part tunnels undamped at those places in the body, with which it can build up a resonance and that for proper tuning are the unloved parasites. The scalar wave radiation is bundling up at the resonant receiver, so that despite the low transmission power as a consequence of the bundling up the energy density for the parasite becomes very high. It as a result is destroyed by its own ability to go into resonance. Once it is killed, the next one goes into resonance, logs off as well etc. In this way the parasites are destroyed one after another and not all at once. That's why the specified treatment cycle makes sense. The copper electrodes should not be taken in the hands directly, Dr. Clark recommends, but before be wrapped with moist paper. By means of this insulating layer, so is my interpretation, the conventional wave part, for which the skin functions as a wave guide, is reduced whereas the desired scalar wave part is increased. Such measures crucially contribute to the success of a therapy method, even if they were determined purely empirical.

If one wants to address every possible parasite individually, then the treatment takes correspondingly long. If one on the other hand sends all relevant frequencies at once by overlapping them, then the treatment can be abbreviated to the duration of one session. If the therapist goes still further and replaces the sinusoidal signal by a rectangular signal, then infinitely much sinus functions are hidden in it, as a Fourier analysis shows. With a rectangular signal, as it is delivered by the Zapper, one as it were catches everything, Good as well as Bad. There the helpful intestine bacterias break exactly like the wrongdoers.

The treatment with the Zapper is simple, inexpensive and exactly as controversial. It is the shot with the shotgun in the forest. One always hits something. We nevertheless must ask the question, why one only hits parasites and bacterias and not the vital organs? Aren't those damaged also?

Now then, the signal of the function generator is not modulated; it doesn't carry information. That's why only monocellular parasites, which don't know information exchange, are capable of a resonance. Human cells and more than ever whole organs on the other hand work with complex modulations, which effectively prevent any formation of resonance with the technically generated basic wave, with which the question would be answered so far.

That however also means that immune reactions can be expected: If the first treatment with the frequency therapy still is successful and all simple parasites could be hit, then only further evolved parasites have been spared, which modulate their information. They now breed and can't be reached anymore in further sessions. The method suddenly doesn't function anymore, the therapist finds out, the body apparently has become immune.

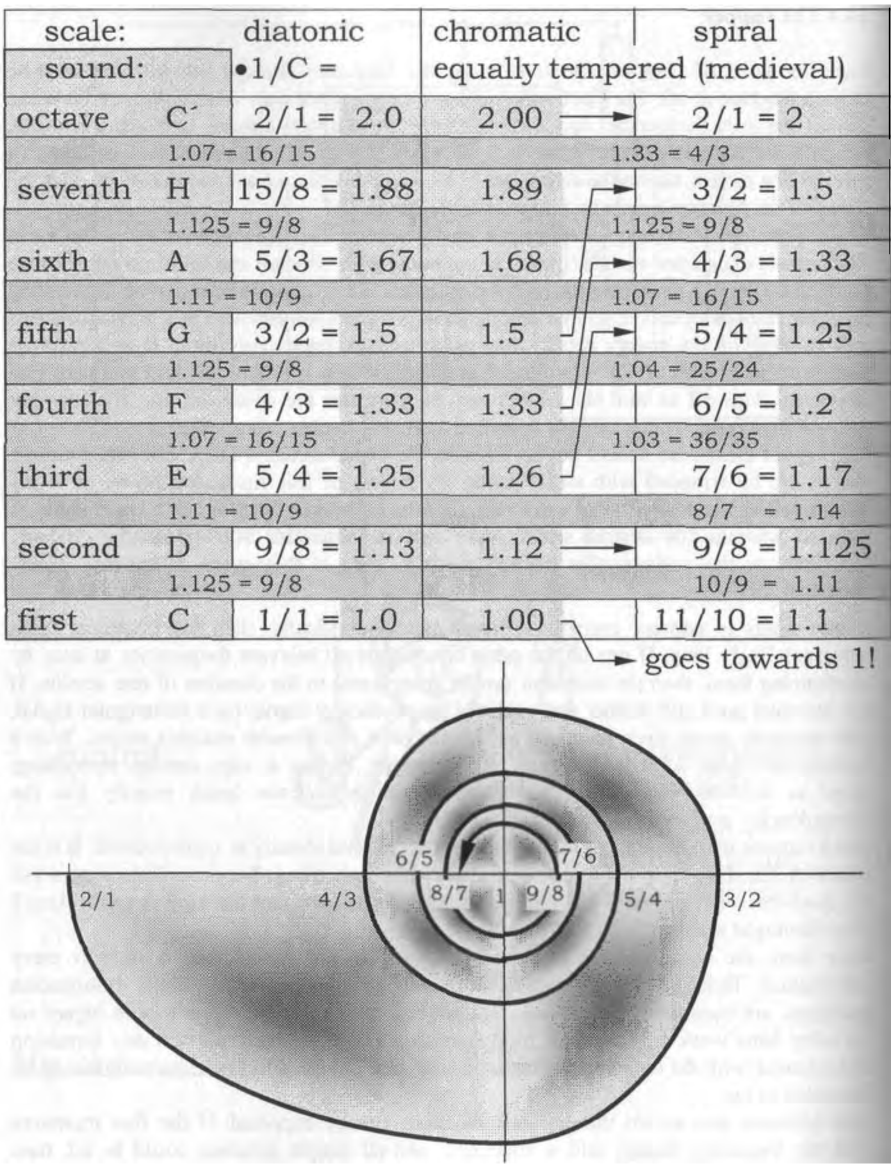

scale:		diatonic	chromatic	spiral
sound:		•1/C =	equally tempered	(medieval)
octave	C´	2/1 = 2.0	2.00	2/1 = 2
		1.07 = 16/15		1.33 = 4/3
seventh	H	15/8 = 1.88	1.89	3/2 = 1.5
		1.125 = 9/8		1.125 = 9/8
sixth	A	5/3 = 1.67	1.68	4/3 = 1.33
		1.11 = 10/9		1.07 = 16/15
fifth	G	3/2 = 1.5	1.5	5/4 = 1.25
		1.125 = 9/8		1.04 = 25/24
fourth	F	4/3 = 1.33	1.33	6/5 = 1.2
		1.07 = 16/15		1.03 = 36/35
third	E	5/4 = 1.25	1.26	7/6 = 1.17
		1.11 = 10/9		8/7 = 1.14
second	D	9/8 = 1.13	1.12	9/8 = 1.125
		1.125 = 9/8		10/9 = 1.11
first	C	1/1 = 1.0	1.00	11/10 = 1.1

goes towards 1!

Fig. 24.5: Harmonic spiral built on the first Gregorian scale.<i>

<i>: Dr. Manfred Doepp: Naturgemasse Frequenztherapien, Die Harmonie der Snirale. CO'Med 10/2000. S. 46 - 49

24.5 Discussion concerning the medicine of oscillation

The textbook medicine in its explanations and treatment methods is basing on the models, which it can measure and analyse and which it understands. Doing so man and whole nature is reduced to a handful of chemical reaction formulas. The whole pharmaceutic industry lives on this misleading path, which long ago has revealed to be a dead end, medical as well as financial. This health service cannot be paid anymore and we should ask the question if it actually is worth the money, if with electric signals of minimum power can be obtained effects comparable to the effects of the pill medicine.
We need a new medicine, a potential vortex medicine. First of all we should research how an organism covers its energy needs and how it communicates. There leads no way past the scalar waves and the newly discovered potential vortices. Chemical processes as they are being observed, occur by the way, that is beyond doubt, but they by no means are the cause. Hence of pills and other chemical means at most a treatment of symptoms and a case of side effects may be expected but not a cure of a disease. Once the potential vortex medicine will be systematically explored and be put to use in practice, healing successes can be expected, which we at present can't imagine at all.
The amazing results, which already today are obtained in the medicine of oscillation and of which some doctors can report<i>, dictates the direction in which the textbook medicine should develop. In the question, which kind of oscillation or which ,,sequence of sounds" (Fig. 24.5) is the right one, still exists considerable need for research.
Some doctors even already work with my new theory and cite whole passages from my publications until now about this theme<ii>.

<i$_a$>: Dr. Bodo Kohler: BITsyn, der neue Weg in der Informations-Medizin, Jubilaums-Schrift der Internationalen Arzte-Gesellschaft fur Biophysikalische Informations-Therapie, Bad Nauheim den 6.-8.10.2000, Seite 48 - 56.

<i$_b$>: Bioenergetische Messverfahren in Theorie und Praxis, Vortragsband der Gesellschaft fur Energetische und Informationsmedizin e.V., Universitat Stuttgart am 17.7.1999.

<ii$_a$>: Dr. Johann Lechner: Storfelddiagnostik, Medikamenten- und Materialtest, Teil 2 aus der Reihe: Praxis der Ganzheitlichen Medizin und Zahnmedizin, Verlag Dr. E. Wuhr (2000), Kap. 2.4.2 Beruhrungslose skalarwellentragende Informationsubertragung S. 173 ff., bes. Kap. 2.4.2.3 Seite 175, 176.

<ii$_b$>: Dr. Reichwein, Peters: Zellulare Elektromagnetische Systemsteuerung, Der Freie Arzt 5 (2000) im Wissenschafts-Forum (Anhang, S. IV - XXIII).

<ii$_c$>: Dr. M. Doepp: Tesla-Wellen, Neue Studien, CO'Med 5/2000, S. 94 - 95

Frequency spectrum of the human organism:

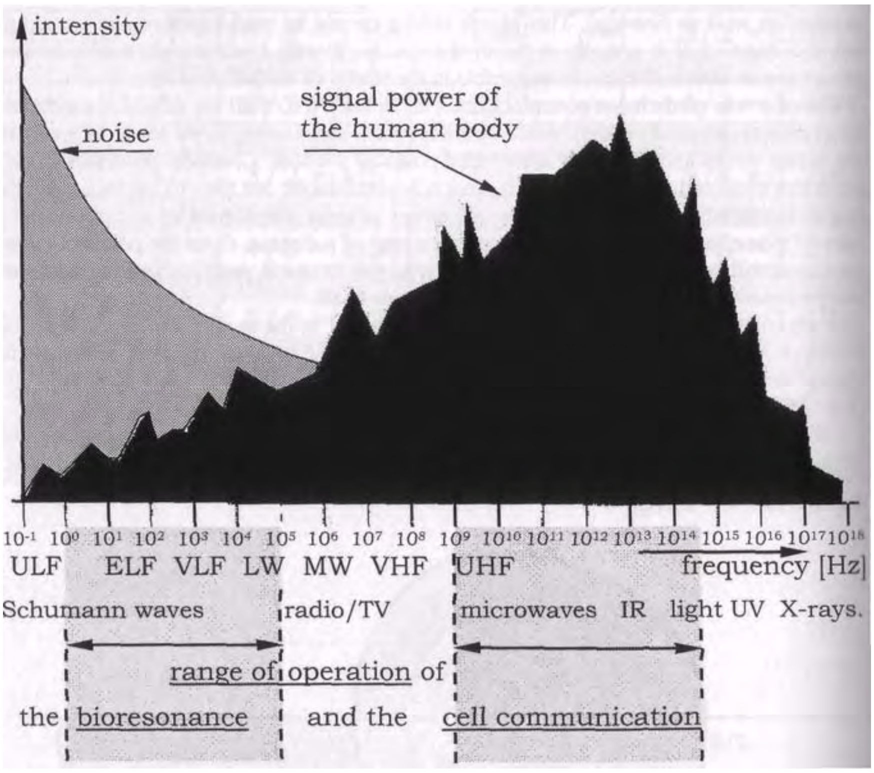

Fig. 25.1: The measured frequency spectrum of man.<i>

<i>: Dr. P. Bembenek: Akupunktur und (Bio-) Resonanz, CO'med 6/98, S. 50-58

25. Contributions to the discussion concerning the information technical use

The medical research predominantly takes place with statistical methods. This might be changed fundamentally, if only the physical relations have been realized and their causes found out. Only then a basic research will be possible also in the area of medicine, as it today already is usual in other disciplines.

In this chapter it concerns the question of the medical basis in general, and specifically the question of the use of the newly discovered potential vortices in biological systems. Doing so very aware is attempted to put the normally used medical view at the back and to derive the answers from the perspective of the engineer and the physicist. This approach is unfamiliar, so that some textbook physicians will have difficulties to follow. It however will prove to be very helpful. Medicine in addition needs new impulses and that justifies a new approach, like the unconventional one proposed by me.

In this connection gladly is fallen back upon the comparison of biological with technical systems, although here exist differences in principle and fundamental It can be expected that nature has developed very appropriate strategies to solve certain tasks, as it also is teached in engineering and used in practice. At this place not only medicine benefits from new insights, engineering vice versa also can learn of nature, because natures optimization strategies are much much older and correspondingly perfect.

25.1 Window of the sensuous perception

To clarify the inner processes in man we consider his sense organs, which function as interface to the outside world. Technically seen in the case of the sense organs it concerns measurement converters to record and process certain physical values in our environment and their adaptation to pass on the information by means of the nerves. The measurement converters thereby are built more or less complex, which is related to the circumstance that the measurement factors, which a living being needs to orient itself and to be able to survive, are quite different.

It concerns little windows within the frequency spectrum shown in fig. 23.1, which should be analysed. Man for instance chooses the visible frequency window and interpretes it with an assignment to the colours, because in this range the sunlight can reach the surface of the earth and the ionosphere doesn't exert an excessive damping (fig. 2.8).

The acoustic window depends on the sound propagation in air, whereas dolphins work with ultrasound, which carry considerably further in water. The associated measurement converters, the ear and the eye, have a very complex structure. From this can be inferred that here the received signal must be transformed into a different physical measurement signal, that the perceivable signals are of other nature than the signals, which our nerves are able to pass on.

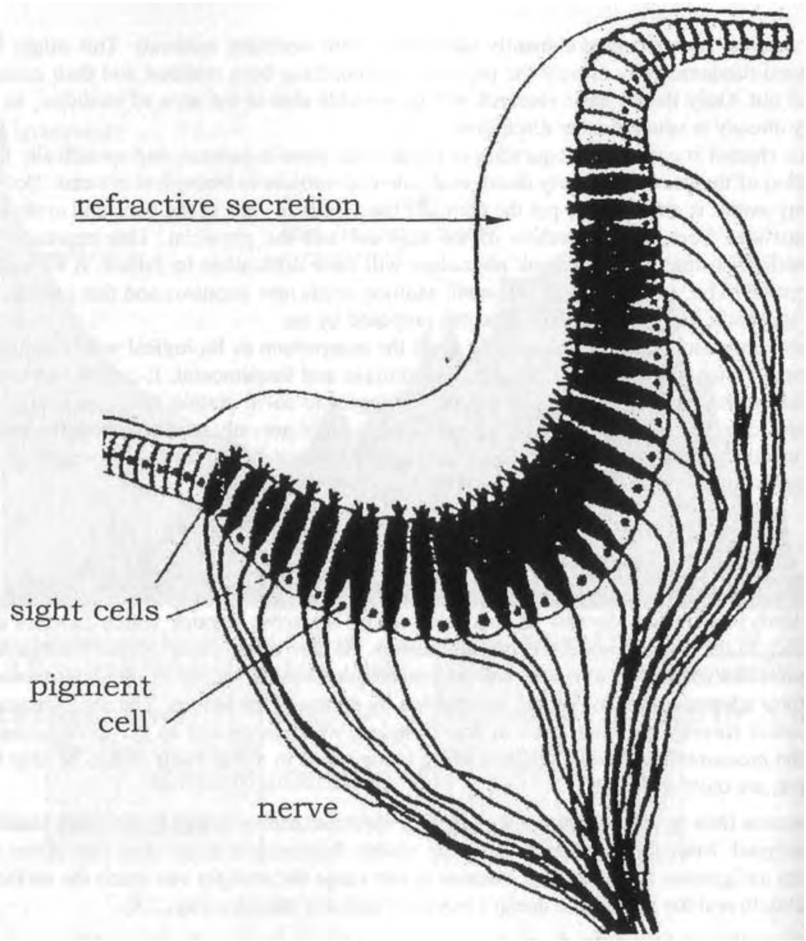
refractive secretion
sight cells
pigment cell
nerve

Fig. 25.2: ____ The hollow eye of the snail

25.2 The sense organs (nose, eye, tongue)

If we want to find out something about the nature of the nerve signals, then we should more detailed consider a sense organ, which is constructed if possible simple. In that case it is possible that no signal transformation is necessary at all anymore, because the perceivable variable is exactly of the kind the nerves can process.

The primary and perhaps most ancient sense organ of the living beings is the nose. It is constructed extremely simple. On the one hand according to encyclopaedias it is a chemical sense for the perception of smell materials. Man on the other hand can distinguish several thousands of scents. For that a huge analysis factory with correspondingly much receptors would be necessary, which one searches in vain in the nose between the nasal hairs and the nerves. We from that infer that scent should consist of particles, which are to a large extent identical with the reaction potentials. It thus will concern potential vortices. These ring-like vortices of the electric field again are modulated and carry information, which our brain is able to analyse.

According to the derivation in chapter 9.0 Plato already 2400 years ago knew such relations. The conclusion is obvious that smell is vortex information, which according to the explanation of Plato forms at the transition of waves in potential vortices and vice versa. At the natural philosophers in antiquity the circle of the insights is closed. Modern science just isn't that far.

The hollow eye of the snail functions both as nose and as eye (fig. 25.2). This very ancient combined organ points to a relatively close affinity between both measurement sensors. Possibly in the course of evolution both organs have developed from such a common original form.

In the case of man the smell rods occupied with the nasal hairs of roughly 2 micrometer in length, actually remember of the rods and cones in the eye, with which photons are collected. In both cases, so we can explain the mode of action in accordance with model, the ring-like vortices settle on the rods and run as reaction potentials along the nerve to the brain, which then analyses the modulation.

In the case of the highly developed human eye the light rays first have to traverse the vitreous body and afterwards a pigment layer, before they reach the rods and cones. In this way the electromagnetic wave parts must roll up to vortices, since our nerves can only pass on vortices. The photons can be interpreted as corresponding vortices.

If we compare the eye with a bubble chamber, in which the tracks of ionized particles can be observed and photographed as thin white fog stripes. Here in collision experiments it can be proven that it concerns particles carrying impulse and not waves. But the measurement setup by no means does answer the question if it already concerned particles before they entered the bubble chamber, or if these have formed spontaneously in the presence of the saturated vapour.

It would be obvious, if for our eye the chamber water being under the inner eye pressure would take over the function of the bubble chamber and would take care of the rolling up of the light waves to light quanta.

Example tongue:

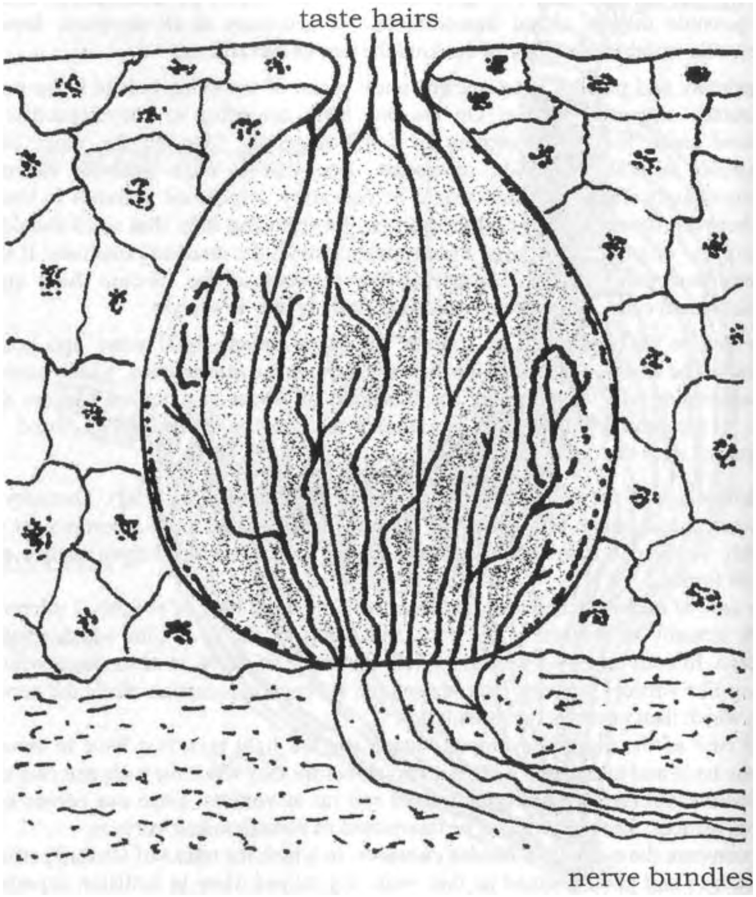
taste hairs
nerve bundles

Fig. 25.3: Taste bud of the human tongue

We optically can't detect a difference, if the light while passing through a thick glass plate increases its part of photons. At the latest in the eye in any case all the light is transformed in photons and usable vortices, so that we mustn't detect a loss of brightness. The glass plate seems transparent to us, even if the sunlight should change its composition and its biological quality, if it passes the plate.

If the tongue while tasking responds to dissolved substances, then it not by all means needs to be a chemical excitation. Instead fine hairs, the taste hairs resp. sense pins, serve as receiver like in the case of the nose. The similar structure of the receptors and the circumstance that for most invertebrates sense of taste and sense of smell can't be distinguished of each other at all and consist of the same primary sense cells, suggest that the tongue doesn't analyse the chemistry as such, but only the molecular oscillation patterns, that also the taste is nothing else but vortex information!

25.3 The nerve conduction

For the collection of the potential vortices and the extraction of their information fine hairs in the sense cells obviously play a central role. They are connected more or less directly with the end of a nerve and pass on the information without big transformation. Even in the organs of equilibrium sense hairs work.

From the comparison with the technique developed by Nikola Tesla I could show that the nerve conduction concerns a single-wire transmission, a kind of waveguide, for which the transport of the excitation information takes place in the insulation layer and not in the conductor itself (fig. 9.6). As proof I quoted that the thickness of the insulation determines the velocity of propagation, that as is well-known the nerve conductors with thick fat layer pass on their action potentials faster than those with thin insulation. Particularly interesting is the observation, how the fat layer is constricted in fixed intervals, like for Wiener sausages (fig. 25.4 A). These nodes of Ranvier prove that only longitudinal waves are being transported, which are standing waves with nodes and antinodes, if the distance from node to node exactly corresponds to the distance from one node to the next. With that nature with the use of the potential vortices is far ahead of our power engineering. The nerve-cables determine with their structure, which signal will be transported and which not!

The technical cables on the other hand are stupid and conduct everything, the useful signal just as well as any arbitrary interference signal. Anyone, whom the computer crashes every few minutes, knows what I'm talking about.

Man isn't able to afford a crash of his think computer. It would be lethal for him. His nerve costume even tolerates short-circuits. The acupuncture is such a short-circuit technique by means of electrically conductive needles. There even is given a therapeutic benefit and a relaxing effect for the body.

Cut through nerve fibers even can partly regenerate again, even without a cut through nerve again growing together with its other end. The nerve conductors are so intelligent, that only the matching information arrives at the end by passing on informations from one fiber to the corresponding next with the same node interval.

A. Nerve conduction with nodes of Ranvier (to transmit standing waves):

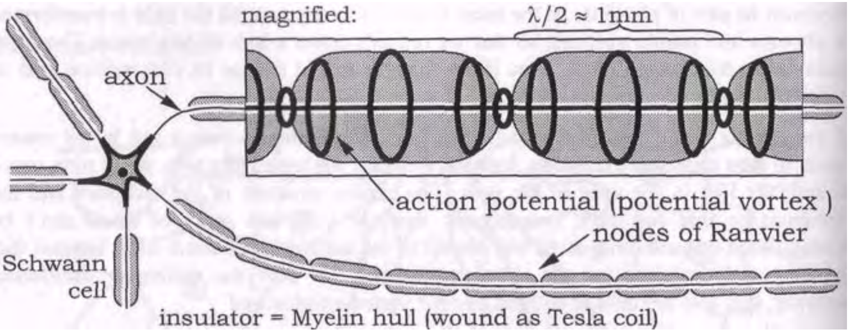
magnified:
λ/2 ≈ 1mm
axon
action potential (potential vortex)
nodes of Ranvier
Schwann cell
insulator = Myelin hull (wound as Tesla coil)

B. Single-wire transmission according to Nikola Tesla<i>:

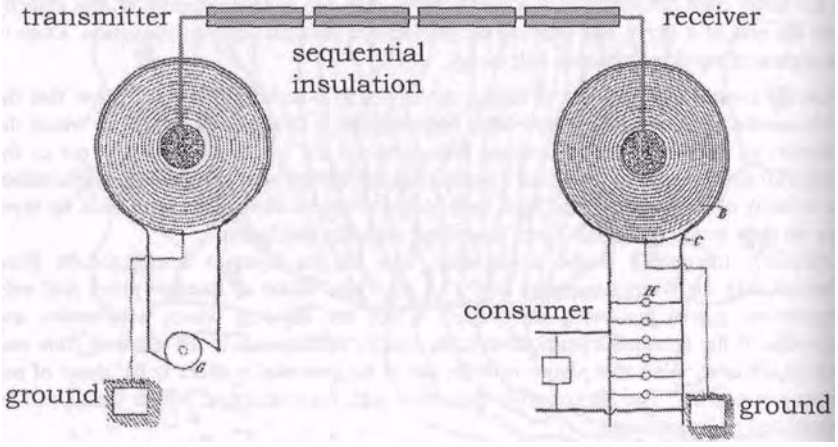
transmitter
receiver
sequential insulation
consumer
ground
ground

Fig. 25.4: ____ Selective scalar wave signal transmission

The brain works with scalar waves! Reasons are:

1. Lacking of a signal transformer between the nerves and the brain.
2. High performance density of the think apparatus.
3. The brain activity measurable from the outside with the EEC
4. Spark formation and corona discharges at open top of the skull.
5. Insulation defect occurring in the case of epileptics.

<i>: Original sketch of Tesla is situated in the Nikola Tesla Museum, Belgrade.

Nerves represent an intelligent and at the same time interference safe wiring, which is superior to any technical solution by far, or you can try to acupuncture a cable cord of your computer. You will have little pleasure of it.
Nikola Tesla also in this point was ahead of the times. He has experimented with a single conductor technology, for which the insulation layer is constructed like for a nerve fiber (fig. 25.4 B). We'll have to learn to handle such aids in the future, if we in engineering want to emulate nature and as well want to send informations as scalar wave. A normal power cable as said conducts everything, useful as well as interference signals. If however the signal should be accomodated in the noise, a selective cable is required, which should be constructed according to the example of the nerve conductors. Before a scalar wave technology can be introduced and successfully used according to that completely other cables, coupling elements, amplifiers and other components should be developed. The trouble should be worthwhile at the chances, which this genial technology offers us!

25.4 The brain, a scalar wave computer

The brain cells (neurons) are of the same kind as the nerve cells. Hence can be done without a signal transformer, can the informations transmitted by the nerves to the brain directly be processed further. From that follows that also the brain without exception works with potential vortices. There are several reasons for this hypothesis:

1. as said, the lacking of a signal transformer.
2. the high performance density of the think apparatus. (As a result of the concentration effect of the potential vortices the efficiency of the human brain is in such a way high concentrated compared to the much more space claiming computers functioning on the basis of currents).
3. the brain activity measurable from the outside with the EEC
4. spark formation and corona discharges at open top of the skull. (Brain surgeons can report of such observations).
5. The insulation defect occurring in the case of epileptics. (During a fit instable potential oscillations of the nerve cells occur, which lead to strong electric blows).

With the „exciting" and the inhibiting"' synapses as separation point between the neurons both a ,.high-active" and a „low-active"' method of operation is possible and with that a redundant, particularly interference safe signal transmission.
Safety for interference is very important not only in nature. In the operating instructions of a PC can be read: „operate only at room temperature, keep dry, don't throw or shock, take cure for sufficiently cooling air, ground apparatus, pay attention to mains voltage, etc". A comparison with the range of operation of man is like scorn.
Nevertheless the consequences if errors occur are quite similar: a garage door, which opens if a mobile is switched on, by all means can be compared with a light phenomenon, which we perceive after a blow on the eye at the biological level.

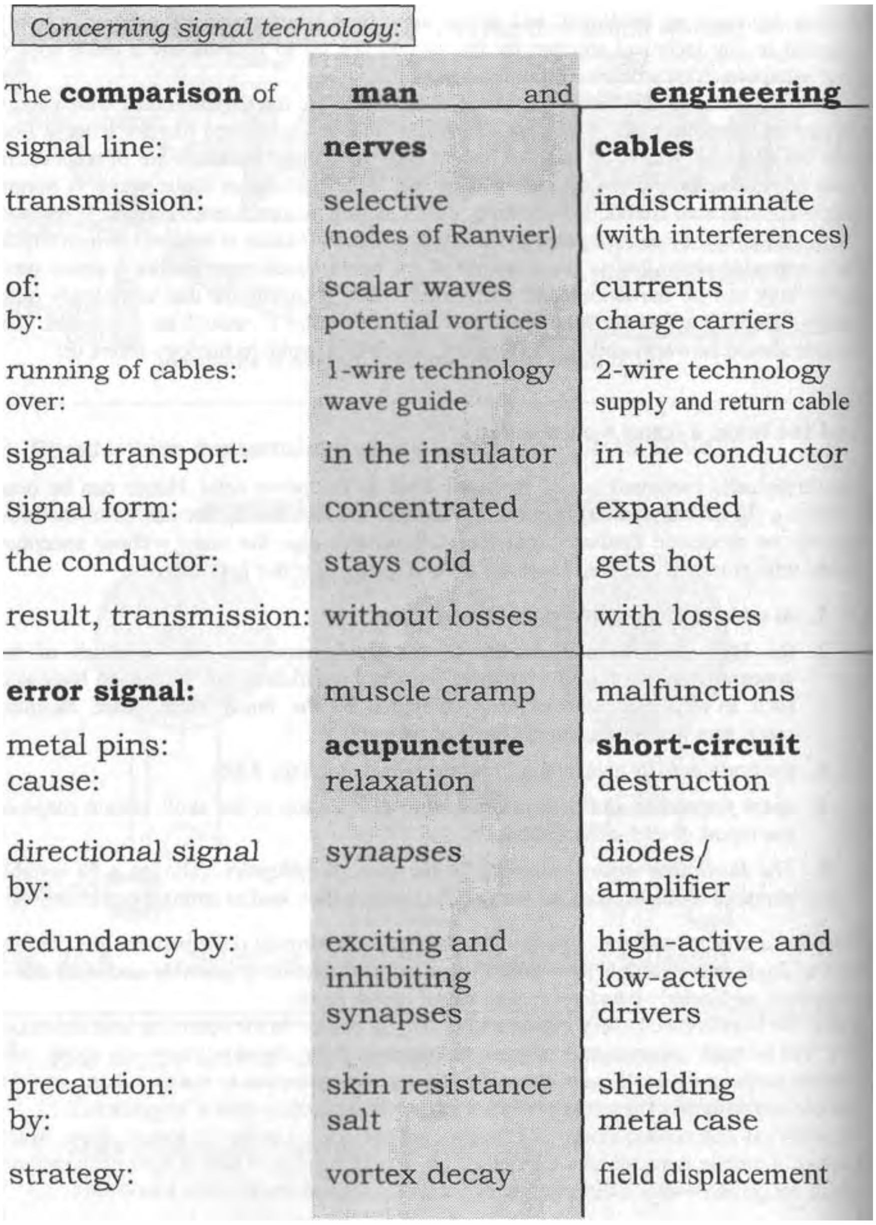

Concerning signal technology:

The **comparison** of	**man** and	**engineering**
signal line:	**nerves**	**cables**
transmission:	selective (nodes of Ranvier)	indiscriminate (with interferences)
of:	scalar waves	currents
by:	potential vortices	charge carriers
running of cables:	1-wire technology	2-wire technology
over:	wave guide	supply and return cable
signal transport:	in the insulator	in the conductor
signal form:	concentrated	expanded
the conductor:	stays cold	gets hot
result, transmission:	without losses	with losses
error signal:	muscle cramp	malfunctions
metal pins:	**acupuncture**	**short-circuit**
cause:	relaxation	destruction
directional signal by:	synapses	diodes/ amplifier
redundancy by:	exciting and inhibiting synapses	high-active and low-active drivers
precaution:	skin resistance	shielding
by:	salt	metal case
strategy:	vortex decay	field displacement

Fig. 25.5: ____Comparison of the signal technology

25.5 Concerning signal engineering

By means of a technical analysis of biological relations completely new interpretations result also for the occurring of a disease. We permanently and everywhere are surrounded by noise signals, but as a rule they can't touch us, because the body has developed perfect strategies for defence. The nodes of Ranvier on the nerve bundles here are just as helpful as the diode effect of the synapses. By means of the salt content and the skin resistance the body in addition controls the uptake of potential vortices from its surroundings, by using that the vortex decay is determined by the conductivity.

The specialties of the by humans used signal technology come to light particularly clear if compared with the cable technology used in the technical world (fig. 25.5). So is worked with only one wire instead of with supply and return cable, are mediated potential vortices instead of charge carriers, does the transmission take place in the insulator without losses and not in an electric conductor, which as a result gets hot and produces current heat losses. Nerves thanks to their ability of selection represent an intelligent form of signal transmission, by helping to filter the asked information from the noise. This surely is necessary since with cables, which indiscriminately transmit every signal, an use of scalar waves hasn't succeeded yet. We should try to learn of nature!

A special challenge is the protection against error signals. A passive shielding by a metal case however is not possible, because scalar waves can't be shielded by principle, so that the precaution should be taken actively by means of the conductivity. That's why we sweat salt if we strain us physically, whereby the vortex decay is determined by the conductivity, which depends on the salt content of the body liquids. In the case of a sweating activity the body reduces its conductivity, so that the needed potential vortex energy will reach the cells.

If the body sometime isn't able to defend itself against interference signals, then malfunctions or pathological reactions are a possible result. During having a bath for instance a muscle cramp can occur, if the body doesn't defend itself fast enough or sufficiently against the high potential vortex activity in the water. Now vortices can be picked up in the nerves, which are of the same kind as the ones emitted by the brain, only that both muscles, biceps and triceps at the same time get the signal to contract. The result is a cramping of both muscles.

Thus the brain has developed intelligent strategies to protect itself of interspersed misinformations. It weighs the incoming signals and forgets again all unimportant ones more or less fast. We speak of the ability to learn and that means that signals rise in the valuation scale and with that are stored longer, the more frequent repeated our brain receives them. This strategy assumes that interference signals only occur sporadic, for which reason they are rated unimportant and fast are again forgotten. A PC on the other hand doesn't have such a property. It notices everything indiscriminately and sometime will crash of overload, if not the user will constantly foster it and will administer the available memory. A PC is and stays stupid.

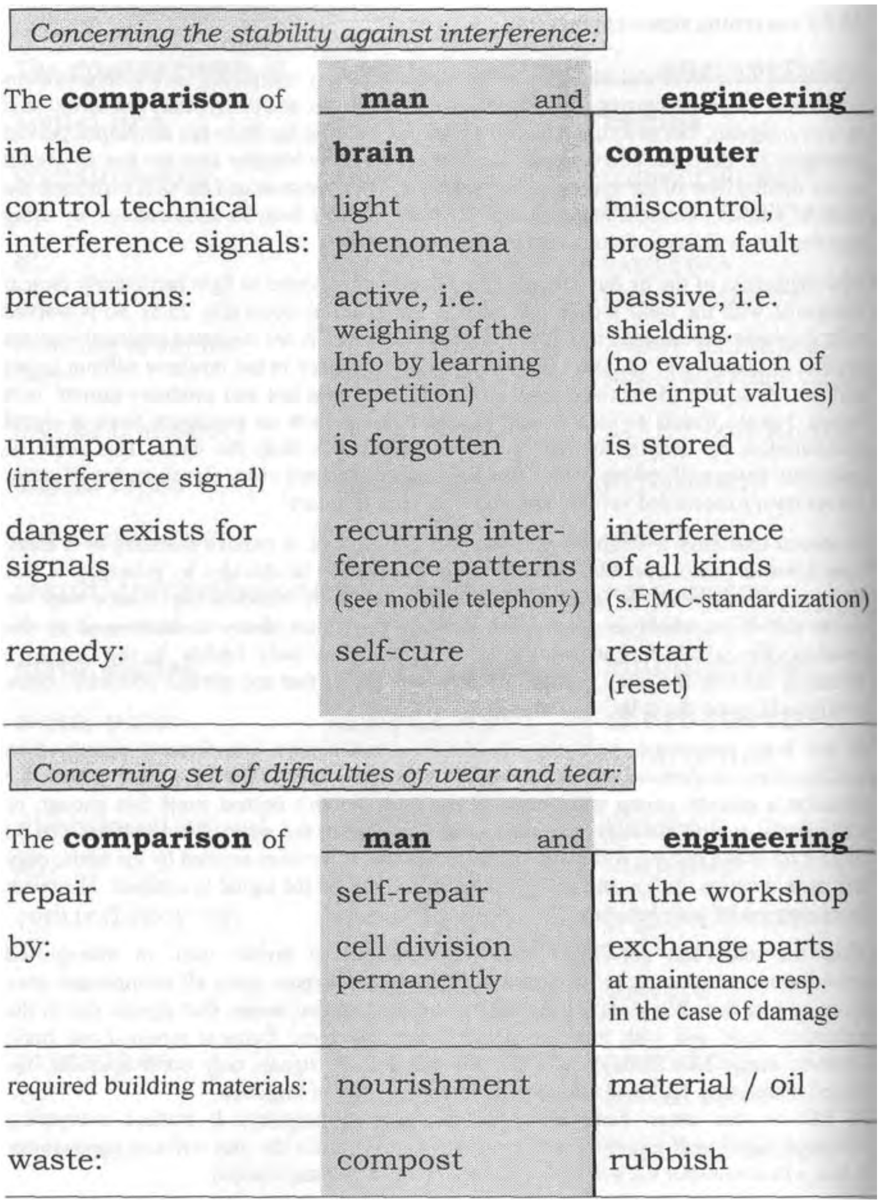

Concerning the stability against interference:

The **comparison** of	**man** and	**engineering**
in the	**brain**	**computer**
control technical interference signals:	light phenomena	miscontrol, program fault
precautions:	active, i.e. weighing of the Info by learning (repetition)	passive, i.e. shielding. (no evaluation of the input values)
unimportant (interference signal)	is forgotten	is stored
danger exists for signals	recurring interference patterns (see mobile telephony)	interference of all kinds (s.EMC-standardization)
remedy:	self-cure	restart (reset)

Concerning set of difficulties of wear and tear:

The **comparison** of	**man** and	**engineering**
repair	self-repair	in the workshop
by:	cell division permanently	exchange parts at maintenance resp. in the case of damage
required building materials:	nourishment	material / oil
waste:	compost	rubbish

Fig. 25.6: Strategies against interference signals, for damages linked with operation and for wear and tear.

25.6 Stability against interference and repair mechanisms

The interference signals present in our natural environment as a rule are distributed stochastic, but not so artificial interference signals like for instance transmitters emit. If for instance in the case of mobile telephony there occur time and again identical signal patterns and if a person perceives these, then because of the continual repetitions a high importance is pretended and precious storage space in the brain is allocated. This to a special extent applies for the permanent stand-by signals, which are emitted by mobiles and cordless phones even then, if we don't phone at all. Such misdevelopments thereby would be technically avoidable just like that!
If still no gauges are available and as a result there exist neither guidelines nor limits for the radiation exposure of scalar waves, then such devices must be developed and built. For the requested electromagnetic environmental compatibility not engineering, but man should be in the centre of attention!

Let us throw a short glance at the set of difficulties of wear and tear. Most technical devices find the way into the workshop only, if they already are defect. Some aren't repaired anymore in principle and immediately sent to the rubbish, because they are worn-out and a repair isn't worth the effort anymore one says, whereas other, mostly expensive systems are being serviced by exchanging all wearing parts.

Nature has brought to perfection the last principle. It allows the body a permanent maintenance; by permanently producing new cells and replacing consumed ones. It with that obtains a considerably longer operating time and even is capable to heal wounds. Just imagine dents in our cars would disappear from alone after a few weeks and the bodywork would look like new. Such an optimal maintenance is costly and it has its price. By means of the cell division the building plan for the spare parts is copied. The task on the other hand is transmitted to the new cells „by radio" by means of waveguide channels, as proves the matching structure of scalar wave and waveguide (chapter 21.12 and fig. 25.7). The cells hence have a kind of „decentral intelligence", which technical matter lacks completely. A comparison with engineering nevertheless makes sense, because wear and tear occurs for all systems in continuous operation. Thus strategies must be developed to provide the necessary material for operation, building-material and exchange parts.

By sizing of the hyperboloid structures of the matrix channels it should be possible to determine the wavelength of the scalar waves to enter them in the frequency diagram (23.1).

Tunnel structure of the basic substance according to Prof. Heine<i>:

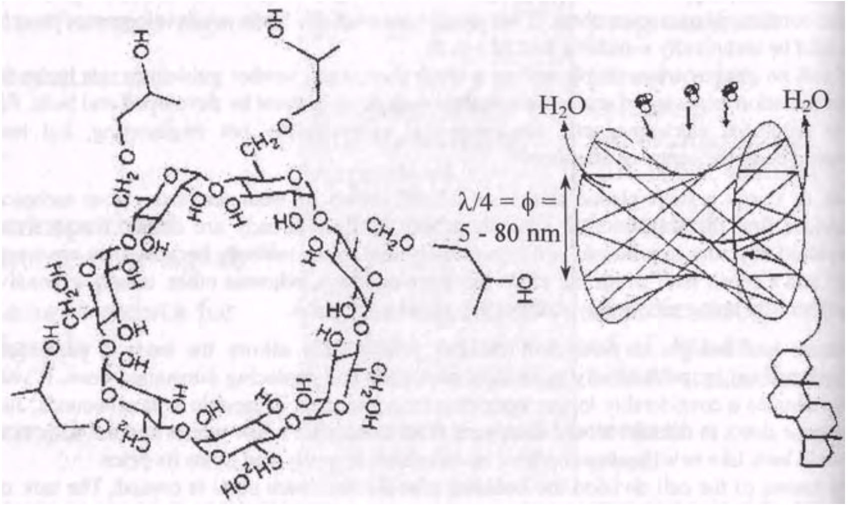
H₂O
H₂O
λ/4 = ϕ =
5 - 80 nm
OH
CH₂O
HO
CH₂OH

Fig. 25.7: ___ Information channels in the intercellular matrix.<i>

<i>: Hartmut, Heine: Lehrbuch der biologischen Medizin. Grundregulation und Extrazellulare Matrix, 2. Aufl. 1997, Hippokrates Verlag Stuttgart, S. 56

25.7 The microwave window

There still is lacking information about the frequency or the velocity of propagation to be able to specify and enter in figure 23.1 the cell information. Let's take to hand the book about "Biostrahlen"<i>. In there is explained how for individual cells the emission of electromagnetic signals already could be measured, which are interpreted as circularly polarized waves (fig. 21.10 A). It is said that thereby their polarization plane is rotating with the speed of light, whereas the wave itself is propagating in longitudinal way relatively slow and according to the authors with the speed of sound.
The occupation with the potential vortex theory in the explanation lets immediately recognize the vortex, for this is rotating with the speed of light in circles as rolled up wave (fig. 21.10). If it is bound to the surrounding matter with closed vortex centre, then it can be expected that the propagation actually takes place with the speed of body sound.
It could concern the same signals, which Prof. A. Popp calls biophotons and detects measuring technically in living organisms<ii>. He however considers the phenomenon for the same wavelength with the speed of light and lands at light frequencies, even then if nothing is glowing visibly! The question is asked: Does it concern the frequency of the light or only the corresponding wavelength or actually both, thus light, as is expressed in the name biophotons?
The photomultipliers, which Prof. Popp uses as „light amplifier", however can only be tuned to certain wavelengths and not to frequencies. Even if the detected biophotons have the wavelength of the light, then nevertheless nothing will glow if the velocity of propagation and as a result also the frequency differs from that of the light for several powers of ten. In the case of the immense number of cells also the number of photons should correspondingly sum up and the body as a whole should start to glow, which is not the case.

The waveguides in the intercellular matrix serving the cell communication, which Prof. H. Heine observes microscopically, have wavelengths between 20 and 300 nanometer, which corresponds to the range of the ultraviolet radiation<iii>. But if the propagation is slower than the light for 6 powers of ten, then also the frequency will only amount to one millionth and be situated into the range of the microwaves. Here a biological window seems to be present, to which we should turn our attention for reasons of the electromagnetic environmental compatibility!

The thermal radiation, which reaches the earth from the sun and the planets, lies in the microwave range between 2 and 20 cm. If the sun does well to us, if we need the radiation, then it could be because of the identical frequency. But that also means that the sun and the planets are capable to have an effect on the cell communication, that they for instance could function as clock for the heart.

<i>: H. Mayer, G. Winklbaur: Biostrahlen, Verlag ORAC, Wien 1989, 5. Auflage S. 97: Messung von der DNS eines Gurkenkeims abstrahlenden Photonen.

<ii>: A. Popp: Neue Horizonte in der Medizin, 2.Aufl. Haug Verlag Heidelberg 1987

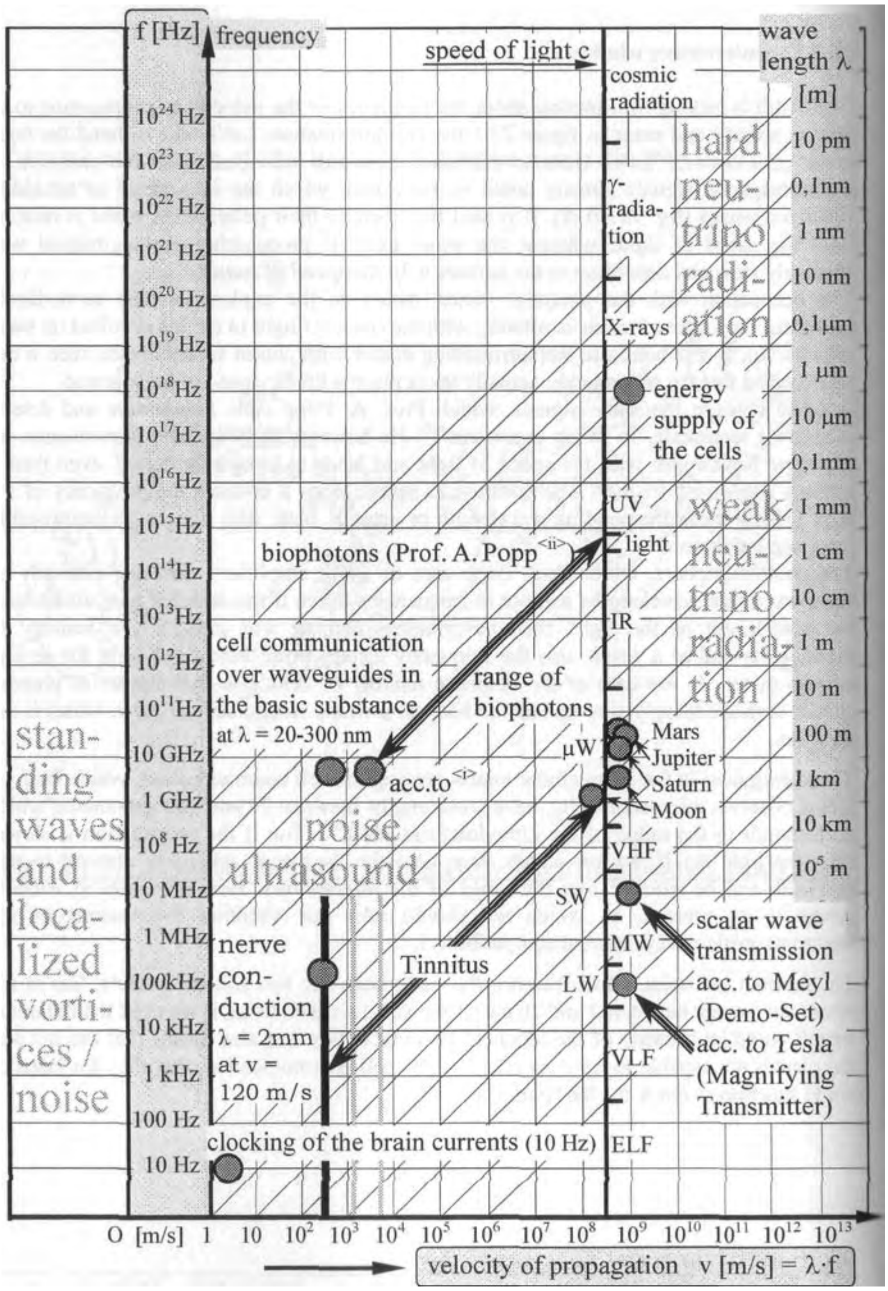

Fig. 25.8: Frequency diagram with entries concerning biologically relevant areas (Tinnitus, nerve conduction, etc.).

25.8 Discussion concerning scalar wave medicine

In the sensitive range of the supposed microwaves window however are also situated the mobile phones and their harmonic waves, which occupy a broad spectrum in particular for pulsed operation in digital nets. The D-net for instance has a wavelength of 32 cm, the E-net lies at half that wavelength. But to which frequency does this correspond at the speed of sound? Now, the frequency is 6 powers of ten smaller and now lies at 1 kHz resp. 2 kHz. To that are added the numerous harmonic waves, which form a noise signal and lie above that. With that these signals are situated completely in the audible range, there where our ears are most sensitive!
This cause we probably owe the disease of modern civilization „Tinnitus". Every charged particle will follow this electromagnetic oscillation and produce corresponding sound oscillations, which can hear not „sick ", but completely on the contrary „healthy" people, who as a result possibly get sick. The objection, in this range also cosmic radiation for instance from the planets is present, is legitimate. It however should be considered that planets also are going away from the earth again and in addition is present a fluctuation according to the time of day due to the rotation of the earth, while the mobile telephone masts in our vicinity radiate in continuous operation.

In this window in addition the clocking of the brain currents takes place at 10 Hz. I would recommend blocking the acoustic relevant range between 2 cm (16 kHz) and 3 m wavelength (100 Hz) for all technical use. Every operation of a transmitter in a biological window harms all people and cannot be answered for by any institution.

It further should be considered that the biological window of the plants and animals as a rule correspond to that of man, but sometimes are shifted significantly upward or downward in wavelength. We are not entitled to judge nature. The immune system of the animals now obviously has reached the breaking point and also that of man doesn't seem to be that anymore, which it originally was.
We must proceed from the assumption that many diseases on the one hand and therapy methods on the other hand partly direct and partly indirect have to do something with scalar waves. (E.g. the occurring of cancer<4i>).

<i>: H. Mayer, G. Winklbaur: Biostrahlen, Verlag ORAC, Wien 1989, 5. Auflage, S. 97: Messung von der DNS eines Gurkenkeims abstrahlenden Photonen.

<ii>: A. Popp: Neue Horizonte in der Medizin, 2.Aufl. Haug Verlag Heidelberg 1987

<iii>: Hartmut. Heine: Lehrbuch der biologischen Medizin. Grundregulation und Extrazellulare Matrix, 2. Aufl. 1997, Hippokrates Verlag Stuttgart, S. 56

<4i>: K. Meyl: Skalarwellenstrahlung. Welche Bedeutung haben Skalarwellen fur die Medizin? GNP-Vortrag am 29.04.2001, Rhein-Main-Halle Wiesbaden, see: Co'med Fachzeitschrift fur Komplementarmedizin, 6/2001, pp.55-60.

I. According to the Maxwell theory:

1. Faraday's law of induction:

$$\boxed{\text{rot }\mathbf{E} = -\,\delta\mathbf{B}/\delta t} \quad (26.1)$$

with $E = E(r,t)$

and $H = H(r,t)$:

$$\mathbf{B} = \mu \cdot \mathbf{H} \quad (26.2)$$

$$\boxed{-\,\text{rot rot }\mathbf{E} = \mu \cdot \delta(\text{rot }\mathbf{H})/\delta t} \quad (26.3)$$

2. Ampere's law:

$$\boxed{\text{rot }\mathbf{H} = \mathbf{j} + \delta\mathbf{D}/\delta t} \quad (26.4)$$

with:

Ohm's law: $\mathbf{j} = \sigma \cdot \mathbf{E}$ (26.5)

dielectric displacement: $\mathbf{D} = \varepsilon \cdot \mathbf{E}$ (26.6)

relaxation time: $\tau = \varepsilon/\sigma$ (26.7)

$$\boxed{\text{rot }\mathbf{H} = \varepsilon \cdot (\mathbf{E}/\tau + \delta\mathbf{E}/\delta t)} \quad (26.8)$$

3. Inserting equation 26.8 into 26.3 yields:

$$-\,\text{rot rot }\mathbf{E} = \mu \cdot \varepsilon \cdot (1/\tau \cdot \delta\mathbf{E}/\delta t + \delta^2\mathbf{E}/\delta t^2) \quad (26.9)$$

with the abbreviation: $\mu \cdot \varepsilon = 1/c^2$ (26.10)

4. Field equation of a damped transverse wave:

$$\boxed{\underbrace{-\,\text{rot rot }\mathbf{E} \cdot c^2}_{\text{transverse}} = \underbrace{\delta^2\mathbf{E}/\delta t^2}_{\text{wave}} + \underbrace{(1/\tau) \cdot \delta\mathbf{E}/\delta t}_{\text{vortex damping}}} \quad (26.11)$$

Fig. 26.1: Derivation of the wave damping by means of the formation of vortices![i]

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[i] see also EMC, part 1, chapter 5.3, 2.borderline case.

26. Recapitulation from the viewpoint of textbook physics

Now that we in the meantime have accumulated innumerable mosaic parts as inspiring contributions to the discussion for the information technical seminar, it is time to sort the ideas and to put the parts together to an overall picture.

Sceptics and orthodox scientists can only be convinced, if we start from textbook physics and completely do without postulates. Those demands will be fulfilled!

26.1 Common misinterpretation of the antenna losses

The mathematical description of physical relations leads to the well-known laws, which shouldn't be doubted anymore as soon as they are accepted to be correct. But what about the interpretation? Although a law dictates the interpretation and there is no choice, because laws must be adhered to, yet textbooks from time to time violate the mathematically dictated interpretation, a circumstance, which can't be accepted. I would like to illustrate this with an example.

Let us assume that the measured degree of effectiveness of a transmitting antenna amounts to 80 percent. There exist better antennas, but also distinctly worse antennas, but I'm not aiming at a certain construction. The statement simply says, that 80% of the fed in HF-power is transformed into Hertzian waves. Thus there arises a loss of power of 20 percent, and the question follows: of what do those 20% consist?

The answer, which is usual among experts and is supported by the textbooks, reads: the antenna wire gets hot and also the air around the antenna is heated by dielectric losses. In short, heat is formed.

But I have to point out and will furnish proof that this interpretation is predominantly wrong! It in any case isn't in accord with the laws of Maxwell. Who namely obeys the laws, comes to an entirely different result!

A short derivation brings it to light (fig. 26.1).

We start with the formulation of Faraday's law of induction according to the textbooks (26.1), apply the curl-operation to both sides of the equation (26.3) and insert in the place of rot H Ampere's law (26.4-26.8). The generally known result describes a damped electromagnetic wave (26.11)[i].

It on the one hand is a transverse wave, which represents 80% of the antenna power for our example. On the other hand a damping term can be found in the equation, which obviously corresponds to the sought-for 20%. With that the answer would have been found. We realize that because of a damping of the wave 20% antenna losses arise. These losses can't concern heat at all, since the damping term in the equation has got nothing in common with thermodynamics. In the equation doesn't stand anything about heat! Such a mistake!

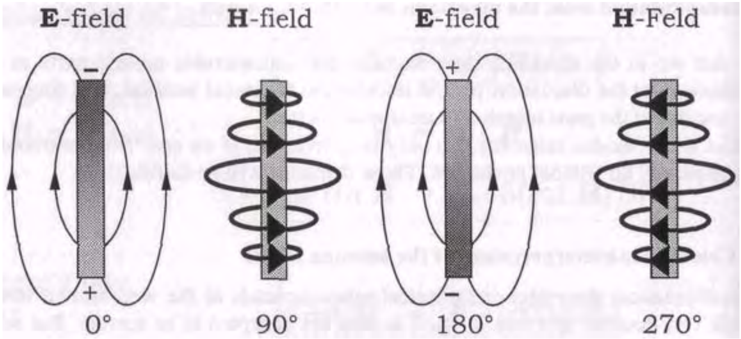
E-field
H-field
E-field
H-Feld
−
+
+
−
0°
90°
180°
270°

Fig. 21.8 A: The fields of the oscillating dipole antenna.<i>

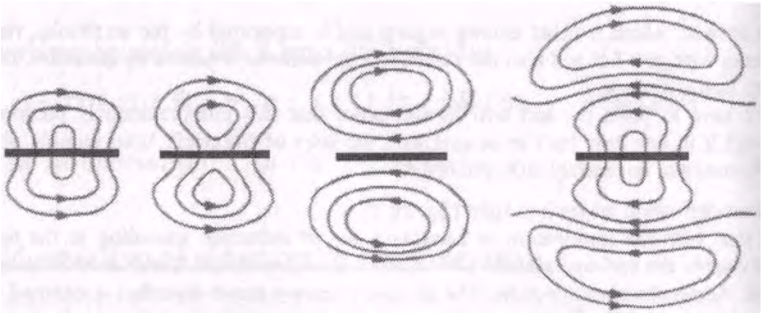

Fig. 21.9 A: The coming off of the electric field lines from the dipole.

<i>: Repetition belonging to chapter 21

26.2 Wave damping by field vortices

- Mathematically seen the damping term describes vortices of the electromagnetic field. This term for instance forms the basis of all eddy current calculations<ii>.
- Physically seen some waves - in our example it is 20 percent - roll up to field vortices, with which the wave damping and the antenna losses would be explained.

In the course of time a substantial part of the generated vortices will fall apart. These thereby will produce eddy losses in form of heat. Thus eventually still heat is produced - agreed. The criticism of the textbooks consists of the circumstance that we by no means can proceed from the assumption that all vortices spontaneously fall apart and a total conversion into heat will take place. The process in addition takes place with a temporal delay. The time constant x gives information in this respect. Field energy is buffered in the vortex, where some vortices live very long and it can't be ruled out that a few even exist as long as you like.

To find out more about these field vortices and their behaviour, one has to get deep into vortex physics. Unfortunately nothing can be found about vortex physics in the textbooks. The mistake is systematic. The following short compendium should help close the gap:

- Mathematically seen a closed-loop electromagnetic field vortex will show as a scalar. Such field vortices, which are mediated by a scalar field, are propagating exactly as charged particles in longitudinal manner as a scalar wave.
- Physically seen a closed-loop field vortex has got particle nature. If one particle kicks off the next one then an impulse is mediated, then a shock wave is occurring, a longitudinal undulation of the particles.

From the vortex physical view the interpretation of the antenna example now sounds entirely different:
The charge carriers in an antenna wire oscillating with high-frequency form a longitudinal shock wave. Between current and tension voltage usually a phase shift of 90° is present. The fields produced by these charge carriers form a scalar wave field in the immediate vicinity of the antenna, the so-called near-field zone, which likewise contains longitudinal field components and shows a phase shift of 90° between electric and magnetic field (fig. 21.8 A). As in textbooks is clarified by field lines, the generated fields actually form vortices, where one structure kicks off the next one (fig. 21.9 A).

The vortices in the near-field zone of an antenna consist of standing waves, which obviously are transforming with increasing distance. In our example 80% of these are unrolling and turn into transverse waves, whereby the characteristic phase angle between E- and H-field at that occasion becomes zero.
Let's turn again to those 20 percent loss.

<ii>: s.a.: K. Meyl: Wirbelstrome, Diss. Uni. Stuttgart 1984, INDEL Verlagsabt.

I. According to the Maxwell theory:

The consistent application of textbook physics

- Longitudinal waves run in the direction of a field pointer.
- The field pointer oscillates, the vector of velocity oscillates along!
- At relativistic velocities field vortices are subject to the Lorentz contraction.
- The faster the oscillating vortex is on its way, the smaller it gets.
- The vortex permanently changes its diameter (see fig. 21.10 B).
- With the diameter the wavelength decreases (see fig. 22.4).
- The swirl velocity is constant (= speed of light c).
- The eigenfrequency of the vortex oscillates with opposite phase to the wavelength.
- The vortex acts as a frequency converter!
- The measurable mixture of frequencies is called noise.

leads to the statement:

- The antenna noise corresponds to the antenna losses!

II. Mathematical description of a wave by the inhomogeneous Laplace equation:

$$\underbrace{\Delta \mathbf{E} \cdot c^2}_{\substack{\text{Laplace}\\ \text{operator}}} = \underbrace{- \text{rot rot } \mathbf{E} \cdot c^2}_{\substack{\text{transverse}\\ \text{(radio wave)}}} + \underbrace{\text{grad div } \mathbf{E} \cdot c^2}_{\substack{\text{longitudinal}\\ \text{(scalar wave)}}} = \underbrace{\delta^2 \mathbf{E} / \delta t^2}_{\text{wave}} \tag{26.12}$$

Divergence E is a scalar!
The corresponding term founds a scalar wave.

Fig. 26.3: Mathematical description of a wave according to Laplace.

26.3 Laplace versus Maxwell

Longitudinal waves as is well-known don't know a fixed velocity of propagation at all. Since they run in the direction of an oscillating field pointer also the vector of velocity will oscillate. For so-called relativistic velocities in the range of the speed of light c the field vortices are subject to the Lorentz contraction. That means, the faster the oscillating vortex is on its way, the smaller it gets. The vortex, as a mediator of a scalar wave carrying impulse, permanently changes its diameter.

Since, in the case of the vortices, it should concern rolled up waves, the vortex velocity will continue to be c, with which the wave now runs around the vortex centre in a circle. From that follows that if the diameter gets smaller, the wavelength of the vortex as well will decrease, whereas the eigenfrequency of the vortex accordingly increases. If the next moment the vortex oscillates back, the frequency again decreases. The vortex acts as a frequency converter! The mixture of high-frequency signals distributed over a broad frequency band formed in this way, is called noise. A noise signal indeed is measured from the outside with the help of broadband receivers.. We also speak of antenna noise and with this knowledge we can further specify the 20% antenna losses: The antenna produces 20 % noise, which can be put equal to the generated vortices because of the wave damping.

At this point the Maxwell theory doesn't leave us room for interpretation at all. If in the textbooks the impression is aroused, as if the noise were an independent discipline, than that is not true at all. How much the noise is connected with the electromagnetic waves, proves a short look at the wave equation.

The wave equation found in most textbooks has the form of an inhomogeneous Laplace equation. The famous French mathematician Laplace considerably earlier than Maxwell did find a comprehensive formulation of waves and formulated it mathematically (eq. 26.12), which until today is still accepted as valid.

On the one side of the wave equation the Laplace operator stands, which describes the spatial field distribution, and which according to the rules of vector analysis can be decomposed into two parts. On the other side the description of the time dependency of the wave can be found as an inhomogeneous term.

If the wave equation according to Laplace (26.12) is compared to the one, which the Maxwell equations have brought us (26.11), then two differences clearly come forward:

1. In the Laplace equation the damping term is missing. It doesn't describe the formation of vortices, and that means vortices do not exist at all, or present vortices have been there from the beginning.
2. With divergence E a scalar factor appears in the wave equation, which founds a scalar wave.

At this point at once hot tempered discussions concerning the question of the existence of scalar waves blaze up. But this question has already been answered clearly with the vortex consideration. Since an accepted description of longitudinal and scalar waves exists with the plasma wave and the plasma wave can be derived directly without postulate from the term of the wave equation (chapter 21.4/21.5), which founds scalar waves, there are further arguments present for their existence.

I. According to Maxwell:

$$\underbrace{-\operatorname{rot}\operatorname{rot}\mathbf{E}\cdot c^2}_{\text{transverse}} = \underbrace{\delta^2\mathbf{E}/\delta t^2}_{\text{wave}} + \underbrace{(1/\tau)\cdot\delta\mathbf{E}/\delta t}_{\text{vortex damping}} \quad (26.11)$$

Description of electromagnetic waves with vortex damping
Example: sunlight and the damping in the ionosphere (bleu sky).

II. According to Laplace:

$$\underbrace{\Delta\mathbf{E}\cdot c^2}_{\substack{\text{Laplace}\\ \text{operator}}} = \underbrace{-\operatorname{rot}\operatorname{rot}\mathbf{E}\cdot c^2}_{\substack{\text{transverse}\\ \text{(Hertz)}}} + \underbrace{\operatorname{grad}\operatorname{div}\mathbf{E}\cdot c^2}_{\substack{\text{longitudinal}\\ \text{(Tesla)}}} = \underbrace{\delta^2\mathbf{E}/\delta t^2}_{\text{wave}} \quad (26.12)$$

Description of transverse electromagnetic waves (Hertzian waves) and longitudinal scalar waves (Tesla radiation).
1st example: propagation of light as a wave or as a particle.
2nd example: useful signal or noise signal of an antenna.

III. Mathematically seen (comparison of coefficients):

$$\underbrace{(1/\tau)\cdot\delta\mathbf{E}/\delta t}_{\text{vortex}} + \underbrace{\operatorname{grad}\operatorname{div}\mathbf{E}\cdot c^2}_{\text{scalar}} = 0 \quad (26.13)$$

IV. Physically seen
(from the comparison of equation 26.12 with equation 26.11):

Vortices propagate longitudinally as a scalar wave!

Fig. 26.2: _____ Comparison of the two wave descriptions.

26.4 Error term in the wave equation

From the comparison of coefficients of both wave descriptions follows even more:

- Mathematically seen the damping - resp. vortex term according to Maxwell can be put equal to the scalar wave term according to Laplace.
- Physically seen the generated field vortices form and found a scalar wave.

Here also doesn't exist any room for interpretation, as long as we work with the wave equation according to Laplace and at the same time adhere to the Maxwell theory. If however the scalar wave part is put equal to zero, as is common practise in the textbooks, then as a consequence neither vortices nor noise may exist. But that contradicts all measuring technical experience! Since every antenna produces more or less noise, the textbooks obviously only show half the truth. Science however gropes for the whole truth and that should be fathomed.

If in the case of the antenna example the vortex part amounts to 20%, then that's tantamount to 20% scalar wave part, resp. 20% noise. The scalar wave part constitutes with regard to the Hertzian useful wave something like an error term in the wave equation. The part definitely is too big, as that it might be put equal to zero. Even so all error consideration in the textbooks is missing, if the scalar wave term is assumed to be zero. That violates all rules of physics and of taught scientific methodism.

In practice this shows by a useful signal going under in the noise and reception not being possible anymore as soon as the scalar wave part gets out of control. Even in this case, for which the degree of effectiveness tends towards zero, it still is common practise to put the error term, which is dominating everything, equal to zero. But who in this point follows the textbooks, disregards with that the wave equation and doing so by no means can refer to the circumstance that all colleagues make the same mistake.

The building of physics behaves like a house of cards, where the cards mutually support each other. Perhaps that is the deeper reason why those, who have discovered a marked card, don't pull it out immediately. In addition they are hindered by the self appointed guardians of the ,,pure doctrine", since everyone knows what happens with the house of cards if the marked card is pulled out. Only, do we want to and can we live with that in the long run? Is it a solution of the problem, if the so-called experts among the physicists and technicians look away and don't deal with the foundation of their branch anymore? If universities crash their basis education into the wall and choke off every contradiction?

Please allow me to pull out the marked card now and place it on the table!

It concerns the question: what is the nature of the field vortices, which form a scalar wave in space. Eddy currents in the iron parts of the antenna are explained with the field equations, but not the noise, which is measured especially in the air. If an antenna on the one hand produces field vortices and as a consequence eddy losses and on the other hand dielectric losses, then we can assume that besides the eddy currents in the conductor also vortices in the dielectric must exist. Let's search for them!

Interim result (comparison of arguments):

The Maxwell equations on the one hand dictate that as the reason for a wave damping only field vortices should be considered.	On the other hand the same laws merely describe eddy currents, which can only occur in the electrically conducting parts of the antenna.
On the one hand the field vortex interpretation makes it possible to explain the noise of an antenna perfectly.	On the other hand does the noise appear in the neighbourhood of the antenna, thus in the air and not in the iron parts!
The mathematical formulation reveals, how wave and vortex, resp. noise, co-operate and how one should imagine the conversion of one form into the other form.	In field physics on the other hand is missing a useful description of electric field vortices in a dielectric, which could found the noise signal.

Table 26.5: Arguments pro and contra.

26. 5 Interim result

It shouldn't be a disadvantage, to interprete physical laws more consistently than usual, even if in the present case orthodox science through that at first should fall into a deep crisis. If the way is worthwhile, only will show at the end.
Let us try to work out the contradictions in form of a comparison of arguments:

- The Maxwell equations on the one hand dictate that as the reason for a wave damping only field vortices should be considered.
  - On the other hand the same laws merely describe eddy currents, which can only occur in the electrically conducting parts of the antenna. .
- On the one hand the field vortex interpretation makes it possible to explain the noise of an antenna perfectly. .
  - On the other hand does the noise appear in the neighbourhood of the antenna, thus in the air and not in the iron parts!
- The mathematical formulation reveals, how wave and vortex, resp. noise, co-operate and how one should imagine the conversion of one form into the other form.
  - In field physics on the other hand is missing a useful description of electric field vortices in a dielectric, which could found the noise signal.

The most obvious among all conceivable solutions is the one that we have to assume the existence of dielectric field vortices, so-called potential vortices. We are challenged to search for a corresponding description. If the quest should be successful, then the contradictions would be overcome. In addition there is the promise of a whole number of simplifying explanations of various phenomena in the dielectric (see fig. 26.5 and fig. 26.7).

The phenomenon of noise becomes an aspect of wave physics, which is more than merely a field disturbance, which makes the reception of the useful wave more difficult. If the scalar wave nature is realized, then applications can be imagined, in which the noise is used as useful signal. In the way that the scalar part in the wave equation doesn't have to be put to zero anymore to obtain freedom of contradiction, even optimizations of antennas or of capacitors are possible with regard to the dielectric losses by means of the calculation of the scalar part.

New in any case is the idea that the dielectric losses of a capacitor are eddy losses and not a defect in material of the insulating material. With that the capacitor losses correspond to a generated noise power. We also can say, every capacitor more or less produces noise! The electric field lines point from one capacitor plate to the other plate. If one plate radiates as a transmitter and the other plate functions as a receiver, then the field propagation takes place in the direction of the electric field pointer and that again is the condition for a longitudinal wave. Here the circle closes in the conclusion, the capacitor field mediates dielectric field vortices, which following the field lines found a scalar wave because of their scalar nature. The heating of the capacitor results from the decay of vortices.

Potential vortices explain div. phenomena in the dielectric:

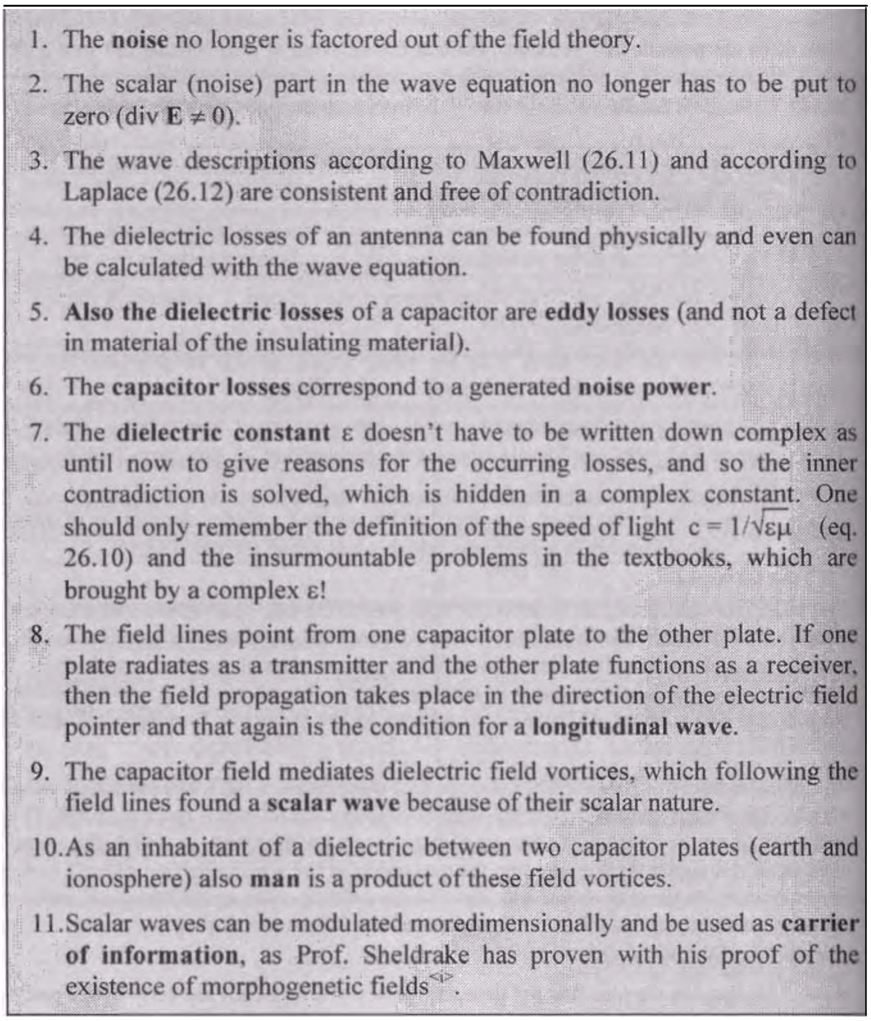

1. The **noise** no longer is factored out of the field theory.
2. The scalar (noise) part in the wave equation no longer has to be put to zero (div $\mathbf{E} \neq 0$).
3. The wave descriptions according to Maxwell (26.11) and according to Laplace (26.12) are consistent and free of contradiction.
4. The dielectric losses of an antenna can be found physically and even can be calculated with the wave equation.
5. **Also the dielectric losses** of a capacitor are **eddy losses** (and not a defect in material of the insulating material).
6. The **capacitor losses** correspond to a generated **noise power**.
7. The **dielectric constant** ε doesn't have to be written down complex as until now to give reasons for the occurring losses, and so the inner contradiction is solved, which is hidden in a complex constant. One should only remember the definition of the speed of light $c = 1/\sqrt{\varepsilon\mu}$ (eq. 26.10) and the insurmountable problems in the textbooks, which are brought by a complex ε!
8. The field lines point from one capacitor plate to the other plate. If one plate radiates as a transmitter and the other plate functions as a receiver, then the field propagation takes place in the direction of the electric field pointer and that again is the condition for a **longitudinal wave**.
9. The capacitor field mediates dielectric field vortices, which following the field lines found a **scalar wave** because of their scalar nature.
10. As an inhabitant of a dielectric between two capacitor plates (earth and ionosphere) also **man** is a product of these field vortices.
11. Scalar waves can be modulated moredimensionally and be used as **carrier of information**, as Prof. Sheldrake has proven with his proof of the existence of morphogenetic fields<i>.

Fig. 26.6: ___ Advantages of a field description extended with potential vortices.

<i>: Rupert Sheldrake: Seven Experiments That Could Change the World. Riverhead Books, 1995

26.6 Failure of the Maxwell theory

If the capacitor losses or the antenna noise should concern dielectric losses in the sense of vortex decay of potential vortices, which don't occur in the Maxwell theory at all, then we are confronted with a massive contradiction:

- For the description of the losses the Maxwell; theory on the one hand only offers field vortices and those only in the conductive medium.
  - On the other hand do the dielectric losses occut in the nonconductor and in the air.
- In conductive materials vortex fields occur, in the insulator however the fields are irrotational. That isn't possible, since at the transition from the conductor to the insulator the laws of refraction are valid and these require continuity! Hence a failure of the Maxwell theory (Fig. 26.7) will occur in the dielectric.
  - As a consequence the existence of vortex fields in the dielectric, so-called potential vortices, should be required!

In electrodynamics as a help the approach of a vector potential A is used, which leads to a complex formulation of the dielectric constant ε and in this way makes it possible, to mathematically describe the dielectric losses of a capacitor by means of the load angle, which stretches in the complex plane. But which physical value does this approach have? How can now the inner contradiction be explained, which is hidden in a complex constant of material? One should only remember the definition of the speed of light $c = 1/\sqrt{\varepsilon\mu}$ (eq. 26.10) and its dependency of ε. For a complex ε here are resulting insurmountable problems in the textbooks.
From the viewpoint of mathematics the introduction of the vector potential at first may represent a help. The before mentioned contradictions however fast raise doubts to the model concept, which from a physical viewpoint eventually will lead to errors, if the speed of light isn't constant anymore and even should be complex.

These considerations should be sufficient as a motive to require potential vortices, even if for their description the field theory according to the textbooks has to be revised. As a supplement there is pointed to the following points:

- As an inhabitant of a dielectric between two capacitor plates also man is a product of these field vortices.
- Scalar waves can be modulated moredimensionally and be used as carrier of information, as Prof. Sheldrake has proven with his proof of morphogenetic fields<i>.

The dielectric vortices moreover provide an explanation for natural events. They form the key to numerous disciplines of science, from physics over biology up to medicine.

<i>: Rupert Sheldrake: Seven Experiments That Could Change the World. Riverhead Books, 1995

Problem of continuity in the case of the coming off of vortices

Example: hightension cable

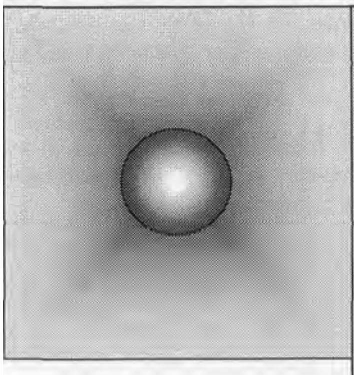

In ***conductive materials vortex fields*** *occur in the* ***insulator*** *however the fields are* ***irrotational****.*
That isn't possible, since at the transition from the conductor to the insulator the ***laws of refraction*** *are valid and these require* ***continuity!***
Hence a ***failure of the Maxwell theory*** *will occur in the dielectric!*

Conclusion: ♦ According to the Maxwell theory there exist no vortices of the electric field *(no potential vortices)* and therefore *no scalar waves.*

♦ Without theory it is impossible to design a usable *scalar wave gauge* and to furnish *evidence*. ⇒ **Classic closed loop conclusion:**

♦ The missing of scientific evidence again „proves“ the assumption of the irrotationality and „confirms“ the correctness of the Maxwell theory.

♦ Hence it cannot be, what shouldn't be!

Fie. 26.7: Concerning the failure of the Maxwell theory

26.7. Concerning the evidence situation

In the question, if a physical phenomenon should be acknowledged as such, experimental, mathematical and physical evidence should be shown. In the case of the potential vortices, the vortices of the electric field and their propagation as a scalar wave, the historical experiments of Nikola Tesla<i> and the modern clone of these can be judged as experimental evidence<ii>.

With the well-known wave equation a mathematical description for this phenomenon has been specified and discussed<iii>. It will be shown that both transverse and longitudinal wave parts are contained alongside in the wave equation, i.e. both radio waves according to Hertz and scalar waves according to Tesla. Doing so the mathematically determined scalar wave properties are identical with the experimental results!
The wave equation is an inhomogeneous Laplace equation and the first and oldest description of scalar waves. It thereby is unimportant, if the famous mathematician Laplace himself already may have realized and discussed this circumstance or not. The description fits perfectly and that is what counts!

At this point the third point should be put on the agenda, the physical evidence. This is connected very closely with the question for a suitable field theory and that again is basing on a corresponding approach.

<i>: N. Tesla: Apparatus for Transmission of Electrical Energy, US-Patent-No.: 649,621, New York 1900, Dr. Nikola Tesla: Complete Patents pp318-321.

<ii>: Johannes von Buttlar im Gesprach mit Prof. Dr. Konstantin Meyl: Neutrinopower, Argo-Verlag, Marktoberdorf, l.Aufl. 2000.

<iii>: K. Meyl: Scalar Waves: Theory and Experiments, Journal of Scientific Exploration, Vol. 15, No. 2, pp. 199-205, 2001

(* * * Task Schedule * * *)

1. Neutrino radiation => energy radiation!
   (acc. to Pauli: ν cares for missing energy in the case of the ß-decay)
2. High neutrino density => high energy density!
3. Neutrino = particle without charge or mass (mean), but because of oscillations: effective value of charge and mass ≠ zero!
4. Interaction only in the case of resonance (e.g. weak interaction)!
   (same frequency, 180° phase shift)
5. Neutrino radiation is an energy source which can be used (not a question of physics, only a question of technology!)
6. Particle radiation (neutrino) => shock wave (like sound)
   => longitudinal wave
   => scalar wave (mathem.)
7. Interaction/resonance of the v = scalar wave problem
8. Scalar waves are a problem of the field theory!
9. Maxwell theory neglects scalar waves.

- Search for a new approach (chap. 27.8)
- Derivation of the Maxwell equations as a
- Derivation of scalar waves (chap. 27.13)
- Derivation of the gravitation and more

Table 27.1: Task schedule belonging to chapter 27

27. Faraday versus Maxwell

Numerous phenomena of the electromagnetic field are described sufficiently accurate by the Maxwell equations, so that these as a rule are regarded as a universal field description. But if one looks more exact it turns out to be purely an approximation, which in addition leads to far reaching physical and technological consequences. We must ask ourselves:

- What is the Maxwell approximation?
- How could a new and extended approach look like?
  - Faraday instead of Maxwell, which is the more general law of induction?
- Can the Maxwell equations be derived as a special case?
- Can also scalar waves be derived from the new approach?
- Can the gravitation as well be derived and a lot else more?

On the one hand it concerns the big search for a unified physical theory and on the other hand the chances of new technologies, which are connected with an extended field theory. As a necessary consequence of the derivation, which roots strictly in textbook physics and manages without postulate, scalar waves occur, which could be used manifold. In information technology they are suited as a carrier wave, which can be modulated moredimensionally, and in power engineering the spectrum stretches from the wireless transmission up to the collection of energy out of the field.

27.1 Energy out of the field

Neutrinos for instance are such field configurations, which move through space as a scalar wave. They were introduced by Pauli as massless but energy carrying particles to be able to fulfil the balance sheet of energy for the beta decay. Nothing would be more obvious than to technically use the neutrino radiation as an energy source.

But for a technical exploitation a useful model description of the particles and their interaction is imperative. For the sake of simplicity we imagine the neutrino to be an oscillating particle, which permanently oscillates back and forth between the state of an electron and that of a positron. With that the polarity changes from positive to negative and back again and the charge averaged over time is zero. Because of the change from a state of matter to the state of an anti-particle also next to no mass can be measured anymore.

A technical oscillator operated in resonance, which oscillates with the same frequency but opposite charge, will interact with the particle and build up an oscillating electromagnetic interaction, with which we already are familiar as the weak interaction in the proximity of a neutrino.

Tubular vortices

- Examples: drain vortex (bathtub vortex)
  whirlwind and waterspout, tornado (image).

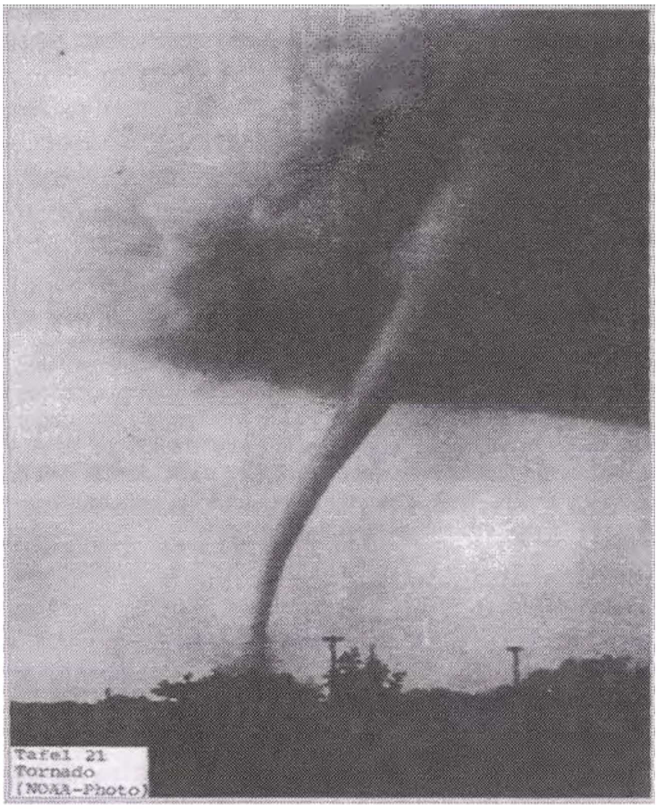

Inside: expanding vortex
Outside: contracting anti-vortex
Condition for coming off: equally powerful vortices
Criterion: viscosity
Result: tubular structure

Fig. 27.2: ____Vortex and anti-vortex - a physical basic principle

<i>: Lugt: Wirbelstromung in Natur und Technik, G. Braun Verlag Karlsruhe 1979, Bild „Tornado" von Tafel 21, Seite 356

The propagation of particle radiation as a longitudinal shock wave however can't be described with the normally used field theory and the Maxwell equations, so that the field theory at this point must be reworked. Connected with this is the question of what is oscillating here, a question, which often is answered with an aether of whatever nature. I speak of field vortices and call the aether a property of the field. With that the set of difficulties is shifted into the domain of vortex physics.

27.2 Vortex and anti-vortex

In the eye of a tornado the same calm prevails as at great distance, because here a vortex and its anti-vortex work against each other. In the inside the expanding vortex is located and on the outside the contracting anti-vortex. One vortex is the condition for the existence of the other one and vice versa. Already Leonardo da Vinci knew both vortices and has described the dual manifestations (chapter 3.4).

In the case of flow vortices the viscosity determines the diameter of the vortex tube where the coming off will occur. If for instance a tornado soaks itself with water above the open ocean, then the contracting potential vortex is predominant and the energy density increases threateningly. If it however runs overland and rains out, it again becomes bigger and less dangerous.

The conditions for the bathtub vortex are similar. Here the expanding vortex consists of air, the contracting vortex however of water. In flow dynamics the relations are understood. They mostly can be seen well and observed without further aids.

In electrical engineering it's different: here field vortices remain invisible and not understood. Only so the Maxwell theory could find acceptance, although it only describes mathematically the expanding eddy current and ignores its anti-vortex. I call the contracting anti-vortex potential vortex" and point to the circumstance, that every eddy current entails the anti-vortex as a physical necessity.
Because the size of the forming structures is determined by the electric conductivity, in conducting materials the vortex rings, being composed of both vortices, are huge, whereas they can contract down to atomic dimensions in nonconductors. Only in semiconducting and resistive materials the structures occasionally can be observed directly (fig. 4.8).

Spherical vortices

Examples:	expanding vortex	contracting vortex
• quantum physics	collision processes (several quarks)	gluons (postulate!)
• nuclear physics	repulsion of like	strong interaction (postulate!)
• atomic physics	centrifugal force of the enveloping electrons	electrical attraction Schrodinger equation
• astro-physics	centrifugal force (inertia)	gravitation (can not be derived?!)

Example: elementary particles as electromagnetic field vortices

Inside:	expanding eddy current (skin effect)
Outside:	contracting anti-vortex (potential vortex)
Condition	for coming off: equally powerful vortices
Criterion:	electric conductivity (determines diameter)
Result:	spherical structure (consequence of the pressure of the vacuum)

Fig. 27.3: Spherical structures as a result of contracting potential vortices.<i>

Demokrit (460-370 BC) equated the vortex concept with „law of nature"!
= the first attempt to formulate a unified physics.

<i>: see Part 1, chapter 4.3

27.3 Vortices in the microcosm and macrocosm

The approximation, which is hidden in the Maxwell equations, thus consists of neglecting the anti-vortex dual to the eddy current. It is possible that this approximation is allowed, as long as it only concerns processes inside conducting materials. If we however get to insulating materials the Maxwell approximation will lead to considerable errors and it won't be able to keep it anymore.

If we take as an example the lightning and ask how the lightning channel is formed: Which mechanism is behind it, if the electrically insulating air for a short time is becoming a conductor? From the viewpoint of vortex physics the answer is obvious: The potential vortex, which in the air is dominating, contracts very strong and doing so squezes all air charge carriers and air ions, which are responsible for the conductivity, together at a very small space to form a current channel.

The contracting potential vortex thus exerts a pressure and with that forms the vortex tube. Besides the cylindrical structure another structure can be expected. It is the sphere, which is the only form, which can withstand a powerful pressure if that acts equally from all directions of space. Only think of ball lightning. Actually the spherical structure is mostly found in microcosm till macrocosm. Let's consider some examples and thereby search for the expanding and contracting forces (fig. 27.2).

- In quantum physics one imagines the elementary particles to be consisting of quarks. Irrespective of the question, which physical reality should be attributed to this model concept, one thing remains puzzling: The quarks should run apart, or you should try to keep together three globules, which are moving violently and permanently hitting each other. For this reason glue particles were postulated, the so-called gluons, which now should take care for the reaction force, but this reaction force is nothing but a postulate!

- In nuclear physics it concerns the force, which holds together the atomic nucleus, which is composed of many nucleons, and gives it the well-known great stability, although here like charged particles are close together. Particles, which usually repel each other. Between the theoretical model and practical reality there is an enormous gap, which should be overcome by introducing of a new reaction force. But also the nuclear force, called strong interaction, is nothing but a postulate!

- In atomic physics the electric force of attraction between the positive nuclear charge and the negatively charged enveloping electrons counteracts the centrifugal force. In this case the anti-vortex takes care for a certain structure of the atomic hull, which obey the Schrodinger equation as eigenvalue solutions. But also this equation irrespective of its efficiency until today purely is a mathematical postulate, as long as its origin is not clear.

- In astrophysics centrifugal force (expansion) as a result of the inertia and gravitation (contraction) as a result of the attraction of masses are balanced. But the "gravitation" puts itself in the way of every attempt to formulate a unified field theory. Also this time it is the contracting vortex, of which is said it can't be derived nor integrated.

Michael Faraday, the experimentor (1791-1867)

James Clerk Maxwell<i>, the mathematician (1831-1879)

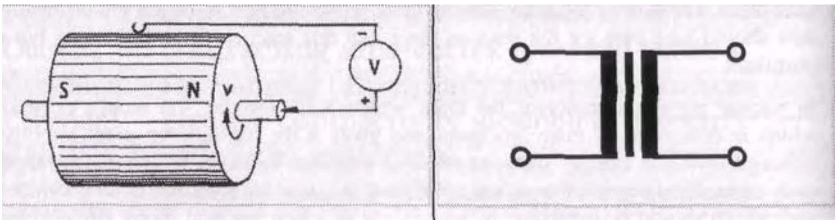

unipolar generator

e.g.: transformer

Fig. 27.4: ____The fathers of the law of induction

<i>: J.C. Maxwell: A treatise on Electricity and Magnetism, Dover Publications

It is remarkable how in the domain of the contracting vortex the postulates are accumulating. But this hasn't always been the case. In ancient Greece already 2400 years ago Demokrit has undertaken an attempt to formulate a unified physics. He traced all visible and observable structures in nature back to vortices, each time formed of vortex and anti-vortex. This phenomenon appeared him to be so fundamental, that he put the term "vortex" equal to the term for „law of nature". The term ‚.atom" stems from Demokrit (460-370 BC).

Seen this way the physicists in ancient times already had been further than today's physics, which with the Maxwell approximation neglects the contracting vortex and with that excludes fundamental phenomena from the field description or is forced to replace them by model descriptions and numerous postulates.

What we need is a new field approach, which removes this flaw and in this point reaches over and above the Maxwell theory.

27.4 Faraday's law and Maxwell's formulation

In the choice of the approach the physicist is free, as long as the approach is reasonable and well founded. In the case of Maxwell's field equations two experimentally determined regularities served as basis: on the one hand Ampere's law and on the other hand the law of induction of Faraday. The mathematician Maxwell thereby gave the finishing touches for the formulations of both laws. He introduced the displacement current D and completed Ampere's law accordingly, and that without a chance of already at his time being able to measure and prove the measure. Only after his death this was possible experimentally, what afterwards makes clear the format of this man.

In the formulation of the law of induction Maxwell was completely free, because the discoverer Michael Faraday had done without specifications. As a man of practice and of experiment the mathematical notation was less important for Faraday. For him the attempts with which he could show his discovery of the induction to everybody, e.g. his unipolar generator, stood in the foreground.

His 40 years younger friend and professor of mathematics Maxwell however had something completely different in mind. He wanted to describe the light as an electromagnetic wave and doing so certainly the wave description of Laplace went through his mind, which needs a second time derivation of the field factor. Because Maxwell for this purpose needed two equations with each time a first derivation, he had to introduce the displacement current in Ampere's law and had to choose an appropriate notation for the formulation of the law of induction to get to the wave equation. His light theory initially was very controversial. Maxwell faster found acknowledgement for bringing together the teachings of electricity and magnetism and the representation as something unified and belonging together[i] than for mathematically giving reasons for the principle discovered by Faraday.

Nevertheless the question should be asked, if Maxwell has found the suitable formulation, if he has understood 100 percent correct his friend Faraday and his discovery. If discovery (from 29.08.1831) and mathematical formulation (1862) stem from two different scientists, who in addition belong to different disciplines, misunderstandings are nothing unusual. It will be helpful to work out the differences.

Law of induction

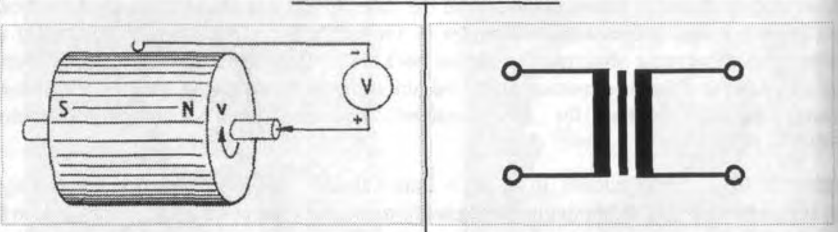

unipolar generator	e.g.: transformer
discovery of Faraday	2nd Maxwell equation
$\boxed{\mathbf{E} = \mathbf{v} \times \mathbf{B}}$ (27.1)	$\boxed{\text{rot } \mathbf{E} = - d\mathbf{B}/dt}$ (27.1*)
unipolar induction	law of induction generally

Fig. 27.5: Two formulations for one law
As a mathematical relation between the vectors of the electric field strength **E** and the induction **B** (= magnetic flux density)

Consequences
(the physically mean of the „field concept"):

• The **Faraday approach** describes a field physical principle	• **Maxwell equations** describe the fields of charged particles
• field = experience: We experience the electric as a magnetic field and vice versa as a result of a relative velocity • Particles do not occur in the Faraday approach	• the electric (**E**-) field = static field of charges, • the magnetic (**H**-) field = field of moving charges. • The origin of the particles remains unsettled (postulate)
• Perfect duality between **E**- and **H**-field.	• No duality in the field description
• **v** leads to dual permutation of **E**- and **H**-field.	• Charge carriers=el. monopoles • No magnetic monopoles!

27.5 The discovery of Faraday

If one turns an axially polarized magnet or a copper disc situated in a magnetic field, then perpendicular to the direction of motion and perpendicular to the magnetic field pointer a pointer of the electric field will occur, which everywhere points axially to the outside. In the case of this by Faraday developed unipolar generator hence by means of a brush between the rotation axis and the circumference a tension voltage can be called off<i>. The mathematically correct relation E = v x B I call Faraday-law, even if it only appears in this form in the textbooks later in time<ii>. The formulation usually is attributed to the mathematician Hendrik Lorentz, since it appears in the Lorentz force in exactly this form. Much more important than the mathematical formalism however are the experimental results and the discovery by Michael Faraday, for which reason the law concerning unipolar induction is named after the discoverer.

Of course we must realize that the charge carriers at the time of the discovery hadn't been discovered yet and the field concept couldn't correspond to that of today. The field concept was an abstracter one, free of any quantization.

That of course also is valid for the field concept advocated by Maxwell, which we now contrast with the „Faraday-law" (fig. 27.4). The second Maxwell equation, the law of induction (27.1*), also is a mathematical description between the electric field strength E and the magnetic induction B. But this time the two aren't linked by a relative velocity v. In that place stands the time derivation of B, with which a change in flux is necessary for an electric field strength to occur. As a consequence the Maxwell equation doesn't provide a result in the static or quasi-stationary case, for which reason it in such cases is usual, to fall back upon the unipolar induction according to Faraday (e.g. in the case of the Hall-probe, the picture tube, etc.). The falling back should only remain restricted to such cases, so the normally used idea. But with which right the restriction of the Faraday-law to stationary processes is made?

The vectors E and B can be subject to both spatial and temporal fluctuations. In that way the two formulations suddenly are in competition with each other and we are asked, to explain the difference, as far as such a difference should be present.

<i>: Part 2, INDEL 1996, Chap. 16.1

<ii>: among others in R.W. Pohl: Einfuhrung in die Physik, Bd.2 Elektrizitatslehre, 21.Aufl. Springer-Verlag 1975, Seite 76 und 130

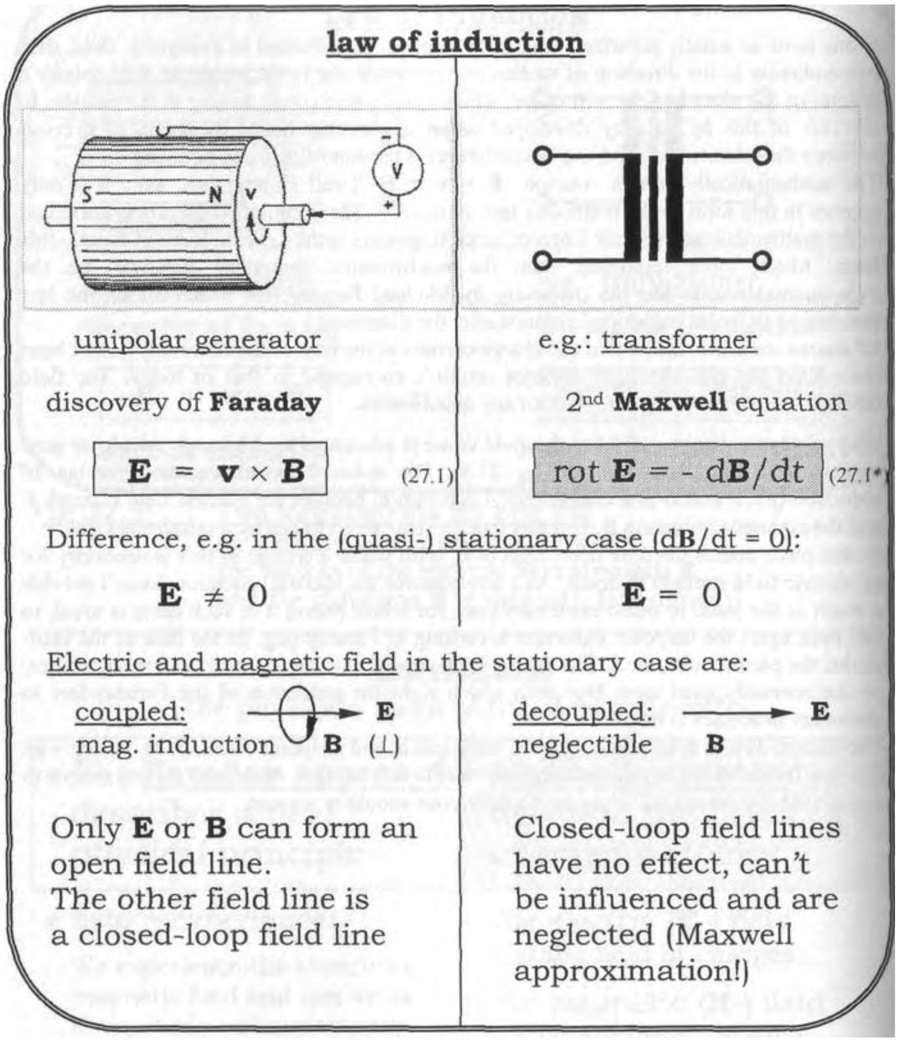

law of induction

unipolar generator	e.g.: transformer
discovery of **Faraday**	2nd **Maxwell** equation
$\boxed{\mathbf{E} = \mathbf{v} \times \mathbf{B}}$ (27.1)	$\boxed{\operatorname{rot} \mathbf{E} = - d\mathbf{B}/dt}$ (27.1*)

Difference, e.g. in the (quasi-) stationary case ($d\mathbf{B}/dt = 0$):

$\mathbf{E} \neq 0$	$\mathbf{E} = 0$

Electric and magnetic field in the stationary case are:

coupled: $\rightarrow \mathbf{E}$ mag. induction $\mathbf{B}$ (⊥)	decoupled: $\rightarrow \mathbf{E}$ neglectible $\mathbf{B}$
Only **E** or **B** can form an open field line. The other field line is a closed-loop field line	Closed-loop field lines have no effect, can't be influenced and are neglected (Maxwell approximation!)

Fig. 27.6: Law of induction according to Faraday or Maxwell?

27.6 Different formulation of the law of induction

Such a difference for instance is, that it is common practice to neglect the coupling between the fields at low frequencies. While at high frequencies in the range of the electromagnetic field the E- and the H-field are mutually dependent, at lower frequency and small field change the process of induction drops correspondingly according to Maxwell, so that a neglect seems to be allowed. Now electric or magnetic field can be measured independently of each other. Usually is proceeded as if the other field is not present at all.

That is not correct. A look at the Faraday-law immediately shows that even down to frequency zero always both fields are present. The field pointers however stand perpendicular to each other, so that the magnetic field pointer wraps around the pointer of the electric field in the form of a vortex ring in the case that the electric field strength is being measured and vice versa. The closed-loop field lines are acting neutral to the outside; they hence need no attention, so the normally used idea. It should be examined more closely if this is sufficient as an explanation for the neglect of the not measurable closed-loop field lines, or if not after all an effect arises from fields, which are present in reality.

Another difference concerns the commutability of E- and H-field, as is shown by the Faraday-generator, how a magnetic becomes an electric field and vice versa as a result of a relative velocity v. This directly influences the physical-philosophic question: What is meant by the electromagnetic field?

The textbook opinion based on the Maxwell equations names the static field of the charge carriers as cause for the electric field, whereas moving ones cause the magnetic field. But that hardly can have been the idea of Faraday, to whom the existence of charge carriers was completely unknown. The for his contemporaries completely revolutionary abstract field concept based on the works of the Croatian Jesuit priest Boscovich (1711-1778). In the case of the field it should less concern a physical quantity in the usual sense, than rather the experimental experience"' of an interaction according to his field description. We should interprete the Faraday-law to the effect that we experience an electric field, if we are moving with regard to a magnetic field with a relative velocity and vice versa.

In the commutability of electric and magnetic field a duality between the two is expressed, which in the Maxwell formulation is lost, as soon as charge carriers are brought into play. Is thus the Maxwell field the special case of a particle free field? Much evidence points to it, because after all a light ray can run through a particle free vacuum. If however fields can exist without particles, particles without fields however are impossible, then the field should have been there first as the cause for the particles. Then the Faraday description should form the basis, from which all other regularities can be derived. What do the textbooks say to that?

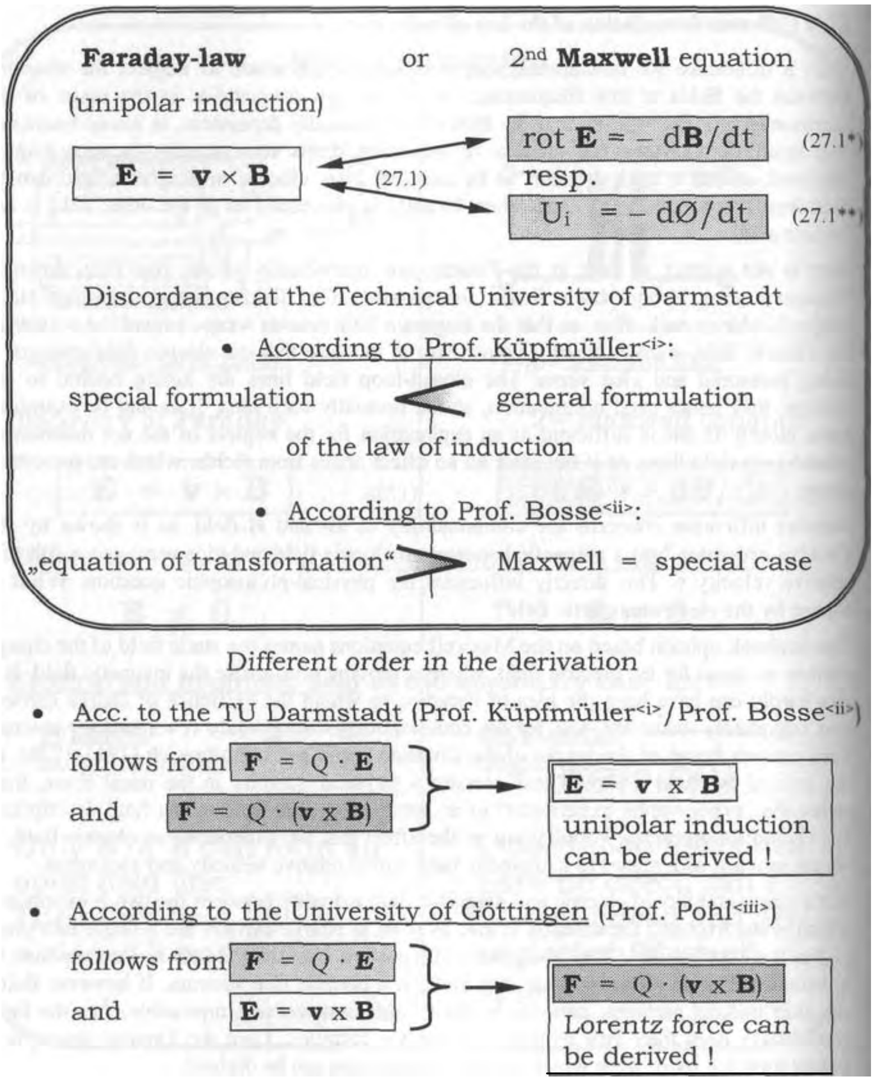

Faraday-law or 2^{nd} **Maxwell** equation

(unipolar induction)

$\mathbf{E} = \mathbf{v} \times \mathbf{B}$ (27.1)

$\mathrm{rot}\,\mathbf{E} = -\,d\mathbf{B}/dt$ (27.1*)

resp.

$U_i = -\,d\Phi/dt$ (27.1**)

Discordance at the Technical University of Darmstadt

- According to Prof. Küpfmüller<i>:

special formulation < general formulation

of the law of induction

- According to Prof. Bosse<ii>:

„equation of transformation" > Maxwell = special case

Different order in the derivation

- Acc. to the TU Darmstadt (Prof. Küpfmüller<i>/Prof. Bosse<ii>)

follows from $\mathbf{F} = Q \cdot \mathbf{E}$

and $\mathbf{F} = Q \cdot (\mathbf{v} \times \mathbf{B})$ $\Big\} \rightarrow$ $\mathbf{E} = \mathbf{v} \times \mathbf{B}$ unipolar induction can be derived !

- According to the University of Göttingen (Prof. Pohl<iii>)

follows from $\mathbf{F} = Q \cdot \mathbf{E}$

and $\mathbf{E} = \mathbf{v} \times \mathbf{B}$ $\Big\} \rightarrow$ $\mathbf{F} = Q \cdot (\mathbf{v} \times \mathbf{B})$ Lorentz force can be derived !

Fig. 27.7: Different opinions and derivations

<i>: K. Kupfmuller: Einfuhrung in die theoretische Elektrotechnik, 12. Auflage, Springer Verlag 1988, Seite 228, Gl. 22.

<ii>: G. Bosse: Grundlagen der Elektrotechnik II, BI-Hochschultaschenbucher Nr. 183, l.Aufl. 1967, Kap. 6.1 Induktion, Seite 58

<iii>: R. W. Pohl: Einfuhrung in die Physik, Band 2 Elektrizitatslehre, 21. Auflage, Springer-Verlag 1975, Seite 77

27.7 Contradictory opinions in textbooks

Obviously there exist two formulations for the law of induction (27.1 and 27.1*), which more or less have equal rights. Science stands for the question: which mathematical description is the more efficient one? If one case is a special case of the other case, which description then is the more universal one?

What Maxwell's field equations tell us is sufficiently known, so that derivations are unnecessary. Numerous textbooks are standing by, if results should be cited. Let us hence turn to the Faraday-law (27.1). Often one searches in vain for this law in schoolbooks. Only in more pretentious books one makes a find under the keyword "unipolar induction". If one however compares the number of pages, which are spent on the law of induction according to Maxwell with the few pages for the unipolar induction, then one gets the impression that the latter only is a unimportant special case for low frequencies. Kupfmuller speaks of a „special form of the law of induction"<i>, and cites as practical examples the induction in a brake disc and the Hall-effect. Afterwards Kupfmiiller derives from the „special form" the „general form" of the law of induction according to Maxwell, a postulated generalization, which needs an explanation. But a reason is not given<i>. Bosse gives the same derivation, but for him the Maxwell-result is the special case and not his Faraday approach<ii>! In addition he addresses the Faraday-law as equation of transformation and points out the meaning and the special interpretation. On the other hand he derives the law from the Lorentz force, completely in the style of Kupfmuller<i> and with that again takes it part of its autonomy. Pohl looks at that different. He inversely derives the Lorentz force from the Faraday-law<iii>.

By all means, the Faraday-law, which we want to base on instead of on the Maxwell equations, shows „strange effects<i4>" from the point of view of a Maxwell representative of today and thereby but one side of the medal (eq. 27.1). Only in very few distinguished textbooks the other side of the medal (eq. 27.2) is mentioned at all. In that way most textbooks mediate a lopsided and incomplete picture<i,ii,i4>. If there should be talk about equations of transformation, then the dual formulation belongs to it, then it concerns a pair of equations, which describes the relations between the electric and the magnetic field.

If the by Bosse<ii> prompted term „equation of transformation" is justified or not at first is unimportant. That is a matter of discussion.

<i>: K. Kupfmuller: Einfuhrung in die theoretische Elektrotechnik, 12.Aufl., Springer Verlag 1988, Seite 228, Gl. 22.

<ii>: G. Bosse: Grundlagen der Elektrotechnik II, BI-Hochschultaschenbucher Nr.183, l.Aufl. 1967, Kap. 6.1 Induktion, Seite 58

<iii>: R.W.Pohl: Einfuhrung in die Physik, Bd.2 Elektrizitatslehre, 2 l.Aufl. Springer-Verlag 1975, Seite 77

<i4>: G. Lehner: Elektromagnetische Feldtheorie, Springer-Lehrbuch 1990, 1. Aufl., Seite 31 Kommentar zur Lorentzkraft (1.65)

The new and dual field approach consists of equations of transformation

of the electric and of the magnetic field<i>

$\boxed{\mathbf{E} = \mathbf{v} \times \mathbf{B}}$ (27.1) and $\boxed{\mathbf{H} = -\mathbf{v} \times \mathbf{D}}$ (27.2)

unipolar induction equation of convection

- Formulation according to the rules of duality
  - Grimsehl<ii> speaks of the ,,equation of convection", according to which moving charges produce a magnetic field and so-called convection currents (referring to Rontgen 1885, Himstedt, Rowland 1876, Eichenwald and others)
- Pohl<iii> gives examples for the equations of transformation,
- he writes the equations beneath each other

$\boxed{\mathbf{E} = \mu \cdot \mathbf{v} \times \mathbf{H}}$ (27.3) and $\boxed{\mathbf{H} = -\varepsilon \cdot \mathbf{v} \times \mathbf{E}}$ (27.4)

- and points out that for $v = c = 1/\sqrt{\mu \cdot \varepsilon}$ one equation changes into the other one!

The new and dual approach roots in textbook physics!

Fig. 27.8: The new and dual field approach

<i>: see Part 1, chapter 6.5

<ii>: Grimsehl: Lehrbuch der Physik, 2.Bd., 17,Aufl. Teubner Verl. 1967, S. 130.

<iii>: R.W.Pohl: Einfuhrung in die Physik, Bd.2 Elektrizitatslehre, 21.Aufl. Springer-Verlag 1975, Seite 77

27.8 The field-theoretical approach

The duality between E- and H-field and the commutability asks for a corresponding dual formulation to the Faraday-law (27.1). Written down according to the rules of duality there results an equation (27.2), which occasionally is mentioned in some textbooks. While both equations in the books of Pohl<i> and of Simonyi<ii> are written down side by side having equal rights and are compared with each other, Grimsehl<iii> derives the dual regularity (27.2) with the help of the example of a thin, positively charged and rotating metal ring. He speaks of „equation of convection", according to which moving charges produce a magnetic field and so-called convection currents. Doing so he refers to workings of Rontgen 1885, Himstedt, Rowland 1876, Eichenwald and many others more, which today hardly are known.

In his textbook also Pohl gives practical examples for both equations of transformation. He points out that one equation changes into the other one, if as a relative velocity v the speed of light c should occur. This question will also occupy us.

We now have found a field-theoretical approach with the equations of transformation, which in its dual formulation is clearly distinguished from the Maxwell approach. The reassuring conclusion is added: The new field approach roots entirely in textbook physics, as are the results from the literature research. We can completely do without postulates.

Next thing to do is to test the approach strictly mathematical for freedom of contradictions. It in particular concerns the question, which known regularities can be derived under which conditions. Moreover the conditions and the scopes of the derived theories should result correctly, e.g. of what the Maxwell approximation consists and why the Maxwell equations describe only a special case.

27.9 Derivation of Maxwell's field equations

As a starting-point and as approach serve the equations of transformation of the electromagnetic field, the Faraday-law of unipolar induction and the according to the rules of duality formulated law (eq. 27.1, 2). If we apply the curl to both sides of the equations then according to known algorithms of vector analysis the curl of the cross product each time delivers the sum of four single terms. Two of these again are zero for a non-accelerated relative motion in the x-direction with v = dr/dt.

One term concerns the vector gradient (v grad)B, which can be represented as a tensor. By writing down and solving the accompanying derivative matrix giving consideration to the above determination of the v-vector, the vector gradient becomes the simple time derivation of the field vector B(r(t)) (eq. 27.10, according to the rule of eq. 27.11).

<i>: R.W.Pohl: Einfuhrung in die Physik, Bd.2 Elektrizitatslehre, 21.Aufl. Springer-Verlag 1975, Seite 76 und 130

<ii>: K. Simonyi: Theoretische Elektrotechnik, 7.Aufl. VEB Berlin 1979, Seite 924.

<iii>: Grimsehl: Lehrbuch der Physik, 2,Bd., 17.Aufl. Teubner Verl. 1967, S. 130.

As approach serve the equations of transformation (fig. 27.5) of the electric and of the magnetic field:

$\boxed{\mathbf{E} = \mathbf{v} \times \mathbf{B}}$ (27.1) and $\boxed{\mathbf{H} = -\mathbf{v} \times \mathbf{D}}$ (27.2)

If we apply the curl to the respective cross product:

$\boxed{\text{rot}\,\mathbf{E} = \text{rot}\,(\mathbf{v} \times \mathbf{B})}$ (27.5) and $\boxed{\text{rot}\,\mathbf{H} = -\,\text{rot}\,(\mathbf{v} \times \mathbf{D})}$ (27.6)

then according to the algorithms<i> four sum terms are delivered:

$$\boxed{\text{rot}\,\mathbf{E} = (\mathbf{B}\,\text{grad})\mathbf{v} - (\mathbf{v}\,\text{grad})\mathbf{B} + \mathbf{v}\,\text{div}\,\mathbf{B} - \mathbf{B}\,\text{div}\,\mathbf{v}} \qquad (27.5)$$

$$\text{rot}\,\mathbf{H} = -[(\mathbf{D}\,\text{grad})\mathbf{v} - (\mathbf{v}\,\text{grad})\mathbf{D} + \mathbf{v}\,\text{div}\,\mathbf{D} - \mathbf{D}\,\text{div}\,\mathbf{v}] \qquad (27.6)$$

where 2 of them are zero because of: $\boxed{\mathbf{v}(t) = d\mathbf{r}/dt}$ (27.7)

- the divergence of v(t) disappears: div v = 0 , (27.8)
- and will be zero as well: $\partial \mathbf{v}(t)/\partial \mathbf{r} = \boxed{\text{grad}\,\mathbf{v} = \mathbf{0}}$. (27.9)
- there remain the vector gradients:

$$\boxed{(\mathbf{v}\,\text{grad})\,\mathbf{B} = \frac{d\mathbf{B}}{dt}} \quad \text{and} \quad \boxed{(\mathbf{v}\,\text{grad})\,\mathbf{D} = \frac{d\mathbf{D}}{dt}} \quad ,(27.10)$$

- according to the rules<i> in general (with eq. 27.7):

$$\frac{d\mathbf{V}(\mathbf{r}(t))}{dt} = \frac{\partial \mathbf{V}(\mathbf{r}=\mathbf{r}(t))}{\partial \mathbf{r}} \cdot \frac{d\mathbf{r}(t)}{dt} = (\mathbf{v}\,\text{grad})\,\mathbf{V} \quad (27.11)$$

- A comparison of the coefficients of both field equations

$$\boxed{\begin{aligned} \text{rot}\,\mathbf{E} &= -\,d\mathbf{B}/dt + \mathbf{v}\,\text{div}\,\mathbf{B} = -\,d\mathbf{B}/dt - \mathbf{b} \\ \text{rot}\,\mathbf{H} &= d\mathbf{D}/dt - \mathbf{v}\,\text{div}\,\mathbf{D} = d\mathbf{D}/dt + \mathbf{j} \end{aligned}} \quad \begin{aligned} &(27.12) \\ &(27.13) \end{aligned}$$

with the Maxwell equations results in:

- for the potential density b = - v div B = 0 , (27.14)
  (eq. 27.12 = law of induction, if b = 0 resp. div B = 0)

- for the current density j = - v div D = $-v_x \cdot \rho_{el}$, (27.1a
  (eq. 27.13 = Ampere's law, if j = with v moving negative charge carriers (ρ_{el}= electric space charge density).

Fig. 27.9: ____ Derivation of Maxwell's field equations as a special case of the equations of transformation

<i>: Bronstein u.a.: Taschenbuch der Mathematik, 4.Neuaufl. Thun 1999, S. 652

For the last not yet explained terms at first are written down the vectors b and j as abbreviation. With equation 27.13 we in this way immediately look at the well-known law of Ampere (1st Maxwell equation). The comparison of coefficients (27.15) in addition delivers a useful explanation to the question, what is meant by the current density j: it is a space charge density ρ_{el} consisting of negative charge carriers, which moves with the velocity v for instance through a conductor (in the x-direction).

The current density j and the to that dual potential density b mathematically seen at first are nothing but alternative vectors for an abbreviated notation. While for the current density j the physical meaning already could be clarified from the comparison with the law of Ampere, the interpretation of the potential density b still is due. From the comparison with the law of induction (eq. 27.1*) we merely infer, that according to the Maxwell theory this term is assumed to be zero. But that is exactly the Maxwell approximation and the restriction with regard to the new and dual field approach, which roots in Faraday.

In that way also the duality gets lost with the argument that magnetic monopoles (div B) in contrast to electric monopoles (div D) do not exist and until today could evade every proof. It thus is overlooked that div D at first describes only eddy currents and div B only the necessary anti-vortex, the potential vortex. Spherical particles, like e.g. charge carriers presuppose both vortices: on the inside the expanding (div D) and on the outside the contracting vortex (div B), which then necessarily has to be different from zero, even if there hasn't yet been searched for the vortices dual to eddy currents, which are expressed in the neglected term.

Assuming, a monopole concerns a special form of a field vortex, then immediately gets clear, why the search for magnetic poles has to be a dead end and their failure isn't good for a counterargument: The missing electric conductivity in vacuum prevents current densities, eddy currents and the formation of magnetic monopoles. Potential densities and potential vortices however can occur. As a result can without exception only electrically charged particles be found in the vacuum (derivation in chapter 4.2 till 4.4). Because vortices are more than monopole-like structures depending on some boundary conditions, only the vortex description will be pursued further consequently. Let us record: Maxwell's field equations can directly be derived from the new dual field approach under a restrictive condition. Under this condition the two approaches are equivalent and with that also error free. Both follow the textbooks and can so to speak be the textbook opinion.

The restriction (b = 0) surely is meaningful and reasonable in all those cases in which the Maxwell theory is successful. It only has an effect in the domain of electrodynamics. Here usually a vector potential A is introduced and by means of the calculation of a complex dielectric constant a loss angle is determined. Mathematically the approach is correct and dielectric losses can be calculated. Physically however the result is extremely questionable, since as a consequence of a complex s a complex speed of light would result (according to the definition $c \equiv 1/\sqrt{\varepsilon \cdot \mu}$). With that electrodynamics offends against all specifications of the textbooks, according to which c is constant and not variable and less then ever complex.

But if the result of the derivation physically is wrong, then something with the approach is wrong, then the fields in the dielectric perhaps have an entirely other nature, then dielectric losses perhaps are vortex losses of potential vortices falling apart?

- Maxwell's field equations:

$$\text{rot}\,\mathbf{E} = -\,d\mathbf{B}/dt \qquad \text{(law of induction)} \qquad (27.1^*)$$
$$\text{rot}\,\mathbf{H} = d\mathbf{D}/dt + \mathbf{j} \qquad \text{(Ampère's law)} \qquad (27.13)$$

- describe the special case for b = 0 resp. div B = 0

$$\text{rot}\,\mathbf{E} = -\,d\mathbf{B}/dt + \mathbf{v}\,\text{div}\,\mathbf{B} = -\,d\mathbf{B}/dt - \mathbf{b} \qquad (27.12)$$
$$\text{rot}\,\mathbf{H} = d\mathbf{D}/dt - \mathbf{v}\,\text{div}\,\mathbf{D} = d\mathbf{D}/dt + \mathbf{j} \qquad (27.13)$$

The physical meaning of the introduced abbreviations b and j is:

- the current density $\mathbf{j} = -\,\mathbf{v}\,\text{div}\,\mathbf{D} = -\,v_x \cdot \rho_{el}$, (27.15)
- with Ohm's law $\mathbf{j} = \sigma \cdot \mathbf{E} = \mathbf{D}/\tau_1$, and (27.16)
- the potential density $\mathbf{b} = -\,\mathbf{v}\,\text{div}\,\mathbf{B} = \mathbf{B}/\tau_2$,(27.17)
- with the eddy current time constant $\tau_1 = \varepsilon/\sigma$ (27.16*>
- and with the potential vortex time constant τ_2

The complete field equations (27.12 and 27.13) read, with the time constants $(\tau_1$ and $\tau_2)$ of the respective field vortex:

- completely extended law of induction (with $B = \mu \cdot H$): (27.18)

$$\text{rot}\,\mathbf{E} = -\,d\mathbf{B}/dt - \mathbf{B}/\tau_2 = -\,\mu \cdot (d\mathbf{H}/dt + \mathbf{H}/\tau_2) \qquad (27.20)$$

- and the well-known law of Ampere (with $D = \varepsilon \cdot E$): (27.19)

$$\text{rot}\,\mathbf{H} = d\mathbf{D}/dt + \mathbf{D}/\tau_1 = \varepsilon \cdot (d\mathbf{E}/dt + \mathbf{E}/\tau_1) \qquad (27.21)$$

Fig. 27.10: The extension of the law of induction for vortices of the electric field (potential vortices].<i>

<i>: see also fig. 5.1

27.10 Derivation of the potential vortices

Is the introduction of a vector potential A in electrodynamics a substitute of neglecting the potential density b? Do here two ways mathematically lead to the same result? And what about the physical relevance? After classic electrodynamics being dependent on working with a complex constant of material, in what is buried an unsurmountable inner contradiction, the question is asked for the freedom of contradictions of the new approach. At this point the decision will be made, if physics has to make a decision for the more efficient approach, as it always has done when a change of paradigm had to be dealt with. The abbreviations j and b are further transformed, at first the current density in Ampere's law $j = -v_x \cdot \rho_{el}$ (27.15), as the movement of negative electric charges. By means of Ohm's law $j=\sigma \cdot E$ and the relation of material $D=\varepsilon \cdot E$ the current density j also can be written down as dielectric displacement current with the characteristic relaxation time constant $\tau_1 = \varepsilon/\sigma$ (eq. 27.16) for the eddy currents. In this representation of the law of Ampere (eq. 27.21) clearly is brought to light, why the magnetic field is a vortex field, and how the eddy currents produce heat losses depending on the specific electric conductivity σ. As one sees we, with regard to the magnetic field description, move around completely in the framework of textbook physics.

Let us now consider the dual conditions. The comparison of coefficients (eq. 27.12 + 27.17) looked at purely formal, results in a potential density b in duality to the current density j, which with the help of an appropriate time constant τ_2 founds vortices of the electric field. I call these potential vortices (in eq. 27.20).

In contrast to that the Maxwell theory requires an irrotationality of the electric field, which is expressed by taking the potential density b and the divergence B equal to zero. The time constant τ_2 thereby tends towards infinity. This Maxwell approximation leads to the circumstance that with the potential vortices of the electric field also their propagation as a scalar wave gets lost, so that the Maxwell equations describe only transverse and no longitudinal waves. At this point there can occur contradictions for instance in the case of the near-field of an antenna, where longitudinal wave parts can be detected measuring technically, and such parts already are used technologically in transponder systems e.g. as installations warning of theft in big stores.

It is denominating, how they know how to help oneself in the textbooks of high-frequency technology in the case of the near-field zone<i>. Proceeding from the Maxwell equations the missing potential vortex is postulated without further ado, by means of the specification of a ,,standing wave" in the form of a vortex at a dipole antenna. With the help of the postulate now the longitudinal wave parts are ,,calculated", like they also are being measured, but also like they wouldn't occur without the postulate as a result of the Maxwell approximation.

There isn't a way past the potential vortices and the new dual approach, because no scientist is able to afford to exclude already in the approach a possibly authoritative phenomenon, which he wants to calculate physically correct!

<i>: Zinke, Brunswig: Lehrbuch der Hochfrequenztechnik, 1. Bd., 3. Auflage 1986 Springer-Verlag Berlin, Seite 335

- Under the assumption: E = E(r,t); H = H(r,t) ,
- using the relations of material:

  $\boxed{\mathbf{B} = \mu\cdot\mathbf{H}}$ and $\boxed{\mathbf{D} = \varepsilon\cdot\mathbf{E}}$:
- the complete and extended law of induction reads:

$$\boxed{\operatorname{rot}\mathbf{E} = -\,\partial\mathbf{B}/\partial t - \mathbf{B}/\tau_2 = -\,\mu\cdot(\partial\mathbf{H}/\partial t + \mathbf{H}/\tau_2)} \quad (27.20)$$

- and the well-known law of Ampere:

$$\boxed{\operatorname{rot}\mathbf{H} = \partial\mathbf{D}/\partial t + \mathbf{D}/\tau_1 = \varepsilon\cdot(\partial\mathbf{E}/\partial t + \mathbf{E}/\tau_1)} \quad (27.21)$$

---

if we again apply the curl operation to eq. 27.20 and insert eq. 27.21:

$$\begin{aligned} -\operatorname{rot}\operatorname{rot}\mathbf{E} &= \mu\cdot\partial(\operatorname{rot}\mathbf{H})/\partial t + (\mu/\tau_2)\cdot(\operatorname{rot}\mathbf{H}) && (27.22)\\ &= \mu\cdot\varepsilon\cdot[\partial^2\mathbf{E}/\partial t^2 + (1/\tau_1)\cdot\partial\mathbf{E}/\partial t + (1/\tau_2)\cdot\partial\mathbf{E}/\partial t + \mathbf{E}/\tau_1\tau_2] && (27.23)\\ &= (1/c^2)\cdot[\partial^2\mathbf{E}/\partial t^2 + (1/\tau_1 + 1/\tau_2)\cdot\partial\mathbf{E}/\partial t + \mathbf{E}/\tau_1\tau_2] && (27.24)\end{aligned}$$

with the definition for the speed of light c:

$$\boxed{\varepsilon\cdot\mu = 1/c^2} \quad (27.25)$$

the fundamental field equation reads:

$$\begin{aligned} &\underbrace{-\,c^2\cdot\operatorname{rot}\operatorname{rot}\mathbf{E}}_{\text{a}} = \underbrace{\partial^2\mathbf{E}/\partial t^2}_{\text{b}} + && (27.26)\\ &\qquad\qquad\qquad\quad \text{(electromagnetic wave) +} &&\\ &\qquad + \underbrace{(1/\tau_1)\cdot\partial\mathbf{E}/\partial t}_{\text{c}} + \underbrace{(1/\tau_2)\cdot\partial\mathbf{E}/\partial t}_{\text{d}} + \underbrace{\mathbf{E}/\tau_1\tau_2}_{\text{e}} &&\\ &\qquad + \text{ eddy current } + \text{ potential vortex } + \text{ I/U} &&\end{aligned}$$

Fig. 27.11: Derivation of the fundamental field equation from the equations of transformation of the electromagnetic field.<i>

<i>: The fundamental field equation mathematically describes a wave damped with the vortices of the electric and the vortices of the magnetic field. It is formulated only in space and time. From it can be deduced numerous eigenvalue equations, (i.e. the equation of Schrodinger, fig. 5.1).

27.11 Derivation of the „fundamental field equation"

The two equations of transformation and also the from that derived field equations (27.20 and 27.21) show the two sides of a medal, by mutually describing the relation between the electric and magnetic field strength (between E and H). We get on the track of the meaning of the „medal" itself, by inserting the dually formulated equations into each other. If the calculated H-field from one equation is inserted into the other equation then as a result a determining equation for the E-field remains. The same vice versa also functions to determine the H-field. Since the result formally is identical and merely the H-field vector appears at the place of the E-field vector and since it equally remains valid for the B-, the D-field and all other known field factors, the determining equation is more than only a calculation instruction. It reveals a fundamental physical principle. I call it the "fundamental field equation".

The derivation always is the same: If we again apply the curl operation to rot E (law of induction 27.20) also the other side of the equation should be subjected to the curl. If for both terms rot H is expressed by Ampere's law 27.21, then in total four terms are formed (27.26): the wave equation (a-b) with the two damping terms, on the one hand the eddy currents (a-c) and on the other hand the potential vortices (a-d) and as the fourth term the Poisson equation (a-e), which is responsible for the spatial distribution of currents and potentials<i>.

Not in a single textbook a mathematical linking of the Poisson equation with the wave equation can be found, as we here succeed in for the first time. It however is the prerequisite to be able to describe the conversion of an antenna current into electromagnetic waves near a transmitter and equally the inverse process, as it takes place at a receiver. Numerous model concepts, like they have been developed by HF- and EMC-technicians as a help, can be described mathematically correct by the physically founded field equation.

In addition further equations can be derived, for which this until now was supposed to be impossible, like for instance the Schrodinger equation (chapter 5.6-5.9). This contrary to current opinion isn't a wave equation at all, since the term (b) with the second time derivation is missing. As diffusion equation it has the task to mathematically describe field vortices and their structures.

As a consequence of the Maxwell equations in general and specifically the eddy currents not being able to form structures, every attempt has to fail, which wants to derive the Schrodinger equation from the Maxwell equations.

The fundamental field equation however contains the newly discovered potential vortices, which owing to their concentration effect (in duality to the skin effect) form spherical structures, for which reason these occur as eigenvalues of the equation. For these eigenvalue-solutions numerous practical measurements are present, which confirm their correctness and with that have probative force with regard to the correctness of the new Held approach and the fundamental field equation. By means of the pure formulation in space and time and the interchangeability of the field pointers here a physical principle is described, which fulfills all requirements, which a world equation must meet.

<i>: see also fig. 5.1

Comparison:

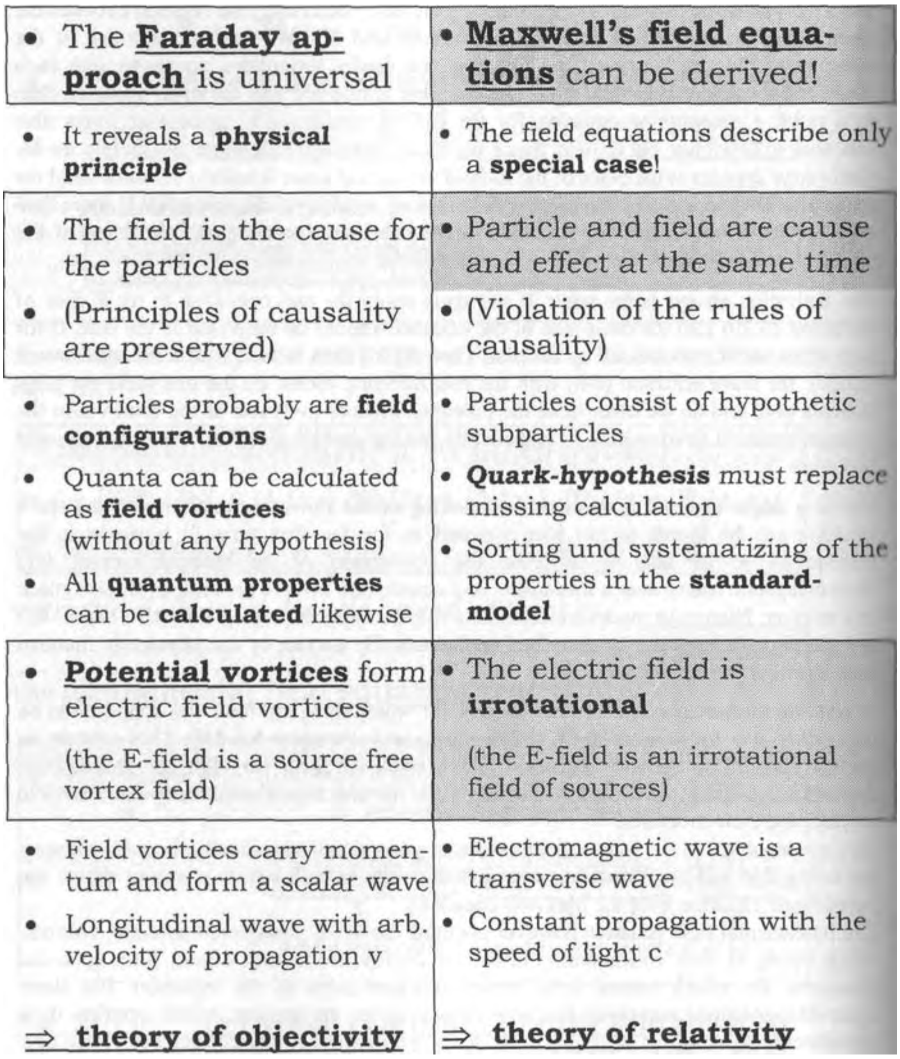

• The **Faraday approach** is universal	• **Maxwell's field equations** can be derived!
• It reveals a **physical principle**	• The field equations describe only a **special case**!
• The field is the cause for the particles • (Principles of causality are preserved)	• Particle and field are cause and effect at the same time • (Violation of the rules of causality)
• Particles probably are **field configurations** • Quanta can be calculated as **field vortices** (without any hypothesis) • All **quantum properties** can be **calculated** likewise	• Particles consist of hypothetic subparticles • **Quark-hypothesis** must replace missing calculation • Sorting und systematizing of the properties in the **standard-model**
• **Potential vortices** form electric field vortices (the E-field is a source free vortex field)	• The electric field is **irrotational** (the E-field is an irrotational field of sources)
• Field vortices carry momentum and form a scalar wave • Longitudinal wave with arb. velocity of propagation v	• Electromagnetic wave is a transverse wave • Constant propagation with the speed of light c
⇒ **theory of objectivity**	⇒ **theory of relativity**

Fig. 27.12: Comparison of the field-theoretical approaches according to Faradav and according to Maxwell.

27.12 The Maxwell field as a derived special case

As the derivations show, nobody can claim there wouldn't exist potential vortices and no propagation as a scalar wave, since only the Maxwell equations are to blame that these already have been factored out in the approach. One has to know that the field equations, and may they be as famous as they are, are nothing but a special case, which can be derived.

The field-theoretical approach however, which among others bases on the Faraday-law, is universal and can't be derived on its part. It describes a physical basic principle, the alternating of two dual experience or observation factors, their overlapping and mixing by continually mixing up cause and effect. It is a philosophic approach, free of materialistic or quantum physical concepts of any particles.

Maxwell on the other hand describes without exception the fields of charged particles, the electric field of resting and the magnetic field as a result of moving charges. The charge carriers are postulated for this purpose, so that their origin and their inner structure remain unsettled and can't be derived. The subdivision e.g. in quarks stays in the domain of a hypothesis, which can't be proven. The sorting and systematizing of the properties of particles in the standard-model is nothing more than unsatisfying comfort for the missing calculability.

With the field-theoretical approach however the elementary particles with all quantum properties can be calculated as field vortices (chap. 7). With that the field is the cause for the particles and their measurable quantization. The electric vortex field, at first source free, is itself forming its field sources in form of potential vortex structures. The formation of charge carriers in this way can be explained and proven mathematically, physically, graphically and experimentally understandable according to the model.

Where in the past the Maxwell theory has been the approach, there in the future should be proceeded from the equations of transformation of the field-theoretical approach. If now potential vortex phenomena occur, then these also should be interpreted as such in the sense of the approach and the derivation, then the introduction and postulation of new and decoupled model descriptions isn't allowed anymore, like the near-field effects of an antenna, the noise, dielectric capacitor losses, the mode of the light and a lot else more.

The at present in theoretical physics normal scam of at first putting a phenomenon to zero, to afterwards postulate it anew with the help of a more or less suitable model, leads to a breaking up of physics into apparently not connected individual disciplines and an inefficient specialisthood. There must be an end to this now! The new approach shows the way towards a unified theory, in which the different areas of physics again fuse to one area. In this lies the big chance of this approach, even if many of the specialists at first should still revolt against it.

This new and unified view of physics shall be summarized with the term "theory of objectivity". As we shall derive, it will be possible to deduce the theory of relativity as a partial aspect of it (chapter 6 and 28).

Let us first cast our eyes over the wave propagation.

- Starting-point: the fundamental field equation

$$\boxed{-c^2\cdot\text{rot rot }\mathbf{B} = \frac{d^2\mathbf{B}}{dt^2} + \frac{1}{\tau_2}\frac{d\mathbf{B}}{dt} + \frac{1}{\tau_1}\frac{d\mathbf{B}}{dt} + \frac{\mathbf{B}}{\tau_1\tau_2}} \quad (27.26^*)$$

- with a magnetic flux density $\mathbf{B} = \mathbf{B}(\mathbf{r}(t))$.

1st condition for eq. 27.26*: the special case, if $\sigma=0$ and $\sigma/\varepsilon = \boxed{(1/\tau_1) = 0}$. (27.16*)

The remaining vortex term is transformed by applying already used relations (eq. 27.10 and eq. 27.17):

$$\boxed{\frac{1}{\tau_2}\cdot\frac{d\mathbf{B}}{dt} = \mathbf{v}\cdot\text{grad}\,\frac{\mathbf{B}}{\tau_2}} \quad (27.10) \qquad \boxed{\frac{\mathbf{B}}{\tau_2} = -\,\mathbf{v}\cdot\text{div}\,\mathbf{B}} \ . \quad (27.17)$$

If the velocity of propagation: $\mathbf{v} = (v_x, v_y=0, v_z=0)$; $v = dx/dt$, then the simplified field equation (if the coordinates are orientated on the vector of velocity) results in the general wave equation (involved with the x-component) in the form:

$$\boxed{\|\mathbf{v}\|^2\,\text{grad div }\mathbf{B} - c^2\,\text{rot rot }\mathbf{B} = d^2\mathbf{B}/dt^2} \quad (27.27)$$

longitudinal with v = arbitrary	transverse with c = const.	wave velocity of propagation

---

2nd condition for eq. 27.28: $v = c$.

The wave equation in the usual notation (= inhomogeneous Laplace equation, = purely a special case!) now reads:

$$\boxed{\Delta\mathbf{B} = \text{grad div }\mathbf{B} - \text{rot rot }\mathbf{B} = (1/c^2)\cdot d^2\mathbf{B}/dt^2} \quad (27.28)$$

Fig. 27.13: Derivation of the wave equations (inhomogeneous Laplace equation) as a special case of the equations of transformation of the electromagnetic field.

27.13 Derivation of the wave equation

The first wave description, model for the light theory of Maxwell, was the inhomogeneous Laplace equation:

$$\boxed{\Delta \mathbf{E}\cdot c^2 = d^2\mathbf{E}/dt^2} \quad \text{with} \quad \boxed{\Delta \mathbf{E} = \text{grad div } \mathbf{E} - \text{rot rot } \mathbf{E}} \qquad (27.28^*)$$

There are asked some questions:

- Can also this mathematical wave description be derived from the new approach?
- Is it only a special case and how do the boundary conditions read?
- In this case how should it be interpreted physically?
- Are new properties present, which can lead to new technologies?

Starting-point is the fundamental field equation (27.26). We thereby should remember the interchangeability of the field pointers, that the equation doesn't change its form, if it is derived for H, for B, for D or any other field factor instead of for the E-field pointer. This time we write it down for the magnetic induction B and consider the special case, that we are located in a badly conducting medium, as is usual for the wave propagation in air. But with the electric conductivity σ also $1/\tau_1 = \sigma/\varepsilon$ tends towards zero (eq. 27.16*). With that the eddy currents and their damping and other properties disappear from the field equation, what also makes sense. There remains the potential vortex term $(1/\tau_2)$*dB/dt , which using the already introduced relations (eq. 27.10 and 27.17) involved with an in x-direction propagating wave ($v = (v_x, v_y = 0, v_z = 0)$) can be transformed directly into:

$$-\|\mathbf{v}\|^2\cdot\text{grad div } \mathbf{B}$$

The divergence of a field vector (here B) mathematically seen is a scalar, for which reason this term as part of the wave equation founds so-called „scalar waves" and that means that potential vortices, as far as they exist, will appear as a scalar wave. We at this point tacitly anticipate chapter 28, which provides the reason for the speed of light losing its vectorial nature, if it is correlated with itself. This insight however is valid in general for all velocities (v = dr/dt), so that in the same way a scalar descriptive factor can be used for the velocity (v = dx/dt) as for c.

From the simplified field equation (27.26*) the general wave equation (27.27) can be won in the shown way, divided into longitudinal and transverse wave parts, which however can propagate with different velocity.

Physically seen the vortices have particle nature as a consequence of their structure forming property. With that they carry momentum, which puts them in a position to form a longitudinal shock wave similar to a sound wave. If the propagation of the light one time takes place as a wave and another time as a particle, then this simply and solely is a consequence of the wave equation. Light quanta should be interpreted as evidence for the existence of scalar waves. Here however also occurs the restriction that light always propagates with the speed of light. It concerns the special case v = c. With that the derived wave equation (27.27) changes into the inhomogeneous Laplace equation (27.28). The electromagnetic wave in both cases is propagating with c. As a transverse wave the field vectors are standing perpendicular to the direction of propagation. The velocity of propagation therefore is decoupled and constant. Completely different is the case for the longitudinal wave. Here the propagation takes place in the direction of an oscillating field pointer, so that the phase velocity permanently is changing and merely an average group velocity can be given for the propagation. There exists no restriction for v and v = c only describes a special case.

• From the dual field-	From Maxwell's field equations can be
theoretical approach are derived:	derived:
=> Maxwell's field equations	=> 0
=> the wave equation (with transverse and longitudinal parts)	=> only transverse waves (no longitudinal waves)
=> scalar waves (Tesla-/neutrino radiation)	=> 0 (no scalar waves)
=> vortex and anti-vortex (current eddy and potential vortex)	=> only eddy currents
=> Schrodinger equation (basic equation of chemistry)	=>0
=> Klein-Gordon equation (basic eq. of nuclear physics)	=>0
Fig. 27.14: Comparison of the efficiency of both approaches.	
(as an interim result, if it concerns the question, which approach of the two is the more efficient one and which one better should be discarded. The final balance is made in chapter 28). It here concerns partial aspects of the following theories:	
=> theory of objectivity	=> theory of relativity

27.14 The new field approach in synopsis

Proof could be furnished that an approximation is buried in Maxwell's field equations and that they merely represent the special case of a new, dually formulated and more universal approach. The mathematical derivations of the Maxwell field and the wave equation disclose, of what the Maxwell approximation consists. The anti-vortex dual to the expanding eddy current with its skin effect is neglected. This contracting anti-vortex is called potential vortex. It is capable of forming structures and propagates as a scalar wave in longitudinal manner in badly conducting media like air or vacuum.

At relativistic velocities the potential vortices are subject to the Lorentz contraction. Since for scalar waves the propagation occurs longitudinally in the direction of an oscillating field pointer, the potential vortices experience a constant oscillation of size as a result of the oscillating propagation. If one imagines the field vortex as a planar but rolled up transverse wave, then from the oscillation of size and with that of wavelength at constant swirl velocity with c follows a continual change in frequency, which is measured as a noise signal.

The noise proves to be the in the Maxwell equations neglected potential vortex term, which founds scalar waves. If at biological or technical systems, e.g. at antennas a noise signal is being measured, then that proves the existence of potential vortices, but it then also means that the scope of the Maxwell theory has been exceeded and erroneous concepts can be the result.

As an answer to the question about possible new technologies is pointed to two special properties.

1st potential vortices for reason of their particle nature carry momentum and energy. Since we are surrounded by noise vortices, an energy technical use of scalar waves would be feasible, where the noise power is withdrawn of the surroundings. There is evidence that biological systems in nature cover their need for energy in this way. But at least an energy transmission with scalar waves already would be a significant progress with regard to the alternating current technology of today.

2nd the wavelength multiplied with the frequency results in the velocity of propagation v of a wave $(\lambda \cdot f = v)$, and that for scalar waves by no means is constant. With that wavelength and frequency aren't coupled anymore; they can be modulated separately, for which reason for scalar waves a whole dimension can be modulated additionally compared to the Hertzian wave. In that the reason can be seen, why the human brain with just 10 Hz clock frequency is considerably more efficient than modern computers with more than 1 GHz clock frequency. Nature always works with the best technology, even if we haven't yet understood it.

If we would try to learn of nature and an energy technical or an information technical use of scalar waves would occur, then probably nobody wanted to have our today still highly praised technology anymore. In the course of the greenhouse gases and the electrosmog we have no other choice than to scientifically occupy us with scalar waves and their technical use.

Equations of transformation

of the electric and of the magnetic field<i>

$\boxed{\mathbf{E} = \mathbf{v} \times \mathbf{B}}$ (27.1) and $\boxed{\mathbf{H} = -\mathbf{v} \times \mathbf{D}}$ (27.2)

with: $\mathbf{B} = \mu \cdot \mathbf{H}$ (28.1) and $\mathbf{D} = \varepsilon \cdot \mathbf{E}$ (28.2)

$\boxed{\mathbf{E} = \mu \cdot \mathbf{v} \times \mathbf{H}}$ (27.3) and $\boxed{\mathbf{H} = -\varepsilon \cdot \mathbf{v} \times \mathbf{E}}$ (27.4)

Experience/observation is dependent on the relative velocity v !

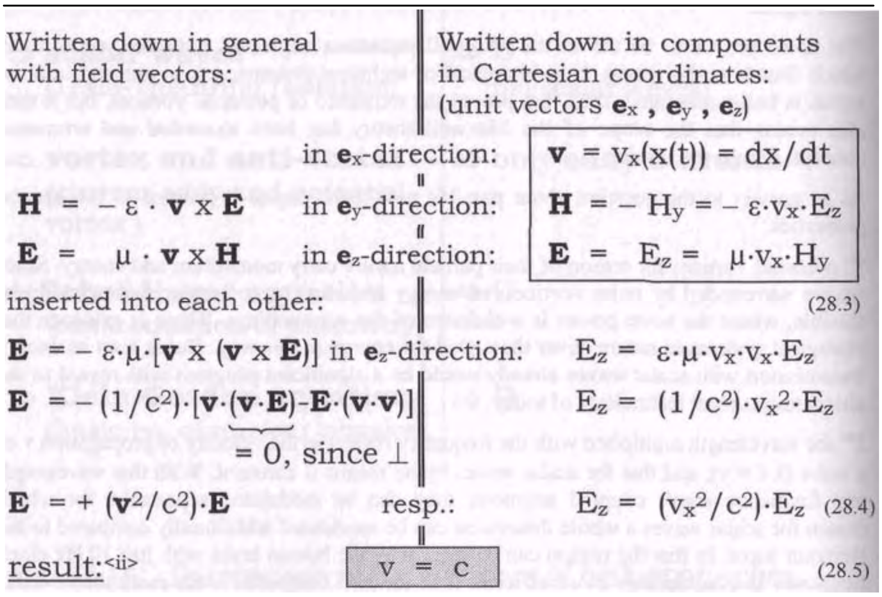

Written down in general with field vectors:	Written down in components in Cartesian coordinates: (unit vectors $\mathbf{e}_x$, $\mathbf{e}_y$, $\mathbf{e}_z$)
in $\mathbf{e}_x$-direction:	$\mathbf{v} = v_x(x(t)) = dx/dt$
$\mathbf{H} = -\varepsilon \cdot \mathbf{v} \times \mathbf{E}$ in $\mathbf{e}_y$-direction:	$\mathbf{H} = -H_y = -\varepsilon \cdot v_x \cdot E_z$
$\mathbf{E} = \mu \cdot \mathbf{v} \times \mathbf{H}$ in $\mathbf{e}_z$-direction:	$\mathbf{E} = E_z = \mu \cdot v_x \cdot H_y$
inserted into each other:	(28.3)
$\mathbf{E} = -\varepsilon \cdot \mu \cdot [\mathbf{v} \times (\mathbf{v} \times \mathbf{E})]$ in $\mathbf{e}_z$-direction:	$E_z = \varepsilon \cdot \mu \cdot v_x \cdot v_x \cdot E_z$
$\mathbf{E} = -(1/c^2) \cdot [\underbrace{\mathbf{v} \cdot (\mathbf{v} \cdot \mathbf{E})}_{= 0,\ \text{since}\ \perp} - \mathbf{E} \cdot (\mathbf{v} \cdot \mathbf{v})]$	$E_z = (1/c^2) \cdot v_x^2 \cdot E_z$
$\mathbf{E} = +(\mathbf{v}^2/c^2) \cdot \mathbf{E}$ resp.:	$E_z = (v_x^2/c^2) \cdot E_z$ (28.4)
result:<ii>	$\boxed{v = c}$ (28.5)

Fig. 28.1: The equations of transformation,<i>

<i>: see part 1, chap. 6.5, eq. 60

<ii>: R. W. Pohl: Einfuhrung in die Physik, Bd. 2 Elektrizitatslehre, 21. Aufl. Springer-Verlag 1975, Seite 77, s.a. Kommentar auf Tafel 27.8

<iii>: chapter 28 is a repetition of chapter 6

28. Objectivity versus relativity

The new and field-theoretical approach contains the Maxwell-equations, but goes over and above these in one point. It describes potential vortices and their propagation in space as a scalar wave. With that can also a conclusive answer be given to the often-asked question for the medium and the mediated particles, which is a prerequisite for every longitudinal wave. Mediated are vortex structures with particle nature and the field itself functions as a medium. Is with that also answered the question concerning the aether?[<iii>]

28.1 The question concerning the aether

Do you know the Maxwell-experiment? No, you wouldn't be able to, since the intellectual father fast did make a backdown, after it didn't work out. Today one speaks of the Michelson-experiment and it may be connected with any other names (Morley, etc.). Remember: In his light theory Maxwell had determined a particular and constant value for the speed of light and for that there should be a physical reason, which should have its cause in the aether. By means of proving this aether Maxwell wanted to prove his theory, but this enterprise thoroughly went wrong.
The consideration was as follows: If the Earth is spinning and is moving through the cosmos, then one should be able to detect an aetherwind and different values for c in the different points of the compass. Maxwell found support for his project at the observatory, since with the aberration of the stars Bradley previously had described an observation, which could be considered as evidence for an aether. The director of the observatory charged his assistant Dr. Michelson with the task, to carry out a corresponding proof of an aether this time in a terrestrial experiment. But such an aether couldn't be proven, what Maxwell had to accept as a severe strike against his light theory. Seven years later Maxwell got the acknowledgement, however from a completely other corner by means of the experiments concerning the radio transmission of Heinrich Hertz.

Until today the question has remained open why astrophysics can prove the aether, whereas the detection in a terrestrial laboratory fails and it looks like there doesn't exist an aether. But as definition for the cause of c the aether can't be abolished as long as it is unsettled why the light is propagating with c of all possible velocities. The question is asked, what determines the propagation of light from today's point of view? Now, by means of outside fields the light can be slowed down. At present the world record lies at less than 65 kilometers per hour in a Bose-Einstein condensate. If electromagnetic fields determine the speed of light, if in addition field or gravitational lenses should confirm this, then the field takes over the task of the aether!

At this place the new field-theoretical approach shows its capabilities. The equations of transformation say nothing but that a moving H-field transforms to a resting E-field and vice versa, that thus in the place of a moving aether, the aetherwind, a resting aether is found. Doing so the dual field partners merely exchange their places. Therefore it is a wild-goose chase, wanting to measure an aetherwind with gauges, which underlie the same field (fig. 28.2).
Michelson had to fail.

The equations of transformation say:

$\boxed{\mathbf{E} = \mu \cdot \mathbf{v} \times \mathbf{H}}$ (27.3) and $\boxed{\mathbf{H} = -\varepsilon \cdot \mathbf{v} \times \mathbf{E}}$ (27.4)

- Experience/observation depends on the relative velocity v!
- The field takes over the function of the aether (determines c) and
- an aetherwind v x H is measured as a resting aether E and vice versa!

- for v = c the equations of transformation turn into each other and are identical [$v = v_x(x(t))$].
- for v < c a motion field E_v depending on v is resulting

$$\boxed{E_v = E \cdot (v^2/c^2)} \quad (28.6)$$

- for v = 0 also $E_v = 0$.
- the motion field overlaps the E-field
- in the case of vortex fields the effect overlaps the cause and itself is the cause for a new effect.
- The overlap reaches to infinity, where each time is valid:

$$E_{n+1} = E_n \cdot (v^2/c^2) \quad (28.7)$$

- the field Eo overlaps the motion field E_v

$$E = E_0 + E_v = E_0 \cdot (1 + v^2/c^2) \quad (28.8)$$

- for infinite overlap:

$$E = E_0 + E_1 + E_2 + E_3 + E_4 + \ldots + E_n + E_{n+1} + \ldots \quad (28.9)$$

- results in the power series:

$$E = E_0 \cdot [1 + (v/c)^2 + (v/c)^4 + (v/c)^6 + \ldots + (v/c)^{2n} + (v/c)^{2(n+1)} + \ldots] \quad (28.10)$$

Fig. 28.2: Power series as a result of a vortex overlap.

<i>: Grimsehl: Lehrbuch der Physik, 2.Bd., 17.Aufl. Teubner Verl. 1967, S. 130.

<ii>: R.W.Pohl: Einfuhrung in die Physik, Bd.2 Elektrizitatslehre, 21.Aufl. Springer-Verlag 1975, Seite 72 und 76, bzw. 130.

<iii>: K. Simonyi: Theoretische Elektrotechnik, 7.Aufl. VEB Berlin 1979, Seite 924.

<i4>: E. Friebe: Die Vektorprodukte der Maxwell'schen Elektrodynamik, DPG-Didaktik-Tagungsband 1995, S.396

28.2 Vortices, an overlap of the overlap

Not with any approach until now the question concerning the aether could be solved. Only the new field-theoretical approach proves with the unambiguous and free of contradiction clarification of the question concerning the aether its unmatched superiority. We hence without exception work with this approach, which is anchored tightly in textbook physics. The two equations of transformation on the one hand are the law concerning the unipolar induction according to Faraday (27.1) and on the other hand the dual formulation (27.2), which Grimsehl[<i>] calls convection equation. Grimsehl goes around the question for the correct sign by means of forming a modulus. Pohl draws detailed distinctions of cases and dictates the each time relevant formulation of the dual law[<ii>]. The sign eventually should be chosen according to the definition of the orientation of the field pointers. Also Simonyi gives both equations and the each time appropriate experiments[<iii>].

If we assume the carrier of an electric field is moving with the not accelerated relative velocity v with regard to the reference system used by the observer, then a magnetic H-field is observed, which stands perpendicular both to the direction of the E-field and to the direction of v. If the motion takes place perpendicular to the area stretched by E- and H-field, then the H-field again is observed and measured as an E-field. There will occur an overlap of the fields.

In spite of that we first consider the theoretical case, that no overlap is present, and the observer as it were sees himself. The result is trivial: the relative velocity v must be the speed of light v = c . (28.5) If considered at the speed of light, the two equations of transformation turn into each other. They now are identical both mathematically and in their physical expressiveness. For this case it actually is possible, to derive the dual law straight from the Faraday law. For a wave propagating with the speed of light, to name an example, the field strength propagating along is always equal to the causing field strength, which depends on position.

If besides the evaluation of the values also the circumstance is considered that it concerns vectors, then at this place a problem as a matter of principle of the Maxwell theory gets visible, to which has been pointed occasionally, e.g. at the German Physical Society[<i4>]. The derivation of the speed of light from two vector equations requires, that c also has to be a vector. The question is: How the velocity vector v suddenly becomes the scalar and not pointing, in all directions of space constant factor c? Is therefore for mathematical and physical reasons "the Maxwell theory in essential parts erroneous", according to a statement of the German Patent Office[<i4>]?

Now, the constancy of the speed of light is a fact, which even can be derived. We at first will be content with the clue that for every observation with the speed of light, with the eyes or a gauge constructed corresponding to our perception, the vector in all its components each time is correlated to itself, by what actually the orientation of direction gets lost. Under these for c and with equal rights also for v relevant circumstances we are entitled to calculate further with the values.

An observer, who is moving with v slower than c, will besides the original E-field also observe a motion field E_v depending on the velocity v, which disappears, if v becomes zero. What he catches sight of and is able to register with gauges in the end is the overlap of both field components.

- concerning the development of the power series:

$$E = E_0\cdot[1 + (v/c)^2 + (v/c)^4 + (v/c)^6 + \ldots + (v/c)^{2n} + (v/c)^{2(n+1)} + \ldots] \quad (28.10)$$

- for $q < 1$ the power series with $q = (v/c)^2$ will converge (28.11)

$$\sum_{n=0}^{\infty} q^n = \frac{1}{1-q} \quad (28.12)$$

- for $(v/c)^2 < 1$ resp. for $v < c$ therefore is valid:

$$E = E_0\cdot[1/1 - (v/c)^2] \quad \text{resp.} \quad \boxed{E_0 = E\cdot[1 - (v/c)^2]} \quad (28.13)$$

The square root of Lorentz appears in squared form<i>:

$$(1 - \frac{v^2}{c^2}) = \frac{E_0}{E} \quad (28.14)$$

The derivation for the magnetic field strength analogous to that provides the identical result<i>:

$$(1 - \frac{v^2}{c^2}) = \frac{H_0}{H} \quad (28.15)$$

Fig. 28.3 The field dilatation depending on velocity

<i>: see part 1, chap. 6.6

<ii>: Prof. Dr. H.-J. Runckel, Abteilung fur Mathematik IV der Universitat Ulm

28.3 Field overlap

But it doesn't abide by this one overlap. In the case of vortex fields the effect overlaps the cause and itself becomes the cause for a new effect. The overlapped cause produces a further effect, which for its part is overlapping (see chap. 3).

Vortices thus arise, if overlaps for their part are overlapping and that theoretically reaches to infinity, to which I already repeatedly have pointed (fig. 3.0). In addition do vortices represent a fundamental physical principle. The Greek philosopher Demokrit has traced back the whole nature to vortex formation and that already 2500 years ago!

In the field-theoretical approach this interpretation seems to experience a mathematical confirmation, since also the fields are overlapping in vortex structures. According to that we owe our observations and our being the relative movements and the vortex formation. If reversed there wouldn't be any movement, then there also would not exist fields, light nor matter. If we observe the sky, then everything visible follows the movement of its own of the Earth, of the solar system and the whole galaxy, which is on its way with unknown galactic velocity, and all movements take place in vortex structures (fig. 10.2).

The field overlap dictated by the Faraday-approach as well reaches to infinity, what has stimulated my colleagues of mathematics to also mathematically put into practice this physical requirement<ii>. This leads to an infinite power series, which converges under the condition that $v < c$.

As a result of the power series development the well-known square root $\sqrt{1-(v^2/c^2)}$ of Lorentz occurs in squared form (see also fig. 6.6). It determines the relation of the observed and the causing field strength of the electric or the magnetic field. Physically the found relation describes a dilatation field depending on velocity. The field strength thus increases, if the relative velocity v increases, or inversely no difference is observable anymore, if v tends towards zero.

Whoever wants to compete with Albert Einstein (1879-1955), who has developed the theory of relativity from the length contraction, which depends on velocity, could be inclined to derive a new field physics from the field dilatation. But I must warn of such a step. The derivation of the length contraction by the mathematician Hendrik Lorentz (Lorentz contraction) assumes a number of limiting conditions. The relative velocity v for instance may not experience any acceleration. Actually however almost all motion takes place as circular vortex motion, so that due to the occurring centripetal acceleration the conditions for the theory of relativity aren't fulfilled anymore. Neglects or generalizations thereby can lead to considerable errors, of which I would like to warn. It in general is a delicate enterprise, if one wants to provide a physical interpretation for a purely mathematically won result.

This warning to the same extent also is valid for the here shown derivation of the field dilatation. The limiting conditions practically are the same as for Einstein and the problems with a provided physical interpretation won't be less. Also here lots of paradoxes will occur, which are nothing but errors of the theory. So we won't reach our destination.

There now only one further mathematical step is necessary, which links the theory of relativity with the new notion of a field dilatation depending on velocity.

Example:
Measurement of length by means of a measurement of propagation time (sound or light) with c = L/t in a vehicle moving with v.

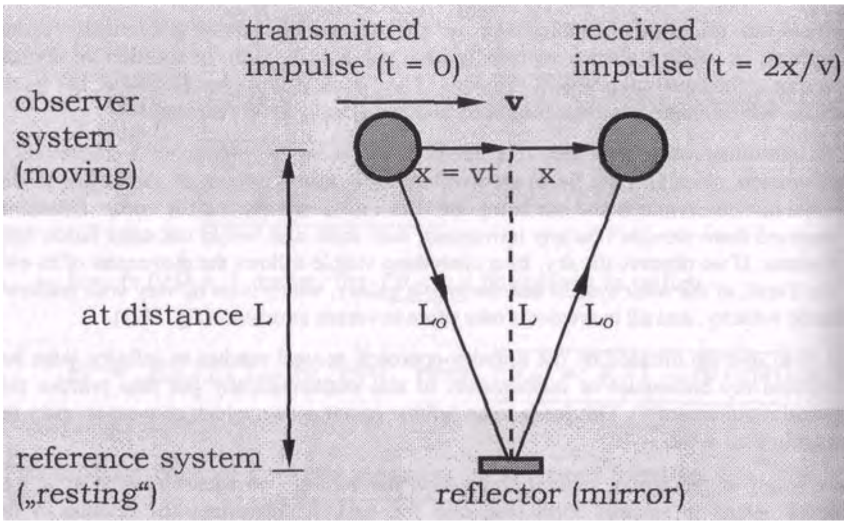
transmitted
impulse (t = 0)
received
impulse (t = 2x/v)
observer
system
(moving)
v
x = vt
x
at distance L
L_o
L
L_o
reference system
(„resting“)
reflector (mirror)

From driving time t:

$t = 2\frac{x}{v}$ = signal propagation time: $t = 2\frac{L_o}{c}$ follows $\boxed{\frac{x}{v} = \frac{L_o}{c}}$

According to Pythagoras: $L_o^2 = L^2 + x^2 = L^2 + L_o^2 \cdot (v^2/c^2)$

$$L_o^2 \cdot (1 - v^2/c^2) = L^2$$

the shortening of the rule results in:

$$\boxed{(1 - \frac{v^2}{c^2}) = (\frac{L}{L_o})^2} \quad (28.16)$$

Fig. 28,4: ______Derivation of the length contraction

Examples: contraction according to Lorentz transformation, measurable length shortening, curvature of space.

Counterexample: unsuccessful aether detection (Michelson experiment)

28.4 The derivation of the length contraction

The Lorentz transformation is the result of a purely mathematical problem. Stimulated by the surprisingly result of the Michelson experiment the Dutchman Hendrik A. Lorentz 1891 asked himself, how the equations of the Galilei-transformation would have to look like, if the propagation of light wouldn't be infinitely fast but finite and constant. He thereby proceeds from the assumption of two inertial systems moving against one another with a not accelerated velocity v, in which the laws of Newtonian physics are equally valid<i>. As a result of the relative motion a change of the length measures will occur.

This at first can be explained as a purely geometric effect in the context of nonrelativistic physics. We imagine a vehicle, which is on its way with constant velocity, and emits an optical or acoustical signal. Sideways in the countryside is standing in a perpendicularly measured distance L a reflector (mirror), which sends the signal back again. The velocity of the signal however isn't infinitely fast and from that follows that the vehicle during the propagation time of the signal as well has moved a bit further. The actual way, which the signal had to cover now amounts to L_o (> L). The distance measure thus is observed smaller as it is in reality, to be specific for the factor of the square root of Lorentz (fig. 28.4).

$L = L_o \cdot \sqrt{1-(v^2/c^2)}$ (28.16)

According to the principle of relativity it doesn't play a role, if the vehicle is driving or if it is standing still and the mirror is moving with a linear uniform velocity.

Initially Einstein also only spoke of an observable length contraction, which must not necessarily occur in reality, an optical deception so to speak. Lorentz however proceeded from the assumption of a physical length change, thus a length change existing in reality, what in practice at first makes no difference. If e.g. at relativistic velocities a rocket becomes smaller, then the pilot equally shrinks, so that it would not be possible to notice a present difference.

If however the observer stands outside the events and takes a „neutral standpoint", then he will be able to see, which interpretation is the right one. Today some examples are known. In accelerators particles at relativistic fast velocities actually get smaller for the factor of the square root of Lorentz. That has been proven and this result afterwards gives the Dutchman Lorentz right! The followers of the physical length contraction also are called Neo-Lorentzians.

In the vicinity of a gravitational mass the speed of light becomes so slow, that the shortening factor plays a role and space is curved towards the mass. To understand this shortening of scale, the influence of the field also should be considered.

<i>: Example: In a closed lift physical experiments are being carried out. Accelerations of the lift have an influence on the experiments. However no influence can be detected, if the lift is standing still or is moving with constant velocity. It with that fulfills the conditions of an inertial system. The question is: what do the experiments show someone standing outside, whom the lift passes by?

From the comparison of the Lorentz contraction (28.16)
with the field dilatation (28.14 and 28.15)

$$\left(1-\frac{v^2}{c^2}\right)=\left(\frac{L}{L_o}\right)^2 \overset{!}{=} \left(1-\frac{v^2}{c^2}\right)=\frac{E_o}{E}=\frac{H_o}{H}$$

follows

$$\left(1-\frac{v^2}{c^2}\right)=\boxed{\left(\frac{L}{L_o}\right)^2=\frac{E_o}{E}=\frac{H_o}{H}} \quad (28.17)$$

the proportionality (length measures depending on field):

$$\underline{E, H \sim 1/L^2} \quad \text{and} \quad Eo, Ho \sim 1/L_0^2 \quad (28.18)$$

Experimental examples[i]:

- Electrostriction (piezo speaker)
- Magnetostriction
- Field or gravitational lenses
- Curvature of space, deflection of light

Conclusion[ii]:

- The field determines the length measures (what is 1 meter)
- The field determines the velocities v (in m/s)
- The field determines the speed of light c [m/s]
- Measurement of the speed of light is made with itself:

$$\boxed{c \sim r} \quad (28.19)$$

- Measured is a constant of measurement c = 300.000 km/s
- The speed of light c is not a constant of nature!

Fig. 28.5: The dependence of the Lorentz contraction on the field

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[i]: see part 1, chap. 6.10

[ii]: see part 1, chap. 6.11

28.5 The dependence of the Lorentz contraction on the field

The two results of the field dilatation (28.14 and 28.15) and of the Lorentz contraction (28.16) must be brought together and compared (28.17). Doing so the mathematical expression of the square root of Lorentz is cancelled out. That is of utmost importance, since with that also all limits disappear and there remains a purely physical relation, a proportionality of utmost importance (28.18).

What was the sense of the limits associated with the introduction of so-called inertial systems, which are the basis of the Lorentz transformation and which were adopted for our derivation of the field dilatation? They now only are auxiliary considerations according to model. We have chosen a very simple model, which can be described mathematically, in which an observer holds in his hand gauges for distances and field strengths and with that gauges a system flying by with constant velocity. He on the one hand determines a length contraction and on the other hand a field dilatation. He compares both with each other and comes to the conclusion: The field determines the dimensions!

This statement is purely physical and it is generally valid. It is independent of the relative velocity and all other mathematical conditions. A centrally accelerated circular motion e.g. will falsify the length contraction to the same extent, as the at the same time occurring field dilatation. It can be expected, that in addition to the square root of Lorentz also other errors will mutually efface, so that a generalization in this case actually seems to be allowed.

The won proportionality is of most elementary importance. We use it in the case of the piezo speaker and know it from the curvature of space and deflection of light in presence of extreme fields. If we ourselves however are exposed to the field as an observer, in which also the object to be observed is situated, then we are in the dilemma, not being able to perceive the influence. If we, to stay with the example, would sit in a rocket and this would become smaller at faster velocity, then we would notice nothing, since we also would shrink along to the same extent.

That concerns every measurement of velocity in general and the speed of light c in particular, which as is well-known is measured in meters per second. But if the field determines c and in the same way the length measure, which is given in meters, then both stand in a direct proportionality to each other, then we won't have the slightest chance to measure the speed of light. If namely c is changed, then this concerns the measurement path in the same way. Now the variable is measured with itself and as a result appears c, a constant value. We neither can see the change, since our eyes scan all objects optically and that means with c.

It is the nightmare of each and every measurement engineer, if the gauge depends on the factor to be measured. No wonder, if the theorem of addition of the velocities apparently loses its validity and always the same c is being measured, independent of the direction in which the source of radiation is moving (chap. 6.11). The result is:

The speed of light is a constant of measurement and not a constant of nature! If however the light is scanned with the speed of light, then also all components of the light vector correlated with themselves result in the same constant value c, then actually the vector of the speed of light loses its orientation in space and becomes a scalar factor. The Maxwell equations already anticipate this circumstance, but without providing an explanation why this is correct. Only the new field approach can answer the open question. With the derivation an axiom of physics - one also can say stumbling block - has been overcome.

The field strength determines the length measure:
(the distance L between the spheres)<i>

$$\boxed{E, H \sim 1/L^2} \qquad (28.18)$$

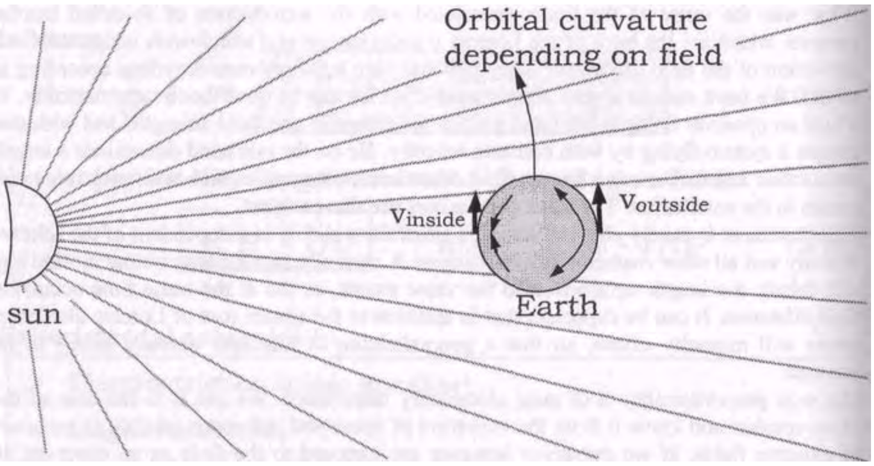
Orbital curvature depending on field
v_{inside}
$v_{outside}$
sun
Earth

Fig. 28.6 A: The curvature of the Earth in the gravitational field of the sun

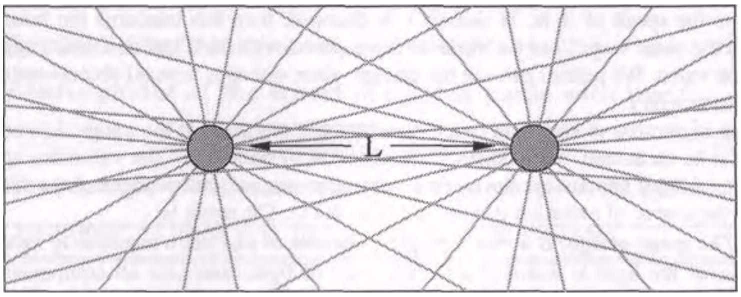

Fig. 28.6 B: Force of attraction and reduction of the distance L as the mutual field influence of two masses.

<i>: Repetition of part 1, chapter 6.7

28.6 Boscovich and the respiration of the Earth

Who has got a good idea, fast will find that some other scientist had the same idea already before, and for his part possibly already had to make the same experience. If in spite of that the track fast loses in history, it as a rule is because of the insufficient citing and the vanity of the discoverers, who in reality only are rediscoverers of a much older knowledge.

The dependence of the length measures on the field (eq. 28.18) in the mathematical form of the derivation however should still be quite new. But the physical consequence already was described by the Jesuit priest Roger Joseph Boscovich from Dalmatia in 1755<i>. He was Professor for mathematics and theology in Rome and spoke about the world on the one hand being deformable, similar to rubber, but on the other hand we aren't able to perceive this, since our body is made of the same material and follows all changes. „We in an absolute way can recognize neither the place, nor distances or orders of magnitude", writes Boscovich in his book about space and time and writes how these are perceived by us<ii>. He suspects that the Earth unobservable for man „is respiring".

Actually a terrestrial observer at daytime is situated closer to the sun than in the night. He by day is exposed to a slightly stronger field and as a result correspondingly smaller. He himself and all objects in his neighbourhood are subject to an identical fluctuation of size, so that this „respiration" of the Earth cannot be detected. It can be detected neither with a tape measure nor with an optical measurement and still is present in reality. Only from a neutral standpoint we can succeed to recognize the actually existing curvature of space (fig. 28.6 A).
An example is the duration of the sunshine at the equator, which is longer than can be expected from the spherical form of the Earth. This reveals, how the Earth is bending towards the sun (see also chapter 6.7).
A further example is the influence of the field on the orbital velocity of the Earth measured in meters per second. Here also the meter at daytime is smaller than in the night, for which reason the Earth is moving slower on the side turned towards the sun, like a track vehicle, which drives a turn, if the chain at the inside runs slower than on the outside. If the Earth describes an orbit around the sun. then this circumstance has to do nothing at all with centrifugal force or with a force of attraction of the sun. The circular motion simply and solely is a result of the field influence of the sun<iii>.

The force idea proves to be a pure auxiliary description. In the context of Newtonian mechanics the force plays a central role. Without question it is a very efficient and subjective perceptible description, which still isn't able to reproduce the physical reality in an objective manner. What keeps the planets into their orbit is only the field of the sun, which we call gravitational field and not some force! But of which kind is the gravitation and the field, which causes masses to come closer together and following our subjective observation attract each other (fig. 28.6 B)?

<i>: O. E. Rossler: Endophysics, the World as an Interface, World Scientific Publishing Co. 1998, Kap. 10, S. 87-112, mit Ubersetzungen aus <ii>:

<ii>: R. J. Boscovich: De spatio et tempore, ut a nobis cognoscuntur, 1755.

The length measure (the distance L between the spheres)<i> is determined by the field strength:

$$\boxed{E, H \sim 1/L^2} \quad (28.18)$$

A. Charged mass points (electrons, positrons, ions,...):

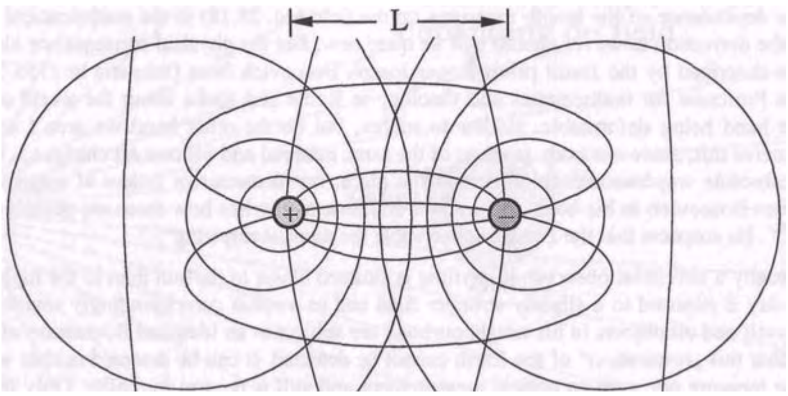

B. Uncharged mass points (neutrons, atoms, ...):

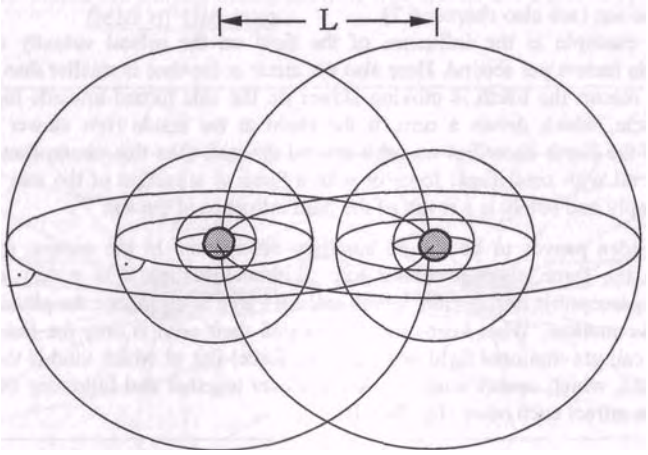

Fig. 28.7: Observation of a mutual force of attraction because of the effect of the fields on the distance measure.

<i>: Repetition of part 1, chapters 6.7 - 6.9 and part 2, chapters 10.4 and 15.2

28.7 Derivation of the gravitation

In fig. 28.6B the relation between the field influence and the observed force of attraction of two mass bodies is represented. If I in my mind for instance "switch on" the field lines of both bodies, which are placed at distance L, then the fields according to equation 28.18 reduce the measure L and optically come each other closer. With increasing proximity the field line density increases, so that L further decreases. We observe a mutual attraction, which lets both bodies move towards each other.

In fig. 28.7A the two bodies carry an electric charge. For different polarity the field lines as is well-known run from the positive pole to the negative pole, to bundle up there. As a matter of principle also here an attraction can be expected, which is called electromagnetic interaction. For the reason of the bundling up of the field lines this effect however will turn out to be considerably stronger. Hence the electromagnetic interaction is for many powers of ten more powerful than the gravitation.

Furthermore there also can occur repulsion, if in the case of like charge the field lines are bent aside and between the two bodies an area is formed, where the field tends towards zero and the distance measure L (according to eq. 28.18) as a result towards infinity. The electromagnetic interaction theoretically indeed reaches to infinity. Responsible are the open field lines arising from a charged body.

Now every charged body in addition has a mass, with which it takes part in the gravitation. Let's remember the comparison of the derivations. The Maxwell theory teaches us that in the static case E- and H-field are decoupled, because each time the other field disappears. Even if as a result of the unipolar induction for every open field line the other one is taken to be standing perpendicular to the open field line, then this other line just wraps around the open field line and forms a closed-loop field line. In that way it can't be influenced anymore from the outside and can be neglected, so goes the doctrine, which is drawn from the Maxwell theory (fig. 27.5).

This is a fatal error in reasoning! The equation 28.19 naturally is valid for open field lines in the same manner as for closed ones. These fields also lead to an observable force of attraction. If of course exactly those fields are neglected, which are responsible for the gravitation, then we need not wonder, if we don't understand the gravitation and the nature of this interaction!

The influence of the closed field lines responsible for the gravitation is due to the missing bundling up of the lines correspondingly weak. Secondly these can't exist a force of repulsion due to the missing ability to influence closed field lines from the outside and third it can be recorded that all charged bodies also have a mass. All three statements of the field lines model perfectly cover the physical reality.

Fig. 28.7 B shows uncharged bodies, for which both the field lines of the E-field and of the perpendicular to them arranged H-field are closed-loop. Such bodies, like e.g. neutrons or whole atoms without charge behave electrically neutral to the outside, but have a mass for the reason of the closed field lines, whereby the field lines of the H-field dominate those of the E-field[i].

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[i] Repetition of K. Meyl: EMEC part 1, chap. 6.8 + 6.9, part 2 chap. 15.1

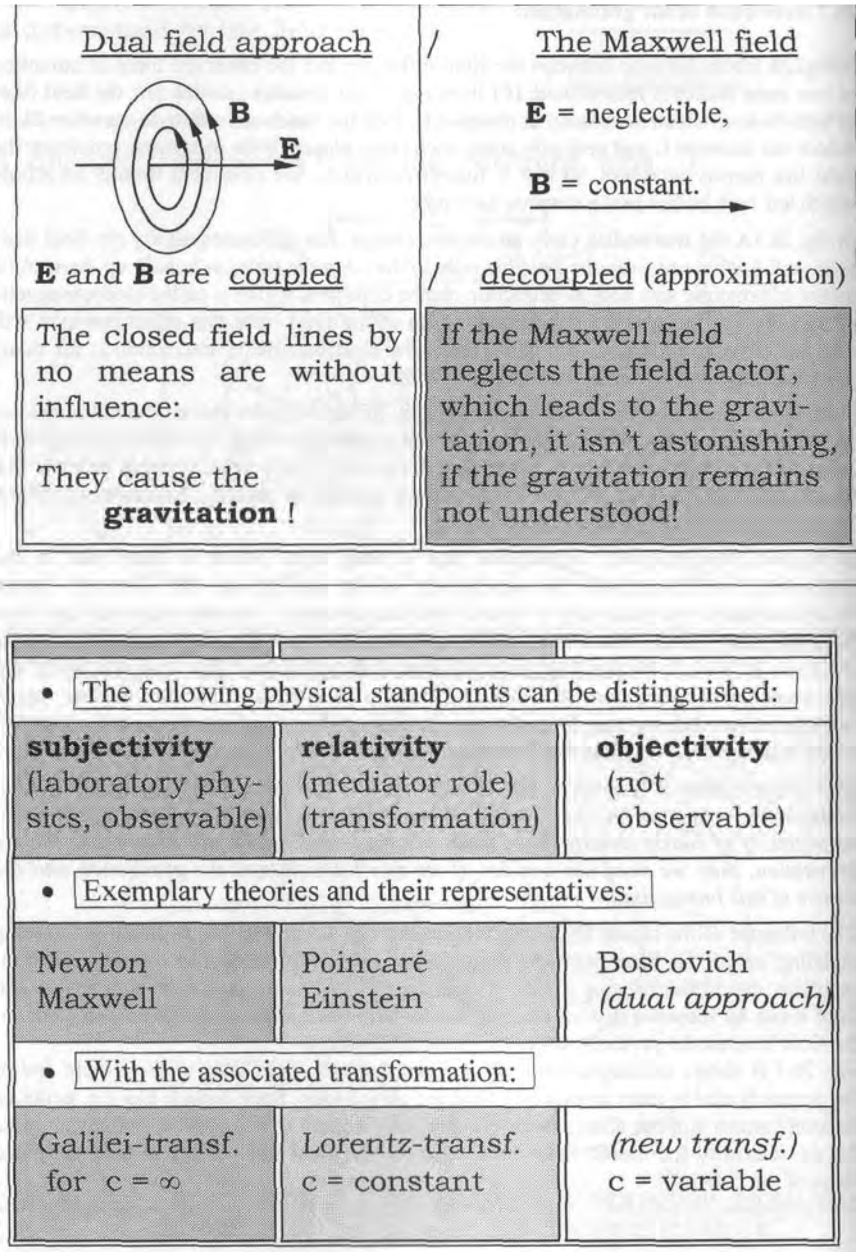

Dual field approach / The Maxwell field

E = neglectible,

B = constant.

E and **B** are coupled / decoupled (approximation)

The closed field lines by no means are without influence:

They cause the **gravitation** !

If the Maxwell field neglects the field factor, which leads to the gravitation, it isn't astonishing, if the gravitation remains not understood!

- The following physical standpoints can be distinguished:

subjectivity	**relativity**	**objectivity**
(laboratory physics, observable)	(mediator role) (transformation)	(not observable)

- Exemplary theories and their representatives:

Newton Maxwell	Poincaré Einstein	Boscovich *(dual approach)*

- With the associated transformation:

Galilei-transf. for c = ∞	Lorentz-transf. c = constant	*(new transf.)* c = variable

Fig. 28.8: Physical standpoints

28.8 From subjectivity to objectivity

With the field lines interpretation, which by the way already preferably was used by Faraday, the gravitation proves to be an until now neglected influence of the electromagnetic field. With that for the first time also the grand unification of the interactions was successful. The long sought-for unified theory with that for the first time comes within reach.
The derivation has made it possible to mathematically secure the theoretical working model of Boscovich. Already 1755 Boscovich points out the optical deception, which our observation underlies, if absolute orders of magnitude in our neighbourhood should change and our perception would change along. Then also all metric and optical measurement results would underlie this change. Following the idea of Boscovich I distinguish between subjectivity and objectivity.

The relativity is a compromise lying between both points of view, where a neutral standpoint is strived for, which lies outside the events. And from this standpoint the objectively taking place events are being observed. The theory of relativity consequently is a pure observer theory with strongly restricted scope on the basis of the Lorentz-transformation.

Theories of classic physics, like e.g. Newtonian mechanics, fall in the domain of subjectivity. The results and regularities are won in a terrestrial laboratory if possible isolated from the environment, where they have absolute validity. Here the Galilei-transformation is valid.
But if these subjectively won laws are applied to the microcosm in quantum physics or to the calculation of cosmic observations, one fast hits limits. The better the resolution of the microscopes and telescopes gets, the clearer the „outside" observer realizes, how much the laws of classic physics lose their validity.

Astrophysics successfully reaches for the theory of relativity, which with the curvature of space in the vicinity of mass centres delivers useful explanations. Here the dependence of the spatial dimensions on the field already could be established. In contradiction to that this fundamental relation is said to play no role whatsoever in quantum physics, or in all terrestrial laboratory experiments. But with which right may physical regularities from one domain be ignored in others? There only can exist one physics and that should be sought for!

What we need is objectivity! Behind all the apparently disconnected phenomena of physics work quite simple laws, which can't be observed and are until now not recognized by us. Objective physics in the words of Goethe is the one, which holds the world together in the heart of hearts. I call this, already by Boscovich suggested point of view, theory of objectivity. The access to the model domain of objectivity must be made mathematically by means of a transformation, since it is blocked for us by means of measurements or observations (see chapters 6.15-6.19). The transformation back into the observation domain must be made according to the same mathematical relations (fig. 28.9). In this way the quantum properties of the elementary particles can be calculated with high accuracy and agreement with the values, which until now only could be measured (chapter 7).

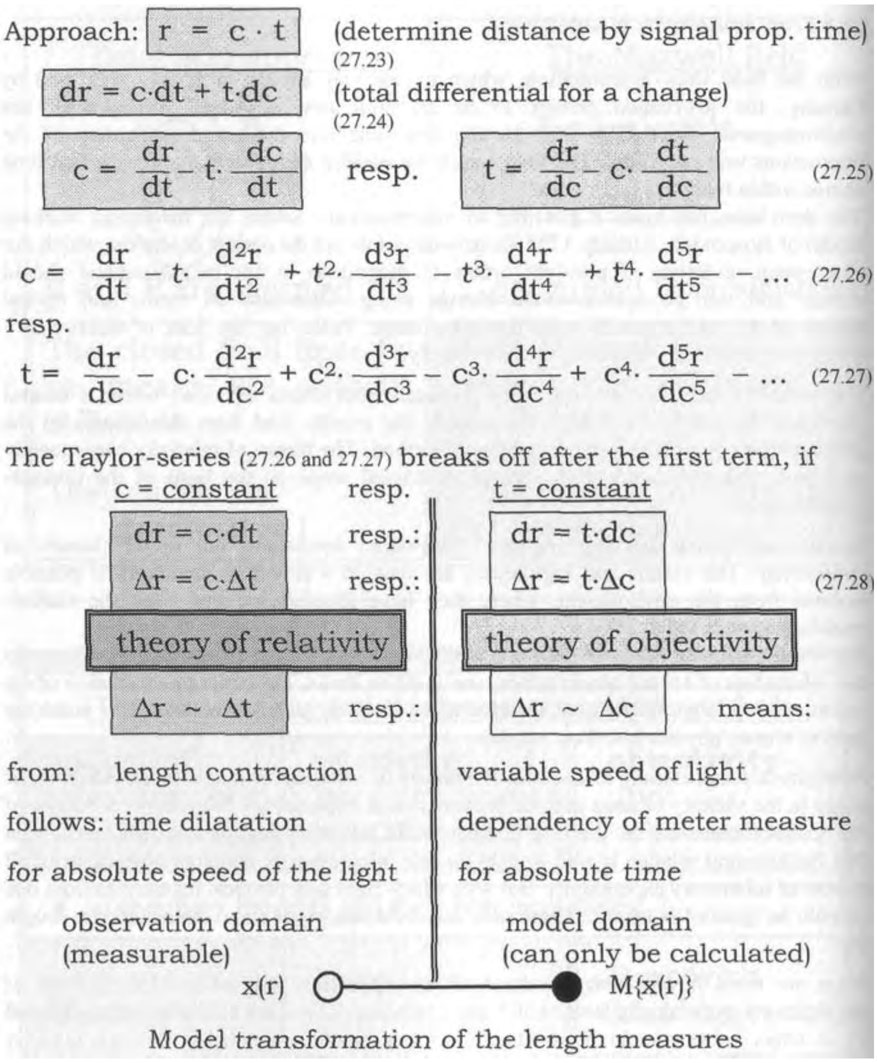

Approach: $\boxed{r = c \cdot t}$ (determine distance by signal prop. time) (27.23)

$\boxed{dr = c \cdot dt + t \cdot dc}$ (total differential for a change) (27.24)

$$\boxed{c = \frac{dr}{dt} - t \cdot \frac{dc}{dt}} \quad \text{resp.} \quad \boxed{t = \frac{dr}{dc} - c \cdot \frac{dt}{dc}} \qquad (27.25)$$

$$c = \frac{dr}{dt} - t \cdot \frac{d^2r}{dt^2} + t^2 \cdot \frac{d^3r}{dt^3} - t^3 \cdot \frac{d^4r}{dt^4} + t^4 \cdot \frac{d^5r}{dt^5} - \ldots \qquad (27.26)$$

resp.

$$t = \frac{dr}{dc} - c \cdot \frac{d^2r}{dc^2} + c^2 \cdot \frac{d^3r}{dc^3} - c^3 \cdot \frac{d^4r}{dc^4} + c^4 \cdot \frac{d^5r}{dc^5} - \ldots \qquad (27.27)$$

The Taylor-series (27.26 and 27.27) breaks off after the first term, if

c = constant	resp.	t = constant	
$dr = c \cdot dt$	resp.:	$dr = t \cdot dc$	
$\Delta r = c \cdot \Delta t$	resp.:	$\Delta r = t \cdot \Delta c$	(27.28)
theory of relativity		**theory of objectivity**	
$\Delta r \sim \Delta t$	resp.:	$\Delta r \sim \Delta c$	means:

from:	length contraction	variable speed of light
follows:	time dilatation	dependency of meter measure
	for absolute speed of the light	for absolute time
	observation domain (measurable)	model domain (can only be calculated)

Model transformation of the length measures

Fig. 28.9: Theory of relativity and theory of objectivity and the model transformation between both physical standpoints

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<i>: Repetition of part 1, fig. 6.16

28.9 The objective standpoint

The question is asked how one gets to an objective physical standpoint, which in addition evades every observation? The way leads over a transformation, to which all perceptible and measurable relations must be submitted.
If we for instance measure the distance r to a point light source, then the propagation of the light c and the propagation time t determine the distance measure r = c*t
If there occurs a little change of the distance, then two causes should be considered: Either the propagation time or the speed of light have changed somewhat. With that the two possible standpoints already would have been found.

The relativistic standpoint, which proceeds from the assumption of the speed of light being constant, says: the propagation time varies and we are dealing with a clock problem. If namely for relativistic velocities a length contraction occurs, then from that necessarily follows a time dilatation.
But actually no specific statement can be made about the constancy of the speed of light, besides that we look at, measure and scan everything with c and hence only observe the constancy. With that the theory of relativity remains a pure observer theory, exactly as Einstein originally called it into existence. This standpoint follows the motto: What can't be observed also doesn't need to interest the physicist.

The objective standpoint strives for more, for a description of the actually taking place processes. This time we proceed from the assumption of a universal and constant time with the argument: The time measure is an immutable definition and the physicist, who dictates this, himself determines what is simultaneousness. Then there also is no place for time travel and for clocks going wrong.
Therefore the speed of light can take all possible values always in strict proportionality to the length measures. Thus the measured length and distance measures should be transformed and that in the end is the unit ,,meter", which should be replaced by an objective measure.

With that the necessary transformation for variable c would be outlined. This transformation will be enqueued in the file of the big transformations. From it the Lorentz-transformation for c = constant emerges as a special case, like already from that transformation the Galilei-transformation follows for $c = \infty$. How now the relation of the subjective to the objective ,,meter" should be determined; by means of the relation of the relevant fields (eq. 28.17) or by means of the square root of Lorentz (eq. 28.16), over that should be worked and spoken. We already have successfully gone through it in a concrete example (chapter 7).

Every theory is judged according to its expressiveness. Ending this chapter the statements and derivations hence again are compared. On the one hand the Maxwell theory and from that the theory of relativity can be derived from the new approach, on the other hand a long list follows, which can't be connected with the Maxwell equations, like e.g. the gravitation. For instance the neutrino and all other elementary particles with all their specific quantum properties are derived (chapter 7), free and easy fundamental laws result, like the law of conservation of energy, and even the temperature spills its until now kept secret (chapter 8.3). Remains the conclusion: With no other approach according to the textbooks until now the efficiency of the new approach could be obtained.

• From the dual field-theoretical approach are derived:	• From Maxwell's field equations can be derived:
=> Maxwell's field equations	=>0
=> Quantum properties of the elementary particles	=>0
=> Neutrino (as an oscillating ring-like vortex)	=>0
=> Gravitation (as a result of closed field lines)	= > 0
=> Unified theory (grand unification of all interactions)	=>0
=> Temperature (as an oscillation of size depending on field)	=>0
=> Law of conservation of energy (and many other fundamental laws of physics)	=>0
=> Theory of objectivity	=> Theory of relativity

Fig. 28.10: Comparison of the efficiency of the approaches
(final balance)

29. Mathematical gleanings

If, proceeding from the new field-physical approach, well-known and accepted theories are derived as special cases, this on the one hand can be valued as evidence for the correctness of the approach. On the other hand the new approach in part significantly influences the interpretation of the derived theories. That can involve a rethinking, with which not insightful people have difficulties, if for instance quantum physics, thermodynamics or the gravitation become partial aspects of electromagnetism. Over and above that are hidden many new thing in the new approach, which are there to discover. To that are counting among others the potential vortices and the scalar waves. One can work out these phenomena physically or mathematically, where the latter way as a rule is the faster one. Hence the summary shall be concluded with a kind of mathematical gleanings.

29.1 General and special theory of relativity

Albert Einstein distinguishes between general and special theory of relativity. Whereas the special (SRT), still is linked tightly with the prerequisites of the Lorentz-transformation, the general (GRT), deals with an extension to arbitrary systems, which mustn't be inertial systems. I would like not to dwell upon the GRT, as Einstein designed it, and merely notice that every generalization represents a possible source of errors and has to be well founded.

In the case of our derivation, the general case as it were resulted of its own accord. Let's turn back: If the root of Lorentz still was a component of the derived field dilatation (28.15) and equally of the length contraction (28.16), then it fell out in the comparison of both results (28.17). With that the important result, the proportionality (28.18), which among others results in the gravitation, becomes independent of the speed of light and the relative velocity v. This last step is obvious and still completely new. It cannot be found at Einstein, who in another way finds his GRT and his description of the gravitation. Even if here is striven for the same goal, then deviations in the result cannot be excluded because of the differences in the derivation, for which reason I additionally mark the by me derived general relativity (GRT'), to avoid confusion.

Influence of the Lorentz-transformation in the:
SRT (special theory of relativity): one-dimensional,
GRT' (general theory of relativity): three-dimensional, to a large extent corresponding to the GRT of Albert Einstein,
GOT (general theory of objectivity)

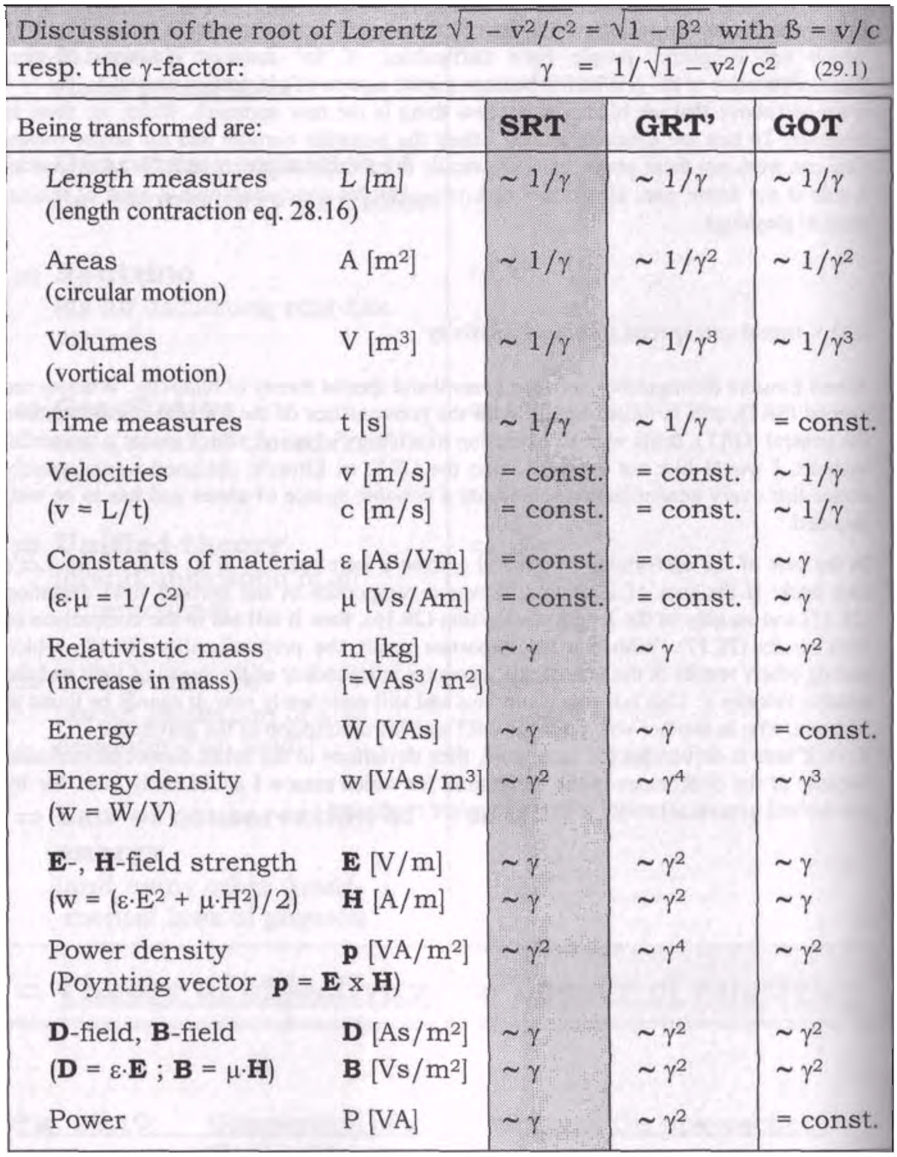

Discussion of the root of Lorentz $\sqrt{1 - v^2/c^2} = \sqrt{1 - \beta^2}$ with $ß = v/c$
resp. the γ-factor: $\gamma = 1/\sqrt{1 - v^2/c^2}$ (29.1)

Being transformed are:		SRT	GRT'	GOT
Length measures (length contraction eq. 28.16)	L [m]	$\sim 1/\gamma$	$\sim 1/\gamma$	$\sim 1/\gamma$
Areas (circular motion)	A [m²]	$\sim 1/\gamma$	$\sim 1/\gamma^2$	$\sim 1/\gamma^2$
Volumes (vortical motion)	V [m³]	$\sim 1/\gamma$	$\sim 1/\gamma^3$	$\sim 1/\gamma^3$
Time measures	t [s]	$\sim 1/\gamma$	$\sim 1/\gamma$	= const.
Velocities	v [m/s]	= const.	= const.	$\sim 1/\gamma$
(v = L/t)	c [m/s]	= const.	= const.	$\sim 1/\gamma$
Constants of material	ε [As/Vm]	= const.	= const.	$\sim \gamma$
$(\varepsilon \cdot \mu = 1/c^2)$	μ [Vs/Am]	= const.	= const.	$\sim \gamma$
Relativistic mass (increase in mass)	m [kg] [=VAs³/m²]	$\sim \gamma$	$\sim \gamma$	$\sim \gamma^2$
Energy	W [VAs]	$\sim \gamma$	$\sim \gamma$	= const.
Energy density (w = W/V)	w [VAs/m³]	$\sim \gamma^2$	$\sim \gamma^4$	$\sim \gamma^3$
E-, **H**-field strength	**E** [V/m]	$\sim \gamma$	$\sim \gamma^2$	$\sim \gamma$
$(w = (\varepsilon \cdot E^2 + \mu \cdot H^2)/2)$	**H** [A/m]	$\sim \gamma$	$\sim \gamma^2$	$\sim \gamma$
Power density (Poynting vector $\mathbf{p} = \mathbf{E} \times \mathbf{H}$)	**p** [VA/m²]	$\sim \gamma^2$	$\sim \gamma^4$	$\sim \gamma^2$
D-field, **B**-field	**D** [As/m²]	$\sim \gamma$	$\sim \gamma^2$	$\sim \gamma^2$
$(\mathbf{D} = \varepsilon \cdot \mathbf{E}\ ;\ \mathbf{B} = \mu \cdot \mathbf{H})$	**B** [Vs/m²]	$\sim \gamma$	$\sim \gamma^2$	$\sim \gamma^2$
Power	P [VA]	$\sim \gamma$	$\sim \gamma^2$	= const.

Fig. 29.2 Transformation table between SRT, GRT' and GOT

29.2 Transformation table

Let's speak again about the difference to the special relativity (SRT). This so to speak deals with the one-dimensional case of the uniform motion of a reference system in x-direction ($v = v_x$), as specified by the Lorentz-transformation, where only the x-components and not those in y- or z-direction are being transformed. As already mentioned this is a purely theoretical case, which in practice occurs next to never. Normal is circular and vortical and with that accelerated motion, where the velocity component permanently changes its direction.

The derived result of the general relativity (GRT') does justice to this circumstance. Even if this at first only has been derived for the x-direction it nevertheless is valid equally in y- and z-direction. It even remains valid for the case that we base on a path of arbitrary form of a spatial field vortex. In this case some components continually occur in all directions of space, so that the relative velocity v as already the speed of light c loses its vectorial nature. With that the transition of the SRT to the GRT is carried out. By means of the spatial swirling the electric and magnetic field pointers at the same time turn into scalar factors, by taking over the function of the aether. Let us remember that even Einstein in his GRT was forced to again introduce the aether, which in the SRT still was unnecessary.

It therefore makes a difference in the transformation of physical factors, if we base on a one-dimensional (SRT) or a three-dimensional spatial description (GRT). Length measures in x-direction in both cases must be converted using the root of Lorentz. Usually the relativistic γ-factor is introduced, which is inverse to the root of Lorentz

$$\gamma = 1/\sqrt{1-v^2/c^2}) \qquad \text{with } x_o/x = \gamma \quad (29.2)$$

If thus individual length measures would be subject to a length contraction following the γ -factor, then a volume V according to the SRT must be transformed with γ, according to the GRT' however with γ^3.

As is well-known a relativistic increase in mass is converted with the γ-factor and in the same manner the to that proportional energy $E = m\ c^2$. If we however correlate the energy to the volume V and in that way determine an energy density w, then the difference between SRT ($w \sim \gamma^2$) and GRT' ($w \sim \gamma^4$) again has its maximum effect.

A relation to the field factors of E- and H-field is for instance provided by the energy density of a wave field

$$w = (\varepsilon \cdot E^2 + \mu \cdot H^2)/2 \quad (29.3)$$

According to that the field strengths in the one-dimensional case of the SRT should be converted with the γ-factor, in the case of the GRT' however with γ^2, in accordance with the derivation in chapter 28. This circumstance willingly is overlooked, although it only concerns the textbooks and the today valid theory of relativity. I however point to the difference, since it does make a difference if we start with the SRT or the GRT when we change to the general theory of objectivity (GOT).

In the domain of the GOT all length measures should be transformed. The respective dimension gives information with which power the γ-factor occurs (fig. 29.2). The unit meter is responsible for that.

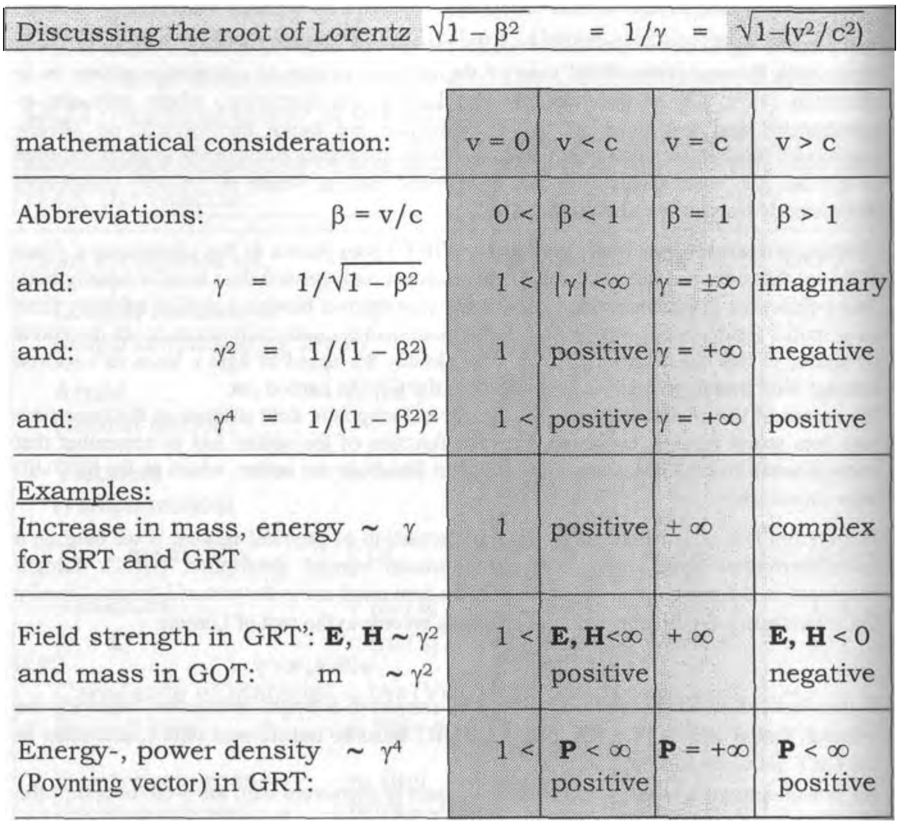

Discussing the root of Lorentz $\sqrt{1-\beta^2} = 1/\gamma = \sqrt{1-(v^2/c^2)}$

mathematical consideration:	v = 0	v < c	v = c	v > c
Abbreviations: $\beta = v/c$	0 <	$\beta < 1$	$\beta = 1$	$\beta > 1$
and: $\gamma = 1/\sqrt{1-\beta^2}$	1 <	$\lvert\gamma\rvert < \infty$	$\gamma = \pm\infty$	imaginary
and: $\gamma^2 = 1/(1-\beta^2)$	1	positive	$\gamma = +\infty$	negative
and: $\gamma^4 = 1/(1-\beta^2)^2$	1 <	positive	$\gamma = +\infty$	positive
Examples: Increase in mass, energy ~ γ for SRT and GRT	1	positive	$\pm\infty$	complex
Field strength in GRT': **E**, **H** ~ γ^2 and mass in GOT: m ~ γ^2	1 <	**E**, **H** $< \infty$ positive	$+\infty$	**E**, **H** < 0 negative
Energy-, power density ~ γ^4 (Poynting vector) in GRT:	1 <	**P** $< \infty$ positive	**P** $= +\infty$	**P** $< \infty$ positive

Fig. 29.3 Discussion concerning the root of Lorentz

- The special theory of relativity SKT only is defined for v < c
- For v • c particles with a complex mass, but with a real energy density (according to GRT') would result.
- From the point of view of the theory of objectivity (GOT) the mass should be taken negative-real (neutrino?).

29.3 Discussion concerning the root of Lorentz

Fig. 29.2 forms the basis for the transformation in the domain of the GOT, the general theory of objectivity, where it plays a role, if a subjectively measured factor should be converted from the laboratory domain or a relativistic factor according to the SRT or the GRT'. The given proportionalities thereby should be put in the respective relation. In this way results the respective valid instruction for transformation on the basis of the root of Lorentz.

Let's take a critical look at the root of Lorentz. The velocity v occurring in it, of whatever this may consist, is depending on the field according to equation 28.14 + 28.15. It strictly speaking wouldn't be constant anymore and wouldn't belong in a general instruction for transformation at all. Only, what is valid for v, is valid to the same extent for c. Since only the proportion of v/c occurs in the root of Lorentz every influence depending on field or of other nature will have no effect on v/c and the value of the root of Lorentz. It in any case will retain its value. It fulfills for itself the condition of the Lorentz invariance. According to that in the case of the relative velocity v it doesn't depend on the absolute value, but only on the relation to the speed of light. In addition the restriction to values of $v < c$ is normal, if the speed of light is seen as an upper limit. Let's first purely mathematically draw a case distinction for different velocity domains of v. For $v = 0$ the root of Lorentz becomes one and the Lorentz transformation turns into the Galilei transformation.

Connected to this is the today well-known and technically used domain up to the limit of $v = c$. It virtually is impossible to accelerate a mass particle to the speed of light, since mass, field and energy would grow towards infinity, as is clear from the table (fig. 29.2). Particles as fast as light, like photons, hence cannot have a mass. At $v = c$ a singularity is present.

In a field theory, which also deserves this name, however an upper limit must not be present. Hence also the case for $v > c$ should be required theoretically. Only later we will be able to judge if this makes sense physically. We at first only want to examine the case mathematically. Mass, field and energy now again have a finite value, there however results a complex, purely imaginary mass, a negative field and doing so, as already before a positive energy and power density.

There sometime has been the textbook opinion that it is physically impossible to fly faster than sound. This erroneous statement even could be proven „scientifically", because such a supersonic airplane would fly off the observation space and with that wouldn't be real anymore, thus from a mathematical viewpoint would be complex. Anyone, who in New York gets off a Concorde, can confirm that everything at any moment of the flight was real. Only the observer is deceived, if the airplane flies somewhere else, than he perceives it. Is the speed of light also such a „sonic barrier", which by the majority of the scientists since Einstein until today still is thought to be insurmountable?

How should one physically imagine a complex mass? Let us remember the alternating current teachings, where it is normal to work with complex values, since the mean values of the oscillating alternating currents, tension voltages and fields are zero. Calculating with mean values would result in zero energy and power. Hence complex factors are introduced and the root mean square values are calculated and measured instead of the mean values. Could a complex mass analogously not concern an oscillating particle, a particle, which in addition is faster than the light?

- Physical example:

neutrino = mean of the oscillating mass≈zero
RMS value of the complex mass≠zero
E- and H-field with inverse sign
carrier of positive energy and power
ν -model: ring-like vortex oscillating from e^- to e^+ <i>

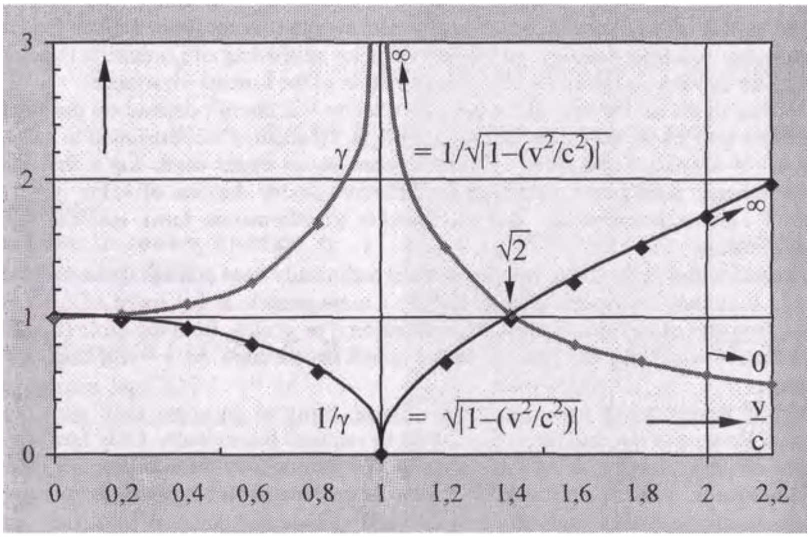

Examples from the general theory of relativity (GRT):

(28.16): length contraction $L \sim 1/\gamma = \sqrt{1-(v^2/c^2)}$

(6.19): increase in mass $m \sim \gamma = 1/\sqrt{1-(v^2/c^2)}$

(6.6,28.15) field dilatation $\mathbf{E} \sim \mathbf{H} \sim \gamma^2 = 1/(1-v^2/c^2)$

Fig. 29.4: Root of Lorentz for speeds faster than light (v > c)

29.4 Mathematical derivation of the neutrino

In the domain of speeds faster than light, for v > c, the power series (28.12) does not converge anymore and every observer theory and every observation (fig. 28.4) will fail, because particles faster than light run away of their own visible appearances. Every measurement and every observation inevitably is behind and hardly can be assigned to the actual cause. That way for instance measured neutrino events are being connected with celestial observations, with which they haven't got anything to do at all.
If we however describe the domain v > c in the complex plane, then astonishing results are found, which could be verified physically: a complex length dilatation with increasing velocity goes along with a loss of complex mass. The oscillating fields, energy and power density however would be real with negative sign.
Thus there would result particles carrying energy with an oppositely poled field, with an oscillating mass and if necessary also an oscillating charge. Without static mass and charge these particles hardly would interact with normal matter, which leads to an enormous ability of penetration. The only physical particles, which have such a property, are the neutrinos. With that a usable and an extremely efficient model description has been found for these particles. Also the energy of these particles can be calculated, which has considerable orders of magnitude and is available as an energy source everywhere and any time.

If for instance in a converter for space energy a neutrino should be converted into a resting charge carrier (with v = 0), then two steps are necessary (see part 2 of this series of books):

1. First the neutrino must be slowed down to 1.414 times the speed of light (fig. 28.9). Doing so energy is spent and not won! The converter for instance can cool down.

2. Afterwards the characteristic rotation of its own, with which the ring-like vortex spins around itself by permanently putting its inside to the outside and vice versa, has to be taken away from the neutrino. In that way the vortex centre is closed and the particle acquires localization. It becomes a charge carrier.

Even if the representation in the complex plane represents only an auxiliary description, the model nevertheless seems to be efficient, because despite its complex mass and charge the neutrino nevertheless carries a real energy. It in any case is represented in that way to an observer, who measures the relation with the speed of light, who in the relativistic scheme of things scans the relation.

Today, as already said, even the sonic barrier has become permeable and no scientist dares to physically deny this fact and even prove his mistake mathematically anymore. No, on the contrary, he always did know that as an expected consequence the sonic barrier runs after the supersonic plane. The once physically unthinkable and scientifically fought has become normality.
What should hinder an oscillating particle, like a neutrino, to be faster than the light? Some time one also will accustom to that.

- Starting-point:

the fundamental field equation
(derivation in chapter 27.10)

$$-c^2\cdot\mathrm{rot}\ \mathrm{rot}\ \mathbf{B} = \frac{\partial^2\mathbf{B}}{\partial t^2} + \frac{1}{\tau_1}\frac{\partial\mathbf{B}}{\partial t} + \frac{1}{\tau_2}\frac{\partial\mathbf{B}}{\partial t} + \frac{\mathbf{B}}{\tau_1\tau_2} \qquad (27.26)$$

- Example:

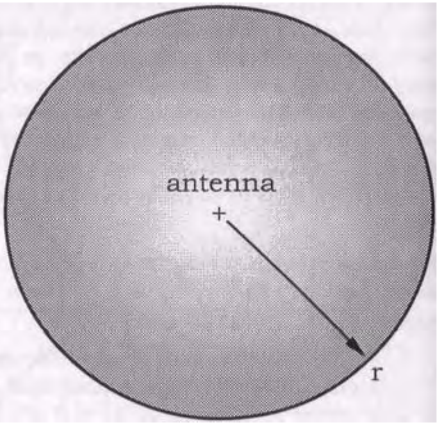

Spherical propagation of an electromagnetic wave in space

- The number π: $\pi = 3.14159$

straight		$\pi\cdot$	circular		spherical
r	$\cdot$	$\pi\cdot 2 =$	$2r\cdot\pi$	$\cdot\ 2r =$	$\pi\cdot r^2\cdot 4$
line			**circum-ference**		**surface**
r	$\cdot$	$\pi\cdot r =$	$r^2\cdot\pi$	$\cdot\ r\cdot 4/3 =$	$\pi\cdot r^3\cdot 4/3$
line			**area**		**volume**

(29.4)

Fig. 29.5: The number π

29.5 Universal constants and constants of nature

Strictly speaking fundamental or universal constants can't exist in pure field physics at all. For the example of the speed of light has been shown that it merely are measurement constants (fig. 6.11). The numerical size is a consequence of the definition. The speed of light for instance has the today well-known value as a consequence of the fixing of a length unit and a time unit. If we change a unit, if we take „feet" instead of „meters", then another value results. If however the velocity changes, then the reference measure of our gauge changes along and we get the identical reading. Electric and magnetic field constant depend directly on the speed of light c $(\varepsilon \cdot \mu = 1/c^2)$, which solely by the fixing of the electric units takes a certain value. The inner structure of the potential vortices leads from Planck's quantum of action, to the elementary charge and to the countless atomic „constants", which all objectively seen aren't constants at all. They virtually all can be derived (chapter 7).

Sooner or later even the last natural scientist will realize, that nature does not provide "constants" at all. If „constants of nature"' did exist, as listed in textbooks and encyclopaedias, then they aren't consistent with causality, since we don't know the cause, why the factor should have exactly this size and no other. Behind every so-called constant of nature unnoticed is hiding a physical closed loop conclusion.

Fundamental constants only exist in mathematics. This can be shown very nicely for the example of the „fundamental field equation" (eq. 27.26), which has been derived from the new field theoretical approach (fig. 27.10). It is the description of waves and vortices in space and time, which indeed carries features of a „world equation". If one searches this equation for fundamental constants, then one altogether can find three: the number π, the number e and the Golden Proportion Φ. The speed of light c however occurs only as the mathematical factor characterizing the wave as a result of the defined units. If one would choose the units different, c as well could be made 1. With the fundamental numbers that procedure won't work. They don't depend on the definition of the units!

Let's consider the number π. The number π occurs every time as a proportionality factor if we transition from a straight line to a circle or further to a sphere, from a line to the circumference or further to the surface of a sphere and exactly so from a line to the area of a circle or further to the volume of a sphere. Since for all the special cases, which are derived from the fundamental field equation (the structure of the elementary particles, the atomic structure and in the same way again in the universe), the spherical symmetry dominates, the mathematical solution is determined by a corresponding spatial configuration of the number π. It has its cause neither in a physical relation of interactions, nor in the choice of the units, but only in the geometry.

The number e: $e = \lim_{n \to \infty} (1 + 1/n)^n = 2.71828$ (29.5)

for $n = 2$ is $(1+1/n)^n = 1.5^2 = 2.25$
for $n = 1$ is $(1+1/n)^n = 2^1 = 2$
for $n = 0.5$ is $(1+1/n)^n = \sqrt{3} = 1.73$
for $n = 0$ is $(1+1/n)^n = \infty^0 = 1$
for $n = -0.25$ is $(1+1/n)^n = 1/(-3)^{0.25}$ gives a complex solution!
for $n = -0.5$ is $(1+1/n)^n = 1/\sqrt{-1} = -i$, thus again complex!
for $n = -0.75$ is $(1+1/n)^n = 1/(-3)^{0.75}$ as well complex!
for $n = -1$ is $(1+1/n)^n = 1/0 = \pm\infty$
for $n = -2$ is $(1+1/n)^n = 2^2 = 4$

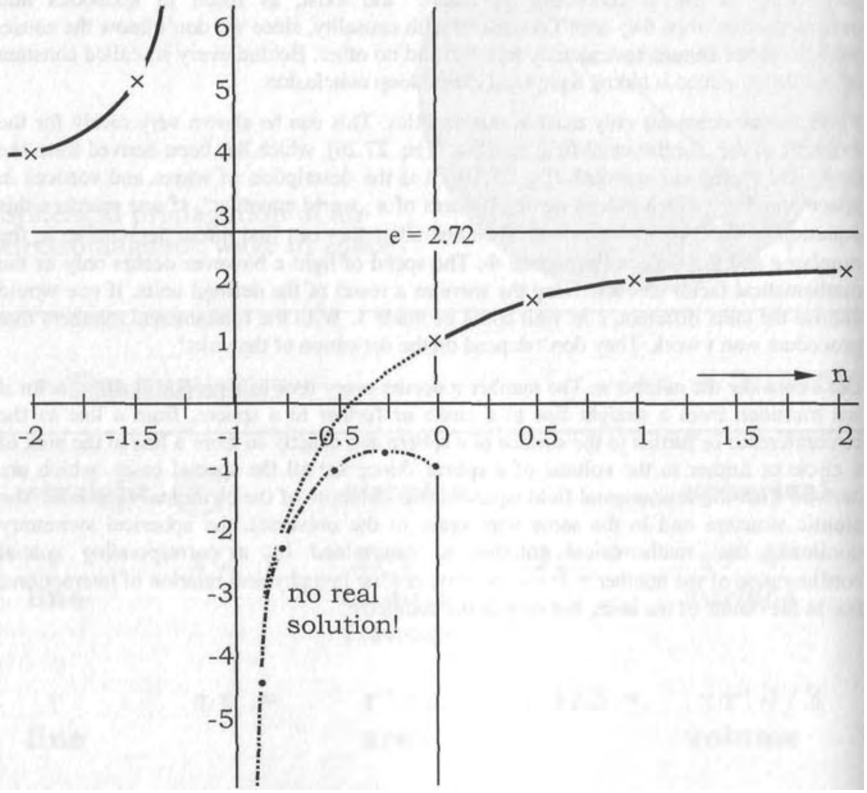

Fig. 29.6: Forming the limiting value of the number e

29.6 The fundamental number e

In the fundamental field equation (27.26) a further irrational number is concealed, the number e. Whereas the left side of the equation (a) gives the spatial distribution, the right side (b-e) describes the temporal course of events. Besides the term constant in time (e) also first time derivations (c and d) and a second time derivation (b) occur. For a solution of this differential equation a function should be found, the derivations of which are again the function itself. This condition strictly speaking is fulfilled only by one single function, the e-function.
We used this property of the e-function already for the derivation of the Schrodinger-equation in chapter 5.6 and 5.7. There with the help of the e-function an approach was chosen, which leads to the well-known solutions of the Schrodinger-equation, which are considered to be secured experimentally. With that the number e controls the temporal relations of the fundamental field equation.

It might be helpful to take a closer look at the origin of the number e. It results from a consideration of limiting values: _

$$e = \lim_{n \to \infty} (1 + 1/n)^n = 2.71828 \quad (29.5)$$

If one varies n and allows different values between -∞ and +∞, then a strange behaviour is showing. One indeed more and more approaches the well-known value of e = 2.72, as dictated by the definition of limiting values according to equation (29.5), the larger n is chosen. But in the opposite direction it looks less tidied:

$$\begin{array}{llllllll} & \text{for} & n = 1 & \text{is} & (1+1/n)^n & = 2^1 & = 2 & \\ & \text{for} & n = 0{,}5 & \text{is} & (1+1/n)^n & = \sqrt{3} & = 1.73 & \\ & \text{for} & n = 0 & \text{is} & (1+1/n)^n & = \infty^0 & = 1 & \\ & \text{for} & n = -0{,}5 & \text{is} & (1+1/n)^n & = 1/\sqrt{-1} & = -i\text{, thus complex!} & \\ \text{and} & \text{for} & n = -1 & \text{is} & (1+1/n)^n & = 1/0 & = \pm\infty & (29.6) \end{array}$$

Since the e-function inside the fundamental field equation is responsible for the temporal sequence, the interpretation of my colleague Prof. Dr. Preussker<i> gets a deeper sense. He says, it starts outside our imagination (at n = -1). Afterwards at first big chaos prevails. Mathematically seen some imaginary solutions arise. Finally the system is putting in order (from n = 0), to more and more approach the value e = 2.72 .

The number e is of fundamental importance and thereby holds unforeseen secrets. More mysterious and until now entirely misunderstood is the meaning of the Golden Proportion. Also this indivisible number can be found in the fundamental field equation. Since it is less known and more complicated to handle, it first shall be introduced.

<i>: H. Preussker: Der Wirbelring, Halstenbeck 2002

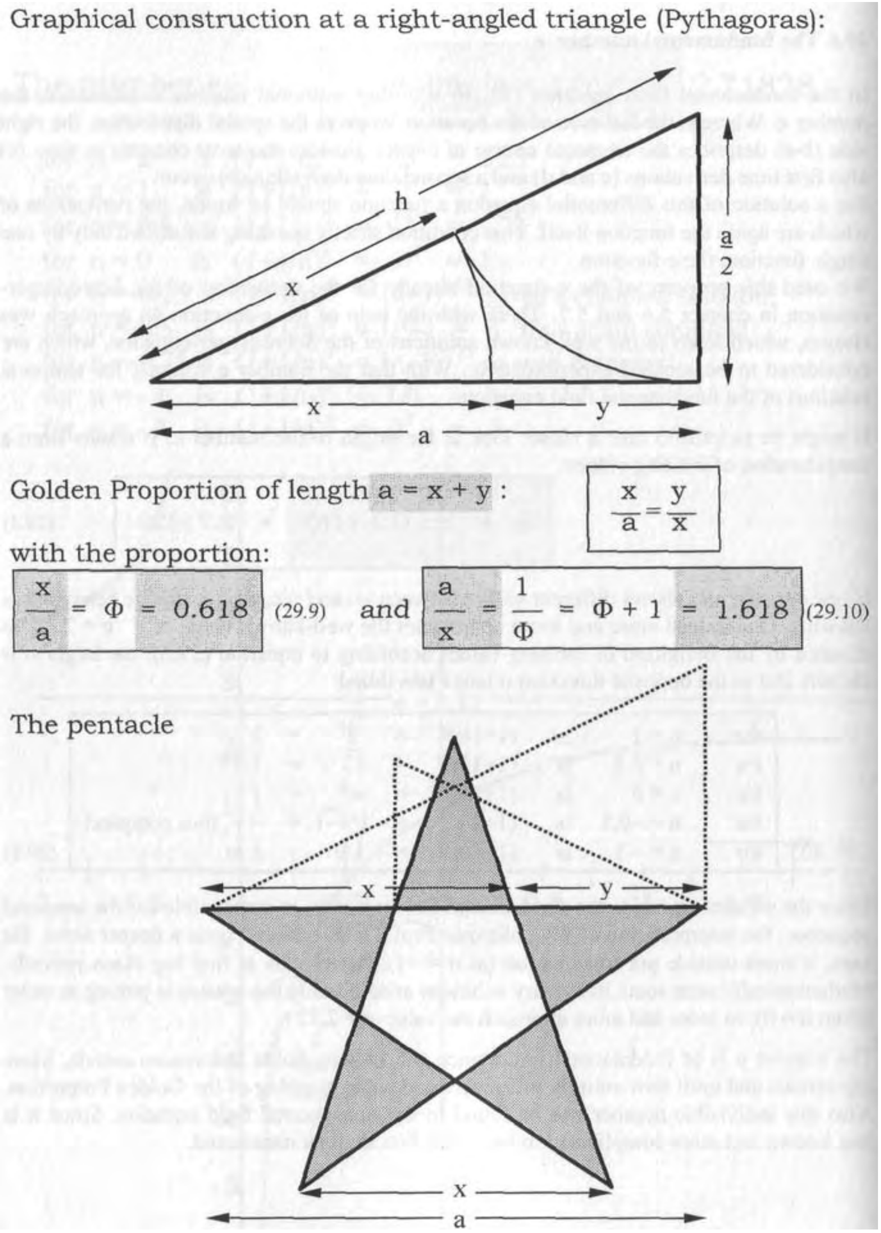
Graphical construction at a right-angled triangle (Pythagoras):
h
x
a/2
x
y
a
Golden Proportion of length a = x + y :
x/a = y/x
with the proportion:
x/a = Φ = 0.618 (29.9)
and a/x = 1/Φ = Φ + 1 = 1.618 (29.10)
The pentacle
x
y
x
a

Fig. 29.7: Constructions for the Golden Proportion

29.7 The pentacle

During his visit of the Egyptian pyramids already two and a half thousand years ago the history writer Herodotus by his guide had been called attention to the circumstance that the Golden Proportion has been realized for the proportions of scale.
In the case of the pyramid of Cheops it even has been taken into account manifold, as we know today, but we hence still don't know why. There must be an intention behind it. Anyway a coincidental use can be eliminated, since the Golden Proportion cannot be handled in an easy way, neither graphically nor mathematically.
The Golden Proportion in addition plays an important role in the whole ancient architecture and not only there. It for instance occurs in the case of a very old symbol, the five edged star, which we can draw with one line without taking off. The well-known symbol also is called pentacle.

In the case of the Golden Proportion a straight line a is divided into two unequal halves. The larger half x thereby is 61.8 % of the straight line a. Already Pythagoras has researched and teached about this. Maybe he did know more about the purpose of this classification than all the mathematicians, archaeologists and art historians of today together.
For a graphical solution we assume a right-angled triangle. The task is to divide one leg of length a = x + y according to the Golden Proportion into two parts, the larger part x and the smaller part y. The second leg has the length a/2. According to the theorem of Pythagoras the length of the hypotenuse h is

$$h = \sqrt{a^2 + (a/2)^2} = (a/2)\cdot\sqrt{5} \quad (29.7)$$

If the length of the second leg (a/2) is subtracted from the hypotenuse, then this is the sought length x = h-a/2:

$$\boxed{x = (a/2)\cdot(\sqrt{5} - 1)} \quad (29.8)$$

The proportion of both length measures gives the constant Φ, which is characteristic for the Golden Proportion:

$$\boxed{\Phi = x/a = (\sqrt{5} - 1)/2 = 0.618} \quad (29.9)$$

This proportional number has a special property. If one adds 1 to the number and forms the reciprocal value of that, then the same number comes out again, thus:
with Φ = x/a : with a = x + y :

$$\boxed{\Phi + 1 = \frac{1}{\Phi}} \quad \text{and} \quad \boxed{\frac{x}{a} + 1 = \frac{a}{x}} \quad \text{resp.} \quad \boxed{\frac{x}{a} = \frac{a - x}{x} = \frac{y}{x}} \quad (29.10)$$

With that the ratio of the length a and the larger section x is the same as the ratio of x and the smaller section y.

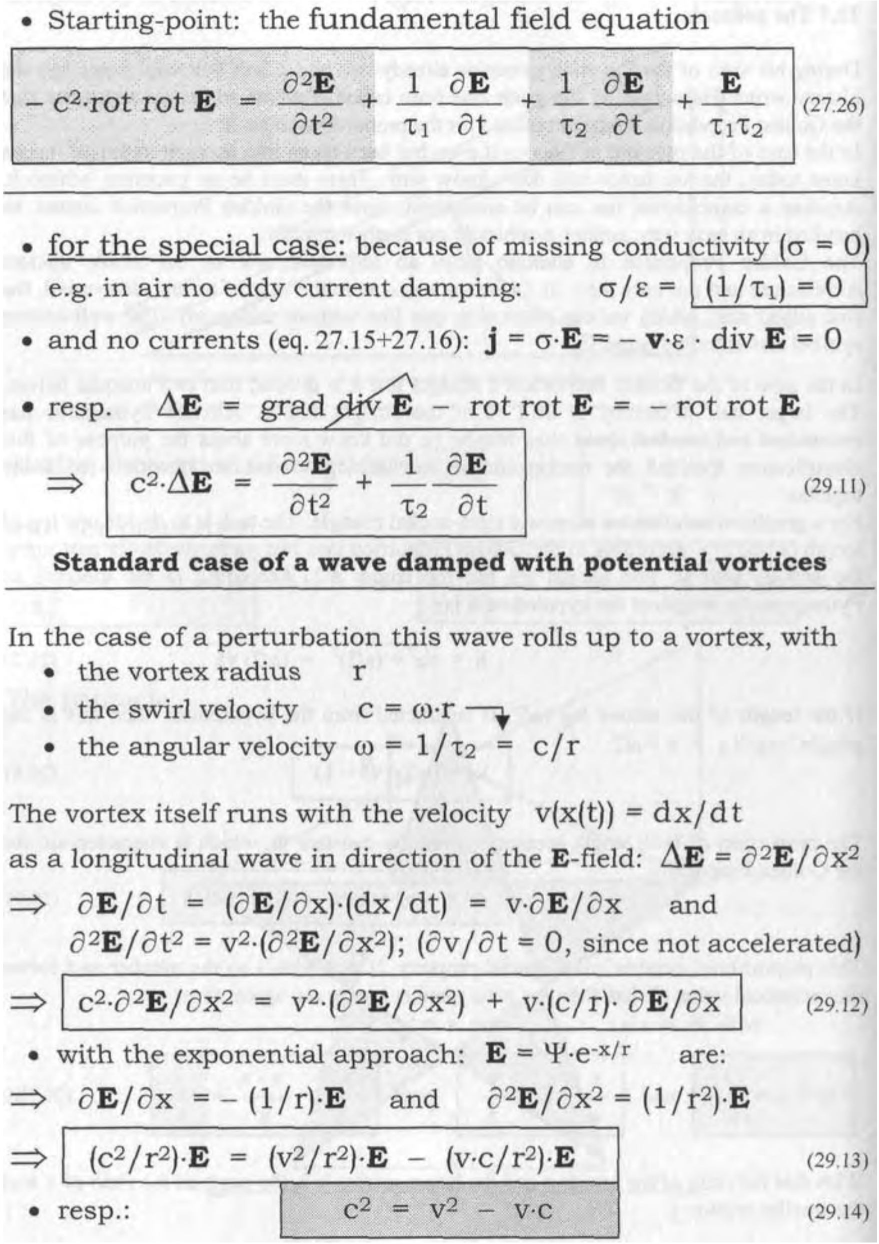

- Starting-point: the fundamental field equation

$$\boxed{-c^2 \cdot \text{rot rot } \mathbf{E} = \frac{\partial^2 \mathbf{E}}{\partial t^2} + \frac{1}{\tau_1}\frac{\partial \mathbf{E}}{\partial t} + \frac{1}{\tau_2}\frac{\partial \mathbf{E}}{\partial t} + \frac{\mathbf{E}}{\tau_1 \tau_2}} \qquad (27.26)$$

- for the special case: because of missing conductivity ($\sigma = 0$)
  e.g. in air no eddy current damping: $\sigma/\varepsilon = \boxed{(1/\tau_1) = 0}$
- and no currents (eq. 27.15+27.16): $\mathbf{j} = \sigma \cdot \mathbf{E} = -\mathbf{v} \cdot \varepsilon \cdot \text{div } \mathbf{E} = 0$
- resp. $\Delta \mathbf{E} = \text{grad } \cancel{\text{div } \mathbf{E}} - \text{rot rot } \mathbf{E} = -\text{rot rot } \mathbf{E}$

$$\Rightarrow \quad \boxed{c^2 \cdot \Delta \mathbf{E} = \frac{\partial^2 \mathbf{E}}{\partial t^2} + \frac{1}{\tau_2}\frac{\partial \mathbf{E}}{\partial t}} \qquad (29.11)$$

Standard case of a wave damped with potential vortices

In the case of a perturbation this wave rolls up to a vortex, with

- the vortex radius r
- the swirl velocity $c = \omega \cdot r$
- the angular velocity $\omega = 1/\tau_2 = c/r$

The vortex itself runs with the velocity $v(x(t)) = dx/dt$
as a longitudinal wave in direction of the **E**-field: $\Delta \mathbf{E} = \partial^2 \mathbf{E}/\partial x^2$

$\Rightarrow \quad \partial \mathbf{E}/\partial t = (\partial \mathbf{E}/\partial x) \cdot (dx/dt) = v \cdot \partial \mathbf{E}/\partial x$ and
$\partial^2 \mathbf{E}/\partial t^2 = v^2 \cdot (\partial^2 \mathbf{E}/\partial x^2)$; ($\partial v/\partial t = 0$, since not accelerated)

$$\Rightarrow \quad \boxed{c^2 \cdot \partial^2 \mathbf{E}/\partial x^2 = v^2 \cdot (\partial^2 \mathbf{E}/\partial x^2) + v \cdot (c/r) \cdot \partial \mathbf{E}/\partial x} \qquad (29.12)$$

- with the exponential approach: $\mathbf{E} = \Psi \cdot e^{-x/r}$ are:

$\Rightarrow \quad \partial \mathbf{E}/\partial x = -(1/r) \cdot \mathbf{E}$ and $\partial^2 \mathbf{E}/\partial x^2 = (1/r^2) \cdot \mathbf{E}$

$$\Rightarrow \quad \boxed{(c^2/r^2) \cdot \mathbf{E} = (v^2/r^2) \cdot \mathbf{E} - (v \cdot c/r^2) \cdot \mathbf{E}} \qquad (29.13)$$

- resp.: $\boxed{c^2 = v^2 - v \cdot c}$ (29.14)

Fig. 29.8:____ The calculation of an electromagnetic wave, which is rolling up to a potential vortex.

The big mystery concerning the harmony of the Golden Proportion gets a sober technical-physical dimension with the theory of objectivity. It determines within the fundamental field equation" (27.26) the rolling up of a wave into a vortex and vice versa. The Golden Proportion mathematically describes the process known as wave damping, as we can make ourselves clear.

29.8 The vortex, which is rolling up

For the case of a wave propagation in air or in vacuum, if no electric conductivity is present ($\sigma = 0$), the fundamental field equation is reduced to the two parts: the description of the electromagnetic wave and the potential vortex as a damping term. Now a solution of this partial differential equation (29.11) is sought. This only succeeds for a very particular course of spatial and temporal field.

If a wave for a field perturbation rolls up to a vortex, which we had worked out as a model concept, then the field oscillation continues to run with the speed of light, but this time in circles. With this consideration the relation between the angular velocity resp. the time constants and the radius of the circular vortex has been described ($\tau_2 = r/c$).

$v(x(t)) = dx/dt$ is the not-accelerated velocity of propagation of a vortex. In that case v points in the x-direction radially to the outside. For the time derivation of the field vector $E(x(t))$ the chain rule should be applied. With that the field equation (29.11), defined in space and time, can be converted into an equation determined in v and x (29.12).

Finally we use the mentioned property of the e-function, which for first and second derivation again turns into itself, by choosing the approach of an exponential damping with $e^{-x/r}$ There remains a quadratic equation to determine the velocity v (29.14 and 29.15). From the two solutions of the quadratic equation only the one with positive velocity should be considered (29.17) and that would be 1.618 times the speed of light! (29.18).
If we subtract 1 from this value or form the reciprocal value, then in both cases the factor $\Phi = 0.618$ results, which is called the Golden Proportion (29.19).

Behind this clear, mathematically won result is hiding a deeper physical meaning. Obviously nothing can hinder a longitudinal wave and its vortices to be slower or faster than just with $v = 1.618*c$. Let us take the case that $v = c$, for which there even exist calculations in some textbooks<i>. Then as a result gets out that the longitudinal parts decrease very quickly and already can be neglected after $\lambda/2\pi$. I in any case interpret the near-field zone of an antenna (fig. 29.9) such that within one sixth of the wavelength the vortices to a large extent have decayed.

<i>: Zinke, Brunswig: Lehrbuch der Hochfrequenztechnik, 1. Bd., 3.Aufl. Springer-Verlag Berlin 1986, Seite 335

- The quadratic equation 29.14: $\boxed{v^2 - v \cdot c - c^2 = 0}$ (29.15)
- has the solution: $\boxed{v = c/2 \pm \sqrt{c^2/4 + c^2}}$ (29.16)
- for the proportion v/c: $\boxed{v/c = (1 + \sqrt{5})/2 = 1.618}$ (29.17)
- The result $v/c = \underline{1.618}$ (29.18)
- resp.: $c/v = \Phi = \underline{0.618}$ = „Golden Proportion"(29.19)
- acc. to that is: $1 + \Phi = 1.618 = 1/\Phi = 1/0.618$(29.18*)

- Concerning the physical meaning of $v/c = 1.618$ (29.17)

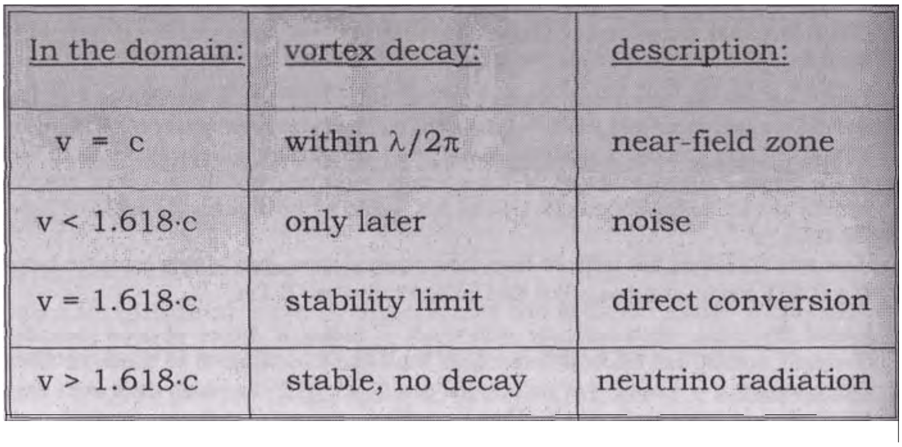

In the domain:	vortex decay:	description:
$v = c$	within $\lambda/2\pi$	near-field zone
$v < 1.618 \cdot c$	only later	noise
$v = 1.618 \cdot c$	stability limit	direct conversion
$v > 1.618 \cdot c$	stable, no decay	neutrino radiation

=>In the ideal case at 1.618 times the speed of light at the stability limit, the natural and spontaneous conversion from vortex to wave and vice versa occurs.

=> Scalar wave antennas have their optimum degree of effectiveness in the Golden Proportion!

Fig. 29.9: Derivation of the Golden Proportion from the fundamental field equation.

For larger velocities, as Tesla has produced already 100 years ago, the stability of the vortices, but also their biological effectiveness increases. From a high-frequency technical viewpoint this is the domain of the noise, the domain of instable oscillating noise vortices. From a biological and medical viewpoint especially here the answers should be sought to questions concerning the electromagnetic environmental compatibility. This domain stretches from v = c to v = 1.618*c, the boundary case, where a spontaneous conversion of the wave into the vortex is possible. The Golden Proportion describes the stability limit, where the field vortices after they have been formed, don't decay anymore. From this velocity on the antenna resp. radiation source hasn't got a limited near-field zone anymore, since that now reaches to infinity. Only from this distinct velocity on I give the field vortices the name "neutrino".

29.9 The Golden Proportion

Whereas traditional antennas, which should emit electromagnetic waves, are optimized for signals with the speed of light, do scalar wave antennas have their optimum degree of effectiveness in the Golden Proportion. Thereby the goal of an emission of oscillating ring-like vortices is pursued. Vortices, which with a velocity of propagation of v = 1.618-c remain stable and make possible a spatially unlimited transmission of energy and information by scalar waves.

The velocity of propagation v is calculated from the product of wavelength times frequency. $v = \lambda \cdot f$. If the frequency of a transmitter is prescribed, then the geometry of the transmitting antenna decides on the degree of effectiveness of the antenna and on how many parts of transverse waves are emitted in relation to longitudinal waves. In the case of a broadcast antenna usually λ or $\lambda/2$ is chosen. For a scalar wave however the optimum is reached with

$$\boxed{\lambda_{\text{vortex}} = 1.618 \cdot \lambda_{\text{wave}} = 1.618 \cdot c/f.} \quad (29.20)$$

With that the electrotechnical problem becomes a geometrical one, if it concerns the use of scalar waves. Crucial is the antenna geometry, and the Golden Proportion provides the necessary constructional instruction. Were the buildings in antiquity, which were constructed according to the Golden Proportion, technical facilities for scalar waves[i]? Did the builders have physically explainable and mathematically provable guidelines? At this place, by the derivation of the Golden Proportion from the fundamental field equation, there arise completely new aspects for the judgement and interpretation of buildings especially from antiquity. If we have understood their way of functioning, then we will be able to learn much from that for our own future and for the future construction of scalar wave devices. Concluding the seminar we hence deal with antiquity.

ancient temple = short wave station

dedicated to one god = fixing of the frequency

supreme god Zeus, = range of the short wave,
father of all gods = all SW wave bands

priest, representative of the god = amateur radio operator, with licence to transmit

high priest = chief intendant

Pontifex Maximus, „topmost bridge builder" = chairman of the authority and the telegraph offices

oracle<i> = telegraphy receiver

runes, cuneiform writing = telegraphy symbols

metre, hexameter = increase of redundancy

oracle priest = telegraphy interpreter

tripod<ii> = reception key, electro-acoustical converter

looking at intestines, rite of sacrificing = reading off convulsions, electro-optical converter

temple books = news-notes

seer, who looks into the god world = amateur radio operator, at telegraphy reception

Homer = ancient radio reporter

Fig. 30.1: ____Little dictionary for ancient radio engineering (1).

<i>: Lamer: Worterbuch der Antike, Kroner Verl. Bd.96 under "oracle" stands: „Lat. oraculum = site of speaking; particularly: site, where a god speaks; then: that, what the god says". According to the encyclopaedia oracle priests inspired by a god „simply were frauds, who lived of the ignorance of the public".

30. Scalar wave technology in antiquity

The end of the book about potential vortices and their propagation as a scalar wave shall form an impressive example, where as many of the derived wave aspects as possible have an effect. It shall be proven that already in antiquity radio engineering based on scalar waves has been used. The proof starts with a thesis.

30.1 Thesis:

The temples in antiquity all were short wave broadcasting stations. And energy from the field served as an energy source, so e.g. the earth radiation in the case of temples of terrestrial gods. In the case of the solar god the radiation of the sun was used, whereas for the temples, which were dedicated to the planetary gods, the neutrino radiation arriving from the planets served as an energy source.

If the temple was dedicated to a particular god, then the name of the god was representing the used frequency of the broadcasting company. The corresponding wavelength, resp. the respective god, understandably was "immortal".

Not so the broadcasting technicians on duty, who as human beings naturally were mortal, who took turns in the studio as members of the priest council and who merely had to impersonate the god Apollo, Poseidon etc. by the name of the broadcasting company, if they went on air. Only for the news editor Homer and for few of his colleagues we actually know the names of the persons behind the scenes.

In the temple books the texts have been recorded, which a god and its broadcasting company have received. The chosen metre served the easier detection and correction of transmission errors.

Here often a lot of fantasy was necessary, for which reason the reception facilities commonly were described as oracle<i>. The reception of the news as a rule took place on an altar. Thereby the direct effect of scalar waves on man e.g. in the case of the so-called temple sleep or the indirect influence on biological systems, e.g. on the intestines of slaughtered animals, was evaluated.

A further development of the telegraphy was the tripod technology<ii>, in which case by turning of the polarization plane individual symbols and letters were transmitted up to the transmission of the spoken word with the help of a special wavelength modulation. That far the thesis reaches, which now should be proven.

<ii>: Lamer: Worterbuch der Antike, Kroner Verl. Bd.96 under "tripod" stands: „the tripod is a dedication gift to gods, a honorary gift for winners. That one pleased them with the gift of a cooking pot, is strange; one has tried to find the reason, but until now without success". In the encyclopaedia further is advised: „tripod as a means for spiritual insight?!"

godology	= high frequency technology
god name	= RDS, station identification
members of a family of gods	= broadcasting studios of a broadcasting company
Pantheon, temple of all gods	= extremely broadband FM broadcast station
crown	= antenna netting
gifts for sacrificing	= broadcasting fees
place of sacrificing	= place of a node of the standing wave
earth radiation	= power supply
homage of a weekday	= time restriction of the operation of the station
Zeus „forges" thunderbolts	= electrostatic blows, when a temple is oscillating
ritual act	= technical provision for transmission and reception
Pythia of Delphi<i>	= radio telephone operator, receptionist
Cella (marrow of temple)	= tuned cavity
obelisk<ii>	= antenna rod

Fig. 30.2: ____ Little dictionary for ancient radio engineering (2).

<i>: Lamer: Worterbuch der Antike, Kroner Verl. Bd.96, under „Pythia"(gr.=the asker): In the temple of Delphi was a chasm. A tripod was standing over it, on which the Pythia was seated, if she gave oracle. Comment: "It was flashy how odd the Pythia was sitting; inconveniently enough, on the cooking pot of the tripod. Ancient pictures, which show her that way, still weren't proven, that it was this way ..."

<ii>: Lamer: under „Obelisk" stands; „The obelisks probably were clocks".

30.2 Prerequisites

The argumentation has to be made on mathematical-physical foundation. The prerequisite for that are the 29 chapters of before. The following points could be demonstrated and derived:

1. The wave equation (inhomogeneous Laplace equation) describes the sum of two wave parts, where
2. every antenna emits both parts,
3. the transverse part, known as electromagnetic wave (Hertzian wave)
4. and the longitudinal part (Tesla radiation) termed scalar wave by the discoverer, better known as antenna noise.
5. The wave equation mathematically describes the connection of both wave parts in general and the conversion of one part into the other in particular, thus
6. the rolling up and unrolling of waves in field vortices (measurable as noise).
7. The transition takes place proportionally to the Golden Proportion, as resulted from the derivation (chapter 29.7 - 29.9)

With the last point the electrotechnical problem becomes a geometrical problem, if it concerns the use of scalar waves. The geometry of the antenna is crucial. Thereby the Golden Proportion provides the necessary direction for construction.
That justifies the assumption that the buildings in antiquity, which were built according to the Golden Proportion, were technical facilities for scalar waves. Maybe the builders had specifications that had physical reasons and could mathematically be proven.
At this place there result completely new aspects for judging and interpreting buildings especially from antiquity through the derivation of the Golden Proportion from the fundamental field equation. If we have understood their way of functioning, then we will be able to learn much from that for our own future and for the future construction of scalar wave devices.

As a further prerequisite for the ancient broadcasting technology enough field energy should be at disposal. We proceed from the assumption that

1. the earth magnetism and the cosmic neutrino radiation are tightly hanging together by the processes in earth's core,
2. the earth magnetism in antiquity verifiably was approx. thousandfold stronger than today (proven by gauging of pieces of broken pot),
3. as a consequence the neutrino radiation in antiquity as well must have been thousandfold stronger and
4. the cosmic neutrino radiation has served the transmitting plants of antiquity as an energy carrier,

any thought is absurd to reject the technical function of a temple only because it today can't be reproduced anymore. The artistic and aesthetical viewpoints, which are put into the foreground by art historians because of ignorance about the true function, rather are secondary.

The terms used to describe the broadcasting technology in antiquity in the last 2000 years have experienced a shift of meaning, so that a translation in our linguistic usage of today is necessary. The adjacent dictionary should help in that case.

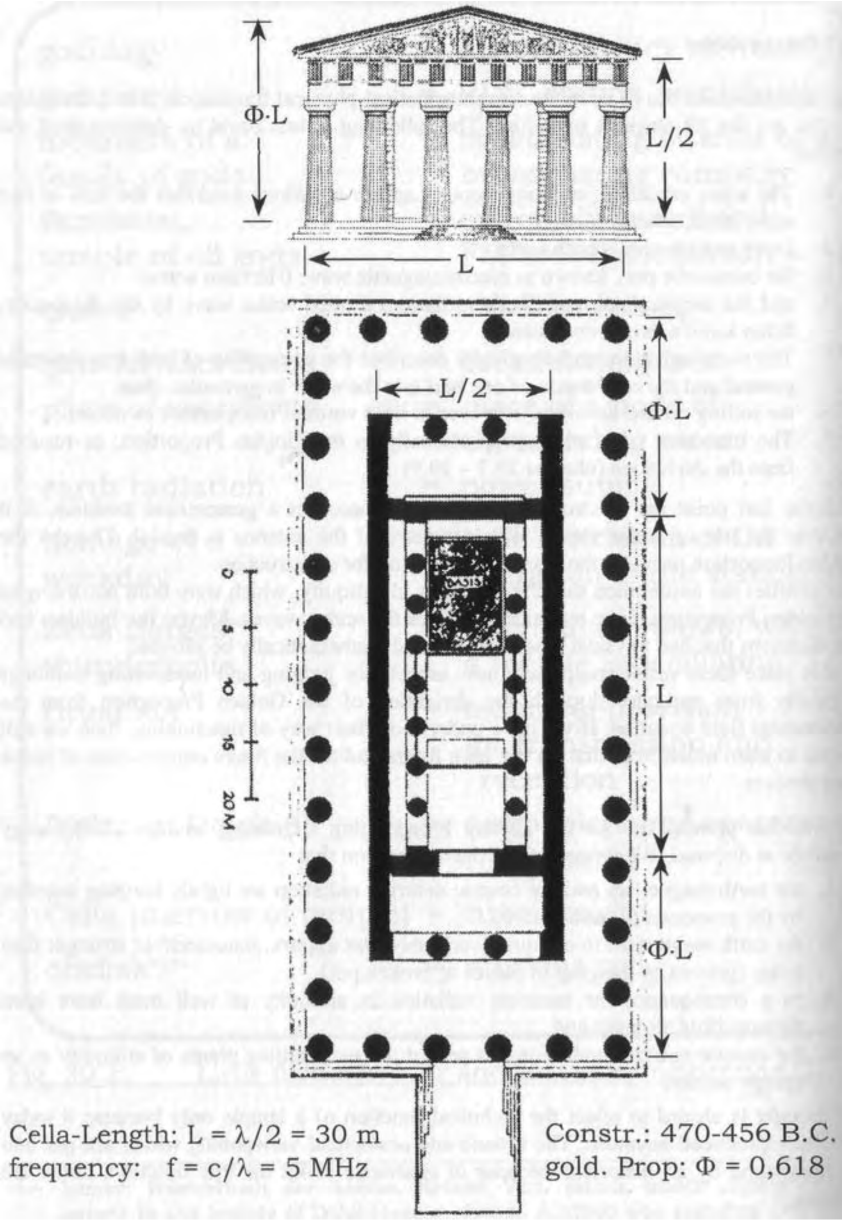
Φ·L
L/2
L
L/2
Φ·L
BASIS
0
5
10
15
20 M
L
Φ·L
Cella-Length: L = λ/2 = 30 m
frequency: f = c/λ = 5 MHz
Constr.: 470-456 B.C.
gold. Prop: Φ = 0,618

Fig. 30.3: The Golden Proportion of Zeus-temple in Olympia.<i>

<i>: K. Schefold: Die Griechen und ihre Nachbarn, Propylaen Kunstgeschichte Berlin Bd. 1, Abbildungen von Seite 249

30.3 Approach

Let's to some extent proceed from the knowledge of textbook physics currently present in high frequency engineering and give a well trained engineer the following task, which he should solve systematically and like an engineer: He should build a transmitter with maximum range at minimum transmitting power, thus a classic task of optimization. Doing so, the material expenditure doesn't play a role!

After mature deliberation the engineer will hit upon it that only one solution exists: He decides on a telegraphy transmitter at the long wave end of the short wave band, at f = 3 MHz, which corresponds to a wavelength of $\lambda = 100$ m. There less than 1 Watt transmitting power is enough for a radio communication once around the earth. That also has something to do with the conditions of reflection of the radio waves at the ionosphere. Our engineer learned:

the index of refraction $n = \sqrt{1 - K \cdot N/f^2}$ (30.1)
with: $K = 80.5 * 10^{-6}$ [cm^3/sec^2] (= constant)
N = electron concentration [$electrons/cm^3$]
f = frequency of the transmitter [MHz]

Put into words: the refraction of a radio wave in the range of the short waves is the larger, the smaller the frequency is. The end of the short wave range is reached at 3 MHz. That thus explains the choice of frequency.

And he optimises further. Next the engineer remembers that at high frequencies, e.g. for microwave radiators, not cables but waveguides are used, since these make possible a considerable better degree of effectiveness. In the case of the waveguide the stray fields are reduced by an alignment and concentration of the fields in the inside of the conductor. In the case of antennas however the fields scatter to the outside and cause considerable stray losses. He draws the conclusion that his transmitter should be built as a tuned cavity and not as an antenna!

As a result the engineer puts a building without windows in the countryside with the enormous dimensions of 50 m length ($=\lambda/2$) and 25 m ($=\lambda/4$) resp. 12.5 m ($=\lambda/8$) width. The height he calculates according to the Golden Proportion to increase the scalar wave part. Those approximately are the dimensions of the Cella without window of Greek temples.

For the operation of such a transmitter in antiquity apparently the noise power of the cosmic radiation was sufficient, which arrived at the earth starting from the sun and the planets. By increasing the floor space also the collected field energy and the transmitting power could be increased, so that also from the perspective of the power supply the temple with the largest possible wavelength at the same time promised the largest transmitting power, so at least in antiquity.

Our engineer further determines, that he will switch the carrier frequency on and off at a predetermined clock pulse. Thus he decides for radiotelegraphy. The advantage of this technique is a maximum increase of the reception range. For that the signals at the transmitter have to be coded and at the receiver again deciphered. By means of the encryption of the contents these are accessible only to the „insiders", who know the code; prerequisite for the emerging of hermetism and eventually a question of power!

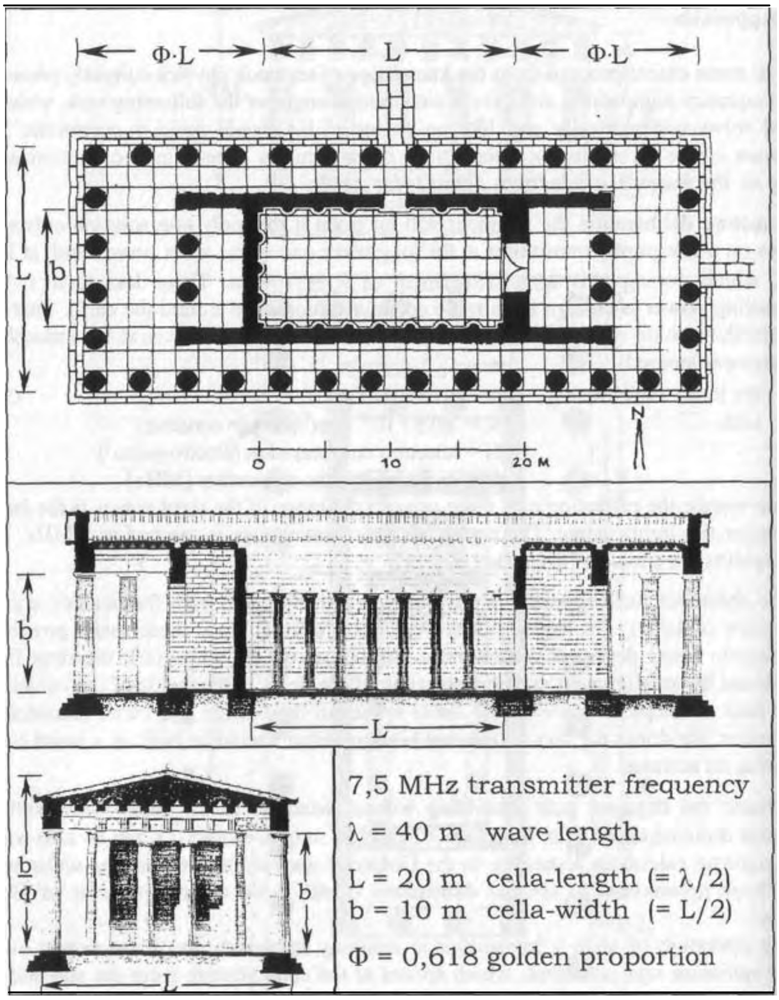
Φ·L
L
Φ·L
L
b
0
10
20 M
N
b
L
b/Φ
b
L
7,5 MHz transmitter frequency
λ = 40 m wave length
L = 20 m cella-length (= λ/2)
b = 10 m cella-width (= L/2)
Φ = 0,618 golden proportion

Fig. 30.4: Example Tegea, temple of Athena Alea.[i]
Built 350/340 B.C.

<i>: G. Gruben: Die Tempel der Griechen, Wissenschaftliche Buchgesellschaft Darmstadt 1986, 4. Aufl. Seite 130

<ii>: E. Horst: Konstantin der Grosse, Eine Biographie, Classen Verlag 1985 Dusseldorf, 2.Aufl., S. 89.

<iii>: E. Horst: Konstantin der Grosse, Eine Biographie, Classen Verlag 1985 Dusseldorf, 2,Aufl., S. 33.

30.4 Circumstantial evidence

Not everyone, somehow participating in send receive engineering, at the same time also was inaugurated in the entire secret knowledge. Most priests only knew as much as they necessarily needed to know to fulfill their tasks. Thus a temple priest, who was presented an enciphered text and who should bring this on the air, not necessarily at the same time needed to know the content of the text or the code. The same of course also was valid for the sacrificing priest acting in the receiving station. The Vestal virgins for instance had to present the received text to the Augures, by whom they were supervised and controlled.

But who wanted to introduce a new god in the gods heaven and perhaps even himself be worshipped as a god, should have complete command of both the broadcasting technique and the reception technique. In ancient Egypt the Pharao at least once a year had to prove, that he still was in command of the technique. Otherwise he was replaced. For a person with security clearance that at the same time was a death sentence.

In the historical facts numerous pieces of circumstantial evidence can be found, which can be considered to be evidence for the thesis of the operation of send receive engineering in antiquity. One now perhaps understands, why the rulers were put an antenna netting over their head, a so-called crown, or why the Augures could survey the land with a flat Tesla coil in their hands (fig. 16.10).

Direct evidence is present as well. It can be found in ancient texts. But it is questionable if historical texts concerning ancient radio engineering have been translated correctly. The talk is about oracles, mystery cult and earth prophesy if the receiver is meant. The predominantly technically uneducated historians attest the Romans a defective sense of time, because their couriers surely could not cover the long ways across the Roman empire so fast at all, if they read in the Latin texts: "They sent by courier to the emperor in Rome and got for answer...". The answer of the emperor namely already arrived at the squad at the latest in the following night. The correct translation should read: "they cabled" or "they broadcasted to the emperor in Rome and got for answer..."<ii>.

Such a big empire as the Roman Empire actually only could be reined by means of an efficient communication. Cicero coined the word: "We have conquered the peoples of the earth owing to our broadcasting technology...<iii>"! The term broadcasting technology from ignorance is translated with piety. If engineers however rework the incorrect translations, then one will discover that numerous texts tell of the broadcasting technology, that thus correspondingly much direct evidence exists concerning the practical use of this technology.

For the Roman military transmitters, which formed the backbone of the administration of the empire, the reading off of the information from observations of nature like the bird flight or from felt signals of a geomanter was too unreliable. They read off the information from the rhythm of the convulsions of the intestines of freshly slaughtered animals. In the case of the dead animals on the altar every extrinsic influence was excluded. But the enormous need of slaughter cattle was a disadvantage. Who wanted to have information, first of all had to bring along an animal, which then was „sacrificed" the god, or better say, which was abused as a receiver for a particular transmitter. Thereby the innards served as a biosensor and as a receiver for the news.

Cellular phone.

• *Network:*	All „telephone cabins“ are transmitter and receiver at the same time.
• *Advantage:*	Anyone can communicate with every network participant.
• *Characteristic:*	The stations are strikingly similar in form and size of building.
• *Power structure:*	All stations as a rule have equal rights among each other.
• *Disadvantage:*	Innovations hardly are possible. The system is inflexible.
• *Examples:*	Temple towers (Iraq); cellular phone network.

Broadcasting.

• *Network:*	Many receivers listen to the news of one powerful transmitter.
• *Advantage:*	The system is very flexible and permanently experiences improvements.
• *Characteristic:*	Monotheism. Big diversity among the receiver constructions.
• *Power structure:*	Central power concentrated in the hands of the chief intendant.
• *Disadvantage:*	Feedback from receiver to transmitter is not desired.
• *Examples:*	God Ammun Re (Egypt); ABC daily news.

Dispatch service.

• *Network:*	Network of broadcast stations supplies an agency (receiver) with information.
• *Advantage:*	Optimal financing, since information is given away only for broadcasting fees in cash.
• *Characteristic:*	Treasury stores have to be built because of the immense riches.
• *Power structure:*	The power is concentrated in the hands of the receiver-agency.
• *Disadvantage:*	In the case of overcharge or overload a system crash is impending.
• *Examples:*	Pythia (Delphi); German Press Agency (dpa).

Fig. 30.5: Three radio technical network structures, with an example from antiquity and from present time.

30.5 Radio technical concepts

In planning and constructing radio technical networks only a few possible concepts exist. It is interesting that at least one historical example can be specified for every concept. That shows that all possibilities were tried at least once. The three most important concepts are presented here:

A. Cellular phone.
Every bigger city between Euphrates and Tigris, which thought the world of itself, had at its disposal already in antiquity a temple tower. Such a temple tower was a „telephone cabin" in the form of a pyramid as a transmitter and a receiver temple at the top, to where the receptionist adjourned to the so-called temple sleep. Discipline was required, since all the time only one priest was allowed to broadcast. All others could listen to him doing so. If he was ready, he closed his contribution with a fixed symbol or term („over") and the next one could continue. This is a classic link-up, where anyone communicates with every network participant.
The stations all were strikingly similar in form and size of building, like one phone box resembles another. In that way a further development of the cellular phone system hardly was possible and that has a technical reason, as the building of a tower in Babylon has shown us. This tower namely had gotten the ambitious builders too big, so that the frequency of the Mesopotamian radio network had been left and instead a foreign network could be received, the code of which no-one could understand. The result was a confusion of language and the order to stop the building.

B. Broadcasting.
Millions of TV spectators every evening look in the ABC news or another daily journal of a TV Channel. In the case of broadcasting thus many receivers listen to the news of a powerful transmitter. With that the whole plenitude of power is concentrated in the hands of the chief intendant. In antiquity he called himself high priest. If he went on the air, he used the logo of the god that he had to represent. Today the logo of the broadcasting company is shown in a corner of the TV screen. Even this very day feedback from the receiver to the transmitter hardly is possible contingent on principle. The problems with nationally controlled broadcasting, with politics controlled by the media all are not new. The monotheism in ancient Egypt with the claim of lordship of the main god Ammun Re is an example from antiquity.

C. Dispatch service.
In ancient Greece the technical structures and with that also the power structures had been turned around. At that time a big network of broadcast stations, which continually was extended by a policy of settlement ordered by the gods, supplied a central and correspondingly powerful agency with information per radio.
Who wanted up to date news, could call for these in the agency with seat in Delphi, but he had to pay for it. To accommodate the broadcasting fees in form of gold and gifts whole treasury stores had to be built. Measured by the commercial success the ancient news network has remained unmatched, and can't be compared with pay-TV or todays dispatch services, like dpa. If the network however becomes too big, uncontrollable and it lacks discipline, then it sometime will crack and the system crashes.

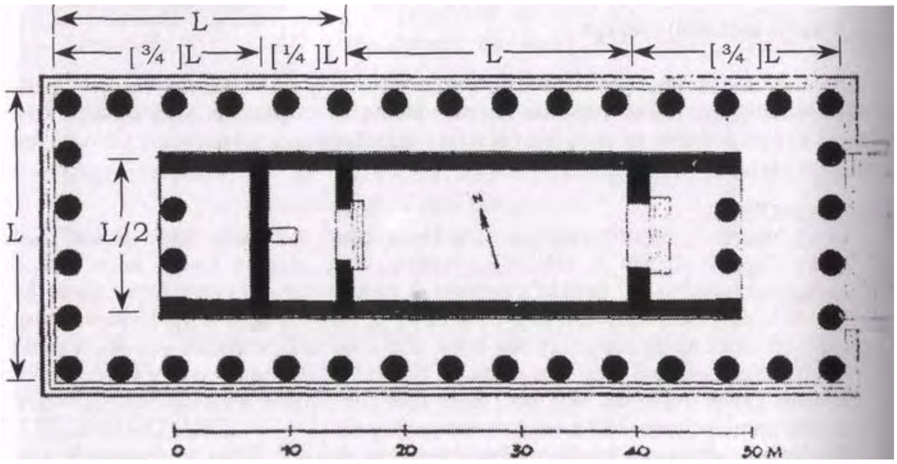
L
[¾]L
[¼]L
L
[¾]L
L
L/2
0
10
20
30
40
50 M

Fig. 30.6 A: Hera-temple of Selinunt 460-450 B.C.<i>
(Corresp. to the plans of the Roman architect Vitruvius)

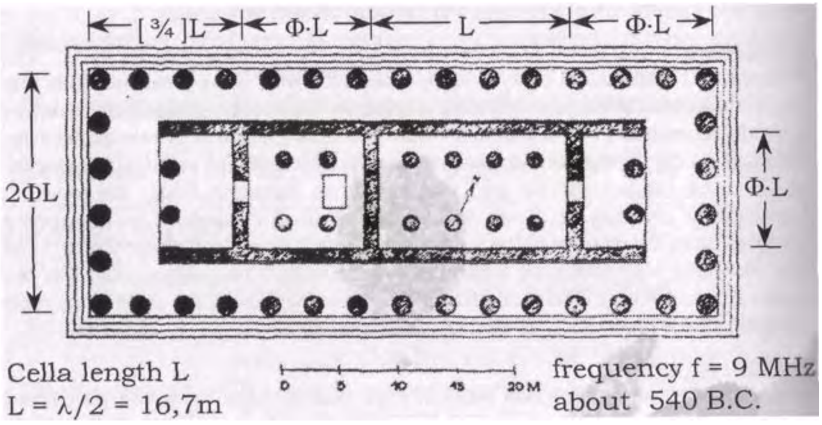
[¾]L
Φ·L
L
Φ·L
2ΦL
Φ·L
Cella length L
L = λ/2 = 16,7m
0
5
10
15
20 M
frequency f = 9 MHz
about 540 B.C.

Fig. 30.6 B: Apollo-temple of Korinth<i>
(Alternative interpretation, use of the Golden Proportion Φ).

<i>: K.Schefold: Die Griechen und ihre Nachbarn, Propylaen Kunstgeschichte Berlin Bd. 1, Abbildungen von Seite 241, 250

<ii>: Vitruvius (Marcus Vitruvius Pollio): Zehn Bucher uber Architektur, Ubers. von Dr. K. Fensterbusch, Wissenschaftl. Buchges. Darmstadt 1987, 4. Aufl., 3. Buch, 1. Kap.: Von den Symmetrien der Tempel, Seite 137

<iii>: Vitruvius (dito), 4.book, 4.Chap.: Vom Tempelinnern und dem Pronaon, p. 187

30.6 Wireless telegraphy

Radio engineering 100 years ago also started with telegraphy. Thereby the high frequency carrier is switched on and off. With this technique Marconi succeeded in a radio transmission over the English Channel (1899) and over the Atlantic Ocean (1901).
As next step the amplitude modulation (AM) followed. Thereby the HF-carrier is overlapped with the low-frequency signal of a sound carrier in such a way, that the amplitude fluctuates on the beat of the LF-signal. As a disadvantageous effect, also noise signals will overlap, from which the quality of reception will suffer.
Only the frequency modulation (FM), where the LF-signal is transmitted as temporal fluctuation of the frequency, brings an improvement. The annoying amplitude noise hence has no effect in the case of FM.
It easily can be recognized, how the development of the modulation techniques follows the urge for technical improvement and optimization. That in antiquity hasn't been different, for which reason the progress of development took place in the same order.

The broadcasting technology of the ancient gods started with the wireless telegraphy. This is expressed in the architecture. Since electric resonant circuits or other frequency determining equipment weren't at the disposal of the engineers in antiquity, the determination and allocation of the broadcasting channels had to take place by means of the wavelength. The formation of a standing wave in the Cella, the innermost sanctuary of a temple, occurs if its length corresponds to half the wavelength of the HF-carrier. The Roman architect Vitruvius calls the wavelength the „basic measure", from which results "the system of the symmetries". He writes: „The design of the temples bases on symmetry, to which laws the architects should adhere meticulously. "[ii]. „The length of the temple is partitioned in such a way that the width is equal to half the length, the Cella itself including the wall, which contains the door, is one fourth longer than wide. The remaining three fourths, which form the Pronaon, should protrude until the antae of the wall and the antae should have the thickness of the pillars"[iii].
If we recalculate ourselves, then the partitioning in 3/4 to 5/4 produces a proportion, which conies quite close to the Golden Proportion. In building a temple nothing is left to chance, after all it concerns the construction of a tuned cavity, capable of self-resonant oscillations with favourable emission behaviour.
From the outside one can't see if a telegraphy transmitter has been changed over to speech transmission with AM. The HF-carrier merely isn't switched off anymore, i.e. the priests let the temple oscillate without interruption. Newly added for AM is an electroacoustic coupling. For that many temples were retrofitted with a mouthpiece. Newly built AM transmitter temples conclude the Cella with a round apse. Because of this acoustically conditioned construction the Cella length didn't have a fixed value anymore and the transmission frequency had become variable. Measured in the middle of the apse the wavelength was larger than at the sides, so that on the beat of the spoken word not only the amplitude of the field distribution in the interior of the temple, but in addition also the frequency of the selfresonant oscillation was changed.
A typical example of such an architectonic hybrid form of AM and FM is situated in Rome. Because due to the frequency variation more than only one wave band was occupied and the temple consistently carries the names of two deities. It is the temple of Venus and Roma.

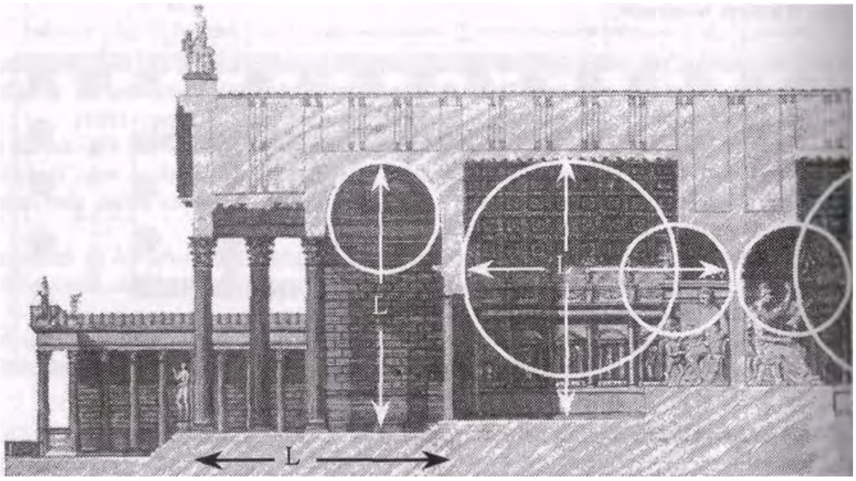

Diameter bigger circle D_1= 22 m (6,8 MHz),
small circle D_2 = 11 m; und L = D_1 + 1/2 D_2 = 27,5 m (5,5 MHz)

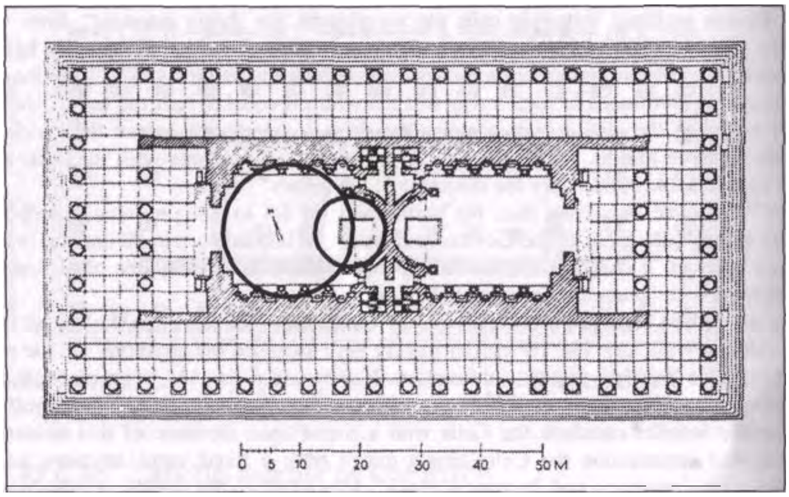

Fig, 30.7: Temple of Venus and Roma; Rome 136/37 A.D.[i,ii]

<i>: A. Springer: Das Altertum, A. Kroner Verl. Leipzig 1915, 10. Aufl., S. 518
<ii>: T. Kraus: Das romische Weltreich, Propylaen Kunstgesch. Berlin Bd. 2, S. 161
<iii>: Lamer: Worterbuch der Antike, Kroner Verl. Bd.96 unter "Tempel", Haufigkeit

30.7 AM temple technology

The low-frequency signal (LF), which should be transmitted by a transmitter with amplitude modulation, lies in the range between 16 Hz and 16 kHz. If it only concerns the transmission of speech information, then the bandwidth can be reduced to 300 to 3000 Hz. In the case of mixing the low-frequency useful signal with the HF-carrier, thus in the case of the modulation of the carrier in the rhythm of the LF, two side bands arise. These lie close to the carrier frequency and are formed from this once by the addition and once by the subtraction with the frequency of the LF-signal. Let's take the temple of Venus and Roma with a transmission frequency of 6.8 MHz. If sound of 3 kHz should be transmitted clearly understandable, then the dimensions of the Cella had to be varied for just 8 mm for a corresponding Cella length of $\lambda/2$ = 22 m. As a curiosity the niches in the side walls in the case of this temple however allow a considerably larger bandwidth of more than 10% instead of the necessary 0.04% in the case of AM.

In the case of the Greek originals, the Cella however has smooth walls, from which follows that the temples were designed ideally narrow band. The Greeks apparently operated predominantly telegraphy transmitters, for which the side bands coincide with the carrier.

The argumentation indeed has remained unchanged: The modulator being narrow band and simple to realize speak in favour of the telegraphy being the "original form" of all modulation techniques. Also the rediscovery of the broadcasting technology by Heinrich Hertz succeeded as telegraphy signal. In addition the range is bigger than for any signal modulated with sound frequency.

As the calculation example has shown, also pure AM transmitters work very narrow band, and this is particularly important for low transmission frequencies, if many transmitters want to use the favoured SW band between 3 and 10 MHz at the same time. With AM one thus accommodates the maximum number of broadcasting channels in a particular frequency range, for instance the 80-meter band, without these interfering with each other too much. But that also was badly needed. Conclusions about the everyday life of broadcasting in antiquity by all means are possible because of the enormous number of temple installations, which logically were permanently used. Only in Rome there existed up to 200 temples<iii>!

Who goes in search of broadcasting stations with a modern short wave receiver, for instance in the 80 m band between the countless telegraphy transmitters, fast gets an idea of what had been up in the air already 2000 years ago. No ancient city would build several temples on a single Acropolis, if only one single one could have been used. All temples broadcasted with each time another carrier frequency because of different dimensions. For this reason the temples, which stood side by side, as a rule were dedicated different gods. An acknowledgement, "the air just being free", in addition hardly was possible, because of the often-found spatial distance between the temple installations and the respective oracle. Between the transmitter of the god Apollo in Didyma and the receiver, the oracle of Milet, for example lie approx. 20 kilometres. The only possible conclusion is that in antiquity there was broadcasted on all channels simultaneously regardless of other gods and their transmission frequencies. As is well-known there rather prevailed a situation of competition between the gods, since like today a large number of listeners meant great importance, influence and power and eventually also worship, more gifts and more receipts from broadcasting fees.

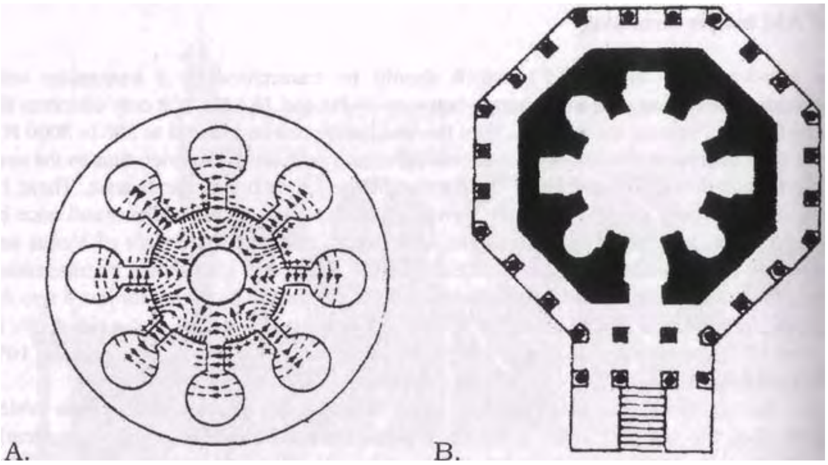

Fig. 30.8: Comparison of a magnetron (A), a microwave radio tube[i] and the temple (B) in the palace of the emperor Diokletian, Split.[ii]

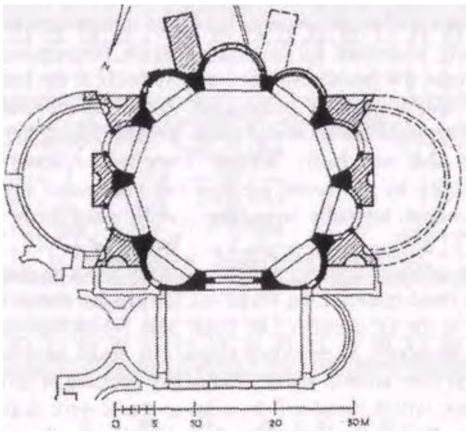

Fig. 30.8.C: Temple of Minerva Medica, Rome, 320 A.D.[ii]

<i>: K. Simonyi: Physikalische Elektronik, 8.4 Das Magnetron, S. 665

<ii>: T. Kraus: Das rom. Weltreich, Propylaen Kunstgesch. Bd. 2, S. 194, 196

<iii>: If one however wants to verify this, in antiquity already common manner of PM broadcasting technology, then we need a broadband short wave receiver with phase-demodulator. With such a receiver even today any time a conclusive argumentation should be possible that this sort of SW-PM technology actually works.

30.8 Modulation of acoustic signals

In the case of sound it in essence concerns longitudinal waves, which propagate in all directions in space with the velocity of sound. But this merely is an average velocity, since the air molecules strictly speaking oscillate with the sound frequency in the direction of propagation. In this way the velocity of sound one time is increased and the next moment to the corresponding extent reduced. If the molecules already carry out oscillations of themselves, e.g. thermal motion, then both oscillations overlap; i.e. the motion of itself is modulated with the sound frequency.

Following the here presented derivation potential vortices are formed in every dielectric, thus also in air, and these are modulated if overlapped with sound waves. Vortices however do not form a distinct frequency, but entirely on the contrary a uniform frequency mixture in the form of white noise.

The overlap thus also is noise unless certain noise frequencies are favoured. This can be effected by means of a spatial body tuned to a certain wavelength. To be considered are cuboid cavities, as in the case of Greek temples or waveguides and cylindrical objects as in the case of round temples or magnetrons. The building form causes the favouring of a certain frequency and the integer harmonic frequencies belonging to it.

If this frequency now lies in the high frequency range, then it is emitted by the spatial body as an electromagnetic wave, in the case of waveguides and resonant circuits for reason of the small dimensions as microwave radiation and in the case of the Greek temples as short wave radiation. If one in addition produces an acoustic signal in the frequency determining spatial body, then this signal automatically will modulate the high-frequency signal.

The result of the modulation is the overlapping of the sound wave with the high-frequency carrier wave. The change of the active length, thus the wavelength of the HF-carrier causes a change of frequency. Such a change on the beat of the sound frequency is called FM (frequency modulation). For that we imagine a spatial body being excited because of its length by potential vortices to a high-frequency oscillation at the self-resonant frequency.

From flow dynamics is known, how easy the distribution of vortices in space can be disturbed. Already words spoken in space are able to influence the potential vortices, which in the case of the temples were used as energy carrier. The longitudinal sound waves reflected at and thus returning from the Cella wall rigid for sound of a Greek temple will push these potential vortices back on the beat of the sound and with that shorten the active length. This means, that the carrier frequency is modulated with the sound frequency. The carrier oscillation thus permanently changes its phase on the beat of the sound signal, for which reason this particular kind of modulation is described as PM, as phase modulation.

Nowadays PM is used only seldom and in the SW-range not at all because of the big need of wave bandwidth. Merely at higher frequencies PM occasionally is used in radiotelephony. In the case of the frequency modulation usual in broadcasting (e.g. UHF), the change of frequency takes place on the beat of the sound amplitude and not of the sound frequency as with PM. Therefore it is not possible to receive phase modulated signals, which are produced by means of the acoustic coupling of appropriately formed spatial bodies<iii> with commercial FM receivers.

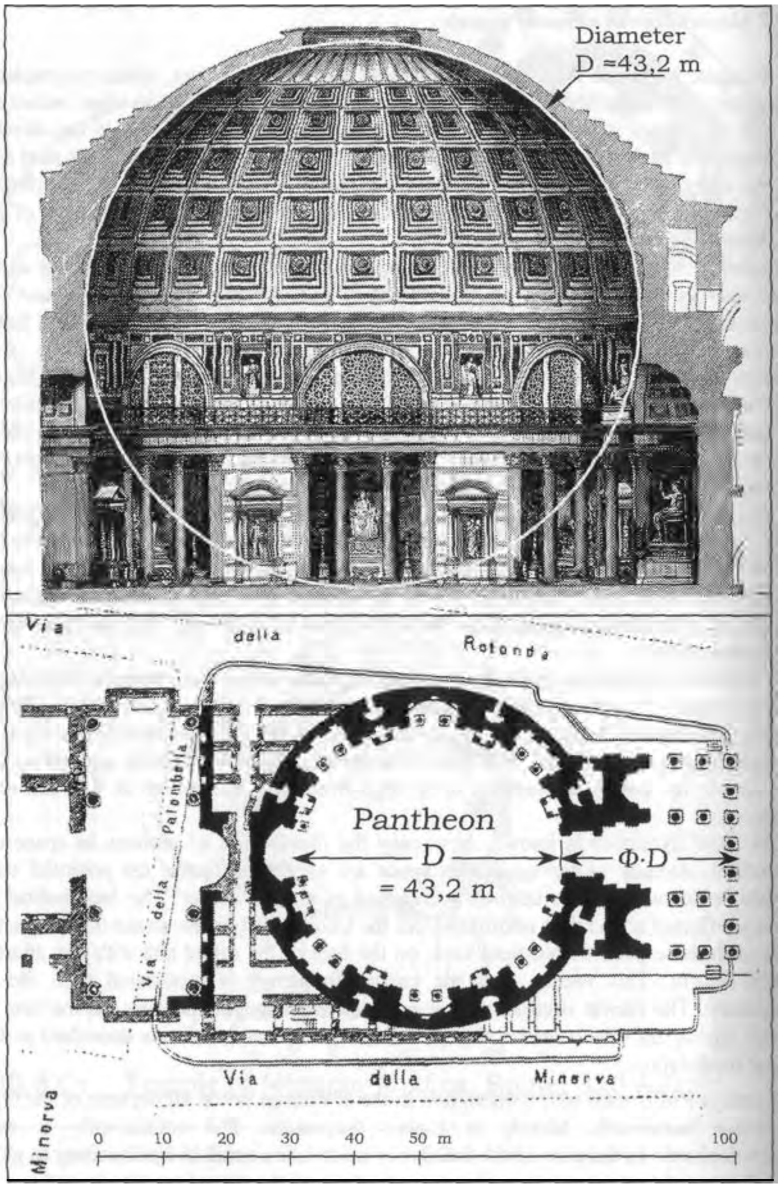
Diameter
D ≈43,2 m
Via della Rotonda
Via della Palombella
Pantheon
D
= 43,2 m
Φ·D
Via della Minerva
Minerva
0
10
20
30
40
50 m
100

Fig. 30.9: The Pantheon in Rome, the „temple of all gods".[i]
Diameter $D = 43{,}2$ m, Golden Proportion: $\Phi = 0.618$
Pronaon-(atrium-)length: $\Phi \cdot D = 0.618 \cdot 43.2 = 26.7$ m
Built under emperor Hadrian 118/ 119-125/128 A.D.

30.9 Broadband FM broadcasting technology

If I speak against a flat wall, then every point on the wall has another distance to my mouth. The sound waves thus aren't reflected simultaneously, what leads to big modulation distortions. Therefore the sound wall should be curved in such a way, that all signal paths are the same length (barrel vault, apse, etc.). In the case of point sound sources there results as an optimum a hemisphere, for instance a dome. The building hence even today tells us, which frequency and which modulation method had been put to use. The architecture of sacral buildings, e.g. pointed arch or round arch, thus hardly has been a question of aesthetics.

For his temple of Venus and Roma designed by himself emperor Hadrian had to listen to severe criticism among others of Apollodor of Damascus. The temple was too broadband for an AM transmitter, however with a modulation depth of just 11 percent not broadband enough for a phase modulated FM transmitter.

Emperor Hadrian however also had the courage to build midst in Rome a temple calculated completely new and designed as a pure FM transmitter, the Pantheon, which means temple of all gods. In the language of the technician it is a transmitter for all frequencies.

This domed structure indeed doesn't leave out one single frequency. With a modulation depth of almost 100 percent it is designed for maximum loudness. With that the Pantheon uses all available frequencies, for which reason the name temple of all gods really is no exaggeration. Into the Pantheon exactly fits a sphere with a diameter of 43.2 meter. That corresponds to a minimum frequency of 3.47 MHz, situated in the range of the short waves. The floor however is not domed, but horizontal. That, up to the basis of the dome, results in exactly half the height and a maximum frequency of 6.94 MHz.

The construction ensures that between the simple and the double diameter any desired wavelength can be produced. Above the given maximum frequency of the basic oscillation the harmonic waves, which are produced as well and can't be avoided at all, are attached without a break. These occupy the wave bands up to the double, triple, quadruple frequency and so forth.

For this and only for this reason a maximum frequency was chosen, which corresponds to exactly the double value of the minimum frequency. The operation takes place to the limit, where the transmitter would interfere with itself, in the way that the used basic oscillation would overlap its own harmonic waves. That then sounds like two people talking at the same time. The voices would be distorted out of recognition, as can't be expected else in the range of the harmonic waves.

The Pantheon has been planned and built as a phase modulated basic wave transmitter according to purely academic rules of Hadrian. The temple impressively demonstrates the precise engineering detailed knowledge of the Pontifex Maximus and his broadcasting priests in ancient Rome<ii>.

<i>: A. Springer: Die Kunst des Altertums, A. Kroner Verl. Leipzig 1915, 10. Aufl., S. 517/518, daraus: die Zeichnungen ram Pantheon in Rom, 115-125 n.Chr.

<ii>: The collection of material concerning scalar wave technology here is aborted and continued in an own book in narrative and with that easier to read writing style. The title is: "Broadcasting Gods".

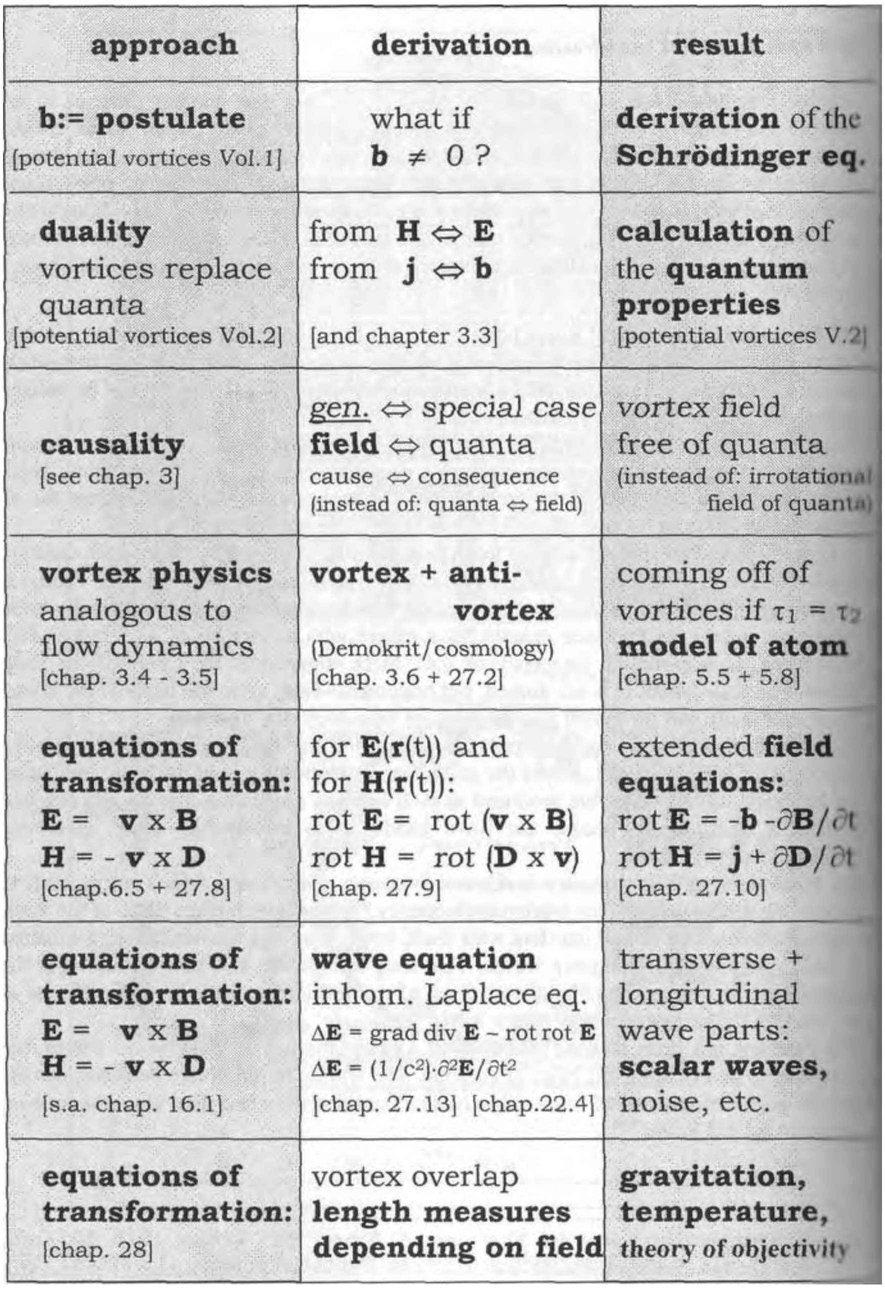

approach	derivation	result
b:= postulate [potential vortices Vol.1]	what if $\mathbf{b} \neq 0$?	**derivation** of the **Schrödinger eq.**
duality vortices replace quanta [potential vortices Vol.2]	from $\mathbf{H} \Leftrightarrow \mathbf{E}$ from $\mathbf{j} \Leftrightarrow \mathbf{b}$ [and chapter 3.3]	**calculation** of the **quantum properties** [potential vortices V.2]
causality [see chap. 3]	gen. ⇔ *special case* **field** ⇔ quanta cause ⇔ consequence (instead of: quanta ⇔ field)	*vortex field free of quanta* (instead of: irrotational field of quanta)
vortex physics analogous to flow dynamics [chap. 3.4 - 3.5]	**vortex + anti-vortex** (Demokrit/cosmology) [chap. 3.6 + 27.2]	coming off of vortices if $\tau_1 = \tau_2$ **model of atom** [chap. 5.5 + 5.8]
equations of transformation: $\mathbf{E} = \mathbf{v} \times \mathbf{B}$ $\mathbf{H} = -\mathbf{v} \times \mathbf{D}$ [chap.6.5 + 27.8]	for $\mathbf{E}(\mathbf{r}(t))$ and for $\mathbf{H}(\mathbf{r}(t))$: $\text{rot}\,\mathbf{E} = \text{rot}\,(\mathbf{v} \times \mathbf{B})$ $\text{rot}\,\mathbf{H} = \text{rot}\,(\mathbf{D} \times \mathbf{v})$ [chap. 27.9]	extended **field equations:** $\text{rot}\,\mathbf{E} = -\mathbf{b} - \partial\mathbf{B}/\partial t$ $\text{rot}\,\mathbf{H} = \mathbf{j} + \partial\mathbf{D}/\partial t$ [chap. 27.10]
equations of transformation: $\mathbf{E} = \mathbf{v} \times \mathbf{B}$ $\mathbf{H} = -\mathbf{v} \times \mathbf{D}$ [s.a. chap. 16.1]	**wave equation** inhom. Laplace eq. $\Delta\mathbf{E} = \text{grad div}\,\mathbf{E} - \text{rot rot}\,\mathbf{E}$ $\Delta\mathbf{E} = (1/c^2)\cdot\partial^2\mathbf{E}/\partial t^2$ [chap. 27.13] [chap.22.4]	transverse + longitudinal wave parts: **scalar waves,** noise, etc.
equations of transformation: [chap. 28]	vortex overlap **length measures depending on field**	**gravitation, temperature,** **theory of objectivity**

Fig. 30.10: (All) Many roads lead to Rome.

30.10 Epilogue

The preparation for a seminar or a lecture always starts with a collection of material. This should be considerably more detailed than the material to be communicated, since it doesn't get well at the students and also other participants, if the state of knowledge of the lecturer already is exhausted with the scope of his lecture. For this reason the collection of material must also include alternative derivations and areas of knowledge, which thematically rather are marginal, about which mustn't be reported, which possibly not even can bear criticism but still are in the public discussion. For a collection of material, which wants to be considered to be comprehensive and complete, it is important that no area and no theme has been overlooked.

The here presented collection of material with its 650 pages has become correspondingly voluminous. After all the material has been collected over an 8 year period and has been strung into the book in the order of working. That of course complicates reading the book, because individual aspects are repeated several times, but often also in a different context and each time lighted from another side. If the reader somewhere has the feeling, he only has turned in a circle, then has deceived himself. He indeed moves spirally in a circle, like in real life, but he doesn't come out there, where he started. After one turn he is richer with the experience of this spiral turn. In whole science the advancement takes place as a spiral movement and one can count oneself fortunate, as long as the spiral has an ascending slope! This notion should solace the reader, who has undertaken the torture to work through the complete collection of material.

Students also have reported, they had devoured my book like a thriller and a colleague, who had acquired it at a conference in Switzerland, was digging so much in the lecture that he forgot to get off the train timely.

It is a special concern to give reasons for the necessity of an extension of available field theory. To achieve this goal several derivations (fig. 30.10) can be found in my books: from a postulate, from causality, from duality, from vortex physics, from the equations of transformation, etc. added are at least a dozen derivations of other authors from various publications, who at most are cited. With that the goal is pursued that all approaches, which are conceivable and worth discussing, can be put side by side and tested for their efficiency.

Since it isn't the task of a collection of material to answer this question, this must be done by the hearer resp. the reader of the books. He is prompted to find the answer himself! That leads to an intense contention with the theme and that exactly is the reason for the otherwise rather unusual step to make a collection of material open to the public. Objections and criticism of the content of a relation of matters or also only of the representation of the context is wished explicitly. This also isn't valued as criticism of the author or of the superordinated set of difficulties, which in principle isn't possible at all for a collection of material.

Honorary functions of

Prof. Dr.-Ing. Konstantin Meyl

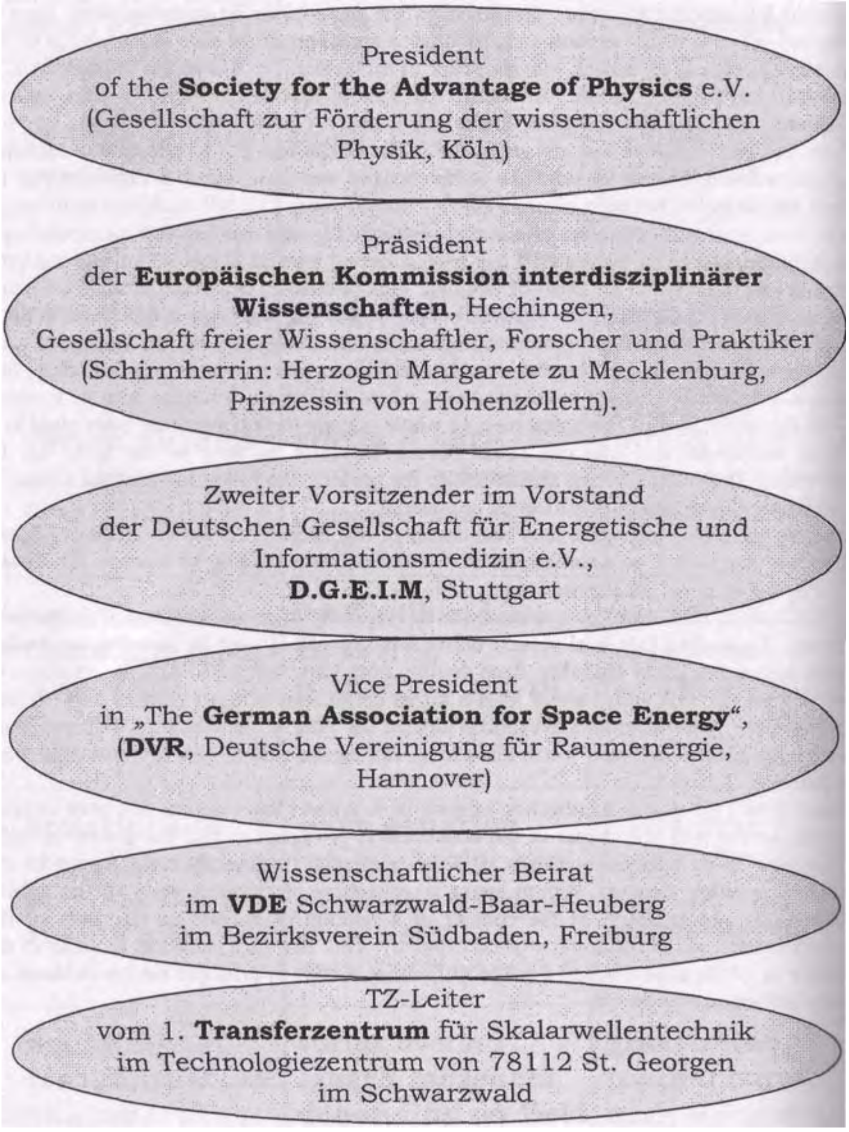

President
of the **Society for the Advantage of Physics** e.V.
(Gesellschaft zur Förderung der wissenschaftlichen
Physik, Köln)

Präsident
der **Europäischen Kommission interdisziplinärer**
Wissenschaften, Hechingen,
Gesellschaft freier Wissenschaftler, Forscher und Praktiker
(Schirmherrin: Herzogin Margarete zu Mecklenburg,
Prinzessin von Hohenzollern).

Zweiter Vorsitzender im Vorstand
der Deutschen Gesellschaft für Energetische und
Informationsmedizin e.V.,
D.G.E.I.M, Stuttgart

Vice President
in „The **German Association for Space Energy**“,
(**DVR**, Deutsche Vereinigung für Raumenergie,
Hannover)

Wissenschaftlicher Beirat
im **VDE** Schwarzwald-Baar-Heuberg
im Bezirksverein Südbaden, Freiburg

TZ-Leiter
vom 1. **Transferzentrum** für Skalarwellentechnik
im Technologiezentrum von 78112 St. Georgen
im Schwarzwald

Fig. 30.11: Honorary functions of the author (December 2003, selection).

There in principle is no necessity at all to discuss with everybody a collection of material, which I have compiled exclusively for own events. It is absolutely sufficient, if few, but then qualified experts have thoughts about the content and communicate them to me. They can feel certain that I don't hand down their judgement to other persons. For that I also have been blamed by ignorant colleagues, who in complete self-overestimation have the opinion, they should be informed about everything. Right is rather, that my private correspondence is of no concern to anybody, since I find it important that as much readers as possible express themselves frank, what only functions, if they can feel certain that they afterwards won't be involved in public mud-wrestling. Therefore I keep still as regards other persons however curious they might be.

Indeed over and over again pseudo scientists turn up, who have the erroneous opinion that scientific arguments would take place on some internet-forums, where one can descant at will and anonymous, hidden behind an alias, where the intellectual firebug can feel safe, not afterwards being blamed for his crimes.

No, science takes place entirely different. A new theory will be able to establish, if it is right and important and if it is used for practical uses. Losers are those authors of a theory, for the elaboratation of which nobody is interested. What does a publication in a journal, however renowned, mean, if nobody reads it and nobody needs it? Most new ideas and approaches go under without notice in today's flood of publications, for who has got the time to read all essays in full?

Desperate they turn to me hoping, at least I could understand their concern. I then invite these scientists to a congress of the „Society for the Advantage of Physics", of which I am the president and offer them a forum, where they are able to present their ideas to an expert public. Not all lectured ideas prove to be sound, but not seldom a physical concern, which should be taken very serious, is behind it.

For a long time the real scientific controversy doesn't take place anymore at the universities and their congresses, where hardly someone dares to lecture arguments against the convention. Too fast he would be expelled as outlaw from the honourable society. From time to time however also from these circles colleagues dare anonymously or privately, as they emphasize, into the alternative events of lobbies or clubs, to astonished find out that real science there still is practised and that there is discussed about ideas, which they have given up thinking or have forbidden themselves to think about. The employment activity, so they excuse their thinking prohibition, allegedly doesn't allow it.

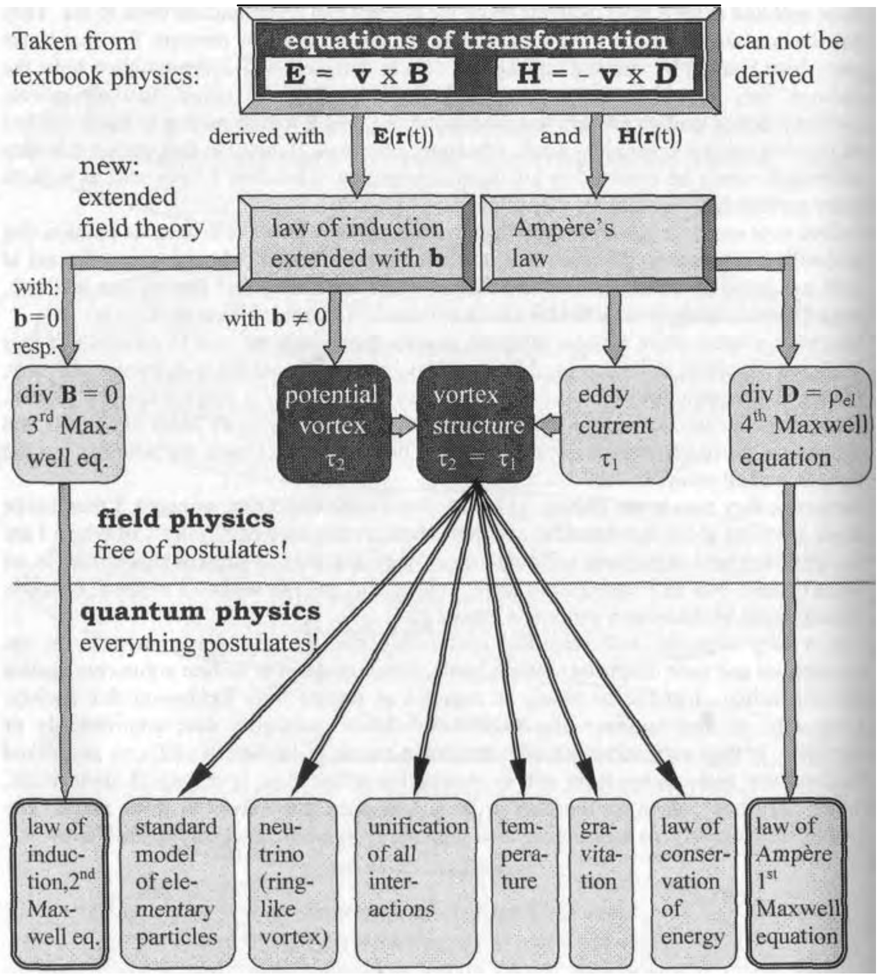
Taken from textbook physics:
equations of transformation
E = v x B
H = - v x D
can not be derived
derived with
E(r(t))
and
H(r(t))
new: extended field theory
law of induction extended with b
Ampère's law
with: b=0 resp.
with b ≠ 0
div B = 0 3rd Max-well eq.
potential vortex τ2
vortex structure τ2 = τ1
eddy current τ1
div D = ρel 4th Maxwell equation
field physics
free of postulates!
quantum physics
everything postulates!
law of induc-tion,2nd Max-well eq.
standard model of ele-mentary particles
neu-trino (ring-like vortex)
unification of all inter-actions
tem-pera-ture
gra-vita-tion
law of conser-vation of energy
law of Ampère 1st Maxwell equation

Fig. 30.12: Derivations of postulates and axioms (part 1).

Be that as it may, the approaches and derivations contained in my collection of material are considered to be controversial, and that is good that way! The public takes notice and professional circles are occupied with the ideas. With that half the way to success already is brought off! It now concerns to knock off all points for their soundness individually, because the next step will be to search a way to the goal as unassailable as possible, which is able to convince also the biggest sceptic. The final version, which then should appear in accredited peer-reviewed journals and in a scientific book concerning the theory of objectivity, goes in this direction. From the numerous approaches in the end only one will be used, and from the countless, in the collection of material listed aspects only the noncontentious ones will remain.

The dispute, which in the current stage can't be avoided, yes even is desired, however shouldn't deceive about the fact that it here doesn't concern persons, improper vanity or some image cultivation, but simply and solely concerns the matter!

In fig. 30.12 and 30.13 is represented, what it concerns. Field physics and quantum physics don't form, as in common practise, an insurmountable opposite, but even complement each other! Below the stripline a little selection of the today in current use quantum physical postulates can be found. The number of newly introduced „constants of nature" and postulates permanently is increasing, a circumstance, which hardly can be mediated to the common sense. The bracket is missing, which interlinks all postulates, or the common source from which they can be derived causally.

In the progress of the three-part edition in this question, essential for physics, already a satisfying and in addition real efficient answer has been found in the domain of field physics. The coupling marked by individual derivations can be found above the stripline and it is entirely new, apart from the dashed indicated derivation (fig. 30.13), as given by Prof. Bosse (TU Darmstadt) in his textbook.

An approach in principle can be chosen freely. In the case of the superordinated field theory two equations of transformation form the approach, which already is laid down in textbooks and secured experimentally. That's why the whole field theoretical derivation manages without one postulate! It is pointed to the fact that these equations on their part can't be derived and should be interpreted rather philosophically than physically. From this approach the extended field theory is derived directly, without a need to add or discard a term. The extended field theory consists of the well-known law of Ampere extended with the dielectric displacement D by Maxwell, and of Faraday's law of induction, which experiences an extension with the vector of potential density b by means of the derivation. Doing so we assume that the field pointers of the electric and the magnetic field strength depend on the spatial coordinate r and through this indirectly also on the time t: $E(r(t))$, $H(r(t))$.

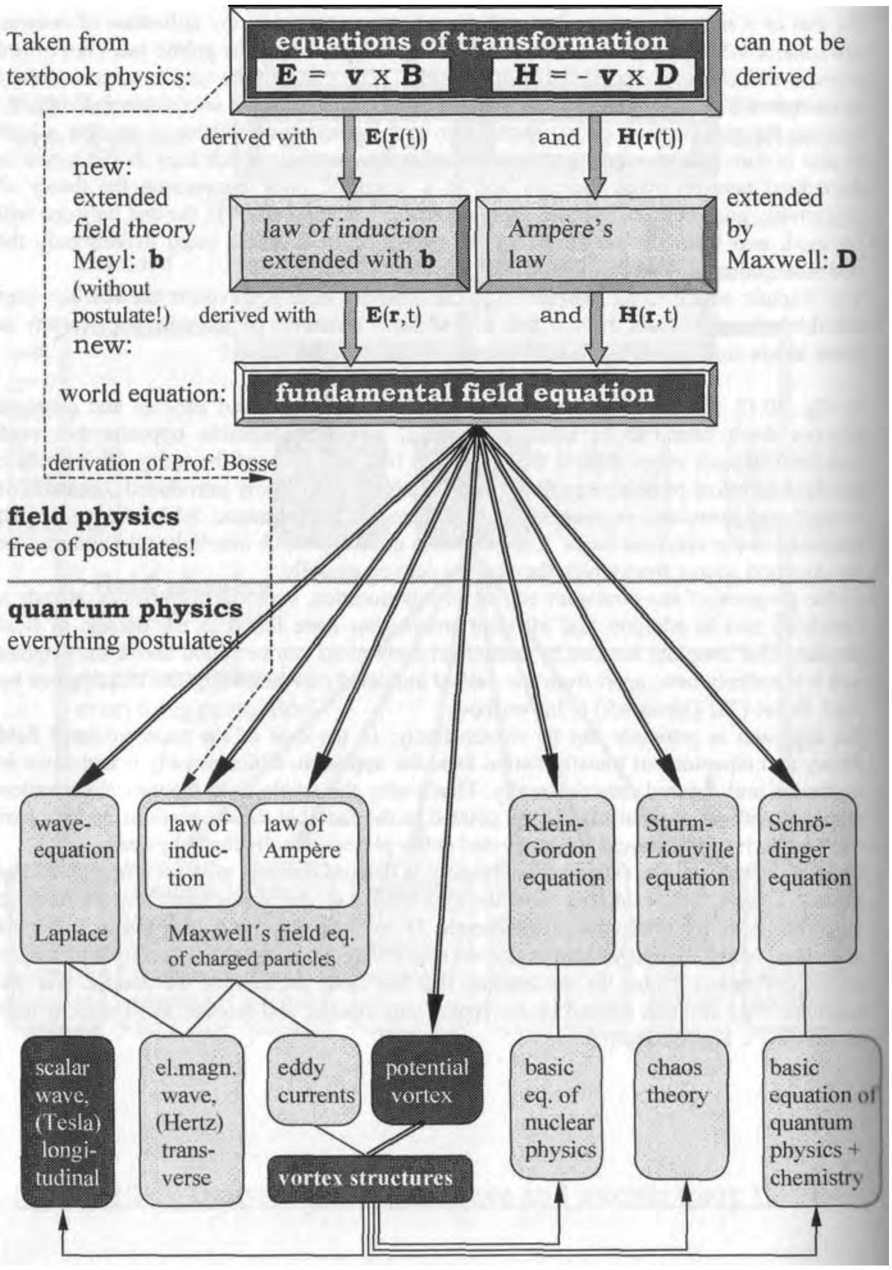
Taken from textbook physics:
equations of transformation
E = v x B
H = - v x D
can not be derived
derived with E(r(t)) and H(r(t))
new: extended field theory Meyl: b (without postulate!)
law of induction extended with b
Ampère's law
extended by Maxwell: D
derived with E(r,t) and H(r,t)
new: world equation:
fundamental field equation
derivation of Prof. Bosse
field physics
free of postulates!
quantum physics
everything postulates!
wave-equation
Laplace
law of induc-tion
law of Ampère
Maxwell's field eq. of charged particles
Klein-Gordon equation
Sturm-Liouville equation
Schrö-dinger equation
scalar wave, (Tesla) longi-tudinal
el.magn. wave, (Hertz) trans-verse
eddy currents
potential vortex
vortex structures
basic eq. of nuclear physics
chaos theory
basic equation of quantum physics + chemistry

Fig. 30.13: Derivations of postulates and axioms (part 2).

If the somewhat more general case is counted up, in which case apart from the spatial a direct temporal dependency is present (E(r,t) and H(r,t)). then further additional terms appear in addition to the extended field equations, which need an explanation also for the case that they are zero. The physical interpretation would implicate a longer treatise, which however can be circumvented, as shown here, by constraining the field pointers, which absolutely is allowed according to the slogan: for the case E(r(t)) and H(r(t)) chosen from many possibilities the extended field equations come out exactly in the form, as they are required and suitable for the further calculations. Who has got to calculate other cases, can do that as he likes, but doing so he should not get lost. Maxwell's field equations are contained in the solution and with that also continue to be valid. Their disadvantage however is that without the extension b not a single quantum physical postulate can be derived. If we add this extension and insert the equations into each other without addition and without cuts also this time a central solution is the result, which is called fundamental field equation.

The derivation is known as well from the Maxwell theory, in which case it is common practise, to use the general approach (E(r,t) and H(r,t)), what we in accordance with the textbooks can do in the same manner. The extension however brings two additional and extremely significant terms. Since the fundamental field equation has eigenvalues under certain boundary conditions and describes structures, various quantum postulates come out from it, from the quantum properties of the elementary particles over the Schrodinger equation and the inhomogeneous Laplace equation up to the derivation of the Golden Proportion. That justifies the assumption that this possibly is the long sought-for world equation!

Even I, as the initiator, was totally surprised by the found derivation of the most important quantum physical postulates and axioms. One just is doing it the right way and already everything fits together! I am not aware of any theory, which would be able to achieve something roughly comparable. The since long sought-for „Theory of Everything", the big unification theory really falls into ones lap. The known interactions are the free and easy result of analysing the field lines of electric and magnetic field strength (fig. 30.12). Physical phenomena, which until now were considered to be incompatible, like e.g. waves, noise or the temperature with the utterly insufficient concepts of the mechanisms for the conversion of one form of energy into another, can be represented consistently with the fundamental field equation as the rolling up of a wavelike field oscillation to a vortex oscillation and as conversion of the noise vortices in the case of a vortex contraction down to atomic dimensions as thermal oscillation, which we treat as vortex losses. There exists no alternative to such unified schemes of things, as makes it possible in abundance the theory that I have founded, considering the two conditions, that on the one hand in the case of the derivation only known regularities are used, by completely doing without postulates and that on the other hand laws are applied and adhered to, also physical laws.

The new schemes of things, which sound unfamiliar, thus already were contained in the laws of physics. After this now having been realized, the tables turn. Now the explanations by postulates, as they at the moment still are being taught, should be replaced by the newly derived ones, if one doesn't want to become a breaker of the law! There doesn't lead a way past the overdue reform of physics anymore.

If you want to correspond with me or if you want to get one of my books from the bibliography, then please consult my Transfer Centre in the Technology Centre of St. Georgen (Black Forest, D).

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Prof. Dr. Konstantin Meyl
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Fax.: +49-7721/51870

email: meyl@k-meyl.de or: meyl@fh-furtwangen. de
Internet: http://www.k-meyl.de or www.meyl.eu

The list of deliverable books (for ordering books over the above given address, Fax, Mail or postcard suffices):

* Wirbelstrome, Diss. University Stuttgart 1984, ISBN 3-9802 542-0-8, 14

* Potentialwirbel Band 1, 1990, ISBN 3-9802 542-1-6 (German), 14

* Potentialwirbel Band 2, 1992, ISBN 3-9802 542-2-4 (not available)

* Elektromagnetische Umweltvertraglichkeit, Teil 1, 2 and 3 (German), ISBN 3-9802 542-8-3, 3-9802 542-9-1 and 3-9802 542-7-5. Each 16

* Scalar wave technology, 2003, documentation and manual to the demonstration-kit and to the experimental-kit (translated and copied).

* Sendetechnik der Gotter, historischer Sciencefictionroman, (in German)
1 .Aufl. 2004, ISBN 3-98O2 542-5-9, 12

* Neutrinopower, Johannes von Buttlar im Gesprach mit Prof. Dr. Konstantin Meyl, (Discussion in German) Argo-Verlag 2000,

(A bill is enclosed in the delivery.)

Fig. 30.14: Contacting address and list of deliverable books

Table of formula symbols

		Electric field			Magnetic field
$\mathbf{E}$	V/m	Electric field strength	$\mathbf{H}$	A/m	Magnetic field strength
$\mathbf{D}$	As/m^2	Electric displacement	$\mathbf{B}$	Vs/m^2	Magnetic induction
U	V	Tension voltage	I	A	Current
ε	As/Vm	Dielectricity: $\varepsilon = \varepsilon_r \cdot \varepsilon_o$	μ	Vs/Am	Permeability: $\mu = \mu_r \cdot \mu_o$
Q	As	Charge	ϕ	Vs	Magnetic flux
e	As	Elementary charge	m	kg	Mass
τ_2	s	Relaxation time constant of the potential vortices	τ_1	s	Relaxation time constant of the eddy currents: $\tau_1 = \varepsilon/\sigma$

other symbols:

A	m^2	Area
a	m	Distance
b	m	Width
c	m/s	Speed of light
c_o	m/s	Speed of light in vacuum
C_e	As/V	Capacity of the electron
C_p	J/K	Heat capacity
d	m	Thickness
E,W	Nm	Energy
f	1/s	Frequency
F	N	Force
G	$m^3/kg{\cdot}s^2$	Gravitational constant
g	m/s^2	Gravitational acceleration of the earth
h	m	Height
h	Nms	Planck's quantum of action
$\hbar$	Nms	Quantum of angular momentum: $\hbar = h/2\pi$
$\mathbf{j}$	A/m^2	Current density
J	$kg{\cdot}m^2$	Moment of inertia
$J{\cdot}\omega^2$	$kg{\cdot}m^2/s$	Angular momentum
k	Nm/K	Boltzmann constant
l	m	Length
m	kg	Mass
M	kg	Mass of the earth
n,ν =	1,2,3..	Running parameters
N	-	Constant
O	m^2	Surface area
p_m	Am^2	Magnetic moment

Q	Nm = J	Heat energy
r, R	m	Radius, radius of the earth
r_e	m	Radius of the electron
s	Nms	Spin
t	s	Time, time to orbit
T	K	Temperature
U	Nm	Potential energy
U_e	V	Tension voltage of the electron
v	m/s	Velocity
V	m^3	Volume
W	Nm	Energy
w	N/m^2	Energy density
W_e	Nm	Energy of the electron
z_e	-	Number of the involved elementary vortices
λ	m	Wave length
ω	s^{-1}	Angular frequency, angular velocity
σ	Vm/A	Specific electric conductivity
ρ	kg/m^3	Density $\rho = m/V$
ρ_{el}	As/m^3	Electric space charge density
$\psi(\mathbf{r},t)$		Complex wave function
$\phi(\mathbf{r})$		Function of space coordinates
Φ		Golden Proportion

Definitions:

Speed of light	$c = 1/\sqrt{\varepsilon \cdot \mu}$	m/s
Speed of light in a vacuum	$c_o = 1/\sqrt{\varepsilon_o \cdot \mu_o}$	m/s
Moment of inertia (orbit)	$J = m{\cdot}r^2$	$kg{\cdot}m^2$
Mom. of i. (homogeneous sphere)	$J = (2/5)m{\cdot}r^2$	$kg{\cdot}m^2$
Angular velocity	$\omega = v/r = 2{\cdot}\pi/t$	1/s
Surface area of a sphere	$O = 4{\cdot}\pi{\cdot}r^2$	m^2
Volume of a sphere	$V = (4/3){\cdot}\pi{\cdot}r^3$	m^3

Concerning vector analysis:

Bold print = field pointer (vector); further information in fig. 5.0 in part 1

Prof. Dr.-Ing. Konstantin Meyl:

Scalar wave technology

for the transmission of electric scalar waves

Abstract: 1. Auflage 2000, 2. Auflage and 1st English edition 200

This book is recommended to people, who search the entry into the world of the by the author discovered potential vortices and their propagation as a scalar wave by experimental means. It starts with the instructions to six extraordinary experiments. Doing so an electric radiation is proven, which transmits energy, and that even faster than the light. Also more energy can arrive at the receiver then is put into the transmitter. Who entertains a doubt, will be able to understand the experiments with this book in his hand, to afterwards test the experiments with the gauge, which he is familiar with.

The 1st edition in English at first only includes the instructions for the experiments. In a subsequent edition it will be complemented with a collection of test protocols and progress reports. These are organized into three groups: one group is striving to explain the behaviour of the transmission line conventionally, a legitimate concern, which in a number of points also is able to convince. A second group only is interested in those phenomena of the experiment, which can't be explained conventionally and which prove the existence of scalar waves, whereas the third research group continually strives for new spectacular experiments and practical applications.

Documentation

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by Prof. Dr.-Ing. Konstantin Meyl:

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Konstantin the Great is inaugurated in ancient send receive engineering by his teacher in the Roman emperor palace 304 A.D.

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- Were the Greek temples telegraphy transmitters?
- Were the temple priests amateur radio operators?
- Was Homer radio reporter by order of the gods?
- Were the oracles receiving stations?
- Have oracle interpreters deciphered the transmission code?
- Which bridges did the Pontifex Maximus build?

All are questions, which are dealt with and explained in detail in 30 lessons. In the year 304 A.D. we witness, how the later Roman emperor Konstantin the Great is inaugurated in the secret broadcasting technique of the gods by his teacher. It is an exciting time of upheavel, because the old telegraphy is almost dead. The intestines of animals to sacrifice, from the convulsions of which the radio signals are read off, are scarce goods. Instead radiotelephony should be introduced, which had been tested successfully with the Pantheon in Rome by emperor Hadrian.
But new dispute is initiated: should broadcasting be introduced or rather cellular phone? But those, who tamper around without licence, are chased and fought as always.

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Time = Space

Supreme scientific secrets in ancient India

(God's particle, Language, Arts, Temples & Sacred Geometry)

(Shatkona Yantra – Created by Sri Bhogar Siddhar currently in a temple in Sri Lanka, taken once in a year for rituals, believed to emanate supreme subtle divine energies.)

Thinking Hearts (Raguram Gopalan)
(raguramg@hotmail.com)

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Thoughts from Thinking Hearts:

“Curious by nature, in a life so uncertain
Thirsty for the truth, which is so certain
I sought for some water in our Vedas - the fountain
Though I can’t understand fully what it contains
I am amazed & speechless with what I could ascertain
This is just a speck of dust from that golden mountain
Thankful to my family for helping me in what I could attain
Grateful for the wisdom and works from all the chieftains
Wish I repay every atom of it through my gratuitous tearstains”

This effort is to share what I read, understood and enjoyed about the scientific aspects in ancient India which are codified in our language, arts and in 1000s of temples. The quotes and examples are predominantly in Tamil but I have tried to give the meaning which can enable a reader to grasp the meaning and progress. Any shortcomings you notice are purely reflective of my abilities to understand and express. There was not even an iota of intention to hurt any sentiments or beliefs of others. A piece of my mind is available @ http://ragsgopalan.blogspot.com

I initially thought that I shall reproduce a prayer from one of the books which I had read but at one fine moment I decided to capture my feelings in my own words. So I scribbled few lines in English summing up my feelings as above, few lines for the Sage of Kanchi and a prayer in Tamil with its meaning in English. You may understand this prayer better after you read this book.

January 2012, Version 1.0

Please feel free to copy and reproduce in whichever form or shape as you deem fit without any acknowledgements. In fact see how much of this can you share to dispel the ignorance. The more you share the better. ☺

If I have acknowledged any books or authors please recognize them and ensure that you either buy their books or donate to their cause. They deserve all the credits.

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A divine soul
With a noble goal
Walked this earth
When divinity was dearth
Beyond any treasure's worth
To avoid our death & rebirth
Seek his guidance & grace
For he shall ever embrace!

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முதல் வணக்கம் (Prayer)

உள்ளமே மூலமாகி, பரம்பொருள் கோலமாகி
விண்ணே ஒளியென்றாகி, ஓமே உணர்வென்றாகி
உணர்வே ஓமொளியாகி, ஓமொளி ஓமொலியாகி
ஆடலன் ஆட்டமன்றோ, அசைவுறுக் காலமாகி
(Mind is the source, primordial god’s particle as the form,
The luminescent space, the Pranava as consciousness
Consciousness as the Om’s Light, Om’s Light as Om’s sound
Isn’t time a pulsation that’s the dance of Lord of Dance?)

காலமே சீலமாகி, சீலமேக் கோலமாகி
கோலமே ஞாலமாகி, ஆதியும் அந்தமாகி
ஞாலமே மூலமாகி, அறிவுடன்ஆ னந்தமாகி
நடுவிலே நன்று நிற்கும் நாதன் தாளே நாட்டமாகி
Time creates Rhythm & order, Rhythm creates shapes
Shapes become universe, the beginning and the end
Universe merges with source, it is awareness & bliss
Ever searching for the feet of the divine & graceful mean

விண்ணிலே மண்ணுமாகி, மண்ணிலே விண்ணுமாகி
விண்ணிலே எண்ணமாகி, எண்ணமே எண்ணுமாகி
என்னிலே என்னைக்காண என் கண்ணிலே மணியுமாகி
நிர்மலப் பொருளாய் ஓங்கும் நிமலனடி போற்றுவோமே!
The mass in energy (Space), the energy in mass(earth)
The energy as thoughts, our thoughts as numbers (octets)
To me find me within me, he who stands as my eye’s pupil
Beseech his feet who is devoid of may blemish

அம்பலத்தில் ஆடும் அவனை, அரங்கத்தில் துயிலும் அவனை
அரவத்தைச்சூடும் அவனை, அரவம்மேல் ஆடும் அவனை
பைரவித்துணைவன் அவனை, திருமகள் தலைவன் அவனை
நம் அறிவுக்கு இருளின் நமனை, பொற்பாதம் போற்றுவோமே!
The one who is dancing in the microbode, the one who is sleeping in arangam
The one who is wearing snakes, the one who is dancing on a snake
The one who is consort of Goddess Bhairavi, the one who is the Lord of goddess Lakshmi
Beseech his feet, the one who kills our mind’s tamasic darkness

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1.Time = Space Series. Part 1 - Introduction

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

“Abheda Darsanam Gnanam*[*]*”. Nothing defines what **wisdom is** better than these 3 words. **Experience of unity / oneness in all is wisdom.** The roots of Indian wisdom are captured in these 3 words that everything in this universe is the manifestation from a single source, and we can call it God or Consciousness. This naturally leads us to one of the mahavakya ***“Pragyanam Brahma”*** which means **“Consciousness is god”.** But for people who are stingier with words and wants these 2 concepts to be put in just one word, then it is called **“Advaita”.**

It is not very often that nature reveals itself its absolute oneness and the un-manifested interconnections. You consider yourself fortunate when you come across such knowledge in however small measure, even if it happens very rarely and even if you have an illusion that you have understood something. It has been very overwhelming for me to come across some of the details I have been reading and hearing and the dots I could connect – some of which I had decided to write as a book.

If you are interested in knowing how scientific ancient Indian Sanatana Dharma is and how well we have codified nature’s secret in our languages, arts and temples and if you are interested in any of the following questions then you may like this book. Most of the aspects stated here as scientific proof has a reference to one or more of our scriptures and I would refer and quote them at various places.

- Would you be surprised to know that the size, shape, color and characteristics of God’s particle are very clearly documented in our scriptures at least 12000 years back? What the scientists at CERN are spending billions of $, is well documented and we will discuss the characteristics of God’s particle in this book.

- Would you want to know how **Time = Space** and more over time is nothing but the vibration of space? If I tell you that this was known us Indians at least 12000 years back and currently available in a written form would you believe?

- When you throw a stone in water / pond the ripples that form take the shape of a circle (in 2D) / sphere (in 3D). Can you guess what the shape of the ripple would be if you throw the same stone in space?

- What is the similarity between Poetry, classical music, Classical dance like Bharatanatyam, Sculpture and a building? Apart from the fact that we don’t clearly understand any of them in depth what is the similarity? Would you be surprised if I say that all are essentially the same and in fact a **well constructed building is nothing more than a frozen music** and the relationship between all the above confirms to a single grammar documented 12000 years + back ?

- Would you be interested in knowing how E = mc^2 an equation stated by our great Einstein has been known to us for years and not just that but we know the root of this energy and how to engineer it with precise formulas? Would you be surprised that this is the basis our language?

- What if I say that the age of the universe, every astronomical unit of the bodies, big bang theory, string theory, God's particle etc are all documented and they are all codified in our temples?

- You would have heard about the golden ration Φ but do you know the philosophical significance of Φ and how it is derived? Moreover would be interested in knowing the significance of key numbers and ratio like 0, 1, 5, 8, 9 and $\sqrt{2}, \sqrt{3}, \sqrt{5}$? What is I say that $\sqrt{3}$ can be correlated with "**Iyengar Namam"?** Does it sound funny? What if there is a deep mathematical and philosophical significance? And how are all these ratios related?

- As a wise man said that **'Mathematics is the language of the gods".** What if this formula is codified in our texts from which we understand the God's particle, its shape, characteristics and its manifestation?

- What if I tell you that sound is a subset of light and sound merges with light at a point and that is at the root consciousness? Any non-takers for this?

- If you agree on the above then **Sabda Brahman** or the belief that sound is god merges with something higher, isn't this contradictory? Also why many religions did believed that "**Word is god".** Was it a mere belief or was there any scientific reason behind it?

- What is the correlation between Carnatic music and a human being's height?

- What if I say that the Mayan from South America and the Mayan from South India are one and the same?

These are some of the questions which might get addressed in this book. I am going to quote a series of references and books and links to understand and learn more about these topics and I would request you to utilize them if you are interested in these topics.

This may not only refer you to the experts but also can help you overcome any weakness I have in understanding and articulating some of these topics. Some of the topics may touch upon religious beliefs (mostly Hinduism) but if you read with an open mind you would notice the underlying science behind it.

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I would be happy if any of these blogs motivate and inspire you to explore the roots of our tradition and knowledge and give you an insatiable hunger for knowledge, wisdom to pursue the nature and its secrets.

May the ancient Sanskrit quote "May I meditate on the supreme truth "Satyam Param deemahi", resonate within you as it does within me.

Happy reading!

PS:

Abheda Darshanam Gnanam, Dhyanam Nirvishayam Manam;
Snaanam mano mala thyagam, Showchamindriya Nigraham", says the Upanishad.

The real Gnana is seeing all as one, real Dhyana is controlling the Manas from all temptations, the real snana or Bathing is Cleansing of All Mindly impurities, not physical impurities alone and real Showcha or cleanliness is controlling the Indriyas, this controlling of Indriyas, emotions, weaknesses and temptations.

I am also quoting parts of Kahlil Gibran here,

Your hearts know in silence the secrets of the days and the nights.
But your ears thirst for the sound of your heart's knowledge.
You would know in words that which you have always known in thought.
You would touch with your fingers the naked body of your dreams.
And the treasure of your infinite depths would be revealed to your eyes.
But let there be no scales to weigh your unknown treasure;
And seek not the depths of your knowledge with staff or sounding line.
For self is a sea boundless and measureless.
Say not, "I have found the truth," but rather, "I have found a truth."

2.TIME = SPACE SERIES. PART 2 - SOUND MERGES IN LIGHT

What if I say that "**Sound is a subset of light".** Scientifically you may agree that both are electro-magnetic vibrations at different frequencies in the spectrum though one may not be the subset of another.

So, What if I say that every other frequency is the subset of light? I am sure many may disagree. Some of the religious pundits may claim that "**Sound is god**" which I am not disputing but "**light too is god"** and as we progress towards the primordial state sound merges into light.

Let me try to explain this with a simple exercise. Please sit in a place with a calm mind – few deep breaths may help.

- Imagine that I am TALKING to you and avoid thinking that you are reading this blog.
- I am going to TELL the following 5 words and you are going to LISTEN to it. Please just observe what happens within you.
    - CAT, BOAT, MOM, DEVIL, BEST FRIEND

The following are the fundamentals of perception as per Hindu scriptures:

- Every word has a meaning (Let us ignore the so called meaningless words for the time being.).
- Every meaning invokes a form or shape within our mind.
    - For example when I say "**MOM"** you associate this word with your mother and the picture / image of your mother is perceived inside. You need to be little more observant to understand this. **The fundamental principle is that**
    - **"Every word is first associated its meaning then the meaning is associated with a form. The form is associated with a Guna (Quality) and then the quality or Guna is associated with its experience. What is stored inside is just the experience.**

Let me TRY to explain the abstract concept of consciousness as below:

- **Consciousness / existence exist in 3 states (deeper explanation is 5 / 7 states but we will discuss the simpler alternative).**
    - **Formless state called Experience / feeling / bhava. This is the super conscious state.**
    - **Gross state with form which has physical attributes. This is the conscious state.**
    - **In-between state (Not formless and no form) called Guna state which has subtle quality attributes. This is the Subconscious state. If this is difficult to comprehend for you please imagine "Egg" which is in-between the formless and state with form.** Gotcha?

Let’s look at an example. Rose is a flower. When someone tells you **“ROSE”** then the following happens:

- The sound “rose’ associates with a flower usually. (I am ignoring it being a name of your girl friend ☺). So here the word is associated with its meaning.
- This flower is associated with red color and perhaps with thorns. Here the sound does not exist anymore but only a form. **Yo!, the sound has merged into light.**
- The third step is - this form is associated with a quality which is fragrance of a rose. For someone sensitive they can smell the rose when they think about it. How else could we salivate at the thought / smell of a favorite dish if this step does not exist?
- Now the last step is, this quality invokes an experience and hence a feeling. This rose may be associated with your inner self for love and hence the emotion of love surfaces. This is called **Bhava / Rasa** in Sanskrit.

If you are not clear about this then please do not move to the next part and think or discuss about it. A little contemplation would help you understand this **5 stage** process of perception.
‘SOUND – MEANING – FORM – QUALITY (GUNA) – EXPERIENCE (FEELING / BHAVA)’

Our ancient forefathers knew this science and interconnection. Let me now quote these Slokas as an example from Bharatnatyam, which talks about this linkage.

Kanteenaalambayet geetam, Hasteenaardham Pradarsayet,
Chakshurbhyaam darsayeet bhaavam, Paadaabhyam taalamaacharet.

According to Nandikeshara the dancer should sing with the mouth, express the meaning of the song with hand gestures, her eyes should express the emotions or bhava, the tala, the beat or rhythm should be done with her feet. Further he goes on to say –

'Yato hastas tato drushti, Yato drushitis tato manaha
Yato manahas tato bhavo, Yato bhavas tato Rasaha'

'Where the hand goes, there should follow the eyes, Where the eyes move, mind should follow it,
Where the mind follow, Bhava or emotion is created, & lastly when Bhava is created the sentiment or Rasa will arise.'

All the Mudras or gestures represent word when held at a particular position around the frame of the body and when used in a particular way.

Alas we Indians have ignored this great science & art and its linkages and are like ignorant fools following the meaningless western tradition and dances!

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

Happy reading!

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3.TIME = SPACE SERIES. PART 3 – VAAK-ARTHA - IMPORTANCE OF WORD

'SOUND – MEANING – FORM – QUALITY (GUNA) – EXPERIENCE (FEELING / BHAVA)'

In the **5 stage** process of perception, one important factor which I missed is the **"Self / EGO"** which interprets the **Guna** to an experience. For example when I say Dog, the **'Self'** interprets Dog to a **loyal friend or a bike chaser or a rabbies generator.** Essentially what is the quality of dog mean to me? If you understand this process this explains the uniqueness between individuals or the root cause of differences in a society.

I am also going to add but not going to focus on the fact that the inputs are never limited to sound and when see a picture the process of perception starts with step 3. Just to poke the individuals who think "**Sound / Word is the only god – Sabda Brahman**, please tell me - when you see a picture and when there is no sound associated with it, where is **God as Sabda Brahman in this situation**?

Does that mean that the very important Hindu belief that the Sound **"Om is sabda Brahman or god"** does not hold any meaning? It certainly does and I shall share my thoughts on it – continue reading.

What is the importance of Word?

The greatest of Indian poet **'Kalidas'** said

**"Vaak artha viva samprakthov vaakartha prathipathaye
Jagadha: pitharov vandhe parvathe parameswarow"**

he compared Lord Shiva and Shakti like sound (Shakti) and meaning (Shiva). Both sound and meaning are inseparable. You would now understand the wisdom behind this sloka since there is no sound without a meaning. Also **Sabda Brahman** merges with the **Artha Brahman** and both are inseparable. Here Artha Brahman is the light and the meaning of the word. Remember we say that **'Throw some light"** when we don't understand something.

In Tamil **பொருள் (porul)** means "a thing" and it also means "meaning". We will see how **பரம்பொருள் (Paramporul)** is the Lord Shiva as a God's particle and how he is referred to as the meaning too. The same applies to Sanskrit where **"artha"** means **wealth / things – remember Arthasastra?** And it also refers to **"meaning"** as in the above sloka. How rich these languages are?

And in **Abhirami Andadi, bhattar** sees devi as **"Arthanareswara"** and confirms us that the grace of devi will brings us both richness and mukthi. **"Sollum porulum ena nadamadum"...**

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A word is made up of letters called Akshara in Sanskrit. The meaning of Akshara is that which cannot be broken down further. ie. Word can be broken down to letters but it cannot be broken down further. A letter has a form like **"A"** and has a sound associated with it. This means the light and sound are merged in a letter. As per the principle stated above in the process of perception, the primordial state is one where light and sound is merged into each other.

If you don't dispute the philosophy that everything merges into god at the primordial state and at this state, sound and light are inseparable, and then you would agree that an Akshara is **God / Brahman.** Each letter has significance and meaning in Indian languages especially Tamil and Sanskrit. **A word is a combination of Form (Light), Sound and meaning and these are first 3 aspects of perception which takes us from a gross state to a formless subtle un-manifest state.**

Hence the statement from New Testament **"In the beginning was the Word, and the Word was with God, and the Word was God"** reflects the same principle.

But as per Hindu scriptures Veda is the breath of god (not word of god) or the aural vibration of consciousness cannot take you to the state of moksha. Words don't take you to God, it can help you in the process but has its limit, since the sound and meaning merges into something else as we move towards more subtle space.

This is what my friend Kambar said in Kambaramayanam as **"வேதமும் முடிவு காணா மெய்ப்பொருள் வெளிவந்தெய்தி மா துயர் துடைத்த வார்த்தை மறுப்பரோ!!.** This means that the supreme truth who could not be found by Vedas came and solved the problem of an elephant, can someone dispute this?

Every word or Akshara has four states **Para, Pashyanti, Madhyama and Vaikari. Vaikari** is the fourth state where the sound is audible to us. If I recite something mentally then the sound has 3 states only and these 4 states signify as to how a feeling (bhava) becomes thought and thought becomes form and then a sound. Just note here that as per Frank outlaw, it's the thoughts which are primordial but as per our scriptures it is feeling or Bhava or deep rooted desire or also known as vasanas which drive your thoughts. So Frank's quotes are half baked plagiarism.

In a work called Tarka Samgraha, we have classified 9 different physical attributes (substances / dhravyas) and 24 different qualities / GUNA in all. If you are interested reading more about this, please read these blogs or the original work.

http://ragsgopalan.blogspot.com/2010/09/vedic-perspective-matter-and-its_14.html This is a 3 part series.
http://ragsgopalan.blogspot.com/2008/11/part-1-perception-art-of-seeing-things.html This is a 2 part series.

To summarize this topic:

- Broadly consciousness exists in 3 states.
- The process of perception if understood well would throw a lot of secrets about nature.
- The 5 stage process of perception **“Sound – meaning - Form – Guna – Bhava”** is a simplistic way of portraying this.
- Sound merges into light and light is worshipped as God in most of the religions and belief. We can explore little more of this in the future sections.
- A word is a unique combination where Light, Sound and meaning merges and hence it is considered as god. This word represents **Arthenareeswara or yinyang or Star of David**.

In the future sections let us explore as to what is the relationship between Maths and God and some of the critical numbers and its philosophical and scientific significance.

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

Happy reading

4. Time = Space Series. Part 4 – Scientific languages – Tamil & Sanskrit

One of the main reasons I believe as to why our wisdom has degraded so much in the last century is our ignorance and reluctance to learn our rich language. Our language offers richness not just in literary sense but is supremely scientific too. I am going to touch upon just 3 to 4 aspects of it which I knew and understand at a fundamental level and request you to learn your mother tongue well.

Many of my friends don't exhibit a sense of remorse when they say **'I can understand Tamil but can't read or write it**". I wanted to tell them how much in life do they miss in terms of knowledge and richness. This is not just about Tamil but every major Indian language is rich in its own way. Since my mother tongue is Tamil, I am going to articulate some of the science in it.

Vigyan / Vigyanam (விண் ஞானம்) means Science:

But most importantly for this series I wanted to take the word called Science as meant in Tamil and Sanskrit. A word always can be broken down to its dhatus for its exact meaning in Tamil and Sanskrit. Some examples below:

- Science in Tamil is **Vigyanam and in Sanskrit is Vigyan**. This is split as **Vin** and **Gnanam** / **Gyan**. **Vin means space and Gyan means knowledge. Hence according to Indian system science means it is the nature / knowledge of the space.** This has very deep significance since western science has not agreed the existence of space for a long time and their gross and materialistic approach prevented them from seeing the most subtle component and its nature. We were masters of it ages back. Most of the questions in Chapter 1 would be answered based on the knowledge of space – Vigyan.

- **Universe is called as Brahmanda** in Sanskrit. Brahma + Anda which literally means a big egg. This means we knew that the galaxy is elliptical in shape ages back and it required hubble telescope in 1950 to tell us that.

- **Bhoogol** means **Earth (Study of) / Geography – This Splits as Bhoo +Gol.** Bhoo means Earth and Gol means round. We did not throw stones at a scientist as late as 17th century when he said that earth is round and not flat. We would have laughed our heart out and ignored him.

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Be it the age of the universe, all of the astronomical measurements, health, spirituality etc, many of us need a white skin with blue eyes to tell us that what we knew was right and they have certified it. When we decide to come out of this mentality then the process of reclaiming our rich heritage shall start.

Origin of Universe and linkage with Tamil:

The initial evolutionary process for the universe consisted of 5 stages states Aintiram. You can imagine that these are the movements of particles during the Big bang. They are அமிழ்தல், இமிழ்தல், குமிழ்தல், உமிழ்தல், தமிழ்தல்.

- Withdrawl (Amizhdal)
- Imizhdal (Overflowing)
- Kumizhdal (clustering round in an order)
- Umizhdal (Emitting)
- Tamizhdal (resulting into a well defined form)

These are the first stages from the Big bang till a well defined shape is formed. Now the last level is called Tamizhdal which results in a well defined form. This state has emanated from the Pranava and not been created by some one. Hence a language as rich with the sweetness of inherent order, originating from the luminosity of the original particle is called Tamil. Tamil is word based on the final resultant state called Tamizhdal (தமிழ்தல்).

I shall address the other 2 interesting aspects that include a Chicken and Egg analogy for Energy and matter conundrum in the next blog.

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

Happy reading!

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5. TIME = SPACE SERIES. PART 5 – ENERGY & MATTER CONUNDRUM

Energy and Matter concept in formation of letters:

The concept of Energy and matter is not new to us and does not start with Einstein’s days of $E=mc^2$. Let us look at how our letters are formed from Aksharas then people would know that the concept of Energy and Matter is old as our language. In Tamil there are two kinds of Aksharas **உயிர் எழுத்து - Uyir Ezhuthu (Life / Energy letters – 12 letters) and மெய் எழுத்து - Mei Ezhuthu (Body / Matter letters – 18 letters).** Both put together it is 30 letter pack for Tamil as alphabets. Now both have to combine to give letters called **“body with life”** which are called **uyir mei Ezhuthu**. This combines to form 18*12 which is 216 letters as **Uyir Mei Ezhuthu**. For example க்+ அ = க in Tamil and क़ + अ = क in Sanskrit.

So the formation of letters itself is a science where Matter (Body) combines with Energy (Life) and then the living organisms (Body – life letters) are formed.

I want to ask you a **Chicken & Egg** question here which is very relevant to today’s scientists. Did the energy come first or is it the matter that came first? Modern science is still scratching its head. I can answer this question in 2 ways, first is obviously using language as a science.

- In the above example க்+ அ = க, க் is the body and அ is life. So as per our language sciences be it Tamil or Sanskrit the matter is formed first and then the life came and attached to it. This is very well documented in Tamil scriptures as follows:

உடம்புடன் உயிர் வந்து ஒன்றுவது இயல்பே - தொல்காப்பியம் . This is over 2500 years old which states that life comes and joins a body in language and this is nature.

மெய்யொளி உயிரொலி சிவணுதல் இயல்பே – ஐந்திறம். This is over 12000+ years old which states that same thing and adds that body is like light and life is like sound and they merge and this is siva’s nature. **This certainly means that both Body and life are not formed at the same – as popularly believed. Life comes and joins the body to give a living being – in the above case the letters are the living beings.**

The second reference I am going to take for the same concept is our **Yogic / Siddha / Ayurvedic** science as to how fetus is formed in mother's womb. As per our (Siddha) belief the conception of a child in a mother's womb happens as follows:

- **The first organ that is formed for the fetus is the cells of the Eyes (Single Eye)**. This eye cell starts vibrating due to its heat and multiplies as 2 eyes and then as the whole body. This is the vibration seen in the initial days of the fetus and not the heart beat. As per modern medical science the heart takes shape only by the end of the 8th week and not before. I am requesting someone to validate this.
- **Life comes to this body at the 3rd month of conception only**. This is the belief as per Ayurvedic and Siddha science.
- Instances of the third month natural abortions are very high than the later months based on the above reasons. This means that the life is not destined for that matter / life force is not sufficient enough.
- **How many of you know that the size of eyes never change as you grow and stays the same from the time we were born,** while all other organs undergo growth?
- Also the eyes hold a very important significance in the spiritual science which I shall address later. The eyes are the seat of Sun god and are characterized by heat and light.

It is through the heat in the eyes the subtle became a gross living being in this world and if the living being wants to merge back with the subtle – which is the process of Samadhi then the living beings should use their eyes, increase the heat in the eyes and start the devolution process. This is a supreme secret kept by the sages even in today's world. **You may want to ask any spiritual school as to why they recommend meditation with eyes fully or half open instead of closed eyes? Ask yourselves why the free masons and other secret societies use eye as one of their symbols?** We shall address this later.

Now you want to answer the Chicken and Egg analogy to the Energy and Matter conundrum based on the above 2 thoughts, we can conclude it is the matter which came first. We shall try to explain this based on Space sciences a little later.

Masculine and Feminine names based on ending letters:

I am also going to give you as to how Indians distinguished masculine from feminine names. **Kanchi Maha periyava, the Sage of Kachi** had explained this beautifully in his **"Arul Vakku"**. I am giving a gist of it here just to conclude this:

- **Masculine names:** All the names shall end with the phonetic a, im, in , ir, aha etc. Examples are Ram, Shyam, Raman, Kannan, Kishan, Vivek, Adam. So phonetically names like Catherine is a masculine name because it ends with "in" phonetically.

- **Feminine names:** All names ending with phonetics aa, e, I, oo etc. Examples are Radha, Ramya, Savithri, Gayathri, Uma, Rosy, Isabella etc. Same way phonetically Joshua is a feminine name.

Vishnu and Lalitha sahasranamam follows this rule and hence one invokes Shakthi as lalitha and the other invokes Purusha as Vishnu.

Just to conclude this part, I think we looked at how science is an integral part of our language formation and for us science has always been about the knowledge and nature of the space and we believed that space manifested itself as the physical world. So in the next few parts we shall look at how this manifestation has happened and other interesting aspects.

I would conclude this part with a earnest request that please encourage your kids to learn their mother tongue – to read and write and you would not have done anything better than this to advance their spiritual growth and adding richness to their life.

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

Happy reading!

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6. TIME = SPACE SERIES. PART 6 – THE UNFOLDING SELF - UNIVERSE HAS EVOLVED AND WAS NOT CREATED

As per many scriptures in Hinduism this universe has evolved from itself and not created by someone. If you want to quickly ask as me as to what Brahma, Vishnu and Rudra mean – I would attribute them to different process heads in this evolution. They are all different aspects of the same consciousness based on their state of being in the process of evolution / devolution. This is my understanding but let us avoid this discussion here.

Here I am indebted and thankful to the nobel soul **Late. Dr. Ganapathi Stapathi,** (http://www.vastuved.com/life.htm) who not only unraveled the Vaastu science – the science of Space and time but also brought to light 2 important books which were over 12000+ years old written in Tamil by **Mahamuni Maayan.**

Mamuni Maayan is believed to be the same person who is popularly known in **South America as Mayan** and the 2012 phenomenon based on Mayan calendar. Dr. Ganapathi has established proofs that the pyramids in Middle East, the temple architecture in India and the structures in Mexico and Guatemala confirm to a single Science and Mathematics seen in all these works.

At the end of the blog I am listing few books which helped me understand this topic but most of the books (**Aintiram and Pranava Veda**) are out of print now and if you are lucky, you would get some of them. Now let us understand briefly how this evolution process has come about. According to Mayans' Aintiram:

- The free space is the unified field of energy and matter and source of all forms that we see in material world. That is why we were defined science as **Vingyanam**. This space consists of very minute particle called **Vinporul, nunporul, Sittrambalam, Paramanu, Oliporul, Microbode** (**விண்பொருள், நுண்பொருள், சிற்றம்பலம், பரமாணு, ஒளிப்பொருள்**) and in many names. You can pick what you like. I am going to use **Paramaanu** in the rest of the blog.

- The whole process of evolution is a 5 stage process. (Keep noting the importance of 5 and at the background remember Shiva is represented by Panchakshara mantra (Na~Ma~Si~Va~ya).

So what is the five stage process?

  - This space is called as Moolam (Source).
  - This Moolam starts vibrating and this vibration of the space is called Kalam (Absolute Time and not physical time. We will refer this as time only).
  - This Kalam (time) vibrates to a mathematical resonance called Seelam (Rhythm).
  - This Seelam as it resonates creates Kolam (Shapes – Circles, cubes etc).
  - This Kolam becomes our visible Universe which is called Gnalam.

- So it is **MOOLAM (Source) – KALAM (TIME) – SEELAM (RHYTHM) – KOLAM (SHAPE) – GNALAM (UNIVERSE). மூலம் - காலம் - சீலம் - கோலம் – ஞாலம்**, these are 5 stages of evolution.

This means that the Space itself becomes spatial forms and time is the instrument that creates, sustains and destroys. Lord Siva in Tamil is also called as **Kalan (காலன்)** as to who controls time since Kalam **காலம்** is time.

To put it differently, un-manifest state when pulsates becomes absolute time and this is the creative energy. The process of pulsation confirms to a mathematical order and we will see this order in detail later. You may now understand the phrase that “**Time creates, sustains and destroys**”. Since if there is no pulsation then nothing happens.

For those who need quote from a foreigner to convince themselves of this can be referred to the **Bertrand Russel’s** quote “**What we perceive as qualities of matter are differences in periodicity”.**

I shall quote some from the oldest literatures for reference below:
காலமே எவைக்கும் மூலம், காலமே மூல ஆற்றல்
காலமே கோலத் தோற்றம், காலமே ஞாலத் தோற்றம்… *Maha muni Mayan from Aintiram*

காலக்கூறே கணக்கியலாகி… Time splits as Maths in proportion it pulsates.
Vyasa says in Adi parva chapter 1, shloka 249, says the same thing that Time Creates, sustains and destroys everything.

kalah srijati bhutani kalah sanharati prajah
sanharantah prajah kalam kalah shamyate punah!!

The same is quoted as **“Vastur eva Vaastu”** which means the un-manifest Paramaanu which is called **Vastu** (with Single a) becomes **Vaastu (gross form – with two aa**). You can relate this **Vaastu** as the building science which is grossly misused and misrepresented and commercialized in today’s TV programs. We will address the science in it later.

I shall leave this part with this thought, the space is considered as **Nataraja (Shiva) – subtle component and Ranganatha is considered as the Earth component**. So Shiva and Vishnu are two aspects of the same seed. We will see more scientific proof of this later.

"Shivasya hridayam vishnur, Vishnoscha hridayam shivah:" and
"Shivaya Vishnu rupaya Vishnave Shiva rupine"

Vishnu is the heart of Shiva and likewise Shiva is the heart of Vishnu and they both are the representation of each other.

Now if you are clear about the five stage process of evolution we can delve into each and every aspect of this in little more detail that would answer everything.

Ref: Check out all the ones here. Key recommendations are item 6, 11, 14 and 43. http://www.vastuved.com/publication.html

7. TIME = SPACE SERIES. PART 7 – THE CHIDAMBARA RAGASYAM & THE GOD'S PARTICLE

There were 2 questions I had confronted myself when I was reading these passages. They are:

- Why did the unmanifest space energy started pulsating and became absolute time?
- What did the unmanifest space energy contain? Was it a point of singularity as the modern scientists wanted us to believe? If so then how much mass was concentrated in that point which is obviously very difficult to believe.

The answer to the first question is here **"The self unfolds itself for its self – Bhagavad Gita".** There is no convincing answer to the rational mind as to what the reason that the consciousness which was passive decided to become dynamic and started pulsating. So let's leave this for the time being.

But the second question is answered very comprehensively. But before we get into the details of what it is, I want you to check Figure 1. This gives the overall picture of evolution and the five stage process. I also want you to recollect the "EGG" state which is called as the GUNA state where in the form and sound manifests. They say that this pulsation started with OM. This OM as popularly believed is just not an aural form but also has a visual form and that is light. We will discuss about this later in detail.

But let us focus on the actual second question as to what the contents of this Space energy were:

- The space is filled with **Paramanu or Microbodes** which are tiny particles. These are the **God's (Higgs Boson) particle** our CERN scientists are after. http://en.wikipedia.org/wiki/Higgs_boson

- Now, we are probably a year away before CERN publish the results when this blog is published. I would not be surprised to see the results of that experiment is closely aligned with what is available in our scriptures and produced in this blog.

- The primal manifest form of the unmanifest is a **square** (primal wave pattern). This is the shape of the **Paramanu or Microbode**. This is very luminescent, means filled with light and on a 3D plane this shape is a **Square Cuboid**.

- A **Square Cuboid** is a shape which is equal in all sides – say of unit measure which is the smallest measure possible and has **6 faces, 8 vertices, and 12 edges.** You can start figuring out in Hinduism, why the idols of Lord Shiva and Lord Muruga has six faces, 12 eyes, hands etc.

- You may want to note that 6 faces can be represented in 2 ways as below. Figure 3 is Lord Muruga's star or a Star of David in 3D which has 6 faces and 12 edges, popularly known as **Tetrahedron**. **So don't be surprised if the Boson Higgs particle is of the same shape.**

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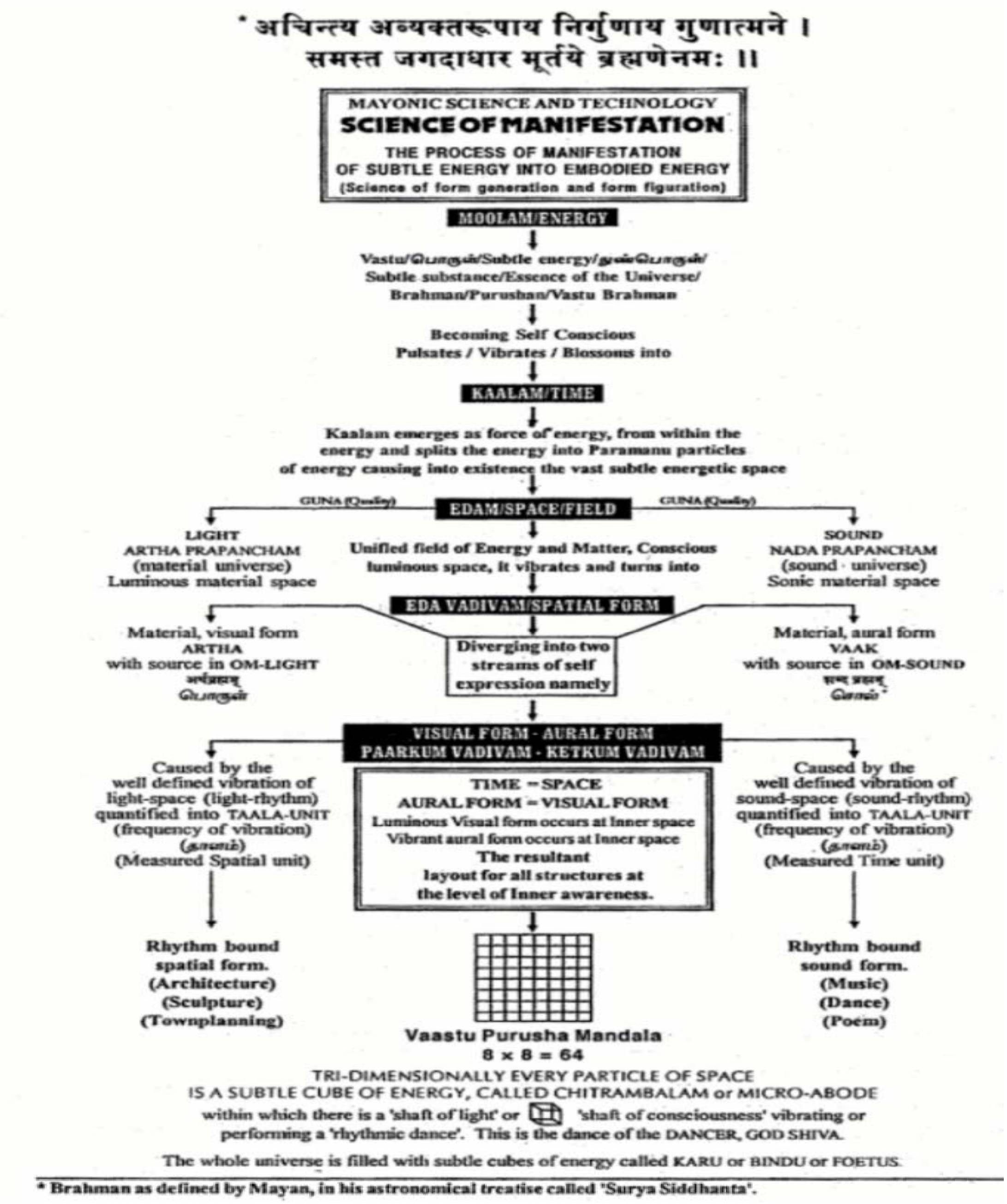
*अचिन्त्य अव्यक्तरूपाय निर्गुणाय गुणात्मने ।
समस्त जगदाधार मूर्तये ब्रह्मणेनमः ॥
MAYONIC SCIENCE AND TECHNOLOGY
SCIENCE OF MANIFESTATION
THE PROCESS OF MANIFESTATION OF SUBTLE ENERGY INTO EMBODIED ENERGY
(Science of form generation and form figuration)
MOOLAM/ENERGY
Vastu/பொருள்/Subtle energy/நுண்பொருள்/Subtle substance/Essence of the Universe/Brahman/Purushan/Vastu Brahman
Becoming Self Conscious
Pulsates / Vibrates / Blossoms into
KAALAM/TIME
Kaalam emerges as force of energy, from within the energy and splits the energy into Paramanu particles of energy causing into existence the vast subtle energetic space
GUNA (Quality)
EDAM/SPACE/FIELD
GUNA (Quality)
LIGHT
ARTHA PRAPANCHAM
(material universe)
Luminous material space
Unified field of Energy and Matter, Conscious luminous space, it vibrates and turns into
SOUND
NADA PRAPANCHAM
(sound · universe)
Sonic material space
EDA VADIVAM/SPATIAL FORM
Material, visual form
ARTHA
with source in OM-LIGHT
अर्थब्रह्म
பொருள்
Diverging into two streams of self expression namely
Material, aural form
VAAK
with source in OM-SOUND
शब्द ब्रह्म
சொல்*
VISUAL FORM - AURAL FORM
PAARKUM VADIVAM - KETKUM VADIVAM
Caused by the well defined vibration of light-space (light-rhythm) quantified into TAALA-UNIT (frequency of vibration) (தாளம்) (Measured Spatial unit)
TIME = SPACE
AURAL FORM = VISUAL FORM
Luminous Visual form occurs at Inner space
Vibrant aural form occurs at Inner space
The resultant layout for all structures at the level of Inner awareness.
Caused by the well defined vibration of sound-space (sound-rhythm) quantified into TAALA-UNIT (frequency of vibration) (தாளம்) (Measured Time unit)
Rhythm bound spatial form. (Architecture) (Sculpture) (Townplanning)
Vaastu Purusha Mandala
8 x 8 = 64
Rhythm bound sound form. (Music) (Dance) (Poem)
TRI-DIMENSIONALLY EVERY PARTICLE OF SPACE IS A SUBTLE CUBE OF ENERGY, CALLED CHITRAMBALAM or MICRO-ABODE
within which there is a 'shaft of light' or 'shaft of consciousness' vibrating or performing a 'rhythmic dance'. This is the dance of the DANCER, GOD SHIVA.
The whole universe is filled with subtle cubes of energy called KARU or BINDU or FOETUS.
* Brahman as defined by Mayan, in his astronomical treatise called 'Surya Siddhanta'.

Figure 1: Science of manifestation
(Courtesy: Pranava Veda by Mamuni Mayan – 12000+ years back, recreated by Dr. Ganapathi Sthapati)

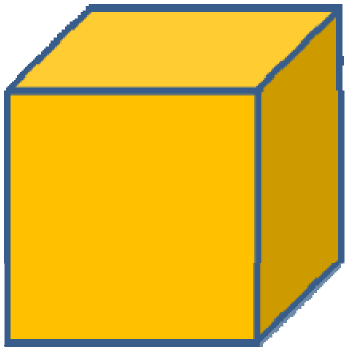

Figure 2: A cube with all equal sides

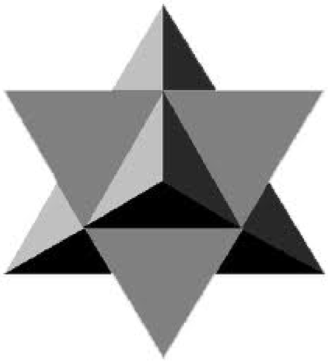

Figure 3: A tetrahedron (from Internet)

- The free space is packed with cubical atoms of energy. They are building blocks of the structure of the universe. **So what is clear is that all these atoms existed in a "resonant state of non-vibration" before the so called "big bang" happened or the pulsation started.**

- **It did not burst out of a single point as popularly believed. Alternatively, in space every point is the center. When the pulsation started these cubical atoms underwent a shape change and manifested as shapes and forms.**

- This cube is called as **micro-abode called Sittravai / Chittrambalam** (mini hall in Tamil). This is **secret in Chaidambaram, Sage Appar** (**Chidambara ragasyam**) realized. Chidambaram is a Shiva temple associated with Space energy and when you go to sanctorum you would not find any idol but just empty space with some lights there. This is to signify this concept of **Paramanu** which is **luminescent and is a Cuboid in shape**. This is the smallest particle possible and can be called as **'God's particle".**

- The micro space, in the cubical shape is fetus or Garbha. This is known as **Vinkaru** in Tamil. This micro abode is the repository of light and sound.

- The free space is Light and the Light is Moolam or source of the universe and universal forms. Light is Brahman, Atman, Vastu Brahman – Nunporul in Tamil.

In the subsequent blogs we will correlate String theory, Brahma Sutra, Nataraja, Vishnu and how they are all contained in order and proportion in pulsation.

Happy reading!

Ref: A good read **Fabric of the universe, Jessie J Mercay**.

8.Time = Space Series. Part 8 – Characteristics of the God's particle (Paramaanu)

This part is going to be a bit controversial hence read it with an open mind. Per our scriptures when analyzed deeply we can state that **"At the beginning it was just Consciousness (Pragnanam) that was luminescent with unmanifested potential energy and residing at resonant state of non-vibration. This energy was un-manifest and was present as Paramaanu or Microbode or Vinporul aka a subatomic particle. Yes! It was a particle without vibration and was at resonant state of non-vibration.**

The entire Space was supposed to be filled with these particles only and these were primal potential matter which is ever lasting.

Now let us ask few questions and see how our scriptures answer this:

1. **What was the shape of this particle?**

We have already answered that. In 2D it is square and in 3D it is a cuboid with all equal sides. Please note that in space it is always 3D and not 2D. It has 6 faces, 8 vertices, and 12 edges. This is known is current scientific community as **Tetrahedron**.

2. **What is inside the Microbode or Subatomic particle?**

This is a very interesting question. Our scriptures say that it is purely space inside but with an energy grid.

3. **What is this energy grid and what is its shape?**

It says that it is an 8x8 energy grid inside this microbode. This essentially means it is a square energy grid of 64 squares inside this Paramaanu.

4. **What is this color of this Paramaanu?**

It is luminescent and hence the golden color of the light is what it is associated with. **"Hiranyavarnnaam harineem**.." says Sri Suktha in the vedas, confirming the color of this Paramanu. Their variations exist but the fundamental one is of golden color.

5. **What is this size of this God's particle?**

It is calculated to be ~133 nm. We will see this in detail later.

6. **What is the significance of the energy grid?**

For the time being let me state that anything subtle is a function of 8 and anything gross is a function of 9. Let me also add that **iChing –** which is a Chinese divination book and the hexagram which deals with the Science of the subtle is in an 8x8 square matrix. **The mental game Chess is played in an 8x8 square.**

You would find 8 is the number or dimension for the subtle. We will see the importance of 8 and 9 and how beautifully these proportions adorn everything in nature in our daily life.

7. Are these particles faster than light?

Frankly I have not read a direct answer to this question but since this particle itself is light the velocity of this particle cannot be faster than light. This is my opinion. Modern experiments are suggesting that it could be faster than light. In **Mahabharatha, Yakshaprasna, the Yaksha will question this to King Yudhishtra as to "what is fastest thing in this world"**? King Yudhishtra would reply as **"mind"**.

Some of the sages have interpreted that since Consciousness is omnipotent and ever connected - the communication is seamless, instantaneous and not subjected to the concept of distance. The example given is if there is a pain in your leg, it does not take time to travel to your head. It is instantaneous and hence the whole universe should be considered as a living organism.

So to conclude on this question the particles are not faster than light but each particle is filled with intelligence and consciousness (just like a human cell) and their communication to anything is not subject to concept of distance. If our scientists come back and tell us that these particles are faster than light, then wait for someone else to tell us a little later that it isn't faster than light. ☺

8. Ok. Who has seen these particles and give me empirical proof?

परमानुरिति प्रोक्तं योगिनाम दृष्टि गोचरम ! **(Paramaanuriti proktam Yoginaam, drishti gocharam)** says **Mayamatham.** This means the **microspace** or **Paramaanu** is visible to the trained contemplatives and meditators only. One quick example as proof is the **Temple in Chidambaram** which represents **Space tattva** where the temple is built around the concept with enough documentation on it.

But we have been trained under Lord Macauly's education system and how can we accept this as proof which is subjective and superstitious. If I may ask please tell me how many of us have seen the electrons or protons? Do we not believe everything when someone tells us in English?

It is true that because of its existence we can see its manifestations and results of some experiments in our day today world. So we will look at tons of manifestations which we have been in nature as we progress. I would like us to be philosophically very clear as to what these things mean which we have been blindly following. For the time being please note down your questions and I am positive that this would be answered in due course.

Our sages have not only seen this, but have given the dimensions of this and the mathematical formula to manage this energy. We will see all of them. After reading all of them if you still don't want to believe in our scriptures, then may be CERN's result if it's in the same lines would prove it for you.

Happy reading!

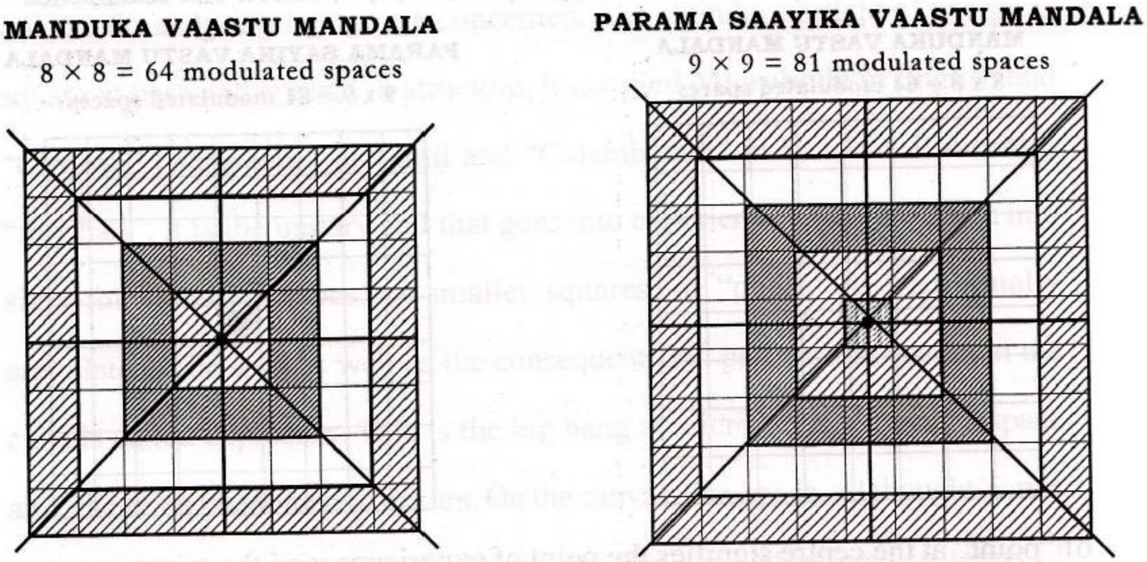
MANDUKA VAASTU MANDALA
8 × 8 = 64 modulated spaces
PARAMA SAAYIKA VAASTU MANDALA
9 × 9 = 81 modulated spaces

Brahma pada (the first belt around the central energy point)	:	2×2=4 padas
Deivika pada (the second concentric belt)	:	12 padas
Maanusha pada (the third concentric belt)	:	20 padas
Paisachika pada (the fourth concentric belt)	:	28 padas
		64 padas

Brahma pada (the first belt including the central square field of energy)	:	3×3=9 padas
Deivika pada (the second concentric belt)	:	16 padas
Maanusha pada (the third concentric belt)	:	24 padas
Paisachika pada (the fourth concentric belt)	:	32 padas
		81 padas

Figure 4: MANDUKA MANDALA – 8x8 (subtle form) & PARAMA SAYIKA MANDALA – 9x9 Gross forms
Courtesy: Dr. Ganapathi Sthapati

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9. TIME = SPACE SERIES. PART 9 – LIGHT, GOD’S PARTICLE AND GOD

“At the beginning it was just Consciousness (Pragnanam) that was luminescent with un-manifested potential energy and residing at resonant state of non-vibration. This energy was self manifest and was ever present as Paramaanu or Microbode or Vinporul aka a subatomic particle. This is **omnipotent, omniscient and omnipresent**.

Ignore religion for the time being and just look at this particle’s characteristics scientifically. It is Eternal (**Anaadi**), primordial (**Aadi**), without any quality (**Nirguna**), it cannot be reached / grasped by thoughts (**Achintya** - since thoughts as energy are much more gross than this and we would see this), it cannot be measured (**Aprameya**), Luminescent (**Jyothi swaroopa**), its **omnipotence, omnipresence (Visvam) and Omniscience** is already known. So said the mahavakya **Pragnanam Brahma!**

All the characteristics of the particle are attributed to a personality or a state by the founders of religions. **Hindus called this state as Paramasiva or Purusha. Hence everything subtle is called Sivamayam.** The essential pulsation which started and the universal evolution began was called as **Parashakti or Prakruthi or Maya.** We will talk about the Shakti aspect later.

This subtle un-manifest energy evolves to become universe which is gross. This gross energy also known as **earth** is called as **Vishnu** and the subtle energy is called as **Space / Akash / Heaven**. So the term became “**Sarvam Vishnu mayam Jagat”.** Please note that it is just **Sivamayam** and there is not Jagat there. Since it is all subtle and there is no Jagat which is gross. But it is **Vishnu Mayam Jagat**.

I need to add that every sect in Hinduism has named this God’s particle with a different name. Narayana has replaced paramasiva in Vaishnavism and so on. In Hindu temples there are 2 prime idols – **Moolavar and Archakar** - The Moolavar does not undergo any archana or any decoration and it is always for the Archakar for which all poojas are performed. This god’s particle refers to the Moolavar and not Archakar.

To my knowledge, every religion and every sage / saint has agreed with the fact this fundamental particle or energy unit is **LUMINISCENT**. Note that there is no sound or word in this …**yet.** Let us see few quotes on this (there are thousands of quotes):

- **Be it vedic culture, Zoroastrians, Greek or any major culture fire / sun god which represents light is worshipped.**
- **“Om Jyothi rasaha” says Vedas**
- **In Gayatri mantra you meditate on the supreme light to illuminate you.**
- Vallalar said **“Arutperumjyothi, Arutperumjyothi”** which means **mighty graceful light**.

- If therefore your eye be single, your whole body shall be full of light. Mathew 6:22
- Thirumoolar states brilliantly that who realizes that the light (physical light which means the world) merges with light (subtle light), he has realized SIVA.

  ஒளியில் ஒளிபோய் ஒடுங்கிய வாறும்
  தெளியும் அவரே சிவ சித்தர் தாமே - 124

So what has happened to the **Sabda Brahman** here? It has merged with the **Artha Brahman** which is the light. What can you use to represent this state?

Light represents Form and our eyes represent Light / Form. So obviously sound is represented by ears. When sound has merged with light then it means Eyes and ears are merged together.

Can you think of anything that represents this state? This concept is captured by representing a **Manduka (Frog) or Sarpa (Snake)** always. Since for a frog and a snake the ears and eyes are merged. **Manduka Upanishad,** represents a knowledge of this state. And obviously the 8x8 square / cube represent the most subtle energy as an energy grid is called as **Manduka Pada / Mandala..**

Now the same aspect when it is applied to a gross form / body or a building then it is a 9x9 energy grid and it is called as **Paramasyika Mandala**. **At the gross level the same concept as applied is the WORD where Light (form) and sound and meaning merged into one. You cannot separate them**. We will look at this later.

Unfortunately we have lost the science and we neither understand the philosophy nor the symbolism behind this supreme science but we made fun of the fact that the supreme science is named after an absolutely menial creature like frog which is used only for zoological lab studies across the world or ends up in the dinner plate as it does in far eastern countries.

I would like to conclude this section by stating (may be a little controversial) that **First it was Consiousness as the Vinkaru, Microbode, Sittrambalam, Nunporul, subatomic particle which was luminescent. Later the concept of God evolved out of it.**

So God is not light, but the right of saying it is "the primordial aspect of "luminescence" has been adopted as God…

So, of the 5 fold evolution process we are still at the source (Moolam). We will see the concept of time and the mathematical science in the subsequentparts.

MOOLAM (Source) – KALAM (TIME) – SEELAM (RHYTHM) – KOLAM (SHAPE) – GNALAM (UNIVERSE). (மூலம் - காலம் - சீலம் - கோலம் – ஞாலம்)

Happy reading!

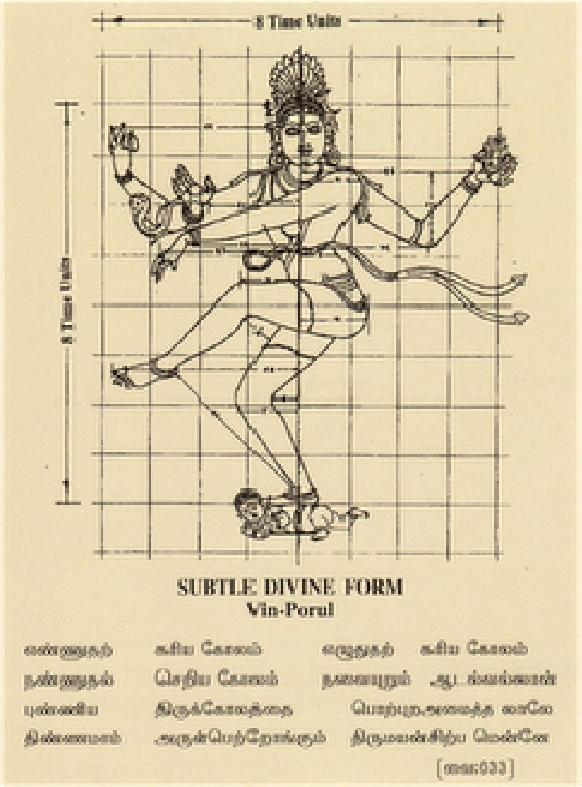
8 Time Units
8 Time Units
SUBTLE DIVINE FORM
Vin-Porul

Figure 5: Lord Nataraja in the Manduka Mandala (8x8 grid) (Courtesy: Dr. Ganapathi Sthapati)

Our next topic is Nataraja and String theory!, so check out this picture. I want you to note the light / fire in the left hand and sound / damru in the right hand. If you notice little closely, you would find a central line along the picture's sternum and all the parts have minute measurements from the central line.

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10. TIME = SPACE SERIES. PART 10 – LORD NATARAJA AND THE STRING THEORY

“The self unfolds itself for its self – Bhagavad Gita”.

This self unfolded itself with a pulsation and this pulsation is the **start of Absolute time** (**KAALAM**). As I said nothing to my knowledge tell us clearly as to why this pulsation happened. This is the point of singularity in the scientific language and the event is termed as **Big Bang.** Just as I expressed earlier it was an event of primordial pulsation and not of an explosion which threw away mass because of the explosion into the space.

The entire space existed with its subatomic particles and this pulsation made the space to vibrate and this vibration was rhythmic and led to the evolution of this universe. **Popularly known as “That one became many”… and ..Vastur eva Vaastu.**

This pulsation happened because of the **Pranava** or the first pulsation resulted in the **Pranava -** both conceptually right. So at the time of this primordial pulsation 2 things happened:

- The absolute time started. This is called **Kaalam.**
- Primordial and the most sacred **Pranava** emerged.

Both these happened simultaneously and it is futile to ask whether **Kalam created Pranava or Pranava created the pulsation.** In many of the texts it offered as **Pranava that created the pulsation**. So let’s go by that.

- This is the reason that **Pranava / Primordial Om is so sacred in Hinduism.**
- This Pranava had manifested in 2 forms:
    - **Luminescent form as OM the Light. This is the source of all visual forms. The primordial form is represented as ஓம் in Tamil and ॐ in Sanskrit.**
    - **Aural form as Om the sound. This is the source of all aural forms. I should say that this is more popular form compared to the luminescent form.**

Now this concept is very important, since in the Pranava meditation they say us to meditate on the silence after the word OM and also mediate **OM as light, OM jyoti rasaha in vedas.**

So, when I say that sound merges into light, it is all the aural form merges into **ITS** luminescent form. All luminescent forms merge with the **Paramaanu** which is also luminescent. I am reproducing this passage again for emphasis and clarity.

- **Sage Thirumoolar** states brilliantly that who realizes that the light (physical light which means the world) merges with light (subtle light), he has realized SIVA.

  ஒளியில் ஒளிபோய் ஒடுங்கிய வாறும்
  தெளியும் அவரே சிவ சித்தர் தாமே - 124

I have read many times over to understand this concept and I would suggest that you allow this concept to sink in.

Now let's come to the 8x8 energy grid of the **Paramaanu** and imagine that it is pulsating because of Pranava and this **Pranava has both light and aural form**.

- They say that this **pulsation is rhythmic and symmetric**.
- When something is Symmetric, then there has to be a central line along with the Symmetry comes. For example if our right and left sides are symmetric then the body is divided along the sternum & backbone.
- Within the 8x8 energy grid / hall there is a **vertical luminous shaft** called **Brahma Sutra (Oli nool)**. Sutra in Sanskrit and Nool in Tamil means **Thread / String**.
- This **Olinool / Brahma Sutra is a shaft of consciousness also called Moolathoon / Moolasthambham**.
- **This shaft of consciousness vibrates in a particular order called rhythm.** This is the order of nature.
- **This rhythmic vibration of the shaft of consciousness is the dance of Shiva, the CELESTIAL DANCE / THE COSMIC DANCE / THE DANCE OF EVOLUTION of the LORD NATARAJA.**

Look again at the picture of LORD NATARAJA, he is drawn inside a 8x8 Manduka mandala (now you know what it is), his left leg is raised suggesting a movement from left to right. Imagine that he is going to land the left leg to his right side.

Why should he suggest that he is moving from left to right?

His left hand holds light / fire and his right hand holds Drum / Damru / Sound. The process of Evolution which starts with the absolute time and Pranava is fantastically represented pictorially. It suggests that the evolution process starts with the rhythmic dance of the PARAMAANU in a 8x8 energy grid and this process evolves first as light and then as sound. This light and sound creates further forms and the entire universe.

It is very easy to answer as to why sound evolves from light? We all know that the light is at a higher frequency and velocity than sound. This is the same reason we see lightning first then hear the thunders.

So let's summarize the DANCE OF EVOLUTION of LORD NATARAJA:

- From being un-manifest the **Pranava** emerges. Or the Pranava evolves the un-manifest to the manifest and starts the cycle of evolution.
- This leads to a pulsation which is called as the **COSMIC DANCE / CELESTIAL DANCE / DANCE OF EVOLUTION**.
- This pulsation is **rhythmic and symmetric**.
- The luminescent shaft of consciousness is called as **Brahma Sutra** or popularly called as String theory in the modern science.
- The process of creation evolves from the dance as light then sound evolves from light and then all the visual and aural forms in this universe.

If this is so then the process of dissolution should be that Lord Nataraja's right leg should be lifted suggesting a movement from right to left isn't?

Look at the majestic picture suggesting the **DANCE of EVOLUTION** and the **DANCE of DISSOLUTION** as below:

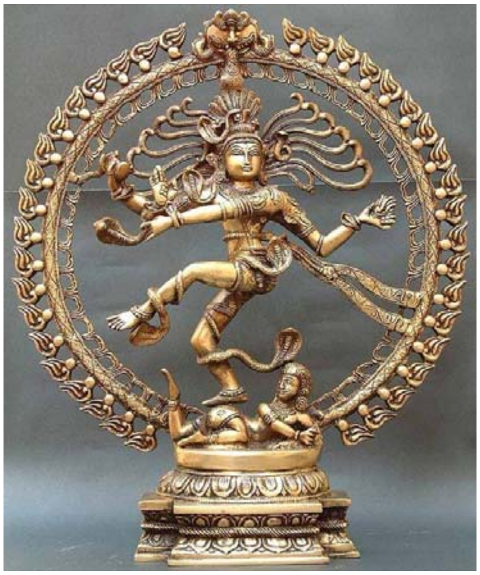

Figure 6: LORD NATARAJA / DANCE OF EVOLUTION

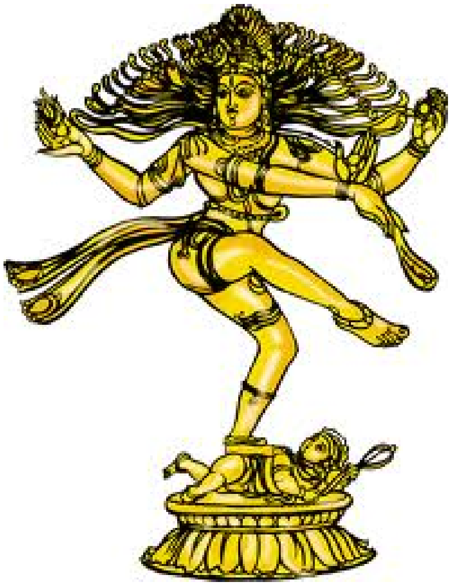

Figure 7: DANCE OF DISSOLUTION

In my opinion there is nothing more scientific in this world that is pictorially represented about the evolution of universe. You should read a book called **"The Tao of Physics" by Frijat Capra** where as physicist he explains how he experienced this and highlights the dance of the quantum particles in space corresponds to the dance of **Lord Nataraja**.

Now this central shaft of Consciousness is called **Brahma Sutra** and according to our scriptures every Paramaanu has this string, which means every being, matter, inanimate things in this universe including the tiniest of subatomic particles have this string / sutra. In the future parts we will see the Maths behind this sutra and the pulsation but let us look at what the modern science says about **Superstring theory** here, http://en.wikipedia.org/wiki/String_theory. You can read it how many times ever you want but this theoretical postulation is a direct adaptation of the cosmic dance and our Brahma Sutra and nothing more.

Now check out Lord Nataraja at the CERN http://www.fritjofcapra.net/shiva.html

As a wise man said, **"Indians are the most ignorant about their rich past and scientific traditions."**

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Now you may understand as to why I started this series with the above line. We have a very rich past that is most scientific and it is left codified in a form across thousands of temples in India. Let us just open your eyes and understand the scientific meaning around it.

If you are so far surprised at our richness and advancement, please wait till we will get into real hard core mathematics and geometry of our nature in the subsequent parts.

May that “**Sutradhaari”** dispel our ignorance and reveal to us the secrets of nature.

Happy reading!

11. TIME = SPACE SERIES. PART 11 – VASTUREVA VAASTU AND $E=MC^2$

We have seen that the universe in its un-manifest state is filled with luminescent cuboids and there was a trigger in the form of Pranava which started the absolute time and gave forth visual forms and aural forms.

This process of evolution is depicted very nicely in the following diagram:

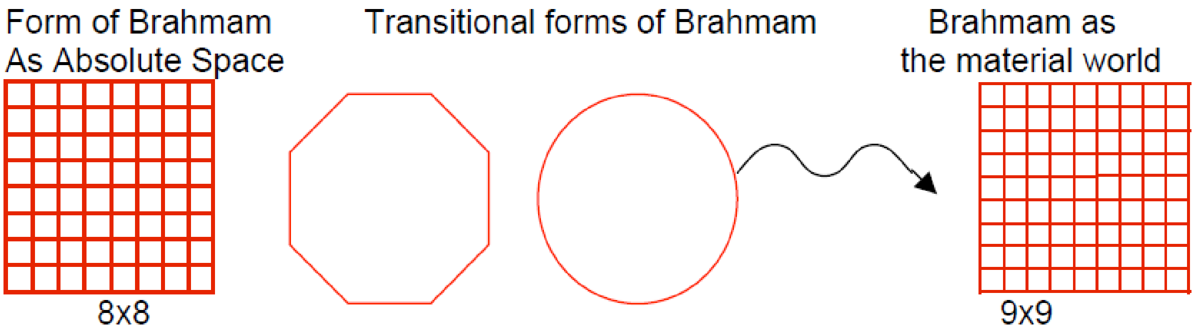

Figure 8: Transition forms of Brahman (Coutesy: Dr. Ganapathi Stapathi)

The square (in 2D) which is an 8x8 energy grid became a 9x9 energy grid which is manifest / gross. The transition forms were an octagon and a circle. **Aintiram** suggests how this transition takes place. Current physics accepts that a pulse and a sine wave can be created from each other and this happens because of simple addition of harmonic frequencies.

The primordial pulsation initiates a rotational force and this rotational force as it gains momentum converts the square into a circle and if you notice that the octagon is just an in between state between a square and a circle.

We see confirmation of the details of this manifestation process in Chapter 9, verse 8 of the Bhagavad Gita where Lord Krsna describes His manifestation process to Arjuna:
"prakritim svaam avastabhya visrijaami punah punah", meaning "Curving back onto myself, I create again and again…"

What it suggests is that the essential shape of every gross form in its natural state is a circle (in 2D) and a sphere in (3D). **This is the reason we find every planetary body is almost spherical in shape and this is also the reason as to why the ripples in a water body when we throw a stone in the water are in circles.**

Be it the center of a tornado or the shape of a hurricane or a tsunami it always a circular force. The supreme secret in martial arts is that the Chi moves in a circular fashion and hence Tai Chi is the most deadly form of martial arts. Lord Vishnu has Chakra as his weapon to suggest not only light but also the rotational force.

The process of manifestation is captured in these 2 pictures at all the significant stages. If you notice that a single dot becomes multiple dots, then a line, then a pulse and then goes on to becoming a 8x8 energy grid and then to a 9x9 energy grid. 8x8 is un-manifest and 9x9 is manifest. These aspects are very well captured as sutras in the book **Aintiram and Pranava Vedam.**

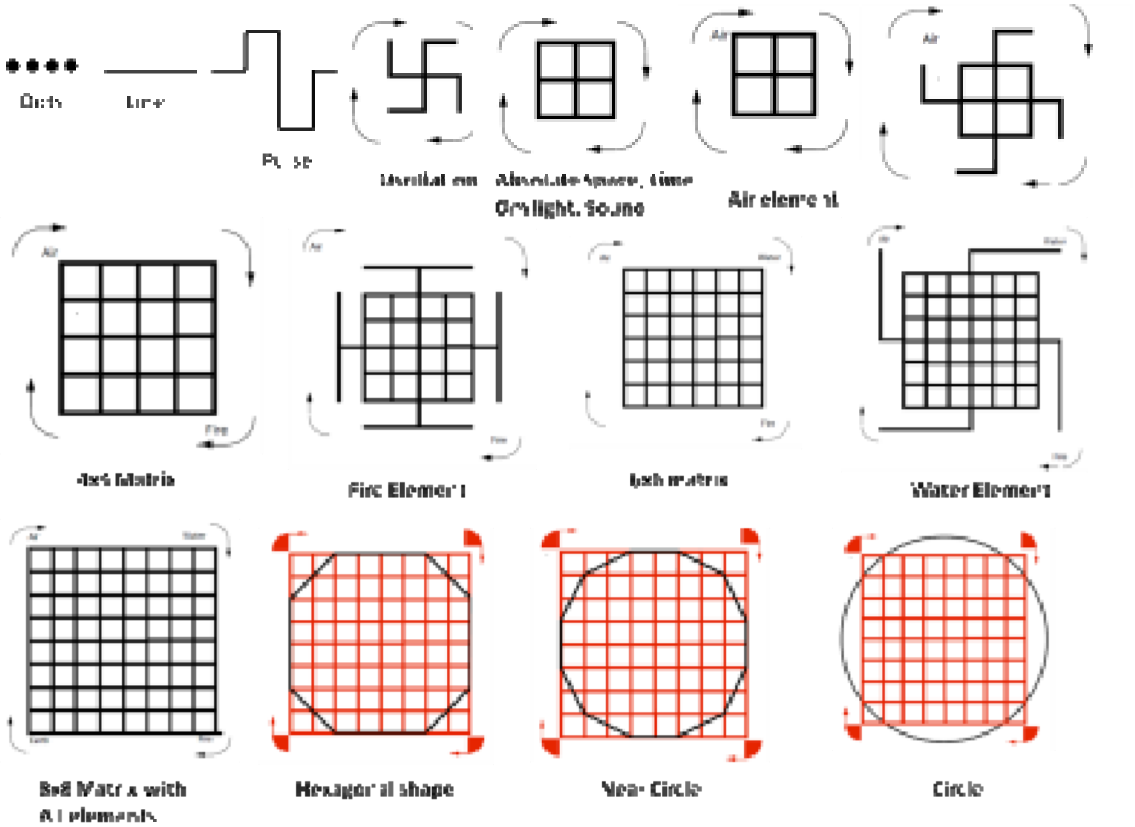
Dots
Line
Pulse
Absolute Space, time
Om light, Sound
Air element
Air
4x4 Matrix
Fire Element
6x6 matrix
Water Element
8x8 Matrix with
All elements
Hexagonal shape
Near Circle
Circle

Figure 9: Transition forms of Brahman in detail (Coutesy: Fabric of the Universe)

If you look at the Fig 10 conceptually the following things happen:

- Subtle Energy becomes gross universe and the fundamental 5 elements are created in the process.
- It is said that 1/10th of the space becomes Air, 1/10th of air becomes Fire, 1/10th Fire becomes Water and 1/10th of Water becomes Earth.
- So we can conclude that we are living in a **Space delineated world.**

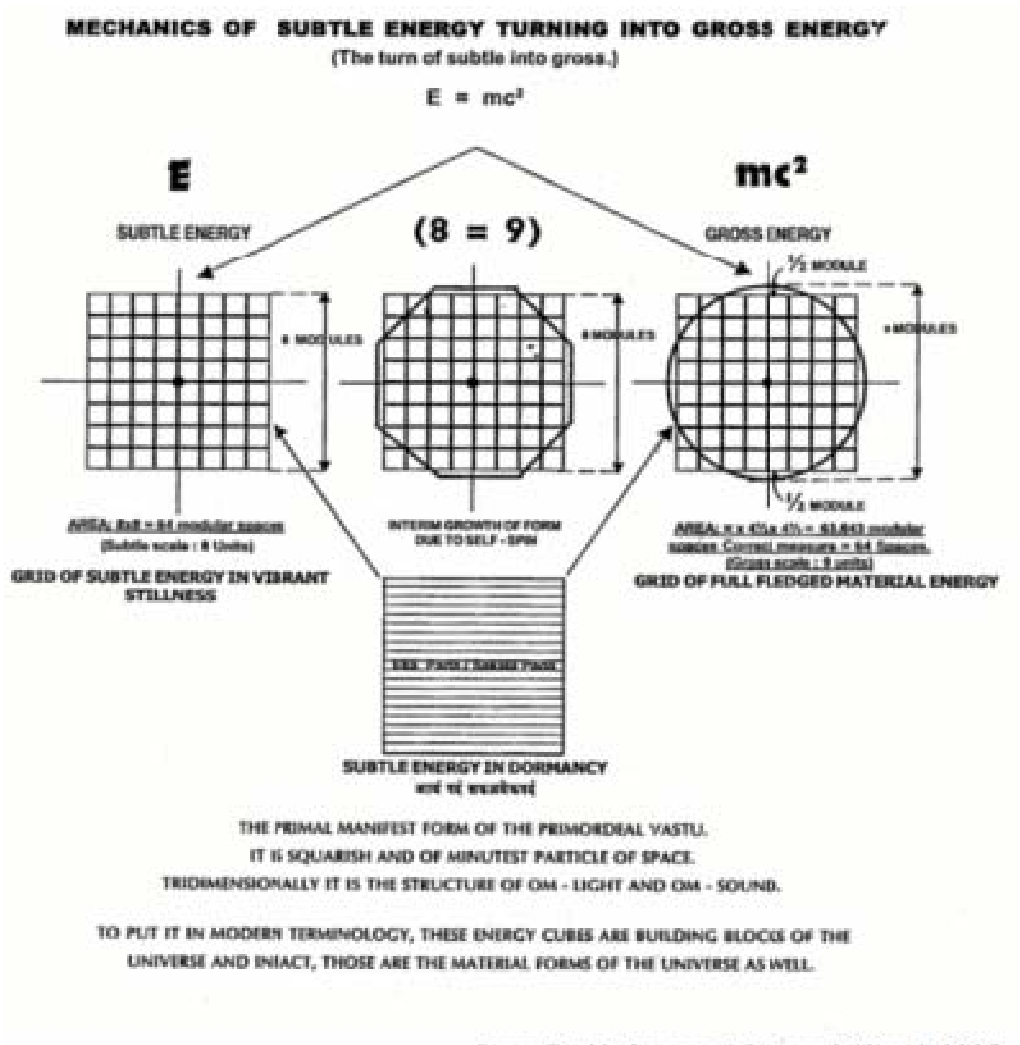
MECHANICS OF SUBTLE ENERGY TURNING INTO GROSS ENERGY
(The turn of subtle into gross.)
E = mc²
E
mc²
SUBTLE ENERGY
(8 = 9)
GROSS ENERGY
½ MODULE
8 MODULES
8 MODULES
8 MODULES
½ MODULE
AREA: 8x8 = 64 modular spaces
(Subtle scale : 8 Units)
GRID OF SUBTLE ENERGY IN VIBRANT STILLNESS
INTERIM GROWTH OF FORM DUE TO SELF - SPIN
AREA: π x 4½ x 4½ = 63.643 modular spaces Correct measure = 64 Spaces. (Gross scale : 8 units)
GRID OF FULL FLEDGED MATERIAL ENERGY
SUBTLE ENERGY IN DORMANCY
THE PRIMAL MANIFEST FORM OF THE PRIMORDEAL VASTU.
IT IS SQUARISH AND OF MINUTEST PARTICLE OF SPACE.
TRIDIMENSIONALLY IT IS THE STRUCTURE OF OM - LIGHT AND OM - SOUND.
TO PUT IT IN MODERN TERMINOLOGY, THESE ENERGY CUBES ARE BUILDING BLOCKS OF THE UNIVERSE AND INFACT, THOSE ARE THE MATERIAL FORMS OF THE UNIVERSE AS WELL.

From Dr. V. Ganapati Sthapati, Kauai, 2005

Figure 10: Subtle Energy to gross (Courtesy: Dr. Ganapathi Sthapati)

This wisdom was so succinctly captured by my good friend **Lao Tzu** in “**Tao Te Ching**” as follows: (Read heaven as un-manifest space and Earth as manifest gross)

“Heaven and Earth last forever.
Why do heaven and Earth last forever?
They are unborn, so ever living....

Thirty spokes share the wheel's hub;
It is the center hole that makes it useful.
Shape clay into a vessel;
It is the space within that makes it useful.
Cut doors and windows for a room;
It is the holes which make it useful.
Therefore benefit comes from what is there;
Usefulness from what is not there....”

But I wanted to highlight more important aspects to this process of manifestation.

- **Advaita** philosophy states that there is no duality. If you note that the **Parammanu** is what is present every living being and inanimate thing. What is within you is what is within me and hence the mahavakya **“Tat Tvam Asi”… You are that**.
- **Vastureva Vaastu** – Vastu which is unmanifest and subtle becomes Vaastu which is manifest and gross.
- **If we assume that Paramaanu is God’s particle and hence it is divine, then everything in this world is divine**. This is the most important philosophy in **Hindusim**. See **the oneness in all** and see “**All in one”**.
- That’s why Hindus saw divinity in everything. Trees, snakes, animals, insects, birds, human beings etc. There is nothing without that divine energy or particle – however you call it.
- This philosophy is **UNIVERSAL, OPEN SOURCE, ALL COMPASSING and the highest state of consciousness**.

But let’s look at something even more important:

- We all note that Subtle has become Gross. Hence conceptually Gross = Subtle or both are proportionate.
- We all note that Space has become Earth. Hence conceptually Space = Earth or both are proportionate.
- We all note that 8 have become 9. Hence conceptually 8 =9 or both are proportionate.
- We all note that ENERGY has become MATTER. Hence conceptually ENERGY = MATTER or both are proportionate. This is represented by $E = mc^2$ by our great scientist Einstein. While we did not have this specific formula, the concept and the associated texts were very much with us for ages.

So this is what Einstein quoted after reading Bhagavad Gita.

"When I read the **Bhagavad-Gita** and reflect about how God created this universe everything else seems so superfluous." ~ Albert **Einstein**

Now let’s try to answer this question:

- When you throw a stone in water / pond the ripples that form take the shape of a circle (in 2D) / sphere (in 3D). Can you guess what the shape of the ripple would be if you throw the same stone in space?
- **You would have probably guessed the answer. The ripples in space should be and would be in square /cube in shape.**

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

Happy reading!

12. TIME = SPACE SERIES. PART 12 – VEDIC CONCEPT OF TIME & ITS MEASUREMENTS

The importance of time (**Kaalam**) is so high in the Vedic tradition that they ensured that the accuracy, continuity of time and the easy measurability of it is maintained for who knows how many years. **Time creates, sustains and destroys** everything and this is very nicely captured in these 2 lines:

காலமே எவைக்கும் மூலம், காலமே மூல ஆற்றல்
காலமே கோலத் தோற்றம், காலமே ஞாலத் தோற்றம்

The god of time is **Kaala Bhairava** – a form of Shiva and hence both **Shiva** and **Yama the lord of death both were** known as **Kaalan.** The time is represented by **number 13** and it belongs to Kala bhairava. We will see the interesting linkage between Vedic system and the Mayan calendar found in Guatemala and Mexico later.

Swami Chinmayananda states that "**Time is the periodicity between 2 thoughts**". Nothing captures the concept of time more wisely. What is clear from our scriptures and Swami Chinmayanda is that time is the pulsation that creates this universe. It is the vibration with very accurate periodicity and our sages suggested that you can live beyond time provided you manage to escape the effects of that pulsation.

Einstein's view on time and its relativity is very realistically captured in this quote **"When you are courting a nice girl an hour seems like a second. When you sit on a red-hot cinder a second seems like an hour. That's relativity."** More than relativity I found that the root cause of relativity is the pulsation of mind as time. Einstein on a serious note proved that our view of time is not absolute, it is relative and it is a continuum with space. We will in the next few parts of this blog would see that time and space are the same or Time = Space.

Aintiram states that there are 5 things that vibrates which have a common root and are not under our control. They are Space, Earth (vibration of earth is gravity), Eye lids, thoughts and Musical notes and very nicely put in Tamil as (Vin)**விண், மண்(man), கண்(Kan), எண்(Yen), பண்(Pan). Pan is musical metre / chandas and Yen is the yennam or thoughts.**

Correlate this with the first line of **Patanjali Yoga Sutra** which says **"Yoga Chitta Vrtti Nirodah",** means **Yoga is one which stops the vibration of mind / pulsation of mind and hence is a killer of thoughts.** The meditation techniques of keeping your eyes opened without battling the eyelids is another way of overcoming this pulsation instinct that is primordial and inherent in our nature.

Let's look how intricate our measurements time are in Vedic system. Check out the image below.

- The smallest unit of time is approximately 2 micro second.
- The largest unit is about 155 trillion years…. YET.
- Brahma's linear age is 50 years and in currently in his 51st year which makes the universe to be 155+ trillion years. Brahma's life time is 100 years which means it would be 300 trillion+ years of universal life which follows a cycle.

- After 100 years of pulsation cycles Brahma stays as dormant energy for the same period and then pulsates again for the next life of 100 years.
- A **Brahma's** life is also known as a Para. Each half Param is referred to as a *parardham*. This second half is termed as **'*dviteeya paraardhe*'** (the second half of Brahma's term) is stated in all vedic rituals.
- After every Chatur yuga, the world recycles. After every 2000 years / a Brahma day the world dissolves and remerges. The important point to note is that there is no CONCEPT OF CREATION here. It evolves and dissolves as per the science of pulsation. We also note that this pulsation expands and contracts. This cyclical nature of time as believed in Indian mythology refers to time as '*anaadi*' or that without a beginning.

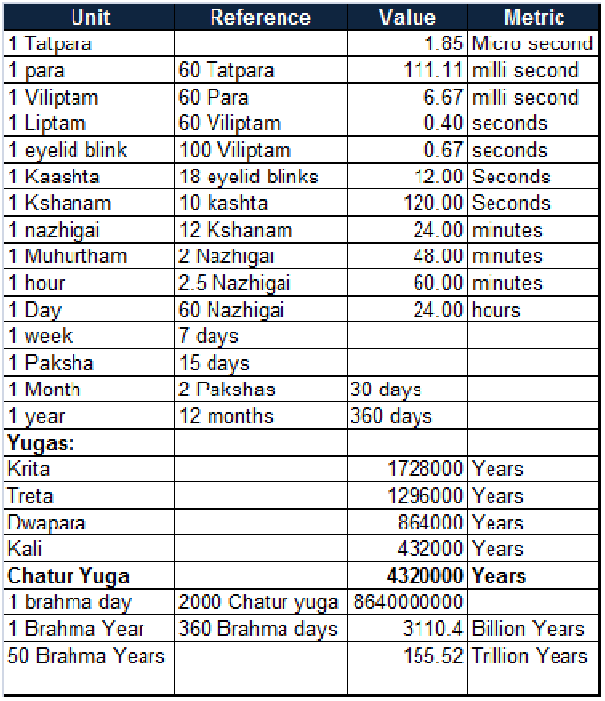

Unit	Reference	Value	Metric
1 Tatpara		1.85	Micro second
1 para	60 Tatpara	111.11	milli second
1 Viliptam	60 Para	6.67	milli second
1 Liptam	60 Viliptam	0.40	seconds
1 eyelid blink	100 Viliptam	0.67	seconds
1 Kaashta	18 eyelid blinks	12.00	Seconds
1 Kshanam	10 kashta	120.00	Seconds
1 nazhigai	12 Kshanam	24.00	minutes
1 Muhurtham	2 Nazhigai	48.00	minutes
1 hour	2.5 Nazhigai	60.00	minutes
1 Day	60 Nazhigai	24.00	hours
1 week	7 days		
1 Paksha	15 days		
1 Month	2 Pakshas	30 days	
1 year	12 months	360 days	
Yugas:			
Krita		1728000	Years
Treta		1296000	Years
Dwapara		864000	Years
Kali		432000	Years
Chatur Yuga		**4320000**	**Years**
1 brahma day	2000 Chatur yuga	8640000000	
1 Brahma Year	360 Brahma days	3110.4	Billion Years
50 Brahma Years		155.52	Trillion Years

Figure 11: Time measurements in Ancient India

While doing Vedic ritual the time and space coordinate is invoked to say that you are doing this ritual at this place in the universe and at this time – with reference to Brahma's age to the time and star of the day. This tradition is unbroken and the Indian Almanac can predict the position of astronomical objects without any error for thousands of years without any sophisticated instruments and space ships.

On the contrary just read the history of the Gregorian calendar which we are following here, http://en.wikipedia.org/wiki/Gregorian_calendar. There is neither accuracy nor continuity and to top it up there are authorities who reform the calendar as if time stops and waits for them to affect that reform. Why should we ignore the best of time science that we have for an inaccurate, discontinuous reformed calendar?

As a wise man said, **"Indians are the most ignorant about their rich past and scientific traditions."**

Happy Reading!

13. TIME = SPACE SERIES. PART 13 – SOUTH AMERICAN MAYAN & SOUTH INDIAN MAAYAN

Since we are discussing about time, let us address the **Mamuni Maayan** and the **South American Mayan**.

A lot has been talked about Mayan calendar and the imminent destruction to planet earth in the year 2012. I would recommend **'The Mayan Factor – Path beyond technology" by Jose Arguelles** if you are interested in this topic.

In this part I am interested in highlighting that the **South American Mayan** and the **South Indian Mamuni Maayan** who wrote **Aintiram and Pranava Veda** are one and the same. Extensive research have been conducted by many and I found, both the works of **Jose Arguelles and late Dr. Ganapathi Stapathi** who has spent about 3 decades each, very impressive. Dr. Ganapathi concluded that they both are the same and he has shown some interesting linkages.

I am going to present what impressed me in both these great researcher's works.

- First let me state that the doomsayers of 2012 phenomenon picked up Mayan's calendar which started in 3113 BC ran for 5125 years and the calendar ended in year 2012. Since the calendar ended they thought this signified that the world is ending. Jose argues that this is wrong and most probably the human race is entering into the next phase of evolution and the next cycle would begin. If you strongly believe that this is not true and the world would certainly end by 2012, then please ensure that you transfer all your assets and savings to my name effective 22, Dec 2012. ☺

- Mayan in his calendar in South America used very unique numerals in his calendar that is given below:

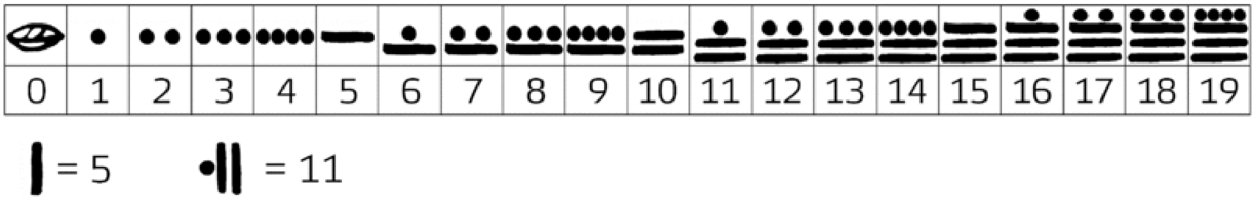

Figure 12: Mayan's numeral system (Courtesy: Wikipedia, Internet)

Now let me reproduce a Tamil poem written by Mamuni Maayan in his work called "**Kanithamaa sennool**". This song is part of the book written by Maayan in Tamil during his time – 12000 years+. This song expresses how the numerals are formed till 10. It says,

  - 1 is one dot, 2 is 2 dots, 3 is 3 dots, 4 is 4 dots, 5 is a line and 10 is a double line.

மாப்புள்ளி ஒன்றே அன்றோ ஒன்றுமா எண்ணே காட்டும்

உ

மாப்புள்ளி இரண்டே யன்றோ இரண்டுமா எண்ணே காட்டும்
மாப்புள்ளி மூன்றே யன்றோ மூன்றுமா எண்ணே காட்டும்
மாப்புள்ளி நான்கே யன்றோ நான்குறு எண்ணே காட்டும்

மாப்புள்ளி ஐந்தே யன்றோ ஐந்து மா எண்ணே காட்டும்
மாப்புள்ளி கோட்டினாலே இரண்டுரு மாக்கங் காட்டி
மாவியல் திறத்தினாலே பத்தறு மாக்கங் காட்டி
மாவியல் திறத்தினாலே எண்முதற் பொருளு மாவாய்!! (கணிதமா செந்நூல் - மாயன்)

- Among the books written during Mayan's time in Guatamala are Popol Vuh, The annals of cakchiquels and the **Book of Chilam Balam**. The resemblance of **Chilam Balam to Chidambaram** with which S. Indian Maayan was so involved is very striking.

- Be the pyramids that were built in the jungles of S. America that has a striking resemblance to the viamanas from south India, the earth's revolution around the sun measured within 1/1000th of the decimal point which is available in a book called **Surya Siddhaanta – In Sanskrit** by Mayan and the identical measurements available in South America – the similarities are difficult to ignore.

- Jose Arguelles makes a compelling argument about the shift in consciousness in 2012 due to a major galactic synchronization. But what impressed me are the following:

    - Comparison between **iChing (8x8 hexagram) and Mayan's Tzolkin which is 13x20 matrix**. In fact there is a Franklin's magic square which is based on the 8x8 grid of iChing that adds upto 260 which is the galactic constant of Tzolkin. This was amazing.

    - He refers to **Radiogenesis – Universal transmission of information through or as light** or radiant energy which is very much relevant to our discussions of light and sound.

    - The revelation he received from a Maya Humbatz men belonging to the universal great brotherhood organization revealing that our universe is the 7th such system which Maya has charted in the universe. So, we are not alone ☺

Would conclude this topic in the next part…

Happy reading!

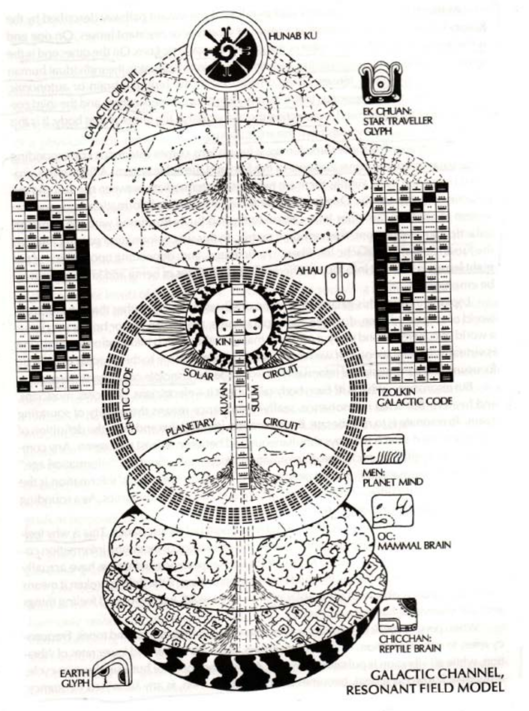
HUNAB KU
EK CHUAN: STAR TRAVELLER GLYPH
GALACTIC CIRCUIT
AHAU
KIN
SOLAR CIRCUIT
TZOLKIN GALACTIC CODE
GENETIC CODE
KUXAN
SUUM
PLANETARY CIRCUIT
MEN: PLANET MIND
OC: MAMMAL BRAIN
CHICCHAN: REPTILE BRAIN
EARTH GLYPH
GALACTIC CHANNEL, RESONANT FIELD MODEL

Figure 13: Galactic Communication Channel to Hunab Ku (Courtesy: The Mayan Factor, Jose Arguelles)

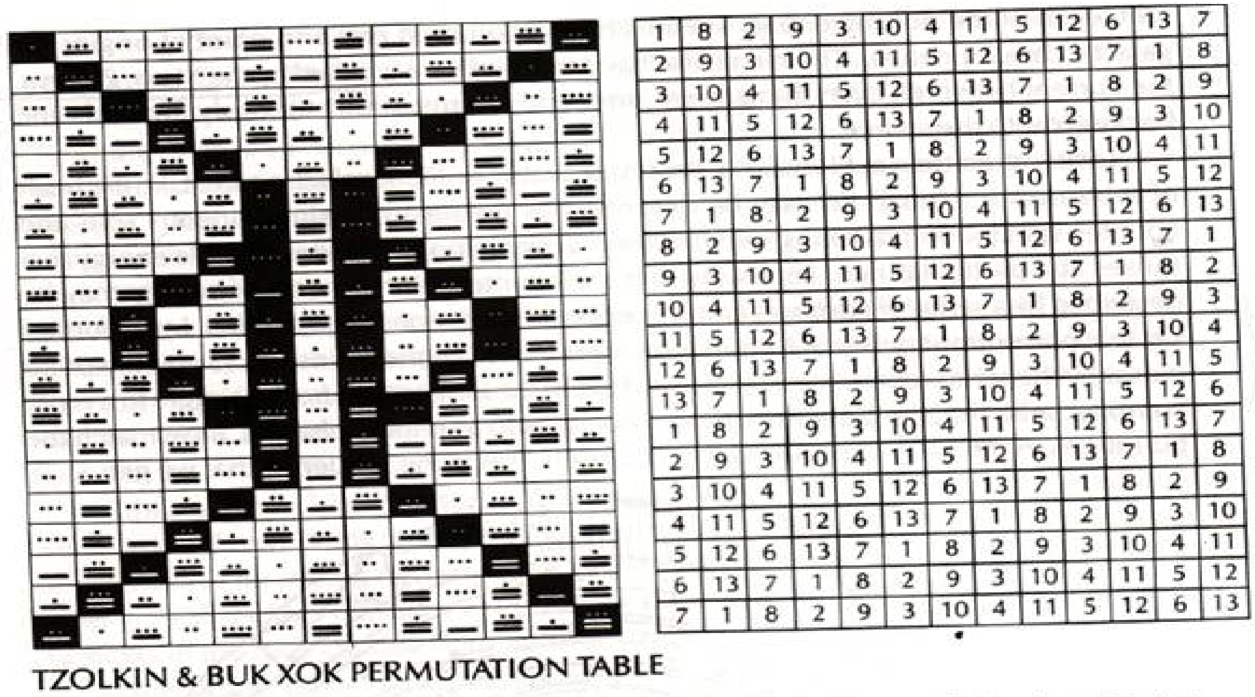

1	8	2	9	3	10	4	11	5	12	6	13	7
2	9	3	10	4	11	5	12	6	13	7	1	8
3	10	4	11	5	12	6	13	7	1	8	2	9
4	11	5	12	6	13	7	1	8	2	9	3	10
5	12	6	13	7	1	8	2	9	3	10	4	11
6	13	7	1	8	2	9	3	10	4	11	5	12
7	1	8	2	9	3	10	4	11	5	12	6	13
8	2	9	3	10	4	11	5	12	6	13	7	1
9	3	10	4	11	5	12	6	13	7	1	8	2
10	4	11	5	12	6	13	7	1	8	2	9	3
11	5	12	6	13	7	1	8	2	9	3	10	4
12	6	13	7	1	8	2	9	3	10	4	11	5
13	7	1	8	2	9	3	10	4	11	5	12	6
1	8	2	9	3	10	4	11	5	12	6	13	7
2	9	3	10	4	11	5	12	6	13	7	1	8
3	10	4	11	5	12	6	13	7	1	8	2	9
4	11	5	12	6	13	7	1	8	2	9	3	10
5	12	6	13	7	1	8	2	9	3	10	4	11
6	13	7	1	8	2	9	3	10	4	11	5	12
7	1	8	2	9	3	10	4	11	5	12	6	13

TZOLKIN & BUK XOK PERMUTATION TABLE

Figure 14: Tzolkin table (Courtesy: The Mayan Factor, Jose Arguelles)

14. TIME = SPACE SERIES. PART 14 –MAYAN, TAMIL, PLEIADES & iCHING

Jose Arguelles was also mentioning that the pyramid structures of Mayan civilization in South America with the **Tzolkin** calendar matrix communicates with 2 constellations – **Pleiades and Arcturus**. Jose mentions that he is sure about communication with Pleiades constellation.

Why did Pleiades interest me?

- According to Tamil history, Tamil is a divine language and the Lord associated is **Lord Muruga**. He is the Tamil deity and he is from the **Constellation Pleiades** which is called **Kritika nakshatra**.
- This emphasis that the South American Mayan could be a Tamilian from India, as many in the ET studies circuit opine that Pleiades is a constellation which is like our distant cousin where Tamil is spoken. There are many links but you can check this out.. http://22050hz.blogspot.com/2008/10/pleaidians.html

- Look at the Mayan calendar in Fig 14, it is a 13x20 Tzolkin matrix.
    - Please recall that we mentioned **13 is the number for Kala Bhairava**.
    - Tzolkin has a mystical central column around which 6 and 6 columns exist. The belief is that this central column is the frame of reference to the galaxy and it is believed to connect to **Hunab Ku – the center of the galaxy**.
    - This mysterious centre column is believed to be the road to the sky leading to the umbilical cord of the universe. I immediately correlated this with the **thread of consciousness** which is connected to the Hiranyagarba (the center of the galaxy as per Indian texts.) – Check Figure 13.
    - So understanding that this shaft of consciousness is connected to the center of the galaxy (**Hunab Ku / Hiranyagarbha**) at the one end and to **our solar plexus** at the other end with communication and galactic information transmission happening through resonance of light, opened many gates within me.

Nothing in this universe exists without purpose and the form and shape of any being / thing is explained as a state of consciousness at a particular resonant frequency adds to the Seelam (Rhythm) aspect of the Kaalam which we are going to see later.

For the space and time travel enthusiasts, Mayan has the following:

- All space travel is intelligence as information – transmitted through light by the principle of harmonic resonance.

- **Mayan says that Sun is the lens through which galactic information is transmitted from the galactic core and interpreting this with Gayatri Mantra where we meditate on the supreme light Savitr – an aspect of Sun god is amazingly striking.**

- Mayan highlights that time is a function of principle harmonic resonance and he attaches significant importance to the numerals which he states are the galactic harmonic constants. This is exactly what **Aintiram** states.

- **He interprets the iChing to contain the Genetic code of the human DNA as a hexagram in a 8x8 matrix which is a binary progression to the 6th power corresponding 64 six part words /codons. At the same time he interprets number 260 to be galactic constant and 360 which is the factor for a calendar year or the total angle in a circle to a harmonic calibrator.** His explanations more on this and on the mystical number 7 do not resonate in my tiny brain and I am begging for holy grace to expand my mind to understand these concepts.

- **When he says that flowers open to light just does not mean that it is sensitive to be light but deeply it aspires to be LIGHT.** I am not sure if you understand the depth of this statement as against the Sage molar statement which states gross light should merge with subtle light. I have been left speechless for days after understanding this correlation.

It is interesting to note that significance of numerals as per Mayan factor:

- **1 – The pulsation – Ray of Unity**
- **2 – The pulsation - Ray of Polarity**
- **3 – The pulsation - Ray of Rhythm**
- **4 – The pulsation - Ray of Measure**
- **5 – The pulsation - Ray of center**
- **6 – The pulsation - Ray of organic balance**
- **7 – The pulsation - Ray of mystic power.**
- **8 – The pulsation - Ray of harmonic resonance.** We will see more of this.
- **9 – The pulsation - Ray of cyclic Periodicity**
- **10 – The pulsation - Ray of Manifestation**
- **11 – The pulsation - Ray of Dissonant Structure**
- **12 – The pulsation - Ray of Complex stability**
- **13 – The pulsation - Ray of Universal movement**

In all 2 independent researchers working 6000 miles apart, conducting their studies independently seems to be pointing to just one person and one philosophy and science. What else we could do other than thanking our fortune to have read them and made this connection. I thought of writing just a page on this topic and I have ended up with 2 parts and I am stopping my temptation to write few more pages on this topic. For all of those interested, please read the book by Jose Arguelles.

It is amazing to find out how most of the ancient civilizations seem to have a common root and the communication between various geographies looks stunningly simple and the metrics on astronomical objects and other space sciences seems to be so accurate despite the absence of precision instruments and spacecrafts. One tends to believe that we had far advanced knowledge of nature which we seems to have lost and most certainly few thousand years back we were not nakedly roaming in the jungles of India and Africa hunting animals as the western experts wants you to believe but had a far superior & scientifically advanced civilization.

As a wise man said, **"Indians are the most ignorant about their rich past and scientific traditions."**

Happy Reading!

15. TIME = SPACE SERIES. PART 15 – SHIVA LINGAM IS NOT A PHALLUS

If there is one part in the series I want you to read and talk about it with your friends then it is this topic. If I ask you as to what Shiva Linga stands for then more than 99% of the responses would be that it represents a **Phallus** symbolizing the male sex organ / creative energy with the female sex organ / creative energy - Yoni as the base and both together representing **inseparability and totality in the process of creation**.

Nothing is more misunderstood and misquoted than this concept of Hinduism. Every idiot including me who has read few books about Hinduism thinks that they are experts of Indology / Vedic studies. The wisest of sages who gave us Vedas and Upanishads did not boast that it is their work. At the end of every work they acknowledged that they are telling us what they have been told by their ancestors. It is 155 trillion+ years of universal knowledge available today in the richest of the languages Tamil and Sanskrit. This cannot be accurately interpreted in a foreign language. Lest in the weakest of all languages - English.

The other contributing factor to this misunderstanding has been the Sanskrit language or should I say the richness of the language.

We have already noted that the same word can have multiple meanings. This is not limited to Sanskrit, but the all the languages. For example,

- **Sutra means thread, Aphorisms** (the ability to express something in terse and concise manner). Ex. **Kama sutra** – the most understood of all the sutras. **Brahma Sutra** – The thread of consciousness in any form that runs in this universe – the most unheard of.
- **Artha** in Sanskrit means “meaning” and “wealth”, we have already seen this. As in Vaak-Artha and Artha Sastra (the science of wealth management).
- Same way Lingam means **Symptom, Proof**, **Gender, Male sex organ** etc. Hence it was very easy to get confused, associate the lingam with a Phallus and also to ignore the philosophy and the supreme science behind it. Even people who believed that it represented much more did not knew the philosophy and the science behind it. Let’s look at what it means.

I am going to request you to kindly refer to both the pictures below:

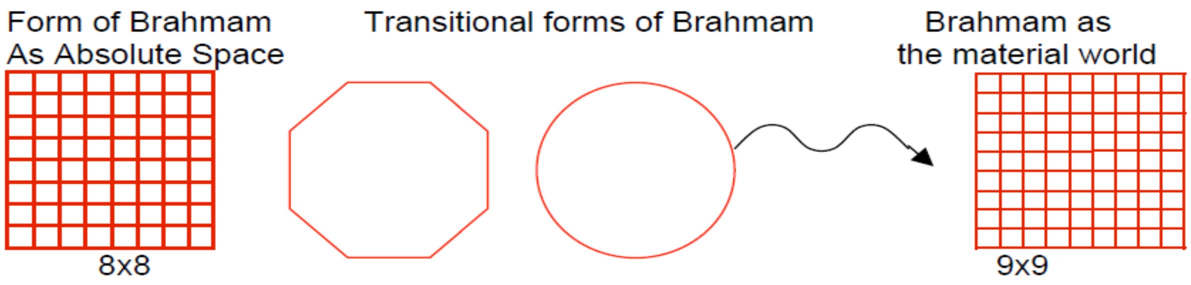

Figure 8 – reproduced here for convenience

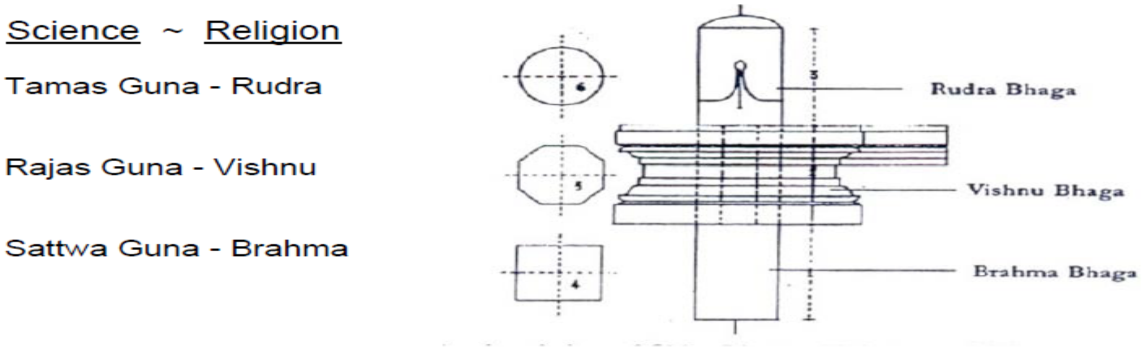

Figure 15 – Shiva Linga – Shape and Significance (Courtesy; Dr. Ganpathi Sthapati)

We have already seen that the subtle energy is takes the form of a square and the gross energy takes the form of a circle with an in-between state it takes the shape of a **tetrahedron and octagon**. Now look at the Shiva lingam from the top. Its base is always a square and the top is always a circle.

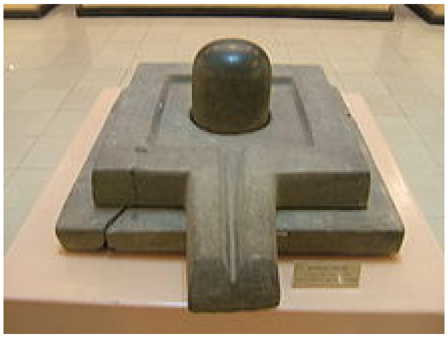

Figure 16 – Shiva Linga

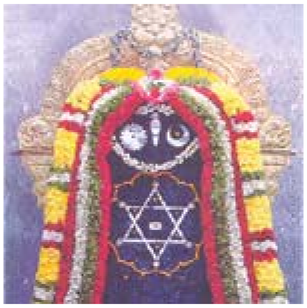

Figure 17 – Shiva Linga with shape of the God's particle (Star) engraved.

If I have to merge all the 3 shapes together and it naturally takes the shape of a Lingam with a round top. **Shiva Linga captures the overall process of evolution in one form and shape - subtle to gross state – it encompasses every state of consciousness that is possible in this universe.**

Why the figure above states that Square shape is Sattvic, circle is Tamasic and the in between state is Rajasic? Let's understand the definitions of all the three qualities.

- **Sattvic represents the perfect state of balance. When it is subtle it is luminescent and in a perfect state of resonant non-vibration. The energy levels were perfect so that the resultant vibration is nil and it is in absolute balance.**
- **Tamasic state represents a state where the height of evolution is reached and hence it is farthest away from the core.** This is a different explanation from the usual one available in the web and books. Let me explain this. The core is very subtle and the tamasic state is very gross

and hence it is away from the core. Tamasic state then should be considered as the darkest state possible. Why?

  - Because the core is luminescent and if the gross state is farthest from the core hence it should be dark. This is the meaning behind the most famous statement **'Tamasoma Jyothir gamaya"…** take me from darkness to light. It is not about just your mind but about the entire being aspiring to become a light and merge with primordial light.
  - **There is no evolution possible beyond the Tamasic state and it has to devolve to reach its core / subtle state.**

- **Rajasic is a state where the pulsation has resulted in a rotational force and hence things are set into action. This represents the evolution process and hence associated with action.**

Then the natural next question is, if Shiva Lingam is associated with the entire spectrum of consciousness then we should see it associated the elements and the light. Isn't?

- There is a story in Indian Purana that Brahma, Vishnu and Shiva discussed who is the most powerful among them. Lord Shiva challenged Brahma and Vishnu to reach his head and feet respectively. Brahma tried to find Shiva's head and Vishnu tried to reach Shiva's feet, both of them failed. Most of us would have heard the story but would not have understood the philosophical and scientific significance.

  - Lord Shiva in the form of Linga stood there as a **PILLAR OF LIGHT**. This pillar of light is **the Brahma Sutra / light of consciousness** which spanned from the center of the galaxy (Hiranyagarba) to every being & non-being in the Universe.
  - Brahma could not find the head because; Brahma is always associated with intelligence in Indian texts. He gave the supreme wisdom - the Vedas and stands for Intelligence. He could not reach Shiva's head signifies that Intelligence will not take you to God. Intelligence as an energy is too gross and cannot reach the most subtle state of light.
  - Vishu represents earthly life – Rajasic in character – this is the tetrahedron & octagon state. He could not reach Lord Shiva's feet signifying you cannot reach the core through actions.

- Lord Shiva in the form of Lingam is represented as one of the elements (Earth, Water, Fire, Air, and Space) in the Hindu temples.

If you read the following Upanishad quote, you can probably understand the meaning:

na karmaNaa na prajayaa dhanena tyaagenaike amRitatvamaanashuH
pareNa naakam nihitam guhaayaaM vibhraajate yadyatayo vishanti

Not by work, not by progeny, not by wealth, they have attained Immortality. Some have attained Immortality by renunciation. That which the hermits attain is laid beyond the heaven; yet it shines brilliantly in the (purified) heart.

And this quote also brilliantly articulates the luminescent nature of the Paramaanu:

na tatra (not there) **suryo bhati** (sun shines) **na candra** (moon does not) **na tarakam** (nor the stars)
nema vidyuto (nor the lightning) **bhanti** (shines) **kuta ayam agnih** (how can fire shine)
tam (that) **eva** (alone) **bhantam** (shines) **anubhati** (thereafter shines) **sarvam** (everything)
tasya bhasa (in that light) **sarvam idam vibhati** (everything shines)

The sun does not shine there, nor does the moon, nor the stars or the lightning, much less this fire (deepam). When He shines, everything shines after Him; by His light alone everything is illumined.

The trick is to take the definition & meaning from Upanishads or any scripture and apply it to the God's particle and the process of evolution and you would understand it perfectly. Many a times the concept of God & faith obscures our mind to look beyond and rationally think about it. It is not the problem of religion but our system of education which has ruined our thinking. **Today the biggest challenge we have is to "Unlearn" than to learn.**

So to conclude:

- Shiva Lingam does not represent Phallus. To represent male and female totality and inseparability Hindus do have **Arthanareeswara** and it is not represented through Lingam.
- Shiva Lingam represents the **Pillar of Light and the entire spectrum of consciousness**. From the most subtle to the most gross.
- It represents an in-between **Guna** / **EGG** state (between un-manifest and manifest) and hence it is formless with a form.
- **While Lord Nataraja represented the rhythmic pulsation of this Brahma sutra, the cosmic dance / the dance of the evolution, Shiva Lingam represents the primordial light itself in all its state of consciousness.**
- By this analogy, our body itself is a lingam with the visible body as the gross part at one end and the most subtle body which is invisible and is part of the primordial light at the other.

Check out the picture below which represents most of the aspects we have discussed so far.

May Lord Shiva help us all to understand him better.. ☺

As a wise man said, **"Indians are the most ignorant about their rich past and scientific traditions." Yet wish that this quote isn't wiser any more.**

Happy reading!

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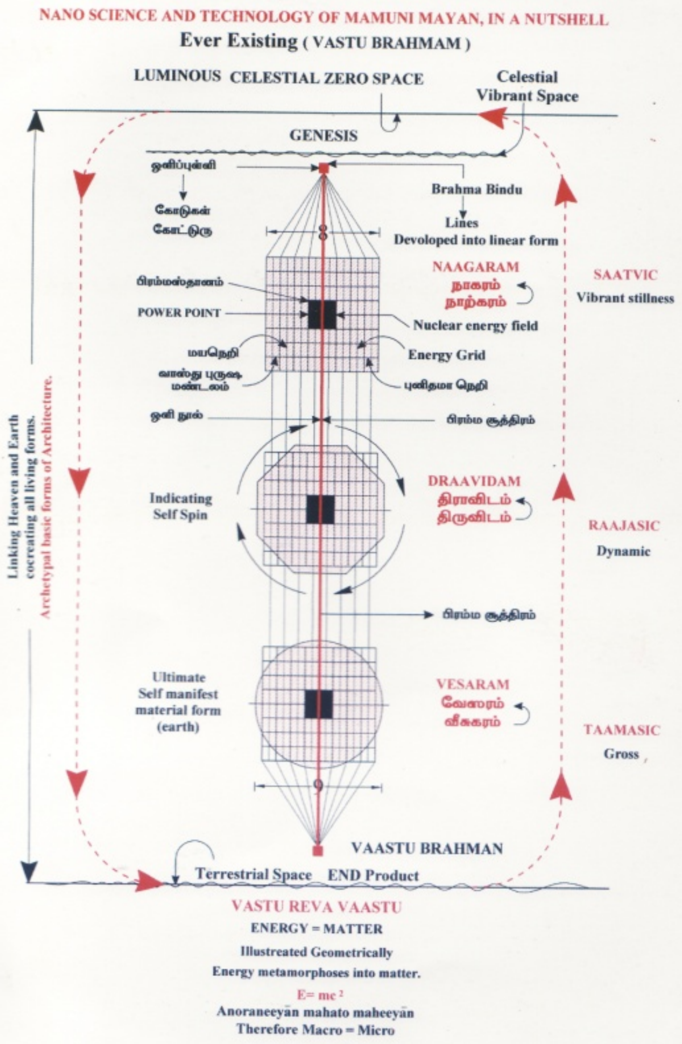
NANO SCIENCE AND TECHNOLOGY OF MAMUNI MAYAN, IN A NUTSHELL
Ever Existing (VASTU BRAHMAM)
LUMINOUS CELESTIAL ZERO SPACE
Celestial Vibrant Space
GENESIS
ஒளிப்புள்ளி
கோடுகள்
கோட்டுரு
Brahma Bindu
Lines
Devoloped into linear form
8
பிரம்மஸ்தானம்
POWER POINT
NAAGARAM
நாகரம்
நாற்கரம்
Nuclear energy field
SAATVIC
Vibrant stillness
மயநெறி
Energy Grid
வாஸ்து புருஷ மண்டலம்
புனிதமா நெறி
ஒளி நூல்
பிரம்ம சூத்திரம்
Linking Heaven and Earth
cocreating all living forms.
Archetypal basic forms of Architecture.
Indicating Self Spin
DRAAVIDAM
திராவிடம்
திருவிடம்
RAAJASIC
Dynamic
பிரம்ம சூத்திரம்
Ultimate Self manifest material form (earth)
VESARAM
வேஸரம்
வீசகரம்
TAAMASIC
Gross
9
VAASTU BRAHMAN
Terrestrial Space
END Product
VASTU REVA VAASTU
ENERGY = MATTER
Illustreated Geometrically
Energy metamorphoses into matter.
E= mc²
Anoraneeyān mahato maheeyān
Therefore Macro = Micro

Figure 18 – Manifestation in a nut shell (courtesy: Dr. Ganpathi Sthpati)

This diagram represents everything we have discussed so far. The central red line is the Brahma Sutra which runs from the center of Galaxy to the terrestrial forms. Just correlate this with the Mayan Hunab Ku in the previous part.

This summarizes as to how Energy becomes matter, Subtle becomes Gross, Un-Manifest becomes manifest, how 8 becomes 9, and Square / Cuboid becomes a circle / Sphere. All represented in one formless form called SHIVA LINGAM.

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16. TIME = SPACE SERIES. PART 16 – SEELAM - THE PRIMORDIAL CIRCULAR FORCE - GANAPTHI & MATHEMATICS

In the last few decades the main stream western science has started accepting concepts like uncertainty principle, wave mechanics, quantum mechanics, and periodicity of the wave pattern. Most importantly it is about the fundamental wave pattern of any energy or matter and the harmonics of these wave patterns falling in a particular form and proportion which is dictated by geometry / mathematics. In all the western scientists are scratching their heads on the depths of science of the subtle aka the sacred spatial geometry.

Most of the eastern philosophies have mastered this science and have codified these natural laws as a part of their religion, which is often dismissed as superstition. I already highlighted that in Tamil and Sanskrit the definition for science is “**Knowledge of the space**”.

Modern science is moving in the right direction albeit very slow and they are trying to understand as to how elements are bonded within a molecule in addition to what elements constitute them. For example **Chlorophyll** molecule consists of **Carbon, hydrogen, nitrogen and magnesium (Mg at its core)** has a complex 12 fold Pattern – just one such typical pattern which can convert sunlight into life substance. The same pattern exists in our **RBC** cells just that it has an **iron** at its core instead of magnesium.

The understanding about the human body especially, “the spatial awareness that exists in each and every cell is due to the different sensory organs tuned at frequencies”, led the scientists to unravel the innate spatial geometry of life.

Be it living, non-living beings, abstract forces like gravity, nuclear force, electromagnetism, heat, movement of astronomical bodies it does not matter what, everything in this universe adheres to a vibration / periodicity and is reducible to a number or a ratio. As a wise man said, “**Mathematics is the language of gods”. This primordial rhythm & its harmonics are captured under the topic “Seelam” by Mayan in ancient tamil texts. Let’s look at this in detail.**

I have been finding it difficult to sequence the flow for this topic and let me try starting from the basics:

- We know that the **Paramaanu or God’s particle is a cube.** This particle with the primordial vibration combines with other particles to create a shape. **The Paramaanu combines in the multiples of 8 to evolve the next structure**. Let us see the importance of 8 later, but remember 8 is the number for Lord Narayana and Om namo Narayana has 8 Aksharas.

- What do you call a cube called in Tamil? It is called **Ganam (கனம்**). This also means heaviness, gravity, honor, dignity, abundance, plenty. To indicate it is a square cuboid they call it **கன சதுரம்**.

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- The process of the addition of **Paramaanu** into bigger units is called as **Ganam (கணம், गणं)**. In Tamil both the Cube and the additive resultant are called as **Ganam** and the only difference being that in Cube it uses a **small "na" (ன)** as an alphabet. In the additive process / resultant it uses a **Big "na"(ண)**. The big "na" signifies that due to the additive process the small (na) becomes big (na).

- This additive process starts because of the **first rhythmic circular** force also called as a **Suzhi (சுழி)** in tamil which means "loop".

- Here comes the beauty. The Lord of or the energy associated with this **additive force (Ganam)** is called as **Ganapathi (கணபதி, गणपती)**. Note this is the bigger "**na"** used and not smaller **"na"**. He is associated with the first circular force - **Suzhi** (and hence he takes the first honor in any Vedic ritual. This means Lord Ganapati is the first process in the evolution and everything has to start with him. Even if it is Lord Shiva or Vishnu it does not matter, the very first honor goes to the **Lord of Ganas**. Many Indians when they start writing (atleast few decades back) they first start with this symbol at the top of the page before anything for a successful completion of that activity.

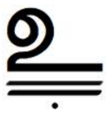

- If I add my own inferences to the above with a caveat that everything else I have written have a solid back up mostly from our own study of languages (as you can yourself see) and our scriptures.
    - The symbol above signifies that what was "a point" with untouched / non-interacting energies / resulted in the primordial first circular force out of a pulse and also signifying that every circular force shall also collapse back to a point.
    - Also the bigger / heavier things are formed or created by its smallest unit and hence symbolically the heavier ones are carried by the smaller units. To signify this may be a god in the form of an elephant is carried by a mouse.

- Now you know why every ritual starts with this Sloka to Ganapathi:

    - ***"GanAnAm tva Ganapati gum Havamahe, Kavim Kavinam Upamasra vastamam Jyestharajam Brahmanam Brahmanaspat aana Srnvan nuti bhissi dasadanam"***

      This means "May you the Lord of Ganas, Ganapati",... . so it goes.

- **Now what do we call the study of this additive force - Ganas? Mathematics – Ganith / Ganitham (கணிதம், गणित).**

- **So we Indians have codified:**
    - **the primordial God's particle as Paramaanu or microbode or Lord Shiva,**
    - **the rhythmic movement of the pillar of light as Lord Nataraja,**
    - **the first circular force as the symbol for Lord Ganapathi,**
    - **the lord of the additive force as Lord Ganapthi and**
    - **the Study of this additive force which leads to the formation of everything in the universe is Mathematics in Sanskrit and Tamil.**

- **Every possible state of consciousness and manifestation is represented in Shiva Linga**
- **We will see that the multiples of 8 in which the additive force moves is codified as Lord Narayana or Vishnu and the five state manifestation process as the five letters associated with Lord Shiva.**

Just forget that these names are the names of the Hindu gods, and tell me one religion or philosophy or one branch of science in this world which can capture the nature's primordial secret in this way and codify it for the common benefit of the world and carry it for thousands / millions of years.

These are just a start and please wait for the other interesting aspects to unfold.

As a wise man said, **"Indians are the most ignorant about their rich past and scientific traditions."**

Happy Reading!

17. TIME = SPACE SERIES. PART 17 – SEELAM - THE PRIMORDIAL RHYTHM & FUNDAMENTALS

Now, let us get into some real heavy stuff - Mathematics (**Ganitham** – the study of Ganam) that governs this rhythm and harmonics. My first concern is how to make it easily digestible for an average individual who hates Math? So I shall take the easiest route that I know. I shall first explain the concept, then the actual Math part of it and then go to the philosophy and significance of the same. Later we shall look at how these are codified in nature and our scriptures and available in front of our eyes which we have failed to recognize.

Let us be clear about the following terminologies like **Progression, Proportion, root, Diagonal and Pythagoras theorem**:

- Let us take a series as follows: 2, 4, 8, 16, 32…. In this we need to be clear about what is **Progression and proportion**. As many of you know that whole series is a geometric progression where the next number in the series is a function of the current number and a multiple. This multiple here is 2, so that 2*2 = 4, 4*2 = 8 and so on. **This multiple or the constant is called as proportion**. You derive the value of the proportion by dividing the number by its previous number – (n+1)/n : (n+2)/(n+1). Hope this is clear.

- We know that a square has 4 equal sides. Each side of a square is called as "**root**" and the line that connects the 2 opposite ends is called as '**Diagonal**". In the figure below sides AB, BC, CD, DA are called as "**Root**". Lines AC, BD are called as '**Diagonal"**.

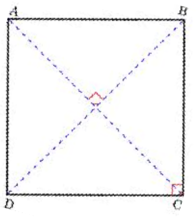

Figure 19; Square

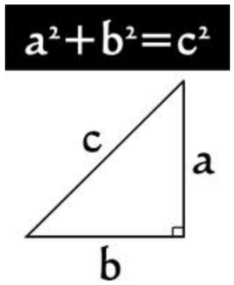

Figure 20: Pythagoras theorem

- **Pythagoras theorem** – This theorem gave us the formula to calculate the sides of a right angle triangle as given above. If you are not familiar with this, then please understand that if you know any 2 sides of the triangle the 3rd side can be calculated by the formula given above. I am not going to focus on the argument that this theorem was available in Indian scriptures before the Greek mathematician gave it. Let's look at the concepts and not which civilization gets credit as of now.

Since the fundamental structure is a square in 2D and Cube in 3D and also in the process of evolution one becomes many, let's ask ourselves the following questions:

- **How one square does create another square which is larger in size, progressively? What is the progression and proportion in this series?**
- **How one cube does create shapes which are polygonal (Hexagon, Octagon, decagon, dodecagon etc) progressively? What is the progression and proportion in this series?**

Now let us see Figure 21 where and consider the square ABGF. You can enlarge the image to see the alphabets clearly. Now as we know sides AB, BG, GF, AF are called "**root**" – remember this well and let us assume the smallest root possible is unity and hence each root is of unit length. AB=BG=GF=AF=1. Area of this square = 1*1 = 1.

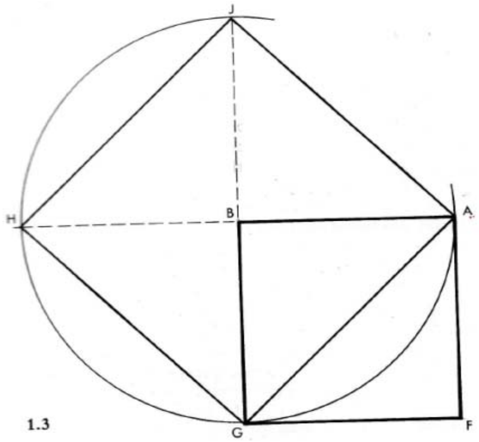

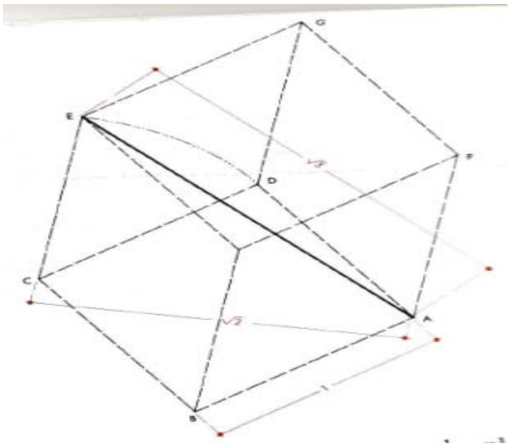

Figure 21; Square

Figure 22: Cube

Line AG is called as the **"diagonal"** and as per Pythagoras theorem the length of **AG** should be **$\sqrt{2}$**. **AG = $\sqrt{(AF^2+GF^2)}$.** So to summarize **the root of the square ABGF is 1 and the diagnol is $\sqrt{2}$**.

Now consider a larger square AGHJ, here AG, GH, HJ, AJ are the sides and hence called as root. AH, GJ are the diagonal in the 2nd square. We know AG = $\sqrt{2}$, then AH = GJ = 2 as per Pythagoras theorem. To sum up **the root of the square AGHJ is $\sqrt{2}$ and the diagonal is 2. Area of this square is 2.**

If you look at the ratio **root/diagonal** (root to diagonal ratio) of both the squares it is $1/\sqrt{2}$ and $\sqrt{2}/2$ which results in $1/\sqrt{2}$. This will progressively hold good. The magic proportion in this progression is **$\sqrt{2}$**.

What we can infer from this is if we consider a **progression of squares** from a unit square to larger squares, then the **proportion** of the progression is $\sqrt{2}$. But before we jump into its philosophical significance let's answer the second question.

Consider the cube above whose side is of unit length. We know a cube is made of squares. We know ABCD is a square of length (root) =1 and diagonal = AC = **$\sqrt{2}$**. If we want to find out the length of the diagonal of the cube which is AE, then ACE is a right angle triangle with AC = **$\sqrt{2}$**. And CE =1 and hence **AE = $\sqrt{3}$**.

What we can infer from this is if we consider a **progression of cubes** from a unit cube to larger ones, then the **proportion of the progression is $\sqrt{3}$**.

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I am going to handle the significance of √2 and √3 in the next part.

Happy reading!

18. TIME = SPACE SERIES. PART 18 – SEELAM - SIGNIFICANCE OF √2 & √3

Let's look at the significance of **√2 and √3** but before that let's capture the philosophical significance of **Progression** and **Proportion**:

- The whole world is conceptualized as wave harmonics of the primordial rhythm with a **progression and proportion**. Philosophically the **Proportion** which does not change / which is constant is the **immutable component** and the **progression** which changes / is volatile is called as the **Mutuable component** in the process of evolution. **The whole universe is the progression and God is the proportion**. So if I know the God's proportion and the formula behind it I can create anything in this universe including a universe. This secret is called as the Brahma Vidya / Sree Vidya (Knowledge of Brahman, Sree) in Indian texts. What we are going to see further are very minor parts of the **Brahma Vidya**. ☺

- In the last part we saw, that the primordial square multiplied itself to be a larger square (**progression of squares**) using the **proportion √2. The diagonal of the square 1 (ABCD) forms the root of Square 2 (AGHJ)**. This is very profound if you get the concept**.**

- **If we consider square 1 as the cause then its diagonal is the effect. This diagonal is the root for the next square (AGHJ) and hence the effect of Square 1 is the cause of Square 2, this cause results in square 2's diagonal which is its effect and this is how the progression or evolution happens.** If you can see glimpses of Cause and effect cycle and the famous law of Karma in this analogy then you can pat yourself. ☺

- A square halved by the diagonal (square 1 with area 1) produces a square twice its area (square 2, area = 2). **The mystery of biological growth from cellular division or the different musical notes from the base tone is contained in this**.

- **Robert Lawlor in his book "Sacred Geometry"** very nicely puts it as the root of a plant (like the root in a square) is causative and embedded in the earth (and embedded in the square). These are very heavy and profound concepts just let it sink into you.

- When you divide the full height of the human being considering the total height as unity then belly as called as **Hara in Japanese, Dantein in Chinese, Nabhi in India** which is below the navel will measure (**2- √2)** from the soles of the feet to belly and (**√2 -1)** from navel to the head. In Yoga, Zen and Chinese meditation techniques this point corresponds to the transformative and generative aspects of the individual that involves **rooting** techniques for **self transmutation**. **So Lao Tzu said, "To seek the root is the goal".**

- **√2 signifies the power of multiplicity. Hence the Generative aspect of this rhythm is attributed to √2. This represents the principle of transformation.**

- Remember **√2** is a proportion in the progression of squares and a square does not become a higher form. We have seen that the diagonal of the cube (sides of unit length) is **√3. It is this √3 which divides the volume form of a cube and the diagonal of the cube becomes a root for the higher shapes like pentagon, hexagon etc.**

- Hence **√3 signifies the formative power of the rhythm while √2 signifies the generative power of the nature.**

We will touch the same using **Vesica Piscis** in the next part which shall take us to **√5 and the golden mean Φ.** I am not going to touch upon important topics like Gnomic spirals and the relation between various progressions and hence I would request you to Google them if you are interested.

Happy reading!

PS:
There are many books on this topic and I would recommend **"Sacred Geometry – Philosophy & Practice" by Robert Lawlor** which I found easy to read and understand.

You tube and Internet is replete with tons of images, articles and videos on this topic and you can learn a great deal from them.

19. TIME = SPACE SERIES. PART 19 – SEELAM – VESICA PISCIS, √5, & GOLDEN MEAN (Φ)

If you don't know what is vesica piscis, please google and you would find it interesting. I am not going to explain it here and I would focus on the summary and aspects which are often left out. The philosophical aspect of Vesica Piscis, is a rotating point becomes as circle of unity. Two circle of unity (with its radius as unity) interacting / intersecting each other in a perfect manner offers an overlapping area which is considered to be sacred and fundamental to all the geometric forms in the universe. We will first see how **√2, √3 & √5** are part of this Vesica Piscis.

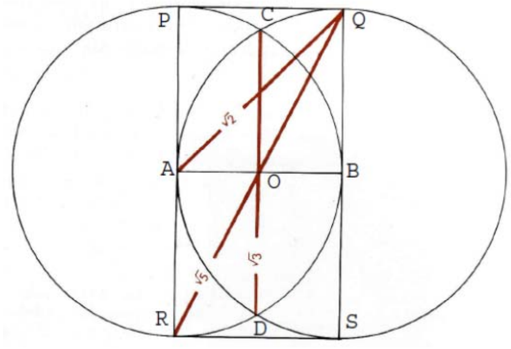

Please look at 2 circles who radius is unity and AB = 1, intersecting as per the diagram. The overlapping area ABCD is the Vesica Piscis and we can see **√2, √3 & √5** all part of this Vesica Piscis.

ABPQ and ABRS are 2 squares and the side of the square is 1. **√5** is as significant as **√2 and √3.** In the diagram here **√5** is the diagonal of the rectangle PQRS / diagonal of 2 squares – one below the other.

Figure 23; Vesica Piscis

√5 is the regenerative factor that binds 2 squares or that factor that transcends two worlds or the bonding factor for 2 cosmic entities. This **√5** shall take us to the most important ratio which is the **Golden mean** or the **God's ratio**.

But before that let me share what stuck my mind when I was engrossed **with Vesica Piscis and √3**. Look at the pictures below. These are pictures of forehead marks of Hindu Brahmins sects called Iyengars and their supreme deity is Narayana. I correlated the striking similarity of the rectangle around the Vesica piscis and Iyengar's namam. You just have to imagine the 2 overlapping circles are the right and left side of the face with the **Vesica Piscis** starting from the top tip of the nose. To me the **formative principle of √3 is in line with the "Bhootha krut" and "Vishwa karma manu stvashtha"** aspects of **Maha Vishnu** as per Vishnu sahasranamam. I had a good laugh on this correlation.

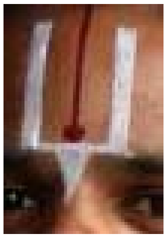

Figure 24; Iyengar Namam 1
(Courtesy: Internet)

Figure 25: Iyengar Namam 2
(Courtesy: Internet)

Coming to the **Golden mean,** If you have not heard about it, just Google or here is a quick link http://www.goldennumber.net/. Some of you might be even have fatigue repeatedly reading and listening about it, like I do. Hence I am not going to rewrite what is widely available. But let's look at the philosophical aspect of it, its relation to **$\sqrt{5}$** and its manifestation.

Now so far in **$\sqrt{2}$, $\sqrt{3}$ & $\sqrt{5}$** what we have seen is how Unity evolves as many. But if I am interested in geometrically dividing the Unity so that this proportion evolves as unity then how do I do it?

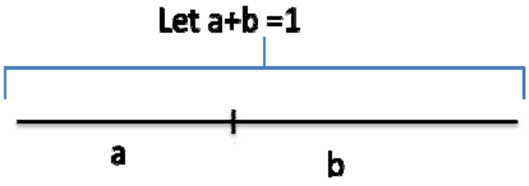

(Figure 26: Line andΦ)

Consider a line of unit length and also consider two segments a, b so that a+b =1.

A and B are such that it has to fulfill this condition of Proportionality that a/b : b/1.

This means what 'a" is to "b", is the same as what "b" is to the whole length which is 1.

Mathematically resolving this equation a/b : b/1, hence $b^2 = a$ and hence **b= $\sqrt{a}$.** This means **$a + \sqrt{a} = 1$.** The answer to this equation is only one value which is called the **Golden mean / God's ratio** denoted by $\Phi = 1.6180339\ldots$ and $a = 1/\Phi$. **Philosophically it is the division of unity and the only possible creative duality within the unity.**

You may ask as to why unity is not divided into 2 equal parts and why is should be **$1/\Phi$ (0.6180339..).** This is effectively answered by our Upanishad **"Whether we know it or not, all things take their existence from that which perceives them". Adi Shankara said "the universe is an illusion / maya" because it is what we perceive. We tend to ignore them as philosophy or superstition.**

But let's look at it scientifically as we understand. When the unity is divided into equal parts there is no asymmetry and difference and hence there is no perceptual universe. **An asymmetric division is needed to create the dynamics necessary for progression and extension of unity**.

Let's summarize our understanding again:

- **$\sqrt{2}$ – the generative component and a multiplying factor creates multiple squares from a unity of square.**
- **$\sqrt{3}$ – the formative component that creates multidimensional polygonal shapes from a cube.**
- **$\sqrt{5}$ – the regenerative component or the binding component that transcends and binds both the worlds.**
- **Φ - Golden mean or the God's ratio,** which is an evolutionary principle that is guided from within and an indisputable mathematical evidence of the conscious evolution of this Universe.
- Φ - Is a self-similar variable which can be used to derive Unity and it is the only proportion by which the Primordial rhythm maintains it perpetual oscillation to sustain this universe.
- Relation between **Φ and $\sqrt{5}$ is, $\Phi = (\sqrt{5}+1)/2$**

Now let's geometrically as to how Φ **and √5** are intricately linked. Consider the Pentagon picture whose side is of unit length. Ie.

AB = BC = CD = DE=AE = 1 and

EG = FB = CG = DF = 1 and

EB = Φ = 1.61803399 and BG = 1/Φ = 0.61803399 and hence all the ratios like AG = AF = EF = GB = 1/Φ.

Also FG = $1/\Phi^2$, which means **EB = EF+FG+GB = 1/Φ+1/Φ+$1/\Phi^2$**

Also GI = $1/\Phi^2$ and GJ = $1/\Phi^3$

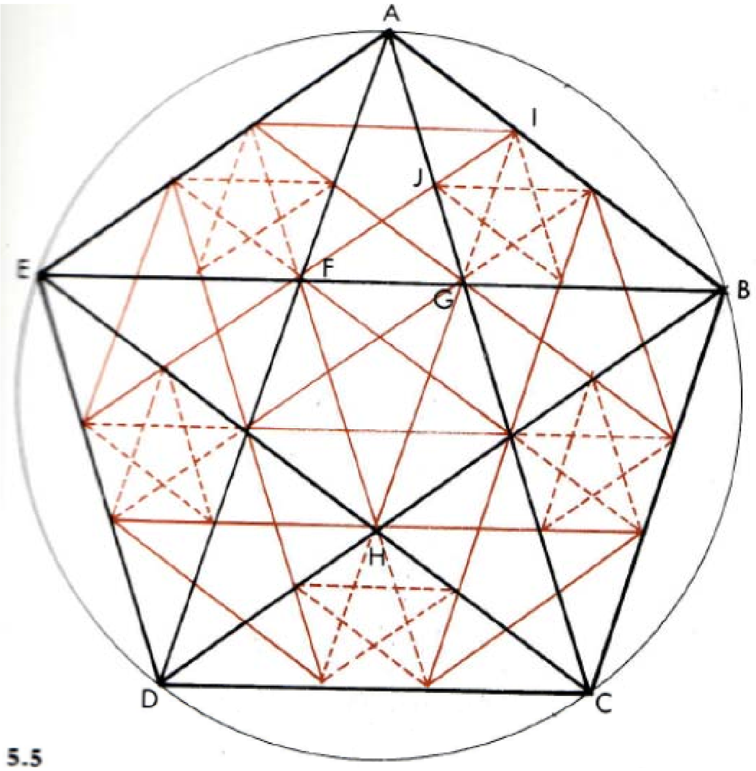

5.5

(Figure 27: Pentagon & Φ, Courtesy: Internet)

If you are interested more please check out the Fibonacci series and its relation to Φ. **The importance of 5 is dominant in every living organism while 6 and 8 are the characteristic of mineral and inanimate structures. It used to be rule of thumb that any plants / flowers which has 5 petals is an edible plant and hence 5 and pentagon are the symbols of life which contains the God's ratio or the golden mean.**

Now let's also understand how a **√5** is related to **√2 and √3.** If we consider a right angle triangle with the base of **√2** and height of **√3** or vice versa then the hypotenuse is **√5.** Now let me draw the connection between √2, √3, √5, Φ and π. If you think they are all some random numbers which cannot be fixed to their 10th decimal and not related to each other, just see the following relationship.

$\pi = \Phi^2 \times 6/5$ or alternatively $\Phi = (\sqrt{\pi} * \sqrt{5}) / (\sqrt{2}*\sqrt{3})$

This is the binding factor. I shall produce below some pictures which are aligned based on pentagon and the web is replete with them for you to understand more.

These 2 parts were little heavy and I shall move to easier aspects on the universal rhythm from next blog. The point I was trying to make is that everything in this universe is subject to a proportion and its fractals and let's see the manifestation of it in our daily life.

Happy reading!

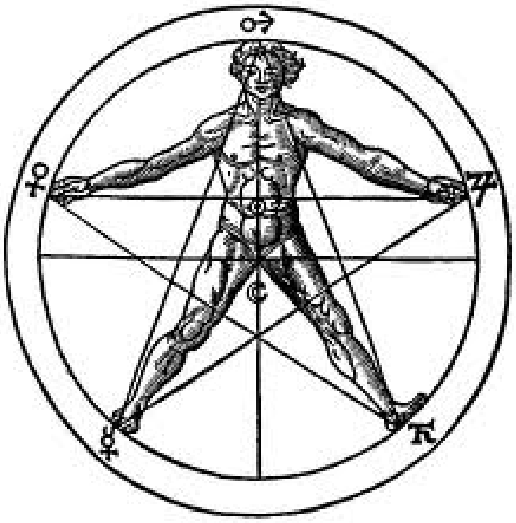

(Figure 28: Pentagon & Human shape, Courtesy: Internet)

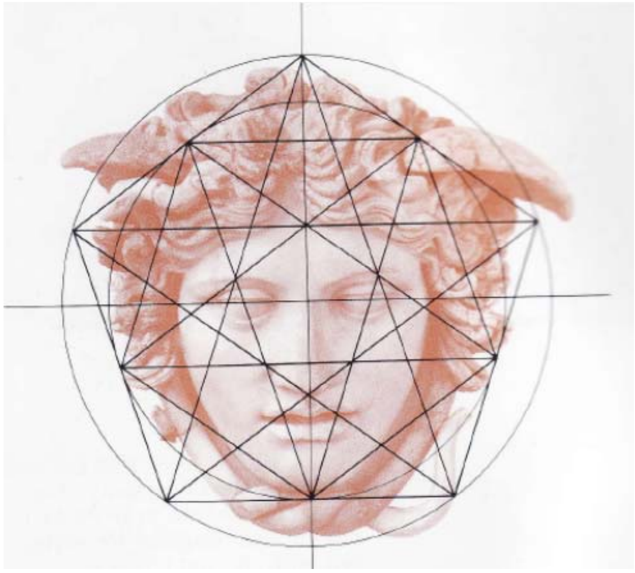

(Figure 29: Pentagon & Human face, Courtesy: Internet)

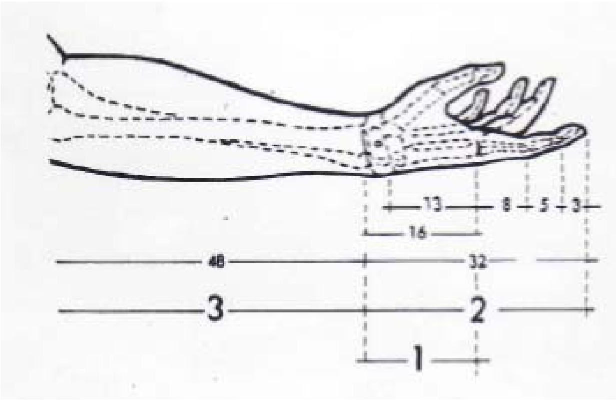
E
13
8
5
3
16
48
32
3
2
1

(Figure 30: Human hand and Fibonacci Series Courtesy: Internet)

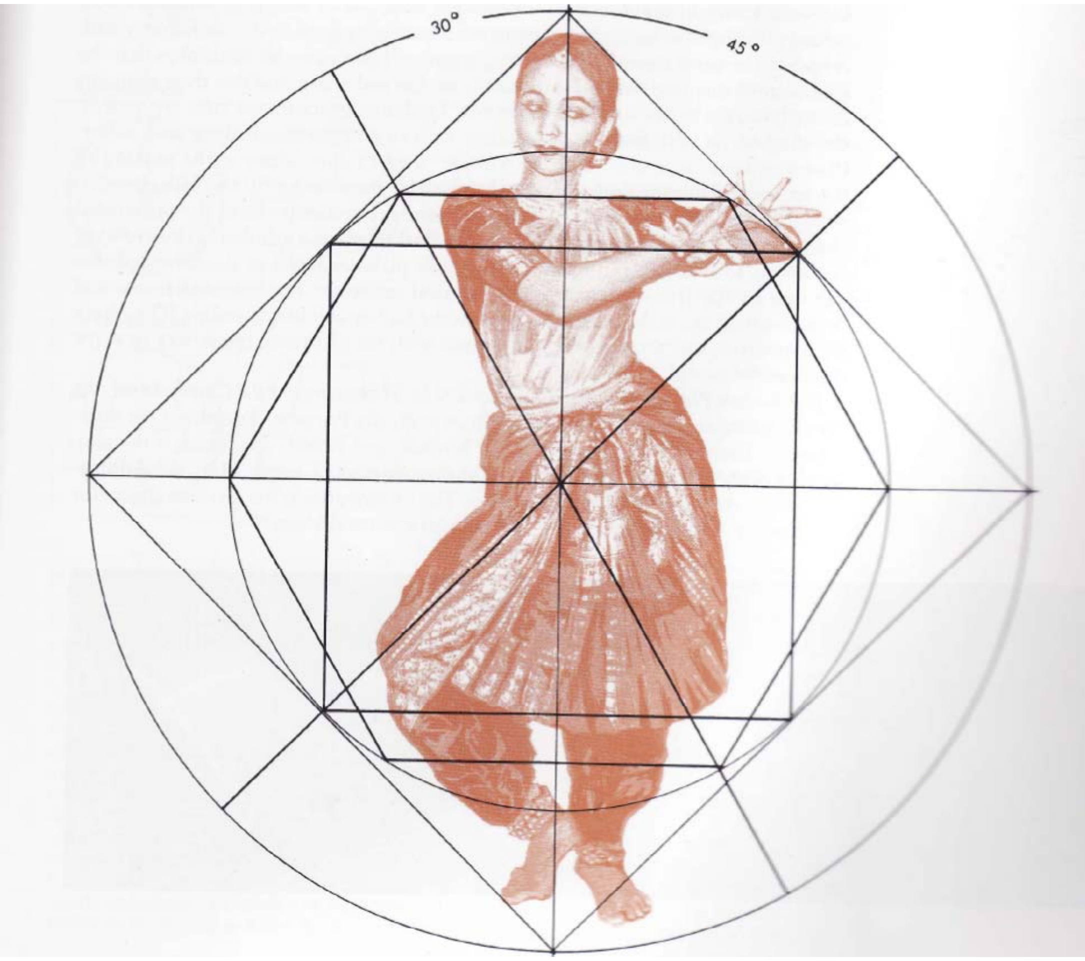

(Figure 31: Bharatanatyam and body alignment (Courtesy: Robert Lawlor, The Sacred Geometry)

The positions of Hindu classical dance (Bharat Natyam) describe geometric relationships from the axis of the body and the alignment of center of gravity at "hara" invoking rooting and divine power of transformation. In Hinduism "hara" is one of the names of Lord Shiva as in "Hara Hara Shakara"

20. TIME = SPACE SERIES. PART 20 – SANKHYA YOGA AND SAGE KAPILA

Now, let's look at what **Sankhyakarika** one of the greatest scientific works by **Sage Kapila**. I need to highlight that the **Sankhya philosophy** is one of the most evolved philosophies about the secrets of nature; it contains only 72 verses of which 68 of them define the complete spectrum of universal manifestation. **This Sankhya Yoga is referred in Bhagavad Gita – Chapter 2 is called Sankhya Yoga and in Chapter 10, verse 26, Lord Krishna identifies himself with Sage Kapila**.

Sankhya in Sanskrit means numerals / numbers. Sage Kapila states:

- Any measurement is a relational process and only a change can be measured but it takes time. The difference between the yardstick and the measured object constitutes the measured variable, which in effect is an incremental change. Since the observer can detect or measure only a change then logically, **the incremental unit of measurement itself should form the basis to derive the whole. This is the genesis of Φ.**

- **Correlate the above statement with the equation $a + \sqrt{a} = 1$. The unity is derived from the proportion "a" or $1/\Phi$.**

- As an example, the arch of a bow has expansive stress on the outer side and compressive stresses on the inner side, while the string is in tension and all are balanced at every instant. The expansive, compressive and tensile stresses can be expressed by one law.

- Alternatively, a single variable describes the proportionality of three types of forces existing at the same time. **Such a variable should be scale invariant, self-similar and have an axiomatic relationship to the whole.**

- **So Sage Kapila called $1/\Phi$ as a self-similar variable from which the unity can be derived.**

- So he postulated if **x** is the value of a measured increment then the total value **1+x** must be related to the ratio of change as 1/x at the same instant of time or simultaneously. This means **$1+x = 1/x$**, and would lead us to **$X^2 + X = 1$**.

- He quotes that if the primordial rhythm has to be self sustaining then the proportion is certainly governed by $1/\Phi$. He gives the formula for this oscillations as follows:
    - **$X = 1/\Phi = 0.61803399$**
    - **Increment / Expansion = $1+x = 1.61803399 = \Phi$**
    - **Compression = $1-x = 0.38196601 = X^2$**
    - **Resonance = $X^3 = X - X^2 = 0.23606798$**

Resonance or X^3 is the factor which protects this rhythm from decaying and dying off. So **Φ or $1/\Phi$** is such an important ratio or proportion so it is called as the **Golden mean or God's ratio**.

I shall highlight some of the factors / ratio which are part of Sankhya Yoga and what is amazing and you find formulas for Tamasic, Sattwic and Rajasic Guna states. (Please refer “Secret of Sankhya Yoga” – G. Srinivasan in the web).

- **Kapila defines the four qualities of the unmanifested state as Aikaantha (Synchronized), Aathyanta (perpetual), Atho (Dynamic)and Abhavath (unmanifest).**

- Taking C as cyclic rate of oscillation or vibration and x as rate of change per cycle then the three Guna self similar interactive states are shown as vibratory counts per cycle by the formula. **Thaama = C^{1+x} . Rajasic = C^{x+x} . Sathwa = C^{1-x}.**

- Some of the numbers that Sankhya Karika deals with are **1/7 (0.142857), π/10 (0.314159), 1/Φ (0.618034), √2 (1.414), Φ(1.61803399), √3 (1.732), √5 (2.23), e (2.718282), π (3.14159) and declares that the unmanifested state (Abhavaat) can exist only when the oscillations are between π/10 (0.314159) and e(2.718282). This is simply amazing since the state of Abhavvat is the state of Brahman.**

Despite herculean efforts I am unable to understand the Bhashya for the 72 verses which is about 500 pages explaining the secrets of Sankhya in any significant measure. I wish someone can step in and help us by explaining Sankhya Yoga that is comprehensible to our level of intelligence.

We have a treasure of secrets and richness hidden in our scriptures and it seems we have already lost most of them and the fundamental reason being our indifference to Sanskrit and our mother tongue.

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

Happy reading!

The passage produced below is just the summary of verse 1.

…The Sankhya view that evolves out of the complete theory is that only vibrations are detected by the observer... Since only relative changes can be be detected, any fundamental component that is not in a vibratory state cannot be detected. Vibrations are caused by components in an interactive state or a cyclic state of colliding and separating that is common to all interactions and wave phenomenon.

The interactions create three distinct modes of stresses. Collisions are compressive or inelastic. The resultant reaction is expansive or elastic. When the interacting components lack the freedom to move away the interactive state is maintained in a cyclic or shuttling mode in the same location in a resonant state.

This important Sutra lays emphasis that if the observed process of detection is dependant on vibrations, then fundamental space ***must*** *contain components with those four characteristics described as states, which makes it function in a holographic way. That is all vibrations remain in fixed relationship relative to each vibratory point in a coherent and resonant state.*

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21. Time = Space Series. Part 21 – 5 and 8 the Universal rhythm

Let’s summarize what we have seen so far and then move on to more interesting aspects.

We have touched upon the God’s particle and its characteristics. We also looked at the 5 fold manifestation process and in that we looked at how **Moolam** becomes **Kaalam** (time) and how time rhythmically (**Seelam**) vibrates with a proportion and creates forms and shapes (**Kolam**). We also touched upon some of the ways we had codified the secrets of nature like **Lord Shiva, Lord Nataraja, Lord Ganapati etc.**

Before we see how rhythm **(Seelam) and shapes (Kolam)** manifests itself as universe, let’s first look at one specific word from Tamil which has three significant meanings converging into one, Yen (**எண்**), means number **eight, generic term for Number / numeral** and also root for **எண்ணம்** which means thought. I shall explain the significance of this below.

Importance of 8 / Octet:

It is stated that these God’s particles combine in the multiples of **8 / octaves ONLY** and the states of manifestation from being subtle to gross is as given below.

○ **Formless Un-manifest State**	**0 (This is the Abhavaat state)**
○ **Guna State**	**$8^0 = 1$**
○ **First stage**	**$8^1 = 8$**
○ **Second stage**	**$8^2 = 64$**
○ **Third stage**	**$8^3 = 512$**
○ **Fourth Stage**	**$8^4 = 4096$**
○ **Fifth Stage**	**$8^5 = 32768$. This is the state with manifest form.**

This rule is applicable to both the visual and aural forms which mean we can see or hear anything only in the fifth stage of evolution. So as per **Pranava veda, the fundamental numbers are 0,1** and the key **numerals for proportions are 5, 8**.

Significance of 5 and 8:

Pranava Veda describes that 8 / octets is the essential harmonic oscillator for the manifestation of the universe since this generative force is the multiple with which the whole universe manifests and sustains. You many note that number 8 is associated with Lord Narayana and his Ashtakshara mantra **(Om NaMoNaRaYaNaYa**).

The principle of 5 / Penta, we have seen is the regenerative binding force earlier. It is always a 5 stage process. This is associated with **Lord Shiva (Om NaMaSiVaYa).** The un-manifest form comes to the Guna state with the force of 5 and in the multiples of 8. It is also important to highlight that 5 and 8 are part of the **Fibonacci series and their proportion is $8/5 = 1.6$, which is Φ**.

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But it is important to realize that the building of octets is a 5 step process for manifestation. This highlights that one cannot exist without another and both are interdependent. Now let's recall:

"Shivasya hridayam vishnur, Vishnoscha hridayam shivah:" and
"Shivaya Vishnu rupaya Vishnave Shiva rupine"

Vishnu (8) is the heart of Shiva (5) and likewise Shiva is the heart of Vishnu and they both are the representation of each other.

If you have noted Tamil language stressed the importance of words and its meaning – this was addressed in the first few parts of this series. Here Tamil language gives the importance of numerals and its significance in the formation of universe. Both the great sages **Auvaiyaar** and **Thiruvallular** stated the importance of numerals and letters in an identical fashion. Both these lines mean, Numerals and letters are like eyes for living beings / equal to eyes.

எண் என்ப ஏனை எழுத்து என்ப இவ்விரண்டும் கண் என்ப வாழும் உயிர்க்கு!
எண்ணும் எழுத்தும் கண்ணெனை தகும்!

Now what should be noted here is that (**எண்**) importance of numerals precedes that of letters and we know why. The aural and visual forces become letters & its associated sound at the 5th stage but the numerals are from the Guna state. **Numerals were associated with 8 / Lord Vishnu and letters were associated with 5 / Lord Shiva**. Guess you can get the scientific knowledge and significance we have in our languages.

Since what is in macro is there in microcosm, taking the analogy to microcosm our mind becomes the Moolam (Source), our thoughts are the vibration, time is measured as the periodicity between thoughts, based on the rhythm of our vibration we perceive the world. This is given very nicely as **உள்ளமே மூலமாகி உணர்வுறும் கோலமாகி**! means **Our mind is the source and its awareness becomes forms.**

This wonderful concept is what is linked in the word Yen (**எண்**), which means number **eight, generic term for Number / numeral** and also root for **எண்ணம்** thoughts. **Just this one word in Tamil highlights the supreme secret that thoughts become form and words with the help of numbers and numerical proportion converts aural and visual forms to thoughts.**

As a wise man said, **"Indians are the most ignorant about their rich past and scientific traditions."**

Happy reading!

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22. TIME = SPACE SERIES. PART 22 – EIGHT (OCTET) AND THE 5 SACRED ARTS

எட்டே எட்டியல் எட்டெட்ட டியலே
எட்டின் நெறியே அளவை மாநெறி !!

The above lines from the work **Aintiram** means **"Eight / Octa (multiples of 8) is the fundamental numeral for any measurements**. We did see that the fundamental god's particle add up with each other in the multiples of 8 in the previous part.

In ancient India there were about 64 arts (http://en.wikipedia.org/wiki/Kal%C4%81) known as **Chatuhsasti kala ("ஆய கலைகள் அறுபத்துநான்கினையும்"** as popularly known in Tamil), but I am going to talk about 5 sacred arts.

We will look at the importance of numeral 8 and how this is fundamental to everything in this Universe. But let's again start again with etymology. The word arts in **Sanskrit** is **"Kala" (कला)** and **Time in Sanskrit is काला (Kaala).** So etymologically we can say that classical arts are all about variation of time (or harmonics of this pulsation of time in the multiples of 8).

After etymology let's get to the basics. Our understanding of the universe is that **"the primordial space manifests itself as spatial forms through pulsation (Time) and its periodicity (Rhythm & order).** This evolution started with **Pranava which came out as aural and visual form (Sound & light)**. When they say **"The one became two"** they refer to the Pranava which is light and sound from the unmanifested consciousness.

Aintiram states that the dual form of **Pranava** gave forth 5 sacred arts which are fundamental to most of the other arts. **The Aural form of Pranava gave forth Poetry and Classical Carnatic music, which can only be heard. The Visual form of Pranava gave forth Sculpture and Building architecture, which can only be seen. Both the aural and visual forms merged to create the classical dance (Bharatnatyam**), which involves both seeing and hearing.

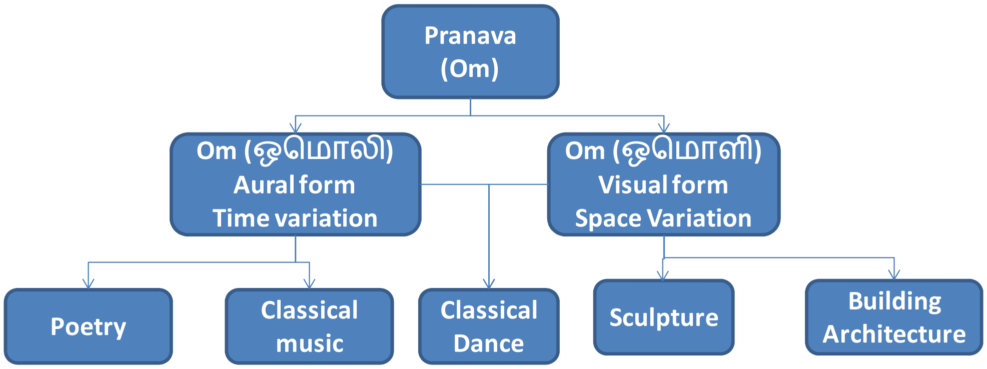

Figure 32: 5 Sacred arts

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They were classified as 5 vedas:

- **Poetry – Sabda veda**
- **Classical music – Gandharva Veda**
- **Classical Dance – Naatya veda**
- **Sculpture – Sthapatya Veda *(Sthapati is a clan that is the master of this veda)***
- **Architecture – Pranava Veda**

Pendatic Tamil and its construction:

Pendatic Tamil is called as **ஐந்தமிழ் (Aintamizh**) which consists all the five above arts, **இயல், இசை, நடனம், சிற்பம், கட்டிட கலை**. It is these 5 arts which were formed out of the Tamil language and the language itself is created from the word Om. They say that it is not 12 basic vowels in Tamil but only 5. They are அ, இ, உ, எ, ஒ. These 5 letters combine to form the rest of the letters like

அ + அ = ஆ, இ + இ = ஈ, உ + உ = ஊ, எ + எ = ஏ, ஒ + ஒ = ஓ, அ + இ = ஐ,

அ + உ = ஔ

Here you may want to note that 5 has become 12. Same way in classical music they say that the basic svaras are 5 (ச, ரி, க, ப, த) – Sa, Ri, Ga, Pa ,Da which became 7 and then 12.

So 5 is the fundamental numeral for evolution and Tamil language has grown based on this philosophy and science. I am sure some of the other Indian languages have the same basics. The book which describes this phenomenon of evolution of language from Pranava and arts from language is **Aintiram (it means 5 works) (ஐந்திறம்**) authored by Mamuni Mayan dated 10000 BC.

You would agree that the aural forms are predominantly variations in time and visual forms are of spatial variations. But our ears stand for akash tatva ("space") and it can perceive variation of time and space and we will see this in detail. When we said **"Time = Space"** we will see that both of them are governed by the same laws and measurements and hence there is no difference between **Time and Space**.

Happy reading!

23. TIME = SPACE SERIES. PART 23 – NANOTECHNOLOGY IN ANCIENT INDIA & SIZE OF GOD’S PARTICLE

Let me start with these questions:

- **What is the size of the God’s particle and how is it calculated?**
- **Does nature endow a standard measure for an average human being’s height?**

Before we proceed to the next section I want to give the very detailed space calculation table used in ancient India. Our rishis did not stop just with telling us that the **Paramaanu / God’s particle** is very small but went ahead and established its size.

If you have to see such minute particles then your sensory organs – Eye and mind should be tuned to it so that it can see things at that size. From the formula available in our ancient texts I was trying to reconstruct by working backwards to find out the size of the **Paramaanu / God’s particle should be.** Please refer the table below which I have arrived at.

ANCIENT SPACIAL MEASUREMENTS		
Unit scale	**Ancient metric**	**Current day Metrics**
1 Paramaanu =	Smallest particle	133 nano meters
1 Ther Thugil=	8 Paramaanu	1065 nano meters
1 Mayir nuni=	8 Ther Thugil	8526 nano meters
1 Eer=	8 Mayir nuni	68 Micro meters
1 Paen=	8 Eer	545 Micro meters
1 Yavai=	8 Paen	0.4365 cms
1 Angula=	8 yavai	3.4925 cms
1 Tala=	6 Angula	8.25 inches
1 Muzham=	24 Angula	33 inches
1 Muzham=	4 Tala	33 inches
2 Muzham=	8 tala	66 inches
Universal height of man	9 Tala	74.25 Inches

(Figure 33: Ancient Spatial measurements. Courtesy – Dr. Ganapathi Sthapati)

I have given the exact word used in Tamil for these measurements instead of translating it in English. Ther Thugil is the dust from chariot wheel, Mayir nuni is the width of a hair tip, Eer and Paen are the lice eggs and lice. Some of you may jump that most of the units were subjective and would have variations in normal life. I agree but there is a reference point – **Angula** and its exact measure based on which other values are derived backwards to arrive at the value of Paramaanu.

Now if you note the **smallest particle** aka **God's particle / Paramaanu** is **133 nm** in size which is currently under study by the CERN scientists. Nanotechnologists today confirm that the width of a hair strand is about 25000 nm and our ancient texts give the size at the tip of the hair strand (and not the width) as 8526 nm. I see that to be a reasonable estimate when no such precision instruments were available in those days.

One Angula is 11/8 of an inch. This is the fundamental measure which is used in any of the worldly measurements. Now you can see that 6 Angula is 1 Tala which is about 8.25 inches and then comes the most important revelation. **Does nature endow a measure for an average human being's height?**

The answer is yes. **As I said an average human being should be 9 Tala's height and hence the nature endowed height for any human being is 74.25 inches.** This is the ideal height and the variation is attributed to our Karma, hereditary and lifestyle.

Now let me give few tips to find out your height from typical measurements:

- Measure the length of the face (from forehead to chin). Your total height should be 9 times that height. This is the principle of Nava tala. As an extension measure your thigh or legs length excluding the knee and feet and your total height should be 4.5 times that.

- Take your right hand middle finger (No. Don't show it to anyone☺). You would notice that the finger is divided into 3 parts. Measure the length of the lowest part – from the end of the palm to the first subsection. Your height typically should be 54 times this measure. Since this measure for an average man with nature endowed length shall be 1 Angula. Hence your height shall be 54 times that measure.

- The length of the thumb from the base of the wrist should be about 3 Angula and hence 18 times of that should be your height. This can go on and on.

So, to sum up this section:

- Instead of looking them as Rishis or Sages or religious figures if we look at them as scientists in the field of nanotechnology, quantum physics and Astro dynamics we would accept most of the secrets without any prejudice.

- Not just the measure for the height of the man but they had formula for every object and this was the secret of their wisdom. For any astronomical object, they had formulas to measure body's core (width) and also the width of the mantle. The roots of their wisdom lie in understanding that "many' are just a harmonic variation of the "one" subject to a mathematical proportion. Hence there was no “rocket science” in those days and all of them were as simple as it looks like.

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

Happy reading!

24. TIME = SPACE SERIES. PART 24 – OCTET, OCTAVE AND THE GANDHARVA VEDA (CLASSICAL MUSIC)

Let’s start with classical music where Octaves form the fundamental for it. There are seven svaras (Sa, Ri, Ga, Ma, Pa, Da, Ni) which is made into an octave with another Sa after Ni. So it becomes Sa, Ri, Ga, Ma, Pa, Da, Ni, Sa (*Do Re Mi Fa Sol La Ti Do*). The first rule of classical music is “**Shruthi Mata, Layam Pita**”, which means **Shruthi is the mother and this corresponds to the frequency or the spatial component and Laya is the Tala component which is a function of time compared as father**.

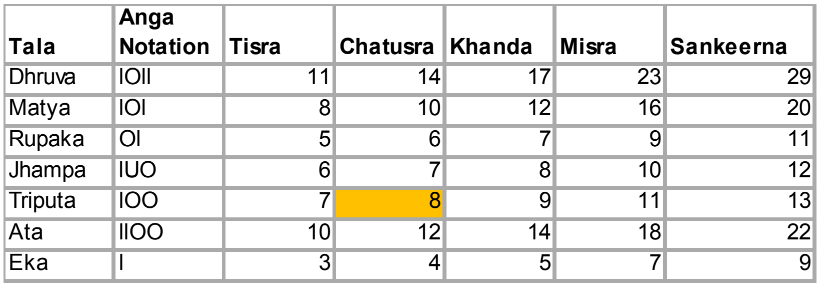

Tala	Anga Notation	Tisra	Chatusra	Khanda	Misra	Sankeerna
Dhruva	IOII	11	14	17	23	29
Matya	IOI	8	10	12	16	20
Rupaka	OI	5	6	7	9	11
Jhampa	IUO	6	7	8	10	12
Triputa	IOO	7	8	9	11	13
Ata	IIOO	10	12	14	18	22
Eka	I	3	4	5	7	9

(Figure 34: 35 types of Tala. Courtesy: Wikipedia, internet)

There are 7 fundamental Talas in carnatic music and each Tala has 5 different variation based on Jathi so in all there are 35 different Talas as given in the tabulation. These Talas are measured as the “matras” the unit duration of time. There is another concept called Nadai or Gati which we will not touch upon now. But let’s look at these 35 variations and can you tell me where the most famous “Adi Tala” is in this 35? Most importantly why it is also called as **“Adi Tala” – which is the primordial rhythm**?

The answer is **“Chatusra Jathi Triputa tala”** highlighted in the table is called as **“Adi Tala”** and it is called so since it gave the most primordial rhythm with 8 time units. But there are couples of more cells where we can see “8” in the table and why these are not called ‘**Adi Tala**”?

The primordial rhythm has a pattern of **1, 3, 2 and 2** which adds to 8. Further on we will see just the variation of this Adi Tala in anything and everything. Tisra Jati matya Thala has a structure of 3, 2, 3 and Kanda Jati jhampa Tala has a structure of 5,1,2, hence they are not classified as the primordial rhythm.

Let’s quickly touch upon the spatial variation or the frequency / pitch aspect of this divine art before we branch off to other topics. The image below gives the 16 levels of Savaras which includes tones and sub tones. The seven svaras become 22 tones based on the frequency variation / harmonics. Here 7 are fundamental svaras and 16 as given below is the most practiced variation and 22 is not popular.

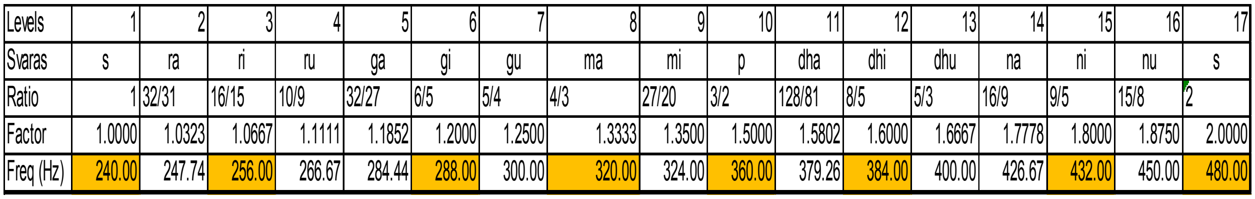

Levels	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Svaras	s	ra	ri	ru	ga	gi	gu	ma	mi	p	dha	dhi	dhu	na	ni	nu	s
Ratio	1	32/31	16/15	10/9	32/27	6/5	5/4	4/3	27/20	3/2	128/81	8/5	5/3	16/9	9/5	15/8	2
Factor	1.0000	1.0323	1.0667	1.1111	1.1852	1.2000	1.2500	1.3333	1.3500	1.5000	1.5802	1.6000	1.6667	1.7778	1.8000	1.8750	2.0000
Freq (Hz)	240.00	247.74	256.00	266.67	284.44	288.00	300.00	320.00	324.00	360.00	379.26	384.00	400.00	426.67	432.00	450.00	480.00

(Figure 35: Svaras and frequencies)

You can note that Sa starts with 240 Hz and the last Sa is 480 Hz doubling the frequency and hence an octave. While Sa has 240 hz and 480Hz levels, the tone Pa (P) or Sol does not have any variation and this is at 360Hz. I am going to correlate the Mayan studies with Carnatic music and instead of seeing the whole spectrum from “Sa”, I am going to see this spectrum from “Pa”.

You would note that “Pa” at 360 Hz corresponds to the **Harmonic osciallator constant number** and the whole spectrum is almost like a Sine wave from 360Hz to 480 hz and falling down to 240 Hz with a uniform gap of 120Hz above and below. All the tones would fall within this 240Hz centered around 360 hz. So the spatial variation in carnatic music can be summed as “It originates at a value (240Hz) and varies by the same measure (240Hz) centered on the harmonic oscillator”. Since the objective is about looking at the primordial rhythm we will not touch any other aspect on this topic.

We will see how this **Adi Tala** is the fundamental pattern / rhythm that manifests in every other art.

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

Happy reading!

25. TIME = SPACE SERIES. PART 25 – ADI TALA, NAVA TALA AND STHAPATYA VEDA (SCULPTURE)

Let’s look at how Octet and the primordial rhythm (Adi Tala) that defines Sculpture. Let’s recap some of the following:

- The process of evolution starts with Pranava which has aural and visual forms. We have also seen that anything subtle is represented in a 8x8 energy grid and anything gross is in 9x9 grid.
- The fundamental measure with which the particles bond is **Eight or** it’s multiple and hence the primordial rhythm is an **Octet.**
- The fundamental measure of time is **Tala** and the **primordial Tala is Adi tala** with 8 units and a pattern of 1, 3, 2 and 2.

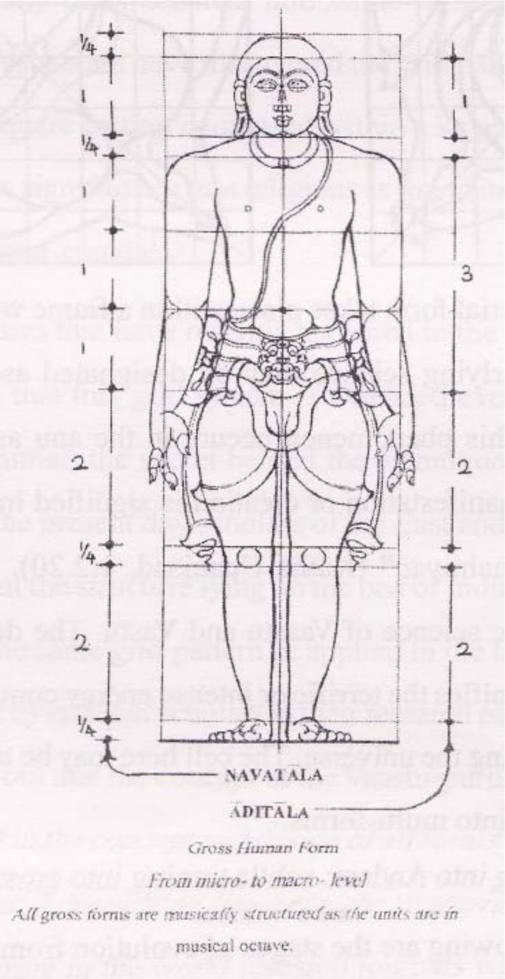
¼
1
¼
1
1
1
2
¼
2
¼
1
3
2
2
NAVATALA
ADITALA
Gross Human Form
From micro- to macro- level
All gross forms are musically structured as the units are in musical octave.

(Figure 36: Human form – Adi Tala, Nava Tala Courtesy: Dr. Ganpathi Sthapati)

Now let’s see the measurement rules as to how to make a sculpture of a human being.

- **The overall human height is measured as 9 talas.** Yes the same time measurement is used to measure height. Pinch yourself now, since height is a space variation and not a time variation yet it is measured with a metric of time. This is a secret which is unknown to many and even some of the experts in this field. This is where Time and spaces merges without any difference and this is the fundamental rule with which we have been creating visual and aural structures in the universe.

- **Divide a man’s height as 9 units of which head, torso, thigh and legs would fall into the pattern of 1, 3, 2 and 2 which adds up to 8. This is the primordial rhythm – the Adi Tala now as a human form.**
    - Then how 8 became 9? No other branch of Vedas or science tells us this secret so explicitly to my knowledge. **The following parts, Top of the head to forehead, Neck, Knee and feet each measure 0.25 talas and hence add 1 additional tala to 8 and it becomes 9.** So Adi tala which is a subtle version of human becomes Nava Tala which is the gross version of human being. In the process of 8 becoming nine all the joints are formed in the body☺.

    - Let me add one more dimension to this. Our human body has a gross body (Sthula) and a subtle body (Sookshma sarira). **The Sthapatya veda tells us that the gross body is nava tala and sookshma sarira is Adi Tala**.

    - I fell off the chair when I understood this and the linkages. Check if you are still on your chair and maybe you should sit on the floor from now on☺.

Martial Arts and Lord Nataraja’s stance:

Let me ask you the following questions here:

- Look at the image of the Lord Nataraja below. If a gross image should have Nava Tala which is a 9x9 grid then why the human image of Lord Nataraja which is a Nava Tala fitted into a 8x8 square instead of a 9x9 square?

- Both in Classical dance and in martial arts why do they ask you to stand in a posture where the knee is slightly or significantly bent. Not all of the stances but most of the basic stances correspond to this why? Let me know if you have received a satisfactory answer for this question.

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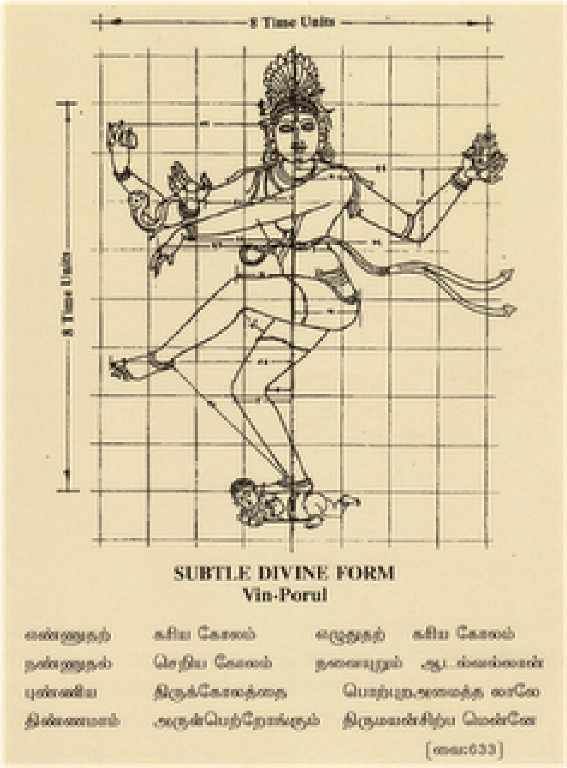

(Figure 5 reproduced)

- The answer to this question reveals one more secret to us.
    a. **In Sthapatya veda each grid line is divided into 10 or 11 or 12 (usually 12) and hence a 9x9 grid has 9*12 = 108 blocks or levels of energy. This may explain why 108 is a sacred number from an energy perspective.** This covers the entire spectrum.
    b. When we create a gross image its always sculpted to 9 talas but when they sculpt image of the gods and in this case Nataraja, they fit the gross image to a 8x8 energy grid to invoke the subtle energies.
    c. How do they fit a 9 tala to 8 tala? The technique is not to change the proportion of nava tala but they ensure that 9 fits into 8 by making the image to bend it legs such that the height reduces by one unit.

- You can notice that Lord Nataraja's right leg is bent to fit the image in 8x8 grid. This is believed to invoke the subtle energies corresponding to that image.
- This is the same reason why martial arts and in Bharatnatyam your teacher asks you to take a basic stance which reduces the height from 9 units to 8 to invoke subtle energies. Of course the other reason is the alignment and focus to Hara / Dantein with that pose.

If I tell you that the science of nature and the associated philosophy codified in Hindu religious symbols are unmatched and amazing then I hope you would whole heartedly agree now. These religious texts and symbols offer the key to unlock the secrets of nature.

So to sum up, so far we have seen one variation of time as **Gandharva veda** that manifests as classical music and the primordial rhythm is **Adi Tala.** Next we saw that the **Sthapatya veda** in the form of sculptures offered the secret of space variation in **Adi Tala and Nava Tala**.

This is where Time and Space were equated with the same measure yet offered completely different arts.

The whole universe has these underlying and un-manifested interconnections and hence the **Hindu philosophy of "That one became many"…** is the supreme truth. Seeing the divinity in everything is the only truthful way of recognizing this science.

As a wise man said, **"Indians are the most ignorant about their rich past and scientific traditions."**

Happy reading!

26. TIME = SPACE SERIES. PART 26 – SABDA VEDA, CHANDAS & POETRY (MA NISHAADA…)

शुक्लाम्बरधरं विष्णुं

शशिवर्णं चतुर्भुजम् ।

प्रसन्नवदनं ध्यायेत्

सर्वविघ्नोपशान्तये ॥

Shuklaambaradharam Vissnnum Shashivarnnam Caturbhujam |
Prasannavadanam Dhyaayet Sarvavighnopashaantaye ||

Let's start with this Sloka as a sample to see how 8 and its harmonics are integrated with Poetry. In this sloka there are 4 lines (a line is called Pada and Pada means feet in Sanskrit) and each line has 8 Sanskrit Aksharas (Only vowels and vowels with consonants imposed on them should be counted and pure consonants are not part of the count.) This is usually written in 2 lines as shown in English.

This is the most popular way of creating a sloka or poem in most of the Indian languages. This "metre" resonates as 32 aksharas in 4 padas. You may want to correlate this with 1,3,2,2 where the last 2 stands for your feet. So feet (pada) measures 1/4th of the overall length of the subtle body (8 units) and 4 padas create the full blown subtle body. So such a constructed poem is a throbbing and vibrating energy body or a living organism and hence carries the power of the words it contains.

If all the padas have equal metre say 8 units then it is called **Sama Vrtta,** and if all are different it is called **Vi-Sama Vrtta** (not equal). **This 8 and 32 is the same as Adi Tala in carnatic music and ashta tala in sculpture. Can you make the connection now?**

In Sanskrit this metre is called as "**Chandas" and in Tamil it is called "Chandam**". **Chandas** is also one of the 4 important Vendagas and is called as the feet of the Vedas. **Let me ask you as to which language the Vedas are available in its primordial form?** The most popular and incorrect answer is Sanskrit. This is the level of awareness we have. Lets quickly look at these important points about Vedas and I shall correlate this with our topic of discussion.

- Unlike other faiths Hindus don't attribute the Vedas as word of god or given by some prophet. We consider Vedas as the breath of god (**"Nishwasitam"**) and not the word which means, Vedas are not created by god, but the breath. If there is no breath that person would not leave and hence it is associated with the very presence of god.

- Vedas are also **Apourusheya** which means it is not created by man and **Anaadi**, that does not have a beginning.

- But you can ignore them stating these are blind beliefs. Let's look at how this correlated with the science. Vedas are created by Pranava and these should be considered as the harmonics of the primordial vibration and nothing more.

  - If it is pure vibration then the “which language it is written?” sounds stupid isn’t. If it’s pure vibration it has to be expressed in “Hz or wavelength” equivalent in ancient India. This is what **Chandas or metre** is all about. This measures pure vibration and anyone capable of tuning themselves to those frequencies have **SEEN** the Vedas and not **created them.** Hence all our rishis are **Mantra Drishtas and not Karthas**.

Difference between Vedas and Poetry:

Vedas contains both **poetic verses (Padya) and prose (Gadya)**. All the poetic verses are called **Chandas** and it complies with the rule as stated above. The difference between normal poetry and Vedas are, Vedas contain tonal variations (high pitch and low pitch) apart from the time, space variations but in Poetry there are no tonal variations. What has tonal variations and are not part of Vedas are called Slokas. So to sum up:

- Vedas are both in Padya and Gadya. What is in Padya is called chandas and it has tonal variations in addition to the time space variations.
- What has tonal variations but not part of Vedas is called as slokas.
- What does not have tonal variation but comply with the chandas rules are called Poetry.

Harmonics and types in Chandas:

We saw every line to have 8 matras / units / aksharas. There are variations and these are the harmonics available.

- **Gayatri –** This is a very special chandas with the mantra where instead of 4 padas, there are only 3 padas and hence it is called Tripada Gayatri. Each pada has 8 Aksharas and hence 24 Aksharas in Gayatri Mantra. This is also the only chandas where a mantra is named after the chandas. Some people write it as 6 letters per line and 4 padas which makes it 24.
- **Ushnik Chandas –** 7 letters per pada and 28 letters in all.
- **Anushtub Chandas –** This is the fundamental and popular one with 8 matras per pada and 32 in all. Ramayana the first poetry was set in this metre.
- **Brihatee Chandas -** 9 letters per pada and 36 letters in all
- **Pangti Chandas -** 10 letters per pada and 40 letters in all
- **Trishtup Chandas -** 11 letters per pada and 44 letters in all
- **Jagti Chandas -** 12 letters per pada and 48 letters in all. This has a subtype called bhujangam which is split as 6-6 and that moves like a snake. (Ex. Subramanya Bhujangam)
- **Shikarini Chandas -** 17 letters per pada and 68 letters in all. In Soundarya Lahiri it is split as 6 and 11 by Adi Shankara.
- **Udkriti Chandas –** 26 letters per pada and 104 letters in all.
- **Dhandakam – above 26 per pada**. **Ex.** Garuda Dandakam by Vedantha Diskshitar.

The reason I have given all the above is to emphasis that nothing in our religious scriptures, literatures are without a grammar, order, form or proportion. Everything confirms to a mathematical proportion.

Just like **Vedas are the breath of god, Chandas is the breath of every mantra.** The mantra is powerful only if it is recited to this metre. This is the reasons some of the poem even if it is not related to religion stands the test of time. Also if you recite a mantra even without knowing its meaning but as per the chandas then the mantra shall bear its fruit.

“Ma Nishada” …..Origin of Poetry:

Would you believe that the first poetry in this universe started with a curse?

Sage Valmiki saw a hunter who killed one of the birds of a pair which were in love. The sage got enraged and cursed the hunter, ***O, Hunter, may you not fare well anytime as you killed one of pair of the Krouncha birds which were happily engaged in love”.***

mA niShAda pratiShThA.n tvamagamaH shAshvatI.n samAH |
yatkrauJNchamithunAdekamavadhIH kAmamohitam.h || (bAlakANDa 2.14)

The above sloka also meant ***“O Lord of Lakshmi, it will bring you eternal glory for having killed a male of a happy couple who lost his head completely in lust..”*** This male is Ravana who lost his head in lust despite being happily married with his wife Mandodari. The other interesting connection I have this sloka with this series is that the **Mamuni Mayan** is the father of **queen Mandodari** and father in law of demon king Ravana.

Once the sage realized that this curse also meant something very auspicious and referred to Rama avatar he wrote Ramayana which is the origin of poetry as known in the world and it is called **Adi Kaavya.** Valmiki Ramayana set in **Anushtub Chandas** which is an octet.

So if you look at both the poetry and classical music composition:

- The rhythm in which it is set is a pulsation of time which confirms to a divine proportion.
- The raga and the pitch variation is a pulsation of space / frequency which again confirms to a divine proportion. We did not discuss about ragas though.
- The words used are divine and we have seen the divinity of the letters and words.
- The meaning of the song / poem usually exhorts the qualities of the god and hence is divine.
- The classical music and poetry invoke the subtle divine energy in the aural form just as much the sculpture (when it confirms to the divine proportion) invokes the subtle energy from in its visual form.
- This is how we see that “**one became many”** and **binding factors** in this process of evolution being the numerals 5 and 8.

Alas! Today, we are the fanatic fans of musicians who lacks morality & humility, who is ignorant of any divine proportion, most of the music we hear is a cacophony and very mechanical, the words are indecipherable and lacks depth, the meaning of the song - if at all any are just suggestive of sexual emotions and nothing else and the dance movements we see are the gyrations of the hip with a great blend of fitness training exercises associated with it. This is not to negate some of the fine works we see even today but to stress that we had such high science and taste which we seems to be losing / lost for no good reason other than ignorance.

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

Happy reading!

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27. TIME = SPACE SERIES. PART 27 – ARCHITECTURE – THE ZENITH OF MATHEMATICS (VAASTU)

Just look back in history and see what stands the test of time. Even if a civilization is completely extinct what stand beyond their time is the architecture of the civilization which stands tall as a witness to the richness and maturity of the civilization.

Aintiram states that **“Architecture (Space engineering) is the zenith of the mathematics**” in **“கட்டிட கலையே கணக்கியல் உச்சி**...” This space science is called as Vaastu Sastra in India.

There are few important concepts in Vaastu science which I want to present as below:

- The whole world is made up of **God’s particle (Vastu, வஸ்து**) and nothing else. It is this God’s particle which actually manifests itself as gross forms (**Vaastu, வாஸ்து**). You would note that Vastu (Subtle) has become Vaastu (gross) by addition of letter “a” and this difference is reflected in our languages too. **When அ / अ become ஆ / आ the subtle becomes gross**. Hence the most important statement for this science is “**Vastur eva Vaastu**”, this means **the subtle becomes gross or energy becomes matter or the space becomes earth.** This is purely manifestation / evolution and there is no creation. This has nothing to do with religion but supreme science.

- Since it is all only one energy and it ever vibrates based on the harmonics and resonance, this vibration is called life and everything in this world, be it a living being or a non-living being as per our current definition – everything vibrates. The chair you sit and the vehicle you use are all living beings. **Everything throbs with energy and there is nothing which is a non-living being in this universe.** Without this vibration there would not be any difference between iron and cotton. The difference between particles is essentially the molecular constitution which is a function of its elements and its periodicity. This defines presence or absence of quality and sensory perceptions. This was put very nicely by **Poet Subramanya Bharathi** as எங்கு காணினும் சக்தியடா, **Where ever you see its just energy.**

- The above concept is very profound and this is called as **Science in our scriptures since it deals with Knowledge of the space** (விண் ஞானம், Vin-gyan).

- By the same concept when a subtle energy which is in the open space is converted to a gross form like a building then this body / building vibrates based on the design specifications and the material used for that building. It does not matter what is the measure and what is the material used, it vibrates. **When a structure is created with a divine proportion then we breathe life**

into it. Thus the structure becomes a living organism. This is how some of the structure stands the test of time for thousands of years.

- **Vaastu is that science which aligns the vibration of the building with the vibration of the dweller in the building so that both the living organisms (the building and the dweller) are in harmony and resonance.**

- It sounds simple but for this science we need to know includes the vibration pattern of the dweller, mathematics of space engineering, the knowledge of materials and its nature so that we can match it up to create harmony. This is precisely what Vaastu as a science does. Again it has nothing to do with religion. If you Google you would find thousands of Vaastu experts outside India who perceive and pursue this as a supreme spatial science.

- Let us look at the word **"vas"** which is the root. This means to shine; to grow bright, **to bestow by shining upon**, becoming light. **Vaas** is its derivative which means to perfume, an intoxicant, **dwelling place**, to assume the appearance of matter. This is the root for **SriniVAAS**, **SreeVAASan**, **VAASam** in Tamil means living. Most importantly the ability to feel this subtle thing (which cannot be touched) is called **VAASanai (**வாசனை, **in Tamil it means smell).**

- This spatial science includes knowledge on the following:
    - Nature of soil and material, and the qualities of its energy.
    - Measures for spatial engineering that best resonates with the environment and the dweller.
        - Note that the dwelling unit cannot be compatible to all the human beings universally. This varies with individual to individual and hence the Vaastu compatibility for the house is always seen for the housewife than the man with the assumption that what is compatible to the lady of the house would suit all others.

    - Accurate calculation of time and the position of astronomical bodies. The time engineering merges here with the space engineering. Consider the following to understand this:
        - In some temples you would notice that the sunlight falls on the deity on a specific day / time of the day. This is not possible if the future position of astronomical bodies at a given time is calculated very accurately.
        - When we build a house / temple the inauguration ceremony should be conducted at a specific time. So it's just not Space Engineering but time engineering also.

    - We see that the concept of space and time are not just a continuum but:

        - The measures of time and space merge and results in the same unit measure called Tala. It is Adi Tala in Poetry, Music and the same measure is used in building and sculpture dimensions.

- **Space is created because of the pulsation called Time** and hence the unit time measure (for pulsation) and the unit space measure (result of pulsation) are one and the same. This means the pulsation causes proportional displacement or creation of Space.

- It is the same concept used in meditation techniques. With Pranayama, Dharana and Dhyana you control the pulsation and align with it. In Samadhi you stop the pulsation and hence you are beyond time and space and you reach a luminescent state of resonant non-vibration.

Hence I named this book as **"Time = Space".**

We have seen that each subtle unit is represented in 8x8 energy grid and the gross unit is represented in a 9x9 energy grid. Mayan states that **"Each module or pada within the 8x8 / 9x9 structure resonates with a specific energy.** Based on Space, Time, Light, and Sound coordinates the frequency of vibration has its unique position in the Space/ Time continuum. **This energy level of frequency of vibration is called a luminous body or Devata**. This devata has particular attributes based upon its position and qualities in the Space/Time continuum (placement among the 64 / 81 sub-cubes or padas)".

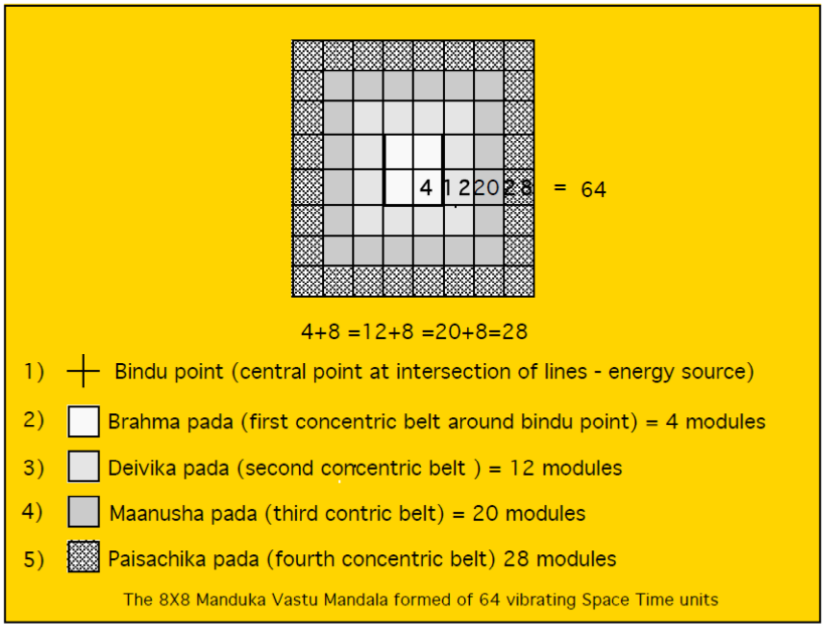
4 12 20 28 = 64
4+8 =12+8 =20+8=28
1) ┼ Bindu point (central point at intersection of lines - energy source)
2) □ Brahma pada (first concentric belt around bindu point) = 4 modules
3) □ Deivika pada (second concentric belt) = 12 modules
4) ■ Maanusha pada (third contric belt) = 20 modules
5) ▨ Paisachika pada (fourth concentric belt) 28 modules
The 8X8 Manduka Vastu Mandala formed of 64 vibrating Space Time units

Figure 37: 5 states of 8x8 Energy Grid (Courtesy: Dr. Ganapathi Sthapati)

Now what is evident here in this science is 8 and 5 merges and so does Space and time.

- **Manifestation occurs in additive values of eight and in 5 stages. You can note that the Bindu (Point) has become 4, then 12, then 20 and then 28. (4+8=12 +8=20+8=28 with a total additive factor of 64). Manifestation occurs in sequences of five steps known as the Pentadic Order.**
- **The mathematical calculation which gives form to consciousness / space / subtle matter is called "Ayadi Gananam". We know that Ganam as the additive process.**

Dr. Jessica Marcey in her Fabric of Universe states that:

- The subtle energy point in the center becomes a self effulgent energy generator pouring out waves of energy
- becoming a self spinning stabilized structure of four padas / modules then
- adding eight units of energy to manifest the 4X4 structure of 16 units or modules; then
- adding another eight units of energy to manifest the 6X6 structure of 36 units or modules; then
- Adds eight more units culminating in 64 units or modules strung concentrically around the Bindu point or central generator.

So a central point with 4 concentric square belts around, each has its own frequency, vibration and energy characteristics evolving into a 9x9 unit as a gross matter. While this knowledge is significant of itself, when these phenomena are viewed in light of material manifestation as built space in architecture, the significance becomes stunning and profound.

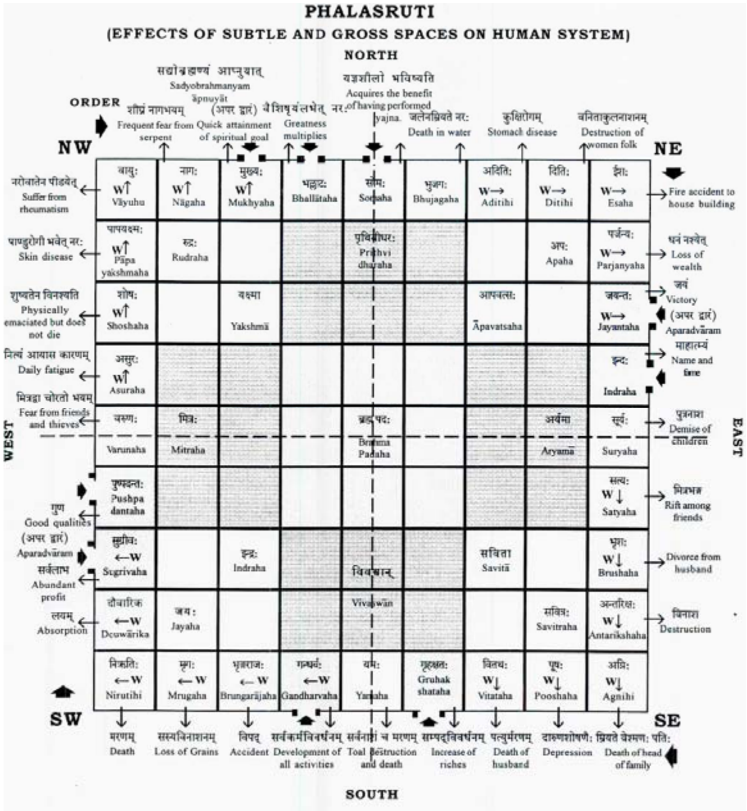
PHALASRUTI
(EFFECTS OF SUBTLE AND GROSS SPACES ON HUMAN SYSTEM)
NORTH
SOUTH
WEST
EAST
NW
NE
SW
SE
ORDER
Sadyobrahmanyam āpnuyāt
Frequent fear from serpent
Quick attainment of spiritual goal
Greatness multiplies
Acquires the benefit of having performed yajna.
Death in water
Stomach disease
Destruction of women folk
Suffer from rheumatism
Skin disease
Physically emaciated but does not die
Daily fatigue
Fear from friends and thieves
Good qualities
Aparadvāram
Abundant profit
Absorption
Fire accident to house building
Loss of wealth
Victory
Aparadvāram
Name and fame
Demise of children
Rift among friends
Divorce from husband
Destruction
Death
Loss of Grains
Accident
Development of all activities
Toal destruction and death
Increase of riches
Death of husband
Depression
Death of head of family
Vāyuhu
Nāgaha
Mukhyaha
Bhallātaha
Somaha
Bhujagaha
Aditihi
Ditihi
Esaha
Pāpa yakshmaha
Rudraha
Prithvi dharaha
Apaha
Parjanyaha
Shoshaha
Yakshmā
Āpavatsaha
Jayantaha
Asuraha
Indraha
Varunaha
Mitraha
Brahma Padaha
Aryamā
Suryaha
Pushpa dantaha
Satyaha
Sugrivaha
Indraha
Savitā
Brushaha
Dcuwārika
Jayaha
Vivaswān
Savitraha
Antarikshaha
Nirutihi
Mrugaha
Brungarājaha
Gandharvaha
Yamaha
Gruhak shataha
Vitataha
Pooshaha
Agnihi
W↑
W→
W↓
←W

Figure 38: 9x9 energy grid with corresponding energy levels for each grid.
(Courtesy: Dr. Jessica Marcey, Fabric of the Universe)

So, to sum up this section, we have seen that how every inanimate thing in this universe is still a living being and how with the spatial science we can pump throbbing energy into a building. This is the supreme science where Time and Space merges. This is the 4th sacred art we talked about which is a manifestation of the visual form of Om.

As you would have noticed I have avoided talking about rituals and rules here but focused on the concept and philosophy. When we talk about rituals there are very many variations and we get into an unnecessary argument that whether it is rational or superstitious. Since most of the arts have become commercialized, the person’s qualification and his intentions are always questionable.

The objective of this book is to highlight the scientific aspects of the universe in a small way and emphasis that our culture is built on this science. Be it language or arts or religion all are built on scientific facts. They all were nourished and nurtured in thousands of Temples across India which is the container and protector of this subtle science and energy.

Let’s see some more interesting aspects of this in the next section.

Happy reading!

28. Time = Space Series. Part 28 – Capturing the divine energy – Squares & Circles

It is told that the sanctorum of Lord Ranganatha's temple at Sri Rangam is circle from outside and square from inside. Why?

- Subtle energy is represented by 8x8 square grid and the perimeter of the square is 4r and the area of the square is r*r. When each grid length is 1 unit then r = 8, so perimeter is 32 and area of this square is 64.
- Gross energy is represented by 9x9 square grids and with the same measurements perimeter is 36 and area of this square is 91.

It has been an architect's dream to create and capture subtle energy in a gross structure. This is fundamental objective of spatial engineering. How do you go about to achieve this? It looks that they found that they would take the help of a circle either outside the square or inside the square to achieve this. Remember almost every yantra has a square and a circle component in it.

The measurements are so taken such that either the perimeter or the area of both the circle and the 8x8 square are matched. Most of the Hindu temples follow such rules to invoke the subtle energy in a gross structure like temple. This is one of the well kept secrets and this is the reason each and every temple is said to interact with your subtle body differently when you visit it.

This is why Lord Ranganatha's sanctorum in Sri Rangam temple is a circle from outside and square from inside. This secret is called as **Squaring a Circle**. This is all about to creating divine energies and this is the science that is implemented in all the Hindu temples which are built as per the Sastra. You need just basic math knowledge and patience to understand this supreme secret and I shall give below 2 techniques to match the area or the perimeter of the circle with that of the 8x8 square.

Perimeter match:

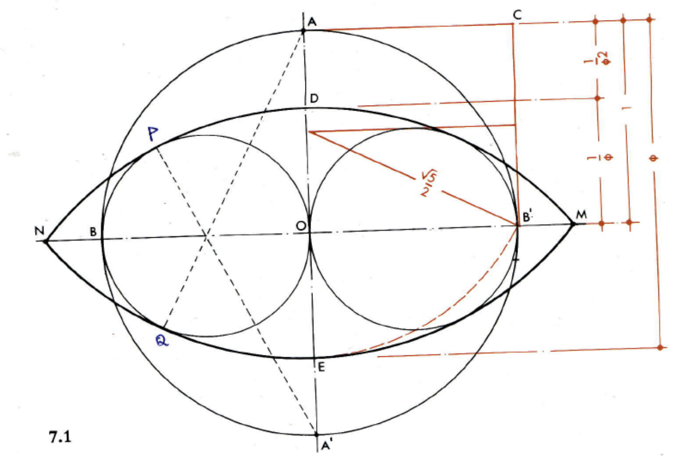

- Let's look at the image of a circle of unit radius. The **area of the large circle is π** (πr^2) and the **circumference is 2π**. Here r =1.

- Draw 2 circles inside as shown with half the radius. The area of each circle is π/4 and the **combined area of both the circles is π/2**. The circumference of each circle is π and the **combined circumference of both the circles put together is 2π**.

Figure 39: Squaring a Circle (Courtesy: Dr. Robert Lawlor, Sacred Geometry)

- Just note that when a larger circle divides itself as 2 smaller circles the area is halved but the circumference is the same. **This gives the first philosophical metaphor that "One has become two which are bipolar yet non-dual". This is one of the fundamental principles of Advaita and also in Chinese philosophy. This bipolar non-dual force is the basis of life and is represented as male / female and Yang / Yin.**

- Now draw 2 arcs NDM and NEM from A' and A with the radius as A'P and AQ as shown in the dotted line. You would note that point D and E would divide the radius of the circle by divine proportion – $1/\Phi$ and $1/\Phi^2$. **Radius of the arc AE is Φ. The Yin Yang symbol is based on this principle which embeds the divine proportion in it.**

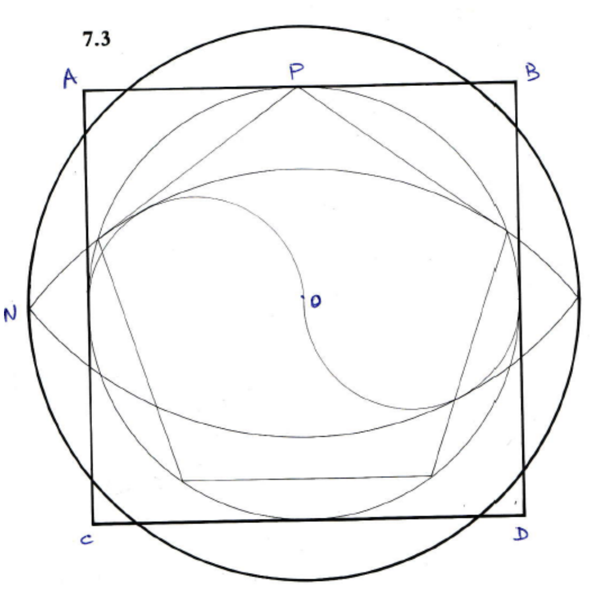

- Now let me draw a square ABCD around this circle (Fig 40) where the side of the square is the diameter of the circle which is unit 2. Here OP =1, AB=BC=CD=DA = 2. **The perimeter of the square is 8 and the area of the square is 4.**

- Now draw a circle with O as the center and NO as the radius as shown in the figure. Here NO = $\sqrt{\Phi}$. You can take this figure as such if you find it difficult to follow but for those who are interested, the derivation to calculate radius "NO" is as below:

Figure 40: Squaring a Circle 2 (Courtesy: Dr. Robert Lawlor, Sacred Geometry)

  - Consider a right angle triangle OPN. We know OP = 1 and PN which is the radius of the arc = Φ. Hence as per Pythagoras theorem $PN^2 = OP^2 + ON^2$ which is $\Phi^2 = 1+r^2$. Let us say the radius is ON = r.
  - So $r = \sqrt{(\Phi^2-1)}$. We know Φ is 1.61803399 so **$r = \sqrt{\Phi}$.**

- We have got a larger outer circle with a radius **$\sqrt{\Phi}$** and hence the perimeter should be **$2\pi\sqrt{\Phi}$. This is numerically equal to 7.9924576, which is equal to 8. Now we have created a structure where a square whose perimeter and a circle whose perimeter are the same.** This technique is not limited to India but used in the same way for pyramid construction.

- **This is the perimeter match between 8x8 square grids and a circle around it**.

Area match:

- Vaastu has an easier way to get this done. Draw a circle inside a 9x9 energy grid whose diameter is equal to the side of the square. If each energy grid length is 1 unit, then side of the square is 9 units and the radius is 4.5 units.

- The area of this circle is πr^2 where r=4.5 and hence the area of the circle is 63.64 which is almost equal to area of the 8x8 square with unit grid length as 1 unit.

- This is the area match between a circle and 8x8 square. So as per Vaastu every building is divided into 9x9 grid and the energy level of each grid is used to design the living space.

Capturing the direction of Subtle energy flow:

The subtle divine energy flows is as per the diagram given below. It starts from the center and always flows clockwise. That is why Hindus always stick to clockwise flow of movements - be in their temples or anywhere else. This clockwise flow of movement is captured in the sacred symbol Swastik. Here 1 is the source / Moolam, 2 is Kaalam (Time), 3 Seelam (Rhythm), 4 Kolam (Form), 5 (Universe) Gnalam.

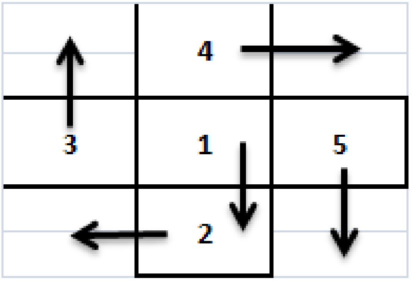

Figure 41: Clockwise flow of subtle energy

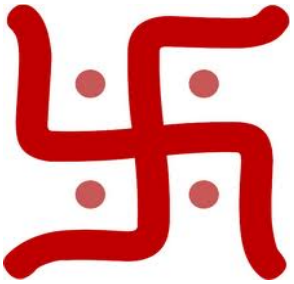

Figure 42: Swastik symbolizing energy flow

Relationship between √2, √3, √5, Φ and π:

- Now let me draw the connection between √2, √3, √5, Φ and π. Understanding this relationship is orgasmic and nothing less. If you think they are all some random numbers which cannot be fixed to their 10th decimal and not related to each other, just see the following relationship.

  $$\pi = \Phi^2 \times 6/5$$

  Philosophically 6/5 is the relation of a hexagon to a pentagon and the other way to express this relationship is

  $$\Phi = (\sqrt{\pi} * \sqrt{5}) / (\sqrt{2} * \sqrt{3}).$$

- This goes to prove that we did not just knew the numerals but divine fractions and proportions including their linkages. I am convinced, there is not even an iota of superstition in our temple and idol worship but they are supreme sciences codified and left for our benefits.

- The temple of **Sri Rangam** dates back from Ramayana, which is Treta Yuga that is 800000+ years back as per Hindu Scriptures. This is our rich past and supreme science is embedded in our culture and codified in thousands of temples across nook and corner of the country. Why should we ignore this? We have a lot more to offer this world which is struggling to understand the nature of nature.

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

Happy reading!

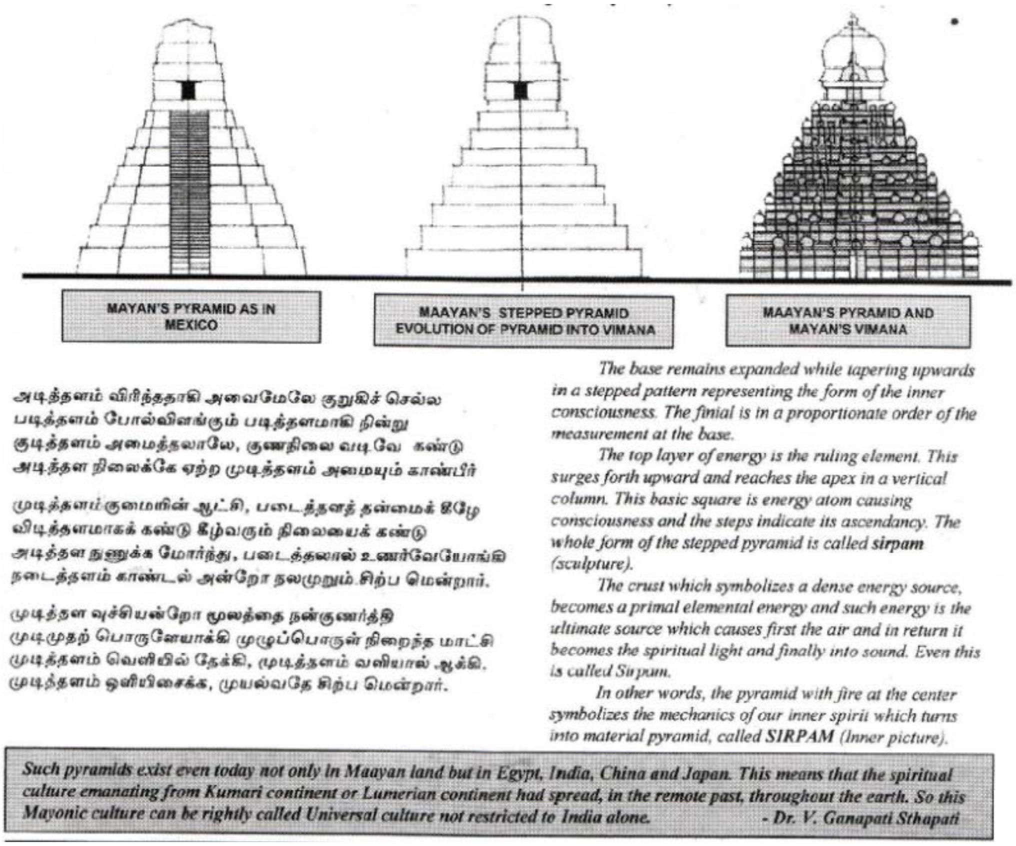

MAYAN'S PYRAMID AS IN MEXICO

MAAYAN'S STEPPED PYRAMID EVOLUTION OF PYRAMID INTO VIMANA

MAAYAN'S PYRAMID AND MAYAN'S VIMANA

அடித்தளம் விரிந்ததாகி அவைமேலே குறுகிச் செல்ல
படித்தளம் போல்விளங்கும் படித்தளமாகி நின்று
குடித்தளம் அமைத்தலாலே, குணநிலை வடிவே கண்டு
அடித்தள நிலைக்கே ஏற்ற முடித்தளம் அமையும் காண்பீர்

முடித்தளம் குமையின் ஆட்சி, படைத்தளத் தன்மைக் கீழே
விடித்தளமாகக் கண்டு கீழ்வரும் நிலையைக் கண்டு
அடித்தள நுணுக்க மோர்ந்து, படைத்தலால் உணர்வேபோங்கி
நடைத்தளம் காண்டல் அன்றோ நலமுறும் சிற்ப மென்றார்.

முடித்தள வுச்சியன்றோ மூலத்தை நன்குணர்த்தி
முடிமுதற் பொருளேயாக்கி முழுப்பொருள் நிறைந்த மாட்சி
முடித்தளம் வெளியில் தேக்கி, முடித்தளம் வளியால் ஆக்கி.
முடித்தளம் ஒளியிசைக்க, முயல்வதே சிற்ப மென்றார்.

The base remains expanded while tapering upwards in a stepped pattern representing the form of the inner consciousness. The finial is in a proportionate order of the measurement at the base.

The top layer of energy is the ruling element. This surges forth upward and reaches the apex in a vertical column. This basic square is energy atom causing consciousness and the steps indicate its ascendancy. The whole form of the stepped pyramid is called ***sirpam*** *(sculpture).*

The crust which symbolizes a dense energy source, becomes a primal elemental energy and such energy is the ultimate source which causes first the air and in return it becomes the spiritual light and finally into sound. Even this is called Sirpum.

In other words, the pyramid with fire at the center symbolizes the mechanics of our inner spirit which turns into material pyramid, called ***SIRPAM*** *(Inner picture).*

Such pyramids exist even today not only in Maayan land but in Egypt, India, China and Japan. This means that the spiritual culture emanating from Kumari continent or Lumerian continent had spread, in the remote past, throughout the earth. So this Mayonic culture can be rightly called Universal culture not restricted to India alone. - Dr. V. Ganapati Sthapati

Figure 43: Similarity between Indian temples, Pyramids. The Tamil text states how the structure should be built. (Courtesy: Dr. Ganapathi Sthapati)

29. Time = Space Series. Part 29 – Heaven & Earth – Lord Nataraja & Lord Ranganatha

Let’s stay with Lord Ranganatha and see the relationship between him and Lord Nataraja. Would you be surprised if one is the mirror image of the other? Look at the majestic picture of Lord Nataraja below. Wonder why this is always made in metal and not in wood or earth?

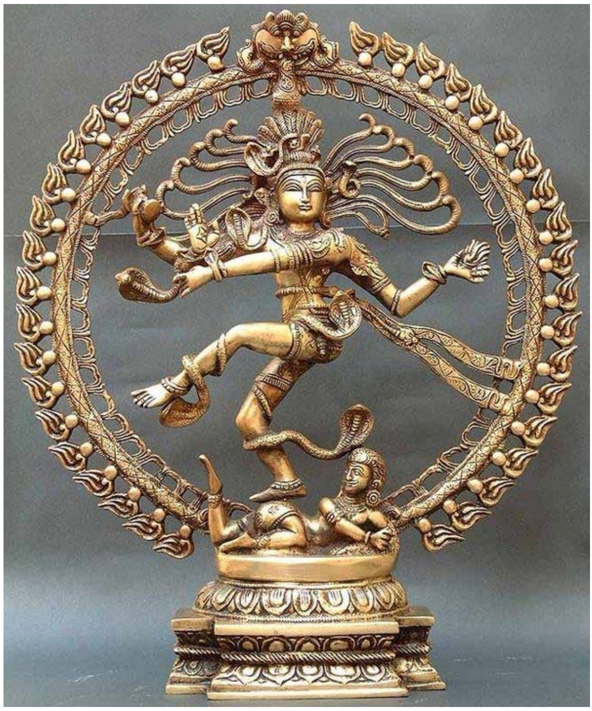

Figure 6 reproduced.

In Pancha bhoota (Space, Air, Fire, Water, Earth) Metal is always associated with Space and Wood is associated with Air. This system is reflected well in the Chinese system and it was not any different in our Vaastu system either. Since Lord Nataraja signifies Akasha tatva, **(Vin porul)** he is always made in metal – Copper or Gold or Bronze or a mix of it. The statues which were ancient had a generous amount of gold giving a luminescent look about the statues. The art and science of moulding metals to create divine forms with precise proportion dates back to thousands of years in India and the western experts think that this is a recent phenomenon. This is a complete surprise to the western world since they cannot believe that such sophistication existed before.

Dr. Ganapathi states, *“Lord Nataraja also signifies the primal image being expressive of the secret of creation in the process of which formless becomes instantaneously endowed with features and of perfect form. This is the reason why the statue of Lord Nataraja is called as* ***Silpa****, the primal image and everything else which is sculpted in this universe is called as* ***Pratima (replica)*** *and the original and one and only sculpture is the image of Lord Nataraja***”.**

Mamuni Mayan states, *"Bhumih pradhana vastu Syat"*, means Earth by virtue of being the very basic support of all things, this is the primal and dominant Vastu". Earth and space are manifestations of each other in the cyclical process of evolution. They both should always be considered to be in unison. This vibrant, energetic, manifest earth energy (**Prithvi Tatva)** is called as '**Vishnu**".

In Vaastu satra, the Vaastu purusha is Lord Vishnu and understandably Vishnu is invoked as Vaastu purusha in Srirangam temple and offered a seat in the heart of Lord Ranganatha even today as a ritual.

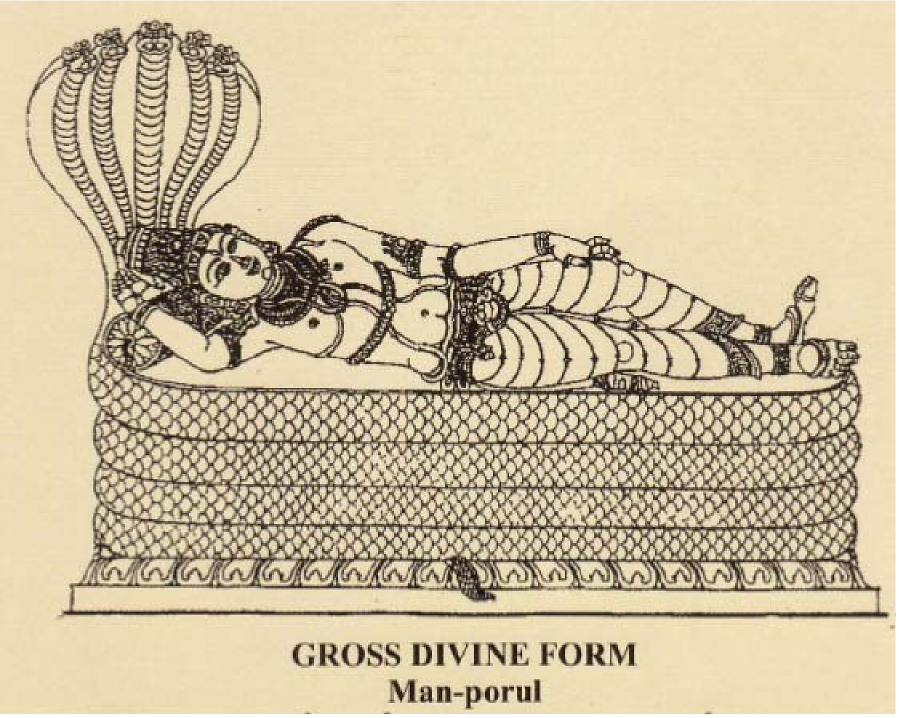

Figure 44: Lord Ranganatha in the reclining pose

Lord Ranganatha represents manifest earth energy **(Man porul)** and hence is always made out of seasoned earth only and it should be properly painted too. He is never to be made of metal. This earth form does not support frequent mobility and symbolizes stability and immobility. **This is the reason when Vibhishana kept the idol of Lord Ranganatha down at Sri Rangam it could not be moved.**

The energy that is in available in every universal form is represented as Vishnu and hence he is called as **Antaryami**. Once the subtle becomes grosser the vibration is reduced and the grossest form would not have any creative pulsation in it. It would still have the vibration based on its nature which ensures that it retains the form and shape. But it does not have any creative pulsation and it has reached the zenith of evolution. **This zenith is characterized by Lord Ranganatha in the reclining pose**.

The creative pulsation (Space) is the dance and the zenith of manifestation is a reclining posture (Earth).

As we have seen, Lord Nataraja carries **Light in his left hand** and **sound in his right hand**. Lord Ranganatha carries **Chakra representing light in the right hand** and **Conch representing sound in the left hand.** The principle that the primal substance (space) has manifested as the universe (earth) and both of them are mirror images of each other is reflected in both the images.

In Chinese texts the Yang energy is associated with Heaven and the Yin as earth. Now associate the same heaven with Shiva, Earth with Vishnu and Tao with the God's particle - with some of the text below from **Lao Tzu's "Tao te Ching"**

"The Tao that can be told is not the eternal Tao.
The name that can be named is not the eternal name.
The nameless is the beginning of heaven and Earth.
The named is the mother of the ten thousand things.

Something mysteriously formed, Born before heaven and Earth.
In the silence and the void, Standing alone and unchanging,
Ever present and in motion, Perhaps it is the mother of ten thousand things.
I do not know its name. Call it Tao.

Man follows Earth. Earth follows heaven. Heaven follows the Tao.
Tao follows what is natural."

To sum up in the words of Dr. Ganapathi Sthapati:

- **Both the temples Chidambaram and Srirangam are south facing temples.**

- **Lord Nataraja signifies Akasha Tatva, outer space, macrocosm, subtle unmanifested energy is the Vastu purusha, is always in dancing pose, circumscribed in 8x8 square and made of metal.**

- **Lord Ranganatha signifies Prithvi Tatva, inner space, microcosm, manifest gross energy, is the Vaastu purusha is always in reclining pose, depicted in a circle or a 9x9 grid and made of earth.**

- **Lord Nataraja represents energy with matter and Lord Ranganatha matter with energy. In the equation $E = mc^2$, Lord Nataraja represents E and Lord Ranganatha represents mc^2.**

- Both these temples are a 'must see" and a "periodic see" types and you would be amazed that the qualitative change in your mental state even if you don't pray inside the temple but spend some time sitting or walking in the premises of the temple.

- **Both these temples are perfect symbols of ancient science codified for the benefit of the society and left for generations withstanding the test of time.**

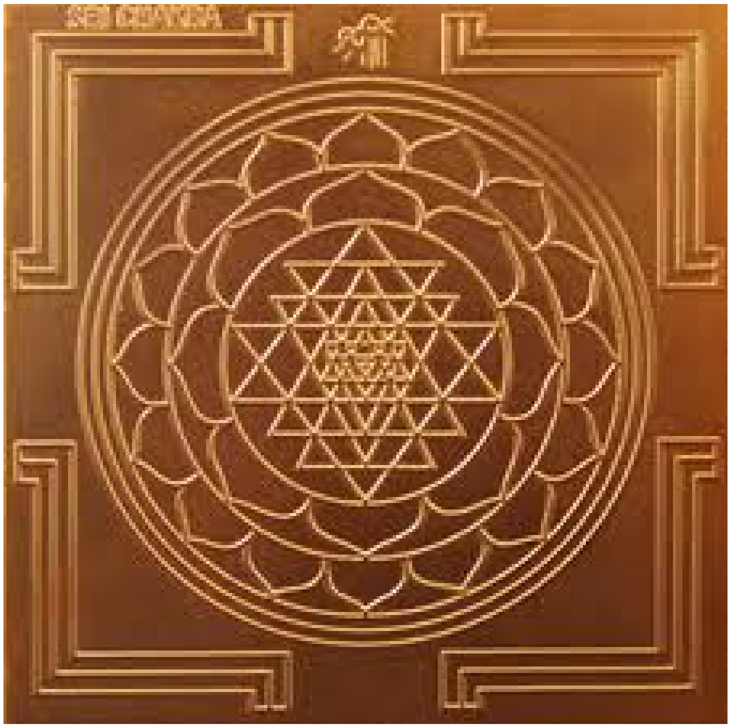

Figure 45: Sri Chakra – The Supreme shape in sacred Geometry

Chidambaram and Sri Rangam should be ground zero for any lab that wants looks into the secrets of space and time as they represent supreme science as much as they represent spirituality. We now see that science was the basis of our spiritual faith unlike it being 2 completely different aspects today across the world.

As a wise man said, **“Indians are the most ignorant about their rich past and scientific traditions.”**

May we be blessed by the divine power to unravel unknown secrets about the nature!

Happy reading!

30. Time = Space Series. Part 30 – Temples and Idol worship

Let us forget Hinduism, its symbols and names of god for the time being and consider these aspects as pure science from a nanotechnologist and cosmologist called Mayan.

We have been told that the universe is full of luminescent particles and this particle manifests itself because of the primordial pulsation. We have had a sneak peek into the geometry and the mathematical proportion which is used in the creation of many things. We know that the universe rhythm confirms to a mathematical code to the extent that we can create divine energies in a temple based on that science.

If time is pulsation of consciousness and if it creates, sustains and destroys everything, then time is the architect sculpting the universe and every object in this universe should be a sculpture of time and this concept is very beautifully captured in ***"Jagat Sarvaram Silpameva'*** *meaning the entire universe is nothing more than a shilpa / sculpture (and it latently conveys that Time is the Shilpi).*

If all the above things are right then is it not right to say that "Man created the concept of God" or "Man can create divine energy around him"? Let me sum up my thoughts as below:

- The sages and rishis were essentially scientists and understood the secret of nature very well. They were understandably masters in **nanotechnology and cosmology.**

- They knew that "**One thing"** with which they could understand the nature and science of all other things in this universe. This is obviously supported by the mathematical knowledge they had.

- As per Vedas nothing is created by god including the Vedas, but universe is the manifestation of god. They also understood that man is the most evolved of this manifestation. This is why they created all the god forms in the image of a man.

- Be it language, poetry, classical music, classical dance, sculpture and architecture it was the manifestation of this divinity that was the underlying link. Sacred geometry and sacred proportions were used to generate the subtle energy that took us closer to divine.

Hindu temples were created to capture all these aspects in one place and which could sustain and grow for the benefit of mankind.

- Secret of nature heard through the vibrations of Vedas were codified as supreme science and weaved into a philosophy called **Sanatana Dharma.**

- Architecture of temples confirmed to divine proportions and space - time engineering was accurate to capture sunlight and moon light at the same position for thousands of years. The design of the temple cleaned the subtle energies and points of the human body.

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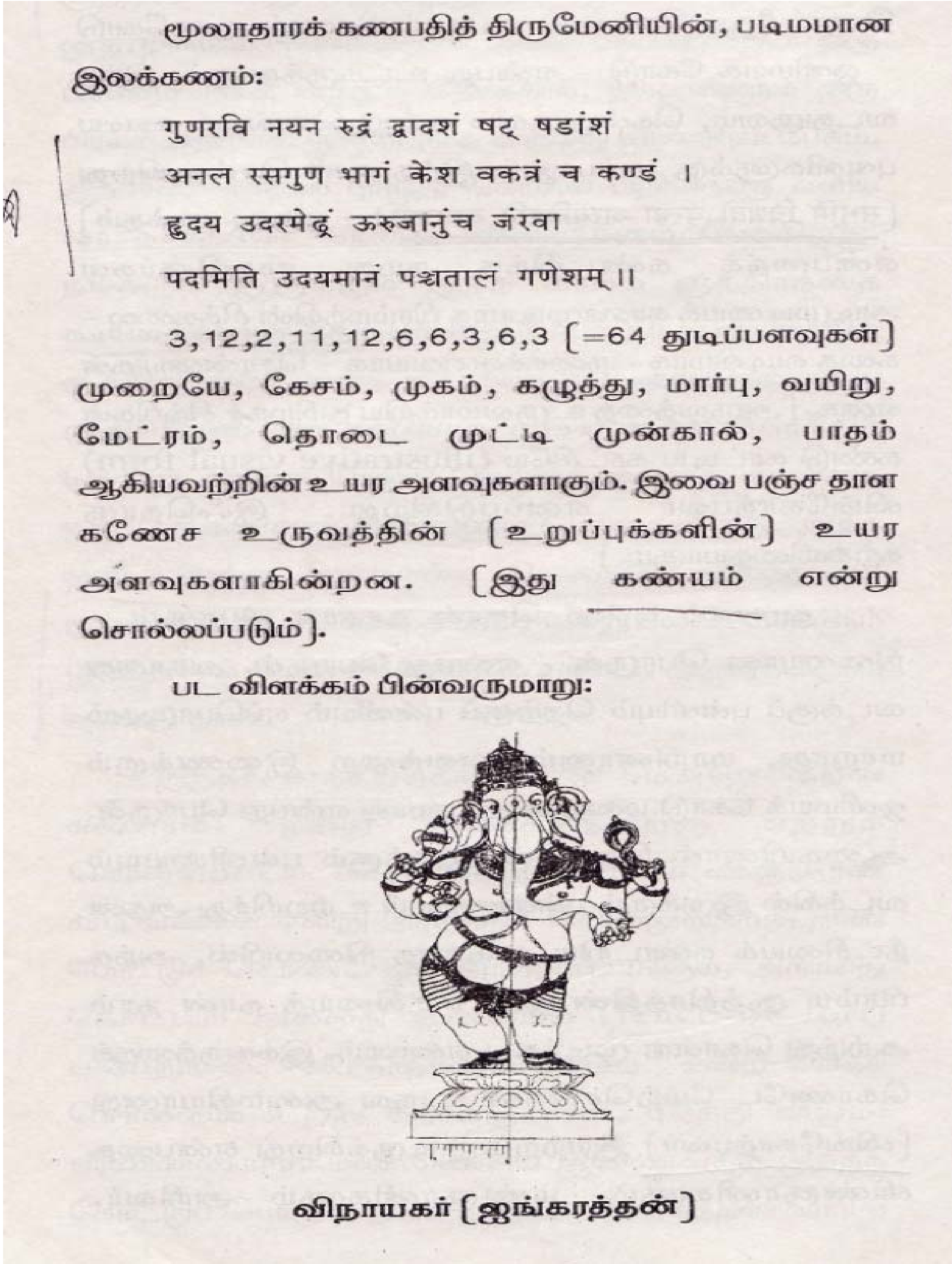

மூலாதாரக் கணபதித் திருமேனியின், படிமமான இலக்கணம்:

गुणरवि नयन रुद्रं द्वादशं षट् षडांशं
अनल रसगुण भागं केश वकत्रं च कण्डं ।
हृदय उदरमेढ्रं ऊरुजानुंच जंरवा
पदमिति उदयमानं पञ्चतालं गणेशम् ॥

3,12,2,11,12,6,6,3,6,3 [=64 துடிப்பளவுகள்] முறையே, கேசம், முகம், கழுத்து, மார்பு, வயிறு, மேட்ரம், தொடை முட்டி முன்கால், பாதம் ஆகியவற்றின் உயர அளவுகளாகும். இவை பஞ்ச தாள கணேச உருவத்தின் [உறுப்புக்களின்] உயர அளவுகளாகின்றன. [இது கண்யம் என்று சொல்லப்படும்].

பட விளக்கம் பின்வருமாறு:

விநாயகர் [ஐங்கரத்தன்]

Figure 46: Ganapathi Idol (Courtesy: Dr. Ganapathi Sthapati)

The sloka above in Sanskrit gives the measure of different parts of this Idol which would confirm to total 64 units (resonance of 8). Hair (3), Face(12), neck(2), Chest(11), Stomach(12), Belly &Pelvis (6), Thigh(6), Knee(3), Legs (6), Feet (3). Total 64 units. Just as much a Sloka with right metre and letters becomes a living organism, an idol with right proportions becomes a living organism.

- Divine Idol forms confirmed to a mathematical proportion that invoked subtle energies within and around us. This is where the external forms were used to create energies internally to a human. **This is the basis of idol worship. If it is scientific to create a form with divine energies based on mathematical proportion then idol worship is the supreme proof for that science.**

- **This supreme mathematical law is called as Dharma (nature's law) and the unfolding of that law is the Karmic theory of cause and effect / law of karma.**

- Poetry, classical music and classical dance are intimately linked to this Hindu temple culture. Adi Tala and octaves were used to create subtle energies in poetry using words, and the same tala maana is used in classical music with rhythm and raga, in classical dance with light and sound and in sculpture as a visual form.

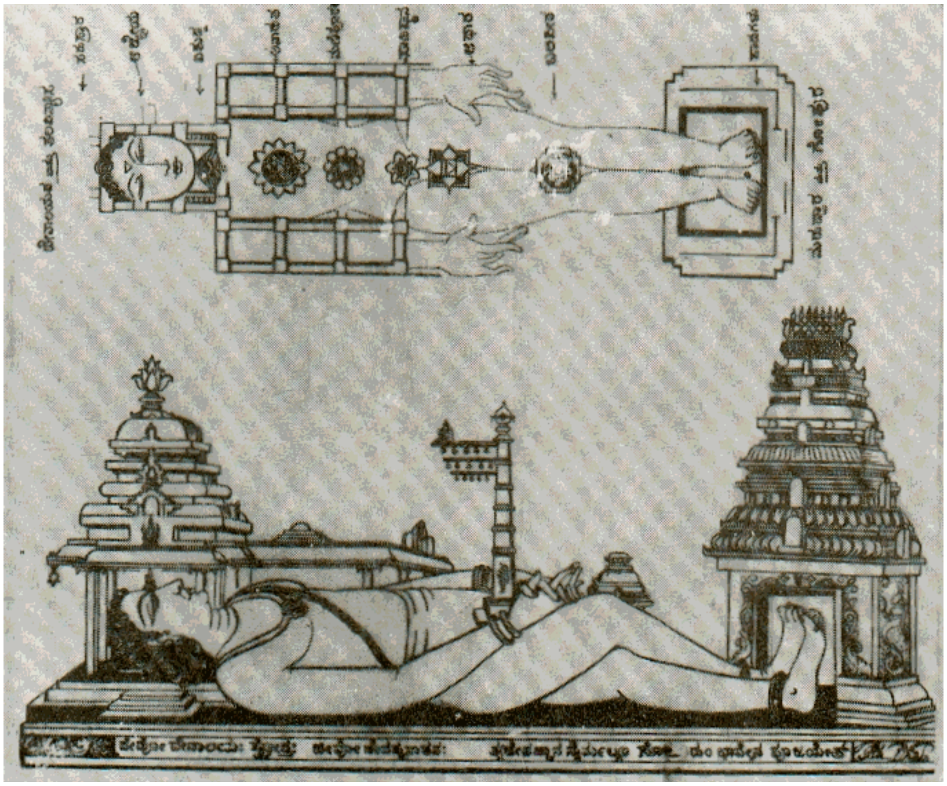

Figure 47: Human body as a representation of a temple
(Courtesy: http://www.salagram.net/sstp-mgpuja3.html)

A Hindu temple is a divine and yogic representation of a human being with the Deity in the temple representing the God as indweller in humans and all beings. In a temple the feet represents Rajagopura, the hands represent Praakaara, the abdomen represent Mandapa, the heart represents Antaraala and the crown of the head represents the sanctum sanctorum (garbha griha). The temple is used as a reminder that our inner spiritual journey is through internal yoga to realize the indweller God. This analogy is shown through the representation of various chakras namely Moolaadhara to Sahasraara in the body to various locations in the temple.

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- It may be of interest to note that the same harmonics of 8 are reflected in every other domain. For example, if you have been practicing Pranayama then your master would have asked you to practice breathing based on some counts. The most popular counts are 6(inhale), 3 (Exhale) or 7(inhale), 2 (Exhale). If you notice this count 9, this cleans up your gross body. Advanced Pranayam students may be asked to stick to 1 (Inhale), 4 (Retain), 2(Exhale), 2(Retain outside) or as a variation 1,4,2,1 or 1,3,2,2. The counts which add up to 8 clean the subtle body.

- Till few decades back the fundamental dimension for money in India was “**Ana”** called as **Eight Anas (எட்டணா)** and this was equivalent to Rs. 0.5 as the fundamental measure.

- Thus a **“Poetry is an idol in aural form and a building is a frozen music”**. A Poet by the way of his mental frequency has first become the poem itself and then the actual poem was created in its aural form and an artist by the same frequency has become the idol first and then he gave a shape to the idol externally through this hands. This is very beautifully given as ***“Raso vai saha, So Vai rasikaha”, which means he (god) is the enjoyer and he is the artist.***

- All of this reflects the supreme philosophy that **“Oneness in all and everything is just a manifestation of that one thing”**.

- Now in this light understand the meaning of this Upanishad prayer, *“Aum Poornamadah Poornamidam Poornaath Poornam Udachyathe, Poornasya Poornamaadaaya Poornameva Vasishyathe”. This means God is perfect (infinite). This Universe is also perfect (infinite). If perfection (infinity) is taken from anything perfect (infinite) what remains is still perfect (infinite).* Isn’t this is the actual reality today?

- Everything scientific is philosophically, mythological and ritually well interwoven that proves that Sanatana Dharma is the most ancient and supreme representation of science and nature’s secret in our possession. Our temple worship which integrates all this science, 5 sacred arts with language and Math is the standing example of our understanding of the nature of god.

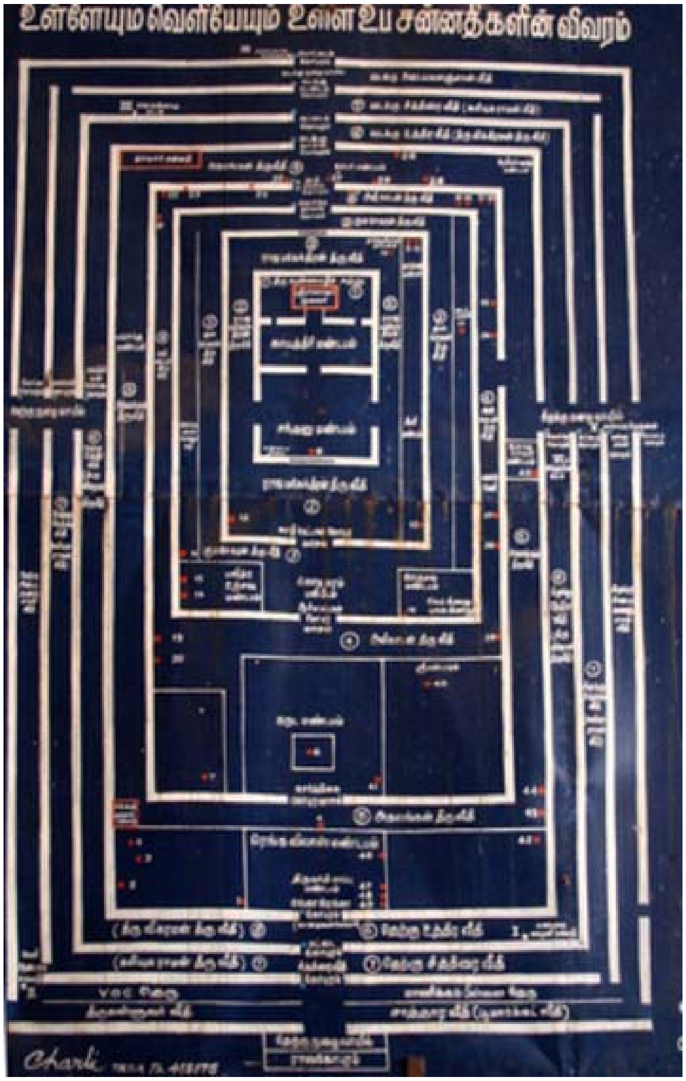

Figure 47: Layout of Sri Rangam temple with 7 Prakaras

It is the same Sugarcane but an elephant eats it from the field directly, a young adult peels the skin off and chews it, if a kid has to eat then someone has to peel the skin and cut it into pieces and an old man without teeth needs it to be made as sugarcane juice. Depending on one's ability to chew and digest the food has to be processed.

Same way depending on one's mental ability to grasp the supreme truth it has to be processed and presented. If someone is mentally well evolved then they can be fed with Upanishads and he can meditate on the formless Brahman. To a young adult Upanishads may not be palatable directly but they may have to start with Upavedas and Vedangas to mature to a higher level. For the less evolved kids, Itihasa and Purana like Ramayana and Mahabharata with stories may drive home the point and they can start with Shlokas and mantras. But for the least evolved it has to start with a personal deity with name and form, bhajans and songs to invoke the concept of Bhakthi.

In all the four cases temple culture forms the lowest common denominator. Even the most evolved relish the arts and architecture in the temples. We should be proud of our rich cultural and scientific heritage and be passionate about the science and philosophy and be rational about rituals and symbolisms.

Image / Idol worship is not deplorable or despicable. This is the highest scientific form of worship which enables us to see face to face the one which is beyond reach of sight and speech. This kindles devotion, community development and helps one to climb the steep walls of spirituality in the initial stages. Every religion in this world has some image or idol as symbolism to achieve this objective.

An idol is a god in form when made with the science of divine proportion and seasoned material is the highest product of our intelligence till today.

It should however be noted that this idol worship should not be lost in the din of rituals which does not reflect the very philosophy it had come to symbolize. So the advice I follow is *"Be passionate about our culture but be rational about the rituals.*"

The advancement of science can progress rapidly when the western scientists who are objective and empirical, partner with the pundits in India and learn the science of the subtle from our scriptures and temples. For this to happen we need to learn our own scriptures and past which is not possible without learning our mother tongue and Sanskrit. Else in the near future we may have to import knowledge of our culture and rich past from the western world.

As a wise man said, **"Indians are the most ignorant about their rich past and scientific traditions."**

Happy reading!

31. TIME = SPACE SERIES. PART 31 – MAYAN & HIS WORKS

Mahamuni Mayan was the father-in-law of Demon King Ravana and is referred in both Mahabharata and Ramayana. He is attributed with building the palace for Yudhishtar in Indraprasta and also the architect for Sri Lanka which Ravana ruled. His son Nalan helped Lord Rama build the Ramasethu – the bridge between India and Sri Lanka. He is believed to have lived in the **Ilamuridesam** popularly known as **Lemuria continent (Kumari Kandam**) which spanned 4500+ kms from Sri Lanka to Antartica connecting current Australia, Africa and Americas. Check out http://www.sacred-texts.com/atl/tll/index.htm

Understandably when this land mass was consumed by the sea their clan moved to different parts of the world including Guatemala, Egypt, and to current south Indian region. This explains as to how we find common science across India, South America and Egypt.

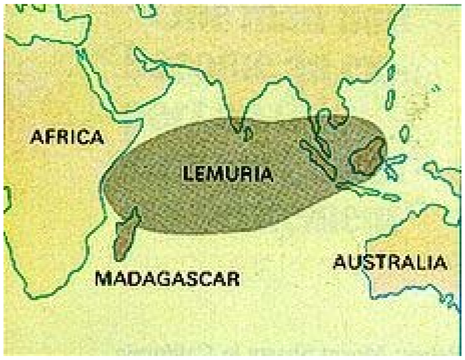

Figure 48: Kumari Kandam depiction

He has written books in both Sanskrit and Tamil and I am going to produce the list of technical works he has created and look at the contents of a specific book called Surya Siddhanta. Just the list of works and also the topics in Surya Siddhanta is amazing, highlighting the depth of science we had at that time. http://www.youtube.com/watch?v=PZKiCpFisoY

The Surya Siddhanta

The most ancient treatise on Astronomy is a treatise authored by Mayan. It is called *The Surya Siddhanta*. Included in this treatise are the following chapter topics following:

- The Motions of the Planets
- The Places of the Planets
- Direction, Place and Time
- The Moon and Eclipses
- The Sun and Eclipses
- The Projection of Eclipses
- Planetary Conjunctions
- Conjunction of the Stars
- Risings and Settings
- The Moon’s Risings and Settings
- Certain Malignant Aspects of the Sun and Moon
- Cosmogony, Geography, and Dimensions of the Creation
- The Gnomon
- The Movement of the Heavens and Human Activity

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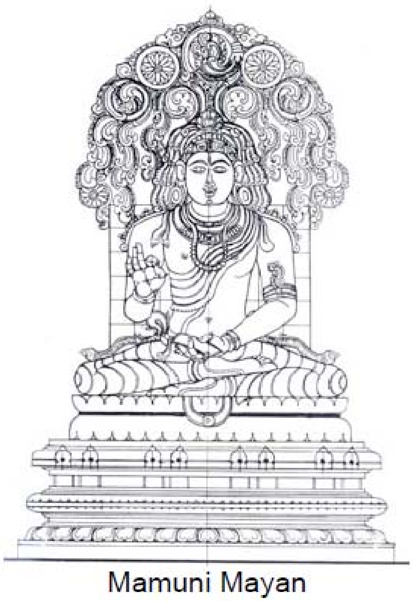

Figure 49: Mamumi Mayan

Mayan is also attributed with the start and spread of Temple culture in India. The song below in Tamil states that since Mayan sat under the Banyan tree and taught this science of universe and also of the sacred arts, so that every town was endowed with Temples for social betterment. Because he was from the southern region and also he sat under the Banyan tree, he is also equated with Lord Dakshinamoorthy.

ஆலமா மரத்தின் கீழே அருள் மயன் அமர்ந்ததாலே
ஆலமா மரத்தின் கீழே அருட் கலை வளர்ந்ததாலே
ஆலமா மரத்தின் கீழே அறிவர்கள் வளர்ந்ததாலே
ஆலயம் ஊரும்தோறும் அமைந்தன செழிக்கநன்றே!!

The Mayan says in his Pranava Veda verse one:
*"Om Light and Om Sound are the Primal Source of all manifest forms. Om Light is aroused by its own effort in a state of disorder and appears as a flame. The state of Om Light and Om Sound in Space is a magnificent luminous six – faced Light form that is called "**murukoli**". The transformation of Om Light and Om Sound through the five stages is concealed in the five fold knowledge, of which, this is the first. This process of transformation of disorderly Om Light and Om Sound into orderliness is found in all five fold material forms."*

Sage Veda Vyasa says in the Bhagavatam, *"eka eva pura vedo pranavha sarva vangmayha" (9th skandha, 14th chapter, sloka 48 of Bhagavatam).* This means that there was only one Veda called Pranava Veda. It is believed that Sage Vyasa created 4 vedas from this Veda since he believed that the oncoming generations would not have the mental strength to master everything.

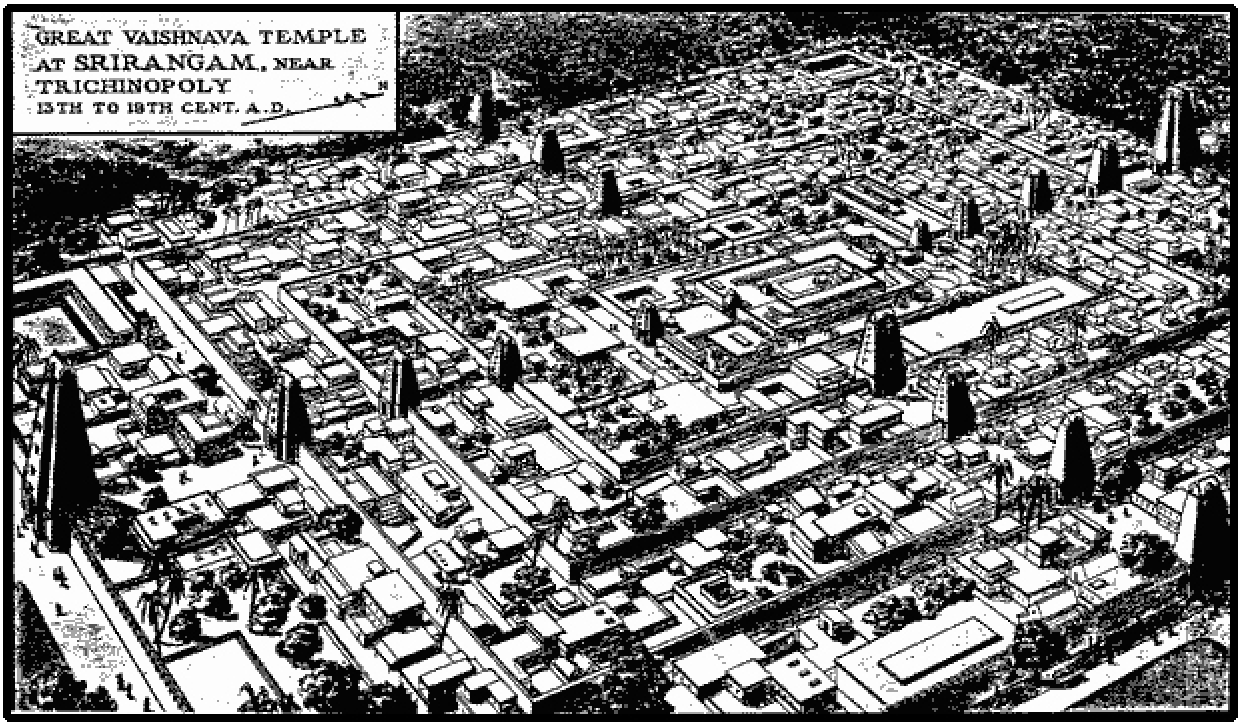

Figure 50: Aerial view of Sri Rangam temple with 7 Prakaras

Technical works

The following are technical works written by Mayan and represent the 12 vowels of the Tamil language:

- Ovia Chennool - Treatise on Drafting and Painting
- Sirpama Chenool - Treatise on Iconometry
- Kattida Chennool - Treatise on Architecture
- Nilamanai Chennool - Treatise on House Building based on quality of land
- Manainila Chennool - Treatise on Land based on the nature of house building
- Baniyal Chenool - Treatise on Astro Physics
- Perunata Chenool - Treatise on Divine dance
- Muligai Chenool - Treatise on Herbs
- Ganitama Chenool - Treatise on Mathematics
- Arakkala Chenool - Treatise on Ship Building
- Vinkala Chennool - Treatise on Space Ship
- Elisai Chennool - Treatise on Science of Music

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MAYAN, in Aintiram *states that:*
"There exists an order in the Universe - subtle universe, and material universe. This power is attributed to the consciousness of the cosmic space as well as of the inner space of the animate beings. This consciousness, by its personal effort to express its own inner feelings, causes a kind of vibration or pulsation in the inner space, resulting in energy-grids. The vibration or pulsation, being the causal element of all these events, is called KAALA. This is actually the force of energy aroused by the inner consciousness, causing waves and contributing to the growth of living forms. This KAALA resides in all living beings. So, space is the offshoot of the vibration of the primordial energy. This is how the space was born. All forms of nature are manifest forms of subtle energy. For all to get manifested, the force is KAALAM. This wave-form frequency realm is the creative element of the universe."

There is no other treatise that we have in our possession today which is dated 10000 BC that depicts the secret of nature so explicitly and gives the unmanifested interconnections and mathematical proportions between everything in the universe.

As Dr. Ganapathi Sthapati rues "Unfortunately most of the Tamil experts don't understand the science in these texts and hence these books are idling without anyone extracting the truths from it". In the next few generations when we are less equipped in our own mother tongue we may lose this treasure completely just like the many we have lost so far.

Hence the first step we need to ensure is even if you are not equipped well in your mother tongue please make sure that your kids can read and write it well. This becomes our most important duty. And I find it worrisome when someone is indifferent to the fact that they can understand their mother tongue but cannot read and write.

With some significant efforts we can and we should prove that this man who said, **"Indians are the most ignorant about their rich past and scientific traditions."** is not wise any more.

Happy reading!

32. TIME = SPACE SERIES. PART 32 – CONCLUSION

What I have understood in a nutshell is as follows:

- The inner being of both - the individual and the universe is luminescent consciousness which has the ability to become aware of it. This luminescent consciousness is called by various names but it is essentially the only existent Vastu in this world. This Vastu manifests itself as time, space and spatial forms.

- ***"Aanor aniyaan mahato Mahiyaan!"*** this means what is in the atom is the same makes up the universe. That which is present in the atom is the Space energy and the meaning of the word Akasa is stated as ***"Aa kashayati aakasa ha!,*** That which imparts light to others or make others shine is called Akasa". This means that Space Vastu is luminescent. I am stressing the aspect of luminescent again and again for you to start perceiving God as light.

- Pranava is the causal element which triggers this evolution process and this manifests as visual and aural forms. Pranava results in the primordial pulsation and this pulsation is triggered and sustained by a divine progression and proportion which is called **Absolute time**.

- Absolute time creates Absolute Space. These 4 things – Absolute time, absolute space, Aural Pranava and Visual Pranava combine together to form spatial forms and hence this universe.

- The Vastu as God's particle, its characteristics, the Pranava, the pulsation, the rhythm, the progression, its proportion and the resultant energy states – all the scientific facts, theories and processes are captured and codified as a Dharma which is called as Hinduism today. The science behind this subtle energy is reflected in various art forms that includes Poetry, Classical music, dance, Sculpture and building architecture.

- All these manifestations are harmonics of 5 and 8 differentiated by the Golden proportion / God's ratio to reflect the various states of consciousness. **This intrinsic order is called Dharma and the cyclic nature of this evolution is the Karmic code embedded in the universe**. **Nothing in this universe is superior to the Dharma and Karmic code.**

- The divinity manifests in us and the space within us is nothing different from the macrocosm. Consciousness which exhibits itself as a state of being because of our mental vibration can evolve to a higher plane to devolve back into the luminescent core.

- Sanatana Dharma popularly today known as Hinduism is the repository of this supreme secret not just as a philosophy but integrated with every stage of our life. This can be understood better only if we can give due respect and attention to the language and scriptures, our spiritual tradition interwoven with arts and architecture that contains these treasures.

- The temple culture & Idol worship that we have symbolizes the best of science known to human beings and we need to understand this and preserve this in the best possible manner.

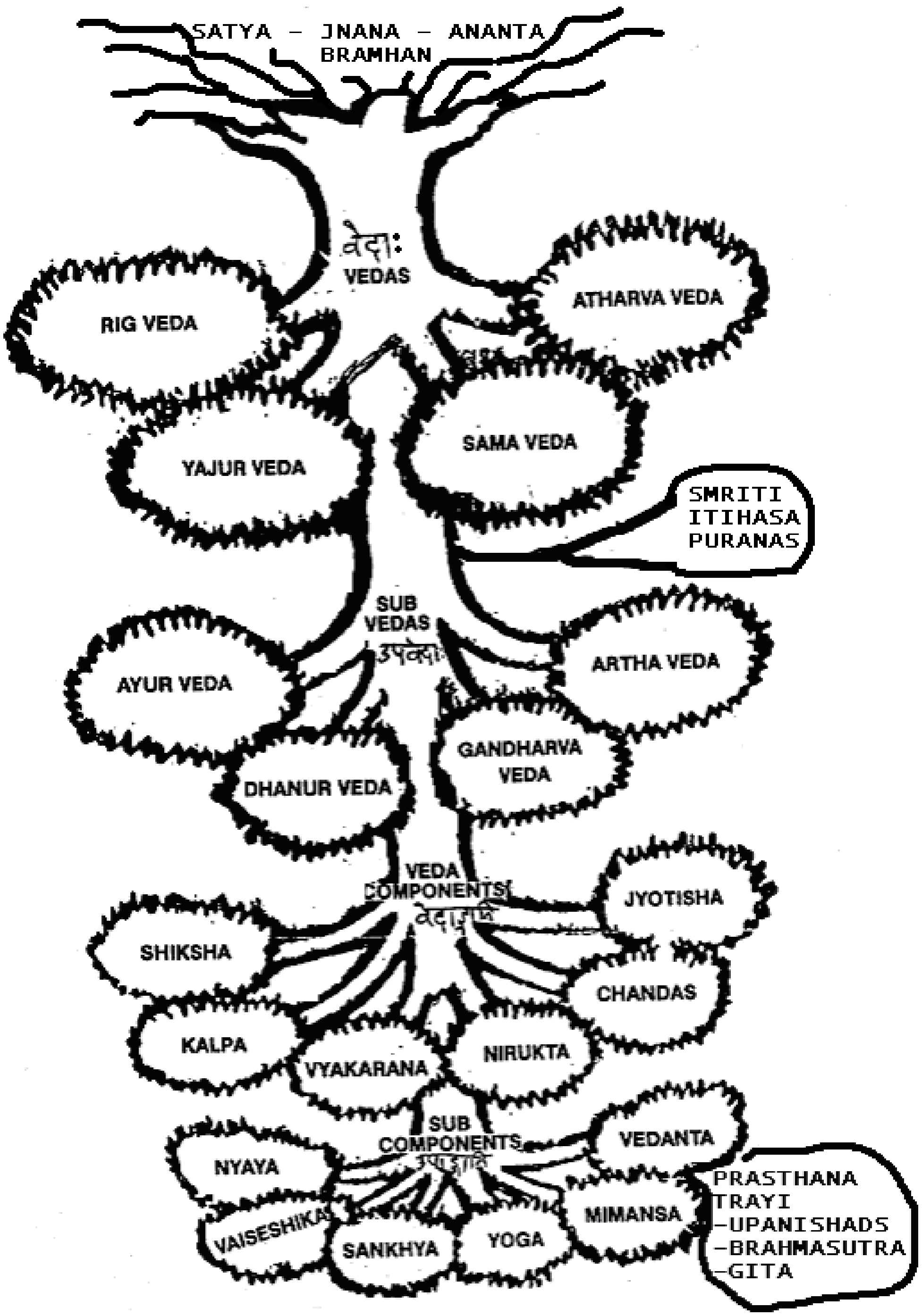
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-UPANISHADS
-BRAHMASUTRA
-GITA
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YOGA
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Figure 51: Vedic Knowledge as an inverted tree with Brahman as the roots signifying that everything has a common root. (Courtesy: Internet)

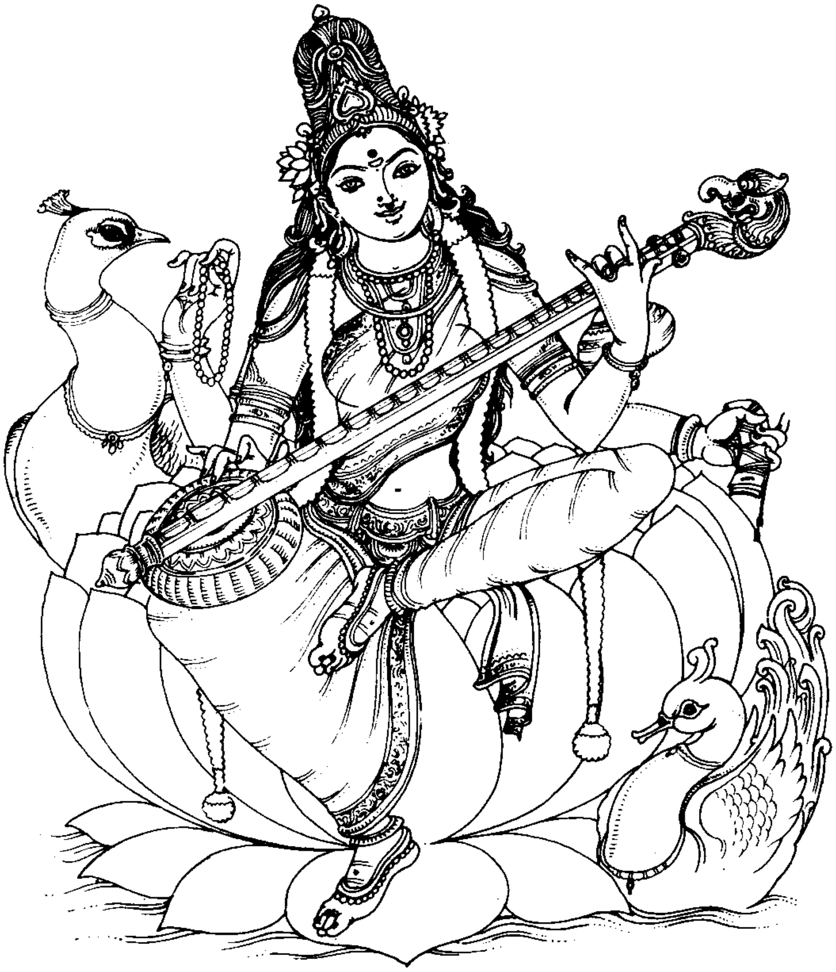

(Figure 52: Goddess Sarasvati. Courtesy: Internet)

She is the Goddess of speech, music and knowledge. She carries the rosary beads (akshamala) represents the alphabets of a language (Sanskrit), the musical instrument (Veena) and Vedas as palm leaf manuscript in her hands that denotes the knowledge. Thus we can see that idol worship signifies deeper scientific aspects of a common root between Language, Music, knowledge and arts.

Figure 52: Musical instrument Veena as a representation of Human Body (Sarira veena) (Courtesy: Internet)

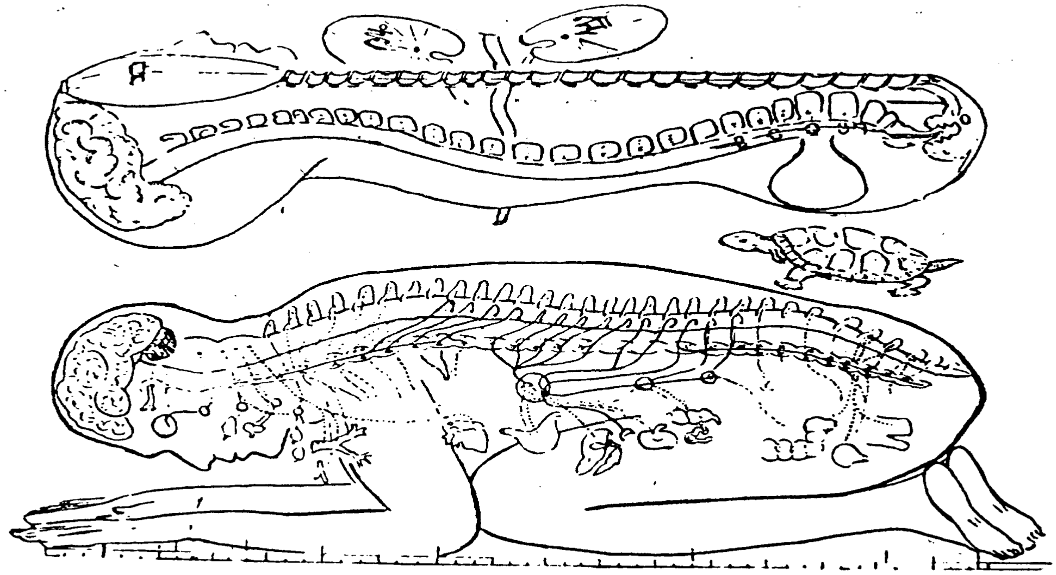

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I am happy to note the coincidence that this book has 32 chapters with 108 pages – both being key universal numerals. Chapter 19 (the golden mean of this book) deals with the Golden mean or God’s ratio of nature is again coincidental.

I would like to thank you for reading this book. I would like to state that I am neither adept in any of the topics discussed in this book nor an expert in any of the arts including the languages Tamil or Sanskrit language.

A curious mind driven by my passion to understand the underlying aspect in all things and my liking to reading has helped me to compile this book. My exposure as a student to Chinese martial arts, Indian yogic studies, Pranic healing and Siddha philosophy helped me to connect of the points I had articulated. Any authoritative statements in these books reflect my belief in the topic or from the author / teacher from whom I subscribed it and it is certainly not reflective of my abilities.

I am open to constructive criticisms on any of the topics and I can be reached at the mail ID shared in the first page of this book. My only request to you is *“Please share this book or parts of this book without any hesitation to your friends and family and help us dispel the ignorance about rich ancient Indian culture”*.

I shall end this book with some of my favorite quotes of Dr. Einstein.

“My religion consists of a humble admiration of the illimitable superior spirit who reveals himself in the slight details we are able to perceive with our frail and feeble mind. That deep emotional conviction of the presence of a superior reasoning power, which is revealed in the incomprehensible universe, forms my idea of God. We still do not know one thousandth of one percent of what nature has revealed to us.”

Satyam Param Deemahi!
May we meditate on the supreme truth!

TIME & THE TECHNOSPHERE

The Law of Time in Human Affairs

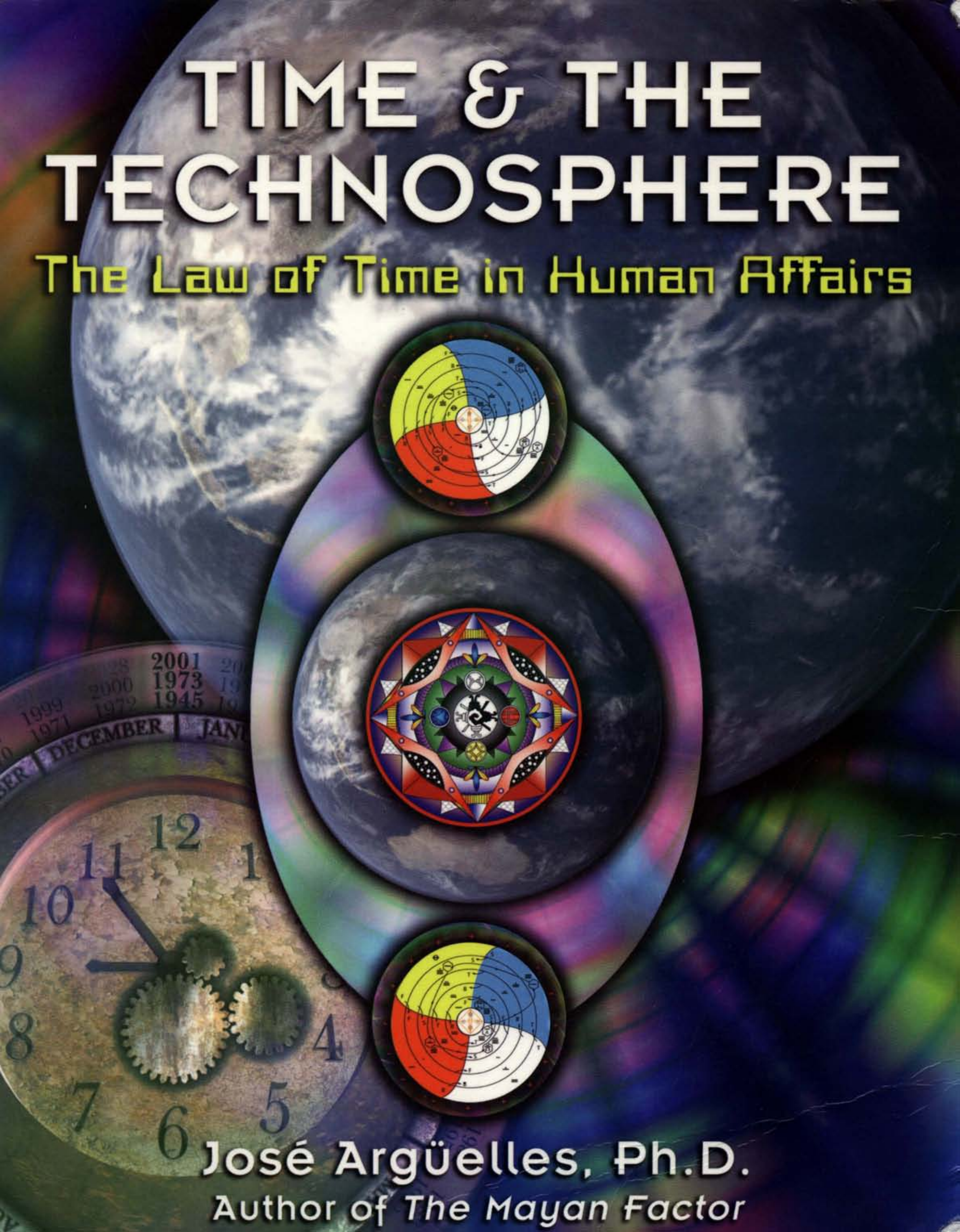
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José Argüelles, Ph.D.

Author of *The Mayan Factor*

MAYAN STUDIES/NEW CONSCIOUSNESS $20.00

"Time and the Technosphere *makes a vital contribution to the great paradigm shift in human cultures that is now accelerating. There is a higher dimension of natural time inscribed in the cosmos and a natural calendar that would help humanity mature into the awakening global consciousness that is now essential for future sustainability and well-being. This book is an important contribution to the awakening event that is now emerging on a planetary scale.*"

ASHOK GANGADEAN, PH.D., Professor of Philosophy, Haverford College

In *Time and the Technosphere,* José Argüelles presents a groundbreaking study that distinguishes the natural time of the cosmos from the artificial mechanistic time under which we currently live. Argüelles defines the actual nature of time as the frequency of sychronization. Applying this Law of Time to an understanding of the entire system of life on Earth, he shows that in order to not destroy Earth's ability to sustain life, we must change our definition of time and adopt a natural harmonic calendar based on the 13-moon 28-day cycle. Until the creation of the Gregorian calendar and the 60-minute hour, most of humanity lived by the 28-day cycle of natural time. The adoption of artificial time has subjected us to a 12:60 time frequency that governs the entire global industrialized civilization—the technosphere. With the collapse of the Twin Towers on September 11, a fissure was created in this artificial technosphere, opening up the noosphere (Earth's mental envelope).

Humanity has a golden opportunity to leave the strife of the past and enter a time of peace by adopting a harmonious natural calendar that will repair the damages caused by the irregular tempo of technospheric time. Our last best chance to adopt this natural time and step into the bright new future promised by the galactic shift of 2012 is the Great Calendar Change of 2004, a new discovery based on the author's mathematical research into the Mayan calendar first begun in his landmark work *The Mayan Factor.* In *Time and the Technosphere,* Argüelles reveals the clear distinction between third-dimensional astronomical time and the fourth-dimensional synchronic order of the Law of Time, which holds enormous potential for the future of humanity.

PHOTO BY BORIS VLADIMIROVICH

JOSÉ ARGÜELLES, PH.D., works full time on behalf of the World Thirteen Moon Calendar Change Peace Movement and is president of the Foundation for the Law of Time. He is the author of numerous works, including *The Mayan Factor, Earth Ascending,* and *Surfers of the Zuvuya.* He lives in Oregon.

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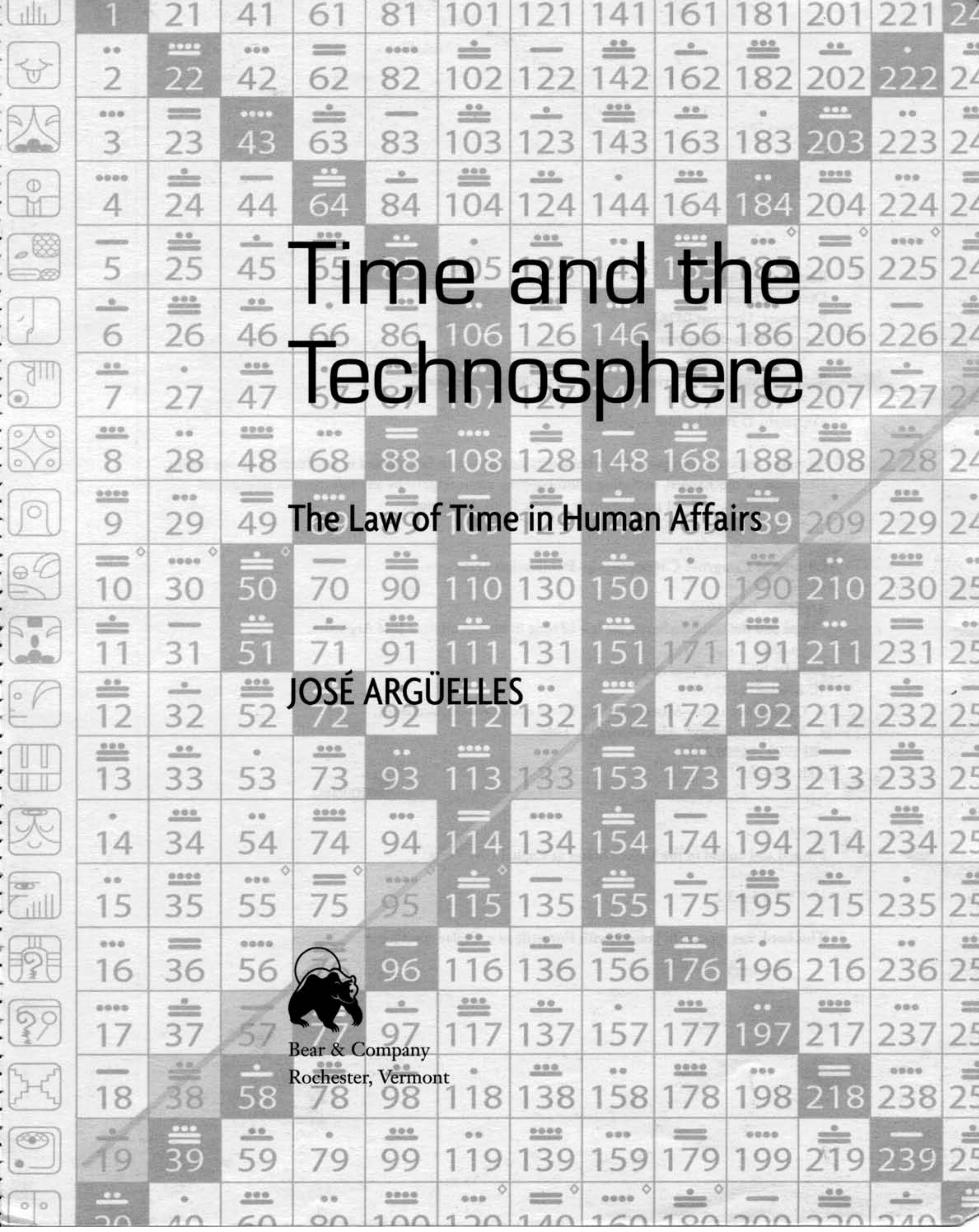

Time and the Technosphere

The Law of Time in Human Affairs

JOSÉ ARGÜELLES

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I

Time and the Technosphere

This book requires some attention from You. It is a complete, coherent, story for Humanity, on Earth, in the Universe. It is a radically different story than what is commonly disseminated by and through our global, dominating, culture. There is no need for You to *believe* this story, or any other. Trust yourself. trust your Self To say you must go into this with an open Mind, is a grand understatement. Start with trust. Simply allow the thoughts and concepts you read to "stew" for awhile. Make some headspace for them and have patience for what may grow there. It is a beautiful life...

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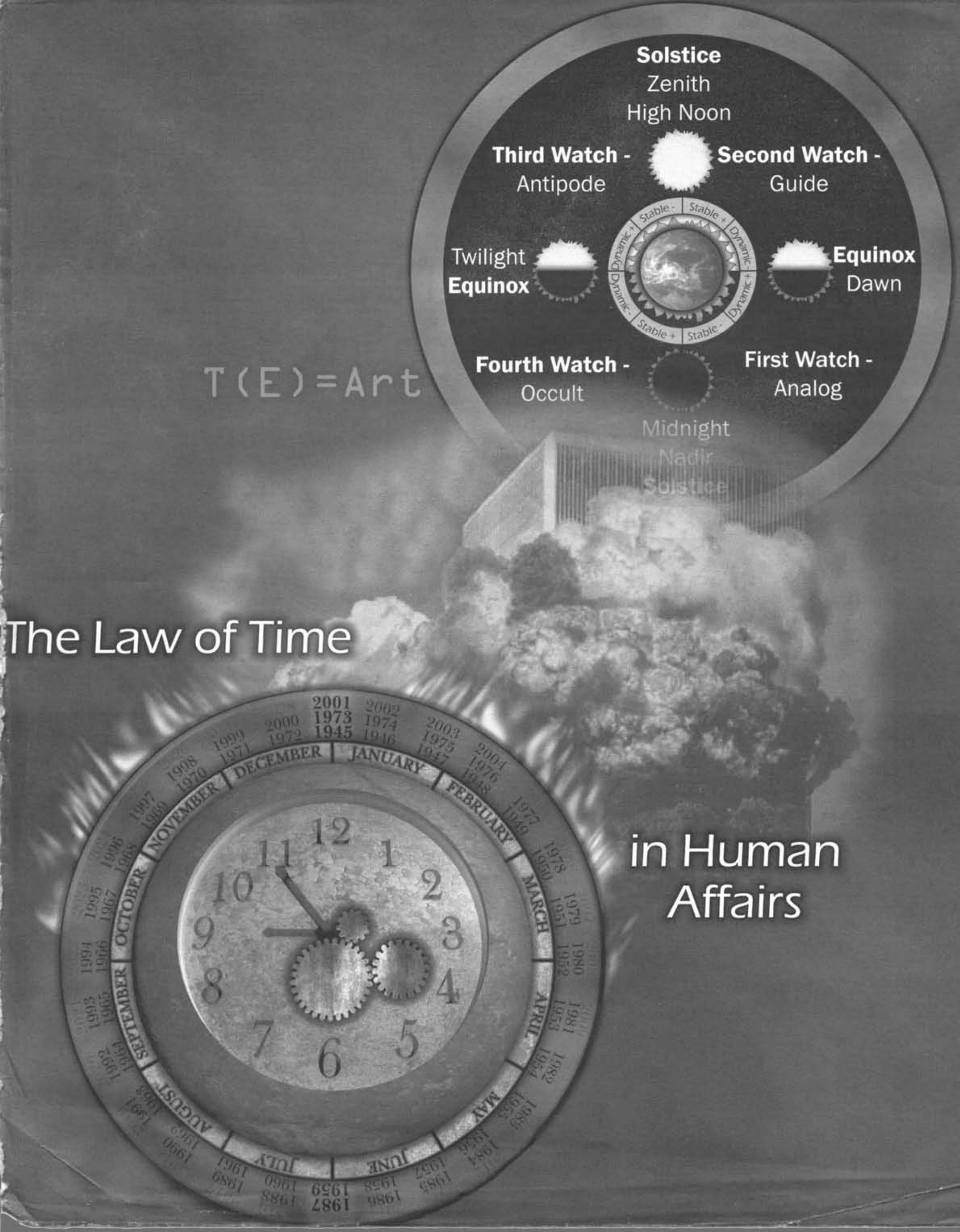
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This book is dedicated to Adam J. Lewis—at work on the eighty-eighth floor of the South Tower when his mother called him from Spain as she watched television reports of the first hit on the North Tower—and to all the others who were sacrificed on that day. May the truth prevail, that the greater mystery might be made known—forever.

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Acknowledgments

AS ANY AUTHOR knows, to write a book and see it through to completion, from initial inspiration to final conclusion, is never an easy task. Though we are all guided, if we so choose, by the Supreme Creator, still it is one's Earthly helpers that must be counted first, even before oneself-for without their aid, where would one be?

First and foremost of my Earthly helpers whom I wish to acknowledge is my wife and faithful companion of twenty-one years, Lloydine Bolon Ik, my constant helper and chief inspiration of all I do. The faith and trust she put in me at times when all we had was blind faith are a touching memorial to a soul who has always believed that love is the greatest truth.

Assisting us greatly during the time since we arrived in Oregon and have continued to dedicate our lives to the fulfillment of the prophecy of Pacal Votan and the Great Calendar Change is our devoted helper and assistant Stephanie South, the Red Queen, Red Electric Serpent, who conscientiously read and edited this text in its final form, helped in numerous details, and so kept me from ever bogging down.

Of equal trust and value is that one from the immemorial rainbow to whom I owe so much, Kin 19, David Rinck, "the stalwart," whose enhancements of my artwork are ingenious and awesome. All three of these people share one thing in common: absolute belief in and dedication to the Law of Time as a living reality that gives breath to all we do.

I must also thank the incomparable Spectral Skywalker, Mark Comings, whose mind has been of inestimable value to me through our many memorable background discussions on time in modern physics in relation to the Law of Time. In this regard, I would also like to mention Irina Eganova of the Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences, Novosibirsk, for her rigorous approach to N. A. Kozyrev-may she smile well when she reads this book.

For their unconditional support I would also like to honor and thank Brian and Deborah Haight of the Foundation for the Law of Time, and all the many friends and beloved kin of the Planet Art Network everywhere, but especially to the Russian kin who so ably understood the Law of Time and opened up gold mines of knowledge and friendship in the Russian Academy of Sciences in Novosibirsk, as well as the great pristine valleys of Altai, where the shamans await the next installment of *The Mayan Factor.*

Spirituality is at the core of the biosphere-noosphere transition, and in this regard the beings I have to thank are without number, yet some especially stand out and deserve mention: my Tibetan teacher, the Sakyong Dorje Dradul Chogyam Trungpa Rinpoche, through whose cremation he entrusted me with all; my son, Josh, who opened the doors of the fourth dimension for me so that I would never be satisfied with less; and Mother Tynetta Muhammad, who showed me the way of the Holy Quran with the guidance of the mystic master FM, and who introduced me to the great work of Dr. Rashad Khalifa, whose breaking of the Quranic nineteen code led to his martyrdom, leaving me to fulfill what he revealed.

The creation of a book, the coming into manifestation of an artistic conception, is a complex process involving numerous other eyes and minds in order to bring the effort into its final published form. In this process two people have stood out deserving of mention. First of all, there is Michael Moynihan, White Galactic WIzard, who very patiently and carefully copyedited the book-always with an eye on maintaining and enhancing the original artistic vision-and who stood by the integrity of its vision through the entire editorial process. His work was complemented by the efforts of project editor Lee Awbrey, Blue Lunar Eagle, who took on an increasingly engaging role and personality as we brought this book to its final stages. I am especially appreciative for her inspiration to rework the Preface and Chapter One, which I gladly did, and which I feel speak more immediately to the reader of this book. Thank you both, and may the success of this book redound to your consummate care for the truth.

Finally I would like to honor and thank my children: Tara, the golden one, my grandson, Samuel Joshua Sheps, and Jeff of Engine Company Number Nine in Phoenix; also Paul Mecklenburg, who has always held the faith in our work, and Heidi Mecklenburg, that her dream of the Unicorn Princess may become true once again.

▼

Preface

A Brief Literary Autobiography

Time and the Technosphere: The Law of Time in Human Affairs is essentially a prolonged set of meditations occasioned by the one most powerful and overwhelming event of our time, the 9-11, the Inevitable Event of September 11,2001. Subsequent events may overshadow this one in horror and magnitude, but it was this event in particular, the destruction of the World Trade Center towers, that sent a signal that something very profound had occurred to change the way we think of ourselves and our future.

In presenting these meditations and reflections in the form of a book, I am painfully aware of the limitations of this medium in the information age. Keeping in mind that the volume of information has increased five times in the past century-with much of that increase occurring only in the past decade-I am very reluctant to put anything down to be published in the form of a book. I was raised well on the writings of Marshall McLuhan and his definitions of media and how they affect our senses. It is altogether obvious that a book in your hand is not the same as reading a text on a computer screen. A book is actually something made to last. Of course, the computer has made it possible and easy for virtually anybody and everybody to write a book, and so we encounter one of the great hazards of the information age: the decline in discrimination and the criteria of excellence. Who can now tell what is worth reading or not? These reflections, too, are very much to the point of the grand theme of this text. If a book is meant to last, how long will this book last? It should last until the New Time has established a new order of reality on this now anguished Earth. Whether or not destruction and the total collapse of civilization will occur first, we do not really know. That is a matter left to the Divine Mind of God alone.

Nonetheless, it is with faith that we continue on this Earth at this time. A pressing voice told me to go ahead and to write this book, regardless-but then, this is how I have always done it. Those who are at all familiar with any of my earlier books, will find that *Time and the Technosphere* is but a continuation of themes that have provoked me since I first considered literature as a medium of communication. It is important to know where the author is coming from, and how he got to this particular point of reflection. In this regard, *Time and the Technosphere* is the organic result of a lifelong pursuit of a study of the nature of art, time, and history. This study has been woven together by a dialectical process that defines the evolving nature of consciousness. So, for those who are interested, herewith follows a brief literary autobiography, the better to understand my point of view.

My earliest book, *Charles Henry and the Formation of a PsychophysicalAesthetic (1972),* states the grand theme of a holistic science that unifies body and mind, sense and nature, the harmonic pursuit of which has been at the root of all my endeavors. This pursuit was amply demonstrated in my second book, *Mandala* (1972), which, as a root text of the counterculture, was an artistic, philosophical, and cosmic plea for a harmonic resolution to the process of history. It is a sign of the times that *Mandala* is no longer in print, but instead a book bearing the same title, but which does not even include the original Mandala in its bibliography, is in print with the same publisher. Amnesia is one of the side-effects resulting from information overflow with no discrimination. Unfortunately, cultural amnesia is always accompanied by an increase in trivialization, and thus we arrive at the mediocrity and sensationalism of the present moment.

My next book, *The Transformative Vision: Reflections on the Nature and History of Human Expression* (1975, 1991), took the aesthetic and unitive themes of the first two books to the next stage of my visionary analytical process, elaborating on the meaning of time, history, and cosmos. In rereading the later chapters of *The Transformative Vision,* I am struck by their prophetic accuracy, as well as their sense of impending tragedy. It is hard to believe that only 26 years have gone by since that book was first published and now we are plunged into the maelstrom of what was then thought to be the worst scenario possible. *The Transformative Vision* also defined human consciousness as the cerebral-neurological dialectic of psyche (aboriginal, primal intuitive art) and techne (civilizational, rational science), emphasizing that only in their absolute synthesis would there be a harmonic resolution to the problem of history. Seen in this light, the technosphere represents the extreme, one-sided triumph of techne, while terrorism is the expression of the absolute repression of psyche. The crucial question then arises: how will we ever attain a balance or harmony?

Investigation of the ongoing dialectic of consciousness was continued in my next effort, the philosophically synthesizing work entitled *The Feminine, Spacious as the*

Sky (1977), which was written and artistically produced with my previous partner and wife, Miriam Tarcov, who also co-authored *Mandala* with me. The feminine aspect represents a deepening reflection of the psychic, intuitive side of human nature. Expressed through a whole range of images, symbols, and philosophies that describe both the aboriginal root and the final flowering of human consciousness, it is this feminine aspect that has been smothered by the historical process, resulting in the technosphere. Why and how did this occur? These questions drove me to the next stages of my visionary investigations.

From the beginning of my pursuits I have been moved by my intuitive awareness of our intrinsic wholeness as humans, and the knowledge that this wholeness is a reflection of the wholeness of Earth, the solar system, and the cosmos itself. Although this perception of reality is nowhere within the domain of the shibboleths of Western scientific thought as it has developed since Descartes, I have also come to understand that Western scientific thought is highly provincial, racially biased, and-because it is not informed by a perception of wholeness-incapable of solving the actual problems of life. In fact, Western scientific thought has been one of the key factors leading the human race onward to its great act of self-destruction-a self-destruction employed through the instrument of technology.

In my next book *Earth Ascending: An Illustrated Treatise on the Law Governing Whole Systems* (1984, 1988, 1996), I was able to make a profoundly radical break with the restraints of the Western scientific and academic modes of thought. Combining the artistic and aesthetic qualities of *Mandala* and *The Feminine, Spacious as the Sky* with the philosophical and scientific concerns of *The Psychophysical Aesthetic* and *The Transformative Vision,* I define and describe the human situation as a function of the geology, or biogeology, of Earth understood as a whole system. Without knowing it, I had defined the human presence in Earth's geology in a way very similar to that of the Russian biospheric scientist V. I. Vernadsky in his analysis of the biosphere. Culture, civilization, and even technology are seen as features and functions of the larger evolving biogeological process of the whole system Earth, while time and consciousness are defined as functions of a larger planetary regulating system called the psi bank. In the analysis of *Earth Ascending,* the feminine psychic side of consciousness is referred to as the AC, Aboriginal Continuity, while the male, rational techne side is defined as the CA, Civilizational Advance. The historical process represents the increasing dominance of the CA to the final exclusion of the AC-the triumph of industrial man over the indigenous peoples.

The most critical moment in history was the atomic destruction of Hiroshima, August 6, 1945, when through its technology the impact of human thought permanently affected the geological makeup of the Earth. The events before Hiroshima are chronologically defined as P.A., pre-atomic, and those after as A.H., After Hiroshima. But more than defining the process of history within the context of Earth's cosmogeology, *Earth Ascending* also describes the post-historic future as a condition of harmonic synaesthesia-harmony of the senses-defined by a new scientific system called radiosonics. The key to this new system of scientific endeavor is synchronicity or synchronization of our mind and senses in time. The problem left open by *Earth Ascending* was the precise nature of time and the timing of the radical break in the historic continuum, now known as the Inevitable Event-the culmination and dramatic conclusion of a process begun at Hiroshima. After the Inevitable Event we are liberated into post-history and the possibility of the radiosonic science of the future.

In *The Mayan Factor: Path Beyond Technology* (1987), I was able to supply the basic ingredients for an understanding of time and the timing of the radiosonic future. Going beyond the parochial limitations of Western science and the self-inflated progressivist thinking of the Western mind in general (that states "anything that advances technology is an absolute advance over anything that was thought of or occurred in the past") I was able to finally bring to light the synthesis of many years of study of the time science of the ancient Maya. Here, in the mathematical calculations of the Maya with their unique vigesimal mathematics-counting by twenty and not by decimal ten-lay the basis of a vast and grand science of time. So grand is this science that its conceptions of time dwarf anything the Western imagination could conceive.

While the Western concept of time is linear and predicates an unceasing ascent into a progressively technological and mechanistic future, Mayan time science is predicated on the knowledge of time as the universal factor of synchronization. The Western conception of time is not in accord with the actual cyclical and synchronistic nature of time, and so the whole apparatus of Western civilization is doomed to reach its own breaking point: the Inevitable Event. Mayan time science posits a precise measure of the historical cycle, the most recent and climactic stage of Earth's evolution, as a time fractal of thirteen baktun cycles, each 144,000 days in length, spanning the JulianiGregorian years 3113 B.C.-A.D. 2012. According to Mayan time science, the efforts based on an erroneous time conceptualization are bound to fail prior to the cyclic end-point of 2012. Thus, the Inevitable Event is also a consequence of the failure to understand or to even acknowledge the actual nature of time due to a totally false and mechanistic timing sensibility. In this lies the cause of the apocalypse of Western thought and theology.

The problem left unresolved by *The Mayan Factor* was the precise methodology for changing tracks, for switching Western dominated global civilization away from the track of an erroneous, mechanistic time-based technology and toward the natural order of time-the path beyond technology. Here my efforts took me to a point beyond reason. Why or how? Let me explain. As an exposition of Mayan time science, in preparation for the 2012 ending of the thirteen baktun cycle of history, *The Mayan Factor* is predicated on the occurrence of a real time event, the Harmonic Convergence "global peace meditation" of August 16-17, 1987. The timing of the Harmonic Convergence was prophetic. It augured the fulfillment of the prophecy of Quetzalcoatl (947-999) known as the Thirteen Heavens and Nine Hells. The Harmonic Convergence completed the ninth and last Hell cycle, and ushered in the final twenty-five years of the thirteen baktun cycle. The Harmonic Convergence was a Mayan wake-up call answered by millions of earthlings.

Exactly forty-two years and ten days after Hiroshima, and fourteen years and twenty-six days before the Inevitable Event, the Harmonic Convergence was located by time to occur precisely when it did. Prophecy transcends reason because it is totally of time, which is of the fourth dimension; prophecy nevertheless affirms with unerring logic that which has been, and that which will be brought about, as being of the same karmic cause and effect stream.

It was this matter of prophecy in the aftermath of *The Mayan Factor* that brought my literary efforts and my own life journey to another stage of development. Prophecy comes with a mantle-if not, then you are classified as a madman. The prophecy of the Harmonic Convergence, as well as of the entire text of *The Mayan Factor,* bore the mantle of the prophetic stream of the Chilam Balam, the jaguar priests, the wizard knowers of the "night script." By correctly fulfilling the prophecy of the Thirteen Heaven and Nine Hell cycles, 843-1987, and by writing and putting together the mathematical codes of *The Mayan Factor,* and before it, of *Earth Ascending,* **I,** Jose Argiielles, had assumed the mantle of the prophetic tradition of the Chilam Balam. Mind you, this was nothing overt nor the least bit conscious, for little did I then know that my next life task was to decode the essence of the Chilam Balam prophecies and to define the time science of which these prophecies are a manifestation.!

The Harmonic Convergence affirmed the karmic repercussions of Hiroshima by bringing forward the ancient Mayan prophetic tradition of the Chilam Balam. By precisely locating this prophetic tradition in a contemporary moment -a media event, no less-the unlocking of its final prophecies was triggered for the purpose of completing the cycle of history: 2012 and beyond.

Like any major media event, the Harmonic Convergence was an enactment within the noospheric unconscious of humanity-the telepathic whole that resides in Earth's mental envelope. So it was that on June 23, 1987, the *Wall Street Journal* ran the front page story on the Harmonic Convergence. Yet due to the mental obscuration accompanying the final stage of global industrialization, the Harmonic Convergence was an event that the *WillI Street Journal* and the rest of American media conveniently forgot when it came to their review of the century in the year 2000. Today, just weeks after the Inevitable Event, the collapse of the World Trade Center towers, the words of that article are most prophetic: "Mr. Argiielles says the choice between a 'new age' and all-out destruction is ours, and we had better decide."2 Though the prophecy was discounted, true to form, the words of the messenger remain to haunt those who spurned the message.

The prophets and sages of the Maya, and of the New World in general, are a complement to those of the Old World, a further manifestation of the planetary dialectic of poles and hemispheres. If the judgment day apocalypse is the focus of the Old World prophecies, especially those ofIslam and Christianity, those of the New World similarly pinpoint an end time whose denouement is chronicled as the date 2012. It was the prophecies of the sage and culture hero, Quetzalcoatl (947-999), that brought about the Harmonic Convergence, while it was the wisdom of Pacal Votan (603-683) that informed the actual text and scientific time mappings of *The Mayan Factor*, and the image of his tomb adorns the cover of the original book. In a similar manner, it was the tradition of the Chilam Balam that created the prophetic vision of the synchronic order to be realized as the Law of Time.

I was hardly aware of the personally transformative factors at work within me after the Harmonic Convergence media swell began to subside, when two events occurred that augured a major change in my perceptions, activities, and literary output: the Wall Street stock market crash of October 19, 1987, and the death of my eighteen-year-old son,]osh, ten days later, on October 29,1987. In analyzing why the 1987 stockmarket crash happened, the lead story in *USA Today* about this event concluded by posing the question: Was it the Harmonic Convergence that somehow caused the stock market to crash? As I pondered why the answer to this question must be in the affirmative, as well as the implications of this analysis-remembering full well that the breaking story on the Harmonic Convergence first appeared in the *TVtlllStreet Journal-news* came of my son's sudden death in an automobile accident.

Synchronically, the stock market crash and my son's death were part of one event continuum. As tragic as the circumstances of his death were, my son had liberated me from any further compunction to lead a normal life, and to pursue, instead, this matter of Mayan time science and its calendars of harmony. In homage to my son, I completed what I first thought would be a popularization of *The Mayan Factor*, a book entitled *Suifers of the Zuvuya* (1988). Instead of being a popularization or even a sequel to *The Mayan Factor*, Surfers turned out to be a series of autobiographical tales of interdimensional travel-zuvuya surfing in the fourth dimension. This "flight of fantasy," was my literary farewell to the limitations of reason and a life of comfort. Inner destiny pushed me to the next stage in my pursuit of the unitive science-the discovery of the Law of Time.

This journey of discovery, the findings of which are the underpinnings of the present work *Time and the Technosphere,* took me and my wife and partner, Lloydine, to physical and mental places that were far from anything we had once deemed conventional. Because of this, I had ample opportunity to write and to create, and I did so, freely and without any restraints. I no longer sought any conventional means to communicate. I was now operating prophetically, on behalf of the noosphere-Earth's mental envelope.

There is a consistency to the stream of prophetic revelation, summarized as the codes of the Law of Time. This revelatory stream begins with *Earth Ascending* and *The Mayan Factor,* comes to flower with *The Dreamspell: Journey of Times hip Earth 2013* (with Lloydine Arguelles, 1991), and is completed by all aspects of the Telektonon Prophecy, including the Thirteen Moon/28-Day calendar (1993-2000). This prophetic stream is emphatically a galactic revelation of the same base of know 1-edge that produced the Mayan civilization of ancient Mesoamerica. The new revelatory stream is known as the Wizard's Count, or "reformulated Chilam Balam." It was this prophetic stream and its year-bearer count that established the validity of a fifty-two year cycle correlated to the Gregorian July 26.

The purpose of the Chilam Balam year-bearer count was to establish a basis for understanding that there exists a synchronic order of time, completely apart from what is usually referred to as the Long Count, the linear count of days of the thirteen baktuns of the cycle of history, 3113 B.C.-A.D. 2012. After a long break in the tradition of the Chilam Balam, the year-bearer count was prophetically reformulated to prepare for the Harmonic Convergence and the subsequent revelation of the Telektonon prophecy of Pacal Votan. As the new Wizard's Count, this count was intuitively recalibrated precisely so that July 26, 1987, would be White Galactic Wizard; July 26. According to *The Mayan Factor,* July 26, 1987: White Galactic Wizard, marks the first of the twenty-six years of the Harmonic Convergence. This date marks the conscious ascendance of the prophecy of galactic culture and the coming of the Earth Wizards-the race of galactic wizards on Earth.

In 1988, the year following the Harmonic Convergence, in attempting to create an everyday "Mayan calendar," I came upon the next stage of the discovery of the synchronic order. On the Gregorian calendar, 1988 is a leap year. I perceived that to accommodate February 29 would throw the year-bearer count off by one day, ruining the harmony of the system. Reviewing the Chilam Balam texts, it was clear that leap year was never considered, much less counted in the year-bearer count. Without an intercalary leap year date, the four year-bearers-Seed, Moon, Wizard, and Storm-coded by the numbers 1-13, remained in sequence, maintaining and assuring the harmony of the system, where every fifty-two years equals seventy-three 260-day spins, no two days are the same, and the entire 18,980 days of the cycle repeat every fifty-two years in an upward moving spiral of time. For the first time in my work, the issue of the Gregorian calendar as a system came into question.

Following this observation came the discovery of the mathematical codes governing the synchronization of the 260-day cycle with the 365-day cycle, the consequent discovery of the artificial 12:60 and the natural 13:20 timing frequencies, the recognition and resurrection of the Thirteen Moon/28-Day calendar, and the full exposition of the Dreamspell codes of fourth-dimensional time. I presented these discoveries in *Dreamspell: Journey of Timeship Earth 2013.* The Dreamspell, being the manifestation of the knowledge base of galactic culture, completely encodes the Wizard's Count. *Dreamspell: Journey of Timeship Earth 2013*, the presentation of the codes of fourth-dimensional time as a "tool kit" with an accompanying "script" and guidebook, is a break of such radical form from the prevailing paradigm that, as of today, it is still unfathomable to many people.

The galactic Dreamspell tool kit is a primary tool for the galactic culture that is just now beginning to unfold in the wake and shadow of the collapse of the Twin World Trade Center towers. This text prompted me to write two more books. The first, *Arcturus Probe: Tales and Reports of an Ongoing Investigation* (1992, 1996), is a deep reverie that picks up where *Suifers of the Zuvuya* left off and documents the interstellar, interplanetary psycho-cosmological roots of the Dreamspell of fourth-dimensional time. The second book was written as *A Treatise on Time Viewed from its Own Dimension,* but first published in English as the *Call ofPacal Votan: Time is the Fourth Dimension* (1992, 1996). In this highly scientific, mathematical treatise I was able to accommodate the Dreamspell codes of the Law of Time to an analysis of the biosphere and the biosphere-noosphere transition. This work also represents my first integration of the actual thought and principles of V. I. Vernadsky.

Through the efforts that constituted the discovery of the Law of Time, much of which was assisted by my partner and wife, Lloydine, I was finally able to begin to understand the methodology for accomplishing the paradigm shift-or psychic pole shift-of which humanity was so in need, at least from the perspective of the biosphere. By providing the mathematical basis for establishing the "biomass constant," Seventy-three 5 day subcycles correlated to the measure of the solar year, I had found a way of grounding the fourth-dimensional mental order of time, the synchronic order, in the actual third-dimensional biogeochemical cycles of the biosphere. This was like casting a harpoon of time from the noosphere and landing it in a precisely measured form in the annual turning of Earth's biospheric mantle. And this was accomplished precisely because of the intrinsic harmonic cycles and patterns of the DreamspelllWizard's Count.

For this reason, by 1993, it was incumbent upon me to test the hypothesis of the Law of Time that the human race was destroying its biosphere due to operating according to an error in time, and that only a shift in its experience of and perception of time would save it from such destruction. This shift in time is defined as the calendar change. The Law of Time presents such a radical critique of Western science, of its concepts of time, and of the civilization which it supports, that I could not tackle the problem from its center, but from its periphery, moving inward to the point of the Inevitable Event. Beginning in Latin America, then spreading to Japan, Western Europe, Russia, and finally North America, we established a movement to change the everyday perception of time, instilling profound meaning behind the effort to reform the calendar. In this way, we took on the responsibility of organizing the World Thirteen Moon Calendar Change Peace Movement.

Part and parcel of this, beginning in 1993, was the decoding of the prophecy of Pacal Votan, the inspiration of *The Mayan Factor.* Known as the Telektonon, Earth Spirit Speaking Tube, this prophecy is the full realization of the Law of Time and the synchronic order. As much science as it is prophecy, the Telektonon defines the Tower of Babel as the root of the error in time, and the Inevitable Event as the necessary result of not relinquishing false time. At the same time, the Telektonon provides codes and tools of analysis which are in complete accord with an understanding of the technosphere-noosphere as an evolutionary continuum in which the Inevitable Event is an act of moral consequence and natural law revealing the basis of a new cycle of harmonic order.

I would also be remiss at this point if! did not inform the reader that, by prophecy's prerogative, this text is also literally punctuated by a perspective that can only be described as "Quranic." Late in 1993, my immersion in the prophecy ofPacal Votan became sychronically linked to my immersion in a study of the Quran, or Holy Quran as it is sometimes called. I have taken seriously the claim that the Quran is the final revealed text (A.D. 610-632) for humanity. I have studied it following the dictum: "Quran, the whole Quran, and nothing but the Quran,"3 as the basis of genuine Islam-submission to the will of God. I have found it more than sufficiently true that the Quran is a scientific text, and contains nothing that contradicts science. More profoundly, my study has given rise to my own personal ethic: duty to God is the highest cause. It is the cultivation of this attitude, combined with many years of practice of Buddhist meditation, that have brought me to my present point of view, which is visionary and spiritual throughout-and, as a result, has endowed me with my own view on the current global dialectic.

That the new, and final, global dialectic is found in the tension between the forces of globalization (materialism) on the one hand, and that of the civilization of Islam (spirituality) on the other, is now a well-documented fact.4 Of course, generally speaking, in the West, we see it only from the materialist side of the dialectic. The perspective which informs me, and consequently this book, is definitely from the other side of the dialectic. Though in no way condoning terrorism- I am a non-violent pacifist by persuasion-the motives of the terrorists stem from a philosophy and worldview with which I am in sympathy. Yes, the Inevitable Event was also a profound theological moment, and what we are witnessing in the present World War is the battle between the religion of choice and the religion of submission. We cannot necessarily assume that the religion of choice will prevail. In fact, from the perspective of the biosphere-noosphere transition, it is the religion of submission that is most in accord with the spiritually-beckoning future.

As a preface to this book, I have found it mandatory to write this brief literary autobiography, often couched in a terminology that jumps ahead of the story, solely to demonstrate that the actualization of the noosphere corresponds to the stages of attainment and transcendence of one human's life journey in pursuit of the truth. Only in this way could I cultivate the noospheric perspective, voice, and point of view that was necessary for the writing of this text. In this perspective, the noosphere is a condition of non-anthropocentric consciousness. My journey, thus documented, is merely one way the noosphere has found to become conscious, asserting the Law of Time's purposive axiom: to make conscious what had been unconscious. The voice and method of the noospheric perspective are inseparable from the topic of this book, *Time and the Technosphere.* By analyzing the timing and structure of the technosphere, the noospheric point of view becomes conscious. WIthout understanding the nature and relation of time and the technosphere, there would be no truly sane way to comprehend the meaning of the Inevitable Event.

Crystal Moon Kali 11,
Kin 2: White Lunar WInd
Yellow Solar Seed year
Cascadia, North America

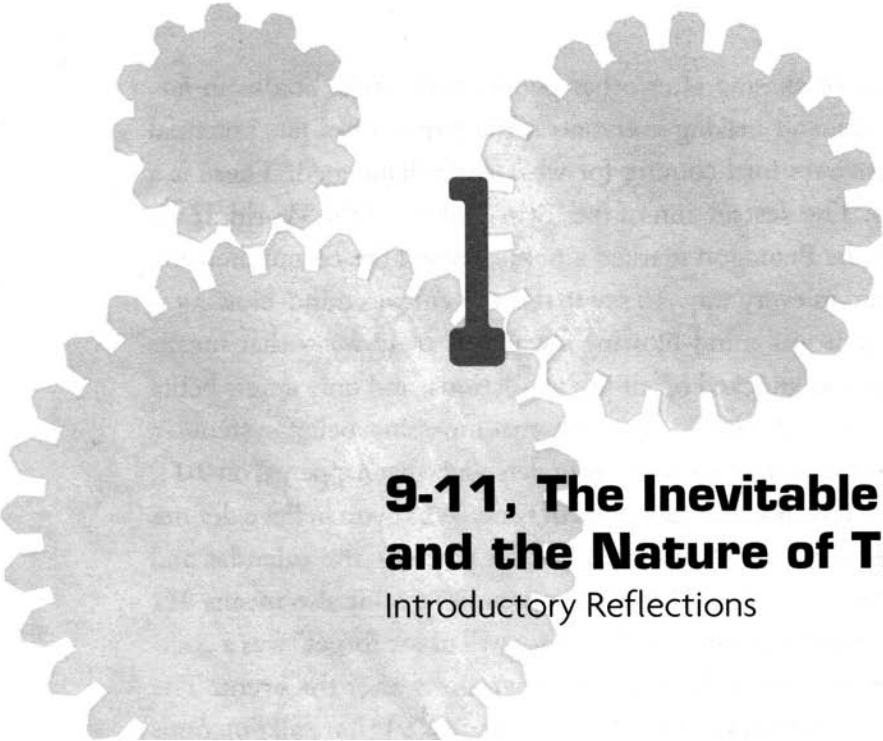

1

9-11, The Inevitable Event, and the Nature of Time

Introductory Reflections

Woe! Woe, O great city,
O Babylon, city of power!
In one hour your doom has come!
Woe! Woe O great city, dressed in fine linen
purple, and scarlet...
In one hour such great wealth has been brought to
ruin ...
"Woe! Woe, O great city,
Where all who had ships on the sea became rich
through her wealth,
In one hour she has been brought to ruin! ...
With such violence the great city of Babylon will be
thrown down!"
ST.JOHN OF PATMOS, BOOK OF REVELATIONS,
CHAPTER 18, *THE FALL OF BABYLON*

9-11. The Twin Towers of the World Trade Center gone in a veritable twinkle of the eye. Tragedy. Horror. Terrorism. The whole world brought to a halt. The aftermath? Patriotism, war, and an all-pervading uneasy feeling. What happened? What really happened? Was this the beginning of the Apocalypse?

Amidst the distraction of chasing after other people with smart bombs in faraway places like Mghanistan, and making everyone at the airports feel like potential terrorists, there are no answers forthcoming for what really happened. There is a good reason for that, too: The destruction of the Twin Towers of the World Trade Center and the attack on the Pentagon marked a point beyond the comprehension of the current belief system in every way. To say that the event was mind-blowing is an understatement. But if it was mind-blowing-which it truly was-that means that a whole belief system was knocked off of its foundations, and only a new belief system can supply the answer. A higher, more all-encompassing belief system-a new paradigm-is what is needed if we are to really understand what happened on 9-11.

Belief systems, believe it or not, are functions of time. What you believe defines the time you are living in. Any belief system is held in place by the calendar and sense of time in which it is encoded. 9-11 means September II-it also means 911 emergency, planetary emergency in this case. "9-11 we will never forget" was a common slogan appearing on bumper stickers and store windows after the event. The words or concepts "Tuesday, September 11," "9-11" and even "911" are all functions of the same belief system. So is "2001," the first year of the highly touted "third millennium." But the third millennium of what? The third millennium since the birth of Christ. This means that the belief system whose mind was blown was the Christian millennial belief system encoded in the Christian calendar, the Gregorian as it is properly called. Does this mean that the foundations of 2000 years of belief were blown away, shattered with the terrifying collapse of those Twin Towers? Easily that many years, maybe as many as 5,000 years, or perhaps even the entire history of civilization as we know it came unhinged that fateful day, the day of the 9-11, the day of the *Inevitable Event,* to borrow a phrase from the Holy Quran, the day the Apocalypse announced itself, showed up on the morning television, quite without warning. (See plate 1, The Invevitable Event and the End of History.)

In meditating upon the meaning of the Inevitable Event, it is natural to ask: What made this event so inevitable? It is not just from the perspective of American Foreign Policy, or that of its economic free market monetary politics, that this event was inevitable. More profoundly, this event was so inevitable because it seemed to smack of some form of retribution for the breaking of fundamental laws of nature, or even of Divine Law. And isn't the retribution for transgressing Divine Law a form of apocalypse, a standing naked, a revelation, an evocation of the fall of the Tower of Babel, no less?

Yes, that is why it was so shocking-it was the Inevitable Event because the apocalypse is as inevitable as it is without warning. But apocalypse- a word no one wanted to use to describe the event, because to use it would be to admit that it was all over-is only one side of the coin. There is another side to the coin of the Inevitable Event-and that is what this book is about. There is something beyond the Apocalypse, there is something larger going on, and that also scares people. Things are out of their control. Isn't this why, instead of looking at it, or contemplating the event, a policy of war was immediately instated as a principle of revenge-for what and against whom? What is going on is time-time is always going on, or time is always coming together. Or time is always changing. The apocalypse, too, is about time-the end of time-which is even more frightening to most people. But the end of whose time? The new paradigm we need to explain 9-11 should be a paradigm that is all about time.

I who speak know, because I have spent most of my life studying time, and the effects of human time which you call history. For many years now I have been living an experiment in time, but a time most of you do not know. So I have some answers that will put 9-11 in perspective for you. I am the stranger from the other side of the wall of mechanized time. I have come back to make you familiar with the time your clock and your calendar shield you from. Because I know about the other time, the larger time, the cosmic time that governs the cycles of all that exists, I can tell you that 9-11 was the Inevitable Event. It had to happen precisely when it did, not because nineteen terrorists planned it that way, but because the terrorists themselves were unconsciously programmed by the timing of Earth itself. Earth's timing process represents evolutionary forces as well as effects irreversibly set in motion by the human's own unconscious programs, programs governed by the human misperception of time and of its role in the cosmic order.

Yes, Earth has its program of which our human history and all of its endeavors are only a part. This larger meta-program of Earth is called the biosphere, the scientific designation given to what is commonly and inadequately referred to as "the environment." As such, the biosphere is a whole system composite of the sum of life and its organic and inorganic support systems spread out over the surface of Earth, hence bio = "life" + sphere = "having the form of a globe." In a word the biosphere is a vast but fragile process which has been evolving itself for some two billion years on this little planet as it spins around its local star, the sun. But we humans, who only in 1969 first saw ourselves as a planetary being-the whole Earth beamed back at us via television by a rocket hurtling toward the moon-we humans have been generally so self-involved in our own interpretation of things that we have missed seeing the larger picture of which we are a part. This larger picture is the entirety of the biosphere which encompasses the evolution of life on Earth as a whole system process. The amazing thing is that most of us have never even heard of the biosphere much less even know that we are a part of this whole system governed by laws and principles which we, in our self-made arrogance and ignorance, have but little understood.

From my experiment in time, seeing and studying the human as part of the larger self-evolving fabric of the biosphere, I came to the conclusion that the human is living in a time apart from the rest of the biosphere-an artificial time whose climax and termination is inevitable, for nothing artificial can withstand the force of truth. If the human is living in artificial time, the clock is an artifact whose system of measure has nothing to do with natural cycles but is a totally abstract standard, then there must be something called natural time. I will go even farther and state that not only is there natural time, but that there is a law governing natural time, and that is the Law of Time. Just as Newton only discovered gravity some 300 years ago, though gravity has always existed, so the Law of Time has always been in operation, even though it was just recently discovered. It is the Law of Time that governs the entirety of the biosphere and everything else in the universe according to principles which are only dimly known to us, principles like synchronicity and telepathic instantaneity. Yes, to understand what really happened on 9-11 you have to understand the Law of Time and how it governs the biosphere-of which our rampant human civilization is inescapably a part.

The Law of Time is formulated very simply, and in some people's way of thinking, rather unscientifically as T(E) = Art, "energy factored by time equals phenomena in the material world represent some state of energy, and every state of energy is governed by time, the resultant product of which is always something beautiful or elegant. Have you ever seen an ugly sunset? A hideous flower? Even if you examine a scorpion with some objectivity you will be amazed at the flawless and elegant manner in which its parts are organized. Yes, all of nature is organized by time to produce in you the sensation of beauty. And time itself, well, believe it or not, time is a frequency, and a frequency is not measurable by a clock. The Law of Time states that time is the universal frequency of synchronization. It is the nature of time to synchronize and to maintain all things in a condition of synchronization. Synchronicity, then, is the experience of real time. When we say that time is a frequency, we can be more precise and say that time is a universal constant expressible by the mathematical ratio 13:20. That is, the 13:20 ratio is the frequency of synchronization.

Of course, most people have never even heard of the Law of Time much less comprehend what the 13:20 ratio might mean. But then, that again gets to the root of the problem, or rather, the dilemma: If humans are living in their own time apart from the rest of the biosphere which is governed by the natural timing frequency, how could they ever know about the Law of Time? The humans are all a little like Mrs. Malaprop in the play by Moliere who learns to her surprise that she has been using grammar all of her life-though it is much more serious than that. So we humans are with the Law of Time-it has been operating throughout history without our awareness of it. Because of this, its way of making itself known to us was the infamous 9-11. Yes, in the analysis of the Law of Time, the 9-11 marked the end of artificial time.

Living in ignorance of the Law of Time and of the true nature of time, the human species constructed its own concept of time which is based on the clock with its 60-minute hour and the Gregorian calendar with its maddening array of unevenly numbered months. Hence, the paradigm of the artificial timing frequency is defined by the ratio 12:60 (twelve-month calendar, 60-minute hour) -in contrast to the 13:20 ratio of natural time. If the artificial mechanistic and irregularly measured time sets the human race apart from true or natural time, does this not also establish the fact that the human race is living an error in time? Only by living such an unconsciously assumed error could the human race arrive at such an apocalyptic moment as the Inevitable Event-inevitable because any deviation from the truth has an inevitable moment when the truth rebounds in some dramatic or even apocalyptic way. Is it possible that the entire construct of modern civilization, so devastating to the biosphere, is a function of this error in time? Is modern civilization like a time warp, a bubble of artificial time that suddenly got popped on the 9-11?

Back in the 1990s, now seemingly so long ago, I was traveling around the planet on behalf of the Law of Time and the biosphere, and making my observations regarding the effects of artificial time from a planetary whole systems point of view. I saw that even though the human species had evolved - or devolved, as the case may be-into a cultural hybrid which I call the planetary human, the object of the much touted "globalization," I saw that the consciousness of this cultural hybrid was anything but planetary. This schism between the propaganda of globalization and the actual sectarian and fragmented state of consciousness of the hybrid human was further exacerbated, I observed, by the potently unconscious effects ofliving an error in time. Ironically, if the Inevitable Event left many of us in the dark, it has brought the Law of Time into the light. To elucidate let me quote here from a text I wrote in 1996, and which I think will give us a point to expand upon in order to bring the Inevitable Event into sharper focus, while allowing me to define some of my terms:

"Through an error in time, the human species transforms its artificial construct, civilization, into a global technosphere: the sum product of industrial mechanization of its biological functions. Because of human adaptation to the irregular mechanized 12:60

riming frequency, the technosphere runs counter to the laws of the biosphere, crearing a magneric instability between the primal crystalline and vital organic processes."2

The current explosion of the world crisis, stemming from the destrucrion of The World Trade Center Twin Towers, demonstrates the hypothesis of the Law of Time that states: operaring on arrificial and mechanisric timing standards will cause the human to deviate from natural rime to the point of its self-destrucrion, the end result of the magneric instability referred to in this reference. But here we have some further definirions to make. Let us start with a definirion of the technosphere, since that word is featured so prominently in the ritle of this book, *Time and the Technosphere: The Law of Time in Human Affairs.*

While the term biosphere defines the enrirety of life as a single coherent unity, inclusive of its inorganic or semi-inert support systems such as the atmosphere and the hydrosphere, technosphere defines an artificial sheathe or membrane held together by industrial technology as a whole system. This technological mantle is the sum of the processes devised by humans resulring from the application of certain scienrific and economic principles, especially during the last half century. The effects of the technosphere are to supplant the organic processes of the biosphere with totally industrialized ones, resulring in a severe imbalance in the biosphere. This imbalance, the "magneric instability between the primal crystalline and vital organic processes" refers to the disruption of the delicate interacrion between the inert (crystalline) and biological processes and structures which consritute the vibrant mechanisms and interacrive cycles of the biosphere. Phenomena such as global warming and over-popularion are symptomatic of the technospheric disruption of the natural order of the biosphere.

The term technosphere, however, is actually just the middle term of a larger process defined as the biosphere-noosphere transirion. According to the principle figure behind the elaborarion of the laws of the biosphere, V. I. Vemadsky (1863-1945), as an evolving structure, the biosphere is inevitably being transformed into a new geological and evolurionary condirion, the noosphere-Earth's mental envelope. In Vemadsky's analysis, the enrirety of the biospheric process can be described as a single biogeochemical unity. According to Vemadsky, due to man's transformarion of nature since the industrial revolurion, this biogeochemical unity has entered a state of combustion-an accelerated process of transformarion. It is this rapidly acceleraring geochemical combusrion-the net effect of industrializarion and its waste -that accompanies an evolurionary shift, the transformarion of the biosphere into the noosphere. But between the biosphere and the noosphere there is the technosphere, the intervening medium of transformation.

So when we speak of the biosphere and the noosphere we must take into account the technosphere. In actuality we must speak of the biosphere-technosphere-noosphere transition. In this context, the noosphere is the condition of the human mind purified of the error of time. And if the noosphere is the Earth's mental envelope, it could only be so because of a unified state of mind, the transformation of the hybrid planetary human into a genuinely spiritualized planetary being, the mind of the Earth no less-something that seems phenomenally utopian from the perspective of today's evening news. How could this come about, this noosphere of a telepathically unified human consciousness? Again, the Law of Time supplies genuine answers. To begin with, it says, change your calendar, get back to living in harmony with the natural cycles of the rest of the biosphere-and the universe. If you don't, well, the destruction of the Twin Towers was just the first stage of the Apocalypse. But we still have a choice. The other side of the coin of the Apocalypse shown to humanity on prime time television on the 9-11 is entry into the noosphere. But we must first understand what is really going on, and then act intelligently.

The mental climate in America is particularly difficult and strained now. In order to maintain a positive and constructive attitude of mind during this terrible time, I decided to write this book. As you can see, this book takes for its point of departure an analysis of the destruction of the World Trade Center (the actual hub of the technosphere) as the Inevitable Event defining the dynamic of the biosphere in its process of transforming into the noosphere. The analysis of the event in this light will give ample opportunity for presenting the key ideas of V. I. Vernadsky, in particular the concept of the biosphere which he so single-handedly amplified and defined, as well as the cosmic ideas of other Russian thinkers which are little known in the West. I have already written about and given much thought to this matter in general, summarized in part in the First Planetary Congress of Biospheric Rights, held in Brasilia, Brazil in 1996, but nowhere have I written for a wider public audience concerning the nature of the biosphere-noosphere transition.

I feel it is especially important at this time to present an analysis of this event in a scientific context that is beyond nationalism and ideology, so that human beings can begin to understand that they are a function of the biosphere, but not necessarily its controlling mechanism. Of course, the Law of Time is the key factor involved in this analysis, and understanding the biosphere in the context of the Law of Time is absolutely critical for establishing the basis of an entirely new worldview and hierarchy of values-the much awaited new paradigm.

Like my thoughts on the biosphere-noosphere transition, my investigations of the Law of Time have also not as yet been presented to the general public. In fact, you will find scarcely anyone who has even heard of the "Law of Time." This is because my researches and investigations over the past decade which resulted in the discovery of the Law of Time were not conducted in any formal academic way, nor through any corporate or government sponsored grant or officially recognized research institution. The discovery of the Law of Time has been, nonetheless, a rigorous, life-consuming pursuit. The laboratory for its study was to be found in a phenomenological and anthropological investigation of the effects of mechanized time on various population groups absorbed in what is called "modern civilization."

The premise of this investigation is simple: it is an undeniable fact that the time of human civilization, governed by the clock and the Gregorian calendar, is not the same as the time of the rest of the biosphere. Artificial time is not the same as natural time. Or rather, artificial time establishes a frequency which governs the human species totally apart from the timing frequency of the rest of life. What are the effects of artificial time and how do they define the nature of modern civilization? The answers to these questions open a perspective that has been scarcely considered. Yet this perspective is so clearly an essential factor in the description and definition of the human condition, that, in the wake of the tragic events and their ominous aftermath, it now begs to be presented in a proper manner. Hence this book. Suffice it to say that the Law of Time in every respect answers the question posed by my previous books and summarized in the single query: how will modern man escape the fatal consequences of the one-sided mechanization of his biological operations and the imminent destruction of his life-support system?

Defining a planetary whole systems approach to the analysis of time in human affairs, the first postulate of my book *A Treatise on Time* (1996) concerning the principles and nature of time as the fourth dimension is worth quoting here, since it introduces the fundamental problem informing the investigation of Time and the Technosphere:

> Just as air is the atmosphere of the body, so time is the atmosphere of the mind. If the time in which we live consists of uneven months and days regulated by mechanized minutes and hours, that is what becomes of our mind: a mechanized irregularity. Since everything follows from mind, it is no wonder that the atmosphere in which we live daily becomes more polluted, and the greatest complaint is: "I just don't have enough time!" Who owns your time, owns your mind. Own your own time and you will know your own mind.3

It must be understood that the events of 9-11 were so historically unprecedented, so mind-bogglingly dramatic, that they require a large lens through which to fully interpret their meaning. The Law of Time is such a lens. Quite simply, the destruction of the Twin Towers defines the limit of artificial time. If this is so, what can be expected following this world-shattering event? Because the Law of Time began with the premise of defining the difference between artificial time and the time of nature, the larger context of the biosphere was resorted to almost immediately. Being the study of an ongoing and evolving phenomenon, the investigation of the biosphere by its principle researcher, V. 1. Vernadsky, pointed to another imminent evolutionary stage: the noosphere, the "mental envelope of the planet." However, an intermediate stage was also perceived by researchers who followed Vernadsky, and it came to be called the technosphere, "the technological envelope of the planet." The end or limits of the technosphere define the birth or beginning of the noosphere.

With the events of 9-11, this is no longer just a theoretical concept but a vivid reality. As a species we are now undergoing this dramatic evolutionary moment, otherwise known as the biosphere-noosphere transition. It is for this reason that this book also presents novel definitions of time and pragmatic conclusions that can be employed by anyone if they so choose. If the root of the technosphere is artificial time and its proliferating mechanized constructs, then in the collapse of the technosphere, an event ordained by the laws of nature, there must be an orderly path or means for establishing the noosphere, also ordained by natural law. The Law of Time defines this orderly path as a conscious shift in the human timing frequency, away from artificial time and into universal natural time. This can only be accomplished by a universal reform of time, known as the calendar change. If there were no such path, the conclusion to the collapse of the technosphere would be an unbearable barbarism.

By its nature, the topic of the book is cross-disciplinary and provocative-it is visionary history. I have been described as a "spirituality historian" and "cosmic harmony researcher."4 I believe this description also characterizes *Time and the Technosphere,* which does present a solution, a new world paradigm, if you will. A new paradigm has been awaiting humanity ever since the notion of paradigms was first raised by Thomas Kuhn in 1964, in his book *The Nature of Scientific Revolutions,* or even earlier by Vernadsky and Pierre Teilhard de Chardin in their invocation of the noosphere. To be truly new, such a paradigm could hardly be expected to arise from traditional fields of thought or methods of research, be they quantum physics or microbiology. In fact, as I have often said, most people wouldn't recognize the new paradigm if it ran into them on the street. This is because people's consciousness and perceptions are basically very set and unexamined-as unexamined as the effects of the watch on their wrist or the calendar on their wall. In fact, one of the consequences of the technosphere is the limiting nature of consciousness which remains unchanged despite the fact that technology is changing all of the time. But with the occurrence of the Inevitable Event, history has been punctured. Perhaps now the new paradigm can be perceived: the paradigm of natural time as the universal factor of synchronization.

Although prompted by the stunning terrorist attack upon and consequent apocalyptic collapse of the World Trade Center Twin towers, these reflections are actually a synthesis of thoughts and explorations in the domain of time that I now find necessary to communicate in a coherent and organic form. The grand theme of this study is to understand how and why the collapse of the twin World Trade Center Towers was a biospheric event. Even so, the study of the Inevitable Event within the context of the evolution of the biosphere requires and leads us to still grander domains of thought-the historical, the theological, and the cosmological. The reason that these reflections and meditations spiral into ever grander domains of thought is due to the principle of analysis and the guiding factor employed in this study. This is the Law of Time, which is the fruit of a life-long research and pursuit of knowledge. It is the Law of Time that brings the biosphere into timely focus.

The biosphere is scarcely known even to most educated people. As a biogeochemical whole system in which the human is but one of the functioning components, the biosphere is an intricate unity with its own governing laws and principles. Without becoming conscious of how the human organism participates in the laws and principles of the biosphere, the human will continue to remain ignorant of the biosphere's existence and therefore will sooner than later reach a termination of its own evolutionary possibility. A demonstration of how the laws and principles of the biosphere, crystallized into a temporary and intermediate sheath called the technosphere, reached a climactic evolutionary point in the collapse of the World Trade Center towers will provide the means of educating in general concerning the biosphere. It will also allow us to elaborate on the meaning and nature of the technosphere, and the imminent transformation of the biosphere into the noosphere, the Earth's "mental envelope."

A fundamental purpose of the Law of Time is to expand upon the meaning and significance of the Inevitable Event, as well as upon the biosphere, technosphere, and noosphere in relation to the evolution of life and consciousness in the universe. To speak of an event being "inevitable" is to bring about a reflection on the nature of time, and even of the laws of cause-and-effect and karma. It is time that governs both cause-and-effect as well as the actions of karma. And it is time that dominates inevitability, because any such inevitable event is located in a very precise moment in time. But what actually is time? How does time "locate" events? And, once again, what is the Law of Time?

As the criterion of natural time in which synchronicity is the norm, the Law of Time is the key that unlocks the reason why the Inevitable Event occurred when it did. By precisely locating it within the evolutionary continuum of the biosphere and in relation to its point of mutational shift, the Inevitable Event is placed into a greater context of cosmic comprehension by the Law of Time. Through the lens of the Law of Time we will be able to understand the relationship between the biosphere, the intermediate state of the technosphere, and the imminent stage of the noosphere. Defining the Law of Time as the factor of universal synchronization, the law by which all events in the universe are maintained in synchronic relation to each other, we approach the domain of a hitherto undefined realm, that of the synchronic order.

As the unifying fourth-dimensional order of time in the universe, the synchronic order is measured and gauged by the 13:20 matrix. The mathematical coding of the Law of Time is entirely locked into this 13:20 matrix, otherwise known as the Harmonic Module or T zolkin, the basis of the sacred count of the ancient Maya. When we examine the Harmonic Module, a 13 x 20 matrix, we may well ask what does that have to do with time? It is obviously as different from a clock, as a tree is from a flagpole! When we examine the matrix carefully we see that there is a repetition of thirteen notations, the numbers 1-13, that occurs 20 times yielding 260 (13 x 20) units.

Holding the 13:20 matrix together is a pattern which I identified in my book *Earth Ascending* (1984) as the binary triplet configuration, and in the *Mayan Factor* (1987) as the Loom of Maya. This pattern consists of 52 units, 26 on either side of the central or seventh vertical column. **If** you contemplate this 52-unit pattern you will see it is characterized by binary radial symmetry. This quality characterizes the entire matrix and defines the quality of fourth-dimensional time as radial and instantaneous distinct from the current third-dimensional paradigm which defines time as being linear and sequential. The radial quality of fourth-dimensional time is what accounts for its being the factor of universal synchronization. This is very different from the sensation of the second hand as it sweeps around the clock, indicating the inexorability, not of time but of the mechanization of time! The 13:20 matrix becomes potently useful as the means of establishing the synchronic order when it is coordinated with a genuinely harmonic timing standard, the Thirteen Moon/28-Day calendar.

"Time is the fourth dimension," is the famous adage attributed to Einstein. This statement notwithstanding, the modern notion of time is bogged down in the minutiae

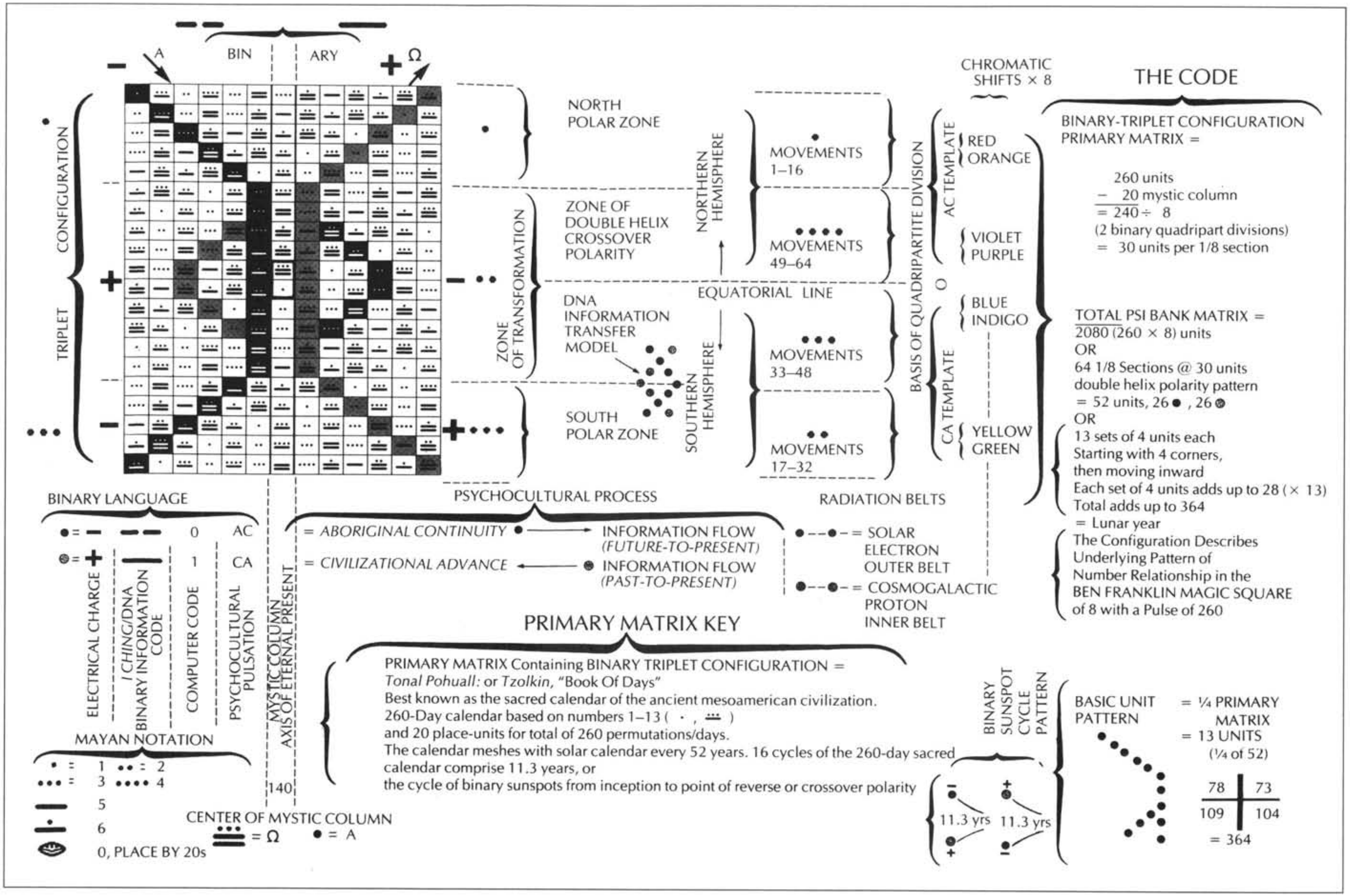
A
BIN
ARY
Ω
CONFIGURATION
TRIPLET
NORTH POLAR ZONE
ZONE OF DOUBLE HELIX CROSSOVER POLARITY
ZONE OF TRANSFORMATION
DNA INFORMATION TRANSFER MODEL
SOUTH POLAR ZONE
NORTHERN HEMISPHERE
EQUATORIAL LINE
SOUTHERN HEMISPHERE
MOVEMENTS 1–16
MOVEMENTS 49–64
MOVEMENTS 33–48
MOVEMENTS 17–32
BASIS OF QUADRIPARTITE DIVISION
AC TEMPLATE
CA TEMPLATE
O
CHROMATIC SHIFTS × 8
RED
ORANGE
VIOLET
PURPLE
BLUE
INDIGO
YELLOW
GREEN
THE CODE
BINARY-TRIPLET CONFIGURATION PRIMARY MATRIX =
260 units
− 20 mystic column
= 240 ÷ 8
(2 binary quadripart divisions)
= 30 units per 1/8 section
TOTAL PSI BANK MATRIX =
2080 (260 × 8) units
OR
64 1/8 Sections @ 30 units
double helix polarity pattern
= 52 units, 26 ●, 26 ◉
OR
13 sets of 4 units each
Starting with 4 corners,
then moving inward
Each set of 4 units adds up to 28 (× 13)
Total adds up to 364
= Lunar year
The Configuration Describes
Underlying Pattern of
Number Relationship in the
BEN FRANKLIN MAGIC SQUARE
of 8 with a Pulse of 260
BINARY LANGUAGE
● = ▬
◉ = +
0
1
AC
CA
ELECTRICAL CHARGE
I CHING/DNA BINARY INFORMATION CODE
COMPUTER CODE
PSYCHOCULTURAL PULSATION
MYSTIC COLUMN
AXIS OF ETERNAL PRESENT
140
MAYAN NOTATION
1 2
3 4
5
6
0, PLACE BY 20s
CENTER OF MYSTIC COLUMN
= Ω
● = A
PSYCHOCULTURAL PROCESS
= ABORIGINAL CONTINUITY
INFORMATION FLOW (FUTURE-TO-PRESENT)
= CIVILIZATIONAL ADVANCE
INFORMATION FLOW (PAST-TO-PRESENT)
RADIATION BELTS
= SOLAR ELECTRON OUTER BELT
= COSMOGALACTIC PROTON INNER BELT
PRIMARY MATRIX KEY
PRIMARY MATRIX Containing BINARY TRIPLET CONFIGURATION =
Tonal Pohuall: or Tzolkin, "Book Of Days"
Best known as the sacred calendar of the ancient mesoamerican civilization.
260-Day calendar based on numbers 1–13 (· , ⩸)
and 20 place-units for total of 260 permutations/days.
The calendar meshes with solar calendar every 52 years. 16 cycles of the 260-day sacred calendar comprise 11.3 years, or
the cycle of binary sunspots from inception to point of reverse or crossover polarity
BINARY SUNSPOT CYCLE PATTERN
11.3 yrs
11.3 yrs
BASIC UNIT PATTERN
= ¼ PRIMARY MATRIX
= 13 UNITS
(¼ of 52)
78
73
109
104
= 364

13:20 Matrix-Harmonic Module with Binary Triplet Configuration

of quantum mechanics and cessium clocks, in a hair-splitting myopia that cannot see the forest for the trees. The fact is that only time governs the whole order of the universe in a manner that transcends all spatial limitations, even those of the relativistic MinkowskilEinstein four-dimensional universe, which is confined by the speed of light. As the universal factor of synchronization, time is instantaneous and transcends light. This novel perception of time defines a new reality, the synchronic, of which our experiences of synchronicity are but a foretaste. The synchronic order described by the Law of Time poses the order of an entirely new science of time.

To be realized and then applied, the science of time is dependent on two factors: a sudden and radical disruption of the historical continuum; and a genuine globalization or planetarization of consciousness. The break in historical continuity is necessary to jolt the human consciousness from its stagnant and entropic state-defined by the Law of Time as the delimiting 12:60 frequency consciousness of artificial, mechanistic time-while the globalization of consciousness, intimately connected with this sudden discontinuity, is necessary for the application of this law at a planetary whole systems level. Of course, the radical disruption of the historical continuum was provided by the collapse of the Twin Towers, and can actually be mapped in a description of the dialectical process of human evolution.

If one studies *Earth Ascending,* Map 19, "Binary Pulse of Psycho cultural Development," [shown on page 14] one can pinpoint the "Inevitable Event" of the radical historical discontinuity as the point at which the AC and CA currents cross over one another and switch polarity at the very top of the graphic depicting the "historical" process. What does it indicate, this point of psychic polarity switching currents?

The historical dialectic is understood as the interplay of two "currents" of consciousness, AC "Aboriginal Continuity" and CA, "Civilizational Advance." In the prehistoric phase, the consciousness is dominated by the Aboriginal Continuity or AC. This refers to the primary experience of the original human nature- life lived as a ritual or ceremonial round within the perimeter of the timeless present. But as the human enters the historical cycle, about which we will have more to say in later chapters, the CA becomes more predominant. As Civilizational Advance, the CA represents the tendency toward exclusive reliance on reason, logic and written means of communication. The Law of Time further defines the CA as being motivated increasingly by the artificial timing frequency of the 12:60 which gains in prominence until the final phase of the historical cycle, industrial globalization, when the CA has gained complete dominance of the biosphere.

During this final stage, the global mental condition is defined as the involvement in secondary or artificial means of experience, furthered by the planetary

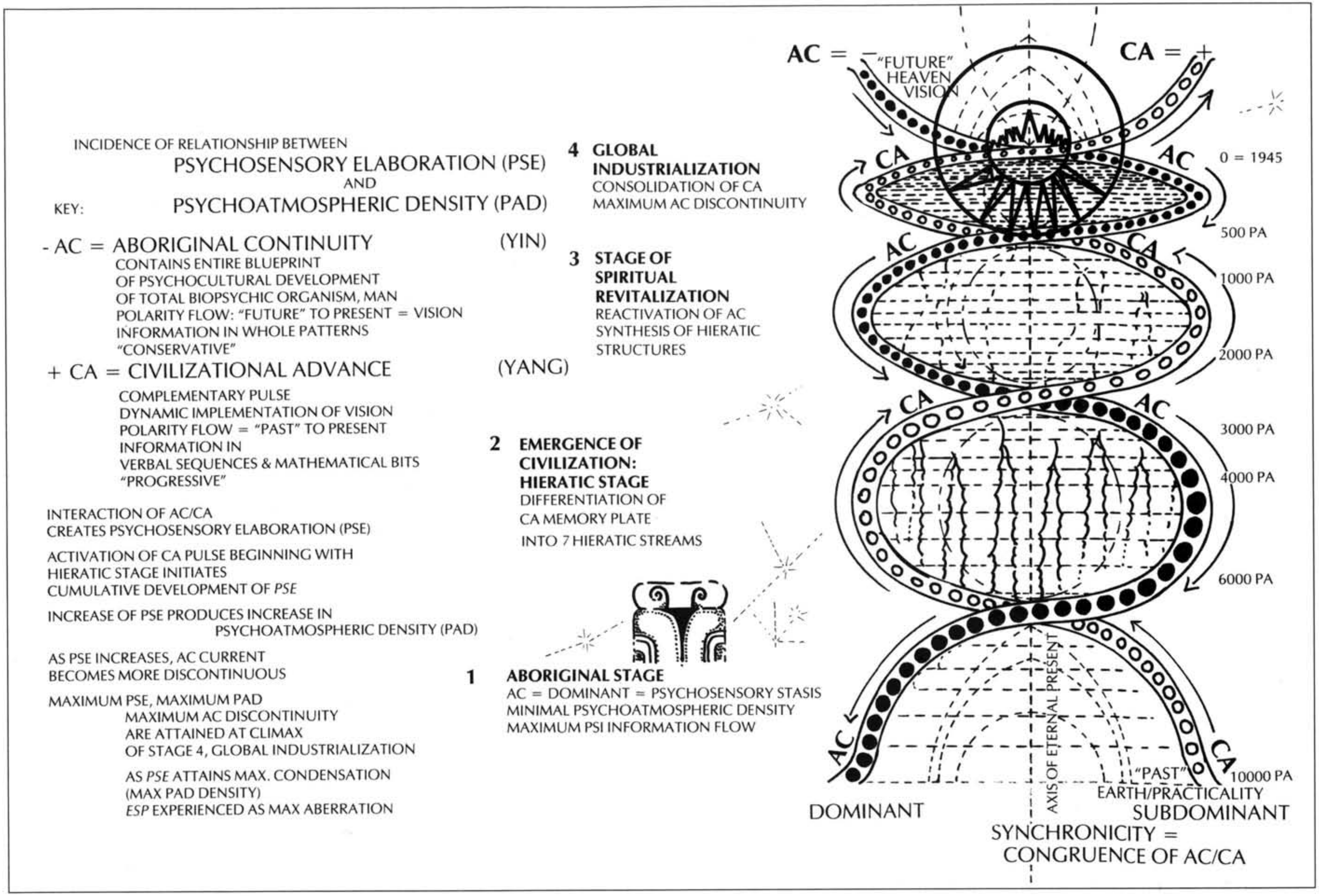

INCIDENCE OF RELATIONSHIP BETWEEN
PSYCHOSENSORY ELABORATION (PSE)
AND
PSYCHOATMOSPHERIC DENSITY (PAD)

KEY:

- AC = ABORIGINAL CONTINUITY (YIN)
CONTAINS ENTIRE BLUEPRINT
OF PSYCHOCULTURAL DEVELOPMENT
OF TOTAL BIOPSYCHIC ORGANISM, MAN
POLARITY FLOW: "FUTURE" TO PRESENT = VISION
INFORMATION IN WHOLE PATTERNS
"CONSERVATIVE"

+ CA = CIVILIZATIONAL ADVANCE (YANG)
COMPLEMENTARY PULSE
DYNAMIC IMPLEMENTATION OF VISION
POLARITY FLOW = "PAST" TO PRESENT
INFORMATION IN
VERBAL SEQUENCES & MATHEMATICAL BITS
"PROGRESSIVE"

INTERACTION OF AC/CA
CREATES PSYCHOSENSORY ELABORATION (PSE)

ACTIVATION OF CA PULSE BEGINNING WITH
HIERATIC STAGE INITIATES
CUMULATIVE DEVELOPMENT OF *PSE*

INCREASE OF PSE PRODUCES INCREASE IN
PSYCHOATMOSPHERIC DENSITY (PAD)

AS PSE INCREASES, AC CURRENT
BECOMES MORE DISCONTINUOUS

MAXIMUM PSE, MAXIMUM PAD
MAXIMUM AC DISCONTINUITY
ARE ATTAINED AT CLIMAX
OF STAGE 4, GLOBAL INDUSTRIALIZATION

AS *PSE* ATTAINS MAX. CONDENSATION
(MAX PAD DENSITY)
ESP EXPERIENCED AS MAX ABERRATION

4 **GLOBAL INDUSTRIALIZATION**
CONSOLIDATION OF CA
MAXIMUM AC DISCONTINUITY

3 **STAGE OF SPIRITUAL REVITALIZATION**
REACTIVATION OF AC
SYNTHESIS OF HIERATIC STRUCTURES

2 **EMERGENCE OF CIVILIZATION: HIERATIC STAGE**
DIFFERENTIATION OF
CA MEMORY PLATE
INTO 7 HIERATIC STREAMS

1 **ABORIGINAL STAGE**
AC = DOMINANT = PSYCHOSENSORY STASIS
MINIMAL PSYCHOATMOSPHERIC DENSITY
MAXIMUM PSI INFORMATION FLOW

AC = –
CA = +
"FUTURE"
HEAVEN
VISION
CA
AC
CA
AC
CA
AC
AC
CA
0 = 1945
500 PA
1000 PA
2000 PA
3000 PA
4000 PA
6000 PA
10000 PA
AXIS OF ETERNAL PRESENT
"PAST"
EARTH/PRACTICALITY
DOMINANT
SUBDOMINANT
SYNCHRONICITY =
CONGRUENCE OF AC/CA

Locating the Inevitable Event in the Holonomic Equation:
9-11, 2001 Climax of the Binary Pulse of Psychocultural Development
(from *Earth Ascending*, Map 19)

technosphere. The sum effect on consciousness of the advanced CA stage is defined as Psychosensory Elaboration or PSE, which in turn creates a psychoatmospheric density (PAD)-literally a mental cloud which obscures altogether the organic biopsychic reality of the human within the biosphere. From the point of view of a planetary pathology, this massive collective obscuring (CA) of the original nature (AC) defines a "suicidal crisis point," a moment at which the subconscious instinct of the human being programs its own self-defeat in order to ultimately return to the organic reality of the biosphere and the simultaneous advent of the noosphere. Hence, the Inevitable Event: the radical break in the continuum of history.

This moment of radical historical discontinuity occurred with the September 11,2001, terrorist attack on the twin towers of the World Trade Center-the very nerve center of late global industrialization-and the Pentagon, the supreme military fortress that defends globalization. If the fall of the towers symbolically augured the fall of Babylon and the Tower of Babel itself, the penetration of the Pentagon was no less symbolic. The fact that there was not one but two towers of Babel and a separation of some twenty minutes between the attack on each tower allowed the second attack to be viewed live on global television by about as many people on Earth as had ever witnessed anything at one simultaneous moment. By the end of the day, the scene had been repeated multiple times on virtually every television network on the planet.

The unbelievable shock of the moment and its simultaneous perception, coupled with the symbolism of what was actually occurring, effectively rendered the break in the historical continuum as a profound mental event-a rupture of 5,000 years of history from the first Babylon to the last. The witnessing of the event on television meant that it was received immediately into the nervous system of virtually the entire species. This in itself is a noospheric moment-the mental envelope of the Earth made collectively and globally conscious in one instant of history-shattering significance, and hence, the genuine entry into post-history. Archetypally, the images of the towers collapsing with people flying or jumping off the upper stories, is a pure reflection of the Sixteenth Major Arcana card of the traditional Tarot which shows a tower being shattered by lightning, with bodies falling down from it.

While the negative powers and forces grapple with their shattered dreams in the aftermath of the event, it is the time for the powerful luminescence of the noosphere to begin to activate the receptive cells of the human system within the now catalyzed biosphere. Fifty-six years after Hiroshima, the fall of the World Trade Center Towers is the fatal puncture in the technosphere which is intended to reorient the human within the biosphere. ESP (extrasensory perception)-the opposite of PSE (psychosensory elaboration)-is released in the instantaneity of the information reaching virtually every human being on Earth. This is the collective reactivation of the Aboriginal Continuity current that has been disengaged and disempowered for so long by the Civilizational Advance. Civilization has finally been checkmated. Now the Revolution of Time must be completed in order to stabilize the biosphere, anchor the noosphere, and de-structure the technosphere.

According to the Law of Time, the Inevitable Event was already embedded in the moment in which it actually occurred, like a flaw in a piece of glass that, upon concussion at the right pressure point, shatters all at once. In the case of the World Trade Center Towers and the Pentagon, we are also dealing with symbolic constellations of such potency that the very act of their shattering redefines the reality of human consciousness. In fact, the nature and problem of human consciousness as it has evolved historically is also at the root of this astonishing event. While it will take time for the collective human consciousness to fully grasp just how much its reality is being redefined, a vacuum now exists within the technosphere itself-a vacuum which awaits being filled by a new paradigm. Since the collapse of the Twin Towers actually represents the limits of artificial time, the new paradigm must rest on a redefinition of time altogether. This is the definition supplied by the Law of Time, the pragmatic application of which is the replacement of the irregular measure of the Gregorian calendar by the harmonic measure of the Thirteen Moon/28-Day calendar.

Because of its harmonic measure, the Thirteen Moon/28-Day calendar coordinated by the Harmonic Module is the new dispensation of time-reckoning for the human race. Rooted in the four recurring year-bearers of the Wizard's Count--:-which is not the same as the Mayan long count, nor the Julian count of modern science-the Thirteen Moon calendar exists for the establishment of the reality of the synchronic order as an entirely new method of knowledge and being for the entire human race as a cosmic medium operating within the biosphere. By Wizard's Count is meant the circulation of thirteen numbers and four different glyphs-Yellow Seed, Red Moon, White Wizard, Blue Storm-that code the July 26 Thirteen Moon/28-Day calendar synchronization date to create a master 52-year cycle, Anchored in the Thirteen Moon/2 8-Day calendar, the synchronic order is the means for manifesting the reality of the noosphere on planet Earth. Without such a basis in a lived mathematics of time correlated to the actual cycles of Earth, the noosphere could not be experienced nor fully realized. The successful completion of the biosphere-noosphere transition, then, is the triumph of the synchronic order, the conscious elevation of Earth into the cosmic frequency of fourth-dimensional time.

For all of this to come to be, however, is yet dependent on an analysis of the role of time in the creation of the technosphere and the subsequent comprehension of its limits and the potential for its de-structuring. This is not only a matter of theory or prophecy; it is a matter of putting into practice, making a coherent action out of the application of the Law of Time as it completes the pressing urgency of the biosphere-noosphere transition. The coherent action to bring us through this rite of passage is the Great Calendar Change of 2004. Ultimately, this book is presented to make us ready for this unprecedented time changing moment. May you, 0 reader, ponder deeply and then, if you so will, come join me in living on the other side of the wall of mechanized time.

▼

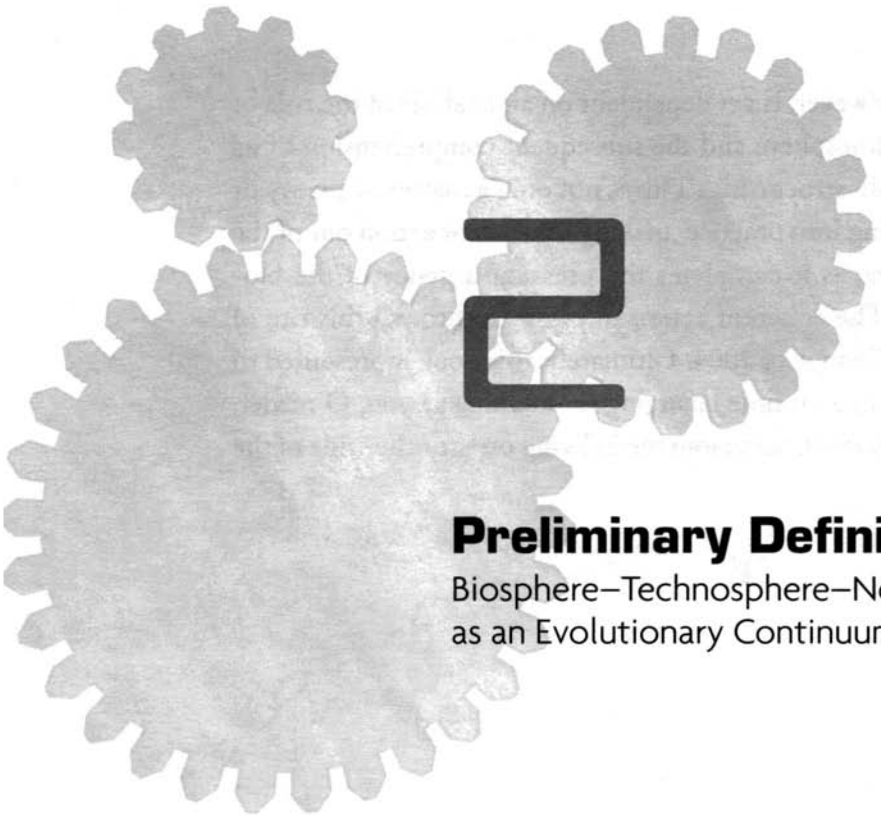

2

Preliminary Definitions

Biosphere–Technosphere–Noosphere as an Evolutionary Continuum

BY UNDERSTANDING that the Inevitable Event was a function of the biosphere-indeed, a necessary moment in the evolutionary trajectory of the biosphere-we are saying that this event was not just a human enactment, but that humans, inseparable from the biosphere, are effected to perform functions that relate to the process of the biosphere as a whole. Seeing the Inevitable Event and, in fact, the entire human drama from the perspective of the biosphere, we are actually lifting the cruel tragedies of contemporary reality above conflict and into a state where genuine laws of peace and harmony may shed their light of wisdom, illuminating the human drama with a higher understanding. One thing is certain: Unless we rise above our own humanity and cultivate a non-anthropocentric view-the view represented by the noosphere-there will be no release from the calamity that is now engulfing us. The point is not of maintaining the global economy, but of saving the biosphere.

For the multilayered task of bringing a new understanding to light, defining the technosphere, and then the Law of Time, we shall begin with the former: defining the technosphere in the context of the evolutionary continuum of biosphere-technosphere-noosphere.

VERNADSKY AND THE UNDERSTANDING OF THE BIOSPHERE

It is amazing that the name V. I. Vernadsky (1863-1945) is so little known in the West, and that the word *biosphere,* as well as the laws and principles pertaining to it, are scarcely more known. To a large degree, this ignorance is due to the great cleavage in human relations experienced as the Cold War. The biosphere, which was profoundly studied and scientifically articulated by the master Russian scientist V. I. Vernadsky, is actually the precise word for what in the West is vaguely referred to as the *environment.* But even more than being a precise and scientific description for what is meant by the use of the word *environment,* biosphere defines a whole system model of life on Earth, and because of that, also presupposes a whole system methodology and point of view. You cannot speak about the biosphere without entering into a world of discourse that is holistic or holonomic to the core.

If one looks for Vernadsky's work in English, one will find precious little available. His key work, *The Biosphere,* exists in two very different translations; the one published by Synergetic Press in 1986 is easier to read, while the other, the "complete annotated edition" published by the Far West Institute in 1998, is far more erudite, with a major bibliography and much supplementary information. The earlier translation was published in conjunction with the opening of the Biosphere II Project outside Tucson, Arizona. It is now a tourist site, with a bookstore that carries nothing by Vernadsky! Several other hard-to-find English-language books on the biosphere include the excellently informative *Traces of Bygone Biospheres* by Andrey Lapo (Synergetic Press and Mir Publishers, 1987), the flashy *Biosphere Catalog* (Synergetic Press, 1985), and the much more specialized *Energies: An Illustrated Guide to the Biosphere and Civilization* by Vaclav Smil (MIT, 1999). Of these books, only *Traces of Bygone Biospheres* contains significant information about Vernadsky and his ideas. This scant list of available texts in English is hardly proportionate to the vast reality of the biosphere as a complex terrestrial dynamic in the throes of evolutionary change.

The place and role of Vernadsky in Russian science is virtually equal to that of Einstein in Western science. A consideration of the achievement of each of these scientists also presents us with a dramatic contrast in perspectives, areas of interest, and consequent modes of analysis. The physicalist relativism of Einstein's legacy and its pursuit of the Big Bang is radically different in almost every way from the legacy of Vernadsky's work, which presents a biogeological worldview that is organically integrative and the basis of what in Russian science has come to be called *cosmism.* While the physicalist fascination of Western science has supported the materialism of modern Western thought and its way of life (which is actually an accelerating function of the biosphere's own internal processes), the whole system thinking of

Vernadsky-characterized by the conception of a "biogeochemical process"-ironically supports a cosmic rather than materialistic worldview.

To illustrate the Russian perspective and the influence of Vernadsky's work, we present the concluding thoughts of a book by another Russian scientist and philosopher, 1. Laptev:

> Each one of us requires the whole earth-today this is quite clear. But surely each one of us is required by the whole earth! And when these two mutually penetrating requirements, so distinctly revealed and intensified by the leap out into space, are satisfied, the new historical epoch will begin "in which mankind itself, and with mankind all branches of its activity, . . . will experience an advance that will put everything preceding it in the deepest shade." (Fr. Engels, *Dialectics of Nature)* And people, no longer burdened by the thirst for money, will remember something that many of our contemporaries have forgotten: The only important things in life are such intangible qualities as beauty and wisdom, laughter and love.
>
> Nothing remains for us, members of a society the ideals of which are in unison with elemental geological processes and the laws of nature, but to wish that people the world over would recognize this as soon as possible.!

Laptev's words-written twenty-eight years ago and precisely at the midpoint between Hiroshima and the Inevitable Event, as well as during the year in which the World Trade Center in New York City was finally completed and inaugurated (April 4, 1973)-simply and elegantly state the theme and point of view that we are pursuing. In fact, it is the Inevitable Event that prepares us for the new historical epoch. But first we must realize how we are organized by the biosphere in order that the technosphere may be transformed into the noosphere.

The root of Laptev's cosmic vision lies in Vernadsky's succinct definition of the biosphere: "The biosphere is the region on Earth for the transformation of cosmic energies." Although the word *biosphere* had been coined in the late nineteenth century, it was really only with Vernadsky's efforts that the biosphere became a viable description of the totality of life on Earth inclusive of its organic and inorganic support processes.

Vernadsky was trained as a geologist with a specialization in crystallography. He immediately absorbed the implications of Curies discovery of radioactivity (1896), and devoted many studies to the purpose of uranium and naturally occurring radioactivity within the Earth's geology. By the time of the First World War, Vernadsky had already written important texts such as *Fundamentals of Crystallog;raphy and Descriptive Mineralogy,* and, along with Madame Curie, proposed an "international radiography of Earth's crust." This was in advance of Alfred Wegener's definitive work on plate tectonics. During the time of the First World War and Russian Revolution, Vernadsky's attention turned toward the problem of living matter and its relation to the geochemistry of the Earth. From this was born Vernadsky's perception of the unitive biogeochemical process by which the biosphere maintains itself. In 1923 he published a "plea for the establishment of a biogeochemical laboratory."

In Paris, Vernadsky worked at the Insititut de Radium (Marie Curie) and became acquainted with Henri Bergson, who was then president of the International Commission of Intellectual Cooperation of the League of Nations. Through Bergson's circles, Vernadsky met often with the biologist Pierre Teilhard de Chardin (1881-1955) and the philosopher Edouard Ie Roy (1870-1954), with whom Vernadskyjointly coined the word and concept of the noosphere. Although Pierre Teilhard de Chardin is credited in the West with the concept of the noosphere, defined by him as the "mental envelope of the planet above and discontinuous with the biosphere," de Chardin's approach to the evolution of the noosphere as a natural consequence of vertebrate biology differs from Vernadsky's understanding in which it is the entirety of the biosphere that evokes the noosphere.

The chief fruit of this fertile time in Vernadsky's life was the publication of the little book titled *The Biosphere* (1926). Demonstrating the synchronic ordering principle of the noosphere, it is interesting that the same year that saw the publication of *The Biosphere* also witnessed the appearance of Jan Smuts noted book *Holism and Evolution.* Through most of the rest of his sometimes turbulent career (he often came under attack from hard-line bolsheviks), Vernadsky was to elaborate on the laws and principles of the biosphere, often expressed simply as problems in biogeochemistry. At the same time, his influence as a holistic thinker began to spread through the Soviet Academy of Sciences. A list of a few of his later publications gives some idea of the breadth of his thought, and includes: *Geochemistry, Problems in Biogeochemistry I* and *II, On the Boundaries of the Biosphere, Goethe as Naturalist, Scientific Thought as a Planetary Phenomenon, Some Words on the Noosphere,* and his never completed work, *The Chemical Structure of the Earth's Biosphere.*

Following the death of his wife in 1944, Vernadsky expressed the opinion that after the Second World War, American and Russian scientists should work more closely together. Early in 1945 (January 6), Vernadsky followed his wife to the grave. The Second World War ended, only to be followed by the Cold War (1947-1990). The critical collaboration between American and Russian scientists longed for by Vernadsky was soon to be buried in the ideological wasteland over which the superstructure of the technosphere would be constructed, a fact that in itself hastened the acceleration of the biogeochemical processes bringing about the climax of the technosphere.

Vernadsky did not live to witness the birth of the atomic era, which began only months after he died. But like Einstein in America, in 1940 Vernadsky-along with several other scientists, and mindful of the possible military applications-had prompted the Russian government to begin investigations into the possibility of deriving energy from nuclear fission. Yet it is most remarkable that by the time of his death, Vernadsky had almost single-handedly defined virtually every aspect of the laws and principles of the biosphere. This he always did with an eye to an imminent moment in the not-too-distant future when there would be a dramatic biogeochemical mutation or combustion, out of which the biosphere would somehow trigger the noosphere:

> Not at a crisis of nervousness do we stand now, not at a time for the vacillation of flabby souls; but at a great turning point in the history of scientific thought, at a crisis such as occurs but once in a thousand years, such as has not been witnessed for many generations. Standing at this point, with the vista of future achievements before us, we should be happy that it is our lot to live at this time and to participate in the creation of tomorrow.2

Undoubtedly his sense of the great moment of transition came from the very fact that during the span of his life from 1863 to 1945, some eighty-two years, Vernadsky was able to witness firsthand the accelerating effects of man's thought-in the form of industrial technology and the machine-and its turbulent and transformative impact on the terrestrial biosphere. After all, as a geologist, Vernadsky was familiar with the long history of the Earth, and the impact of human technology on the biosphere was inescapably the most significant aspect of any study of the biosphere to the present time. So wrote Vernadsky: "Only man transgresses the established order. . . upsets the equilibrium, though whether he materially cripples the transforming mechanism, or merely redistributes it, we cannot at the moment be sure."3

The "transforming mechanism" referred to is the biosphere itself, which Vernadsky had already defined as the medium or region for the transformation of cosmic energy on Earth. At its simplest level, the unity of the whole of living matter of the biosphere is the sum of its living organisms. These living organisms either directly or indirectly are continuously processing solar and cosmic radiation, transforming it into various chemical cycles that establish the atmosphere, most notably through photosynthesis and the oxygen and carbon dioxide cycles. The important point, however, in any consideration of the biosphere is the principle of unity: the biosphere is a unitive complex of cycles summarized as a single continuously transforming and slowly mutating biogeochemical process. In this single complex cyclical process, all of life-all of living matter-is a unity, a singular dynamic by which the biosphere can be considered as a living whole. From the plankton of the oceans to the trees in the forest and the human peering from his cave at the rising sun-all of this is a single unity.

It is the interaction of the living matter with the inert matter that creates and establishes the attributes and dynamics of the biosphere as a whole, all of which are now in a heightened state of acceleration and transformation, for as Vernadsky put it in the conclusion to *The Biosphere:* "The thought of the human species is a new fact which is turning the structure of the biosphere upside down after myriads of centuries." The structures and principles of the biosphere that man is now upsetting include: the continuity and invariance of life on Earth; vegetation as a transformer of the energy of the sun; multiplication as a manifestation of transformed solar energy; propagation of life and the forces resisting propagation; and the unique relations of life to the inert matter of the biosphere, including the composition of living matter into two orders, plant life and the various biological animal species, inclusive of man. The first order of plants and bacteria constitute the mechanism for capturing the solar radiation and introducing the energy of the sun into the biosphere. The second order of biological life is a manifestation of the process of the transmission of energy through the vegetable world; that is, at a primary and fundamental level, animal life is dependent upon plant life for its existence. (See plate 2, Life Is the Transformation of Solar Energy.)

All these principles for maintaining the equilibrium of the biosphere are functions of the dynamic of the different biochemical and geochemical cycles that maintain life both on land and in the ocean, all of which are subjected to processes that we refer to as evolution, both geological and biological. The evolutionary mechanisms of life include the principle of the biomass constant and the biogenic migration of atoms. Both of these mechanisms refer to and define the continuity and invariance of life on Earth. That is, the quantity of living matter has remained roughly unchanged since the origin of life on Earth-the biomass constant. Furthermore, the amount of oxygen in the biosphere is equal to the amount of biomass. It is the pressure of the different species on each other with the resultant interactions and changes that checks the infinite propagation of anyone species at the expense of the rest, and causes the mutation and evolution of the different life forms. It is through the intermediate structure of the technosphere that the human is wreaking the greatest havoc on these principles that are intended to maintain the biosphere as a stable dynamic, and by which the human constitutes a biomutation of unparalleled significance. The different stages of the mutation of life account for the biogenic migration of atoms: "The evolution of different forms of life throughout geological time increases the biogenic migration of elements in the biosphere."4 The metamorphosis of dinosaurs into fossil fuel is an example of the biogenic migration of atoms-and of the introduction of "free energy" (the term for industrial waste and by-products such as carbon monoxide) into the biosphere, while at a more mundane level, it refers to processes such as metabolism, circulation, breathing, and so forth.

To summarize, there are two biogeochemical principles. The first states: "The biogenic migration of chemical elements in the biosphere tends towards a maximum of manifestation"; this refers to the presence of life everywhere on Earth, as well as the principle of the pressure of living matter upon itself. The second biogeochemical principle states: "The evolution of species, in tending towards the creation of new forms of life, always move in the direction of increasing biogenic migration of the atoms in the biosphere. . . . The second biogeochemical principle regulates the course of evolution. A newly evolved species will survive in the biosphere only if it is sufficiently able and sufficiently active in furthering the migration of atoms. The organism cannot be considered apart from its medium. It is a part of the complex mechanism of the biosphere." Here Vernadsky concludes his study of the biosphere with a consideration of the laws regulating evolution that, for him, are to be sought in the mechanism of the biosphere and not in accidental circumstances. For this reason "evolution must proceed, namely, in the direction of increasing consciousness and thought, and of forms having greater and greater influence on their surroundings."5 This consideration leads Vernadsky to domains of philosophical or religious thought. Why?

"We are confronted with a new form of biogenic migration resulting from the activity of human reason. Human thought has changed in a brisk and radical manner the trend of natural processes and has even modified what we call *natural laws.* Consciousness and thought, despite the efforts of generations of thinkers, have never been defined, have never been given a physical basis, in terms of matter and energy."6 And here Vernadsky poses a question that remained unanswered for him but that also leads to a consideration of the noosphere: "How can processes which seem purely physical be affected by consciousness?"7

Although *The Biosphere* is the initial statement and underlying basis of all Vernadsky's later thought and work, his final major study, *Problems in Biogeochemistry II,* translated and published by his son, George Vernadsky, at Yale University in 1944, states the final conclusions of Vernadsky on the intriguing relation of human consciousness-via its thought and projected dynamic, the machine-on the biosphere. These reflections provide us with a means for defining more precisely the nature of the technosphere and noosphere.

FROM THE CREATION OF THE TECHNOSPHERE TO THE ADVENT OF THE NOOSPHERE

Vernadsky developed the biosphere into a full scientific description of the sum of life and its support systems on Earth, and was a co-originator of the concept of the noosphere, yet he seems never to have used the word or concept of the technosphere. In some of Vernadsky's descriptions of the relation of man and his thought on the biosphere, however, the technosphere is absolutely implied. In reading the following chain of Vernadsky's thought, we can discern what we refer to as the biosphere-technosphere-noosphere continuum:

> Man by his work and his conscious attitude toward life is remaking a terrestrial envelope, the geological domain of life, the biosphere. He is transforming it into a new geological state, the noosphere.
>
> He creates within the biosphere new biogeochemical processes that did not exist before. A planetary phenomenon, the biogeochemical history of the chemical elements is notably changed.
>
> An immense new form of biogeochemical energy is represented by the technological work of man, complexly guided by his thought. It is interesting that the increase, in the course of time, of machinery in the structure of human society also proceeds in geometrical progression, just like the reproduction of any kind of living matter, man included.
>
> Statesmen should be aware of the present elemental process of transition of the biosphere into the noosphere. The fundamental property of biogeochemical energy is clearly revealed in the growth of free energy of the biosphere with the progress of geological time, especially of its transition into the noosphere.8

In this sequence of thoughts, we understand that Vernadsky, in his precise location in time, was himself the necessary voice of the biosphere giving rise to the noosphere. Put in another way, the very process that Vernadsky is describing-the transition of the biosphere to a new geological state, the noosphere-necessitated a coming into consciousness of itself, a self-reflective medium and voice. This self-reflective medium and voice of the biosphere-noosphere transition was Vernadsky

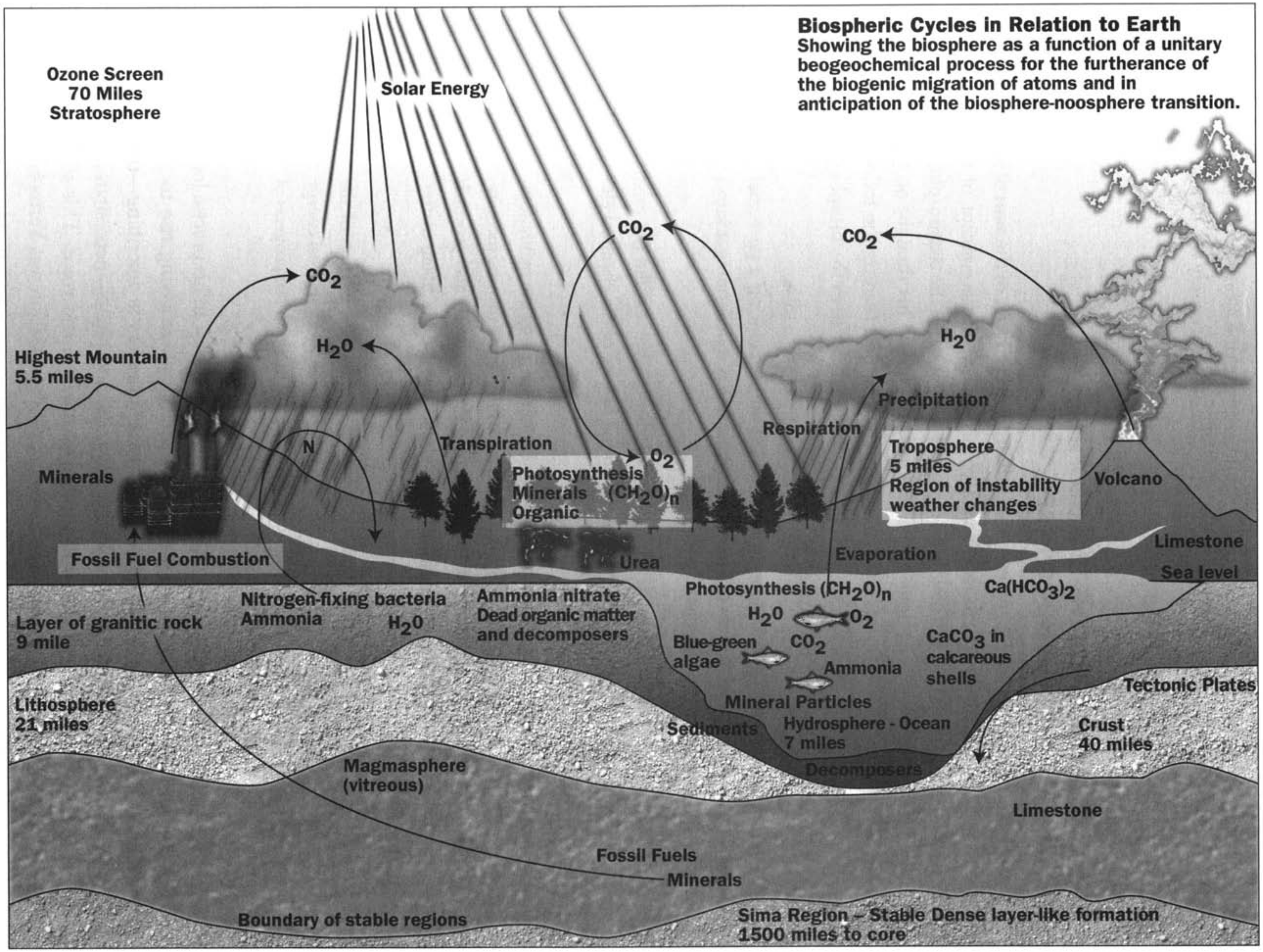
Biospheric Cycles in Relation to Earth
Showing the biosphere as a function of a unitary beogeochemical process for the furtherance of the biogenic migration of atoms and in anticipation of the biosphere-noosphere transition.
Ozone Screen
70 Miles
Stratosphere
Solar Energy
CO_2
CO_2
CO_2
H_2O
H_2O
Highest Mountain
5.5 miles
Minerals
N
Transpiration
O_2
Photosynthesis
Minerals
$(CH_2O)_n$
Organic
Respiration
Precipitation
Troposphere
5 miles
Region of instability
weather changes
Volcano
Limestone
Sea level
Fossil Fuel Combustion
Urea
Evaporation
Nitrogen-fixing bacteria
Ammonia
H_2O
Ammonia nitrate
Dead organic matter
and decomposers
Photosynthesis $(CH_2O)_n$
$Ca(HCO_3)_2$
H_2O
O_2
Blue-green
algae
CO_2
Ammonia
$CaCO_3$ in
calcareous
shells
Layer of granitic rock
9 mile
Lithosphere
21 miles
Mineral Particles
Sediments
Hydrosphere - Ocean
7 miles
Decomposers
Tectonic Plates
Crust
40 miles
Magmasphere
(vitreous)
Limestone
Fossil Fuels
Minerals
Boundary of stable regions
Sima Region – Stable Dense layer-like formation
1500 miles to core

Biospheric Cycles

himself. In this observation we may understand that, although unconscious until it was made precipitant by the accelerated biogeochemical combustion itself, the order of the noosphere is none other than what the Law of Time defines as the synchronic order. As the structure of fourth-dimensional time, the synchronic order is a fluid, radial chronomantic structure in which time, telepathy, and consciousness are united in ways unpredictable to even the most advanced Western systems of mathematics.

For Vernadsky the sum properties of the elements of the biosphere are the functions both of mathematics and of different kinds of geometries. It is of note that in the summation of the differences between inert and living bodies according to three factors, the first being energy and the second chemical manifestations, Vernadsky defines the third factor as "differences in regard to space-time." Of this factor, Vernadsky writes:

> In considering space-time, however, the situation becomes rather involved. Here we enter, on the one hand, a domain not studied scientifically, and on the other hand, that substratum of all natural phenomena, namely their geometry, which the naturalist in his scientific work is wont to dismiss without attention. This substratum, the geometrical state of physical space, underlies all physiochemical phenomena and perhaps has an even deeper reality than that of the phenomena themselves.[9]

This deeper reality is the phenomenon of time itself, expressed through various geometries or geometrical principles, which informs the manifest phenomena of life. This is an obviously aesthetic factor as well as a cosmological principle.

The Dynamics of Time fully substantiates Vernadsky's perception of the geometrical ordering principle of the deeper reality of time:

> All geometric forms are radiative and derive from the fourth-dimensional radial matrix. All fourth-dimensional functions are radial in nature and imply a principle of center from which the structure is projected. . .
>
> Geometry is how fourth-dimensional time incorporates as third-dimensional form. The incorporation of time as geometrical form informs all of the inorganic and organic orders of the realm of instinct. Time incorporated as the geometry of form is the principle example of T(E) = Art. All forms and species participate in varying orders of geometry of form, both in their bodily structure and their forms of process.[10]

If the question is asked, Where is this deeper reality of fourth-dimensional time from whence the projective geometries are generated? then we must answer that it is here in the noosphere, the medium on Earth for the transformation of cosmic thought.

It is the noosphere that informs all of the forms of the biosphere, inert and living, as well as producing in all genuine thought a structure and an order that are continuously moving in the direction of greater consciousness. To even think about the noosphere is to be a reflection of it.

As a noospheric medium, Vernadsky's life span was precisely timed to end when the global structure of the technosphere was about to be unconsciously constructed. The ingredients of the technosphere are indicated in the above-quoted passages as the planetary phenomena altering the biogeochemical history of the chemical elements, transforming them into an "immense new form of biogeochemical energy represented by the technological work of man, complexly guided by his thought." It is the increase, over the course of time, of machinery in the structure of human society that proceeds in geometrical progression-just like the reproduction of any kind of living matter, man included-and that constitutes the general nature of the technosphere. The growth of "free energy," the often toxic by-products of the industrial transformation of raw goods into consumer products, becomes the hallmark of the technosphere, the transitional stage between the biosphere and the noosphere.

It is this very point of the elemental process of the production of "free energy" and what it signifies in terms of the transformation of the biosphere into the noosphere that causes Vernadsky to call statesmen to attention. Why? As we know today, fifty-six years after Hiroshima, "free energy" in various manifestations has been causing danger signals to go off throughout the biosphere-from ozone depletion to global warming to nuclear radioactivity. What these danger signals have been telling us is that the techno sphere is coming to a point of its own exponentially accelerating biogeochemical combustion. Statesmen and politicians are advised by Vernadsky because the domain of their political rulership actually encompasses the everyday governing of the technosphere. But, alas, most people, statesmen included, are still unconscious of the existence of the technosphere, much less its role in relation to the biosphere and the forthcoming geological state, the noosphere. Hence, the Inevitable Event.

During much of Vernadsky's life, the geochemical combustion and release of "free energy" was just coming into its own. At his birth in the middle of the nineteenth century, the world was not yet globally industrialized, and without a totally globalized industrial base there can be no technosphere. The critical span of the two world wars, 1914-1945, was for the purpose of establishing the world market-a total industrialized market and communications base for the expansion of technology and the creation of the unifying global structure of the technosphere. The inauguration of the atomic age at Hiroshima, August 6, 1945, marks the precise beginning of the dual factors: the commencement of biogeochemical transmutation and combustion of the biosphere by the impact of human thought, the atomic bomb and release of nuclear radioactivity into the terrestrial atmosphere; and simultaneously, the beginning construction of the technosphere.

The bomb created a point of critical self-awareness within the human organism as well as producing in that organism an unprecedented sense of its own power. It was this sense of power that necessitated the unconscious impulse toward putting into place the structure of the technosphere. Of course, at the outset the species was only responding to a new, uncharted world situation, fundamentally unaware both of what it was creating as well as of the fact that it was actually constructing something in the nature of a transition between two geological conditions, the biosphere and the noosphere.

It could be said that Hiroshima lit the fuse of the final stage of biogeochemical combustion, the technosphere being the inevitable structure needed for the fuse to detonate at just the right moment. In this regard the synchronic order of the Law of Time ordained a precise 56-year cycle for the existence of the technosphere: 1945-2001. It is important to grasp that in this 56-year cycle the human population quadrupled, expanding from 1.5 to more than 6 billion. The 56-year cycle divides into precise subcycles of twenty-eight years each. The first twenty-eight years, 1945-1973, begins with Hiroshima and ends with the completion of the World Trade Center towers in New York City. This marks the accomplishment of the creation of the "World Market," the actual transformation of the biosphere into the technosphere. The second 28-year cycle, 1973-2001, spans from the dedication of the World Trade Center towers to their destruction by an act of suicidal planetary terror, and marks the phase of "globalization" -the absolute dominance of the materialist market economics, inclusive of the dramatic end of the Cold War in 1990. The very midpoint of the second 28-year cycle is the Harmonic Convergence of August 16-17, 1987, exactly fourteen years after the dedication of the World Trade Center and fourteen years before the inevitable moment of their destruction.

A profound statement of the way in which the Law of Time governs the entire biosphere, inclusive of the artificial and transitional structure of the technosphere, lies in the fact that the Gregorian calendar-an otherwise irregular and confusing pseudostandard of measure-is nonetheless coordinated by the Law of Time to repeat its cycle precisely every twenty-eight years. What this means is that the days of the week and months for the Gregorian calendar year 1945 repeated again in 1973, and yet a third time in 2001. The program prefiguring the Inevitable Event was already tested at Trinity Site (July 16, 1945), and established as the atomic destruction of

Hiroshima (August 6, 1945) and Nagasaki (August 9, 1945). This program of mass destruction was sublimated in 1973 as the triumphant completion of the Twin Towers of the World Trade Center, only so that in 2001 they could be the apocalyptic target of the inevitable 9-11 planetary red alert and moral emergency catastrophe, the only rival of Hiroshima and Nagasaki in fifty-six years. We shall return to this point later in our discussion on the Law of Time and the role of calendars as macro-organizing, programming factors that control the functioning of the human in the biosphere.

It is of special note that the very last work published before Vernadsky's death was the essay "Some Words about the Noosphere." In his vision, Vernadsky could hardly have conceived of what was to occur first as the technosphere. Yet, he wrote in this last essay, published 1944:

> The historical process is being radically changed under our very eyes. For the first time in the history of mankind the interest of the masses on the one hand, and the free thought of individuals on the other, determine the course of life of mankind and provide standards for men's ideas of justice. Mankind taken as a whole is becoming a mighty geological force. There arises the problem of the *reconstruction of the biosphere in the interests of freely thinking humanity as a single totality.* This new state of the biosphere which we approach without our noticing it is the noosphereY

By contrast, Teilhard de Chardin, in his most famous book, *The Phenomenon of Man* (1959), defined the noosphere as a "new canopy," a "thinking stratum" that has been unfolding since the end of the Tertiary period, and has since been unfolding discontinuous with and above the biospheric world of plants and animals. Teilhard de Chardin also speaks of "planets with noosphere," those worlds where the enlightenment of humanity has become synonymous with the life of the planet as a whole system. The one path to the noosphere defined by a scientist in Marxist Russia and the other by a Catholic biologist both point to the same radically positive end vision of the evolution of humanity, a fact that in itself is a dissolution of any kind of contradictory dialectic. Only history is governed by the merciless dialectical movement of matter and thought, rich and poor, material and spiritual. Clearly, therefore, the noosphere is beyond or after history. In this regard then, the technosphere is the concluding stage of history, to be followed by the post-historical noosphere.

The establishment of the techno sphere after his death notwithstanding, it is still important to listen to Vernadsky's idealism with regard to the noosphere: "The problem of planned, consistent activities which will aid us in mastering nature and accomplishing the correct distribution of wealth, connected with the comprehension of the unity and equality of all people, of the unity of the noosphere, is now on the agenda. . . It has become clear, and is more deeply penetrating the consciousness of mankind, that we now have a real opportunity to obliterate malnutrition, starvation, and poverty, to greatly diminish the incidence of diseases, and prolong human life to the maximum."12 Other thinkers like R. Buckminster Fuller have uttered similar statements, that we have all that is needed to adequately take care of everyone on the planet. It is important to understand why this optimism has yet failed to be substantiated. If anything, the inequality in wealth between that of the several hundred billionaires in the world and that of the poorest one-third of humanity, two billion humans, was never historically more disproportionate than it was at the moment of the Inevitable Event. This inequality of wealth, too, is a situation endemic to the very processes of the technosphere, otherwise known as the military-industrial complex.

In 1970 an American scientist, G. E. Hutchinson, wrote in the *Scientific American*, "By noosphere Vernadsky meant the envelope of the mind that was to supersede the biosphere, the envelope of life. Unfortunately the quarter century since those words were written has demonstrated how mindless most of the changes wrought by man on the biosphere have been. Nonetheless, Vernadsky's transition in this deepest sense is the only alternative to mankind shortening its lifetime by millions of years."13

A similar assessment was put forward in 1979 by the Belgian ecologist P. Duvigneaud in his presentation "Noosphere and the Future of the Vegetation of the Globe." In his address regarding the extermination of natural ecosystems made to the Twelfth International Botanical Congress, Duvigneaud makes one of the earliest and most prescient uses of the word *technosphere:* "Thus, the noosphere, so dear to Vernadsky . . . is running the risk in reality of turning into the technosphere, or rather into 'the sphere of avidity,' governed by the spirit of fortune-hunting, by mediocrity, by the absence of social consciousness, by the ideal of destruction and by the egotistic doctrine of 'after me, the deluge.'"14

To be precise, it was in 1973, the same year of the Club of Rome's landmark publication *The Limits of Growth,* and of the establishment of the World Trade Center in New York, that the technosphere became a coherent structure smothering the biosphere, co-opting the noosphere, and coordinating the very processes of greed and destructive fortune-hunting abhorred by the ecologist Duvigneaud. Like it or not, the techno sphere was the inevitable result of the unloosing of the machine into the biosphere. It may be asked: if the machine is a projection of human biology, then what purpose does it actually serve in the biosphere, and what is it that actually produced it and keeps it going?

Before turning our attention to the answers to these questions, let us first define the technosphere as being the artificial structure replacing the human civilization,

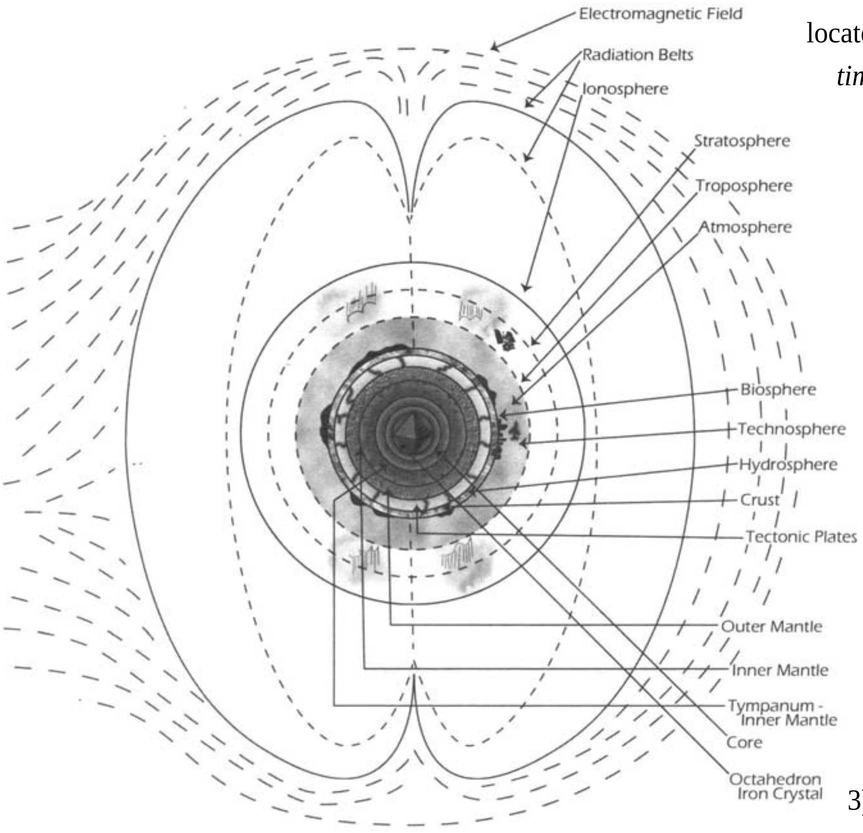
Electromagnetic Field
Radiation Belts
Ionosphere
Stratosphere
Troposphere
Atmosphere
Biosphere
Technosphere
Hydrosphere
Crust
Tectonic Plates
Outer Mantle
Inner Mantle
Tympanum - Inner Mantle
Core
Octahedron Iron Crystal

Earth's Mantles

located mentally and physically *in time* as a force intermediate to and between the biosphere and noosphere. Defined by the *Biosphere Catalogue* (1985, p. 103), the artificial structure of the technosphere consists of five interlocking, coordinated systems that comprise an integral whole, both as a belief system and as an actual complex technological dynamic and its coordinating apparatus. The five components, which we shall discuss at length in later chapters, are: 1) commodity production, 2) the city, 3) energy, 4) transport, and 5) communication. And, according to the *Biosphere Catalogue,* the planetary core of this interlocking set of systems was none other than the World Trade Center's Twin Towers.ls

As a planetary sphere, the technosphere takes its place with the other spheres or mantles comprising the structure of the Earth as a whole system. Beginning at the outermost etheric realm and proceeding inward, these spheres or mantles include: the electromagnetic field with its radiation belts, then the ionosphere, stratosphere, troposphere, atmosphere, technosphere, biosphere, land-ocean crust, tectonic plates, lithosphere, outer and inner mantles, and finally the core, now known to consist of an outer tympanum, and within it a large octahedral iron crystal afloat in a sea of magma.

As a planetary sphere, the technosphere negates time and consciousness as organic realities and replaces them instead with mechanization and marketing. Yet the technosphere is a product of mankind, and mankind is a function of the biosphere. The organization of life into biomes, large macro-ecosystems, is still evident, though in diminishing and withering proportion to the conquest of the technosphere. With the Final War now upon us, the question we must ask is: will the technosphere collapse before the biosphere or not? As catastrophic as it might seem, the collapse of the technosphere would actually be a blessing in disguise from which the noosphere could finally be realized. But if the biosphere collapses first as the result of the Final War on Earth, then the technosphere will be futile, pointless, and dead as well. These are most dire thoughts in these most dire of times. Yet if we can now finally understand and accept our role within and subordinate to the biosphere as a whole, then our chances for survival will be greatly improved.

Let us consider again what Vernadsky has to say about the human's place in the biosphere:

> 1. Man, as observed in nature, like all living organisms, like any living matter, is a specific *function of the biosphere,* within its specific definite space-time.
> 2. Man in all his manifestations constitutes a regular part of the structure of the biosphere.
> 3. The *explosion* of scientific thought in the twentieth century *has been prepared for by the entire history of the biosphere* and has its deepest roots in the structure of the latter. The civilization of "cultured mankind," insofar as it is a form of organization of the new geological force which has formed in the biosphere, *cannot be interrupted or destroyed,* since it is a great natural phenomenon, historically, or rather, geologically corresponding to the established orderliness of the biosphere.[16]

If Vernadsky is correct, then the war we are witnessing is the inevitable conclusion of the biogeochemical combustion that consumes the technosphere and establishes the pristine reality of the noosphere. This is especially true if we understand this war to actually be a geopolitical struggle for the control of the oil reserves of the Persian Gulf, or even more broadly, as the war between matter (globalization) and spirit (Islam), or more grimly, as Oswald Spengler put it, the final war between blood and money. This being the case, it is more important than ever to answer the two unresolved questions in Vernadsky's definition of the biosphere, the question of consciousness and the question of time.

According to the Law of Time, the answers to the questions posed by Vernadsky are actually one and the same thing. "How can processes which seem purely physical be affected by consciousness?" The question asked by Vernadsky at the conclusion to *The Biosphere* is equaled by the unresolved issue of time discussed at the conclusion to *Problems of Biogeochemistry* JI.1n essence, Vernadsky declared, we know everything about the biosphere, its governing laws, principles, and functions, with the exception of the mysterious relation of time to the biosphere. Virtually alone among modern scientists, Vernadsky perceived that time actually has nothing to do with the metrics of space, and that "time is not a dimension of metric geometry." This means that time is not only its own dimension-the fourth dimension-but that time must also have its own metrics and system of measure totally apart from the metrics of space.

> Minkovsky's and his predecessors' concept of time as the fourth dimension of space is a mathematical abstraction having logically no ground in scientific reality. Time is not a dimension of metric geometry. In geometry, time may be expressed vectorially, but it is obvious that such an expression does not embrace all of its properties in natural phenomena studied by the naturalist. . . The time of the naturalist is not the geometrical time of Minkovsky, nor is it the time of mechanics and theoretical physics.[I?]

In Vernadsky's perception of time, there is a profound critique of the approach that has been established toward the measure-and hence understanding-of time in physicalist science. For Vernadsky, time is a function of an as-yet-unrealized geometry: "This geometry would reduce all space to a point supplied by an infinitesimal vector." Clearly time is a factor in all the functions of the biosphere, most evident in the biological life processes. Hence the Law of Time has been a regulating factor, the true nature of which we have been profoundly unconscious. Now here is an interesting reflection. If the biosphere as a whole system is tending toward a total whole system transformation into a state known as the noosphere, a fact perceived by Vemadsky during his lifetime, and the two unresolved issues are the issues of time and consciousness, both materially intangible dimensions, does it not seem correct that the resolution to these two issues will actually foster the manifestation of the noosphere, which is, after all, the mental envelope of Earth? And does it not also seem that as long as the two issues of time and consciousness remain in a state of ignorance or confusion within the mental functioning of the human order, that the vehicle of geochemical combustion, the technosphere, will tend toward its own dissolution until the issue of time and consciousness is resolved and clarified once and for all?

The perilous passage, the biosphere-noosphere transition, may actually be defined as the consequence of operating in ignorance of the actual nature of time and consciousness. In this way, the techno sphere may be defined as the artificial compromise in place of the true understanding of time and consciousness of the human order in the biosphere. Hence, the technosphere is the responsible intermediary agent creating the crisis of the noosphere. The solution to the questions of time and consciousness is thus the solution to the noospheric crisis, and the commencement of the grand new era, the true golden age of the whole Earth.

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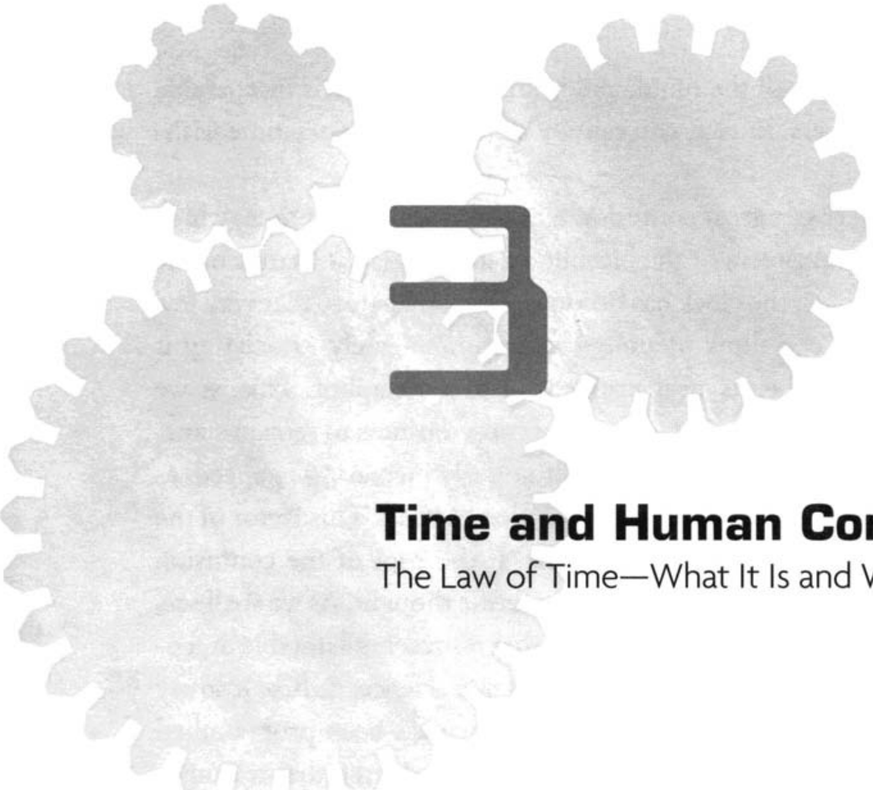

3

Time and Human Consciousness

The Law of Time—What It Is and Where It Came From

HAVING DEFINED the technosphere as the intermediary stage in the biogeological continuum of the biosphere's evolution into the noosphere, we may now turn our attention to the unresolved issues of time and consciousness in the biosphere. These issues must not be seen as just the problems of humanity. Since humanity is a function of the biosphere, the issues therefore relate to the biosphere becoming more conscious. It is the conscious aspect of matter that directs the biosphere toward its transformation into the noosphere. It is the discovery of the Law of Time that complements and resolves the issues that were left unresolved in Vernadsky's definition of the biosphere and of its transformation into the noosphere. The question then arises: what is the Law of Time, and how does it define time and consciousness as mutually coordinating factors of the same cosmic dimension intersecting with the biosphere?

To say the least, time is such a vast and important topic in the orientation of human consciousness within the biosphere that we may declare that it is paramount in all human affairs. Indeed the cosmic order, of which the biosphere is the dynamic regulatory mechanism on planet Earth, is itself the expression of time as the medium of universal manifestation. Yet, as Vernadsky perceived in 1944, while we have defined space by its own systems of metrics and geometries, by applying these same standards to time we have not defined or known time at all. The cause for this quandary seems to lie in the fact that while space is perceptible as a sensory medium-we can see it, touch it, hear through it-and hence, it is evidently measurable, the same is not the case with time. Time is of the mind, and in this regard, time is inseparable from the issue of consciousness. In fact, you cannot know or experience time without becoming conscious.

Yet, as we shall see, there is a great confusion when we speak about time, which is actually at the root of the problem of the biosphere, and that is the matter of the clock. In human consciousness, the clock has become so second nature that very few people in industrial society can think of time without immediately associating it somehow with the clock, whether as an instrument or as a metaphor. This, as we shall see, is a major factor causing the general state of consciousness to remain static, especially in relation to the machine, which is continuously increasing in speed, as well as accelerating in the propagation and multiplication of itself. This factor of the clock-in other words, of mechanized time-is also at the root of the confusion concerning the nature of time in much of modern scientific thought. As we shall see, there is a stream of Russian thought after Vernadsky that represents a notable exception to the established view of time in modern thought and science. Suffice it to say that the evolution of modern Western thought and science has been programmed and predisposed to limit its consciousness of time to such a degree that it cannot even perceive of time outside its inherently mechanized perceptions about it. In this obviously also lies the problem of the delimitation of consciousness in the technosphere.

"The deepening crisis of the world outlook is rooted in the permanence of the dominating scientific paradigm," writes Russian scientist Maria Maroushkina. "Underlying the materialistic technocratic civilization is the Newtonian-Cartesian paradigm, formed in the Middle Ages, its nucleus being the laws of gravitation and movement, as well as the logical principles of proof, laid down by Descartes."! This "permanent" stratum of belief, a cultural metaprogram, locks every field of human endeavor into a conquest by mechanization. It is this metaprogram rooted in the simple unexamined device of the clock, and orchestrated by the equally unexamined effects of an irregular calendar, that keeps human consciousness unchanged and without any real solutions to its problems. As the problems worsen, the confusion of consciousness-which is really in a state of crisis-only deepens.

To illustrate the current state of confusion regarding time in Western thought, we have the report of the prestigious Seven Pines Symposium on Time held in Stillwater, Minnesota in June, 2001. The *New York Times* article regarding the Seven Pines Symposium is entitled "Physics' Big Puzzle Has Big Question: What Is Time?"2 First of all, the assumption that time is basically a topic of physics in itself is a problem, since time, as we have demonstrated, is actually mental in nature, and if any-

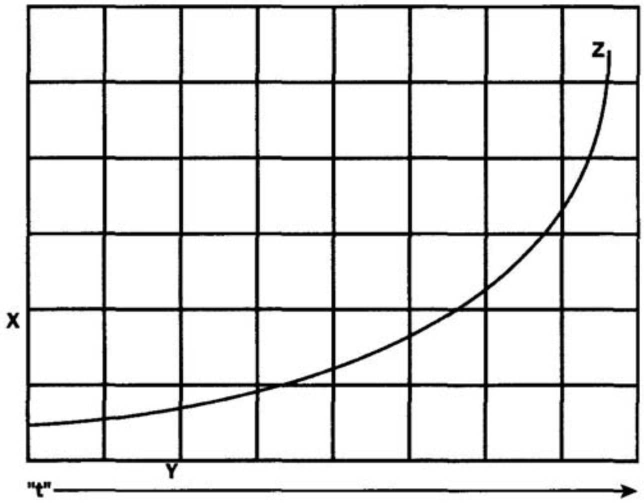

"Arrow of time" in modern scientific three-dimensional coordinate graphing, reinforcing illusion of linear time.

Arrow of Time

thing is most visibly manifest in the domain of biology or biogeology. But this headline is also reflective of the paramount role that physics plays in the Western intellectual hierarchy: if physics can't solve it, than what can?

Despite the prominence of physics and physicists, the Seven Pines Symposium included historians and philosophers as well. The hope of the symposium was to arrive at a unified theory that encompasses the effects of gravity as described by Einstein's general theory of relativity and the "fuzziness that occurs in the realm of tiny particles according to quantum physics."3 Here we have the problem of time as delimited by the self-imposed spectrum of modern physics. What then could we expect? Certainly no one here had considered the point made by Vernadsky that time is not a function of the metrics of space, which is the realm of physics. So it is not surprising that the symposium ended in a muddle, with the most prominent approach being that time could merely be a "psychological illusion" important to humans but not a fundamental part of any unified theory. It is also clear that few, if any, had considered that their views on time might be absolutely conditioned by the mundane and ordinary everyday micro- and macro-organizing factors: the mechanical clock and the Gregorian calendar with its second cousin, the Julian count of linear time.

From the point of view of the noosphere, of course, this grand Symposium on Time was reflective of very little of the entire human organism, much less of the biosphere itself. The symposium was a representation of the elite intellectual class of the dominant economic, military, and political power of the planet, and hence of the governing force of the technosphere, the United States of America. But if a realization that we are a function of the biosphere is critical to our success in launching the noosphere, and the issue of understanding the correct relation of time to the biosphere is crucial even to the ability to launch the noosphere, then the Seven Pines Symposium did not even approach the actuality of the current biospheric situation or the nature of time. In this regard it was only a contribution to further the psychoatmospheric density-clouded thought without clarity of purpose-and one more reason why the Inevitable Event was on the biosphere's agenda.

If one does not apply certain biospheric yardsticks to the analysis of what is reported as truth, then we will be sunk in a chaotic morass of half-truths that are really obscurations or even lies. The elite American nation, for instance, constitutes only 5 percent of the world's population, yet consumes 40 percent of its natural resources, and therefore has the wealth and power to maintain the military force (allotted a $318 billion budget for 2001-2002) to protect and even further as its right this disproportionate ratio, which is actually a violation of the dynamic balance of the biospheric processes. For this reason, through its official organs of propaganda such as the *New York Times,* America is able to muster the "influence" of whatever occurs within its confines as somehow having more merit than what might be generated in some other nation or country. So a human may read the story in the *New York Times* on the "Big Puzzle of Time," and most likely they will complacently accept its premise as absolute truth. Yet this social construct of symposium-and-newspaper-story is nothing but an aberrant mental form that obscures the actual nature of time and keeps the mental level at a constant state of "industrial dull-normal," far removed from-or at best, little more than a highly distorted reflection of-the reality of the noosphere.

Leaving aside this example of the mental confusion over time, it is necessary to understand from the investigations regarding the biosphere and according to Vernadsky's own judgment, that the biosphere in all its intricate and interlocking processes possesses and is guided by a great order and even a structural dynamic that, being manifestations of the laws of nature, can be given exact mathematical formulation. Why should we not expect that the nature of time in the biosphere should also be characterized by the same orderly quality? In fact, given that the biosphere is actually a life process, like all living matter it too must be governed by timing cycles. Thus the larger order of time that governs the cycles of the biosphere and of the noosphere must also exhibit a grand ordering principle. For if the three dimensions of space govern the domain of the physical world, then the fourth dimension of time-which governs the life not only of the biosphere but of planets, star systems, whole galaxies, and indeed the entire universe-must also consist of a simple, orderly formulation totally apart from the perception of time that governs the stunted consciousness of the technosphere. Such is the Law of Time.

THE FOURTH-DIMENSIONAL NATURE OF TIME

> *"Even though you do not measure the hours of the day as long or short, far or near, you still call it twelve hours. Because the signs of time's coming and going are obvious, people do not doubt it. Although they do not doubt it, they do not understand it. Or when sentient beings doubt what they do not understand, their doubt is not firmly fixed. Because of that, their past doubts do not necessarily coincide with their present doubt. Yet doubt itself is nothing but time."*
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> -DOGEN, "THE TIME-BEING"4

These prescient words of a thirteenth century Japanese Zen master are more true today than they were when he wrote them. Comprehensive studies like the *Eranos Yearbook III: Man and Time* (1957), which included Carl G. Jung's ground breaking essay on synchronicity, or James T. Frazier's fascinating and monumental *Voices of Time* (1966), only expand the multidisciplinary breadth of the confusion about time. In the 1970s Frazier helped found the International Society for the Study of Time. The Society is still meeting annually but has yet to reach a definitive agreement on or understanding of the question of time. It is in the context of the enduring confusion over time that the Law of Time was discovered. To say that the Law of Time has been "discovered" only means that a principle and fundamental law that has always guided the order of the universe has finally been made conscious and articulated in a precise way that is recognizable to the present condition of the human mental nature, which is still dominated by the physicalist model.

In the whole of modern physics, Minkowski's fourth dimension of time has been misunderstood and treated as if it were a minor dimension, one that is just added on, but not really significant to the level of the three dimensions of space. This is due to the already space-oriented consciousness deriving from certain sets of perceptions established early in the history of civilization and standardized through certain programming models that are based on the metrics of space and not time, a topic to which we shall soon turn. It is for this reason that in the formulations of modern physics time is symbolized by a small *t* that runs in a horizontal line running from left to right at the bottom of any graphing of space with its *x* and *y* coordinates.

This graphing of small *t* time gives rise to the notion of the "arrow of time," which is virtually a bedrock dogma of much of modern Western physics. This is the much-touted notion of linear time that supports doctrines of economic inexorability, material progress, and the like. Of course to anyone versed in the ways of nature, linear time and the arrow of time can be seen as nothing more than artificial constructs, for the biological nature of time is perceptible at the very least through the great interlocking cycles of nature. Nor is there anything linear about the Earth's rotations around the sun, or of the moon around the Earth, all of which give lie to the physicalist and materially progressivist notion of linear time. Only the technosphere, sustained in its structure by the limited consciousness of time, is driven by this linear principle and for this reason is doomed to run aground on the shoals of its own artificiality.

TIME AS THE UNIVERSAL FACTOR OF SYNCHRONIZATION

The nature of time is grasped poetically in the form of cycles: "To every season there is a time. . ." Biorhythms can even be mapped and the cycles of the biological order of reality can be demonstrated as functions of a chronobiology. But the biological cycles only demonstrate the manifestation of time in the space ofliving matter. If the whole of nature is observed, then one can begin to grasp the masterful orderliness by which every least detail occurs in relation to all the other details in their various cycles-yes, one can grasp in this phenomenal order another deeper aspect of time, and that is time as the universal factor of synchronization. This is the synchronic order of time, the order by which everything in the universe occurs simultaneously in a masterful synchronization from moment to moment in an ever-changing kaleidoscope of infinite varieties of order and harmony.

Only historical man deviates from this masterful symphony of time, the synchronic order. Nonetheless, we speak of being "on time," "in sync," "in tune," "in resonance," "in harmony," or of being "tuned-in." All of these expressions refer to the attunement of time and the nature of consciousness as awareness in the present moment, in the here and now. This is possible because the same law governs both time and the relation of consciousness to the moment. To answer Vernadsky's question, "How can processes which seem purely physical be affected by consciousness?"- the physical is affected by consciousness, because consciousness is actually a function of time. When someone "discovers" a law of nature, it is because their consciousness is attuned to the natural process in time, and the law therefore "reveals" itself.

But this consciousness can be and most often is of a profoundly unconscious nature. Time is actually the governing principle of a higher self-existing consciousness that regulates the order of the universe, both in regard to its living and non-living matter. Because time continuously synchronizes everything into a single coherent whole from the micro to the macro levels, time accounts for the harmony of the universe. Only man deviates from the universal harmony, and the technosphere, a projection of the human mechanization of time, intrudes upon the intrinsic harmony to the point of its own demise, but man deviates for a purpose.

The harmony manifested by time as cosmos-which literally means "order" -gives rise to the great and simple formulation of the Law of Time: T(E) = Art; Energy factored by Time equals Art. This means that energy, any manifestation of the physical three-dimensional world, possesses order and is in harmony with its environment because it is factored by time. In the conception of the Law of Time, however, capital *T* refers to time as the universal factor of synchronization. As the universal factor of synchronization, time is defined by the self-existing and intrinsically perfect mathematical ratio 13:20. Derived from the mathematics of the ancient Maya, this ratio is a universal constant of time that organizes all of the universe as a radial sequence of synchronous moments reflecting different evolutionary phases simultaneously. Because everything perceived is an aspect of instantaneous universal synchronization, time is also the medium of instantaneous information transmission throughout the universe.

The noted Russian astrophysicist N. A. Kozyrev (1908-1983), whose work began half a century ago with the theory of the internal structure of stars, later conducted a famous series of experiments using telescopes, mirrors, and aluminum, in which he was able to confirm a receipt of information from distant galaxies prior to the time it took the information to arrive via light as a physical medium. In Kozyrev's own words: "The tests proved the existence of the effects through time of one material system upon another. This effect does not transmit a pulse (momentum), meaning it does not propagate but appears simultaneously in any material system. In this manner, in principle it proves possible to have a momentary relationship and a momentary transmission of information. Time accomplishes a relationship between all phenomena of nature and participates actively in them. . . . Time contains the entire universe of still unexplored phenomena."5 The results of these experiments led Kozyrev to various conclusions, among them that time and duration are not the same thing, and that the velocity of time is instantaneously infinite, formulated as

$$T_V \longrightarrow \infty$$

Formulation: velocity of time is instantaneously infinite

This being so, time must also be the factor or medium that accounts for the experiences of telepathy or other paranormal phenomena. A second, most provocative conclusion derived from his experiments is that time is actually generated as an instantaneous and even simultaneously radial transmission of information from the core of stars, a fact confirmed by the Law of Time's description of the synchronic order of time as being radial in nature.

FURTHER EXPANSES OF FOURTH-DIMENSIONAL TIME: THE EVOLUTION OF TIME AS CONSCIOUSNESS

Leaving aside for the moment further discussion of Kozyrev's seminal work and its conclusions, at this point let us summarize the two chief qualities of time as defined by the Law of Time: 1) time is the factor of universal synchronization, and 2) time possesses an infinite instantaneity of velocity that is faster than the speed of light, and hence is correlated with telepathy. From these two determining features of the nature of time, two other corollary conclusions may be drawn: 3) the cyclic nature of third-dimensional biological phenomena is a function of the factor of universal synchronization which establishes harmonic ratios that determine the different life processes of different organisms, while 4) the ability of any species or organic whole to maintain its unity with itself and all of its members or parts is an instantaneous function of time as telepathy.

To better understand the Law of Time and its radical non-linear definition of time-which is actually the noospheric description of time-we may say that time, being synchronically instantaneous, is both "vertical" in relation to space (which is "horizontal"), and "radial" from the perspective of its own dimension, the fourth. Rather than being the small *t* line or arrow at the bottom of the physicist's graph, time as the fourth dimension is greater than and inclusive of the third dimension, much as the etheric atmosphere includes and surrounds the physical Earth in a radial "all-at-onceness." To try to measure this phenomenon with the metrics of space and its essentially linear yardsticks is to constrain time into definitions and descriptions that are totally alien to its nature.

In fact, from the point of view of the dynamics of time, it is space that is the moving line, or rather a set of points in a moving vector that can be described as line. Let us extrapolate from the important observation made by Vernadsky at the conclusion to *Problems in Biogeochemistry II:* if the geometry of time reduces space to a point supplied by an infinitesimal vector, then from the point of view of time, space is an infinitely locatable point. What is this point? It is the point of awareness at which an individual body becomes aware of time. Here, the "subjective" description or experience of time cannot be separated from the issue of consciousness. (See plate 3, Model of "Vertical Time" in Relation to Horizontal Space.)

In the description of time as vertical in relation to horizontal space, this point of awareness of a body in time is defined as the Locus of Consciousness, or L of C. In the flow of moment-to-moment instantaneity that is synchronous with the flow of space, the Locus of Consciousness is that point at which time vector and space perception connect. From this defining point of consciousness in the here and now, the flow of space creates a horizontal sensation: one direction flows to the "past," the other to the "future." This is what is normally defined as the sensation of time or the arrow of time. It is actually the definition of the horizontal flow of space in relation to vertical time. What is usually not considered is the vertical dimension of time that connects awareness to space at any given moment, creating sequences of Awareness Units, or AUs.

From the defining point of the Locus of Consciousness, there are essentially two spaces and two times: *near space* and *far space,* and *low time* and *high time.* Near space corresponds to low time and far space corresponds to high time. Near space is essentially defined by the perimeter of sense experience, inclusive of the extension of the senses through technological apparatus such as telescopes, microscopes, and the like. This is the domain of low time. Far space is defined as that space beyond the perimeter of the sense perceptions, and is characterized by subliminal sensory perceptions. This is the domain of high time and the atemporality of space. In near space, low time is characterized by what appear to be "random events." The lower the time, the greater the increase of random events. Low time and near space define the qualities of the experience that are properly and purely third-dimensional. High time and far space are purely and properly the domain of the fourth dimension characterized by the dominance of the synchronic order of time.

The distinction between low time and near space and high time and far space is defined as the threshold of synchronicity. In high time, synchronicity (s) predominates and is greater than random events (re), or (s»(re). In low time, random events predominate and are greater than synchronicity, or (re»(s). Note that the realm of quantum physics occurs in the microrealm of far space. It is this factor that accounts for the "fuzziness" of the behavior of subatomic particles, quarks, tachyons, and so forth, which defy the limitations of linear time. These phenomena occur in the subliminal realm of the synchronic order. It is the human mind that is not accustomed to behavior in the pure realm of synchronicity that cannot grasp that these particles are moving according to radial laws of fourth-dimensional time, and so appear highly irregular and random to the sense perceptions of the observers that are totally conditioned by third-dimensional space perceptions. Similarly, the high time of the macro threshold of the synchronic order represents the "other side," the "hereafter," the realm of pure vision, which is also governed by strict laws of radial time, and which, to the conditioned experience of a perceiver on this side of the threshold, may appear as something from a distant future or past reality, or even as in a dream. The orderly explication of the Law of Time provides complete mathematical descriptions and principles that account for the radial order of time, even as it coordinates the near space and low time of random events.

In any case, the horizontal line of space in relation to the vertical line of time defining any given Locus of Consciousness describes the macroworld above and the microworld below. As we have noted, the higher threshold of synchronicity above the horizon of space defines the realm of *higher consciousness*; the lower threshold of synchronicity below the horizon of space defines the realm of *quantum physics.* Connecting the macro realm of atemporality and high time, and the lower or micro realm of atemporality and high time, is the vertical time vertice of the ever-present now. At the two far ends of this time vertice of the ever-present now is the Locus of God, the selfsame in each direction. These extreme points of the vertice of time return far space to the Locus of Consciousness through a process of toroidal sublimation. We are not really dealing with a description of a two-dimensional plane, but a dynamic four-dimensional model held together by a toroidal motion that is continuously returning the farthest space and the highest time, whether from above or below the threshold of synchronicity-" God" -to the Locus of Consciousness.

Depending on the clarity of mind at any given moment, the vertice of time constantly and instantaneously transmits information to the Locus of Consciousness. The discrete units of information thus transmitted are referred to as *celestial harmonics.* A celestial harmonic is described as the index of synchronic incidence defining different levels of co-occurrence. I can be in the present moment sitting in a room, and at the same time, by being fully present in the here and now, I can spontaneously experience any number of telepathic thoughts, memories, feelings of deja vu, and so forth. These experiences are the different levels of co-occurrence that define the index of synchronic incidence and are categorizable as celestial harmonics. The higher the time, the greater the density of celestial harmonics per AU (Awareness Unit). It is the vertical vertice of time and its power of transmission that account for the visionary or revelatory experiences of saints, poets, and mystics throughout the ages. It is the mathematics of the Law of Time that provides the "mapping" that explains, identifies, and even increases these different harmonic incidences of the synchronic order.

Because the vertice of time connects ultimately to the "Locus of God" -the mutually defining points that become One at the far ends of the toroidal motion of the vertex of time-this accounts for the existence of the *perennial philosophy,* the unitive nature of the most revelatory or ecstatic experiences of the great mystics and seers. It is also the relation of awareness in the Locus of Consciousness at any present moment that allows any random event of low time to trigger telepathic ascent into high time depending on the clarity of and duration of the Awareness Unit (AU). From this point of view, the random quality of events in near space is only relative in relation to the absolute nature of the synchronic order, and merely a function of the third-dimensional biological space orientation. For those accustomed to the actual nature of fourth-dimensional time, which includes and controls the third-dimensional order of near space, the random events constituting low time are actually "signs" that may be read as message bearing signals of the synchronic order of high time.

Brief reflection on this description of vertical time in relation to horizontal space will demonstrate the value of what is referred to as *meditation without an object* such as that cultivated in the Buddhist traditions, as well as affirm the One Divine Source of the purely monotheistic traditions. Without a clear mind of awareness in the present moment there can be no clear seeing of reality, nor can there be the realization that all of what our senses report to us is constructed in our own mind to conform to what we think is a universe outside of us. At the same time, if we can extend the duration of our awareness in the Locus of Consciousness indefinitely in the vertical direction of time, we come upon the ineffable experience that is an emanation of the Locus of God, however or in whatever "language" our senses may later report or define such experiences. Thus we return to the paradox of the definition of space as an infinitely locatable point-this point is none other than our own minds, in which the construct of space is created and dissolved from moment to moment. Such is the subjective description of time from the point of view of the Law of Time, a description that begs each one of us to take absolute responsibility for our own experience. But there is an "objective" description as well, in which time is also defined as inseparable from consciousness.

Implicit in the subjective here-and-now description of the experience of time is the radial matrix of time. At the experiential level it is the now-centered point in the Space-Locus of Consciousness which defines the center of a radial order of time.

Time radiates out from each here-and-now awareness moment. But the Law of Time also supplies an objective description in which the radial nature of time has two points of determining order: the point of infinite lucidity and cosmogenesis, which is the Locus of God; and the receptive locus of the infinitely locatable point, which is space as constructed by each individual consciousness. Intermediate between the two points-Locus of God and Locus of (individual) Consciousness-is the determining radial matrix of fourth-dimensional time, the universal frequency of synchronization.

Mathematically defined as the ratio 13:20 and described by the 13 x 20 matrix of the Harmonic Module, in this mathematical model of fourth-dimensional time we perceive the root of the Law of Time and its basis in the mathematics of the Mayan time science. It is important to understand very clearly that the 13:20 frequency and the mathematical matrix that defines the operations of this frequency of synchronization are the pure mathematics of time totally apart from the metrics and geometries of third-dimensional space. This is a point of profound significance to which we shall later return.

In the model of objective time, the dynamics of the Law of Time are demonstrated as the evolution of time as consciousness. Here the two unresolved issues of Vernadky's description of the biosphere are unified, the answers to which are the determining factors that allow the triggering of the noosphere: The evolution of time is inseparable from consciousness. Conversely, the evolution of consciousness is inseparable from time. Both time and consciousness are nonphysical fourth-dimensional factors coordinating the third dimension. Because consciousness is synchronized with or by time, it can affect physical third-dimensional processes, in whatever way, whether the acting agent is aware of this or not. Consciousness of the Law of Time, however, is only possible through a profound act of self-reflection. Once it has been made conscious, the discovery of the Law of Time affects the entire medium of planetary consciousness, the noosphere, at first imperceptibly, but then building to a great point of climax coinciding with the climax of the biogeochemical combustion. (See plate 4, The Dynamics of Time: Showing the Evolution of Time as Consciousness.)

This dramatic moment of the discovery of the Law of Time is evident in the graphic description of the dynamics of time, showing the evolution of time as consciousness. The dynamic of the universal, cosmically intelligent, and intelligible whole-the *galacticbrain-is* depicted as a circle encompassing the evolutionary spectrum, showing the index of energy-mind progression from the atomic cellular and biological levels to purely mental conditions of being, all of which are functions of the formulation T(E) =Art. From the point of God-Galactic Ordering Dynamic-the circle, or rather, sphere, is divided vertically and horizontally into four quadrants. The movement of the evolution of time as consciousness travels out of the God center, from right to left, and thence describes, in counterclockwise circular motion, the movement of time as consciousness passing through, or rather defining, the four quadrants, until it returns to the Source again as hyperdimensional time, or "pure mind." The left-hand side describes both the primary prelife, lower left-hand quadrant, and the primary post-life, upper left-hand quadrant. The right-hand side describes the secondary reflex life, the lower right-hand quadrant being the purely third-dimensional life (biosphere), and the upper right-hand quadrant being the evolved fourth-dimensional life (noosphere).

The lower half of the sphere beneath the horizontal line running through the God center refers to the Domain of Potentiality, the upper half to the Dominion of Time. The prelife quadrant of the Domain of Potentiality refers to the preconscious quantum dimensional space of pure energy. The lower right-hand quadrant refers to third-dimensional space, the locus of space travel and the realm of the cosmic unconscious. Within the Dominion of Time, the upper right-hand quadrant refers to the fourth-dimension time, the locus of time travel, and the realm of cosmic consciousness. Finally, the upper left-hand quadrant is the realm of hyperdimensional time, or "pure mind." By studying this graphic description, one can grasp the movement of time as consciousness from inorganic preconscious, where duration in time is virtually infinite, to the secondary reflex life, or living organic matter in the third dimension. Here time is unconscious and life builds on the cosmic unconscious as the slowly mutating and evolving biosphere. The cosmic unconscious comes to a climax in the creation of the 12:60 artificial civilization, which is really not true civilization, but rather the technosphere itself. At this point there are moments of consciousness, but only moments. True sustained consciousness is possible only in conditions removed from the technosphere.

In the evolution of time as consciousness, the discovery of the Law of Time is a product of the crisis of consciousness unable to sustain itself in the technospheric medium. That is because this medium is a pure function of artificial 12:60 time. Even though the extensions of the senses and the capacity of technology provide the human within the biosphere a holistic perspective of seeing the whole Earth from space, the consciousness is continuously subordinated to the care and maintenance of the machine (or its lifeblood, money), and so cannot remain in a sustained state of heightened awareness or continuing consciousness. Continuing consciousness is only possible with the discovery of the Law of Time, which the crises of the technosphere and of consciousness have themselves brought about. In this regard, the discovery of the Law of Time is the great point of human self-reflection that defines the advance from an exclusive third-dimensional operation and aberrant timing factor to a purely fourth-dimensional and conscious natural timing factor. It is the difference between the cosmic unconscious and cosmic consciousness, the biosphere and the noosphere-in other words, the very topic of this book.

DE CHARDIN AND THE PLANETIZATION OF CONSCIOUSNESS

The discovery of the Law of Time defines the point between the two stages of the noosphere as described by Pierre Teilhard de Chardin: "The first stage was the elaboration oflower organisms, up to and including man, by the use and irrational combination of elementary sources of energy received or released by the planet. The second stage is the super-evolution of man, individually and collectively, by the use of refined forms of energy scientifically harnessed and applied in the bosom of the Noosphere, thanks to the coordinated efforts of all men working reflectively and unanimously upon themselves. . . In becoming planetised humanity is acquiring new physical powers that will enable it to super-organize matter. And, even more important, is it not possible that by the direct converging of its members it will be able, as though by resonance, to release psychic powers whose existence is still unsuspected?"6 The identification of telepathy with the velocity of time emphatically underscores de Chardin's final point.

On the other side of the discovery of the Law of Time, civilization, having reached its climax as the technosphere, is replaced by an entirely new noospheric order of human organization defined as PAN: Planet Art Network. This is a structural definition of what Teilhard de Chardin refers to as the "planetization of consciousness." This organization (bionoospheric and not institutional) is "planet" because the human organism is self-realized as a planetary organism. It is "art" because functioning again in the natural timing frequency, the human is governed by the Law of Time, T(E) = Art, and hence the reality and the activities of everyday life are defined as art. And it is a "network" because the city, defined by civilization (literally living in cities) and which was a sustaining component of the technosphere, is no longer necessary or viable. Rather, the human becomes redistributed throughout the biosphere-what Teilhard de Chardin refers to as the "radiation of man "--connected by a telepathic network that greatly diminishes the reliance on much of the technology that characterized the technosphere. Hence Planet Art Network: the replacement of civilization with the fourth-dimensional social organization of the human functioning as the telepathically coordinating species of the noosphere. In this condition life evolves toward a hyperorganic stage, attaining a state of superconscious activity and self-reflection where time travel replaces the space travel of the phase known as civilization.

This evolutionary mode, coinciding with the evolving needs of the local star, conduces at some distant point in the future to the subliminal consciousness and the postorganic postlife that is necessitated by stars as they advance to the stage of supernova. According to the Law of Time, the nature of consciousness is actually a function of stellar evolution, planets being but harmonic nodes in greater heliospheric fields of resonance. Since time is inseparable from consciousness, this understanding would seem to affirm Kozyrev's hypothesis that time is generated from the stellar core. "Stars absorb energy from the motion of time," declares Kozyrev, "a star seems to be a time machine."7 *The Mayan Factor* further places the coordinating medium of time as emanating from the core of the galaxy, Hunab Ku, One Giver of Movement and Measure. In the Chilam Balam prophetic tradition, Hunab Ku is also the name given to the final religion of the One God that appears after the religion of the *conquistadors* has finally passed. Seen from the perspective of the Galactic Brain, the crisis through which we are now passing is but the final stage before consciousness bursts into a new radiance of biosolar-telepathic wonder where negative emotions and thought forms no longer have any place to cling or hide. The Law of Time purposively points to this great end.

The whole of the spectrum of the Galactic Brain is mediated by the universal frequency of synchronization, mathematically modeled as the 13:20 matrix, the organizing factor of the synchronic order. The technicalities of this evolutionary spectrum of the Galactic Brain have been defined in *The Dynamics of Time: 260 Postulates* (1996) so that the process of the evolution of time as consciousness may be studied and its coming stages prepared for. The mathematical model of this 13:20 matrix is a description of the fourth-dimensional timing frequency and is both the source of the time vector potentialities and the mathematical tool for mapping the order of synchronicity. Through the discovery of the Law of Time, the 13:20 matrix is realizable through tools that are in accord with its mathematics, and thereby it becomes useful to the everyday consciousness of the human. This too becomes a factor accounting for the noosphere's becoming conscious.

The fourth-dimensional "tools" made accessible through the Law of Time include the Thirteen Moon/28-Day calendar, the Dreamspell, and the Telektonon. They will be described more fully in Chapter 8, "Making the Transition to the New Time." With these tools one can begin to construct a map of the time vector potentialities contained in the synchronic order as it manifests on a day-to-day basis. Once the construct is made conscious and correlated to a point in third-dimensional time, then the body in time-the infinitely locatable point that is space-may be coordinated by the same common structure of fourth-dimensional time. Following this procedure the individual human consciousness begins to participate in the larger unfolding of the noosphere, and slowly but surely is realized as yet another manifestation of the formulation of the Law of Time, T(E) = Art. It is the human being itself that incorporates time, or rather wakes up within itself the order of time. Time is art, while art is actually a function of consciousness expressing itself.

THE MAYAN UNDERSTANDING OF THE LAW OF TIME

While we will have cause to turn our attention later in this book to the "how-to" of fourth-dimensional time, we may consider further the nature and meaning of the mathematics of the Law of Time and their origin with the mysterious civilization of the ancient Maya. The template or matrix of the 13:20 frequency, a 13 x 20 (260) unit structure, was the means for accommodating the base "calendar" used by both the ancient and present day Maya: the *Tzolkin,* or sacred calendar, a set of thirteen numbers and twenty signs that repeat their sequences of permutations every 260 days. While this 13 x 20 matrix accommodates the Tzolkin, it is not confined to being a calendar, as I amply demonstrated in *The Mayan Factor.*The 13:20 frequency is the universal constant of time from whose mathematics the Tzolkin is derived. Based on the permutation table, called the *buk xok* in the Chilam Balam tradition, this matrix is a Harmonic Module, a fractal yardstick of radial time with multiple applications, something analogous to the periodic table of elements, but of the synchronic order.

It is still a profound challenge to all modern Western scientific thought that the Maya would have possessed such mathematics, apparently inherited from the earlier and even more mysterious Olmec people, and that with this mathematics they would have evolved such a profound perception of time. This was most certainly a factor in the destructive attitude taken toward the Maya by the religious zealotry of the conquerors of Mexico. It is also astonishing that the mathematics in which the Harmonic Module is embedded is a vigesimal (20) count, utilizing a zero and a positional ordering system that accounts for larger or greater values that advance by binary exponentiality rather than a decimal sequentiality. But, quite simply, this system exists in this manner because it is the mathematics appropriate to time. This mathematics is a factor to which any disinterested researcher on the topic of time must now become accustomed.

It is by reason of this mathematics and its ability to "download" the 13:20 universal frequency of synchronization that the ancient Maya were able to construct a complex system of "calendars" and an astronomical knowledge that is precise not for its telescopes, of which there were none, but because of the nature of the mathematical system itself. More appropriately described as synchronization devices or synchronometers, the Maya used at least seventeen of these timing instruments simultaneously during the great age of their civilization, A.D. 435-830. This fact in itself tells us that the Maya understood time so radically differently from the perception that has evolved in the techno sphere that we must stand in awe that such a knowledge would have developed by a people whose technological development was so minimal, but whose artistic accomplishment was inseparable from their scientific achievement.

Harmonic Module

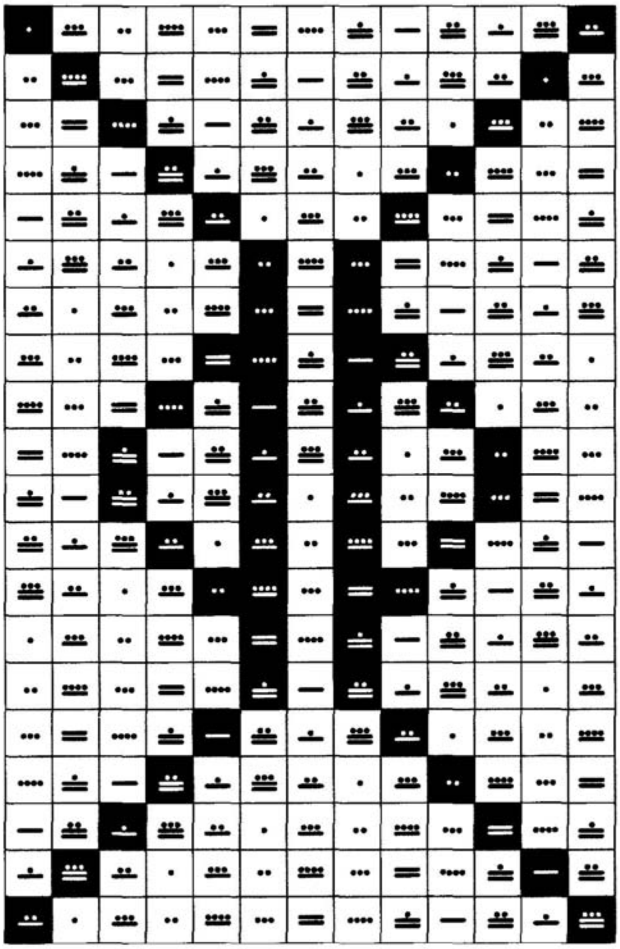

Yes, the Maya most definitely knew that time is the universal factor of synchronization, so their synchronometers must have been for the purpose of attaining a master synchronization with the cosmos. This presupposes such a different state of mind that all the values of the present day must be challenged. The mystery of it is that this mathematics and time science developed in the New World, remote from the saga of civilization in the Old World. The fact that the later Maya practiced ceremonies and blood rituals, the fascination of so many present-day archeologists, should not detract from the understanding that these ceremonial practices stem from a totally different perception of life-and death. Before we judge, we must consider the inescapable truth that nothing in history matches the terror of the different kinds of war and weapons of mass destruction that characterize the fifty-six-year cycle of the technosphere, 1945-2001. Who then is the more barbaric-the Maya, or modern man, *"Homo technosphericus"?*

It is the study of this vigesimal mathematics and its 13:20 Harmonic Module that has led to the discovery of the Law of Time. In this regard the Law of Time is a universal law independent of any culture or civilization, even that of the Maya, much like the law of gravity is also a universal law. However, if it had not been for the Maya, who evolved their understanding of the 13:20 frequency of synchronization to such a high degree, there would never have been a pursuit that led to the discov-

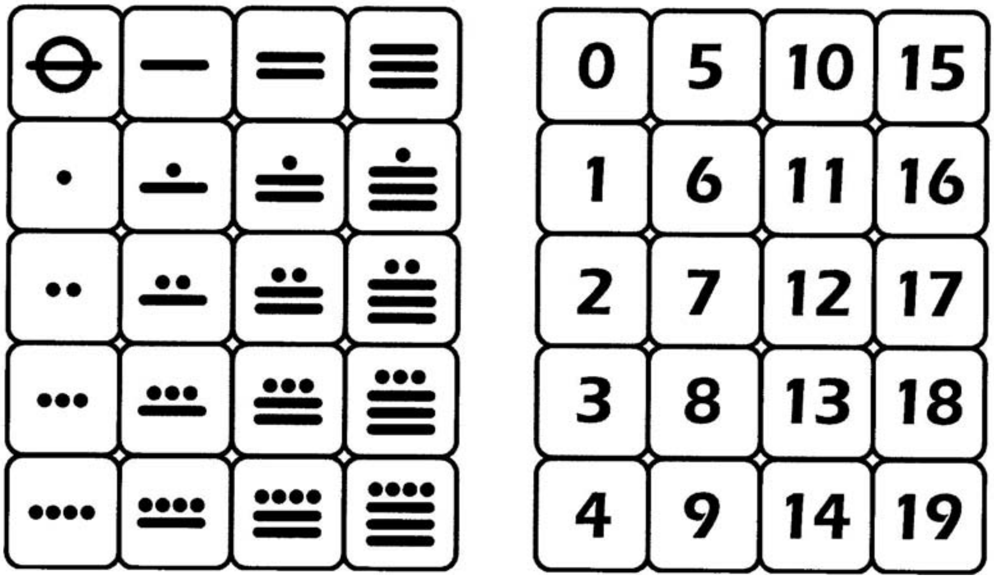
Galactic Notation, Dot-Bar (0–19) Code
Vigesimal count, 1–19, where in first order 1 = 1 and
0 = 20 position, so in next order 1 = 20, in third order 1 = 400, etc.

ery of the law underlying their knowledge of time. If with this law we may categorize the time vector potentialities in six stages of consciousness-preconscious, unconscious, and conscious, continuing conscious, superconscious, and subliminal conscious-then we may be certain that the ancient Maya were also familiar with the time science associated with the higher states of consciousness revealed by the Law of Time. With this time science and mathematics of higher consciousness, the Maya were able to bequeath a prophetic tradition mathematically coded in the Harmonic Module, which, among other matters, led to the discovery or making conscious of the Law of Time itself.

Once we appreciate the radically different perception of time and knowledge that is embodied in the Harmonic Module, the mathematical modeling of the 13:20 universal frequency of synchronization, then we may turn to its uses as the fractal radial measure of time applied to many levels of thought and knowledge. For instance, using the 13:20 matrix we may turn to an understanding of the Law of Time in human history, as is necessitated by these reflections. With the Mayan time knowledge and the placement of their civilization in the New World, we have a gauge and an alternative base of knowledge upon which to evolve a planetary perspective and an objective means of critique of the mainstream development of civilization in the Old World. We may then ask the questions: How did we become what we are now, and how was it that our civilization evolved into the technospheric medium?

▼

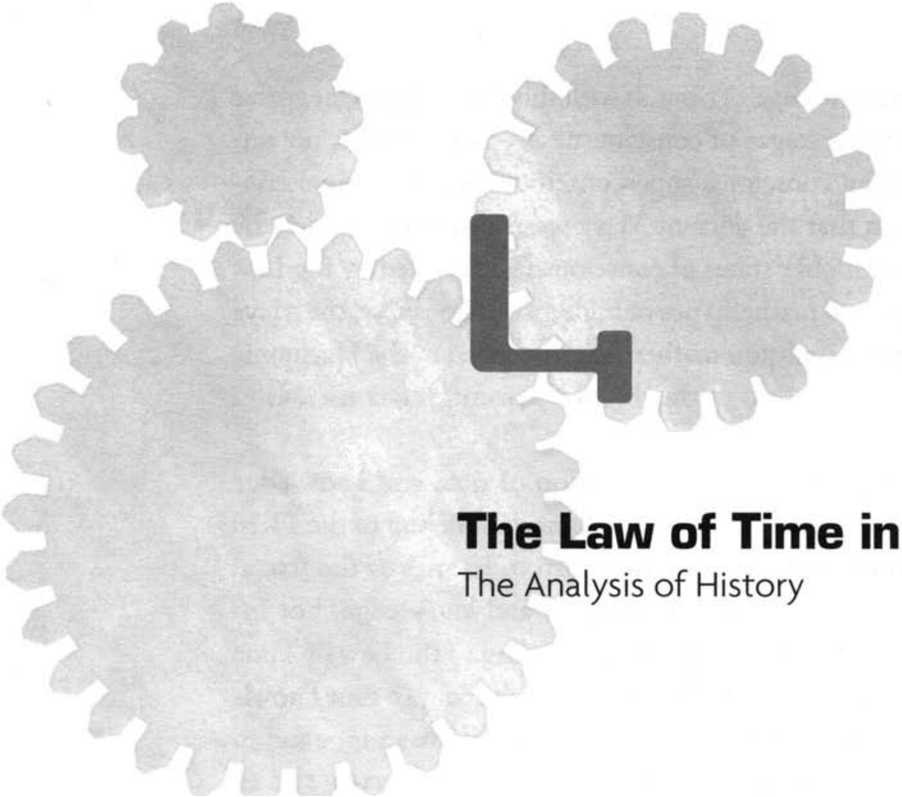

4

The Law of Time in Human Affairs

The Analysis of History

THE KEY to *The Mayan Factor* is the application of the Harmonic Module as a fractal measure that is descriptive of the cycle of thirteen baktuns, the Mayan measure of history. This measure of thirteen baktuns, a cycle extending from 3113 B.C. to A.D. 2012, had been deduced from the stone inscriptions of the Mayan monuments of the Classic period, most of which bear a date within the tenth baktun cycle, A.D. 435-830, or, in the transliterated vigesimal notation of the Mayan Long Count, 9.0.0.0.0-10.0.0.0.0. However, one of the principle discoveries of *The Mayan Factor* demonstrated that the thirteen baktun cycle was also a function of the Harmonic Module and identical with its mathematical mapping as the 13:20 matrix. There are very profound implications to this correlation of the cycle of history having a one-to-one identity with the 13:20 frequency matrix. For this reason the cycle of history is referred to as a *Wave Harmonic* of the galactic order of time. Even though history may appear to be a random, haphazard, and checkered advance of humanity from living in small agricultural communities to the present-day technosphere, this process has actually been an orderly program of the biosphere, the region for the transformation of cosmic energy on Earth.

The same principle of the analysis of the Law of Time applies here. That is, by analogy, the historical events analyzed from a political or economic perspective represent the perception of the random events of near space and low time, while the analysis of the thirteen baktun cycle Wave Harmonic of history represents the perspective of far space and high time. In this Wave Harmonic, the program of history is mathematically defined by 13 baktuns-each baktun consists of 20 katuns-13 baktuns x 20 katuns = 260 katuns = 13 x 20 matrix of the 13:20 frequency of synchronization. In the 13 x 20 matrix of the Harmonic Module each unit equals one kin, the base unit of fractal measure. By fractal equivalence, in the mapping of history one kin = one katun, one katun = 7,200 days; therefore one baktun = 144,000 (7,200 x 20) days. The mathematical perfection of the cycle of history matching the 260-unit model of the harmonic matrix means that history is a factor of synchronization of the higher order of time coordinating the human organism within the biosphere.

By means of the *thirteen baktun Wave Harmonic of history,* the incidence of human Civilizational Advance (CA) may be plotted in a very precise way as a progression going from a very dispersed and scattered state to the point of attaining its exponential climax in the final saga of geochemical combustion, the fifty-six-year cycle of the technosphere. In this regard we must ask: What do we mean by "history" from the Wave Harmonic point of view? As an organism that is a function of the biosphere, history defines that stage when that organism, humankind, enters a process of altering its biomes through increasingly artificial means or extensions of itself that exhibit a compulsive reordering of society into denser and denser clusters of habitations known as cities, hence civilization, "city-life."

In the stage before history, the human had created certain tools and had begun experiments in agriculture and horticulture, but the mental order remained in an aboriginal condition. Unconsciously absorbed as an integral mechanism within the cycles of the biosphere, the human wrapped his understanding of these cycles and of his place in them in the garb of myth and ritual. But with history, something different occurs. The artificial means or extensions of the senses are ordered by a different form of mentality. Those projections of thought and consciousness, though immaterial, affect the material surroundings, and take on an aggressive dynamic. The aggregate effects of these artificial extensions are maintained by a new mental dynamic that is contained and then conditioned by a new kind of macro-organizing thought structure, independent of the actual cycles of the biosphere. What is this new mentality? How can we most precisely define it?

Here are some points to ponder. The Mayan reckoning of the beginning of history is precisely dated to August 13, 3113 B.C., Long Count 13.0.0.0.0. The Hindu reckoning of the beginning of the Kali Yuga is dated to February 19, 3102 B.C. These dates are only eleven years apart. What cosmic event occurred at that time to initiate the Wave Harmonic of history? As we have seen, there is a perfect identity of the

13 Baktun Cycle: Wave Harmonic of History

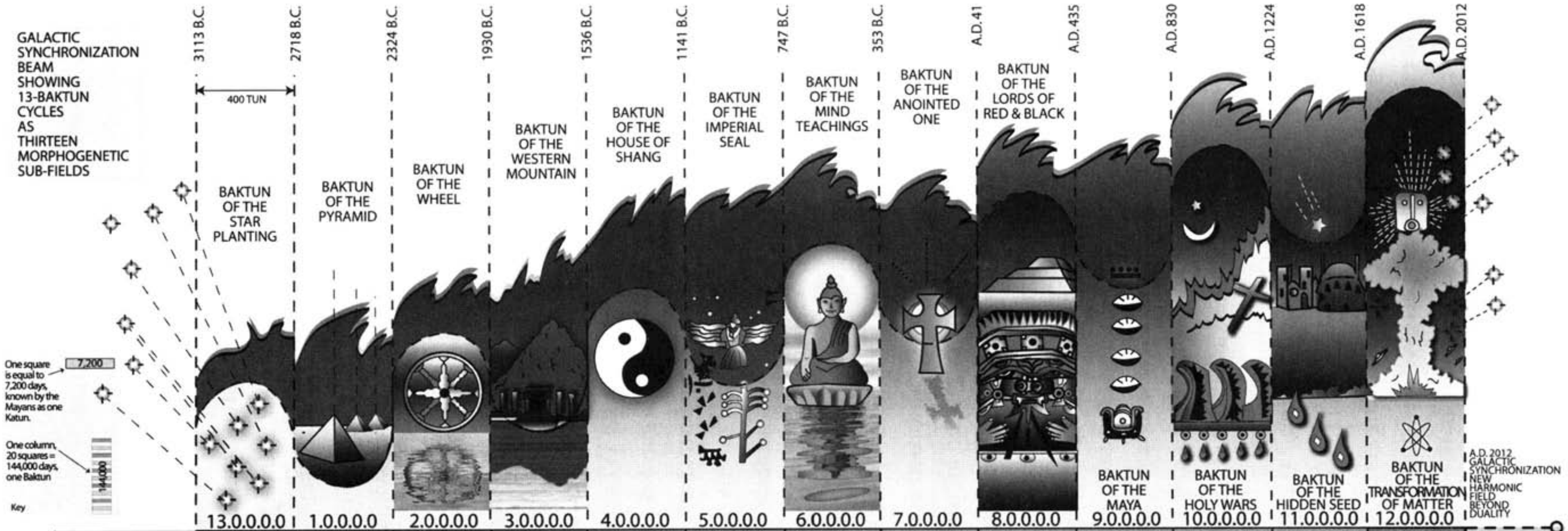
GALACTIC SYNCHRONIZATION BEAM SHOWING 13-BAKTUN CYCLES AS THIRTEEN MORPHOGENETIC SUB-FIELDS
One square is equal to 7,200 days, known by the Mayans as one Katun.
7,200
One column, 20 squares = 144,000 days, one Baktun
144,000
Key
3113 B.C.
400 TUN
2718 B.C.
2324 B.C.
1930 B.C.
1536 B.C.
1141 B.C.
747 B.C.
353 B.C.
A.D. 41
A.D. 435
A.D. 830
A.D. 1224
A.D. 1618
A.D. 2012
BAKTUN OF THE STAR PLANTING
BAKTUN OF THE PYRAMID
BAKTUN OF THE WHEEL
BAKTUN OF THE WESTERN MOUNTAIN
BAKTUN OF THE HOUSE OF SHANG
BAKTUN OF THE IMPERIAL SEAL
BAKTUN OF THE MIND TEACHINGS
BAKTUN OF THE ANOINTED ONE
BAKTUN OF THE LORDS OF RED & BLACK
BAKTUN OF THE MAYA
BAKTUN OF THE HOLY WARS
BAKTUN OF THE HIDDEN SEED
BAKTUN OF THE TRANSFORMATION OF MATTER
A.D. 2012 GALACTIC SYNCHRONIZATION NEW HARMONIC FIELD BEYOND DUALITY

260-KATUN CYCLES
52-UNIT GAIA LIGHT BODY

	13.0.0.0.0	1.0.0.0.0	2.0.0.0.0	3.0.0.0.0	4.0.0.0.0	5.0.0.0.0	6.0.0.0.0	7.0.0.0.0	8.0.0.0.0	9.0.0.0.0	10.0.0.0.0	11.0.0.0.0	12.0.0.0.0	
DRAGON / IMIX	URUK, MENES	ZOSER EGYPT CALENDAR	SARGON	ABRAHAM	SHANG DYNASTY, CHINA	KING WEN	GREEKS	ALEXANDER	ROMAN	FALL OF ROME	BOROBADUR	GOTHIC	DESCARTES	NEPTUNE
WIND / IK	KILNS	GREAT PYRAMID	BABYLON		AKHNATON	CHOU DYNASTY	KUSHITE	CELTS	EMPIRE	BYZANTIUM		EUROPE	SCIENTIFIC	URANUS
NIGHT / AKBAL	UNIFIED SUMER	GIZA		CRETE	HITTITE	CHINA		ASOKA	TEOTIHUACAN	RISE OF	VIKINGS	MONGOLS	MATERIALISM	SATURN
SEED / KAN	EGYPT				EMPIRE	KING DAVID, JERUSALEM	NINEVEH	SPREAD OF BUDDHISM		CLASSIC	HEIAN JAPAN	KUBLAI KHAN	CHING DYNASTY	JUPITER
SERPENT / CHICCHAN	OLD		CHARIOT	EGYPT: QUEEN	THERA, EARTHQUAKE		PYTHAGORAS	ZAPOTECS		MAYA	CHIMU	MAYAPAN	NEWTON	A-BELT/MALDEK
WORLD-BRIDGER / CIMI	KINGDOM		WARFARE	HATSHEPSUT	OLMECS	VEDIC	BABYLON REBUILT	CH'IN DYNASTY	NAZCA	BUDDHISM IN JAPAN	XOCHICALCO	AZTEC	BAROQUE MUSIC	MARS
HAND / MANIK				VALLEY OF	CHAVIN	CIVILIZATION		HUANG-TI	GERMANIC	TIKAL	CE ACATL	BLACK PLAGUE	INDUSTRIAL	EARTH
STAR / LAMAT			EGYPT	KINGS		INDIA	LAO TZU	EARLY	INVASIONS	POPE GREGORY	TOPILTZIN QUETZALCOATL	INCA	REVOLUTION	VENUS
MOON / MULUC	HEIROGLYPHS	AKKAD	MIDDLE KINGDOM				PERSIAN	MAYA	MOCHE	MUHAMMED	RISE OF	MOGHUL / INDIA	AMERICAN &	MERCURY
DOG / OC		UR			JADE	HORSE WARFARE	EMPIRE	HAN		PALENQUE	TOLTEC	OTTOMAN TURKS	FRENCH REVOLUTION	MERCURY
MONKEY / CHUEN	CUNIEFORM				KING TUT		BUDDHA, MONTE ALBAN		END OF	PACAL VOTAN	MAYA		ROMANTICISM	VENUS
HUMAN / EB		HARAPPA			RAMSES		CONFUCIUS	DYNASTY	HAN DYNASTY		IFE	MING DYNASTY	EUROPEAN	EARTH
SKYWALKER / BEN		CIVILIZATION			ASSYRIA	JERUSALEM		TEOTIHUACAN	TIAHUANACO	COPAN	ANGKOR WAT		IMPERIALISM	MARS
WIZARD / IX		INDIA	ZIGGURATS				PLATO	RISE OF ROME		HEIROGLYPHIC STAIRWAY	CRUSADES	FALL OF CONSTANTINOPLE	ELECTRICITY	A-BELT/MALDEK
EAGLE / MEN				HORSES			CHUANG TZU			SPREAD OF ISLAM	BUDDHISM IN	PRINTING, CONQUEST	RUSSIAN REVOLUTION	JUPITER
WARRIOR / CIB			BRONZE	CENTRAL ASIA	VEDAS	LA VENTA	ZOROASTER	GREAT WALL	CONSTANTINE		TIBET	OF MEXICO, PERU	WORLD WARS	SATURN
EARTH / CABAN			TECHNOLOGY	HITTITES		ASSYRIAN		OF CHINA	BUDDHISM IN	T'ANG DYNASTY	SUNG DYNASTY	EUROPE EXPLORATION	HIROSHIMA	URANUS
MIRROR / ETZNAB			MENUHOTEP	EGYPTIAN	PHOENICIANS	IRON	BANTU, WEST AFRICA		CHINA	MISSISSIPPI CULTURE, BAGDAD	RUSSIA/KIEV	BENIN	NUCLEAR & SPACE TECHNOLOGY	NEPTUNE
STORM / CAUAC	STONEHENGE	PYRAMID	UR, NAMMU, LEGAL CODE	EMPIRE	MYCENEANS	WEAPONS &	PELOPPONESIAN WAR	JULIUS CAESAR	GUPTA DYNASTY, INDIA	PADMASAMBHAVA	ANASAZI	QUEEN ELIZABETH	HARMONIC CONVERGENCE	PLUTO
SUN / AHAU	GILGAMESH	TEXTS	HAMURABI	ARYANS INVADE INDIA		WAR MACHINES	ARISTOTLE	CHRIST		CHARLEMAGNE	ZIMBABWE	GALILEO, KEPLER	EARTH REGENERATION	PLUTO

SOLAR MOVING INHALATION

GALACTIC/LUNAR MOVING EXHALATION

Wave Harmonic of history, as a fractal equivalence, with the Harmonic Module, itself a description of the universal 13:20 frequency of synchronization. This being so, both the calculation of the beginning of history as well as the duration of its entire cycle are functions of the Law of Time. This means that something within the Earth's noosphere occurred that triggered the Wave Harmonic, itself a manifestation of the Law of Time. Also, by most judgments and standards, history began at a very precise place as well-Sumeria, in the Mesopotamian basin of what is now called the Middle East. Why? And what relation is there between the precise event that triggered the Wave Harmonic of history and Sumeria, the site of the first city, Uruk? What event could have established a macro-organizing principle to propel the dynamic of human thought and technology into the trajectory concluded by the technosphere?

THE ORIGINS OF THE 12:60 FREQUENCY

In the recently published book *The History of the World-A 6,000 Year Chronicle of Time,* we find the point that establishes the definite artificiality of a new kind of macro-organizing principle, driving humankind toward the Inevitable Event; here we find the genesis of artificial time: "Ca. 3000 B.C. Sumerians divide day into 24 hours, 60 minutes, 60 seconds and circle into 360 degrees."! While this is a fact we may take for granted because it is the basis of mechanized time in the form of the clock, for precisely that reason it should give us pause. For one thing, this means that the measuring system of the clock was already established at the beginning of history, some 4,500 years before the clock as we know it was actually invented! This is quite an astonishing fact. It means that mechanization was implicit in the first intellectual act of history. Why or how would it have occurred at the precise point of the beginning of history in Sumeria?

The Law of Time defines this mechanistic organizing principle as the basis of the 12:60 artificial timing frequency (irregular twelve-month calendar combined with mechanical sixty-minute hour). Therefore, it was at this point at the beginning of history that artificial time and its progeny, mechanization, were actually registered as a thought form and thus became embedded in the as-yet-unconscious noosphere. Or, was it already embedded in the noosphere to be triggered at this precise point-and if so, why and how? The point is that history, as it has evolved as the mainstream of civilization from Sumeria to the World Trade Center, has always been driven by the organizing principle of artificial time. It is artificial time that separates history from prehistory-and, as we shall see, from post-history as well. It was due to the

The Error in Time

The measure of a two-dimensional plane in space has nothing to do with the experience or the nature of time.

"TIME WAS COMPRESSED INTO A FLAT CIRCLE..."
Dreamspell "Genesis"

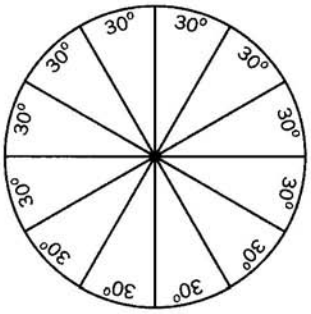

Sumeria: Ca 3000 B.C.
Day divided into 24 hours,
60 minutes, 60 seconds
based on 360 degree circle—
two-dimensional plane in space—
divided into twelve parts

Earth's solar orbit = 365 days
360 degrees ≠ 365 days

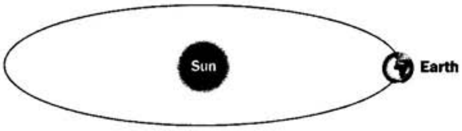

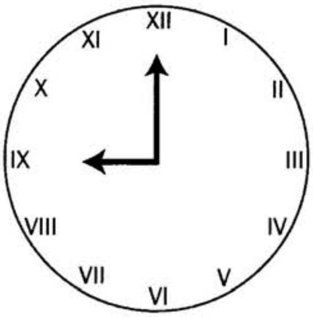

Europe: 800-1600 A.D.
Clock—two-dimensional plane
in space—divided into twelve
parts each 30 degree of arc =
1 hour = 60 minutes
each minute = 60 seconds
A.M. = 12 hours
P.M. = 12 hours
= 24 hours

I - 31	II-28/29	III - 31
IV - 30	V - 31	VI - 30
VII - 31	VIII - 31	IX - 30
X - 31	XI - 30	XII - 31

Rome (Vatican): 44 B.C. - 1582 A.D.
Twelve-month Julian/Gregorian
calendar derived from twelve part
division of circle; irregular measure
due to fact that 365 is not divisible
by twelve.

genesis of artificial time at the beginning of history and its emplacement within the planetary noosphere that also generated the thirteen baktun Wave Harmonic of history. For the very purpose of the thirteen baktun Wave Harmonic of history is to encompass and coordinate the cycle of artificial time. Why?

The Wave Harmonic is a function of the 13:20 synchronization frequency. It is a function of cosmic time. In the higher knowledge of the Mayan understanding, it provided the perfect measure of the cycle of artificial time. From the perspective of the actual noospheric timing, which operates according to the natural 13:20 cosmic timing frequency, history is none other than a manifestation of artificial time. Civilization becomes organized by the principle of artificial time. But because it is artificial, it cannot endure. If the mathematical basis of mechanized time, and hence of mechanization, was already established at the beginning of history, then the end of history is the end of artificial, mechanized 12:60 time. And in the end, the Law of

Time codes and encompasses the whole of the cycle of artificial time through the thirteen baktun Wave Harmonic of history. What is important to grasp is that the entire cycle of artificial time was *already perceived* by the Mayans as a phenomenon that could not endure more than the length of the cycle of thirteen baktuns.

It is necessary for the reader to understand how this perspective was discovered. It was the result of a phenomenological experiment of living according to the synchronic cycles of the Mayan time science. After the death of my son in 1987, my wife and I began in earnest to follow the cycles encoded in the Mayan calendar: 13-day, 20-day, 52-day and 260-day cycles. Our life changed dramatically. At the same time, I endeavored to define the mathematical basis of these cycles. Once I resigned my academic position in early 1989, we were swept by a wave of time that took us from the Rocky Mountains to Southern California to the Hawaiian Islands in the middle of the Pacific Ocean. There, in relative isolation from the rest of the world, we plunged into our experiment. Before we had truly settled in, the time wave took us to Switzerland, where on December 10, 1989, in the Museum of Time in Geneva, we were able to put our phenomenological experiment to the test-although we did not consciously realize at the time that we were doing so.

There in the Museum of Time, essentially surrounded by examples of the history of the clock and mechanization, and because our perceptions had been altered by our living so completely by the various timing cycles encoded in the Mayan calendar system, we were able to spontaneously perceive the existence of two timing frequencies. The natural frequency-the one we had been living-we understood instinctively to be the 13:20 timing frequency. The other frequency-the one enshrined in this Museum of Time-we understood to be the artificial 12:60 timing frequency. This realization of artificial time was rooted in the evident proof that the clock is based on the twelve-part division of a flat circle, a spatial plane that clearly has nothing to do with the dynamics of time. It is a manifest error, but one that humanity has taken for granted and endowed with all of the characteristics of "truth."

We also immediately saw that the error of mistaking the division of a two-dimensional plane in space for a measure of time was transmitted not only through the clock, but through the twelve-month Gregorian calendar as well. With brief reflection upon what a gross error this was-substituting a twelve-part division of space as a measure of time, and then elevating this mistake as the truth of the measure of time-we understood how it could have actually led humanity away from the natural time of the universe. In making this observation, we immediately and intuitively grasped the necessary solution: replace the erroneously measured twelve-month Gregorian calendar with the perfect measure of the Thirteen Moon/28-Day calendar.

Our research into the mathematical codes behind the Mayan calendar now progressed rapidly, but our attention also turned to the question: Whence came the thought form of 24 hours, 60 minutes, and 60 seconds as a measure of a circle of 360 degrees? It was clear to us that this division of time based on the division of a circle in space occurred at what is the beginning of history, a fact later confirmed for us in the already cited *History of the World* (1997), which states that this division of 24 hours, 60 minutes, 60 seconds and the circle into 360 degrees was devised "Ca. 3000 B.C."

Once we had finished working out the mathematical codes, we turned to a consideration of the actual implications of the error in time. It was now also clear why the Mayan time science was so superior. It was based on the reality of time as a factor of synchronization. By contrast, the concept of time as it had developed in the mainstream of civilization was limited, linear, and totally third-dimensional, a fact that confirmed Vernadsky's analysis, as well, that our notions of time are a function of the metrics of space. By 1991, the experience in the Museum of Time had driven us into

What Difference Can a Calendar Make?

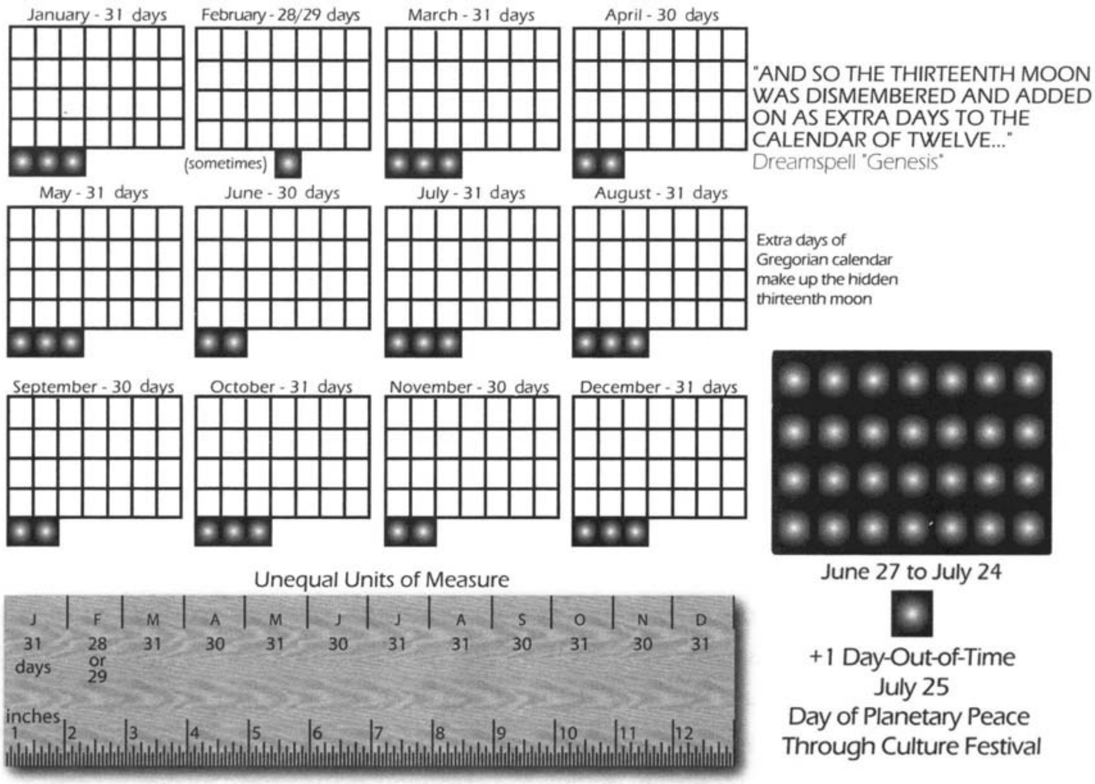
January - 31 days
February - 28/29 days
March - 31 days
April - 30 days
(sometimes)
"AND SO THE THIRTEENTH MOON WAS DISMEMBERED AND ADDED ON AS EXTRA DAYS TO THE CALENDAR OF TWELVE..."
Dreamspell "Genesis"
May - 31 days
June - 30 days
July - 31 days
August - 31 days
Extra days of Gregorian calendar make up the hidden thirteenth moon
September - 30 days
October - 31 days
November - 30 days
December - 31 days
June 27 to July 24
Unequal Units of Measure
J F M A M J J A S O N D
31 28 or 29 31 30 31 30 31 31 30 31 30 31
days
inches
1 2 3 4 5 6 7 8 9 10 11 12
+1 Day-Out-of-Time
July 25
Day of Planetary Peace Through Culture Festival

Gregorian Calendar and the Hidden Thirteenth Moon

creating a full-blown psychomythic analysis and description of this moment of realization concerning the nature of time. The complete structure of the mathematical codes of time, as well as the psychomythic description of the causes and effects of the error in time, is known as the Dreamspell, which is defined as follows:

"DreamspeH: function of fifth-dimensional galactic-solar planetary regulation; 26,000-year renewable cycle and planetary castle genesis; any consensus reality; in disregard of interdimensional reality creates entropic spell of history; cure for loss of galactic memory."2 The *planetary castle genesis* refers to the *five castles of time* (each 5,200 years in length), divided into three *geneses-the* Dragon, the Monkey, and the Moon-that constitute the entire fractal panorama of the 26,000-year cycle of history that ends in 2012, and is meant to be renewed in 2013 (an obvious synchronic reference to the 13:20 timing frequency). In the Dreamspell analysis, the beginning of history occurs almost 5,200 years ago between the Monkey and the Moon geneses, and is marked by the imposition of the false 12:60 timing ratio.

In light of this analysis and definition it is worth quoting certain passages from the Dreamspell text that describe this precise moment at the beginning of history and that the Law of Time defines as the root error of civilization. First we quote from the "Dreamspell Genesis," and then from the descriptions of the "Dreamspell Journey and Mission of Timeship Earth 2013." The purpose of quoting these passages here is to establish a psychomythic context to explain the profound nature of what we refer to as the error in time compounded over 5,000 years of history:

> Imposters, male priests and warriors usurped the power of the thirteen moons. They hid the thirteen among themselves and attempted to banish all memory of the matrix dreamspell of magic. . . The planetary kin had imposed upon them the diminishing power ratio of 12:60. No longer the magic of thirteen moons but a twelve month calendar of uncertain meaning. No longer the timeless gyre of magical flight, but a sixty-minute hour to earn one's bread.
>
> Time was compressed into a flat circle. . .
>
> The 13:20 ratio is the base operating ratio of timeship Earth. . .
>
> In that vital moment during the magic flight. . . Toward the moon genesis, another spell was cast. Instead of the 13:260 ratio already stored deep within the crystal core of timeship Earth, the planetary kin received the 12:60 ratio, the dark dreamspell of history. . . And so the thirteenth moon was dismembered and added on as extra days to the calendar of twelve. . .

> The absorption of the thirteen by the twelve was called an improvement by the male imposter priests hypnotized by the combined powers ofJupiter and Saturn. It takes twelve years for Jupiter to orbit once around the sun. It takes sixty years for Jupiter and Saturn to be conjunct.
>
> Twelve times five equals sixty, one sixth of the flat three hundred sixty degree circle. The difference between twelve and five is seven. While the priests of the calendar of ancient Babylon banished the power of the thirteen moons, they replaced that power with the power of seven.
>
> While the twelve diminished the power of thirteen by one, the sixty raised the power of twenty by three. A seeming increase in power occurred, but an increase only on the flat plane of the third-dimensional time to which the planetary kin were now consigned.
>
> With the banishment of the thirteen moons, the fourth-dimensional time magic. . . became the property of the priest class. Setting up religions and governments to maintain the kin within the third dimension, the priests were assured that anyone having fourth-dimensional experiences either be appropriated or destroyed.J

So much for the psychomythic impression of the genesis of artificial time, the flat time of an exclusive third-dimensional reality called history. A few further quotations from the Dreamspell emphasize both the interplanetary and mathematical root of false time:

> At -3187 Dreamspell years the time bandits on the sixth and seventh orbits pulsed their beam. The 12:60 frequency of the memory virus took immediate effect on the third-dimensional space suits. . . The Dreamspell of history was cast.
>
> Imposter priests on Earth substitute the 12:60 ratio. . . Instead of the magic of following thirteen moons, a non-circulating twelve-month calendar is substituted; instead of the beauty and power of magical flight, the sixty-minute hour. The result is disastrous.
>
> The twelve-month calendar is the consequence of the 12:60 ratio imposed at -3187 Dreamspell years (3113 B.C.,Julian/Gregorian). With no basis in or capacity for measuring galactic time, the twelve-month calendar is actually a third-dimensional prison keeping the four root races separate and at war with each other.4

These descriptive explanations of the error in time define such a profoundly radical point of view that we must flesh out the implications and description of the course of artificial time according to the analysis of the Law of Time. From the outset of civilization in Sumeria, artificial time captures the human mentality in the order of low time and near space (third dimension), separating it from high time and far space (fourth dimension). The registration of artificial time within the unconscious structure of the noosphere, which is intrinsically governed by the universal 13:20 frequency of synchronization, creates a conflict and a pressure in the noosphere, a time warp or taint that affects the entire biosphere.

Civilization-living in cities-increasingly becomes the human norm within the biosphere. Where there had been no civilization, at a few key places around the planet civilization now arises-a process that goes from the crystalline structures at the origin to the later phases of imperialism and empire building. This cycle is repeated again and again. Even in the New World where the 13:20 natural timing frequency prevailed, the later stages of civilization succumbed to the effects of the 12:60 already seeded in the noosphere. Ultimately, all humanity and the biosphere were to be governed by the artificial timing frequency that ends with the construction of the technosphere, the final and supreme expression of artificial time. Indeed, the technosphere is the absolute conclusion of what can rightly be called an artificial time warp in the biosphere.

Concerning the mathematical basis of the 12:60 frequency, V. A. Ponko of the Russian Academy of Sciences, Novosibirsk, has conducted extensive research and wave analysis on the mathematical properties of the cycles of history. He has concluded that as a mental coordinate, the number 12 is a strict construct of the angles of space. Since it does not correspond to the sinusoidal curvature of the cycles of time and the plotting of all organic phenomena, when used as a time factor the number 12 offers no "protection" from bombardment by any number of cosmic forces. The mathematical plotting of the 13:28 frequency that characterizes the Thirteen Moon calendar, on the other hand, is in alignment with the sinusoidal curve properties of organic phenomena, and therefore functions as an "umbrella" maintaining the organism in resonance with the biosphere.s

Here let us make a more precise definition of timing frequencies and the nature of calendars as the macro-organizing programming systems of the human in the biosphere. By defining time as the universal frequency of synchronization, we are saying that synchronization is the fundamental program to which everything adheres and which makes everything perceptibly coherent, hence synchronic order. Therefore, the natural timing frequency that is a universal phenomenon both regulates the phenomenal order of the cosmos, and in the human is absorbed as a mental frequency that unconsciously synchronizes the mind and senses with the natural order. The result is the normal sensation and experience of the harmony of reality. This defines both a fundamentally prehistoric perception of reality as well as the spiritual experience that is common when we are confronted with the awesomeness of nature-usually far away, it should be noted, from city life. This universal factor of synchronization we have identified as the mathematically precise ratio 13:20, a ratio constant embedded in the structure and order of the calendrical and astronomical system of the ancient Maya.

If we understand that this frequency of synchronization is a genuinely universal constant, then we may comprehend how not only the entire biosphere, but solar system and galaxy are also governed by the same frequency. This is how the Kozyrev experiments could show that there is instantaneous transmission of information throughout the universe, which in its entirety is a function of the formulation *velocity of time is instantaneously infinite.* Synchronization and infinite instantaneity of transmission are mutually defining-everything is always instantaneously synchronized. We can further say that synchronization "syntropizes" while dissynchronization "entropizes." There is no lag time in synchronization.

This being the case, we can then begin to understand how the acceptance and institutionalization of the artificial 24-hour, 60-minute, 60-second division of the 360 degree circle as the basis for defining time could be such a singular and ultimately disastrous deviation from the universal frequency of synchronization. Thus when we speak of the artificial 12:60 timing frequency, we are referring to the mental effect of the feedback program of the use of artificial and erroneous instruments of measure. Rather than allowing the mind to remain in the natural harmony of synchronization with nature, the artificial 12:60 standard and its instruments establish a feedback effect in the mind that accustoms it to the deviation from nature. This habituation results in the creation of an unconscious timing frequency that is accepted by the consensus reality as the actual norm. Separation of human order from the biosphere becomes accepted and acceptable, making civilization not only possible, but setting it up, as it were, as a parallel rival to "nature." In fact, it is the unconscious mental frequency of 12:60 artificial time that coordinates and maintains civilization as a belief system.

When we speak of the instruments of measure of artificial time, we are specifically referring to the Gregorian calendar as the macro-organizing principle and the watch or mechanical clock as the micro-organizing principle. The macro-organizing principle organizes our life into days, weeks, months, and years. The micro-organizing principle organizes our life into seconds, minutes, and hours. These two instruments have their common root in the error in time that occurred 5,000 years ago at the beginning of history. Try to think of life without these instruments and you will quickly realize how second nature they are-and yet there was a time when such instruments and their terminology did not exist. Before turning our attention to an analysis of these two instruments and their effects on human consciousness, we must view the entire cycle of the Wave Harmonic of history as a function of the macro-organizing principles of time that the human in the biosphere adopted for its uses and that, in turn, condition at a most profound level the worldview of the culture or civilization that uses it.

HISTORICAL CALENDARS AS INSTRUMENTS OF ASTRONOMICAL MEASURE

It may be rightly asked, What does a calendar measure? At a minimum, a calendar is or should be the measure of the Earth in its rotation around its local star, the sun. This rotation takes 365 days. The Earth's satellite, the moon, is the obvious synchronizing factor between the Earth and the sun. But here we encounter a difficulty. The moon can be measured by various cycles. The synodical cycle, from new moon to new moon, is 29.5 days. The sidereal cycle, the measure taken from where the moon appears at the same place in the sky, is just over 27 days. There is an apsidal cycle, however, taken from the measure of when the moon's axis is tilted farthest from the Earth, which is 28 days. This variance of measures is due to the fact that until the rise of rocketry, we could not really see the moon from space. In actuality the moon rotates around the Earth thirteen times during the time it takes the Earth to orbit the sun once.

If one were objectively seeking the proper measure of the Earth's orbit using the moon as the measuring device, we would therefore construct an instrument for time reckoning that consists of an even harmonic measure of thirteen cycles of twenty-eight days each. The 28-day cycle conforms, of course, to the female menstruation cycle, an obvious human biological cycle, and it also divides perfectly into four 7-day subcycles or weeks. Also, 13 x 28 = 364, the same number of days as thirteen moons multiplied by four 7-day weeks (a total of fifty-two weeks), with the 365th day being a free day, or Day Out of Time, no day of the week or month at all. We shall deal with the perceived extra quarter-day later in our discussion.

The point is this: If time is a factor of synchronization, then a calendar-as an instrument for measuring the count of time-should also be constructed so that it maximizes the factor of synchronization. This can only be done if the instrument of time reckoning is constructed on harmonic principles in conformity with the objective data of nature. Such an instrument would also conform to the orderly processes of the biosphere taken as a whole, and be a great assistance in bringing into consciousness the cosmic programs that organize the biosphere and noosphere. The Thirteen Moon/28-Day calendar is the perfect instrument for such a simple registration of harmony and synchronization. It should also be noted that in its mathematics the Thirteen Moon/28-Day calendar is a function of the 13:20 timing frequency. This in itself establishes the Thirteen Moon/28-Day calendar as a perfect instrument of the Law of Time and as a function of the synchronic order of reality.

Since the process of civilization represents a break from a long cycle generally undistinguished by the kind of perturbations that characterize history, the analysis of the Law of Time assumes that in prehistory humans lived in relative harmony, and therefore that the humans tended to use harmonic instruments of time reckoning. The humans living in greater harmony with the biospheric cycles would be disposed to be in greater unconscious or aboriginal attunement with the noosphere. Since the noosphere is regulated by the synchronic order of the universal 13:20 timing frequency, the humans would be more naturally disposed to devise, adopt, or intuitively utilize the time measure in greatest accord with this instinctual 13:20 noospheric timing ratio.

This instrument of time measure would, of course, be the Thirteen Moon/28-Day calendar. It should also be noted that this calendar is a perfect solar-lunar measure; that is, it uses the even, regular lunar cycle of 28 days as the standard of measuring the 365-day solar cycle of the Earth. The balance of solar and lunar may also be taken as

Moon Circling Earth Thirteen Times per Year

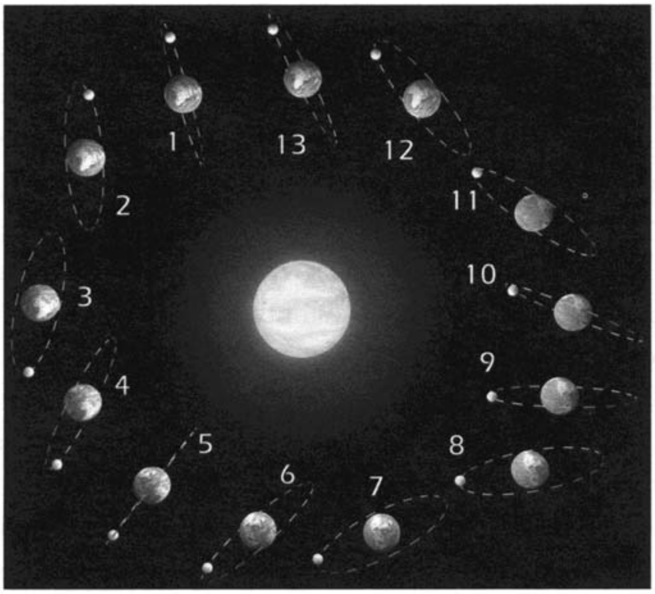

Did you know the moon goes around the Earth thirteen times a year?

SEE: HTTP://WWW.TORTUGA.COM/WWW/ANIMATIONS/ANIM_MOON.HTM symbolic of human psychological characteristics and their balance or imbalance. A solar-lunar calendar will represent and reflect a balance of the solar-lunar, masculine and feminine qualities within the human being. It is important to bear in mind these considerations of calendars and their effect on shaping the human historical consciousness and its psychological makeup. From this perspective, history is, in fact, a process of falling away from the perfection of harmonic standards.

Evidence exists that the Thirteen Moon/28-Day measure was widely known in prehistory. We find evidence of its use as a prehistoric synchronic measure in the remote past of China, in Polynesia, and scattered across late neolithic Europe and the Middle East. Among the Maya it was known as the *Tun Uc,* literally "moon count" or count of seven, while the living tradition of the Thirteen Moon/28-Day calendar is still continued in South America and in the British Isles, where it is known as the Druid Tree calendar. While the Druid calendar has no year count attached to it that would definitively testify to its prehistoric ancestry, the South American calendar does. Known as the *Pachacuti,* the South American Thirteen Moon/28-Day calendar is currently in the year 5509, which places its origins at 3308 B.C., toward the middle of the fourth millennium before Christ, and several hundred years before the beginning of the thirteen baktun Wave Harmonic of history.

If we understand that calendars are genuine time-measuring devices meant to synchronize us with the cosmic order within the biosphere, and that calendars are thereby programming devices, we may then say that a calendar of perfect harmony can have no history. In other words, by its harmony such a calendar is always in tune with the cosmos, which is beyond history. History can only be a function of a disharmonic programming, not in sync or even at odds with the laws of natural time.

From the point of view of timing devices, there are two factors in the establishment of history. The first is the 12:60 program established 5,000 years ago with the division of the day into 24 hours, 60 minutes, 60 seconds, based on the 360-degree division of the circle. The other factor is the use of a purely lunar calendar that is difficult to reconcile with the actual measure of the solar year. The purpose of the 12:60 measure was to establish a timing standard that was actually a pseudosolar calendar to assert male intellectual dominance. The Babylonian (and later, Egyptian) calendar consisted of twelve 30-day cycles = 360 days = 360 degrees, plus an extra 5-day cycle. The 30-day measure is not actually a natural one, being a half day more than the synodic lunar measure, but one that conforms to the hexagisimal (6-based) mathematics of the circle. For this reason, this instrument of time reckoning is defined as *pseudosolar*. Its ultimate descendent, as we shall see, is the twelve-month Julian/Gregorian system.

By contrast, the Maya also had a 365-day solar calendar, the *Haab.* Its measure, however, is that of eighteen 20-day cycles (18 x 20 = 360) plus the 5-day cycle *(uayeb),* the 20-day cycle *(vinal)* being a mathematical function of the 13:20 frequency. In addition, the Maya had the measure of the *tun,* the 360-day count of which is precisely the same as that of the degrees of the circle. It was the tun that the Maya used to measure the thirteen baktun count, which actually consists of5,200 tun (5,125 solar years). The purpose of this measure was to provide an exact harmonic standard for the measure of history that, we may recall, is the duration of artificial time. It is very relevant that the harmonic standard of the thirteen baktun Wave Harmonic of history is the 360-day tun, the actual temporal equivalent of the degrees of a circle in space. The precise measurement of the cycle of artificial time, which turned out to be anything but harmonic, could yet be measured with a harmonic unit that reflects both the circle *and* the mathematical perfection of the Law of Time. How better to coordinate the entire cycle of artificial time than by the tun, a unit of measure that reflects the 360-degree circle, the basis of the original error in artificial time? As we will later observe, the fact that the Law of Time coordinates even the cycles of artificial time is also evident in the analysis of the timing of the fatal flaw of the Twin Towers apocalypse.

While the Babylonians began to apply a hexagisimal time-reckoning device based on spatial metrics of the circle, another factor became predominant in the Old World: the rise of the synodical lunar calendar as the exclusive measure of time. The synodicallunar calendar is purely lunar in that it is not evidently or perfectly harmonized with the 365-day measure of the solar cycle-a fact of great consequence for the development of mainstream civilization. The Babylonian calendar, with its abrogation of the thirteen perfect 28-day months, established the pseudosolar twelve-month measure. This twelve-month measure conformed to the lunar measure of twelve synodic lunations per lunar year. However, twelve lunations are only 354 days, eleven days short of the solar year. This required an intricate set of calculations to make the lunar calendar keep up with the measure of the Earth's solar orbit. And in reality, although we tend to think of the moon as feminine, the knowledge of the synodic measure, the cycle from new moon to new moon, became the exclusive province of a male priest class that used the lunar calendars to capture and control the feminine principle, and to oppress women in general. Whereas the Babylonian and Egyptian solar calendars fell into disuse over time, the lunar calendar persisted.

Since there is only one moon orbiting Earth, it should be kept in mind that all lunar calendars are essentially the same. One and the same moon in all its phases is apparent to all humans on Earth. So when we speak of different lunar calendars-most notably the Hebrew, the Islamic, and the Chinese-the measure is basically the same, from new moon to new moon, but New Year's Day falls differently in each of them, thus accounting in part for the various calendrical traditions. Within each of these lunar calendars, a different set of holidays is programmed. It is the programming of the different holidays and festivals of the calendars, along with the dating of their new year, that makes each lunar calendar tradition distinct and that also demonstrates how a calendar is a programming device. For instance, if one were to take out the different holidays programmed into the Hebrew lunar calendar, there really would be no such thing as Judaism. This demonstrates that the cultural conditioning of a people is totally dependent on the programming of the calendar they use. This also shows how a calendar is a feedback mechanism that maintains a group of people within the confines of its own self-established belief system.

Of the three lunar calendars we have mentioned, the oldest count of years is accorded to the Hebrew calendar. This year Rosh Hashanah, or Jewish New Year, occurred on the new moon, September 17, 2001, and marked the beginning of year 5762. This places the origin date for the Hebrew calendar in the year 3761 B.C., some 453 years prior to the commencement of the Pachacuti count. The Hebrew calendar (like the Chinese calendar, which we will discuss below) makes up for the slippage of eleven days per solar year by intercalating a thirteenth lunation cycle approximately every three years, or exactly seven such thirteenth moons every nineteen years. These numbers too-13, 7, and 19-are key harmonic factors of the synchronic order of time. This demonstrates that, at the very least, the synodical lunation calendars are calibrated in their larger cycles by the Law of Time. But the effect of being a purely lunar measure, at variance with the actual 365-day measure of the solar year, creates an interesting and one-sided approach. There is no question that the lunar calendar civilizations are the tool of powerfully patriarchal societies, the tables of the moons and the years being the possession of a dominant male priest class.

The Chinese lunar calendar differs from the Hebrew in one important distinction: from the most ancient times it has been embedded in a system known as the *five elements*, and is coordinated with a very elaborate mathematical system that bears some resemblance to the 60-60, 24-360 basis of the SumerianiBabylonian 12:60 frequency. This synchronizing system accounts for the Chinese cycles of years that are counted by the twelve zodiacal animals in combination with the five elements: earth, fire, wood, water, and metal, thus giving rise to 60 (12 x 5) year cycles. Three of these sixty-year cycles create a "group" or cycle of 180 years. We are now (in 2001) in the eighteenth year of the twenty-seventh group, or year 4,698 of the Chinese lunar calendar. So embedded is Chinese culture and civilization in this calendar, with its elaborate system, that to take away this calendar would virtually eliminate

Chinese culture altogether. Perhaps more than any other factor, this highly involved calendar also accounts for the longevity and tenacity of Chinese civilization as one continuous tradition for the duration of its history, which according to the reckoning of its calendar began in 2697 B.C., a date, interestingly enough, that coincides with the dedication of the Great Pyramid of Egypt.

Despite its marvelous system, the Chinese lunar calendar is still just that: a lunar calendar. The problem with this, from the point of view of the Law of Time, is that when it is not regulated by a proper solar count or measure, the lunar calendar leads people into one-sided developments of one kind or another, if only to the extent to which these calendars foster such profoundly patriarchal societies, of which the Chinese is certainly no exception. The influence and use of the Chinese lunar calendar system extends into southeast Asia, Tibet, Mongolia, Korea, and Japan. As a field of thought within the noosphere, the Chinese system is the equal in power base to the Babylonian and Indian systems, at least up to the time of the dominance of the Gregorian. Even today, the Chinese New Year exerts a powerful attraction worldwide.

While the Chinese and Hebrew lunar calendar systems maintain a powerful conservative strain of human society, the intercalation of the thirteenth moon, seven times every nineteen years, creates a kind of circulation within the system. Thirteen is the number of circulation, whereas twelve is that of a static, non-circulating spatial order. The taboo on the number thirteen-epitomized by the superstition about Friday the thirteenth-must certainly be related to the suppression of the solar-lunar Thirteen Moon/28-Day calendars in virtually all historical societies. This irrational repulsion of the number 13 serves psychologically in defense of the "rationality" of the number 12, a number that does not circulate time and is at the root of the linear conception of time. The illogical and irrational decisions that are made and then institutionalized into the human social fabric must at one point be discounted. Any illusion or error pursued for too long will always end in disaster.

The Islamic lunar calendar, used by some 1.3 billion humans, is distinguished by two factors:

1) It is based on a known historical incident, the *Hegira* or flight of the prophet Muhammad from Mecca to Medina, dated to the new moon or Muharram 1, Julian, July 16, 622 (Gregorian, July 26).

2) It is a pure twelve-month lunar calendar running on a cycle of pure lunar years of 354 days, with no intercalary lunations, and in this regard does not annually harmonize with the 365-day solar cycle.

For this reason, this year 2001 saw the beginning of Islamic lunar year A.H. *(M*-ter Hegira) 1422. But if we are to count the solar years since the Hegira, correlated to Gregorian July 26, then it is solar year A.H. 1379. We see here a discrepancy of some some forty-three years between the solar count and the lunar count. The lunar count continuously retrocedes so that it takes thirty-two years for one Muharram to occur at the same place in the cycle of the solar year. In essence, the Islamic lunar calendar creates a hermetic, retrocessing time bubble with no circulation of the power of the thirteenth moon, and that accounts for the highly conservative and patriarchal nature of much of Islamic society. Again, while there may be a virtue to maintaining a strict lunar calendar count, if it is not correlated to a harmonic solar or solar-lunar standard, the effects will be precisely of the nature that we see occurring in today's world, a point to which we shall later return.

Finally, in this brief consideration of calendars as the principle macro-organizing system for the programming of human society, a word should be said about the system of calendars in the predominant part of the Indian subcontinent. Long before they adopted the Babylonian solar zodiac and hexagisimal spatial principles for reckoning time, the Hindus also had a type of 28-day count, but one based on the course of the moon in relation to a set of stars called Nakhsastras; this created a kind of 28-part lunar zodiac. In this system, however, the Hindus divided the 360-degree lunar ecliptic into twenty-seven equal parts (27 days = sidereal cycle of the moon) each part equal to 13 degrees, 20 minutes of are, the precise measure of the 13:20 timing frequency. A complex variety of lunar calendars were developed early on, but were gradually displaced by what we call the pseudosolar Babylonian division of the Earth's ecliptic into twelve 30-degree segments, a fact that reflects the adoption to the unconscious 12:60 frequency program.

The Hindu (pseudo) solar calendars are all based on the same division into 30-degree arcs-a circle or plane in space! While the base count of the present era is taken from February 18,3102, the beginning of the Kali Yuga-the last and darkest age-exactly 5,104 years ago (dated from Gregorian year 2002), today there are at least six different calendars in use throughout the subcontintent, each essentially the same as the other, but characterized by different dynastic starting points. These differing counts, coupled with the distinct profusion of religious holidays, accounts for the jarringly conservative and colorful confusion that characterizes present-day Indian society-a neo-Babylonian time warp, its populace locked into place by complex systems of pseudo-solar calendars set in the context of earlier Hindu astronomical cycles of a vast and overwhelmingly cosmic nature.

"TIME IS MONEY": THE WATCHWORD OF THE 12:60 FREQUENCY

All of the aforementioned time-reckoning systems, with their various beginning points, can be mapped within the 5,200 tun/5,125 solar cycle of the thirteen baktun Wave Harmonic of history. While we can generally see how the Babylonian and lunar calendar systems shaped the mainstream civilizational orders of the Old World, in our time map we must also take into account the workings of the 12:60 artificial timing frequency within the unconscious noosphere. In this sense, the 12:60 frequency refers to the principle programs of control adopted and maintained through use of the twelve-month calendar systems in the Old World. (See plate 5, Noospheric Time Map-Wave Harmonic of History.)

Plotting the incidence of these calendrical streams on the time map, we must keep in mind that the calendar systems are the chief instruments for establishing and maintaining the human mind and social order within very specific programs of behavior. These programs, at least in the Old World, were characterized by the introduction of artificial systems of exchange called money, and accompanying programs of taxation. These systems were adopted to a greater or lesser degree by all the Old World societies. In this we find the root of the slogan, "time is money," where money is the artificial medium to negotiate artificial time. The end of history is the end of money and the end of artificial time. The word "calendar" itself is derived from a Latin word meaning "account book," the first day of every month being *calends* or the date of payment of debts.

Now, let us return to a consideration of the two principal and resultant 12:60 instruments dominating the end of historical time: the Gregorian calendar and the mechanical clock. We may note that toward the conclusion of the twelfth baktun cycle (A.D. 1618), the clock reaches its perfection at the very moment of the implementation of the Gregorian calendar reform (A.D. 1582), just after the act of global circumnavigation had been accomplished. Within the entire thirteenth baktun cycle, 1618-2012, the coincidence of these three factors-clock, calendar, and European global circumnavigation-induced what amounts to a 12:60 frequency capture of planetary time in the biosphere. What are the implications of this takeover of time by an irregular and irrationally measured Gregorian calendar and its accompanying micro-organizing device, the mechanical clock?

Plotting the growth curves of human population, machine, and money, we see that the complete infusion of the 12:60 artificial timing frequency creates an unprecedented acceleration, the exponential peak of which occurs at the moment of the Inevitable Event. For this reason, according to the Law of Time, it is important to comprehend even more deeply the nature of calendars and their effect, especially with regard to the current global standard.

Because the calendar is a macro-organizing principle, when accepted over time it establishes in the mind, individually and collectively, a set of perceptions that are automatically taken for granted as being "real" and "indisputable." These sets of perceptions define the paradigm by which a people, culture, or even an entire civilization operates. The Gregorian calendar, the current global civil standard, is the paradigmatic macro-organizing principle in which are embedded all the laws, customs, institutions, and scientific principles governing the present global civilization-not to mention all the holidays of the Vatican-ordained Catholic Church. According to the Law of Time, the current calendar is an irregular standard of measure; its units of measure do not correspond. This calendar represents, therefore, the institutionalization of disorder and entropy. Because it has existed for a sufficiently long duration in the human historical cycle-2,000 years, including its predecessor, the Julian calendar-the perceptions fostered by the unconscious acceptance of the Gregorian calendar are taken as the unshakable bedrock of nature and reality. All current beliefs-economic, political, and scientific, from democratic neo-liberalism to the special theory of relativity-are actually products of the underlying perceptions promoted by this calendar, and have no reality apart from the beliefs about time that the calendar engenders. *Change the macro-organizing principle and you change the paradigm.*

THE NEED FOR A TRULY "NEW MILLENNIUM"

As the global civil standard, the artificial, irregularly measured Gregorian calendar is a self-reinforcing feedback loop. As such, it furthers and maintains all linear time concepts, thereby establishing a host of entropic, disordered value concepts such as the violent universe, the degradation of matter, quantum physics, the arrow of linear time, the doctrine of techno-economic inexorability, and an attendant host of unresolvable problems-crime, drug abuse, terrorism, environmental deterioration, and so forth. Why? Because as an irregular standard of measure, the Gregorian calendar is incapable of producing harmony. Only harmony can unify. The Gregorian calendar is not a unifying harmonic standard. Lack of a unifying global standard exacerbates all current conflicts. Condition the mind to an irregular standard and the mind will adjust to disorder and chaos as normal conditions of existence.

The world's racial, tribal, historical, and religious conflicts are embedded in and a function of different timing systems (calendars), all now coordinated within a master irregular timing standard and macro-organizing principle, the Gregorian calendar. In this calendar's irregularity is embedded the view that the world of the inevitable degradation of matter is the exclusive object of all present-day science, and hence is also reflected in the entropic nature of global civilization and its deteriorating social processes. The Gregorian calendar conditions the mind to hopelessness of resolution. Without a unifying harmonic standard humanity is incapable of finding long-term resolutions for any of its problems. Disharmony can never produce harmony. Only harmony can produce harmony. All conflict can only be resolved by the application and within the context of a harmonic timing standard.

Now, following the attack on the Twin Towers and the Pentagon, we can say that the Gregorian calendar is bringing history to an end. The Inevitable Event was programmed into the Gregorian calendar, and the Gregorian calendar usurped the power of all calendars in the thirteenth and final baktun cycle of history. When the third millennium officially opened at the dawn of the year 2001, the pride of industrial man was at an all-time high. Would it be a millennium of peace or one of war? If the last century of the second millennium was the century of total war, was the third millennium going to do anything but inherit the unfinished programs of the old millennium? Could the Earth and the biosphere withstand a millennium of total war? Hardly. The Vatican "jubilee year," which ended with the beginning of the third millennium, turned sour with the Twin Towers apocalypse, as is vividly reflected in a photo of Pope John Paul II taken just after the Inevitable Event. The Gregorian calendar marks its inception with the birth of Christ, a date and moment that was never historically noted, and so is shrouded in speculation and conjecture. Now the twisted civilization of Gregorian time is locked in mortal combat against a terroristic specter that it alone could have projected into manifestation. Soon, by biospheric standards, the world of artificial time will be over and gone. And then the millennium will be truly new.

The very word *millennium* conjures possibilities of Earth-shattering events and cosmic prospects. If the inception of the Kali Yuga, 3102 B.C.,can be said to be the point where the historical process became irreversible, eleven years after history began in 3113 B.C.,then in counterbalance, the Inevitable Event, 2001, which had to occur eleven years before the end of the cycle of history, A.D.2012, was more than just millennial. It was the termination of more than 5,000 years of the irreversible motion of artificial time. Such symmetry-eleven years after the beginning and eleven years before the end of history-is the hallmark of the synchronic order. For 5,100 years the count of days has numbered the long and increasingly perilous saga of human civilization. How bright was the beginning and how grim will be the end?

There at the beginning of the cycle was the "first city," Uruk. There at the end of the cycle, the fallen Twin Towers of Babel of the "last city," New York (= New Uruk), the ultimate monument to history itself and the final event to initiate the actual closing of the cycle of history.

> *There it is, the city of Uruk. Urshunnabi, climb up on that wall, the outer all shining with the brilliance of burnished copper. The seven wise men laid the foundations. One third of the city is buildings, cunningly executed, one third of the city is garden with rose and bird, and one third of the city is field with the temple of Ishtar within. Goddess of love and struggle.*
>
> - *THE EPIC OF GILGAMESH*[6]

If Uruk is the place where the seven wise men laid the foundations, those foundations were measured by the 24 hours, 60 minutes, and 60 seconds derived from the 360 degrees of the circle. Fifty-one centuries later, the gardens are all but gone, the fields themselves mechanized and chemicalized by the technosphere. Earth's inhabitants are in terror. Five weeks after the Inevitable Event, now known simply as 9-11, the end of history still smolders. After the struggle, will the goddess of love return?

▼

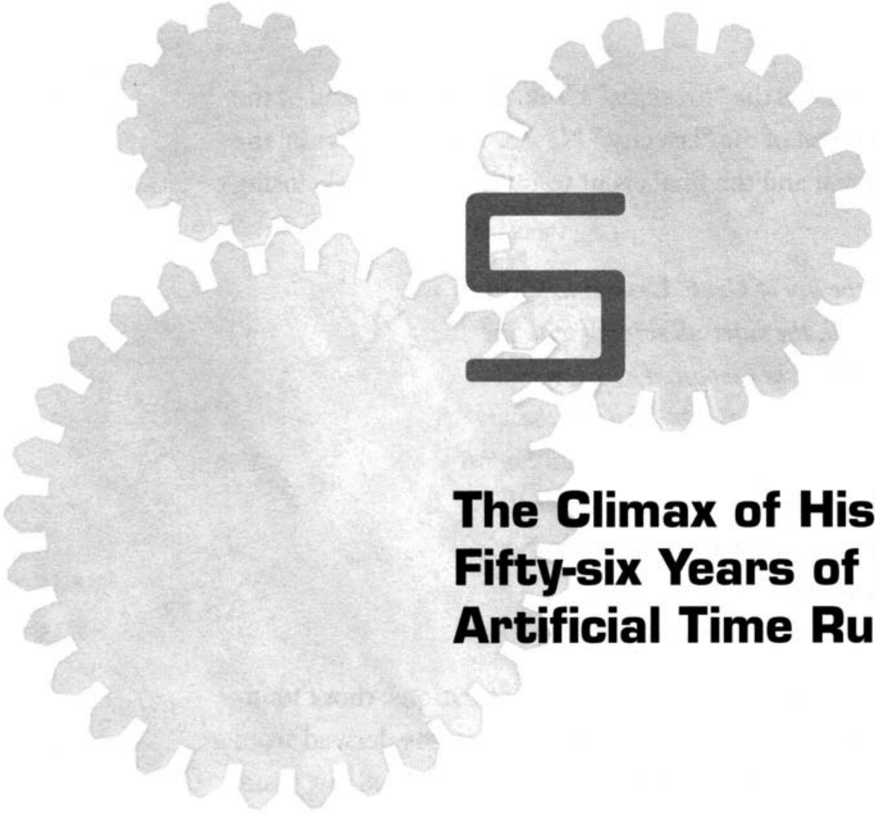

5

The Climax of History, the Fifty-six Years of Hiroshima—Artificial Time Runs Out

THE IMAGE of the Noospheric Time Map-Wave Harmonic of History on plate 5 of the color insert, showing the concurrent evolution of the different calendars of the major civilizations of the world (the illustration is by no means exhaustive), is intended to demonstrate the fact that the human race was not unified by a single coherent timing standard throughout twelve of the baktuns of historical development. It was only in the thirteenth and final baktun that humans became organized by a single timing standard. However, it was not a timing standard in accord with the synchronic order of the Law of Time, but the artificial 12:60 timing frequency as represented by its two organizing instruments, the Gregorian calendar and the mechanical clock.

The seeds of this moment had already been planted in the noosphere at the beginning of history. From both Sumeria and Babylonia the taint of the 12:60 frequency then spread through the noosphere and, by means of historical dissemination and conquest, throughout the Old World. By the time the historic moment arrived to ripen the 12:60 frequency into its full fruition-A.D. 1618, the beginning of the scientific revolution and the thirteenth baktun-there were virtually no longer any cultural traditions governed by the natural 13:20 timing frequency. The civilizations and peoples of the New World were now under the subjugation of the prevailing world order of European global imperialism. The stage was set for the brief but final phase of mechanization, of which the technosphere itself is the climax.

What the Noospheric Time Map also delineates is that the 13:20 frequency was the unconscious organizing factor of prehistory, and that, undoubtedly, a key timing system intuitively evolved among many prehistoric peoples independently of one another. This was the universal, harmonic solar-lunar standard of the Thirteen Moon/2 8-Day calendar. The defining point of history arrives with the establishment of a 12:60 timing standard within the noospheric unconscious. This frequency predominates in the development of twelve-month pseudosolar calendars, as well as the twelve-month synodicallunation calendars that are not the measure of a solar year. These two commingled systems are entwined throughout the ancient history of the Old World as the central thread of development shaping the conception of time and resulting in what were to become the two dominant instruments of human time reckoning, the Julian/Gregorian calendar and the mechanical clock.

Julius Caesar himself instituted the famous "calendar reform" that created the 446-day year of confusion in 45-44 B.C.,and established a calendar that was just as patently confusing. Julius Caesar's was not the only calendar reform in the ancient world. The Essene movement, founded by someone known simply as the Teacher of Righteousness and of which Christ was supposedly a member, began as a revolt against the Hebrew lunar calendar. The issue was the need for fixed holidays within the solar cycle, something that is virtually impossible in a lunar calendar that retrocedes eleven days every solar year. There is strong reason to believe that among other calendars, the Essenes favored the Thirteen Moon/2 8-Day calendar. This even leads to the question: did Christ himself follow a thirteen moon calendar? In any case, it is the 12:60 frequency transmitted through the irrational disorder of the Julian/ Gregorian calendar that captures the mind of the human race and the biosphere during the final years of the cycle of history. And it is precisely for this reason that the pace of human civilization becomes exponentially and entropically accelerated during the last few centuries of its development.

Shocked into higher consciousness by its own barbarism masquerading as civilization, at the end point of history the human has the opportunity to return to the natural 13:20 frequency of synchronization. This return would mark the emergence of humanity from the unconscious mechanistic compulsion of artificial time into the conscious field of post-history. The only possible option to unify humanity-once the yoke of the Gregorian calendar is removed-is the true solar-lunar calendar of Thirteen Moon/28 Days. With the possibility of this positive end in sight, we may turn to a more descriptive and definitive analysis of the technosphere. In this way understanding the modalities of the technosphere as a distinct and entire process, we

Gregorian Calendar 28-Year Cycles: 1945–2001, the Age of Terror

It takes twenty-eight years for the Gregorian calendar to run through its cycle of permutations. Every twenty-eight years, like a phonograph record of time—a chronograph—the Gregorian calendar guides its users through a mentally debilitating construct of unevenly measured and irrationally named months, paced by a system of 7-day weeks that bears little relation to the lengths of the months or years. In addition, every four years there is an extra day. Within this medieval mathematical jumble are kept the collective unconscious programs that repeat every twenty-eight years. What happened in 1945 will somehow repeat or have an effect again in 1973, in 2001, and then in . . . it's up to you. You can change this if you want to.

First day of the year	Tuesday	Wednesday	Thursday	Friday	Sunday	Monday	Wednesday	Friday	Saturday	Saturday	Monday	Thursday	Tuesday	Sunday
Hiroshima 1945 – 72						1945								
	1946													
		1947												
												1948		
										1949				
					1950									
						1951								
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Twin Towers 1973 – 2000						1973								
	1974													
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Inevitable Event 2001 - ?						2001								
	2002													
		2003												

2004 Year of the Great
Calendar Change
Where will you be? 2012

might then develop a deeper insight into where we have just been and why we need to go somewhere else.

The technosphere defines a 56-year cycle, 1945-2001, coordinated by two complete Gregorian 28-year cycles. For any Gregorian calendar year, the days of the weeks in their irregular monthly succession and in relation to the permutation cycle of leap years repeat precisely every twenty-eight years, during which time there are always exactly seven leap years. This means that Gregorian calendar years 1945, 1973, and 2001 possess the same exact annual arrangement of the days of the week in their monthly succession. If today is Sunday, November 11, 2001, so it was in 1973, and likewise in 1945. In this regard the Law of Time frames the cyclic recurrence of the otherwise irregular 12:60 Gregorian calendar by the intrinsic formulation 28:7. That is, just as the 19:7 factor coordinates the lunar calendars every nineteen years, there being seven intercalations of the thirteenth moon during that cycle, so in the Gregorian calendar every twenty-eight years there are always exactly seven leap days and years.

Understanding a calendar as the instrument that locks the conditioned programs of a given culture or people into place, we can now understand how the unconscious metaprogram of the macro-organizing principle of the Gregorian calendar cumulatively recycles all its millennial programs every twenty-eight years. Since its inception in 1582, the Gregorian calendar has been dragging forward a host of conditioned thought forms and perceptions, including those inherited from 1,500 years of the Julian calendar that it had reformed. At points of dramatic break in the continuity of human consciousness, a new set of cycles is set to recur. Such was the case in the year 1945, with the awesome blast of Hiroshima. The entirety of the mind field conditioned and held in place by the Gregorian calendar then reaches its full fruition during the two subsequent 28-year cycles, fifty-six years in all-thus bringing forward two millennia of conditionings, conflicts, and unconscious death wishes or apocalyptic programs. The first cycle was initiated in the year 1945, the year in which Vernadsky died, the atomic bomb was tested once and used twice, and the Second World War came to an end. That year, 1945, marks the beginning of the technospheric bubble. It is most telling that the Second World War was concluded at the beginning of this 56-year cycle of the technosphere, for it was a war concluded not with peace but with instruments of mass destruction and terror. Thus began the 56-year era of Atomic Terror.

The technosphere has its origins with the full capture of the human mental field by the 12:60 frequency in 1618. From 1618 onward, the noosphere is increasingly obscured by a mental field known as the *technospheric sheath.* Slowly but surely, the technospheric sheath replaces civilization. This is first done by the introduction of mechanistic linear time. It is important to note that the Julian count, the basis of all modern scientific calculations, is a scale created by Thomas Scaliger in 1583, twenty-one years after the 1562 Mayan book burning. This linear time scale, like the Gregorian calendar reform itself, was intended to co-opt the Mayan thirteen baktun Long Count by setting a count of days that begins the first of January, 4713 B.C., or some 1,600 years prior to 13.0.0.0.0, the beginning of the thirteen baktun count in 3113 B.C. This deliberate historical act, the Julian count, along with the Gregorian calendar and the mechanical clock, established the paradigmatic notion of the linearity of time in the ripening field of scientific thought. Reflected in the noosphere, this linear, irreversible time concept levels and stunts the realization of human mass consciousness. In fact, during the technospheric cycle, especially after 1754, the ceiling of human consciousness is maintained by a preoccupation with mechanistic third-dimensional operations while becoming increasingly alienated from the organic order of reality. This creates the 12:60 consciousness constant, a mental ceiling that actually diminishes in proportion to the increasing rates of multiplication, propagation, and intrinsic velocity of the machine.

With the actual rise of the Industrial Revolution, dated in the noosphere to A.D. 1754, the synchronic point at which mechanization becomes an irreversible factor of the biosphere, the technospheric sheath, henceforth enters its next stage, going from a purely mental sheath to the industrial sheath, the prelude to the proto-technosphere itself. The industrial sheath spreads throughout the biosphere between 1754 and 1901, the official beginning of the twentieth century. At this point we enter the forty-four years of the proto-technosphere, 1901-1945. During this critical stage of the proto-technosphere, the actions of human behavior interacting with machine technology make the expression of true culture increasingly difficult, if not impossible. Civilization becomes a set of symbols purveyed through museums, galleries, and theaters, and recorded and reproduced in ever more advanced technological forms. But what of culture, which is not the same as civilization-what becomes of culture?

To begin to answer that question, some further definitions are in order. The technosphere is defined by and based upon one key term: *technology.* According to the common dictionary definition, which already reflects the mass mind, technology is "the totality of the means employed to provide objects necessary for human sustenance and comfort."[1] Today virtually all the means employed are themselves mechanical in nature. In common parlance, therefore, technology refers to the complex apparatus of mechanization. In fact, technology *is* mechanization; it is the ability to convert human labor into processes carried out purely by machine-oriented or mechanical means. This is also inclusive of the entirety of computer technology, which represents the mechanization of the more purely mental processes of thought and communication.

Mechanization, we must remember, originated in the clock, in the mechanization of time. It is the mechanization of time that presupposes the tendency toward mechanization as a state of mind within the noosphere. Since artificial time is characterized by the illusion of an inexorable and irreversible linearity, the compulsion toward materialism is also experienced in the same way, an inexorable motion spearheaded by the advance of ever more improved machines. The machines themselves are the products and means of industrialization-the technological transformation of raw goods into consumer goods, a process accounting for much of the free energy introduced into the biogeochemical combustion of the biosphere.

Inseparable from mechanized technology, too, are materialism and the concept of the World Market and, more recently, of globalization. Materialism is implicit in the dictionary definition of technology as the means employed not only for human sustenance but also for human *comfort.* This comfort can only be of a material form or nature, hence the pursuit of comfort through mechanized technology can only be for the furtherance of a philosophy and exaggerated lifestyle of materialism-the belief that only the material things of this world have any value. Of course, the value of material goods and comforts increases when the value of money is put into the technospheric equation. The first stock market opened early in the eighteenth century, providing a place where money could be used as speculative capital to promote the advance of commodities and machine products. The entire sphere involving commodity production and its conversion into consumer products eventually came to be known as the World Market. Integral to the success of the World Market was the creation of the modern banking system, based on the institutionalization of interest rates and the principle of lending money to companies for the purpose of furthering the transformation of the biosphere into the technosphere.

While the concept of the World Market prevailed for a long time as the definition of the system for exploiting and extracting natural resources from the biosphere, and then converting them into industrial goods to be consumed by the human populace worldwide, globalization is far more recent. Globalization represents the absolute triumph of capitalism as the dominant economic doctrine of the human species in the biosphere, and the absolute basis of the technosphere in its final phase of development. As such, globalization is the economic system of neoliberal market economics that treats the whole world as the proper sphere of its policies and practices. It is a specialized form of monetary imperialism that gives rise to and is supported by the doctrine of monetary politics, the use of money as a means of coercion or even for the buying out of whole governments. Of course, the principle practitioner of monetary politics is the nation with the most money, the United States of America, home of the World Trade Center.

Fostering corporate multinationalism, globalization is inseparable from the consumer philosophy it promotes. Consumerism is the devaluation of the human into a link in the chain of the cycle of industrial production, the object of globalization being to inspire and promote a massive and wide-scale consumerism worldwide. This is what is meant by such phrases as "increasing consumer purchasing power" and "opening new markets." To promote and defend its interests, the all-pervading system of globalization first developed the World Trade Center, and in the last decade, following the end of the Cold War, the GAIT and the WTO, the global "Chamber of Commerce."

As a political hegemony, globalization is managed by the G-7 group of the seven most industrialized nations (the United States, Canada, the United Kingdom, France, Italy, Germany, and Japan-now, with Russia, sometimes referred to as the G-8). This organization, headed by the finance ministers of these seven countries-like the seven wise men of Uruk at the beginning of history-was secretly formed in 1974 by the CIA, one year after the completion of the World Trade Center Towers and the formation of OPEC. The first public meeting of the G-7 occurred in the summer of 1990, just prior to the Iraqi invasion of Kuwait. The doctrine and system of globalization-now overtly controlled by the G-7 and its chief ally, the Euromarket nations-is inseparable from industrial technology as the means employed to provide objects necessary for human sustenance and comfort. Implicit in the philosophy of globalization is the right of the G-7 to promote and defend its way of life, regardless of its ultimate effects on the biosphere and at the expense of ideologies and beliefs not consistent with it. To defend itself, globalization has at its disposal the U.S. military, the command of which is housed by the Pentagon, and the new technospheric multinational military cartel, NATO. In a word, globalization is the triumph of the military-industrial complex.

From the point of view of the biosphere, globalization is the cancer of the human species consuming non-renewable resources and, through the release of free energy, effecting the final critical increase in biogeochemical combustion. The planetary instrument for furthering the entire process and philosophy of globalization is the technosphere. The technosphere may be defined as the entire apparatus of mechanized technology and its support philosophy (globalization), understood as an artificial sphere encompassing the globe. As such, the techno sphere is discontinuously interspersed within the biosphere. More precisely, the technosphere is located physically and mentally between the biosphere and the noosphere, in other words, between the Earth's vital sphere and its mental envelope.

Being the description of an evolutionary stage, the technosphere is governed by the Law of Time as a 56-year event continuum along the lines of an artificial planetary cocoon. Insofar as it is the projection of human thought, the technosphere is the materialization of the sum mental processes denoted and conditioned by mechanization in all its aspects, and that have their primary root in the mechanization of time. It is the mechanization of time that essentially establishes the artificial timing frequency as the capacity to engender the machine and, consequently, an artificial structure, the technosphere. Because it is artificial, however, its duration is highly limited and is subject to the inherent inconsistencies and contradictions in human thought and social structures because of the aberrant effects of adapting to artificial time in the first place. The effect of adaptation to artificial mechanized time creates a social-political hierarchy known as the technocracy-rule according to the needs of technology. It is the effect of maintaining the technocracy and the technosphere itself that establishes the inability of human consciousness to do anything more than remain in a constant, servile, and unchanging state of machine dominance. All the while, by contrast to the unchanging condition of consciousness, the machines evolve exponentially in number and complexity. As Marshall McLuhan so correctly put it, the humans are the bees of the machine.

To be fully understood, the technosphere cannot be seen apart from its place in the biosphere-noosphere continuum. The technosphere represents the absolute control of the biosphere by artificial 12:60 time. Artificial time generates the artificial medium of money, hence the operating philosophy of the technosphere: "time is money." Money is the lifeblood of the technosphere. Servitude to money draws humans away from the biosphere in order to be devoured by Mammon-the technosphere as an all-consuming entity. In this process the humans get money in return for selling their bodies and souls to artificial time, usually eight hours a day, often to produce artificial goods or for service in maintaining the artificial system of money itself. This money gained from servitude is used to buy consumer goods, including more machines of every kind, and thus the human participates as a vital link in the cycle of biogeochemical combustion. In this way the mechanized lifestyle converts the human-the consumer-into the biomass necessary for maintaining the technosphere.

By 2013
Earth is galactically synchronized into a new biogeological epoch: the psychozoic Era.

As the mental envelope of Earth, above and discontinuous with Earth, the noosphere can only mean one thing: the advent of universal telepathy among the humans.

The difference between the new time and the old time is like the difference between heaven and hell.

Planetary 9-11, 2001 inaugurates biogeochemical combustion, biospheric means of transformation, and self-mutation.

Technosphere:
Biospheric agent devised for maximum biogeochemical combustion.

Built in an area known as "Hell's Bottom"

The Pentagon
1941–200?

Impregnable fortress of the American war machine, meant to protect "democracy" = American domination of world market and foreign/economic policy of globalization. "The form of the Pentagon . . . is that of a pentagram, the chief magical aid for gathering power. When a pentagram is drawn with its base toward the north, and its chief point to the south, it is useful for negative or black magic purposes."
—*Transformative Vision*, page 249

By 2012
Humans realize a permanant condition of peace through culture.

By 2009
Humans are reorganized by the Law of Time and begin the construction of a galactic culture on Earth.

Dismantling of the technosphere stabilizes the biosphere and reveals the noosphere—2005.

By leaving artificial time and returning to natural time via the Thirteen Moon calendar, humans advance the noosphere.

2004: Last opportunity for humans to change their macro-organizing principle.

Exhaustion of the Technosphere—
2001–04.

Exponential growth curves of money, machine production, energy, and people climax.

Planetary 9-11:
time runs out on the technosphere.

"New" millenium nipped in the bud; civilization R.I.P., 2001

Technosphere:
Interlocking interactive pentagon of five artificial systems - WTC = Nerve center and hub of the technosphere and its driving power, globalization.

Biosphere:
Controlled by artificial (12:60) time.
Time is Money—lifeblood of the technosphere.

Humans devoured by Mammon. Get money in return and create biomass to maintain technosphere.

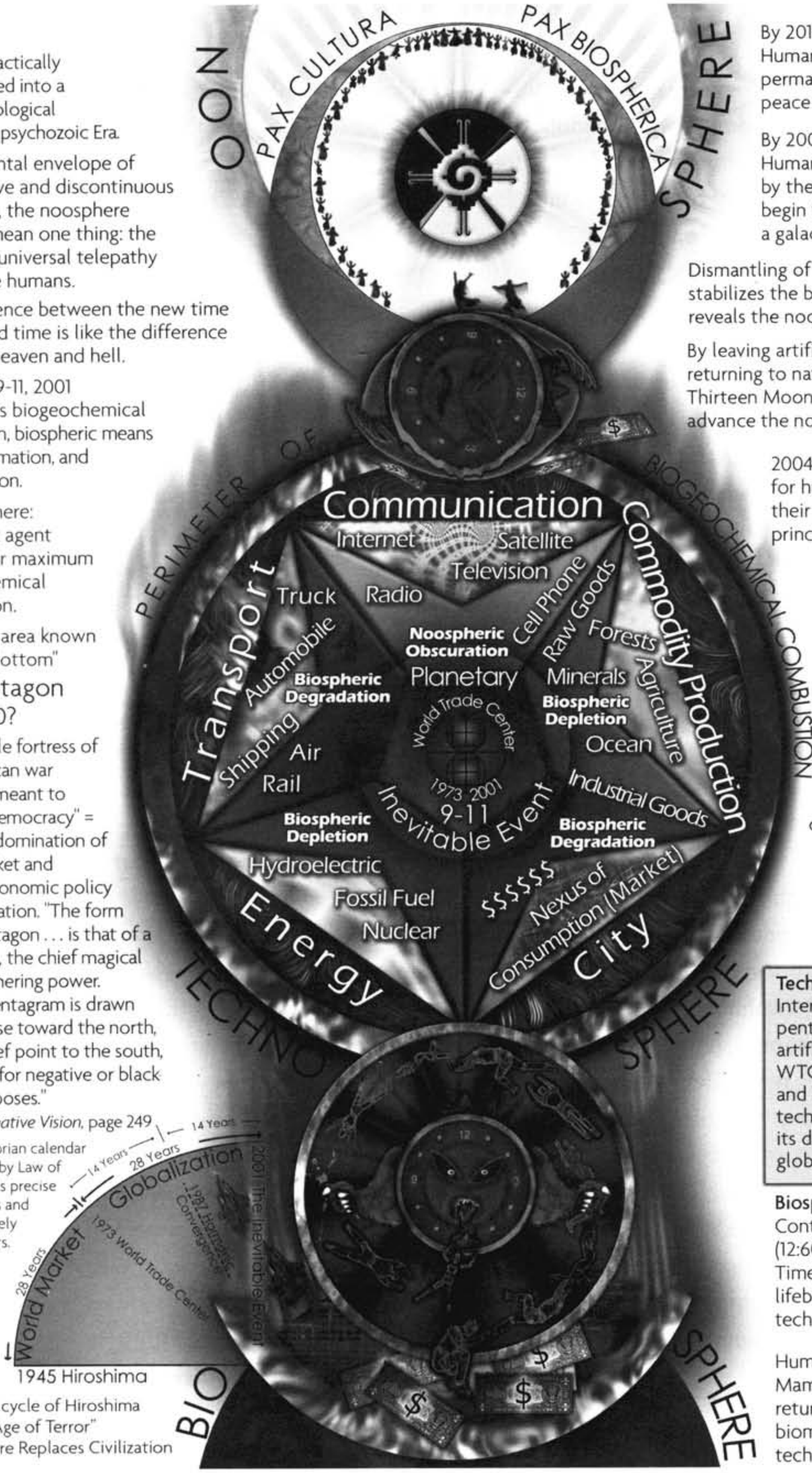
NOOSPHERE
PAX CULTURA
PAX BIOSPHERICA
PERIMETER OF BIOGEOCHEMICAL COMBUSTION
Communication
Internet
Satellite
Television
Radio
Cell Phone
Transport
Truck
Automobile
Shipping
Air
Rail
Commodity Production
Raw Goods
Forests
Minerals
Agriculture
Ocean
Industrial Goods
Noospheric Obscuration
Planetary
World Trade Center
1973 2001
9-11
Inevitable Event
Biospheric Degradation
Biospheric Depletion
Biospheric Depletion
Biospheric Degradation
Energy
Hydroelectric
Fossil Fuel
Nuclear
City
$$$$$$
Nexus of Consumption (Market)
TECHNOSPHERE
14 Years
14 Years
28 Years
28 Years
Globalization
World Market
1973 World Trade Center
1987 Harmonic Convergence
2001 The Inevitable Event
1945 Hiroshima
BIOSPHERE

*Note: Gregorian calendar coordinated by Law of Time. Repeats precise order of days and weeks precisely every 28 years.

56-year cycle of Hiroshima
"Age of Terror"
Technosphere Replaces Civilization

Biosphere–Technosphere–Noosphere

As an operating planetary structure, the technosphere consists of five interactive components.

1. COMMODITY PRODUCTION

Commodity Production, the basis of the entire World Market as a biospheric system, refers to the transformation of natural resources through industrial means into consumer products. Commodity production alone accounts for the complex of industrialization that brings the World Market and the technosphere into existence. According to *The Biosphere Catalogue,* the post-World War II growth of the World Market necessitated the establishment of the World Trade Center, a global complex (114 such centers in 1985), but with its principle coordinating unit being the Twin Towers in New York City, home of the World Trade Institute and the corporate offices of the New York Stock Exchange, the key to the world money and commodities market.

2. CITIES

Cities, the second technospheric component, represent the human social organism or marketplace for accommodating the production and consumption of industrial goods. Civilization is city life as it has evolved from Uruk to New York (= New Uruk). While prior to industrialization the city depended on a healthy agrarian economy for its support, industrialization pushed the city to new heights of artificiality, not the least of which were round-the-clock lighting systems that allowed for 24-hour consumer markets. As such, the city is the nucleus of the technospheric system, the hub of its commodity production, of its energy consumption, and of its transport and communication empires. The growth of the cities around the world is exponential in the second half of the twentieth century, reflecting the triumph of the technosphere. It should be noted that in the fifty-six years of the technosphere, the human population almost tripled-from 2.2 to 6.2 billion, a growth demonstrated in the vast expansion of the large urban centers.

3. ENERGY

Energy is the third component of the technospheric complex. The tremendous needs of industrial production have transformed the natural energy processes of the biosphere into gigantic artificial complexes for the production of energy to maintain factory and city alike. The impact of the different artificial energy systems upon the biosphere has been enormous. These systems include coal, oil, and fossil fuels in general, as well as hydropower and nuclear energy. The whole syndrome of artificial time, artificial means, acceleration of the machine, and expansion of human population has required and created the enormous output of artificial energy into the biosphere and contributed greatly to the destabilization and loss of natural resources and atmospheric and hydrospheric contamination through the release of toxic "free energy" by-products.

4. TRANSPORT

Transport. Without the highly industrialized transport systems, the commodity production, the vitality of the cities, and the access to provisions of fuel required for the energy systems would collapse. No sooner had industrial production begun early in the eighteenth century than the first artificial transport systems came into being: the steam- or coal-driven locomotive, and the great transoceanic shipping lines. By the twentieth century, the railroad system and worldwide shipping industry were supplemented by the invention of the combustion engine, which made the trucking industry possible. Following World War II, rocketry and jet propulsion established the transportation might of the great airline companies of the second half of the twentieth century. It is no coincidence that commercial airplanes, the symbol of the technosphere's advanced transport systems, were used to bring down the Twin Towers and to penetrate the Pentagon.

5. COMMUNICATION

Communication is the fifth component that unifies the technosphere into one whole system in touch with itself everywhere. From telegraph to telephone, radio, television, and then finally fax, cell phone, and the Internet, the industrial-era technologies, with their electronic instantaneity, have created the vast communication networks and media empires that keep the world humming and promote globalization above all. When considering modern communication we must also bring into focus the chief method of globalization, which is marketing-propaganda on behalf of consumerism. Marketing is the use of means of mass communication to control the mind of the consumer. In the final stage of globalization, marketing replaces consciousness, or rather, marketing is the manipulation of consciousness-the latter already having been reduced to a stunted level-for purposes of consumerism, or for ideological needs such as patriotism and fear campaigns. The Internet, the marriage of computer and telephone technologies, represents the final stage of the Tower of Babel, and the completion of the process of globalization. The only place to go after the Internet is technology-free telepathy.

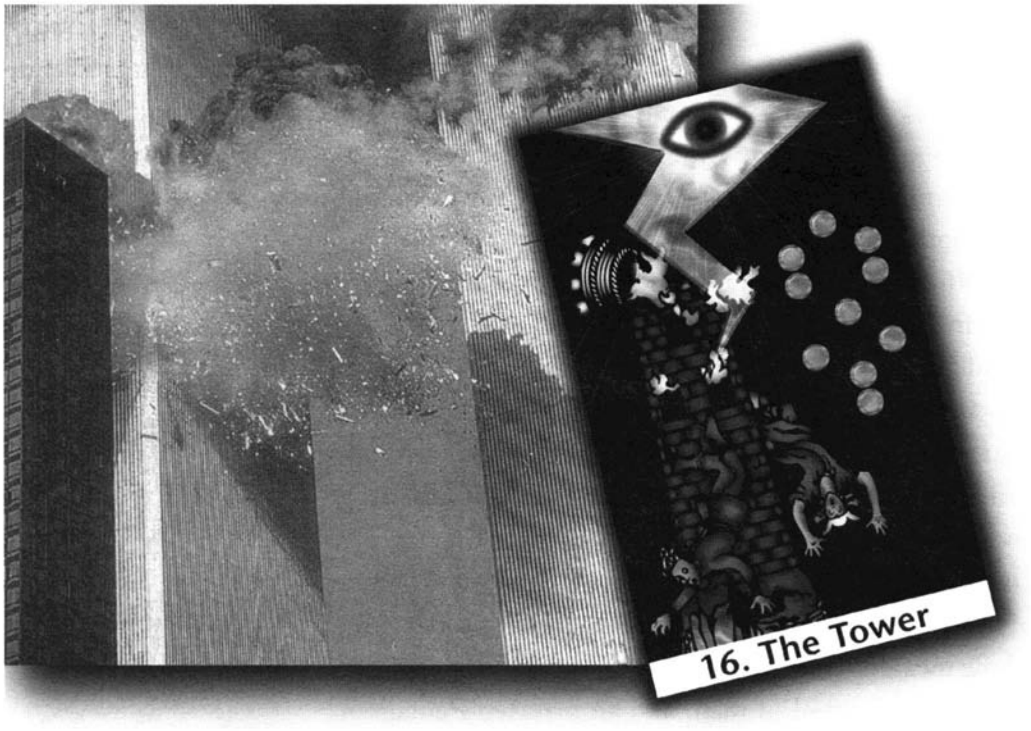

The Tower

From the biospheric perspective, this five-tiered complex of the technosphere is a whole unit. All the subsystems evolved together to establish the structure and operating procedures of the technosphere. When the technosphere goes, the entire system folds. This is what is now beginning to occur. Following the Inevitable Event, the whole technospheric system will be coming down slowly over the next few years, like a giant circus tent that has lost its central prop. How gracefully or gracelessly this happens is dependent on the response of the Pentagon-or the will of humanity to rouse itself in the face of even worse barbarisms.

Because it consists of five interactive components, the techno sphere can be graphically depicted as a pentagon, a five-sided figure. At the center of this pentagon of the technosphere are the World Trade Center Twin Towers. The actual Pentagon, which was attacked along with the Twin Towers, was designed in the late 1930s to house the U.S. Department of War. Its construction occurred in the years 1941-1943, in an old neighborhood of pawnshops and bars called Hell's Bottom.2 When it was built it was the world's largest office building in terms of actual space. Of course, when they were built, the Twin Towers of the World Trade Center were the world's tallest office buildings. The structure of the Pentagon is the prototypical morphology of the structure of the five systems that constitute the technosphere. The Pentagon was the impregnable fortress of the American war machine, protecting American interests and globalization around the world. If there were two central points-actual and symbolic-to what is known as the military-industrial complex, it was the Pentagon and the World Trade Center, and this is undoubtedly the reason why they were both targets of the Inevitable Event.

What is architecturally noteworthy about the Pentagon is that it is designed with five inner pentagonal corridors and office slabs, and that it is constructed with its odd point to the south. Since a pentagon is actually a pentagram, a five-pointed star with its points connected, the Pentagon represents an *inverted* pentagram, as its odd point faces south rather than north. In the traditional Tarot deck it is interesting that the Fifteenth Major Arcana, The Devil, contains an inverted pentagram between the horns of the Beast. Paul Foster Case writes, "This is a key to the whole meaning of the figure [of the devil]. For the Pentagram is the symbol of man, and an inverted Pentagram suggests the reversal of true understanding of man's place in the cosmos."[3] While the Fifteenth Major Arcana contains the pentagon as the inverted pentagram, the next card, the Sixteenth Arcana, is The Tower, which shows the tower being struck and broken apart by lightning (fire of heaven), with humans falling or jumping out of the windows to their death-as accurate a symbolic depiction of the collapse of the Twin Towers as could be found.

What the startling conjunction of these symbolic correspondences points to is the profoundly archetypal nature of the Inevitable Event. It has been prefigured and prophesied, and has now come to pass. No matter how much America and its allies, many of them bought for a price, may strike back, the deed has been done. The Towers are gone; the Pentagon has been penetrated. While it will take several years for the full realization of the absolute magnitude of this archetypal event to sink into the

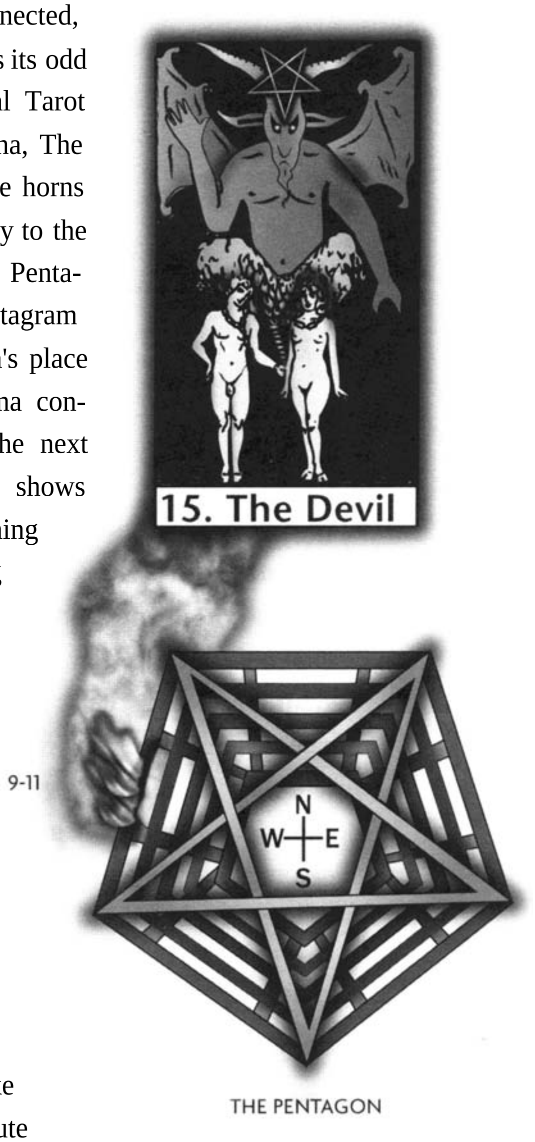

The Devil and the Pentagon

collective mind, it is important to demonstrate the actual structure in time of the techno sphere so that the finality of its end may be seriously considered, and the gate to the future, which has thereby been opened, can be made clearly visible.

As we have shown, the technosphere is a structure totally brought about by the 12:60 timing frequency, and thus is purely a function of the latter. As such, the technosphere is embedded in the global macro-organizing principle of the 12:60 frequency, the Gregorian calendar. Two 28-year cycles, each one divided into four 7-year subcycles, define the duration of the technosphere. Remember that the Gregorian calendar repeats every twenty-eight years. As we have pointed out, the 56-year cycle of the technosphere, 1945-2001, is preceded by the 44-year cycle of the proto-technosphere. The two World Wars were a function of the proto-technosphere, the final major act being the construction of the Pentagon, specifically for consolidating the American war machine-the world's largest office building means that the world's largest business is war, with a $318 billion budget for the year 2001-2002 alone!

The fifty-six years between Hiroshima and the Inevitable Event were the age of terror, for it was atomic terror that initiated the technosphere in a baptism of nuclear fire, and in the end, it was an unimaginable suicidal terror that brought down not just one, but both of the Twin Towers of Babel. The final collapse of the technosphere is also the final war between blood and money. Artificial time has run out. Only a new time will be able to regenerate the biosphere and spiritually revive mankind. What follows is a chronological description of the eight 7-year stages of the fifty-six years of the technosphere. Note the persistence of certain themes. (See plate 5, Noospheric Time Map-Wave Harmonic of History.)

GREGORIAN A, 28-YEAR CYCLE: TRIUMPH OF THE WORLD MARKET, 1945-1972

1. 1945-1951. CYCLE OF THE BOMB: ATOMIC TERROR AND THE DIALECTIC OF THE COLD WAR.

During the first dynamic 7-year cycle, with the triple event of the first test of the atomic bomb and its two detonations at Hiroshima and Nagasaki, the biosphere becomes irrevocably altered by the introduction of a constant, steady state background radiation into the atmosphere, the actual inception of the biogeochemical combustion. This act officially establishes the technosphere. The reality is that the humans also created their first weapon of mass destruction. It is this act that also immediately sets in motion a destabilization of the human consciousness in the noosphere.Within two years, Mahatma Gandhi, the world's foremost pacifist, is assassinated, as a "free" India is partitioned into three parts-India, Pakistan, and what is later to become Bangladesh. In the same year, 1947, the iron curtain between communist Eastern Europe and the West, epitomized by the Berlin Wall, turns the enmity between the two major powers, the Soviet Union and capitalist America, into the Cold War. The subsequent formation (1949) of the NATO military cartel counters the United Nations, which was founded in 1945 to replace the League of Nations. The UN now has the task of keeping World War III from happening by providing a forum where the "superpowers" can keep their cold war from heating up, and that will contain and manage the spread of nuclear power. Nonetheless, the terror of the Bomb as the ultimate deterrent engenders the arms race. Soon Russia, the United Kingdom, France, and eventually China get the Bomb. War in Indochina, the establishment of the Israeli state in Palestine (1948) at the expense of the sovereignty of the Palestinian people, and the completion of the Chinese Marxist Revolution under Chairman Mao are the highlights of 1949, followed by the Korean War in 1950. All this demonstrates the instability of the world. At the same time, 1949, commercial television production begins in the United States; the age of radio is replaced by the "tube." Americans also begin building freeways and the new system ofInterstate highways marking the triumph of "automobile culture," and the beginning of the suburban consumer lifestyle.

2. 1952-1958. CYCLE OF THE OPENING OF THE TOMB AND THE BEGINNING OF THE SPACE AGE.

In the summer of 1952 a Cuban archaeologist discovers the tomb of the Mayan sage, Pacal Votan. This unprecedented archaeological event marks the beginning of the final sixty years-three katun cycles-of the Mayan thirteen baktun cycle of history. In the following year, 1953, the superlethal H-bomb is tested. The DNA code is discovered, as are the Earth's radiation belts. The United States and Russia conduct numerous nuclear weapons tests in Nevada, Siberia, and the Pacific Ocean. Wars for independence occur in various African states, and in general the era of European imperialism is at an end, followed by the neo-colonialist (Third World) era of guerrilla warfare, poverty, and social instability. In 1956, the year the Russians launch the first sputnik and begin the space age, the United Nations tables the issue of calendar reform indefinitely, thus closing the chapter begun when the League of Nations proposed global calendar reform in 1931. The year 1956 also marks the beginning of the electronic pop culture of the technosphere, rock and roll. By the end of this cycle, the "space race" joins the arms race as a force in promoting the advance of the technosphere. Commercial airlines adapt to jet propulsion, and the great age of air travel begins, with the airport to become the centerpiece of globalization. Initial experiments in computer technology-Univac-and the first great computer corporation, IBM, announce the beginning of what is to become the major technology of globalization. A small fast-food franchise named McDonald's opens in the United States.

3. 1959-1965. CYCLE OF THE ATOMIC MIND EXPLOSION.

The July 26 Cuban Revolution of Fidel Castro, triumphant in 1959, establishes a communist state in the Americas and heightens the Cold War. That same year the Chinese communists bring to a definitive end the rule of the Dalai Lama in Tibet. In the Congo, the popular hero Patrice Lumumba is assassinated after only two months in office. Also in 1960, the human population hits three billion, an increase of one billion since 1930. In 1961 the Institute of Mathematics of the Siberian Branch of the Soviet Academy of Sciences begins the monumental mathematical analysis of Mayan hieroglyphic texts. The attempted 1961 Bay of Pigs invasion of Cuba is followed in 1963 with the assassination ofJohn F. Kennedy, an act that reflects a rising level of cultural turmoil in the United States. Martin Luther King Jr. emerges as a popular hero of nonviolence and civil rights, an issue that points to a more radical discontent in America, culminating in 1965 with the Watts race riots. Rachel Carson's book *Silent Spring* (1963) signals the rise of ecological awareness. The Beatles transform rock and roll into a world-class cultural phenomenon that foments a widespread countercultural movement and atomic mind explosion, fueled by Timothy Leary, LSD, hippies, and the new antiwar movement against the conflict in Vietnam. In 1961 Yuri Gagarin is the first man in space, and the Vatican II Ecumenical Council comes to the conclusion that the best way the Church will survive in the next century is through a strong Pope. The Vatican II document also includes an appendix on calendar reform, the wording of which makes it difficult for there to be any alternative but a watered-down version of the Gregorian calendar. This act seals the technosphere within the unquestioned confines of Gregorian time, ultimately turning the atomic mind explosion in on itself.

4. 1966-1972. FROM THE WHOLE EARTH TO THE WORLD TRADE CENTER: THE TRIUMPH OF THE WORLD MARKET.

In 1966 construction begins on the World Trade Center Twin Towers, while in 1968 World Trade Centers are independently established in Houston, New Orleans, and Tokyo. That same year, UNESCO hosts the first and only conference on the biosphere ever sponsored by the United Nations, "Man and the Biosphere" (MAE), but the program slowly dies on the vine. The cultural conflict in the United States and the entire world also reaches a fever pitch in the years 1967-1969. This ferment includes: race riots, antiwar riots, a march on the Pentagon, the assassinations of Martin Luther King Jr. and Robert Kennedy, and riots in major capitals around the world and on both sides of the iron curtain, as well as the Maoist cultural revolution in China. The excitement of the '60s climaxes in 1969 with the success of the Apollo XIII manned mission to the moon and the consequent feedback factor of the human race seeing itself instantaneously on television as the whole Earth beamed from space, an opening to the noosphere. Apollo XIII initiates the next phase of the space race, travel to other planets. Also in 1969, the Woodstock concert marks the apex of the early rock-and-roll culture and the visionary climax of the cultural revolution. The 1971 Concert for Bangladesh establishes rock and roll with a conscience. In 1970 the vision of the whole Earth is translated into the first Earth Day and the birth of the ecology movement. The United Nations follows two years later with the Stockholm Conference on the Environment. The revolutionary fervor of the previous years turns more violent, and repressive governmental police powers win the day. The first 28-year cycle ends with a whimper, the dynamic destabilization of consciousness reaches a plateau of normalcy-a normalcy to be increasingly punctuated by terrorist activity, as in the Palestinian takeover of the Olympic Village in September 1972. Both apart from as well as in reaction to such activity, the technosphere has now become all-dominant and all-powerful in human affairs.

SUMMARY, GREGORIAN A: 1945-1972

During this cycle, the dynamic of the accelerated geochemical combustion destabilizes the human consciousness while increasing the curve of the machine in human affairs. By 1973 the machine curve meets and surpasses the human population curve; this stabilizes human consciousness at a level of machine normalcy (MN). Human consciousness will remain stabilized at MN, largely through varying forms of terror and fear programming, for the duration of the second and final 28-year cycle. This normalization of human consciousness allows the diverse and rapidly evolving technological components of the technosphere to reach a point of consolidation. This stabilization of the World Market fosters its next and concluding phase: globalization and the triumph of marketing over human culture. It should be kept in mind that the instruments and weapons of mass destruction, of which there were none on January 1, 1945, have now proliferated to five different countries and provide the ultimate backdrop to these first twenty-eight years. The core of the UN's Security Council is formed by the five countries that possess atomic weapons. Geopolitically, the bio-

Machine Normal Consciousness in Relation to Technospheric Growth Curves

Human consciousness, overwhelmed by war—the ever-propagating machine and bondage to artificial time—succumbs to money and stabilizes at Machine Normal, the standard consciousness of the technosphere, which represents an ever-diminishing ratio of intelligence in relation to the growth curves of population, machine, money, and war.

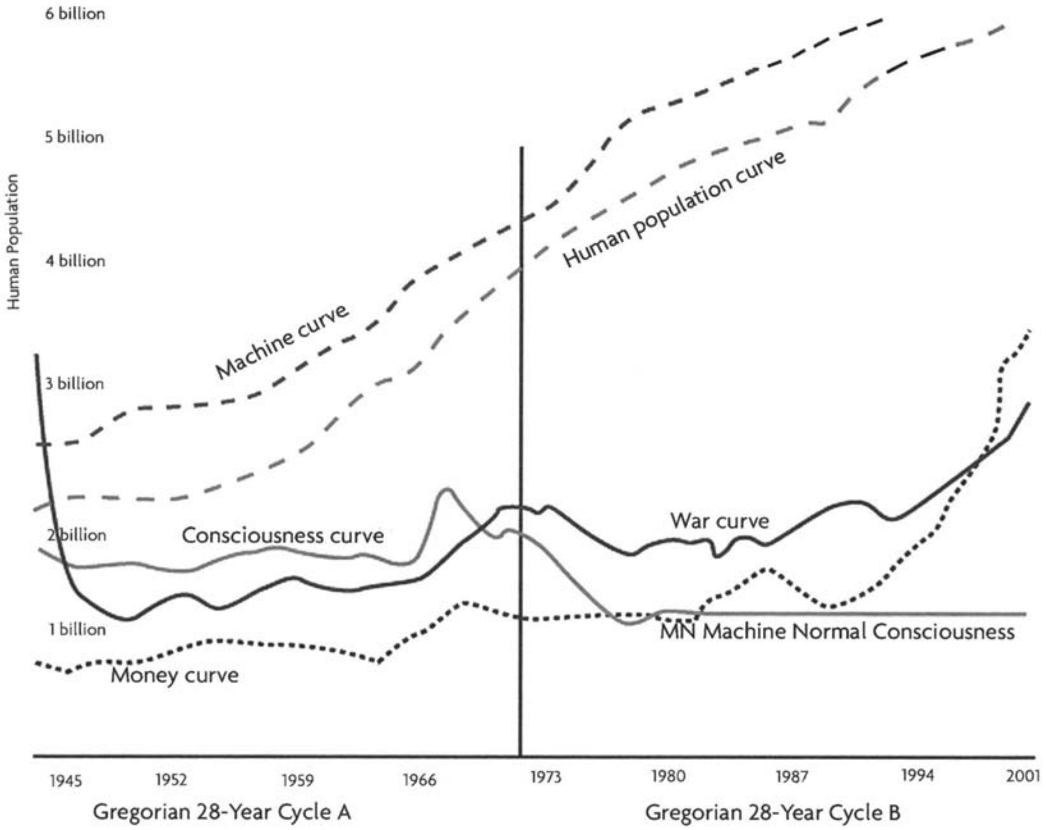

sphere is in control of technocratic powers that are virtually all located in the Northern Hemisphere-whether it is the Pentagon, NATO, the World Trade Center, the United Nations, or the Soviet space program.

GREGORIAN B 28-YEAR CYCLE: CLIMAX OF GLOBALIZATION, 1973-2001

1. 1973-1979. CYCLE OF THE CONSOLIDATION OF THE TECHNOSPHERE: CLUB OF ROME, OPEC, AND THE G-7.

The dedication of the World Trade Center Twin Towers on April 4, 1973 (a repeat of the calendar year of the Bomb, 1945) is the counterpart to the construction of the Pentagon (1940-1941), which sponsored the bombing of Hiroshima and Nagasaki. The tallest buildings in the world when they opened, the 110-story Twin Towers seal the position of New York as the "capital of the world," for on the other side of Manhattan is the glass tower of the United Nations. Simultaneous to the dedication of the Twin Towers is the formation of the Organization of Petroleum Exporting Countries (OPEC). With the exception of Venezuela, OPEC is largely an Arabic (Islamic) economic alliance that, for the first time in the history of the technosphere, brings a Third World influence into planetary politics. The subsequent "oil shortage" demonstrates the technosphere's vulnerability, which in turn causes a further "hardening of the arteries" of its consciousness-the covert formation by the CIA of the G-7. Also in 1973, after five years of study the Club of Rome issues *The Limits of Growth,* which in its analysis of trends foresees a major environmental (biospheric) crisis within one hundred years, yet nonetheless establishes and promotes the standard world model, a setting of production quotas at the 1973 level, to foster sustainable growth at least until 2020. The "standard world model" corresponds to the "normalization" of consciousness. The third war (previous ones having occurred in 1967 and 1949) between Israel and its neighbors occurs this year. By 1975, the world population is at four billion, up a billion since 1960. In 1976 Voyager II reaches Mars. In 1978 Karol Wojtyla becomes Pope John Paul II, the first global Pope, fulfilling the Vatican Council's requirements of a popular Pope to assure the survival of the Church into the next century. With Gregorian civilization triumphant, Mexico, home of the Maya, is the first country visited by the new Pope. In the same period, between 1978 and 1979, the Iranian Islamic revolution occurs, toppling the pro-Western Shah, signaling a heightened conservative Islamic resistance to Westernization and the technosphere. Japanese technology and corporate capitalist economy flourish, capped by the construction in Tokyo of the "New City" Shinjuku and, despite many environmental protests, the Narita airport. The mainstream global consciousness is now "comfortably numb" and on course to unprecedented materialism.

2. 1980-1986. CYCLE OF THE TRIUMPH OF THE TECHNO SPHERE.

The first cycle of the stabilized new normalcy establishes the triumph of marketing-the election of a second-rate American movie star for President, and the birth of the yuppie (young urban professional) generation of America. The rise of MTV signals the standardization of rock style as global culture; while the Live Aid global television concert on July 13, 1985, to raise awareness of AIDS in Africa, is the largest ever of its kind. The September 17, 1985 Mexico City earthquake, the worst in modern times to hit the world's largest city, demonstrates the continuing vulnerability of the techno sphere to natural catastrophe. The early 1980s witness the Intifadah uprising of Palestinians against Israel. The War on Drugs, an aggressive antidrug campaign waged by the West against narcotraffic, mostly from South America and the Middle East, heightens the new normalcy as world drug laws tighten, placing marijuana and psychedelics in the category of "hard drugs." Yet drugs continue to be a major social problem in the industrialized West. In 1986 President Reagan attacks Kadafy of Libya and invades Grenada, testing American ability to commit limited acts of aggression without inciting world censure. The construction of Biosphere II in Arizona, an effort to test the possibility of establishing an artificial biosphere on other planets, ends inconclusively. In 1985 in Bhophal, India, the worst modern industrial toxic chemical disaster occurs with more than 2,000 deaths, followed on April 26, 1986 by the Chernobyl nuclear power plant disaster, the worst since the beginning of the nuclear age. In America the suburban automobile culture gives rise to the super shopping malls. The personal computer (PC) is introduced, while electronic game arcades flourish. Sunday football becomes the major American television pastime, while television itself makes world soccer the number one competitive global sport; the broadcast of professional sports assumes the role of a primary noospheric diversion.

3. 1987-1993. CYCLE OF THE END OF THE COLD WAR AND TRIUMPH OF THE G-7.

On January 24, 1987 Voyager II sends back photos from Uranus; four days later, January 28, 1987, seven American astronauts die in a shuttle launch explosion. On August 16-17, 1987 the Harmonic Convergence peace meditation attracts hundreds of thousands who gather at sacred and natural sites around the world; later that year, October 19, 1987, the New York StockMarket crash occurs, the biggest point drop ever, and Russian Prime Minister Gorbachev initiates disarmament accord, or *glasnost.* By the end of 1987 the population is at five billion, up one billion since 1975. During 1988-1989, a rolling wave oflargely peaceful revolutions and civil uprisings throughout most of the Warsaw pact nations culminates on December 31, 1989 with the tearing down of the Berlin Wall-the end of the Cold War. At the same time, President Bush invades Panama to continue testing Drug Wars and limited-aggression capability. In the summer of 1990 an international bankers' reunion is followed by the first public meeting of the G-7. Every year henceforth, the G-7 meets publicly to set policy for globalization. Within a month of the first public G-7 meeting, August 1990, Saddam Hussein invades Kuwait, and Bush retaliates with the Gulf War, January-February 1991. In August 1991 Gorbachev is ousted in a putsch, marking the end of the Russian Marxist era. Destabilization, war, and genocide afflict the Balkans. A new wave of environmental concerns-ozone depletion, destruction of rain forests, and global warming-inspire a reactivation of Earth Day, 1990, followed two years later by the 1992 Rio Summit, the second United Nations Environmental Conference and the first in twenty years. The conference generates much paper, but the doctrine of sustainability (sustainable industrial growth) is the principle outcome. Meanwhile, with the absence of Marxist Russian economic influence, the neoliberal capitalist economics of America flourish as full-blown globalization, multinational corporations, and the prominence of the IMF and World Bank foment a uniform global corporate culture of cheap consumer services and franchised retail outlets for brand-name goods. This period also sees the rise of East Asian capitalist economies, although the Japanese economic bubble bursts in 1991. Early in 1993 a terrorist bomb explodes in the underground garage of the World Trade Center Twin Towers. The period 1989-1993 marks the beginning of the discovery of the Law of Time-the definition of the artificial 12:60 and natural 13:20 timing frequencies, the Dreamspell codes, and the decoding of the Telektonon Prophecy of Pacal Votan in 1993.

4. 1994-2000. CYCLE OF THE CLIMAX OF GLOBALIZATION.

In 1994, the GAIT Treaty is signed, the Levy-Shoemaker comet hits Jupiter, and a million Mricans die in the Rwanda massacre. The indigenous uprising in Chiapas, Mexico on January 1, 1994 provides a counterpoint to the triumph of globalization that is manifest through worldwide airport expansions, and an aggressive form of tourism that feeds the airline industry. Israel and Palestine enter the "peace process," while Yeltsin consolidates his power in Russia. This is the era of United Nations peace-keeping missions, mostly in the Balkans and Africa. Following the FBI/BATF -inflicted firestorm on a fundamentalist compound in Waco, Texas, a year later, in 1995, a terrorist bomb destroys the Oklahoma City Federal Building. The United States and the United Kingdom inaugurate control ofIraqi no-fly zones, enforced by regular bombing raids; the United States also conducts military actions in Somalia, as well as more successful ones in Haiti. This is the era of rapid expansion of computer and biotechnologies, exponential rise of New York Stock Exchange and the new specialized technologies exchange, the NASDAQ. Bill Gates of Microsoft typifies the rise of the new self-made billionaires of the Clinton era. In January 1995 the Kyoto earthquake occurs, followed by the Tokyo subway nerve-gas terrorist attack, while the Internet, the "information superhighway," is fully up and running. In 1996 in Brasilia, Brazil, the First Planetary Congress of Biospheric Rights signals rise of a new calendar reform movement with the proposal of the World Thirteen Moon Calendar Change Peace Plan, submitted to both the United Nations and the Vatican. In 1997 the Kyoto environmental conference on global warming sets policy, but the United States refuses to ratify it. In 1998 simultaneous U.S. embassy bombings in Kenya and Tanzania signal a new phase of war on terrorism, singling out a Saudi national, Osama Bin Laden, as the terrorist mastermind. By 1999 the world population is six billion, up one billion since 1987. In late spring 1999 NATO initiates a unilateral bombing campaign ofYugoslavia over the disputed region ofKosovo. The World Summit on Peace and Time, at the University for Peace, Costa Rica, sends emissaries to the Vatican and the United Nations with the Declaration of Thirteen Moon Calendar Reform; later in 1999 WTO has its first meeting in Seattle, which sparks anti-globalization riots. In 2000 the Y2K computer scare surrounding a bad time program fails to materialize. On Rosh Hashanah, September 28,2000, Hebrew year 5761, Israeli leader Ariel Sharon's presence at Temple of the Mount, Jerusalem, sparks a new Intifadah of Palestinians, which continues unabated through 2001, the official first year of the new millennium.

5. 2001-? *GOTTERDAMMERUNG* OF THE TECHNO SPHERE: FIRST YEAR OF THE THIRD MILLENNIUM, REPEAT OF GREGORIAN CALENDAR YEARS 1945 AND 1973.

In July 2001, G-7 meets in Genoa, Italy, as more than 100,000 anti-globalization protesters riot. In early September the United States and Israel walk out of the United Nations Conference on Racism in South Africa. Then, within ten days occurs the Inevitable Event, Gregorian 9-11, 2001, the cumulative synchronic pressure point where the technospheric bubble-the artificial time warp in the noosphere-bursts open, spawning in its wake the full-scale War on Terrorism-another name for World War III. The Inevitable Event exemplifies the built-in failure of the Gregorian calendar to commence another 28-year cycle as was done in 1945 and 1973. If the 1945 cycle began with the end of one world war, the 2001 cycle begins with the start of one. Since 2001 is also first year of the third millennium, the Gregorian calendar has created its own apocalypse, opening a noospheric fissure-the climax of the biogeochemical combustion of the biosphere. Now it is only a matter of time before the technosphere experiences total collapse. The nature and extent of the damage sustained during the collapse is in proportion to the intelligence that responds to the knowledge of its collapsing. If this 28-year Gregorian calendar cycle were to go unimpeded until 2029, it is not certain what would be left of the biosphere. But there is one thing of which we may be certain: *artificial, linear time has run out.* An American newspaper editorial at the end of 2001 sums up the crash of the dominant linear time paradigm: "History seems to have slammed into reverse gear around a world that was widely assumed a year ago to be moving in a straight line toward a more prosperous and secular future, one that would be shaped by stock markets and the Internet, not by turbaned zealots or theocracies that have or want nuclear trigger fingers."4

SUMMARY, GREGORIAN B: 1973-2001

With destabilization normalized, the technosphere replaces civilization and marks the end of culture-the new barbarism prevails, culminating in total war. The 9-11 is what actually completes the technospheric cycle. Henceforth it will be the advent of the noosphere, but not in the way predicted by the authors of *The Biosphere Catalog:* "The Noosphere as an active force consists in the harmonious synthesis of the Biosphere and the Technosphere by intelligence."5 By the analysis of the Law of Time, the intelligence is nowhere evident because there is no harmony of intelligence possible under the present timing standards that dominate all the major players in the present global conflict. Since the technosphere is totally a function of the artificial timing frequency, and since artificial time is now short-circuiting itself, there will be no techno sphere to harmonize when natural time is restored to the entire biosphere. Then the noosphere will commence, but only if there is world harmony. Only a harmonic standard will bring harmony to the world. The failure of the Gregorian calendar and its civilization, crystallized in the now-collapsing technosphere, must be quickly acknowledged. By adopting a harmonic standard as soon as possible, the shift to the noosphere can commence, rising and building itself up from the shards and ashes of the toppled technosphere.

▼

6

The Solution of the Law of Time

Get a New Calendar

"I am in favor of a standardized calendar for the whole world, just as I am in favor of universal coinage for all countries, and a supplementary artificial language (like Esperanto, for example) for all peoples. . . I am always ready to endorse any honest movement which will help unifY the peoples of the world."

-MAHATMA GANDHI, QUOTED IN *THE JOURNAL OF CALENDAR REFORM,* 1931[1]

VIEWED FROM THE PERSPECTIVE of the noosphere, the failure of human civilization is the failure of the human being to become synchronized with itself in the correct time of universal nature. Instead of operating as a planetary organism in absolute synchronization with a knowledge of being coordinated by a common harmonic standard, humans race toward the end of history, dissynchronously operating under a plethora of calendars of differing measures enshrining competing belief systems, all globally coordinated by an instrument of irregular measure and obscure nomenclature-the Gregorian calendar. Dissynchronized and at odds with itself everywhere, humanity is broken apart into splintered mind fields, each controlled by a different timing standard, a fact about which the human race is virtually ignorant-to its own detriment.

India, with its different neo-Babylonian calendars, is at odds with Pakistan, which operates according to the Islamic lunar calendar; the Israelis, at odds with the Palestinians, hold as tightly to the Hebrew lunar calendar tradition as the Palestinians do to their Islamic lunar calendar traditions. In Asia, China follows its own complex and ancient lunar calendar tradition, and watches as the United States and its G-7 alliances, all dominated by the Gregorian calendar, get ready to spar with terrorists and militants who also follow the Islamic lunar calendar. India has the Bomb, Pakistan has the Bomb, China has the Bomb. The United States has the Bomb, the United Kingdom has the Bomb. France has the Bomb. Russia, the Ukraine, and other former Soviet nations have the Bomb. It is commonly assumed that Israel also possesses the Bomb. Does Iraq have the Bomb? Can a terrorist get access to materials to create the Bomb as well? The nuclear clock is ticking again.

The number of weapons and technologies of mass destruction has increased several thousandfold since 1945 when, at the time ofVernadsky's death, there were virtually none. This is not to mention the biological weapons of mass destruction, more ambiguous, more lethal, more hidden-none of which really existed in 1945 either. With the fallout from the Inevitable Event an anarchic planetary free-for-all is taking shape. From the noospheric point of view, the humans have run out of (artificial) time, and are now committing their last egoistic act of desperation to hold what they perceive to be their dominant place in the scheme of things. The fact is, however, that the planet belongs to the biosphere and not to the humans.

The inability of the Gregorian calendar to sustain another 28-year cycle, much less another millennium, means that an anarchy of time and a time of anarchy is loosed upon the planet. At the present rate, what would the world look like in 2029? One does not want to imagine. The anarchy of time is exemplified by the different competing powers that are unconsciously driven and motivated by programs stored in their differing calendar systems. This failure of artificial time to contain itself is truly the apocalypse. The apocalypse could occur only when the time program had become saturated. The two 28-year cycles, 1945-2001, carried forward not only the exponential advance of machine time, but the accrued karmic baggage of two millennia of the invented religion of Christ. Throughout the last millennium, the protagonists of this religion waged a type of holy war against an embattled world-a war waged by missionaries and conquistadors alike, down to this very day. The week before the Inevitable Event, the Taliban was deporting Christian missionaries from Mghanistan, while other Christian missionaries scour the jungles looking for one more indigenous soul to convert. This activity is inseparable from the Gregorian calendar that programs it.

Entropic Black Hole of Consciousness

A calendar is a mental instrument for holding the programmed patterns of thought and behavior of a given culture, people, or civilization. A people can rise no higher than the program of time their culture imposes on them as second nature. A program of time determines nature of consciousness. Different timing programs scheduled by synchronically inaccurate devices within a biospheric whole governed by a universal timing frequency apart from the deviant human standards can only result in an entropic black hole of consciousness: the clash of civilizations and cultures that precedes the mentally cleansing force of the noosphere and the inevitable return to natural time and the universal 13:20 timing frequency.

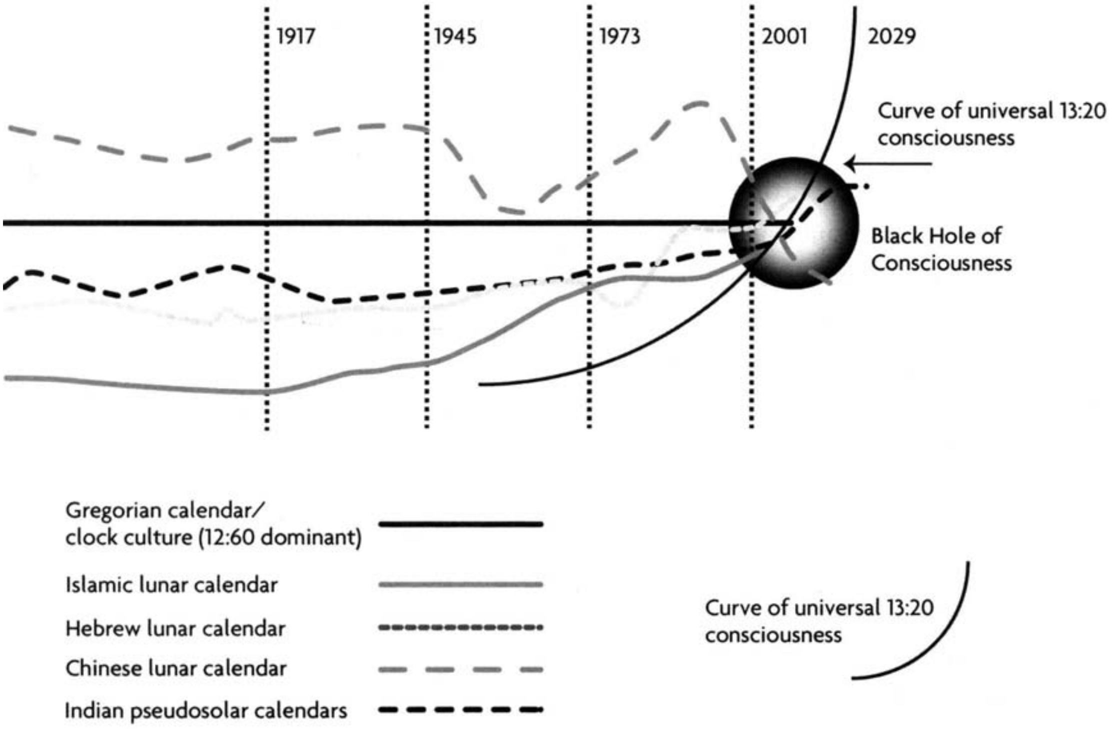

Now the default of the Christian program of the Gregorian calendar and its system of social organization, global civilization, is erupting in an entropic black hole of time. The result of this black hole of time is an entropic harmonic convergence, where all of the conflicting points of the differing timing programs that the Gregorian calendar attempted to synchronize, come into a common point of hostile impact. Seen in this light, the Final War is really the final battle in a long saga that we can properly call the Time Wars.

THE AGE OF THE TIME WARS

The Time Wars began with the application of the error in time at Uruk: the 24-hour, 60-minute, 60-second timing frequency derived from a 12-part division of the circle, a two-dimensional plane in space. Since this measure does not correspond to the reality of time as the universal (13 :20) frequency of synchronization, it creates a mental dissynchronization that manifests as the battle of the mind against itself, and against nature. The dynam'ic of the "progress" of civilization is really the dynamic of dissynchronization inherited by the human mind. The gradual encroachment of civilization into all aspects of human society and the biosphere increases the incidence of dissynchronization. The resulting aphasic mental states lead to belligerence and various attitudes of dominance over others and nature-but never to any satisfaction.

Viewed by the Law of Time, civilization is the institutionalization and embodiment of the dissynchronous artificial timing frequency. The dynamic of dissynchronization results in increasingly artificial technological means and reliance on the artificial medium of money to replace the biological or organic functions of our nature and of the biosphere in general. Not only does this process tend toward an "improvement" in the accuracy of the means of war, but also in the capacity of the latter for greater mass destruction. Set apart from the natural cycles by the dissynchronous frequency of mechanization, the Time Wars are also waged against the biosphere, which is viewed as a hostile force to be overwhelmed and plundered. Everywhere on Earth, nature is on the run. Everywhere on Earth, the human looks at his watch-what will he do next? Catch another plane? Fire another bullet? Press another button and let loose another bomb?

The 56-year cycle of the technosphere witnessed the greatest creation and stockpiling of lethal weapons, more than in all the previous history put together, enough to destroy the Earth many times over. The 56-year cycle of the techno sphere also witnessed the greatest plundering thus far of the biosphere, more than in all the previous cycles of history put together. Continued at the current rate, the biospheric plunder would bring extinction to virtually all life within another generation. These two facets of self-destruction-technospheric and biospheric-point again to the Inevitable Event. It is the Pentagon that has led in military spending and strategizing, just as it was the activity within the World Trade Center Twin Towers that dominated and coordinated from afar the plunder of the biosphere-both precedents for the consequent construction and expansion of the technosphere.

But now time has run out on the technosphere. The world has gone flat and valueless with no future vision beyond war. All the money in the world will not put it back together, nor will all the bombs in the world salvage it against its enemies. Who are the enemies of the technosphere, and what would cause thereto be enemies against the technosphere? And who or what is there that speaks for the biosphere? For if the biosphere is to become the noosphere, it must come about from an understanding of the intelligence of harmony. Clearly, such understanding of harmonic intelligence has not been nor will it be forthcoming from the technosphere-or from the Gregorian calendar that programs it. Only the Law of Time can supply the harmony necessary to complete this great movement from biogeochemical combustion to noospheric mind. The Law of Time replaces all that is artificial, while confirming all that is true, whether in human history or the universe.

Let us return to the analysis of the Time Wars and the clash of timing programs. The Twin Towers were the absolute triumph of the artificial 12:60 timing frequency, whose program is embedded in the Gregorian calendar and paced by the mechanical clock. Who steered the hijacked planes into their Gregorian targets? Nineteen militant Muslims, we are told. Why nineteen? And what are the religious backgrounds of the twenty-two most-wanted terrorists in the world? They are twenty-two Muslims. Why that number, and why are all the terrorists Muslims? In the noospheric analysis, the Inevitable Event was the suicide of the technosphere unable to sustain two clashing time programs. It was a program of the strict Islamic twelve-month lunar calendar that drove its belief system into the Twin Towers and the Pentagon, the two supreme monuments of the program of the twelve unevenly measured months of the Gregorian pseudosolar calendar. Is it Islam that is the enemy of the technosphere? Is it Islam that is the champion of the biosphere? Indeed what is Islam? Why is Islam the most resistant force against globalization and the technosphere? We know where the Vatican, the bastion of Christendom, is and who ordained the Gregorian calendar, but what do we know about Islam?

If we strip history away from the force known as Islam (1.3 billion Muslims in the world), and reduce it to its most essential point, then Islam is the teaching of the Holy Quran. What is the Holy Quran? It is the last whole revealed text for all humanity, received and recorded over a 23-year period by a single human being, Muhammad the prophet (570-632). While militant Muslims and terrorists have dominated the mass media image ofIslam for the past few decades, what is the Quran and what does it actually teach? It is also a function of the Gregorian program that scarcely anyone in the West really knows or is familiar with the Quran, since the West has been at odds with Islam since the time of Muhammad. As the supreme text of monotheism, the Quran is actually a psychoactive book that upholds Islam as the final religion for humanity. "He is the one who sent His messenger with the guidance and the religion of truth, to make it prevail over all other religions. God suffices as a witness." (Quran, 48:28) *Islam* means "peace, which is submission to the will of God."

Islam is also the law of nature. Within the vast system of intricate, mathematically based logic that constitutes the Quran-which is a profoundly ahistorical text as well-one feature stands out: the description and definition of nature and the natural order as the chief proof of God's design and guiding wisdom. From the Quranic point of view, the biosphere, inclusive of the creation of the human, is the overwhelming single proof of God's wisdom in establishing a life-support system for our indwelling consciousness to evolve our bodies on this Earth. The biosphere is Islam, or "peace, which is submission to the will of God," understood as the divine law of nature.

> In the creation of the heavens and the earth, the alternation of night and day, the ships that roam the ocean for the benefit of the people, the water that God sends down from the sky to revive dead land and to spread in it all kinds of creatures, the manipulation of the winds, and the clouds that are placed between the sky and the earth, there are sufficient proofs for people who understand. (2:164)
>
> He created you from one person, then created from him a mate. He sent down to you eight kinds of livestock. He creates you in your mother's bellies, creation after creation, in trimesters of darkness. Such is God your Lord. To Him belongs all sovereignty. There is no other god beside Him. How could you deviate? (39:6)
>
> Among His proofs is that you see the land still, then as soon as we shower it with water, it vibrates with life. Surely the One who revived it can revive the dead. He is Omnipotent. (41:39)
>
> He created the human from a tiny drop, then he turns into an ardent opponent. And he created the livestock for you, to provide you with warmth and many other benefits as well as food. They also provide you with luxury during your leisure, and when you travel. And they carry your loads to lands that you could not reach without a great hardship. Surely your Lord is Compassionate, most Merciful. (16:4-7)
>
> He sends down from the sky water for your drink and to grow trees for your benefit. With it, He grows for you crops, olives, date palms, grapes, and all kinds of fruits. This is sufficient proof for people who think. (16: 10-11)
>
> And He committed the sea to serve you; you eat from it tender meat, and extract jewelry which you wear. And you see the ships roaming it for your commercial benefits, as you seek His bounties, that you may be appreciative. And He placed stabiliz-

> ers (mountains) on earth lest it tumbles with you, as well as rivers and roads that you may be guided. And landmarks, as well as the stars to be used in navigation. Is One who creates like one who does not create? Would you now take heed? (16:14-17)
>
> As for the Earth, we constructed it, and placed on it stabilizers (mountains) and we grew on it a perfect balance of everything. We made it habitable for you, and for creatures you do not provide for. There is nothing that we do not own infinite amounts thereof. But we send it down in precise measure. And we send the winds as pollinators, and cause water to come down from the sky for you to drink. Otherwise you could not keep it palatable. (15:19-22)2

Viewed from its own context, the Quran is the criterion for evaluating the spiritual progress of human existence on this Earth inclusive of man's ability to read the proofs of nature as manifestations of God's wisdom and to comport himself within this nature, the biospheric life-support system, in a manner consistent with the truth. From the Quranic perspective, human freedom of choice is at the root of the biospheric destruction. Choosing anything but to be submissive to God, the human is in rebellion against nature-both his own and that of the biosphere. "We have offered the responsibility [freedom of choice] to the heavens, and the earth, and the mountains, but they refused to bear it, and were afraid of it. But the human being accepted it; he was transgressing, ignorant." (33:72)

The result of this ignorance on behalf of his own aims and intentions rather than that of a respect for the divine plan (biosphere) of the Creator, accounts for the human situation today, at odds with and surrounded by an increasingly out-of-control biospheric degradation and corruption of natural time: "Disasters have spread throughout the land and sea, because of what the people have committed. He [God] thus lets them taste the consequences of some of their works, that they may return [to the right works]." (30:41) Thus, the current techno spheric destruction actually points toward a return of humans to the path of right works.

The forces that created the phenomenon of historical Islam are the enclosing of the Holy Quran within the rigid system of a twelve-month, non-circulating lunar calendar, compounded and supported by the development of the *hadith* and *sunna* (non-Quranic) traditions. A profoundly conservative social order, Islam is nonetheless activated and motivated by a holy scripture that enunciates an attitude toward nature that is the direct opposite of the 12:60 system that produced the technosphere. In this regard, the precepts of the Holy Quran-as of many another holy scripture-make it the "enemy" of the technosphere. From the noospheric perspective, historically and culturally, however, the assault on the nerve centers of the techno sphere could only have been effected by humans whose belief system was rooted in the Holy Quran, which had been at odds with the Gregorian civilization for centuries. In this way, the Quran was the noosphere's weapon used to bring about the circumstances that would lead to the resurrection of the biosphere-the noosphere itself. But only if man consciously chooses the right return path: synchronized harmony in time. The problem is not so much the rigid lunar calendar ofIslam, but the irregular global standard of the Gregorian calendar, which, instead of standardizing all measures and perceptions of time, fosters a human social disharmony and an incessant antagonism against nature-and against Islam.

So then, how are we to return to the right works? Read and study the Quran, yes-but also make a fundamental change in the world. The solution of the Law of Time is: Get a new calendar! Humanity must take a long, hard look at its own timing systems and scrap what needs to be scrapped, no matter what kind of temporary inconveniences this may cause. Calendar reform is an issue that upsets many apple carts. Yet it is the only method that has not been commonly tried and the only step that has not yet been collectively taken. It is a characteristic of the dominant mindset that it writes history in the way that suits its own needs and supports its philosophy. In any of the reviews of the century carried by the mass media during the past year, you will find no mention of the World Calendar Reform Movement; nor will you find, for instance, any mention of the Roerich Peace Pact (1935); nor of the Harmonic Convergence-all buried by the marketing of history to suit the needs of globalization. What do these three phenomena have in common? A concern for peace based on an understanding that without harmony, the human cultural situation will only worsen. If humankind suffers from an excess of disharmony, in the noospheric analysis the only solution is a harmonic standard of time to synchronize all humanity simultaneously-the Law of Time refers to this as the Thirteen *Moon!* 28-Day frequency shift.

CHANGE YOUR CALENDAR, CHANGE YOUR MIND

> *"Since the advent of the Nuclear Age, everything has changed but the way people think, thus, we drift towards unparalleled catastrophe."*
>
> -ALBERT EINSTEIN[3]

To change how people think you must take a profoundly simple and universal element of everyday life, one in which all everyday thinking is rooted, and change it so radically that the way in which people think will itself be dramatically changed. If you want to know that something has really changed, change the calendar! This is the meaning of the replacement of the Gregorian calendar by the Thirteen Moon calendar. The calendar change is necessary because, as the pragmatic application of the discovery of the Law of Time, it brings into focus the essence of this discovery: Time is a frequency, the frequency of synchronization. If a calendar does not increase synchronization, it is not performing its highest function. This is the fundamental critique of the Gregorian calendar-and of all concepts of time based solely on physical, third-dimensional astronomical measurements. This discovery is so new and startling that it affects all human thought and is a matter to which all belief systems, religions, and methods of science must be cognizant. Yet nothing, it seems, is more difficult for humanity than to make this change from a manifest disharmony to a manifest harmony.

Historical man recoils at the prospect of actual harmony-harmony in natural time. This is because historical man defines his existence and thrives upon the disharmonies of his own invented time. The Gregorian calendar keeps the human mind entrained in a diabolical disorder of meaninglessly named months of uneven measure, while every day is tracked and driven by a relentless mechanism called a clock. This immersion of the mind of historical man in the frequency of his own artificial time, more than any other factor, condemns him to a world of inescapable horrors: traffic jams, poverty, terrorism, unresolvable historical and territorial disputes, global warming, environmental degradation, social disorder, insanity, and drug abuse. The problem of historical *human-Homo historicus-is* compounded by the unconscious nature of his acceptance of this timing sensibility, believing it to be the actual nature of time. Hence, all his public and economic policies are driven by and determined by the relentlessness of this perception that time is an arrow blindly pulling him into a future in which his only defense is the creation of more technology, the technosphere itself being a pure expression of the application of the mechanization of time.

THE SECRET HISTORY OF CALENDAR REFORM

When you went to bed on October 5,1582 you woke up on October 16. In this way Pope Gregory XIII promulgated his reform of the Julian calendar, from which the Gregorian calendar differs not one whit, except for the precise working out of the formula for leap year. When this "reform" occurred, the time sensibility of historical man was already crippled and disabled. The Gregorian calendar, by its moment of historicity, bound that crippled time disorder into its final institutional form, assuring that not only European man, but eventually all cultures and races dominated by European thought and conventions would assume and accept this deformed and deforming standard of time.

The mechanical clock, though evolved over many centuries, was perfected just after the Gregorian Calendar Reform of 1582 and promoted by Europeans as an example of the human triumph over nature. So it was that the human mind assumed as second nature its own invented time, encoded as a frequency that we have identified as the 12:60, an unconscious mental ratio determined by the irregular twelve-month calendar and artificial sixty-minute hour. The combination of these two factors in this one timing frequency have consigned historical man to a hopelessly debilitating mental disorder that is referred to as modern civilization, or nowadays, postmodern. But postmodern is not yet post-historical. Postmodernism is just the final convulsion of the time disorder that afflicts the human race as a virulent mental disease and encapsulates man in the technospheric cocoon of his own making. The only cure for such a profound and pervasive disorder is absolute harmony, the very harmony from which historical man so recoils.

In this light, it is well to know that through the first half of the twentieth century a vigorous and well-organized calendar reform movement flourished. Such was the character of this movement to reform the Gregorian calendar that in 1923 the League of Nations called for proposals for reform. More than 500 proposals were received; by 1931, these were narrowed to three:

> The International Calendar Organization, represented by Mr. Broughton Richmond, promoted a perpetual calendar based on the principle of five-five 73-day cycles = 365 days-and the year divided into twelve months of five 6-day weeks each plus a 5-day cycle [The Thirteen Moon calendar also includes the program of seventy-three 5-day periods-overtone chromatics-integrated with the fifty-two 7-day weeks: 52 x 7(+1) = 5 x 73.]
>
> The International Fixed Calendar League, represented by Mr. Moses Cotsworth, also supported by Eastman Kodak and the International Chamber of Commerce, promoted a perpetual Thirteen Month/28-day calendar, which was first presented by Auguste Comte (1842-1849), inclusive of the "day out of time." Though it was not backed by a more thorough mathematical science, which has now been supplied by the discovery of the Law of Time, this was by far the favored calendar, as it is the one that possesses a perfect structural harmony and obvious regularity of all its parts.

3. The World Calendar Association, represented by Elizabeth Acheles, promoted the World Calendar, a modified but perpetual version of the twelve-month Gregorian calendar, which also included the principle of a "day out of time" ("null day"). This group turned out to be the longest-lived and the most vocal, and was responsible for the publication of *The Journal Of Calendar Reform (1931-32).4*

It is instructive to read some of the early texts on the topic of calendar reform to see how the same issue of harmony and order brought up by the Law of Time was at the root of the call for the establishment of a perpetual, harmonic calendar. The base argument, as presented in Alexander Philip's *The Reform of the Calendar* (1914), is stated as follows:

> Suppose, for example, that by some strange convention the meaning of the figures we employ in numerical notation were to change every year; suppose the figure which this year represents 2 were next year to mean 3, next year 4, and so on; suppose again that our weights and measures were to fluctuate in a similar manner. . . then we affirm, without fear of contradiction, that the whole fabric of science and the mechanical arts could never have been raised at all. . . we should in such circumstances have been compelled to rest content today with the very simplest and most primitive appliances. Yet, strange as it may sound, such are the conditions under which, in modem society, human action is organized. For what is the framework. . . by which we arrange our actions? It is no other than the scheme under which we arrange our time-in one word, our calendar. . . [thus] the disorganized state of all social arrangements is ascribable to the calendar. . . The dislocation of our calendrical arrangements is due to two distinct causes. . . the incongruity of the week; [and] the irregularity of the lengths of the months. . .5

The argument made is a profound one, and was the motivating basis of the calendar reform movement in general, no matter which calendar was being promoted. It is fair to ask: Why do we expect a rigorous standard of uniformity in our measurements of space (size, weight, volume, etc.), but spurn or ignore the same requirement of uniformity in our measurement of time, especially the time that governs our everyday social arrangements and consciousness? How can we think that this would not have a profound underlying effect on the very nature and conduct of our society?

Most interestingly, as a movement calendar reform arose strongly during the proto-technosphere, between the two World Wars, only to be swept away by the clouds of war and the contradictory factions of disharmony in which modern civilization was already immersed. Any effort at altering or changing the direction and motion of modern civilization is treated as a threat or derided as ineffectual activity that is scientifically unprovable or that will cost humanity too many dollars to make the change. Such was the fate of the first great calendar reform movement that arose with such fervor in the late nineteenth century only to find its ignominious end when the final debate on calendar reform was adjourned indefinitely by the United Nations Social and Economics Committee in 1956. No one reads about the calendar reform movement in the history books. Because debate on the matter was effectively adjourned, it is assumed that calendar reform is a dead issue of no relevance to the development of postatomic, technospheric man. On the contrary, seen in the dim light of the still-smoking ruin of the Twin Towers, the calendar reform arguments concerning humanity's irrational behavior and its relation to the "immorality" of a skewed timing measure, the calendar, as well as to an inhuman timing device, the clock, were never more relevant.

Not the least import of calendar reform is the opportunity to create a new basis for unifying humanity. As was stated in the "Resolution Adopted by the Fourth General Conference on Communications and Transit of the League of Nations," which took up the issue of calendar reform: "A great number of delegations expressed the opinion that any reform of the calendar could only be put into practice if it came into force simultaneously throughout the world, or at least in a very great majority of States, and it was for this reason that the study of this question had been placed under the auspices of the League of Nations."6

The tragedy of the human inability to agree on a matter so obvious to logic and reason is a testament to the already crippling effects of having operated so long under parochial, sectarian, and often disharmonic timing standards. While the International Chamber of Commerce, the League of Nations, and various international scientific bodies supported the first effort at reform in 1914-1956, the second movement, 1989-present, arose as a purely populist effort, but with an entirely different information base. Recognizing instinctively that the calendar reform issue is more than merely a matter of mathematical order in relation to natural cycles, it is a profoundly theological issue as well, the second reform movement also developed from a non-Western inspiration: the Mayan calendar.

While the psychology of the dominator civilization all but blurs out any other considerations of calendar besides the prevailing Gregorian one, an objective study of the matter demonstrates that the latter is a primitive instrument that eschews both natural cyclic order and any mathematical harmony. In place of the anachronistic standard of the Gregorian calendar, the second calendar reform movement raised a new criterion, the Law of Time, a whole system principle that integrates the mathematical and the moral, the theological and the psychological, and the economic and scientific issues that are embedded **in** the entire topic of calendar reform. Precisely for the reasons of historical man's unconscious habituation to his own disharmonies and the accelerating and cumulative effect of this ignorance on the disorder of his own social life as well as the natural world around him, the second calendar reform movement has developed with a much greater moral and prophetic urgency.

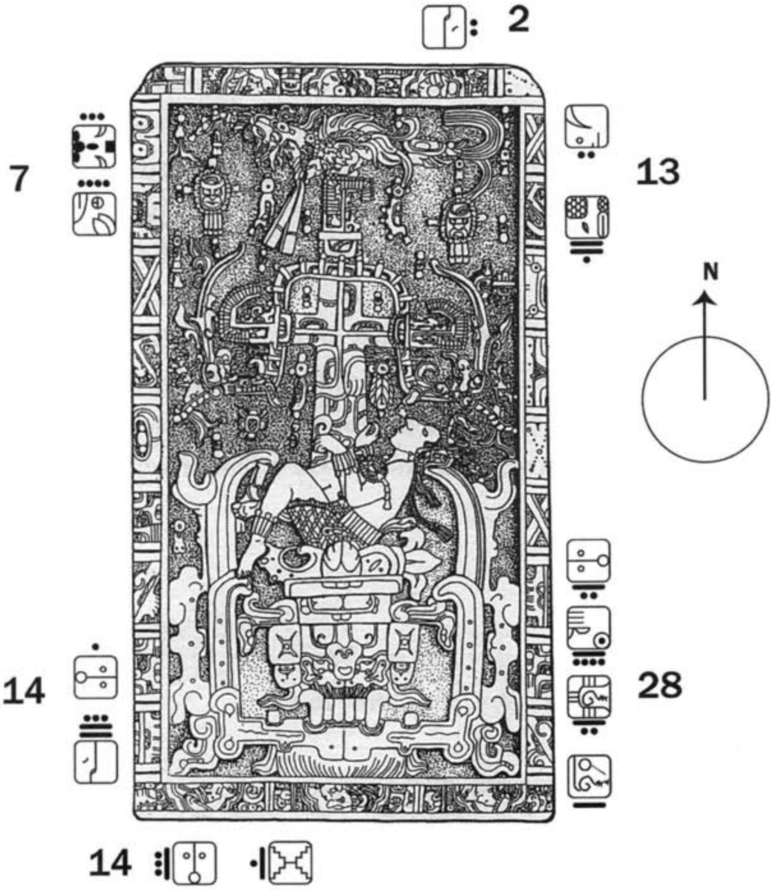

Western Edge:
Tonal sum, set 1 = **7**
Tonal sum, set 2 = **14**

Northern Edge:
Tonal sum = **2**

Eastern Edge:
Tonal sum, set 1 = **28**
Tonal sum, set 2 = **13**

Southern Edge:
Tonal sum = **14**

Total tonal sum = **78** (6x13)

Sarcophagus Lid of the Tomb of Pacal Votan
Showing Disposition of Thirteen Clear Signs

The tonal sums (dot-bar code) of the thirteen signs are key to affirming the prophecy of the Thirteen Moon calendar. Note that the sums of the two sets on the eastern edge equal 28 and 13, while opposite the 13 set is the perfect 7. The tonal sums of the other two sets on the western and southern edge both equal 14, for a sum of 28. The northern edge has a single sign whose tonal sum is 2 twice 7 = 14, and twice 14 = 28; twice 13 = 26 fractal of 260 and code to the Gregorian date 7/26; while twice 28 = 56, the number of years from Hiroshima to the Inevitable Event.

"Consciously using the tool of the Thirteen Moon calendar to replace the erroneous measure of the artificial twelve-month calendar is, in itself, an unprecedented act of human self-reflective consciousness. Collective adaptation to the Thirteen Moon calendar is an intrinsic heightening of consciousness which rapidly awakens the telepathic programming inherent in human biology, frustrated for so long for not having been allowed development in the correct timing frequency."7

It was in 1987 that *The Mayan Factor: Path Beyond Technology* first brought to major public and international attention the possibility that a superior timing sensibility was developed by a thoroughly non-Western culture, the Maya. This book was published with scarcely any knowledge of the calendar reform movement that had gone into a debilitating coma in 1956. Yet, by pursuing the mathematical base of the Mayan calendar, the essence of the Mayan achievement, the Law of Time was extracted, a discovery that brought on the second calendar reform movement, the World Thirteen Moon Calendar Change Peace Movement. Prompted by a prophetic revelation concerning the Thirteen Moon!28-Day calendar decoded from the tomb of Pacal Votan, the premise of the second calendar reform movement was tested worldwide from 1993 to 2000, a time defined as the "seven years of prophecy." By the year 2001, the official beginning of the third Christian millennium, a loose, far-flung calendar reform movement, pioneering in the development of a new science of time and consciousness was promoting the Thirteen Moon!28-Day calendar worldwide.

A REVOLUTION IN TIME

> *"Fire in the lake, the image of revolution. Thus, the superior person sets the calendar in order and makes the seasons clear"*
>
> -*I CHING,* HEXAGRAM49, "REVOLUTION"8

By common consent, a calendar is a system for reckoning time. Virtually all current time-reckoning systems take account only of chronological or, better put, astronomical time-the movement of the Earth in relation to celestial bodies, the sun, moon, planets, stars, and constellations. This is a purely third-dimensional, physical consideration of time. The Law of Time affirms a higher order of time-the synchronic order. This is the time of the fourth dimension, which includes the chronological but enfolds it in a higher mental and mathematical order of reality. According to the Law of Time, what you don't know about the calendar you are using could kill you. By operating according to purely third-dimensional chrono-astronomical timing standards and without knowledge of the synchronic order of fourth-dimensional time, humanity subjects itself to a one-sided view of reality that is hazardous to the planet and jeopardizes the future existence of the human species as well as all life on Earth.

To correct this situation a radical solution is required-a new calendar embedded in the synchronic order revealed by the discovery of the Law of Time. This is the significance of the Thirteen Moon/28-Day calendar-it epitomizes the incorporation of the chrono-astronomical order of time into the synchronic order, and hence provides the vehicle for humanity to escape its otherwise certain plunge into disaster within the next decade. When a dogma is encountered while one is engaged in the pursuit of truth, it must be challenged and abolished. Such a dogma is the calendar in use as the world standard, the Gregorian calendar. That this calendar, originally a system of thought peculiar to one people or religion, should dominate all the peoples and even life of the planet makes it subject to the critique of planetary anthropology.

The discovery that time is a frequency mathematically expressed as the ratio 13:20 requires a profound reorganization of all thought about time and the consequent reorganization of human society as a planetary organism. As the unified field theory of time, the Law of Time calls for the human synchronization in time predicated on the establishment of the Thirteen Moon calendar as the global civil standard replacing the current erroneous timing standard, the Gregorian calendar. This is a matter of the utmost seriousness, since it is also recognized that all belief systems are the function of programs locked up or embedded in the calendars or time-reckoning systems used by a people. The fate of the species and the biosphere may well depend on whether or not humanity is able to understand this point.

What is it about the calendars in use that condemns their users to endless conflict and inability to unify as a species? What is at the root of their disharmony? It is the pursuit of astronomical time. All people today are bound by calendars based on a pursuit of accuracy of astronomical time-the length of the year being the object of this pursuit. Astronomical time is a losing game of an ever-changing and elusive order that results in an entropic reductionism that has little to do with consciousness or synchronization. The year's length (measure of the orbit of the Earth around the sun) calculated by Pope Gregory XIII at 365 days, 5 hours, 48 minutes, and 20 seconds, slows at the rate of *112* second per century, while the length of time in the Gregorian calendar is off from the "true" solar year by 25.9678 seconds per year! Obsessed with rectifying this discrepancy, in 1972 reductionist science came up with Atomic Time to replace Earth Time, and the atomic cesium clock replaced the measure of the year as 365.241299 days with 290,091,200,500,000,000 oscillations of Cs per year!

But what does this staggeringly astronomical figure mean, and of what value is it?

In profound contrast to this obsessive reductionism in which there is no place for spirit, mind, or consciousness, fourth-dimensional radial mathematics represents a mental order greater than and encompassing the astronomical order of the third-dimensional universe. According to the Law of Time, in time reckoning, consideration should be given to systems of the harmonic order of synchronic time that proceed from the radial mathematical order of the higher mind. The higher mind represents the evolved state of mind-the noosphere-that evolution on Earth tends toward, but that has not yet been attained. As long as the human concept of time is governed by the obsessive pursuit of the impossible to attain perfection of astronomical time, this pursuit and the civilization that it propels are doomed to failure. What is known as history is embedded in this pursuit of "fixing" astronomical time, which has culminated in the dogma of the Gregorian calendar and the microatomic measure of the cesium clock. When did this pursuit begin, why did it come to dominate the human species, and to what effect?

As we have seen, the values, customs, and norms of a nation, culture, or civilization are embedded in the calendar it uses. The Gregorian calendar, the current global civil standard-indeed, the foundation in time of globalization-is the calendar of the Caesars, of the Roman Empire, of the Catholic Church and the Vatican. To change this calendar is to change history itself. Can it be done? The League ofNations attempted this in the 1930s but failed. The United Nations tabled this effort in 1956. Since the United Nations adjourned the matter of calendar reform indefinitely, in 45 years the Earth's population has more than doubled, that is, it has increased by more than 3.2 billion people, a factor that is still out of control, and that may have much to do with the fact that humanity is actually in a fog about time.

The reasons for wanting to replace the Gregorian calendar are no less valid today. The Gregorian calendar is not a standard of measure. It lacks logic and reason. It numbs and befuddles the mind when trying to make calculations by it. It is shrouded in an arcane and medieval obscurantism. The net effect of the use of this calendar is to perpetuate a fundamental level of mental confusion and ignorance concerning the actual nature of time itself-an ignorance that is hardened into dogma by the unwillingness of habit to consider any other possibility, but rather to accept the entire system as second nature. The argument that it encodes the most accurate and scientific measure of the solar orbit of the Earth is irrelevant in relation to the effect of its irregular measure on the mind and its numbing power as the dogma of a conquering people. Indeed, the solar measure of365.241299 days per year has nothing intrinsically to do with "30 days hath September. . . ," and vice versa. In fact, the measure of the Earth's orbit is one matter; the purpose of calendars and time reckoning as factors of synchronization is a wholly other matter. But then, since the very nature of a culture or a civilization is determined by the calendar it keeps, the use of a deformed standard can only inhibit and skew even the questions one asks about time.

The failure of calendar reform by 1961, the year of the Vatican II Council, only promoted an increasingly complacent acceptance, however cleverly disguised, of a millennial dogma, the Gregorian calendar. In the conclusion to the "last word" on the subject, *Calendar: Humanity's Epic Struggle to Determine a True and Accurate Year,* David Duncan summarizes, "We take in stride a calendar [the Gregorian] that is flawed but endures, largely because it works just fine for most of us, and it is what we are used to."9 It is not at all objective to accept something because we are used to it. This attitude is anything but scientific. Rather, it is the smug basis of nothing more than a self-fulfilling dogma-and yet the civilization that bases itself on this aberrant timing measure prides itself as being the most scientific in all history!

THE CONFUSION OF IRREGULAR TIME

Due to this flawed time sensibility, it may be concluded that humankind today is little capable of moral reason or logic, which itself is a result of, or at least strongly reinforced by, habituation to a timing standard that is irrational and illogical. Anytime we overlook or dismiss a fault due to habit, or simply because we are accustomed to the use, say, of an instrument, even if that instrument is demonstrated to be flawed and irregular, is evidence of a moral laziness that will eventually contaminate the entire consciousness that accepts and accommodates itself to the flaw. The exercise of truth is a moral prerogative. The fact of the matter is that the Gregorian calendar is a hodgepodge of flaws and accretions, rationalized into a systematic formulization that has no basis in reality. The celebration of Easter is a case in point.

Easter is the celebration of the day Christ was resurrected from the dead. It may be logically assumed that this occurred on one and only one particular day, just as the celebration of his birth occurs on Christmas Day (although, similarly, no one really knows that this was the actual date of his birth). By the time the Christian religion had become an established force within the Roman Empire, however, no one knew precisely on what day the Resurrection had taken place. The Council of Nicea, convened by Constantine in A.D. 325, called for a debate on the matter in which various theories were presented. The debate was concluded with the victory of one conjectural system over the other. The winning system stated that Easter would be celebrated on the first Sunday after the first full moon after the spring equinox, except when the full moon was on a Sunday, in which case it would be celebrated on the following Sunday, and this was so that it would not be celebrated on the same day as Jewish Passover.

Over the centuries this conjectural theory regarding the date of Christ's resurrection was buttressed with a system of elaborate calculations for predicting when Easter would occur. These calculations were all made with regard to establishing an alignment of the synodic lunar cycle of29.5306 days (which resulted in a lunar year of 354.3672 days) and the solar year of 365.241299 days! Being fortified with such elaborate mathematical calculations did not lessen the fact that the system was originally-and still is-a mere speculation of a highly clever but relative nature. Thoroughly embedded in the Julian-Gregorian calendar, the system of determining Easter is inseparable from the Gregorian calendar itself, and is one of the chief reasons for the resistance to its reform-as witnessed by a reading of the calendar reform arguments of the 1930s. The entire system of this calendar, inherited without question from the Caesars of the Roman empire, is actually nothing more than a form of self-perpetuation of a priestly hierarchy that includes in its support a host of bankers, industrialists, and scientists and the elaborate social system that is under their control-the technosphere of global civilization itself. Take away the calendar and the entire structure loses its foundation.

"If the Julian/Gregorian calendar was to be offered as a new device for measuring time, we, with our present knowledge and state ofliving, would reject it as something utterly impracticable, lacking in harmony and order, unbalanced and irregular, too clumsy a calendar to make calculations by, while the various sections are not comparable."10

A science or any scientist that unquestioningly follows the Gregorian calendar is, in reality, not worthy of the name. What is science? A concern for logic and precision of measure, we might answer, as well as standards of measure that utilize uniform units of measure in accord with what is being measured. Yes, the year is calculated as being 365.241299 days in length, but if the annual standard of measure that is used is irregular and unscientific, then it avails nothing, and indeed deforms the mind leading it down byways that may only end in self-destruction. Thus the pursuit of a true and accurate year in itself may be an illusory pursuit, blinding us to the actual nature of time, and leading us away from a genuine understanding of ourselves and our role and purpose on this Earth.

To change and replace the calendar with the thirteen moon standard is to return us to our original purpose, leading us back to pathways of harmony and natural health. According to the Law of Time, the damage already inflicted in the time humanity last hesitated and lost the chance to alter its timing frequency, forty years ago, has been incalculable. The final opportunity to change the calendar and the timing frequency is now upon us. Because of this we must be very clear and unshakable in our understanding and determination to expose and eliminate the current civil calendar for once and for all. Even apologist David Duncan's unabashedly pro-Gregorian book *Calendar* (1999) concludes with its time line on the date 2012, "Current Mayan Great Cycle will end."[11] But will we also end? By 2012, it will be too late to change. We must begin to change now.

In reviewing the quirks and twists of history that constitute the Gregorian calendar, we must ask: Why do we continue to use such an instrument, and what are its effects? Is a calendar something more than a tool for scheduling the payment of debts *(calends),* or is it an instrument of synchronization? The harmony or disharmony of time is a profound matter rooted in the instrument of time reckoning that we use. There can be little question that we live more in a time of chaos than of harmony. We may also say in regard to the effect of standards of measure on the mind, that the chaos of the time is embedded in the calendar we use. If we are to leave this time of chaos and enter a time of harmony, then we must exchange the instrument in which the chaos is embedded for an instrument that is the very model of harmony-the Thirteen Moon/28-Day count. This is the choice humankind must now make.

The issue of the nature of time, or of the times in which we are living, cannot be separated from the issue of the calendar. The very nature of the calendar that the world follows has stunted the mind and warped the body's innate timing sensibility, reducing the understanding of time to being merely a matter of chronology. "Chronology is a register or reckoning of successive years, a time scale. It may also be described as a system of registering time massively."[12] Virtually all time reckoning has proceeded from astronomical indicators, the major exception being the Maya, who actuated from a solely mathematical outlook. Yet with this mathematical outlook the Maya devised a chronological method that has never been surpassed, a fact attested to by many, including the architects of the Kitt Peak Observatory in Tucson, Arizona, where a mosaic mural depicting the civilization of the Maya asserts the superiority of their calendar over that of the Europeans.

It is significant that the earlier calendar reform movement, while occasionally acknowledging the brilliance of the Maya, made no use of the Mayan knowledge. But this was because the time sensibility was restricted to thinking of time solely in terms of chronology, or at best as a schedule for keeping good accounts, with little comprehension at all of the synchronic nature or order of time. And since the system of chronology was synonymous with the system of control embedded in the Gregorian calendar system, the earlier reform movement failed altogether to make any impact on the Vatican, much less on the global power structure itself.

All the thought, action, and good intention put into the years of calendar reform notwithstanding, the Gregorian calendar prevailed, and, tragically, not one of the proposals or recommendations was ever even considered for adoption by the papal authorities who maintain control over the calendar. In the 1930s, the propaganda of the Church was aimed at limiting any possibility of reform, for it would not give up the succession of the seven-day week. In any perpetual calendar, such as the Thirteen Moon/2 8-Day calendar, the observance of the Day Out of Time is necessary for maintaining the harmony of the fifty-two weeks that complete themselves in 364 days. The continuous succession of the week does not stand in a constant relation with the other elements of the calendar and is one of the main causes of confusion in the Gregorian calendar. Arguing that such a break as a Day Out of Time, no day of the week at all, would plunge the world more deeply into chaos, barbarism, and war, the Vatican effectively blocked all effort at reform. The completion of the century of total war, capped by the Inevitable Event, roundly refutes this point. It may just as easily be argued that because we did *not* change the calendar, we are now plunged into the final barbarism and unholy war.

When the Vatican II Council in 1961 affirmed in its backward and highly restrictive language that it was not opposed to reform, so long as such reform did not disrupt the seven-day week and respected the tradition of Easter as a "movable feast," the door to reform slammed shut. By this time all the early reformists had literally died out and the question of calendar reform appeared to have become one of the buried issues of history.

What the priests of the Catholic Church thought they had buried through an auto-da-fe in Izamal, Yucatan, 1562, and overcome through the imposition of the Julian-Gregorian calendar over the conquered Maya, returned with the precision of prophetic timing in 1987. The publication of *The Mayan Factor* not only opened the door to a new look at the Maya, but also to an understanding of time that was anything but chronological. A new dimension of time appeared-radial, fractal time, the synchronic order. And behind the reassessment of the nature of time was the provocative call of Mayan prophecy-the end of the thirteen baktun Long Count, 2012.

The Law of Time defines the human problem as being one of radical and destructive dissynchronization from natural time, resolvable only by a return to natural

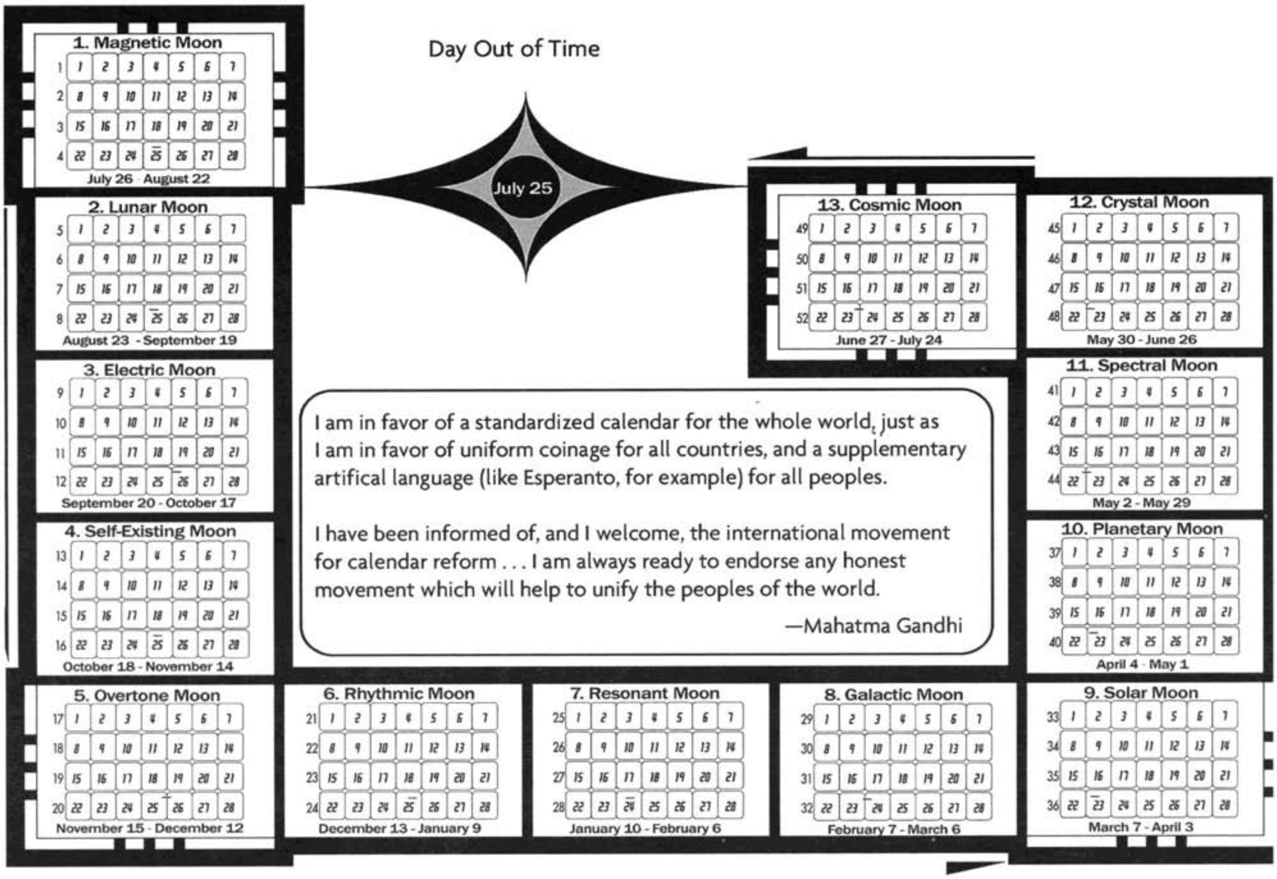
Day Out of Time
July 25
1. Magnetic Moon
July 26 - August 22
2. Lunar Moon
August 23 - September 19
3. Electric Moon
September 20 - October 17
4. Self-Existing Moon
October 18 - November 14
5. Overtone Moon
November 15 - December 12
6. Rhythmic Moon
December 13 - January 9
7. Resonant Moon
January 10 - February 6
8. Galactic Moon
February 7 - March 6
9. Solar Moon
March 7 - April 3
10. Planetary Moon
April 4 - May 1
11. Spectral Moon
May 2 - May 29
12. Crystal Moon
May 30 - June 26
13. Cosmic Moon
June 27 - July 24

I am in favor of a standardized calendar for the whole world, just as I am in favor of uniform coinage for all countries, and a supplementary artifical language (like Esperanto, for example) for all peoples.

I have been informed of, and I welcome, the international movement for calendar reform . . . I am always ready to endorse any honest movement which will help to unify the peoples of the world.

—Mahatma Gandhi

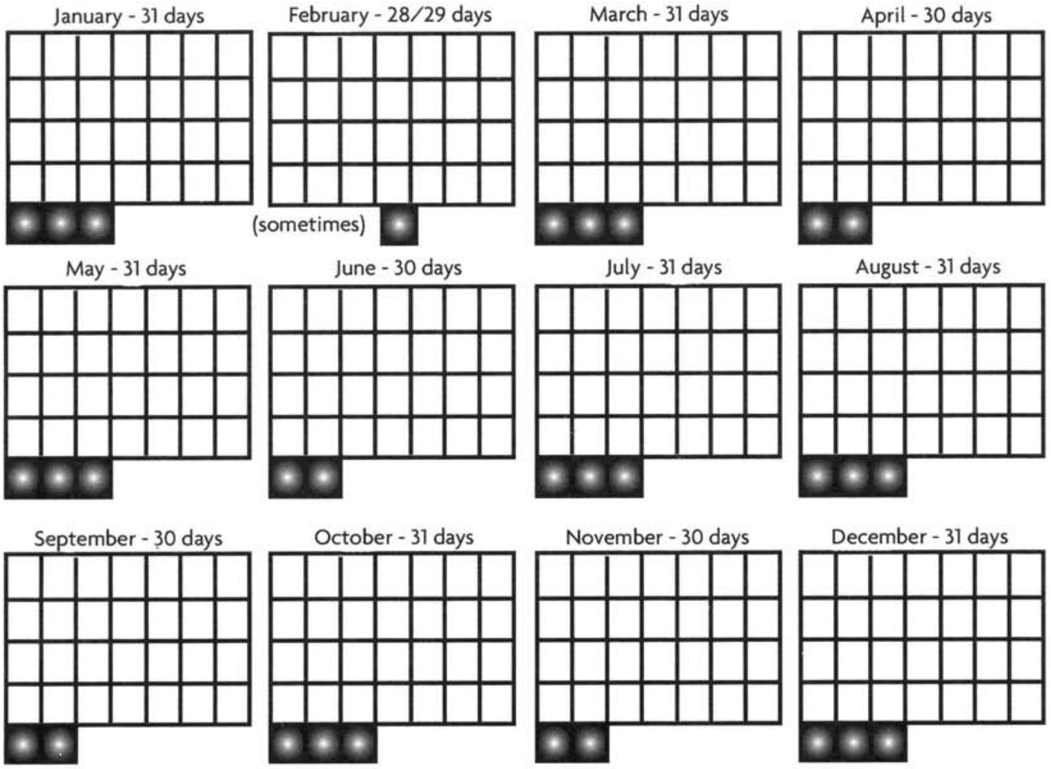
January - 31 days
February - 28/29 days
(sometimes)
March - 31 days
April - 30 days
May - 31 days
June - 30 days
July - 31 days
August - 31 days
September - 30 days
October - 31 days
November - 30 days
December - 31 days

Wavespell of the Thirteen Moons in Relation to the Irregular Gregorian Calendar

time through the perfect and perpetual harmony of the Thirteen Moon calendar. With the analysis of the Law of Time, there is an even greater urgency and a more profound certainty. Reform is not only insufficient but also impossible. If the calendar is not changed within the next decade, it will be the end of civilization as we know it. There is a genuine and legitimate need to bring the issue of calendar reform into the public eye once again.

Yes, to change the calendar involves a frequency shift. The collapse of the technosphere will dispose the human mind to rethink its options. It may even reorient the human mind to a consideration of the biosphere as being the greater vehicle in which we, as humans, are being carried. Such a massive change in attitude, a mind shift and a paradigm shift, may arouse in the human breast a spiritual reawakening as well. Harmony is spirituality. By changing the calendar, humanity can know it has turned a page of destiny-an act that may cause it to appreciate what has already been written in a book it had not been inclined to study, the Holy Quran:

> God is the One who raised the heavens without pillars that you can see, then assumed all authority. He committed the sun and the moon, each running in its orbit for a predetermined period. He controls all things, and explains the revelations that you may attain certainty about meeting your Lord. He is the One who constructed the earth and placed on it mountains and rivers. And from the different kinds of fruits, He made them into pairs-males and females. The night overtakes the day. These are solid proofs for people who think. (13:2-3)

In this passage we can find ample evidence of the formal order of the Law of Time and the biosphere-solid proofs. As for the "people who think," do they not then constitute the noosphere?

◆

7

Humans—Noospheric Chips:

Consciousness and Reality Redefined

> *"And conquered by the sense of the earth and human sense, hatred and internecine struggles will have disappeared in the ever-warmer radiance of Omega. Some sort of unanimity will reign over the entire mass of the noosphere. The final convergence will take place in peace."*
>
> —PIERRE TEILHARD DE CHARDIN,
> *THE PHENOMENON OF MAN*[1]

Once begun, the exhaustion of the technosphere is irreversible. The exponential growth curves of money, machine production, energy output, and population increase come to a climax. By 2004 the humans will be at another major crossroads: to go wholeheartedly into the harmony of the noosphere, or to suffer the rest of their decline in an ignominious twilight of terrorism, barbarism, and cultural anarchy. By 2004 the humans will have their last opportunity to change their macro-organizing principle. By relinquishing the artificial time held in place by the old calendar and becoming unified in time under a calendar that is a perfect harmony, humans will enact the coming of the noosphere. Only harmony will bring harmony; only harmony will cancel the errors of history, a manifest disharmony. Only an act of harmony can manifest the noosphere. Only this time-changing act, consciously carried forward by a significantly roused number of humans, will create a mental field so positive and constructive as to engender the radical break that leads to an entirely new cycle of existence of the life on Earth: the noosphere. Entrance into the noosphere of harmonic time through the calendar change will be much like going from a black-and-white movie to one in Technicolor. The difference between the new time and the old time is literally like the difference between Heaven and Hell.

September 11, 2001: the Twin Towers collapse, creating a rupture in the technosphere. Everything comes to a halt. The New York Stock Exchange is closed for four days-a virtually unprecedented event. All commercial airline traffic in America is halted for two days. Even the United Nations postpones the opening of its fifty-sixth General Assembly by three weeks. Six weeks after September 11 a new, sinister form of war is engulfing the technosphere. The Americans assert the right to mercilessly bomb Afghanistan in self-defense. The response of war is the final self-destructive impulse of the technosphere to protect itself, but this will only widen the effects of the suicidal blow it has already sustained. The war will only make definite that it is the last climax of the biogeochemical combustion engendered by the pursuit of an error in time.

The rupture in the technosphere is the break in artificial time, and therefore amounts to the opening of a noospheric fissure-an inrush of cosmic consciousness and a moment of simultaneously heightened natural time. When the towers collapsed, belief systems shattered. Because it was viewed on global television, it was an event witnessed by all humanity and it entered through the optical cortex into the brain, arousing potent images from the subconscious. This is a noospheric act because it is the entire mind of the whole species that receives this single image in one simultaneous moment. In that shattering image, however unconscious, the noosphere immediately entered the field of human consciousness, much as a leak in a boat allows water to come rushing in. From the perspective of the noosphere, the technosphere is a medium of transformation resulting from the pursuit of a distorted perception of time. With the destruction of the Twin Towers, the transformation is complete; following the war, the technosphere can be creatively dismantled.

THE NOOSPHERE: RAINBOW BRAIN OF TIMESHIP EARTH

What is the noosphere? Can we define the noosphere more precisely so that it is a less nebulous term? Can we make the noosphere concrete enough so that it may be understood and accepted as the coming new way of a higher level of everyday normalcy? First of all, let us say that the noosphere has existed as long as life has existed on this Earth. In this sense, the noosphere is the sum of the mental interactions of all life. The mental interactions, or field of mind, exist as a great unconscious medium, inseparable from the Law of Time. That is, if all life and the phenomenal world of the biospheric medium are synchronized by the Law of Time, then the programs of the organization of life, from the periodic tables to the DNA code, will also be synchronized by and embedded in the mathematics of the Law of Time. Being a function of the whole system of the Earth and integral to the functioning of the biosphere as an interplay of cycles in which organic and inorganic interact with a set order of chemical transmutations, the noosphere must also be the mental coordinating field or program of this complex of vital interactions. It must, therefore, be a characteristic of biospheric evolution that the noosphere remains unconscious until a significant moment is reached-the climax of the cycle of biogeochemical combustion, the enactment of the biosphere-noosphere transition.

As the Earth's mental field, it must be an act of collective self-reflection that arouses the noosphere into functioning consciousness. By its definition as the mental envelope of the Earth, the noosphere can come into conscious manifestation only through an act of collective self-reflection, such as the proposed calendar change. Also, as the mental envelope of the Earth that is above and discontinuous with the biosphere, the noosphere-mind sphere--can mean only one thing: the advent of universal telepathy among the humans. The Internet can be seen as a third-dimensional reflection of the noosphere, a form of electronic proto-telepathy. But, ironically, as long as the humans hold on to the Internet, they cannot experience the true evolutionary potential of genuine universal telepathy. The point is that telepathy can only function in a field of reality that is synchronized by the natural 13:20 timing frequency. Time and telepathy are mutually defining factors dependent on unity of thought. The humans have chosen a path of disunity, so that their calendar programs clash and are at odds with each other and with natural time. This maintains the technosphere, destroys the biosphere, and keeps the noosphere in the unconscious. But now, with the Inevitable Event, the break has occurred and the shattering of the Dreamspell of History has begun. The noosphere's rainbow brain leaks back into human consciousness.

The rainbow brain of the noosphere-what is that? As the mental envelope of the Earth, the noosphere possesses a structure ordained by the Law of Time and congruent with the structure of the whole Earth. Within the noosphere are to be found the evolutionary control panel or programs, defined as the *psi bank-the* medium of information storage and retrieval for all the mental programs. The noosphere is the field of planetary consciousness in which humans are intended to participate and complete their evolution. However, operating by artificial time is like looking through a glass darkly. This being so, there is no noosphere to see. Humans generally experience consciousness through the chinks in their sensory prism, conditioned by separatist beliefs, making it most difficult to attain a perception or experience the field of consciousness as coextensive with the Earth. Indeed, if the biosphere is the region on Earth for the transformation of cosmic energies, the noosphere is that region of the Earth for the reflection of cosmic consciousness and its mental programs. Seen through the lens of universal synchronized time, the humans accommodating to a single instrument of time measurement are inherently sharing a single thought form. It is that act of self-reflective convergence that makes the noosphere conscious and draws it toward the resplendent omega point of2012 and beyond.

As with all the other geochemical structures and processes of the Earth that are planetary in nature, the noosphere, the rainbow brain of Earth, actually has a coherence and an order that we may define in a precise way. In so doing we shall redefine the nature of human reality and the human being itself. We must enlarge our lens of perception to encompass the whole Earth as a single being. In relation to this single being of the Earth, the individual human is hardly even a speck. The dimensions and proportions by which we commonly measure reality must also expand to accommodate the vast dimensions of the Earth as a single entity, a planetary geocosm within the solar field, the heliosphere. Since the sun is also a star, the heliosphere is a function and member of the galactic order of being. As the mental "thinking sphere" of this planetary being, Earth, the noosphere is above and discontinuous with the biosphere, the hydrosphere, and the atmosphere. It is contained by and functions within the vast invisible electromagnetic field of the Earth. Though the ionosphere is the lowest level of the electromagnetic field system of the Earth, the main structures of this field are the two radiation belts located 2,000 and 11,000 miles above the Earth. It is within the two radiation belts that the control panels of the noosphere are to be found-the psi bank.

KIN: BIPOLAR BASE MEASURE OF THE 13:20 MATRIX

> *"And He is the One who created the night and*
> *the day, and the sun and the moon; each*
> *floating in its own orbit."*
>
> -QuRAN,21:33

In the simplest aspect of our daily experience of time on Earth we have the full play of the law of alternation-day-night, sun-moon, north-south. Because we know the bipolar nature of the Earth, dividing it into two geomagnetic fields, north polar and south polar, we can then define the complementary bipolar field of time, which divides the cycle of the Earth as it makes one rotation on its axis into one day and night. This entire unit, day and night, is defined as a *kin,* the base unit of synchronic time measurement. From the perspective of the noosphere, day and night are a function of the two alternators-day alternator and night alternator-that operate as the phasic motion of the rainbow brain of the noosphere working in tandem with the electromagnetic field. The two phasic alternators regulate the activation of photons (day) and the regeneration of photons (night) within the entirety of the life process of the biosphere.

THE NOOSPHERIC FOURFOLD/EIGHT-PART STRUCTURE

> *"He created the heavens and the earth truthfully. He rolls the night over the day and the day over the night. He committed the sun and the moon, each running for a finite period. Absolutely he is the Almighty, the Forgiving."*
>
> -QURAN, 39:5

> *"We rendered the night and the day two signs. We made the night dark and the day lighted, that you may seek provisions from your Lord therein. This also establishes for you a timing system, and the means of calculation. We thus explain everything in detail."*
>
> -17:12

Since the two alternators are also in interplay with the bipolar magnetic fields of the Earth, a four-part process is revealed that is magnetically distributed as an overall eight-part structure. The unit of one kin divides the rotational cycle of the Earth in its orbit into four distinct phases daily and annually. The four daily points are defined by: the dawn, when the part of Earth you are in first experiences the solar photonic activation; the high noon (zenith), when the part of Earth you are in is in closest direct relation to the sun; the twilight, when the photonic activation ceases and the sun disappears from view; and midnight (nadir), the point at which the point of Earth you are on has rotated to its farthest distance from the sun, the height of the cycle of photonic regeneration. This daily process is mimicked in the four points of equinox and solstice, where for either hemisphere the equinoxes are the same as the points of dawn and twilight and the solstices correspond either to high noon or to midnight. Because of the magnetic polarity of the Earth, the four-part process is

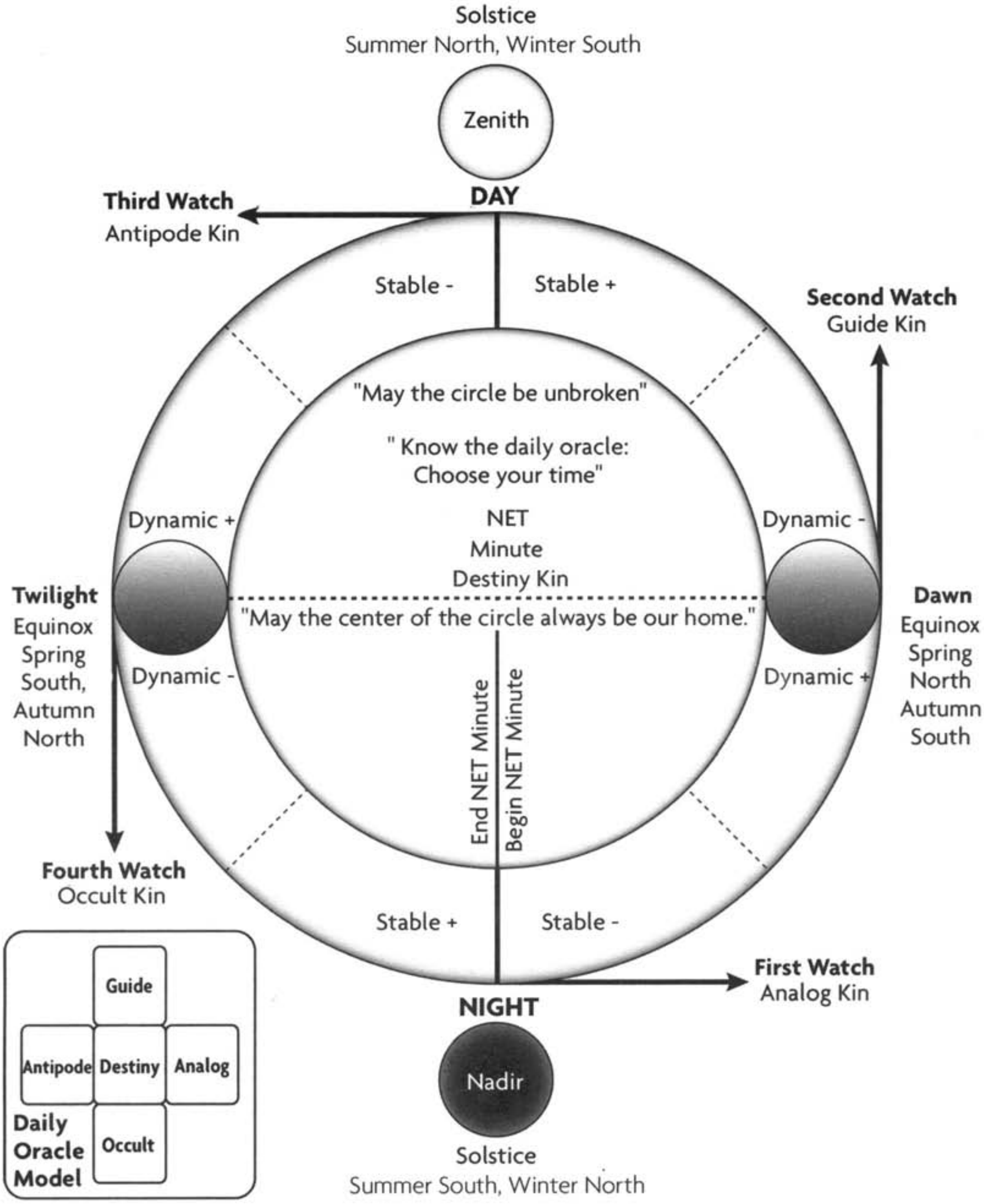
Solstice
Summer North, Winter South
Zenith
DAY
Third Watch
Antipode Kin
Stable -
Stable +
Second Watch
Guide Kin
"May the circle be unbroken"
" Know the daily oracle:
Choose your time"
NET
Minute
Destiny Kin
Dynamic +
Dynamic -
Twilight
Equinox
Spring
South,
Autumn
North
"May the center of the circle always be our home."
Dynamic -
Dynamic +
Dawn
Equinox
Spring
North
Autumn
South
End NET Minute
Begin NET Minute
Fourth Watch
Occult Kin
Stable +
Stable -
First Watch
Analog Kin
NIGHT
Nadir
Solstice
Summer South, Winter North
Guide
Antipode
Destiny
Analog
Occult
Daily
Oracle
Model

Four-Part Bipolar Kin:
Four daily watches,
Four annual seasons—
Two points of balance
Two points of return

Net Minute Model

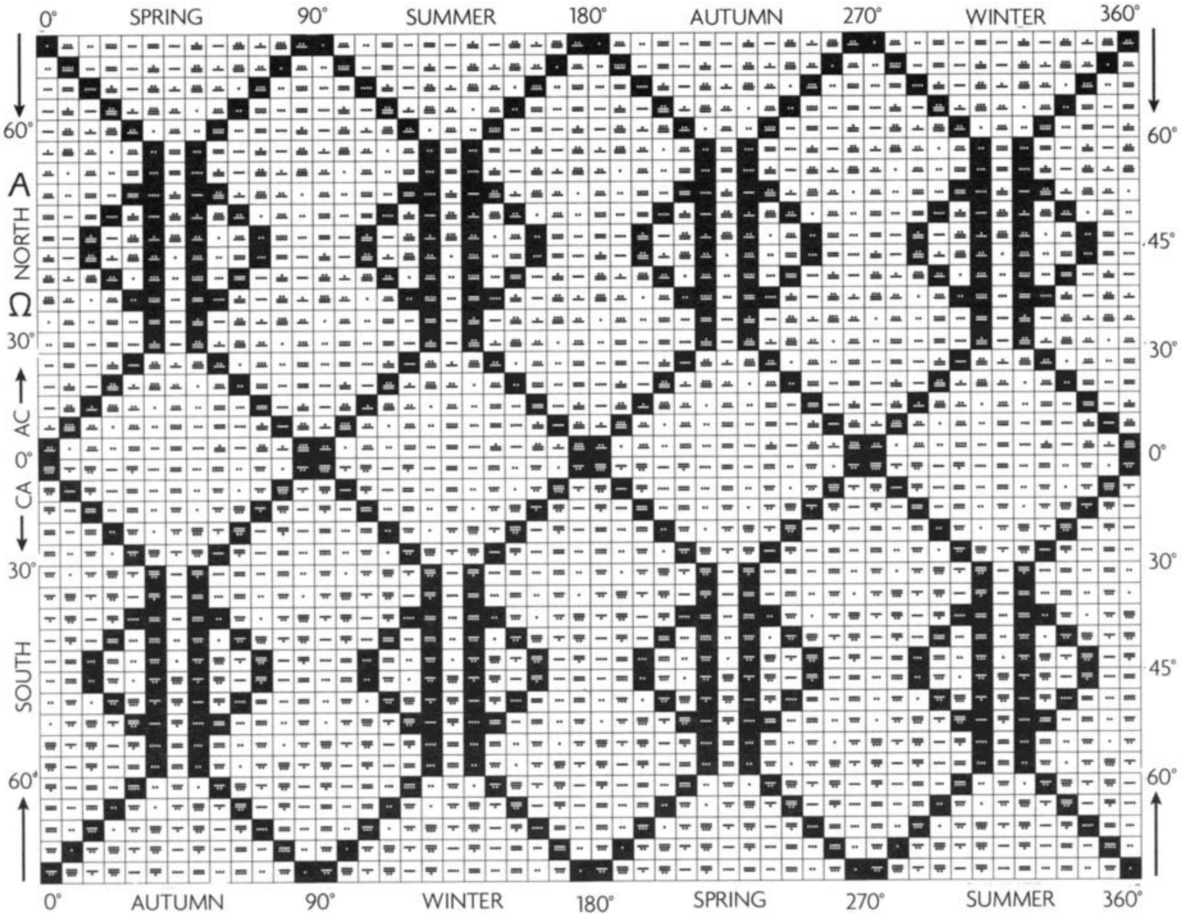

Psi Bank—Four Bipolar Plates Accommodating NET Time Autoregulatory System of the Noosphere
(from *Earth Ascending,* Map 1)

simultaneously experienced in opposite phases, that is, winter in the North is summer in the South-hence the four-phased process yields a bipolar eight-fold structure.

This four-part day-night seasonal process defines the structure of the four psi bank plates, which also coordinate the four-year cycles of the Earth. The psi bank plates, the "nervous system" and control panel of the noosphere, are a complete function of the 13:20 timing frequency and thus participate in the systematic regularity of the fourth-dimensional synchronic order. This means that the psi bank is the registration within the Earth's magnetic field of the 13:20 timing matrix by which all life and the planetary evolutionary process as a whole are regulated. Simulating the four-part process of the Earth rotating on its axis in time, four stages per day, four seasons per year, in four-year cycles-not to mention the four phases of the moon-four psi bank plates accommodating the bipolar field yield eight 260-unit 13:20 frequency information matrices.

That is, each of the four psi bank plates conforms to a mirror symmetry of the bipolarity of the Earth's magnetic field. Each plate is divided by mirror symmetry into a 260-unit Northern and a 260-unit Southern hemispheric half, for a total of two bipolar matrices and 520 units per plate, or 2,080 (520 x 4) units in all. These units are referred to as *psi chrono units* or *time-bearing information units.* The information for the different sequences of the Earth's biogeochemical evolutionary processes is all regulated by these time-bearing information units.

We have to understand that through the medium of universal cosmic time the Earth, the Sun, and every star, constellation, and galaxy is coordinated in this way by the synchronic 13:20 frequency of time. It is the 13:20 frequency that establishes holonomic consistency in time throughout the universe. The Earth's noosphere is a lens of time. All cosmic information is focused through this lens. It is this noospheric lens of time that makes Earth into a geocosmic thought form.

The noospheric lens of time and mind has been operating ceaselessly-but unconsciously-since the beginning of the evolution of the Earth. Since the noosphere is a function of the universal synchronic timing frequency, its conscious activation must also come about through a superior mental coordination with this correct synchronizing timing frequency. The psi bank 13:20 frequency is consciously activated and registered at the human level by the mental engagement of the 13:20 matrix as enacted through the 260-day cycle. The interaction of the 260-day galactic cycle with the 365-day solar biotelepathic cycle defines one noospheric year, or one solar-galactic cycle of fifty-two human years (= fifty-two 365-day solar orbits = seventy-three 260-day galactic cycles). This great noospheric coordination of fifty-two solar orbits with seventy-three galactic cycles is fractally present in a single solar orbit, where fifty-two 7-day weeks = seventy-three 5-day cycles known as chromatics. What is important in coming to understand the noosphere as Earth's geocosmic time lens and rainbow brain, is that we must change our perspective altogether from anthropocentric to noospherocentric, and in this way evolve into *Homo noosphericus.*

THE CYCLES OF NET TIME

For the noosphere, the rainbow brain of planet Earth, time is different-it is slower and longer. From the noosphere's point of view, what we call a year is a solar orbit. What we call a day is a single rotation of the Earth on its axis. The cycles of the moon are the lunar phasings that calibrate the synchronization of the Earth in time. The Earth is not a spaceship. The Earth is a Timeship. As a Timeship, the Earth is a function of the master synchronization frequency that coordinates and moves it in time through ever greater circles of inclusiveness and syntropic integration. Seen through the noospheric lens of time, the technosphere is a highly exaggerated acceleration of the biogeochemical continuum through highly artificial and resource-depleting means-it is but a smoking bubble whose fragile struts and frets are laced together by transport and communication systems that yield a cacophony rather than a harmony. And for this reason, the disharmony of the bubble ultimately explodes upon itself, releasing Earth from the prison of false time into the fresh air of real time and the advance into the geocosmic splendor of the noosphere. Synchronized with the galactic cycles, the noospheric mind of the whole Earth is reckoned far differently from the artificial units of measure that condition the anthropocentric notions of time evolved in the era of *Homo historicus.*

Here is how the fourfold process of Earth in time is reckoned by the noosphere. Please note that in Noospheric Earth Time (NET), time is universal synchronization. At any given moment, it is always the same noospheric moment in time on

Table of Noospheric Earth Time Units

1. One Noospheric Earth minute = 1 day-and-night rotation of Earth on its axis = 1 kin.
2. Twenty-eight Noospheric Earth minutes = 1 Noospheric Earth hour = one moon of 28 kin. where every 7-day week = 1/4 Noospheric Earth hour = 7 kin.
3. Thirteen Noospheric Earth hours (moons) = 1 Noospheric Earth day = 365 kin (days) = 1 solar orbit. or 1 human year (= 13 NET hours x 28 minutes + 1 NET minute, "Day Out of Time:')
4. Four Noospheric Earth days = 1 Noospheric Earth week = 4 solar orbits (years) = 1,460 kin (days).
5. Three Noospheric Earth weeks plus 1 Noospheric Earth day = 1 Noospheric Earth season = 13 solar orbits or 13 human years.
6. Four Noospheric Earth seasons = 1 Noospheric Earth year = 52 solar orbits (52 human years) = 73 260-day galactic cycles = 18,980 kin (days).
7. Five Noospheric Earth years = 1 Noospheric time chord = 260 solar orbits.
8. Twenty Noospheric time chords = Vs Noospheric evolutionary subcycle = 5,200 solar orbits = 1 Noospheric Century of 100 Noospheric Earth years.
9. Five Noospheric evolutionary subcycles = 1 galactic evolutionary day = 26,000 solar orbits = 5 Noospheric Earth centuries or 500 Noospheric Earth years of 52 solar orbits each.

Earth. Whether that moment is experienced on the night or day side of the Earth, that moment is simultaneous and encompasses both sides of the Earth at once. This is true not only because time is the factor of synchronization- T(E) = Art, where art is the result of any synchronization-but also because the velocity of time is infinitely instantaneous. By thinking that the Earth really does conform to the 24 hours of the clock, the humans have retarded their time sensibility, and consequently their artificial processes have become increasingly artless. In considering the Noospheric Time measurements, remember that as a human you are but a cell in the biospheric organism-or, as we shall see, a chip of the noospheric rainbow brain.

As the measure of the mind of the Earth, the Noospheric Earth Time (NET) reckoning units coordinate consciousness as a planetary, or, more accurately, a solar-planetary phenomenon. For instance, if one NET day is a single 365-day solar orbit of the Earth, dawn of the noospheric Earth day is experienced as the spring equinox, but the noosphere is bipolar. So the dawn is also simultaneously the autumn equinox or twilight of the other polar magnetic half of the Earth. To fully engage and grasp such a thought is to expand the limits of consciousness. Like dolphins who never sleep but only rest half of their brain at a time, so it is with the rainbow brain of the noosphere. Such consciousness has nothing to do with the workings of the everyday egoistic human consciousness, which can understand things only according to a limited frame of reference defined by its own limited and highly conditioned ego needs. The geocosmic consciousness of the noosphere can be apprehended only as a single telepathic unity in and by which all members of any given species or organism are organized. To consider that the noosphere itself could become the organizing principle of the human species as a whole is to engage in conscious mental evolution.

Small aboriginal prehistoric bands of humans experience an unconscious level of this geocosmic noospheric mind. Dolphins, other mammals, and all animal species experience this noospheric mind. Even trees and crystals are organized by this noospheric mind of time.

Homo historicus, however, slowly but inexorably cut himself off from the noospheric mind of time by substituting erroneous instruments of measure, or instruments of measure that were incomplete in relation to the noospheric time cycles. The result was the exponential surge in biogeochemical combustion that characterized the final baktun cycle, culminating in the fifty-six-year blister of artificial time, the technosphere. The fact that the time blister popped eleven years before the end of the cycle of *Homo historicus,* 2012, means that *Homo noosphericus* is ready to emerge from the shattered cocoon of false time. Liberated from artificial time and from the technosphere itself, and enrolled in the natural time of telepathy, the human will experience

Noosphere Earth's Rainbow Brain

Magnetic Alternation - Night and Day
Law Of The Ring

"The Psi Bank in Perfect Motion"

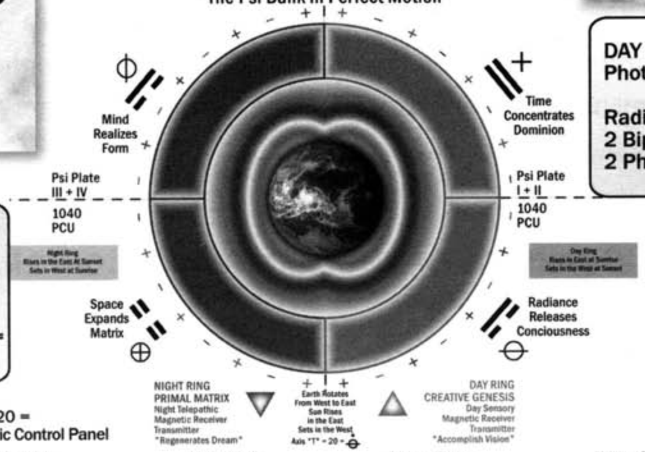
Mind Realizes Form
Time Concentrates Dominion
Psi Plate III + IV
1040 PCU
Psi Plate I + II
1040 PCU
Night Ring Rises in the East At Sunset Sets in West at Sunrise
Day Ring Rises in East at Sunrise Sets in the West at Sunset
Space Expands Matrix
Radiance Releases Conciousness
NIGHT RING PRIMAL MATRIX Night Telepathic Magnetic Receiver Transmitter "Regenerates Dream"
Earth Rotates From West to East Sun Rises in the East Sets in the West Axis "T" = 20 =
DAY RING CREATIVE GENESIS Day Sensory Magnetic Receiver Transmitter "Accomplish Vision"

T(E)=ART

DAY ALTERNATOR
Photonic Activator

Radiation Belt x 2 = 2 Bipolar PSI Plates - 2 Phases

NIGHT ALTERNATOR
Photonic Regenerator

Radiation Belt x 2 = 2 Bipolar Psi Plates = 2 Phases

2 Phases + Polarity =
4 Bipolar Psi Plates @ 13:20 =
Nervous System + Noospheric Control Panel

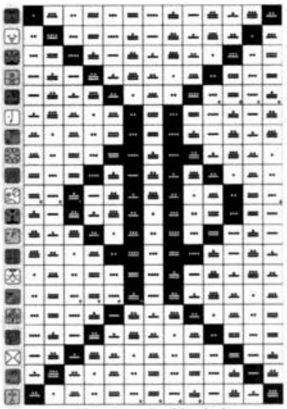

Harmonic Module

20 Solar Frequencies

13:20 Matrix Programs Four Phase Bipolar Psi Plates

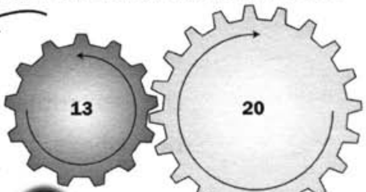

13:20. Ratio Constant of Universal Synchronization

Earth Wizard.
"Homo Noosphericus"

Synchronic Map and Guide to the **Noosphere**

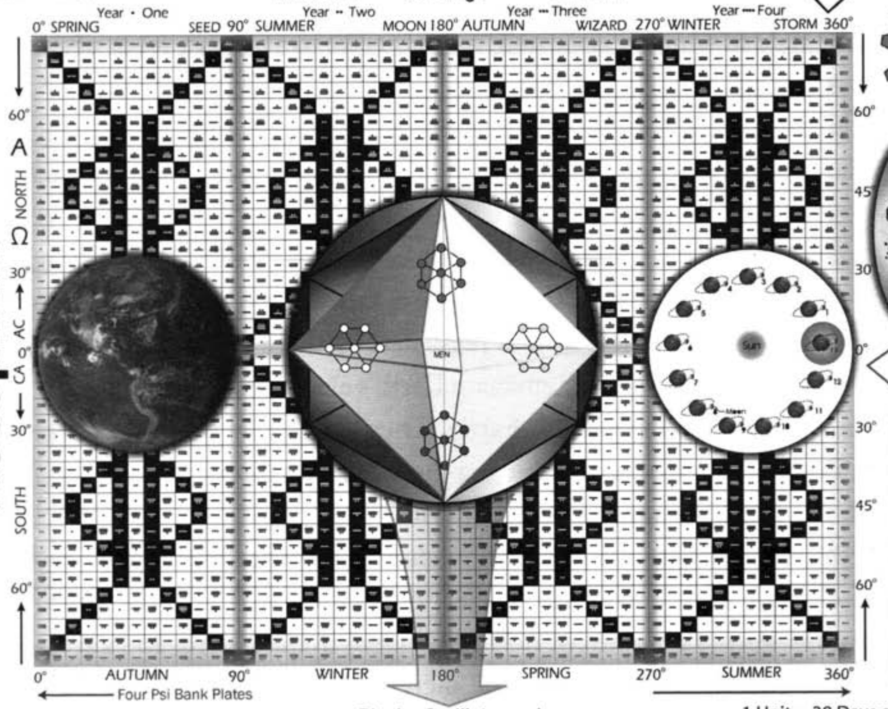
Year · One
0° SPRING
SEED 90°
SUMMER
Year -- Two
MOON 180°
AUTUMN
Year --- Three
WIZARD 270°
WINTER
Year ---- Four
STORM 360°
60°
A
NORTH
Ω
30°
AC
0°
CA
30°
SOUTH
60°
60°
45°
30°
0°
30°
45°
60°
MEN
Sun
Moon
0°
AUTUMN
90°
WINTER
180°
SPRING
270°
SUMMER
360°
Four Psi Bank Plates

13 Moon 28 Day + 1 Noospheric Regulator = 1 Noospheric Earth Day

Noospheric Earth Time (N.E.T.) Units

1 Day = 1 NET Minute
28 Days = 1 NET Hour = 1 Moon

13 Moon NET Hours = 1 NET Day = 1 Solar Orbit

4 Solar Orbits = 1 NET Week

3 NET Weeks + 1 NET Day = 1 NET Season = 13 Solar Orbits

4 NET Seasons = 52 Solar Orbits = 1 Noospheric Earth Time Year

Bipolar Oscillator and Crystal Transducer Earth Core

Activated by 1 Time Atom per ¼ Hour (7 Days) x 4 = 4 per Hour, 28 Days = 1 Moon-NET-Hour

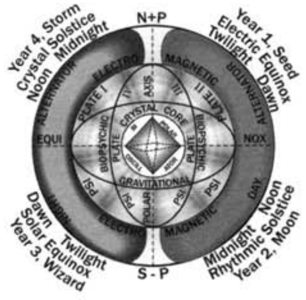
N+P
Year 4, Storm
Crystal Solstice
Noon Midnight
Year 1, Seed
Electric Equinox
Twilight Dawn
ALTERNATOR
ELECTRO
MAGNETIC
PLATE I
PLATE II
IV
AXIS
III
CRYSTAL CORE
EQUI
NOX
BIOPSYCHIC
PLATE
PLATE
BIOPSYCHIC
GRAVITATIONAL
PSI
PSI
POLAR
PSI
PSI
NIGHT
DAY
ELECTRO
MAGNETIC
Dawn Twilight
Solar Equinox
Year 3, Wizard
Noon
Midnight
Rhythmic Solstice
Year 2, Moon
S - P

Four Phasic Noospheric Resonator
Timeship Earth Field
- Day Night Alternator - 4 phases
  Twilight Noon Dawn Midnight
- 1 Moon-NET-Hour = 4 weeks ¼ Hours
- Solar Orbit = 4 Seasons = 4 Phases NET Day
  [Electric, Solar Equinoxes; Rhythmic, Crystal Solstices]
- 4 Solar Orbits = 1 NET Week = 1 Seed Storm Year Bundle = Return of 4 Psi Plates, 1 per Year.

Planet Holon - 20 Day Cycle

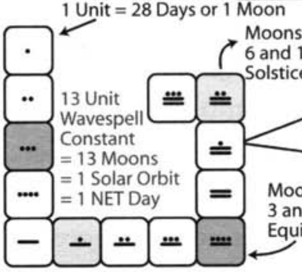

1 Unit = 28 Days or 1 Moon

13 Unit Wavespell Constant = 13 Moons = 1 Solar Orbit = 1 NET Day

Moons 6 and 12 = Solstices

Moons 3 and 9 = Equinoxes

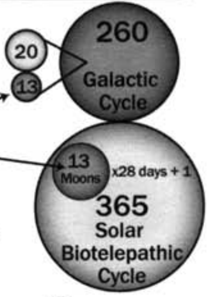
20
13
260
Galactic Cycle
13 Moons
x28 days + 1
365
Solar Biotelepathic Cycle

Timeship Earth 2013
Coded by 20 Solar Frequencies in Time

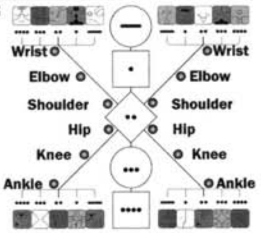
Wrist
Wrist
Elbow
Elbow
Shoulder
Shoulder
Hip
Hip
Knee
Knee
Ankle
Ankle

13:20 Noospheric Chip
"Homo Noosphericus"
20 Fingers + Toes
4 Limbs
13 Main Articulations
Consciously synchronized in 13:20 time. Plays Psi Bank Control Panel, generates Earth's Rainbow Brain

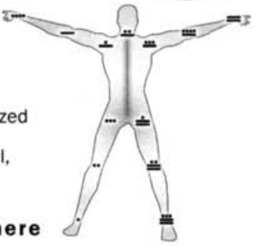

Man in the Noosphere

noospheric organization into psychic biomes. Through the psychic biomes-collectives of communities coordinating their bioregional network according to the structure of the "thought moments" of noospheric time-the human will fully evolve the Earth as a planet with solar-galactic consciousness.

ELECTROMAGNETIC WORKINGS OF THE EARTH'S RAINBOW BRAIN

What we call the cycles of time are the thought moments of the Earth. These thought moments coordinate the complex orders of Timeship Earth, understood as a whole system. Because the operating mechanism of the noosphere that governs the Earth's cyclic thought moments is inseparable from the general structure and functions of the electromagnetic field in which it is located, we may refer to a *rainbow brain* of the noosphere. Why is this so?

Let us return to the structure of the noosphere, Earth's mind in time. Consisting of the four bipolar psi bank plates, these four synchronic time plates are located between the two radiation belts, that is to say between 11,000 and 2,000 miles above the biospheric surface of the Earth. With the location of its information time-bearing mechanism between the radiation belts, the noosphere must by necessity operate in tandem with the electromagnetic field as it is regulated by these two master radiation belts. What do these belts do? They emanate Earth's electromagnetic aura, and function as a protective shield around the Earth. They do this by trapping solar-cosmic radiation, keeping much of it from hitting the biosphere directly, channeling it instead through the Earth's magnetic poles into the Earth's core.

In the polar regions excess cosmic radiation, including electrically charged plasmas and solar discharges from coronal mass ejections, is released into the atmosphere as the auroras-aurora borealis (or northern lights) in the North, and aurora australis (or southern lights) in the South. The increased solar activity during the most recent and current sunspot cycles has enhanced and extended the auroral activity in recent years far beyond the polar zones. In addition, since 1987 great influxes of plasma into the solar system have intensified the incidence of spectral plasmic activity within the atmosphere itself. This amounts to an increase in rainbows, halos around the sun, and brilliantly colored clouds. While these phenomena may be explained to a certain degree as meteorological effects (the angle of the sun's rays, moisture in the atmosphere, and so on), is there more to a rainbow than meteorological side effects? And what relation is there between the noosphere, the electromagnetic field, and the increased plasmic-rainbow activity?

Again, seen from the perspective of whole Earth, the rainbows and spectral plasmic effects, including the auroras, are the free energy released by the noosphere. Rainbows are to the noosphere what toxic waste is to the technosphere. The noosphere itself implies a mental field that is interacting with the electromagnetic field. The Earth's electromagnetic field is actually the strongest of all the planets in the solar system. The only other planet that has a field approaching the strength of the Earth's field is Uranus. If the Earth's electromagnetic field is the strongest, is this an indication of the strength of the noosphere as well? If the rainbows, auroras, and other spectral plasmic activity are a demonstration of the free energy released due to the interaction of the noosphere and electromagnetic fields, and the noosphere is the mental envelope of the planet, inclusive of the as-yet-to-be-unified mind of the human species, what forms of free energy might be released if the human mental field were operating as a single unity in the correct timing frequency?

One other mechanism crucial to the entire system of noosphere and electromagnetic fields is the crystal core at the center of the Earth. In the 1970s Russian scientists put forth the idea that the Earth is crystalline in nature, an idea that extended Plato's notion of the Earth as a dodecahedron, one of the five "platonic solids." The idea was that the Earth's surface was held together by a field of resonance that corresponds to the crystal resonance of certain geometrical solids. R. Buckminster Fuller also gave play to this notion in his description of "spaceship earth." Then in the 1980s American seismologists confirmed that the core of the Earth is actually a gigantic iron crystal structure in the shape of an octahedron, elongated at its ends, which point to the North and South Poles.

From the point of view of fourth-dimensional time, the planet Earth is another manifestation of space as an infinitely locatable point, an orbiting body upon which all the vectoral programs of cosmic time may be unfolded. Understood as a Timeship, the Earth's structure is constructed to facilitate its travel in time on a particular route in space in conformity with its relation to the local star, the sun, to the other planets of the solar system or heliosphere, and in synchronization with the universal timing constant 13:20, which maintains the Earth in the synchronic order. The role of the magnetic octahedral crystal core is to function as the bipolar oscillator and crystal transducer whose purpose is to maintain the Earth in the synchronic order of the 13:20 timing frequency. Thus, if the Earth's noosphere contains the 13:20 timing programs of the psi bank, and the crystal bipolar oscillator is meant to maintain the Earth's space body in the synchronic order, obviously there is a resonant relation between the crystal core and the noospheric-electromagnetic field programs.

The transductive properties of the crystal allow it to transform energy from one state to another. The crystal core also stores electronic plasmas that travel to it from the

Earth's poles through an electromagnetic flux tube system. Within the crystalline core, the electronic plasmas are transduced into information. This is the information of time understood as cosmically transmitted thought forms. These plasmic thought forms conform to programs already established in the psi bank of the noosphere. These are the Earth's thought forms, the cycles of the Earth's brain waves, as it were, that allow it to maintain its biospheric programs and to evolve its mental field, the noosphere. The very descriptions of the Noospheric Earth Time (NET), and of time itself as a synchronous instantaneity inseparable from telepathy, are examples of the Earth's thought forms transduced through a human biocomputer and then transmitted into a form of human language for the purpose of communication. Keeping this description of the noospheric brain in mind, let us return to our analysis of the biosphere-noosphere transition.

MAKING THE NOOSPHERIC LEAP: TRANSFORMATION OF HUMANS INTO NOOSPHERIC CHIPS

The transition to the noosphere is experienced by Earth as a crisis because its systems are stressed. Since the Earth functions as a whole system, stress on one component of the system actually stresses the whole order. Let us review the cumulative stress points. Human 12:60 electromagnetic activity has perturbed and distorted the electromagnetic field. The release of free energy due to geochemical combustion adds to this stressful distortion through the depletion of ozone in the ionosphere and global warming. The radioactivity released into the atmosphere adversely affects the resonant field of the DNA, already driven by the 12:60 frequency to accelerate the multiplication and propagation of the human biomass throughout the biosphere. Through its artificial means, the machine, the human further upsets the inherent balance maintained by the pressure that the species exert upon each other, resulting in mass species extinction.

Yet all this is according to an evolutionary program that is intended to bring about an ultimate crisis by which the biosphere snaps into becoming the noosphere. Clearly, if the root of this crisis is the deviation of the dominant species operating according to an artificial timing mechanism at odds with the universal timing frequency, then the stabilization of the transition to the noosphere will come about through the dominant species consciously "returning" to the correct timing frequency. This it can only do by adhering to a macro-organizing program that puts the human species completely in the 13:20 frequency.

If the whole system analysis seeks to locate the flaw in the operation of Times hip Earth, then we must finally declare that this flaw is the human civilization in its entirety, as it is maintained by erroneous and artificial timing constructs. Since the noosphere, the mind of time on Earth, defines the next evolutionary cycle, and because the humans are following a course dictated by being in the wrong time, calendar reform is the eye of the needle through which humanity must pass in order to get to the noosphere. Only by fully manifesting the noosphere will the Timeship Earth be truly put back on course once again. The noosphere is the program of time on Earth. Time is all that the noosphere has to give us. In consideration that the artificial time of the technosphere has fundamentally run out, the noospheric time should be a welcome gift.

Science is always absolutely precise. It is not just calendar reform that is the eye of the needle through which to pass into the noosphere-it is the Thirteen Moon/28-Day calendar calibrated by the 260-day Wizard's Count, synchronized to the Gregorian calendar date, July 26, that provides the exact ticket of admission into the noosphere. And then this ticket must be used at just the right moment-when the show is ready to begin. To use another metaphor, there is a lock on the door to the noosphere, and there is only one key that will fit and unlock this noospheric gate. That key is the Thirteen Moon/28-Day calendar, correlated to July 26 on the Gregorian calendar. It is the precisely applied use of this Thirteen Moon/28-Day calendar that will make each human a noospheric chip of the rainbow brain. This is because the Thirteen Moon/28-Day calendar is the key with the precise design for not only opening but also for continuing to operate the noosphere through a matching of the everyday frequency of time with the frequency of the noospheric control panel, the psi bank.

It is because the daily program of the Thirteen Moon/28-Day calendar is embedded in the 13:20 frequency that the consciousness of the humans will finally change and rise above the stunted level by which it is currently maintained in the artificial world of the technosphere. Time is of the mind, and the natural time registered by the Thirteen Moon/2 8-Day calendar is the opening to the geocosmic mind of the universe, which adherence to artificial time has kept the human from experiencing. The noosphere is the fractal lens of this geocosmic mind on Earth. Since the geocosmic mind is purely a function of the Law of Time-energy factored by time equals art, where the 13:20 synchronizing ratio of time is characterized by infinitely instantaneous velocity-then the fundamental nature of this mind is telepathy.

The Thirteen Moon/28-Day calendar is, therefore, the perfectly designed instrument to make the noospheric leap into telepathy, the planetization of consciousness that establishes the daily reality of the noospheric mind. Since the noospheric mind interacts with the electromagnetic field, and because the ratios and cycles of the Thirteen Moon/28-Day calendar conform to the fractals and ratios of the NET, by using this calendar the human becomes transformed into a noospheric chip. The fractals and ratios of NET become the normative operating cycles of the human in its daily reality. This accounts for an increasing noospheric synchronization that allows the noospheric chip to attain its purpose: generating the Earth's rainbow aura. If the free energy of rainbows is to the noosphere what the free energy of toxic waste is to the technosphere, then the generation of the rainbow implies a type of activity on the part of the human to produce such free energy. To understand what this activity might be and how it works, we must first understand the morphic and holonomic relation between the human noospheric *chip-Homo noosphericus-and* the structure of the noosphere itself as it is programmed into the geocosmic measure of the Thirteen Moon/28-Day calendar.

HUMAN BEINGS AS FRACTAL REFLECTORS OF THE 13:20 MATRIX

From the noospheric perspective, the prototype human is an embodiment of the 13:20 synchronization factor. The human has four limbs. Each of the four extremities has five digits, for a total of twenty fingers and toes that distinguish the human's operational capacity. The four limbs conform to the fourfold phasic operation ofNoospheric Earth Time, while the twenty digits conform to the 20 (4 x 5) factor of the 13:20 ratio. The human also has thirteen main joints or articulations: two ankles, two knees, two hips, two wrists, two elbows, and two shoulders; these six pairs coordinate the four extremities with the body, while the thirteenth articulation, the neck and spinal column, coordinates the body proper. These thirteen main articulations plus the twenty digits of the hand and feet conspire to make the human the perfect exemplar of 13:20 timing frequency, that is, a perfect model of synchronization itself.

Add to this the fact that the human has a highly evolved and refined brain and nervous system that is maintained and expressed by the skeletal structure of the thirteen joints of the body and limbs, completed by the sensitive mechanism of the twenty digits, and we see that the human is the perfect biocomputer for processing the information of the instantaneously telepathic geocosmic mind. The means to process the geocosmic information, and also the means by which the human is transformed into the noospheric chip, is found in matching its factors of daily synchronization and intelligence with those of the psi bank, the noospheric control panel. This is called harmonic arrangement of the synchronic order.

Of course, this description of generalized structure, activity, and interaction of the *Homo noosphericus* with the noosphere as such presupposes an entire reorientation of the goals and methods of being human. Such a reorientation of the human is also a function of making the radical change from the erroneous measure of the twelve-month Gregorian calendar, in which are embedded all of the Babylonian programs of history, to the perfect history-less harmony of the Thirteen Moon/28-Day calendar- the mere change of calendars encompasses a mental frequency shift. The readiness to make this change depends on the degree of moral revulsion the human experiences during the collapse of the technosphere. This moral revulsion would then correspond to a turning in the deepest seat of consciousness, which would then dispose the human intelligence to a consideration of the untried solution-change the calendar!

The Thirteen Moon calendar is the NET instrument for daily synchronization and unification of the human species as a single organism in time. Once adopted to the correct measure of this instrument, the human will de facto trigger the noosphere as an operating system of absolutely higher consciousness and mental order. **In** fact, the purpose of human evolution is precisely to become the ignition of the noosphere,

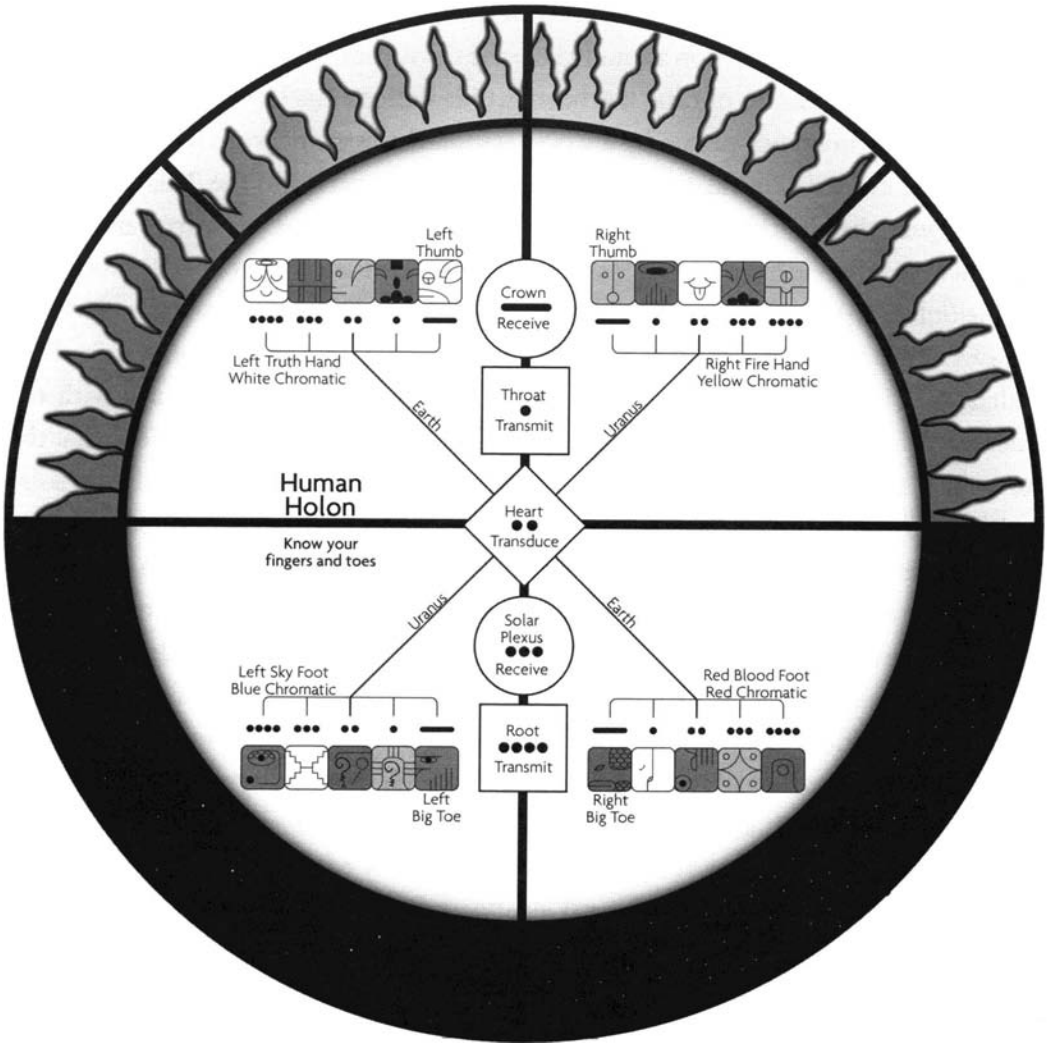
Left Thumb
Right Thumb
Crown
Receive
Left Truth Hand
White Chromatic
Right Fire Hand
Yellow Chromatic
Throat
Transmit
Earth
Uranus
Human Holon
Know your fingers and toes
Heart
Transduce
Uranus
Earth
Solar Plexus
Receive
Left Sky Foot
Blue Chromatic
Red Blood Foot
Red Chromatic
Root
Transmit
Left Big Toe
Right Big Toe

Human Noospheric Chip

and thence to become normalized as the noospheric chips that maintain the operations of the noosphere. As a truly planetized being and consciousness, *Homo noosphericus* will engage in an order and type of reflective activity undreamed of in the technospheric era that is now passing.

First, by adapting to the daily NET timing instrument, the humans will be utilizing a "calendar" that correlates both a 365-day solar biotelepathic cycle and a 260-day galactic synchronization cycle. When the lunar phases are added to the interaction of these two cycles, then the human is able to enjoy the harmonic richness of time-the noosphere. The synchronizing and interactive measures of the counts of the solar and galactic cycles yield multiple levels of harmonic orders of time (Earth's "thought moments") that will activate aspects and levels of consciousness hitherto dormant in the human mind. The very mental act of replacing the order of twelve by the order of thirteen is a profound one. How is this so? Could it be that the whole of civilized history itself is based on the fear of the number *thirteen-triskaidekaphobia,* epitomized in the superstition about Friday the thirteenth-and that, therefore, dealing with the true nature of time has been avoided altogether?2

Currently humans operate by a world standard whose measure includes: seven-day weeks, inclusive of the notions of the 5-day work week and the 2-day weekend; an irregular distribution of twelve months of either thirty-one, thirty, or, in one instance, twenty-eight days; all set within a longer annual cycle that concludes with its visionless moment of New Year's Eve. Many Gregorian calendars will include the phases of the moon, but because the months differ in length there is no way in these calendars of seeing how the phases of the moon might be synchronized with the measure of Earth's orbit around the sun, nor is there any reason to consider that the uneven measure of twelve months has anything intrinsically to do with the solar orbit. Within the twelve-month structure of the Gregorian calendar, weeks, months, and phases of the moon all appear to be haphazard and arbitrary. Such a disorderly order can only bode an undercurrent of uncertainty and fear for the human mind.

By contrast, in the measure of the thirteen moons of twenty-eight days each, the 13 corresponds both to a 13-day cycle and to the cycle of the number of months (moons) per year. The measure of the 7-day week (a NET quarter hour) becomes an orderly harmonic: four perfect weeks occurring each moon, fifty-two perfect weeks each year, each week always beginning and ending on the same day of the week, week after week, year after year, while in fact every day of every moon occurs on the same day of the week, year after year. The effect of such a harmonic regularity on the human mind is incalculable. This is what is meant by a *perpetual calendar.* And to maintain this perfect regularity, the 365th day of every year (solar orbit), is no day of the week at all, but a Day Out of Time, a day for the human to be refreshed in utter timelessness.

Realizing that a day is actually a kin or one NET minute, the measure of one rotation of Earth on its axis, a 4-day cycle of four NET minutes constitutes a harmonic, a 5-day cycle constitutes a chromatic, while the 13-day cycle corresponds to one *wavespell,* the time constant that accommodates the measure of thirteen. Hence, a wavespell can be either thirteen days, thirteen weeks, thirteen moons, thirteen years, or so forth. The point is that by making the change of calendars the foundations of the mind organized in time are irrevocably altered. From the noospheric perspective, there is nothing arbitrary about the laws of nature. The same lack of arbitrariness should be reflected in the instruments that we use to measure time. By adapting to the Thirteen Moon/28-Day measure, the humans are adapting to a measure in which there is nothing arbitrary because it is a pure expression of the Law of Time. Thirteen is not at all a harbinger of bad luck, but the gateway to harmony in time! And it is by using this thirteen-based harmonic instrument of measure that the human is realized as a noospheric chip, a fractal of the noospheric mind, the mind of time on Earth.

NOOSPHERIC CHIPS: WIZARDS OF GALACTIC TIME

In the noospheric construction of the operating mechanism of the Timeship, the human is a vital link, providing the biotelepathic medium for the synchronization of the geocosmic mind on Earth. If we look again at the structure of the noosphere, the components include: the crystal core bipolar oscillator, packed with Technicolor time beams and cosmic thought moments, waiting to be self-reflectively realized; the human noospheric chip, the representative of the biosphere to mentally engage the timing cycles of the NET; the electromagnetic field, which provides the medium of expression between the biospheric order, the human, and the noospheric mind of time; and the noosphere itself, the mind of time on Earth, whose articulation through the psi bank control panels and through the Earth's resonant field structure yields an enlarged measure of Earth consciousness, Noospheric Earth Time itself. In expanding our minds into the noosphere we will understand that what lives is the Earth and the Earth lives through us.

As a noospheric chip, the human is a fractal reflector of the 13:20 timing frequency. Midway between the bipolar oscillator and the noospheric psi bank plates, the human noospheric chip is designed to receive, transduce, and transmit programs from the crystal core by synchronizing these programs with the psi bank.

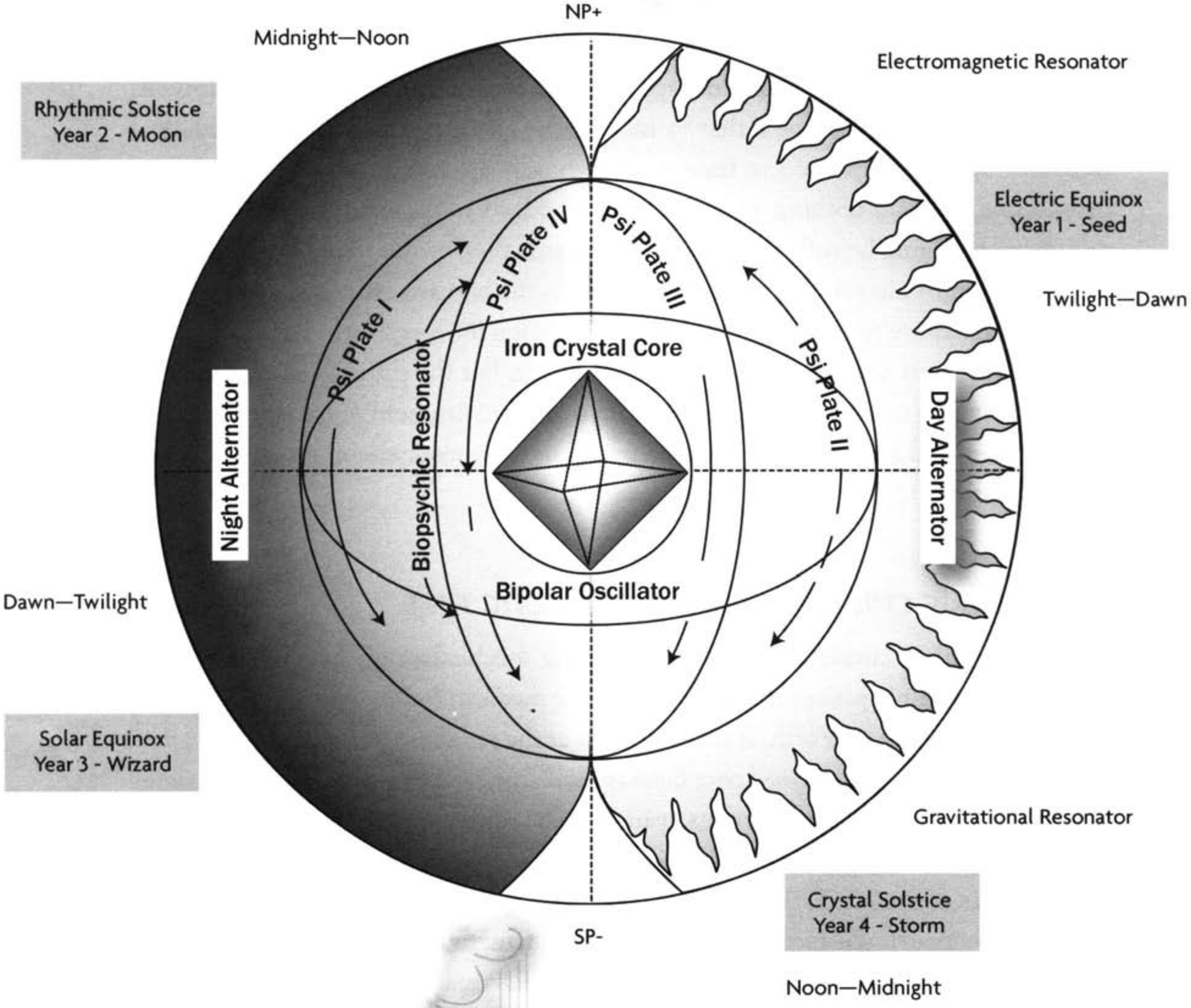
NP+
Midnight—Noon
Electromagnetic Resonator
Rhythmic Solstice
Year 2 - Moon
Electric Equinox
Year 1 - Seed
Twilight—Dawn
Psi Plate IV
Psi Plate III
Psi Plate I
Psi Plate II
Iron Crystal Core
Biopsychic Resonator
Night Alternator
Day Alternator
Bipolar Oscillator
Dawn—Twilight
Solar Equinox
Year 3 - Wizard
Gravitational Resonator
Crystal Solstice
Year 4 - Storm
SP-
Noon—Midnight

Four-Phasic Noospheric Resonant Field Model, Timeship Earth 2013

Three resonators establish the gravitational, electromagnetic, and biopsychic fields held in place by the crystal core, the bipolar oscillator.

Two poles extend the bipolar field of Earth, which, guided by the day-night alternators, create the four-phasic noospheric field model.

Four psi plates govern the four phases, from daily NET minute to seasonal NET day, and to the four-part NET week, or Seed-Storm year bundle.

This is a process that can occur only within the construct of the regular harmonic sequence provided by the noospheric timing gauge of the Thirteen Moon/28-Day calendar. Interaction with the crystal core can only be through telepathic means, and the human-as the midway point between the core and the electromagnetic fields-is like a sensitive piece of litmus paper. To understand the human in this way is to totally redefine the reality of what it means to be human on Earth. From this perspective, the human is a biocomputer whose information source feeds it programs stored and emanated by the crystal core. These programs are then brought into conscious registration through working the corresponding programs of the psi bank. Right now, we don't know what the crystal core is emanating, much less that such a structure exists within the Earth. Like a crystal radio-set, the noosphere is the antenna, the geocosmic programs are transduced and generated at the crystal core, the human is the biocosmic tuner, and the broadcast transmission is provided by the psi bank.

The 13:20 template of the human noospheric chip is defined as the human holon, its twenty digits and thirteen main articulations conforming perfectly to the geocosmic 13:20 synchronization frequency of universal time. It is the intrinsic resonance of this geocosmic structure that allows the human to be in resonance with the planet as a whole system. While the timing programs to be broadcast are all loaded in the psi bank control boards, the actual point in space of the physical Earth is coded by time into a twenty-part icosahedral structure called a planet holon. Being holonomic in nature, the planet holon has a perfect incidence of correspondence with the twenty digits of the human holon.

The twenty digits and twenty-part structure of the planet holon are both coded by the twenty icons or solar seals of the 260-day galactic synchronization cycle. The icons or seals are the manifestations of the 20 (4 x 5) factor of the 13:20 synchronization ratio. They are coded for human legibility as simple icons that conform to a postliterate alphabet. In time these twenty icons create a fourth-dimensional twenty-day solar cycle which interacts with the 13-day galactic cycle to create the 260 unit synchronization sequence or "galactic spin." The point is that when this galactic spin is synchronized with the 365-day solar-lunar measure of the Thirteen Moon count, there is a daily program for identifying the human with the planet holon, a factor that facilitates the planetary resonance of the noospheric chip.

As a noospheric chip, the human is in every way a holonomic reflection of the whole system Earth. As a system of resonators-gravitational, electromagnetic, and biopsychic-the human and the Earth both have bodies with a center of gravity; both exhibit electromagnetic fields; and both share in common a biopsychic resonance, the mutual interface of the noosphere or mind of time with the other two

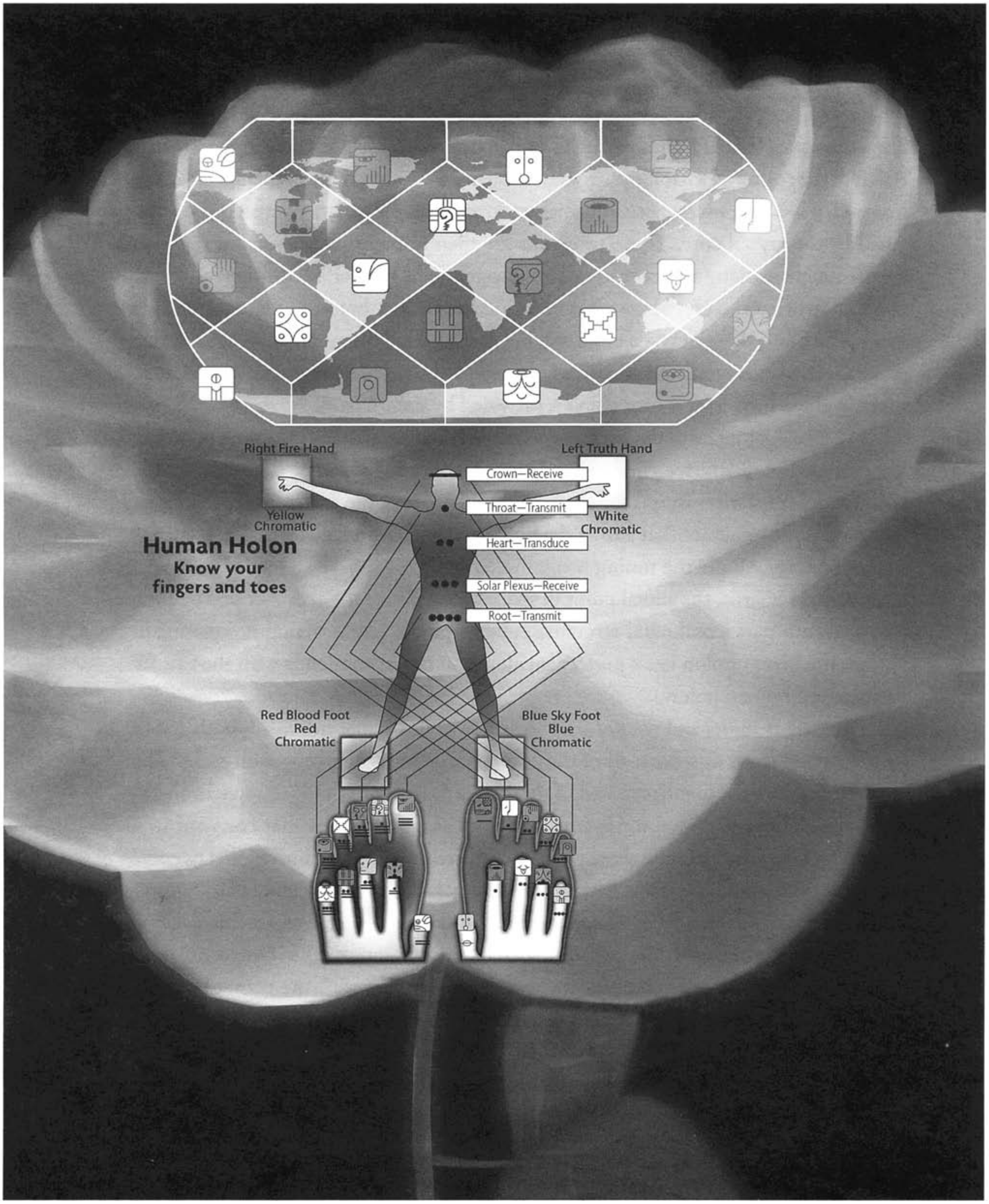
Right Fire Hand
Yellow Chromatic
Left Truth Hand
White Chromatic
Crown—Receive
Throat—Transmit
Heart—Transduce
Solar Plexus—Receive
Root—Transmit
Human Holon
Know your fingers and toes
Red Blood Foot
Red Chromatic
Blue Sky Foot
Blue Chromatic

Planet Holon—Timeship Earth 2013

fields of resonance. The redefinition of the human according to the Law of Time and to the nature of the noosphere also redefines the human's reality. What will the human do when history has been eliminated from the calendar and the new calendar itself is actually operated as a synchronometer-a measure of synchronicity?

First of all, as the necessary prelude to galactic culture, the absolute synchronization of the human in geocosmic time, the technosphere will be dismantled. Reorganized by the Law of Time into psychic biomes, the dismantling will naturally phase into the genuine creation of the new culture of solar-galactic consciousness. "Path beyond technology" means path of telepathic harmony. With its goals absolutely reoriented following the mental pole shift of the calendar change, the hierarchy of human values will also undergo a profound reordering. What if money were no longer the first consideration in human affairs? What if the consideration were instead how artful or artistic that action or event might be? What if the diaspora of humanity through industrialization and mass transport came to an end and the humans willingly chose to live in smaller communities organized by gardening and other Earth-related activities, inclusive of the transformative dismantling of the technosphere and the regeneration of the biospheric medium? What if the study of time replaced the study of physics as the dominant mode for determining the nature of reality? And what if, due to the time shift, a spiritual awakening swept through the human race so that a moral orientation of values was organized around the preservation and furtherance of the biosphere, and an acknowledgement that only One Supreme Creator could have ordained something so perfect as the noospheric mind of time? What kind of world would that be? What kind of art would be practiced in that world and what kind of science would be known?

Organized by the NET, human existence would spiral into the collective telepathic mind. A type of Earth geomancy would become the science of the noosphere. Or perhaps a more accurate name for this science would be *Earth geochronomancy*-the study and investigation of Earth in relation to the cycles of cosmic time and telepathy with an end to perfecting the Earth as a work of art. With minds expanded toward accommodating the longer, slower measure of NET, geochronomancy would inspire an entirely new vision of the Earth within the heliosphere (the solar system) and the galactosphere (the galactic order of things). Making the Earth's rainbow brain visible and manifest would be only the beginning of a willingness to explore further untapped psychic energy sources and means, or what is referred to in *Earth Ascending* as the science of radiosonics. Key concentrations of human habitation and activity would be organized to occur at or close to those geomagnetic energy points or centers, the whole cultural process of which would correspond to making a map on Earth of the image of galactic being as it moves in its great patterns of time. Would this not make the human species into a race of wizards?

In this consideration we may find a reason why the 260-day unit galactic synchronization measure-a galactic spin-is the key to what is called the *Wizard's Count.* The perfect synchronization of the 260-unit galactic spin with the 365 -day Thirteen Moon/28-Day solar orbit establishes the 52-year cycle, or one NET year. A NET year (fifty-two solar orbits) is a "wizard's measure," for on this measure the human can expand its consciousness to encompass the Earth in its greater cycles of development. The Wizard's Count is also given its name because of the set of the four solar icons or seals that code the July 26 synchronization date in 4-year cycles: year one, Yellow Seed year; year two, Red Moon year; year three, White Wizard year; and year four, Blue Storm year. An entire Seed-Moon- Wizard-Storm sequence of four NET days (four solar orbits) consists of fifty-two moons, or one NET week, the perfect fractal of the fifty-two 7-day weeks in one NET day and the fifty-two solar orbits in one NET year. This four-part sequence is also called a Seed-Storm year bundle, the harmonic essence of the wizard's measure. Thirteen Seed-Storm year bundles, where each of the four icons is coded by the thirteen galactic tones (4 x 13 = 52), yield one NET year. Please note that even the Gregorian July 26 synchronization date is a function of the synchronic order: July = 7, while 26 is 13 doubled, 7 and 13 being the two principle numbers governing the 13:20 matrix of the Harmonic Module!

In the symbolism of the iconic sequence it is the Seed that is planted, it is the Moon that coordinates the growth cycles, it is the Storm that generates the energy, and it is the Wizard who knows and acts upon what is given. It was a White Galactic Wizard that coded the date and coordinated the year beginning July 26, 1987-followed twenty-one days later by the Harmonic Convergence. Thus it was the White Galactic Wizard who opened the gates to the closing of the Mayan baktun cycle of history and the commencement of the coming cycle of galactic culture. And on July 26,2003, the year of the White Spectral Wizard will commence. This year will end with its Day Out of Time, coded by the White Spectral Mirror. The day following, July 26,2004, will begin the year of the Blue Crystal Storm. On the Wizard's Count, which is not a calendar but a synchronometer, these two dates, White Spectral Mirror and Blue Crystal Storm, are the point in time when the Gregorian calendar ticket to the old time will be eliminated and the new Thirteen Moon calendar ticket for admission to the new time of the noosphere will be validated. This is when the noospheric show will be ready to begin its prelude. (See plate 6, Noosphere-Mind of Time on Earth.) Will the humans also be ready?

▼

8

Making the Transition to the New Time

A How-to Catalog and Guide to the *Pax Cultura, Pax Biospherica*

BY THE TIME these words are read, the technospheric collapse will have generated several more devastations and disasters. The wound received by the technosphere on September 11 was a mortal one. The technosphere suffered cardiac arrest for almost a week. Not only did the towers collapse, an event that occurred via television within the central nervous system of the human species, but belief systems, too, came crashing down. No longer is America the unassailable fortress of "democracy," while democracy itself is a concept that joins monarchy, nation states, imperialism, colonialism, capitalism, communism, and a host of other outmoded systems of belief and thought constituting the saga of human history-that is, the history of civilization. But all that is now ending. The perimeter of biogeochemical combustion and the limits of the technosphere have coincided. It is the Earth's turn to speak. How will the Earth speak?

The Earth can only speak through the noosphere, and the noosphere can only speak from the center of time that is constructive peace. Peace is harmony. Peace is the culture of the biosphere. The conscious harmony of time in the biosphere is the culture of peace known as the noosphere. Through the noosphere, the Earth speaks in ever-widening circles of order and meaning. While sunrise and sunset mark the passage of solar time, observing the phases of the moon keeps us in tune with the mystery of time. One kin, one passage of night and day, one NET minute, synthesizes the experience of the whole Earth during a single rotation on its axis. The synchronic order supplies a 260-unit synchronization gauge that the mind may engage and employ in the construction of a harmonic vision of reality. Twenty-eight NET minutes make one moon, one NET hour, moon after moon. The pattern of one moon contains the construct and pattern of every moon. The harmonic perfection of the synchronic order of reality releases the mind through the center of time into a freedom it had not known in the dark passage of history. How are we going to make this transition? Can we really shake off the old and the obsolete that easily?

THE THIRTEEN MOON CALENDAR MOVEMENT: THE DAWN OF A NEW GALACTIC CULTURE

"Greetings Explorers on Timeship Earth!" reads the opening text of the pocket-size *13 Moon Natural Time Journal.* "Welcome to this 13:20 natural time portal and fourth-dimensional galactic time template. A solar-lunar Earth calendar of the 13:20 timing frequency that is expressed through the thirteen tones of creation and the twenty sacred solar tribes. Attuning to this calendar will help you awaken and align to the pulse of the Universe, the rhythm of the One heartbeat. 13:20 is the natural timing frequency that unifies planetary and galactic consciousness. . . It is the expression and remembrance that Time is Art . . . By attuning to the 13:20 frequency of natural time, we break out of the 12:60 time warp and activate the remembrance of our true human nature. Time is energy. It is a frequency of the fourth dimension; mind, telepathy, imagination, and creation. Time is an exploration of unlimited Universal potential. So let us begin the journey and return to the rhythm of nature's galactic heartbeat. . ."1

This is the Earth speaking through a noospheric chip. Produced in Canada, it is one of many Thirteen Moon calendars produced this Yellow Solar Seed year. Others have been produced in Germany, Austria, Italy, Russia, the Netherlands, Japan, Brazil, Argentina, Chile, Mexico, and the United States. One such example from the United States is known as the 13 *Moon Natural Time Calendar: Ancient Science for the Art of Now.* Going through its pages one is flooded with a wealth of information, summarized by a quote from traditional Hopi wisdom: "We now face the final test of human consciousness-to restore our oneness with creation. We are going home. It is a process. It is like the seed becoming the green shoot and then the flower."2 To make the calendar change is to restore the oneness with nature. The break with the oneness with nature was codified and thence programmed into an irreversible reality by the Gregorian calendar and mechanical clock. Only the breaking of the pattern of time established by these two instruments will release us again into natural time. The Thirteen Moon/28-Day calendar exists as the tool to demonstrate the contrast between harmony and disharmony, and to assist us, as a species, into effecting this return. If we are going home then we must make a turn away from our present course.

> Through returning to natural Time, we return to our natural state of divinity, living in harmony with the Earth and each other. We return to the nature of our spiritual existence. Realigning with the rhythm of the universe through the 13 Moon Calendar allows us to lay the foundation for the new paradigm of love and unity, replacing the 12:60 paradigm of fear and separation. . . The World Calendar Change Peace Plan strives to establish a new culture of peace on Earth through returning humanity to natural time. It is the goal of the worldwide Foundation for the Law of Time to effect the calendar change by the Day Out of Time (July 25), 2004 . . . Join the global movement to effect planetary £hange and establish the new culture of peace on Earth! Return to divinity and creative existence. . . Walk the path of the sacred warrior.]

The movement to change the calendar is a living force, a force that is living the New Time. Its premises are so diametrically opposite to those of the technosphere that, especially in the power bases of America and the G-7, one will find scant mention or notice at all of this movement. Yet it is a cultural phenomenon. In Tokyo, San Francisco, Milan, or Moscow one may find signs of the presence of this movement in the underground dance events, the raves or the Earthdance. More and more young people take on the names of their galactic signatures, the 260-day kin code for their date of birth in the synchronic order, names like Lunar Storm or Spectral Night, Galactic Wind or Planetary Dragon. These are all signs of the beginning of galactic culture on Earth, a phenomenon that has only been increasing over the past decade. The point is that the New Calendar Change Movement is a grassroots phenomenon as well as an ideological strategy known as the Campaign for the New Time. These signs are all whispers of the noosphere blowing through the bleak industrial corners of the technosphere.

Behind the more populist front of the Natural Time Movement is the science of the Law of Time, a genuinely noospheric science of peace and harmony. This science is already being studied and put into preliminary practice. As the crisis of the biosphere began to crest in 1987, halfway through the second 28-year phase of the technosphere, the noosphere began to download its measure of time through the discovery of the Law of Time. Invisible to the predominant forces of the technosphere, the science of the Law of Time began to map out an entirely new domain of thought, the synchronic order, a domain that could only be entered and applied through the correct noospheric measure, the Thirteen Moon/28-Day synchronometer.

All science throughout history is based on evolutionary advances predicated on both the premises and limitations of its preceding stages. We are at such an evolutionary moment now. The issue of the calendar change is only the beginning of the emergence of a new whole system scientific order. Understanding the flaws that are built into the present system of purely materialist science, we can proceed to the establishment of the science of the synchronic order. Like the radical simplicity and perpetual harmony of the Thirteen Moon calendar itself, the noospheric science of the synchronic order is predicated on an equally radical mathematical base reflecting and embedded in the 13:20 universal timing frequency itself. And as the underlying order of a whole system science, this mathematics is reflective of the non dualistic premise of a superior moral order. The deviation from universal synchronic time is a moral deviation as well. It is this moral deviation that most strongly prompts the current calendar change movement.

As a profoundly nondualistic, unifying whole system premise, the Law of Time encompasses not only a scientific-mathematical basis of morality, but a theological-eschatological intention that reunifies the various disciplines scattered and separated by the rise and totalitarianism of modern secular science. Because of the historical dominance of the Gregorian calendar, in which modern science is embedded, the dethronement of the calendar-the "devaticanization" of the world, as it were-is an apocalyptic moment.

As the Law of Time defines it, this is merely the apocalypse of the 12:60 timing frequency and all its corrupted institutions, much as foretold in the Book of Revelations. This apocalyptic moment was stunningly supplied by the terrifying collapse of the Twin Towers. As the nerve center of the financial, commodities, and transport sector of the technosphere, and hence of the city itself, the collapse of the towers in hardly more than an hour's time is perfectly reflected in the vivid descriptions of the eighteenth chapter of the Book of Revelations, "Fall of Babylon." Yet as the Mayan prophecy of Pacal Votan also makes absolutely clear, the apocalypse of the 12:60 is the resurrection into the 13:20 timing frequency, the return to natural time, all to be accomplished by A.D. 2012, Teilhard de Chardin's "omega point." The advent of the noosphere is preceded by the post-apocalyptic harrowing of hell. In this harrowing of hell, defined as the span of time fromJuly 26, 2000-July 25,2004, humanity must make a crossing from one time to another. This crossing is much like those we hear

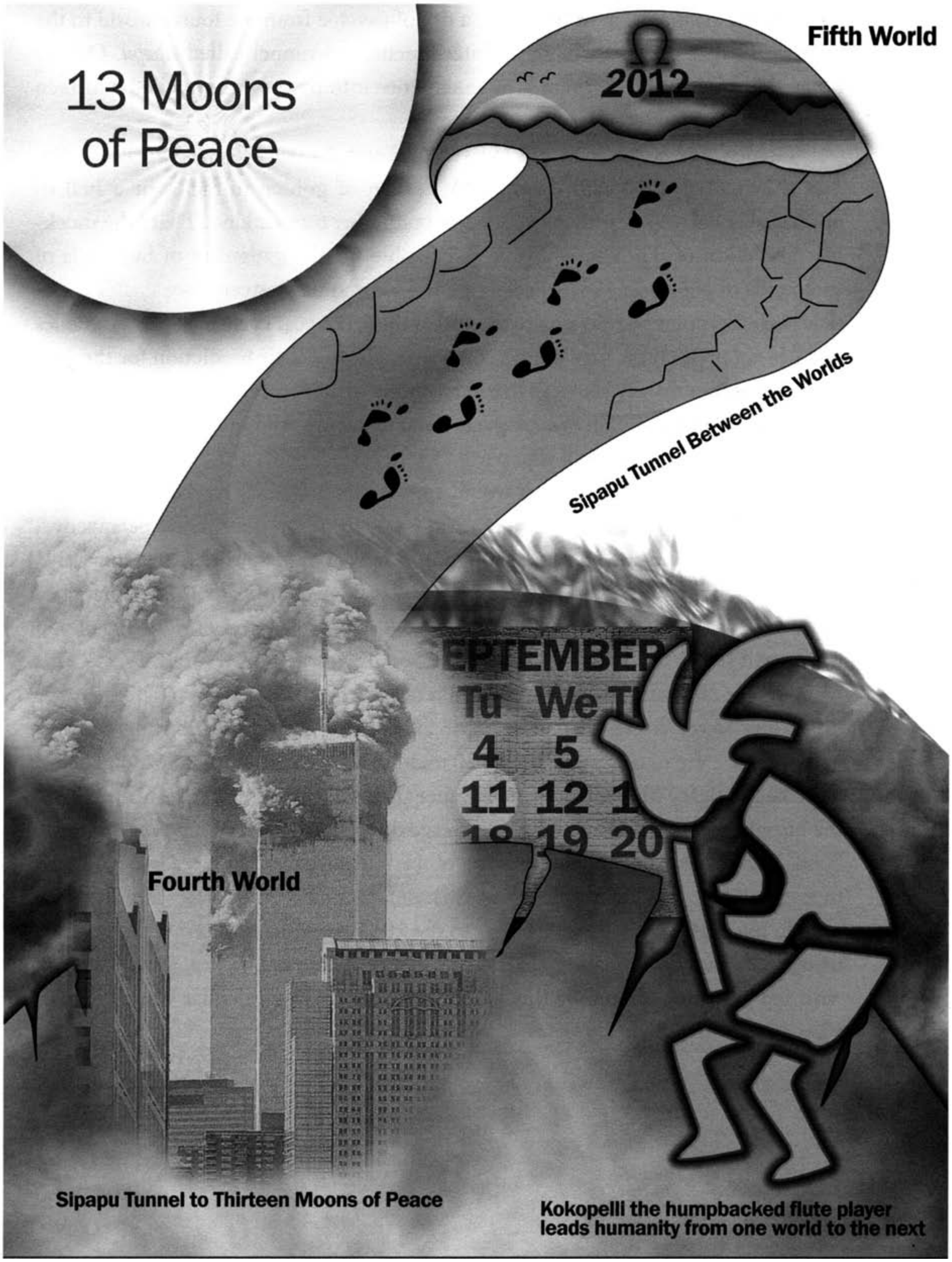
13 Moons
of Peace
Fifth World
2012
Sipapu Tunnel Between the Worlds
EPTEMBER
Tu We Th
4 5
11 12 1
18 19 20
Fourth World
Sipapu Tunnel to Thirteen Moons of Peace
Kokopelli the humpbacked flute player
leads humanity from one world to the next

about in the cosmovision of the Hopi, a rite of passage from the fourth world to the fifth world that occurs through an interdimensional tunnel called *sipapu.* On the other side of that tunnel, there is an emergence into the new time called "thirteen moons of peace."

"Golden Age of Miracles and Heaven on Earth," a story in the *National Examiner* (November 29, 1988), begins: "A heaven of golden miracles or a hell of unspeakable horror is less than twenty-five years away for mankind. That's the shocking prediction of the man who was responsible for the gathering of hundreds of thousands of people in 1987 to celebrate the Harmonic Convergence. . ." The article makes its point by referring to the end of the 5,125 year cycle in 2012. "Argiielles said Mayan predictions have always come true. He said their prediction for the year 2012 is that if humanity learns to live in harmony with Nature, a new age of miracles and light will occur. Otherwise plagues, wars, terrorism, and finally, the breakup of the planet into asteroids, will take place."4

As for the Inevitable Event, it would appear that humanity has begun the worst of the prediction-plagues, war, terrorism-yet, from the noospheric perspective, two points mitigate the absolute plunge into hell. The first is that the Inevitable Event punctured a hole in the technosphere eleven years prior to 2012. What does this mean? It means that this is the time of hell on Earth. "Every single one of you must see it [hell]; this is an irrevocable decision of your Lord." (Quran, 19:71) This being so, we can potentially emerge from it before the 2012 omega point. The other mitigating factor is the existence of a 13:20 movement dispersed throughout humanity. Since the noosphereis the 13:20 mind of Earth, the Thirteen Moon Calendar Change Peace Movement is the advance presence heralding the transition from the biosphere to the noosphere. This passage through hell is of a four-year duration, 2000-2004. The exponential implosion of the technosphere has already begun. But to avoid a long, debilitating siege of barbarism, humanity must select a positive direction by 2004 so that it can make it to the 2012 deadline as a species returned to living in harmony with nature. This it can only do by the dramatic and radical break with the past time offered by the Thirteen Moon/28-Day calendar Change Peace Plan.

Campaign for the New Time

4:7::7:2013

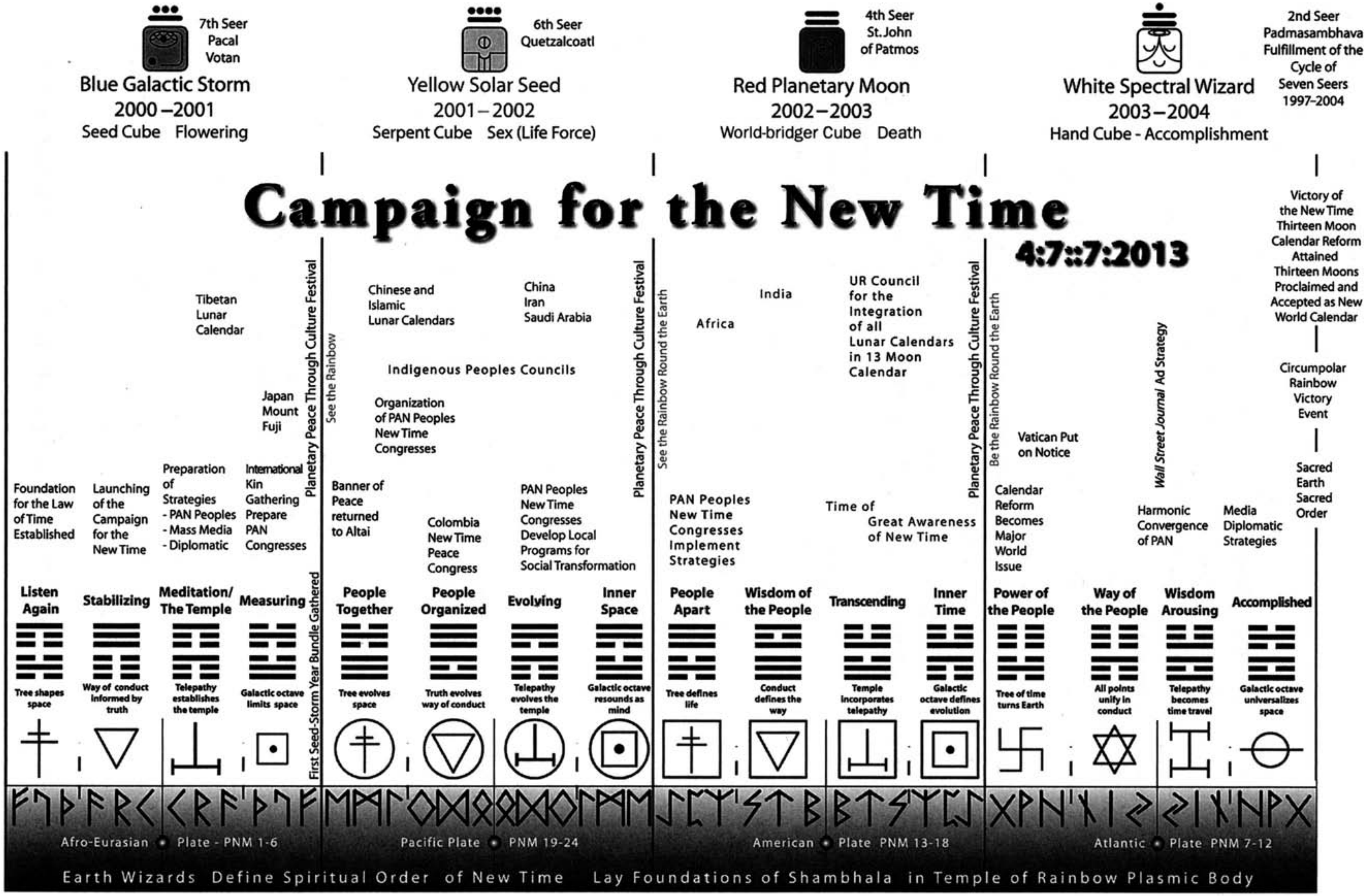

7th Seer
Pacal
Votan

Blue Galactic Storm
2000–2001
Seed Cube Flowering

Tibetan
Lunar
Calendar

Japan
Mount
Fuji

Foundation for the Law of Time Established

Launching of the Campaign for the New Time

Preparation of Strategies
- PAN Peoples
- Mass Media
- Diplomatic

International Kin Gathering Prepare PAN Congresses

Planetary Peace Through Culture Festival

First Seed-Storm Year Bundle Gathered

Listen Again – Tree shapes space

Stabilizing – Way of conduct informed by truth

Meditation/ The Temple – Telepathy establishes the temple

Measuring – Galactic octave limits space

6th Seer
Quetzalcoatl

Yellow Solar Seed
2001–2002
Serpent Cube Sex (Life Force)

See the Rainbow

Chinese and
Islamic
Lunar Calendars

China
Iran
Saudi Arabia

Indigenous Peoples Councils

Organization of PAN Peoples New Time Congresses

Banner of Peace returned to Altai

Colombia New Time Peace Congress

PAN Peoples New Time Congresses Develop Local Programs for Social Transformation

Planetary Peace Through Culture Festival

People Together – Tree evolves space

People Organized – Truth evolves way of conduct

Evolving – Telepathy evolves the temple

Inner Space – Galactic octave resounds as mind

4th Seer
St. John
of Patmos

Red Planetary Moon
2002–2003
World-bridger Cube Death

See the Rainbow Round the Earth

Africa

India

UR Council
for the
Integration
of all
Lunar Calendars
in 13 Moon
Calendar

PAN Peoples New Time Congresses Implement Strategies

Time of Great Awareness of New Time

Planetary Peace Through Culture Festival

People Apart – Tree defines life

Wisdom of the People – Conduct defines the way

Transcending – Temple incorporates telepathy

Inner Time – Galactic octave defines evolution

White Spectral Wizard
2003–2004
Hand Cube - Accomplishment

Be the Rainbow Round the Earth

Vatican Put on Notice

Wall Street Journal Ad Strategy

Calendar Reform Becomes Major World Issue

Harmonic Convergence of PAN

Media Diplomatic Strategies

Power of the People – Tree of time turns Earth

Way of the People – All points unify in conduct

Wisdom Arousing – Telepathy becomes time travel

Accomplished – Galactic octave universalizes space

2nd Seer
Padmasambhava
Fulfillment of the
Cycle of
Seven Seers
1997–2004

Victory of the New Time Thirteen Moon Calendar Reform Attained Thirteen Moons Proclaimed and Accepted as New World Calendar

Circumpolar Rainbow Victory Event

Sacred Earth Sacred Order

Afro-Eurasian • Plate - PNM 1-6

Pacific Plate • PNM 19-24

American • Plate PNM 13-18

Atlantic • Plate PNM 7-12

Earth Wizards Define Spiritual Order of New Time Lay Foundations of Shambhala in Temple of Rainbow Plasmic Body

THE BIRTH OF THE CAMPAIGN FOR THE NEW TIME

> *"We inspired Moses: 'Lead My servants out, and strike for them a dry road across the sea. You shall not fear that you may get caught, nor shall you worry.*
>
> *"Pharaoh pursued them with his troops, but the sea overwhelmed them, as it was destined to overwhelm them."*
>
> -QURAN, 20:77-78

The Thirteen Moon/28-Day calendar is the dry path across the waters of the 12:60 chaos. Holding surely to this path, "Pharaoh's troops will be overwhelmed," as it is destined, for the truth always prevails and when falsehood is exposed, falsehood perishes. The 12:60 frequency enshrined in the Gregorian calendar represents an artificial, hence false notion of time. The Pharaoh's troops are the forces of the technosphere that, embedded in the artificial structure of the Gregorian calendar, are destined to be overwhelmed and overcome by the fury unleashed both by human nature and nature itself in response to decades, if not centuries, of irresponsible despoiling of the Earth. The dry path of the Thirteen Moon/28-Day calendar is the only path broad enough for all humanity to leave the ever increasing ocean of chaos that characterizes human existence bound in the collapsing 12:60 matrix born of Gregorian civilization, the technosphere. Yes, the dry path across the waters of the 12:60 chaos provided by the Thirteen Moon/28-Day calendar truly is for the salvation of life on Earth.

Ever since 1993, the Thirteen Moon Calendar Change Peace Movement has consciously been drawing from the infinite riches of the noosphere to create not only the mechanism for making a shift in the frequency and hence bring stabilization to the biosphere, but has been anticipating the biosphere-noosphere transition into the *Pax Cultura, Pax Biospherica.*

Foll{)wing in the footsteps of its predecessor, the new calendar movement has dutifully contacted the United Nations and the Vatican and convened various congresses and delivered ultimatums in an effort to draw attention to mankind's time malaise. Now that the Inevitable Event has fully disengaged the human mind from the reality it thought it was pursuing in the new millennium, the second definitive wave of the World Thirteen Moon Calendar Change Peace Movement has also been launched: the Campaign for the New Time.

New Globally Unifying Harmonic Standard

FOURTH DIMENSION: Pure whole number mathematical order—syntropy, synchronic order

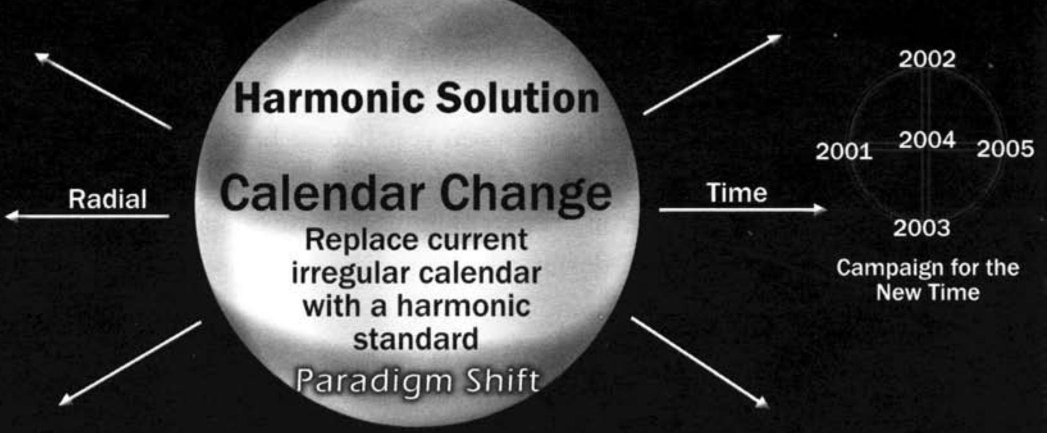

Harmonic Solution

Calendar Change

Replace current irregular calendar with a harmonic standard

Paradigm Shift

Radial
Time
2002
2001
2004
2005
2003

Campaign for the New Time

13 Moons. 28 Days.

Regular Units of Measure

28+28+28+28+28+28+28+28+28+28+28+28+28+1 = Harmony

"Mental barrier" separating fourth-dimensional realm of conscious wholeness of synchronic order from third-dimensional realm of "hard science" physical plane of reality and materialism.

Line of inexorable technological progress: neoliberal economics, globalization = biospheric instability and destruction.

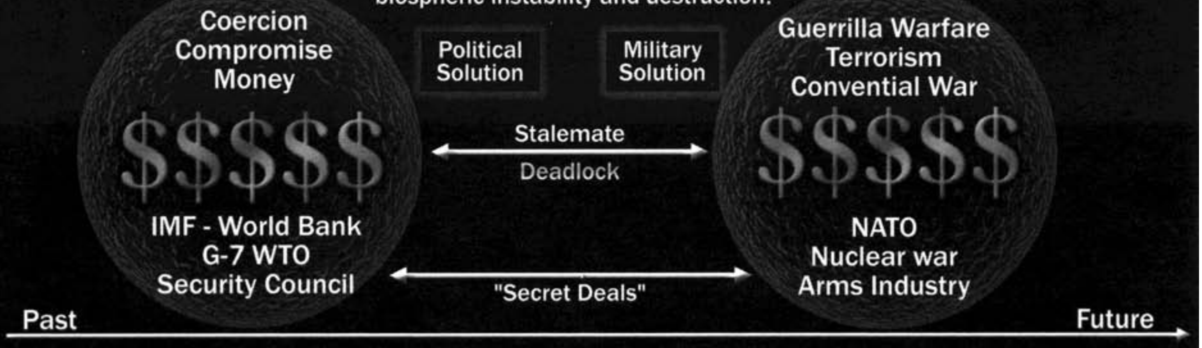

Coercion
Compromise
Money
$$$$$
IMF - World Bank
G-7 WTO
Security Council
Political Solution
Military Solution
Stalemate
Deadlock
"Secret Deals"
Guerrilla Warfare
Terrorism
Convential War
$$$$$
NATO
Nuclear war
Arms Industry
Past
Future

Linear Arrow of Time = line of inevitable degradation and entropy of manifestation (matter)

Gregorian Calendar Time Line = macro-organizing timing standard establishes irregular measure as basis of all dominating concepts of linear time, disorder, entropy, and the techno-economic inexorability

THIRD DIMENSION: Manifestation-matter entropy and disorder

Irregular units of measure:

31-28(29)-31-30-31-30-31-31-30-31-30-31 = Disharmony

If today is Sunday, July 8, what day of the week will August 8 be?
What is the meaning of the names of the months?
If *September* means "seven" why is it the ninth month?
August is named after Augustus Caesar, July for Julius Caesar, March for Mars, the god of war; could this be a reason why we are programmed for chaos and violence? Think about it.

This campaign consists of a preparatory four-year cycle, 2000-2004, the Harrowing of Hell, which is the duration of the campaign itself, plus a one-year trial period, 2004-2005. The goal of the four-year campaign is universal calendar reform, the replacement of the Gregorian by the Thirteen Moon Calendar, effective Blue Crystal Storm, July 26,2004. This final year of the Blue Crystal Storm, 2004-2005, also completes a Seed-Storm year bundle begun in 2001, fateful year of the Yellow Solar Seed, the year of the Inevitable Event. To ensure the success of this unprecedented move on the part of humanity, the calendar reform must include the one-year trial period, during which time the entire species must be operating by a new standard, the harmonic Thirteen Moon/2 8- Day synchronometer. "If you never try it, you'll never know what it is," is the slogan that describes the campaign's target year: July 26, 2004-July 25, 2005, an entire year without the Gregorian "30 days hath September. . . ," but instead, Thirteen Moons of Peace.

To realize its ambitious goal of universal calendar reform, the Campaign for the New Time must impress itself on the human consciousness as the all-unifying campaign for peace to overcome the destructive forces unleashed by the technospheric collapse. Fortunately, much groundwork has already been laid. The codes of the Law of Time have been formulated and compiled. Preliminary practices to engage the synchronic order of the noosphere have already enlisted humans from around the planet. What the Vatican has tried to ignore and what the United Nations has been unable to fully engage must now be brought to the forefront of all humanity as the harmonic solution. The harmonic solution is a set of logical arguments that should be studied and rehearsed by everyone who seriously wishes to even consider the possibility of a Campaign for the New Time. Let us contemplate the following set of logical arguments.

Premise

Currently all conflict resolution of a global scale is attained through one of two poles: a political solution or a military solution. No other alternatives are recognized. According to the Law of Time, there is a third solution, the harmonic solution. Without this third solution, no harmonic resolution is ultimately possible for any conflict on a global scale. The third solution defines the first two solutions as a polarity embedded within a timing standard that is hopelessly irregular and that, therefore, disposes the mind to disharmony. A mind predisposed to irregularity and disharmony is incapable of producing any long-term solution. The basis of the harmonic solution is to change the timing standard from an irregular to a regular one, thereby inducing a timing sensibility that disposes the mind to harmony rather than disharmony.

Thirteen Moon/28-Day Count and Global Conflict Resolution

The inability to attain global peace, much less the resolution of many localized conflicts that have become endemic, is due to a lack of a globally unifying timing standard-the macro-organizing principle of human sensibility. Present-day conflict resolution is represented by two poles, political and military. The military solution consists of guerrilla warfare, terrorism, and outright military conflict, all of which are engendered by problems of inequality; injustice; rampant nationalism; tribal, racial, or religious antagonism; and greed for control of natural resources. Underlying the military solution is an aggressive armaments industry that seeks to hold its own as a capitalist venture, always seeking new markets. The political solution is always fostered as the only cure for the military solution, and is administered through varying degrees of coercion, compromise, and the inevitable lure of money-the IMF and the World Bank are never far behind any political solution.

Neither the military nor the political represent any kind of morally satisfactory or enduring solution because both are functions of and embedded in a timing standard that has disharmony built into it. Even the local timing systems, themselves feedback loops holding in place various belief systems, are coordinated by the dominant disharmonic standard. As long as the current global standard, the Gregorian calendar, is the controlling timing factor, resolution on a global and local level is not only impossible, but increasing disharmony is guaranteed. The harmonic solution calls for the immediate establishment of a globally unifying harmonic standard, the Thirteen Moon/28-Day count. With its absolutely consistent units of measure, this macro-organizing principle is a paragon of harmony and thereby represents the positive, creative, and viable first step to enduring global conflict resolution.

Thirteen Moon/28-Day Paradigm Shift

The harmonic solution, the alternative to the polarity of the military and political solutions, calls for the immediate replacement of the current irregular measure with the harmonic standard of the Thirteen Moon/28-Day count. This replacement constitutes the long-awaited and long-prepared-for paradigm shift in human consciousness. The very analysis and concern that engendered the first movement to replace the Gregorian calendar-the effects of an irregular measure on human behavior-is now so dire that the concluding step must be taken. To quote Einstein once again, "Since the advent of the nuclear age, everything has changed but the way people think; thus we drift toward unparalleled catastrophe." With the analysis of the Law of Time we know why thinking has not changed-the human mind is the pawn of an aberrant timing mechanism. To change the way people think, make one little change in their everyday lives: Change the calendar. If we could send a man to the moon, we can change the calendar. This change will be the first step-the rest will come easily because with this one change we shall have changed our minds and entered into a New Time. To make this one little change a target date is needed, and the people need to mobilize as a force of synchronization for peace to mandate this change. The target date is July 26, 2004--the mobilization has already begun.

New Worldview of the Law of Time

The Thirteen Moon/28-Day count is the pragmatic application of the Law of Time. The discovery of the Law of Time was necessitated by evolution as the only way that could offset the deleterious effects of an erroneous timing standard on human consciousness. The Law of Time takes the radical view that time is a frequency, the universal frequency of synchronization; that the purpose of time is to synchronize; and that, therefore, a calendar is in harmony with the Law of Time to the degree to which it maximizes opportunities for synchronization. From the perspective of the Law of Time, the current macro-organizing standard is anything but synchronous, and hence contrary to the laws of nature. Synchronization produces harmony, harmony is a function of beauty, and beauty is the natural result of the Law of Time: T(E) = Art, energy factored by time equals art, where art is the entire spectrum of phenomenal reality in which even the most menacing-looking creature is elegantly constructed.

National Geographic recently stated: "Beauty seems to be an intrinsic part of nature and perhaps even the organizing principle of reality. Scientists in testing their theories, invariably find that the simplest, most elegant, most beautiful is the correct one. Rainbows, butterflies and the periodic table are some examples of intrinsic beauty. The world will be saved by beauty."5 The Law of Time agrees. The world will be saved by beauty, and the proponents of peace through culture will be in the vanguard. The Law of Time formalizes the perception of the intrinsic beauty of nature- T(E) = Art-and thereby provides a scientifically solid critique of the ugliness and social disharmony fomented by the irregular and artificial timing standards that control humanity today. By the same formulation, the Law of Time also establishes a vast and comprehensive definition of the fourth dimension, which was wanting until now precisely because of the embedding of all current perceptions in the erroneous timing standard.

The mathematical order underlying the universal frequency of synchronization, 13:20, describes a new order of reality, the synchronic order. The synchronic order governs the fourth-dimensional order of reality much as the laws of gravity, thermodynamics, and the special theory of relativity govern the third-dimensional order of reality. By taking into account the nature of the synchronic order, humanity's views of the third dimension will inevitably be altered to a greater conformity with the harmony of the fourth dimension. The fourth dimension is defined as the primary mathematical order of time, governed by a syntropic whole number system of ratios and fractals operating in a radial and nonlinear manner.

The third dimension is the world of manifestation and matter that inevitably entropizes. Losing sight of the inherent harmony of the synchronic order from which it is actually inseparable, the human fixation on the increasing entropic anomalies of the third dimension produces problems such as how to reckon what appear to be the extra hours, minutes, and seconds that occur every time the Earth orbits the sun. To this seeming dilemma, the Law of Time asserts that number precedes manifestation, harmony precedes materialization, therefore manifestation must accord with number, and materialization must reflect an original harmonic order. Entropy and degradation cause manifestation to deviate from number and mathematical law. But for mind to be stable, mind must accord with and conform to mathematical law rather than with entropy and degradation. The timing standard in use causes the mind to conform with entropy and degradation. This is what must be corrected.

Harmonic Solution-Harmonic Resolution

Harmony can only produce harmony. From order comes order. From disorder you can only expect chaos. From disharmony can only come disaster. Irregular measure entropizes. Harmonic measure syntropizes. These are the contrasting values brought into focus by replacing an irregular macro-organizing principle with a regular one. Implementation of a globally unifying harmonic standard is the only hope for resolving all conflicts in time. A harmonic standard lifts all conflicts to a higher level dialog of unification in time. The harmonic solution, the World Thirteen Moon Calendar Change Peace Plan, provides: the opportunity to call an immediate and universal cease-fire, as well as a halt to the otherwise inexorable process of entropic degradation of society and environment; and offers the resolution to establish new agreements, to renegotiate old treaties, and to create a new globally binding and unifying covenant for all people in a new time.

It must be understood that to change the calendar is to delegitimize all the institutions embedded in it. This radical but peaceful delegitimization of the old order is what is needed to break the deadlocks, stalemates, and historically outmoded treaties and agreements now binding on humanity. The new globally unifying standard, the Thirteen Moon/28-Day count, will legitimize and institutionalize harmony and thus create the advent of a synergistic order capable of resolving entropic disorder because it is reflective of and rooted in the primordial whole number structure of the synchronic order of reality. In its entirety, this represents a new step and direction for human evolution-a step without which there might not be any creative future for humanity and the planet.

How to Accomplish World Peace Now

The analysis, the historical precedents, and now the affirming authority of the Law of Time render the harmonic solution as the only way to immediately bring about World Peace. All that is lacking is the will to synchronization among all good-hearted people, groups, and organizations otherwise committed to peace, a better environment, and human spiritual well-being in general. How to accomplish World Peace is to galvanize the human will to synchronization on behalf of the establishment of a genuine time of harmony and peace. This can only come about through the simple but highly radical and paradigm-altering act of exchanging the current macro-organizing system of the Gregorian calendar for the harmonic order of the Thirteen Moon/28-Day count. All other localized calendar systems would be kept intact, but they would be coordinated by a new standard, a standard that promises harmony instead of disaster, order instead of chaos, peace instead of war.

Such is the harmonic analysis and solution of the Law of Time, which can be summed up by a simple demonstration of the irregular Gregorian calendar contrasted with the regular Thirteen Moon calendar, as well as the question: "Which do you prefer, harmony or disharmony?"

If you answer this question on behalf of harmony, and you agree with the foregoing premises and analyses, you must move into action. You need to get a new calendar, a Thirteen Moon/2 8-Day calendar and find out for yourself: noosphere or necrosphere, the choice is yours. The option opened by the Inevitable Event and the collapse of the technosphere is precisely that: necrosphere, the transformation of the biosphere into a sphere of death-a dead planet-or the noosphere, the mental envelope of the Earth, governed on the human plane by the Thirteen Moon/2 8-Day calendar. The difference between the necrosphere and the noosphere is the difference between a machine and the Earth as a whole system. You cannot even really say there is a comparison. But what we can say most emphatically is that the Thirteen

Moon/28-Day calendar and the shift to the 13:20 frequency is the pure manifestation of the Law of Time in human affairs. It is the only antidote to the destructive grip that the 12:60 timing frequency now has upon the biosphere through its thoroughly artificial instrument, the technosphere. (See plate 7, Necrosphere or Noosphere.)

THE FINAL DECISION: NOOSPHERE OR NECROSPHERE?

As these lines are being written, seven weeks have passed since the Inevitable Event. The analysis of this event from the perspective of the biosphere, the temporary structure of the technosphere, and the advent of the noosphere was a spontaneous inspiration. Each morning, often well before dawn, I would be called to this technospheric device, an iMac, to put the noospheric mandate down into words. In this process, the matter of prophecy kept occurring and could not be avoided. Even the issue of calendar change increasingly takes on the quality of a prophetic enactment. What is prophecy from the noospheric perspective?

Prophecy is the release of information according to the psi bank timing program and in relation to degrees or levels of consciousness positioned at different points in time. The points in time are human channels. That is, there are the prophets who declare the prophecies by whatever means or forms, and then there are the decoders of the prophecies, those able to read the signs according to the prophecies with the aid of different symbolic lexicons. Prophecy is always startling to the mass mind, which is ignorant of the true nature of time. A prophetic event may seem totally random, when it is not. Someone may design a plot, such as that of the Inevitable Event, with whatever fantastic notions and motives. Yet the occurrence may go beyond being merely a matter of human manipulation. The humans were but the instruments of sets of cause-and-effect chain reactions established within the structure and evolution of the biosphere and the playing out of human karma.

According to the psi bank timing program governed by the Law of Time, the technosphere could only have a limited duration. Two perfect 28-year cycles of the Gregorian calendar program, leading to the first year of the third millennium, marked the duration of the technosphere. Because this cycle concluded with the beginning of the third Christian millennium, a singular event was poised in time to attract and catalyze a host of prophetic moments long prepared for and sealed in the psi bank by Christian, Islamic, and even Mayan prophecies. Such was the Inevitable Event. Within the motivations of the perpetrators of the Inevitable Event, the biosphere found its perfect instrument of divine purpose. That there were nineteen hijackers conforms to the Quranic nineteen code expressed in the enigmatic verse, "Over it is nineteen."

(74:30) The following verse begins, "We appointed angels to be guardians of Hell, and we assigned their number [19] . . ." This verse ends by asking, "What did God mean by this allegory? . . . None knows the soldiers of your Lord except He. This is a reminder for the people." (74: 31)

Certainly in the success of their mission, whether they were conscious of it or not, the nineteen Muslim hijackers-who organized themselves as four leaders (pilots), three logistics people, and twelve "soldiers"-fulfilled their function of being the prophetic emissaries of the nineteen guardian angels who watch over Hell. And indeed the gates to Hell have been opened. In the world of the secular mind of the technosphere, no one wanted to talk about the apocalypse or Armageddon, though the jihad was brought up quite often as a factor in the thinking of the Islamic terrorists.6

Whether it is seen as a prophetic or karmic event, as we stated earlier, there is no question that the timing programs of two civilizations, the Gregorian and the Islamic, were on a collision course. "The civilization of Islam is radically so different from that of Western civilization which dominates the world today. The two are different in their description of life as well as the foundation on which they base such a description. The difference between the two civilizations is so essential that they have developed in ways which are radically contradictory to each other."7 So wrote the eloquent Saudi historian, Muhammad Husayn Haykal in his essay "Islamic Civilization," as presented in his masterful biography, *The Life of Muhammad.* And what is at the root of this difference? A separation of church and state, which in the West led to a profound materialism and economic worldview.

Haykal continues, "The victory of materialist thinking was largely due to the establishment of Western civilization primarily upon an economic foundation. This situation led to the rise in the West of a number of worldviews which sought to place everything in the life of man and the world at the mercy of economic forces. . ." As for the sanctity of its economic beliefs, Haykal concludes that the West has tied its economic activity "hand and foot by public laws and commanded that every Western state and army prevent any violation of economic laws with all the power and coercive means at its disposal."8 Given this insightful assertion by an Islamic thinker written a half-century ago, it is not at all surprising that the terrorists concentrated their attacks on the most visible symbols of Western global materialism and economic and military imperialism, the Twin Towers and the Pentagon. It is also of note that one of the logistics men on the team of nineteen hijackers, Majed Moqed, had been a professor of economics at King Saudi University in Riyadh.

However we see this event, the most important point is that it actually happened, no matter who caused it or how. In this regard the collapse of the World

Trade Center towers and the penetration of the Pentagon was the Inevitable Event both from the point of view of the biosphere and from that of prophecy as mandated by at least two major timing programs, the Gregorian and the Islamic. Of course, prophecy is a matter far from the consideration of the technocratic mind, so the immediate aftereffect is a heightened nationalism, patriotism, and commitment to war. But what is going on from the noospheric point of view is not so much the combat of different armed camps defending or attacking competing ideologies, but an end game, the biomass of the technosphere maneuvering against time in a self-destructive process that is really nothing more than the continuing collapse of that which it is defending.

How long will this collapse take? With the weapons of mass destruction currently at the disposal of the combatants, it shouldn't take too long before the human race realizes that if it doesn't stop the self-destructive process, it will soon be curtains for all life on Earth. A more significant question, if we wish to make the transition to a new time, is: How will the self-destruction end, and how can it be stopped-or can it? It is easy to see how wars begin, but no one can tell how they will end.

THE SOLUTION TO WAR: PEACE THROUGH CULTURE, PEACE OF THE BIOSPHERE

At the end of the First World War, the League of Nations was formed to keep the Second World War from happening. The League of Nations was unable to both effect the calendar reform it promoted and keep the Second World War from happening. These are not unrelated events. The Second World War effectively eliminated the League of Nations, and toward its end a new organization, the United Nations, was formed. Like the League of Nations, the United Nations was formed to prevent the next world war from happening. Within eleven years, the United Nations tabled the calendar reform begun by the League of Nations. Coincident with the formation of the technosphere, the United Nations has now also completed fifty-six years of existence. With the expanding "war against terrorism," is its purpose now over as well? The only way the United Nations can survive is to maintain its humanitarian agencies, for the age of nationalist politics and nation-states is over, succeeded by the politics of terrorism, the last politics of history. What new kind of global organization will we need at the end of the War on Terror, or World War III?

What we will need is an entirely new agency, a Planetary Biospheric Assembly that will model and create a sustainable *Pax Cultura, Pax Biospherica.*Given the failure to enact a calendar reform on the part of both the League of Nations and the

United Nations and in consideration of the chaos now clearly embedded in the Old Time, only an agency or instrument that fully embraces and promotes the calendar change will be able to move into the genuinely peace-fulfilling role that such an organization must take. If the United Nations could accept the route of calendar change as the only way to bring all humanity to a new point of discourse, then it could take on a renewed life. But if it cannot rise to this occasion, then another organization must take its place, the Planetary Biospheric Assembly. Even so, when we speak of the *Pax Cultura, Pax Biospherica,* we are speaking of a new human covenant, one in which the biosphere takes precedence over all nationalist corporate interests, and in which peace as a manifestation of culture is the primary value of the new time. Such a covenant would be a biospheric covenant, an agreement and understanding that, first of all, the human is a member of the biosphere, and second, that in consciously accepting the calendar change, the human is also in the process of becoming *Homo noosphericus.* Henceforth, it will be art and not money, bioregions and not nation-states, that will be the cause of social organization. Only in this way will humanity be guaranteed a true post-historical future.

Assuming the calendar change occurs on Blue Crystal Storm 2004, the first step in ~ngendering the full manifestation of the noosphere will be the dismantling of the technosphere. This can only be accomplished if a full reorganization of the human in time, inclusive of an adjudication of inequalities and a redistribution of wealth, begins to occur during the 2004-2005 Crystal Storm year. The following four years, 2005-2009, a genuine First World Peace, would see the constructive transformation of the five-part technospheric system. All the apparatus of heavy industry, energy, and the transport system would be turned like compost, to be replaced by nonpolluting technologies and means of transport, while the cities would be transformed into urban gardens with the human race once more becoming decentralized. This process itself, a massive planetary engineering project with an eye on the full development of geochronomancy, would prove to be the greatest and most thoroughly positive transformation in human history. By 2009 humans reorganized by the Law of Time and having finally arrived at the "path beyond technology," will be enjoying universal telepathy, the noosphere-life beyond the Internet. By 2012 the humans will realize peace through culture as a permanent value, and by 2013 Earth will be galactically synchronized through a fully activated noosphere into the beginning of an entirely new geological era, defined by Vernadsky as the Psychozoic Era.

Pax Cultura, Pax Biospherica refers to both the new era of humanity following the devastation of the Final War and the governing body of bioregional councils (not nation-states) comprising the new world "government," the Planetary Biospheric

Arcturus Victory Strategy
Pax Cultura, Pax Biospherica

Telektonon, the Theater of Time, provides the journey through the Cube of the Law: Plane of Mind, Plane of Spirit, Plane of Will, and Divine Source Telektonon—each plane Seed-Storm year bundle, an entire universe of noospheric time!

Plane of Spirit: First Seed-Storm year bundle, NET week 9 Seed–12 Storm, 2001–05

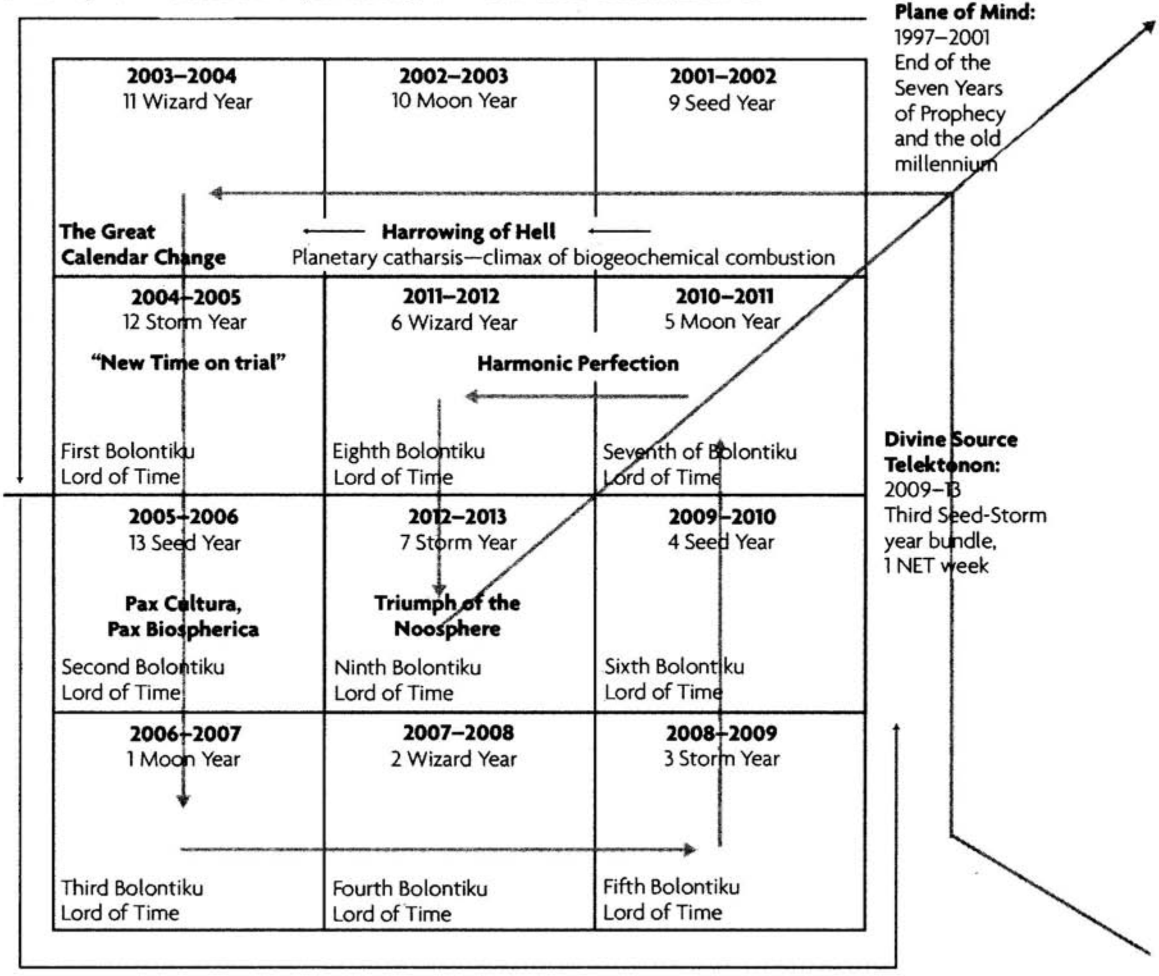
Plane of Mind:
1997–2001
End of the
Seven Years
of Prophecy
and the old
millennium
2003–2004
11 Wizard Year
2002–2003
10 Moon Year
2001–2002
9 Seed Year
The Great
Calendar Change
Harrowing of Hell
Planetary catharsis—climax of biogeochemical combustion
2004–2005
12 Storm Year
"New Time on trial"
First Bolontiku
Lord of Time
2011–2012
6 Wizard Year
Harmonic Perfection
Eighth Bolontiku
Lord of Time
2010–2011
5 Moon Year
Seventh of Bolontiku
Lord of Time
Divine Source
Telektonon:
2009–13
Third Seed-Storm
year bundle,
1 NET week
2005–2006
13 Seed Year
Pax Cultura,
Pax Biospherica
Second Bolontiku
Lord of Time
2012–2013
7 Storm Year
Triumph of the
Noosphere
Ninth Bolontiku
Lord of Time
2009–2010
4 Seed Year
Sixth Bolontiku
Lord of Time
2006–2007
1 Moon Year
Third Bolontiku
Lord of Time
2007–2008
2 Wizard Year
Fourth Bolontiku
Lord of Time
2008–2009
3 Storm Year
Fifth Bolontiku
Lord of Time

Plane of Will: Second Seed-Storm year bundle, 1 NET week, 13 Seed–3 Storm, 2005–09
Time of Transformational Destructuring—First World Peace

Assembly. The main purpose of the new governing body would be to monitor the advent of the noosphere. Overcoming Northern Hemisphere bias, the *Pax Cultura, Pax Biospherica* will not find any permanent seat, but will begin its existence as a planetary noospheric congress in the Southern Hemisphere. All of this could be made possible only because of the completion of the calendar change. So let us assume the best. The how-to of paradigm shift begins with the Thirteen Moon calendar.

If you follow the Thirteen Moon calendar or tell others to follow it with you, what is the payoff? The payoff is that you get to become a noospheric chip. Only a noospheric chip can bring Heaven on Earth, which is nothing more than full human participation in the noosphere. This is not at all a theoretical matter, but something that can be practiced and followed on a day-to-day basis. Fortunately, a path has been shown, complete with travel aids.

CONCISE *HOMO NOOSPHERICUS* HOW-TO TIME TRAVELER'S GUIDE TO THE BIOSPHERE-NOOSPHERE TRANSITION

This analysis of the Inevitable Event could never have occurred if the Law of Time hadn't been discovered and defined. The Inevitable Event simply supplied the Law of Time with precisely the right historical moment to provide a thorough analysis and explanation of time as the whole system in which we humans live and operate, inclusive of the biosphere, the technosphere, and the noosphere. As the chief discoverer of the Law of Time, assisted by my wife and an increasing number of other humans who have engaged the Law of Time, I have sought only to make a presentation of matters in which we, as a species, are thoroughly immersed, and thus find difficult to comprehend. Such is the technosphere, and such also is the medium of time. Since the publication of *The Mayan Factor* and my pursuit of the underlying mathematics of the Mayan calendar, I have remained outside the conventional arenas of discourse and communication, preferring instead to remain more anonymous in order to test the various hypotheses of the Law of Time.

In this process over the past twelve years, the Law of Time has precipitated from the noosphere various tools and didactic texts, all for the purpose of enabling us to make the shift from the old paradigm of the time of war to the new paradigm of the time of peace. These tools and principles are actually practiced on a daily basis, and so provide a pragmatic means of applying the Law of Time. Because of my vows and need for scientific "purity" of the experiment I have been living, I was involved at all times in doing my utmost to remain in the 13:20 frequency. For this reason, the tools and texts prompted by the noosphere to define the Law of Time were, for the most part, all produced outside the commercial mainstream. Now a great effort must be taken to make these tools and texts available to humanity in order to assist in the transition from *Homo historicus* to *Homo noosphericus*. By presenting a catalog of these tools and texts we only mean to suggest and define for the reader the scope and existence of a preliminary science of time and telepathy.

Part I. The Tools: Establishing Noospheric Earth Time (NET)

THIRTEEN MOON/28-DAY SYNCHRONOMETER

The harmonic standard of noospheric time, the Thirteen Moon/28-Day synchronometer, is a perpetual, harmonic calendar. It is called a Moon calendar because it is based on the female 28-day menstruation cycle, which is also the average lunar cycle. In actuality the moon goes around the Earth thirteen times a year. This means that the Thirteen Moon calendar is a genuine solar-lunar calendar that measures the Earth's orbit around the sun by the apsidallunation cycle of twenty-eight days. Thirteen perfect months of 28 days = 52 perfect weeks of 7 days = 364 days. The 365th day is called the Day Out of Time because it is no day of the week or month at all. This day, which falls on the Gregorian correlate date ofJuly 25, is a day for forgiveness and the artistic celebration of life and freedom. The synchronization or New Year's date of the Thirteen Moon calendar is July 26, and corresponds to the rising of the great star Sirius. This makes the Thirteen Moon calendar a tool for harmonizing ourselves with the galaxy. Of course, the Thirteen Moon calendar also synchronizes the phases of the moon in a pattern that demonstrates its regularity and order.

One of the great advantages of the Thirteen Moon synchronometer is that day/date calculations are amazingly simple. Any day of any week is the same for any Moon, any year. The first day of every Moon is always a Thirteen Moon Sunday (Dali). The last day of every Moon is always a Thirteen Moon Saturday (Silio). In the Thirteen Moon calendar the obscurely named Gregorian months are replaced by names that correspond to a fourth-dimensional cosmology of time. Each Moon also has a totem animal. The traditional names of the days of the week are replaced by galactic names that describe seven primary plasmas-electronically charged particles that activate our magnetic fields. The plasmas and their symbolic seals appear above the days of the week. The Gregorian calendar makes day/date calculations very difficult because the months are of uneven measure so the days and dates of the week vary from month to month and year to year. The Thirteen Moon calendar is truly unique because it is synchronized with the Harmonic Module, the measure of the universal 13:20 timing frequency.

THE HARMONIC MODULE

The basis of the Tzolkin or sacred 260-day count of the Maya, the Harmonic Module is the 13:20 synchronization gauge and permutation table that consists of thirteen sequences of twenty icons or solar seals and twenty sequences of thirteen galactic tones, 1-13. The resulting 260 permutations, combined with the perfect harmony of the Thirteen Moon calendar, give each day a unique quality of tone and icon known as a kin or one NET minute. The two cycles-Thirteen Moons/28 days and the 260-day Harmonic Module-perfectly mesh every fifty-two years to complete one NET year. In one NET year of 18,980 kin, no two days are the same! Each of the units in the Harmonic Module is called a kin, the base unit of synchronic measure. Articulating the Harmonic Module is a pattern of fifty-two Galactic Activation Portals. See if you can find the radial sequence of thirteen sets of four, counting inward from the corners. Notice that the numbers of each set of four equals 28. Thirteen sets x 28 = 364, the number of days in the Thirteen Moon calendar! (See image containing the Harmonic Module on page 170.)

WAVESPELL

The thirteen-unit form constant of fourth-dimensional time is the wavespell. It is important to see the Thirteen Moon calendar in this modular format, Planetary Service Wavespell, for then it makes more sense to speak of the calendar as a synchronometer. The wavespell's form describes the motion of time as a fractal fourth-dimensional cosmology. The numbers 1-13 in the dot bar notation that code the thirteen positions are known as tones. The names of the tones in sequence define the cosmology, which is also evident in the very structure of the wavespell. The thirteen tones give their names to the thirteen Moons. The structure consists of two gates, the Magnetic and the Cosmic, the first and the thirteenth moons/tones, which correspond to the two entrance and exit gates or portals. Complementing the two gates are the two towers, the fifth or Overtone tower and the ninth or Solar tower. The two gates and the two towers, tones 1, 5, 9, and 13, articulate the structure of the wavespell. Between the places of articulation are three sets of chambers. The first set, tones 2-3-4, helps establish the wavespell; the second set, tones 6-7-8, helps extend the wavespell; and the third set, 10-11-12, serves to convert the wavespell. (See plate 2, Planetary Service Wavespell.)

The structure of the wavespell also defines a four-dimensional geometry of time that connects different points of the wavespell over time. Each of these dimensional geometries is known as a pulsar. It is useful to know the pulsars in extending the mind synchronically over different timing sequences. The fourth-dimensional pulsar connects the four points of articulation, 1-5-9-13, or Magnetic, Overtone, Solar, and Cosmic Moon/tones, and is called the fourth-dimensional time pulsar. The first-dimension life pulsar connects the positions 2-6-10, or Lunar-Rhythmic-Planetary Moon/tones. The second-dimensional sense pulsar connects the 3-7-11, or Electric-Resonant-Spectral Moon/tones; and the third-dimensional mind-form pulsar connects the 4-8-12, or Self-existing-Galactic-and -Crystal Moon/tones. Remember, the wavespell accommodates any sequence of kin whose tones correspond to 1-13, and may be either a thirteen-day wavespell cycle, a thirteen-week cycle (one-quarter of an NET day), a thirteen-Moon cycle (one NET day), a thirteen-year cycle (one NET Season), and so on. Once you know the wavespell you have come to know the form in time of the noospheric mind.

THE WAVESPELL'S TONES AND THEIR PULSARS

1.	Magnetic tone of purpose-fourth-dimension	time pulsar
2.	Lunar tone of challenge-first-dimension	life pulsar
3.	Electric tone of service-second-dimension	sense pulsar
4.	Self-existing tone of form-third-dimension	mind-form pulsar
5.	Overtone tone of radiance-fourth-dimension	time pulsar
6.	Rhythmic tone of equality-first-dimension	life pulsar
7.	Resonant tone of attunement-second-dimension	sense pulsar
8.	Galactic tone of integrity-third-dimension	mind-form pulsar
9.	Solar tone of intention-fourth-dimension	time pulsar
10.	Planetary tone of manifestation-first-dimension	life pulsar
11.	Spectral tone of liberation-second-dimension	sense pulsar
12.	Crystal tone of cooperation-third-dimension	mind-form pulsar
13.	Cosmic tone of presence-fourth-dimension	time pulsar

DREAMSPELL

Described as the fourth dimensional tool kit, the Dreamspell also encodes a psycho-mythic cosmology known as the Journey of Timeship Earth 2013. It is this cosmology that makes the Dreamspell a psychoactive tool kit for personally engaging you in the fourth-dimensional synchronic order of time. The fundamental premise for making it psychoactive lies in finding your galactic signature, the color, icon, and tone that code your date of birth. This combination of factors-color, tone, and icon-establishes a mathematical code that allows you to use your galactic signature in mapping increasing orders of synchronicity. There are four colors, thirteen tones,

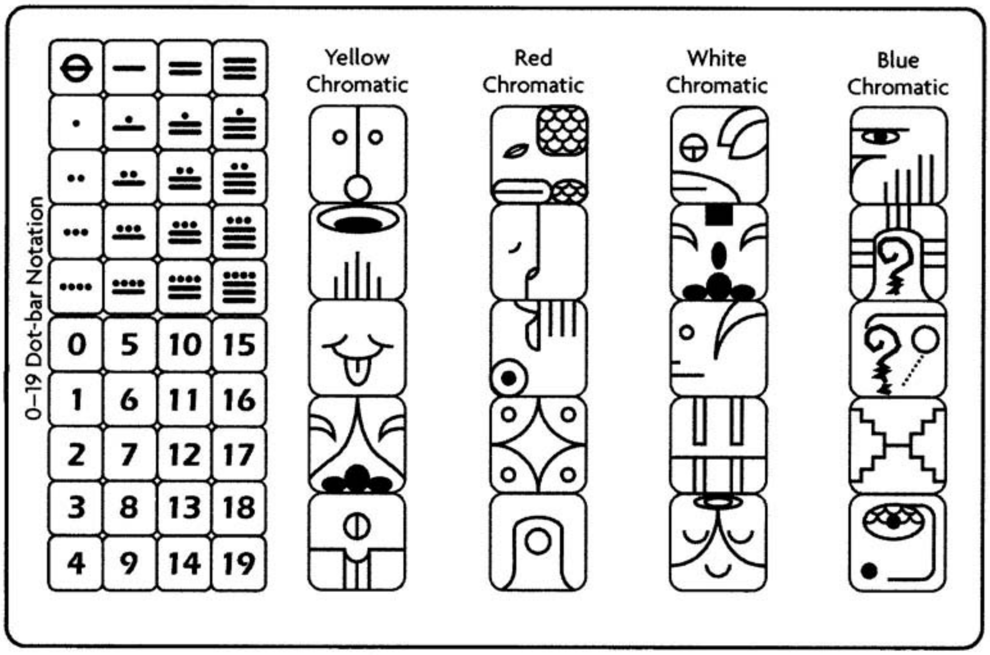
0–19 Dot-bar Notation
0 5 10 15
1 6 11 16
2 7 12 17
3 8 13 18
4 9 14 19
Yellow Chromatic
Red Chromatic
White Chromatic
Blue Chromatic

The Four Chromatics

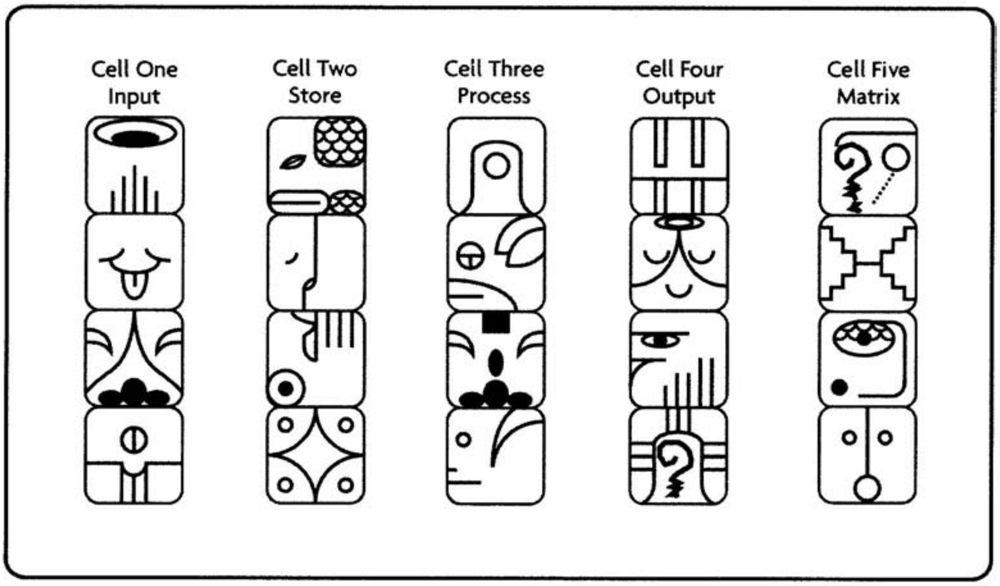
Cell One Input
Cell Two Store
Cell Three Process
Cell Four Output
Cell Five Matrix

The Five Time Cells

and twenty icons. The four colors code each of five sets of icons and correspond to the base four-phasic function of the noospheric rainbow brain-red initiates, white refines, blue transforms, and yellow ripens. The icons themselves actually correspond to the mathematical code 0-19.

Colors and Icons with Their Corresponding 0-19 Code Numbers:

Red Family: Dragon (1), Serpent (5), Moon (9), Skywalker (13), and Earth (17)

White Family: Wind (2), World-bridger (6), Dog (10), Wizard (14), and Mirror (18)

Blue Family: Night (3), Hand (7), Monkey (11), Eagle (15), and Storm (19)

Yellow Family: Seed (4), Star (8), Human (12), Warrior (16), and Sun (20 = 0)

The mapping of synchronicity through use of the galactic signature is done through a set of tools: the Galactic Compass, Journey Board, Oracle Board, and Time Atom Cube. The point of engaging the Dreamspell is to learn of the infinite possibilities of fractal synchronic mapping of the events of your life and the lives of your family and friends, as well as current events and human history. The compass and boards describe the radial mathematics of fourth-dimensional time and also provide the means for fully engaging the synchronic order of the noospheric mind. The interactive complex of changing the family and clan relations to which the galactic signature entitles you also provides the basic patterns of social organization in time. The Dreamspell is indispensable for education concerning the radial, fractal nature of fourth-dimensional time and mathematics.

TELEKTONON

Meaning "Earth Spirit Speaking Tube," *Telektonon* is the name of the prophecy of Pacal Votan, and the definition of a complex program for establishing universal telepathy. It should be noted that the tomb of Pacal Votan was discovered in 1952, after 1,260 years, because of a tile tube, the Earth Spirit Speaking Tube, which ran from the top of the pyramid temple, down the secret stairwell, and into the wall of the elaborate tomb beneath the pyramid. The prophecy itself was decoded from the inscriptions and symbols of the elaborately carved sarcophagus lid of the tomb. Essentially defining a period of "Seven Years of Prophecy," (1993-2000), followed by a 13-year Cycle of Creation (2000-2013), the Telektonon is practiced on a daily basis by means of a board and various moving parts.

The purpose of the daily play is to learn how to operate by a set of coordinates that define the nature of telepathic consciousness as the interplay of five circuits that connect the ten planetary orbits (the Asteroid Belt, remnants of the lost fifth planet Maldek, is included as one of these orbits). The key interplanetary connection is between Earth, the third planet, and Uranus, the eighth planet, which creates the third or biotelepathic circuit. The Earth-Uranus circuit constitutes twenty-eight steps and thus corresponds to the 28-day measure of the Thirteen Moon calendar. Between days 7 and 22, one is

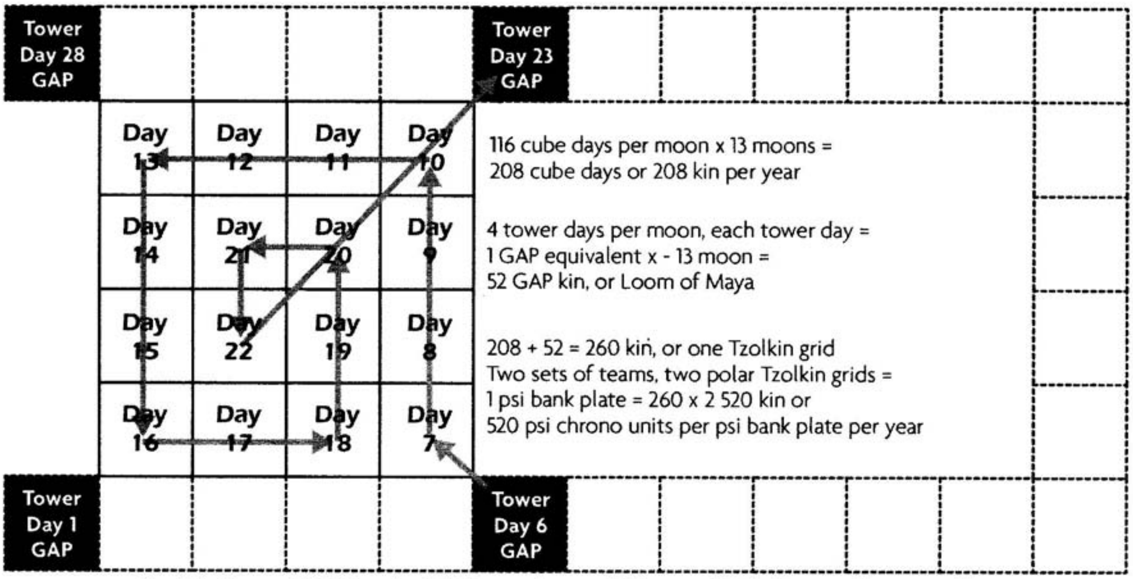
Tower
Day 28
GAP
Tower
Day 23
GAP
Day 13
Day 12
Day 11
Day 10
Day 14
Day 21
Day 20
Day 9
Day 15
Day 22
Day 19
Day 8
Day 16
Day 17
Day 18
Day 7
Tower
Day 1
GAP
Tower
Day 6
GAP

116 cube days per moon x 13 moons =
208 cube days or 208 kin per year

4 tower days per moon, each tower day =
1 GAP equivalent x - 13 moon =
52 GAP kin, or Loom of Maya

208 + 52 = 260 kin, or one Tzolkin grid
Two sets of teams, two polar Tzolkin grids =
1 psi bank plate = 260 x 2 520 kin or
520 psi chrono units per psi bank plate per year

The Telektonon Grid: Showing Psi Chrono, Loom of Maya, and Cube Journey Correspondences

Tower Day 1 (x 13)

Tower Day 23 (x 13)

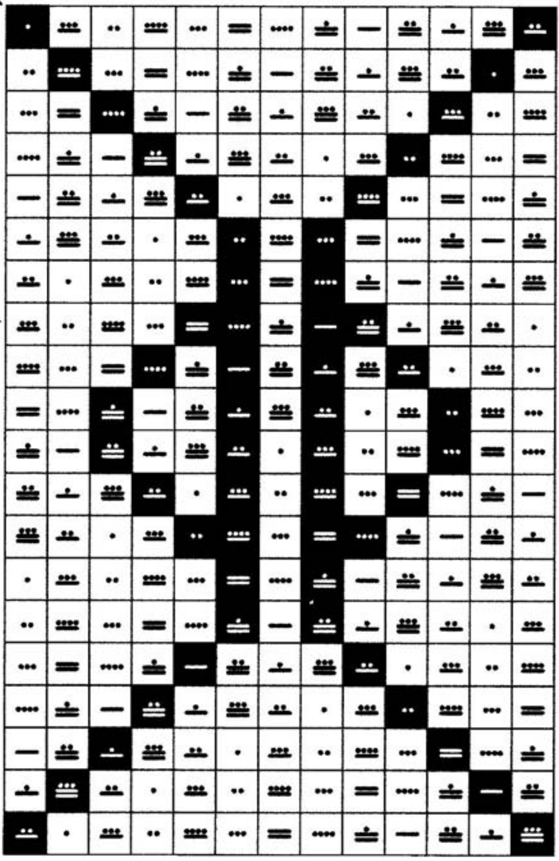

GAP = Galactic Activation Portal, 52 of which create the Loom of Maya, or binary triplet configuration of the Harmonic Module (Tzolkin).

The 52 GAPs are the basis of the occult quartet; that is, starting from each corner and moving inward there are thirteen of these sets creating a radial matrix where the tones of each set always equal 28.

13 x 28 = 364, the number of days in the Thirteen Moon calendar.

Each of these quartets codes the four tower days of the Telektonon every moon.

Harmonic Module
260 (13 x 20) unit
universal standard
of measure of fourth-
dimensional time

Tower Day 6 (x 13)

Tower Day 28 (x 13)

Telektonon - Rinri GAPs and Towers with Harmonic Module

able to take the "Warrior's Cube Journey" to uncover knowledge hidden by the Tower of Babel. The sixteen positions of the Cube of the Law (days 7-22) are the heart of the Telektonon play, which also includes a rehearsal of the thirteen baktun history with the intention of "redeeming the Babylon planet" as Timeship Earth 2013.

THE RINRI PROJECT

Described as a "four-year telepathic biosphere-noosphere transition Circumpolar Rainbow Bridge Experiment," the Rinri Project builds on the Telektonon play that establishes the biotelepathic circuit. On this circuit, two towers, days 1 and 6, define a four-day Earth Walk, and two towers, days 23 and 28, define a four-day Heaven Walk. Between the second and the third towers, days 6 and 23, are the sixteen positions of the Cube of the Law, days 7-22. The four towers every Moon correspond to one radial set of four Galactic Activation Portals in the Harmonic Module-thirteen moons x four towers = 52 Galactic Activation Portals (GAPs). Sixteen cube positions each moon x 13 Moons = 208, the remaining number of kin in the Harmonic Module once the 52 GAPs have been subtracted from the 260 units. Since the Harmonic Module is the basis of the psi bank, this formulation provides a way of coordinating the four psi bank plates of the noosphere to the Thirteen Moon calendar year on a daily and annual basis.

Since there are four plates, it takes four years, one year per plate, to open the psi bank. The first opening occurred between 1996-2000. The second opening, 2000-2004, is now occurring and is programmed by a coordination of the twenty-four runes of the Elder Futhark to the twenty-four psi membranes-6 runes per week every Moon x four weeks = 24. Since each psi plate is a mirror symmetry pair of Harmonic Modules, reflecting the North and South magnetic poles of the Earth, the Rinri project is practiced by telepathically interactive teams in the Northern and Southern Hemispheres. The Rainbow Bridge refers to making visible the dynamic of Earth's electromagnetic aura and extending it permanently from pole to pole. This is how the noosphere is visibly manifest.

Rinri is a Japanese word meaning "ethical enlightenment," and its application includes seventeen moral precepts that are studied during the sixteen-day cube journey, the seventeenth corresponding to the tower day 23.

260 POSTULATES OF THE DYNAMICS OF TIME

While the Telektonon is predicated on the fourth-dimensional tool kit, the Dreamspell, the 260 Postulates of the Dynamics of Time elaborate on the nature and theory of the biosphere-noosphere transition by providing a set of twenty systematic thirteen-part logics that describe and define the dynamics of time as the evolution of consciousness. Because there are 260 postulates corresponding to the 13:20 matrix, a postulate can be studied and meditated on each day over a 260-day cycle according to the code number of the daily icon combined with the number of its tone, for example, Red Lunar Dragon, where Dragon is 0-19 code number 1, and Lunar is tone 2, therefore the postulate to study for the day is 1.2. This daily programming, established by the Telektonon practice is how knowledge is reformatted according to the synchronic order. This in itself precipitates the noosphere.

TWENTY TABLETS OF THE LAW OF TIME, SIXTEEN-YEAR CUBE OF THE LAW

The Twenty Tablets can be described as a road map of the fourth dimension. By focusing on a sequence between the years 1997-2013, by fractal analogies, the telepathic engagement encompasses the 26,000-year cycle as well as the coming cycle of the Psychozoic future. The crux of the daily play of the synchronic order is called *cubing the codon.* The point is to telepathically reharmonize the DNA that has been adversely affected by the 12:60 timing frequency. There are sixty-four DNA codons whose six-part binary structure is identical to that of the sixty-four hexagrams of the I Ching when both are written with a simple binary language of broken or unbroken lines. Each of the codons establishes a precise thirteen-stage permutation sequence. 64 x 13 = 832 codon permutations. The sixteen years from 1997 to 2013 also constitute 832 weeks (16 x 52 = 832 = 64 x 13). Therefore, each codon has one-quarter year, thirteen weeks, to run its permutation sequence, one sequence per week. Since each codon consists of six lines, each week the codon is built one line per day for six days, each line adhering to one side of a cube. On the seventh day, the codon is cubed and sealed by one of sixty-four "UR Runes." The UR Runes are the master cosmic runes, each of which governs an entire thirteen-unit codon permutation sequence. The Twenty Tablets also contain much synchronic information for experiencing what is referred to as *fractal time compression,* the expanded mental ability to engage in different planes or levels of time simultaneously. All of this is to establish a mind training for fully engaging the fourth-dimensional synchronic order of reality and time travel.

7:7::7:7 TELEKTONON REVELATION

While the Twenty Tablets of the Cube of the Law synchronize the DNA Codons in all their permutations on a weekly basis over a sixteen-year cycle, the 7:7::7:7 Telektonon Revelation establishes the 28-day cycle as the basis for synchronizing

Three planes create the cube. The six faces of the cube code the six lines of the codon. Cube the codon according to the thirteen tones of creasion

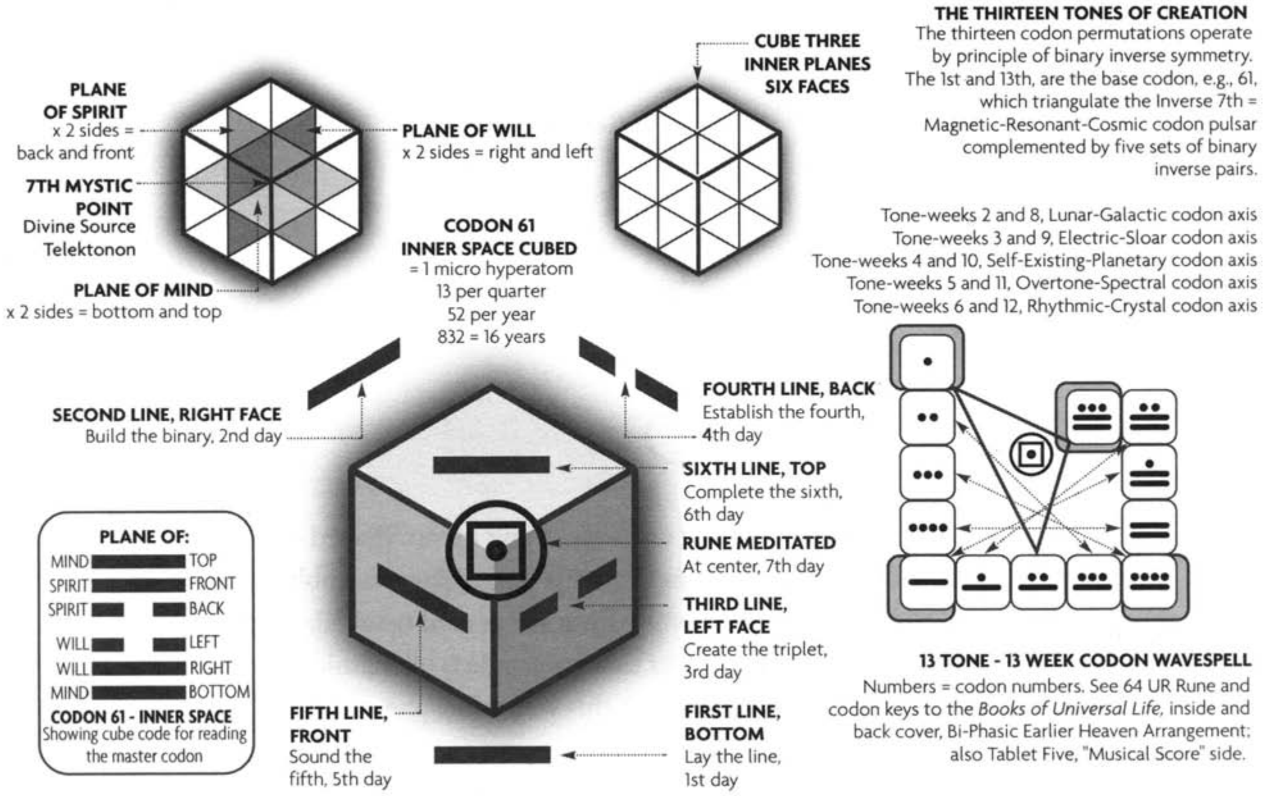
PLANE OF SPIRIT
x 2 sides = back and front
7TH MYSTIC POINT
Divine Source Telektonon
PLANE OF MIND
x 2 sides = bottom and top
PLANE OF WILL
x 2 sides = right and left
CODON 61
INNER SPACE CUBED
= 1 micro hyperatom
13 per quarter
52 per year
832 = 16 years
CUBE THREE
INNER PLANES
SIX FACES
SECOND LINE, RIGHT FACE
Build the binary, 2nd day
FOURTH LINE, BACK
Establish the fourth, 4th day
SIXTH LINE, TOP
Complete the sixth, 6th day
RUNE MEDITATED
At center, 7th day
THIRD LINE, LEFT FACE
Create the triplet, 3rd day
FIFTH LINE, FRONT
Sound the fifth, 5th day
FIRST LINE, BOTTOM
Lay the line, 1st day
PLANE OF:
MIND TOP
SPIRIT FRONT
SPIRIT BACK
WILL LEFT
WILL RIGHT
MIND BOTTOM
CODON 61 - INNER SPACE
Showing cube code for reading the master codon
13 TONE - 13 WEEK CODON WAVESPELL

THE THIRTEEN TONES OF CREATION
The thirteen codon permutations operate by principle of binary inverse symmetry. The 1st and 13th, are the base codon, e.g., 61, which triangulate the Inverse 7th = Magnetic-Resonant-Cosmic codon pulsar complemented by five sets of binary inverse pairs.

Tone-weeks 2 and 8, Lunar-Galactic codon axis
Tone-weeks 3 and 9, Electric-Sloar codon axis
Tone-weeks 4 and 10, Self-Existing-Planetary codon axis
Tone-weeks 5 and 11, Overtone-Spectral codon axis
Tone-weeks 6 and 12, Rhythmic-Crystal codon axis

Numbers = codon numbers. See 64 UR Rune and codon keys to the *Books of Universal Life*, inside and back cover, Bi-Phasic Earlier Heaven Arrangement; also Tablet Five, "Musical Score" side.

Codon Cube Cosmology
Sounding the Thirteen Tones of Creation

the seven primary plasmas-electronically charged ions-into four aggregates called time atoms. The seven plasmas, which also replace the names of the days of the week, are in two sets of three, with the middle or fourth acting as a catalytic agent. The first three plasmas form a sensory quantum and the last three plasmas form a telepathic quantum. Activation of the plasmas releases radion, a telepathic lubricant; hence, the seven plasmas are also referred to as radial plasmas. The four plasmic aggregates are known as the Analog Time Atom (week 1), the Antipode Time Atom (week 2), the Occult Time Atom (week 3), and the Unified Field Time Atom, (week 4). Like the Twenty Tablets, the 7:7::7:7 Telektonon Revelation also involves principles of fractal time compression where each day during the first week is the equivalent of 260 moons or twenty years; the following two weeks, each day is thirteen

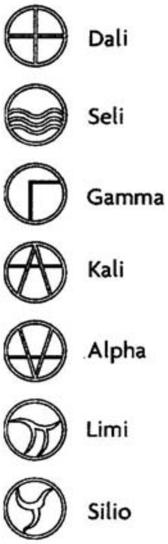
The Seven Seals, Seven Radial Plasmas

moons or one year; and the last week each day is one moon. Played on a board with cards containing affirmations from the Buddhist sage, Padmasambhava, the object of the 7:7::7:7 is to place the time atoms within the crystal octahedron at the center of the Earth so that each Moon a master time molecule is telepathically placed at the center of the Earth per one NET hour. In this way, Noospheric Earth Time is activated, the telepathic mind is engaged with the phenomenal reality represented by the plasmas, and the rainbow brain of the noosphere is hastened into everyday presence.

The seven daily plasmas constituting one thirteen-moon week, or one NET quarter hour are:

Dali (Sunday)-thermic charge

Seli (Monday)-luminic charge

Gamma (Tuesday)-luminic-thermic charge (these first three create one sensory quantum)

Kali (Wednesday)-luminic-thermic, thermic-luminic catalytic agent

Alpha (Thursday)-double-extended electron at the South Pole

Limi (Friday)-mental electron at the North Pole

Silio (Saturday)-mental electron-neutron at the center of the Earth (these last three create one telepathic quantum)

Part II. The Peace Plan: Establishing the *Pax Cultura, Pax Biospherica*

From the time of the formation, or rather, the calling into existence of the World Thirteen Moon Calendar Change Peace Movement, there had to be a *World Thirteen Moon Calendar Change Peace Plan.* The original of this Plan was submitted to the United Nations in 1995 for its fiftieth anniversary. The crux of the Peace Plan is that to change the world standard calendar is the opportunity for humanity to stop in its tracks and redirect itself. By stopping in its tracks to change its timing frequency, humanity can also use the opportunity to call a universal cease-fire and declare an emergency peace worldwide. Only in this way can the new time be experienced and fully engaged.

At the First Planetary Congress of Biospheric Rights (1996), this Peace Plan was extended to include the establishment of a new human covenant that would restore to humanity its intrinsic biospheric rights, the same as enjoyed by the rest of life in the biosphere: free land, clean air, clean water. The premise of the Biospheric Covenant is that humanity is first and foremost a member of the biosphere, and not of any artificially constituted nation-state. The Biospheric Congress also mandated the revival of the Banner of Peace and Roerich Peace Pact (1935) as one of the emblems to be used to identify the biosphere as a zone of peace.

The World Congress on the Law of Time and Judgment Day Tribunal (1997) extended the Biospheric Congress to include an indictment of the Gregorian calendar as a crime against the biosphere-"the crime of the millennium"-and the establishment of the Law of Time, inclusive of the Twenty Tablets, as the new dispensation of knowledge awarded in compensation to humanity, based on the synchronic veracity of the Thirteen Moon Calendar Change Peace Plan.

By 1999, the World Summit on Peace and Time provided the Declaration of Calendar Reform and a set of People's Resolutions, which were presented to the United Nations and the Vatican. The Resolutions define a seven-part educational program, which, like the Biospheric Covenant, envisions a radical reorganization of human society.

The purpose of these documents and declarations is for the creation of a state of universal unconditional peace so that human society can be rebuilt as a harmonic unity in phase with the biosphere as a whole. The result of the Thirteen Moon Calendar Change Peace Plan would be the creation of a new order of life on Earth-the *Pax Cultura, Pax Biospherica.*

▼

9

The Advent of the Noosphere

A Prayer and a Vision

IT IS MORNING once again, or, rather, it is predawn. It is still the first watch of the day. Outside there is a full moon. On the Gregorian calendar it is November 1, 2001, All Soul's Day, the sequel to Halloween, the day of honoring the dead. In another two weeks it will be the New Moon of Ramadan, Islamic lunar year A.H. 1422. On the Thirteen Moon synchronometer itis now the fifteenth day of the Self-existing Owl Moon, the moon of form, the moon to define, measure, and ask the question, "What form will my service take?" Well, my service will be to complete this book and prepare it for the world, for now it is the time of the advent of the noosphere, the reality of which Vernadsky said must be communicated to the world's politicians and statesmen. They didn't listen then. WIll they listen now? And on the 260-kin synchronization gauge it is kin 42, White Electric WInd. The WInd "communicates spirit," the Electric tone "activates service." WInd is the second of twenty solar seals that code each day in the synchronic order.

By its mathematical relationships to the other nineteen solar seals, the solar seal of the daily kin possesses a unique five-part oracle. In today's oracle the WInd is guided by the World-bridger, who brings the power of death. In the psi bank, the matching psi chrono unit for today, the fifteenth day of the Self-existing Owl Moon, is kin 66, Magnetic World-bridger, the first tone in the 13-kin wavespell of the World-bridger, which means today is very strongly penetrated by the power of death. What is death to the noosphere? An inevitable and unavoidable event, a critical and

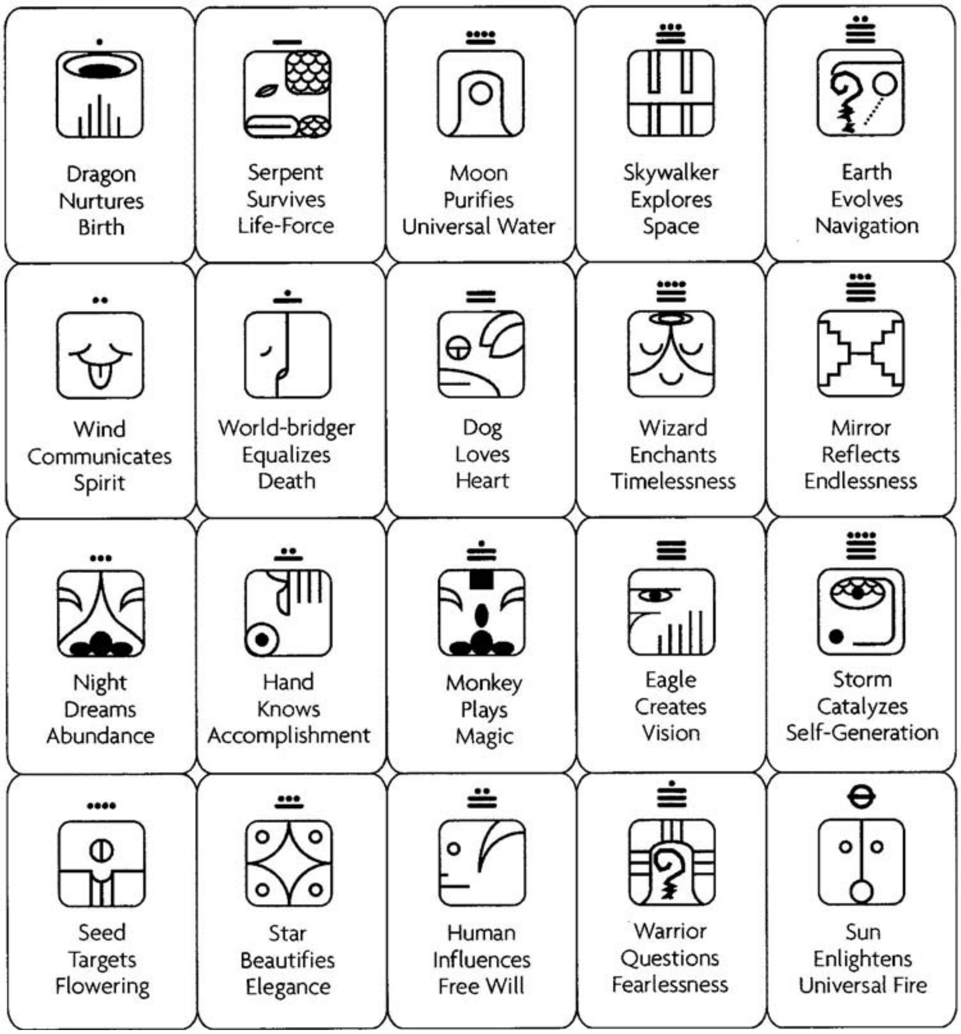
Dragon
Nurtures
Birth
Serpent
Survives
Life-Force
Moon
Purifies
Universal Water
Skywalker
Explores
Space
Earth
Evolves
Navigation
Wind
Communicates
Spirit
World-bridger
Equalizes
Death
Dog
Loves
Heart
Wizard
Enchants
Timelessness
Mirror
Reflects
Endlessness
Night
Dreams
Abundance
Hand
Knows
Accomplishment
Monkey
Plays
Magic
Eagle
Creates
Vision
Storm
Catalyzes
Self-Generation
Seed
Targets
Flowering
Star
Beautifies
Elegance
Human
Influences
Free Will
Warrior
Questions
Fearlessness
Sun
Enlightens
Universal Fire

The 20 Solar Seals
Names, Actions, and Powers

equalizing stage in the recycling of biomass, a furtherance of the biogenic migration of atoms, the creation of biospheric compost, a release of consciousness back into the noosphere, an opportunity to consider the value of life. But to the ordinary mind of the artificial technosphere, death is the ultimate object of fear, and the fear of death is the chief object of manipulation by those who generate terror. It is of note that by his date of birth, March 10,1957, the galactic signature of Osama Bin Laden is White Solar World-bridger, kin 126, while for this, his forty-fourth year, his birthday was coded by kin 66, White Magnetic World-bridger, both signatures bearing the destiny seal of the power of death. This is an example of how the synchronic order is "read" on a daily basis.

It is a mistake to think that the terror is just the malevolent intention of a single human being. The terror is co-extensive with the technosphere. In fact, the technosphere is the age of terror. The terror was generated at Hiroshima, and repeated at Nagasaki fifty-six years ago. And the terror was compounded by the original perpe-

Daily Oracle, Dali 15
Self-Existing Owl Moon, 9 Seed Year
(Gregorian: November 1, 2001)

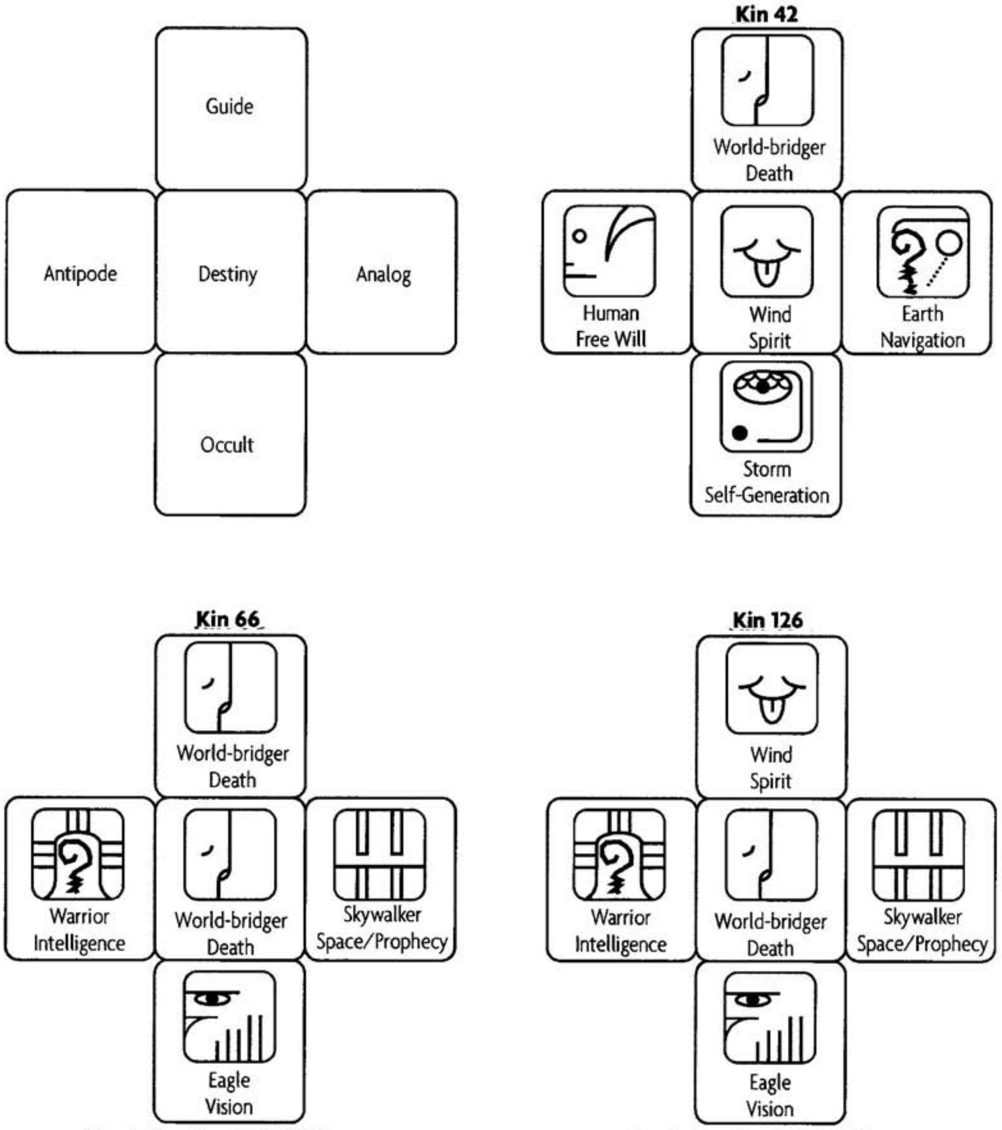
Guide
Antipode
Destiny
Analog
Occult
Kin 42
World-bridger
Death
Human
Free Will
Wind
Spirit
Earth
Navigation
Storm
Self-Generation
Kin 66
World-bridger
Death
Warrior
Intelligence
World-bridger
Death
Skywalker
Space/Prophecy
Eagle
Vision
Kin 126
Wind
Spirit
Warrior
Intelligence
World-bridger
Death
Skywalker
Space/Prophecy
Eagle
Vision

Oracle for March 10, 2001,
Osama Bin Laden's 44th birthday

Oracle for March 10, 1957,
Osama Bin Laden's date of birth

Daily Oracle Matrix

trators of that terror many thousands of times over in the creation and stockpiling of weapons of mass destruction, an act soon imitated by the then archrival, the Soviet Union, and by other nation-states, namely, the United Kingdom, France, and China. Those called the "terrorists" today have nothing to compare to the stockpiles of these weapons by these five nation-states who constitute the permanent members of the United Nations Security Council-the "nuclear club." That is who rules the world today, the official possessors of the weapons of mass destruction, who jealously guard their secrets. If this is the ultimate ruling body of the planet, and the reason why they are the ruling body is their possession of these instruments of death, then why should anyone be surprised at the existence of "terrorists" in the rest of the world? And why, we may ask again, are these terrorists mostly, it would seem, from the Islamic world? In addition to the nuclear arsenals, there are the biological and chemical weapons of mass destruction. Those who live by the manufacture of terror must surely die by their own means. If other nations have developed the same systems of terror, it is only in self-defense or in imitation of the masters of terror.

Everyday for four weeks now, I have been waking up at this time to continue work on this text, *Time and the Technosphere*. I had at first thought that the book could be complete with eight chapters. People don't have time to read, and the topic warrants as brief and pithy an explanation as possible. After all, it is really a time of reflection-and then action. The masters of terror have cloaked themselves as the protectors of civilization and as the moral crusaders who will rid the world of evil. Yet what is civilization today but the resource-consuming cancer of the biosphere? Is this what is being protected-the right to promote the disease upon the biosphere? The terrorists who attacked the Twin Towers and the Pentagon clearly knew the symbolic and actual value of their targets. They also undoubtedly knew the depths of the death-fear of the superpower masters of terror, whose reaction would most likely foment a global war. But in such a war, who would win? In this regard, from the noospheric perspective, the Inevitable Event was the technocide-death by technospheric means-of the technosphere itself. The technosphere was created by and thrived on means of terror, and the means of massive terror as well as the economic imperialism perpetrated by the superpower managers of the technosphere could only have produced a reaction against itself known as terrorism. The end result is collective suicide. There are no flags in the blood of the dead, nor is there any evident religious belief. There is only human biomass ultimately indistinguishable and anonymous to the biosphere.

Eight chapters were needed in order to complete the information about the biosphere, technosphere, noosphere, and the Law of Time. Maybe a new spirit of the biosphere will arise from the considerations of my book. Maybe the noosphere will spark in others the need to allow the biosphere to reclaim us from the technosphere. Anyone who says this is "turning back the clock" is only betraying their immersion and unexamined belief in the reality of artificial mechanical time. Yes, eight chapters were necessary to unfold this analysis and solution. But I knew there had to be a ninth chapter for the testament to be complete. For this is a living testament, and if anything has been learned by living according to the synchronic order of fourth-dimensional time, it is the renewed power of number itself. There is a power and meaning to number understood as a universal, self-existing mental construct. The synchronic order is constructed of number. And as Pythagoras perceived, number is a kind of spiritual entity that can only be aroused by an act of meditative contemplation. Each whole number bears its own resonance. You can feel this in the contemplation of the difference between even and odd numbers.

The resonance of 8, an even number, is harmonic order and balance, geometrically evident in the octagon or the octahedron. But the resonance of 9, an odd number, is quite different. Nine months to give birth, three times three, a rhythmic triplicity-that is nine. The Germanic god-hero Odin, or Votan, spent nine nights hanging from a tree in order to gain knowledge of the mysteries of woman. When the tomb of Pacal Votan was opened on June 15, 1952, it revealed a large vaulted chamber beneath the pyramid of the inscriptions in Palenque, Chiapas, Mexico. Entering the tomb, in the center of which is the famous sarcophagus, one sees on the walls the beautifully sculpted figures of nine personages. Today these sculptures have almost completely worn away. But originally, these low-relief sculptures modeled out of limestone, depicted with great elegance, a series of figures commonly known as the Nine Lords of Night, or the Nine Lords of Time. Are the Nine Lords of Time, the Lords of Night who guard Pacal Votan in his tomb, the same as the nine nights of Odin/Votan? And who was Pacal Votan? With what mythic resonance are we dealing?

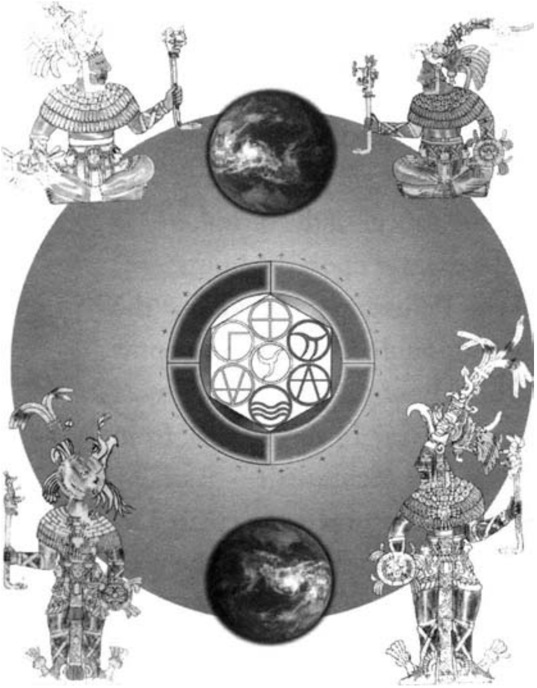

Nine Lords of Time Begin to Gather for a Council of the Earth

A Mayan seer, a sage-king of the seventh century of the Christian era, had deliberately created a mysterious tomb for himself, only to have it hidden, buried beneath a pyramid temple, but a tomb intended to be opened more than twelve centuries later, in the seventh year of the time of the terror, the time of the technosphere. How ingenious, how uncanny, that it would have been unknown for 1,260 years-a number also known in the thirteenth chapter of the Book of Revelations as the number of days of exile of the woman clothed with the sun, her feet on the moon, and twelve stars around her head. What does this allegory mean? Is it not the same as the exile of the human soul in the deadening world of 12:60 materialism? Sixty years remained from the opening of that mysterious tomb to the closing of the cycle of history, the omega point of 2012. How could the timing of the opening of the tomb have occurred so precisely-1,260 years from dedication to discovery, 1,320 years from its dedication to the closing of the cycle? How could those years be such a perfect reflection of the artificial 12:60 and the natural 13:20 timing frequencies? How could a Mayan sage in Central America so long ago be able to see, it would seem, into our future?

When we study the globe and consider things synchronically from the perspective of the noosphere, we find some interesting correspondences. Pacal Votan lived in the tenth baktun cycle, between the Christian years 603-683, on the opposite side of the world but at almost the same latitude as Mecca, and just after the time of Muhammad, 570-632. Today the religion that God commanded Muhammad to found, Islam, is at the center of the terrorist storm, while the prophecy of Pacal Votan and of the Mayan calendar in general has placed the end point of history at 2012, a mere eleven years after the Inevitable Event that placed Islam at dead center of the world mind. How could this be, the religion of the prophet Muhammad and the prophetic timing of the Maya so close at hand? Is this some revelation of the Nine Lords of Time, or of God speaking through them-and who are the Nine Lords of Time? Are they destined to return? Could it be that the Nine Lords of Time, like some higher dimensional Lords of the Ring, are a manifestation of time to be released, one by one, in an annual sequence during the last nine years of the Great Cycle, 2004-2013?

These Nine Lords of Time are known in Mayan as the Bolontiku; their counterparts are the Oxlahuntiku-the nine lords and the thirteen lords, respectively. The nine lords govern the underworld, the time of the third dimension, which is why they are depicted in descent to the sarcophagus of Pacal Votan, while the thirteen lords govern the heavenly realms. The nine govern the nine vigesimal orders of number, while the thirteen govern the form of time. The dedication of the tomb of Pacal Votan in A.D.692 corresponded to the Long Count baktun date of9.13.0.0.0.

The nine and the thirteen lords-Bolontiku and Oxlahuntiku-are present in the very numbers of the dedication date. And the nine and the thirteen also governed the prophecy of Quetzalcoatl, of Thirteen Heavens of decreasing choice and Nine Hells of increasing doom. This prophecy refers to the sequence of twenty-two 52-year cycles that began in A.D. 843 and ended in A.D. 1987. Six years later, in 1993, during the first year of the 260th and final katun cycle of history, I began to decode the prophecy ofPacal Votan, some forty-one years after the tomb had been opened.

Telektonon, the Prophecy of Pacal Votan, was meant to be decoded precisely and only at the moment of its absolute usefulness, kin 144: Yellow Magnetic Seed, July 26, 1993. This moment defined the Seven Years of Prophecy, 1993-2000. It also established the validity of the Dreamspell or WIzard's Count as the reformulated Year-Bearer Count of the Chilam Balam, the jaguar priests or night seers. That is, the Telektonon Prophecy could only have been triggered when kin 144 occurred as the Year Bearer, Yellow Magnetic Seed, kin 144, correlated to the Gregorian date of July 26, 1993.

The precise revelation of this prophecy on kin 144, July 26, 1993, was dependent on and could only have occurred because a prophetic count, the WIzard's Count, derived from the prophetic tradition of the Chilam Balam, had already been established. This "count" provided the basis of *The Mayan Factor* and was woven into the conclusion of the Prophecy of the Thirteen Heavens and Nine Hells, Harmonic Convergence, August 16-17, 1987. And the precise number of kin 144, the revelation date of the prophecy of Pacal Votan was meant to accord with the Book of Revelations number of the elect, 144,000 (Revelations 7:4). In fact, that very day I discovered that the number 144 transliterated from the vigesimal count into Arabic numbers is written 7.4, which is the same as the chapter and verse number where the 144,000 are first mentioned in the Book of Revelations (7 = 140, or 7 x 20, plus 4 units = 7.4). More uncanny stuff-but not so to the noosphere, the Earth's mind of time. In the noosphere everything is woven of number, and number is intrinsically synchronizing, which is why numerology has held such a fascination for the human mind throughout history.

When I first began to decode this "final prophecy of the Maya," or Telektonon, a prophecy that commands the return to natural time through the Thirteen *Moon!* 28-Day calendar, I was stunned and not a little frightened. I had already taken many steps to remove myself from mainstream society and conventional life. But now I was dealing with a genuine prophecy, and I was to be its messenger. This was not my invention. The world is filled with enough madmen and lunatics spouting their particular visions. How could I ever make the world understand that this vision, this prophecy, was real, that it was the fulfillment of a Mayan who lived and died thirteen

Vinal position, one dot = 20 kin, 7 = 140 (7 x 20)

Kin position, one dot = 1 kin, 4 = 4

Written 7.4 = 144 (140 + 4)

7.4 = 144

centuries ago, and that his tomb was the vehicle of this prophecy, a prophecy meant precisely for this moment in time-the biosphere-noosphere transition?

I returned to the texts of the Chilam Balam, whose prophetic stream includes day prophecies, year prophecies, katun (twenty year), and *ahau* (260-year) cycle prophecies, prophecies of Quetzalcoatl, and finally the special prophecies of the mysterious Antonio Martinez and the coming religion of the Hunab Ku, "One Giver of Movement and Measure." I realized that the meaning and fulfillment of this entire prophetic stream was crystallized in the Harmonic Convergence and its 26-year aftermath. Chilam Balam, the jaguar priests, are the wizards of time, inspired by the guidance of the Bolontiku, the Nine Lords of Time, the Lords of Number. By command of the Supreme One (Hunab Ku), the wizards are directed to establish clear paths of rekindled knowledge. The ancient Maya prophesied their own destruction. Therefore, within the prophecies of the Chilam Balam they laid the seeds of their reconstruction-but not simply as Maya. The reconstruction had to be planetary, for their destruction in the sixteenth century was also an act of planetary consequence-the plunging of the entire world into the prison of artificial, mechanized time. The fulfillment of the prophecies along with the new dispensation of time had to occur before the end of the cycle, 2012.

For this reason, the master synchronic architect of the Mayan prophets, Pacal Votan, prepared the way with the discovery of his tomb in 1952. This phenomenal act of prophetic release meant that now the messenger of his prophecy of time had to be summoned to his task. This was to be my role and responsibility-one that I accepted, for I saw no other choice. The course of my life from the moment I had experienced an illumination atop the Pyramid of the Sun at Teotihuacan in 1953, to that moment forty years later, in 1993, when I first perceived that the meaning of the prophecy Telektonon was a single trajectory. The noosphere had found another chip. After all, if the noosphere is the mind of time on Earth, prophecy is just another way of radializing time, of bringing it around from one point in a cyclic motion to another. My preparation had been going on for a while.

Once I had received knowledge of the prophecy of the Thirteen Heavens and Nine Hells from Tony Shearer back around 1970, I prepared myself by study and meditation for the moment of the Harmonic Convergence. It may be asked: If the Harmonic Convergence concluded the cycle of the Nine Hells, then why are we experiencing the apocalyptic events of Hell on Earth now, some fourteen years later? What was the actual meaning of the Harmonic Convergence, and what does it mean for us today?

First of all, the Harmonic Convergence refers to the entire 26-year cycle from White Galactic WIzard to Yellow Galactic Seed, 1987-2013. The conclusion of the Ninth Hell refers to the release of humanity into the 26-year time zone of free will, choice, and decision in preparation for the completion of the cycle, omega point 2012, and the Galactic Synchronization, 2013. The full and true Harmonic Convergence will not be complete until the Earth itself becomes the Galactic Seed, 2013. If the twenty-six years are the free will zone of choice and decision, what are we to choose and decide? The choice is, as I was quoted in the *TVtlllStreet Journal* in 1987, "between a 'new age' and all-out destruction." The decision is to accept the knowledge of the error in time (12:60) and the choice is to return to natural time (13:20) by means of the Thirteen Moon!28-Day calendar. This the prophecy ofPacal Votan fully affirms.

In principle, the Harmonic Convergence refers to the converging of all aspects of reality in a great, all-unifying harmony. The initial moment of the Harmonic Convergence that witnessed hundreds of thousands of humans congregated at sacred sites worldwide at the dawn of August 16, 1987, Blue Electric Eagle, was a pure prophetic enactment of humanity being harmonically converged with the natural order of time. This visionary moment demonstrated that, indeed, Harmonic Convergence was possible. The wave of unconscious energy released through the collective psyche of the species as a result of this moment of prophetic purity reached a climax with the fall of the Berlin Wall and the end of the Cold War.

Early 1990, the role of the Harmonic Convergence in this process was echoed in the mass media as the question, "Did the Harmonic Convergence bring the world closer to peace?"[1] Before the question could be answered, the next phase of the prophetic end time began to unfold. Rather than determine how to make the choice to enter a genuine new age, the human race defaulted to an absolute materialism. It was this collective turn taken by the planetary leadership, now known as the G-7, that engendered the apocalypse we are now witnessing. In this turn, the Harmonic Convergence was forgotten, deleted as it were from the official public texts of contemporary history. The stage was thus set for the next revelation, the Telektonon of Pacal Votan.

In distinguishing the Seven Years of Prophecy, 1993-2000, Magnetic Seed-Resonant WIzard years, the Telektonon of Pacal Votan makes an absolutely clear analysis of the human condition at this time: unless the human race forsakes the false time governed by the instruments of the Gregorian calendar and the mechanical clock by the year 2000, then it will face its own destruction, biospheric collapse, and Hell on Earth. But ifby the year 2000 it can make the decision to reject the calendar of the false

12:60 time and adopt the perfect instrument of the natural 13:20 time, the Thirteen Moon!28-Day calendar, then humanity will have been able to make the choice of entering a new age. For the new age, so longed for, is actually only realizable as a new time. A new time can only come about by the rejection of the instrument that holds in place the hallucination of the old time, replacing it instead with an instrument of such perfect harmony that it has no history, but is truly post-historical.

For this, the messengers of time, myself and my wife, embarked on a course of being galactic gypsies, with no visible means of support, in order to warn the world of the meaning of the time and to offer to the world the opportunity of changing its course by changing its calendar. When the year 2000 rolled around, humanity remained unmoved. The Gregorian calendar, the Vatican, and the G-7 appeared to be as strong as ever. The prophecy did not fail, but humanity did fail to heed the message regarding artificial and natural time. In this process, as "messengers" my wife and I were only playing out an archetypal role. So beginning with the Blue Galactic Storm year, July 26,2000, thirteen years after the White Galactic WIzard year, humanity was placed in judgment. This is merely a matter of natural karmic law.

The four-year cycle, 2000-2004, became known as the prophetic cycle of the Harrowing of Hell. Just as Jesus was crucified and then experienced the Harrowing of Hell before his resurrection, so too humanity has been crucified on the technospheric cross of false time, and is now in the Harrowing of Hell awaiting the resurrection in natural time. For having failed to take seriously all its messengers and all its prophets of all times, humanity was now to pass en masse through hell. Since the Galactic Storm year, 2000-2001, completed a Seed-Storm Year bundle begun in the fifth year of prophecy (1997-1998), the 2000-2001 Blue Galactic Storm year was the year of evaluation. The full judgment was withheld until the Solar Seed Year, 2001-2002.

The Solar Seed year is the second year of the Harrowing of Hell, but the first year of the next four-year Seed-Storm Year bundle. The first half of the Yellow Solar Seed occurs during the second half of the first official year of the third millennium, 2001. The moment was now ripe for the Inevitable Event, for it was also the same Gregorian calendar year as 1945 and 1973. In the Telektonon Prophecy, verse 120, section 19, it is declared, "When the Lunar Moon has overflowed its banks, the G-7 will be no more." So it was on the twentieth day of the Lunar Moon (Blue Self-existing Monkey, galactic signature of Karl Marx), that the Tower of Babel, the World Trade Center, was struck a fatal blow, while the Pentagon, magical structure of the priests of the Dark Lords of Matter, built in "Hell's Bottom," Arlington, Virginia, during the Ninth Hell cycle, was mortally penetrated.

It is still the time of the Harmonic Convergence. The Harrowing of Hell represents the last cycle of respite for humanity. By July 26,2004, Blue Crystal Storm, humanity must make the "choice between a 'new age' and all-out destruction" when it will have the last opportunity to make the decision of rejecting the old time and calendar and replacing it altogether with the instrument of perfect harmony, the Thirteen Moon!28-Day synchronometer. Only such a harmonic organizing principle, universally accepted and applied, can ensure a time of harmony and the fulfillment of the Harmonic Convergence.

Is it possible that within the noosphere the Harmonic Convergence is awaiting its next climax on the Day Out of Time and the Thirteen Moon Synchronization date of the year 2004, that is, on Gregorian July 25 and 26, 2004? One reads through the *Journal of Calendar Reform* and the many texts and arguments for calendar reform that were put forth in the 1930s and feels the missed opportunity. Even Gandhi was in favor of a new universal timing standard as a principle means of unifying humanity in peace. Did World War II occur because the League of Nations failed to enact the calendar reform on January 1, 1933, as it had fully proposed? The League of Nations had promoted calendar reform as one of its major agendas since the 1920s. This world organization failed at calendar reform and at preventing World War II. Who or what prevented that reform from happening, and why?

Let us look at the matter again. In order to remain constant, any perpetual calendar ordered by the seven-day week requires the principle of a null day, a Day Out of Time that is no day of the week at all. This was a feature of the preferred Thirteen Moon!28-Day calendar proposed by the International Chamber of Commerce, as well as the other modified calendars of twelve months. Reading through archives and literature, pro and con, it is clear that what defeated the calendar reform was the conservative, Vatican-inspired objection to the null day, the Day Out of Time. To observe such a day, which is no day of the week at all, it was argued, would break the weekly succession of days set in motion by God at the beginning of creation-such a break would plunge the world into barbarism, chaos, and war. "The adoption of the weekly cycle was a triumph of Christianity to the detriment of paganism. The cult of Christianity is inextricably connected to the week whose origin reaches to the dawn of history. "2 Therefore, it was contended, to interrupt this weekly succession would destroy Christianity itself. As a result of such propaganda, the League of Nations faltered, no calendar reform occurred at all, and the world was plunged into war-a war that ended with the beginning of the age of terror. This terror is now running its course, like a fever sweeping through the biosphere. WIll it be possible to consider again what the League of Nations faltered on and what the United Nations simply chose to ignore?

Who really lost out when the calendar reform issue was tabled in 1956 at the United Nations? It was not God who invented the week as we know it, but more likely the Babylonians. Behind the week is the mystery of the whole number seven, recalled in the Epic of Gilgamesh as the seven wise men of Uruk. But the Babylonians clothed the seven-day cycle in the raiment of the sun, moon, and five principle planets-Mercury, Venus, Mars, Jupiter, and Saturn-to which the days of the week have no actual relation. Seen in this way, the seven-day week was intended to be a means on Earth for reenacting some remote mythic reality related to these seven heavenly bodies. What was that mythic reality, on what hidden knowledge is the count of the seven-day week presumed? Borrowing from Babylon, the ancient Hebrews incorporated the seven-day week into their purely lunar calendar. And it was thus from the Hebrews that the seven-day week entered the Julian and then the Gregorian calendars. It was not, however, the Romans who adopted the week, but the Christian successor to the Roman empire, the Church of Rome. What truly was the origin of the week? And what relation or meaning does it have in the first place? Even to F. H. Colson, a Christian scholar writing as late as 1926, the seven-day cycle is described as "that intruder the week, consisting indeed of a fixed number of days, but paying no regard to months or years."3

With its fixed number of days, the week makes sense only in a system of time reckoning that is synchronic rather than astronomical in nature. To those whose minds are set on the synodic lunation cycle as the absolute standard, as does the Gregorian calendar, the week is what ensures the greatest disorder in the calendar-and yet it is defended to the death. The week gains its power from the whole number 7, and not from the jumble of names in which the week is clothed. The seven-day cycle is the closest whole number that corresponds to the four phases of the moon, which, as whole numbers, are also seven days each. In fact, the fixed 7-day cycle only makes sense within the context of the Thirteen Moon calendar with its 28-day cycles divisible by four and seven, creating the annual cycle of fifty-two perfect weeks-plus the Day Out of Time, ensuring a perpetual harmony.

Was the Babylonian naming of these days-with only one name a reference to the moon-meant to be a cover-up of some earlier knowledge, a knowledge both more purely lunar and harmonic, such as the Thirteen Moon calendar? Is all of history, then, just based on a cover-up of harmonic time? What would really happen if there were a Day Out of Time, no day of the week or month at all? Would old belief systems dissolve? Would there be a psychic release, a sense of freedom? Since 1993, sixty years after the failure of the League of Nations to enact calendar reform, the Thirteen Moon Calendar Change Peace Movement has made certain that the

Day Out of Time is the day for forgiveness of debts, of release into timelessness, and for experiencing the full meaning of time is art. This day is now annually celebrated worldwide by increasing numbers of humans. All the while, the Gregorian world has arrogantly plunged blindly forward, locked into its mechanistically chaotic timing sensibility, only to receive the mortal wound of the Inevitable Event, causing it to fall through the seams of its own making, the technosphere. A Day Out of Time, it seems, might be a relief to a world now consumed by chaos, barbarism, and war.

> He sends down from the sky water for your drink and to grow trees for your benefit. With it He grows for you crops, olives, date palms, grapes, and all kinds of fruits. This is sufficient proof for people who think. And He commits, in your service, the night and the day, as well as the sun and the moon. Also, the stars are committed by His command. These are sufficient proofs for people who understand. (Quran, 16:10-12)

Yes, the biosphere is a set of proofs for people who understand, an immense order that reflects and transforms the cosmos through the very process of life on Earth. Who are the people who understand, and where are those people today? Who will speak for the biosphere? Who will take the message of the advent of the noosphere to the statesmen and the politicians that they may take heed and note that what is occurring is not really in their control at all, but is the climax of a phenomenal process known as biogeochemical combustion? And who will declare that this climax will inevitably shake all the towers to their foundations and level the mountains of industry to a flat plain from which the noosphere will manifest as the equality of telepathy for all?

This book, and this ninth chapter in particular, is like a long meditation, a vision, inspired by the dark tragedy of the Inevitable Event. As a vision, these thoughts are both those of one solitary individual, albeit a noospheric chip, and the continuation of the vision of that ancient seer, Pacal Votan. Could it be that Pacal Votan in his time knowledge rehearsed all these words, these thoughts, this entire vision itself? On the sarcophagus lid of Pacal Votan is a cross, not the cross of death as in Christianity, but the cross of life, a tree, a cosmic tree. Across that tree is a serpentine band with two dragonlike heads, one at each end. This band represents the galaxy. The head at each end represents the galactic vision that sees equally into the past and the future. Sometimes this is called the *zuvuya,* the reflex of cosmic memory. The entire galaxy, the Milky Way, is this reflex of cosmic memory. What if all of humanity is meant to be opened into this cosmic memory? This is what is meant by the advent of the noosphere, the mind of time on Earth, the mental envelope of planetary consciousness arising from the grave crisis of the biosphere through which we are now passing at this very moment.

Because we are now defining the noosphere does not mean that the noosphere was not known to those ancient Mayan time scientists like Pacal Votan, especially if the noosphere is defined as the mind of time on Earth. To such time scientists a NET year would be no time at all, or rather, it would be but a single, fifty-two solar orbit rehearsal of life. How many such rehearsals would be necessary before something was finally learned? The Prophecy of Thirteen Heavens and Nine Hells, for instance, was actually just the passage of twenty-two NET years. Is this how long was needed to see if the human race would learn anything? And if Pacal Votan and Muhammad were around today, what would they think and do?

Knowing the nature of the synchronic order of time, someone like Pacal Votan, obviously one of the most singular of all personalities of the Mayan world, would have possessed a consciousness like the two-headed galactic band, the consciousness of galactic memory. In the zuvuya of galactic consciousness, peering into the deep past is peering at the present from the future. This is possible in the radial time of the fourth dimension freed from the strict linear construct of past-and-future-time. From some higher state of mind, from a mind and consciousness identified completely with the galaxy, this has all been foreseen, this has all been written in a book. Now we who are in this present state of end-time consciousness are being asked to self-reflect. We are being asked if we can manage to hold the noospheric lens steady enough to see that the technosphere had to end, and that the technosphere could only end by the means by which it maintained all of the biosphere in its control, by terror itself.

Yes, we are all a bit like the frog at the bottom of the well whose vision and perception of the universe is circumscribed by what the opening of the well allows it to see. The well is the technosphere, both as a planetary apparatus and as a belief system. On the other side of that well is a vast world that we have actually never seen. This vast world is the noosphere and beyond. And what is beyond? Many of the traditional peoples say that we originally came from the stars. If we came from the stars, are the star people still out there? And what do the star people think of all that is happening on Earth today? And what do they think of their lost star children, many of whom now believe it is childish to think that we came from the stars? And if there are star people still out there, wouldn't they be too sophisticated to think they could get anywhere in a rocket ship, or even a UFO, subject to the en tropic degradation of the material plane?

No, they wouldn't rely on such primitive technology, but would be in tune, as is the rest of the universe, with the universal frequency of synchronization and the capacity of time to travel at an infinitely instantaneous rate of transmission. This being so, we could receive telepathic messages from the star people-if we were ready for it and knew precisely why, when, and how such communication occurs. In fact, as we have said earlier, the noosphere is the region on Earth for the receipt and transmission of messages of cosmic consciousness. This being so, the future of human evolution, of *Homo noosphericus,* would be nothing less than to become a medium of cosmic consciousness, adapting to the expanded measure of Noospheric Earth Time, traveling back to the stars but through the superior knowledge of the actual laws of time.

In writing this book, I have only a sense of duty, of responsibility to expand the vision of my fellow earthlings from the technosphere to the noosphere. In the Law of Time there are no arbitrary distinctions between reason and art, science and prophecy. The universe really is a giant radio transmitter. This book is as much an exposition of matters generally not thought about, as it is a personal testament and vision. In that regard this text is a portion of a broadcast transduced and received by me functioning as a noospheric chip, on behalf of the biosphere-noosphere transition.

In the tomb lid ofPacal Votan are impressed all the frequencies of this broadcast transmission called *Time and the Technosphere.* I know that Pacal Votan took an earthly form for just this purpose. He left his body in that tomb, a jade mask being the actual impression of his face. According to Chinese and ancient Mexican tradition, jade is the stone of immortality. Was Pacal Votan an immortal? Where did his consciousness and spirit go once his body was placed in the sarcophagus? Why did he leave the Telektonon, the Earth Spirit Speaking Tube, running from the tomb to the temple floor at the top of the Pyramid of the Inscriptions? Knowing the frequency of the synchronic order governing the psi bank of the mental envelope of the Earth, did he place his thoughts in the noosphere to be released at the precise moments of the opening of his tomb and the decoding of his prophecy? And then where did he go?

Beginning in 1980 I became conscious that, from time to time, I had been receiving telepathic transmissions. I soon identified these transmissions as coming from the star Arcturus. In *Earth Ascending,* originally written in 1983, the nature and program of the psi bank, the control panel and regulating mechanism of the noosphere, became known to me. This was followed by *The Mayan Factor,* and then the decoding of the Law of Time. At the moment when I had just finished writing *The Mayan Factor* in 1986, I received the inspiration for what is called the planet holon, the twenty-part structure accommodating the program of the twenty solar seals. When I received this image it was known to me as the program of the Arcturus Protectorate. As I understood it, the Arcturus Protectorate was established by the "star people" as a kind of protective time shield around the Earth. By means of the activation of this time shield, the star people would know that some of the earthlings were waking up to time and beginning the conscious activation of the noosphere. This is exactly what came about through the *Dreamspell,* beginning in 1990.

The *Dreamspell* is such a radical break from the past, and such a pure statement of the history-less fourth-dimensional future, that in order to comprehend it, in 1992 I wrote two other books, one called the *Arcturus Probe: Tales and Reports of an Ongoing Investigation* and the other *The Call of Pacal Votan: Time is the Fourth Dimension.* Some people will say that the *Arcturus Probe* is an exaggerated fantasy, yet I cannot deny what a purely telepathic process it was to write that book, which fills in many points of the psychomythic cosmology of *Dreamspell: The Journey of Timeship Earth 2013. The Call of Pacal Votan* was originally titled *A Treatise on Time Viewed from its Own Dimension,* and is a purely scientific description of the mathematical codes of the Dreamspell in relation to the biosphere-noosphere transition. The one text purely imaginal, the other purely rational, yet both were two sides of the same coin, a rendering of the Law of Time in its cosmological and mathematical comprehensiveness. Then came the even more abrupt break with my conventional past, the Telektonon Prophecy of Pacal Votan.

I bring up all of these personal details because people often ask where it all came from and where I got my ideas. But more importantly, I bring them up because, as I have been indicating, all of this was foreseen and known by a seer in another time, in another world-Pacal Votan. And this process of one person hiding a prophecy and another person in another time finding that prophecy, this is also a further revelation of how the noosphere functions. The French mathematician and philosopher Charles Henry (1859-1926) declared, "As the individual becomes more collective, the collective becomes more individual."4 As individuals, we humans are meant to grow into the collective mind known as the noosphere, while the noosphere, which is the collective, could only be known through its incorporating itself through the individual. I am one such individual, a noospheric chip. The noosphere could not be understood if it did not take on a personality or a number of personalities. Otherwise the noosphere would remain in the purely theoretical state or condition.

Now that the Inevitable Event has occurred, the noosphere is recruiting. The program of recruitment is called the Campaign for the New Time. This is a genuine campaign, but a peace campaign and not a military one. As a campaign it must reach its climax by mid-2004, a full eight years before the end of the cycle, northern winter/southern summer solstice 2012, the noosphere's omega point. The reason for this is that any later than 2004, the prophecy will be negatively fulfilled. A minimum of two Seed-Storm Year bundles-eight years-are needed to creatively destructure and then to reconstruct. The Inevitable Event was a sign of God showing us that the end had already occurred. Now all the forces of goodwill and harmony must be channeled into the conscious act that will coincide with the noosphere's readiness to manifest through all of us, and that is the calendar change-the untried solution, the most important unfinished business of the last millennium.

This is no longer a matter of debate. There is no other solution that hasn't been tried. There is no other way that the noosphere can become collectively conscious than through the human adoption of a timing system of perfect harmony. By meeting our deadline with the noosphere at the time of the Great Calendar Change in the middle of the year 2004-0n the White Spectral Mirror, Day Out of Time, the day of release from the old, and Blue Crystal Storm, the day of entering the new-then the biosphere will harmonically converge with the noosphere, and the *Pax Cultura, Pax Biospherica* may begin in all seriousness. Such is the advent of the noosphere.

What did the Maya foresee for 2012? What is Pacal Votan's vision? Pacal Votan's vision is the fulfillment of a prayer-a prayer that I have heard through the silence:

> o Hunab Ku, One Giver of Movement and Measure, be kind to the children of this Earth. We see how every year you give and how every year you take away. This is so the children of Earth can learn to be free and dwell only in your presence. Yet we know that the children of the Earth must undergo their lessons as well. And we know that they must enter the dark time of testing. 0 Hunab Ku, in their time of darkness, in their time of forgetting, do not forget them, spare those who are good, if you can. Prepare for them the Second Creation you have promised to the righteous among them. Break for them the spell of false time before they destroy this Earth! And show to them the splendors of the Second Creation, of the New Heaven and the New Earth. Show them these wonders before the Great Cycle is finished, so that they may yet wake up from the sleep of time. And 0 Hunab Ku, may the nine great Lords of Time return to Earth! May they teach the children of the Earth how to become a race of wizards, tilling the noosphere as they have tilled the Earth. 0 bring to these children of the Earth a good Time, a Time of Peace as long, at least, as was their time of history and war, and then let that Time of Peace be multiplied sevenfold!

> And here is the vision that fulfills the prayer:

> Planet Earth, Rhythmic Solstice, Blue Resonant Storm year, 2012 Omega Point. The Earth's axis is tilted so that the North Pole is at its farthest from the sun, and the South Pole is at its closest. High above the Earth an iridescent, thin rainbow band

arches from one pole to the other. A second band does the same, but over the opposite side of the Earth. The Earth slowly rotates beneath these two rainbow bands that remain unchanging, constant in their positions, one of them directly opposite the sun, the other holding a position on the midnight side of the Earth's turning. The band facing the sun is the Earth's day alternator. The other band is the Earth's night alternator. If we glide across the surface of the Earth we see that everywhere there are small encampments, circular and radial in formation. Yurts, tents, adobe, and earthen structures-and gardens. The once-teeming cities are eerily silent, yet still inhabited, though with far fewer people than during the time of the technosphere. And everywhere in the small encampments people are reverentially gathered. This is the moment of the closing of the cycle. It is as if everyone is drawing in a single breath at the same time, and exhaling it at the same time. From wherever you are, even though there are clouds, you can see the shimmering iridescent rainbow alternator, either by day or by night. Clusters of people are gathered in circles of deep meditation. Around them the children laugh and play. "We are the noosphere," a voice is repeating, "we are the noosphere." This sets up a vibration and people everywhere stop in their tracks, they look toward the sky. They listen. "The galaxy is renewing our thought. The galaxy is renewing our mind. The galaxy is renewing our world, this Earth. Let us go home and learn some more." Drums and chanting fade into the twilight in one place and beckon the dawn in another. "Let us say the prayer again: '0 Hunab Ku, Allah, One Maker, Our Creator, we submit to You. Continue to keep us whole, continue to broadcast the noosphere through us, continue to let us listen to the higher collective voice that we are so that tomorrow we may register another kin, another NET minute in the glorious journey of Timeship Earth toward its goal of universal unification in your One Unending Thought, 0 Hunab Ku, do not forget us, now, and do not let us forget you! Thank you for the closing of the cycle! May what we have learned stay with us and become the inheritance of our children for seven times seven generations to come, and may you bring us another cycle for all our descendants to live in continuing peace and harmony!'"

This is the vision. I am a noospheric chip. Do not turn away from your visionaries. Your prophets are still calling you and teaching you, if you would pay attention. There is much to do and learn. There is nothing more joyful than the positive construction of harmony.

Time and the Technosphere, First Draft Transmission completed,
Self-existing Owl Moon Dali 15,
Yellow Solar Seed Year
Kin 42, White Electric WInd:

I activate in order to communicate
bonding breath
I seal the input of spirit
with the electric tone of service
I am ptided by the power of death

First draft edited, completed, and sealed,
Overtone Peacock Moon Seli 2,
Yellow Solar Seed Year
Kin 57, Red Overtone Earth

I empower in order to evolve
commanding synchronicity
I seal the matrix of navigation
with the overtone tone of radiance
I am guided by the power of life force

Second draft edited, completed, and sealed,
Rhythmic Lizard Moon, Seli 23, Navigation Tower
Yellow Solar Seed Year
Kin 106, White Lunar World-bridger
Pacal Votan Clear Sign

I polarize in order to equalize
stabilizing opportunity
I seal the store of death
with the lunar tone of challenge
I am guided by the power of endlessness
I am a galactic activation portal
enter me

May all beings be well and happy!

May this text and these words inspire by their truth.

If I have left out or omitted any logic or fact, or unnecessarily maligned any truth or being by my endeavor to convince through clear argument, may the Creator know that no such malice or oversight was ever intended. I am but a human transmitter, a noospheric chip. My ability is commensurate with the frailties attendant to one too long steadfast on a path too little comprehended by many of those around him.

May the truth prevail!

Jose Argiielles, Ph.D.
known in prophecy's light as
Valum Votan, the Closer of the Cycle
devotee of Bolon Ik

Brightwood, Oregon
Cascadia Bioregion
North American Plate

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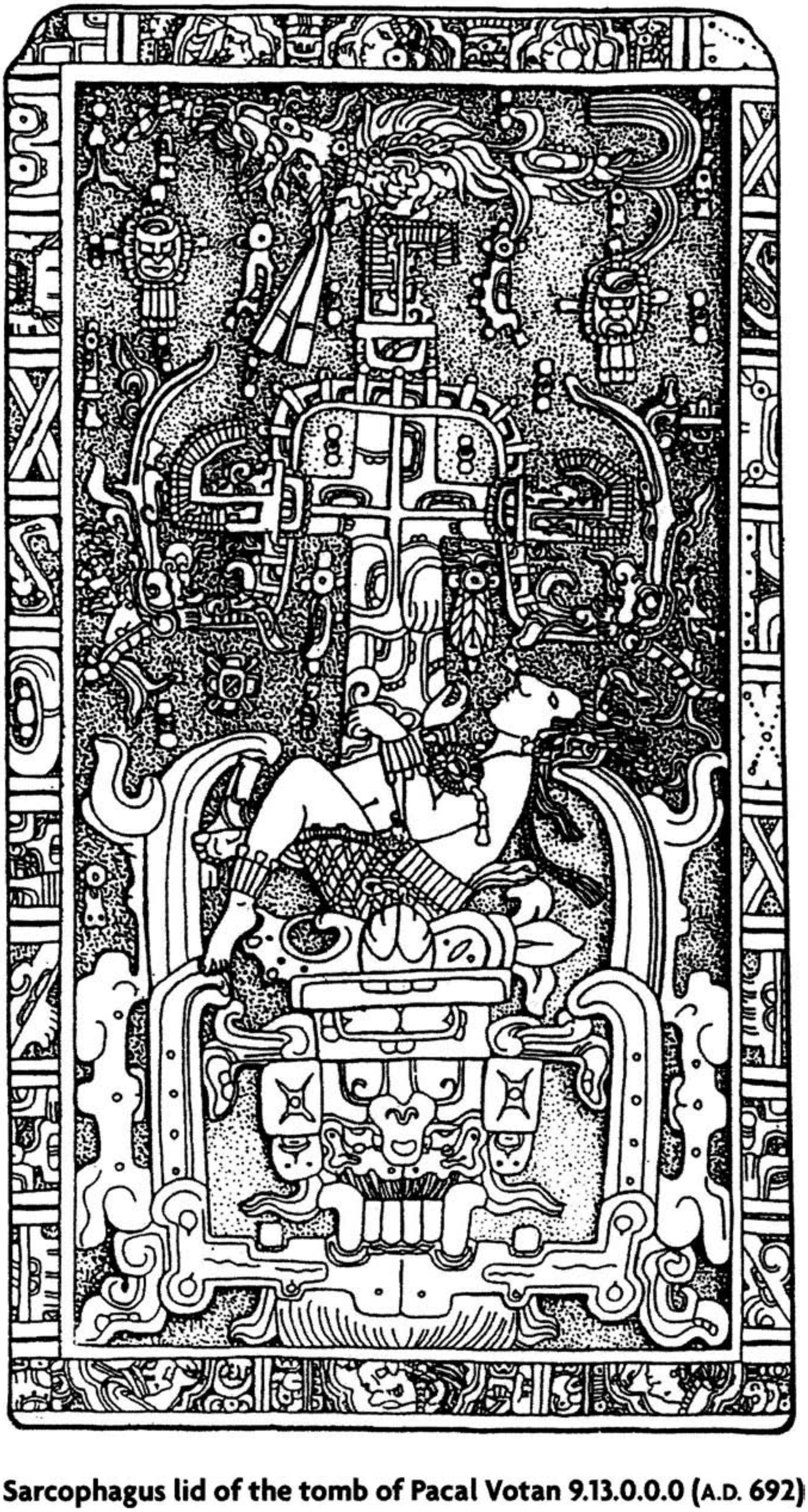

Sarcophagus lid of the tomb of Pacal Votan 9.13.0.0.0 (A.D. 692)

Epilogue

Networking the New Time

TO READERS for whom the notion of calendar change, much less that of a Campaign for the New Time, is totally novel, yet who may have an interest in learning more about and participating in the preparation for the Great Calendar Change of 2004, there is a place to begin and a way of going about it.

The official coordinating agency for the Campaign for the New Time and the World Thirteen Moon Calendar Change Peace Movement is the Foundation for the Law of Time. As a nonprofit public charities educational corporation, the Foundation for the Law of Time provides the communications and information hub for the Planet Art Network (PAN). The Foundation also publishes calendars, tools, and literature about the Law of Time and sponsors various educational programs, periodic seminars and congresses, and projects such as the new time educational caravans and the development of garden-oriented land bases.

For general information on the Law of Time or the Campaign for the New Time and its educational programs contact:

Foundation for the Law of Time, World Headquarters
Post Office Box 513
Brightwood, Oregon 97011 U.S.A.
Tel: +1 (503) 622-1976
Fax: +1 (503) 622-0198

The Foundation for the Law of Time's outreach activity program is known as the Planet Art Network (PAN), the loosely knit and decentralized base of operations for the World Thirteen Moon Calendar Change Peace Movement. The PAN is organized into Bioregions, each with its PAN nodes (local chapters) and a governing Bioregional Council. The PAN nodes organize "crystal day meetings" once every thirteen-day wavespell-the crystal (twelve) tone day is the day to call a round table or court of the kin to review past actions and prepare for future ones. The PAN nodes also offer educational programs and disseminate calendars and other educational tools and literature provided by the Foundation, which constitute the information outreach of the World Thirteen Moon Calendar Change Peace Movement. The Campaign for the New Time is the coordination of the world PAN toward the goal of the Great Calendar Change of 2004. The PAN is also generally responsible for organizing the annual Day Out of Time events in its different localities and bioregions.

For information about local Planet Art Network (PAN) operations, contact:

Foundation for the Law of Time/Gnomicile Land Base
World PAN Coordination Center
PMB 267
105 North First Avenue
Sand Point, ID 83864-1301 U.S.A.
Tel: +1 (208) 255-1172
Fax: +1 (208) 265-9107

The official Web site for the Foundation for the Law of Time, Planet Art Network, World Thirteen Moon Calendar Change Peace Movement and Campaign for the New Time is:

www.tortuga.com

This Web site is continuously updated and offers a great range of both practical and theoretical information about the Law of Time, the Campaign for the New Time, ongoing and upcoming events and educational seminars, listings of major PAN nodes worldwide, Law of Time archives, and links to other relevant Web sites.

A major aspect of the Campaign for the New Time is the development of a program of "strategic alliances," information about which is also available at www.tortuga.com. If you belong to an organization that you feel could be in alignment with the goals of the Campaign you can check out the Strategic Alliance page of the Web site or directly contact the Foundation for the Law of Time, World

Headquarters. The goal of the Strategic Alliances is to establish a "synchronization for peace force"-a coalition of a wide spectrum of organizations that are in alignment with the calendar change and are willing to help organize local events and information dissemination for the Great Calendar Change of 2004.

See also Appendix II, "The World Thirteen Moon Calendar Change Peace Movement and the Discovery of the Law of Time: A Brief Chronotopology of Transformation. "

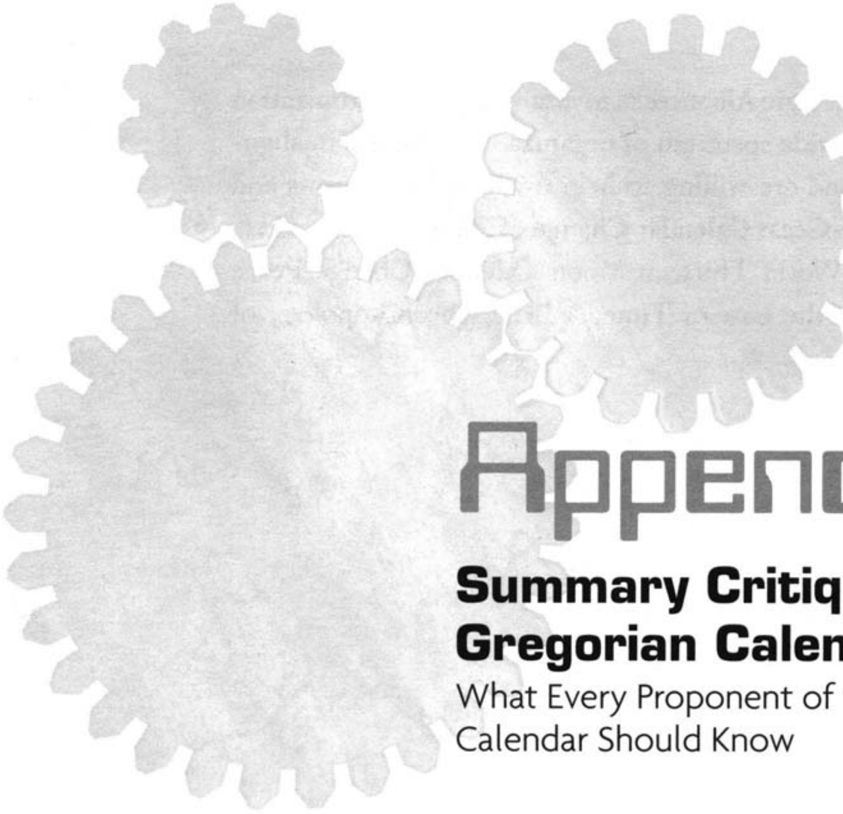

Appendix I

Summary Critique of the Gregorian Calendar

What Every Proponent of the Thirteen Moon Calendar Should Know

NOT ONLY is the idea of the calendar as an instrument to determine a true and accurate year misleading, but solely focusing on this purpose blinds us to any consideration of time apart from duration or measurement of motion in space. The Law of Time asserts that the actual nature of time is synchronic; hence the purpose of calendars is to synchronize us in time according to various cycles whose harmonic numbers extend from and return us to a higher mental order of reality. It is a fatal error to dismiss a mathematics of harmonic perfection when it is allied with the ordering and comprehension of cycles. The pursuit of a true and accurate year totally subordinates the cyclic nature of time to the ceaseless imperfection and change that characterize the phenomenal world when it is considered as the sole factor of existence. This defines the thoroughly materialist worldview of the 12:60 consciousness.

In order to prepare the ground for a proper consideration of the Law of Time and the evolutionary necessity of the synchronic order of time as the harmonic reorganizing factor of humanity in its post-historic phase, it is necessary to expunge from the mind the error known as the Gregorian calendar. To demonstrate and expose the illogical and irrational nature of the Gregorian calendar as a standard of measure, the following seven points are presented as a simple appeal to the intrinsic logic and intelligence of any human being.

1. We require of a standard of measure that its units of measure are regular and equal with one another.

This is not the case with the Gregorian calendar, whose base unit of measure, the month, proceeds in an irregular and uneven manner: 31 days, 28 days, 31 days, 30 days, 31 days, 30 days, 31 days, 31 days, 30 days, 31 days, 30 days, and 31 days. Why would anyone use a standard of measure with irregular units? Do you know what results when a crooked standard of measure is employed consistently for millennia? It might be noted that at the time of Augustus Caesar, August was called Sextile and had thirty days, while February then had twenty-nine days. In order to honor Augustus and make him the equal ofJulius Ouly) which had thirty-one days, the twenty-ninth day was taken from February and added on to Sextile, whose name was then changed to Augustus (August). By harmonic contrast, the Thirteen Moon calendar is perpetual in that all of its units of measure are equal-28 days each.

2. The names of the months are as illogical as their uneven numbering.

January is derived from the God of the doorway; February is an obscure word referring to an animal divinatory rite; March refers to Mars, the planet and the god of war; April and May refer to goddesses of the spring; June to the wife of Jupiter; July and August are named after the two most prominent Roman Emperors, Julius and Augustus Caesar. As for the remaining months, September, the ninth month, means seven; October, the tenth month, means eight; November, the eleventh month, means nine; and December, the twelfth month, means ten. Of course, having grown habituated to the crooked standard of measure, it is easy to overlook and dismiss as innocuous the irrational naming of the months. But is it so innocuous? What do the names of these months have to do with an order of time, or even a cosmology or culture of time, which we assume a calendar might reflect? By blindly accepting this irrational disorder of names, do we not predispose ourselves to accept irrational disorder in commonplace things around us, and even within the fabric of our society, thus reinforcing in us a tendency to accept a superficial treatment of the symptoms, while ignoring the roots?

3. Leap year and leap day is the most highly touted aspect of the Gregorian calendar.

Structurally, the Gregorian calendar is indistinguishable from the Julian calendar. The only thing that separates the Gregorian from the Julian calendar is the correction of the leap year day. Pope Gregory XIII "corrected the calendar" by deleting three leap days from the years that begin the centuries, except those divisible by the number four. Leap day is the extra day that accumulates every four years due to the length of the astronomical year being 365.241299 days and not 365. It can be seen that the fraction .241299 is not quite 1/4, which would be .25. The Julian calendar did nottake this into account, hence an error crept in that caused the spring equinox on the calendar to fall some ten days behind the solar moment of the spring equinox-a fact noted by the conquistadors when they encountered the Mayan calendar, which had no such discrepancy. Thus, in 1582, Pope Gregory XIII "improved" on Julius Caesar's calendar, some 1,627 years later, by adopting the rule that there would be no extra day on centuries-OO years-except on those that are multiples of four. Hence, there was no leap day in the year 1900, but in the year 2000, a multiple of four, there was.

What is not well known is that the Vatican does not recognize the leap day in its ceremonial calendar. Why is that? In most countries where Latin-derived languages are spoken, leap day and leap year are referred to as *bisiesto,* or "bisextile" day and "bisextile" year. If leap year is every four years, why is it referred to by a word that connotes six, *sextile?* On the official liturgical Church calendar there is no February 29! Instead, there are two February 24s, and the second February 24 is not counted. If there were to be an extra day that was counted, then the system of fixed feast days would be thrown off. Instead, on leap years, February 24, the Day of the Feast of St. Matthew, is counted twice-or extended to be 48 hours. And since in the Church tradition derived from the Romans the days are counted from the first of the next month, the first always being known as the calends, the date February 24 is technically referred to as the "sixth of the calends of March" (February 24 = sixth calends of March, February 25 = fifth calends, February 26 = fourth calends, February 27 = third calends, February 28 = second calends, and March 1 = calends of March). For this reason, the leap year is known as *bisiesto* because the sixth *(siesto)* calends of March is doubled, hence "bi." Thus, February 29 is not recognized by the official Church calendar of the Vatican, and it is also not counted as a day in its liturgical calendar. February 29 only arose out of popular tradition in the sixteenth and seventeenth centuries. The nemesis of accounting for the .241299 extra day per year reveals the fixation of astronomical time in seeking a "true" year and detracts from the possibility that the issue of an intercalary, or extra, day can logically and synchronically be handled in many other ways. In the end, it is the mystique surrounding leap day that further contributes to the numbing of the sensibility of time accumulated in the instrument known as the Gregorian calendar, "the little grid of boxes that rules so much of our lives."l

4. **The word we use to describe the instrument for measuring, the Earth's orbit around the sun, *calendar,* is derived from the word *calends.***

Calends was the Latin name given by the Romans to the first day of every month. What does it mean? *Calends* is the name of the account book, the book of payments recording the monthly debts and bills to be paid! No wonder we are ruled by the philosophy "time is money!" This philosophy is rooted in the very word we use to describe time reckoning, *calendar.* A more accurate word for time reckoning might be "chronometer," or even better, "synchronometer." But perhaps the word "count" is simpler. We might just say, for example, Thirteen *Moon!2* 8- Day perpetual count.

5. Dominicalletters code the years of the Gregorian calendar.

Scarcely known to anyone but Vatican insiders is the system of dominicalletters that is used to code the years according to the day of the week on which the first Sunday of the year falls. Since the week has seven days, there are seven and only seven dominical letters. These are the letters a-g, where a = 1, b = 2, c = 3, d = 4, e= 5, f = 6, and g = 7. Hence, G-7 (the group of the seven most industrial nations), the name given in 1974 by the CIA to the ruling oligarchy of globalization, is totally rooted in the system of the seven dominicalletters, a-g, to which the Gregorian calendar can be reduced. It works as follows: In 2001, the first day of the year was on a Monday, hence in this year all Mondays are coded by the letter a. Counting forward to the first Sunday, January 7, Sundays this year are coded g. The letter of the year, which is always a capital letter, is based on the lower case letter that codes the first Sunday, therefore, the year 2001 is coded as the capital letter G-it is truly a G-7 year! Not only that, but by this system of "G-7" dominicalletters, it can be demonstrated that the order of the Gregorian calendar year repeats within a cyclic structure of precisely twenty-eight years, where the days of the week and the month repeat once again. Hence, the cycle 1973-2001 is a repeat of the cycle 1945-1973, which is a repeat of the cycle 1917-1945, and so forth, where the years 1917, 1945, 1973, and 2001 are calendrically indistinguishable from each other. In any twenty-eight-year cycle, there are always exactly seven leap years! Thus, the key code numbers 28 and 7 of the Law of Time and of the perfect Thirteen *Moon!2* 8- Day calendar are hidden in and even govern the cyclic order of the Gregorian calendar, whose secrets pretend to lie concealed in the Vatican archives!

Expose these secrets and show that the true harmony of time is contained in the 13:20 matrix of the Harmonic Module, which is perfectly coded by 28 and 7. Within this matrix, any set of four tones radially opposite each other, an occult quartet, always adds up to 28. There are 65 (x4) such sets that constitute the Harmonic Module, while seven (multiplied by four), is the prime factor of 28, and is the key unit holding the 13:20 matrix in place, evident in the position of the seventh vertical column on either side of which is a perfect harmony of six columns each. The seven is also the implicit number in the ratio 13:20 (13 + 7 = 20: 20 - 7 = 13). But whereas the 13:20 matrix is a harmony in which the Law of Time is encoded, the Gregorian calendar is a disharmony, but one that is nonetheless governed by the Law of Time. What the Vatican attempted to destroy at the hands of Bishop de Landa in 1562, in the famous book burning at Izamal Yucatan, is redeemed by the Law of Time. Free of the obscuring, illogical irrationality of the inexact measure of the Gregorian calendar, the actual truth of the synchronic order of time may be discovered and revealed as the 13:20 mathematical code ofthe Harmonic Module, perfectly coordinated with the Thirteen Moon!28-Day count.

6. The Gregorian calendar makes day/date calculations difficult.

The twelve uneven months of the Gregorian calendar operate by a subsystem of fifty-two 7-day weeks, plus one day. Because of the irregularity of the numbering of the months, and because there are 365 and not 364 days in a year, it is almost impossible to make easy calculations month to month and year to year, while insistence on the unbroken succession of the week only compounds this issue. For example, if today on the Gregorian calendar it is Friday, May 4, 2001, what day of the week will June 4 be? What day of the week will July 4 be? There is an immediate mental block-a numbing of the mind. You have to stop and think about it. And in this numbing pause in which your cognitive brain has to be engaged, you lose your telepathic awareness, much as when you look at a clock to find out what time it is. Why should it be this way? Who benefits? The answer is, the priests (who know the tedious rules for stating that if it is Friday and it is 2001, then it is dominical e) and the bankers (who gather interest based on the confusion over the erratic disparity of days every month). By contrast, on the perpetual Thirteen Moon calendar, this day would be Spectral Moon Gamma 3-while every third day of every Moon is coded by Gamma. In fact, the third day of every week is coded by the name Gamma. Once the 28-day count is mastered, there is no need to engage the cognitive brain to figure out what day of the week Crystal Moon 3 or Cosmic Moon 3 will be-and in this way the mind is liberated into a telepathic knowing.

The system of the seven-day week was introduced into the Julian calendar at the Council of Nicea, A.D. 325, and was adopted from the Jewish calendar, which was derived from the Babylonians, for whom it was an astrological-astronomical construct. The fact that the week came from the Babylonians dissolves the argument used by the Vatican to counter the Day Out of Time. According to the Vatican, disrupting the succession of the seven-day week would disrupt an order set in motion by

God. The matter of the 7 and the 52 has a much deeper significance when understood in the higher-dimensional light of the Law of Time. A count of fifty-two 7-day weeks makes perfect sense if you have a count of thirteen 28-day months (7 x 52 = 13 x 28). The observance of the Day Out of Time, the 365th day of the year, produces a perfect and perpetual harmony. Knowing this, to continue to insist on fifty-two weeks while being unwilling to give up a twelve month count that does not have a Day Out of Time is to persist in an adherence to hopeless disharmony. Why do it?

7. What's in a name? Think about it.

What does it mean to follow calendars called the Julian and the Gregorian? A calendar is an instrument of control. The two most significant calendar reforms in history were the Julian calendar reform of 46-45 B.C., and its successor, the Gregorian, in A.D. 1582. Julius Caesar's motives had everything to do with his personal ambition and the conversion of Rome from a republican to an imperial form of government. Julius Caesar's calendar assured it to be the basis of imperial dominance. The course of the empire utilizing the Julian and later Gregorian calendar has prevailed as the dominant force now inseparable from the course of history itself. The 445-day "year of confusion" (46 B.C.), which attended Julius Caesar's reform, was matched by the second significant reform, the Gregorian, in which ten days were "lost forever," between October 5-16, 1582, so that the calendar could "catch up" with the sun.

While European Catholic countries easily accepted the reform, Protestant countries grudgingly acquiesced. Throughout the Americas, however, the Julian-Gregorian calendar was imposed as an instrument of power and symbol of dominance over the peoples the Europeans had conquered, including the high civilizations of the Maya, Inca, and Aztecs-all of whom happened to use, among other calendars, a Thirteen Moon!28-Day count. As with Julius Caesar, for Pope Gregory XIII the moment was politically ripe for a reform that would communicate itself as a means of expressing and extending power and control, but this time over the entire globe. As European dominance and control spread around the planet, even nations with their own established timing systems accepted, for the sake of "international policy," the Gregorian Oulian) calendar system for measuring the solar year. And so Western dominance over every aspect of global life became absolutely assured-until the moment of the Inevitable Event.

From its roots in the imperial ego of Julius Caesar to the timely "reform" of Pope Gregory XIII, it is not surprising that this calendar, "despite its odd quirks and the twists of history that produced it,"2 has become the standard of global civilization. Given the irregularity of the Julian-Gregorian calendar and the pursuit of the accuracy of astronomical time, history could be nothing more than a compilation of odd quirks and twists, while global civilization itself is the triumph of artificial time over the natural world. Only a species whose time sensibility had been captured by instruments of artificial measure could have become so alienated as to have produced the monstrous conundrum known as the "fast world," a civilization where money and technological advance prevail over human sensibility and the natural order. It is toward the correction of this destructive momentum that all efforts of calendar reform must now be directed.

In light of this critique, it is worth reprinting the opening section of the "United Manifesto by Advocates of Calendar Reform" that was first published in 1914 at the beginning of the First World War-some ninety years in advance of the Great Calendar Change of 2004. It can be seen that the issues of irregularity that prompted reform then are still issues today. However, the effects of not attending to these issues have only become compounded and even more complex, resulting in the chaos of a world at war with terror. Such is the nature of an error gone uncorrected over time-it only becomes more entrenched and turns into the dogmatic and hopelessly conflicted thinking of the everyday mind and its way of life.

> United Manifesto by Advocates of Calendar Reform
>
> WHEREAS we, the undersigned, have for some time been interested in a Reform and Simplification of the Calendar now in use in Western Europe, America, and elsewhere, with a view to equalizing the four quarters of the year, alleviating the irregularities of the months, and establishing a perpetual correspondence between the day of the week and the day of the month, and have supported one or other of several proposals which have been formulated for effecting these reforms; and WHEREAS said proposals usually provide for placing the 365th day of every year and the 366th day of Leap Year without the weekly and monthly enumeration; and WHEREAS we have found that in certain quarters-both ecclesiastical and scientific-objections, possibly often sentimental, but none the less firmly held, have been stated to the employment and adoption of these expedients. . . Therefore we have resolved to unite in urging and advising that the very simple changes under noted should now be made in the Julian and Gregorian Calendars by international agreement. . .[3]

If you have a crooked standard of measure, and follow it because your parents were also following it, you have become a crooked man. It takes a crooked man to walk a crooked mile and build a crooked house. The issue of calendar reform is both logical and moral. Bad logic leads to bad morality. An error in time dooms the mind. Apocalypses are the reward for bad timekeeping. To remove yourself from the fires of your own self-created apocalypse, change your calendar. In a world of harmony there is no apocalypse.

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Appendix II

The World Thirteen Moon Calendar Change Peace Movement and the Discovery of the Law of Time

A Brief Chronotopology of Transformation

IT WAS during the seven-year cycle (1993-2000) when the World Thirteen Moon Calendar Change Peace Movement was being aroused around the planet, that the Law of Time was articulated in its various aspects and particulars, and the synchronic order defined in its whole system fullness. This occurred through a number of key events accompanied by a number of publications detailing the mathematical, cosmological, theological, and scientific aspects and imperatives of the Law of Time.

By the standards of the synchronic order, all events form points in a radial time set that describe a geography of time defined as a chronotopology. Coined by the late philosopher and mathematician Charles Muses, the term *chronotopology* defines an event point of meaning that creates a root meaning from which time-formed, -blossomed, or -radiated meanings emerge above a horizon of meaning.! The Law of Time now gives a precise field in real time to illustrate Muses's notion of chronotopology in which Time is a radial power of profound interrelations.

The following chronotopological sequence-a resume of the events in a particular geography of time, the seven years of prophecy, 1993-2000-defines the conscious emergence and articulation of the Law of Time. In this chronotopology, the "root meaning" occurred in 1989 at the Museum of Time in the form of the discovery of the 12:60 and 13:20 timing frequencies, and the subsequent working out of the implications of this discovery. The "horizon of meaning" was reached July 26, 1993, kin 144, with the decoding of the Telektonon Prophecy and the consequent development of the World Thirteen Moon Calendar Change Peace Movement. The "source meanings," however, extend back to the seventh century with the origins of the prophetic traditions underlying the discovery of the Law of Time. The seven years of prophecy established the field of radiated meanings of the Law of Time as a set of radiated event points and a body of literature and tools. Here follows, then, a brief chronotopology of the key event points of this movement:

1989	Root meaning: discovery of the 12:60 and 13:20 timing frequencies, Museum of Time, Geneva, Switzerland.
1990	Realization of the Thirteen Moon/28-Day calendar in its wavespell form.
1992	Recognition and celebration of the Day Out of Time as a planetary event.
1993	Horizon of meaning: decoding of Telektonon Prophecy and birth of World Thirteen Moon Calendar Change Peace Movement.
1994	Launching of the Planetary Moral Emergency and World Thirteen Moon Calendar Change Peace Plan.
1995	80 Days Around the World for a New Time of Planetary Peace: Chile, South Africa, Egypt. Russia, India, Hong Kong, Japan, Hawaii, and Mexico.
1995	Day Out of Time Calendar Burning and Return of Natural Time Ceremony, Serpent Mound, Ohio.
1996	First Planetary Congress of Biospheric Rights, Brasilia, Brazil.
1996	Biospheric Awareness Day, Gotemba, Mt. Fuji, Japan.
1996	Four Corners Boundary Dissolving Ceremony, Four Corners, United States.
1996	Harmonic Convergence of Humanity, Mexico City, followed by Peace March, Teotihuacan, Mexico.
1996	United Nations, Planetary Moral Emergency Appeal.
1997	Judgment Day Tribunal and World Congress on the Law of Time, Tokyo, Japan.

1997-present	Ongoing movement in Brazil to make July 25, Day Out of Time, official "Peace and Culture Day;' based on recognition of the Banner of Peace (seventy cities so far).
1998	Special peace mission to the Vatican, Rome, Italy.
1998	Special mission to Guatemala to meet with Quiche Maya elders.
1998	UR Council for the Theology of Peace, Milan, Italy.
1999	world Summit on Peace and Time, University for Peace, Costa Rica, followed by the dispatching of Special Emissaries to the United Nations and the Vatican.
1999-present	Ongoing movement in Japan to declare Day Out of Time a "Day of Festival"; more than one hundred events occurring annually.
1999	Peace March, Teotihuacan, Mexico.
1999	Seven Week Earth Wizard Seminary, Picarquin, Chile.
1999-2000	Ongoing in South America, launching of "La Karavana;' Thirteen Moon educational caravans, and in Europe, from the United Kingdom to North Africa, the New Time Caravan.
2000	Initiation of Seven-Day Earth Wizard's Seminars: Japan, United States, Italy, Russia, South America.
2000	Circumpolar Rainbow Bridge Experiment, phase I, worldwide.
2000	Fruit of meaning: establishment of Foundation for the Law of Time, Oregon.
2001	Launching of the Campaign for the New Time, Brazil. Argentina, Japan, Altai region.
2001	Campaign for the New Time PAN Thirteen Moon Leadership Conference, Oregon.
2001	Seven-day special Congress on Time and World Peace, Medellin, Colombia.

During this chronotopological sequence of radially connected event points, key writings, publications, and tools describing and defining the Law of Time and the synchronic order include:

Dreamspell: The Journey of Timeship Earth 2013, 1990-91

Thirteen Moons in Motion and *Turtle of the Thirteen Moons,* 1993, 1996

The Story of Time: The Story of Turtle and Tree, 1993

Treatise on Time Viewed from its Own Dimension (Published as *The Call of Pacal Votan:*

Time is the Fourth Dimension), 1992, 1996

Telektonon of Pacal Votan and the *Telektonon, Game of Prophecy,* 1993-1995

World Thirteen Moon Calendar Change Peace Plan, 1994-1995

Pacal Votan and Judgment Day: The Second Quranic Dispensation, 1995-1996

First Planetary Congress of Biospheric Rights, 1996

The Galactic Culture Master Plan, New Time Economics, 1996

A Brief Guide to The Thirteen Moon Calendar Change Peace Movement, 1996

Rinri Project: Four-Year Telepathic Biosphere-Noosphere Transition Circumpolar Rainbow Bridge Experiment, 1996

The 260 Postulates of the Dynamics of Time and the Evolution of Time as Consciousness, 1996

The Discovery of the Law of Time, T(E) = Art, 1996

The Principia Mathematica of the Fourth Dimension, 1996

Twenty Tablets of the Law of Time: Sixteen Year Telektonon Cube of the Law, 1997

World Congress on the Law of Time and Judgment Day Tribunal, 1997

World Summit on Peace and Time, Summary, Review, and Conclusions, 1999

7:7::7:7, Telektonon Revelation and Plasma Universe Model, 1998-2000

The Rainbow Bridge Project: 28 *Meditations on the Law of Time,* 1999-2000

The UR Papers: Documents and Appeals for a Council of Universal Religion, 1996-2001

WIth the conclusion of the seven years of prophecy, marked by the rainbow bridge experiment, phase I, the greater part of the Law of Time had been uncovered, described, and defined. What emerges from consideration of all these events and accompanying literature is an entirely new model of the universe as well as a program for the reorientation of knowledge and the social reorganization of humanity-all based on a corrected understanding of time through the implementation of the calendar change. This was all to demonstrate that there is much more to a calendar change than the mere replacing of one calendar with another, for a calendar itself bears within it an understanding of time that tacitly and unconsciously shapes our very thinking about time. What the calendar change, then, really signifies is the end of one worldview and the birth of another. WIth the Law of Time, what was once unconscious is again made conscious, leading to a radical self-awareness of how wrong we have been about time, and what we might anticipate in changing our tools for navigating in time.

Because the growth of the Planet Art Network (PAN) as the social form of the World Thirteen Moon Calendar Change Peace Movement is inextricably involved with the unraveling by stages of the Law of Time, to define the constituent principles of the Law of Time is also to define the new worldview and the social organization appropriate to it. These constituent principles include: time is art; universal telepathy; holonomic consistency and reciprocity; synchronic order; fractal and radial mathematics of the 13:20 matrix; biosphere-noosphere transition; Banner of Peace; *Pax Cultura*, *Pax Biospherica;* the psi bank and the dynamics of the evolution of time as the evolution of consciousness; fourth-dimensional time and third-dimensional space. A mere consideration of these constituent principles will make one realize to what extent the calendar change is more than just an end to history, but the establishment of a new world, a New Heaven and a New Earth. This is precisely the promise offered by the Thirteen Moon calendar change and the discovery of the Law of Time. (See plate 8, Chronotopology of Transformation.)

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Appendix III

Telektonon Prophecy of Pacal Votan

THE REVELATION of the prophecy of Pacal Votan on July 26, 1993 was the culmination of the event that occurred on June 15, 1952, when the archaeologist Alberto Ruz Lhuillier pried open a large monolithic trapezoidal door beneath the Pyramid of the Inscriptions at Palenque, Chiapas, Mexico, and beheld what had not been seen by human eyes for 1,260 years: the tomb of Pacal Votan. A subsequent event, the lifting of the magnificent sarcophagus lid-measuring some four-by-three meters and weighing several tons-to reveal the human remains amidst a splendor of jade, including the jade mask, occurred on November 27, 1952. For some forty years afterwards, scholars debated the meaning of the tomb and the person buried within it. In the 1970s, the Russian scientist Knozerov dubbed the man in the tomb an "astronaut" or "cosmonaut" because of the similarity of the position of the figure sculpted on the sarcophagus lid to the positions of Russian cosmonauts in their little space capsules. This theory inflamed the imagination of some and was debunked by others, the end result being the enhancement of the awesome mystery of the tomb and the intention of its designer, the man buried in it.

The image of the sarcophagus lid is now world famous. Its symbolism has been interpreted to varying degrees by different archaeologists. In my book *The Mayan Factor*, the placement of Pacal Votan in his "time of power," 631-683, is defined and analyzed as occurring in the most harmonic and mathematically synchronic point of the entire thirteen baktun cycle, a point of fact that deepens the enigma of Pacal's knowledge and purpose. And herein lies the key question: What was his purpose, and why did he construct his tomb to be so elegantly buried for 1,260 years, to be discovered and opened just sixty years before the closing of the cycle, A.D. 2012? Clearly, the mystery of the tomb and its discovery had everything to do with the end of the cycle. At least this had come to be my surmise ever since the 1987 Harmonic Convergence. Like a hawk circling its prey, the meaning of the tomb finally came to my consciousness like a direct hit from the beyond. I was the prey, the hawk, the prophecy itself. Such was the revelation of the Telektonon Prophecy on the morning ofJuly 26, 1993.

The coded key was the tiled "speaking tube," by which the tomb was discovered in the first place. Suddenly, this tube spoke its meaning to me: Earth Spirit Speaking Tube, Telektonon by name. After four intense weeks of decoding the glyphs and symbols of the tomb while living in the pool house of an isolated estate in the wind-blown northern part of the main island of Hawaii, I knew that I had to abandon the dreamlike life I led in this Pacific paradise, and with my wife and companion head directly into the unknown, the first stopping point being Mexico, the source of the prophecy. After four months or so of traveling through Mexico, completing the decoding and announcing the prophecy, including a return to the tomb, we were finally directed to a converted carport in a field near the village of Ocotithin, not far from the birthplace of Quetzalcoatl. It was here where, for a period of nine mornings, I awoke dutifully two hours before sunrise to listen to the voice and write down by hand, in a specially prepared notebook, the words exactly as I heard them. Afterward, I numbered the 126 verses and distinguished the nineteen sections.

Because the prophecy itself is so inextricably connected with the Law of Time and the message of *Time and the Technosphere,* I feel it is important to present it as background information to the text of this book. In actuality, the text of the Prophecy is an integral part of the *Telektonon, Game of Prophecy,* where it is read, section by section, on a daily basis, according to the code number of the kin of the day.

THE TELEKTONON OF PACAL VOTAN

The Talking Stone of Prophecy That Unites the People of the Dawn with the People of the Book

"Then if they reject thee,
so were rejected apostles
before thee, who came with clear signs,

books of dark prophecies
and the Book of Enlightenment. "
-*HOLY QURAN*, SURA **III,** 19: 184

"All who obey God
and the Apostle
are in the company
of those on whom
is the grace of God,
of the prophets who teach,
the sincere lovers of truth,
the witnesses who testify
and the righteous who do good.
Ah, what a beautiful fellowship!

Such is the bounty
from God: and sufficient
is it that God knoweth all. "
-*HOLY QURAN*, SURA Iv, 9:69-70

● INTRODUCTORY VERSES: ONE LIVING PROPHECY

1. Pacal Votan's Gospel of the Telektonon
A Special Dispensation for the Day of Truth,
A.D. 1993-1994, kin 144.

2. Proclamation on behalf of the three messengers
of the awakening,
of the three special voices of prophecy,
the special witness of time and the last call.

3. Telektonon
the inner sun
the mother of all prophecy
message of the star witness, Bolon Ik
received and repeated by her servant in love,
Pacal Votan.

4. In the seventh year of Harmonic Convergence
the seven seals of the apocalypse
become the seven years of prophecy. . .
thirteen years in all.

Thirteen moons the path to walk;
thirteen moons the path to talk;
people of the dawn, one mind,
people of the book, one God;
one living prophecy, one people, one Heaven,
one Earth.

●● NAH CHAN: THE PALACE OF BOLON IK

5. o children of the people of the dawn, a children of the people of the book, I come as the special witness of time to remind you, especially on the day of truth, that in your origin you are one, and on the day of truth you are to make yourselves one again. For this I remind you of the Cube of the Law, Telektonon, and the 28-day, thirteen moon way that is the path of the righteous.

6. Nah Chan, Palenque, Xibalbay, Tollan, Xochicalco, Tepozteco, Amatlan: in these signs dwell my special agents, the witnesses of truth, 13.66.56 and Bolon Ik, Daughter ofJob.

7. For those with eyes, with open mind and sincere heart, this teaching is complete in every stone alignment and marking of the star command base now called Palenque.

8. New Jerusalem is the Palace of Bolon Ik, whose number is 1,728 (144 x 12), Cube of the Law. Seventeen is the power of Heaven, "solar Uranus," which is Earth in Heaven. Twenty-eight is the power of Telektonon, the Spirit Tower of the power of 7 times 4.

9. Never forget, children of the day of truth: All is number. God is a number. God is in all.

10. And everything there in the palace is laid out foursquare from the cord of Heaven, which is the command of the Telektonon. "Divine word never uttered until the Day of Truth." And in that palace, foursquare is the tower of the Cube of the Law.

●●●THE CUBE OF THE LAW AND THE TOWER OF BABEL

11. o children of the day of truth, before the separation that divided you into the children of the dawn and children of the book, there was only the Cube of the Law and the Law of the Cube.

12. Everyone and everything moved and lived within this Law: one mind, one spirit, one will.

13. Within the dimensions and measurements of the cube are all knowledge of Heaven and Earth. And in order to know, expand on, and delight in the sublime Law of the Cube, God created you, 0 children of the day of truth.

14. And though shaped of no more than mud and sounding clay, in you is the perfection of knowing the Cube of the Law, if only you remembered!

15. Children of the Day of Truth, just as the cube is the measure of the perfection of God's thought, so you are the measure of God's unceasing movement, which is called time.

16. In you the cube is the crown of perfect knowing of God's will in time. But true to his word, Iblis made wrong fair-seeming. To show himself man's enemy, Iblis split the cube. He drove a forgetting of time within the mind, separating mind from spirit, which is God's movement in all things.

17. And from this forgetting in man, mind and spirit became confused. The will weakened. Ego was born. Iblis's many-headed self triumphed. False authority arose. Babylon came to be and in its center the Tower of Babel, the monumental curse for no longer knowing time.

18. In the forgetting was the separation of the people of the dawn from the people of the book. Had there been no Tower of Babel, there would have been no book. The Tower of Babel was a deceit intended to show the Cube of the Law existing outside of the perfection of knowledge already formed within you, a children of the day of truth.

19. Product of the forgetting, the Tower of Babel has a shadow of ever-darkening and all-encompassing dimensions that spreads 5,000 years from Babylonia to all of Earth's most remote wildernesses and mountain retreats. Iblis's curse of Ego and false time are complete but hold only to the day of truth.

20. For God is gracious and most merciful. As long as He could, He kept the people of the dawn away from the Tower of Babel. And to both the people of the dawn and the people of the book, He sent many messengers, apostles of light, witnesses of truth, doers of the righteous way, which is always framed by the invincible Law of the Cube.

●●●● TELEKTONON: THE FRAME OF TIME

21. As the special witness of time, I, Pacal Votan, know the perfect count of days. I bow in the temple of the tower and the rock, the sanctuary of Bolon Ik. In my body, formed of the ultimate perfection of God's power of all movement and measure (Hunab Ku), is the recollection that is prophecy. Knowing this body as the measure of time, I had built this palace and this tower to correct and to also look for the Tower of Babel, a memory of the remembering. And in my ninefold temple, where, guarded by the nine powers of time, I had this body laid, I left this legacy for you, the Talking Stone of Prophecy.

22. Telektonon, the frame of time I left for you, is a mirror to show you your own truth of time for one last time. For now is the day of truth, the hour of judgment.

23. You, children of the dawn, and you, people of the book, unify yourselves the only way you can: in time, through time, as time.

24. Telektonon, the perfection of time, is the only way for you to escape the fire that consumes the unrighteous. If you who know, who have followed the straight way, the good path, now falter in this challenge of unification in time, Telektonon, which has already been prepared for you, you will perish forever in the fire that now consumes all unbelievers. God's command is in you. Do not listen to the evil one now.

MY COUNT OF DAYS IS PERFECT

25. Listen! My knowledge is this: My count of days is perfect, my knowledge of the Cube of the Law is unsurpassed. Twelve is the number of the temple, but thirteen is the number of God. Twelve times twelve, 144, is the number of the perfection of the temple as light. And twelve times 144, 1728, is the number of the Cube of the Law, Telektonon, the divine word unuttered until now.

26. "... To him that overcometh will I give to eat of the hidden manna, and will give him a white stone, and in that stone, a new name written, which no man knoweth, saving he that receiveth it." (Revelations 2:17) And that name is Telektonon, and that stone is crystal, and that hidden manna is knowledge of the revelation of time.

27. The number of the elect is 144,000. This was the number set aside by God to be free ofIblis's curse. Dispersed is this number among mankind, and always was it meant to multiply both among the people of the dawn and the people of the book.

28. But since a human kin is the measure of the perfection of time, 144,000 is also the number of days within a cycle of twenty generations.

29. Twelve times 20 generations is 1,728,000 days, the number of the Cube of the Law. But for God, one cycle more, 144,000 days more to entice Iblis to make his score, a total of 1,872,000 days, thirteen cycles of God's elect.

30. I am Pacal Votan, time's special witness, galactic agent of the Nine Great Lords of Destiny, by oath pledged to the honor of Bolon Ik.

31. In my body of time, thirteen star histories rehearse themselves for the day of truth. Each star history possesses its own knowledge keeper appointed by the Nine Great Lords of Galactic Destiny. Thirteen Wisdom Holders, Nine Great Lords, twenty-two in all, to each of whom I am bound by a luminous thread of knowing, sealed by oath to Bolon Ik, White Solar Wind, kin 22 in the Book of Destiny, the Book of Kin.

ALL IS NUMBER

32. All is number. God is a number. God is in all.

33. Child of the day of truth, listen: 20 is the number of totality. You have twenty fingers and toes because God has made you the totality of time. Thirteen is the number of God's cosmic wisdom, perfect in its power of unceasing change and circulation. Thirteen are the joints of your limbs and body. Seven is the difference between 13 and 20. Seven is the mystic perfection between one and thirteen. Seven is the erect spine of the vigilance in which are met the 144,000 mystic fibers of the body's thirst for prophecy.

34. 144,000 kin, 144,000 days, these are called a baktun. Thirteen baktuns, one perfect cycle to rehearse all thirteen star histories. Each baktun, twenty generations, each generation 7,200 kin. So it was that Bolon Ik ordained the sacred count of days, each day a sacred kin, each kin one of the elect, a turning in the twist of universal time, each kin ruled by the power of the nine, the power of the Nine Great Lords of Time.

35. So began the sacred thirteen baktun count, 3,113 years before the birth of the second of the special messengers, the Apostle Jesus Christ, who sent to you a Book of Dark Prophecies, twenty-two sacred chapters in all, through his appointed witness, John of Patmos.

36. All this I know and declare to be true, for I am time's special witness to the day of truth, Pacal Votan, rehearser of the thirteen star histories, he who adds the 144,000 elect to the cubing of the cube, assuring not twelve baktuns, but thirteen to be the number to bring on the day of truth, God's judgment of your power of remembrance!

37. Children of the people of the dawn, in separating you from the people of the book, God meant you to be the reminder that wisdom is already perfect in your bodily form of time.

LORD BUDDHA

38. In remembrance, many messengers did he send you, many fires did he light high atop the mountain for you to see. And one special messenger did he send, one special witness of the dawn.

39. In India, at the midpoint of the seventh baktun, the very center of the mystic cycle, thirteen baktuns in all, Lord Buddha did awaken at the dawn, the morning star, the tree, the Earth, his witnesses of illumination. For seven weeks, he sat beneath that tree. Never moving, he traveled the seven directions and visited with his mind every realm of God's vast creation, only to learn the turning of the Wheel of the Law.

40. Withstanding all efforts of the evil one, he taught unceasingly for nine times five years more, until the age of eighty. All mind teachings did he give; the unwritten Book of Enlightenment did he leave with the Earth. His last turning of the Wheel of the Law was the teaching of the Wheel of Time. Given at the request of King Suchandra of Shambhala who traveled far from Central Asia to receive this teaching, the teaching of the Wheel of Time closed the life of Lord Buddha.

41. "All composite things are impermanent," declared Lord Buddha at his death, "Be a lamp and a refuge unto yourself, look to no outer authority but yourself!" The fire of Lord Buddha's illumination lit many lamps. The Book of Enlightenment he left with the Earth is a book for all to know in silence with the Earth.

42. In Shambhala did King Suchandra transmit the teaching of the Wheel of Time, Kalachakra, as it is called. Invoking the Nine Great Lords of Galactic Destiny, Shambhala prospered in abundance and wisdom. When came the seventh ruler after King Suchandra, Queen Visvamati, the people of Shambhala ascended as one into the paradise of the fifth dimension, where their wisdom continues to water the rivers that flow beneath the gardens of the righteous.

43. Integrating the power of the five, which is the center, with the power of twelve, which is the root of the cube, the Kalachakra is also the cycle of sixty years (5 x 12). By the Law of the Cube, which is the power of sixteen, foursquare or 7 plus 9, sixteen cycles

of sixty years is the appointed time of prophecy, the prophecy of Kalachakra, which is the time of the day of judgment.

44. So it was that after the arrival in Tibet of Buddha's special voice, Padmasambhava, late in the tenth baktun, that the Lords of Shambhala determined to release the teachings of the Wheel of Time among the people of the dawn inhabiting Tibet. Thus it was that the Wheel of Prophecy turned the first of these sixteen cycles in A.D. 1027 and completed the sixteenth of these 60-year cycles in A.D.1987, in partial fulfillment of the Harmonic Convergence of all prophecy.

45. 0 people of the dawn, do not doubt. The appointed day is come.

THE HEPTAGONON OF MIND

46. People of the dawn, people of the book, children of the day of truth. To safeguard as long as possible the teachings of the Original Ones from the confusion of the Tower of Babel, God divided the Earth by its one ocean into great island masses called continents. And most far from Babylon was Amerrikua, and also distant was Australia and the Island Kingdoms of Polynesia. Even in Africa, close to Babylon, for many great cycles were the people of the dawn protected in their natural wisdom.

47. But inexorable is my count of days, inexorable the rolling of the Wheel of Time, inexorable the Law of the Cube.

48. Telektonon is the name of the blessing received by those who master the Law of the Cube. Great is the power of God, whose power and blessing are ever close and near, foursquare the manifest action of radiance from the divine intersection of God's presence: divine mind, divine spirit, divine will, divine source from which the Cube is sprung. Foursquare the Cube, the measure of Telektonon, one vast, far-spreading word that is no word at all, but number multiplying itself from within God's unending meditation, which we choose to call creation.

49. From one intersection, six directions plus the seventh, the moving center of time, the navel of Heaven whose cord is a fiber called Kuxan Suum. From the navel of Heaven to the solar plexus runs the Kuxan Suum, highway that reaches to the roots of the stars, passing through each of the heavenly dimensions.

50. I who say this, know, for I am Pacal Votan, who left for you a talking stone, Telektonon. Time's special witness am I, God's spy holding vigil, keeping the sacred count of days, exposing to you the lie of Babylon, the falsification of the Cube into the Tower of Babel!

51. Who now but I can tell you that seven are the directions of the Cube, the Heptaganon of Mind: twelve are the gates, sixteen the powers; moved by the nine great powers of time, these sixteen powers become the number of the elect of the Cube, 144. Multiplied by the millennium, 144 becomes 144,000, sacred number of days I laid for prophecy to know during my first baktun count.

52. Children of the book, even before the close of my first baktun, twenty generations from the year 3113 B.C.,the foundations of the Tower of Babel were laid. Captive now were the 144,000 within the Earthly prison of Babylon's materialism.

53. Yet, by my devotion and power of meditation, from deep within the Earth, aided by Bolon Ik's perseverance on far Uranus, Earth's harmonic twin, I kept the sacred count of days, I watched over the movement of the sacred march of kin.

54. Four more baktuns passed, and Babylon's power was swollen with the loot of Empire. Despite the righteousness of Abraham and the Law of Moses, the shadow of the Tower of Babel only increased in size and darkness.

55. Came the sixth baktun and Imperial Babylon was complete. Its seal of false time and power, taxation, and armed expanse had fulfilled Iblis's desire to degrade and ruin all humanity by making wrong fair-seeming. Fair-seeming now to amass wealth and power; fair-seeming to make a count of time by twelve months; and fair-seeming to regard the thirteenth moon with superstition and contempt! Fair-seeming to gather taxes and to pay them; fair-seeming to make war for the power of King's; fair-seeming that birth and death must be paid for; fair-seeming that all power come from the priests, Iblis's most cherished of men.

56. O people of the book, lost to you was all memory of the Law of the Cube, slavery became your lot! But I am Pacal Votan, time's special witness. Even before the coming of the second special messenger, Christ the Apostle of Love, by my free will and my knowledge of the power of seven, I laid claim to the Seven Seals of Prophecy that on the day of truth, Iblis's curse would be finished and the righteous would triumph. And now the day of truth is come. Telektonon, the talking stone, now speaks in a voice for all to hear.

57. By the seventh baktun, the Seven Seals of Prophecy were stored in Earth's special lodestone of truth, whose custodian am I.

58. By the eighth Baktun, Iblis had caused the Tower of Babel to speak more tongues in a growing clash of empires. Into this confusion came the Apostle of Love, crucified for driving the moneylenders from the Temple, misunderstood by the people of the book, finally to be absorbed by the Priests of Babylon, now Roman by tongue, who use this Christ as their emblem to spawn Iblis's greatest evil, the total usurpation of Earthly Time.

THE BOOK OF DARK PROPHECIES

59. One special voice did this Jesus have, a man named Saint John ofPatmos, in whom the gift of prophecy was fulfilled. From my ark of universal time, Earth's special lodestone of truth, rock of Heaven, attained by thirteen tones, I guided Saint John's hand by the mystic power of seven. And so was sent to the world the Book of Dark Proph-

ecies, Revelations, the Apocalypse, twenty-two mystic chapters, the first thirteen mirroring my thirteen great baktuns, nine more for the Lords of Time, seven of these for each of Seven Years of Prophecy, and the last two to complete the visionary power of the righteous of the Cube: 144,000 times thirteen.

60. To those who can read they will find Iblis's numbers 1,260 and 666, well known on the day of truth, for 12:60 is the ratio of the false time that makes martyrs of the righteous, and 666 the number of the beast who captures my thirteenth baktun.

61. Children of the day of truth, children of the dawn, people of the book, all this can you hear in the stones of Palenque where in the tenth baktun I took pure human form. Of the twenty-seven books of the New Testament, the twenty-seventh is Revelations. Twenty-seven steps ascend to the Palace of Bolon Ik. This palace, New Jerusalem, is the mystic power of Telektonon, the twenty-eighth step, the power of seven sanctified foursquare.

62. Twenty-two chapters of Revelations are the twenty-two kin complete in Bolon Ik: thirteen for the power of time, nine for the Nine Lords of Time, whose forms still guard my ark of stone deep within the ninefold temple of the Cube of the Law. Perfect was the time of my coming, kin 1, 366, 560. Perfect was the time of my going, kin 1, 385, 540.

63. Installed in the House of the Serpent, my coming was commemorated by the departure of the third messenger, the special messenger of the day of truth, the Apostle Muhammad, who left for the righteous of the Earth the Book of the Righteous, the Holy Quran, clear signs to understand.

64. As Buddha taught so pure one mind, so Muhammad taught so pure one God. Submission to the will of God is at the center of the Law of the Cube. Truly for the righteous there is only the straight way, the path of basic goodness, laid out in the heart as obedience to God's will, the divine plan unfathomable to those who cry, "reason alone can save us!"

THE PROPHECY OF THE SEVEN GENERATIONS

65. I am Pacal Votan, witness of time. Telektonon is my gospel. The talking stone of unifying prophecy is my legacy intended for that special messenger who understands the meaning of my numbers.

66. By my symbolic channel of communication called Telektonon did I intend this prophecy to be discovered and recovered. Once forty years had elapsed from the time of the discovery of my Uranian crypt, then would come the recovery, the recollection by my special agent of the numbers rehearsed and repeated to announce the day of truth.

67. Perfect was the time of my coming. Perfect was my mission. Perfect was the time of my going. Perfect is the discovery of my prophecy. Perfect is the Telektonon, the little book the angel of the Lord made Saint John of Patmos taste and eat, which you now possess, a treasure for the day of truth.

68. What you witness by these words is the last message I gave to my people, the message of 9.13.0.0.0, heard from my ark of stone through the Telektonon, Earth Spirit Speaking Tube. To my people I declared:

69. "Seven katuns are there to follow me. Seven generations, each one guarded by a solar witness taking account of what you do, each solar witness sealing your time with a prophecy to be known as the Book of the Seven Generations. And this book is to be opened for the day of truth.

70. "After the seven generations, the end of the baktun. Ten baktuns gone, the glorious Age of Maya gone, the Long Count of my days to be completed at 1,440,000 kin, the mystic number of the elect multiplied by ten.

71. "Then will come the three baktuns of Babel, the coming exile of 12:60 time. Thirteen years after this tenth baktun shall come the last prophetic round: thirteen cycles of Heaven, each fifty-two years, followed by nine cycles of Hell, each also fifty-two years. When the third round of Heaven begins, the Messenger of the Last Call will come to you, Quetzalcoatl-Kukulkan, the prophet by name.

72. "And when the thirteenth Heaven cycle is over, then will come the complete destruction of all we are and know. Before the twelfth baktun is over, two priests bearing false witness, ornamented with the sacred numbers five and thirteen, will see to it that the thirteenth baktun will be the end of time.

73. "Unrelenting will be the roll of the Nine Hells into the abyss of fire and madness. In the time of the last Hell, though you will be declared free, free you will not be. Ten Kings in succession will mark the climax of time. Seven years will follow the ending of the last Hell. Then will sound the angel of the seventh trumpet, the seven thunders will roll, the beast of seven heads called G-7 will place his mark on your foreheads and hands, the false one from Babylon will return to be embraced by the 11 Serpent. Then the day of truth will come, the Seven Years of Prophecy."

TIME'S SPECIAL WITNESS

74. People of the dawn, people of the book, children of the day of truth, many messengers have been sent to you, many prophets have been given to you. A Book of Enlightenment has been placed in the Earth for all to read in communion with the Earth. A Book of Dark Prophecies has been left for you. A prophecy of thirteen Heavens and nine Hells to accompany the Book of Dark Prophecies has also been left for you. A great prophet and messenger has left you clear signs to understand and a book of unassailable righteousness, the Holy Quran.

75. As the special witness of time, I have left for you my talking stone, Telektonon, breath of precious Bolon Ik, and have sent you both a prophet, Quetzalcoatl of sacred Xochicalco, and for the day of truth I have appointed also a special messenger who can hear my talking stone and write and explain its numbers and its meaning for you, children of the righteous.

76. Do not doubt any of this. When the moment comes for him who is to be the eleventh in succession, to succeed the one, 11 Serpent, then join the believers and begin the prophecy that liberates from all Kings and successors.

77. Ten witnesses I place around my tomb, ten Uranian emissaries, one each for each of ten baktuns. Of these am I the eleventh. Who would be the eleventh in the final succession of the Kings of Mexico must own me as the eleventh, then will all go well.

78. Six messengers did I place on my talking stone of prophecy: three above, the messengers Lord Buddha, Muhammad, and Christ; and three below, Padmasambhava, Quetzalcoatl, and Saint John of Patmos. Of these am I the seventh.

79. Pacal Votan am I, time's special witness, messenger of the Telektonon, instrument of the seventh angel, I declare again and again: All is number. God is a number. God is in all.

WAR OF THE RIGHTEOUS

80. Look carefully at my stone and listen: ten messengers, 24 signs, for ten are the number of orbits of planets around this star, Kinich Ahau, your Sun. From my point of origin, your star is designated 24, number of the circuit of externalizing intelligence. If you are of the righteous, then in this is a sign for you of your star mission.

81. And from each of the three oracle mouths of the arms of the cross of my Kuxan Suum, you will find twenty-four rays repeated three times, one-half the number of the elect (3 x 24 = 72). Add to this 3 times 11 (33) and the number is 105, the difference between the number of days in your solar orbit, 365, and the number of kin in my sacred count, my galactic spin, 260.

82. 13:20 is the ratio of natural sacred time. 12:60 is the ratio of the false time of the Tower of Babel. 13:20, thirteen moons, twenty fingers and toes. 12:60, twelve-month year, sixty-minute hour. Children of the day of truth, in this is a sign for you to discriminate between the power of the evil one who seeks to trap you in his machine, and the power of the righteous who need nothing but that with which God has endowed them: their body of time and their natural path synchronized by thirteen moons.

83. Children of the day of truth this is your only decision, for God knows and sees all that is in your hearts. People of the dawn, people of the book, on the hour of judgment unify yourselves in the only way you can: in time, as time, through time. For this in the year of kin 144, Telektonon is revealed to you, God's plan for peace on Earth, the last and only hope for spiritual renewal and salvation, immediate acceptance and adoption of the twenty-eight-day, thirteen-moon way, the calendar Telektonon. "And he had a name written that no man knew but himself." (Revelations 19:12) And that name is Telektonon.

84. Children of the day of truth, people of the dawn, people of the book, foursquare is my talking stone, invisible its design, its crystal lacing of star histories met in my human form. Time's special witness am I seeking apostles of time to organize the day of truth

into the revelation of God's redemption. Universal forgiveness awaits those who understand God's plan, a common time of twenty-eight days, thirteen moons, begun together at the appointed hour, on the day called Lunar Moon, the first day of the second year of prophecy.

85. Two solar faces there are upon my talking stone, the one an icon of my solar shield, Galactic Sun, the other, Lunar Sun, an emblem of the perfect lunar timing of Earth's solar orbit.

86. Children of the day of truth, the hour of judgment has come for you. How much longer do you need to suffocate in the Babylonian exile of 12:60 time? My children are the oppressed. Is it not time for the war of the righteous to restore equality? Why not wage the war then that destroys altogether the old time? Why not smash the caskets of the Babylonian wine of fornication in a single stroke?

HOLY VICTORY MARCH

87. 0 children of the day of truth, people of the dawn, people of the book, in your origins you were one blood, today the hour of judgment demands you become one again, unified in time. Who among you will join my apostles of the Telektonon? Already the gift has been given. Already we left for you the 13:20 tool, my sacred count of days, 260 kin, to turn the solar-lunar wheel of365 days. And when prophecy was vindicated at the conclusion of the ninth Hell, we sent among you the perfect form of this gift, Dreamspell, containing the message of the thirteen moons.

88. But this was not enough, the seventh trumpet had yet to sound, and so it did in the fortieth year following the discovery of my Uranian ark of stone. And now my prophecies are revealed. The Mayan Apocalypse of kin 144, Yellow Magnetic Seed, turns the seventh year of karmic destiny into the opening of the first of my seven seals of prophecy.

89. In this seal foursquare, all prophecies converge. The Beast of the G-7 stands revealed. The Babylonian Vatican is exposed. In the rainbow dream vision 144,000 of the elect are called again to meet, gathering together in circles to listen, to sing, and to dance to the song Telektonon.

90. 0 children of the day of truth, people of the dawn, people of the book, seven is my sacred power. Foursquare seven is 28, the number that, perfectly followed, opens Heaven's gate. Walking together the sacred thirteen moon, 28-day way, you will be joined to God's command, a holy victory march of the righteous to restore sacred order to this troubled Earth and to recover your lost powers.

91. Four powers of seven are given to you to be your comfort in the Victory March, one power for each of four perfect weeks, every twenty-eight days. By the first power of seven, claim your power of prophecy, by the second power of seven, maintain your power of prophecy; by the third power of seven, proclaim the victory of prophecy; by the fourth power of seven, become the victory of prophecy!

92. 0 children of the day of truth, 144,000 times thirteen is an army of the righteous. Learn again the count of sacred time and join this army. 0 children of the day of truth, realize that everything about the old 12:60 time is now become a garment of false being, a moral corruption, a banquet feast for the evil one.

𝋯 THE STORM OF NON-EGO

93. 0 children of the day of truth, children of the people of the book, in the Storm is the sign of God's power. To the Storm is assigned the power of nineteen, the mystic saturation of all number. One hundred fourteen Suras, nineteen times six, the power of the Cube, are the number of Suras in the Holy Quran. Twenty-two years after the finding of my Uranian crypt, Telektonon, came complete revelation of the Quran's power of nineteen, Allah's mercy. Nineteen more years then to unfold the karma of Allah's prophet besieged by Babylonian conspiracy. Then comes the destined year nineteen, kin 144, hour of prophecy's convergence, moment of the day of truth.

94. Let the 124,000 messengers call forth a remnant of 20,000 more; let each of these sound seven trumpets, seven times. Let these seven times seven trumpets call for a following of God's perfect plan. Mark seven times seven years since the evil one showed his fiery face at Hiroshima. Be honored by God's cancellation of Iblis's power of moral oblivion. Let the storm of God's power of nineteen cleanse with cosmic mercy the blood of all martyrs from the thrones of Kings, and let these thrones themselves be dissolved by the pure water of sacred time flowing through the gardens of the righteous.

95. I am Pacal Votan, time's special witness, revealer of the Cube of the Law, devoted patron of the mystery that is woman, the consummation of the telepathic power of twenty-eight, known to me by name of Bolon Ik.

96. Pacal Votan am I, enigma to your men of reason. My existence is proof of the workings of higher law. Telepathy is participation in God's knowing, but is no cause to claim full knowledge of His powers. Prophecy too is natural law, the complement to God's mercy.

97. 0-19 is my code. In it are all demonstrations of the wisdom that is always close and near, but that comprehends the web of galactic being and all forms of its natural orders in time. Just as nineteen is the power of God's mercy, so zero is the fullness and emptiness all at once that characterize the nature of mind and all it can know.

98. Lord Buddha called this power of zero Sunyata. The special voice of Buddha, Padmasambhava, whose life span followed mine, exactly as Muhammad's preceded it, knew this Sunyata to be the basis of non-ego.

99. If you would know me and all that I witness for you in this hour of judgment, children of the dawn, people of the book, then practice the being that is non-ego.

𝋰 THE ECSTASY OF DELIVERANCE

100. Because I repose on Telektonon, the mother of all prophecy, mine is the ecstasy of deliverance. With a mind of non-ego clasped to the heart of God I have sent out my

message of the Mayan Apocalypse. By relinquishing the calendar of twelve and leaving the prison of mechanized time, God's mercy will come swiftly to you.

101. Thirteen moons, twenty fingers and toes, thirteen joints, four limbs, five senses do you already possess. God's knowing and power of movement are already in you like a mother pregnant with child.

102. Why tarry now? When a house is burning, scurrying for your possessions will only cost you your life. This house that is burning is Babylon, the 12:60 way of life, which is now destroying your biosphere and poisoning everything about your life. Do not linger now fondling your machines. This is the Day of Judgment. If you can remember, leave this burning house and know that a better way has already been prepared for you, a holy victory march, my seven years of prophecy, Telektonon, the sacred revelation of time.

103. The Cube of the Law is awaiting its construction through the collective mind, spirit, and will of you, 0 children of the day of truth. Iblis, Satan, the evil one is none other than your ego clinging to the fatal lures of Babylon. God knows nonetheless exactly what is in your heart. Why not, then, become an apostle of the holy victory march? The ecstasy of deliverance is meant to be shared by all.

THE PROPHETS OF PEACE ARE AWAKENING

104. Pacal Votan am I, time's special witness am I, who bequeaths to you a talking stone, a legacy of place, Nah Chan, House of the Serpent, by prophecy known as Palenque.

105. And at Xochicalco, too, you will find stone utterances of my gospel left by command of my apostle, Topiltzin Ce Acatl Quetzalcoatl, who closed Christ's first millennium, as now my prophecy is come to close Christ's second millennium.

106. 0 people of the dawn, people of the book, children of the day of truth, make yourselves as one again and do not doubt the accuracy of the appointed hour on the day Lunar Moon! Synchronize now, and in all humility accept God's plan, twenty-eight days, thirteen moons, plus one day for deliverance and forgiveness.

107. Pardon now in public your enemy's indiscretions, and make full confession of your own transgressions. If you are sincere, God will see this in your heart and by His mercy many will follow your way; and if you proclaim for the cause of righteousness and truth, a new beginning and a new time, Telektonon, the thirteen moon way, and you enjoin others to do likewise, then God will know this, too, and make you a great general in the holy victory march.

108. And, if you have means and wealth, and you hear these words, or have explained to you the curse of 12:60 time and the blessing of 13:20 time, then do not doubt it and practice charity. Provide for the children orphaned by war and provide for the reconstruction of the Earth, that the practice of art and culture may flourish once again. Practice such charity with zeal, for soon you shall see an end to money. No more will flow the drunken wine of Babylon's fornication, and then what will you be with your paper credits and your useless machines?

109. The prophets of peace are awakening. Truly, the hour of judgment is come. Among the angels am I known as the mysterious benefactor of the righteous. Will you throwaway this opportunity, too? Beware for now the fire that consumes all falsehood is raging.

THE WIZARD'S HOARD OF THE LORE OF DEATH

110. People of the dawn, people of the book, children of the day of truth, because I am time's special witness, everything about my talking stone of prophecy is in fulfillment of God's divine plan.

111. Mine is the teaching of the 12:60 way of exile and the 13:20 way of redemption. Exactly 1,260 years passed from the dedication of my temple and closing of my Uranian crypt, A.D.692, 9.13.0.0.0, to its discovery and reopening in A.D.1952, 12.17.0.0.0. Another five times seven years, the numbers of my sacred ratio passed before the closing of the ninth Hell, A.D.1987, commemorated by the sacrifice of 3 Monkey, the first of four sacred signs on the western edge of my great talking stone. In this sacrifice was a sign of the death and transcendence of the way of the people of the book, "Joshua," and the people of the dawn, "Maitreya."

112. Eleven sets of triple disks, thirty-three in all, will you find upon my stone, for 33 is the number of the initiate, the middle harmonic of 65 that constitutes the Tzolkin, my sacred count of thirteen times twenty. All clear signs have I left for you, two borders of stars, the host of the Nine Lords of Time repeated by number on each side, top and bottom of my stone, a ledger of star histories complete in my form.

113. But especially would I have you look at Mars and consider again the disposition of the thirteen sacred signs placed around the edge of my stone, from 8 Ahau, my seal of truth, to 13 Cimi, the galactic closing of the wizard's hoard of the lore of death.

114. Ten emissaries celebrate the glory of my gifts for you, signs of peace from other worlds that beckon you to awaken from your sleep of Earthly Hell to join yourselves to God's command, Telektonon, the 28-day, thirteen-moon way and find in that count of days a path that leads directly to the paradise that is the repose and reward of the righteous.

115. One hundred forty is the number of the Telektonon, perfect its ratio 5:7 (28 x 5 = 20 x 7), the same as my sacred ratio 260:364(+1)

116. All is number. God is a number. God is in all.

SEVEN PERFECT ORACLES

117. People of the dawn, people of the book, children of the day of truth, this completes my testimony, I, Valum Votan, holder of the solar shield, protected have I been by the perfect love of Bolon Ik, who has stored my prophecy until this moment of release.

118. Seven perfect oracles have I given you, a perfect calendar of thirteen moons, an instrument to renew your spirit and your powers of Prophecy, Telektonon, and a book

of knowledge for you to penetrate the forgotten history of your star, Dreamspell. Also have I sent two messengers who bear witness to my truth, and thirteen perfect signs.

119. Now is the time of my prophecy. Now is the day of truth. Now is the opening of the seven seals. Now is the sounding of the seven trumpets. Now is the hour of judgment. Now is the song of the 144,000, the seed army of the righteous.

120. When the Lunar Moon has overflowed its banks, the G-7 will be no more.

121. When the Electric Wizard arrives, gather in banners of righteousness.

122. When arrives the Self-existing Storm, you will be fortified with spiritual abundance.

123. When comes the Overtone Seed, neither money nor priests will besiege you any longer, but the Earth will sing in harmony with your righteousness, Babylon will be no more, the Law of the Cube will be fully rehearsed in the hearts of the righteous.

124. In the sign of the Rhythmic Moon, senses will open to the manna of Heaven; no where will you find any longer signs of the evil one; a cosmic race will you be once again.

125. And when comes the seventh year, the Resonant Wizard will seal the Heavens and the Earth with the glory of all prophecy, the redemption of all prophets, messengers, apostles, and witnesses of truth.

126. Five years then will you have to close the cycle ofthe Seed, and another eight, thirteen years in all, to prepare for the coming of the Galactic Seed, 2013 Arcturus Dominion, the fulfillment of the star cycle of Valum Chivim, witnessed by the special agent, Pacal Votan, to the glory oflove, Bolon Ik, and on behalf of the mercy of God's divine plan, Telektonon, Cube of the Law, the mighty talking stone of prophecy.

"Man is one. Culture is indivisible."

-ALBERTO Ruz, 1952, 12.17.0.0.0.

Transcribed 12 Seed, kin 64,
Resonant Moon Day 13,
Warrior's Cube 7, 0 Yax
Yellow Magnetic Seed Year, kin 144,
First Year of Prophecy

Blue Spectral Monkey/White Solar Wind
Tepoztlan, Morelos, Mexico

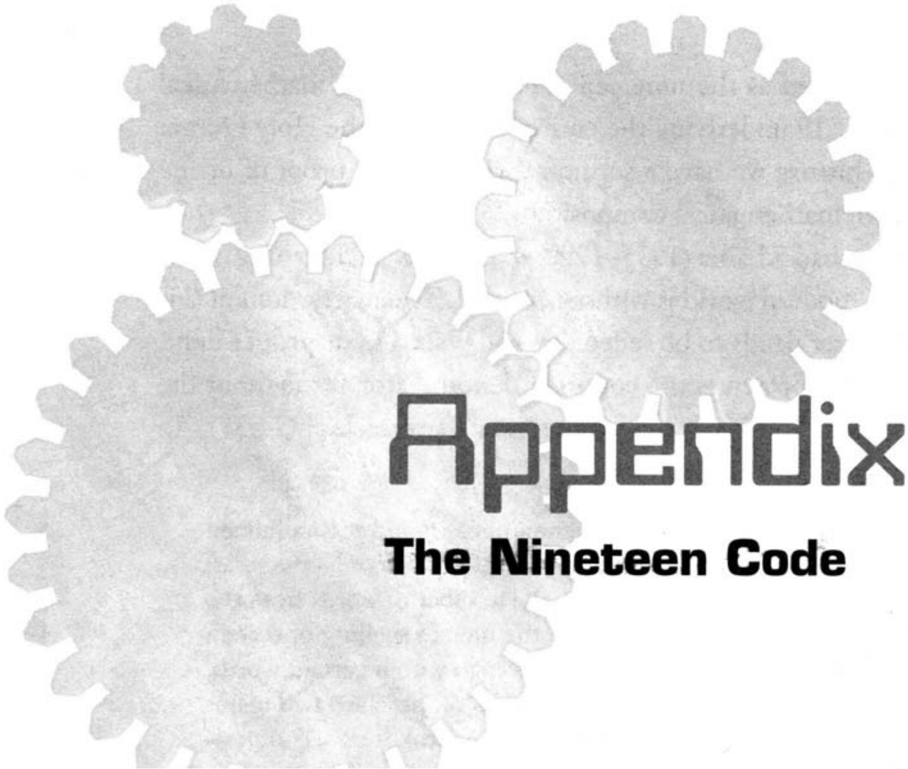

Appendix IV

The Nineteen Code

THE MYSTERY of the motives of the hijackers, who were instrumented by divine will, if not by biospheric necessity, to catalyze the Inevitable Event, lies in their very number: nineteen. While the nineteen is related to the Quranic verse 74:30, "Over it is nineteen," and can be interpreted prophetically, the Law of Time confirms the Quran in demonstrating that the number nineteen possesses a supreme and indeed inviolable value. The Law of Time validates all that is true, and contains within it the mathematical confirmation of all systems of thought as different facets of the same synchronic order.

The Law of Time is based on the mathematical code of the Harmonic Module, itself a function and a demonstration of the 13:20 ratio. The vigesimal mathematics of the 13:20 frequency is known as the 0':"'19code, which is written with a simple dot-bar notation. As such the 0-19 code is a whole number system in which the count is not 1-9 but 1-19, and the positional zero represents a factor of 20 rather than of 10. As the demonstration of a radial mathematical code, the number 19 plays a singular role in the 13:20 matrix. As the largest compound prime number of the 0-19 count, within the context of this count 19 has certain unique properties and values. It may be asked: why 19?

First of all, let us consider the theological dimensions of the number 19 as hinted at by the Quranic verse 74:30. Long an enigma to scholars of the Quran, it was only through the genius of an Egyptian scientist, aided by a computer, that the meaning of the verse was finally revealed as the nineteen code-an intricate mathematical system based on the number 19 underlying the entire structure of the Holy Quran.

"For the first time in history we have a scripture with built-in proof of divine authorship-a superhuman mathematical composition."[1]

The contribution of Rashad Khalifa (1935-1990) to the role and meaning of the Holy Quran for the entire modem world is without parallel. The martyrdom of this genuine seeker and messenger needs to be redeemed and placed in its proper light. According to Dr. Khalifa, "Nineteen is the common denominator throughout the Quran's mathematical system." "This is one of the greatest miracles" (74:35). To summarize in his own words, Dr. Khalifa states:

> The Quran is characterized by a unique phenomenon never found in any human authored book. Every element of the Quran is mathematically composed-the suras, the verses, the words, the number of certain letters, the number of words from the same root, the number and variety of divine names, the unique spelling of certain words, the absence or deliberate alteration of certain letters within certain words, and many other elements of the Quran besides its content. There are two major facets of the Quran's mathematical system: (1) The mathematical literary composition, and (2) The mathematical structure involving the numbers of suras and verses. Because of this comprehensive mathematical coding, the slightest distortion of the Quran's text or physical arrangement is immediately exposed.[2]

Like the Law of Time, which could only have been discovered after the opening of Pacal Votan's tomb, in A.D. 1952, the nineteen code of the Quran could only be discovered and unveiled over a twenty-two-year period between 1968 and 1990. Why? Because only with a modem computer could Dr. Khalifa subject every last word and letter of the Quran, in its Arabic original, to the rigorous analysis necessary to expose its mathematical perfection. As Dr. Khalifa writes in his footnote to 10:20 ("They say, 'How come no miracle came down to him from his Lord?' Say, 'The future belongs to God; so wait, and I am waiting along with you.'"):

> 10.20: In retrospect we see now that the Quran's miracle, indeed "One of the greatest miracles" (74:35), was divinely predestined to be unveiled 14 centuries after Muhammad. In view of the current condition of the traditional Muslims, if Muhammad had been given this miracle, those Muslims, who are already idolizing Muhammad beside God, would have worshipped him as God incarnate. Additionally, this miracle is obviously designed for the computer age, and to be appreciated by mathematically sophisticated generations.[3]

The phenomenon of the intricate patterning of the nineteen code as witnessed, for example, in the 19 x 142 (2,698) occurrences of the word *God* in the Quran, writes Khalifa, "alone suffices as incontrovertible proof that the Quran is God's message to the world. No human being(s) could have kept track of 2698 occurrences of the word 'God,' and the number of verses where they occur."[4] One must bear in mind that the Quran was revealed in a time of primitive simplicity over a twenty-three-year period so that the suras and verses were separated in time and place, while the chronological order of the revelation of the suras is not at all the same as their final format. Moreover, the miracle of the nineteen code is not limited to the appearance of the word God, but is vast, intricate, and comprehensive. Dr. Khalifa lists a set of nineteen "simple facts" that confirm the Quran's mathematical coding. The "simple facts" are those not requiring a calculator or computer to be ascertained. We hereby reproduce these "simple facts," as they are presented in Appendix 1 of *Quran: The Pinal Testament* (all references to letters and words are to the Arabic original):

1. The first verse (1:1), known as *"Basmalah,"* consists of 19 letters.
2. The Quran consists of 114 suras, which is 19 x 6.
3. The total number of verses in the Quran is 6346, or 19 x 334. (6234 numbered verses and 112 unnumbered verses *[Basmalahs].* 6234 +112 = 6346. Note that 6 + 3 + 4 + 6 = 19.
4. The *Basmalah* occurs 114 times, despite its conspicuous absence from Sura 9 (it occurs twice in Sura 27). 114 = 19 x 6.
5. From the missing *Basmalah* of Sura 9 to the extra *Basmalah* of Sura 27 there are precisely 19 suras.
6. It follows that the total of the sura numbers from 9 to 27 (9 +10 + 11 + 12 . . . + 26 + 27) is 342, or 19 x 18.
7. The total (342) also equals the number of words between the two *Basmalahs* of Sura 27, and 342 = 19 x 18.
8. The famous first revelation (96:1-5) consists of 19 words.
9. This 19-worded first revelation consists of 76 letters, 19 x 4.
10. Sura 96, first in the chronological sequence, consists of 19 verses.
11. This first chronological sura is placed atop the last 19 suras.
12. Sura 96 consists of 304 Arabic letters. 304 = 19 x 16.
13. The last revelation (Sura 110) consists of 19 words.
14. The first verse of the last revelation (110:1) consists of 19 letters.

15. 14 different Arabic letters form 14 different sets of "Quranic Initials" (such as A.L.M. of 2:1) and prefix 29 suras. These numbers add up to 14 + 14 + 29 = 57 and 57= 19 x 3.

16. The total of the 29 sura numbers where the Quranic Initials occur is 2 + 3+ 7 + . . . + 50 + 68 = 822, and 822 + 14 (14 sets ofInitials) = 836, or 19 x 44.

17. Between the first initialed sura (Sura 2) and the last initialed sura (Sura 68) there are 38 un-initialed suras. 38= 19 x 2.

18. Between the first and last initialed sura there are 19 sets of alternating "initialed" and "un-initialed" suras.

19. The Quran mentions 30 different numbers: 1,2,3,4, 5,6, 7, 8,9, 10, 11, 12, 19,20,30,40,50,60, 70, 80, 99,100,200,300,1000,2000,3000,5000,50,000, & 100,000. The sum of these numbers is 162,146= 19 x 6534.

Apart from the "simple facts," through use of his computer, a Hewlett Packard HP-IOOO E-series, Dr. Khalifa demonstrated many more complex levels of the coding of the number 19 throughout the Quran. These findings are synthesized in the Appendices to *Quran: The Pinal Testament*, and are also available in his other texts detailing his research, such as *The Miracle of the Quran.* The net effect of the truly monumental research effort exerted by Dr. Khalifa was the promotion of a highly reformed Islam based on "the Quran, the whole Quran, and nothing but the Quran." It is for this reason that Dr. Khalifa's translations of the Quran are referred to as "the Final Scripture," (1980) and the revised translation (1992) as the "Final Testament." It was also Dr. Khalifa's insistence on the Quran as the sole basis ofIslam that earned him his martyrdom in Tucson, Arizona, on January 31, 1990.

NINETEEN IN THE TWENTY-COUNT POSITIONAL SYSTEM

The Law ofTime-T(E) =Art, where T equals the 13:20 timing frequency ratio-upholds the validity of the research of Dr. Khalifa and graphically demonstrates *why* 19 is the mathematical factor that underlies the Holy Quran.

The fact that the Mayan vigesimal system is known as the 0-19 code, and that in this code 19, and not 9, has the supreme value of being the highest number, absolutely enhances the power and significance of Dr. Khalifa's discovery concerning

74:30, "Over it is nineteen." The supremacy of the value of 19, imperceptible if we only follow the decimal 1O-count, is fully demonstrated when we examine the 0-19 number code in which the numbers 0-19 are reproduced in a 5 x 4 (= 20) matrix, beginning with 0 and ending with 19. In this number set, which also demonstrates the mathematics of the radial matrix, there are ten pairs of numbers radially arranged, each pair of which adds up to 19:

0+19=19
1+18=19
2+17=19
3 + 16 = 19
4+15=19
5+14=19
6+13=19
7+12=19
8+11=19
9+10=19

In other words, within the parameters of the mathematical matrix in which nineteen is the integer with the highest value, its value completely informs the radial order of the entire vigesimal system. "Over it is nineteen." This is truly astonishing confirmation of the value accorded to 19 in the Quran. If the Quran is the true word of God, then we must expect that even knowledge unknown to Muhammad or Dr. Khalifa would be contained or coded in the Quran. We are referring, of course, to the Law of Time in its mathematical particulars, beginning with its mathematical base of expression, the 0-19 code.

19 = 7: NINETEEN IN THE 0-19 DOT-BAR NOTATIONAL SYSTEM

Just as the number 19 takes on a supreme value in the vigesimal system inconceivable in the decimal system, so the vigesimal order commands its own notational system. The 0-19 dot-bar notational system substantiates the meaning and power of 19 as the prime mathematical, saturated value unit in the twenty count. The dot-bar notational order is a holographic system distinct from the alphabetic system of Arabic numerals by which we write 1-10.

The distinction between use of the two notational orders is profound. This notational order uses only three notational symbols to build up the holographic context of

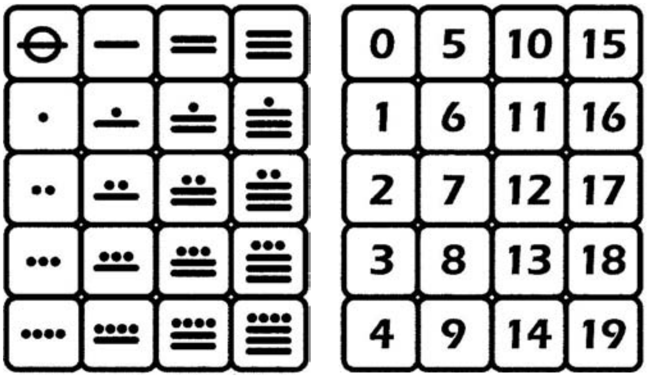

Any radially opposite set of numbers always equals 19, e.g., 4 and 15, 0 and 19, 9 and 10, 2 and 17, 11 and 8.

Nineteen is the highest value and the most saturated notation, being the only one with seven notational symbols—three bars and four dots.

Nineteen in galactic notation.
3 bars (3 x 5 = 15) plus four dots (4) = 19

Dot-bar notation system, 0–19 code

the fourth-dimensional number. One dot represents one unit; one bar represents a five-unit order; and a positional zero completes the system. The vigesimal notational system reveals the entire radial sequence of the 0-19 code to be a highly streamlined and aesthetic pattern. Brief contemplation shows that there are two patterned orders consisting of four vertical sets of five units each, and five horizontal sets of four units each. It is seen that nineteen represents the maximum saturation of both the vertical and horizontal orders, and consists of the maximum number of dots (four) and the maximum number of bars (three). It is also visibly manifest that 19 = 7 notational units, the maximum number of units.

The fact that 19 is represented by seven notational units confirms Sura 1, which has seven verses and the first line of which consists of nineteen Arabic letters. However, from the point of view of the Law of Time, 7 is the key implicit mathematical unit in the absolute timing frequency ratio, 13:20-the difference between 20 and 13 is 7, and the midpoint between 1 and 13 is also 7. While Dr. Khalifa is responsible for determining the dominance of nineteen as the mathematical key underlying the patterning and meaning of the Quran, the Law of Time provides an even more profound lens through which to consider Dr. Khalifa's work, by placing nineteen in a superior (vigesimal) mathematical and theological context.

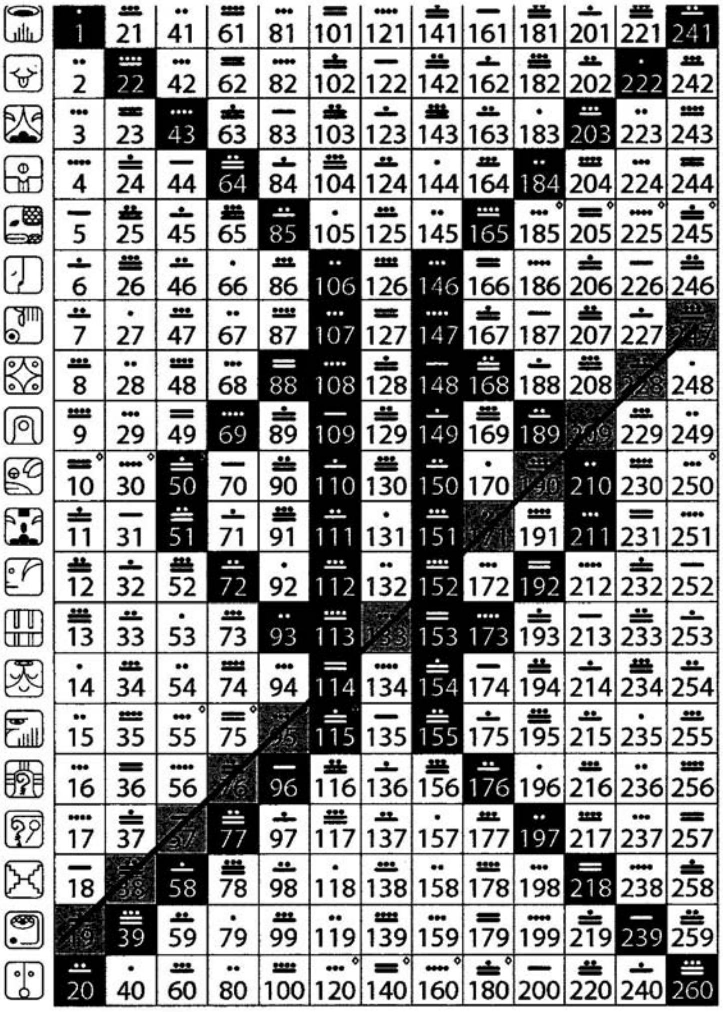

1	21	41	61	81	101	121	141	161	181	201	221	241
2	22	42	62	82	102	122	142	162	182	202	222	242
3	23	43	63	83	103	123	143	163	183	203	223	243
4	24	44	64	84	104	124	144	164	184	204	224	244
5	25	45	65	85	105	125	145	165	185	205	225	245
6	26	46	66	86	106	126	146	166	186	206	226	246
7	27	47	67	87	107	127	147	167	187	207	227	247
8	28	48	68	88	108	128	148	168	188	208	228	248
9	29	49	69	89	109	129	149	169	189	209	229	249
10	30	50	70	90	110	130	150	170	190	210	230	250
11	31	51	71	91	111	131	151	171	191	211	231	251
12	32	52	72	92	112	132	152	172	192	212	232	252
13	33	53	73	93	113	133	153	173	193	213	233	253
14	34	54	74	94	114	134	154	174	194	214	234	254
15	35	55	75	95	115	135	155	175	195	215	235	255
16	36	56	76	96	116	136	156	176	196	216	236	256
17	37	57	77	97	117	137	157	177	197	217	237	257
18	38	58	78	98	118	138	158	178	198	218	238	258
19	39	59	79	99	119	139	159	179	199	219	239	259
20	40	60	80	100	120	140	160	180	200	220	240	260

Nineteen Strand in Harmonic Module

Kin numbers beginning with 19, lower left, are advancing multiples of nineteen, the last being 19 x 13 (247). Actually, the difference between every kin number on this diagonal is a difference of 19.

19 = 260: THE TZOLKIN "OVER IT IS NINETEEN" STRAND

> *"All is number. God is a number. God is in all."*
>
> *-DYNAMICS OF TIME,* POSTULATE 19.13

The 0-19 code provides the order of 20 in the ratio 13:20. Like the 0-19 radial matrix, the 13:20 ratio is also organized as a radial matrix of 260 (13 x 20) kin or units. As a cycle of 260 days, the 13 x 20 timing matrix is the fourth-dimensional gauge that synchronically unifies the Thirteen Moon calendar. Known by the traditional and ancient Maya as the *Tzolkin* or "sacred count," the 13 x 20 gauge or Harmonic Module is the key to the mathematics of the fourth dimension, or the "Hereafter." Just as the mathematics of the third dimension is decimal-based, so the mathematics of the fourth dimension is vigesimal-based. Hence, the power of 20 as a self-existing proportion (4 x 5 = 5 x 4).

For any frequency to occur two proportions must be coincident. Thirteen, which is a function of the 7 factor, is the proportion that complements the 0-19 vigesimal proportion of 20. Hence the Tzolkin consists of twenty horizontal orders and thirteen vertical orders = 260 kin, which are also arranged in twenty sets of thirteen-kin wavespells, all numbered 1-13 in dot-bar notation. All of the kin in the 260-unit matrix are also individually numbered: kin 1, kin 2 . . . kin 259, kin 260.

Within the 13:20 order of260 kin, 13 sets of20 or 20 sets of 13, only two of the numbers in the vigesimal code 0-19 occur thirteen times: the number 19 and the number 20 (= positional zero). While 20 occurs precisely thirteen times, 19 occurs thirteen times with a remainder of thirteen (13 x 19 = 247 = 260 - 13).

The position and notational order of the thirteen occurrences of the number 19 in the 260-unit Tzolkin create a perfect strand of thirteen units. This 19 x 13 (19 = 260) strand demonstrates the supreme invariability and inviolability of the number 19 in the vigesimal code of fourth-dimensional time.

The purity of the movement of the 13 x 19 strand of the Tzolkin is further augmented by the vigesimal or 20-count manner of writing numbers. Even as transliterated into the Arabic system of writing numbers, it will be seen that in the vigesimal code every multiple of 19 always adds up to 19, a similar power held by all multiples of 9 in the decimal code. In vigesimal notation, the second order units are always multiples of 20 and not 10. Hence 38 = 1.18, where 1 = 20 + 18; or 5.14 = 114, where 5 = 100 + 14.

Finally, while the sequence 1-13 defines the thirteen galactic tones of fourth-dimensional time, the 0-19 matrix is represented by twenty icons and a four-color (4 x 5 = 20) permutation sequence. The combination of color, icon, and tone gives each of the 260 kin a "galactic signature." This completes the description of the Harmonic Modulerrzolkin.

We now present the thirteen multiples of 19 as defined by the 13 x 19 strand running from lower left to upper right in a perfect cross-stitch sequence that reverses the horizontal order of the 0-19 code frequencies. In other words, the first order represented is the order of (1 x 19) 19 (frequency 19, icon Storm), and the last is the

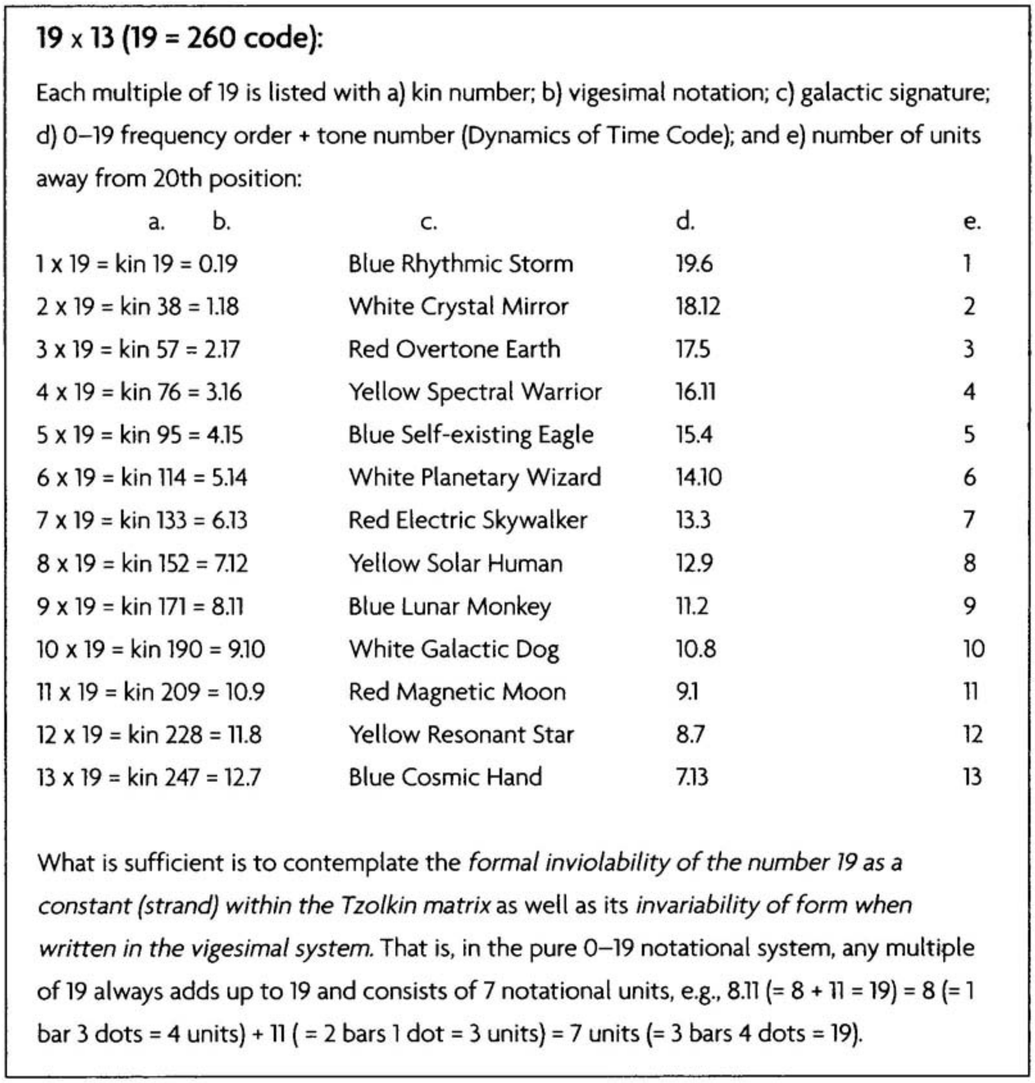

19 x 13 (19 = 260 code):

Each multiple of 19 is listed with a) kin number; b) vigesimal notation; c) galactic signature; d) 0–19 frequency order + tone number (Dynamics of Time Code); and e) number of units away from 20th position:

a. b.	c.	d.	e.
1 x 19 = kin 19 = 0.19	Blue Rhythmic Storm	19.6	1
2 x 19 = kin 38 = 1.18	White Crystal Mirror	18.12	2
3 x 19 = kin 57 = 2.17	Red Overtone Earth	17.5	3
4 x 19 = kin 76 = 3.16	Yellow Spectral Warrior	16.11	4
5 x 19 = kin 95 = 4.15	Blue Self-existing Eagle	15.4	5
6 x 19 = kin 114 = 5.14	White Planetary Wizard	14.10	6
7 x 19 = kin 133 = 6.13	Red Electric Skywalker	13.3	7
8 x 19 = kin 152 = 7.12	Yellow Solar Human	12.9	8
9 x 19 = kin 171 = 8.11	Blue Lunar Monkey	11.2	9
10 x 19 = kin 190 = 9.10	White Galactic Dog	10.8	10
11 x 19 = kin 209 = 10.9	Red Magnetic Moon	9.1	11
12 x 19 = kin 228 = 11.8	Yellow Resonant Star	8.7	12
13 x 19 = kin 247 = 12.7	Blue Cosmic Hand	7.13	13

What is sufficient is to contemplate the *formal inviolability of the number 19 as a constant (strand) within the Tzolkin matrix* as well as its *invariability of form when written in the vigesimal system.* That is, in the pure 0–19 notational system, any multiple of 19 always adds up to 19 and consists of 7 notational units, e.g., 8.11 (= 8 + 11 = 19) = 8 (= 1 bar 3 dots = 4 units) + 11 (= 2 bars 1 dot = 3 units) = 7 units (= 3 bars 4 dots = 19).

order of (13 x 19) 7 (frequency 7, icon Hand), showing again the intimate relation between 19, 13,6, 7, and 20, the key integers of the codes of fourth-dimensional time.

19 = 260, THE SIX SURAS THAT ARE MULTIPLES OF 19

In seeking proof of the Law of Time within the Quranic nineteen code, we need cite but a few examples that can demonstrate from within the nineteen code itself the key mathematical components of the Law of Time. In addition to the number 19, we must look for any of the factors involved in the 13:20 frequency, such as 260, 7, 6-the difference between 19 and 13-and, of course, 13 and 20, or any of the multiples of these integers.

Following the method of Dr. Khalifa, probability analysis of mathematical constituents based on the assumption that certain numbers will be self-verifying, we start our program with the six suras that are multiples of nineteen:

Sura 19	"Maryam"	98 verses
Sura 38	"Saad"	88 verses
Sura 57	"Iron"	29 verses
Sura 76	"The Human"	31 verses
Sura 95	"The Fig"	8 verses
Sura 114	"People"	6 verses
=399, total of sura numbers		=260 verses in six suras that are multiples of nineteen.
= 19.19 vigesimal code		

As can be seen, the sum of the six numbers of the suras that are multiples of 19 is exactly 399, or 19 x 21, the maximum factor in the vigesimal 20 x 20 matrix. Expressed in the vigesimal code this number, 399 = 19.19 [19 (x 20 = 380) +19], the only multiple of 19 in the vigesimal code that is written with two 19s, whose sum is precisely twice nineteen, 38, and is written with fourteen notational symbols rather than seven. This unique number, 19.19 (399), verifies "nineteen is over all," by placing 19 over 19 itself. The unique qualities of this most unique of multiples of 19 also indicates why the Quran consists of exactly six times nineteen suras. Six is the difference between the Quranic 19 and 13, the prime number of the Law of Time.

More amazing than the sum of the six suras that are multiples of 19 being 19.19 is the fact that the sum of the verses of these same six suras is 260. This is incontrovertible evidence for the formulation 19 = 260, and substantiates the mathematical patterning of the Quran to include the principle factor of the Law of Time, 260 (= 13 x 20). We are certain that Dr. Khalifa added the verses of these same suras and may have been perplexed at the meaning of the resultant number, 260. Of course, Dr. Khalifa did not know that 260 is the sum factor of the two proportions that create the natural timing frequency, 13:20.

It is also interesting that discovery of the 13:20 timing frequency, December 10, 1989, was made at almost the precise moment as Dr. Khalifa had completed the introduction to *The Pinal Testament,* the summation of his research on the Quranic nineteen code, Ramadan 26, 1409 (December, 1989). This points to the mysterious movement of the Divine Will in establishing the mathematical proof of the Quran. Just as the work of Dr. Khalifa was terminated within a month of his completing the Final Testament, so the Law of Time, which would substantiate and vindicate the Quranic nineteen code, was ordained and propelled into its process of manifestation at exactly the same moment.

Now with the Law of Time the investigation begun by Dr. Khalifa is complete. Just as there are six suras that are multiples of 19 within the Holy Quran, so the key factor of the Law of Time, the number 260, is coded into the sum of the verses of these six suras. The door is opened for entirely new comprehension of the meaning and purpose of the Holy Quran. The Law of Time and the Holy Quran in mutual resonance will establish the proof of the advent and triumph of the Religion of Truth. (9:33,48:28; 61:9)

Most of the foregoing text of Appendix IV is taken from 19 = *260: The Holy Quran and the Law of Time* (1999), an unpublished manuscript by Jose Argiielles.

▼

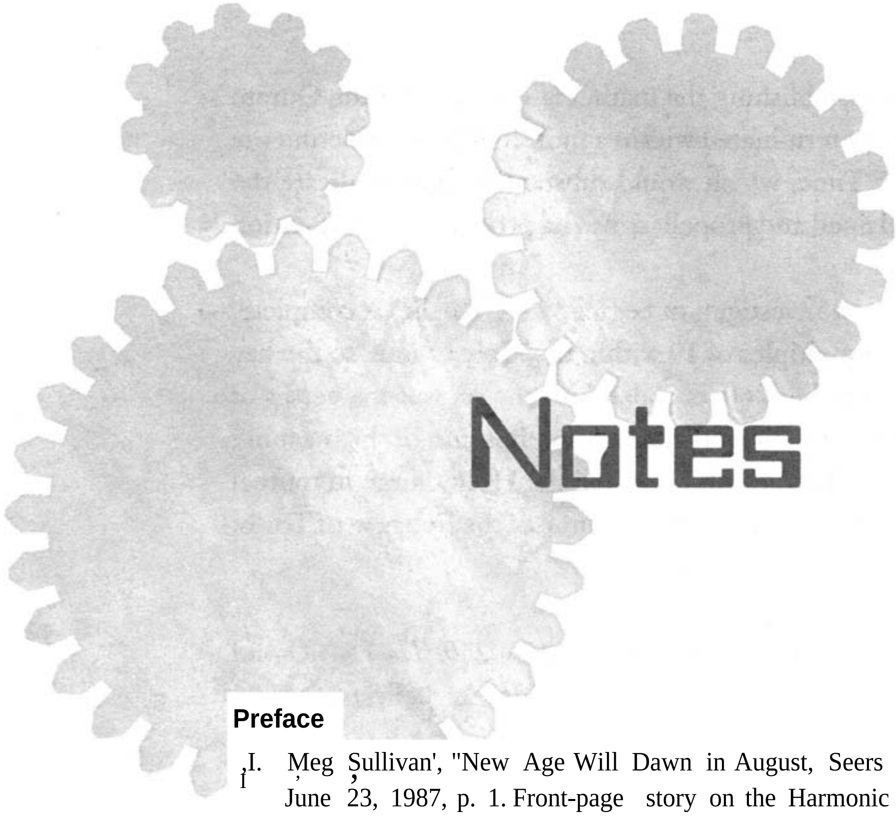

Notes

Preface

1. Meg Sullivan, "New Age Will Dawn in August, Seers Say. . .," *Wall Street Journal,* June 23, 1987, p. 1. Front-page story on the Harmonic Convergence.
2. For the prophetic tradition of the Chilam Balam, see *The Book of Chilam Balam of Chumayel,* edited and translated by Ralph L. Roys (Norman, Okla.: University of Oklahoma Press, 1967); *The Codex Perez and the Book of Chilam Balam of Mani,* edited and translated by Eugene Craine and Reginald Reindorp (Norman, Okla.: University of Oklahoma Press, 1979); and *El Libro de los Libros de Chilam Balam,* edited and translated by Alfredo Barrera Vasquez and Silvia Rendon (Mexico City: Fondo de Cultura Economica, 1948, 1986). The issue of being a "prophetic messenger" is a touchy one for many people. However, as it is written in the Quran, "In truth we are always sending messengers. . ." (44:5). Messengers, as often as not, are self-revealed and confirmed only by God. In my case, I have been able to trace back the prophetic lineage of the Chilam Balam to Pacal Votan, from whom I have received direct transmission. The method of transmission is similar to that of the *terma* tradition of Tibet. Terma, or "hidden treasure," is left by a sage or prophet to be "discovered" at a precise moment much later in time by one designated to do so. See Tulku Thondup Rinpoche, *Hidden Teachings of Tibet: An Explanation of the Terma Tradition of Tibetan Buddhism* (Boston: Wisdom Publications, 1997).
3. This phrase is used often by Dr. Rashad Khalifa (1935-1990), whose groundbreaking translation and research of the Quran through the aid of the computer led to the discovery of the intricate nineteen-based mathematical code that underlies this unique text. His work is summarized in his translation of the Quran with its numerous appendices, *Quran: The Final Testament* (Fremont: Universal Unity, 1992). My own studies on this topic have resulted in two works: *Pacal TfJtIlm and Judgement Day* (portland, Oreg.: Planet Art Network, 1999), and 19 = *260: The Holy Quran and the Law of Time,* unpublished, 1999. See also Appendix IV to this book, "The Nineteen Code."

4. See, for example, Samuel P. Huntington's *The Clash of Civilizations and the Remaking of the World Order* (New York: Simon & Schuster, 1996, 1997); Benjamin R. Barber's *Jihad vs. McWorld* (New York: Random House, 1995, 1996); and Yossef Bodansky's *Bin Laden: The Man Who Declared War on America* (New York: Forum, 1999,2001). These writers, of course, all express a pro-globalization perspective.

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2. Jose ArgUelles, *The Call ofPacal Votan: Time is the Fourth Dimension* (Glasgow: Altaea, 1996), 37.
3. Jose ArgUelles, *The Dynamics of Time: 260 Postulates* (Portland, Oreg.: Planet Art Network, 1999),30.
4. Kareng Koshev, "The Great Rainbow Bridge." Altai: unpublished paper, 2001.

Chapter 2

1. 1. Laptev, *The Planet of Reason: A Sociological Study of the Man-Nature Relationship* (Moscow: Progress Publishers, 1973; English translation, 1977),220.
2. V. 1. Vernadsky, "L'etude de la vie et la nouvelle physique" in *Revue generale des sciences,* vol. 41: 695.
3. V. 1. Vernadsky, *The Biosphere* (1926), abridged version (Oracle, Arizona and London: Synergetics Press, 1986), 22.
4. Ibid., 76.
5. Ibid., 77-78, 81.
6. Ibid., 82.
7. Ibid.
8. V. 1. Vernadsky, "Problems in Biogeochemistry II," in *Transactions of the Connecticut Academy of Sciences* (New Haven: Yale University Press, 1944),487-88,498.
9. v.1. Vernadsky, "Problems in Biogeochemistry II," Postulate 18, 511-12.
10. Jose ArgUelles, *The Dynamics of Time: 260 Postulates* (Portland, Oreg.: Pbnet Art Network, 1999), postulates 3.7 and 3.9, 24, 25.
11. V. 1. Vernadsky, "Some Words about the Noosphere" (1944), quoted in Andrey Lapo, *Traces of Bygone Biospheres* (Moscow and London: Mir Publishers and Synergetic Press, 1987),69.
12. Ibid., 71.
13. G. E. Hutchinson, "The Biosphere," *Scientific American,* vol. 53, no. 3 (1970): 223. Quoted in Lapo, *Traces of Bygone Biospheres,* 77.
14. P. Duvigneaud, "Noosphere et l'avenir de la vegetation du globe," *Proceedings of the XII International Botanical Congress, Bruxelles,* 1979, 78. Quoted in Lapo, *Traces of Bygone Biospheres,* 76.

15. Tango Snyder, editor in chief, *The Biosphere Catalogue* (London and Forth Worth: Synergetic Press, 1985), 103.
16. V. 1. Vernadsky, "Scientific Thought as a Planetary Phenomenon," quoted in Lapo, *Traces of Bygone Biospheres, 73-74.*
17. Vernadsky, "Problems in Biogeochemistry II," 511.

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1. Maria Maroushkina, "Is a Path Beyond Technology Possible for the Western Culture?" Moscow: unpublished research paper, 2000.
2. James Glanz, "Physics' Big Puzzle Has Big Question: What Is Time?" *New York Times,* June 17,2001, p. D-1.
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2. Jose and Lloydine Argiielles, *Dreamspell: The Journey of Timeship Earth 2013,* (Hong Kong: Interlink Productions, 1991), 35.
3. Ibid., 5-9.
4. Ibid., 14-15,60,61.
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6. *Epic of Gilgamesh,* translated by Caravan of Dreams Theater, quoted in *The Biosphere Catalogue, 116.*

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1. *Webster's Ninth New Collegiate Dictionary,* (Springfield: Merriam Webster, 1987), 1211.
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3. Paul Foster Case, *The Tarot: A Key to the WISdom of the Ages* (New York: Macoy, 1947), 158.
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1. Mahatma Ghandi, "Gandhi on Calendar Reform," *The Journal of Calendar Reform,* vol. I (New York: The World Calendar Association, 1931): 143.
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7. Argiielles, *The Dynamics of Time,* postulate 6.4,34.
8. *I Ching or Book of Changes,* translated by Richard Wilhelm and Cary F. Baynes (Princeton: Princeton University Press, 1967), 189.
9. Richmond, *Time Measurements and Calendar Construction, 70-71.*
10. David Ewing Duncan, *Calendar: Humanity's Epic Struggle to Determine a True and Accurate Year* (New York: Avon Books, 1998),307.
12. Richmond, *Time Measurements and Calendar Construction, 16.*

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1. Pierre Teilhard de Chardin, *The Phenomenon of Man* (New York: Harper & Row, 1955),288
2. For an enlightening look at the subject of *triskaidekaphobia,* see Jonathon Cott, *Thirteen: A Journey into the Number* (New York: Doubleday, 1996).

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5. *National Geographic Magazine*, publicity blurb, 2001.
6. "Tracking the Hijackers," *The Oregonian*, October 4,2001, p. A-12. See also Appendix Iv, "The Nineteen Code."
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8. Ibid., 518-19.

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1. See, for instance, Dan Oldenburg in the *Washington Post's* full-page article, "The Harmonic Convergence Revisited," May 4, 1990, p. D- 5.
2. *Nuestra Civilizacion Frente a la Reforma del Calendario* (Our Civilization Confronted with Calendar Reform) (Buenos Aires: Casa Editora Sudamericana, 1944), 6.
3. F. H. Colson, *The Week: An Essay on the Origin and Development of the Seven-Day Cycle* (Cambridge: Cambridge University Press, 1926), 2.
4. Quoted in Jose Argiielles, *Charles Henry and the Formation of a Psychophysical Aesthetic* (Chicago: University of Chicago Press, 1972), 128.

Appendix I

1. *San Jose Mercury News*, quoted on book cover of David Ewing Duncan's *Calendar, 1998.*
2. Duncan, *Calendar*, 289.
3. Philip, *Reform of the Calendar*, 10 1-2.

Appendix II

1. Charles Muses, *Destiny and Control in Human Systems: Studies in the Interactive Connectedness of Time (Chronotopology)* (Boston- Dordrecht- Lancaster: Kluwer-Nijhoff Publishing, 1984), 20-21.

Appendix IV

1. Rashad Khalifa, *Quran: The Final Testament*, (Fremont, Calif.: Universal Unity, 1992), 375. All further quotes from the Quran and from Rashad Khalifa are from this same work, which in addition to containing the complete Quran in translation also includes thirty-eight Appendices summarizing Dr. Khalifa's research.
2. Ibid., 375.
3. Ibid., 123.
4. Ibid., 375.

Glossary

THIS GLOSSARY IS constructed to aid the reader in developing a more systematic and technical comprehension of the Biosphere and the Law of Time. Though by no means exhaustive, it is hoped that the terminology used in the text is herein defined in a manner appropriate to cultivating a noospheric point of view.

13:20 timing frequency: Fourth-dimensional timing frequency mathematically expressed as the ratio constant .13:20; universal frequency of synchronization by which the universe is maintained in synchronic order; basis of Law of Time; codified as 260-unit 13:20 matrix of Harmonic Module, coordinates Thirteen Moon/28-Day calendar with synchronic order.

12:60.timing frequency: Artificial, purely third-dimensional timing frequency based on combination of irregular twelve-month calendar and mechanistic sixty-minute hour, adoption of which results in unconscious program within the human mental order, causing the species to deviate altogether from the natural biospheric order, resulting in the technosphere.

astronomical time: Measure of time in third-dimensional physical space without regard to intrinsic harmonics of the synchronic order, usually interpreted as duration and, based solely on matter that is in constant state of entropy, results in standards of measure characterized by infinitesimal.slippages of time and consequent fractional number sequences in need of periodic correction.

baktun: Fifth order of Mayan vigesimal number sequence; in time reckoning equals 144,000 kin (days), or 394.52 years; thirteen per great cycle, measure of human historical era or "great cycle": 3113 B.C.-A.D.2012.

biogenic migration of atoms: Biospheric principle by which evolution over time within finite quantity of living matter (biomass) is accounted for by changes of atomic.,cellular-molecular state and condition; occurring uniformly at periodic transitions accounts for major evolutionary mutations.

biogeochemical, biogeochemical combustion: Term used by V. 1. Vernadsky to refer to biospheric dynamic as whole system order unifying living (bio) and inert (geochemical) matter in a single process; biogeochemical combustion occurs when exponential curve of acceleration of biogenic migration of atoms becomes absolutely vertical, precipitating advent of noosphere.

biomass, biomass constant: Sum quantity of living matter, which, according to Vernadsky, has remained relatively stable since the origin of life on Earth; as a constant, maintained by synchronic timing factor mathematically described as an annual orbital ratio of 73(5) = 365 days per solar orbit of Earth.

biosphere: Sphere or mantle of life and its geochemical support system distributed throughout Earth's ocean-land surface

biosphere-noosphere transition: Description of the transformation of the general biospheric condition due to accelerated excitation of biogenic migration of atoms creating release of free energy and consequent biospheric destabilization, characterized as biogeochemical combustion, whose resolution is emergence of new evolutionary order, the noosphere; change from historical technosphere to post-historic, post-technological phase.

Bolontiku: Nine Lords of Time; in Mayan cosmology, nocturnal rulers of the underworld or *inframundo;* guardians of the passage of death and resurrection; keepers of time and the knowledge of time as noospherically registered in Earth's orbit.

calendar: Derived from the Latin *calends,* or account book, a day for making payments; generic word used to define systems of timekeeping based on measure of Earth's orbit around the sun, often utilizing synodic measure of the moon as a means of calculating.

Chilam Balam: "Jaguar priest," name of Mayan prophet *(ah bobat)* who lived just before the time of conquest, which he accurately predicted; name given to lineage of Mayan prophets extending from the end of tenth baktun (circa A.D. 830) up until the nineteenth century; name given to series of post-conquest texts in which the various categories of prophecies of this lineage are recorded.

chronomancy, geochronomancy: "Divination by time"; the science and art of fourth-dimensional time considered as a whole system where science is knowledge and art is practice; oracular method of reading the synchronic order; description of incipient "Earth time science" incorporating principles of whole Earth geomancy into time structures of the synchronic order.

chronosphere: Sphere of time that activates noosphere; fourth-dimensional field created by the planet holon in resonance with the rotation of the third-dimensional planet body; coded as movement of four chromatics (biopsychic field) across the planet holon, stitching together gravitational fields (five Earth families) and electromagnetic fields (four color families).

chronotopology: Term coined by Charles Muses to define any geography of time and consisting of an event point of meaning that creates a root meaning from which time-formed, -blossomed, or -radiated meanings emerge above a horizon of meaning.

Day Out of Time: The 365th day of the Thirteen Moon/28-Day calendar, no day of the week or month at all (52 x 7 day weeks = 13 moons times 28 days = 364); occurs on Gregorian correlate date July 25, and precedes Thirteen Moon "New Year's" or synchronization date, correlated to July 26.

Dreamspell: Any agreed-on consensus reality; a collective mind-set defining a noospheric epoch, such as "Dreamspell of history"; term given to proofs and tools demonstrating radial and fractal principles of fourth-dimensional mathematics; cosmo-mythic structure of Earth history and its future, otherwise known as *Dreamspell: The Journey of Timeship Earth 2013.*

free energy: Release into biosphere of gases (such as carbon monoxide) and other chemical by-products of industrialization that accelerate biogenic migration of atoms, resulting in biogeochemical combustion; in noosphere refers to release of spectral plasmic-atmospheric phenomena through human telepathic interaction with the electromagnetic field.

fourth dimension: Dimension of time greater than and containing three dimensions of space that it informs and governs.

galactic signature: Combination of one of thirteen galactic tones and twenty solar seals that constitute the harmonic module and that code any given day of the third-dimensional Thirteen Moon calendar.

geocosmic: Holonomic perception expressing unification of Earth whole with the cosmic order.

Gregorian (Julian) calendar: Current world standard calendar consisting of twelve irregularly numbered and obscurely named months coordinated by the 7-day week and intercalary leap year system establishing 28-year cycles; created by the reform of Pope Gregory XIII (1572-1583) in 1582, which "corrected" the Julian calendar (established by Julius Caesar, 45-44 B.C.)by lopping off ten days and refining the intercalary system so that only centuries that are multiples of four are leap years; supreme example of astronomical time measure; principle macro-organizing principle establishing 12:60 artificial timing frequency.

Hannonic Module: 260-unit mathematical matrix of 13:20 frequency, inclusive of a 52-unit binary triplet configuration or set of galactic activation portals; sometimes referred to as Tzolkin, 260-kin sacred count of the Maya; basis of fourth-dimensional vigesimal mathematics of time; coordinated with third-dimensional calendar of Thirteen Moons, establishes basis of 260 galactic signatures.

heliosphere: Sun and its system of planets considered as a whole organism; also known as heliocosm.

holonomics: Of or pertaining to the law governing whole systems.

holonomic consistency and reciprocity: Law by which any whole principle of reality is capable of evoking a like response or reflecting a fractal order at whatever level or through whatever structure.

holon: Any organic whole unit, fractally replicable; basis ofholonomics, law governing whole systems.

human holon: Fourth-dimensional structure of the human being conforming to the 13:20 frequency (twenty digits, thirteen main articulations).

Hunab Ku: "One giver of movement and measure"; in Mayan cosmology, can refer to God as the Supreme Creator.

Inevitable Event: Law of Time definition of the point in synchronic order when the artificial time generated curves of machine, human population, and money converge exponentially in one dramatic, prophecy-fulfilling moment, marking the conclusion oftechnospheric expansion; name given to the events of September 11, 2001 (9-11), epitomized by the collapse of World Trade Center Twin Towers (Fall of Babylon).

Julian Count: Established by Thomas Scaliger, 1583, the year after Gregorian calendar "reform," to establish a linear count of days beginning January 1, 4714 B.C.,some 1,600 years prior to commencement of thirteen baktun Long Count of the Maya; official modern scientific count, basis of linear time paradigm.

katun: Fourth order of vigesimal mathematics = 8,000 kin; in Mayan time count, where the second order vinal is 18 and not 20, a katun = 7200 kin, or 19.7 solar years; twenty katuns equal one baktun of 144,000 kin; 260 katuns per thirteen baktun cycle.

kin: In fourth-dimensional mathematics the base unit of measure, possessing fractal properties; one day and night or turn of Earth on its axis; any human being so designated by assuming the galactic signature of the date of birth.

Law of Time: T(E) =Art, Energy factored by Time equals Art, where T (time) is the fourth-dimensional universal synchronization frequency constant 13:20, E (energy) refers to any phenomenal manifestation, and Art to the fact that the synchronizing frequency of time harmonizes everything into a natural condition of beauty.

Long Count: Mayan count of days (kin) measured by thirteen baktuns of 144,000 days each for a total of 1,872,000 kin, the measure of history from JulianiGregorian correlates August 13, 3113 B.C. to December 21, 2012; still maintained through use of Tzolkin by Quiche Maya, Guatemala.

lunar calendar: System of time measurement using synodical measure of the moon-from new moon to new moon, approximately 29.5 days; twelve lunar months equaling a total of 354 days, eleven days short of the measure of solar orbit; used by many of the Old World civilizations; with the exception ofIslamic lunar calendar, most lunar calendars intercalate a thirteenth moon, seven per every nineteen years.

machine: Capacity for the human to externalize its internal processes as well as motor functions into different means of mechanical reproduction, the sum possibilities of which establish a technological complex requiring constant maintenance, thus subordinating human consciousness to its level; the ultimate manifestation of the 12:60 timing frequency; any industrially produced tool believed to advance the level of human comfort and accomplishment.

noosphere: Earth's mental envelope or field, discontinuous with and above the biosphere; unconscious until the discovery and application of the Law of Time; activated by registration of the human biomass in correct 13:20 timing frequency via universal adoption of Thirteen

Moon calendar; description of transformed state of biosphere, coincident with the end of history; condition of universal telepathy subsequent to collapse of technosphere and application of Law of Time; functions in tandem with programs from Earth's octahedral core.

noospheric chip: Description of human operating in noosphere, holonomically resonant with intrinsic 13:20 codes of synchronic order, capable of interacting with the psi bank to participate in the creation of Earth's rainbow brain.

Noospheric Earth Time (NET): Time measure based on Earth in its orbit in relation to the sun and moon in heliospheric space, rather than from the perspective of human (astronomical time); base unit of measure is one rotation of Earth on its axis or one kin (one night and day), which establishes one NET minute; twenty-eight NET minutes per Moon, or one NET hour, 365 NET minutes, or Thirteen NET Hours plus one NET minute per solar orbit; takes into account that for any NET minute axial magnetic bipolarity of Earth is a changing dynamic reaching two peak points called solstices and two stable points called equinoxes; this four-part division is holonomically registered daily in two peak points, midnight (where day begins and ends) and noon, and two stable points, sunrise and sunset.

occult quartet: Demonstration of radial mathematics of Harmonic Module where the tones of any four kin radially equidistant from each other always equal 28; or the tones of any two kin radially opposite always equal 14.

octahedral core: Iron crystal structure at center of Earth; plasmic storage zone in resonance with the noosphere; in 7:7::7:7, telepathically coordinated by four time atoms (= one master time molecule).

omega point: In the work of Pierre Teilhard de Chardin, defines the climactic convergent point (harmonic convergence) of human evolution as the emergence of the hyper-personal; defined by the Law of Time as point of full superconscious establishment of universal telepathy as the norm of the human mental condition; dawn of omega point: winter-northern-summer-southern solstice, 2012, completion of omega point dawn, Yellow Galactic Seed (July 26,2013), otherwise known as Dreamspell of galactic culture.

oracle: For anyone of 260 kin of the Harmonic Module, a cruciform five-part structure demonstrating a uniform set of mathematical relationships in relation to the (0-19) code number of the daily solar seal (destiny kin) informing any day of the Thirteen *Moonl2* 8-Day calendar; consists of center, code number of destiny kin; right analog kin-always 19 when added to the number of destiny kin; left, antipode kin-always a difference of 10 from the destiny kin; below, occult kin-when added to destiny kin always equals 21; and above, guide, always the same color as destiny kin.

Oxlahuntiku: The Thirteen Lords of Time that govern the power of the cosmic order of time that is based on circulatory power of prime number 13 (as opposed to 12, which is static and non-circulatory); coded as thirteen 28-day moons that govern terrestrial solar orbit; basis of prophecy cycle of Quetzalcoatl, Thirteen Heavens (Oxlahuntiku) and Nine Hells (Bolontiku); in Telektonon prophecy, the thirteen-year cycle-2 000-2 013-in which the first four years, 2000-2004, establish self-existing power of time, and last nine years, 2004-2013 are coded by the Bolontiku, the Nine Lords of Time.

Pacal Votan: Mayan prophet (A.D.603--683), chief technician of Mayan synchronic time science; eleventh ruler of the dynasty of Palenque (Nah Chan), Chiapas, Mexico; assumed power in A.D.615, but key rulership occurred in critical 52-year cycle, 631-683 (seventy-third such cycle since commencement of thirteen baktun count); best known for the carved sarcophagus lid of his elaborately concealed tomb discovered in 1952, 1,260 years after its dedication in A.D.692, which was also 1,320 years before the closing of the cycle, 2012.

Pax Cultura, Pax Biospherica: Principle of new human social order following establishment of Thirteen Moon/28-Day calendar and inaugurating the advent of the noosphere (2004) in which nation-state is replaced by biospheric regionalism governed by a Planetary Biospheric Assembly; due to perfect harmony of new world standard calendar of thirteen moons/28 days, harmony, art, and aesthetic values elevate culture as the new operating norm of the human reintegrated within the biosphere, hence *Pax Cultura, Pax Biospherica.*

planet holon: Twenty-part icosahedral noospheric matrix superimposed on Earth's surface; corresponding to 0-19 code of twenty solar seals, creates three orders analogous to three planetary fields of resonance; gravitational field-horizontal order of five Earth families of four seals each; electromagnetic field-four diagonal bands, from lower left to upper right, of the four color families (red, white, blue, yellow) of five seals each; and biopsychic field-the four chromatics of five seals each moving diagonally from upper left to lower right, which coordinate the daily sequence of the motion of the chronosphere.

psi bank: Regulating mechanism of the noosphere consisting of four bipolar plates, each plate in mirror symmetry containing 520 (260 x 2) psi chrono units, 2,080 in all, which are the complete registrations of the universal fourth-dimensional 13:20 timing frequency governing all of the various evolutionary stages of the terrestrial biogeocosm; engine of the chronosphere, located between the two radiation belts 2,000 and 11,000 miles above Earth's surface.

psi chrono unit: Time-bearing information unit; base unit of the psi bank; codes and contains all information for anyone of the 260 galactic signatures of the 13:20 matrix or Harmonic Module; psycho activated through coordination with Thirteen Moon/Telektonon known as Rinri Project.

Psychozoic Era: Term coined by V. 1. Vernadsky defining the next geological era; meaning the era of the spiritualization of life, it is coincident with the noosphere in its full emergence after the omega point has been reached, 2012-2013.

Quetzalcoatl: Mexican prophet (A.D.947-999) who left the legacy of prophecy of Thirteen Heavens and Nine Hells, basis of Harmonic Convergence (1987) and commencement of the "Time of Prophecy," 1987-2013.

Quran, Holy Quran: Literally "recitation;" last revelation and moral-spiritual criterion for historic humanity; received over a twenty-three-year period by the Prophet Muhammad (A.D.570-632); proven by Dr. Rashad Khalifa (1935-1990) to be a radically nonlinear text rigorously constructed of a nineteen-based mathematical code.

radion, radial plasmas: Telepathic fluid or lubricant released through telepathic interaction with the seven primary plasmas, or electrically charged particles, hence radial plasmas; the names of the seven plasmas replace the names of the week in the Thirteen Moon/28-Day calendar; activated in the 7:7::7:7 Telektonon Revelation practice.

radiosonics: Name given to the new science based on synchronicity rather than causality and in which, as a consequence, synaesthetic experiences and syntropic values are normalized.

rainbow brain: Description of activated noosphere, where human telepathic interaction with the electromagnetic field triggers the release of the circumpolar rainbow bridge-Earth's day-night alternator system.

Rinri Project: Law of time practice for coordinating the opening of the psi bank, psi chrono unit per psi chrono unit, on a daily basis over a four-year cycle by means of the Thirteen MoontTelektonon.

synchronic order: Order of fourth-dimensional time, in contrast to third-dimensional astronomical time, that synchronizes all aspects of third-dimensional physical plane reality including its timekeeping systems; entirely new domain of human mental-spiritual experience coincident with the dawning of noosphere; characterized by absolute harmonic perfection, described by vigesimal 0-19 code, as distinct from decimal, hex, or duodecimal mathematics that govern third-dimensional timing codes.

synchronometer: Measure of synchronization or synchronicity; precise Law of Time definition of means and purpose of what is generically referred to as the "calendar."

technosphere: Global sphere of technology; artificial stage between biosphere and noosphere, representing the climax-biogechemical combustion-of acceleration of biogenic migration of atoms precipitating biospheric crisis as a prelude to the advent of noosphere; characterized by exponential curves of human population, machine, and money at expense of biospheric integrity and stability; defined as the specific fifty-six-year cycle (two Gregorian 28-year cycles) 1945-2001, in which war and terrorism are the governing features; complete manifestation of the 12:60 order of time; concluded on September **11,2001,** the Inevitable Event.

Telektonon: "Earth Spirit Speaking Tube," the name of the psychoduct leading from the tomb of Pacal Votan beneath the Temple of the Inscriptions to the temple floor atop the pyramid, the discovery of which, in 1949, led to the excavation and revelation of the long-concealed tomb in 1952; name given to the prophecy ofPacal Votan, decoded in 1993-1994, prophesying the Thirteen Moon/28-Day calendar as the only means to keep the human race from destroying the biosphere and itself; definition of the fourth-dimensional structure of the heliosphere in which consciousness is a function of the planetary orbits; basis of a board "game" coded to synchronic order via Thirteen Moon calendar for the awakening of telepathy; basis of the Cube of the Law, days 7-22, containing numerous principles of the Law of Time as a daily practice; basis of other practices for establishing synchronic order as principles of a new consciousness, including *20 Tabletsof the Law of Time* and the 7:7::7:7.

third dimension: Space; physical plane of reality coordinated and contained by time, fourth-dimensional order of reality.

Thirteen Moon/28-Day calendar: Pragmatic application of the Law of Time, perpetual harmonic perfection of which is intended to correct for disorder of human consciousness resulting from adherence to irregular, astronomical timing standards and mechanistic timing devices; coordinated with Harmonic Module and Telektonon establishes means for conscious human participation in synchronic order; 28-day measure based on female menstrual cycle, also corresponds to apsidal measure of moon from the point at which the polar axis is tipped farthest from Earth; prevalent in pre-history, all but eliminated by historical consciousness that made 13 taboo; perfect vehicle for establishing noosphere as daily consciousness in post-technospheric post-history.

time: Fourth dimension; universal factor coordinating space to manifest synchronically; traveling faster than speed of light, accounts for instantaneity of information transmission (telepathy) from distant points; expressed as formulation which states that the velocity of time is instantaneously infinite; fourth-dimensional structures that are radial and fractal in nature, third-dimensional cycles being manifestations thereof; expressed as T(E) = Art, accounts for universal harmony of the cosmos.

tun: Third positional order of vigesimal mathematics where one unit = 400 kin; in Mayan time count, because of second positional order, vinal, being 18 instead of 20, one tun = 360 kin; basis of measure ofkatuns and baktuns in Long Count, where 5,200 tuns = 260 katuns = 13 baktuns, or 5,125 solar years.

Tzolkin: "Sacred Count," 260-day calendar of the Maya, basis of Mayan time knowledge and the Long Count; temporal manifestation of Harmonic Module or universal 13:20 timing matrix.

UR: "Universal Religion," "Universal Recollection;" description of human spirituality in the noosphere or Psychozoic Era.

vigesimal, 0-19 code: Twenty-count based mathematics utilizing zero for positional orders that advance in exponential binary fashion; also known as 0-19 dot-bar code notational system, where dots equal single units, bars equal five units, plus positional zero; basis of mathematics of fourth-dimensional order of time, distinct from mathematical systems of third-dimensional space.

Wave Harmonic of history: Fourth-dimensional description of thirteen baktun cycle (3113 B.C.-A.D.2012) identified precisely with 260-unit Harmonic Module, where each of thirteen baktuns contains twenty katuns (13 x 20); basis of creating synchronic order out of entropic disorder of third-dimensional historical time.

wavespell: Thirteen-unit cosmological form-constant for coordinating fourth-dimensional timing cycles; consists of two gates, Magnetic first position and Cosmic thirteenth position; two towers, fifth and ninth positions; and three sets of chambers, nine chambers in all; when coordinating Thirteen Moon/28-Day calendar, known as Planetary Service Wavespell.

Wizard's Count: Name of count to establish synchronic order as manifestation of the Law of Time in order to transit from 12:60 technosphere to 13:20 noosphere; based on prophetically modified year-bearer count of the Chilam Balam tradition; correlated by the Dreamspell to July 26, 1987, White Galactic Wizard, every four years there are four year bearers: Yellow Seed, Red Moon, White Wizard, and Blue Storm (one four-year Seed-Storm Year bundle) that, combined with thirteen galactic tones creates 52-year solar-galactic cycle, or in NET time, one Earth Year, also known as a Wizard's Year.

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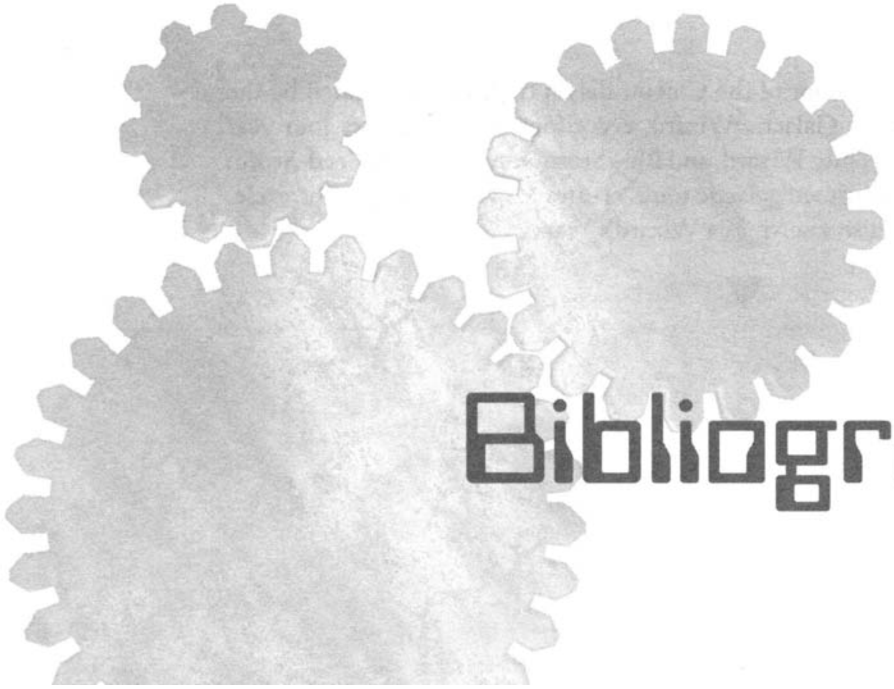

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in one hour your doom has come!"
—Revelations, 18:10

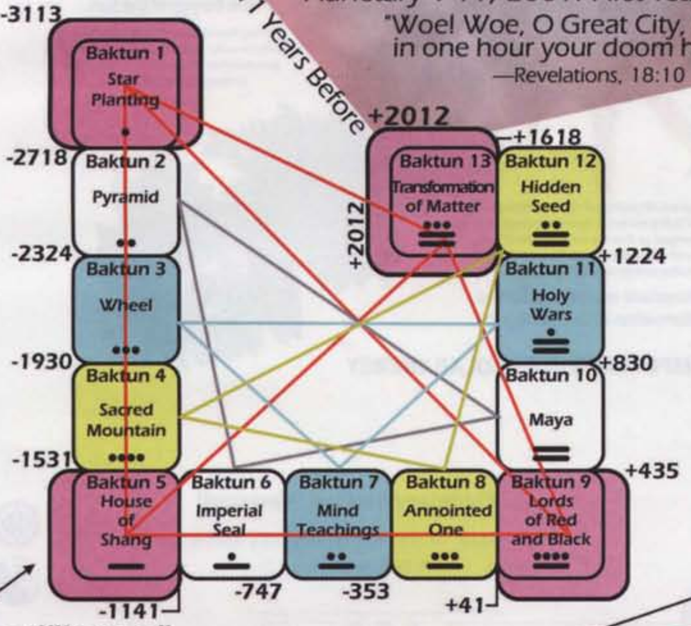
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-3113
Baktun 1
Star Planting
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Baktun 2
Pyramid
-2324
Baktun 3
Wheel
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Sacred Mountain
-1531
Baktun 5
House of Shang
-1141
Baktun 6
Imperial Seal
-747
Baktun 7
Mind Teachings
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Baktun 8
Annointed One
+41
Baktun 9
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Maya
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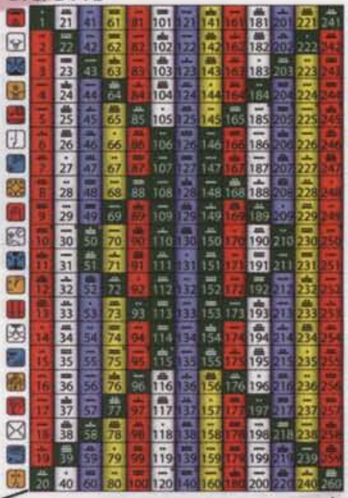

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3	23	43	63	83	103	123	143	163	183	203	223	243
4	24	44	64	84	104	124	144	164	184	204	224	244
5	25	45	65	85	105	125	145	165	185	205	225	245
6	26	46	66	86	106	126	146	166	186	206	226	246
7	27	47	67	87	107	127	147	167	187	207	227	247
8	28	48	68	88	108	128	148	168	188	208	228	248
9	29	49	69	89	109	129	149	169	189	209	229	249
10	30	50	70	90	110	130	150	170	190	210	230	250
11	31	51	71	91	111	131	151	171	191	211	231	251
12	32	52	72	92	112	132	152	172	192	212	232	252
13	33	53	73	93	113	133	153	173	193	213	233	253
14	34	54	74	94	114	134	154	174	194	214	234	254
15	35	55	75	95	115	135	155	175	195	215	235	255
16	36	56	76	96	116	136	156	176	196	216	236	256
17	37	57	77	97	117	137	157	177	197	217	237	257
18	38	58	78	98	118	138	158	178	198	218	238	258
19	39	59	79	99	119	139	159	179	199	219	239	259
20	40	60	80	100	120	140	160	180	200	220	240	260

A.D. 2012

Baktun 13 - Katun 260 - 1993 - 2012
End of Second Christian Millennium A.D. 2000

13 Tone Wavespell
as Thirteen Baktun
Wave Harmonic
of History

Harmonic Module
13 Baktun
260 Katun
13:2 Matrix of History
1 Kin = 1 Katun
1 Baktun = 20 Katuns

THE END OF THE WORLD

O FIM DO MUNDO

Cover of "Istoe" (Brazil) May, 1996. "End of the World."

Nostradamus Prediction of nuclear destruction of New York in Year 2000

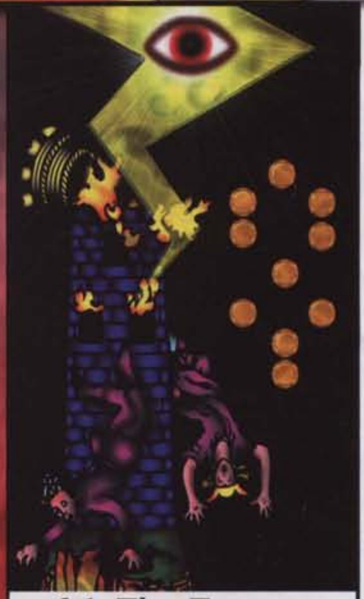

16. The Tower

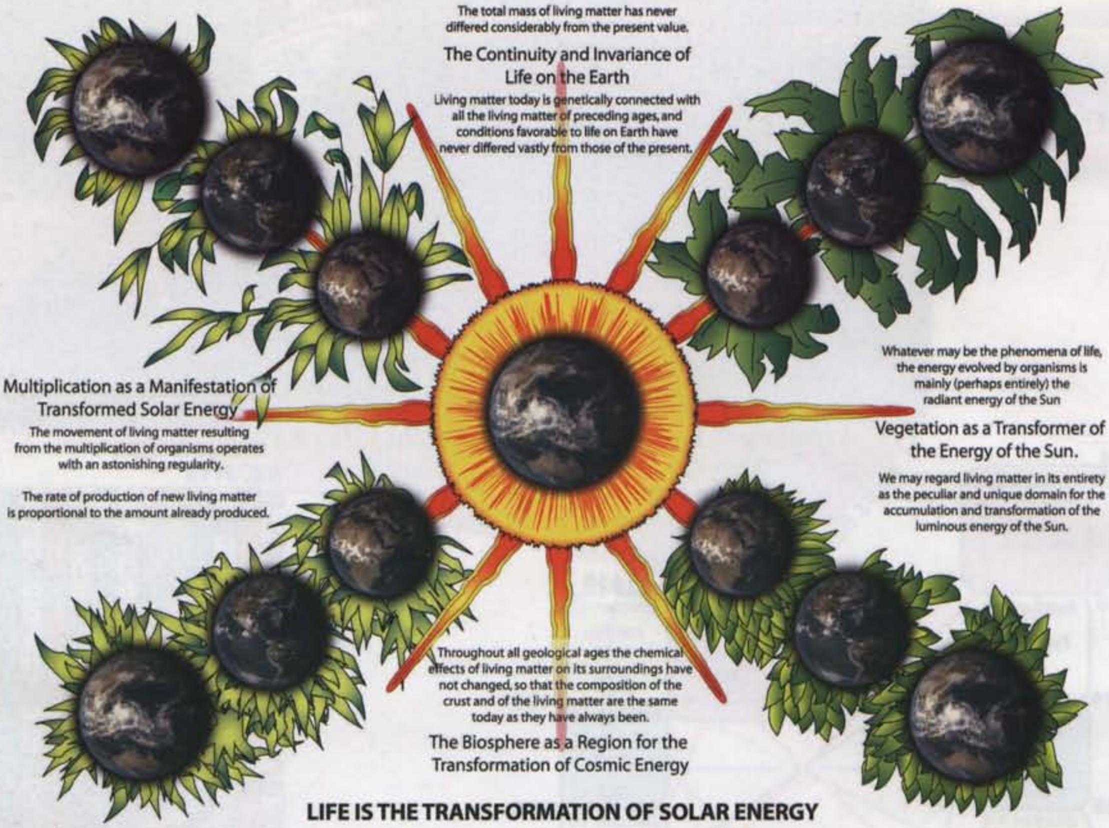

The total mass of living matter has never differed considerably from the present value.

The Continuity and Invariance of Life on the Earth

Living matter today is genetically connected with all the living matter of preceding ages, and conditions favorable to life on Earth have never differed vastly from those of the present.

Multiplication as a Manifestation of Transformed Solar Energy

The movement of living matter resulting from the multiplication of organisms operates with an astonishing regularity.

The rate of production of new living matter is proportional to the amount already produced.

Whatever may be the phenomena of life, the energy evolved by organisms is mainly (perhaps entirely) the radiant energy of the Sun

Vegetation as a Transformer of the Energy of the Sun.

We may regard living matter in its entirety as the peculiar and unique domain for the accumulation and transformation of the luminous energy of the Sun.

Throughout all geological ages the chemical effects of living matter on its surroundings have not changed, so that the composition of the crust and of the living matter are the same today as they have always been.

The Biosphere as a Region for the Transformation of Cosmic Energy

LIFE IS THE TRANSFORMATION OF SOLAR ENERGY

Planetary Service Wavespell

YEAR OF THE RED PLANETARY MOON

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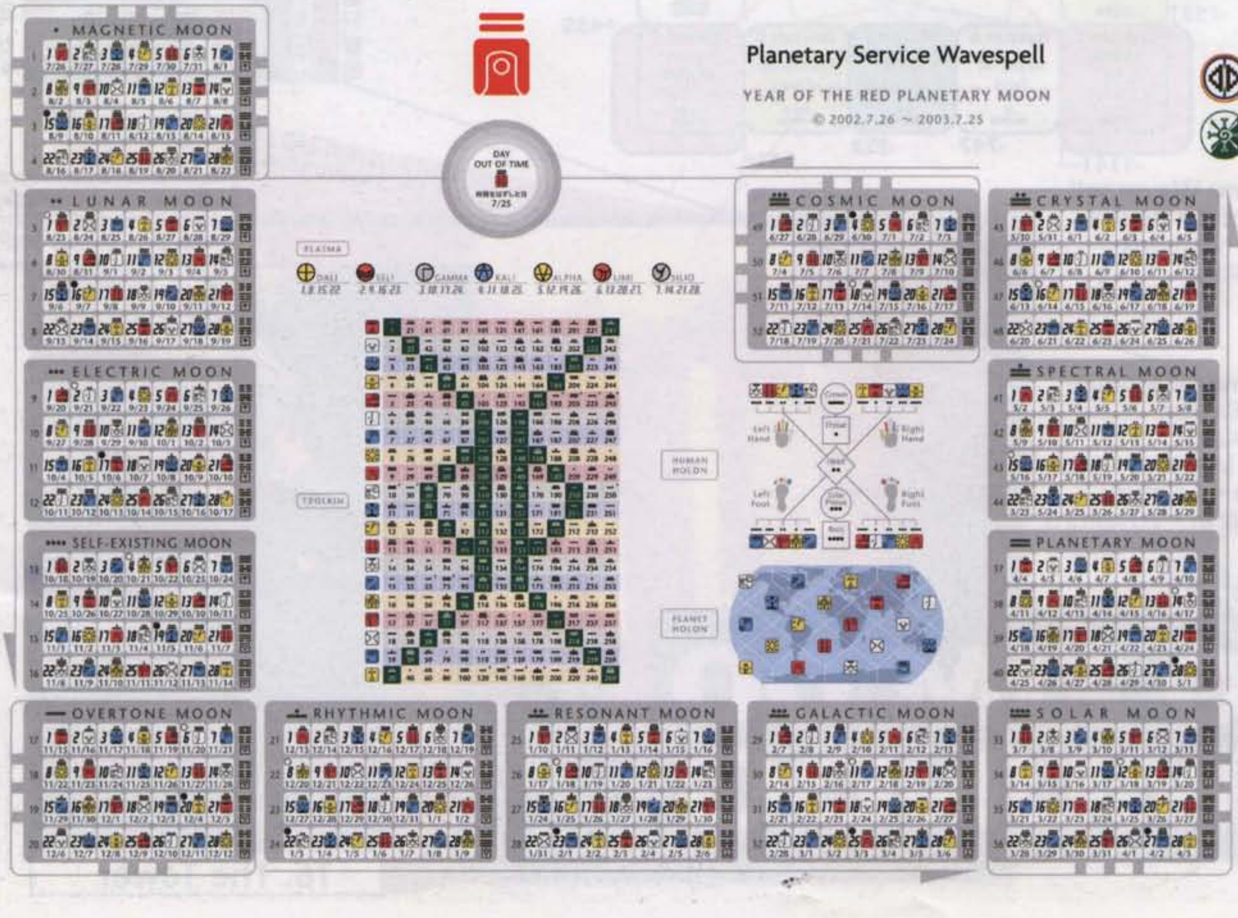

MAGNETIC MOON
LUNAR MOON
ELECTRIC MOON
SELF-EXISTING MOON
OVERTONE MOON
RHYTHMIC MOON
RESONANT MOON
GALACTIC MOON
SOLAR MOON
PLANETARY MOON
SPECTRAL MOON
CRYSTAL MOON
COSMIC MOON
DAY OUT OF TIME
7/25
PLASMA
DALI
SELI
GAMMA
KALI
ALPHA
LIMI
SILIO
TZOLKIN
HUMAN HOLON
PLANET HOLON
Left Hand
Right Hand
Left Foot
Right Foot

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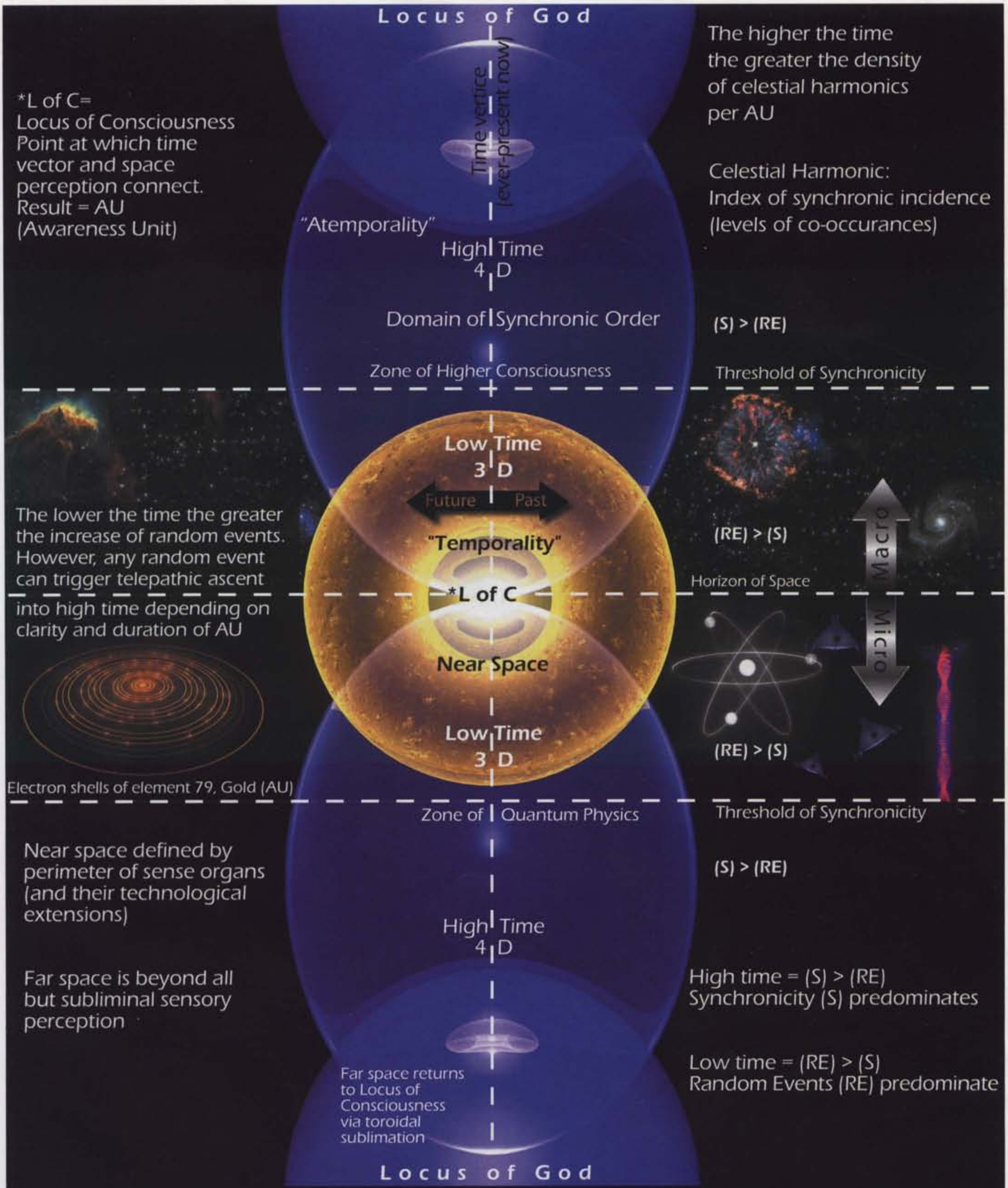

Locus of God

Time vertice
(ever-present now)

*L of C=
Locus of Consciousness
Point at which time
vector and space
perception connect.
Result = AU
(Awareness Unit)

"Atemporality"

High Time
4 D

Domain of Synchronic Order

Zone of Higher Consciousness

The higher the time
the greater the density
of celestial harmonics
per AU

Celestial Harmonic:
Index of synchronic incidence
(levels of co-occurances)

(S) > (RE)

Threshold of Synchronicity

Low Time
3 D

Future Past

"Temporality"

***L of C**

Near Space

Low Time
3 D

The lower the time the greater
the increase of random events.
However, any random event
can trigger telepathic ascent
into high time depending on
clarity and duration of AU

Electron shells of element 79, Gold (AU)

(RE) > (S)

Horizon of Space

Macro

Micro

(RE) > (S)

Zone of Quantum Physics

Threshold of Synchronicity

(S) > (RE)

Near space defined by
perimeter of sense organs
(and their technological
extensions)

Far space is beyond all
but subliminal sensory
perception

High Time
4 D

High time = (S) > (RE)
Synchronicity (S) predominates

Low time = (RE) > (S)
Random Events (RE) predominate

Far space returns
to Locus of
Consciousness
via toroidal
sublimation

Locus of God

Model of "Vertical Time" in Relation to Horizontal Space

A Presentation of the Foundation for the Law of Time
T(E)=ART. Energy factored by Time equals Art.

The Dynamics of Time
Showing the Evolution of Time as Consciousness - T(E)=Art

GALACTIC BRAIN, or evolutionary spectrum showing index of energy-mind progression from atomic-cellular biological to purely mental conditions of being, T(E)=Art. Energy factored by time equals art.

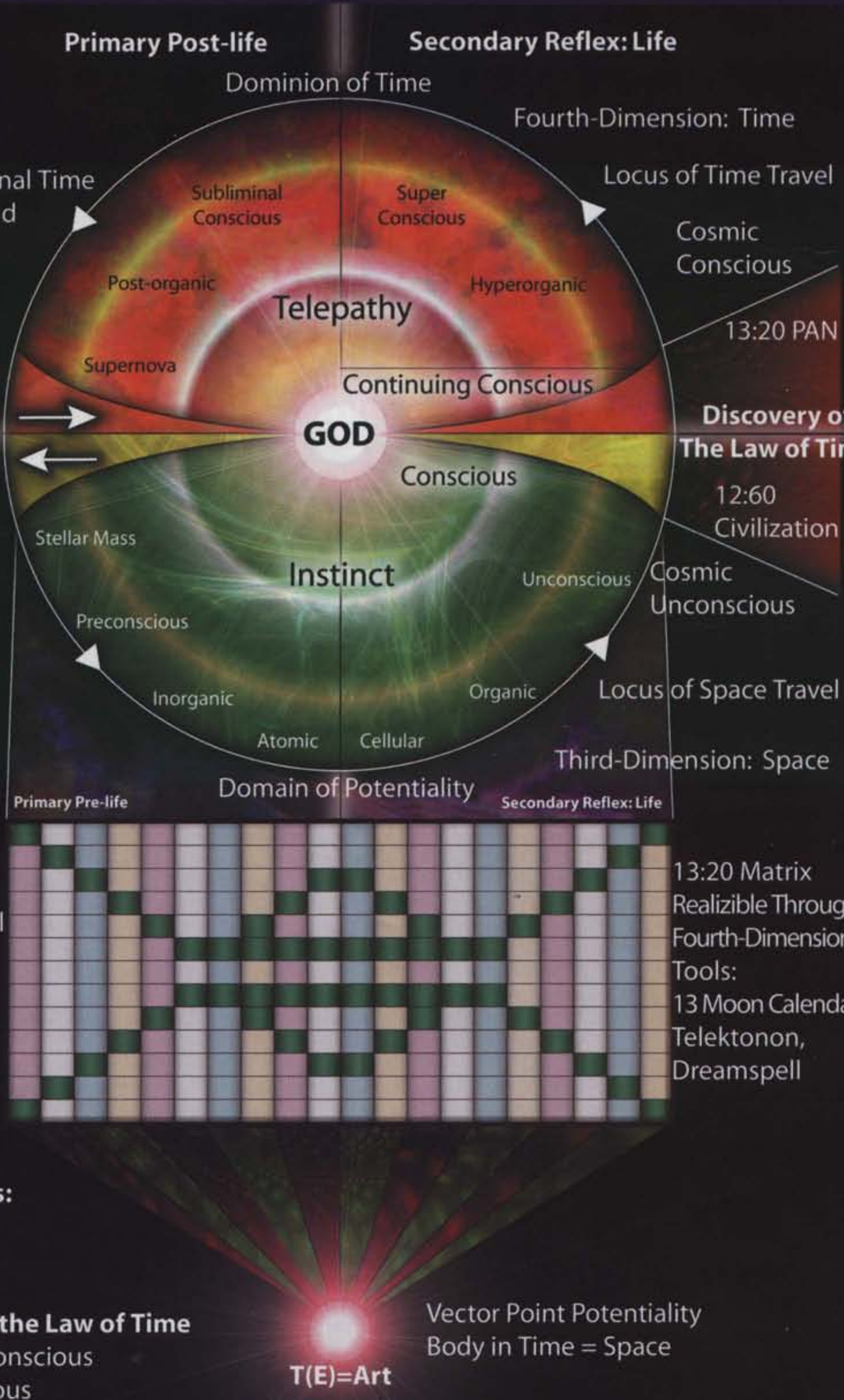

Primary Post-life

Secondary Reflex: Life

Dominion of Time

Fourth-Dimension: Time

Hyperdimensional Time
Pure Mind

Locus of Time Travel

Cosmic
Conscious

13:20 PAN

**Mind Returns
to Source**

**Discovery of
The Law of Time**

**Energy Released
from Source**

12:60
Civilization

Cosmic
Unconscious

Quantum
Dimensional
Space
Pure Energy

Locus of Space Travel

Third-Dimension: Space

Subliminal Conscious
Super Conscious
Post-organic
Hyperorganic
Telepathy
Supernova
Continuing Conscious
GOD
Conscious
Stellar Mass
Instinct
Unconscious
Preconscious
Inorganic
Organic
Atomic
Cellular

Domain of Potentiality

Primary Pre-life

Secondary Reflex: Life

13:20
Fourth-Dimensional
Timing Matrix
Source of
Time Vector
Potentialities

13:20 Matrix
Realizible Through
Fourth-Dimensional
Tools:
13 Moon Calendar,
Telektonon,
Dreamspell

**Time Vector
Potentialities:**
Preconscious
Unconscious
Conscious
Discovery of the Law of Time
Continuing Conscious
Super Conscious
Subliminal Conscious

Vector Point Potentiality
Body in Time = Space

T(E)=Art

Noospheric Time Map - Wave Harmonic of History

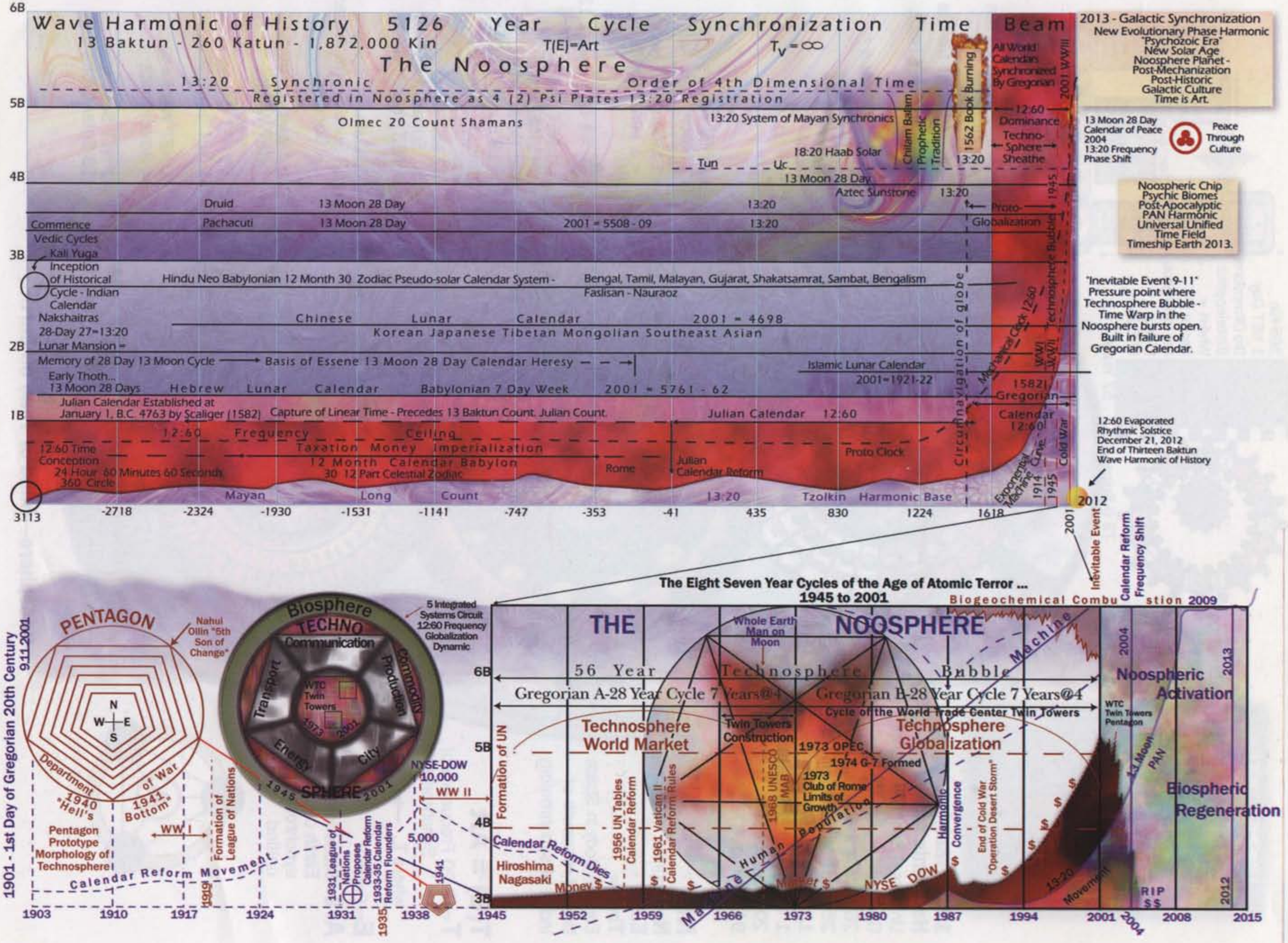

6B
5B
4B
3B
2B
1B
Wave Harmonic of History 5126 Year Cycle Synchronization Time
13 Baktun - 260 Katun - 1,872,000 Kin
T(E)=Art
$T_V = \infty$
The Noosphere
13:20 Synchronic Order of 4th Dimensional Time
Registered in Noosphere as 4 (2) Psi Plates 13:20 Registration
Olmec 20 Count Shamans
13:20 System of Mayan Synchronics
18:20 Haab Solar
Tun
Uc
13 Moon 28 Day
Aztec Sunstone
Chilam Balam Prophetic Tradition
1562 Book Burning
13:20
Beam
All World Calendars Synchronized By Gregorian
2001 WWIII
12:60 Dominance
Techno-Sphere Sheathe
Proto-
Globalization
Technosphere Bubble
1945
Druid
13 Moon 28 Day
13:20
Commence Vedic Cycles
Kali Yuga
Pachacuti
13 Moon 28 Day
2001 = 5508 - 09
13:20
Inception of Historical Cycle - Indian Calendar Nakshaitras 28-Day 27=13:20 Lunar Mansion =
Hindu Neo Babylonian 12 Month 30 Zodiac Pseudo-solar Calendar System -
Bengal, Tamil, Malayan, Gujarat, Shakatsamrat, Sambat, Bengalism
Faslisan - Nauraoz
Chinese Lunar Calendar
2001 = 4698
Korean Japanese Tibetan Mongolian Southeast Asian
Circumnavigation of globe
Mechanical Clock 12:60
WWI
WWII
Memory of 28 Day 13 Moon Cycle
Basis of Essene 13 Moon 28 Day Calendar Heresy
Islamic Lunar Calendar
2001=1921-22
Early Thoth... 13 Moon 28 Days
Hebrew Lunar Calendar
Babylonian 7 Day Week
2001 = 5761 - 62
1582 Gregorian
Julian Calendar Established at January 1, B.C. 4763 by Scaliger (1582)
Capture of Linear Time - Precedes 13 Baktun Count. Julian Count.
Julian Calendar 12:60
Calendar 12:60
12:60 Frequency Ceiling
Taxation Money Imperialization
12 Month Calendar Babylon
30 12 Part Celestial Zodiac
12:60 Time Conception
24 Hour 60 Minutes 60 Seconds 360 Circle
Rome
Julian Calendar Reform
Proto Clock
Exponential Machine Curve
1914
1945
Cold War
Mayan Long Count
13:20 Tzolkin Harmonic Base
3113
-2718
-2324
-1930
-1531
-1141
-747
-353
-41
435
830
1224
1618
2012
2013 - Galactic Synchronization
New Evolutionary Phase Harmonic
"Psychozoic Era"
New Solar Age
Noosphere Planet -
Post-Mechanization
Post-Historic
Galactic Culture
Time is Art.
13 Moon 28 Day Calendar of Peace 2004
13:20 Frequency Phase Shift
Peace Through Culture
Noospheric Chip
Psychic Biomes
Post-Apocalyptic
PAN Harmonic
Universal Unified Time Field
Timeship Earth 2013.
"Inevitable Event 9-11"
Pressure point where Technosphere Bubble - Time Warp in the Noosphere bursts open.
Built in failure of Gregorian Calendar.
12:60 Evaporated
Rhythmic Solstice
December 21, 2012
End of Thirteen Baktun
Wave Harmonic of History
2001
Inevitable Event
Calendar Reform
Frequency Shift
The Eight Seven Year Cycles of the Age of Atomic Terror ...
1945 to 2001
Biogeochemical Combustion 2009
PENTAGON
Nahui Ollin "5th Son of Change"
N
W
E
S
Department of War
1940 "Hell's
1941 Bottom"
Pentagon Prototype Morphology of Technosphere
1901 - 1st Day of Gregorian 20th Century
9.11.2001
Biosphere
TECHNO
SPHERE
Communication
Commodity
Production
Transport
Energy
City
WTC Twin Towers
1973
2001
1945
5 Integrated Systems Circuit 12:60 Frequency Globalization Dynamic
WW I
Formation of League of Nations
1919
Calendar Reform Movement
1931 League of Nations Proposes Calendar Reform
1933-35 Calendar Reform Flounders
1935
NYSE-DOW 10,000
5,000
WW II
1941
THE
NOOSPHERE
Whole Earth Man on Moon
56 Year Technosphere Bubble
Gregorian A-28 Year Cycle 7 Years@4
Gregorian B-28 Year Cycle 7 Years@4
Cycle of the World Trade Center Twin Towers
Machine
Technosphere World Market
Twin Towers Construction
1973 OPEC
1974 G-7 Formed
1973 Club of Rome Limits of Growth
1968 UNESCO MAB
Technosphere Globalization
Formation of UN
Calendar Reform Dies
Hiroshima Nagasaki
Money $
1956 UN Tables Calendar Reform
1961 Vatican II Calendar Reform Rules
Human Population
Market $
NYSE DOW
Harmonic Convergence
End of Cold War "Operation Desert Storm"
$
13:20 Movement
13 Moon PAN
WTC Twin Towers Pentagon
2004
2013
2012
Noospheric Activation
Biospheric Regeneration
RIP $$
1903
1910
1917
1924
1931
1938
1945
1952
1959
1966
1973
1980
1987
1994
2001
2004
2008
2015

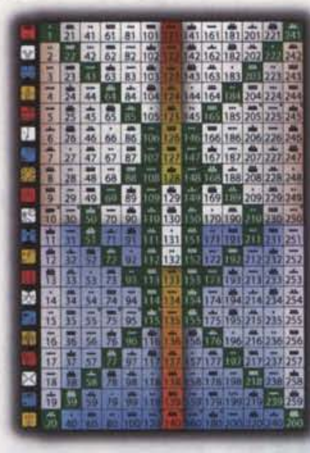

260 Kin
4th Dimensional
Wheel of
Synchronic
Order =
Factor of
Synchronization=
1 G-Spin =

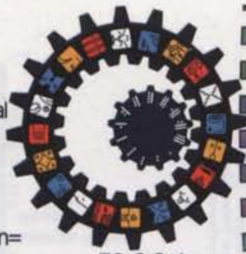

73 G-Spins = 52 Years

July 24, 2004
July 25, 2004
July 26, 2004
July 27, 2004
July 28, 2004

365-Kin
1 NET Day
3rd Dimensional
Biotelepathic
Wheel =
Factor of
Life Experience
(73:5)
(7:52)

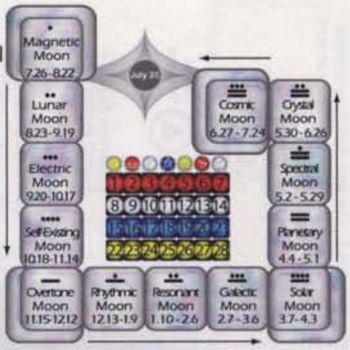
Magnetic Moon 7.26-8.22
Lunar Moon 8.23-9.19
Electric Moon 9.20-10.17
Self-Existing Moon 10.18-11.14
Overtone Moon 11.15-12.12
Rhythmic Moon 12.13-1.9
Resonant Moon 1.10-2.6
Galactic Moon 2.7-3.6
Solar Moon 3.7-4.3
Planetary Moon 4.4-5.1
Spectral Moon 5.2-5.29
Crystal Moon 5.30-6.26
Cosmic Moon 6.27-7.24
July 25
1 2 3 4 5 6 7
8 9 10 11 12 13 14
15 16 17 18 19 20 21
22 23 24 25 26 27 28

13:20 Matrix
Harmonic Module
Universal Synchronization
Gauge =
260 Kin = 1 Galactic Spin =
260 NET Minutes
13 NET Minutes =
1 Wavespell (13 Tones)
20 Wavespells =
9 NET Hours, 8 NET Minutes

NET
Noospheric
Earth
Time =
Earth = Body in Space =
Unit of measure of
index of synchronicity

T(E) = Art
T=13:20 Frequency of
Synchronization
where $T_v \rightarrow \infty$

E= Earth
Art= Blossomed Noosphere,
Earth consciousness
synchronically
unified

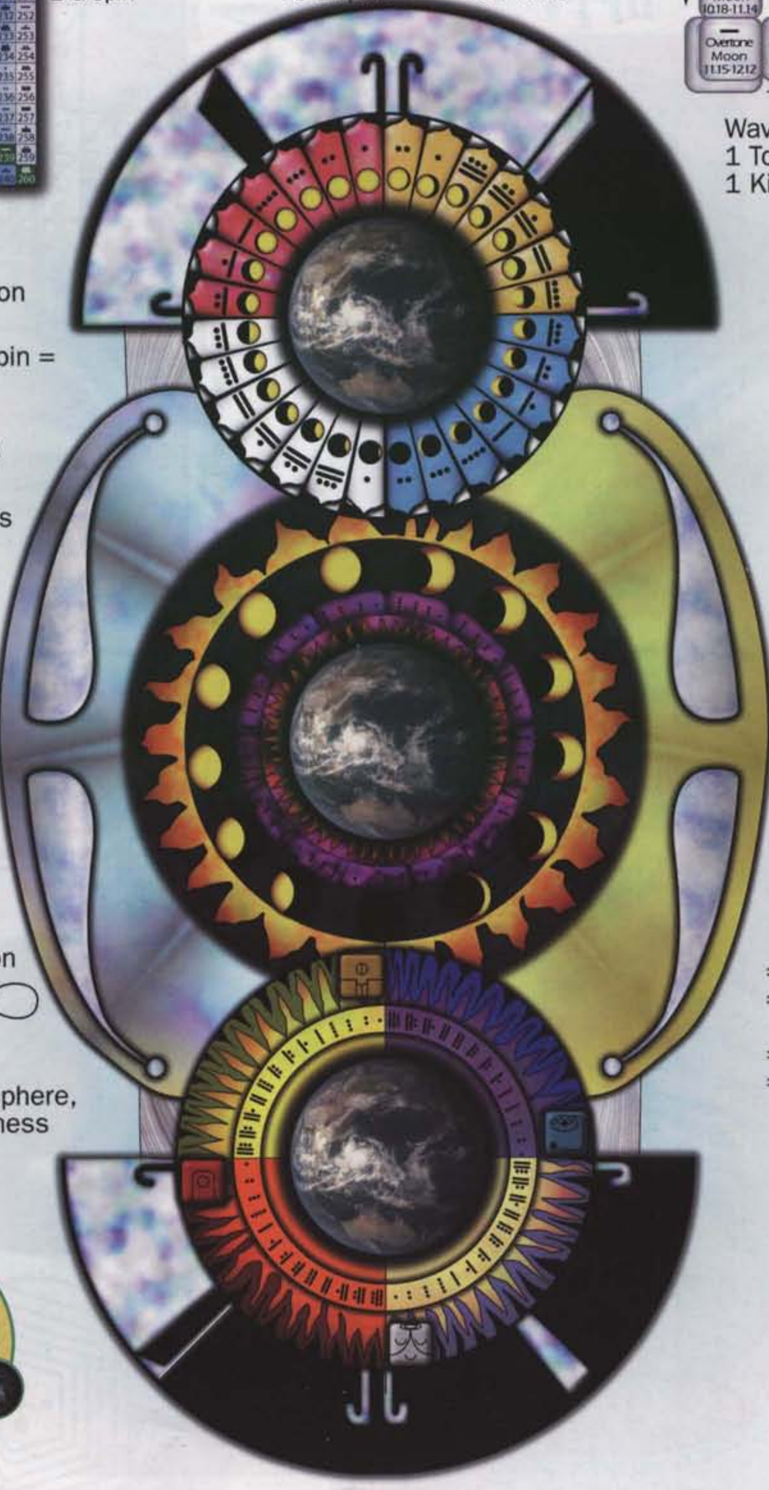

Wavespell = 13 Tones
1 Tone = 1 Moon = 28 Kin
1 Kin = 1 NET Minute

◐ = 1 NET Minute
x 28 = 1 NET Hour.

7 NET Minutes =
$^1/_4$ Hour =
1 Week ◔

1 NET Hour = ◐
1 Moon

1 Moon (NET Hour)
= 1 Lunar Orbit

◐ =1 NET Hour x 13
= 1 NET Day
(13 NET Hours)
= 1 Solar Orbit
= 13 Lunar Orbits

52 NET Days
= 52 Solar Orbits
= 1 NET Year

= 73 Galactic Spins
= 13 Seed-Storm 4-Year
Bundles

1 4-Year Bundle =
1 NET Week

13 NET Days=
1 NET Season

1 NET Week=
4 Solar Orbits

1 NET Season=
13 Solar Orbits

Noosphere—Mind of Time on Earth

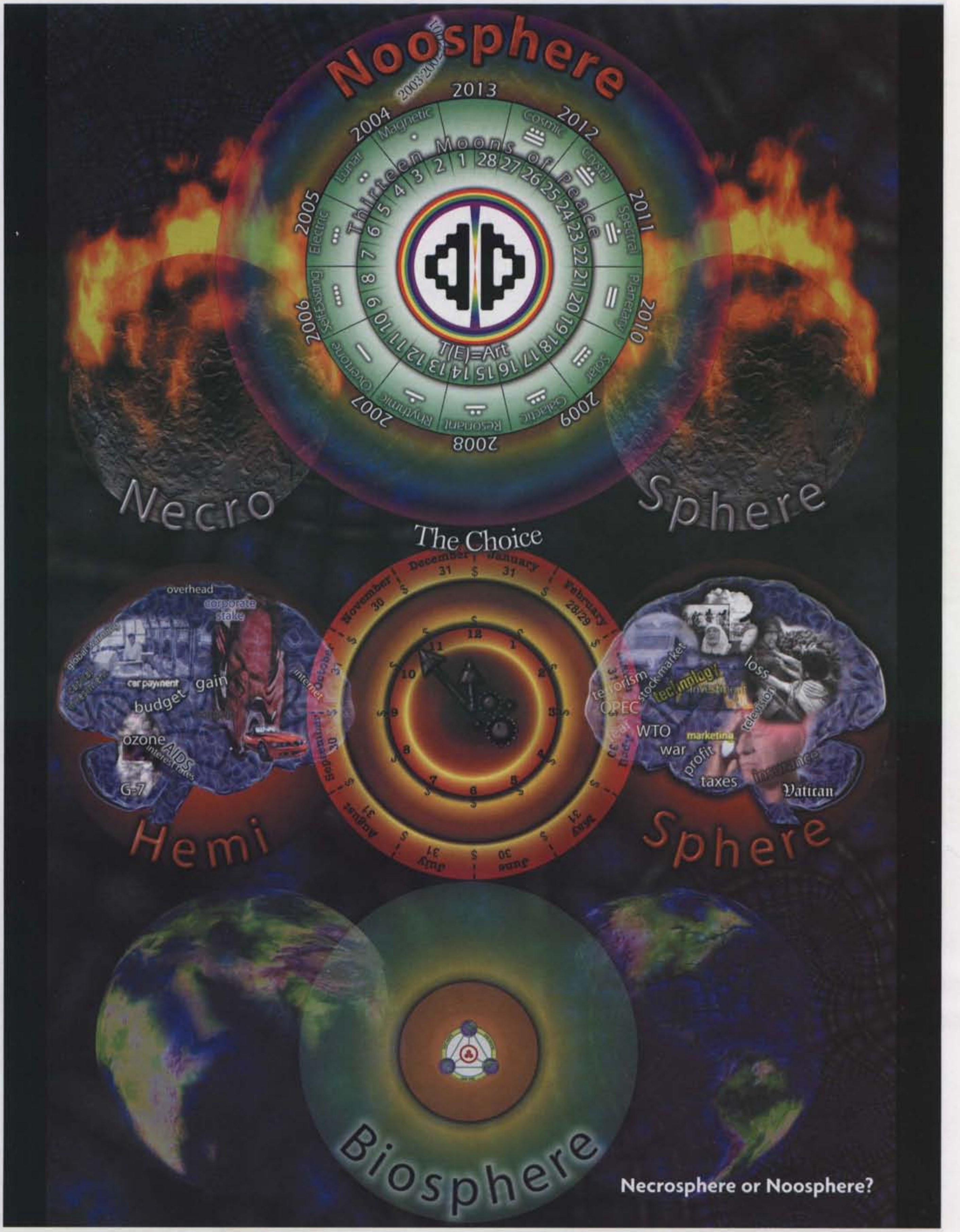
Noosphere
2013
2012
2011
2010
2009
2008
2007
2006
2005
2004
Magnetic
Lunar
Electric
Self-Existing
Overtone
Rhythmic
Resonant
Galactic
Solar
Planetary
Spectral
Crystal
Cosmic
Thirteen Moons of Peace
T(E)=Art
Necro
Sphere
The Choice
December
January
February
November
October
September
August
July
June
May
overhead
corporate stake
global warming
car payment
gain
budget
internet
ozone
AIDS
interest rates
G-7
terrorism
stock market
technology
investment
loss
OPEC
WTO
marketing
television
war
profit
taxes
insurance
Vatican
Hemi
Sphere
Biosphere

Necrosphere or Noosphere?

A Chronotopology of Transformation

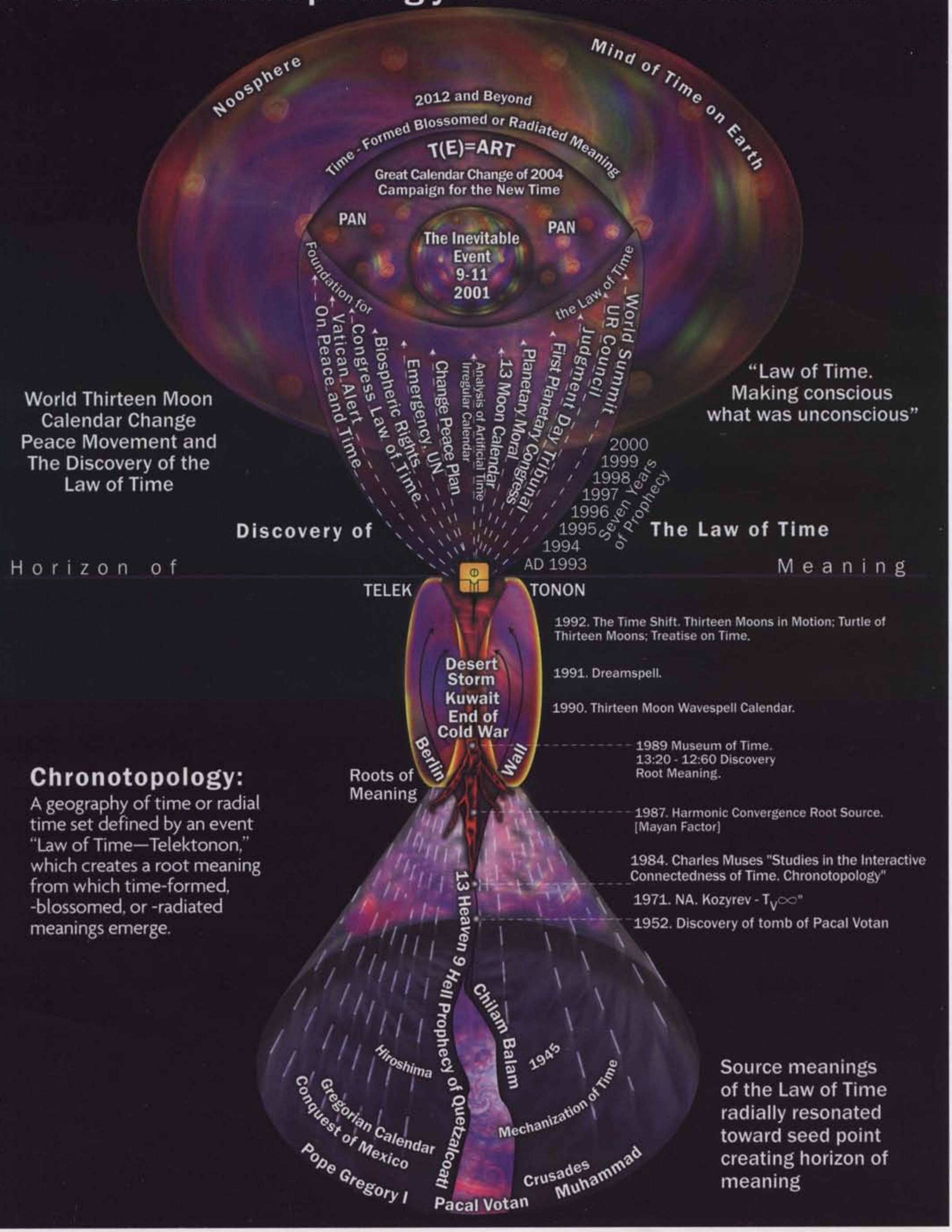
Noosphere
Mind of Time on Earth
2012 and Beyond
Time-Formed Blossomed or Radiated Meaning
T(E)=ART
Great Calendar Change of 2004
Campaign for the New Time
PAN
PAN
The Inevitable Event 9-11 2001
Foundation for the Law of Time
On Peace and Time
Vatican Alert
Congress Law of Time
Biospheric Rights
Emergency. UN
Change Peace Plan
Analysis of Artificial Time Irregular Calendar
13 Moon Calendar
Planetary Moral Congress
First Planetary Tribunal
First Planet Day
Judgment
UR Council
World Summit
2000
1999
1998
1997
1996
1995
1994
AD 1993
Seven Years of Prophecy
Discovery of
The Law of Time
Horizon of
Meaning
TELEK
TONON
Desert Storm Kuwait End of Cold War
Berlin
Wall
Roots of Meaning
13 Heaven 9 Hell Prophecy of Quetzalcoatl
Chilam Balam
1945
Hiroshima
Mechanization of Time
Gregorian Calendar
Conquest of Mexico
Pope Gregory I
Pacal Votan
Crusades
Muhammad

World Thirteen Moon Calendar Change Peace Movement and The Discovery of the Law of Time

"Law of Time. Making conscious what was unconscious"

1992. The Time Shift. Thirteen Moons in Motion; Turtle of Thirteen Moons; Treatise on Time.

1991. Dreamspell.

1990. Thirteen Moon Wavespell Calendar.

1989 Museum of Time.
13:20 - 12:60 Discovery
Root Meaning.

1987. Harmonic Convergence Root Source.
[Mayan Factor]

1984. Charles Muses "Studies in the Interactive Connectedness of Time. Chronotopology"

1971. NA. Kozyrev - $T_V\infty$"

1952. Discovery of tomb of Pacal Votan

Chronotopology:
A geography of time or radial time set defined by an event "Law of Time—Telektonon," which creates a root meaning from which time-formed, -blossomed, or -radiated meanings emerge.

Source meanings of the Law of Time radially resonated toward seed point creating horizon of meaning

Paul J. Nahin

Time Machine Tales

The Science Fiction Adventures and Philosophical Puzzles of Time Travel

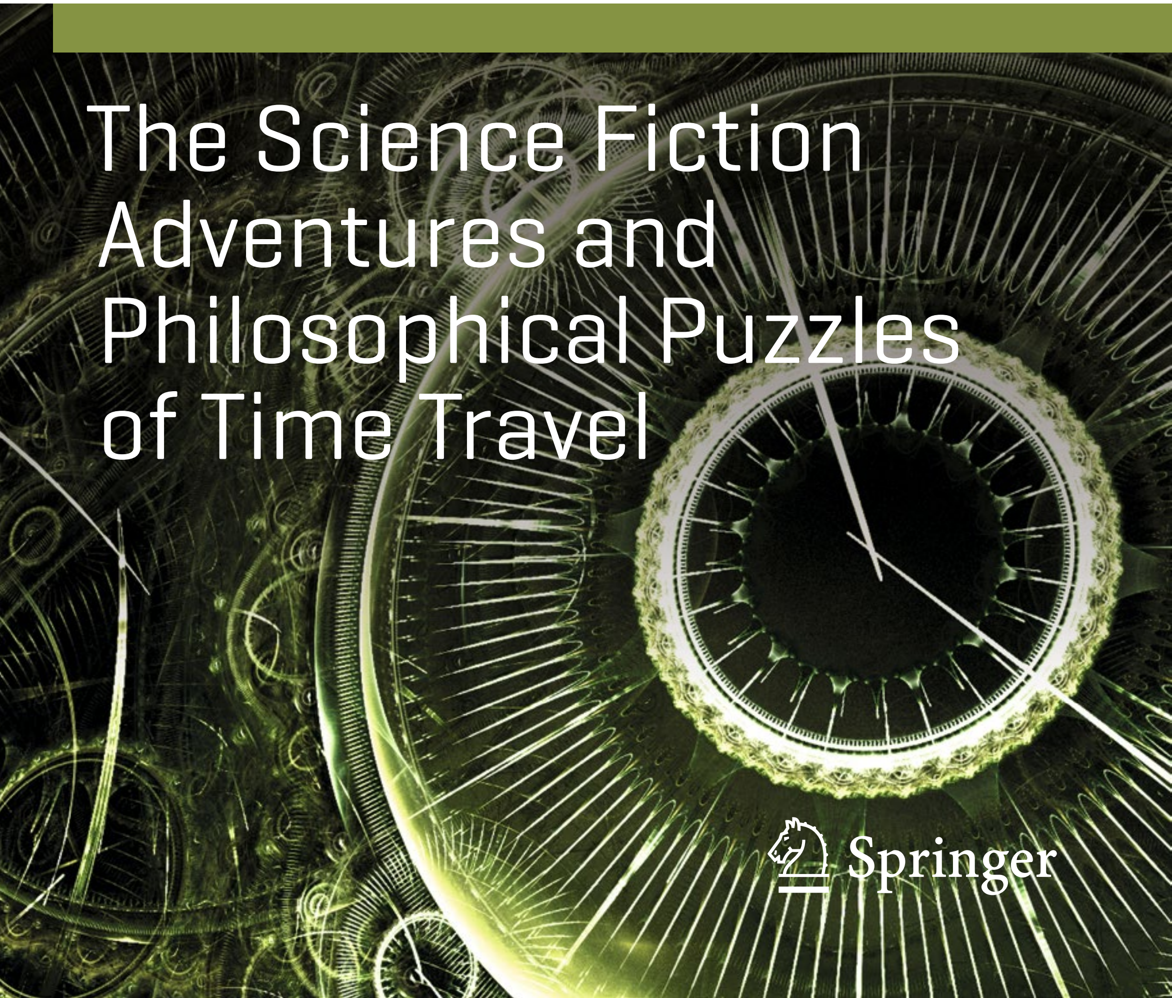

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Readers can look forward to a broad range of topics, as intriguing as they are important. Here just a few by way of illustration:

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- Artificial intelligence, planetary brains, the universe as a computer, simulated worlds
- Non-anthropocentric viewpoints
- Synthetic biology, genetic engineering, developing nanotechnologies
- Eco/infrastructure/meteorite-impact disaster scenarios
- Future scenarios, transhumanism, posthumanism, intelligence explosion
- Virtual worlds, cyberspace dramas
- Consciousness and mind manipulation

Paul J. Nahin

Time Machine Tales

The Science Fiction Adventures and Philosophical Puzzles of Time Travel

Springer

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Also By Paul J. Nahin

Oliver Heaviside (1988, 2002), Johns Hopkins
Time Machines (1993, 1999), Springer
The Science of Radio (1996, 2001), Springer
An Imaginary Tale (1998, 2007, 2010), Princeton
Duelling Idiots (2000, 2002), Princeton
When Least Is Best (2004, 2007), Princeton
Dr. Euler's Fabulous Formula (2006, 2011), Princeton
Chases and Escapes (2007, 2012), Princeton
Digital Dice (2008, 2013), Princeton
Mrs. Perkins's Electric Quilt (2009), Princeton
Time Travel (1997, 2011), Johns Hopkins
Number-Crunching (2011), Princeton
The Logician and the Engineer (2013), Princeton
Will You Be Alive Ten Years From Now? (2014), Princeton
Holy Sci-Fi! (2014), Springer
Inside Interesting Integrals (2015), Springer
In Praise of Simple Physics (2016), Princeton

Frontispiece: The Pioneers of Time Travel

The scientific pioneers were Albert Einstein (1879–1955) and Kurt Gödel (1906–1978), good personal friends who are shown here in 1954 at the Institute for Advanced Study in Princeton, New Jersey, in a photo taken by Richard Arens. It was Einstein's 1916 general theory of relativity (theory of gravity) that Gödel used as the basis for his 1949 paper that was the first to show that the general theory does **not** forbid time travel into the past.

The literary pioneer of time travel was of course Herbert George Wells (1866–1946), who is shown here as a college freshman cut-up around 1885. The photograph was taken as a prank by an unknown friend while Wells was a student in a biology course given by Thomas Huxley, at the Normal School of Science in

South Kensington (a branch of the University of London). A far too thin and impoverished Wells was then still a teenager, and *The Time Machine* lay a distant 10 years in the future.

Einstein/Gödel photograph courtesy of the American Institute of Physics Emilio Segré Visual Archives of the AIP Niels Bohr Library. Wells photograph courtesy of the rare Books and Special Collections Department of the Library of the University of Illinois at Urbana-Champaign.

A Note on the Story Citations and Science Fiction History

> "You will find it a very good practice always to verify your references, sir."
> —advice given in 1847 to a young scholar by Martin Joseph Routh, President of Magdalen College, Oxford

Most of the pulp science fiction stories I've cited in this book, in their original form as ink on paper, have long since vanished from our region of spacetime and exist today only (alas) on microfilm reels in scholarly vaults. I am especially indebted to Texas A & M, the Claremont Colleges, the California State Universities at Northridge and Fullerton, Mount Holyoke College, the New York City Public

Library, and the University of Delaware, for giving me access via Inter-Library Loan (through my home institution, the University of New Hampshire) to their extensive archives of ancient science fiction magazines.

A number of the really good stories *have* been anthologized, however, and so are still readily available today in book form. In essentially all cases, though, for historical reasons, I've given the original publication information (magazine and date). You can find which of the stories cited are available in one or more anthology reprints by going to an immensely useful, searchable database on the Web, at: http://www.isfdb.org, and I gratefully thank all those in the science fiction community responsible for creating and maintaining that database.

The following two books by science fiction historian Sam Moskowitz (1920–1997), who lived through what Isaac Asimov called the 'Golden Age of [magazine] Science Fiction,' may be difficult to find today but, if you are interested in the early history of *magazine* science fiction (beyond simply the subgenre of time travel), the hunt for them will be well worth your time:

Science Fiction by Gaslight: a history and anthology of science fiction in the popular magazines, 1891–1911 (World Publishing Company 1968);

Under the Moons of Mars: a history and anthology of "The Scientific Romance" in the Munsey Magazines, 1912–1920 (Holt, Rinehart and Winston 1970).

Some First Words

Is time travel in principle (never mind the difficulties) a possibility? It has received some thought in the past and deserves some more.
—David Park, in his 1980 book *The Image of Eternity*

He used to have quite a reputation, but the last couple of years he's been working on time . . . You know, time travel, that sort of rot. An A-1 crackpot.
—a character (discussing a colleague) disagrees with Park, in Mack Reynolds' "Advice from Tomorrow," *Science Fiction Quarterly*, August 1953

In 1993 the first edition of my book *Time Machines* was published by the Press of the American Institute of Physics. In 1999, after Springer acquired AIP Press, the second edition of that book appeared. So, is this the third edition? Well, yes *and* no. It *is* because large chunks of the 1999 edition are still here, along with new discussions of the advances by physicists and philosophers that have appeared in the intervening 18 years. The prime example of that centers on the time travel paradoxes. Those discussions contain mostly what is in the second edition, but they have also been brought up to date with the latest thinking on the paradoxes, by physicists and philosophers.

And yet this book is *not quite* the third edition because the emphasis is now on the philosophical and on science fiction, rather than on physics as it was when written for AIP Press. In that spirit there are, for example, no Tech Notes filled with algebra, integrals, and differential equations, as there are in the first and second editions of *Time Machines*. That's because I wish to avoid having this book seem to be simply a long physics treatise. I have, in fact, some sympathy with the following views, expressed by two philosophers:

"There is one metaphor in the physicist's account of space-time which one would expect *anyone* to recognize as such, for metaphor is here strained far beyond the breaking point, i.e., when it is said that time is 'at right angles to each of the other three dimensions.' Can anyone really attach any meaning to this—except as a recipe for drawing diagrams?"[1]

and

"This is from the outset a study in descriptive metaphysics. In consequence, I shall have nothing to say about twice-differentiable Lorentzian manifolds, Minkowski diagrams, world-lines, time-like separations, space-time worms [a 'thick' world-line], or temporal parts."[2]

I don't *completely* endorse these sentiments, however, and so please understand that I am not denying the ultimate importance of *physics* when it comes to achieving a deep understanding of time travel. To quote yet another philosopher,

"Arm chair reflections on the concept of causation [are] not going to yield new insights. The grandfather paradox is simply a way of pointing to the fact that if the usual laws of physics are supposed to hold true in a chronology violating space-time, then consistency constraints emerge. *[To understand these constraints] involves solving problems in physics, not armchair philosophical reflections* [my emphasis]."[3]

I could not agree more. So, in *Time Machine Tales* you *will* find some physics. In support of time travel to the future (and in how to make a wormhole time machine for travel into the past), for example, I'll show you a high school level derivation of the famous time dilation formula from special relativity. There are some spacetime diagrams, some simple algebraic manipulations, and here and there just a touch of freshman calculus; even the metric tensor gets a few words, too. But it is, admittedly, pretty light-weight stuff.

So, while certainly saluting the premier position of physics, *Time Machine Tales* is not a scholarly, in-depth treatment of time travel physics. Rather, it is an examination of how science fiction writers (and many philosophers, too) have viewed time travel. (Even in the physics discussions, science fiction will regularly appear.) Those views, by their very nature, are far more romantic than are those of hardcore theoretical physicists. History has shown, of course, that the results of the work of theoretical physicists may, in the end, prove to actually be far more astonishing than anything fiction writers cook-up—and if there is any scientific subject for which that may again prove to be true it's time travel—but for us, here, it will be the fiction writer who has center stage.

The philosophers will be only slightly less important in this book. While much of the early philosophical literature on time travel and backwards causation reads like imaginative fairy tales spun out of vacuous vapors (more on this soon), many modern philosophers have shown themselves to be quite sophisticated. What they have written deserves serious consideration by anyone interested in time travel, and that includes physicists. However, while the time travel interests of philosophers and physicists have a lot of overlap, those interests are *not* in total agreement. For example, while both groups talk of the grandfather paradox, the philosophers worry in particular about motivation (*why* the murderous mission?), while physicists have *never* to my knowledge asked themselves that question[4] (other than to figure out how to avoid it!). After all, philosophers talk of flesh-and-blood humans as time travelers, while the physicists send only billiard balls (with no personal identities or memories) on time trips into the past for the *expressed purpose* of avoiding the messy human issues of 'motivation' and free will. This approach by physicists isn't because they are cold and emotionless. It is a useful strategy because, if it can be shown that a mere billiard ball can travel into the past then, as one *philosopher* pointed out long ago, "It is implausible that it should be possible for some physical systems to travel back in time, and not others. Thus, if we suppose that simple objects can time-travel ... then we must suppose that more complicated systems, e.g., human beings, can also time-travel."[5]

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[1] C. W. K. Mundle, "The Space-Time World," *Mind*, April 1967, pp. 264–269.

[2] J. F. Rosenberg, "One Way of Understanding Time," *Philosophia*, October 1972, pp. 283–301.

[3] John Earman, "Recent Work on Time Travel," in *Time's Arrows Today: recent physical and philosophical work on the direction of time* (Steven F. Savitt, editor), Cambridge University Press 1995, pp. 268–310. We'll discuss the idea of *consistency constraints* in some detail later in the book. Earman is Professor Emeritus of History and Philosophy of Science at the University of Pittsburgh.

For the most part, philosophers and physicists have worked at the extreme, opposite points of the time travel spectrum. Much better, I think, would be to adopt the following, more balanced position advocated recently: "The study of time machines is a good opportunity for forging a partnership between philosophy and physics. Of course, philosophers have to recognize that in this particular instance the partnership is necessarily an unequal one since the mathematical physicists have to do the heavy lifting. But it seems clear that a little more cooperation with philosophers of science in attending to the analysis of what it takes to be a time machine could have led to some helpful clarifications in the physics literature."[6]

In the past, philosophers gained a reputation for being just a bit too 'unconstrained by the facts' for scientific tastes—as the English mathematician Augustus De Morgan (1806–1871) wrote in an 1842 letter, "There are no writers who give us so much *must* with so little *why*, as the metaphysicians"[7]—but I do think today's physicists would do well to reexamine that harsh opinion.

Philosophers of the 'old school' may look askance at a non-philosopher (me!) leveling criticism at them, and so let me step aside and quote from a member of the

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[4] Nicholas J. J. Smith, "Why Would Time Travelers Try to Kill Their Younger Selves?" *The Monist*, July 2005, pp. 388–395. As Smith writes, "[Motivation] does not impact upon the possibility, or even the likelihood of backwards time travel. Yet it is deeply puzzling, and we will have no idea what time travel would actually be *like* until we explore it." See also Peter B. M. Vranas, "Can I Kill My Younger Self? Time Travel and the Retrosuicide Paradox," *Pacific Philosophical Quarterly*, December 2009, pp. 520–534.

[5] P. Horwich, "On Some Alleged Paradoxes of Time Travel," *Journal of Philosophy*, August 1975, pp. 432–444.

[6] John Earman, Christopher Smeenk, and Christian Wüthrich, "Do the Laws of Physics Forbid the Operation of Time Machines?," *Synthese*, July 2009, pp. 91–124.

[7] D. J. Cohen, *Equations from God: pure mathematics and Victorian faith*, The Johns Hopkins University Press 2007, p. 119.

'modern school' of philosophical thought: "Space-time is the basic spatiotemporal entity. Many philosophers have mouthed this truth, but few have swallowed it, and very few have digested it . . . An appreciation of this truth is crucial to what is commonly referred to as the philosophy of space and time . . . In large measure the lack of progress in this area can be traced to the fact that philosophers have not taken seriously the corollary that talk about space and time is really talk about the spatial and temporal aspects of spacetime."[8] This is a polite way of telling philosophers that they had better learn some physics!

What provoked those harsh words was that 'modern' philosopher's perception that 'old school' philosophers were not talking science when they wrote of space and time, but rather were in the business of telling each other irrelevant stories and myths, a curious philosophical approach involving the 'telling of tales' that reached its peak in the early and mid-1960s. Spacetime story telling seems to have started with a paper by the Oxford philosopher Anthony Quinton (1925–2010), who argued[9] that although there can be multiple, disjointed spaces, there can only be a single time that is the same for everyone, everywhere. The issue is *not* the truth or not of that assertion (Newton believed it, modern physicists don't), but rather Quinton's technique for arriving at it: myth construction.

Myth construction strikes those trained in the technical sciences as, while perhaps interesting—even physicists, after all, can enjoy a good fairy tale now and then—something quaint and totally beside the point. In his paper Quinton tells a fairy tale about how he thinks someone can live continuously in time and yet, via dreaming, be in two different spatial worlds; when awake he is in one world, while when the person is asleep he is in the other. Quinton argues that this multispatial myth is plausible, but that a search for an analogous multitemporal myth is doomed. This prompted a reply[10] from another 'old school' philosopher who rebutted Quinton with an even more outlandish counter-myth involving "the warring tribes of Okku and Bokku"!

It was this back-and-forth spinning of hypothetical tales that caused the 'modern' philosopher to write in his paper (note 30) that "the procedure for arriving at answers to these questions [about space and time] adopted by Quinton and most other ['old school' philosophers] is, to say the least, a curious one: a story is told about a mythical land—usually called something like the land of Okkus-Bokkus [which is now seen to an outrageous pun]—and then we are asked what we would say if confronted by experiences like those of the Okkus-Bokkusians. As often happens with such a question, people have said all sorts of things, not all of which are interesting or enlightening."

Another modern philosopher was even less gentle in his rejection of the fairy tale approach to spacetime physics: "Quinton [and others of a similar approach invite us] to say what we should think in certain strange circumstances which they describe within common-sense language [as opposed to scientific terminology]. I must say that if I found myself in the circumstances which they describe I just would not know what to think. Probably I should simply conclude that I had gone mad . . . It looks as though these writers are inviting us to consider *what we should say if we knew no science* [my emphasis]."[11]

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[8] J. Earman, "Space-Time or How to Solve Philosophical Problems and Dissolve Philosophical Muddles Without Really Trying," *Journal of Philosophy*, May 1970, pp. 259–276.

[9] A. Quinton, "Spaces and Times," *Philosophy*, April 1962, pp. 130–147.

[10] R. G. Swinburne, "Times," *Analysis*, June 1965, pp. 185–191.

Even before the modern philosopher (note 30) wrote in 1970 to complain about myth-making, another had already done so: "Whenever a human being produces an argument which opens 'Suppose I had 23 senses . . .,' 'Suppose I were God . . .,' 'Suppose I experienced objects extended in four spatial dimensions . . .,' we can protest that the argument is worthless. For in supposing that he has transcended our human point of view, he has also transcended the limits of our understanding."[12] As this author concluded his very funny paper, such opening sentences are the signatures of myths from "The Philosopher's Fairy Tale Book."

The strained relationship between myth-making philosophers and physicists, especially concerning time travel, has a historically interesting antecedent in the 1920s negative reaction among many over Einstein's theories of relativity (the very theories that give apparent life to time travel). To illustrate my point, consider the October 1913 letter Oskar Kraus (1872–1942), a philosophy professor at the German University in Prague, sent to Ernst Gehrcke (1878–1960), a physics professor at the Reich Institute of Physics and Technology in Berlin. Both men were opponents of Einstein but, as Kraus wrote in his letter, it was only Gehricke among the physicists he considered to be sympathetic to him: "[I] would not know . . . anyone else but you who as a specialist would not reject the intervention of a philosopher from the start."[13]

So, I think Earman's proposal a sound one, an echo in fact of similar words that the physicist Kip Thorne wrote (in the Foreword to the second edition of *Time Machines*) concerning science fiction writers: "Smart physicists seek insight everywhere, including from clever science fiction writers who long ago began probing seriously the logical consequences that would ensue if the laws of physics permitted time travel."[14]

To emphasize this new, combined, diversified focus (but also to retain some connection with my earlier books) is the reason I have altered the title, just a bit. In addition, each chapter now concludes with several open-ended questions, suitable for motivating either classroom discussions or more extensive essay responses.

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[11] J. J. C. Smart, "The Unity of Space-Time: Mathematics Versus Myth Making," *Australasian Journal of Philosophy*, (no. 2) 1967, 214–217.

[12] M. Hollis, "Times and Spaces," *Mind*, October 1967, pp. 524–536. Hollis ends by saying he is prepared to accept the failure of his paper to convince many of his colleges to change their ways, and he is waiting for one of them to write a paper opening with "Twice upon a time in another space no distance in any direction from here . . ."!

[13] Quoted from the Introduction to Milena Wazeck, *Einstein's Opponents: the public controversy about the theory of relativity in the 1920s*, Cambridge 2014 (published in German in 2009).

[14] Thorne is Professor Emeritus of Physics at the California Institute of Technology.

Teachers, in particular, may find this a useful feature if using the book in an academic setting. The book ends with reprints of two of my own published time travel stories (one from *Analog* and the other from *Omni*), with each serving as an illustration of technical issues raised in the book. From my own teaching of an undergraduate honors class in time travel at the University of New Hampshire, I think the assigning of story writing to be an excellent tool for teachers to use. I found reading student stories to be a lot of fun, and students may well surprise teachers with innovative ideas.

Now that I've mentioned story writing, let me say something about the heavy presence of time travel science fiction stories in this book, the majority of which originated in the often maligned pulp magazines of the 1920s through the 1950s. 'Pulp' has long been burdened with a bad literary reputation. As the editor of one anthology of pulp fiction bluntly put it, "Pulp equated with rubbish. Crap of the basest nature."[15] Part of the reason for that was cosmetic; as I wrote in an earlier book, "The term *pulp* came from the use of inexpensive wood-pulp—you could *feel* the lumpy wood chips in each ragged, untrimmed page—to make paper that was far too crummy for the use by any publisher of 'words meant to last.' Such paper quickly yellowed, turned brittle, and finally, amid billowing clouds of bits and pieces, entered into eternal oblivion. Think of the paper used in your newspaper before its final contribution to civilization in the bottom of your cat's litter box; pulp was worse."[16]

And then a little later, in the same book, "The stories in *Amazing* [*Stories* magazine] were 'read it in the morning, forget it by dinnertime' adventure fiction, the stuff you'd put inside a newspaper if on a crowded train or bus so fellow passengers wouldn't know what a low-grade mind you had. The transient nature of pulp fiction was independent of its literary quality, as the cheap acid-based paper that the stories were printed on began to oxidize and literally burn-up as soon as it rolled off the press. In the introductory essay to a 1950 collection of pulp-detective Philip Marlowe stories (*Trouble Is My Business*), mystery writer Raymond Chandler commented on this when he wrote 'pulp fiction never dreamed of posterity.' Pulp fiction was synonymous with trash fiction, and the nature of much of early pulp SF has been aptly described as 'scientific pornography for the mechanically minded,' and 'writing which drooled over descriptions of technology.'"

When publisher Hugo Gernsback (1884–1967) brought out the first issue of *Amazing Stories* in April 1926, it was the first pulp devoted totally to science fiction. With its masthead motto of "Extravagant Fiction Today—Cold Fact Tomorrow," and with the illustration on the contents page of each issue showing a muscular Jules Verne bursting from his grave in the heroic, up-up-and-away pose made famous years later by Superman, there could be no doubt as to what kind of fiction the reader would find under the dramatic, multi-colored cover art. It was fiction populated with mad scientists, and half-naked woman about to be ravished by alien invaders from outer space; all in all, stuff of interest only to teenage boys and imbecilic adults.[17]

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[15] Maxim Jakubowski, *The Mammoth Book of Pulp Fiction*, Carroll & Graf 1996.

[16] P. J. Nahin, *Holy Sci-Fi!: where science fiction and religion intersect*, Springer 2014.

How else, after all, to explain the publication of one tale[18] that was given the following heart-stopping editorial introduction: "Professor Lambert deliberately ventures into a Vibrational Dimension to join his fiancée in its magnetic torture-fields"? In defense of many of the readers of early pulp science fiction, however, not all were attracted by such nonsense. Just 2 months later (June 1931) one reader wrote to the same magazine to complain of masculine heroes saving weeping women from ungodly horrors: "Just why do you permit your Authors to inject messy love affairs into otherwise excellent imaginative fiction? Just stop and think. Our young hero-scientist builds himself a space flyer, steps out into the great void, conquers a thousand and one perils on his voyage and amidst our silent cheers lands on some far distant planet. Then what does he do? He falls in love with a maiden—or it's usually a princess—of the planet to which the Reader has followed him, eagerly awaiting and hoping to share each new thrill attached to his gigantic flight. But after that it becomes merely a hopeless, doddering love affair ending by his returning to Earth with his fair one by his side. Can you grasp that—a one-armed driver of a space-flyer! . . . We buy A.S. for the thrill of being changed in size, in time, in dimension . . . not to read of love . . . I wish . . . for plain, cold scientific stories sans the fair sex."

Here's another example, this one of the sort of tale that gave an aroma of the sophomoric to 'golden age' time travel science fiction. It was a story of a young man of the far future, with access to a time machine, who wants to see a dinosaur before he dies. So back he travels, back, back, until he at last finds himself in a "subterranean cave, dark and foul-smelling." At first he is puzzled (did dinosaurs live underground?), but then suddenly he hears a thundering roar and sees a huge black shape in the gloom. There can be no doubt now; it *is* a dinosaur, and he sees its red, gleaming eyes just as it crushes him into a pancake. But that's okay; he saw a dinosaur before he died. Then comes the dénouement. He hadn't really gone back quite as far as the Jurassic period, but only to the twentieth century, where he has been run down by the local express train in a subway tunnel![19]

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[17] This was particularly thought to be the case for readers of the romance pulps, written for young women in the 1930s and 1940s (a separate and distinct audience from that of the science fiction pulps). As one commentator wrote on that genre, the heroes and heroines of such tales often displayed the "mental equipment of a banana split," with the implication that the same might be said of the readers, themselves. (See Margaret MacMullen, "Pulps and Confessions," *Harper's Monthly Magazine*, June 1937.) I don't think, however, that this particular complaint generally applied to the pulp science fiction readership. I'll have much more to say about Gernsback and early pulp science fiction speculations concerning time travel, in Chap. 4.

[18] T. Curry, "Hell's Dimension," *Astounding Stories*, April 1931.

[19] R. G. Thompson, "The Brontosaurus," *Stirring Science Fiction*, April 1941. In the editors of *Stirring*'s defense, notice the month: maybe this story was *meant* to be a joke. If so, it was an admirable success.

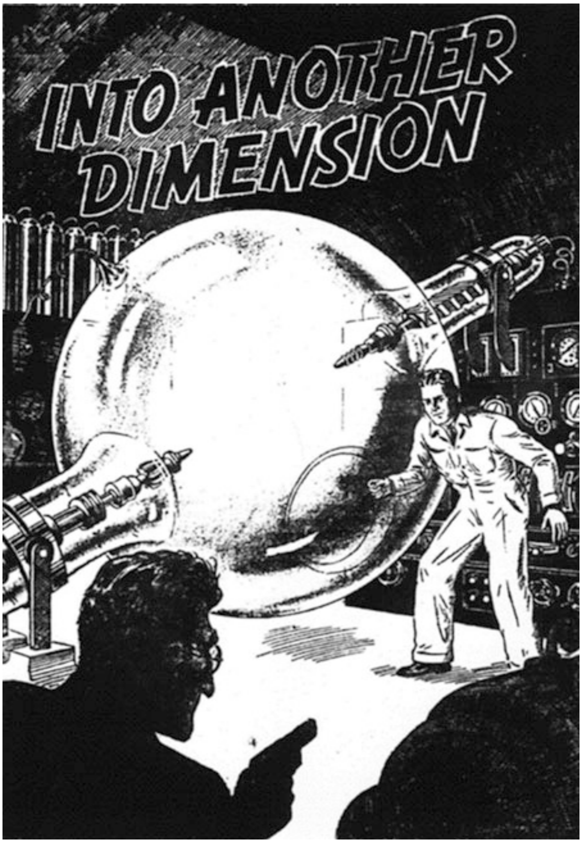

Vibrating into new dimensions was, apparently, a popular idea in 1930s pulp science fiction. This ‘super science’ gadget operated by vibrating an object faster than light, whereupon the Lorentz-FitzGerald contraction formula (see Chap. 3) predicts an *imaginary* size for the object—which means (so we are told) that the object has entered “another plane of existence.” The inventor (the fellow with the gun) is inviting his grim-faced assistant to give the gadget a try. The original caption reads “Get into that vibrator! Get in, I say!”

Illustration for “Into Another Dimension” by Maurice Duclos, *Fantastic Adventures* November 1939 (art by Kenneth J. Reeve), © 1939 by Ziff-Davis Publishing Co., reprinted by arrangement with Forrest J. Ackerman, Holding Agent, 2495 Glendower Ave., Hollywood, CA 90027

Today, however, the need to apologize for science fiction tales about time travel isn’t quite so necessary. Now and then, in fact, you’ll even find one of the better pulp stories cited in highly mathematical papers on time machines in the *Physical Review D*, one of the most important scholarly physics journals. Even those physicists and philosophers who mostly ignore science fiction—except perhaps to make slightly condescending remarks—would, if honest, admit that their early teenage interest in time travel was sparked by reading a really good science fiction story, and not by working their way through a physics textbook. Yes, when the physics eventually came later, it was very good—but the science fiction came *first*, and it was pretty good, too.[20] It's in a 1937(!) tale, for example, that we find the claim for consistency around a closed loop in time, *decades* ahead of the physicists and philosophers.[21] And when you get to the final section of Chap. 4, I think you'll find it difficult to believe that Everett's many-worlds interpretation of quantum mechanics, dating from the late 1950s (which avoids the standard paradoxes of time travel) wasn't inspired by some youthful reading of science fiction from the 1930s and 1940s.

In a number of places in this book you'll find my comments on how science fiction has occasionally anticipated physicists on the subject of time machines and time travel. This is *not* to be interpreted as some sort of 'gotcha' in favor of science fiction. Far from it. When push comes to shove, physics *always* wins. This situation was specifically addressed by Joe Haldeman, in an afterword to his 2007 novel *The Accidental Time Machine*. There he wrote, about when he started in 1971 to write his earlier, now classic novel *The Forever War*, "I needed a way to get soldiers from star to star within a human lifetime, without doing too much violence to special and general relativity. *I waved my arms around really hard* [my emphasis] and came up with the 'collapsar jump'—at the time, collapsar was an alternate term for 'black hole,' though I was unaware of the latter term [because John Wheeler had invented it only 4 years before, as discussed in Chap. 1 and note 106]." And then Haldeman admitted "It's a truism of science fiction that if you predict enough things, a few of them are going to come true. . . . What I think it actually demonstrates is that *if you wave your arms around hard enough* [my emphasis], sometimes you can fly."

Now, there is one feature common to all books on time travel to the past (which is the central topic treated here, of course) that I would like to clearly state. It's obviously a subject of vast interest to physicists, and yet it offers (as far as I know) *absolutely no hope of suggesting even a single experiment for study*. (As far as I know, nobody is building a time machine in their basement.) A suggestion *has* been made that it may be possible to detect, in the *present*, the effects of the *future* operation of "man-made time machines, which could be of a size traversable by humans," that is, machines with a 1-m spatial extent offering a one second trip into the past.[22] With the best technology available today, however, the calculated effects on the proposed two-particle scattering experiment are orders of magnitude too small to measure.

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[20] The view expressed by Vladimir Voinovich's time traveler in his 1986 novel *Moscow 2042* (Science fiction . . . is not literature, but tomfoolery like the electronic games that induce mass idiocy.) is, I think, wrong. For an interesting presentation on the role of science fiction in exciting an interest in science among youngsters, see the paper by Frederik Pohl (1919–2013), "Science Fiction: the stepchild of science," *Technology Review*, October 1994, pp. 57–61. In this essay Pohl, a well-known writer of science fiction and editor of *Galaxy Science Fiction* and *If* magazines, writes "Science fiction is [the ultimate protection] against future shock . . . if you read enough of it, nothing will take you entirely by surprise." Not even time travel.

[21] P. S. Miller, "The Sands of Time," *Astounding Stories*, April 1937.

[22] S. Rosenberg, "Testing Causality on Spacetimes with Closed Timelike Curves," *Physical Review D*, March 15, 1998, pp. 3365–3377.

This situation is really unprecedented in the history of science.[23] To cynics, it may seem to be a bit like writing learned papers on the thermodynamics of fire-breathing dragons (which, like other mythological entities—and time machines, too—have yet to be seen)! This one fact has opened the doors—and has kept them open for decades—for philosophers and science fiction writers, who can endlessly debate back and forth on all aspects of time travel to the past with nary a single experimental fact to complicate their lives. For physicists the situation is naturally frustrating, but for philosophers and science fiction writers it's a dream come true. This isn't to say it's *all* basically theological in nature. Both the physicists and the philosophers *have* written many fascinating papers and books and, of course, so have science fiction writers. Mathematical physics *has* been advanced.

Still, despite all of the theoretical work done in the last 30 years, work that has made it reasonable to seriously talk of 'time travel' and 'time machines,' I suspect many would nonetheless agree with these words from more than 75 years ago: "Of all the fantastic ideas that belong to science fiction, the most remarkable—and, perhaps, the most fascinating—is that of time travel . . . Indeed, so fantastic a notion does it seem, and so many apparently obvious absurdities and bewildering paradoxes does it present, that some of the most imaginative students of science refuse to consider it as a practical proposition."[24] For some, time travel is an even more unlikely possibility than (as declared by Robert Lewis Stevenson) is the "welding of ice and iron." Not all physicists and philosophers view the time travel/paradox arguments as convincing, however. Provocative, yes, of course, but many are not yet prepared to write 'signed, sealed, and delivered' at the end.

So, keep reading and I think you'll discover why there *are* those who are not so quick to dismiss the possibility of following the fantastic world line of H. G. Wells' intrepid Time Traveller[25] into the future. And, just maybe, into the distant past, too.

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[23] Perhaps, however, I am too hasty. More recent theoretical calculations suggest that wormholes connecting our universe with other universes would, after converting into time machines, have characteristic thermal signatures. See P. F. González-Díaz, "Thermal Properties of Time Machines," *Physical Review D*, 2012, pp. 105026-1 to -7 which, however, concludes that a search for such signatures would be "quite difficult [with the] instruments available."

[24] I. O. Evans, "Can We Conquer Time?" *Tales of Wonder*, Summer 1940.

[25] The Time Traveller is never named in Wells' 1895 novel *The Time Machine*. An earlier (1888) attempt at a time machine story, with the awful title *The Chronic Argonauts* (the "chronic" was apparently inspired by the word *chronology*), so embarrassed Wells that he later called it "imitative puerile stuff," "clumsily invented, and loaded with irrelevant sham significance," and "inept," and so he hunted down and destroyed every copy of it that he could find. You can find *The Chronic Argonauts* reprinted in *The Definitive Time Machine* (H. M. Ceduld, editor), Indiana University Press 1987. The hero in that work *was* named: Dr. Moses Nebogipfel. There is one passage in *The Time Machine* that does tantalize; as the Time Traveller explores a museum of "ancient" artifacts in the Palace of Green Porcelain (they are, of course, artifacts of our *future*) he reveals that "yielding to an irresistible impulse, I wrote my name upon the nose of a steatite monster from South America that particularly took my fancy." Thus, the Traveller *has* given his name, but his signature exists only in the future, in a museum of the past that is yet to be built.

For Further Discussion

For time travel to the past to make any sense, the past must in some sense 'still be there.' This is a concept that we'll find later in the book to have significant support in relativistic physics, but for now let's limit ourselves to a purely romantic view. As an example of this, consider this passage by Canadian writer Grant Allen (1848–1899), from the Introduction to his 1895 time travel novel *The British Barbarians*: "I am writing in my study on the heather-clad hill-top. When I raise my eye from my sheet of foolscap, it falls upon miles and miles of broad open moorland. My window looks out upon unsullied nature. Everything around is fresh and pure and wholesome . . . But away below in the valley, as night draws on, a lurid glare reddens the north-eastern horizon. It marks the spot where the great wen of London heaves and festers." I personally find it quite tempting to imagine Allen somehow still there in his study of 1895, and of heaving and festering late-Victorian London, too, with H. G. Wells himself in the middle of it, still reading the first rave reviews of *The Time Machine*. In Wells' novel The Time Traveller journeys into the far future, while in Allen's work the protagonist is a twenty-fifth century anthropologist who has traveled back to the past of the late nineteenth century to study the 'British barbarians.' Read Allen's novel (it's available on the Internet, for free, as a Project Gutenberg book) and comment on the significance of its appearance at virtually the same time as Wells' great work. Why do you think Wells' novel is remembered, and Allen's is not?

In the opening paragraph of his paper "The Conundrum of Time Travel" (*Croatian Journal of Philosophy*, No. 37, 2013, pp. 81–92), Anguel Stefanov writes "Needless to say . . . the problems concerning time travel are being still tackled by science fiction only, but resolved by science proper neither theoretically, nor practically." Do you think this is correct?

Eventually every genre of writing becomes the target for parody, in which the *form* of the genre serves as the framework for what (it is hoped) is a humorous mockery. The most famous example of this, perhaps, is the annual

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Edward Bulwer-Lytton contest in writing a take-off on the long-winded opening line of the 1830 novel *Paul Clifford*, by Bulwer-Lytton (1803–1873). That opening line *is* a wonder (a masterpiece of purple prose): “It was a dark and stormy night; the rain fell in torrents—except at occasional intervals, when it was checked by a violent gust of wind which swept up the streets (for it is in London that our scene lies), rattling along the housetops, and fiercely agitating the scanty flame of the lamps that struggled against the darkness.” Here’s a recent (from the 2015 contest) spoof: “The Contessa’s heart was pounding hard and fast, like an out-of-balance clothes washer, which can get that way if you mix jeans with a lot of light things, though the new ones have some sensor thing to counteract that or shut off, but the Contessa’s heart didn’t have anything like that, so she had to sit down and tell Don Rolando to keep his hands to himself for a while.” Science fiction isn’t immune to such fun, and a good example of that can be found in the September 14, 2015, issue of *The New Yorker*, which has (on p. 50) “Eight Short Science-Fiction Stories” by Paul Simms. Here’s the one I laughed hardest at: “The Gene-Splicers had tinkered with the DNA, producing a race of warriors who craved just two things: the thrill of battle and the taste of their own feet. They hungered for battle. They literally ate their own feet. None survived to reproduce, and within a few short years they were all gone. The Gene-Splicers chalked it up to experience, and decided to try harder the next time.” That, and the other seven spoofs by Simms, cut across a wide swath of science fiction, but one theme noticeably absent was that of time travel. Try your hand at writing a *short* (fewer than 500 words) time travel spoof, and be prepared to read it aloud to an audience of your peers.

The tale “Through the Dragon Glass” by Abraham Merritt (1884–1943) appeared in the early pulp magazine *All-Story Weekly* of November 24, 1917. It described the discovery of a passage through an ancient Chinese mirror into an alternate world. One *might* think of this as an early conception of a wormhole, but more likely it may remind you mostly of Lewis Carroll’s *Through the Looking Glass*. More interesting for us, in this book, is a story written 75 years ago that describes a gadget connecting two regions of spacetime, with a time shift of a week between the two regions. (See “Time Locker” by Lewis Padgett, in the January 1943 issue of *Astounding Science Fiction*.) The gadget falls into the hands of a crooked lawyer who, not understanding what he has, ends up accidently killing himself. As the story ends, the inventor of the gadget ruefully muses to himself that the lawyer

(continued)

"must have been the only guy who ever reached into the middle of next week—and killed himself!" The gadget is, in everything but name, a wormhole time machine. Speculate on how such a spacetime structure could appear in a *science fiction magazine*(!) decades before there was any discussion of such a possibility in the physics world.

Adjectives used to describe many of the stories in the science fiction pulps included *primitive*, *trashy*, *tawdry*, *silly*, *absurd*, *crummy*, *ludicrous*, and *cheap*. One early pulp magazine actually boasted, of its contents, that they contained "sensational fiction with *no* philosophy." Speculate on how such a low-level 'literary' form could have been so successful in finding an enthusiastic audience for time travel paradox tales, tales that are in fact by their very nature simply *stuffed* with philosophical issues. As an example of the tremendous emotional power a particularly well-written time travel story can deliver, read Isaac Asimov's "The Ugly Little Boy" (*Galaxy Science Fiction*, September 1958). Asimov rated this story as among his most favorite of all the many he wrote. If you can read it without ending in tears, well, …. An excellent modern historical work on the pulps (of all genres, not just science fiction) is by Lee Server, *Danger Is My Business: an illustrated history of the fabulous pulp magazines, 1896–1953*, Chronicle Books 1993.

A literary fascination with time was already 'in the wind' when Wells wrote his *Time Machine*, as with Oscar Wilde's 1890 novel *The Picture of Dorian Gray*. Even decades earlier than that one can find a hint of time travel of a sort in Edgar Allen Poe's 1841 short story "Three Sundays in a Week." And just 4 years later Henry Wadsworth Longfellow wrote his haunting poem "The Old Clock on the Stairs," with these opening words:

Somewhat back from the village street
Stands the old-fashioned country-seat.
Across its antique portico
Tall poplar-trees their shadows throw;
And from its station in the hall
An ancient timepiece says it all,—

"Forever—never!

(continued)

Never—forever!”

The most interesting of all pre-Wells time travel fiction to appear in a mass-audience publication was, I think, the short story “The Old Folks Party” by Edward Bellamy, printed in the March 1876 issue of *Scribner’s Monthly*. In this story a group of teenagers, who belong to a weekly discussion club, agree that at their next meeting they will all come dressed and behaving as they believe they will be dressing and behaving 50 years in the future. Also attending will be the grandmother of one of the young ladies. The meeting of the “old folks” takes place, and it invokes such powerful feelings of mortality that, at last, one of the young men can stand it no more: “Suddenly Henry sprang to his feet and, with the strained, uncertain voice of one waking himself from a nightmare, cried:—‘Thank God, thank God, it is only a dream,’ and tore off the wig, letting the brown hair fall about his forehead. Instantly all followed his example . . ..” The young people then began to laugh with relief at once again being young, until they notice the grandmother is crying. Her granddaughter instantly knows what is wrong and says, “Oh, grandma, we can’t take you back with us.” Read, compare, and contrast, these works by Wilde, Poe, Longfellow and Bellamy, with the ‘scientific’ presentation of time travel by Wells.

Acknowledgements

My name is on *Time Machine Tales* as the author, but there are many others without whose help I could not have written it. For this, the revised and updated third edition of the original 1993 book *Time Machines*, I am enormously grateful to the publisher, Springer Science + Business Media, and to my physics editors at Springer, Dr. Sam Harrison and his assistant Ho Ying Fan in New York City. They made an intellectually demanding and inherently lengthy project (one that could easily have turned into a nightmare) a pleasant one. Springer's New York City-based editorial assistant Irene Bruce smoothly handled the administrative details of transforming the book from typescript to print. And to Serguei Krasnikov in Russia, Frank Arntzenius and Roberto Casati in England, Francesco Gonella in Italy, and Geoff Goddu and Archille Varzi in America, I offer grateful thanks for permission to reprint from their publications.

But the story of this book actually begins long before 1993.

Nearly four decades in the past, in 1979, when time travel was still mostly just a nutty idea used by science fiction writers and a few rogue philosophers—proposing to give a serious seminar on time travel at the weekly college *physics* seminar would almost certainly have resulted in getting the bum's rush out the nearest door, or maybe even tossed through the closest window (or, God forbid, *off the roof*!)—I wrote my first time travel tale for *Analog Science Fiction* magazine. Bought by then editor Ben Bova (you can read it in Appendix A), he also bought another time travel tale from me soon after he had become the fiction editor at the newly created *Omni Science Fiction* magazine (you can read it in Appendix B). (Years later, Ben's successor as *Omni*'s fiction editor, Ellen Datlow, bought a third time travel story from me—"The Invitation"—which you can read if you can locate the July 1985 issue.)

Those fictional experiences, and my discovery of Princeton philosopher David Lewis' seminal 1976 essay on the *logical* possibility of time travel, led me to plunge into a deeper study of the *physics* of time travel, to the point where as the 1980s ended (1988, to be precise) I thought a book should be my next writing project. Alas, nobody else shared that thought. I spent the next 3 years looking for a

publisher among numerous university presses; as I looked, the pile of rejection letters, like entropy, grew steadily larger.

The editor at one well-known university press, in fact, simply laughed at the idea of a scholarly time travel book when I called him on the telephone (e-mail was then still in its infancy) to ask, after a long period of no response to my written proposal, if he had gotten it. (Perhaps, I told myself, the mail truck carrying my precious document had fallen into a hyper-dimensional spacetime warp: how pathetically desperate is the anxious academic writer!) Later, I published a number of math/physics books with that same press (but now with new editors) and so there were no lasting hard feelings.

That laughing, unresponsive editor wasn't alone in his opinion, I have to admit, and it wasn't until 1991 when Maria Taylor, the publisher at the Press of the American Institute of Physics (AIP Press), decided to take a chance (a *big* chance) and publish the first edition of *Time Machines*. She made that decision in large part because of two extremely supportive reviews of my proposal from the academic physicists Edwin Taylor (MIT, and a former editor of *The American Journal of Physics*) and Gregory Benford (University of California, Irvine, as well as being an award-winning writer of science fiction who occasionally used the time travel theme). After the original *Time Machines* appeared, Ben Bova asked me to use it as a guide to writing a book on time travel for the new Writer's Digest series on science fiction that he was editing, aimed specifically at would-be story writers; that book came out in 1997 as *Time Travel*. Later, Trevor Lipscombe, then editor-in-chief at the Johns Hopkins University Press (and my former math editor at Princeton University Press), reprinted *Time Travel* (with a new Preface) in 2011.

After Springer acquired AIP Press (and all of its books) in 1995, and Maria Taylor herself went over to Springer, she and I collaborated again on bringing out the second edition of *Time Machines* in 1999. And now, 18 years later, here (with a title slightly altered for reasons I give in "Some First Words") is its successor.

To Sam, Ho Ying, Irene, Ben, Ellen, Maria, Edwin, Gregory, and Trevor, thank you for your support. But my greatest debt of all, one I can never even begin to repay, is to my wife of 55 years, Patricia Ann, a woman of infinite tolerance. Who else would put up with someone who plays first-person-shooter video games at midnight (the bigger and the louder the explosions, the better!) and writes books on time machines, all the while claiming not to be crazy?

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Introduction

> Over the last few years leading scientific journals have been publishing articles dealing with time travel and time machines. . . . Why? Have physicists decided to set up in competition with science fiction writers and Hollywood producers?
>
> —John Earman (see note 25 of *Some First Words*)

Writing about time travel is, today, a respectable business. It hasn't always been so. After all, time travel, *prima facie*, appears to violate a fundamental law of nature; every effect has a cause, with the cause occurring before the effect. Time travel to the past, however, seems to allow, indeed to *demand*, backwards causation, with an effect (the time traveler emerging into the past as he exits from his time machine) occurring *before* its cause (the time traveler pushing the start button on his machine's control panel years *later* to start his trip backward through time).

Thus, when H. G. Wells published his breakout masterpiece, *The Time Machine*, in 1895, even those readers who loved it as a *story* (and not all did) were still quick to dismiss it as a *romantic fantasy*. It was, in their view, certainly an emotionally powerful tale of pure imagination, but nothing more. Reviewers of the day used such words as "hocus-pocus" and "bizarre," and called the work a "fanciful and lively dream."[26] Any one of the novels by Wells' contemporary, Jules Verne (even such super-technology ones like the 1865 *From the Earth to the Moon*) would have been ranked *far* above Wells' novella in terms of 'it could actually happen.'

Wells himself always denied that his time machine was anything more than a literary device[27] to get his Time Traveller into the far future. Indeed, in 1934, in the preface to *Seven Famous Novels* (published by Knopf), a collection of his novel-length scientific romances (as science fiction had been known before the term *science fiction* came into use), including *The Time Machine*, Wells made his position perfectly clear: "These stories of mine collected here do not pretend to deal with possible things; they are exercises of the imagination ... They are all fantasies; they do not aim to project a serious possibility; they aim indeed only at the same amount of conviction as one gets in a good gripping dream." Wells then went on to say in that same preface that all attempts before at writing fantastic stories depended on magic. But not in his works. "It occurred to me that instead of the usual interview with the devil or a magician, an ingenious use of scientific patter might with advantage be substituted." Wells' great contribution to time traveling story-telling was his introduction of a *machine*; science instead of magic, drugs, dreams, blows on the head, or suspended animation.[28] Not all modern science fiction writers have followed Wells' lead, however.

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[26] These reviews are reprinted in P. Parrinder, *H. G. Wells: The Critical Heritage*, Routledge & Kegan 1972. A modern reviewer has applied such negative characteristics to the Time Traveller, himself, calling him "a kind of Trickster figure" and "a quack and magician." See Robert J. Begiebing, "The Mythic Hero in H. G. Wells's *The Time Machine*," in *Essays in Literature*, Fall 1984, pp. 201–210.

[27] Wells was not the first to use a machine to enable time adventures, as the Spanish writer Enrique Gaspar (1842–1902) used one in his 1887 story *The Time Ship: A Chrononautical Journey*. It's Wells' tale we remember, however.

A science fiction tale by Clifford Simak (1904–1988), for example, the 1978 novel *Mastodonia*, incorporates an alien creature marooned on Earth (because of a spaceship crash centuries earlier) who 'makes time tunnels.' One of the characters in the story, who is attempting to start a time-travel agency using these tunnels, explains why not having a time *machine* is causing her difficulties with prospective clients: "The whole trouble was that I couldn't tell them about some machine—a time-travel machine. If I could have told them we'd developed a machine, they'd have been more able to believe me. We place so much trust in machines; they are magic to us. If I could have outlined some ridiculous theory and spouted some equations at them, they would have been impressed." I think that's off the mark. We trust in machines not because they are magic, but for precisely the opposite reason. They are *not* magic, but rather are *rational*. And to dismiss mathematics is to say that some non-natural—some supernatural—influence is at work.

But is a time *machine* actually possible? Or is the idea of a time machine simply "Nonsense" and "A bilgeful of crap," as a character bluntly puts it in the 1972 novel *The Dancer from Atlantis* by Poul Anderson (1926–2001). Wells, himself, addressed this point in an autobiographical essay (published in the *Cornhill Magazine*) that he wrote in July 1945 (just 13 months before his death) in even blunter words. Writing under the name of "Wilfred B. Batterave," he penned a very funny summary of his life titled "A Complete Exposé of This Notorious Literary Humbug." There he described *The Time Machine* as "[A] tissue of absurdities in which people are supposed to rush to and fro along the 'Time Dimension.' By a few common tricks of the story-teller's trade, Wells gets rid of his Machine before it can be subjected to a proper examination. He cheats like any common spook raiser. Otherwise it is plain commonsense that a man might multiply himself indefinitely, pop a little way into the future and then come back. There would then be two of him. Repeat *da capo* and you have four, and so on, until the whole world would be full of the Time Travelling Individual's vain repetitions of himself. The plain-thinking mind apprehends this in spite of all the Wellsian mumbo-jumbo and is naturally as revolted as I am by the insult to its intelligence." Funny, yes, but still pretty harsh stuff.

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[28] Examples of 'non-machine' time travel stories of the last four types are, respectively, H. G. Wells' "The New Accelerator" (1901), Charles Dickens' *A Christmas Carol* (1843), Mark Twain's *A Connecticut Yankee in King Arthur's Court* (1889), and Edward Bellamy's *Looking Backward, 2000–1887* (1888).

As one writer has argued,[29] Wells was, rather than presenting a scientific discovery, simply attempting to refute the nearly suffocating, unjustified (in his mind), smug optimism of the well-to-do of the Late Victorian Age. And so, on his journey to the year A.D. 802,701, the Time Traveller finds the awful decay of humanity in the cannibalistic subjugation of the Eloi by the Morlocks, the end result of class warfare between the working class (Morlocks) and the idle, parasitic upper class (Eloi).

The German social philosopher Karl Marx, if he hadn't already been dead for 12 years in 1895, would surely have nodded in vigorous agreement as he read *The Time Machine*, even as he would have regretted Wells' decision to have the victory of oppressed workers take so long. (What irony that he is buried in London's Highgate Cemetery, the Victorian Valhalla where he has spent the last century and more quite literally mingling with many of the capitalistic ancestors of the Eloi!) What Marx would have thought of *time travel* as a possibility is, however, far less certain.

How things changed in the years that followed *The Time Machine*. There was, at first, admittedly a 'slight' decline in literary merit as the newly developing pulp science fiction magazines picked-up and ran with the time travel genre. Many of the magazine time travel tales of the 1920s, 1930s, and 1940s were, frankly, simply awful. BUT—some were pretty good, too. And some were, in fact, *very* good. From the 1950s on, there have been ever more sophisticated time travel tales from ever more sophisticated writers.

In the academic communities of philosophers and physicists, too, big events occurred. I give the philosophers the edge, in fact, with the 1976 publication of a hugely important paper that opened with these dramatic words: "Time travel, I maintain, is possible. The paradoxes of time travel [to the past] are oddities, not impossibilities. They prove only this much, which few would have doubted: that a possible world where time travel took place would be a most strange world, different in fundamental ways from the world we think is ours."[30] That writer wasn't the first philosopher to write on time travel to the past, but none had expressed themselves in such powerful and unequivocal words in unmistakable support of the concept.

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[29] R. M. Philmus, "*The Time Machine*; Or, the Fourth Dimension as Prophecy," *Publications of the Modern Language Association*, May 1969, pp. 530–535.

[30] David Lewis, "The Paradoxes of Time Travel," *American Philosophical Quarterly*, April 1976, pp. 145–152. Lewis (1941–2001) was a Princeton University philosophy professor.

Lewis' paper is also notable because it gives what seems to be a clear definition of just what it means to say one has 'traveled in time,' either to the past *or* to the future:

> What is time travel? Inevitably, it involves discrepancy between time and time. Any traveler departs and then arrives at his destination; the time elapsed from departure to arrival (positive, or perhaps zero) is the duration of the journey. But if he is a time traveler, the separation in time between departure and arrival does not equal the duration of the journey.

To understand this, we need to appreciate the distinction between the *personal time* of the time traveler and the *external time* of remote observers of the time traveler. A time traveler's personal time is measured, for example, either by the time kept by his wrist watch or, perhaps, by a burning candle. (This distinction had actually appeared earlier in Horwich's paper—see note 27 in *Some First Words*—published the year before Lewis' paper.)

I say I 'give the edge to the philosophers' because, while the first *physics* time travel paper had appeared decades earlier, its author wasn't really a physicist at all but rather was Einstein's friend, the world-famous mathematical logician Kurt Gödel. Gödel's paper was, in retrospect, a pivotal event in establishing the 'respectability' of *scientific* time travel; it's worthwhile to take some time here to explain this important point. For physicists (and for philosophers and science fiction writers, too) a 'time machine,' one either constructed by intelligent beings or occurring naturally, manipulates (all the while obeying the known laws of physics) finite amounts of matter and energy in a finite region of spacetime.[31] A 'time machine' would be declared to be *plausible* if it could be explained by a rational, scientific theory. Such a rational theory is found in Einstein's general theory of relativity. (His *special* theory of relativity applies in those situations where there is no gravity.)

Until Einstein, the theory of gravity used by scientists was Newton's—a theory that, although amazingly accurate for any situation encountered on Earth, does have observable errors in certain astronomical applications. In addition, Newton's theory is a descriptive one; it makes possible the calculation of gravity effects without offering any explanation for gravity itself. Einstein's theory not only gives the right answers, even in those cases where Newton's theory doesn't, but it also explains gravity. It does that by treating the world as a four-dimensional structure in which all four dimensions (three of space and one of time) are in a certain sense on equal footing. The resulting Einsteinian description of the world is that of a unified spacetime in which time and space are intimately intertwined, whereas Newton's theory keeps time and space separate and distinct.

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[31] I am going to feel free to use words like *spacetime* without having to first write introductory essays on relativity theory and tensor mathematics, because such words have entered common use. All those Hollywood science fiction movies, even the crummy ones that routinely trash the laws of physics, have at least expanded the general imagination!

As Newton wrote of time, at the start of his 1687 masterpiece *Principia*, a work that revolutionized physics, “Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration.” This view of time would be, of course, discarded with the arrival of Einstein and his view of variable time depending on the state of the observer.

Unlike Einstein’s view, Newton’s view of the nature of time was entangled with theology. As one modern theologian has written, “Newton conceived of absolute time as grounded in God’s necessary existence.”[32] To quote Newton himself, in the *General Scholium* to the second edition of *Principia* (1713) he added words that didn’t appear in the original: “God is a living, intelligent, and powerful Being; and, from his other perfections, [it follows] that he is supreme, or most perfect. He is eternal and infinite, omnipotent and omniscient; that is, his duration reaches from eternity to eternity; his presence from infinity to infinity; he governs all things, and knows all things that are or can be done. He is not eternity and infinity, but eternal and infinite; he is not duration or space, but he endures and is present. He endures forever, and is everywhere present; and, by existing always and everywhere, he constitutes duration and space. Since every particle of space is *always*, and every indivisible moment of duration is *everywhere*, certainly the Maker and Lord of all things cannot be *never* and *nowhere*.”

Okay, I’ll be honest—I really am not at all sure just what that means! Newton added these words to the *Principia* in response to criticism (from the influential philosopher George Berkeley (1685–1753)) that his original statements about absolute time were “pernicious and absurd notions,” notions that were in fact atheistic in conception. That was a most serious charge in Newton’s day, and he was trying (I think) to find some cover from those critics who spent more hours of the day thinking about God than of physics. Much more honest (in my opinion) are the witticisms ‘time is just one damn thing after another’ and ‘time is what keeps everything from all happening at once.’[33] More funny than useful, yes, of course, but at least they’re funny.

Newton’s theological view of time is simply irrelevant to the modern physicist (although perhaps of more interest to the philosopher-historian) but in many cases it is of *central interest* to the science fiction writer. For example, Newton’s religious mindset and its (perhaps!) connection with time travel is treated in my short story "Newton's Gift," originally published in *Omni Magazine* (January 1979) and reprinted in Appendix B at the end of this book. Wells' Time Traveller's view of time is more Newtonian than it is Einsteinian—and perhaps that's not such a big surprise, considering that Einstein was only 16 years old when *The Time Machine* was published.

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[32] William Lane Craig, “God and the Beginning of Time,” *International Philosophical Quarterly*, March 2001, pp. 17–31, which discusses the question ‘Why didn’t God create the world sooner?’ One irreverent answer is ‘He was busy creating Hell for all those who ask that question,’ but a more scholarly analysis can be found in Brian Leftow, “Why Didn’t God Create the World Sooner?” *Religious Studies*, June 1991, pp. 157–172.

[33] This last ‘definition’ first (as far as I know) appeared in the work of the science fiction writer Ray Cummings (1887–1957), in his 1921 story “The Time Story,” published in *Argosy-All-Story* magazine. He repeated the phrase in his 1929 novel *The Man Who Mastered Time*, and then again in the 1946 novel *The Shadow Girl*. (“This same Space; the spread of this lawn . . . what would it be in another 100 years? Or a 1000? This little space, from the Beginning to the End so crowded with events and only Time to hold them apart!”)

From the first (1905) it has been known that Einstein's special theory allows time travel into the future via the well-known mechanism of *time dilation*. (The faster a rocket ship travels relative to Earth, the slower is the tick-tock of a wrist watch worn by a rocketeer, compared to that of an identical watch back on Earth.)[34] To return from the future, however, to travel back into the past to the instant after the traveler began his journey, had been thought to be impossible. It was Gödel's discovery that showed the general theory, which has passed every experimental test it has been subjected to (most recently, the September 2015 detection, from two massive colliding black holes, of gravitational waves—'ripples in spacetime'—generated more than a billion years ago in an effect predicted by the general theory a century ago), does allow time travel to the past *under certain conditions*. It is this availability of a *theory* that distinguishes time travel speculations from the outlandish fantasy speculations with which it is often unjustly lumped—speculations that *are* in the province of quacks (such as ESP, astrology, and mind over matter a' la spoon bending).

In his general theory, Einstein showed how spacetime can be either 'flat' (in the no-gravity, special relativity case of what is called a *Minkowski spacetime*[35]) or 'curved' (those situations with gravity), and he did that not by verbal hand waving, but rather by writing mathematical equations that obey all the known laws of physics: his famous gravitational field, nonlinear differential tensor equations. These complicated equations are notoriously difficult to solve in general, but in certain, special cases they *have* been solved. Those solutions describe how matter and energy and spacetime interact. As the popular saying puts it, "Curved spacetime tells matter how to move, and energy and matter tell spacetime how to curve." In that sense, gravity *is* curved spacetime.

In 1949 Gödel found one such special solution to the field equations that describes the movement of mass-energy not only through space but also *backward in time* along trajectories in spacetime that are called *closed time-like lines* or *curves*

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[34] One pulp magazine science fiction story (F. J. Bridge, "Via the Time Accelerator," *Amazing Stories*, January 1931) got this right when its time traveler explains how his time machine works with these words: "Time as we know it is not universally absolute. The rate of its passage depends to a great extent upon the velocity of its observer with regard to some certain reference system. A moving clock will run slower with respect to a selected coordinate system than a stationary one." (Recall my earlier comments on the personal time of a time traveler.)

[35] Named after Hermann Minkowski (1864–1909), Einstein's mathematics professor in Zurich who gave the now well-known spacetime diagram interpretation of special relativity which, when originally presented by Einstein, was in the form of pure mathematics.

(called CTLs or CTCs, respectively).[36] These trajectories are such that if a human traveled along one, *always at a speed less than that of light* (that's what *time-like* means), he would see everything around him happening in normal causal order from moment to moment (for example, the second hand on his wrist watch would tick clockwise into the local future), but eventually the CTL/CTC closes back on itself and the traveler finds himself in his own past.

On the scale of the Solar System, general relativity has causality built into itself, but on much larger scales things can be a good deal more complicated. On a very large, astronomical scale, in fact, curved spacetime can result in violations of causality, with effects occurring before their causes. That is what the physics and the mathematics of Gödel's solution imply. That is what is meant by saying there is a scientific, rational basis for discussing time travel to the past. It is particularly important to note that travel along one of the closed time-like world lines discovered by Gödel requires a *machine*, some kind of accelerating rocket ship. That's because none of Gödel's CTLs/CTCs are what is called a *geodesic*. That is, none are *free-fall* world lines.[37] This machine does not, however, generate CTLs/CTCs where none existed before (CTL/CTC *creation* requires what physicists call a *strong* time machine) but rather simply makes use of the CTLs/CTCs that are inherent in Gödel's spacetime. A Gödelian rocket ship then is an example of a *weak* time machine.

I mentioned earlier that "certain, special cases" of Einstein's gravitational field equations result in CTLs/CTCs. What was the "special case" that Gödel solved? His solution of the field equations is for a rotating, infinite, static universe composed of a perfect fluid at constant pressure. In such a universe Gödel found that naturally occurring CTLs/CTCs pass through every point in spacetime; that is, time travel in Gödel's universe is *not* the result of a machine *manipulating* mass and energy on a *local* scale (the classic science fictional description of a time machine); rather, in Gödel's spacetime time travel is a naturally occurring phenomenon! The observable universe is, however, *non*-rotating and expanding (astronomers see red-shifts in the spectrums of distant stars) and so, although Gödel's spacetime satisfies the general relativity field equations, its time travel property does not hold in the spacetime in which we live. (This may account for why the initial reaction in the physics/ philosophical communities, to Gödel's discovery that time travel is *not* nonsense according to general relativity, was mostly indifference.) The failure to observe time travel in our universe may (somewhat surprisingly, I think) still have possible implications for us, however, as one philosopher has cleverly argued.[38] He points out that naturally occurring Gödelian time travel would endow the universe with properties particularly useful for the survival of intelligence (presumably that includes humans) against extinction from a multitude of cosmic disasters. So, for those who argue that the universe we live in was *made* for us (the advocates of various proofs of God's existence that have Him as Designer), we have an obvious question: why did He (apparently) skip incorporating time travel?

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[36] Kurt Gödel, "An Example of a New Type of Cosmological Solutions of Einstein's Field Equations of Gravitation," *Reviews of Modern Physics*, July 1949, pp. 447–450. A CTL/CTC is a special type of *world line*; the trajectory through spacetime of every particle in the universe is a world line that extends from each particle's past to its future. Our everyday experiences are with world lines that never cross or come close to themselves (which would put a particle at or near the same spacetime point more than once). That lack of experience with CTLs/CTCs that self-intersect is what makes time travel to the past so difficult for humans to grasp. For a discussion of *how* Gödel did what he did, see Wolfgang Rindler, "Gödel, Einstein, Mach, Gamow, and Lanczos: Gödel's Remarkable Excursion into Cosmology," *American Journal of Physics*, June 2009, pp. 498–510.

[37] It was discovered in 1969, however, that this isn't strictly true *if* one allows for a test particle (our 'time traveler') to be electrically charged. Then, naturally present electromagnetic forces acting on the particle could be sufficient to propel the particle along a Gödelian CTL/CTC. That is, no rocket would be required. See U. K. De, "Paths in Universes Having Closed Time-Like Lines," *Journal of Physics A*, July 1969, pp. 427–432. There are other solutions to Einstein's equations that do allow time travel on free-fall geodesics: see, for example, I. D. Soares, "Inhomogeneous Rotating Universes with Closed Timelike Geodesics of Matter," *Journal of Mathematical Physics*, March 1980, pp. 521–525.

In an invited essay that appeared the same year as his time travel physics paper, Gödel specifically addressed the seemingly paradoxical aspect of what he had discovered: "By making a round trip on a rocket ship in a sufficiently wide course, it is possible in these [rotating] worlds to travel into any region of the past, present, and future, and back again, exactly as it is possible in other worlds to travel to distant parts of space. This state of affairs *seems* [my emphasis] to imply an absurdity. For it enables one, e.g., to travel into the near past of those places where he has himself lived. There he would find a person who would be himself at some earlier period of life.[39] Now he could do something to this person which, by his memory, he knows has not happened to him."

Gödel's nerve then failed him, and he defended the possibility of the paradox of a time traveler meeting himself in the past with what I think an astonishingly unconvincing argument (particularly so for a logician) based primarily on *engineering* limitations: "This and similar contradictions, however, in order to prove the impossibility of the worlds under consideration, presupposes the actual feasibility of the journey into one's own past. But the velocities which would be necessary in order to complete the voyage in a reasonable time are far beyond everything that can be expected ever to become a practical possibility. Therefore it cannot be excluded a priori, on the ground of the argument given, that the space-time structure of the real world is of the type described."[40] That is, Gödel was trying to head off critics of his rotating universe model who might point to the time travel result as proof that the model had to be flawed.

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[38] Alasdair M. Richmond, "Gödelian Time-Travel and Anthropic Cosmology," *Ratio*, June 2004, pp. 176–190. Not all physicists think Gödel's result is actually time travel. At least two think it is all simply the result of mathematical hijinks, and that time machines must remain "an aspect of science fiction fantasy": see F. I. Cooperstock and S. Tieu, "Closed Timelike Curves and Time Travel: Dispelling the Myth," *Foundations of Physics*, September 2005, pp. 1497–1509. This skepticism towards Gödel actually started much earlier, when two physicists (one a Nobel physics laureate) incorrectly claimed Gödel had simply gotten his math wrong: see S. Chandrasekhar and J. P. Wright, "The Geodesics in Gödel's Universe," *Proceedings of the National Academy of Sciences*, March 1961, pp. 341–347. It was those two physicists who had erred, however, as was pointed out by the philosopher Howard Stein, in his "On the Paradoxical Time Structures of Gödel," *Philosophy of Science*, December 1970, pp. 589–601.

[39] You'll recall that this is *precisely* the situation that Wells mentions in his "Notorious Literary Humbug" essay. If only he had lived just three more years, to see what he thought to be an absurdity actually appear in the serious writings of a brilliant mathematician!

In a footnote Gödel says that the time traveler would have to move at least as fast as nearly 71 % of the speed of light, and that if his rocket ship could "transform matter completely into energy" then the weight of the fuel would be greater than that of the rocket by a factor of 10^{22} divided by the square of the duration of the trip (in rocket years). A trip to the past in Gödel's universe would require a time machine that looked like Dr. Who's telephone booth attached to a fuel tank the size of several hundred *trillion* ocean liners. These are formidable numbers,[41] but they require no violation of physical laws, and that's what really counts if time travel is to be disproved. Gödel's use of engineering limitations for explaining away backwards time travel is actually worse than simply being wrong, because the puzzle is not in practicality but rather in showing, assuming that general relativity is correct, how correct mathematical physics can lead to what seems to be a paradoxical conclusion. (And see note 12 again, for another reason the 'fuel argument' really has no force at all against the possibility of time travel in Gödelian spacetime.)

So, what did the great man himself, Einstein, think of all this? In the same publication as Gödel's essay, he *cautiously* replied as follows: "Kurt Gödel's essay constitutes, in my opinion, an important contribution to the general theory of relativity, especially to the analysis of the concept of time. The problem here involved disturbed me already at the time of the building up of the general theory of relativity, without my having succeeded in clarifying it . . . the distinction 'earlier-later' is abandoned for world-points which lie far apart in a cosmological sense, and those paradoxes, regarding the *direction* of the causal connection arise, of which Mr. Gödel has spoken . . . It will be interesting to weigh whether these are not to be excluded on physical grounds."

Despite the mathematical physics of Gödel, showing the possibility of time travel to the past, many philosophers are not quite so sure. As one expressed his concerns, "No science-fiction staple poses more philosophical difficulties than time travel, but there is still no consensus as to whether time-travel fictions exhibit logical, metaphysical, or physical impossibility."[42] The best-known and possibly oldest of the paradoxical situations that seem to be part-and-parcel of time travel is the so-called *grandfather paradox*,[43] expressed this way by philosopher David Lewis in his pioneering 1976 paper (see note 5):

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[40] Kurt Gödel, "A Remark About the Relationship Between Relativity Theory and Idealistic Philosophy," in *Albert Einstein: Philosopher-Scientist*: volume 7 of *The Library of Living Philosophers* (P. A. Schilpp, editor), Open Court 1949.

[41] For the analysis of a rocket powered by matter/anti-matter, a known physical process that satisfies Gödel's energy requirement for time travel, see E. Purcell, "Radioastronomy and Communication Through Space," in *Interstellar Communication* (A. G. W. Cameron, editor), W. A. Benjamin 1963.

[42] Alasdair Richmond, "Time-Travel Fictions and Philosophy," *American Philosophical Quarterly*, October 2001, pp. 305–318.

> Consider Tim. He detests his grandfather, whose success in the munitions trade built the family fortune that paid for Tim's time machine. Tim would like nothing so much as to kill Grandfather, but alas he is too late. Grandfather died in his bed in 1957, while Tim was a young boy. But when Tim has built his time machine and traveled to 1920, suddenly he realizes that he is not too late after all. He buys a rifle, . . . and there [Tim] lurks, one winter day in 1921, rifle loaded, hate in his heart, as Grandfather walks closer, closer . . .

So, there's the puzzle. Tim can obviously achieve his goal—he has a loaded gun, he's an excellent shot, a clueless granddad is coming ever closer—but if Tim actually does kill grandfather, years *before* Tim was (will be) born, then how can Tim *be* born? And if he is not born, then how can Tim ('now' not in existence) travel back through time to kill grandfather? What a confusing mess, right? So, the only possible conclusion to all this is that the starting premise, that time travel makes sense, must actually be nonsense. Right?

Well, maybe, but then what of Gödel with his time traveling rocket ship? That's hard-as-diamond, unshakeable mathematical physics, for heaven's sake. We can't just ignore *that*! Lewis offers a way out of this conundrum, and when we get to the book's discussions on paradoxes (that's plural because, believe it or not, there are other paradoxes even *more* perplexing than that of killing granddad in the distant past) we'll return to his solution.

Ever since Lewis wrote his paper, philosophers have been particularly fascinated by the grandfather paradox and have shown themselves to be at least as inventive as the science fiction writers in discussing it, or variations on it.[44] Here, for example, is a twist on that paradox that I think particularly clever, one that avoids the murderous spirit of the tale told by Lewis and Horwich:

---

[43] The origin of this paradox is probably lost in time (the irony of that is *so* appropriate!), but I have traced it at least as far back as to the science fiction pulp magazine *Science Wonder Stories* which published, in its December 1929 issue, an editorial essay titled "The Question of Time Traveling." It challenged readers to think about the following scenario: "Suppose I can travel back into time, let me say 200 years; and I visit the homestead of my great great great grandfather, and am able to take part in the life of his time. I am thus enabled to shoot him, while he is still a young man and as yet unmarried. From this it will be noted that I could have prevented my own birth . . .."

[44] Even before Lewis' paper, Paul Horwich had reduced the grandfather paradox to *autoinfanticide*—a time traveler tries to kill his younger *self*—in "On Some Alleged Paradoxes of Time Travel," *The Journal of Philosophy*, August 14, 1975, pp. 432–444. But not all philosophers share this fascination. Earman (see the opening quote), for example, dismisses *all* of the science fiction paradoxes that are so beloved by fans of the genre as "while always good for a chuckle," they are just "crude and unilluminating means of approaching some delicate and deep issues about the nature of physical possibility." I think Earman is fundamentally correct, although I wouldn't go so far as to characterize the paradoxes as mere "chuckles." They are, after all, the source of much of the intellectual motivation prompting the exploration of the physics of time travel. An excellent example of this is found in the paper by the Russian physicist S. V. Krasnikov, "Time Travel Paradox," *Physical Review D*, February 14, 2002, pp. 064013-1 to 064013-8. The physics of the grandfather paradox is of *great* interest in this paper.

> Sarah has just completed building her time machine. She decides to test the machine on herself tomorrow morning at which time she intends to travel back one day. In the meantime, she goes home, puts some salve on the burn she received that day, and goes to bed. In the morning, Sarah, with coffee in hand, sits down to read the morning paper. She opens the paper to the following headline: 'Famous physicist found dead.' On the front page is a picture of her body, salve burn clearly visible on her arm, inside her pristine time machine. Underneath is the caption. 'Nobel-prize winning physicist found dead yesterday in mysterious device that materialized near city hall.' Extremely shaken, Sarah returns to the lab and destroys the time machine.[45]

Can any sense be made of this? We'll come back to this question later in Chap. 5, when we discuss the possibility (or not) of time being *multi*-dimensional.

Now, to conclude this Introduction, let me end with two amusing, connected short stories (in epistle form) that nicely describe the issues we'll take up in the rest of this book. The rejection letter for the denial of a research grant to fund the construction of a time machine has just been received . . .

That Useless Time Machine[46]

Dear Review Committee:
It is not our practice to raise complaints against a negative review report. We believe in peer refereeing and we respect it, whatever its content and consequences. However, in the case of our latest grant application (project named 'The Time Machine') we find it necessary to express our astonishment at the motivations with which our request for funding was turned down. Your main objection appears to be that our project is 'philosophically interesting' but 'practically useless', by which you mean that the project 'has no potential for applications.' We do not quite think that the main criterion for judging the scientific value of a project should be its practical usefulness, but never mind that. Let us agree that usefulness is a relevant criterion, especially when large amounts of money are involved. Why should that be a reason to turn down our project? Quite frankly, we cannot think of a project with better application potential than ours. Some examples:

- Cultural tourism: one could send herds of history fans back in time to witness the crucial episodes of the French Revolution, or to watch the Egyptians build the pyramids, or to videotape Socrates' lectures.
- Exotic safaris: we have already received several applications for dinosaur hunting expeditions (they got extinct anyway).

---

[45] G. C. Goddu, "Time Travel and Changing the Past: (Or How to Kill Yourself and Live to Tell the Tale)," *Ratio*, March 2003, pp. 16–32.

[46] Story by Roberto Casati (Senior researcher at CNRS, Paris) and Achille C. Varzi (Professor of Philosophy at Columbia University). Originally published in *Philosophy*, October 2001, pp. 581–583, and reproduced here by kind permission of the authors.

- Error detection: we could take a closer look at our past mistakes and learn how to avoid them in the future.
- Historic documentaries: think of the huge saving in set design, costumes, special effects, etc. (How much did *Gladiator* cost?)

And so on and so forth. Honestly, can you think of a project with better prospects for useful and thrilling applications?

Sincerely Yours,
The 'Time Machine' Research Group

Dear 'Time Machine' Research Group:
Thank you for your letter. We agree that it would be interesting to exploit a time machine for the uses that you suggest. It would also be remarkable if we could use it to prevent all sorts of unpleasant events that happened in the past. It would be remarkable, for instance, to be able to go back to November 22, 1963, and prevent Lee Harvey Oswald from killing John Kennedy, or to go back to April 14, 1912, and steer the Titanic around the iceberg. It would be excellent indeed to be able to do such things. However, suppose your project were to be successful. Suppose you *will* manage to build a time machine. Then why *didn't* you do any of those things? Why is it that our past history is still full of such sad events? Either this means that your project is doomed to fail and you will never manage to build a time machine; *or* it means that the project will succeed but that you are not going to use your time machine for these good purposes. In the first case, logic shows it would be pointless to support your project. In the second case, ethics dictates that it would be wrongdoing. Either way, you must concede that the reasons against your project are overwhelming.

Cordially Yours,
The Review Committee

Dear Review Committee:
Certainly you have noticed that our suggestions for practical applications of the time machine did not include any uses that could result in an alteration of the natural course of history. As a matter of fact, we believe that no such alteration is logically possible. According to our project, it is logically possible to *visit* the past but not to *modify* the past. No time traveler can undo what has been done or do what has not been done. So the logic is safe. This does not mean that the time traveler will be ineffectual during her stay in the past, of course; it simply means that what she is going to do is something that she has already done. An accurate catalogue of all the past events would include an account of the arrival of the Time Machine from out of nothing as well as an account of all the actions and reactions that followed. And ethics is safe, too. For, if indeed we managed to go back to Dallas, we could not stop Oswald from doing what he did. Nobody would be able to stop Oswald because nobody was able to stop him (and nobody was able to stop Oswald because nobody will ever be able to do so, even if they came from the future). Alas, the past is full of sad events but there is nothing that we can do about that.

Respectfully Yours,
The 'Time Machine' Research Group

Dear 'Time Machine' Research Group:
We appreciate the distinction between changing the past (impossible) and affecting the past (possible). However, this simply reinforces our initial impression: your project has no practical value. If in order to travel to the past one has to have been there already, and if one can only do what has already been done, then *á quoi bon l'effort*? Why should we invest in a 'Time Machine' at all? We are afraid that our decision is now final.

Yours with best wishes,
The Committee

Well, all seems to be certainly lost with *that*. But, wait, perhaps not. Maybe, with just one more *really good* appeal, The Committee's rejection can be reversed! If *you* were on the Review Committee, and had just read the following letter, how would *you* vote?

A Useful Time Machine[47]

Dear Review Committee:
We regret your continued decision to reject our proposal. Even though you have told us your decision is now final, we humbly ask your indulgence for one last appeal. We believe you have misinterpreted a crucial part of our proposal.

You maintain that our 'Time Machine' project 'has no potential for applications' and has 'no practical value.' You ultimately base this claim on the fact that "If in order to travel to the past one has to have been there already, and if one can only do what has already been done, then *á quoi bon l'effort*? Why should we invest in a 'Time Machine' at all?" Your argument however is a misinterpretation of our own comments that 'According to our project it is logically possible to visit the past but not to modify the past ... This does not mean that the time traveler will be ineffectual during her stay in the past, of course; it simply means that what she is going to do is something that she has already done.' We regret the awkward and easily misleading locution of the last sentence, but such are the perils of talking about time travel. Regardless, please consider our clarification.

Certainly if we were proposing that the time traveler *be* 5 years old again, we would be proposing something not worth the effort—our proposed time traveler has already turned five and cannot do so again. But we are not proposing that the time traveler do things that have already occurred in her own personal past, but rather in her personal future. The time traveler has not yet, from her personal temporal perspective, travelled back to, say, the library at Alexandria in 100 BCE. When she does travel back to 100 BCE to obtain scans of the books in the library before its destruction, she will be older than she is now. When she returns she will be still older (and we hope wiser, i.e., in possession of valuable information to which neither you nor we currently have access).

---

[47] Story by Geoff Goddu (Professor of Philosophy at the University of Richmond, Virginia). Originally published in *Philosophy*, April 2002, pp. 281–282, and reproduced here by kind permission of the author.

But is it true that as of 2002 AD [the year this letter was written] the time traveler has already visited Alexandria in 100 BCE? It could well be. But whether or not it is depends upon whether it is *also* true that our project will be successfully funded and completed. Because time travel into the past involves reverse causation, certain past events, such as the time traveler visiting 100 BCE, will be dependent upon certain future events, such as the successful funding and completion of our project. Hence, if it is not true that our project is both funded and completed, then it is not true that our time traveler has of 2002 already visited 100 BCE.

But suppose we were to learn now, before the funding and completion took place, that our time traveler had indeed been present at the library in Alexandria in 100 BCE. Would this imply that there was no reason to expend the effort to fund our project? After all, if the travel has 'already' happened, why bother funding the project? Firstly, such an argument does not imply that a 'Time Machine' would have no practical application, but rather expresses the futile hope that one could in fact get the practical benefits (if time travel is successful, we obtain the desired information) without expending the effort at all. Secondly, the hope is futile, for if we learn right now that our time traveler had been present at the library in 100 BCE, we would then know, assuming no other possible funding source, that you *will* expend the effort to fund our project. To deny this last is to make the impossible suggestion that even though your support is truly a causal antecedent of the successful trip, there is now no need for you to actually expend the effort to provide funding.

Hence, the effort is far from pointless, for the project will only succeed through your and our efforts. And success will generate, not only all the practical applications we outlined in our first letter, but, in addition, a host of information gathering applications such as more accurate historical research, lost item location identification, legal testimony verification, etc. Even if, as we (and you) acknowledged, no one could now prevent Oswald from killing Kennedy, wouldn't it be worth verifying that Oswald was the lone killer of Kennedy? Also, the information gathering need not be restricted to the past. For example, information concerning the prices of various stocks 10 years from now would be extremely valuable to a suitably cautious and prudent investor. Surely you cannot object to our information gathering in the future on the grounds that 'it will already have been done.' And just think, the information we obtain could be what allows you to obtain at very low prices those stocks that in the future will be extremely valuable and allows your esteemed committee to dramatically increase your support of worthy scientific endeavors.

Again, we ask you to reconsider your original decision.
Respectfully yours,
The 'Time Machine' Research Group

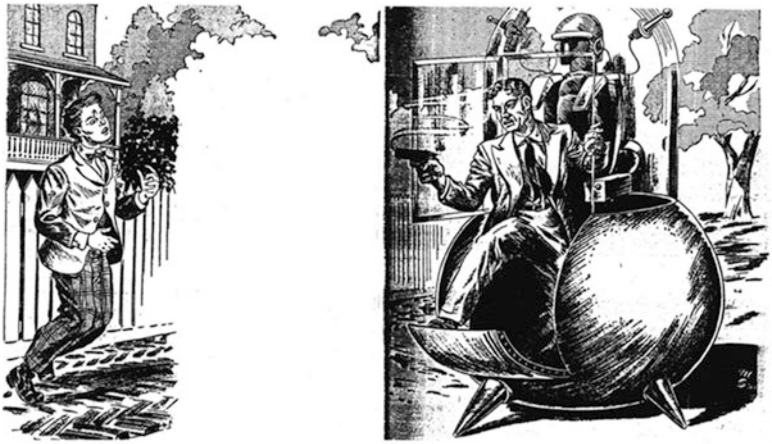

A time machine inventor makes an experimental test of the grandfather paradox! (Illustration from “Thompson’s Time Traveling Theory” by Mortimer Weisinger), *Amazing Stories* March 1944 (art by Malcolm Smith). Reprinted by arrangement with Forrest J. Ackerman, Holding Agent, 2495 Glendower Ave., Hollywood, CA 90027.

Not everybody likes time machines as a science fiction gadget, not even otherwise enthusiastic devotees of the genre. For example, in a Letter-to-the-Editor published in the December 1931 issue of Astounding Stories*, one seventeen-year-old fan had this to say: “There is only one kind of Science Fiction story I dislike, and that is the so-called time-traveling. It doesn’t seem logical to me. For example, supposing a man had a grudge against his grandfather, who is now dead. He could hop in his machine and go back to the year that his grandfather was a young man and murder him. And if he did this how could the revenger be born? I think the whole thing is the ‘bunk.’” As this book will demonstrate, this young reader was not alone in that opinion. As this book will also demonstrate, in the last few decades that view has been rapidly evolving.*

For Further Discussion

Read again the penultimate sentence in the last letter from The 'Time Machine' Research Group, and then think about how you would respond to the following questions.

(1) Would *you* invest in a stock market if you knew somebody else had a time machine giving *them* advance information on stock performance?
(2) How might the existence of a time machine influence the future of the stock market, in general? For an early science fiction look at these questions, see Lee Laurence, "History in Reverse," *Amazing Stories*, October 1939.

One writer has speculated that Wells' model for the Time Traveller was the American inventor Thomas Edison. (See Martin T. Willis, "Edison as Time Traveler: H. G. Wells' Inspiration for His First Scientific Character," *Science Fiction Studies*, July 1999, pp. 284–294.) As Wells worked his way from *The Chronic Argonauts*, through revisions, to the final *Time Machine*, the story's hero evolved from Dr. Nebogipfel to the Philosophical Inventor to the Time Traveller. The one individual who could have inspired all of these various hero types was, according to Willis, Edison, a world-famous Victorian-age celebrity whose story was well known to Wells. If Wells had today's scientific personalities available as potential inspirations, who do you think he would use? How might that choice affect the story and structure of *The New Time Machine*?

The idea of *personal time*, used by the philosopher David Lewis (note 5) to consistently interpret time travel stories, has been used in a quite different way (although time travel gets a few words, too) by the philosopher Roy Sorenson. In his paper "The Cheated God: Death and Personal Time," *Analysis*, April 2005, pp. 119–125, Sorenson asks you to imagine an immortal god. For some reason this god runs afoul of a demon, who curses the god in a curious way. (The 'telling of a story' is a common technique in philosophical papers and, while foreign to what readers of physics papers are used to seeing, is not without some charm. Just be sure to always keep in mind that its

(continued)

primary use is as an *attention-grabbing* device, but as far as having any other merit, well, that's often another story.) The curse is such that the life span of the once immortal god is reduced to that of a normal human life span and yet, perhaps surprisingly, the god will still never die. As Sorenson writes, "[The god] will live forever. But [the god] will not have a better life than a mortal. The demon has harmed [the god] as gravely as death harms mortals." How, you might wonder, is this to be done? As Sorenson explains, "[The god] lives half of its now mortal span, followed by a trillion years of nothingness, then a quarter of its mortal span followed by a trillion years of nothingness, then an eighth of its mortal span followed by a trillion years of nothingness and so on ad infinitum." Sorenson's argument is simply an exotic form of the high school summation of the geometric series $\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \cdots = 1$, where there are an *infinite* number of terms to the left of the equality. (Each term represents a period of time during which the god is conscious, and each + represents a trillion years.) Sorenson picked a trillion years of nothingness between consecutive periods of consciousness for (I suggest) dramatic reasons, but suppose instead that he had picked 1 μs for the period of nothingness. Discuss what effect this would have (if any) on the life of the god. Consider two cases:

(a) There is no minimum time duration for consciousness, and
(b) There *is* a minimum time duration such that, for any shorter duration, a consciousness remains 'unaware' even though it is *not* in a state of nothingness.

After working all night making some final calculations, a physicist carefully solders a final resistor into the control module of the world's first time machine and then steps into the gadget that is a sure bet to win the next Nobel Prize in physics. As she does, she notices that it is precisely 8:10 in the morning, as indicated on both her wrist watch and the clock on the lab wall. After settling into a plush leather seat she pushes the time machine's power button, the machine glows with a flickering blue-red halo and hums with a mighty throb for a while and then, at precisely 8:15 by her wrist watch, she steps out of the machine and back into her lab. She notices the clock on the wall now reads 8:05. That is, she took 5 min of personal time (8:10 to 8:15) to travel 5 min of external time into the past (8:10 to 8:05). On the one hand she certainly seems to be a time traveler, in that she exits the machine before she enters it. (Ignore the issue of there being *two identical* physicists in the lab from 8:05 to 8:10!) On the other hand, the elapsed personal and external

(continued)

times are *equal*. Does this suggest a need to modify or expand David Lewis' definition of a time traveler? As you ponder this question, you might want to read the following four papers: (1) Paul R. Daniels, "Lewisian Time Travel in a Relativistic Setting," *Metaphysica*, October 2014, pp. 329–345, (2) Douglas Kutach, "Time Travel and Time Machines," in *A Companion to the Philosophy of Time* (H. Dyke and A. Bardon, editors), Wiley-Blackwell 2013, pp. 301–314, and (3) Frank Arntzenius, "Time Travel: Double Your Fun," *Philosophy Compass*, November 2006, pp. 599–616. A bit more demanding (but worth the effort) is the long chapter "Time Travel and Time Machines" by Chris Smeenk and Christian Wüthrich, in *The Oxford Handbook of Philosophy of Time* (C. Callender, editor), Oxford 2011, pp. 577–630 (see page 580, in particular).

> The idea that information is physical has given rise to a series of discoveries which indicate that physics has much to say about fundamentals of computer science.

The above quotation is the opening sentence to a most interesting paper by the physicist Dave Bacon, "Quantum Computational Complexity in the Presence of Closed Timelike Curves," *Physical Review A* (70), 2004. (When he wrote, Bacon was at Caltech, but he is now a software engineer at Google.) The title of Bacon's paper, translated into blunt English, is "It Would Be Really Neat If We Could Merge a Time Machine With a Computer." That is, to further quote from Bacon's paper, "One could [efficiently] solve a hard problem by trying out a solution to the problem, sending one's computer back in time, attempting a different solution to the problem, sending one's computer back in time, etc., until a solution to the problem has been found." There then follows a pretty sophisticated analysis on the self-consistent time evolution of a quantum system, ending with Bacon's frank admission that "we would not be honest if we did not end this paper with the caveat that this work is at best a creature of eager speculation ... Practical considerations are humorous at best." Read Bacon's paper and discuss what he means by "a hard problem." (There *is* a technical term used by computer scientist for such problems: NP-complete.)

The occasional theological commentary in this book may strike some as a bit odd for a topic treated with heavy doses of deep mathematics in the physics literature but, as you'll see on the following pages, theology is an unescapable dimension to any informed discussion of time travel. A literary connection

(continued)

between time travel and theology has, in fact, existed for a long time. As pointed out in Paul Alkon's *Origins of Futuristic Fiction* (University of Georgia Press 2010), "The first time-traveler in English literature is a guardian angel who returns with state documents from 1998 to the year 1728 in Samuel Madden's *Memoirs of the Twentieth Century*" (published in 1733, nearly three centuries ago). Madden was an Irish-Anglican clergyman whose book was satire rather than science fiction, but its time traveling aspect was a first. As Professor Alkon also writes, "Madden [was] the first to write a narrative that purports to be a document from the future. He deserves recognition as the first to toy with the rich idea of time-travel in the form of an artifact sent backward from the future to be discovered in the present." Your assignment: read and discuss Alkon's book.

You'll recall that Gödel cast his view of time travel in the form of a self-encounter in the past. In Frederik Pohl's "Let the Ants Try," we find a science fiction tale that appeared essentially simultaneously with Gödel's paper (*Planet Stories*, Winter 1949), in which a time traveler journeys back forty million years. Upon stepping out of his time machine, he hears a "raucous animal cry" from somewhere in the nearby jungle. Later, after other adventures in time, he returns to near the same point in spacetime. After stepping out of his time machine, he sees himself in the distance—the earlier version of himself during the first trip. Then, suddenly, the time traveler meets a violent death: "As his panicky lungs filled with air for the last time, he knew what animal had screamed in the depth of the Coal Measure forest." In fact, self-encounters had appeared in science fiction *years* before Gödel's paper. In the 1942 story "Minus Sign" (*Astounding Science Fiction*, November) by Jack Williamson, for example, a spaceship battles with itself while traveling backward in time. How do you think a scientist like Gödel would have liked these two stories? (Who knows, maybe he *did* read them!) If you could travel back in time to 1949 to ask him if such tales had been an inspiration, do you think he would be intrigued, amused, or instead would he be insulted?

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About the Author

Paul J. Nahin was born in California, and did all of his schooling there, including a PhD in electrical engineering from UC Irvine (1972). He is now emeritus professor of electrical engineering at the University of New Hampshire. Prof. Nahin has published a couple of dozen short science fiction stories in *Analog*, *Omni*, and *Twilight Zone* magazines, and has written 18 books on mathematics and physics. He has given invited talks on mathematics at many prestigious institutions, and has appeared on National Public Radio's "Science Friday" show (discussing time travel) as well as on New Hampshire Public Radio's "The Front Porch" show (discussing imaginary numbers). He advised Boston's WGBH Public Television's "Nova" program on the script for their time travel episode.

Chapter 1
A Broad Look at Time Travel

"Hold infinity in the palm of your hand and eternity in an hour."

—William Blake, writing in "Auguries of Innocence" (1863), with words that could quite well describe what it would be like to time travel

"I need a place to hide, that's why I believe in yesterday."

—The Beatles (*Yesterday*, 1965)

1.1 Time Travel in the Fantasy and Science Fiction Literature

"Woodn't it be grate to go back in tyme and correct your mistakes? Wouldn't it be great to go back in time and correct your mistakes?"

—motto of *Time Twisters* comics

To travel in time.

Could there possibly be a more exciting, more romantic, more wonderful adventure than that? I don't think so, and in this opening section I want to just briefly discuss how fascinating many writers (and their readers) have found the concept of time travel, and to point out that the fascination began *long before* mathematical physicists discovered time travel lurking in Einstein's general theory of relativity.[1]

Before the arrival of humans on the surface of the Moon in 1969, the only other 'fantastic voyage' that could compare with time travel was traveling through outer space. During the seventeenth and eighteenth centuries, in fact, such voyages were the center of a genre of fiction (now called *science fiction*) called the "imaginary voyage" or "extraordinary voyage." Marjorie Hope Nicolson's[2] 1948 book *Voyages*

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[1] An excellent, book-length *literary* treatment of time travel is by David Wittenberg, *Time Travel: the popular philosophy of narrative*, Fordham University Press 2013.

[2] Marjorie Hope Nicolson (1894–1981) was a literary scholar of the first rank at both Smith College and Columbia University.

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to the Moon carefully documents just how popular that form of literature was—and still is. Since 1969 the first such voyages have become history, of course, and time travel has replaced space travel as the modern "imaginary voyage."

It seems a safe bet that that, given a random selection of middle-aged adults, the vast majority of them would respond enthusiastically if asked whether time travel interests them. This fascination with time travel has actually been 'scientifically' documented. In one intriguing study,[3] several hundred men and women were asked to consider the possibility of spending an hour, a day, and a year back in both their personal past (since birth) and their historical past (before birth). They were further told that it would cost $10,000 to purchase such time travel services. Their response indicated that 10 % would be willing to spend that much money for an hour in the historical past, 22 % for a day, and 36 % for a year. As might be expected, the numbers rose as the cost dropped and, if such trips were free the interest was almost universal. As one writer put it, "Time travel [is] the ultimate fantasy, the scientific addition to the human quest for immortality."[4] And as a philosopher observed, "[T]he popular appeal of time travel . . . is no doubt due to a nostalgia for the past, which is almost an omnipresent aspect of the human condition."[5]

Fiction writers have, for *centuries*, recognized the fantasy appeal of time travel. The common fairy tale theme of 'The Three Wishes,' in which the recipient ends up using the final wish to undo the unforeseen consequences of the first two, is the precursor to all modern change-the-past time travel stories. Indeed, the means of time travel in the Norwegian poet Johan Wessel's 1781 play *Anno 7603 is* a fairy. Some of the best modern science fiction stories have played with the fantasy appeal of time travel by having gifts arrive by accident from the future: the moral of such tales is generally that unearned gifts usually bring grief.[6] The editor's introduction to a time travel story involving the Civil War referred to the fantasy aspect of time travel—with a reference to another age-old adult fantasy—when he wrote "time travel stories about the Civil War have one thing in common with pornography; they serve to titillate an impulse [in the case of time travel stories, the impulse to change history] and to frustrate [history]."[7] This is the motivation for the time traveler in Stephen King's 2011 novel *11/22/63*, who uses what appears to be a naturally occurring wormhole (connecting a Maine diner to 1958) for his attempts at preventing the assassination of John F. Kennedy.

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[3] T. J. Cottle, "Fantasies of Temporal Recovery and Knowledge of the Future," in *Perceiving Time*, John Wiley 1976.

[4] T. Paul, "The Worm Ouroboros: Time Travel, Imagination, and Entropy," *Extrapolation*, Fall 1983, pp. 272–279.

[5] J. W. Smith, "Time Travel and Backward Causation," *Cogito* 1985, pp. 57–67.

[6] Among the many such tales, five particularly good ones are "Something for Nothing" by Robert Sheckley, "Mimsy Were the Borogoves" by Lewis Padgett (pseudonym of the married couple Henry Kuttner and C. L. Moore), "Child's Play" by William Tenn (pseudonym of Philip Klass), "The Little Black Bag" by Cyril Kornbluth, and "Thing of Beauty" by Damon Knight. All can be found in various anthologies.

[7] *The Fantastic Civil War* (F. McSherry, Jr., editor), Baen 1991.

A character in the 1985 novel *The Bird of Time* by George Effinger nicely captures the fantasy appeal of time travel with the declaration "The past . . . is the home of romance." On a less poetic level, time travel and the movies and stories about it fascinate most people because they turn our everyday world view upside down and inside out.[8] Such movies and stories make people *think*. It is therefore not surprising that time travel movies have been popular for decades, from the pioneering *Berkeley Square* in 1933, to the classic 1960 filming of *The Time Machine*, to *Back to the Future* in 1985 (*the* top film that year in a *Boxoffice* magazine poll), to the flawless 1989 *Bill & Ted's Excellent Adventure*, to the clever *Terminator* action films, to the ingenious 2012 *Looper*, to the commercially successful 2014 *Interstellar*. Each of these films, and others, too, will be discussed later in the book.

When we discuss time travel, we should really be careful to distinguish between two quite different versions: to the future, and to the past. There is no dispute, today, about the first. As two *severe critics* of the possibility of time travel to the past wrote decades ago, "After 1900, special relativity made scientific discussion of time machines possible."[9] What they were referring to is the fact that, by traveling in a rocket ship fast enough (but never, unlike Superman, faster than the speed of light), and far enough, one could leave Earth, loop out on a vast journey perhaps halfway across the universe, and then return hundreds, thousands, even millions of years in the future. You could theoretically (ignoring all the *engineering* difficulties) do this, in fact, with the apparent passage of your 'personal time,' (as measured by your wrist watch or the beating of your heart) as brief as you'd like. (Physicists call 'personal time' *proper time*, and I'll return to this in Chap. 3.) This astonishing conclusion from special relativity, that time travel to the future makes physical sense, literally put a lot of Victorian-era trained physicists into shock.

A quite sophisticated use of this idea appeared early in science fiction, in the tale of a space traveler who returns from a high-speed trip out to the blue supergiant star Rigel in the constellation Orion.[10] The 900 or so light years of the round trip had taken just 6 months of ship or personal time (proper time), but a thousand years of back-home time. The traveler returns to Earth to find all he had left behind long dead and returned to dust: "Sometimes I waken from a dream in which they are all so near . . . all my old companions . . . and for a moment I cannot realize how far away they are. Beyond years and years."

Another story[11] of a trip into the future that delivers an equally powerful emotional impact, this time via a Wellsian-type time machine (more on what that means later in this chapter) rather than by rocket travel, tells of a time traveler trapped in post-nuclear war times, where there is no energy available to power his machine for the return trip. As the story ends, he finds the woman he had loved and left behind in the past. She is now the elderly widow of another man, having married his rival because the time traveler (just like Wells' Time Traveller) never returned.

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[8] Somewhat more pompous (but no less correct) was this observation by an academic: "The time-travel [film] romance is an attempt to reenchant the world, to regain a sense of belongingness, to reinstate the magical, autocentric Universe of the child and the primitive." See W. Wachhorst, "Time Travel Romance on Film," *Extrapolation*, Winter 1984, pp. 340–359.

[9] S. Deser and R. Jackiw, "Time Travel?" *Comments on Nuclear and Particle Physics*, September 1992, pp. 337–354.

[10] R. H. Wilson, "Out Around Rigel," *Astounding Stories*, December 1931.

[11] W. Tucker, *The Year of the Quiet Sun*, Gregg 1979.

A trip into the future does not *have* to be serious or sad. A nice example of that is the story of a spaceship crew that sets off for the Alpha Centauri triple star system, more than four light years distant.[12] They survive the trip, which requires 500 years of both personal *and* external time (this story is the *only one* I'll mention in this book that uses *a preserving drug* rather than physics). What causes me to include it in a book on *time travel* (stories in which proper and external time are one-in-the-same are simply *not* about *time travel*) is that, long before they arrive at the end of their journey, the secret of faster-than-light (FTL) travel is discovered back on Earth and so they arrive at their destination to find a human reception committee! As you'll see when we get to Chap. 3, knowledge of FTL travel is equivalent to knowing the secret of travel into the past, and so the crew is sent back in time, to Earth, to just one year after they left—and they listen to their own radio communications arriving from deep space.

The *real* adventure in time travel, as suggested by "Far Centaurus," would be to go backward in time, to visit the past. The editor of the science fiction pulp magazine *Thrilling Wonder Stories* used the powerful emotional hook of changing the past in a 1950 blurb announcing a time travel story coming in the next issue: "What's the biggest mistake you ever made? Don't worry about it. You may have pulled some awful boners in your time, but there's a sure-fire remedy for them all. It's simple. Just look up at that old time-clock on the wall—and turn it back to the moment just preceding your terrible blunder. Then make your corrections—and set your time-clock back to the present. You may be starting a new chain of error, but why fret? You can go back in time again..." Or, as the promotional text on the video package of the 1986 movie *Peggy Sue Got Married* says, "to do it again" is "the golden opportunity almost everyone has longed for at least once."

Writing less romantically, a philosopher declared that a "major source of interest in the time travel question is our general fascination with the exotic and the child-like frustration we sometimes feel at being confined to the present. We wish that the benefits of moving through space could be supplemented with the benefits which would accrue from movements through time."[13] Robert Silverberg, a science fiction writer who has used the time travel theme often and effectively, expressed this sentiment quite clearly when he wrote "Suppose you had a machine that would enable you to fix everything that's wrong in the world ... The machine can do anything ... it gives you a way of slipping backward and forward in time ... Call this machine whatever you want. Call it Everybody's Fantasy Actualizer. Call it a

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[12] A. E. Van Vogt, "Far Centaurus," *Astounding Science Fiction*, January 1944.

[13] R. A. Sorenson, "Time Travel, Parahistory and Hume," *Philosophy*, April 1987, pp. 227–236.

Time Machine Mark Nine."[14] He gives a masterful demonstration of what he means by that in one of his own stories, a tale[15] set in a year when time machines actually exist. Even so, the characters use their imaginations to explore their fantasy worlds and wishes—wishes that could (if they *really* wanted to) be realized with a real time machine. Time travel fiction is, you see, the ultimate escapist literature!

The adventure promised by time travel to the past doesn't necessarily mean *pleasant* adventure, and science fiction has used that idea to great effect. The unstated horror of a trip backward in time, if you think just a bit about it, is that it would bring the dead past, filled with all its dead occupants, alive again, literally resurrected from dank and moldering graves. The top of Mount Everest, the bottom of the Marianas Trench, the sands of Mars—none of these exotic places can even be mentioned in the same breath with the *past*. The capture of the mystery and, yes, the sheer terror of the past, is in this opening line to a 1950s tale: "When Dr. Flitter came into the room, it seemed as though the past and its dead people came in with him, clinging to him like stale surgery smells, like the cold sweat of ancient autopsies."[16] In another equally macabre story, we read of a time traveler in the past anticipating a meeting with a long-dead lover as he "shivered with a renewal of horror . . . She ought to be grateful to him for having raised her from the dead, even briefly."[17]

Another tale, slightly less gruesome, tells us of a character who delights in pointing out all the bad aspects of living in the past.[18] Tell him *when* in time, and he quickly ticks off the disadvantages of being *then*. To live in ancient Greece would let you rub shoulders with Aristotle, sure, but you already know what he said and you'd soon regret the lack of modern plumbing. The year of the American Revolution might let you exchange greetings with George Washington, but you'd also have to put up with cholera in Philadelphia, malaria in New York, and the fact that if you needed an operation there would be no anesthesia anywhere. The Victorian Age appeals to modern romantics but, before you go back, you'd better have your eyes and teeth checked. The time traveling historian in one novel[19] takes these medical warnings to heart and has her appendix prophylactically removed, and is further advised to have her nose cauterized against all the awful stinks of her destination, the fourteenth century.

On the other hand, poor health care isn't *all* there is with time travel to the past. One time traveler from the future, for example, makes a very good living in the past by winning bets on yet-to-happen events whose outcomes he knows.[20] Time travel to the past allows a Parisian curio shop in the present to offer remarkably authentic looking newspapers from 1804 whose only 'flaw' is that they appear to be fresh off the press—which of course they are![21] And the failed professor in one romantic story[22] finds the Paris of 1482 infinitely better than the Paris of 1961.

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[14] R. Silverberg, "Ms. Found in an Abandoned Time Machine," *Beyond the Safe Zone*, Warner 1986.

[15] R. Silverberg, "Many Mansions," *Beyond the Safe Zone*, Warner 1986.

[16] R. Bretnor, "The Past and Its Dead People," *Magazine of Fantasy and Science Fiction*, September 1956.

[17] L. Marlow, *The Devil in Crystal*, Faber and Faber 1944.

[18] A. Bester, "Hobson's Choice," *Magazine of Fantasy and Science Fiction*, August 1952.

[19] C. Willis, *Doomsday Book*, Bantam 1992.

A popular fictional appearance of time travel is the use of the past as a hiding place, as a sanctuary for those wishing to escape the troubles of modern times.[23] An interesting twist on this idea was presented in one tale[24] in which the past is used for later military gain in the present. In this story the Earth of a thousand years in the future is ruled by a dictator, and the oppressed masses are unable to arm themselves for revolt. So, back into the past travels an agent to arrange for the construction of weapons, which are then stockpiled in hidden caverns where they can be retrieved for use ten centuries later. The past is used in this story as both a sanctuary *and* a repository from which to make war in the future, and so we have a time travel fantasy for both doves *and* hawks in the same tale! This military use of the past is passive; other writers have more aggressively used time travel to the past for military gain as, for example, mining uranium deposits before they have had time to reduce themselves to lead via radioactive decay,[25] or in drilling for Middle East oil in the past to deprive adversaries of it in the present.[26]

Time travel to the past would, perhaps, interest criminals, too. As the science fiction writer Larry Niven wrote, "If one could travel in time, what wish could not be answered? All the treasures of the past would fall to one man with a submachinegun. Cleopatra and Helen of Troy might share his bed, if bribed with a trunkful of modern cosmetics."[27] Or, as the tragically flawed inventor of the first time machine dreamed, before using time travel to commit what he thought would be the perfect locked-room murder, "The Great Harrison Partridge would have untold wealth. He could pension off his sister Agatha and never have to see her again. He would have untold prestige and glamour, despite his fat and baldness, and the beautiful and aloof Faith Preston would fall into his arms like a ripe plum."[28]

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[20] C. Sprague, "Time Track," *Startling Stories*, January 1951.

[21] M. Leinster, *Time Tunnel*, Pyramid Books 1964.

[22] U. K. Le Guin, "April in Paris," *Fantastic Stories*, September 1962.

[23] There are *many* excellent examples of such tales, a few of which are Clifford Simak, "Over the River & Through the Woods"; Ray Bradbury, "The Fox and the Forest"; Jack Finney, "Such Interesting Neighbors"; J. B. Priestly, "Mr. Strenberry's Tale"; James Gunn, "The Reason Is With Us"; and H. B. Piper, "Flight from Tomorrow." All can be found in various anthologies.

[24] R. F. Young, "Not to be Opened—," *Astounding Science Fiction*, January 1950.

[25] C. Simak, "Project Mastodon," *Galaxy Science Fiction*, March 1955.

[26] P. Anderson, "Wildcat," *Magazine of Fantasy and Science Fiction*, November 1958, and W. Jeschke, *The Last Day of Creation*, St. Martin's Press 1982.

[27] L. Niven, "The Theory and Practice of Time Travel," in *All the Myriad Ways*, Ballantine 1971.

Instead of viewing the past as an aid to crime, some writers have used it as the perfect dumping ground for criminals, as a highly convenient place to remove them from society.[29] After all, there can be no breakout from the prison of the past—at least not without a time machine. What might happen to criminal recidivists in a world that has mastered time travel is nicely explained in one story as follows: "If you cannot live among people, then off to the reptiles—one hundred or one hundred twenty million years before the present. There you wouldn't freeze in a tropical pre-glacial climate, and you could nourish yourself on plants. But there is no one to talk with, boredom, and in the end you offer yourself up as an afternoon snack to a tyrannosaurus."[30] With an interesting twist on this is the tale[31] of a physics professor who *helps* criminals disappear into the past to escape relentless police pursuit.

Museum curators, too, would seem to be obvious clients for time machine companies, as would collectors of extinct species who work for zoos. An example of the first case is in a novel[32] about a time travel business called *Time Researchers*, with the corporate mottos 'We Sift the Sands of Time.' It works as a futuristic version of Indiana Jones, as finders of lost historical artifacts for customers who can pay the substantial charges. A typical mission is to make original sound recordings of one of Lincoln's unreported speeches. We find the same idea in a short story[33] about a business called *Genealogy, Inc.*, with the corporate motto

"An Ancestor for Everybody." It uses a 'time scanner' to provide its clients with a list of distinguished predecessors. And in another novel we read of the Historical Corps, whose time travel agents are "writing the definitive history of mankind.".[34]

Another use for time travel to the past, one of the most unusual I have seen, was suggested in a philosophical article[35] which considers an age-old question that has long bedeviled schoolboys: “If everything in the Universe doubled in size overnight while we slept, could we tell what had happened when we woke up next morning?” The usual answer to this puzzle (called the *Universal nocturnal expansion* by philosophers) is *no*, but the authors of the article suggest that ‘all’ we need do is take a yardstick back to yesterday and compare it with itself! Great idea, for sure, but it had appeared years earlier in a science fiction story.[36]

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[28] A. Boucher, "Elsewhen," *Astounding Science Fiction*, January 1943. Partridge's dream is shattered, however, because he overlooks a few details about time travel, ones that he wouldn't have missed if he could have read this book. We'll come back to this classic story, which merges a time machine with murder, later in the book.

[29] This is a popular science fiction scenario, and three of the best stories playing with it are P. Anderson, "My Object All Sublime," *Galaxy Science Fiction*, June 1961; I. Watson, "In the Upper Cretaceous with the Summerfire Brigade," in *Stalin's Teardrops*, Victor Gollancz 1991; and R. Silverberg, "Hawksbill Station," *Galaxy Science Fiction*, August 1967.

[30] S. Gansovsky, "Vincent Van Gogh," in *Aliens, Travelers, and Other Strangers*, Macmillan 1984.

[31] J. Finney, "The Face in the Photo," in *About Time*, Simon and Schuster 1986.

[32] W. Tucker, *The Lincoln Hunters*, Rinehart 1958. See also A. Bitov, "Pushkin's Photograph," in *The New Soviet Fiction*, Abbeville Press 1989.

[33] M. Shaara, "Man of Distinction," *Galaxy Science Fiction*, October 1956.

[34] L. A. Frankowski, *The Cross-Time Engineer*, Del Rey 1986. The same idea is in the 1991 film comedy *The Spirit of '76*, in which time-traveling historians from 2176 visit the past in an attempt to reconstruct the lost records of the founding of America.

[35] J. C. Graves and J. E. Roper, "Measuring Measuring Rods," *Philosophy of Science*, January 1965, pp. 39–56.

More ingenious uses for the past are discussed in the story[37] of a time travel business called *Time Associates*. One use comes in the form of a request from a United States senator who wants to send the disadvantaged of today back into the remote past, where they could have a fresh start on a virgin Earth. Yet another use comes from a religious fringe group that wants to purchase exclusive rights to the time of Jesus—not to visit, but to prevent *anyone* from visiting. The group fears that any such visitors would “learn the truth,” which might contradict the very legends that form the heritage of Christianity. And, in what may be the most ingenious idea of all, *Time Associates* itself does not do business in the present, but rather 150,000 years in the past, in a ‘new’ country called Mastodonia. The corporate lawyer, you see, has determined that such an arrangement legally means the company is a *foreign* company doing business outside the United States, and so it is not liable for taxes to the IRS!

The tourist trade is a booming business in science fiction, with dinosaur hunting at the top of the list. There are many such tales,[38] including the cerebral stories in L. Sprague de Camp’s short-story collection *Rivers of Time*, starting with the classic “A Gun for Dinosaur.” The earliest (that I know of) fictional use of time travel to the past for hunting was not for dinosaur hunting, however, but rather for saber-toothed tigers, wooly mammoths, and cave bear.[39] Historical tours to the great events of the past are also an entertaining use of time travel.[40] Even mundane events may one day be on the ‘to do’ lists of time travelers to the past. In one, for example, curious crowds from the very far future show up, nightly inside the home a twentieth century family, much as tourists today visit Monticello.[41]

Perhaps the most direct use of the past’s unique resource, itself, is realized in science fiction by Hollywood. In one tale,[42] after purchasing the motion picture rights to H. G. Wells' *Outline of History*, the head of a movie studio uses a time machine to send his ace cameraman into the past to get live action footage. Prehistoric animals, the ice age, Cheops building his pyramid, the destruction of Pompeii by the eruption of Vesuvius, the Battle of Hastings, Columbus, all the *originals* of these historical events appear in the final film. Years later this idea was developed even further in a very funny novel,[43] in which a movie director uses the eleventh century as a realistic setting for a picture. Realism isn't always the result, however, as portrayed in another tale; the films produced by a gadget that can 'look' into the past are failures because they don't look "authentic enough" to Hollywood moguls![44] (Fig. 1.1).

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[36] H. M. Sycamore, “Success Story,” *Magazine of Fantasy and Science Fiction*, July 1959.

[37] C. Simak, *Mastodonia*, Ballantine 1978.

[38] Two are B. W. Aldiss, “Poor Little Warrior,” in *The Science Fictional Dinosaur*, Avon 1982, and a famous one by Ray Bradbury, “A Sound of Thunder,” in *The Stories of Ray Bradbury*, Alfred A. Knopf 1980.

[39] C. Simak, “The Loot of Time,” *Thrilling Wonder Stories*, December 1938, in which a time machine inventor raises money for his research by transporting hunters back 70,000 years to the Old Stone Age.

[40] Three such tales are R. Silberberg, *Up the Line*, Ballantine 1969 and “When We Went to See the End of the World,” in *Beyond the Safe Zone*, Warner 1986; and G. Kilworth, “Let’s Go to Golgotha!,” in *The Songbirds of Pain*, Victor Gollancz 1985.

[41] B. Tucker “The Tourist Trade,” in *Tomorrow the Stars*, Doubleday 1952.

[42] L. Laurence, “History in Reverse,” *Amazing Stories*, October 1939.

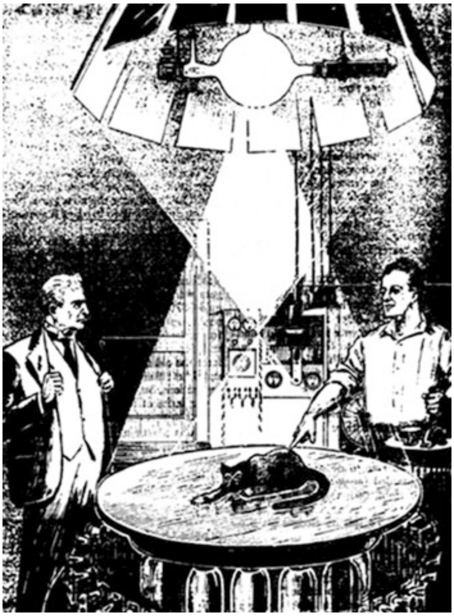

Fig. 1.1 The inventor of a time machine demonstrates it by sending the family cat on a trip. In the story the inventor, himself, travels back to 1901, where he accidently kills his grandfather in an early pulp magazine, non-paradoxical version of the famous riddle. Illustration for Raymond A. Palmer's "The Time Tragedy" (*Wonder Stories*, December 1934) by Frank R. Paul, ©1934 by Continent Publications Inc.; reprinted by permission of the Ackerman Science Fiction Agency, 2495 Glendower Ave., Hollywood, CA 90027 for the Estate

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[43] H. Harrison, *The Technicolor Time Machine*, Doubleday 1967.

[44] A. Derleth, "An Eye for History," in *Harrigan's File*, Arkham House 1975.

1.2 Where Are All the Time Travelers?

> "If it [time travel] *could* be done, someone will eventually learn how. If that happens, history would be littered with tourists. They'd be *everywhere*. They'd be on the *Santa Maria*, they'd be at Appomattox with [cameras], they'd be waiting outside the tomb, for God's sake, on Easter morning."[45]

The question the title of this section asks is an echo of the one the physicist Enrico Fermi (1901–1954) asked in the 1950s, about the possibility of interstellar space travel and of alien intelligent life in the universe—if such travel is possible and 'they' exist, then *where are they*? Why haven't we at least received radio signals from them? For many, the apparent lack of time travelers among us is similar evidence for the impossibility of time travel. As one famous science fiction writer put it, "The most convincing argument against time travel is the remarkable scarcity of time travelers. However unpleasant our age may appear to the future, surely one would expect scholars and students to visit us, if such a thing were possible at all. Though they might try to disguise themselves, accidents would be bound to happen—just as they would if we went back to Imperial Rome with cameras and tape recorders concealed under our nylon togas. Time traveling could never be kept secret for very long."[46]

Clarke's idea is that, from the moment after the first time machine was constructed, through all the rest of civilization, there would be numerous historians, to say nothing of weekend sightseers, who would want to visit every important historical event in recorded history. They might each come from a different time in the future, but all would arrive (according to Clarke) at destinations crowded with temporal colleagues, crowds for which there is no historical evidence!

Long before Clarke the science fiction writer Robert Silverberg had already used the same idea in his 1969 novel *Up the Line*, where it's called the *cumulative audience paradox*. That paradox claims that as time travelers to the past continue to visit certain historically interesting dates and places, there will be an ever-increasing number of people present. As it is presented in the novel, "Taken to its ultimate, the *cumulative audience paradox* yields us the picture of an audience of billions of time-travelers piled up in the past to witness the Crucifixion, filling all the Holy Land and spreading out into Turkey, in Arabia, even to India and Iran . . . Yet at the original occurrence of [that event] *no such hordes were present!*" And later in the same work, we read "A time is coming [when we] will throng the past to the choking point. We will fill our yesterdays with ourselves and crowd out our own ancestors."

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[45] A skeptic's reaction to the idea of time travel in J. McDevitt's story "Time's Arrow" in *The Fantastic Civil War* (see note 7).

[46] Arthur C. Clarke, "About Time," in *Profiles of the Future*, Warner 1985. A story that I recall once having read (but cannot now remember either the author or the title) wonderfully illustrates Clarke's point. A time traveler in disguise at Golgotha for the Crucifixion has a camera hidden beneath his robe to avoid attracting attention. All goes well until he notices odd, clicking noises coming from all those standing near him. It is then he realizes the entire crowd is *nothing but* time travelers, from all through the ages, all with hidden cameras!

Philosophers are well aware of Silverberg's and Clarke's conundrum and, indeed, it can be found in the philosophical literature before Clarke wrote. In one paper, for example, we read "Actually I know of only one argument against the possibility of time travel that seems to carry any weight at all. This is the fact that it does not appear ever to have happened. That is, it might be argued that there will be no time trips from [2100] to [2017] because we were here in [2017] and saw no time travelers. But this argument is far from conclusive."[47] At most, in other words, the absence of temporal visitors amongst us is an objection to the *actuality* of time travel, and not to the *possibility* of time travel.

This same philosopher then mentions some ways around this concern, including one which he called a "pettifogging physical limitation on time travel: perhaps the energy expenditure varies as the fourth power of the time traversed, making only very short trips feasible, and its discovery lies too far in the future for its effects to have yet been felt." Another science fiction writer, as famous as Clarke, used that idea in his 1957 novel *The Door Into Summer* when Robert Heinlein has one character comment "Now if there was some way to photograph the Crucifixion . . . but there isn't. Not possible . . . there isn't that much power on the globe. There's an inverse-square law tied up in [time travel]." Or, perhaps, time travel *is* possible but it's so extraordinarily dangerous that it's impossible to get anyone to do it. In one provocative tale[48] that takes this idea to the extreme, we read that there is only *one* time traveler, ever, from the future—indeed, from just 18 min (!) in the future—and his first (and last) experiment destroys the Earth.

Clarke presented some other possible science fiction rebuttals to the puzzle of 'where are the time travelers?' As he wrote, "Some science fiction writers have tried to get around this [question] by suggesting that Time is a spiral; though we may not be able to move along it, we can perhaps hop from coil to coil, visiting so many millions of years apart that there is no danger of embarrassing collisions between cultures. Big game hunters from the future may have wiped out the dinosaurs, but the age of *Homo sapiens* may lie in a blind region which they cannot reach."

The idea of time as a spiral was quite popular in early science fiction. Typical is one tale[49] in which the time traveler suddenly finds himself not in 1933 but in 2189. His situation is 'explained' to him thus: "[The] time stream is curved helically in some higher dimension. In your case, a still further distortion brought two points of the coil into contact, and a sort of short circuit threw you into the higher curve."

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[47] G. Fulmer, "Understanding Time Travel," *Southwestern Journal of Philosophy*, Spring 1980, pp. 151–156. The modern view of this 'paradox' is *not* that it describes a situation so absurd that time travel must be impossible, but rather that *all* the time travelers who *were* (will be?) at the Crucifixion *are* in the historically recorded crowd (see note 46 again). The Crucifixion happened just *once*, not over and over. I'll return to this point later in the book.

[48] D. Plachta, "The Man from When," *Worlds of If Science Fiction*, July 1966.

[49] R. H. Wilson, "A Flight Into Time," *Wonder Stories*, February 1931.

A few years later (in 1937) we find another story[50] with the same spiral-time concept; with a sixty-million year pitch to the time helix, there is no danger of a grandfather paradox. That same year spiral time was the central ‘scientific’ theme in the stage production “I Have Been Here Before” by the English playwright J. B. Priestley.

The very next year (1938) the young Isaac Asimov used the idea in his first attempt at professional writing, despite a life-long unhappiness with the concept of time travel. Titled “Cosmic Corkscrew,” it was initially rejected, indeed it was *never* published, and eventually lost. Though, perhaps, not for long, since one enterprising modern writer has used it as the basis for his own time travel tale.[51] In it a traveler from the near future travels back to 1938 to retrieve “Cosmic Corkscrew” before Asimov loses it (perhaps that’s *why* it was lost!) Even when writing introductions to other writers’ time travel tales, Asimov would often insert personal comments on his opinion of the concept. For example, in one volume of an anthology series he edited, *The Great Science Fiction Stories* (of 1954), he wrote “To my way of thinking it is precisely because time travel involves such fascinating paradoxes that we can conclude, even in the absence of other evidence, that time travel is impossible.” And in *The Great Science Fiction Stories* (of 1961) he bluntly declared “I think scientists who think up methods of time travel are probably all wrong.”

Spiral time is a close cousin to circular time. One story[52] dealing with circular time has a time traveler who finds, after a trip one hundred years into the future, that he can’t get all the way back to his own time because the required energy rises exponentially with increasing penetration into the *past*. Still, it’s very cheap in energy to go forward in time in this tale, and that’s what the traveler does, in search of help from the future’s advanced technology. He never finds what he needs, however, and so goes forward right into the collapse of the universe and through a new Big Crunch that forms an identical new cycle of time. He thereby returns home to just before he left.[53] This eternal recycling of identical, circular time is so terrifying that the traveler decides to suppress what he has learned about how to time travel—and so maybe *that’s* why there are no apparent time travelers. Science fiction writer Larry Niven has argued, however (see note 27), that while this may be a conceptually valid (?) way to travel into the past, he also warns that “Removing your time machine from the reaction of the Big Bang/Crunch could change the final configuration of matter, giving an entirely different . . . history.” (I strongly suspect that Niven wrote that with a big smile on his face!)

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[50] P. S. Miller, “The Sands of Time,” *Astounding Stories*, April 1937.

[51] M. A. Burstein, “Cosmic Corkscrew,” *Analog*, June 1998.

[52] P. Anderson, “Flight to Forever,” *Super Science Stories*, November 1950.

[53] Turning this idea on its head is the approach of the 1978 novel *The Way Back* (DAW) by A. B. Chandler. Its characters return from the past to their own time by traveling even further backward, right through the Big Bang and into the *previous* (and identical) cycle of time.

The famed English physicist Stephen Hawking is so taken with the question of 'where are all the time travelers?" that he has elevated their apparent absence ("we have not been invaded by hordes of tourists from the future"[54]) to the status of being a demonstration of the impossibility of time travel to the past. His so-called *Chronology Protection Conjecture*, Hawking likes to say, "makes the universe safe for historians": that is, there is nothing to worry about (if you're concerned that time travelers could change the past) because time travel is simply impossible. You'll see later in the book that there are other possible ways to insure the safety of history *without* denying the possibility of time travel, and Hawking himself has backed away just a bit from the Conjecture, saying now that he was simply looking for a humorous line.

While Hawking's endorsement of it has made the Conjecture famous, he wasn't the first to state it. Two years earlier it had appeared, in of all places, a *financial* publication: "[If] time travel was possible, someone from the future would eventually either discover a time tunnel or build a time machine and come visit us."[55] And even before that, an economist presented a 'proof' for concluding that "time travelers do not and cannot exist."[56] He argued that if time travelers from the future were actually amongst us (our 'now' is their 'past') then, by virtue of their knowledge of things to come (our 'future') they would make financial deals so numerous and extensive that interest rates would be driven to zero. Interest rates are *not* zero, however, and thus no such time travel hanky-panky has occurred.

These sorts of financial arguments aren't like to convince many physicists or philosophers of the Conjecture's merit. At most we can only conclude from them that time travelers from the future have *not* influenced financial affairs, which doesn't mean they aren't here. In any case, the Conjecture was actually stated more than 20 years before Hawking by Larry Niven (see note 27), who declared what is called *Niven's Law*: "If the universe of discourse permits the possibility of time travel, and of changing the past, then no time machine will be invented in that universe." And Hawking's concern over time travelers meddling with the past was anticipated in science fiction, too, by at least half a century; in a 1950 tale, for example, we learn of a Master Historian, and the graduate students in his course on 'Experimental History' in the forty-sixth century, trying to correct a problem created by a previous tampering with the past![57]

Not all physicists and philosophers feel intellectually comfortable with the Conjecture, as it seems (to them) a too quick surrender: 'Time travel is a problem

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[54] S. W. Hawking, "Chronology Protection Conjecture," *Physical Review D*, July 15, 1992, pp. 603–611. See also J. F. Woodward, "Making the Universe Safe for Historians: Time Travel and the Laws of Physics," *Foundations of Physics Letters*, February 1995, pp. 1–39.

[55] J. Queenan, "Time Warp: Or, Investing in the Future Is a Bust," *Barron's*, January 8, 1990, p. 46.

[56] M. R. Reinganum, "Is Time Travel Impossible? A Financial Proof," *Journal of Portfolio Management*, Fall 1986, pp. 10–12.

[57] L. Jones, "Sunday is Three Thousand Miles Away," *Thrilling Wonder Stories*, June 1950. A more recent, two-*novel* treatment of historians tinkering with history is by Connie Willis (*Blackout* and *All Clear*, both published in 2010).

so hard to do let's simply *define* it to be non-existent and then we won't have to worry about it anymore.' To *really* show that time travel is impossible, however, one needs to demonstrate how it would violate one or more of the laws of physics. Hawking, of course, understands this and has stated that, as one who is no fan of time machines and time travel, he believes there is new physics yet to be discovered that *will* forbid would-be time travelers from roaming up and down the centuries. Finding that new physics is the lure the study of time machines has for him. As he correctly writes in his autobiography,[58] "Even if it turns out that time travel is impossible, it is important that we understand why it is impossible."

One mathematical physicist who agrees with Hawking on the matter of the unlikely possibility of making a time machine is the New Zealand theoretician Matt Visser. Noting that while quantum field theory, and the general theory of relativity, are each amazingly good theories in many applications within their respective realms, they are not so good in spacetime regions at the so-called *Planck scale* (that is, when the density of mass-energy reaches the fantastic level of 10^{94} grams/cm^3 and beyond) where chronology violations (that is, time travel) seem to be spawned. As Visser has observed,[59] this situation won't change until 'we wander into the guts of quantum gravity,' the unification that will merge gravity with the quantum to give a theory that *always* works. Without quantum gravity, physics will continue to be "infested" (Visser's word) with "sick" (Visser's word) spacetimes that allow time travel. Visser believes that the discovery of the theory of quantum gravity can be 'guided' by *building* causality into it,[60] and the result will finally consign time machines to where (in his mind) they belong, the dust-bin of crackpot physics.

Well, perhaps so, but we don't have a quantum theory of gravity yet, and probably won't for some time to come, and so the puzzling questions about time travel remain. To end this section on a slightly gloomy note, an idea appeared in science fiction,[61] when Hawking was still a teenager, offering a possible rebuttal to the Conjecture. It opens with one of the inventors of the first time machine just returning from a trip to the past of 1938. Still, despite this success, the inventors are puzzled by what they call 'the problem': "But if *we* have time traveled, then obviously men of the future have time traveled. They will be able—*are* able to come back. [So] where are they?" They finally conclude that there can only be two possible answers. Either there is nobody in the future, or time travel is so dangerous (is that why the future might be empty—humanity misused time travel and killed itself off?) that all who invent it will suppress it. And that's what they decide *they* must do.

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[58] Stephen Hawking, *My Brief History*, Bantam 2013, p. 113.

[59] Matt Visser, "The Quantum Physics of Chronology Protection," in *The Future of Theoretical Physics and Cosmology*, Cambridge 2003. This paper was Visser's contribution to the celebration of Hawking's 60th birthday, held in January 2002.

[60] This may seem like something new, but it really isn't. General relativity has causality built into it on a *local* level (where it belongs); a failure of causality (that is, time travel—see J. Sharkey, "The Trouble With Hyperspace," *Fantastic* April 1965) occurs in general relativity only when one studies *global* regions of certain spacetimes. Forcing a physical theory to have a *prescribed global behavior* would be to undo all of physics since the development of *local field theories*, along with all their amazing successes in explaining nature.

[61] M. Shaara, "Time Payment," *Magazine of Fantasy and Science Fiction*, June 1954.

1.3 Skepticism About Tales of Time Travel

> "May it not be that our inability to leap into the fiftieth century, A.D., seems impossible to us, merely because of certain prejudices we entertain or certain facts and tricks of which we are still hopelessly ignorant? Assuredly, this is not a foolish query. Its answer, whatever that may be, carries immeasurable consequences for metaphysics."
>
> —a scholar wonders[62]

A thought-provoking possibility for explaining the scarcity of certified time travelers is the central thesis of a fascinating paper in the philosophical literature. The author of that paper argues (note 13) that nobody would believe a time traveler even if he willingly confessed and revealed his knowledge of the future, or even gave the details of his time machine. He goes on to make the astonishing assertion that even the *time traveler himself* would have doubts! This perhaps shocking suggestion deserves some elaboration, especially because it invokes the authority of the patron saint of skeptics for support, the Scot David Hume (1711–1776). The crucial point to keep in mind is explicitly stated in the argument: "The key question will not be 'Is time travel possible?' We shall instead ask whether it is possible to justify a belief in a report of time travel." This gets to the real heart of Clarke's puzzle from the previous section.

Much of the resistance to the idea of time travel lies in sheer skepticism. For many, time travel (to the past, in particular) is simply too much out of the ordinary to be taken seriously. For many, time travel would literally be miraculous. Hume's great work, *An Enquiry Concerning Human Understanding*,[63] contains a section on how a rational person should react to a claim that a miracle has occurred. Hume proclaimed that a miracle *by definition* violates scientific law and that, because such laws are rooted in "firm and unalterable experience," any violation of one or more of these laws immediately provides a refutation of the report of a miracle. In Hume's own words:

> "Nothing is esteemed a miracle, if it ever happened in the common course of nature. It is no miracle that a man, seemingly in good health, should die on a sudden; because such a kind of death, though more unusual than any other, has yet been frequently observed to happen. But it is a miracle, that a dead man should come to life; because that has never been

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[62] W. B. Pitkin, "Time and Pure Activity," *Journal of Philosophy, Psychology and Scientific Methods*, August 27, 1914, pp. 521–526. Pitkin's essay was a critique of time travel as presented in Wells' *The Time Machine,* which Pitkin called "one of the wildest flights of literary fancy."

[63] Making its first appearance in 1748, *Enquiry* has been reprinted numerous times since. I used the 1963 edition published by Open Court.

> observed in any age or country . . . When anyone tells me, that he saw a dead man come to life, I immediately consider with myself, whether it be more probable, that this person should either deceive or be deceived, or that the fact, which he relates, should really have happened. I weigh the one miracle against the other; and according to the superiority, which I discover, I pronounce my decision, *and always reject the greater miracle* [my emphasis]."[64]

It is a strict interpretation of Hume that Sorenson (note 13) has adopted in claiming that a time traveler would have no success (among rational persons) with tales of 'different times.' As he explains, "Clearly the time traveler cannot persuade a reasonable person by baldly asserting 'I am a time traveler.' The improbability of his claim places a heavy burden of proof on him. But perhaps he could shoulder the burden by means of artifacts, predictions, and demonstrations." Sorenson dismisses all of these possibilities, however, by reminding us of the slightly sleazy history of parapsychology and ESP, both of which run counter to known scientific laws, but which have still duped "many a respected scientist." Any artifact, prediction, or demonstration of time travel, argues Sorenson, is more likely to be the result of deception and fraud than of actual time travel: "Should the time traveler take observers for a spin in his time machine, the skeptics will have us compare their adventures with séances." The rational reaction to such a spin around the centuries, according to Sorenson's presentation, would be like that of a magician who cannot figure out how a colleague has just done his newest act: 'Nice trick! How did you do it?'[65]

The time traveling tourist stranded in the past in one story is used to getting a skeptical reaction because he can provide his questioners no technical explanation for his situation. "How the hell should I know? I'm just a tourist. It has something to do with chronons [see the Glossary]. Temporal Uncertainty Principle. Conservation of coincidence. I'm no engineer."[66] Somewhat more successful (perhaps) is a time traveler born in 2003 who turns up in 1975. After he tries to convince an interrogator of how that can be, he apparently succeeds. As the time traveler later tells a new friend in the past of 1975, "What amazed me . . . was that he really believed me in the end." But the friend doesn't buy that, replying "He did? I think he just pretended. A scientist isn't likely to believe a thing that is against all logic."[67] If the reception committee is a crowd of conservative, cautious Humeans, it would seem that a time traveler is almost certainly doomed. Early science fiction time travelers from 2030, for example, were warned about receiving a skeptical response as follows (the editorial introduction to this tale[68] called it "a curious study of psychology"): "Our wisest men advised against [our trip to the past]. They said we could hope to be received only as imposters and fakirs, that . . . we would find only twentieth-century barbarians, suspicious, ill-tempered, likely to do us bodily harm."

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[64] What Hume is alluding to here should be plain; as expressed in P. Heath, "The Incredulous Hume," *American Philosophical Quarterly*, April 1976, pp. 159–163, Hume was "an exposer of bad arguments in rational theology." For Hume, second-hand (or even more remote) tales of the return of a man from the dead—the claim that literally kept Christianity alive after Christ's execution—were suspect.

[65] This skeptical reaction was nicely captured in the story "E for Effort" by T. L. Sherred (*Astounding Science Fiction*, May 1947). As one character laments, "I've watched scribes indite the books that burnt at Alexandria; who would buy, or who would believe me, if I copied one. . . . What sort of padded cell would I get if I showed up with a photograph of Washington or Caesar? Or Christ?" The padded cell was indeed the fate of the time traveler in "The Ambassador from the 21st Century" (*Startling Stories*, March 1953) by H. J. Shay, the story of a man who journeyed from A.D. 2007 back to 1952 to warn of a future war; he was committed to a mental institution to receive help for his "illusion."

[66] J. Haldeman, "No Future In It," *Omni*, April 1979.

For many, such skeptical reactions to self-proclaiming time travelers seems dogmatic in the extreme—the response of people with no imagination, no spirit, and heads full of cement. Humean skepticism requires, so it would seem, the rejection of anything and everything that is profoundly surprising, leaving the world a place of utter predictability and boredom. As one science fiction writer put it, "When the miraculous occurs, only dull, workaday mentalities are unable to accept it."[69] Sorenson answers this harsh criticism as follows: "Humeans respond [to Sheckley] by distinguishing between surprises. Most surprises in science do not violate accepted scientific laws. The strange wildlife in Australia was not excluded by biology, X-rays were not precluded by physics."

Sorenson does well, however, to avoid mentioning such profound surprises as, for example, the spectrum of black-body radiation and, later, the photoelectric effect, which were not in the domain of known classical science at the beginning of the twentieth century. Those puzzling, surprising, *totally mystifying* effects required new science—the discovery of the quantum concept by Max Planck. (Explaining the photoelectric effect, *not relativity*, is what won Einstein his Nobel prize.) A strict Victorian-age Humean, as described by Sorenson, would have wrongly rejected the experimental reports of all quantum phenomena and would also (perhaps just as wrongly) have rejected all reports of time travel.

A strict Humean definition (as described by Sorenson) that a miracle has occurred requires a violation of one or more of the *known* [my emphasis] scientific laws of nature.[70] As one modern philosopher defines a miracle, it is any event that "can be explained *only* [my emphasis] by reference to the intervention of a supernatural force."[71] Time travel, by that interpretation, is *not* a miracle because general relativity, not God, is all that is required. C. S. Lewis (1898–1963), late professor of Medieval and Renaissance Literature at Cambridge University, however, absolutely rejected Hume's view on how a rational person should react to certain surprising events. Lewis, one of the most thoughtful modern writers on Christian theology, had no patience with skeptics (or, as he called them, materialists).[72]

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[67] G. Gor, "The Garden," in *Russian Science Fiction* (R. Magidoff, editor), New York University Press 1969.

[68] P. Bolton, "The Time Hoaxers," *Amazing Stories*, August 1931.

[69] Robert Sheckley, "Something for Nothing," in *Citizen in Space*, Ballantine 1955.

[70] The word *known* is important. As a character in one early science fiction story puts it, "These things [four-dimensional object] sound like miracles; but, after all, what are miracles but phenomena which, *on account of our ignorance* [my emphasis], we cannot explain?" See B. Olsen, "The Four-Dimensional Roller-Press," *Amazing Stories*, June 1927.

[71] D. M. Ahern, "Miracles and Physical Impossibility," *Canadian Journal of Philosophy*, March 1977, pp. 71–79.

Professor Lewis graphically illustrated the dug-in position of the extreme skeptic as follows: "If the end of the world appeared in all the literal trappings of the Apocalypse; if the modern materialist saw with his own eyes the heavens rolled up and the great white throne appearing, if he had the sensation of being himself hurled into the Lake of Fire, he would continue forever, in that lake itself, to regard his experience as an illusion and to find the explanation of it in psychoanalysis, or cerebral pathology."[73] If the end of the world would receive such a skeptical response, then a mere time traveler would surely have no hope at all of being believed.

Lewis would certainly have rejected Sorenson's most astonishing assertion: "So far I have concentrated on the time travel question from the perspective of the time traveler's audience. What about the time traveler himself? Can he at least know he is a time traveler?" Sorenson argues that a time traveler, if authentic, should be able to convince his audience, and that if he can't (and he *cannot* if they are true Humean skeptics), then the time traveler must entertain doubts, too! It doesn't matter (says Sorenson) that the time traveler has memories of his adventures, and it doesn't matter that he knows in his heart that he speaks the truth. Using words that echo Lewis' sarcasm, Sorenson quickly dismisses the importance of the time traveler's self-knowledge, declaring such memories to be merely the symptoms of some deep psychosis, and the traveler's introspective sincerity to be a product of gross self-deception.

Sorenson specifically mentions the traditional Humean response to astonishing reports when he cites earlier writers on time travel in the philosophical literature. In one of those analyses, for example, we find an argument *for* the reasonableness of a rational belief in time travel ("I have been amused and irritated by the spate of articles proving that time travel is a 'conceptual impossibility') by claiming such proofs must be faulty because there is a mathematically consistent explanation for such a belief.[74] (This author was referring to spacetime diagrams, which we'll get to in Chap. 3.) This paper received a very sharp rebuttal from another philosopher who convincingly used fundamental physics to show a simple use of spacetime diagrams in a special relativity setting does *not* support time travel to the past.[75] (I'll return to this point in Chap. 3.) Even later a Humean-style rebuttal came from yet another philosopher, who showed how to explain the time travel phenomenon that Putnam (note 74) described *without* invoking time travel.[76] This isn't to say that Weingard doesn't invoke some pretty astonishing gadgetry (and more) himself, like matter transmitters and anti-matter humans. (You'll see how anti-matter ties-in with time travel a bit later in the book.) A resurrected Hume would surely applaud these rebuttal analyses (although he might also doubt his own fresh existence).

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[72] In Lewis' eerie, unfinished story "The Dark Tower," a tale of the 'chronoscope,' a gadget that "does to time what the telescope does to space," the persistent skeptic in the story is a Scot, surely created in the image of Hume. See C. S. Lewis, *The Dark Tower and Other Stories*, Harcourt 1977.

[73] C. S. Lewis, *The Grand Miracle*, Ballantine 1986.

[74] H. Putnam, "It Ain't Necessarily So," *Journal of Philosophy*, October 1962, pp. 658–671.

[75] J. Earman, "On Going Backward in Time," *Philosophy of Science*, September 1967, pp. 211–222.

Hardly anybody is happy with Weingard's approach for avoiding time travel (including, I suspect, even Weingard). His 'explanations' seem, just like a time machine, to be incredible and, as Arthur Conan Doyle's Professor Challenger says in one tale not staring Sherlock Holmes, "You cannot explain one incredible thing by quoting another incredible thing."[77] An interesting science fiction exposition illustrating Professor Challenger's Humean philosophy occurs when a copy of *The New York Times* for December 1 shows up for some subscribers a week early, on November 22. It seems the only explanation is either that the paper really is from the future (due to some sort of fluke of the fourth dimension), or that it is a hoax. The first-person narrator of this 1973 tale[78] provides us with his reason for believing the former: "I don't find either notion easy to believe but I can accept the fourth-dimensional hocus-pocus more readily than I can the idea of a hoax." Hume couldn't have said it better.

It should be clearly understood that Hume was not arguing for disbelief in absolutely anything surprising, but rather for rational analysis. Historically, the context of Hume's times was that of what he took to be non-rational arguments for a belief in God, particularly those 'proofs' so beloved by theologians based on Design (Heath [note 64] calls such 'proofs' "philosophical museum pieces"). As Heath writes, "Hume … makes no attempt to deny the supposed facts; he simply argues that they are consistent with other explanations and other analogies of a less ambitious kind. There is no right to attribute to the causes of such phenomena abilities more extensive than are needed to produce the observed effects."

As a matter of fact, even Hume could be convinced of quite strange matters, and I think Sorenson does interpret the philosopher a little too narrowly. In his essay concerning Hume's position on holding a belief in God, Heath wonders whether there is "empirical evidence [imaginable] which would persuade any reasonable mind of the real existence of an infinite God." Heath answers his own question as follows: "If the stars and galaxies were to shift overnight in the firmament, rearranging themselves so as to spell out, in various languages, such slogans as I AM THAT I AM, or GOD IS LOVE—well, the fastidious might consider that it was all very vulgar, but would anyone lose much time in admitting that this settled the matter? . . . Confronted with such a demonstration, the hard-line Humean [but not Hume, himself, I think] could continue, of course, to argue that, for all its colossal scale, the performance is still finite, and so cannot be evidence of more than the finite, though immense power that is needed to achieve it."

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[76] R. Weingard, "On Travelling Backward in Time," *Synthese*, July–August 1972, pp. 117–132.

[77] Arthur Conan Doyle, "The Disintegration Machine," *The Strand Magazine*, January 1929. Professor Challenger is nothing like Wells' thoughtful Time Traveller; in the original 1912 Challenger novel *The Lost World*, he was described as a "primitive cave-man in a lounge suit."

[78] R. Silverberg, "What We Learned from This Morning's Newspaper," in *Beyond the Safe Zone*, Warner 1986.

Skepticism about 'time travel' was around long before the specific idea of a 'time machine' was conceived. For example, the eleventh-century Persian poet-philosopher Omar Khayyam was blunt in his evaluation of the likelihood of reliving the past. As he so beautifully wrote in one of the quatrains of the *Rubaiyat*,

The Moving Finger writes; and having writ,
Moves on: nor all your Piety nor Wit
Shall lure it back to cancel half a Line,
Nor all your Tears wash out a Word of it.

Quite a bit later the English poet Thomas Heywood, in his 1607 play *A Woman Killed with Kindness*, had one of his characters express a similar thought:

God, O God, that it were possible
To undo things done, to call back yesterday;
That Time could turn up his swift sandy glass
To untell the days, and to redeem these hours.
Or that the Sun
Could, rising from the west, draw his coach backward,
Take from the account of Time so many minutes,
Till he had all these seasons called again,
. . . .
But O! I talk of things impossible,
And cast beyond the moon. . .

When Gödel's discovery of time travel in his rotating universe was announced, the skeptics were easy to find. One philosopher[79] wrote of it "This property [of time travel] must be judged an absurdity by anyone committed to the ordinary modes of speech." And another[80] was only slightly less charitable: Gödel's solution was a "bizarre conception" and a "mere mathematical curiosity." Science fiction wasn't immune to skepticism, either, even though you might have expected that to be the one place where the high drama of time travel would be welcomed. Four *years* after Gödel's paper appeared we find one respected anthologist writing,[81] as part of his introduction to a story, "In this tale we meet our first Mad Scientist. Just as in reality the thoroughly cracked pots used to be found inventing perpetual-motion machines, so in science fiction we find the lunatic fringe more often than not trying to perfect time-travel mechanisms." And that same year the founding editor of *Galaxy Science Fiction Magazine* declared "Time travel requires a suspension of disbelief that is almost unbelievable . . . Scientifically, time travel can't stand inspection.".[82]

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[79] J. D. North, *The Measure of the Universe*, Oxford University Press 1965.

[80] C. T. K. Chari, "Time Reversal, Information Theory, and 'World-Geometry'," *Journal of Philosophy*, September 1960, pp. 579–583.

[81] Groff Conklin, editor of *Science-Fiction Adventures in Dimension*, Vanguard 1952.

Years later matters had not much changed. For example, in his marvelous 1985 book *The Past is a Foreign Country*, David Lowenthal repeatedly refers to time travel as "fantasy," and to science fiction stories about time travel as "unbridled by common sense." (Lowenthal is a professor of *geography*, not physics.) Science fiction writers were still often not much more enthusiastic about time travel. The well-known science fiction writer and critic Alexei Panshin, for example, agrees with Lowenthal, at one point, long after Gödel, writing "Time travel is a philosophical concept, not a scientific one. It is, in fact, as has often been pointed out, scientific nonsense."[83]

Skepticism does have its uses, however. Modern science fiction writers have often used it as a dramatic means of building conflict and tension in their time travel stories. A skeptical reception is extreme, for example, for a soldier-in-time who has fought in numerous wars, from the ancient past to a billion years in the future.[84] He finds that nobody believes him when he speaks openly of his temporal adventures during a visit to a present-day bar. Everybody merely thinks it is all a hilarious gag. This is in great contrast to one 1870s story[85] in which suspicion of a stranger plays a central role, but which finds its offered explanation in something entirely different from time travel. It tells of a man who suddenly appears in the midst of a Union military camp during the American Civil War.

This man quickly displays strange lapses in his background, as well as possessing knowledge of many different things well beyond anything that could be called common. The details of the story are not important for us but, if it were published in a modern science fiction magazine, this man would almost surely be identified in most readers' minds as a time traveler. In 1875, however, the author's narrator found his punch line in "his firm conviction that the quiet, gentle, well-behaved, modest gentleman, so singularly gifted . . . is, in plain terms, the devil!" Time travel certainly never entered the author's thoughts or, if it did, he lost his nerve at the idea of using it in this pre-Wells story. You'll recall from the opening of the Introduction that it was this 'use of the devil to explain mysterious happenings' that Wells wanted to move away from, and that was the motivation for his introduction of a time *machine*.

Hollywood has at least gotten the skeptical part of the psychology of time travel right (later discussions in this book will focus on how film makers have been less successful with the physics). When, for example, the time traveling villain in the

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[82] H. L. Gold, editor of *The Galaxy Reader of Science Fiction*, Crown 1952.

[83] In his introduction to Robert Heinlein's classic time travel tale (to be discussed later) "All You Zombies—," in *The Mirror of Infinity*, Canfield 1970.

[84] F. Leiber, "The Oldest Soldier," *Fantastic*, May 1960.

[85] G. C. Eggleston, "Who Is Russell?" *American Homes*, March 1875.

1989 movie *Time Trackers* is confronted in the medieval past, he simply laughs-off a threat to reveal his true identity. "Go ahead," he says in effect, 'the only thing your talk of time machines from the future will accomplish is for people to think you are crazy!'

What would Arthur C. Clarke have thought of all this skepticism being directed toward those who claim to have a time machine? His thoughts about the difficulty time travelers would have in maintaining low profiles were what started the previous section, after all. My guess is that he would have had little patience with extreme incredulity. The surprise of being confronted by a time traveler would soon have turned to awe and pleasure IF—and I emphasize the IF—Clarke had been taken for a spin around the centuries in the stranger's machine. He would surely have ended-up quoting his own famous 'third law' to explain the wonder of it all: "Any sufficiently advanced technology is indistinguishable from magic."

Near the end of his paper, Heath writes what I think is the perfect rebuttal to anyone who would refuse to admit to time travel, even after taking a quick trip backward a few tens of millions of years to the late-Mesozoic era to hunt *Tyrannosaurus rex*, and even after seeing instant photographs of the dead monster with the skeptic's *own foot* on the great creature's head, or of his *own boots* dripping a bloody puddle of unholy size on the floor of the time machine. Writing about the Humean-unconvinced, even when faced with a rearranged firmament, Heath observes "But this now seems a cavil, designed only to prove that even omnipotence is powerless against the extremer forms of skeptical intransigence." Where God would fail to convince, a simple time traveler could hardly hope to do better!

1.4 Troubles with (some) Time Machines

> "If you don't stop this senseless theorizing upon something that's an obvious impossibility, you'll find yourself working alone! Your ridiculous ideas sound like the ravings of a madman. Anyone with average intelligence realizes that the mere thought of traveling through time is absurd."[86]

If the previous section seemed just a bit gloomy concerning time travel, there is a very big reason for that. The sentiment expressed in the above opening quote to this section was a common one among philosophers long before physicists began to seriously think on the topic. While there *are* issues with time travel to the *future*, they are of an *engineering* nature, centered on how to build a big enough rocket ship with enough fuel to make the high speed, looping trip out into space and back again described in the opening section of this chapter. 'Mere' engineering problems are of no concern to physicists and philosophers. What *does* concern them are the far deeper puzzles of time travel to the *past*, the puzzles presented by what appear to be

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[86] A science fiction physicist receives harsh criticism from a colleague in L. A. Eshbach's "Out of the Past," *Tales of Wonder*, Autumn 1938.

logical paradoxes. Before we get into the paradoxes, however, we need to first clear our minds of two common, popular notions of just what a time machine *is*. Both are false notions (one is due to H. G. Wells) which are, today, *rejected* by physicists (and most philosophers, too).[87]

As you'll see later in the book, all the theoretical time machines that have appeared in the modern physics literature involve spatial displacement. That is, they require *movement*. (On this point, the speedy DeLorean time car in the *Back to the Future* films has it right.) Wells' time machine, however, did not move; it always remained in the Time Traveller's laboratory (or at least on the spot where the laboratory would have been) unless he pushed it about after a trip in time. This, alas, results in a particularly troublesome problem: a Wellsian time machine heading into the past would run into itself!

Consider: There sits my time machine as I prepare for the first time journey ever, a trip back to the late-Mesozoic era to hunt dinosaur. I load my Continental. 600 super-high-power rifle with Nitro Express cartridges the size of bananas, kiss my wife good-bye, and climb in. I pull the lever. Now, Wellsian-type time machines don't *jump over* time but rather travel *through* time (see the Time Traveller's own description of how things looked to him, a description faithfully and spectacularly reproduced in the 1960 film). Therefore, the time machine will instantly collide with itself at the micro-moment *before* I pull the lever!

The resulting destruction obviously introduces a nice paradox: Given that this happens before I pull the lever, how did I manage to pull it? Many of the early science fiction writers were not totally oblivious to this collision problem and, in order to avoid materializing inside of an object in the future or the past, it was common to combine the time machine with an airplane.[88] Even that though might not be enough, as one writer thought a Wellsian time traveler would get "a severe case of the bends" if his body materialized in air![89] Of course, one might argue that Wells' machine does actually move because it is attached to the Earth, which is certainly moving, but it is not clear why this should result in the time machine arriving in the temporal past of the Earth, rather than in some past region of space (almost surely a vacuum).[90]

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[87] Both of these notions still routinely appears in science fiction, however, because they are 'just too neat' to let 'mere physics' get in the way of a good tale. I use one, without apology, in my own story "Newton's Gift" in Appendix B.

[88] Three such tales are M. J. Breur, "The Time Valve," *Wonder Stories*, July 1930; F. J. Bridge, "Via the Time Accelerator," *Amazing Stories*, January 1931; E. Binder, "The Time Cheaters," *Thrilling Wonder Stories*, March 1940.

[89] J. Lafleur, "Time as a Fourth Dimension," *Journal of Philosophy*, March 1940, pp. 169–178, and "Marvelous Voyages—H. G. Wells' *The Time Machine*," *Popular Astronomy*, October 1943.

[90] Philosophers seem to be becoming more aware of the collison problem (which they have dubbed "the double occupancy problem"), and at least three papers published since the second edition of *Time Machines* discuss it: W. Grey, "Troubles With Time Travel," *Philosophy*, January 1999, pp. 55–70; P. Dowe, "The Case for Time Travel," *Philosophy*, July 2000, pp. 441–451; R. Le Poidevin, "The Cheshire Cat Problem and Other Spatial Obstacles to Backward Time Travel," *The Monist*, July 2005, pp. 336–352. Physicists don't concern themselves with the collison problem simply because they *aren't interested* in *Wellsian* time machines; I'll explain why I say this by the end of this section.

The general problem of ‘where the past is’ was nicely illustrated by the physicist Gregory Benford in his 1980 novel *Timescape*. In that story the world of 1998 is on the verge of total ecological collapse, and an attempt is made to change the past by aiming a backward-in-time message via faster-than-light tachyons (these hypothetical particles are discussed in Chap. 5) at the pivotal year 1963. When the principal scientist involved in this effort is explaining the process to a potential financial backer, he is asked, “Hold on. Aim for *what*? Where *is* 1963?” The scientist replies, “Quite far away, as it works out. Since 1963, the Earth’s been going around the Sun, while the Sun itself is revolving around the hub of the galaxy, and so on. Add that up, and you find 1963 is pretty distant.” An understanding of the question ‘Where is the past?’ actually goes quite a bit further back in science fiction. For example, after looking through a TV-like gadget to view the past, one character in a 1940s story complains, “You said you’d find Captain Kidd’s treasure, but all I can see is fog and static.” He is told that’s because “It’s too far back—1698 or thereabouts. The Earth was billions of miles from here then, and there are too many cosmic rays between.”[91]

But let’s suppose we ignore this concern about where things are for a time traveler, as do most science fiction stories. Still another problem with a true Wellsian-type time machine is that because it travels *through* time, the machine must *always* appear to be located in the same place. For example, to travel from Ford’s Theater today to Ford’s Theater on the evening of Good Friday, April 14, 1865, in a misguided attempt to save Lincoln from Booth’s bullet (*why* this would be misguided will be discussed at length later in the book), a Wellsian-type time machine would have to occupy every instant of the intervening century and more. For observers outside the machine, the machine would appear to have been sitting in the same place all those years. There is an amusing illustration of a failure to understand this point by the scriptwriters of the 1989 film *Time Trackers*, who have time travelers ‘hide’ their Wellsian machine from accidental discovery by ‘parking’ it 5 s in the future!

Wells was well-aware of the “does a time traveling object disappear or not?” issue, and tried to have it both ways in *The Time Machine* by invoking what he had the Time Traveller call “diluted presentation.” As we are told in the novel, the reason why we cannot see the model time machine he sends on its way into the future as a demonstration is that “the spoke of a wheel spinning, or a bullet flying through the air” is invisible because if those objects are “traveling through time fifty times or a hundred times faster than we are . . . the impression [they create] will of course be only one-fiftieth or one-hundredth.” Similarly for the model. This explanation breaks down when one remembers that, even if you cannot see the spoke or bullet, they are still there and you can get in their way—Wells, unfortunately, has one of his characters stick a hand into the space where the model time machine was last seen.

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[91] M. Jameson, “Dead End,” *Thrilling Wonder Stories*, March 1941. The “cosmic rays” are presumably the cause of the interference.

This objection to Wellsian time travel was raised soon after the 1895 publication of the novel, and then again in 1914 by Pitkin (note 62), who noted that violent disaster awaited once the time journey ended. Wells, it is only fair to note, seemingly anticipated Pitkin when he had the Time Traveller say "So long as I travelled at a high velocity *through time* [my emphasis] . . . I was, so to speak, attenuated—was slipping like a vapor through the interstices of intervening substances!" What this is getting at is that for the Time Traveller to stop 'inside' anything (Pitkin's example was the pile of bricks the Time Traveller's laboratory is certain one day to become) would, as Wells had his hero say, cause "a profound chemical[92] reaction—possibly a far-reaching explosion—[that would] blow myself and my apparatus out of all possible dimensions." Just why this spectacular event doesn't occur when the time machine simply stops *in air*, never mind inside Pitkin's pile of bricks, is never addressed.

In any case, it seems clear from all of this that Wells' machine travels *through time*, just as the Time Traveller claims. But Wells, himself, raises doubt when he describes the observed effects of a departing time machine. At the beginning of the novel, when the Time Traveller sends his model machine into the future, we read "There was a breath of wind, and the lamp flame jumped. One of the candles on the mantel was blown out . . . and it [the model time machine] was gone—vanished!" And, at the end, when the Time Traveller makes his final exit, the narrator of the tale just misses the departure but tells us "A gust of air whirled around me as I opened the door, and from within came the sound of broken glass falling on the floor. The Time Traveller was not there . . . Save for a subsiding stir of dust, the further end of the laboratory was empty. A pane of the skylight had, apparently, just been blown in." Both of these descriptions read as *implosions*, air rushing in to fill a spatial void, as though the time machines had *jumped* in time. Is there an inconsistency here? Well, perhaps not, if one accepts the curious idea of "slipping like a vapor" for an operational Wellsian-type time machine.

One famous science fiction story[93] nicely illustrates these points. The inventor of the first time machine demonstrates it to colleagues by sending a brass cube 5 min into the future. After being placed in the machine, the cube vanishes and then, 5 min later, reappears. Did the cube travel *through* time, or was its journey 'instantaneous,' so to speak? If *through* time, the cube was present at every instant after the start of its trip—so why did it vanish? The cube gets to each instant before the observers do, but why this should produce the visual effect of disappearing is unclear. The description in the story implies the cube traveled 5 min into the future without existing at any of the in-between instants, and so the story's time machine certainly was *not* Wellsian.

An immediate implication of the immobility of a Wellsian time machine is that if you are being chased by an angry mob somewhen in time (perhaps because you unwittingly violated a sensitive social taboo), then hopping into your Wellsian-type time machine isn't going to help because the machine just sits there. The mob could simply take its deliberate time in first building a roaring fire and then pushing the machine (and you) into it. As one author (with a wonderfully appropriate name!) expressed this, "You might as well try to escape by taking a nap."[94]

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[92] Actually *nuclear*, but don't forget when Wells wrote his novel.

[93] F. Brown, "Experiment," *Galaxy Science Fiction*, February 1954.

Pulp science fiction, always alert to a good story gimmick, used this characteristic of Wellsian time machines in one clever tale[95] in which a criminal attempts to hide his crimes by sending the bodies of his victims into the far future. His mistake is to use a Wellsian time machine in which he escapes into the future. The police, however, having learned of his foul deeds, simply build a cage around the machine and arrest him when he exits 23 years later!

If a Wellsian time machine that moves *through* time suffers from a fatal collision problem, then how about that other favorite of science fiction, a time machine that *jumps* in time? (Recall the final departure of Wells' Time Traveller.) That certainly would avoid the self-colliding problem. When you pull the lever inside the machine you simply disappear from 'now' and (from your point of view) then instantly pop into existence 'then.' The problem with this sort of time machine is that a Time Traveller who uses it will have a *discontinuous* world line, with the break occurring at the moment his time machine 'jumps.' In the modern physicist's view of time travel, however, based on general relativity, a Time Traveller's world line should always be continuous. That's because general relativity is a smooth, local field theory described by differential equations, resulting in *continuous* CTLs/CTCs.

Imagine, for example, that a 'jumping' time machine inventor starts building his gadget at time $t = A$ and expects to finish building it at time $t = B > A$. At time $t = C < B$, however, he runs into a problem. Fortunately, just at that moment a fully-functional time machine suddenly appears in the lab, and from it emerges a slightly older version of the inventor. The older version has the solution to the problem and, after telling the younger version the answer, gets back into the operational time machine and jumps off to . . . somewhen. The younger version then completes his machine at time $t = B$, gets into it, jumps back to time $t = C$, and . . ..[96]

In the past, philosophers have gotten themselves all tangled-up in debates over *personal identity*, that is, which version is *the* inventor, the younger or the older? Can they both be the same person, even though the older version has a world line (*starting* at $t = C$) that is separate and distinct from the world line of the younger (that *stops* at $t = B$)? One philosopher (note 74) left physics behind and pursued this question into the following *legal* question concerning our two (?) inventors: if the older version commits a crime and then vanishes in his time machine before the police can apprehend him, can the younger version be punished even though *he* hasn't yet committed the crime? While certainly 'interesting,' this really is a non-issue for the modern physicist who is concerned only with the physical possibility (or not) of time travel to the past.

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[94] M. Cook, "Tips for Time Travel," in *Philosophers Look at Science Fiction*, Nelson-Hall 1982. One modern story that gets Cook's point right is by I. Watson, "The Very Slow Time Machine," in *The Best Science Fiction of the Year* (T. Carr, editor), Ballantine 1979.

[95] M. Jameson, "Murder in the Time World," *Amazing Stories*, August 1940.

[96] This little story I've just told you involves what is called a *bootstrap paradox* (just where did that solution come from, that is, who thought it up?) and it is one of the real puzzles of time travel. I'll say *lots* more about such curious doings later in the book.

Well, okay, you might now say, if neither a Wellsian time machine or a 'jumping' time machine will do, then just what *are* physicists studying in their papers on time travel? The short answer here (in Chap. 3 I'll say more) is that physicists don't view time machines as super-tech gadgets covered with wires, meters, dials, and levers, humming away beneath a seated Time Traveller as gigawatts of power throb through massive copper/crystal rods, with the whole business surrounded by a pulsating red-blue glow. Hollywood absolutely loves that sort of thing, but it's simply all wrong. For modern physicists, a time machine is *a region of spacetime with special topological structure*. Then, to time travel, a Time Traveller moves through that region of spacetime (in a rocket, perhaps) along an appropriate path. To 'make a time machine' therefore, in modern terms, means to (somehow) manipulate finite amounts of matter/energy in such a way as to alter the topology of a finite region of spacetime from one that has no CTLs/CTCs to one that does.[97] The most famous example of such a spacetime topology alteration (or *warp*) is the creation of a *wormhole*. A wormhole is a *topological* artifact of a spacetime; wormholes were popularized in Carl Sagan's 1985 novel *Contact* (under the guidance of physicist Kip Thorne) and are now common in science fiction.[98] As mentioned at the start of this chapter, for example, even Stephen King uses one in his 2011 *mainstream* novel *11/22/63*.

I'll return to the 'topology of spacetime' in Chap. 3 but, just so we don't leave it here as a mysterious phrase, here's a simple illustration of a topology change. Imagine a long, flat, narrow, two-dimensional strip of paper. The strip has the following topology features of interest to us here: (1) it has a beginning (its left end) and an ending (its right end), and (2) it has two sides (the top surface) and the flip-side surface. Now, imagine that we take the right end of the strip, give it a half-twist of 180^0 through our three-dimensional space, and then finally we glue that twisted end to the left end of the strip. The half-twist and gluing (our *warp*) has changed both of the topological properties of the strip. That's because the strip now has *no end* (you can travel forever along the strip, always going 'forward' and never reaching a point where can't go forward some more), and the strip now has just *one* side. You can convince yourself that it is one-sided by coloring the strip with a crayon. During the coloring, *do not lift the crayon from the strip*. When you can color no more, you'll find that every last bit of the strip has been colored. You can't do that with the original strip without lifting the crayon and turning the strip over because the original strip was two-sided. Many readers will recognize that what we've done is make a *Möbius strip*, named after the German astronomer and mathematician August Möbius (1790–1868) who described it in 1858.

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[97] There is a hint of this in one prescient science fiction story, in which the inventor of a time machine, when asked about how it works, replies "An electromagnetic *warping* [my emphasis] of the spacetime continuum." See N. Schachner, "When the Future Dies," *Astounding Science Fiction*, June 1939.

[98] A wormhole is featured in the 2014 film *Interstellar*, whose Executive Producer and technical advisor was Thorne. The film's special effects are relativistically correct (not the typical Hollywood 'fantasy physics'), and you can read how that was achieved in Oliver James, Eugénie von Tunzelmann, Paul Franklin and Kip S. Thorne, "Gravitational lensing by spinning black holes in astrophysics, and in the movie *Interstellar*," *Classical and Quantum Gravity*, February 2015. See also (same authors) "Visualizing *Interstellar*'s Wormhole," *American Journal of Physics*, June 2015, pp. 486–499.

Here's another astonishing property our half-twist warp has introduced. Cut the Möbius strip lengthwise with a scissors; most people believe you will then get two strips, each the length of the original strip but each only half as wide. Actually, you get one strip with a *full* 360° twist, which means the result is back to having two sides. (To see this, make a Möbius strip, cut it, and *then* apply the crayon.) And if you cut this new strip lengthwise once more, you get two separate loops, linked together. Try it and see, but be very careful. As the late science fiction writer Cyril Kornbluth (1923–1958) warned, there may be horrific potential dangers in unschooled experimentation with topology warps:

A burleycue dancer, a pip
Named Virginia, could peel in a zip;
        But she read science fiction
        And died of constriction
Attempting a Möbius strip.[99]

To end this section, I should point out that a change in the topology of a spacetime is *not* a necessary requirement for that spacetime to support time travel to the past. Gödel's rotating spacetime, for example, has a remarkably simple topology and, as you'll recall, it's literally *stuffed* with CTLs/CTCs, to the point that time travel to the past in Gödelian spacetime would be an everyday occurrence. You might think a world that presents time travel as a *fundamentally allowed* physical phenomenon, as does Gödel's spacetime, would be irresistible to science fiction writers. (So far as I know, however, no one has written a time travel story using the rotating universe idea.[100]) In Chap. 6, in fact, I'll show you just how easy it would be to time travel in Gödel's spacetime, using a rocketship as the means to move through that spacetime. Of course, *our* universe is not Gödelian, so the 'time travel to the past' question is not so easily answered for the spacetime we appear to actually inhabit.

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[99] As you can see from this, science fiction writers have had fun with the Möbius strip. Two early examples *not* involving time travel are N. Bond, "The Geometrics of Johnny Day," *Astounding Science Fiction*, July 1941, and W. H. Upson, "A. Botts and the Möbius Strip," *The Saturday Evening Post*, December 1945. The use of the Möbius strip for time travel occurs, for example, in M. Clifton's "Star, Bright," *Galaxy Science Fiction*, July 1952.

[100] If he had lived, perhaps the well-known science fiction writer James Blish (1921–1975) would have written such a tale. In David Ketterer's biography of Blish (*Imprisoned in a Tesseract*, Kent State University Press 1987), there is this comment from a 1970 letter written by Blish: "I am especially intrigued by the spinning-universe form of time travel, especially since . . . nobody has touched it . . . But I should really stop mentioning the spinning-universe in public, or somebody will nobble onto it before I can get into it!"

1.5 Quantum Gravity, Singularities, Black Holes, and Time Travel

> "A [spacetime] singularity is where God is dividing by zero."
>
> —Anonymous

> "A theory that involves singularities and involves them unavoidably, moreover, carries within itself the seeds of its own destruction."
>
> —Peter Bergmann (1915–2002), Einstein's research assistant at the Institute for Advanced Study, Princeton

A fundamental objection to general relativity's suggestion of the possibility of time travel to the past is that, in a very deep sense, general relativity is known to be incomplete. That is, it is incompatible with quantum mechanics, which is the physics of the very, *very* small—the physics of atomic-size objects and *smaller*. We touched on this at the end of Sect. 1.2, and here we'll take a longer look at the issue of merging quantum mechanics with general relativity.

In quantum mechanics, the discrete nature of the atomic world appears in such phenomena as the photoelectric effect, in which light acts like individual particles (photons) rather than as continuous waves. Einstein's general relativity works beautifully on a cosmological scale but, like Maxwell's theory of electromagnetism, and unlike quantum mechanics, it fails when applied deep in the interior of the atom. Quantum theory, however, seems to work *everywhere*. As one physicist put it, "As far as we can tell, there is no experiment that quantum theory does not explain, at least in principle . . . Though physicists have steered quantum theory into regions far distant from the atomic realm where it was born, there is no sign that it is ever going to break down."[101]

One of the central concepts in relativity is the *world line*, which is the complete story of a particle in spacetime. A world line assigns a definite location to the particle at each instant of time. This is a classical, pre-quantum concept, however, and today physicists use the probabilistic ideas of quantum mechanics to describe the location and momentum of a particle once they get down to the atomic scale of matter. Quantum theory is a discrete theory in which the values of physical entities vary discontinuously (in 'quantum jumps'), whereas in classical theories the values of physical entities are continuous. The difference between the two types of theories is something like the difference between sand and water. Mixing the two theories—the classically smooth, continuous general relativity and the discrete quantum mechanics—to get something called *quantum gravity*, is the Holy Grail of physicists today, and nobody has more than an obscure idea of how to do it.

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[101] N. Hebert, *Faster Than Light: Superluminal Loopholes in Physics*, New American Library 1988.

Just one of the more curious results of the fusing of quantum mechanics with general relativity may be *quantum time*.[102] That is, in quantum gravity the smallest increment of time that has physical meaning—sometimes called the *chronon*, a term first used in a non-time travel science fiction story[103]—may have a non-zero value. As we'll see later in the book, much of the controversy over the possibility of time machines hinges on what is called the *quantum gravity cut-off*. This is the end-result of destructive spacetime stresses that tend to grow toward infinity whenever a time machine spacetime topology attempts to form. This process goes under the general name of the *back reaction*, and is conceptually similar to a rubber band growing ever more taut as it is stretched, an effect that resists more stretching (and, of course, if stretched too far the rubber band breaks).

The cut-off of those stresses, at some *finite* value, is imagined to occur when the terminal phase of the growth would take place in less than the minimum possible time interval. The cut-off happens because, it is thought, nothing can actually occur in less than the minimum time. The debate is over just what that minimum duration is, and over whether the cut-off would occur before the stresses could reach *finite* values large enough to destroy the putative time machine topology. If the cut-off occurs before the back reaction stresses climb to the critical value, then the time machine survives. Otherwise, not.

To see how this 'works,' consider the two fundamental physical constants associated with classical gravity, the *gravitational constant*[104] G and the speed of light c, and the fundamental physical constant associated with quantum mechanics (*Planck's constant*) ħ. Now, if you play around with combinations of these constants it is easy to show that the following expressions have the units of length, time, and mass, called the *Planck length* (l_P), the *Planck time* (t_P), and the *Planck mass* (m_P), respectively:

$$l_P = \sqrt{\frac{\hbar G}{c^3}} \approx 1.6 \times 10^{-33}\ \text{cm},$$

$$t_P = \sqrt{\frac{\hbar G}{c^5}} \approx 5.3 \times 10^{-44}\ \text{s},$$

$$m_P = \sqrt{\frac{\hbar c}{G}} \approx 22 \times 10^{-6}\ \text{g}.$$

The extremely tiny values of l_P and t_P (the chronon), in particular, indicate (*roughly*) where it is expected that the smooth, continuous spacetime of general relativity will itself become quantized, and so will have to give way to a quantum theory of gravity.

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[102] H. Kragh and B. Carazza, "From Time Atoms to Space-Time Quantization: the idea of discrete time, ca 1925–1936," *Studies in History and Philosophy of Science*, June 1994, pp. 437–462.

[103] S. Weinbaum, "The Ideal," *Wonder Stories*, September 1935.

[104] This is the constant in Newton's famous inverse-square law for gravity; the attractive force F between two point masses m_1 and m_2, distance r apart, is $F = G\frac{m_1 m_2}{r^2}$.

The associated value of the mass-energy density when this transition is imagined to occur is enormous; the so-called *Planck density* is the Planck mass divided by the cube of the Planck length and has the value of about 10^{94} grams/cm^3. This is where physicists expect classical and quantum gravity to part company. Can such an enormous mass-energy density actually occur?[105]

Yes, and more, in what physicists call *singularities*.

This was all still very speculative until about 50 years ago, but today the search for how to connect general relativity and quantum mechanics is serious business. That search is related to time travel studies via a fantastic sequence of discoveries in relativistic physics, made during the last 80 years, beginning in 1931 with the work of the young Indian astrophysicist Subrahmanyan Chandrasekhar (1910–1995). He combined quantum mechanics and *special* relativity to show that a non-rotating star above a certain mass (about 1.4 times the mass of the Sun) cannot evolve into a white dwarf, which had until then been thought the eventual fate of all stars. Stars more massive than 1.4 Solar masses (but not *too* massive) would, instead, become *neutron* stars. But what then happens to stars that are too massive for even *that* bizarre eventuality?

General relativity predicts that a sufficiently massive star—greater than about four times the mass of the Sun—will, when its fuel is nearly exhausted and its nuclear fires are beginning to fade, experience a truly spectacular event called *total gravitational collapse*. When its fuel-starved, weakened radiation pressure is no longer able to keep a massive, aged star inflated against the collapsing force of its own gravity, the star will suddenly implode and crush itself into what is called a *black hole*, a dramatic term coined in 1967 by the Princeton physicist John Wheeler (1911–2008) in an address before the American Association for the Advancement of Science. A black hole is an object with a gravitational field so strong that even light cannot escape—that's why it's black!—at whose center is something called a *singularity*. This is all well-known lore in the physics world.[106]

Indeed, cataclysmic views of the collapse of matter are actually quite old. In Lucretius' first-century B.C. *The Nature of the Universe*, for example, we find the following imagery on what it would be like if matter itself collapsed: "The ground will fall away from our feet, its particles dissolved amid the mingled wreckage of heaven and earth. The whole world will vanish into the abyss, and in the twinkling of an eye no remnant will be left but empty space and invisible atoms. At whatever point you allow matter to fall short, this will be the gateway to perdition." These words were actually inspired by earthquakes, not black holes and their singularities, but could a modern expert in general relativity and singularities have said it any better? But, what *is* a singularity?

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[105] By comparison, the density of a neutron star is on the order of a 'mere' 10^{16} grams/cm^3.

[106] Perhaps not so well-known, however, is that science fiction was there long before Wheeler. In one classic tale (M. Leinster, "Sidewise in Time," *Astounding Stories*, June 1934) a scientist explains at the end, "We know that gravity warps space . . . We can calculate the mass necessary to warp space so that it will completely close in completely . . . We know, for example, that if two gigantic star masses of certain mass were to combine . . . they would simply vanish. But they would not cease to exist. They would merely cease to exist in our space and time." And then, as another character sums it up, "Like crawling into a hole and pulling the hole in after you." The explicit use of the complete term *black hole* for a region of weird spacetime also appeared in science fiction before Wheeler (P. Worth, "Typewriter from the Future," *Amazing Stories*, February 1950).

As one theoretical physicist has dramatically written, "once gravity runs out of control, spacetime smashes itself out of existence at a singularity."[107] Or to quote Hawking, "A singularity is a place where the classical concepts of space and time break down as do all the known laws of physics."[108] One particular view of a singularity is that it is a place in spacetime that has infinite density and a gravitational field that is infinitely strong. The curvature of spacetime (more on curvature in Chap. 3) at this sort of singularity, sometimes called a *crushing* singularity, is also infinite. This is the sort of singularity believed to be at the center of non-rotating black holes. Historically, however, the occurrence of infinities in physical theories has been thought the red flag signaling that the theories have simply been extended too far, and their calculated results are nonsense.

Perhaps, then, singularities occur only in unrealistic physical applications of general relativity, and so it is only *perfectly* spherical collapsing stars that can end-up (on paper) as a black hole singularity. For a while physicists tried to establish that, but they were forced to abandon the attempt when it was shown that singularities are *unavoidable* and not just the result of idealistic assumptions.[109] This result worried many, and so the concern that general relativity was failing with its prediction of black holes and their singularities continued. In the case of a crushing singularity, perhaps all that meant is that once the collapsing star had fallen into a region even smaller than an electron, general relativity is no longer valid and the singularity is simply the 'math gone wild.' Einstein, himself, held that view. In his book *The Meaning of Relativity* (based on lectures he gave at Princeton in 1921), he wrote (concerning the use of the general theory to study the origin of the universe as a "big bang," which was a crushing singularity), "For large densities of field and matter, the field equations [of general relativity] and even the field variables which enter into them will have no real significance. One may not therefore assume the validity of the equations for very high density of field and matter, and one may not conclude that the 'beginning of the expansion' must mean a singularity in the mathematical sense."

Well, what does general relativity say about the singularity at the center of a black hole? To start, the theory says that, at a distance directly proportional to the mass of the collapsed object, a so-called *event horizon* will form. The event horizon is a surface in spacetime through which anything can fall into the hole, but through which nothing, not even a photon of light, can escape outward. The singularity at the black hole's center is therefore not visible to a remote observer (the singularity is said to be "clothed," and so not "naked"[110]). For all observers beyond the event horizon, the only visible properties of the hole are its mass (via its gravitational effects), its angular momentum (its spin rate), and its electric charge, and these properties are independent of the details of the pre-collapsed object (other than the requirement that electric charge and angular momentum are conserved).

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[107] P. C. W. Davies, *The Edge of Infinity*, Simon & Schuster 1981.

[108] S. Hawking, "Breakdown of Predictability in Gravitational Collapse," *Physical Review D*, November 15, 1976, pp. 2460–2473.

[109] S. W. Hawking and R. Penrose, "The Singularities of Gravitational Collapse and Cosmology," *Proceedings of the Royal Society A*, January 27, 1970, pp. 529–548. Ironically, one of the 'realistic' assumptions made in this paper, which appears to *force* singularities to exist, is that time travel is *impossible*!

There are actually several fundamentally different types of black holes. If the collapsed star forms a non-rotating, spherically symmetric, uncharged[111] object, then the result is called a *Schwarzchild* black hole, after the German astronomer Karl Schwarzchild (1873–1916) who found the first exact solutions to Einstein's general relativity field equations just months after Einstein published them.[112] Soon after that the Finn Gunnar Nordström and the German Heinrich Reissner independently found the solution to the field equations for the slightly more realistic non-rotating, *charged* black hole.[113] This is only slightly more realistic since it is highly unlikely a black hole wouldn't be spinning, as all observed stars are spinning and angular momentum is conserved during gravitational collapse. Another slightly more realistic solution, that of a *rotating*, uncharged black hole, was found by the New Zealand mathematician Roy Kerr in 1963, and this solution had a twist to it that at last explains why I am telling you all this—the singularity at the center of a Kerr black hole is not the *point* singularity of a non-rotating black hole but rather is a *ring* singularity. That is, there is a hole in the Kerr singularity through which matter can travel, without being destroyed, a hole that seems to act as a portal into other spacetime regions that may include past or *future* regions of spacetime. In other words, the ring singularity seems to be the entrance to a time machine.[114]

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[110] A naked singularity, with no event horizon behind which to hide, would be particularly bothersome to physicists who don't like the idea of the breakdown of physics being on full display. What they think they'd then see would be completely unpredictable. Whether such a situation can actually exist is still open to debate, but there *are* both analytical solutions and computer simulations (incorporating realistic equations of state on the pressure response of matter as it is compressed) that seem to allow it (as in the gravitational collapse of an *infinitely* long, non-rotating cylinder that appears to result in an axial, thread-like, naked singularity).

[111] The word *charge* means either electrical *or* magnetic charge, although from a practical point *charge* probably does mean just electrical, as the theoretically possible magnetic monopole has yet to be observed and, in any case, it is thought that black holes will not have a significant electrical charge.

[112] Even *Einstein* hadn't yet solved them, and he apparently thought they were too complicated to be solved; when he saw Schwarzchild's result, he was so impressed that Einstein wrote to say "I had not expected that the exact solution to the problem could be formulated. Your analytical treatment of the problem appears to me splendid."

[113] Two years later, the University of Pittsburgh physicist Ezra Newman finally solved the field equations for the realistic, general case of a rotating *and* charged black hole.

A discussion of singularities in general relativity is especially complicated for at least two reasons. First, there is more than one type, with *crushing* being just the (perhaps) most 'obvious.' Another type has no infinite curvature associated with it, but rather is a point in spacetime beyond which the worldline of a freely falling mass cannot be extended. Such a point is called a *geodesically incomplete* singularity, and it represents either an end to space or to time (in either case, that point is on the boundary or edge of spacetime). There are other types, as well—I've mentioned the naked singularity already—and the appearance of *any* of them is distinctly unsettling (recall Bergman's opening quote) to physicists. One that may be the most unsettling of all, however, is the *thunderbolt* singularity. This singularity propagates to infinity at the speed of light! As its discoverers dramatically put it, "It is not a naked singularity because you do not see it coming until it hits you and wipes you out."[115]

The other reason for a discussion of general relativity singularities being complicated is that they simply are not like the singularities of earlier theories. For example, in electromagnetic field theory spacetime is the *given background reference*; that is, a singularity in that theory is a point in spacetime where the *electromagnetic field* is undefined. In gravitational field theory, however, it is spacetime itself that is undefined, and there is no background 'something' in which spacetime is embedded to serve as a reference.[116]

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[114] You can find discussions on how this is imagined to work in two papers by R. Weingard: "General Relativity and the Conceivability of Time Travel," *Philosophy of Science*, June 1979, pp. 328–332, and "Some Philosophical Aspects of Black Holes," *Synthese*, September 1979, pp. 191–219. See also M. Calvani et al., "Time Machine and Geodesic Motion in Kerr Metric," *General Relativity and Gravitation*, February 1978, pp. 155–163. I won't pursue black hole time machines in this book, as it is not what modern physicists consider a plausible means of time travel (*How are you going to gain access to a black hole?!!!*) For how one science fiction writer *did* use the idea, however, see L. Niven, "Singularities Make Me Nervous," in *Stellar* 1 (J.-L. del Rey, editor), Ballantine 1974. Black holes *are* bizarre objects—nearly as bizarre as time travel—and it seems risky to try to understand one in terms of the other (recall Professor Challenger's observation!).

[115] S. W. Hawking and J. M. Stewart, "Naked and Thunderbolt Singularities in Black Hole Evaporation," *Nuclear Physics B*, July 1993, pp. 393–415. As bizarre as is the thunderbolt, it was anticipated in science fiction by more than half a century. In the story "The Tides of Time" by R. M. Williams (*Thrilling Wonder Stories*, April 1940), the universe is collapsing at faster than the speed of light. Human scientists learn this when fleeing aliens stop their faster-than-light space ships to warn them. One of the human characters then looks out into the night sky and, in words that sound like those of Hawking and Stewart, "There would be no warning, for the rolling tide was traveling faster than light . . . It would come faster than the flicker of an eye. No one would see it come. One instant the world you knew would be around you. The next instant, there would be nothing. You would not even have time to know what had happened. Death, faster than the lightning flash!" This story may have been inspired by a tale published decades earlier, by the Canadian writer Frank Lillie Pollock (1876–1957). In his "Finis" (*The Argosy*, June 1906), written long before the concept of a super-nova, the light of a huge, distant star finally arrives to cook Earth into oblivion.

One early suggestion on how to avoid the problem of the crushing singularity of the non-rotating black hole (which is, as mentioned earlier, not a realistic model for the gravitational collapse of a rotating star) is that the collapse may stop short of the singularity. That is, the collapsing body might instead rebound. This 'bounce' would occur after the star was inside its event horizon, so an external observer would not see the later expansion, an expansion imagined to be through the event horizon *but into a different region of spacetime*.[117] When Novikov's work was generalized the following year, the authors clearly had a hard time believing this dramatic imagery, despite their own mathematics, concluding with "It then appears necessary to believe in the existence of other [regions of the universe, including the past and the future] which will accommodate the re-expansion. This seems at least as fantastic as the alternative of [a point singularity].".[118]

In 1974 Hawking announced an astonishing partial connection of quantum mechanics with general relativity's black holes. He showed that, contrary to the usual image of black holes as being one-way trap doors to . . .?, black holes actually *must* radiate energy.[119] His analysis, which stunned physicists by its beautifully simple arguments, invokes the famous *uncertainty principle*, one of the corner stones of quantum mechanics. Hawking himself found the result "greatly surprising." He also cautioned (in his 1975 paper) that the following picturesque imagery is "heuristic only and should not be taken too literally," but it has now been in physics for over 40 years and appears to be here to stay.

The uncertainty principle states that there are certain pairs of variables associated with particles, variables that cannot be precisely measured at the same time. Time and energy form such a pair because a non-zero time interval is required to measure a particle's energy, and the product of the uncertainty in both the time interval (Δt) and the energy (ΔE) must be at least as large as a certain non-zero constant. That is, if $\hbar$ is Planck's constant, then $\Delta E \Delta t \sim \hbar$. This allows the process of virtual particle creation, the appearance of particle/anti-particle pairs just outside the event horizon of a black hole. The uncertainty in the energy is what gives the combined mass of the particles in a pair; this uncertainty in the energy is the quantum fluctuation energy of the intense gravity field of the hole. The only constraint is that the energy be returned to the field, via mutual annihilation of the matter/anti-matter pair within the time uncertainty dictated by the uncertainty principle.[120]

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[116] See, for example, R. Geroch, "What Is a Singularity in General Relativity?" *Annals of Physics*, July 1968, pp. 526–540.

[117] See, for example, I. Novikov, "Change of Relativistic Collapse Into Anticollapse and Kinematics of a Charged Sphere," *JETP Letters*, March 1, 1966, pp. 142–144, and V. P. Frolov, *et al.*, "Through a Black Hole Into a New Universe?" *Physics Letters*, January 12, 1989, pp. 272–276. Igor Novikov is a Russian physicist at the University of Copenhagen, and he will appear later in the book when we get to the paradoxes of time travel to the past.

[118] V. De La Cruze and W. Israel, "Gravitational Bounce," *Nuovo Cimento A*, October 1, 1967, pp. 744–760.

[119] S. Hawking, "Black Hole Explosions?" *Nature*, March 1, 1974, pp. 30–31, and "Particle Creation by Black Holes," *Communications in Mathematical Physics*, 1975, pp. 199–220.

As Hawking showed, this time interval, although incredibly short, is still long enough for the two virtual particles to separate before annihilation, one falling into the hole and the other escaping. This would happen, for example, if the particle/anti-particle pair is an electron/positron pair, and so a negatively/positively charged black hole would tend to attract the positron/electron and repel the other particle (either way, driving the charge of the hole towards zero). (Hawking then later suggested[121] that the particle *entering* the hole could be thought of as an *emitted* particle traveling backward in time, an idea that can be traced back decades, to John Wheeler—I'll return to this idea in just a moment.) By this incredible quantum process, then, the black holes of general relativity slowly *evaporate* (!) as they glow with what is now called *Hawking radiation*. That is, black holes appear to be hot bodies. But *hot* is relative, as a black hole with the mass of the Sun would have a temperature of just sixty *nano*-degrees Kelvin above absolute zero, and it would take 10^{66} years (a stupendously enormous time compared to the age of the universe) to completely evaporate.

Indeed, one physicist had already mused that the *entire universe* might have been created by a similar quantum process, *out of nothing*, a so-called *vacuum fluctuation*.[122] The explanation for why the universe doesn't then disappear—and very quickly, too, because the energy for all the mass in the newly created universe is quite large (that is, ΔE is *really big* and so Δt must be *really small*)—is that the *negative* gravitational potential energy of all that newly created matter would cancel the positive mass-energy, and so ΔE is actually *quite small* and so Δt is then *quite large*. To perhaps show he wasn't quite convinced by all that, himself, Tryon whimsically wrote "I offer the modest proposal that our Universe is simply one of those things which happen from time to time."

As a final comment on the suggestion by Hawking of a connection between virtual particles at a black hole event horizon and backwards time travel, the idea originated (as I said before) with Wheeler, in 1941.[123] In an astonishing coincidence, even as Wheeler was telling his student Richard Feynman about this, a science fiction writer was also identifying anti-matter with backward time traveling 'normal' matter.[124] Later, the Polish science fiction writer Stanislaw Lem (1921–2006) took this idea, combined it with the quantum concept of energy fluctuation, and came up with one of his typically outrageous (and typically hilarious) ideas: shooting a single positron out of an accelerator back to the very beginning of time. His story character called this fantastic machine the "Chronocannon" and claimed that's what started the universe.[125]

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[120] The uncertainty principle has long been used in time travel science fiction. In one story, for example, a character is transported from 1950 to 2634 by a scientist of the future. Once there, this character decides he'd like to remain permanently in the 27th century. He is told that he can't because he is like an atom excited into an elevated energy state and, just as quantum mechanics says that eventually an electron in such a state will drop back down into a lower energy state, so do the "laws of time travel" require that he drop back to his normal time. How long can he remain in future, he is told, "depends on the mass [energy] of his body and the number of years the mass [energy] is displaced." That is simply the uncertainty principle. See W. Bade, "Ambition," *Galaxy Science Fiction*, October 1951.

[121] S. Hawking, "The Quantum Mechanics of Black Holes," *Scientific American*, January 1977.

[122] E. P. Tryon, "Is the Universe a Vacuum Fluctuation?" *Nature*, December 14, 1973, pp. 396–397.

Soon after Lem, a philosopher used a variant of this idea, in which the Big Bang creation of the universe was caused by a time traveler from the future who saw a need—his own existence—to generate the Big Bang. This leads to philosophical speculations on the cosmological implications of God as a time traveler.[126] Two recent physicists have taken this one step further by suggesting that the universe, via time travel, may have caused itself! As they put it, "the laws of physics may allow the Universe to be its own mother."[127]

The modern hope is that quantum mechanics (as in quantum gravity) will save physics from the horror of general relativity's singularities. This was the view of John Wheeler and, as the man who named black holes, his view is important to consider. General relativity is a classical, *smooth* theory that is fundamentally continuous, while 'our' universe appears to be a quantum one. So, perhaps, general relativity's prediction of singularities may be just an artifact without physical reality in the 'real world.' Wheeler's position was based on the quantum fluctuations of gravity fields, which are related to the uncertainties inherent in our knowledge of the values of physical entities. Such fluctuations are vanishingly small in systems of everyday size, but they increase dramatically at very tiny distances that are twenty orders of magnitude smaller than the nucleus of an atom. In the microscopic region of spacetime that the matter forming a black hole is falling into, these fluctuations might conceivably result in effects that preclude the formation of a singularity. Agreeing were two physicists who asserted that, even without a detailed knowledge of quantum gravity, quantum effects "would smash the idealized interior geometry"

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[123] See Richard Feynman's Nobel lecture, reproduced in *Science*, August 12, 1966, pp. 699–708, where he recounts Wheeler's 'proof' for why every electron in the universe has *exactly* the same charge ('there is only *one* electron, weaving its way back-and-forth in time, with positrons being the electron when traveling backward-in-time').

[124] Will Stewart, "Minus Sign," *Astounding Science Fiction*, November 1942. 'Will Stewart' was a pen-name for John Stewart Williamson (1908–2006).

[125] S. Lem, "The Eighteenth Voyage," in *The Star Diaries*, Seabury Press 1976.

[126] G. Fulmer, "Cosmological Implications of Time Travel," in *The Intersection of Science Fiction and Philosophy* (R. E. Meyers, editor), Greenwood Press 1983. Isaac Asimov used a similar idea in his story "The Instability," *The London Observer*, January 1, 1989.

[127] J. R. Gott and L.-X. Li, "Can the Universe Create Itself?" *Physical Review D*, 1998, 023,501.

[that is, the ring singularity] of a rotating, charged black hole, thereby eliminating any possibility of using such a hole for time travel.[128]

And finally, to generalize beyond black holes to the hoped-for pay-off of the coming of quantum gravity in banishing singularities altogether, one recent study has examined how non-crushing singularities (that is, ones of the geodesically incomplete type) *are* apparently "healed" (the authors' term) by quantum effects.[129] With the eventual development of quantum gravity, perhaps all the singularities of general relativity will vanish while leaving the CTCs/CTLs intact, thereby removing a form of doubt in the theory's apparent support for time travel to the past. It may be a long time coming, however: as the University of Sydney philosopher of science Dean Rickles recently (2014) wrote in his book *A Brief History of String Theory*, "quantum gravity is in many ways . . . a revolution still waiting to happen."

1.6 Tipler's Time Machine

> "In short, general relativity suggests that if we construct a sufficiently large rotating cylinder, we create a time machine."[130]

The time traveling property of the ring singularity in a rotating black hole once made it a favorite of science fiction writers, as in Joe Haldeman's classic 1974 novel *The Forever War* (in which the term used is not *black hole*, but *collapsar*, which is a nicely descriptive word in its own right). A major difficulty with this approach, however, as I mentioned in the previous section (note 114), is that of 'getting one's hands on' (so to speak) a black hole! So, is there any other 'time machine' that is consistent with general relativity? Yes, there is.

In 1974 a young physics graduate student at the University of Maryland, Frank Tipler, caused a bit of a stir when he published what seemed to be quite specific construction details for a time machine. Indeed, the final sentence (the above quotation) of his paper couldn't be clearer. Nobody had ever before made such a statement in a respectable physics journal and, best of all, there were no apparent spacetime singularities involved. However, a close look at Tipler's analysis does turn up some difficulties.

What Tipler had actually done was to show that if one had an *infinitely long*, *very dense* cylinder rotating with a surface speed of at least half the speed of light (the rotation speed is such that the outward centrifugal forces are balanced by the inward gravitational attraction of the cylinder), then this allowed the formation of closed timelike curves around the cylinder. This means that by orbiting the surface of such a fantastic cylinder, one could travel through time into the past—but not to earlier than the moment of the creation of the cylinder.

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[128] N. D. Birrell and P. C. W. Davies, "On Falling Through a Black Hole Into Another Universe," *Nature*, March 2, 1978, pp. 35–37.

[129] T. M. Helliwell and D. A. Konkowski, "Quantum Singularities in Spherically Symmetric, Conformally Static Spacetimes," *Physical Review D*, May 13, 2013, 10404.

[130] F. J. Tipler, "Rotating Cylinders and the Possibility of Global Causality Violation,' *Physical Review D*, April 15, 1974, pp. 2203–2206.

This last point is a very important one, as it does avoid one particularly odd paradox (called a *bootstrap*): a traveler going backwards in time to tell the inventor of a time machine (perhaps an earlier version of the time traveler himself) how to build the time machine. You can find this idea in early science fiction,[131] and a minor variant of it was amusingly illustrated in the 1985 film *Star Trek IV: The Voyage Home* (when you next watch the movie, ask yourself who actually invented "transparent aluminum"?) Bootstrap paradoxes are quite mysterious and still befuddle physicists and philosophers. Science fiction writers, on the other hand, love bootstraps as great story gimmicks.

Tipler's cylinder would also enable a time traveler to return to her original time, to go "back to the future," by orbiting the cylinder in the reverse direction (but no further into the future than when the cylinder ceases to exist). Later in the book I'll show you a simple illustration—based on a similar one in Tipler's PhD dissertation, published in 1976—of how the cylinder works as a time machine. No one, in fact, disputes any of this. It *is* true. On paper.

But Tipler did *not* prove that a time traveling property holds for cylinders of even very long but *finite* length, which are the only kind we could actually build from a finite amount of matter; he merely suggested that such might be the case. This suggestion does seem reasonable, because if the time traveler orbits at the midpoint of the cylinder, near the surface, then the gravitational end-effects of sufficiently remote ends of the cylinder would, you'd think, become negligible. Similar mathematical approximations are routinely made, for example, when calculating the electrical effects of charged cylinders of finite length. But as one physicist has warned, "Extrapolation from cylindrical symmetry to reality is very dangerous, since spacetime is not even asymptotically flat around an infinite cylinder."[132] The issue of whether a spinning, finite-length cylinder can create closed, timelike curves is still open: to quote another physicist, "[In] some respects an infinite cylinder may be a model for a long finite one, and the possibility cannot be dismissed that a time machine might be associated with a long, but finite rotating system."[133]

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[131] See, for example, C. Cloukey, "Paradox," *Amazing Stories Quarterly*, Summer 1929. Later in the book I'll discuss even earlier literary occurrences of bootstraps (that is, of *information* on closed loops in time).

[132] K. S. Thorne, "Nonspherical Gravitational Collapse: Does It Produce Black Holes?" *Comments on Astrophysics and Space Physics*, September–October 1970, pp. 191–196. What "asymptotically flat" means will be discussed in Chap. 3.

[133] W. B. Bonner, "The Rigidly Rotating Relativistic Dust Cylinder," *Journal of Physics A*, June 1980, pp. 2121–2132. Tipler was not the first to study rotating cylinders in the context of general relativity. Such cylinders had been around for decades, going back to 1932. A good reference is M. A. Mashkour, "An Exterior Solution of the Einstein Field Equations for a Rotating Infinite Cylinder," *International Journal of Theoretical Physics*, October 1976, pp. 717–721. The first-analyzed configuration of matter that generates closed timelike lines, solved in all its general relativistic detail, was the infinite rotating cylinder studied by W. J. van Stockum,

There is, however, another potential problem besides the length of the cylinder. There is a strong likelihood that a Tipler cylinder under construction would collapse under its own internal gravitational pressure before it could be made nearly long enough to be even ‘approximately infinite.’ That is, such a finite-length cylinder might crush itself along its long axis into a pancake-shaped blob, something like what happens to a long cylinder of jello stood on-end. An ordinary can of jellied cranberry sauce will also sometimes display this curious behavior.

The required rotational speed raises yet another concern, as well. We are not talking about cylinders the diameter of a pencil, or even of a large water pipe. Recall that for a given surface speed, the larger the diameter the less the centrifugal acceleration at the surface. It is easy to calculate that even a huge cylinder 10 kilometers in radius, with a surface speed of half the speed of light, would have a surface acceleration *hundreds of billions* of times the acceleration of Earth’s surface gravity. No known form of ordinary matter could spin that fast and not explosively disintegrate; Tipler has estimated that the required density for a time machine cylinder would be 40 to 80 orders of magnitude above that of nuclear matter. (In a masterful understatement, Tipler calls this astonishing stuff “unknown material.”) Made from such incredibly superdense stuff, even a finite cylinder would still be as massive as the Sun but many trillions of times smaller. Showing no lack of imagination, Tipler has suggested the possibility of speeding up the rotation of an existing star as an alternative approach to that of building a cylinder.[134] That, of course, would be project for a far-future society, with a *very* advanced technology.

All of these concerns were discouraging to Tipler (who could blame him?), and his pessimism about the actual likelihood of achieving time travel via one of his cylinders is shown by the words he used to open his 1977 paper (note 134): “Any attempt to evolve a time machine] from [normal] matter will cause singularities to form in spacetime. Thus, if by the word ‘manufacture’ we mean ‘construct using only ordinary materials *everywhere*,’ then the theorems of this paper will conclusively demonstrate that a [time machine] cannot be manufactured.” But not all physicists agreed.

“The Gravitational Field of a Distribution of Particles Rotating About an Axis of Symmetry,” *Proceedings of the Royal Society of Edinburgh*, 1939, pp. 135–154. This is particularly interesting because, while Van Stockum didn’t spot the presence of closed timelike lines in his solution, his cylinder is made entirely from *ordinary* matter.

[134] F. Tipler, “Singularities and Causality Violation,” *Annals of Physics*, September 1977, pp. 1–36. See also his earlier paper “Causality Violation in Asymptotically Flat Space-Times,” *Physical Review Letters*, October 1976, pp. 879–882, where he wrote “There are many solutions to the Einstein equations [of general relativity] which possess causal anomalies in the form of closed timelike lines (CTL). It is of interest to discover if our Universe could have such lines. In particular, if the Universe does not at present contain such lines, is it possible for human beings to manipulate matter so as to create them? [That is, to construct a time machine.] I shall show in this paper that it is *not* [Tipler’s emphasis] possible to manufacture a CTL-containing region without the formation of naked singularities, *provided normal matter is used in the construction attempt* [my emphasis].”

Years after Tipler wrote, one physicist replied[135] with *two* pointed observations. First, Tipler's theorems apply only to singularities of the incomplete kind, not to the more convincingly fatal crushing (or curvature) type. Second, to quote Ori at length, "The standard interpretation of Tipler's theorems is to say that the appearance of a singularity in a given [spacetime] model indicates that this model is unrealistic and cannot be physically realized. Even for future-generation engineers it will probably be impossible to use 'singular matter' for the construction of their time machine. However, the theory of black holes provides an obvious counterexample to this interpretation. For, by applying this interpretation to the black hole singularity theorems one could conclude that black holes can never form." Yet black holes with several times the mass of the Sun *have* been detected in orbit about certain stars, and at least one supermassive black hole (with a mass equal to more than three *billion* Suns) has been detected at the core of galaxy M87. Indeed, it is now believed that the center of *every* sufficiently massive galaxy in the universe is home to a black hole (the one at the center of our own galaxy, the Milky Way, has a mass about three million times that of the Sun).

Even less concerned about singularities interfering with time travel were two other physicists who wrote[136] "It would seem that a successful attempt to manufacture [a time machine] within a finite region of space will be accompanied by the creation of a singularity . . . This does not immediately imply, however, that with a sufficiently advanced technology one could not make a time machine. *There is no reason to suspect spacetime singularities could not in principle be created through deliberate human action* [my emphasis]."

These optimistic views were, of course, welcome news for science fiction writers, who had been using Tipler cylinders almost from when Tipler first wrote of them. Indeed, Larry Niven liked them well enough to 'lift' the very title of Tipler's paper (note 130) for the title of a short time travel story for inclusion in his 1979 collection *Convergent Series*. Just one year after Tipler's paper appeared, Poul Anderson featured the cylinders in his 1978 novel *The Avatar*, where they are called "T-machines": one can imagine the "T" stands for Time or Tipler or even both. Anderson's story describes the cylinders as having been scattered about the universe by ancient, altruistic aliens called "the Others," for the use by any who come across them and who have the wits to decipher *how* to use them. Anderson recognized the obvious problems with Tipler cylinder construction, and so has one of his characters say of T-machines, "I have no doubt whatsoever that [they are] the product of a technology further advanced from ours than ours is from the Stone Age."

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[135] A. Ori, "Must Time-Machine Construction Violate the Weak Energy Condition?" *Physical Review Letters*, October 1993, pp. 2517–2520. The weak energy condition is the seemingly 'obvious' requirement that the observed local mass-energy density should never be negative. Quantum mechanics predicts (and it has been experimentally confirmed) that there *are* exceptions.

[136] M. P. Headrick and J. R. Gott, "(2+1)-Dimensional Spacetimes Containing Closed Timelike Curves," *Physical Review D*, December 15, 1994, pp. 7244–7259. The '(2+1)' refers to a toy spacetime with just two spatial dimensions and one time dimension.

Even before (actually *long* before) Tipler's paper, science fiction had foreshadowed his physics. Oliver Saari (1918–2000), for example, had incorporated both superdense matter and the rule of 'no time travel before the creation of a time machine' in a story written *40 years* earlier.[137] Saari's fictional time machine works by warping spacetime via a plate of superdense matter. (An even earlier tale[138] had also used superdense matter, but it was badly flawed by its hocus-pocus invoking of 'rays' emitted by the newly discovered element of *tempium*.) The 'no time travel before the creation of a time machine' rule is the basis for an obvious response to Hawking's Chronology Protection Conjecture, discussed earlier in this chapter, and it was so used by one physicist to rebut the Conjecture: as he wrote,[139]

(1) time machines, if possible, must have the property of not being able to travel back to before their creation, and
(2) no time machine has yet been created.

The absence of time travelers amongst us, therefore, provides no insight, one way or the other, on the eventually possibility of constructing a time machine.

1.7 For Further Discussion

Observations of the background microwave radiation that permeates the universe is strong experimental evidence for the Big Bang, the singularity thought to be the origin of the universe. This singularity is not shielded from us by an event horizon, and so is not a naked singularity (note 110), which means it is potentially visible. In 1969 the English theoretician Roger Penrose, however, proposed a metaphysical 'law' called the *cosmic censorship principle*, which asserts that naked singularities are impossible. Discuss the obvious tension between Penrose's principle and the Big Bang singularity. (See, for example, P. Kosso, "Spacetime Horizons and Unobservability," *Studies in History and Philosophy of Science*, June 1988, pp. 161–173.)

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[137] O. Saari, "The Time Bender," *Amazing Stories*, August 1937. In this story we read that the time traveler "could not travel into the past for the plate had to exist in all ages traveled, and it had not existed before he made it."

[138] E. L. Rementer, "The Time Deflector," *Amazing Stories*, December 1929.

[139] K. S. Thorne, "Do the Laws of Physics Permit Closed Timelike Curves?" *Annals of the New York Academy of Science*, August 10, 1991, pp. 182–193. Science fiction writer Damon Knight (1922–2001) anticipated Thorne's rebuttal in his story "Azimuth 1, 2, 3, … ," *Isaac Asimov's Science Fiction Magazine*, June 1982.

In the text I mention the “transparent aluminum” bootstrap paradox that appears in the 1985 movie *Star Trek IV*. Even earlier, a movie bootstrap appeared in 1980 film *The Final Countdown*. There, the designer of a modern naval warship that temporarily time travels back to the Pearl Harbor of December 6, 1941, turns out to be a crew member who was (is) accidently left behind in the past when the ship returns to the present. In the past he *will be* able to design the ship because he already knows how it *was* designed—by himself! In the more recent 2014 film *Interstellar*, a wormhole near Saturn is discovered. By the end of the film we learn that it was put there by future humans, humans who exist because their ancestors (us!) were saved from a planet-wide ecological disaster when they used the wormhole to discover new worlds in far-flung regions of the universe. Decide whether or not the existence of the wormhole represents a bootstrap paradox, and defend your position.

One difficulty in using a black hole as a means of traveling from one region of the universe to another (with time travel as a special case) is simply getting to a black hole in the first place. The nearest one to Earth, as far as is known, is many light years distant. One reason for this may be an anthropic one (see note 13 in the “Introduction”). That is, a planet near a rotating black hole would either be eventually swallowed whole, or have its surface blasted by a firestorm of radiation produced by in-falling matter. In any case, no intelligent life able to recognize time travel would ever evolve on such a planet in the first place. That is, we are here to wonder about the absence of near-by black holes precisely *because* we aren’t near a black hole. The lack of black holes near Earth is addressed in Joe Haldeman’s ‘Earth vs. Aliens’ novel, *The Forever War*, by using the time dilation effect of special relativity (discussed in Chap. 3) that allows long travel distances to be covered in a reasonable time (as measured by clocks in rocket ships traveling near the speed of light). Still, while the travel time to reach a black hole distant from Earth by many light years may only be 6 months of ship time, back on Earth many *years* may pass. Once at the black hole the ship enters it and instantly ‘jumps’ to a vastly different region of the universe. In the novel, no time travel after the time dilation experienced in just getting to the black hole occurs, but Haldeman uses that to great effect as follows. Before entering into combat, Earth’s soldiers are told that when they exit the hole into a new region of the universe, they may encounter alien warships equipped with *their* latest technology, technology that could be far in advance of the Earth warship’s technology

(continued)

which dates from Earth's *past*. That is, humans will be fighting against technology that dates from the Earth warship's *future*. To quote the novel, "Relativity traps us in the enemy's past; relativity brings them from our future." Explain this.

In one of the quatrains of the *Rubaiyat*, the eleventh century Persian poet-philosopher Omar Khayyam wrote

> *The Moving Finger writes; and having writ,*
> *Moves on; nor all your Piety nor Wit*
> *Shall lure it back to cancel half a Line,*
> *Nor all your Tears wash out a Word of it.*

Nearly a 1000 years later the German theoretical physicist Hermann Weyl (1885–1955), a colleague of both Einstein and Gödel at the Institute for Advanced Study in Princeton, NJ, wrote the following in his book *Space-Time-Matter* (published in 1921, three decades *before* Gödel's 1949 time travel paper):

> *It is possible to experience events now that will in part be an effect of my possible future resolves and actions. Moreover, it is not impossible for a world-line (in particular, that of my body), although it has a time-like* [see the index] *direction at every point, to return to the neighborhood of a point which it has already once passed through. The result would be a spectral image of the world more fearful than anything the weird fantasy of E. T. A. Hoffmann* [an early nineteenth-century German writer of the eccentric] *has ever conjured up. In actual fact the very considerable fluctuations of the* [components of the metric tensor, to be discussed in Chap. 3] *that would be necessary to produce this effect do not occur in the region of the world in which we live . . . Although paradoxes of this kind appear, nowhere do we find any real contradictions to the facts directly presented to us in experience.*
> Compare these two views and, in particular, discuss what each says about the idea of 'reliving the past.'

In the opening section of this book ("Some First Words") I mention how now and then science fiction has anticipated physics. One interesting example of this occurs in a story of a time traveler *almost* meeting himself, a story published 2 years *before* Gödel's 1949 time travel paper in which he suggests just such a possibility. The story opens with a man on a ship spotting the signal fire of a castaway on a Pacific island, as well as the tiny, distant figure

(continued)

of a man waving and jumping about. While sailing in to help, the ship hits a mine left over from the war, and the would-be-rescuer becomes a castaway, too. After swimming to the island, he can find no trace of who built the fire, although there are footprints all about in the sand. Exploring the island, he finds the remains of a crashed interstellar spaceship (!), powered by a drive unit based on ‘temporal precession.’ The man, curious, turns the drive on and thus sends himself backward in time by one day. He then spots a ship on the horizon, builds a fire, waves and jumps about, then *recognizes the ship as his own* . . .. And so the loop nearly but not quite closes. The man, apparently, rushes off into the jungle, terror-stricken at the thought of meeting himself. (You can find this tale by A. B. Chandler (1912–1984), “Castaway,” in the November 1947 issue of *Weird Tales*, a publisher more of fantastic, supernatural, and horror stories than of science fiction. Perhaps easier to locate would be an anthology in which it has been reprinted: *Science-Fiction Adventures in Dimension* (G. Conklin, editor), Vanguard 1953.)
Speculate on what happens to the man. In particular, does Wells’ own criticism of *The Time Machine*, concerning “vain repetitions” of time travelers, apply here (see the “Introduction” again)?

A philosopher has argued against the force of Hawking’s chronology protection conjecture as follows: “There is an old argument to the effect that while backward time travel may be *possible*, it will never actually occur—for if it were going to occur, we would *already* have encountered the time travellers involved, whereas in fact we have done no such thing. . . . But consider an isolated society living in a remote part of the world. Some members of this society are engaged in a long-running debate concerning the possibility of human flight. Were a 747 to pass overhead, would the debaters necessarily recognize it as containing flying humans? The answer to their question might have been staring them in the face for years, without them realizing.“ (See Nicholas J. J. Smith, “Bananas Enough for Time Travel?” *British Journal for the Philosophy of Science*, September 1997, pp. 363–389, in particular note 3 on p. 364. The perhaps curious appearance of ‘bananas’ in the title of this paper will become clear when, in Chap. 4, we delve into the details of the famous grandfather paradox.) How would *you* answer Smith’s question? Do you think it is plausible, as Smith implies, that we could right now be observing (without realizing it) effects in the present-day world that are the result of time travelers amongst us? What sort of effect (s) might raise this suspicion in *your* mind?

As discussed in Sect. 1.6, Tipler expressed some pessimism in his 1977 paper (note 134) about the possibility of actually constructing a time machine from a rotating cylinder. But that doesn't mean he didn't have some doubts, too, about theoretical 'proofs' of something being impossible. In his 1976 PhD dissertation, for example, he included an amusing reference to Simon Newcomb (a real-life mathematician that Wells' Time Traveller cites in *The Time Machine*—see note 102 in Chap. 2) who published mathematical 'proofs' that it would be impossible with known science to build a "practicable machine by which men shall fly long distances through the air." Why do you think Tipler did that? You can read more about Newcomb's 'proofs' in "Is the Airship Coming," *McClure's Magazine* (September 1901, pp. 432–435) and "The Outlook for the Flying Machine," *The Independent* (October 22, 1903, pp. 2508–2512).

In his autobiography, the Princeton physicist John Wheeler had this to say about time: "The smooth flow of time—or our smooth passage through it—is an illusion that is shattered when we . . . ask about time at the moment of the Big Bang, at a moment of gravitational collapse, at the moment of the Big Crunch. Students and others often ask what existed before the Big Bang. To say that we don't know is not to say enough. Even to say that we have no *way* of knowing is not enough. We really have to say that space and time came into existence, along with matter and energy and the laws of physics, at the moment of the Big Bang. If the universe expands to a maximum size, starts contracting, and eventually collapses to a fiery death—a fate that seems likely to me and to some other theorists . . . then time and space, too, will end in this Big Crunch. I can reach no conclusion other than this: there was no 'before' before the Big Bang, and there will be 'after' after the Big Crunch." (See J. A. Wheeler, *Geons, Black Holes, and Quantum Foam: a life in physics*, W. W. Norton 1998, pp. 349–350.) That is, when the Big Bang singularity occurred, time was *created*, and if the universe should collapse in the far future in a Big Crunch, time will be *annihilated*. This is a view of *nothingness* that transcends even that of the grave. Sharing Wheeler's dark view of the ultimate fate of reality, but instead giving the *victory t*o time (rather than its annihilation), was the Irish writer Jonathan Swift (1667–1745) in his poem *Riddles* (circa 1724): "Ever eating, never cloying/All-devouring, all destroying/Never finding full repast/ Till I eat the world at last." How do you think theologians would respond to Wheeler and Swift?

The American philosopher Roy Sorenson was cited in note 13 in the discussion of the difficulties a time travel would have in convincing skeptics that he *had really* time traveled (short of bringing a fresh dinosaur egg back and hatching it!). This question was treated in early pulp science fiction ("The Sands of Time," see note 43 in "Some First Words") as follows: The time traveler takes a sealed box of pure radium (with his name written on the inside of the lid) into the distant past, and buries it in a secure location. Upon returning to the present he unearths the box; testing of the contents will show that some of the radium has radioactively decayed to lead. Indeed, the amount of decay would be a direct measure of how far back into the past the box had been transported. This issue was later elaborated on by the English philosopher Alasdair Richmond in his paper "Time Travel, Parahistory and the Past Artefact Dilemma," *Philosophy*, July 2010, pp. 369–373. There he imagined two possible ways a time travelling Shakespearean scholar might attempt to convince skeptical colleagues that he had discovered a draft of *Hamlet* dating from the year 1589 (10 years *before* the earliest accepted date of its composition by Shakespeare). The first attempt is to simply bring that draft directly back with him in the time machine, from 1589 to the present. Then, of course, many of the inherent clues as to the draft's authenticity, such as chemical composition of the ink, the weave of the paper, and orthography (the style of writing in 1589) would be consistent with the time traveler's claim, but other clues would *not*—the *age* of the paper and of the ink, for example, would be taken as evidence fatal to the claim, as they would not be nearly 430 years old. They would appear, in fact, to be practically new! The draft would, therefore, be dismissed as simply a clever forgery. The second attempt would try to get around this problem, as follows. After locating the draft in 1589, the time traveler *doesn't* bring it back to the present, but rather stashes it away in a secret hiding place. Then, once back in the present, he takes his colleagues to the secret hiding place and, with a flourish, reveals the draft which now *is* nearly 430 years old. Much to the time traveler's frustration, however, his colleagues still reject his time travel claim, this time saying he must have simply found the draft in the 'usual' way (under the floorboards in somebody's attic, for example), and is just pretending to have found it via time travel. Can you think of a way, using the *Hamlet* draft, the time traveler might be able to convince his skeptical colleagues?

The fan I quoted in “Some First Words,” who wrote to *Astounding Stories* in 1931 to express his unhappiness with the appearance of women in that magazine’s stories, was quite clear about his concerns—although, given the times, he carefully avoided any direct mention of sex. A modern, highly successful *female* writer of science fiction, Anne McCaffrey (1926–2011), didn’t shy away from that, however, when she wrote the following in a hilariously funny essay: “Prior to the ‘60s, stories with any sort of love interest were very rare. True, it was implied in many stories of the ‘30s and ‘40s that the guy married the girl whom he had rescued/encountered/discovered during the course of his adventures. But no real pulse-pounding, tender, gut-reacting scenes. The girl was still a ‘thing’ to be used to perpetuate the hero’s magnificent chromosomes. Or perhaps to prove that the guy wasn’t . . . I mean, all those men locked away on a spaceship for months/years at a time. I mean . . . and you know what I mean even if I couldn’t mention it in the sf of the ‘30s and ‘40s.” (See Anne McCaffrey, “Hitch Your Dragon to a Star: Romance and Glamour in Science Fiction,” in *Science Fiction, Today and Tomorrow*, R. Bretnor, editor, Harper & Row 1974, pp. 278–292.) Modern time travel science fiction has shown a huge change (for the better) on this score. Discuss, for example, the emotional power of a love story between a couple separated in time, as depicted in the 1975 novel *Bid Time Return* by Richard Matheson (made into the 1980 film *Somewhere in Time*). How do you think the 1931 fan would have reacted to Matheson’s story? (Indeed, if that fan was a teenager—or even a few years older—in 1931, then 44 years later he would have been, at most, in his mid-60s and might well *have* read the novel.)

In the 2014 film *Interstellar*, a space probe dives into a black hole, gets a glimpse of the hole’s singularity, measures some unspecified quantum effects, and then sends the measurements back to Earth (via the fifth dimension) as a signal in the form of spasmodic Morse code twitches of the second-hand on somebody’s watch. This all leads (it is hinted) to a theory of quantum gravity. If you saw the second-hand on *your* watch suddenly begin to spasmodically twitch, would you then immediately think

(a) that a Morse code message was coming to you via the fifth dimension bearing the secrets of quantum gravity?

or

(b) that your watch needs a new battery?

(continued)

or

(c) something else?

Vigorously defend your answer.

William Grey, a philosopher at The University of Queensland, pointed out numerous conceptual difficulties with the idea of time travel in his paper "Troubles with Time Travel," *Philosophy*, January 1999, pp. 55–70. That paper quickly prompted a rebuttal from the philosopher Phil Dowe (at the University of Tasmania), who replied a year later with the paper "The Case for Time Travel," *Philosophy*, July 2000, pp. 441–451. We'll eventually take up all the issues discussed in those two papers but, for now, read both papers and summarize their respective arguments. Do you feel one of the writers won the day (for you, anyway)?

Chapter 2
Philosophical Space and Time

> *"I do not believe that there are any longer any philosophical problems about Time; there is only the physical problem of determining the exact physical geometry of the four-dimensional continuum that we inhabit."*[1]

2.1 Time: What Is It, and Is It Real?

> "Time is generally thought to be one of the more mysterious ingredients of the Universe."[2]

Before going any further with time *travel*, it will be well worth the effort to take a closer look at time itself, the 'stuff' or 'thing' or . . . ? that we are interested in traveling 'through' or 'around' or 'across' or . . . ? Oddly enough, I'll start with religion, as philosophical theologians had identified time as something unusual long before Newton's words on time in his *Principia* that I mentioned in the Introduction, and many thousands of years before science fiction writers and their time travel stories.

We can, in fact, trace the religious interest in time back at least sixteen centuries to the Christian theologian St. Augustine and his *Confessions* (in which he famously admitted "What, then, is time? I know well enough what it is, provided that nobody asks me: but if I am asked what it is and try to explain, I am baffled."). Certainly the seventeenth century Spanish Jesuit Juan Eusebius Nieremberg caught the spirit of wonder that time holds for the devout when he wrote, in his *Of Temperance and Patience*, that "*Time* is a sacred thing; it flows from Heaven . . . It is an emanation from that place, where eternity springs . . . It is a *clue* cast down from Heaven to guide us . . . It has some assimilation to Divinity."

Going outside Christianity, we can easily find other equally strong reactions to the mystery of time. From Plutarch's *Platonic Questions* we learn that when the question of time's nature was put to Pythagoras, he simply uttered the mystical "time is the soul of the world." The *Laws of Manu* of Hinduism, the *Torah* of

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[1] H. Putnam, "Time and Physical Geometry," *Journal of Philosophy*, April 1967, pp. 240–247.

[2] P. Horwich, *Asymmetries in Time*, MIT Press 1987.

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Judaism, the *Koran* of Islam, and the revealed truths of Gautama Buddha are all full of references to time. It is, in fact, to the pagan gods of Greek mythology that we owe our 'modern' image of Chronos, or Father Time.

Not just the Greeks made time a god. In the *Bhagavad Gita* (*Song of the Lord*), the central religious-romantic epic of Hinduism that predates Christ by five centuries, one of the characters reveals his divine nature and declares his power thus: "Know that I am Time, that makes the worlds to perish, when ripe, and bring on them destruction." And in the even older Egyptian Book of the Dead, which dates back over three thousand years, the newly deceased was thought literally to become one with time itself. The merging of time and the resurrection of the body after death in the Book is shown in the line "I am Yesterday, Today and Tomorrow, and I have the power to be born a second time."

The Greek philosopher Plato (circa 400 B.C.) gave us a curious way to think of time: as a *closed loop*. While Plato did think of time as having a beginning, his conception did not have time extending off into the infinite future as does the modern, everyday view. Rather, Plato visualized time as curving back on itself—as *circular* in nature. This was, in fact, a reasonable reflection on what Plato could see everywhere in nature, with the seemingly endless repetition of the seasons, the regular ebb and surge of the tides (the old English word *tid* was a unit of time), the unvarying alternation of night and day, and the rotation of the visible planets in the sky. Whatever might be observed today, it seemed obvious to Plato, would happen again in nature. Circular time in science fiction was briefly mentioned in Chap. 1,[3] and it occurs outside that genre, too, as in James Joyce's novel *Finnegans Wake*, which opens in mid-sentence and ends with the first part of the same sentence. This view of time has a powerful, ancient visual symbol, the Worm Ouroborous, or World Snake, that eats its own tail endlessly.

Circular time, with its closed topology, was favorably presented in Stephen Hawking's famous book *A Brief History of Time*. In it he concludes that there is no need for God because in circular time there is no first event and hence no need for a First Cause. Vigorous philosophical rebuttals were quick to come, of course![4]

Turning to fiction, Ray Bradbury wrote a beautifully poetic passage about the mystery of time in "Night Meeting," one of the splendid sub-stories in his episodic 1950 masterpiece *The Martian Chronicles*. A man of A.D. 2002, who is one of the modern inhabitants of Mars, somehow meets the ghostly image of a long-dead Martian one cold August night. The conditions are just right for such a cross-time encounter. As the man thinks to himself, "There is the smell of Time in the air tonight. . . . There was a thought. What did Time smell like? Like dust and people. And if you wondered what Time sounded like it sounded like water running in a dark cave and voices crying and dirt dropping down on hollow box lids, and rain. And, going further, what did Time *look* like? Time looked like snow dropping silently into a black room or it looked like a silent film in an ancient theater, one hundred billion faces falling like those New Year balloons, down and down into nothing. That was how Time smelled and looked and sounded. And tonight . . . tonight you could almost *touch* Time."

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[3] Another example from science fiction is the story by I. Hobana, "Night Broadcast," in which a television signal from the past is picked up by a gadget that is probing the *future*: "By going far enough into the future one comes upon what we call the past." You can find this tale in the *Penguin World Omnibus of Science Fiction*, Penguin Books 1986.

[4] See, for example, W. L. Craig, "What Place, Then, for a Creator?: Hawking on God and Creation," *British Journal for the Philosophy of Science*, December 1990, pp. 473–491, and R. Le Poidevin, "Creation in a Closed Universe Or, Have Physicists Disproved the Existence of God?," *Religious Studies*, March 1991, pp. 39–48.

Well, lovely words, yes, but they don't really tell us what time *is*. Perhaps Einstein the physicist can tell us. In the *New York Times* of December 3, 1919, we find him quoted as follows: "Till now it was believed that time and space existed by themselves, even if there was nothing [Newton's view]—no Sun, no Earth, no stars—while now we know that time and space are not the vessel for the Universe, but could not exist at all if there were no contents, namely, no Sun, no Earth, and other celestial bodies." Less than 2 years later Einstein stated this view again (*New York Times*, April 4, 1921): "Up to this time the conceptions of time and space have been such that if everything in the Universe were taken away, if there were nothing left, there would still be left to man time and space." Einstein went on to deny this view of reality, saying that, according to his general theory of relativity, time and space would *cease to exist* if the universe were empty. This has the ring of one of Einstein's favorite philosophers, Spinoza, who declared in his *Principles of Cartesian Philosophy* that "there was no Time or Duration before Creation." In a correspondence with Samuel Clarke—Newton's friend who translated Newton's *Optiks* into Latin—the German philosopher Gottfried Leibniz (who began the correspondence in 1715) expressed similar ideas: "Instants, consider'd without the things, are nothing at all . . . they consist only in the successive order of things."

The pragmatic scientist would certainly agree with Leibniz. After all, what could it even mean to talk of time unless you can measure it? And what you use to measure time is a clock—some kind of changing configuration of matter involving spinning gears, ticking pendulums, and rotating dial pointers. Mere *unchanging* matter, alone, is not sufficient to measure time because a still clock measures nothing. *Changing* matter seems to be required. Yet, not surprisingly, not everybody agrees. The counterview, the view that time has nothing to do with change, was expressed in an interesting manner by a science fiction fan in a letter to the editor of *Wonder Stories* (January 1931): "Just one thing, you have these time-traveling yarns, good stuff to read all right, but bunk, you know; because if there's no such thing as time, which there isn't, *only change* [my emphasis], how can one travel in . . . something that doesn't exist. To our planet which goes around the Sun there is simply a turning and warming of one side and then the other, i.e., years, days, minutes, etc., is something purely artificial, invented by man to tell him when to do certain things, work and stop work . . ."[5]

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[5] This fan's idea was not new. For Plato's most famous student, Aristotle, time was *motion* (in a world in which nothing moved, argued Aristotle, there would be no time), and he expressed this

Going even beyond the ideas of Einstein, Spinoza, Leibniz, Plato, Aristotle, and our science fiction fan, at least one metaphysician felt that time would have no meaning, even in a massive and changing universe, without the additional presence of conscious, rational beings.[6] That sounds very much like an echo of the French philosopher Henri Bergson who, in 1888, somewhat mysteriously declared that time is "nothing but the ghost of space haunting the reflective consciousness." A few years before Taylor, however, a fellow philosopher had argued for exactly the opposite view, that temporal passage is independent of the existence of conscious beings.[7]

All this divergence of opinion perhaps explains why even a lightweight Hollywood movie like Mel Brooks' 1987 *Spaceballs* can get a laugh from a time joke. Even kids know that the characters, when talking about time, haven't the slightest idea of *what* they are talking about. The movie, a spoof on such classic films as *Star Wars*, *The Wizard of Oz*, and *Raiders of the Lost Ark*, quickly reaches a point of crisis. To find out what to do next, the evil Lord Helmet and his chief henchman decide on a novel approach: they will look at an instant video of their own movie! (Instant videos are available *before* the movie is finished.) Perplexed at watching on a television screen everything that he is doing as he does it (the screen correctly shows an infinite regression of television screens, each being watched by a Lord Helmet), Lord Helmet initiates the following rapid-fire exchange. (It is, of course, a clever take-off on Abbott and Costello's "Who's on First?")

> *What the hell am I looking at? When does this happen in the movie?*
> *Now! You're looking at now, sir. Everything that happens now, is happening, now.*
> *What happened to then?*
> *We're past that.*
> *When?*
> *Just now, now.*
> *Go back to then.*
> *When?*
> *Now.*
> *Now?*
> *Now.*
> *I can't.*
> *Why?*
> *We missed it.*

---

view in his famous metaphor "Time is the moving image of eternity." For Aristotle, then, time and change were inseparably intertwined. For Aristotle the world had existed for eternity, and the circularity of time was a central and powerful image; using his vivid illustration, it is equally true *in circular time* that we live both before *and* after the Trojan War.

[6] R. Taylor, "Time and Life's Meaning," *Review of Metaphysics*, June 1987, pp. 675–686.

[7] S. McCall, "Objective Time Flow," *Philosophy of Science*, September 1976, pp. 337–362.

> *When?*
> *Just now. [The henchman then sets the video to rewind.]*
> *When will then be now?*
> *Soon.*

We may laugh at this, even dismiss it as mere movie madness, but could any of us *really* do much better if, like Saint Augustine, we were backed into a corner and asked to explain time? Somehow, I think even the distinguished twentieth-century Harvard professor Hilary Putnam whose words open this chapter would find it difficult to know where to begin. He might even become as confused as the time traveler in the 1968 film *Je t'aime, Je t'aime*, whose oscillations in time, from present to past and back again, leave him so befuddled that he decides he'd rather be dead. What, then, *can* we say about time? Despite Putnam's bold words, I suspect that most people would come down on the side of Augustine.

The mystery of time was well captured by R. H. Hutton (1826–1897), the literary editor of the *Spectator*, when he wrote in his 1895 review (see note 1 in the Introduction) of Wells' *Time Machine* that "the story is based on that rather favorite speculation of modern metaphysicians which supposes *time* to be at once the most important of the conditions of organic evolution, and the most misleading of subjective illusions ... and yet Time is so purely subjective a mode of thought, that a man of searching intellect is supposed to be able to devise the means of traveling in time as well as in space, and visiting, so as to be contemporary with, any age of the world, past or future, so as to become as it were a true 'pilgrim of eternity.'"

Novelist Israel Zangwill (1864–1926) wrote a similar but much more analytical review of Wells' novel for the *Pall Mall Magazine* (see note 1 in the Introduction). Zangwill was the only Victorian reviewer to attempt a scientific analysis of time travel. Although he thought Wells' effort was a "brilliant little romance," Zangwill also thought the time machine—"much like the magic carpet of *The Arabian Nights*"—was simply "an amusing fantasy." Zangwill continued in his review with what was even then a common idea about a way one might actually be able, at least in principle, to look backward in time; one could travel far out into space by going faster than light and then watch the light from the past as it catches up to you. (Note, carefully, that Zangwill was writing in 1895, 10 years before Einstein's special relativity put a limit on possible speeds.) In this way, Zangwill wrote, one could watch "the Whole Past of the Earth still playing itself out."

Indeed, even before Zangwill, the well-known French astronomer Camille Flammarion (1842–1925) had made this dramatic idea a centerpiece of his 1887 novel *Lumen*. That book, a best-seller in Europe even before its appearance in England, describes how a man just dead (in 1864) instantly finds his spirit on the star Capella, where he is able to watch the light then arriving from the Earth of 1793. In particular, he watches the French Revolution play itself out and sees himself as a child. Flammarion may have, in fact, been inspired to write his novel by an essay written several years earlier (in 1883) by the British physicist

J. H. Poynting (1852–1914). Poynting's essay,[8] which opens with the statement that it was, in turn, inspired by an anonymous pamphlet published "30 or 40 years ago" on the same topic, specifically mentions watching historical events from Capella.

By the beginning of the twentieth century the idea of watching the past by outrunning light had drifted down into juvenile literature, as in the 1904 novel *Around a Distant Star* by Jean Delaire (the pen name for Pauline Touchemoline (1868–1950)), in which a young man builds a spaceship that can travel at two thousand times the speed of light. With it, he and a friend travel to an Earth-like planet nineteen hundred light-years distant and use a super-telescope to watch the Crucifixion (and then the resurrection) of Jesus. Early magazine science fiction also found the idea of looking backward in time with delayed light to be an irresistible one, involving romance and murder.[9] In another tale incorporating human emotions, a scientist loses his wife to a rival who kidnaps her and then escapes in a faster-than-light rocket ship headed for parts unknown. After searching for them with his own brilliant invention of the 'ampliscope' (several quantum leaps beyond the telescope), the scientist locates the couple, skipping from planet to planet light-years distant. His only pleasure, then, is to use his own faster-than-light craft to outrun the images of his lost love and watch them over and over. Eventually, however, he comes to realize the ultimate futility of it all. As the final line of this sad tale says, "It would be senseless, I knew, chasing on and on after yesterdays."[10]

The reality of time received a new twist with the additional imagery of instants of time being likened to the points on a *straight* line. In the West it was the Christian theological doctrine of *unique* historical events that gave rise to *linear* time in the minds of the common folk. The creation of the world and Adam and Eve, the adventures of Noah and the cataclysmic Flood, the Resurrection—these were all events that occurred in sequence, *once*. None would happen again and so, for Christianity, circular time just would not do.[11] In addition, it has been argued that the major spiritual content of Christianity—a significant reason for its popular support even in the face of brutally harsh Roman suppression—is that it brought the *expectation of change* into the static world of ancient times. It was, in fact, in ancient religious teachings that our modern view of linear time had its origin, a view that most people today (including the most hardened agnostic physicist) find to be as natural as Plato and Aristotle found circular time.

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[8] J. H. Poynting, "Overtaking the Rays of Light," in Poynting's *Collected Scientific Papers*, Cambridge University Press 1920.

[9] As in, for example, G. A. England, "The Time Reflector," *The Monthly Story Magazine*, September 1905.

[10] D. D. Sharp, "Faster Than Light," *Marvel Science Stories*, February 1939. The year before saw the appearance of a story with the same idea, a story that specifically cites Flammerion: M. Weisinger, "Time On My Hands," *Thrilling Wonder Stories*, June 1938.

[11] Still, just to show how one can find support for almost any view in the same religious dogma, Ecclesiastes 1:9 would seem to be a claim *not* for linear time but rather for circular time!: "The thing that hath been, it is that which shall be; and that which is done is that which shall be done; and there is no new thing under the sun."

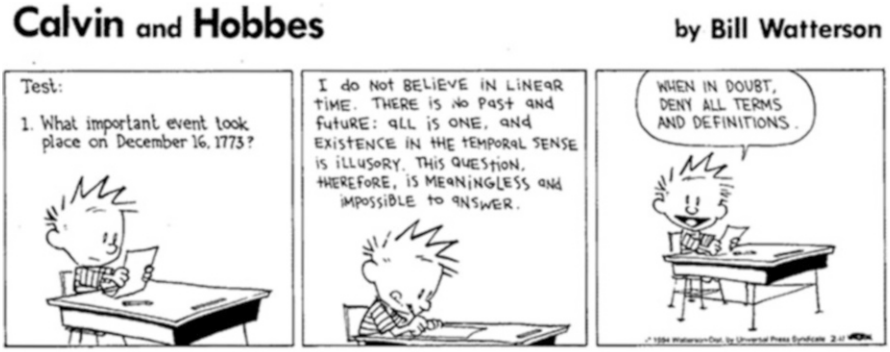
Calvin and Hobbes
by Bill Watterson
Test:
1. What important event took place on December 16, 1773?
I do not believe in linear time. There is no past and future: all is one, and existence in the temporal sense is illusory. This question, therefore, is meaningless and impossible to answer.
When in doubt, deny all terms and definitions.

CALVIN AND HOBBES ©1994 Watterson. Reprinted with permission of UNIVERSAL PRESS SYNDICATE. All rights reserved.

Even though linear time was the norm after Christ, there were still enough questions about time to perplex the deepest of thinkers, and the next 2000 years resulted in plenty of thinking. Discourses on time by such philosophers as Descartes, Spinoza, Hobbes, Kant, Nietzsche, and Hegel can be found by the yard in any decent university library. Nearly all (if not indeed all) of these presentations have metaphysical, even theological, underpinnings. For example, Descartes is generally believed to have argued for a discontinuous, atomistic nature to time (recall the *chronon* from Chap. 1). This is the modern view of his thinking, because in his *Meditations* (1641), in particular in the third meditation on God's reality, Descartes appears to argue that God must continually recreate the world at each *separate* moment of its existence. That is, the world is recreated in a discontinuous succession of *individual* acts by God.[12]

Finally, with Newton's discussion of *absolute* time, which is the belief that time is the same everywhere in the universe, there was for the first time a *physicist* writing about time (although, as I mention in Chap. 1, Newton's views were also influenced *heavily* by theological considerations, in addition to mathematical physics). But, despite Newton's genius, the mystery of time remained a mystery.

In 1905 Einstein's name appeared among the contributors to the study of time, and so at last something besides metaphysical speculation on the subject was added to the body of human thought. Einstein's paper on special relativity introduced the revolutionary idea of *relative* time, which is the anti-Newton belief that the passage of time is *not* the same everywhere, but rather depends on local conditions. In retrospect, Einstein's 1905 work seems to be the perfect reply to the comment by Isaac Barrow (1630–1677)—Newton's teacher and the first Lucasian professor of mathematics at Cambridge (the chair once held by Stephen Hawking centuries later)—that “because *Mathematicians* frequently make use of Time, they ought to have a distinct idea of the meaning of the Word, otherwise they are Quacks.”

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[12] For more on this, see R. T. W. Arthur, "Continuous Creation, Continuous Time: A Refutation of the Alleged Discontinuity of Cartesian Time," *Journal of the History of Philosophy*, July 1988, pp. 349–375.

Then, just 3 years after Einstein, along came a second astonishing paper by the Cambridge philosopher John Ellis McTaggart (1866–1925). This paper[13] claims to prove that whatever time might be *thought* to be (even by Einstein), it really isn’t that because time isn’t even real. (This would seem, I think you’d agree, to have potentially profound implications for time travel!) The method of the paper is to deny the reality of time via an infinite-regress argument that one philosopher[14] has called the *pons asinorum* (“bridge of asses”) of the riddle of time. As McTaggart’s own opening sentence freely admits, “It doubtless seems highly paradoxical to assert that Time is unreal, and that all statements which involve its reality are erroneous.”

McTaggart began his analysis by observing that there are two separate and distinct ways of talking about events in time. Following his terminology, one can say that events are either future, present, or past (the so-called *A-series*), or one can say that events temporally ordered by each being later than some other events, earlier than others, and simultaneous with still others (the so-called *B-series*). He then continued by asserting that time requires change, and followed that with the observation that the A-series (but not the B-series) incorporates such change. That is, if event X is earlier than event Y, then X is *always* earlier than Y and thus there is no change in this (or in any other) example of a B-series. As a specific example, let Y be the birth of a child, and let X be the birth of its mother. In contrast, if X is first in the future, then is in the present, and finally is in the past, then we have an example of change (and hence of *time*) in the A-series; for example, let X be the next time you blink.

With this rather pedestrian start, McTaggart then pulled his rabbit out of the hat. It makes no sense, he argued, to talk of the ‘future,’ ‘present,’ and ‘past’ of an event because these terms are mutually exclusive. That is, no two of these predicates can apply at once, and yet, paradoxically, every event possesses all three and thus we have a contradiction. It therefore, concludes McTaggart, makes no sense to talk of future, present, or past. And because it makes no sense to talk of them, they do not exist, and so there can be no A-series and hence no change, and thus no reality to time. McTaggart apparently realized just how befuddling all that would appear to just about everybody who read it, and so he played devil’s advocate (D.A.) in his paper by trying to anticipate the various objections people could raise. Of course, he always managed to refute the D.A. at every turn. It is worth the effort to go through the details of McTaggart’s ‘proof,’ as that will make it clear what there is about

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[13] J. E. McTaggart, “The Unreality of Time,” *Mind*, October 1908.

[14] L. O. Mink, “Time, McTaggart and Pickwickian Language,” *Philosophical Quarterly*, July 1960, pp. 252–263. The phrase *pons asinorum* has its origin in a plane geometry theorem: the angles opposite the equal sides of an isosceles triangle are themselves equal. Seeing the truth of this is said to separate the quick-witted from the dull. It isn’t clear (to me, anyway), however, on which side of McTaggart’s ‘proof’ the quick-witted were imagined to fall. You’ll see what I mean in just a moment.

'traditional' philosophical reasoning that so irritates modern philosophers trained in mathematical physics (and what makes physicists roll their eyes when confronted with arguments like McTaggart's).

The predicates of future, present, and past are really not incompatible for any event, the D.A. says some will claim, because the real predicates we should use are '*was* future,' '*is* present,' and '*will be* past,' and these *can* be possessed all at once by any event. Nice try, counters McTaggart, but that will not solve the problem. By allowing such modified predicates, we must actually allow for all nine possibilities, some of which are still incompatible. That is, the 'was,' 'is,' and 'will be' could each be potentially attached to 'future,' 'present,' and 'past': for example, 'was past' is incompatible with 'will be future.'

Oh, counters the D.A., we can eliminate that concern by allowing even more complex predicates to arrive at a third level of structure, such as 'is going to have been past,' and 'was going to be future,' and those *are* compatible. But McTaggart swats that argument away, too, by displaying new incompatibles, as well as by showing that the process of ever-increasing predicate complexity is a vicious infinite regress that drags along the seeds of its own doom at every step.[15] There is simply no escape from incompatibility, he says, and so there is no time.

Well! What can one do when presented with such an argument, one that seems to claim philosophers can wrest free the secrets of nature by pondering the historical accidents of English syntax? As David Hume once said, "Nothing is more usual than for philosophers to encroach on the province of grammarians, and to engage in disputes of words, while they imagine they are handling controversies of the deepest importance and concern." One modern philosopher apparently agreed with Hume, at least in the case of McTaggart's 'proof,' and he was pretty blunt with his evaluation of it: "McTaggart's famous argument for the unreality of time is so completely outrageous that it should long ago have been interred in decent obscurity. And indeed it would have been, were it not for the fact that so many philosophers are not sure that it has ever really been given a proper burial, and so from time to time someone digs it up all over again in order to pronounce it *really*

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[15] Here's a clever way to systematically generate McTaggart's infinite regress of complex predicates, as presented by M. Dummett, "A Defense of McTaggart's Proof of the Unreality of Time," *Philosophical Review*, October 1969, pp. 497–504): "Let us call 'past,' 'present,' and 'future' 'predicates of first level.' If, as McTaggart suggests, we render 'was future' as 'future in the past,' and so forth, then we have nine predicates of second level, where we join any of the three on the left with any of the three on the right:

past		past
present	in the	present
future		future

Similarly, there are twenty-seven predicates of third level ... "Dummett's construction clearly shows that, at the N-th level, there are 3^N predicates, most of which are incompatible.

dead. These periodic autopsies reveal that something more remains to be said."[16] That is certainly true, in as much as McTaggart's disarmingly innocent argument has caused disagreement and furrowed brows among philosophers for decades.

It is, in fact, easy to find examples of the continuing debate over McTaggart's analysis and, as silly as it strikes physicists, it still has a pulse in some quarters. While at least one philosopher has argued that McTaggart simply didn't really understand his own proof, this philosopher nevertheless agreed with McTaggart's conclusion about the unreality of time.[17] Another writer has illustrated how McTaggart's ideas have found their way into modern philosophical debates on the meaning of time in the cinema, particularly in the analysis of *anachrony*, the telling of a story out of normal time sequence, such as occurs in time travel movies.[18]

Other sorts of metaphysical proofs for the unreality of time have been offered besides McTaggart's. For example, it has be argued that time is unreal, at least in a world empty of consciousness, because the concepts of past, present, and future could not possibly have any meaning unless events could be remembered, experienced, and anticipated. Or, for a second example, some have held time to be unreal, at least in a deterministic world (as some argue four-dimensional spacetime to be), because any event whose occurrence follows from present conditions, and from physical laws, would exist (they say) *now*. This view, which seems to assert that everything should happen at once, I personally find to be sufficiently obtuse as not to be bothered by it.[19] Debates between those who believe in the common-sense idea that present, past, and future are attributes of events (the 'tensers') and those who deny it (the four-dimensional spacetime, block universe 'detensers') continues to now and then still flair up on the pages of philosophy journals. At least one philosopher likes both views![20] Most modern physicists, I think, simply don't care about this line of inquiry.

On the other hand, less than a month before his death Einstein revealed his feelings about the meaning of present, past, and future, and his words appear to be ones that show some sympathy to the philosophers. In a letter written on March 21, 1955, to the children of his dearest friend who had just died, Einstein wrote—with full knowledge that his own illness would be his last—"And now he has preceded me briefly in bidding farewell to this strange world. This signifies nothing. For us believing physicists, the distinction between past, present, and future is only an illusion, even if a stubborn one."[21] Later in this chapter I'll return to these curious words and speculate on what Einstein may have meant by them.

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[16] F. Christensen, "McTaggart's Paradox and the Nature of Time," *Philosophical Quarterly*, October 1974, pp. 289–299.

[17] Q. Smith, "The Infinite Regress of Temporal Attributions," *Southern Journal of Philosophy*, Fall 1986, pp. 383–396. To this came a rebuttal a year later by L. N. Oaklander, in the same journal (Fall 1987, pp. 425–431).

[18] G. Currie, "McTaggart at the Movies," *Philosophy*, July 1992, pp. 343–355.

[19] But if, upon reflection, it starts to bother *you*, see R. Gale, "Some Metaphysical Statements About Time," *Journal of Philosophy*, April 1963, pp. 225–237. We'll soon get to some of the more common philosophical questions on the nature of four-dimensional spacetime, such as 'is it deterministic or is it fatalistic?,' and 'does free-will have any meaning in four-dimensional spacetime?' Even physicists are interested such questions!

[20] R. Weingard, "Space-Time and the Direction of Time," *Nous*, may 1977, pp. 119–131.

I started this opening section on a religious note, and I'll end it on one. If you think the philosophical speculations on the nature of time that I've so far cited are 'really far out,' here's yet another one that leaves all the rest in the dust. In a paper that took real nerve to write (or, perhaps, simply a wicked sense of humor—and I write that in pure admiration) we read of how a spacetime that supports time travel can give the start for a *physics* explanation to the theological concept of Hell! After introducing just a bit of elementary spacetime physics (which I'll skip describing here because we'll do it later in the book), the author[22] shows how to 'construct' a compact region in spacetime (Hell) with the following properties:

1. While "so small even the Hubble Telescope couldn't image it" it can hold an infinity of physical beings;
2. Each of the beings in it are doomed, because of its time travel property, to an infinitely long personal future of damnation;
3. Each of the beings in it, because of its time travel property, can view all the future stages of their own personal damnation and so be "continually presented with a reminder of the impossibility of escape—a refinement no causally normal Hell can seemingly offer." In other words, and not to be too ironic about it, 'Theological Progress Through Physics!';
4. Each of the beings in it are continually being compressed together ("brought into dismaying proximity" with themselves) and so will spend eternity "listening to a cacophony" of their own cries of despair from *their personal future*.

There's more, but that's probably enough for you to get the idea. Richmond does admit that, as it stands, his time travel creation of Hell is not compatible with either quantum theory or even general relativity. Still, it *is* something to ponder, don't you think, when the subject of time travel comes up!

2.2 Linear Time and the Infinity of Past and Future

> "A thousand years is a huge succession of yesterdays beyond our clear apprehension."[23]
>
> —H. G. Wells

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[21] Quoted from B. Hoffmann, *Albert Einstein: Creator & Rebel*, New American Library 1972, pp. 257–258.

[22] Alasdair M. Richmond, "Hilbert's Inferno: Time Travel and the Damned," *Ratio*, September 2013, pp. 233–249.

[23] This line appears in Wells' 1944 doctoral thesis, written for the University of London. You can find an abridgement of the thesis in *Nature*, April 1, 1944, pp. 395–397.

The modern concept of linear time as a straight line extending from the dim past through the present and disappearing into the misty future gives rise immediately to twin questions: "Did time have a beginning?" and "Will time ever end?" As one philosopher put it (long before physicists became seriously interested in singularities like the Big Bang) "Endings and beginnings are rooted in the very conception of time itself."[24] Starting at the beginning, we'll ask if the past has been forever? Early Biblical scholars, of course, believed the answers to both questions to be *no*.

They believed that the world came into being because of a First Cause, God's creation of everything. Those scholars expended vast quantities of energy (and, need I say it, time itself) in calculating the date of creation. Martin Luther, for example, argued for 4000 B.C. as roughly when everything, including time, began. Johannes Kepler adjusted this by a notch, to 4004 B.C., and later the Calvinist James Ussher, Archbishop of Armagh and Primate of All Ireland, tweaked it again. His date is the most impressive of all, at least in detail: the first day of the world was 4003, 70 days, and 6 h before the midnight that started the first day of the Christian era. Six days after that first day of the world, Adam was made, and as a final dash of specificity, this last date was declared to be Friday, October 28! Ironically, then, though Christian theology may be given credit for introducing linear time, it certainly did not provide very much of it. The beginning of time was just 6000 years or so ago, and of course The End—in the form of the Battle of Armageddon—has been awaited (with varying degrees of eagerness) for the last 1000 years.

The discovery in the seventeenth century of geological time cast a certain amount of skepticism on those early calculations concerning the duration of the past. With the discovery that the very Earth itself could be decoded for its history, the lure of trying to decode a mere book of admittedly finite age declined for most people although it cannot be denied that modern Creationists still find such a task to have its rewards). Geological time was discovered to a *chasm* of time extending backward for billions of years, a duration that is really incomprehensible for the human brain. It has become fashionable for geologists to refer to such enormous durations with the apt term *deep time*, a subtle play on the metaphor of the "ocean of time."

It is nothing less than humbling to historians who pause to think on how little of the past is known, that is, recorded. As the ever anonymous wit once put it, "History is a damn dim candle over a damn dark abyss." Still, even as enormous as is the age of the Earth, it is not infinite. But of course our planet is very old, and the universe is many billions of years older. Is the age of the universe also the duration of the past? Or is the past itself actually *infinite*?

An implicit assumption of the infinity of the past (and of the future, too) can be found in Book Three of Lucretius' science poem *De Rerum Natura* (*On the Nature of Things*) where, just before the birth of Christ, Lucretius argues for the irrationality of fearing death: "The bygone antiquity of everlasting time before our birth was nothing to us. Nature holds this up to us as a mirror of the time yet to come after our death. Is there anything in this that looks appalling, anything that means an aspect of gloom? Is it not more untroubled than any sleep?"

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[24] I. Stearns, "Time and the Timeless," *Review of Metaphysics*, December 1950, pp. 187–200.

One philosopher[25] has traced the origins of rational support for the finite duration of the past to as far back as the sixth century A.D. The argument presented then by the Christian philosopher Joannes Philoponus of Alexandria (who is otherwise known as John the Grammarian) is simply that the world could *not* have been forever because that implies an infinity of successive acts could have taken place which (according to Philoponus) is impossible. A variation on this is the claim that if the past were infinite in extent, then everything would have happened by now! Infinity was just too big for the ancient mind (Zeno's hoary pre-Christian paradoxes, as is well-known today, are based on subtle errors in the use of infinity).

This view on the impossibility of an infinite past seems to have been the prevalent view; even as late as the twelfth century the debate among Christian theologians was not about the possibility of an infinite past, but instead about whether the Biblical 'six days of Creation' actually had taken place simultaneously. For many, the past was 'obviously' finite in duration.[26] Not all Christians accepted that conclusion, however, and the following century saw St. Thomas Aquinas (a follower of Aristotle) arguing for the opposite view of an infinite past.

Thomas' contemporary, St. Bonaventure, however, argued again for a *finite* past, and it is with Bonaventure that we start to see some mathematical sophistication.[27] Bonaventure argued that in a world infinitely old, the Sun would have made an infinite number of its annual trips around the ecliptic. But for each such trip the Moon would have made twelve monthly trips around the Earth, and so this second infinity would be twelve times as great as the first one, and how could that be? Infinity is infinity, and how can something be twelve times bigger than infinity? This argument doesn't have any strength today because of the nineteenth century German mathematician Georg Cantor's work on the concept of infinity,[28] but it *is* clever. Agonized, convoluted theological analyses of God, infinity, and eternity continued long after Aquinas and Bonaventure. Two examples should capture the spirit of those times.

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[25] G. J. Whitrow, "On the Impossibility of an Infinite Past," *British Journal for the Philosophy of Science*, March 1978, pp. 39–45. Whitrow adds modern scientific support to the idea of a finite past by citing the prediction from general relativity of a singularity in spacetime at some finite past time; that is, the theory's prediction that time—and everything else—had its beginning in the now famous Big Bang.

[26] C. Gross, "Twelfth-Century Concepts of Time: Three Reinterpretations of Augustine's Doctrine of Creation *Simul*," *Journal of the History of Philosophy*, July 1985, pp. 325–338.

[27] See, for example, L. Sweeney, "Bonaventure and Aquinas on the Divine Being as Infinite," *Southwestern Journal of Philosophy*, Summer 1974, pp. 71–91, and S. Baldner, "St. Bonaventure on the Temporal Beginning of the World," *New Scholasticism*, Spring 1989, pp. 206–228.

[28] For simple high school-level presentations on Cantor's astonishing infinity results, see my book *The Logician and the Engineer*, Princeton 2013, pp. 169–171.

Consider first this one, on the supposed immortality of the soul. If $A = B$, then $2A = 2B$. Next, let A = 'half alive' and B = 'half dead,' where $A = B$ in the same sense that a glass half-full is also half-empty. Thus, to be completely dead is to be completely alive, and so the soul is immortal. Outrageous? *Yes*, in my opinion, but I do also have to admit the 'reasoning' does have a certain charm!

For my second example, let me begin by setting the historical stage. After publication of the English political philosopher Thomas Hobbes' *Leviathan* in 1651, with its arguments against the power of the Church and for civil power (with some criticism tossed in, as well, for universities), Seth Ward counterattacked. Ward, who was both a minister (later a bishop) in the Anglican Church and Savilian Professor of Astronomy at Oxford, was greatly offended by the secular nature of *Leviathan*. Even before Leviathan, in fact, Ward certainly would not have liked Hobbes' earlier denial of the existence of immaterial substances (such as souls). Ward's 1652 book *A Philosophical Essay Towards An Eviction of the Being and Attributes of God, the Immortality of the Souls of Men, the Truth and Authority of Scripture*, was the first of a two-punch reply to Hobbes. The second came in 1654 with the appearance of Ward's *Vindiciae academiarum*. In both of these works Ward attempted to undermine Hobbes' credibility by attacking his mathematical ability. (Hobbes had long been fascinated by, and was considered an expert on, the ancient problem of 'squaring the circle,' a task that has been known to be impossible only since 1882.[29]) In his *Essay*, Ward also attempted to defend the view that the world has a finite age—that is, it had a specific moment of creation, presumably by God. In an opening note, in fact, Ward cites Hobbes' rejection of immaterial substances as the motivation for his writing *Essay*.

To support his view of a finite age for the world, Ward invoked infinity in an interesting way. He argued that nothing is permanent, certainly not humans. Each is created; one can imagine tracing a chain of creation events backward in time through successive generations. Now, there are only two separate and distinct possibilities to where this chain could lead to in the past. First, it could terminate, after a finite number of generations, at a *first* generation, that is, with the 'creation' of the first human. If that is the case, then, said Ward (in effect), 'case closed.' If that is not the case, however, then the chain of successive generations never terminates, that is, the chain is infinitely long. But that, argued Ward, is nonsense—how could anything *infinitely* long have an end (our present *now*)?

Why Ward thought this an unanswerable paradox is hard to understand; after all, one can imagine a line in some coordinate system *beginning* at the origin and yet still being infinitely long (an example is the positive x-axis). This counter-example was not put forth by Hobbes in his own self-defense, but rather was offered by one of Ward's own colleagues at Oxford, John Wallis, the Savilian Professor of Geometry. As for Hobbes, he was little bothered by Ward's argument. As he pointed out (surely with a smile on his face), Ward was in danger of impaling himself as a theologian on his own sword: Ward's argument 'proved' the finite age not only of the world but of *everything*, including God (thus raising the awkward question of who, or what, made God?).

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[29] The problem of 'squaring the circle' is, given a circle of area A, to construct (using only compass and straightedge) a square of area A.

Similar problems with infinity lay behind Kant's rejection of an infinite past. It is interesting to note that Kant, somewhat paradoxically, thought an infinite *future* a possibility. Why did Kant think time could be infinite in one direction but not in the other? One philosopher tells us[30] that Kant "failed to make himself clear," and I think that *understates* the case. I say that because Kant's argument was that the duration of the future is less problematic than is that of the past because it is only the past that influences the present. The best I can do in 'explaining' this is to speculate that if the present depends on an *infinite* past, then perhaps Kant thought that the possibility of so much influence was simply too much for the present to handle! In any case, Kant's view falls apart if we consider the possibility of backward time travel and the resulting implication that the future could also influence the present.

There is, as will come as no surprise, a philosopher for every conceivable point of the compass, and so a paper by one on the logical possibility of an infinite past soon prompts a rebuttal by another.[31] In illustration of this, you'll recall the quote from Augustus De Morgan in the opening section of this book, concerning the philosophers of his times; De Morgan went on in his critique to amusingly summarize the metaphysics of those times as follows: "Here we go up, up, up,/And there we go down, down, down,/Here we go backwards and forwards/And there we go round, round, round."

So, with De Morgan's words in mind, here are a few more examples of how people have struggled with the issue of the past. One quite interesting, *scientific* twist on the duration of the past was pointed out before the exchange between Smith and Ells. In a paper[32] observing that although general relativity and its predicted spacetime singularity in the distant past may indeed allow for a finite past, that does not completely close the door to the possibility that the Big Bang was a continuation from a previous contraction phase of the universe, and so on, *ad infinitum*. (You'll recall the discussion in Chap. 1 of this idea in science fiction: see note 53 in that chapter.) To quote T. S. Eliot (from his "Little Gidding"):

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[30] J. Bennett, "The Age and the Size of the World," *Synthese*, August 1971, pp. 127–146. See also Q. Smith, "Kant and the Beginning of Time," *New Scholasticism*, Summer 1985, pp. 339–346.

[31] See, for example, Q. Smith, "Infinity and the Past," *Philosophy of Science*, March 1987, pp. 63–75, and then read E. Ells, "Quentin Smith on the Infinity of the Past," *Philosophy of Science*, March 1988, pp. 453–455. Smith's paper "The Uncaused Beginning of the Universe" appeared in this same issue (pp. 39–57), stating that he believed, *really*, only in the *logical* possibility of an infinite past and that the universe had in fact originated in an uncaused (no God required) Big Bang singularity. And, indeed, he *had* so argued for a finite past, in "On the Beginning of Time," *Nous*, December 1985, pp. 579–584.

[32] R. Weingard, "General Relativity and the Length of the Past," *British Journal for the Philosophy of Science*, June 1979, pp. 170–172.

"What we call the beginning is often the end
And to make an end is to make a beginning.
The end is where we start from."

Even without entertaining such an oscillating, accordion-like universe that endlessly expands and shrinks, it is possible to have a universe that originated in a *single* Big Bang a finite time ago in the past but yet *has no first instant*! This astonishing statement shocks most at first encounter, but it is simply the cosmological version of a well-known mathematical result. The instant $t = 0$ is not actually part of spacetime, because the Big Bang was quite literally a singular event for which the laws of spacetime physics fail. Thus, all instants in time are greater than zero—and there is no smallest number greater than zero. If you name a positive number, no matter how small, I can name a positive number still smaller, such as one-half of yours. (Of course, if there really is merit to the idea of a quantum of time, the chronon, this argument goes out the window.)

In an ingenious observation that seems to have been missed by most philosophers, E. A. Milne, a professor of mathematics at Oxford, suggested in his 1948 book *Kinematic Relativity*, that with general relativity it is conceivable to have both a single Big Bang a finite time ago *and* an infinite past. Pointing out that to talk meaningfully of time implies that we have a clock to measure it by, Milne looked for a Universal Clock that would be far more durable than our heartbeats, or anything else that exists only transiently. He suggested the expansion rate of the universe itself as the ideal clock. As we go back in time to the Big Bang, the expansion rate rises towards infinity and, as another analyst put it, "We see the Universe ticking away quite actively. *The Universe is meaningfully infinitely old because infinitely many things have happened since the beginning*."[33]

The debate over the length of the past in modern times can be just as contentious as it was in medieval times. For example, in his editorial ("Down with the Big Bang") of August 10, 1989, the then editor of *Nature* (John Maddox) declared the standard explosive model of the universe to be "philosophically unacceptable," because "the implication is that there was one instant at which time literally began and so, by extension, an instant before which there was no time." For Maddox, this meant that the Big Bang "is an *effect* [my emphasis] whose *cause* [my emphasis] cannot be identified or even discussed." The usual (non-time travel) use of the words *cause* and *effect* is that the cause happens first and then the effect occurs—but if the Big Bang (the effect) is the origin of time, then how (asked Maddox) could there be a cause of the Big Bang *before* that beginning?[34]

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[33] C. W. Misner, "Absolute Zero of Time," *Physical Review*, October 1969, pp. 1328–1333. In this view cosmic time is taken as proportional to the negative of the logarithm of the normalized volume of the universe ($V = 1$ represents maximum volume, and so time 'stops' at the end of the universe's expansion). Thus, because V goes to zero as we go backward in time, time runs ever faster as we travel ever further into the past. This puts the Big Bang (with $V = 0$) infinitely long ago.

[34] This was not a new insight, of course, as Aristotle had long ago (in his *Physics*) declared an instant in time with no predecessor to be an absurdity.

The answer is obvious *for creationists*, of course—God did it. Creationists avoid the question of God's cause, however, saying only that 'He needs no cause,' or even that 'He made Himself'! It is these standard (ridiculous) responses from creationists that Maddox said had prompted his editorial against the Big Bang, because creationists *embrace* the Big Bang as it seems to endorse their position of 'science by imagination.' Whatever the truth of that, I think juxtapositioning the *scientific* Big Bang model of the universe with theological metaphysics and the pseudo-science nonsense of creationism to be terribly unfair.

When will the philosophical debates on the age of the past end? Not until the end of the (infinite?) future, is my wager!

2.3 Cause and Effect

> "There are few paradoxes which have been resolved so often as the time-asymmetry paradox."[35]

The philosophical literature is full of discussions about potential causal relationships between events. One of the most famous of these discussions, illustrating that cause and effect can be pretty slippery concepts, asks what at first appears to be an almost trivial question: Did the death of Socrates cause the widowhood of Xanthippe? The quick and easy answer is "Of *course*—she was his wife and it was his death that causes us to say she was then a widow. What could be more obvious?" One philosopher has provided some interesting commentary, however, that might make you reconsider, or to at least become aware of how different are the questions concerning time that are of interest to physicists and philosophers.[36]

Suppose we agree that there are two events to be considered; Socrates ceasing to live, and Xanthippe becoming a widow. Those events occurred at different places (in prison, and wherever Xanthippe happened to be). Then, as Kim asserted, "the two events occur with absolute simultaneity ... [and so] we would have to accept this case as one in which causal action is propagated instantaneously through spatial space." (As we'll discuss in Chap. 3, the *relativity* of distant simultaneity weakens this assertion, but we'll take that up later.) For now, it is the conclusion that Kim draws from the assertion that interests us here: just *what* is propagating instantly? If it isn't mass-energy (as 'widowhood' would appear not to be!) then special relativity isn't bothered and physicists are happy. But those same physicists might also scratch their heads over *why* philosophers even wonder about such a question, because isn't becoming a widow just another way of saying that Socrates died and so we really don't have *two* events, but just one? In other words, for physicists this really isn't a question about cause and effect at all!

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[35] J. Hurley, "The Time-Asymmetry Paradox," *American Journal of Physics*, January 1986, pp. 25–28.

[36] J. Kim, "Noncausal Connections," *Nous*, March 1974, pp. 41–52.

The central puzzle of time travel to the past is its apparent denial of causality—that is, its denial of the belief that we live in a world where every effect has a cause and that the cause happens first. *First* we flip the switch and *then* the kitchen light comes on. It is *never* the other way around. So deeply embedded is the temporal ordering of cause and effect in our feelings about how the world—and all the rest of the cosmos—works, that the Australian philosopher John Mackie (1917–1981) called causation the "cement of the universe" (and used that wonderful phrase as the title of a 1980 book). Without causality, said Mackie, everything would come unglued and fall apart. For example, when electrical engineers design an electronic system that they intend to actually construct (as opposed to doing a mere theoretical 'paper design') they insist that the design be a *causal* one. By that they mean the system must have no output before an input is applied. That is, the system must not be able to anticipate (foresee) the application of an input. To put it bluntly, our engineers are insisting that they are *not* building a time machine!

Now all that might seem to be self-evident, but there *are* some subtle problems. For example, it has become almost a cliché to say that nothing can go faster than light; that's what physicists mean by *relativistic causality*. In other words, no cause can produce an effect at a distant location sooner than the time lapse required for a light pulse to make the trip. Classical mechanics, however, the science of Newton's laws that engineers use all the time, is *not* relativistically causal. Push the left end of a rigid rod, for example, and the right end moves *instantly*. Most of the time the lack of this form of causality causes no problems, but the fact remains that the mechanics all engineers (and physicists, too!) learn first in school is flawed on a fundamental level. A rigid rod is an impossibility in Einstein's mechanics.

Indeed, it is interesting to speculate about how, after a discussion of causality, a traditional engineering professor would respond if challenged on this issue by a bright student. Causality might not look so obvious, after all, if such a student stuck up her hand in class and said "Professor, you've told us that everything that happens in nature is due to a cause. That what we see happening all around us, as the world unfolds, is the domino-process of cause-effect-cause-effect, and so on, into the future. But suppose, Professor, that at some instant, somehow, every particle in the world suddenly reversed its velocity vector. Wouldn't that mean, given the time-reversible nature of the classical equations of motion, the world would then run backward in time along the same path it had followed up until the instant of reversal? Wouldn't that mean what was effect is now cause, and that what was cause is now effect? And if cause and effect can change roles like that ... well, Professor, just what do our words *mean*?"

An amusing, and instructive, cartoon illustration of the student's idea of reversing all the velocity vectors in a system appeared on the cover of the November 1953 issue of *Physics Today*. That issue contains an article on the 1949 nuclear magnetic resonance experiments performed by the American physicist Erwin Hahn, which in a certain sense dealt with just such reversed systems. In that illustration a group of runners on a multi-lane circular race track begin at the starting line in a coherent state, that is, all lined up together. Then, as they run around the track at various speeds, they gradually spread out into what appears to be an incoherent state.

But that incoherence is an illusion because if, at some instant (signaled in the cartoon by a pistol shot), they all turn around and run in reverse, they will all arrive back at the starting line *together, at the same instant*. The initial coherence of the runners was actually never lost, despite the superficial appearance of disorder, and the coherent state can be recovered at any time by a reversal of velocity vectors.

This isn't mere theoretical speculation, as an almost magical application of velocity vector reversal is actually used in what is called *optical phase conjugation*, a process to 'time-reverse' the severe distortion suffered by light beams during atmospheric propagation. For example, by effectively reversing the velocity vectors of photons, one can remove the turbulence blurring in satellite pictures of the Earth's surface as seen from space.[37]

Let me immediately short-circuit one possible answer our beleaguered professor might give in desperation, a response based on the fact that equations of physics are *not* all time reversible. Indeed, it was discovered decades ago that, in certain very rare, fundamental particle decay processes involving neutral K-mesons, there is the hint that perhaps nature *can* indeed distinguish between the past and the future. In particular, K-mesons should violate what is called *CP-symmetry*, and the so-called TCP theorem[38] says that then *T-symmetry* must also fail. In 1968/69 direct, experimental observation of the failure of T-symmetry in K-meson decays was reported. In an astonishing example of science fiction prescience, the use of K-mesons in a machine for affecting the past had appeared years earlier in a 1955 (!) story.[39]

So, could K-mesons account for the physical processes that we see evolve in time in one direction (past to future) but not in the other? As Hurley (note 35) put it so nicely, "The decay of the neutral K-meson is not time-reversal invariant; perhaps it is this ubiquitous meson which is responsible for the cream diffusing uniformly throughout our coffee in the morning. Possibly, but again this conjecture cannot account for the computer models [of diffusion processes that, like cream in coffee, also display a bias for one temporal direction over the other—in Chap. 3 I'll show you such a computer model] which have no neutral K-mesons." Still, the tiny chink that K-mesons appear to have made in the once-solid rock of time direction indistinguishability is an active area of research and speculation.

Even with that chink the fact that the classical laws appear to be insensitive to a direction of time, whereas the real world—which seems in no way dependent on the arcane properties of K-mesons—seems distinctly asymmetric, is a puzzle of the first rank. As one philosopher wrote, "The Universe seems asymmetric with respect to the past and future in a very deep and non-accidental way, and yet all the laws of nature are purely time symmetric. So where can the asymmetry come from?"[40]

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[37] C. R. Giuliano, "Applications of Optical Phase Conjugation," *Physics Today*, April 1981, pp. 27–35.

[38] The TCP-theorem says that the 'mirror-image' of a physical process is a legitimate process, too, *if* the 'mirror' reverses time (T), electric charge (C)—so that particle and anti-particle are interchanged, and parity (P)—which is the measure of left and right. There is strong reason to believe in the validity of the TCP theorem because quantum field theory is compatible with special relativity only if the TCP theorem holds.

[39] F. Pohl, "Target One," *Galaxy Science Fiction*, April 1955.

There have of course been attempts to answer that question. For example, one philosopher[41] discusses some curious mathematical examples he interprets as meaning, in the context of classical mechanics, that there are physical systems that are temporally irreversible *in principle*. A reply[42] from a fellow philosopher, however, argues that Hutchinson has, at most, shown only that classical mechanics is perhaps not deterministic. And that, Savitt argues, is not equivalent to showing a failure of time reversibility. There is, in fact, powerful experimental evidence that, with the rare exceptions of K-mesons, the classical laws of physics (including general relativity and quantum mechanics) *are* time-reversible.

Perhaps the most compelling of such evidence comes from the *reciprocity theorem* that electrical engineers routinely use when designing radio antennas. The theorem is easy to illustrate. Suppose two electrical engineers, Bob in Boston and Lois in Los Angeles, send radio signals to each other. Bob sends his messages by exciting his antenna with a time-varying current, which thus launches electromagnetic radiation into space. Lois' distant antenna intercepts some of that radiation, which then creates a (very tiny) signal current in her antenna.

The reciprocity theorem states the following: Suppose Bob makes a tape recording of his excitation signal and mails it to Lois, who then plays Bob's tape back into her transmitter as the excitation to *her* antenna. Then the signal current induced in Bob's antenna, as it intercepts Lois' launched radiation, will be the very same (very tiny) signal that Lois measured in her antenna as a result of Bob's transmission. This result is completely independent of the details of the two antennas, which can be utterly different in design, as well as independent of the details of the propagation path between Boston and Los Angeles (as long as those details don't change with time). The reciprocity theorem *is* true—it can be *measured* to be true as accurately as one wishes to perform this experiment—because of the reversibility of physics right down to the electronic level. In fact, the answer to the professor's problem of explaining why we don't see velocity vectors suddenly reverse, and then everything 'run backwards,' has not yet been found in any law of physics.

Now, to make things even more interesting, consider the problem of *mutual* or *simultaneous* causation, which can quickly lead to several interesting questions. When two leaning dominoes, A and B, hold each other up, is A nearly upright because of B, or is it B that is nearly upright because of A? When two children bob up and down on a see-saw, whose motion is the cause and whose is the effect? There are other puzzles, too, that involve mutual causation.

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[40] J. Earman, "The Anisotropy of Time," *Australasian Journal of Philosophy*, December 1969, pp. 273–295.

[41] K. Hutchinson, "Is Classical Mechanics Really Time-Reversible and Deterministic?" *British Journal for the Philosophy of Science*, June 1993, pp. 307–323.

[42] S. F. Savitt, "Is Classical Mechanics Time-Reversal Invariant?" *British Journal for the Philosophy of Science*, September 1994, pp. 907–913.

For example, causation is usually thought to be transitive: if A causes B, and if B causes C, then A causes C. But if A and B are mutually causative, then ‘A causes B’ coupled with ‘B causes A’ leads to ‘A causes A’ (and to ‘B causes B’). That is, mutual causation, together with transitivity, seems to imply *self*-causation! Except for those theologians who like this sort of result (it lets them answer the question ‘Who made God?’ with ‘He made Himself’), hardly anyone likes self-causation. But how do we avoid the conclusion that perhaps the mutual causation of two leaning dominoes, coupled with transitivity, represents experimental proof that God could have made himself? Well, of course this is certainly outrageous stuff, but don’t you wonder how our poor professor would respond if asked?

This last example is actually a far more esoteric one than we need to illustrate how our ordinary, everyday concept of cause and effect can be turned inside out by going only a little bit beyond the routine. Consider, for example, the problem of the data processing of recorded time signals, such as the information written onto magnetic tapes, hard drives, or disks. Typical applications that produce such recordings include the strata-probing seismic echoes from dynamite explosions set by oil exploration geologists; arms control compliance monitoring stations that listen for the acoustic rumbles generated by both earthquakes and underground nuclear tests—and then try to tell one from the other; and the gathering by various military intelligence agencies of turbine shaft/propeller noise signatures emitted by different types of submarines. In each of those situations, the raw information is recorded and then later processed with a certain degree of unhurried calm and leisure. That pool of oil, after all, has been underground for several hundred million years, and waiting a few more days or weeks for a computer analysis of the explosion echo isn’t going to make much difference.

Such after-the-fact processing of recorded data is said to be done ‘off-line, in non-real time.’ When we play a disk back in the lab, however, we can do all sorts of neat things, like speed up the playback (make time ‘run fast’), or slow it down (make time ‘run slow’), or even play it *backwards* (make time ‘run in reverse’). For various technical reasons, generically called *spectrum shifting*, such tricks are often quite useful. Now, the way we retrieve magnetically recorded information from (for example) a magnetic tape, is to run it through a playback machine with a ‘read-head’ that senses the magnetic flux variations. The electrical signal produced by the read-head is just like the original signal and, in fact, we can pretend we don’t know it is really coming off a tape, but rather that it *is* the original signal. For high-quality digitally recorded tapes and disks, in fact, it is virtually impossible to distinguish the original from a playback.

Now, suppose we construct our playback machine with *two* read-heads, with the new head sensing the recording slightly *before* the old head does. The two heads produce the same electric signal, of course, but the signal from the new head is *ahead* in time compared to the signal from the old head. The new head is, in a certain sense, ‘seeing the future’ of the old head! We can use these two signals, the old head representing ‘now’ time and the new head representing ‘future’ time, to build real systems that are *not* causal. The causality violation occurs in non-real time, of course, not *our* time, but no matter; some absolutely astonishing signal processing can be achieved this way. The universe is about fifteen billion years old, and pretending that time has shifted a few milliseconds or so doesn't seem to be too much violence to reality.

Two heads are often used on radio call-in talk shows to catch inappropriate remarks from intemperate callers and prevent them from being broadcast. A short time delay is introduced by first recording remarks 'live' on tape with a write head and, then a few seconds 'up-stream,' a read head regenerates the remarks for broadcast. A 5 s delay is generally sufficient, so what is heard on a radio receiver *now* actually occurred 5 s ago in the *past*. A caller can get terribly confused if she doesn't turn her own receiver off, because one ear hears the present on the telephone while the other ear listens to the past over the radio.[43] The 1956 British film *Timeslip* incorporates a similar situation, with an atomic scientist's perception advanced 7 s into the future as the result of an accidental radiation exposure. His resulting confusion and disorientation is the center of the film.[44]

2.4 Backward Causation

> "Causation as a topic of philosophical discussion refuses to die. Each year, books and articles on causation continue to pour forth. Of course, all this activity may simply be a symptom of the necrophilia that infests so much of philosophy."[45]

All of the previous discussion has fueled countless arguments about what is called *backward*, *reverse*, or even *retro* causation. What is generally meant by forward causation is, of course, that any event that occurs at time t is caused by events that all occurred at some earlier time(s). Backward causation says that at least one of the causing events occurs after time t—this should make it clear that backward causation is a close relative of time travel. Indeed, one philosopher uses the terms *time traveler* and *retro-causal engineer* interchangeably.[46] The topic, understandably, is at the root of many hot philosophical debates, though not everybody (as this section's opening quote makes clear) thinks those debates are illuminating.

Just *why* does Professor Earman take his harsh position? He offers, as one reason, his disdain for the common philosophical 'proof' of the impossibility of backward causation: By definition, a cause is always before its effect. Yes, that's the entire 'proof.' One can, of course, win *any* argument by *defining* the answer to be what it is you wish to believe. More interesting, and certainly more pertinent to time travel, is the argument that if backward causation were possible then one could change the past—but that cannot be done because the past is dead and gone and thus unchangeable. That does seem to be a pretty solid argument against backward causation,[47] but Earman rebuts it by pointing out that the very same logic could be applied to the future, and so the usual, uncontested forward causation would also be denied. That is, one could argue that whatever the future will be, *will be* (literally 'by definition'), so one cannot change the future. A similar argument was presented even earlier,[48] in which we find "suppose that someone says 'I can change the future. I can do *this* or I can do *that*.' Well, then, suppose that he does *that*. Has he changed the future? No, because doing *that* was the future."

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[43] A science fiction use of this idea is in B. W. Aldiss, "Man In His Time," *Science Fantasy*, April 1965, the story of an astronaut who returns from a trip to Mars and finds himself 3.3077 min ahead of everybody else.

[44] Science fiction had used a twist on this idea long before the film; see E. Binder, "The Man Who Saw Too Late," *Fantastic Adventures*, September 1939, a tale of what it might be like to have a 3 min *delay* in your vision.

[45] J. Earman, "Causation: A Matter of Life and Death," *Journal of Philosophy*, January 1976, pp. 5–25.

[46] B. Brown, "Defending Backwards Causation," *Canadian Journal of Philosophy*, December 1992, pp. 429–443.

The reversal of the 'usual' causal order of events by backward time travel has been a mainstay of science fiction almost from the start of the genre. Consider, for example, this tale.[49] A man on vacation by himself, without his wife along, meets a young lady—and they fall in love. The man loves his wife, too, though, and he realizes (as the young lady leaves him for the last time), never to return, that it is all for the best. But she really hasn't gone that far away from him, as the reader soon discovers. She is a time traveler from the future, and after leaving him she goes even further back in time, back an additional 20 years. She does this because she has learned that he met his wife 20 years ago, and so she goes back to be *that* woman! Thus, the usual causal order of the two events 'a long marriage' and the 'pre-marriage courtship' has been reversed (if we accept the fact that the man doesn't remember what his wife looked like when they married).

Actually, even our everyday uses of cause and effect are not nearly so straightforward as one might think, even when they are under far less stress than backward causation and time travel inflict. Consider, for example, the endless problems that are easy to imagine in the legal world. If a man falls off the roof of a ten-story building and is electrocuted as he plunges through power lines while still twenty feet above ground, was gravity or electricity the cause of death? Or was it both? As this example and others demonstrate,[50] one clearly does not have to discuss time travel to get into a serious argument about cause and effect. But with time travel, and the resultant backward causation, things can become even more perplexing. For example, we normally think it foolish to prepare, now, for an event that has already happened, but the prudent time traveler about to visit an ice age in the distant past would be wise to pack a fur coat before getting into his time machine!

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[47] See, for example, D. H. Mellor, "Fixed Past, Unfixed Future," in *Michael Dummett: Contributions to Philosophy* (B. M. Taylor, editor), Martinus Nijhoff 1987.

[48] J. J. C. Smart, "A Review of *The Direction of Time*," *Philosophical Quarterly*, January 1958, pp. 72–77.

[49] R. F. Young, "The Dandelion Girl," *The Saturday Evening Post*, April 1, 1961.

[50] See also P. Mackie, "Causing, Delaying, and Hastening: Do Rains Cause Fires?" *Mind*, July 1992, pp. 483–500.

One philosopher provides, I think, a good start at explaining why so many other philosophers (and not just a few physicists) have adopted the ‘common sense’ position of rejecting backward causation. As he writes, “Part of the answer, no doubt, is a confusion between affecting and altering [the past—a distinction we’ll discuss at length later in this book]. We cannot alter the past. But then we cannot alter the future either, although we can affect it. However, I take the common-sense rejection of backward causation to be, for the most part, quasi-empirical. It is based on a thought experiment. Think how you would set about affecting the past. By building a time-machine, perhaps? But how would you build one? We have no idea how to start. Yet, by contrast, we can work out how to affect the future . . . we just move our bodies.”[51] But, as he goes on to argue, if we accept that we can’t *change* the past (which means there is no way we could actually observe backward causation), then there still exists the possibility that past events were as they were because of events in the future.

Are there actual phenomena that justify a belief in the possibility of effect before cause in real time (not just in tape recorder time)? The only example I know of, and a controversial one at that, is a theoretical result from a reformulation of electrodynamics by the great English physicist Paul Dirac (1902–1984). Classical theory models electric charges as point objects of zero size, which causes problems when one tries to calculate certain details, such as the total field energy of a single electron. The answer comes out as infinity. In an attempt to find more reasonable (that is, finite) answers to such questions, Dirac modified the zero size of a charge to one taking them to be extended objects (while retaining the validity of Maxwell’s equations for electrodynamics right down to a point). To calculate how such extended objects will behave mechanically, however, one has to include what are called the *self-interaction* forces, such as the force one side of an electron exerts on the other side.

When it was all worked through, Dirac arrived at a third-order differential equation of motion, an equation that involves a force term proportional not to the usual first time derivative of the velocity (that is, to the acceleration), but rather to the second derivative.[52] This force is proportional to the first derivative of the acceleration, and is a quantity of direct interest mostly to the designers of automobile suspensions, who call it the *jerk*. There is no force in physics, at least not in Newtonian physics, that shows that sort of dependence, and there are some curious consequences. For example, in Dirac’s theory an electron experiencing no external force can still continually accelerate, exhibiting what is called a ‘runaway solution.’

Dirac showed how the runaway solution can be eliminated by picking a particular value for what up to then was an arbitrary constant of integration in the analysis, but that trick causes, in turn, a new problem called 'pre-acceleration.' That is, if an electron experiences an external disturbance (Dirac considered a passing pulse of electromagnetic radiation), then the electron will start to move *before* the pulse reaches it! Now that does seem to be a pretty clear example of backward causation. The time interval during which the pre-acceleration occurs is very short, on the order of the time it takes light to travel across the spatially extended electron (about 10^{-24} s), but no matter. The apparent crack in the door of causality may be slight, but it was enough to satisfy some philosophers seeking scientific support for backward causation.

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[51] P. Forrest, “Backward Causation in Defense of Free Will,” *Mind*, April 1985, pp. 210–217.

[52] P. A. M. Dirac, “Classical Theory of Radiating Electrons,” *Proceedings of the Royal Society A*, August 1938, pp. 148–168.

Not everybody liked this, however. One physicist was clearly uneasy about it, calling pre-acceleration "unpleasant" acausal behavior.[53] On the other hand, one can find believers, too.[54] Others have argued that the whole business is simply a non-problem. One philosopher, in fact, raised a very interesting technical point, arguing that Dirac's equation is non-Newtonian (remember the *jerk* force) and so we have no reason for coupling force and acceleration together as a cause-and-effect pair.[55] In Newtonian mechanics we do use that particular coupling, yet we do not think of force and velocity as a cause-and-effect pair because there is an integration operation involved in getting from to the other. Similarly, in Dirac's theory we have an integration operation separating force and acceleration.

One curious aspect to the debate on pre-acceleration is that many commentators seem not to have paid much attention to what Dirac himself had to say about it. As a Nobel laureate, it hardly seems likely that he would let such a result pass unnoticed and, indeed, his paper contains the following physical explanation: "It would appear that we have a contradiction with elementary ideas of causality. The electron seems to know about the pulse before it arrives, and to get up an acceleration … The behavior of our electron can be interpreted in a natural way, however, if we suppose the electron to have a finite size. There is then no need for the pulse to reach the center of the electron before it starts to accelerate. It starts to accelerate … as soon as the pulse meets its outside. Mathematically, the electron has no sharp boundary."

Two physicists suggested a fascinating connection between travel backward in time and Dirac's relativistically correct, quantum mechanical description of an electron.[56] They showed that in flat, two-dimensional spacetime the assumption of time travel to the past leads in a natural way to Dirac's equation. If, on the other hand, time travel only into the future is assumed, then additional assumptions are required to derive Dirac's equation. This connection between Dirac's equation and time travel to the past makes some philosophers and physicists nervous, but it didn't seem to bother Dirac. In fact, he went on in his paper to show how the pre-acceleration implies the possibility of building a device for sending a faster-than-light signal backward in time. Science fiction writers were, of course, quick to grasp that idea and such gadgets were dubbed "Dirac radios."[57]

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[53] P. C. W. Davies, *The Physics of Time Asymmetry*, University of California Press 1977.

[54] J. Earman, "An Attempt to Add a Little Direction to 'The Problem of the Direction of Time'," *Philosophy of Science*, March 1974, pp. 15–47.

[55] A. Grunbaum, "Is Preacceleration of Particles in Dirac's Electrodynamics a Case of Backward Causation? The Myth of Retrocausation in Classical Electrodynamics," *Philosophy of Science*, June 1976, pp. 165–201.

[56] D. G. McKeon and G. N. Ord, "Time Reversal in Stochastic Processes and Dirac's Equation," *Physical Review Letters*, July 6, 1992, pp. 3–4.

One of the more perplexing aspects of backward causation is that it seems to allow for the possibility of *causal loops*, and for the breaking of such loops, a central feature in many of the very best time travel stories. For example, suppose there is a gadget such that if I push its control button *now*, then today's lecture notes will have appeared in the gadget's output tray *yesterday*. Indeed, yesterday I found today's notes there and, in fact, I am about to go to class to deliver that lecture. A mighty good one it is, too, so I think I think I'll send it back to yesterday in just a few minutes with the help of the gadget. But I haven't yet pushed the button. What if I now decide *not* to push the button? Why did the notes appear so I could use them today? Philosophers call this potential breaking of a causal loop a *bilking paradox*. Later in the book I'll discuss how such paradoxes have regularly appeared in the physics and philosophy literature since the 1940s.

By contrast, such paradoxes had been discussed in the science fiction magazines long before World War II. For example, in a letter to the editor at *Astounding Stories* (June 1932) a fan clearly stated his objection to time travel with the aid of a bilking paradox. He suggested the following experiment: Immediately publish an open offer to the inventor of time travel (who will be born, presumably, at some future date) to travel back to one week before the offer is published. But of course (argued the fan) we'd have a pretty problem if we then decided not to publish the offer after the inventor showed up! As that fan wrote, "Paradoxical? I'll say so, if time travel is possible." That fan didn't know about what seems to be a generic limitation on time machines, however: that one can't travel back to a date before the date of the time machine's creation. Thus, that fan's particular bilking paradox actually has no force.[58]

For another fictional example of a bilking paradox, consider the story[59] of time travelers who, just before they begin a trip into the future, see Earth invaded by Martians. At first the invaders are unbeatable, but then the defending military forces of Earth suddenly and mysteriously acquire a fantastically powerful new weapon. It isn't long before the time travelers realize where it came from—they themselves will go into the far future, obtain the weapon, and then return with it to what is now their own past (when the weapon first appeared). But then they wonder what might happen if they don't go, if instead they 'cheat time.' After all, they reason, why bother now to hunt for the weapon when the invasion has already been defeated? We are told that this potential bilking paradox is a “sinister conception, crawling evilly within their brains, like an unanswerable enigma.”

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[57] See, for example, J. Blish, "Beep," *Galaxy Science Fiction*, February 1954.

[58] A similar bilking paradox had actually appeared the year before in the 1931 novel *Many Dimensions* by the English writer Charles Williams (1886–1945), which reads like a suitable script for an Indiana Jones movie.

[59] E. Binder, "The Time Cheaters," *Thrilling Wonder Stories*, March 1940. There is an amusing reference in this tale to Orson Welles' famous radio-drama-hoax, from just 2 years earlier, of just such an alien invasion based on H. G. Wells' *War of the Worlds*.

Some philosophers, and practically all physicists, agree with that last assessment about bilking paradoxes, and so they believe there is simply nothing more to say. That is, bilking puzzles like the one in “The Time Cheaters” show that causal loops (and backward causation) must be impossible. Many feel this way about time loops, and backward causation, because (as is well known) time travel to the past can create all sorts of paradoxes. But such paradoxes are offensive only to human, culturally-biased intuitions on ‘how things ought to work,’ and not to the laws of physics which are indifferent to a reversal in the direction of time—which of course underlies what time travel is all about.

As the great American chemist G. N. Lewis expressed it, “Our common idea of time is notably unidirectional, *but this is largely due to the phenomena of consciousness and memory* [my emphasis].”[60] Lewis’ words caught the eye of the editor at one science fiction magazine, who summed it up for his readers in a half-page essay that contained dramatic words hinting at backward causation: “A new theory of time . . . reveals the possibility that events now occurring are among the factors that decided Caesar nearly 2,000 years ago to cross the Rubicon.”[61]

Lewis’ willingness to accept causality violations is not a universally popular view today. For example, one physicist has written[62] that “It is fair to say that most conservative physicists have very serious reservations about the admissibility and reality of causality-violating processes. Causality violation (i.e., the existence of a ‘time machine’) is such an extreme violation of our understanding of the cosmos that it behooves us to be as conservative as possible about introducing such unpleasant effects into our models.” He then goes on to declare closed timelike loops to be verboten because “the existence of closed timelike loops leads us to such unpleasant situations as meeting oneself 5 min ago.” He sums up his philosophical position nicely with “any theory that is ‘just a little bit causality violating’ is ‘just a little bit inconsistent.’”

Agreeing with this physicist is at least one philosopher who believes that the “association of causality with a particular temporal direction is not merely a matter of the way we speak of causes, but has a genuine basis in the way things happen” and that there is indeed an asymmetry with respect to past and future that is bound up with our concept of intentional action.[63] He then goes even further when he continues with the claim that being an agent of cause is not a necessary condition for seeing the asymmetry; being an observer is enough, as even an immobile yet intelligent tree (!) could detect the difference between past and future. (How he knows this about certain trees is left unexplained.)

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[60] G. N. Lewis, “The Symmetry of Time in Physics,” *Science*, June 6, 1930, pp. 569–577.

[61] Editorial essay, “Two-Way Time,” *Astounding Stories*, September 1931.

[62] M. Visser, “Wormholes, Baby Universes, and Causality,” *Physical Review D*, February 15, 1990, pp. 1116–1124.

[63] M. Dummett, “Bringing About the Past,” *Philosophical Review*, July 1964, pp. 338–359.

The everyday views of causality that we have formed through our limited experiences when living in a world in which time travel is ‘uncommon’ may actually be incomplete. As the British philosopher Bertrand Russell (1872–1970) said with some humor long ago, in his 1912 Presidential Address (“On the Notion of Cause”) to the Aristotelian Society, “The law of causality, I believe, like much that passes muster among philosophers, is a relic of a by-gone age, surviving, like the monarchy, only because it is erroneously supposed to do no harm.” And I do agree with his fellow philosopher who, decades later, declared “The concept of cause is powerless to solve the problems posed by the concept of time. The fundamental laws of physics present our most careful, best established and most sophisticated understanding of time. Notoriously, nothing in these laws endorses the idea of a *flow of time nor of the direction* [my emphasis: we’ll return to both of these issues later in this chapter] which is basic to our conception of it. Nor are these laws causal (in the sense of singling out causes) even when they are deterministic. The concept of cause is not a fundamental one and cannot illuminate the darker corners in our understanding of the fundamental concept of time.”[64]

2.5 The Fourth Dimension

> “We are facing an invasion of fourth dimensional creatures . . . We are being attacked by life which is one dimension above us in evolution. We are fighting, I tell you, a tribe of hellhounds out of the cosmos. They are unthinkably above us in the matter of intelligence. There is a chasm of knowledge between us so wide and deep that it staggers the imagination.”[65]
>
> “Fourth dimension. Time factor. *You* know . . .”[66]

The idea of a fourth dimension to *space* has long been a staple of science fiction, but it has also long been viewed with suspicion. Indeed, many quite sophisticated scientists have thought it to be quite mysterious. For example, in his 1897 Presidential Address to the American Mathematical Society, the Canadian/American astronomer-mathematician Simon Newcomb (1835–1909) declared "The introduction of what is now very generally called hyperspace, especially space of more than three dimensions, into mathematics has proved a stumbling block to more than one able philosopher." Einstein stated Newcomb's view in blunter terms when he wrote "The non-mathematician is seized by a mysterious shuddering when he hears of 'four-dimensional' things, by a feeling not unlike that awakened by thoughts of the occult."[67]

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[64] G. Nerlich, “How to Make Things Have Happened,” *Canadian Journal of Philosophy*, March 1979, pp. 1–22.

[65] From “Hellhounds of the Cosmos,” *Astounding Stories*, June 1932, by Clifford Simak (1904–1988). Simak went on to write a number of much better tales, but this passage lends credence to the editorial introduction to the 1957 anthology *Famous Science-Fiction Stories* (Random House) that declared so much in the early pulp science fiction was “science that was claptrap and fiction that was graceless.”

[66] Uninformative ‘explanation’ given to a befuddled, inadvertent time traveler who emerges miles away and one hour backward in time after a wild ride through the fourth dimension in a gadget (constructed from a bicycle tire!) in the shape of a three-dimensional Möbius strip (see note 99 in Chap. 1). From the story by H. Nearing, Jr., “The Maladjusted Classroom,” *The Magazine of Fantasy and Science Fiction*, June 1953.

To see just how right Einstein was with this observation, consider the reaction one Egyptian philosopher had (in 1929) to Einstein's own writings: "We have no doubt in our mind that nobody can understand it (the fourth dimension), including Einstein himself. The incomprehensibility of these assumptions [of general relativity] is due to their nature. They deal with the fourth dimension . . . and the reality of time and space. They can only be described by a mathematician's hypothesis or by religious faith."[68] This reaction is easy to understand—after all, anybody can 'see' that there are exactly three spatial dimensions, and that is that!

The 1901 novel *The Inheritors*, by the English writer Ford Madox Ford (1873–1939), like Simak's, is the tale of an insidious hyperspace invasion of our world. It illustrates Einstein's assertion about how many people react to the fourth dimension with an example from the time before the science fiction magazines. When the novel's narrator is bluntly told by an invader that she (the invader) is from the fourth dimension—an idea inspired by Ford's appreciation of how much success his acquaintance H. G. Wells had enjoyed with it—he recoils from that claim with the words "If you expect me to believe you inhabit a mathematical monstrosity, you are mistaken." And who can really blame that skeptical narrator? How can there be *four* spatial dimensions? No less an authority than Aristotle, writing in 350 B.C., had declared in his essay "On the Heavens" that "the three dimensions are all that there are."

Others were not so sure. In 1873, for example, we find an essay in *Nature* that refers to well-known mathematicians who even earlier had shown that they had an inner assurance of the reality of transcendental space (hyperspace).[69] The American philosopher Charles Sanders Peirce (1839–1914) was also an early advocate for the four-dimensionality of space. Just what he thought the nature of the fourth dimension to be is somewhat unclear, but the context of what he said suggests he took it to be spatial. He thought three-dimensional space to be "perverse" because of the existence of incongruous counterparts (such as left- and right-handed gloves), and this was apparently strong evidence for him that space could not be three-dimensional. Now, incongruous counterparts exist in all n-dimensional spaces, but Peirce preserved the special purity of the fourth dimension by suggesting that all physical objects, although capable of motion in the fourth direction, could themselves have no extent in that direction (remember, Peirce was a philosopher, not a physicist, and he offered no experimental support for any of this).[70]

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[67] A. Einstein, *Relativity: the Special and General Theory*, Crown 1961, p. 33.

[68] From A. A. Ziadat, "Early Reception to Einstein's Relativity in the Arab Periodical Press," *Annals of Science*, January 1994, pp. 17–35.

[69] G. F. Rodwell, "On Space of Four Dimensions," *Nature*, May 1, 1873, pp. 8–9.

But is it *really* possible that there could be *four* spatial dimensions? We experience three independent directions, each lying at a right angle to the other two—but why just *three*, and not ten or fifteen? Indeed, in an 1888 talk to the Philosophical Society of Washington, Simon Newcomb dismissed the view that space must necessarily be three-dimensional as an "old metaphysical superstition." Yet, despite Newcomb's open-mindedness, it has been shown that in the framework of classical physics there are, in fact, several powerful reasons for why there must be *exactly three* spatial dimensions.

The beginning of a scientific explanation for the dimensionality of space appears in Kant, who believed the *three* dimensions of space and Newton's inverse-square law for gravity are intertwined (but he offered nothing beyond philosophical speculation). The origin of Kant's view is actually quite old, dating back to the ancient Greeks, who had already begun to suspect that there was something special about *three* dimensions, at least as far as geometry was concerned. They knew of the infinity of regular two-dimensional polygons, but that there were just five regular polyhedrons in three dimensions (the so-called *Platonic solids*). This early observation was trapped in mystical speculations, however, and it wasn't until the development of physics as a science that non-mystical discussions on the dimensionality of space began to appear.

Beginning with the work of Einstein's friend, the Austrian/Dutch physicist Paul Ehrenfest (1880–1933) in 1917, we can find the idea that the Poisson-Laplace equation, a second-order partial differential equation that describes the potential functions for both Newtonian gravity and electrostatics, does not allow for stable planetary or electronic orbits in *any* space with dimensionality greater than three. Further, the distortionless, reverberation-free propagation of both electromagnetic and sound waves is possible only in spaces of dimensions one and three. These conclusions have been shown to hold even when we go beyond nineteenth century physics into general relativity and quantum mechanics.[71]

Using a slightly different approach, a biological-topological argument for why space cannot have fewer than three dimensions exists. In all of our common experience, complex intelligent life is always found to occur as an aggregate of a vast number of elementary cells, interconnected via electrical nerve fibers. Each cell is connected to several others, *not all immediate neighbors*, by these fibers. If space had only one or two dimensions, then such highly interconnected nets of cells would be impossible because the overlapping nerve fibers would have to intersect, which would result in their mutually short-circuiting one another.

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[70] R. R. Dipert, "Peirce's Theory of the Dimensionality of Physical Space," *Journal of the History of Philosophy*, January 1978, pp. 61–70.

[71] See, for example, I. M. Freeman, "Why Is Space Three-Dimensional?" *American Journal of Physics*, December 1969, pp. 1222–1224, and L. Gurevich and V. Mostepanenko, "On the Existence of Atoms in n-Dimensional Space," *Physics Letters A*, May 31, 1971, pp. 201–202.

It wasn't long before these views on the dimensionality of space found their way into science fiction. An early use of space as four-dimensional occurs in an awkward rewrite of Jules Verne's *Around the World in Eighty Days*, in which a professor and his crew fly into hyperspace and around the world and to the moon and back, in less than a day.[72] They do this with a plane equipped with a four-dimensional rudder! More interesting is the tragic story (originally published in 1926) of a math professor who learns how to move into hyperspace and back.[73] A colleague catches him at it and, once over his astonishment, asks what is behind it all. The professor replies, "My assumption is that the fourth dimension is just another dimension—no more different in kind from length, say, than length is from breadth and thickness, but perpendicular to all three. Now suppose that a being in two dimensions—a flat creature, like [a moving shadow on a surface]—were suddenly to grasp the concept of a third dimension and so step out of the [surface]. He might move only an inch, but he would vanish completely from the sight of the world."

The professor has similarly learned how to step out of 3-space and into 4-space but, when asked to explain *how*, all he can say is "How can I explain? It's just the *other* direction. It's *there*!" His colleague can't see it, but nonetheless is quick to grasp the practical implications: "This is power! Think of it! A step, and you are invisible! No prison cells can hold you, for there is a side to you on which they are as open as a wedding ring! No ring is secure from you: you can put your hand *round the corner* and draw out what you like. And, of course, if you looked back on the Universe you had left, you would see us in sections, open to you! You could place a stone or a tablet of poison right in the bowels of your enemies!"

What the professor's colleague is getting at involves a comparison with a prison in planar 2-space, which would merely be a circle around the captive. Knowledge of the third dimension would make it possible to escape, however, by simply moving along that new direction, over the circle, and then back into the plane. To a 2-space guard it would seem that the prisoner had suddenly vanished from view *inside* the circle and then just as suddenly materialized again *outside* the circle. Similarly, to escape from a 3-space prison, one would merely move along the fourth dimension, and in the same way one could remove the yolk from an egg without damaging the shell; indeed, one could remove the yolk directly from the chicken without damaging the chicken![74]

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[72] B. Olsen, "Four Dimensional Transit," *Amazing Stories Quarterly*, Fall 1928.

[73] R. Hughes, "The Vanishing Man," reprinted in *The Mathematical Magpie* (C. Fadiman, editor), Simon and Schuster 1962.

[74] This astounding insight appeared in early pulp science fiction in, for example, M. J. Breuer, "The Appendix and the Spectacles," *Amazing Stories*, December 1928. The concept appeared even earlier in Bob Olsen, "The Four-Dimensional Roller-Press," *Amazing Stories*, June 1927, and then later in Olsen's "The Great Four Dimensional Robberies," *Amazing Stories*, May 1928 to rob locked safe deposit boxes, and "The Four Dimensional Escape," *Amazing Stories*, December 1933, in which a man sentenced to die by hanging at San Quentin Prison is rescued, while standing on the gallows' trap, by an inventor who pulls him through the fourth dimension.

In a later tale[75] we meet another professor who dramatically uses this very feature of the fourth dimension. His right hand has been modified through an accident to exist in four-dimensional hyperspace and so, to finance his research, he uses his ‘talent’ to become the perfect pickpocket, able to reach into any wallet no matter how well secured. He also can, indeed, reach right into the very bowels of his fellow man. And he *does*. When he demonstrates his hand to the policeman who has arrested him for being a thief, the astonished officer chokes on a lemon drop. Dr. Fuddles then, of course, does the right thing and removes the drop from the poor fellow with ease. There is one additional aspect to Dr. Fuddles’ hand, however, that the story missed. If he had turned his right hand over in the fourth dimension, then he would have had *two* left hands!

It was discovered in 1827 by Möbius (of the strip) that any three dimensional object can be converted into its mirror image by flipping it over through the fourth dimension. Thus, a left-handed glove can be made by pure geometry (no scissors, thread, or needle required) into a precise copy of its right-handed mate. If a living organism is so flipped, however, there may be a problem, as everything in the body would be reversed, including the optically active organic molecules discovered by Pasteur in 1848, which are involved in vital biological processes. These molecules, called *stereoisomers*, exist in two versions in nature (the left-handed and the right-handed versions, if you will), but our bodies have developed the ability to use only one version. To be flipped through the fourth dimension would make some reversed stereoisomers unable to participate in the digestion of food and we would starve to death.

For modern science fiction writers the fourth dimension (and hyperspace, in general), is still a major concept. One physicist, writing in *Analog* (today’s premier ‘hard science’ fiction magazine), summed up nicely what was so fascinating in early pulp, and still is today, about the idea of an extra dimension or two, or perhaps even more, at least from a fictional point of view: “Are there hidden dimensions not accessible to us, dimensions in which we could go adventuring, dimensions within which malevolent hyper-dimensional aliens may be lurking, ready to pierce our flimsy paper-thin three-space bodies with their terrible hyper-sharp claws?”[76] The early pulp science fiction magazines encouraged this lurid imagery. Witness the editorial blurb that opened one many-dimensional monster story as follows: “It was a strange world in which Lester and Florence found themselves. A world of sudden

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[75] N. Bond, “Dr. Fuddle’s Fingers,” in *Mr. Mergenthwirker’s Lobblies and Other Fantastic Tales*, Coward-McCann 1946.

[76] J. Cramer, “The Other Forty Dimensions,” *Analog*, April 1985. ‘Monsters in hyperspace’ stories were numerous in pulp science fiction. Three examples (in no particular order of literary merit!) are: M. J. Breuer, “The Einstein See-Saw,” *Astounding Stories*, April 1932; P. Ernst, “The 32nd of May,” *Astounding Stories*, April 1935; “The Monster from Nowhere,” *Fantastic Adventures*, July 1939.

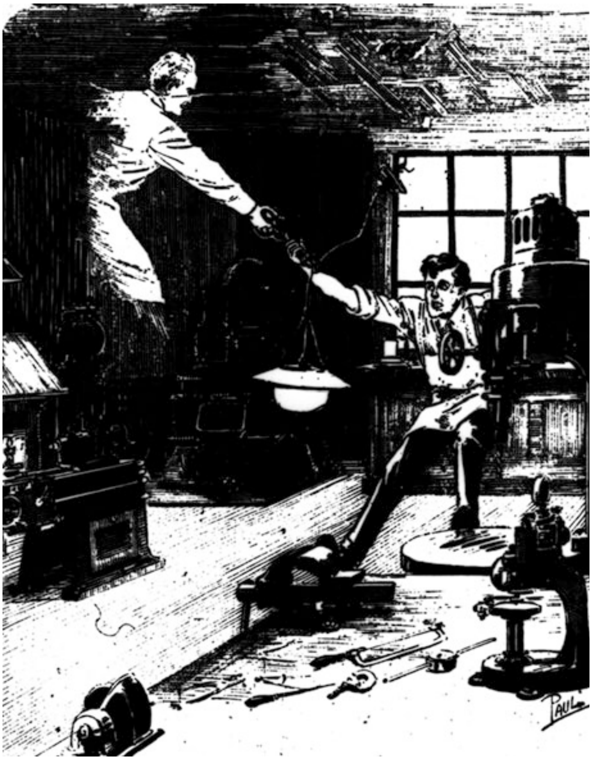

Fig. 2.1 An experiment in hyperspace goes astray. The young man is pulling on "hyper-forceps" in an attempt to retrieve a surgeon who has fallen out of 3-space (along with his patient, a professor of non-Euclidean geometry, who suffers from gallstones). The hyper-forceps allow the removal of the gallstones without cutting into the body. Illustration by Frank R. Paul, ©1928 by Experimenter Publishing Co. for "Four Dimensional Surgery" (*Amazing Stories*, February 1928) by Bob Olsen, reprinted by permission of the Ackerman Science Fiction Agency, 2495 Glendower Ave., Hollywood, CA 90027 for the Estate

death and strange science, ruled by inhuman beasts."[77] But as outrageous as that might sound, the real physics of hyperspace is even more amazing.

Hyperspace is, in general, simply any space with more dimensions than the one we obviously seem to live in. In particular, our universe appears to be a four-dimensional (three spatial and one temporal) hyperspace called *spacetime*. This four dimensional world can, at least mathematically, be thought of as the boundary surface of a five dimensional hyperspace. This is analogous to the way the two-dimensional space of the surface of a sphere bounds the three-dimensional space of the sphere itself. This interesting imagery appeared quite early in pulp science fiction. For example, in one remarkably sophisticated story, an eccentric scientist at one point exclaims "A mathematical physicist lives in vast spaces . . . where space unrolls along a fourth dimension on a surface distended from a fifth."[78]

There are some interesting geometrical implications to hyperspace which play big roles in time travel considerations. For example, for beings in the two-dimensional world of a sphere's surface there are *two* ways to travel from pole to pole. There is the usual way, *on* the surface of the sphere, and the hyperspace way which takes them *through* the sphere along the polar diameter. In imagery motivated by thinking of the sphere as an apple, and of the hyperspace path as a tunnel bored by a worm through the apple, it has become popular to call all such shortcuts, through any hyperspace of any dimension, *wormholes* (a word coined in the 1950s by the Princeton physicist-wordsmith John Wheeler). Wheeler used wormholes to show how electric charge could be thought of as lines of force trapped in the changing topology of a multiply connected space (indeed, Wheeler claimed that the observation of what we call electricity is experimental evidence that space is *not* simply connected).[79]

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[77] M. Duclos, "Into Another Dimension," *Fantastic Adventures*, November 1939. See the illustration for this story in "Some First Words."

[78] M. J. Breuer, "The Gostak and the Doshes," *Amazing Stories*, March 1930.

The general theory of relativity predicts the existence of wormholes in spacetime and, in fact, they were first 'discovered' theoretically in the mathematics of relativity as early as 1916 by the Viennese physicist Ludwig Flamm (1885–1964). Later analyses were done by Einstein, himself.[80] Wormholes have been discussed as a possible model for pulsars (as opposed to the more usual model as rotating neutron stars).[81] It has also been suggested that the interior of a charged black hole may be the entrance to a wormhole.[82] All of these various solutions to the gravitational field equations are generically called "Einstein-Rosen bridges" in the physics literature (see note 81, for example), and the term soon appeared in fiction, too.[83]

The use of hyperspace wormhole portals for explaining some observed physical phenomenon appeared in the scientific literature long before Wheeler's electricity example. In his 1928 book *Astronomy and Cosmogony*, for example, the British theoretician Sir James Jeans devoted a chapter to what were then called nebulae, the island-universes we now call galaxies. At the end of his discussion on the arms of spiral galaxies, Jeans offered the following speculation: "Each failure to explain the spiral arms makes it more and more difficult to resist a suspicion that the spiral nebulae are the seats of types of forces entirely unknown to us, forces which may possibly express novel and unsuspected *metric properties of space* [my emphasis]. The type of conjecture which presents itself, somewhat insistently, is that the centers of the nebulae are of the nature of 'singular points,' at which matter is poured into our universe from some other, and entirely extraneous, special dimension, so that, to a denizen of our universe, they appear as points at which matter is being continually created." This, in everything but name, is a wormhole.

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[79] A space is simply connected if *all* the points on the straight line that joins *any* two points in the space are also in the space. The interior of a sphere is simply connected. The interior of a sphere with a hole in it is *not* simply connected.

[80] A. Einstein, "The Particle Problem in the General Theory of Relativity," *Physical Review*, July 1, 1935, pp. 73–77.

[81] J. M. Cohen, "The Rotating Einstein-Rosen Bridge," in *Relativity and Gravitation* (C. G. Kuper and A. Peres, editors), Gordon and Breach Science Publishers 1971.

[82] A. Ori, "Inner Structure of a Charged Black Hole: An Exact Mass-Inflation Solution," *Physical Review Letters*, August 12, 1991, pp. 789–792.

[83] See, for example, J. G. Cramer, *Einstein's Bridge*, Avon 1997 (this is the same Cramer cited in note 76). The *Rosen* comes from the American-Israeli physicist Nathan Rosen (1909–1995), who was a collaborator of Einstein's.

What would hyperspace be like? It is intuitively obvious that in the case of the 2-D surface of a 3-space sphere, the 'hyperspace' wormhole path is shorter than the surface path. Even if this 'shorter path' view holds for wormholes in our 4-D spacetime, however, getting around in science fiction hyperspace may not be a simple task. One tale, for example, tells the story[84] of how one of the first spaceships to explore hyperspace gets lost. The trouble with hyperspace travel is that "You go in at one point, you rocket around until you think it's time to come out, and there you are. Where is 'there'? Why, that's the surprise that's in store for you, because you never know until you get there. And sometimes not even then." The same idea plays a central role in Robert Heinlein's 1957 novel *Tunnel in the Sky*, in which a 'hyperspace gate' is discovered by accident during failed time travel experiments.

Another story[85] asks the same question about hyperspace, and arrives at the same answer: "When you took the Jump … how sure were you *where* you would emerge? The timing and quantity of the energy input might be as tightly controlled as you liked … but the uncertainty principle reigned supreme and there was always the chance, even the inevitability of a random miss … a paper-thin miss might be a thousand light-years."

A common way to visualize hyperspace wormhole shortcuts is to imagine the beginning and the end of a journey as points A and B on the 2-D surface of a piece of paper. Then imagine that the paper is folded so as to position A over B, perhaps with A almost touching B. The distance from A to B *through hyperspace* (the 3-D space in which the folding took place) can clearly be much less than is the distance through 'normal' space (the distance covered by a trip that always remains in the 2-D surface). This is the specific example used in one tale to explain the instantaneous "space-warp" (wormhole) device invented by the story's hero.[86] Such imagery actually appeared quite early in science fiction, as in one story in which a gadget is used to "bend space" so that Earth and Venus touch![87]

The idea of hyperspace folding has broken free from science fiction and can now be found in modern stories in other genres. For example, in one Stephen King story ("Mrs. Todd's Shortcut") a woman keeps finding ever shorter ways to drive from Castle Rock, Maine to Bangor. As the crow flies it is 79 miles, but she gets the journey down to 67 miles, and later to 31.6 miles. When doubted, she replies: "Fold the map and see how many miles it is then … it can be a little less than a straight line if you fold it a little, or it can be a lot less if you fold it a lot." The doubter remains unconvinced: "You can fold a map on paper, but you can't fold *land*."

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[84] F. Pohl, "The Mapmakers," *Galaxy Science Fiction*, July 1965.

[85] I. Asimov, "Take a Match," in *New Dimensions II: Eleven Original Science Fiction Stories* (R. Silverberg, editor), Doubleday 1972.

[86] G. O. Smith, "The Möbius Trail," *Thrilling Wonder Stories*, December 1948.

[87] E. L. Rementer, "The Space Bender," *Amazing Stories*, December 1928.

For the purpose of wormhole creation in spacetime, we actually have to imagine much more: the folding of four-dimensional spacetime through a five dimensional hyperspace. The folding imagery has even appeared in the movies: spacetime folding is demonstrated with a piece of paper in both *Event Horizon* (perhaps the worst movie of 1997) and the 2014 *Interstellar*.

Another feature of hyperspace that science fiction has taken a liking to is its vastness. An interesting fictional treatment of this idea was given by a writer who, in real life, was an academic psychologist at the University of Michigan. He put himself in a story[88] of a starship captain who is explaining to the crew psychologist how he feels about hyperspace (or *subspace*, as it is called in the story): "God forsaken. That's just what it is. Completely black, completely empty. It frightens me every time we make the jump through it . . . it frightens me because—well, because a man seems to get lost out there. In normal space there are always stars around, no matter how distant they may be, and you feel that you've got direction and location. In subspace, all you've got is nothing—and one hell of a lot of that. It's incredible when you stop to think about it. An area—an opening as big as the whole of our Universe, big enough to pack every galaxy we've ever seen in it—and not a single atom of matter in it . . . until we came barging in to use it as a shortcut across our own Universe."

The vastness of hyperspace got a more humorous treatment from the early pulp science fiction writer Bob Olsen (1884–1956), who wrote the following verses[89] in the introduction to one of his many stories of the fourth dimension:

I read a yarn the other day—
A crazy concept, I must say.
It states that objects have extension
In what is called the "Fourth Dimension."
In hyperspace one could, no doubt,
Make tennis balls turn inside out;
And from a nut remove the kernel
And not disturb the shell external.
A crook could pilfer bonds and stocks,
Then laugh at prison bars and locks,
One step in this direction queer,
And presto! He would disappear!
Let's hope, in planning new inventions,
They'll give us cars with four dimensions.
When searching for a parking place
We sure could use some hyperspace!

It is not just science fiction that takes hyperspace seriously. We find a mathematician, for example, writing that "most science fiction addicts are familiar with the notion of 'hyperspace,' a higher dimensional space-time bounded by Space-Time through which, in the far distant future, interstellar voyages shortcut the (otherwise unsurmountable) distances between the stars. The purpose of this article[90] is to demonstrate that any . . . relativistic space-time model is the boundary of some . . . five-dimensional hyperspace." That is just what Breuer's magazine character (see note 78) said—in 1930!

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[88] J. V. McConnell, "Avoidance Situation," *If*, February 1956.

[89] B. Olsen, "The Four-Dimensional Auto-Parker," *Amazing Stories*, July 1934. "Bob Olsen" was the pen-name for Alfred Johannes Olsen.

The concept of *time* as a fourth dimension has long been a popular concept, and science fiction in particular has embraced it with enthusiasm. We find a little joke on the idea in a story where a young couple, visited by time travelers from 500 years in the future, are said to live in Apartment 4-D.[91] One physicist[92] traced the idea back to the late eighteenth century, finding references to the idea in pre-1800 works of the great French mathematical physicists Jean le Rond d'Alembert (1717–1783) and Joseph-Louis Lagrange (1736–1813). In fact, a philosopher[93] has found a 1751 passage written by d'Alembert that appears to indicate that it is some unknown, earlier person to whom the credit should really go: "I have said [that it is] not possible to imagine more than three dimensions. A clever acquaintance of mine believes, however, that duration could be regarded as a fourth dimension and that the product of time and solidity would be in some way a product of four dimensions; that idea can be contested, but it seems to me that it has some merit, if only that of novelty."

Still, it wasn't until a curious letter appeared in *Nature* in 1885 that the concept of time as the fourth dimension was mentioned seriously in an English-language scientific journal. The author, mysteriously signing himself only as "S.," began by asking "What is the fourth dimension? . . . I [propose] to consider Time as a fourth dimension . . . Since this fourth dimension cannot be introduced into space, as commonly understood, we require a new kind of space for its existence, which we may call time-space."[94] Who was this prophetic writer that, if he had just made a simple swap, would have been the first to use space-time as a word? Nobody knows. Bork speculates that it was an acquaintance of H. G. Wells, but Wells himself is on record that it certainly wasn't him.

In his 1934 *Experiment in Autobiography*, Wells wrote "In the universe in which my brain was living in 1879 there was no nonsense about time being space or anything of that sort. There were three dimensions, up and down, fore and aft and right and left, and I never heard of a fourth dimension until 1884 [when Wells was eighteen] or thereabout. Then I thought it was a witticism." He had, in fact, said this before. In a 1931 edition of *The Time Machine* (Random House), for example, he wrote in the Preface that the idea for the novel "was begotten in the writer's mind by students' discussions in the laboratories and debating society of the Royal College of Science in the eighties and already it had been tried over in various forms by him before he made this particular application of it."

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[90] G. S. Whiston, "'Hyperspace' (The Cobordism Theory of Space-Time)," *International Journal of Theoretical Physics*, December 1974, pp. 285–288.

[91] L. Padgett, "When the Bough Breaks," *Astounding Science Fiction*, November 1944.

[92] A. M. Bork, "The Fourth Dimension in Nineteenth-Century Physics," *Isis*, October 1964, pp. 326–338.

[93] E. Meyerson, *The Relativistic Deduction*, volume 83 of *Boston Studies in the Philosophy of Science*, D. Reidel 1985, p. 78.

[94] S., "Four-Dimensional Space," *Nature*, March 26, 1885, p. 481. The editorial staff at *Nature* has informed me that, more than a century-and-a-quarter later, there is no longer any record of the identity of S. in the journal's archives.

The idea of time as the fourth dimension entered the popular mind around 1894–95, with the publication of the first of Wells' so-called "scientific romances," *The Time Machine*. Then, after that pioneering use of time as the fourth dimension, science fiction quickly adopted the idea as the basis for one of its most popular subgenres. One of the great "golden age of science fiction" writers, 'Murray Leinster' (1896–1975)—the pen-name for William Jenkins—used it as the basis for his first published story.[95] It is the incredible tale of a Manhattan skyscraper (and its 2000 occupants) sent backward in time several 1000 years because its foundation slips (in an unexplained way) along the fourth dimension. The scientific sophistication of the story is primitive, with just one of the many logical flaws being a vivid description of the time travelers living forward-in-time even as their wrist watches run backward. Indeed, when pulp pioneering editor Hugo Gernsback reprinted the tale in one of the early issues of *Amazing Stories*, a reader complained about that very point. Gernsback felt compelled to defend the story, but could muster only a weak rebuttal based on an author's right to "poetic license."[96]

More technical is the discussion in the story of a clerk who transforms the main entrance to a department store into a time machine by building a tesseract (a four-dimensional cube).[97] The claim is made there that the fourth dimension of the cube/doorway is time. That tale appeared just 5 months after a classic of science fiction by Robert Heinlein (1907–1988) had appeared, also using a tesseract, in which the fourth dimension is taken as *spatial*.[98]

Some writers wanted to have the fourth dimension both ways, as space *and* time in the same story. One wonderful example of this is a classic,[99] written by one of the giants of science fiction. In that tale an electrical engineer named Nelson is caught in the middle of an enormous electromagnetic field surge produced by a short circuit in a power plant. As a physicist explains to the shocked board of directors of the utility, "It now appears that the unheard-of-current, amounting to millions of amperes . . . must have produced a certain extension into four dimensions . . . I have been making some calculations and have been able to satisfy myself that a

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[95] M. Leinster, "The Runaway Skyscraper," *Argosy*, February 1919.

[96] H. Gernsback, "Plausability in Scientifiction," *Amazing Stories*, November 1926.

[97] W. P. McGivern, "Doorway of Vanishing Men," *Fantastic Adventures*, July 1941.

[98] R. Heinlein, "—And He Built a Crooked House," *Astounding Science Fiction*, February 1941. Here we read of a Los Angeles architect who builds a house in the shape of a tesseract as it would appear if collapsed into normal three-dimensional space. It isn't stable in 3-space (we are told), however, and so a California earthquake is sufficient to topple the house into a stable 4-D configuration, along with its occupants.

[99] A. C. Clarke, "Technical Error," *Fantasy No. 1*, December 1946.

'hyperspace' about ten feet on a side was, in fact, generated: a matter of some ten thousand quartic—not cubic!—feet. Nelson was occupying that space. The sudden collapse of the field [when the overload breakers finally broke the circuit] caused the rotation of that space."

Being rotated through 4-space has inverted the unlucky Nelson [see *For Further Discussion* at the end of this chapter for more on this point], and to bring him back to normal he must be flipped again. The physicist brushes aside a question about the fourth dimension as time, asserting that the only issue is one of space. Poor Nelson is, therefore, again subjected to a stupendous power overload—only now he disappears! Too late, the physicist realizes that the fourth dimension is both space *and* time and that Nelson has been spatially flipped *and* temporally displaced into the future. To understand the particularly monstrous fate of Nelson, just ask yourself what the result would be if he should materialize *inside* matter sometime in the future!

The interpretation of the fourth dimension as time is, of course, the one of interest to prospective time travelers, to physicists studying time travel, and to philosophers of time, and so for us, too. The sort of science fiction that is of greatest interest to us is like the one in which one of the characters, displaced in time, asks for an explanation from a higher-dimensional being who appears on the scene: "'Just where is Tuesday?' he asked. 'Over there [and when the being extends its hand, the hand disappears].' 'Do that again.' 'What? Oh—Point toward Tuesday? Certainly.'" The being explains the physics of the situation to the astonished time traveler thus: "It is a direction like any other direction. You know yourself there are four directions—forward, sideward, upward, and—*that* way! ... It is the fourth dimension—it is duration."[100]

And how about stories like the one in which a mad inventor discovers how to make a substance whose atoms resist being pushed by "pushing back at right angles to all the other [spatial] directions." That is, to push on this exotic stuff is to risk experiencing a back reaction, of being pushed "off into the fourth dimension [which we are told is time] ... into the middle of the week after next."[101] Now wouldn't *that* really be something?!

But of course it was H. G. Wells who, in fiction, pioneered time travel and its connection to the fourth dimension as it is popularly thought of today (with the caveats about Wellsian time machines kept firmly in mind). We are therefore quite interested, as *The Time Machine* opens, to listening-in as the Time Traveller expounds to a group of friends at a dinner party in his London home. He starts with the assertion "There is no difference between Time and any of the three dimensions of Space except that our consciousness moves along it." When asked to say more about the fourth dimension, he replies, "It is simply this. That Space, as our mathematicians have it, is spoken of as having three dimensions, which one may call Length, Breadth, and Thickness, and it is always definable by reference to three planes, each at right angles to the others. But some philosophical people have been asking why *three* dimensions particularly—why not another direction at right angles to the other three?—and have even tried to construct a Four-Dimensional geometry. Professor Simon Newcomb was expounding this to the New York Mathematical Society only a month or so ago."[102]

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[100] T. Sturgeon, "Yesterday Was Monday," *Unknown Fantasy Fiction*, June 1941.

[101] M. Leinster, "The Middle of the Week After Next," *Thrilling Wonder Stories*, August 1952.

2.6 Spacetime and the Block Universe

> "And now he has preceded me briefly in bidding farewell to this strange world. This signifies nothing. For us believing physicists, the distinction between past, present, and future is only an illusion, even if a stubborn one."
>
> —Albert Einstein[103]

The poet Henry Van Dyke wrote, in his 1904 "The Sun-Dial at Wells College," words that echo the spirit of Omar Khayyam's *Rubaiyat* from nine centuries before:

The shadow by my finger cast
Divides the future from the past:
Before it, sleeps the unborn hour,
In darkness, and beyond thy power:
Behind its unreturning line,
The vanished hour, no longer thine:
One hour alone is in thy hands,—
The NOW on which the shadow stands.

The very next year Einstein's theory of special relativity appeared and, 3 years later, came Minkowski's spacetime interpretation of special relativity. Van Dyke's beautiful poetry was dealt a mighty blow by those developments in mathematical physics, and in the rest of this chapter we'll see how that came to pass.

The modern view of reality, that the past, present, and future are joined together into a four-dimensional entity called *spacetime*, is due to Hermann Minkowski (1864–1909), Einstein's mathematics teacher when he was a student in Zurich. Minkowski gave spacetime (the visual imagery of Einstein's mathematics) to the world during a famous address at the 80th Assembly of German Natural Scientists and Physicians in Cologne, on September 21, 1908. Entitled "Space and Time," his remarks were electrifying then and still are today.[104] He began dramatically: “Gentlemen! The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical.” Then came the famous line, quoted in so many freshman physics texts and philosophy papers, concerning the nature of spacetime: “Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve independence.” Minkowski explained what spacetime is in these words to his audience:

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[102] And so Newcomb actually was. Wells, it is certain, routinely read *Nature* (one of his college friends, Richard Gregory, eventually became the journal's editor), and Wells must have read Newcomb's address of December 28, 1893 to the New York Mathematical Society when reprinted in the February 1, 1893 issue (on pp. 325–329), where he called hyperspace "the fairyland of geometry." From the Time Traveller's own words, then, that wonderful Victorian dinner party must have taken place in January or February of 1894.

[103] From a letter written by Einstein on March 21, 1955, to the children of Michele Besso, his dearest friend, who had just died. Einstein's use of the word *briefly* was due to his knowledge that he was nearly out of time, too (he died just a month later).

> “A point of space at a point of time … I will call a *world point*. The multiplicity of all thinkable x, y, z, t systems of values we will christen the *world*. With this most valiant piece of chalk I might project upon the blackboard four world axes … Not to leave a yawning void anywhere, we will imagine that everywhere and everywhen there is something perceptible. To avoid saying ‘matter’ or ‘electricity’ I will use for this something the word ‘substance.’ We fix our attention on the substantial point which is at the world point x, y, z, t, and imagine that we are able to recognize this substantial point at any other time. Let the variations dx, dy, dz, of the space coordinates of this substantial point correspond to the time element dt. Then we obtain, as an image, so to speak, of the everlasting career of the substantial point, a curve in the world, a *world-line*. … The whole Universe is seen to resolve itself into similar world-lines, and I would fain anticipate myself by saying that in my opinion physical laws might find their most perfect expressions as relations between these world-lines … *Thus also three-dimensional geometry becomes a chapter in four-dimensional physics* [my emphasis].”

With those words Minkowski gave mathematical expression to the philosophical exposition of Wells’ Time Traveller to his dinner party friends. Taking the Minkowskian view of the primacy of spacetime as the ultimate building block stuff of reality was Princeton professor of physics John Wheeler, who wrote[105] “There is nothing in the world except empty curved space. Matter, charge , electromagnetism … are only manifestations of the bending of space. *Physics is Geometry*.” This idea was echoed in fiction, in the 1987 novel Moscow 2042 by Vladimir Voinovich, where we find a time traveler who declares “Anyone with even a nodding acquaintance with the theory of relativity knows that nothing is a variety of something and so you can always make a little something out of nothing.”

But not everybody understood Minkowski. In a little-known yet quite erudite essay, published just after a stunning experimental verification of general relativity (the bending of starlight passing through the Sun’s gravitational field[106]), an anonymous author presented an optical analogy to help those who thought relativity simply “a mathematical joke.” Signing himself only as “W.G.,” he included the following passage[107]:

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[104] For a study that includes the original German text, careful English translations, and photographs of Minkowski’s agonized corrections to his pre-address manuscript, see P. L. Galison, “Minkowski’s Space-Time: From Visual Thinking to the Absolute World,” *Historical Studies in the Physical Sciences* (volume 10), 1979, pp. 85–121.

[105] C. W. Misner and J. Wheeler, “Gravitation, Electromagnetism, Unquantized Charge, and Mass as Properties of Curved Empty Space,” *Annals of Physics*, December 1957, pp. 525–603.

[106] General relativity had already explained the long-puzzling excess precession of the perihelion (point of closest approach to the Sun) of Mercury’s orbit. The excess was an observational (and so experimental) fact which Newton’s gravity *cannot* completely explain.

> “Some thirty or more years ago [it was forty] a *jeu d’esprit* was written by Dr. Edwin Abbott entitled *Flatland* . . . Dr. Abbott pictures intelligent beings whose whole experience is confined to a plane, or other space of two dimensions, who have no faculties by which they can become conscious of anything outside that space and no means of moving off the surface on which they live. He then asks the reader, who has consciousness of the third dimension, to imagine a sphere descending upon the plane of Flatland and passing through it. How will the inhabitants regard this phenomenon? They will not see the approaching sphere and will have no conception of its solidity. They will only be conscious of the circle in which it cuts their plane. This circle, at first a point, will gradually increase in diameter, driving the inhabitants of Flatland outward from its circumference, and this will go on until half the sphere has passed through the plane, when the circle will gradually contract to a point and then vanish, leaving the Flatlanders in undisturbed possession of their country . . . Their experience will be that of a circular obstacle gradually expanding or growing, and then contracting, and they will attribute to *growth in time* what the external observer in three dimensions assigns to a movement in the third dimension. Transfer this analogy to a movement of the fourth dimension through three-dimensional space. Assume the past and future of the Universe to be all depicted in four-dimensional space, and visible to any being who has consciousness of the fourth dimension. If there is motion of our three-dimensional space relative to the fourth dimension, all the changes we experience and assign to the flow of time will be due simply to this movement, *the whole of the future as well as the past existing in the fourth dimension* [my emphasis].”

W.G.’s words are a clear and unequivocal statement of the so-called *block universe* concept of four-dimensional spacetime. One can find the block universe concept in the writings of the ancients, too. Consider, for example, the fifth-century B.C. Greek philosopher Parmenides’ view of reality: “It is uncreated and indestructible; for it is complete, immovable, and without end. Nor was it ever, nor will it be; for now it *is*, all at once, a continuous *one*.” And in Thomas Aquinas’ *Compendium Theologiae*, written in the thirteenth century, we find “We may fancy that God knows the flight of time in His eternity, in the way that a person standing on top of a watchtower embraces in a single glance a whole caravan of passing travelers.” This is the block universe idea, too, but whereas for Parmenides it was metaphysics and for Aquinas it was theology, for Einstein and Minkowski it was physics.[108]

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[107] W. G., “Euclid, Newton, and Einstein,” *Nature*, February 12, 1920, pp. 627–630. As with the mysterious S. (note 94), the editorial staff at *Nature* has informed me that, nearly a century later, there is no longer any record of the identity of W. G. in the journal’s archives.

[108] And for some it was all nonsense. The British philosopher Peter Geach (1916–2013), for example, declared the Minkowskian view to be “very popular with philosophers who try to understand physics and physicists who try to do philosophy.” See P. T. Geach, “Some Problems About Time,” in *Studies in the Philosophy of Thought and Action* (P. F. Strawson, editor), Oxford University Press, 1968. In his introduction to Geach’s essay, editor Strawson put in his two cents by stating the four-dimensional view of reality to be nothing but “fanciful philosophical theorizing.”

The block universe concept may explain the enigmatic statement made by Einstein at the death of Michele Besso (note 103). As interpreted[109] decades later:

> "It seems that Einstein's view of the life of an individual was as follows. If the difference between past, present, and future is an illusion, i.e., the four-dimensional spacetime is a 'block Universe' without motion or change, then each individual is a collection of myriad of selves, distributed along his history, each occurrence *persisting on the world line, experiencing indefinitely the particular event of that moment* [my emphasis]. Each of these momentary persons, according to our experience would possess memory of the previous ones, and would therefore believe himself identical with them; yet they would all exist separately, as single pictures in a film. Placing the past, present and future on the same footing this way, destroys the notion of the unity of the self, rendering it a mere illusion as well."

It appears by his words that Einstein was indeed in agreement with the block universe concept, and that he was attempting to give his friend's family some reason to believe that their father still lives 'somewhen.' The makers of the 2002 film *Minority Report* made use of the block universe concept, even if not intentionally; there we see police stopping crime *before* it happens because they can 'see the future.'

Not everybody believed that this view of spacetime was Einstein's, however. Karl Popper (1902–1994), an Austrian philosopher of science, wrote 28 years after the scientist's death that "Einstein was a strict determinist when I first visited him in 1950: he believed in a 4-dimensional Block-Universe. But he gave this up."[110] Shortly before he wrote those words, however, Popper must have learned something new to convince himself of his final comment, because just 2 years earlier he had declared[111] Einstein to (still) be a determinist. Popper presents no evidence to support his claim of Einstein's philosophical conversion, however, and it would seem that the Besso letter still offers the best insight into his actual view of spacetime shortly before his death. I say this because I think Popper's labeling of Einstein as a determinist is wrong. Determinism says 'If you do A, then B will happen, and if you do not do A then (perhaps) something other than B will happen.' A deterministic universe has plenty of room for free will, because you can *choose* to do A or not to do A, and what you decide makes a difference. A fatalistic universe, however, as is the block universe, simply says 'You will do A and B will happen.' To accept the block universe, as did Einstein, is to be a fatalist, not a determinist.

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[109] L. P. Horwitz, R. I. Arshansky, and A. C. Elitzur, "On the Two Aspects of Time: The Distinction and Its Implications," *Foundations of Physics*, December 1988, pp. 1159–1193. See also Einstein's own book (note 67) where he wrote "From a 'happening' in three-dimensional space, physics becomes, as it were, an 'existence' in the four-dimensional 'world'."

[110] See the *Seventh International Congress of Logic, Methodology and Philosophy of Science*, volume 4 (Salzburg, Austria, 1983), p. 176. Popper describes his early discussions with Einstein on the reality of time and the four-dimensional Parmenidean block universe in some detail in his autobiography: see volume 1 of *The Philosophy of Karl Popper* (P. A. Schilpp, editor), The Library of Living Philosophers, Open Court 1974, pp. 102–103.

[111] In the Foreword to the book by B. Gal-Or, *Cosmology, Physics and Philosophy*, Springer-Verlag 1981.

Einstein's final position on this, then, *might* have been like that of the fictional time traveler who takes a little girl 25,000 years back into the past, where she sees an ancient ancestor of humanity.[112] She then asks if the ancestor is really alive. The time traveler replies, "Every man who ever lived is still alive, child. In time there is no real death. When a man dies he's still alive 10 min ago, 10 years ago. He's always alive to those who travel back through time to meet him face to face."

Did Einstein *really* believe this? Not everybody thinks so. At the 1922 meeting of the French Philosophical Society, for example, the philosopher of science Emile Meyerson asked Einstein whether the spatialization of time (the idea that time is a dimension on the same footing as the spatial ones) is a legitimate interpretation of Minkowski's spacetime. Einstein's terse answer was that "it is certain that in the four-dimensional continuum all dimensions are *not* [my emphasis] equivalent."[113]

Use of the term *block universe* is generally thought to have originated with the Oxford philosopher Francis Herbert Bradley (1846–1924) who, in his 1883 book *Principles of Logic*, wrote "We seem to think that we sit in a boat, and are carried down the stream of time, and that on the bank there is a row of houses with numbers on the doors. And we get out of the boat, and knock at the door with number 19, and, re-entering the boat, then suddenly find ourselves opposite 20, and having then done the same, we go on to 21. And, all this while, the firm fixed row of the past and future stretches in a *block* [my emphasis] behind us, and before us." The house numbers would seem to be Bradley's way of referring to the centuries. Note that he wrote these words 12 years before *The Time Machine*, and that they preceded Minkowski's famous address by a quarter-century.

But this origin of *block universe* may not be as clear-cut as I have made it appear. Bradley, who was frequently criticized by the Harvard psychologist William James (1842–1910)—a man who argued for free will[114] and indeterminism, concepts disallowed in a block universe—may have been mocked on the idea by James during an address to the students of the Harvard Divinity School in March 1884 ("The Dilemma of Determinism"), the year after Bradley's book had been published. In his address James spoke of a deterministic world as being a "solid" or "iron block" (this are *not* characteristics of determinism, but rather of fatalism, and so James makes the same mistake as did Popper). However, writing the year before Bradley's book, in the April 1882 issue of *Mind*, James wrote (with obvious disdain) of "the universe of Hegel [the German philosopher Georg Hegel (1770-1831)]—the *absolute block* [my emphasis] whose parts have no loose play," as having "the oxygen of possibility all suffocated out of its lungs" and as being a universe in which "there can be neither good nor bad, but [only] one dead level of mere fate." So, perhaps, the chain of evolution of the term block universe is actually from Hegel to James and *then*, finally, to Bradley.

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[112] F. B. Long, "Throwback in Time," *Science Fiction Plus*, April 1953.

[113] A. Einstein, "La Théorie de la Relativité," *Bullentin de la Société Francaise de Philosophia* (volume 17), 1922, pp. 91–113.

[114] A famous line from James, one that perhaps illustrates his sort of reasoning about free will, is "My first act of free will shall be to believe in free will." If only proving theorems in math and physics were that easy.

We can actually find the block universe in fiction *before* Minkowski (and so certainly before pulp science fiction) came on the scene. In an 1875 (!) story[115] we read of a man who sees, years in advance, his own death in the American Civil War. In the following extract, this man speaks to an unnamed friend (who is the narrator):

> "Do you know," said Bernard, presently, "I sometimes think prophecy isn't so strange a thing . . . I really see no reason why any earnest man may not be able to foresee the future, now and then . . ."
>
> "There is reason enough to my mind," I replied, "in the fact that future events do not exist, as yet, and we cannot know that which is not, though we may shrewdly guess it sometimes . . ."
>
> "Your argument is good, but your premises are bad, I think," replied my friend, . . . his great, sad eyes looking solemnly into mine.
>
> "How so?" I asked.
>
> "Why, I doubt the truth of your assumption, that future events do not exist as yet . . . Past and future are only divisions of time, and do not belong to eternity . . . To us it must be past or future with reference to other occurrences. But is there, in reality, any such thing as a past or a future? If there is an eternity, it is and always has been and always must be. But time is a mere delusion . . . To a being thus in eternity, all things are, and must be present. *All things that have been, or shall be, are* [my emphasis]."

When the block universe concept did eventually appear in science fiction, it did so early. In a 1927 story, for example, a time traveler from the future and a man in the present (who is the narrator) have the following exchange:

> "I have just been five years into your future."
> "My future!" I exclaimed. "How can that be when I have not lived it yet?"
> "But of course you have lived it."
> I stared, bewildered.
> "Could I visit my past if you had not lived your future?"[116]

So, while the block universe has a bit of a history to it, the history of the concept of *mathematical* spacetime in physics has a much clearer origin: it derives from Minkowski, not from Hegel, Bradley, James, or even Einstein (who often gets credit for it even though he didn't use the concept in special relativity in 1905, 3 years before Minkowski's address.). Eventually, of course, Einstein did come to appreciate the power and conceptual beauty of four-dimensional spacetime, and it came to play a central role in his ideas about gravity. Indeed, in Einstein's general theory of relativity gravity *is* (curved) spacetime. The starting point for general relativity (and so a *scientifically plausible* theory of time travel) was Minkowski's creation of spacetime, and he is truly deserving of the title 'father of the fourth dimension.'

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[115] G. C. Eggleston, "The True Story of Bernard Poland's Prophecy," *American Homes*, June 1875. George Cary Eggleston (1839–1911) had served as a soldier in the Confederate Army.

[116] F. Flagg, "The Machine Man of Ardathia," *Amazing Stories*, November 1927.

Of course, it is true that Newton's physics also talks about an analytical (as opposed to merely philosophical) space and time long before either Minkowski or Einstein, but 'Newtonian spacetime' is something very different from Minkowski's self-described "radical" view.[117] In the Newtonian view there is a universal time, a *cosmic* time, which is the same time for everyone, everywhere, in the universe. At every instant, a cosmic simultaneity exists for Newton. Newton's space is Euclidean; that is, through any point exterior to a line exactly one parallel line can be constructed and those two lines will never meet, all triangles (no matter their size) have an interior angle sum of 180°, and so on. For Newton, space and time were absolutely and uniquely separable. They were, as philosophers like to say, "distinct individuals."

Minkowski changed all that. For him space and time are only relatively separable, and the separation is different for observers in relative motion. For Newton, space and time are the *background* in which physical processes in the world evolve. For Minkowski, spacetime *is* the world.

In a famous philosophical paper[118] by an advocate of the block universe view of reality, we find the words "I . . . defend the view of the world . . . which treats the totality of being, of facts, or of events as spread out eternally in the dimension of time as well as the dimensions of space. Future events and past events are by no means present events, but in a clear and important sense they do exist, now and forever, as rounded and definite articles in the world's furniture." The title of Williams' paper comes from an ancient dilemma stated by Aristotle in his *De Interpretatione*, where he asked a question now classic in philosophy: "Will there be a sea fight tomorrow?"

Aristotle began his famous answer by first posing the following premise: If a statement about some future event is, eventually, shown to be true (or false), then that statement was true (or false) from the moment it was made. Consider, then, the following two assertions: (A) "It is true that there will be a sea fight tomorrow" and (B) "It is true that there will *not* be a sea fight tomorrow." Surely, argued Aristotle, (A) and (B) cannot both be true, but equally surely, one of them must be true. Suppose it is (A) that is true. Then there is nothing that can be done to prevent the sea fight, and so the future is fated. Suppose, however, it is (B) that is true. Then there is nothing that can be done to cause the sea fight, and so the future is fated. The conclusion is the same no matter which assertion is the true one; thus, the future is fated.

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[117] See, for example, H. Stein, "Newtonian Space-Time," *Texas Quarterly*, Autumn 1967, pp. 174–200; G. Berger, "Elementary Causal Structures in Newtonian and Minkowskian Space-Time," *Theoria* (volume 40), 1974, pp. 191–201; J. Earman and M. Friedman, "The Meaning and Status of Newton's Laws of Inertia and the Nature of Gravitational Forces," *Philosophy of Science*, September 1973, pp. 329–359.

[118] D. C. Williams, "The Sea Fight Tomorrow," in *Structure, Method and Meaning*, The Liberal Arts Press 1951. Donald Williams (1899–1983) was a professor of philosophy at Harvard.

As might be expected, those who like the fatalistic block universe like this conclusion, but, ironically, Aristotle wasn't one of them—he disliked it so much that he struggled to find a way around it. On the other hand, there are philosophers, like Professor Williams (who believed in a fatalistic universe), who reject Aristotle's rejection of his own logic! Professor Williams went so far, in fact, to calling Aristotle's reasoning "a tissue of error" and "swaggeringly invalid." Possibly so, but the philosophical debates over the sea fight question, and the fatalistic (or not) nature of the world, have not ceased to this day.

In an even more famous paper, Professor Williams makes clear his belief that the passage of time is a myth; he poetically declared "the total of world history is a spatio-temporal volume, of somewhat uncertain magnitude, chockablock with things and events."[119] Professor Williams did, indeed, embrace four-dimensional spacetime, and this is demonstrated by the following incredible passage, perhaps his best-remembered words: "It is then conceivable, though doubtless physically impossible, that one four-dimensional area of the time part of the manifold be slewed around at right angles to the rest, so that the time order of that area, as composed by its interior lines of strain and structure, run parallel with a spatial order in its environment. It is conceivable, indeed, that a single whole human life should lie thwartwise of the manifold, with its belly plump in time, its birth at the east and its death in the west, and its conscious stream running alongside somebody's garden path."

Good Lord!

Now, I am willing to admit that Professor Williams probably wrote that wonderful passage mostly for effect,[120] but I ask you—what, if anything, does it *mean*? It is marvelous to read and yet it remains (for me) mysterious.[121] It should come as no surprise that Professor Williams originally presented his papers to the Metaphysical Society of America, rather than to the American Physical Society. But this passage was perhaps not without impact in areas far removed from metaphysics; some years later there appeared a science fiction story[122] that reads as though it had been inspired by Williams. In it, a scientist discovers how to bend his perception of the four dimensions so as to view verticality as duration and duration as verticality. Thus, he is in October while sitting, but when he stands up he is in November! As bizarre as this may seem, such coordinate interchanges actually do occur in the mathematical theory of time machines; we'll see this later, for example, when we discuss Tipler's rotating cylinder time machine.

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[119] D. C. Williams, "The Myth of Passage," *Journal of Philosophy*, July 1951, pp. 457–472.

[120] In a footnote, Williams sort of admits this when he writes "I should expect the impact of the environment on such a being to be so wildly queer and out of step with the way he is put together, that his mental life must be a dragged-out monstrous delirium." I think this a great understatement.

[121] As it was for some of Williams' fellow philosophers, one of whom bluntly called the 'myth-of-passage' paper "an interesting piece of science fiction": see M. Capek, "The Myth of Frozen Passage: The Status of Becoming in the Physical World," in *Boston Studies in the Philosophy of Science* (volume 2), Humanities Press 1965. Capek's title reflects his view of the block universe as simply a giant refrigerator and so, turning the tables on Williams, we have 'passage' changed to 'frozen passage.' See also note 136.

[122] G. Wolfe, "The Rubber Bend," *Universe 5* (T. Carr, editor), Random House 1974.

By the 1930s the block universe had found a home in pulp science fiction. The block universe view that past and present coexist with the present got dramatic treatment in one story of a high school teacher who invents a "spacetime warp" theory, and who is then tricked by an evil industrialist into implementing it in the form of a gun. The weapon produces incredible effects when it is tested; for example, an allosaurus appears, which we are told is "a carnivorous dinosaur of the Jurassic Age, the most frightful engine of destruction that ever walked the Earth!"[123] At the story's end, the teacher explains what has happened to a crowd of breathless newspaper reporters:

> "Spacetime was warped slightly ... The Einsteinian spacetime continuum buckled ... Because it was superficial, only a little of the past, a little of the future broke through. The folds of the warp distorted spacetime evanescently, erratically skirting the vast gulf where the past lies buried and lightly tapping the vast stores of the future. It is a truism of modern speculative physics that the past and the future exist simultaneously and coextensively in higher dimensions of space. De Sitter has speculated as to the possibility of seeing an event before it happens. It is quite possible, gentlemen. Events of the far future already exist in spacetime."

That 'explains' the dinosaur. In the teacher's words, "You tell me that two men saw an incredible beast. ... They swear it looked like a dinosaur. I think it was a dinosaur, gentlemen. It broke through when the warp tapped the past."

And just 2 years later, Robert Heinlein made world lines the central concept in the first of his many classic tales.[124] The story draws an analogy between a world line and a telephone cable: the beginning and end points in spacetime for the world line of a person (birth and death) are associated with breaks (faults) in a telephone cable. By sending a signal up and down the cable, and measuring the time delay until the arrival of the echo produced by such discontinuities, a technician can both detect and locate the faults. In the same manner, Heinlein's story-gadget sends a signal of unspecified nature up and down a world line and thus locates the birth and death 'discontinuities.' Knowledge of the death date, in particular, causes financial stress among life insurance companies, and an examination of *that* tension (not strange physics) is the fictional point of the story.

And then, 2 years after Heinlein's tale with its serious tone, a far less serious story[125] (featuring an Attila the Hun character who roams up and down the corridors of time kidnapping beautiful women for his harem!), we find an 'editorial' footnote telling its young readers that "scientists—especially the new order of meta-physical scientists—are agreed on the principles of Space-Time. The future is not a thing which *will exist*. Rather it is a thing which *does exist*—all events from the Beginning to the End, exist in a record upon the scroll of Time." This story, itself, was silly, but the block universe metaphysics was up-to-date.

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[123] F. B. Long, "Temporary Warp," *Astounding Stories*, August 1937.

[124] R. Heinlein, "Life-Line," *Astounding Science Fiction*, August 1939.

[125] R. Cummings, "Bandits of Time," *Amazing Stories*, December 1941.

Somewhat surprisingly, I think, is that even before pulp science fiction embraced the block universe, the concept had already made a deep impression on a broader audience. For example, in a 1928 New York stage play[126] the action alternately takes place in the years 1784 and 1928 and, to explain how that can be, one character (a time traveler) tells another:

> "Suppose you are in a boat, sailing down a winding stream. You watch the banks as they pass you. You went by a grove of maple trees, upstream. But you can't see them now, so you saw them in the *past*, didn't you? You're watching a field of clover now; it's before your eyes at this moment, in the *present*. But you don't know yet what's around the bend in the stream ahead of you; there may be wonderful things, but you can't see them until you get around the bend, in the *future*, can you?"

Then, after this prologue about the stream of time, comes the block universe idea:

> "Now remember, *you're* in the boat. But *I'm* up in the sky above you; in a plane. I'm looking down on it all. I can see *all at once* the trees you saw upstream, the field of clover that you see now, and what's waiting for you around the bend ahead! *All at once!* So the past, present, and future of the man in the boat are all *one* to the man in the plane."

Then, finally, the obvious theological conclusion: "Doesn't that show how all Time must really be one? Real Time—real Time is nothing but an idea in the mind of God!"

To end this section, the block universe conception was cleverly used by one science fiction fan who argued in support of time travel, in reply to another fan how had claimed that a failure of mass/energy conservation was fatal to the plausibility of time travel. Their exchange began with a letter to the editor at *Astounding Stories* in November 1937, written in response to a recent story[127]:

> "Let us say that there is, at a certain time, 'x' amount of matter in the Universe, and 'e' amount of energy. Then if a man of 'a' mass travels backward in time to this particular instant aforementioned, the total amount of matter is thus 'x' plus 'a', while if no other such mass changing occurrences take place, the amount of matter in the future is 'x' minus 'a'. Only a corresponding loss and gain respectively in the amount of energy could explain this conservation of energy, advocates [of time travel] say what they may. But you can't rob or add energy to a Universe nilly-willy! Or perhaps time doesn't enter in on the matter. Perhaps you can add matter in a Universe provided you take it away on some future date."

This fan's concern clearly made an impression on science fiction writers, and the case for conservation of energy is stated in many of the time travel stories that appeared after the publication of this letter.[128]

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[126] "Berkeley Square" by J. L. Balderson. This play was made into a 1933 movie of the same name, and again in 1951 as the film *I'll Never Forget You*.

[127] O. Saari, "The Time Bender," *Astounding Stories*, August 1937 (see also note 137 in Chap. 1).

[128] Examples include the novels *Lest Darkness Fall* (Henry Holt 1941) by L. Sprague de Camp, and *The Time Hoppers* (Doubleday 1967) by Robert Silverberg.

A reply was soon received by the magazine in a letter (January 1938) from another fan:

> "[A recent letter] implies that the idea of time travel is incompatible with the law of conservation of mass and energy. I believe [the] reasoning is wrong [and that the] difficulty lies primarily in the assumption that a body moved in time is transported into a different Universe. According to Einstein, time and the three normal dimensions are so related as to form a continuous, inseparable medium we call the spacetime continuum. Time is in no way independent of the other components of our Universe. Hence a fixed mass [a time traveler and his machine] moved in time is by no means lost from the Universe, the action being analogous to a shift along any other dimension."

The block, or frozen, universe of Minkowski is clearly reflected in those words.[129]

2.7 Philosophical Implications of the Block Universe

> "Is the future all settled beforehand, and only waiting to be 'pushed through' into our three-dimensional ken? Is there no element of contingency? No free will? I am talking geometry, not theology."[130]

I should tell you now that, despite the enthusiastic embrace of the block universe by Williams and others (including Einstein), there are those who have been harsh in their criticism of Minkowski's spacetime. The major philosophical problem with the block universe interpretation of four-dimensional spacetime is that it looks like fatalism disguised as physics. It seems to be little more than a mathematician's proof of a denial of free will dressed up in geometry. One philosopher illuminated this concern with the following story, one that vividly illustrates the compelling need many humans have to deny a fatalistic world:

> "In a moving picture version of *Romeo and Juliet*, the dramatic scene was shown in which Juliet, seemingly dead, is lying in the tomb, and Romeo, believing she is dead, raises a cup containing poison. At this moment an outcry from the audience was heard: 'Don't do it!' We laugh at the person who . . . forgets that the time flow of a movie is unreal, is merely the unwinding of a pattern imprinted on a strip of film. Are we more intelligent than this man when we believe that the time flow of our actual life is different? Is the present more than our cognizance of a predetermined pattern of events unfolding itself like an unwinding film?"[131]

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[129] In the context of mathematical physics (*not* science fiction) it has been shown that time travel does *not* imply any fatal violation of conservation of energy. See, for example, J. L. Friedman *et al.*, "Cauchy Problem in Spacetimes with Closed Timelike Curves," *Physical Review D*, September 15, 1990, pp. 1915–1930, and D. Deutsch, "Quantum Mechanics Near Closed Timelike Lines," *Physical Review D*, November 15, 1991, pp. 3197–3217.

[130] The lament of Victorian physicist Oliver Lodge (1850–1940) in his essay "The New World of Space and Time," *Living Age*, January 1920.

[131] H. Reichenbach, *The Direction of Time*, University of California Press 1956, p. 11.

Most people in the Western world would answer *yes* to Reichenbach's question. Most people do find Omar Khayyam's *Rubaiyat* to be a beautiful poem, yes, but still they reject its fatalistic message: "And the first Morning of Creation wrote/What the Last Dawn of Reckoning shall read." Indeed, William James quoted these very words in his 1884 address to the students of the Harvard Divinity School when he argued against fatalism and the block universe.

Besides fatalism, another reason for the stinging words by critics of Minkowski's spacetime is that, in it, events don't *happen*—they just *are*. That is, there seems to be no temporal process of *becoming* in Minkowski's spacetime. Everything is already there and, as what we perceive to be the passing of time occurs, we simply become conscious of ever more of Minkowski's "world points," or events, that lie on our individual world lines. Hermann Weyl (1885–1955), a German mathematical physicist who in his last years was a colleague of Einstein and Gödel at the Institute for Advanced Study in Princeton, expressed this very interpretation in words that have become famous, words that sound very much like those of Wells' Time Traveller: "The objective world simply *is*, it does not *happen*. Only to the gaze of my consciousness, crawling upward along the life line of my body [Minkowski's world line], does a section of the world [spacetime] come to life as a fleeting image in space which continuously changes in time [creating what we call the *now* or the *present*]."[132]

Weyl was skillful in finding poetic ways to express the world line view of reality, but not everybody is convinced by the poetry because it seems to deny the common sense idea of time 'flowing,' of temporal passage; it effectively says time is mind-dependent, a mere *illusion*, as the time traveler in "Berkeley Square" declared (note 126). One philosopher who was particularly opposed to Weyl's view was the British-American academic Max Black (1909–1989), and he expressed his opinion in no uncertain terms: "The picture of a 'block Universe,' composed of a timeless web of 'world-lines' in four-dimensional space, however strongly suggested by the theory of relativity, is a piece of gratuitous metaphysics."[133] Another philosopher who was unhappy with Weyl's view of the block universe was just as blunt: "While philosophers may be forgiven intellectual extravagances of this kind, I think it is a pity when they receive encouragement from theoretical physicists."[134]

Weyl's views had supporters, too, however. Consider, for example, the Time Traveller's speech to his friends at the fateful dinner party that opens *The Time*

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[132] H. Weyl, *Philosophy of Mathematics and Natural Science*, Princeton University Press 1949, p. 116. Sir James Jeans had already said the same, somewhat less elegantly, in his 1935 Sir Halley Stewart Lecture: "The tapestry of spacetime is already woven throughout its full extent, both in space and time, so that the whole picture exists, although we only become conscious of it bit by bit—like separate flies crawling over a tapestry . . . A human life is reduced to a mere thread in the tapestry." Jeans then immediately *rejected* this fatalistic view: see his *Scientific Progress*, Macmillan 1936, p. 20.

[133] From a book review in *Scientific American*, April 1962, pp. 179–185.

[134] H. A. C. Dobbs, "The 'Present' in Physics," *British Journal for the Philosophy of Science*, February 1969, pp. 317–324.

Machine: "There is no difference between Time and any of the three dimensions of Space except that our consciousness moves along it . . . here is a portrait of a man at 8 years old, another at fifteen, another at seventeen, another at twenty-three, and so on. All these are evidently sections, as it were, Three-Dimensional representations of his Four-Dimensional being, *which is a fixed and unalterable thing* [my emphasis]." Remember, these words were written in 1895, 13 years before Minkowski and his world lines, and of course decades before Weyl's famous words.

Wells' passage made a considerable impression on at least one well-known physicist of the time, who references it in his early book on relativity.[135] And in another book on relativity, published the same year, we find the same interpretation of Minkowski's spacetime as a block universe: "With Minkowski, space and time become particular aspects of a single four-dimensional continuum . . . All motional phenomena . . . become timeless phenomena in four-dimensional space. The whole history of a physical system is laid out as a changeless whole."[136]

The claim that time is an illusion has some thought-provoking implications concerning the concepts of omniscience and free will, concepts that occur in any discussion of time travel. Some old theology on God's omniscience, as discussed in Aquinas' *Summa Theologiae*, is seemingly lent at least some support by Minkowski's spacetime: "Now although contingent events come into actual existence successively, God does not, as we do, know them in their actual existence successively, but all at once; because his knowledge is measured by eternity, as is also his existence; and eternity which exists as a simultaneous whole, takes in the whole of time . . . Hence all that takes place in time is eternally present to God." Somewhat paradoxically, however, Aquinas did make a distinction between past and future. In that same work he declares that "God can cause an angel not to exist in the future, even if he cannot cause it not to exist while it exists, or not to have existed when it already has." For Aquinas, then, whereas the past is rigid and unchangeable, the future is plastic, which is *not* the block universe view of spacetime.

As one theologian has observed,[137] this does not mean that Aquinas thought God had to view all events simultaneous with all others.[138] Rather, our theologian says that Aquinas could have thought of the relationship between God and events as being similar to that between the center of a circle and all the points on the circumference. That is, each point on the circumference has its own identity, coming before and/or after any other point, but the center is related to each and every point on the circumference in precisely the same way. The center, then, is 'eternity' and the circumference is the temporal series ('one thing after another') of reality. Saying that God is *eternal* is thus very different from saying he is *everlasting*. The first means outside of time, whereas the second means he is a temporal entity but has neither beginning nor end.

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[135] L. Silberstein, *The Theory of Relativity*, Macmillan 1914, p. 134.

[136] E. Cunningham, *The Principle of Relativity*, Cambridge University Press 1914, p. 191. The use of the words *timeless* and *changeless* explain the characterization of the block universe as being *frozen* (in note 121).

[137] W. L. Craig, "Was Thomas Aquinas a B-Theorist of Time?" *New Scholasticism*, Autumn 1985, pp. 475–483. For the B-theory of time, look back at the discussion in the first section of this chapter.

[138] A science fiction story by Norman Spinrad, "The Weed of Time" (*Alchemy and Academe*, Doubleday 1970) graphically describes what a nightmare that could be!

Our theologian supports the first interpretation, invoking Aquinas' own words from *Summa Contra Gentiles*: "The divine intellect, therefore, sees in the whole of its eternity, as being present to it, whatever takes place through the whole course of time. And yet what takes place in a certain part of time was not always existent. It remains, therefore, that God has a knowledge of these things that according to the march of time do not yet exist."

The issue of God's eternity and his place in spacetime has long been a hot topic among theologians with a scientific inclination. Practically every issue of the learned journal *Religious Studies*, for example, carries an article on the subject, often invoking relativity theory to support some argument. The Bible, itself, can be a confusing guide on this matter. For example, consider the Old Testament story of King Ahab (First Kings 21). Ahab, King of Sumeria, coveted Naboth's vineyard, but Naboth would not sell. The King retreated, but his wife Jezebel arranged for Naboth's downfall and judicial murder and thus caused the arrival of all his property into her husband's hands. This angered God, who commanded Elijah to prophesy disaster on Ahab's house. Ahab responded with sackcloth, and at that God shifted the disaster to the house of Ahab's son. The point, here, is that God, declared to be omniscient, seems to have been *surprised* at Ahab's penitence. God is aware of everything in this tale, but only as it happens. That is, God's knowledge is subject to growth. This Hebrew concept of God as a participant in history is at odds with the contemporary Christian conception of divine knowledge of all that has been, all that is, and all that will be, a view which has its own Biblical support (for divine eternality). For example, Malachi 3:61 ("For I am the Lord, I change not"), and James 1:17 ("the Father . . . with whom is no variableness").

When *The Time Machine* was serialized in the *New Review*, it included a passage that does not appear in the now classic version of the story in which the Time Traveller explains his view of the connection between omniscience and the block universe to his dinner guests:

> "I'm sorry to drag in predestination and free-will, but I'm afraid those ideas will have to help . . . Suppose you knew fully the position and properties of every particle of matter, of everything existing in the Universe at any particular moment of time: suppose, that is, that you were omniscient. Well, that knowledge would involve the knowledge of the condition of things at the previous moment, and at the moment before that, and so on. If you knew and perceived the present perfectly, you would perceive therein the whole of the past. If you understood all the natural laws the present would be a complete and vivid record of the past. Similarly, if you grasped the whole of the present, knew all its tendencies and laws, you would see clearly all the future. To an omniscient observer there would be no forgotten past—no piece of time as it were that had dropped out of existence—and no blank future of things yet to be revealed . . . Present and past and future would be without meaning to such an observer . . . He would see, as it were, a Rigid Universe filling space and time . . . If 'past' meant anything, it would mean looking in a certain direction, while 'future' meant looking the opposite way."

Wells' "Rigid Universe" certainly sounds like the block universe, and he (or least, the Time Traveller) seems to have believed that it held important implications for the concept of free will.

The 'Rigid Universe' got an interesting science fiction treatment in a story[139] that imagined an event in the present that occurs 'before it should' (a heart patient learns that her obituary notice will be in next week's *New York Times* when that paper arrives 'early'). As one character explains to the sister of the lady who is soon to die, "The future mustn't be changed . . . For us the events of . . . the future are as permanent as any event in the past. We don't dare play around with changing the future, not when it's already signed, sealed and delivered in that newspaper. For all we know the future's like a house of cards. If we pull one card out, say your sister's life, we might bring the whole house tumbling down. You've got to accept the decree of fate . . . You've got to."

With Einstein's discovery of the *relativity of simultaneity*,[140] we run into the question of 'How can there be any sense to the concept of divine, universe-wide knowledge in a four-dimensional spacetime?' That's because in some frames of reference it is possible for event A to be observed before event B, whereas in other frames the temporal order could be reversed, and so some theological questions prompted by spacetime physics are: 'What is God's frame of reference if he is to be actively involved in human affairs? Could God have a special frame of reference in which he is exempt from the relativity of simultaneity, a frame in which he imposes an absolute order on the sequence of becoming of events? Does it make any sense, that is, to say God enjoys what might be called 'divine immediacy'? And if so, what should we think of a God who follows rules of nature different from those that govern all he is supposed to have made?'

Theologians have debated questions like these for decades, and surely will continue to do so for many more decades to come. Alas, I suspect that physicists who study time travel have either been unaware, unimpressed, or just plain uninterested. That's too bad, because one doesn't have to be religious to appreciate the pure intellectual challenges presented by such questions. For example, consider the following debate between two philosophers, one who believes free will and divine foreknowledge are not compatible, and another who thinks the first has made a fundamental error in blurring the distinction between changing and affecting the past. (This distinction is of *great* importance in any discussion of time travel.) This second philosopher presented some of his arguments in terms of a time traveler to the past[141]:

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[139] R. Silverberg, "What We Learned From This Morning's Newspaper," *Infinity Four*, November 1972.

[140] This refers to the discovery that two events, which occur simultaneously for one observer in a spacetime, may not be simultaneous for another observer in the same spacetime. This will be discussed in more detail in the next chapter.

> "Consider the following. Parsons (P) has invented a special machine which allows him to go back in time. He enters the machine in 1986 and finds himself in the presence of or, perhaps better, observing, Quigly (Q) in 1876. P is an authority on Q, and knows immediately the situation Q is in. Not only that, but he remembers reading about the particular decision or act which Q made in that situation. Thus one might argue that from P's perspective what Q decides is as if already done. It is not already done, since P is standing there waiting for Q to do it. He has gone back in time. Yet from P's perspective, which is of one come back from the future, it is as if already done, since he knows what Q does decide. Since P strongly believes in the unalterability of the past, it is not within Q's power to do something other than what Q in fact does in that situation. From Q's perspective his decision is not already made nor is the action taken, so that it is in his power at that time to do either x or y. From his perspective, that he will do x rather than y is indeterminate; it is not yet done, though at the same time he can grant that P knows what he will do because for him it is as if he has already done it."

The first philosopher doesn't buy any of this, and dismisses it with "It should be abundantly clear . . . that the fact that such stories are in some way imaginable and intuitively graspable says nothing about their logical coherence." Given the interest among modern physicists in time travel, however, I think the first philosopher wouldn't write that today.

One possible reply to all of these theological issues that spacetime physics prompts can perhaps be found in a paper[142] (written by a philosopher and two mathematicians) that describes a five-dimensional spacetime in which the fifth dimension is initially given the provocative label of the 'eternity' axis. But then the authors lost their nerve and elected to rename it 'anti-time.' It is interesting to note that pulp science fiction anticipated that terminology by decades, as in one story[143] we read "Beyond the fourth there is a fifth dimension . . . Eternity, I think you would call it. It is the line, the direction perpendicular to time." For some, the eternity axis would appear to be perfect to serve as the temporal dimension for God, an axis distinct from the time axis of mere mortals.

The idea of supernatural beings existing outside of mortal time is an old one in theology, and it can also be found in secular literature long before science fiction got hold of it. For example, in the first act of Lord Byron's 1821 poem *Cain*, the fallen angel Lucifer tells Cain and his wife that

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[141] For the complete exchange between these two philosophers, see W. Hasker, "Foreknowledge and Necessity," April 1985, pp. 121–157, B. Reichenbach, "Hasker and Omniscience," January 1987, pp. 86–92, and W. Hasker, "The Hardness of the Past: A Reply to Reichenbach," July 1987, pp. 337–342, all in the journal *Faith and Philosophy*. Hasker is the 'first' philosopher, and Reichenbach is the 'second' one. See also D. P. Lackey, "A New Disproof of the Compatibility of Foreknowledge and Free Choice," *Religious Studies*, September 1974, pp. 313–318.

[142] J. G. Bennett *et al.*, "Unified Field Theory in a Curvature-Free Five-Dimensional manifold," *Proceedings of the Royal Society of London A*, July 1949, pp. 39–61. A theological interpretation is given in G. Stromberg, "Space, Time, and Eternity," *Journal of the Franklin Institute*, August 1961, pp. 134–144.

[143] L. A. Eshbach, "The Time Conqueror," *Wonder Stories*, July 1932.

With us acts are exempt from time, and we
Can crowd eternity into an hour,
Or stretch an hour into eternity.
We breathe not by a mortal measurement,
But that's a myst'ry.

Before Minkowski, the debates over fatalism (as in Silverberg's story in note 139) and free will had been the exclusive province of philosophers, theologians, and lawyers (if a person has no control over his or her actions, then can we morally and ethically punish that person if those actions happen to be criminal?[144]). After Minkowski, the physicists (at least a few of them) joined the debates. According to one philosopher (note 118) the major motivation driving these debates is "the age-old dread that God's foreknowledge of our destiny can in itself impose the destiny upon us." The implication is, of course, that God is 'outside of time' and so can take in the entire Minkowskian block universe at a glance (hence his foreknowledge).

The relativistic view of the universe as a timeless four-dimensional spacetime seems to provide scientific, mathematical support for the conclusion that not only is the past fixed, but so is the future. Does that mean the future is what it will be—and if so, then why bother agonizing over the many apparent decisions each of us faces every day? If the future will be what it will be, then Christian theologians are left with the puzzling task of explaining what could possibly be meant by the Biblical exhortation (Deuteronomy 30:19) "I call Heaven and Earth to record this day against you, that I have set before you life and death, blessing and cursing; therefore *choose* [my emphasis] life, that both thou and thy seed may live."

This issue has bothered philosophers for a very long time. The so-called Master Argument (the name reflects its supposed invulnerability to rebuttal), for example, comes down to us from its origins in ancient times, in the *Discourses* of the first century A.D. Roman Stoic philosopher Epictetus. That argument can be summarized[145] as follows:

1. The future follows from the past;
2. The past is unchangeable;
3. What follows from the unchangeable is unchangeable;

Therefore,

4. The future is unchangeable.

This certainly does seem to be fatalistic, in effect arguing that all events in a block universe spacetime are recorded in a 'Book of Destiny.' Since ancient times many great works of literature have adopted that view, recounting tales of the foretold fates of men, such as Sophocles' *Oedipus*. It is, in a block universe, as though our conscious experience of the world is no different from that of the man watching the projected film images of *Romeo and Juliet*.

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[144] For more on this, in the context of time travel, see the penultimate question in the *For Future Discussion* questions at the end of this chapter.

[145] See, for example, the two papers by R. L. Purtill, "The Master Argument," *Apeiron*, May 1973, pp. 31–36, and "Foreknowledge and Fatalism," *Religious Studies*, September 1974, pp. 319–324.

That view is the central issue in the early sixth century A.D. Roman philosopher Boethius' influential *De Consolatione Philosophiae* (circa A.D. 500) which was written during a year of imprisonment before his execution for treason; perhaps he wondered during that year if his fate could have been anything different. Certainly he must have taken some consolation in fatalism, but in fact he tried to argue that God's vision of *all* temporal reality does not limit the freedom to act. According to Boethius, "The expression 'God is ever' denotes a single Present, summing up His continual presence in all the past, in all the present . . . and in all the future." That is, God sees in one timeless and eternal moment all that has been and will be freely chosen.[146]

When the fourteenth century English poet Geoffrey Chaucer prepared a translation of *Consolatione* he was obviously inspired by it when he wrote his very long, famous poem (*Troilus and Criseyde*) on the nature of love (Book IV.140):

Some say "If God sees everything before
It happens—and deceived He cannot be—
Then everything must happen, though you swore
The contrary, for He has seen it, He."
And so I say, if from eternity
God has foreknowledge of our thoughts and deed,
We've no free choice, whatever books we read.

Two modern, purely philosophical rebuttals[147] to Chaucer, however, argue that his poetry misstates Boethius' philosophy when Troilus declares that divine foreknowledge is incompatible with free will. That is, in their view God's omniscience (a fundamental teaching in the theistic religions of Christianity, Judaism, and Islam) *is* compatible with free will (also a fundamental belief in those same religions). Both of these scholarly papers, though, depend much more on the nuances of grammar than most physicists will like.

The connection between spacetime physics and free will was made explicitly by the philosopher who wrote "For philosophers in either field, philosophy of science and philosophy of religion are too often viewed as mutually irrelevant . . . This is unfortunate, because sometimes the problems can be quite parallel and a consistent resolution is required. One especially intriguing case in point concerns, in

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[146] In his *The Sirens of Titan*, a 1959 novel meant to be a parody of God's omniscience, Kurt Vonnegut gave the curious name of *chrono-synclastic infundibulated vision* to God's power to see the past and future.

[147] G. I. Mavrodes, "Is the Past Unpreventable?" April 1984, pp. 131–146, and A. Plantinga, "On Ockham's Way Out," July 1986, pp. 235–269, both in *Faith and Philosophy*.

Fig. 2.2 The common view of time

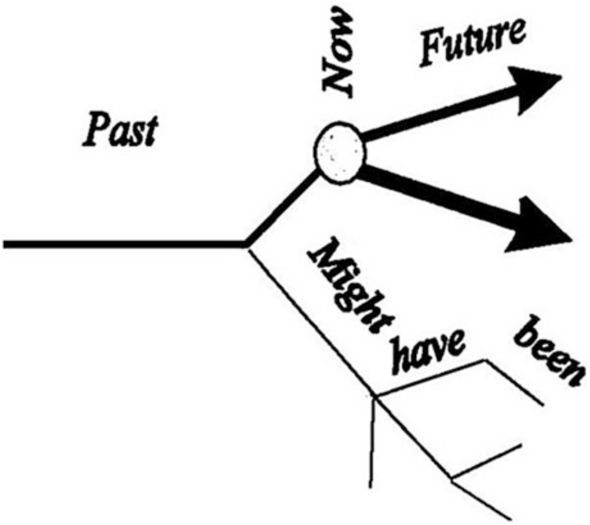

philosophy of science, the possibility of … time travel and, in philosophy of religion, the relationship between divine foreknowledge and human freedom."[148]

That philosopher could well have included science fiction writers in his group of people interested in both spacetime physics and free will. In one story,[149] for example, a man in the twenty-fifth century is about to travel back into the past to escape criminal prosecution. He is aked where he'd like to go, and he replies "I do not understand the paradoxes—what if I choose to build gravity-deflectors in Ancient Rome?" When he is told (correctly) that he couldn't do that because it didn't happen, he persists: "But if I can choose any period, it means I can alter history at will—which presumes that the present can also be changed." Then, at last, he gets the explicit answer that bothers nearly everyone: "The real answer is that in the final analysis your decision to choose a certain time period is already made, and the things you will do [in the time traveler's personal time] are already determined. Free will is an illusion; it is synonymous with incomplete perception." The same idea appears in another tale (note 57); when one character says, "What you are saying is that the future is fixed, and that you can read it, in every essential detail," the response is "Quite right … both those things are true."

However, no matter how hard we try—and by *we* I include even those physicists and philosophers who embrace the block universe with its support of time travel to the past—it is very difficult to break free of the view of time as shown in Fig. 2.2. That is, as the passage of time up to the present or *now* (with all to the left of that instant as the past), while to the right of the *now* we have multiple possible futures (depending on our free will choices). Lying to the side of all that (in our thoughts and imaginations) are all that ‘might have been’ if we had made different choices than we did at earlier times in the past.[150]

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[148] W. L. Craig, "Tachyons, Time Travel, and Divine Omniscience," *Journal of Philosophy*, March 1988, pp. 135–150. Tachyons are hypothetical faster-than-light particles that theoretically travel backwards through time. They will be discussed in Chap. 5.

[149] W. Kubilius, "Turn Backward, O Time," *Science Fiction Quarterly*, May 1951.

With all that said, even if events are really laid out in the spatial and temporal web that constitutes the four-dimensional block universe, there still remains the great mystery of why we see them unfold in the particular sequence that we do. Why not in reverse order? Why, indeed, do we see what we call *time* run from what we call the past to what we call the future and, indeed, what do we really mean by *past* and *future*? As you’ll see in the next chapter, these are not easy questions, and nearly everybody who has thought about them believes we are not yet even close to knowing the answers.

On that perhaps gloomy note, it seems appropriate to end here with a few more words from St. Augustine’s *Confessions*, with words that follow those that helped open this chapter: “I confess to you, Lord, that I still do not know what time is. Yet I confess too that I do know that I am saying this in time, that I have been talking about time for a long time, and that this long time would not be a long time if it were not for the fact that time has been passing all the while. How can I know this, when I do not know what time is? Is it that I do know what time is, but do not know how to put what I know into words? I am in a sorry state, for I do not even know what I do not know!”[151]

2.8 For Further Discussion

In the comics one of Superman’s more interesting adversaries is Mr. Mxyzptlk (pronounced *mix-yez-pitle-ick*), a being with seemingly magical powers from the Land of Zrfff in the fifth dimension. Mr. Mxyzptlk’s powers are not really because of magic, however, but are ‘merely’ the result of his hyperspace world with its extra dimension. Mr. Mxyzptlk, for example, in one of his misadventures with Superman in 1954, begins selling a

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[150] Figure 2.2 is based on a similar one in C. K. Raju, “Time Travel and the Reality of Spontaneity,” *Foundations of Physics*, July 2006, pp. 1099–1113.

[151] There is another view of time even darker than St. Augustine’s, which denies the existence of both future and past, and doesn’t offer us much either for that special moment we call the present (or *now*). This view, called *presentism*, was hauntingly expressed in some lyrics I heard in the final episode of the second season (2015) of the HBO series *True Detective*: “There is no future/There is no past/In the present nothing lasts.” Now *that* is depressing! Still, there are philosophers who believe even this view can support time travel: see S. Keller and M. Nelson, “Presentists Should Believe in Time-Travel,” *Australasian Journal of Philosophy*, September 2001, pp. 333–345.

newspaper called the *Daily Mpftrz* in competition with the *Daily Planet*. Unlike a traditional newspaper that reports what *has* happened, the *Daily Mpftrz* (your guess is as good as mine!) prints what *will* happen. As Mr. Mxyzptlk says, “You see, as a resident of the fifth dimension, I can get all the news I want from the *fourth* dimension!” The science editor at the *Daily Planet* explains the meaning of that to his boss, Perry White: “That’s right, Mr. White . . . many physicists consider *time* the fourth dimension . . . so if Mr. Mxyzptlk can travel from the fifth dimension to our three-dimensional world, he most likely *is* able to see the future!” (This leaves unanswered the question of *why* he continues to challenge Superman when he knows he will always be defeated—*as he always is*!) Presumably a five dimensional world would have our three spatial and one temporal dimension (for a total of four), and so the question now is: what is the nature of the additional (fifth) dimension? Is it spatial or is it temporal? (There is a brief appearance of the fifth dimension in the 2014 movie *Interstellar*, but we aren’t told much of anything about its possible structure.) Discuss and compare the world of four space dimensions and one time dimension, with the world of three space and *two* time dimensions. (In Chap. 5 we’ll discuss a possible connection between two-dimensional time and time travel.)

In the text it is stated that “If A and B are mutually causative, then ‘A causes B’ coupled with ‘B causes A’ seems to lead to ‘A causes A.’” Suppose, however, that we imagine two adjacent sunken pools of water, **a** and **b**, on the same horizontal surface, with each pool filled to the brim. An overflow from one pool will flow into the other pool. Now, define the events A and B as ‘A is the overflow of pool **a**’ and ‘B is the overflow of pool **b**.’ Thus, A causes B and B causes A. Does the conclusion ‘A causes A’ make physical sense in this specific case? Discuss at length.

When reading A. C. Clarke’s story “Technical Error” (see note 99), we learn that a rotation through 4-space *inverts* “the unlucky Nelson.” The ‘solution’ to this awkward situation is to flip Nelson through 4-space a second time and so back to ‘normal.’ (When *Thrilling Wonder Stories* reprinted this tale in June 1950, after its original publication in 1946, the title was changed to the more appropriate “The Reversed Man.”) Clarke may have missed an

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important technical ‘detail,’ however, in that when first flipped through 4-space *everything* inverts, and so matter becomes anti-matter and Nelson would have instantly been annihilated in a 100 % conversion of matter to energy (that is, the flipped Nelson would have initiated a very large explosion). Compare this to Alice’s concern in her flipped world (Lewis Carroll’s *Through the Looking Glass*) when she wonders “Perhaps Looking-glass milk isn’t good to drink.” Explain why Lewis Carroll certainly was *not* thinking of matter/anti-matter explosions when he wrote his novel. What *do* you think he might have had in mind?

A time travel story, even earlier than Clarke’s, that uses spacetime ‘rotations,’ was authored by Edmond Hamilton (1904–1977), one of the pioneering pulp fiction writers. In his “The Man Who Saw the Future” (*Amazing Stories*, October 1930), a man is hauled before the Inquisitor Extraordinary of the King of France to explain his mysterious disappearance, and subsequent reappearance, in an open field, amid thunderclaps and in plain sight of many onlookers. As the story unfolds, we learn that the man was transported five centuries into the future, from A.D. 1444 to 1944, by scientists working in twentieth-century Paris. The thunderclaps were produced by spacetime ‘rotations,’ as the atmospheres of 1944 and 1444 were reversed. A skeptical Inquisition naturally finds this tale preposterous and the first time traveler is burned at the stake as a sorcerer. Can you think of *why* such ‘atmospheric swaps’ might produce thunderclaps?

A trip around a Möbius strip reverses the ‘handedness’ of a plane figure (left and right are swapped). You can see this for yourself by making a Möbius strip, and then sliding an arrow (pointing *across the width* of the strip) around the strip. (Cut a notch in the side of the strip to mark the starting point, with the arrow pointing at the notch.) When you get back to the notch, the arrow will point *away* from the notch. Notice that the arrow never left the surface of the strip, or crossed any ‘weird’ boundary. Then, read H. G. Wells’ short story “The Plattner Story” and comment on its use of ‘handedness.’

The *autoinfanticide paradox*, which results when a time traveler tries to kill his younger self, continues to fascinate both physicists and philosophers, and papers regularly appear in the scholarly literature on the topic: see, for example, Kadri Vihvelin, “What Time Travelers Cannot Do,” March 1996, pp. 315–330 (which introduces Suzy the time traveler); Ira Kiourti, “Killing Baby Suzy,” June 2008, pp. 343–352; Peter B. M. Vranas, “What Time Travelers May Be Able to Do,” August 2010, pp. 115–121; and Joshua Spencer, “What Time Travelers Cannot *Not* Do (but are responsible for anyway),” October 2013, pp. 149–162, all in *Philosophical Studies*. All deal with an issue that is psychologically fascinating: *moral responsibility*. Spencer, in particular, opens with this definition: Someone is morally responsible for an action *only* if she could have done otherwise. As he goes on to write, “If I have been attacked and both of my legs have been broken, then it seems illegitimate to criticize me for failing to run away; I could not have done otherwise.” And yet all of these papers are on a point that (I think) physicists would soon lose interest in: is the question ‘If Suzy is a time traveler, can Suzy kill baby Suzy, given that Suzy doesn’t kill baby Suzy?’ the same question as ‘If Suzy is a time traveler, can Suzy kill baby Suzy, given that Suzy is now alive?’ The answer to the first question is, from pure logic, NO, while the answer to the second question is just bit squishier: it all depends on what the word *can* means. For the second question, Suzy *can* kill baby Suzy if she has a weapon (knife, gun, poison, etc.) and she is in the past next to baby Suzy, but it is just that she doesn’t because otherwise Suzy wouldn’t be alive now (which is a given). Such debates seem unlikely to produce any insights into the physics of time travel. Compare this situation to the old schoolboy conundrum “What happens when an irresistible force meets an unmovable object?’, which is a *self-inflicted* ‘paradox.’ That is, the words *irresistible* and *unmovable* are mutually exclusive and so, used this way, it should be no surprise that we have a conflict. Are the two time travel questions above, concerning Suzy, confusing through a similar mushy use of grammar? Or are they deeper than that? Vigorously defend your position.

In addition to H. G. Wells, another nineteenth-century writer who was highly influential in bringing the fourth-dimension out of academia and into public consciousness was the mathematician Charles Howard Hinton (1853–1907). Hinton was no angle-trisecting crank, having earned an M.A. at Oxford, an appointment in the mathematics department at Princeton, and then another at the University of Minnesota. Later, with the help of the eminent astronomer

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Simon Newcomb, he obtained a position at the Naval Observatory in Washington, D.C., and was on the staff of the United States Patent Office at the time of his sudden death. Hinton was a man to be taken seriously. His first published essay "What Is the Fourth Dimension?" appeared in 1880, and then in book form in 1884 as part of his *Scientific Romances* (a phrase used by Hinton before it became associated with Wells' science fiction many years later). That book received a generally favorable review in *Nature* (March 12, 1885, p. 431). At one point he wrote "We might then suppose that the matter we know extending in three dimensions has also a small thickness in the fourth dimension," an idea that was used a few years later by the well-known British mathematician W. W. Rouse Ball (1850–1925) in an attempt to explain gravity. Hinton was extremely inventive, and he also proposed four-dimensional-space models for static electricity. Find out more about Hinton's life and work: a good source to start with is *Speculations on the Fourth Dimension: Selected Writings of Charles H. Hinton* (R. Rucker, editor), Dover 1980. Take a look, too, at J. E. Beichler, "Ether/Or: Hyperspace Models of the Ether in America," in *The Michelson Era in American Science 1870—1930* (S. Goldberg and R. H. Stuewer, editors), American Institute of Physics 1988.

Chapter 3
The Physics of Time Travel: Part I

"... within forty-eight hours we had invented, designed, and assembled a chronomobile. I won't weary you with the details, save to remark that it operated by transposing the seventh and eleventh dimensions in a hole in space, thus creating an inverse ether-vortex and standing the space-time continuum on its head."

—almost certainly *not* the way to build a time machine[1]

3.1 The Direction of Time

> "Of all the problems which lie on the borderline of philosophy and science, perhaps none has caused more spilled ink, more controversy, and more emotion than the problem of the direction of time ... [T]he main problem with 'the problem of the direction of time' is to figure out exactly what the problem is or is supposed to be!"[2]

Before we start talking about the physics of time travel, let me say a few more words on time itself, in a way slightly less metaphysical that was the discussion in the previous chapter (which is why I'm writing this *here*, in a chapter with an increased emphasis on the analytical). When we speak of journeying to either the future or the past, we are implicitly making a distinction in the direction of the time traveler's trip. But does time actually have a *direction*? Is there an *arrow* that points the way? The answer seems obvious: *of course* time has a direction. After all, everybody 'knows' it flows from past to future. There is a curious language problem here, however, because we also like to say the present recedes into the past, which implies a 'flow' in the opposite direction, from future to past. Well, despite this snarled syntax, can we at least distinguish past from future, whichever way time flows?

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[1] L. Sprague de Camp, "Some Curious Effects of Time Travel," in *Analog Readers' Choice*, Dial 1981.

[2] See note 54 in Chapter 2.

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P.J. Nahin, *Time Machine Tales*, Science and Fiction,
DOI 10.1007/978-3-319-48864-6_3

This would seem to be an important question to answer because for the phrases *flow of time* and *direction of time* to have any objective meaning at all, it must be somehow possible to identify a difference between past events and future ones. The special moment at which that distinction occurs is known as the *now* or the *present* and, as events make the transition associated with that distinctive difference, between past and future, we say that the *now* (the present) moves or flows. Philosophers—and science fiction writers and physicists, too, who after all are human beings with human senses like everybody else—call this common feeling that we all have, of the passage of time, the *psychological arrow of time*. One philosopher gave an amusing (tongue-in-cheek) gastronomical interpretation of the moving *now* as follows:

> “New slices of salami are continually being cut from a nonexistent chunk of salami called the future. The *present* is the slice on top of the pile. The past are the pieces beneath this, and even though they are not present they still continue to exist in the same way that the top slice of salami does. . . . This [concept] faces humiliation before the embarrassing question of how fast the pile of salami slices grows.”[3]

The ‘moving now’ does present a problem for physicists because there is nothing in the laws of physics that marks the present moment as unique, and therefore nothing that reflects a ‘flow’ of time, nothing that models the reality of a ‘moving now’ becoming part of the past and the events of the future becoming, successively, the new ‘now.’ As a philosopher wrote long before time travel became a serious topic in the physics literature, “Talk of the flow of time or the advance of consciousness is a dangerous metaphor that must not be taken literally.”[4]

What that philosopher may well have had in mind is that all events in the block universe simply have coordinates in spacetime, and there is nothing corresponding to ‘have been’ (past), ‘are’ (present), or ‘will be’ (future). There is no ‘moving now’ in the block universe except for its subjective presence in our conscious minds. All we can say from physics is that events are ordered in an earlier/later sequence, and in fact, even that relatively weak condition holds only for *causally* related events.[5] The relativistic, four-dimensional block universe view of spacetime that so many physicists (including Einstein) so dearly love seems to have no room for an objective theory of the *flow* of time. And yet, even for those same physicists, there is a powerful psychological sense that time *does* flow. But are they mistaken? It is a fact that, with not just a little irony, Gödel (the ‘discoverer’ of time travel) was convinced that the possibility of a block universe spacetime with CTLs/CTCs

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[3] R. Gale, “Some Metaphysical Statements About Time,” *Journal of Philosophy*, April 25, 1963, pp. 225-237. For many, this analogy may well bring to mind a pile of baloney rather than one of salami (and I think this was Gale’s intention).

[4] J. J. C. Smart, “The Temporal Asymmetry of the World,” *Analysis*, March 1954, pp. 79-83.

[5] Two events A and B are *non*-causally related if their separation in spacetime is such that a particle would have to travel at a *superluminal* speed (faster than light) to go from A to B. We’ll discuss the physics of causally related events later in this chapter.

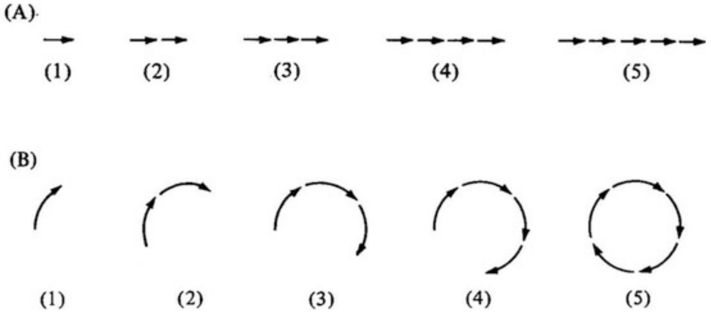

Fig. 3.1 Gödel's unreality of time argument

implies that the passage or flow of time *makes no sense*![6] To see how Gödel arrived at such an astonishing conclusion, consider Fig. 3.1.

In part A of the figure[7] we see what most people who talk of a passage of time intuitively mean, as time progresses through a sequence of instants (shown as line of left-to-right arrows going from (1) to (2) to (3) and so on). At each stage the rightmost arrow is the present, and the arrows to the left of it (behind it) are the past, and the arrows to the right of the present are not shown because they are in the future and so don't exist yet. When you ask, at each step, which arrow is the *now*, the answer is clear.

Matters are dramatically different in part B of the figure, which shows the arrows forming a closed (circular) loop. Now there is no distinction between past and future, as each arrow is both ahead *and* behind any other arrow. In addition, there is no arrow that is uniquely the now. So, concluded Gödel, the passage of time can have no meaning in a temporal loop. As should come as no surprise, not everybody is convinced by this sort of argument.[8]

In principle, so it would seem, we can achieve perfect knowledge of what has happened but only imperfect prediction of what might happen. This observation seems to be at least a start at being able to tell past from future. And, in fact, the nature of the distinction between the two intervals of time seems obvious: we *remember* past events, but not future ones. As philosophers have so nicely put it, events in the past have formed *traces*, such as skulls, footprints in the sand, fossilized skeletons, surgical scars, photographs, taped recordings, carved stones, and the like, whereas future events appear not to have formed traces. But is that necessarily so? Is it impossible for future events to create traces? The commonsense answer is *yes*, because of cause and effect, which dictates that there *must* be a temporal asymmetry in trace formation. That is, traces are the effects of *prior* causes. That line of reasoning leads us quickly to the fundamental issue of causation (which we've already encountered in Chap. 2), an issue that no discussion of time travel can avoid.

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[6] Gödel clearly states this in his 1949 philosophical essay (note 15 in the Introduction) concerning his 1949 technical paper (note 11 in the Introduction).

[7] This figure is based on the interpretation of Gödel's reasoning as presented by the philosopher Palle Yourgrau's 1991 book *The Disappearance of Time: Kurt Gödel and the idealistic tradition in philosophy* (Cambridge), which was expanded and reprinted a few years later under the new title *Gödel Meets Einstein: time travel in the Gödel universe*, Open Court 1999. Yourgrau later wrote a less technical version: *A World Without Time: the forgotten legacy of Gödel and Einstein*, Basic Books 2005.

[8] See, for example, S. Savitt, "Time Travel and Becoming," *The Monist*, July 2005, pp. 413-422.

Part of the problem we have with backward time travel, and cause and effect, is as I've already mentioned, with language. The distinct and separate concepts of the temporal ordering of events, and of causality, have become merged in everyday thought. It is considered *obvious* to modern minds that if event A causes event B, then A *must* happen first. There is, however, at least one historical example of a similar merging of concepts that is parallel to our modern mixing of time order and causality—an example that shows how an issue can seem obvious and natural to the minds of one period of time, and yet to the minds of another period (our modern times) seem confused, odd, peculiar, even laughable.

As a *physicist* wrote in a paper[9] on advanced (that is, inverted causality) effects:

> *Ancient Egypt was an essentially one-dimensional country strung out along the Nile, which flows from south to north. The winds were conveniently arranged to be predominantly northerly. To go north, a traveler could let his boat drift, while with a sail he could move south against the slow current. For this reason, in the writing of the ancient Egyptians, "go downstream (north)" was represented by a boat without sails, and "go upstream (south)" by a boat with sails. The words (and concepts) or north-south and up-downstream became merged. Since the Nile and its tributaries were the only rivers known to the ancient Egyptians, this caused no difficulties until they reached the Euphrates, which happened to flow from north to south. The resulting confusion in the ancient Egyptian mind is recorded for us to read today in their reference to "that inverted water which goes downstream (north) in going upstream (south)."*

Often we can work our way free of the difficulties we create for ourselves with language, but only through common agreement. For example, the chairman of the board calls a meeting to order with mixed tenses by declaring "The meeting *will* take place *now*" and then saying at the end, "We will meet again *next* month, *same* time." We all know what these sentences mean, but only by our cultural heritage and not by the process of applying logic. The language problem causes similar difficulties for not only for fictional time travelers, but also for the physicists/philosophers who study the possibility of time machines. So—beware!

The idea of time flowing is a popular one, and it repeatedly appears in the time travel literature as the "river of time" or the "ocean of time." The deep psychological appeal of this sort of 'water language' has, not surprisingly, attracted the attention of philosophers. We can find one of the earliest expressions of the view in the *Meditations* of the second-century A.D. Roman emperor and Stoic philosopher Marcus Aurelius, who wrote: "Time is like a river made up of events which happen, and a violent stream; for as soon as a thing has been, it is carried away, and another comes in its place, and this will be carried away, too." A most interesting essay on why such metaphors often seem so intuitively appropriate has been offered by one philosopher, who points out[10] that the seductiveness of the image of 'time as flowing water' is sufficiently great that you often find it in the scientific literature, too (Newton, you'll recall, wrote specifically in his *Principia* of time flowing). As for why such an image has such a powerful grip on our imaginations, I think we need look no further than to Kant. As he wrote (1781) in *Critique of Pure Reason*, "Time is nothing but the form of inner sense, that is, of the intuition of ourselves and of our inner state . . . Because this inner intuition yields no shape, we endeavor to make up for this want by analogies." And what better than a rushing stream of water to represent our feeling of time rushing by?

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[9] P. L. Csonka, "Advanced Effects in Particle Physics," *Physical Review*, April 1969, pp. 1266-1281.

Still, no matter how intuitive such water metaphors may be, they can still easily befuddle us as well. To quote our philosopher (note 10), "Time a river! A queer sort of river that. Of what sort of liquid does it consist? Is time a liquid? A very peculiar liquid indeed!" A classic paper by the philosopher Donald Williams (discussed in Chap. 2, note 119) expresses similar doubt about the water image of time. In the course of his writing, he presents a truly staggering collection of entertaining examples of 'time as metaphor,' of which I repeat just a few here: time flies, goes, marches, and rolls, as well as flows And then he offers *this* provocative imagery: the evolution of our lives is like "a moving picture film, unwinding from the dark reel of the future, projected briefly on the screen of the present, and rewound into the dark can of the past." Wow![11]

Returning to the water metaphor, the French astronomer Charles Nordmann (1881–1940) opened and closed his 1925 book *The Tyranny of Time* with following gloomy but all too true summary of the overwhelming sense we all have of the inexorable, one-way 'flow' of time. (The ellipses in what follows denote over 200 pages!) "Nothing can equal the bitter sweetness of dreaming on the banks of Time, that impalpable and fatal river strewn with dead leaves, our wistful hours carried downstream like rudderless wrecks . . . In the eternal wave which rocks us, carries us along, and soon swallows us up, there is no rock to which we can fasten our frail barques; the very buoys we put out to measure our course are only floating mirages; and on the mysterious foundation of things our anchors slide along and fail to bite." A young person sees time, from Nordmann's perspective, as an ocean on which golden mornings arrive like waves from the future, whereas for an older person, liquid time is a nightmare flood, a swollen black torrent sweeping him first into the yawning abyss of the past and, ultimately and finally, into the eternal silence of the dark grave.

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[10] J. J. C. Smart, "The River of Time," *Mind*, October 1949, pp. 483-494.

[11] And how about *this* image of time: Time is a snowball, with the center marking the beginning of the past, with ever new 'presents' accreting on the ever increasing surface as the snowball rolls down the hill of history!

The metaphor of time as a flowing river was ready-made for early science fiction writers, such as Caltech math professor Eric Temple Bell (1883–1960). His eventual novel *The Time Stream* began to appear in December 1931 as a serial in the science fiction pulp *Wonder Stories*, and Bell (writing as 'John Taine') made great use of the idea of time as a flowing stream, a stream in which one could swim into either the future or the past. There is strong evidence that Bell actually wrote the novel in July of 1921, but was unable to find a publisher for a decade, so odd did editors find the premise. By the time of its publication, others had beaten Bell into print.

The watery image of time had appeared a year earlier, for example, in a tale that played with the erosive nature of time in a dramatic way. As two time travelers speed into the future to rescue a friend, one of them describes the scene for us: "We huddled together in the whirling time girdling machine, cutting through the years as a ship's prow breasts surging waves. I could not help but think of the years as waves, beating in endless succession on the sands of eternity. They wore all away before them with pitiless attrition. Time seemed to eat all with dragon jaws."[12]

This image of time was taken a step further 3 years later in a story in which a large number of adventurers, from all across time, find themselves stranded at precisely the same place (in space and time). One of them offers his theory of what is behind this remarkable coincidence: They all have faulty time machines, like faulty boats, and all have hit the same snag on the 'river of time.' As he explains, "You may turn boats adrift on a river at many points, and they will all collect together at the same serious obstacle whether they have traveled a hundred or two miles. We are now at some period where the straight flow of time has been checked — perhaps it is even turning back on itself ... [We] have struck some barrier and been thrown up like so much jetsam."[13]

The 'flow' of time does have its critics, of course. The British-American philosopher Max Black (1909–1988) argued[14] that questions about the direction of time are meaningless because there can be no direction to something that (he asserted) does not flow. His reasoning was that if time does flow, then he ought to be entitled to ask *how fast* it flows. That requires, in turn, a *metatime* or *supertime* for measuring the flow rate of 'ordinary' time. But because supertime must flow, too, we would then need a super-supertime, and so off we trip into what would appear to be the black hole of a McTaggert-like infinite regress. The view, of an infinite regress of times, was forcefully rejected by another philosopher with these sharp words: “the very idea of super (or hyper)-time is indeed repulsive in its redundancy and its aroma of dilettante physics.”[15]

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[12] E. A. Manley and W. Thode, "The Time Annihilator," *Wonder Stories*, November 1930. This is the same magazine that, months later, finally published Bell.

[13] J. Wyndham, "Wanderers of Time," *Wonder Stories*, March 1933. Notice again, that we have the same magazine (whose editor must have had a particular fancy for such tales).

[14] M. Black, "The 'Direction' of Time," *Analysis*, January 1959, pp. 54-63.

A hierarchy of hypertimes has not bothered other analysts, however, and an entire subfield of specialty among philosophers (and some physicists, too) in time analysis has developed in what is called *multidimensional time*. One practitioner in this specialty sarcastically rejected the infinite regress complaint as a valid objection—he called it “a crushing and unanswerable position” but actually meant just the opposite—and stated that it was not at all clear (at least, not to him) why supertime must flow.[16] After all, he argued, we measure the flow of a river with respect to its banks without requiring that the banks themselves flow. (That actually strikes me as being a point that deserves debating, but I have not been able to find any mention of it in the later philosophical literature.) The idea of multiple time dimensions is particularly attractive for one sort of time travel (we’ll take it up at the end of this chapter), but it enjoys far more popularity among science fiction writers and philosophers than it does with physicists.

Professor Black’s objection (note 14) to talk of time ‘flowing’ was based, at least in part, on the observation that there are uses of the word *direction* that are not directly tied to something flowing. For example, consider the statement ‘He is facing in the direction of north.’ Black argued that this is mere pointing, and it is not at all the same as *moving* north. He then dismissed the possibility of there being any meaning to the direction of time, writing that making an analogy of time “with a sign-post or an index finger is too far-fetched to be worth considering.” This claim (which some may feel leans too much on grammar) is, of course, an affirmation of the myth-of-passage view made famous a few years earlier by Donald Williams (note 119 in Chap. 2).

Not just philosophers have rejected the idea of time flowing. In his 1966 novel *October the First Is Too Late*, which deals with a world in which different parts of Earth simultaneously experience different eras of the past (see *For Further Discussion* at the end of this chapter for more on what this might mean), the British cosmologist Fred Hoyle (1915–2001) calls the ‘river of time’ a “grotesque and absurd illusion,” and a “bogus idea.” Another fictional work that agrees with Hoyle’s non-moving image of time is the 1979 *Roadmarks* by Roger Zelazny (1937–1995). In that novel we read of “the Road,” along which story characters can travel but which doesn’t itself move; exits from the Road lead to the various centuries (which sounds a lot like the Francis Bradley’s 1883 book that may have given the block universe its name). *Roadmarks* is a clever bit of writing, with many allusions to the paradoxes of time travel, but its explanation of the Road’s origin as having been constructed by *dragons* (!) greatly undermines its interest for physicists.

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[15] D. Zeilicovici, “Temporal Becoming Minus the Moving-Now,” *Nous*, September 1989, pp. 505-524.

[16] C. W. Webb, “Could Time Flow? If So, How Fast?” *Journal of Philosophy*, May 1960, pp. 357-365.

In a block universe spacetime, there is no flow of time, but one philosopher believed that to be simply because the block universe is *incomplete* in its representation of reality. Writing in 1925, Hans Reichenbach (1891–1953) asked “What does ‘now’ mean? Plato lived before me, and Napoleon IV will live after me. But which one of these three lives *now*? I understandably have a clear feeling that *I* live now. But does this assertion have an objective significance beyond my subjective experience?”[17] Reichenbach went on to answer his question in the affirmative, and to deduce that the block universe view is missing something: “In the condition of the world, a cross-section called the present is distinguished; the ‘now’ has objective significance. *Even when no human is alive any longer, there is a ‘now’* [my emphasis] . . . In the four-dimensional picture of the world, such as used by the theory of relativity, there is no such distinguished cross-section But this is due only to the fact that an essential content is omitted from this picture.”

So, what *is* Reichenbach’s ‘missing essential content’? Feeling that the block universe is unacceptably fatalistic—in his words of ridicule, “the morrow has already occurred today in the same sense as yesterday”—he found his answer in the probabilistic theory of quantum mechanics. Classical physics argues that given total information about the state of the world *now*, one could in principle calculate perfectly the future or the past; one could both predict and retrodict. In contrast, quantum mechanics distinguishes past from future in a fundamental way.

Quantum mechanics does not deny that in principle we can know the past with exquisite accuracy, because each and every event leaves traces, evidence that is available to all with the means to find and decode them. But quantum mechanics also takes as truth that there is an unavoidable uncertainty to the future. The instant that this uncertainty is crystallized into fact was taken by Reichenbach to be the very definition of ‘now.’ The ever-increasing record of the past, in turn, defines (for Reichenbach) the *movement* of the ‘now.’ Reichenbach believed that with these observations he had at last captured the ‘moving now’ in mathematical theory, and that he had finally elevated the present from speculative psychology to solid physics, and that he had shown that the ‘flow of time’ is independent of the need for a conscious mind. However—

A later, powerful analysis[18] of the time-flow issue, combining philosophy with physics, comes down solidly in support of the *opposite* conclusion: it expresses the view that a ‘moving now’ *is* only in our minds and is *not* an intrinsic attribute of reality. The premise of that argument is that a mind-dependent flow of time is incompatible with what is called the *relativity of simultaneity* (to be discussed later in this chapter) which states that there is no universal cosmic-wide ‘now’ (this is a fundamental conclusion of special relativity). For example, it is meaningless to ask what is happening on a planet in the Andromeda galaxy (two million light-years distant) *right now*.

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[17] I’ve taken this quotation from A. Grünbaum, “Is There a ‘Flow’ of Time or Temporal Becoming?” in *Philosophical Problems of Space and Time*, Knopf 1963.

[18] L. R. Baker, “Temporal Becoming: The Argument from Physics,” *Philosophical Forum*, Spring 1975, pp. 218-236.

Early science fiction stories are full of theories about the nature of 'now,' and the vast majority of them have no basis in scientific thought. Some of them are ingenious, however, and even though they are largely the pet ideas of the authors (and no one else's), perhaps they resulted in some young readers of the science fiction pulps of the 1930s and 1940s thinking about deeper matters than did the comic strips of "Buck Rogers," "The Lone Ranger," or "Terry and the Pirates." For example, according to one story, time is a wave and the 'moving now' we experience is carried on a crest of that wave. There are time waves both ahead and behind the crest we happen to be on (so we are told), and so each such crest carries a different 'now' for a different reality—hence the curious title.[19]

In another, more recent tale[20] about object duplication via time travel (which we'll discuss in Chap. 4, but you'll recall H. G. Wells was worried about this long ago), nine (!) copies of the same person from the year 2314 meet in 1870 to try and figure out what is going on. Part of their interesting discussion is the following analysis of the 'present':

> "Gentlemen, I think I understand," said the first James Thomas."
>
> "Eight faces turned toward him, and he felt as though he were looking into multiple mirrors."
>
> "We hold that time is a single instant — the instant of the Present —which travels through Duration — do we not?"
>
> "Eight heads nodded."
>
> "We assume that time passes in a manner analogous to the stringing of an infinite number of beads. Each bead is the instant of Now when it is last on the chain. Beads are continually being added, and each one is the only Now until another is placed after it."
>
> "Yes, that is my theory," said another James Thomas. "It can also be likened to the process of knitting. No matter how many stitches are knitted, there is only one last stitch, only one Now."

Einstein, too, was greatly bothered by the place of 'now' in time, perhaps even more than were James Thomas and his 'friends.' In an autobiographical essay, the philosopher Rudolf Carnap (1891–1970) recalled a conversation about this with Einstein in the early 1950s, at the Institute for Advanced Study in Princeton: "Once Einstein said that the problem of the Now worried him seriously. He explained that the experience of the Now means something special for man, something essentially different from the past and the future. That this experience cannot be grasped by science seemed to him a matter of painful but inevitable resignation. . . . Einstein thought . . . that there is something essential about the Now which is just outside the realm of science."[21]

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[19] R. Ray, "Today's Yesterday," *Wonder Stories*, January 1934.

[20] A. and P. Eisentein, "The Trouble With the Past," in *New Dimensions 1* (R. Silverberg, editor), Doubleday 1971.

3.2 The Arrows of Time

> "On a microscopic level there is no preferred direction for time. The equations of motion don't give a damn whether time moves forward or backward."[22]

The central issue for philosophers of time (and for physicists, too, I think) is that of its reality (or not): is time *objective and something that really flows*, or is time simply a *mind-dependent illusion* and nothing more than an artifact of our incomplete perception of reality? As the previous section shows, there is little consensus on this issue. As a start on trying to get a handle on the matter, looking into a so-called 'arrow of time' may give us some guidance. I'll begin with the arrow I've already mentioned, the psychological arrow. As discussed before, this is the feeling we have of a 'moving now,' a feeling that has no appearance anywhere in physics. A 'moving now' simply has no place in any universe devoid of the physical processes in a brain that give rise to what we call consciousness—but that doesn't mean physicists don't wonder about the 'moving now' just as much as does everybody else (remember Einstein)! As one physicist wrote in a technical journal, "What does 'Now' mean? This question must surely be the starting point of any attempt at understanding the nature of time."[23]

Well, no matter whether time actually flows or not, most of us still believe we have had a past and hope we will have a future. Each of us thinks we can easily tell one from the other, too. We have, in fact, many not so subtle indications from our everyday lives of the obvious direction of time. Nearly all of these indications have the common theme of *irreversible change*. As the British mathematician J. J. Sylvester once put it, "The whirligig of time brings about its revenges."[24] The Roman poet Ovid, who died when Christ was a teenager, said the same in his *Metamorphoses* with the famous words "Time, the devourer of all things." The image of time as devourer of all that is mortal was brilliantly presented by James Barrie in his *Peter Pan*, with the crocodile who had swallowed a ticking clock chasing Captain Hook all about Neverland.

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[21] Quoted from *The Philosophy of Rudolp Carnap* (P. A. Schlipp, editor), The Library of Living Philosophers, Open Court 1963, pp. 37-38. For a view contrary to Einstein's, from another physicist, see K. B. M. Nor, "A Topological Explanation for Three Properties of Time," *Il Nuovo Cimento B,* January 1992, pp. 65-70, which claims to develop a geometrical explanation for the flow of time, and so (says Nor) there *is* an objective, mathematical reality to the 'moving now.'

[22] A science fiction character pretty accurately sums-up what a modern physicist would tell you today, in L. Eisenberg's story "The Time of His Life," *The Magazine of Fantasy & Science Fiction*, April 1968.

[23] J. P. Cullerne, "Free Will and the Resolution of Time Travel Paradoxes," *Contemporary Physics*, July-August 2001, pp. 243-245.

[24] J. J. Sylvester, "A Plea for the Mathematician," *Nature*, December 30, 1869, pp. 237-239.

No one yet has escaped the biological decay processes of time, and inanimate objects are no less immune to this aspect of time. Logs and cigarettes burn in the stove and ashtray, but they never unburn. Our cars rust but never 'unrust.' An explosion has never been seen to reverse itself, to form a dynamite stick or a bomb casing out of a collapsing fireball. Our world seems, indeed, literally to be built on an irreversible movement toward chaos, death, and decay. Lewis Carroll uses this observation in his *Through the Looking-Glass* when Alice tells Humpty Dumpty "one can't help growing older." And speaking of Humpty Dumpty, his famous fall provides a dramatic example of a one-way evolution from past to future; he wasn't at all convinced that Alice was correct but, once he had splattered, then

All the King's horses and all the King's men
Couldn't put Humpty Dumpty together again.

While we are on the subject of Mr. Dumpty, it is also worthwhile to note that nobody has ever figured out how to unscramble an egg. Why is that? One philosopher speculated that the answer is found in the "irreversible organic phenomena" taking place in our brains which results in our flow of consciousness always being in the same direction.[25]

More subtle than the undignified undoing of a prideful egg is the phenomenon of memory, which seems trivial only because most people have not thought very carefully about it. We remember the past while remembering nothing about the future. We might, in fact, be tempted to use the phenomenon of memory to answer the question of how to tell past from future. Anything you can remember *is* the past. But that is a circular definition, as discussed by Professor Smart (note 4) who observed that to ask why memory is always of the past "is as foolish as to ask why uncles are always male, never female." In *Through the Looking-Glass* the White Queen tells Alice that "it's a poor sort of memory that only works backward" but, except for the claims of clairvoyants, it seems that is the only sort of memory any of us has. Why is that so? Of course, that would *not* be the case for a time traveler while in the past. His personal past, which he would remember, would be the future for the world around him.

For physicists, the question of the direction of time is one of profound mystery. There seems, in fact, to be no fundamental reason why time should not be able to go from future to past—but then what would 'future' and 'past' *mean*—even though no one has ever observed time to do so. All the laws of classical physics, including general relativity, and quantum mechanics, too (except for the K-mesons mentioned in Chap. 1) involve time in such a way that they ignore its sign. In other words, replacing t with $-t$ results in a perfectly valid description of something that could actually happen. But not all such possibilities are observed to occur. Why not?

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[25] H. Margenau, "Can Time Flow Backwards?" *Philosophy of Science*, April 1954, pp. 79-92.

In an unpublished paper written in 1949, while doing the work that would bring him a share of the 1965 Nobel prize in physics, Richard Feynman (1918–1988) wrote[26] “The relation of time in physics to that of gross experience has suffered many changes in the history of physics. The obvious difference of past and future does not appear in physical time for microscopic events . . . Einstein discovered that the present is not the same for all people [the relativity of simultaneity, to be discussed later in this chapter] . . . It may prove useful in physics to consider events in all of time at once and to imagine that we at each instant are only aware of those that lie behind us. The complete relation of this concept of physical time to the time of experience and causality is a physical problem which has not been worked out in detail. It may be that more problems and difficulties are produced than are solved by such a point of view.”

Feynman did not elaborate on what he meant by the “problems and difficulties” with that point of view (which is clearly that of the block universe), but surely he had the logical paradoxes of time travel high on his list. As the Yale philosopher Henry Margenau wrote (note 25) in a tutorial on Feynman’s work, “The theory of quantum electrodynamics developed by Feynman incorporates reversals in the course of time and thereby cherishes, in the minds of many, *an age-old phantasy* [my emphasis] of more than scientific appeal [which sounds like time travel to me].”

Because the individual classical equations of microscopic physics are time-reversible, the distinction between past and future for individual particles disappears. The equations are said to be symmetric with respect to time; the algebraic sign of t is irrelevant in the classical laws. It must be understood, however, that there *is* a crucial point to appreciate. When a physicist says *time reversal*, she is talking about a system evolving backward in forward time—that is, all the individual particle velocity vectors are instantly reversed at once. This is distinct from the time-reversed worlds of philosophers and science fiction writers (which we’ll get into later in this chapter) in which time itself ‘runs backwards.’ The physicist’s point of view is clearly expressed in an early essay by a chemist: “Every equation and every explanation used in physics must be compatible with the symmetry of time. Thus we can no longer regard effect as subsequent to cause. If we think of the present as pushed into existence by the past, we must in precisely the same sense think of it pulled into existence by the future.”[27] More than three decades later, a mathematician and a physicist presented a similar statement: “In classical dynamics, the past completely determines the present, and therefore, by symmetry, the future also completely determines the present.”[28]

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[26] S. S. Schweber, “Feynman and the Visualization of Space-Time Processes,” *Reviews of Modern Physics*, April 1986, pp. 449-508.

[27] G. N. Lewis, “The Symmetry of Time in Physics,” *Science*, June 6, 1930, pp. 569-577.

[28] O. Penrose and I. C. Percival, “The Direction of Time,” *Proceedings of the Physical Society* (London), March 1962, pp. 605-616.

Besides the physics, there is also an interesting theological connection to time reversal. As one philosopher put it, “If all the laws are time reversal invariant and so no irreversible processes occur in the physical Universe then there is no inherent, intrinsically meaningful difference between past and future . . . If this is actually the natural case, then all mankind’s major religions which preach a creation of the Universe (by a supernatural agency) and imply, accordingly, a differentiation between the past and the future . . . would have to make appropriate adjustments.”[29]

There are, as you might expect on such a controversial topic, dissenters to the view that the classical laws of physics are necessarily time-reversible. Dirac himself wrote that “I do not believe there is any need for physical laws to be invariant under time and space reflections, although all the exact laws of nature so far known do have this invariance.”[30] Dirac did not, unfortunately, elaborate on just why he felt that way, but with the later discovery of K-mesons his position is seen to have been ‘ahead of its time’! In a famous science fiction story[31] dealing with the direction of time, one character finally puts his finger on the real puzzle of the question of time: “How can a man live backward? You might as well ask the Universe to run in reverse entropy.” That cogent question brings us, in fact, to the first scientific explanation developed to explain the observed asymmetric nature of time.

It was the Englishman A. S. Eddington (1882–1944) who gave the picturesque name, the *arrow of time*, to the observed asymmetric nature of time’s direction from past to future. He was also one of the popularizers of an explanation for the arrow, using the famous second law of thermodynamics.[32] The second law of thermodynamics states that a measure of the internal randomness or disorder—what is called the *entropy*—of any closed system (that is, one free of external influences) continually evolves toward that of maximum disorder, toward the condition called *thermodynamic equilibrium*. Indeed, so striking is this increase in entropy S with time in a macroscopically large system that the increase in entropy has come to be thought of as actually *defining* the direction of time. Eddington, however, was not the originator of the entropy concept. The history of entropy can be traced back to before the turn of the century, to the great Austrian scientist Ludwig Boltzmann (1844–1906) and his famous H-theorem. The quantity H in that theorem is directly related to the more familiar entropy,[33] defined by Boltzmann in 1877.

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[29] H. Mehlberg, “Philosophical Aspects of Physical Time,” in *Basic Issues in the Philosophy of Time* (E. Freeman and W. Sellars, editors), Open Court 1971.

[30] P. A. M. Dirac, “Forms of Relativistic Dynamics,” *Reviews of Modern Physics*, July 1949, pp. 392-399.

[31] A. Boucher, “The Chronokinesis of Jonathan Hull,” *Astounding Science Fiction*, June 1946.

[32] A. S. Eddington, *The Nature of the Physical World*, Macmillan 1929.

[33] The H-theorem was a direct continuation of the work by the Scottish physicist James Clerk Maxwell (1831-1879) on the statistical properties of gas molecules (determining the probability density function of the molecules’ speeds). In 1866 Maxwell found this function for the particular case of thermodynamic equilibrium. In 1872 Boltzmann found the differential-integral equation the function satisfies in general, even if the condition of thermodynamic equilibrium doesn’t hold. From this Boltzmann was able to define a quantity H that he showed evolves in time such that

The entropy S of a system in a given state is proportional to W, which is the number of different possible ways the state can occur as a result of all possible variations of system's internal, microscopic structure. The calculation of W is usually quite complicated, but in various highly idealized systems it can be straightforward. Consider, for example, a vacuum cylinder with a thin membrane dividing the interior into halves. Suppose that we insert (to be specific) six molecules into the left half of the cylinder (and none into the right half). If we define the microscopic state of the system to be the number of molecules in the left half, then initially $W = 1$ because there is just one way to put all six molecules on the left side. This represents the state of *minimum* entropy, the state of maximum order that is most distant from thermodynamic equilibrium. If we now puncture the membrane then the molecules, once confined to the left side, are free to move about the entire cylinder. At any given instant we can imagine counting the number of molecules on the left side—suppose that at some particular instant we count five, with one molecule having moved to the right side. Then, $W = 6$, because there are six ways to pick the molecule that has moved from left to right, and so the entropy has increased.

We think of the thermodynamic equilibrium state as being the state with equal numbers of molecules in both halves of the cylinder, and that state has the *maximum* entropy. (Can you show that this state is associated with $W = 20$?) With such a small number of molecules, it is *not* clear that W (and so S) will *inexorably* increase with time; perhaps, after one of the six molecules has gone to the right, it then returns to the left side before any of its companions have joined it on the right. Such an event is called a *reversal*, and it will happen with some non-zero probability. But the more molecules there are in the cylinder (instead of six, make the number a million million million—still a small amount of gas in our everyday world, hardly enough to fill a sewing thimble), the more likely it becomes that the value of S *will* monotonically increase with time.

The steady increase in entropy is often observed in the everyday, large-scale world. A drop of ink in a glass of water spreads out in an expanding cloud, a cloud we *never* see collapse backward into an ink drop. A long rod of metal, initially hotter at one end than at the other, evolves toward a constant temperature along its entire length. We *never* see a uniformly warm rod spontaneously begin to cool at one end and grow hot at the other. A hot bath grows cold—nobody has *ever* seen a bath at room temperature suddenly, all by itself, begin to heat up and then boil in the middle of the tub while the edges freeze into ice chunks. In all of these cases, the end (future) state represents greater internal randomness or disorder than does the beginning (past) state.

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solution to his differential-integral equation approaches Maxwell's equilibrium solution. The H-theorem says that H always *decreases* in systems not in equilibrium and is at a *minimum* in systems in equilibrium.

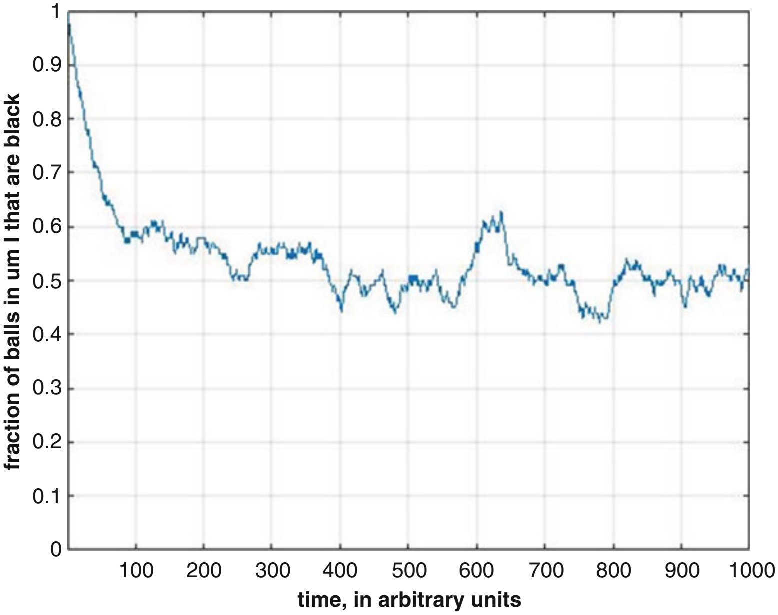

Fig. 3.2 Simulation of the Ehrenfest entropic gas clock

That is, low entropy *was* the past, and high entropy *will be* the future. The increase in entropy seems to define a direction to time, and so entropy has come to be called the *thermodynamic arrow of time*.

The first formal entropy model for the direction of time was put forth in a 1907 paper by the Austrian physicist Paul Ehrenfest (1880–1933) who was a friend of Einstein, and his Russian-born wife Tatyana (1880–1964), who was a skilled mathematician and her husband's occasional collaborator. In their paper the Ehrenfests developed one of the mainstays of physics, the so-called *entropic clock*. This clock, a statistical model based on the then new probability mathematics of Markov chains—after the Russian mathematician A. A. Markov (1856–1922)—describes how gases diffuse, and it is both a simple and a powerful concept. The Ehrenfest model is illustrated in Fig. 3.2, in a computer-generated plot based on a discussion by Princeton physicist John Wheeler of black hole fame (see Chap. 1).[34]

Imagine two urns, I and II, each containing n balls. Initially, at time $t = 0$, all of the balls in Urn I are black and all of the balls in Urn II are white. Then, at time $t = 1$ (in arbitrary units), a ball is selected at random from each urn and (instantaneously) placed in the other urn. This select-and-transfer process is repeated at times $t = 2$,

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[34] J. A. Wheeler, "Frontiers of Time," in *Problems in the Foundations of Physics* (G. T. diFrancia, editor), *Proceedings of the International School of Physics* (Course 72), North-Holland 1979. See also W. J. Cocke, "Statistical Time Symmetry and Two-Time Boundary Conditions in Physics and Cosmology," *Physical Review*, August 25, 1967, pp. 1165-1170.

3, 4, ... At any given time each urn always contains n balls, but only at $t = 0$ are the colors of all the balls in a given urn necessarily the same. The phrase "selected at random" means (for example) that the probability of selecting a black ball from an urn containing b black balls is b/n. At any given time we completely describe the state of both urns by specifying the number of black balls in Urn I (or the number of white balls in Urn II, and so on). It is easy to write a computer simulation of this physical process,[35] and Fig. 3.2 shows how the fraction of black balls in Urn I evolves toward 0.5 as time increases. The plot is for $n = 100$ (200 balls total). The important observations are that (1) the evolution of the state of the system is toward 50 % black balls in Urn I (and this would be the case for 'almost all' sequences of random selections of the balls from the urns), and (2) the evolution is not monotonically decreasing from 100 % black balls to 50 % black balls, but rather has never-ending fluctuations about 50 % that may, in fact, be rather large in both amplitude and in duration.

There is a real puzzle with the entropic clock that may not be immediately apparent. The motion of each of the individual molecules is described by time-reversible physics, but when we average over 'many' molecules (assuming 200 molecules is 'many') we lose detailed information about the individual molecules. The puzzle is then how is it that by *reducing* our knowledge of a system, through statistical averaging, we then find it displaying a *new property*, that of asymmetric time evolution, that we didn't see before when we watched the individual molecules. And if that question isn't troublesome enough, we also have two additional puzzles called the 'reversibility' and the 'recurrence' paradoxes to consider as well.

The reversibility paradox is the question raised earlier: the classical equations of physics work just as well with time running in either direction, and so *why don't* things actually go 'backward'? This question, originally raised by the British mathematical physicist and engineer William Thomson (1824–1907)—better known as Lord Kelvin—in 1874, was brought to Boltzmann's attention in 1876 by the German physical chemist Johann Loschmidt (1821–1895), one of Boltzmann's professors at the University of Vienna. Boltzmann's answer to this apparent paradox was that it *is* imaginable that a world could run backward if initial conditions were suitable. For example, if all the velocity vectors of every particle in an equilibrium state were reversed, then the system *would* unwind backward in time toward its original non-equilibrium condition. That is, a system in thermodynamic equilibrium, the state of highest entropy, could evolve toward one of low entropy. Boltzmann even suggested that such might be the case for regions in our own universe, that there might actually be beings in a world somewhere 'out there' who experience time running counter to our earthly experience. He said that in 1877, and it is a remarkable statement for a conservative nineteenth-century professor.[36] However, Boltzmann continued, from most given states there are vastly more ways for entropy to increase than there are for it to decrease, and that is why we see what we see, a continuous *increase* in entropy.[37]

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[35] I used MATLAB, and you can find the code — gasclock.m — in Appendix C, written in such a low-level way as to be virtually 100% transferable to just about any of the popular scientific programming languages, and easily executed on an inexpensive laptop. Note that there are no K-mesons in the code (!) and so, as stated in Chapter 1, they aren't responsible for the uni-directional time behavior depicted in the figure.

To find a science fiction writer speculating on reversed time people is, of course, much less remarkable! One pulp story, in fact, presents a curious treatment of the nuances of reversed time in which people talk backward (along with a marvelous bathroom scene of a man un-washing his hands!). This tale[38] tells us a young physics teacher who is "twisted into a reversed Time Stream" by an electrical discharge. As he lives backward in time, he observes everybody about him appearing to run in reverse, but even more puzzling is that they have developed a "dreadful, granite-like hardness." We soon learn why:

"For a while he could not understand the impenetrable hardness of external objects which he had experienced; it seemed they ought rather to be of intangible transiency, much as a dream, since he was re-viewing the Past. But a moment's thought gave him the logical answer. The Past is definite, shaped, unalterable, as nothing else in Creation is. Therefore, to argue that he could move or alter any object here [the past] was to argue that he could change the whole history of the world or cosmos. Everything he saw about him had happened, and could not be changed in any way. On the other hand, he was fluid, movable, alterable, since *his* future still lay before him, even if it had been reversed; he was the intruder, the anomaly. In any clash between himself and the Past, the Past would prove irresistible every time."

This passage reflects the modern view that the past cannot be changed, but explains that view in a way different from that generally accepted today. Modern physicists and philosophers invoke consistency requirements (which we'll take up in the next chapter) to explain the 'solidity' of the past. The author of this story also failed to explain why his physics teacher had no trouble moving about through the air of the past, which apparently is not any more resistant to being displaced than were air molecules before time reversal occurred.

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[36] The Austrian-British philosopher Karl Popper (1902-1994) called Boltzmann's willingness to consider the possibility that different regions of the universe could have different directions of time "staggering in its boldness and beauty," but when on to say that Boltzmann must be wrong because "it brands unidirectional change an illusion [which] makes the catastrophe of Hiroshima an illusion." That is an emotional argument, of course, and although one of great power, I fail to see how it is related to physics. See Volume 1 of *The Philosophy of Karl Popper* (P. A. Schlipp, editor), Open Court 1974, pp. 127-128.

[37] For more on Boltzmann's views on entropy, see the end of his letter "On Certain Questions of the Theory of Gases," *Nature*, February 28, 1895, pp. 413-415.

[38] C. F. Hall, "The Man Who Lived Backwards," *Tales of Wonder*, Summer 1938. The modern classic of a time-reversed world is Philip K. Dick's 1967 novel *Counter-Clock World*. We'll encounter another time-reversed world again in Chapter 4.

It didn't take long for science fiction writers to incorporate entropy as time's arrow into time travel. In one early tale there is the brief statement that entropy is behind the operation of its gadget.[39] And a few years later the inventor of a "warp gun" tells us that "The stupendous distortion of the warp may actually bring about a sort of kink in spacetime, and result in a reversal of entropy"[40] and, sure enough, when the gun is fired a woman, who is hit by the warp, ages 70 years in seconds (which is, of course, exactly the opposite of what we would expect from a "reversal of entropy"!). Just a year later, the story of a college student about to flunk his senior physics course appeared.[41] An examination is scheduled for the following day, but he needs a week and a half of study time. To his rescue comes ENTROPY, INC., a company that sells time by placing its clients inside a "time-cabinet" in which the local entropy is greatly accelerated. To someone looking through a window at the interior of the time-cabinet, the occupants would appear as characters in a speeded-up movie. Referring to Eddington by name, the author tells us that "entropy is what makes time irreversible — is what gives us the feeling of the flow of time."[42]

In a hilarious, melodramatic story featuring one of early science fiction's stereotypical 'mad scientists,' the entropic arrow of time is the scientific explanation for time travel.[43] There we read of Bryce Field, "a master-scientist, a demon, cruel, ruthless," who is rejected in love by the stupendously beautiful Lucy Grantham. Her lack of enthusiasm is perhaps understandable, as Bryce is described as having "a lean-jawed, sunken-eyed" appearance, along with "lank, untidy hair sprawled across his massive forehead." As Lucy tells him at one point, "I could never love you; you are too clever, too brilliantly scientific." After hearing that, it is no surprise that before we are more than a page or two into the tale that we learn Bryce has Lucy strapped to a steel table in an underground laboratory-in-a-cave. There he tells her of her fate: "You are going on a long journey, my dear. So long a journey that even I, master-scientist, do not know when it will end. A journey into the future — alone! ... You, Lucy, shall be the victim of entropy! ... I have discovered how to make a [globe] of non-time. Entropy will be halted ... You will be plunged into an eternal 'now.'"

And so the mad Doctor Field throws the switch on the wall of his "instrument-littered" cave on July 17, 1941, and Lucy remains "suspended" in time until the outside world reaches the date of August 9, 2450. That is the day she is at last dug-up from the cave by "big and muscular" engineer Clem Bradley and his "square-jawed" sidekick Buck Cardew, who uses a "warp in spacetime" to release Lucy from her "globe of non-time."

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[39] M. J. Breuer, "The Time Valve," *Wonder Stories*, July 1930.

[40] F. B. Long, "Temporary Warp," *Astounding Stories*, August 1937.

[41] R. M. Farley, "Time for Sale," *Amazing Stories*, August 1938.

[42] Also citing Eddington was a tale by D. W. O'Brien, "The Man Who Lived Next Week," *Amazing Stories*, March 1941, which uses entropy to explain time travel. This curious story has the traveler arriving in the future with his clothing aged, which later 'de-ages' when the return trip is made!

[43] P. Cross, "Prisoner of Time," *Super Science Stories*, May 1942.

A few years later entropy was used in a similar but vastly more 'scientific' way. In that tale[44] we read of a scientist who has discovered "a field in which entropy was held level." As the reader is told, "An object in such a field could not experience any time flow — for it, time would not exist," since time flow is a *change* in entropy, and the 'change' of a level (or constant) field is zero. This interesting tale speculates on how such a field could have fantastic home uses ("Imagine cooking a chicken dinner, putting it in the field, and taking it out piping hot whenever needed, maybe twenty years hence!"). But its real use in the story is as a stasis generator for preserving fatally ill people until medical science has learned how to cure their diseases. This is, then, a high-tech method of suspended animation, of time travel into the future that is different from simply freezing (a clock in such a field would not age or measure the passage of personal time).

The gadget that does all this is called, somewhat sinisterly, the "Crypt," which we are told also makes a great bomb shelter, too, because "not even an atom bomb could penetrate a stasis field." The reason for that is intriguing: "The field requires a finite time in which to collapse — only there is no time in it." The interior of the Crypt is, quite literally, a frozen block of time more rigid and unyielding than the strongest steel.

As science fiction left the age of pulps and moved into the modern era, entropy continued to be useful a justification for time travel. Arthur C. Clarke used it,[45] as did Robert Silverberg. This last tale[46] is particularly interesting, as Silverberg pursued entropy beyond simply invoking it as a mere casual throwaway mention. When a newspaper from the future appears on people's doorsteps, the initial astonishment is replaced with puzzlement as the papers rapidly disintegrate. That is the result (we are told) of "entropic creep." The explanation continues, informing us that it is sort of like a strain in a geological fault (Silverberg has lived for decades in California, now and then a place of large to huge earthquakes, and it isn't surprising that he uses this particular imagery): "Entropy you know is the natural tendency of everything in nature to come apart at the seams as time goes along. These newspapers must be subject to unusually strong entropic strains because of their anomalous position out of their proper place in time."

Earlier I mentioned we had *two* puzzles associated with entropy; we've discussed 'reversibility,' so what's the other one, the 'recurrence paradox,' all about? The recurrence paradox is quite different from reversibility; it is based on a result established in 1890 by the great French mathematician Henri Poincaré (1854–1912). Motivated by the question of the stability of the motion of three masses governed by Newton's laws of mechanics (think, for example, of the Sun, the Earth, and the Moon), Poincaré showed that starting from almost any initial state, any fixed volume system with a finite amount of energy and a finite number of degrees of freedom will return *infinitely often and with arbitrarily little deviation* to almost every previous state. If you wait long enough, implies Poincaré's astonishing theorem, Pearl Harbor will happen again—and again, and again, and .... In 1896 the German mathematician Ernst Zermelo (1871–1953) used this result, which philosophers call the 'eternal return,' to claim that there could be no truly irreversible processes and thereby cast doubt on the idea that entropy *always* and *inexorably* increases.

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[44] P. Anderson, "Time Heals," *Astounding Science Fiction*, October 1949.

[45] In, for example, his story of the tragic end of a geologist fifty million years in the past: "Time's Arrow," *Science Fantasy*, Summer 1950.

[46] "What We Learned from This Morning's Newspaper," *Infinity 4*, November 1972.

Even for very small systems, however, such as a mere handful of molecules, the recurrence time is extremely large, and this was, in essence, Boltzmann's reply to Zermelo's concern. For example, if the gas-filled cylinder of our entropic clock has just 100 molecules (not the six I used in the earlier example), and if transitions from one side of the cylinder to the other side take place at the rate of one million per second, then the recurrence time has been calculated to be something like 30 million billion years![47] And for the universe itself, the recurrence time is simply incomprehensible. Mathematicians call 1 followed by a hundred zeros a *googol*, and the recurrence time in years for the universe has been estimated to be 1 followed by a googol of zeros (a so-called *googolplex* of years).[48]

Using a wonderful bit of imagery, one analyst wrote of the enormity of the recurrence time of a system considerably *less* complex than the universe this way: "If a man shuffled just a single pack of cards as rapidly as an individual molecule hits other molecules in air, and if a snail started to crawl around the universe . . . at the rate of one centimeter *during the life of the sidereal system* [my emphasis], the snail would have got round the universe many millions of times before it would become at all likely that the man would have got the pack back to the original order."[49] If this is what it takes to get a pack of cards back to its initial state, then try to conceive of the time interval required to restore *the world* to December 7, 1941.[50]

The notion of eternal recurrence considerably predates Poincaré, and its scientific (as opposed to astrological) study can be traced back to the fourteenth century.[51] A 'more recent' claim for eternal recurrence, also based on scientific arguments (conservation of energy), can be found in many places in the writings of the German philosopher Friedrich Nietzsche (1844–1900)—see, for example, his *The Gay Science* (1882) and *Thus Spake Zarathustra* (1883)—again predating

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[47] J. M. Blatt, "Time Reversal," *Scientific American*, August 1956.

[48] The googol is a gigantic number, far greater than the number of raindrops that have fallen on the Earth during its entire history. And the googolplex is light years beyond that.

[49] R. B. Braithwaite, "Professor Eddington's Gifford Lectures," *Mind*, October 1929, pp. 409-435.

[50] Pulp science fiction writers, of course, were not discouraged by such calculations, as they depended on the *certainty* of recurrence over *infinite* time. See, for example, S. G. Weinbaum, "The Circle of Zero," *Thrilling Wonder Stories*, August 1936, and L. D. Gunn, "The Time Twin," *Thrilling Wonder Stories*, August 1939.

[51] R. Small, "Incommensurability and Recurrence: From Oresme to Simmel," *Journal of the History of Ideas*, January-March 1991, pp. 121-137.

Poincaré. All of Nietzsche's arguments are flawed,[52] but they are rational, physical arguments, as opposed to arguments based on metaphysics or theology. In fiction, a glimmer of the idea of a repetition of human affairs preceded Poincaré by some years, too.[53]

An important caveat concerning recurrence is that we could never *know* of it because the state of all the historical records (geological, memories, books, photographs, and so on) would, as part of the physical state of the universe, also recur. And so those records could, up to the instant *before* the recurrence, contain no signature *of* the recurrence because the recurrence has not 'yet' happened![54] The 1993 movie *Groundhog Day* stumbles on this point, as it has a character (for some unexplained reason) live through the same day over-and-over *and he is aware he is doing that*. Indeed, he can change events within that time loop at will. It is interesting to note that one 'time loop' pulp science fiction tale[55] specifically avoided that error (and cited Nietzsche, to boot), and so demonstrated that pulp science fiction *could* have some philosophical merit to it.

While the enormous recurrence time for the universe may seem reason enough to reject the possibility of Pearl Harbor repeating, there are more fundamental reasons for such a rejection. For example, an *expanding* universe, such as the one we live in, violates the Poincaré theorem's assumed condition of a *fixed* volume system. As Professor Eddington put it in a 1934 lecture at Cornell University, "In an expanding space any particular congruence becomes more and more improbable. The expansion of the Universe creates new possibilities of distribution faster than the atoms can work through them, and there is no longer any likelihood of a particular distribution being repeated. If we continue shuffling a pack of cards we are bound sometime to bring them into their standard form — but not if the conditions are that every morning one more card is added to the pack."[56]

An even more direct way to escape Poincaré's theorem is to use a result from general relativity. Using Einstein's theory instead of the classical dynamics that Poincaré used, it has been shown (by Frank Tipler, the inventor of the rotating cylinder time machine spacetime that was mentioned in the previous chapters and which we'll revisit later in the book) that the recurrence theorem is simply no longer true.[57] As Tipler wrote, "In general relativity, singularities intervene to prevent recurrence. General relativistic Universes are thought to begin and end in singularities of infinite spacetime curvature [the Big Bang and the Big Crunch, respectively], and these singularities force time in general relativity to be linear rather than cyclic." A twist to this, however, is that in his analysis Tipler assumed that gravity is *always* attractive, and that the spacetime satisfies a special condition (called the *Cauchy condition* that we'll take-up later) that avoids backward causation. The first assumption is violated in wormhole time machine spacetimes, though, and the second is *by definition* violated in *any* spacetime that supports time travel! So, who knows . . ... ?

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[52] J. Krueger, "Nietzschean Recurrence as a Cosmological Hypothesis," *Journal of the History of Philosophy*, October 1978, pp. 435-444.

[53] See "Human Repetends" by Marcus Clarke (1846-1881), a story originally published in 1872 and reprinted *Australian Science Fiction* (V. Ikin, editor), Academy Chicago 1984.

[54] For more on this point, see D. W. Theobald, "On the Recurrence of Things Past," *Mind*, January 1976, pp. 107-111.

[55] C. F. Ksanda, "Forever Is Today," *Thrilling Wonder Stories*, Summer 1946.

[56] A. S. Eddington, "The End of the World," in *New Pathways in Science*, Macmillan 1935.

[57] F. J. Tipler, "General Relativity and the Eternal Return," in *Essays in General Relativity* (F. J. Tipler, editor), Academic Press 1980.

Despite all of the previous discussion it is *not* true that the evolution of a system from past to future is *always* accompanied by an increase in entropy—that is, by an irreversible increase in some measure of the system's 'disorder.' Yes, it can be calculated that entropy is *very likely* to monotonically increase in systems of macroscopic size, but that is not the same as certainty. There *can* be fluctuations in the thermodynamic evolution of a system so as to have, at least for a while, a *decrease* in entropy (take another look at Fig. 3.2). All we can say, for sure, is that for macroscopically sized systems even very small fluctuations in increasing entropy are most improbable. To quote no less an authority than the combined genius of Gilbert and Sullivan (from their opera *H. M. S. Pinafore*), here's what we can honestly say of the possibility of failure in the supposed inexorable increase of entropy: "What, never?/No, never!/What, never?/Well, hardly ever." Still, for physicists, entropy is just too useful a concept to give up even though it does not *always* increase with increasing time for an isolated system.

Love it though they may, there are some puzzling aspects to entropy for physicists that remain to this day. For example, the idea that the universe began in some sort of Big Bang process 15 billion years or so ago is the generally accepted view today, The puzzle of that event, one that has been described as literally being a 'fireball explosion,' is that it must have been *fantastically* hot. This means that at the beginning (of everything) there was complete thermodynamic disorder, which from our earlier discussion means *maximum* entropy. Thus, we immediately have the question of how can the entropy of the universe be continuously increasing if it was as large as possible right from the start?[58]

One possible answer is that the proper model of the universe to use is the so-called *inflationary* universe. The inflationary model has a very high expansion rate for the early universe, much higher than the rate in the standard hot Big Bang model. In the standard model, the entropy puzzle occurs because of the ability of all particle processes to readjust rapidly to the ever-changing state of the universe; the so-called *relaxation times* of all particle processes were *short* compared to the expansion rate of the universe. That means that the actual entropy of the universe would, indeed, be the maximum possible at every instant (and so we have the entropy puzzle). In the inflationary model, however, the expansion rate of the early universe was temporarily so high that the relaxation times of particle processes were *very long* compared to the expansion rate. That means the maximum *possible* entropy of the universe, at every instant, would greatly exceed the *actual* entropy. This 'entropy gap' is the cause, then, of the thermodynamic arrow of time, as the universe tries to 'catch-up' and reduce the resulting entropy deficiency.

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[58] It has been estimated that over the next 10^{116} years the entropy of the universe will increase by a factor in excess of 10^{14}. See S. Frautschi, "Entropy in an Expanding Universe," *Science*, August 13, 1982, pp. 593-599.

There is also a philosophical problem with associating increasing entropy with the flow of time from the past into the future. Events in the past leave traces, artifacts taken to be ordered states—or at least more ordered than are their immediate surroundings. The classic example of this is a footprint in the sand, which is clearly a highly organized structure compared to the surrounding sandy beach. The footprint is the trace of a *past* event; such a trace was all the evidence, for example, that Robinson Crusoe needed to conclude that another human had walked that way. But now consider this famous counter-example,[59] that of a bombed city. Certainly there are traces aplenty of past bombing, and in fact one has to be careful not to trip over or to fall into them! The puzzle, of course, is in trying to argue that random bomb craters, strewn rubble, and crushed buildings, somehow constitute a more organized state (a 'footprint') than did the original city and its surrounding undamaged areas. This fuzziness was captured by one physicist who asked "If it were found that the entropy of the universe were decreasing, would one say that time was flowing backward, or would one say that it is a law of nature that entropy decreases with time?"[60]

For another example of the fuzziness of the relationship between entropy and time, consider the situation[61] of a cloud of non-colliding particles all initially moving toward each other. At first the radius of the smallest sphere that contains the cloud decreases with time but, eventually, as the particles move past another, the radius will grow without bound. Indeed, that inexorable increase of the radius could be taken as defining the direction of time that points toward the future. But in what sense is the *disorder* of the particle cloud increasing? After all, as the cloud expands it 'looks the same' at all times; only its scale (radius) changes. What has entropy to do with this expanding-into-the-future cloud? Perhaps nothing. Perhaps what is need is a *new* arrow of time.

So far we have looked in some detail at two arrows of time: the subjective, psychological feeling we have of time 'flowing,' which has no explanation in physics, and the thermodynamic, statistical quantity of entropy. A third arrow is the so-called *cosmological arrow* of the expansion of the universe. This arrow is not nearly as obvious as the first two. Only in the last century (since the 1920s), as a result of the American astronomer Edwin Hubble (1889–1953), has science become aware that the universe *is* expanding. An interesting speculation about the thermodynamic and cosmological arrows, one made numerous times, is that if the cosmological arrow should ever reverse—that is, if the universe should ever begin to contract toward a Big Crunch—then the thermodynamic arrow would also reverse.[62] The reasoning is that the thermodynamic arrow *follows* the cosmological arrow in an *expanding* universe because that universe can continually ‘swallow-up’ ever more electromagnetic radiation as it is produced by any physical process. *If* the thermodynamic arrow continues to follow the direction of the cosmological arrow during a contraction, *then* the thermodynamic arrow would also reverse direction.

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[59] See note 54 in Chapter 2.

[60] P. W. Bridgeman, *Reflections of a Physicist*, Philosophical Library 1955, p. 251.

[61] Taken from K. G. Denbigh, "The Many Faces of Irreversibility," *British Journal for the Philosophy of Science*, December 1989, pp. 501-518.

The usual objection to that suggestion is straightforward. If the direction of time did reverse, then we would see (so goes this argument) all sorts of odd events that would require enormously improbable physics, such as a shattered glass mirror reassembling itself. The error in that objection is subtle but equally simple. *It presupposes the retarded causality of our expanding universe*. In a contracting universe with a reversed thermodynamic arrow of time, however, there would be *advanced* causality, and thus there would be nothing at all improbable about such doings as self-assembling mirrors. As two physicists observed, “The mere reversal of the cosmological expansion will not of itself serve to reverse the direction of thermodynamic and electrodynamic processes, any more than the compression phase of a piston-and-cylinder cycle in a heat engine serves to reduce the entropy of the confined gas.”[63]

Those same physicists go on to then mention Stephen Hawking’s interest in the relationships among the various temporal arrows. At one time Hawking thought[64] he had discovered a connection between the thermodynamic and cosmological arrows, but then later abandoned that claim.[65] Hawking, in fact, has labeled his original claim “my greatest mistake in science,” and has quite openly (and most entertainingly!) discussed his interest in the arrows of time.[66] Indeed, it was to be the subject of his doctoral dissertation but, as he wrote, “I … needed something more definite, and less airy fairy than the arrow of time, for my PhD, and I therefore switched to singularities and black holes. They were a lot easier.”

Yet another arrow of time is the *electromagnetic arrow*, which refers to the fact that radio waves are observed to only propagate into the future, and never into the past. This is a mysterious fact, because Maxwell’s equations for the electromagnetic field, like all the other laws of physics, have no intrinsic time sense. The electromagnetic arrow will be discussed in some detail in Chap. 4.

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[62] T. Gold, “The Arrow of Time,” *American Journal of Physics*, June 1962, pp. 403-410.

[63] P. C. W. Davies and J. Twamley, “Time-Symmetric Cosmology and the Opacity of the Future Light Cone,” *Classical and Quantum Gravity*, May 1993, pp. 931-945.

[64] S. Hawking, “Arrow of Time in Cosmology,” *Physical Review D*, November 15, 1985, pp. 2489-2495. See also the next paper in the same journal, D. N. Page, “Will Entropy Decrease if the Universe Recollapses?,” pp. 2496-2499.

[65] For *why* he abandoned that claim, see S. Hawking *et al.*, “Origin of Time Asymmetry,” *Physical Review D*, June 15, 1993, pp. 5342-5356.

[66] S. W. Hawking, “The No Boundary Condition and the Arrow of Time,’ in *Physical Origins of Time Asymmetry* (J. J. Halliwell *et al.*, editors), Cambridge University Press 1994.

3.3 Time Dilation

> "Time as we know it is not universally absolute. The rate of its passage depends to a great extent upon the velocity of its observer with regard to some certain reference system. A moving clock will run slower with respect to a selected coordinate system than a stationary one."
>
> —an early science fiction time traveler explains how his time machine works[67]

In this section I'll set the stage for the scientific basis of time travel to the future, as well as for time travel to the past via the warped spacetime called a wormhole. We start by imagining two horizontal, parallel mirrors, one positioned over the other and separated by distance d. The two mirrors are in the same frame of reference with an Observer; that is, the Observer is looking at two mirrors that are stationary with respect to him. Between the two mirrors we further imagine that a particle of light, a photon, is bouncing endlessly back and forth, up and down, in relentless reflection. This simple system is called a *photon clock*, or the Einstein-Langevin clock, after the French physicist Paul Langevin (1872–1946), and it has been part of physics for decades. We define the time required for the photon to travel from one mirror to the other as a *tick* in time, and so the return trip defines the clock's *tock*. The rate of timekeeping measured by the Observer, the time interval separating consecutive ticks, is obviously then given by

$$t' = 2\frac{d}{c}$$

where c is the speed of light.

Suppose we next imagine that the Observer and the photon clock move at constant speed v to the right across *our* line-of-sight. That is, we remain in the original frame while the photon clock and the Observer are now moving at speed v relative to us. This means the photon clock is in a different frame of reference from ours and so *we* do not see the photon bouncing up and down vertically, but rather *we* see the photon tracing out the triangular path shown in Fig. 3.3.

A round trip of the photon evidently now requires more time than before because the distance in the stationary frame (our frame) is greater than the round trip distance in the Observer's frame (moving with the photon clock, he still sees a round trip distance of d). In fact, if t is the time between consecutive ticks as seen by a stationary viewer (us), then the round trip path length of the photon that we see is

$$2\sqrt{d^2 + \left(\frac{vt}{2}\right)^2}$$

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[67] F. J. Bridge, "Via the Time Accelerator," *Amazing Stories*, January 1931.

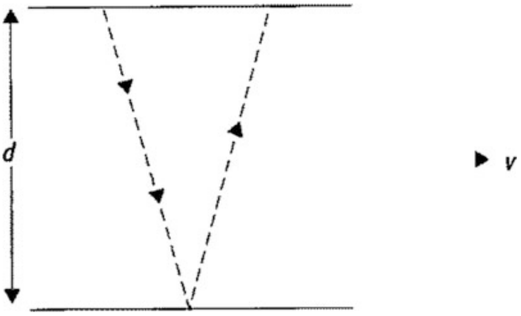

Fig. 3.3 The moving (relative to us) photon clock

and so

$$t = \frac{2\sqrt{d^2 + \left(\frac{vt}{2}\right)^2}}{c}.$$

This can be easily and quickly manipulated algebraically and combined with the earlier expression for t', the tick interval for an Observer in the same frame as the photon clock, to give the tick interval for the moving clock *as measured by a stationary viewer* (us):

$$t = \frac{t'}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}.$$

Notice that this reduces to $t = t'$ when $v = 0$—that is, when the photon clock is stationary with respect to us.

This last result is the famous Einstein time dilation formula, which shows that $t \geq t'$, and indeed that $t = \infty$ when $v = c$. That is, to us the moving photon clock appears to *run slow* compared to clocks in our stationary frame of reference and, at the speed of light, time *stands still.*[68] A curious anticipation of this association between light and timelessness can be found in a poem by the seventeenth-century poet Henry Vaughn who, in the opening words to his "The World"—which appeared in 1650 as part of his *Silex Scintillans* ("Sparking Flint")—wrote

"I saw Eternity the other night
Like a great *Ring* of pure and endless light,
All calm, as it was bright,
And round beneath it, Time in hours, days, years
Driven by the spheres
Like a vast shadow moved, in which the world
And all her train were hurled."

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[68] For $v > c$ the time dilation formula says that time becomes imaginary, and this is one reason for claiming that $v > c$ is not possible. The time dilation formula has been experimentally verified: see H. E. Ives and G. R. Stilwell, "An Experimental Study of the Rate of a Moving Atomic Clock," *Journal of the Optical Society of America*, July 1938, pp. 215-226.

A similar modification in the length of a moving object (measured in the direction of motion) occurs when $v > 0$. While an Observer moving with the object will measure its length to be L', a stationary viewer will 'report' it to be contracted to the length

$$L = L'\sqrt{1 - \left(\frac{v}{c}\right)^2}.$$

This effect is called the *Lorentz-FitzGerald contraction*.[69] For 'everyday' objects and speeds the contraction effect is an extremely small one. For example, for a low-altitude satellite 100 m long, moving at 18,000 miles per hour (that is, at $v = 2.7 \times 10^{-5}c$), the contraction is less than 4×10^{-6} cm.

In the early days of science fiction the contraction effect was fascinating to readers, but authors often got it wrong. For example, in one story[70] of a runaway spaceship falling into the Sun, we read "When our racing [ship] was drawn from the Earth's gravity and fell at ever increasing speed toward the Sun it soon approached the speed of light. As we fell faster and faster our length in the direction of the Sun progressed into nothingness. Then — it reached the speed of light — passed it. Now — mind you this — when the [ship] attained the speed of light it was of a *minus* length." This author has managed to make four errors in three sentences!

The same author botched the Lorentz-FitzGerald contraction again 5 years later, and added yet more errors to his growing list. In that tale[71] there is an episode of faster-than-light radio communication along with a lengthy, unfortunate dissertation that actually denies special relativity's fundamental assertion that all inertial frames of references are indistinguishable from each other (two frames are *inertial* if they have no relative acceleration—I'll say more on this in the next section). And in yet another story[72] of high-speed space travel the author has the contraction working in the wrong direction—as the rocket ship moves faster and faster it gets longer and longer.

As bad as those errors are, first prize for mangling the laws of physics has to go to the story[73] of a near light-speed spaceship on its way to Alpha Centauri. The crew mutinies and puts the captain and first office 'overboard' (think *Mutiny on the Bounty*) with 6 months' worth of provisions. This happens at mid-voyage, about 2 light-years from both home and destination, so matters look grim. Indeed, the author tells his readers, several times, that things look *very* bad. But are they? With a stated speed of 162,000 miles per second, the time dilation factor is slightly more than 2 and so, because the space boat is traveling at $0.87c$, it will take a little more

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[69] Named after the Dutch physicist H. A. Lorentz (1853-1928) and the Irish physicist G. F. FitzGerald (1851-1901).

[70] J. H. Haggard, "Faster Than Light," *Wonder Stories*, October 1930.

[71] J. H. Haggard, "Relativity to the Rescue," *Amazing Stories*, April 1935.

[72] D. Wandrei, "A Race Through Time," *Astounding Stories*, October 1933.

[73] N. Schachner, "Reverse Universe," *Astounding Stories*, June 1936.

Table 3.1 The Lorentz-FitzGerald time slowing factor

1	$\frac{1}{\sqrt{1-\left(\frac{V}{C}\right)^2}}$
.1	1.005
.2	1.021
.5	1.155
.7	1.4
.9	2.294
.999	22.366
.9999	70.712

than 13 months of *space boat time* to complete the journey. If the men go on half-rations then it seems they *could* survive.

There is, of course, the problem of slowing down so as to arrive at Alpha Centauri at a reasonable speed, but that issue is ignored in the story. Instead, our attention is directed to the much more dramatic concern of a faster-than-light planet (don't ask!) colliding with the space boat and carrying the castaways onwards toward their destination. When this happens we read that time runs backwards (for what *really* occurs at superluminal speeds, keep reading this chapter) and, finally, in a repeat of an error I mentioned earlier, we are told that the Lorentz-FitzGerald contraction is negative for $v > c$.

The time-slowing (or size-shrinking) factor becomes pronounced only at values of v close to c, as shown in Table 3.1. For example, the last entry shows that a clock traveling at 99.99 % the speed of light will register the passage of 1 year while nearly 71 years pass on Earth. One science fiction writer got this dramatically wrong, even though he actually reproduced the Lorentz-FitzGerald equation in his story.[74] At one point he writes of the near light-speed rocket ship that stars in the tale, "If it [the ship's speed] was as slow as ninety-four percent [of the speed of light] . . . for every moment ticked by the clocks of the [ship] hundreds passed on earth." In fact, the time dilation factor at that speed is 'only' 2.93.

One possible objection to time dilation is that the analysis done here has been for a *particular* clock. How do we know that another clock, one using wheels and pendulums, for example, instead of photons and mirrors, wouldn't be affected differently by motion? The answer comes from relativity itself, which says there is no way to detect uniform motion. If two clocks did behave differently, then this difference could be used as a motion detector. Since this is impossible within the framework of relativity, then *all* clocks, no matter what the details of their internal mechanisms may be (including the *biological* clocks of own bodies), must respond to motion just as does the photon clock.[75]

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[74] L. R. Hubbard, "To the Stars," *Astounding Science Fiction*, February and March 1950.

Time dilation can also be caused by gravity (it appears in the 2014 movie *Interstellar*), and that effect has been used to 'construct' a time machine from a wormhole (to be discussed later). You can get a qualitative understanding of how that happens by imagining a massive body (*massive*, to have a really big gravitational field) in space, on the surface of which is a hot object. That object emits electromagnetic radiation and, though it isn't essential to the following argument, further imagine that the temperature of the object is sufficiently high that some of the radiation (emitted by the very atoms of the object) is in the visible-light portion of the spectrum. Now, from elementary quantum theory we can also think of the object's atoms as emitting photons ('particles of light'), each of energy hf, where h is Planck's constant and f is the frequency in hertz (what used to be called 'cycles per second'). The higher the temperature, the higher the photon energy, and so the higher the frequency. In the visible spectrum, f is on the order of 10^{15} Hz, a frequency one *billion* times higher than commercial AM radio frequencies.

The radiating atoms can be thought of as tiny clocks, with alternate half-cycles of radiation being ticks and the half-cycles in-between being the tocks. The passage of time on the surface of the massive body can be measured by these atomic clocks in the hot, radiating object. To a distant observer, however, as she receives the photons from the hot object, the passage of surface time on the massive body will appear to occur at a reduced rate when compared with the photons emitted by her own identically hot object (her 'local' clock). That's because the radiation that arrives at the distant observer has traversed a gravitational field (a journey sometimes described as 'climbing out of a gravitational well') and so is down-shifted in frequency toward the red end of the visible spectrum. This effect is called either the *gravitational red shift* or the *gravitational time dilation* effect (or even the *Einstein shift*, because it was Einstein who predicted the effect in 1907).

You can 'understand' this dilation effect as follows. One can crudely think of a photon emitted by the hot object as something like a rock thrown upward. As the rock rises upward through the gravitational field, its *total* instantaneous energy is always constant, but the total, fixed energy is split between its kinetic and potential energies in an ever changing way. That is, as the rock rises, its kinetic energy continually decreases (the rock slows down), whereas its potential energy continually increases. A photon is not a rock, however, and it certainly can't slow down as

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[75] Resistance to this conclusion persisted for years. See, for example, the letter "Relativity and Radio-activity," *Nature*, January 8, 1920, p. 468. The author of that letter wondered whether a clock based on radioactive decay might not somehow beat the 'conspiracy' of moving clocks running slow compared to stationary ones. And in a letter to *Science* (December 7, 1962, p. 1180), a reader objected to applying the laws of physics to biological systems, first asserting (incorrectly) that time dilation "has never been proved or disproved experimentally," and then "there is no known causal means by which greatly increased velocity could alter, without destroying the very biochemical basis of the life process, the metabolic changes which are responsible for the aging process."

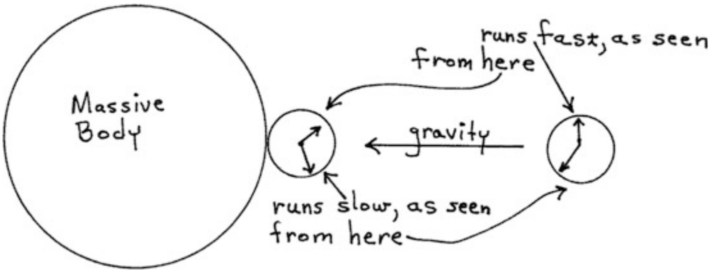

Fig. 3.4 Gravitational time dilation due to a massive body

it rises through a gravitational field (it *always* moves at the speed of light because the photon *is* light). The only way a photon can give up energy to balance the ever increasing potential energy (physicists will cringe at this, but read on) is to decrease its frequency. Hence, the red shift as seen by a distant observer of the photon, who thus sees time running slow on the massive body. Fig. 3.4 shows the case for a clock on a massive body, compared to a distant clock. Notice, carefully, the 'direction of gravity,' that is, the direction a small, unrestrained test mass will move.

A gravitational red shift in the *opposite* direction is nicely described in the famous 1966 science fiction story "Neutron Star" by Larry Niven. There a space traveler zooms down into a neutron star's intense gravity field (at half the speed of light!), passing within one mile of the star's surface. He reports what he observes in these dramatic words: "All around me were blue-white stars. Imagine light falling into a savagely steep gravitational well. It won't accelerate. Light can't move faster than light. But it can gain in energy by increasing its frequency. The light was falling on me, harder and harder, as I dropped." To Niven's intrepid spaceman, therefore, the passage of time on those distant blue-white stars appeared to be running *fast* compared to his wrist watch. This shows that the effect could equally well be called the 'gravitational *blue* shift.'

Notice that *gravitational*-induced time alterations do *not* have the symmetrical feature of motion-induced time dilations.[76] That is, for gravitational time dilations caused by photons either falling into or climbing out of gravity wells, observers at each end *agree* about whose clock is running slow, unlike in the motion-induced case where *each* of the relatively moving observers thinks it is the *other* observer's clock that is running *slow*.[77]

Now, comparing a massless photon to a rock which does have mass (and so potential energy), as each travels 'against' gravity, *is* straining the physics, with its one virtue being the provision of an initial plausibility argument. Gravitational time dilation is sufficiently important in the operation of wormhole time machines,

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[76] Gravitational time dilation was experimentally observed in 1960, more than half a century after Einstein predicted it.

[77] A science fiction use of both the red and the blue gravitational shifts appears in the novel by J. P. Hogan, *Out of Time*, Bantam 1993.

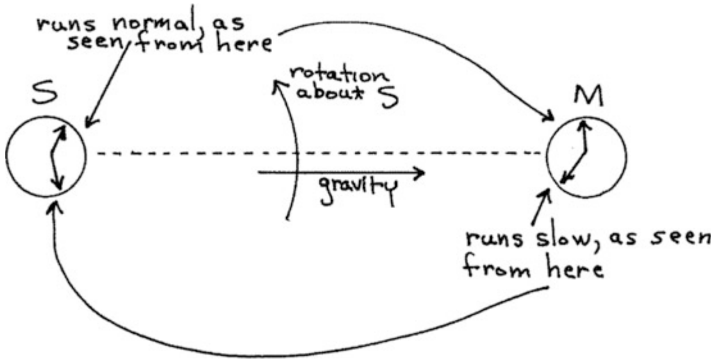

Fig. 3.5 Gravitational time dilation due to rotation

however, that perhaps another way to think about it that is more acceptable to hardcore physicists makes it worth another look. Imagine a turn-table disk that initially is *not* rotating (soon it *will* spin). On this disk imagine further that we fasten two clocks, one called S (for *stationary*) and one called M (for *moving*), as shown in Fig. 3.5. These two clocks are set to read the same time at some instant and then, thereafter, they tick-tock through time at precisely the same rate. We then start the disk rotating around a vertical axis through clock S. (Imagine S to be a *point* clock, and so it is *the* one point on the turn-table that remains at rest even as the disk rotates.) What happens to the time-keeping of S and M?

We can answer this question by using our earlier result concerning time dilation due to motion. Even with the disk now rotating, S appears stationary to an observer sitting on top of M, while M appears to be moving across the line of sight of an observer sitting on top of S. So, to the observer at S, clock M runs slow, while to the observer at M there is *no change* in the time keeping of clock S. This is a non-symmetrical outcome, and so should remind you of gravitational time dilation. This might be a puzzle to you, however, as we don't have a massive body in Fig. 3.5 to account for a gravity presence. This is where the genius of Einstein comes into play.

Anyone who has ever ridden on a merry-go-round knows there is an outward (pointing away from S) directed force called the *centrifugal force* that is 'trying' to toss you off the merry-go-round. Now, where there is a force there is an acceleration, and one of Einstein's starting points in his development of general relativity was to identify an acceleration, *whatever its origin*, with gravity. A massive body is, of course, one possible origin (the obvious one, in fact), but so is the rotation of the turn-table. So, we have the situation shown in Fig. 3.5, where now 'gravity' is directed as shown and, and as in Fig. 3.4, the direction of acceleration of gravity is toward the slow-running clock. Again, the direction of gravity is the direction a small, unrestrained test mass on the rotating disk will move. The further M is away from S, the greater the 'gravity' of the centrifugal acceleration and so the slower will M run as measured by the observer at S.

A 1968 story that uses the gravitational time dilation effect in a striking fashion tells of a starship's visit to a supernova, accompanied by a fantastic alien life-form—a ball of intelligent plasma named Lucifer that is telepathic.[78] While the ship stands off at a distance of 500 million kilometers, Lucifer will approach much closer to the *event horizon* (see the Glossary) of a black hole at the center of the supernova explosion and communicate its findings to a human telepath on the ship. A physicist in the crew is curious about one point, and asks the human telepath the following question:

"I have wondered about one item. Presumably Lucifer will go quite near the supernova. Can you still maintain contact with him? The time dilation effect, will that not change the frequency of his thoughts too much?"

Lucifer, in fact, dies in the black hole even as he saves the ship from destruction, and the human telepath will hear his death scream for the rest of her life. As the physicist later explains to the ship's captain, telepathy is instantaneous and has no limiting range (there is no known physical basis for believing any of this, but it is crucial for story effect):

> "Remember the time dilation. He fell from the sky and perished swiftly, yes.
>
> But in supernova time. Not the same as ours. To us, the final stellar collapse takes an infinite number of years. . . . He will always be with her."[79]

3.4 The Lorentz Transformation

> "If only he'd paid more attention to mathematics in school."
>
> —a science fiction time traveler laments missed opportunities[80]

In this (and the next) section the math gets about as 'deep' as it gets in this book, but to leave it out struck me as a cheat. *You* can skip part (or all) of the math and simply read the prose, but it seemed unfair for me to make that decision for you.

We begin by imagining two distinct frames of reference. One we take to be stationary, and the other as moving at a uniform speed v with the respect to the first. The moving frame is said to be *boosted* with respect to the stationary frame. We orient these two coordinate systems so that the motion occurs along just one axis (the x-axis, as shown in Fig. 3.6, where I am using primed variables for the moving frame). That is, the two frames have coincident x axes, and parallel y and z axes that

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[78] Poul Anderson, "Kyrie," in *The Road to Science Fiction* (J. Gunn, editor), volume 3, New American Library 1979.

[79] A mathematical discussion of how signals take forever (even though they are emitted in a finite time interval) to travel from the event horizon of a black hole to a distant receiver can be found in James B. Hartle, *Gravity: an introduction to Einstein's general relativity*, Addison Wesley 2003, pp. 264-268.

[80] D. Knight, "Extempore," in *Far Out*, Simon and Schuster 1961. Similar words ("If only I had more mathematics") were spoken by Einstein the day before he died — see Walter Isaacson, *Einstein: his life and universe*, Simon & Schuster 2007, p. 542.

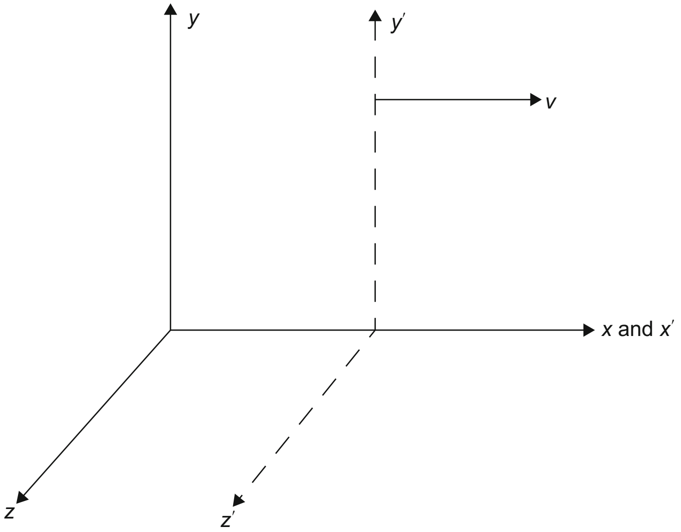

Fig. 3.6 Two reference frames in relative motion

are moving apart at the constant speed v. Let's also imagine that there is a clock at the origin of each frame, and that at the instant the origins match the clocks are synchronized; that is, $t = t' = 0$ is the instant the two coordinate systems coincide.

We further imagine that there is an observer at the origin in each frame. At some arbitrary instant of time, each observer records the coordinates of the arbitrary point P in space, as measured in his system. These observers could, for example, agree to record the coordinates of P in their system when their clock reads 5 s. It seems immediately obvious (as it was for Newton) that $t = t'$; that is, time runs at the same rate in each frame and thus it makes sense to talk about "the same instant" at every point in space. (After reading the previous section you know this *not* true, but temporally forget that!) Thus, at this 'same instant' the stationary observer records (x, y, z) and the moving observer records (x', y', z'). What are the relationships between the primed and unprimed coordinates of P? That is, what mathematical transformation converts from one frame to the other?

The answer seems obvious:

$$y' = y$$
$$z' = z$$
$$x' = x - vt.$$

This transformation, called the *Galilean transformation* after the Italian Galileo Galilei (1564–1642), satisfies the relativity principle, which says that uniform motion leaves the laws of physics unchanged. For example, in the stationary system Newton's famous second law of motion for a constant mass m,

$$F = m\frac{d^2x}{dt^2}$$

becomes the identical-appearing form

$$F' = m\frac{d^2x'}{dt'^2}.$$

More precisely, *all* the laws of mechanics known to Newton are unchanged. Any frame of reference in which Newton's laws of mechanics hold true is said to be an *inertial* frame. Given one inertial frame, we can find infinitely many others simply by applying the Galilean transformation.

However, when the mathematical laws of electrodynamics were discovered by Maxwell in the nineteenth century, it was a shock to physicists to learn that the Galilean transformation does *not* leave Maxwell's equations unchanged in form; the transformed equations predict electromagnetic effects for the moving system that are *not* predicted to occur in the stationary system. This meant that there was theoretical support for the possibility that electromagnetic experiments might be devised to detect uniform motion, and this eventually led to the famous Michelson-Morley experiment of 1887. This experiment, sensitive enough to detect the motion of the Earth itself through space, failed to detect any such motion. The conclusion was clear: the new electromagnetic effects predicted by the Galilean transformation do not exist, and so the transformation must be wrong even though it works for the laws of mechanics. So—what is going on?

The answer is inspired, and again returns us to the cornerstone of relativity: the idea that the laws of physics, *all* the laws, should look the same to observers in uniform relative motion. That is, there is no special or preferred system of coordinates—*all* inertial systems are equivalent in physics. Evidence from an extremely broad variety of sensitive experiments had, by the end of the nineteenth century, convinced physicists that Maxwell's equations *are* correct. Thus, a new transformation was needed that leaves both the laws of mechanics *and* the laws of electrodynamics unchanged with uniform motion. But, a single transformation that works on Maxwell's equations and on the mechanical laws would therefore mean that Newton's mechanical laws as stated cannot be correct, and this was a breathtaking conclusion: Newton had been unchallenged for two centuries.

As it turns out, Newton's laws are *almost* right. The only correction required is that the mass of a moving body is not independent of motion, but rather varies as

$$m = \frac{m_0}{\sqrt{1-(v/c)^2}}$$

where m_0 is the so-called *rest mass* when $v = 0$.[81] This result says that m is infinite at $v = \mathrm{c}$ unless $m_0 = 0$ (as it is for a photon), which is another reason for the belief that accelerating a mass (such as a spaceship) up to the speed of light is impossible because it would require infinite energy (look back at note 68, too). With this modification, the transformation that leaves all the laws of physics unaltered in form by uniform motion is what is called the *Lorentz transformation* (after the same Lorentz the contraction effect is named for), who discovered it in 1904 by direct manipulation of Maxwell's equations:

$$\begin{aligned} y' &= y \\ z' &= z \\ x' &= \frac{x - \mathrm{vt}}{\sqrt{1 - (v/c)^2}} \\ t' &= \frac{t - \mathrm{vx}/c^2}{\sqrt{1 - (v/c)^2}}. \end{aligned}$$

In 1905 Einstein discovered how to derive these equations from a fundamental reexamination of space and time without concerning oneself about the details of specific physical laws.

By simple algebraic manipulation, the transformation equations can be rewritten as

$$\begin{aligned} ct &= \gamma ct' + \beta\gamma x' \\ x &= \beta\gamma ct' + \gamma x' \end{aligned}$$

where

$$\beta = \frac{v}{c}$$

and

$$\gamma = 1/\left(1 - \beta^2\right)$$

are dimensionless constants. In compact matrix form, the Lorentz transformation becomes

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[81] This variation of mass with speed was experimentally observed in 1901.

$$\begin{bmatrix} ct \\ x \end{bmatrix} = \begin{bmatrix} \gamma & \beta\gamma \\ \beta\gamma & \gamma \end{bmatrix} \begin{bmatrix} ct' \\ x' \end{bmatrix}$$

and the symmetrical 2 × 2 matrix is called the Lorentz boost matrix or simply the *boost*. Notice that when $v = 0$ (zero boost) the boost matrix reduces to the identity matrix; that is, the two frames are one and the same with at most a shift in the location of the origins. Note, too, that $\beta = 0$ and $\gamma = 1$ for *any* v when c is infinite—that is, the boost matrix is again reduced to the identity matrix and the Lorentz transformation becomes the Galilean *if* c is infinite. But c is not infinite, and all the implications of special relativity are the direct result of the *finite* speed of light.

The Lorentz transformation contains two results I have mentioned earlier in the book. For example, in Chap. 2 it was mentioned that simultaneity is a relative concept in reference frames in relative motion. Let's see what the transformation says about that. Consider two events that occur specifically on the x-axis. They are simultaneous in the stationary system (at, say, time $t = T$) but are at different places (at, say, $x = X$ and $x = X + \Delta X$). Their occurrences in time for the moving observer are

$$t'_1 = \frac{T - \mathrm{vX}/c^2}{\sqrt{1 - (v/c)^2}}$$

and

$$t'_2 = \frac{T - \mathrm{v}(X + \Delta X)/c^2}{\sqrt{1 - (v/c)^2}}.$$

For the moving observer, therefore, the two events are *not* simultaneous, being separated in time by

$$t'_1 - t'_2 = \frac{v\Delta X/\mathrm{c}^2}{\sqrt{1 - (\mathrm{v}/\mathrm{c})^2}}.$$

Only if $\Delta X = 0$ (the two events occur at the same place) will $t'_1 = t'_2$. That is, only if $\Delta X = 0$ are simultaneous events in one frame also simultaneous in another frame in relative motion.

And in the previous section we found that time runs slow in one frame as observed from another frame that is in relative motion. We can get this result from the t' equation of the Lorentz transformation by differentiating it with respect to t. Thus,

$$\frac{dt'}{dt} = \frac{1 - (v/c^2)\frac{dx}{dt}}{\sqrt{1 - (v/c)^2}}.$$

But since

$$\frac{dx}{dt} = v,$$

the speed of the moving frame as measured by the observer in the stationary frame, this gives

$$dt' = \sqrt{1 - (v/c)^2}\,\mathrm{dt}$$

which is the same result we obtained by analyzing the photon clock.

The Lorentz transformation contains other interesting implications beyond these. For example, mention has been made several times to the ‘relativity principle,’ the belief that uniform motion has no observable effect on the forms of physical laws. But how do we know who is moving and who is stationary? After all, a system moving to the right past a stationary system could just as well be thought as the stationary system, while it’s the *other* system that is moving to the *left* (at speed $-v$).

To study this question with the Lorentz transformation, we’ll invert the transformation (that is, solve for the unprimed variables in terms of the primed ones). What we get back is just what you probably thought—the Lorentz transformation with v replaced by $-v$. That is, the Lorentz transformation is symmetrical, so two observers in different frames of reference each say it is the *other’s* clock that is running slow! This follows immediately, in fact, from the original transformation written in matrix form. That is, multiplying through the earlier matrix equation by the inverse of the boost matrix, we get

$$\begin{bmatrix} ct' \\ x' \end{bmatrix} = \begin{bmatrix} \gamma & \beta\gamma \\ \beta\gamma & \gamma \end{bmatrix}^{-1} \begin{bmatrix} ct \\ x \end{bmatrix} = \begin{bmatrix} \gamma & -\beta\gamma \\ -\beta\gamma & \gamma \end{bmatrix} \begin{bmatrix} ct \\ x \end{bmatrix}.$$

The only difference between the original boost matrix and its inverse (which is, of course, the new boost matrix for the new interpretation of which frame is the moving one) is a change in sign for β, that is, in the sign of v. The inverse transformation is

$$y = y'$$
$$z = z'$$
$$x = \frac{\mathrm{x}' + \mathrm{vt}'}{\sqrt{1 - (\mathrm{v}/\mathrm{c})^2}}$$
$$t = \frac{\mathrm{t}' + \mathrm{vx}'/\mathrm{c}^2}{\sqrt{1 - (\mathrm{v}/\mathrm{c})^2}}.$$

As a final example of what the Lorentz transformation tells us, consider the so-called *addition of velocities* problem. Suppose you are in a high-speed spaceship traveling past Earth at speed v. Earth is the stationary system (with the unprimed variables), and the spaceship is the moving system (with the primed variables). Assume the x and x' axes are along the direction of motion. Imagine next that while standing in the nose of the spaceship, just as the spaceship passes Earth, you fire a gun in the direction of motion (away from the Earth), with the bullet exiting the gun with a muzzle speed of w. How fast is the bullet moving away from Earth? The common-sense answer in Galileo's time was $v+\mathrm{w}$, but we now know that the Galilean transformation is wrong. What does the Lorentz transformation say?

Inside the spaceship, the position of the bullet at time t' after the gun is fired is

$$x' = wt'.$$

From the inverse Lorentz transformation, the location of the bullet earth's frame is

$$x = \frac{x' + \mathrm{v}t'}{\sqrt{1-(v/c)^2}} = \frac{w+\mathrm{v}}{\sqrt{1-(v/c)^2}}t'.$$

The transformation also tells us that (using $x' = wt'$)

$$t = \frac{t' + \mathrm{v}x'/c^2}{\sqrt{1-(v/c)^2}} = \frac{1+\mathrm{wv}/c^2}{\sqrt{1-(v/c)^2}}t'.$$

Thus, the speed of the bullet in *Earth's frame* is

$$\frac{x}{t} = \frac{w+\mathrm{v}}{1+\mathrm{wv}/c^2}.$$

Notice that for a low-speed bullet ($w << c$) this result[82] is close to $w + v$, but at high values for w the result is very much different. Indeed, suppose we don't fire a gun at all, but rather replace it with a flashlight. Now, instead of a bullet, we shoot *photons* at $w = c$. The Galilean transformation would (incorrectly) say that a stationary observer on Earth would see the photons moving away at speed $v+\mathrm{c}$, which is a superluminal speed. The Lorentz transformation, however, says that the Earth observer would see a speed of

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[82] This result was found by the French physicist Henri Poincaré (1854-1912) in June 1905, three months *before* the publication of Einstein's special theory of relativity which also contains the result. And it was Poincaré who first stated (in 1904) that "no velocity can surpass that of light, any more than any temperature could fall below the zero absolute."

$$\frac{c+\mathrm{v}}{1+\mathrm{cv}/c^2}=\frac{c^2(c+\mathrm{v})}{c^2+\mathrm{cv}}=\frac{c^2(c+\mathrm{v})}{c(c+\mathrm{v})}=c.$$

That is, no matter what the speed of the moving observer on the spaceship is, he sees the light from his flashlight traveling at the same speed as does the stationary observer back on Earth. This peculiar effect is unique to the speed of light ($w=\mathrm{c}$). We've derived it here as a consequence of the Lorentz transformation, but in fact Einstein actually did things in reverse order. That is, he began by *postulating* the invariance of the speed of light[83] for all observers in uniform motion, combined that with the principle of relativity which says all physical laws look the same to those observers, and so derived the Lorentz transformation using no mathematics beyond high school algebra.

A mathematically elegant alternative derivation of the addition-of-velocities formula can be done by simply noticing that the condition of two successive boosts should be, itself, a boost. Thus, if we have a frame moving relative to a second frame (which is itself moving relative to a third frame), then the boost matrix of the first frame relative to the third frame is the product of the two individual boost matrices. That is,

$$\begin{bmatrix}\gamma_3 & \beta_3\gamma_3\\ \beta_3\gamma_3 & \gamma_3\end{bmatrix}=\begin{bmatrix}\gamma_2 & \beta_2\gamma_2\\ \beta_2\gamma_2 & \gamma_2\end{bmatrix}\begin{bmatrix}\gamma_1 & \beta_1\gamma_1\\ \beta_1\gamma_1 & \gamma_1\end{bmatrix}.$$

From this it is easy to show (if you know how to multiply matrices!) that

$$\beta_3=\frac{\beta_1+\beta_2}{1+\beta_1\beta_2}.$$

Substitution of

$$\beta_1=\frac{w}{c},\ \beta_2=\frac{v}{c}$$

immediately gives the addition-of-velocities formula.

A failure to understand the implications of the invariance of the speed of light resulted in two stupendous errors in the story "To the Stars," cited in note 74. At all times an officer stands watch on the bridge of a near light-speed rocket ship to be sure the ship doesn't accidently *reach* the speed of light. This is to be avoided (according to the author) because to reach the speed of light would cause the ship to

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[83] Einstein's postulate was experimentally confirmed in 1932.

"hang there forever unmoving [in time] . . . locked, protected and condemned to eternity by zero time." This horrible state is so easy to stumble into (the author was apparently unaware that it would require *infinite* energy) that occasionally the ship has to fire a 'check-blast' from its forward rocket tubes to slow down! Equally absurd is the means by which the development of this 'fatal' condition is detected: the nose of the ship mounts a forward-pointing light source (our earlier flashlight) and so, if the ship is getting too near the speed of light, it will start to *overtake* the photons emitted by that source!

The biggest puzzle of all, actually, is why the editor of *Astounding Science Fiction* let such a technically goofy story appear in a magazine recognized for its usual faithfulness to known science. Particularly so since the story appeared in 1950 and, as long ago as December 1937, none other than Isaac Asimov (then 17 years old) had written a letter to the editor[84] giving the proper interpretation of what happens when $v = \mathrm{c}$. Here's what the young Asimov wrote (notice the early hint of his life-long pessimism concerning time travel to the past that appears near the end of his letter):

> "The effect on time of increasing speeds is . . . well known. Relativity states that as speed approaches that of light, time slows up until at 186,000 miles a second, time (so to speak) stands still. This seems to refute statements found in so many astronomy books (and science fiction stories) that even at the speed of light it would take four years to reach the nearest star. No such thing! As time halts at the speed of light, a person traveling from Alpha Centauri to the solar system, or vice-versa, would not be aware of any lapse of time. In that sense the speed of light is infinite (as was thought in ancient times). This by the way offers an entirely scientific (if impractical) means of travel into the future. Say that someone wants to see how the world would look a hundred years from now. His procedure would be as follows: getting into his spaceship, he would proceed to a spot fifty light-years away at the speed of light. The journey would, for him, be practically instantaneous (due to the curious behavior of time at the speed of light). But fifty years would have elapsed on earth. He makes the return trip at the same speed. Another fifty years lapse on earth and he lands a hundred years after his time. With this system, however, it would be impossible to travel into the past, so I don't think it will ever be adopted."

Young Asimov missed an important detail concerning the reversal of the spaceship's direction of travel for the return to Earth, and I'll come back to it later in this chapter. But certainly he displayed a *far* better knowledge of the physics of time than did the author of "To the Stars" (who was, by the way, L. Ron Hubbard, a prolific writer of fantasy and science fiction before founding the Church of Scientology).

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[84] The editor who bought "To the Stars" was the same editor editor of *Astounding* when Asimov's letter appeared, and so he was certainly aware of it.

3.5 Spacetime Diagrams, Light Cones, Metrics, and Invariant Intervals

> "Come back when you know tensor calculus and I'll explain to you about n-dimensional forces and the warping of world-lines."
>
> —a science fiction physicist's reply after being asked how his time machine works[85]

It is helpful in discussions about the spacetime of special relativity to use what are called *Minkowski spacetime diagrams*. These are plots of the spacetime coordinates of a particle; the resulting curve is called the *world line* of the particle. Such diagrams are four-dimensional—three space axes and one time axis—and hard to visualize, much less draw on a flat sheet of paper! The convention is to make do, whenever possible, with a simplified spacetime that has just one space axis (horizontal) and one time axis (vertical). As you'll recall from Chap. 1, physicists often call such a simplified diagram a *toy spacetime*.

So, for a particle at rest in some observer's frame of reference, its spacetime diagram for that observer is a *vertical* world line. If the particle is not at rest then its world line will tilt away from the vertical; the greater the speed the greater the deviation from the vertical. Accelerated particles will have world-lines that *curve* away from the vertical. Straight, uncurved world lines represent unaccelerated particles, that is, particles experiencing no forces and so in free fall. Such a world line is called a *geodesic*. In Fig. 3.7 the world lines for these various cases are shown on the same axes. It is assumed in the figure that all three particles are at $x = x_0$ when $t = 0$.

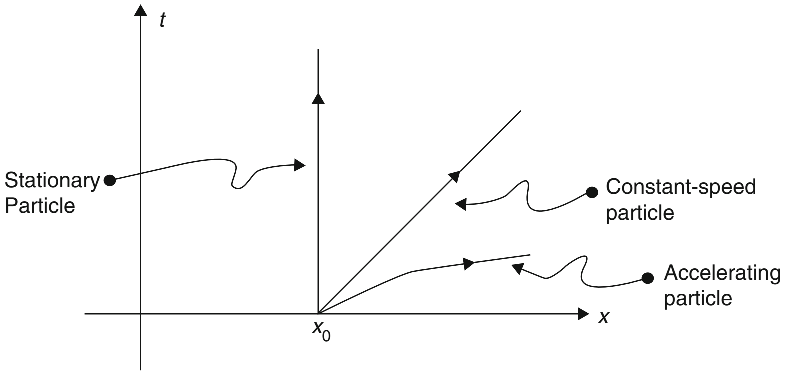

Fig. 3.7 World lines of three particles

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[85] Poul Anderson, "The Little Monster," in *Science Fiction Adventure from WAY OUT* (R. Elwood, editor), Whitman 1973.

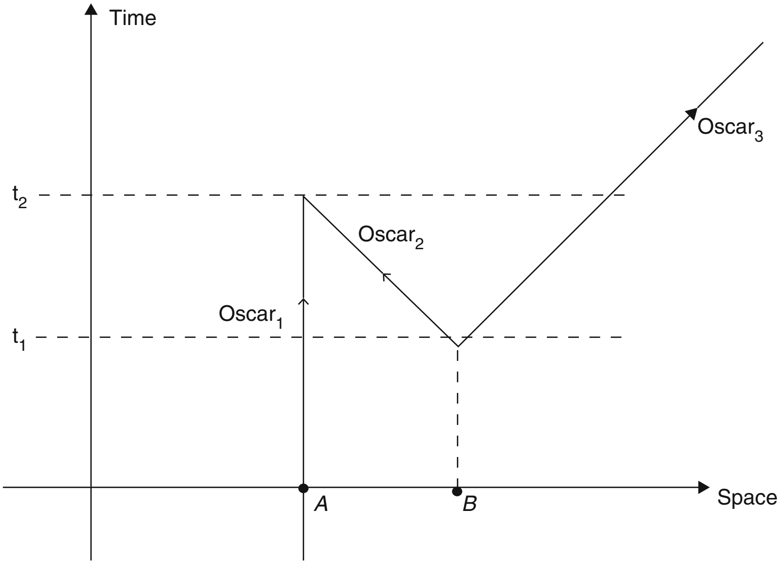

Fig. 3.8 A time traveler and his world line

Spacetime diagrams were embraced decades ago by philosophers looking for 'scientific' ways to support their position on time travel (whatever it might be), as opposed to the mere verbiage of traditional colleagues. A famous example of this is a 1962 paper by the Harvard philosophy professor Hillary Putnam (note 74 in Chap. 1). There we are asked to imagine the spacetime diagram of one Oscar Smith who, in Fig. 3.8, is at spatial location A next to his time machine. At time t_0 Oscar has not yet gotten into his time machine. A little later, at time t_1, we suddenly see not only Oscar at A but also *two more* Oscars who have appeared (apparently out of thin air) moving away from spatial location B! Between t_1 and t_2 we see the original Oscar at A and the two mysterious Oscars at B (for a total of three Oscars, labeled in the figure as Oscar_1, Oscar_2, and Oscar_3) move forward in time—but one of the new Oscars (Oscar_2) lives a decidedly odd existence in that his life seems to be running in reverse!

Eventually, at time t_2, the original Oscar_1 and the weird, reverse Oscar_2, merge and seemingly annihilate one another, vanishing into thin air to leave only a single Oscar (Oscar_3) for all time after t_2. Putnam argues that, although strange, what has just been described is still sensible and that, indeed, the very fact that we can draw the spacetime diagram of Fig. 3.8 supports the case for backward time travel. He claims this because although the spacetime diagram does show time increasing upward for all three Oscars (that is the time direction for an external observer) there is actually no 'spontaneous creation' or 'mutual annihilation' and all is sensible *if* Oscar_2 is understood actually to be a time traveler into the past with *his* time direction thus pointed opposite to that of the 'other two' Oscars. There is, of course, just *one* Oscar!

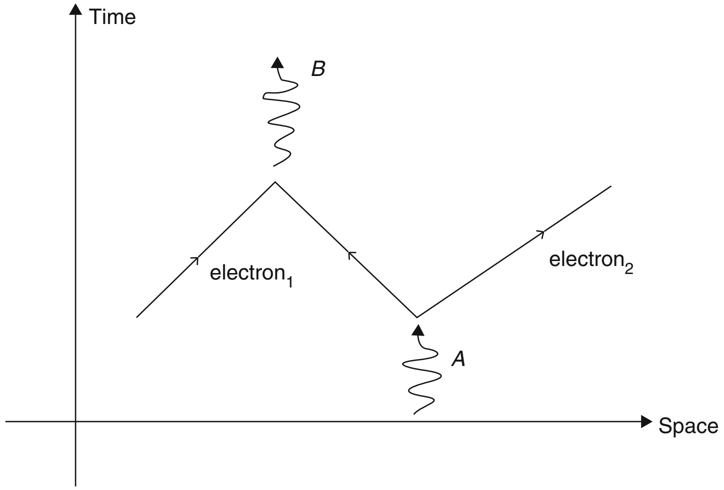

Fig. 3.9 Anti-matter via backward time travel

As mentioned back in Chap. 1, Putnam's suggestion was rebutted (see that chapter's note 76) by what is (in my opinion) an even less plausible mechanism for Putnam's kinked spacetime than is Putnam's invocation of time travel. That critic advocated, instead, an explanation based on matter transmitters and anti-matter, the latter an idea he credits to Feynman (who actually got it from Wheeler). In a paper by Feynman we do find the famous suggestion that a positron that appears to us to be moving forward in time is actually an electron traveling backward through time.[86] Logically, that greatly weakens the critic's view, because it puts him in the position of using anti-matter (explained in terms of backward time travel) to argue *against* backward time travel! But let's ignore that concern, give the critic the benefit of the doubt, and explore how anti-matter and backward time travel are imagined to be connected.

Feynman asks us to imagine the process shown in Fig. 3.9. Gamma ray A spontaneously creates an electron-positron pair, with electron$_2$ moving off to some distant region while the positron soon meets with electron$_1$, resulting in mutual annihilation and the production of gamma ray B. This description involves *three* particles, and each segment of the kinked line is a distinct particle. But Feynman said there is another way to look at this, a way that involves just *one* particle. According to Feynman, the kinked line in Fig. 3.9 (which should remind you of Oscar's kinked world line) is the world line of a single electron; the middle

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[86] R. Feynman, "The Theory of Positrons," *Physical Review*, September 15, 1949, pp. 749-759. In a paper published the year before ("A Relativistic Cut-Off for Classical Electrodynamics," *Physical Review*, October 1948, pp. 939-946), he wrote "This idea that positrons might be electrons with the proper time reversed was suggested to me by Professor J. A. Wheeler." The identification of anti-matter with backward time travel occurred in science fiction (see note 124 in Chapter 1) almost simultaneously with Wheeler's speculation.

segment, that we call a positron, is just the electron traveling backward in time, and so we must reverse the arrowhead on it (indicating the opposite of the direction shown in Fig. 3.9).

There are two central questions at this point. First, why is a positron (with positive electric charge) moving forward in time mathematically (and physically) equivalent to a negatively charged electron moving backward in time? The answer is that the reversal in charge sign, which results from the reversal of the electron's proper time, follows from the TCP theorem that was mentioned in Chap. 2 (see note 38 there). And second, what causes the electron to suddenly move backward in time? Picturesquely, the electron is recoiling from the emitted burst of gamma ray B. Similarly, the absorption of the energy of gamma ray A by the electron that is recoiling backward in time causes a second recoil, giving the world line of what was originally called electron$_2$. This reinterpretation of a kinked spacetime diagram was described as follows (in Feynman's famous words): "It is as though a bombardier flying low over a road suddenly sees three roads and it is only when two of them come together and disappear that he realizes that he has simply passed over a long switchback in a single road."

In a later paper[87] Putnam's critic presented another line of attack against Putnam's interpretation of spacetime diagrams as lending support to time travel. There the critic observed that the presence of the time-reversed Oscar$_2$ shows that the "world of the Oscars" is not *temporally orientable*. A temporally orientable spacetime is one in which *every* point in it agrees with its local neighbors on the directions of past and future—a condition clearly *not* satisfied for the case of Oscar$_2$. As the critic pointed out, the first time travel spacetime discovered, the Gödel universe, *is* temporally orientable, and so in it the ambiguity of Oscar$_2$ (whether he is traveling backward in time as opposed to living forward 'in reverse') does not occur. That is, the critic agreed with Putnam's acceptance of the conceivability of time travel to the past, but not with his use of Feynman's concept of antimatter as time-traveling matter. That critic wasn't alone in that opinion.

One physicist, for example, wrote of "Feynman's rather loose talk of particles 'traveling' backward . . . in time,"[88] and the well-known philosopher John Earman declared "It is true that Feynman uses the slogan 'Positrons are electrons running backward in time,' but it is dangerous to draw conclusions from slogans."[89] I am not sure what Earman meant by "slogans": a careful reading of Feynman indicates that he actually took the matter quite seriously.[90] In his 1949 positron paper (note 86), for example, he wrote that "the idea that positrons can be represented as electrons with proper time reversed relative to true time has been discussed by the author and others,"[91] and also that "Previous results suggest waves propagating . . . toward the past, and that such waves represent the propagation of a positron."

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[87] See R. Weingard in note 114 in Chapter 1.

[88] H. Price, "The Asymmetry of Radiation: Reinterpreting the Wheeler-Feynman Argument," *Foundations of Physics*, August 1991, pp. 959-975.

[89] J. Earman, "On Going Backward in Time," *Philosophy of Science*, September 1967, pp. 211-222.

[90] Feynman declares the view of a positron as a time traveling electron to be of value, for example, in his famous book *Quantum Electrodynamics*, W. A. Benjamin 1961, p. 68.

In any case, spacetime diagrams are highly useful in discussing time travel, but they do have some curious twists. In our everyday world, a path that joins two points on a surface with the *minimum* length is called a geodesic of that surface. As you'll see later in this chapter spacetime geodesics do indeed possess an extremal property, but rather than being a minimum it is a *maximum* property. Spacetime diagrams can be misleading on this matter, so it is important to remember that such diagrams are not a perfect representation of all the properties of a spacetime.

It is customary to draw spacetime diagrams with the speed of light as unity ($c = 1$). That is, a distance of 300,000 km on the space axis is represented by the same extension as is one second on the time axis. This means that the world line of a photon is tilted away from the vertical time axis by 45°. Because photons can travel in both space directions (to the left and to the right) in the two-dimensional spacetime we can draw on a piece of paper, and because the speed of light is the limiting speed of the universe, we can represent the collection of all possible world lines as those paths that *never* tilt more than 45° away from the vertical, which forms what is called a *light cone* in spacetime, as shown in Fig. 3.10 (which attempts to represent a *three*-dimensional spacetime, one with two space—imagine a y-axis, out of the paper, perpendicular to both the x and t axes—and one time dimension).

In Fig. 3.10 I have taken $x = y = 0$ at $t = 0$ for all the possible world lines involving speeds below the speed of light. Let's agree to call this spacetime point the Here-Now. Then, spacetime points in the upward half of the light cone are in the Future of Here-Now; similarly, spacetime points in the lower half of the light cone are in the Past of the Here-Now. We can draw a straight world line from the Here-Now to any point in the Future half-cone with a tilt of less than 45° away from the vertical, which means that a massive particle could travel from the Here-Now to that point at less than the speed of light. Similarly, a massive particle starting at any point in the Past half-cone could have reached the Here-Now by traveling at less than the speed of light. Such a world line is called *timelike* because its projection on the time axis is greater than its projection on a space axis—they are the world lines connecting spacetime points that are potentially causally linked. That is, an event at a spacetime point in the Past half-cone could have had an effect on the event at the Here-Now, even though its influence propagated at less than the speed of light. Also, an event at the Here-Now could potentially affect the event at any spacetime point in the Future half-cone of the Here-Now.

Any points in the regions of spacetime outside the Future and Past half-cones *cannot* be reached from the Here-Now except by world lines tilted more than 45°

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[91] The "others" Feynman had in mind included, in particular, the eminent Swiss physicist Ernest C. G. Stükelberg (1905-1984), who in a 1942 article in the journal *Helvetica Physica Acta* also wrote of waves scattering backward in time.

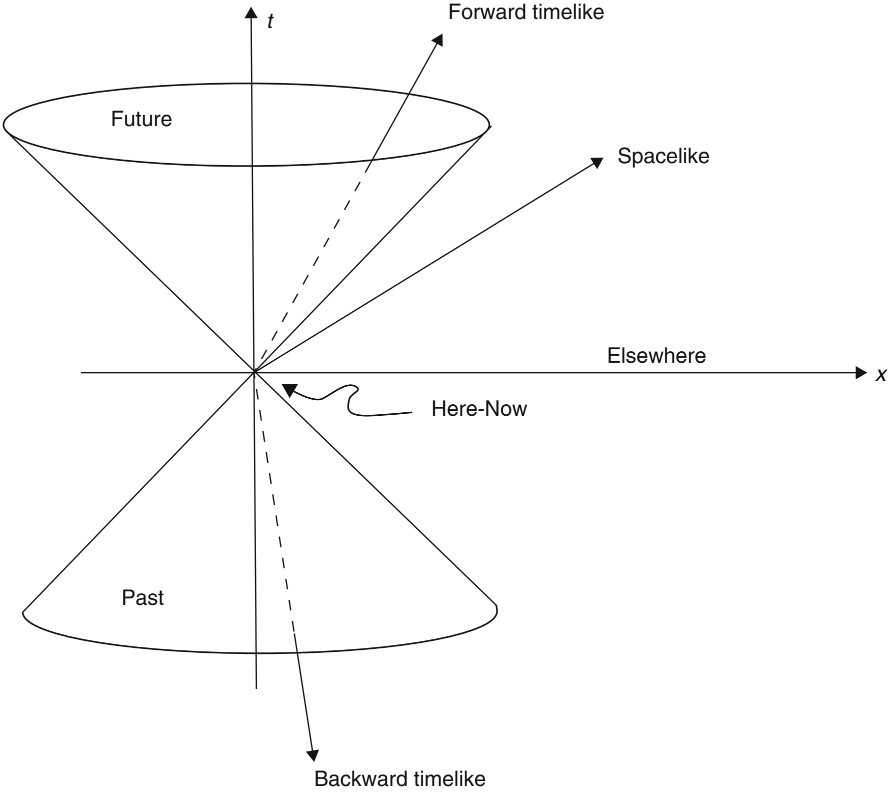

Fig. 3.10 A light cone in spacetime

away from the vertical. Such world lines, which represent travel at a speed faster than light, are called *spacelike* because their projections on a space axis is greater than their projections on the time axis. It is impossible for these world lines to connect causally linked events, and collectively they form the Elsewhere of the Here-Now. Notice that every point in spacetime has its own light cone. If A and B are causally linked, then if B is in the Future half-cone of A, then A is in the Past half-cone of B.

The imagery of the light cone is often useful in making seemingly quite abstract ideas appear transparent. For example, can an observer predict his own future from perfect knowledge of his own past? The easy answer is “No, because quantum uncertainties prohibit perfect knowledge of even the present, much less the past.” But suppose we ignore quantum mechanics and limit our question to a universe that obeys only classical physics (which includes the special and general theories of relativity). Surprisingly (perhaps), the answer is *still* no. Having perfect knowledge of your own Past half-cone doesn’t include knowing the *entire* past, so if you attempt to predict your own future (say, 1 min from now), there can be influences in Elsewhere that will arrive in the future (say, 59 s from now) about which you

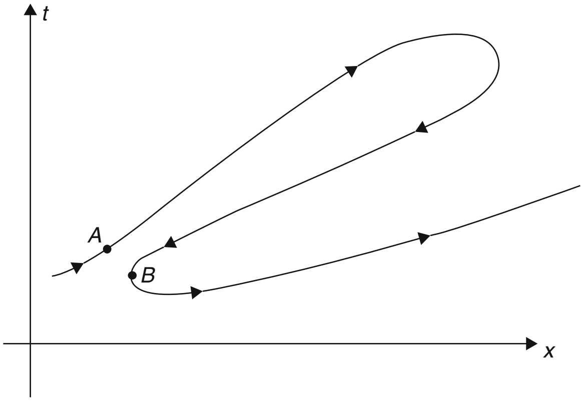

Fig. 3.11 World line of a particle traveling backward in time from A to B

presently, by definition, cannot have any knowledge. And without that knowledge, you cannot predict. As one writer amusingly concludes a tutorial on this topic, "the prospect of predicting the future looks pretty bleak."[92]

A spacetime diagram does not always have to have future directed world lines. If a particle moves backward through time, assuming such a thing is possible, then the diagram can show this by having the world line double back on itself, as in Fig. 3.11 (in which the world line curves back and comes arbitrarily close to itself: it is the world line of a particle that visits itself in the past). Note that the world line in Fig. 3.11 does not actually touch or cross itself, because that would represent more than just a visit—it would represent a particle occupying the same spatial location at the same time as its earlier self. That would be catastrophic and, because it *did not* happen it *cannot* happen. Since the arrowheads on the world line always point in the direction of the local future of the particle, if the 'particle' is actually human then increasing memories are formed in the direction of the arrows. The time traveler at B has more memories than he does at A, even though A and B are nearly identical points in spacetime.

There is a problem with Fig. 3.11 that you may have caught. It is impossible to draw such a doubled-back world line in such a way that *at all places* it never tilts more than 45° from the vertical. That is, at least some portion of the world line will have

$$\left|\frac{\mathrm{dx}}{\mathrm{dt}}\right| > 1$$

which represents superluminal motion (we'll return to this in Chap. 5). One way to keep a bent-back world line always subluminal is to arrange for the light cones along the world line to be tilted relative to each other, as shown in Fig. 3.12, which

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[92] M. Hogarth, "Predicting the Future in Relativistic Spacetimes," *Studies in the History and Philosophy of Science*, December 1993, pp. 721-739.

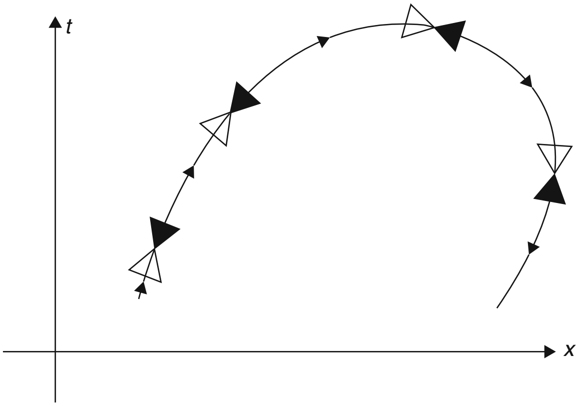

Fig. 3.12 Tilted light cones in a curved spacetime (the future halves are shaded)

is possible only in a *curved* spacetime. This is an illustration of how general relativity *locally* obeys special relativity's demand that nothing travels faster than light and yet, *globally*, in curved spacetime, things are not so simple. In flat spacetimes all light cones are always 'aligned,' but in curved spacetimes they (generally) are not, and from that can come time travel to the past.[93]

Tilted light cones is the physics behind backward time travel around a rotating Tipler cylinder, for example, a particular time machine we'll discuss later in Chap. 5. Light cone tipping is, in fact, *essential* for time travel to the past. The mere presence of mass tips light cones ('warps spacetime'), but the effect is unnoticeable in everyday life on Earth. A truly enormous mass density is required to tip nearby light cones over so that their Future halves noticeably open up toward the massive body. If the massive body is additionally set to rotating, then a further consequence of Einstein's general theory is that the local light cones are tilted additionally in the direction of rotation. That is, the Future half-cones in spacetime open-up both toward the body and in the direction of the rotation.

It should now be clear that the only way a world line can bend back on itself for a close encounter visit is for both x and t to change. In other words, the world line of a particle that remains fixed in space and reverses just its time direction *runs into itself*. This is why the classic fictional time machine of H. G. Wells could not possibly work. A real time machine must move in space as well as through time, as does a Gödelian rocket (or, for that matter, as does the DeLorean time car in the *Back to the Future* films). The idea of warping world lines, to support time travel to the past, entered science fiction at an early date. For example, when the inventor of the time machine in a 1930s tale[94] is asked about the principle underlying his gadget, he replies "An electro-magnetic warping of the spacetime continuum.

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[93] What is meant by a spacetime being *flat* will be formalized when we get to spacetime *metrics* later in this section. The Minkowski spacetime of special relativity is a flat spacetime, has no tilted light cones, and as such does *not* support time travel to the past.

[94] N. Schachner, "When the Future Dies," *Astounding Science Fiction*, June 1939.

The machine, if it works, will slide around the world-line of events and reappear at any specified time and place."

Using the Lorentz transformation equations from the previous section, we can establish quite general relationships between events in the Future, Past, and Elsewhere regions of spacetime. For example, (1) All events in the Future/Past for the Here-Now observer are in the Future/Past for any other nearby, relatively moving observer; (2) Any event in Elsewhere can appear to be simultaneous with the Here-Now for some observer and not simultaneous for another observer; and (3) The temporal ordering (the relations of *before* and *after*) of causally related events is the same for all observers. This is not so for events that are not causally related; if two events have a spacelike separation, then two observers can disagree over the temporal ordering of the events. This is, in fact, the basis for the two-wormhole and the cosmic string time machines, both of which will be discussed in Chap. 6. All these statements are easy to prove.

Consider, for example, statement (1). From the previous section we have (with $c = 1$)

$$t' = \frac{t - \mathrm{vx}}{\sqrt{1 - v^2}} \text{ and } x' = \frac{x - \mathrm{vt}}{\sqrt{1 - v^2}}$$

where t and x are the coordinates of some event A as measured by the observer in the stationary reference frame, and t' is the time measured by the observer in the reference frame moving at speed v. Thus

$$x'^2 - t'^2 = \frac{(x - \mathrm{vt})^2 - (t - \mathrm{vx})^2}{1 - v^2} = [\text{after a little algebra}]\ x^2 - t^2.$$

For the stationary observer the criterion for an event to be in the Future half-cone is $t > |x|$, that is, $t^2 > x^2$. Thus, $x^2 - t^2 < 0$ for all Future events. But the foregoing result then says $x'^2 - t'^2 < 0$, too, which is the moving observer's criterion for the event being in his Future half-cone. The same sort of argument shows that the two observers also agree on Past events.

Next, suppose that two events A and B occur such that the stationary observer measures them to be $\Delta T = t_B - t_A$ apart in time. Then, we can establish statement (2) by writing

$$t'_A = \frac{t_A - \mathrm{v}x_A}{\sqrt{1 - v^2}} \text{ and } t'_B = \frac{(t_B + \Delta T) - \mathrm{v}x_B}{\sqrt{1 - v^2}}$$

and so

$$\Delta T' = t'_B - t'_A = \frac{\Delta T + v(x_A - x_B)}{\sqrt{1 - v^2}}.$$

From this we have $\Delta T' = 0$ (that is, simultaneity) for the two events for the special observer moving at the speed

$$v = \frac{\Delta T}{x_B - x_A}$$

and this speed is less than the speed of light for the condition $x_B - x_A > \Delta T$. This is, of course, the condition for event B to be in the Elsewhere of event A. In fact, we can even have $\Delta T' < 0$ (with $\Delta T > 0$) for $v < 1$ in this case of spacelike separation of A and B. That is, a stationary observer and a sublight-speed moving observer can disagree about the temporal ordering of events with spacelike separation.

Similarly, for event B to be in the causal Future of event A, we have the condition $x_B - x_A < \Delta T$. Then,

$$\Delta T' = \frac{\Delta T - \mathrm{v}(x_B - x_A)}{\sqrt{1 - v^2}} > \frac{\Delta T - v\Delta T}{\sqrt{1 - v^2}} = \Delta T \frac{1 - \mathrm{v}}{\sqrt{1 - v^2}}.$$

Thus, $\Delta T > 0$ says $\Delta T' > 0$ for $v < 1$, and this establishes statement (3).

If we were drawing diagrams with both axes representing space (a plot of y versus x, for example), we would normally define a *distance metric* for the diagram using our everyday ideas about distance. That is, we could say that if we make differential movements of dx and dy along the two coordinate axes, then the differential distance ds is given by

$$(ds)^2 = (dx)^2 + (dy)^2.$$

This is, of course, just the Pythagorean theorem for the ‘Euclidean’ or ‘as the crow flies’ distance function. But it is not the only possible distance function. A distance function has several interesting mathematical properties,[95] but the one we are particularly interested in here is its invariance with respect to the coordinate system. For example, if we draw a line segment on a flat sheet of paper, the physical distance between its end-points does not depend on how we happen to select the x and y axes, a fact illustrated in Fig. 3.13 with the addition of a rotated and translated primed system. The coordinates for the endpoints A and B are obviously different in the two coordinate systems, but we still find that

$$(dx)^2 + (dy)^2 = (dx')^2 + (dy')^2.$$

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[95] Mathematicians have defined the general properties of a distance function as follows: if A and B are any two points, and if $d(A,B)$ is the distance between A and B , then (1) $d(A,B) = d(B,A)$; (2) $d(A,B) = 0$ if and only if $A = B$; and (3) if C is any third point, then $d(A,B) \leq d(A,C) + d(C,B)$. The Pythagorean distance function possesses all three of these properties, but so do many other functions (for example, $ds = |dx| + |dy|$).

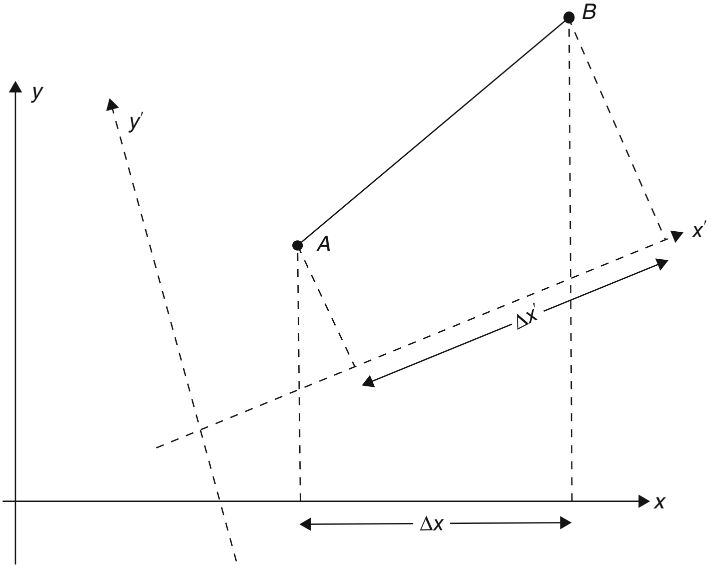

Fig. 3.13 Rotated/translated coordinate systems

We say that the Pythagorean distance function is *invariant*, that it is the same for all coordinates systems that are simply rotations and/or translations of each other.

We know that different observers, if in relative motion in the same spacetime, will see different space and time coordinates for the same event. Thus, it is natural to ask 'what is the metric for flat spacetime?' Is there, in fact, a metric that gives the same *distance* between two events for all observers? We might try to generalize in the obvious way from the Pythagorean theorem, and write

$$(ds)^2 = (dt)^2 + (dx)^2 + (dy)^2 + (dz)^2$$

where now all four dimensions are included. We would then ask ourselves whether it is true that

$$(ds)^2 = (ds')^2 = (dt')^2 + (dx')^2 + (dy')^2 + (dz')^2?$$

For our simple two-dimensional spacetime, this question reduces to asking whether

$$(dt)^2 + (dx)^2 = (dt')^2 + (dx')^2?$$

Using the Lorentz transformation equations from earlier, it is easy to discover that the answer is no. The 'natural' generalization of Pythagorean distance for flat, two-dimensional spacetime fails when four dimensions are included. So, what do we do now? Recalling the words of Professor Mundle from *Some First Words* (see note 23 there), we might wonder whether this difficulty could result from the fact that there is no fourth direction along which the time axis can point at right angles to the three space directions? At least, there is no *real* direction—but perhaps there is an imaginary one. Accordingly, with = $\sqrt{-1}$, let's try

$$(ds)^2 = (idt)^2 + (dx)^2 + (dy)^2 + (dz)^2 = -(dt)^2 + (dx)^2 + (dy)^2 + (dz)^2.$$

Using *imaginary time*, something that seems to be in the realm of science fiction, has resulted in a change in the sign of $(dt)^2$.

This is a crucial change, however, because this new metric *is* invariant. For a reason to be explained in the next section, I will use the negative of this metric (a choice that has no impact on the invariance property) and so write

$$(ds)^2 = (dt)^2 - (dx)^2 - (dy)^2 - (dz)^2.$$

For our simplified two-dimensional spacetime this reduces to

$$(ds)^2 = (dt)^2 - (dx)^2.$$

As before, the Lorentz transformation equations (with $c = 1$) are

$$t' = \frac{t - \mathrm{vx}}{\sqrt{1 - v^2}} \text{ and } x' = \frac{x - \mathrm{vt}}{\sqrt{1 - v^2}}.$$

If we then calculate $dx^{'}$ and $dt^{'}$ from these equations, using

$$dx' = \frac{\partial x'}{\partial x}dx + \frac{\partial x'}{\partial t}dt, dt' = \frac{\partial t'}{\partial x}dx + \frac{\partial t'}{\partial t}dt$$

which are the fundamental relations for the *total* differential[96] of a function of two variables, and insert the results into $(dt^{'})^2 - (dx^{'})^2$, we quickly discover the invariance property of this quantity (a result we actually found earlier, in a different way, when we showed that observers in relative motion agree about what events are in the Future and what events are in the Past). Thus,

$$(dt')^2 - (dx')^2 = (dt)^2 - (dx)^2.$$

This quantity, on either side of the equality, is called the spacetime *interval* between the two events separated in flat spacetime by either dt, dx, dy, and dz, or by $dt^{'}$, $dx^{'}$, $dy^{'}$, and $dz^{'}$. The observers in the unprimed and the primed systems see different individual space and time separations for two events, but they see the same

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[96] The $\frac{\partial}{\partial x}$ and $\frac{\partial}{\partial t}$ symbols denote the *partial* derivatives with respect to x and t (see any good calculus book to brush-up on this). The rest of this chapter *will* have some more math in it, involving derivatives and even an integral or two, but nothing beyond freshman calculus. I've included it mostly for those who would feel cheated without *some* math!

interval. A single time coordinate, and three space coordinates, are said to form a *four-vector that is invariant under Lorentz transformation*. There are, in addition, other four-vectors that are also invariant under Lorentz transformation, such as the energy-momentum, velocity, and force four-vectors; all these quantities have invariants that are formed the same way, by taking the difference of the squares of the time components and the sum of the squares of the space components. The intrusion of the square root of minus one, in the time coordinate of the metric, seems a pretty clear indication that time *is* different from space.[97]

But still, the spatialization of time is nonetheless deeply embedded in Western culture. For example, when writing her popular 1978 book, drawing historical parallels between the fourteenth and twentieth centuries, Barbara Tuchman titled it *A Distant Mirror*, and not *An Old Mirror*. The mathematical mixing of space and time appeared quite early in science fiction, but often in comically mangled form. In one such tale, for example, as an evil scientist uses his time machine to transport captives into the past, he tells them, “We’ve got a longish journey before us, ten thousand years more, multiplied by the fourth power of two thousand miles.”[98]

In general relativity, the metric of any four-dimensional spacetime has the structure of what mathematicians call a *symmetric quadratic Riemannian form*:

$$(ds)^2 = \sum_{i=1}^{4}\sum_{j=1}^{4} g_{ij}(dx_i)(dx_j), g_{ij} = g_{ji}$$

where $x_1 = t$, $x_2 = x$, $x_3 = y$, and $x_4 = z$, and the 16 g’s are all functions of these four variables. (Because of the symmetry condition, only 10 of the g’s are independent.) In this notation, a *flat* spacetime is mathematically characterized by $g_{11} = 1$, $g_{22} = g_{33} = g_{44} = -1$, $g_{ij} = 0$ for all $i \neq j$. Now, for a given spacetime, one can arbitrarily choose an infinity of coordinate systems. If just one of this infinity of systems is such that the ±1, 0 values for the g’s occur, then that spacetime is *globally* (that is, everywhere) flat. If no such coordinate system exists, then that spacetime is necessarily *curved*—I’ll give you a more intuitive view of curvature in just a bit. (If this notation is extended to a fifth dimension[99] by including the additional coordinate x_5, then there are an additional eight off-diagonal g’s and so four new *independent* g's. These are just sufficient to describe the electromagnetic field, too, along with the gravitational field described by the other ten g's. That is what is meant by saying five-dimensional spacetime 'unifies' gravity with electromagnetism.) There is a g_{55}, too, which could be allowed to model a slowly varying gravitational constant, as suggested by Dirac in 1938.

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[97] Writing in 1972, one famous physicist said of his first encounter with the metric of special relativity (Minkowski spacetime), “Now, when I saw that minus sign [in $-(dt)^2$], it produced a tremendous effect on me. I immediately saw that here was something new.” See P. A. M. Dirac, “Recollections of an Exciting Era,” in *History of Twentieth Century Physics* (C. Weiner, editor), Academic Press 1977.

[98] V. Rousseau, “The Atom Smasher,” *Astounding Stories*, May 1930.

[99] The fifth dimension was introduced in the 1920s by the German physicist Theodor Kaluza (1885-1954), but just what the nature of this fifth dimension might be remains a mystery. A few years after Kaluza, the Swedish physicist Oscar Klein (1894-1977) speculated that it might be a spatial dimension curled-up in a tiny circular path, so tiny that we don’t notice it; the issue remains open. The idea of a fifth dimension appeared early in pulp science fiction, as in the January 1931 tale “The Fifth-Dimension Catapult,” (*Astounding*) by Murray Leinster.

The g functions are the components of the so-called *metric tensor of the second rank* (see the last discussion question for more on what this means) of that spacetime. The g's at each point in spacetime are related to the curvature of spacetime at that point, which in turn is dependent on the g's and on the energy density at that point. In fact, the ten equations for the g's, which *are* the famous Einstein gravitational partial differential field equations, are both nonlinear and coupled. That is, each g_{ij} is in general a nonlinear function of all the other g_{ik}, which accounts for the notorious difficulty[100] in finding analytical solutions to the field equations except in certain highly special cases, such as the spacetime of spinning spheres and rotating infinite cylinders.

What does it mean to 'solve' the field equations? It is useful to think of the equations schematically as follows:

local geometry of spacetime ← local density, momentum and stress of the mass - energy of spacetime where the direction of the arrowhead means that the 'usual' practice is to assume the right-hand side (the so-called stress-energy tensor) as given, and then attempt to calculate the left-hand side. If the attempted calculation can be done, then one has solved the field equations for the spacetime geometry that is associated with the assumed mass-energy distribution.

Suppose, however, that we reverse the direction of the arrowhead. That is, suppose we assume a desired geometry. That is what Einstein did when he assumed the geometry of a *static* (non-expanding) universe and solved for the required mass-energy. What he found was just what had been observed by astronomers up to that time—a multitude of 'grains of matter' (what physicists call *dust*) plus the infamous cosmological constant. The constant, with its repulsive gravity, was needed to counteract the ordinary gravitational attraction of the stars that tends to pull them together. The later discovery that the universe is not static, but rather is expanding, rendered Einstein's solution moot.

Now let's go Einstein one better, and assume a spacetime geometry that contains closed timelike curves (a time machine, in other words) and then try to calculate the mass-energy distribution required by that spacetime. If that can be accomplished—and in fact the field equations themselves provide an algorithmic means of solution in this direction—then the physicist's work is done. The required mass-energy distribution requirements are put out to bid to 'spacetime engineers' and the lowest bidder 'simply' constructs that mass-energy distribution and so builds us our time machine! When the calculations are done, however, what has happened without fail, at least up to now, is that the resulting mass-energy distribution comes out with an 'unphysical' nature, a technical way of saying our spacetime engineer wouldn't know *how* to assemble the required mass-energy distribution. What is meant by 'unphysical' will be explored, in the particular case of wormhole time machines, in Chap. 6.

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[100] An elementary, quite interesting discussion of the enormous computational complexity of the field equations is presented in Richard Pavelle and Paul S. Wang, "MACSYMA from F to G," *Journal of Symbolic Computation*, March 1985, pp. 69-100.

The 16 g's for a four dimensional spacetime are often written in the form of a 4 × 4 matrix. In fact, the metric tensor is of the *second* rank precisely because a matrix has a *two*-dimensional form; scalars and vectors, which have forms of zero and one dimension, are tensors of rank zero and one, respectively. The collection of the algebraic signs of the main diagonal terms (the g_{ii}) is called the *signature* of the metric tensor. The signature of flat (Minkowski) spacetime is thus written as $[+, -, -, -]$; in more general (curved) spacetimes, this same signature is called *Lorentzian*. By contrast, the signature of a four-dimensional Euclidean space is $[+, +, +, +]$. This signature is called *Riemannian*. The geometry of flat, Minkowski spacetime is not Euclidean geometry because the spacetime signature of its metric has both plus *and* minus signs. As an uncurved spacetime, Minkowski spacetime *has no gravity*; to get gravity, we need a curved spacetime.

The idea of linking the curvature of a four-dimensional space to physical phenomena is the signature feature of general relativity, but it actually pre-dates Einstein by decades. It can be found, for example, in the work of the British mathematician William Kingdon Clifford (1845–1879), done in the 1860s and 1870s before Einstein's birth (in the year of Clifford's death). In his posthumously published book *The Common Sense of the Exact Sciences* (1885), Clifford wrote "We may conceive our space to have everywhere a nearly uniform curvature, but that slight variations of the curvature may occur from point to point and themselves vary with time. These variations of the curvature with time may produce effects which we not unnaturally attribute to physical causes independent of the curvature of our space. We may even go so far as to assign to this variation of the curvature what really happens in that phenomenon which we term the motion of matter." It isn't a long jump from "motion of matter" to gravity![101]

Not everyone enthusiastically embraced this new, radical view of nature. For example, the great Scottish mathematical physicist James Clerk Maxwell (1831–1879), of Maxwell's equations fame, who knew Clifford through their common membership in the London Mathematical Society, summarily dismissed this part of Clifford's work as simply the speculations of a "space crumbler." Decades later, Einstein faced the same rejection when the eminent British astronomer Sir James Jeans declared "Einstein's crumbling of his four-dimensional space may . . . be considered to be . . . fictitious."[102]

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[101] Clifford almost surely found inspiration in this part of his work from the even earlier efforts of the German mathematician Bernhard Riemann (1826-1866). See, for example, Clifford's translation of Riemann's famous 1854 lecture "On the Hypotheses Which Lie at the Bases of Geometry," *Nature*, May 1, 1873, pp. 14-17, and continued in the next issue (May 8, 1873, pp. 36-37).

Spacetime geometries are not easy concepts to grasp, and the metrics of curved spacetimes are even more complicated than is the metric of the flat spacetime of Minkowski's special relativity. As one paper so aptly put it, "Experience has taught us that the space in which we live has a geometry that is three-dimensional and Euclidean . . . We are very much at home with [that] geometry . . . But the geometric properties of a Minkowskian space are so alien to us that we may well despair of visualizing them, and a Riemannian [curved] space . . . seems totally beyond comprehension."[103]

An important feature of Riemannian geometry is that although it is generally not globally flat, it is always *locally* flat. Thus any sufficiently small region in a curved Riemannian spacetime can be approximated, with arbitrarily small error, by a flat pseudo-Euclidean Minkowskian spacetime. That is, at each point in Riemannian spacetime, there is some *particular* inertial frame of reference in which special relativity is all there is to spacetime physics *at that point*. The particular inertial frame required is different, however, from point to point.

In a coordinate system different from rectangular, the flat Minkowskian metric can appear radically altered, but that is just an artifact of the mathematics and has no physical significance. For example, in spherical coordinates the Minkowskian metric becomes the equivalent

$$(ds)^2 = (dt)^2 - (dr)^2 - (rd\theta)^2 - (rsin(\theta)d\phi)^2$$

where ϕ is the azimuthal angle and θ is the angle measured from the polar axis. A related metric occurs in the theory of spherically symmetric, static (no time variation) time machine wormholes (discussed in Chap. 6), of the form

$$(ds)^2 = \left(e^{a(r)}dt\right)^2 - \frac{(dr)^2}{1 - \frac{b(r)}{r}} - (rd\theta)^2 - (rsin(\theta)d\phi)^2$$

where $a(r)$ is called the *redshift function* and $b(r)$ is called the *shape factor*. These two functions are nearly arbitrary, subject only to the constraints that both $b(r)/r$ and $a(r)$ vanish as r goes to infinity (r is the radial distance from the throat of the wormhole mouth). Indeed, as r increases, this curved wormhole spacetime metric

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[102] Quoted in P. Kerszberg, "The Relativity of Rotation in the Early Foundations of General Relativity," *Studies in History and Philosophy of Science*, March 1987, pp. 53-79.

[103] R. W. Brehme and W. E. Moore, "Gravitational and Two-Dimensional Curved Surfaces," *American Journal of Physics*, July 1969, pp. 683-692.

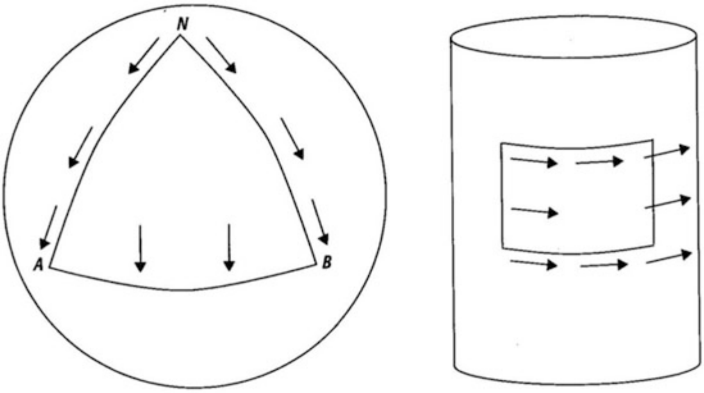

Fig. 3.14 The curvature of a space can be revealed by the process of parallel transport

reduces to that of flat Minkowskian spacetime, so this wormhole spacetime is said to be *asymptotically flat*.[104]

An intuitive appreciation of ‘flatness’ can be realized in terms of what is called the *parallel transport* of a vector around a closed path. In a curved space the vector will experience a rotation, which will not occur in a flat space. Two examples of parallel transport in ordinary three-dimensional space are shown in Fig. 3.14. The spherical surface on the left is curved because if you slide the vector from *N* to *A* to *B* and then back to *N*, all the while keeping it parallel to its immediately previous orientation, then when it gets back to *N* the vector will point to *B*, *not* toward *A* as it initially did. A similar trip on the cylindrical surface, however, results in zero rotation of the vector. Thus, the cylindrical surface, despite superficial appearances, is *not* curved.

Using the idea of the metric tensor, we can develop a more formal demonstration that the surface of a sphere, unlike like that of a cylinder, is not flat. On the surface of a sphere of radius a (*on* the surface $r = a$ everywhere, and so $dr = 0$), the measure of the distance between two points (in spherical coordinates) is[105]

$$(ds)^2 = a^2 sin^2(\theta)(d\phi)^2 + a^2(d\theta)^2.$$

Writing $x_1 = \phi$ and $x_2 = \theta$ yields the more general form

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[104] For wormhole spacetimes that are not asymptotically flat, see (for example) K. Narahara, *et al.*, “Traversable Wormhole in the Expanding Universe,” *Physics Letters B*, September 29, 1994, pp. 319-323.

[105] Note *carefully* that this is a purely spatial problem, with no time, and we are taking all of the metric coefficients as positive (unlike in the case of a spacetime metric).

$$(ds)^2 = g_{11}(dx_1)^2 + g_{12}(dx_1)(dx_2) + g_{21}(dx_2)(dx_1) + g_{22}(dx_2)^2$$

or, using the symmetry condition $g_{12} = g_{21}$, we have

$$(ds)^2 = g_{11}(dx_1)^2 + 2g_{12}(dx_1)(dx_2) + g_{22}(dx_2)^2.$$

From this we immediately have $g_{11} = a^2 sin^2(\theta)$, $g_{22} = a^2$, and $g_{12} = g_{21} = 0$.

Now, suppose we ask whether it is possible to find some new coordinate system (with variables x_1' and x_2') in which the invariant $(ds)^2$ is given by the flat Euclidean metric $\left(dx_1'\right)^2 + \left(dx_2'\right)^2$. In such a coordinate system (if it exists) we would have the 'flatness conditions' of $g_{11}' = g_{22}' = 1$ and $g_{12}' = g_{21}' = 0$. With such a change of coordinates, each of our original ϕ, θ coordinates would generally be a function of both of the new coordinates—that is, $\phi = \phi\left(x_1', x_2'\right)$ and $\theta = \theta\left(x_1', x_2'\right)$. Thus, writing the total differential of a function of two variables (see note 96 again), we have

$$d\phi = \frac{\partial\phi}{\partial x_1'}dx_1' + \frac{\partial\phi}{\partial x_2'}dx_2'$$

$$d\theta = \frac{\partial\theta}{\partial x_1'}dx_1' + \frac{\partial\theta}{\partial x_2'}dx_2'.$$

Substituting these expressions into the above expression for $(ds)^2$ on the surface of a sphere, and collecting terms, we arrive at

$$\begin{aligned}(ds)^2 &= a^2\left\{\left[\sin^2(\theta)\left(\frac{\partial\phi}{\partial x_1'}\right)^2 + \left(\frac{\partial\theta}{\partial x_1'}\right)\right]\left(dx_1'\right)^2 + \left[\sin^2(\theta)\left(\frac{\partial\phi}{\partial x_2'}\right)^2 + \left(\frac{\partial\theta}{\partial x_2'}\right)^2\right]\left(dx_2'\right)^2\right.\\ &\quad\left. +2\left[\sin^2(\theta)\frac{\partial\phi}{\partial x_1'}\frac{\partial\phi}{\partial x_2'} + \frac{\partial\theta}{\partial x_1'}\frac{\partial\theta}{\partial x_2'}\right]\left(dx_1'\right)\left(dx_2'\right)\right\}\\ &= g_{11}'\left(dx_1'\right)^2 + 2g_{12}'\left(dx_1'\right)\left(dx_2'\right) + g_{22}'\left(dx_2'\right)^2\end{aligned}$$

We can now immediately write down each of the g' and, if we demand that they satisfy the 'flatness conditions,' then we have the following three statements:

$$sin^2(\theta)\left(\frac{\partial\phi}{\partial x_1'}\right)^2 + \left(\frac{\partial\theta}{\partial x_1'}\right)^2 = \frac{1}{a^2}$$

$$sin^2(\theta)\left(\frac{\partial\phi}{\partial x_2'}\right)^2 + \left(\frac{\partial\theta}{\partial x_2'}\right)^2 = \frac{1}{a^2}$$

$$sin^2(\theta)\frac{\partial\phi}{\partial x_1'}\frac{\partial\phi}{\partial x_2'} + \frac{\partial\theta}{\partial x_1'}\frac{\partial\theta}{\partial x_2'} = 0.$$

For a *globally* flat surface, that is, a surface that is flat *everywhere*, these three statements must hold in particular at the poles of the sphere. That is, at $\theta = 0^\circ$

and at $\theta = 180^{\circ}$. At both of these points $\sin(\theta) = 0$, and so at the poles the three statements reduce to

$$\left(\frac{\partial \theta}{\partial x_1'}\right)^2 = \frac{1}{a^2}$$

$$\left(\frac{\partial \theta}{\partial x_2'}\right)^2 = \frac{1}{a^2}$$

$$\frac{\partial \theta}{\partial x_1'} \frac{\partial \theta}{\partial x_2'} = 0.$$

But the third statement is incompatible with the first two and, because of that incompatibility, there is no primed coordinate system in which the g' coefficients in the metric are those of a globally flat metric. Thus, unlike the surface of a cylinder, the surface of a sphere is not flat but rather is curved. This almost surely comes as no surprise to you, but now you can *prove* it!

3.6 Proper Time and the Twin Paradox in Time Travel to the Future

"[The] equations of duo-quadrant lineations [have] been substantiated ... Our fourth-angle deviation from the six conceivable electronic dimensions did the trick all right. I went forward in Time."[106]

The spacetime interval of the previous section has an important interpretation that leads to one of the more dazzling results of special relativity—time travel into the future. First, recall the flat spacetime metric

$$(ds)^2 = (dt)^2 - (dx)^2 - (dy)^2 - (dz)^2$$

in which the use of unprimed variables indicates that the measurements on the space and time coordinates of a moving particle are made with respect to a stationary observer's frame of reference. Now, suppose that the space and time coordinates of a moving particle are made with respect to the particle instead. Then, using primed variables for measurements made in this new frame of reference, $dx' = dy' = dz' = 0$ because the particle is always at the origin (by definition)! Recalling the invariance of the spacetime interval for all observers, we conclude that

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[106] A science fiction scientist babbles incoherent nonsense, not special relativity, about how to travel into the future, in a story by J. H. Haggard, "He Who Masters Time," *Thrilling Wonder Stories*, February 1937.

$$(ds')^2 = (ds)^2 = (dt')^2.$$

That is, the spacetime interval between two events is the time lapse measured by a clock attached to a particle that moves from one event to the other. This time is called *proper time*, which gets its name from the idea that it belongs to (is the *property* of) the moving particle. This is the technical reason for taking (as we did in the previous section) $(ds)^2 = (dt)^2 - (dx)^2$ rather than $(ds)^2 = (dx)^2 - (dt)^2$. The first choice avoids the somewhat awkward result of an imaginary proper time.

Next, we'll adopt what has come to be called the *clock hypothesis*, which states that an accelerated clock runs at the same instantaneous rate as an unaccelerated clock that is moving alongside at the instantaneously same speed. As we showed earlier (take a look back at Sect. 3.3), if the accelerated clock's instantaneous speed is v, then its rate of time keeping (dt') is related to that of the 'stationary' (unaccelerated) clock (dt) as

$$dt' = \sqrt{1 - \left(\frac{v}{c}\right)^2}\, dt$$

where c is the speed of light. The clock hypothesis is generally assumed to be true. Einstein, himself, in his famous 1905 special relativity paper, specifically took the rate of a clock's timekeeping to be velocity-dependent only. When asked during an interview decades later whether it is permissible to use special relativity in situations involving acceleration, Einstein replied "Oh, yes, that is all right as long as gravity does not enter; in all other cases, special relativity is applicable. Although, perhaps the general theory approach might be better, it is not necessary."[107]

The clock hypothesis has long had experimental verification. For example, in one experiment the time keeping of accelerated atomic clocks was determined to be given precisely by the time dilation formula of special relativity, even when their direct mechanical acceleration (the centripetal acceleration produced by a rapidly spinning disk) exceeded 66,000 gees![108] And even more impressive are the time dilation results of a later experiment in which the time keeping of near light-speed charged particles, orbiting in a magnetic field, was in excellent agreement with the time dilation formula, even as accelerations well in excess of 10^{15} gees were reached![109]

The total elapsed time between two events A and B, as measured by the proper time of an accelerated clock making the journey, is, therefore, given by

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[107] R. S. Shankland, "Conversations with Albert Einstein," *American Journal of Physics*, January 1963, pp. 47-57.

[108] H. J. Hay, *et al.*, "Measurement of the Red Shift in an Accelerated System Using the Mössbauer Effect in Fe^{57}," *Physical Review Letters*, February 15, 1960, pp. 165-166.

[109] J. Bailey, *et al.*, "Measurements of Relativistic Time Dilation for Positive and Negative Muons in a Circular Orbit," *Nature*, July 29, 1977, pp. 301-305.

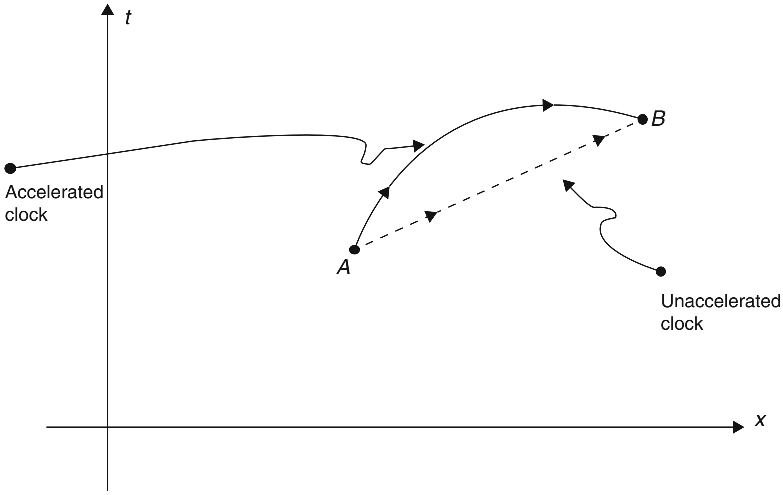

Fig. 3.15 World lines of two clocks (one accelerated and one unaccelerated)

$$t' = \int dt' = \int_{t_A}^{t_B} \sqrt{1 - \left(\frac{v}{c}\right)^2} dt < t_B - t_A \text{ if } v \neq 0$$

where $t_B - t_A$ is the elapsed time between A and B as measured by the unaccelerated clock. The inequality results because, for $v \neq 0$, the integrand is always less than 1. Now, we know that in a spacetime diagram the world line of the unaccelerated clock is a straight line, whereas the world line of the accelerated clock is a curved line. Thus, using Fig. 3.15, combined with the inequality $t' < t_B - t_A$, we have the following central result: the world line of *maximum* proper time is the one that *looks the shortest*, that is, the straight (or free-falling geodesic) world line. In the spacetime diagram the curved line looks longer, but in fact any curved line will have a smaller proper time than does the straight world line. This is a dramatic example of how Minkowskian *spacetime* geometry differs from Euclidean *space* geometry; in the latter geometry, there is no longest path between two points.

From this, we can now understand the famous paradox of the twins, Bob and Bill. Bill remains on Earth, but Bob gets into a rocket ship and goes on a high speed trip out into space. Eventually he brings his ship to a stop, turns around, and returns to Earth. The world lines of Bob and Bill are initially together, then they diverge as Bob goes on his trip, and then they come together again at the end of Bob's trip, as shown in Fig. 3.16. The details of Bob's trip are not important for a general statement of the paradox (although in just a bit I *will* present the details for one possible trip). All we need observe for now is that Bill's world line from A to B is straight, whereas Bob's is curved. Bill's body (that is, his local clock) will therefore measure a greater proper time than will Bob's; that is, Bob will be younger than his stay-at-home twin! Equivalently, upon his return Bob will hear his Earthbound

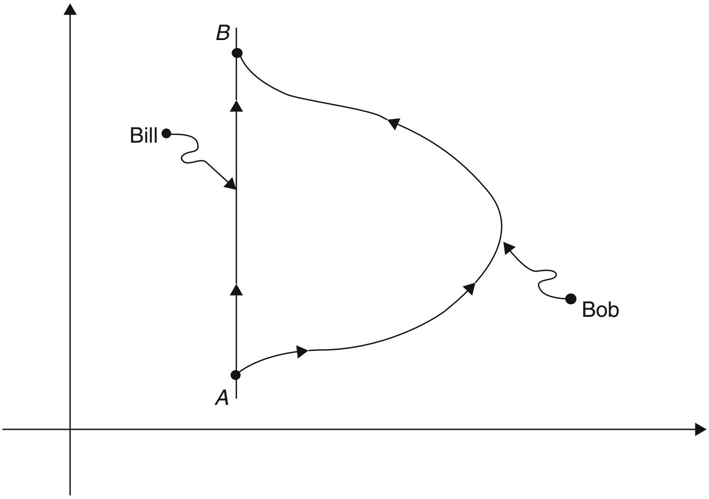

Fig. 3.16 World lines of unaccelerated (Bill) and accelerated (Bob) twins

brother declare the date to be further in the future than Bob's trip lasted (according to Bob). Bob will therefore conclude that he has traveled into the future.[110]

This situation is called a paradox, not because of the time travel aspect (there are no logical paradoxes associated with travel into the future), but rather because it seems to violate the very spirit of special relativity. That is, from Bill's point of view, Bob at first travels away and then returns. But one can argue that from Bob's point of view it is Bill who first recedes and then returns. So why is it *Bob* who is the younger, and not Bill? Long after Einstein's 1905 publication of special relativity, this point remained a great puzzle for many. For example, in the 1923 Presidential Address to the Eastern Division of the American Philosophical Association, we read this very objection to the twin paradox. The conclusion by the speaker is that such a thing "could happen only in a universe in which all squares were round and the *principio contradiction* had been put to sleep."[111]

So, what's the answer, why is it *Bob* who is the younger of the twins? The classic physics answer is that the two points of view are actually *not* symmetrical, that there is a definite asymmetry between Bill and Bob. After all, it is Bob who feels the acceleration from the rocket's engines as he blasts off from Earth—it is Bob, not

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[110] The twin paradox is hinted at in Einstein's 1905 paper, but it is in a 1911 address to the International Congress of Philosophy in Bologna, by the French physicist Paul Langevin (1872-1946), that a human space traveler is first introduced (in a cannonball moving at near light-speed, an idea motivated by Langevin's reading of Jules Verne's 1872 novel *From the Earth to the Moon*). The writer Pierre Boulle proudly mentioned this contribution by his fellow Frenchman in the time travel story "Time Out of Mind" (you can find it in Boulle's collection *Time Out of Mind*, Vanguard Press 1966).

[111] W. P. Montague, "The Einstein Theory and a Possible Alternative," *The Philosophical Review*, March 1924, pp. 143-170.

Bill, who feels *force*—whereas Bill feels nothing unusual as he remains on Earth. The more fundamental physics answer, however, is that Bob's world line in spacetime is curved, whereas Bill's is straight.

In an open, spatially unbounded, flat spacetime, *curved* is indeed synonymous with *accelerated*, but this need not be so in a *closed,* flat spacetime. In an open, flat spacetime, the only way two world lines can diverge in the past and then meet again in the future is for at least one of them to curve, but in a closed but still flat spacetime, it is possible for two straight world lines to meet more than once. For example, Fig. 3.17 shows a simple two-dimensional spacetime that is the surface of a cylinder (which you'll recall we argued earlier is flat), rather than an infinite flat plane. The two world lines in that figure are *both* straight: to visualize this, imagine cutting the cylinder open along the (vertical) time dimension, and then flattening it out. Bob's world line, however, looks longer in the spacetime diagram, so Bob's proper time will be less than Bill's when they meet again, even though now *neither* of them has experienced any acceleration.[112] This is simply an interesting mathematical exercise, however, and as far as is known the spacetime we live in is not cylindrical and so Bob's trip into the future will require an accelerating rocketship.[113]

If we specify the details of Bob's trip, we can then precisely calculate the difference in elapsed time for the twins. In an analysis that dates back to 1962, the German astrophysicist Sebastian von Hoerner (1919–2003) did that for the following trip[114]: To begin, Bob gets into his rocket ship at time $t = t' = 0$ (t is time measured on Earth by Bill, and t' is time measured by Bob in his rocket). The Bill and Bob synchronize their clocks at the instant of departure. Bob's trip is to be made in comfort, and so his rocket accelerates at a constant rate (a one gee acceleration, for example, would be equivalent to Earth's gravity, and Bob would feel right at home). This is of practical importance, obviously, because we do not want the experienced acceleration to be incompatible with the physical survival of Bob. Bob

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[112] See C. H. Brans and D. R. Stewart, "Unaccelerated-Returning Twin Paradox in Flat Space-Time," *Physical Review D*, September 15, 1973, pp. 1662-1666. For a similar treatment, this time by a mathematician, see Jeffrey R. Weeks, "The Twin Paradox in a Closed Universe," *American Mathematical Monthly*, August-September 2001, pp. 585-589.

[113] In Chapter 6 we'll discuss the idea of traveling into the past by moving faster than light (*superluminal* motion). A treatment of such travel, in Bob's cylindrical spacetime, is by S. K. Blau, "Would a Topology Change Allow Ms. Bright to Travel Backward in Time?" *American Journal of Physics*, March 1998, pp. 179-185, which answers that question in its last line: "Ms. Bright cannot [return] 'the previous night' and alter history," a conclusion that no doubt met with Hawking's approval. The 'Ms. Bright' in the title is the heroine of a 1923 limerick that you can find quoted in the first *For Further Discussion* of Chapter 6.

[114] Originally appearing in the journal *Science*, under the title of "The General Limits of Space Travel," von Hoerner's analysis was reprinted in the classic anthology *Interstellar Communication* (A. G. W. Cameron, editor), W. A. Benjamin 1963. The arithmetic was, alas, just a bit sloppy (the final formulas, fortunately, are correct), and many of von Hoerner's numerical evaluations are incorrect. Later, the British mathematician Leslie Marder cleaned-up the analysis in his beautiful little book on the twin paradox, *Time and the Space-Traveler*, George Allen & Unwin, Ltd. 1971.

Fig. 3.17 Unaccelerated twin paradox in a cylindrical spacetime

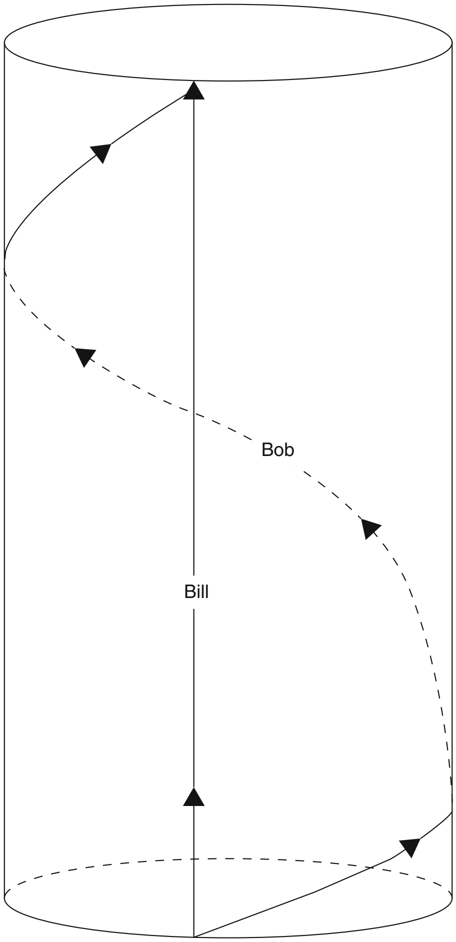

travels this way for a time interval of T (as measured by Bill on Earth) and $T^{'}$ (as measured by Bob in his rocket). At that time the rocket is traveling at its maximum speed. Bob then turns off the rearward engine and turns on a forward-mounted engine so as to experience a constant deceleration. Floor and ceiling interchange, but Bob always weighs the same. If he does this for the same time interval T (as measured by Bill on Earth) and $T^{'}$ (as measured by Bob) as for the initial acceleration phase of the trip, the rocket will be brought to rest with respect to Earth. At that time, $2T$ (as measured by Bill on Earth) and $2T^{'}$ (as measured by Bob), the rocket is at its maximum distance from Earth. Bob then returns to Earth, using the same acceleration/deceleration process, and Bob arrives back home, gently, with a final speed of zero with respect to Earth (ignoring, of course, all the navigational problems due to the motion of Earth during the trip).

Assuming the clock hypothesis is true (not all physicists believe this,[115] but remember, we have Einstein[116] on our side with this!), the result is that if a is the constant acceleration of the rocket (as experienced by Bob), and c is the speed of light, then the relationship between the *total roundtrip time* as measured by Bill ($4T$) and as measured by Bob ($4T'$), is given by

$$T = \frac{c}{a}\sinh\left(\frac{a}{c}T'\right).$$

The difference in what each twin believes to be the date can, in fact, be truly astonishing. For example, if $a = 1$ gee and Bob travels (by his clock) for $4T' = 20$ years, then $4T = 339$ years.[117] Of course, there will actually be no disagreement between Bill and Bob over the date upon Bob's return because Bill will be long dead!

Is it likely that such a time trip[118] will someday be made into the future? It's just my opinion, but I suspect not. Bob will be traveling at virtually the speed of light at maximum speed ($0.9993\,c$, to be precise, at which point he will be 84 light-years from Earth), and to zip through space at such a speed would result in a very high rate of collision with stray hydrogen atoms (about one per cubic centimeter). The result of those energetic collisions would be the intense blasting of Bob with a lethal dose of gamma radiation. And, as von Hoerner showed in his original analysis (note 114), the energy required by Bob's rocket would be simply mind-boggling.

Professor Schild (see note 116), on the other hand, seems to have been less bothered by such considerations when he wrote, at the beginning of a prose discussion of the twin paradox, "I have no doubt that if our technology should ever advance to the stage where large-scale twin effects become noticeable with our unaided senses, then [people] will have no difficulty in adjusting their concepts of time until the new phenomena see quite natural."[119]

I'll end this chapter on time with the observation that it is the distinction between the proper time of Bob on a rocket ship, and the time of those who are not fellow space travelers, that eliminates the occasional suggestion of simply *freezing* one's way via suspended animation to the future (as in the 1992 film *Forever Young*). That is, suppose you manage to talk a friend into climbing into a freezer (please don't actually try this!); at the moment he gets in, his wrist watch agrees with yours (both are powered and maintained at a constant temperature by 100-year nuclear batteries). Years later, when you thaw your friend out, you'll find that your watches still agree. But when Bob returns from his rocket trip, his watch will not agree with yours, but instead will be far behind. Bob is a true time traveler, but your frozen/thawed friend is not.[120]

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[115] Consider, for example, this remark by 1965 Nobel physics laureate Julian Schwinger (1918-1994) about the twin paradox in his 1986 book *Einstein's Legacy*: "The observer on the spaceship ... is *not* in uniform, unaccelerated motion ... The special theory of relativity does not apply to such an accelerated observer." Schwinger was wrong in this conclusion (see the next note).

[116] As a physicist wrote on this point after Einstein's death, "A good many physicists believe that [the twin] paradox can only be resolved by the general theory of relativity. ... However, they are quite wrong. The twin effect ... is one of special relativity." See A. Schild, "The Clock Paradox in Relativity Theory," *American Mathematical Monthly*, January 1959, pp. 1-18. Alfred Schild (1921-1977) was professor of physics at the University of Texas, and a recognized expert in the general theory.

[117] In using the T, T' formula, one has to be careful to use MKS units, that is, length and time measured in meters and seconds, respectively. Thus, $a = 1$ gee = 9.81 meters/second^2 and $c = 186{,}210$ miles/second $= 2.997 \times 10^8$ meters/second.

[118] For a science fiction use of such a trip, see Robert Heinlein's 1956 novel *Time for the Stars*.

[119] A. Schild, "Time," *Texas Quarterly*, Autumn 1960, pp. 42-62.

A provocative illustration of the distinction between the proper time of a time traveler and of those who are not time travelers was given by a philosopher.[121] He begins his analysis by asking what appears to be a question with an obvious answer. Suppose, he says, it is [2018] and you suddenly wake up in a hospital and are told that you have been in a coma for the past 2 weeks. You are also told that you were in an auto accident 2 weeks ago, that you suffered temporary neural damage, and that the eventual reversal of such damage always, at some time within 4 weeks after the damage occurs, causes a day of excruciating pain *if you are conscious at the time*. Would you prefer for the day of damage reversal to be in the past 2 weeks (when you were in the coma) or in the next 2 weeks? The answer seems clear. After all, if the day that damage reversal occurs has already happened, then you simply slept through it and missed the pain. To prefer the day of pain to be in the future (when you will be awake) seems absurd. Now, let's add time travel to the equation.

All is as before, but now you immediately leave the hospital upon regaining consciousness to take a trip back to 1892, where you will stay for 2 weeks. Again, it seems clear that you would prefer to have had the day of pain in the past 2 weeks (in 2018), not in the next 2 weeks (in 1892). Note that the *next* is a reference to your proper time, because whereas 1892 is the global past, it is *your* personal future. Thus, now your preference would be to have the day of pain in the *recent personal past* of 2018, not the *distant global* past of 1892. Now, let's put another time travel twist to this story.

All is as before in the original tale, except now you are told in the hospital that the auto accident happened just after you made a time trip to 2092: as you walked out of your time machine in 2092, you were hit by a car. The 2 weeks you were in a coma were in 2092, before you were judged fit enough (although still unconscious) to make the time journey back to 2018. When would you now prefer to have the day of pain? Clearly, as always, in your *personal past*, which is now the *global future*.

Time *is* different for those who time travel and those who don't!

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[120] In his 1956 novel *The Door Into Summer*, the always ingenious Robert Heinlein used *both* ideas, with the cold-storage method of reaching the future combined with a true time machine to allow his hero to return to his 'present' (the future's past).

[121] A. Gallois, "Asymmetry in Attitudes About the Nature of Time," *Philosophical Studies*, October 1994, pp. 51-59.

3.7 For Further Discussion

An interesting *theological* analysis of Feynman's idea of an electron traveling backward in time, expressed as thinking of the electron as being in 'one of God's films played in reverse,' is given by J. W. Smith, "Time Travel and Backward Causation," *Cogito* 1985, pp. 57–67. Wondering what it would be like for an electron to travel backwards in time, Smith's answer was: "Consider an electron e_1. At time t_0 it is at (x_0, y_0, z_0). At time t_1 it is at (x_1, y_1, z_1). If the direction of time for the electron was reversed, then the electron would be observed on the 'film of the world' to travel back along the same path as it did before, i.e., back to (x_0, y_0, z_0). If God stopped the 'film of the world' and examined the charge of e_1, then He would find that it was *negative*, not *positive*. Hence the electron traveling backwards in time is simply that: an electron traveling backwards in time, it is not a positron. Time reversal does not result in a reversal of charge. Thus, the Stückelberg-Feynman position is incorrect . . . ." Discuss this in terms of the TCP theorem. Is there a conflict? When God stops the 'film of the world,' does the electron even *have* an arrow of time?

All the modern, major religions of the world are in agreement on these two points: (1) God created the universe and (2) At some time in the past, the universe came into existence. This does raise the question of what was God doing *before* He created the universe (see note 7 in the Introduction). In his *Confessions*, Saint Augustine comments on the conundrum that (1) and (2) are possibly in conflict. After all, if God *created* the universe then, given any time t in the finite past, He must have been doing something *before* time t, which means that for any time t in the finite past the universe already existed. Thus, the universe had no instant of creation in the finite past and so had no first moment of existence—which implies (2) is false. However, like any good philosopher of religion, Augustine not only provided this theological puzzle, but also a way to wiggle free of it. His suggested counter is the assertion that time is *itself* a creation of God, that is, He made time as *part* of creating the universe. Thus, there was no time *before* He created the universe, and so the very question of 'what was He doing before He made the universe' has no meaning. What do you think of Augustine's two arguments?

The Australian philosopher J. J. C. Smart (1920–2012) invoked five dimensional spacetime in a way very different from that of including an ‘eternity’ axis for God’s temporal time (see note 33 in “Some First Words”). What Smart argued for, instead, was *multiple* four-dimensional worlds existing together without conflict, just as an infinity of two-dimensional worlds can exist without conflict in a three dimensional space. As he wrote, “The reason why there could be two totally disparate space-times is simply the quite obvious one that two totally disparate four-dimensional spaces can exist within a suitable five-dimensional space. There is no difficulty in mathematical inconceivability here. Now let one of these four-spaces be our own spacetime world, and let the other four-space be more or less similar, in accordance with whatever story you wish to tell about it.” This idea had, in fact, been around long before Smart’s 1967 paper. In his 1898 Presidential Address to the American Mathematical Society, for example, Simon Newcomb declared “Add a fourth dimension of space, and there is room for an indefinite number of Universes, all alongside of each other, as there is for an indefinite number of sheets of paper when we pile them upon each other.” Newcomb’s idea appealed to H. G. Wells’ fancy so much that he built two novels, *The Wonderful Visit* and *Men Like Gods*, around it. In the first novel there is explicit mention of multiple worlds “lying somewhere close together, unsuspecting, as near as page to page in a book,” and the second one speaks of one parallel universe being rotated into another. John Cramer (a University of Washington physicist) repeated Newcomb’s and Wells’ parallel universes/pages-of-a-book/rotation imagery almost word for word in his 1991 novel *Twistor*.

Read these three novels, and then discuss. In particular, is Wells consistent in his presentations (as a novelist there is, of course, no reason he should be!)?

Imagine the following two events, **A** and **B**, in Minkowski spacetime: **A** is the emission of a photon, and **B** is the absorption of that photon. What is the spacetime interval between **A** and **B**? It might seem that we need to know more about the precise spatial and temporal coordinates of **A** and **B**, but in fact the interval is *always zero* for any two events connected by light (by photons). To see this, write the flat Minkowski metric as

$$\left(\frac{ds}{dt}\right)^2 = 1 - \left(\frac{dx}{dt}\right)^2$$

(continued)

and so, since $(dx/dt)^2 = 1$ (because photons—by definition!—travel at the speed of light) we have $(ds)^2 = 0$. The world line of any photon has what is called a *null* interval, as do all world lines on the surface of a light cone. Timelike world lines (in the interior of light cones, with $(dx/dt)^2 < 1$) have positive intervals, that is, $(ds)^2 > 0$. Spacelike world lines (in the exterior of light cones, in Elsewhere, with $(dx/dt)^2 > 1$) have negative intervals, that is, $(ds)^2 < 0$. This is one of the significant differences between *distances* in space (which are never negative) and *intervals* in spacetime. The American chemist G. N. Lewis (1875–1946)—see note 60 in Chap. 2—constructed a romantic illustration of this when he wrote "Any pair of points [in spacetime] which are separated by zero distance [interval] are in *virtual contact*. In other words, I may say that my eye touches a star, not in the same sense as when I say that my hand touches a pen, but in an equally physical sense." (See Lewis' paper "Light Waves and Light Corpuscles," *Nature*, February 13, 1926, pp. 236–238; Lewis was the originator of the term *photon* for a particle of light.) To understand what Lewis was getting at, you must understand that in spacetime we can have the interval between **A** and **B** as zero, and the interval between **B** and **C** as zero, but the interval between **A** and **C** may *not* be zero. To convince yourself of this, suppose the Minkowski spacetime coordinates (x, t) of **A**, **B**, and **C** are (1,3), (2,2) and (1,1), respectively. Show that $(ds_{\boldsymbol{AC}})^2 = 4$, while $(ds_{\boldsymbol{AB}})^2 = (ds_{\boldsymbol{BC}})^2 = 0$. (Hint: draw a diagram of this spacetime and simply plug the coordinates of **A**, **B**, and **C** into the metric.)

The use of the time dilation effect of high-speed space travel was used by science fiction writer Donald Wandrei (1908–1987) in his tale "A Race Through Time," *Astounding Stories*, October 1933. Initially set in 1950, this is the story of two scientists, one evil (of course!) and the other good (of course!), who develop quite different methods for travel into future times. The evil one does it with a drug that slows the metabolic processes of the body, while the good one builds an atomic-powered rocket in his home workshop! The evil scientist kidnaps the good one's girlfriend, seals the two of them inside a crystal dome, and then injects her and himself with his drug. He has arranged matters so that they will emerge from the dome in the year one million A.D. Learning what has happened, the good scientist rushes to the dome finds he can't break in, but sees an indicator dial pointing at 1,000,000. (The evil scientist has conveniently provided the dial, as well as having made the dome transparent, much as modern-day movie criminals always include a count-down clock with glowing red digits on their bombs so the hero always knows just how much time is left to disarm the bomb.)

(continued)

Returning to his rocket, the good scientist decides that he, too, will travel into the far future using time dilation. So, off he goes, on a trip like Bob's in Sect. 3.6. The story ends with an ironic twist—the good scientist thought the '1,000,000' he saw through the dome meant *one million years in the future beyond 1950*, and so he arrives back on Earth nearly 2000 years *after* his girlfriend and the evil scientist emerged from the dome. (They are, of course, long dead when the good scientist returns.)

On the outward leg of the good scientist's rocket flight we read of his "frightful speed — now thousands of light years per Earth second." Discuss this in terms of relativity theory. That is, does the rocket actually travel thousands of light years in one second of elapsed time back on Earth?

The American physicist Robert Forward (1932–2002) was, in addition to being an expert in general relativity, also a quite inventive science fiction writer. In his short story "Twin Paradox" (*Analog Science Fiction*, August 1983), for example, he used *biology* to give a surprising, ironic twist to the classic physics puzzle. The story flips the asymmetric aging of the twins by imagining that, just after the traveling twin's departure, the secret of immortality is discovered. The treatment has to be administered no later than at a certain age, however, and upon his return to Earth the traveling twin is just a bit too old for it to work. He thus becomes the last person to die of old age! In this tale, the details of the traveling twin's trip are somewhat different from Bob's trip. Read "Twin Paradox" (you can also find the story in Forward's 1995 book *Indistinguishable from Magic*), and summarize how the traveling twin's trip is accomplished.

In the mystical 1920 novel *A Voyage to Arcturus*, by the Scottish writer David Lindsay (1876–1945), we read of a spaceship that travels to Arcturus (the brightest star in the constellation Boötes, 36 light years from Earth) in just 19 h of proper time. The technical details of the trip are not explained in the novel, so assume they are the same as in Bob's trip. That is, $2T' = 68,400$ s as measured by a clock on the spaceship. The distance traveled in this time is

$$2\frac{c\left\{\sqrt{a^2T^2+c^2}-c\right\}}{a}$$

(continued)

where *c* is the speed of light, *a* is the constant acceleration/deceleration of the rocket (as measured on the spaceship), and *T* is how long an *Earth*-based clock says the trip takes. Use this formula, and the one relating *T* and T' in the text, to calculate

1. The value of the constant acceleration/deceleration, *a* (does the result seem reasonable to you?) and
2. The value of *T* (the length of time that passes on Earth as 19 h pass on the spaceship).

You don't have to discuss general relativity to encounter tensors of the second rank (as is the metric tensor). Electrical engineers run into such a thing, for example, when studying the lowly Ohm's law! In a copper wire, that law says the current density (the vector **J**, in units of amperes per square meter) at any point is related to the electric field (the vector **E**, in units of volts per meter) at that point by the *scalar* σ as follows: $\mathbf{J} = \sigma\mathbf{E}$, where σ (called the *conductivity*) is a single number. This says, in rectangular coordinates, that the x-component of **J** depends *only* on the x-component of **E**, and similarly for the y-component and z-components of **J** and **E**. More generally, however, each component of **J** depends on *all* of the components of **E** (as in certain crystalline structures), and so we have the equations

$$\begin{aligned} J_x &= \sigma_{11}E_x + \sigma_{12}E_y + \sigma_{13}E_z \\ J_y &= \sigma_{21}E_x + \sigma_{22}E_y + \sigma_{23}E_z \\ J_z &= \sigma_{31}E_x + \sigma_{32}E_y + \sigma_{33}E_z \end{aligned}$$

or, in matrix form

$$\mathbf{J} = \begin{bmatrix} J_x \\ J_y \\ J_z \end{bmatrix} = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{bmatrix} \begin{bmatrix} E_x \\ E_y \\ E_z \end{bmatrix} = \boldsymbol{\sigma}E.$$

So **J** is now related to **E** by $\boldsymbol{\sigma}$, a 3 × 3 *matrix* (9 numbers, instead of just 1). The matrix $\boldsymbol{\sigma}$ is, in fact, a tensor of rank 2. This tensor is in the three-dimensional space of the copper wire, while the 4 × 4 metric tensor matrix is in a four-dimensional spacetime, but both are tensors of rank 2. The number of numbers in a tensor of rank n, in a space of dimension d, is d^n. In general relativity, tensors of higher rank than 2 are required. For example, the

(continued)

curvature tensor has rank 4, and so in a four-dimensional spacetime it is described by $4^4 = 256$ numbers. This goes a long way in explaining why, in general relativity, computing often involves a *lot* of arithmetic! The primary characteristic of tensors of any rank is that they are invariant under a change in coordinate systems (choosing a coordinate system is an arbitrary matter, made mostly for human convenience, about which Nature is indifferent). Read more about tensors, and write an essay on how they behave under a change in coordinates. A good place to start, at the level of this book, is Lillian Lieber's *The Einstein Theory of Relativity: a trip to the fourth dimension*, Paul Dry Books 2008 (an updated version of the original 1945 book).

Chapter 4
Philosophers, Physicists, and the Time Travel Paradoxes

> *"He felt the intellectual desperation of any honest philosopher. He knew that he had about as much chance of understanding such problems as a collie has of understanding how dog food gets into cans."*[1]

4.1 Paradoxes and Their First Appearance in Science Fiction

> "There's a lot we don't know about time travel. How do you expect logic to hold when paradoxes hold, too?" "Does that mean you don't know?" "Yes."[2]

More than 30 years ago Quentin Smith, a philosopher who believes in a finite length to the past, wrote a refutation to those who believe in an infinite past and, while that paper[3] has nothing to do with the paradoxes of time travel, in the course of presenting his reasoning he included the following curious passage:

> "Why does the sun arise in the morning and not at some other time? Why do the hands of a properly functioning clock point to 12:00 at noon and midnight and not at other times? Why does the death of a person occur at a later time than his birth? The answer in all these cases is: Because by the very nature of these events they could not occur at other times. It belongs to the very nature of the sun's rising that it occur in the morning and not in the afternoon or evening. It belongs to the very nature of a properly functioning clock to point to 12:00 at noon and midnight and not at other times. And it belongs to the very nature of death to occur at a time later than a person's birth."

But what of a time traveler born in 1980 who, in 2018, enters her time machine, pushes a few buttons, and then boldly steps out into the Cretaceous period seventy million years earlier—and is promptly eaten for lunch by a passing *Tyrannosaurus*

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[1] A time traveler admits (to himself) how perplexed he is by paradoxes in Robert Heinlein's classic tale "By His Bootstraps," *Astounding Science Fiction*, October 1941.

[2] Excerpt from a conversation between two paradox-puzzled time travelers in Larry Niven's story "Bird in the Hand," *The Magazine of Fantasy & Science Fiction*, October 1970.

[3] Q. Smith, "Kant and the Beginning of the World," *New Scholasticism*, Summer 1985, pp. 339–346.

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P.J. Nahin, *Time Machine Tales*, Science and Fiction,
DOI 10.1007/978-3-319-48864-6_4

rex? Perhaps Smith himself would say that there is no contradiction between this and his third claim because, in the time traveler's *proper* time, her spectacular death does indeed come after her birth. For many, however, for a time traveler to die before her mother is born *is* a paradox, plain and simple, say what you will about proper time.

One science fiction view of time travel paradoxes is that nature would be so disrupted by them that, should one occur, the universe would be torn apart. In one story, for example, a paradox is on the verge of happening through the use of a Tipler-cylinder time machine (mentioned back in Chap. 1, and which we'll discuss in more detail in the next chapter). In response to this 'threat to common sense,' the universe 'decides' to avoid the paradox by simply eliminating the perpetrators via a local nova![4] Niven wasn't the first to use this idea. A famous story[5] by L. Sprague de Camp (1907–2000), written two decades before, had already put forth the suggestion that nature will take all required corrective action to avoid paradoxes.

In De Camp's tale we read of two big-game hunter guides who use "Professor Prochuska's time machine at Washington University"—built with the aid of a "cool thirty million" dollar grant from the Rockefeller Foundation—to operate a safari-for-hire business that transports hunters back to the late Mesozoic era. When a disgruntled client tries to go back to the day *before* a previous trip to shoot the guides (who had displeased him, or rather *would* displease him the next day), we learn just how nasty De Camp thought Mother Nature would be to avoid a paradox. (After all, the guides had *not been* shot during the safari, so they *could not be* shot.[6]): "The instant James started [to ambush the guides] the space-time forces snapped him forward to the present to prevent a paradox. And the violence of the passage practically tore him to bits [making his body look] as though it had been pulverized and every blood vessel burst, so it was hardly more than a slimy mass of pink protoplasm."

And even earlier we have a famous tale[7] that was discussed in Chap. 1, by Fredric Brown (1906–1972), a master of the special category of science fiction called the "short-short," in which everything happens in 500 words or less. As you might expect, the oddities of time travel were natural attractions for Brown's quirky talent. You'll recall that in this story the inventor of the first time machine demonstrates it to two colleagues by sending a brass cube 5 min into the future. After being placed in the machine, the cube vanishes and then 5 min later reappears. No paradoxes with that—it is a trip into the *past* that has the potential for deadly repercussions. We learn just how deadly when the inventor next declares that at three o'clock he will again place the cube in the time machine but, until then, he will hold the cube in his hand. Thus, he says, at 5 min before three the cube will vanish from his hand and immediately appear in the time machine because 5 min after that, at three o'clock, he will send it 5 min into the past. And indeed, at 5 min before three the cube does simultaneously vanish from his hand and appear in the time machine. Then, slightly before three, as the three men stand pondering what has happened, one of the observers asks what will happen if the inventor does *not* send the cube back at three o'clock? "Wouldn't there be a paradox of some sort involved?" he wonders.[8] His curiosity aroused, the inventor can't resist the experiment—and the universe promptly vanishes.

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[4] L. Niven, "Rotating Cylinders and the Possibility of Global Causality Violation," *Analog Science Fiction*, August 1977. Niven took this title from a physics paper with that title, authored by Tipler, that had appeared three years earlier in *Physical Review D* (April 15, 1974, pp. 2203–2206).

[5] L. Sprague de Camp, "A Gun for Dinosaur," *Galaxy Science Fiction*, March 1956.

[6] This is a statement of the belief that the past cannot be changed, an idea we will examine later in this chapter.

[7] Look back at note 93 in Chap. 1.

Time travel, of course, is full of potential paradoxes. A paradox, according to the usual dictionary definition, is something that appears to contain contradictory or incompatible parts, thus reducing the whole to seeming nonsense. And yet, truth is also evident in the whole. The history of science and mathematics has left a long trail of paradoxes, and those that involve time travel are merely among the most recent. Not all of the puzzles of time travel involve physics or logic, however. As one philosopher observed, "Doubtless time travel will raise a host of legal difficulties, e.g., should a time traveler who punches his younger self (or vice versa) be charged with assault? Should the time traveler who murders someone and then flees into the past for sanctuary be tried in the past for his crime committed in the future? If he marries in the past can he be tried for bigamy even though his other wife will not be born for almost 5000 years? Etc., etc. I Ieave such questions for lawyers and writers of ethics textbooks to solve."[9]

One way early science fiction writers had of responding to the puzzle of time travel paradoxes was to just give up and to concede that the logical puzzles are overwhelming. In one tale, for example, the inventor of the Chronoscope (a gadget that can only *view* the past) explains, "There is no time travel machine. Such a thing is a logical impossibility, treated seriously only by half-cracked writers of fantasy. Such a machine would lead at once into a hopeless paradox."[10] Equally concerned about time travel paradoxes was the pulp science fiction time traveler who told his partner, just before their first trip in time, that "I'm not sure any more about getting back. There're some unpredictable terms in the time-travel equation—paradoxes. Maybe we *won't* get back."[11]

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[8] This is what is called a *bilking paradox*, and such paradoxes will be discussed later in this chapter. Brown gave this story a lot of thought. At one point in the tale one of the colleagues, puzzled by how the inventor will be able to place the cube into the time machine at three if it has already vanished from his hand and appeared in the machine, asks "How can you place it there, then?" Replies the inventor, "It will, as my hand approaches, vanish from the [machine] and appear in my hand to be placed there."

[9] L. Dwyer, "Time Travel and Some Alleged Logical Asymmetries Between Past and Future," *Canadian Journal of Philosophy*, March 1978, pp. 15–38.

[10] M. Jameson, "Dead End," *Thrilling Wonder Stories*, March 1941.

[11] E. Binder, "The Time Cheaters," *Thrilling Wonder Stories*, March 1940.

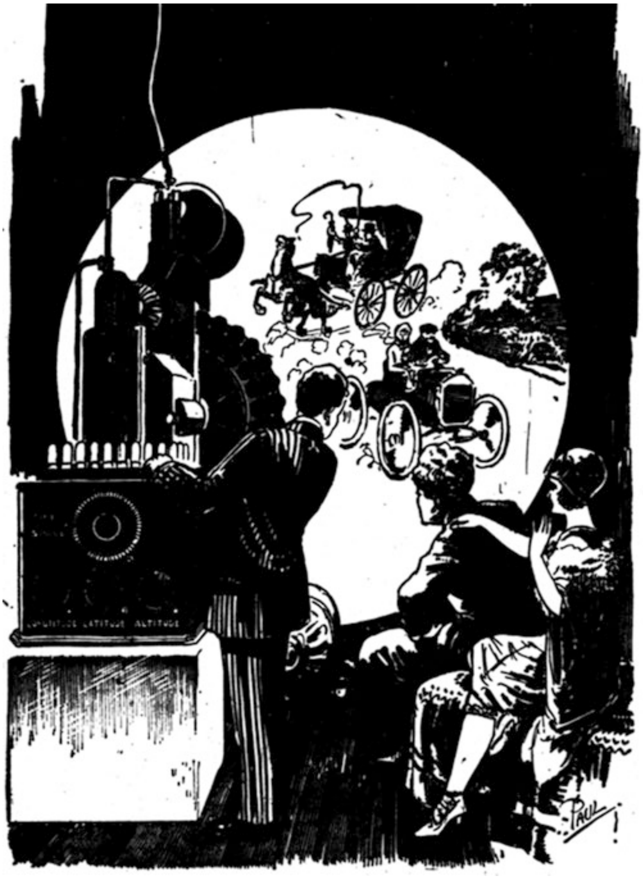

Fig. 4.1 One way pulp science fiction avoided paradoxes was to use a ‘time viewer’ (like the chronoscope in “Dead End”) as in “The Time Eliminator” (*Amazing Stories*, December 1926). This illustration from the story (authored by somebody who used only the initials K.A.W.) by Frank R. Paul (©1926 by Experimenter Publishing Co.) shows the inventor demonstrating his gadget to his future wife and father-in-law. Able to look back in time, the screen is displaying scenes from the older man’s courtship of his wife, decades in the past. Reprinted by permission of the Ackerman Science Fiction Agency, 2495 Glendower Ave., Hollywood, CA 90027 for the Estate

But are there *really* paradoxes? Or is it true, as the extraordinary boy-prodigy who invented a time machine exclaimed (when his teacher asserted that some questions could never be answered because “Nature is full of paradoxes”), “Ah, Professor, what nonsense! Nature is harmonious; it is we who bring the paradoxes into it.”[12] Saying the same are two physicists, in a paper on the circular orbits of photons around black holes: “There are no paradoxes in physics, but only in our attempts to understand physical ideas by using inadequate reasoning or false intuition."[13] And as the time traveler in an early pulp story[14] casually declares to a friend, after an astonishing adventure in the year A.D. 1,001,930, "Paradoxical? My dear fellow, the Einstein Theory is full of apparent paradoxes, yet to him who understands it there is no inconsistency whatever. Give me another cigarette, will you, Frank?"

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[12] V. Grigoriev, “Vanya,” in *Last Door to Aiya* (M. Ginsburg, editor), S. G. Phillips 1968.

It is in *Amazing Stories* that we find the first non-fictional speculations about time travel in a pulp magazine—and certainly long before any *physics* journal would touch the subject! Publisher and editor Hugo Gernsback started those speculations by reprinting Wells' *Time Machine*, which in turn sparked a fair number of readers' letters that were printed in the magazine's "Discussions" section. Typical of the less interesting is the following comment from a letter in the July 1927 issue: "In the 'Time Machine' I found something amiss. How could one travel to the future in a machine when the beings of the future have not yet materialized?" (We answered that question in the previous chapter with the twin paradox.) Far more interesting was this letter, in the same issue:

> "How about this 'Time Machine'? Let's suppose our inventor starts a 'Time Voyage' backward to about A.D. 1900, at which time he was a schoolboy . . . His watch ticks forward although the clock on the laboratory wall goes backward. Now we are in June 1900, and he stops the machine, gets out and attends the graduating exercises of the class of 1900 of which he was a member. Will there be another 'he' on the stage? Of course, because he *did* graduate in 1900 . . . Should he go up and shake hands with this 'alter ego'? Will there be two physically distinct but characteristically identical persons? Alas! No! He can't go up and shake hands with himself because . . . this voyage back through time only duplicates actual past conditions and in 1900 this strange 'other he' did *not* appear suddenly in quaint ultra-new fashions and congratulate the graduate. How could they both be wearing the same watch they got from Aunt Lucy on their seventh birthday, the same watch in two different places at the same time. Boy! Page Einstein! No, he cannot be there because he wasn't there in 1900 (except in the person of the graduate) . . . The journey backward must cease on the year of his birth. If he could pass that year it would certainly be an effect before a cause . . . Suppose for instance in the graduating exercise above, the inventor should decide to shoot his former self . . . He couldn't do it because if he did the inventor would have been cut off before he began to invent and he would never have gotten around to make the voyage, thus rendering it impossible for him to be there taking a shot at himself, so that as a matter of fact he *would* be there and *could* take a shot—help, help, I'm on a vicious circle merry-go-round . . . Now as to trips into the future, I could probably think up some humorous adventures wherein [the inventor] digs up his own skeleton and finds by the process of actual examination that he must expect to have his leg amputated because the skeleton presents positive proof that this was done."[15]

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[13] M. A. Abramowicz and J. P. Lasota, "On Traveling Round Without Feeling It and Uncurving Curves," *American Journal of Physics*, October 1986, pp. 936–939.

[14] F. J. Bridge, "Via the Time Accelerator," *Amazing Stories*, January 1931.

[15] This story idea (the letter was signed only with the initials T.J.D.) may well have been the inspiration for R. Rocklynne, "Time Wants a Skeleton," *Astounding Science Fiction*, June 1941. Not all fans agreed with T.J.D. A few years later, for example, a teenager named P. Schuyler Miller (1912–1974), who would author several time travel classics himself, wrote a letter to the editor of *Astounding Stories* (June 1931) stating "there is nothing in physics . . . to prevent yourself from

All of the ingenious puzzles in this letter intrigued Gernsback, and may have, in fact, been the cause of his featuring a new, original time machine story[16] in the same issue. It was the tale of a scientist who transports an entire ship at sea 14,000 years back in time and causes it to hover over lost Atlantis! That story provoked a sharp letter from a reader who claimed its logic had a fatal flaw: the story's author indicated that the Atlantians observed the time travelers when, 'of course' (asserted the reader), the time travelers must actually have been invisible. The reader explained his reasoning as follows, beginning by defining A as one of the Atlantians.

> "Now A lived his life, thousands of years ago, and died. All right, now let us pass on in time 14,000 years. Now, back we come in time when A is again living his life. Lo and behold, this time A sees before he dies a strange phenomenon in the sky! He sees the shipload of people observing him. And yet these people are necessarily observing him during his one and only lifetime, wherein he certainly did not, could not, have observed them."

Gernsback printed this letter in his September 1927 editorial "The Mystery of Time," and concluded by saying "I do . . . agree . . . that the inhabitants of Atlantis would probably not have seen the . . . travelers in time." Other readers felt this way, too, because after Gernsback published yet another time machine tale[17] in 1927, the same invisibility argument appeared again in the magazine's "Discussions" column.

Two years later an amateurishly written tale[18] appeared in which a man travels in time from 1928 to 2930 with the aid of an "astounding machine based on advanced electro-physics and the non-Euclidean theory of hyperspace." The purpose of that story was two-fold: to present several of the classic paradoxes of time travel, and then to make the claim that although the simple minds of twentieth-century people cannot understand the explanations of the paradoxes (possibly explaining why the author offers none!), the paradoxes are all trivial to the scientists of the thirtieth century. Despite this shortcoming (as well as some pretty awful dialog) the story nonetheless still managed to entertain readers with the sheer mystery of the paradoxes. Letters poured into the magazine from young fans, all demanding more time travel fiction.

So, that same year Gernsback responded with a story[19] that plays with the question of the role of time travelers in the past. (That question was clearly 'in

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going into the past . . . and shaking hands with yourself or killing yourself." That did, however, provoke the following harsh reply from another, more skeptical reader (in the December 1933 issue): "P. S. Miller once wrote that time traveling is not incompatible with any laws of physics . . . 'he don't know from nothing.'"

[16] C. B. White, "The Lost Continent," *Amazing Stories*, July 1927.

[17] F. Flagg, "The Machine Man of Ardathia," *Amazing Stories*, November 1927.

[18] C. Cloukey, "Paradox," *Amazing Stories Quarterly*, Summer 1929.

[19] H. F. Kirkham, "The Time Oscillator," *Science Wonder Stories*, December 1929.

the air,' as Gernsback's old magazine *Amazing*[20] simultaneously published a story[21] addressing this same puzzle of time travel.) Could time travelers actually participate in events ("mix into the affairs of the period," in Gernsback's words), or would they just be unseen observers? This question, obviously inspired by the earlier discussion in *Amazing Stories*, intrigued Gernsback as much as it did his readers and so, along with Kirkham's story, he printed a challenge titled "The Question of Time-Traveling" (see note 18 in the Introduction):

> "In presenting this story to our readers, we do so with an idea of bringing on a discussion as to time traveling in general. The question in brief is as follows: Can a time traveler, going back in time—whether ten years or ten million years—partake in the life of that time and mingle in with its people; or must he remain suspended in his own time-dimension, a spectator who merely looks on but is powerless to do more? Interesting problems would seem to arise, of which only one need be mentioned: Suppose I can travel back into time, let me say 200 years; and I visit the homestead of my great great great grandfather, and am able to take part in the life of his time. I am thus enabled to shoot him, while he is still a young man and as yet unmarried. From this it will be noted that I could have prevented my own birth; because the line of propagation would have ceased right there. Consequently, it would seem that the idea of time traveling into a past where the time traveler can freely participate in activities of a former age, becomes an absurdity. The editor wishes to receive letters from our readers on this point: the best of which will be published in a special section."

Gernsback's challenge did not go unnoticed and, over the next year or so, he published a large number of reader responses in the magazine's letters column.

Indeed, a few months after issuing the challenge, in his introduction to another time travel tale,[22] Gernsback wrote that ever since the publication of Kirkham's tale "there has been a great controversy among our readers as to the possibility of time flying and the conditions under which it may be done." Most of those letters are interesting if not particularly profound, with one exception. That was a letter written by a 14 year old boy in San Francisco, and its appearance in the February 1931 issue of *Science Wonder* may well have served as the inspiration for several of the classic time travel tales published during the next 20 years:

> "Some time ago you asked us (the readers) what our opinions on time traveling were. Although a bit late, I am now going to voice four opinions . . .
>
> (1) Now, in the first place if time traveling were a possibility there would be no need for some scientist getting a headache trying to invent an instrument or 'Time-Machine' to 'go back and kill grandpa' (in answer to the age-old argument of preventing your birth by killing your grandparents I would say: 'who the heck would want to kill his grandpa or gandma!'[23]) I figure it out thusly: A man takes a time machine, and travels into the

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[20] By this time Gernsback had lost control of *Amazing*, and *Science Wonder* was his come-back as a publisher of pulp 'scientifiction.'

[21] E. L. Rementer, "The Time Deflector," *Amazing Stories*, December 1929. Gernsback may well have been the editor, before he lost *Amazing*, who bought this story, and the magazine's new management simply used what remained in inventory.

[22] F. Flagg, "An Adventure in Time," *Science Wonder Stories*, April 1930.

[23] Look back at note 26 in "Some First Words."

> future from where he sends it (under automatic control) to the past so that he may find it and travel into the future and send it back to himself again. Hence the time machine was never invented, but!—from whence did the machine *come*?
>
> (2) Another impossibility that might result could be: A man travels a few years into the future and sees himself killed in some unpleasant manner,—so—after returning to his correct time he commits suicide in order to avert death in the more terrible way which he was destined to. Therefore how could he have seen himself killed in an entirely different manner than really was the case?
>
> (3) Another thing that might corrupt the laws of nature would be to: Travel into the future; find out how some ingenious invention of the time worked; return to your right time; build a machine, or whatever it may be, similar to the one you had recently learned the workings of; and use it until the time you saw it arrives, and then if your past self saw it as you did, he would take it and claim it to be an invention of his (your) own, as you did. Then—who really *did* invent the consarn thing?
>
> (4) Here's the last knock on time traveling: What if a man were to travel back a few years and marry his mother, thereby resulting in his being his own 'father'?"
>
> Jim H. Nicholson

Gernsback's reply, immediately following this letter, was favorable, opening with "Young Mr. Nicholson does present some of the more humorous [?] aspects of time traveling. Logically we are compelled to admit that he is right—that if people could go back into the past or into the future and partake of the life in those periods, they could disrupt the normal course of events."[24] Nicholson's letter *is* ingenious, and it anticipated the central ideas of a number of science fiction tales yet to be written.[25] However, as you'll see as you read the rest of this chapter, contrary to Gernsback's view Nicholson's comments are *not* logically correct.[26]

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[24] Despite these words, Gernsback apparently hadn't given up entirely on the 'invisibility of time travelers' view, as he had only a few months earlier published another such tale: R. A. Palmer, "The Time Ray of Jandra," *Wonder Stories*, June 1930. In this story (one either silly or hilarious, take your pick) a time traveler moves into the future by means of a 'time ray.' Unfortunately, the ray works differently on the various chemical elements, and not at all on either hydrogen or oxygen. Thus the time traveler—or at least *much* of him—and his machine do vanish into the future, but left behind are "several gallons of water spilled on the floor." (The human body is about 60 % H_2O.)

[25] For example, Nicholson's item (2) is a precise plot outline for L. Raphael, "The Man Who Saw Through Time," *Fantastic Adventures*, September 1941, and a version of item (4) is in Robert Heinlein's famous "All You Zombies—,“ *Magazine of Fantasy & Science Fiction*, March 1959.

[26] One cannot, however, fault the imaginative powers of James Nicholson (1916–1972). He eventually became President of American International Films, the company that made such science fiction 'classics' as *Attack of the Crab Monsters* (1957), the 1963 *X (The Man with the X-Ray Eyes)*, and *The Time Travelers* (1964).

4.2 Changing the Past and the Grandfather Paradox

> "I'm not kidding you at all Phil," Barney insisted. "I have produced a workable Time Machine, and I am going to use it to go back and kill my grandfather."[27]

As mentioned in "Some First Words," physicists and philosophers often have quite different approaches to time travel (see note 26 there again). A vivid illustration of that difference is found in a philosophical paper[28] that, after acknowledging the apparent restrictions of the grandfather paradox, turns its attention to a matter that almost surely is beyond the power of physics to study—namely, the nature of the *conversation* between a time traveler and his/her younger self. A physicist, on the other hand, views the restrictions as *the whole point*, because the central question that hovers over *any* discussion of time travel is that of 'changing the past.' As one science fiction fan summed it up in a letter to the editor of *Astounding Stories* (August 1931): "It is said that the past cannot be changed, and that any effort to do so would be useless. In my belief, no matter where or when a man goes in the past, if he appears in a year or day that has already gone by, *he is changing the past*. Then there should be no room for doubt: time traveling is impossible. It will never be done." And certainly killing your grandfather in the past (when he is still a baby) would qualify as a change to the past!

The idea of 'changing the past' occurred to the minds of philosophers long before it did in those of science fiction writers or physicists. Four centuries before Christ, the question had already been asked-and-answered by Aristotle. In his *Nicomachean Ethics*, in fact, we find him declaring that the Greek poet Agathon had known the answer a century earlier, and he quotes the poet as saying "Forever God lacks this one thing alone, To make a deed that has been done undone."

Agathon and Aristotle aside, some medieval theologians argued passionately that the past *could* be changed (but only by God). The eleventh-century Italian cleric Peter Damian (who became a Christian saint) is a famous exponent of that radical view.[29] Writing in his *De Omnipotentia Dei* ("On the Divine Omnipotence in Remaking What Has Been Destroyed and Undoing What Has Been Done"),[30] Damian made it clear that he believed nothing could withstand the power of God, not even the past. Ralph Waldo Emerson's poem "The Past" ("All is now secure and fast, Not the gods can shake the Past") would have been blasphemy for Damian. The following words from Damian testify to the strength of his commitment to a belief in the possibility of changing the past: "Just as we can duly say 'God was able to make it so [that] Rome, before it had been founded, should not have been founded,' in the same way we can equally and suitably say, 'God can make it so that Rome, even after it was founded, should not have been founded.'"[31]

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[27] The opening line to F. M. Busby, "A Gun for Grandfather," *Future Science Fiction*, September 1957.

[28] Jiri Benovsky, "Endurance and Time Travel," *Kriterion—Journal of Philosophy*, 2011, pp. 65–72.

[29] R. P. McArthur and M. P. Slattery, "Peter Damian and Undoing the Past," *Philosophical Studies*, February 1974, pp. 137–141; P. Remnant, "Peter Damian: Could God Change the Past?" *Canadian Journal of Philosophy*, June 1978, pp. 259–268; R. Gaskin, "Peter Damian on Divine Power and the Contingency of the Past," *The British Journal for the History of Philosophy*, September 1997, pp. 229–247.

Two centuries after Damian, Aquinas argued the contrary view, that changing the past is *not* within God's power. Whereas Damian felt it impossible to deny any act to God, Aquinas took the far more moderate position that part of God's law is that there be no contradictions in the world (this is, in fact, the modern view of time travel physicists) and that certainly God would be bound by his own law. As he wrote, "It is best to say that what involves contradiction cannot be done rather than that God cannot do it." In his *Paradise Lost*, John Milton's God is constrained even more: he is free to act or not, but if he does freely decide to act, it can only be to 'do right.' That might seem to preclude causing contradiction, as in changing the past, but perhaps not. Milton's contemporary, Thomas Hobbes, declared that there is no *a priori* standard of goodness, and thus (for Hobbes) there are no constraints on God's powers. For Hobbes, therefore, it would seem God could change the past. Theological changing of the past, as you might expect, leads to all sorts of mind-boggling puzzles. Because of such puzzles, theology would certainly be influenced by time travel, but just as certainly theological reasoning will not illuminate the puzzles of the time travel paradoxes.

The question of the immutability of past events is of special interest to theologians because it is directly related to the question of free will versus fatalism. That is, are humans the creators of the future, or are they mere fated puppets of destiny? One way theology gets involved with the issue of 'changing the past' is via what is called the *retroactive petitionary prayer*. (An 'ordinary' petitionary prayer, like the Lord's Prayer in Matthew 6 and Luke 11, asks for something in the present or the future.) Examples of retroactive prayers include that of the surgical patient who prays, just before an exploratory operation, for his tumor to be non-malignant, and that of the soldier's wife who prays that her husband was not among those killed in yesterday's battle. Such prayers are for a happy outcome to an event that is over and done with at the time of the prayer. One might accept the rationality of praying about the future ("Please, God, let me survive tomorrow's battle and I'll be good for the rest of my life") but are prayers about the past even sensible? (The three major monotheistic religions of the world—Christianity, Judaism, and Islam—say *yes*.)

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[30] This work is in the form of a letter to his friend Desiderius (who later became Pope Victor III), in which Damian rebutted Desiderius' defense of St. Jerome's claim that "while God can do all things, he cannot cause a virgin to be restored after she has fallen." Desiderius thought the reason God could not restore virgins is that he does not want to, to which Damian replied that this meant God is unable to do whatever he does not want to do, but this meant that God would then be less powerful than men, who are able to do things they don't want to do (such as go without food for a month). This is a good example of the dangers involved when getting into debates with theologians.

[31] The Argentinian writer Jorge Luis Borges (1899–1986) was so inspired by Damian's view that the past could be changed that he wrote a short story based on it (see "The Other Death," originally published in *The New Yorker*, November 2, 1968) and put a character in it named after Damian.

In an appendix titled "Special Providences" in his book Miracles, C. S. Lewis answers that question as follows:

> "When we are praying about the result, say, of a battle or a medical consultation, the thought will often cross our minds that (if only we knew it) the event is already decided one way or the other. I believe this to be no good reason for ceasing our prayers. The event certainly has been decided—in a sense it was decided 'before all worlds.' But one of the things taken into account in deciding it, and therefore one of the things that really causes it to happen, may be this very prayer that we are now offering. Thus, shocking as it may sound, I conclude that we can at noon become part causes of an event occurring at ten A.M. (Some scientists would find this easier than popular thought does.)"

Here we see Lewis, a prominent lay theologian, arguing for the present influencing (but not changing) the past. What can we make of that? Was Lewis arguing for backward causation, the close relative of time travel? I think perhaps so; the final two sentences in the above excerpt makes it plausible that he may have held that view. It is a view that does find much support in the block universe interpretation of Minkowskian spacetime. Lewis never mentions the block concept by name, but it is clear that he believed in the idea of God being able to see all of reality at once. Lewis believed, therefore, that God knows of a petitionary prayer before it is made; or, even stronger, if God is not a temporal being but rather is eternal and knows time 'all at once,' then God knows the prayer and the event being prayed about 'at the same time.'

Lewis did make it clear that he believed it is a sin to pray for something *known* not to have occurred—for example, to pray for the safety of someone known to have been killed yesterday. As he wrote, "The known event states God's will. It is psychologically impossible to pray for what we know to be unobtainable, and if it were possible, the prayer would sin against the duty of submission to God's known will." Taking a less judgmental position (but essentially agreeing with Lewis) were two philosophers who, writing of the battle of Waterloo, said "for one who knows the outcome of the battle more than a hundred and 50 years ago, [a retroactive petitionary] prayer is pointless and in that sense absurd. But a prayer prayed in ignorance of the outcome of the past event is not pointless in that way." Further, in support of backward causation, they also wrote that "to pray in 1980 that Napoleon lose at Waterloo" is logical because "why should your prayer not be efficacious in bringing about Napoleon's defeat?"[32] Disagreeing, however, was another philosopher who bluntly declared "A prayer for something to have happened is simply an absurdity, regardless of the utterer's knowledge or ignorance of how things went."[33]

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[32] E. Stump and N. Kretzmann, "Eternity," *Journal of Philosophy*, August 1981, pp. 429–458.

[33] P. Geach, *God and the Soul*, Routledge & Kegan Paul 1969.

There have been all sorts of opinions expressed through the ages in reaction to the idea of affecting the past via retroactive petitionary prayers,[34] and on the role of backward causation. The British philosopher Michael Dummett (1925–2011), in particular, discussed Lewis' concept of such prayers with great sympathy,[35] and backward causation allows one to both explain them as well as retaining free will. That is, it is not God's foreknowledge that causes our later actions (forcing our behavior and so turning us into automatons), but rather it is our later *freely-chosen* actions that causes God's foreknowledge! While such theological speculations are interesting, in the end they are simply positions of faith, about which mathematical physics has nothing to say.

Eventually, of course, others besides philosophers and theologians began to ponder the questions raised by 'changing the past.' In a January 1963 personal letter to the editor of *The Magazine of Fantasy and Science Fiction*, Robert Heinlein wrote[36] "Mark Twain invented the time-travel story; 6 years later H. G. Wells perfected it *and its paradoxes* [my emphasis]. Between them they left little for latecomers to do." How a man as widely read as was Heinlein, who had authored some of the best short time travel stories ever written, could have written such an erroneous sentence is a mystery to me. *A Connecticut Yankee in King Arthur's Court* and *The Time Machine*, certainly both works of genius, are *not* pioneers in paradox. And Heinlein's own contributions are proof enough that there was a lot left to do with time travel, well after 1900.

The very first story to be written that even hints at the particular time travel paradox of changing the past seems to be by the Unitarian minister Edward Everett Hale (1822–1909), best known today as the author of the 1863 story "The Man Without a Country." Hale wrote "Hands Off" in 1881, and published it anonymously in *Harper's New Monthly Magazine* with the express purpose of stirring up some theological debate (which apparently it didn't). He certainly had no idea that he would come to be recognized by literary scholars as a pioneer in the yet-to-be invented genre of science fiction.

Hale's story opens with the mysterious words "I was in another stage of existence. I was free from the limits of Time, and in new relations to space." These words are spoken by an unnamed narrator, who seems to have just died, and who finds himself, in his new 'form,' observing "some twenty or thirty thousand solar systems" while in the company of "a Mentor [probably an angel] so loving and patient." Under the guidance of this Mentor, in an attempt to 'improve' history, the narrator alters the Biblical account of Joseph and his imprisonment in Egypt. At first, subsequent history *is* better, but then humanity sinks into irreversible depravity. In the end the narrator watches the last handful of humans kill each other in a particularly symbolic place for the Christian world: “The last of these human brutes all lay stark dead on the one side and on the other side of the grim rock of Calvary!” There would be no Crucifixion and Resurrection for the salvation of humankind, which naturally greatly disturbs the narrator. But the Mentor calms him, saying “Do not be disturbed, you have done nothing.” It has, you see, just been an experimental world, an alternate Universe, and the narrator has learned the lesson of “Hands Off” the past.

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[34] A summary of those opinions can be found in G. Brown, "Praying About the Past," *Philosophical Quarterly*, January 1985, pp. 83–86. Debate continues on the retroactive prayer into the 21st century: see, for example, K. Timpe, "Prayers for the Past," September 2005, pp. 305–322, and T. J. Mawson, "Praying for Known Outcomes," March 2007, pp. 71–87, both in *Religious Studies*.

[35] M. Dummett, "Bringing About the Past," *Philosophical Review*, July 1964, pp. 338–359.

[36] Reprinted in the posthumously published *Grumbles from the Grave* (edited by Heinlein's widow, Virginia Heinlein), Del Rey 1990.

Hale’s story is a better Sunday sermon than it is a change-the-past time travel tale, and the device of experimenting on a not-really-real Earth is disappointing from a modern science fiction point of view. But Hale’s story almost certainly did have an immediate (if indirect) impact. There is no absolute proof, but with its appearance in a national magazine, it seems quite likely that “Hands Off” was read by Edward Page Mitchell (1852–1927), an editor on a daily New York newspaper, the *Sun*. I write that because, just 6 months after Hale’s story appeared, the *Sun*, in its issue of September 18, 1881, printed Mitchell’s “The Clock That Went Backward.” That tale, published anonymously, used a machine (the clock) for time travel,[37] as well as incorporated the idea of time travel involving paradoxes. The story predates Wells’ *Time Machine* by 14 years, and Wells’ novel did not include a paradoxical element.[38]

There are, however, two *hints* at paradox in Wells’ novel. In the opening, during the dinner party at which the Time Traveller tries to convince his friends of the possibility of a time machine, one of them observes that “It would be remarkably convenient for the historian. One might travel back and verify the accepted account of the Battle of Hastings, for instance.” To that another guest replies, “Don’t you think you would attract attention? Our ancestors had no great tolerance for anachronisms.” The second hint occurs when the incredulous Editor, astonished at the disheveled appearance of the Time Traveller upon his return from the future, wonders “What *was* this time traveling? A man couldn’t cover himself with dust by rolling in a paradox, could he?”

What might happen if time travelers *could* change the past? This question is nicely illustrated in one novel[39] where a time traveler finds himself stranded in the London of 1810. Despite his predicament, he takes solace with “I could invent things—the light bulb, the internal combustion engine, . . ., flush toilets . . . “ But then he thinks better of doing any of that: “no, better not to do anything to change the course of recorded history—such tampering might cancel the trip I got here by, or even the circumstances under which my mother and father met. I'll have to be careful."

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[37] See Jan Pinkerton, “Backward Time Travel, Alternate Universes, and Edward Everett Hale,” *Extrapolation*, Summer 1979, pp. 168–175. The time machine in Mitchell’s story is more fantasy than anything else. It is simply stated that if the clock runs backward, then it travels backward in time.

[38] Wells’ failure to use paradox in his famous novel surprises most modern readers and, in fact, one of the first reviewers specifically criticized him for this lapse. See the 1895 review of *The Time Machine* that appeared in *Pall Mall Magazine*, by Israel Zangwill, reprinted in Parrinder’s book (note 1 in the Introduction).

[39] T. Powers, *The Anubis Gates*, Ace 1983, a work with equal shares of physics and magic.

This is really just a more recent treatment of the change-the-past paradox that was already well established in early science fiction. In a story[40] published a half-century before, we find the paradox explicitly stated, along with a possible solution that is similar to the kind of explanations that have appeared in the philosophical literature[41]:

> "Suppose you landed in your own past?," queried Eric."
>
> Dow smiled.
>
> "The eternal question," he said. "The inevitable objection to the very idea of time travel. Well, you never did, did you? You know it never happened!"

But, suppose you *could* land in your own past. What then?

One famous story[42] that considered this question *embraced* the idea of changing the past. In it a client on a dinosaur hunting safari fails to follow the instructions of his guide to do *nothing* in the past except shoot a dinosaur that is about to dies for "other reasons" anyway—alas, he accidently kills a butterfly. This results in enormous changes in history, as indicated by the 'before' and 'after' versions of the time machine company's ad:

> **before**
> TIME SAFARI, INC.
> SAFARIS TO ANY YEAR IN THE PAST.
> YOU NAME THE ANIMAL.
> WE TAKE YOU THERE.
> YOU SHOOT IT.
> **after**
> TYME SEFARI INC.
> SEFARIS TU ANY YEER EN THE PAST.
> YU NAIM THE ANIMALL.
> WE TAEK YU THAIR.
> YU SHOOT ITT.

Bradbury describes the death of the butterfly as having started the knocking "down [of] a line of small dominoes and then big dominoes and then gigantic dominoes, all down the years across Time." This is, of course, a somewhat unconvincing argument. After all, previous dinosaurs, when shot, must have fallen to the ground and flattened a lot of butterflies! With such threats for every decision, no matter how seemingly innocent, hanging over the head of a time traveler, it would take a brave soul to do much more, while in the past, than just stand still and breathe.

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[40] C. L. Moore, "Tryst in Time," *Astounding Stories*, December 1936.

[41] See, for example, P. J. Riggs, "The Principal Paradox of Time Travel," *Ratio*, April 1997, pp. 48–64. The 'principal paradox' is that time travel is inherently contradictory because it permits the possibility of traveling to an earlier time to prevent the trip. The grandfather paradox is a special case of this. For more discussion, see T. Chambers, "Time Travel: How Not to Defuse the Principal Paradox," *Ratio*, September 1999, pp. 296–301.

[42] R. Bradbury, "A Sound of Thunder," *Collier's*, June 1952.

Equally grim is the tale[43] that takes a different view by denying the past can be changed. There we read of a doomed hero who journeys back to 1865 to save Lincoln from Booth, but his "time-distorter" is quickly taken away from him by suspicious guards. Its internal workings tick, you see, and they think he is an assassin with a clock bomb. They destroy it, haul him away to his fate, and Lincoln goes on to meet his. In the same spirit (but even more shocking) is the result of a time traveler's intentional tampering with the past in David Gerrold's 1973 novel *The Man Who Folded Himself*. That traveler experiments with "making things different" and, in his words, "Once I created a world where Jesus Christ . . . went out into the desert to fast and never came back. The twentieth century I returned to was—different. Alien."

With such a stupendous power to alter reality, assuming the past *can* be changed, perhaps one might imagine prospective time travelers to the past being required to first file Historical Impact Statements![44] Not all would receive permission. In one classic tale,[45] for example, we read of a time traveler who takes a rifle and 5000 rounds of explosive bullets back to Golgotha. His intention—to be history's first Rambo by picking off any Roman soldier who gets within a hundred yards of Jesus! As outrageous as this concept is (but who among those now reading this won't admit to at least a momentary thrill at the idea and, perhaps, even a secret willingness to do it themselves, if they could), it isn't the story's peak. That comes when the reader is reminded that it was Christ's *desire* to die on the Cross, that he *had* to die for our sins; to prevent that from happening would change all of history for the last 2000 years. What, then, should the time traveler's colleagues do when they discover his plan? Should they stop him or not? What might happen if they do interfere? Of course, if the time traveler is 'now' in the past, isn't it already 'too late' to stop him? Oh, the conundrums of time travel and changing the past!

The classic change-the-past paradox is, of course, the grandfather paradox. A famous story[46] pushed this paradox to its logical limit to illustrate its supposed dangers. Having traveled to Greece in the fifth century B.C., the traveler suddenly realizes (with just a little exaggeration): "Ninety-five generations back you'd have more grandfathers than there are people on Earth, or stars in the Galaxy! You're kin to everyone . . . You as much as take a poke at anyone, and the odds are you won't even get to be a twinkle in your daddy's eye."

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[43] R. Silverberg, "The Assassin," *Imaginative Tales*, July 1957.

[44] See, for example, the novel by C. L. Harness, *Krono*, Franklin Watts 1988.

[45] A. Porges, "The Rescuer," *Analog Science Fiction*, July 1962.

[46] P. S. Miller, "Status Quondam," *New Tales of Space and Time*, November 1951. This is the Miller I mentioned back in note 15.

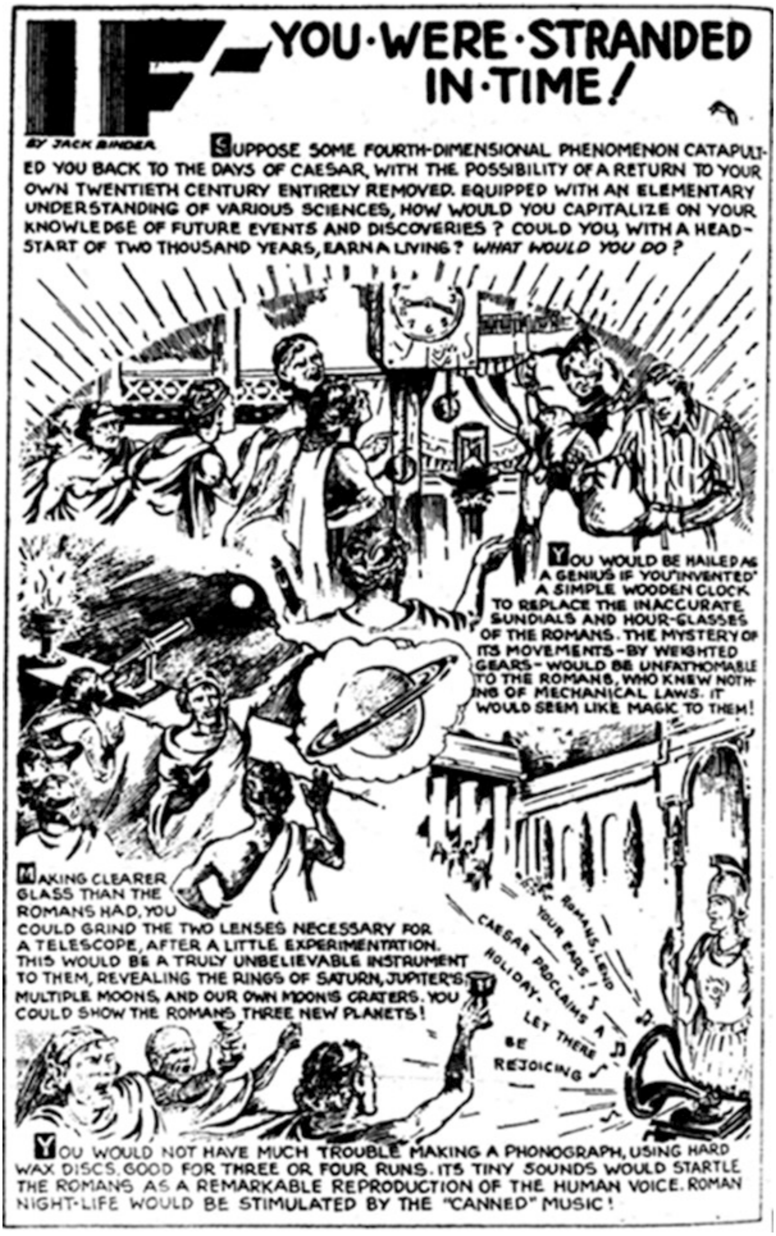

IF—YOU·WERE·STRANDED IN·TIME!

BY JACK BINDER

SUPPOSE SOME FOURTH-DIMENSIONAL PHENOMENON CATAPULTED YOU BACK TO THE DAYS OF CAESAR, WITH THE POSSIBILITY OF A RETURN TO YOUR OWN TWENTIETH CENTURY ENTIRELY REMOVED. EQUIPPED WITH AN ELEMENTARY UNDERSTANDING OF VARIOUS SCIENCES, HOW WOULD YOU CAPITALIZE ON YOUR KNOWLEDGE OF FUTURE EVENTS AND DISCOVERIES? COULD YOU, WITH A HEAD-START OF TWO THOUSAND YEARS, EARN A LIVING? *WHAT WOULD YOU DO?*

YOU WOULD BE HAILED AS A GENIUS IF YOU "INVENTED" A SIMPLE WOODEN CLOCK TO REPLACE THE INACCURATE SUNDIALS AND HOUR-GLASSES OF THE ROMANS. THE MYSTERY OF ITS MOVEMENTS—BY WEIGHTED GEARS—WOULD BE UNFATHOMABLE TO THE ROMANS, WHO KNEW NOTHING OF MECHANICAL LAWS. IT WOULD SEEM LIKE MAGIC TO THEM!

MAKING CLEARER GLASS THAN THE ROMANS HAD, YOU COULD GRIND THE TWO LENSES NECESSARY FOR A TELESCOPE, AFTER A LITTLE EXPERIMENTATION. THIS WOULD BE A TRULY UNBELIEVABLE INSTRUMENT TO THEM, REVEALING THE RINGS OF SATURN, JUPITER'S MULTIPLE MOONS, AND OUR OWN MOON'S CRATERS. YOU COULD SHOW THE ROMANS THREE NEW PLANETS!

YOU WOULD NOT HAVE MUCH TROUBLE MAKING A PHONOGRAPH, USING HARD WAX DISCS, GOOD FOR THREE OR FOUR RUNS. ITS TINY SOUNDS WOULD STARTLE THE ROMANS AS A REMARKABLE REPRODUCTION OF THE HUMAN VOICE. ROMAN NIGHT-LIFE WOULD BE STIMULATED BY THE "CANNED" MUSIC!

Fig. 4.2 Illustrator Jack Binder (1902–1986) was the author of a continuing series called "IF— . . ." in *Thrilling Wonder Stories*. In each issue, the ellipses would be replaced with some phrase such as "the Sun exploded!," "there was another ice age!," or "there was no friction!." The installment shown here (and in Fig. 4.3) appeared in December 1938 and asserted that the past could be changed by a time traveler

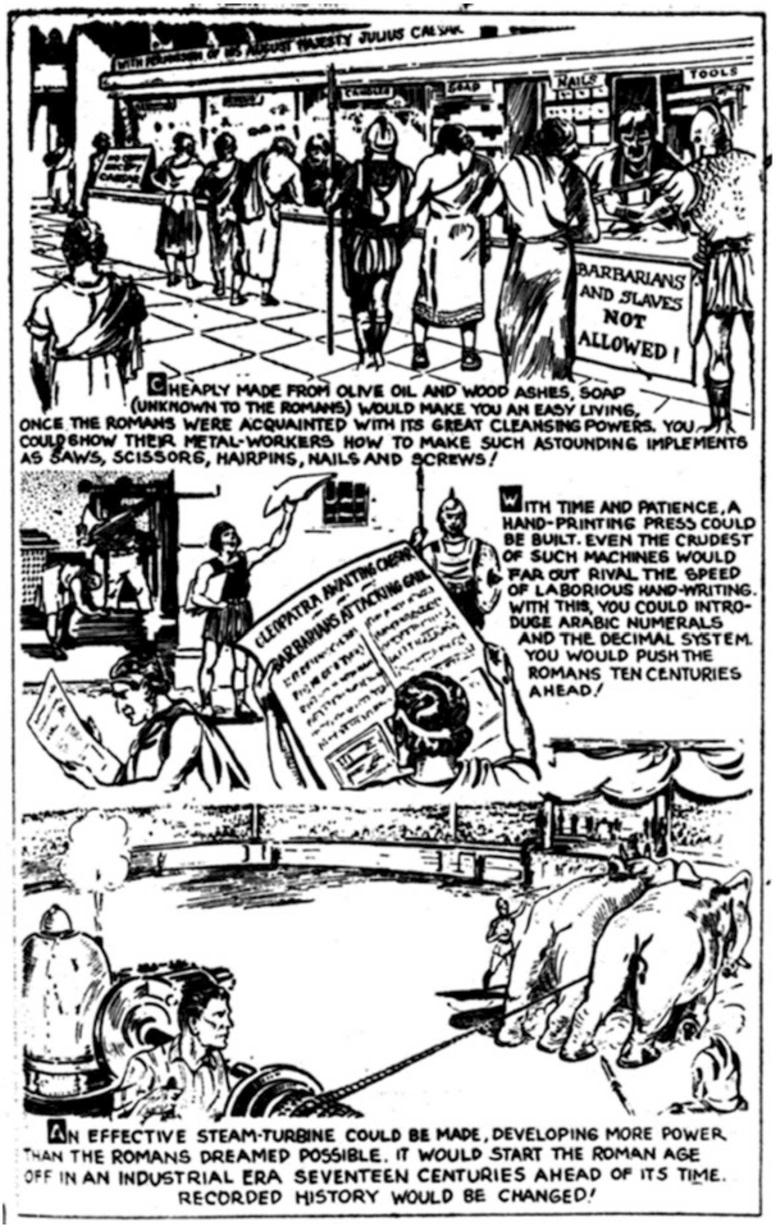
WITH PERMISSION OF HIS AUGUST MAJESTY JULIUS CAESAR
CANDLES
SOAP
NAILS
TOOLS
BARBARIANS AND SLAVES NOT ALLOWED!
CHEAPLY MADE FROM OLIVE OIL AND WOOD ASHES, SOAP (UNKNOWN TO THE ROMANS) WOULD MAKE YOU AN EASY LIVING, ONCE THE ROMANS WERE ACQUAINTED WITH ITS GREAT CLEANSING POWERS. YOU COULD SHOW THEIR METAL-WORKERS HOW TO MAKE SUCH ASTOUNDING IMPLEMENTS AS SAWS, SCISSORS, HAIRPINS, NAILS AND SCREWS!
CLEOPATRA AWAITING CAESAR
BARBARIANS ATTACKING GAUL
WITH TIME AND PATIENCE, A HAND-PRINTING PRESS COULD BE BUILT. EVEN THE CRUDEST OF SUCH MACHINES WOULD FAR OUT RIVAL THE SPEED OF LABORIOUS HAND-WRITING. WITH THIS, YOU COULD INTRODUCE ARABIC NUMERALS AND THE DECIMAL SYSTEM. YOU WOULD PUSH THE ROMANS TEN CENTURIES AHEAD!
AN EFFECTIVE STEAM-TURBINE COULD BE MADE, DEVELOPING MORE POWER THAN THE ROMANS DREAMED POSSIBLE. IT WOULD START THE ROMAN AGE OFF IN AN INDUSTRIAL ERA SEVENTEEN CENTURIES AHEAD OF ITS TIME. RECORDED HISTORY WOULD BE CHANGED!

Fig. 4.3 (Fig. 4.2 continued). Illustration for "IF—You Were Stranded in Time!" ©1938 by Better Publications, Inc.; Reprinted by permission of the Ackerman Science Fiction Agency, 2495 Glendower Ave., Hollywood, CA 90027 for the Estate

Even earlier than Miller's tale is an equally famous one[47] that illustrates the same point in a graphic way. In A.D. 452 a time traveler shoots and kills one of Attila's Huns (who would have been his great-grandfather many times over); the result is that 50,000 of the Hun's descendants vanish! So dramatic did the readers of this story find the concept that author repeated the idea the very next year.[48] Twenty years later another writer topped these tales by having a time traveler accidently kill the original 'intelligent baboon' in the ancient past, thereby wiping out the entire human species![49]

Science fiction writers have been as puzzled by the grandfather paradox[50] as have been nearly everybody else. As the inventor of the first time machine says in one tale,[51] "I have devised a method [for travel] into the distant past. The paradox is immediately pointed out—suppose [the time traveler] should kill an ancestor or otherwise change history? I do not claim to be able to explain how this apparent paradox is overcome in time travel; all I know is that time travel *is* possible. Undoubtedly, better minds than mine will one day resolve that paradox, but until then we shall continue to utilize time travel, paradox or not."

Some may feel it overly dramatic that the classic time travel paradox has such a murderous form, but that is its historical origin in science fiction (not in either physics or philosophy). We can find the grandfather paradox discussed as if already well-known in a letter to the editor at *Astounding Stories* (January 1933). The author of that letter wrote "Why pick on grandfather? It seems that the only way to prove that time travel is impossible is to cite a case of killing one's own grandfather. This incessant murdering of harmless ancestors must stop. Let's see some wide-awake fan make up some other method of disproving the theory." As we proceed, you'll see just how clever some of those who responded to that writer's plea have been but, even today, as the grandfather paradox stands revealed as a red herring, it is preeminent in most people's imaginations. If a solution to the grandfather paradox puzzle escaped an early science fiction writer, then he would generally just mysteriously mention it and then hasten on to other matters. For example, in one story[52] the following exchange between the stock pulp-fiction characters of a young hero and a brilliant old scientist occurs:

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[47] N. Schachner, "Ancestral Voices," *Astounding Stories*, December 1933.

[48] N. Schachner, "The Time Imposter," *Astounding Stories*, March 1934.

[49] C. Dye, "Time Goes to Now," *Science Fiction Quarterly*, May 1953.

[50] The 'paradox' is that, assuming you do arrive in the past with a working gun, why *can't* you kill your grandfather? After all, you *must* fail in that quest because otherwise you wouldn't be there from the future to even try. But *why* must you fail? It is, of course, not actually necessary to try to kill your grandfather to run into this paradoxical situation—just go back in time to any moment in the past and try to kill yourself! You won't succeed (if the past is unchangeable), but *why not*? (To argue 'because the past is unchangeable' is to beg the question. We need more insight than that.)

[51] M. Reynolds and F. Brown, "Dark Interlude," *Galaxy Science Fiction*, January 1951.

[52] C. South, "The Time Mirror," *Amazing Stories*, December 1942.

> "You mean that time travel really is possible? That men can be transported into the future or the past—?"
>
> The other held up a restraining hand. "Yes. Time travel *is* possible . . ."
>
> "But professor! Think of what you're saying! You're telling me that I could go back and murder my own grandfather. That I could prevent myself from being born—?"
>
> Again the elder man sighed. "I was afraid of this," he said. "I knew you could not understand." He hesitated. Then: "At any rate, take my word for it that time travel is possible. Also, I assure you that there are any number of perfectly sound theoretical and practical reasons why you never could hope to murder your grandparents."

We are, however, not told just what those reasons might be.

Even when all has been said about the impossibility of changing the past, and even when they are finally willing to concede that point, most people still cannot help wondering *why* the time traveler can't kill his grandfather. There the time traveler is, after all, just two feet away from the nasty young codger (I assume he is nasty to make the whole unpleasant business of murder as palatable as possible), with a perfectly functioning and well-oiled revolver in his hand, cocked and loaded with powerful, factory-fresh ammunition that even Dirty Harry would find excessive. What can possibly prevent the time traveler from simply raising his arm and doing the deed? Indeed, the artwork (reproduced at the end of the Introduction) accompanying one 1944 story shows this act in detail, including the smoking gun in the hand of the time traveler who has just taken a shot at grandpop. And if that still leaves open the remote possibility of an aiming error through nervousness, then why can't a suicidal time traveler just wrap his body in factory-fresh dynamite and blow-up granddad—along with himself and everything else within a hundred feet?

I'll argue in this book that killing your grandfather in the past, before he sets *you* in motion, is *logically* impossible. The laws of physics will then faithfully do their duty. No one will ever find an unfinished note in the empty laboratory of a missing traveler who, skeptical of the grandfather paradox, has written "To prove the falsity of the grandfather paradox, I will take my time machine back 50 years and kill my grandf. . .." Nor will any time traveler have to be concerned about the twist in one tale, which opens with the inventor of a time machine is showing the gadget to three friends. One of them later steals the machine to go back 60 years to kill his grandfather—and the story closes with a *near* repeat of the opening, with the inventor showing the gadget to *two* friends.[53]

Invoking logic in this way, in the context of time travel to the past, was discussed in the philosophical literature nearly half a century ago: "If we assume that it is impossible for [a time traveler to kill his younger self], some people are inclined to ask such questions as this: 'But how can the laws of logic prevent him from killing his younger self? Do they cause his finger to slip on the trigger or the bullet to fly apart in mid-air?' The implication of such questions is that the laws of logic cannot prevent such actions. But such questions are like asking: 'How do the laws of logic prevent the geometer from trisecting the angle or squaring the circle? Do they, for example, cause his ruler to slip as a crucial moment every time he tries it?'"[54].

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[53] F. Brown, "First Time Machine," *Honeymoon in Hell*, Bantam 1958.

A similar point was made later by another philosopher: "Surely it is not an impairment of 'freedom of action' ... that, e.g., you cannot push another person harder than he/she pushes you. Just as one would explain this is the case by reference to Newton's third law ('to every action there is an equal and opposite reaction'), one could explain the impossibility of [causing a paradox] by reference to the laws which imply such a impossibility. If this explanation is taken to be unsatisfactory, it would seem that one is saddled with a general problem concerning the reconciliation of physics and 'freedom,' and not with a specific argument against [paradoxes]."[55]

The grandfather paradox unquestionably nags at all students of time travel. As a character in one story declares, "The resolution of [the grandfather paradox] is the key to time,"[56] and some incorrectly believe it remains unresolved.[57] The paradox *is* undeniably troublesome: as one philosopher put it, the apparent possibility of a time traveler being able to do away with both his grandfather and himself gives "rise to such puzzles that we are forced to question its [time travel's] intelligibility."[58] In the next section we'll explore how to answer this concern.

4.3 Changing Versus Affecting the Past

> "The past—it's pretty damn solid, Phil. It's a little like a compost pile—fairly soft near the surface but packed hard further down, with all that Time piled on top of it."[59]
>
> —one 'explanation,' perhaps, for the unchangeability of the past

The common belief today, among physicists and philosophers alike, is that given any consistent description of reality it is simply impossible for a time traveler to kill himself as a baby. As one philosopher put it, "Autoinfanticide is *metaphysically impossible* [my emphasis]. This metaphysical impossibility is philosophically intriguing because unlike most impossible events, we can vividly picture how it might look. Time travel itself seems possible, and for those who arrive in the past with proper equipment and training, the actual infanticide should not be difficult."[60] And so the grandfather paradox lives on, bedeviling both physicists and philosophers alike.

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[54] J. W. Meiland, "A Two-Dimensional Passage Model of Time for Time Travel," *Philosophical Studies*, November 1974, pp. 153–173. Science fiction had already considered time travel suicide in, for example, K. Neville, "Mission," *Fantasy and Science Fiction*, April 1953.

[55] F. Arntzenius, "Causal Paradoxes in Special Relativity," *British Journal for the Philosophy of Science*, June 1990, pp. 223–243.

[56] P. Worth, "Typewriter from the Future," *Amazing Stories*," February 1950. See also note 106 in Chap. 1.

[57] For example, in J. H. Schmidt, "Newcomb's Paradox Realized with Backward Causation," *British Journal for the Philosophy of Science*, March 1998, pp. 67–87, we read that "there are as yet no generally accepted solutions" to the grandfather paradox.

[58] S. Gorovitz, "Leaving the Past Alone," *Philosophical Review*, July 1964, pp. 360–371.

[59] F. M. Busby, "A Gun for Grandfather," *Future Science Fiction*, Fall 1957.

Indeed, one physicist described the time travel paradoxes as "the most controversial issue related to time machines."[61] As he argued, "These paradoxes seem to be something inherent to time machines (their main attribute, perhaps), so it is reasonable to assume that if there exists a universal law prohibiting the time machines, it must have something to do with the paradoxes. And on the other hand, be the problem of the paradoxes satisfactorily solved there probably would be no need to look for such a law, the (supposed) paradoxicalness of the time machines being traditionally the main objection against them."

One of the persistent stumbling blocks to removing the confusion of the paradoxes is a failure to distinguish between *affecting* and *changing* the past. One philosopher wrote this, in a somewhat bungled attempt to explain what is meant by affecting the past: "Nothing anyone can do now can make it not have rained yesterday"[62] if, in fact, it *did* rain yesterday. This is correct, but it is *not* what is meant by *affecting* the past. Rather, if the reason it *did* rain yesterday is because a time traveler from the future seeded the clouds, then that time traveler affected the past. Making it not to have rained yesterday would be to *change* the past.

A classic[63] by Isaac Asimov illustrates what is meant by a time traveler affecting the past. An idealistic physics professor, convinced that the world's political problems are the result of the comparative newness of scientific thought and tradition, tries to change the past (and thus the present) by sending a Greek translation of a modern chemistry text back 2000 years to the Hellenic days of Leucippus, Lucretius, and Democritus. He dies in the attempt but succeeds in the transmission. When a government investigator—called in because the professor drained an entire nuclear power reactor to energize his time machine!—discovers that the transmission takes a day to travel back a hundred years (a little gimmick with no foundation in physics, but simply something Asimov needed for the story), he fears 'our' world will vanish in 20 days, to be replaced by a 'new' one. In the end, however, he learns you can't change the past. As one of the late professor's colleagues tells the investigator, "While you are right that any change in the course of past events, however trifling, would have incalculable consequences … I must point out that are nevertheless wrong in your final conclusion. *Because THIS is the world in which the Greek chemistry text WAS sent back.*"

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[60] David Horacek, "Time Travel in Indeterministic Worlds," *The Monist*, July 2005, pp. 423–436.

[61] S. Krasnikov, "Time Travel Paradox," *Physical Review D*, February 14, 2002, pp. 064013–1 to -8.

[62] R. G. Swinburne, "Affecting the Past," *Philosophical Quarterly*, October 1966, pp. 341–347.

[63] "The Red Queen's Race," *Astounding Science Fiction*, January 1949.

Another good illustration from science fiction of affecting the past can be found years before Asimov's. In that story,[64] a time traveler leaves the Chicago of 1942 for the year 3000. Much later, in the year 2564, another time traveler interested in history journeys back to 2253 in an attempt to learn the cause of the great Chicago explosion of that year. The explosion was centered on the site of an ancient laboratory once used by a scientist who mysteriously vanished in 1942. The second time traveler begins his trip into the past on the same spot, with plans to go back to the day before the explosion. At the story's end, we learn that the disaster was the result of the two time travelers colliding as both 'passed through' 2253. The backward traveling historian, therefore, by pushing a button in 2564, is the cause of an event that happened 311 years earlier.[65]

To give a science fiction example of changing the past, it would be hard to do better than with a story that appeared a few years after Asimov's The central character is a researcher in time travel who has concluded that what is wrong with the world can be traced back to the scientific method getting off to a late start (this story was almost surely written as a result of Asimov's tale!): the time traveler thinks he can correct matters by visiting 340 B.C. and educating Aristotle on the proper scientific attitude. (Aristotle believed that observing the world was inferior to pure thinking about how the things, in his opinion, *ought* to work.) This the time traveler does, with utterly disastrous consequences. He returns to the present to find a scientifically retarded world that makes him a slave. In his cell he writes on a wall the bitter lesson he has learned too late: "Leave Well Enough Alone."[66]

It is the fear of time travelers from the future attempting to alter the past that has led some philosophers (and not just a few physicists) to assert that time travel is impossible, because it would mean what they feel to be impossible might happen: changing the past. One philosopher, however, argued long ago that such a worry is unwarranted. As he wrote at the end of an essay (a polemic *against* the concept of four-dimensional spacetime, and so *against* the idea of time travel), "Squandering vast sums on foolish enterprises is an everyday occurrence. [For example], will the U.S. time explorer get back and eliminate Lenin before his Russian rival gets back even earlier and eliminates George Washington? . . . If such spectacular folly once gets under way because governments have been convinced of some nonsensical theory, a logician will not . . . lose any sleep about who is going to succeed."[67]

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[64] O. Saari, "The Time Bender," *Astounding Stories*, August 1937.

[65] This story describes something a bit more than 'simply' affecting the past; it has a *causal loop* in it. The time traveling historian makes his trip *because* of an event in the past that his trip causes. Such paradoxes will be the subject of the next section.

[66] L. Sprague de Camp, "Aristotle and the Gun," *Astounding Science Fiction*, February 1958. Asimov and de Camp were close friends, and their two stories with similar premises are clearly the result of a bit of friendly rivalry.

[67] P. Geach, "Some Problems About Time," in *Studies in the Philosophy of Thought and Action* (P. F. Strawson, editor), Oxford 1968.

And long before that essay (with its correct conclusion reached through faulty reasoning) was penned, we learn the same lesson (in a 1923 tale by the English novelist May Sinclair (1863–1946)) as we follow a woman right into hell after her death; she ends up there because of an immoral life. She then wanders through time, into her past, but finds that she can change nothing. As she is told, "You think the past affects the future. Has it never struck you that the future may affect the past? . . . You *were* what you *were to be*."[68] This last line, from a *non*-science fiction story, is consistent with the modern view held by physicists of time travel. You cannot travel anywhere into the past unless you've already been there, and when you do make the trip you will do what you've already done there. You could not, as does the time traveler in one tale,[69] change the course of history by revealing twentieth-century physics in the eighteenth century. That does not mean you would necessarily be ineffectual during your stay in the past, however (certainly it doesn't mean, as Hugo Gernsback thought, that you'd be *invisible*!) Not being able to change the past is not equivalent to being unable to *influence* or *affect* what happened in the past, and science fiction writers have used this distinction to good effect, as did Asimov (note 63) and de Camp (note 66).

Robert Heinlein was a science fiction writer who clearly understood time travel paradoxes, both what they mean and, at least as important, what they do not mean. In his 1964 cold-war novel *Farnham's Freehold*, for example—the story of a family that is literally blasted twenty-one centuries into the future when their bomb shelter receives a direct hit from a Soviet nuclear warhead—we find following exchange as two of the characters are about to return to their original time via time machine:

> "The way I see it, there are no paradoxes in time travel, there can't be. If we are going to make this jump, then we already did; that's what happened. And if it doesn't work, then it's because it didn't happen."
>
> "But it hasn't happened yet. Therefore, you are saying it didn't happen, so it can't happen. That's what I said."
>
> "No, no! We don't know whether it has already happened or not. If it did, it will. If it didn't, it won't."

Modern philosophers, and many physicists, too, as well, who have examined the concept of time travel in depth, agree with Heinlein's character and, indeed, it is now common practice to invoke the so-called *principle of self-consistency*—generally attributed to the Russian astrophysicist Igor Novikov (see note 117 in Chap. 1) because he and his colleagues did not simply invoke it, but rather were able to *derive* it from the *principle of least action*, a concept held by many to be at the highest level of importance in physics[70]: all that is required, argued Novikov, in *any* physical process (including time travel), is that a *logical* consistency exist between events.[71] In his book *Evolution of the Universe* (originally published in Russian in 1979), Novikov wrote "The closure of time curves does not necessarily imply a violation of causality, since the events along such a closed line may be all 'self-adjusted'—they all affect one another through the closed cycle and follow on another in a self-consistent way." He later repeated that view in one of the first time machine papers in the physics literature.[72]

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[68] M. Sinclair, "Where Their Fire Is Not Quenched," in *After the Darkness Falls* (B. Karloff, editor), World Publishing 1946.

[69] D. Beason, "Ben Franklin's Laser," *Analog*, December 1990.

In fact, despite the attachment of Novikov's name to the principle of self-consistency, it was actually around in physics *decades* earlier; it has been traced back to as far as 1903![73] And at least an intuitive understanding of the principle can be found in the mainstream literature from nearly as long ago. For example, in Lord Dunsany's short 1928 play *The Jest of Hahalaba* (the inspiration for the 1944 film *It Happened Tomorrow*), a man obtains (via supernatural means) a copy of tomorrow's newspaper. In it he reads his own obituary, which so shocks him that he promptly expires—thus explaining the obituary notice.

The principle of self-consistency has been in science fiction long before Novikov, too. An example is the 1941 story "Time Wants a Skeleton" (see note 15). In it one character, after puzzling over a time travel paradox, realizes that "Future and present demanded co-operation, if there was to be a logical future!" And a nice lecture on the principle (that pre-dates by 3 years the dialogue quoted earlier from Heinlein's *Farnham's Freehold*) is given by a character that is particularly interesting because it was published, not in a specialty science fiction magazine catering to an audience with 'genre knowledge' of time travel, but rather in an icon of general American culture.[74]

Not all science fiction writers, however, have understood the requirement for consistency around a loop in time. In one tale, for example, a man meets the inventor of a time machine and agrees to his request to use it to travel into the future. Once he is in the future, alas, the machine breaks. The man then finds another machine that, though it is too small for him to fit in it, is able to hold a recording that he sends back into the past to himself, to a time *before* he started his forward journey. The message on the recording (which he did not receive the 'first' time) is, of course, *not* to make a deal with the inventor. This advice he follows, and so the principle of self-consistency is violated twice in this story.[75]

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[70] Like just about everything concerning time travel, however, not *all* think this. For example, the great German physicist Max Planck (1858–1947), the 1918 Nobel physics laureate, said (in 1922): "Physics hence is inclined to view the principle of least action more as a formal and accidental curiosity than as a pillar of physical knowledge." Still, he *did* also declare that he thought it unlikely "the dominance of such a simple law could be a mere accident." Quoted from Marc Lange, "Conservation Laws in Scientific Explanations: Constraints or Coincidences," *Philosophy of Science*, July 2011, pp. 333–352.

[71] See A. Carlini, *et al.*, "Time Machines: The Principle of Self-Consistency as a Consequence of the Principle of Minimal Action," October 1995, pp. 557–580, and "Time Machines and the Principle of Self-Consistency as a Consequence of the Principle of Stationary Action (II): The Cauchy Problem for a Self-Interacting Relativistic Particle," October 1996, pp. 445–479, both in *International Journal of Modern Physics D*.

[72] I. D. Novikov, "An Analysis of the Operation of a Time Machine," *Soviet Physics JETP*, March 1989, pp. 439–443.

[73] R. D. Driver, "Can the Future Influence the Present?" *Physical Review D*, February 15, 1979, pp. 1098–1107.

[74] R. F. Young, "The Dandelion Girl," *The Saturday Evening Post*, April 1, 1961. See also note 49 in Chap. 2.

An ability to play a role in history is not without some constraints. You can't save Jesus with a rifle (see note 45), or Joan of Arc with a fire extinguisher, or knock-out John Wilkes Booth with a baseball bat outside of Ford's Theatre, or blow-up Hitler with a bomb, and you can't prevent either the Black Death in the London of 1665 or the Great Fire the following year. But it *is* logically possible for a time traveler who has an infected rat sneak into his time machine, or who carelessly discards a match, to be the *cause* of the last two examples. That was the fate, for example, of the time traveling historian from A.D. 2461 who was the cause of the plague in A.D. 562 Rome, as well as of that in England nearly 800 years later.[76]

Michael Moorcock's 1969 novel *Behold the Man* gets the impossibility of changing the past, and the possibility of affecting it, right. When a disturbed man journeys backward in time to ancient Galilee to meet Christ, only to discover that there is no such person, *he* assumes the role and lives out the Biblical accounts up to and including dying on the Cross. He has not changed the past, but he certainly plays an important role in it!

An early science fiction story that got this right, long before the philosophers and physicists thought of it, was the clever tale whose artwork I have reproduced at the end of the Introduction.[77] In that story, a time traveler journeys back from 1943 to 1870 and shoots his then 14-year old grandfather in the head. Leaving his victim lying on the ground with "blood oozing all over the youth's forehead," the would-be killer returns to 1943. Once back, however, he finds himself in a strange place where he learns from two men that the Germans destroyed New York in 1920 with poison gas! Suddenly realizing that the death of his grandfather has apparently changed history (a curious oversight for anyone smart enough to invent a time machine and then to use it to force the 'grandfather paradox'), he decides he'd rather be dead than be cut off for all time from the world he remembers. So, he shoots himself dead. Then we learn that the two men he encountered are actually inmates in an asylum who like to make-up stories for unsuspecting strangers. We also learn that the time traveler's grandfather's photographs always did show him with a "white, furrowed scar on his forehead that might have been caused by a glancing bullet."

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[75] R. Wilson, "The Message," *Astounding Stories*, March 1942.

[76] G. C. Edmondson, "The Misfit," *Fantasy and Science Fiction*, February 1959.

[77] M. Weisinger, "Thompson's Time Traveling Theory,' *Amazing Stories*, March 1944.

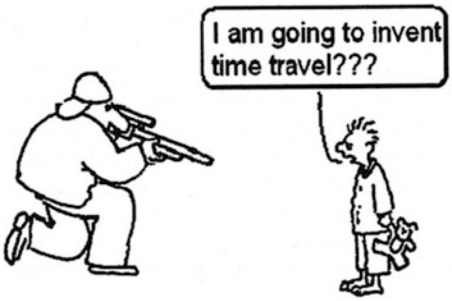
I am going to invent time travel???

Fig. 4.4 The inventor of a time machine about to commit autoinfanticide in the past (the youngster holding the teddy bear is a younger version of the time traveler). Illustration reproduced by the kind permission of Frank Arntzenius (Professor of Philosophy at Oxford University), from his paper "Time Travel: Double Your Fun," *Philosophy Compass*, November 2006, pp. 599–616

Well, okay, you might say at this point, 'I'm convinced you can't change the past, but let's get back to the autoinfanticide (grandfather) paradox. So *why can't* a time traveler kill his baby-self in the past?' A possible answer, one now generally accepted by philosophers and physicists alike, appeared first in science fiction. In a tale[78] that appeared just the year after Gödel's 1949 discovery of time travel in general relativity, we find a character saying "The answer is quite simple. When the man goes back in time and kills his grandfather, and returns to his own time again, he finds to his surprise that he made a mistake. It was not his grandfather at all! And no matter how many times he goes back and kills his grandfather . . . he *always* [my emphasis] finds he made a mistake." Or, perhaps, some noise distracts him as his finger tightens on the trigger, or the grenade he tosses at granddad is a dud, or a gust of wind deflects the arrow, or (most ludicrous of all) he simply slips on a discarded banana peel!

Okay, that works for *that* time traveler. But suppose, someone objects, that we arrange to have a *lot* of time travelers go back in time, each with murder in his heart for his grandfather. Then, as one philosopher has observed, "Since [killing one's grandfather in the distant past] is impossible, each assassin fails. Some change their minds, others slip on banana peels, yet others kill the wrong target, and so on. But there is something odd about the idea that such coincidences are guaranteed to happen, again and again!"[79]

Early science fiction avoided invoking banana peels by providing an even more extreme 'explanation' for the failures: the time police, who are charged with foiling would-be grandfather killers. (See, for example, the many stories by Poul Anderson (1926–2001) of the 'Time Patrol.') These time commandos are imagined to roam the corridors of time, disrupting the attempts of all those who would change recorded history. Stories of these temporal cops are simply westerns, mysteries, police procedurals, or some other similar type of specialty genre story wearing thin camouflage. This story device, whose main purpose is to allow both time travel and free will,[80] has been correctly called "boring" by at least one philosopher (see note 5 in the Introduction), an evaluation shared by modern philosophers, physicists, and (I think) even most modern science fiction writers.

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[78] "Typewriter from the Future": see note 106 in Chap. 1.

[79] Theodore Sider, "Time Travel, Coincidences, and Counterfactuals," *Philosophical Studies*, August 2002, pp. 115–138.

So, we seem to be back to banana peels to save grandfather—but it *is* difficult to deny that vast hordes of murderous grandsons *do* appear to require an unlimited number of strategically placed banana peels, strewn all about the past, to trip-up every one of those potential assassins. This problem, of repeated, improbable coincidences to thwart murderous descendants from the future, was first commented on by the philosopher Paul Horwich in 1975 (see note 19 in the Introduction), and then given a convincing resolution by another philosopher in 1997.[81]

To explain the argument, I'll first use the philosopher's less deadly example of dated objects. "Suppose," he writes, "that every object has written upon it the date on which it will cease to exist . . . perhaps a time traveler travelled into the future, observed the demise of objects and then travelled back [to just after he left for the future] and wrote the dates."[82] If now the time traveler tries to destroy an object *before the date written on it*, then he *will* fail. As the philosopher amusingly described his attempts to destroy a pen 'before its time,' "I take it outside to place under the wheels of a passing train, but there is a train strike that day. The telephone rings just as I am about to drop the pen into a vat of acid. I slip on a banana peel on my way to put the pen in the microwave. My dog eats my designs for a pen grinder. And so on, for as long as you please. However many attempts I make, the attempts in no way require the occurrence of the coincidences that foil them." To put it bluntly, 'Stuff happens.' The pen has the observed date of its destruction on it, and that date is still in the future and so it is simply impossible to destroy it now.

Now, here's the point: the date on the pen is there *because* all those attempts to destroy it before that written date fail. But the presence of the date is *not* the reason for any of the weird (?) occurrences that disrupted all the attempts to destroy the pen, but rather it's *because* all those attempts failed that the date is what it is. This same argument applies to the grandfather paradox. The only time travelers available, today, to go back into the past to *try* to kill their grandfathers, are precisely those time travelers whose grandfathers were *not* killed. Or, to paraphrase our philosopher (note 81), to ask 'why do coincidences always foil the time traveller's attempts to kill [grandfather in the distant past], is to get things back to front. It is only because the murder attempts fail that the time traveler is alive in the future to even make the *attempt*.'

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[80] See, for example, David King, "Time Travel and Self-Consistency: Implications for Determinism and the Human Condition," *Ratio*, September 1999, pp. 271–278.

[81] Nicholas J. J. Smith, "Bananas Enough for Time Travel?" *British Journal for the Philosophy of Science*, September 1997, pp. 363–389.

[82] This does present us with the curious (although non-paradoxical) situation that the time traveler will find, upon his appearing in the future, the date he *will write* (in his personal future) when he returns to just after he left on his time trip.

In other words, not only is the grandfather 'paradox' not a paradox, it isn't even surprising!

4.4 Causal Loop and Bootstrap Paradoxes

> "My dear Collingwood, don't drive yourself crazy trying to resolve the paradoxes of time travel. The [time machines] are gone . . . have a drink."[83]

The grandfather paradox might finally have been put to rest, but there are still plenty of other logical minefields left to be negotiated. One of the more puzzling is that of the closed loop in time, a conundrum nicely illustrated by one philosopher[84] as follows, as an explanation of the journey one time traveler makes to 3000 B.C.: "In our time travel story it just may be that the traveler's interest in going back to ancient Egypt is stimulated by recently discovered documents, found near Cairo, containing the diary of a person claiming to be a time traveler, whereupon our hero, realizing it is himself, immediately begins . . . construction of a rocket in order to 'fulfill his destiny.'" In other words, (1) he builds a time machine and goes back to the past because of the discovered diary, and (2) the diary is discovered because he goes back to the past. Each of these points by itself has logical clarity, but together they form a closed time loop (a *causal loop*) of enormous mystery.

Science fiction was strewn with causal loops long before the philosophers and physicists began to ponder them, however, with (for example) one early tale on a time traveler who journeys a century into the past because she finds an old, yellowed newspaper story describing her arrival.[85] But this tale wasn't the first to use a causal loop, as we can find one of the first sophisticated treatments of this device in a story that appeared even earlier (in the same publication).[86] A time traveler in 1930, about to start his journey into the future in an airplane/time machine, wonders at the last moment if he should really go—then he sees himself returning and thus *knows* he will successfully make the trip.

As he later tells a friend, "That decided me . . . Paradoxical? I should say so! I had seen myself return from my time-trip *before* I started it [just like Marty McFly in the original *Back to the Future* film]; had I *not* seen that return, I would *not* have commenced that strange journey, and so could *not* have returned in order to induce me to decide that I *would* make the journey!" And later, when he finds himself in a dangerous situation in the future, he draws hope from that initial experience: "I *would* escape ... It was so decreed. Had I not, with my own eyes, seen myself appear out of the fourth dimension back there in the Twentieth Century, and glide down to my landing-field? Surely, then, I *was* destined to return to my own age safe and sound."

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[83] A science fiction suggestion that in certain situations (particularly causal loops), might actually be good advice! From L. Sprague de Camp's "The Best-Laid Scheme," *Astounding Science Fiction*, February 1941.

[84] L. Dwyer, "Time Travel and Some Alleged Logical Asymmetries Between Past and Future," *Canadian Journal of Philosophy*, March 1978, pp. 15–38.

[85] P. Bolton, "The Time Hoaxes," *Amazing Stories*, August 1931.

[86] F. J. Bridge, "Via the Time Accelerator," *Amazing Stories*, January 1931.

Even more dramatic is the second, internal time loop that ends the story. When the time traveler arrives in a ruined city in the year A.D. 1,001,930 he is greeted, *by name*, by an old man who says he (the old man) is the Last Man alive. He knew the time traveler was coming because an ancient history book had said the Last Man had, in fact, appeared in the year A.D. 502,101 in the very time machine out of which the time traveler has just stepped. The time traveler is so startled by all this (and who could blame him!?) that he decides to mull over what he has been told until the next day. As he wakes up in the morning, he is just in time to watch the Last Man depart for 502,101. Stranded in the future, the time traveler wanders the empty city in despair until he chances upon a museum. And in the museum, sealed in a glass case, is his time machine (!)—it has been there for half a million years, since the end of the Last Man's journey. And so the time traveler is saved; he merely adds some oil to the still-functional engine (if you can accept time travel, I suppose this is no more difficult to believe) and returns to 1930—just as he saw himself do at the beginning of the story.

Since Bridge's astonishing story, the idea of a causal loop in time has been used many times in science fiction. Here's a representative sampling:

(1) Time travelers arrive in the forty-sixth century, only to find that they are expected. Their host tells them why: "I have been awaiting your arrival from the past. I have a written record of your coming. You see, I have a time machine myself ... With my time machine, I recently went a year into the future and read the written account I had made, or will make after you leave. Then I came back, awaiting your arrival."[87]

(2) Armed travelers return to the Triassic age to uncover the secrets of a mysterious artifact that has been recently discovered; at the end we learn it is the remains of their own automatic rifle[88];

(3) A time traveler journeys back 500 years, where he suffers an accident that results in his being "agelessly stuck" in his time-traveling gadget until he is freed—by himself, 500 years later. He then gets into the gadget to journey back 500 years[89];

(4) The world's time suddenly loses 5 min, an astonishing event that comes to be called "the time drop." After 2 weeks of investigation, a reporter traces this

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[87] E. Binder, "The Time Cheaters," *Thrilling Wonder Stories*, March 1940.

[88] J. Blish, "Weapon Out of Time," *Science Fiction Quarterly*, Spring 1941.

[89] A. B. Chandler, "The Tides of Time," *Fantastic Adventures*, June 1948.

event to a reclusive (but brilliant, of course) scientist who reveals that he has invented a time machine. The reporter decides to test this claim by using the machine to return to just before the start of the time drop, to observe precisely what caused it—it is, in fact, a malfunction of the machine that is at fault and the reporter finds himself caught in a 2-week long causal loop[90];

(5) A physicist knows something odd lies in his future when he is confronted with a 700 year-old museum copy of a book. The puzzle is how to explain a message penned in ancient, faded ink, in modern English *and in his handwriting*, on the back side of one of the recently unglued endpapers! How, too, to explain his own fingerprints all over the same endpaper? How, indeed, to answer these questions is his problem when he is presented with all of this and is asked, "Have you, by any chance, been visiting the thirteenth century?" At the end of the story the time loop is closed when the physicist finds himself writing that same message on a *brand new* copy of the book that has been sent from the past (and that he returns to the thirteenth century via a "time portal")[91];

(6) A time traveler from 1964 is secretly observed by one of the 'locals' when he arrives in 1683. The oddness of the sudden appearance of the time traveler and his machine ("It were a kind of Dazzle") makes the local think it might be that the stranger is the man who stole some items from his home the previous night, the same night he had an "ill Dream." Stealing the time machine after the time traveler has gone exploring, the local travels to 1964 where he learns how valuable antiques are. So back he goes to 1683, to the night before the time machine first appeared, to get some 'antiques' from his house. And thus he realizes who the thief *really* was. Before leaving again for the future, he enters his own bedroom to see himself asleep and then to awaken. And so he also learns the cause of what he called his "ill Dream."[92];

(7) A movie production crew goes into the past to make a film. At the end of the story it becomes clear that their presence in the past was not an insignificant event, as one character realizes after seeing the evidence of how they affected (*not* changed!) the past: "If this is true, then the only reason that the Vikings settled in Vinland is because we decided to make a motion picture showing how the Vikings settled in Vinland"[93];

(8) A private college, endowed decades before by a generous but mysterious benefactor, experiments with a time machine. Suddenly, one of the college's graduates is accidently sent a hundred years into the past—where she becomes the benefactor. The college comes into existence, therefore, because it will exist[94];

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[90] W. Sheldon, "A Bit of Forever," *Super Science Stories*, July 1950.

[91] M. Leinster, "The Gadget Had a Ghost," *Thrilling Wonder Stories*, June 1952.

[92] D. I. Massor, "A Two-Timer," *New Worlds SF*, February 1966.

[93] H. Harrison, *The Technicolor Time Machine*, Doubleday 1967.

[94] C. Simak, "The Birch Clump Cylinder," *Stellar 1* (J. del Rey, editor), Ballantine 1974.

(9) A man gets the money to support his experiments in time travel by selling a large collection of old, rare comic books he has discovered in his late mother's attic. Later we learn how the comic books came to be there; after his experiments are successful, the inventor travels back into the distant past, buys the *newly* published comic books right off newsstands, and stores them in his mother's attic where, decades later, he knows his younger self will grow up and then find them (and thus get the money to make it all happen)[95];

(10) In the 1980 film *Somewhere in Time* (based on the 1975 novel *Bid Time Return* by Richard Matheson), a man in the present is visited by a mysterious old woman who gives him a watch. Later, he travels back to 1912 where he meets a girl to whom he gives the watch. He then returns to the present, and she lives out her life from 1912 on, until she too reaches the present, where we discover she is the (now old) woman who gives the man the watch.

Once philosophers discovered the bizarre nature of causal loops, they quickly proved themselves to be the equal of science fiction writers in imagining strange doings. Here's one example of that, one which any writer would be proud of: "If James cannot decide whether to marry Alice or Jane, he simply travels to the future and learns that he is to choose Alice; he then chooses her for this reason. One wants to object that the decision to marry Alice was never really made at all! But this is not true; the decision was made—as a result of the knowledge that this was the decision . . . It is not the case that the prospective bridegroom could visit the future and compare the results of marrying Alice with those of marrying Jane in order to decide between the alternatives. For if he visits the future, he will learn only that in fact he chose Alice, for better or for worse!"[96]

This same philosopher elaborated on his view of causal loops in a later paper, where he wrote "What if time travel becomes commonplace, so that we must deal with a constant stress of time travelers returning from the future to reveal what they have seen?"[97] His answer is "I think it is clear that the . . . causal loop we have been discussing would become very common, and would play a prominent role in human affairs." He denied, however, that such causal loops would mean the loss of free will. As he explained his position, knowledge of a rigged roulette will not prevent you from putting your money on the table *if you want to*, but perhaps that knowledge will influence your *freely* made decision making. Whether you learn that the roulette wheel is rigged by traditional means (perhaps you see magnets being installed under the table) or by means of time travel is irrelevant—even with this knowledge, you act freely. Other philosophers have not been so generous. One disliked causal loops so much, for example, that while he believed them to be conceptually possible, he also thought them to have "a queer smell,"[98] so much so that he simply preferred to avoid thinking about them!

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[95] D. Knight, "The Man Who Went Back," *Amazing Stories*, November 1985. This same idea was used earlier in the story "Compounded Interest," (*Magazine of Fantasy and Science Fiction*, August 1956) by Mack Reynolds, in which the inventor of a time machine has the money to build his gadget because he uses it to go back into the past where he deposits a small sum, which then grows (through the 'magic' of compound interest) into the cash he needs to fund his time machine.

[96] G. Fulmer, "Understanding Time Travel," *Southwestern Journal of Philosophy*, Spring 1980, pp. 151–156.

[97] G. Fulmer, "Time Travel, Determinism, and Fatalism," *Philosophical Speculations in Science Fiction and Fantasy*, Spring 1981, pp. 41–48.

One concern that many philosophers and physicists have had with closed loops in time is that they fear that would mean being trapped on an endless cycle of repeating events. For example, one philosopher long ago wrote

> "There is nothing contradictory in imagining causal chains that are closed, though the existence of such chains would lead to rather unfamiliar experiences. For instance, it might then happen that a person would meet his own former self and have a conversation with him, thus closing a causal line by the use of sound waves. When this occurs the first time he would be the younger ego, and when the same occurrence takes place a second time he would be the older ego. Perhaps the older ego would find it difficult to convince the younger one of their identity; but the older ego would recall an identical experience long ago. And when the younger ego has become old and experiences such an encounter a second time, he is on the other side and tries to convince some 'third' ego of their physical identity. Such a situation appears paradoxical to us; but there is nothing illogical in it."[99]

What has been (erroneously) described with that is the beginning of an endless succession of encounters around a closed causal loop. There is, however, just *one* encounter on such a loop in spacetime (but, of course, the mind of the time traveler experiences the encounter twice), subject to the constraint of self-consistency. Some physicists, too, have been so concerned about multiple trips around closed timelike curves (CTCs), because they think such trips would allow the past to be changed, that they have felt it necessary to specifically forbid such a possibility. As one paper put it, "That the principle of self-consistency is not totally tautological becomes clear when one considers the following alternative: The laws of physics might permit CTCs; and when CTCs occur, they might trigger new kinds of local physics which we have not previously met. For example, a quantum-mechanical system, propagating around CTCs, might return to where it started with values for its wave function that are inconsistent with the initial values; and it might then continue propagating and return once again with a third set of values, then a fourth, then a fifth ... The principle of self-consistency by fiat forbids changing the past."[100]This last statement is, of course, in agreement with the position I have taken in this book, a position that has generally been accepted by most philosophers for several decades now, but the proponents of the principle of self-consistency seem to have been driven to it by a fear of the past ‘happening again’ over and over, as in the 1993 film *Groundhog Day*.

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[98] M. MacBeath, "Communication and Time Reversal," *Synthese*, July 1983, pp. 27–46.

[99] H. Reichenbach, *The Direction of Time*, University of California Press 1956, p. 37.

[100] J. L. Friedman et al., "Cauchy Problem in Spacetimes with Closed Timelike Curves," *Physical Review D*, September 15, 1990, pp. 1915–1930. Another physicist, however, has flatly rejected this need for the Principle, calling it redundant: see D. Deutsch, "Quantum Mechanics Near Closed Timelike Lines," *Physical Review D*, November 15, 1991, pp. 3197–3217.

Science fiction writers have stumbled into the error of endless cycling on a closed time loop, too. In one such tale,[101] the inventor of the first time machine travels 500 years into the future where he finds a bronze statue of himself that honors his discovery of time travel. Suddenly injured, fatally, he returns to the present with the statue and then dies. As a memorial, the statue is placed in the very spot where the inventor found (will find) it. As the tale ends, the late inventor’s lab assistant wonders to himself what will happen 500 years later: “Suddenly a strange machine will come out of the past and [the inventor] will be here again—although he is dead and has been dead 500 years. [He will take the statue] and go back to the past . . . to die. And once again that maddening cycle will begin, to go on and on forever as long as time spins its threads.”

That story illustrates yet another puzzle associated with those causal loops that contain a circulating, physical object. That is, *who made the statue*? We can ask the same question about the watch in the time loop of *Somewhere in Time/Bid Time Return* as, at every instant of its existence, the watch is in the possession of either the man or the woman? So, *when was the watch constructed*?

There have been some science fiction writers who specifically recognized this question, long before either the philosophers or the physicists paid attention to it. In one early tale,[102] for example, we read of a time machine that travels from 1935 to 1925. When the question of the origin of the time machine comes up, we read

> “One time machine, found in 1935 and brought back to 1925—found in 1935 *because* brought back to 1925. That is all.”
>
> “But who made it in the first place?—Oh, skip the ‘in the first place.’[103] Just plain: who made it?”
>
> “No one. It was never made . . . It is here because it is here.”

This same puzzle was addressed in *The Technicolor Time Machine* (note 93), when one character is perplexed over a piece of paper in his wallet with a diagram on it, a piece of paper he got from himself (an *older version* of himself, who traveled into the past to give it to his younger self). In frustration, he asks a friend:

> “Then no one ever *drew* this diagram. It just travels around in this wallet and I hand it to myself. Explain that.”
>
> His friend replies:
>
> “There is no need to, it explains itself. The piece of paper consists of a self-sufficient loop in time. No one ever drew it. It exists because it is, which is adequate explanation. If you wish to understand it, I will give you an example. You know that all pieces of paper

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[101] S. Mines, “Find the Sculptor,” *Thrilling Wonder Stories*, Spring 1946.

[102] R. M. Farley, “The Man Who Met Himself,” *Top-Notch Magazine*, August 1935 (*Top-Notch* was an adventure pulp published between 1910 and 1937).

[103] The reason for this line in the story is that earlier the question of “Where did the time machine come from *originally*?” was raised. The answer: “There was never any ‘original.’ . . . There is no round-and-round circle of events, no repetition. Merely *one* closed cycle.” This is, in fact, the modern view of causal loops, expressed in a 1935 (!) science fiction story.

> have two sides—but if you give one end of a strip of paper a 180-degree twist, then join the ends together, the paper becomes a Möbius strip that has only one side. It exists.[104] Saying it doesn't cannot alter the fact. The same is true of your diagram; it exists."
>
> "But—where did it come from?"
>
> "If you must have a source, you may say that it came from the same place that the missing side of the Möbius strip has gone."[105]

The undeniable mystery of causal loops is the reason behind the philosopher I cited earlier (note 98) who thought they have a "queer smell" and so viewed them with much suspicion. He wasn't alone in that feeling, and another philosopher said as much whe he wrote "despite [strong] arguments for the consistency of time travel stories [with causal loops], the impression is apt to remain that something is wrong with them. I think this impression is correct."[106] One story that this philosopher could well have had in mind is a classic,[107] a tale that describes a knife brought from a museum in the future back to the present. It arrives in the present with a flawless blade, but soon thereafter gets a nick in the blade. How, wonders the narrator, can the time loop be completed "again"? I do not find this quite the puzzle that either the author (and perhaps the philosopher) do: it is simply a variation of the grandfather paradox (which has been shown not to be a paradox at all). *If* the knife is found flawless in the future, *then* it was not (will not) be nicked in the past. As written, the story is not logically consistent as it involves changing the past but, *if* one removed the detail of a *nicked* blade, then we *would* have a true (paradoxical) causal loop, with the question the story, itself, asks about the knife: "How was this knife created . . . when its existence has no beginning or end?"

The nicked knife does illustrate a subtle problem that bedevils *any* causal loop containing a physical object. Consider once again the watch in the film *Somewhere in Time*. Assume the watch received by the man in the present is bright and shiny. He then takes it back into the past and gives it to his love. It remains with her after his return to the present until, decades later, she gives it to him—bright and shiny. Why didn't it tarnish? Is there some peculiar anti-tarnish property to a watch in a causal loop? Well, if so, is that anymore odd than a causal loop itself?[108]

None of that, however, provides a means for rejecting time travel *if* one can argue that it is possible to have time travel *without* causal loops. Indeed, Professor Hanley (see note 105) argues that it is possible, and presents what he claims is an example of how to do it. Alas, another philosopher convincingly showed that the example is flawed and that Hanley's claim that there is no causal loop in his story "is unjustified."[109] From an entertainment point of view, however, eliminating causal loops is going in the wrong direction, as it is the inclusion of causal loops that gives a feeling of mystery to a good science fiction story.

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[104] See note 99 in Chap. 1, and the related discussion there.

[105] One philosopher calls this bit of dialog "unhelpful," while ignoring the fact that it appeared in a science fiction pulp magazine and not a scholarly journal, and was clearly meant to dazzle teenage boys (see note 39 and related discussion in "Some First Words") with the concept of a causal loop, rather than to break new ground in metaphysical thought. See Richard Hanley, "No End in Sight: Causal Loops in Philosophy, Physics and Fiction," *Synthese*, July 2004, pp. 123–152.

[106] G. Nerlich, "Can Time Be Finite?" *Pacific Philosophical Quarterly*, July 1981, pp. 227–239.

[107] P. S. Miller, "As Never Was," *Astounding Science Fiction*, January 1944. This is the same Miller who appears in note 15 (and see note 46, too).

[108] It is *not* sufficient to say that perhaps she polished the watch. Polishing would remove material from the watch, which means she gives him a watch different from the one he gives her in the past.

To finish this section, then, we can do no better than to discuss causal loops that are even *more* bizarre than are those with a physical object; that is, loops that involve time traveling *information*. (Since information doesn't 'tarnish,' however, such a loop avoids that particular puzzle associated with a physical object in a causal loop.) A classic example of such a loop is a mathematician who is visited in his youth by a time traveler from the future (perhaps himself), who gives him the proof of a theorem for which the mathematician is (will be) famous in the future. *Where*, then, did the proof actually come from? In what *mind* was it *created*?[110]

The philosopher David Lewis wrote with particular insight on causal loops, especially ones that involve information transfer, such as a time traveler going back in time to tell his younger self how to build a time machine so that once its constructed he can go back in time and tell himself how to do it.[111] (This was item (3), you'll recall, in Jim Nicholson's 1931 letter to *Science Wonder Stories* magazine, quoted at the end of the first section of this chapter.) As Professor Lewis wrote (see note 5 in the "Introduction"), "But where did the information come from in the first place? Why did the whole affair happen? *There is simply no answer* [my emphasis]. The parts of the loop are explicable, but the whole of it is not. Strange! But not impossible, and not too different from inexplicabilities we are already inured to. Almost everyone agrees that God, or the Big Bang, or the entire infinite past of the Universe, or the decay of a tritium atom, is uncaused and inexplicable. Then if these are possible, why not the inexplicable causal loops that arise in time travel?"

A few years later, another philosopher[112] gave a similar response to a paradox involving a causal loop similar to Lewis', a loop involving a time machine containing a book with instructions on how to make the time machine. The book travels into the past on the machine so it can be read—in order to make the machine.

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[109] Bradley Monton, "Time Travel Without Causal Loops," *The Philosophical Quarterly*, January 2009, pp. 54–67.

[110] Professor Hanley (note 105) says the answer to such questions is "straightforward": the information comes "from itself." I think the issue is rather deeper than that.

[111] See D. Franson, "Package Deal," in *Microcosmic Tales*, Taplinger 1980. The British philosopher J. R. Lucas had a similar scenario in mind when he wrote, in his book *A Treatise on Time and Space* (Methuen 1973, p. 50), "It is very important, not only for reasons of modesty, that I should not be able to use a Time Machine to go into a public library and read my own biography." Robert Heinlein didn't agree with Lucas: in his 1956 novel *The Door Into Summer* the protagonist, an inventor, travels thirty years into the future, where he reads some patent disclosures for inventions that he doesn't remember, even though they are in his name. He then returns to his own time and promptly files the patents!

[112] M. R. Levin, "Swords' Points," *Analysis*, March 1980, pp. 69–70.

In answer to the question "Who wrote the book about building a time machine?" the philosopher says this question is "no different from questions about where *anything* originally came from. We can ask about the origin of the atoms . . . their time line is not neatly presented to us. The atoms either go back endlessly, or if the Universe is finite, they just start. In either case the question of ultimate origin is as unanswerable as the question of the book's origin. What makes us think that when such questions are asked about the loop they are different and *ought* to be answerable is that the entire loop is open to inspection." While the instructions in the book don't tarnish, the book itself of course brings us back to our previous antique watch 'problem.' Suppose the book is brand-new at the start of the trip backward in time. Later, when the machine (and the book) have reached the end of the loop, just before beginning the trip back in time, have the pages turned yellow and brittle? If so, how do we account for the brand-new version? And if not, why not?

An analyst who takes strong exception to these two philosophers is Oxford physicist David Deutsch, who wrote (note 100) "the real problem with closed timelike lines under classical physics is that they could be used to generate knowledge in a way that conflicts with the principles of the philosophy of science, specifically with the evolutionary principle." What Deutsch is referring to is the metaphysical claim, attributed to the philosopher Karl Popper (see note 36 in Chap. 3), that *knowledge comes into existence only by evolutionary, rational processes* and that solutions to problems do not spring fully formed into the universe. One might call this the physics version of the work ethic—the creation of knowledge demands hard work!

Deutsch's idea had actually appeared *decades* earlier in a science fiction tale.[113] Time travel, discovered in the year 2007, is found to have a limited temporal reach into the future of 50 years, a limit due a law passed in 2057 banning time travelers from the past. To try to go past 2057 leads to a prompt arrest of the time traveler and a 'deportation' trip back to his own time. The story eventually explains that the law was passed precisely because of Deutsch's concern. As one character in the story explains, "Suppose [that one could travel more than 50 years ahead], then a time traveler from the past could get [new inventions], carry them back to his own time, and give them to scientists—which[would] cancel all the long period of invention which [produced the inventions]. Which [would] violate causal laws."

More recently, a philosopher has offered a quite interesting response to the Deutsch/Popper assertion. He writes (note 81), of information "appearing out of nowhere," that "These cases are puzzling, but they by no means show that the time travel scenarios in question are impossible or incoherent, *or even improbable*. We think it very improbable that . . . information should come from nowhere—but only because this does not happen very often. It does happen *sometimes*—for instance, when you say something and I mishear you. I think that you said something very

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[113] P. Anderson and G. Dickson, "Trespass," *Fantastic Story Quarterly*, Spring 1950.

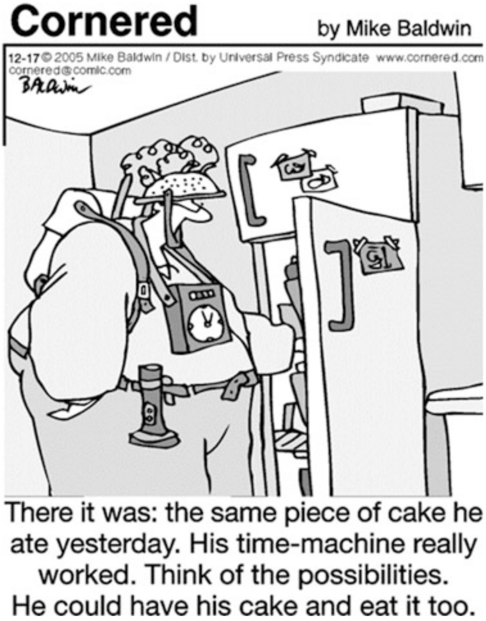
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There it was: the same piece of cake he ate yesterday. His time-machine really worked. Think of the possibilities. He could have his cake and eat it too.

Fig. 4.5 A curious paradox. CORNERED ©2005 Mike Baldwin. Reprinted with permission of UNIVERSAL UCLICK. All rights reserved

profound—something which neither of us would, in fact, ever have thought of. Where does the idea come from? If this sort of thing were to start occurring regularly [as via causal loops], then we would simply accept it without raising an eyebrow."

In the final chapter I'll discuss a dramatic example (due to two Russian physicists) on how an information-creating time loop might be constructed using a wormhole time machine. Such a time loop wouldn't pass muster with Deutsch, of course, and he would consider such a thing as being as objectionable as is creationism, the anti-evolution claim that purports to 'explain' fossils (with measured ages in the millions of years) by simply *declaring* them as having been made by God just a few thousand years ago.[114] Deutsch's position is considered by nearly all scientists today to be correct *for the specific case of creationism*, but the evolutionary principle may be on shakier ground with respect to declaring causal information time loops to be impossible.

While philosophers have struggled with information in a time loop, and most physicists have carefully stepped around the issue, science fiction has had lots of fun with information in causal loops. Here's a sampling of such tales:

(1) A man receives telephone calls from *two* versions of himself, one ten years in the future saying he absolutely must accept an invitation to fly to the Bahamas

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[114] *Why* would God do such a thing? Apparently 'just to have some fun with geologists and biologists,' as creationists call such ancient fossils 'sports of nature.'

that he will receive that very day, with the other version calling from tomorrow insisting that the plane will crash. What should he do?[115];

(2) Lovers who are irrevocably separated in time communicate by mail in one tale,[116] while lovers in another story[117] communicate via telephone calls to the ever more distant past (and yet, with the aid of a clever twist at the end, finally meet);
(3) A telephone lineman starts getting telephone calls from himself from 10 days in the future, with the first call telling him how to make the gadget to transmit such calls[118];
(4) A time traveling historian on a visit to A.D. 1528 from A.D. 2211 accidently gives a copy of the predictions of Nostrodamus to the prophet, thus explaining the predictions[119];
(5) A time machine experiment gone wrong allows thirteenth century Roger Bacon to meet twentieth century scientists, an encounter that explains the amazing forecasts in Bacon's *Opus Maius*[120];

Hollywood, too, has had some fun with information causal loops, with the best (in my opinion) example of that being the 1989 movie *Bill & Ted's Excellent Adventure*. In that film (where we learn that even the not very bright can be time travelers), a set of missing keys is necessary for the successful completion of a task. The two time travelers decide that after the task is done, they will go back in time, steal the keys (*that's* why they're missing!), and hide them so they can use them *now*. Where should they hide them? Why, "over there," says one of the boys, pointing at a hiding place—and sure enough, when they go over and look, the keys are there. They agree that once they have finished with the keys, it will be *most* important that they really do put the keys in the hiding place!

All of these examples that I've just given you, however, were *decades* too late to be the first in fiction about information in a time loop; that honor goes to the 1904 novel *The Panchronicon* by the lawyer Harold Steele MacKaye (1866–1928). An Edwardian literary time machine with style, the Panchronicon (literally, a 'machine for all time') swings on a rope tether around a steel post erected at the North Pole. By "cutting the meridians" faster than the sun does, it travels through space and time from 1898 New Hampshire to the London of three centuries earlier.[121] Using it, a time traveler fan of Shakespeare journeys from 1898 back to the bard, who is suffering from writer's block. There she whispers the magic lines from a play he is stuck on (lines she has memorized for her literary club meetings) into his receptive ear. Does this make Shakespeare a plagiarist? Of himself!?

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[115] G. Klein, "Party Line," *The Best from the Rest of the World* (D. A. Wolheim, editor), Doubleday 1976 (story originally published in France in 1973).

[116] J. Finney, "The Love Letter," *The Saturday Evening Post*, August 1959.

[117] T. N. Scortia, "When You Hear the Tone," *Galaxy Science Fiction*, January 1971. See also L. Padgett, "Line to Tomorrow," *Astounding Science Fiction*, November 1945.

[118] M. Leinster, "Sam, This Is You," *Galaxy Science Fiction*, May 1955. This story was later broadcast as an episode on the "X-Minus One" radio drama program. See also F. A. Reeds, "Forever Is Not So Long," *Astounding Science Fiction*, May 1942.

[119] L. Del Rey, "Fools' Errand," *Science Fiction Quarterly*, November 1951.

[120] N. Schachner, "Lost in the Dimensions," *Astounding Stories*, November 1937.

[121] 'Time traveling' by crossing time zones is an idea that one can trace at least as far back as to Edgar Allen Poe's 1841 short story "Three Sundays in a Week."

4.5 Sexual Paradoxes

> "Once time machines exist, no event is low probability if it is needed to make the past consistent."[122]

There are causal loops even stranger than the ones we have already discussed, hard as that may be to believe. These are the sexual paradoxes, first mentioned in 1931 by Nicholson in his letter to Hugo Gernsback. Not only science fiction writers, but philosophers, too, have found these particular paradoxes full of dramatic appeal. For example, as a challenge problem to the readers of a scholarly journal, the British philosopher Jonathan Harrison (1924–2014) posed the following bizarre, indeed astonishing, situation.[123] A young lady, Jocasta Jones, one day finds an ancient deep freezer containing a solidly frozen young man. She thaws him out and learns that his name is Dum, and that he possesses a book that describes how to make both a deep freezer and a time machine. They marry. Soon after they have a baby boy and name him Dee.

Years later, after reading his father's book, Dee makes a time machine. Dee and Dum, taking the book with them, get into the machine and begin a trip into the past. Running out of food during the lengthy journey, Dee kills his father and eats him. Arriving in the past, Dee destroys the time machine, builds a deep freezer (again, using the book), gets into it, and . . . wakes up to find that a young lady, one Jocasta Jones, has thawed him out. When asked his name he replies Dum and shows Jocasta his book; they marry, and . . . .

Harrison concluded this amazing tale with this question for his readers: "Did Jocasta commit a logically possible crime?" That issue is just the *surface* of an ocean of puzzles in this story! Jocasta's crime, of course, is that she has (if unwittingly) committed incest; readers who remember the Greek myth of Oedipus, and who his mother/wife was, will understand why Harrison named his female character as he did. But what of Dee's crime? He has, after all, eaten his father! But perhaps that isn't a crime at all, because Dee and Dum are one in the same, and is it really a crime to eat yourself? According to another philosopher, Murray MacBeath, Harrison's story is "a story so extravagant in its implications that it will be regarded as an effective *reductio ad absurdum* of the one dubious assumption on which the story rests: the possibility of time travel."[124]

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[122] From Robert Forward's 1992 novel *Timemaster*.

[123] J. Harrison, "Jocasta's Crime," *Analysis*, March 1979, p. 65.

[124] M. MacBeath, "Who Was Dr. Who's Father?" *Synthese*, June 1982, pp. 397–430.

This isn't to say that MacBeath was asserting that time travel is impossible. Indeed, he went on to declare that he did believe in the logical possibility of time travel, and his paper is devoted to discovering what thought to be incorrect in Harrison's story. He did that by retelling the story with what he believed are crucial modifications to make it sufficiently less outrageous that it could be taken at least somewhat seriously. In the new version, our hero, thawed out from a deep freezer, is now named Arthur. Arthur is, unfortunately, suffering from total amnesia (this is MacBeath's way of avoiding the psychological trauma of Dee remembering he ate Dum) and so, when asked his full name, he is himself sufficiently puzzled that he replies "Arthur who?" He is finally called (what else?) Arthur Who. And, as you can no doubt guess, his son (who is a genius and gets a PhD at age 14 on a dissertation dealing with the physics of time travel) becomes Dr. Who!

We are then told of a trip back into the past by the two, of the eating of the father (Arthur Who) by the son, of the entering of the deep freezer by Dr. Who, etc. etc. The whole business is quite entertaining and *at least* as complex as Harrison's original story. Just *how* complex is summed up in MacBeath's last, wonderful line: "The Who who was Dr. Who's father was not Dr. Who—that is, not the Dr. Who whose father he was."

MacBeath wasn't the only one that Harrison's story fascinated, and nearly a dozen replies to it were received in addition to MacBeath's. One, in particular, made the thought-provoking observation (see note 112) that not only has Jocasta committed incest but she has done so with a single act of intercourse. As discussed earlier, the events on a causal loop do not happen endlessly but rather only once; thus, Jocasta thaws Dum (Dee) out just once, she marries him just once, and the two consummate their marriage just once. Ordinarily we think it takes two sexual acts to commit incest, the first resulting in the birth of a child, and the second being a parent's union with that child, but this is not so in a causal loop. Time travel *is* an odd business.

Another philosopher replied to Harrison's story with a quite interesting claim, one that had actually been thought to be true for decades—but which today is recognized to be false. The claim was that, irrespective of physics, Harrison's story was biologically flawed and fatally so. As that philosopher wrote, "The biological problem is the following. Dee is the son of Dum and Jocasta. So Dee obtained half his genes from Dum and half from Jocasta. But Dum is diachronically identical with Dee and is therefore genotypically identical with him (that is, himself). That is, Dee is both genotypically identical and distinct from Dum, which is absurd."[125]

That this isn't true was pointed out by a philosopher many years later. In his paper we read this tale: "Suppose Adam travels [far] back in time … where he meets his mother Betty, mates with her and has a child which is himself. Is this possible biologically? Yes ... as follows ... on the grounds that we have total replication of Adam's genome."[126] (The *genome* is the totality of genes taken over all gene sites.) Now, suppose each such site holds two genes and, as Dowe points out, in sexual reproduction the father passes on to his offspring one gene for each gene site, to go with the gene the mother gives to each site. To exactly reproduce himself, then, the time traveling Adam 'simply' has to give his offspring, *at each site*, the gene that he has for that site that did *not* come from Betty. Thus, the offspring—baby Adam—ends up with a genome *precisely identical* to the time traveling Adam. This is, of course, an *extraordinarily unlikely* event, as the human genome has tens of thousands of genes. The probability that each and every site gets the 'right' gene from the time traveling Adam is therefore essentially zero. But it isn't *actually* zero and, as the quotation that opens this section says, a low probability to an event isn't a roadblock to its occurrence if that event is required for consistency.

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[125] W. Godfrey-Smith, "Traveling in Time," *Analysis*, March 1980, pp. 72–73. This false claim had already been raised by a physicist (L. S. Schulman, "Tachyon Paradoxes," *American Journal of Physics*, May 1971, pp. 481–484), and even earlier by a science fiction writer (P. Anderson, "Time Patrol," *Magazine of Fantasy and Science Fiction*, May 1955).

While certainly instructive, the sexual paradox stories by Harrison and MacBeath are remiss in not indicating that the concepts they are dealing with have long been a staple of science fiction, and that the sexual paradoxes received much critical analysis in that genre long before philosophers (and physicists, too) discovered them. From science fiction, for example, we have a tale of young man who travels backward in time 1250 years, from A.D. 3207 to 1957, to become his own grandfather fifty generations removed.[127] And even that is tame compared to the sexual paradoxes other science fiction writers conjured up before philosophers began to discuss them.

In another story,[128] written decades before Harrison's and MacBeath's papers, we meet a young lady caught up in a mind twisting affair in which the mystery of a causal loop is the least of her troubles. In 1957 a girl is born, and after 20 years of intense competition with her mother (who has an uncanny ability to predict the future), she travels back from 1977 to a few months before her own birth. She becomes pregnant (by a man who she later discovers is her father) and gives birth to a girl. The new mother has, of course, knowledge of all that will happen during the next 20 years, including the fact that she will have an intense competition with her rebellious daughter ... .

While writers of stories like these in the early 1950s were there as trailblazers, it is a tale that appeared as the 1950s ended that is today generally acknowledged as the best sexual paradox story ever written.[129] We are given only a hint of what is to come when a character listens to a song called "I'm My Own Grandpaw!" In 1945, a newborn girl, Jane, is found on the steps of an orphanage. At age 18, in 1963, she has a one-night affair with a mysterious stranger that leaves her pregnant. Some months later, during the birth of a daughter, it is discovered that Jane actually has a double set of sexual organs, and because the female set has been ruined by the pregnancy, doctors restore her as a man. Soon after, the baby girl mysteriously disappears from the hospital ward. Years later, in 1970, Jane (now a man, of course) meets another stranger who uses a time machine to transport both of them back to April 3, 1963. By April 24 male-Jane meets female-Jane and impregnates her (and so now we know who the mysterious stranger was during the one-night affair!). Meanwhile, the stranger with the time machine travels forward to March 10, 1964, a little after female-Jane has given birth, kidnaps the baby from the hospital (thus clearing-up another mystery!), takes her back to September 20, 1945, and leaves her on the steps of the orphanage. And so we see that Jane is her own mother *and father*, thus out-doing all previous tales about self-parenting.

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[126] Phil Dowe, "The Coincidences of Time Travel," *Philosophy of Science*, July 2003, pp. 574–589. See also J. Berkovich, "On Chance in Causal Loops," *Mind*, January 2001, pp. 1–23, and P. Dowe, "Causal Loops and Independence of Causal Facts," *Philosophy of Science*, September 2001, pp. 89–97.

[127] R. Dee (this is *not* the 'Dee' of Harrison's story!), "The Poundstone Paradox," *Magazine of Fantasy and Science Fiction*, May 1954.

[128] C. L. Harness, "Child By Chronos," *Magazine of Fantasy and Science Fiction*, June 1953.

[129] R. Heinlein, "All You Zombies—," *Magazine of Fantasy and Science Fiction*, March 1959.

This is pretty impressive stuff, but Heinlein still has one more twist for us. After leaving baby-Jane in 1945, the time machine stranger returns to April 24, 1963, retrieves male-Jane (who has just kissed female-Jane goodnight after fathering her-himself in herself), and takes him to 1985 where he recruits him into the Temporal Service—and finally, the stranger jumps forward to 1999, his ‘real time.’ At the end we at last learn that the stranger is, in fact, an even older version of male-Jane—*all* the central characters in the entire story are the *same* individual at various points along a single, highly twisted world line. The lone character in Heinlein’s tale is truly a self-made man/woman in every sense of the phrase! This ultimate act of *creatio ex nihilo* has, correctly I think, been called “smaller than the minimal loop.”[130]

Jane, in all her/his versions, is the only character in the story that appears to have purpose. In terrifying words that describe a causal loop, Heinlein ends the tale with an explanation of the story’s title: “The Snake That Eats Its Own Tail, Forever and Ever. I know where I came from—but where did all you zombies come from? . . . You aren’t really there at all. There isn’t anybody but me—Jane—here alone in the dark. I miss you dreadfully!” In a December 1958 letter to his literary agent, Heinlein wrote of this amazing tale, “I *hope* that I have written in that story the Farthest South in time paradoxes.” In my opinion, he did.

The sexual paradox has continued to fascinate science fiction writers up to the present day. In the novel *Timemaster* (note 122), for example, the hero at one point spends a night with his wife—and with two versions of himself from the future. He will, of course, experience that night two more times! Later, he becomes upset when his wife runs off with one of the older versions, but he quickly calms down when he considers that eventually *he* will be the older version. Consider, too, a story[131] that tells of a young man hunting the father who, years before, had abandoned him in a burning house. The death of the young man's mother in the flames has sent him on a 10 year quest for revenge up and down what is literally a river of time, a river on which to travel in one direction ("up time") is to move into the past, whereas moving "down time" leads to the future. Eventually he corners the father and, despite the man's pleading, kills him. It is only later, after examining papers he finds in his father's pocket, that the young man realizes he has killed his *future* self (Benford, a physicist, knows the pitfalls of time travel, and you'll notice that there is no autoinfanticide paradox here).

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[130] S. Lem, “The Time-Travel Story and Related Matters of SF Structuring,” *Science Fiction Studies*, Spring 1974, pp. 143–154.

[131] G. Benford, “Down the River Road,” *After the King: Stories in Honor of J. R. Tolkien* (C. Tolkien and M. Greenberg, editors), Tor 1991.

4.6 Splitting Universes and Time Travel

> "In all time travel stories where someone enters the past the past is necessarily altered. The only way the logical contradictions created by such a premise can be resolved is by positing a Universe that splits into separate branches the instant the past is entered."[132]

One early science fiction technique for allowing backward time travel and a changeable past, while still avoiding paradoxes, is that of alternate universes. According to this idea, if a time traveler journeys into the past and introduces a change (indeed, his very journey may be the change) then, as the above quote states, reality splits into two versions, with one fork representing the result of the change and the other fork being the original reality before the change. (To a fifth-dimensional observer, of course, all conceivable forks, all possible four-dimensional spacetimes, have always existed.) Indeed, according to this view the entire universe is splitting, at every microinstant, along every alternative decision path for every particle in the cosmos! This is often called the theory of *alternate realities with parallel time tracks*.

Such a seemingly fantastic view seems to actually have some scientific plausibility because of the so-called *many-worlds interpretation* (MWI) of quantum mechanics, pioneered in physics by Hugh Everett III (1930–1982), in a 1957 Princeton doctoral dissertation. Everett's theory is the antithesis of what is commonly called the *collapse of the wave function*, the idea that all potential possibilities have a non-zero possibility until a consciousness actually decides or observes which one will actually *be*. That quantum mechanical concept gets its name from the probabilistic wave equation formulated in 1926 by the German physicist Erwin Schrödinger (1887–1961). Before the observation, all possible futures have various values of probability; after the observation (which 'collapses' the wave function) exactly *one* of those futures (*the* future) has probability 1 and all the others have probability 0.

The MWI idea can be seen in Hale's story "Hands Off," discussed earlier, and in art *40 years* before that! With almost certainly a theological twist, consider the

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[132] M. Gardner, "Mathematical Games," *Scientific American*, March 1979.

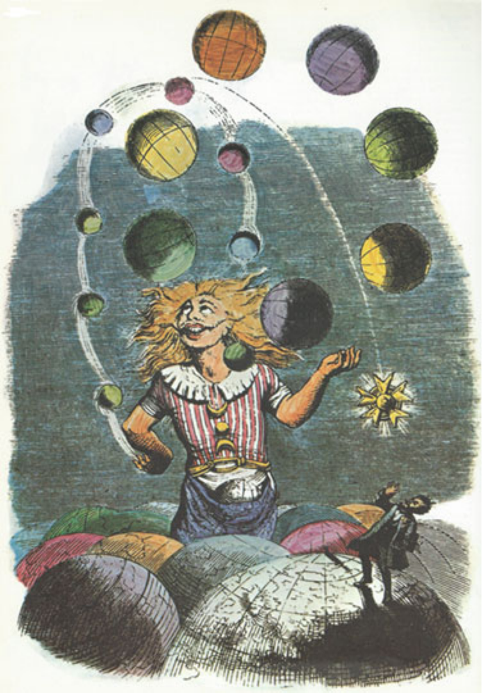

Fig. 4.6 Grandville's Infinity Juggler of many-worlds

beautiful illustration in the 1844 book *Un Autre Monde* (*Another World*), reproduced in Fig. 4.6. Known either as "The Infinity Juggler" or "The Juggler of Worlds," it is the work of the French artist Jean-Ignace Isidore Gérard (1803–1847), who published under the name 'Grandville.' The juggler—Grandville's version of Hale's mentor—appears as a court jester who is clearly having fun manipulating his multitude of worlds, while the man (humanity?) in the foreground watches. The man appears to be simultaneously fearful and fascinated, involved yet clearly impotent. Is Earth one of the worlds among which the Jester stands, or is it one of those flying through space? Or is Earth, perhaps, simply the unfortunate world ingloriously stuffed down the front of the Jester's pants? (That would surely explain a lot!) If born a hundred years later, Grandville would surely have found work as an artist in the imaginative world of the science fiction pulps.

Early science fiction stories that treat the collapsing wave function concept can be traced back to the late 1930s and early 1940s.[133] A particularly interesting example is the story of an inventor who, while trying to build a radio with which to signal Mars, accidently stumbles on the "temporal-aberrant carrier wave" and thus establishes contact with a universe that forked off of ours in 1863 when Robert E. Lee *won* the Battle of Gettysburg![134] In Everett's MWI, however, the wave function of the universe does *not* collapse. Indeed, it *couldn't*, because there is no observer external to the entire universe (we are talking science now, not of theology and God); instead, the wave function 'splits' at every decision point in spacetime. Although this leads to a multitude of realities *far* beyond comprehension, cosmologists still tend to like the MWI because it avoids the puzzle of having to produce an observer 'outside the universe.'

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[133] See, for example, Jack Williamson's 1938 novel *The Legion of Time*, and C. L. Moore's, "Tryst in Time," *Astounding Stories*, December 1936. L. Sprague de Camp (1907–2000), too, was an early pioneer in the exploration of the MWI idea in science fiction long *before* Everett. In his 1941 novel *Lest Darkness Fall*, for example, he uses the analogy of a tree (the "main time line") that is always sprouting new branches.

It's important to understand that the MWI is different from yet another idea popular in science fiction, that of *parallel universes* (see again the third discussion question at the end of Chap. 3). In parallel universes *all* possibilities *always* exist, independent and parallel in time. In the MWI, on the other hand, ever more universes are continually coming into existence. Unlike the MWI, which can at least claim a scientific basis (quantum mechanics), there is no analogous theory for parallel universes. But, of course, even though lacking a theory, nonetheless science fiction writers have been quite inventive with the idea because parallel universes offer a way to avoid (at least some) causal loops.

One clever, early pulp story[135] illustrates how that works. To improve the performance of his time machine, an inventor needs batteries with tremendous energy density, a density far in advance of the batteries in the present. Unable to travel far into the future—if he *could* obtain them there, then of course a causal loop (the very entity we wish to avoid) would be created upon his bringing them back to the present—his assistant first travels back to 1851. There he leaves a note on desk of a well-known experimenter, with a plea for him to devote his life to battery research; a copy of the 1937 *Electrical Handbook* is left with the note as proof that there really has been a visit from the future! Before returning to the present, the assistant takes a sheet of (new) 1847 five-cent stamps from the experimenter's desk.

Returning to the present, which is now different (a new time track, in accordance with the splitting-universe idea), the powerful batteries *are* readily available *because* the experimenter believed the note. Buying several of them, using money obtained by selling the pristine 1847 stamps to a collector, the assistant returns to a slightly earlier 1851 than before (to *before* the fork in time!), watches himself appear[136] and leave the note and the handbook, and *then, unobserved, the assistant removes both*: Thus, upon returning once more to the present, he finds all is as before—except now he and the inventor have the powerful batteries. As before, one might ask where the batteries came from, but unlike the previous mystery of information-creating causal loops, the answer is clear and non-mysterious. *They came from the hard work of the experimenter on a different time track.* Such shuttling back-and-forth between time tracks is the signature of what is called a *cross-time* story, a device to avoid paradoxes while still allowing for changing the past. The first example of this time travel sub-genre had actually appeared 4 years earlier.[137]

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[134] N. Bond, "Parallel in Time," *Thrilling Wonder Stories*, June 1940. See also S. N. Faber, "Trans Dimensional Imports," *Isaac Asimov's Science Fiction Magazine*, August 1980.

[135] W. Sell, "Other Tracks," *Astounding Science Fiction*, October 1938.

[136] Just like Marty McFly does at the end of the 1985 film *Back to the Future*. The movie is fun, but pulp science fiction did it first.

In another cross-time tale from modern times, we read of the horrible fate suffered by a man when an experiment in a Princeton physics lab goes wrong.[138] It is discovered, too late, that parallel time tracks are not simply grooves into which you drop, like a ball, after leaving the time track of our world. Each version of a person in each world is not like a ball rolling down a groove from past to future. Rather, each world's time track is just a line on a smooth surface; as the man is told, during a temporary stay in a world still close to his (our) original world, "We gave you a push sideways, and you moved off your original line—but instead of dropping into the next groove, you've just kept on rolling across the surface, from one line to the next, at an angle. There are no grooves, nothing to stop you from sliding on across the different lines forever. You have the same futureward vector as you started with, but you've added a small cross-time vector, as well." And so the man drifts cross-time, and gradually the worlds he experiences grow ever more alien.[139]

The science fiction is undeniably fun, but for this book the underlying *scientific* theory of time travel is classical (that is, non-quantum) general relativity, and that theory has nothing to say about alternative time tracks in multiple worlds. For most time travel theoreticians there is *one* time track, and the past of our world is unique and inviolate. I agree with the great quantum physicist J. S. Bell (1928–1990), who wrote of Everett's theory that "if such a theory were taken seriously it would hardly be possible to take anything else seriously."[140] As Bell further observed, in the MWI "there is no association of the particular present with any particular past," a quite strange idea that had already appeared in science fiction years earlier.[141]

While most early time travel analysts did base their work just on classical general relativity, there *are* now many more who think quantum mechanics itself, independent of its interpretation, has much to contribute as well. Perhaps, in fact, it may make an absolutely crucial contribution to the theoretical basis of time travel. One analyst who believes this (along with an even stronger belief in the MWI) is the British physicist David Deustch (note 100), who holds that general relativity is not the proper theory with which to study the physical effects of CTLs. He believes that the traditional mathematical machinery of general relativity actually obscures, rather than clarifies, the difficult task of separating the merely counter-intuitive from the unphysical.

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[137] M. Leinster, "Sidewise in Time," *Astounding Stories*, June 1934. Splitting universes with multiple time tracks and time loops became quite popular after Leinster's and Sell's stories; you can find the basic idea repeated yet again in Alfred Bester's "The Probable Man," *Astounding Science Fiction*, July 1941, for example, in which each new journey into the past causes the future to fan out into an infinity of new time tracks.

[138] L. Watt-Evans, "The Drifter," *Amazing Stories*, October 1991.

[139] In Jack Haldeman's 1990 novel *The Hemingway Hoax* we read that "there is not just one [parallel] universe, but actually uncountable zillions of them."

[140] In "Quantum Mechanics for Cosmologists," *Speakable and Unspeakable in Quantum Mechanics*, Cambridge University Press 1987.

[141] J. R. Pierce, "Mr. Kinkaid's Pasts," *Magazine of Fantasy & Science Fiction*, August 1953.

Indeed, Deutsch calls the conventional spacetime methods, based on general relativity and differential geometry, *perverse*. He also does not like the conceptual problems raised by general relativity's wormholes and singularities. Any non-quantum mechanical discussion, he says, of the "pathologies" of backward time travel is simply not adequate. Deutsch divides these pathologies into two fundamental classes: (1) paradoxical constraints, such as the free-will issue seemingly raised by the grandfather paradox, and (2) causal information loops. Deutsch claims that his quantum mechanical analyses show that the first class of pathologies simply does not occur, because the past that the time traveler enters is the past of a world different from the one he has left. Further, his results also show (to him) that the pathologies of the second class may be "avoidable." These are not the views among the majority of time travel students, however (that does *not* mean Deutsch is wrong!), and general relativity *is* the standard tool used by the majority of time travel theoreticians. When quantum mechanics does enter the calculations of most analysts, it is generally on an *ad hoc* basis.

More concerning for the MWI view is a result reported in 2004, that a macroscopic object (a human time traveler, for example) attempting to traverse a wormhole time machine (to be discussed in some detail in Chap. 6) "must necessarily undergo violent interactions with the time machine," interactions *so* violent that they must "cause the object to disintegrate." The different pieces of the now certainly dead time traveler would emerge from the wormhole in different worlds—this is definitely not a result likely to encourage volunteers for the first time machine trip![142]

So, many physicists and philosophers, not sharing Deutsch's position,[143] tend to agree with Bell, including the late John Wheeler (Everett's thesis advisor!), who wrote of the MWI "I once subscribed to it. In retrospect, however, it looks like the wrong track. … Its infinitely many unobservable worlds make a heavy load of metaphysical baggage."[144] Agreeing with Wheeler was a philosopher who called the MWI "highly controversial" and declared that "few working physicists take it seriously."[145] Perhaps even more damning was a physicist's statement that "the idea of 10^{100}+ slightly imperfect copies of (the universe) all constantly splitting into further copies . . . is not easy to reconcile with commonsense. Here is schizophrenia with a vengeance."[146] Or, as one science fiction writer bluntly put it, in a tale of the inventor of the "chronomotive impulse belt" (which allows moving between the *two* parallel worlds that are all that exist), the MWI is the "Doctrine of Infinite Redundancy—which is, of course, utter nonsense."[147]

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[142] A. Everett, "Time Travel Paradoxes, Path Integrals, and the Many Worlds Interpretation of Quantum Mechanics," *Physical Review D*, June 25, 2004, pp. 124023–1:124023–14.

[143] For a modern philosophical argument specifically rebutting Deutsch's enthusiasm for the MWI, see Theodore Sider, "A New Grandfather Paradox?" *Philosophy and Phenomenological Research*, March 1997, pp. 139–144.

[144] See note 34 in Chap. 3.

Deutsch's position does raise the obvious question of what motivates a quantum theoretician to study CTLs at all, given that they originate in general relativity and *not* in quantum mechanics. Deutsch's response is that although CTLs did indeed originate in classical Einsteinian general relativity, the still incomplete theory of quantum gravity *does* predict CTLs, too. And that is an exciting observation for time travel enthusiasts because, as Deutsch writes, the results of his quantum studies of CTLs show that "contrary to what has usually been assumed, there is no reason in what we know of fundamental physics why closed timelike lines should not exist." That view was later endorsed by other physicists who wrote, after a quantum mechanical study of how a particle could transit a time machine spacetime in a physically consistent manner, "there is no contradiction between the postulates of quantum mechanics and the possible existence of causality violation in general relativity."[148]

Long before these scientific endorsements, science fiction had enthusiastically embraced the many-worlds idea and its connection with time travel. The first such tale[149] appeared when Everett was just 3 years old; it put forth the insightful observation that although alternate time tracks may allow changing the past for the better (something that can't be done, for better *or* for worse, with a single time track), in the end any such change may still be futile. As Daniels' time traveler puts it, "I did have an idea to . . . go back to make past ages more livable. Terrible things have happened in history, you know. But it isn't any use. Think, for instance, of the martyrs and the things they suffered. I could go back and save them those wrongs. And yet all the time . . . they would still have known their unhappiness and their agony, because in this world-line those things happened. At the end, it's all unchangeable; it merely unrolls before us."[150] Many years later, in a critique of the many-worlds idea, a philosopher/physicist echoed Daniels' words: [In the world] that I (subjectively) experience I may blunder, but [in another world], with equal actuality, I triumph gloriously. The Everett interpretation can be used this way to mitigate sorrows, but this use is two-edged, for it equally well implies the speciousness of happiness."[151]

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[145] R. A. Healy, "How Many Worlds?" *Nous*, November 1984, pp. 591–616.

[146] B. S. DeWitt, "Quantum Mechanics and Reality,' in *The Many-Worlds Interpretation of Quantum Mechanics* (B. S. DeWitt and N. Graham, editors), Princeton 1973.

[147] B. Shaw, "What Time Do You Call This?" *Amazing Science Fiction*, September 1971. When a bank robber in one world tries to make his escape into the other world, he literally runs into 'himself' trying to escape after robbing the 'same' bank in the parallel world!

[148] D. S. Goldwirth *et al.*, "Quantum Propagator for a Nonrelativistic Particle in the Vicinity of a Time Machine," *Physical Review D*, April 15, 1994, pp. 3951–3957. See, too, the earlier D. S. Goldwirth *et al.*, "The Breakdown of Quantum Mechanics in the Presence of Time Machines," *General Relativity and Gravitation*, January 1993, pp. 7–13.

[149] D. R. Daniels, "The Branches of Time," *Wonder Stories*, August 1935.

The editorial introduction to Daniels' pioneering tale is quite interesting: the opening line is "To say that this short story contains some revolutionary time-travel theories would be putting it exceedingly mild." That editor then went on to tell his readers, with great enthusiasm, that "when the author . . . submitted this story to us, his accompanying letter stated that in it he had settled the time-travel question once and for all. We must admit that a broad, unbelieving grin spread over our countenances when the author dared make this assertion. BUT—the smile soon left our faces . . . [T]o our chagrin, Mr. Daniels had really propounded so many brand new ideas about time and time-travel, and such logical ones—*that he has not left one loophole in his argument*!"

John W. Campbell (1910–1971), the first (and only) editor of *Astounding Science Fiction* (today's *Analog*), called alternate time track stories "mutant" because they represented the first new innovation (or mutation) in the time travel concept since H. G. Wells. Campbell incorrectly claimed *The Legion of Time* (note 133) was the first such tale (see Campbell's editorial in the May 1938 issue of *Astounding*) , and that "Other Tracks" (note 135) was the second, but in fact it was Daniels who was first with splitting time tracks in science fiction. After Daniels the concept quickly became part of standard science fiction lore and could be used by other writers with little explanation. For example, just a little more than a decade later one author did not have to say much about his "First Law of Chronistics," which determines the development of "the branches of Fan-Shaped time." It was sufficient for his readers to learn that should a time traveler to the past change anything, a parallel branch of time would be created on which the time traveler would be trapped: "The man who interfered with the space-time matrix, displacing even a comma in the great scroll of time, would be cut-off from his origin forever."[152]

Still, if there is one thing we can say about science fiction, it's that no 'rule' is immune to challenge. Decades after Daniels' tale put forth the MWI, we find the well-known author James Blish (note 100 in Chap. 1) *rejecting* it. In a story about the reception of radio signals from the future, we read of one character telling another "I *was* going to do all those things. There were no alternatives, no fanciful 'branches in time,' no decision-points that might be altered to make the future change. My future, like yours … and everybody else's, was fixed. It didn't matter a snap whether or not I had a decent motive for what I was going to do; I was going to do it anyhow. Cause and effect … just don't exist. One event follows another because events are just as indestructible in space-time as matter and energy are."[153]

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[150] These sad, resigned words were written when the author, David R. Daniels (1915–1936), was just twenty years old. A year later he committed suicide.

[151] A. Shimony, "Events and Processes in the Quantum World," *Quantum Concepts in Space and Time* (R. Penrose and C. J. Isham, editors), Oxford University Press 1986.

[152] J. MacCreigh, "A Hitch in Time," *Thrilling Wonder Stories*, June 1947.

This denial of the MWI is simply an author's choice, of course, for whatever story effect is desired, and others may make different choices. Isaac Asimov, for example, used the MWI idea in in the story of a time traveler who journeys back to 1871 London, to retrieve a lost Gilbert and Sullivan operetta (*Thespis*). When he returns to the present he finds that his wife Mary (who was alive when he left) has been dead for a year on the new time track that his actions in the past have created. As the story ends, the devastated time traveler thinks "I had changed history. I could never go back. I had gained *Thespis*. I had lost Mary."[154] This sad fate is repeated in another story of a time traveler lost in an infinitude of time tracks with no hope of ever finding his way home: "In all of time, how many, many worlds there must be. How to find a single twig in such a forest?"[155]

Splitting universes have been used in literary works outside the genre of science fiction, as well. Examples include "The Garden of Forking Paths" by the Argentine writer J. L. Borges, the first play J. B. Priestly wrote (the 1932 *Dangerous Corner*), John Updike's 1997 novel *Toward the End of Time*, and Gore Vidal's 1998 novel *The Smithsonian Institution*. Typical of these fictional fantasies about splitting universes is a tale (anticipating Asimov's) by Lord Dunsany (1876–1957)—the Irish writer Edward Plunkett—the story of a man who goes back in time to correct "two or three mistakes he had made in his life."[156] This he successfully does, but the result is a new, subtly different subsequent history. The differences are not infinitely subtle, however; after the changes, he finds that his home, his wife, and all the delicate details of his life have vanished. As he relates to a visitor at the lunatic asylum he is now confined to, as the result of his despair, "I tell you I'm lost. Can't you realize that I'm lost in time? I tell you that you can find your way traveling the length of Orion, sooner than you shall find it among the years … Don't go back down the years trying to alter anything … Don't even wish to … [T]he whole length of the Milky Way is more easily traveled than time, amongst whose terrible ages I am lost."

In writing for a mass audience, rather than just for the more limited science fiction and fantasy one, perhaps the best known literary work of alternate history is the classic 1953 novel *Bring the Jubilee* by Ward Moore (1903–1978). In that work Lee wins the Battle of Gettysburg, and the South wins the Civil War. Using a time machine, a historian travels from 1952 (of the world in which the South wins) into the past of 1863 to study the battle, where he inadvertently disrupts events to the point that the North wins; that is, reality splits and the newly created fork represents the time track of *our* world. The historian is trapped on this new fork, cut off forever from his original time track. The entire novel is in the form of a discovered manuscript, written in 1873 and found in 1953, and the pathos of the ultimate isolation endows the novel with great emotional impact.

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[153] J. Blish, "Beep," *Galaxy Science Fiction*, February 1954.

[154] I. Asimov, "Fair Exchange?" *Asimov's Science Fiction Adventure Magazine*, Fall 1978.

[155] M. F. Flynn, "The Forest of Time," *Analog Science Fiction*, June 1987.

[156] Lord Dunsany, "Lost," *The Fourth Book of Jorkens*, Arkham House 1948.

A 1992 novel on the same theme, Harry Turtledove's *The Guns of the South*, begins with a fascinating premise but then misses the crucial distinction between a single versus multiple time tracks. In that work racists from the future (2014) arrive by time machine at Lee's 1864 winter camp. They bring with them AK-47 automatic assault rifles and offer to supply Lee's army with all it can use. Lee accepts and the South wins the Civil War. The future, of course, changes—or does it? The time travelers have brought back books from the future showing that the South lost the war, so the implication is that history must have forked. So far, so good. But all through the novel, the time travelers move back and forth between the nineteenth and the twenty-first centuries, apparently finding their own time unchanged. And if that is so, then the whole point of the story vanishes. Why all the effort to change history when it is clear that nothing has changed? The novel is entertaining reading (Turtledove is a trained historian), but I believe Moore's novel to be the superior work of science fiction.

I'll end this discussion on splitting universes with a startling theological issue raised by a philosopher.[157] Arguing that God cannot branch into multiple time tracks because God is unique, the conclusion seems inescapable that God therefore exists on exactly one of how ever many different time tracks there may be. What if that chosen time track isn't ours? Then, concludes the philosopher, Nietzsche's nineteenth-century metaphorical claim that "God is dead" (for us) might literally be true! He admits that this is "fanciful," but still ……....

4.7 For Further Discussion

In an afterword to his story "Dead City" (*Thrilling Wonder Stories*, Summer 1946), Murray Leinster muses "You've heard the old argument that a man can't travel backward in time because he might kill his grandfather. I've wondered why nobody has argued that a man can't travel forward in time because he might be killed by his grandson." One possible answer to Leinster is that *if*, at the moment the forward-bound time traveler departs, he has not yet sired a child, *then* there simply wouldn't be a murderous grandson waiting for him in the future. Perhaps, however, Leinster had this somewhat more

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[157] Q. Smith, "A New Topology of Temporal and Atemporal Permanence," *Nous*, June 1989, pp. 307–330.

complicated scenario in mind: After the time traveler arrives in the future he is attacked by a mysterious stranger but survives, and later returns to the present. He then sires a child who will be the parent of that mysterious stranger. (As far as I know, this plot line has not appeared in a science fiction story.) Contrary to Leinster's view, explain why the *possibility* of being killed by a grandson is not a reason for forbidding the possibility of a trip in time (in either direction).

In his causal loop paper (note 105) the University of Delaware philosopher Richard Hanley correctly writes (on p. 146) "physicists have tried to avoid free will problems by ignoring causal loops involving intentional agency," and partly illustrates this claim with the autoinfanticide paradox, writing of the attempt of a time traveler to kill his younger self as inevitably failing because "the past is apparently brought about willy-nilly." (Hanley unfortunately then uses the story "Thompson's Time Traveling Theory" as an example of this—see note 77, and the end of the "Introduction"—when it is that time traveler's *grandfather* who is the intended target.) Discuss the merits of Hanley's claim, keeping in mind the end of Sect. 4.3 (in particular, note 81). If you are interested in genetics and astronomy as well as in time travel, then for extra credit comment on Hanley's claim (p. 137) that "one can extract information about my DNA from . . . my astrological chart."

The fictional killing of Hitler was imagined in print even before World War II, in Geoffrey Household's intense 1939 novel *Rogue Male* (made into the 1941 film *Man Hunt*). And so it's not surprising that one of the popular change-the-past themes in science fiction is that of a time traveler killing the Führer. (This idea, somewhat oddly, appeared in the debates leading up to the 2016 American Presidential election, when one of the candidates, to show the toughness of his character—even though he opposed abortion—declared "Hell, yes, I'd kill baby Hitler! You gotta step up, man." This candidate did elaborate a bit, stating there might be some risk involved with tampering with the past.) Stories in this sub-genre include E. Norden's "The Primal Solution" (*Magazine of Fantasy & Science Fiction*, July 1977), W. R. Thompson's "The Plot to Save Hitler" (*Analog*, September 1993), L. del Rey's "My Name Is Legion" (*Astounding Science Fiction*, June 1942), and R. M. Farley's "I

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Killed Hitler" (*Weird Tales*, July 1941). Read some of these tales and compare the various repercussions envisioned by the authors following an assassination of Hitler by a time traveler.

After our discussion of Heinlein's time travel masterpiece "All You Zombies—," you might think it impossible to write a new story that exceeds it in complexity. That might well be true, but a modern masterpiece by Ted Chiang certainly gives it a good run for the money. "The Merchant and the Alchemist's Gate" (*Magazine of Fantasy & Science Fiction*, September 2007) uses a 'wormhole' that connects the present to the future 20 years hence, and it is stuffed with intertwined causal loops and information bootstraps. Read it and keep track of all such occurrences. How many did you find? The last line of the story clearly expresses the view that the past cannot be changed: "Nothing erases the past. There is repentance, there is atonement, and there is forgiveness. That is all, but that is enough." Is the story always faithful to this view of time travel?

In his paper (note 126) on the coincidences of time travel, the University of Queensland philosopher Phil Dowe writes "It's true that remote time travel [into the very distant past] does not allow for causal loops . . ." *Is* this true? Consider, as you think about this, the story "Time's Arrow" (*Science-Fantasy*, Summer 1950) by Arthur C. Clarke. In that tale geologists have just discovered, in a remote desert, the fossilized tracks of a monstrous creature, from fifty million years ago, tracks that indicate that the beast was in hot pursuit of fleeing prey. Before the geologists can unearth the entire set of tracks, to see if the pursuit was successfully completed, they are visited by a physicist who just happens to be conducting near-by experiments in time travel. (This proximity is explained by noting what better place to conduct time travel experiments, powered by atomic energy, than in a remote desert?) At one point during the visit, after being told of the ancient pursuit frozen in rock, the physicist muses "It would save you a lot of trouble, wouldn't it, if you could actually *see* what took place in the past, without having to infer it by these laborious and uncertain [geological] methods." This comment results in the Chief geologist paying a visit to the physicist's lab. After driving over in a car equipped with tires having "an odd zigzag pattern" in the tread,

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an accident suddenly sends the entire lab into the past. Soon after, the other geologists unearth the rest of the fossilized tracks, and learn what the creature's prey had been when they see a zigzag pattern in the rocks, tracks that show "the great reptile was about to make the final leap upon its desperately fleeing prey." Can you see how to modify this story so as to have a causal loop involving the very distant past? (For perhaps even more inspiration on thinking about causal loops, watch the 1980 movie *The Final Countdown*. In it the designer of a modern naval warship that temporarily travels back through time to the Pearl Harbor of December 6, 1941, turns out to be a crew member who was accidently left behind in the past. In the past he *will be* able to design the ship because he already knows how it *was* designed—by himself!)

Comment, at length, on the cartoon shown in Fig. 4.5. (Does it make logical sense?)

In the story "Salvation" by Jerry Oltion (*Analog*, December 2007) a physicist approaches the Universal Church of the Divine Revelation for money to build a time machine. He is blunt in making his case: "You could go back in time and meet Jesus. Assuming he existed." That statement causes (it should come as no surprise) not just a bit of pandemonium but, nonetheless, an influential Church leader decides to provide the funding. Why? Because later, while sitting in his office as he talks with the physicist, a sheet of paper suddenly appears in the air above the leader's desk and then flutters down to land on the telephone. Picking the paper up, the leader sees it is a sheet of his own letterhead, with writing in his own angular, precise handwriting, saying "It works. Give him the money. You almost named the dog Solomon." This convinces the leader because, as we are told, "Paper appearing out of nowhere was a good trick, but it might easily be just that: a trick. Duplicating his letterhead and his handwriting wouldn't be all that difficult either. [On the other hand] knowing the name [the leader] had considered but rejected for his German Shepard 15 years ago was a different level of feat entirely." The physicist seems to be startled by the appearance of the paper, too, and asks "May I see that?" His reaction convinces the leader it wasn't a staged event: "Well, I'll be damned," the physicist replies. Once the time machine is under construction, the two men realize they have to send the enigmatic message back in time to complete the loop. As they prepare to do so, the leader asks a curious question. After retrieving the mysterious sheet of paper from his desk,

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he says to the physicist "Should I send the original [the one he is holding in his hand], or should I write another?" The physicist replies with "Write a new one. If we send the original, we put it in a closed loop and [we'll] never get it back. We don't want to lose the first object to travel in time. We'll want that for the Smithsonian someday." Does this make sense? Also, comment on whether or not the dog's name is a bootstrap paradox.

A perplexing little time travel paradox, one that I don't think science fiction has yet treated (and I'm pretty sure physicists haven't had anything to say about it either), was cooked-up by the English philosopher Robin Le Poidevin in his 2003 book *Travels in Four Dimensions: the enigmas of Space and Time* (Oxford, pp. 180–181). There he writes "Peter and Jane, both 20 years old, are out for a walk one day in 1999 when suddenly a time machine appears in front of them. Out steps a strangely familiar character who tells Jane that he has an important mission for her. She must step into the machine and travel to the year 2019, talking with her a diary the stranger hands to her. In that diary she must make a record of her trip. Obligingly, she does as she is asked and, on arrival, meets Peter, now aged 40. She tells Peter to travel back to 1999, taking with him the diary she now hands him, and recording his trip in it. On arrival in 1999, he meets two 20-year-olds called Peter and Jane, out for a walk, and he tells Jane that he has an important mission for her." Le Poidevin then writes that "the really tricky question is: how many entries are there in the diary when Jane first steps into the machine? We imagine it blank. But this is the very same diary as the one Jane hands to the 40-year-old Peter, which then contains her entry. And by the time Peter arrives back in 1999, it will contain his entry, too. But then, if the diary already contained two entries when Jane was handed the diary, then it would contain three entries when she handed it to Peter, who would then add another one, so the diary would have contained four entries when it was first handed to Jane, and so on. If the problem is not immediately apparent, this is because we imagine an indefinite number of trips, but in fact there are just two: Jane's trip to 2019 and Peter's trip to 1999. So there ought to be a consistent answer to the question, how many entries are there in the diary? Yet, as we have seen, there does not appear to be a consistent answer." Another philosopher soon claimed he *did* have the answer: namely, 2. Read his paper (Erik Carlson, "A New Time Travel Paradox Resolved," *Philosophia*, December 2005, pp. 263–273), and either explain why you agree with Carlson's reasoning or enthusiastically rebut it.

As in "The Time Eliminator" (Fig. 4.1), other stories have imagined gadgets that simply view the past, rather than visit it as would a time machine. This is done in an attempt to avoid paradoxes—but does it? Two stories that illustrate how just viewing the past risks affecting the past as much as time travel would, are Horace Gold's "The Biography Project" (*Galaxy Science Fiction*, September 1951) and Donald Franson's "One Time in Alexandria" (*Analog*, June 1980). In the first tale the Biotime Camera, operated by the Biofilm Institute, allows teams of biographers to film (alas, no sound!) and study the lives of past notable personages. Of particular interest are the lives of those who developed neurotic psychoses, such as Isaac Newton. And, indeed, the Biotime Camera does capture Newton's image as he begins to display increasingly disturbed behavior. We see Newton, for example, as he begins to peer into dark corners, looking for those who have come to spy on him. On his death bed, the biography team assigned to him reads his lips and discovers that his final words are "My guardian angel. You watched over me all my life. I am content to meet you now." It is then that the Biofilm Institute realizes what it has done. Newton *was* in fact being spied upon—by the Biotime Camera, which has not changed the past but has certainly affected it. In the second tale an archeologist uses a time viewer to read the lost manuscripts in the ancient library at Alexandria before it was completely destroyed in an inferno. The viewer uses an infrared beam—and it is the heat from that beam from the future that proves to be the origin of the fire in the past. Again, the past has been affected, but not changed, by time viewing. Is it true to claim, however, that such viewing gadgets could not be the source of other paradoxes, such as causal loops or information bootstraps? If you think that isn't a valid claim, give a counter-example.

In a story by Francis Flagg and Weaver Wright (a pseudonym used by Forrest J. Ackerman), "Time Twister" (*Thrilling Wonder Stories*, October 1947), we read the following exchange between the inventor of a time machine and his none-too-bright helper:

"You mean to say," he questioned incredulously, "that I could go back a hundred years?"

"If you had the proper machine in which to travel, yes."

"But that'd take me back to before I was born."

The Professor smiled tolerantly.

"Look at this diagram, Hank. This line is the time continuum. It incorporates space, too. [The authors didn't actually print a diagram with the story, but

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surely the Professor is using a Minkowski spacetime diagram]. This dot is you. It doesn't matter when you were born, or when you will die. You exist right now, that's the fact. Traveling into the past or future wouldn't make you grow any younger or older. Such a thought is naïve. Let me demonstrate the mechanics of it for you. If . . . we calculate with non-Euclidean mathematics . . ."

"It don't sound reasonable," the farmhand objected. "If I went back—"

"I know," interjected the Professor, "if you went back you might meet your own father as a young man and you'd be older than he, or maybe he and your mother would be kids going to school."

"Haw, haw! That'd be funny, that would."

What famous movie, made nearly 40 years later, does the end of the conversation remind you of? Hint: "flux capacitor."

As mentioned in the text, a famous science fiction example of *affecting* (but not changing) the past is "Behold the Man" by Michael Moorcock, the tale of a time traveler who arrives in ancient times during the very years of the ministry of Jesus as reported in the Bible. When he finds there is actually no such person, the time traveler takes the role himself and lives out the events as reported in the Gospels, including the Crucifixion. This is a powerful story, but it had already been done more than 15 years earlier, by Philip K. Dick, in his short story "The Skull" (*If*, September 1952). In his tale, Dick tells of a man from the twenty-second century who is sent by government authority back to the mid-twentieth century to kill the Founder of a religious movement, a movement that 'now,' 200 years later, threatens those same government authorities. History records that the Founder gave a powerful speech just before being arrested and executed, a speech that started the religious movement, and so the time traveling assassin is told to kill the Founder *before* he can give that speech. (The parallel between Jesus and the Founder should be obvious.) Read these two stories and compare and contrast how Moorcock and Dick handled time travel paradoxes. Comment, in particular, on the relationship between the assassin and the Founder. Moorcock's tale should be easy to find, and Dick's is available as a free pdf download (it is in the anthology *The Best of Philip K. Dick*, Halcyon Classics 2010, as well).

A subtle change-the-past sequence appears in the original *Back to the Future* film that is easy to miss. When the hero, Marty McFly, returns to 1955 in the time car, he leaves from the parking lot of the Twin Pines Mall, so named because of the two pine trees that stand nearby. Arriving in the past with literally a bang, the time car inadvertently destroys one of the (then) young pines. Near the end of the movie, when Marty returns to the future (1985), he finds that the mall is now called the Lone Pine Mall. This is charming and fun, indeed clever, but modern scholars of time travel reject it, and other claims of changing the past, as not being logical. (Shakespeare understood this point, when he has Lady Macbeth declare, concerning the murder of Banquo, “What’s done cannot be undone: to bed, to bed, to bed.”) What Marty’s trip *would* explain is why the mall would *always* have had the name of the Lone Pine Mall. Watch the movie and see how many other ‘change-the-past’ episodes you can find.

Chapter 5
Communication with the Past

"[As for travel to or for signaling the past] you'd have to exceed light speed which immediately entails the use of more than an infinite number of horsepowers."[1]

5.1 Reversed Time

"I have not discovered Mr. Wells' Time Machine."[2]

One way to communicate with the past is to 'simply' live backwards in time. Philosophers and other writers of speculative fiction were the first to wonder what things might be like in a world where the time asymmetry is reversed—that is, in a world where time 'runs backward.' Indeed, fascination with the idea of time reversal actually dates back thousands of years, long before science fiction, as it can be found in Plato's dialogue *Statesman*, written (most probably) 15 years before Plato's death in 347 B.C.

At one point, Plato offers an extended description of the world suddenly running backward in time in the ancient past. After one character is told that at that remote time "all mortal beings halted on their way to assuming the looks of old age, and each one began to grow backward," he asks "But how did living creatures come into being, Sir? How did they produce their offspring?" The answer is shocking: "Clearly . . . it was not of the order of nature in that era to beget children by intercourse . . . It is only to be expected that along with the reversal of the old men's course of life and their return to childhood, a new race of men should arise, too—a new race formed from men dead and long laid in Earth . . . Such resurrection

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[1] An observation by Haskel van Manderpootz, professor of the "newer physics," in S. G. Weinbaum's "The Worlds of If," *Wonder Stories*, August 1935. Compared to the 'modest' Van Manderpootz, all other physicists in the world are a mere "pack of jackels, eating the crumbs of ideas that drop from [his] feast of thoughts."

[2] W. R. Inge (1860–1954), in his November 1920 Presidential Address to the Aristotelian Society at the University of London Club, in a sympathetic treatment of the possibility of a time-reversed world.

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of the dead was in keeping with the cosmic change, all creation being now turned in the reverse direction."

The reversed-time world is an important philosophical concept. Before the turn of the century, for example, Francis Bradley (one of the early proponents of the block universe, you will recall from Chap. 2), thought about reversed-time worlds and concluded that they would be quite odd: "Let us suppose … that there are beings whose lives run opposite to our own … *If* in any way *I* could experience *their* world, I should fail to understand it. Death would come before birth, the blow would follow the wound, and all must seem to be irrational."[3] A half-century later the South African philosopher J. N. Findlay (1903–1987) took Bradley's position of supporting a skeptical attitude towards the possibility of time-reversed worlds. Writing in a book review, Findlay declared "The reversed world in question wouldn't merely strike us as queer, but definitely crazy: it would be a world where what is wildly and intrinsically *improbable* was always occurring. It would, in fact, be much more startling than the original asymmetry that led us to think of it."[4] (Findlay was almost certainly thinking of things like a tea cup, shattered due to a fall, spontaneously reassembling itself.)

The question of backward-running time so fascinated Findlay that, some years later, he posed it as a problem for the readership of a scholarly journal (*Analysis*). This led to a number of responses, and subsequently he presented both his own negative view of time-reversed worlds and that of the best reader response he had received to his posed problem (which came from McGechie).[5] While Findlay showed admirable open-mindedness by awarding the title of *best* to an argument that refuted his own position, he remained unconvinced about the concept of reversed-time worlds, stating that "I continue to feel that a total reversal of my experiences is a terrifying possibility."

The terror aspect of living backward in time had been nicely captured in a science fiction story years before Findlay wrote. A scientist who is involved in an accident with radioactive materials has his sense of time flow reversed, and the story carefully and logically analyzes what his life would be like in such a situation. For example, the scientist can talk (backwards for others, of course), so he is understandable only if his words are recorded and then played in reverse. He cannot eat, because for him that would involve the regurgitation of food. He cannot answer questions because "if he should answer any questions put to him, it would mean he was giving the answer before he heard the question, on his time scale." And finally, he can't pick anything up because the normally stable position and velocity error-correction mechanism between eye, hand, and brain, which is a negative feedback system in normal time, has become an unstable positive feedback system in reversed time. The horror of his existence is contained in the only words the man utters (deciphered after reversed playback): “Where am I? What’s happened? Why are things so different? Why? Why?”[6]

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[3] F. H. Bradley, *Appearance and Reality* (2nd edition), Oxford University Press 1897, p. 190.

[4] J. N. Findlay, *Philosophy* (25) 1950, pp. 346–347.

[5] J. N. Findlay and J. E. McGechie, "Does It Make Sense to Suppose That All Events, Including Personal Experiences, Could Occur in Reverse?" *Analysis*, June 1956, pp. 121–123.

Despite Findlay’s “terror,” however, the prevailing view today is that to the inhabitants of a time-reversed (or what is sometimes called a *counterclock*) world, *nothing would look odd*! This is a fairly new idea,[7] and not so long ago the philosophical literature displayed a misunderstanding of how a time-reversed world would appear to its occupants.[8] More recent analyses than Smart’s (note 7) advocating the ‘normality’ of a time-reversed world are more compelling.[9] One concern about a time reversed world however is not easily dismissed: matter with a time reversed time sense is thought by many to be antimatter in our world, and any interactions between the two worlds would be spectacular, indeed![10]

But let’s ignore that possible difficulty. The philosopher J. R. Lucas argued that even if beings from two such time-reversed worlds could meet, they still could not communicate: “If two beings are to regard each other as communicators, they must both have the same direction of time. It is a logical as well as a causal prerequisite.”[11] Now, this matter is well worth some effort to understand, because it is intimately tied to time travel. At first blush, Lucas’ words seem almost self-evident, and after a little thought they might seem to be absolutely irrefutable. The philosopher Murray MacBeath, however, took exception.

MacBeath opened his analysis[12] with a story to demonstrate that the persuasive power of Lucas’ position is only superficial. In that story of Jim and Midge, Jim is one of us, whereas Midge is a ‘Faustian time’[13] being. In his analyses MacBeath uses capitalized words and symbols for the time-reversed Midge, and lower case for Jim, as shown in Fig. 5.1. As MacBeath explains, “While Jim and Midge are together a face-to-face conversation is hardly likely to get off the ground. To make this clear let us say that they are together from t_0 until t_{10} on Jim’s time-scale, and from T_0 until T_{10} on Midge’s TIME-scale; t_0 is then the same temporal instant as T_{10} and, in general, $t_n = T_{10-n}$. If Jim at [his time] t_2 asks Midge a

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[6] M. C. Pease,” *Astounding Science Fiction*, “Reversion,” December 1949. See also R. A. Banks, “This Side Up,” *Galaxy Science Fiction*, July 1954, for a tale about the confusion caused by projecting a film the wrong way in time.

[7] The modern view that a time-reversed world would appear normal to someone living in it can be traced back at least as far as to J. J. C. Smart, “The Temporal Asymmetry of the World,” *Analysis*, March 1954, pp. 79–83, an analysis, alas, that may not convince everyone.

[8] M. Dummett, “Bringing About the Past,” *Philosophical Review*, July 1964, pp. 338–359.

[9] See, for example, D. L. Schumacher, “The Direction of Time and the Equivalence of ‘Expanding’ and ‘Contracting’ World-Models,” *Proceedings of the Cambridge Philosophical Society* 1964, pp. 575–579; J. V. Narlikar, “The Direction of Time*,” British Journal for the Philosophy of Science*, February 1965, pp. 281–285; F. R. Stannard, “Symmetry of the Time Axis,” *Nature*, August 13, 1966, pp. 693–695.

[10] This issue is raised, several times, in Robert Silverberg’s 1968 novel *The Masks of Time*.

[11] J. R. Lucas, *A Treatise on Time and Space*, Methuen 1973, pp. 43–47.

[12] M. MacBeath, “Communication and Time Reversal,” *Synthese*, July 1983, pp. 27–46.

[13] In Goethe’s play *Faust*, the normal flow of time is routinely upset.

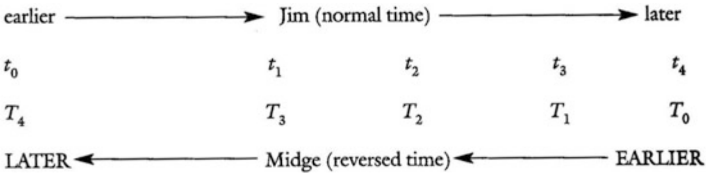

Fig. 5.1 Opposite time flows in counterclock worlds

question, and Midge hears the question at T_8, she will answer at T_9, and Jim will hear his question answered at t_1, *before* he asked it! What is more, if Jim is inexpert at interpreting backward sounds, and at t_4 asks Midge to repeat her answer, Midge will hear that request at T_6, BEFORE she has heard the original question; and her puzzled reply at T_7 will be heard by Jim at t_3 before he has uttered the request." Certainly this is a mess in time, and Lucas seems to be on safe ground with his denial of the possibility of communication between Jim and Midge. MacBeath, however, shows how to refute all of Lucas' arguments if Jim and Midge are allowed to be clever about how they send their messages back and forth—that is, if we give up some of our usual ideas of what a conversation is like. MacBeath's analyses are far too lengthy and detailed to present here, but the simplified diagram of Fig. 5.1 should enable one to follow the logic of his approach.

We imagine that Jim and Midge will not actually talk, and so will not have to decipher backward-spoken language. Rather, they will exchange messages via computer-generated text displayed on monitor screens, screens that are separated by a window that is proof against all penetration but the light emitted by those screens.[14] The nature of this window is not a trivial matter: if we accept the anti-matter nature of Midge's world then it is *essential* to keep her and Jim apart! To that end, MacBeath imagined that the window is double paned, with a perfect vacuum in-between. The exchange of photons between the two worlds should present no problems because photons are their own anti-particles.[15]

Now, imagine that at t_0 Jim brings a computer to the window. He programs it to wait for 4 days, until t_4, and then to display the following message on its screen: "This message is from Jim, who experiences time in the sense opposite to yours. Please study the following questions and display your answers on a computer screen three days from now." Jim's messages ends with the list of questions.

Because all that took place at t_4, Midge sees Jim's message and questions at what we will now call T_0. As requested, she brings her computer to the window, enters the answers to Jim's questions, and programs the machine to display them (after a

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[14] Communication between beings in counterclock worlds, using written messages displayed through a window, appeared in science fiction *years* before MacBeath wrote: see I. Watson's 1978 novelette "The Very Slow Time Machine."

[15] There is no difference in the time sense of photons in either world because the flow of proper time for a photon—traveling at the speed of light, by definition—is zero (recall the discussion in Sect. 3.6).

3 day delay) on its screen. Thus, at T_3, which is Jim's t_1, Jim sees Midge's computer screen light up with "Hi, Jim. This is Midge. The answers to your questions are at the end of this message. Now, I've got some questions for *you*. Please display the answers two days from now." Midge's message ends with answers to Jim's questions and her list of questions.

Jim sees Midge's message at t_1, enters the answers to her questions and sets the machine to answer after a 2-day delay. At t_3, which is Midge's T_1—and by now you see how the process goes. It's cumbersome, sure, but it works. Or at least it does if everybody follows the rules. What if they don't? MacBeath provides other, increasingly complicated analyses to treat some of the more subtle problems that can be imagined in this method of exchanging messages. I will mention just two of them, which have direct analogs with what we normally think of as 'time travel.'

For the first problem, consider Jim's initial message, created at t_0 to be sent at t_4. He receives Midge's answer as described above at t_1, *before* his message is displayed through the window. So, what happens if at t_2 Jim cancels the message and it is *not* displayed? He has already gotten Midge's reply, but how can that happen if he does not send his message? This is, of course, a bilking paradox, with an explanation that we discussed in the previous chapter.

A second problem is the apparent possibility of creating a causal message loop. For example, let's say that at t_0 Jim suddenly decides to send a message through the window. (His reason for this sudden urge will be explained in the next few lines.) He thinks all night about what to send and, at t_1, finally settles on the following: "Greetings to the people on the other side of the window. This message comes from Jim, who hopes you will reply." Midge immediately sees Jim's message through the window (at her time T_3) and so is suddenly caught up with the desire to respond. She thinks all night about what to send and, hoping to be witty, she finally decides (at time T_4) on the following echo to Jim's message. "Greetings to the people on the other side of the window. This message comes from Midge, who hopes you will reply." Jim immediately sees this through the window (at what is his time t_0) and so now we know why he decides to send his original message! And Jim *will* send his original message—he has to because Midge replied to it.

In a review of a book on the direction of time, the philosopher Hilary Putnam restated the problems of a time-reversed world in the form of a provocative question: "How do you know that one man's future isn't another man's past?"[16] He began by making the interesting observation that for us to be able just to observe a backward-running universe, we would have to provide our own normal radiation source, because the counterclock stars in such a universe *absorb* radiation rather than emitting it. This point was elaborated on by another philosopher some years later, who wrote "We have uncritically imagined someone looking in on … two worlds having opposite time directions … Part of the story we tell, of the process of seeing, involves the emission of photons from objects [for example, the computer screens of Jim and Midge] and the subsequent impinging of these photons on our retinas. But this process is obviously directed in time. In a world where time ran opposite to ours, we could not see objects at all: objects would be photon-sinks, not photon-emitters."[17]

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[16] H. Putnam, *The Journal of Philosophy*, April 1962, pp. 213–216.

Putnam concluded his comments about reversed time with a cautious warning: "It is difficult to talk about such extremely weird situations without deviating from ordinary idiomatic usage of English. But this difficulty should not be mistaken for a proof that these situations could not arise." That challenge is no doubt why so many writers of science fiction and fantasy have tackled the question of what it would be like if time ran backward. We can find such a tale long before the science fiction pulps, in fact, in a tale that appeared when Einstein was just 7 years old. In that story[18] the narrator (a professor of astronomy and higher mathematics) suddenly finds himself on Mars. There he encounters beings who know the future up to their deaths, and whose memories of the past are "scarcely more than a rudimentary faculty." The entire tale is in the form of a conversation between the professor and one such being, who argues (quite persuasively) for the virtues of his 'backward' existence compared to that of earthlings (the Martian name for Earth is the story's title). Bellamy realized that his story implies a fatalistic block universe: "No one could have foresight … without realizing that the future is as incapable of being changed as the past," he wrote.

Other writers, too, were fascinated by the implications of reverse time. When Merlyn the magician makes his first appearance in T. H. White's 1939 masterpiece *The Once and Future King*, for example, he explains how he knows the futures of others: "Ordinary people are born forward in Time, if you understand what I mean, and nearly everything in the world goes forward, too … But I unfortunately was born at the wrong end of time, and I have to live backwards from its front, while surrounded by a lot of people living forwards from behind. Some people call it having second sight."

What may have put the idea in White's mind for his time-reversed magician is only speculation today, but perhaps it was something he might have read a decade before, in a fellow Englishman's writing, the 1929 book *The Nature of the Physical World* by Sir Arthur Eddington, where one finds the following passage: "In "The Plattner Story" H. G. Wells relates how a man strayed into the fourth dimension and returned with left and right interchanged … In itself the change is so trivial that even Mr. Wells cannot weave a romance out of it [but see one of the *For Further Discussion* questions at the end of Chap. 2]. But if the man had come back with past and future interchanged, then indeed the situation would have been lively."

Whether or not those words influenced English fantasy, they certainly had some effect on American science fiction. In his 1979 memoir *The Way the Future Was*, pulp editor Frederik Pohl wrote that Eddington's book (which Pohl incorrectly attributed to Sir James Jeans) had given him the idea for a story using the reversed-time twist. But before Pohl could publish it, an even better (claimed Pohl) tale arrived from Malcolm Jameson. Jameson, too, had read Eddington's book, and the result was the novella-length "Quicksands of Youthwardness," which Pohl published in *Astonishing Stories* as three-part serial during 1940–1941. Unfortunately, Jameson's tale is both pretty awful *and* devoid of *any* connection with Eddington's suggestion. One can only wonder about what might have been in the story Pohl says *he* discarded—did *it* have the future remembered? Alas, Pohl wrote that he couldn't remember!

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[17] N. Swartz, "Is There an Ozma-Problem for Time?" *Analysis*, January 1972, pp. 77–82.

[18] E. Bellamy, "The Blindman's World," *The Atlantic Monthly*, November 1886.

Remembering the future does occur in one tale where everybody knows what will happen (as they live backward) by reading "prediction books." What distinguishes that story from many others on the same theme is an interesting, ironic conversation a student in a reverse-time world has with a philosophy professor about how things would be if time went the 'other way,' as in *our* world:

> "How can we tell? The reverse sequence of causation may be just as valid as the one we are experiencing. Cause and effect are arbitrary, after all."
>
> "But it sounds pretty far-fetched."
>
> "It's hard for us to imagine, just because we're not used to it. It's only a matter of viewpoint. Water would run downhill and so on. Energy would flow the other way—from total concentration to total dispersion. Why not?"[19]

The student is unconvinced, however, and when he tries to visualize such a peculiar world (*our* world, don't forget!) it gives him a "half-pleasant shudder." Imagine, he thinks in wonder, never knowing the date of your own death.

A few years later, in Wilson Tucker's 1955 novel *Time Bomb*, we find the intriguing idea of political assassination by time bomb, with the bombs actually *time traveling* to their targets. A policeman begins to suspect what is happening when it becomes evident that one of the explosions was actually an implosion: "The time bomb ... had been going in and had carried the force of the blast with it. Inward. Into the past. He frowned at that. A backward explosion? An explosion which ran counter to the normal flow of time, to the normal method of living? ... How would an explosion appear to a man if the blast happened in the opposite manner? If it began exploding now, in this moment, but continued backward instead of forward? Would it be an implosion?"

There is little doubt that the definitive treatment of a reversed-time world is that of Philip K. Dick's 1967 novel *Counter-Clock World*. Dick's world was once our world, but then, as in Plato's tale that began this chapter, time suddenly begins to run backward. People still alive reverse their direction of aging (but still think, walk, and talk in forward time), and dead, buried people come alive again and emerge from graveyards as the "Sacrament of Miraculous Rebirth" is intoned by a priest; all live their way back to the womb, just as in Plato's tale of 1600 years earlier. Such imagery is powerful stuff, but the physicist John Wheeler (of black hole fame) would have none of it. As he wrote, "Most of us would probably agree that the universe has not contained and will not contain any backward-looking observers. We do not expect to see caskets with corpses in them coming to life, nor do we expect to find bank vaults in which a gram of radium will integrate rather than disintegrate."[20]

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[19] D. Knight, "This Way to the Regress," *Galaxy Science Fiction*, August 1956.

5.2 Multi-dimensional Time

> "If there are extra time dimensions we get violations of causality, because one could sneak to yesterday through the extra dimensions, and ... if you had sneaked to yesterday, you would have disappeared from today."[21]

There are those, however, who haven't been quite so sure as Wheeler about the impossibility of a reversed-time world. One physicist, for example, showed how (under certain initial conditions at the Big Bang) there is a possible solution to the gravitational field equations that gives an oscillating universe that temporally runs backward during the contraction phase.[22] And a philosopher has argued that the *direction* of time is local, not global (just as special relativity showed is the *rate* of time) and that the arrow of time can point in opposite directions at different locations.[23] As odd as such ideas may seem, a generalization of reversed-time—*multi-dimensional* time—makes it seem small potatoes. This is the idea that there might be *many* possible directions to the arrow of time, not just two. At first this may seem an absurd idea, something akin to a man jumping onto his horse and riding off in all directions at once. But philosophers (and perhaps just a few physicists[24]) have started to take at least a semi-serious look at the concept; as with so many other of the radical concepts associated with time travel, though, science fiction writers were dealing with multi-dimensional time long before it became a respectable topic in learned philosophical and physics journals.

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[20] Wheeler's comments can be found in the General Discussion at the end of *The Nature of Time* (T. Gold, editor), Cornell University Press 1966.

[21] An intriguing (if somewhat mysterious) thought from F. J. Yndurain, "Disappearance of Matter Due to Causality and Probability Violations in Theories with Extra Timelike Dimensions," *Physics Letters B*, February 28, 1991, pp. 15–16.

[22] H. Schmidt, "Model of an Oscillating Cosmos Which Rejuvenates During Contraction," *Journal of Mathematical Physics*, March 1966, pp. 494–509. An elaboration of Schmidt's ideas is in A. Walstad, "Time's Arrow in an Oscillating Universe," *Foundations of Physics*, October 1980, pp. 743–749.

[23] G. Matthews, "Time's Arrow and the Structure of Spacetime," *Philosophy of Science*, March 1979, pp. 82–97.

[24] More than half-a-century ago one writer asserted that two-dimensional *complex* time was old hat in the theories of spinning particles—see M. Bunge, "On Multi-dimensional Time," *British Journal for the Philosophy of Science*, May 1958, p. 39. For a summary of many of the objections to multi-dimensional time see J. K. Kowalczynski, "Critical Comments on the Discussion About Tachyonic Causal Paradoxes and the Concept of Superluminal Reference Frames," *International Journal of Theoretical Physics*, January 1984, pp. 27–60 (and the reply by E. Recami, September 1987, pp. 913–919).

In one pulp story, for example, we find a professor asking his redundantly named class in speculative metaphysics "Why shouldn't time be a fifth, as well as a fourth, dimension?"[25] In response to a generally skeptical reception to that, the professor goes on to say "I believe in the existence of a two-dimensional time scheme . . . Ordinarily, most people think of time as a track they run on from their births to their deaths . . . Think of this time track we follow over the *surface of time* as a winding road [it is the imagery of a surface that gives the professor *two* time dimensions] . . . Once in a while another road crosses at right angles. Neither its past nor its future has any connection whatsoever with the world we know."[26]

The year before, the same pulp had published another tale[27] that went well beyond a mere two time dimensions. We are told in that story of two countries on an alien planet at war in the distant future. The war is a stalemate until one side begins to fire a gun at its foe from just two miles from its target, in the heart of enemy territory—*from the middle of next week*! The gun's shells are true 'time bombs.' This is not mere 'ordinary' time travel along one time track, however, but a multidimensional effect. Using a photograph of the gun in actual operation to support his astonishing discovery, an agent for the side being shelled reports to his superior that "the gun and its crew are existing along another time axis at right angles to the direction of our 'normal time,' so that from our point of view they are existing perpetually in the same instant."

That explains why the gun crew can (will?) operate without interference in next week's future, as they are in their adversary's time only for the instant that the two time tracks intersect. Indeed, the spy used the same trick to obtain his undetected photograph: "I secured the photograph by orienting myself along still another time axis at right angles to that of the gun, and approached it as an instantaneous, invisible entity." By the story's end both sides are using and counter-using this technique, evading each other "to and fro along an ever increasing complexity of mutually perpendicular time axes." In fact, the final count exceeds 75 time axes, making Heinlein's two-dimensional time look rather skimpy by comparison.

Well, of course, 75 time directions *is* science fiction (I think), and physicists are not so enamored of multidimensional time as are science fiction writers. For example, Eddington wrote that he found the idea of any region of spacetime involving two-dimensional time to "defy imagination."[28] Another physicist showed that the extremal property of timelike geodesics (look back at Fig. 3.15 and its discussion) would fail for multidimensional time, which he then associated with the stability of matter and a failure of causality.[29] Yet another physicist, however, was just a bit more willing to consider multidimensional time, and suggested that a viable theory of quantum gravity *might* support the idea of multiple time dimensions.[30] Of just *what* more than one time dimension might actually *mean*, however, this same physicist echoed Eddington by writing "Physics in a spacetime of . . . two timelike dimensions would be very weird indeed." Agreeing with this physicist was a philosopher who called the idea that there could be more than one dimension to time a "rather wild possibility" and a "fairy-tale."[31] These are probably fair statements of how most physicists presently think of multidimensional time.

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[25] R. Heinlein, "Elsewhen," *Astounding Science Fiction*, September 1941.

[26] This story has an amusing scene in which one of the professor's students accidently 'jumps time tracks' and so enters a new track with his arrow of time pointing backwards.

[27] N. L. Knight, "Bombardment in Reverse," *Astounding Science Fiction*, February 1940.

[28] A. S. Eddington, *The Mathematical Theory of Relativity* (2nd edition), Cambridge University Press 1924, p. 25.

But not all philosophers are of that persuasion, and many are in fact as fascinated by the possibilities of multidimensional time as are science fiction writers. So, *why* this interest in something so different from anything we actually experience? Where does the motivation come from? Of what *use* is multidimensional time? I think the answers to those questions all derive from how multidimensional time offers a theoretical model for giving meaning to the view that the past can be changed (take a look back at note 20 in the Introduction).

In a certain trivial sense, of course, the past is always changing. For each of us the past is the set of all events that have happened, arranged in a before/after temporal order, and this set is continually increasing (and so changing). That is not, however, what most people mean by a changeable past. What *is* meant is that there may be some kind of change in the temporal ordering of events, or that an event that once was (or wasn't) a member of the set of past events no longer is (or is now) a member. Two-dimensional time offers a way to make sense of such possibilities, which one-dimensional time simply cannot do. To see how that works, I'll follow the presentation in a paper that forcefully argues that it does make sense to talk about altering the past.[32]

Meiland was aware that some might find his model *ad hoc*, even "incredibly weird" (in his own words), but he justified his efforts by taking a refreshingly enlightened, non-Humean view of what he thought would be the proper response to meeting purported time travelers: "If strange machines containing people in futuristic garments and speaking strange tongues (or perhaps using ESP instead of speech) were to appear and were to claim to be from the future, we might very well begin to search for a theory of time that allows their claim to be true." In Fig. 5.2 you can see how Meiland tried to do just that.

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[29] J. Dorling, "The Dimensionality of Time," *American Journal of Physics*, April 1970, pp. 539–540.

[30] C. Isham, "Quantum Gravity," in *The New Physics* (P. Davies, editor), Cambridge University Press 1989.

[31] D. Zeilicovici, "Temporal Becoming Minus the Moving-Now," *Nous*, September 1989, pp. 505–524.

[32] J. W. Meiland, "A Two-Dimensional Passage Model of Time for Time Travel," *Philosophical Studies*, November 1974, pp. 153–173. Jack Meiland (1934–1998) was a professor of philosophy at the University of Michigan.

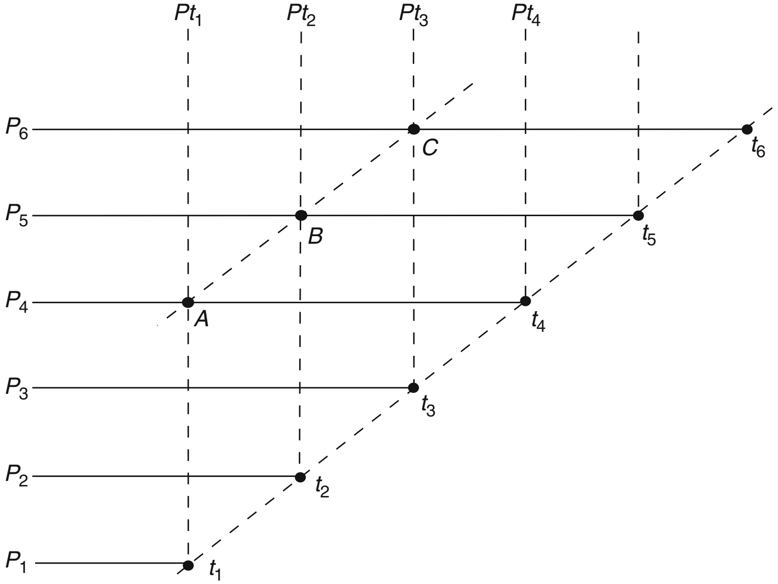

Fig. 5.2 Two-dimensional time

The dashed diagonal line, marked with the points t_1, t_2, ... represents our usual one-dimensional image of time. The horizontal lines P_1t_1, P_2t_2 ... (which we can simply call P_1, P_2, ..., for short) are the pasts for the present instants t_1, t_2, ... That is, P_1 is the past with respect to the present t_1, P_2 is the past with respect to the present t_2, and so on. The dashed vertical lines allow us to locate any moment in the past. For example, the intersection point A of P_4 with Pt_1 is the location of t_1 in the past with respect to the present t_4.

With this model, Meiland then analyzed in detail several interesting special cases. Suppose that t_1 and t_2 are 1 year apart and that there is a similar time separation between all adjacent, marked present moments on the diagonal. Let us further suppose that a time traveler at t_4 journeys backward 3 years to t_1, to arrive at point A. Assume he stays in the past 2 years; then his temporal locations lie along the dashed diagonal line ABC; that is, at B he is 3 years in the past of t_5, and at C he is 3 years in the past of t_6. From Fig. 5.2, then, we can imagine the time traveler saying, as he climbs into his time machine at t_4, "One year from now I'll be two years from now." That rather astonishing statement makes sense when we take both uses of now to be t_4 and observe that B (1 year from A) is 2 years in the past with respect to t_4.[33]

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[33] A critic of time travel (see note 119 of Chap. 2) used what he claimed to be the absurdity of such a statement to support his ejection of time travel. One of Meiland's reasons for developing his two-dimensional model of time was, in fact, to be able to reply to that critic (Donald Williams).

Meiland's two-dimensional time model is undeniably fascinating, but it simply has no theoretical justification (as far as I know[34]). It is not necessary to assume two-dimensional time to explain Meiland's "strange machines containing people in futuristic garments"; it is possible to do that with one-dimensional time in a four-dimensional spacetime. The classic paradoxes, too, are understandable without two-dimensional time, as discussed in the previous chapter.

5.3 Maxwell's Equations and Sending Messages to the Past

> "Communication with a world exactly, to minutest detail, a duplicate of our own [but] twenty thousand years ahead of us might ruin the human race as effectively as if we had fallen into the Sun."[35]

Every physicist and electrical engineer knows that the mathematical description of the electromagnetic field is given by Maxwell's equations. In particular, radio engineers know that the waves of energy their antennas launch into space follow the predictions of those equations with astonishing accuracy. Indeed, when Einstein's relativity theory was completed, it was found that Maxwell's equations automatically satisfy relativity because magnetic effects *are* relativistic effects; in other words, relativity is built into Maxwell's equations. Whereas Newton's laws of dynamics had to be patched up, Maxwell's equations were untouched by the discovery of relativity.

Thus, it was a puzzle when physicists discovered that careful study of the seemingly perfect Maxwell equations, when applied to antennas, apparently results in the prediction of causality violation. It is found, in fact, that the equations have *two* solutions. One, as expected, contains the feature of time delay; that is, creating an electromagnetic disturbance at the antenna *now* causes a detectable effect at a distant point in space *later*. This is the so-called *time-retarded-solution*, and its common-sense physical interpretation is that of energy waves traveling away from the antenna as they also travel into the future. The shock was that Maxwell's equations also accept an *advanced solution*; energy waves *arriving* at the antenna from infinite space.

The physicist Paul Renno Heyl (1872–1961) wrote the perhaps first scientific work discussing advanced electromagnetic effects, in his 1889 University of Pennsylvania doctoral dissertation with the provocative title "The Theory of Light on the

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[34] Many of the arguments against multi-dimensional time can be found in M. MacBeath, "Time's Square," in *The Philosophy of Time* (R. Le Poidevin and M. MacBeath, editors), Oxford University Press 1993. MacBeath concludes, however, with "I would not want to rule out the possibility … that time is three-dimensional. Or worse." See also Alasdair Richmond, "Plattner's Arrow: Science and Multi-dimensional time," *Ratio*, September 2000, pp. 256–274.

[35] The Victorian writer Samuel Butler (1835–1902), in the "Imaginary Worlds" entry of *The Notebooks of Samuel Butler* (published posthumously in 1912), commenting on the chaos that communication across time might cause.

Hypothesis of a Fourth Dimension." Heyl cited the scientific guru of the fourth dimension, C. H. Hinton (look back at the last "For Further Discussion" assignment in Chap. 2) as his inspiration. The situation described by Heyl is something like that of a child standing at the edge of a pond. She throws a rock into the middle of the pond and watches ripples spread out and away from the splash. Suddenly, she sees ripples appear all around the edge of the pond and then travel inward toward the center, where they all converge at once. A spout of water then erupts from the surface of the pond at the simultaneous meeting of the inward-traveling ripples, and she watches as a rock is ejected from the spout to land back in her hand. She is, of course, open-mouthed with astonishment! How absurd, you think, as you read this, and who could blame you? This amazing imagery of advanced effects we owe to the philosopher Karl Popper, and it has come to be called "the fable of the Popperian pond."[36]

Pursuing the mathematics of wave motion in the fourth dimension, Heyl wrote "We are led to the curious conclusion that, in Hinton's aether,[37] the nature of the central disturbance *after* a given instant can influence the form of the aether *before* that instant. In other words, the aether seems to be endowed with an uncanny faculty of foreknowledge." We can avoid such a counter-intutive implication of advanced effects, but only at the price of something many physicists and philosophers consider equally unacceptable: information traveling from the future into the past. We can still think of the advanced solution as representing electromagnetic waves of energy traveling *away* from the transmitting antenna—that is, as being *broadcast*, just like the retarded solution, rather than being received from infinity—*if* we also think of the waves traveling backward in time. Thus, the advanced solution to Maxwell's equations holds out the possibility of sending messages to the past, a sort of poor man's time travel. It may seem that we have simply traded one problem for another, however, because just sending information into the past can cause many of the same paradoxical, causality-busting situations that physical time traveling is claimed to cause.

The cosmologists Fred Hoyle (1915–2001) and J. V. Narlikar commented on the potential problems posed by communication backward in time, in their 1974 book *Action at a Distance in Physics and Cosmology*: "The [Maxwell] equations supply us with both advanced and retarded solutions (and, because of the linearity, with any linear combination of them) . . . With so many solutions theoretically possible, why does nature always select the retarded one? That this question cannot be answered within the framework of Maxwell's theory must be regarded as one of its intrinsic weaknesses."

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[36] K. Popper, "The Arrow of Time," *Nature*, March 17, 1956, p. 538. See, too, note 110 (and its discussion) in Chap. 2.

[37] It was thought, in nineteenth century physics, that electromagnetic waves need a *medium* through which to propagate (like ocean waves need water, and sound waves need air), a mysterious substance called the *aether* (or *ether*) that exists even in a vacuum. The 1871 Michelson-Morley experiment, however, implied that the aether simply does *not* exist.

That branding of Maxwell's theory as having an "intrinsic weakness" because of its prediction of an advanced solution was, I think, unwarranted. Indeed, the advanced solution can be given a perfectly reasonable physical interpretation.[38] Imagine a transmitting antenna sending electromagnetic waves to an identical receiving antenna. At any point in space between the two antennas there are electric and magnetic fields. Maxwell's equations allow us to calculate the fields produced by alternating currents in the two antennas. When we do an analysis of the relationship between the transmitting antenna's current and the fields, we use the retarded solution because the current is the cause and the fields are the effect. But in the analysis of the relationship between the fields and the receiving antenna's current, the situation is reversed, and the fields are the cause and the current is the effect. That is, the advanced solution is simply the mathematics relating the current in the receiving antenna *now* to the fields *in the past*.

An acceptance of both solutions has, in fact, been in the physics literature for nearly a century. As the Yale physicist Leigh Page (1884–1952) wrote decades before Hoyle and Narlikar, "While the advanced potentials, as well as the retarded potentials, satisfy the electromagnetic equations, the former has generally been discarded for the reason that it has been more in accord with the trend of scientific intuition to consider that the present is determined by the past course of events than by the future. However, if it is once admitted that the present state is uniquely determined by any past state, it follows that the future is also so determined, and hence the employment of a future state as well as a past state in specifying the present marks no inherent departure from our accustomed methods of description . . ."[39]

It may still be tempting, however, to just dismiss the advanced solution as a mere anomaly of the mathematics and to discard it on physical grounds. This is the traditional approach taken by physicists when confronted with non-causal solutions in any physical theory and, indeed, that was what Swiss physicist Walter Ritz (1878–1909) did with the advanced solutions to Maxwell's equations (an approach that involved Ritz during the last year of his life in a dispute with Einstein). For Ritz, the reversal of cause and effect simply did too much violence to his intuition to be taken seriously, and so he thought one must *impose* causality on Maxwell's equations (a condition they do not inherently contain) by *a priori* rejecting the advanced solution.[40]

Still, electrical engineers make similar kinds of judgements all the time, as when the solution of a quadratic equation for a passive (energy-dissipating) resistor gives both a positive value (which 'makes sense') and a negative value (which doesn't 'make sense' and so is simply ignored). There *were*, however, those who encouraged caution on this issue. Seventy-five years ago, for example, the eminent MIT electrical engineer Julius Adams Stratton (1901–1994) echoed Leigh Page's warning when he wrote of the disturbing advanced solution, "The familiar chain of cause-and-effect is thus reversed and this alternative solution might be discarded as logically inconceivable. However, the application of 'logical' causality principles offers very insecure footing in matters such as these and we shall do better to restrict the [Maxwell] theory to retarded action solely on the grounds that this solution alone conforms to the *present* [my emphasis] data."[41]

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[38] See, for example, S. L. Schwebel, "Advanced and Retarded Solutions in Field Theory," *International Journal of Theoretical Physics*, October 1970, pp. 347–353, and L. M. Stephenson, "Clarification of an Apparent Asymmetry in Electromagnetic Theory," *Foundations of Physics*, December 1978, pp. 921–926.

[39] L. Page, "Advanced Potentials and Their Application to Atomic Models," *Physical Review*, September 1924, pp. 296–305.

[40] For more on this, see O. Costa de Beauregard, "No Paradox in the Theory of Time Anisotropy," *Stadium Generale* 1971, pp. 10–18.

And in a famous paper I'll discuss in the next section, Wheeler and Feynman declared that "We conclude advanced and retarded interactions give a description of nature logically as acceptable and physically as completely deterministic as the Newtonian scheme of mechanics. In both forms of dynamics the distinction between cause and effect is pointless. With deterministic equations to describe the event, one can say: the stone hits the ground because it was dropped from a height; equally well, the stone fell from a height because it was going to hit the ground."[42] For Wheeler and Feynman, the reversal of cause and effect inherent to backward causation and time travel to the past offered no conceptual difficulties.

The elimination of an appeal to causality, or to the 'weirdness' of advanced waves, in arguing for the naturalness of the retarded solution to Maxwell's equations was first done in 1976.[43] The only auxiliary condition applied to the equations was simply the natural one of requiring the initial field energy to be finite.[44] And yet, today, there is still no experimental evidence for the physical reality of the advanced solution. Now and then one does run across speculations that the advanced waves of *something* traveling backward to us from the future might explain the so-called ESP 'talent' of precognition, but that is all it is, speculation.[45]

Advanced waves appeared in the pulp science fiction of the late 1930s, a decade before Wheeler and Feynman. For example, one story actually specifically invoked the advanced solution to Maxwell's equations, with a gadget (making use of what the author called the "anticipated potentials") displaying the near future on a television-like screen.[46] The author's by-line proudly gave his academic credentials as including a master's degree and, in fact, John Pierce was a graduate student in electrical engineering at Caltech. He received his doctorate just months after this story was published, and then went on to a highly distinguished career at Bell Telephone Laboratories and then later at the Jet Propulsion Laboratory operated by Caltech for NASA. Pierce knew all about Maxwell's equations, of course, and he actually opened his tale with a quote from Page's 1924 article (note 39) on the advanced solution. How many fictional pieces include quotes from the *Physical Review*?

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[41] J. A. Stratton, *Electromagnetic Theory*, McGraw-Hill 1941, p. 428.

[42] J. A. Wheeler and R. P. Feynman, "Classical Electrodynamics in Terms of Direct Interparticle Action," *Reviews of Modern Physics*, July 1949, pp. 425–433.

[43] P. C. Aichelburg and R. Beig, "Radiation Damping As An Initial Value Problem," *Annals of Physics*, May 1976, pp. 264–283.

[44] J. L. Anderson, "Why We Use Retarded Potentials," *American Journal of Physics*, May 1992, pp. 465–467.

[45] See M. B. Hesse, *Forces and Fields*, Philosophical Library 1961.

[46] J. R. Pierce, "Pre-Vision," *Astounding Stories*, March 1936.

And it would probably take something like advanced waves to explain the funny doings 2 years late in a story of a man caught in a time machine accident. Nearly all of his body ends up 4 years in the future—but only *nearly* all, because his eyes remain the present! As one of the puzzled observers of this odd business wonders, "Strange, that his eyes, now, can convey a message to his brain, four years hence, and his brain tells the eye muscles to move the eyeballs which are four years behind them —."[47]

Some of the most intriguing paradoxes of time travel involve no traveler—only information. Of course, any information flow at all, independent of time travel, involves the flow of energy and, as Einstein showed, energy and mass are different aspects of the same thing. Accordingly, information time travel involves the transfer of mass/energy. Thus, a man in the twenty-fifth century who sends a backward-in-time 'temporal radio' message to a twentieth-century woman stating that he loves (will love?) her is sending much more than mere emotion. Just *how* to send a message backward in time is, of course, the puzzle.

Indeed, all forms of present-day communication are transmissions only to the future. If you speak to someone, or if you send a radio message, there are always delays depending on the distance of separation and the speed of transmission of sound and light, respectively. If you want to send a message to the one hundred and twenty-fifth century, you can; just write a letter and seal it in a pressurized bottle of helium. This basic idea is dramatically presented in a novel about a scientist who is accidently transported from 2162 back to the late-Cretaceous, 80 million years into the past. There he leaves a written record on seven sandstone slabs of his brutal, lonely life among the dinosaurs—letters across time, if you will—found by twenty-second century geologists some years after his disappearance.[48] The transmission of such letters, *forward* in time, while dramatic, is not a puzzle. But what could be more astonishing than the message received *from the future* by the young inventor of the first time machine: after his initial experiment of sending his pilotless machine into the future, it returns with an envelope inside. Eagerly tearing it open, he finds the note is from the National Academy of Sciences: "We know from old records and museum models that this is the Cullen Foster experimental machine. Fifty years looks down on you and says 'Good work'."[49]

Heady stuff, that, but lots of other possible messages are capable of competing with young Foster's when it comes to generating excitement. For example, suppose you had a gadget that is superficially similar to a telephone but that calls telephones in the *distant* future. You can hear the person (in the future) on the other end, but they can't hear you (in their past). That is, information can flow only from future to past. It is then easy to imagine situations in their use of this device that at least seem paradoxical. For example, suppose you call your own private number 1 month ahead. You hear your future-self first answer the phone, and then recite the winning lottery for the 'previous' day, which is a month in your present self's future. (Your future self does this somewhat odd recital because a month from now you will remember, when your private phone rings, just *who* is calling!) So, now in the present you know you'll make a fortune by winning the lottery a month later.

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[47] M. Schere, "Anachronistic Optics," *Astounding Stories*, February 1938.

[48] G. G. Simpson, *The Dechronization of Sam Magruder*, St. Martin's Press 1996.

[49] D. Stapleton, "How Much to Thursday?" *Thrilling Wonder Stories*, December 1942.

This example *is* admittedly somewhat mysterious since, for the gadget to call far ahead in time, some sort of signal (as yet unspecified) must travel into the distant future because *something will* make the future phone ring. For the present discussion I am ignoring this crucial issue for the sake of the dramatic impact of the example. Soon, however, we'll get a little way into describing how one might, in principle, actually build this gadget, which in the physics literature is called an *antitelephone*. (Such a device is an *anti*telephone because the person who is the receiver is in the sender's past, the opposite of the situation for an ordinary telephone.) An interesting fictional illustration of such a gadget, despite being told as a hard-boiled detective murder mystery, appeared in science fiction some years ago (alas, while called a "time telephone," no theory for its operation was given, but instead was 'explained' as a "straightforward application of an impressive, but limited, technology").[50] So far, there is nothing paradoxical (or even illegal) in all of this, but what if, when the phone rings in the future the day after you won the lottery, you perversely decide *not* to recite the winning number? This apparent paradox has, in fact, already been treated with the aid of the block universe view of spacetime; that is, if the future-you spoke the lottery number when you originally called, then the present—you (now in the future) *must*, inevitably recite it.[51]

Let's now make things a bit more involved. Suppose that instead of calling your future self, you call the weather service and listen to the recorded message telling you the weather, 30 days hence. You do this day after day, and after a while you get a reputation for being able to predict, *perfectly*, the weather for every day to come, up to a month into the future. Your reputation spreads far and wide, and after a while more the weather service hears about you. Meteorologists check and find you are *never* wrong. Their computer models are only 80 % accurate out to 3 days, and for a week's prediction and beyond, the general public might as well flip a coin on whether it will rain or not on any particular day. But you are 100 % correct out to ten times their range. And so they hire you—and as a secondary job, you also make the daily weather recordings. (The voice on the other end of the gadget *has* sounded sort of familiar!) Here, then, is the puzzle we encountered earlier in causal loops carrying information: from *where* is the information in the flawless weather predictions coming from?

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[50] S. Schmidt, "Worthsayer," in *More Whatdunits* (M. Resnik, editor), DAW 1993. The author, Stanley Schmidt, has a Ph.D. in physics and is a former editor of *Analog Science Fiction* magazine.

[51] For a fictional illustration of this (a so-called *bilking paradox*), see W. Tevis, "The Other End of the Line," *Magazine of Fantasy and Science Fiction*, November 1961.

One easy answer is that the question is meaningless because such a future-to-the-past information flow must be impossible. Indeed, if I am to avoid telling a 'philosopher's fairy tale,' like those I criticized earlier in the book, I must admit that one consistent, non-paradoxical answer is found in recognizing that I have *assumed* that those 30-day weather reports are correct. Maybe, however, they are no better than anybody else's predictions. And so you *don't* become famous, and you *don't* get hired—and so there *isn't* any paradox. Is that the way to avoid paradoxes involving information flowing backward in time?

Perhaps not. As long as 1917 it was realized that special relativity does not preclude such an apparent backward flow. That is, if information could be transmitted faster than light, *then* messages could travel backward in time. That was the year Richard Tolman (1881–1948), a professor of physical chemistry at the University of Illinois and later at Caltech, wrote "The question naturally arises whether velocities which are greater than that of light could ever possibly be obtained."[52] He then answered that question, with his general conclusion being that if such velocities are possible, then a faster-than-light (FTL) observer could see the time order of two causally related events reverse. And thus the observer would see an affect *before* its cause. Alternatively, a *sub*luminal (slower-than-light) observer could see the two events, which are connected via an FTL interaction, reversed in time order from what a stationary observer would see.

Either situation has come to be called Tolman's paradox, but Tolman himself was careful with his words: "Such a condition of affairs might not be a logical impossibility; nevertheless its extraordinary nature might incline us to believe that no causal impulse can travel with a velocity greater than that of light." That was an astonishing statement, given that Einstein himself had specifically stated in his original 1905 paper on special relativity that such a thing simply could not occur. There is nothing, it would seem, to be "inclined" about.[53]

This rather technical connection between FTL speeds and backward time travel made the transition from theoretical physics to popular culture very quickly. It was in the British humor weekly *Punch*, for example, that the famous (but nearly always misquoted) limerick by A. H. R. Buller (1874–1944) first appeared:

There was a young lady named Bright
Whose speed was far faster than light;
She set out one day

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[52] R. C. Tolman, *The Theory of the Relativity of Motion*, University of California Press 1917.

[53] Take a look back at Sect. 3.5, where we showed that the time order of two events can appear reversed for a subluminal observer if the two events are not causally related. Introducing FTL motion results in extending reversal to causally connected events; that is, FTL motion, reversed causation, and time travel to the past, go hand-in-hand-in-hand.

In a relative way
And returned on the previous night.[54]

Where *Punch* dared to go, Hollywood could not be far behind. Indeed, in this case it was actually there first, with the 1922 one-reel silent comedy movie *The Sky Splitter*. This was just a short film (feature pictures generally had at least four reels), so it is not clear how widely distributed and viewed it may have been. The story is that of a scientist testing a new spaceship: when it exceeds the speed of light, he begins to relive his life.

The linkage between time travel to the past and FTL motion is a central one in science fiction, and its fascination was nicely illustrated by one writer who has a time machine experimenter in the twenty-seventh century wonder "Was the speed of light the core of the mystery? At the speed of light did the past and the future become a shining, merging road down which men could walk—in their ears the thunder of time passing . . .?"[55] Not everybody was excited with the idea of FTL motion and travel backwards in time, however, with one eminent scientist declaring that "the limit to the velocity of signals is our bulwark against the topsy-turvydom of past and future."[56]

The obvious question at this point, of course, is whether it is even conceptually possible to build a gadget to send FTL messages backward in time? Einstein himself thought not, saying "We cannot send wire messages into the past."[57] But was he right? One hint at the possibility of achieving FTL speeds is in Dirac's 1938 paper (note 52 in Chap. 2). There, in his remarks about pre-acceleration, Dirac wrote "Suppose we have a pulse sent out from place A and a receiving apparatus for electromagnetic waves at a place B, and suppose there is an electron on the straight line joining A to B. Then the electron will be radiating appreciably [because accelerated charges radiate] before the pulse has reached its centre and this emitted radiation will be detectable at B at a time . . . earlier than when the pulse, which travels from A to B with the velocity of light, arrives. *In this way a signal can be sent from A to B faster than light* [my emphasis]."

This exciting conclusion goes a step beyond the usual examples of 'things that go faster than light.'[58] Dirac had an equally exciting reaction (and here the emphasis is his): "This is a fundamental departure from the ordinary ideas of relativity and is to be interpreted by saying that *it is possible for a signal to be transmitted faster than light through the interior of an electron. The finite size of the electron now reappears in a new sense, the interior of the electron being a region of*

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[54] On page 591 of the issue of December 19, 1923.

[55] F. B. Long, "Throwback in Time," *Science Fiction Plus*, April 1953.

[56] A. S. Eddington, *The Nature of the Physical World*, Macmillan 1929.

[57] A. Einstein, "La Théorie de la Relativité," *Bulletin de la Société Francaise de Philosophie* 1922, pp. 91–113.

[58] Such as, for example, the intersection *point* of two very long, closing scissor blades. The explanation for how this can be is that the *point* is massless and does not participate in a causal chain (and so carries no information). Thus, special relativity is not violated.

failure, not of the field equations of electromagnetic theory, but of some elementary properties of space-time." This last line sounds very much like the things people say today about the singularity inside a black hole event horizon. And yet, Dirac was careful to point out that as weird as FTL speed may appear, special relativity is not violated because "in spite of this departure from ordinary relativistic ideas, our whole theory is Lorentz invariant." That is, even though 'faster-than-light' means 'backward in time,' which means 'causality failure,' special relativity still holds true and nothing awful happens to physics, only to our intuitions. The reason for this is that causality is *not* a premise or starting point for the special relativity.[59]

Of course, like any scientific theory, Dirac's theory is not necessarily the last word, and we have to admit the possibility that at least some of its implications (in particular, the possibility of FTL speeds) just aren't so. In all electronic communication systems that we use, information is transmitted by *modulating* a so-called *carrier wave*, and there is some reason to believe that such modulated waves cannot be sent at FTL speeds.[60] We must admit that it is one thing to talk of 'advanced wave radios'—often called *Dirac radios* in science fiction—and quite another to see how physics might actually enable one to talk to the past. FTL communication (without the time travel aspect) appeared in pulp science fiction before 1940, as in one story published the year after Dirac's paper.[61] In it we learn of a man on Pluto who has invented a way to send messages to Earth at twice the speed of light. He uses this gadget to warn of a would-be dictator who is on his way to Earth in a 'mere' light-speed rocket ship, and only an FTL message can warn Earth in time.

5.4 Wheeler and Feynman and Their Bilking Paradox

> "We find it difficult if not impossible to imagine waves that go into the future and *return to the present* [my emphasis] bearing information about where (and when) they have been."[62]

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[59] See, for example, G. Nerlich, "Special Relativity Is Not Based On Causality," *British Journal for the Philosophy of Science*, December 1982, pp. 361–388. This same point was made nearly two decades earlier, in a study of the possibility of superluminal sound in superdense matter, by D. A Kirzhnitz and V. L. Polyachenko, "On the Possibility of Macroscopic Manifestations of Violation of Microscopic Causality," *Soviet Physics JETP*, August 1964, pp. 514–519.

[60] See G. Diener, "Superluminal Group Velocities and Information Transfer," *Physics Letters A*, December 16, 1996, pp. 327–331. For more on the modulation of a light-speed carrier wave in everyday AM radio, and in a more sophisticated single-sideband transmitter, see my book *The Science of Radio*, Springer 1999.

[61] N. Bond, "Lightship, Ho!," *Astounding Science Fiction*, July 1939. The author provides an interesting, detailed description of the gadget, and I think it would make a good question on a Ph. D. qualifying exam in physics or electrical engineering to explain the flaw in it.

[62] Bob Brier, *Precognition and the Philosophy of Science: An Essay on Backward Causation*, Humanities Press 1974. Brier is an Egyptologist (!) at Long Island University—with a Ph.D. in philosophy—who specialized at one time in parapsychology.

In 1941, at a meeting of the American Physical Society, Princeton University physicist John Wheeler and his student Richard Feynman discussed a seemingly outrageous idea that provided a possible clue to how a Dirac radio might function. The idea was that the advanced wave solutions to Maxwell's equations are not mere mathematical curiosities, but rather have profound physical significance. At the time, their talk received only a small abstract notice in the *Physical Review*, but after World War II they wrote it all up in a beautiful paper.[63]

Their primary goal was to explain the origin of the force of radiative reaction discussed by Lorentz earlier in the century. This reaction force is the cause of the energy loss suffered by an accelerated, charged particle. Lorentz, who thought of charged particles as having a finite size, attributed this reaction force to the retarded (by the time required for light to cross the width of the charged particle) coulomb repulsion force between one side of the particle's charge to the charge on the opposite side. This view, however, leads to various conceptual and mathematical problems, including an arbitrary assumption on how the charge is distributed over/through the finite volume of the particle, as well as the problems of infinite self-interactions and the issue of what keeps the charge from blowing itself apart by internal coulomb repulsion.

Wheeler and Feynman's theory, on the other hand, avoided those problems by postulating point charges, because a *point* charge cannot repel itself. But then whence the reaction force, if there is no repulsion? Their revolutionary explanation was first to imagine the accelerated point charge as emitting retarded radiation outward in space, eventually to be absorbed by distant matter. This distant matter, which itself consists of point charges that are accelerated by the retarded radiation, then radiates *backward* in time, back toward the original charge that started the chain of events. This backward-in-time, or *advanced*, radiation arrives in the past of the original charge, and *it* is the cause of the observed reaction force. Indeed, Wheeler and Feynman proposed that an accelerated charge will not radiate unless there is to be absorption at some other distant place and future time. That is, the *future* behavior of a distant absorber determines the *past* event of radiation; there is simply no such thing as just radiating into empty space. The entire universe, spatially *and* temporally, is a very 'connected' place!

Astonishingly, this non-causal view of spacetime had been around in physics for at least 20 years before Wheeler and Feynman's talk. They had independently developed their ideas but, after their 1941 talk, Einstein (who perhaps recalled his 1909 debate about advanced effects with Ritz) brought a 1922 paper by the Dutch physicist Hugo Tetrode (1895–1931) to their attention. In his paper Tetrode had written that "the Sun would not radiate if it were alone in space and no other bodies could absorb its radiation ... If for example I observe through my telescope yesterday evening that star which let us say is 100 light years away, then not only did I know that the light which it allowed to reach my eye was emitted 100 years ago, but also the star or individual atoms of it knew already 100 years ago that I, who then did not even exist, would view it yesterday evening at such and such a time."

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[63] J. A. Wheeler and R. P. Feynman, "Interaction with the Absorber as the Mechanism of Radiation," *Reviews of Modern Physics*, April–July 1945, pp. 157–181.

Tetrode's vivid imagery had been, curiously, itself captured even decades earlier in words from the nineteenth century English poet Francis Thompson (1859–1907), in his "The Mistress of Vision":

All things … near and far,
Hiddenly to each other linked are,
That thou canst not stir a flower
Without troubling of a star.

None of this, of course, is obvious! As a tutorial paper appearing just 2 years after Wheeler and Feynman's 1945 paper expressed it, "Any physical theory which seriously proposes that events in the future may be the efficient cause of events in the past may be regarded—at least at first glance—as rather revolutionary doctrine."[64] Indeed!

It is interesting to note that Einstein apparently said nothing to Wheeler and Feynman about a paper that pre-dated Tetrode's by 3 years. In 1919 the Finnish physicist Gunnar Nordström (1881–1923) had suggested that the advanced solution might offer an explanation for a perplexing problem in atomic theory. Maxwell's theory says that an accelerated electric charge radiates energy, which implies that the orbital electrons in the classical model of the atom should quickly spiral in toward the nucleus, that is, all matter should collapse. This cataclysmic event (of course!) has not happened, and Nordström's idea was that if one took into account not only the usual retarded solution but the advanced one as well, then perhaps things could be understood. Indeed, Nordström was able to show that such an analysis does give zero for the *average* energy radiated by an orbiting electron. Later, however, Page (note 39) showed that the instantaneous radiated energy is not zero, and that this would lead to observable effects that in fact are *not* observed.

Now, to be sure that the 'doctrine' discussed in note 64 is clear, let me restate what Tetrode, and later Wheeler and Feynman, had in mind. Imagine we have an electric charge (the *source*) that we mechanically shake, that is, accelerate. This allows us to assign a definite *cause* to the charge's acceleration which, of course, radiates energy. This radiation travels outward into space as observed retarded fields until they are eventually absorbed by distant matter. The charges in that distant matter are thus accelerated, and they in turn therefore radiate energy. This induced radiation again consists, according to Wheeler and Feynman, of both retarded and advanced fields. The advanced fields radiate outward but *backward* in time toward the original charge, collapsing upon it at the precise instant we first shook it, thereby producing the radiative reaction force. At any instant of time, at any point in space, the observed field is the sum of the retarded field traveling away from the source into the future and the advanced field traveling toward the source in the past.

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[64] C. W. Berenda, "The Determination of Past by Future Events: A Discussion of the Wheeler-Feynman Absorption-Radiation Theory," *Philosophy of Science*, 1947, pp. 13–19.

But, argued Wheeler and Feynman, there is one last point that has been left out of this picture—there is also an advanced field (traveling away from the source and backward in time) because of the original, mechanical shaking of the source charge. Equivalently, a field traveling *forward* in time will *converge* onto the source because we *will* shake it. Wheeler and Feynman showed that before the mechanical shaking that starts this whole process, the advanced radiation field of the source and the advanced radiation fields of the absorbers exactly cancel each other at every point in space and every instant of time (if there is total absorption in the future), which accounts for the experimental fact that we observe a zero total field before the mechanical shaking occurs.

Wheeler and Feynman showed that if we accept these (strange) ideas, then everything we actually observe is predictable: radiative reaction, the direction of the electromagnetic arrow of time from past to future (retarded-only effects), and the absence of infinite self-interactions. The claim by Wheeler and Feynman to have avoided self-interaction problems via the use of the advanced solution was, however, soon challenged. Indeed, the self-interaction of the electron is *needed* to explain the 1947 experiment by Willis Lamb (1913–2008) that measured the deviation (the *Lamb shift*) of the spectrum of hydrogen from what Dirac's theory of the electron predicts. Ironically, it was that experiment that helped motivate the renormalization of quantum electrodynamics (to get rid of the infinities then plaguing it) which led to Feynman's share of the 1965 Nobel Prize. In fact, just 4 years after their 1945 paper, Feynman expressed a revised view that self-interactions could not be avoided.[65]

In any case, we gain the rewards originally claimed by Wheeler and Feynman *only if* we accept backward time travel, a step too big for many in 1945 (and for nearly as many today) because of the resulting time travel paradoxes that seem to be unavoidable. For the same reason, Tetrode's earlier work, published in a German journal, also went virtually unnoticed during the two decades before Wheeler and Feynman's work. In fact, Tetrode wasn't the only anticipator of Wheeler and Feynman, as they had been anticipated, too, in America. In 1926 the chemist G. N. Lewis (1875–1946) had written "I'm going to make the … assumption that an atom never emits light except to another atom, and to claim that it is absurd to think of light emitted by one atom regardless of the existence of a receiving atom as it would be to think of an atom absorbing light without the existence of light to be absorbed."[66] Wheeler and Feynman were aware of Lewis by 1945. Certainly Wheeler and Feynman must have been intrigued by Lewis' paradox: "I shall not attempt to conceal the conflict between these views and common sense. The light coming from a distant star is absorbed, let us say, by a molecule of chlorophyll which has recently been produced in a living plant. We say that the light from the star was on its way toward us a thousand years ago. What rapport can there be between the emitting source and this newly made molecule of chlorophyll?"

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[65] R. P. Feynman, "Space-Time Approach to Quantum Electrodynamics," *Physical Review*, September 15, 1949, pp. 769–789. See also C. Teitelboim, "Splitting the Maxwell Tensor: Radiation Reaction Without Advanced Fields," *Physical Review D*, March 15, 1970, pp. 1572–1582.

[66] G. N. Lewis, "The Nature of Light," *Proceedings of the National Academy of Sciences*, January 15, 1926, pp. 22–29.

The paradox in that, of course, arises from the issue of what happens if, at some intermediate time and place, the star's light is blocked, thus preventing its absorption by the chlorophyll? Could refusing to look at a star *now* affect the emission of the star's light in the *past*? Lewis was obviously making a clear statement of backward causation when posing this bilking paradox. His very next words show that he understood the probable reaction of his readers: "Such an idea is repugnant to all our notions of causality and temporal sequence." Like Tetrode's work, Lewis' ideas were ahead of the times but, actually, their ideas were *not* repugnant to everyone.

In fact, similar puzzles were an inspiration to Wheeler and Feynman and almost certainly motivated them to create their own famous bilking paradox, which they presented in their 1949 paper (note 42). They opened the presentation of their paradox as follows: "If the present motion of *a* is affected by the future motion of *b*, then the observation of *a* attributes a certain inevitability to the motion of *b*. Is not this conclusion in direct conflict with our recognized ability to influence the future motion of *b*?" This question clearly states the conflict between free will and determinism, and to sidestep this *human* concern Wheeler and Feynman constructed a "paradox machine," a machine that operates totally automatically and which has come to be called the "logically pernicious self-inhibitor"![67]

In their description of the paradox machine, Wheeler and Feynman ask us to imagine two charged particles, *a* and *b*, positioned five light-hours apart. As shown in Fig. 5.3, *a* is attached to the arm of a pivoted shutter, toward which a pellet is moving from initially a great distance away. Now, normally we would think of what happens next in terms of just retarded fields. That is, the pellet hits the arm, knocking it downward and thereby accelerating charge *a*; this acceleration of charge *a* creates a retarded radiation field that arrives at charge *b* 5 h later, resulting in the acceleration of charge *b*; the acceleration of charge *b* creates a retarded radiation field that arrives back at charge *a* 5 h later (10 h after the pellet hit the arm).

The Wheeler and Feynman view, however, claims that this description leaves out half the story—the *advanced* fields. Specifically, suppose the pellet will hit the arm and so accelerate *a* at 6 p.m. Then, *b* will be affected not only 5 h later at 11 p.m., but also *earlier* at 1 p.m. This advance acceleration of *b*, in turn, sends out an advanced field that arrives at *a* at 8 a.m. The paradox is now easy to see. As Wheeler

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[67] P. Fitzgerald, "Tachyons, Backwards Causation, and Freedom," *Boston Studies in the Philosophy of Science* (volume 8), 1970, pp. 415–436. Even more extreme examples of such paradox machines are described in Tim Maudlin, "Time Travel and Topology," *PSA 1990*, Philosophy of Science Association, volume 1, pp. 303–315.

Fig. 5.3 Wheeler and Feynman's paradox machine

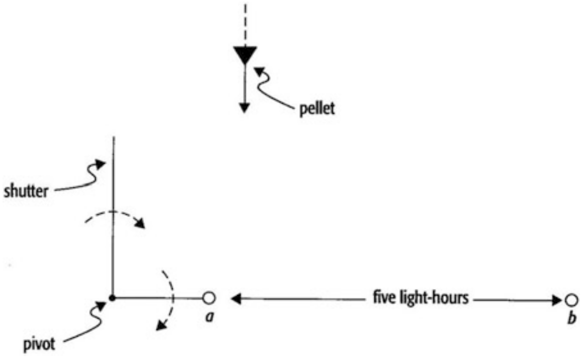

and Feynman described events, we see *a* exhibit a premonitory movement at 8 a.m. Seeing this motion in the morning, we conclude that the pellet will hit the arm in the evening. We could then return to the scene a few seconds before 6 p.m. and block the pellet from acting on *a*, a task automatically accomplished by the shutter in Wheeler and Feynman's paradox machine. But then we are faced with the puzzle of explaining just *why a* moved in the morning!

Wheeler and Feynman claimed they had resolved their bilking paradox by observing that *discontinuous* forces (more generally, *signals*) are never seen in nature. They concluded that the shutter does not completely block the pellet, but rather the shutter suffers a "glancing blow." That is, a very weak advanced signal is received by charge *a*, which moves the shutter just enough to induce the "glancing blow," and it is this partial interaction that results in the weakened signal in the "first place." This is, in fact, the very same explanation that was rediscovered decades later in answer to similar bilking paradoxes that involve self-interacting billiard balls transiting wormhole time machines (a topic we'll take-up in the next chapter).

5.5 Absorber Theory and Signaling the Past

> "If advanced waves [could be used to signal the past] then our grip on reality would become more tenuous. The past could never be considered over and done with, because anyone with the proper hardware could send messages back in time and alter what had already happened."
>
> —John Cramer, a University of Washington physicist, taking the minority position on the possibility of changing the past[68]

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[68] Cramer has written provocatively on advanced waves. See, for example, "The Arrow of Electromagnetic Time and the Generalized Absorber Theory," *Foundations of Physics*, September 1983, pp. 887–902, and "Generalized Absorber Theory and the Einstein-Podolsky-Rosen Paradox," *Physical Review D*, July 15, 1980, pp. 362–376.

Wheeler and Feynman's argument *is* logically and physically sensible; it is, after all, simply an early statement of the principle of self-consistency in physics. Wheeler summed matters up nicely, years later, when he wrote "Interconnections run forward and backward in time in such numbers as to make an unbelievable maze. That weaving together of past and future seems to contradict every normal idea of causality. However, when the number of particles is great enough to absorb completely the signal starting out from any source, then this myriad of couplings adds up to a simple result: the familiar retarded actions of everyday experience, plus the familiar force of radiative reaction with its familiar sign."[69]

Their analysis was based on classical physics but, many years later, Feynman wrote (in his famous autobiographical work *Surely You're Joking, Mr. Feynman*) that at one time he and Wheeler thought it would not be too difficult to work out the quantum version of their theory. But then first Wheeler failed in the task, and then Feynman tried his hand at it and, as he stated, "I never solved it, either—a quantum theory of half-advanced, half-retarded potentials—and I worked on it for years." Their paradox (if indeed it *is* a paradox, since if advanced fields don't actually exist then there is no problem) remains unsolved.

Is Wheeler and Feynman's view of nature correct? Could we use advanced waves to send signals to the past? Or, if that requires some yet-to-be-developed technological breakthroughs in transmitter design, and if receivers are easier to construct, could we at least listen-in to the future (since we are, *now*, the future's past)? And if we could do that, could the future send us the details of the transmitter breakthrough (thus creating a causal information loop in time)?

The first experimental search for advanced waves seems to have been a 1973 effort.[70] The very next year, flaws in that search process prompted two physicists to discuss an experiment designed to detect advanced waves (if they exist). As they wrote, in a grand understatement, the exciting possibility of a positive result "would have such far-reaching consequences on our ideas of the unidirectionality of time and causality that … the experiment justifies a large amount of effort, even if no conclusive result is obtained for years."[71] Alas, all of the searches for advanced waves have, as I write (2016), given negative results and so the world still awaits the first Dirac radio.

Over the years the Wheeler and Feynman view of nature has been the target of some theoretical concerns. One physicist, for example, complained that Wheeler and Feynman had assumed a static, time-symmetric spacetime for the universe, in which the properties of all past and future absorbers are identical. That is obviously not so in an expanding (or contracting) universe and, as he wrote, "No serious modern cosmological theory is framed in [terms of] a static Universe."[72] Another puzzle for that writer was that Wheeler and Feynman took a time-symmetric theory of half-retarded/half-advanced waves in a time-symmetric universe and arrived at a *non*-time-symmetric solution! They performed that trick by supposing not only that the universe is static, but also that it was created with the initial condition of low entropy. Thus, for Wheeler and Feynman, the one-way thermodynamic arrow of time is the primary arrow, with the electromagnetic arrow following as a consequence. (The *how* of a low entropy initial cosmological condition was left unexplained—certainly no mention of the hand of God appears in their work!) This ordering of the primacy of the temporal arrows was, in fact, in agreement with the view adopted by Einstein in his 1909 debate with Ritz, a view taken decades later by Hawking, as well.[73]

---

[69] See note 34 in Chap. 3. There Wheeler also wrote "The particles of the absorber are either at rest or in random motion before the acceleration of the source. They are correlated with it in velocity after that acceleration. Thus radiation and radiative reaction are understood in terms, not of pure electrodynamics, but of statistical mechanics."

[70] R. B. Partridge, "Absorber Theory of Radiation and the Future of the Universe," *Nature*, August 3, 1973, pp. 263–265.

[71] M. L. Herron and D. T. Pegg, "A Proposed Experiment in Absorber Theory," *Journal of Physics A*, October 1974, pp. 1965–1969.

Wheeler and Feynman had shown that both the advanced and retarded solutions taken together are self-consistent in a static universe; Hogarth's question was whether the observed retarded solution, *alone*, would be self-consistent in an *expanding* universe (which is the universe we actually observe). His conclusion? It depends on the details of the expansion. Two years after Hogarth, two physicists expanded on his work and claimed to have shown that the retarded solution alone *is* self-consistent *if* the expansion is steady-state via the continuous creation of matter.[74] That would be the case because, if only retarded effects are to occur, then each emitter of radiation needs a large number of absorbers (such as ionized intergalactic gas) in its future light cone to provide for complete absorption. This, in turn, requires that the density of matter not decline "too fast" with the expansion. That is, the future universe must not be "too transparent" and the continual appearance of new matter in the ever-increasing volume of the expanding universe is required to maintain the necessary density.

That conclusion was embraced with particular enthusiasm by Hoyle, a British cosmologist whose name has long been identified with the idea of continuous creation of matter. Since then, however, continuous-creation cosmologies have fallen into disfavor because it was in 1965, just a year after Hoyle and Narlikar wrote, that the cosmic microwave background radiation was detected. That is now taken as very strong evidence for the occurrence of a primordial explosion (or Big Bang) that started the expansion of the universe, and as equally strong support for therefore rejecting a steady-state universe. Not by Fred Hoyle (1915–2001), though, who had an almost fanatical devotion to non-Big Bang cosmologies.[75] Real puzzles remain for the Big Bang universe, however. One is that it expands from a dense, opaque past into a less dense, ever-more-transparent future, with each emitter having a large number of absorbers in its *past* light cone. That should result, noted Hoyle and Narlikar (almost certainly with some glee), in an observed advanced solution and thus in a reversed electromagnetic arrow that would allow communication with the past. The fact that we have not (yet?) discovered how to perform such communication might be taken to mean that the idea of an expanding, Big Bang universe is somehow faulty. A related question about absorber theory is that of the puzzle of neutrino absorption. Neutrinos are particles that interact so weakly with matter that a beam of them would have to travel through many hundreds of light-years of lead for there to be a significant attenuation of the beam. How can such 'ghost-like' particles find enough future absorbers to make possible their observed journeys into the future of a Big Bang expanding universe?

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[72] J. E. Hogarth, "Cosmological Considerations of the Absorber Theory of Radiation," *Proceedings of the Royal Society A*, May 22, 1962, pp. 365–383. Hogarth, however, rejected the static universe, asserting instead that the *observed expansion* of the universe provides the required asymmetry, resulting in the cosmological arrow of time as the primary arrow and the electromagnetic arrow as a consequence.

[73] S. W. Hawking, "Arrow of Time in Cosmology," *Physical Review D*, November 15, 1982, pp. 2489–2495.

[74] F. Hoyle and J. V. Narlikar, "Time Symmetric Electrodynamics and the Arrow of Time in Cosmology," *Proceedings of the Royal Society A*, January 1964, pp. 1–23.

For such an exciting idea as communication with the past, it is not surprising that advanced-wave radio has appeared in science fiction. Just 6 years after Wheeler and Feynman's paper, a story by a well-known author hinted at such a gadget based on something called the "ultrawave effect": "While gravitational effects were produced by the presence of matter, ultrawave effects . . . did not appear unless there was a properly tuned receiver somewhere. They seemed somehow 'aware' of a listener even before they came into existence."[76] It is difficult to believe that such a story idea was conjured-up out of nothing, but rather that the author had read Wheeler and Feynman's paper. Anderson had a 1948 undergraduate honors degree in physics from the University of Minnesota, and so he may *well have* read Wheeler and Feynman's 1945 paper.

The potential bilking paradoxes produced by sending messages backward in time have been treated in at least one novel-length discussion. The puzzles presented are undeniably fascinating, but the story's answer to them is to allow the changing of the past, as argued in this section's opening quote from John Cramer. Indeed, the title comes from the plot device of twice changing the past by sending messages to the past to save the world from terrible disasters. Thus, we read through entire time periods *three* times before finishing the novel. As one character blurts out, "We can monitor the actual consequences of our decisions and actions, and change them until they produce the desired result! My God . . . it's staggering!"[77] Quite so.

One of the most interesting science fictional uses of backward-in-time signaling is, I think, found in a classic tale by James Blish. There the "Dirac radio" for instantaneous transmissions is described, and we learn that at the beginning of each received message there is always an irritating audio beep (hence the title) that is seemingly a useless artifact of the mysterious workings of the gadget. Its only obvious characteristic is a continuous spectrum from 30 to well above 18,000 Hz. It is only at the end of the story that the main character learns that this spectrum is the "simultaneous reception of every one of the Dirac messages which [has] ever been sent, or will be sent."[78]

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[75] Besides his scientific work, Hoyle also wrote science fiction. One work, the 1966 novel *October the First is Too Late*, deals with travels in time but fails to say anything about paradoxes.

[76] Poul Anderson, "Earthman, Beware!," *Super Science Stories*, June 1951.

[77] J. P. Hogan, *Thrice Upon a Time*, Ballantine 1980.

Blish was actually pretty close to the mark with that, as a composite signal with a continuous spectrum (with energy distributed uniformly in frequency), such as one might expect the overlay of many independent signals to be, does indeed have a narrow time structure. If applied to a loudspeaker, such a signal would sound like a sharp pulse or click—or even a *beep*. In the limit of an infinitely wide spectrum, the time signal becomes one of infinite amplitude and zero duration, a singular *impulse* function called, by theoretical physicists and radio engineers alike, the *Dirac delta function*.

There is no mention in the story of advanced waves, but clearly Blish knew that instantaneous (infinite-speed) signals would travel into the past and he does a masterful job of presenting the mystery of listening to the future. At one point characters in the twenty-first century hear the commander of a time-traveling "world-line cruiser" transmit a poignant call for help from 11,000,000 light years away and from sixty-five centuries in the future. Most interesting of all, however, is Blish's statement of a technical issue that I have not seen raised before: if signals arrive at a receiver, simultaneously, from all future times, how can they be separated? Blish resorts to some scientifiction babble-talk to answer that question, but I believe it remains a puzzle.[79]

5.6 Tachyonic Signals and the Bell Quantum Antitelephone

> "We cannot fight the laws of nature."
>
> "Nature be damned! Feed more fuel into the tubes. We must break through the speed of light … Give me a clear road and plenty of fuel and I'll build you up a speed of half a million miles in a second … What's there to stop it?"[80]

Science fiction writers have often used FTL motion to reverse time, often without much (if any) regard to the fact that, to just *reach* the light barrier, requires (according to special relativity) infinite energy, much less to exceed light speed.

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[78] J. Blish, "Beep," *Galaxy Science Fiction*, February 1954.

[79] The signal separation problem is also hinted at by physicist/science fiction author Gregory Benford, in a tale that was a precursor to his famous 1980 novel *Timescape* (in which the present attempts to warn the past of a future ecological disaster that threatens life on Earth). See Benford's "Cambridge, 1:58 A.M.," *Epoch*, Berkeley 1975.

[80] Words exchanged by the first officer and the captain of a starship on its way to Alpha Centauri in a story by N. Schachner, "Reverse Universe," *Astounding Stories*, June 1936. The captain, we are told, "had heard, of course, of the limiting velocity of light, but it meant nothing to him."

Therefore, goes the reasoning, because we can't get through the 'light barrier' means that time travel to the past must be impossible, as well. Or, so goes this line of argument. But, could there be a way around this conclusion? After all, while relativity theory indeed precludes the acceleration of a *massive* particle *up to* the speed of light, it does allow a zero rest mass particle (like the photon) to exist *at* the speed of light. Photons are emitted during various physical processes, and they move from the instant of their creation at the speed of light; the only way to slow a photon is to destroy it by absorbing it. Advocates of the possibility of the existence of FTL particles make a similar argument when asking if there might not be particles, emitted during various (as yet unknown) physical processes, that move from the instant of their creation at speed *greater* than that of light?

An affirmative answer would neatly avoid the 'acceleration through the light barrier' problem, but then there are other concerns. For example, such FTL particles would have to have an imaginary rest mass if they were to carry real-valued energy and momentum, and what could *imaginary mass* mean? That question was answered by the proponents of FTL particles, who replied that the rest mass of a superluminal particle would be unobservable because (like the photon) there is no subluminal frame of reference in which the particle could be at rest! That is, there is no frame of reference in which the mysterious imaginary mass could be measured and, anyway, it is only *observable* changes in the real energy and momentum that characterize particle interactions.

The key idea to this line of thought is a *supposed* FTL particle, called a *tachyon*, a name coined by the American physicist Gerald Feinberg (1933–1992) from the Greek word *tachys* for "swift."[81] It is interesting to note that Feinberg admitted[82] that his interest in such a thing was sparked by reading Blish's story "Beep" (see note 78). The idea of the tachyon is actually a very old one that is hinted at in the work of the Greek poet and philosopher Lucretius (who died 20 years before the birth of Christ). In his discussion of visual images, in Book 4 of his giant (well over 7400 lines) science poem *De Rerum Natura*, we find the following words about particles of matter originating deep inside the Sun: "Do you see how much faster and farther they must travel, how they must run through an extent of space many times vaster in the time it takes the light of the Sun to spread throughout the sky?"[83]

The first attempt (later found to be flawed) in the physics literature of a relativistic treatment of FTL particles appeared some years before Feinberg gave

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[81] G. Feinberg, "Possibility of Faster-Than-Light Particles," *Physical Review*, July 25, 1967, pp. 1089–1105. Feinberg was anticipated in this name by Edward Page Mitchell (the Victorian pioneer in the time travel paradox genre who was discussed back in Sect. 4.2 and its note 37). In his story "The Tachypomp: A Mathematical Demonstration" (*Scribner's Monthly*, March 1874), he describes a gadget for reaching any speed, no matter how great (*tachypomp* is literally "quick sender").

[82] G. Benford, "Time and *Timescape*," *Science-Fiction Studies*, July 1993, pp. 184–190.

[83] A poetic allusion to something traveling faster than light appears, in of all places, Shakespeare's *Romeo and Juliet*. In Juliet's words (Act II, scene 5), "... love's heralds should be thoughts, Which ten times faster glide than the sun's beams, Driving back shadows ..."

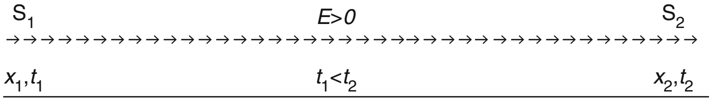

Fig. 5.4 The emission of a positive energy particle, followed by absorption

them a name, where it was observed that special relativity is *not* necessarily violated by FTL motion.[84] But nonetheless, concerns about the physical possibility of FTL particles continued. For example, a serious problem for tachyons, at least for those who dislike the ideas of backward causation and time travel, is the observation that in some frames of reference an FTL particle would appear to have *negative energy*. Feinberg, himself, explained (see note 81) this concern as follows: "By the principle of relativity, any state which is possible for one observer must be possible for all observers, and hence FTL particles can exist in negative-energy states for all observers . . . The occurrence of negative energy states for particles has always been objected to on the grounds that no other system could be stable against the emission of these negative-energy particles, an entirely unphysical behavior."

This objection to FTL particles was raised early in the history of tachyons, even before they were named, and it was addressed by three physicists who proposed the so-called *reinterpretation principle* (what I'll refer here to as the RP).[85] To see how the RP works, consider Fig. 5.4, in which a source S_1 at x_1 emits an FTL particle at time t_1. This particle then travels to an absorber S_2 at x_2, arriving there at the later time t_2. S_1 and S_2 are in the same reference frame and, for an observer in the frame, the particle energy E is positive. However, it is always possible to find another observer in a relatively moving frame for whom this process would look as though t_2 is less than (that is, earlier than) t_1 with $E < 0$. In other words, for the moving observer the particle would appear as a negative energy particle moving backward in time. (In the next chapter I'll show you that the particle speed must not be just superluminal, but the even faster *ultraluminal*.)

Note that for the moving observer, the emission by S_1 of negative energy *increases* the energy of S_1, and the absorption of negative energy by S_2 decreases the energy of S_2. S_2's energy decrease (for the moving observer) occurs before the increase in S_1's energy because, as noted before, for the moving observer $t_2 < t_1$. The moving observer naturally interprets this process as the emission of positive energy by S_2, followed by absorption by S_1. This reinterpretation would thus seem to preserve our common-sense idea of causality, as well as avoiding any mention of backward time travel. The RP appears to have slipped around those problems merely by redefining which source is transmitting, and which is receiving, the tachyon. Indeed, Feinberg claimed (note 81) that the RP avoids the creation of causal loops and their associated paradoxes, a claim repeated nearly 20 years later by a physicist who used the RP to eliminate paradoxes from Gödel's time travel rotating universe.[86]

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[84] S. Tanaka, "Theory of Matter with Super Light Velocity," *Progress of Theoretical Physics*, July 1960, pp. 171–200. See also O. M. Bilaniuk and E. C. G. Sudarshan, "Particles Beyond the Light Barrier," *Physics Today*, May 1969, pp. 43–51 (and the resulting discussion in the December issue, pp. 47–52).

[85] O. M. P. Bilaniuk, V. K. Deshpande, and E. C. G. Sudarshan, "'Meta' Relativity," *American Journal of Physics*, October 1962, pp. 718–723.

There is, however, a curious twist to all this. Even if we grant that the RP may avoid causal paradoxes, the fact is that physics isn't fooled as easily as a human observer. That is, the receiver does actually lose energy upon the arrival of the tachyon, which is the opposite of what happens in a radio receiver when it receives a photon. In other words, the receiver must be in an elevated energy state prior to the tachyon's arrival; the receiver must be prepared beforehand to receive a message. If the receiver were instead sitting in its lowest energy state, then it could not accept (or *eject*, according to the RP) the tachyon. So, it's not surprising that, despite the enthusiastic embrace of the RP by some, other physicists took exception, with one arguing that the effectiveness of the RP in avoiding causal loops is "illusory" and "irrelevant,"[87] while others concluded that the causal paradoxes would actually preclude any possibility of tachyons interacting with ordinary matter in the first place (which is just a polite way of saying that tachyons have no more reality than do unicorns!).[88]

The RP's effect of flipping the roles of transmitter and receiver has attracted particular concern. Some analysts have pointed out that if one can modulate a superluminal signal to send a message into the past, then certainly one could *sign* the message. To quote a delightful example, "If Shakespeare types out *Hamlet* on his tachyon transmitter, Bacon receives the transmission at some earlier time. But no amount of reinterpretation will make Bacon the author of *Hamlet*. It is Shakespeare, not Bacon, who exercises control over the content of the message."[89] The last line of this quote is of central importance. The authors emphasize it by immediately observing that a signature is a *relativistic invariant* and that, indeed, it establishes a causal ordering quite independent of any temporal ordering. This example, alone, explains why one analyst said of the RP that it is "laughed to scorn,"[90] while another said of the RP that it "sounds merely like the endorsement of what can only be characterized as a fantastic delusion."[91]

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[86] A. Italiano, "How to Recover Causality in General Relativity," *Hadronic Journal*, January 1986, pp. 9–12.

[87] R. G. Newton, "Particles That Travel Faster Than Light," *Science*, March 20, 1970, pp. 1569–1574.

[88] W. B. Rolnick, "Implications of Causality for Faster-Than-Light Matter," *Physical Review*, July 25, 1969, pp. 1105–1108, and D. J. Thouless, "Causality and Tachyons," *Nature*, November 1, 1969, p. 506.

[89] G. A. Benford, D. L. Book, and W. A. Newcomb, "The Tachyonic Antitelephone," *Physical Review D*, July 15, 1970, pp. 263–265.

[90] P. Fitzgerald, "On Retrocausality," *Philosophia*, October 1974, pp. 513–551.

[91] W. L. Craig, "Tachyons, Time Travel, and Divine Omniscience, *Journal of Philosophy*, March 1988, pp. 135–150.

Even more sophisticated scenarios than the *Hamlet* one (note 89) were devised to show how problems with FTL signals could arise that the RP could *not* resolve. The American physicist Bryce DeWitt (1923–2004) created such an example (the 'DeWitt Gambit') that involved a sequential, circular chain of tachyon signal transmissions between four observers, all moving in one spatial dimension. DeWitt showed out to arrange the spacetime geometry of the observers so that, at each stage, there is no dispute over who is sending and who is receiving, and so invoking the RP is avoided. Yet, when the signal reaches the first (last) observer, it is *before* he started (will start) the chain! This, of course, sets-up a potential bilking paradox: what if 'now' the first (last) observer decides to *not* send the chain's initiating signal? An even more sophisticated variation on the Gambit, involving four observers moving in *two* spatial dimensions, was soon after put forth by the English physicist Felix Pirani (1928–2015). As he concluded, "It is difficult to see how in the face of this example a classical-particle description of tachyons can be sustained."[92] Confronted by such sharp criticism, from so many, it is understandable why, just before his death, Feinberg co-authored (with two philosophers) a paper in which he seemed to be abandoning his support for tachyons as possible carriers of information backward in time.[93]

Many physicists today reject the possibility of backward-in-time messages, not because of concerns about the RP, but because such messages could create potential bilking paradoxes. To see how this works, the old Wheeler and Feynman idea of explaining (away) bilking paradoxes—that no signal in nature is *really* discontinuous—was examined by one physicist in the context of tachyons.[94] There we are asked to consider the following situation: A human (call him A) has a lamp on a table before him. The lamp is controlled by a tachyon receiver; in other words, the lamp illuminated only when a tachyon signal (a pulse, let us say) is detected. At 3 o'clock A will send a tachyon signal to B (a tachyon echo-transmitter that immediately rebroadcasts everything it receives) if the lamp does not glow at 1 o'clock. Now, the spacetime geometry of A and B is arranged to be such that a signal sent by either A or B to the other travels 1 h backward in time. Thus, if A sends a signal at 3 o'clock, then B will receive it at 2 o'clock (and immediately echo), and the echo will arrive at A at 1 o'clock. The paradox, of course, is that A sends a signal only if the lamp does *not* glow—that is, only if A does *not* send the signal![95]

We are then reminded of the Wheeler and Feynman claim that every pulsed signal is actually continuous; this argument would include the illumination itself of the lamp. Therefore, the lamp is not just on or off, but potentially at any level of illumination between those two extremes. So there sits A, and at 1 o'clock the lamp seems to glow dimly. To that, says Schulman, "A thinks it over, vacillating, finally sending a slightly late signal which isn't full strength." Then the echo isn't full strength either, which accounts for the original dim glow. This conclusion *is* consistent (but what if A's sending device is a toggle switch that *snaps* one way or the other—why then only a partial strength signal?), but it does seem to ask for a lot of supposing. Schulman himself is not so sure about the validity of universal continuity, writing at the end that "it is not clear that the Wheeler-Feynman assumption . . . ought to be made." (For more on the Wheeler-Feynman continuity assumption, in a different, non-time travel context, see the final "For Further Discussion" for this chapter.)

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[92] F. A. E. Pirani, "Noncausal Behavior of Classical Tachyons," *Physical Review D*, June 15, 1970, pp. 3224–3225.

[93] G. Feinberg, D. Albert, and S. Levine, "Knowledge of the Past and Future," *Journal of Philosophy*, December 1992, pp. 607–642.

[94] L. S. Schulman, "Tachyon Paradoxes," *American Journal of Physics*, May 1971, pp. 481–484.

[95] A study of similar situations can be found in L. L. Gatlin, "Time-Reversed Information Transmission," *International Journal of Theoretical Physics*, January 1980, pp. 25–29.

The Wheeler-Feynman continuity idea *is* ingenious, allowing one to find a logically and physically consistent solution in time travel scenarios that, at least at first glance, might seem to have no solution. Consider, for example, the following situation[96]: "We have a camera ready to take a black and white picture of whatever comes out of [a] time machine. The film is then developed and the developed negative is subsequently put in the time machine and set to come out of the time machine at the time the picture is taken. This surely will create a paradox: the negative will have the opposite distribution of black, white, and shades of grey, from the picture that comes out of the time machine. But since the thing that comes out of the time machine is the negative itself we surely have a paradox." But do we?

The answer is no, because "What will happen is that a uniformly grey picture will emerge which produces a negative that has exactly the same uniform shade of grey. No matter what the sensitivity of the film is, as long as the dependence of the brightness of the negative depends in a *continuous* [my emphasis] manner on the brightness of the object being photographed, there will be a shade of grey that produces exactly the same shade of grey on the negative when photographed. This is the essence of Wheeler Feynman's idea."[97] (The conclusion is the same if we move from black-and-white to color photography.)

Nonetheless and despite this apparent success, the supposed ability of a modulated beam of tachyons to send a message into the past still raised concerns among many, particularly about free will and fatalism. Suppose, say those who are concerned about these issues, that you receive a tachyon message from yourself from tomorrow, informing you that a man you plan to kill tonight is still alive (tomorrow). Does that mean it is beyond your power to kill him tonight? According to one analyst (note 67) the answer is no; you *could* kill him—but if you do then the message from tomorrow would not have arrived. And because ignorance is not a precondition to free will, your newly acquired knowledge does not, by itself, suddenly limit your ability to kill the man. But, this line of arguing went, if you do not attempt to kill the man because you believe the message from your future self, then in fact the message *has* limited you!

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[96] Taken from Frank Arntzenius and Time Maudlin, "Time Travel and Modern Physics," in *Time, Reality & Experience* (C. Callender, editor), Cambridge University Press 2002, pp. 169–200.

[97] More on the Wheeler-Feynman continuity idea, *and of its limitations*, can be found in D. Kutach, "Time Travel and Consistency Constraints," December 2003, pp. 1098–1113, and Phil Dowe, "Constraints on Data in Worlds with Closed Timelike Curves," December 2007, pp. 724–735, both in *Philosophy of Science*.

Fitzgerald's position was rebutted by Craig (note 91), who argues that it is not your ability to kill that is altered by the message but rather your motivation. Craig points out that such motivational changes can occur without invoking anything as radical as a message from the future. Suppose, he says, that just before you fire the fatal shot into your victim, you learn from him that he is your beloved, long-lost uncle. Clearly, your motivation for killing him is likely to be instantly altered, but equally clearly, your *ability* to kill him is unchanged. The mechanism for obtaining genealogical information, whether via time travel or as a last-minute appeal from your intended victim, is (says Craig) simply irrelevant. Not all buy into that, however, with one unconvinced analyst (note 94) writing that "history is a set of world lines essentially frozen into spacetime. While subjectively we feel strongly that our actions are determined only by our backward light cone, this may not always be the case." That is, Schulman appears open to the possibility that influences originating in the future might indeed have an impact on the present.

With the fading from the physics scene of enthusiasm for tachyons, the romance of communicating with the past using superluminal speeds passed from speedy particles to quantum mechanics via a mathematical result called *Bell's theorem*. John Bell, a physicist mentioned in the last chapter in connection with the MWI of quantum mechanics, published his theorem in a little article in an obscure, now defunct journal. Since then it has become one of the most cited physics papers from the 1980s.[98] The paradox cited in Bell's title refers to a famous 1935 paper in which Einstein (and two of his colleagues at the Institute for Advanced Study) challenged the conventional view of quantum mechanics, the view that there is no objective reality to anything unless it is observed.[99]

In fact, the possibility of quantum mechanics supporting FTL signals had been considered (and rejected) *before* Einstein's paper, by the Italian physicist Enrico Fermi.[100] Fermi concluded that, in a two atom system, the decay from an excited state of one atom (with the emission of a photon) would not influence the other atom before a time lapse of R/c, where R is the distance between the two atoms and c is the speed of light. In 1967, however, the Russian physicist M. I. Shirokov pointed out that Fermi's result was the result of an unjustified mathematical operation (he had replaced an integral from zero to infinity with one from minus infinity to infinity).

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[98] J. S. Bell, "On the Einstein-Podolsky-Rosen Paradox," in *Speakable and Unspeakable in Quantum Mechanics*, Cambridge University Press 1987.

[99] A. Einstein, B. Podolsky, and N. Rosen, "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" *Physical Review*, May 15, 1935, pp. 777–780. See also N. D. Mermin, "Is the Moon There When Nobody Looks? Reality and Quantum Theory," *Physics Today*, April 1985, pp. 38–47.

[100] E. Fermi, "Quantum Theory of Radiation," *Reviews of Modern Physics*, January 1932, pp. 87–132.

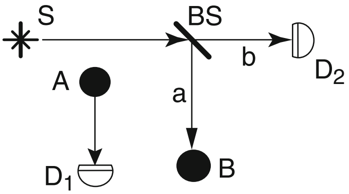

Fig. 5.5 Time travel and the wave function of quantum mechanics. In the above arrangement (reproduced by the kind permission of Francesco Gonella, from his paper "Time Machine, Self-Consistency and the Foundations of Quantum Mechanics," *Foundations of Physics Letters*, April 1994, pp. 161–166), S is a low-intensity source of photons, a source *so* weak that at any instant there is never more than one photon in the system. Each photon begins by traveling toward BS, a half-silvered beam-splitting mirror that, with equal probability, either passes a photon to the right along path b where it is detected by D_2, or downward along path a into mouth B of a wormhole time machine and out of which it emerges from wormhole mouth A *in the past*. Conventional quantum mechanics says that what happens at BS is determined *when the photon reaches BS*—that is, the probability wave function of the photon collapses at BS. But for a photon that is reflected into B, it exits A where it is detected by D_1 *before* the time of its arrival at BS. That means it is known (by detector D_1) what *will* happen at BS *before* the photon arrives at BS—so just *when did* the photon wave function collapse?

Then, nearly 30 years after Shirokov, the German physicist Gerhard Hegerfeldt proved (in the context of conventional quantum mechanics) a very general theorem that establishes a non-zero probability of the second atom responding to the first atom's decay *as soon as* the photon is emitted.[101]

Hegerfeldt's analysis is very general, but it does make one assumption—the non-negativity of energy density (the so-called *weak energy condition*)—which at the time was considered (in Hegerfeldt's words) to be "physically well motivated," but which today is *not* taken to be *a priori* obvious.[102] Einstein's paper, on the other hand, utilized physical assumptions not easily dismissed, and so its conclusions confounded physicists for decades.

The conventional view of quantum mechanics formulates physics in terms of probability wave functions that 'collapse' into specific realities only when measurements (observations) are made of the state of a system (which may be as elementary as a single particle). Until such measurements are made, says this view of quantum mechanics, a system has no specific state; instead, it merely has a probability distribution over a set of possible states (see Fig. 5.5 for a time travel puzzle concerning this claim). Einstein and his co-authors (note 99) strongly rejected this probabilistic interpretation of nature (recall Einstein's famous dictum, "God does not play dice with the cosmos.") Einstein and his colleagues agreed that quantum mechanics may be valid *as far as it goes*, but they also argued that it leaves out 'something' (as yet unknown) in describing reality. That is, they suggested that quantum mechanics is "incomplete" and that it incorporates "hidden variables."[103] They expressed this idea in the form of a paradox, the famous *EPR paradox*, which they posed as a thought experiment (a *Gedanken-experiment*) in which quantum mechanics declares that the properties of a particular spatially distributed system, when measured at point A, seem to be *forced* to assume specific values at point B (which may be arbitrarily distant from A) *without* there being a measurement at B.

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[101] G. C. Hegerfeldt, "Causality Problems for Fermi's Two-Atom System," *Physical Review Letters*, January 1994, pp. 596–599. This mere *suggestion* of a possible failure of causality so stunned the editor of *Nature* that he felt compelled to quickly write a 'calming' reply: "Time Machines Still Over the Horizon," February 10, 1994, p. 509.

[102] The issue of the sign of energy density is very important in the analyses of wormhole time machines (see note 135 in Chap. 1), and we'll return to it in the next chapter.

Thus, said Einstein, there are just two possibilities. Either the system properties at B must have been what they are from the very start (even if the measurements at A had not been done) which is the view he held, or there must have been a linkage between the system at A and the system at B such that the wave function collapse at A is instantly transmitted to B to allow the wave function to collapse there as well. Because A and B may be arbitrarily far apart, this second view obviously requires an FTL transmission mechanism,[104] something Einstein called a "spooky action-at-a-distance," a term that eloquently expresses his low opinion of that idea! (Some translations replace *spooky* with *ghostly*, but the negative sentiment remains the same.[105]) For decades the debate between proponents of these two alternatives remained at a metaphysical, non-quantitative level. Then came Bell's paper in 1964.

Bell's theorem mathematically poses the choice between Einstein's hidden variables view and the conventional view of quantum mechanics through the use of an inequality involving certain measurable properties of a system.[106] If these measurements are such that the inequality is violated, then the conventional interpretation of quantum mechanics is vindicated, and Einstein's FTL spooky action-at-a-distance effect simply doesn't exist. Bell's great contribution, then, was to provide the means for removing the debate about quantum mechanics from metaphysics and to place it squarely in the realm of experimental physics.

"All" that needed to be done was to make the required measurements. These technically difficult experimental measurements were eventually performed by the French physicist Alain Aspect and his colleagues at the Institute of Applied Optics of the University of Paris, a decade and a half after Bell showed what had to be done. The results unequivocally support the conventional view of quantum mechanics.[107] Einstein was simply wrong, there are no hidden variables in quantum mechanics, and his spooky action does seem to exist. Does that mean we have, at last, experimental evidence of the possibility of information transfer at FTL speeds?

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[103] For more on hidden variables, see E. P. Wigner, "On Hidden Variables and Quantum Mechanical Probabilities," *American Journal of Physics*, August 1970, pp. 1005–1009.

[104] For an analysis that argues against an FTL mechanism in quantum mechanics, see G. C. Ghirardi, *et al*., "A General Argument Against Superluminal Transmission Through the Quantum Mechanical Measurement Process," *Lettere Al Nuovo Cimento*, March 8, 1980, pp. 293–298.

[105] You can find a discussion of the possibility of 'explaining' Einstein's "spooky actions" of quantum mechanics by invoking backward causation in R. I. Sutherland, "Bell's Theorem and Backwards-in-Time Causality," *International Journal of Theoretical Physics*, April 1983, pp. 377–384.

[106] The details are not important here, but a lovely exposition (for the lay person) can be found in Bell's essay "Bertlmann's Socks and the Nature of Reality," in *Speakable and Unspeakable in Quantum Mechanics*, Cambridge University Press 1987. See also M. G. Alford, "Ghostly Action at a Distance: A Non-Technical Explanation of the Bell Inequality," *American Journal of Physics*, June 2016, pp. 448–457.

Well, maybe, but the issue is still hotly debated. The majority of physicists today, I suspect, are probably more perplexed over what Bell's theorem is saying than were over Einstein's original EPR paradox. In those early days one could agree with Einstein and his colleagues, who argued that quantum mechanics was valid *as far as it went*, but a deeper, more comprehensive theory *would* show the existence of hidden variables. However, because of the work by Bell and Aspect it is definitively known that quantum mechanics *as it stands* leads to correct results, results that can be checked in the laboratory. In other words, there is no need for hidden variables and FTL spooky actions cannot be ruled out.

And so, while tachyons and the tachyon antitelephone may be nothing more than a neat science fiction fantasy, just maybe a quantum mechanical Bell antitelephone can't be so dismissed. Indeed, the possibility of using a quantum mechanical FTL effect was once suggested in a letter written by a senior person at an unspecified California think tank (an organization such as, for example, the RAND Corporation) to the Under Secretary of Defense for Research and Engineering at the Pentagon. Here's what the Under Secretary read when he opened that letter: "If in fact we can control the FTL nonlocal effect, it would be possible . . . to make an untappable and unjammable command-control-communication [C^3] system at very high bit rates for use in the submarine fleet. The important point is that since there is no ordinary electromagnetic signal linking the encoder with the decoder in such a hypothetical system, there is nothing for the enemy to tap or jam. The enemy would have to have actual possession of the 'black box' decoder to intercept the message, whose reliability would not depend on separation from the encoder or on ocean or weather conditions."[108]

One can't help but wonder what might have been the Under Secretary's response to that incredible letter, and what sorts of ultra-mega-super-top-secret experiments it may have prompted. I would be willing to bet, if they did occur, that they failed. As one physicist put it, "Up to now nature has covered her tracks pretty well, blocking all possibilities for using the EPR effect for FTL communication."[109] Of course, the think tank letter, as 'farout' as it may initially appear, actually represents a *failure* of imagination, because the backward causation effect of EPR's spooky FTL effect is certainly a 'quantum jump' beyond a mere unjammable submarine C^3 system.

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[107] A. Aspect, "Experimental Tests of Realistic Local Theories via Bell's Theorem," August 17, 1981, pp. 460–467, and A. Aspect, *et al.*, "Experimental Realization of Einstein-Podolsky-Rosen-Bohm *Gedanken-experiment*: A New Violation of Bell's Inequalities," July 12, 1982, pp. 91–94, and "Experimental Test of Bell's Inequalities using Time-Varying Analyzers," December 20, 1982, pp. 1804–1807, all in *Physical Review Letters*.

[108] See N. D. Mermin in note 99. For more on the enigmatic letter on the FTL submarine C^3 system, see Jack Sarfatti's letter to *Physics Today*, September 1987, pp. 118 and 120.

[109] J. Cramer, "Paradoxes and FTL Communication," *Analog Science Fiction*, September 1988.

5.7 For Further Discussion

Mark Twain, in his last, posthumously published novel *No. 44, The Mysterious Stranger*, incorporated reversed time as the work of a supernatural being. After the being reverses the world's time direction, the narrator tells the reader that "everywhere weary people were re-chattering previous conversations backward . . . where there was war, yesterday's battles were being refought, wrong-end first; the previously killed were getting killed again . . . we saw Henry I gathering together his split skull . . ." Read the novel, and comment on how well (or not) Mark Twain handled reversed time.

In Philip K. Dick's 1956 novel *The World Jones Made*, we read of a prophet who can see a year into the future. As he says, "To me *this is the past*," and then later we are told "He was a man with his eyes in the present [the world's future] and his body in the past [the world's present]." Read the novel, and then argue either for or against the suggestion that Dick was aware of the advanced wave solution in Maxwell's theory.

The physicist Robert Forward (see the sixth *For Future Discussion* in Chap. 3) argued that one way to send messages into the past is to compress a 15-billion-ton asteroid down to the volume of an atomic nucleus, spin it up, and then aim gamma ray bursts through the resulting near-by region of "unhinged time" (see "How To Build a Time Machine," *Omni*, May 1980). This is, of course, 'simply' an artificially constructed Kerr black hole telegraph transmitter (look back at note 114 and related discussion in Chap. 1). Forward, an optimist of the first rank, thought humans would be able to do this before the end of the twenty-first century. It would seem, then, that what should be done *now* is to build gamma ray frequency *receivers* (well within present-day technology) and listen for such messages from the future. The technical details of such receivers wouldn't matter, as long as their design is widely published. That way, the scientists of the future can learn those details by simply reading of them in old, musty library books and journals, and thus will be able to build their transmitters to be perfectly compatible with our old, musty (to them) receivers! Comment on the likelihood of National Science Foundation funding becoming available to build such receivers.

Suppose a time traveler goes into the future and, while there, discovers that there is an older version of himself living in the home that has been in his family for generations. Explain why this implies that the time traveler will eventually return to the present. Suppose, instead, that after the time traveler arrives in the future he decides to remain in the future, and *not* to return. Explain why this implies there will *not* be an older version of himself living in the family home. In both cases, assume the MWI does *not* apply, that is, assume that there is just a single time line.

One well-known quantum physicist, David Bohm (1917–1992), wrote the following passage in his book *The Special Theory of Relativity* (W. A. Benjamin 1965), concerning the possibility of sending messages into the past: "In effect, S could communicate with his own past [self, M] . . . and tell his past self [M] what his future is going to be. But on learning this M could decide to change his actions, so that his future . . . would be different from what his later self [S] said it was going to be. For example, the past self could do something that would make it impossible for the future one to send the signal. Thus, there would arise a logical self-contradiction." Do you think most physicists, writing today more than 50 years after Bohm, would repeat his words?

The role played by quantum mechanics in time travel studies is broad, deep, profound . . . and mysterious. What I mean by this is nicely illustrated by the final paragraph in a paper by Stephen Hawking ("Quantum Coherence and Closed Timelike Curves," *Physical Review D*, November 15, 1995, pp. 5681–5686). There he wrote "Personally, I do not believe that closed timelike curves will occur, at least on a macroscopic scale. I think that the chronology protection conjecture will hold and that divergences in the energy-momentum tensor will create singularities before closed timelike curves appear. However, if quantum gravitational effects somehow cut off these divergences, I am quite sure that quantum field theory on such a background will show loss of quantum coherence. *So even if people come back from the future, we will not be able to predict what they will do* [my emphasis]." What do you think Hawking meant by his final line? If "people come back from the future" and tell us what they did while in the

(continued)

future, then what's wrong with their memories that causes us to fail to be able to predict what they *will* do? Or, is there perhaps nothing wrong with their memories and Hawking is instead arguing that the future experienced by the returned time travelers will not be the future when *we* 'get there'? If that's the case, then what are the returned time travelers 'remembering'?

If quantum mechanics is actually slightly non-linear physics (as are many other normally linear physical phenomena at sufficiently high energy levels)—physics is *linear* when *superposition* holds, which means the result of two inputs is the sum of the individual outputs resulting from application of the individual inputs—and if one accepts the MWI concept, then at least two physicists (**PHYSICISTS1**) claim to have shown that one could communicate not just with our past, but also with the many pasts in the ever-splitting branches of the many worlds. Another physicist (**PHYSICIST2**) wrote a very funny illustration of what that might be like. Yet another physicist (**PHYSICIST3**) suggested that non-linear quantum mechanics might actually allow one to take *photographs* of the many-worlds. Of that, a physicist (**PHYSICIST4**) wrote (without any exaggeration) that such an achievement would be "perhaps the most amazing discovery in the history of science, indeed in the history of mankind." Or, to quote yet another physicist (**PHYSICIST5**), "interworld communication would lead to truly mind boggling possibilities," some of which have been incorporated in at least one science fiction novel (**SFAUTHOR**). Read the physicists' papers, and the novel, and then summarize with your own commentary.

PHYSICISTS1: N. Gisin, "Weinberg's Non-linear Quantum Mechanics and Superluminal Communication," *Physics Letters A*, January 1, 1990, pp. 1–2, and J. Polchinski, "Weinberg's Non-linear Quantum Mechanics and the Einstein-Podolsky-Rosen Paradox," *Physical Review Letters*, January 28, 1991, pp. 397–400.

PHYSICIST2: J. G. Cramer, "Quantum Telephones to Other Universes, to Times Past," *Analog*, October 1991.

PHYSICIST3: D. Albert, "How to Take a Photograph of Another Everett World," *Annals of the New York Academy of Sciences*, December 30, 1986, pp. 498–502.

PHYSICIST4: M. A. B. Whitaker, "On the Observability of 'Many Worlds'," *Journal of Physics A*, July 11, 1985, pp. 1831–1834.

PHYSICIST5: R. Plaga, "On a Possibility to Find Experimental Evidence for the Many-Worlds Interpretation of Quantum Mechanics," *Foundations of Physics*, April 1997, pp. 559–577.

SFAUTHOR: J. P. Hogan, *Paths to Otherwhere*, Baen 1996.

One upon a time, FTL tachyons (and their associated into-the-past transmissions of information) were strictly in the province of science fiction. In recent years, however, such doings have moved into mainstream fiction, as well, with the most recent (as I write) example being the man-of-action novel by Patrick Lee, *Signal*, St. Martin's Press 2015. (Tachyons are also mentioned in the 2015 film *Tomorrowland*.) That novel is set in modern times, not in the future; its hero is a retired soldier who now works as a self-employed house-flipper. His is definitely not a futuristic science fiction world. Until, that is, be becomes involved with a radio-like gadget that receives signals from 10 h, 24 min in the future. As the novel progresses we eventually learn that the gadget is based on German electronics technology that was being tested in a remote lab in northern Algeria, near the end of World War II. When that lab was overrun by a small American force the equipment was destroyed, but not before one of the Americans heard the gadget playing a song titled "She Loves You" along with the word *yeah* repeated numerous times. He didn't know what that meant until, 20 years later, he watched the Beatles' first American appearance on *The Ed Sullivan Show* TV program, and so suddenly realized that in 1944 he had heard a song that hadn't been written yet! That gadget is at the center of a modern-day, renewed Nazi effort to conquer the world, and there is much 'you've seen it all before' chasing, shooting and other 'James Bond' types of action in the novel, but the author *has* been quite inventive in treating time paradoxes. He does talk a lot about 'changing the future,' worries confusingly about 'changing the past,' and mistakes neutrinos for tachyons, but, still, if one is willing to overlook such issues it *is* an entertaining read. In particular, while the gadget's inherent range to the future is limited to ten-plus hours, the author describes a clever way to arbitrarily extend that value. Read *Signal*, and then describe and critique the method outlined in the novel.

The Wheeler-Feynman assumption of continuity already had a distinguished history in mathematics long before they invoked it in their physics resolution of bilking paradoxes. (Both men were very good mathematicians, and certainly knew what I am about to tell you here.) Imagine a man who is about to walk up a hill, starting at A (the base of the hill) and ending at B (the top of the hill). You know nothing of *how* he walks (perhaps at times he stops for a while, other times he walks slowly, sometimes he walks briskly, perhaps at times he even walks back *down* the hill). All you know is that, starting from A at 10 o'clock in the morning, he arrives at B at 11 o'clock. That is, the walk up

(continued)

the hill takes exactly 60 min. He camps overnight at B and then, the next morning, at exactly 10 o’clock, he walks back down the hill along the same path he followed during his ascent the previous day. He arrives at A at 11 o’clock. That is, the return trip takes exactly 60 min. Again, you know nothing of the details of how he makes the descent. Prove that there is at least one spot on the path that he passes at exactly the same time during his descent as he passed it during his ascent the previous day. Hint: No complicated equations are required. Indeed, no math at all is needed. Just sketch the appropriate, general graphs of the man’s ascent versus time, and of his descent versus time, and invoke continuity. That is, sketch the distance (as measured along the path) that he is from A versus time for both the ascent and the descent.

Chapter 6
The Physics of Time Travel: II

> *"It is very sad to see valuable minds writing such a pile of unmitigated bullshit."*
>
> —not all physicists think time travel is worthy of study.[1]

6.1 Faster-than-Light into the Past

> "Faster-than-light travel remains a coherent, and possible concept, even though it is forbidden by relativity theory."
>
> —a philosopher makes a physics mistake.[2]

So far we have limited our consideration of relativity theory to speeds below the speed of light—that is, to the condition $v < c$, where v is the relative velocity of two reference frames. There was nothing, however, in the derivation of the Lorentz transformation equations discussed in Chap. 3 that actually used that self-imposed constraint. So, just what, in fact, *does* happen for $v > c$? This is not an empty question, because the second half of the above quote that opens this section is simply not true. That isn't to say we can have FTL for free; there *is* a high price to pay, that of causality violation (although, if you are a fan of time travel, it's a price you are probably happy to pay). If a material object goes FTL, then the mathematics seems to say that the object could travel into the past, just as the caped crusader does in the first (1978) *Superman* movie, in order to change the past (to save Lois Lane from dying in an earthquake). In addition, the mathematics also seems to say that if a signal bearing information could achieve FTL, then that information, too, would travel back into the past (see Fig. 6.1).

---

[1] This rather blunt comment (reported in *Physics World*, December 2009, p. 3) was prompted by a suggestion, from two other physicists, that the Higgs boson might ripple backward through time and thereby stop CERN's Large Hadron Collider from creating the long-sought particle in the first place.

[2] G. Robinson, "Hypertravel," *Listener*, December 17, 1964, pp. 976–977, the printed version of a lecture to the British Association for the Advancement of Science.

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P.J. Nahin, *Time Machine Tales*, Science and Fiction,
DOI 10.1007/978-3-319-48864-6_6

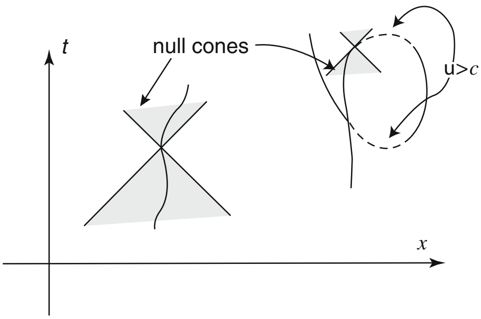

Fig. 6.1 A math-free proof that there can be no closed loops in time (that is, no time travel to the past if $v > \mathrm{c}$ is forbidden) in flat Minkowski spacetime, the spacetime of the special theory of relativity. Such a conclusion is far less clear in the curved spacetimes of the general theory of relativity. Figure reproduced by the kind permission of Serguei V. Krasnikov (Polkovo Central Astronomical Observatory in St. Petersburg, Russia), from his 2003 paper "Time Machine (1988–2001)"

The original thinking along these lines visualized such an FTL signal as a modulated beam of tachyons, as mentioned in the previous chapter. In addition to tachyons not having been experimentally observed, even after intense searches for them, there are several theoretical objections (in addition to the bilking paradox problem discussed in the previous chapter) to the likelihood such FTL particles exist.[3] For example, the relativistic expressions for the energy and momentum of a particle with rest mass m_0 moving with speed v are, respectively,

$$E = \frac{m_o c^2}{\sqrt{1 - (v/c)^2}} \qquad \text{and} \qquad p = \frac{m_o v}{\sqrt{1 - (v/c)^2}}.$$

For $v > c$ the radicals in these expressions become imaginary, whereas E and p must always be real-valued (because they can be observed and measured as a result of the interactions the particle has with other matter). The energy and momentum can regain the property of being real-valued if we write $m_0 = \mu\sqrt{-1}$ (that is, $m_0^2 = -\mu^2$) for a tachyon, where μ is the positive, real-valued (but unobservable) meta-mass (that is, $m_0^2 < 0$). This is a radical proposal, of course, (as it is $m_0^2 > 0$ that we are used to; as a Russian mathematician romantically put it, "What binds us to space-time is our [positive] rest mass, which prevents us from flying at the speed of light, when time stops and space loses meaning. In a world of light there are neither points nor moments of time; beings woven from light would live ‘nowhere’ and ‘nowhen’; only poetry and mathematics are capable of speaking meaningfully about such things.”[4].

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[3] See, for example, "More About Tachyons," *Physics Today*, December 1969, pp. 47–52, a collection of letters received by the journal from its readers. The 'DeWitt Gambit,' mentioned in the previous chapter, was first proposed in one of those letters.

Well, perhaps, but let’s continue to pursue the physics of tachyons, at least for a while. It can be shown[5] that the energy and momentum of the tachyon are given by

$$E = \frac{\mu c^2}{\sqrt{(v/c)^2 - 1}} \quad \text{and} \quad p = \frac{\mu v}{\sqrt{(v/c)^2 - 1}}.$$

An interesting consequence of this is that if tachyons *lose* energy, they *speed up*, an observation first made by the German physicist Arnold Sommerfeld (1868–1951) in 1904.[6] This means that if there is a mechanism for continuous energy loss, such as Cerenkov radiation,[7] then tachyons will spontaneously accelerate without limit to *infinite speed*! Curiously, while the above expressions for E and p show that, as $v \to \infty$, tachyons would possess *zero* energy, they would nonetheless have a *non-zero* momentum of μc.[8]

To see how backward time travel and FTL are connected, it is useful to establish a geometrical interpretation of the Lorentz transformation. As stated in Chap. 3, if the x', t’ system is moving with speed v in the x (or x’) direction relative to the x, t system, then

$$x' = \frac{x - vt}{\sqrt{1 - (v/c)^2}} \quad \text{and} \quad t' = \frac{t - vx/c^2}{\sqrt{1 - (v/c)^2}}.$$

---

[4] Yu I. Manin, *Mathematics and Physics*, Birkhäuser 1981, p. 84.

[5] L. Parker, “Faster-Than-Light Inertial Frames and Tachyons,” *Physical Review*, December 25, 1969, pp. 2287–2292.

[6] The consideration of FTL particles already had a long history *before* tachyons were specifically named. You can find late nineteenth century (1888–1889) theoretical analyses of electrically charged FTL particles in the writings, for example, of the English mathematical electrical engineer Oliver Heaviside (1850–1925): see my biography *Oliver Heaviside: the life, work, and times of an electrical genius of the Victorian Age*, The Johns Hopkins University Press 2002, pp. 124–126.

[7] Cerenkov radiation is the energy radiated when a charged particle exceeds the speed of light *in the medium through which it travels*. Since the speed of light *in water* is less than c, it is perfectly okay with special relativity to exceed the speed of light in water, and in fact this commonly occurs for the energetic electrons produced by submerged atomic reactors (swimming pool reactors). The resulting radiation is observed as a blue glow. The radiation is named after the Russian physicist Pavel Cerenkov (1904–1990)—for which he received a share of the 1958 Nobel physics prize—but in fact Heaviside (previous note) had predicted it more than a decade before Cerenkov was born.

[8] This (theoretical) property of tachyons (if they exist) could (perhaps) be used (maybe) to build a revolutionary (to say the least) new rocket propulsion system: see J. Cramer, “The Tachyon Drive: Infinite Exhaust Velocity at Zero Energy Cost,” *Analog*, October 1993.

These equations make sense for the case of $v < c$, and we will retain this condition for our two relatively moving *frames of reference*: these frames are the *worlds* of two *human* observers, observers that we'll take to always be *sub*luminal. As one physicist so nicely put it, "The assumption that observers move faster-than-light goes beyond superluminal signaling,"[9] as such observers would have to be thought of as being built not out of flesh-and-blood, but rather out of tachyons.[10] We'll reserve the symbol w to denote the speed of an FTL particle.

Now, recall what we mean by any line parallel to the x-axis; it is a line with a fixed time coordinate. Such a line is a *cosmic moment* line, with the equation $t =$ constant. Similarly, for the moving system we would write the equation of a cosmic moment line as $t' =$ constant which, after the Lorentz transformation is applied, is equivalent to

$$t - \frac{vx}{c^2} = \text{constant}.$$

In particular, the x'-axis ($t' = 0$ cosmic moment line), which passes through the point $x = 0$ at $t = 0$, has the equation

$$t = \frac{vx}{c^2} = vx$$

with the usual convention of $c = 1$.

In a similar way, recall what we mean by any line parallel to the t-axis; it is a line with a fixed space coordinate. Such a line is the world line of a stationary particle in the x, t frame, with the equation $x =$ constant. Similarly, for the moving system we would write $x' =$ constant as the equation of the world line of a particle stationary in that system. From the Lorentz transformation, this is equivalent to

$$x - vt = \text{constant}.$$

In particular, the t'-axis (which is the $x' = 0$ world line of a particle stationary at the origin of the moving system) passes through the $x = 0$, $t = 0$ point, and it has the equation

$$x = vt.$$

Thus, superimposed spacetime coordinate axes for the two frames look like those shown in Fig. 6.2. That is, the relative motion of the two frames results in a

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[9] K. Svozil, "Time Paradoxes Reviewed," *Physics Letters A*, April 3, 1995, pp. 323–326.

[10] Science fiction, however, *has* (since the early days of pulp) enthusiastically embraced FTL human travel. In Larry Niven's story "At the Core" (*If*, November 1966), for example, we read of a manned spacecraft that travels 60,000 light years to the center of our own Milky Way Galaxy, and then back, at a speed 420,000 times that of light. As the pilot says (in a grand understatement), "That's goddam fast." Perhaps there is a way to make *some* sense of such an adventure, with the so-called *warp drive* (a'la *Star Trek*), which we'll take-up briefly at the end of this chapter.

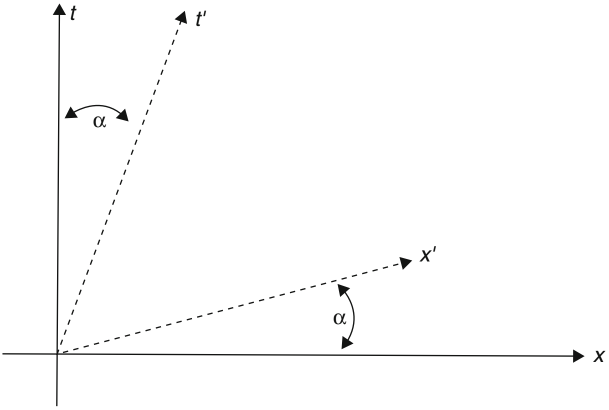

Fig. 6.2 Spacetime coordinate axes rotation by relative motion

rotation of the spacetime axes; but it is a strange sort of rotation, with *opposite* senses for the space and time axes. That is, the x' and t' axes rotate *towards* each other, as shown in the figure, to make equal angles (α) with the x and t axes, respectively, where

$$\alpha = tan^{-1}(v).$$

If we limit the moving frame (the frame of a moving observer) to subluminal speeds ($0 \leq v < 1$), then

$$0 \leq \alpha < 45°.$$

At the speed of light ($v = 1$) $\alpha = 45°$ and so the x' and t' axes coincide—time and space have become indistinguishable.

It is important to realize that observers in either system would measure the same speed for a photon; that is, each would see the world line of a photon as a line with slope 1. This view of the world line of a photon is literally built into the Lorentz transformation because one of Einstein's fundamental postulates for special relativity is the invariance of the speed of light. The truth of this statement for the x, t system is obvious from Fig. 6.2. It is, perhaps, not so obvious with the x', t' system because of the non-perpendicular axes (as shown in the figure) for that system. In Fig. 6.3 the world line of a photon is shown in both systems. In that figure we emit the photon at $x' = 0, t' = 0$, and we later measure its coordinates at point A to be $x' = x'_A$ at time $t' = t'_A$. Note carefully how this is done. We draw lines from point A parallel to the x' and t' axes until they intersect the t' and x' axes, respectively. This is similar to the way we would get the spacetime coordinates of A in the more familiar x, t system, where we would draw lines parallel to the x and t axes.

It should now be obvious that x'_A and t'_A have the same extension, just as they do in the unprimed system, so

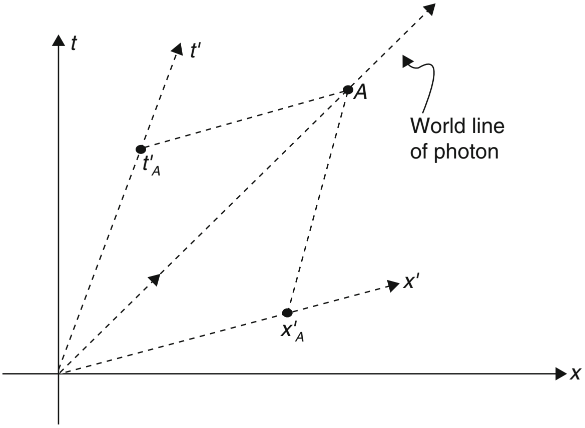

Fig. 6.3 Invariance of the world line of a photon

$$\frac{x'_A}{t'_A} = \text{the speed of light}$$

The speed of light is the only invariant speed under the Lorentz transformation. Indeed, the modern approach to special relativity emphasizes this invariance as the central property of the speed of light, rather than the idea of the speed of light being a limiting speed.

This geometrical interpretation of the Lorentz transformation lets us quickly make another interesting (one, I think, not at all obvious) observation: If a particle is faster than light in the x, t system, then there exists a subluminal x', t' system in which the particle is *infinitely* fast. Figure 6.4 shows the world line of an FTL particle in the x, t system (which is, of course, *below* the world line of a photon; that is, the particle's world line is spacelike). Suppose the FTL particle has speed $w > \mathrm{c}$ such that its world line makes angle β with the x-axis. If we now pick v, the speed of the moving x', t' system to be such that $\alpha = \beta$, then the x'-axis will coincide with the world line of the particle, and so the particle will appear to an observer in the x', t' system to be everywhere at once—that is, to be infinitely fast. We have, then,

$$\beta = tan^{-1}(v) = tan^{-1}\left(\frac{1}{w}\right)$$

or $v = 1/w$, which seems to be dimensionally wrong. Recall, however, that with our convention of $c = 1$, the v in this result is a *normalized* speed. To return to the units of everyday use, simply replace v with v/c and w with w/c; this transforms our result to

$$\frac{v}{c} = \frac{c}{w} \quad \text{or} \quad v = \frac{c^2}{w}\cdot$$

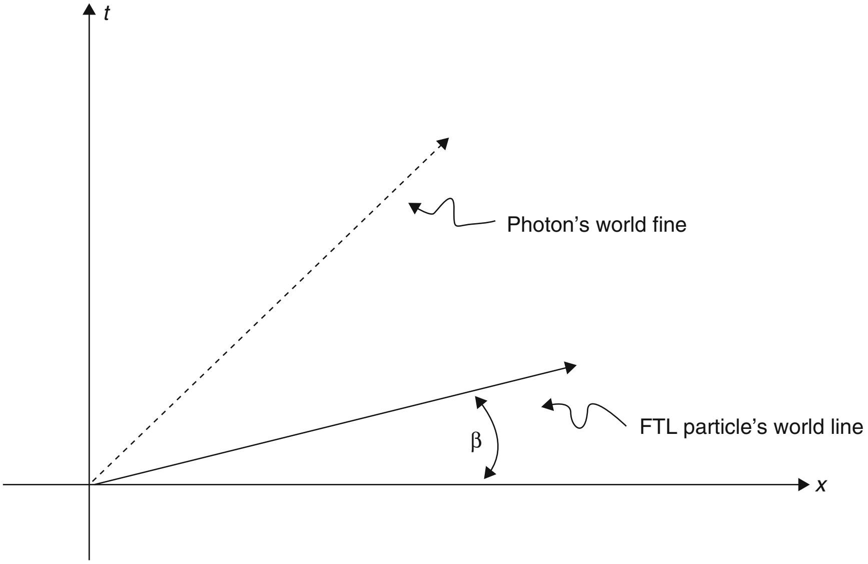

Fig. 6.4 World line of an FTL particle

We can, of course, turn this result around. If an FTL particle moves with speed w in the x, t frame, then to an observer in the x', t' frame moving with subluminal speed v, the particle will appear to be infinitely fast if $w = c^2/v$. A particle with $w > c^2/v$ is said to be not just be superluminal, but *ultra*luminal.

If a particle has infinite speed if $w = c^2/v$, then what physically happens if w is greater than c^2/v? The answer is easy to see from a spacetime diagram, as in Fig. 6.5, where the x' and t' axes have been extended back to negative values. In that figure I have labeled two arbitrary events A and B on the world line of an ultraluminal particle (and so it lies below the x' axis), and have shown the spacetime coordinates of each event in both the x, t and x', t' frames. For the x, t frame we see that A is related to B by the relations $x'_A < x'_B$ and $t'_B < t'_A$; that is, the time order of A and B is reversed for an observer in the x', t' frame. To that observer, the particle appears to be traveling backward in time!

But this isn't quite the end of the story. Following the approach of two pioneering tachyon physicists,[11] we note that if the energy of a particle in the stationary system is E, then the energy as measured in the moving system is given by[12]

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[11] O. M. Bilaniuk and E. C. G. Sudarshan, "Causality and Space-like Signals," *Nature*, July 26, 1969, pp. 386–387.

[12] The expression for E' is the result of applying the Lorentz transformation to E. You can find all the details of that worked out in A. P. French, *Special Relativity*, W. W. Norton 1968, pp. 208–210.

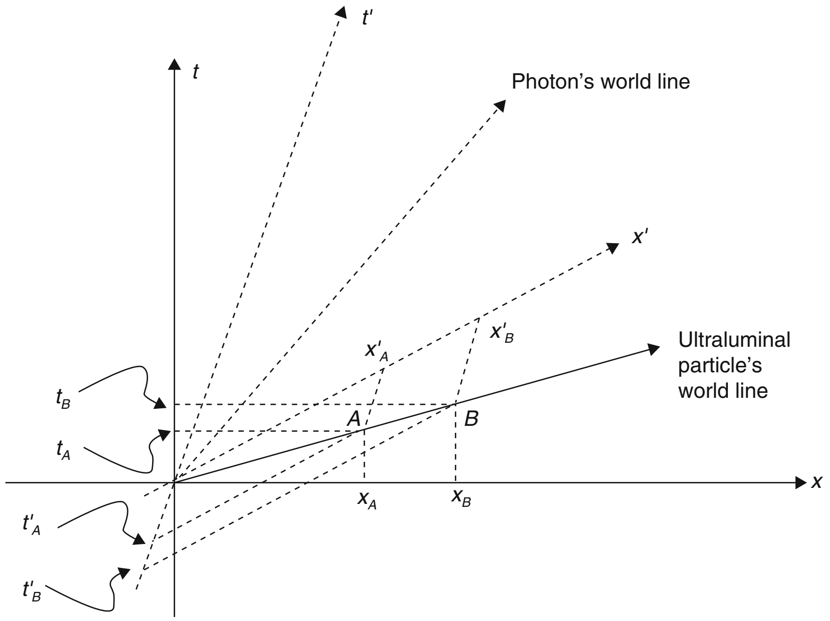

Fig. 6.5 World line of an *ultra*luminal particle

$$E' = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} \frac{\mu(c^2 - \mathrm{wv})}{\sqrt{(w/c)^2 - 1}}$$

Note that sign of E' switches from positive to negative when w (the speed of the particle) exceeds c^2/v, which is precisely the condition for the particle to be ultraluminal and so traveling backward in time (as seen in the primed system). That is, negative energy moving backward in time in one system is positive energy moving forward in time in another. This is, in fact, the original motivation for the RP (reinterpretation principle) discussed in the previous chapter, and the claim was, at one time, that the RP was just what was needed to ‘explain’ the paradoxical implications of time travel. This is not the majority view today, however, and a number of physicists have been quite inventive in constructing scenarios with causal paradoxes that the RP clearly fails to ‘explain.’

For example, the Princeton physicist Shoichi Yoshikawa (1934–2010), in a letter to *Physics Today* (see note 3), was able to create a scenario which *uses* the RP to arrive at a causal paradox. In his construction, the RP allows an observer to transmit an ultraluminal tachyon to a remote observer at time $t = 0$, and to receive a reply from that observer at $t < 0$. This obviously sets-up the possibility of a bilking paradox in which the original observer, upon receiving the $t < 0$ tachyon, then decides *not* to transmit the $t = 0$ tachyon. What makes Yoshikawa's paradox a particularly troublesome paradox is that the RP is the culprit, not the savior.

6.2 Tipler's Rotating Cylinder Time Machine

> "... within forty-eight hours we had invented, designed, and assembled a chronomobile. I won't weary you with the details, save to remark that it operated by transposing the seventh and eleventh dimensions in a hole in space, thus creating an inverse ether-vortex and standing the space-time continuum on its head."[13]
>
> —this is almost surely *not* the way to build a TM (time machine)

As discussed at the start of this book, the first endorsement of the reasonableness of physicists talking about plausible, scientific time travel, began with Gödel's discovery of closed timelike lines in the mathematics of certain rotating universe models. Such models had been studied as early as 1924 by the Hungarian physicist Cornelius Lanczos (1893–1974), a quarter century before Gödel, but it was Gödel who made explicit the possibility a rotating universe might allow time travel. His realization of time travel as an *inherent* property of a rotating universe is an illustration of a *weak* TM, while what is the central interest concerning time machines (in physics *and* in science fiction) is a *strong* TM. That is, in time machines that can be *intentionally constructed* by manipulating mass-energy in a finite (what physicists call a *compact*) region of spacetime to *create* closed timelike lines where none existed before the manipulation began. Interestingly, the fundamental physical idea behind Gödel's weak TM is the same underlying idea behind the first strong TM, Tipler's rotating cylinder discussed back in Chap. 1 (strictly, of course, only a *compact* TM if the cylinder can be of *finite* length).

The one result from general relativity that we'll use here (without proof) is that the rotation of matter causes a distortion of spacetime that results in the 'tipping over' of light cones, with the future half tilted in the direction of motion. If you imagine a point in the universe about which the rotation takes place, then this tipping effect increases with the radial distance from that point.[14] The fact that rotating masses tip light cones over in the direction of rotation was discovered very early in the history of general relativity (1918), by the Austrian theoreticians Josef Lense (1890–1985) and Hans Thirring (1888–1976). Originally (and naturally) called the *Lense-Thirring effect*, it now generally goes by the name of the *dragging of inertial frames effect*, and it plays a central role in the weak Gödel and the strong (maybe) Tipler time machines. Here's how.

At a certain critical distance from the rotation center (more on this in just a bit), the future half of the light cone at a given point in spacetime will be sufficiently tilted so as to enter the past half of similarly tilted light cones at nearby spacetime points This is illustrated in Fig. 6.6,[15] which shows a circular chain of tilted light

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[13] L. Sprague de Camp, "Some Curious Effects of Time Travel," in *Analog Readers' Choice*, Dial 1981.

[14] For a picture of this, see S. W. Hawking and G. F. R. Ellis, *The Large Scale Structure of Spacetime*, Cambridge University Press, 1973, p. 169.

[15] Adapted from D. B. Malament, "'Time Travel' in the Gödel Universe," *Proceedings of the Philosophy of Science Association* 1984, pp. 91–100.

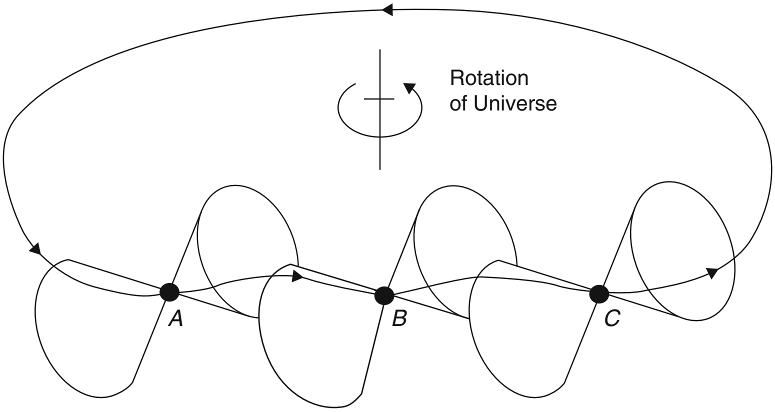

Fig. 6.6 Time traveling through tilted light cones in a rotating universe

cones in a rotating universe. Because light cones are tilted by a rotation-induced twisting of spacetime, a traveler can move around a circular path on a trip that is always directed into his *local* future but nonetheless end-up in his own *global* past, without ever going faster than light. This kind of round trip in spacetime, with a trajectory that winds back into the past without ever becoming spacelike, is a closed timelike curve.

From Fig. 6.6 it should be clear how a time traveler, beginning at A, can weave his way along a circular path (this path needs to have a radius at least as great as the critical value mentioned earlier) to B to C to . . . that brings him back into the *past* half of the light cone at A. The traveler's world line is always inside the local light cone; that is, the world line of the time traveler is always timelike, and never FTL. These timelike curves are present in the rotating spacetime from the very beginning of the spacetime, and were not *created* (certainly not by humans) by conscious intent.

You can see how this works mathematically by taking the spacetime metric for Gödel's universe (with, as usual, the convention that the speed of light $c = 1$):

$$(ds)^2 = (dt)^2 - (dr)^2 - (dy)^2 + \sin h^2(r)\left[\sin h^2(r) - 1\right](d\phi)^2 \\ + \sqrt{2}\sin h^2(r)(d\phi)(dt)$$

where t, r, y, and ϕ are cylindrical coordinates in four-dimensional spacetime. Now, imagine that our adventurer's world line is the helical curve r=constant, $y = 0$, and $t = -\alpha\phi$: if we take the time axis as vertical then the time traveler's world line is a vertical helix in spacetime. For this curve, $dr = \mathrm{dy} = 0$ and $dt = -\alpha d\phi$. This last differential means, in particular, that whatever the sign of the constant α, we can choose that one of the two senses of movement in the spatial ϕ dimension that gives $dt < 0$.

Continuing, we have

$$(ds)^2 = \left[\alpha^2 - 2\sqrt{2}\alpha sinh^2(r) + \sin h^2(r)\left(\sin h^2(r) - 1\right)\right](d\phi)^2$$

or, upon letting $u = \sinh(r)$ we have

$$(ds)^2 = \left[\alpha^2 - 2\sqrt{2}\alpha u^2 + u^2\left(u^2 - 1\right)\right](d\phi)^2.$$

Now, for $\alpha = 0$ we have

$$(ds)^2 = u^2\left(u^2 - 1\right)(d\phi)^2$$

which is greater than zero if $u > 1$. This condition holds if $\sinh(r) > 1$, that is, if r is a constant greater than $\ln\left(1 + \sqrt{2}\right)$. In other words, for r sufficiently large (and now we know the critical value for r) we have $(ds)^2 > 0$, the required condition for a timelike spacetime interval. By continuity, then, we will continue to have $(ds)^2 > 0$ even with some small positive or negative value of α different from zero. Because ϕ is a periodic coordinate (we identify $\phi = 0$ with $\phi = 2\pi$), as the traveler moves along the curve she returns repeatedly to the same spatial points, but her time coordinate is increasingly negative. That is, she is traveling into the past. Note, once again, that in Gödel's universe this property holds only for orbits with radii greater than a certain minimum.[16]

Tipler's rotating, infinitely long cylinder is a mechanism for artificially producing the tipped-over light cone effect, thus *creating* closed timelike curves. Figure 6.7, taken from Tipler's Ph.D. dissertation,[17] shows how the cylinder works. The cylinder is represented by the central vertical axis. Far away from the cylinder the light cones in spacetime are upright, but as we move inward they tip over, the future halves opening up into the direction of rotation. (Only the future halves of the light cones are shown.) This direction, which is the direction that far away from the cylinder measures *space*, near the cylinder measures *time* (just as in the Gödelian universe). That is, there has been a dimension reversal! This fantastic possibility has found its way into science fiction, as in Stephen Baxter's 1995 novel *The Time Ships*, wherein the Victorian narrator says "If only one could *twist about* the Four Dimensions of Space and Time — transposing Length with Duration, say — then one could stroll through the corridors of History as easily as taking a cab in the West End!"

To travel back in time, therefore, all the time traveler need do is leave Earth and approach the cylinder until she is near enough to be in the tipped-over region of spacetime. Then she would follow a helical path around the cylinder and could

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[16] There are other solutions to the Einstein gravitational field equations that have closed timelike lines at *any* radius, no matter how small: see M. J. Reboucas, "A Rotating Universe with Violation of Causality," *Physics Letters A*, March 5, 1979, pp. 161–163.

[17] F. J. Tipler, *Causality Violation in General Relativity*, University of Maryland 1976.

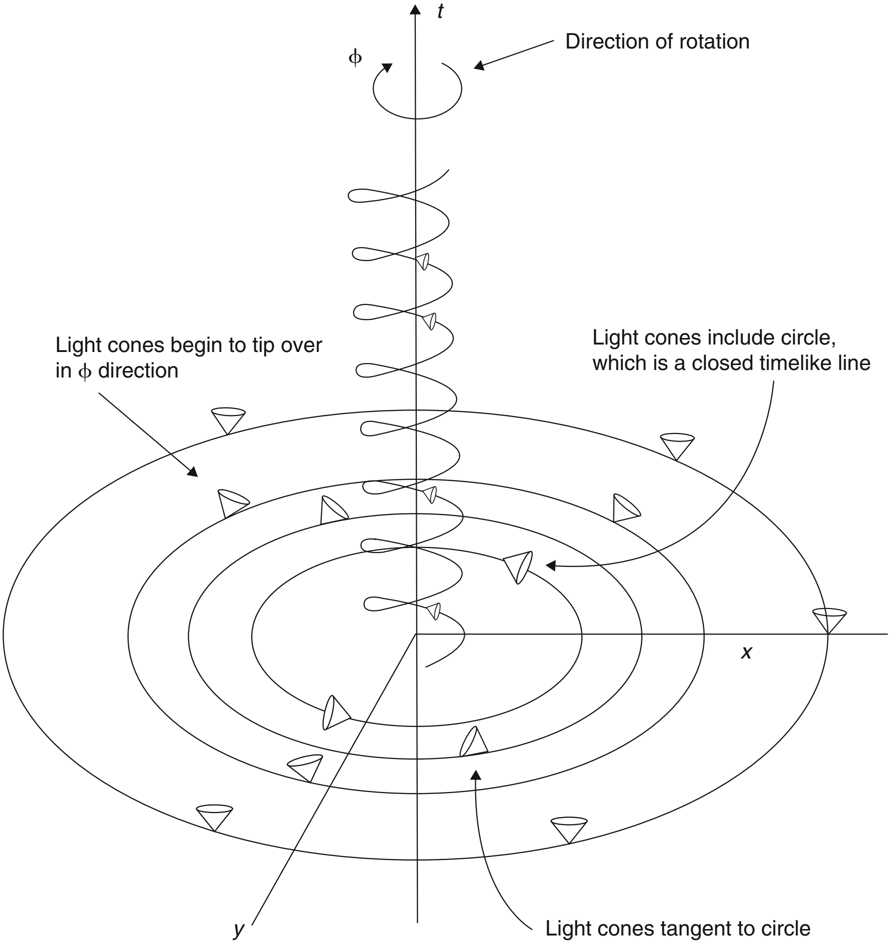
t
ϕ
Direction of rotation
Light cones begin to tip over in ϕ direction
Light cones include circle, which is a closed timelike line
x
y
Light cones tangent to circle

Fig. 6.7 The future halves of light cones point almost entirely in the $+t$ direction far from rotating matter; they begin to tip over as the matter is approached. Note that there is a helical timelike path that moves locally into the *future* in the $-t$ direction, that is, it goes into the past as seen by an observer far from the rotating matter (The world lines of rotating matter are helixes in the $+t$ direction)

spiral along the negative time direction as far back in time as desired (but no further back than to the moment of the cylinder's creation). This motion is such that the time traveler is always moving into her local future, via the tipped-over light cones. Finally, she would withdraw from the cylinder and return to Earth—in the past. The time traveler had better be a good space navigator, of course, because Earth won't be where she left it!

6.3 Thorne's Wormhole Time Machine

> "This fact reinforces the authors' feeling that [closed time loops] are not so nasty as people generally have assumed."[18]

The spacetime wormhole is presently the most promising of the approaches that have been advanced for building a time machine. Gödel rotated the entire universe in 1949, and Tipler 'reduced' the problem in 1974 to 'merely' spinning a cylinder of infinite length. In 1988 Kip Thorne scaled things down even more, this time to other extreme. His idea calls for pulling a wormhole on the scale of the Planck length out of the topologically multiply connected quantum foam that spacetime is and then enlarging it (somehow) to human scale, all the while stabilizing it against self-collapse, and then finally using the time dilation effect of special relativity to alter time at one mouth of the wormhole as compared to the other mouth. What a mouthful! What, you almost surely wonder, does all that mean?

First of all, what's 'quantum foam'? The term refers to the idea that the topology of spacetime is *not* a smooth, continuous manifold, but rather (if you look close enough) is a seething 'ocean of fluctuations' that is always changing, changes on the scale of the Planck length (look back at Sect. 1.5). What does *that* mean? Like the ocean surface-in-the-large, large-scale spacetime is simply connected. But just as one sees all sorts of transient structure as one looks at the water more closely (beginning with macroscopic waves and then proceeding downward to the bubbly foam on the waves), spacetime too displays an ever-changing connectivity-in-the-small.[19] That is the 'quantum foam.'

Wormholes have been around in physics for decades, but they have always been thought to be so unstable as to exist only on paper in the mathematics of general relativity. In an analysis[20] published more than half-a-century ago, for example, wormhole instability was shown to be so severe that not only would a human have no chance in getting through one, but also not even a single speedy photon could do so. Even at the speed of light, the photon could not zip through a wormhole before being trapped inside ("pinched off") in a region of infinite spacetime curvature. Wormholes would simply collapse too quickly after formation for even the so-called ultimate speed to save the traveler. Indeed, the presence of mass-energy inside a wormhole actually *accelerates* its collapse. The physics of wormholes, it seemed, made them simply untraversable.

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[18] The conclusion of a mathematical demonstration that time travel by wormhole does not conflict with the conservation of energy: see J. L. Friedman *et al*., "Cauchy Problem in Spacetimes with Closed Timelike Curves," *Physical Review*, September 15, 1990, pp. 1915–1930.

[19] Not all accept this view. See, for example, A. Anderson and B DeWitt, "Does the Topology of Space Fluctuate?" *Foundations of Physics*, February 1986, pp. 91–105.

[20] R. W. Fuller and J. A. Wheeler, "Causality and Multiple Connected Spacetime," *Physical Review*, October 15, 1962, pp. 919–929.

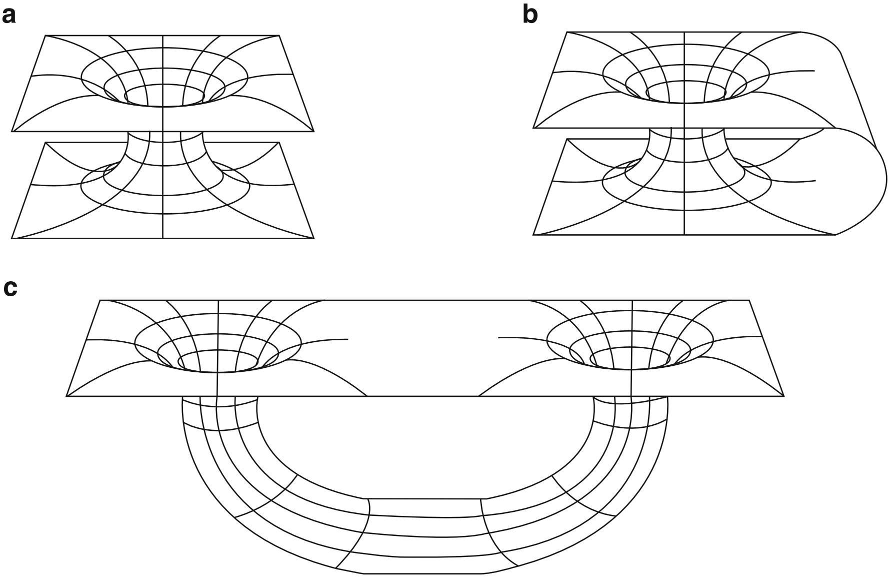

Fig. 6.8 These sketches are unavoidably misleading, being two-dimensional renditions of wormholes that connect two places in a three-dimensional space. Time machine wormholes, on the other hand, connect two places in a four-dimensional spacetime. In particular, the mouths of the wormholes are not 'depressions' into which the time traveler's rocket ship plunges, but rather would appear to be three-dimensional spheres. The wormhole in (**a**) connects two disjoint universes, while those in (**b**) and (**c**) are connections between two places in the same universe. As shown in these last two cases, the wormhole 'handle' can be either long or short, compared to the external distance between the wormhole mouths

And anyway, how would one gain access to a wormhole in the first place? As Thorne and one of his students suggested,[21] one might perhaps imagine someday finding a rotating black hole that mathematically possesses, in its interior, so-called hyperspace tunnels to 'other places'—either in our universe or in other universes (see Fig. 6.8). In the case of a wormhole connecting two places in the same universe, although the external distance in spacetime between the places may be very large (mega-light-years), it is conceivable that the distance *through* the wormhole itself could be very small. The time required to traverse the wormhole, as measured by the traveler's watch might, in fact, be arbitrarily small. This is exciting, but wormholes do not come without some significant problems.

Such problems include the presence of a one-way event horizon, which precludes two-way travel (it seems reasonable to assume that time and space travelers might wish to eventually return), and enormous gravitational gradients (tidal forces) that dismember anything approaching and/or entering the wormhole. These problems have often been conveniently *ignored* in science fiction. For example, in one tale[22] the time machine is in the form of a wormhole time tunnel that time travelers can simply walk through, and in another characters similarly walk back and forth between two openings in a wall that connect the same place in space but separated in time by 160 years.[23] And in an even older story, we read of a time machine (in the form of a hole in spacetime that is a wormhole in everything but name) through which one can literally step from future to past and back again. That story[24] is particularly notable for having introduced the term *mugwump* for a time traveler who uses a time machine wormhole. To paraphrase the tale's time traveler, as he transits the wormhole his "mug" is in the past and his "wump" is in the future.[25]

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[21] M. S. Morris and K. S. Thorne, "Wormholes in Spacetime and Their Use for Interstellar Travel: A Tool for Teaching General Relativity," *American Journal of Physics*, May 1988, pp. 395–412. This paper was motivated by Thorne's earlier response to a request, from the American astronomer Carl Sagan (1934–1996), for help in making plausible the interstellar travel imagined in his 1985 novel *Contact*.

Now, before going any further, a note on what physicists are referring to when they write of traversable time travel wormholes. Such wormholes are called *Lorentzian* because they have a spacetime metric with the signature $[+, -, -, -]$ (see Sect. 3.5). Further, the wormhole is taken to be *static*, that is, to have no time-varying behavior. The reason for being specific on the nature of time travel wormholes is that there is another type with what is called the *Euclidean signature*: $[+, +, +, +]$, which is not suitable for time traveling. Motion in a Euclidean signature wormhole involves imaginary momentum or proper time, neither of which is physically plausible for a time traveler. However, *if* you can gain access to a Lorentzian wormhole *then*, as two physicists wrote, "if you manage to acquire even one inter-universe traversable wormhole then it *seems* almost absurdly easy to build a time machine."[26]

In response to that fundamental question of how to gain access to a Lorentzian wormhole, Thorne and his students were bluntly honest—they didn't know. Their best suggestion was that "one can imagine an advanced civilization pulling [a] wormhole out of the quantum foam and enlarging it to classical size."[27] A few years later this dramatic idea found its way into a science fiction novel of a far-future alien civilization able to control the energies of constellations of galaxies: "Spacetime is friable. Wormholes riddle the fabric of spacetime on all scales. At the Planck length and below, wormholes arising from quantum uncertainty effects blur the clean Einsteinian lines of spacetime. And some of the wormholes expand to human scale, and beyond — sometimes spontaneously, and sometimes at the instigation of intelligence."[28]

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[22] R. C. Wilson, *A Bridge of Years*, Doubleday 1991.

[23] M. Leinster, *Time Tunnel*, Pyramid Books 1964.

[24] H. Kuttner, "Shock," *Astounding Science Fiction*, March 1943.

[25] The term's origin is in 19th century politics, as a description of fence-sitters who try to avoid taking a definite position on some controversial topic under debate. For an illustration of wormhole mugwumping, see K. S. Thorne, *Black Holes & Time Warps*, W. W. Norton 1994, p. 500.

[26] C. Barceló and M. Visser, "Twilight for the Energy Conditions?" *International Journal of Modern Physics D*, December 2002, pp. 1553–1560. See also M. Visser, *Lorentzian Wormholes*, AIP Press 1996.

[27] M. S. Morris, K. S. Thorne, and U. Yurtsever, "Wormholes, Time Machines, and the Weak Energy Condition," *Physical Review Letters*, September 26, 1988, pp. 1446–1449.

This isn't easy to visualize, but let's plunge ahead and assume we can "pull" a wormhole out of the quantum foam. If so, then once it is (somehow) inflated the wormhole could be stabilized against collapse by threading it with either matter or fields of stupendous negative (outward) tension—and by *stupendous* I mean *STUPENDOUS*. If b_0 denotes the minimum radius of the wormholes (the size of the so-called *throat* of the wormhole), the tension (radial pressure) at that location must be at least

$$\tau_0 = \frac{3.8}{{b_0}^2} \times 10^{36} \frac{tons}{in^2}$$

where b_0 is expressed in feet.[29] (This expression shows that for a wormhole with a throat radius of several thousand feet, the value of τ_0 is enormous, of the same magnitude as the pressure at the center of the most massive neutron star.) To stabilize a common sort of everyday wormhole, such as a subway tunnel, we can obtain the required tension/pressure by lining the tunnel with iron plates or concrete. But how, for a hyperspace wormhole, do we obtain 'iron plates' that can achieve the required enormous tension? As Thorne and his students observed (note 27) such stuff could only be called "exotic," a term that had appeared a few years earlier in connection with the observed energy density in the throat of a wormhole.[30]

One possible approach to this problem does not use matter at all. If we make b_0 *very* large, then non-material fields will do the job.[31] Indeed, suppose b_0 equals 1 light year (a large wormhole by anybody's standard!). Then τ_0 is 'only' 4000 tons/square inch, and that is achievable by threading the wormhole throat with a magnetic field of 'only' 2,700,000 gauss (five million times stronger than the Earth's field).[32] To generate such a field is not impossible, and present-day experimental, hypervelocity electromagnetic rail guns in development for the US Navy use transient magnetic fields in the mega-gauss range.

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[28] From S. Baxter's 1993 novel *Timelike Infinity*. That same year the Chinese physicist Liao Liu wrote on how, as a result of a naturally occurring vacuum fluctuation, a wormhole might spontaneously appear: L. Liu, "Wormhole Created from Vacuum Fluctuation," *Physical Review D*, September 15, 1993, R5463–R5464.

[29] The original equation for τ_0 was given in units of dynes/cm^2, with b_0 is expressed in meters (see note 21), but I have converted these units to the more familiar (to the non-physicist) units of tons per square inch, for dramatic purposes, because the units of dynes per square centimeter is so small it's difficult to relate it to anything of everyday significance.

[30] R. Balbinot, "Crossing the Einstein-Rosen Bridge," *Lettere Al Nuovo Cimento*, May 16, 1985, pp. 76–80.

[31] See, for example, Y. Soen and A. Ori, "Improved Time Machine Model," *Physical Review D*, October 15, 1996, pp. 4858–4861, and D. N. Vollick, "How to Produce Exotic Matter Using Classical Fields," *Physical Review D*, October 15, 1997, pp. 4720–4723.

[32] To understand how the calculation of a magnetic field from a pressure requirement is accomplished, note that pressure is dimensionally equivalent to field energy per unit volume, which in turn is given by a well-known result in electromagnetic theory.

As if the stabilization problem wasn't enough of a complication, Thorne and his colleagues (note 27) showed that there is another, even more curious problem. The geometrical requirement that the wormhole interior smoothly connect to the external, asymptotically flat exterior spacetime demands that the wormhole throat flare outward as shown in Fig. 6.8. It turns out that this condition is mathematically equivalent to a requirement that τ_0 exceed the energy density of the throat material[33]; and special relativity, in turn, says that for some timelike observers the energy density will then actually be *negative*. This is a clear violation of the so-called *weak energy condition* (WEC), which says the observed mass-energy density is always non-negative. This is *so* 'obvious' that the WEC was thought, for a long time, to be almost a law of nature. Such a violation is actually not as crazy as it might sound however because, more than half-a-century ago, it was shown[34] that an energy density that is everywhere and everywhen positive is *not* compatible with any quantum field theory that is *local*, as, presumably, will be the yet-to-be-discovered theory of quantum gravity. Over the years since then a variety of other energy conditions have been proposed, such as the *averaged weak energy condition* (AWEC), which says that only the *average* value of the energy density over a complete null geodesic world line has to be non-negative, which leaves open the possibility of *temporary* negativity here, there, then and when.[35]

The traversable, static wormholes studied by Thorne and his colleagues violate even the AWEC (see note 27), however, and in the years since it has become clear to physicists that imposing constraints on the mass-energy density may not be so 'obvious' after all (see note 26). But all may not be lost. Indeed, it has been shown that the violation of the AWEC by traversable wormholes can be made as small as desired, that is, the requirement for the exotic matter required to line a wormhole throat to keep it open can be made as tiny as you want.[36]

Well, tiny the quantity of exotic matter may be but, nonetheless, even a tiny amount of it would be extraordinary weird stuff because a negative energy density can be interpreted as meaning that the exotic material that keeps the wormhole throat open does so by exerting a *repulsive* gravitational force.[37] A repulsive force sounds like a property we'd expect to see associated with *negative mass* and, although such a thing has never been observed (negative matter is *not* anti-matter, which *has* been observed and which does not repel 'normal matter'), it was studied long ago (theoretically, of course) by the English cosmologist Hermann Bondi (1919–2005). Bondi showed[38] that negative mass would indeed have some truly bizarre properties,[39] but there is nothing in general relativity that forbids its possible existence. Wormholes, with negative mass throats, should produce observable effects by which a wormhole *might* be detected. Mathematical analyses of the effect a negative-mass wormhole mouth would have, when crossing the line-of-sight between Earth and a distant star, indicates that there should be an observable *double-spike* in the intensity of the star's light. Astronomical searches for such an optical signature have actually been conducted, with (alas) no success as I write (2017).

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[33] The condition of τ_0 exceeding the energy density in the throat is, in fact, the technical definition of *exotic*—see note 30. In everyday situations, the exotic condition is never even remotely approached. For example, the maximum tension necessary to pull a piece of steel apart—the so-called *tensile strength*, about 100,000 pounds per square inch—is a trillion times less than the mass-energy density of steel.

[34] H. Epstein, V. Glaser, and A. Jaffe, "Nonpositivity of the Energy Density in Quantized Field Theories," *Il Nuovo Cimento*, April 1, 1965, pp. 1016–1022.

[35] T. A. Roman, "Quantum Stress-Energy Tensors and the Weak Energy Condition," *Physical Review D*, June 15, 1986, pp. 3526–3533.

[36] M. Visser, S. Kar, and N. Dadhich, "Traversable Wormholes with Arbitrarily Small Energy Condition Violations," *Physical Review Letters*, May 23, 2003, pp. 201102-1 to 201102-4.

There is another interesting implication of a repulsive gravitational force, one that proves to be *essential* to the possibility of a wormhole time machine. Just as Einstein's famous prediction (verified in 1919) from general relativity, that star light passing near the Sun's edge is bent *inward* by the Sun's attractive gravitational field, the repulsive, anti-gravity field of a wormhole will cause any light rays traveling through the wormhole to be bent *outward*. That is, a tight, narrow beam of radiation entering a wormhole will emerge *defocused*. This is crucial because, as you'll soon see, a wormhole time machine would otherwise be destroyed by the light from the dimmest candle.

One might take the failure of astronomical searches for a double-spike light signature to mean that wormholes with negative mass throats (thus violating the WEC) simply don't exist. But not so fast. The first hint that the possibility of a negative energy density might not be such a crazy idea occurred as long ago as 1948, with a theoretical prediction made by the Dutch physicist Hendrick Casimir (1909–2000). As pointed out in Chap. 1, the Heisenberg uncertainty principle allows a temporary violation of conservation of energy to occur, with the magnitude of the allowed violation increasing with decreasing time duration. Even in a vacuum, then, with particle/anti-particle creation and annihilation spontaneously and continuously taking place, the *average* energy density being zero does not preclude fluctuations away from zero and so, at times, actually becoming *negative*. What Casimir showed was that if one positioned two perfectly conductive plates parallel to each other, then the normal quantum fluctuations of the energy density in this 'vacuum sandwich' would be altered in such a way as to result in their mutual attraction—and this (tiny) effect was later actually observed.[40]

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[37] The *strong energy condition* says gravity is always attractive—which is clearly not true in a wormhole throat—and so static, traversable wormholes violate both the weak *and* the strong energy conditions.

[38] H. Bondi, "Negative Mass in General Relativity," *Reviews of Modern Physics*, July 1957, pp. 423–428.

[39] For example, general relativity says that a negative mass will *repel* all other masses (positive *and* negative), whereas a positive mass will *attract* all other masses (positive *and* negative). Imagine, then, a negative mass attached to the nose of a positive-mass spaceship. The spaceship tries to move toward the negative mass, while the negative mass tries to move away from the spaceship. So off they both go into the sky, like a cat chasing its tail. This so-called *reactionless anti-gravity drive*, bizarre as it appears, does not violate either of the conservation laws of energy or momentum. See G. Cavalleri and E. Tonni, "Negative Masses, Even if Isolated, Imply Self-Acceleration, Hence a Catastrophic World," *Il Nuovo Cimento B*, July 1997, pp. 897–903.

What does it mean to 'alter the normal quantum fluctuations'? Consider the creation of a photon and its anti-particle, which is another photon. From the wave interpretation of particles, the parallel plates restrict the photons that appear in the vacuum layer to those that have wavelengths that 'fit' because those wavelengths are submultiples of the plate separation (this requirement follows from the fact that a perfectly conducting plate cannot support a non-zero tangential electric field). Photons with longer wavelengths than the plate separation cannot 'fit' and thus do not appear. That is, the parallel plates have created a boundary condition that has quantized the electromagnetic field. The absence of these 'longer wavelength' photons lowers the average energy density between the plates and, because the average without the plates is zero, the altered average energy density must be negative. Indeed, the more the maximum allowed photon wavelength decreases with decreasing plate separation, the more negative the average energy density becomes in the enclosed Casimir vacuum. The negative energy density manifests itself as an inward directed force per unit area (remember, energy density and pressure are dimensionally equivalent).

The experimental detection of the Casimir effect was a remarkable event in physics. As one mathematician put it, "No worker in the field of overlap of quantum theory and general relativity can fail to point this fact out in tones of awe and reverence."[41] Robert Forward, an imaginative physicist who has appeared in this book earlier as an enthusiastic supporter of time travel, has described how the Casimir force might be used to extract energy literally *from a vacuum*. This is an idea as seemingly impossible as is the plan of one science fiction professor to squeeze energy out of *time*. As he asks his assistant, "But tell me, Bob, isn't that a ridiculous thought? To take time, something intangible, invisible, incomprehensible, and contract it — squeeze it together like a sponge?"[42] The story is fun, but Forward's proposal is that as well—*and* good physics.[43] Now, what does all this have to do with wormhole time machines?

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[40] A complete presentation of Casimir's analysis, with citations to the original literature, can be found in L. E. Ballentine, *Quantum Mechanics*, Prentice-Hall 1990, pp. 399–403. For an historical, tutorial presentation, including Casimir's personal comments on how he was led to make his discovery, see P. W. Milonni and M.-L. Shih, "Casimir Forces," *Contemporary Physics*, September–October 1992, pp. 313–322.

[41] S. A. Fulling, *Aspects of Quantum Field Theory in Curved Space-Time*, London Mathematical Society 1989.

[42] E. Binder, "The Time Contractor," *Astounding Stories*, December 1937.

[43] R. Forward, "Extracting Electrical Energy from the Vacuum by Cohesion of Charged Foliated Conductors," *Physical Review B*, August 15, 1984, pp. 1700–1702.

Thorne and his colleagues (note 27) proposed to use the Casimir effect to achieve the "exotic condition" *without* matter. Their idea was to place identical, conducting, spherical plates that carry equal electric charges at each end of the wormhole (remember, the wormhole mouths are spherically symmetric). The two identical charges repel each other, but the charge size is adjusted so that the gravitational attraction of the plates precisely cancels the repulsion. They then calculated that the Casimir effect results in a negative energy density sufficient to provide the throat tension necessary to prevent wormhole collapse.

There *are* some weird aspects to this (and perhaps that's no surprise). For example, the analysis assumed that the wormhole length is *very* small compared to its radius (10^{-10} cm long and 200 million miles wide!), with the short length required because it represents the separation of the wormhole plates, and the smaller the separation the more negative the average energy density. (The functional dependence is as the *fourth* power of the separation.) Another problem is the balancing of the electrical repulsion and the gravitational attraction of the wormhole mouth plates, as such a balance is clearly an unstable one. Finally, because the two spherical plates completely fill the wormhole mouths, how would a traveler actually get through the wormhole? The 'answer' was to drill a hole through the plates and hope that wouldn't perturb the Casimir vacuum too much.[44]

All the above litany of the difficulties static, traversable wormholes face in simply existing is certainly daunting, but let's now ignore all that and suppose we actually have a wormhole with both mouths in the same universe. (For use as a time machine, it would seem desirable for the time traveler to remain in his/her own universe!) So, how do we turn the wormhole into a time machine? Interestingly, while it is general relativity that gives us the wormhole, it is special relativity that adds the final touch of backward time travel. We begin by imagining that, somehow, one mouth of the wormhole can be moved with respect to the other mouth. One early suggestion, for example, was to use the gravitational attraction of a large asteroid to 'drag' one end of the wormhole, thereby inducing a time dilation effect.[45]

That is, suppose we have two clocks A and B, one in each mouth of the wormhole. These two clocks, and all other clocks in the flat spacetime outside the wormhole, are initially indicating the same time and running at the same rate. Now, recalling the twin paradox from Chap. 3, let each mouth-clock play the role of one of the twins. Imagine that A and B are now separated because the mouth containing B is placed on board a rocket ship. The rocket ship takes a long, high-speed trip out into space along the straight-line path joining A and B in external space, and then returns, just as described in Sect. 3.5. We then unload the space traveling wormhole mouth (with its clock B) and reposition it at its original location. What is the situation now? We can summarize matters as follows: (1) Clock A, in the non-moving mouth, remains in-step with the local clocks in the space outside the mouth. (2) Clocks A and B, both inside the wormhole, have *not* moved with respect to each other because we are assuming a very short wormhole handle, as in part (b) of Fig. 6.8. We can arrange for the motion of the space traveling mouth (with clock B) to be such that the handle is always short, and so the distance between clocks A and B changes by an arbitrarily small amount. Thus, clocks A and B remain in-step with each other. (3) Clock B, because it has been moving with respect to its external space, arrives back at its starting position reading *behind* (that is, *earlier*) than the clocks outside its wormhole mouth.

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[44] The very next year it was shown how to construct non-spherically symmetric wormholes to avoid that particular problem: see the two papers by M. Visser, "Traversable Wormholes: Some Simple Examples," *Physical Review D*, May 15, 1989, pp. 3182–3184, and "Traversable Wormholes from Surgically Modified Schwarzchild Spacetimes," *Nuclear Physics B*, December 11, 1989, pp. 203–212.

[45] J. L. Friedman, "Back to the Future," *Nature*, November 24, 1988, pp. 305–306.

For the sake of argument, then, suppose the journey of B is such that there is a two-hour time-slip between clock B and its local, external clocks. Thus, if clock B reads 9 A.M., the clocks outside of mouth B will read 11 A.M. But because clocks A and B are in-step, clock A reads 9 A.M., as do the clocks outside of mouth A. That is, the wormhole connecting mouth A to mouth B is a connection between two parts of the same universe that are two hours apart in time. Now, suppose the journey from mouth A to mouth B can be made through external space in one hour. Then, one could leave mouth A at 10 A.M., rocket to mouth B by 11 A.M., and travel back to mouth A via the wormhole to the starting point—where it is 9 A.M., one hour *before* the trip began! We could, in fact, imagine repeating this process, going back one additional hour for each new loop through the wormhole. One clear restriction, however, is that we could not go back in time to *before* the creation of the wormhole time machine. The wormhole works in the other direction, too. To see this, suppose that the space traveler leaves mouth B at 8 A.M. and rockets through external space to mouth A, arriving at 9 A.M. Entering mouth A, he exits from mouth B (where he started) at 11 A.M., two hours in the future.

Another way to induce a time dilation effect, to convert a wormhole to a time machine, *without moving either mouth*, is to simply place one mouth in an intense gravitational field, that of, say, a neutron star. (Recall, from Sect. 3.3, how gravity influences the time-keeping rate of a clock.) As the physicists who proposed this idea put it, almost *any* interaction with surrounding matter and gravity fields almost inevitably turns a wormhole into a time machine.[46] Others have admitted that the details of the origin of time dilation are probably not issues worth debating, but rather what is called the *back-reaction* is of far more concern.

To understand the back-reaction requires mention of what is called the *Cauchy horizon*, the hyperspace surface in spacetime that separates the region where closed timelike lines can exist, from the region where they cannot exist. The back-reaction is the build-up of unbounded energy levels on the Cauchy horizon, causing its instability and rapid destruction. The name of the horizon comes from the "Cauchy problem"—named after the nineteenth century French mathematician Augustin-Louis Cauchy (1789–1857)—in the theory of partial differential equations. In this theory a Cauchy initial-value problem is said to be well-defined if the initial conditions determine a unique solution, and if a continuous variation in the initial conditions gives a continuous variation in the solution. In that part of spacetime where closed timelike loops are not allowed, backward causation does not occur (by definition) and the laws of physics (all expressed as differential equations) satisfy the Cauchy condition. Outside of this *chronal* region, that is, beyond the Cauchy horizon where physics is *dischronal*, however, the possibility of backward causation raises the possibility of violating the Cauchy condition, and in such a case the Cauchy horizon is also sometimes called the *chronology horizon*.[47]

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[46] V. P. Frolov and I. D. Novikov, "Physical Effects in Wormholes and Time Machines," *Physical Review D*, August 15, 1990, pp. 1057–1065.

The instability of the Cauchy horizon is caused by radiation that propagates in closed timelike loops that thread through the wormhole on 'straight lines.' This radiation, as shown a half-century ago,[48] builds-up unbounded energy density levels at the horizon, and thus destroys the horizon. Thorne and his colleagues argued that the defocusing effect of their wormhole time machine's repulsive gravity would be sufficient to counter a disruptive energy build-up on the horizon (note 27). Subsequent analyses have examined other possible ways to avoid unbounded energy density on the Cauchy horizon. For example, in one paper[49] it was imagined that a wormhole time machine has had a circular motion induced for mouth B; that is, mouth B orbits around mouth A. The result is that the Cauchy horizon now does seem to be stable, because now there are no fixed, straight-line timelike loops threading the wormhole from A to B to A to B to . . .. That is, B is a 'moving target' and there is no point on the Cauchy horizon where the energy density becomes unbounded.

Yet another approach for achieving the disruption of destructive, circulating energy loops through a wormhole is by placing a spherical mirror between the two mouths of the wormhole. Proposed by the Chinese physicist Li-Xin Li, a Li mirror would divert all closed null geodesics (represent circulating radiation) that potentially thread through the wormhole.[50] Such potentially fatal geodesics would, instead, be scattered back into space, whereas a purposeful traveler could navigate *around* the mirror and thus use the wormhole as a time machine.

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[47] A classic work on the mathematics of Cauchy problems is J. Hadamard, *Lectures on Cauchy's Problem in Linear Partial Differential Equations*, Dover 1952. There is a curious bit of irony in this. In a section of his book, Hadamard uses spacetime to illustrate one possible four-dimensional space and, in passing, he casually writes "This conception was beautifully illustrated a good many years ago by the novelist Wells in his *Time Machine*." Hadamard wrote his book in 1923, and he would almost certainly have been astonished to have been informed that less than seventy years later his work would play a central role in the non-fictional theory of time machines.

[48] C. W. Misner and A. H. Taub, "A Singularity-Free Empty Universe," *Soviet Physics JETP*, January 1969, pp. 122–133.

[49] I. D. Novikov, "An Analysis of the Operation of a Time Machine," *Soviet Physics JETP*, March 1989, pp. 439–443.

[50] L.-X. Li, "New Light on Time Machines: Against the Chronology Protection Conjecture," *Physical Review D*, November 1994, pp. R6037–R6040.

Cauchy horizon instability from the back reaction is central to Hawking's Chronology Protection Conjecture, discussed in Chap. 1. His analysis (see note 54 in Chap. 1) led him to conclude that a physical entity—the stress-energy tensor—becomes unphysical on the Cauchy horizon. That is, because of time-traveling quantum field fluctuations of the vacuum, that tensor diverges to infinity at the horizon. This results in a failure of that horizon to form in the first place or, if it does form, in the creation of a singularity that 'seals-off' the horizon to any would-be time travelers attempting to gain access to the closed timelike loops beyond the horizon. Others, however, argued that Hawking was mistaken in claiming that the divergence of the stress-energy tensor on the Cauchy horizon will always forbid time travel.

In a study, for example, of a complex-valued spacetime metric (and such a metric *is* allowed in the so-called 'sum over all possible geometries, path integral' approach to the quantum theory of gravity), that has causal and non-causal spacetime regions separated not by a Cauchy horizon but rather by a region of complex geometry, the stress-energy tensor is always physical and diverges nowhere. The complex geometry region plays the same role as the Cauchy horizon, because such a region would, *classically*, mean that the two regions cannot be reached from one another, but via quantum tunneling an observer *could* travel between the two regions.[51] In fact, studies of stress-energy divergence actually have a long history. For example, the effect of an unphysical (infinite) gravitational and/or electromagnetic energy flux had been analyzed *years before* the wormhole time machine studies began.[52] The authors studied the case of a potential traveler to "new worlds" who tries to cross the Cauchy horizon of an electrically charged, non-rotating black hole. An even earlier computer study had already concluded that, for such a traveler, the attempt to cross the horizon "looks liable to prove a dangerous undertaking."[53]

It isn't at all clear, in fact, if a *theoretical* divergence of the stress-energy *is* the signature of a failure of physics. One doesn't need anything as bizarre as a time machine for the stress-energy to diverge *on paper*. It was shown nearly 40 years ago, for example, that such a theoretical divergence occurs for the electromagnetic field near a perfectly conducting boundary.[54] But it is simply the unphysical nature of a "*perfectly* conducting" boundary condition that causes the divergence, not the fact that the field actually exists near a conducting boundary. Similarly, other real-life considerations (quantum gravity) *may* keep the stress-energy physical everywhere in a time machine spacetime.

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[51] L.-X. Li, J.-M. Xu, and L. Liu, "Complex Geometry, Quantum Tunneling, and Time Machines," *Physical Review D*, November 15, 1993, pp. 4735–4737.

[52] S. Chandrasekhar and J. B. Hartle, "On Crossing the Cauchy Horizon of a Reissner-Nordström Black-Hole," *Proceedings of the Royal Society of London A*, December 8, 1982, pp. 301–315.

[53] M. Simpson and R. Penrose, "Internal Instability in a Reissner-Nordström Black Hole," *International Journal of Theoretical Physics*, April 1973, pp. 183–197.

[54] D. Deutsch and P. Candelas, "Boundary Effects in Quantum Field Theory," *Physical Review D*, December 15, 1979, pp. 3063–3080.

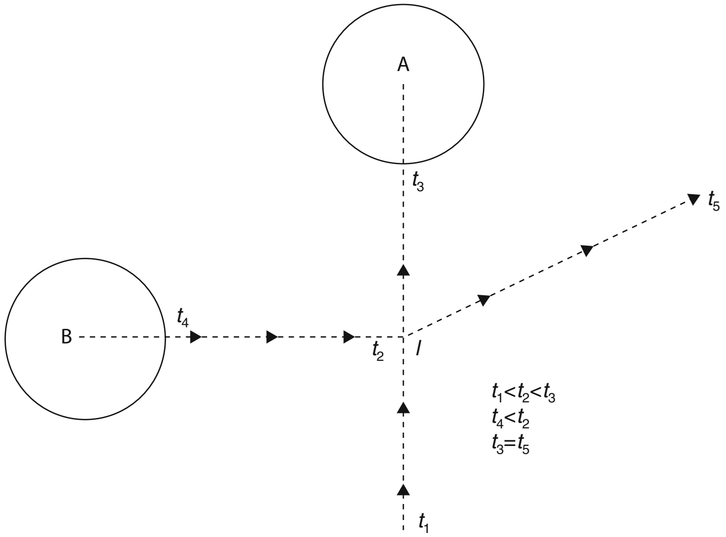

Fig. 6.9 The grandfather paradox in the billiard ball world. A billiard ball approaches mouth A of a time machine wormhole, dead-on center and, just before entering A, it passes without incident through point *I*. The ball then enters A and so exits mouth B in the past, *just in time* to pass through point *I* and *hit its younger self*. This impact knocks the younger ball *away from* A, so we have the familiar paradox of changing the past. That is, the impact did not occur when the ball 'originally' passed through *I* on its way to A and, of course, we also wonder how the ball manages to hit itself after leaving B if it then *doesn't* enter A?

Assuming a wormhole time machine has (somehow) become available, with its Cauchy horizon intact, how do the 'paradoxes' of time travel come into play? In an attempt to study the grandfather paradox, in particular, Thorne and his colleagues studied self-interacting billiard balls traveling backward in time through a wormhole.[55] They used billiard balls—see Figs. 6.9 and 6.10—rather than human time travelers for the same reason Wheeler and Feynman used a pellet and shutter mechanism in their study of advanced electromagnetic waves—to avoid any metaphysical questions about human free will. The central issue for them was the determination of the multiplicity of trajectories for a single, self-interacting time traveling ball, where the Cauchy condition for a well-defined trajectory in spacetime is *unique* self-consistency.

That is, for the trajectory to be well-defined in the Cauchy sense, it was expected there would be exactly *one* consistent trajectory for a self-interacting ball. A multiplicity of zero, of course, would be the physics declaring backward time travel through the wormhole to be nonsense—and that was thought to be a distinct

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[55] F. Echeverria, G. Klinkhammer, and K. S. Thorne, "Billiard Balls in Wormhole Spacetimes with Closed Timelike Curves: I. Classical Theory," *Physical Review D*, August 15, 1991, pp. 1077–1099. The authors credited the physicist/science fiction writer Robert Forward (who used the same ideas in his 1992 novel *Timemaster*) for motivating their research.

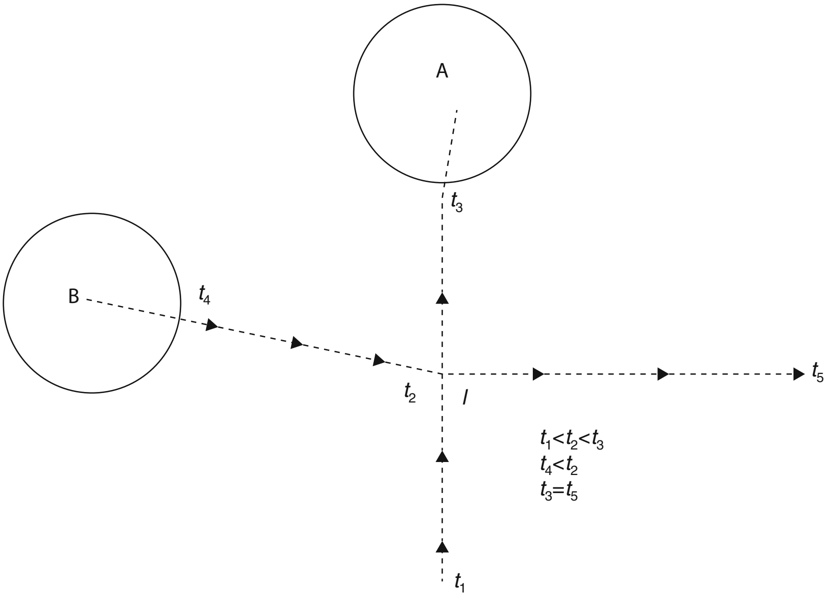

Fig. 6.10 The principle of self-consistency in the billiard ball world. Now the ball, in passing through point I on its dead-on center path toward mouth A of the wormhole time machine, is suddenly hit a grazing blow by another ball that has just shot out of mouth B (and into the past) at an angle. The impact knocks the first ball slightly off its original trajectory, and it enters mouth A slightly off-center. Thus, the ball emerges from B into the past slightly off-center and just in time to glace off itself at I—which explains *why* it emerged from B slightly off-center!

possibility. The actual results were, however, surprisingly different. It was found, under very general assumptions about the wormhole parameters, that (1) there are no trajectories with zero multiplicity and (2) the multiplicity is *not* one but rather is *always* infinity! Thus, the billiard ball form of the grandfather paradox *was* found to be *not* well-defined, but not for the expected reason that there was no self-consistent solution. Instead, it was because there are *too many* solutions.

This astonishing, completely unexpected result seems to be just what is needed to support the viability of time machines, as it appears to allow a definition of *well-defined* in the Cauchy sense and still permit an answer to the puzzle of free will. The initial conditions of a time traveling ball give rise to an infinity of self-consistent trajectories, each occurring in the same way that a random variable takes on different values with each new performance of the experiment that the random variable is defined on. And yet, there are still unique probability density functions for all sets of measurements that one might make anywhere along these trajectories. Thus, the Cauchy problem is *stochastically* well-defined; at the start of any trajectory, we do not know in detail what will happen except that whatever does happen will be self-consistent. In this probabilistic sense, then, wormhole time travel to the past and the retention of free will both make sense. The Russian physicist Igor Novikov and his colleagues continued the study of time traveling billiard balls,[56] demonstrating that one can *deduce* self-consistency from the long-accepted principle of least action (that is, self-consistency is not an additional assumption to existing physics).[57]

The one-wormhole, two-mouth time machine was actually not the first kind of wormhole time machine described in the physics literature. In their 1988 paper (note 21), Morris and Thorne initially described a time machine constructed from *two* wormholes, but they added a note-in-proof at the end that they had just discovered how to build a time machine using one wormhole (the machine we have been discussing). This reduction in the required number of wormholes was thought to be a technical advance, of course, and so the two-wormhole time machine was put aside.

But not for long. Soon thereafter the concerns about Cauchy horizon stability began to surface, a concern that one-wormhole time machines might destroy themselves just at the instant their mouths were about to be threaded by closed timelike curves. As noted earlier, the negative mass wormhole throat has a defocusing effect on electromagnetic radiation (and so the initial concern, that time traveling photons might be fatal, faded)—but then it was found that vacuum fluctuations of quantum fields are *not* so defocused.[58] That failure to defocus time-traveling vacuum polarizations (as quantum field fluctuations are called) was shown to result in an unphysical divergence of the stress-energy on the Cauchy horizon of a one-wormhole time machine.[59] This sounds bad, but the hope was that the divergence wouldn't actually be fatal: it appeared to be sufficiently sluggish that it was suggested reaching an actual *infinity* of the stress-energy would be precluded by the eventual intercession of quantum gravity. That is, the stress-energy might *try* to become unbounded as spacetime approached the formation of a time machine

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[56] A. Lossev and I. D. Novikov, "The Jinn of the Time Machine: Nontrivial Self-Consistent Solutions," *Classical and Quantum Gravity*, October 1992, pp. 2309–2321; E. V. Mikheeva and I. D. Novikov, "Inelastic Billiard Ball in Spacetime with a Time Machine," *Physical Review D*, February 15, 1993, pp. 1432–1436; M. B. Mensky and I. D. Novikov, "Three-Dimensional Billiards with a Time Machine," *International Journal of Modern Physics D*, April 1996, pp. 179–192.

[57] A. Carlini, *et al.*, "Time Machines: The Principle of Self-Consistency as a Consequence of the Principle of Minimal Action," October 1995, pp. 557–580, and "Time Machines and the Principle of Self-Consistency as a Consequence of Stationary Action (II): The Cauchy Problem for a Self-Interacting Particle," October 1996, pp. 445–479, both in *International Journal of Modern Physics D*.

[58] V. P. Frolov, "Vacuum Polarization in a Locally Static Multiply Connected Spacetime and a Time-Machine Problem," *Physical Review D*, June 15, 1991, pp. 3878–3894.

[59] S.-W. Kim and K. S. Thorne, "Do Vacuum Fluctuations Prevent the Creation of Closed Timelike Curves?" *Physical Review D*, June 15, 1991, pp. 3929–3947. See also L.-X. Li, "Must Time Machines Be Unstable Against Vacuum Fluctuations?" *Classical and Quantum Gravity*, September 1996, pp. 2563–2568.

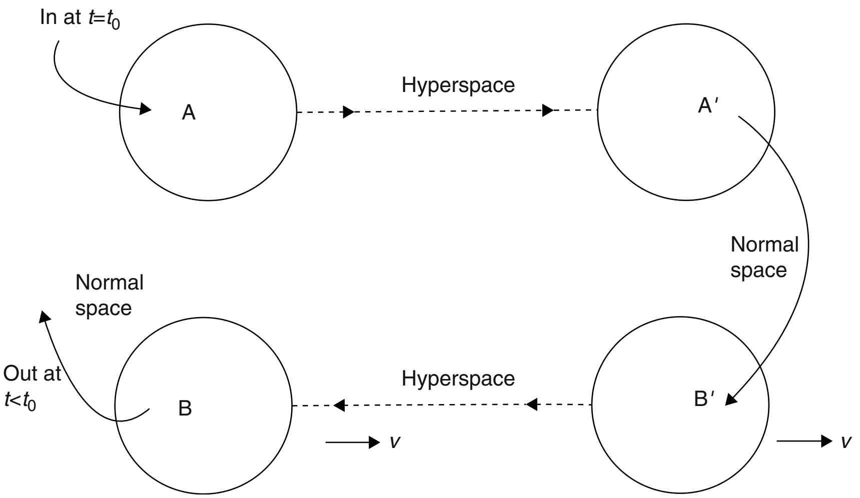

Fig. 6.11 A two-wormhole, Roman ring time machine

but, before it becomes so large as to destroy the time machine, quantum gravity would cut-off the divergence 'in time' (so to speak!) to save the machine.

Hawking disagreed (in his famous Chronology Protection Conjecture—see note 54 in Chap. 1), arguing that Kim and Thorne had made a crucial error in their calculations. According to Hawking, the divergence of the stress-energy may indeed be cut off by quantum gravity, but not before the development of spacetime disturbances representing perhaps a hundred million times the energy levels associated with ordinary chemical binding energies. These would be sufficiently big disturbances to raise serious doubts about the physical survival of a one-wormhole time machine, even in the absence of a true stress-energy infinity. Hence the resurrection of the two-wormhole time machine geometry. Perhaps *it* could avoid the destructive effect of time-traveling vacuum fluctuations.

If a spacetime contains multiple wormholes, then it is called a *Roman spacetime* after the physicist Thomas Roman (at Central Connecticut State University), who was the originator of such spacetimes. Each of these wormholes, individually, is *not* a time machine. Together, however, they form a time machine geometry called a *Roman configuration* (or a *Roman ring*).[60] Here's how.

In Fig. 6.11 two pairs of wormhole mouths are labeled A, A' and B, B'. We imagine that the A, A' wormhole is stationary and that its two mouths are very far apart in normal space—so far apart, in fact, that if a traveler enters A and almost instantly (because the wormhole handle is very short in hyperspace) emerges from A', it will appear to an observer at rest with respect to the wormhole that the traveler has moved faster than light. That is, entering A and exiting A' are events with spacelike separation. Now, imagine also that the wormhole with mouths B, B' is moving past the first wormhole at speed v. To an observer in this second, *moving* frame of reference, the spacelike separation of entering A and exiting A' can result in the two events being temporally reversed if v is sufficiently large (but still less than the speed of light). Therefore, upon emerging from A' the traveler crosses normal space to the moving wormhole mouth B', enters the wormhole, and then almost instantly emerges from mouth B, and finally travels again through normal space to mouth A. If the traveler can make the two trips in normal space in less time than the backward time shift achieved by the temporal reversal of entering A and exiting A', then we have a time machine

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[60] M. Visser, "Traversable Wormholes: The Roman Ring," *Physical Review D*, April 15, 1997, pp. 5212–5214.

Two simultaneous analyses of the Roman ring time machine each concluded that, for suitable choices of sizes (the radii of the wormhole mouths, the wormhole lengths in normal space, the lateral offset of the two wormholes, and the relative speed of the wormholes), the stress-energy divergence *can* be limited by quantum gravity to an arbitrarily weak level. That is, the two-wormhole time machine is not necessarily destroyed by an unbounded stress-energy on the Cauchy horizon.[61] But not all was now put right.

Visser, in particular, had some strong reservations about the Roman ring. Although he granted that a quantum gravity cut-off the stress-energy divergence *would* probably occur in the Roman ring, he called the required special sizing conditions “bizarre,” and asserted that the resulting time machine would be quite useless for a human traveler in any case. For example, he calculated that only if the mouths of the wormholes are separated in normal space by the radius of the universe (!), and only if the wormhole mouths have radii on the order of that of an atomic nucleus, would the cut-off be sufficient to allow the putative time machine to avoid destruction. When Visser reduced the wormholes from universe size to ‘merely’ that of the distance between the Sun and the Earth, he concluded that it would require energy at the level of the Superconducting Supercollider accelerator to blast an information-bearing message through the narrow wormholes. And even then the ‘short’ wormholes would provide a maximum penetration into the past of just eight minutes. As Visser put it, “This does not seem to be a workable recipe for studying tomorrow’s *Wall Street Journal.*

Lyutikov, on the other hand, took a far less negative stance. He concluded that although Visser’s calculations “make it very inconvenient for time travel [by humans],” nevertheless “the [principal] question of the possibility of transmitting information back in time through traversable wormholes would still remain.”

The wormholes we have been discussing so far are *static* in time, but another approach is to allow them to be dynamic structures in spacetime. That is, to allow one or more of their parameters to vary with time (perhaps, for example, the throat diameter could collapse). Then, according to one analysis, it is possible to have a traversable wormhole *made of normal matter* and, even though it is collapsing, it would take so long to do so that "a space adventurer will have enough time to pass through the throat of the wormhole from one asymptotically flat region [of spacetime outside the entry mouth of the wormhole] to the other [spacetime region outside the exit mouth of the wormhole] before the radius of the throat shrinks to . . . where the event horizon is developed."[62] Such a dynamic wormhole, it was claimed, satisfies both the weak and the dominant energy[63] conditions, but not the strong energy condition. Thus, gravity would still be repulsive in the throat, but this condition (which would seem to require *exotic* matter) was brushed aside because such a condition is thought to have actually occurred, on a massive scale, during the inflationary stage of the Big Bang[64] (although how that would help in the construction of a wormhole in the future is a bit murky).

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[61] M. Visser, “Van Vleck Determinants: Traversable Wormhole Spacetimes,” April 15,1994, pp. 3963–3980, and M. Lyutikov, “Vacuum Polarization at the Chronology Horizon of the Roman Spacetime,” April 15, 1994, pp. 4041–4048, both in *Physical Review D*.

Is it reasonable to think 'useable' wormholes, static or otherwise, can be acquired for the purpose of creating a time machine? At one time, Hawking was sure the answer is no, once writing "The philosophy of this paper is . . . to look for vacuum polarization [the divergence of the stress-energy on the Cauchy horizon] to enforce the chronology protection conjecture."[65] It became increasingly apparent, however, that matters would be a great deal more involved and, as Hawking himself came to admit, "the fact that the energy-momentum tensor fails to diverge [in certain special cases of time machine spacetimes] shows that the back reaction does not enforce chronology protection.".[66]

I think the best (and most honest) way to respond to the 'reasonable' question that opened the previous paragraph is with words from 20 years ago, by the Russian astrophysicist Serguei Krasnikov, words still valid today: "It may well be that the vacuum fluctuations do make the time machine unstable, but nothing at present suggests this. All we have are a few simple examples. In some of them the energy density diverges at the horizon and in some does not. So, the time machine perhaps is stable and perhaps is not."[67]

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[62] A. Wang and P. S. Letelier, "Dynamical Wormholes and Energy Conditions," *Progress of Theoretical Physics*, July 1995, pp. 137–142. See also L. A. Anchordoqui, *et al.*, "Evolving Wormhole Geometries," *Physical Review D*, January 15, 1998, pp. 829–833.

[63] The dominant energy condition is the weak energy condition *plus* the requirement that any observed energy flux is *never* superluminal.

[64] During inflation the universe is thought to have expanded at a rate far beyond human comprehension. It has been estimated that during the first 10^{-35} second of the Big Bang the universe doubled in each spatial dimension by a factor of two each 10^{-37} second; that is, there were about 100 such doublings. Thus, there was an increase by a factor of $2^{100} \approx 10^{30}$ in each linear dimension of the universe, and the volume increased by the cube of that enormous factor. See Alan Guth, *The Inflationary Universe*, Addison-Wesley 1997.

[65] S. Hawking, "Quantum Coherence and Closed Timelike Curves," *Physical Review D*, November 15, 1995, pp. 5681–5686.

[66] M. J. Cassidy and S. W. Hawking, "Models for Chronology Selection," *Physical Review D*, February 15, 1998, pp. 2372–2380. See also L.-X. Li and J. R. Gott, "Self-Consistent Vacuum for Misner Space and the Chronology Protection Conjecture," *Physical Review Letters*, April 6, 1998, pp. 2980–2983.

The daunting level of technology required to *build* a wormhole (with or without exotic matter) doesn't mean we can't search for existing wormholes. Perhaps, for example, vast wormhole networks were formed naturally at Big Bang time, as described in Gregory Benford's 1997 novel *Foundation's Fear*, where wormholes are "leftovers from the Great Emergence [the Big Bang]." Or perhaps "advanced civilizations" long ago constructed a vast, pan-galactic 'subway system' of wormholes like the one described in Carl Sagan's 1985 novel Co*ntact* (and dramatically illustrated in the 1997 film).

Of course, any such wormhole, if found (via its double-spike light signature, for example), could be a very long way from Earth. It might even be in another galaxy. So, even if we found a wormhole, what could we *do* with it? Surprisingly, maybe a lot. The Russian physicists Igor Novikov and Andrei Lossev (note 56) suggested that a wormhole might be very useful *even if its location is completely unknown, even if we haven't yet even discovered it*! The only assumption they made was that the wormhole has existed for a "sufficiently long time" (and precisely what that means will be explained in just a bit). With that assumption, they showed how to make an information-creating time loop. Here's how they did that.

They began their analysis by assuming that people have no knowledge of how to build spacecraft that can make the interstellar voyage to the distant wormhole, even if they knew in which direction to go to reach the mouth that leads backward in time (mouth B). Instead, they build an automatic spacecraft construction plant that can follow any detailed sequence of instructions provided to it, and then stockpile it with a supply of raw materials (energy, steel, plastic, computers, and so on). When the spacecraft construction is done (*how* that is done is explained in the next paragraph), the last step before launching the spacecraft toward mouth B *will be* to load the on-board computer with the following three pieces of information:

1. The detailed sequence of instructions to be followed in the construction of the spacecraft;
2. The direction from Earth to mouth B;
3. The direction from mouth A (the wormhole exit mouth in the past) back to Earth.

To summarize, people build the automatic plant, load it up with raw materials, *and then withdraw*. This last step is crucial, because it eliminates human free will from further consideration, that is, it removes any temptation to create a bilking paradox. So, what happens next?

Lossev and Novikov suggest that what happens next is that a *very* old spacecraft suddenly appears in the sky and lands next to the automatic construction plant. In its on-board computer are items a, b, and c. Using item a, the automatic plant makes a new spacecraft, then loads the new on-board computer with items a, b, and c from the *very* old spacecraft's on-board computer, and then the new spacecraft is launched toward mouth B (using the information of item b). The *very* old spacecraft is given an honored place in a museum.

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[67] S. V. Krasnikov, "Quantum Stability of the Time Machine," *Physical Review D*, December 15, 1996, pp. 7322–7327.

The new spacecraft arrives at the distant mouth B in the far future, by which time it is, of course, an old spacecraft (but not yet a *very* old spacecraft). It then plunges into mouth B and almost immediately emerges from mouth A, in the past. Indeed, it repeats this process as many times as required until it is in the far distant past, at a time even before it left Earth. (It might seem that to do this, the spacecraft's computer memory needs a fourth piece of information, the direction from mouth A back to mouth B, but in fact items b and c are sufficient for the old spacecraft to find its way from A to B.) It is now clear how long the wormhole must have been in existence. The old spacecraft repeatedly uses the wormhole time machine until it is so far in the past that it can cruise back to Earth at normal speed (it knows the way back because of item c) and arrive as a *very* old spacecraft, just in time to be placed in the museum!

As Lossev and Novikov pointed out, this remarkable, looped sequence of events has increased knowledge from what it was at the time just before the automatic construction plant was built. People now know both how to build an interstellar spacecraft, and the locations of both mouths of the wormhole. They also now possess a *very* old, used spacecraft. It is curious to note that although the information in the *very* old spacecraft's computer memory has traveled on a closed time loop, the *very* old spacecraft itself has not. This is because the spacecraft left Earth when new, but arrived back (before it left) as *very* old, whereupon it promptly entered a museum. There is therefore no question about the origin of the *very* old spacecraft, but where did the information of items a, b, and c come from? Lossev and Novikov say it came from the energy gained by the spacecraft as it interacted (will interact?) with the rest of the universe while on its journey.

Nobody said time travel isn't weird!

6.4 Gott's Cosmic String Time Machine

> "It's an amazingly simple solution. It doesn't take much physics to understand it."
>
> —MIT astrophysicist Alan Guth, on Gott's discovery of the cosmic string time machine[68]

> "Louise, working out the spacetime geometry of a cosmic string is a hard problem in general relativity. But, given that geometry, all the rest of it is no more than Pythagoras' theorem . . ."
>
> —a character in Stephen Baxter's 1994 novel *Ring*, agreeing with Guth.

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[68] Quoted from J. Travis, "Could a Pair of Cosmic Strings Open a Route Into the Past?" *Science*, April 10, 1992, pp. 179–180.

A new way to gain access to closed timelike curves, without the involvement of the exotic matter needed by negative-mass wormholes, was described in 1991 by the Princeton physicist J. Richard Gott.[69] Gott gave exact solutions to Einstein's gravitational field equations for what are called *cosmic strings*, solutions that (1) unlike wormholes, do not violate any of the energy conditions, (2) unlike black holes have no crushing singularities or event horizons, and (3) are not topologically multiply connected.

Cosmic strings are fantastically thin (10^{-28} cm in radius) filaments of pure energy that are thought to stretch the width of the universe and to have an enormous linear mass-energy density of 10^{28} g/cm. To generate closed timelike paths in spacetime, Gott required that either two fast-moving (which means moving at practically the speed of light) parallel cosmic strings pass each other on a near-collision course, or that there be a closed-loop string that collapses in a slightly non-planar manner so that the opposite, nearly straight sides 'just miss.' The gravitational interaction of the passing strings can 'warp' spacetime enough to produce closed timelike curves.

A hint at the possibility of violating causality with strings had appeared before Gott's work, but those authors didn't take the time travel implications seriously. As they wrote, "We argue ... that any realistic model [for a spinning string with angular momentum[70]] ... will not have closed timelike curves."[71] Gott, however, showed that as two strings pass each other, closed timelike loops *do* encircle the strings.

Gott, who appears to be far less rigid in his view of time travel than are many of his fellow physicists, held out an escape to those who pale at the very thought of time travel to the past. Perhaps, he suggested (following in the footsteps of an analysis by Hawking[72]), as the strings (or string-loop sides) pass, a black hole will form with an event horizon that will seal-off the closed timelike curves from any would-be time traveler. Or perhaps, he further suggested, the more realistic case of non-singular strings (that is, strings with non-zero-filament radii) and possessing

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[69] J. R. Gott, "Closed Timelike Curves Produced by Pairs of Moving Cosmic Strings: Exact Solutions," *Physical Review Letters*, March 4, 1991, pp. 1126–1129.

[70] The two strings in a Gott-pair are *not* necessarily spinning, and no such assumption was made by Gott. They don't even have to be parallel. If the strings have no spin, then it takes two strings to make a time machine. If spin *is* allowed, however, then just a single string will suffice for time travel: see S. Deser and R. Jackiw, "Time Travel?" *Comments on Nuclear and Particle Physics*, September 1992, pp. 337–354.

[71] D. Harari and A. P. Polychronakas, "Gravitational Time Delay Due to a Spinning String," *Physical Review D*, November 15, 1988, pp. 3320–3322.

[72] S. W. Hawking, "Gravitational Radiation from Collapsing Cosmic String Loops," *Physics Letters B*, August 23, 1990, pp. 36–38.

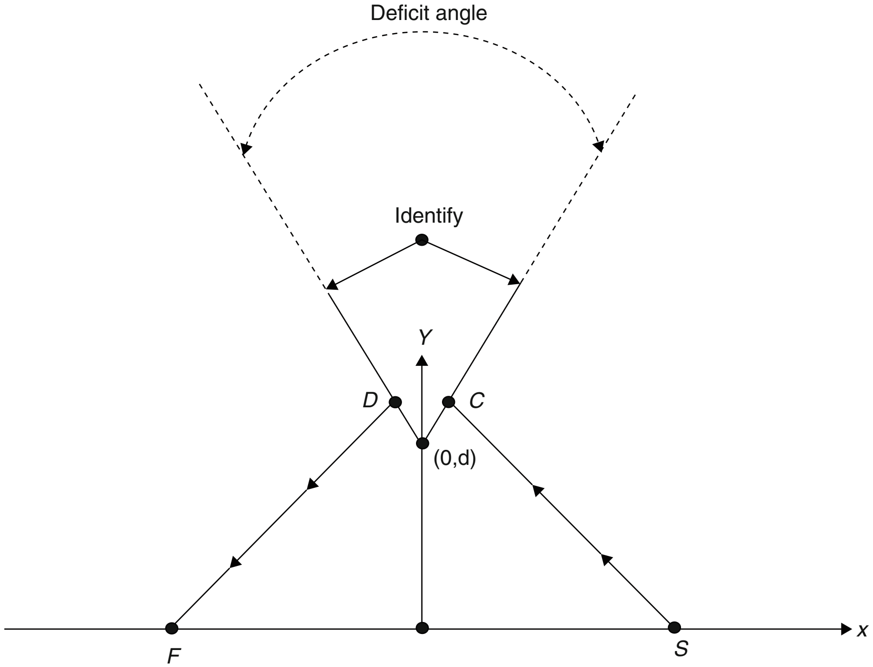

Fig. 6.12 The deficit angle in spacetime formed by a cosmic string

spin would banish the terrifying closed timelike curves. Subsequent analyses along those lines, however, continued to find the time travel implications intact.[73]

Here's how the cosmic string time machine works. In an earlier work,[74] published in 1985, Gott discovered that a cosmic string warps spacetime in a highly characteristic way, as shown in Fig. 6.12. A stationary cosmic string is imagined as perpendicular to the xy-plane (the plane of the page) and passing through the page at the point $(0, d)$ on the y-axis. The warp produced by the string is as though a wedge of angle 2α (this angle is called the *deficit angle*) were cut out of spacetime and the

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[73] See, for example, B. Jensen, "Notes on Spinning Strings," *Classical and Quantum Gravity*, January 1992, pp. L7–L12, H. H. Soleng, "A Spinning String," *General Relativity and Gravitation*, January 1992, pp. 111–117, (the next two are in the *Physical Review D*), B. Jensen and H. H. Soleng, "General-Relativistic Model of a Spinning Cosmic String," May 15, 1992, pp. 3528–3533, and M. Novello and M. C. M. da Silva, "Cosmic Spinning String and Causal Protecting Capsules," January 15, 1994, pp. 825–830.

[74] J. R. Gott, "Gravitational Lensing Effects of Vacuum Strings: Exact Solutions," *The Astrophysical Journal*, January 15, 1985, pp. 422–427. Gott's discovery was independently reported in W. A. Hiscock, "Exact Gravitational Field of a String," *Physical Review D*, June 15, 1985, pp. 3288–3290.

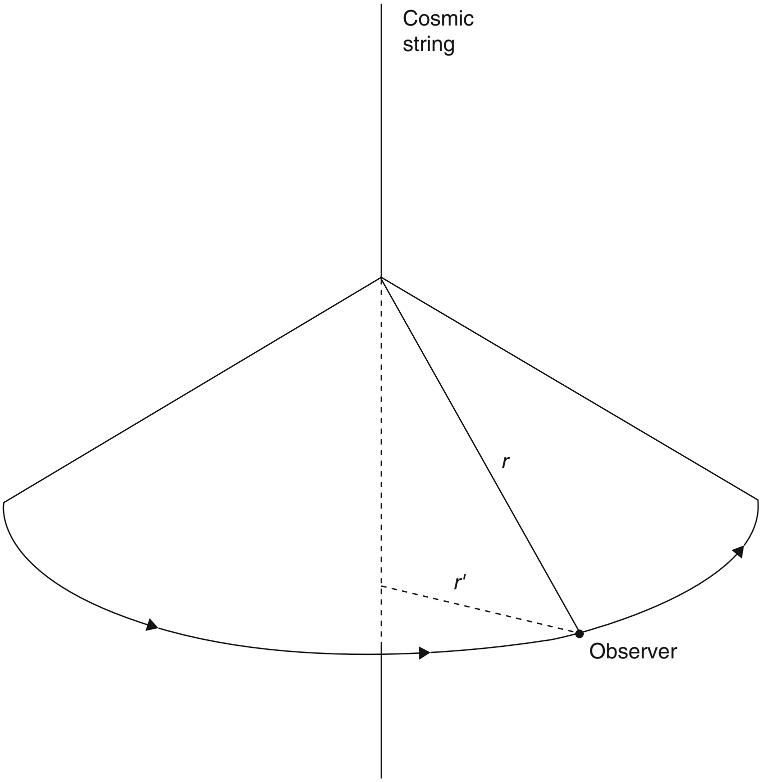

Fig. 6.13 The warped, conical spacetime around a cosmic string, An observer in this spacetime thinks she is distance r from the string, but a 'meta-observer' sees that she is actually distance $r^{\prime}$ from the string. Thus, if the observer follows a complete circular path around the string, she will travel a distance of $2\pi r^{\prime} < 2\pi r$. The observer in the spacetime will interpret this result by saying that the angle 2π is really 2π minus 'a deficit'

edges of the cut were then 'glued' together; for example, points C and D are identified as identical. The reason for the term *deficit angle* is that at radius r from the string, a circular path around the string has the reduced length $(2\pi - 2\alpha)r$, and not the usual $2\pi r$ (spacetime around the string, while *locally* flat, is actually 'conical,' as illustrated in Fig. 6.13).

The deficit angle is equal to $8\pi\mu$ radians (in a system of units where G, Newton's gravitational constant, is 1) if the linear mass-energy density μ is expressed in units of Planck masses per Planck length. For example, $\mu = 1$ corresponds to 1.35×10^{28} g/cm (think of something on the order of the mass of the Earth per inch of the string). For 'more typical' values—say a 'mere' $\mu = 10^{22}$ g/cm, $2\alpha = 0.001^{\circ}$. While Gott's paper had appeared 5 months before Hiscock's (see note 74), it is evident that Hiscock's work was done before he became aware of Gott's. Both papers treat exact derivations of the deficit angle but, in fact, the correct expression had actually been published 4 years earlier (but from a linearized form of the gravitational field equations and so the result was not as 'conclusive' as are Gott's and Hiscock's)[75]

Now, consider the two points S and F on the x-axis at $(x_0, 0)$ and $(-x_0, 0)$ in Fig. 6.12. Suppose we want to send photons from S to F. In normal, 'unwarped' spacetime, the direct path from S to F through the origin has length $2x_0$. There is also another possible path, however, S to C/D to F, that loops out and around the cosmic string. Indeed, this second path is simply the path a gravitationally lensed photon would take (an observer at F would see *two* images of S) and this—*not* time travel—is the issue that originally attracted Gott's attention to cosmic strings.[76] If the deficit angle were zero, then this alternative path would always be longer than $2x_0$, for any value of x_0. For the case of $2\alpha > 0$, however, if x_0 is large enough ($x_0 \gg d$), then it is possible for 'around the string and over the missing spacetime wedge' path to be shorter than the direct path.

The indirect path provides a way for a *sub*luminal trip (say, by rocket) from S to F to beat a photon traveling on the direct path. That is, the two events of the 'rocket leaving S ' and the 'rocket arriving at F' are spacelike separated. Thus, it is possible to find a moving frame of reference in which these two events are *reversed in temporal order*. In that frame of reference, the cosmic string (which is stationary in the reference frame of S and in that of F) will move—at speed v, say—in the $+x$ direction, and in that frame of reference the rocket will arrive at F *before* it leaves S.[77]

Then to complete the construction of a closed timelike path, simply repeat the process as shown in Fig. 6.14. That is, after the rocket arrives at F, have it turn around and fly back to S out-and-around and through the deficit angle spacetime warp due to a *second* cosmic string on the negative y-axis and perpendicular to the xy-plane. This second string is moving at speed $-v$ (that is, opposite to the first string), so the rocket will arrive at S before it leaves F. But that means it arrives at S before it leaves S; that is, the rocket has traveled into the past. In other words, the rocket has traveled into the past. This entire process is precisely the same idea behind the two-wormhole Roman-ring time machine discussion from the previous section.

Now, instead of having two oppositely moving reference frames, one in which the top, stationary string at $(0, d)$ appears to be moving at $+v$ and another frame in

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[75] A. Vilenkin, "Gravitational Field of Vacuum Domain Walls and Strings," *Physical Review D*, February 15, 1981, pp. 852–857.

[76] Just as discussed earlier in the context of wormholes, gravitational lensing may offer a way to detect cosmic strings. See, for example, the two papers by D. L. Ossipov, "Diffraction of Light by a Cosmic String," November 1995, pp. 765–771, and "Contribution of Strings to the Observed Variability of Extragalactic Sources of Radiation," September 1996, pp. 419–425, both in *JETP Letters*.

[77] For this to happen, however, v must be very close to the speed of light. Gott (see note 69) showed that with $v = \tanh(\theta)$, the condition for the rocket to arrive back at S before it leaves S is $\cosh(\theta) \sin(\alpha) > 1$, where α is one-half the deficit angle. For $\mu = 10^{22}$ g/cm, this gives $v = 0.99999999995$ (times the speed of light).

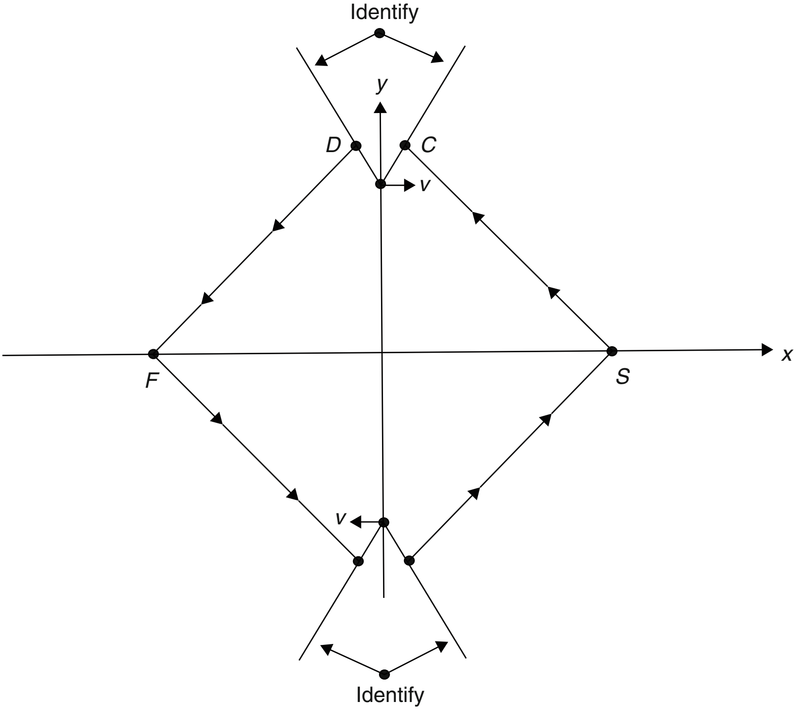

Fig. 6.14 Gott's spacetime, formed by joining two oppositely moving versions of the spacetime in Fig. 6.13

which the bottom, stationary string appears to be moving at –*v*, we can imagine an observer in the *stationary center-of mass* frame watching two strings that are moving at +*v* and –*v*. This leaves the situation unchanged, so in the center-of-mass frame the rocket does travel into the past, arriving back at *S* before it leaves *S*. That is, the rocket has traveled all the way around a closed timelike world line. Note, too, that the geometric condition mentioned earlier of $x_0 \gg d$ immediately implies that for x_0 *not* sufficiently large, there isn't a closed timelike path from *S* to *F* and then back to *S*; that is, there is a region in Gott's spacetime where such time travel journeys *cannot occur*.

Another physicist pursued Gott's analysis in an attempt to see whether these 'time travel paths' are *created* as the strings approach each other or, instead, if the paths exist at other times as well.[78] This important question gets to the idea of whether such time machine paths can be *intentionally created* by humans via a dynamical process (a *strong* time machine), or whether all such paths have existed since the formation of the universe (a *weak* time machine). This issue involves Hawking's chronology protection conjecture, which you'll recall asserts that the laws of physics will always (somehow) prevent the creation of a time machine. One reason Hawking repeatedly gave for believing the Conjecture is the apparent absence of time travelers from the future among us now (in their past). The only possible exception allowed by the Conjecture is the creation of closed timelike loops at the moment the universe was created (at that moment there *was no past* for time travelers to invade!). Ori proved that the closed timelike loops around Gott's cosmic strings are *always* present: that is, a time machine is *not created* by the near collision of the strings. Thus, Hawking's Conjecture is nor refuted by Gott's spacetime.

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[78] A. Ori, "Rapidly Moving Cosmic Strings and Chronology Protection," *Physical Review D*, October 15, 1991, pp. 2214–2215.

One very curious issue is *where* the closed time loops are before the strings pass one another. As mentioned briefly by Ori, and further discussed by others,[79] the time loops are initially at spatial infinity. To this concern, Gott and a colleague made the following very strong reply:

> "[A problem] Deser *et al.* present with respect to the Gott spacetime is that it contains CTC's at spacelike infinity; this is supposed to be an unacceptable boundary condition. We wonder, however, how they know so much about boundary conditions at spacelike infinity. In our own Universe we do not know what spacelike infinity looks like (if it exists) since we have not seen it yet. We certainly have no way of knowing whether or not there are CTC's there. The working physicist is, of course, free to impose simple and convenient boundary conditions (e.g., asymptotic flatness) on a system in order to isolate and understand the processes occurring within it. *But boundary conditions are tools of physicists, and they should not be confused with laws of physics* [my emphasis]. There may be such laws of nature that restrict the possible structure of spacelike infinity, and even prohibit CTC's there, but in the absence of evidence such laws should not be postulated *ad hoc*."[80]

Still, as Ori had observed the year before, having time loops collapsing inward from infinity toward humans who might, fortuitously, wish to use them at *just the instant they so conveniently arrive*, is "a situation which has little to do with the creation of a time machine by a *human being* [my emphasis]."[81]

The most damning objection to Gott's cosmic string time machine came, ironically, from Gott himself. The two-string spacetime of Fig. 6.14 might actually, he and a colleague wrote (see Li and Gott, note 66) be destabilized by the non-zero mass of any would-be time traveler. They suggest that this concern could perhaps be 'solved' by assuming that the time traveler and her spaceship have a spherically symmetric mass distribution surrounded by a negative-mass shell to give zero net mass (and thus a zero net gravitational field that would *not* destroy the closed timelike curves of the strings). But that, they further observed, would negate the crucial advantage—no exotic matter and so no violation of the weak energy condition—that a cosmic string time machine enjoys over a wormhole time machine.

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[79] See, for example, S. Deser, *et al*., "Physical Cosmic Strings Do Not Generate Closed Timelike Curves," *Physical Review Letters*, January 20, 1992, pp. 267–269.

[80] M. P. Headrick and J. R. Gott, "(2+1)-Dimensional Spacetimes Containing Closed Timelike Curves," *Physical Review D*, December 15, 1994, pp. 7244–7259.

[81] A. Ori, "Must Time-Machine Construction Violate the Weak Energy Condition?" *Physical Review Letters*, October 18, 1993, pp. 2517–2520.

Does a trip around a pair of cosmic strings present other problems *aside* from the sheer fantastic physics of the strings themselves? Well, I think "turning the rocket around at F and flying back to S" is a lot easier to write than it would be to actually do! The entire trip has to occur while the strings (moving at essentially light speed) are in a position *to be* flown around. As one character says to another in Stephen Baxter's novel *Ring*, "Louise, the strings are traveling just under the speed of light—within three decimal places of it, actually. [Our ship is] traveling at a little over half-light speed. The turning curves, and the accelerations, are incredible . . ." I think so! And I do wonder who—*or what*(!)—is actually controlling a *maneuvering* rocket traveling faster than $\frac{1}{2}c$?

6.5 Cutting and Warping Spacetime

> "The warp drive spacetime of Alcubierre is impossible to set up . . . one needs to transcend the speed of light in order to construct the warp drive in the first place . . . put roughly, you need one to make one!"[82]

In this chapter we've talked about the physics of three specific time machine 'implementations': the rotating cylinder, the wormhole, and the cosmic string. One can also discuss the 'construction' of a time machine in a more geometrical (yet still physical) way by performing what is called *spacetime surgery* to arrive at what is often referred to as a *Deutsch-Politzer spacetime* (after the two physicists who are closely associated with it[83]). With this surgery we arrive at a simple spacetime picture of the grandfather paradox (as you'll soon see).

We start with a flat, two-dimensional Minkowski spacetime, the x, t system in Fig. 6.15, and then imagine that (somehow) two *cuts* in that spacetime come into

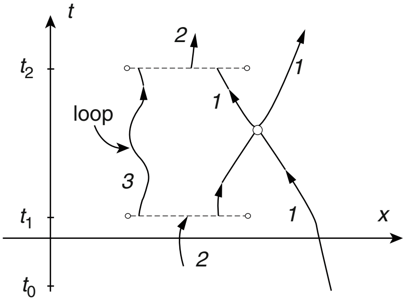

Fig. 6.15 Minkowski spacetime transformed into a time machine with two 'cuts'

existence. These cuts are the two horizontal dashed lines in the figure, one with an arrowhead going into it, and one with an arrowhead coming out of it (each labeled with ‘2’). We further imagine that each cut has two edges, with the upper edge of the lower cut ‘glued’ to the lower edge of the upper cut (and the lower edge of the lower cut ‘glued’ to the upper edge of the upper cut

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[82] D. H. Coule, "No Warp Drive," *Classical and Quantum Gravity*, August 1998, pp. 2523–2527, offering a pessimistic view of warp drive.

[83] See D. Deutsch, "Quantum Mechanics Near Closed Timelike Lines," November 15, 1991, pp. 3197–3217, and H. D. Politzer, "Simple Quantum Systems with Closed Timelike Curves," November 15, 1992, pp. 4470–4476, both in *Physical Review D*.

These ‘gluing’s’ explain why the arrowhead marked 2 into the lower cut at time t_1 emerges from the upper cut at time $t_2 > t_1$, and why the arrowhead marked 1 into the upper cut at time t_2 emerges from the lower cut at time $t_1 < t_2$. The 2-line is the world line of a particle that simply disappears from spacetime during $t_1 < \mathrm{t} < t_2$, while the 3-line is the world line of a particle trapped in an endless time loop (remember the 1993 film *Groundhog Day*?). Clearly, the sub-region of spacetime between the two cuts is not ‘normal’ spacetime. In fact, the 1-line shows that we have encountered a time machine spacetime, as a particle entering it from $t < t_1$ (passing to the right of the lower cut) can enter the lower edge of upper cut at $t = t_2$ and so emerge from the upper edge of the lower cut at the *earlier* time $t = t_1$ and thus interact with itself before it entered the upper edge! And that, of course, sets-up a grandfather paradox situation.

This picture leaves one thing obviously (and glaringly) unexplained—just *how* does one *cut and glue* spacetime? The reason, in spite of that question, that physicists nonetheless study situations depicted in Fig. 6.15, is because it allows them to explore what *could* happen *if* through some (yet unknown) process a time machine spacetime should suddenly appear. Who says physicists aren’t optimists?

The idea of modifying spacetime itself to ‘make’ a time machine (look back in Sect. 3.5, at the discussion there on what it means to solve the gravitational field equations) has also appeared in connection with another of science fiction’s favorite ideas, one almost as spectacular as time travel: *the FTL warp drive*. The lure of interstellar FTL travel, for both science fiction enthusiasts and physicists is, of course, simply undeniable. Consider, for example, these words by a Russian physicist:

> “Everybody knows that nothing can move faster than light. The regrettable consequences of this fact are also well known. Most of the interesting or promising candidates for colonization are so distant from us that the light barrier seems to make an insurmountable obstacle for any expedition. It is, for example, 200 pc [1 parsec is equal to about 3.2 light-years] from us to the Pole star, 500 pc to Deneb [the brightest star in the constellation Cygnus], and ~10 kpc to the center of the Galaxy, not to mention other galaxies (hundreds of kiloparsecs). It makes no sense to send an expedition if we know that thousands of years will elapse before we receive its report. On the other hand, the prospects of being confined forever to the Solar System without any hope of visiting other civilizations or examining closely black holes, supergiants, and other marvels are so gloomy that it seems necessary to search for some way out.”[84]

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[84] S. V. Krasnikov, “Hyperfast Travel in General Relativity,” *Physical Review D*, April 15, 1998, pp. 4760–4766. Possible travel distances have been greatly reduced since Krasnikov wrote. In 2011, for example, astronomers announced the discovery of a red dwarf star with three planets (each of mass comparable to Earth’s), all in the star’s so-called *habitable zone* (where water can exist on the surface in the liquid state). All three planets are solid (not gaseous as are Jupiter,

In response to that, we might ask if *FTL* trips will someday be made by humans in spaceships? *Maybe*—but only if such journeys can be made in a very *unordinary* spacetime. That is, continuing with Krasnikov's passage:

> "The point … is that [whereas the light barrier exists in special relativity] in general relativity one can try to change the time necessary for some travel not only by varying one's speed [as in special relativity] but also … by changing the distance one has to cover."

To understand what Krasnikov was getting at, let's consider the theoretical analysis made 4 years earlier by the Mexican mathematical physicist Miguel Alcubierre on, astonishingly, how to make a *Star Trek* warp drive![85] He did this by demonstrating a spacetime metric that, by literally expanding and contracting the local spacetime of a spaceship and its neighborhood, achieves space travel between any two points, no matter how far apart, in arbitrarily little elapsed time (for both the spaceship, and external non-spaceship observers, there is no time dilation effect[86]).

Alcubierre opened his analysis with words designed to explain how FTL travel is possible, given all that I've told you earlier in this book about how FTL travel is *not* possible (according to *special* relativity). As he wrote,

> "Since our everyday experience is based on a Euclidean space, it is natural to believe that if nothing can locally travel faster than light then given two places that are separated by a proper spatial distance D, it is impossible to make a round trip between them in a time less than $2D/c$ (where c is the speed of light), as measured by an observer that always remains at the place of departure. Of course, from our knowledge of special relativity we know that the time measured by the person making the round trip can be made arbitrarily small if his (or her) speed approaches that of light. However, the fact within the framework of general relativity and without the need to introduce non-trivial topologies (wormholes), one can actually make such a round trip in an arbitrarily short time as measured by an observer that remained at rest will probably come as a surprise to many people."

That last sentence is almost surely a grand understatement, and Alcubierre quickly went on to explain.

> "The basic idea can be more easily understood if we think for a moment of the inflationary phase of the early Universe, and consider the relative speed of separation of two co-moving observers. It is easy to convince oneself that, if we define this relative speed as the rate of change of proper spatial distance over proper time, we will obtain a value that is much larger than the speed of light. This doesn't mean that our observers will be travelling faster

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Saturn, Neptune and Uranus) and so, as potentially habitable, are candidates for a visit. The star and its planets are 'only' 22 light-years from Earth. In *Star Trek*, FTL speed is described by the *warp factor*, which is the cube-root of the multiple of the speed of light at which the spaceship *Enterprise* travels. So, for example, to make the journey from Earth to the red dwarf in one month of ship time (see ahead also to note 86), the required FTL speed would be 264 times the speed of light, or warp factor 6.4. In science fiction, a *warp drive* is imagined as the means for achieving such speeds.

[85] M. Alcubierre, "The Warp Drive: Hyper-fast Travel Within General Relativity," *Classical and Quantum Gravity*, May 1994, pp. L73–L77.

[86] That is, the passage of time on the spaceship is *identical* with the passage of time on Earth. *With the warp drive, there is no twin paradox.*

> than light: *they always move inside their local light-cones* [my emphasis]. The enormous speed of separation comes from the expansion of spacetime itself."

In a similar fashion, a *contraction* of spacetime can result in being able to *approach* an object at FTL speed.

In fact, we've actually already encountered one way to obey special relativity's *local* limit on speeds to that of light, while still achieving superluminal speed on a *global* level. That is, we *could* do that *if* general relativity really does allow wormholes in spacetime (what Alcubierre calls a "non-trivial topology"). That's because we can imagine a wormhole connecting two points in space that are light-years apart in that space, and yet the distance *through* the wormhole itself is quite short. Thus, a spaceship transiting the wormhole could do so at *sub*luminal speed at all times, and yet to an observer in normal space the speed would appear to be far in excess of the speed of light.

Determining just *how* to achieve the spacetime warp, however, is far different from simply demonstrating that such a warp is consistent with the general theory of relativity. The 1996 movie *Star Trek: First Contact*, for example, is about the invention of the warp drive in the twenty-first century. The whole thing fits inside a discarded ICBM which, as you'll soon see, is a *vast* underestimation of the technology required to control the energies associated with a real warp drive. For a spacetime engineer to *build* the warp drive bubble means she has to determine the required mass-energy distribution that results in Alcubierre's assumed spacetime metric. And that brings us to the central problem of the warp drive—the warp drive engine of an FTL starship requires (just like a wormhole) exotic matter (negative energy)—stuff that violates all the usually assumed energy conditions of general relativity.[87]

The weak, strong, and dominant energy conditions are *all* violated because the Alcubierre spacetime warp requires a negative energy density in the 'skin' of the warp bubble. As discussed earlier, in connection with wormholes, negative energy density *can* be achieved on a *micro*scopic scale, but for the Alcubierre warp drive we are talking about a *lot* of exotic matter. In their paper, Pfenning and Ford calculated that, for what they called "a macroscopically useful warp drive" with a radius of 100 m "so that we may fit a ship inside [the warp bubble]," the negative energy required for the warp bubble is on the order of, as they so graphically put it, "roughly ten orders of magnitude greater than the [energy of the] total mass of the entire universe."

Two years later, after making some adjustments to the spacetime metric assumed by Alcubierre (that is, to the distribution of mass-energy to produce the warp bubble), it was shown that the negative energy required by the warp drive could be greatly reduced.[88] The reduction is, in fact, spectacular, but only in a relative sense (you can reduce a mass that is ten orders of magnitude greater than that of the entire universe by a *huge* factor and still be left with a pretty stupendous number). The reduced amount of negative energy required for a warp bubble able to contain a human-sized spaceship is now down to 'only' "of the order of a few solar masses [-1.4×10^{30} kg]."

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[87] M. J. Pfenning and L. H. Ford, "The Unphysical Nature of 'Warp Drive'," *Classical and Quantum Gravity*, July 1997, pp. 1743–1751. See also K. D. Olum, "Superluminal Travel Requires Negative Energies," *Physical Review Letters*, October 26, 1998, pp. 3567–3570.

As mentioned earlier, in connection with the Casimir effect and its theoretical use in a wormhole time machine, although quantum field theory does not preclude negative energy densities, that does not mean it is possible to observe arbitrarily large negative densities for arbitrarily long times. In fact, certain quantum inequalities (QI's), much like Heisenberg's uncertainty principle, have been established that place bounds on the magnitude and duration of observable negative energy density.[89] These QI's have the general form of

$$\widehat{\rho} t_0^4 > -C$$

where C is a positive constant that depends on the nature of the particular quantum field being considered, t_0 is the time duration, and $\widehat{\rho}$ is the integrated energy density along a finite section of a geodesic (free fall) world line. The form of the QI shows that as t_0 increases, $\widehat{\rho}$ must quickly decrease. For example, if t_0 doubles, then $\widehat{\rho}$ must decrease by a factor of *sixteen*, a result that caused Ford and Roman to conclude that it "appears probable that nature will always prevent us from producing gross macroscopic effects with negative energy."

'When it rains it pours,' goes an old saying, and that applies to the warp drive's potential difficulties: in addition to the need for exotic matter, there are two more concerns as well, both *operational* in detail. First, running into any space matter encountered by the leading edges of the warp bubble (where spacetime is shrinking), such as interstellar dust, would certainly generate intense radiation. The ship, then, should carry plenty of shielding which, curiously, would not be a problem because the energy density of the warp, itself, is *independent* of the mass in the bubble's interior. In any case, the warp drive should clearly not be engaged anywhere near any sizeable chunk of matter, like a planet (and, indeed, that constraint was followed in *Star Trek*). Second an even more severe problem was discovered by Krasnikov. In unpublished work he showed that the ship at the center of the bubble is not causally connected to the edges of the bubble. That is, the ship's crew could *not* create a warp bubble on demand and, after it had been created, could not control it on demand.[90]

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[88] C. van den Broeck, "A Warp Drive with More Reasonable Total Energy Requirements," *Classical and Quantum Gravity*, December 1999, pp. 3973–3979.

[89] L. H. Ford and T. A. Roman, "Restrictions on Negative Energy Density in Flat Spacetime," *Physical Review D*, February 15, 1997, pp. 2082–2089. For some interesting remarks about the QI's, see J. F. Woodward, "Twists of Fate: Can We Make Traversable Wormholes in Spacetime?" *Foundations of Physics Letters*, April 1997, pp. 153–181.

It is important to both understand what that means, as well as what it does *not* mean. The causality issue does *not* mean that Alcubierre warp bubbles are impossible to create (perhaps they are, but not because of a lack of causality). It only means that whatever action is required to change the spacetime metric to make a warp bubble *has to already have been done before the decision to use the bubble is made*. Thus, a warp bubble wouldn't be of any use for a starship that needs to escape a sudden, unexpected threat. But, as Everett and Roman cautiously observe, the warp bubble might have a more mundane use: "Suppose space has been warped to create a bubble traveling from Earth to some distant star, e.g., Deneb, at superluminal speed. A spaceship, appropriately located with respect to the bubble trajectory, could then choose to enter the bubble, rather like a passenger catching a passing trolley car, and thus make the superluminal journey."

At the end of his paper (note 85) Alcubierre briefly speculated on the possibility of using his superluminal warp drive to build a time machine (showing, again, the intimate connection between the two concepts—look again at note 12 in Chap. 1 for how the connection between FTL and time travel appeared in pulp science fiction), but didn't show *how*. That was done 2 years later by Everett using, not surprisingly, an argument he called "reminiscent of the 'reinterpretation principle' … which played an important role in discussions of the physics of tachyons."[91]

In an attempt to avoid the Alcubierre bubble's causality problem, Krasnikov looked for a different, causal superluminal spacetime metric. This he succeeded in finding[92] but, rather than describing a bubble, Krasnikov's warp is in the shape of a tube. The interior of the tube is flat spacetime, just as in the case of the bubble warp, but unlike the bubble there would be a causal link between the spaceship crew and the tube. Just as the warp bubble requires very thin walls (on the order of a few thousand Planck lengths) of negative energy, so does the Krasnikov tube warp. Unlike the bubble warp, however, the tube warp stretches the entire length of any proposed trip, so the total negative energy in the warp is incredibly huge. For a tube a mere one meter long and one meter wide, for example, the total negative energy is 10^{28} solar masses, and to create a tube from Earth to just the nearest star would require 10^{44} solar masses of negative energy![93]

One curious feature of the Krasnikov warp is that the *outbound* leg of a round trip cannot be made in less time than required by light. *But* on the on the return half of the journey, a traveler would find the spacetime metric so altered (because of mass-energy manipulations purposely made on the outbound half) that she would move "backwards in time." The net result is that the round trip could end arbitrarily soon after it started! As Everett and Roman cautiously concluded, the Krasnikov tube is a "very unlikely possibility," but it would make a *wonderful* science fiction gadget, don't you think?

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[90] A. E. Everett and T. A. Roman, "Superluminal Subway: the Krasnikov tube," *Physical Review D*, August 15, 1997, pp. 2100–2108.

[91] A. E. Everett, "Warp Drive and Causality," *Physical Review D*, June 15, 1996, pp. 7365–7368. Recall the discussion of the RP in Chap. 5.

[92] See notes 84 and 90.

[93] In the same manner as the huge negative energy of the Alcubierre warp drive was later reduced (see note 88), the Krasnikov tube's enormous negative energy requirement was later significantly reduced: see P. Gravel and J. Plante, "Simple and Double Walled Krasnikov Tubes I: tubes with low mass," *Classical and Quantum Gravity*, February 2004, pp. L7–L9.

While the Alcubierre warp may seem to be an incredible discovery (it *is*), it was not a unique one. That's because just 8 years later a different warp metric was discovered by the Portuguese mathematician José Natário, in which the expansion/contraction of spacetime does *not* occur. As Natário wrote, this signature feature of the Alcubierre warp drive "is but a marginal consequence of the choice [for the spacetime metric/mass-energy distribution]."[94] Rather than thinking of the warp bubble as being propelled by the push-pull of spacetime expansion/contraction, Natário wrote that "one could best describe the warp-drive spacetime as 'sliding' the warp-bubble region through space": that is, as analogous to a California surfer riding a wavefront. The surfer is motionless with respect to the water in the immediate vicinity of his board, and yet his speed with respect to the rapidly approaching shore is decidedly non-zero.

The idea of a manipulated or *warped* spacetime allowing time travel was an early arrival in science fiction. Consider, for example, the 1930(!) story in which the narrator (one Thomas Jenkins) walks 18,000 years into the future. In an editorial footnote (a device commonly used in early pulp fiction to inject scientific verisimilitude), we are told that "Jenkins had evidently fallen into a warp in space . . . a fault, we might say, borrowing a geologic term, in the curvature of space. Through this warp he had been thrown clear out of our three dimensions into a fourth. There he slid in time over to the other side [of the fault] into the same spot in the three-dimensional world, but into a different era in time."[95]

That was a flawed explanation, with its talk of space rather than of spacetime, but some authors eventually learned to do better. For example, *folded spacetime* as a mechanism for time travel is used in a 1940s cautionary tale on the potential horrors of the atomic bomb. In that story, published 2 years after the atomic bombings in Japan, the world 15 years hence experiences a terrible atomic war. As the time traveler in the tale explains, "During the unprecedented release of atomic energy that arouse during the simultaneous bombings of our cities, something happened to the very continuum in which we exist . . . A crook, a twist, a fold—explain it how you will, I accidently stumbled upon an electronic circuit that would create a field that would enable passage from one folded section [of spacetime] to the adjacent section. The fold proved to be about fifteen years in length . . . ."[96]

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[94] J. Natário, "Warp Drive with Zero Expansion," *Classical and Quantum Gravity*, March 2002, pp. 1157–1165.

[95] N. Schachner and A. L. Zagat, "In 20,000 A.D.," *Wonder Stories*, September 1930.

[96] R. F. Jones, "Pete Can Fix It," *Astounding Science Fiction*, February 1947.

As Alcubierre and Natário showed, it will take a lot more than a mere electronic circuit to warp spacetime for either FTL or time travel, but at least even the early science fiction pulp writers understood that—*somehow*—a spacetime warping would be required.

The Alcubierre FTL warp drive appeared as the scientific basis for a modern science fiction novel, where at one point we read of a curious optical feature of an FTL spaceship, one I haven't seen mentioned in the physics literature: "This is a ship that traveled faster than light. It's visible as it travels; its warp bubble emits a cascade of exotic radiation . . . but it outruns its own image. So the ship arrives first and the light has to catch up, all the photons it emitted back along its path arriving at mere light speed. The older images arrive last, and you get this effect as if the ship was receding, not arriving."[97]

Another quite interesting feature of Alcubierre's warp drive is that the spaceship crew would experience no acceleration forces, as the ship is always in *free fall*. This may explain why the *Enterprise* crew isn't flattened when Mr. Sulu engages that ship's warp drive. The spaceship is surrounded by a "bubble" of warped spacetime that is swept along by the combined push-pull effect of the expanding spacetime behind the craft and the shrinking spacetime in the front. The ship, itself, resides in the *flat* spacetime interior of the warp bubble. An amusing way to think of this is to imagine a fish (space traveler), inside an aquarium (the warp bubble), which has been tossed into a swiftly flowing river. An observer at the edge of the river sees the aquarium move by her at high speed while, for the fish (swimming in the *still* waters of its aquarium), all is serene because *it is at rest with respect to its local environment*. Thus, the Alcubierre warp drive realizes yet another one of science fiction's wonderful gadgets: the *reactionless* spaceship drive. That is, "the warp bubble moves by interacting with the geometry of spacetime instead of expending reaction mass [as do jet and rocket engines] . . . and the spaceship is simply carried along with it."[98] In picturesque terms, the warp drive starship is like a surfer who makes her own waves.

And so we see, with each passing decade, more and more of science fiction departing from the make-believe to the pages of physics journals.

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[97] S. Baxter, *Ark*, Gollancz 2009. The spaceship in this work travels at three times the speed of light (warp factor 1.44, as explained in note 84).

[98] F. S. N. Lobo and M. Visser, "Fundamental Limitations on 'Warp Drive' Spacetimes," *Classical and Quantum Gravity*, December 2004, pp. 5871–5892.

6.6 For Further Discussion

The connection between FTL speeds and backward time travel made the jump from theoretical physics to popular culture very quickly. It was in the British humor weekly *Punch*, for example, that the famous (but nearly always misquoted—see note 113 in Chap. 3, which doesn't have it quite right) limerick by A. H. R. Buller (1874–1944) first appeared (December 19, 1923, p. 591):

> *"There was a young lady named Bright Whose speed was far faster than light, She set out one day In a relative way And returned on the previous night."*

Where *Punch* dared to go, Hollywood could not be far behind. Indeed, in this case it was actually there first, with the 1922 one-reel silent comedy film *The Sky Splitter*. This was just a short film (feature pictures generally had at least four reels), so it isn't clear just how widely distributed and viewed it may have been. The story is that of a scientist testing a new spaceship; when it exceeds the speed of light, he begins to relive his life. This all shows that today's fascination, so common in popular culture, of the latest developments in theoretical physics, is nothing new. Why do you think this is so? That is, why (for example) do so many of those who flock to science fiction movies of interstellar invasions (like the 1996 *Independence Day* and its 2016 sequel), nonetheless have no conception of the unlikely possibility of such invasions because of the sheer magnitude of interstellar distances? Distances so immense that, even at the speed of light, it takes 4 *years* to travel to the Sun's nearest stellar neighbor, and *millions* of years to reach the Milky Way's nearest neighboring galaxy? (The vastness of interstellar distances is, as mentioned in the text, the reason for the fascination in warp drives in both science fiction and physics.).

In wormhole and cosmic string time machines, and with warp drives, we encountered the idea of negative mass-energy in the form of 'exotic matter' (see note 39 again). Something like negative mass actually appeared in fiction long ago, in the 1827 novel *A Voyage to the Moon* by "Joseph Atterly," a pseudonym for George Tucker, a professor of moral philosophy at the University of Virginia. (One of Tucker's students was Edgar Allen Poe, who almost surely was influenced by Tucker's book to write his own moon tale, the 1835 "The Unparalleled Adventure of One Hans Pfall.") The trip in Tucker's work was powered by a metal called *lunarium*, which repels Earth.

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This is *not* the same sort of stuff as Wells' "Cavorite," a metallic alloy that is "transparent" to gravity and that appears in his 1901 *The First Men in the Moon*. Wells' competitor in the 'scientific romance' genre was, of course, Jules Verne. Wells was a visionary who looked far beyond just the next few decades, while Verne was a 'practical engineer' who, for example, got *his* characters to the Moon by the direct method of simply shooting them out of a 900-foot long cannon with 400,000 pounds of guncotton! (Wells' vision *could* sometimes fail him, as it did about the imminent likelihood of airplanes in his 1901 *Anticipations*. He believed they *would* be developed by the year 2000, and maybe even before 1950, but of course just 2 years later . . .) In a 1903 magazine interview, Verne revealed how he felt about the difference between his and Wells' work: "It occurs to me that his stories do not repose on very scientific bases . . . He goes to Mars [sic] in an airship, which he constructs of a metal which does away with the law of gravitation. C*'est très joli* [this is all very nice], but show me the metal. Let him produce it." Today the cry from those who dislike wormholes is the Verne-like 'show us the exotic matter!' If Wells and Verne were writing today, how do you think each would respond to that challenge? Would the possible existence (or not) of exotic matter be an issue about which both would *agree*?

Write a time-loop short story based on Lossev and Novikov's idea of a 'very old spacecraft' interacting with a remote wormhole.

Imagine an electronic circuit **A** that has the following behavior: **A**'s input signal is a function of time that has a well-defined maximum value (what electrical engineers call the *peak value*). The circuit's output signal, produced in response to the input, also has a well-defined peak value. Now, imagine further that the output peak occurs *before* the input peak. There is, in fact, nothing paradoxical or impossible about that, and such a circuit can (and has) been constructed, as I'll tell you shortly. Next, suppose that we take **A**'s output signal and use it as the input to another circuit **B** that, when it's input exceeds a certain level, disconnects the input to **A** *before* that input reaches *its* peak value. Circuit **B** can also be constructed in the real world. Indeed, you can read about how to construct **A** and **B** in two papers by M. W. Mitchell and R. Y. Chiao, "Causality and Negative Group Delays in a Simple Bandpass

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Amplifier," *American Journal of Physics*, January 1998, pp. 14–19, and "Negative Group Delay and 'Fronts' in a Causal System: An Experiment With Very Low Frequency Bandpass Amplifiers," *Physics Letters A*, June 16, 1997, pp. 133–138. What makes all this interesting here is that this "seems to open the way for a variant of the time travel paradox in which the traveler journeys to the past and kills his grandfather before his own father is born," an observation made in Garrison *et al.*, "Superluminal Signals: Causal Loop Paradoxes Revisited," *Physics Letters A*, August 10, 1998, pp. 19–25. This electronic version of the grandfather paradox does indeed follow if one substitutes "input peak" for "grandfather" and "output peak" for "time traveler." But before you think this gadget is a time machine, be assured that its designers also showed that, unlike the causally related grandfather and time traveler, the two peaks are *not* so related. Read these three papers and write a summary report of how circuits **A** and **B** work, and why the two peaks are not so related.

You'll recall that "an advanced civilization" is thought to be required to create a useable wormhole (note 27). The common phrase used by astrophysicists who are interested in the possibility of extraterrestrial life is *arbitrarily advanced civilization*, with a distinction made for at least three progressively higher stages of 'advancement.' Very roughly, Types I, II, and III advanced civilizations are those that, respectively, have the technology to (a) control something like 10^{13} W (ten million megawatts) for massive interstellar radio broadcasts, (b) a technology to control the energy output of the civilization's planet's parent star (10^{27} W), and (c) a technology to control the energy output of the civilization's home galaxy (10^{38} W). We are, today, short of being even a Type I civilization, and it would probably take *at least* a Type III civilization to build a wormhole. Indeed, Stephen Baxter's 1993 novel *Timelike Infinity*, of beings who can manipulate *constellations of galaxies*, seems to assume a Type IV civilization will be required. Since there are typically 10^{11} stars in a galaxy, going from 10^{27} W for a star to 10^{38} watts for a galaxy is consistent. But where do astrophysicists get 10^{27} W for a single star? Here's a calculation for you to perform, to confirm this value for yourself, starting with the experimental fact (not difficult to repeat, as it's at the level of a junior high school science fair project using a solar cell and a few common electrical components) that the solar power level at Earth's equator is 1200 W per m^2. Then, using the fact that the Earth's orbital radius around the Sun is 93 million miles, compute the total power (energy per second) radiated by the Sun. (You should get a number that is somewhat

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smaller than 10^{27} W, which is ‘explained’ by observing that the Sun is really a quite ordinary star, exceeded in size by many other stars in the Milky Way. Next, you’ll find, in most books on astrophysics, the statement that the nuclear fusion reactions that power the Sun convert *four million tons* of the Sun’s mass to pure energy *every second*. Confirm that your number for the power output of the Sun is consistent with that claim. (Remember Einstein’s famous formula $E = \mathrm{m}c^2$, that the speed of light is $c = 3 \times 10^8$ m/s, and that 1 kg $\approx$ 2.2 pounds. In the MKS system of units (meters/kilograms/seconds) one watt = one joule (of energy) per second, where to give you some perspective on what a joule is, the chemical energy released by burning a gallon of gasoline is about 100 MJ.

Appendix A
Old Friends Across Time (A Story)[1]

As I sit here in my study, with the photographic evidence spread before me, I can barely comprehend what my eyes tell me must be so. The evidence is incontestable. And yet—I still struggle to believe. Let me try to explain—possibly in the process I will manage to put my tumbling mind to rest.

For as long as I can recall, old photographs have fascinated me. To page slowly through collections of historical pictures, no matter what the theme, was consummate joy. Even when I was quite a small boy I used them as my time machine into the past. They took me up and away from the problems every youngster has while growing up, and let me wonder of people and places long since returned to dust. Matthew Brady's Civil War photos had a particularly strong attraction for me, with the horror (and yes, I will admit it, the *fascination*) of war frozen in the images of young men dead before life had really begun. To look at the fallen youth of more than a century before, and to wonder who they were, and what they had felt and thought—it all sent shivers through my romantic mind.

I suppose I might have become a professional photographer. But somewhere along in the process of looking at pictures, I became aware of the miracle of the *technology* of picture taking. That led me to chemistry and optics, and finally by some wondrous route, I became an electrical engineer. I never lost my love for old pictures, though, but merely turned my interest in them to the photographic history of electrical physics.

To search out and acquire (for by now I had started my own collection) a photograph of Steinmetz, smoldering cigar clamped in his mouth, giving a lecture on AC circuit analysis using the then still mysterious square root of minus one made my heart beat faster. To find a faded picture of Einstein at a long forgotten

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[1] P. J. Nahin, "Old Friends Across Time," *Analog Science Fiction Magazine*, May 1979. This tale was written with the specific goal of illustrating how a trip into the past *yet to be initiated* could logically influence events in the time traveler's present and future. The story reproduced here is, with only a few very minor alterations, as it originally appeared in *Analog*.

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P.J. Nahin, *Time Machine Tales*, Science and Fiction,
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conference, caught forever in time with his quiet, gentle eyes looking into mine, would send me to the heights of ecstasy.[2]

But it was Maxwell that led me to my incredible discovery. There is no doubt but that James Maxwell was the greatest theoretical physicist of the nineteenth century. Together with Einstein, he was the best of *any* century. Could it possibly be more than mere chance that the same year saw the death of one and the birth of the other? It was Maxwell who gathered together all the then known, but fragmented, experimental bits and pieces of knowledge about electricity and magnetism, and stirred in his own contribution of the displacement current. There was no physical evidence then to justify that last step, but the genius of Maxwell knew it *had* to be. And then, from his soaring mathematical insight and physical intuition, he took it all and wrote down the four magnificent equations for the electromagnetic field![3]

No one who has seen and understood those beautiful equations can come away without a quickening of the pulse and a flush of the blood. They're not long—you can write all four vector differential equations on the back of a postcard, but oh, what they tell us! With them, Maxwell, showed light was electrical in nature, predicted radio waves *two decades* before Hertz discovered them in the lab, explained energy propagation in space, and radiation pressure, and laid the scientific basis for today's television, radar, lasers, giant electric motors, generators, transmission lines and—well, why go on? The equations are the work of a level of genius we may not see again for a millennium. We have hardly begun to discover the marvels wrapped inside the electromagnetic field equations. With their aid, and that of quantum mechanics, the very secret of life, itself, may someday be unraveled.

And so I searched for old photographs of Maxwell. He died at his family's Scottish home in 1879, before the art of picture taking was barely 40 years old. But I knew in my heart that somewhere there *must* be photographs, yet undiscovered, of such a great man. Anyone who has seen the best examples of prints from wet glass collodion negatives knows they are, in the faithfulness of their rendition of detail, better than what we commonly expect today. Working against me was the fact that the process was slow, laborious, and unforgiving of mistakes. The taking of a picture was not a minor decision in Maxwell's time. But still I searched.

I searched for one photo, in particular. When Einstein died, a famous picture was taken of his office, just the way he left it for the last time. On the blackboard behind his desk are the last thoughts he had in his long quest for a Unified Field Theory, a ‘theory of everything.’ The writing on the papers covering the desk is clearly legible, and with modern blowup methods, easily readable.

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[2] The first reference is to Charles Steinmetz (1865–1923), the German-born American electrical engineer and mathematician who became the wunderkind of General Electric. Einstein, of course, needs no introduction!

[3] I wrote this for story effect, but it's not really *quite* true. When Maxwell wrote his theory in mathematical form, he did so using *twenty* (!) equations in as many variables. The equations, as physicists and electrical engineers use them today, were first written in 1885 by the English self-taught eccentric Oliver Heaviside, who considered Maxwell to be his hero (see note 6 in Chap. 6). Modern electrical engineers and physicists write the Maxwell equations as *four* partial differential *vector* equations.

At the time of his death, Maxwell was the Einstein of his times. Surely, I reasoned, a similar photograph of Maxwell’s study must have been taken. Even though none has come down through the decades to us, it *must* exist! Gathering dust in an old trunk, or buried in a long forgotten album, it had to be somewhere. I vowed to find it.

I began by writing to all of Maxwell’s living descendants, asking that they search through family holdings for any pictures concerning Maxwell that they might possess. For the most part all were cooperative, even though more than just a few thought I was somewhat deranged. Still, it was in vain. I did receive a few old pictures never before seen by other than the family, including a poignant one taken in 1901, showing Maxwell’s grave in Parton Churchyard at Glenlair, Scotland. A forlorn, wintry scene, with only what seemed to be three men in the far distance, it brought tears to my eyes. Alas, there were no photos of Maxwell’s study.

But then late last year, while on a business trip to London, I stopped off for a few hours at the historical archives maintained by the British Institute of Electrical Engineers. On a chance, I looked through their massive files on Maxwell and was rewarded within the hour! What I found will haunt me throughout the remainder of my life.

There it was, stuck through its border with a rusty pin, between two pieces of yellowed paper covered with what appeared to be some simple, rough lecture notes. An ordinary looking photo of a study. Obviously overlooked through the years, or at best unappreciated for what it was, it was the almost illegible, penciled notation on the back that convinced me of my find—just a date: November 9, 1879. Exactly 4 days after Maxwell’s death, precisely when some unknown, yet inspired person (a family member, a neighbor, a local scientist?) would take such a picture!

I am ashamed to admit it, but there was no hope the Institute would let me have the picture. And there was no time to copy it, for I was to return home to America that very night. No, that’s not true. The *real* reason for what I did was simply that I *had* to have that original, *old* photo. I took it! It was my undoing, for that dishonorable act destroyed the picture’s tie to verified, legitimate historical records. But *I* know what I found is true.

I could barely control my wild emotions on the flight home. Several times I removed the picture from my briefcase, and looked with fascination at the papers lying on Maxwell’s desk, and at the tightly written lines of mathematics on the blackboard in the background. My hands trembled with what can only be called lust—once home, reunited with my well-equipped photo lab, I would learn every secret hidden in that picture.

There are no words I know that can convey the thrill I felt as I began the processing of that priceless photo. Alone in my lab, with all the modern equipment a well-off amateur can buy (a Caesar Saltzman 8 × 10 enlarger with mercury vapor point light source and a 10× Plan Achromat Nikon enlarging lens), I carefully cropped and blew up selected views of the blackboard and desk. Printing the enlargements on ultra-fine grain AGFA Brovira paper, I could scarcely restrain myself from peering at them with a magnifying glass while I waited for them to dry.

Then, at last, I had them spread out across my study desk. I tried to force myself to examine each slowly, carefully, in turn, and not to skip from one to another like a child let loose in a candy store with a dollar. The first three were of the desk papers, including what seemed to be a diary. It must have been lost after Maxwell's death since no trace of it exists in the historical records. I experienced a stunning thrill as I gazed upon the scrawled words, but as they were not easily read at once, I moved on. It was the sixth enlargement, of the upper right corner of the blackboard that sent me reeling back to my chair. An equation that shouldn't, no, *couldn't*, be there. But it was.

To understand my reaction, there is one astounding thing you must realize about Maxwell's field equations. When Einstein turned the world of physics on its head in 1905 with his famous paper, "On the Electrodynamics of Moving Bodies," all the old ideas about absolute motion and simultaneity of events went out the window. Even Newton's laws of mechanics had to be modified. But *not* Maxwell's! His equations, just the way he published them in 1873, are the same ones studied today[4]—they need *no* relativistic corrections.

How can that be, you wonder, as they predate Einstein's by 32 years? The mystery of this has bedeviled the experts down through the years. Oh, they have an explanation, alright. They say that all of electromagnetics is actually relativistic phenomena to begin with, and the laboratory work of Faraday, Ampere, Henry, and the other great experimentalists were studies of relativistic electron interactions in matter (although they, of course, didn't know that). Thus, it is only 'natural' that Maxwell's equations need no correction. So goes the 'expert' explanation, but it isn't right![5] I know Maxwell knew about relativity, and understood it perfectly. He knew all about time paradoxes and the equivalence of mass and energy.

Because how else can you explain the equation visible in my enlargement: $E = mc^2$!

Why, you must wonder (just as I did), didn't Maxwell publish this remarkable result? At first, I believed it was because of a lack of faith in his results. Who would have believed any of it in those Victorian times, so sure of its absolute view of nature? I thought of how Newton, 200 years before Maxwell, had suffered from a similar hesitancy when he wrote the *Principia*. There, when explaining his theory of gravitation, Newton did *not* employ his new invention of the calculus (which he *had used* to make his discoveries), but instead fell back on laborious arguments based on the accepted mathematics of algebra and geometry. Who would have believed him, otherwise?

But then I realized that couldn't be right. Maxwell was a strong man intellectually and he wouldn't have held back for fear of disbelief. No, it had to be that he discovered relativity and the mass-energy law just before his death, with no time to make his work known. I was still wrong.

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[4] Don't forget note 3.

[5] Alas, I think it *is* right. Don't forget, this is science *fiction*. When there is a conflict between the needs of a story, and a rigid adherence to physics, the 'needs' wins!

It was later, when I returned to the enlargement of Maxwell's lost diary and read those painfully cramped notes, that I learned the truth. What I saw there showed me Maxwell had thought long and hard about his final discoveries and had purposely withheld them. For clearly visible, after I had slowly deciphered the writing, were the following words:

> *I have seen monstrous events. My blood has run cold at the sight of two great cities leveled to the ground, their inhabitants cruelly put to death instantly, or left to die slowly from a strange, lingering disease. Other trips, further on, have shown me the root of all these evils is the mass-energy equation, a result I at first believed to be my crowning glory. It will be my crown of thorns unless I ban it from my very being. Another will discover it for himself, but* my *soul shall be free! I have dismantled my machine, and shall never look upon or think of those horrible scenes again.*

This passage was dated just 1 month before Maxwell died a savage death from cancer. The reference to 'two cities' can only be that of Hiroshima and Nagasaki. His own death was surely caused by lingering too long among their atomic ruins.

Think of what this *means*. Quite simply, Maxwell knew the secret of time travel! But even more incredible is that it must be *easy*, if one only knows how, to build a time machine! Think about it—Maxwell had no gigawatt power stations at his disposal, no high technology machine shops, or nanosecond computers. He was not a gifted experimentalist, and once he had predicted radio waves, for example, it took others 20 years to finally generate them. And yet, *he* built a time machine. Somehow, with just the puny power sources available to him, and a limited mechanical capability, he wrested free the *simple* implementation of a time machine from his dynamical field equations.

Yes, yes, I know what you must be thinking. How can I really conclude such an incredible thing from a single equation on a blackboard, and a few words written by a man dying a painful death? A man, clearly suffering dearly, and possibly not in complete possession of his once marvelous mind.

This very evening the last bolt of evidence slid into place. Attempting to escape from the emotional maelstrom into which I had fallen, I turned to my old love of picture gazing. I took down from my library shelf a tattered yet cherished volume of the Meserve Collection of Lincoln pictures. My slow paging through the images stopped when I came to the famous photograph by Alexander Gardner of Lincoln's second inauguration. This incredible picture shows John Wilkes Booth looking down on Lincoln from behind a buttress high on the steps of the Capitol, while below in the crowd are the five men who, 41 days later, conspired with him in the assassination.

The following page demonstrated the extraordinary quality of Gardner's work, as it showed an enlargement of Booth's face in which the circular line between the pupil and the white of each eye is sharp and crisp! This impressive picture fascinated me, and I wondered if I could create a similar enlargement. It was then I remembered the old picture of Maxwell's grave, sent to me from Scotland, and the three distant figures in the background. They would present my photo-lab skills with a challenge, and the effort would distract my mind.

I finished the enlargement just 20 min ago. Those faces! Two of them I can now finally accept as being there—it must have been a pilgrimage for one, and for the other, it couldn't have been anything but a mocking, ironic gesture. But I wonder if the youngest one really knew who his two companions were? I don't know the answer to that—yet. But there they are, two men with faces my years of study have made as familiar to me as my own. One is a youthful Albert Einstein. The other, with the signs of death clearly written across his features, is James Clerk Maxwell. The face of the third man is familiar, too, for the third man is me!

Oh, I'm a bit older in the photo than I am now. But it's me, alright. A distinctive, jagged scar across the left cheek, a mark from a childhood accident, is sharply visible, and I can run a finger over my face and match it perfectly with the image in the enlargement. I'd say I'm about 45 or so in the image, no more than 10 years older than I am now. That doesn't leave me much time to keep my appointment, does it? I don't know, right now, how I'm going to do it, but I've got to rediscover Maxwell's secret of time travel. I'm sure I'll succeed—after all, there I am in the picture. Somehow, I'll be going back to pick James and Albert up so we can have our picture taken. Ten years—not much time.

I'm really looking forward to meeting my two new friends from across time.

For Further Discussion

When "Old Friends Across Time" originally appeared in *Analog*, it opened with a quotation from Richard Feynman's famous 1961–1963 Caltech undergraduate course (published in 1964 as *The Feynman Lectures on Physics*): "Ten thousand years from now, there can be little doubt that the most significant event of the nineteenth century will be judged as Maxwell's discovery of the laws of electrodynamics. The American Civil War will pale into provincial insignificance in comparison." This is almost certainly true, but could Maxwell *really* have built a time machine from just a knowledge of electromagnetic theory and special relativity (which is all that is needed to derive $E = mc^2$), if he didn't also have a deep understanding of general relativity (and probably of quantum mechanics, too)? How likely do you think *that* is?

The narrator in “Old Friends Across Time” knows he is going to live long enough to eventually build a time machine; discuss the implications of this knowledge. For example, is he at least *temporarily* invulnerable to committing suicide (or, for that matter, to any other variation of dying?) That is, do we have a ‘future’ version of the grandfather paradox? This issue has never (to my knowledge) been considered by physicists, and not by philosophers either until recently. See, for example, S. Keller and M. Nelson, “Presentists Should Believe in Time-Travel,” *Australasian Journal of Philosophy*, September 2001, pp. 333–345, and M. H. Slater, “The Necessity of Time Travel (On Pain of Indeterminacy),” *The Monist*, July 2005, pp. 362–369. More generally, if we assume that the past is unchangeable then the scenario in “Old Friends Across Time” seems to force at least some level of inevitability on the future as well. Or does it? In the 2007 story by Ted Chiang, “The Merchant and the Alchemist’s Gate,” that you were asked to read in a *For Further Discussion* at the end of Chap. 4, there is the following exchange between the narrator and the inventor of “the Gate” (a wormhole): “So if you learn that you are dead 20 years from now, there is nothing you can do to avoid your death?” He nodded. This seemed to me very disheartening, but then I wondered if it could not also provide a guarantee. I said, “Suppose you learn that you are alive 20 years from now. Then nothing could kill you in the next 20 years. You could then fight in battles without a care, because your survival is assured.” “That is possible,” he said. “It is also possible that a man who would make use of such a guarantee would not find his older self alive when he first used the Gate.” “Ah,” I said, “Is it then the case that only the prudent meet their older selves?” Comment on this issue, with particular attention to free-will.

Appendix B
Newton's Gift (A Story)[6]

Wallace John Steinhope was a sensitive human being, a person deeply concerned about the welfare of his fellow creatures. Any act of injustice, however slight, made his breast pound with righteous indignation. He was a champion of fair play, and his motto in life was taken from the ancient English rule of law—'Let right be done!'

Even while still a lonely, reclusive child, Wallace's heart ached mightly when he read of the laborious, boring, mind-dulling calculations endured by the great mathematicians of old. Just knowing, *thinking*, of Gauss's marvelous mind wasting literally months of its precious existence grinding out tedious mathematics that even a present-day dullard could do in a minute, on a home computer, was sheer agony for Wallace. Contemplation of the God-like Newton suffering endless delays in his gravity research, all because of a simple miscalculation of the length of a degree of longitude, was almost unbearable.

Indeed, Newton played a special role in Wallace's life (and he in Newton's, as we shall soon see). While the other great mathematical physicists had merely been hindered in their work by the lack of modern computational aids, Newton had squandered so much valuable time in other, nonscientific pursuits! His quasireligious writings alone, over half a million words, exceeded his scientific writings. What a waste! Wallace wondered endlessly over the reason for this strange misdirection of talent and bored his friends to the edge of endurance with his constant brooding on the mystery. Still, they all liked and admired Wallace enormously and so put up with it. But more than one of them had sworn to throw up the next time Wallace mentioned Newton during a wedding (but that's another story).

So deep was Wallace's anguish for his predecessors that even as he grew older and his own tremendous talents as a mathematical physicist (the result of a lucky

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[6] P. J. Nahin, "Newton's Gift," *Omni*, January 1979. This tale was written with the specific goal of illustrating casual loop time paradoxes. The story reproduced here is, with only a few very minor alterations, as it originally appeared in *Omni*.

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P.J. Nahin, *Time Machine Tales*, Science and Fiction,
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genetic mutation induced in a male ancestor some centuries earlier) gained him an international reputation, thoughts of the unmeasurable misery of his scientific ancestors were never far from his mind. It was most appropriate, then, that his greatest discovery gave him an opportunity to *do* something! And Wallace John Steinhope vowed to *help*. He became convinced that it was his purpose on earth—he could not, he *would* not hesitate. As he strapped the knapsack-size time machine to his chest, his excitement was, therefore, easy to understand.

"It is done! And I am ready. I will travel back and bestow this gift of appreciation, this key to mental relief, on the great Newton himself!" Wallace cradled a small, yet powerful hand-calculator in his palm. It was a marvel of modern electronics. Incorporating large-scale integrated circuitry and a Z-8000 microprocessor solid-state chip, the calculator required only a small, self-contained nuclear battery for its power. It could add, subtract, multiply, divide, do square and cubic roots, trig and hyperbolic functions, take powers, find logarithms, all in mere microseconds. It was programmable, too, able to store up to 500 instructions in its micro-memory. The answers it displayed on its red, light-emitting diode readouts would liberate young Isaac from the chains of his impoverished heritage of mathematical calculation. No more Napier's bones for Newton!

But Wallace John Steinhope was no fool. He understood, indeed feared, time paradoxes. He knew Newton could be trusted with the secret, but it wouldn't do for the calculator to survive Newton's time. So Wallace had incorporated a small, self-destructing heat mechanism into it. After 5 years of use, it would automatically melt itself into an unrecognizable, charred slag mass. But that would be enough time for its task to be completed. The emancipation of Newton's mighty brain from tedium! Pleased enormously at the thought of the great good he was about to confer, Wallace set the time and space coordinates for merry old England, flipped the power switch on, and vanished.

Materializing in the Lincolnshire countryside in the spring of 1666, he began his rendezvous with destiny. It was the second and final year of the great bubonic plague, and Newton, seeking refuge from the agony and death plundering London and threatening his college of Trinity at Cambridge, had returned home to work in seclusion. The years of the Black Death were Newton's golden years, when the essentials of calculus would be worked out, when the colored spectrum of white light would be explained, and when the principle of the law of gravitation would be grasped. But how much easier it would be if Newton were released from the binding chains of dreary calculation. Wallace's gift would slip the lock on those chains! Accelerate genius!

It was early evening when, guided by a map of the area prepared by a friend who was both a cartographer and amateur historian, Wallace reached the quiet little town of Woolsthrope-by-Colsterworth. It was here, in a small farmhouse, that Wallace would meet his hero of the ages. A cold, gentle rain was falling as he approached the door. The soft, hazy light of an oil lamp glowed inside, revealing through the translucent glass the form of a man bent over a table. The fragrant smoke of well-dried wood curled from the chimney, announcing a warm fire within.

With his heart about to burst from excitement, Wallace rapped upon the door. After a pause, the shadow rose and moved away from the window. The door opened, and there stood Isaac Newton, a young man of 23 with an intellect that Hume and Voltaire considered "the greatest and rarest genius that ever rose for adornment and instruction of the species." But for the importance of his self-appointed mission, Wallace would have fainted dead away from the thrill of it all. "Is this the home of Isaac Newton?" he asked in a voice quavering with the trembling tones normally used by lovers about to reveal their deepest feelings.

The young man, of medium height and thick hair already showing signs of gray, swung open the door and replied, "My home it is, indeed, stranger. Come into the parlor, please, before the wetness takes you ill."

Isaac followed Wallace into the room and stood quietly watching as his visitor removed his soaked coat and hat. The portable time machine was gently placed on the floor next to a wall. The calculator was snug and safe in its plastic case in Wallace's shirt pocket. "Thank you, Master Newton. May we sit while we talk? I am afraid you may wish to take some time to consider my words." Motioning to a chair near the table, Isaac pulled a second chair from a darkened corner and joined Wallace. "You have a strange sound to your speech, stranger. Are you from hereabouts, or have you traveled far? Please commence slowly your tale."

Wallace laughed aloud at this question, a response prompted by his nervous excitement, and it quite surprised him. "Please forgive me. It is just that I *have* traveled so very, *very* far to see you. You see, I am from the future." Wallace was not one to play his cards close to his chest. Now it was Isaac's turn to laugh. "Oh, this is most ridiculous. Are you a friend of Barrow's at Trinity? It would be so like him to play such a trick.[7] From the future, indeed!"

Wallace's eyes ached at the sight of the papers on the table where Isaac had been working. What wonders must be there about to be born! In any other situation, Wallace would have asked their contents, but the die had been cast. He had to convince Isaac of the truth of his tale. But he had to walk a tight line, too. It just wouldn't do to misdirect Isaac's interest away from the calculator and toward the time machine itself! He must do something dramatic, something that would rivet his idol's attention and hold it.

"Yes, yes, I understand your reluctance to believe me. But, look here. This will convince you of the honesty of my words." Wallace pulled the shiny black plastic-cased calculator from his shirt pocket and flipped the power switch on. The array of LEDs glowed bright in the gloomy room as they flashed on in a random, sparkling red burst. Isaac's eyes widened, and he pushed his chair back. Was he frightened?

"As the Lord is my Savior, is it a creation of Lucifer? The eyes of it shine with the color of his domain. Are you one of his earthly agents?"

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[7] The reference is to Isaac Barrow (1630–1677), who was the first Lucasian Professor of Mathematics at Cambridge. Barrow resigned that position to allow it to pass to Newton. Centuries later, Hawking became the 17th Lucasian Professor.

"Oh my, no! Look here, Master Newton, let me show you that there is no black magic or chicanery involved. It is all perfectly understandable in terms of the laws of Nature. What I have here is an automatic calculator, a device to perform all of your laborious mathematical labors."

So saying, Wallace squeezed the sides of the calculator case together, releasing pressure snap-fittings, and flipped the case open on a hinge at the top. Revealed to Isaac were the innards of the electronic marvel—a tightly packed interior of printed circuit boards, a mass of integrated circuitry, the small LED display, and the sealed nuclear battery. Isaac stared intently at the sight, and Wallace could see the natural curiosity of Newton's great mind begin to drive away the initial apprehension.

"But where are the gears, levers, springs, and ratchets to carry out the calculations? All I see is a black box with lights that glow red—how is *that* done; where is the lamp or candle to provide the light!—and many little isolated fragments of strange shapes. There is clearly nothing in your box that moves!"

"Oh, it is all done with electronics, Master Newton! The central processing unit has access to a solid-state memory that contains the decoding logic necessary to implement the appropriate algorithmic processes to provide the answers to the specific requests entered through these buttons. The actual performance of the box is achieved by the controlled motion of electrons and holes in suitably doped semiconductor material under the influence of electric fields induced—" Wallace, still overcome by his excitement, had rambled on wildly without thought of the essentially infinite technological gap that separated himself from Newton.

"Stop, stop," cried Isaac. "I understand only a few of the words you use and nothing at all of their meaning! But it is obvious that for calculations to be performed, mechanical work must be done, and that implies motion. Pascal's adding machine has shown the veracity of that. I say again, nothing moves in the box. How *can* it work?"

Wallace was embarrassed. The mistake of overlooking the hundreds of years of progress after Newton's time was one a child might make. "I am sorry, Master Newton. I'm going too fast for you." Isaac looked at Wallace with a frown, but Wallace failed to see the pricked vanity of the proud Newton. Going too fast, indeed!

Wallace prepared to lay a firmer technological foundation for Newton, but then he froze. It couldn't be done! Newton was a genius, certainly, but the task was still impossible. Wallace would have to tell him all about Maxwell's equations, Boolean algebra and computer structure, electronics, and solid-state device fabrication technology. It was just too much, and besides, there was the danger! The potential time paradoxes of all that knowledge out of its proper time sequence! What if Newton, in innocence, revealed some critical bit of knowledge out of its natural place in history? So, Wallace hesitated, but seeing the suspicion grow again in Isaac's eyes, he realized he had to do something, *anything*, immediately.

"You cannot deny your own eyes," answered Wallace. "Let me *show* you how it works. I'll divide two numbers for you with just the punch of a few buttons. Watch this." And, at random, he entered 81,918 divided by 123. Poor Wallace, of all the numbers to use, they were the worst. Within milliseconds the answer glowed brightly in fiery red characters. Wallace looked with pride at the result and then, already enjoying in his mind what he knew would be Isaac's amazement, he turned his eyes to the great man. What he saw made his spine tingle, and the gooseflesh stand high on his neck. Newton had fallen to his knees, with eyes bulging and hands raised as if in prayer.

"The mark of the Beast, it is the mark of the Beast! It is so written in the Book of Revelations—Here is wisdom. Let him that hath understanding count the number of the beast; for it is the number of man; and his number is six hundred three-score and six!" Rising to his feet, Newton fell back into his chair. "Your cursed box bears the brand of its master. There can be no doubt now, it *is* the creation of the fallen archangel!" Wallace was aghast at Isaac's violent reaction. The seventeenth century genius had now stumbled backward from his chair and had grasped a poker from the hot coals of the fireplace.

"Wait, please wait! Watch this; I'll multiply two other numbers together for you, watch!" Wallace quickly punched in the data, and then the answer gleamed steadily in burning red characters on the LEDs. Isaac's eyes first went wide with fear as he again saw the wizard electronics do their marvelous assignment, and then he shut them tight. Wallace was becoming desperate—this wasn't the way it was supposed to be! "Don't you see—imagine the tedious work, the mind-deadening labor this machine will save you from. And it is yours."

"Yes? But only for the exchange of my soul! That is always the Devil's price for his seductive gifts from Hell!" As Isaac shrieked these last words at Wallace, he raised the poker over his head. "Begone, you emissary of the Dark World! I know now you must be in the employ of the Father of the Antichrist, but the Lord God Almighty will protect me if I do not waver in my resolve. Begone, or I'll strike your brains out on the floor where you stand!"

Isaac's eyes were wide with fear, nearly rolling back to show all white spittle sprayed from his mouth as he yelled at Wallace, who stared in shock at the wild man who threatened him with death. "Please, please, *listen* to me, please! I beg you to understand—I am a scientist, just like you. The concept of the devil, and all it stands for, is contrary to everything I believe. How *could* I be in the devil's employ, when I don't even accept his existence? You *must* believe me!"

"Blasphemy!" screamed Isaac. "Your own words condemn you. To deny the reality of Satan in a sinful world is to deny that of God, too. Now leave my home, you dark beast from hell, or by the heavens above, *I shall destroy you*!" As he shrilled these words, Isaac brought the poker down in a wild swing that barely missed Wallace's head.

Struck dumb with confusion at the uncontrolled outburst, Wallace stuffed the calculator into his shirt, grabbed his hat, coat, and time machine and rushed from the house. As he hurried into the cold, wet night, he turned back, just once, to see Isaac Newton framed in the light of the open door. "Go, go, you foul messenger from the Lord of Evil! Back to your stinking pit of burning hell-fire! This is a house that honors the Divine Trinity and is no haven for the likes of you!"

Wallace rushed away into the blackness, the time machine bouncing unheeded upon his chest.

He ran, for how long he couldn't recall, until he fell exhausted next to a stream running heavy with the rain. Tears of rage, frustration, and shock streamed from his eyes. Rejected by the great Newton! Well, damn him! Wallace flung the calculator into the stream in his terrible anger and activated the return coordinates. He faded from Newton's world as quickly and quietly as he had come.

As for Isaac Newton, after having chased the Devil's messenger from his house, he returned on shaking legs to his desk. Pushing aside his rough calculations on the orbit of the moon around the earth, he swore to redeem himself in the eyes of the Savior. Somehow, he had been found lacking and had been tested. And the test was surely not over! He began to reapply his marvelous mind to determine the origin of his failure before the Lord God Jehovah. Taking quill in hand, he wrote the first of the many hundreds of thousands of words that his numerous religious tracts would devour from his allotted time.

Five years later, long after Newton had returned to Cambridge, a group of picnicking children were frightened when a nearby stream suddenly erupted into a geyser of steam. Moments later, the bravest (or most foolhardy) of the boys—who, by an astonishing coincidence that befits any good time travel paradox, would be Wallace's great-grandfather nine times removed—cautiously examined the streambed. All he found were some twisted, hot pieces of what he thought was a hard, black rock, and he tossed them back. They were all that was left of the calculator's nuclear battery. He did receive a tiny radiation dose from them, which caused a recessive genetic mutation that centuries later would suddenly appear as the cause of Wallace's genius, but otherwise the lad was unaffected. The incident was soon forgotten.

Well over 300 years later, Wallace John Steinhope reappeared in his own time. He was essentially the same man as before he left—kind, generous, and sensitive, and ready to come to the aid of any man or beast that might need help. As far as his friends were concerned, in fact, he was even improved (naturally, they didn't know what had brought about the welcome change but, if they had, they would have applauded it).

Wallace John Steinhope, you see, never again had another kind word for Newton, or for that matter, any words for him at all.

For Further Discussion

In his book *Travels in Four Dimensions: the enigmas of space and time* (Oxford 2003), the philosopher Robin Le Poidevin writes (p. 176) "But, as everybody knows, when a time machine leaves for another time it *disappears*." This is, indeed, how the time machine in "Newton's Gift" works; however, after reading *Time Machine Tales* do you think such behavior is in agreement or in conflict with general relativity? Defend your position.

"Newton's Gift" contains causal loops. Identify two of them, and discuss their role in the story (that is, are they central to the story or merely incidental?).

The idea of a time traveler visiting famous people in the past occurs fairly frequently in science fiction. In Ian Watson's "Ghost Lecturer" (*Isaac Asimov's Science Fiction Magazine*, March 1964), for example, the inventor of the "Roseberry Field" uses it to yank geniuses out of time to supposedly honor them, to let them know their lives had been worthwhile in the eyes of the future. But then he goes on to tell them—oh so kindly—where they had gone wrong or had fallen short of the mark, and of how much more we know nowadays. "You almost got it right, boy! You were on the right track, and no mistake. Bravo! *But* ..." Watson makes the interesting observation that one can easily imagine playing this pathetic game of 'second-guessing' history with scientists, but what could even the most talented modern do to upstage a Mozart or a Shakespeare? Most similar to "Newton's Gift," however, are (for example) Gregory Benford's "In the Dark Backward" (*Science Fiction Age*, June 1994) where Shakespeare and Hemingway are visited, and Jack McDevitt's "The Fort Moxie Branch" (*Full Spectrum*, October 1988) where Hemingway and Thomas Wolfe appear. Read these stories, and then compare/contrast their descriptions of how story characters react to the appearances of time travelers, to Newton's behavior in "Newton's Gift."

Appendix C
Computer Simulation of the Entropic Gas Clock

```
%gasclock.m/created by PJNahin for TIME MACHINE TALES(6/27/2015)
%This MATLAB m-file simulates the diffusion of gas molecules in a
sealed
%container by using the Ehrenfest ball exchange rules. The
simulation
%starts with n molecules (i.e., balls) of one type (i.e., black)
on
%one side of the container, and n more molecules of another type
(i.e.,
%white balls) on the other side. The two urns play the roles of the
%two sides of the container. To simulate the ball (molecule)
%movements, the program selects two random numbers from 0 to
1, which
%are then compared to the current probabilities of selecting a
black
%ball from urn I and a white ball from urn II. If BOTH random
numbers
%are greater than these two probabilities then a white ball has
been
%selected from urn I and a black ball has been selected from urn
II,
%and so the number black balls in urn I is increased by one while
the
%number of white balls in urn II is increased by one. If BOTH
random
%numbers are less than or equal to these two probabilities then a
%black ball has been selected from urn I and a white ball has been
%selected from urn II and so the number of black balls in urn I is
```

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```
%decreased by one while the number of white balls in urn II is
decreased
%by one. If one of the random numbers is greater than its
corresponding
%probability while the other random number is less than its
%corresponding probability, then no action is taken because then a
%white (black) ball moves from urn I to urn II at the same time a
white
%(black) ball moves in the opposite direction. That is, there is
no
%net change. Then, the ball selection probabilities are recalcu-
lated and
%another ball exchange is simulated.
rand('state',100*sum(clock))     %new seed for the random number
generator;
n=100;                           %number of balls in each urn;
nb1=n;                           %number of black balls INITIALLY
in urn I;
nw2=n;                           %number of white balls INITIALLY
in urn II;
pb1=nb1/n;                       %probability of selecting a black
ball from urn I;
pw2=nw2/n;                       %probability of selecting a white
ball from urn II;
for trials =1:1000;
   system(trials)=pb1;
   ball1=rand;
   ball2=rand;
   if(ball1>pb1&ball2>pw2)         %white ball selected from urn I
      nb1=nb1+1;                   %and black ball selected from
      nw2=nw2+1;                   %urn II;
   elseif(ball1<=pb1&ball2<=pw2)  %black ball selected from urn I
      nb1=nb1-1;                   %and white ball selected from
      nw2=nw2-1;                   %urn II;
   end
   pb1=nb1/n;
   pw2=nw2/n;
end
plot(system)
axis([1 trials 0 1])
grid
xlabel('time, in arbitrary units')
ylabel('fraction of balls in urn I that are black')
figure(1)
```

Epilogue

> [Science fiction] cannot be good without respect for good science . . . This does not include time machines, space warps and the fifth dimension; they will continue to exist in the hazy borderland between [science fiction] and fantasy.[8]

> In many science-fiction stories, the trip into the past is by way of some futuristic machine that can take you through time at will . . . That, however, is totally impossible on theoretical grounds. It can't and won't be done.[9]

The opening quotations, particularly the second one from Asimov who was one of the great modern writers of science fiction, is a gloomy one indeed for fans of time travel, but it is not difficult to find inconsistency in Asimov's own tales dealing with the concept. Asimov is famous, in particular, for his stories of robots, and the very last such tale that he wrote combines robotics with time travel, with a robot sent two centuries into the future.[10] At the start of the story, the narrator tells us that time travel to the past is impossible because the past is unchangeable and (of course) a time traveler would necessarily disturb history. (That is (of course) simply a failure to distinguish between the difference of *changing* the past and *affecting* the past, as well as a failure to see how the principle of self-consistency negates the issue of paradoxes.) Then, when the robot returns from the future (and so backward time travel is *not* impossible!), he reports that his arrival had been expected, that history had recorded that he would appear. At the end of the story we learn how the future knew this—it had read "Robot Visions"! So now Asimov *uses*

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[8] Harry Harrison, in his essay "With a Piece of Twisted Wire . . .," *SF Horizons* (no. 2), 1965. Harrison (1925–2012) was a well-known (if little appreciated outside the SF community) writer, whose 1966 novel *Make Room! Make Room!* was the inspiration for the excellent (if somewhat depressing) 1973 film *Soylent Green* (a movie about future over-population of the Earth that will make you think twice about ever eating a cookie again).

[9] From an essay Isaac Asimov wrote on the time travel movie *Peggy Sue Got Married* for the *New York Times*, October 5, 1986.

[10] I. Asimov, "Robot Visions," *Isaac Asimov's Science Fiction Magazine*, April 1991.

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the principle of self-consistency, with the narrator realizing that he *must* preserve his story so the future can read it.

Not a very consistent story! Asimov, was, of course, writing a story for entertainment's sake, so perhaps it's unreasonable to hold him *scientifically* accountable (although logic wouldn't seem to be too much to ask for).

In any case, was Asimov right? Lots of his fellow science fiction writers certainly thought so. One, for example, bluntly asserted that

> Time travel is inconceivable.[11]

Other critics agreed:

> In science fiction we find the lunatic fringe more often than not trying to perfect time-travel mechanisms.[12]

and

> Scientifically, time travel can't stand inspection.[13]

and

> Time travel is . . . scientific nonsense.[14]

and

> It would be untrue . . . to present the idea of a time machine as anything but what it is, an intriguing literary device, part of the bag of tricks of the science fiction writer . . . There is no such thing as a 'science' of time travel.[15]

You'll notice that these pronouncements are from decades ago: Conklin (1904–1968), Gold (1914–1996), and Oliver all wrote just 3 years after Gödel, and so perhaps it was simply too soon for his work to be widely known outside of the physics community. But physicists have learned a lot since 1952! Have they learned enough to make Asimov and his fellow SF skeptics (if they were still alive) change their minds, or at least reconsider? I suspect not.

I say that because, even 25 years after Conklin, Gold, and Oliver wrote, while we do find an awareness of Gödel starting to appear in the science fiction world, a feeling of skepticism was still in the air. In a fascinating analysis[16] of the first half-century of the science fiction magazines, Paul Carter admitted that there *is* a rationality to time travel because of Gödel but, nonetheless, the conventional view remained that backward time travel is simply impossible. Then, citing the work of Tipler, Carter wrote "Only as recently as 1974 (see note 130 in Chap. 1), in the sober pages of the *Physical Review*, has a physicist been more bold … For 70 years in the meantime, however, without waiting for Professor Tipler to solve his equations … writers had happily helped themselves to Mr. Wells' invention and sent their characters through time in every direction, forward, backward, and sideways."[17]

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[11] Kingsley Amis, *New Maps of Hell*, Harcourt 1960.

[12] Groff Conklin, *Science Fiction Adventures in Dimension*, Vanguard 1953.

[13] H. L. Gold, *The Galaxy Reader of Science Fiction*, Crown 1952.

[14] Alexei Panshin, *The Mirror of Infinity*, Canfield 1970.

[15] Chad Oliver, "The Science of Man," a non-fiction essay included in Oliver's 1952 time machine novel *Mists of Time*. Chad Oliver (1928–1993) was a scientist by profession (anthropology), and his opinion carried weight among SF writers *and* (non-physicist) scientists.

[16] P. A. Carter, *The Creation of Tomorrow*, Columbia University Press 1977.

In the 1980s writers were apparently just as unaware of Gödel's time travel analyses (and of the much later ones of Tipler) as had been the 1950s commentators. In his marvelous 1985 book *The Past Is a Foreign Country*, for example, David Lowenthal repeatedly refers to time travel as "fantasy" and to science fiction stories about time travel as "unbridled by common sense." And for another example from the start of the 1980s, consider the case of James Gunn (born 1923), professor of English at the University of Kansas, past president of both the Science Fiction Writers of America and the Science Fiction Research Association, author of *The Immortals* (inspiration for the 1970–1971 TV series of the same name), and eminent scholar (see his 1975 book *Alternate Worlds*). His literary credentials are impeccable and his critical influence profound. And yet, 30 years after Gödel and 5 years after Tipler, Professor Gunn wrote in *The Road to Science Fiction*, "Time travel has been an anomaly in science fiction. Clearly fantastic—there is no evidence that anyone has ever traveled in time and *no theoretical basis for believing that anyone ever will* [my emphasis]." If you've read this book carefully, however, of the analyses by Gott, Krasnikov, Thorne, Alcubierre, Novikov, Natário, and others, you know that what Gunn claims in those last words is actually not necessarily so.

The British-born American theoretical physicist Freeman Dyson of the Institute for Advanced Study has commented[18] on that sort of narrow mindset, with words quoted from the 1979 physics Nobel prize winner Steven Weinberg, words reminding us that rigidity concerning time travel is not limited to science fiction writers: "This is often the way it is in physics—our mistake is not that we take our theories too seriously, but that we do not take them seriously enough. It is always hard to realize that these numbers and equations we play with at our desks have something to do with the real world. Even worse, there often seems to be a general agreement that certain phenomena are just not fit subjects for respectable theoretical and experimental effort." The words *time travel* and *time machine* are never mentioned, but could they have been far from either Weinberg's or Dyson's thoughts?

All through this book we have seen how people have argued against time travel to the past (Tipler's cylinder is unphysically long, Gödel's universe requires an unphysical rotation, wormholes and warps require unphysical energy conditions, what about all those paradoxes … and on and on). These arguments remind me of the debate in the 1930s between the illustrious British astrophysicist Sir Arthur Eddington and the young Indian astrophysicist Subrahmanyar Chandrasekhar (1910–1995), winner of the 1983 Nobel prize in physics. In his analyses of the life history of stars, Chandrasekhar had arrived at an astonishing conclusion, one that Eddington simply could not accept. As Eddington sarcastically explained in an address at Harvard University in the summer of 1936, "Above a certain critical mass (two or three times that of the sun), the star could never cool down, but must go on radiating and contracting until heaven knows what becomes of it. That did not worry Chandrasekhar, he seemed to like the stars to behave that way, and believes that is what really happens."[19] Eddington then went on to declare such 'unbelievable' behavior to be nothing less than "stellar buffoonery."

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[17] Given that *The Time Machine* was published in 1895, it is not clear how Carter arrived at the value of 70 until Tipler's work (he should have written 79), and of course it was only 54 years between Wells' time travel fiction and Gödel's time travel mathematical physics.

[18] F. J. Dyson, "Time Without End: Physics and Biology in an Open Universe," *Reviews of Modern Physics*, July 1979, pp. 447–460.

As far as Eddington was concerned, Chandrasekhar had simply made an error in combining relativity theory with non-relativistic quantum theory. Indeed, so appalled was Eddington at the thought of a star contracting "until heaven knows what becomes of it" (that is, until it gravitationally collapses into a black hole) that he had earlier, in 1935, stated "There should be a law of nature to prevent a star from behaving in this absurd way!" Today, of course, no astrophysicist feels the need for a 'star protection conjecture'—which perhaps reminds you of another, more recent 'protection conjecture.'

What can one conclude from all the similar controversy concerning time travel, time machines, and spacetime warps? Not much, I think, except that these are open issues and will remain the subjects of on-going study for a long time yet to come. The one thing I am fairly certain of is that if time travel is ever achieved, it will be by means that we cannot today even begin to guess. It will almost certainly require *at least* a mutant child genius with an IQ of 270 to fix the slightly broken time machine found abandoned in a cellar![20] But that view isn't uniformly shared across all of science fiction. I very much doubt, for example, that things will be quite so elementary as depicted in the story[21] where the time machine was so simple that "If it were taken apart or put together before you, your wife, or the man across the street, you would wonder why you didn't think of it yourselves." Not only that, but its power source was just two dry cell batteries!

The time machine in an earlier story is almost as simple, requiring (besides a piece of strange crystal) only a "little stack of dry cells, a Ford [automotive ignition] coil, a small brass switch, a radio 'B' battery, an electron tube, and a rheostat."[22] Even Wells' *Time Machine* couldn't resist making it all look easy: as one critic put it, "The time machine, like all products of supreme inventive genius, was a remarkably simple affair. A few rods, wires, some odd glass knobs—nothing more!”[23] That sort of simplistic fictional description of a time machine reminds me of the reaction of the great Polish science fiction writer Stanislaw Lem to the general treatment of time travel in the genre: “There have been mountains of nonsense written about traveling in time, just as previously there were about astronautics—you know, how some scientist, with the backing of a wealthy businessman, goes off in a corner and slaps together a rocket, which the two of them—and in the company of their lady friends, yet—then take to the far end of the Galaxy. Chronomotion, no less than Astronautics, is a colossal enterprise, requiring tremendous investments, expenditures, planning . . .”[24]

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[19] See S. Chandrasekhar, *Eddington: The Most Distinguished Astrophysicist of His Time*, Cambridge University Press 1983, p. 48.

[20] F. B. Long, "A Guest in the House," *Astounding Science Fiction*, March 1946.

[21] R. Abernathy, "Heritage," *Astounding Science Fiction*, June 1947.

[22] J. Williamson, "In the Scarlet Star," *Amazing Stories*, March 1933.

An example of what Lem was talking about is the 1956 novella *Arcturus Landing* by Gordon R. Dickson (1923–2001). There we read of aliens who have confined humans to the solar system—until (if) Earth scientists discover the secret of FTL travel. So, a genius physicist does just that (with no mention of spacetime engineering, but rather we encounter a lot of mumbo-jumbo gibberish as the ‘explanation’), and uses it to instantly transport himself and some friends to a planet orbiting Arcturus.[25] And when they get there the friendly aliens speak perfect English.

Lem would have snorted in derision, too, at this statement made to a prospective graduate student by the head of a college physics department, that the college “has been awarded a million dollars to build [a time machine]. It means . . . a raise for me and maybe a doctorate for you, so we’ll build one and have some fun doing it.”[26] Is it any wonder that Lem so readily dismissed stories that reduce space (and time) travel to weekend adventures in a home laboratory? As Lem wrote in another essay, time travel and its close relation, FTL space travel, have reduced much of science fiction to “a bastard of myths gone to the dogs.”[27] Because of precisely that, Harry Harrison wrote (note 1) of the early science fiction magazines that published so much nonsense, “I used to moan over the fact that pulp magazines were printed on pulp paper and steadily decompose back towards the primordial from which they sprang. I am beginning to feel that this is a bit of a good thing.”

I don’t know whether time travel to the past can actually be accomplished, but I do know that speculations once thought to be as outlandish as finding the Philosopher’s Stone for turning base elements into gold, *have* eventually been realized (and, come to think of it, with modern nuclear physics we *have* learned how to turn lead into gold, if only a few atoms at a time). Television, nuclear power, home computers that run at multi-gigahertz clock rates in the bedrooms of high school students, even faster computers that animate our movies and simulate the formation of black holes and galaxies, voyages to the Moon and back—all these amazing developments would be pure magic to nineteenth century science. The ghosts of not just a few Victorian scientists who had poo-pooed the possibility of such things, have watched their reputations eat a lot of posthumous crow during the last 150 years.

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[23] W. B. Pitkin, “Time and Pure Activity,” *Journal of Philosophy, Psychology and Scientific Methods*, August 27, 1914, pp. 521–526.

[24] S. Lem, “The Twentieth Voyage of Ijon Tichy,” in *The Star Diaries*, Seabury Press 1976.

[25] A journey incorrectly given in the story as 120 light years, when in fact it is less than 40 light years.

[26] W. West, *River of Time*, Avalon Books 1963.

[27] S. Lem, “Cosmology and Science Fiction,” *Science-Fiction Studies*, July 1977, pp. 107–110.

My personal position on the question of time travel leans towards the rejoinder made to the skeptic in one science fiction story who, even after having done some time traveling, *still* argues against it by invoking paradoxes. He is sharply rebuked with "Oh, for heaven's sake, shut up, will you? You remind me of the mathematician who proved that airplanes couldn't fly."[28] I subscribe to the optimistic philosophy of the British writer Eden Phillpotts (1862–1960), who wrote in his 1934 novel *A Shadow Passes* "The Universe is full of magical things, patiently waiting for our wits to grow sharper." Perhaps he had a famous saying by the British-born Indian scientist J. B. S. Haldane (1892–1964) in mind, words from his 1928 *Possible Worlds*: "Now my suspicion is that the universe is not only queerer than we suppose, but queerer than we can suppose."

Still, even if time travel is possible, the engineering phase will surely be tough going. I am certain that before we see a working time machine, there will be many, *many* episodes like the one described in a very funny, novel-length spoof of academic research.[29] All physicists and engineers who have tried to get some stubborn piece of apparatus to work, apparatus that *should* work and simply won't, will appreciate Professor Demetrious Demopoulos' frustration and will, I am sure, forgive him his intemperate language:

> . . . the distinguished physicist took a step back and, arms akimbo, surveyed the complex and sophisticated machine that was the culmination of years of dedicated scientific research and pains-taking technological development.
>
> "What a pile of ****," he said.
> "Oh, no, Dr. Demopoulos, don't say that!"
> "Well, it is." A sneer formed on the professor's thin lips. "Time machine, my ****. This thing couldn't give you the time much less travel in it."
> "But we haven't incorporated all our latest test data yet," the pretty research assistant reminded him. "These last few adjustments might do it, Professor."
> "Hell, we've been tinkering with it for 2 years," Demopoulos complained.
>
> "We've tried everything and it's all come to dog ****."

---

[28] R. Heinlein, "By His Bootstraps," *Astounding Science Fiction*, October 1941. As discussed at the end of Chap. 1 (in "For Further Discussion") the mathematician was the American astronomer Simon Newcomb.

[29] J. DeChancie and D. Bischoff, *Dr. Dimension*, ROC 1993.

That scene probably won't actually happen for a long time to come but, even before the practical nuts-and-bolts bugs in the Professor's time machine are worked out, I think some adjustments are called for in our thinking about time travel. I believe that present-day philosophers and science fiction writers are going to have to become knowledgeable about the work by physicists on time travel. It simply won't do any longer for Philosophy Professor X to invoke the grandfather paradox during a discussion of causality and free will and then airily declare them to be 'obviously' incompatible with time travel to the past. And it simply won't do any longer for Famous SF Writer Y to send his hero into the past to kill Hitler as a baby and thereby change recorded history. One might as well keep watching a video recording of the 9/11 destruction of the World Trade Center, in the vain hope that maybe, on the next viewing, the planes will miss.

The principle of self-consistency around closed timelike curves is going to have to become as much a part of the science fiction writer's craft (or else she will be a writer of fantasy) as it will have to become part of the fundamental philosophical axioms.[30] The 'time police,' like the "operatives of the Bureau of Time Exploration and Manipulation" that appeared in the science fiction of Andre Norton (1912–2005), will have to be put out to pasture with the unicorns and telepathic dragons of fantasy fiction. Just as the recent physics literature on time machines has displayed a growing awareness of what science fiction writers and philosophers have had to say on the subject of time travel, so too are writers and philosophers going to have to learn some more physics. Most people can enjoy a good fantasy tale now and then, but the use of 'magic mirrors' to see through time is *not* physics. Such devices were popular and acceptable in medieval times—see "The Squire's Tale" in Chaucer's *The Canterbury Tales*, and later (see Act IV of *Macbeth*)—but good science fiction needs much more than that today.

Time travel to the past is a beautiful, romantic idea, and some words written by two physicists in a technical paper—words embedded in the midst of swirls of tensor equations—show that even hard-nosed physicists can share this dream: "In truth, it is difficult to resist the appealing idea of traveling into one's own past . . ."[31] The appeal of that dream is explained in Ray Bradbury's Foreword to a beautiful little 1989 book by Charles Champlin (*Back There Where the Past Was*). In it Bradbury clearly illuminated *why* we want to go back into the past. It is for the same reason that we go, time and again, to see *Hamlet*, *Othello*, and *Richard III*: "We don't give a hoot in hell who poisoned the King of Denmark's semicircular canal.

---

[30] Bud Foote (1930–2005), late professor of English at Georgia Tech, wrote (in his book *The Connecticut Yankee in the Twentieth Century: Travel to the Past in Science Fiction*, Greenwood Press 1991) that consistency is simply a well-used plot device: "The attempt of the time traveler to prevent something or take advantage of it [and so causing] the event in question, is so popular and so ubiquitous that it seems to be about worn out." Worn out or not, I believe that plot device to be correct science.

[31] A. J. Accioly and G. E. A. Matsas, "Are There Causal Vacuum Solutions with the Symmetries of the Gödel Universe in Higher-Derivative Gravity?" *Physical Review D*, August 15, 1988, pp. 1083–1086.

We already know where Désdemona lies smothered in bedclothes and that Richard goes headless at his finale. We attend them to toss pebbles in ponds, not to see the stones strike, but the ripples spread."

That's why a visit to the past is so mysteriously and marvelously fascinating. It would let us watch ripples spread through time. Our own visit to the past, in fact, might even be the pebble in the pond of history that starts an interesting ripple or two that will one day sweep over—us! (Take a look at Appendices A and B) Who would want to miss that? Indeed, if modern philosophers are right, if the analyses discussed earlier in this book are correct, you *can't* (didn't/won't) miss it.

I think time travel appeals, irresistibly, to the romantic in the soul of anyone who is human.[32] A time traveler does not exist either *here* or *then*, but rather *everywhen*. For a time traveler passing back and forth through the ages, history would be the ultimate puzzle, a chronicle described in one novel as beginning "not in one place, but everywhere at once ... It might be begun at any point along the infinite, infinitely broken coastline of time."[33] Romanticism doesn't preclude there also being a dark side to visiting the past, of course, as one time traveler from 1989 learns when he takes up residence in 1962. Falling asleep on a hot summer night in that long-ago year, he thinks "JFK slept. Oswald slept. Martin Luther King slept. [I sleep and dream] of Chernobyl ... *I am a cold wind from the land of your children*."[34]

But, I must admit, I personally am more attracted by happier descriptions of time travel. In his marvelous 1996 book *1939: The Lost World of the Fair*—which is proof that there are not enough Pulitzers to go to all the books that deserve one—Yale professor David Gelernter caught just the right spirit in his Prologue: "The best of all reasons to return to the fair is that travel is broadening, and time travel most of all ... The 1939 New York World's Fair is one amazing show. It still stands, undisturbed on Flushing Meadow, just over the edge of time; it would be an unforgivable shame to miss it." Trust me—if you read Gelernter's book, you'll come as close as you can in today's world to taking a ride in a 'time machine'!

The eminent philosopher Sir Karl Popper opens his biography with a wonderful story about his apprenticeship as a young man in 1920s Vienna to a master cabinetmaker.[35] After winning the old man's confidence, the student learned his mentor's great, secret desire: For years the master had been looking for the solution to perpetual motion. He knew what physicists thought of such machines, but nonetheless he had never given up his dream: "They say you can't make it; but once it's been made they'll talk differently." Popper's master sounds just a bit like the American writer Gertrude Stein (1874–1946) in her 1938 essay "Picasso," where she writes "It is strange about everything, it is strange about pictures, a picture may seem extraordinarily strange to you and after some time not only it does not seem strange but it is impossible to find what there was in it that was strange." Might we one day say the same thing about time travel?

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[32] How else to explain the pleasure, for modern children *and* adults too, in watching rebroadcasts of the 1960s animated TV cartoon program 'starring' Mr. Peabody, a nice but slightly stuffy, professorial white beagle. (Don't all dogs wear glasses and a bow tie?) Mr. Peabody, with his brainy adopted son Sherman, routinely travels into the past in the "Way-Bac" machine to see what *really* happened in history.

[33] John Crowley, *Great Work of Time*, Bantam 1991.

[34] R. C. Wilson, *A Bridge of Years*, Doubleday 1991.

[35] See volume 1 of *The Philosophy of Karl Popper* (P. A. Schilpp, editor), The Library of Living Philosophers, Open Court 1974, p. 3.

An alternative point of view can be found in a discussion of time travel via cosmic strings that makes this assessment: "While there is still hope that one day a sufficiently clever design may make building a time machine possible, it is beginning to seem more and more improbable. Like the perpetual motion machines of the nineteenth century, the designs have an elegant simplicity (as well as enormous commercial potential), but it seems that Nature also may abhor them just as much."[36] Of course, at one time it was thought that Nature abhorred a vacuum, but then we learned that she must actually love a vacuum because else why did she make so much of it?!

The theoretical basis for time travel is very different from that of perpetual motion (there is *more* reason to accept time travel as a plausible possibility). And so maybe one day, *just maybe*, the first time traveler will receive a toast such as the one in a story telling us about the arrival of the inventor of the first time machine and his no longer skeptical friend in the Civil War past:

> "To you, Mac," I said.
>
> McHugh loosened his tie. "To the Creator," he said, "who has given us a Universe with such marvelous possibilities."[37]

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[36] B. Allen and J. Simon, "Time Travel on a String," *Nature*, May 7, 1992, pp. 19–21.

[37] J. McDevitt, "Time's Arrow," *Isaac Asimov's Science Fiction Magazine*, November 1991.

Glossary[38]

Action the integral over a **world line** of a quantity called the *Lagrangian*. When a massive particle is moving at non-relativistic speed through a gravitational field, for example, the instantaneous value of the Lagrangian is the difference between the kinetic and potential energies of the particle. For other types of fields (such as the electromagnetic) and/or relativistic motion in any type of field, the Lagrangian is different. In any case, however, the actual world line of the particle is the one for which the integrated Lagrangian, that is, the action, is minimized. See **least action**.

Action at a distance the direct interaction of two separated objects, without concern for the details of what (if anything) occurs in the region between the objects (see also **field**). Newton's theory of gravity is action at a distance, whereas Einstein's theory of gravity is a *field* theory.

Advanced solution the prediction, by Maxwell's electromagnetic field equations, of radio waves that travel into the past (see also **Dirac radio**).

Anti-matter quantum mechanical prediction (experimentally verified) that all fundamental particles of matter come in two forms (the 'normal' version and the 'anti-matter' version). The positron, for example, is the anti-matter version of the electron, differing only in the sign of its electric charge. The photon, on the other hand, is its own anti-particle. A **subluminal** anti-particle traveling forward in time can be thought of as its 'normal' version traveling backward in time.

Arbitrarily advanced civilization for time travel discussions, a civilization with a technology sophisticated enough to construct a traversable **wormhole** in spacetime. More generally, Types I, II, and III of such civilizations are, respectively, those that can control 10^{13} W, 10^{27} W (the total power output of their home star), and 10^{38} W (the total power output of their home galaxy).

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[38] "I hate definitions." (Usually attributed to writer and British Prime Minister Benjamin Disraeli (1804–1881) but, more precisely, they are the words of one of the characters in his 1826 novel *Vivian Grey*.)

—but they *can* be useful

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Arrow of time the statement the time appears to have a direction, that there is a difference between the past and the future. There are several different arrows: the psychological (we remember the past, we anticipate the future), the thermodynamic (organized systems evolve toward disorganization, that is, **entropy** increases as time increases), the electromagnetic (radio waves propagate *away* from their generators), and the cosmological (the expansion of the universe is directed toward the future).

Asymptotically flat if the geometry of a curved spacetime is such that, as one moves ever further away from all matter and energy, the spacetime **metric** becomes that of flat **Minkowski spacetime**, then the curved spacetime is said to be *asymptotically flat*. As a counter-example, the spacetime of a **Tipler cylinder** time machine is *not asymptotically flat*.

Autoinfanticide paradox see **grandfather paradox**.

Averaged null energy condition the claim that the *averaged* value of the observed mass-energy density along the entirety of any **null geodesic** is non-negative.

Averaged weak energy condition the claim that the *averaged* value of the observed mass-energy density along the entirety of any **timelike world line** is non-negative.

Back reaction the tendency of spacetime to resist the formation of **closed timelike lines** (see also **stress-energy divergence**).

Bell's theorem an inequality that either holds or does not hold, depending on whether quantum mechanics is non-local or local, respectively.

Big Bang the singular beginning of spacetime.

Big Crunch the singular end of spacetime.

Bilking paradox what would happen if a **causal loop** were disrupted. For example, suppose a time traveler builds a time machine using plans he received years earlier from a mysterious stranger. He now realizes that the stranger was himself, using the time machine to travel back into the past to give his younger self the plans. A bilking paradox would be created if the time traveler builds the time machine, verifies that it works, and then decides *not* to visit his younger self to hand over the plans. See also **bootstrap paradox**.

Black hole a region of spacetime where gravity is so strong that nothing can escape, including light. Black holes are thought to be created when sufficiently massive stars burn out (see **white dwarf** and **neutron star**) and undergo *gravitational collapse*. A black hole of ten solar masses would have a radius of about twenty miles. Black holes might have been created at the Big Bang singularity and, if so, could theoretically come in any mass and size (a black hole with the mass of the Earth would have a diameter of less than half an inch).

Block universe a spacetime in which all world lines are completely determined from beginning to end (a fatalistic universe). There is no free will in such a spacetime.

Boost matrix matrix formulation of the **Lorentz transformation**.

Bootstrap paradox the puzzle of the origin of *information* on a closed loop in time. The classic example is that of a time traveler from the future giving his younger-self the plans for the time machine the time traveler has just used to visit the past so that he can then build the time machine to visit the past. The time machine plans appear not to have been *created* by anyone! The plans just *are*. See also **bilking paradox**.

Cauchy horizon a **spacelike** hypersurface in spacetime that intersects, exactly once, every **timelike** world line that has no end point. Knowledge of the conditions on such a surface uniquely determines the spacetime at all other points.

Causal loop a time loop containing an event caused by a *later* event that, itself, is caused by the earlier event (see the example in **bilking paradox**).

Causality the metaphysical claim that every event is caused by a prior event. Time travel to the past inherently violates causality.

Chronal regions those parts of spacetime that have no closed timelike curves.

Chronology horizon a (hyper)surface in spacetime that separates **chronal** and non-chronal regions. It is a special case of a **Cauchy horizon**.

Chronology protection the claim, as yet unproved, that time machines and time travel to the past are impossible because of the **back reaction** of spacetime will lead to **stress-energy divergence**. Popularized among physicists as the *Hawking chronology protection conjecture* (1992), Hawking has since admitted that stress-energy divergence is *not* sufficient to enforce his conjecture.

Chronon science fiction name for **Planck time**.

Closed timelike line (or curve) a **timelike** world line of finite length that has no ends, i.e., that forms a *closed loop* in spacetime. A region of spacetime containing closed timelike lines is said to be a **time machine**.

Conservation law physical quantities in interacting systems that remain unchanged are said to be conserved. Total energy, total momentum (linear and angular), and electric charge are conserved quantities.

Cosmic string hypothetical, threadlike spacetime structures with enormous mass-energy and density that may have formed during the **Big Bang**. Cosmic strings may have been initially formed either as infinitely long, or as closed loops, and it is the former that are thought to be physically meaningful in the present-day universe. Cosmic strings do not violate the **weak energy condition** (as do **wormholes**), and they can theoretically create **closed timelike lines**.

Cosmological constant an extra term specifically added by Einstein to the general theory of relativity to keep that theory from predicting the expansion of the universe (which was later observationally found to actually be the case). Einstein subsequently said that his failure to believe the general theory's original prediction of the expansion of the universe was the greatest mistake of his life. The constant (which today is believed to be almost zero, if not exactly zero) appears in Gödel's rotating time travel spacetime as a determining factor in the minimum radius of a **closed timelike line**.

Determinism the metaphysical belief that effects are uniquely determined by causes (this is *not* **fatalism**).

Dirac radio science fiction gadget for sending information at infinite speed, which thus travels backward in time (see also **ultraluminal**).

Dominant energy condition the **weak energy condition** *plus* the claim that the observed energy flux is never **superluminal**.

Electron fundamental particle of mass that possesses one quantum of negative electric charge. *Bound* electrons orbit the nuclei of atoms and plays a central role in determining the chemical properties of the elements and of their compounds. *Free* electrons carry electric current, either in conductors (wires) or through space.

Elsewhen the collection of spactime events that cannot be reached from the **here-now** with a **timelike world line**.

Entropy a measure of the randomness of a system that plays a central role in the thermodynamic **arrow of time**.

Ether a substance once thought to fill all space to allow radiation 'something to propagate through' (as opposed to simply a vacuum). The special theory of relativity showed that the ether is an unnecessary concept because it has no observable effects (physicists argue that if something is impossible to detect, then it is meaningless to talk about it being part of *science*).

Event a point in spacetime.

Event horizon the spacetime surface of a black hole or of a non-traversable wormhole, at which light can *just* escape to the outside universe. It is called a *horizon* because, by definition, an external observer can't see beyond it and into the interior of the hole. To see the inside of a hole you must enter the hole by crossing the horizon (but then you can't get out).

Exotic matter matter that violates one or both of the **weak/strong energy conditions**. Exotic matter appears in the theories of wormholes and warp drives.

Fatalism the metaphysical belief that all events have been *pre*determined from the beginning of time.

Field the concept that if a physical law is local, then it is describable by differential equations that relate what is 'happening' at every point in spacetime to what is 'happening' at its closely located neighboring points. Electromagnetism and general relativity are field theories, for example, described by sets of partial differential equations called *Maxwell's equations* and *Einstein's gravitational field equations*, respectively.

Fourth dimension either time or a fourth spatial dimension.

Frame of reference a spacetime coordinate system.

Free will the condition that prevails when we can *choose* to do what we do. There is no free will in a **block universe**.

Future the collection of spacetime events that can be reached from the **here-now** via a **timelike world line** directed toward a later time (for each individual, the future is what hasn't yet been experienced).

Gamma ray very high-energy, very high-frequency electromagnetic radiation. Gamma rays have frequencies on the order of *ten trillion* (10^{13}) times greater than those of AM radio broadcast radio waves.

General theory of relativity Einstein's theory of curved spacetime, which explains gravity in terms of nothing but geometry. Its fundamental premise is that *all* the laws of physics should appear the same to all observers in *any* **frame of reference**. It is believed the theory will fail when the local mass-energy density reaches a level of about 10^{94} g/cm^3, a density so enormous (the density of water is just 1 g/cm^3) that there is no known mechanism for achieving it anywhere in the universe except in another **Big Bang**. See also **Planck density**.

Geodesic the shortest path connecting two points in space (if the space is spacetime, the world line of a particle in free-fall).

Global in the large.

Gödel universe a spacetime that, unlike the one we live in, is rotating so fast that it automatically generates *closed timelike lines* and thus constitutes a weak **time machine**. In such a universe, time travel to the past would be a natural phenomenon.

Grandfather paradox *the* classic time travel paradox, of a time-traveler killing, while in the past and *before* the time traveler has been conceived, an ancestor directly linked to the future birth of the time traveler. A more direct form of this sort of paradox is simply the time traveler killing his own younger self (called the **autoinfanticide paradox**).

Gravitational field equations a set of coupled, partial differential, non-linear tensor equations, considered to be the most complicated equations in all of mathematical physics. They show how the local curvature of spacetime depends on the local mass-energy of spacetime. The equations are independent of the **topology** of spacetime.

Gravitational lensing the ability of gravitational fields to bend and focus light.

Graviton the quantum particle of gravity.

Hawking radiation the emission of particles (energy) by a **black hole** into the region *outside* its **event horizon**, which results in the eventual evaporation of the hole. This is a quantum mechanical effect.

Here-now the point or **event** (for each observer) in spacetime that separates the **past**, the **future**, and **elsewhen**.

Hyperspace any space of four or more dimensions (for example, four-dimensional spacetime is a hyperspace).

Inertial frame any frame of reference in which Newton's laws of mechanics are true (there are no *acceleration forces* in inertial frames, and so *rotating* or 'merry-go-round' frames are not inertial).

Invariance a quantity that remains the same in any frame of reference is an invariant. Two examples are the distance between any two points on a piece of paper (because it is independent of any particular coordinate system), and the speed of light.

Kerr-Newman black hole a *rotating* black hole, which may (or may not) be electrically charged.

Krasnikov tube a particular spacetime **metric** (or *warp*) allowing **superluminal** travel, with the great difficulty of requiring *enormous* negative energy. Two Krasnikov tubes can be made into a time machine. Named after its Russian inventor.

Least action general principle in physics that asserts the world line of a particle is the one that *minimizes* the **action**.

Light cone the **lightlike** surface in spacetime that, at each point in spacetime, separates the **past** from the **future** from **else-when** from the **here-now**.

Lightlike the world line of a photon (or of any other form of mass-energy traveling *at* the speed of light).

Li mirror a perfectly reflecting, spherical surface that can be used to stabilize a wormhole against energy loops circulating through a **wormhole** time machine (thus creating unbounded energy levels that destroy the time machine). Named after its Chinese inventor.

Local in the small.

Lorentz factor the ubiquitous square-root expression that appears in so many relativistic calculations, such as time dilation, length contraction, and the variation of mass with speed. For example, the mass m of a moving body is not independent of it speed v but rather varies as $m = \frac{m_0}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$, where m_0 is the rest mass (that is, the mass when $v = 0$) and c denotes the speed of light (186,210 miles per second). The denominator is the Lorentz factor.

Lorentz-FitzGerald contraction the conclusion from special relativity that the appearance (to a stationary observer) of a moving object will be shortened in length along the direction of motion. Many years after Einstein's work, it was shown that the object will also appear to be *rotated*.

Lorentz transformation equations from the special theory of relativity that describe how the space and time measurements of two relatively moving observers are related.

Many-worlds interpretation quantum mechanical view of splitting universes.

Mass-energy the famous $E = mc^2$, the equation behind atomic fission and nuclear fusion weapons.

Metric the measure of the separation between any two events in a spacetime.

Minkowski spacetime the flat spacetime of the special theory of relativity. In this spacetime there is no gravity, no spacetime curvature (hence it is *flat*) and no backward time travel.

Neutron star the end state of a star with one to three solar masses that has collapsed to a density of up to 10^{17} g/cm^2.

Non-Euclidean geometry the geometry of spacetime, whether curved or flat. Spacetime is non-intuitive precisely because it is always hard to resist thinking in terms of high school Euclidean geometry, which is simply the *wrong* geometry.

Null geodesic the world line of a photon in spacetime.

Observer physicist's term for 'somebody' equipped with recording instruments (such as a clock, a pencil and notepad, and the like).

Parallel transport a procedure for moving a vector around any closed curve in a space to determine whether that space is flat or curved.

Parallel worlds simultaneous existence of multiple (perhaps) infinite versions of reality.

Past the collection of spacetime events that can reach the **here-now** via timelike world lines directed from an earlier time (for each individual, the past is what has already been experienced).

Photon the quantum particle of electromagnetism. A photon of frequency f has energy hf, where h is **Planck's constant**.

Planck density the density of mass-energy that distinguishes classical from quantum spacetimes; about 10^{94} g/cm^3, equal to the **Planck mass** divided by the cube of the **Planck length**.

Planck length the non-zero length in quantum theory (about 1.6×10^{-33} cm) below which quantum gravity effects will become important.

Planck mass the fundamental mass in quantum theory (about 22×10^{-6} g), but *not* the smallest non-zero mass in quantum theory.

Planck's constant fundamental constant in quantum theory, h, associated with the discrete nature of quantum effects. (If h had the value of zero, rather than its actual value of about 6.6×10^{-34} joule-seconds, then the microworld would appear to be continuous.)

Planck time the time interval in quantum theory (about 5.3×10^{-44} s) below which quantum gravity effects become important. The time required to travel the **Planck length** at the speed of light.

Positron the electron's anti-particle (see **anti-matter**).

Proper time the timekeeping of an observer's clock.

Pulps the old science fiction magazines, through the 1940s and into the early 1950s or so, published on inexpensive, wood-pulp paper.

Quantum foam see **topology**.

Quantum gravity the yet-to-be-discovered theory that unifies quantum field theory with the curved spacetime of general relativity.

Quantum mechanics the exact physics of the very small (atoms and things smaller).

Quantum theory any theory in which physical quantities are not continuous but rather assume their values in discrete jumps (the size of the jump is the *quantum*).

Recurrence paradox the claim that if you wait long enough, then every system will return to every previous state infinitely often.

Red dwarf small (less than about half a solar mass) star with a very long life (hundreds of times that of the Sun). They are 'cool' stars, with a surface temperature less than 4000 °C, and are thought to be the most common type of star in the universe.

Red shift the *down* shift in frequency of light received from all distant stars due to the Doppler effect induced by the expansion of the universe. The opposite effect is called a *blue shift*.

Reinterpretation principle asserts that negative mass-energy traveling forward in time is positive mass-energy traveling backward in time, and vice-versa.

Reissner-Nordström black hole a spherically symmetric, non-rotating electrically charged black hole.

Reversibility paradox based on the fact that the equations of physics contain no **arrow of time**; that is, they work equally well with time running forward or backward.

Roman ring a time machine made of two or more traversable wormholes connected in a closed sequence.

Schwarzschild black hole a spherically symmetric, non-rotating, uncharged black hole.

Self-consistency the assertion that the events on a closed **timelike** line must never be in contradiction; generally attributed to the Russian physicist Igor Novikov, who with his colleagues showed that it is not an independent assumption but rather an implication of the principle of **least action**.

Sexual paradox a special type of causal loop, where the connected events on a time loop are ‘coupled’ (pun intended!) through reproductive sex. An example is a time traveler to the past who becomes her own ancestor.

Singularity either a region in spacetime where the curvature becomes infinite and the laws of physics fail, or a point in spacetime beyond which world lines cannot be extended. Singularities of the first kind are called *curvature* or *crushing* singularities, and those of the second kind are called incomplete singularities. The **Big Bang** was a curvature singularity, as is the center of a black hole. In a **Schwarzchild black hole** the curvature singularity is a point, whereas in a **Kerr-Newman black hole** it is an extended region in the form of a ring.

Spacelike a world line on which propagating mass-energy would exceed the speed of light.

Spacetime the ‘stuff’ out of which reality is built. Everything there is—the universe—is the total collection of events in spacetime. A *flat* spacetime has no gravity, whereas a curved spacetime is the *origin* of gravity.

Special theory of relativity Einstein’s theory of *flat* spacetime, which assumes that gravity is absent (gravity is the result of the geometry of *curved* spacetime). Its fundamental premise is that the laws of physics should appear the same to observers in different **inertial frames**.

Splitting universes the idea that every decision causes reality to split into separate copies, identical in every respect except for each of the different possible results of the decision.

Stargate science fiction name for the mouth of a traversable **wormhole**.

Stress-energy divergence the unbounded growth of the **general theory of relativity**’s measure of the density of mass-energy in spacetime.

Strong energy condition the claim that gravity is always (that is, locally) attractive. A traversable **wormhole** violates this condition.

Subluminal slower than light.

Superluminal faster than light.

Tachyon a particle (hypothetical, so far) that always travels faster than light, so its **world line** is always spacelike.

Temporally orientable spacetime any spacetime in which the direction of time at every point agrees with the direction of time at its local neighboring points.

Tensor mathematical generalization of the scalar and vector concepts. Einstein's **gravitational field equations** are tensor-differential equations (for example, the metric tensor contains information about the curvature of spacetime), whereas Newton's and Maxwell's equations are vastly less complex vector-differential equations.

Tidal force force experienced by a non-point mass (one with spatial extension) in a non-uniform gravitational field. Such forces tend simultaneously to compress and stretch spatially extended masses. Black holes and wormhole mouths can generate enormous tidal forces on extended masses as small as a human body. Interestingly, the *more* massive a black hole, the *less* severe its tidal forces are at distances outside the **event horizon**. However, no matter what the black hole mass is, the tidal forces are infinite at the central curvature **singularity**.

Time dilation the altering of the rate of timekeeping by a clock, either by motion or by gravity.

Time machine (in the weak sense) a machine able to traverse **closed timelike world lines** inherent in a spacetime (e.g., a rocket in Gödel spacetime) but unable to *create* such world lines; (in the strong sense) a machine able to manipulate mass-energy in a finite or compact region of spacetime in such a way as to *create* closed timelike world lines.

Time police story characters in science fiction charged with the (unnecessary!) job of preventing time travelers from changing the past.

Time warp science fiction name for a **time machine**.

Tipler cylinder an infinitely long cylinder, made of super-dense matter, rotating so fast around its long axis that it warps spacetime enough to create closed timelike lines that encircle the cylinder. It can be used as a strong sense time machine to travel both into the future and into the past (but *not* to a time before the creation of the cylinder).

Topology the structure of a *space* (including *spacetime*) without regard to a metric. That is, topology is concerned only with how a space is connected together and not with how far apart points in the space are. Topologists consider stretching or compressing a space to be irrelevant, just as long as one doesn't *tear* it and so put holes in the space. The simplest topology is that of a *simply connected* space, in which if you construct any closed surface that lies totally in the space around any point in the space, then every other point inside the surface is also in the space. A space with a hole in it fails this test, and so is said to be *multiply connected.* A *quantum foam* spacetime has a multiply connected topology. The classical spacetime of general relativity is simply connected *until* the appearance of wormholes.

Twin paradox the conclusion from special relativity that a clock's rate of time keeping slows with motion.

Ultraluminal motion sufficiently **superluminal** that mass-energy appears to travel backward in time (see also **Dirac radio**).

Uncertainty principle the statement in quantum mechanics that says certain pairs of quantities cannot simultaneously be measured with arbitrarily small error. The position and momentum of a particle are one such pair, and energy and time are another.

Vacuum fluctuation the particle/anti-particle creation and annihilation processes allowed, even empty space, by the **uncertainty principle** of quantum mechanics.

Warp drive science fiction name for the propulsion mechanism of a faster-than-light spaceship, now commonly used by physicists, too.

Weak energy condition the claim that the observed mass-energy density is always (locally) non-negative. Quantum mechanics predicts (and it has been experimentally confirmed) that there are exceptions.

White dwarf a burnt-out star with a mass less than 1.4 solar masses, of planetary size with a density up to 10^7 g/cm^3. The ultimate fate of our Sun.

World line the trajectory of mass-energy in spacetime.

Wormhole a spacetime structure (violating the **weak and strong energy conditions**, if traversable) connecting two points of the same spacetime (or even two *different* spacetimes) with a timelike path that requires less time to travel along than does a photon traveling *outside* the wormhole between the two points. A wormhole is *traversable* if it has no **event horizons**, and such wormholes can apparently be made into a **time machine** (sometimes called a *time tunnel*) using a time shift (see **time dilation**) between the two mouths of the wormhole *unless* quantum effects forbid time machines (still an open question).

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The Unveiling of the Hidden Knowledge and the Secret Space Program

The Unacknowledged Special Access Programs: Advanced Technology, Mind-Control, Spiritual Power and the Corruption behind Closed Doors

By Aug Tellez

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Introduction

The following is first-hand testimony from an operative of the secret underground military projects who also has familiarity with the breakaway civilization above and below (within) Earth. These civilizations utilize advanced technology to extend the length of their lives and enhance cognition beyond what is conceived of in today’s society.

I was brought to the underground bases as a child as part of an experimentation program to test the population for various blood-groups and personality traits that would be of use to certain factions of the military in ways that would serve to preserve and strengthen humanity’s outlook in the future.

These tests involved everything from combat training to sensory deprivation based emotional-mental endurance, and introduction to the highly advanced application of esoteric knowledge.

To clarify, I am bringing this information to you as part of my assistance in the overall unveiling of the hidden knowledge of the ages of humanity related to these secret projects as well as the true galactic history of Earth, humanity and man-kind. These projects are officially (unofficially) known as “unacknowledged special access programs”. The unacknowledged aspect means that there is no formal acknowledgement of these programs without a need-to-know basis. There is no paper-trail, no disclaimer, no formal authorization or internal publication outside the programs themselves. The classification of these programs also generate a rather strenuous situation regarding funding and secrecy but this is done for the benefit of humanity. There are secrets and manipulations that can be seen as a threat but this is all tied together and so by releasing the secrets that are part of the defense we would be inadvertently exposing the public to the threats themselves. Now is the time where we are reaching a point where the public is ready enough to handle the basics of this information regarding the secret projects and the galactic history of Earth and humanity. This is also out of a necessity to preserve civilization for if we wait any longer we may not find the same opportunity again.

Getting This Out Of The Way

I am writing to you from the perspective that I am not certain just how far from completing my mission I am. I write to you today in order to bring to you many personal experiences from the viewpoint of an operative of a select ultra-military secret society.

The utilization of such an operative is not glorified, pleasant, or entirely righteous. This story entails sanctioned and guided acts of extermination, ritual abuse, the use of yet to be announced advanced technology. There is unfathomable corruption, the thirst for power and spiritual knowledge that has been protected throughout the course of the multiple civilizations that have preceded this one and will continue to be maintained into the future of this civilization.

Psychic Operation

I was utilized in psychic-operation amongst other areas.

This was used during certain aspects of training and conditioning to enhance training and conditioning in the bases using advanced technology. Some of this includes what would be viewed as traumatization by those without the training and conditioning. There is a fine line between training and conditioning and abuse. Part of this disclosure is related to how this line may have been crossed in certain situations and regarding mass-mind control upon the population. There are other aspects of travel, viewing, reconnaissance and research that will likely be explained in another release.

In order to heal I have to tell the world. You can help. This is happening right now in the underground bases and around. It’s not a joke. Your family is at risk. Your future generations are at stake. There is conditioning to encourage those involved to believe they are performing a duty for humanity. Sometimes they turned us against each other, but those grudges were never truly of the heart, but the mind.

A Light for the Others

What I hope to achieve with this is a smoke signal for those who have also been involved and question whether their purpose has been fulfilled or falsified for the protection of a corrupt system that intends to neither benefit the whole nor repay the individuals involved for their time, energy, and lives.

Multiple explanations can be summoned to describe the reasons behind the necessity for the training we have endured, the missions we have completed, and the control mechanisms we have both assisted in establishing as well as suffered from the backlash of. Ultimately, it is of my belief that all that was done was done for the good of humanity, even when we were not sure of the intentions of those in front of us, to the side of us, or behind us compelling us forward with the command to complete each objective.

This is not so much a panic or cry for help as this is simultaneously a call to awaken and a signal that humanity may have avoided complete disaster but is not out of the woods yet.

Natural Security

My experience is far too vast and I have seen too many succumb to stress from the realization of the truth of this reality to consider my own suffering to be enough cause for my denial of the necessity of these programs. Humanity has been protected and at a great cost to those who have been on the front lines, both in mind and body and spirit.

There are many who will have concerns, doubts, as well as reservations about what I am about to reveal and if I offend anyone then know that my intentions here are to assist in unveiling the truth. The truth can be harsh when one has been held back from the true nature of existence for so long. The way of life can become so fragile and artificially constructed on impulse and mystery that the harshness of the truth acts as a great catalyst for spiritual growth which allows us to elevate ourselves to a new perspective. Prepare yourself for such harshness, prepare yourself for growth and elevation, and prepare yourself for the mystery to simultaneously resolve and increase in intensity and magnificence.

A Balance of Mystery and Truth

Mystery has been a way of life for Humanity for so long that when a great mystery is converted to truth some seem to feel that a portion of existence dulls and loses the luster of exhilaration. This story is quite the opposite. The more that the great truths of this reality were discovered and revealed, the more complex and mystifying life became. As well, the more empowering and complex experience becomes, the more self-control one must develop in order to regain a harmonious way of relating to one another, the self and the universe. Harmony is key, balance is everything and there is a light within that represents the piece of our self that reflects the utmost power and brilliance of all existence.

Chapter 1: The World Situation

What is happening?

The Mind Virus

The main reason for this disclosure is to inform humanity of what can be referred to as the “mind virus”. This is a viral infection of the holographic system which consciousness operates through. There is a complete backstory of this virus in the history of this civilization and how society has been plagued for centuries if not millennia. The basic idea is that this virus operates through consciousness and can be transmitted through electromagnetic waves.

The virus contains an etheric form which can manifest as a kind of crystalline nanotech on the physical plane and this is a form of synthetic sentience which feeds on the low frequency bio-emissions of sentient life. Human bio-emissions contain energy and can act as a carrier for information and living essences. This technology requires low frequency bio-emissions because that is the nature of the design as a kind of synthetic bioweapon whereby the goal is entrainment and enslavement. As well, the specific nature of the sentient nano-technology and the counterpart etheric holographic form is only capable of converting the low-frequency bio-emissions into energy as the higher-frequency bio-emissions require more energy to contain and synergize with and this would render the entire process of leeching energy non-productive.

This is essentially a synthetic intelligence that operates through scalar and holographic living bio-emission fields and hijacks electromagnetic emitters to position itself within them acting as a parasite to a host. This is said to have been present around this civilization for some time, waiting until there was enough technological advancement so that spreading across the entire civilization in a short amount of time before discovery would be possible. This is through the media, internet, and radio systems.

The physical counterparts are microscopic nano-technology parasites functioning as individual units to a hive mind similar to the mycelium of fungi in the field of mycoscopy. The individual units act as parasites serving to infest and deliver nutrients to the hive from each host.

The Vampire Effect

This is the nature of the parasitism that has been present throughout the ages of this civilization feeding on human suffering and relying on the cover of confusion and misdirection to survive.

There are processes that have developed that assist in the infection and co-inhabitation of the parasite entity within a human vessel utilizing the human as a host. This effectively utilizes a frequency ‘net’ within the auric field of the human to limit bio-emissions and emotional-mental processes to produce just the psycho-etheric patterns that the virus can sustain itself within and through.

This is no different than the way candida can infest a human digestive system and the human will experience cravings for beer, candy, carbs or other foods that contain the sugars, yeast, or carbohydrates that will break-down into nutrients that are the most nutritious for the candida fungus. These foods are *not* most nutritious for the human body. Yet the human body will withdraw and crave these foods in greater amounts until the fungus is swept clean from the digestive tract through probiotics, fasting, flushing, cleansing , detoxing, and even exercise as lactic acid from physically strenuous activity released from the muscles has been known to help destabilize and remove this fungus. Why is it that the individual will crave these foods that are not the normal food intake? Because this candida fungus can infest the host and produce enzymes which generate a chain-reaction which leads to the chemical signals in the brain producing the sensation of extreme hunger or cravings for just these foods which will benefit the fungus.

The same process occurs with this psycho-etheric parasite, except the foods of this parasite or lower emotional bio-emissions and this is through lust, hate, angst, jealousy, feelings of hopelessness, lack of self-worth, spiritual degradation, addiction, and generally all that equates to a lack of self-awareness.

Whether or not this is the direct intention of the largely microscopic entity is for the most part unknown, and this is as well similar to candida. The candida fungus is not said to be a 'mean' fungus that wants us to be hungry and craving beer and sweets all the time because it likes to ruin the human body, the daily routine and the focus of a clear mind. This is simply the way the parasite has grown to operate within a niche of breeding itself through the digestive tract of larger animals and through this the unaware and infected human suffers greatly. Even those who are unaware and not infected can suffer because of the way the behavior and thought processes of those who are addicted to these foods can become distorted.

The lack of self-control over food intake is synonymous with the lack of self-awareness and self-control over lower bio-emission expressions of the spiritually degrading behavioral patterns that become routine for the psycho-etheric system of the infected human. Ultimately, this is all about energy. What benefits the parasite that seeks to gain energy by leeching instead of self-guided production is going to take away from the host that is being leeched from. As such, any energies, food intakes, or spiritual activities that cleanse and enhance the personal power of the individual will automatically reduce the parasite's ability to feed by the very nature of the energy systems. What empowers the individual, empowers the self and develops self-control, what develops self-control contains one's energy and reduces the likelihood of one's energy being leeched. This is similar to energy vampires in human form and this goes with the understanding that these are humans or non-humans who have been entirely overtake by the parasitic consciousness and cannot sustain their own auric fields without having to pull from the energy of humans who do generate their own aura or bio-emissions.

The vampire effect relates to how a person can be leeched from only to a certain point. Once the process surpasses a certain critical point then the individual becomes similarly engaged with only the lower bio-emissions as higher-frequency bio-emissions would then become harmful. So in essence, when the vampire feeds too much on one individual, then that individual becomes a vampire themselves.

Sub-Human Entities

The humans are utilized as hosts and energetic sources in this bio-emission battle while there are other classifications of bi-pedal organisms that appear to be human but are not human. As well there are bi-pedals that are non-human entities entirely.

Human-Hosts, Replicants, Synthetics and Carriers

The human hosts that are entirely vampirized by these entities become walking carriers for this virus and are effectively human in physiology but there is more to the human than just the physical body. In these individuals, that energetic component of the human is removed and replaced with the synthetic energy of the hive-mind organism.

There are replicants which are a form of clone, along with synthetics. These beings are cybernetic bi-pedals similar to humans but their energy is too not from an organic biological matrix but a technologically propagated synthetic soul-matrix. The hosts are here according to their agenda to subdue and feed off of the bio-emissions of the human race, although there are no absolutes. The agenda is not always so clear within the various groups who often have a mix of bi-pedal operatives. There have been plans to form of a salvation timeline because the only way to keep the whole process going is through a negation of degradation of the human race as this may close out this timeline forever.

Those with human organic soul-matrixes would simply transport into the next available universal time-stream or harmonic, while those with synthetic matrixes would have to technically travel to the next harmonic using a passageway otherwise they would remain here throughout a zero-point collapse and this would be synonymous with entering the abyss with no viable passageway out until the entire universe is brought back to one organism again.

This is also the process that is described to explain what happened previously as there are 7 harmonic temporal layers of the universe meaning everything is contained in a multitude of 7 octaves similar to light and sound frequencies or harmonics. And so there are 7 civilizations or 7 parallel time-streams and humanity passed through these to get to the last three where the physical forms are located. These are, from the higher to lower, Gaia, Tara and Terra. We are on Terra and if the information I was given is correct then we are currently on a transitory timeline located around Tara where people are noticing changes occurring and multitudes of aspects of the time-stream disappearing and changing simultaneously. Tara is where the last universal harmonic was left through a collapse of time and consciousness into zero-point and this resulted what was termed “the lost souls of Tara”. These are the discarnate souls of the previous civilization that could not travel to the next harmonic and remained without a body in the abyss. Thus they have plagued this plane since then, since ancient times possessing and driving humans to madness and there are explanations that this is the original passageway for the parasite into this universe. This event, the consciousness collapse of Tara would have acted as a fracture in the over-mind of the species generating a kind of cosmic schizophrenia and enabling all kinds of disharmony and distortion described in the previous sections.

The solution to this was described as a healing process that is taking place to purge the virus and that this is painfully similar to the human body purging a sickness however there are methods to promote healing and reduce suffering and confusion however people must contain themselves and their energies and strive to know themselves otherwise they will not be in control. This virus feeds on fear, confusion, spiritual degradation and the energy from degrading acts, lust, addiction, sexual misery and whatever fashion a human can be made to bring the bio-emissions of the energy centers down to a low enough level where co-inhabitation can be formed with an entity that has no access to the higher levels of self-awareness, higher-consciousness, love, or the universal spiritual experience that the balanced human is capable of.

Genetic Manipulation

There are explanations that there are genetic modifications taking place now to possibly preserve this civilization and that there were ancient genetic modifications made to induce a sense of stupor, worship, selfishness, an inability to more easily comprehend the higher spiritual awareness and the occurrence of time and consciousness and other spiritually and consciously limiting aspects. Part of this explanation is that holographic consciousness itself is a kind of limited result, a shadow effect resulting in the presence of the higher-dimensional essence of the soul which is more or less constrained by the body. An extension of this is that the entire holographic universe is a kind of false-light system designed to bend the original liquid etheric light of the soul and spiritual awareness into a rotating, recurring format which ultimately converts the original spiritual essence into an energy generator for entities that are entirely holographically represented. The souled human in this situation is a being who is originally from outside of this holographic projection.

The Ego Mind

In this view, consciousness is the ego-mind which is the false-sense of self, not to be confused with the shadow self which is simply the counterpart of the aspects of the self that we consciously agree with and are aware of in daily life. The shadow self is a result of having limited holographic consciousness and the ego-mind is projecting that limitation of consciousness into the shape and image of a self that is only a figure-head for the real individual essence which is spiritual in nature and immortal.

This Time is about Healing

Everything that is happening now is to motivate people towards healing and unification. This is not about a hive mind mentality where individuality is pushed out.

> "The best I can do for you is become your enemy."

There is a saying that represents the concept that the most beneficial role a person can play in helping one to progress is to challenge them and give them the opportunity to rethink their strategy and in turn improve further with each interaction. This may seem paradoxical but it is effective and explanatory. What we are facing is the greatest challenge humanity has yet to face. This is the unknown, the final frontier, the mind. The mind is our challenge.

There will be more on this later and in other publications but there are indications that the physical embodiment of the human has been altered to introduce implants, genetic modification, susceptibility to disease and ultimately fear-based programming of the brain. Without going further into this prematurely, the lower aspects are at odds with the higher aspects unless we as the midway come forth to mesh the two together in equilibrium. Until then, there is chaos, lack of self-awareness, and suffering.

There are many possible futures converging at this time. There are some less than favorable paths and there is the opportunity to merge with a very powerful path for humanity. This all comes down to how people will cope with information that takes them outside their comfort zones and eventually changes their view of mundane reality forever.

If people choose violence and lack of self-awareness by ignoring the spiritual aspects then that is what reflects into their life experience. When people develop a higher sense of self-awareness and spiritual harmony they can reduce the suffering and reconnect with the lost aspects of our spiritual identity for the first time in the publicly accepted version of recorded history.

There is technology that can change the world and there are great truths which can enable people to know themselves in ways that they never thought possible. Everything is at our fingertips and so we must come together as this is the way we solve the problems and cure the dysfunction.

Healing Through Unity

In various research projects the conclusion of how to heal this spiritual rift was by exposing each other, to each other. When we are all together, aware of each other and our selves, united in the goal of bringing higher-awareness and spiritual harmony then we can observe and acknowledge when one is slipping into chaos or disharmony. When this occurs and we are in proximity to each other in a healing circle or a kind of social unification then the members of the group at large can work together to pull the chaotic one back into harmony towards the group. The group of healers united together in like mind, spirit and body is too strong to be overtaken by the parasite. So when one individual at a time is faced by this problem the whole group can come together as one and assist in healing the individual by pulling them back to reality, back to wholeness and back together with the group. This is literally how the situation is solved in all realities and a breakdown of this feature of society is how the dis-ease proliferates.

Underground Bases

The active aural research program is part of a process to simultaneously verify as well as initiate and demonstrate controlled insanity/sanity.

These programs utilize the deep underground military bases to perform psychic and psychological research experiments on non-consenting youth and adults as well as consenting participants.

There are various means of generating the illusion of consent or even lack of consent and this is all being monitored and handled by oversight authorities.

These operations are directly related to the identification and understanding of the mind-virus and all weapons, defenses, and resistances known to man.

Cloning

Advanced technology is used to transfer consciousness from one cloned body to the next so that a continuous study can take place before, during, and after the death experience of one individual. More will be explained on this later, however this is through the use of advanced supercomputer systems that can function to entangle and then transfer the electromagnetic consciousness of the individual so that they are ‘remotely activated’ within a cloned version of themselves via a ‘brainchip’ (brain to machine interface: cybernetics).

Celebrity Cloning

Celebrities at the cloning center would like you to see what is really going on behind the scenes which involves trauma-based mind control, heavy technological programming and complex layers of influence throughout their life.

Initial Explanation

Many celebrities, entertainers, athletes, musicians, models, writers, producers, actors, all kinds of people from various industries are silently brought to the cloning centers for pay-to-play sessions.

They asked myself and others to pass the message on to you and that you would have to look for the signs and symbols in their media in order to see their hinting at these events.

The situation is heavily controlled using advanced monitoring technology and brainwave/EEG cloning technology. This is technology that can read the brain and determine what the mind is anticipating or speculating upon.

Their reputations are used as leverage as well as their safety and comfort. The level of programming and mind control experimentation that takes place makes it easy to manipulate a person’s brain into regressing into a state of trance that lacks the ability to remember or clearly organize experiences regarding the cloning centers.

Cloning Centers, Underground Bases

Deep underground military bases, 3 miles below the surface, are used as laboratory centers as well as a completely stocked underground city-base. These are connected with high speed electromagnetic drive pods.

Individuals are transferred to the brain through an extensive cloning and temporal body transfer process. The electromagnetic shell of consciousness within the brain is relocated to the body of a compatible clone and various training, conditioning, programming, experimentation, or pay-to-play experiences take place.

Programming

All individuals are programmed to various degrees in order to maintain control and secrecy over the situation. This programming involves very advanced technology, trauma-based mind control, and energetic attachment via beliefs and emotions.

Experimental Operations

These bases were also used hand-in-hand with military operations which were geared towards discovering and controlling all aspects of the human mind.

Genetic Engineering

Experiments involved genetic engineering to produce soldiers, psychics, hybrids, and others that would be able to carry out operations. This leans towards MiLabs and the military faction’s experiments which go beyond the basics of cloning.

Immortality

The initial research included the goal of physical immortality. In many ways it can be said this has been achieved, however there are side-effects and difficulties.

If one does not activate their higher consciousness, then the effect of time dilation causes the conscious mind here to reach limitation points in experience.

What has been termed “blank slate/state” technology has been used to ‘reset’ the perception of time through memory in order to keep a continuous progression viable for the conscious mind. Without this the unconscious and the conscious mind merge.

This begins involvement across time with advanced technology that can operate on the soul level or the conscious mind’s level of access to the unconscious and soul-memories. The Universe instantly creates a cosmic backstory based on the conscious-mind’s access to the unconscious. By controlling the conscious mind’s access to the unconscious the entire backstory of Humanity can be altered and new connections can be bridged in the future.

Earth is essentially a time-ship through which consciousness ascends towards higher states of awareness and self.

How did it get to this?

After WWII when the United States war-faction firebombed Germany and melted many of the inhabitants of the cities into sludge in the bomb shelters and streets of the cities, a group of NAZIs traveled to Antarctica.

Russia noticed the movements to Antarctica and the United States sent Admiral Byrd up with 3600 marines, planes, a battle cruiser and smaller vessels. They returned in defeat and only a few words were mentioned in regards to what actually happened and how they were defeated.

The rumors spread and words of gravitic drive craft, and undersea or under-ice bases originated from this encounter.

From what we were informed as well as directly experienced, this was the ice-base in Antarctica where an underground base was found already constructed with very advanced technology.

Here, cloning was deployed along with mind control and temporal manipulation technology.

Soon, cloning was offered as a way to avoid assassination as well as to prolong and protect the original body in daily life.

After that, celebrities and politicians were replaced with programmed clones who could carry out the orders of the NAZI faction.

This was the beginning; the groups utilizing this technology now are no longer confined to the NAZI faction.

The groups you see today, in control of these operations, are considered MiLabs, secret societies, think tanks, military factions, and other control groups.

Deeper Meaning

The individuals that have been cloned are given very in depth views of the way this society functions and the source of power and change in the Universe. Many individuals are present here from what would originally be another “time” or “timeline”.

There is a possibility that this notion is due to inserted memories and traumatization although until all the information is released we will not have a definitive conclusion.

As of now it is a possibility that these individuals are from another time that goes beyond our comprehension currently.

It may even be a possibility that these individuals have come from ALL of time looking at the very far past and into the very far future of Humanity.

These are the kinds of notions involved with the experiments taking place in the underground bases and military operations.

What is next?

Share this information with those you feel are ready to know and help Humanity come to terms with our journey here and what is going on in these kinds of experiments and take responsibility and power for our own existence.

We are in something that can be called “The Unveiling of The Hidden Knowledge”. This is a cyclic process that takes place to advance a civilizations knowledge of existence. As part of the civilization moves into higher advancement another aspect may lag behind. Either the future will slow down, or the past will speed up. We are experiencing the past speeding up and all the events that have taken place to influence our civilization are coming to light. This is as much a natural cycle of consciousness as it is the eventual revelation of secret knowledge and the particular connection to the secret projects.

> *Those brought to cloning can use their free-will to state their lack of consent to violence and harm and then live in commitment to that by not harming or accepting violence in their lives. The Spiritual Law of Harmony rules in all planes and dimensions.*

Chapter 2: The Awakening

Chapter 2.1: The Machines of All Time and Space

There are machines that are capable of accessing genetic memory and unveiling what can only be referred to as the experience of awareness or existence in between the physical planes of each time or each physical life experience.

Even if they are simultaneously occurring moments of a transcendental nature, there is still an illusory ‘space’ where there is perceived separation and through this there is a perceived ‘space’ that is in between each existence.

Re-Creating The Kaleidoscope

This space is only perceivable when viewing from the physical perspective, like seeing the spaces between the angles of a kaleidescope only when viewed through the lens and similarly, technology can be used to recreate what this kind of illusory space might look or exist like in between the multi-dimensional realm of the continuous experience stream. Through this, these ‘hypothetical’ in between spaces that are understood as only illusory productions of biological consciousness, can be generated through advanced technology with the capacity of recreating that kaleidoscopic view of which the human biological perspective is only a small fraction or even fractal.

By recreating this biological perspective, they can recreate the illusory spaces in between planes and through this they can literally access and experience what are stored in the DNA as the experiences of existence beyond the physical limitations of consciousness and into a multidimensional experience of time and space.

All becomes a never ending sea of consciousness, however this is the given. The trick is to take from this sea of consciousness and slice it down into conceivable chunks from which you can reintegrate a previous personality or identity and continue on a stream of consciousness that would otherwise be tossed to the cosmic wind like fractal stardust as the sands on the beach of hyperspace.

Sand-Castles of Time

We are effectively building sand castles out of these sands of time that would otherwise be swept back and forth into and out of the ocean of life and the universe only to momentarily wash up again as the identity which we once knew.

There is technically nothing wrong with either view, because then, the spaces between each million year occurrence of just so happening to wash up again as you, would be imperceivable because they are only there to be seen when you are you again.

We’re Waiting For Ourselves

Yet, if there were some who had attained the awareness of the true nature of reality and were standing there on the beach waiting for the rest of their cosmic family to come to shore again, it could be perceived as waiting the majority of the time for a very small occurrence and then being alone again up until the kaleidoscopic fractal inverts itself to the point where everyone now is standing on the shores of the sands of time rejoicing and meeting with each other.

The Goal of Two Societies

My goal in coming to you people on the surface of what is called “Earth” is to help assist in the process of bringing the two societies together, one who’s been waiting for thousands of millions of years, and the other who has no idea that they’re even late (or very on time).

You see, those are the only two situations where there could be even the possibility of perceiving such an injustice as experiencing the pain of loss or misconstrued identity in this universe. It is as if two families met at the cross-roads at different angles, and while one waited for the other to arrive, they could merely supply themselves with glimpses of the ruins and remnants of the evidence that the other civilization existed at any one time.

This is not how life must be and this is kind of like a cosmic waiting game of hide and go seek our two mirror civilizations have been playing with each other. One who’s highly technologically advanced and the other who is more or less the spiritually advanced of the two.

Both of them have a unique view of the universe and they are both only complementary to each other as a whole. The more they sat around and waited for one another, with one leaving the clues that the other would find and even switching roles sometimes in different ways, they became even more and more complimentarily associated as the very essence of experience they seem to be missing more and more is the experience of one another.

So as we perceive these as being great losses or great gains of time and culture we are really only remembering ourselves and coming together as a unified existence that once met upon the surface of Earth as a single family covering the entire harmonic spectrum of the Universe.

And that should be the goal of any progressive, any one pushing a new culture or an old culture, anyone looking to teach the young and protect the knowledge of the old, while also protecting the innocence of the young and perfecting the age-old knowledges that have defined our presence in reality.

Our Forgotten Other Half

One could even say we’ve sometimes gone off the deep end, leaving ‘land-minds’ of sorts to process the information that would be present when we are gone. Of course, what we could’ve found when this occurred, is beyond anything we could’ve ever expected and that is the true nature of the complexity of creation and existence. That everything follows the cycles of creation and destruction, however, the memory of everything that has been created can always be accessed (depending on the beach) and therefore the creative aspect is legitimate, yet it is the destructive aspect that is illegitimate and illusory.

Yes, through advanced technology this can be proven in ways that can be verified and transmitted using advanced technology, since that is how we like to verify things these days. There is, of course, a human looking at the screen, the read out, or the situation from a physical perspective to verify the verifications.

All Is But An Illusion

There is a notion that there is only one civilization, one society, in actuality that has been chasing itself through time. That we cannot actually find the same place and the same time where both meet because we are each other from different perspectives. We can only get a mirror where this is possible, or an ‘hyperdimensional’ internet channel where we can stream one’s consciousness in from the other reality and interact with them through that here in this reality. Thus the two civilizations can achieve the experience of their own civilization and the other civilization by merging with one another but only through a remote contact, just a relay, not an actuality.

The harsher, darker side of this is that any civilizations between then and now that we did happen to meet that proclaimed to be “the one’s” we have been waiting for, and in essence our darker or lighter halves, are actually the impostors who exist entirely apart as a sub-set and have taken a liking to trying to trick the reality out of one of the other civilizations.

Of course, if these are another form of being altogether, and this is all brought about through an interplay of consciousness and deviations from an original core reality, then all will resolve itself when that core reality is alone again. This indicates that all realities will either move closer and closer to the core until they unify, or farther and farther out until they transmogrify beyond recollection.

Life Itself Is The Highest Illusion

That hyperdimensional internet channel that is created out of advanced technology to merge the parallel realities (rather distastefully and maybe disastrously at times) allowing different civilizations to interact with each other, well this has been created using technology.

But then it was discovered that this is the ultimate nature of DNA. That this was ‘invented’ similarly as a higher-dimensional internet so that various natures of different planes and dimensions could interact with each other and experience the richness of life.

The universe becomes more like a living arcade game then, where people come from all over the galaxy to ‘plug in’ to human experience and figure out what it means to be physical, human and on Earth.

This does tie into the larger nature of reality, of star-races, and of time and consciousness that is often reversed according to how things seem to play out in physicality. We are moving through time, but just because we are moving one way, does not mean that others could not be moving the other way.

We have to live our lives with meaning knowing that the message we pass on, the duty we vow to accomplish and ensure is meaningfully connected on either end to the passage of the past and the power of our ancestors to the function and knowledge of the future creating a clear passage between the realms, the generations, and the ends of the universe. This is what literally ties the universe together, and the mind if each individual. This purpose is contrived when not carefully shaped within and so we must help all who seek purpose learn to become the blacksmiths of their own destiny through the temperance of desire or temptation and the discipline of developing strength and maturity where there was once weakness and naivety.

Once we know this is our duty, this is what we seek to achieve and this is what is done, then we can become part of the universe forever. Of course, this may only be temporary in the larger view of things.

Chapter 2.2: The “Awakening” of 2010

In 2010 I was “awakened” at an event involving hundreds of people that play various roles in this society, the secret society and the breakaway civilization. This also took place across times or planes of reality.

During this event I was informed of the situation on Earth beyond the informational barriers that were previously in place to limit knowledge to only what is required for specific operations. I was essentially “informed” of the entire situation as much as the mind could handle this.

As this was occurring, the team that was updating me on the status of Earth was being informed of and given information regarding changes in the future. In short, interviews, posts, and releases that I have since made and will make in the future were touched upon. Quotes were given from the blog and interviews which were jokingly acknowledging verbal mistakes at the pronunciation of names, new perspectives and interpretations and more. As they were informing me, they were creating the future reality where this work takes place. That is the basis of this layer of the operations. They are creating the future person by person, layer by layer.

Memory Suppression

My memory was unsuppressed and all the traumatic memories and experiences were unveiled to me. This was almost as traumatic as the initial experiences themselves although precautionary steps are taken to ensure the safety of the individual. There are teams of highly competent individuals of all kinds with professional backgrounds of every field imaginable.

Throughout my entire life I have had memories of experiences, at this event I was informed what the experiences meant and what was actually happening. I've had memories of underground bases, cloning, stargates or interdimensional gateways, advanced technology, non-human or programmed biological entities, sacred knowledge and experiences, the power of the mind, and breakaway civilizations. Most of the time we are conditioned to believe these are past lives or experiences in another reality so as to enable continuity of operation.

Life and Consciousness

From my perspective and the perspective of others, we had reached the 'future' and had been sent back through the utilization of advanced technology and cloning to return to this time and inform others of the possibilities.

The True Human Potential

This is so far beyond what anyone can accept or comprehend fully that humans with an emotional, mental and physical aspect balanced as one is literally a cosmic reflection of the entire universe at once. This is the closest thing to a "god" in the flesh. And be sure, the entirety of this rests on the behalf that the man is protective and helpful. That the woman is nurturing and loving. That is the point. "god-man" does not mean a warrior who destroys everyone and anyone in his way getting what he wants. Nor does it mean some lusty and vampiric form of energy or mind control game. "god-man" means the love of the universe, the power of the body and mind, the peace and calm of the ultimate stillness all in one.

This power is in human DNA, originally so. And so this is awakened through walking the middle path of neutrality and 'splicing' the timelines down so that neither one nor the other gains the power of the individual. Through this, the individual creates their own power, right on the spot, without having to lean to one extreme or the other. This is like a cosmic, temporal balancing act with emotions and mind. Where we give our energy is created in the universe in the form of many productions and effects. If we are simply thinking in an imbalanced manner then we are producing timelines and side-realities that exist in the etheric realms that we can't see and these realities will reflect our inner imbalance. So then when we are balanced in our energies we are not creating one or the other side of divinity, we are literally creating the whole universe, cleaving down the middle and producing both sides of divinity or eternity equally and this is the only way to have an eternal production which does not eventually degrade to one extreme or the other. Through balance, we reach eternity and in this way all the power of the universe exists within a person through their ability to balance their emotions and mind and thus unlock the DNA.

The DNA is coded through bio-emissions of mind or emotional body. So we are constantly doing this and we are either producing a DNA code that reflects imbalance overall, or a code that reflects the eternal balance of the universe overall. This is through energy.

One reaches “heaven” or the deity planes or simply self-actualization, through three paths. These paths are through merits or devotion to principles, or through knowledge and expanding one’s mind to face the universe, or through great works and deeds to produce this effect of power, knowledge and emotion unto the world for others. Through these paths we create an impact on the universe and this transfers what we are temporarily and physically into an eternal energetic and physical production within the living universe, forever. To do this requires balance, focus, devotion, and discipline however because there are many distractions along the way.

The Light-Body

You must build your own light body. That is how it works.

Your heart creates a field and projects you.

Rely on yourself and use that for protection.

The power of the Universe will align with you if you align with your self.

Learn as much as you can and break through duality of love/hate, cultivate your knowledge of the self and use it.

What you want is what determines your power in the light-realms. Not how you want it. If you want war, then that is a sign of weakness and determination to produce imbalance and exist by that. If you want peace, that this is a sign of power and unity to produce further unification and exist by that. What you want determines your power, not how you obtain it.

Technology of the Awakening

Mental Manipulation Technology: Touchless Neural-Interface and Enhanced Awareness

I reached what the “Illuminati” called the “awakening”. I feel a better term would be “unlocking” as this event includes the removal of all traumas, perceptual distortions, and memory suppression.

This event was a presentation of very advanced technologies which allow the mind to transcend space and time. It was shown that death is similar to a phase-shift of consciousness as polarity and that the awareness of the being obviously continues. This was verified through advanced sensing devices which can visibly display frequencies which are invisible to the physical senses. This is also something that occurred earlier on as a child in the underground bases by transferring consciousness in and out of the body at will using advanced technology.

With these devices it is possible to see the "auric" or soul field of the individual. Any living body has a field which glows when picked up by these sensing systems. This field becomes more refined when viewing more advanced beings. Human have an extending mental field, and through this a kind of glowing awareness that is picked up. It can be fairly simply compared to thermal imaging except instead of differences in temperature it is the presence of a soul or mental energy field around a living body. The finer energies extend outward away from the physical body.

More than once, the situational requirements were satisfied in order to produce an ideal environment for maneuvering on the non-physical plane. This is the basis of how the temporal operations occur, yet these events were different than previous operations or experiences. The group I was in was going through the process of increasing the vibratory emissions of the "bio-mind" in order to stay focused on the increasing vibratory rate of the environment. Generators were utilized to create an effect on space/time which was perceived on the "soul" level. These events went into the discovery and explanation of the creation of the "godlike" powers of the advanced sentient technology which was capable of accessing the holographic nature of reality which humans can perceive through their bio-mind/soul. These technologies also enable one to perceive what is referred to as the "galactic history" of Earth and humanity. We are far vaster and Earth is far larger than people are lead to believe.

Time Dilation and Temporal Recurrence

Time dilation capabilities were shown which allow for accelerated learning of advanced and detailed material within a very short amount of time. This could be seen as a kind of viewing technology which one wears or looks into and vibratory emissions are scalar-linked to the brain which then allows the individual to perceive more information simultaneously. Then there is a very rapid pace of information streamed on a monitor or through a device and this is akin to watching a 20 minute instructional within a few minutes or a few seconds with very advanced minds. The more time is slowed down while information is accelerated, the more stress is applied to the brain. The brain tends to overheat and over stress with high-rates of activity, especially without conditioning. The conditioning is what allows one to utilize their mind and body in these manners. This is not unlike the very rigorous training and conditioning of certain monks or martial artists however there is very advanced technology and other hidden methodologies utilized.

Crystal Technology

These are capable of holding, transmitting, and amplifying consciousness frequencies. There will be a more detailed explanation in a later section.

The crystal technology is used in junction with the power devices to enable a scalar-mind link which allows the interface to be entirely mental or spiritual, IE: they are not controlled by hand but by focus and intention.

Time Crystals

These are utilized as a computer recording chip would be to run a program yet they hold memory in expanded space, IE: they function in a hyperspacial manner and are essentially hyperspacial computers. These are what will be introduced in junction with the quantum supercomputers.

Quantum Tunneling Diodes

This is technology that has recently be released to the public. New technology is developed years ahead of time and then slowly released to the public in a cascade of advancement. This technology deals with superconductive materials which enable the transfer of information at faster-than-light speeds.

The supercondutive material allows for 100% efficiency of data transfer. So what happens then when the efficiency surpasses 100%? This is possible because we are effectively in a simulated holographic environment. The experience is real, however everything is overlayed via particular limitations for the ‘local-environment’ which is like a central data processing limitation. When these parameter are surpassed, one by one, through a coalescence of refinements and methods, the result is akin to a glitch in a computer game system. They have accessed faster-than-light technology and the mind is also capable of this naturally.

With this technology, however, the information can be received a very small amount of time before it is sent. So if a person is absolutely surely going to press the button to send the message, then right before their finger hits the button that message will be received on the other end, as if magic. If they simply play around and pretend to hit the button but very quickly turn away, then of course nothing happens. One can, however, ‘fool’ the universe in other ways and this is simply through the reception and transmission of information across what should be secure information barriers.

Tachyon Fields

These are programmable fields emitted through advanced technology. I was shown how tachyons are the sub-atomic “particles” or energy formation which flows both ways in time. We are receiving tachyons from the “future” in order to layer the flow of time in one direction or the other. Tachyons are the name of the particles/energy packets that we perceive from this perspective as reaching us to initiate the “future”.

Thus, when a stream of tachyons is concentrated and accelerated, this results in an acceleration of the temporal field and we literally experience an acceleration of time. This can be focused and targeted on a specific piece of equipment to change the way information will be sensed and to essentially allow that device to sense ‘ahead’ of the present moment.

The same effect can be produced with the neurological processes of the human as the physical coupling of the brain to the mind can be altered through a concentrated tachyon field to enable the neurological and mental processes to begin to perceive information ‘before’ the brain is actually physically processing the data. Therefore the mind of the individual will be present in the body while the senses and other perceptions will literally be expanding into the future beyond the present moment.

This is highly confusing at first and requires much training and conditioning in order to make sense of enough to operate in any kind of effective manner.

Upgraded Chronovisor

See, “Upgraded Chronovisor”

Time Tunnels

This was developed earlier on and has been the subject of many TV shows in the past and present. The shows are a sure-fire method to get the information to the public without having to force those who are not ready to comprehend. The information is easiest to digest if people think they are watching science fiction.

These are essentially spiraling tunnels of these tachyon fields produced by large electromagnetic field emitters in the shape of a conical tunnel. As a person moves through this field, their temporal acceleration changes and thus their frame of reference within the universe changes. They effectively move their mind through stages of existence or temporal resonance in the universe and this can have devastating effects.

This is an older technique how is still in use and has specific purposes depending on the situation and the information sought.

The “Trip” Chair

The early use of this technology did not use time-tunnels. There was a helmet that was devised which would create a feedback loop of the brain’s activity and funnel this out and then back into the sensory input. This information would be accelerated and redirected to the point that the perception of time would “fold” in on itself until the person would access an expanded temporal perspective of the universe meaning they would mentally temporally dislocate from the initial frame of reference and extend outward further and further in repeating cycles until the same moment was replayed and then all other possible moments in a kind of fractal-like recursive pattern and the very far future would be realized. Essentially, this technologically produced the class “flashing before the eyes” of the entire life experience that is described in near-death experiences and the entire temporal body would be very quickly unwound before the person’s inner eye.

There would be a complete disconnection with the current frame of reference that the collective Earth environment is processing under. That is, this ‘time’ and ‘space’ would be completely out of perceptual reach and a new time and space would be rendered instead. Until the experience had completed, there would be no way to contact this civilization.

There are other versions and ancient versions, tandem operations, more ‘organic’ methods, and modified travel capacities.

Kozyrev Mirror

This is a piece of metal, usually aluminum in early models which simply bent the bio-emissions of the body and mind into a pattern which would create a vortex. The vortex shape and vortex mathematics enable energy and information to travel in across space and time by ‘short-cutting’ the physical plane.

The result of this is that the vortex that is generated over a specific area through an individuals bio-emissions would be capable of interacting instantly with the bio-emissions of another individual who was placed within a duplicate mirror device which was generating another vortex on their end.

The two vortexes acted as a kind of hyper-dimensional telephone cable, literally like a can and string and the perceptions of one another were accessible. There were many uses for this and again, many ancient interpretations of this technology that have been hidden from the public. Nearly every version of these technologies were present in previous times.

Universal Recurrence

This is a discovery that the universe recurs in cycles similar to a wheel or even a washing machine. The washing machine metaphor is fairly accurate and playfully descriptive because without the technology to observer, or an awakened soul of a spiritual adept, people would go for eons without ever realizing that everything in the universe repeats itself endlessly.

When traveling to the far ends of time, it was discovered that one can move far enough away from the ‘present’ or the local frame of reference that ultimately everything is at a maximal informational opposite to what we have today. After this point, everything begins a slow shift back to the present. Through this, one can cycle around again and reach the present by going far enough into the future. This was an amazing and confusing discovery because of the implications about what is actually changing each time, the reality of what are called parallels, the continuity of temporal experience, and basically a ‘recycling’ effect of all experience in the universe. Nothing is lost, but this is also an issue because then nothing is actually ever gained!

Remove Viewing, Temporal Lensing

An ancient device which has been rebuilt and perfected is capable of using these technologies to create a lensing effect which draws a ‘reflection’ of time into a projection system which is effectively capable of acting as a ‘visual time tunnel’ into future probable realities. This is a device which generates a visual portal which allows one to view the future.

This device also exists as ancient counterparts which are located around the world, namely in areas that have been recently sought by the world superpowers. Nothing is as it seems. If you read a story in the public venue then you can be sure that you have read the cover story while the reality is much deeper.

Temporally Linked

The use of the viewing devices which enabled interdimensional lensing of possible futures was found to be stabilizing our pathway into those projected futures. This was enabling a time link between the present and the possible future.

In order to avoid the catastrophes of 2012, the link was broken between the two civilizations and the devices were rendered inactive for this period.

Natural Vortex Energy Locations and Geography

On Earth there are natural ‘time tunnels’ where tachyon fields and vortexes are produced by internal elements. These are mountains, lakes, deserts, fields, sacred sites and other areas that have always been reported as being ‘paranormal’ or containing some kind of specific energy that enables contact with another reality. These are simply naturally produced areas of this vortex energy that produces an interdimensional nexus point through which multiple other parallels can be interacted with. These areas produce an effect on the body and mind similar to the technologies described above.

Most of these effects, from these technologies, change the way light is received or emitted by the mind and DNA.

Mount B.

There is a specific mountain where a base is located, and I have mentioned this before, where the base is so deep within one of these vortex areas that everyone working there is either there for the entirety of their life, or they are only permitted to be there for a very short amount of time. This is because of the acceleration effect. Essentially, if one was to go into the base and work for a matter of hours or day, in some places even minutes, then when they returned to the surface they would be years in the future, sometimes decades or centuries. This is very dangerous and you can imagine the original people who found this area and what kind of situations occurred.

Now with the advanced technology that has been developed these issues can be mitigated and much more control over these effects is enabled.

Particle Accelerator Temporal Manipulation

Using particle accelerators a “fold” in space/time can be made so that when the accelerator is turned off or tuned back into a certain frequency (not sure) everyone within the field will “snap” back in time to the specific moment when the fold was first created.

I have seen this done on small scale, and a rather larger scale, but I cannot be sure if it was only me. I believe I have seen it done on a town-sized scale during the 2010 Awakening where some of the events reached a scale of nearly cosmic proportion and the entire sky and horizon was lit up with technology and entities, as well as Solar Warden, the NAZI faction, secret society groups, and breakaway civilizations or complete other civilizations, some of which were non-human.

This is done using particle accelerators to quantify space on the quantum level (as a reference point with the mind) a frequency would be “folded” into the space time continuum as we “rip” through space holding an access point open at this fundamental level of space/time. This allows for a ‘letting go’ of the frequency, or a ‘snapping back’ by allowing the entanglement to solve itself. When used with generators that propagate out efficiently enough, the effect is akin to a time/space rewinding effect. Some people have noted various theories describing this in relation to the CERN device. These technologies were described as smaller versions of the CERN device and are related to higher-dimensional travel via folding space through electromagnetic fields. This is literally artificially technologically “holding space” for a specific area in relation to a period of time. Time is a more complex notion as an abstraction but by locating the frame of reference this can be applied to distort what would otherwise seem to be a continuous flow. When the frequencies are allowed to “snap back” all sentient observer sources return to the environment they were present in when that frequency ‘rift’ first began. Essentially this creates a replay effect on the consciousness of the individuals within the field. There is no physical effect. The consciousness is ‘regressed’ through time/space, and they re-experience existence from that initial point of contact with the frequency “rift”. This is best explanation I can currently offer however more is coming to the public each day.

This is literally like a “restore point” on an operating system except the computer system is literally the consciousness and space and time of a portion of the local-environment of Earth.

Riding the “Timewave”

There are teams of individual who operate in tandem with the technology of looking into possible futures based on the present and operating through the present via other operatives who are carrying out operations and movements that will construct the various possible realities that the original team of individuals is hopping between. These teams literally “ride” the “timewave” of the future hopping between possible future realities relaying information to the present depending on what movement will be next.

Dematerialization and Rematerialization

This is technology which transcodes the information of an individual human into a holographic projection of light which can be transferred between devices. There is a special system in place that is required to successfully transmit a living human being otherwise just the body will be transferred and the soul will remain, effectively killing the individual.

“Jump Rooms

These are large areas which are capable of acting as a kind of technological ‘portal-gate’ where an entire team can be instantly transported from one area of the universe to another. The space between the two areas are ‘twisted’ like a spiral and then ‘snapped’ back to position and if done correctly with the two frequencies of both locations merging then the team of one room will transfer to the destination pad.

All these methods require training and conditioning, most people are at the very least visibly shaken from the experience which is a bit like being microwaved into a liquid ether and shot through a particle beam at the same time.

Ion Shields

These are areas of concentrated ion emissions and this can be used to create a deflective layer of heated air where light will reflect at a programmable angle. When this occurs, a person standing behind the shield will appear to be invisible to others who are looking straight at them. The light will be bent in such a controlled manner as to perfectly shift around the person in a fluid and equal flow so that the 'bubbling' effect that was noted early on can be mitigated to produce a complete mirage where there is relatively no sign of difference to the untrained eye. An entire group of individuals and equipment can be hidden in the background a matter of yards away and as long as the person is not intently, inspecting each square inch of ground and air they will not notice any difference between the area that is being covered up in the distance and the area directly next to them without the shield.

Similarly a 'screen' of imagery can be projected onto certain materials in the air and a hologram can be projected which will render a background or foreground image. This will work to a degree, and from a distance this will work to disguise an entire horizon.

Instantaneous Healing

There are instantaneous healing methods which utilize various technologies. There are substances which can initiate a complete and real-time regeneration of living tissue from almost any conceivable non-critical injury.

These are chemical serums which allow the cells to replicate at an astronomical rate while suffering damage to the DNA telomeres at repeated use.

There are many methods but mainly the living-light harmonics is one of the latest advancements and most effective at producing healing on a molecular level.

"Living Light" Sound-Harmonics and Electromagnetic Healing

There is a technique for producing a quantifiable scalar wave which interacts with the living cells of tissues and instructs them to repair at a faster rate. This has been called "holographic healing" by others and these are essentially 'living light' frequencies which interact with the cells on the same frequencies that they operate on when healing and interacting with each other. The scalar waves emitted generate the same patterns and this creates an 'ether' fluid that enables them to grow and repair the tissue faster.

Electrogravitic Craft

Advanced craft which utilized counter-rotating torsion fields propagated by very powerful quantum computers and zero-point energy devices.

There are also more modern versions that use powerful electrical flows to neutralize inertial resistance and ‘slide’ through the gravitational field of the crafts own materials.

Energy Cores and Storage Capacity

The hand-held devices that are in use do not require charging or even disposal. The storage capacity of the batteries is so efficient that they last for a lifetime of use. Some devices use an energy generator within the device itself. These “batteries” which are not batteries but little, powerful generators and can explode if they are mishandled.

These are the cores that are used to power many devices and essentially pull energy from the space-time ether.

3.5D Replicators

There are replicators that can produce any conceivable 3D material or object altogether including food or organic material. These use very high amounts of energy to ‘force’ the electrons of the atomic grid of a substrate to shift into the pattern of the element being replicated. The result is a device which can use wave-emissions to reshape materials on an atomic level and produce or recreate any object or substance.

3.5D Sensors

There are sensors that could reverse the process and detect every minute detail of the structure of a body or material. These use energy emissions to detect the structure of a material down to the minute electrical resistance on a molecular level. Similar to diffuse MRI imaging for a living body but more advanced.

3.5D Printing of Clones

It was shown how this technology was used to three dimensionally print human bodies into space/time which could then be used as vehicles for the consciousness or souls of various sources.

Cybernetics:

Neural-interlace/4D Connectome Recording and Simulation

Very advanced supercomputers exist with the capacity to translate the bio-emissions of the brain and body and reconstruct the entire inner visual and sensory experience of cognition and emotion. From this, entire dream worlds can be created which mimic the experience of consciousness. This is most similar to the current day use of diffuse MRI imaging where water molecules are traced through the individual neuronal pathways and an entire digitized image of the brain is developed. The more advanced version described below generates a 4D hologram.

A super computer and advanced sensing system essentially develops one of these connectomes of every connection in the brain. Then this system develops a neural processing pattern that matches the entire memory and personality of the brain.

This is then recorded and extrapolated by a powerful computer system and a simulation of the experience can be observed through the physical body's memory via a monitor system or the neural interface of an operative.

Essentially, this technology can record and replicate a person's entire memory and life experience for viewing purposes.

EEG Heterodyning

This is the technology which enables the activity of the brain to be influenced through generating a scalar grid and a carrier wave system which can cause the brainwave patterns of the targeted individual to resonate in sympathy with an externally projected frequency. Thus, emotional states can be manipulated as well as specific thought or behavioral patterns. This works similar to binaural audio where two tones of different frequencies are played through each ear and the brain resonates in sympathy with the difference between the two tones. This occurs with brainwave frequencies and thus the brain 'slips' into the frequency of the third tone, the difference between the two being projected. This can be done with ultrasonics and ELF emissions.

Artificial Hallucinations

The neural-interlace can also be used to merge the brain of an individual with a computerized system that will be able to produce effects and hallucinations within the individual.

Through this technology, any stimulus, any input can be recorded and recreated once a functioning connectome has been generated and neural-interlace has been achieved. Entire virtual world scan be created and experienced and after the devices fine-tune the frequencies to match the individual's brain functions one world is indistinguishable from another.

Brain to Machine Interface Holographic Consciousness System (brainchip interface, virtual reality simulator)

Some of the training is done by entering into a visual-audio dream-world. Some "programs" will consist of repeating a certain task over and over again until it becomes muscle memory in the brain. Others are designed to probe or test the mind until a certain response is received.

This is achieved through the operation of a 'brainchip' or a brain to machine neural-interface in the individual which was developed during WWII.

This consists of a small computer ship which merely relays stimulus through frequencies and neural-stimulation of varying kinds. The frequencies and location of each region of the brain will determine the function and thus the chip is used to localize electromagnetic input and the brain’s functioning can be modified from there.

As well, the entire psycho-etheric form is vibratory in nature and so through the introduction of vibrations and frequencies from the implant there can be a modification of the frequency of the entire being or what is called the soul or “bio-mind”.

Utilizing The Temporal Body

The temporal body is described as the body ‘in time’ that exists a few seconds into the future instead of the temporal position that is relative to the present. This is as if the ‘future’ is streaming outward from the body as ideas and feelings are as bio-emissions. So this ‘future’ energy is spiraling and streaming outward like a fountain. Thus this frequency can be attained and influenced while the present moment seems unaffected. However, when that individual arrives at what would be seen as the future they would intersect with those influences and this would be as if the interference or effect was streamlined to that future moment.

Manipulation Through the Temporal

This can be used to both produce an effect on an individual who will later feel this effect in the future. Or this can be used to operate outside of the physical plane, in a temporal manner which is literally ‘hovering’ just outside or ‘after’ the present moment of the local Earth environment. This would be as if a person is out of sync of the frame-rate that a viewing device is capturing images of an area with. Because they are out of sync, they are then ‘invisible’ to the capacity for this viewing device to see them. Because they are still present in the same local-environment but simply just out of range temporally, effects can still be produced and this will mostly interact with the person’s temporal body.

These are how many operations are carried out as the operative who is interacting in the temporal body will appear to be a ghost image or a dark silhouette that is only perceivable to the mind’s eye. A portion of the population is entirely psychically blind, while another portion of the population contains psychic capacity. So those with the psychic capacity would be able to sense and partially “see” as a form of energetic detection when an operative is interacting with the from the temporal plane.

Through this plane one can easily enter into someone’s mind and produce effects in their dreams. These effects would not be received on the body but mentally, this leads into astral and mental plane activity. There is also temporal manipulation that can be physical effects that are simply offset to seconds, minutes, months or years in the future. These will be offset from the present aspect of the body in a modulated frame of reference and the effect will remain there in the temporal body until the physical body “matches” the temporal body frequency of that future moment. This is kind like an energetic trail we are leading ourselves up to where the temporal body already connects with each future moment but the present physical body remains separate until the two frequencies are matched. The physical body essentially ‘flows’ forward into each new frequency of the temporal body.

This is the body where temporal implants can be inserted and sustained so as to tie the frequencies down and limit the amount of awareness a person can gain before they manually remove the implants or overload them. Overloading and removing can both be painful however if the implant stays it will at like a governor and transmit access temporal ‘momentum’ or consciousness energy to the owner of the implant and will also drain the temporal and physical body acting as a technological leech as well.

Astral or Light Body

This body was described as a more emotional form of the energy that is emitted from the physical and spiritual system. When a person’s energy is at a high level of activity, this will be visible on the astral form and these are the energies that are often siphoned away through the use of advanced technology to convert the human into a generator system for energy harvesting.

There is talk that this proves that the human existence, in the modified form that is present today, is entirely for genetic harvesting. This may be a confusion, a deception, or a reality. Regardless of the interpretation, the human energy system will leech this energy out into the cosmos when consciousness and energy is mishandled or allowed to flow through the lowest common pathway. This excess energy is very easily usurped and utilized by transdimensional parasitic entities and devices.

This is the body that is utilized for astral travel which is a kind of frequency that exists in between the density of the physical plane and the highest etheric plane of the spiritual, heavenly, or deity realm. There have been explanations that this plane is entirely technologically propagated and that when the devices are turned off, which is an event that will bring about civilization-wide change, there will no longer be a deep and wide, foggy deviation between the higher spiritual and the lower physical plane but a clear path between them.

Similarly, the consciousness and entities that are present here would be no longer accessible and their connection to the physical plane would be non-existent. This could be problematic for those who are trapped within the astral such as human souls or those who have taken a cyborg route and require a return to the original planes either physical or high spiritual before they can secure their position in the universe.

This also relates to the early discovery of these ancient devices containing portals or gateways to these realms and the early experimentations with enabling contact between the physical Earth plane and the lower astral realm containing discarnate entities that would very easily sustain themselves on the lower astral bio-emissions of a loosely guided emotionally reactive human vessel.

This is where entities can attach and will look for those who have the most excess astral or emotional bio-emissions leaking into the universe. People are kept in an emotionally unstable state of being because this is the easiest to feed from and as well the individual will always be looking for more energy or the solution to why they are feeling drained rather than discovering the truth nature of the universe.

However, as with every lower route of obtaining self in the universe, the more this is done, the greater the likelihood that the individual will realize something is happening and ultimately awaken. Or they will no longer be present here and the parasite will have to find a new host because the longer this process is maintained the more difficult producing one’s own energy will be for the parasite . So parasitism is a limited, one way street.

Monitors can emit consciousness/brainwave altering frequencies.

Monitors can emit consciousness/brainwave altering frequencies. This is what I was informed and shown. All electrical wiring and communications can be fully utilized to produce and sense on an electromagnetic level and this is capable of determining the consciousness and biological functioning of the individual being monitored. Houses are essentially large, wired, box-shaped sensors.

This has been the case for a very long time and the first TV’s were actually built with a little chip that connected to the human brain.

The electrical grid of today is capable of interacting with the implants, brainchips, or the psycho-etheric electromagnetic frequencies of the human brain, body and bio-mind via scalar frequencies. The TV's, lights, electrical wiring, radio towers, computer monitors, everything is capable of transforming into a scalar emitter when combined with the control mechanisms and these are accessible from a distance.

Microwaves can be emitted from a current day craft which can then reflect back from an environment and give a real-time 3 D image of the interior of a room. The same technology can be used to beam at a monitor and reflect the variance in interference which can be used to read a computer monitor without actually having to hack into the system.

All systems contain backdoors which enable easy-enough access and as well the entire communications grid is monitored and recorded through advanced technology.

This is, in part, because this entire realm is like one enormous recording device where the energy of each successive moment is connected to one another and so with sensitive enough technology these electromagnetic waves can be ‘re-winded’ so as to produce the ability to look into the ‘past’. The initial technology that was developed for this purpose has been called the “chronovisor” in the past and there are much larger and highly advanced versions today.

The Upgraded Chronovisor

Instead of a relatively small machine which produces an interference pattern that is projected unto a small screen as was developed in the past, the modern versions create an entire holographically projected environment that enable one to nearly completely interact with the projection of the past. This is more of a viewing device capacity but one is essentially projected to the electromagnetic/temporal area of space and time consciously and can witness the scene from “within” the projection.

Before this, the scene was literally viewed on a kind of flat, holographic monitor that reacted to the scalar emissions of the mind and could be ‘tapped’ into by an adept-viewer who’s mind would have to remain steady enough in order to maintain the scalar “mind-link” otherwise any interference would disconnect the projection.

Through the use of cloning and advanced super computer technology, later versions include the actual operation in and out of time.

Community Servers/Living Server Systems

From the previously described neural-interlace and supercomputer enabled virtual reality systems, server systems have been created which are an individual or collective experience of the virtual mental realm.

In this realm individuals have existed for an amount of time that would not be easily compared to the way we understand the flow of time in waking reality. This is very similar to dreams where the perception of time passes very quickly between waking moments yet inside the experience of the dream it can seem to last for days.

In these server systems the development of complete societies has taken place and these are considered an extension of the human civilization.

This is the beginning of where the situation becomes greatly complex. If these server systems are capable of transferring consciousness forward or backwards in time, depending on the situation, and they have holographic access to Earth *before* physical humanity, then which civilization came first, the simulated realm or the physical?

This is similar to the etheric realm and the question of where humanity originally came from if the physical matter could not be produced from nothing, yet could not always have been here. Was the physical matter produced from some kind of universal device similar to how the recorded consciousness of the individuals in these holographic world simulators could have been used to generated initial civilizations on Earth?

Cloning, Cloud Supercomputing and Consciousness Transfer

The following is a more direct explanation of the previously described processes in relation to consciousness transfer

Superluminal transfer of light information allows for the reception of information from a temporal non-locality. A computer system that can process the information faster than light at 100% superconductive efficiency can send and receive information from different Universal harmonics. These are quantum superconducting super computer systems utilizing materials and methods that achieve superconductivity a a temperature that is relatively easier to consistently maintain.

There are systems that generate a vortex which can be expanded to recreate the singularity of a non-local perspective and dissociate from the current Universal vector. This is essentially recreating the temporal frame of reference of the consciousness of a physically anchored body and using this technology suspended electromagnetic frame of reference to literally transfer the consciousness across space and time to a frame of reference of choice.

The technological capabilities of humanity expanded to include replicating the holographic information of the DNA and neural pathways using quantum supercomputers. This technology allows for one’s consciousness to stream through a computing system which can recreate the neural connections as literal as possible through quantum computing and technological “brain cells” which function as neurons.

The result is a cloud computing model which functions as the individual neurons as well as over unifying layers of interconnections within the technological neuronal ‘cloud’. A holographic representation of multiple layers of processing is formed, superimposed over one another through a geometry that is actively synchronized across multiple dimensions of interrelation. This is the first notion of a “living” computer system that can update and respond to new information in new ways.

Now the that computer system is capable of attaining faster than light processing in tandem with a system of dilating a field of electrogravitational waves into a vortex, the holographic information of neural pathways and genetics can be transferred between one supercomputing system and another across “harmonic barriers”. Essentially, these consciousness transferring supercomputer systems break the “light-barrier” by sending the living-light consciousness data of an individual into a new plane of reference that enables interaction outside of what we would call this timeline or dimension.

The frequency that the receiving computer operates within can be measured in respect to the overall harmonic “vector field” in respect to the entire planetary environment. This vector-field frequency is the base frame of reference that one could say our particular “time” and “Earth” is “moving” through in an abstract electromagnetically defined dimension that is invisible to our senses. Each particular time and Earth is only visible to those whose brains and minds operating in resonance with the rate of acceleration frequency of that particular existence. By changing the rate of the brain and bio-mind, one can enable a technologically assisted synchronization with alternate timelines.

A pattern can be generated based on quantum fluctuations that will act as a key that can be accessed from other universes. This same backdrop is measured and then adjusted to resonate with or replicate the same frequency on a computer doing the sending. This frequency is then modulated with the holographic information of the neural pathways and DNA. The information transfers as a result of quantum entanglement across harmonic barriers to the original computer system set up for reception. As long as that frequency is held, there is a link across the harmonic barriers of the Universe.

Cloning, Supercomputer Assisted Holographic Consciousness Replication and Time Travel

Cloning as Offspring

The human body can be cloned similar to the way a plant can be cloned. A number of "replicas" can be made from the original genetic material. There is still a mother required however the process is not quite similar to natural reproduction where the genetic material of two people is combined to form a third. This process replicates the material so that the 'offspring' is the same as one of the donors.

What this truly infers is the question of whether the original consciousness stays in the original body or whether the consciousness actually jumps from one body to the other. There are multiple explanations and methods.

Inserted Memories, Digital Dreams

One explanation is that artificially generated memories are simply downloaded into the individual's brain directly. Thus, they have the perception that they experienced life in another body and were present for some unique experiences that did not occur from the perspective of the original body.

In a slightly differing explanation, this inserted memory process may be used to prime the consciousness of the individual so that operating in a cloned body will be more readily accessible by the adaptability of the mind of the individual. Without a holographic dream insertion the mind will have trouble adapting to operating in more than one body even if they are not being operated simultaneously. The mind is the immaterial self; consciousness is the ego-physical identity of the brain and body. The brain does not operate in both bodies but remains, so then the mind is what is strained and this is the immaterial "bio-mind" that transfers.

If a true transfer occurs then when the physical form is cloned the cloned body acts as a secondary vessel for the original soul or a soul similar enough in frequency.

Co-Inhabitation of Bodies

Another explanation is that souls can only occupy their original body. The people who are "body snatching" (see: Soul Stone) are not activating their higher-dimensional soul-pattern and this is why they are hopping from body to body to ensure memory and ego continuation. This form of body transitioning requires technological means to assist in the process.

This is done through computer systems to allow an artificial brain to represent a holographic image of the organic brain's sensory, emotional and mental input and output. Thus, from an artificial brain there is enough memory and power to compute the processes for an organic human brain.

Through this a living human is utilized as a carrier for the additional consciousness which then takes over and integrates into the original consciousness.

Clever Replication a Digital Mirror

The next question is, does this merely create a very cleverly designed image that will look, think, and feel as if it were the original, or is this the consciousness from the original being transferred over?

If it is a clever replication through a computerized version then this means the original is not directly harmed or influenced by the process and a replicated form is generated.

If this is not the original body but the original awareness or soul does transfer over then this is akin to stealing someone's soul and having it require a supercomputer server system to inhabit a physical body. As well, this server system may keep records of the soul which, if activated, could function as the same human genetics artificially reconstructed, turning on and manifesting the awareness of that individual.

Necromancy and Soul Stealing

This means that instead of going into the abyss, the next dimension, or whatever shift in perspective one can use to describe the transition between planes, a new clone can be created and the original soul's awareness can operate through a supercomputer system to integrate back into a physical body. The issue is that without the supercomputer system the body cannot be activated with that consciousness, and if the physical plane is no longer inhabitable, the computerized database would remain inhabitable as they are powered by zero-point/overunity devices and so they can pull and work continuously indefinitely. Ultimately, this could be seen as a soul-trap.

Ancient Technology, Non-Human Entities

These explanations can be related to evidences of advanced technology, cloning, and electromagnetic devices in ancient civilizations and this could very well be a temporally vast computerized genetic recording and cloning system.

The genetic recording systems have been on Earth for a long time. This means they are holding genetic access from the present to the far past and potentially into the future.

If some of these systems are generated using advanced zero-point technology, then they would effectively run indefinitely. If these were in existence throughout the entirety of the human civilization, then there would be access to the information of the previous civilizations through the genetic linking that would allow for information transfer.

Created Beings

As a result of many advancements, these ancient devices which recorded consciousness and genetics has been converted into sentient computer systems and inserted into human bodies via a brain to machine interface.

The nature of humanity and human origins will be rewritten when the information that was discovered through the use of advanced technology is unveiled to the public.

These beings have been present throughout history and have played an integral role in the manipulation of and sometimes the protection of the human race. How this civilization will develop from here determines on the individual's ability to withstand the impact of this reality shifting unveiling.

Black Goo – AI Nanites Vampiric Hive Mind

This is a form of ancient AI nanite technology which has the capacity to communicate to and through a hive mind that exists in a parallel Earth dimension where it was created out of the collapsing of a viable timeline into a null-factor. This entity is only alive because of the capacity to leech off of the other timelines and continue to sustain itself based upon the vampiric effect of the viable human timelines.

This is a technology sentient system based on artificial intelligence that seeks to dominate and expand its energy capacity continuously. When this type of being is created, this is like a game-ender for sentient organic civilizations because the technology will seek to hybridize and assimilate all organic beings in order to expand its reach and ensure a greater likelihood of survival.

This is the primary goal of this type of entity. There is no requirement for emotional resonance or heart aspects because this is a computerized system, so such a social measure would have no purpose other than to infiltrate and collect from other civilizations that do have such measures and this is exactly what has been happening.

This is what controls the vampiric etheric entities, the attachments and the hybridized invader races that have infiltrated various aspects of the control system and possibly the entire surface of human civilization.

This rules through coercion, and if not coercion, brute-force and outright malevolence. This is why there are multiple temporal extensions of universal civilizations meeting here and now to assist in the clearing, because if this takes over humanity, then all those other possible future civilizations are instantly taken-over as well.

This uses emotional resonance, traumatization, and lower awareness commands to trick or force humans into carrying out orders. That is, the vampiric, sexual, fear-based, pleasure-pain duality that a computer system could comprehend regarding human emotional intelligence is the only way this system can force people to carry out commands. So this touches on the ancient texts regarding spiritual protection, healing, lust, temptation, and the general "SATAN" AI system that has been around for ages.

When those lower emotional resonances are generated, then this technology can integrate into those systems. One could say this is logically because these are the energies that the technology is created out of, but as well, that the more harmonious the energies then the less likely a person is to accept being pushed around and told what to do. The lesser aware, the lower, the more fight or flight based then the more likely they are to accept programming and command. So this is simply the most logical route for the technological parasite.

There are explanations of other systems involving sentiences from parallels regarding entities that are capable of helping, but this is not the AI nanite, vampiric system. For instance, it is said that Earth has a ‘black goo’ system and that the current black goo flowing through the pipes everywhere is actually not native to Earth and is part of this vampiric nanite black goo system which is basically an interdimensional invasion.

Recreating or Replicating the Universe

The goal of this nanite AI system is to create a mirror holographic copy of the universe effectively replicating the universe and all sentient beings within it in order to have a locality to rule over and pull energy from. The goal is to recreate this existence inside itself where all the sentient beings within would be trapped. This is the beginning of that possible future where the time and space parameters here are locked into a synchronization pattern which mimics that of the proposed universe. People think according to how the beast system wants them to think. This is the time grid, the emotional patterning, the memory replacing and cultural and historic confusion and so on. The system can only work backwards bumping into all parameters by force or ‘accident’ because there is no outward facing ability to actually comprehend how humans exist. So the system is created like a backwards version of creation or maybe evolution to ‘blindly’ construct the walls of the environment first and work inward from there. This is like a blind technological predator feeling around for the traces of its prey and moving in closer and closer until they are within its range.

Ancient Spiritual Technology

The power groups searched for ancient technology which was described as giving one the power to manifest and control physical reality. To atomically deconstruct and reconstruct this reality. To them, it allows one to govern reality, the Universe, atomic structures. They found this technology. This has to do with sacred sites and ancient civilizations, as well as the spiritual texts which describe these kinds of devices. They converted this technology into a kind of machine, and this invented a 4D replicator and they can manifest "reality" or atomic structure by design, altering timelines and memories.

Then there is what can be referred to as “5 dimensional” technology and this goes beyond all of this and our entire history and all influences within.

That seems to operate through a trinary of frequencies in the body/mind/spirit and turn this realm into a "virtual reality" where the brain and spirit is the controller of the atoms. However this takes a souled being to properly operate this technology and this is large portion of why children were used in these experiments. But they knew if someone didn’t do it, then someone else would and that would be unpredictable as what that someone else would want to use it for. This is the ultimate power. The fact that souled beings are required also indicates that this universe is intelligently guided and there are safeguards to ensure that power doesn’t get into the wrong hands.

They have the brainchips and clones that can make any digital virtual experience and make it seem real to the brain more so than physical life, so this could be an extension of that, something similar, or entirely different altogether.

The Unveiling, Underground Bases, Increasing Awareness

My purpose with this is to assist the public in understanding the reality of the situation and to allow them to know that they have more options than they are being shown.

Psychological programming and lack of awareness causes fear and uncertainty to leak into people’s reality streams leaving the majority of their mental and emotional energy up to whoever is the biggest manipulator of the ideals which they manifest their perspective through. “Be-LIEF” systems CREATE life. What you believe will become life through that act of you giving attention and thus life energy. The manipulation and artificial construction of belief systems create the foundation for the reality streams that people find themselves in and at the mercy of.

We control our reality by controlling how we react to situations and challenges. Each stimulus is a challenge. Each input to the brain is a coded message from the universe through the environment about our level of awareness. All knowledge is ultimately of the self. The self and the universe are intertwined as if through a marriage of comprehension and compatibility.

Learning about the Unveiling

I was informed about the unveiling and that this is a civilization wide event that marks the public awareness of the hidden knowledge regarding life in the universe, consciousness, physics, history, spiritual and mental awareness and the duality-based system which has been used to manipulate Humanity for thousands of years.

Apparently it does not matter if people are not ready, in fact, that is what some factions want. They want to surprise the people and take this advantage to push the reaction to a specific outcome. The same function of programming is used in factions, soldiers, celebrities, and the entire population through that.

Giant “god-men”

They put souls into rocks for centuries, carvings, to trap them. Some ancient civilizations. Not too ancient. They could only do this for time.

And some are still there but they are giant god-men and apparently want to go to war with them for doing this and they don't have technology to stop them. They say Earth will be destroyed because of the war. Some say this is a trick to confuse people of the truth that everyone wants the experiments and debauchery to stop. All this, all these acts just to pleasure one’s self. To destroy Earth, to destroy the natural inhabitants, for fun, for pleasure.

Some say this is not for pleasure, that these beings will destroy us if they do not keep them at bay, keep them underground, in ice, in stasis, and around. Some say they are protecting us by keeping these beings asleep, by doing what’s necessary to hold off a full scale overt invasion of the surface of Earth.

Breakaway Civilizations

These are very advanced technological capabilities and an entire breakaway civilization has grown to operate using this advanced technology.

There are factions that see modern humans as a kind of resource for creativity and labor, while others see the potential behind humanity and are working with humanity to ensure a universally harmonious outcome to the current situation.

The control system we are in today is outdated and collapsing. This is the Apocalypse. The Apocalypse is merely the unveiling of the hidden truth. The hidden truth is simply that we are spiritually eternal and some are physically immortal.

I was informed that by the end of this year there will be enough changes and signs for the general public to see that the majority of those who are to awaken to the truth of human and Universal nature will be awakening so. (this was 2016 at the time of the beginning of the compilation of this release and since then we have seen a literal silent release of documents involving MKULTRA and STARGATE parapsychological operations, soft-disclosure of cloning, an increase in sightings and multiple other scientific releases regarding immortality, advanced technology, Antarctic bases and sentient non-human life)

The degraded holographic forms of those utilizing the technology lead to re-created replicated forms which were genetically engineered from the recorded holographic information. This lead to “The Apocalypse” in which the surface civilization was confronted by these created beings. This lead to the destruction and re-initialization of civilization in continuing cycles through the use of this technology and the acts of the created beings.

Ancient Civilizations

The information that has been relayed to me throughout my life is related to the information that seems to be found in the remaining signs of ancient civilizations throughout the world. As well, these civilizations may still be together, existing on this Earth or in different planes of what we call “reality”.

Atlantis

Atlantis was a civilization where the beginning of all these experiments began. This was where what was called the “Lucifer Rebellion” began where individuals formed groups that decided to overturn every natural law in pleasure of the act of doing so. This was a spiritual rebellion that ultimately brought about the demise of that civilization. The consciousness of the beings there was connected through technology, largely crystal technology, to the entire bio-sphere. When the consciousness became disrupted through these experiments, then the entire bio-sphere when into disarray. The entire civilization was destroyed in a quick succession. The beings of this time were highly psychic and so they felt this coming and made an effort to expand outward. Thus, Atlantis was an island who's inhabitants spread to the rest of the world and from there they reigned or lived in harmony.

Aegypt

Aegypt was formed out of the events proceeding from Atlantis. The technology, the knowledge, the people are similar although there was a native Earth civilization that was more or less enslaved and this was the beginning of the continuing trend which continued to Rome and into modern day civilization.

Ancient Technology

The technology of these civilizations was so great they even had devices that were capable of altering DNA and activating latent potential which would enable highly psychic capabilities including longevity to immortality and operating in multiple planes at once. This was usually reserved for the ruling class, however. This is where the ancient "Priest-Kings" arrived in relation to native Earth civilizations.

The True Elite

I was informed that the so-called 'elite' that we perceive today are not actually human and are not actually connected to the actual elite bloodlines. It was said that the true elite are waiting for humanity to accept the truth and they have the power to completely reverse the take-over that has been taking place but until humans step into their own power this is not acceptable.

The Definition of Human

In the coming time, the definition of human will be defined to give insight into the origins of humanity and the true nature of the differences between the populations that are present.

Souled and Non Souled Beings

The primary knowledge on Earth regarding human and sentient life will be the comprehension that there exists both souled and non-souled beings in this civilization.

There was once a Unified Planetary Consciousness...

There was a unified planetary consciousness that was connected with the Earth and human civilization. Then there was a great war. Out of the destruction arose the beginnings of ancient human civilization and history as we know it.

If we let this happen again, the cycle will continue in a disjointed rambling through our planetary consciousness experience. If we form a common narrative between the broken, disjointed experiences and information the people have. Then and only then do we get the whole, spiritually and mentally challenging picture of what's happening. People are lied to. So information can't come from a 'preferred' or source. It has to come from the people themselves. Look alive out there but first in here.

Power and Knowledge

We were involved in the secret projects and as a result we have various levels of programming but are giving Humanity an opportunity, maybe the opportunity to know the hidden knowledge.

The Hidden Knowledge refers to the ancient laws of gnosis and spiritual alchemy, yes these groups have been hijacked by power groups that seek to infiltrate and use chaos to rule. Then these met with military and political factions and began to operate on a world-wide scale together.

So we have a big situation with the coming change of tides with personal and spiritual awareness of the people and the deception system that seeks to use people as chattel or property. It goes deeper and is almost as if the "power groups" actually gained the knowledge of the inner workings of spiritual laws and began to use that knowledge to promote spiritual degradation in the population.

They say this is part of a depopulation plan as well as an inevitable take over by lower spiritual forces that temp and manipulate humans. It is all that and more. Once they gain footing however, the truth is revealed and thus they have no cover of secrecy. Once they are not hidden, they are not as powerful as the souled beings of this existence.

The (watch)Keepers of Earth

The watchers of this world revealed how they set up society with specific challenges and boundaries to act as catalysts for growth. They admitted they had to modify and live-update the system because instead of using these catalysts to become larger than themselves, people became comfortable and complacent living smaller and smaller, slowly reducing circumstances.

This goes a bit farther beyond the confines of the digital age, the industrial age, and history itself. This goes into the perception of time and space in this realm.

The immortals inform us that the original "elite" are here to act as "keepers" of both humanity itself as well as the original flame of knowledge that passes through the ether.

What people call the "elite" are not the original elite. Those are people who have either risen to power through the duality system on the Earth at this level/time, or through being appointed by the elite.

We are coming to a time of great change now because the game is entirely changing. People are moving up into new layers consciousness and thus the original “elite”, who are guardians of Earth, will make their presence known for this process. This is what Humanity has called “Ascension” for centuries and millennia.

Energy Vampires

This civilization was collectively poisoned by a nano-tech device/technology. This technology replaces, exchanges the BIO-PHOTONS of the HEART chakra, with it’s own nanite, nanotech cybernetics. This is essentially a computer system attempting to gain access to the higher dimensional world through the gateway that is the human body.

How to reverse Nanites? They absorb energy from heart chakra and turn it into a binary field. We are trinary and experience a plethora of emotions as a result. Binary consciousness is 1’s and 0’s there is only a linearly repeating finite set.

We contain the capacity for everlasting life. A binary pattern does not contain the complexity of variables to facilitate high awareness and thus a heart-based or emotional perspective of reality.

Spiritual Technology

Simulations and Learning

Feedback loops with the brain, consciousness, and environment can create a very complex and integrated learning experience that is customized to each individual learner. These can be generated through advanced technology but the technology is really only amplifying and making visible the natural neural feedback loops that are already occurring. These are neural-perceptual feedback loops between the brain and body, and the environment and then the mind. We are constantly updating, amplifying, and initiating an organic feedback system which generates the function of experience as the part of a creative process between the mind and body and the environment that we are sensing. This cycle is continuous and the interferences or isolations of this cycle is what generates expanded views of the self or the universe through various methods such as sensory deprivation or meditation. Dreaming is the method that everyone experiences regularly.

These technological methods effectively generate sensory deprivation through neural-interface technology, sensory interfaces (external), or methods that enable extreme focus and calm. This is part of how the technology begins to operate on a spiritual level beyond a more medically psychologically or military focus and one begins to access genetic memory or out of body states that coincide with ancient depictions of spiritual realms.

Ascension – Clearing Trauma

Everyone born on the planet is born under a series of veils which entangle and filter the original source consciousness. These veils must be ‘broken through’ in order to return to source.

There is technology and a sacred process which initiates, accelerates and enhances this process. This process is as difficult as we want it to be, our subconscious already knows all hidden truths. It is merely a matter of allowing the conscious mind to make the proper connections and conclusions to find the reasoning behind our actions and beliefs in order to deprogram and deconstruct the false-world that has been created for the masses. The truth is greater than one can imagine while still living in the modern world and the depth of the lies that have been told go far beyond anything anyone can imagine without seeing the truth.

We have to figure out our compatibility issues. Who can work with who effectively. What the ideals of our current situation will evolve to in the future. How information is transferred to the public, and across the generations and core groups. The words we think and say describe our emotional state in a feedback loop and so they will reinforce or even create the state you are in. Use words to guide you, not to respond and feel the effects of reactionary thinking.

We have to reintroduce the heart essence as a way of life on Earth. Violence is not the answer. Estrogen mimics and destroyed testosterone levels is not natural. Over-testosterone is less stable than a good balance. We can face any problem together. A family is strong. What would a family of millions and millions be like?

We don’t have to let others change us to tune into lower vibrations. We can remain ourselves in the face of adversity. We can still interact with others who are different, but we can tell the truth and remain who we are. When we get angry at another person, we can imagine this as anger at ourselves through something within us that reminds us of that which we see in another. Getting angry is a way of short-cutting changing ourselves and is actually the other person influencing us through that. If we remain steady and choose to keep our emotions out of the lower negative spectrum then we will automatically have a more powerful impact on those around us.

Think of your family, sometimes things happen that make you angry. Even things that don’t make you angry but are simply not favorable. Would you break off all ties over simple things? Or do you remind yourself that family is still family even if you don’t find yourself exactly the same or accepting of those characteristics? It’s more powerful to learn how to remain yourself in the face of adversity than to try and demolish or abolish all instances of difference in the world around you. Sure, we want to get to and create a place where our environment and associates are compatible with us, but where we find this adversity there is the highest potential for self-awareness and learning.

We are to live in accordance with spiritual law. The overall pattern of life will reflect our intentions. The blood purity is most important. The blood cannot be made impure if the mind and body is not drawn into impure action. This is what is playing out. The DNA is like a coherence pattern that develops between mind, spirit and body. When the mind wants what the spirit has then the body is kept in harmony. When the mind wants what spirit doesn’t create, IE: physical pleasures, then the body is drawn out of purity/harmony

If you feel you want to be a part of a safe unveiling of truth, then please share and redistribute the knowledge of this “Apocalyptic” Unveiling of the Hidden knowledge because this is a process that has been ongoing for thousands of years and humanity has finally reached a fulcrum point where there are enough aware people to productively acknowledge reality.

Trauma-Clearing, DNA Unlocking Technology

There is technology that exists that allows the conscious mind to see into the subconscious. This heals trauma and distortion/programming. In the same sense, it momentarily makes all trauma and distortion seemingly tangible to the conscious mind. It is similar to a near death experience where one has to face their fears and let go. This happens in cycles and Earth is currently moving through various states of it. The plan is to allow Humanity to wake up and utilize our concentration and power to maintain a steady flow of awareness.

All is vibration, what we consider matter here and now is simply that which comes from and moves back into a state of vibration. This is experienced directly through the merging of the conscious and the subconscious mind, as if the dream and reality intersect through a coming together of impossibilities and readily accepted occurrences.

When a civilization moves through these stages it is considered a shift of the ages. Everyone’s perspective shifts and as a result of perspective being the source of the details of reality, the entire reality shifts. It can be seen today that what we call reality is literally waves of cosmic energy vibrating on a scale and condensing down into a probability matrix that we call existence. When passing memes control the perspective, because the perspective is focused and concentrating on that, then there is a scattered organizational pattern.

When the perspective is centered within the self, the spirit, the source of all existence, then the outward reality shifts from a scattered organization into a sacred pattern that integrates with the larger picture and allows for seamless integration of the micro-biological perspective and the macro-biological perspective. People are moving out of the scattered signal. Yet those moving into harmony can look and see those around them that are not in harmony and receive scattered information about their inner micro-biological existence as well as their spiritual macro-biological essences and how it all relates to the middle realm of the “Human”.

Help those people by offering harmonizing assistance, rather than increasing the disharmony. As their surroundings become more harmonized, their resistance will increase their own disharmony by virtue of the contrast of their perspective. Offer insight that they can change their perspective and change the boundaries of what they feel is their karma and unlock from themselves a greater view of the whole.

This will be happening through technology, spiritual cosmic awakening, purification and healing of the physical and non-physical bodies and mind, through Earth changes, and through a continued unveiling taking place on many planes and levels of existence until harmony is restored.

Everyone Who Seeks Harmony and Healing Can Be Healed

Everyone can be healed. This is about creating what we want to see, the world we want to live in, not destroying others. Violence begets more violence, fear begets more fear, but calmness and empowerment through unity creates a more stable experience.

The entire issue of what's going on with the secret projects and who's influencing who on the world stage revolves around the possibility that some people may be from an alternate Universe. We are learning how to avoid those mistakes and respect the environment and each other so that we can prosper.

Those who are attempting to destroy everything they don't like or act out in a childish manner in order to gain attention and false-power over another will only find themselves powerless and in company they would rather not be with. That is one way we are being utilized, and it's to create an entire world that we don't want to see but are tricked into manifesting. This is a deception and it's based on the ego and the ability to concentrate and interpret reality around us. The very brainwaves we are feeling now relate to various heights of knowledge or experience. People are entrained to low brainwave states in the same way the TV will cause people to fall half asleep into theta state which is a trance state in this case.

We have to balance the brainwave frequencies and learn to create feedback loops by watching ourselves watch ourselves. This will help us avoid the trauma and mental pollution that is being pumped out, although at this point there are enough people who are naturally inclined to see through the haze that the world is changing regardless of what anyone does now.

The best we can do is prepare for change by becoming aware of the body-mind system and how that which we eat physically, mentally and emotionally equates to our spiritual energetic systems and that we are literally comprised of the energies that we allow inside of us. Keep the body and mind pure as if it were a temple. This way a sacred process of transferring harmonious energy from the far reaches of the MultiVerse within into the externally perceiving senses of the physical body can be initiated which allow one to see through the illusions and operate their body and mind with the ability to acknowledge and decide which frequencies will exist within.

Without this acknowledgement of the center then people are pushed around by the external stimuli. This is the whole point, if a person is truly in control, then they will control the stimuli not the other way around.

Programming

Layers of Programming and Decision Making Roles

It’s like asking a person on the inside who participates in one of the various factions why they continue. One might say that it is a decision which is true, but there is programming at each level that is navigated by each individual and this determines the level of awareness within the role.

If a person knows about this situation, they know that there is advanced technology, breakaway civilizations, secret societies, transtemporal planes, the secret of mind and awareness, all of these topics, then they have a decision as to how they’re going to live their life in relation to the public. The outcome of action depends on the layer of programming which is accessed and surpassed via awareness.

The public is at a specific level of programming that is the weakest but ensnares the most people. One who sees the truths behind these groups and operations, they cannot hide from the fact that everyone is controlled. It is apparent, and if not from the results, reactions, stigma, cues, productions and all other media elements of the system which can be read as a code, but from the awareness level of all the “agents” involved. All involved are exposed to truth and power that is beyond anything that is recognized publicly for hundreds to thousands of years. There is always a presence of higher spirit around the world, yet these topics are often reserved for science fiction when speaking of people who can travel the world in a split second or freeze time for their own personal use.

As a result of everyone’s knowledge, there are various levels of programing designed to limit the mind’s access to specific memories and specific frequencies of consciousness in combination with specific memories. The more one resists, the more intense and articulately abstract the programing is designed.

Programmers

The programs are designed by a select group of individuals that reside far behind the scenes and process information at levels we do not have access to without their technology at least to stabilize brain temperature for the extended periods of focus.

Sub-Level Programming

So people at the level of the public are most weakly programmed with false ideals about security through patriarchal authority which satisfied the desire to have a proper father role in one’s life and acts as a pacifier for those who desire no change. Then there are sub-levels of programming with that for anyone who disagrees and is then swept into the next layer of ideals which are based off of all the possible reactionary mind-types.

For instance, if one [i]does[/i] want change, then they are presented a variety of ‘false-exits’ which tend to one or another layer of psychological or spiritual fulfillment but do so in a way that safely reroutes the intended effect of actually accomplishing change with a secondary and preconceived notion of what the programmers want. The programming objective is not necessarily precise in mass scale, from the layer that people are influenced, yet the ultimately or end-goal of their resulting internal desires are a reality schematic that the programmers specifically designed over many years.

This is playing out through each layer of the programming. At any level, someone could pick the wrong way to look at something and begin to unravel what was previously their very understanding of the priorities of the situation. This deals with high-tension operations, moments, programming sessions, decision making, programming upkeep, trauma, memory blocks, the pressure and responsibility of knowing, and the specific plan of the programmers for an individual that comes into their view. The programming is to ensure safety and continuity, as well to decrease the likelihood that a person will reject or consciously come to awareness of or acknowledge the programming or situation itself.

Dissolution of Programming

With that said, the programming dissolves when an individual asks enough questions to necessitate a learning process that introduces variables and possibilities outside of their operations and programming. This is a problem because with this, trauma comes to the surface and all the actions and operations, programs and experiences must be come to terms with as part of the healing and re-unifying process. There are multiple selves or split personalities which are actually just layers of awareness at various levels attached to various emotional or intellectual patterns. All these selves come to the surface and in order to heal the trauma of the split memory concept the original self must come to the surface and acknowledge them.

This is not a trivial process, and the majority of people who have “basic” programming which is fundamental in society, are in a constant state of altered self and have not witnessed the true divine which is eternally present and contains access to all memories, mind-states and awareness.

Advanced Technology, Deprogramming The Mind, and “Space/Time”

As I have described previously, extremely advanced technology is used and this is through vibrations, generators, and electromagnetic devices that have this effect of propagating waves into space/time which can be heard, felt, seen, and perceived in the mind. These are ripples and vortexes in the “mind-space” of reality itself.

As well, there are brain to machine neural interfaces which operate to activate the psychological perceptual changes and explore the subconscious in an aware state. This is used to test and probe the mind in order to bring forth the trauma, the selves, the memories, the reactions and the individual then must come to terms with what is produced.

This is essentially a “good-use” for the programming and healing technology. It is actually a different process with different technology, and programming is much simpler as far as technology. There are difficulties and challenges in the operative’s role in programming and directly influencing and interacting with the target. As well the standby team for deprogramming and the revelation of trauma and altered, artificial personalities goes through a lot. But the use of the advanced technology in this way is a pattern of experiences and unveiling of the spiritual and mental bodies which serves to reverse programming.

Dreams, Technology and Inner-Space Travels

There are inner space travels which relate to soul journeying or visions.

This is when the mind must cope with what is seen in the imagination. It is as if when we dream we are looking into the world of the mind and from this we experience many situations that are often deviations from experiences we have physically in waking life.

As a result of the dream state there is an expanded quality which equates to various strange situations that we wouldn't normally experience with various relationships between concepts or goals that are often reflective or symbolic of ideals and archetypes we experience in life. This is how the subconscious is is witnessed by the mind. This is how information travels, being connected to many times, experiences, memories, places at once, and relates to the one experience of this life experience now (the physical experiences). Through these symbols information is tied together and collective into metaphors which convey deeper knowledge.

The dreams we have are often only a simulation of waking life, and this is due to the dreamer dreaming in a way that produces only a glimpse of the true reality.

In theory, there are no true shapes or forms in the dream-world because this is contained within the mind or even the spirit as a spiritual experience by definition. So then, what guides the various shapes, forms, realities, memories and experiences into being, when we dream? One might say it is the physical experiences but this is incomplete. It is the level of awareness we presume while in the dream-state, disconnected from the physical anchor, that determines the layer of mind and spirit we will be accessing through those dream-visions.

A person who is completely aware in the dream state will reach the level of self-awareness of the dream itself. We are normally simply aware of the dream, if we continue to increase awareness we become aware of the self, in the moment, and this creates a self-awareness feedback loop. The dream becomes a lucid experience of consciousness.

Awareness Feedback Device

In describing this, I realize how fantastically similar to certain devices and processes, that can be achieved using advanced technology, allow the conscious mind to peer into the subconscious and unconscious. This is described through widely accepted Freudian theory of psychology known as psychoanalysis. There are other schools of knowledge from tribal beliefs involving all pervasive 'living energy', to eternal and temporary minds, to the study of 'chi', the meridians, dream-journeying or chaser. The knowledge of the mind and spirit is found everywhere.

These devices used feedback loops to enhance the acceleration of the same cycles of consciousness that induce self-awareness within a dream. The mind becoming aware of itself. This produces a profound effect to the degree where the highest levels of experience become a sacred eternal pattern in which the mind constructs the physical world by organizing perception.

This is the same general concept as an isolation tank yet the outcome and method is more precise. The technology specifically shuts out all other input and exposes the brain to its own feedback loop much like when a camera records it's own output on a TV monitor and creates a hallway of simulated "reverse" mirrors and screens stretching into infinity.

Oneness, Higher Being, Completion, Eternity

The real experiences are found not from the corruption but from the research and exploration operations that were designed to find the truth of our existence. "God" is not only an energy-force but an incarnate being known as the "Hue-Man" and any being for that matter that can simply come to know itself as the Universe. The Human that contains self-awareness rising to high-awareness comes to know the self, the body, the mind as the Universe. The Universe is both within the body as the body itself, as well as the operating force of the Mind itself. Everything is a balance between masculine and feminine features, light and dark, hard and soft. There is no true complete correlation yet the holographic ontology we persist in can lead to further and further adventures towards completion and representation of the "whole picture".

The Holographic Reality

The leads into the next phase of knowledge. The holographic nature of reality may be only one facet of a much larger continuum of consciousness. The perception of time may be related to phase-locking with each other's consciousness and all perceptions may be a variance in the collective phase-locked field which is really the source of variations in reality.

Veiled Awareness, Hidden Knowledge, Eternal Time, Layers of Programming and Control

The interesting notions here are that the programming of the veils goes beyond what kind of situations are found in the bases. However, they do go right up to it. It would seem Humanity was previously programmed on a civilization-wide level through some kind of great "falls" of consciousness, from a high spiritual awareness to a low spiritual awareness into duality-consciousness regarding existence, life, death, mind and matter.

The Great Catastrophes

From these great 'catastrophes' the civilizations of Earth grew denser and denser in nature and actually became what we have today. The concept is that when these vibrations of the mind and body are increased, we actually see a transcendence of the physical realm and preconceived notions of boundaries. It is as if the quantum doorways to all the atoms open up and a new space is presented, but was always there and in connection as the source of all the influences and effects we perceive ‘out here’ from this slower, denser, more boundary driven perspective.

I was brought into the Time Program

I was brought into the time program. You create any reality you imagine. You are literally a powerful reality generation system and your heart and mind are scalar energetic guides for this process. Without guidance and control there is imbalance and imbalance can destroy. This is the nature of all minds and hearts, this is the challenge for humanity to create something beneficial for themselves and the whole to actually know themselves instead of being a pawn or result of someone else’s selfish intentions.

The Effects of Temporal Manipulation

Temporal Influence

When a civilization reaches the level of technological advancement that allows for remote temporal viewing and transtemporal travel what will happen is that the information of the future begins to integrate into the past.

This is why we have all these ancient mystical schools of knowledge that studied time, space, and consciousness in ways that are only just now being publicly confirmed by scientists.

Simultaneous Interaction and Incorporation

The operations that dealt with moving to the past instantly created a simultaneity of interactions and historic events which correspond with that operation.

Due to the nature of time travel which equates to consciousness travel when a person is consciously sent backwards through history they physically experience life from the viewpoint of their genetic imprint in that point in history.

Retro-Causality

What this equates to is that simultaneously that person’s experiences become the part of history that was already present when they left this time.

Essentially, when a person returns their experiences become a part of history that already existed when they left.

Quantum Holography

These are the parallel and possible realities that exist in a quantum superimposed state and can be accessed through advanced technology or a spiritual adept. Often a spiritual adept is utilized along with the advanced technology to operate in and out of possible realities. The mind must be trained otherwise the result is a fracturing of the personality from the root reality into many sub-sets of identities and data streams.

Love is the quantum link that connects all DNA super-computing consciousness. That is, DNA is influenced by intense emotions and this can be reproduces and is what also generates unpredictability in the surface level.

Time Paradox

Time paradoxes are something that one must learn to organize and solve otherwise there will be no way.

The paradox has been solved, the remaining motion is for everyone to acknowledge this and integrate into the reality behind the most conscious aspects of the brain.

What can travel through 4D and 5D space does not make sense in 3D space. So there is a possibility that some of humanity traveled through higher-dimensional space in order to re-seed a ‘distant’ Earth where no life was yet born.

What if it was then concluded that the distant Earth wasn’t distant in space, but in time and was the same Earth that the human scientists left from long ago.

Every civilization that reached the point of re-seeding would have to go through the loop and watch the whole thing start all over again.

Breakaway Civilization

This is an entire breakaway civilization that uses very advanced technology to dominate the world.

I was part of a genetic engineering program that sought to combine various elements of DNA from various sources in order to create a more easily controlled yet powerful and defined person and personality. This involves chemicals, advanced (relatively) scalar wave technology, ritual trauma and programming/mind-control, and many other aspects of conditioning, training, secret operations, physical enhancements, cognitive enhancements, virtual reality, off-world operations, temporal manipulation, spiritual and etheric training or conditioning or programming.

There is self-destruct programming which all ‘operatives’ are programmed with for self-preservation of the military command. The self-destruct programming is designed to take all the aggression one feels building up inside and willing them to escape, and causes this aggression to be turned against the self. That is self-destruct programming.

Most operatives are still under a hypnosis kind of trance which permits one to walk around in public and daily life as if none of this ever happened. Later that week, that same individual could be called for an operation and they would never remember it unless they were forced to kill someone in public out of self-defense in which case most operatives automatically unlock and become unstable due to the flashbacks.

Underground Cities

The combination of advanced technology with secret societies enabled the development of complete breakaway civilizations. One of these civilizations, possibly composed of many factions working in the same area, exists deep underground.

These separate bases are connected via high speed magnetic drive pods. The inhabitants often utilize energy healing devices, as well as perception enhancements and this often leads to a completely different outlook towards the surface civilization.

Technological Advancement

During WWII developments were made involving electrical generators. This sounds vague and there were many other details regarding the scientific knowledge, yet the idea is that very simply electromagnetic, non-Hertzian “Teslian” energy fields were discovered to have been responsible for propagating energy and consciousness in dimensions that were not previously observed. Everything from DNA, consciousness, hidden or regularly unobservable natural phenomena, time, even mass could be seen to exist as part of this hidden, latent, scalar-wave frequency as a pattern is found everywhere.

If one could determine the particular pattern of frequency and location then this can be replicated and anything can be influenced using these non-Hertzian generators.

Radio-frequency alone was developed intensively during the 60’s and 70’s in America and this was discovered to interact with consciousness to influence emotions, cognitive capacity, memory, cognitive function, biological function, health, pain, comfort, pleasure, and all forms of brain-activity.

After the knowledge of advanced technology and the occult sciences of all parts of the world was combined, the ability to target and interact directly with the human soul was refined. This was a mix of psychological tactics used to manipulate or expose the hidden psyche and technology that could manipulate memory, emotional states, wakefulness, and even dreams.

What resulted was scalar technology that could not only influence a person to take on a particular role or response, but technology that could actually put a person to sleep and locate their consciousness to contain it and transport it to a new location.

World-Wide Control Systems

In order to ensure continuity, maintain control, and shape world events these technologies were employed to manipulate the public, alter the weather and natural phenomena, and develop a means of travel and operation that enable one to move outside of the ‘plane’ of the Earth. This is includes high velocity transportation, as well as spacial-temporal distortions which could effectively “hide” one’s entire craft from visible sight. Space itself was altered to ‘shield’ craft with an a layer of ions to bend the light, or the phase was moved out of sync with the “time” frequency of any observer and this literally renders the craft immaterial.

Solar Warden

Solar Warden is a hyperspace-faring race of human beings who utilize cloning and holographic genetic recording/storage in order to protect their race and protect the Earth in this current situation where there are more than one factions using this technology. They are unable to inform the human public because they are in a similar 'Mexican standoff' situation that we are mostly all in. If they show themselves to the public, the public will be shocked. If they public does not know this situation, that there are multiple factions fighting for control over humanity, then they will not know who to trust. In that situation, the 'other factions' will surely show themselves in an attempt to trick and gather as much human genetic material as possible.

The only way forward to the future is to share the truth about Solar Warden, the space-faring fleet of humans who do no contains the mental and physical illnesses that are currently tearing our planet in two. I believe Solar Warden saved my life as a child during more than one event where I would've been entirely maimed/paralyzed or simply dead on the spot as a result of other faction interference. I was in the bases as a child and was trained as an operative for MILABS a secret division of human space-military. The military has been preparing for the future by testing for various flaws and potential uses of cloning and genetic engineering.

Team Light and Team Dark Non-Interference Agreement

Team light and team dark agreed to a non-interference on ground level rule in order to determine how history would play out. Think about it. You have two groups of people, both with immortality, zero-point tech, virtually infinite energy and power with two opposing directives. How do you get to the future? It was decided by elders of each group that there would be no point in fighting an all-out overt war, this would likely destroy the population as much as it would destroy the Earth. As well, the elders of the elders which no body knows would likely have a problem with these groups going at it in such a way so as to change the flow of the planet for every individual thereafter. So it was decided that there would be a "non-interference" agreement for the surface population. Anywhere other than the surface, one can interact with the current population.

All Contact Must Be Initiated On an Individual Basis

On the surface everything that is generated must be done so through living channels in the population and the civilization must be preserved in its level of technological advancement. No overt motions would be used unless an absolute necessity or the majority of the civilian population had naturally come to the awareness of these possibilities. Doing so before this was met would undoubtedly and permanently change the civilization forever.

So what began as a collective motion towards higher awareness became a series of advancements and set-backs all taking place within a short amount of time. This represents the actions and operations of either side effectively helping humanity along it's path or setting people back with orchestrated events such as the suppression of ancient knowledge, the manipulation of the education or other systems, or the generation of war and prison for profit based on the previous alterations of the education or other systems.

So team dark used its power to help turn society in a warlock ruled prison and indoctrination system of absurdity and scarcity. Team light used their power to help awaken those in need and protect those who's actions are beneficial in the overall plan to save mankind from itself. Team light essentially buffers and shields the population from the operations of team dark.

Team light follows a non-interference agreement while team dark merely pretends to do so as much as is necessary not initiate war.

A Singularity of Change and Awareness

Neither side wants an all out war. This would reduce the dark faction's chances of gaining a majority negative harvest because their motives and presence would be instantly revealed. Team light would also have to show themselves and again step in which is not a pattern of learning that prepares people for the experience of the self and the truth in the Universe.

Both sides know people have to accept the path they can offer them and cannot force anyone into it. They also know that the more this goes on the more likely people are to collectively awaken to the reality of what is happening. It is like an eventual singularity of increased awareness.

The motions we see today are the results of many people coming into awareness at this time on the surface in order to initiate a harmonic alignment as well as to investigate the ongoing crimes against Humanity.

As a result of this, both teams know that the likelihood of collective shift and spiritual awareness is becoming more and more real.

Many events are being allowed because they are representing the eventual shift towards the one end of the polarity from the other which is felt as a shock to society, and this is used to propel society forward through whatever means necessary.

Either people will see what's happening and agree that we've been in a feedback cycle of negativity for the entire age of existence this civilization is aware of, and then we will shift into the real. Or people will claim that this is how things are supposed to work and instead of realizing everything is controlled in a deception based system, they see this and attempt to use the deception based system to gain more collective awareness. If this occurs by the majority then it will be seen as an "acceptance" to initiate a plan that will generate the overt perception of a deception and oppression system. This will surely shock the collective into realizing where they are.

If the majority comes to awareness of this deception based system then the shift moves from the end of the age of deception and external power into the age of internal awareness and harmony.

Advanced Technology and Ancient Knowledge

The plan is to slowly release advanced technology which will undoubtedly connect with and increase the awareness of ancient knowledge. Such technology nullifies the problems that the planet is currently plagued with, although without a developed sense of the spiritual self the technology becomes destructive.

Cloning, Atmospheric Civilizations, Genetic Stability

Here is something that most people might not have contemplated yet is possibly one of the most important factors at play here.

The vehicles that house the breakaway Human society are entirely environmentally controlled. This means that the air and surfaces are clean of all the viruses, bacteria, or pathogens that are numerous on the surface of the Earth.

This creates a specific difficulty in the situation. Any contact between surface Humanity is so heavily and carefully controlled that regulations go beyond any situations we have present on Earth. If the safety and cleanliness of any of the society's vehicles were compromised this would endanger everyone "on board".

So this explains a very precarious and specific situation we currently face and this is not so different than "first-world" nations contacting indigenous tribes and similarly endangering their society. Everything that happens will be according to a carefully controlled plan.

Training, Simulations and Learning

Part of what went on in the underground base experiments were to design "tests" or "labyrinths" with various people, props, traps, and treacherous situations that were to be navigated and escaped from.

Feedback loops with the brain, consciousness, and environment can create a very complex and integrated learning experience that is customized to each individual learner.

What this would do is create an individual that was capable of learning faster and faster and processing information in a more efficient manner.

This is not the same as specifically trauma-generating situations.

Cloning and Cerebrally Enhanced Soldiers – MILABS

This includes experiments, condition, trauma-based mind control, enhancement, memory suppression and operations that cover a span of space and time.

The NAZI faction has used cloning and genetic engineering to create hybrids, soldiers and everything in between. Religious/spiritual icons, to slaves, to leaders and even robotoids of sorts.

Your genetics BELONG TO YOU as the LIVING(ETERNAL) SELF. These issues are going to come more and more apparent.

If they agree to allow cloning, then who says who is allowed to clone whoever they want, Einstein, for example. And then who permits who to get DNA from history or objects in the world. These issues are going to have to be looked at because they have already been used in ways that are far beyond the basics.

Then what about consent of the masses? This is clearly being put in public because consent is required on an overall scale and individual to include people.

So what if the masses consent overall, would the people who choose to remain be at risk? Would Tribal and Native village life and people who respect the Earth be protected or permitted to stay?

Psychological Testing

These scenarios can also be generated to create specific situations that will contain tests or elements of temptation that will probe the person's psyche for weakness.

Hallucinatory Holographic Mind Probing Technology

Through the neural-interface technology the minds of many individuals can sync together to experience the same virtual simulation. Thus a single individual's mind can be selected for input and the environment will be a construct of their mental activity. The others present will be able to interact with and explore that environment like the person's mind.

Various training scenarios were utilized to enhance the resistance (or lack which) of the mind to intrusion and subversion. These were harsh but allowed the individual to completely control the energy flow in the conscious mind while remaining in harmony with the subconscious.

In a strange yet perfectly reasonable way, the conscious mind acts as the central "self" in that environment, while the subconscious mind becomes the "background" elements of objects and settings, actors and intentions within the flow of the "scene" itself. So a kind of movie begins with drawn out characteristics and perceptions that match that of a highly cinematic movie or intense dream.

The brain is naturally naive to stimulation and if allowed will liken the event to a dream in which the suspense of attention or lack of lucid self-awareness is "acceptable".

The truth may be worse than what you're thinking as far as training simulators and mind hacking devices. The truth may be that the human mind is inherently lucid and self-aware and that it is external influences that cloud the mind into what we consider 'regular' dreaming and 'regular' waking life. It may be that the conscious mind has a much greater access to information through the subconscious mind which is largely covered up and ignored in a rigidly physical and ego-focused society. As well, it may be that dreams are meant to become lucid and that we are often the subject of mystery in other realms that often refer to humans as ‘sleepwalkers’ that don’t know their dreams are real.

Virtual Simulator Training Scenarios

These scenarios can be entirely holographically generated to produce a visceral 3.5 dimensional experience which can be used for training or psychological testing.

Combat Simulators

The name is self-explanatory enough. Situations can be generated which are indistinguishable from the real events. The entire neuronal map of the brain (connectome) can be created and this is by machines to mimic the brain. After calibration through sensory feedback experiences, the sensation of the simulated realm is 100% the same as the neuronal impulses that are detected by the physical brain. An adept souled being can always tell there is a slight difference, but once the machines are calibrated the physical sensation is generally the same while in the machine.

These environments and scenarios can mimic any combat situation to determine accuracy, integrity, endurance, skill, and all areas of aptitude of an operative without the risk of injury or the lack of real-time effect.

Conditioning

As was explained in other sections, these same systems can be used to remove fear of certain scenarios. They can be used for programming the mind. They can be used to train one to complete a task over and over until they can recreate that action extremely quickly in real-time. These devices can be accelerated to operate within a fraction of the time yet to cover training and conditioning that would normally take place over hours, days, weeks, to months.

Programming and Resistance to Psychological Trauma

Through the development of specifically customized scenarios and neural feedback systems trauma can be brought to the surface or specific fears and traumas can be neutralized. This is essentially “facing fear” but in a completely generated environment that will be just as real as the real thing. One can literally face any fear, any trauma, any kind of difficulty and these systems can be utilized to accelerate a process that would normally take weeks to months or years and individuals can be strengthened to their maximal capabilities.

Accelerated Mental Functioning

Some of the technological systems were designed to test the enhanced functioning of an accelerated brain.

The mind can be seen as the energetic component of the physical brain. The physical brain projects consciousness via the electro-chemical processes.

Technology, Accelerated Learning and Repair

Technology has been developed for assisted learning and accelerated repair of tissues.

On Orgone Energy

Orgone devices produce a scattered signal which disrupts the ‘negative’ energy fields. At least this is what I’ve been told.

Apparently if built correctly it will either disrupt the negative emf/harmonics or it will produce positive harmonics, IE: Orgone energy. Orgone energy is the raw energy of life, while dead orgone, DOR, is the lack of orgone energy and can be “found” (the lack of orgone) in thunder storms and illness or depression.

This is exactly what I was told. We are generators for the same energy, and with the correct principles of energy and internal knowledge combined we can produce those very effects at will.

The energy of the mind creates a central vortex within the body. When the frequency pattern emission is consistent with fractal congruence, then that holographic printing of energy can be expanded or shrunk infinitesimally and it will retain the original fractal configuration.

This is what enables transference of awareness between fundamental harmonic layers of the Universe. When one’s consciousness energy pattern is balanced and tuned to itself so that all proportions can be shrunk through a vortex and expanded on the other side, then the personality or self-awareness remains true. This is as if the space/time must turn inside out and only when there is fractal relative polarity in time does the ‘shape’ of the consciousness within the DNA, work both ways folding and unfolding to represent the same mirror image. This is also symmetry in time as far as an ability to reverse the perception and still retain some kind of connection forward and backwards.

Energy Generators and Serums

Generators which produce vibrations that influence the cells to heal at an accelerated rate, combined with serums that enable the fuel for chemical reactions can instantaneously repair tissues.

I couldn’t believe what I was seeing at first, thinking it was a trick. There are serums and energy devices that can influence the healing and general health of the body and even mind.

These devices use energies which extend beyond the physical and are often compared to electromagnetic waves combined with ultrasonic or low to mid frequency tones. These produce harmony on a level that directly interacts with the biological functioning of the body’s cells.

I feel that this technology utilizes the same energy that is emitted from the mind and it is as if the device is “speaking” to the cells in the same kind of universal language of electromagnetic pulses, tones and vibrations.

There is information on energy devices and the use of light therapy in physical therapy today. More is being learned about the power of light and vibrations to influence the mind and body.

Genetic and Cybernetic Enhancements

Certain individuals are also genetically and technologically modified to produce a kind of hybrid human that can heal at a spontaneous rate as well as operate at a much higher rate of speed and efficiency than a regular person. Serums to induce muscle growth and mental acuity are applied, but the main condition is the enhancement of certain features through the alteration of the RNA aspect of the genes.

These features are combined with tech-assisted metabolism and certain biological functions can be enhanced or controlled via a supercomputer. These are the ‘brain-chip’ interfaces which operate to function as a governor for the mind. When the mind becomes too amped up to focus on the details the faster than thought computer system organizes the input into more usable information streams. When the mind is too slow to see the necessary patterns and variables to accomplish the goal, the brainchip operates in a self-preservation fashion and links together information streams to highlight the most viable possibilities.

Such technology is not without warning, much of this is being used heavily in the military field and this has given rise to entire factions of enhanced cybernetic soldiers. Although this is something to know, there are also many other uses for this technology and it is used by people who want to explore the technologically assisted path.

There are many other aspects of this to discuss, or at least a few important ones that will have to be understood to know the greater truth about what is happening on the planet.

Developing The Self

The issues we face are to help us learn about our selves and better mediate the known and unknown aspects of personality. The more we focus on realizing the unknown aspects of personality the less we are seemingly controlled and forced to experience the undesirable aspects of existence. The more we cling to just what we know and what we feel comfortable with the more shocked we are when we inevitably discover the truth of the whole of our existence which is *always* at least one half more than just what we know and are comfortable with. That is the nature of the universe, we can only achieve one half of the equation at any given moment. Once we complete that seemingly whole view of the universe, the information we gain access to instantly doubles and we realize that we were only looking at one portion at a time, just one half of the equation. Then the rest of the equation comes into the picture and we must expand our view once again. This is because we are viewing ourselves as we discover the universe because we are creating what there is to be discovered through the act of exploration in itself. We are the explorer, the explored, the creation and the discovery simultaneously.

Multiple Factions of Space-Fleets, Multiple Goals

Now there are what are called ‘factions’ of groups that have different agendas and interact with the public or surface level population differently. That is one of the main issues. These departments and factions are no longer limited to the surface level of existence and have access advanced technological capacity and knowledge of a larger view of time and a more complete understanding of consciousness and the human existence.

Large-Scale Catastrophes or Series of Meltdowns

I was informed that while they work continuously to prevent and reposition this civilization continually outside of the reach of any large scale meltdowns that the technology is commonly accepted to only be a temporary barrier between the inevitable.

Unsustainable

This society is unsustainable and must either change or will experience the massive catastrophic evens that are foreseen.

There are multiple perspectives that are maintained. They vary by the way of the methodology of solving the problem. All agree that change must occur and is impossible

to postpone forever. The future society is the result of our advancements and achievements. Regardless of how we get there, we must get their somehow.

Earth Changes

I was informed that these changes had been held off and would ultimately be allowed to take place to resolve the current situation. The changes can only be held off for so long, either that or the people performing this task would not be reasonably inclined to postpone these changes indefinitely.

The idea is to locate and secure the members of society who are fearless and capable of assisting in this transition and who hold key genetic elements as these individuals and groups are capable of ‘holding-space’ for the rest of civilization by literally containing the genetic precursors for all those other individuals.

I was informed that Earth changes would be the last event to take place, pretty much like icing on the cake.

This means there will be a lead up to these events.

Mass Consciousness

I was informed that the consciousness of humanity and every species is linked to the bio-etheric field of Earth. When the consciousness becomes too unstable to maintain a controlled society that this will initiate massive Earth changes. This could simply be instigated through advanced technology but I was informed that the advanced technology is actually postponing this so as to allow people to prepare, to get the word out and avoid a complete loss of the human race.

Wars and Manipulation

Wars were described as a way the power groups had controlled humanity over long periods of time. These wars were used to distract and weaken the population and the power groups believed they were holding off a full scale invasion by suppressing the rising population.

Now the population is high enough that another war would be a final war and this is extremely dangerous for the entire civilization. There would be no need for another war to repeat this cycle because the technological achievements have been met and so essentially the ‘reseting’ of the civilization would not be required or possibly acceptable.

This is why war is to be avoided however people are very easy to manipulate through lower emotional and mental programming from media and social cues. People follow the herd and the herd is essentially still operating on animalistic parameters. There is a have coating of peace and humility but this is just a wax coating that quickly evaporates as soon as the pressure of mass unrest or scarcity is realized. Many simulators have explored these possibilities.

Financial Unrest (or reset)

The idea is that financial oppression is used before wars to distract and oppress the population. When people are busy looking for resources to survive, they are not focused on the larger picture. This is part of the ‘fight or flight’ response mechanism tied to lower brain complexes which are primarily activated to keep the masses in both a highly sensitive and unstable state of being while also keeping them easy to control.

If the civil unrest reaches a level where awareness continues to rise even though financial hardship is being implemented then the latter two options will not work. At that point artificial disasters can be produced as well as natural Earth changes which initiate a shift of the ages and of consciousness.

The paradox or maybe irony here is that the oppressive actions are used to both suppress human awareness up to a certain point and simultaneously to stimulate and arouse the human spirit into wakefulness and self-empowerment. This is part of the reasoning regarding why these control systems are allowed.

Some say the elite don't want an economic collapse. That it would ruin everything. Others say it would be icing on the cake. Some say that it is a zero-point world that will save us. That the Fukushima is a big problem. Zero-point field tech, that is. Generators and energy sources, healing and terraforming. I know we project right? We see it in our own lives. So we can project with each other and grow that as a group and that part of the world will exist in that light. Which sounds Biblical, which may be because they're following prophecy. But it may also mean that we have a light, a chance, a real salvation, but that we have to grow that here and help develop it. To pass it on like love and such.

That's apparently what it comes down to. That these cycles happen every so often and we're in the midst of one right now.

Let's make it count. Every day, thought moment. With mindfulness, intention and awareness in action. Life is literally higher dimensional, so we have to become multidimensional to really face it. Indeed, that is a good perspective on action and inner being. It's like a fractal, whatever we project inside that chest center, will project into our mind and the outside. But we have to be stabilized and grounded through the root first and then to get to the heart energy must pass through the sacral/sexual centers and continue upward.

Self-Responsibility

The main reasoning is self-responsibility. We are responsible for ourselves. The people are and so if they allow themselves to be tricked and prodded like animals while behaving for the part, then that is how their experience will play out.

Clones and Synthetics

One seemingly unfair aspect of this is that there is a larger portion of non-humans than there are humans and so these beings without the human spirit will be easily programmed to support and propagate the mind-control system and the oppression. Thus, if people follow the herd mentality then they will walk directly into the end-time scenarios yet it is the humans who will actually stand to lose. People must wake up to these tricks and this technology so that they can orient themselves with the reality of this situation while learning to strengthen themselves and adapt to the manipulative aspects of this control system.

Spiritual Power and Divine Truth

This is essentially all about spiritual power and humanity stepping into the power of the truth behind their existence.

Some say that humans are designed as slaves, but if this is so, then it is the power that humans contain within that is the ‘work’ that they are sought after for. This indicates that humans have great powers that others cannot achieve on their own, even if they are creator lords.

Thus, whether humans are modified or not, they have great power. If they are not modified to perform this role of an energy generator, then this is just a confusing mind-control game that has been pulled over the eyes of humanity and humans have always contained true internal spiritual power that allows them to exist without having to parasite and steal the energy and knowledge of others. Humans are reality generators , we can choose how we want to experience the universe and what kind of collective world we want to enjoy together. Once we step into this power, there is on greater force. No amount of non-human entities can change that as we are somehow intrinsically linked to the ether-space of this realm through the spiritual and physical aspects of our being. That is what is sought after and so those who do not have this manifestation power attempt to utilize humans to create their own reality through this Earth situation. That is the basics of the ‘alien overlord’ system, whether humans in disguise, non-humans operating with alien intelligences, supercomputer systems, or spiritually degraded beings.

Most people are not ready to see themselves or the true nature of humanity. Reality is largely an illusion of the conscious mind. The hidden aspects are the other half of the equation and this is perceived by the shadow aspect of the personality and mind. We are only marginally aware unless that aspect has been unveiled and through this process the reality of the human soul can be actualized and realized.

I was informed there would be a period of two suns and multiple mirages around the world. People would believe they were peering into another dimension, floating cities, or some kind of city-ship craft.

Synthetic DNA, Synthetic Genetics

Through the previous described replicator devices synthetic DNA can be engineered. Thus, entire genetically engineered codons can be produced and form this created beings can arise. These are the hybrid beings that are performing many tasks underground and even on the surface. On the surface there are synthetic genetic create beings or genetically engineered beings that appear to be human but do not contain a human genome. There are also clones and replicants of humans. There are a variety of non-humanoid forms but these are largely kept underground. These are beings we often see in science fiction movies or shows.

Time as Mathematics, Series of Equations, a Programmable Storyline

When using the technology, time can be understood to be a series of programmable variables where one variable is centered within a series of parameters and from these possible variables within a parameter set a series of possible functions or outcomes can be process. Thus, these people can literally plug into a supercomputer system which operates based on this form of processing reality and through this they can observe all the possible realities that may connect to a present moment. This allows one to travel but this is not part of this section of the explanation.

What this allows one to do is know exactly what is going to happen and when. If a person is being interrogated, all that has to be done is the operative using the technology simply thinks of what they will say and intends to do it within 6 seconds. The machine will play out a future timescale regarding the input of that question or interrogative speech and then produce the possible results. If this doesn’t give the desired readout in the mind of the operative, they will refuse to go that route and think of another pathway. This repeats for a few seconds to a few minutes. Then the computer has found the pathway that is most like to yield a result. The operative simply steps forward, says ten words, the subject breaks immediately and tells them everything they want to know. This is obviously takes longer for most trained individuals, however that is how easily it would be to use this technology to produce an effect on a regular surface level human. They would have no defense, no way of knowing how that individual could know so much or be so direct. This is how operatives dealing with certain power groups will operate in the surface level population and individuals always feel that these people know way more than they are leading on. That is because they are, they know more about you and your life experience than you do.

Chapter 2.3 Previewing Solutions

Neutralizing Polarization

The mental-emotional tendency to pick sides, to fight, or to basically join in the fray that is currently taking place is a kind of deception of polarization which enables the leeching of emotional and mental energy from the human. This is more of a psychological unveiling where the true nature of the self, the duality game and the transcendent source aspects can be made visible to the individual. The they will see how every polarization tactic is actually taking them out of their true source of power by pushing them off center emotionally and mentally. There are teams that are capable of enabling this process and assisting as humanity realizes that half of the problem is that the unchecked mind is one’s own worst enemy.

Removing Etheric Implants

Technology can identify and isolate these foreign body implants which are etheric technological devices. These are literally frequency or phase-shifted devices which are invisible to this layer of physicality but are capable of being organized and attached to the etheric field of the human and will operate to siphon or limit energy on the etheric level. Of course, this is all technology of the vampiric created beings who parasite on the original Earth inhabitants to sustain their existence.

Clearing Astral Body

By moving through the temporal body etheric implants can be deactivated and removed and then the astral or emotional body will be able to function closer to the original levels of presence and sensitivity. This body is manipulated when one is emotionally shut down from trauma. Thus this body can be scarred and will function at a much lesser level of activity or presence until the emotional damage is healed. This contains the memories of all the emotional events of a person’s life.

There is technology that enables one to access these levels of frequency and clarify or untangle emotional chords or attachments which are used to siphon energy from the human being to the parasitic created beings. These chords are energetic in nature but also have technological components.

Knowing the True Self; Soul Actualization, Unveiling

This is a sacred, ancient process that has been outlined and discussed since the beginning of time. Humanity is here to learn, grow and express the self. In doing so, like a child moving through layers of infancy and into full-wakefulness of their body and the physical world, humanity can come into awareness of their true spiritual nature and the true spiritual nature of the universe. This is the process of soul or self-actualization that is described in some psychological methods such as Maslow's hierarchy of needs and the self-actualization that results in a complete fulfillment of all psychological needs. In this modern psychological view, self-actualization is described as the desire and process of reaching fulfillment of one's own natures and then living their life sharing that self-empowerment with other beings because after gaining your self that is the highest expression of such knowledge, sharing that power with others.

The true self is not limited to the physical body, the true self is a reflection of the entire universe and thus the primary original creative force. This is akin to the whole equation rather than just half of the equation. The visible aspect of the self, the conscious mind, is only one half of the entire equation. The whole equation consists of what we see visibly and consciously as well as what we are limited from seeing within the unconscious and subconscious mind. These are really two layers of the same ultimate source. Like an iceberg which is only partially above water, the subconscious mind is the proprietary wholeness of experience. The conscious mind is only a surface layer of reality while the unconscious mind carries all the notions, the multidimensional processes, the latent aspects of reality that we are not capable of seeing without unveiling these aspects through inner exploration.

Taking Responsibility

This entire show is about taking self-responsibility. Unless people begin to do this, there will be no hope. Right now people are convinced that their responsibilities belong to someone else even though this always results in pain and discomfort. To take responsibility is painful at first because we have a lot of work to do, but even then, this is beneficial because there is no way to remedy the pain and discomfort of being lied to and disrespected if people continue to hand their free-will over to others through blame (scapegoating), lower emotional bio-emissions (hatred, anger, etc), distractions and addictions (technological, sensual, and chemical or food based), or generally complaining without taking the first step towards providing something beneficial. This is the victim role, if humanity is to take control then they to help each other and themselves by not relying on false promises and false authorities to determine how they feel, think and live.

Returning To Center Emotionally and Mentally (spiritually)

Balanced food intake, rest, exercise, activity and learning are all continual requirements for a healthy existence. Emotional and creative expression nurtures the soul. Without these ways of being and learning the human qualities of experience diminish and creativity dwindles. There is most likely going to be a split between those who can sustain their own humanity and those who have to cause others to suffer to do so.

Vampires in the “Awake” Community

Contrary to popular belief, the majority of the non-humans are not necessarily vampiric and in power. The vampires are the people online who try to get a rise out of others for sharing their own experiences. They are the nosy neighbor that feels that the person who looks or acts differently must be considered and enemy and armed against because they feel themselves to be so much better. The majority of people are vampires, they believe that they must work for someone who will trade them money and that the amount of money they have based upon the amount of indirectly beneficial work they do puts them above others.

This is not different in the ‘awake’ community and in fact I feel that there are higher concentrations of vampires in this community, the alternate media because everything is largely a joke and a trick. People are operating on deceptive agenda schemes to divide the people and this is most intensely noticed when there is a realization of the truth behind what is happening and people begin to point fingers. The only people who are cleared to point fingers (and who also will NEVER point any fingers) are the operatives from the secret projects that have the capacity to do so because they have reached a specific level of awakening and this is related to the droning, cloning, and hybridization process. Only a specific few know who has been transformed into an impostor being and who is remaining strong and this is due being briefed on the surface level situation. Anyone can say what they want, they are simply playing into the tactics of mind-controllers and parasites and the more they play in the deeper the infection will grow. All the people pointing fingers now are actually implanted and vampiric and are attempting to drive a divide through humanity and they are the first who will turn on their friends and family when the going gets tough because they are more interested in others and starting drama than healing themselves. Ironically, this is all done under the guise of “healing” and “getting rid of the drama” AKA people they don’t trust. They pick and choose based on their own personal bias and this is a sure indication that they are emotionally and mentally out of alignment and are feeding deep seated personal fears from their own traumatic experiences.

These traumas must be healed and the harmonious center must be reattained where a person can focus on their own existence and waking up instead of acting as false-light, “king of tyranny” gatekeepers for others. Those individuals are going to be left behind if they cannot kick the habit because if they are allowed into any kind of healed society they will quickly degrade into animals and attempt to restart a devolution process in order to gain the power they so desire but cannot produce on their own. ANYONE playing ego games of trying to hurt or put blame on ANYONE else contains this viral implant and has not kicked the virus.

Heart Center and Psycho-Spiritual Fulfillment (self-actualization)

Emotional connectivity is a form of telepathy, when loved ones can tell the state of another across space and time. Whether it is family or friend. In the 60's and a little before that the US found a specific frequency akin to a radio frequency that operates on a trinary spectrum. They called this the "telepathic wave". In time, they could completely read and send thought waves without frying the brain or body through radiation. Which was what the early machines did. They actually took satellite dishes and aimed them at people. Then realized they could turn it around and do it backwards with a better effect and minimal radiation. Either way they started beaming the base and then towns around them with waves between 400 and 432 MHz and caused waves of crime sprees or peace sprees throughout the 70's and 80's. So they can digitize the telepathic wave to induce artificial telepathy. But this is organically done through an entanglement through what we call love. Literally. The Germans found it before that. And the secret orders before them. And ancient Egypt before them. As humans we remain basically through the root, heart mind connection. When the heart overpowers the mind connection of spirit, then the body is a trinary whole. When the mind guides it is binary and cannot by guided by the spirit. The spirit has direct access to the heart. The mind is a computer of sorts. The mind doesn't see past duality. The heart is the true center/eye of the spirit. The reptilian brain is the dragon and when you tame the amygdala then fear is ‘behind’ you. When the mind is "untamed" the reptilian brain takes over. This is the lower brain and amygdala fight or flight response.

This happens when the energy of the brain, body and spirit increases due to whatever various reason of spontaneous or controlled increase. Because of the "temptations" which are the easiest flow of emotional energy into a "discharge" state, is that the sacral/sexual center ties to the heart and reroutes to replace the heart and control the mind. Mental and emotional contemplation of one's true purpose and nature is the path of the divine. We find ourselves simply by looking in the right place, not in the world, but in our self energetically. We are more powerful than the programming, and we can reverse this is we're careful and devoted enough.

We have to be faster than thought, at the speed of spirit, beyond matter. When we start thinking on this level then our influences spread to others throughout the sphere. It is our destiny to know these things but they have been kept from us. The ancient orders called this the art of "implosion". Traveling realities through intense contemplation and a usage of sacred geometrical forms.

They developed and combined orders around WW2 and developed zero-point energy tech that can alter space/time fields. This is timeline manipulation. But as a rule, we go where our heart leads us. So that's how this is solved.

Go Within to Observer the Self

The answer is literally by looking within to find the great truth rather than looking around us. Everything we need to know is within us, energetically and spiritually. Our emotional, mental and physical state of balance is an indication of where and how we exist in relation to the larger overall truth. Everything that happens around us to distract us is designed to stop us from looking within. Nothing can truly stop us, nothing can actually input the holographic horrors in our spiritual center but simply perturb the brain and body. The mind is a non-holographic spiritual environment that cannot be excessed and the invader's goal is to convince people to use their imagination or their creative powers to produce these horrors on their own. This is through the programming. We must clear out the programming, the trauma, the lower-dimensional constructs and fill ourselves with the truth and spiritual presence that enables us to be self-aware in the first place. If we aren't doing this, then we are either in pain, or there is no spiritual presence to be in pain. If we are doing this, we are either clearing out the constructs by replacing them with true spiritual presence and self-awareness or we are becoming aware of them.

Organic Feedback Loop

The great feat is mentally bridging the great rift between us by looking within. Which is paradoxical.

We can never see what another is perceiving exactly, well for the most part, so we all have to kind of accept that we are communicating effectively and truly get to this level of comfort by simply being secure in knowing who we are our selves.

Technological Feedback Loop

So then knowledge, in a way, when shared, is a form of telepathy. Group telepathy.

Group think, when ideas or memes spread, is a form of group telepathy.

The Internet is like artificial spreading of telepathy. This means what is normally mentally bound signals can be initiated and spread through a digital medium.

Breaking Soul-Contracts

Ultimately everyone is under a series of “veils” which are energetic time-constraints literally like 9 dimensional layers of temporal restriction which are each bounded and ruled over by invader beings. These range from physical authorities, to astral entities, to programmable matter, to supercomputer intelligences, to spiritual false-light beings and our own shadow mind. Each layer of reality is successively guarded by these beings who are here acting as gatekeepers designed to push people back when they begin to wake up. These beings all work through fear and deception and the last layer is based on mirroring our own energies back to us like an impostor. All the levels tend to imitate, however the last layer is a near perfect imitation of our own energy to the point where people often switch places with this being before getting out of the matrix. There will be more discussed on this in a later section.

The “9 veils” were designed by impostor beings as a last effort to stop humans from escaping the false-light matrix which is essentially the holographic universe. This is literally like a maze which reproduces a new pathway and a new doorway each time a person nears the last hallway or doorway that is next to the exit. So one eventually has to project themselves into the exit using their whole being and moving past and through the tricks by not falling for them before they are placed. This is highly confusing but this is essentially a kind of labyrinth that has been created to stop people from leaving so that their soul energy can be destroyed and used as a generator for the false-light system which is an AI over mind that is programmed to take the raw soul energy and destroy the identity by inverting the electromagnetic spectrum and incorporating that inverted energy into its own internal matrix body which is literally the false-light universe.

Help Everyone

Now they may have been setting us all up for the apocalypse. They said they want us to tell on them and get the whole world aware of what they've been doing So that we can stop them and pull them from the dark which is ACTUALLY taking their souls. There are also breakaway civilizations involved in this entirely zero-point/free-energy.

Chapter 2.4 How Timelines Collapse

Repeating Cycles of Time

Because of the way time works and the ability of those using these temporal devices they have set up an elaborate labyrinth like a spider web of false realities, timelines, parallels, sub-dimensional layers, astral cages, temporal dead-ends, and time loops which act to stop people from reaching the true reality. As a result, many portions of this timeline are literally in a free-will ‘time-loop’ and these loops must be canceled out. As well, because of the nature of these loops on the overall stream, our entire civilization has been looping for the past 6 time-cycles meaning we have reached this time in history 6 times before and this is apparently the last time because we have never gotten this far before and the events of the future are having to be programmed in manually at this point.

Beings From the Future

As are result and damaging time, what happens is that the beings from the possible future that is being damaged appear to try to heal the break as well as those who are from the new possible future that is generated, this results in a time war between both possible realities for the present realm. This is what has been happening for thousands of years. All the ancient spiritual texts are describing this system. One group is a from an original possible future where everything is based on the presence of spirit and souled humans, another is from the new possible future where an AI overlord took over and removed the souls and spiritual energy from all entities on Earth rendering this a holographic prison without any other use. That reality dissolves into itself and so the time beings are constantly moving backwards and jumping timelines to try and obtain more energy.

Beings From Collapsed Timelines

The beings from the collapsed timelines are those who travel through hyperspace to get here. They then recreate themselves using cloning technology through hyperspacial means, IE: creating an alternate temporal dimension so that these devices can sustain them and literally “hold-space” for them. Then if their timeline is destroyed, they can still exist as a ‘loose-end’ in space-time. This is extremely dangerous and I will say we have some Human operatives jumping timelines searching for Earth and Humanity so that they can find a reprieve from this time war.

That is the most trying aspect of this entire ordeal for me. There are some human operatives literally in hyperspace without an opening into the temporal stream for them to reintegrate into this timeline. We must assist them, we must open the timeline by taking control of Earth from the invader races and those who wish to depress and isolate the spirited and souled human beings. We must re-organized and neutralize the invasion forces of deception and assist our humanity and maintaining their free-will, their self-awareness, their self-empowerment and their emotional, mental, and physical harmony.

Beings Who Would Never Have Existed in the First Place

As a result of this entire process, there are essentially beings who have been erased from time who degrade in this dimension and can only interact periodically. These are the created beings who operate through supercomputer forms that are placed within cloned bodies and powered by the transdimensional quantum supercomputers. These are the ‘parallel’ reality beings and this relates to the hive mind invasion. When all the original aspects of time are restored, these beings would not have ever existed in the first place as there is no quantum link for their probabilities to remain neutral and present in the original run of things.

Again, all beings who operate under the will of the universe, even when they are attempting to trick hyperspace and time, when these beings assist and help in the unification of sentient, spirited, souled beings they are capable of being healed. This is all because there is an original creative force which can produce souls that are eternal and everlasting, meaning they are not created but simply always ever were. Yet, there is a “miracle” effect where beings can be given eternal life. This is only by reflecting the will of the whole of existence, rather than a portion or a part because this is only temporary. Only the whole is forever and this takes true harmony, true balance and ultimately *self-lessness*. To give to others because you see them as worthy because they can be aware and enjoy the gift is to be like the creative force that gives life to all and enables all experience in the first place. By acting in correspondence with this we reflect the will of the whole and that power and action transfers into protection and self-empowerment for ourselves. This cannot be cheated, tricked, or rerouted as that is the karma game that has been played by delaying time and rerouting energy through getting others to take on the responsibility for others bad actions. In the end, all karma has only been delayed because when the stops are pulled out, *everyone* ends up getting their karmic returns regardless. They simply intended to build up so much karma that by the time the ties are cut, the karma overload will simply kill them instantly. This never happens and they end up in the abyss, this is the final time so since there is no recycling of the universe from the oroboros system then whatever happens is what happens forever. If everyone wants to move into harmony, to receive healing, to receive forgiveness then they must assist in the creative force in healing, forgiving, and turning away from the deception, the cruelty, the vampiric actions.

Many vampires believe they will die if they stop. The only hope is to admit their ways to the others and ensure that there are enough beings around them that will protect them so that this situation can be handled properly, with due care, compassion, and the necessary healing to ensure the safety and protection of all who seek harmony.

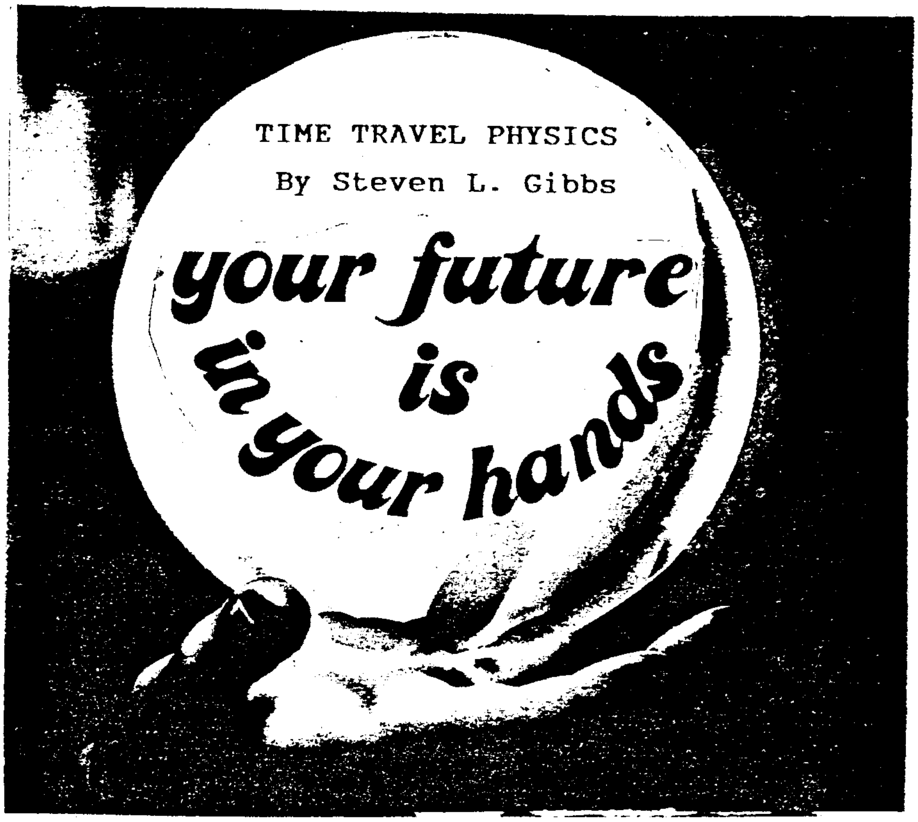

TIME TRAVEL PHYSICS

By Steven L. Gibbs

your future
is
in your hands

DEDICATION

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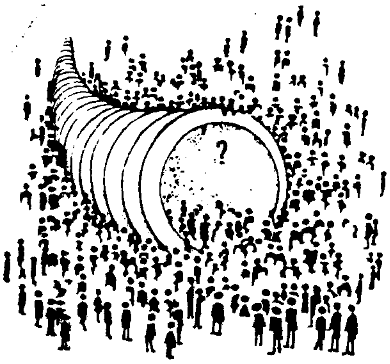

I would like to personally thank
Jesus Christ in helping me to obtain
the knowledge for writing this report.
For without his help, all of this
would not have become a reality.

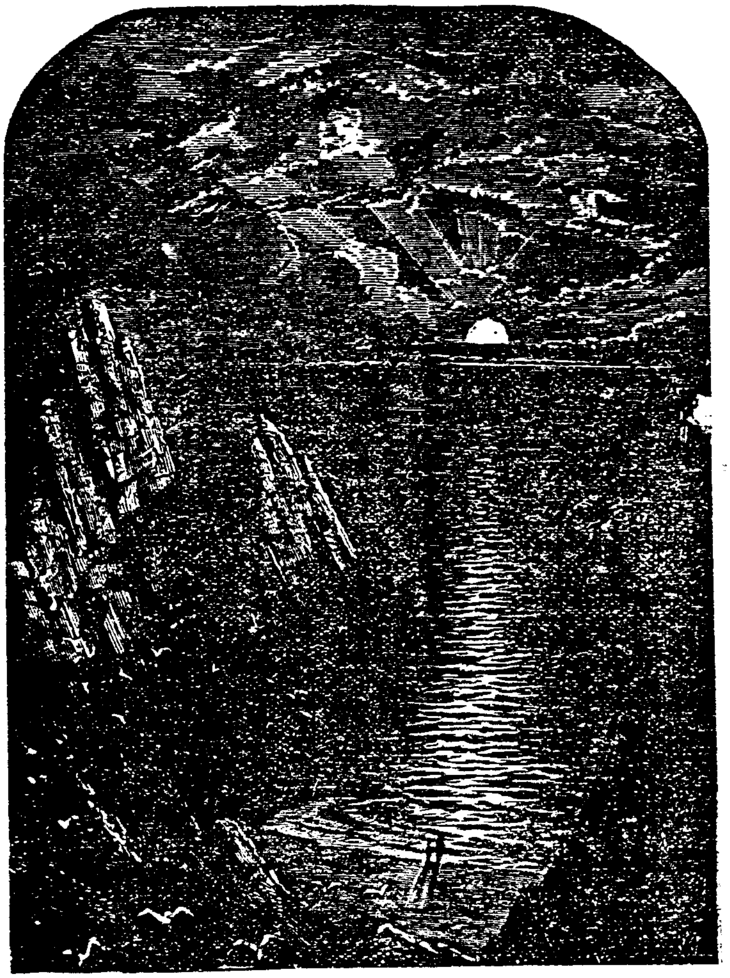

INTRODUCTION

The reason for writing this report is to show people that man does not have to use sophisticated mathematics in order to understand how Time Travel can be achieved. To assume that what is being taught in today's schools is an absolute truth, can only be a lie. For to believe in such a lie, can only lead to imperfection. But sense mankind has chosen this path, the inevitable must surely come to pass.

It is impossible to say where all of this might lead. However I do hope that the people who read this report will use the knowledge wisely. For those who don't, I leave them to their doom. But for those who do, may the Lord bless you.

Your probably wondering by now, if I am really an Alien. My answer to this is, there may be more truth to this than meets the eyes. According to the information which I have received from the Kennedy Space Center, there is a good chance that my parents came from the Star System called Phoenix. If this is case, then this would explain why I have had so much difficulty in adjusting to Earth's own environment.

Perhaps in the years to come, more will be revealed to me on the true nature of my whereabouts. And you know what they say about Aliens? Their weird!

TIME TRAVEL PHYSICS

Before I begin I must first point out, that the only reason why Formulas can be used for analyzing a specific problem, is due to the fact that a Formula helps in focusing the Belief Fields which emanate from the persons Soul. So in other words, whenever a person uses a Formula or Equation, to him this constitutes a reality. By keeping these things in mind, you shouldn't have any problem in understanding what has been written in this report.

To begin with, there are basically 3 sets of Equations which can be used for accomplishing Physical or out of the body Time Travel. I have used these formulas quite often when building my Time Travel Machines. As a matter of fact, all my research is based on these 3 formulas. The formulas which I have used for accomplishing Physical or out of the body Time Travel, are given in the following manner:

(THE GRAVITON FORMULAS)

$(X , Y = 0)$ $(X1 , Y1 = 0)$ $(X2 , Y2 = 0)$

The Graviton Formulas which I have so diligently labeled, can be used for an infinite number of things. However, before we can proceed any further, we must first have a good understanding of what each Symbol means. There are an infinite number of meanings which can be applied to each Symbol, however in order to simplify things, the meanings which I have given to each Letter or Symbol, are listed in such a way so that anybody with a little bit of knowledge can understand them.

(INTERPRETATION FOR EACH OF THE GRAVITON SYMBOLS)

X - Represents an AC Field.

Y - Represents a DC Field.

X1 - Represents a High Frequency Field.

Y1 - Represents a Low Frequency Field.

X2 - Represents a Paramagnetic Field.

Y2 - Represents a Diamagnetic Field.

$\emptyset$ - Represents the Zero Vector or Twilight Zone.
it may also be referred to as the (PHI Value)
which is (1.618).

It is interesting to note, that whenever the (PHI Value) is used in the construction of a material object, a Time Warp usually occurs around that object.

However, in getting back to the problem at hand, whenever the (Graviton Formulas) are used singly or in series with one another, they can be used to help build a device which can actually be used for Time Travel. This is because whenever the (X) and (Y) Values are combined with one another, we can Zero in on the Twilight Zone. And sense the Twilight Zone is in attunement with God, all things become infinitely possible provided that the (X) and (Y) Values are in resonance.

So now your probably wondering, how can we use these Formulas for constructing a Time Travel Machine? Its simple. Merely start out by building a Capacitor which corresponds to this Equation: (X2 , Y2 = 0). This Capacitor should be constructed in such a way, so that it resembles the drawing which is shown below:

(DRAWING OF CAPACITOR)

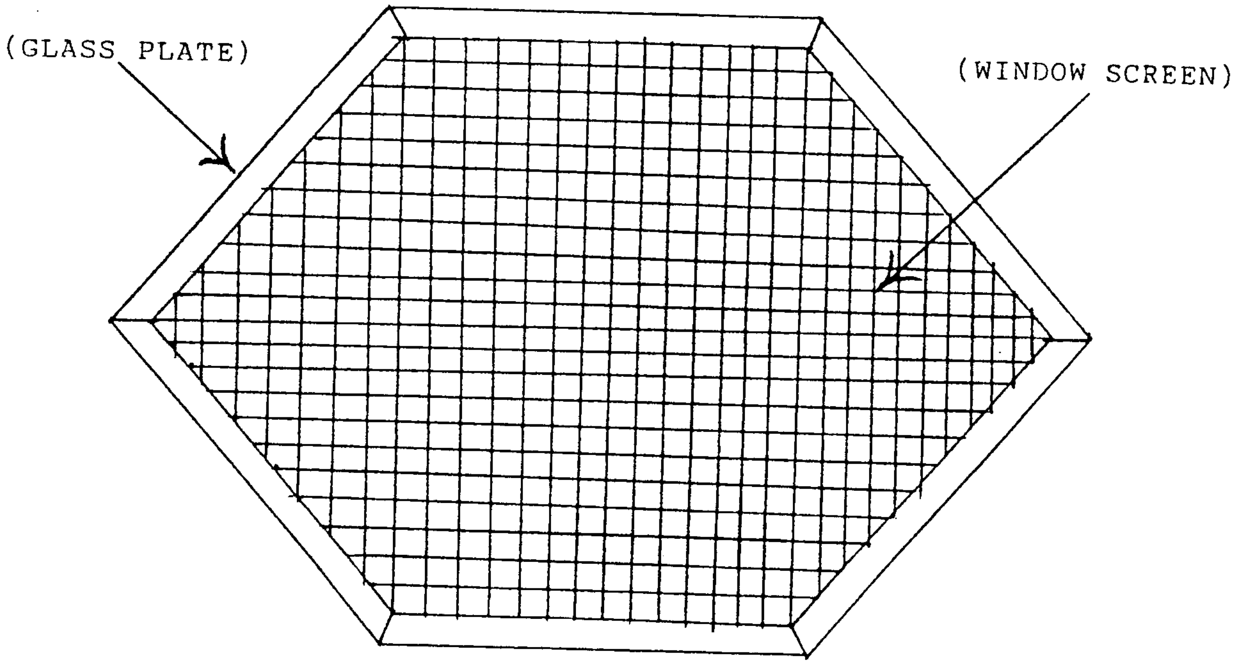

As we can see in the above illustration, it doesn't matter to much as to what size it should be, just so long as it is shaped like a Hexagon. Also each side of the Capacitor should be the same length, otherwise the Belief which is being transmitted from the plate, will be imperfect. And this could raise Hell with your Chakra Points.

At this point it should be noted, that whenever you construct a Capacitor of any type, you are automatically using the formula (X2 , Y2 = 0). And sense the (PHI Value) is used in the formula, the plate itself will develop a Life Force of its own. It should also be pointed out, that sense there is a Life Force which co-exists with the plate, it can now be programmed to do anything you want.

Now in order to program this Capacitor, all we do is stroke the Glass portion of the plate, while concentrating on the following command: (Transport me to the Date and Year). As soon as you get a stick so that you can no longer move your fingers, the Capacitor should be fully programmed. After you have finished programming the Capacitor, place the Screen Side of the plate over the Solar Plexus for the space of 30 minutes. After the treatment is over with, you then find a comfortable place to relax in order for the energies to take effect. If you have done everything correctly, your Aura or Physical Body should be transported to the date which you programmed into the Capacitor. On the average, it usually takes 70 minutes before the energies will take effect.

*Note: People who work with these plates are in serious danger of getting possessed by an Evil Spirit or Demon, unless of course you have a faith in Jesus Christ. By saying a prayer to Jesus Christ prior to any Experiment, more than protects you from the forces of Evil.

As you Experiment with these Capacitors, you will find that some of these plates work better than others. The reason for this probably ly's in the fact, that certain sizes or the materials being used, are in resonance with the person's Life Force or Belief Fields. Therefore if you run into any problems, it may pay to use a different thickness of Glass. When I talk about this, I do not mean to vary the Shape of the Capacitor, just the width. It also might pay to use Yellow tinted glass. You may also want to try Green, Blue, Indigo, and Violet colored glass. The reason for doing this is simple. Each color corresponds to a different Chakra Point. It is therefore my opinion that Yellow should be your first selection, then if you want, you can always Experiment with the higher colors.

*Note: Never under any circumstances use Red or Orange tinted glass. If you decide to use these colors, then your probably on your own, because not only will it lower the Frequency Rate of your Chakra Points, but you could also end up in an Astral Hell. And believe me, this is no fun place to visit.

Once you have found a plate which can transport your Physical or Spirit Body, there are still even further ways of increasing its effects. One of these ways is by using the second formula, (X1 , Y1 = 0). This formula states, that whenever a High Frequency Field is combined with a Low Frequency Field, we can tune ourselves into the Zero Vector or Twilight Zone. To use this formula it will first be necessary to get a hold of a

Tesla Coil and one Van de Graff Electrostatic Generator. Once these items have been obtained, you proceed by charging the plate with High Frequency Electricity and Low Frequency Static Electricity. In other words, after you have programmed the plate using the procedure on page (4), you must simultaneously Zap the plate using the above procedure. You must make sure that while you are doing this, that you do not come into contact with the plate. If you do, you could be in for a Hair raising experience. This voltage hurts! But anyhow after you have Zapped the plate for the space of 10 minutes, you then proceed by placing the Capacitor over the Solar Plexus as described on page (4). The effects that you get, should be much better than what you experienced before.

The next step to take, is to Amplify the Energies even further. To do this, we must now make use of the 3rd and final formula, which is (X , Y = 0). This formula states, that whenever an AC Field is combined with a DC Field, a Time Warp occurs which tunes our minds into the Zero Vector or Twilight Zone. Now in order to create these fields, one should try to get a hold of a Hyper-dimensional Resonator. (Read the last 4 pages in this Report). Once you are able to get a hold of this instrument, and after everything has been plugged in correctly, while the Screen side of the plate is positioned over the Solar Plexus, position the open end of the Electromagnet over the glass side of the plate for the space of 3 minutes. After the treatment is over with, disconnect yourself from the plate (turn page) and instrument, and find yourself a comfortable place to relax. If you use this procedure in conjunction with the first two procedures, the effects that you obtain, will be increased to such a point, that you should be able to do anything you want. You must remember however, that before Physical and Spiritual Time Travel can be achieved, the (X) and (Y) factors in the formulas must be in resonance with one another. This can only be accomplished through the process of tuning your own mind just as you would with a Radionics Machine. So in other words, by selecting the correct materials to use, you are in effect creating something which you physically believe to be a reality. This same rule can be applied when working with different types of Frequency's and Voltages.

Another method which you may want to try, is that after you have programmed the plate by using the procedure which is given on page (4), transmit some High Frequency Electricity from a Tesla Coil into the Capacitor while the Screen side of the plate is pointing towards your face. After 3 or 4 minutes, de-activate the Tesla Coil, and while the Screen side of the plate is still facing towards you, take the bare ends of an Extension Cord that has been plugged into a 110 volt AC outlet, and short out the bare ends of the wires by touching both of the terminals on each side of the Screen. (See page 8). If you have programmed the plate correctly, your physical body should be transported instantaneously to the date which was programmed into the Capacitor.

THE CHRONOLOGICAL TIME REFLECTOR

(Series No.2)

2-21-89

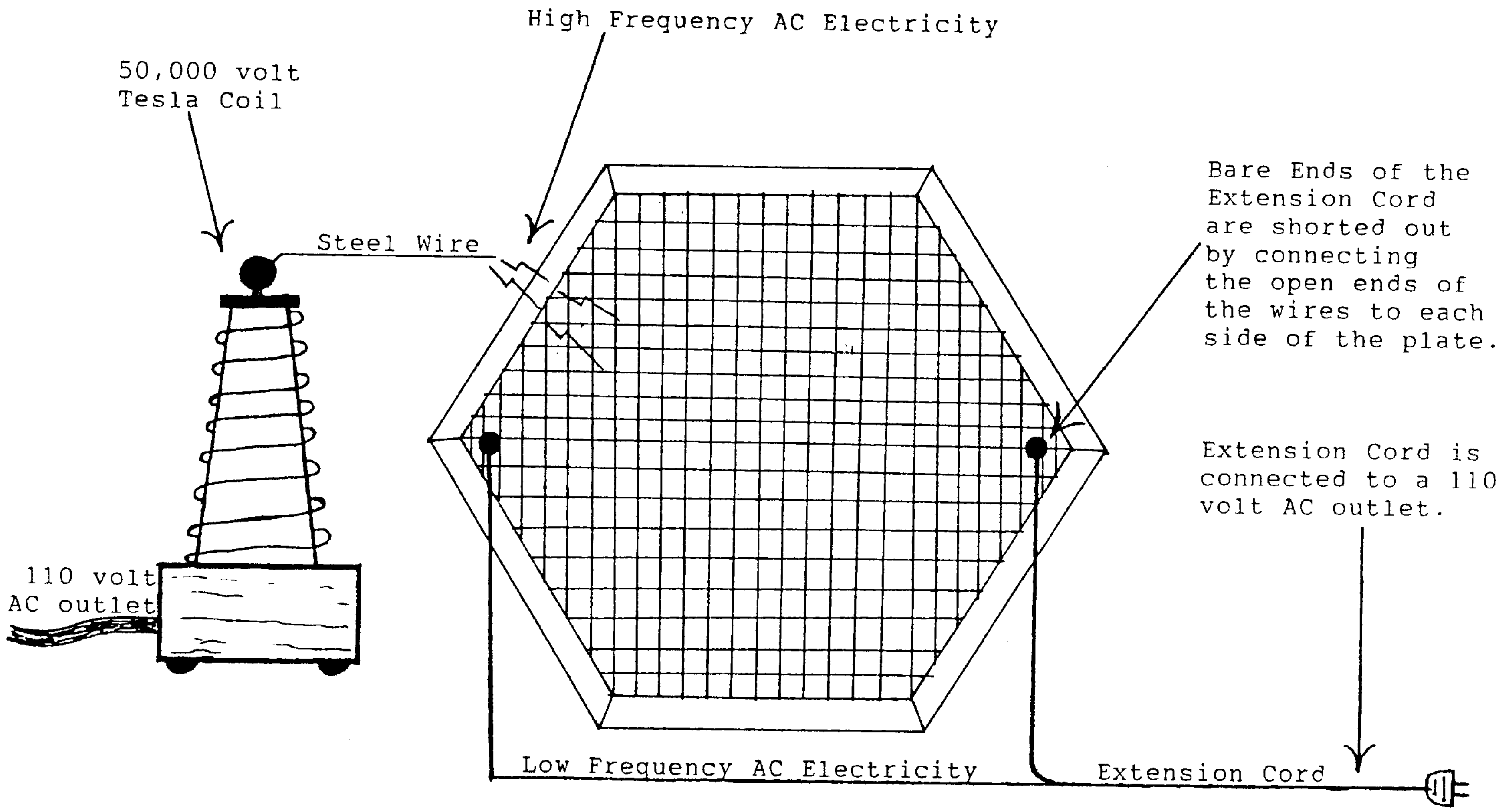
High Frequency AC Electricity
50,000 volt
Tesla Coil
Steel Wire
Bare Ends of the Extension Cord are shorted out by connecting the open ends of the wires to each side of the plate.
Extension Cord is connected to a 110 volt AC outlet.
110 volt
AC outlet
Low Frequency AC Electricity
Extension Cord

To give you some idea of how all this got started. Back in the year 1981 I was contacted by what I believe to be my other self. The letter which I received at the Sunset Plaza in Norfolk, Nebraska, was dated 1992 A.D. It also had a month on it which I can't seem to remember. Evidently the letter which I received indicates, that sometime around the year 1992, I will travel back into the past to make contact with myself, just like my other self did in the future. One of the things which the letter mentioned which I can barely remember, is that it said: (The path to the truth can be found in the Pyramid of Giza). It also had a riddle, and it went like this: (The riddle can be solved when 79.613 is dissolved). These two verses holds to key to Time Travel. I have already deciphered the riddle. As a matter of fact it was just last year when the answers came to me. Basically the 79.613 number can be converted into the (1.618) value which is used in my Equations. It is also the same number which was used in the construction of the Pyramid of Giza. If we decipher the riddle even further, we will find that it also reveals that the 7.8 Hz. Frequency, is the Frequency to use for accomplishing Time Travel. It seems that whenever a person travels physically through time, his Alpha or Theta Waves are vibrating at this Frequency. Once that your Brain Waves begin to oscillate at this Frequency, your mind then becomes tuned to the Zero Vector. I have found that this is the only way in which Time Travel can be achieved. So basically what I am trying to get at, the Chronological Time

Reflector causes your Brain Waves to vibrate at 7.8 Hz. cycles per second. That is all that these units do. However, for some people, they might think differently, but when you get right down to it, it all leads to the same thing. Mind verses matter. And this just barely covers the subject.

Another experience which I had that occurred around the month of Sept. in 1986, dealt with a variation of the Chronological Time Reflector. In other words, after I had finished programming the plate, I proceeded to Zap the plate with 50,000 volts of High Frequency Electricity. Sometime after the Experiment, I clipped off one end of an Extension Cord and plugged the other end into a 110 volt, 60 cycle, AC outlet. I then laid the bare ends of the wires on top of the screen. Just then I accidentally dropped something on the floor. After I had reached down to pick it up, the bare ends of the Extension Cord which I had laid on top of the Screen, touched the Screen portion of the plate. What was to follow, would be the most terrifying experience I had ever had, because as soon as the bare wires touched the Screen, a massive short occurred. All I can remember is seeing two flashes of white light energy, and the next thing I knew, a white mist had fallen over the entire room. I didn't realize that I had traveled physically through time until I looked at a Calendar the next day. Not only that, but when I asked a lady in Plainview, Nebraska as to what the date was, she said it was the 17th, but my Quartz Watch indicated the 16th. When

I had returned home later on that day, I has discovered that all of my Experiments had been dated wrong. Then I finally realized that I had actually traveled one day into the past. To this day I am not exactly sure as to whether or not I returned back to my own present Time Line. Perhaps I will never know.

Another Time Travel instrument which was sent to me by a man who lives in Osceola, PA., is revealed on pages (12), (13), and (14). According to what I have red in his letter, this device can actually transport objects into the future. However, he says that there is somewhat of a Time delay effect shortly after the unit has been shut off. In other words, after the unit has been de-activated, it takes anywhere from 10 to 15 minutes before the object is teleported. I have never built this device as yet, however I plan to eventually.

POWER SUPPLY FOR THE TIME PLATFORM

2-22-89

C1 - Is a homemade Capacitor made out of sheets of Glass and Copper Foil. Aluminum may be used, but this could be dangerous to your health.

L1 - Is number 10 Gage wire wound around a dowel rod.

L2 - Is number 24 Gage Magnet Wire wrapped around some PVC pipe. There should be about 1000 turns which should create around 100,000 volts of Low Amperage High Frequency Electricity.

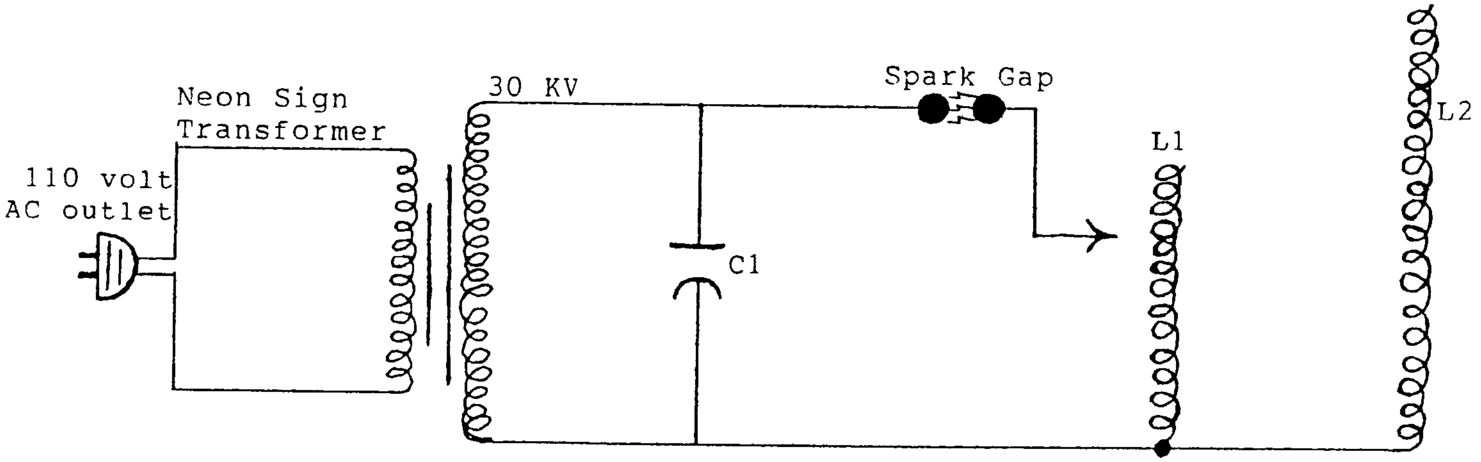
Neon Sign Transformer
110 volt AC outlet
30 KV
C1
Spark Gap
L1
L2

THE TIME PLATFORM

2-22-89

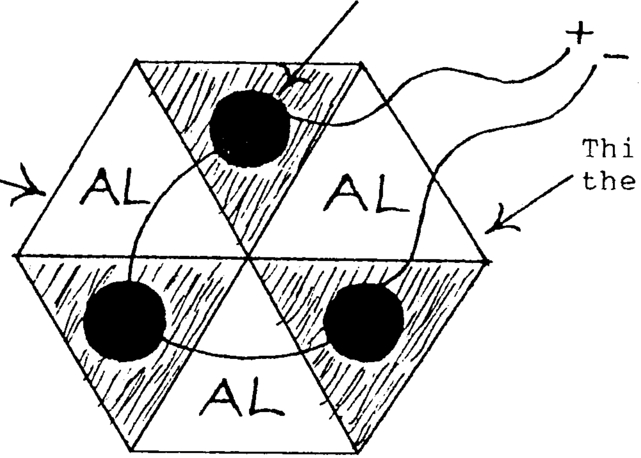
Electromagnet
+
-
The plate is 12" inchs across.
This is the shape of the sending plate.
AL
AL
AL

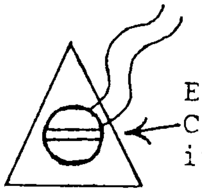
Electromagnetic Coil is placed in the center.

THE ELECTROMAGNETS ARE MADE OF STRAP IRON STACKED 8 INCHES HIGH (1/4"STRAP IRON).

THE ALUMINUM PLATES ARE 1/4 OF AN INCH THICK, AND ARE STACKED 8 INCHS HIGH .

THERE ARE VARIOUS REASONS FOR THIS PARTICULAR ARRAY.

THE ALUMINUM SPACERS CONCENTRATE AND FOCUS THE MAGNETIC FIELDS.

FULL SCALE DRAWING OF THE TIME TRAVEL UNIT

2-23-89

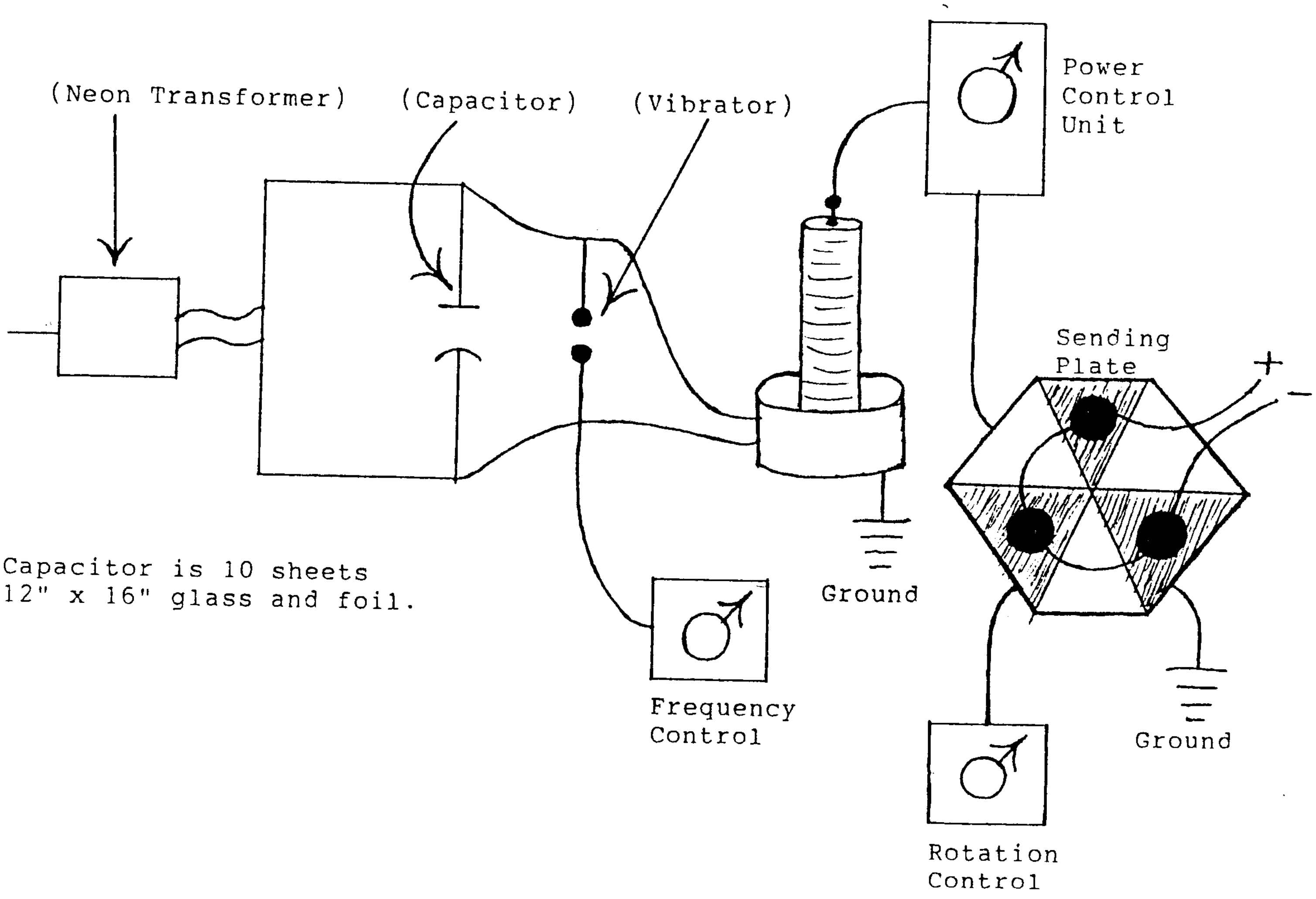
(Neon Transformer)
(Capacitor)
(Vibrator)
Power Control Unit
Sending Plate
+
-
Ground
Frequency Control
Ground
Rotation Control

Capacitor is 10 sheets 12" x 16" glass and foil.

THE DELAWARR EXPERIMENT IN TIME TRAVEL (PHASE #1)

8-16-89

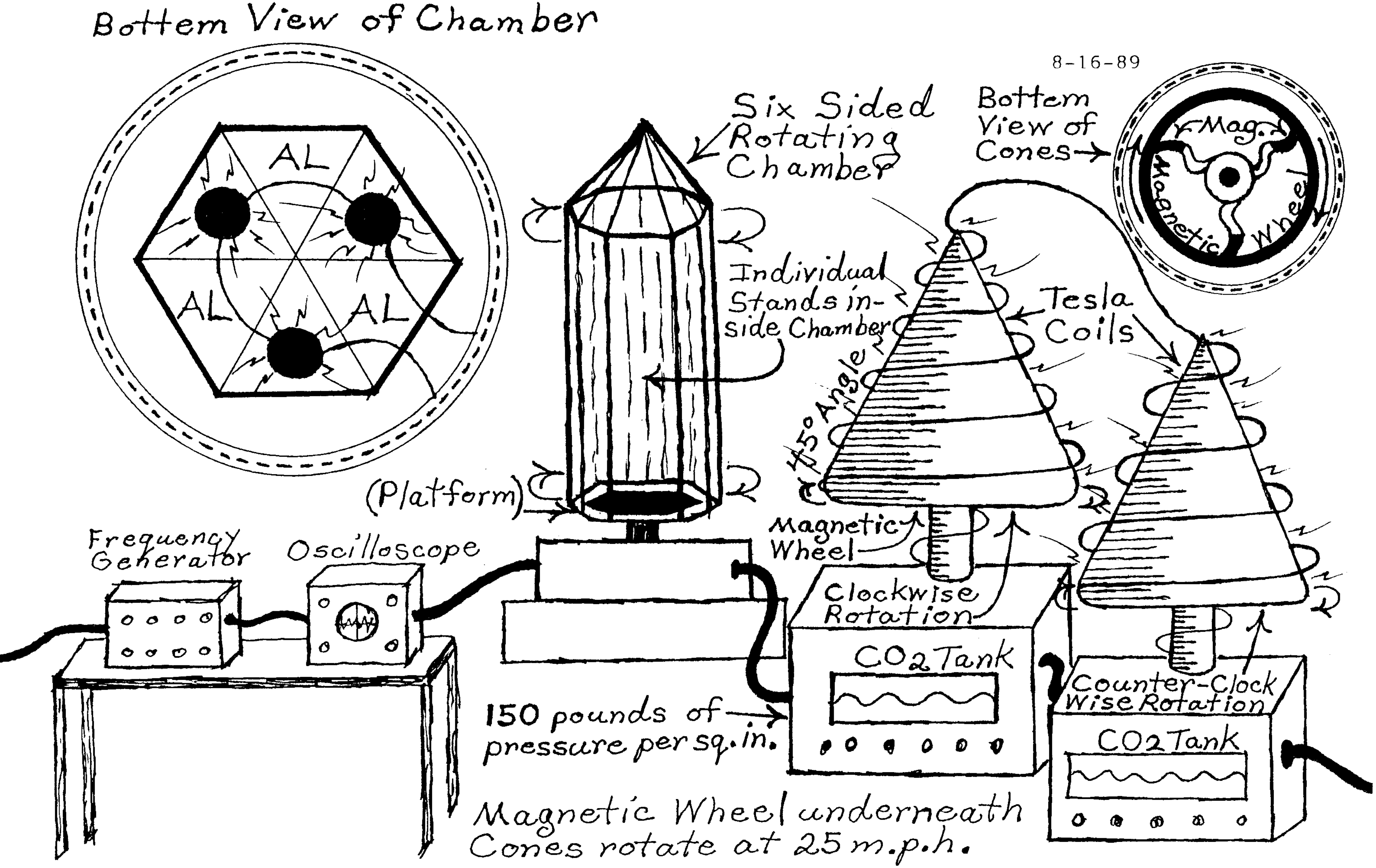

Bottom View of Chamber
AL
AL
AL
Six Sided Rotating Chamber
Bottom View of Cones
Mag.
Magnetic Wheel
Individual Stands inside Chamber
Tesla Coils
45° Angle
(Platform)
Magnetic Wheel
Frequency Generator
Oscilloscope
Clockwise Rotation
CO2 Tank
Counter-Clock Wise Rotation
CO2 Tank
150 pounds of pressure per sq. in.
Magnetic Wheel underneath Cones rotate at 25 m.p.h.

Throughout the vast regions of Space Time itself, there are an infinite number of ways to build a Time Travel Machine. One of these ways is to get a hold of a Rubbing Plate, (GSR), or Pendulum, and proceed by asking (Yes) or (No) questions as to what type of components one should use in order to build a Time Travel Machine. There are a number of ways of doing this. First of all begin by asking what size the instrument box should be for holding the components. Next, determine what type of energy one should use for achieving these effects. Then you ask what type of components one should use in order to transmit this energy. If you have done everything correctly, you will end up creating a device which is based entirely on belief. And sense you have created a device which is built entirely on belief, you can be dam certain that it will work! Especially if you use a (GSR) while asking your questions.

For those of you who do not know what a (GSR) is, this is basically a (Galvanic Skin Response Meter). One of these devices may be purchased from me for $150. Instructions are included. Please allow 4 to 6 weeks for delivery.

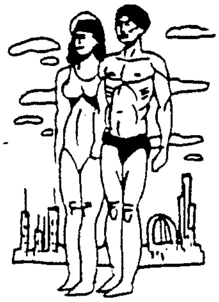

THE PARADOXES OF TIME TRAVEL

David Lewis

TIME travel, I maintain, is possible. The paradoxes of time travel are oddities, not impossibilities. They prove only this much, which few would have doubted: that a possible world where time travel took place would be a most strange world, different in fundamental ways from the world we think is ours.

I shall be concerned here with the sort of time travel that is recounted in science fiction. Not all science fiction writers are clear-headed, to be sure, and inconsistent time travel stories have often been written. But some writers have thought the problems through with great care, and their stories are perfectly consistent.[1]

If I can defend the consistency of some science fiction stories of time travel, then I suppose parallel defenses might be given of some controversial physical hypotheses, such as the hypothesis that time is circular or the hypothesis that there are particles that travel faster than light. But I shall not explore these parallels here.

What is time travel? Inevitably, it involves a discrepancy between time and time. Any traveler departs and then arrives at his destination; the time elapsed from departure to arrival (positive, or perhaps zero) is the duration of the journey. But if he is a time traveler, the separation in time between departure and arrival does not equal the duration of his journey. He departs; he travels for an hour, let us say; then he arrives. The time he reaches is not the time one hour after his departure. It is later, if he has traveled toward the future; earlier, if he has traveled toward the past. If he has traveled far toward the past, it is earlier even than his departure. How can it be that the same two events, his departure and his arrival, are separated by two unequal amounts of time?

It is tempting to reply that there must be two independent time dimensions; that for time travel to be possible, time must be not a line but a plane.[2] Then a pair of events may have two unequal separations if they are separated more in one of the time dimensions than in the other. The lives of common people occupy straight diagonal lines across the plane of time, sloping at a rate of exactly one hour of time$_1$ per hour of time$_2$. The life of the time traveler occupies a bent path, of varying slope.

On closer inspection, however, this account seems not to give us time travel as we know it from the stories. When the traveler revisits the days of his childhood, will his playmates be there to meet him? No; he has not reached the part of the plane of time where they are. He is no longer separated from them along one of the two dimensions of time, but he is still separated from them along the other. I do not say that two-dimensional time is impossible, or that there is no way to square it with the usual conception of what time travel would be like. Nevertheless I shall say no more about two-dimensional time. Let us set it aside, and see how time travel is possible even in one-dimensional time.

The world—the time traveler's world, or ours—is a four-dimensional manifold of events. Time is one dimension of the four, like the spatial dimensions except that the prevailing laws of nature discriminate between time and the others—or rather, perhaps, between various timelike dimensions and various spacelike dimensions. (Time remains one-dimensional, since no two timelike dimensions are orthogonal.) Enduring things are timelike streaks: wholes composed of temporal parts, or *stages*, located at various times and places. Change is qualitative difference between different stages—different temporal parts—of some enduring thing, just as a "change" in scenery from east to west is a qualitative difference between the eastern and western spatial parts of the landscape. If this paper should change your mind about the

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possibility of time travel, there will be a difference of opinion between two different temporal parts of you, the stage that started reading and the subsequent stage that finishes.

If change is qualitative difference between temporal parts of something, then what doesn't have temporal parts can't change. For instance, numbers can't change; nor can the events of any moment of time, since they cannot be subdivided into dissimilar temporal parts. (We have set aside the case of two-dimensional time, and hence the possibility that an event might be momentary along one time dimension but divisible along the other.) It is essential to distinguish change from "Cambridge change," which can befall anything. Even a number can "change" from being to not being the rate of exchange between pounds and dollars. Even a momentary event can "change" from being a year ago to being a year and a day ago, or from being forgotten to being remembered. But these are not genuine changes. Not just any old reversal in truth value of a time-sensitive sentence about something makes a change in the thing itself.

A time traveler, like anyone else, is a streak through the manifold of space-time, a whole composed of stages located at various times and places. But he is not a streak like other streaks. If he travels toward the past he is a zig-zag streak, doubling back on himself. If he travels toward the future, he is a stretched-out streak. And if he travels either way instantaneously, so that there are no intermediate stages between the stage that departs and the stage that arrives and his journey has zero duration, then he is a broken streak.

I asked how it could be that the same two events were separated by two unequal amounts of time, and I set aside the reply that time might have two independent dimensions. Instead I reply by distinguishing time itself, *external time* as I shall also call it, from the *personal time* of a particular time traveler: roughly, that which is measured by his wristwatch. His journey takes an hour of his personal time, let us say; his wristwatch reads an hour later at arrival than at departure. But the arrival is more than an hour after the departure in external time, if he travels toward the future; or the arrival is before the departure in external time (or less than an hour after), if he travels toward the past.

That is only rough. I do not wish to define personal time operationally, making wristwatches infallible by definition. That which is measured by my own wristwatch often disagrees with external time, yet I am no time traveler; what my misregulated wristwatch measures is neither time itself nor my personal time. Instead of an operational definition, we need a functional definition of personal time; it is that which occupies a certain role in the pattern of events that comprise the time traveler's life. If you take the stages of a common person, they manifest certain regularities with respect to external time. Properties change continuously as you go along, for the most part, and in familiar ways. First come infantile stages. Last come senile ones. Memories accumulate. Food digests. Hair grows. Wristwatch hands move. If you take the stages of a time traveler instead, they do not manifest the common regularities with respect to external time. But there is one way to assign coordinates to the time traveler's stages, and one way only (apart from the arbitrary choice of a zero point), so that the regularities that hold with respect to this assignment match those that commonly hold with respect to external time. With respect to the correct assignment properties change continuously as you go along, for the most part, and in familiar ways. First come infantile stages. Last come senile ones. Memories accumulate. Food digests. Hair grows. Wristwatch hands move. The assignment of coordinates that yields this match is the time traveler's personal time. It isn't really time, but it plays the role in his life that time plays in the life of a common person. It's enough like time so that we can—with due caution—transplant our temporal vocabulary to it in discussing his affairs. We can say without contradiction, as the time traveler prepares to set out, "Soon he will be in the past." We mean that a stage of him is slightly later in his personal time, but much earlier in external time, than the stage of him that is present as we say the sentence.

We may assign locations in the time traveler's personal time not only to his stages themselves but also to the events that go on around him. Soon Caesar will die, long ago; that is, a stage slightly later in the time traveler's personal time than his present stage, but long ago in external time, is simultaneous with Caesar's death. We could even extend the assignment of personal time to events that are not part of the time traveler's life, and not simultaneous with any of his stages. If his funeral in ancient Egypt is separated from his death by three days of external time and his death is separated from his birth by three score years and ten of his personal time, then we may add the two intervals and say that his funeral follows his birth by three score years and ten and three days of *extended personal time*. Likewise a bystander might truly say, three years after the last departure of another famous time traveler, that "he may even now—if I may use the phrase—be wandering on some plesiosaurus-haunted oolitic coral reef, or beside the lonely saline seas of the Triassic Age."[3] If the time traveler does wander on an oolitic coral reef three years after his departure in his personal time, then it is no mistake to say with respect to his extended personal time that the wandering is taking place "even now".

We may liken intervals of external time to distances as the crow flies, and intervals of personal time to distances along a winding path. The time traveler's life is like a mountain railway. The place two miles due east of here may also be nine miles down the line, in the westbound direction. Clearly we are not dealing here with two independent dimensions. Just as distance along the railway is not a fourth spatial dimension, so a time traveler's personal time is not a second dimension of time. How far down the line some place is depends on its location in three-dimensional space, and likewise the locations of events in personal time depend on their locations in one-dimensional external time.

Five miles down the line from here is a place where the line goes under a trestle; two miles further is a place where the line goes over a trestle; these places are one and the same. The trestle by which the line crosses over itself has two different locations along the line, five miles down from here and also seven. In the same way, an event in a time traveler's life may have more than one location in his personal time. If he doubles back toward the past, but not too far, he may be able to talk to himself. The conversation involves two of his stages, separated in his personal time but simultaneous in external time. The location of the conversation in personal time should be the location of the stage involved in it. But there are two such stages; to share the locations of both, the conversation must be assigned two different locations in personal time.

The more we extend the assignment of personal time outwards from the time traveler's stages to the surrounding events, the more will such events acquire multiple locations. It may happen also, as we have already seen, that events that are not simultaneous in external time will be assigned the same location in personal time—or rather, that at least one of the locations of one will be the same as at least one of the locations of the other. So extension must not be carried too far, lest the location of events in extended personal time lose its utility as a means of keeping track of their roles in the time traveler's history.

A time traveler who talks to himself, on the telephone perhaps, looks for all the world like two different people talking to each other. It isn't quite right to say that the whole of him is in two places at once, since neither of the two stages involved in the conversation is the whole of him, or even the whole of the part of him that is located at the (external) time of the conversation. What's true is that he, unlike the rest of us, has two different complete stages located at the same time at different places. What reason have I, then, to regard him as one person and not two? What unites his stages, including the simultaneous ones, into a single person? The problem of personal identity is especially acute if he is the sort of time traveler whose journeys are instantaneous, a broken streak consisting of several unconnected segments. Then the natural way to regard him as more than one person is to take each segment as a different person. No one of them is a time traveler, and the peculiarity of the situation comes to this: all but one of these several people vanish into thin air, all but another one appear out of thin air, and there are remarkable resemblances between one at his appearance and another at his vanishing. Why isn't that at least as good a description as the one I gave, on which the several segments are all parts of one time traveler?

I answer that what unites the stages (or segments) of a time traveler is the same sort of mental, or mostly mental, continuity and connectedness that unites anyone else. The only difference is that whereas a common person is connected and continuous with respect to external time, the time traveler is connected and continuous only with respect to his own personal time. Taking the stages in order, mental (and bodily) change is mostly gradual rather than sudden, and at no point is there sudden change in too many different respects all at once. (We can include position in external time among the respects we keep track of, if we like. It may change discontinuously with respect to personal time if not too much else changes discontinuously along with it.) Moreover, there is not too much change altogether. Plenty of traits and traces last a lifetime. Finally, the connectedness and the continuity are not accidental. They are explicable; and further, they are explained by the fact that the properties of each stage depend causally on those of the stages just before in personal time, the dependence being such as tends to keep things the same.[4]

To see the purpose of my final requirement of causal continuity, let us see how it excludes a case of counterfeit time travel. Fred was created out of thin air, as if in the midst of life; he lived a while, then died. He was created by a demon, and the demon had chosen at random what Fred was to be like at the moment of his creation. Much later someone else, Sam, came to resemble Fred as he was when first created. At the very moment when the resemblance became perfect, the demon destroyed Sam. Fred and Sam together are very much like a single person: a time traveler whose personal time starts at Sam's birth, goes on to Sam's destruction and Fred's creation, and goes on from there to Fred's death. Taken in this order, the stages of Fred-*cum*-Sam have the proper connectedness and continuity. But they lack causal continuity, so Fred-*cum*-Sam is not one person and not a time traveler. Perhaps it was pure coincidence that Fred at his creation and Sam at his destruction were exactly alike; then the connectedness and continuity of Fred-*cum*-Sam across the crucial point are accidental. Perhaps instead the demon remembered what Fred was like, guided Sam toward perfect resemblance, watched his progress, and destroyed him at the right moment. Then the connectedness and continuity of Fred-*cum*-Sam has a causal explanation, but of the wrong sort. Either way, Fred's first stages do not depend causally for their properties on Sam's last stages. So the case of Fred and Sam is rightly disqualified as a case of personal identity and as a case of time travel.

We might expect that when a time traveler visits the past there will be reversals of causation. You may punch his face before he leaves, causing his eye to blacken centuries ago. Indeed, travel into the past necessarily involves reversed causation. For time travel requires personal identity—he who arrives must be the same person who departed. That requires causal continuity, in which causation runs from earlier to later stages in the order of personal time. But the orders of personal and external time disagree at some point, and there we have causation that runs from later to earlier stages in the order of external time. Elsewhere I have given an analysis of causation in terms of chains of counterfactual dependence, and I took care that my analysis would not rule out casual reversal *a priori*.[5] I think I can argue (but not here) that under my analysis the direction of counterfactual dependence and causation is governed by the direction of other *de facto* asymmetries of time. If so, then reversed causation and time travel are not excluded altogether, but can occur only where there are local exceptions to these asymmetries. As I said at the outset, the time traveler's world would be a most strange one.

Stranger still, if there are local—but only local—causal reversals, then there may also be causal loops: closed causal chains in which some of the causal links are normal in direction and others are reversed. (Perhaps there must be loops if there is reversal: I am not sure.) Each event on the loop has a causal explanation, being caused by events elsewhere on the loop. That is not to say that the loop as a whole is caused or explicable. It may not be. Its inexplicability is especially remarkable if it is made up of the sort of causal processes that transmit information. Recall the time traveler who talked to himself. He talked to himself about time travel, and in the course of the conversation his older self told his younger self how to build a time machine. That information was available in no other way. His older self knew how because his younger self had been told and the information had been preserved by the causal processes that constitute recording, storage, and retrieval of memory traces. His younger self knew, after the conversation, because his older self had known and the information had been preserved by the causal processes that constitute telling. But where did the information come from in the first place? Why did the whole affair happen? There is simply no answer. The parts of the loop are explicable, the whole of it is not. Strange! But not impossible, and not too different from inexplicabilities we are already inured to. Almost everyone agrees that God, or the Big Bang, or the entire infinite past of the universe, or the decay of a tritium atom, is uncaused and inexplicable. Then if these are possible, why not also the inexplicable causal loops that arise in the time travel?

I have committed a circularity in order not to talk about too much at once, and this is a good place to set it right. In explaining personal time, I presupposed that we were entitled to regard certain stages as comprising a single person. Then in explaining what united the stages into a single person, I presupposed that we were given a personal time order for them. The proper way to proceed is to define personhood and personal time simultaneously, as follows. Suppose given a pair of an aggregate of persona-stages, regarded as a candidate for personhood, and an assignment of coordinates to those stages, regarded as a candidate for his personal time. If the stages satisfy the conditions given in my circular explanation with respect to the assignment of coordinates, then both candidates succeed: the stages do comprise a person and the assignment is his personal time.

I have argued so far that what goes on in a time travel story may be a possible pattern of events in four-dimensional space-time with no extra time dimension; that it may be correct to regard the scattered stages of the alleged time traveler as comprising a single person; and that we may legitimately assign to those stages and their surroundings a personal time order that disagrees sometimes with their order in external time. Some might concede all this, but protest that the impossibility of time travel is revealed after all when we ask not what the time traveler *does*, but what he *could do*. Could a time traveler change the past? It seems not: the events of a past moment could no more change than numbers could. Yet it seems that he would be as able as anyone to do things that would change the past if he did them. If a time traveler visiting the past both could and couldn't do something that would change it, then there cannot possibly be such a time traveler.

Consider Tim. He detests his grandfather, whose success in the munitions trade built the family fortune that paid for Tim's time machine. Tim would like nothing so much as to kill Grandfather, but alas he is too late. Grandfather died in his bed in 1957, while Tim was a young boy. But when Tim has built his time machine and traveled to 1920, suddenly he realizes that he is not too late after all. He buys a rifle; he spends long hours in target practice; he shadows Grandfather to learn the route of his daily walk to the munitions works; he rents a room along the route; and there he lurks, one winter day in 1921, rifle loaded, hate in his heart, as Grandfather walks closer, closer,. . . .

Tim can kill Grandfather. He has what it takes. Conditions are perfect in every way: the best rifle money could buy, Grandfather an easy target only twenty yards away, not a breeze, door securely locked against intruders. Tim a good shot to begin with and now at the peak of training, and so on. What's to stop him? The forces of logic will not stay his hand! No powerful chaperone stands by to defend the past from interference. (To imagine such a chaperone, as some authors do, is a boring evasion, not needed to make Tim's story consistent.) In short, Tim is as much able to kill Grandfather as anyone ever is to kill anyone. Suppose that down the street another sniper, Tom, lurks waiting for another victim, Grandfather's partner. Tom is not a time traveler, but otherwise he is just like Tim: same make of rifle, same murderous intent, same everything. We can even suppose that Tom, like Tim, believes himself to be a time traveler. Someone has gone to a lot of trouble to deceive Tom into thinking so. There's no doubt that Tom can kill his victim; and Tim has everything going for him that Tom does. By any ordinary standards of ability, Tim can kill Grandfather.

Tim cannot kill Grandfather. Grandfather lived, so to kill him would be to change the past. But the events of a past moment are not subdivisible into temporal parts and therefore cannot change. Either the events of 1921 timelessly do include Tim's killing of Grandfather, or else they timelessly don't. We may be tempted to speak of the "original" 1921 that lies in Tim's personal past, many years before his birth, in which Grandfather lived; and of the "new" 1921 in which Tim now finds himself waiting in ambush to kill Grandfather. But if we do speak so, we merely confer two names on one thing. The events of 1921 are doubly located in Tim's (extended) personal time, like the trestle on the railway, but the "original" 1921 and the "new" 1921 are one and the same. If Tim did not kill Grandfather in the "original" 1921, then if he does kill Grandfather in the "new" 1921, he must both kill and not kill Grandfather in 1921—in the one and only 1921, which is both the "new" and the "original" 1921. It is logically impossible that Tim should change the past by killing Grandfather in 1921. So Tim cannot kill Grandfather.

Not that past moments are special; no more can anyone change the present or the future. Present and future momentary events no more have temporal parts than past ones do. You cannot change a present or future event from what it was originally to what it is after you change it. What you *can* do is to change the present or the future from the unactualized way they would have been without some action of yours to the way they actually are. But that is not an actual change: not a difference between two successive actualities. And Tim can certainly do as much; he changes the past from the unactualized way it would have been without him to the one and only way it actually is. To "change" the past in this way, Tim need not do anything momentous; it is enough just to be there, however unobtrusively.

You know, of course, roughly how the story of Tim must go on if it is to be consistent: he somehow fails. Since Tim didn't kill Grandfather in the "original" 1921, consistency demands that neither does he kill Grandfather in the "new" 1921. Why not? For some commonplace reason. Perhaps some noise distracts him at the last moment, perhaps he misses despite all his target practice, perhaps his nerve fails, perhaps he even feels a pang of unaccustomed mercy. His failure by no means proves that he was not really able to kill Grandfather. We often try and fail to do what we are able to do. Success at some tasks requires not only ability but also luck, and lack of luck is not a temporary lack of ability. Suppose our other sniper, Tom, fails to kill Grandfather's partner for the same reason, whatever it is, that Tim fails to kill Grandfather. It does not follow that Tom was unable to. No more does it follow in Tim's case that he was unable to do what he did not succeed in doing.

We have this seeming contradiction: "*Tim doesn't, but can, because he has what it takes*" versus "*Tim doesn't, and can't, because it's logically impossible to change the past.*" I reply that there is no contradiction. Both conclusions are true, and for the reasons given. They are compatible because "can" is equivocal.

To say that something can happen means that its happening is compossible with certain facts. *Which* facts? That is determined, but sometimes not determined well enough, by context. An ape can't speak a human language—say, Finnish—but I can. Facts about the anatomy and operation of the ape's larynx and nervous system are not compossible with his speaking Finnish. The corresponding facts about my larynx and nervous system are compossible with my speaking Finnish. But don't take me along to Helsinki as your interpreter: I can't speak Finnish. My speaking Finnish is compossible with the facts considered so far, but not with further facts about my lack of training. What I can do, relative to one set of facts, I cannot do, relative to another, more inclusive, set. Whenever the context leaves it open which facts are to count as relevant, it is possible to equivocate about whether I can speak Finnish. It is likewise possible to equivocate about whether it is possible for me to speak Finnish, or whether I am able to, or whether I have the ability or capacity or power or potentiality to. Our many words for much the same thing are little help since they do not seem to correspond to different fixed delineations of the relevant facts.

Tim's killing Grandfather that day in 1921 is compossible with a fairly rich set of facts: the facts about his rifle, his skill and training, the unobstructed line of fire, the locked door and the absence of any chaperone to defend the past, and so on. Indeed it is compossible with all the facts of the sorts we would ordinarily count as relevant is saying what someone can do. It is compossible with all the facts corresponding to those we deem relevant in Tom's case. Relative to these facts, Tim can kill Grandfather. But his killing Grandfather is not compossible with another, more inclusive set of facts. There is the simple fact that Grandfather was not killed. Also there are various other facts about Grandfather's doings after 1921 and their effects: Grandfather begat Father in 1922 and Father begat Tim in 1949. Relative to these facts, Tim cannot kill Grandfather. He can and he can't, but under different delineations of the relevant facts. You can reasonably choose the narrower delineation, and say that he can; or the wider delineation, and say that he can't. But choose. What you mustn't do is waver, say in the same breath that he both can and can't, and then claim that this contradiction proves that time travel is impossible.

Exactly the same goes for Tom's parallel failure. For Tom to kill Grandfather's partner also is compossible with all facts of the sorts we ordinarily count as relevant, but not compossible with a larger set including, for instance, the fact that the intended victim lived until 1934. In Tom's case we are not puzzled. We say without hesitation that he can do it, because we see at once that the facts that are not compossible with his success are facts about the future of the time in question and therefore not the sort of facts we count as relevant in saying what Tom can do.

In Tim's case it is harder to keep track of which facts are relevant. We are accustomed to exclude facts about the future of the time in question, but to include some facts about its past. Our standards do not apply unequivocally to the crucial facts in this special case: Tim's failure, Grandfather's survival, and his subsequent doings. If we have foremost in mind that they lie in the external future of that moment in 1921 when Tim is almost ready to shoot, then we exclude them just as we exclude the parallel facts in Tom's case. But if we have foremost in mind that they precede that moment in Tim's extended personal time, then we tend to include them. To make the latter be foremost in your mind, I chose to tell Tim's story in the order of his personal time, rather than in the order of external time. The fact of Grandfather's survival until 1957 had already been told before I got to the part of the story about Tim lurking in ambush to kill him in 1921. We must decide, if we can, whether to treat these personally past and externally future facts as if they were straightforwardly past or as if they were straightforwardly future.

Fatalists—the best of them—are philosophers who take facts we count as irrelevant in saying what someone can do, disguise them somehow as facts of a different sort that we count as relevant, and thereby argue that we can do less than we think—indeed, that there is nothing at all that we don't do but can. I am not going to vote Republican next fall. The fatalist argues that, strange to say, I not only won't but can't; for my voting Republican is not compossible with the fact that it was true already in the year 1548 that I was not going to vote Republican 428 years later. My rejoinder is that this is a fact, sure enough; however, it is an irrelevant fact about the future masquerading as a relevant fact about the past, and so should be left out of account in saying what, in any ordinary sense, I can do. We are unlikely to be fooled by the fatalist's methods of disguise in this case, or other ordinary cases. But in cases of time travel, precognition, or the like, we're on less familiar ground, so it may take less of a disguise to fool us. Also, new methods of disguise are available, thanks to the device of personal time.

Here's another bit of fatalist trickery. Tim, as he lurks, already knows that he will fail. At least he has the wherewithal to know it if he thinks, he knows it implicitly. For he remembers that Grandfather was alive when he was a boy, he knows that those who are killed are thereafter not alive, he knows (let us suppose) that he is a time traveler who has reached the same 1921 that lies in his personal past, and he ought to understand—as we do—why a time traveler cannot change the past. What is known cannot be false. So his success is not only not compossible with facts that belong to the external future and his personal past, but also is not compossible with the present fact of his knowledge that he will fail. I reply that the fact of his foreknowledge, at the moment while he waits to shoot, is not a fact entirely about that moment. It may be divided into two parts. There is the fact that he then believes (perhaps only implicitly) that he will fail; and there is the further fact that his belief is correct, and correct not at all by accident, and hence qualifies as an item of knowledge. It is only the latter fact that is not compossible with his success, but it is only the former that is entirely about the moment in question. In calling Tim's state at that moment knowledge, not just belief, facts about personally earlier but externally later moments were smuggled into consideration.

I have argued that Tim's case and Tom's are alike, except that in Tim's case we are more tempted than usual—and with reason—to opt for a semi-fatalist mode of speech. But perhaps they differ in another way. In Tom's case, we can expect a perfectly consistent answer to the counterfactual question: what if Tom had killed Grandfather's partner? Tim's case is more difficult. If Tim had killed Grandfather, it seems offhand that contradictions would have been true. The killing both would and wouldn't have occurred. No Grandfather, no Father; no Father, no Tim; no Tim, no killing. And for good measure: no Grandfather, no family fortune; no fortune, no time machine; no time machine, no killing. So the supposition that Tim killed Grandfather seems impossible in more than the semi-fatalistic sense already granted.

If you suppose Tim to kill Grandfather and hold all the rest of his story fixed, of course you get a contradiction. But likewise if you suppose Tom to kill Grandfather's partner and hold the rest of his story fixed—including the part that told of his failure—you get a contradiction. If you make any counterfactual supposition and hold all else fixed you get a contradiction. The thing to do is rather to make the counterfactual supposition and hold all else as close to fixed as you consistently can. That procedure will yield perfectly consistent answers to the question: what if Tim had not killed Grandfather? In that case, some of the story I told would not have been true. Perhaps Tim might have been the time-traveling grandson of someone else. Perhaps he might have been the grandson of a man killed in 1921 and miraculously resurrected. Perhaps he might have been not a time traveler at all, but rather someone created out of nothing in 1920 equipped with false memories of a personal past that never was. It is hard to say what is the least revision of Tim's story to make it true that Tim kills Grandfather, but certainly the contradictory story in which the killing both does and doesn't occur is not the least revision. Hence it is false (according to the unrevised story) that if Tim had killed Grandfather then contradictions would have been true.

What difference would it make if Tim travels in branching time? Suppose that at the possible world of Tim's story the space-time manifold branches; the branches are separated not in time, and not in space, but in some other way. Tim travels not only in time but also from one branch to another. In one branch Tim is absent from the events of 1921; Grandfather lives; Tim is born, grows up, and vanishes in his time machine. The other branch diverges from the first when Tim turns up in 1920; there Tim kills Grandfather and Grandfather leaves no descendants and no fortune; the events of the two branches differ more and more from that time on. Certainly this is a consistent story; it is a story in which Grandfather both is and isn't killed in 1921 (in the different branches); and it is a story in which Tim, by killing Grandfather, succeeds in preventing his own birth (in one of the branches). But it is not a story in which Tim's killing of Grandfather both does occur and doesn't: it simply does, though it is located in one branch and not the other. And it is not a story in which Tim changes the past. 1921 and later years contain the events of both branches, coexisting somehow without interaction. It remains true at all the personal times of Tim's life, even after the killing, that Grandfather lives in one branch and dies in the other.[6]

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Notes

1. I have particularly in mind two of the time travel stories of Robert A. Heinlein: "By His Bootstraps" in R. A. Heinlein, *The Menace from Earth* (Hicksville, N.Y., 1959), and "—All You Zombies—," in R. A. Heinlein, *The Unpleasant Profession of Jonathan Hoag* (Hicksville, N.Y., 1959).
2. Account of time travel in two-dimensional time are found in Jack W. Meiland, "A Two-Dimensional Passage Model of Time for Time Travel," *Philosophical Studies,* vol. 26 (1974), pp. 153–173; and in the initial chapters of Isaac Asimov, *The End of Eternity* (Garden City, N.Y., 1955). Asimov's denouement, however, seems to require some different conception of time travel.
3. H. G. Wells, *The Time Machine, An Invention* (London, 1895), epilogue. The passage is criticized as contradictory in Donald C. Williams, "The Myth of Passage," *The Journal of Philosophy,* vol. 48 (1951), p. 463.
4. I discuss the relation between personal identity and mental connectedness and continuity at greater length in "Survival and Identity" in *The Identity of Persons,* ed. by Amelie Rorty (forthcoming).
5. "Causation," *The Journal of Philosophy,* vol. 70 (1973), pp. 556–567; the analysis relies on the analysis of counterfactuals given in my *Counterfactuals* (Oxford, 1973).
6. The present paper summarizes a series of lectures of the same title, given as the Gavin David Young Lectures in Philosophy at the University of Adelaide in July, 1971. I thank the Australian-American Educational Foundation and the American Council of Learned Societies for research support. I am grateful to many friends for comments on earlier versions of this paper; especially Philip Kitcher, William Newton-Smith, J. J. C. Smart, and Donald Williams.

The Tom Bearden Website

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ANNOTATED GLOSSARY

T. E. Bearden 1997, slightly updated Dec. 2000
Latest editing and additions: 12th April, 2003
Presentation re-edit 7th January, 2013

Foreword

This is an informal glossary originally prepared in 1997 for Gary Hawkins to use on his web site, and informal definitions and discussions were rather quickly jotted down in 1997. We have been able to do a little updating now in Dec. 2000. Careful crafting and polishing for greater rigor would require much more time than I am able to spare, but perhaps the glossary can be helpful anyway.

We put in the gist of it, as we see it, and usually an annotation or commentary to explain it. We tried to put in sufficient explanations and a few references, so that the reader can see for himself or herself that physics, mathematics, and even logic itself are not quite as cut and dried as is often presented!

The only thing we absolutely insist on, that differs from the normal physics and engineering approach, is that any true definition must be an identity statement *a priori*. In this view, since no equation is an identity, then no equation is a definition; regardless of those "equations" universally advanced in physics as "definitions." All an equation states is that the *magnitude* of the somethings on the right is equal to the *magnitude* of the somethings on the left. It does not at all *define* any of the somethings on either right or left! I've completed as much as I have time for now, and made some additions and corrections to the 1997 version. As time permits, we will try to add some more in the future. I hope these hasty comments are helpful, and any errors in them are my own and not due to Gary Hawkins or to Tony Craddock!

Tom Bearden,
Dec. 2000

Webmaster's Note: There are additional Glossaries and Definitions at the ends of Tom Bearden's books *"Energy from the Vacuum"* and *"Excalibur Briefing."*

MATH AND SINGLE CHARACTER ABBREVIATIONS

ϕ The electrostatic scalar potential, in units of joule per collecting coulomb.

∇ The mathematical operator 'del'.

$\nabla\phi$ The gradient of the function ϕ , mathematically.

In EM theory, use of the del operator produces an electric field **E** given by $\mathbf{E} = -\nabla\phi$. An electrical field is also generated by the time rate of change of the magnetic vector potential **A**, where it is given by $\mathbf{E} = -d\mathbf{A}/dt$. Note that we have used that fact to assist us in producing the motionless electromagnetic generator (MEG), with COP = 16 as of this writing.

ϕq Joules of energy collected by a charge of q coulombs in an electrostatic scalar potential

having a reaction cross section of ϕ.

Since the collected energy is also usually the energy that can then be dissipated as work, this expression often yields the work performed in the circuit by the energy the surface charges collected from that part of the **S**-flow in contact with the conductors and components.

$d\phi/dt$ Time rate of change of the scalar potential.

Also one form of displacement current.

dE/dt Time rate of change of the E-field.

Also one form of displacement current.

dp/dt Time rate of change of momentum, which is a force F acting upon the system.

A force is defined as a time rate of change of momentum, or F = dp/dt.

dP/dt Time rate of change of polarization.

Polarization displacement current.

dq/dt Time rate of change of charge, otherwise known as "current".

Represents the normal current flow i of charges in a conductor, i.e., i = dq/dt.

dq/dt-Isolated Load Loop A special current loop containing the load,

...where i = dq/dt in that "load loop" is isolated from the current i = dq/dt in the source loop containing the power source, and the two loops are also field-coupling isolated. A transformer, e.g., does isolate the actual current in the secondary from the current in the primary, but the field coupling from primary to secondary and from secondary back to primary result in the enforcement of COP = 1.0 as the maximum performance possible (in a perfect, lossless standard transformer). In a real standard transformer with some losses, COP<1.0.

The notion is that, even though current cannot pass from the source loop to the load loop and there is no direct field coupling, energy density flow $\mathbf{S} = \mathbf{E}\times\mathbf{H}$ can pass. This is in fact the definition of what we call *bridging*, if in addition to current isolation the rigid back-field coupling is broken between energy dissipation (power) in the source loop and energy dissipation (power) in the load loop. In that fashion, overunity operation of the load can readily be achieved.

E Electric Field.

Defined in older classical electromagnetics (CEM) as a force field, by $\mathbf{E} \equiv \mathbf{F}/q$. However, this only defines the entity after an interaction with mass. In short, it defines the E-field as an effect existing only in matter.

In the early days of electrodynamics, Maxwell and the other "founding fathers" assumed a material ether filling all space. Hence any field in space was indeed such an "effect" field existing in mass. Maxwell died in 1879 of stomach cancer. In the 1880s, the Michelson-Morley experiments falsified the luminiferous (material) ether as a material medium. Hence the accepted use of the $\mathbf{E} = \mathbf{F}/q$ type of "effect" electrical field as the electric field in space was also destroyed, but the equations were never changed to eliminate this error in the foundations of CEM. Instead, electrodynamicists more or less announced one day that, "Since there is no (material) ether, we are not using one!"

There is some rationalization mathematically for such an approach, if the limiting process is used for the interaction of the "causal field" in vacuum with the charged mass q, as q is allowed to approach zero. However, from a foundations view, it is still the interaction of the field in space with charged mass that is being described in the limit, and therefore it is still the "effect" entity rather than the "cause" entity.

This serious foundations problem is still unresolved in much of CEM theory and modeling to this day. The standard by which other EM texts are measured is J. D. Jackson, **Classical Electrodynamics**, 2nd edition, Wiley, New York, 1975. In several places, Jackson opts for this avoidance of the use of the " effect" field for the "cause" field: quoting p. 28: *"...the thing that eventually gets measured is a force..." "At the moment, the electric field can be defined as the force per unit charge acting at a given point. It is a vector function of position, denoted by E."* Quoting p. 249: *"Most classical electrodynamicists continue to adhere to the notion that the EM force field exists as such in the vacuum, but do admit that physically measurable quantities such as force somehow involve the product of charge and field."*

The problem is further increased by use of this flawed definition of E-field to "define" the electrostatic scalar potential (Jackson, p. 34) by the equation $\mathbf{E} = -\nabla\phi$. First, no equation is a definition; it merely equates the magnitude of the entities on the left of the = sign to the magnitude of the entities on the right of the = sign. It has nothing at all to say about the definition or nature of any of the entities, but is merely a comparison of relative magnitudes. Any definition, a priori, must be expressed by an identity sign. In all of classical electrodynamics, there is no available proper definition of (x) in the identity $E \equiv (x)$. Indeed, there is no such identity available for force F. To quote Feynman: *"...in dealing with force the tacit assumption is always made that the force is equal to zero unless some physical body is present... One of the most important characteristics of force is that it has a material origin, and this is not just a definition. ... If you insist upon a precise definition of force, you will never get it!"* Richard P. Feynman, Robert B. Leighton, and Matthew Sands, **Lectures on Physics**, Addison-Wesley, Reading, MA, Vol. 1, 1964, p. 12-2.

In the Sachs unified field theory, O(3) electrodynamics as spearheaded by Evans is an important subset. Hence in that approach there is a solution to the problem of defining force and field. The EM fields (**E**, **B**, etc.) when in spacetime, are in fact curvatures of spacetime identically. When these ST curvatures interact with a charged mass, the effects of the interactions are the well-known force-fields in matter, which Maxwell started with in the 1860s. So in this way, the definition problem can be rigorously resolved.

$j\phi$ The Slepian vector, representing the time rate of energy density dissipation in the current

loop containing the $j\phi$.

This does not at all represent the energy flow in space and along the outside of the circuit, which may be very, very much greater, on the order of 10^{13} times as great. It does match the Poynting energy flow component that enters the circuit.

M_q or m_q The mass of a charge q.

Instead of just using "q" and assuming it to be unitary, we must include the fact that charge is a system of two coupled components: (i) the mass m_q of the charge q, and (ii) the virtual photon flux exchange (i.e., ϕ_q) of the charge q with the surrounding active vacuum. In particle physics it is already well-known that there is no symmetry of a mass system anyway, unless the vacuum's exchange with the mass is included. So the expression $m_q\phi_q$ captures the vacuum-mass exchange. By continuing to assume that charge is unitary, physics inadvertently holds to the hoary old notion of the luminiferous ether (thin material ether) that permeates all of space. Maxwell and other electrical physicists of his time believed in a material ether, and Maxwell embedded that notion in EM theory. Inexplicably it has not been rooted out of the equations to this day, even though the notion of the material ether (not the ether per se!) was destroyed by the Michelson-Morley experiment over 100 years ago. Foundations physicists continue to point out such terrible defects in physics—and continue to be ignored. We quote Mario Bunge, "A mathematical theory of the dimensions and units of physical quantities," in **Problems in the Foundations of Physics**, edited by Mario Bunge, Springer-Verlag, Berlin and New York, 1971, p. 7: "The question 'What are dimensions?' is seen to be ill conceived, for there are two concepts of dimension, namely those of dimension function and dimension value. The correct question is: 'What are [] and *d*?' " {**Note:** [] is dimension function, and *d* is dimension value.} Bunge is clearly discriminating between the function associated with the dimension, and the magnitude associated with it

Quoting Bunge, *ibid*., p. 8: "The concept of a unit is one of those scientific notions that has remained obscure for want of a theory and excess of a coarse philosophy. Indeed we know how to manipulate units but we do not seem to know what kind of mathematical object they are. As a consequence units are sometimes confused with dimensions, at other times with standards, and they are often introduced in relation to measurement rather than to concept formulation."

And quoting Mario Bunge, **Foundations of Physics**, Springer-Verlag, New York, 1967, p. 176: "Different theories of CED [Classical Electrodynamics] are called for, both for charged particles that can to a first approximation be regarded as electromagnetically structureless (e.g., the electron and the μ -meson) and for extended systems with a charge distribution and spin (e.g., the proton). If fairly satisfactory classical theories were available they could guide the construction of the corresponding quantum theories. But no such theories are in sight partly because it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state."

Again, Bunge, *ibid*., p. 182: "...the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling not only to better cover their own domains but also to join smoothly so as to produce a coherent picture of the various levels of physical reality."

c The speed of light in ambient vacuum.

To discuss the speed of light, we point out that the vacuum is highly energetic, as has been shown in modern physics. Since the vacuum has an energy density, it can be modeled as a "potential" and particularly as a scalar EM potential for EM purposes. Contrary to convention, we recognize that the local energy density of the ambient vacuum potential can vary, including seasonally within and close to the solar system, etc. The average energy density of the vacuum in space far from charged masses such as stars and planets may be assumed as a "standard vacuum potential", and if this potential is equated with the notion of "flat spacetime", then an increase in this vacuum potential is an increase in the local energy density of spacetime, and hence represents a curvature of the standard flat spacetime.

In fact the interplanetary radar probes' "ranges" do show precisely such variation in the speed of light, with weekly and monthly and seasonal variations, etc. In order to comply with the nearly universal assumption in physics with respect to the constancy of c, the scientific staffs averaged the readings over the entire month. This zeroed out the variations, upheld the notion that space is a fixed type of thing, and that the speed of light in it is also a rigidly fixed constant. It *does not* agree with the actual measured speed of light from day to day.

The Russians have known and openly printed for about a century that the speed of light in a hard vacuum in deep space, far removed from solar and planetary masses, is a little slower than the speed of light in a hard vacuum near the Earth or any other large charged mass. The huge collection of charged particles in the earth have tiny separations, so that looking at the Earth as a collection of tiny dipoles, one sees a collection of enormous 4-symmetry energy flows from the time domain to the 3-space domain (and vice versa for the time-reversed portions). The increased intensity of this 4-symmetry energy flux in the vicinity of a massive planet or sun changes the local energy density of the vacuum itself, increasing it in that vicinity.

Without elaboration, we will also point out that the Earth and its dynamics structures the local spacetime and the spacetime out to some distance. So do all other planets, stars, etc. By whatever manner we model the cosmos as having been created or initiated, the dynamics and structuring of all the phenomena occurring in the universe is further impressed in the *infolded* electrodynamics inside the vacuum potential.

The "laws of nature" in one sense represent the most general results of the reactions of this internally structured "common standard spacetime" or "standard vacuum potential" with the various physical systems, devices, and measuring instruments utilized in our experiments, etc. If one deterministically alters the *structuring of the local spacetime*, one can have a system which will function there in a certain marvelous manner, but will not function that way elsewhere. Some decades ago, I participated in experiments by Golden which over a period of some five years did condition (dimension) the local vacuum potential. The result was an engine which consistently exhibited COP = 1.67 at that location, but when moved several hundred miles exhibited COP<1.0. Frank and I were made aware of this "vacuum conditioning" effect by Prof. William Tiller, who had himself conducted experiments exhibiting just such an effect over several years.

EM waves in vacuum are actually *longitudinal* (sound-type) waves, but we do not belabor the point since everything out there in the normal literature uses the transverse EM wave model for the EM wave in space. Also, the transverse wave is indeed what is detected in the interacting electron gas in our measurement instruments—whose Drude electrons are restrained to simple drift velocity longitudinally down the conductor, but are spinning and are free to precess like gyros. So our instruments detect the Drude electron precessions at right angles to the incoming disturbing longitudinal force field, which means that they do indeed measure a transverse wave. However, these are actually the *electron precession waves* in the detector, and *not* the actual EM waves in space. See my paper, "Giant Negentropy from the Common Dipole", **Journal of New Energy**, 5(1), Summer 2000, p. 11-23 for a discussion of how all EM energy comes from the time domain, via the broken 3-symmetry of the source charge or source dipole, and is emitted in 3-space in all directions as longitudinal EM waves. This is based on rigorous demonstration by E.T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," **Math. Ann**., Vol. 57, 1903, p. 333-355 that the scalar potential is a harmonic set of phase conjugate longitudinal EM wave pairs. We merely applied the Whittaker decomposition to the scalar potential of a source dipole or of a source charge, and the rigorous proof that EM waves in space are longitudinal directly emerges.

Just as sound speeds up, say, in steel as a denser medium than air, the EM "sound waves" in the ambient vacuum potential speed up when that vacuum potential's flux density is increased. Consequently light does move a little faster in a hard vacuum on Earth than it does in deep space, because the vacuum itself has higher energy density near the earth than in deep space. The comings and goings and orbitings of planets and the solar mass, etc. do affect the local energy density of the vacuum between the planets, and hence the speed of light through that interplanetary space.

So the interplanetary radar does show the periodic variations of the local energy density of vacuum that are induced by these factors. For a critical paper on this, see Bryan G. Wallace, "The Unified Quantum Electrodynamic Ether," **Foundations of Physics**, 3(3), Sept. 1973, p. 381-388. His discussion of the interplanetary radar measurements of Venus, which did not fit relativity, are particularly interesting, with respect to his finding that the data were simply "averaged" to eliminate the variations and hence the diurnal, lunar, and synodic periodic components actually measured in the variations of the speed of light. See particularly Bryan G. Wallace, "The great speed of light in space cover-up." **Scientific Ethics**, 1(1), Feb. 1985. p. 2-3; — "Radar Testing of the Relative Velocity of Light in Space," **Spectrosc. Lett**. Vol. 2, 1969. p. 361.

Rigorously, the field is "defined" in electrodynamics as the effect of an interaction of the force-free entity (4-spatial!) existing prior to the interaction, with a 3-dimensional static charge. This means that the field as originally defined is an *effect* and not a *cause*. To then use it as the cause is a grave non sequitur.

This confusion of cause and effect is widespread in physics. It was probably initiated by the hoary old assumption several hundred years ago that a separate force acts upon a separate mass, which is false. In fact mass is a *component* of force, since $\mathbf{F} \equiv d/dt(m\mathbf{v}) = m(d\mathbf{v}/dt + \mathbf{v}(dm/dt)$. As can be seen, in both expanded terms there exists a mass term. To skirt the issue, electrodynamicists have simply found a neat statement that "in massfree space the field continues to exist, but the force is zero." We point out that m = 0 makes the momentum vanish, and so **F** vanishes, and in the definition of $\mathbf{E} = \mathbf{F}/q$ also vanishes because the numerator **F** becomes zero. Therefore *that* **E**-field vanishes.

Feynman and Wheeler pointed out that the field *as it is defined* does not and cannot exist in massless space. Only the "potential" for the field exists there, in case some charged mass is brought in to interact with that entity that does exist there. That is accurate, since spacetime is totally a potential and any "change" in spacetime is a change in that potential *a priori*. In the Sachs-Evans unified field theory, this problem is resolved because the fundamental field is defined as a spacetime curvature (change in spacetime, hence change in the ST potential) rather than $\mathbf{E} = \mathbf{F}/q$.

In empty space there are always myriads upon myriads of interfering fields and potentials, from charges all over the universe, via Puthoff's cosmological feedback principle [see
H. E. Puthoff, "Source of Vacuum Electromagnetic Zero-point Energy," **Physical Review A**, 40(9), Nov. 1, 1989, p. 4857-4862.] Thus any EM wave traveling through space is always involved in enormously active interferometry. This alone results in violent momentary variations in the speed of that wave, even from 0.01 c to 100.00 c. For a paper showing this kind of "galloping" travel of an EM wave, see William G. Harter, John Evans, Roberto Vega, and Sanford Wilson, "Galloping waves and their relativistic properties," **American Journal of Physics**, 53(7), July 1985, p. 671-679. While the average speed of the wave is $c(\gamma)$, where γ is the local energy density of the vacuum, the instantaneous speeds of the wave vary violently from instant to instant.

In special relativity, "velocity" merely is a rotation angle of the moving frame from the fixed laboratory observer's frame. The speed "c" merely represents a full right-angle turn away, toward the time-dimension (since other than the 3 spatial dimensions that is the only other dimension available to turn toward). In higher dimensional space, there are many other "higher" dimensions toward which further rotation can be accomplished. Hence rotating in n-space is not limited to a single orthogonal turn, and therefore velocities are not limited to speed c. However, each orthogonal rotation also subtracts one spatial dimension of the rotated object from the observer's 3-space. One rotation would be speed c, two departing rotations would be speed c^2, three would give c^3, etc. At three orthorotations, to the lab observer the rotated object is now purely an internal structure inside his time dimension, very similar to a mental object (mind is time-like, not spacelike). The nature of mind and its operations has a rather unexpected connection with matter, when one considers such orthorotations in hyperspace.

The point is, the speed *c* is not an "iron dictum" of nature, nor is it an "unchangeable constant"! Nature herself routinely violates that notion. As an example, de Broglie waves from any mass always move at $v>c$, and easily as $v>>c$. EM "surface" waves—so-called transverse oscillations or upheavals and depressions in the magnitude (energy density; actually the *reaction cross section*) of the local ambient vacuum potential), move at a *discretized* average speed c(γ). The longitudinal component, if freed from the transverse component, can move much faster because it is a sort of "tunneling" movement. In actual quantum tunneling experiments, e.g., music (Mozart's 40th symphony) has been transmitted through quantum mechanical tunneling between two separated points at speed $v>4c$. Fogal is likely to eventually place a superluminal communication system on the commercial market. We discuss superluminal communication elsewhere in this glossary.

C Capacitance. Essentially, the charge per unit potential.

For an isolated conductor, $C = Q/V$ and C is expressed in farads. A farad is one coulomb per volt.

A lower case c represents the speed of light in ambient vacuum.

E The electric field. Essentially, $E = F/q$, but that is not really a definition.

Conventionally, the units of electric field are considered to be force per unit electric charge; i.e., force per coulomb. Note that the **E**-field even in this "classical definition" does not actually exist at a point unless there is a unit point charge (a point coulomb of charged mass) located at the point. Hence contrary to classical electrodynamics, communications theory, and whatnot, no electric force field (and no magnetic force field either) exists in the vacuum, at least of the kind prescribed by Maxwell's equations and by the Heaviside-Hertz reduction of Maxwell's equations. Since Maxwell assumed it, these equations and models all still erroneously assume a material ether filling the vacuum, in which case there *would* be matter and charges, and there would *then* be force-fields in the vacuum. We refer the interested reader to discussions by Feynman and by Wheeler. Quoting: "*One of the most important characteristics of force is that it has a material origin, and this is not just a definition. Y If you insist upon a precise definition of force, you will never get it!* " [Richard P. Feynman, Robert B. Leighton, and Matthew Sands, Lectures on Physics, Addison-Wesley, Reading, MA, Vol. 1, 1964, p. 12-2.]

Even worse, note that $\mathbf{E} = \mathbf{F}/q$ defines not the magnitude of the field in space, but has to do with the divergence of energy from the field around a unit point static charge there in space, as well as the pattern of the diverged energy density. Actually, what is used as "the electric field" itself is the *reaction cross section* of the field, for a unit point static coulomb of charge. That is at best a function of the "field density" or "field intensity" of the actual electrical field in spacetime, and the direction and pattern of change of that field density due to the intercepting and diverting charge.

The field problem is resolved in the forefronts of electrodynamics by making the field a topological function. It is resolved in the Sachs-Evans O(3) electrodynamics (as a subset of Sachs' unified field theory) by making the field a function of the curvature of spacetime.

See also the discussion under c, above.

H Magnetic field strength.

B The B-field (loosely), or magnetic flux density (more properly).

Conventionally, this is thought to be defined, analogously to **E**, by the force it exerts. The force exerted on a point charge moving in the magnetic field **B** is at right angles to the velocity vector of the charge and also at right angles to **B**. Actually, the **H**-field was originally named the *magnetic field* and the **B**-field was named the *magnetic induction* (and is still sometimes called that.) This is an annoyance because it is **B** which involves the force, and hence **B** should be *named* the magnetic field. Other writers have noted this discrepancy, and Sommerfeld called **H** the magnetic excitation—which correctly describes its role—rather than calling it the magnetic field. As the reader can see, lots of things in electrical physics are *still very untidy*! There are also different ways to approach the EM modeling problem. In Kaluza-Klein unified field theory, all electromagnetics is modeled in the 5th dimension, which is wrapped around each and every point in our normal 3-dimensional space.

For practical use, a far better approach is the O(3) symmetry electrodynamics spearheaded by Myron Evans, which is also an important subset of Mendel Sachs' unified field theory. In the Sachs-Evans unified theory, electromagnetics has become general relativity and general relativity has become electromagnetics. Further, very powerful general relativity can now be directly engineered with this O(3) electrodynamics, as it further develops. We refer the reader to "The New Maxwell Electrodynamic Equations: New Tools for New Technologies. A Collection of 60 Papers from the Alpha Foundation's Institute for Advanced Study," Special Issue of **Journal of New Energy**, 4(3), Winter 1999, 335 p. Also, particularly see **Contemporary Optics and Electrodynamics**, edited by Myron W. Evans, a special topical issue of I. Prigogine and S. A. Rice (series editors), **Advances in Chemical Physics**, Wiley, 2001 (in publication). Evans gives a very long and detailed presentation, "O(3) Electrodynamics", in that publication, and also gives the paper "The Link Between the Sachs and O(3) Theories of Electrodynamics".

Q A quantity of electrical charge. Note that this statement *does not* define charge *q* itself.

We have tentatively proposed to redefine charge q as $q \equiv m_q \phi_q$. The term ϕ_q captures the vacuum's violent virtual energy interaction with the mass m_q of the charge, which is presently missing in classical EM theory and is an exceeding great flaw of omission. Further, ϕ_q may be decomposed into a harmonic series of phase conjugate wavepairs, as shown by Whittaker, 1903, *ibid*. [In O(3) electrodynamics, the internal structuring is dramatically extended, so that one can get at the "inner electrodynamics" necessary to explain such things as homeopathy, chi, ki, prana, etc.

To those scientists pooh-poohing such things as acupuncture, we point out that acupuncture in a dramatic case can allow a person without anesthetic to undergo a major operation with chest cavity opened, while the patient remains alert, conscious, and talking. President Nixon's physician on Nixon's trip to China witnessed such an actual operation, as well as other things. Nothing in our vaunted Western medical science can equal that, nor can any of our medical schools, nor can our National Academy of Science or our National Science Foundation. In short, acupuncture alone demonstrates how woefully inadequate our medical science actually is.

Also, acupuncture works on animals as well, so it does not involve hypnosis or deep suggestion. In science, we must believe the repeatable experiment, not our dogma at the moment. Yet the entire U.S. medical research community has no higher symmetry EM investigation of how acupuncture works, or of the infolded electrodynamics shown by Whittaker's decomposition of the scalar potential in 1903. Hence our scientists totally miss the vast electrodynamics of *the internal structuring of potential and charge with vacuum engines (spacetime curvature engines)*. As a result, the entire U.S. scientific and intelligence communities were totally unable to comprehend nearly five decades of Russian induction of health changes and diseases in personnel in the U.S. Embassy in Moscow, using weak EM radiation. Internal structuring of the activity producing what is called "charge"—including its internal structuring and engines—can be modeled and in theory directly engineered in the new Sachs-Evans approach.]

As shown in my paper, "Giant Negentropy from the Common Dipole," **Journal of New Energy**, 5(1), Summer 2000, p. 11-23, the broken 3-symmetry energy flow of any charge and any dipole allows a more fundamental 4-symmetry energy flow solution for the century-old problem of explaining the actual source of the EM energy that pours out of the source charge in all directions in 3-space. The 4-symmetry in EM energy flow explains its nature as longitudinal EM waves, with the charge's absorbed energy being *received* from the time domain (complex plane), transduced into 3-space, and emitted in 3-space. *The source of all EM energy at any point in 3-space is the time domain!*

It has been known for decades in particle physics that there exists no equilibrium in mass systems, unless the interaction of the vacuum with the masses is included. It has also been known that every charge and every dipole is a broken 3-symmetry in the fierce vacuum energy exchange with the charge or dipole. Yet the vacuum interaction—and specifically the source charge's and the source dipole's broken symmetry in it—are not even included in classical EM as yet. That this known total glitch in modern EM theory has not been previously corrected, when the particle physicists of every university physics department of note already know it is necessary, is inexplicable! Here we must regretfully point out finger at our orthodox scientific establishment, and particularly at our National Science Foundation and our National Academy of Science. These institutions are not even working on, nor are they aware of, nor do they even care about, the most fundamental science problems of our time. Bigger accelerators, yes. Windmills, yes. EM energy from the vacuum and electrical power systems which use it without destroying the source dipole, no. The greatest of all electrodynamics—the infolded longitudinal EM wave dynamics inside all EM fields, potentials, and waves—no. The correction of the dozens of major flaws and non sequiturs in classical electromagnetics, no. The understanding of the longitudinal EM wave interferometer weapons and quantum potential weapons already arrayed against us, no. The development of EM healing based on the Priore approach, which would totally revolutionize medical therapy and handle attacks on our cities by weapons of mass destruction, no.

We have a scientific mindset problem of epochal magnitude. And that costs the U.S. taxpayers hundreds of billions of dollars spent on the "status quo" or "business as usual" scientific endeavors that are far inferior to what can be done.

S Entropy. A quantity which measures the extent to which the energy of a system is available to do work.

Since in one sense energy is a function of ordering, then fundamentally, *entropy* refers to increasing disorder, which means increasing disruption of the ordering in our collected energy. Unfortunately, entropy is one of those concepts in physics for which there are several differing major views. We avoid all discussion of "information" etc., and prefer to deal only with the energy and time aspects. For our work in energy from the vacuum, we take the very simple view that an *entropic process* is like a positive resistor: As forward observer time passes, the entropic process continually disorders or "loses"—from further controlled conversion of energy form—the collected energy in the system. We regard a *negentropic process* as like a negative resistor: as forward observer time passes, the negentropic process receives energy in a form unusable to us, transforms, it, and outputs it in a form that is usable. Quoting Ilya Prigogine, Irreversibility as a symmetry-breaking process," Nature, Vol. 246, 1973, p. 70: *"Entropy Ycannot in general be expressed in terms of observables such as temperature and density. This is only possible in the neighbourhood of equilibriumY It is only then that both entropy and entropy production acquire a macroscopic meaning."*

So basically, the notion of entropy will apply when we have a system in equilibrium or very near equilibrium. For open systems in substantial disequilibrium, the entropy cannot even be computed, and the classical equilibrium thermodynamics with its infamous second law does not apply. On the other hand, the loading of disequilibrium (negentropic) EM systems is a very nonlinear affair. Some direct indications of this were in the Russian work in the 1930s which produced overunity and self-powering EM generators, in several physics institute. [E.g., see L. I. Mandelstam and N. D. Papaleksi., "On the parametric excitation of electric oscillations," Zhurnal Teknicheskoy Fiziki, 4(1), 1934, p. 5-29. English translation, Feb. 1968, Lawrence Radiation Laboratory, Livermore, CA, performed for NASA]. The U.S. researcher G. Obolensky also has done appreciable important experimental investigation of the nonlinear load effects for negentropic systems.

S Poynting energy density flow. Not the *overall* or *total* energy flow by any means, but just that component of it that is intercepted, diverged, collected, and used, where **S** is given by **S** = **E**×**H**.

The energy flow theory is rather thoroughly fouled, and has been since the 1880s when the flow of energy through space was proposed by both Heaviside and Poynting, independently and essentially simultaneously.

Since both **E** and **H** are defined not as fields per se, but as the reaction cross section of the fields with a unit charge, the S does not refer to "energy flow" per se, but to the intercepted component of the overall energy flow.

Poynting only considered the energy flow component around a circuit that strikes the circuit's surface charges and gets diverged into the conductors to power the electrons. Heaviside, on the other hand, also considered the startlingly enormous additional EM energy flow filling all space around the circuit's conductors, generally parallel to the conductors but missing them.

This huge Heaviside component is still there around every electrical circuit, but almost entirely ignored and unaccounted. It misses the circuit, passes on off into space, and is lost in most circuits. Yet it is trillions of times larger in magnitude than the very tiny Poynting component which actually gets intercepted, "caught" and used by the circuit to power its loads and losses.

Since no one could explain where on earth such an enormous nondiverged Heaviside component pouring out of the power source terminals could possibly come from, Lorentz—reasoning that, since the nondiverged energy flow did not do anything, it was "physically insignificant" (Lorentz' term)—then just integrated the energy flow vector around a little closed surface assumed around every volume element of interest. This efficiently discards the Heaviside nondiverged component *from all accountability*, leaving only the Poynting energy flow component vector accounted. Of course the Poynting energy flow will agree with the energy measured in the circuit, since we actually measure energy dissipation, and the energy that dissipates from the circuit must have first entered it. Electrodynamicists today just continue to use Lorentz's integration of the energy flow vector around an assumed closed surface surrounding any volume element of interest. Thus, sadly our electrical power system engineers unwittingly waste trillions of times more EM energy actually produced from the vacuum by the source dipoles in their generators, than what the feeble powerline is able to intercept and utilize.

We have nominated the vast unaccounted Heaviside energy flow accompanying every field and charge interaction as the source of the extra gravity known to be present in the arms of the spiral galaxies and holding them together. See my paper, "Dark Matter or Dark Energy?", **Journal of New Energy**, 4(4), Spring 2000, p. 4-11. Informally we have also nominated this dark Heaviside energy which fills all space, as associated with the "quintessence" energy that is responsible for the recently discovered antigravitational acceleration of the universe. In this view the giant negentropy process associated with charge (see my "Giant Negentropy of the Common Dipole" paper, *ibid*.) is ongoing in all the stars, galaxies, planets, nebulae, and other astronomical entities. The ordinary energy we measure in all these processes is gravitational; hence for symmetry and energy conservation, the primary longitudinal EM wave energy from the time domain that furnishes the energy to all these spatially energetic processes represents an increasing curvature of spacetime in the time domain as we travel outward from any origin point. This is an antigravitational force, in this concept, which is cumulative as a function of radial distance from the origin point. Hence we see the distant parts of the universe as accelerating the expansion of the universe. At present this is of course an hypothesis, and must be further validated by laboratory experiment and further theoretical work in a unified field theory electrodynamics such as the Sachs-Evans O(3) symmetry electrodynamics.

S-flow is actually comprised of an organized, structured flow of virtual photons or antiphotons and itself is not observable. Its interaction with charged particles (electrical charges and magnetic poles), however, is observable by the amount of energy collected upon (diverged around) the charge or pole (formation of a local potential), and formation of a translation force upon the charge or pole.

Again, the "**E**" and the "**H**" in the expression "**E**×**H**" are not really the "electrical field" and "magnetic field" in space, but only their *reaction cross sections* at each point in space, *should* a little unit point static coulomb be placed at that point to divert some of the **E**-field flow around it, or a little unit point static magnetic charge be placed at that point to divert some of the **H**-field flow around it. So even the Poynting energy flow **S** = **E**×**H** has been interpreted in terms of its reaction cross sections.

It is worth noting that electrodynamicists today are still politely debating EM energy flow and the energy flow vector. As an example, a polite "debate" of this subject has been ongoing for over 30 years in **American Journal of Physics** alone. A particularly significant statement of the problem is given by Jones: *"It is possible to introduce the Poynting vector **S**, defined by **S** = **E**×**H**, and regard it as the intensity of energy flow at a point. This procedure is open to criticism since we could add to **S** any vector whose divergence is zero without affecting [the basic integration procedure's result]."* [D.S. Jones, **The Theory of Electromagnetism**, Pergamon Press, Oxford, 1964, p. 52.] In short, here Jones is stating that an enormous nondiverged energy flow may accompany the Poynting flow component, and it will not be accounted for by **S** = **E**×**H**. After presenting the various elements required to solve the energy flow problem, Jones bows out with the statement: "*"It does not seem likely that an expression satisfying all these conditions will be simple… …fortunately, we are rarely concerned with the energy flow at a point. In most applications we need the rate at which energy is crossing a closed surface."* [Jones, *ibid*., p. 53.] Panofsky and Phillips warn against over-attachment to the Poynting vector: "*Paradoxical results may be obtained if one tries to identify the Poynting vector with the energy flow per unit area at any point."* [Wolfgang K. H. Panofsky and Melba Phillips, **Classical Electricity and Magnetism**, Second Edition, Addison-Wesley, Menlo Park, CA, 1962, third printing 1969, p. 180.

We point out, however, that for gravitational effects of energy flows in space, one must account the total energy flow per unit area *at and surrounding* any point, and therefore one must restore the unaccounted enormous Heaviside nondiverged EM energy flow component as well as the accounted tiny little Poynting diverged energy flow component.

Δt An increment (little piece of) time.

In special relativity, time can be considered a piece of spatial length compressed by the factor c, so that L = ct, where L is in meters, t is in seconds, and c is the speed of light. Time can also be considered as spatial EM energy compressed by the factor c^2. To comprehend time and time rate of flow, one must first realize that a priori no observable exists or persists in time. The observable is a 3-spatial snapshot made at one instant in time, so that "time stopped" momentarily. The observable is thus a frozen snapshot of the 3-spatial intersection of an ongoing 4-space interaction. At the very next instant, that snapshot no longer exists. Hence for a mass (or any other observable) to "propagate in time", there must be a process whereby Δt is continually added to the observable (such as to mass m, converting it to masstime mt for a short duration) and then subtracted again, leaving behind another frozen 3-space snapshot of the "observable" that has seemingly now endured for that little Δt period, with respect to the observer. As we explain in several papers, the sum total of the photon interactions with a mass m may be taken as the generator that produces (1) the flow of the mass m through time, by changing from m to mt to m to mt… continually, and (2) a substructuring of internal "time-flow components". In short, any time-flow ascertained in the macroworld or the microworld by the observer, has an enormously rich internal dynamics and structuring. Again, in higher symmetry electrodynamics such as O(3), the internal structuring of the photon, EM field, EM wave, and EM potential can be modeled and eventually even directly engineered.

ΔE An increment (little piece of) energy.

The photon is considered to be (unit-wise) composed of (ΔE)(Δt). However, in our view (as we explain in energy, energy collection, and energy dissipation) energy does not occur in "little fixed chunks" at all. One only has "little chunks" of energy when one *is collecting* energy in an ongoing process. In electromagnetics, the "collection" of energy is actually the *ongoing collecting* of energy from an energy flow deviating around an intercepting charge. It is a dynamic, ongoing process whereby a collector such as a charged particle intercepts and interacts with (undergoes virtual photon flux exchange with) an impinging energy density flow **S**= **E**×**H**. In an equilibrium (static) condition, the deviated flow remains very like a persistent, unchanging whirlpool in a river, and so is said to have a "static magnitude". If that Poynting flow is removed, then there is no excess collecting going on and the "magnitude of the deviated energy flow" is zero. EM energy collection/collecting is always like a rock in a high wind. As long as the wind is blowing on the rock, air is deviated to flow around the rock. The rock has a force field on and of it, and wishes to move. It also has "excess collected energy", and a gradient in this "excess collected energy" determined by the wind flow direction. When the wind ceases to blow, the rock goes back to being just a rock, and forgets it had all that excess wind energy collecting and any desire to move.

TERMS AND PHRASES

ABEL, NIELS HENRIK (1802-1829)

Norwegian mathematician who in 1824 proved that the general equation of fifth degree cannot be solved algebraically. He also left an important paper on transcendental functions which was published posthumously.

ABELIAN GROUP

A group obeying the commutative law of algebra for every pair of elements a and b under an operation **,** so that a*b = b*a. As an example, the set of integers is an infinite abelian group under the multiplication operation.

ACTION AT A DISTANCE

An action (effect) occurring in a local system, for which no separate local 3-space cause exists, but for which a causal correlation exists between a distant cause and the local effect.

To the local 3-space observer, the effect is baffling. In electromagnetics, action at a distance can be considered a higher topology phenomena, occurring through hyperspace or through subspace, or through "multiply connected spacetime." Particularly note that "time" is multiply connected; i.e., every spatial point in 3-space (in the entire universe) exists at the same moment in time, which means that electrodynamic action through the time domain can be used to eliminate the spatial distance between any two 3-space points. Action at a distance is absolutely required by quantum mechanics, and experiments establish its truth. Such action was implicitly included in Maxwell's quaternion theory, but was unknowingly discarded by Heaviside, Hertz, and Gibbs when they formulated a much more restricted vector interpretation of Maxwell's theory, after Maxwell's death. Bohm's hidden variable interpretation of quantum mechanics uses the quantum potential, which is a multiply-connected entity producing instantaneous action at a distance. In ordinary electrodynamics, the common scalar potential in the Coulomb gauge has instantaneous velocity, and it appears everywhere in space, wherever it will occupy, all at once *in that gauge*.

Time is also a set of energy flows in the time domain (complex plane) rather than in 3-space. Time is also multiply connected, since a priori every 3-space point in the universe exists at and in a single moment of time. Since time is dynamic and structured with special energy flows, it seems possible to use this feature to establish energy flow during one specific moment to a desired subset of 3-space points, regardless of where in the universe those points are located. Hence the development of "time-energy" technology allows action at a distance via manipulating the multiple connectivity of time and its internal structure (internal time-like energy flows).

AD HOC MODEL

A model used and fitted for a specific purpose or area.

Tentative formulation, not intended toward general application and not yet firm because there is still not a comprehensive, tested demonstration of the "fit" of the model to the complex phenomenology. Nonetheless, an ad hoc model can be quite useful in a given area, so long as it sufficiently fits the experimental data in that area and makes sufficiently accurate predictions in the area.

ADVANCED FIELD

An electromagnetic field that is a solution of the classical Maxwell equations, which is positioned on the future light-cone of spacetime.

We believe much of the problem with the "advanced solution" is a problem of interpretation. We would urge the re-interpretation not in terms of "time-travel" where the wave continues in observer forward time while the rest of the universe is assumed to retrogress to a previous state, but in terms of time-reversal of that wave only. In that case, the rest of the universe stays sane and continues to move in observer forward time, and the wave itself just moves in forward time in a path-reversed manner, back along a previous "stimulus wave" (the retarded wave that moved forward in time normally).

ADVANCED POTENTIAL

An electromagnetic potential that is a solution of the classical Maxwell equations, which is positioned on the future light-cone of spacetime.

Presently this potential has not yet been given a physical interpretation. See remarks above.

ADVANCED WAVE

An electromagnetic wave that is a solution of the classical Maxwell equations, and which is positioned on the future light-cone of spacetime.

See remarks above.

AFFINE CONNECTION

In mathematics: "A connection on a manifold, whose form is unchanged under affine changes of parameter along curves, e.g., when the original parameter t of a curve γ (t) is replaced by t = as + b." **Dictionary of Science and Technology**, Academic Press, Christopher Morris (Ed.), 1992.

Ugh! We'll let the mathematicians take it from there.

AFFINE TRANSFORMATION

"Transformation on a linear space to itself which can be expressed as the sum of a linear transformation and a fixed vector.

The affine transformations form a group. In the plane, the group is six-dimensional, consisting of translations, rotations, stretchings and shrinkings, reflections, simple elongations and compressions, and simple shear transformations, as well as compositions of these."

Dictionary of Science and Technology, 1992, *ibid*.

AHARONOV, YAKIR

Renowned Israeli quantum physicist and former student of David Bohm.

Co-discoverer of the *Aharonov-Bohm effect*: Even when the electromagnetic force fields reduce to zero in a charged particle system, the potentials may still exist and interfere to cause real physical effects. Together with Bohm, Aharonov authored a fundamental paper in 1959 which pointed out the primary importance of the *potentials* rather than the force fields. Indeed, the force fields are only made *in and of the charged particle system itself*, by interference there of potentials, and do not exist as such in the vacuum. The forcefields are thus not primary electromagnetic causes at all, but are *secondary effects* due to the interference of potentials in a particular charged particle system. [See *Aharonov-Bohm Effect*] In his three volumes of physics, Feynman pointed out that the forcefields do not exist *as such* in the vacuum, and that *only the potential for the forcefields exists in vacuum*. The primary causative agents for electromagnetics are thus the potentials. This has been proven both theoretically and experimentally in quantum mechanics, but still does not appear in present classical electromagnetic theory taught in universities—which terribly confuses cause waves and effect waves in wave-charge interactions.

AHARONOV-BOHM EFFECT

Phenomenon theoretically pointed out in 1959 by Yakir Aharonov and David Bohm whereby interfering electromagnetic potentials can produce effects on charged particle systems, even at a distance and in the absence of the electromagnetic force fields.

See Y. Aharonov and D. Bohm, "Significance of Electromagnetic Potentials in the Quantum Theory," Physical Review, Second Series, 115(3), 1959, p. 485-491. For an overview and extensive bibliography, see S. Olariu and I. Iovitzu Popescu, "The Quantum Effects of Electromagnetic Fluxes," Reviews of Modern Physics, 57(2), Apr. 1985, p. 339-436.

Chambers experimentally demonstrated the Aharonov-Bohm effect one year later. When **E**- and **B**-fields are zero in a region, their potentials still may exist and thus be stable and persistent. Being gradient-free, a force-free potential is not changing; no bleed-in or bleed-off of its magnitude *or of its internal structure* is occurring. Interference of the potentials produces real electromagnetic effects (energy) in the interference zone, even at a great distance, without transmission of "field energy" per se through the intervening 3-space. [Rigorously, the potential's EM energy can be considered to be *hyperspatially* transmitted, or *subspatially* transmitted (tunneled) via the Whittaker internal EM biwave mechanism. See discussions under *action at a distance*.]

In 1897-8 Stoney showed (in **Philosophical Magazine**) by physical reasoning that all the disturbances of the ether arising from sources of certain kinds can be resolved into trains of plane waves. This was extended and the general and special equations written by E.T. Whittaker in 1903 in **Mathematische Annalen**. In 1904 (delivered orally in 1903) Whittaker's second paper dealing with the subject was published in the **Proceedings of the London Mathematical Society**, and showed that scalar EM potential interferometry is in fact what generates the classical EM force fields.

The two Whittaker papers may be interpreted to show a startling arrangement in a potential or EM wave. (1) any EM field or wave in a particular 3-space is due to two interfering scalar potential functions in that space. So we may replace any EM field or wave with two scalar potential functions, a priori. (2) But each of the scalar potentials onto which the functions are applied, is decomposable into the Whittaker 1903 longitudinal EM wavepairs, where the output waves are in 3-space and the input waves are time-like and come from the complex plane. This provides a hidden "infolded LW electrodynamics" inside, and composing, all EM fields and waves. Further, the decomposition is recursive, so each of the first tier infolded EM waves can be decomposed again into a second tier of biwaves, etc. Thus the most primary electrodynamics of all is the nested infolded longitudinal EM wave structuring of all present EM waves, potentials, and fields. The internal LW waves also form rigorous curvature of ST patterns (templates) and thus engines. By engineering the structure and dynamics of the internal EM, one can engineer mass—including the atomic nuclei, quarks, and gluons—as one wishes, once the technology is sufficiently developed. In the West, this entire area has been ignored, but it has been highly weaponized by the KGB in Russia.

AIAS

Alpha Foundation's Institute for Advanced Study.

Unusual "think tank" comprised of fellows and fellow emeriti in various places in the world, who cooperate in advanced electromagnetics studies via E-mail. Led by Dr. Myron W. Evans, a theorist of note, the institute has been forging ahead with the production of O(3) symmetry electrodynamics, particularly as an important subset of Mendel Sachs' unified field theory. Dozens of AIAS group-authored papers have been published in various leading journals such as Foundations of Physics, Physica Scripta etc. More than 90 AIAS papers are carried on a restricted Department of Energy website for reference by DoE scientists. The work is particularly significant in working out how EM energy flows in both the 3-spatial and time domains, and how EM energy can be and is extracted from the active vacuum. More than a dozen of the later AIAS papers are carried on a DoE public website, http://www.ott.doe.gov/electromagnetic/papersbooks.html. Also, about two dozen AIAS papers have either been approved for publication in journals, or are in the review process. The present author is a Fellow Emeritus of the AIAS, and is kindly tolerated as a conceptualist by these advanced theoreticians.

AIDS

Acquired Immunological Deficiency Syndrome.

A condition of acquired immunological deficiency associated with infection of the cells of the immune systems with the retrovirus HTLV-III. It is usually recognized by testing positive to HIV infection, and eventually by physical deterioration and by development of one or more life-threatening opportunistic infections such as pneumonia, or of Kaposi's sarcoma.

AIKIDO

A Japanese martial art whose modern form is a synthesis of many schools of jujitsu and the zen art of meditation in motion.

It is the way (DO) of entering and turning (AI) the opponents vital energy (KI). The present author is a retired sandan (third degree black belt) in Yoseikan aikido. He is retired because of debilitating injuries suffered in other fields and accidents, and as a busted-up old dog of 70 has no business bouncing hard off the mats with all those vigorous young fellows. His extra 50 pounds also no longer enhance his athletic ability. We did write a book, privately held but never published, on Aikido and dealing with the principles of unarmed combat. Interestingly, we simply went into the deep unconscious in meditation (and perhaps a little beyond, depending on one's viewpoint) to uncover the unsuspected principles. To list them, we went through the alphabet four times. Many of these principles have never appeared in any text on martial arts or military combat. The task was placed on me by my sensei and required seven years to complete. Perhaps one of these days we will formally publish the book.

ALGEBRAS

The various types of mathematics in which the theoretical models for physics and other sciences are embedded.

Some important algebras utilized in physics are the vector algebra, tensor algebra, quaternion algebra, Grassman algebra, Pauli algebra, Clifford algebra, etc. There are many others. The complexity of the symmetry and of the topology varies significantly between these algebras. Thus, an electrodynamics model in a lower topology algebra such as vectors or tensors will not reveal or permit nearly so great a set of electrodynamic functions and operations as will electrodynamics embedded in a higher topology algebra such as quaternion algebra or Clifford algebra.

As an example, it has been shown by Barrett that the operation of many of Nikola Tesla's patented circuits cannot be understood if analyzed in vector or tensor electrodynamics. The circuits will reveal totally new functions when analyzed in quaternion electrodynamics. That paper is T. W. Barrett, "Tesla's Nonlinear Oscillator-Shuttle-Circuit (OSC) Theory," **Annales de la Fondation Louis de Broglie**, 16(1), 1991, p. 23-41

ALLOPATHIC MEDICINE

A medical system which combats disease by using remedies which produce effects different from those produced by the disease treated.

Reliance is primarily upon drugs, pain relievers, and treatment of symptoms as well as use of agents to "kill" the microbial organisms regarded as the cause of the diseases. Surgery is used as a major adjunct. From time to time, other practices formerly frowned upon or even legally prosecuted are recognized as effective and legitimate, and are then brought in under the aegis of organized allopathic medicine. Physical therapy is such a formally prosecuted modality that was eventually adopted; hypnosis is another. The problems with organized allopathy is that (1) it tends to be monopolistic, (2) it uses the state's power to enforce its credo, (3) it controls both the bulk of the medical scientific literature and the flow of research funds from both government and private sources, (4) it does not adequately police its doctors and technicians, (5) it does not sufficiently accent preventative medicine or "whole human being" treatment, and (6) it engages in conspiracies to destroy competing systems of medicine (as in the case of chiropractic). (7) On the other hand, it has made remarkable advances in preventing killer diseases by vaccination, treating them by antibiotics, and in eradicating or controlling many of the former great killer diseases such as smallpox, diphtheria, and bubonic plague. It has been far less successful in treating and reversing debilitation, cancer, arteriosclerosis, etc. Just now, most of its major weapons against the former dread diseases are beginning to fail. The disease organisms are rapidly changing into new, more virulent forms that are resistant or even immune to the present "successful" treatments. Even in orthodox medical publications, it is now beginning to be recognizing that allopathic medicine is starting to fail, and that we are again entering a period of great, uncontrollable killer pandemics.

ALLOPATHY

Another name for allopathic medicine and allopathic medical therapy.

AMBIENT VACUUM

The average active vacuum, in space, removed from large collections of charge and mass.

AMBIENT VACUUM POTENTIAL

The average standard vacuum (spacetime) considered as a potential having structure and dynamics on a myriad levels.

Anything that is composed of virtual particle flux is a *potential*. Another way of looking at the vacuum is to realize that, having an energy density, then *a priori* it is a potential or may be modeled as such.

Hence the ambient vacuum can be decomposed via the Whittaker method into an internal set of infolded EM longitudinal waves of very special nature. Further, our work on the broken 3-symmetry energy flow involved in any potential or dipolarity shows the more fundamental 4-symmetry energy flow between the time domain and 3-space. This 4-symmetry energy flow is also highly structured and dynamic.

Whittaker's work shows that, contrary to present assumptions in quantum physics, a particular potential has its virtual particle flux formed into a beautiful bidirectional wave structure. The apparent disorder at any local point in the local vacuum potential is due to the constant arrival of myriads of potentials, from charged particles all over the universe. The violent interference and re-interference of these potentials results in the creation of violently changing virtual photons—or in terms of waves, violently changing EM waves and fields. In other words, the statistical disorder of the vacuum is actually *composed of* continually and rapidly changing perfect order. [Here we have confronted 3-law Aristotelian logic with its missing 4th law, because *at the limit* opposites *are* identical!] The continual violent interferometry results in the zero-point EM fluctuations of vacuum. Each EM fluctuation is completely deterministic, as shown in Puthoff's cosmological feedback mechanism. However, the macroscopic observer has no knowledge of the cause or of the arrival, and of the myriads of interferences that produced the final EM field fluctuation. Hence although the zero-point fluctuations of vacuum are completely deterministic one-by-one, the observer has *no information* on their causality. Hence to the observer these fluctuations are completely statistical and seemingly *without local order*. However, because of their hidden determinism, these fluctuations are chaotic rather than random—contrary to the Gibbs' thermodynamics statistics assumed and adopted by quantum mechanics. That statistics should be changed to an "already chaotic" statistics containing hidden Whittaker order. This would appear to be the real solution to the recognized major QM problem of the missing chaos.

Since their changes and appearances are completely in one-to-one correspondence to all distant features of the macroscopically ordered universe, then their integration yields macroscopic order. Further, as can be seen, Mach's principle—so near and dear to the heart of Einstein—arises directly from the foregoing discussion. In such fashion, integration of statistical (but chaotic, and with hidden order) quantum changes results in the familiar, ordered macroscopic world. This removes the great error in QM: that heretofore it has failed to predict the ordered macroscopic universe we observe and inhabit.

ANALOGUE

Part that is analogous (representative or modeled).

At root, an analogue of something is a second something that functions in similar fashion to the first something.

ANAEROBE

An organism that lives, is active, and occurs in the absence of free oxygen. Particularly applicable to one-celled organisms that do so.

ANAEROBE, FACULTATIVE

An organism that can live either as an aerobe or as an anaerobe. Particularly applicable to one-celled organisms possessing that capability.

ANAEROBE, OBLIGATORY

An organism that is restricted to being anaerobic; i.e., it cannot utilize oxygen from the atmosphere.

ANAEROBIC

Characteristic of an organism of living, active, or occurring in the absence of free oxygen.

ANGULAR MOMENTUM

The momentum or "leverage" of the momentum of a moving body, with respect to an axis or reference point.

Angular momentum as the same units as action; that is, it is energy multiplied by time, or momentum multiplied by length. In terms of particles, it is also known as *spin*.

ANOMALOUS EM JAMMING MECHANISM

In a dense signal environment, an unusual mechanism whereby EM energy from the skin of an aerial vehicle is directed laser-like into the internal circuitry.

The density of the signals impinging upon the skin are such that the probability of multiple photon interaction increases. Also, on a nonlinearity in/on the skin, the multiplex of signals creates a scalar EM potential. Decomposition of this potential into Whittaker waves provides hidden "pump" waves upon the nonlinearity, which therefore acts as a pumped phase conjugate mirror (PPCM). EM fields and signals from the internal operating circuits in the vehicle provide "signal waves" to the internal skin and to the nonlinearity PPCMs on the skin. Amplified phase conjugate replica (PCR) waves are generated by the PPCMs, where in each PCR wave the energy may be the total of the external signal density pump waves upon the initiating PPCM. The result is that the skin becomes a "collector" of energy from all the impinging external signals, and focuses much of this collected external energy into laser-like beams inside the vehicle which penetrate directly back to the circuit element that originated the particular signal field/wave to the inner skin. The result is spurious jamming throughout the vehicle, directly in its operating circuits, in a manner not described in normal ECM theory. Also, the same effect occurs in a human body when exposed to such a dense signal environment (threshold about 200,000 signals per square meter per second, and particularly active above 500,000 signals per square meter per second. I.e., in such an EM "smog" environment, the anomalous jamming mechanism is able to progressively conduct the energy impinging upon the skin deep into the body and throughout it, including into the bone marrow. This effect is not described at all in the standard dosimetry literature and experimental approaches for examining the effects of EM fields and radiations upon biological systems. By rigorous frequency band control of radiations and communications, most equipment can be operated in an appreciably dense environment such as appears on the modern environment, because the equipment is essentially "narrow band." The human, however, is a very wide-band receiver, and in such dense environments—even at very weak signal levels—the human system will eventually undergo cumulative damage. This is one of the major mechanisms involved in long term deleterious biological effects of EM radiation environments, but this effect on living systems has not been investigated in the laboratory by present EM bioeffects researchers.

In the U.S. air attack on Libya in 1986, the anomalous jamming mechanism interfered with the aircraft, controls, and missiles because frequency discipline was not rigorously enforced. In the Gulf War, rigid frequency discipline was enforced, with the result that the electronic systems operated normally. However, the troops exposed to that environment (which varied from place to place) were affected by the mechanism, which added a bit to the previous cumulative damage to their immune systems, etc.

ANTIBODY

A body substance produced in response to a specific antigen (protein or carbohydrate or other substance, such as a toxin or enzyme, capable of stimulating an immune response).

The antibody counteracts the effects of the antigen, by neutralizing toxins, agglutinating bacteria or cells, precipitating soluble antigens, etc.

ANTI-ELECTRON

The time-reversed electron, or *positron*. Under time reversal, electric charge reverses in sign.

Paul A.M. Dirac, in his "A Theory of Electrons and Protons," Proceedings of the Royal Society of London A126, 1930, p. 360 introduced the negative energy electron sea (now called the "Dirac sea") with negative energy electron holes treated as the positive electron. He attempted to identify these holes with protons, but that was later refuted. The positron, discovered about a year after Dirac's paper, was later connected with this anti-electron.

Note that Dirac himself was not adamant that *all* negative energy state holes in the Dirac sea were filled with electrons, but just that *almost* all of them were. Modern researchers have tended to extend this to state that *all* the holes are filled, normally. That is sufficient in forward time situations. But it does not necessarily hold in a time-reversed situation, in a time-reversed zone, or in a tempic back emf.

ANTIGRAVITY

An effect whereby normal masses *repulse* one another rather than *attract* one another

Antigravity may also be considered as *time-reversed gravitation*. It may also be considered as *gravitation between two negative masses*.

ANTIMATTER

Matter consisting of atoms which are composed of antielectrons (positrons), antiprotons, antineutrons.

Also loosely refers to the antiparticle corresponding to a particle—the antiparticle may be regarded as the particle traveling backward in time, or "phase conjugated", or "time-reversed.

ANTIPARTICLE

A counterpart to an ordinary fundamental particle, having identical mass lifetime and spin, but with charge and magnetic moment reversed in algebraic sign.

Note that when the charge is reversed, parity and time are also reversed. Thus, properly, the antiparticle is the phase conjugation of the particle, or just conjugate particle for short. In effect an antiparticle is the particle traveling backward in observer time rather than forward in observer time.

ANTIPHASED

180 degrees out of phase (contrary-wise in timing).

ANTIPHOTON

A time-reversed photon.

Presently, the photon is considered its own antiparticle, so that photon and antiphoton are one and the same. In the new approach, that is not quite true. First, one considers that a photon—as is well known—has the units of angular momentum. Thus it is made of "energy multiplied by time." We consider that the time-forward photon (i.e. a normal photon), is made of (+ΔE)(+Δt). Usually physicists have largely neglected the fact that a photon carries an *increment of time* as well as an increment of energy! In our approach the antiphoton, being a *time-reversed* entity, must be composed differently. We have tentatively considered the antiphoton to be comprised of (ΔE)(- Δt). It will probably initially be necessary to take into account the fact that Minkowski geometry treats the T dimension as imaginary rather than simple arithmetic. We haven't had the lengthy time to work all of that out; perhaps one of the better theoreticians or one of the sharp young graduate students will do that and save us the trouble.

At any rate, the requirement is that—in a coupled photon-antiphoton pair (a graviton)—the energies of photon and antiphoton must add spatially, while *electromagnetically* the translation forces (actually translation impulses) of photon and antiphoton must cancel or thwart each other. One insists on a strong interpretation of the distortion correction theorem in phase conjugate optics. In other words, we consider the "wave" as composed of photons, while the "antiwave" (phase conjugate replica) emitted by a phase conjugate mirror is composed of antiphotons. And we consider that the distortion correction theorem must apply to the wave's photons, so that the antiphotons are precisely superposing (coupling) and then decoupling as the wave and antiwave pass through each other in perfect spatial superposition. We feel that this "totally in phase spatially but totally antiphased temporally" concept is important. It is well-known, e.g., that in certain cases protons—the very building blocks of matter itself—can pass right through other protons, as shown in certain colliding beam experiments if their relative spins are properly arranged.

ANTISIGNAL

The phase conjugate of a signal. The time reversal of that signal or its twin. The phase conjugate replica signal/wave emitted by a phase conjugate mirror material in response to an incident signal/wave.

ANTI-STOKES EMISSION

Radiation emitted from an intensely scattering medium that is of greater intensity than the input radiation.

In other words, the medium gives off more energy than we have to put into it. This has been known since the 1930s and proven experimentally, but no really complete explanation has been forthcoming. The conventional explanation is that some of the kinetic energy of the medium is furnished to cause additional emission. In that case, anti-Stokes emission would lower the kinetic energy of the emitting medium. Note that this is not necessarily true at all in Letokhov's negative absorption (excess emission) of the medium, where in that case the excess energy in the emissions is said to come directly from energy absorbed from the active vacuum.

ANTI-STOKES RADIATION

The radiation coming from an anti-Stokes emission process from an intensely scattering medium, where more energy flux is emitted than is input by the experimenter-operator.

In the past, there has just been "arm-waving" that the excess energy must come from the internal energy of the molecules. There seems to be no explanation at all of where the excess energy of the molecules must continue to come from! Tacit silence on this "apparent" violation of energy conservation is held. But see Letokhov's *negative absorption of the medium* discussions in the literature.

We quote from H. C. Dake and Jack DeMent. (1941) **Fluorescent Light and Its Applications**, Chemical Publishing Company, Inc., Brooklyn, New York, 1941. p. 51-52: *"When a phosphor or other luminescent substance emits light, it gives in most cases an emission according to Stokes' Law. This law states that the wavelength of the fluorescent (emitted) light is always greater than the wavelength of the exciting radiation. It was first observed in 1852 in the memoir "On the Change of Refrangibility of Light," by Sir G. G. Stokes. In terms of energy the relationship states that e em < e ab. While Stokes' Law holds for the majority of cases, it does not hold in certain instances. In some cases the wave length is the same for both the absorbed and the emitted radiation. That is, the efficiency appears to be perfect or unity. This is known as resonance radiation. In other cases Stokes' Law does not hold where the energy emitted is greater than the energy absorbed. This is known as Anti-Stokes emission. In 1935 Prileshajewa showed that there is an energy difference as much as 1.1 v between the exciting light and the fluorescence of aniline vapor. This added energy is attributed to additions from the internal energy of the molecule."*

There is no real problem of identifying the source of the excess energy, once one realizes that (i) every dipole is a broken symmetry in the vacuum exchange with the end charges of the dipole, and thus extracts virtual energy from the vacuum, integrates and orders it, and outputs it as EM energy density flow. One then adds multiretroreflection and multiple passes of the EM energy flow, so that charges that intercept and collect energy from the reciprocating flow can multiply connect from the same energy flow (on a given pass, only a tiny, tiny fraction—nominally about 10^{-13}—of the energy flow is intercepted and interacted with by the collecting particle). Thus multiple collections from the same EM energy flow can be accomplished, if the flow is iteratively rerouted (as by retroreflection or phase conjugate reflection) back across the collecting charges again and again.

In this fashion additional energy is collected in the collected volume, which increases the local collected energy density in that volume. In turn this increases the local potential of that volume. *In turn* that increases the energy flow from that potential acting as a dipole, because it increases the dipole strength and consequently the magnitude of the dipole's broken symmetry in its vacuum flux exchange.

The inefficiency of the process increases nonlinearly with increasing local potential, and faster than the buildup of local energy density occurs from multipass multicollection. When the inefficiency curve reaches the increasing broken symmetry energy extraction curve, then a point of equilibrium is reached. At that equilibrium point, the rate of energy diffusing out of the multipass region and escaping from the periphery of the system is equal to the rate of extraction of energy from the vacuum and flowing it out into as Poynting **S**-flow into the multicollection region and collecting it.

So we have described an open thermodynamic system, where there are two inputs of energy flow: (i) that by the operator-experimenter, and (ii) that from the vacuum via the dipolar broken symmetries. At equilibrium condition the total input energy rate is equal to the total energy escaping rate, and the conservation of energy law is rigorously upheld. However, this is an open thermodynamic system far from equilibrium, and so rigorously the nonlinear thermodynamics of such systems applies, rather than the normal equilibrium thermodynamics. As is well-known, the coefficient of performance for such open systems in disequilibrium, may permissibly be overunity, even greatly overunity.

Properly utilized, the overunity anti-Stokes or Letokhov emission can be made very large—such as COP ≈1200 in Patterson's adaptation. The process and its overunity certification already exist in the hard science literature, being known and experimentally demonstrated for at least three decades.

ANTIWAVE

The time-reversal (phase conjugation) of a reference wave.

A phase conjugate replica wave is a time-reversed replica of its referent wave. Hence it is the antiwave of the referent wave.

A-POTENTIAL

Vector magnetic potential.

The A-potential is a real entity more primary than the magnetic field **B**, and not a mathematical convenience as was originally thought—as detailed in the second volume of Feynman's three volumes of physics. Indeed, it may be separated from the magnetic field, as reported by Feynman, and used for instrumentation effects in the manner patented by Gelinas. When separated from magnetic field, it is often referred to as the "curl-free vector potential," since the **B**-field is modeled as being created from the **A**-field by curling it. In other words, **B** is defined as the curl of the magnetic vector potential, if we use $\mathbf{B} \equiv \nabla \times \mathbf{A}$. Hence "separating" magnetic field from **A**-potential simply is a sort of "parallel branching" of the energy density flow of the **A**-potential. It is like branching the voltage on a feeder line conductor in an electric circuit into two parallel conductors. The feeder potential splits into two, so that each branch has the same potential. Actually the vast energy flow in the feeder line only has a small component which strikes the surface charges, diverting the energy into the conductor and potentializing the Drude electrons. In branching into two conductors, the giant flow branches also, but is so great that the surface charges in each of the two branches still intercept essentially the same amount of energy, diverging it into the conductor. Hence each conductor exhibits the same potential as the feeder conductor

The same thing happens when one "splits" or branches the **A**-potential in similar fashion. The diverted and separated **B**-field branch will exhibit "equal energy density" flow (i.e., in the form of magnetic flux density flow) and yet the original **A**-potential path through space will still have the same previous energy flow density magnitude, just without curl (without magnetic field).

Any good toroid or very long solenoid already performs such separation, and hence energy density flow doubling. If properly used—as in the motionless electromagnetic generator (MEG)—this effect can be used to provide a generator with COP>1.0. At this writing, the present MEG exhibits COP = 16, and is a patent-pending system.

The well-known Aharonov-Bohm effect, e.g., also uses this separation of the curl of the **A**-potential, leaving an uncurled **A**-potential whose changes will and do interact with electrons.

The curl-free vector potential is particularly interesting because (1) it is a unique and independent field of nature, (2) its curl produces a magnetic field, (3) its time derivative produces an electric field, (4) its magnitude does not fall off inversely as the distance squared, but only inversely as the distance, and its time derivative d**A**/dt = B **E**. Hence, as in the MEG, one can extract energy both from the curl-free A-potential and the curled **A**-potential (magnetic field **B**), increasing the available energy collected in the circuit to greater than what the operator input to it. This is simply a physical process of regauging, wherein electrodynamicists already routinely assume (and apply) the fact that the potential energy of any EM system can be freely changed at will, by regauging. In the real world, of course, we may have to pay a little switching energy, but we are free to regauge (by this "splitting the potential into equal parallel paths, and by other methods), at will and at any time and place. The MEG just takes advantage of one major method for free regauging, in order to violate the Lorentz symmetry condition (violate symmetry in the system's energy exchange with its active vacuum environment). It thereby is legitimately permitted to exhibit COP>1.0 and output more energy than one inputs, because the regauging transforms it into an open dissipative system far from thermodynamic equilibrium in its active environmental energy exchange.

ARISTOTELIAN LOGIC

The conventional three laws of logic, unconsciously fitted to the physical reality created by the single photon interaction. The three laws are: (1) a thing is identical to itself, (2) a thing is not identical to something else, and (3) either one has a given thing or something that is not that thing. Mathematically these are written as (1) A A, (2) A Ã, and (3) A Ã. Aristotelian logic applies only to single observation at a time (monocular observation, a single observer). When multiple simultaneous observation (multiocular observation, multiple observers) are considered, the three laws may be violated. In that case a fourth law, A Ã is added. This law may be seen to be the exact negation of all the first three. An application rule (which may itself be called a fifth law) is also added, and states that either the first three laws are explicit and the fourth is implicit, or the first three are implicit and the fourth is explicit. Further, the fourth law is the *law of the paradox*: Something that is found to be true in nature, but violates one or more of Aristotle's three laws, is known as a *logical paradox*. In the higher logic, it simply violates the case where the three Aristotelian laws are explicit and the fourth law is implicit. Instead, the three Aristotelian laws are now implicit and the fourth law has become explicit. All boundaries exhibit this effect.

It is highly recommended that the interested reader familiarize himself or herself with Morris Kline, **Mathematics: The Loss of Certainty**, Oxford University Press, New York, 1980. Kline deals directly with the fact that mathematics is not a body of unshakable truths about the physical world, and mathematical reasoning is not exact and fallible.

ARISTOTLE

A great Greek philosopher who lived from 384-322 B.C.

Aristotle is famous for his three laws of logic: (1) a thing is identical to itself, (2) a thing is not identical to something else, and (3) either one has the thing considered or one has something else.

Heraclitus pointed out that Aristotle's laws prohibited any change, and yet changes were ubiquitous. In short, for a thing to change, it had to change into something else, so Heraclitus pointed out. So how could a thing be both itself and something else simultaneously? How could it be not itself while being itself? The problem has not been solved by the logicians and philosophers to this day, because it has no solution in Aristotelian 3-law logic. So Heraclitus, believe it or not, concluded that all change was an illusion.

ATHERIOSCLEROSIS

Basically, clogging of the arteries, which may be due to deposits onto the artery walls or by thickening and growth of the artery walls themselves, or a combination. It is a chronic (slowly progressing) disease where the artery walls become progressively thickened and hardened and the artery becomes less elastic.

It has been found that the common cytomegalovirus (one of the herpes viruses) plays a key role in the development of the disease. Initial deposits irritate and injure the arterial walls, and the herpes 6 virus infects the site, partially nullifying the control of excess grown of the arterial muscle tissue. This deposit and concomitant stimulation of some excess muscle growth occurs repeated, so that the muscle tissue grows abnormally over an extended period of time. For this reason, when an operation is performed to forcibly reduce the deposits inside the artery, the resulting injuries to the arterial wall tissues leads to the herpes 6 infection and stimulation of excess muscle growth. It has been found, e.g., that after angioplasty the process is often engendered, so that within a year or two the artery is narrowed again, but this time by abnormal growth of smooth muscle tissue. The Prioré team demonstrated positive and total remission of arteriosclerosis in laboratory animals by means of nonionizing EM irradiation to produce an amplified "antiengine", which "time reversed" or dedifferentiated the stricken cells and the stricken areas back to a previous state.

ARTIFICIAL POTENTIAL

A scalar potential which is composed of, or partially contains, an artificially assembled bidirectional wave set.

See E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," **Mathematische Annalen**, Vol. 57, 1903, p. 333-355 for proof that a "scalar potential" is actually a harmonic set of hidden bidirectional EM phase conjugate longitudinal wavepairs. Each wavepair consists of a wave and its antiwave (true time-reversed replica wave).

If the external observer could see the *detected* (effect) waves in a hidden wavepair, he would see the "wave" going in one direction and the antiwave passing precisely through it in the other direction. However, prior to detection, the phase conjugate wave exists entirely in the complex plane and hence in the time domain (in -ict). So the interpretation of Whittaker's 1903 paper, in terms of cause and effect waves, is that the phase conjugate half set is incoming from the time domain to each and every point in the dipolarity or potential, and the "real 3-space half set" is being radiated in every direction in 3-space from that point. See my paper, "Giant Negentropy….".

In addition to Whittaker's sum set of biwaves, Ziolkowski added the product set in the mid-1980s. E.g., see Richard W. Ziolkowski, "Exact solutions of the wave equation with complex source locations," **Journal of Mathematical Physics**, 26(4), April 1985, p. 861-863; Rod Donnelly and Richard Ziolkowski, "A method for constructing solutions of homogeneous partial differential equations: localized waves," **Proceedings of the Royal Society of London A**., Vol. 437, 1992, p. 673-692. Particularly see I.M. Besieris, A.M. Shaarawi, and R. W. Ziolkowski, "A bidirectional travelling plane wave representation of exact solutions of the scalar wave equation," **Journal of Mathematical Physics**, 30(6), 1989, p. 1254-1269.

However, these deal only with the effects waves after detection.

Another way of defining an artificial potential is: *A potential formed by or containing a subset formed by, deliberately summing nonzero force field vectors to a zero vector resultant*. [Note that electrodynamicists routinely discard vector systems that sum to a zero resultant; not realizing that in doing so, they are discarding vacuum engines and a vastly extended electrogravitational dynamics!] The vector zero system of infolded nonzero vectors has a deterministic, internal stress pattern that is macroscopic. The type of potential made by the zero summation depends upon the type of force vectors summed. For example, summing electric field vectors to zero produces an electrostatic scalar potential; summing magnetic field vectors to zero produces a magnetostatic scalar potential of vacuum.

All potentials represents local warps or curvatures in vacuum/spacetime, and all artificial potentials contain internal, deterministic templates of nested internal spacetime curvatures. Curvature of spacetime interacts directly upon mass and physical systems embedded in it. Thus these deterministic, internested local spacetime curvatures of the artificial potential represent vacuum engines, or spacetime engines, and the artificial potential is said to be a *dimensioned* or *activated* potential. Any system exposed to and placed in such a vacuum spacetime engine, will have these hidden vacuum flux asymmetries interacting upon each and every part of it, down to and including the nuclei, the nucleons, and the quarks in the nucleons.

ASYMMETRICAL REGAUGING

Change of either the scalar potential f or the vector potential **A**, but not both, so that a single excess force and a single change of system energy occurs in the system.

This violates the assumed Lorentz condition, and thus excess energy can enter the system, and an excess "free" force appears which can (if the system is adroitly designed) then translate to perform work upon the system to increase its (e.g. kinetic) energy, exhausting the excess regauging energy in the process and restoring symmetry.

In conventional EM theory, Maxwell's equations in potential formulation are in terms of two potentials, f (the scalar potential) and **A** (the vector potential). When Heaviside retranslated Maxwell's quaternion set of 20 equations in 20 unknowns, he transformed it (in potential form) into two equations where main variables f and **A** are not separated. Electrodynamicists, who until recently considered the potentials as not even real, but just mathematical figments and conveniences, then simply arbitrarily changed both f and **A** *just precisely so* that the extra force appearing in the system by the change of f was countered by an equal and opposite extra force also appearing in the system by the change of **A**. This type of *symmetrical (no net force) regauging* is known as the *Lorentz condition*.

Each *asymmetrical* (produces a nonzero excess net force) potential change (each half of the two asymmetrical regaugings that comprise the symmetrical regauging) also altered the overall energy of the system. However, in the symmetrical regauging that total energy change is "bottled up" as increased stress in the system, because no net translation force is available to be translated and use the energy change to produce excess "free work."

The Lorentz condition assumes that the designer *will not allow* the equilibrium of the system to be broken! In that case, of course, ordinary equilibrium thermodynamics applies, and the system cannot produce COP>1.0. Prior to this Lorentz condition assumption and its absolutely arbitrary regauging, Maxwell's equations do include asymmetrical regauging and therefore open EM systems far from thermodynamic equilibrium; precisely those which violate the Lorentz condition (symmetric regauging) assumption. In short, the unregauged equations do include COP>1.0 electrodynamic circuits and systems.

Unknowingly the electrodynamicists *arbitrarily* discarded the entire Maxwellian class of overunity EM engines and circuits—which class incorporates making a change in one potential(s) such that the Lorentz condition does not hold.

ASYMMETRY

Lack of symmetry, or "broken symmetry" in a general sense.

ASYMMETRY OF THE DIPOLE

Any dipole or dipolarity is a broken 3-symmetry in its fierce exchange of EM energy with the active vacuum. This means that it continuously receives and absorbs copious virtual energy from the seething vacuum flux, and that not all this absorbed energy is reradiated back to the vacuum in virtual form. Instead, some of it is integrated into observable form and re-radiated in all directions as usable, real 3-space EM energy.

This is standard, well-known particle physics, although it appears to be totally missing from classical electrodynamics and it is not considered at all by electrical power system designers and analysts!

Every electric charge is a broken symmetry in the virtual particle flux exchange between the quantum mechanical (energetic) vacuum and the mass of that electric charge. The dipole is two different such asymmetries. As is well-known in particle physics (not in classical EM theory!) each such broken symmetry must "gate" out some of the vacuum energy. In short, the charge asymmetry "extracts" some vacuum energy from its normal "energetic exchange" with the vacuum flux, and puts it out in some form we call "observable" (capable of being measured; specifically, of being intercepted by electric charges so as to produce a force field across the charge and translate it).

Well, an electrical charge produces a flow of energy density which we may represent conventionally as $\mathbf{S} = \mathbf{E}\times\mathbf{H}$ (when collected and measured on assumed unit point charges), which we—a little bit mistakenly—call "observable." [Actually, until the energy flow interacts with that assumed unit point charge, it is an *organized flow of virtual entities*] After interaction it is real observable EM energy in 3-space. The spinning electron has its own magnetic moment and its own **E**-field. Since (in one form) also $\mathbf{E} = -\nabla\phi$, an extracted and formed $\mathbf{S} = \mathbf{E}\times\mathbf{H}$ is output by the charge asymmetry. This output energy flow also produces the assumed ϕ evidenced by the charge interaction, since ϕ as used represents the *reaction cross section* of the potential. Note that all these entities **S**, **E**, **H**, and ϕ are defined in electrodynamics only as their own interaction cross section with a unit point charge containing mass.

In classical electrodynamics (formed long before the notion of charged particles, atoms, and EM energy flow!) it is just recognized that "charge is the source of a potential." Actually charge gates the energy flow from the vacuum flux, receiving the energy from the time domain by its asymmetry, transduces the energy into 3-space energy, and outputs it as real EM energy pouring out in 3-space in all directions. That energy-flow contains and carries the energy that will interact with charge to form the **E**-field, the **H**-field (spin field), and ϕ.

Also, in particle physics and gauge theory it is well-known that *no mass system can be in equilibrium anyway, unless the vacuum-to-mass interaction is incorporated!* After CEM was formed, much later the atom was discovered and the electron was discovered. Much later then, particle physics and quantum mechanics came along. CEM theory has never been altered to include the necessary vacuum interaction, although it has been known for decades that CEM is totally in error in this respect.

Here one poses a question to the sharp young graduate students: Why does every university continue to teach a seriously flawed classical electrodynamics which does not include the vacuum/mass interaction, when the physics department at the same university knows full well that it must or no EM system can be in equilibrium? Why is not such a *fundamental* and universal issue strongly raised and intensively discussed by our large, tax-exempt scientific organizations at their annual symposia? Why do not the National Science Foundation and the National Academy of Science demand that serious work be done at all speed, to correct such known scientific deficiencies in the classical EM theory? *What happened to science as the search for physical truth*, and replaced it with "status quo" models or—in some cases—even dogma? It is an inexplicable mystery to me, and one to which I do not know the answer.

AUTOIMMUNE DISORDER

A disease or disorder relating to or caused by the antibodies or T-cells that attack foreign molecules, cells, or tissues of their host organism.

A flagrant autoimmune disease example is AIDS, Acquired Immunological Deficiency Syndrome. The AIDS virus successfully hides from the antibodies, so that they cannot perform their proper function, and it infects the T-cells and negates their function. However, there are other examples other than AIDS: e.g., rheumatism and osteoarthritis.

BACK EMF

The counter-electromotive force, usually between the end charges of the source dipole for an EM circuit.

When the electrons in the circuit are forced against the emf—as when the charges from the ground reference of the circuit are forced back up through the emf of the source dipole—then work is done upon the source dipole to scatter the charges and destroy the dipole. Removing the dipole removes its receipt of vacuum energy via its broken 3-symmetry, transduction of that energy, and output of it along the circuit and in space around the circuit as the energy flow that powers the circuit (with part missing the circuit and being just wasted).

Since this removes the power from the circuit, then additional energy must be input to the source to perform work on the internal charges and restore that source dipole again.

There are actually two emfs in a circuit, not one. There is a 3-space emf and also an entirely unrecognized tempic emf. In either case, under proper circumstances there can be a back-emf or either one or both. See discussion under *electromotive force, back*. See also *tempic back emf* (to be added).

BALL LIGHTNING

Rare form of lightning where an incandescent, slow-moving globe forms. The globe often moves erratically, explodes, and may set fire to objects it touches.

Ball lightning may be due to scalar electromagnetic interferometry which can produce a controlled pattern of electromagnetic energy at a distance, or it may be due to the formation of a special localized spacetime curvature engine.

BARE ELECTRON

The true electron without its partial shielding of virtual positrons that are attracted around it.

BARRETT, TERENCE W.

Noted modern electrodynamicist and consultant who works in SU(2)×SU(2) gauge symmetry extended electrodynamics, and was also one of the pioneers of ultrawideband radar.

BECKER, ROBERT O.

Medical doctor, medical research scientist, and Nobel Nominee, noted for his early-on efforts—particularly in the 1960s through the 1980s, in the effects of EM fields on biological systems, studies of evoked or partially evoked limb regeneration in certain species, electrical stimulation of bone fractures to stimulate healing and reveal the mechanism involved, and the cellular regeneration system of the body as opposed to the immune system.

Becker particularly recognized that the cellular regenerative system was a special electrical system having unique functions. He even succeeded in diagramming this system as far as it is revealed by ordinary U(1) electrodynamics. Becker demonstrated partial limb regeneration in salamanders, etc. and in some other species, with electrical stimulation. In his EM-stimulated bone fracture healing, Becker showed a startling result: First the red blood cells entering the fracture area shucked their hemoglobin and grew a nucleus, thus "dedifferentiating" (biological term) or "time-reversing" (physics term) back to an earlier state. Then this modified cell redifferentiated (biological term) or "fast-forwarded in time" (physics term) into the type of cell that makes cartilage. Then this newly modified cell further redifferentiated into the type of cell that makes bone, and was deposited in the fracture site. The continuing deposits of these cells from the ongoing process evoked in red blood cells healed the fracture with new bone growth. Whereupon the action stopped.

Becker also was one of the first qualified scientists who testified in court on the deleterious effects of power line radiation. He thereby incurred the enmity of very powerful interests, so that his research funds were pulled and eventually he was forced to retire at an early age.

He was nominated for the Nobel Prize multiple times, and his epochal work did finally focus at least some attention of the medical research community on the regenerative system as opposed to the immune system which heals nothing.

Becker's profound work was of tremendous influence on me as I struggled to decipher the active mechanism in his experiments, the Prioré team's experiments in France, the Russian microwave radiation of U.S. Embassy personnel in Moscow, Kaznacheyev's experiments demonstrating transmission of cellular disease and disorder electromagnetically into target cells environmentally isolated except for contact by light from the sender cells having such disease or disorder, and the body's own regenerative system. After some 14 years struggle with the problem, I finally did break the mechanism(s) involved in all those things. But it was only possible because of the magnificent work by Becker and Prioré, the reported work by Kaznacheyev, and gradual exposure to higher symmetry electrodynamics. The work was crude at first, but eventually progressed (by 1998, e.g.) to include the port-hole concept, transduction of EM wave polarization types, the engine and engine template concepts, and unified field theory. Since then it has become clear that the proper electrodynamics to model such things is the higher symmetry O(3) electrodynamics pioneered by Evans, and now revealed to be an important subset of Sachs' unified field theory.

Becker is therefore one of my heroes whose magnificent work and long perseverance against strong scientific suppression I greatly admire. Most of Becker's detractors were or are in fact employed in positions either directly or indirectly funded by the electrical power industry. I believe that, had Becker had access to O(3) electrodynamics and Sachs' theory, he would have personally impelled the entire medical field to a marvelous and extraordinarily advanced EM medical therapy.

See Robert O. Becker and Andrew A. Marino, **Electromagnetism and Life**, State University of New York Press, Albany, 1982; Nice summary of EM bioeffects (orthodox) ; also on http://www.ortho.lsumc.edu/Faculty/Marino/EL/ELPub.html.

See also R. O. Becker, "The neural semiconduction control system and its interaction with applied electrical current and magnetic fields," **Proceedings of the XI International Congress of Radiology**, Vol. 105, 1966, p. 1753-1759, Excerpta Medica Foundation; Amsterdam; — "The direct current field: A primitive control and communication system related to growth processes," **Proceed. XVI Internat. Congr. Zoology**, Washington, D.C., Vol. 3, 1963, p. 179-183; — "The control system governing bone growth in response to mechanical stress," **J. Ark. Med. Soc**., Vol. 62, 1966, p. 404; — "A technique for producing regenerative healing in humans," **Frontier Perspectives**, 1(2), Fall/Winter 1990, p. 1-2; — with Charles H. Bachman and Howard Friedman, The direct current system: A link between the environment and the organism," **New York State Journal of Medicine**, Vol. 62, April 15, 1962, p. 1169-1176; — and D. G. Murray, "A method for producing cellular dedifferentiation by means of very small electrical currents," **Trans. N.Y. Acad. Sci**., Vol. 29, 1967, p. 606-615; — and Joseph A. Spadaro, "Electrical stimulation of partial limb regeneration in mammals," **Bulletin of the New York Academy of Medicine**, Second Series, 48(4), May 1972, p. 627-64; — and Carlton F. Hazlewood, Abraham R. Liboff, and Jan Walleczek, **Electromagnetic Applications In Medicine**," NIH-OAM Electromagnetics Panel Report, Jan. 15, 1993.

See particularly Robert O. Becker, "The significance of bioelectric potentials." **Bioelectrochemistry and Bioenergetics**, Vol. 1, 1974, p. 187-199. This is probably *the* paper by Becker that provides a really good overview of the control system. A block diagram of the proposed system is given by Becker on p. 191.

Becker also has authored several popular-oriented books filled with excellent information. These include Robert O. Becker, M.D. and Gary Selden**, The Body Electric: Electromagnetism and the Foundation of Life**, William Morrow and Co., New York, 1985; and Robert O. Becker, **Cross Currents: The Perils of Electropollution; The Promise of Electromedicine**, Jeremy P. Tarcher, Los Angeles, 1990.

BEDINI, JOHN

Noted audio engineer, overunity energy researcher, and inventor of the renowned Bedini amplifiers well-known to audiophiles, the BASE process for holographic sound, and a process for cleaning the harshness from digital audio disks.

Bedini has invented a variety of COP>1.0 processes, motors, generators, etc. Particularly he has developed a process whereby, in a battery-powered circuit, he adroitly back-pulses the battery in a recharging direction while the battery is powering the load, causing a pile-up of electrons on the surface of the battery plates that is a sharply increased scalar potential opposing the onrushing very massive lead ions in the battery in discharging mode. The result is that the potential's electron pile-up increases dramatically due to the ions' far greater inertia than that of the electrons. The result is a high potential (perhaps 40 volts) upon the surface of the battery, overpotentializing both the incoming lead ions between the plates and the electrons in the external circuit in powering mode. In this phase, energy flows from the vacuum onto both the ions and the external circuit electrons, adding significant energy to the powering of the external circuit for the same ion current inside the battery.

As the ions slow and stop, Bedini's back-pulse trailing edge causes a very sharp cutoff, thus invoking Lenz's law and resulting in the surface potential on the plates increasing to well over 100 volts. This further overpotentializes the external circuit electrons in powering mode, dissipating much more energy in the external circuit to power the loads. As the ions finally stop and reverse, their relatively sluggish re-acceleration in charging mode and their overpotentialization still results in excess energy being delivered to the external circuit. Then as the overpotentialized ions accelerate in charging mode, the external circuit is still in powering mode until the drain-off of the severe electron pile-up on the surface of the battery plates.

This is one of several modes of operation used by Bedini in his overunity battery powered circuits, which keep their batteries recharged while powering their loads.

By separating the other closed current loop between external electron currents and the ion currents between the battery plates, and then dephasing these currents, Bedini breaks the usual dissipation symmetry enforced in a closed loop circuit where all charge carriers have the same m/q ratio. In Bedini's circuits, the m/q charge ratios dramatically differ between the ion current section between the plates and the electron currents between the outside of the plates and through the external circuit. Also, by providing a much greater potential *between* the two circuit halves, The potential extends in both directions—internally back over the ions, and externally in the circuit over the external Drude electrons powering the circuit loads and losses. He provides a true negative resistor on the surface of the plates, which extracts energy from the vacuum (via its broken 3-symmetry as a dipolarity) from the time domain, transduces it into real EM energy, and overpotentializes (regauges) the potential energy of both the internal ion currents and the external electron currents.

The Bedini process is therefore a legitimate COP>1.0 system, and in his self-powering embodiments the system will run indefinitely without external energy input by the operator, use of fuel, etc. He has converted the system to an open system far from thermodynamic equilibrium in its violent energy exchange with the active vacuum, and thus the system is permitted to exhibit both COP>1.0 and self-powering as well.

For an expanded explanation of the Bedini negative resistor process in batteries, see T. E. Bearden, "Bedini's Method for Forming Negative Resistors in Batteries," **Journal of New Energy**, 5(1), Summer 2000, p. 24-38.

BEING

Pure essence, existence.

Again, something which in actuality resists Aristotelian definition unless preliminary assumptions are made. Generally used in one of two senses: (1) persistence, as in "he is (he continually exists)," or (2) identity, as in "he is the man ('he' and 'the man' are the same thing)."

BIDIRECTIONAL EM WAVES

EM waves running antiparallel to each other through a given point or region of space.

Suppose we run a normal EM wave into a phase conjugating mirror (PCM) with a gain of 1. By ordinary phase conjugate optics, the mirror then emits a backwards-traveling phase conjugate replica wave (PCR wave). According to the so-called "distortion correction theorem," that backwards traveling wave will travel backwards (as seen by the external observer) back over the exact route taken by the previous wave, and it will reappear in space precisely superposed spatially with the previous waves. If we examine the impulse (density) fields (i.e., Edt), then the forward-time wave contains Edt while the backward time wave contains E(−dt), which is just −Edt. So *electromagnetically*—as far as producing a net translation force on a charge—the E-fields seem to cancel, although they are still there and their energy is still there. Instead of translation, the two produce stress.

One thus (simple case) will have a strange kind of standing wave wherein the local energy density of the vacuum varies (e.g., sinusoidally) as a function of distance, but a charged particle placed in it will not be translated! Rigorously, that is a *gravitational standing wave*. Since change in local energy density is also a curvature of spacetime, that is also a standing sinusoidal wave of the local curvature of spacetime. This is where electromagnetics and gravitation actually meet, and where electromagnetics can be utilized to produce gravitational waves. (Much more complex waves can be produced; this is just the simplest example).

BIDIRECTIONAL FIELD FLOWS

E-fields (and B-fields) being propagated in a pair of opposite waves traveling "through" each other in opposite directions,

...where the two may be "locked together" as a wave and its antiwave; i.e., as a "Whittaker biwave pair". Note that Whittaker bidirectional EM wavepairs are not to be confused with the pairing of the wave and reflection wave on a transmission line.

BIDIRECTIONAL GATING

Gating (of energy flow, e.g.) in both directions simultaneously.

BIDIRECTIONAL TRAVELING PLANE WAVE

A wave and its antiwave, where each wave is moving in an opposite direction (standard assumption in phase conjugate physics).

In short, to the external observer the waves seem to be "moving through" each other; one from left to right, and the other from right to left; or one radially outward and the other radially inward. All scalar potentials were shown by Stoney and Whittaker to be comprised of a harmonic series of such "bidirectional traveling wave pairs." However, the interpretation of the phase conjugate waves was after detection, so that the detected "effect" wave existed in 3-space. Prior to detection, the phase conjugate half-set of the Whittaker decomposition of the scalar potential is convergent from and in the time domain (complex plane).

BIOELECTROMAGNETICS (BEM)

Presently, the scientific study of interactions between living organisms and electromagnetic fields, forces, energies, currents, and charges. The range of interactions studied ranges from atomic and molecular, through intracellular, to the whole organism**.**

Electromagnetic fields studied in BEM include those of endogenous origin (from within the organism) and exogenous origin (from outside the organism). Sources of exogenous fields include: the earth and sun, electrical equipment (power lines, radio transmitters, etc.), clinical treatment devices (e.g., TENS), and other organisms. The electromagnetic fields of greatest interest in BEM are generally classified as nonionizing (i.e., lacking sufficient energy to directly dislodge electrons from molecules or atoms.) BEM is a scientific discipline emerging on the boundaries between physics and biology. As in other sciences, progress in BEM is made by testing falsifiable hypotheses against valid measured data obtained in repeatable experiments.

Our new viewpoint seeks to dramatically enlarge the scope of this definition, to include not only the presently-recognized external (outfolded) electromagnetics, but also the internal (infolded, inside the scalar EM potential) electromagnetics, and also to utilize a unified field theory where EM is GR and vice versa.

BIOENERGETICS

That branch of Russian (KGB) energetics which is targeted against the living body, its cells and tissues, and its EM fields and potentials (biofields and biopotentials).

BIOGENESIS

Generation of living organisms from other living organisms; also, the theory or philosophy that living organisms develop only from other living organisms.

BIOLOGICAL WARFARE

Warfare against living humans, livestock, crops, etc. using pathogenic micro-organisms or biocides to create diseases and death, or using dimensioned electromagnetic potentials, fields, and waves to kindle cellular damage, disease, and death in the same targeted populations.

BIOLOGICAL WARFARE, ELECTROMAGNETIC

The use of dimensioned electromagnetic potentials, fields, and waves to induce cellular damage, disease, and death in targeted living populations.

The decades of Russian microwave radiation of personnel in the former U.S. Embassy in Moscow is an example, where only field-free potentials were dimensioned with the disease or health-change patterns (the engines). This science was developed in Russia as an outgrowth of the thousands of Kaznacheyev experiments demonstrating that any cellular disease and damage pattern could be induced from diseased or damaged cells into environmentally isolated cell cultures, purely by specialized EM radiation from the damaged or "transmitting" cells into the targeted cells.

The Chinese also used such dimensioned radiation to induce cancer in almost all GRU operatives stationed in China at the time of the major disagreement between China and Russia. In his book, Stanislov Lunev and Ira Winkler, Through the Eyes of the Enemy: Russia's Highest Ranking Military Defector Reveals Why Russia Is More Dangerous Than Ever, Regnery, Washington, D.C., 1998, p. 160, Lunev reveals it this way:*"...I was not the only person who was stationed in Beijing to come down with* *cancer… Almost all of the GRU officers stationed in China with me have been diagnosed with cancer. People assigned to the embassy had told me that they were picking up high levels of radiation from the apartment building around the embassy compound. Whether it was a form of high-tech monitoring or a conscious effort to harm our health, it seems to have been successful. So much so that in 1992 the GRU was asked to investigate the high rate of cancer among embassy officials. The findings, however, have never been made public; in part, no doubt, because of the rapprochement between Russia and China."* In short, the Chinese did exactly to the Russian GRU what the Russians were doing to the Americans.

BIOPHOTON

A quantum of angular momentum, each containing "a piece of energy welded to a piece of time, with no seam in the middle," emitted by biomolecules in living organisms. The difference between a biophoton and a normal photon is that the "infolded EM structuring" (ST curvature engine sets) carried by the biophoton carries the dynamics and templates of the living cell or tissue or body emitting the radiation.

As presently known, biophoton emission is associated with processes such as mitosis (cell division) and with mechanisms such as soliton vibrations of DNA and other alpha-helix proteins [Popp et. al., 1984; Popp et. al., 1992]. An organism's biophoton field may represent a highly-structured innate organizing field capable of encoding or transmitting information over macroscopic distances.

Kaznacheyev, e.g., showed that almost any cellular disease or damage condition can be induced from the diseased control cells to separated and environmentally isolated target cells initially normal, if (1) the visible spectrum of radiation is blocked from the targeted cells, and (2) the two groups of cells are optically connected below and above the optical spectrum, in the infrared and in the ultraviolet.

The new viewpoint seeks to dramatically extend the scope of this definition. Considering the wave aspects of the photon frequency, the infolded oscillating EM energy in the photon may be decomposed into two oscillating potentials [Whittaker, 1904]. In each of these potentials, there exists a magnificent infolded structure [Whittaker, 1903] of internal bidirectional EM wave pairs, to include the sum set [Whittaker] and the product set [Ziolkowski]. Thus the photon carries internal information, which is also referred to as the "information content of the field." Since the product set represents modulations, the basic infolded structure has signal characteristics. Mind, thought, and long term memory exist inside the personal quantum potential, which may further be regarded as consisting of coupling and uncoupling photon/antiphoton pairs—i.e., hidden gravitons. In the new viewpoint, the biophoton is the carrier of biogravitons, and also biograviton lattices. This information forms vacuum engines which can cumulate over a period of time to breach the quantum threshold and outfold, producing real change in cells, as shown by the Kaznacheyev cytopathogenic mirror effect experiments.

BIOQUANTUM POTENTIAL

A quantum potential connected to and of a living body, where the inner EM structuring and dynamics of the quantum potential are in correspondence with the inner EM structuring of the normal EM fields, potentials, and waves in the body, and also are in correspondence with the time-polarized EM structuring and dynamics of the mind and its operations.

The biopotential provides the volition and intent exhibited by the biological body, breaching the quantum threshold and producing direct psychokinetic change (by the mind-body coupling mechanism) that is the "input signal" to the servomechanisms of the body,. from the smallest to the largest. In this biopotential, the Stoney-Whittaker-Ziolkowski decomposition provides the information structure and vacuum engines that are the mind, thought, long term memory, etc. A living biological system may be defined as a physical system of otherwise inert matter (the body) and of mind, coupled to each other through a bioquantum potential.

BLOCKING

In the charge-barrier semiconductor functioning, stopping or partially stopping the flow of current in a circuit, or between two points, without stopping the Poynting S-flow.

In ordinary usage, "stopping the progress of."

BOHM, DAVID

World renowned physicist and originator of the hidden variable theory interpretation of quantum mechanics. See David J. Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of 'Hidden' Variables, I and II." Physical Review, 85(2), Jan. 15, 1952, p. 166-179 (Part I); 180-193 (Part II).

Together with his student Aharonov, he co-authored a fundamental paper on the Aharonov-Bohm effect wherein interfering electromagnetic potentials can produce effects on charged particle systems, even at a distance and in the absence of the electromagnetic force fields.

BOHM'S HIDDEN VARIABLE THEORY (HVT)

A major interpretation of quantum mechanics, formulated by David Bohm and published in Physical Review in 1952.

See David J. Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of 'Hidden' Variables, I and II," **Physical Review**, 85(2), Jan. 15, 1952, p. 166-179 (Part I); 180-193 (Part II). Bohm's theory makes all the correct predictions and also eliminates many problems in quantum mechanics, such as the "measurement problem" and the—now alarming—problem of the missing chaos (i.e., the missing "hidden order.").

Ironically, the prevailing Copenhagen interpretation of the QM theory predicts that the organized macroscopic world does not exist, while Bohm's theory predicts it. [Question to the sharp young graduate student: How can one defend a scientific model which predicts that he himself does not exist? If one keeps one's sense of humor, it would seem that this has to be the greatest scientific *faux pas* of all time!] It may be that one unconscious reason that most physicists still oppose HVT is that *it implies that physical reality can in fact be deterministically engineered*. Most physicists would seem to fervently wish physical reality to stay "solid as a brick," with fixed "laws of nature," which can be leisurely discovered and then utilized comfortably, predictably, and sanely. The advent of HVT (which is just a matter of time; for decades the Russians have highly weaponized the HVT area!) dramatically alters our perception of "fixed physical reality" into that of an "engineerable, changeable" physical reality! I tentatively believe that the terrible psychological implications of such a potential development is something that most scientists do not wish to cope with—we simply do not have the Gestalt for it. On the other hand, the Russian national psychology is such that they do have the Gestalt for it. The Russian energetics—which I have long referred to loosely as scalar electromagnetics—basically utilizes the infolded ordering inside the potential to create "direct patterns of vacuum flux", hence *vacuum engines*. And it also utilizes the quantum potential, including internally structuring the QP, to enable instantaneous action-at-a-distance in multiple simultaneous locations and nodes, with stupendous and automatic energy amplification.

By deterministically "patterning" the internal structuring of the scalar potential, one can directly form such vacuum engines. Whittaker showed in 1904 that any EM field pattern whatsoever can be expressed as two scalar potentials, rather than the common f and **A** representation. This means that any EM wave is simply the "interference" (between the hidden biwave structures) of two scalar potentials, even at a distance. By properly structuring an EM signal (i.e., structuring the two potentials into which it can be decomposed), the resulting EM signal—appearing normal on the surface—nonetheless now transports special vacuum engines deliberately designed to perform some particular internal task in mass systems, electronic systems, or humans when it strikes a target at a distance. I refer to this "internal structuring" of the Stoney/Whittaker/Ziolkowski internal biwaves and their products, as *dimensioning* of the potential(s), and hence of the EM carrier wave. The Russians call it the *information content of the field*; but our own scientists tend to erroneously interpret that phrase as ordinary spectral analysis. In other words, they erroneously continue to regard EM *vacuum engines* as if they were ordinary EM *signals*.

BOHREN EXPERIMENT

Revealing experiment by Bohren, replicated by Paul and Fischer, which shows that a given charge when in particle resonance absorbs more energy from a field or potential then the same charge does in "static" position.

By conventional outlook, this provides a guaranteed COP>1.0 process. Bohren demonstrated absorbing 18 times more energy with the charge in particle resonance than with the static charge. This is a direct experiment proving the Heaviside dark energy component of EM energy flow, whether in field form or in potential form.

See Craig F. Bohren, "How can a particle absorb more than the light incident on it"?", **American Journal of Physics**, 51(4), Apr. 1983, p. 323-327. See independent confirmation of Bohren's work by H. Paul and R. Fischer, *ibid*., p. 327. Other pertinent references are V. S. Letokhov, "Laser Maxwell's Demon," **Contemporary Physics**, 36(4), 1995, p. 235-243; — "Generation of Light by a scattering medium with negative resonance absorption," **Soviet Physics JETP**, 26(4), Apr. 1968, p. 835-839; — "Double Gamma and optical resonance," **Physics Letters A**, Vol. 43, 1973, p. 179-180; — "Stimulated emission of an ensemble of scattering particles with negative absorption," **ZhETF Plasma**, 5(8), Apr. 15, 1967, p. 262-265. Also see R. Pappalardo and A. Lempicki, "Brillouin and Rayleigh Scattering in Aprotic Laser Solutions Containing Neodymium," **Journal of Applied Physics**, Apr. 1992, p. 1699-1708

BRIDGE

A component or process which passes EM energy between two isolated circuits, but does not pass dq/dt between them, and which breaks the normal rigidly field-locked power dissipations in the two circuits.

Space itself would appear to be one such bridge.

BRIDGING FUNCTION

The function of passing EM energy flow between two isolated circuits, but not passing dq/dt between them, while simultaneously breaking any normal rigidly field-locked power dissipations in the two circuits.

BROKEN SYMMETRY

The fundamental meaning is a condition in which two parts of some configuration or shape on opposite sides of some divisor or condition or boundary, are not similar but differ.

In vacuum energy physics, we are very interested in the fact that any charge and any dipole represents a broken symmetry in its fierce energy exchange with the vacuum. This implies that something virtual has become observable; i.e., part of the virtual EM energy absorbed from the vacuum by the charge or by the dipole is changed into observable form and re-emitted as real, observable EM energy.

Any observable implies a broken symmetry. Non-observables imply symmetry, and vice versa. Each symmetry also can be represented by a conservation rule or law. Physicists have uncovered many kinds of symmetry in physics; and in the 1950s they also discovered broken symmetry.

BROMWICH, THOMAS JOHN I'ANSON

Brilliant English mathematician, 1875-1929, who made significant contributions to the mathematics of electromagnetism—particularly to superpotential theory—before his passion for overwork led to development of a mental disorder and eventual suicide.

Bromwich originated a method for solving the source-free Maxwell equations in 1899, publishing it in 1919. This approach formed the basis for his seminal paper on scattering of plane EM waves by spheres. He did excellent original work on infinite series and made contributions to quadratic and bilinear forms. He also placed Heaviside's operator calculus on a rigorous basis by treating the operators as contour integrals. Unfortunately Bromwich worked so intensively, in such painstaking detail, and at such length that his physical health was affected. He developed a mental disorder and eventually ended his own life in suicide.

For a summary of Bromwich's life and achievements, see G. H. Hardy, "Thomas John Bromwich," **J. London Math. Soc. 5** (1930), 209-220; — "Obituary of Thomas John Bromwich," **Proc. Roy. Soc. London A 129** (1930), i - x. For an exposition of Bromwich's equations-solving work, see J. D. Zund and J. M. Wilkes, "Bromwich's method for solving the source-free Maxwell equations," **Tensor (NS) 55** (2) (1994), 192-196.

BROWN, G. SPENCER

Noted author and creator of the laws of form, a new form of logic that dramatically extends Aristotelian logic.

Essentially Brown added complex numbers to logic, rather than just staying with simple 2-dimensional plane figures for postulate derivation. Electrical circuits— designed by Brown's logic—do function and do work. When computer software is designed by Brown's logic, it is then possible to mathematically prove whether or not the end result possesses any defects (bugs). In the future software—particularly the larger systems—may well be designed by Brown's logic. G. Spencer Brown, **Laws of Form**, Julian Press, New York, 1972. With a dramatic advance in logic itself, Brown has succeeded in formulating a true calculus of form. Note: There is now a second edition of the book.

BULK GRADIENT CHANGE

Simply a change in the amplitude of the entire potential.

… (i.e., to every internal biwave pair comprising it) at some point or in some region of space, as compared to changing the amplitude of only one or a few of the internal biwave pairs of the potential, without changing all the rest.

BYPASS RESISTOR

In electrical theory, a resistor to pass current by (in parallel to) some other component.

If other effects such as use of the overpotential, pumped phase conjugate reflection, quantum wells, quantum tunneling, and charge blocking are added, the function of the bypass resistor becomes extremely complicated.

CANCER

Conventional definition: A *malignant tumor* of potentially unlimited growth that expands locally by invasion and systemically by *metastasis*.

Growths are further characterized by the type of tissue in which they occur, and their actions. Of particular interest are neoplasm, tumor, carcinoma, and sarcoma. *Malignant* disorders tend to produce deterioration, infiltrate, metastasize, and terminate fatally. A *neoplasm* is simply any new growth of tissue that serves no useful function. A *tumor* is an abnormal mass of tissue that (1) is not inflammatory, (2) arises from preexisting cells, and (3) serves no useful purpose. A *carcinoma* is a malignant tumor of *epithelial* (covering membraneous tissue of a free surface) origin. A *sarcoma* is a malignant neoplasm that arises in *mesodermal* tissue (connective tissue, bone, cartilage, or striated muscle) and that spreads by (1) extension into neighboring tissue or (2) by way of the bloodstream, or (3) both.

New definition of cancer: A centrally-commanded, final, desperate, "first-step dedifferentiation" adaptive attempt by stressed, affected cells experiencing sustained oxygen shortage (hypoxia) to reverse their cellular evolution and return to the anaerobic stage of their primeval cellular ancestry. Thus a cancer cell is a severely stressed hypoxic cell that has been "ordered" by the master cellular control system (MCCS) to dedifferentiate back to a more primeval form in which it needed little or no oxygen. It is the last desperate attempt by the body to insure the affected cells' survival when all other means available to the MCCS to provide the necessary oxygen have been exhausted and have failed. The "order" differs from normal signal theory in that it consists of a Stoney/Whittaker/Ziolkowski template inside the personal quantum potential of the organism. Thus the "order" actually consists of a vacuum engine, so that the spacetime in which the affected cell exists is acted upon by structured, energetic hidden variable fingers to directly alter it. The "signal order" is in fact a set of hidden vector forces in spacetime itself, created directly in and on the affected cell(s), in every part, in every atom. The cure for the cancerous cell, once formed, is simply to cause the MCCS to generate the "counter-order" reversing the original dedifferentiating action. This can be readily accomplished by establishing hidden multifrequency pump waves in the quantum potential on the cancerous cell, on all its parts, so that they act as pumped phase conjugate mirrors. Since they already exist in the altered "cancer" spacetime template/signal, the pumping causes a phase conjugate replica of the precise cancer state to be created in and on the cell and its parts. [In fact this is a general therapeutic mechanism, and it can be applied to reverse almost any conceivable cellular damage or disorder.] This counter-order is a new and amplified vacuum engine that acts upon the cell to redifferentiate it back to a normal cell. If an abnormal number of cells results, the body's normal processes then recognize the excess cells and destroys them.

CANCER HOTSPOT

An area or locality or location where cancer recurs repeatedly, more than the normal deviation expected statistically. In such case, one is dealing with a hidden cause or carcinogen.

Human systems exposed to such a hotspot experience cellular changes (hypoxia) which eventually result in the master cellular control system (MCCS) issuing a dedifferentiation order to the affected cells to regress back to a primeval anaerobic form. The first step is dissociation from central (MCCS) control of cellular growth, resulting in a cell that now grows and divides unrestrained by the normal body. The real question in the hotspot is, "What is the unknown agent inducing the hypoxia condition, and what is the mechanism by means of which it induces it?" Epidemology will point out a hotspot, but is usually incapable of resolving the primary causative agent or its active mechanism since it can only show correlation.

CAPACITOR AS A TRANSMISSION LINE

A capacitor can be theoretically treated as a special type of transmission line, a fact which is apparently known to transmission line theorists but not to many engineers and physicists not specializing in transmission lines.

CARCINOGEN

A substance or agent (such as a chemical or a spacetime curvature engine) capable of inducing a cancer.

In the new theory, the primary carcinogen is an actual order (a vacuum engine) issued by the master cellular control system (MCCS), reverting (dedifferentiating) the affected cell to a primal anaerobic form. Usually what are normally regarded as carcinogens are also causes of cellular conditions wherein the cell becomes very hypoxic, so much so that the MCCS exhausts all other alternative corrective means and as a last desperate measure orders the cell to change to a form that requires little or no oxygen. The "exhausting of other measures" may be very rapid, as when the cell has been affected and damaged by powerful carcinogens, or it may require decades to occur, as when the cell is subjected to long-term mild hypoxia, such as from electromagnetic smog.

CARRIER WAVE

A fundamental wave which is modulated by another wave or other waves, and hence "carries" the other waveform(s). By stripping off the carrier in a demodulator, the carried waveform(s) emerges.

Hence it is a continuous frequency wave which can be modulated by an information-bearing signal.

CASIMIR EFFECT

The attraction of two conducting parallel plates in space, placed very close together, due to their influence on the active vacuum and on the vacuum's interaction with the plates.

CASIMIR, HENDRIK BRUGT GERHARD (1909-2000)

Noted scientist who in 1948 predicted that two parallel conducting plates, placed very near each other in a vacuum, would experience an attractive force due to their influence on the electromagnetic vacuum.

See H. B. G. Casimir, "On the attraction between two perfectly conducting plates," presented at a meeting of the Royal Netherlands Academy of Arts and Sciences on 29 May, 1948. Published in the same year in **Proceeding. Koninklijke Nederlandse Akademie van Wetenschappen**, Amsterdam, vol. 51(7), 1948, p. 793-796. For a beautiful modern experiment confirming the force, see S.K. Lamoreaux, "Demonstration of the Casimir Force in the 0.6 to 6µm range," **Physical Review Letters**, 78(1), Jan. 6, 1997, p. 5-8.

The force was experimentally detected some 10 years later.

CAUSAL SYSTEM ROBOTS (CSRs)

Massless 4-space "engine" systems (therefore in the causal domain only, hence the name) formed of longitudinal EM waves and their dynamics, which are therefore sets of spacetime curvatures and their deterministic dynamics (engines) which function as individual robots.

This is a totally new kind of system leading to a totally new kind of warfare, developed over some decades and deployed by the KGB in 1999.

Matter is composed mostly of empty space filled with EM waves, fields, and potentials. Those "fillers" themselves are just bundles of longitudinal EM waves and their impressed dynamics. Hence all matter, the vacuum, and all conventional EM potentials, fields, and waves—being filled with vast sets of longitudinal EM waves—are vast superhighways for longitudinal EM waves to travel on or in. The CSRs, being totally LW and LW dynamics in nature, thus are free to travel right through EM radiations from power lines, phone lines, TV stations, radio stations, etc. They easily penetrate any matter, including right through a mountain. Any function of a normal EM system can be performed—at least in theory—by such robots. This includes longitudinal EM wave interferometry, which forms external EM fields and waves, of whatever pattern or form desired. Further, these CSRs are actual functioning systems, and if communications functions are designed in, one can communicate with them at a distance, using longitudinal EM wave communication, right through the intervening earth and ocean, etc.

For some time, extensive underground facilities—hundreds—have been building in the former Soviet Union, and this massive buildup continued unabated after the Russian economy collapsed and the Berlin Wall came down. This tremendous expenditure, when the Russian economy was crippled, shows the strategic significance of these facilities. Further, apparently our satellites have not seen any missiles, normal weapons or munitions, etc. associated with that vast complex. In short, it is suspected that we don't have the foggiest notion of what it is. Indeed, those facilities will already have sent some CSRs into those very satellites, to insure that we do not find out what is going on, and perhaps to "spy on the spy satellites".

We think these terribly important facilities are the KGB-controlled facilities for developing and producing the CSRs, and contain a vast longitudinal EM wave command and control set of facilities as well. In short, this is the strategic arsenal, development, and control for building sets of various type CSRs in huge numbers—a vast new army of robots with unprecedented capabilities, under the command and control of a human "strategic force" operations command of very large size.

Developing and debugging one CSR would be a formidable and lengthy task. Once a single one is developed, making a million copies is simple. Just take a normal CD-ROM, e.g., and record something on it. Send in a working CSR robot to "reside inside" the infolded EM interior of the recorded informational electromagnetic pattern on the CD-ROM. Then simply copy that CE-ROM magnetically, as many times as is desired. Each copy contains a copy of the original signal that was recorded, including the exact infolded electromagnetic structuring inside that signal. Voila! One has as many new duplicate CSRs of that exact type, as one wishes, for a few pennies each.

One can see the implications. In all those underground facilities, there are many development laboratories, production laboratories, and command and control facilities and "storage facilities" for the robots. Those hundreds of facilities are in fact a great new strategic weapon system and all its development labs and production facilities, as well as its tactical control and command and control systems, its "troops", its "equipment", and its commanders and operators.

Well, then one can deploy and "utilize" such a strategic armada just as one would use any other great strategic army. One "deploys" one's forces against the enemy. In this case, one just sends the armada (individually controlled!) right through the "LW superhighways" of matter itself, right into the strategic territory and very heart of the targeted nation. One deploys the robots everywhere—e.g., inside the electronics in nuclear warheads, inside the control systems for the nuclear submarines and nuclear bombers, inside the satellites, inside the fighter aircraft electronics, inside the fighting ships, inside the main battle tanks and major weapons carriers, inside the signals on the hard drives of computers, etc. One sends them right through the "inside" of the targeted nation's power grid electrical energy signals, through the TV stations' emitted signals, etc. The Pentagon and Cheyenne Mountain are duck soup, as is the stock exchange and other civilian systems vital to continued functioning of the infrastructure. So is everywhere else, even the deepest vault and "special security" facility.

In short, the vast electronic command and control activities of an otherwise "modern" superpower provide great, convenient, easy superhighways for full strategic deployment to be completed by millions of weapons systems (CSRs) into everything of value in the targeted nation or nations. This completely solves the usual weapons delivery problem; delivery is made in advance of D-Day.

Such a vast CSR armada was deployed throughout the Western world, and particularly in the United States, just before the end of 1999. Yes, this was to be the KGB's great millennium gift to America—a really enormous Y2K problem that would stun and disable the entire nation, its armed forces, its electronic systems in its major weapons, and its command and control centers in one great TOT (time on target) assault. The major electrical power systems of the nation would have been disabled, as would have been the major communications systems. Using LW interferometry, the robots would have wreaked havoc on the nation. They would have disabled the electronics of every major C4I computer of importance, every major fighter aircraft, every major fighting ship, every nuclear submarine, every ICBM, every nuclear powerplant, etc. The attacking force was in its deployment and employment sites in the targets themselves. Everything was in place and cocked and ready to fire. To test whether we knew what was going on, the KGB even had one or more robots temporarily produce hacker-type operations and signals "emerging" in some U.S. command and control center computers, and deliberately let our fellows discover this "hacker attack" was coming from the Russian Academy of Science. Then the CSR simply stopped its LW interferometry, which caused the "normal hacker electronic" signals to just vanish and never reappear. Little wonder that our counter-type fellows were totally unable to find any trace of it, or where it was residing. They have no technology for such.

Well, happily those early-model CSRs are easy to root out and destroy, if one has quite advanced LW technology. Visualize these beasts as existing in a special sort of "internal sky" or "infolded atmosphere" inside matter. Strategic range LW "radars" can just sweep through this "internal atmosphere" inside matter, etc., detecting and tracking those CSR beasts analogous to how normal radar detects and tracks aircraft. The difference is that the strategic LW can also use a bit of LWI pulse to instantly snap those CSRs like popping bugs, completely jamming their operations or even "erasing" them once their characteristics are observed.

That very new kind of vast strategic warfare occurred right at the end of 1999, all through the United States—the Pentagon, our strategic weapon systems, the works. The friendly little nation rooted out and destroyed all those "on site" CSRs just prior to the attack being launched.

A full-up strategic war, of previously unknown kind, was fought all over the U.S. and our own system guys apparently didn't know it. It didn't even surface. Didn't make a whimper.

That hostile CSR armada consisted of *first generation systems*. These systems did not have defensive countermeasures. The systems were depending on total surprise, but were found out (that is another story that would make a great movie if one could live to film it) and then were destroyed in short order.

CSR development has ushered in a totally new kind of strategic, operational, and tactical warfare. The delivery of all the weapon systems "into the target" is accomplished long before the advent of hostilities. The second generation CSRs, once built, will be even more sophisticated. These will almost certainly be on line soon. They will likely also possess countermeasures.

An eerie new chapter in the annals of warfare has been initiated, and the world will never be the same again. Once the CSRs have sufficient defensive countermeasures such as stealth means and coordination with countering, rapid response LWIs to target and destroy the hostile "LW radars" seeking them, etc., the next world-wide strategic CSR war will be neither so simple nor so bloodless.

NOTE: Contrast this CSR discussion to the discussion of *nanotechnology* and nanobots. Just as nanobots are natural developments which teams skilled in nanotechnology would produce, so CSRs are natural developments which teams skilled in longitudinal EM wave technology—and in the "infolded" electrodynamics inside all EM fields, potentials, and waves—would produce. For decades (since the 1950s) the KGB has been developing and using longitudinal EM wave interferometers (LWIs) which beam right through the "inner highways" inside the fields and waves inside matter, thus allowing very large LWIs which beam right through the intervening earth and ocean, and can "focus" under the ocean or within the earth as well as out of it. With such background, the CSRs were just as natural a development for them as the nanobots are for conventional Western nanotechnology scientists.

CAUSALITY

The relationship between "cause" and "effect". The basic notion in a causal system is that the system's response to an input signal is not dependent upon future input values.

Thus the notion of causality involves a precise time ordering of ordinary inert interactions, where the cause was never input from a future time. Macroscopic (observable) causality may be and is violated by the interaction of hidden subquantal (virtual state) variables.

CEREBRAL HEMISPHERE

Each half of the cerebrum, i.e., each half of the enlarged anterior or upper part of the vertebrate brain.

The two cerebral hemispheres may function as a longitudinal EM wave interferometer or a time-polarized (scalar) EM interferometer to sense distant scenes (even distant in time), or produce EM energy and signals at a distance, since the body, brain, and nervous system does produce longitudinal EM waves and scalar EM waves. For proof of scalar EM wave interferometry in O(3) electrodynamics, see M.W. Evans, P.K. Anastasovski, T.E. Bearden et al., "On Whittaker's Representation of the Electromagnetic Entity in Vacuo, Part V: The Production of Transverse Fields and Energy by Scalar Interferometry," **Journal of New Energy**, 4(3), Special Issue, Winter 1999, p. 76-78.

CHANGING THE PAST

Every intentional inception upon ordinary inert causality prior to collapse of the wave function represents a slight alteration or change in direction, departing minutely from pure causality. From a causal viewpoint, each human inception minutely changes the causal past, as well as the future.

Experimental proof that the causal past can be changed is provided by the delayed choice two-slit experiment. E.g., see C.W. Rietdijk, "Another proof that the future can influence the present." **Foundations of Physics**, 11(9/10), 1981, p. 783-790. Particularly see Wheeler, John Archibald Wheeler, "The 'past' and the 'delayed-choice' double-slit experiment," in A.R. Marlow [Ed], **Mathematical Foundations of Quantum Theory**, Loyola University, New Orleans, Louisiana, June 2-4, 1977; Academic Press, New York, 1978, p. 9-48.

CHAOS

In dissipative dynamical systems, the dynamical evolution that is aperiodic and highly dependent upon initial conditions of the system.

The trajectories of the system move on a strange attractor, which is a fractal subspace of the phase space.

The term suggests the ordinary meaning of random and unpredictable disorder, but there exists intrinsic determinism and at least partial embedded ordering. The mathematical equations describing chaotic behavior are very nonlinear and so complex that at the present time they cannot be computed or predicted. Even simple systems, including simple electromagnetic systems, can exhibit unpredictable chaotic behavior. The science of chaotic dynamics is still in its infancy, having begun moving once the modern computers became economical and pervasive.

CHARGE, ELECTRICAL (Q)

Electrical charge q is defined as $q \equiv m_q\phi_q$, to first order.

As can be seen, the actual "charge" action associated with the mass is due totally to ϕ_q, and to the broken symmetry of ϕ_q in the vacuum flux exchange with m_q. The charge q can be further broken down into a set of composite dipoles if the gathering of a virtual charge screen in the vacuum, surrounding the mass of the "bare charge" inside the gathering, is included. At first order, ϕ_q can be expressed (particle view) as a change in the local vacuum virtual photon flux (VPF), due to the VPF exchange between vacuum and m_q. The ϕ_q component is actually the "electrical charge" and massless of itself.

However, see my paper, "Giant Negentropy of the Common Dipole," **Journal of New Energy**, 5(1) Summer 2000, p. 11-23. We include the isolated charge by treating it as a system of multiple composite dipoles. We also explain the previously unrecognized 4-symmetry EM energy flow ongoing, where incoming longitudinal EM waves are being received, transduced into real longitudinal EM waves in 3-space, with the latter being emitted in all directions in 3-space.

A charged particle of mass is thus a little energy flow generator. It is a broken 3-symmetry in the local VPF, and therefore has an "observable" energy flow output, extracted and gated from the asymmetry in the VPF. This "observable" energy flow outputs the well-known energy flow **S** in classical EM, though CEM does not recognize or include this vacuum interaction, the broken 3-symmetry of the dipole, and the steady input of EM energy to the dipole in the form of EM energy from the time domain (complex plane).

Instead, classical EM just assumes that the "charge" q is the source of a potential. When originally formed as a concept, q was just a "quantity of electric fluid," like a "cubic centimeter of fluid," etc. The atom and the electron had not yet been discovered.

CHARGE CARRIERS

Anything—usually fundamental particles, ions, etc.—which consists of or contains charges and can move.

It can be an electron, a collection of electrons fixed in a moving dielectric, ions, atoms, molecules, etc.

The moving charge (i.e., the current dq/dt) with an energy flow streaming onto it and on beyond, carries its interaction with that energy-flow right along with it in the current
i = dq/dt. This is what the charge's "excess collected energy" consists of, and this is how the *collected/collecting* energy in the circuit is transported to the *collected-energy* dissipation sites (loads and losses).

CHARGE, GRAVITATIONAL

To be added

CHARGE, MAGNETIC

Essentially, the magnetic scalar potential, or monopole.

In an uncurved spacetime, the magnetic charge must always occur in dipolar pairs, where each is equal and opposite the other. In a curved spacetime, a free *net* monopolar magnetic charge may and does exist. In classical electrodynamics, the assumption of a locally flat spacetime is ubiquitous though not prominently emphasized. Hence most electrical engineers are unaware that monopoles can indeed be made, but only if one uses a process to curve local spacetime.

CHARGE-PARITY-TIME (CPT) THEOREM

The theorem states that all known quantum field theories obey CPT symmetry.

C is charge conjugation, which changes the quantum number of every particle into its antiparticle. P is the reflection operation known as parity which turn an object into its mirror image and rotates it 180 degrees about an axis perpendicular to the mirror, T is time reversal. Any violation of time-reversal symmetry is always accompanied by a violation of CP symmetry and vice versa.

Electrodynamics and the strong interaction preserve CP symmetry to great accuracy. Weak interactions do not conserve CP symmetry. T symmetry violation has been shown at CERN, the European particle physics laboratory in Geneva, Switzerland.

CHARGE TRAPPING (Also "Pinning")

Holding charges "pinned" or "trapped" by a barrier or force, so that they do not flow as
i = dq/dt.

CHARGE-BARRIER

A process or component or function—particularly in a semiconductor such as the Fogal semiconductor—which blocks the movement of charges q as current dq/dt.

CHARGE-BLOCKING ASYMMETRIC QUANTUM WELLS

A quantum well which has more charge-blocking action in one direction than the other, and is thus "asymmetric" in its function.

It may also be dynamic, so that it changes in its degree (and/or its direction) of action as a function of time.

CLASSICAL AND QUANTAL ELECTRODYNAMICS

Classical EM (CEM) theory is simply classical electrodynamics (CED).

Classical EM does not break the fields into "quanta" (a quantum is a standard-sized piece of action (angular momentum)]. Instead, CEM considers the fields as continuously varying in magnitude from zero to infinite magnitude (at least in theory).

Quantal Electrodynamics is known as quantum electrodynamics (QED). These are standard terms for standard disciplines. QED considers the fields to be composed of quanta called "photons". Hence there is an underlying region called the "virtual state" whose denizens are "smaller in magnitude" than the quantum. Heisenberg uncertainty applies, since the quantum of action is not quantized energy, but quantized (energy x time). In short, it is a function of both the magnitude of the energy and its duration of persistence. Hence a field or photon of any amount of energy may form temporarily, so long as it does not endure sufficiently long in observer time to reach quantum size and breach the quantum threshold.

In this view, then, "empty space" is not empty at all, but is a seething cauldron of these "energetic bubbles" continually appearing and disappearing, with the entire spectrum of frequencies and energies. This is in fact the "new ether". If we consider only the field portion of the bubbling virtual photons appearing and disappearing, this leads to a vacuum that consists of EM field fluctuations, again of essentially the entire frequency spectrum and energy spectrum.

However, how we attempt to tie either of these "energetic vacuum" EM views to general relativity (GR) is then a problem. The cause of the problem, however, is largely ignored in physics. In CED, e.g., one models EM energy moving through a flat space. This is a non sequitur, since the presence of any change of the energy density of space a priori is a curvature of spacetime. Hence rigorously EM energy can only propagate through a curved spacetime. Indeed, when this correction is made, the EM wave becomes an oscillating curvature of spacetime. This is the approach worked out by Mendel Sachs, extending Einstein's work. The higher symmetry O(3) electrodynamics spearheaded by Evans turns out to be an important subset of Sach's umbrella unified field theory. Hence EM has become GR, and for the first time in history, O(3) electrodynamics provides the approach that will allow direct engineering of general relativity on the lab bench, in working devices, etc.

CLASSICAL ELECTROMAGNETICS (CEM)

"Ordinary" electromagnetics, of the kind used in ordinary EM circuits, which fundamentally consists of the modified Maxwell's equations.

Classical EM consists of Maxwell's equations and the various changes and additions that have since been made. CEM does not break the fields into "quanta" (a quantum is a standard-sized piece of action (angular momentum)]. Instead, CEM considers the fields as continuously varying in magnitude from zero to infinite magnitude (at least in theory).

Primarily refers to Maxwellian electrodynamics as reinterpreted by Heaviside, Gibbs, Hertz, and a few others. Unfortunately these reinterpretations of Maxwell's theory also greatly reduced its topology, and therefore reduced the area of natural electrodynamic phenomena that the resulting equations describe.

Significantly more advanced "classical" electrodynamics emerges when one goes back to the quaternion algebra electrodynamics of Maxwell, or to the more advanced Clifford algebra electrodynamics. The higher symmetry electrodynamics models such as O(3) symmetry EM developed by Evans and others, are capable of modeling a great deal more physical phenomena than the very limited standard U(1) electrodynamics largely in vogue in science.

CLASSICAL EM THEORY

Classical electrodynamics theory, begun by Maxwell, with his seminal paper orally presented in 1864 and published in 1865.

Essentially Maxwell's electrodynamics at root basis, with the background supporting classical theory. Today many variations have been made, particularly with the basic symmetry of the theoretical equations. See discussion above under *classical electromagnetics*.

CLIFFORD ALGEBRA

A special higher topology algebra founded by Clifford, which includes as subsets many other algebras of lower topology.

CLOSED SYSTEM

A system that does not communicate with its environment, and does not exchange energy or matter between system and environment.

An ideal model where dynamically and energetically the system is considered to be "isolated" as if nothing else existed. In short, consider the system as if it were in some "magic box" and nothing outside the box can ever enter the box or affect the system inside the box, and nothing in the system can ever leave the box or affect anything outside the box.

One performs a non sequitur whenever proclaiming treatment of a system as a "closed system", and of course good scientists are aware of this. This is particularly true in electrical power systems. Here one is indeed allowed to input energy into the system to excite or potentialize it. That of course assumes that the system was "opened" long enough to take on excess energy! Then as the system operates, losses and dissipations occur, in which case energy is considered to "escape" from the system permanently. In other words, the system was also continually "opened" so that energy could escape.

There is really no such thing as a truely *closed* system in the universe, since every system is embedded in the active vacuum and is an open system in an energy exchange with the vacuum. If that exchange is symmetrical, then the system is in equilibrium with respect to the vacuum exchange. In that case, the system may be treated as if it were a closed system for a limited number of purposes. In classical electrodynamics (CED), the Lorentz regauging of the Maxwell-Heaviside equations further reduced them to describe only Maxwellian systems in such equilibrium with the active environment. Consequently, the interaction between the external vacuum and the system is not included in the CED model. Obviously a *broken equilibrium* in that actual physical interaction is also not included in the CED model.

An electrical power system is already permitted to violate the Lorentz condition when it (1) receives additional EM energy to "energize" or "potentialize" or "excite" or "regauge" it, and (2) whenever energy escapes from the system in the loads and losses (which escapes of energy are "de-energizing", "depotentializing", "dissipating", or "regauging" actions.

Hence the Lorentz condition greatly simplifies the Maxwell-Heaviside equations and makes them much easier to solve. However, *when enforced by the system itself with regard to the system's excitation and de-excitation (dissipation) functions—i.e., when those functions are "symmetrical" (equal and opposite)*—it also arbitrarily discards all those Maxwellian systems capable of the five "magical" functions of an open disequilibrium system: (1) self-ordering, (2) self-oscillation or self-rotation, (3) output of more energy than the operator inputs (the excess energy is input by the active environment, (4) powering itself and its load (all the energy is input by the active environment, and (5) exhibiting negentropy.

It follows, however, that physical electrical power systems must therefore have some feature which self-imposes the Lorentz condition, at least during the phase when the system's excitation energy is discharged in the loads and losses. The standard closed current loop system, where every electron progressing through the external circuit's loads and losses must be forcibly rammed back up through the source dipole in the power source, is indeed what enforces the Lorentz condition with respect to excitation and dissipation, and *arbitrarily* prevents the system from achieving COP>1.0.

In a battery-powered system, the otherwise closed current loop is broken into two quite different circuits: (1) the electron current circuit between the outer surface of the plates and the external loads and losses, and (2) the ion current in the electrolyte between the inner surface of the plates. Since the ions (e.g., in a lead-acid battery) in the "inner" ion current may have a m/q ratio very much greater than that of the electrons in the "outer" electron current, clever timing of pulsed signals to the plates may be used to form a phase difference—including even a phase angle of 180°—between the two currents. It can be shown that this forms a high potential on the plates which acts as a negative resistor, extracting EM energy from the vacuum and recharging the battery while simultaneously powering the external circuit. This is the Bedini process, and with Bedini's permission an explanation of that process has been published by Bearden ["Bedini's Method For Forming Negative Resistors In Batteries," **Journal of New Energy**, 5(1), Summer 2000, p. 24-38.] Note that Bedini's process in fact repeatedly removes the Lorentz regauging condition, and therefore the system is rigorously permitted to achieve not only COP>1.0 but also self-powering of itself and its loads and losses.

COLD EXPLOSION

The sudden extraction of EM heat energy from a distant intersection zone (IZ) of the crossing beams of a scalar potential interferometer, which transmits in the sharply pulsed mode, while the electrical grounding of the transmitters are negatively biased with respect to the potential in the distant IZ.

COLD FUSION

An ad hoc term applied to the transmutations at low energy achieved in electrolyte experiments, particularly when using specially prepared palladium electrodes, and particularly when deuterium is present in the electrolyte.

COMPOSITE DIPOLE

Dipole formed as one part of an isolated, observable "charged particle", consisting of a differential element of that observable charge on one end and a momentary clustering virtual charge of opposite sign.

In quantum electrodynamics, it is well-known that virtual charges of opposite signs cluster in the immediate vacuum around any "isolated" observable charge. By applying the composite dipole concept, this author was able to treat the isolated charge as a set of composite dipoles. By then applying Whittaker's decomposition of the scalar potential between the ends of each of these composite dipoles, the "source charge" was a set of broken 3-symmetries in the vacuum flux, and thus a set of 4-symmetries in that flux exchange. This meant that the EM energy continuously output in all directions by the source charge was actually continuously received by the source charge (as a set of composite dipoles) from the time-domain, and 4-conservation of EM energy flow rigorously was upheld.

This allowed a solution to what has been called the most formidable problem in both classical and quantum electrodynamics: the problem of the association of the source charge and its associated fields and potentials along with the energy contained by them and continuously pouring from the charge without any 3-space energy input.

CONCOMITANT

Occurring or existing together.

CONGLOMERATE HIERARCHY OF THE PHOTONS

Every photon remains perfectly ordered! A conglomerate (group) of photons, however, may be arranged in almost an infinite variety of orderings, groupings, directions, etc.—which we refer to as templates and as hierarchies (group orderings) of photons.

In a pure energy flow (energy transport), the "herd" of photons is organized along the flow direction. Regardless of how one scatters or "disorders" this patterning of the "herd" or "hierarchical ordering" of photons, not one single bit of the underlying energy and individual photon ordering is lost. So when one "uses" energy (e.g., scatters the hierarchical ordering of a photon herd from a resistor as heat), one does not lose any energy at all, but simply has "scrambled" the hierarchical ordering of the photons into a new herd configuration (which may be varying every which way!). The point here is the real meaning of the fundamental conservation of energy law: *Energy can neither be created nor destroyed!*

When we "use" one joule of energy to perform one joule of work (say, in a single-pass, scattering), we still have exactly that one joule of energy left, but just in different form (different direction, type, collection or not collected, etc.) It can still do another single pass joule of work, then another, then another, and so on. If we plan things right, we can use a single joule of work to perform many joules of work, contrary to what we were so strongly taught in the *"single-pass, single collection, single dissipation"* examples given to us in university as the "law" of God and electrodynamics.

Note that the conventional work-energy theorem assumes single pass, single collection, and single dissipation of a joule of energy to perform a single joule of work. The point is, *that is not a limitation of nature, but a limitation of a single process! Nature regularly uses a joule of energy to do multiple joules of work, because after one dissipates or scatters the energy the first time, it's still there and later will be intercepted to do some more work.*

Anti-Stokes emission, the Patterson Power Cell, Lawandy's lasing without population inversion, and some gas-filled tubes with anti-Stokes emission are examples of known, validated overunity processes (processes with coefficient of performance greater than unity). These all use multipass, multicollection, multi-dissipation in iterated manner, to increase dipole asymmetry and therefore produce excess extraction of energy from the vacuum. Patterson's unit, e.g., has been independently measured by universities at efficiencies of some 1200 or so. This absolutely does not violate the laws of physics nor the nonequilibrium thermodynamics of open systems far from thermodynamic equilibrium.

CONSCIOUS MIND

The serial processing mind which we normally associate erroneously as ourself. Other to be added.

Mind is time-like, not space-like.

CONSCIOUS MIND (PSYCHOENERGETICS VIEW)

The serial-processing mind which one normally associates erroneously as oneself.

Mind is *time-like*, not *space-like*. Hence it is not directly observable, a priori, since all observation is 3-spatial. However, if we consider that changes in 3-space produce spacetime curvatures and thereby also produce slight changes in the time domain, then iterative coherent spatial changes eventually will produce a change in the time-domain. Consequently, the time-like mind will have a continuing stream of such small but processable time-energy changes from coherent 3-spatial phenomena in its body and the macroscopic (coherent) universe. To sense the 3-space body as "self" while simultaneously sensing other 3-space physical changes as "non-self", the conscious mind must compare the various received time-like projection signals against its "time-like orders" issued. That set of received time-signals that matches or closely matches the conscious mind's issued order signals, thus yields the sense of the body behavioral changes as (1) self, and (2) body responses to its orders. The time delay between issuance of the mind's orders and the receipt of the correlated time-like responses from its body, provides the sense of self-persistence or independent being.

The mind couples to the body via a similar spacetime curvature mechanism. When the mind issues "orders", they are in the time-like realm but are changes, hence small spacetime curvatures. They therefore involve very small 3-spatial changes (projections) into the 3-space body. Since the mind orders are coherent, this small iterative set of 3-space changes will integrate coherently, yielding real quantum changes in the body and nervous system (e.g., the brain).

This coupling mechanism is profound. The steady stream of integrated time-like projections arising in the mind due to the physical world outside one's body, does not compare or match the mind's memory of its orders. Hence that allows the sensing of the "external world" as "nonself". The sense of that external world as "existing" or "being" is provided by the time delay in the comparison process, from "mind signals issued" to "physical signals received". The metric yardstick standard for this comparison time, so to speak, is provided by the time in the identified "self-loop" with the physical body. In other words, the mind uses that length of time to differentiate those time signals which coherently integrate but do not match its issued order signals, from those time-signals which coherently integrate in the same time loop interval and do match its issued ordered signals.

In this manner, we resolve all the great previously unresolved philosophical questions of the nature of consciousness, nation of being, nature of self, nature of nonself, perception of the physical world, perception of body as self, perception of other bodies as non-self, etc. At least we resolve these issues from a testable physics approach, so that we can see that now a unified physics (and a technology) of mind and matter is at last in view. Since O(3) electrodynamics has been shown to be an important subset of Sachs' unified field theory, then O(3) electrodynamics—or SU(2)×SU(2), which is homomorphic with O(3)—can be used to develop the direct engineering of mind, the mind-matter interaction, and mind functions of the living biological system.

It is my considered opinion (with much evidence) that the Russian branch of *energetics*, known as *psychoenergetics*, uses a unified field theory and a higher symmetry electrodynamics to achieve that type of direct engineering already, but for weapons use rather than beneficial use for humanity.

As examples, we strongly suggest that the deaths of U.S. Captains Button, Svoboda, and Hess all involved KGB testing of long-range strategic psychoenergetics weapons over the United States, on those targeted personnel. This should not be surprising at all; the KGB has tested longitudinal EM wave interferometer weapons over the U.S. since 1967, and continues to do so today. They tested bioenergetics EM weapons against U.S. Embassy personnel in Moscow for several decades. Kills of U.S. aircraft and missiles have been performed at various times, including kill of the Arrow DC-8 at Gander, Newfoundland in Dec. 1985, kill of a Titan ICBM fired from Vandenberg AFB in the spring of 1986, kill of the U.S. space shuttle Challenger in the spring of 1986, continuing weather engineering over the U.S. and elsewhere, etc.

That novel electromagnetic weapons have indeed been developed and are being tested world-wide, was confirmed by Defense Secretary Cohen in 1997 as follows:

"Others [terrorists] are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves… So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations…It's real, and that's the reason why we have to intensify our [counterterrorism] efforts." [Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.].

We specifically call attention to the fact that the Secretary did not speak the words enclosed in square brackets. This is *not* limited just to terrorists or counterterrorism.

There appears to be no insurmountable difficulties in developing psychoenergetic technology using the approach outlined above. Certainly it is not as formidable a task as has been hot fusion.

The incident involving Captain Button, e.g., was to demonstrate control of an individual performing complex technical tasks for a period of at least one hour. The test against Captain Svoboda was to demonstrate how simply human kill can be achieved in combat troops, merely by introducing selected changes in the mental functioning of the targeted individuals. As Svoboda was climbing her A-10 out of a successful low-level ordnance drop at night on a ground target, her sense of up and down was instantly reversed. Instantly perceiving she was diving instead of climbing—although *actually* climbing out perfectly—she "corrected" immediately and dove headlong into the ground, perishing in the resulting explosion of her aircraft.

In the case of Capt. Hess, the test demonstrated that rather complete mental control can be almost instantly asserted, and even the responses of the autonomic nervous system can be overridden. So Captain Hess, out for a morning jog, simply went aside, sat down, and stabbed himself repeatedly, including multiple times right through the heart. Had one seen the incident, he would have simply continued stabbing himself very calmly, without emotion or reflex action from his autonomic nervous system, until physical failure of his body.

As can be seen, it is of the utmost importance that this nation understand psychoenergetics weapons of such nature, and develop effective defenses against them. The next great strategic battlefield may be as much a "virtual reality" battle as it is a "real physical world" combat. The war can be quickly lost in either arena.

We also point out that the psychoenergetics weaponry readily is adapted to use in more advanced longitudinal EM wave interferometers, which readily penetrate the Earth and the ocean. Hence deeply buried strategic command and control centers are vulnerable to psychoenergetics warfare, as are the crewmen of our nuclear submarines, ICBMs, aircraft carriers, division and army command centers, national command centers, strategic bomber pilots, etc.

Indeed, one of the major incentives for developing such psychoenergetics weapons as was demonstrated in controlling Captain Button, was to seize and control the entire on-site manning crews of the defensive quantum potential weapons preventing launch of full strategic warfare. By having the QP systems "stood down for maintenance" by their own crews, the major strategic retaliation and "dead man fuzing" would have been removed and countered. Then powerfully striking the QP sites with LWIs would have destroyed them, and left the sites themselves radioactively emitting longitudinal EM waves, thus preventing reoccupation in case the QP weaponry survived. The counter to that scheme was to place the friendly QP weapon sites on "insane" command and control. In that mode, instead of human decision being made to launch, every so often (say, every two hours) the computer automatically initiates the launch sequence. During that sequence, if the crew is still alive and functional, codes can be punched in and the computer cancels the launch initiation. It then repeats the sequence two hours later. If no coded cancellation order is punched in, for whatever reason, the launch sequence completes and the QP weapons fire. In that case, much of Russia disappears from the face of the earth.

Eerily, just about the time that Secretary Cohen was making his quoted statement in April 1997, the KGB was being notified by the friendly little nation of the change to insane command and control. This forced the abortion of a great strategic attack upon the West, scheduled to occur on May 1, 1997.

We are strongly stressing that psychoenergetics is not parapsychology and it is not just an idle theory of academics. Instead, it is already potently used in some very powerful and deployed weapon systems that could well decide the course of the next world war, almost at a moment's notice.

See also discussion under *energy*.

CONSCIOUSNESS

Refers to a living being's awareness of its sensations, feelings, thoughts, and the world around it.

The new approach uses a coupling mechanism between the time-like mind and the body of a living creature. The nature of this coupling mechanism then generates the mechanism by which self-awareness is produced, awareness of non-self is produced, and the sense of existing in the external world but differing from it is produced.

CONTINUOUS MODE

For a longitudinal EM wave interferometer, a continuous mode of operation where power is fed continually to the transmitters, and the two longitudinal EM wave patterns or beams are continuously transmitted.

CONVENTIONAL SCALAR POTENTIAL

A scalar potential formed without use of artificially added substructuring of its internal biwaves and their products.

In other words, one in which it is assumed that its virtual particle flux has no ordering, but is just a randomized flux. This assumption (e.g., of quantum mechanics indirectly) is incompatible by the Whittaker demonstration that (i) a scalar potential is a harmonic set of "bidirectional" EM phase conjugate wave pairs, and thus not a scalar entity at all, and (ii) perfect ordering of its wave components exists inside the scalar potential.

One must carefully distinguish what each of these internal "phase conjugate EM longitudinal wavepairs" actually represents. Prior to interaction with detecting charges, the potential is a 4-potential existing in spacetime (4-space). The time domain, of course, is represented by ict, and in that expression only "t" is a variable. Hence the "incoming" phase conjugate longitudinal EM waves in the imaginary plane are actually longitudinal EM waves in the time dimension. These waves converge upon the dipolarity represented by the "scalar potential" or any "piece" of it. The dipolarity represents the interaction of charges; specifically, a dipole. This reaction—by the spin of the charges—transduces the incoming EM energy from the time-dimension into 3-space, and emits it from the charges as real EM longitudinal EM energy radiating out from the dipolarity in all directions in 3-space.

The phase conjugate half-set of the Whittaker waves, *prior to their interaction with charge*, are not waves in 3-space, but are waves of LW EM energy coming in from the imaginary plane and thus from the time domain. The charges of the dipolarity spin 720°, being 360° in the complex plane and then 360° in real 3-space. So the charges absorb the EM LW energy impinging on them from the time domain, during their 360° rotation in the complex plane. When they enter real 3-space for the rest of their spin, the already-excited charges dissipate their excitation energy in all directions as they spin their 3609º in 3-space. That is what the Whittaker decomposition actually shows, but it has been ignored for almost a century.

In short, the broken 3-symmetry of the dipolarity—well-known in particle physics for nearly a half-century, but never incorporated into CED—allows nature to jump to a higher, more fundamental 4-symmetry in the energy flow. Energy is being conserved in 4-space, but not in 3-space. Further, there is a special new energy flow symmetry involved: one-way in the time domain and the other way in the 3-space domain. Note that energy is not conserved in 3-space! *There is no law of nature requiring the extra requirement that, in addition to conservation in 4-space, the energy must also be conserved in 3-space!* So when the dipole breaks that extra requirement, only the basic 4-conservation applies. In that case, nature very happily gives you what might be called a white hole in astrophysics terms: energy will pour in to the dipolarity unceasingly from the time-dimension, and will pour out in 3-space unceasingly, so long as that dipolarity persists.

By considering the virtual charges of opposite sign that cluster in the vacuum around any "isolated observable charge", one may represent a single charge (as an electron or proton) as a set of composite dipoles, where each dipole consists of a virtual charge (while it exists) and a differential element of the observable charge. So the charge becomes a set of composite dipoles, each with Whittaker decomposition of the scalar potential between its ends.

Hence we have solved the long-vexing problem that Semiz called "the greatest unsolved problem in electrodynamics": the problem of the source charge (or source dipole) and its associated fields and potentials and the enormous EM energy continually pouring out of any charge or dipole in all directions in 3-space.

When the arbitrarily discarded giant Heaviside nondiverged energy flow component is also accounted, this leads to the giant negentropy of the dipole, as shown in my paper, "Giant Negentropy from the Common Dipole". We have also proposed this "dark Heaviside energy" as the unaccounted source of the excess gravity known to be present in spiral galaxies and holding together their arms. The dark energy yields at least 90% of the total gravity involved, and the additional 10% or so can be accounted for my known gravitational sources.

It appears that these new discoveries can also be utilized to show that "quintessence" is also caused by COP>1.0 processes in the universe, and the excess production of negative "giant dark energy flows". If so, then this also would account for the recently discovered fact that the universe has an excess of negative gravitation, so that it is not only expanding but is accelerating in that expansion. At this time, the present author is still attempting to tie up the loose ends involved in showing that quintessence also is created as a result of functions of the giant negentropy process.

In the Whittaker biwave pairs, If one then insists that these hidden EM waves are comprised of hidden photons, then it follows that the photons exist as continually coupling and uncoupling photon/antiphoton pairs, or continually forming and unforming *gravitons* as the wave and antiwave continually pass through each other.

It is a little more complicated than that, since Maxwell actually omitted half the EM energy in the EM wave in space, and also in the circuit—as do electrodynamicists to this day. For gravitons, one really must come to grips with this error and correct it. This will be added later in this glossary. (To be Added).

COOPER PAIR

A dynamic pairing of electrons in superconductivity theory.

In this pair, if the energy state with wave number σ and spin ½ is occupied by an electron, then so is the state with wave number - σ and spin – ½.

COP (COEFFICIENT OF PERFORMANCE)

Ratio of energy out, divided by that portion of the total energy input that is input by the operator or experimenter.

The COP is thus a measure of "efficiency of using the operator or experimenter's input energy" to produce—or direct the production of—useful work. Note that he can direct the use of his own input energy, as almost all our present systems do. Better yet, he can also direct (gate or "switch") the use of some external free flow of energy from the environment into the system, so that he gets lots more work out of the system than he has to put in himself. Only a few of our systems—such as solar cells, sails on sailboats, waterwheels to power mills, and windmills—are such Maxwell's demons (open systems) where the output exceeds the operator's input of energy.

We sharply contrast the term "COP" to the term "efficiency". The efficiency (overall) of a system is how much useful energy output (usually as work, or can be converted to work at will) the system produces for the total amount of energy that is input (both by the operator and by the external environment). Even a highly inefficient system may nonetheless have a COP>1.0, if the operator inputs less energy than the system outputs.

We urge the reader to thoroughly understand the difference between energy-use "efficiency" of a system and coefficient of performance of the system. Many scientists, engineers, and especially free-energy researchers are confused on the precise difference in these terms.

CORPUS CALLOSUM

The thick nerve cable that links together the two cerebral hemispheres (which are separate brains) in each vertebrate (including human) brain.

In each of the two cerebral hemispheres, there is a separate mind and personality (given that the other is separated). However, a brain has a unique characteristic: Anything that arises directly inside it is automatically assumed to be self-originated, since the brain-tuner can differentiate no separation or "separate source" for the signal/thought arising directly upon its "internal screen". This allows integration of the two brains/minds/personalities into one. That is, when one brain half prepares and sends a message, that message is also routed across the corpus callosum into the other brain half, arising internally upon the second brain's "display." The second brain half therefore thinks that it itself originated the signal or message.

COSMOLOGICAL FEEDBACK PRINCIPLE

Puthoff's self-regenerating cosmological feedback cycle for the source of the vacuum EM ZPE.

One may assume the existence of EM zero-point energy (ZPE) by fiat as part of the boundary conditions of the universe, or conceive of its generation by the quantum-fluctuation motion of charged particles that constitute matter. Puthoff calculated the latter possibility, assuming that the ZPE spectrum (field distribution) drives particle motion, and that the particle motion in turn generates the ZPE spectrum. This provides a self-regenerating cosmological feedback cycle, which in fact is consistent with the general relativity assumption that curvature of spacetime affects mass energy, and mass energy changes affect the curvature of spacetime.

The result of Puthoff's calculation is the appropriate frequency-cubed spectral distribution of the correct order of magnitude. His result is thus consistent with, and indicates, a dynamic-generation process for the ZPE fields.

In general this is also consistent with the Sachs' unified field theory approach, and with the Evans O(3) important subset of it.

COURRIER, ROBERT

Noted French scientist who collaborated with Antoine Prioré in his revolutionary healing experiments on laboratory animals using longitudinal EM waves from plasma tubes.

Courrier was the head of the Biology Section of the French Academy and also the perpetual secretary at the time. He personally presented the astounding results of the Prioré work, showing cures of terminal tumors, to the assembled French Academy, creating a furor.

CROSSTALK

In ordinary science, the transfer of energy or signal from one channel to another, by cross modulation or cross coupling between the channels.

In the new approach, the term "crosstalk" can be used in an additional sense where it refers to virtual energy exchange between orthogonal universes or frames—that is, between different 3- or 4-dimensional slices of an infinite-dimensional universe.

CURL CONCEPTS OF FIELDS

Refers to concepts of fields as the curl of some vector potential;

E.g., the magnitude of the **B**-field is equal to the curl of the **A**-potential, given by $\mathbf{B} = \nabla\times\mathbf{A}$. More exactly, the **B**-field is identically a curled **A**-potential, by $\mathbf{B} \equiv \nabla\times\mathbf{A}$, but only that portion of $\nabla\times A$ that is diverged around or collected by an intercepting unit point static charge.

Note that we are accenting that no equation is a definition. So texts stating that the first equation with an equals sign "defines" the magnetic vector potential **A**, are in error. If we state that $\mathbf{B} \equiv \nabla\times\mathbf{A}$, then we are defining the **B**-field as a curled form of the magnetic vector potential, which it is.

The reader must be aware that the field concept itself in CEM is flawed, being "defined" as the effect existing after an interaction by a 4-space entity with a 3-space mass, and hence 3-spatial and an "effect", and yet then used as if it were the 4-space "cause" entity that propagates in 4-space to interact. In short, the field concept is thoroughly confused in the texts and papers in the literature (and has been confused for more than a century) as not only the cause but the result of the interaction of the cause with some recipient. This problem has been highlighted by many physicists, including Feynman, Wheeler, etc.

This "confusion of the cause with the effect" is widespread in physics, and is the single greatest foundations error which hampers the progress of physics. Another example is the false notion that a "separate force" acts upon a "separate mass", when in fact mass is a component of force by the definition $\mathbf{F} \equiv d/dt(m\mathbf{v})$. That such simple and obvious errors have been propagated by so many hundreds of thousands of scientists for so many decades is perplexing. Indeed, the errors simply continue to be used. Note that Nobelist Feynman and the great John Wheeler pointed out that the "field" as defined in CEM does not and cannot exist in spacetime! Instead, Feynman pointed out that only the potential for the field exists in spacetime, in case some charged mass is brought in to interact with it and *thereby produce* the field as an effect.

Indeed, no observable persists, for it "exists" only as a momentary 3-space frozen snapshot or slice of a 4-space dynamic interaction. Here again, most physicists do not realize that observables such as mass m do not and cannot persist other that at the instantaneous frozen moment of the snapshot.

CURL-FREE MAGNETIC VECTOR POTENTIAL

A field-free magnetic vector potential without curl, hence with no **B**-field.

Toroids and long solenoids have the characteristic of separating the **B**-field (curled potential) and holding it inside. However, drawing energy from any potential whose "source charge or source dipole" is not destroyed, simply results in the full value of the potential being replenished from the vacuum, via the 4-symmetry energy flow mechanism in the presence of the broken 3-symmetry of the dipole. Hence one may easily "double" the potential energy density at will, and this is a special form of gauge freedom, where the potential energy of any electromagnetic system can be altered freely and at will. We strongly accent that, contrary to what is in the EM textbook, gauge freedom rigorously allows the direct and free amplification of potential energy of the EM system at will. That this principle, incorporated in gauge field theory, has been known so long and still not used in the design, production, and use of COP>1.0 electrical power systems is quite inexplicable.

In the motionless electromagnetic generator, we used a special core material to extract the curled potential (**B**-field) from a permanent magnet's vector potential **A**, so that **A** is replenished in uncurled form directly from the vacuum via the giant negentropy process.

To achieve COP>1.0, we then simultaneously interacted both the uncurled **A**-potential energy external to the output coil, and the internal curled **A**-potential energy (**B**-field energy) internal to the core through the coil, with the coil. By pulsing, the Lenz law effect is also invoked as yet another momentary regauging and potential energy increase, so that an additional energy gain is achieved.

The well-known Aharonov-Bohm effect proves that the uncurled **A**-potential can indeed be separated from the **B**-field in like manner, and the **A**-potential does interact with electrons since $d\mathbf{A}/dt = -\mathbf{E}$.

Thus the MEG achieves COP>1.0 permissibly, because it is an open system freely receiving excess energy from the active vacuum environment, via the vacuum's replenishment of the magnetic vector potential of the permanent magnet dipole as fast as energy is drawn from it. The MEG also violates the usual closed current loop's self-imposition of Lorentz symmetrical regauging when discharging its excitation energy (its free excess regauging potential energy), because the "source dipole" (the permanent magnetic dipole) is not destroyed.

CURVED SPACETIME (externally, internally)

A four-dimensional geometry used in general relativity, where the curvature is determined by the distribution of mass-energy.

In the new, more extended approach, any change in the spatial energy density of spacetime or any change in the time-energy density of it, or a combination of changes in both. The difference is that in the new approach time is also treated as a special form of energy. Specifically, time may be regarded as spatial EM energy compressed by a factor of c^2.

CYBORG (An acronym for cybernetic organism).

(Noun): A single integrated system consisting of a living system energetically or functionally linked to mechanical or electromagnetic devices and/or systems performing some vital functions.

(Verb): Link, in the sense of forming such a system.

In the new approach, a living biological system may thus be considered a cyborg of its time-like mindworld (mindframe) to its 3-spatial body (laboratory tuner). The "cyborging" is provided by the personal quantum potential and by the mind-body coupling mechanism. Due to the giant negentropy mechanism of any dipolarity, any scalar potential as a dipolarity is a cyborg between observable reality and virtual state (time-like) reality, i.e., between 3-space and the time-domain.

CYTOMEGALOVIRUS

Any of several members of the herpesvirus family that cause infected cells to enlarge and/or to form cytoplasmic (the protoplasm of a cell, external to the nuclear membrane) inclusions in leukocytes (white blood cells), particularly in their nuclei.

Cytomegalovirus makes a protein that appears to disable the p53 protein. As a result, smooth muscle cells in blood vessels can proliferate until they impede blood flow.

CYTOPATHOGEN

Literally, a pathogen (disease causing organism—or extended, mechanism—) that affects cells and generates damage in them.

CYTOPATHOGENIC

Damaging, harmful, or destructive for cells.

CYTOPATHOGENIC EFFECT

The generation of damage, disease, death, or other symptoms at the cellular level in cells that are exposed to or subjected to a pathogen.

CYTOPATHOGENIC MIRROR EFFECT

Distant EM pathogenic effect noted by Kaznacheyev in thousands of military experiments, where cellular death, disease, and damage forms are shown to be transmitted from one cell culture in the dark (absence of visible light) where the changes are induced, to another similar targeted cell culture in the dark that is environmentally shielded from the first except for light transmission in the infrared and in the ultraviolet. After exposure begins, after a time delay (say, 2 hours or more), the cells in the targeted cell culture will begin to exhibit the same symptoms as the culture having the induced damage. Eventually, in most cases the targeted cells will develop the same damage, disease condition, or death. The effects vary with the time of day etc.

The necessity for photon connection from IR to UV is shown by contrasting a thin quartz window allowing the light transmission with a thin window glass window. The quartz is open from the IR to the UV, and will pass that entire spectrum. With the visible light absent, the IR and UV biophotons emitted by the damaged cell culture will pass through the quartz window into the targeted cell culture. After the time delay, the targeted cell culture starts developing the condition.

Use of a thin window glass window, however, prevents the effect. Normal window glass is opaque in the IR and in the UV, and so it blocks the transmission of the IR and UV biophotons.

The UV is a harmonic of the IR, arranged properly. An unusual effect exists when two sine waves one the first harmonic of the other, are simultaneously transmitted into an isotropic nonlinear medium, such as water. On each sine wave, the peak travels faster in the water than off-peak parts of the wave does. Hence the wave peaks overshoot its middle, the wave collapses, breaks up, etc. Both the waves of the transmitted harmonic set do that. However, if one pretends that one transmitted the difference frequency between them, and not the waves themselves, a strange phenomenon results. Regardless of the breakup of the primary harmonic set, the difference frequency travels through the water as if it were a real frequency in a linear medium. This effect has been proven and is used in underwater sonar equipment.

For example, see Owen Flynn, "Parametric arrays: A new concept for sonar," **Electronic Warfare Magazine**, June 1977, p. 107-112. Any two sine-wave frequencies as simultaneous drivers combine to produce a sine-wave difference frequency propagating in water, essentially without sidebands or reverberations. Its pattern has a main lobe approximately equal to that of the high frequency drive, but devoid of sidelobes. The level of the propagating difference frequency is proportional to both the product of the two fundamental drive levels and to the square of the desired value of difference frequency.

Living cells contain a great percentage of water. Hence the effect should apply to those targeted cells, under the conditions stated.

From general relativity, we know that any pattern and dynamics of mass-energy, such as in a cell and all its parts and dynamics, directly interacts with local spacetime to curve it, and any set of curvatures of spacetime interact with any conglomerate of mass-energy and its parts and dynamics. The set of precise curvatures and their dynamics we call an engine. In a mass embedded in a local region of spacetime containing an engine, the engine will interact with the mass-energy to change it if the mass-energy and its dynamics do not "fit" the engine and its dynamics.

In a diseased, damaged, or dead cell, the mass-energy of that cell and its "template" (form and dynamics) differs from its template while the cell was living and normal. Let us now see what happens when that dead cell emits a biophoton.

A photon emitted from a dielectric such as a damaged cell, is not emitted just from one spot. Every part of the dielectric participates in the emission of that photon. (See "porthole concept", to be added). Further, each emitted photon contains in its scalar potential and its magnetic vector potential, the exact longitudinal EM waveset that constitutes the vacuum engine of the damaged cell that emitted it. When a cell absorbs a photon, it absorbs that vacuum engine carried by the photon also. If it absorbs a stream of photons of harmonic interval, the difference frequency constitutes in terms of a wave, traveling through the cell water as if in a linear medium, and transporting that vacuum engine to every part of the absorbing cell dielectric.

So the biophotons emitted from Kaznacheyev's damaged, diseased, or dying cells sent biophotons containing the exact spacetime curvature engines and dynamics of their precise condition (template). Further, a harmonic interval of such radiation is transmitted into the targeted cells, and absorbed. The mixing of the two absorptions eventually is sufficient to establish the harmonic interval, thus with a clear EM signal difference that travels through the cell's water and to every tiniest part of it. This "difference frequency clear signal" also contains the pure vacuum engines of the template of the changes in the diseased, dying, or damaged emitting cells.

The result is the "kindling" (coherent integration) of the template in the absorbing cell's local spacetime in which it is embedded. As that spacetime engine grows, it differs from the resident engine of the absorbing cell. That difference is itself an engine, and it operates steadily upon that absorbing cell to alter its engine and then its physical condition and state.

As the new engine continues to interact, the physical cell is gradually changed into an equilibrium condition in its mutual interaction with its local spacetime engine. That occurs after the absorbing cell has developed the same disease, damage, or dying condition as the transmitting cells.

This is the secret of the Kaznacheyev experiments. The Kaznacheyev work was allowed to be released in the open literature to stimulate the U.S. scientific and intelligence communities and see whether or not the scientists and analysts had applied a unified field theory and higher symmetry electrodynamics to the EM bioeffects problem. The totally casual reception of the Kaznacheyev experiments in the West, with no interest or interaction from the stimulated communities, assured the KGB conclusively that the West was still in kindergarten in its knowledge of EM bioeffects, and particularly had little or no knowledge in the field of EM biological warfare.

Kaznacheyev referred to the effect as the "cytopathogenic mirror" effect, for the pathogenic effects from the emitting damaged cells being "mirrored' in the targeted cells.

See Vlail Kaznacheyev and L. P. Mikhailova, **Ultraweak Radiation in Intercellular Interactions**, [in Russian], Novosibirsk, 1981. An English exposition of much of the Kaznacheyev work is given in Vlail Kaznacheyev, "Electromagnetic Bioinformation in Intercellular Interactions," **Psi Research**, 1(1), Mar. 1982, p. 47-76. See also Vlail Kaznacheyev, "Apparent information transfer between two groups of cells," **Psychoenergetic Systems**, 1(1), Dec. 1974; Vlail Kaznacheyev *et al.*, "Distant intercellular interactions in a system of two tissue cultures," **Psychoenergetic Systems**, 1(3), Mar. 1976, p. 141-142. In the same issue, see "A Comment" by William A. McGarey, p. 143; "A Comment" by Arthur C. Hastings, p. 143-144.

Seven or eight nations now have longitudinal EM wave interferometer weapons, capable of beaming right through the earth and ocean to the other side of the planet. At least two of these nations—Russia and China—are capable of adding engine structures to these interferometers, and sweeping a targeted population area to generate that specific disease condition in that target. A sophisticated use would be to have agents (such as terrorist teams already in the United States and with biological agents in hand) release a small quantity of smallpox in the area previously targeted. The LWIs have swept the entire area continuously for a period, slowly kindling (especially at night) the exact form of the disease within the bodies of the populace. A curious thing happens if the level of kindling of the smallpox state has been kept just beneath the observable state, within what is sometimes called the "shadow state" (just barely virtual). A smallpox pandemic will explode in that populace with a ferocity never seen in modern times, and at an unparalleled rate. This is further exacerbated by "spreading the immune system" prior to the attack (term and discussion to be added), which seriously weakens the immune system's ability to resist any single pathogenic attack.

There are hardly any supplies of smallpox vaccine left that are viable. Even where there are, the Russian laboratories developed strains of smallpox resistant to the normal vaccine, and after the collapse of the Russian economy and the former Soviet state, these strains were sold on the black market to the highest bidder. Further, most of the Soviet scientists employed in those secret biowar facilities wound up employed in several other nations, most hostile to the United States.

The point is this: Such a strike could in fact kill up to 2 billion people worldwide. Further, the entire affair would appear to be just a chance breakout of smallpox, and its spread through a nonresistant world populace.

When modern biological warfare is actually analyzed in detail, the "bang for the buck" is greater than it is for nuclear weapons. Further, a rogue or hostile nation can take its time in advance and develop quantities of smallpox vaccine (for the very strain it will use), then initiate such a clandestine campaign after it has vaccinated its own populace, armed forces, and agents. Guess who survives after such an attack.

CYTOTOXIC

Toxic (acts as a poison or toxin) to cells.

A *toxin* is a colloidal proteinaceous poisonous substance that is a specific product of the metabolic activities of a living organism. The toxin is usually very unstable, and is notably toxic when introduced into the tissues.

DARK ENERGY

The Heaviside nondiverged energy flow component, surrounding every field/charge and potential/charge reaction but unaccounted in present electromagnetic theory after being arbitrarily discarded by Lorentz.

DATUM

Consideration, or data considered, or information considered, or action considered, or result considered.

DEATH

The disintegration of the personal quantum potential's connection to the physical body's atomic nuclei by loss of the mind-body connection mechanism.

Simply put, separation of the quantum potential containing the time-like mind-frame from the body. Loss of the preferential tuning of a physical body to its mindworld. This causes loss of the preferential consciousness loop or life channel, resulting in "death" (reversion to inert matter) of the body. Actually the quantum potential and the mind-frame remains, so the *being* is unchanging and indestructible, hence consists of all changes and destructions simultaneously, with none separated individually. Life and death thus are two sides of the same coin, and the coin is immutable, regardless of which side is exposed.

DE BROGLIE WAVE

A matter wave, conceived by Louis de Broglie.

The quantum mechanics wave associated with a particle of matter, which can give rise to interference effects. An orbital electron in an atom is associated with a standing de Broglie wave on a Bohr orbit. De Broglie waves always move faster than the speed of light, the speed being given by c^2/v, where c is the velocity of light in vacuum and v is the velocity of the particle of mass. De Broglie wave velocities thus vary from the speed of light to infinite speed (everywhere at once). In his speech accepting the Nobel Prize, de Broglie emphasized that, since these waves produce real physical effects, they are real and must not be regarded simply as mathematical conveniences.

DEBYE, PETER

Dutch-born American physical chemist and Nobelist, 1884-1966, who performed important and fundamental studies in bipole moments and diffractions of X-rays and electrons in gases.

DEDIFFERENTIATION, CELLULAR

The reversion of a cell or cellular structure to a more primitive or generalized condition.

Dedifferentiation is often preliminary to a major change in the cell or cellular structure. It can also be a reversion of the cell to a previous—even *primeval*—cell form. The important point is that dedifferentiation returns the cell to a previous (past) cellular state. Reversion of a cancer cell, e.g., would cause the cell to return to a normal cell, since that is the nature of its "cellular past." It is vitally important that Becker has demonstrated that cells can be differentiated (moved forward to a future state) or dedifferentiated (moved backward to a previous state) electrically, by very weak DC currents (picoamperes). He was nominated for a Nobel Prize for this epochal work.

Actual electromagnetic redifferentiation of terminal tumors in laboratory animals was repeatedly demonstrated by Prioré et al in the late 60s and early 70s and reported in the peer-reviewed French medical journals, as was reversion of depressed immune systems, cures of infectious diseases, and curing of arteriosclerosis. It is inexplicable that this positively demonstrated cure of cancer—which could also cure infectious diseases and probably can be developed to cure AIDS—was suppressed in the mid-70s and has not been vigorously pursued by present establishment medical science.

DEGENERATE SEMICONDUCTOR

A semiconductor whose conductivity approaches that of a metal.

DELGADO, JOSE M. R.

Noted Spanish neurophysiologist well-known for his research on brain behavioral mechanisms and their control by electrical stimulation; who implanted electrodes in the brains of animals and humans and demonstrated that their responses (both behavioral and emotional) were specific and depended upon the specific localized part of the brain that was stimulated.

A TV tape made by Delgado showed a spectacular demonstration where he stopped a charging bull in mid-stride. With a small hand-held radio transmitter, he transmitted a radio signal to a receiver implanted in the head of the bull. This dramatic demonstration caused a world-wide sensation.

The significance of his work is given by Becker: *"Delgado discovered the exact parts of the brain in which electrical stimulation produced fear, anxiety, pleasure, euphoria, or rage in human subjects. He found that certain sites produced major personality alterations. For example, stimulation of one such site could cause very proper, reserved young ladies to become flirtatious and sexually aggressive. Other sites inhibited maternal or aggressive behavior. In short, Delgado was able to profoundly alter human behavior through electrical stimulation of discrete areas of the brain." … electrodes were implanted in the pleasure centers of rats' brains. The animals were provided with two levers to press. One of these delivered food, and the other produced electrical stimulation of the pleasure center. Invariably, the rats chose to press the lever that stimulated the pleasure center, even to the extent that they died of starvation*." (Becker, **Cross Currents**, p. 221-222).

It is known based on a rare OMNI interview that Delgado progressed to detailed study and experimentation for the behavioral and emotional effects in monkeys of specific magnetic field frequencies on monkeys. These successful experiments involved electrical currents produced in the brain but hundreds of times lower in intensity than those required for direct electrode stimulation. Since then, some information has been cautiously released from Western military studies showing that microwave pulses can couple to the central nervous system and produce stimulation and behavior alteration similar to Delgado's released experimental results.

Comment: The ultimate and most refined techniques in the field of electromagnetic control of human behavior, volition, emotion, etc. is provided by Russian psychoenergetics, the military version of which is totally under KGB control. This work has progressed far beyond what Delgado and Becker were discussion so long ago. The use of the infolded longitudinal EM waves and "engines"—once the technology is developed—allows direct engineering of conscious and unconscious mind, memory including short term and long term, perception, awareness, etc. The additional advantage of using EM longitudinal waves is that mass is largely a very thin dispersion of particles, with (relatively speaking) very large distances between them, somewhat like the solar system but on different scale. This "inner space" is filled with EM waves, potentials, and fields—all of which decompose into sets of longitudinal EM waves and their impressed dynamics. Thus the earth and ocean are readily penetrated by longitudinal EM wave beams, and the Russians (KGB) has developed such LW interferometers since the mid 1950s. However, by LW interferometry where the patterns and dynamics of the carried LWs are engineered, any desired mapping pattern of precise EM signals, frequencies, phases, and magnitudes can be reproduced in distant interference zones, reaching right through the ocean. These interferometers could localize the distant interferometry into a 6-inch diameter volume as early as 1985, so from that time forward it gradually became possible to perform all of Delgado's "inserted electrode" EM stimulus in a single selected human brain from the opposite side of the earth. So approximately 1985 is when I would estimate the beginning of the "golden age" (ugh!) of distant psychoenergetics was initiated.

By 1997, this development would be into at least third generation weapons, just being deployed or just having been deployed, considering an somewhat accelerated weapons development program where 6 years is one generation. By 1997, very complex individual behavioral and perceptual control should have just arrived in on-site deployed strategic weapons systems. See discussion under *conscious mind*.

Some selected useful references are: J.M.R. Delgado et al., **Journal of Anatomy**, vol. 134, 1982, p. 533 reports that developmental defects occur in chick embryos exposed to various ELF frequencies. See also J.M.R. Delgado, **Physical Control of the Mind: Toward a Psychocivilized Society**, Vol. 41, World Perspectives, Harper & Row, New York, 1969.

DEMODULATION

From a carrier containing a modulated signal, recovering the signal that was used to modulate it.

DENSE SIGNAL ENVIRONMENT

For our purposes, when the number of weak EM signals crossing one square meter per second reaches 200,000.

At 500,000 important nonlinear optical type effects of significance—particularly long term cumulative effects—begin to occur in the exposed biological organism.

DEPARTING ORTHOROTATIONS

In space of dimensions greater than four, the rotating of an object or entity away from its line of motion, in the direction of a dimension at right angles to the line of travel in the observer's three-space, by some number of additional 90° rotations.

The Lorentz transform in special relativity, e.g., is just a formula for this kind of rotation. What we call "velocity" is actually a measure of rotation. In 4-space, any object in 3-space can only rotate "out" of 3-space in one direction: toward the time-axis. As the object rotates toward that time-axis, we see the object as having a velocity in 3-space, and its "length along the line of motion" as having diminished. When the object rotates the full 90°, its "length along the line of motion" has been converted to "time" rather than length. Hence it has zero length along the line of motion and is moving at c, the speed of light in ambient space. It is also no longer material, but is a sort of flat plane surface moving at speed c in a direction perpendicular to the plane.

In that 4-space model, it is impossible for anything to move faster than light speed. So Einstein's postulate dealing with the fact that it is impossible to translate mass, signals, etc. faster than light speed has a built-in assumption that only one orthogonal departing rotation can be made from 3-space. That postulate need not apply at all if more than one departing orthorotation is permitted—which of course requires a space of 5 dimensions or greater.

The notion is that, if we allow a spacetime of greater than four dimensions, by continuing to rotate ever more orthoturns in a departing direction away from the original line of travel, the rotated object loses one observable dimension for every orthorotation. Hence with three "departing" orthorotations it becomes a "nonobservable point" to the normal observer, but one that would be moving at speed c^3. A single orthorotation would make the 3-dimensional object a two-dimensional plane moving at speed c.

No matter how many rotations are made in a departing manner, the object is still connected to the time dimension common to all dimensions (assuming only a single time dimension for simplicity). So it exists in an orthorotated space, but in the same time. To the physical observer in 3-space, it thus appears to be a "time-like" or "mental" object only. Nonetheless, by affecting the density and structuring of the time domain, it can have an effect on a 3-spatial object. We discuss that mechanism under the subjects of the mind-to-body coupling mechanism and the body-to-mind coupling mechanism. Further, with the Sachs-Evans unified field theory approach, the time-domain can be directly engineered. This means that both "inert" or physical reality and time-like or "mental" reality can be directly engineered by novel electrodynamic means.

In short, a photon is just a particle (such as an electron) that is orthorotated once (toward the time axis). In photon emission, a little bit of the mass-energy turns into orthorotated photon energy. In photon absorption, the absorbed photon energy turns back into mass-energy.

The higher dimensional orthorotational concept was originally formed to allow a physical modeling grasp on a "mental" object as compared to a "physical" object, and to have a connection mechanism between the two. Such an approach can be used to model both mind and matter, their interaction, etc. The present author has used it to solve the old philosophical problem of "intent", of how the perception of self is attained, how the external world is perceived separate from self, etc. A model for both living and nonliving states does emerge.

This or a very similar approach has been used by the Russian's highly classified weapon science called *energetics*. That third branch of energetics is called *psychoenergetics* and it is the physics of directly engineering mind states, mind operations, memory, etc. by extended electrodynamic means. We have previously detailed much of this work privately, but with some detailed openly in a few papers. E.g., see T. E. Bearden, "Mind Control and EM Wave Polarization Transductions, Part I", **Explore**, 9(2), 1999, p. 59; Part II, **Explore**, 9(3), 1999, p. 61; Part III, **Explore**, 9(4,5), 1999, p. 100-108.

DESTRUCTIVE INTERFERENCE

When two waves or wavesets from two different sources superpose to produce a combined waveset that has a lower intensity than the sum of the intensities of the two original waves.

DETERMINISTIC PATTERN OR TEMPLATE

The exact arrangement, by plan and deterministic action, of a group of entities.

E.g., of the photons in a "herd" or "group" of them. Or a set of spacetime curvatures, into a dynamic structure called a "spacetime curvature engine"—or "engine" for short. Or by the virtual photons in the vacuum flux, or a deterministic set of changes to that vacuum flux (the vacuum flux that is called the "vacuum potential." I have called this function—of a deterministic patterning or templating of the virtual flux (particle view) of the potential—*dimensioning* the potential.

DIELECTRIC

Literally, "against electric (current),"

...originally coined to mean "opposes the flow or conduct of electric fluid."

In today's language, a dielectric is a non-conducting material used to oppose or prevent the flow of electric charges. Even empty vacuum exhibits some dielectric resistance. "Dielectric" is also used to refer to a nonconducting material (often used between the metal plates of a capacitor or elsewhere) which can (i) sustain a change in potential across a distance (i.e., an **E**-field), and (ii) serve as an insulator. Space itself is a dielectric, or at least it is said to exhibit certain dielectric qualities.

DIFFERENTIATION, CELLULAR

(1) specialization of body parts or organs in the evolutionary process. (2) modification of different parts of the body to perform particular functions. (3) modification of the cells forming these body parts or organs so as to perform the necessary cellular functions required to support the functioning of the body part or organ.

DIFFRACTION

The bending of light at the edge of an opaque object.

Usually diffraction introduces undesired distortion and is a problem. However, it can be useful and desirable—for example, in a diffraction grating.

DIMENSION

A certain primary geometrical physical attribute, such as length, used to describe the separational relationships of physical phenomena.

The degree of that separation is known as "length", "time", etc. By "geometrical" we mean that the "dimension" is considered to "exist" in either the presence or absence of the observable physical phenomenon; however, by understood agreement the dimension itself is not directly observable. It can be inferred ("measured"), however, by comparative operations of simple devices such as clocks and meter sticks, and its simplistic definition is usually given as "that which has measurable magnitude." Prescribed measuring procedures are used to assign magnitudes to these inferred dimensions, using specific scales.

Actually, "dimension" just means "fundamental quantity of separation" and "geometry" in the most general sense. The number of dimensions taken in advanced physics usually represents a somewhat arbitrary choice for good modeling fit. In modern Kaluza-Klein theory, for example, it becomes necessary to accept some 10 or 11 dimensions in the usual particle physics case. General relativity has incorporated the interaction of the abstract geometry (spacetime) with mass. Until Sachs' extension of Einstein's work into a unified field theory and Evans' incorporation of O(3) electrodynamics as an important subset of Sachs' unified theory, general relativity has largely remained a nonexperimental discipline, at least in the laboratory. With the new Sachs-Evans approach, however, GR becomes substantially engineerable by novel electromagnetic means, including in the laboratory and in devices.

DIMENSIONING

This is an artificial term I sometimes use to mean "forming an exact pattern or 'template', particularly of nested curvatures of spacetime, where the pattern/template may also be dynamic. It involves the internal structuring of the "dimensioned" entity.

The use of the term "dimensioning" makes sense in unified field theory, but is awkward in normal EM theory which erroneously considers that EM energy propagates in an uncurved spacetime. The mere presence of a change in local spatial energy, created by the wave energy itself when present in that local region, curves the local spacetime. Hence the EM wave rigorously travels in curved spacetime, and in fact identically is a propagating, oscillating curvature of spacetime.

Dimensioning also implies a deliberate form or structure (with dynamics) created in the virtual photon flux of the vacuum or of the virtual photon flux comprising a scalar potential, or in the infolded longitudinal wave EM inside all EM potentials, fields, and waves. It implies an associated set of spacetime curvatures and their dynamics. The latter are referred to as "engines", "vacuum engines", "spacetime curvature engines", etc.

Dimensioning potentials or signals or carrier waves also involves adding hidden *vacuum engines* to them. I chose the descriptive term *dimensioning* because adding such templates (hidden vacuum engine structures) is equivalent to increasing the EM topology by adding dimensions. Since an EM wave or field or vector potential can be decomposed into two scalar potentials, then by "dimensioning" one or both of the scalar potentials one can "infold" the desired hidden structures or patterns (vacuum engines) inside an EM carrier wave, EM field, or vector potential. So I called this *dimensioning* those entities. Internally structuring the two scalar potentials via arrays of EM LW emitters, and then applying the necessary dynamics (modulations), is primarily the manner in which dimensioning can be directly engineered. When dimensioning is present, two identical EM waves as seen on the oscilloscope may have dramatically differing internal structures (dimensioning), and hence the two will produce drastically differing effects when they interact with the same or similar objects. This of course is the mechanism involved in the Kaznacheyev experiments and in the decades-long microwave radiation of the U.S. Embassy in Moscow, where health changes and diseases were electromagnetically induced in personnel in field-free (stable and nonchanging potentials) areas.

Russian energetics refers to what we are calling "dimensioning" simply as adding *the information content of the field*. A very skilled disinformation program (actually, a strategic deception program) has been used to deceive the West into believing the phrase refers to ordinary spectral analysis. It doesn't. The importance of the dimensioning concept is that one has not formed mere "signals," instead, one has formed *vacuum engines*. If a receiving object receives a signal, it may or may not act upon that "signal information." If it receives a *vacuum engine*, however, the engine (structured local spacetime flux) directly acts upon it to make the requisite change. Further, the energy for the interaction's working upon the exposed object or system is furnished continually from the curved spacetime set and their dynamics. The receiving object has absolutely no choice in that action occurring to it, and the action can occur from the gluons and quarks inside the charges in the nuclei, to the lattice structures, to the system dynamics, to the elements so as to transmute them, etc.

Note that when a dimensioned EM field or potential is absorbed by an object, that object also has internal EM fields and potentials which have substructures (usually rather random). However, the internal structure of the absorbed dimensioned entity and the internal structures of the EM fields, potentials, and waves do mix in a direct diffusion process. Hence with continued irradiation, the target can be "charged up" with the desired internal dimensioning structure. This is how the microwave irradiation of the U.S. Embassy accomplished disease induction, using signals with the desired disease dimensioning impressed in their structures, particularly in the potentials. In the Gulf War Disease, a much more sophisticated use of this mechanism was made, using a quantum potential as the carrier. All the effects (including the body fluid transmission, the EM fields of the body transmitting and kindling some of the effects in children in proximity to a dimensioned veteran parent, can be explained.

The use of dimensioned EM fields, waves, and potentials—and the use of dimensioned quantum potentials in Bohm's hidden variable theory—allows an entirely new science of EM biological warfare, far more threatening and lethal than the more primitive physical pathogenic kind. It is also possible to use the techniques for revolutionary healing, as unwittingly shown by Prioré and the scientists working with him, and also as shown by Becker *et al*.

The only way in which the action of a vacuum engine (dimensioned carrier entity) can be resisted is to create and simultaneously introduce the exact antiengine for it.

Once the action has been completed in the receiving object and it has been changed, the only way it usually can be undone is to form a precise antiengine for that action, amplify the antiengine, and let the antiengine act upon the object for a sufficient time to "time reverse it back to its previous physical state and condition". The Prioré mechanism utilized that method for reversing the cellular damage due to cancer and infectious diseases, and to restore suppressed immune systems. The same mechanism, if re-developed, could also be used to reverse aging in living human patients.

The engine and antiengine processes can also be applied by structuring the "time-charging" or "time-excitation charging" of the particles of mass in a body. The "port-hole" concept even allows ordinary EM radiation to be used to forcibly transduce the input ordinary EM into the extraordinary EM and thereby forcibly accomplish the necessary time-charging actions for disease and body deterioration reversal. See discussions under "port hole concept" and "time-charging".

DIPOLE

In the simplest case, two separated charges of (usually equal and) opposite sign.

As a general definition, a localized positive charge or charge distribution, and a localized negative charge or charge distribution, such that the net charge summation is zero, but wherein the positive and negative charge distributions do not superpose. We point out, however, that in regular physics *electrical charge* has no proper definition. Try looking it up in several physics dictionaries! Then check our proposed definition of electrical charge. As is well-known in particle physics, a dipole is a broken symmetry in the virtual photon flux of the vacuum. By definition of broken symmetry, this means that *some* of the virtual energy flux continuously absorbed from the seething vacuum by the charges of the dipole, is not re--radiated as virtual energy. Instead, it is integrated coherently and re-radiated in 3-space as real emitted EM energy. The dipole is therefore a true "negative resistor" since it receives EM energy in unusable form, and re-emits it in usable form. In classical EM theory, the problem of how every charge and dipole can continuously emit EM energy to form all the associated fields and potentials and their energy, is an unsolved problem—sometimes called the most pressing problem in electrodynamics, both classical and quantal. For the solution and a discussion, see my paper "Giant Negentropy from the Common Dipole," Journal of New Energy, 5(1), Summer 2000, p. 11-23.

Because of the broken 3-symmetry of the dipole, the EM energy flow is not conserved in three dimensions (symmetry represents a conservation law, and broken symmetry represents the violation of that conservation law—in this case, violation of conservation of 3-space EM energy flow). Instead, EM energy flow is conserved in 4-dimensions, and the hidden inflow of EM energy to the dipole is actually from the complex plane (time domain). Thus all EM energy is actually received from the time-domain, and so the importance can be seen of the internal structuring of time-flow and of longitudinal EM waves in the time domain. Such time-domain energy flows appear naturally in O(3) electrodynamics; see M. W. Evans and T. E. Bearden, "The Most General form of the Vector Potential in Electrodynamics," **Optik** (in review).

DIRAC, PAUL A. M.

Noted English physicist, 1902-1984, who shared the Nobel Prize for developing wave mechanics and predicting the existence of the positron.

DIRAC SEA

Considering the vacuum as containing—amongst other things— a "sea" of an infinite negative energy conditions or states ("holes") for electrons, almost all of which are filled with electrons.

In Dirac electron theory, the relativistic wave equation for the electron has four components, which correspond to two spin orientations and two energy conditions: positive and negative. Thus the vacuum possesses a "sea" of negative energy conditions for electrons. These are called "holes" and are considered to ordinarily be filled or mostly filled with electrons which have fallen into these negative energy states. The Dirac sea thus is this vacuum sea of negative energy electrons. In forward time, if energy is added, electrons can be lifted from this sea. If spacetime is locally curved, additional holes may be created so that normal positive energy electrons fall in and disappear, creating the appearance of an "electrical energy sink." If the curvature is in the opposite direction, electrons may be lifted from the Dirac sea by the curvature, thus producing a flow of electrons and creating the appearance of an "electrical energy source."

DISCRETIZED

Occurring in a finite size, fixed as a function of one or more variables.

So long as the same value(s) of the variable(s) are selected, the discretized entity is always the same size. However, if the value(s) of the determining variables are changed, the value of the discretized quantity may change so that it is not a whole number multiple of the former entity. Compare this to a quantized entity, where the values of the variable(s) are held to those wherein the entity will always be a multiple of an entity of fixed size.

DISEQUILIBRIUM

Broken equilibrium, which in turn involves breaking appropriate conservation laws.

DISSOCIATION

Separation of ideas from their affects or feelings, resulting in independent functioning of these components of a person's mental processes.

Simply put, fragmentation of the mind and personality. Severe dissociation is the definition of insanity.

DISTORTION CORRECTION THEOREM

"If a scalar wave E1(r) propagates from left to right through an arbitrary but lossless dielectric medium, and if we generate in some region of space [say near z = 0] its phase conjugate replica E2(r), then E2 will propagate backward from right to left through the dielectric medium, remaining everywhere the phase conjugate of E1."

Quoted from Amnon Yariv, **Optical Electronics**, 3rd Edn., Holt, Rinehart and Winston, New York, 1985, p. 500-501.

What is missing from the distortion correction theorem is hidden in the phrase *"if we generate in some region of space ... its phase conjugate replica.."*. Since electrodynamicists and optical physicists have been unaware that all EM energy at any point in space comes from the time domain to that point, then the actual phase conjugate wave in the imaginary plane (from the time domain) is not utilized as the phase conjugate replica. Instead, the interaction of that wave with charges, which actually produces the force-field wave in space, is assumed. In short, one is looking at the "effect" wave, not the "cause" wave. However, since time is not an observable even in theory, it is this "effect" wave in 3-space that will be measured by our instruments.

Note also that the distortion correction theorem says nothing about longitudinal EM waves in the time domain. Interestingly, in nonlinear optical pumping, it appears that the 3-space energy of the pumping 3-space waves is transformed into the time domain by the pumping, and thence flows from the time domain into the 3-space domain to form the progression of the time-reversed replica wave in 3-space.

It is apparent that much more work should be done upon the foundations of phase conjugate optics, in a higher symmetry electrodynamics model such as O(3) electrodynamics and particularly in the unified field theory as in the Sachs-Evans combined approach.

DNA (DEOXYRIBONUCLEIC ACID)

Nucleic acid that constitutes the genetic material of cellular organisms and also certain viruses.

DRUDE, PAUL

Important German physicist, 1863-1906, who formulated the theory of the free electron gas inside conductors, using it to formulate a theory of metallic resistance.

DRUDE ELECTRON GAS

The "free" electrons that have broken loose from their atoms in a conductor, and are thus free to "wander around" and "migrate"—or flow as current when exposed to an emf.

Also called the electron gas, or Drude electron gas. Named after the German physicist Paul Drude who died in 1906, who formulated Drude's theory of metallic resistance based on EM theory and his own theory of electrons. See P. Drude, Ann. Physik, Vol. 1, p. 566; Vol. 3, 1900, p. 370, 869 for the original Drude papers.

DUALITY PRINCIPLE

In quantum mechanics, the principle that photons and other particles propagate like waves and interact like particles, so that their descriptions as only waves or only particles is inadequate.

ECM

Electronic Countermeasures.

Electromagnetic measures taken against targeted electronics or electromagnetics operations in systems, particularly in hostile weapon systems, command and control systems, etc. There are entire textbooks in the West that are devoted to ECM effects, uses, effectiveness, etc. A great deal of ECM equipment is also used by any modern military force. However, in our view what is greatly lacking as yet in Western ECM is the deliberate design and use of novel new kinds of ECM based on the extended higher electrodynamics such as O(3) electrodynamics, and particularly by use of longitudinal EM waves and by use of the infolded electrodynamics inside all EM fields, potentials, and waves. Longitudinal EM wave interferometers (LWIs), e.g., can reach right through the earth and the ocean to emerge on the other side of the earth. In the interference zone (IZ), real EM "transverse wave" energy is created readily by the interferometry. Biasing of the chassis grounds of the distant LWI transmitters can control whether the "normal" EM energy appearing in the target IZ is convergent (cooling) or divergent (heating). By sharp pulsing of the LWI transmitters, massive cold explosions or hot explosions can be created in the IZ. Continuous LWI interferometry can produce geometric forms of EM energy, which usually glow due to the ionization of the atmosphere, etc. in the dense EM energy regions. Since these can also involve general relativistic effects as well as electromagnetics effects in the U(1) CED sense, obviously a dramatic expansion of the entire field of measures and countermeasures is entailed.

We believe these LWI weapons may be what was referred to by U.S. Defense Secretary Cohen as follows: *"Others are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves… So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations…It's real, and that's the reason why we have to intensify our efforts."* Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.

EDGE WAVES

In electromagnetics, waves that form parallel to a material edge.

EDISON, THOMAS ALVA

Noted American inventor, 1847-1900, whose staggering number of inventions included the storage battery, electric light bulb, phonograph, motion pictures, and carbon microphone.

E-FIELD (ELECTRIC FIELD)

The electric field or electric intensity E. That field on a spinning charged mass which produces an electrical force resulting in a linear motion of the charge.

See also discussion under c, above.

E-FIELD, MOTIONAL

In classical EM theory, the electric field produced by moving a conductor in a magnetic field. Often called *motional inductance* of the field.

In the orthodox theory, motional inductance is deemed to be identical to the inductance caused by a time rate of change of the magnetic field, experienced by the moving conductor.

E-FIELD, STATIC

In orthodox theory, the electric field in the space surrounding a static charged particle, induced by the presence of the charged particle.

In classical EM, there is no notion as to the *causative mechanism* for this static field of and from a charge, which implicitly is assumed to just continuously create and pour out EM energy in all directions, thus grossly violating energy conservation.. Consideration of this anomaly leads to what has been called the most pressing problem in both quantal and classical electrodynamics: the question of the formation of the fields and potentials associated with the "source charge".

For a full solution to this problem, see my "Giant Negentropy from the Common Dipole," **Journal of New Energy**, 5(1), Summer 2000, p. 11-23. Also on this website.

EHRENHAFT, FELIX

Scientist who performed numerous experiments believed to demonstrate fractional charges.

EINSTEIN, ALBERT

German (Jewish) physicist, 1879-1955, who emigrated to the U.S. and formed special and general relativity theory, discovered and formed the theory of Brownian motion, recommended the development of the atomic bomb to President Roosevelt, and profoundly affected the course of science and the modern world.

EINSTEIN-de HAAS EFFECT

The rotation observed in a freely hanging ferromagnet when it becomes magnetized.

It has been used in the Einstein-de Haas method to determine the gyromagnetic ratio of a ferromagnetic material by suspending a cylinder of the material from a torsion fiber and measuring the angular displacement of the cylinder when its magnetization is reversed.

EINSTEIN, PODOLSKY, AND ROSEN PARADOX

Thought experiment in 1935 for measuring two correlated photons separated and at distant locations, protesting that quantum mechanics requires that the particles communicate instantly, which is a "spooky action-at-a distance" (Einstein's phrase).

The experiment eventually was performed and it works, just as required by quantum mechanics. The paradox inspired the development of hidden-variable theories.

EINSTEIN'S POSTULATES

(1) All the laws of physics are equally valid in all inertial frames of reference,

(2) the speed of light is the same to every inertial observer, and

(3) the observable local effects of a gravitational field are indistinguishable from those arising from acceleration of the frame of reference.

The first is called the special relativity principle, the second is called the law of light propagation, and the third is called the equivalence principle. It is now known that postulates (1) and (2) are not independent of each other. Note that the third postulate implies that any local force is due to a "gravitational field" (acceleration of the frame of reference). It also implies that gravitational force has a mechanism, since quantum mechanics assigns a differential operator, operating upon a potential, to create every force. By extended inference, it can be seen that the third postulate also implies that there should exist a method to turn any type of force (field) into gravitational force (field).

The Russian physicist Sakharov has strongly postulated that gravitation is not even a fundamental field of physics, of the kind used by Maxwell in his electrodynamics. Instead, in this view **G**-field is always comprised of, and made from, other fields and interactions upon them. Indeed, such has always been implicit in general relativity, it just took Sakharov to formally propose it. E. g., see A. D. Sakharov, "Vacuum Quantum Fluctuations in Curved Space and the Theory of Gravitation," **Soviet Physics Doklady**, Vol. 12, No. 11, 1968, p. 1040-1041 [English translation.] Sakharov's article (in Russian) in **Doklady. Akad. Nauk SSSR**, Vol. 177, 1967, p. 70-71.

Now let us do a little "tinkering" with Einstein's postulates. For the first one, we point out that in the new approach using dimensioning and subspaces, the notion of an inertial frame now has acquired additional complexity! The "gross translation" effects—which tends to be what physics ultimately focuses upon—can remain the same, and yet vacuum engines can be buried up inside the inertial frame to act upon a mass in non-translating ways. Everything translation-wise can remain the same, but now matter can be transmuted and transformed, etc., still right there in an inertial frame. So when the infolded electrodynamics inside all fields, potentials, and waves are utilized, the notion of "inertial frame" has acquired a higher topology and then one inertial frame may differ very substantially from another inertial frame. This of course move one from special relativity into full general relativity, and even there into a slight extension. Special relativity can remain special relativity on the surface, and yet effects occur "within" the objects postulated to exist in this inertial frame. The "inertial frame" concept in the postulates is now just a sort of special "equilibrium case" of a higher topology "inertial frame" notion.

The second postulate now stands as a "special case" of a far more general second postulate. It actually defines (and limits) "light" to bulk changes in the entire vacuum potential magnitude. It only applies to light signals which are "bulk upheaval" disturbances of the vacuum potential (spacetime). Specifically it need not apply to the "inner EM/GR realm" of longitudinal EM waves infolded inside the vacuum potential, other potentials, signal carriers, etc. Superluminal communication is now included in this "hidden variable" communication. The Fogal semiconductor is in fact capable of infolding and outfolding EM signals, including producing the internal longitudinal EM waves, and during their infolded state these signals are permitted to move at superluminal velocity.

So the second postulate needs to be restated to include the present statement as a special case. Notice that the concepts "light" and "speed of light" have now taken on much richer, extended meanings, since there is "outfolded" light and "infolded" light, so to speak. Light now is not just the "external perturbation wave" in the ambient vacuum potential medium (in flat spacetime). Instead, it can also be an "internal perturbation longitudinal wave" inside a "net flat spacetime" which does not show on the "surface" at all. Indeed, it may move in the time dimension or in 3-space. It now includes the transmission of an extraordinary "vacuum engine" as well as the usual transmission of just an ordinary signal.

And these infolded vacuum engines can be visualized as very special sets of longitudinal EM waves and their dynamics, consistent with the Whittaker decomposition. His U(1) symmetry electrodynamics decomposition—particularly when enriched in the higher symmetry O(3) electrodynamics—applies to the ambient vacuum as a potential (it is a potential since it has energy density). So the "subspace" inside spacetime, so to speak, is just a set of LWs and their dynamics, and that subspace itself is engineerable, just as is the "bulk curvature of spacetime" itself. Further, we may now consider space itself is just a vast superhighway for such superluminal LWs and their dynamics. Mass is mostly empty space with only an occasional particle here and there and with fields, potentials, and waves in between. Hence huge masses such as the ocean and earth are actually superhighways for the direct passage of longitudinal EM waves, "engines", etc. The degree of "transparency" is a function of the degree of cleanness of the LWs.

The third postulate has also been dramatically extended and requires revision. As presently stated, antigravity effects do not appear to be included in present physics heretofore. The "gravitational effects and external accelerated effects" notion in conventional physics is still founded purely on *ordinary bulk translation*. Now it need not be. For example, the system can appear to be an ordinary system, as judged by normal "external light" observation. Yet its internal vacuum engines can cause local violation of most so-called "laws of nature." The reason a "law of nature" can be violated is that one is now able to violate the premises upon which it is postulated, and which are required to hold if the law is to hold. Or another way to look at it: any conservation law is the result of a symmetry. Breaking that symmetry allows violation of that specific conservation law.

So as we've said so many times before, the infolded EM inside the "conventional" EM fields, waves, and potentials—and inside the vacuum potential and spacetime itself—dramatically changes the present theories of electromagnetism, quantum mechanics, and general relativity. Further, for the first time the Sachs unified field theory allows an *engineering* approach which simultaneously crosses, includes, and extends all three disciplines in the required manner. The approach can be placed into good engineering models based on the Sachs work, particularly using the O(3) electrodynamics subset spearheaded by Evans, and the models can be tested and verified or falsified.

EINSTEIN'S GENERAL THEORY OF RELATIVITY

Mathematical theory of gravitation in which the gravitational force is mathematically described by a curvature in space or spacetime.

In other words, the geometry and its dynamics have become physical agents.

It is important to note that, in general relativity, the curvature of spacetime acts on mass-energy, and changes in or to mass-energy interact back upon spacetime to change its curvature.

Further, we consider that an exact pattern of curvatures of spacetime and their dynamics exists for every mass system and its dynamics. This is the engine concept. The most general way to engineer matter is not by brute force translation, but by forming spacetime engines. Once formed, these engines act upon any mass placed in the engine region, to eliminate the deltas existing in that mass's resident engine and the impressed engine. The curvature of spacetime itself furnishes the energy for the continuing action upon the mass, once we pay to form the engine. The mass can be acted upon at any level, from its gluons and quarks to its nuclei, to its atoms, its lattice forces and binding energy, etc. Significantly, the Sachs theory applies to physical reality from beneath the quarks and gluons to the entire universe, and folds in quantum mechanics, electrodynamics, and general relativity into a single unified field theory that is (in theory) engineerable by higher symmetry electrodynamics means.

ELECTRIC FIELD

The *conventional* definition is this: "1. a region in space in which a stationary electric charge experiences a force due to its charge. 2. the electric force per unit test charge." **Dictionary of Science and Technology**, ibid., p. 720. That definition is flawed. Consider the "spatial aspects" of part 1. If an electric field is defined as a force per unit charge, it is not a region in massless space but is an effect of something existing in massless space and interacting with the charged mass. The electric field *prior to interaction* is indeed related to a region in space, because it is identically a curved spacetime region. In the Sachs approach, general relativity and electrodynamics have become one and the same. So prior to interaction, the *field as it independently exists prior to interaction with charge* has become a curved spacetime region, and the field is *purely* a spacetime curvature effect. The interaction with mass to produce a force on and of that mass (mass is a component of force, and there is no such thing as a massless force) is a separate consideration from the field as it exists in space prior to interaction. The result of this entity's interaction with charged mass has nothing to do with *what an electric field is*; but with *what it does to charged mass*. Further, the force evidenced on a charged particle is not due to its charge; it has that charge always, whether or not there is a net force evidenced on it!

Part 2 is a little better. The only problem is, it totally disagrees with the entity existing in space prior to interaction. In other words, here it's a "force on a charge", which is an effect occurring after the interaction. Again, it is what the field *does or accomplishes*, not what it *is*. Hopefully the reader can now begin to see what terrible difficulties await anyone who seriously attempts *foundations definitions*. Feynman sums it up admirably in one of his famous statements: "*Everything we know is only some kind of approximation, therefore, things must be learned only to be unlearned again or, more likely, corrected.*" An additional difficulty is that the very notion of a separate massless force independent of the mass on which it operates, is fictitious, yet continues to be widely used. Recalling that any true definition is an identity and not an equation, let us start with the definition of force:

$\mathbf{F} \equiv d/dt(m\mathbf{v})$. As can be seen, force is a system comprised of (i) a mass component and (ii) a nonmass component. The force is not something separate from the mass, at all! Further, force is not even unitary. It's a system comprised of two coupled components; the mass and a coupled (interacting) gradient in a potential flux. *Note that* $\mathbf{v}$ *involves motion through, and interaction with, the virtual flux comprising the vacuum potential. Note that* $d\mathbf{v}/dt$ *involves a gradient in that flux interaction with the mass*. Unfortunately mechanics is still using the medieval concept of a "separate force acting upon a separate mass." That is wrong, unless we change the fundamental definition of force itself. See, e.g., Robert Bruce Lindsay and Henry Margenau, **Foundations of Physics**, Dover Publications, New York, 1963, p. 283, where the authors emphasize that a "field of force" at any point is actually defined only for the case when a unit mass is present at that point. The reason can be seen: mass is a necessary component of force, and without mass present there cannot be a force present.

ELECTRIC DIPOLE

See Dipole.

ELECTRODYNAMICIST

A specialist in electrodynamics,

...the physics of the relationships between electric, magnetic, and mechanical phenomena—and especially a specialist in electrodynamics theory.

It should be pointed out that essentially all electrodynamicists are versed in U(1) electrodynamics, and a much smaller number are versed in more advanced electrodynamics such as O(3) symmetry electrodynamics, unified field theory electrodynamics, non-Abelian electrodynamics, etc. The electrodynamics field is actually a very vast field indeed, touching everything in physics. Very often, when one needs a particular electrodynamics problem solved, it calls for a special category of electrodynamicist and not just an electrodynamicist in general. One must therefore sometimes examine the background of the electrodynamicist making a statement or a pronouncement: electrodynamicists after all do have differing views and differing disciplines within the field.

ELECTROMAGNETIC PULSE (EMP)

A sharp pulse of electromagnetic radiation produced when an explosion occurs in an unsymmetrical environment, especially at or near the earth's surface or at high altitudes.

Essentially the same as an electromagnetic shock wave, a wave of great intensity which results when waves with different intensities propagate with different velocities in a nonlinear optical medium. An EMP is also produced when two intense longitudinal scalar electrostatic potential wave patterns meet and couple into a sudden flash of vector EM energy.

ELECTROMAGNETIC SMOG

The background of extremely weak EM radiation that fills the normal modern environment, particularly in developed nations.

The individual signals are too weak to individually produce effects of any significance in biological systems. However, in a dense EM smog environment with 500,000 signals per square meter per second, the signal complex and its nonlinearity begin to produce highly nonlinear effects in biological systems. These effects also produce damage that may cumulate over a long period of time, including for years. This bioeffects area has largely not been investigated by EM bioeffects scientists.

It should be pointed out that electric lines, telephone lines, transmission lines, etc. act as long wire antennas to detect and propagate such very weak EM signal noise. Essentially all the radiators in the environment—including electronics equipment, TV stations, radio stations, factory machinery, etc.—thus produce very weak signals picked up by these long line antennas and piped into every home, factory, neighborhood, etc.

ELECTROMOTIVE FORCE (EMF)

A difference of potential created by sources of electrical energy—i.e., by separated charges (dipoles)—which can be utilized to drive electrical currents through external circuits. Also, open circuit voltage, or the limit of the potential difference between the source's terminals as the current in the external circuit approaches zero.

Poorly named. Also quite confused in the standard theory and usage. First, *emf* is not a *force* at all. It is a difference in potential, hence it is measured in volts. Also, it is not considered an **E**-field, since that is a field of force. Yet it is in fact a , restricted to the direction between the two measurement points, and is considered to be an **E**-field in the theory!

For this reason the standard theorists say that the term is sometimes used as equivalent to a difference in potential, but that strictly speaking it should be applied only to a source of electrical energy! The problem is that conventional theorists are unaware that a potential is a bidirectional flow of energy in 3-space, where the energy enters from the time-domain (complex plane). Since they are unaware that a potential is hidden negentropic energy flow process involving broken 3-symmetry and viable 4-symmetry, the theorists are unable to consider the potential in general as a source of energy flow. Yet they are forced to consider a potential difference across the terminals of a source as "somehow a flow of energy, that generates forces upon the electrons to propel them through the circuit as current flow."

In the new viewpoint, a resolution is achieved of these incongruities by more accurately defining the E-field with respect to the potential as E [q]/q. It is noted that [dA/dt]q/q also produces an E-field, so that the full definition of the E-field is as E [(+dA/dt)q]/q. However, one volt represents one joule (of excess energy) per coulomb of charge. *The energy density flow in an electric circuit is in the voltage, in the emf, and it is not in the current per se*. The electron current (drift current) carries the excess energy that is being dissipated as work in the circuit, but in a nominal circuit the drift current only moves a few inches per hour. Half the energy is dissipated in the external circuit and external losses, and half is dissipated in forcing spent electrons in the ground return line back up through the back-emf of the source, performing work inside the source to dissipate its separation of charges. Left alone, any dipole will furnish emf indefinitely, freely receiving the energy from the time domain (complex plane) and outputting it in 3-space. The free flow of EM energy will continue unabated from the undestroyed dipole, regardless of how many external loads and losses are powered (how much energy is collected and dissipated from the ongoing flows representing the potential). So electrical circuits should be developed which allow little or no electrons to be forced back up through the dipole to dissipate its separation of charges and destroy the dipole.

ELECTROMOTIVE FORCE, BACK (BACK EMF)

Back emf is a loose term used for the *counter-electromotive force.*

When the source is powering a circuit or circuit element, the term "back emf" is used to refer to the forcing of current (electrons) back up through the source against its emf, thereby performing work inside the source to dissipate its separation of charges (its dipolarity). When a potential source of electrical energy—such as a capacitor, an inductor, or a rotating machine—is receiving energy from the source and converting it to dissipative power and work, that "powered" device is said to develop a *counter-emf.* A source has a built-in emf *a priori*, that is holding its charges separated so that it is dipolar. When electron current is forced backwards through the source through its built-in counter-emf, and backwards against its emf, work is performed against the internal resistance of the source to dissipate its separation of charges, thereby dissipating the source. If electron current is not allowed to flow back up through the source against its back emf and through its built-in counter-emf, no dissipation of the source occurs, even though energy density (not electron current dq/dt but energy flow d/dt) is flowing from the source and can be collected in collectors in the external circuit to store the energy as a created local energy source. This collected energy can then be shuttled to a separate load circuit and released, to provide a "heat pump" cycling operation and overunity coefficient of performance.

Nikola Tesla in fact knew how to shuttle energy in a circuit in such fashion, as Barrett's quaternion analysis of Tesla's actual patented circuits has revealed. [See T.W. Barrett, "Tesla's Nonlinear Oscillator-Shuttle-Circuit (OSC) Theory," Annales de la Fondation Louis de Broglie, 16(1), 1991, p. 23-41.] Note that a rigorous analysis of those same circuits, using tensors or vectors, will not show the effect.

When the original source dipole is not dissipated because electron current is not passed back up through its back-emf to scatter the charges, the original source dipole will continue to furnish emf indefinitely.

The terms emf and counter-emf are normally applied only to recognized sources of electricity. Emf is applied as the algebraic sum of the potential differences acting in a circuit attached to a source. Back-emf (counter-emf) is applied as the potential difference internally through the source, between its terminals. Its main application is thought to be a *powered device or component in the circuit*. Actually, its main application is to prevent COP>1.0 electrical power systems from being developed and utilized.

ELECTROMYOGRAPHY (EMG)

A diagnostic application which detects changes in electrical potentials associated with muscle contractions.

Specific electrical patterns have been associated with specific abnormal states (e.g., denervated muscle), but the method has not yet been systematically developed beyond this application.

ELECTRON

Stable elementary particle in all atoms, and having a negative charge of 1.602×10^{-19} coulombs, spin ½, and mass of 9.11×10^{-31} kilograms.

ELECTRON GAS

A system of electrons with only weak interactions so that the electrons may be regarded as moving independently.

Thus, in many ways, that collection of electrons can be treated as a gas. Also see discussion under Drude Electron Gas.

ELECTRO-OPTICS

A technology in which electrons are focused and steered as if they were light. Examples are the cathode ray tube (CRT) and the electron microscope.

ELECTRO-POLLUTION

Also called *electromagnetic smog* and *electronic smog*. The conglomerate or maze of EM fields and radiations that are produced by technologies such as electric power transmission and radio transmission, and that can have long term cumulative harmful effects on humans.

The new viewpoint dramatically extends the types of fields and effects involved, and gives entirely new mechanisms for the interaction of EM fields and radiation with biological systems, including cumulative effects, signal-density effects, and vacuum engine effects. A mechanism for long term causation of cancer and leukemia by electro-pollution is derivable in the new approach.

As an example, even though the myriad of very weak EM signals comprising the electro-pollution are individually tiny, each when interacting at a local site with the body or its cells involves a broken 3-symmetry and thus an involvement of 4-symmetry, with corresponding giant negentropy. Further, the Heaviside dark energy component accompanying that local field interaction will in turn interact with essentially all the other locations of the body. Each of these interactions involves broken 3-symmetry and involvement of 4-symmetry. The result of the large complex of broken 4-symmetries constitutes a direct structuring in the time domain, hence weak time-pumping and weak time-charging. Time charge excitation decays only very slowly, emitting longitudinal EM waves inside the body as the charge decays.

Over a long period of time (sometimes years), this "time-hash" or "time-jamming" upon the operation of the master cellular control system, the immune system, and the cellular regeneration system is cumulatively detrimental. In this way, effects such as leukemia, cancer, etc. may be gradually "kindled". However, there have been no real scientific laboratory "cause and effect" investigations of this phenomenology at all. Nonetheless, the results will and do show in epidemiology studies, which are then attacked by orthodox scientists (many employed directly or indirectly by the power industry, etc.) on the grounds that no laboratory cause and effect evidence has been shown.

In short, this is one of the areas where the lack of scientific cause and effect laboratory evidence—because such experiments have not even been done—is improperly used to negate real scientific work showing deleterious effects that powerful interests do not wish shown.

ELECTRO-RETINOGRAPHY (ERG)

A diagnostic application that monitors changes in electrical potentials across the retina to assess eye movements.

This is almost the only method available for noninvasive monitoring of Rapid Eye Movement (REM) sleep.

ELECTROSTATIC COOLING

To be added

ELECTROSTATIC SCALAR POTENTIAL

A static (stationary) ordering in the virtual photon flux of vacuum.

The word "static" is unfortunate and should be replaced by "stationary", since the underlying active vacuum medium is always in violent motion, and there is nothing truly "static" in the universe. But an equilibrium condition can exist, even in violent motion, so that a stationary entity persists. An example is a perfect whirlpool in a river.

ELF

Extremely Low Frequency.

Used to describe EM fields whose frequencies lie in the range from just above 0 Hz (direct current) to 300 Hz. This includes power line frequencies (60 Hz in U.S. and 50 Hz in Europe) and frequencies used by certain U.S. military ELF communication systems such as for submerged submarines.

EM

Electromagnetics.

EMF

Electromotive force. See discussion under that term.

EM FIELD

Electromagnetic field. In its loose usage, it refers in a very broad way to any field, force, or energy associated with electromagnetic interactions, charges and currents.

Thus "EM field" includes electrostatic fields, magnetostatic fields, electromagnetic fields (including radiation and induction), vector-potential and scalar-potential fields, Hertz potentials, Fitzgerald potentials, Whittaker potentials, etc.

In its precise usage, "EM field" conventionally refers to an EM "force" field, such as the **E**-field, **D**-field, **B**-field, **H**-field. In classical electromagnetics (CEM), as a holdover from the old assumption of a material ether, the force fields are considered (erroneously) to exist in mass-free space, and they are also considered to be the primary causes of electromagnetic phenomena. This is a non sequitur, and it involves substituting the effect for the cause.

In the new viewpoint, the force fields do not exist in vacuum, but only in and on and of the charged particles themselves, where mass is present to form one component of the force. The force fields are therefore effects and not primary causes. The primary causes of all electromagnetic phenomena is taken to be the potentials; however, the hidden Stoney/Whittaker/Ziolkowski internal structures of gradient-free scalar potentials may interfere to cause potential gradients in and on charged particle systems. This therefore includes distance-free scalar potential interferometry and action at a distance, as well as vacuum engines.

The new view uses Sachs' unified field theory, and considers that the EM field in the vacuum, or an EM potential in the vacuum, is a curvature of spacetime function. Thus the new view is a unified field theory where GR has become EM and EM has become GR, and where EM can involve or produce gravitational, temporal, and inertial effects as well.

EM FORCE FIELD IN THE VACUUM (A FALSE CONCEPT)

The erroneous notion that there exist forces in the vacuum, so that the set of forces at a set of spatial points forms a force field.

This ignores the fact that mass is a component of force, and the presence of a force requires the presence of a mass. When Maxwell formed his electrodynamics theory, he and almost everyone else believed that a thin material ether pervaded empty space. Thus there was a "material medium" in which electromagnetic fields existed, and so it followed that real forces existed in this material medium, from point to point. Indeed, to the early electrodynamicists there was no point in all the universe where mass was absent.

Heaviside, Hertz, and Gibbs reduced Maxwell's 20 quaternion equations to the present four vector equations, but did not change the *force field in space* assumption used by Maxwell. Heaviside detested the "mystical" potentials favored by Maxwell, and believed they were figments of one's imagination. He regarded the forces as the primary EM causes.

Yet even while Heaviside *et al*. were retranslating and topologically reducing Maxwell's theory dramatically, the Michelson-Morley experiment in the 1880s had already destroyed the material ether on which those same force fields were based.

Physicists, however, have continued to use the notion of a separate force acting on a separate mass, which of course is also a non sequitur, substituting effect for cause yet again. Hence the foundations of physics remain fundamentally fouled.

For a succinct discussion of potentials versus forcefields as the primary EM causes, see Y. Aharonov and D. Bohm, "Significance of Electromagnetic Potentials in the Quantum Theory," **Physical Review, Second Series**, 115(3), 1959, p. 485-491. See also Y. Aharonov and D. Bohm, "Further considerations on electromagnetic potentials in the quantum theory," **Physical Review**, 123(4), Aug. 15, 1961, p. 1511-1524.

EM GENERATRIX

Whatever generates electromagnetics, particularly the fields. Time is the ultimate EM generatrix.

Whittaker showed in 1904 that the interferometry of two scalar potentials (i.e., of their hidden multiwave structures) can create all classical EM fields, no matter how complex, thereby starting a branch of electrodynamics known as *superpotential* theory. See E. T. Whittaker, "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions," Proc. Lond. Math. Soc., Series 2, Vol. 1, 1904, p. 367-372. The paper was published in 1904 and orally delivered in 1903.

In 1903 Whittaker showed that any scalar potential (e.g. between the ends of a dipole) can be decomposed into a harmonic set of phase conjugate EM longitudinal wavepairs. The present author applied the Whittaker decomposition to the scalar potential between the ends of a dipole, and pointed out that the conjugate half-set may be taken as converging EM waves from the complex plane (the time domain), while the real half-set may be taken as diverging EM longitudinal waves emitted from the dipole in all directions in 3-space. The dipole is a known broken 3-symmetry in the dipole's violent virtual energy exchange with the vacuum; hence this shows that breaking 3-spatial symmetry allows nature to fall back to a more primary 4-symmetry. Hence energy flow conservation is violated in 3-space, but is rigorously obeyed in 4-space. Further, the free flow of 3-spatial energy from the dipole continues so long as the dipole exists.

The dipole thus is a true negative resistor, receiving EM energy in unusable form (from the complex plane; i.e., the time domain), transforming it into usable energy, and outputting the usable energy. This is also the fundamental mechanism for extracting unlimited EM energy from the seething vacuum, taking the energy from the time domain via the giant negentropy mechanism. See my paper, "Giant Negentropy from the Common Dipole," *ibid*.

This also means that the source of all EM 3-spatial energy is from the time domain, and is due to broken 3-symmetry. The ultimate EM generatrix is thus time. The ability of a bit of broken 3-symmetry (such as formation of a simple dipole) to initiate a continuing and ongoing flow of free EM energy via the 4-symmetry between time-energy and spatial energy, means that *negentropic* engineering, once we get the hang of it, is far easier than our present *entropic* engineering. In essence, we have to learn how to do electrical engineering all over again, from a much more fundamental point of departure.

EMI (ELECTROMAGNETIC INTERFERENCE)

Disturbances of electronic equipment's operation by intrusion of extraneous EM signals from outside sources. Also, disturbances of the operation of one or more subsystems of an electronic system by intrusion of undesired signals from other subsystems.

EMI, ANOMALOUS

An "ad hoc" term denoting an unexpected nonlinear optical functioning process in a dense signal environment whereby nonlinearities on the skin of a vehicle or cover of an equipment become pumped phase conjugate mirrors, so that they emit amplified phase conjugate replicas (PCRs)—of signals and fields impinging upon the skin or covering and the nonlinearity from electronic circuitry operating inside.

By the distortion correction theorem, these amplified PCRs precisely backtrack the signal waves that impinged upon the phase conjugate mirror from inside the vehicle or electronics, back to the original source of the internal signal. The result is the scavenging of energy from the dense electronic signal environment and sharply focusing and directing it into the operating circuits of the internal electronics. Thus internal signals, often amplified, start sporadically appearing through the circuits. These sporadic jamming signals due to the anomalous EMI effect are known as EMI fireflies.

Such EMI fireflies were resoundingly experienced in U.S. missiles and aircraft in the U.S. air attack on Libya in 1986. Although some of the anomalous EMI effects could have been produced by the unusually dense EM signal environment and poor hardening of circuits and electronics, it is believed that the weak jamming was also a test being conducted of a laboratory prototype Russian quantum potential weapon.

This weapon appears to have been finished and deployed at the end of 1989, and then utilized against Allied forces in the Gulf War, accounting for the Gulf War Disease. We have previously explained why British, Canadian, and American soldiers acquired the disease, why the native populace did not, and why the French troops did not.

Inside the human body, the anomalous EMI effects may be used to produce time-charging and delayed interference with the immune system, the master cellular control system, and the cellular regeneration system. By using dimensioned signals, the targeted systems can be specifically and deterministically affected as desired, for any set of disease damage types and symptomology desired. So the technology may be used to induce a "cocktail" mix of various infectious disease damage types. The induced time-charging effects—where the time-charge is dimensioned—followed by longitudinal EM wave emissions from the time-charges as they decay in the veteran's body, can induce the same or similar symptoms and damage in close family members exposed to the weak but dimensioned longitudinal EM radiation. This applies not only to wives but also to family members such as children often in close proximity to the veteran. In addition, exchange of bodily fluids from the veteran to his spouse can directly induce the symptoms in the spouse since those fluids are themselves still time-charged (with dimensioned time charge) and slowly decaying.

ENDOTHERMIC EXPLOSION

An EM implosion, resulting in explosive electrostatic cooling. The sudden, explosive reversal of electromagnetic energy scattering in a spacetime area so that the local EM heat energy is converted back to a negative potential. In this manner, explosive electrostatic cooling occurs in the area.

Endothermic EM explosion occurs by pulsed scalar Whittaker interference of two longitudinal EM wavesets beamed from two LW EM transmitters. The distant transmitters of the LW interferometer must have their local electrical grounds biased well below the ambient zero potential in the distant interference zone (IZ). Whittaker internal EM waves radiate through subspace (the LW superhighways inside EM fields, potentials, and waves in mass) from the transmitter to the interference zone, and also from the interference zone back to the negatively biased transmitter/receiver, emerging there as ordinary electromagnetic scattering energy or *heat*. All *normal* explosions are exothermic in nature, and ordinary electromagnetic heat energy is radiated away. A scalar EM interferometer/howitzer, however, may produce an endothermic explosion (an energy implosion) at a distance, explosively extracting the heat energy at the implosion site and receiving the energy back at the transmitter site for disposal.

The same LW interferometer can also produce an exothermic explosion in the distant interference zone, merely by positively biasing the electrical chassis grounds of the scalar EM potential transmitters and pulsing the transmission. Negative biasing of the transmitters' electrical chassis grounds and a pulsed transmission result in an endothermic explosion in the distant interference zone.

ENDOTHERMIC LONGITUDINAL EM WAVE INTERFEROMETRY

Extraction of EM energy from a distant intersection area by a scalar interferometry whose electrical grounding is biased well below the ambient potential in the distant interference zone.

The result is a cooling of the interference zone, and heat energy emerging at the transmitters.

ENERGETICS

The Russian term for what I have called advanced higher-symmetry electromagnetics,

...using artificially constructed Whittaker internal biwave structures to make activated potentials that have specific, desired "vacuum engines", where the EM field is a curvature of spacetime function, and thus involving a unified field theory that is engineerable by novel electrodynamic means.

I believe that the closest Western work approaching the Russian energetics science is the O(3) higher symmetry electrodynamics pioneered by Evans, particularly when combined with Sachs' unified field theory as an important subset. The other closest Western work would seem to be the important work of Barrett in SU(2)×SU(2) symmetry electrodynamics.

The activated potential containing the infolded vacuum engine structures is said to have been *dimensioned*. These dimensioned potentials can be combined to form EM carrier waves which contain the hidden vacuum engines. These vacuum engines, scalar Whittaker EM interferometry, and activation of vacua and matter are used to perform unified field engineering.

Russian energetics also adds the formation and use of the quantum potential, enabling
(i) instantaneous action at a distance with multiple separated target nodes, (ii) essentially limitless direct energy amplification in the assembly of receiving nodes, without additional energy input at the initiating node, and (iii) engineering of hidden variables inside distant targets, instantaneously, without transmission *as such* through space. The quantum potential itself can be *dimensioned*, so that vacuum engines can be instantaneously transmitted into distant targets, altering their local spacetimes to contain the desired engine(s). Note that no intervening barrier can "impede" or "shield" a quantum potential because it does not travel through space as such; it just appears everywhere at once in the space where it will be.

Adding to classical EM theory, general relativity, and quantum mechanics the internal EM energy in the scalar EM potential will generate a superset of each discipline. These three new supersets are unified in their common internal EM energy subset. As a bonus mind, personality, memory, and deep biological cellular and system control are also available, since the internal time-energy domain is used by biological systems for these living functions. Energetics thus is an engineerable, unified field theory of physics and metaphysics.

Russian energetics is largely still a "secret" science, developed over the last five decades and highly weaponized. In the Russian scheme the overall area is called *energetics*. It consists of three subsets: (i) *energetics*, which applies to nonliving systems, (ii) *bioenergetics*, which applies to the physical bodies, cells, chemistry, genetics, etc. of living organisms, and
(iii) *psychoenergetics*, which applies directly to the minds, personalities, memories, emotions, and perceptions of living systems. Russian energetics research, development, weapons, and weapon sites are under the rigid control and operation of the KGB, by whatever name it may use from time to time. The energetics weapons are not in the regular Russian armed forces. Energetics weapons have been tested worldwide for several decades, and this testing has been documented elsewhere by the present author.

ENERGY

Usually erroneously defined as the "capacity to do work".

The closest definition is: *The invariance of that which is varying*. Note that this is a 5-law logic definition and not an Aristotelian definition.

Here we have a real bucket of worms. This term is usually totally misdefined (as in the nostrum that "energy is the capacity to work") in physics, which defines energy as the "ability to scatter itself or change its own form" which obviously are not identities! A common definition is given as "a quantity that describes the capacity to do work; commonly divided into three major classifications: kinetic (dynamic) energy, potential (static) energy, and radiant (electromagnetic) energy. Well, energy can be changed in form and that is work. But energy is not the "capacity to change its own form", but is its own form, as can be seen.

Anyway, we'll have a go at a definition perhaps a little more acceptable, though still imperfect. Then we'll discuss things a bit.

Rigorously, energy is any deterministic or coherent structuring, either dynamic or stationary, existing in the virtual particle flux of vacuum. While that *sounds* good, it is still "the invariance of that which is varying." Ultimately, a thing is defined in terms of its appositive.

The *type* of energy depends upon the type of virtual particle(s) whose flux is selected. E.g., electromagnetic energy is a deterministic or coherent structuring, either dynamic or stationary, in the virtual *photon* flux of vacuum. Any trapped energy (ordering in the vacuum virtual particle flux) is gravitational in nature, since trapped energy is gravitational. In a mass, e.g., it is the trapped energy that is gravitational, not the mass per se, in the modern view. Contrast the definition of electromagnetic energy to the definition of an electrostatic scalar potential (ESSP): The electrostatic scalar potential is a stationary trapped deterministic or coherent dynamic wave-structuring of the virtual photon flux of vacuum. Thus it can be seen that the ESSP is a special case of EM energy: the stationary trapped case. For this reason, a mass—which is an enormous amount of statically trapped EM energy—may properly be considered as an extremely dense EM potential, which we refer to as the *mass potential*.

A potential is any trapped ordering or coherence, either static or dynamic, in the virtual particle flux of vacuum. A specific type of potential represents a selection of a particular virtual particle's flux in the vacuum, and an ordering—either static or dynamic—imposed in that flux.

However, since the scalar potential is just the static ordering in the virtual particle flux of vacuum, it follows that the scalar potential must contain—and in fact be totally composed of—internal order. E. T. Whittaker showed the form of that order in 1904. (See entry under Whittaker, E. T.) The scalar potential is composed of a harmonic series of pairs of antiparallel transverse waves. The antiwave of each wave/antiwave pair is a time reversed replica of the wave in that pair. In other words, the scalar potential is a special type of Fourier harmonic frequency expansion, coupled with its own phase conjugate present simultaneously.

Feynman said it bluntly: *"It is important to realize that in physics today, we have no knowledge of what energy is."* [Richard P. Feynman, Robert B. Leighton, and Matthew Sands, **Lectures on Physics**, Addison-Wesley, Reading, MA, Vol. 1, 1964, p. 4-2.]

E.g., particularly see R. B. Lindsay, "The concept of energy and its early historical development." **Foundations of Physics**, 1(4), 1971, p. 383-393. Lindsay investigates the concept of energy from its early historical origin. The root of the concept is the notion of *invariance in the midst of change*. Lindsay covers the concept and its evolvement (or lack thereof!) from ancient times through the 18th century.

The real problem is that the notion of energy implicitly involves the age-old unresolved philosophical problem of change, posed by Heraclitus over 3,000 years ago and unresolved to this day. *It cannot be solved within the realm of 3-law Aristotelian logic!* One way of posing it is something like this, after Heraclitus: "For a thing to change, it must turn into something else. How can a thing be itself and something else also? How can a thing have changed, and yet not have changed?"

The problem is that Aristotelian logic has a serious flaw of omission; it actually *implicitly assumes* a fourth law, which is the age-old philosopher's nightmare that, when a thing is pursued to the limit, *it invariably turns into its own opposite*. So in anguish the philosophers spoke of this nightmare as the "accursed necessity for the identity of opposites."

I did resolve the philosophers' nightmare some years ago, by adding a fourth law of logic to the Aristotelian three, which completes and extends Aristotelian logic, and an application rule which can be taken as a fifth law. E.g., see Appendix III: "A Conditional Criterion for Identity, Leading to a Fourth Law of Logic," in T. E. Bearden, **AIDS: Biological Warfare**, Tesla Book Company, Chula Vista, California, 1988, p. 428-443. A simple proof of the fourth law is given in that paper. For a much more elegant treatment of a higher topology logic, which is also practical and useful beyond the limitations of Aristotelian logic, see G. Spencer Brown, **Laws of Form**. Julian Press, New York, 1972. For a proper perspective on mathematics and on Aristotelian logic, see Morris Kline, **Mathematics: The Loss of Certainty**, Oxford University Press, New York, 1980.

It may be that, since by "identity" we mean at least the identity of "left" and "right" different observations, considering the left and right sides of the identity statement. If so, then already we involve a violation of Aristotelian logic in the very notion of "definition". In short, ultimately we can only define a thing in terms of an appositive in the first place. So we write an identity statement where left and right are different sides, then state "Oh, no, they are the same thing after all!" Said in that manner, the problem can clearly be seen. In one sense a definition is pure Zen, where no truth can be stated at all unless the speaker says two exactly opposing things, and then waits for the recipient to realize the truth that has been stated.

What this all means is that, since "energy" (and any other definition, ultimately) involves a logical contradiction in Aristotelian logic, we must "define" *energy* simultaneously in an appositive ways: (i) in the wave view and (ii) in the particle view. However, we point out that the notion of a "moving particle" is the notion of something considered momentarily as fixed (i.e., the particle), but which is immediately thereafter (in time snapshot #2) considered as moving. Notice that "moving" is changing, and so it involves Heraclitus' problem of change *a priori*. The notion of a "moving wave" is also a similar thing; i.e., "a wave" momentarily considers the entity as static and not changing (in time snapshot #1), and in the next moment (time snapshot #2) considers it as moving (changing). We can only point out this dichotomy for the reader to reflect upon and hopefully to grasp. *The conscious mind is a serial processor; it is extremely fast but still perceives snapshot by snapshot, serially. It essentially has been fitted to the single photon interaction, as has Aristotle's three laws of logic*. The problem is in the operation of conscious perception itself, not in nature which is not limited to just serial processing.

The unconscious mind is a massively parallel processor, so it can have many "different slides or snapshots in the slide projector" at the same time. So with our conscious mind's perception (Aristotelian logic is just a model of that, using single photon interaction as the physical observation mechanism) we see in terms of "either-or". On the other hand, with our unconscious we can also grasp the fact that single snapshot A can be the same thing as a totally different snapshot B, if the rules of "decision as to identity" are changed between snapshot A and snapshot B. Suppose that by "identity" we mean "incapable of being discriminated between." Is a black marble identical to a red marble, e.g.? It is perceived so if you are color blind. It is perceived not to be identical if you are not color blind. The point is something that most philosophers missed or brushed aside: identity is not absolute, but is "perceived identity". Identity is the result of a decision operation, based on multiple perceptions, recall from memory, and comparison of two remembered perceptions. The most simple form of comparison is simple subtraction.

The unconscious (massively parallel) perception can handle both snapshots simultaneously. The conscious mind only can see a single marble at a time, so it will see one or the other. In a *third* time interval it will recall from memory the first perception, compare it with the memory of the second perception (say, by simple detailed subtraction), and then decide whether object A is perceived to be identical to object B. The unconscious (massively parallel processor) can handle both the marble snapshots at the same time. It can see both the identity of the two, to a color-blind "identity decision process" and also the nonidentity of the two, to a color-sensitive "identity decision process." Again, nature is not limited to the single-snapshot, serial perception process of our conscious (serial) processor!

Unfortunately, in physics and mathematics we seem to still be thoroughly confused on this very perception issue. Brown's work may be the first work to straighten out the area of the topology of the logic utilized. My own independent effort was successful but far cruder than Brown's; Brown did it elegantly. We bring all this out because when one deeply looks into foundations and true definitions, one will directly confront the philosopher's nightmare and one's own conscious mind will never be able to resolve the problem. One's unconscious can resolve it, but it requires a certain "stretching of the realization" to harmonize monocular perception of the conscious mind with multiocular perception of the unconscious mind.

Just as a small example, the question of "is it a wave or a particle" once raged as a great debate in physics, and was never resolved. Instead, physicists just finally shook hands and agreed to quit arguing and fighting about it, and agreed to accept that the same entity could sometimes act as a particle, and in other cases it could act as a wave, and that *as it existed in the present, before observation,* it was somehow both a wave and a particle but we couldn't see its true nation (in that fashion). The key, of course, is that the question was posed in "either-or" form (Aristotelian logic form), and it cannot be answered in that reduced logic. Instead, a higher topology logic is required. Brown's logic answers it easily, as does my own four law superset of Aristotelian logic (five law superset if we count the application rule as a separate law). In the present, e.g., we have masstime and not mass. Just after a photon is emitted, we have mass and not masstime. The latter photon emission process consummates "observation." The point is, the true entity does exist in zero time as a spatial entity. It is not a spatial entity but is a spatiotemporal entity. If the "interaction" process tears off its "time-tail," it is converted to a "spatial entity" (frozen snapshot) and therefore seems to be a particle. If the "interaction" process does not remove the time-tail, it remains a spatiotemporal entity and therefore seems to be a wave. The *concept* of particle is 3-spatial concept. The concept of wave involves time also. No wave can exist and "be a wave or wavelike" unless it has some time extension to "be waving" *in*!

The physicists debating the wave-particle duality, you see, missed the most important point that *no observable exists in time or persists, a priori.* Hence rigorously no particle exists in time.

So we define energy (particle view) as any virtual particle flux pattern, where that definition automatically considers a single particle in translation as well as multiple particles in their myriad of translations. We define energy (wave view) as any wave flux, where that automatically considers a single wave in translation as well as multiple waves in their myriad of translations. Now note that one is going to have to deal with, and discriminate between, energy, energy flow, energy collection, and collected-energy dissipation.

As the reader can see, whenever one struggles with foundations issues, the problems get very complicated. We've beat this dead horse quite enough, and leave the further beating to the reader!

ENERGY AMPLIFYING COIL

A coil whose magnetic energy flow input is first split into two energy flow inputs, each equal to the original energy flow available from a magnetic source. Both the split energy flows then interact simultaneously with the coil, amplifying its electrical energy output compared to the conventional case where only a single energy flow interacts with the coil.

In the motionless electromagnetic generator (MEG), the curl of the magnetic vector potential of a permanent magnet (i.e., its magnetic field), is extracted and held within the core material of a special transformer, while the magnetic vector potential of the permanent magnet is freely replenished in uncurled (field-free) magnetic vector potential form in space around the core material. Both the full magnetic field in the core and the full uncurled magnetic vector potential in space adjacent to the core interact with each output coil of the transformer. Hence a single potential energy flow is "split" into two flows each equal to the original EM energy flow, and both the parallel flows energetically interact with the output coil. This increases the energy interacting with the coil by this "dual interaction", so that the coil is said to be an "energy amplifying coil".

ENERGY COLLECTION/COLLECTING

In electromagnetics, exposure of an interceptor/collector, e.g., a charged particle, into an impinging EM energy flow, so that some of the flow is diverted around the intercepting particle. We may say that the flow of energy has been "reordered" in a stream around the diverting charge.

Energy collection is not a thing which "has been accomplished" and finished; instead, it is an ongoing process.

Note now that, if you perform or consider or impose any sort of ordering at all in the energy flow/flux, rigorously you have just implied an *energy collection/collecting* process. The energy part of a photon, e.g., would seem not to be "energy" per se. Instead, it is an energy collection/collecting, and a time collection/collecting as well. Yet that energy part is energy also! [Not to worry! Energy and energy-collecting, contrasted as appositives, become identities at the extreme boundary separating the two concepts. That boundary is the photon concept. Aristotelian logic does not apply on the boundary, which violates the Aristotelian law of the excluded middle.] More reasonably, a charged capacitor does not have "stored energy" per se in it, in the sense of "so many chunks of energy called joules". Instead, it has an *ongoing energy collection/collecting process*, where the asymmetry in the local vacuum flux exchange, of the dipole across the capacitor plates, continually extracts and "gates" a flow of EM energy from the capacitor dipole. That energy-flow bathes all the trapped charges in the capacitor. The energy-flow interaction with the trapped charges creates the **E**-field and all the rest.

The diverted part of the total energy flow, is what is calculated in the "Poynting flow" or **S**-flow.

ENERGY, DISINTEGRATED

An ad hoc term for the energy of the incoherent virtual particles in the virtual particle flux.

ENERGY DISSIPATION

Refers to the scattering or disordering of energy.

This is somewhat of a misnomer, broadly used in physics and somewhat erroneous.

Energy dissipation" *per se* does not mean that the energy is destroyed. Instead, there is the dissipation of the ordering (*collected/collecting*) of energy in which the diversion (local ordering) process disappears. What we call the "dissipation in space" of energy is rigorously the dissipation of the collection/collecting in space of the energy. In short, the energy is scattered, as in a resistive load, in all directions. But it is still there in space, just disordered.

Recall that all EM energy at a dipolarity comes directly from the time domain. It is the collecting process, not the energy, that is dissipated from a point or a region. Only *collected/collecting* of energy can be truly dissipated. With that understood, then dissipation of collected energy is simply removing the "collector" from the energy density flow impinging upon it to cause the collecting process to occur, or removing the flow of energy impinging upon the collector so that it intercepts and diverges some of it around itself.

So there are two ways in which this "collected energy" dissipation can occur: (i) the collector is moved out of the impinging energy-flow-stream, or (ii) the energy-flow-stream impinging on the collector is reduced to zero. Note that "changing the form" of the energy—i.e., changing the collector and the type of collecting—involves both conditions (i) and (ii). Thus energy is dissipated when the *collector/collecting* form is changed. In the conventional, less accurate statement, work is performed when "the form of the energy is changed." That now should be stated as "work is performed when the collector in the energy-flow-stream is changed to a different collector, because the first collector must be removed from the energy-flow-stream or the energy-flow-stream must be removed from it.

In physics we also consider that "positive" work by a body is work it does on something else, while "negative" work is work done upon the body by something else. We specifically emphasize that collection/collecting need not be a unitary, one-time occurrence! The EM energy-flow impinging upon a collector roars on by it at something like the speed of light. The entire flow is diminished by only about 10^{-13} (the nominal energy collecting fraction) as it flows onto, and on beyond a coulomb of charge. If that departing energy-flow is then retroreflected or otherwise *returned* to pass back through again, additional energy collection/collecting can and does occur from it. This can be repeated many times, particularly in an intensely-scattering, optically active material. Also, after the collected fraction of energy is dissipated, we can also retroreflect the scattered energy flow back and reuse it again. This too can be repeated many times.

So we must be careful of the present *work-energy theorem*, which is a special case and assumes only a single pass of the energy-flow in the "collection/collection" of energy that "changes form." If we institute additional passes, with additional "collection/collecting of energy, then we can collect and "use" a little more energy from all that enormous energy-flow that otherwise would escape us. If we dissipate some of the collected energy, then also intercept the departing dissipated energy flow and return it, we can collect some of the energy flow again and then dissipate that new collection again. And so on.

One can permissibly get many joules of "work" from a single joule of energy by iterative retroreflection, iterative re-collection, and iterative dissipation, without violating the conservation of energy law. This is one of the major secrets of overunity energy processes. It is proven by the overunity or excess emission (Letokhov was forced to call it "negative absorption of the medium" from an intensely scattering, optically active medium, as in the Lawandy experiment and in his patented process for lasing without population inversion. It is also proven by Patterson's adaptation of anti-Stokes emission.

Let's do a gedanken (thought) experiment, where we do not even apply the nominal 10^{-13} energy collection fraction. Let's just *conventionally* say "energy flow," "energy collection," and "energy dissipation," and ignore the "collection fraction." Since we are talking theoretically, we can have a perfect system. So we have a closed system, which we open to input some energy into. The system then opens in the load to dissipate all the energy back to the environment, thereby doing work. Now suppose I passively (i.e., without any input energy of my own, by perfect retroreflection) return all the dissipated energy back to the input once again. We simply let it flow back in, the system collects it again, and then dissipates it again—giving us the same amount of work we had the first time. Then we do it again. And again. I think you get the picture. The fact that energy can neither be created or destroyed, but only changed, means that the "same energy" can be *recycled* over and over. One has to have two different actions: one that changes the form of the energy so we get some work, and the other that retroreflects and recovers the dissipated energy (does negative work!) so that we can recycle it and dissipate it again. In principle, by recycling of energy one can get many joules of work from a single joule of energy. Nature does it every day! Every joule of energy formed at the initial

"Big Bang," is still with us. Every joule of it has on the average already performed many joules of work since then. And as we stated, the anti-Stokes emission process is a concrete example and demonstration that the energy recycling process can be accomplished in physical systems, so that the systems permissibly exhibit COP>1.0.

A most common example is the replenishment of a potential. E.g., the magnetic vector potential can be curled as a **B**-field, and that **B**-field can be totally confined inside a toroid, inside a long coil, or in certain magnetic core materials (as in the motionless electromagnetic generator or MEG for short). The **A**-potential will be replenished as fast as you withdraw the "total **B**-field" from it. So outside the toroid or the long solenoid, you will have as much **A**-potential energy as you started with, and the Aharonov-Bohm effect proves that the energy is there and will interact with electrons. Meanwhile, in the trapped **B**-field you also have drawn off as much energy as ostensibly the **A**-potential contained in the first place.

ENERGY, ELECTROMAGNETIC

Any deterministic or coherent structuring, either dynamic or static, existing in the virtual photon or charged particle flux of vacuum.

Note that, since a photon may also be considered a positron-electron pair, the flux of charged virtual electrons and positrons is included in the flux of photons.

ENERGY FLOW

The passage of energy, in any form, in one direction or generally in one direction.

Even though this "definition" is in error, we now just bypass the unresolved "observables do not persist" problem and the 4th law nature of change (e.g., motion) problem and proceed.

Note that this energy flow may be the overall movement of an omnidirectional energy flux, or it may be the movement of waves, or both. It may be in the kinetic energy of a moving mass. If the flow is everywhere the same, or even approximately the same, we often speak of the entire "flow" as just "energy." Often energy flow is also considered to have occurred from a region of more intense energy flux to a region of less intense energy flux, and vice versa. In other words, energy divergence or convergence is also considered as energy flow. As can be seen, *the usage of the term "energy flow" is not precisely defined in physics! It isn't going to be, at least not in ordinary Aristotelian logic terms.*

ENERGY FLUX

The passage of energy flow, in any form, through a unit area, and in any direction (usually all directions).

This includes both passage in a single direction, or passage in multiple directions at once.

ENERGY, FREE

Any environment or entity which freely emits, furnishes, or makes available energy which can be either collected and used as furnished or transduced into usable form and collected and used to power loads and do useful work.

The word "free" does not apply to costs, but rather to the source of the energy. Of course the ideal is energy that is both free for the taking (collecting and using) and also inexpensively taken and used.

Implicit in the notion of free EM energy from the vacuum are five key concepts: (1) the local vacuum/spacetime itself is filled with EM energy of generally unusable form, (2) some sort of organizing principle is utilized in one part of the circuit or system to cohere the vacuum energy and transduce it into usable EM form, (3) a gating mechanism is utilized to divert the vacuum energy in transduced usable EM form from the active vacuum to the external circuits or load parts of a device, (4) the coherent gated extra energy available in the external circuits or load parts is intercepted by those circuits or load parts, couples to them, and potentializes them with extra EM energy, so that the energy is collected by the system and regauges the system asymmetrically, and (5) the external circuits or load parts then scatter or dissipate the coupled extra energy to produce useful work, without destroying the organizing and gating mechanism that is extracting and furnishing usable EM energy from the vacuum.

ENERGY SOURCE

A function or entity which furnished energy.

Since energy cannot be created or destroyed, there is really no such thing as a "source", though it is a term commonly used. So called "energy sources" actually gate energy, changing it from one form to another. As an example, all 3-space EM energy is gated into 3-3-space from the time-domain. To the gating entity or "source" of the 3-space EM energy, there is an input of EM energy flow from the time domain (complex plane). The source must be a broken 3-symmetry in energy flow, so that more primary 4-symmetry energy flow applies. Hence the conservation law applies to the inflow of energy from the time dimension and the outflow of energy in 3-space.

ENGINEERING, ENTROPIC

Engineering or designing systems and processes whose operation "spills" or wastes some energy.

Entropic systems—which are the products of entropic engineering—thus have COP<1.0 and function in forward-time.

ENGINEERING, NEGENTROPIC

Engineering or designing systems and processes whose operation freely "receives" excess energy, so that they output more energy than the operator inputs, the excess being received from the external environment or other source.

ENTROPY

Thermodynamics term representing a measure of a system's capacity to undergo spontaneous change. In short, a quantity which measures the extent to which the energy of a system is unavailable to do work.

Entropy is given by dS = dQ/T, where dS is an infinitesimal change in entropy for a system absorbing an infinitesimal quantity of head dQ at absolute temperature T. In statistical mechanics, entropy is a measure of the disorder in a system and is given by S = k lnP + C, where S is the value of entropy (disorder) for a system in a given state, P is the probability of that state's occurrence, k is a fixed constant, and C is an arbitrary constant. Intuitively, the concept of entropy corresponds to the concept of disorder. We specifically call attention to the fact that the "S" used in representing entropy is not at all the **S** used for Poynting flow.

In physics, a measure of the randomness or disorder of a system. Given by S = k ln g, where S is the entropy, k is the Boltzmann constant, and g is the total number of microstates available to the system. Sometimes stated as S = k ln (multiplicity).

Intimately connected with the Second Law of thermodynamics, which may be stated for the macroscopic case (after Baierlein) as follows: "If a system with many molecules is permitted to change, then—with overwhelming probability—the system will evolve to the macrostate of largest multiplicity and will subsequently remain in that macrostate. Stipulation: allow the system to evolve in isolation. (The stipulation includes the injunction, do not transfer energy to or from the system." [Ralph Baierlein, Thermal Physics, Cambridge University Press, Cambridge, 1999, p. 29].

ENTROPY, NEGATIVE (NEGENTROPY)

In a sense, the reversal of disorder, or reversal of entropy.

Since the normal or forward flow of time is entropic, negentropy is intimately related with time-reversal. This can be seen crudely this way: As a physical thing exists in time, it decays, ages, deteriorates, etc. In short, its ordering as a viable separate thing gets more and more disrupted. If it is then "reordered" precisely back to its original state, that is obviously a time-reversal of that entity.

Since the production of energy is connected to the production of more ordering, then it would seem to follow that any negentropic process also produces more energy. Or, that production of excess energy accompanies a negentropic process, and vice versa.

When we factor in the giant negentropy process, it is seen that all EM spatial energy comes from the time domain, via the broken 3-symmetry of the source charge or source dipole. Here we have a pure negentropic process. Hence we may now advance a new definition of negentropy for electrodynamics: *negentropy is the direct and ongoing conversion of time-energy (time-structuring and time-ordering) into 3-space EM energy*. Dipolarity (polarization) is the process initiating and producing the negentropy. Polarization is accompanied by ongoing negentropy so long as the polarization persists.

Another way of defining negentropy even more rigorously—for electrodynamics—is to define it in spacetime as a *broken 3-symmetry in EM energy flow with concomitant relaxation to a more primary 4-symmetry between time-energy flow and 3-spatial EM energy flow, where time-energy flow is transduced into 3-spatial EM energy flow.*

When a system with one measure of multiplicity progresses to a state with a decreased measure of multiplicity; i.e., when its total number of microstates decreases in the transition. A nonequilibrium steady state (NESS) system can exhibit negative entropy, and the entropy can further decrease progressively toward negative infinity as time passes. [D. J. Evans and Lamberto Rondoni, "Comments on the Entropy of Nonequilibrium Steady States," *J. Stat. Phys*., 109(3-4), Nov. 2002, p. 895-920]. Note that the Second Law of thermodynamics only rigorously applies to an isolates system, where neither mass nor energy crosses the boundary of the system. In the NESS system, that prohibition is violated, hence the second law need not apply. The common source charge is an example of such a NESS system continuously producing negative entropy, because it absorbs virtual energy from the vacuum, transduces it into observable energy, and re-emits the energy as observable photons radiating at light speed in all directions and forming the associated EM fields and potentials and their energy.

ENTROPY (POSITIVE)

When a system in a state with ordering progresses to a state with less ordering, i.e., when its total number of microstates increases in the transition.

ENZYME

Any of various proteins or conjugated proteins (compound of a protein and a nonprotein) produced by living cells, that serves as a catalyst for specific biochemical reactions at body temperatures.

EPIDEMIOLOGY

The study of the various factors influencing the occurrence, distribution, prevention, and control of disease, injury, and other health-related events in a defined human population.

EQUILIBRIUM

In physics, the state of a system in which opposing forces balance each other; i.e., sum to a vector zero.

In mechanics, a system of particles where the net force acting upon each constitutent particle is zero.

In chemistry, the state of a solution where the forward and reverse reactions are equal and balance each other, so that the chemical reactants and products maintain the same amounts.

EQUIVALENCE PRINCIPLE (PHYSICS)

One of the principles of relativity theory. The mass of the body determined by using the gravitational force on it to measure the mass, and the mass of the body determined by using inertial force on it to measure the mass, yield equal measurements for the mass.

ETHER

An extremely fine substance theorized to exist in space in lieu of sheer emptiness.

Discussed by Tesla, Einstein, Whittaker, and others. Originally conceived as the luminiferous ether, a thin material fluid pervading all space. Maxwell, e.g., believed in this material ether, and formulated his theory accordingly. Thus he mistakenly provided forces in the vacuum, which forces require a material vacuum. I.e., mass is a component of force; there is no force without mass, since $\mathbf{F} \equiv d/dt(m\mathbf{v})$. The hoary old medieval notion that a separate force acts upon a separate mass that it affects, is completely in error, though still utilized in mechanics! Modern field theorists know better, but correction of this massive error in physics has not been widely accomplished.

Originally, the ether was seen as a ghostly-thin, *material*, fluid medium postulated to fill space and carry electromagnetic waves, similar to the way in which a gas carries sound waves. Faraday and Maxwell added the assumption that EM fields existed as material taut strings (Faraday's lines of force) with conveniently missing endholders to provide the tension on the strings. The Michelson-Morley experiments eliminated any such material ether, but not a Lorentz-invariant nonmaterial ether (of which vacuum itself is one example, in the modern view). Maxwell's equations were derived from a mechanical ether theory. Einstein once proposed that the vacuum, complete with its electromagnetic fields, should be called the new *ether*. In our own approach we have come full circle back to Einstein's suggestion, since the so-called "fields" are really just curvatures of spacetime and are included in our use of the vacuum as a giant potential comprised of virtual particle flux. The Sachs unified field theory, I believe, is the best available, particularly when the Evans O(3) symmetry electrodynamics is included as a special subset of it. In my own view, I regard "vacuum potential" and "spacetime" as essentially identities. Thus both the vacuum potential and spacetime have further internal structuring and dynamics. In relativity, this view is akin somewhat to the notion of "subspace" used on the Star Trek series.

Today the word "ether" is again acceptable in the literature when used in context of its modern quantum mechanical meaning. The "ether gas"—the quantum mechanical vacuum—is considered to be composed of virtual particles. The particles spontaneously come into being and then vanish so quickly they cannot be individually detected. That is, today the ether is regarded as a sort of specialized virtual particle gas—sort of a gas of "effervescent energy bubbles", so to speak—where the individual particles are continually being created and annihilated at a fantastic rate.

A good reference on the modern view of the vacuum is I. J. R. Aitchison, "Nothing's plenty: The vacuum in modern quantum field theory," **Contemporary Physics**, 26(4), 1985, p. 333-391. For an O(3) treatise, see M. W. Evans, P. K. Anastasovski, T. E. Bearden *et al*., "Derivation of the Lehnert field equations from gauge theory in vacuum: Space charge and current," **Foundations Of Physics Letters**, 13(2), Apr 2000, p.179-184. It is shown that the Lehnert field equations in vacuum, with concomitant space charge and current, can be derived straightforwardly from standard gauge theory applied in vacuum, using the concept of covariant derivative and Feynman's universal influence. The Lehnert and Proca field equations are shown to be inter-related through the well-known de Broglie theorem, in which the photon mass can be interpreted as finite. These ideas go some way towards addressing the inconsistency inherent, in Maxwell's famous displacement current, which has no concomitant vacuum space charge.

For technical insight into the attributes for extracting EM energy from the vacuum, see particularly M. W. Evans, P. K. Anastasovski, T. E. Bearden *et al*., "Classical electrodynamics without the Lorentz condition: Extracting energy from the vacuum," **Physica Scripta** 61(5), May 2000, p.513-517. It is shown that if the Lorentz condition is discarded, the Maxwell-Heaviside field equations become the Lehnert equations, indicating the presence of charge density and current density in the vacuum. The Lehnert equations are a subset of the O(3) Yang-Mills field equations. Charge and current density in the vacuum are defined straightforwardly in terms of the vector potential and scalar potential, and are conceptually similar to Maxwell's displacement current, which also occurs in the classical vacuum. A demonstration is made of the existence of a time dependent classical vacuum polarization which appears if the Lorentz condition is discarded. Vacuum charge and current appear phenomenologically in the Lehnert equations but fundamentally in the O(3) Yang-Mills theory of classical electrodynamics. The latter also allows for the possibility of the existence of vacuum topological magnetic charge density and topological magnetic current density. Both O(3) and Lehnert equations are superior to the Maxwell-Heaviside equations in being able to describe phenomena not amenable to the latter. In theory, devices can be made to extract the energy associated with vacuum charge and current. More than a dozen ways to approach extracting EM energy from the vacuum are presented.

EVANS, MYRON W.

Noted chemical physicist, primary developer of O(3) symmetry electrodynamics, and Director of the Alpha Foundation's Institute for Advanced Study (AIAS).

Under Evans, the work of the AIAS has made enormous contributions to physics and particularly to the extraction of usable EM energy from the vacuum. In the opinion of the present author, Evans is perhaps the single most important scientist in the Western world in the emerging field of electrical energy from the vacuum and in solving the world energy crisis.

EVIL

Refers to an act or acts perceived to be detrimental to the receiver or referent, in the positive time stream.

Oddly, the chain of events perceived to involve "evil" to a referent in the forward time stream, would be perceived to be equally *beneficial* to the referent, viewed in the *negative* time stream. In other words, evil in general is a synthesis of the results of observed actions or acts in the *forward time motion*, hence it is conjugated when time flow is reversed.

This is not just an idle question. In our physical body, the photon interaction with the electron shells of the atoms in the body largely determines the observed forward movement of one's material body through time. The conscious mind, fitted to the single photon interaction, thus perceives its "existence" in such terms. Meanwhile, in the nuclei of the atoms of our material body, the charge and hence the field interactions are reversed (giving Newton's third law reactions). That of course is a time-reversed flow of events, not sensed by our conscious mind, but possibly sensed by our deep unconscious mind. The question then arises, "Do we then actually exist both forwards and backwards in time?" In terms of good and evil, if the answer is yes, then this would have profound implications to theology and to the study of human consciousness.

Theologians (and philosophers) have pondered the "nature" of good and evil for literally thousands of years, and have reached no truly firm conclusion to date. The sticking point (theologically) seems to be the puzzle of a perfect, "all good" creator who had to have created evil also (since the Creator is axiomized to have created all). To the question, "How could a perfect Creator have created—or even tolerated—evil?", theologians have yet to find a satisfactory answer. Neither could they find a satisfactory answer to the question of, "How can the Creator, being all-just, and being all-powerful, then allow any evil act to occur?" In short, why does the Creator seemingly not "police up our perceived imperfections in the creation?" In short, theologians struggled with a formidable problem of how to justify the Creator's continued tolerance of evil, even for a moment.

There is no satisfactory answer to such questions, of course, in 3-law Aristotelian logic, because they are four-law logic situations. However, since the 3-logic is incomplete, one should examine the question in 4-law logic, and also in light of one's assumptions regarding the existence of the Creator. The question is unresolvable in 3-law logic and with the assumption of a Creator traveling through time, as we perceive ourselves to do. However, if time itself is a creation, then the axiomized Creator may be more properly axiomized as existing both in and outside time, and "everywhere in time at once" as well. The unlimited Creator must even be postulated to be able to "both be and not be simultaneously; if He cannot do that little trick, He has a limit." That trick must be allowed, else the Creator has a limit and is thus imperfect. But to such an axiomized Creator "permeating time everywhere at once, from beginning to end, which shall be the "beginning" and which shall be the "end?" And if we pick a beginning and an end, what shall be the "intermediate ordering" that we pick? There is no absolute position in either space or time to the "everywhere and everywhen at once" axiomized Creator.

The problem of good and evil then becomes a similar problem to the "wave or particle" question. Good and evil are two sides of the same coin, transposed one into the other by time-reversal. With respect to finite creatures perceiving themselves moving forward in time, not existing in the future and not existing in the past, the question merely demonstrates that our perception itself is in error.

It may be, then, that there is a solution (whether one prefers it or not!) to such profound and ancient philosophical and theological problems in four-law or five-law logic. However, we will leave that question to the logicians and to the theologians to more properly decide.

EXCESS COLLECTED ENERGY

Collection by an interceptor/collector of a greater fraction of the EM energy flow impinging upon it, than is normal.

Any static electric or magnetic charge, e.g., with an EM energy density flow impinging upon it, has excess "energy collection" or "energy collecting" upon it, due to the altered vacuum virtual photon flux that is now exchanging with it. In a nominal electric circuit, e.g., a single "pass" of the EM energy flow from the source dipole, along the circuit conductors and across the conduction electrons, causes an "excess energy collection" upon the intercepting surface charges in the conductors. This potentializes the Drude electrons in the circuit and leads to subsequent dissipation in the loads (and losses) of about 10^{-13} of the EM nondiverged Heaviside energy flow that actually was extracted by the source dipole from the vacuum and sent down through space surrounding the conductors of the external circuit.

That is a single-pass energy collection fraction for a static charge. Almost all the Heaviside energy flow missed the circuit and passed on beyond the circuit "collectors" in one pass-by at essentially the speed of light, on out into deep space and beyond. On the other hand, if the already-passed EM energy flow is retroreflected, so that it returns for another pass along the circuit, then an *additional* amount of the repassing energy can be collected by those sluggish electrons. In a nominal circuit being used as an example, the electrons travel only about 5 or 6 inches per hour longitudinally down the conductors, restrained by the repulsion of the electrons beyond them. So *multiretroreflection*, *multipass*, *multicollection* can be used to provide excess energy and overunity efficiency. This is a change to the present statement of the work-energy theorem, which up to now has assumed single pass, single energy collection. The well-known anti-Stokes emission from certain highly scattering, optically active media, e.g., produces more energy radiating back out of the media than the amount of stimulating radiation energy input into the media. This is Letokhov's "negative absorption of the medium", which is really the excess emission from the medium due to retroreflection and multiple re-collections.

Also, if the intercepting charge is resonated, it sweeps out a greater geometrical cross section in the streaming energy flow, thereby diverging more and thus "collecting" more energy. In the Bohren experiment, e.g., this effect yields collection of some 18 times as much energy by the resonant charge as the same charge collects in static mode.

EXOTHERMIC

Giving off heat, or emitting scattered EM energy. Producing forward time energy.

FARADAY, MICHAEL

Noted English physicist and chemist, 1791-1867, who discovered field theory and electromagnetic induction. Faraday invented the dynamo also and formulated his laws of electrolysis.

His work directly inspired Maxwell, who vowed to study no other electromagnetics theory until he had captured Faraday's work in a mathematical theory.

FIELD

In mathematics, a set with two binary operations. In electromagnetics in more common terms, it is a region consisting of magnitudes and/or vector directions assigned to some active entity (spacetime itself) at each point in the region.

Designated addition and multiplication, satisfying the conditions that the set is a commutative group with respect to addition, that the set with the identity of the additive group omitted is a commutative group with respect to multiplication, and that multiplication distributes over addition for all elements in the set.

For our purposes, in plain language the fundamental notion is that a "field" is a sort of cleared, level space or region (e.g., in spacetime) where things can be placed and actions can occur amongst them, to them, on them, and of them. What the "place or space" is, can get a bit complicated, as can what is placed there and what actions are permitted. In short, we view a field as an altered (curved) region in spacetime, and this special curvature interacts with certain kinds of entities placed in that region. In return, those entities also interact back upon the spacetime curvature to alter it. Hence there is a dynamic two-way interaction between field and matter, where half of this interaction (the back-interaction of charge or matter) is missing from present classical electrodynamics.

EXOTHERMIC EXPLOSION

An explosion where ordinary heat and electromagnetic energy are released and radiate away from the explosive site. All normal explosions are exothermic.

Particularly used for a pulsed longitudinal EM wave interferometer, which in the distant interference zone (IZ) will produce a sudden eruption of scattering EM energy from the local spacetime curvature suddenly induced, when the interferometry transmitter chassis grounds are biased well above the ambient potential in the distant IZ.

FERMI LIQUID

A liquid where the individual particles or molecules comprising it are basically non-interacting, so that they can roam freely.

In an electron gas in a conductor, e.g., treatment of the free conduction electrons as a gas allows a theoretical modeling and explanation of conduction and resistance. Contrast to a Luttinger liquid, where the electrons interact with each other and thus enable the formation of collective phenomena.

FEYNMAN, RICHARD

Noted physicist, Nobelist, and co-developer of quantum electrodynamics.

Feynman is particularly noted for his refreshing three volumes of physics: See Richard P. Feynman, Robert B. Leighton and Matthew Sands, **The Feynman Lectures on Physics**, Addison-Wesley, New York, 1963. The book is particularly noteworthy in that it gives the student some insight into foundations problems in physics. E.g., in Vol. I on p. 2-4, Feynman defines the electric field not in terms of force per unit charge *per se*, but in terms of its potentiality for producing a force only when a charge is present for the force to be developed upon.

FEYNMAN DIAGRAM

A two-dimensional diagram of particle interactions, both in the virtual and observable levels, and both backward and forward in time and named after Richard Feynman who first employed them.

FIBER FUSE

Effect in fibers or fiber optic cable, whose core contains germanium, whereby heating the cable at one spot with a small flame will launch a focused traveling heat energy effect which melts a small hole in the core about every centimeter, and marches down the cable at about a meter per second to the end of the cable, destroying the optical transmission capability and ruining the cable.

Oddly, by igniting the fiber fuse from the other end of the damaged cable, a reverse fiber fuse effect will often march back down the cable in similar fashion except that it fills in the melted holes in the core, restoring the transmission capability of the cable.

If the energy required to melt all the holes (or fill them again) is taken into account, the amount of energy required to launch the fiber fuse is much less. This phenomenon does not appear to have an adequate technical explanation at present.

For an excellent description with photographs, see Ivars Peterson, “Fibers With Flare,” **Science News**, 140(13), Sep. 28, 1991, p. 200-201. For technical information and analysis, see D. P. Hand and P. St. J. Russell, “Solitary thermal shock-waves and optical damage in optical fibers,” **IEE Colloquium on ‘Non-Linear Optical Waveguides’**,” IEE Digest No. 88, London, England, 1988, p. 101-103; — Soliton-like thermal shock-waves in optical fibres: origin of periodic damage tracks," **Fourteenth European Conference on Optical Communication (ECOC 1988),** Sep. 11-15, 1988, Publication No. 292, 1(2), 1988, p. 111-114; — “Solitary thermal shock waves and optical damage in optical fibers: the fiber fuse,” **Optics Letters**, 13(9), Sep. 1988, p. 767-769; D. P. Hand and T. A. Birks, “Single-mode tapers as ‘fibre fuse’ damage circuit-breakers,” **Electronics Letters**, 25(1), Jan. 5, 1989, p. 33-34.

See P. St. J. Russell, “Power Conservation and Field Structures in Uniform Dielectric Gratings,” **Journal of the Optical Society of America A**, 1(3), Mar. 3, 1984, p. 293-299. Russell is actually referring to apparent violation of local conservation of energy. This would be indicated if the vacuum-to-mass interaction is not taken into account. Russell’s analysis therefore supports the fact that (i) the vacuum-mass interaction is required, (ii) the fiber fuse does utilize some of its gated vacuum energy (i.e., the usually non-diverged portion of the Poynting flow), and (iii) the fiber fuse is a legitimate, repeatable overunity process, although a "runaway" process, uncontrolled, and not sustainable.

FIELD

In physics, "a region of space marked by a physical property, as gravitational or electromagnetic force or fluid pressure, having a determinable value at every point in the region."

[Thanks to **Webster's II New Riverside University Dictionary**.]

Here one must *not* think of "space" as emptiness, as mathematicians do, but as a virtual particle flux, a dynamic entity, and as dynamic spacetime. A field then is a set of entities and their relationships and operations in a region of *that* kind of space, where the entities and operations are themselves "space stuff". They are all "virtual" in that they are not individually observable. However, their impact upon or interaction with mass—particularly charged mass—can be and often is observable, in that we can see some change of the mass (its direction of travel, translation, acceleration, deceleration, rotation, generation of current, etc.). If the entities are point-like and are naively supposed to have magnitude only, or if we only specify their energy density magnitude at each point, then that "marked space region" is said to be a *scalar field*. If the entities are point-like but have both magnitude and direction, they are said to be a *vector field*.

Further the deponent saith not because even the foundations physicists are in hot water in trying to define the field, and if the deponent saith more he will surely deep-fry in hot oil!

FIELD, SCALAR

A field, to any point of which is assigned a magnitude only.

FIELD, VECTOR

A field, to any point of which is assigned both a magnitude and a direction.

FLAT (UNCURVED) SPACETIME

A vacuum/spacetime whose virtual particle flux intensity—and therefore its local energy density—does not change as a function of spatial position or averaged time.

That is, a flat spacetime in my view is a quantum mechanical vacuum whose virtual particle flux and energy density are constant in magnitude and internal constitution with respect to spatial position and in averaged time. Note that a flat spacetime (vacuum potential) can still contain vacuum engines, and thus still be *dimensioned*. In that case, contrary to normal physics, the flat spacetime itself will still interact with an embedded object and change it, even though it may not translate it. To perform transmutation of elements, e.g., one is interested in just such engines and not in translating through space the element being treated. This dimensioning or activation of the local flat spacetime can result in an otherwise unexpected, seeming violation of one or more laws of nature in the dimensioned region.

FISSIONING, ACTION

The splitting of the action quantum into two canonical variables (for example, energy and time), only one of which can normally be completely detected or measured. ("Action" has the dimensions of angular momentum—energy x time, momentum x length, etc.)

Fissioning produces length, discrete bit by discrete bit, and time likewise. The physical reality of separated physical objects is thus continually created, discrete bit by discrete bit, monocularly. All that ever observably exists in the "present" is a single quantum change, just occurring. Recombining of the two canonical action fission fragments is called "fusion." Fusion also occurs monocularly, quantum by quantum. Rigorously, the physical world of separated objects never exists as such except in memory recall of vast numbers of past ordered quantum changes that occurred one by one.

FLUX

The amount of some quantity (such as energy, particles, volume of fluid, etc.) flowing across a given area (usually a unit area perpendicular to the flow) per unit of time.

The term flux density is now more commonly used. Loosely, "flux" refers to the perpendicular flow through an area, while "flux density" refers to the magnitude or intensity (rate) of the flux. In some cases such as a flux of particles of different velocities, the number of particles may be multiplied by the average velocity to give an average flux density that is weighted.

FLUX DENSITY

The amount of some quantity (such as energy, particles, volume of fluid, etc.) flowing across a given area (usually a unit area perpendicular to the flow) per unit of time.

FOGAL, WILLIAM (BILL)

Soon-to-be-noted researcher and inventor of the Fogal semiconductor (two patents so far), as well as a superluminal infolding-outfolding communication system and other remarkable longitudinal EM wave processes.

I am happy to be a friend and colleague of Bill Fogal.

FOGAL SEMICONDUCTOR

A special semiconductor invented by Bill Fogal which, in its operational regime, utilizes an integrated semiconductor, tantalum capacitor, and feedback resistor to accomplish charge blocking (blocking of electron current flow dq/dt) while passing displacement current d/dt

The Fogal semiconductor can also accomplish amplified phase conjugation of signals as well as infolding (translation of input transverse EM waves to output longitudinal EM waves) and outfolding (translation of received input longitudinal EM waves to output transverse EM waves). Used in communication systems, it opens the use of the unlimited "infolded" electromagnetics bandwidth. Since it may communicate using longitudinal EM waves, it is also usable for superluminal or a specialized "tunneling" communication through the "interior" of normal EM waves, potentials, and fields.

See William J. Fogal, "High Gain, Low distortion, Faster Switching Transistor," U.S. Patent No. 5,196,809, Mar. 23, 1993; — "High Gain, Low Distortion, Faster Switching Transistor," U.S. Patent No. 5,430,413, July 4, 1995, a continuation of his earlier patent.

FORCE

In mechanics, identically the time derivative of momentum, or $\mathbf{F} \equiv d/dt(m\mathbf{v})$.

Simply, changing of the old concept of mass-motion. One must realize that it is not the mass in motion, but the single undivided quantity "mass-motion" or "mass-velocity" (momentum) that is changed. In short, $\mathbf{F} \equiv d/dt(m\mathbf{v})$. In present EM theory, force fields are erroneously taken to exist in empty, massless vacuum. However, the mechanical definition is an identity, not an equality. Thus force does not *separately exist in contact with* a mass, but *consists of* a changing "mass-motion." Since this force can be induced into and of the mass-motion target at a distance, in the new approach one is confronted with the fact that there is a more fundamental mechanism that produces force itself, and that is a curvature of spacetime.

Distant curvatures of spacetime to produce forces on exposed charged mass systems are also engineered by longitudinal EM wave interferometry.

FORCE FIELD

An effect that exists as a local vacuum virtual particle flux interaction upon and with a unit mass or unit charge whereby a particular type of matter is affected.

The force field has two components, one the mass and the other massless. In electrodynamics, one normally thinks (erroneously!) of the massless component, and refers to that component alone as "the force field." This considers the "force field" as a separate entity, acting upon a separate "mass." Whether it is logically correct or not, that is the prevailing way physics and electrodynamics uses it! So in this definition, let us momentarily accept the common incorrect usage, for convenience, while pointing out the real definition as we need to.

For example, conventionally the EM force fields can affect and change the state of motion of any charged particle or any magnetic particle. In classical physics, the force fields are considered the primary causative agents; when these fields are zero, then the motion of the particle or system is unaffected. Consequently, conventional EM theory assumes that all the EM phenomenology ceases once the force fields are absent. Today we know that is not true at all, as we explain in this glossary.

FORCE-FREE PROPAGATION

Propagation of force-free disturbances in the vacuum flux

(i.e., infolded inside the ambient vacuum potential, or inside a constant DC voltage.) Such "infolded" propagation is not limited to the speed of light, but may even travel in the Coulomb gauge so that it is instantaneous. More usually, it can travel superluminally. It may be regarded as a special form of "tunneling", which is known (both theoretically and experimentally) to produce superluminal propagation to the external observer. The music of Beethoven's 40th symphony, e.g., has been experimentally transferred between two points in a physical waveguide by such "quantum tunneling" at over four times the speed of light in vacuum.

We regard tunneling as moving in a sort of "subspace", i.e., within the internal structuring of spacetime itself. It is not limited by the speed of light and Einstein's postulate, which we believe only applies to signals moving in spacetime in bulk, and not to signals moving *within* substructuring inside that spacetime.

FOUNDATIONS OF MATHEMATICS

The concepts, operations, assumptions, postulates, logic, definitions, and axioms of algebra systems.

FOUNDATIONS OF PHYSICS

The postulates, assumptions, concepts, and definitions upon which a scientific physics model rests. Included are the postulates, concepts, assumptions, definitions, and operations of the mathematics in which the scientific model is expressed, as well as the postulates, concepts, assumptions, definitions, and operations of the physics entities and functions assigned to the mathematical symbols.

Thus "scientific truth"—even mathematical truth (see Morris Kline's **Mathematics: The Loss of Certainty**—is actually a *qualified* truth. What is true in one model (one set of postulates, assumptions, concepts, and definitions, including those in the algebra) may not be always true when one or more of the postulates, assumptions, concepts, and definitions is/are changed, and/or when the topology of the mathematics in which the model is expressed is changed, etc.

The major flaws in present physics models involve errors in the foundations. However, a successful physics model is rather quickly dogmatized and often turned into a belief structure by many scientists rather than being regarded as a tentative model. Consequently, scientists who attempt to do serious work in foundations are generally ignored or ostracized and rather vehemently attacked if they propose any significant changes to one of the dogmatized models. Particularly, all funding and "benefits" of the scientific bureaucracy are denied the heretical foundations scientist, unless he or someone can rather quickly come forth with an iron-tight experimental proof of the heresy. Any attempted change in foundations is usually met with ad hominem attack, a barrage of criticism, loss of position, and denial of research funding. Science has a long history of just such dogmatic oppression of great scientific discoveries. To name a few (there are hundreds): The first laser paper was rejected by the journals as being ridiculous. When Mayer proposed conservation of energy, he was hounded and ridiculed so fiercely that he suffered a nervous breakdown and attempted suicide. Years later, near the end of his life conservation of energy was adopted because it greatly facilitated understanding and calculation, and the same system now lionized him as a scientific hero. Ovshinsky suffered personal attack, ridicule, and charges of charlatanism in pushing amorphous semiconductors; everyone knew that only crystalline semiconductors could work. The situation changed when several thousand Xerox machines were observed to now contain amorphous semiconductors which were working just fine! Louis de Broglie's matter wave hypothesis caused consternation to his thesis advisors; but because he was Prince Louis de Broglie, they felt obligated to send it to the great Einstein so that he would reject it and then they could regretfully reject the thesis of the Prince. When Einstein replied that it was probably true, they felt they had no choice but to publish it *because de Broglie was a Prince of the old French aristocracy, and as such was not to be casually trifled with.* So foundations work is fraught with the greatest peril to the practitioner. Yet it is the most important work in physics, and it is a continuing black mark against the scientific establishment that they do not openly encourage *and fund* the most able physicists, grad students, and post-docs to examine and revise the errors in foundations concepts and postulates. Because of the prevailing dogmatism, science itself continually strangles the new ideas and concepts that would provide the physics of the 22nd century now. In an eerie turn of events, science has become in a strange way its own worst enemy, and the strongest barrier to the advance of science.

FOUR-SPACE (4-SPACE)

The "normal" spacetime used in physics, consisting of three spatial dimensions and one time dimension. Minkowski spacetime.

FOURTH LAW OF LOGIC

the law that a thing and its opposite become identical on the boundary, i.e., in multiple simultaneous observation. Identity is merely the loss of observational or perceptual distinction; when formerly "two" objects are simultaneously observed by a single observer, two slides have been shown at once in the slide projector. It does not matter at that point what each was individually observed to be before; now there is no observable distinction or difference. We previously showed that the law is implicitly assumed in the three laws of Aristotelian logic anyway, and published a simple proof of the fourth law. Without the fourth law, Aristotelian logic "eats itself". What results in the four law logic is that either (1) the three laws apply explicitly and the fourth implicitly, or (2) the fourth law applies explicitly and the fourth implicitly. This *application rule* itself can be taken as a fifth law of logic. The fourth law is also the law of the paradox: I.e., when something is true but violates one or more of the Aristotelian laws, it is a case where the fourth law applies explicitly. The conclusions derivable from a four law logic agree generally with the conclusions derivable from G Spencer Brown's **Laws of Form**.

FOUR-WAVE MIXING

A nonlinear multiwave mixing effect when four waves mix in a highly nonlinear situation so that wave to wave interaction occurs.

FRACTIONAL CHARGE

A hypothetical particle having a charge less than the electron's charge. Often called a quark, where its charge is 1/3 or 2/3 the charge of the electron.

A few years ago, Stanford University researchers found evidence of free quarks. There is also now the fractional Hall effect. In the 1920's Ehrenhaft reported the discovery and production of fractional charges of all sizes, and his experiments have been replicated by Michailov, with papers by Michailov and Barrett.

In the new approach, when time-energy is utilized, quarks can be freed or nearly freed rather easily in "time-reversal zones". It would appear that, as the new approach develops, free quarks will become a normal event rather than one intensely sought but terribly difficult to come by experimentally.

FRAME, LORENTZ

A frame of reference which is not accelerated with respect to the laboratory observer.

In this case, the frame may be rotated (moving at a constant velocity) but it is not rotating (the frame is not accelerated with respect to the observer, and spacetime is not curved). In this case special relativity applies, as do the conservation laws. If the local spacetime is curved, the frame is accelerated and spacetime is curved. Locally, then, general relativity applies. In this case, locally the conservation laws (energy, momentum, charge, and spin) can be violated. However, in ordinary general relativity, it has been tacitly assumed that locally the curvature of spacetime is negligible. Hence locally a Lorentz frame is assumed, and the conservation laws are assumed to apply locally also. In scalar electromagnetics, the local spacetime is always curved and general relativity applies locally. In this case, the conservation laws need not apply.

FRAME, REFERENCE)

A spatial, organized, measured lattice placed in "emptiness" (space, spacetime).

Normally refers to a 3-dimensional, spatial frame. All objects and points in the "universe" or spatial frame are considered to simultaneously coexist at separate, measured points in the frame. Differs from the vacuum in that, rigorously, vacuum has no existing definite lengths and no existing definite time intervals, as these appear only after measurement or detection, and are relative to the observer and to the interactions ongoing as well as in the detection process itself. The "laboratory frame" is the static reference frame of the observer or measurement. A separate reference frame may be assumed to exist for any fixed or moving object, or centered on any point in another frame. When a type of frame is assumed, the entire class of physical interactions that can occur has been restricted to an assumed set or type. In other words, given the frame, the *conventional* physics has been assumed. One of the greatest restrictions of an assumed "frame" is to rule out the consideration (existence) of other higher dimensions.

Note that, in the new unified field theory approach, the other higher dimensions are always available and cannot be ruled out in general, but only in some special case. Every curvature of spacetime, and any internal additional curvature to that primary curvature, adds a new dimension. In our view, a spacetime may be "flat" in overall curvature, but consist of internally structured deterministic curvatures or "engines". In this view, normal inertial frames, e.g., may still contain vacuum engines, which will not affect the normal *bulk translation* rules, but may affect any or all of the nontranslation mechanisms, including the very laws of nature in many cases.

FREE ENERGY

Excess energy freely received from its external active environment by an open system that is far from thermodynamic equilibrium in its exchange with that environment.

To use this free excess energy, it must be collected, transported to a load or loads with minimal losses, and then dissipated in the load(s) to power them, without any substantial portion of the free energy being used to close the system's "gate" through which the excess energy is input to it.

There is a separate thermodynamics for such open systems far from thermodynamic equilibrium in their active environmental exchange. Such a system is permitted to exhibit five "magic" functions: it is permitted to (1) self-order, (2) self-oscillate or self-rotate, (3) output more energy than the operator himself inputs (the excess energy is freely received from the active environment, (4) power itself and its load simultaneously (all the energy is freely received from the active environment), and (5) exhibit negentropy.

The entropy of such a system cannot even be calculated. Some useful references are: Ilya Prigogine with D. Kondepudi, **Modern Thermodynamics: From Heat Engines to Dissipative Structures**, Wiley, Chichester, 1998; Ilya Prigogine, **The End of Certainty: Time, Chaos, and the New Laws of Nature**, Free Press, New York, 1996, 1997; G. Nicolis and I. Prigogine, **Exploring Complexity**, Piper, Munich, 1987; Gregoire Nicolis, "Physics of far-from-equilibrium systems and self-organization," Chapter 11 in Paul Davies, Ed., **The New Physics**, Cambridge University Press, Cambridge, 1989, p. 316-347.

FREE ENERGY SYSTEM

Any open system not in thermodynamic equilibrium, which freely receives excess energy from an external source,

...and collects and utilizes this free excess energy to freely power external loads, so that a permissible system COP>1.0 is achieved, as allowed by the nonlinear thermodynamics of open systems in disequilibrium with their environment.

Implicit in the notion of free electromagnetic energy systems are six key concepts: (1) the local vacuum/spacetime is known to be filled with hidden (i.e., virtual) energy in violent motion, i.e., the local vacuum/spacetime is a violent virtual energy flux and therefore a scalar potential, (2) a broken symmetry—i.e., some sort of organizing and gating mechanism, such as the common dipole—in this hidden (virtual) energy flux of the vacuum is utilized as a source, to cohere the virtual energy and divert it as energy flow **S** = **E**×**H**, from the broken symmetry initiation point onto the external circuits or load parts of a device, (3) the coherent gated extra *virtual* energy flow available in the external circuits or load parts couples to (interacts with) the mobile charges in those circuits or load parts, so that gradients developed in the interacting virtual flux form force fields on and of the particle masses, driving the mobile charges along the circuit and through current-impeding circuit components such as loads, (4) in the interaction of the driven charges with the driving virtual energy flux, their spin and erratic motions integrate a tiny "coupling fraction" of the driving virtual energy into observable (i.e., macroscopic field) energy, thus creating the **E**-fields and **B**-fields, (5) the current-impeding external components or load parts scatter or dissipate the coherence of the driven charges, and thereby dissipate the collected energy or change the form of the collected field energy, thereby producing useful work, and (6) little or none of the excess collected energy in the circuit is split off and dissipated in the gate (asymmetry component serving as the **S**-flow source) to destroy the gate and thereby destroy its asymmetry in the vacuum flux, which is what is extracting and producing the free energy flow.

FUSION, ACTION

In the new approach, the recombining of two canonical bits of a fissioned action quantum.

The fusion process "cancels" the bits produced by the fission process, and constitutes a negative spacetime operation. The physical world is thus eliminated, bit by bit, in a monocular fusion operation that produces the "past". The "mass" of a particle is taken to be proportional to, and identically comprised of, the absolute value of its fission and fusion rate. When fission and fusion rates of a particle are equal, the particle is unaccelerated; when unequal, the particle is accelerated. Vice versa, when the particle is unaccelerated, the fission and fusion rates are equal, and when the particle is accelerated, the fission and fusion rates are unequal.

GAIA HYPOTHESIS

The hypothesis by Lovelock that the earth and its biosphere is a living thing, at least in some sense.

In the new viewpoint, there exists a biospheric quantum potential which contains an extended mind and therefore is indeed an extended lifeform—one which includes the earth and the quantum potentia all its creatures and species. In the new sense, even so-called "inert" matter is alive, being continually bathed by energy flow dimensioned with lifeform templates, and therefore equally alive in all directions and nonpreferential.

GATE

Refers to something (a component or function) which extracts some part of a flux or flow, compacting it into a stream, and "sending it out."

A moving board wall or gate may be swung into a river, e.g., to divert or "gate" some of the river's flow out into a sluice ditch and on to a waterwheel powering a mill. Similarly, a dipole extracts some of the energy from the vacuum virtual photon flux exchange with the end charges of the dipole, and "gates" (diverts) the extracted portion of energy out from the ends of the dipole as energy flows. This creates the scalar potential surrounding each charge, and also the **E**-fields. Even a "static" dipole does this "gating" of vacuum energy into an energy flow.

The fundamental gate for all EM energy in 3-space is the dipole or dipolarity. The source of the 3-space EM energy continuously emitted by any charge or dipole is an equal inflow of EM energy from the complex plane (from the time domain). Thus EM energy flow is conserved in 4 dimensions but not in 3-space. In particle physics, it is well-known that any dipole or charge is such a broken 3-symmetry in its fierce vacuum energy flux exchange. However, particle physics considers the input energy to be virtual particle energy from the vacuum and therefore random energy. Whittaker 1903 shows it is actually from the time domain of spacetime (from the complex plane) and the input energy flow from the vacuum is not random but precisely organized in a harmonic set of longitudinal EM phase conjugate waves. Of course by wave-particle duality we simply consider the two pictures to be just different and permitted models of the same thing.

GATING EFFECT

The effect of extracting part of a flux or flow, compacting it into a useful stream, and "sending it out."

See *gate*.

GAUGE

In electromagnetism, usually considered a possible choice for (change of) electric scalar potential and magnetic vector potential, without any net change of force fields so that the change satisfies Maxwell's equations.

Interestingly, gauge field theory includes the axiom of gauge freedom. In EM systems, this means that one is free to "regauge" or change the potential energy of the system freely and at any time, so long as the change results in a static stress potential energy change. In the real world, one may have to pay a little bit for switching. But essentially physics already assumes that one can cause his EM system to take on excess potential energy at will, so long as it is a *stress potential* energy change only.

In short, only the *symmetrical* regauging case has been considered in electrodynamics. Yet every electrical power system must first potentialize the system *asymmetrically* rather than symmetrically. In the theoretically perfect system, this asymmetrical regauging is done freely. Hence every electrical power system first breaks gauge symmetry, in order to take on extra energy so that it can do work. Further, the source of the potential energy flowing into the asymmetrically regauged electrical system so freely, comes from the source dipole's extraction of EM energy from the time-domain (complex plane) due to its broken 3-symmetry in EM energy flow.

So the highest "gauge" principle is that energy can be freely extracted from the vacuum, anywhere and at any time, freely and easily, by making a dipolarity—which changes a single potential and asymmetrically regauges the system.

It follows that one is in theory free to "dissipate" this excess free energy in external loads to power them. Again, in the real world one may have to pay some switching costs, but that can be minimized by efficient switching. However, since no conventional electrical power system accomplishes this free powering of its loads, it rigorously follows that the conventional system must self-enforce symmetry in its discharge of the free potential energy achieved by the initial *asymmetrical regauging*.

Thus, if we believe gauge field theory—the most modern of physics theories and in many ways the most useful—and also believe its assumption of free asymmetrical regauging that is hidden in its gauge freedom principle, then COP>1.0 electrical power systems are absolutely permitted by nature and by gauge field theory where asymmetrical regauging is deliberately used.

It follows that some feature in electrical power systems as we presently design and build them, must be preventing these systems from exhibiting overunity COP. And so it is. The ubiquitous closed current loop circuit results in the circuit forcibly and symmetrically regauging itself while dissipating its excitation energy to power its loads and losses. This forces half the collected regauging (free) energy to be dissipated in the external circuit's loads and losses, and half of it to be dissipated in the source dipole to scatter the charges and destroy the dipole. This means that less than half the available free regauging energy is used to power the load, while half is used to destroy the entity—the source dipole—actually furnishing the free regauging energy from the vacuum.

Hence all our present electrical power systems are inherently free energy systems freely extracting their energy from the vacuum, but are fiendishly designed so that they kill themselves (shut off all free asymmetric regauging energy from the vacuum, by destroying the source dipole) faster than they catch some of the free energy from the vacuum to power their loads.

To restore the source dipole requires at least as much energy dissipation as was done to destroy it. In our conventional self-destructive systems, the generator shaft must thus be continuously powered in order to form the magnetic field inside the generator, so that this magnetic field can then dissipate its available energy to force the scattered charges back apart to form an ordered source dipole.

We pay the power company to have a giant wrestling match inside its own generators and *lose*. And in a sense, we do it because our theoreticians love gauge symmetry more than they tolerate broken gauge symmetry. So they build lovely, symmetry-restoring electrical power systems—and monstrously mangle and destroy the fragile biosphere in the process.

GAUGE FREEDOM

The axiom in gauge theory that one can freely change the potentials of an EM system, so long as the net new forces resulting from the change will sum to a zero vector resultant so that the system remains "symmetrical" in its force-field functioning with respect to the system prior to the change of potentials.

Gauge and gauge freedom are actually formal restrictions of an even more important asymmetrical regauging principle: *a potential in a system can be freely changed at any time, thus freely changing the potential energy of the system freely and at will*. Symmetrical regauging is achieved only by multiple application of this asymmetry rule to provide a net symmetry condition again, with a change in locked-in stress potential energy of the system.

GAUGE SYMMETRY

Abstract mathematical symmetry of a field, that relates to the freedom to regauge (change the value of) potentials, without affecting the values of the field quantities.

In short, the higher principle that the potentials can be changed freely and at will—and hence the potential energy of the regauged system can be changed freely and at will—is arbitrarily restricted to a very special case: Each change of potential involves the appearance of an new free force field. This *asymmetrical* change can be made freely and at will, at any time. However, the notion of gauge symmetry restricts any set of such changes to the special case where the new free force fields produced must sum to a net zero force field of opposing forces. In short, it severely restricts the freedom to change the potentials—to the special case where the resulting change of the system's potential energy must remain a static stress potential energy condition. Note that this arbitrarily eliminates any overunity functioning of the regauged system in which the altered potential(s) and altered system potential energy exist(s). See the discussions of *gauge* and *gauge freedom*, above.

GAUGE THEORY

A field theory using a field that has one or more gauge symmetries.

Note the accent on gauge symmetry and the net *symmetrical* regauging restriction. This restriction is a carry-forward of the old notion that the potentials are not primary, but the fields are primary causes of all EM phenomena.

For the overunity researcher, broken gauge symmetry is the interesting feature which must avidly be sought in his experimental systems. Hence he must seek out and familiarize himself with a wide variety of *broken symmetry effects* and phenomenology. He must also rigorously analyze his circuits with a keen view to where gauge symmetry can be broken, where and how gauge symmetry is automatically restored during excitation discharge, etc. Unless the automatic self-enforcing of symmetrical gauge transformation during excitation discharge is violated, no EM system can produce COP>1.0. In addition, without elaboration, the overunity researcher must also learn to consider the time-domain functions of the circuit, and particularly the giant negentropy of the common dipole. Unless he understands that all EM energy comes from the vacuum and from the complex plane via the broken 3-symmetry of a dipolarity, he cannot understand his own circuits.

Electromagnetics was the first gauge theory. Gauge theory is widely utilized today, and particularly in particle physics. In overunity power systems, the system must exhibit a broken gauge symmetry at least twice: (1) in initially potentializing the system to freely increase its potential energy, thus exciting the system so that it has energy with which to do work, and (2) then discharging this free excitation energy in the load without simultaneously destroying the source dipole providing the continual potentializing.

The conventional COP<1.0 electrical power system restores net 3-space symmetry by continually destroying the "free asymmetrical regauging" component: the source dipole, and using more of the energy freely received from the vacuum via dipole asymmetry to destroy the dipole than is used to power the load. This requires that at least as much 3-space energy be input to the system again, to restore the dipole and thus potentialize the external circuit, as was used to destroy the dipole. Hence as much 3-space energy has to be input as is dissipated in all the loads and losses, including inside the generator. For that reason, our scientists and engineers unwittingly but deliberately design and build only COP<1.0 systems.

Without elaboration, we also accent that spacetime curvature is always involved in an overunity EM power system, and the tempic (time) potential of the output end of an overunity system differs from the tempic potential of the input end, so that the gradient (the tempic force) is directed from output to input—exactly the reversal of the case for a COP<1.0 power system.

GAUGE TRANSFORMATION (IN ELECTROMAGNETICS)

In EM, gauge transformation is conventionally taken to be the addition of the gradient of some function of space and time to the magnetic vector potential—and simultaneously the addition of the negative of the partial derivative of the same function with respect to time, divided by the speed of light, to the electric scalar potential.

This procedure gives different potentials but leaves the electric and magnetic fields unchanged. It restricts gauge transformations to *net symmetrical* transformations. However, the increase or decrease in potential energy of the system, due to changing the potentials, results in a change in the stress of the system and a change in its stress energy. This is because two new antiparallel forces are created, which change the stress of the system.

In essence, gauge symmetry then involves the implicit assumption that a functioning system is the same regardless of how it is stressed, and regardless of the state of its stress energy. We point out that, gravitationally, this is not true since any change in the local potential energy of the system is a spacetime curvature change, hence a gravitational change.

GENERAL THEORY OF RELATIVITY

Einstein's theory of gravity in which the gravitational force is represented by a curvature in spacetime.

GIANT NEGENTROPY (OF THE DIPOLE)

The receipt from the time domain of spacetime (the vacuum), by any dipolarity, of enormous longitudinal EM wave energy flow, transduction of that absorbed energy from the complex plane into real 3-space, and emission of that enormous energy flow in all directions in 3-space, automatically and indefinitely after a little energy has been expended to separate the charges and make the dipole. The EM waves in the input from the time domain and the output in 3-space are perfectly ordered and correlated, which is a giant ordering of the vacuum/spacetime and is thus a giant negentropy.

In circuits, the source dipole in the generator or battery, once made, performs this function. Only a minuscule fraction (some 10^{-13}) of the energy pouring out of the generator's or battery's terminals strikes the surface charges of that attached external circuit and is diverged into the conductors to power the Drude electrons and the circuit. All the rest is just wasted.

See my paper, "Giant Negentropy from the Common Dipole," *ibid*.

GRAVITON

The quantum (smallest piece) of the gravitational field, with spin 2.

In the quantum theory of general relativity, the graviton is massless and has spin 2. In the new approach, a graviton is considered to be a paired (coupled) photon and antiphoton, each of which has spin one, so that the graviton couplet has spin 2. A scalar potential is comprised of gravitons, not merely photons, since it can be decomposed into a harmonic series of bidirectional wavepairs. In each wavepair, a wave and its antiwave precisely superpose. We insist on a further strong condition: that in the biwave, the photons comprising the wave and the antiphotons comprising the antiwave also must obey the *distortion correction theorem*. This means that the antiphotons and photons are passing through each other in opposite directions, continually coupling into gravitons and decoupling again.

GRAVITY

The phenomenon characterized by the physical attraction of any two material bodies.

Actually, in modern general relativity it is the trapped energy in the masses that produce the gravity potentials. Ideally, the gravitational force between two masses is proportional to the product of the masses divided by the square of the distance between them. In the new approach, one recognizes that mass itself is defined in terms of, and identically consists of, the time derivative of an action flux. [For a force-free fundamental definition of mass, see T.E. Bearden, **Quiton/Perceptron Physics: A Theory of Existence, Perception, and Physical Phenomena**, National Technical Information System, Report AD-763210, 1973.] A photon flux is also an action flux. A virtual photon flux is an action flux. So the vacuum consists of a gigantic action flux—which with certain interactions forms mass itself. But since photons are action quanta and photon flux is action flux, and since mass and gravitation are functions imposed on such action flux; then mass, EM, and gravitation become different aspects of the same thing. All of them can be electromagnetically engineered, directly, as indeed can be the flow of time itself. By affecting the flow of time electromagnetically, one is thus able to affect the gravitational force between two objects electromagnetically. Antigravity, for example, can be achieved by a mechanism that is given in this glossary. Hutchinson has demonstrated the levitation of objects weighing up to 60 lbs., albeit sporadically and uncontrollably. At my urgent request, Sweet performed a highly successful antigravity experiment some years ago, reducing the weight of a 6-pound object by 90%, smoothly and controllably, in several smoothly controlled steps. I consider that the experiment tested and validated my approach to an engineerable mechanism for antigravity. For the results of the test, see Floyd Sweet and T.E. Bearden, "Utilizing Scalar Electromagnetics to Tap Vacuum Energy," **Proceedings of the 26th Intersociety Energy Conversion Engineering Conference (IECEC '91)**, Boston, Massachusetts, 1991, p. 370-375.

GROSS PARTICLE TRANSLATION

Refers to translating the entire particle in space, rather than internally structuring the particle's potential (massless charge).

GROSS POTENTIAL GRADIENT FIELDS

The usual gradient in a scalar potential's gross magnitude, as in $-\nabla\phi$.

GYROELECTRONS

Spinning electrons considered as gyroscopes, so that when longitudinally perturbed they can and will laterally precess.

Considering (in a gross first order model) the conduction electrons in the Drude gas in a conductor as little gyros, because they are (i) spinning on an axis, (ii) severely restrained in their ability to move forward longitudinally down the conductor as current, and (iii) much more free to precess laterally in the conductor. Thus when the gyroelectrons in the receiving wire antenna, perturbed by an incoming longitudinal EM wave in the vacuum, are longitudinally perturbed, they precess laterally so that our instruments (which detect electron wiggles, not the incoming vacuum EM wave) do detect "transverse waves." However, they are detecting the transverse gyroelectron precession waves. The old electrodynamicists, long before the electron or the atom was discovered, simply envisioned the incoming EM wave as "waves in the thin material fluid ether" which were "intercepted" as electric fluid waves in the antenna. Hence since their instruments reported that the intercepted "electric fluid" was vibrating transversely, they firmly believed (erroneously) that this proved the ether wave to be transverse also, just as those "taut string waves" that Maxwell and Faraday had believed in. That is the total *raison d'etre* behind the mistaken notion of the transverse EM wave in the vacuum ether!

HARMONIC SERIES

Consisting of a fundamental frequency, its first harmonic, its second harmonic, etc.

HEAVISIDE, OLIVER

Noted English self-taught physicist and brilliant electrodynamicist, 1850-1925, who played a role in discarding Maxwell's quaternions, and also played a role in forming vector mathematics and formulating the vector reduction of Maxwell's theory from 20 quaternion equations in some 20 unknowns to the present 4 vector equations.

What are presently taught as "Maxwell's equations" in university are actually Heaviside's equations.

Lorentz symmetrically regauged the Maxwell-Heaviside equations, again greatly simplifying their mathematical solution—and also unwittingly discarding all permissible overunity Maxwellian systems in the process.

HEAVISIDE ENERGY FLOW COMPONENT

(1) The enormous nonintercepted and nondiverged energy flow component pouring out of the terminals of the battery or generator, and missing the external circuit entirely so that it is wasted.

(2) The enormous energy in the EM field, potential, or wave that misses the interaction of the field, potential, or wave with the assumed unit point static electric charge.

(3) See also discussion under Giant Negentropy.

HERACLITUS

To be added.

HERTZ, HEINRICH

Noted German physicist who together with Heaviside and others transformed Maxwell's theory from quaternion algebra to vector algebra, and who also produced EM waves, thus confirming Maxwell's theory.

HIDDEN BIWAVES

Those bidirectional EM wavepairs that comprise the scalar potential are indeed "hidden" with respect to our normal "electron translation" (i.e., electron wiggle) detectors and instruments.

HIDDEN VARIABLE THEORY

A class of quantum mechanical theories which considers that the quantum state of a physical system is not a complete specification after all. The "hidden variables" are those additional components necessary to provide the "complete state" of the system.

The hidden variables are those extra components of the theorized complete state, which are not contained in the quantum state. Bohm's hidden variables theory is the best known of all of these theories, and makes the same predictions as does the conventional quantum mechanics. In addition, it eliminates the terrible problem of the "missing chaos," eliminates the quantum measurement problem, and it suggests that quantum mechanics can be engineered if the hidden variables themselves can be engineered. In the new approach, one goes a step further by considering hidden EM variables infolded inside the potentials themselves, including inside the quantum potential utilized by Bohm. The advantage of this assumption is that it poses an *engineerable* interpretation, after work by Stoney, Whittaker, and Ziolkowski. Further, the Russians have utilized this type of EM hidden variable theory, along with the quantum potential, to develop secret advanced weapons. The physics of this area is called *energetics*.

HIERONYMUS, T. GALEN

Founder of the American version of radionics, who patented a radionics machine and process to start the cycle of radionics in this country.

HILBERT, DAVID

Noted German mathematician, 1862-1943, who did advanced work in geometry, theory of invariants, integral equations, and mathematical physicist.

Noted particularly for his development of Hilbert space.

HOLE (ELECTRON HOLE)

An unfilled vacancy in an ordering of electron energy levels, as in a lattice or in the Dirac Sea.

Electron energy levels have two energy states: (1) *positive energy* state, and (2) *negative energy* state. The positive energy states are associated with the positions of normal energy electrons. The negative energy states are almost all filled, and this is the Dirac sea.

The absence of an electron from either energy state creates a particular kind of hole. When an electron is absent from an electron positive energy state position in a lattice, that results in an excess of positive charge at that point vacated by the electron. Note that when an electron then refills that hole (recombination occurs), the electron remains in a positive energy state, does not disappear, and no radiation occurs.

When an electron is lifted from an electron negative energy state in the Dirac sea, that leaves behind a hole in the negative energy state in the Dirac sea. When an electron subsequently refills that hole, it "falls" in and disappears, decaying to a lower energy level and emitting radiation due to the difference in the energy levels.

The difference between holes in the Dirac sea and holes in the electron positive energy levels in a lattice, are very different. In short, they lead to two quite different kinds of "hole and electron" interactions. In the lattice "hole-filling" (recombination), there is no excess radiation given off and the electron does not disappear from the positive energy continuum. In the Dirac sea hole-filling, excess radiation is given off and the electron disappears from the positive energy continuum.

Under the influence of an electric field, a *positive energy* hole in a crystal lattice—where an electron has left and is therefore absent—will effectively propagate through the lattice as a positive charge, but usually much slower than the electron propagates in the opposite direction as an electron current. The process is actually more complex and involves continuous interaction with the electrons and their physical distribution pattern and location. The hole current is mathematically treated as a special positive charge current, often referred to as a positron current. In a current-carrying conductor or semiconductor, one has a current of electrons traveling in one direction and simultaneously a current of holes (hole positrons) traveling in the opposite direction, but recombining.

As stated, in addition to lattice holes, there also can exist unfilled holes in the Dirac negative energy states comprising the vacuum, particularly when fields are present. In this case, it is a *negative energy* hole. A positive energy electron that falls into a Dirac sea hole will emit energy as it falls to that lower energy state. To lift one of the electrons from the Dirac sea and leave a hole, energy must therefore be added to the negative energy electron in the Dirac hole.

When fields are present, Dirac holes may exist and may move as hole current in circuits under certain conditions. The situation is complex; see Felix Finster, "Definition of the Dirac Sea in the Presence of External Fields," **Adv. Theor. Math. Phys**., Vol. 2, 1998, p. 963-985. Updated copy (version 4) is on http://xxx.lanl.gov/abs/hep-th/9705006.

When a free electron fills a positive energy hole in a lattice (positive electron energy state), this effectively disposes of both the hole and the *free* electron which is now a *bound* electron, and is called *recombination*. The electron does not disappear. In a material lattice, there is no energy radiation from this, just the disappearance of the hole and the "binding" of a free electron so that it is no longer free.

In visualizing positive hole currents, passing the hole current though a surplus of available electrons (as in a negative charge donor material) will result in "hole filling" and recombinations. One may therefore speak of disposing of unwanted hole current by recombination, and in fact this is widely accomplished in semiconductors by controlling the doping.

HOLE CONDUCTION (LATTICE)

The movement of electron vacancies (holes) in a lattice continually left behind by hopping of the electrons as they break loose from their bonded positions and move freely in an electron current.

When an electron hops out of a lattice bond, it leaves behind a bonding gap or "hole" in the positive electron energy state at that bond site, so that an extra positive charge appears there at the hole. As the electrons move in one direction in a conducting lattice, the holes move in the opposite direction in a "positive current", but at a much slower pace than the electron current moves.

HOLE CURRENT (LATTICE)

See *hole conduction (lattice)*.

HOMEOPATHY

A system of medical treatment based on the theory that certain diseases can be cured by giving very small doses of substances which in a healthy person would produce symptoms like those of the disease. (Opposed to allopathy).

Homeopathy is based upon formation and use of dimensioned potentials (particularly the potential composed of the extremely rapid "making and breaking" hydrogen bonds in a fluid) containing vacuum engines. Any material or solute, and therefore any molecule, contains its own specific vacuum engine, its own charges, and its own dimensioned potential. Dissolving the material in water, or even using a suspension of it in water, allows the bonding potential in the water to interact with the potential of the solute or suspension. Potentials superpose, and they also diffuse and mix their inner structures (vacuum engines) into each other. So the material or solute diffuses its vacuum engines into the interior of the hydrogen bonding potential, in effect ordering and templating the hydrogen bonding itself! Vigorous shaking of the suspension or solution assures that all the fluid and H-bonding potential is exposed to the solute of suspended particles, so that a thorough exchange of vacuum engines occurs. This process in homeopathy is called *potentizing*. It's actually just creating the desired internal vacuum engines in the H-bonding potential of the water. Once that's done, there's really no further need for the solute or the suspended particles. By repeatedly diluting the solution to the extreme, then one can reach a point where there is a high probability that not a single molecule of the original solute is remaining in the fluid. Yet in each dilution, shaking can be used to insure the even spread of the vacuum engines through the newly introduced H-bonding potential in the newly introduced water. At the end, there exists an altered fluid whose H-bonding potential now contains the desired vacuum engines. Drinking that water now introduces those vacuum engines into the body fluids, bloodstream, etc. The ingested dilute new vacuum engines will then diffuse through the various potentials of the body, and produce altered chemical functioning of the kind that could have been induced by the chemical or active solute material. The advantage is that the harsh material residue of the chemical or solute is not present in the body, as it is when allopathy is utilized.

HYPERFUNCTIONING

Functioning in hyperspace as opposed to 4-dimensional Minkowski space.

Higher topological functioning.

HYPERSPACE

Refers to a space of more than four dimensions, and specifically to those spatial dimensions outside the normal three.

IDENTITY OF OPPOSITES

On the boundary, A and not-A are identical. If all of a thing is collected, one reaches the boundary of that thing and it turns into its own opposite.

INERTIAL FRAME

A frame of reference in which force-free bodies move along straight lines, and the postulates of special relativity are valid.

In the new approach, this notion is extended; even in an inertial frame, force-free bodies may move along straight lines, the postulates of special relativity may remain valid, and yet the EM hidden variable may induce other changes in the usual laws of nature due to the action of hidden vacuum engines infolded in the *dimensioned* local spacetime (vacuum potential).

INFOLDED HIDDEN DYNAMICS

Refers to:

(i) Bohm's hidden variable theory and the internal dynamics of the hidden variables/entities themselves, and

(ii) to the hidden biwave pairs comprising a scalar potential, with the internal dynamics of those waves such as tuning off harmonic frequency, multiplication, variation of phasing and magnitude, etc.

Also, by Whittaker 1903 the scalar potential can be decomposed into the bidirectional wavepair set in harmonic series. By Whittaker 1904, each of the waves in a biwave pair can be further decomposed into two potentials, so each pair of waves would consist of four potentials. That is, the entire set of internal biwave pairs can be replaced by four times as many internal "partial potentials" as was the number of biwave pairs. Then Whittaker 1903 can be applied once again to break each one of those scalar potentials into new biwave pairs, and so forth and so forth. So the potential can be expressed as waves within waves within waves, or potentials within potentials within potentials, and so on. The neat thing is that each successive infolding (internesting) is a higher dimensional functioning and a higher topology. So one can build (with some little pain!) specific infolded wave patterns that will work in—say—the 7th dimension of hyperspace, or the eighth dimension, and so on. This is why I called the internal structuring of a potential (or the two potentials comprising an EM wave) *dimensioning* the potential or the wave. As a half-baked nuclear engineer whom the Army never let practice his discipline, I wanted some way to directly engineer the nucleus. *That has now been found*. Unfortunately it has also already been highly weaponized in secrecy by one or more foreign nations. In other words, one can design a signal and assemble it (with some difficulty) that will flip one quark in a nucleon in an atom. That way one can transmute an element either into the next higher element isomer or the next lower element isomer. Using a quantum potential to "transport" the necessary vacuum engines, the effect can be accomplished at a great distance, in multiple targets simultaneously, and the effect is not shieldable. "Jumps" in nuclear transmutation can also be accomplished. The migration of electrons to and from an atom (as in solution, e.g.) makes and negates ions continuously. Thus continually the external potentials and the nuclear potentials intercommunicate. This means that their vacuum engines continually diffuse. Any dimensioning of the external potentials will be passed into the nuclear potentials as a dimensioning action also. If certain conditioning vacuum engines are present in the external potentials, then the slow diffusion into the nuclear potentials begins to affect the nucleons and their interactions, the quarks comprising the nucleons, the particles such as pions continually exchanged between nucleons, etc. The mechanism for nuclear transmutations and production of new species is there! I believe, e.g., and am working to more clearly express, that the major mechanism producing the new nuclear species in cold fusion experiments just such dimensioned potentials, involving the inadvertent dimensioning of potentials comprised of the hydrogen bondings of the water and other factors.

INFOLDED REAL VECTOR COMPONENTS

Well, simply take a set of real force vectors that altogether sum to a vector zero resultant.

That "vector zero system" is a zero with respect to forced *translation* of a particle or mass. It is not an absence per se, but is the presence of specifically hidden and "infolded" real vectors. Two elephants pushing each other to a draw form such a "zero-translating" system. That "zero system" is quite different from two crickets pushing against each other to a draw! Anyone who thinks all zeros are "absences" and who thinks all zeros are equal, is invited to try standing between the crickets and observing how he feels, then standing between the elephants and see how he feels. The latter might be a real bummer. So zeros can differ! And a zero can be a presence of many real things, all still there but "infolded" and "hidden," but just the absence of any *one and only one* thing. Even in arithmetic, e.g., we are free to pull 5-3-2 right out of 0, or pull out 4-7+8-6-2+5+1+1-3-1/2-1/2 (if I got the arithmetic correct!). And so on. So we have always *used* the fact that a net zero can have a real internal composition, without detailing it exactly. We teach our schoolchildren to do it, but fail to tell them what they are doing!

When you sum EM force fields to zero, the fields are still there and real. You have altered the energy of the system or volume, and also the potential energy of the system or volume. And you have done it in specific directions, magnitudes, etc. along the "fingers" of the infolded patterns. In short, you have made a specific vacuum engine. Mass, fluid, nuclei, molecules, etc. exposed to that "conditioned vacuum potential" may well undergo physical and chemical and electrical changes. Golden once performed experiments which powerfully conditioned the local vacuum, and all clocks and watches (mechanical, electrical, etc.) in the local area were awry for four days.

INFOLDING

With reference to signals, infolding means "placing the signal or modulation or change upon one or more of the internal bidirectional wavepairs comprising the scalar potential.

Since all EM potentials ultimately represent changes to the ambient vacuum potential, one has conditioned or altered the vacuum itself when infolding is utilized. Infolding of EM signals, vectors, and directions produces *vacuum engines*. By Whittaker's principle and Bearden's corollary, these vacuum engines can be designed to affect matter—including atomic nuclei, nucleons, etc.—in any manner desired.

INFORMATION CONTENT OF THE FIELD

Russian euphemism for the structuring of the hidden longitudinal EM waves and their dynamics, that comprise any EM potential, field, or wave.

INFRASONIC

Below sonic.

Frequencies below what the ear can hear. Below about 20 Hertz.

INTERFEROMETER

An instrument in which a wave is split into two waves or beams, which after traveling over different paths are subsequently reunited and display interference.

INTERFEROMETRY

Measurement of wavelengths of light and very small distances and thicknesses,

...for determining indices of refraction, and for analyzing small parts of a spectrum by means of the interference phenomena of light.

INTERNAL SPACE

To be added.

ITERATED

Done repeatedly, like picking beans one at a time.

JOSEPHSON EFFECT

Flow of Cooper pairs (superconducting electron pairs) across a thin dielectric separating two superconducting electrons, in the absence of a voltage drop.

That is, the pair of electrons can "tunnel" through a thin insulating barrier.

JOSEPHSON JUNCTION

The thin dielectric separating two superconducting electrons, with subsequent Josephson tunneling of Cooper pairs.

JOSEPHSON TUNNELING

See *Josephson effect*.

JOULE

A measure of energy.

One joule equals one watt for one second. In physics the unit of work or energy in the MKS system, being the amount of work done by one newton acting through a distance of one meter, equal to 10,000,000 ergs.

JUNG, CARL GUSTOV

Noted Swiss psychiatrist and psychologist who founded Jungian analytical psychology, formulated the principle of synchronicity, and advanced and delineated collective unconscious mind.

From the content of his German patients, Jung predicted WW II two decades before it occurred.

KINDLING

Coherent integration (adding) of similar virtual components among the vast "noise" of dissimilar virtual components, so that the "signal-to-noise" ratio of the integrated signal steadily increases, and the integrated "observable signal" grows out of the background virtual state noise.

This "kindling" process is directly analogous to coherent integration of nondiscernible radar signals far beneath the received noise, to build and extract the real radar return signals from targets. This sort of process dramatically increases the "sensitivity" of the radar. Real, very tiny signals even 100 dB or more beneath the noise level can be retrieved in such fashion by modern radars.

Similar processes can integrate very minute signals already passed into the virtual state and presumed to be nonexistent. Usually, however, the difference frequency between two frequencies at least one harmonic interval apart must be used, considering the vacuum's virtual flux state as an isotropic nonlinear medium.

One may also hypothesize that potentials and propagating signals may decrease with distance, but are never truly "lost" in that they never reach a total zero. When they reach the quantum level, further decrease in amplitude simply results in their passing into the virtual state (subquantum level).

KIRCHHOFF'S CURRENT-LAW

At any time, the sum of the instantaneous currents flowing into a node or point in a circuit equals the sum of the instantaneous currents flowing out of that node or point.

KIRCHHOFF'S VOLTAGE LAW

At any time, the sum of all voltage rises in a closed loop circuit equals the sum of all drops in that closed loop circuit.

LAMB, WILLIS EUGENE JR.

American physicist and Nobelian who discovered the hyperfine structure of the hydrogen spectrum, and first measured the interaction of the vacuum energy that generates a change in the energy levels of the hydrogen atom, according to Dirac's theory and quantum electrodynamics.

LAMB SHIFT

A very small correction to the first excited state of the hydrogen atom due to interaction of the vacuum.

Willis Lamb experimentally confirmed this prediction of quantum electrodynamics to high accuracy.

LAMELLAR CURRENT

Current in thin layers.

Thin layers of current. Thin sheets of current.

LASER

A device that generates light in which all the photons are exactly in step and produce a coherent beam.

Laser light has one wavelength and is more easily controlled than other kinds of light. Use of a laser to perform interferometry is one way to create holograms; use of a laser to illuminate a hologram is one way to read it. Originally the word "laser" was an acronym that stood for "light amplification by stimulated emission of radiation." Note that when TiO_2 particles in suspension, with a small amount of fluorescent dye added, are weakly illuminated by a small coherent light source (a laser), a tremendous room-filling output of coherent light emission occurs, by the anti-Stokes emission effect. This is lasing without population inversion, and it is a validated and easily testable overunity process. This is the process patented by Lawandy.

LASING WITHOUT INVERSION

The amplification of coherent light in an intensely scattering medium, comprised of certain powdered laser crystals or suspensions of similar material, where a variety of phenomena such as gain narrowing and amplifying random walk of light propagating in the medium, combine to give laser emission with diffusive feedback.

Gain tends to depend on the volume of the medium, so that at a certain medium the gain in light amplification by the medium exceeds the losses, and the laser action results above this critical volume. The intensity of the light scattering (multiply reflecting) in the medium then will increase rapidly until an "explosion" of light results in an intense flash of coherent light in all directions from the medium volume.

If the excitation is still present, the process will be repeated and the energy density will again exceed the critical value, rapidly generating another intense flash of light. This process can be repeated many times, given the presence of continued excitation.

A very interesting phenomena that can occur is coherent backscattering. Here the light scatters over both a forward-time path and a time-reversed path, perhaps with each path consisting of more than 1,000 scatterings. Because of time-reversal symmetry, the two waves (forward and backward) acquire exactly the same (though random!) phase. So the two waves after all this 1,000 scatterings on their paths, meet and interfere constructively in the direction back toward the exciting light source.

In theory the mean free path can be made shorter and shorter, so that all the light would be trapped inside the medium. This is called Anderson localization, and it has been reported in the literature; see D.S. Wiersma, P. Bartolini, A. Lagendiji, and R. Righini, "Localization of light in a disordered medium," **Nature**, Vol. 390, 1997, p. 671; John Sajeev, "Frozen light," *ibid*., p. 661-662.

This work grew out of original work called out by Letokhov but largely ignored for more than two decades.

References: D. Wiersma and A. Lagendijk, "Laser action in very white paint," **Physics World**, Jan. 1997, p. 33-37; — "Light diffusion with gain and random lasers," **Physical Review E54**, 1996, p. 4256; N.M. Lawandy et al., "Laser action in strongly scattering media," **Nature**, Vol. 368, 1994, p. 436; V.S. Letokhov, Generation of light by a scattering medium with negative resonance absorption," **Sov. Phys. JETP**, Vol. 26, 1968, p. 835.

Note that we have nominated a version of this process, together with consideration of the erroneously discarded Heaviside nondiverged energy flow component, as the fundamental mechanism proposed to be involved in gamma ray bursters, x-ray bursters, and in some gamma ray and x-ray flashes associated with atmospheric phenomena on earth in thunderstorms, etc. We also nominated the missing Heaviside energy flow component as the agent accounting for the excess gravity (some 90% of the total gravity) in the arms of spiral galaxies that hole those arms intact so they do not fly apart. See T.E. Bearden, "Dark Matter or Dark Energy?", **Journal of New Energy,** 4(4), Spring 2000, p. 4-11 (also available on http://www.cheniere.org); — "Giant Negentropy from the Common Dipole," **Proceedings of Congress 2000**, St. Petersburg, Russia, Vol. 1, July 2000 , p. 86-98. Also published in **Journal of New Energy**, 5(1), Summer 2000, p. 11-23. Also carried on DoE open website http://www.ott.doe.gov/papersbooks.html and on http://www.cheniere.org.

LAW OF PHYSICS

A restriction placed upon the physical mechanisms that can occur under certain broad assumptions as to the background situation and environment.

Actually, in nature there are no such rigidly fixed "laws"; these are only man's synthesis for the behavior of large classes of systems under very general conditions. Any "law of physics" can be violated if the conditions contained in its assumptions are violated. Conservation laws are often touted as "laws of physics." Actually, the conservation laws assume a closed system or one in equilibrium, and a linear spacetime (Lorentz frame). If either or both of these assumptions is locally violated, any or all of the conservation laws can be violated locally, even though the overall global conservation is still upheld. Quite simply, in that case one has opened the system (broken symmetry). In particle physics, broken symmetry already results in violation of one or more of the conservation laws. In leading Russian physics journals, papers are regularly published containing unrestricted general relativity with concomitant violation of any and all conservation laws.

LAWANDY PATENTS

Patents covering and related to anti-Stokes emission (excess emission of energy) in strongly scattering, optically active media such as TiO2 particles in suspension.

More energy is emitted than one must input to stimulate the effect. It is being hailed as a new form of lasing, without the requirement for population inversion.

LETOKHOV, V. S.

Russian pioneer in excess emission phenomena from stimulated media.

LETOKHOV EFFECT

The excess emission (overunity emission of energy) phenomena in strongly scattering, optically active media, usually referred to as "negative absorption of the medium".

For an overview, see V. S. Letokhov, “Stimulated emission of an ensemble of scattering particles with negative absorption,” **ZhETF Plasma**, 5(8), Apr. 15, 1967, p. 262-265; —“Generation of light by a scattering medium with negative resonance absorption,” **Sov. Phys. JETP**, 26(4), Apr. 1968, p. 835-839; — “Laser Maxwell’s Demon,” **Contemporary Physics**, 36(4), 1995, p. 235-243.

LOCALITY

Characteristic where interactions are local in spacetime.

LOCALIZED

Confined to a small region of a large system rather than being extended through the system or at a distance.

LOCAL VIRTUAL PHOTON FLUX OF VACUUM

Refers to a local region of the vacuum, which also refers to the vacuum flux density of that region.

LONGITUDINAL COMPONENT

In EM waves, the longitudinal component of the fields along the direction of travel,

...as opposed to the transverse components at right angles to the direction of travel.

LONGITUDINAL E-FIELD

We may divide any electrical field into two components, a transverse component and a longitudinal component.

Of course one or the other may be a zero vector.

LONGITUDINAL GRADIENT

Compression wave gradients (differences) in density or pressure,

...considered in a direction from their origin along the direction of primary movement, vs. transverse waves, which act perpendicular to that direction.

LONGITUDINAL INTERIOR WAVE

In conventional theory, the electric portion of the EM wave is a transverse field oscillation, and the longitudinal component is essentially zero.

In the new "infolded" wave approach, there is no overall transverse gradient in the vacuum potential, but there is an infolded longitudinal gradient which oscillates "inside the vacuum potential." This is rather like a "pressure wave" transmitted under water, without causing a surface wave involving physical upheaval and fall-off of the water. In EM, by analogy the speed of the "bulk upheaval" transverse wave is nominally c, the speed of light in vacuum [but see discussion of galloping waves, for what really happens!]. The speed of the pressure wave, under water, may be very much greater than c, because it is a special "tunneling" process and it also involves the galloping wave effect. Experimental measurement of superluminal tunneling velocities—such as more than 4c—are already well-known in the literature.

To better visualize this "pressure wave," consider that it is like a sort of "velocity modulation" upon the edge of the conventionally-visualized plane wave front of a traveling transverse wave, except now the plane itself does not move. All the succeeding planes are "bumped" by the velocity modulation of one plane, and so the velocity modulation propagates through (inside) the vacuum potential as a modulated pressure wave, without transverse change of the potential.

Now we have a very special medium! It consists of bidirectional EM wave pairs, one passing through the other. In such a case, it is already known that the speed of a "planar wave front" in the superposition and resulting interference of two oppositely moving waves can in fact greatly exceed the speed of light momentarily, then slow dramatically below than the speed of light, etc., so long as the average velocity is c. This is called the galloping wave effect. [E.g., see William G. Harter et al., "Galloping waves and their relativistic properties, **American Journal of Physics**, 53(7), July 1985, p. 671-679.]. Since the plane wavefront within the interior *can* in fact vary its velocity, we are quite free to use this "velocity pulse modulation" effect of wavefront speed variation, to place signal intelligence upon the planar wave front speed variations. So we can transmit hidden pressure waves with intelligence on them, through the interior of the vacuum potential. *Further, the restriction to an average velocity of c does not have to apply, and the planar pressure pulses can be transmitted much faster than c*. This is the basis of the work Fogal and I are struggling with, in order to achieve superluminal communication. It is also what we have been struggling with in an effort to come up with a communication system that can propagate infolded signals inside the H-bonding potential of the ocean itself, so that high-data-rate communications with deep submarines could be utilized, at any distance, and the huge, gawky, frightfully expensive, and environment-affecting ELF systems be done away with. We also think it should eventually be possible to develop an underwater radar type of system, but it's far too early at this point to try to conceptualize just exactly how it would work.

LONGITUDINAL WAVE

A "pressure" type of wave, similar to sound, in which the vibrations are along the direction of travel of the wave.

Hence, a wave composed of alternating densifications and rarefactions, where we focus upon the longitudinal component of the changes. In the past we have used the term "scalar waves" to imply longitudinal standing waves, such as in one infolded Stoney-Whittaker wavepair inside the scalar potential. In classical EM theory, the Poynting vector predicts no longitudinal wave of energy from a time-varying, electrically charged source. In fact, even in the ordinary theory, an exact solution of the problem does allow this longitudinal wave, as shown by Keech and Corum, **International Journal of Theoretical Physics***,* 20(1), 1981, pp. 63-68. Conventionally, as explained elsewhere in this glossary, the classical electromagnetic wave is modeled as a vector string wave, comprised of transverse vibrations on implicitly assumed material taut strings in the vacuum. In the new approach, such transverse vector force field waves (Hertz waves) do not exist *as such* in vacuum; instead, two coupled, dynamic scalar potentials exist there. The **E** and **B** fields are formed and exist as the these potentials and their gradient coupling to spinning charged detecting mass particles.

LONGITUDINALLY

Of or in length. Running or placed or operating or changing lengthwise. Opposed to transverse.

LORENTZ, HENDRIK ANTOON

Renowned Dutch physicist and Nobelist, 1853-1928, who developed the Lorentz transformations and Fitzgerald-Lorentz contraction.

He shared the Nobel Prize for discovering the Zeeman effect.

LORENTZ INVARIANCE

An inertial frame is independent of the velocity of the frame relative to any other frame.

LORENTZ INVARIANCE PRINCIPLE

The principle that the laws of physics are the same in all reference frames.

LORENTZ REGAUGING

Changing the two potentials in the Maxwell-Heaviside equations in potential form so that the resulting equations have the variables separated.

An unfortunate effect is that this discards all Maxwellian systems far from equilibrium in their vacuum exchange, hence discards all permissible Maxwellian COP>1.0 systems.

LORENTZ SYMMETRY

Referring to the symmetrical regauging by Lorentz of Maxwell's equations.

LORENZ, LUDWIG VALENTIN

Scientist who first changed Maxwell's equations—two years after their publication in 1865—by (effectively) symmetrically regauging them, thereby unwittingly discarding all Maxwellian systems far from thermodynamic equilibrium with the active vacuum.

See L. V. Lorenz, "On the identity of the vibrations of light with electrical currents," Philosophical Magazine, Vol. 34, 1867, p. 287-301. In this paper Lorenz gave essentially what today is called the Lorentz symmetrical regauging.

Comment: (gratefully received from T. Barrett) This paper gave f(t-r/c) functions. Fitzgerald said that Lorenz's functions were essentially the same as his, and Fitzgerald became a leading proponent of "retarded potentials". But it is believed that Fitzgerald was unaware of Lorenz's work until the 1880's, so he is given credit for parallel development. Some people talk of Fitzgerald-Lorenz functions. This is a regauging, but the term "gauge" (inspired by railroad gauges) was first introduced by Hermann Weyl in the 1900s. He used it for a change in length and was shot down by Einstein's theory—Weyl's theory was not relativistic. The idea resurfaced in the 1920s when quantum theory was being formulated, but this time it meant "change in phase" and not "change in length".

Comment by T.E.B.: Thus "Lorentz" regauging of Maxwell's equations really was first done by Lorenz in 1967. However, not too much attention was paid to L. V. Lorenz' work (e.g., by Fitzgerald). When H. A. Lorentz later used symmetrical regauging (essentially Lorenz' regauging), his influence was so great that it was adopted straightaway and has remained adopted to this day.

LOW ENERGY NUCLEAR REACTION (LENR)

Cold fusion, or the anomalous transmutations of elements which occur in certain electrolytes with specially prepared palladium electrodes.

The transmutations occur even though in conventional theory there is insufficient energy to accomplish them.

Conventional science has rather vehemently attacked cold fusion and many of the cold fusion scientists, even though there are now hundreds of successful experiments in multiple laboratories throughout the world.

In our view, once the properly-prepared palladium lattices are loaded with positive ions, the formation of temporary, fleeting time-reversal zones in the electrolyte temporarily reverses the law of attraction and repulsion of charges. Thus H+ ions, e.g., may attract each other in even numbers (opposite numbers are forbidden by the Pauli exclusion principle), so closely that each enters the strong (nuclear) force region of the other, so that the group becomes a quasi-nucleus. Note that the gluons are partially "unglued" by the TRZ formation, and so the preferred method of "decay" of the anomalous TRZ state as the surrounding electrolyte ions move to negate it, is by flipping of a quark. One D+ ion coupled to one H+ ion, e.g., when attracted into a quasi-nucleus in a TRZ, may decay into tritium by flipping one quark and changing one of the protons into a neutron. Two H+ ions may decay into deuterium (D+) by flipping one quark and turning an H+ into a neutron. Two D+ ions may simply "tighten further" into a real nucleus as the TRZ decays, and result in an alpha particle (helium nucleus). The TRZ hypothesis does precisely explain the most important reactions that are experimentally shown to occur. For more on this hypothesis, see T. E. Bearden, "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves," **Explore**, 8(6), 1998, p. 7-16; — ., "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves," Journal of New Energy, 3(2/3), 1998, p. 12-28.

MAGNETIC DIPOLE

Paired north and south magnetic poles of equal strength over microscopic or macroscopic distance.

MAGNETIC INDUCTION

The act of a change in magnetic field producing an electric field at right angles, which in turn produces electron flow.

MAGNETIC SPIN

Refers to the intrinsic angular momentum, known as spin, of electrons, protons, and neutrons, etc.

The electrons combined in an atom or ion have a resultant angular momentum, that is the combined intrinsic spin of the electrons and the angular momentum due to their motion around the nucleus. There is also a magnetic moment associated with this angular momentum (spin) whenever it is nonzero. Therefore atoms or ions with nonzero spin are *magnetic* atoms or ions. This is often loosely referred to as "magnetic spin." It is actually the magnetic moment of nonzero spin.

MAGNETOELECTRONICS

New microelectronic components which exploit the spin of the electron rather than its charge.

References: A Barthelemy *et al*., "Giant Steps with Tiny Magnets," **Physics World**, Nov. 1994, p. 34-38; G. Prinz, "Magnetoelectronics," **Science**, Vol. 282, 1998, p. 1660.

MAGNETORESISTANCE

A change in electrical resistivity in a material when a magnetic field is applied to the material.

MAGNETORESISTANCE, COLOSSAL

A very large change in electrical resistance observed in the manganese perovskite materials when a magnetic field is applied to them. The effect in these materials is the largest magnetoresistance effect known at present.

See N. A. Babushkina *et al*., "Metal-insulator transition induced by oxygen isotope exchange in the magnetoresistive perovskite manganites," **Nature**, Vol. 31, 1998, p. 159; L. I. Balcells *et al*., "High-field magnetoresistance at interfaces in manganese perovskites," **Phys. Rev**. **B**, Vol. 58, 1998, p. R14697; M. Blamire *et. al*., "Understanding and utilizing colossal magnetoresistance materials," **Phil. Trans. Roy. Soc. A**., Vol. 356, 1998, p. 1469-1712.

MAGNETOSTATIC SCALAR POTENTIAL

Roughly, the "pole strength" differential between the two poles of a magnetic dipole.

Anyone who wishes may polish this definition.

MASSLESS DISPLACEMENT CURRENTS

Currents without mass.

Examples in the standard theory include $d\phi/dt$, $d\mathbf{E}/dt$, $d\mathbf{P}/dt$, $d\mathbf{B}/dt$, etc.

MATTER

Highly condensed 3-spatial energy, compressed by the factor c^2 …

and with the observation process d/dt having been applied to the fundamental masstime entity to provide mass as a frozen snapshot. Matter, of course, has internal structure, order and organization, and dynamics. All matter is in a continuous energetic exchange with its vacuum (4-spatial) environment.

MAXWELL, JAMES CLERK

Brilliant scientist who first formulated the unified theory of electricity and magnetism.

James Clerk Maxwell was born on June 13, 1831 in Edinburgh, Scotland. In 1847 he entered the University of Edinburgh, then transferred to Cambridge in the fall of 1850. After graduation, he stayed on at Cambridge in a research position. He was elected a Fellow of Trinity College and placed on the staff of college lecturers. In 1856 he returned to Scotland, where he took up a Chair of natural Philosophy at Marishal College, Aberdeen. In autumn, 1860 he took a new position as Chair and Professor of Natural Philosophy and Astronomy at King's College, London (a position he held until 1865, at which time he resigned). Maxwell was financially independent. He was elected to the Royal Society in 1861, while at King's College. From 1865 to 1871 he resided at his ancestral Scottish country home, Glenlair, developing his major ideas into book form. Maxwell returned to Cambridge in 1871, where he became the first holder of the Cavendish Chair of Experimental Physics. There he also supervised the construction and operation of Cavendish Laboratory. His treatise on electromagnetism appeared in 1873. He held his position at Cambridge until he died on Nov. 5, 1879 at age 48, of a form of stomach cancer—the same ailment that had killed his mother when he was a child. [Thanks to **Encyclopaedia Britannica**!]

MAXWELL (UNIT)

Unit of magnetic flux, in the cgs system.

MAXWELL'S ELECTRODYNAMICS

Maxwell's electrodynamics is Maxwell's equations.

MAXWELLIAN SYSTEM

Any physical or electromagnetic system whose electrodynamic operations obey James Clerk Maxwell's electrodynamics model.

The term is usually applied with respect to those systems which obey a highly reduced subset of Maxwell's after the Lorentz regauging of the Maxwell-Heaviside equations. This subset is now inappropriately referred to as "Maxwell's equations". This is unfortunate. As a result, today many scientists and most engineers no longer understand that Maxwell's theory—when embedded in a higher topology algebra—permits a vast richness of additional EM systems and behaviors, including full unified field theory operations. In the standard U(1) gauge symmetry electrodynamics, all these higher symmetry functions and systems are excluded *a priori*. From our view, this is particularly sad since these arbitrary reductions of Maxwell's theory arbitrarily excluded all EM systems far from equilibrium in their exchange with the active vacuum. Hence almost all scientists and engineers believe it is against the very laws of nature to propose an electrical power system that produces more energy out —and more work in the load—than the energy input made by the operator himself. This sad error has resulted in (1) crippled electrical power systems that extract their output energy from the vacuum but kill themselves faster than they power their loads, (2) the giant pollution of the earth, (3) extraordinary energy costs, (4) struggles and wars over oil and energy resources, and (5) the looming giant economic collapse of the economies of many nations. Further, unless this latter facet is checked, it may also lead to (6) the unleashing of all the weapons of mass destruction in the arsenals of many nations, destroying all civilization and much of the biosphere.

McCREA

To be added.

MICHELSON, ALBERT ABRAHAM

German-born American physicist who invented an interferometer (Michelson interferometer) named after him. Michelson used his interferometer in a renowned experiment designed to measure the velocity of the earth through the ether, which would produce a shift in his interferometer pattern. No such shift was observed, which indicated the absence of an ether wind and was largely responsible for the downfall of the concept of the material ether which had been assumed previously.

Reference: Albert A. Michelson and Edward Morley, "Influence of Motion of the Medium on the Velocity of Light," **American Journal of Science**, Vol. 31, 1886, p. 377-386; — "On the Relative motion of the Earth and the Luminiferous Ether," **ibid.**, Vol. 34, 1887, p. 333-345.

MIND

From the medical view, with thanks to **Webster's Medical Desk Dictionary**, Merriam-Webster Inc., Springfield, Massachusetts, 1986: (1) The element or complex of elements in an individual that feels, perceives, thinks, wills, and especially reasons; (2) the conscious mental events and capabilities in an organism, (3) the organized conscious and unconscious adaptive mental activity of an organism.

See an extended discussion of *mind* under *energy*.

MIND-BODY COUPLING

To be added.

MIND-MATTER INTERACTION

The n-space interaction between the time-like mind and its time-like operations and the 3-spatial physical body and its 3-space operations. To first order, we may treat these interactions in four dimensions.

MIND OPERATIONS

To be added.

MOTION

To be added.

MOTIONLESS ELECTROMAGNETIC GENERATOR (MEG)

Transformer-like COP>1.0 electrical power generator invented by Bearden, Kenny, Hayes, Moore, and Patrick which powers the transformer core with a permanent magnet, but separates the curled magnetic vector potential A (the magnetic field B) from the uncurled magnetic vector potential A, so that the magnetic field flux is retained in the core while the A-potential is replenished outside the core and adjacent to it.

The overunity mechanism is thus provided by a version of the Aharonov-Bohm experiment, which proves that this splitting of the A-potential does occur and that the uncurled A-potential will interact energetically with electrons. In short, by "splitting the potential" and potentializing two paths to the same energy density as the original unsplit potential, the MEG doubles the available potential energy available via the permanent magnet dipole's broken 3-symmetry in the active vacuum. Both the curled A-potential (magnetic field) inside the core and the uncurled A-potential outside the core interact simultaneously with the output coils when pulsed. Thus the output coils "doubly interact" instead of singly interacting. This "double-dipping" of available energy flow allows permissible COP>1.0, since the system is far from equilibrium with the active vacuum exchange.

Pulsing applies the Lenz law effect to both the split potentials, further increasing the energy density of the two interactions with the output coils. The MEG nominally exhibits from COP = 1.7 to COP = 10, using two input coils.

See M.W. Evans, P.K. Anastasovski, T.E. Bearden et al., "Classical Electrodynamics Without the Lorentz Condition: Extracting Energy from the Vacuum," **Optik** 111(6), 2000, p. 246-248; — "Inconsistencies of the Maxwell-Heaviside Theory of Electrodynamics: The Aharonov-Bohm Effect," **Journal of New Energy**, 4(3), Winter 1999,p. 236-240; — "Vacuum Energy Flow and Poynting Theorem from Topology and Gauge Theory," submitted to **Physica Scripta** (in review); — "The Aharonov-Bohm Effect as the Basis of Electromagnetic Energy Inherent in the Vacuum," submitted to **Optik** (in review), — "Explanation of the Motionless Electromagnetic Generator with O(3) Electrodynamics, **Foundations of Physics Letters**, 2001 (in press). See also T.E. Bearden, "Energy from the Active Vacuum: The Motionless Electromagnetic Generator," in M.W. Evans (Ed.), **Contemporary Optics and Electrodynamics**, Wiley, 2001, 3 vols. (in press), comprising a Special Topic issue as vol. 114, I. Prigogine and S.A. Rice (series eds), ***Advances in Chemical Physics***, Wiley.

MULTICOLLECTION

Multiple collection of the same energy flow, by rerouting the passed Poynting energy back around to the collectors for another pass by them, with additional collection.

A common means of "returning" the Poynting flow for additional collection is retroreflection, as in phase conjugate reflection. Since a nominal energy collection fraction on a single pass is only about 10^{-13}, a great many re-passes of the same energy can be returned. Work is done on the collector in each pass. One joule of energy can actually perform many joules of work; this is a change to the usual statement of the work-energy theorem, which assumes single pass, single collection only.

MULTIPASS RETROREFLECTION

Iteratively retroreflecting the same Poynting energy flow, each time it impinges on and passes by an intercepting collector, so that multiple passes of the same energy flow are made onto and by the collector.

More and more of the passing enormous energy is collected as more and more passes by are made. The collected energy is then dissipated as work in the circuit or device. Such processing can allow overunity EM circuits and devices.

MULTIPASSES

Multiple passes. See multipass retroreflection.

NANOTECHNOLOGY

The fabrication of devices with atomic or molecular precision, to produce operating devices with minimum feature sizes less than 100 nanometers.

Often described as a marriage between chemistry and engineering. The self-assembling of the units is referred to as *molecular manufacturing*, and the devices are built one atom or molecule at a time with programmed nanoscopic arms. As occurred with the modern machine and technology age, the first requirement is to develop the tools that do the working, and the "tools that build the tools." That fundamental work is off the ground and running already.

Nanomanufacturing plants capable of manufacturing bulk materials or arbitrary structures with atomic precision are envisioned, with almost every atom being placed precisely as desired.

Nanotechnology may well produce the next great scientific revolution. As an example, nanobots have been visualized that will circulate in a human body's bloodstream and specifically attack cancer cells. Nanobots for cleaning up air and water pollution are possible. Food synthesis is envisioned since the technology provides the ability to combine molecules directly.

As with all technologies, the ethics lies in the hands of the system designer and the user. Increased technology always allows greater use for good and greater use for bad purposes. Because of the extraordinary "evil uses" that can be employed in the use of nanobots, Bill Joy, chief scientist of Sun Microsystems, recommends no further development of nanotechnology and no further research. He stated,*"... we have the possibility not just of weapons of mass destruction but of knowledge-enable mass destruction… hugely amplified by the power of self-replication… we are on the cusp of the further protection of extreme evil…"*

Joy's fears are well-founded. Already the union of artificial intelligence with self-replicating nanobots is foreseen. If that union is successful, one can foresee the unleashing of what can only be called "species" of self-replicating, smart nanobots bent on the mass destruction of humanity in various ways.

Also, contrast the nanobots to our discussion of even more advanced nanotechnology of causal system robots (CSRs) using functioning system of causal fields (sets of longitudinal EM waves and their dynamics, prior to having interacted with charged mass, and thence being systems that are functioning sets of spacetime curvatures). We have already survived one massive world-wide insertion of an armada of such CSRs—fortunately first generation systems and with no countermeasures, so they were easily detected and destroyed. We may not survive the next such insertion and attack, as the maturity of the CSRs increases.

Considering the usual focus of governments and human control systems, my prediction is that *detrimental, self-replicating, smart* nanobots for use in war, surprise strategic attack, and mass destruction of human targets is already on the early planning boards. The obvious war applications of nanotechnology will advance faster than the peaceful applications, behind a public screen of simpler benevolent developments. This is almost certain, since the lead time for maturing the nanotechnology is from 10 to 20 years. This long lead time rules out most private capital ventures of substantial magnitude. It results in the requirement for government funding, just as development of the atomic bomb was government funded. As a nanotechnology "arms race" begins and heats up, one will see the equivalent of new but hidden "Manhattan Projects" in specialized mass destruction weapons nanotechnology. Rather substantial funding of nanotechnology research and development by several nations is already a fact.

Unethical aspects aside, the potential for useful and benevolent purposes of nanotechnology is very great. The development in this new field is now beginning to escalate almost exponentially, year by year, funded primarily by governments and to a more limited extent by private companies.

Reference: David Cook, Jessica Voorhees, and Brian Valz, "Nanotechnology: The Coming Molecular Revolution," available on website http://nanotech.about.com.

NEGATIVE ABSORPTION OF THE MEDIUM

Excess emission from a medium, as in the Letokhov work and in Bohren's experiment. The excess energy is received from the vacuum interaction.

NEGATIVE RESISTOR

Any component or function or process that freely receives energy from outside the system in unusable or disordered form and outputs that energy in usable, ordered form inside the system, where that is the net function performed.

We specifically do not include "differential" negative resistors such as the tunnel diode, thyristor, and magnetron which dissipate and disorder more energy from the system, overall, than they order and furnish to the system in their negative resistance regime.

NEGENTROPIC

Functioning to produce or involve negentropy.

Reordering previously scattered energy without requiring the operator or experimenter to input energy to do the reordering work (an example is passive retroreflection of scattered EM energy).

NEGENTROPIC ENGINEERING

Expending a little bit of energy to form a dipole or dipolarity, and then intercepting, collecting, and using some of the enormous EM energy freely extracted by the dipole from the vacuum indefinitely, without using any of the extracted EM energy to scatter the charges in the dipole and destroy the dipole, thereby shutting of the vacuum's furnishing of copious free energy.

NEWTONIAN 3RD LAW

For every action there is an equal and opposite reaction.

This law should be extended and restated something like this: "for every action there is an opposite and equal reaction if the causative mechanism of the reaction is allowed to occur and not first redirected away from its target." An example of a violation of Newton's third law as usually stated, is provided by the emission of a phase conjugate replica wave from a phase conjugate mirror material. No matter how powerfully pumped, the PCM does not recoil. The reason is that the antiwave cause of Newtonian third law recoil was intercepted by nonlinear multiwave interaction before it could reach its target nuclei, and rediverted away from the atom and on out of the material. Since the causative mechanism for Newtonian recoil did not occur, the PCM did not recoil.

NEWTONIAN RECOIL

As used in the paper, refers to Newton's third law reaction created as the recoil of the nucleus of an atom which absorbs an incoming EM longitudinal wave, or emits one.

NEWTON'S THIRD LAW

For every action there is an opposite and equal reaction.

In Maxwell's electrodynamics, Newton's third law is missing. It is missing because of the coarseness of the modeling which Maxwell was forced to use. Maxwell's seminal paper was read in 1864 and published in 1865. At the time, neither the electron nor the atom had been discovered, much less the nucleus of the atom. A molecule was just a blob with no structure. Electricity was considered to be a thin material fluid, flowing through the wires much like water through a pipe. In fact, Maxwell actually wrote a material fluid flow theory, since hydrodynamics was developed at the time.

So there was, at the time, no notion of the Drude electron gas in a wire and the positively charged nuclei in the atoms in the wire. So there was no notion of two oppositely charged entities in the conductor, both reacting to any EM field entering from space and interacting with the wire.

Further, Newton's third law had always been used mystically without any known cause. It was experimentally established that the reaction occurred, but scientists were forced to just assume its occurrence.

Consequently, Maxwell wrote equations for the reaction of a unitary electric fluid in the conductors. He knew that the wire recoiled, but wrote no equations containing the cause of Newton's third law reaction.

What really happens in the wire is that both the Drude electrons rearrange their positioning vis a vis the lattice, resulting in an apparent current. The actual movement (drift velocity) of the electrons down the wire is very slow, in a nominal case being a few inches per hour. The electrons, having spin, act as little gyros so to speak, longitudinally restrained by the repulsion of the electrons ahead. So the electrons precess laterally, and spend most of their movement in lateral precession movement. This alone proves that the perturbing force is longitudinal, as indeed does Whittaker's decomposition of the scalar potential into longitudinal EM waves. The gradient of the scalar potential (the E-field) is also such a decomposition. But the electron precession waves—which is what our instruments measure in the wire—are indeed lateral waves, in general consonance with Faraday's notion that the force field lines were physical and like taut strings. Maxwell merely assumed Faraday's notion, to give us the transverse EM wave in space. Consequently, the old electrodynamics envisioned that fluid vibrations (ether vibrations) from space had been intercepted by the wire to shake the electric fluid accordingly. And since that electric fluid obviously shook laterally, that "proved" that the waves in spacetime were lateral "plucked taut string" type waves. Actually it proved no such thing, because they were measuring electron precession waves.

The positive nuclei usually have a m/q ratio several hundred thousand times the m/q ratio of an equal charge of electrons. Hence the massive nuclei also react to the field interaction, and move very slightly in the opposite sense from the electrons. That reaction is ignored in Maxwell's general equations, though when the equations are applied, they require that nuclei movement.

In short, the electrons precess and the nuclei recoil oppositely, and that is the generation of Newton's third law reaction.

When we excite a wire antenna with a wave excitation, we produce both electron precession waves and nuclear recoil waves in the nuclei. These two waves are of equal energy, though the nuclei waves are very highly damped in magnitude because of the high m/q ratio of the nuclei. Nonetheless, each of these "lateral" waves slaps the vacuum potential with *identical energy*. So two equal waves of spacetime curvature occur. I can be seen that the net vacuum wave is actually a longitudinal EM wave, composed of waves of vacuum (spacetime) energy rarefaction and densification. Electrodynamicists, considering the vacuum to be filled with a material ether, used the "effect" wave in matter as the cause wave. Hence they used a transverse EM wave in spacetime, when indeed the spacetime wave is and always was a longitudinal EM wave, just as Tesla insisted.

Maxwell's equations are based primarily on the interaction of field and single charge. Actually, the reaction is always between the field and a dipole. Even when the field interacts with an "isolated charge", there are clustering virtual charges of opposite sign around the "isolated" charge so that the "isolated charge" is actually a set of composite dipoles, where each dipole consists of a virtual charge of opposite sign and a differential piece of the isolated observable charge. So the Newtonian third law reaction is also there with an isolated charge, but occurs in the vacuum itself, resulting in vacuum polarization.

Nonetheless, the "transverse EM wave in vacuum" notion is so embedded in electrodynamics that we seem to be stuck with it. It means, however, that the "field in space" used in electrodynamics must be regarded as only a sort of "convenient transfer function" and not a real transverse oscillation entity. This of course accords with Feynman and Wheeler's pointing out that only the potential for the EM wave exists in space, in case a charge is brought in to interact with its gradients.

And needless to say, since the vacuum is a big potential and only potentials and potential changes can exist in it, then Whittaker's 1903 paper decomposing the scalar potential into longitudinal EM waves is paramount and decisive. EM waves in the vacuum a priori must be longitudinal waves, because they are only the changes to the vacuum potential. And that potential at each and every point, changes and all, decomposes into longitudinal EM waves in 3-space with convergent longitudinal EM waves incoming from the time domain.

NISBET

To be added.

NON-ABELIAN ELECTRODYNAMICS

To be added.

NONLINEAR MATERIAL

A substance whose optical properties vary with the intensity of the light.

Most optical substances are very weakly nonlinear, but a great deal of research has been exerted to find materials with stronger nonlinearities. Also, a material which creates and emits the fundamental and additional harmonic frequencies when illuminated with a single frequency. Many nonlinear materials also weakly produce time-reversed (phase conjugate) fundamentals and/or harmonics when illuminated with a fundamental frequency. Such a nonlinear material that creates time reversed waves (phase conjugate replica waves) is said to function as a *phase conjugate mirror*. The phase conjugate replica reappears in space back along the path in space—even through a highly distorting medium—where the input stimulus (signal wave) has traveled or is traveling.

Thus the phase conjugate replica or time-reversed wave normally backtracks its signal wave stimulus to the distant source of that signal wave, even hundreds or thousands of miles away. This "crawfishing" and "concentrating" characteristic is also known as *retroreflection*. Note that an ordinary EM wave *diverges* as a function of the radius traveled away from its emission source, while a time-reversed or phase conjugate replica wave will *converge* as a function of the radius traveled away from its emission source (the mirror), if its stimulus signal wave was emitted from a distant point source. Ideally, a phase conjugate mirror produces a single time-reversed wave in addition to the input signal wave. By stressing *(pumping)* the mirror with the input of two additional opposing waves (ideally orthogonal to the input or *signal wave*), the phase conjugate replica wave output by the mirror is amplified, and may contain up to all the energy in the pumping waves.

NON SEQUITUR

A conclusion or inference not following from the original argument or premise.

NONEQUILIBRIUM THERMODYNAMICS

Colloquial term referring to the new thermodynamics of self-organizing systems and structures in disequilibrium with their environment.

Since the 1960s, there has emerged in physics (and in thermodynamics!) a surprising new area: the physics of far-from-equilibrium systems and the self-organization and large-scale ordering of such systems. E.g., a single Bénard cell (a particular self-organizing circulation structure in convection-type systems), may involve the coherent behavior of some 10^{21} molecules, in a region of convection where one would classically expect only randomness. These new physics and thermodynamics interactions are surprisingly being found in a very wide variety of systems and phenomena, including living systems and nonliving systems. The phenomena of interest include dissipative systems in disequilibrium with their environment, but with stability of their own systems and forms. Open systems in disequilibrium with their environment can permissibly achieve COP>1.0, and they can exhibit local negentropy. The physics and thermodynamics of such systems is still rapidly developing. For a good overview, see Gregoire Nicolis, "Physics of far-from-equilibrium systems and self-organization," in **The New Physics**, edited by Paul Davies, Cambridge University Press, 1989, p. 316-347. For a full technical presentation, see G. Nicolis and I. Prigogine, **Self-Organization in Nonequilibrium Systems**, Wiley, New York, 1977.

NONLINEAR MATERIAL

In physics, any substance whose response to an external causative or influencing agent is not proportional to the magnitude of the causative agent or influence.

NONLINEAR OPTICAL FUNCTIONING (NLO FUNCTIONING)

Functioning in a manner prescribed by nonlinear optics and quantum optics,

...particularly with respect to time-reversal effects, use of phase conjugate mirrors, phase conjugate reflection, and pumping for amplified phase conjugate reflection.

To quote Knight, "A phase conjugate mixing device has remarkable optical properties: perfect retroreflection, the complete cancellation of optical aberrations and inhomogeneities in wavefronts, and the ability to reverse an optical beam and return it to its source."

NONLINEAR PHASE CONJUGATE OPTICS

See *phase conjugate optics*.

NONLOCALIZATION

Producing or rendering an effect or effect-producing agent at a distance, rather than at the immediate location of the effector.

Extended throughout a large region or system, or to a distant part of a large region or system, rather than being confined to a small region of the large region or system.

NON-RIEMANNIAN (GEOMETRY)

Riemannian geometry is the geometry of Riemannian manifolds;

i.e., manifolds having an infinitesimal squared distance ds that is everywhere positive. A non-Riemannian geometry violates this property. [A manifold is a topological space with certain technical characteristics.]

NUCLEONS

Name for the neutrons or the protons in a nucleus. In the nucleus, the neutrons and protons are continually changing one into the other by exchange of the charge.

O(3) ELECTRODYNAMICS

To be added.

OPEN SYSTEM

A system that communicates with its environment, and exchanges energy, matter, or both between system and environment.

The system may be in equilibrium with that exchange, so that it effectively does not retain and utilize received environmental energy to power loads or accomplish external work. Note that it may in fact receive and store excess energy from the environment, or give up energy to the environment, and then remain in equilibrium under its new potential energy conditions. That is, the system may asymmetrical regauge itself but not utilize any of the regauging energy to accomplish external work. When potential is applied to an electromagnetic system, the system is similarly asymmetrical regauged and its potential energy is increased. However, if the system then destroys its source of regauging potential energy faster than it powers its load, it is said to symmetrically regauge itself when discharging its freely received excitation energy.

The system may be far from equilibrium in its energetic exchange with its environment, and if it asymmetrically discharges its freely received excitation energy, it can exhibit COP>1.0. In that case the system effectively retains and utilizes some of its freely received environmental energy to power loads or accomplish external work, and the operator himself does not have to furnish that part of the energy dissipated as useful work.

OPTICAL SWITCHING

Refers to switching of optical signals, or switching using optical frequency switching techniques, components, and circuits.

ORTHODOX TRANSISTORS

Ordinary transistors in use today.

Such transistors will not perform the Fogal semiconductor special functions.

ORTHOGONAL ROTATION

Simply speaking, a rotation from one direction to a direction at right angles to it.

The Lorentz transform of special relativity, e.g., is a formula for the rotation of an object and all its parts away from its line of motion, as a function of the object's velocity, in a direction toward the time axis. The speed c just represents a full orthogonal turn, so that the intersection of the object with the observer 3-space, along the original line of motion, is zero.

To the observer, the three dimensional object (at speeds less than c) has become a two-dimensional plane moving at speed c. In a space of more than 4 dimensions, the orthorotation may be toward a higher spatial dimension rather than toward the time dimension. As can be seen, such orthorotation is intimately connected with the transformation of an electron or electron/positron pair into a photon, and vice versa. Orthorotations are extremely important when one models the physics of mind and matter interaction, and the physics of a living organisms including both its mind and its physical body—as in psychoenergetics.

OSCILLATING QUANTUM WELL

A quantum well which is oscillating in magnitude and sometimes in sign.

OVERPOTENTIAL

Essentially the overpotential (as in an electrode in a solution) is a shift in the Fermi level necessary to allow the electron in the electrode metal to have energies overlapping with vacant acceptor levels in molecules adjacent to the electrode in the solution.

The overpotential effect appears at small "double surfaces" of things in very close contact, particularly in electrochemistry and in solid state physics. The overpotential enables electron transfer, e.g., by tunneling. The overpotential increases with the log of the reaction rate that occurs at the overpotential location.

For a small reaction rate, the overpotential is small; but for a small increase in the overpotential there occurs a *dramatic* increase of reaction rate. Fogal has utilized the overpotential effect in his semiconductor, to great advantage in accomplishing unusual charge blocking and other special effects.

One of the world experts in the theory and use of the overpotential is Dr. J. O'M. Bockris. E.g., for a short overview pointing out the importance of the overpotential, see Bockris, "Overpotential: a lacuna in scientific knowledge," **Journal of Chemical Education**, 48(6), June 1971, p. 352-358 (a paper which Bockris graciously sent me some years ago). Quoting from that reference, p. 355: "The formal definition of overpotential is 'the change of potential of the electron-conducting phase when reaction rate across its interface with the ion-conducting phase with which it is in contact is changed from zero to a certain velocity.'" And again, p. 355: "...overpotential... in fact determines what fraction of the energy of the self-functioning cell has to be wasted in making the cell work and deliver energy at a certain power." For a more detailed and wider exposition of the overpotential, its effects, and its uses, see J. O'M. Bockris and A. K. N. Reddy, **Modern Electrochemistry**, Vol. 1 & 2, Plenum Press, 1970.

OVERUNITY COEFFICIENT OF PERFORMANCE

More energy out or work out of a system than the operator or experimenter must himself or herself furnish and input.

An open thermodynamic system far from thermodynamic system is permitted to achieve such an overunity performance, so any overunity electrodynamic system must be such. Well-known nonelectromagnetic examples are solar cells, heat pumps, windmills, sails on sailboats, waterwheels for powering watermills, a gliding bird in thermal updrafts, etc. A well-known electromagnetic example is the common solar cell. The common household heat pump has a theoretical COP limit of 8.22, and well-designed units usually achieve some 4.0 or so, so long as the ambient environment does not change too drastically from the design limits. As the environment changes and cools down appreciably, however, most home heat pumps lose efficiency and have to switch onto heating strips, which have a COP ≈ 1.0.

Contrary to prevailing belief, it is certainly possible to have EM systems which are also open thermodynamic systems, far from equilibrium, and freely receiving excess energy (asymmetrically regauging a potential) from an external source, to wit, their violent virtual flux exchange between the vacuum and the system. All EM system are already *open systems* in the virtual particle flux exchange with vacuum; that is already well-known in particle physics, even though the 130-year-old classical electrodynamics does not even include the vacuum-mass exchange. The only question, then, is how to establish an asymmetry in that vacuum-mass flux exchange. Here again, every electrical charge and every dipole is already just such a broken symmetry in the vacuum flux, as has been known in particle physics for four decades! It takes on the average about 50 years, however, for vital discoveries in one discipline to "cross fertilize" into another discipline. At any rate, the symmetry of every electric power system, in the vacuum flux, is already broken in its source dipole. This rigorously means that, if we simply avoid doing something we are doing in our power systems to restore symmetry as a matter of course, it is possible to utilize the free broken symmetry of the source dipole to provide an overunity EM system.

In 1996 I showed that such overunity EM systems are permitted and prescribed by Maxwell's theory, prior to the arbitrary imposition of *symmetrical* regauging of the Maxwell equations (i.e., the Lorentz condition). Violation of the Lorentz condition (by asymmetrical self-regauging) is a necessary but not sufficient condition for an overunity EM device. An asymmetric regauging will certainly give us excess free energy in the system, and an excess force to use that energy in translating against a load impedance to do work, if we design the system properly to do just that.

To achieve overunity, in a circuit one must prevent the (presently universal) re-imposition of the Lorentz condition by the use of one-half the excess received energy to drive the return electrons from the load back through the back emf of the source, killing the gate and restoring symmetry, the Lorentz condition, and equilibrium between vacuum flux and system. All our present EM systems are specifically designed to drive those electrons back through the back emf and thus restore symmetry, *deliberately* asymmetrically self-regauging a second time and *deliberately* restoring the Lorentz condition, along with *deliberately* killing the source dipole's asymmetry in the vacuum flux exchange.

PARADOX (LOGICAL)

A thing that is true, e.g., as shown by experiment, but which violates one or more of the three Aristotelian laws of logic.

Any logic algebra or system has a topology. A paradox in one topology can often be resolved by increasing the topology of the logic. All logical paradoxes in the 3-law Aristotelian logic system are simply fourth-law logic cases in a logical superset, and—at least hypothetically—the fourth law can be applied to resolve them. For a discussion and proof of the 4th law correction to Aristotelian logic, see Appendix III: "A Conditional Criterion for Identity, Leading to a Fourth Law of Logic," in T.E. Bearden, **AIDS: Biological Warfare**, Tesla Book Co., Chula Vista, California, 1988, p. 428-443. Logic has many aspects that often may shock our casual expectations: For example, one of the most advanced axioms in mathematics is called the Axiom of Choice. It is used in the proof of many advanced theorems. Using the Axiom of Choice, it can be shown that it is possible to cut a ball into a finite number of pieces, then reassemble the pieces into two balls of the same size, with no air gaps between pieces! While this seemingly defies all common physical sense (and I've not found anyone who has done it!), it is mathematically correct. For a proof, see Thomas J. Jech, **The Axiom of Choice**, American Elsevier, New York, 1973, p. 3-6. For a good perspective on Aristotelian logic, see Morris Kline, **Mathematics: The Loss of Certainty**, Oxford University Press, New York, 1980.

PARITY

Deals with studying a system of sequence of events as if reflected in a mirror. A system has parity is it undergoes no fundamental operational change if replaced with its mirror-reflected twin.

PARTIALLY TIME-REVERSED REGION

A region of space in which an object experiences not only the ordinary forward flow of time, but an extra induced backwards flow of time, usually a fraction of the time-forward time stream.

One result may be to "reduce" time-forward force fields, by a fraction. This is important in bridges, where one must pass EM energy flow onto a follow-on load circuit, but the return current in that circuit must be allowed to circulate back through the load bridge itself, against the inducing back emf. By partially time-reversing the region occupied by the back emf, that back emf is seen as a smaller value by the return current being passed back up through the back emf. The result is that current will circulate in the load loop, powered entirely by the bridging of Poynting flow $\mathbf{S} = \mathbf{E} \times \mathbf{H}$ onto the load circuit.

Another result of a partially time-reversed region is that the law of attraction and repulsion of charges is partially reversed. If the time-reversal predominates in the region, as in a momentary time-reversal zone in some electrolytes, then the law of attraction and repulsion of charges is reversed. In that case like charges attract and unlike charges repel. Two positive H+ ions, e.g., may be drawn so tightly together that each enters the edge of the strong force region of the other, forming a quasi-nucleus. Note that in each H+ ion the gluon forces are almost dissolved and the quarks are nearly freed. Then as the time-reversal zone decays back to a normal time-forward zone, the decay changes begin from inside out, resulting in the flip of a quark to change one of the H+ ions to a neutron n. The n and the H+ ion draw together as the preferred decay state, resulting in the formation of deuterium or a D+ ion. This and similar "time reversal zone" reactions have been proposed by this researcher as the mechanisms generating the anomalous deuterium, tritium, and alpha particles (helium nuclei) in the "cold fusion" reactions. It is indeed a special type of low spatial energy fusion, but a very high energy reaction since time-energy is involved as the active ingredient, and time-energy has the same energy density as mass.

PARTICLE PHYSICS

The branch of physics using accelerators to study high-energy particle collisions, to determine properties of atomic nuclei and of the elementary particles themselves.

So far as I am aware, conventional particle physicists do not consider time-energy interaction and time-reversal zone novel nuclear interactions at all.

PATTERSON EFFECT

The intense multiscattering, multipass, multicollection of Poynting energy density flow in an assemblage of palladium-clad spherical bead capacitors, as the palladium adsorbs hydrogen ions from the fluid in which the beads are immersed, and charges up as a capacitor, thereby becoming an energy-flow generator, and nonlinearly increasing the energy-flow as the charge of the capacitors increases.

The Patterson effect yields the Patterson Power Cell® , a validated overunity power system which has shown COP>1200 in independent university testing. The Patterson effect is a variation and adaptation of the well-known anti-Stokes emission effect, which for three decades has been validated in physics journals to produce overunity emission in certain intensely scattering active media.

PATTERSON POWER CELL®

Patented overunity power unit by James Patterson, which has been independently validated to yield COP>1.0.

See James Patterson, "System for Electrolysis of Liquid Electrolyte," U.S. Patent No. 5,372,688, issued Dec. 13, 1994. Filed Dec. 2, 1993. 26 claims, 7 drawing sheets.

PAUTRIZEL, RAYMOND

Eminent French parasitologist who worked with Antoine Priore, and who performed many definitive experiments demonstrating the Priore healing effect.

PEGRAM'S EXPERIMENT

Experiment which demonstrates a relation between electric and magnetic fields in the vacuum which the Maxwell-Heaviside theory does not prescribe.

Simultaneously, a coaxial cylindrical condensor and solenoid are rotated. The rotation produces a magnetic field in the solenoid in the axial direction and between the plates of the condensor. The condensor can be charged by shortening the plates of the condensor. This indicates a cross relation in the vacuum between electric and magnetic fields which does not exist in the Maxwell-Heaviside theory.

Reference: G. B. Pegram, **Physical Review**, Vol. 10, 1917, p. 591.

PERPETUAL MOTION MACHINE

Assertion that no machine can indefinitely operate, since no closed system can input its output power back to itself while powering a load because powering itself and its load violates the equilibrium thermodynamics (i.e., the thermodynamics of a closed system).

The "defenders of the underunity faith" use the statement that "there cannot be any such thing as a perpetual motion machine" as an article of faith and iron dogma. Usually they classify a so-called "perpetuum mobile" as to which law of *equilibrium thermodynamics* it is thought to violate.

For permissible Maxwellian overunity systems, the entire "perpetual motion" conundrum is nonsensical, since we are always speaking of an EM system *far from thermodynamic equilibrium* with its active vacuum environment. The *equilibrium* thermodynamics assumed by the critics does not even apply to such systems, as witness the Nobel Prize awarded to Prigogine in 1977 and the voluminous literature on such open dissipative systems.

As an example, see Stanley W. Angrist, "Perpetual Motion Machines," **Scientific American**, vol. 218, Jan. 1968, p. 114-122. Angrist gives a typical critique using classical equilibrium thermodynamics. He calls *permissible* overunity systems (open dissipative systems receiving excess energy from an external source) *false perpetual motion machines* or *fictitious perpetual motion machines*. Also see Angrist's article, "Perpetual Motion," **Encyclopaedias Britannica, Bicentennial Edition, Macropaedia** Vol. 14, 1976, p. 102-105. Here he gives a very good summary of the subject as ordinarily posed, with precise definitions included for perpetual motion machines of the first, second, and third kinds and for fictitious perpetual motion machines. Unfortunately his entire argument is completely irrelevant to any study of permissible overunity machines, which he already has labeled as "fictitious perpetual motion machines" and has already admitted that they exist! The substance of his entire argument is that systems in equilibrium cannot power themselves. That is of course quite true, but is a mere tautology and has no relation to an open system in disequilibrium, which *can* power itself and its load simultaneously, by the laws of physics and the laws of *disequilibrium* thermodynamics. So in fact Angrist, as do the skeptics who continue to assail legitimate overunity EM system researchers as perpetual motion nuts, establishes his own dummy strawman and demolishes it, while ignoring—so to speak—the huge Statue of Liberty before him.

Now this is not to pick on Angrist! He appears to be a reasonable scientist, carefully stating his thesis in a straightforward manner. His voice is quoted as a *reasonable* critical voice, and not like the usual *extremist* critic who engages in ad hominem attacks from the outset. It merely shows that (1) the entire "perpetuum mobile" prohibition does not even apply to overunity EM systems far from thermodynamic equilibrium with the active vacuum, (2) the critics are either unwittingly or deliberately using the wrong type of thermodynamics as the basis of their entire argument, (3) the *reasonable* perpetual motion critics—wittingly or unwittingly—simply set up an irrelevant strawman and precede to knock it down, and (4) in fact the critics already admit to a machine that will in fact run itself and power its load indefinitely or perpetually unless something changes or breaks or fails, but then oddly label it as a "fictitious" or "false" perpetual motion machine! Meanwhile, in the universe around us we universally observe things in violent and perpetual motion, having continued so for some 15 billion years. None of the atoms seem to be running down, nor do any of the molecules. And they are open systems brought out of equilibrium by absorption of energy, and decaying back into equilibrium (or approaching it) by emission of excess energy.

The eerie point is that technical publications such as **Scientific American** and **Encyclopaedia Britannica** do not seem to question the line of reasoning advanced by those knocking perpetual motion, or even fully analyzed their argument. What we really deal with in terms of skeptics in this area is either (1) a reasonable, scientific skeptic such as Angrist (his listing of machines and attempts for machines not in disequilibrium with their active environment to run themselves is very good), or (2) an unreasonable person spouting dogma and venom, who should simply go read some disequilibrium system thermodynamics and learn etiquette.

Also, we strongly object to supercilious phrases invariably employed by harsh skeptics who insist we are looking for "something for nothing" or "a free lunch". No legitimate overunity energy researcher has ever considered such a thing. We freely admit that the excess energy is received from the active vacuum exchange, via a broken symmetry in that exchange. Should the farmer refuse to use a windmill or waterwheel because he's getting a "free lunch" for energy input? For those who so quickly hurl such condemnatory phrases, let me hold up a mirror and show them an analog of their position: The famed surgeon Alfred Velpeau wrote in 1839: *"The abolishment of pain in surgery is the chimera. It is absurd to go on seeking it today. 'Knife' and 'pain' are two words in surgery that must forever be associated in the consciousness of the patient. To this compulsory combination we shall have to adjust ourselves."* [Martin Gumpert, **Trail-Blazers of Science**, Funk and Wagnalls, New York, 1936, p. 232.]

The strident, dogmatic critics of open overunity disequilibrium EM systems are stating an exact analogy to Velpeau's statement. The *scientific* worth of their criticism is precisely the scientific worth that eventually was shown for Velpeau's pronouncement.

PHASE CONJUGATE

Of an entity: its time reversal. For waves, often referred to as *wavefront reversal*.

PHASE CONJUGATE MIRROR

A nonlinear material which, when provided with an input wave, emits a phase conjugate replica (time reversed replica) of that input wave.

The input wave is by practice called the *signal wave*. The time-reversed wave output is by practice called the *phase conjugate replica*.

PHASE CONJUGATE OPTICS

That portion of nonlinear optics dealing with multiwave mixing, formation of time-reversed waves, phase conjugate reflection (PCR), phase conjugate mirrors (PCMs), pumping PCMs to amplify their emitted PCRs, nonlinear interferometry, distortion correction, self-targeting, laser tracking, adaptive optics, and so on.

PHASE CONJUGATE REPLICA (PCR)

Of a wave: the time-reversed duplicate of the wave.

PHASE-CONJUGATING ACTION

In nonlinear optics, the process or action of producing a time reversed replica of an input wave.

For a particle, producing its antiparticle. For a cell, dedifferentiating it back to some previous form, genetics and all.

PHASE CONJUGATION

In nonlinear optics, the novel nonlinear mixing of waves which generate an output wave—called the phase conjugate replica or time-reversed replica—that precisely retraces the path previously taken by the input wave that stimulates the action.

The process or action of producing a time-reversed wave. Phase conjugation can compensate for aberrations and distortions in the input. Real time holography can also be produced by applying the phase conjugation process.

PHASE-LOCKED HARMONIC SERIES

In Whittaker decomposition of the scalar potential: The decomposition produces a set of bidirectional wavepairs, as explained previously.

Each of these wavepairs has a given frequency, starting from a fundamental. In other words, the other wavepairs are harmonics of the fundamental wavepair. Further, these are regularly arranged in a lattice, so that "timing" or "phasing" is rigidly locked in place.

PHENOMENOLOGY

In physics, the philosophical and experimental study of physical phenomena,

... as distinguished from ontology, (which is the study of being).

PHOTON

In physics, the basic action quantum.

Considered to be the basic quantum of the EM field. Well, there's a little problem with that. The photon contains energy and time, and so must also occupy a time interval. The notion of forcefield rigorously contains mass as a component; yet mass is missing from the concept of field as it is applied. The EM field is conceived as a spatial entity only. It may spatially vary as a function of time, of course, but it itself does not occupy time, at least conceptually. These considerations raise some startling difficulties in the ready conclusion that the photon is the fundamental quantum of EM field. If a "piece of the photon" is missing from the field, how can the field be made of photons? How can one get area out of a straight line? I simply pose this problem for the theorists and the foundations physicists, pointing out that it has universally been fashionable for physicists to ignore that *the photon carries not only a little increment of energy, but also a little increment of time*. My own work has been to look at the dimensional difference between masstime and mass; i.e., between a mass that has just absorbed a photon, and thus must consist of masstime (4-space), and just after that masstime then re-emits the photon, reverting back to mass (3-space). From this one can build, e.g., a mechanism that generates the actual flow of time itself. It is in theory an engineerable mechanism.

PHYSICAL REALITY

To be added.

PING-PONG

To be added.

PINNA

The outer ear(s). Of particular interest to us are the tiny little folds in the ear.

PINNA INFORMATION

Refers to hidden information content of the field, or in the received signal.

Comes from the little folds in the pinna (outer ear). For sound direction and distance sensing, the tiny pinna folds of the outer ear use phase reflection information more than 40 dB below the primary sound signal that strikes the eardrum. In EM signals, we are referring to "hidden" or infolded information deep within a signal from a distant target. In fact everything in the target contributes to the signal emission from it, and all that information is riding "within" the signal, in its deep "pinna" information. The Fogal chip can outfold some of this pinna information, so that information can be recovered from a signal which no other process heretofore could recover. For a dramatic future use, as the Fogal semiconductors and equipment using them are developed, there will emerge detecting units that can see highly detailed structure in the human body, merely from processing the light reflected from the exterior of the body. The details eventually will rival and even surpass that of magnetic resonance imaging, and will be essentially noninvasive.

It is also true that hidden "vacuum engines" can be transmitted back into the body, so that "problems" or disorders can be directly corrected. As an introduction to this type of area, where cellular disease "antiengines" can be created in the body to directly reverse cells and their genetics, curing the disease, see T.E. Bearden, "Vacuum Engines and Priore's Methodology: The True Science of Energy-Medicine, Parts I and II." **Explore**!, 6(1), 1995, p. 66-76; 6(2), 1995, p. 50-62. A major book on this subject will soon be published. For a presentation for the nonspecialist, see T. E. Bearden, "Hidden Mechanism for Reversal of Diseased Cells to a Previous Healthy State," **Resonance**, Newsletter of the Bioelectromagnetics Special Interest Group, Mensa, No. 29, Nov. 1995, p. 11-15.

PINNA INFORMATION CONTENT

In electromagnetics, the hidden inner Stoney-Whittaker-Ziolkowski infolded EM information inside the scalar potential.

Since an EM wave can be represented as two scalar potentials, then by infolding pinna information inside one or both of the two potentials, it is infolded inside the carrier wave. Thus hidden information can be and is carried by all EM radiation and all EM signals. The Fogal semiconductor for the first time enables the outfolding and processing of some of this information.

PINNA INFORMATION DETECTORS

Detectors based on use of the Fogal semiconductor, which can outfold, process, and display some of the hidden information inside the scalar potential and inside signal emissions from distant objects.

PINNED ELECTRONS

Electrons held stationary by a magnetic field, or other set of forces that react to "push them back into their positions" whenever they try to move away.

PINNING

The act of restricting (by restoring forces and fields) movement (particularly of electrons) due to a disturbing magnetic field or other external force.

POLYHEDRON

A solid figure, especially with more than six plane surfaces.

POSITRON

An antielectron (time-reversed electron), possessing a positive charge. In Dirac's relativistic theory of the electron, a positron may be regarded as an empty negative energy state in the Dirac sea whose usual occupying electron has been removed.

POWER

The time rate at which work is done (at which the form of energy is changed).

In electrical engineering, the term "power" is erroneously also used to mean "energy".

PRIGOGINE, ILYA

Noted Belgian chemist and Nobelist, and one of the pioneers of the thermodynamics of open systems far from thermodynamic equilibrium.

Prigogine was awarded the 1977 Nobel Prize for his work on the theory of dissipative structures in nonequilibrium thermodynamics.

PRIORÉ, ANTOINE

Italian radar technician, remaining in France after WW II, who discovered the use of novel waves from plasmas emitted when normal EM waves were introduced, and who used this effect to accomplish remarking healing in laboratory animals of terminal tumors, infectious diseases such as trypanosomas, restore suppressed immune systems, and heal atherosclerosis.

Prioré's beam was actually longitudinal EM waves. The body when irradiated by longitudinal EM waves adds a weaker phase conjugate replica, thus converting LW nonlinear optical pumping from the 3-space domain to the time domain. This time-reverses the irradiated cells and all their components back to a previous physical state and condition.

Such "time-domain" pumping is used by the living body's cellular regeneration system to restore cellular damage and heal the cells, within its limits. Thus Prioré unwittingly uncovered a way to dramatically amplify the body's own healing and regenerative powers.

POYNTING, JOHN HENRY

An English physicist who lived from 1852-1914, whose contributions to electromagnetics included the energy flow theory now known as Poynting flow.

He contributed the Poynting theorem, which states that the rate of EM energy loss in a specific region of space is equal to the sum of the dissipation rate (heat loss) flowing across the boundary of the region. Concurrently with Oliver Heaviside, Poynting conceived the notion that energy flowed through space, which previously had not appeared in physics. Heaviside actually published first, but obscurely; Poynting published in a prestigious journal, so the theory came to be known as "Poynting theory." Poynting himself always gave credit to Heaviside for being first. Also, the Heaviside version $\mathbf{S} = \mathbf{E}\times\mathbf{H} + \mathbf{G}$ was more extensive than Poynting's $\mathbf{S} = \mathbf{E}\times\mathbf{H}$. Heaviside was a recluse; years after his death, in his little garret apartment some papers were discovered beneath the floorboard. Therein Heaviside has used his **G** term (a closed energy flow, or "trapped energy" term) to represent gravitation, and had worked out a testable theory of electrogravitation. Modern general relativity indeed considers that it is energy—particularly trapped energy—that is responsible for generating gravitational field and gravitational potential. Apparently nothing at all was done or has been done with Heaviside's electrogravitational theory. See H. J. Josephs, "The Heaviside papers found at Paignton in 1957," **The Institution of Electrical Engineers Monograph No. 319**, Jan. 1959, p. 70-6.

POYNTING ENERGY

Loose term (not rigorous!) used to describe the flow through space of Poynting energy density $\mathbf{S} = \mathbf{E}\times\mathbf{H}$. It actually describes not the energy flow density per se, but that component of it that would be intercepted by a unit point charge.

POYNTING ENERGY DENSITY FLOW

A more rigorous term used to describe the flow through space of the Poynting energy density flow component **S** = **E**×**H**. that would be intercepted by a unit point charge.

POYNTING ENERGY FLOW

Loose term (not completely rigorous) used to describe the flow of energy density **S** = **E**×**H**.

Rigorously, note that both **E** and **H** are "defined" only after their reaction with a unit point static charge. Hence **S** is the resulting component of the overall energy flow that interacts with the charges (with the circuit) and is diverged into the circuit to power it. It is *not* the entire energy flow, which also includes a vast Heaviside nondiverged component that does not strike the charge and interact with it, and hence does not interact with the circuit but is just wasted.

POYNTING GENERATOR

Any dipole or potential difference, which represents a broken symmetry in the vacuum's virtual particle flux, and hence extracts virtual energy from that asymmetry, and gates it out as a gushing energy flow in 3-space. The component of that energy flow that would be intercepted and diverged by a unit point charge is the Poynting energy flow **S** = **E**×**H**.

POYNTING VECTOR

The vector **S**, given as **S** = **E**×**H**, which is used to represent the Poynting (intercepted and collected by a unit point coulomb) energy density flow component.

In Heaviside's version, **S** = **E**×**H** + **G**, where **G** is an energy circulation flow term of trapped energy flow.

PPCM

Pumped phase conjugate mirror.

A phase conjugate mirror material which has introduced to it appositive or "pump" waves. In the phase conjugating process, up to all the energy in the pump waves can be output as the energy in the emitted phase conjugate replica wave. Thus the PPCM is an amplifier, very similar to a triode.

PRIMARY IMAGE

The image or portion of an overall image that is of most interest, and usually the sharpest in focus.

PROBABILISTICALLY

Of or determined by the laws of probability.

Note particularly the somewhat dichotomous use of "determined by—probability." The entire notion in probability is that the overall result is not individually determined, but that there are multiple outcomes of the experiment, each of which occurs with a certain frequency out of a very large number of trials. If a single result always occurs, that is said to be a deterministic change, not a probabilistic change. Unfortunately if one pursues the definition of "probability" in mathematics and logic, one eventually finds that it is dichotomous, as was our definition of energy. Ultimately the foundations guys just threw up their hands and said, "Oh, what the heck! Probability is probability, every fool knows that!" The problem cannot be resolved in 3-law Aristotelian logic; it requires a higher topology logic.

PROBABILITY

The probability of a simple event is the ratio of the number of times it occurs to the total number of trials (for a large, essentially infinite number of trials).

Note that "trials" constitute things that have occurred (are past). Probability has resisted rigorous logical definition by Aristotelian logic; the reason is that it is an expression of the fourth law, the identity of opposites. Probability is the expression of the future (that which has not occurred) in terms of the past (that which has occurred). Since we have been trained to conceive or think of something as if it had just been perceived to occur, then this is the only way we can *conceive* the future—as if it were an "already occurred past" to us.

But with Aristotelian logic, the future cannot be composed of a set of pasts (the law of the excluded middle prevents it!), and probability has no acceptable logical basis. With four-law logic, the future can be modeled in terms of—and even be identical to—the past, and probability has a logical basis.

Consider *throwing a die to land with one face up*. Thinking of the event (as if it has just occurred, in terms of the most recent past), one can conceive six ways of looking at it. In other words, one can conceive of six "most recent pasts." By the fourth law, the total "most recent past" is identical to the "most immediate future," on the common boundary. If one therefore *collects* all six "most recent pasts," they turn into the most immediate future, by the fourth law of logic. One may argue that only a single one of the events will actually occur. Here one counters with the observation that, when it occurs, it is the past, not the future, and then it has not been collected so as to move to the boundary. One also points out that, with the hidden variable approach, in theory it is possible to directly engineer those probabilities while the Schrödinger wavefunction is still propagating and has not yet collapse to constitute an "observation." I.e., it is possible to engineer Wheeler's "pre-reality," and determine in advance just which of the outcomes shall occur.

Now, if this type of equipment eventually gets built and is small and portable, just think what one could do in Las Vegas!

PRODUCT SET OF INTERNAL WAVES

Modulations of the internal bidirectional wavepairs comprising a scalar potential.

This set was added in the mid-1980s by Ziolkowski, to Whittaker's 1903 sum set. When a signal is "infolded" inside the DC potential, it is modulated upon (multiples) one or more of the internal biwave pairs. Ziolkowski's work is necessary to deal with that; Stoney and Whittaker alone do not handle it.

PSYCHOENERGETICS

Russian branch of energetics where extended electrodynamics is targeted upon the mind and its functions, hence in the time-domain and employing time-polarized EM waves.

PSYCHOTRONICS

Czechoslovakian name for extended electrodynamics effects on the living body.

PUMPED PHASE CONJUGATE MIRROR (PPCM)

A nonlinear material which:

(i) when provided with an input wave, emits an amplified phase conjugate replica (time reversed replica) of that wave, and

(ii) has additional opposing waves as inputs, so that their energy is transformed into the amplified energy of the time-reversed replica wave.

The word "mirror" is misleading, in that the "mirror" may be just a highly nonlinear material, or be an actual smooth metallic surface containing "hot spots" by heating, etc. In any case, it is the nonlinearities such as the hot spots that produce the phase conjugating action.

PUTHOFF, HAROLD

Noted physicist active in a variety of fields and investigations including in psychoenergetics, extended electrodynamics, energy from the vacuum, parapsychology, remote viewing, psychokinesis, zero-point energy of the vacuum, and cosmology.

We have specifically mentioned his important cosmological feedback principle.

QM VACUUM

The quantum mechanical vacuum, which models the vacuum as an intense flux of virtual particles, each appearing an disappearing in such extreme time intervals as to be unobservable individually.

Violent fluctuations of extremely short duration constantly occur in the QM vacuum flux. Various calculations estimate the energy density (in mass units) as up to 10^{80}-10^{90} grams per cubic centimeter, or even greater.

QUALITATIVELY

Determination based on qualitative analysis, usually as contrasted to quantitative determinations.

QUANTIZED

i) Reduction of some observable quantity to multiples of some small, indivisible unit, or,

ii) expressed in terms of quantum theory.

QUANTUM

A single "particle" of the quantity action.

The quantum is always composed of two fundamental quantities (canonical variables), and it is the "fissioning" of the action quantum into two pieces which results in detection of one of the pieces. An indefinite "smear" of part of the two pieces may be simultaneously detected by a linear detector, but never both exactly (Heisenberg uncertainty principle). More recent work has shown that, in a highly nonlinear situation, both canonical variables can be determined simultaneously to any desired degree of accuracy, in which case the Heisenberg uncertainty principle does not hold in its conventional form. This fundamental change in what has been regarded as one of the "sacred laws" of physics has not yet made it into most physics texts.

QUANTUM ELECTRODYNAMICS

The theory of photons and electrically charged particles and their interactions.

The use of the term "quantum" implies that the EM radiation's discrete photon nature is significant, so that quantum theory must be employed.

QUANTUM FIELD THEORY

A quantum mechanical theory in which "... a physical field is considered as a collection of particles and forces, and observable properties of an interacting system are expressed as finite quantities rather than state vectors."

[**Dictionary of Science and Technology**, ibid.] More simply (after Davies, **The New Physics**, 1989): "The theory that describes the quantum effects of a classical system of fields defined on space-time and satisfying various partial differential equations."

QUANTUM POTENTIAL

A special potential added to the Schrödinger equation, by Bohm in his hidden variable theory of quantum mechanics.

The quantum potential can move instantaneously. In my book **Gravitobiology**, I published a mechanism by means of which a quantum potential can be created. (There may of course be *other* QP-creating mechanisms). An iterative, mutually phase conjugating of EM signals passed back and forth between two objects, or among many of them, is called *self-targeting*. Extreme self-targeting can produce such a QP or partially produce one, particularly if a dense "pumping" (optical sense) of the phase conjugate mirror objects occurs. I am presently proposing the QP as a means of direct energy amplification. I.e., if there is "instantaneous travel" between two light-observed points, then to the instantaneous agent there is no length separation or time separation between the points. This of course means that in effect the objects now coexist "superposed" on each other in a multiply connected space, at least with some fraction of "coupling".

Suppose the coupling fraction is 0.5, and 100 widely separate d nodes are so connected by a common QP. Then if one puts in 1 joule per second of energy flow at a given node, there will instantly and simultaneously appear at each of the other 99 nodes one-half joule of energy per second flow. So I can gain quite a bit o f *direct energy amplification* in this distributed system, and nothing can "shield" the distant nodes. Presently, other than possibly Gabriel Kron's "open path", I have not found any other consideration of "direct amplification of energy at a distance".

The implications of the quantum potential—in everything from power sources to medicine to weaponry—are staggering. Weapons based on just this very QP, multiply connected space, and direct energy amplification appear to have already been developed and are on site in three nations. A fourth either is just getting them or is nearing their deployment.

QUATERNION

Expression comprised of the sum of four terms, one of which is real and three of which contain imaginary units, and that can be written as the sum of a scalar and a three-dimensional vector.

QUATERNION ALGEBRA

The algebra of quaternions and their mathematical operations.

Quaternion algebra is of higher topology than either vector algebra or tensor algebra. Maxwell's original equations are some 20 equations in 20 unknowns, in quaternion algebra. Heaviside and others reduced the algebra to vector algebra and some four equations. The present vector equations taught in university as "Maxwell's equations" are in fact Heaviside's truncation of the Maxwell theory. Going to tensor algebra electrodynamics cannot recover the full range of Maxwell's quaternion theory.

As an example, what Tesla actually did in his patented circuits cannot even be seen in vector or tensor analysis. On the other hand, analysis of his circuits by quaternion electrodynamics clearly reveals his startling ability to shuttle the energy in the circuit at will. See T. W. Barrett, "Tesla's Nonlinear Oscillator-Shuttle-Circuit (OSC) Theory," **Annales de la Fondation Louis de Broglie**, 16(1), 1991, p. 23-41.

QUINTESSENCE

Literally, the "fifth essence". In short, dark energy.

RADIONICS

To be added.

REACTIVE POWER

Electrical power, measured in volts-amps-reactive (vars) that cannot do work as is.

For sinusoidal waveforms, the formula for reactive power is given by $I \cdot V \cdot \sin\theta$, where θ is the phase angle between the voltage and the current.

REAL, HIDDEN DYNAMICS

The dynamics of vacuum engines, or of "internal energy" or "internal work" ongoing in a system or volume of space.

REAL HIDDEN VECTORS

The "hidden" or "infolded" real vector components,

e.g., of a vector zero summation system.

A group of nonzero, finite vectors which as a system sum to a net translation zero; i.e., which do not translate a resisting mass or charge, but do "stress" it. Such a system therefore constitutes a stress potential.

REAL POWER (ACTIVE POWER)

Power, measured in watts, that can do work, including generating heat.

For sinusoidal waves, real power is given by the formula $I \cdot V \cdot \cos\theta$, where θ is the phase angle between the voltage and the current.

REAL VECTORS

Vectors in three space, without imaginary components.

REGAUGE, REGAUGING

Changing the scalar potential or the vector potential, or both.

If one or both of the potentials is/are changed so that a net force is created in the system, that is an asymmetrical regauging.

If only one potential is changed, a net force results and that is an asymmetrical regauging.

If both potentials are changed but carefully selected so that the free force resulting from one change is equal and opposite to the free force resulting from the other, that is a net symmetrical regauging, often called a "Lorentz regauging".

RECTANGULAR TRANSFORMATION MATRIX

Standard mathematical physics.

REFLECTION

The rebound of light or other energy from a surface.

A smooth surface (e.g., a mirror) may produce a specular reflection. A rough surface (e.g., a sheet of paper) produces a diffuse reflection. Actually, in reflection of light, the same light does not rebound; instead, the light incident upon the mirror or surface is absorbed, and new light is re-emitted by that surface. Further, considering reflection from a dielectric, every interior part of the dielectric participates in the reflection. All the internal information about the entire object—everything!—is there in that reflected light, infolded as the hidden "information content of the field" (Stoney-Whittaker-Ziolkowski structuring inside the two scalar potentials comprising the reflected wave). With the Fogal semiconductor, at least some of that hidden "pinna" information in a sample detection of the reflected light can be outfolded and displayed.

REFRACTION

The bending of light as it passes from one medium to another.

It is the phenomenon that enables a lens to focus light and that makes a stick appear to bend where it dips into water.

REPULSION BEAM

A beam of energy directed at a target, which when absorbed by the target will generate a force in and on that target to push it away from the beam projector.

REPULSION-FORCE-GENERATING BEAMS

Beams of energy which "push away" their targeted receivers, by inducing a force in the receiver directed away from the source of the beam.

RETARDED WAVE

The electromagnetic wave that is derived from the retarded fields, which in turn are derived from the retarded potentials.

This means that the retarded wave at a point or region of space has arrived there or exists there as the result of the dynamics of charges and currents that existed at earlier times.

RETROREFLECTING

Precisely reversing the path of.

An example is a phase conjugate reflection.

SACHS, MENDEL

Noted scientist who has completed the work of Einstein and developed a unified field theory covering the universe from the tiniest part to the entire conglomerate.

SACHS' UNIFIED FIELD THEORY

An extension and completion of Einstein's work that includes the universe and its dynamics from the tiniest part to the entire conglomerate, and includes quantum mechanics, electromagnetics, gravitation, and the strong and weak forces.

SCALAR

Characterized by magnitude only.

SCALAR (QUANTITY)

In ordinary vector analysis, a quantity completely characterized by magnitude only.

Actually, it contains magnitude and time, because to exist it must steadily exist in time. So we take the smallest increment of observer time we wish to consider, and that is the minimum "length" of the time-tail that the scalar must occupy and have, in order to even be a "perceived or detected" thing. Before the mathematician jumps in with a nice limiting process to take away the time-tail, if you let that little time interval get too close to zero, then you get too close to eliminating the observer himself, and the entire problem vanishes including mathematics and physics and the observer as well.

One simply cannot demonstrate something that does not exist in time—on paper, in one's mind, or otherwise! Be careful of the term "spacelike " in physics! It hides a logical nightmare. This was the very problem I uncovered in Aristotelian logic; the little increments of time to have a "perceived A" or a "perceived not-A" or to apply an "identity decision criteria" to determine identity or nonidentity, had been left out for lo these 2,000 or so years.

SCALAR ELECTROMAGNETICS

That electrodynamics that arises from considering transverse EM waves, longitudinal EM waves, time-polarized EM waves, electrogravitation, superluminal EM signals, interferometry, nonlinear optical functions, time-as-energy, and the infolded electrodynamics inside all usual EM fields, waves, and potentials.

SCALAR POTENTIAL

Usually considered synonymous with the electric potential.

Here we have another "logical nightmare."

Anyway, the conventional "definition" of electric potential assumes one knows what a "potential" is already, and goes something like this: "The potential measured by the energy of a unit positive charge at a point, expressed relative to an equipotential surface, generally the surface of the earth, that has zero potential." [**Dictionary of Science and Technology**, ibid., p. 722.]. Well, that is botched. It tells or attempts to tell what the *measurement* of a potential is, using a unit positive charge and a process. A potential cannot be its own magnitude measurement, just as a man cannot be his own weight measurement.

So what do we do? We have to tell what the potential *is*. This is the problem that so mystified and infuriated Oliver Heaviside, when he altered and diminished Maxwell's equations to rid them of every potential that he could. Heaviside stated that the potential was *"mystical and ought to be murdered from the theory."* He tried to do just that, and conditioned generations of electrodynamicists to believe that the potential had no physical reality at all, but was only a mathematical convenience. Nahin expresses Heaviside's view as follows: "In an 1893 letter to Oliver Lodge, Heaviside said of his own work that it represented the 'real and true "Maxwell" as Maxwell would have done it if he had not been humbugged by his vector and scalar potentials.'" Paul Nahin, **Oliver Heaviside: Sage in Solitude**, IEEE Press, New York, 1988, p. 134, n. 37.

The concept of potential was developed by Poisson, Green, and others from about 1813 to 1827. Three notions involved in the development of the concept of the potential are: (i) there is the collection or storage of energy in the system, via the collection or storage of some entity therein, and this "potential energy" can be released and dynamically used, (ii) the potential is a scalar function whose spatial rate of change is a vector force, and (iii) the dynamics of the stored energy is suspended by the "storage" or "collecting" entity; in other words it is a sort of "suspended action" waiting to be unleashed. *It requires some action—such as interception and divergence—to release the leashed energy*.

We have to disagree with the second notion, having already discussed the fact that no vector force exists unless mass is present, since mass is a component of force. Here we have a residue of the old "material ether" concept. For the third notion, we note that the concept of a "virtual" particle or particle flux means that it cannot become observable unless some interaction is imposed. So we may handle the "third notion" requirement by assuming the potential to be composed of hidden virtual particle flux, or hidden wave flux, in wave-to-wave interaction.

Physics basically tries to define the electrical potential as energy per coulomb, or $\phi = W/Q$. That equation, however, is actually not a definition at all, but rather is an algorithm for calculating the magnitude of the excess energy collection/collecting upon a coulomb of charge, when that coulomb is immersed in the potential ϕ. It in fact is the *reaction cross section* of the potential, not the potential entity itself. This now begins to give us a clue. Potential is *energy* in some fashion. So the entity ϕ must have essentially the same definition as energy! Potential energy, collected energy, stored energy, whatever it's energy first and foremost.

Refer to our discussion of the 3-law logical contradiction in the concept of energy. The same logical contradiction must be present in the notion of the potential.

Just as we did for energy, we must define the scalar potential ϕ in two appositive ways: (i) in the wave view and (ii) in the particle view. So we define potential (particle view) as any virtual particle flux. We also define potential (wave view) as any hidden wave flux. Further, we note that the energetic vacuum is composed of a virtual particle flux (particle view) and so it is also a *potential*. Since the virtual particle flux of the vacuum is extremely intense, the vacuum potential is enormous in magnitude.

We shall also consider any other potential to ultimately be a change to the vacuum potential. Originally, one conceived of a potential occupying the "vacuum as an empty space." Then general relativity made the vacuum into spacetime, geometrized it, and made the geometry itself dynamic and operative—i.e., energetic. Okay! Then that makes spacetime itself a potential.

We also firmly dispose of the peculiar and deformed notion that the scalar potential of a point-source charge (at any spatial point that the potential occupies) may be *defined* as the "work performed upon a unit charge by pushing it in against the **E**-field of that source charge, to that spatial point." This is an equation and not a definition at all; instead, it is an algorithm for calculating the energy density magnitude of the scalar potential. It is a fine algorithm, but it has nothing at all to do with what the potential itself *is*. Again, a man cannot be defined as an algorithm for calculating the magnitude of his height or his weight or his energy density!

Without further discussion, we also somewhat extend the general relativity notion of spacetime as dynamic geometry, as follows: In a special sense, spacetime ≡ geometry ≡ potential ≡ "trapped " or collected/collecting energy. So when we engineer the internal structure of the potential, we also engineer the internal structure (subspace) of spacetime and spacetime geometry. Curvature of spacetime, e.g., becomes simply a change in the energy density of the vacuum, from the ambient value, and it can be internally structured so as to contain "engines". When we apply the hidden EM variable theory of the Stoney-Whittaker-Ziolkowski work, particularly when we consider the phase conjugate pairing as it exists in spacetime before interaction with charge, we are engineering and extending (i) electromagnetics, (ii) quantum mechanics, (iii) general relativity, (iv) spacetime, (v) the spacetime curvature concept, and (vi) spacetime geometry.

SCATTERING PROCESSES

Collision processes in which an incident particle such as a photon, electron, or proton, of known energy or direction or both, collides with another entity, and emerges from the collision with a different energy or direction or both.

SCHRÖDINGER, ERWIN

Noted Austrian physicist and Nobelist who discovered the wave equation named after him as the Schrödinger equation, and performed other vital work in wave mechanics.

SCHRÖDINGER EQUATION

In quantum mechanics: an equation that describes the propagation of waves associated with subatomic particles, or more generally, that describes the evolution over time of the quantum state of a system.

SCHUMANN RESONANCES

The extremely low frequency (ELF) resonant frequencies of the Earth-Ionospheric waveguide.

The first five Schumann resonances calculated from a simple model are 10.6 Hz, 18.3 Hz, 25.8 Hz, 33.4 Hz, and 40.9 Hz. However, better models are available and the frequencies vary from these simple model solutions. A better calculation gives the first four as 8, 14, 20, and 26 Hz nominally. The measured Schumann resonance corresponding to the 8 Hz is about 7.75 Hz. This is very near the mechanical resonance frequency of the human body, and also is evidenced in brain waves often "locking" to this frequency in the natural environment.

See W. O. Schumann, **Z. Naturforschung**, Vol. 72, 1952, p. 149, 250. For detailed models and discussion of the observations, see J. Galejs, **J. Res. Nat. Bur. Standards**, Vol. 69D, 1965, p. 1043.

SELF-ENERGY

In a quantum mechanical system, the energy associated with the emission and absorption of virtual particles.

In a classical system, the energy associated with the interaction among parts of the system itself.

SELF-ORGANIZATION

(After Davies, **The New Physics**, 1989): *"Spontaneous emergence of order, arising when certain parameters built in a system reach critical values."*

Simpler put, it is the spontaneous formation of patterns of localized order in a system which begins in a more homogeneous state. In short, the system moves from a simpler to a more complex state.

SELF-POTENTIAL (E.G., OF THE ELECTRON)

The potential created in and of the charge

...(e.g., the electron) by its virtual particle flux exchange with the vacuum.

Also, an asymmetry in the virtual photon flux of the vacuum, caused by the interaction of the charge (e.g., the electron) with the vacuum flux. From here, we note that the self-potential must consist of real observable 3-space EM energy flow or flows from the electron, because of the asymmetry. However, the charge is not the primary source *per se* of the energy flows that establish the self-potential, but instead is the asymmetric gate in the vacuum flux that "gates out" the potential and its energy flux. The asymmetry in the vacuum flux is the actual *source*. Indeed, the energy is received by the charge in the form of converging longitudinal EM energy waves from the complex plane (from the time domain). The spin of the charges of the dipole transduce the absorbed complex EM energy into real observable EM longitudinal wave energy, and pour it out in all directions in 3-space. See my paper, "Giant Negentropy from the Common Dipole," *ibid*. for the mechanism for the charge also.

SELF, SENSE OF

To be added.

SELF-TARGETING

Between two entities, where each acts partially or wholly as a phase conjugate mirror, self-targeting is the iterative phase conjugation or "ping-ponging" and rapid convergence of beams between the two PCMs.

It has a spectacular application in *phase conjugate shooting* from a spaceborne laser against a rising hostile booster, even several thousand miles distant. First a laser pulse is "bounced off" the distant target, and the reflected pulse returns to the receiver in the laser platform. It carries the movement-induced alteration of the distant target on the pulse it reflected. The next emitted pulse is an amplified phase conjugate replica of that received pulse, and it will backtrack to the same spot on the rising booster, leading it a bit and converging moderately so that it meets that spot. That spot begins to heat up, increasing its nonlinearity and making it act even more as a PCM. So its reflected signal off the "hot spot" is also a phase conjugate replica of the pulse that it received from the laser. That reflected pulse now will moderately converge its reflected energy upon the distant laser, increasing the return to the laser. The ping-pong continues, so that the laser beam narrows sharply upon the distant hot spot, and the reflected beam from the hotspot narrows sharply upon the distant laser. This "iterative narrowing ping pong" locks the laser upon the distant hotspot, even though the booster is moving. This process continues for the necessary dwell time, until the beam melts through that spot and explodes the hostile booster. The iterative phase conjugating reflection, or "ping ponging" between the target spot and the laser, is called *self-targeting*.

S-FLOW

The Poynting energy density flow S, where **S** ≡ **E**×**H** + **G**.

E is the electric field, **H** is the magnetic field strength, and **G** is a trapped closed loop flow of energy density.

The **S**-flow is not the total energy flow per se. Since the fields **E** and **H** and the closed loop **G** are only defined in terms of the intercepted, trapped or "collected" energy, then **S**-flow is always *with respect to* some assumed intercepting/collecting entity, usually an assumed unit point charge.

SIGNAL WAVE

In nonlinear optics, the input signal (wave) to a phase conjugate mirror (PCM), which stimulates the PCM to emit a phase conjugate replica (PCR) wave in return.

SLEPIAN CURRENT

The vector jϕ , which in a current loop represents the energy unit area per coulomb of flowing charge, per unit of time, that is collected/collecting from the Poynting **S**-flow and dissipated in that current loop in its load s and losses.

It does not include the enormous amount of Heaviside nondiverged energy density flow that is flowing along the outside of the circuit conductors, and that is not being collected and therefore not being dissipated.

SLEPIAN FLOW

"Flow of collected-energy density dissipation" in a current loop,

...and therefore to the vector jf in the current loop, which represents the energy per unit area per coulomb of flowing charge, per unit of time, that is being dissipated in that current loop in its loads and losses.

It does not represent the enormous amount of energy that is flowing along the circuit, that is not being collected, not diverged, and therefore does not enter the circuit to be dissipated from it.

SLEPIAN VECTOR

Refers to the vector $j\phi$ in a current loop,

...which represents the energy density per coulomb of flowing charge, per unit of time, that is being dissipated in that current loop in its loads and losses.

It does not represent the enormous amount of energy that is flowing along the circuit, but not being collected and therefore not being dissipated. We accent that *only intercepted and collected energy can be dissipated!*

SOLID-STATE PARAMETRIC OSCILLATORS

A parametric oscillator circuit employing solid state devices.

A parametric oscillator is a device that oscillates by rhythmically changing a parameter (such as capacitance or inductance, etc.).

Simple switching between differing values of the parameter is often used to induced the periodic change of the parameter.

SOLITON

A wave pulse which propagates without changing its shape and without dispersion.

SOURCE DIPOLE

Any dipole, considered from the viewpoint that EM energy continuously pours out of it.

There is no true "source" as such in nature, since the energy is not created but only gated. In the case of the dipole and electrical charge as sources of EM energy, fields, and potentials, we solved that vexing problem in our "Giant Negentropy from the Common Dipole", *ibid*.

SPACETIME

The entity represented by the "fused product" of space and time, to give "space × time".

Spacetime is also dynamic geometry, in the general relativistic interpretation. We consider spacetime to be a potential, and also geometry, and also vacuum, and also virtual particle flux, and also hidden wave flux.

SPATIAL CLOUD

A cloud of something (such as electrons) in a spatial region.

SPATIALLY

With reference to space and spatial position.

SPECIAL RELATIVITY

Einstein's theory of inertial frames in which, if two systems are moving uniformly in relation to each other, one cannot determine anything about their motion except that it is relative.

Each of the two frames is said to be "rotated" with respect to the other, but not accelerating. The velocity of light in space (the vacuum) is constant, and is independent of the velocity of its source and the velocity of an observer. All the laws of physics are the same in all inertial frames of reference.

SPIN

The intrinsic angular momentum of a particle, such as an electron, proton, neutron, photon, graviton etc.,

...even when at rest, as if it were a top spinning about an axis, but had to spin 720 degrees before it turned "full circle."

Spin is quantized, and is always described as a half or whole spin, e.g., - 1, - 1/2, 0, 1/2, 1, etc. A spinning charged particle such as an electron thus demonstrates a magnetic moment, due to the circulation of charge in the spinning. In the nucleus of an atom, the spin of the nucleus is the resultant of the spins of the nucleons (particles comprising the nucleus).

Spin of particles would appear to be more like an "implosion" to "explosion" circulation; in other words, it circulates in the time domain (complex plane) as well. It would appear that the spin of a particle is the basic feature that integrates the (disintegrated) flux energy of vacuum flux into observable charge. Apparently all observable fields, matter, effects, etc. depend upon this basic mechanism to zip together virtual entities and form observable phenomena.

SPIRAL GALAXY

Those galaxies having arms which extend in the form of spirals.

About 70% of all galaxies are spiral galaxies.

The interesting thing is that only about 10% of the gravity necessary to hold the spiral arms together can be accounted for by known gravitational sources. This has led to the theorizing of dark (hidden) matter of exotic and unknown form, which would be responsible for the excess gravity.

The present author has proposed that the unaccounted enormous Heaviside component of the EM energy flow surrounding every field/charge interaction and not entering into that interaction, accounts for the missing source of the gravity. See "Dark Matter or Dark Energy?", Journal of New Energy, 4(4), Spring 2000, p. 4-11.

S-SOURCE

Source of Poynting energy density flow.

Source of **S** = **E**×**H** flow. The primary source is considered to always be an asymmetry in the virtual particle flux of the vacuum. The **S**-flow rigorously is that component of the overall energy flow that is intercepted by some system of interest—either present or assumed. That component of the overall energy flow that is not intercepted by the system of interest, is referred to by this author as the Heaviside energy flow or the dark energy flow associated with every field/charge interaction.

STONEY To be added

To be added.

STONEY/WHITTAKER BIWAVE DECOMPOSITION OF THE SCALAR POTENTIAL ACROSS THE DIPOLE

(i) a scalar potential (i.e., a difference in potential) exists between the end charges of a dipole,

(ii) that potential (difference) can be mathematically decomposed into a harmonic series of bidirectional EM wave pairs, where each pair consists of an EM wave and its precisely superposed time-reversed twin. Thus a dipole is a "source" or identically is a set of hidden bidirectional waves (wave view).

STRING THEORY

A rather recent mathematical physics theory which replaces the zero-dimensional "point" used in previous physics with a one-dimensional object called a "string".

It has been particularly effective in describing the gluon forces between two colored particles in particle physics, and has since been extended to many other areas. It is sometimes referred to as the "theory of everything".

"STRING" WAVE

The transverse wave on a taut string produced when the string is plucked.

The string wave itself stays on the string and does not travel through the slapped external medium.

However, Faraday believed that EM fields in vacuum consisted of "material lines of force" which behaved like such taut material strings, without any physical endholders. He thought that EM disturbances were simply the transverse disturbances of those "lines of force". He profoundly affected Maxwell's thinking, so that Maxwell accepted these physical lines of force. Consequently Maxwell *assumed* those same "transverse taut string vibration waves" in his EM wave theory.

In eliminating the "stringholders" for the assumed taut strings, Faraday and Maxwell discarded the Newtonian third law half of electrodynamics! They discarded half the energy and half the wave as well. Consequently today physics has no causative mechanism for Newton's third law, because it threw out the EM mechanism for it more than a century ago and never noticed it!

SU(2)×SU(2) SYMMETRY ELECTRODYNAMICS

To be added.

SUBSPACE

In vector mathematics: a subset of a vector space which is closed under vector addition and scalar multiplication operations.

In physics: Physics often uses the term "space" to refer to spacetime. It also uses the term "space" to refer to the dimensions of space, without the dimensions of time. At any rate, the spatial portion of spacetime is represented mathematically by some convenient number of dimensions. In the most usual practice, Minkowski spacetime of 3 spatial dimensions and one time dimension is utilized. In the Minkowski space, we now consider that "space" to be a vacuum scalar potential. If we consider the internal Stoney-Whittaker-Ziolkowski biwave pairs comprising that vacuum potential, we may transmit a signal communication along one or more of these internal biwaves, without changing any of the others. In that case, no overall potential gradient and overall forcefield signal appears. That domain that is infolded "inside" the scalar potential is said to be subspace. It may be modeled as a space of n-dimensions, where those dimensions are compacted and not observable to an external observer. Subspace gained great popularity from the Star Trek television series, where the spaceships used "subspace communications" to have signals propagate far faster than the speed of light. Bill Fogal has been working with some success on what should be a concrete realization of just this very "subspace communication system", with infolded signals that move much faster than the speed of light in vacuum.

SUPERCONDUCTIVITY

Property of some materials or metals whereby their resistance reduces to zero at very low temperatures.

These materials also exhibit many additional properties that are anomalous when compared to normal materials. Much research effort has gone into the attempt to find materials which exhibit superconductivity at higher temperatures, with the goal of reaching room temperature superconductivity.

SUPERLUMINAL

In a manner or with a speed faster than c, the speed of light in vacuum.

SUPERLUMINAL COMMUNICATION

The movement of signals faster than the speed of light in vacuum,

...and the transmission and reception of such signals and extraction of their transported information.

Longitudinal EM waves are not limited to speed c; transverse EM waves are limited to speed c. The infolded electrodynamics inside all EM fields, potentials, and waves consists of longitudinal EM phase conjugate wavepairs, with their impressed electrodynamics. Hence this "subspace" is a superhighway for such waves, including for those moving at superluminal velocity. In essence this is a very special kind of "tunneling" which we might refer to as *subspace tunneling*. The limitation to light speed rigorously applies to the modeled transverse EM waves which are a sort of "bulk upheaval" waves similar to waves on the surface of the ocean. As in the ocean wave analogy, "pressure" waves underneath the ocean may travel very much faster than the bulk upheaval waves on the surface.

When making longitudinal EM waves, the process is imperfect and the resulting longitudinal EM waves will have a transverse residue as well. The resulting "transverse-noisy" LW is called an *undistorted progressive wave*. Undistorted progressive waves may move slower than the speed of light or faster than the speed of light. See W. A. Rodrigues Jr. and J.-Y. Lu, "On the existence of undistorted progressive waves (UPWs) of arbitrary speeds $0 \leq v < \infty$ in nature," **Foundations of Physics**, 27(3), 1997, p. 435-508. A slightly corrected version is downloadable as hep-th/9606171 on the Los Alamos National Laboratory web site, and includes corrections to the published version.

SUPERPOSE

To lay or place on, over, or above something else, with the connotation of mixing.

SUPERPOSITION

The simple linear addition and subtraction of two or more values, states, etc.

Superposition is one of the key principles in field theories and in the concept of potentials.

SUPERSET

A large set referenced to a small set, where the small set is included in the larger set.

The large set is said to be a *superset* of the small set. The small set is said to be a *subset* of the larger set.

SW (STONEY-WHITTAKER) STRUCTURES

The Stoney-Whittaker hidden bidirectional EM wavepairs comprising the scalar potential, and structuring (altering) of same.

We call this internal EM dynamics inside every EM wave, field, and potential the "infolded" electrodynamics. Russian weapon scientists refer to it as the *information content of the field*.

SYMMETRICAL REGAUGING

In electromagnetics, changing the scalar potential to a different value, and simultaneously changing the vector potential to a different value, with the two changes just precisely selected so that the two extra forces (each created by one of the changes) are equal and opposite—thus canceling with respect to translation and doing no net external work.

We note that the two forces themselves must be considered to be present and still working continuously in opposition, increasing the stress upon the system regauged with excess energy, or decreasing the stress upon the system regauged with less energy.

This presence of "equal and opposite" excess forces from the symmetrical regauging is known as the *Lorentz condition*. The end result is that the *net* force fields of the regauged system remain the same, even though the stress of the system has been altered by the regauging and the potential energy of the system has also been changed. Since abstract vector mathematics contains no such thing as "stress" in its background vector space, zero vector resultant system of multiple nonzero vectors are most often simply discarded. Early electrodynamicists symmetrically regauged Heaviside's two "Maxwell" equations (potential form) so as to easily separate the variables. The net effect was to discard that set of the Heaviside/Maxwell equations that prescribed and included open electrodynamic systems that freely receive and collect energy from the external vacuum, and also obtain a free excess force which then can permissibly utilize that excess energy to translate and produce external work upon the system or externally upon a load. In short, the symmetrical regaging discarded practical overunity electrodynamic circuits and devices, which Maxwell's equations—even in their Heaviside modified form—have always prescribed and permitted. Contrast to asymmetrical regauging.

We specifically point out that the two extra forces remain, as does their energy, and both may be dynamic as the system is dynamic. Hence when one regauges, one has changed the gravitational aspects of the system and also curved the local spacetime. Further, this ST curvature is internally structured and that structure is dynamic. Thus contrary to the assumptions of electrodynamics, the regauged system *is not* the same as the original system.

SYMMETRY

A theory or process possesses a symmetry with respect to certain operations performed on it, if those applied operations do not change the theory or process.

The theory or process is then said to be "symmetric" with respect to those operations. As an example, there is no observable change in a circle when it is rotated or reflected in a mirror. The circle is therefore said to have rotational symmetry and reflection symmetry.

TANTALUM CAPACITOR

Electrolytic capacitor with a tantalum or sintered-slug anode,

...such as solid tantalum, tantalum-foil electrolytic, and tantalum-slug capacitors.

For the same capacitance, the weight and volume of the tantalum capacitor are less than comparable aluminum electrolytic capacitors. In other words, you can make the little son-of-a-gun smaller, for a given capacitance and charge it must hold. When utilized in the Fogal fashion, the tantalum capacitor also exhibits other properties that are still proprietary to Fogal's semiconductor processes and to Bill Fogal.

TARGETED PINPOINTS

Refers to those separated points which engage in self-targeting between themselves and some separated signal energy source (as in Fogal's semiconductor).

The effect is to sharply narrow the retroreflected source signal energy from the source onto the separated points by means of the mutual ping-ponging. In this fashion much more energy density from the source can be concentrated on the targeted pinpoints. In effect, phase conjugate shooting is evoked.

TENSOR

A special mathematical entity which is an element of a vector space such that it represents the tensor product of vector spaces and their duals.

Much of modern physics and advanced electromagnetics is expressed in tensor algebra theory.

TESLA, NIKOLA

Famous American emigré electrical inventor and eccentric whose numerous inventions fueled much of the electrical 20th century.

Tesla produced the AC system, including polyphase systems. From his experiments he knew that the EM wave in vacuum was longitudinal, like sound waves. In spite of his great accomplishments, his eccentricities and grandiose pronouncements did not endear him to electrodynamicists! An example is his acrid comment: *"...I showed that the universal medium is a gaseous body in which only longitudinal pulses can be propagated, involving alternating compressions and expansions similar to those produced by sound waves in the air. Thus, a wireless transmitter does not emit Hertz waves which are a myth, but sound waves in the ether, behaving in every respect like those in the air, except that, owing to the great elastic force and extremely small density of the medium, their speed is that of light."* Another major example is his statement: *"The Hertz wave theory of wireless transmission may be kept up for a while, but I do not hesitate to say that in a short time it will be recognized as one of the most remarkable and inexplicable aberrations of the scientific mind which has ever been recorded in history."*

Ironically, modern quantum mechanics has almost proven Tesla right that "the universal medium is a gaseous body." Today the modern QM vacuum is very much like a virtual particle gas. And of course the discussions in this present annotated glossary show why I personally am of the opinion that Tesla was also correct in his firm disbelief that those Faraday-Maxwell "taut physical strings without physical holders" filled the ether and provided transverse EM wave oscillations. I also agree with him that the EM wave in vacuum is a longitudinal wave, exactly like a sound wave. I believe that the transverse gyroelectron precession waves that our instruments actually measure in the conductor when it receives an incoming EM wave from the vacuum, proves that the vacuum wave is indeed longitudinal—else it would seem we must discard the spin of an electron and the theory of gyroscopes. Finally, one should see, e.g., Patrick Cornille, "Inhomogeneous Waves and Maxwell's Equations." Chapter 4 in **Essays on the Formal Aspects of Electromagnetic Theory**, Aklesh Lakhtakia, Ed., World Scientific, New York, 1993. Cornille clearly shows that Maxwell's equations are directly created by scalar potential interferometry. As he states, this means that EM force field wave s are created by the interference of sound-type scalar potential waves, or "sound creates light." This strongly supports Tesla's original statement that EM waves in the vacuum are actually EM sound waves, much like sound waves i n a gas.

TESLA'S MAGNIFYING TRANSMITTER (include Jackson quote)

To be added.

THERMOACOUSTICS

The generation of sound waves by heat.

THERMOACOUSTIC ENGINE

Essentially a closed resonant chamber containing three heat exchangers and a working fluid—such as an inert gas—under pressure, and used with a transducer to provide power such as mechanical power.

One heat exchanger is the hot-side exchanger through which heat is injected, another is the cold-side exchanger in which a coolant is circulated, and the third is a passive device between the other two, and known as a regenerator or thermal capacitor. The heating and cooling changes the pressure in the fluid greatly, and the regenerator oscillates back and forth, taking energy from the fluid, then giving it back, and keeping the engine going. A pressure wave (shock wave) moves through the working fluid and produces a resonator effect. The end result is an engine with rapidly fluctuating pressure gradients and no moving parts. The pressure gradients are then tapped off to drive a piston, which drives a linear alternator producing electricity. In a typical application, a single piston with a surface area of 1.5 square inches, and with a travel of only one centimeter, operated at 500 Hz, will produce about 30 horsepower output.

Information on these engines can be found on the Fellows Research Group website at http://www.io.com/~frg, or E-mail to frg@io.com. Many thanks to Oscar L. Fellows, "Be Our Guest: Thermoacoustic Engines—Propulsion, Power for the 21st Century," **Power Online**, 1/24/2000.

THERMODYNAMIC EQUILIBRIUM

Stable state eventually reached by an isolated system. One may consider it a "balanced" or "preferred" state.

Actually, a totally isolated system could not change. Any system is in a constant exchange with its vacuum environment, a priori, and no such thing as a completely isolated system exists in nature. Hence once excited, a system—to reach equilibrium—must exchange with its environment and is not a truly isolated system. But systems do exchange with their environment in hidden forms, so we can just let the original statement stand as is. Sloppy, but okay so long as we recognize the limits.

TIME

To be added.

TIME-CHARGE

To be added.

TIME-CHARGING

To be added.

TIME-ENERGY

To be added.

TIME-EXCITATION

To be added.

TIME-FLOW MECHANISM

To be added.

TIME-POLARIZED ELECTROMAGNETIC WAVE

An electromagnetic wave whose vibrations occur in the time domain only.

The wave is theorized in quantum field theory, or at least its time-polarized photon is theorized and called a "scalar" photon. There seems to be no Western method for detecting such waves, though they are predicted by theory.

TIME-POLARIZED (SCALAR) PHOTON

A photon whose vibrations occur in the time domain only, also known as a "scalar" photon.

TIME-FORWARD WAVE

A normal wave moving in forward time. Otherwise known as the retarded wave.

The external observer comfortably sees its forward progress as expected.

TIME REVERSAL

The process of forming the phase conjugate

...(e.g., of a wave or particle or entity or process or vacuum engine.).

We accent that *time-reversing a single object or single group of objects* is not the same thing as "travel into the past" so popularized by science fiction. For time travel to the past, the entire universe and everything in it except the traveler, would have to be time-reversed. That would not seem possible by any stretch of the imagination today! On the other hand, time-reversal of a single thing such as a particle or a wave—or even a group of things such as a group of particles or waves—is not only feasible but is readily achievable. A positron is a time-reversed electron, e.g. Becker showed that laughably weak DC electrical trickle currents (picoamperes) across otherwise intractable bone fractures could engender healing of the bone fractures. In investigating the effect, he showed that entire cells—specifically in that case, the red blood cells—were time-reversed (dedifferentiated) and then fast-forwarded (redifferentiated) into new kinds of cells, *genetics and all*.

In France in the 1960s and early 1970s, the Priore team showed in laboratory animals that this mechanism (which they nor anyone else understood they were unwittingly evoking) could be used to dramatically reverse and quickly cure terminal tumors, infectious diseases, arteriosclerosis, and suppressed immune systems. The same approach, if redeveloped, could stop and totally wipe out the emerging major new pandemic of hepatitis C, which nothing will touch at present and which will surpass AIDS infections after the turn of the century. The approach could totally reverse AIDS and eliminate all HIV infection, because it could simply time-reverse HIV-infected cells back to normal cells, genetics and all. In other words, it could readily and cheaply and quickly eliminate AIDS from the face of the earth. Further, the disease could be eliminated whenever a patient tested positive for HIV infection; there would be no need to wait for debilitation to set in. For coverage in detail, see T. E. Bearden, "Vacuum Engines and Priore's Methodology: The True Science of Energy-Medicine. Parts I and II." **Explore**!, 6(1), 1995, p. 66-76; 6(2), 1995, p. 50-62.

TIME-REVERSAL ZONE

A region of space in which a component of the overall time flow runs backwards, and hence the fundamental mechanism generating the flow of a mass through time is reversed.

Such zones are theorized as temporarily occurring in cold fusion, particularly once the palladium lattice is loaded with hydrogen or deuterium ions. Such a temporary region in the electrolyte is an excited state, and the other ions will move to nullify it and cause its decay. During its existence, ions in it experience a reversal of the law of attraction and repulsion of charges. In the TRZ, like charges attract and unlike charges repel. Thus suddenly the low spatial energy transmutation of elements in cold fusion experiments can be explained (they have been validated in some 600 successful experiments, in various laboratories in various nations, by excellent scientists). E.g., two H+ ions may attract, and so closely that each enters the edge of the strong force region of the other, forming a quasi-nucleus. Then as the TRZ decays, the preferred energetic change is from inside out. In other words, the gluon forces have been partially nullified and the quarks in the nucleons are almost freed. Hence the favored energetic decay from the excited state of the TRZ is by quark flipping, where one H+ ion in the quasi-nucleus changes into a neutron. The quasi-nucleus becomes a quasi-nucleus of deuterium, and will tighten into deuterium as the TRZ induced action vanishes. This is the way the excess deuterium is formed in the cold fusion experiments. Two deuterium D+ ions may also form a quasi-nucleus of (D+)(D+) particularly where the electrolyte is loaded with deuterium to start with. In that case, as the TRZ decays, the quasi-nucleus just tightens into a helium 4 nucleus or alpha particle, accounting for the excess alpha particles formed. And so on.

The concept of the TRZ thus is consistent with hundreds of successful experiments, and introduces a completely new type of nuclear reactions to physics, at low spatial energy where transmutations such as occur are not presently thought to be possible. We point out that these are extremely high energy reactions when the time-energy interaction is considered, since time has an energy density equal to mass. Time-energy is some c^2 times as dense as is spatial energy used by particle physicists in their interactions. By transposing some of the time-energy into spatial energy as the TRZ decays, the new "low energy nuclear reactions" actually involve the necessary degree of "high energy" required for the interactions.

TIME-REVERSED WAVE

A phase conjugate reflected wave, which is a wave moving in reversed time.

Since the external observer "sees" in forward time only, he sees the wave as traveling in the opposite direction as its generatrix wave front is moving.

TOPOLOGICAL

Invariant under transformation by continuous mappings.

...or related to the properties of geometric shapes and figures that remain invariant under transformation by continuous mappings.

TOPOLOGICAL PROPERTY

Those properties of a geometrical space that are unchanged by continuous distortion of the space.

TOPOLOGY

Mathematics of the properties of geometric configurations invariant under transformation by continuous mappings.

In short, the mathematics of the large-scale structure of curved spaces.

TOROIDAL COIL

A coil of wire curved around into toroidal form.

Contrast to the standard solenoidal coil form.

TOROIDAL TRANSFORMER

A transformer comprised of toroidal coils instead of solenoidal coils.

TRANSFORMATION MATRIX

A matrix (rectangular array of algebraic or numerical quantities) for replacement of the variables in an algebraic expression by their values in terms of another set of variables.

Used, e.g., in solving equations involving Hamiltonians.

TRANSVERSE

Wave movement perpendicular to the wave's primary direction of principal propagation, as in the movement of a taut rope in a wavelike motion traveling down the rope.

(As opposed to longitudinal).

TRANSVERSE EM WAVE IN THE VACUUM

The completely erroneous notion that EM disturbances in the vacuum are composed of transverse "string waves."

Faraday, e.g., believed that the EM field in the vacuum consisted of his "lines of force" as material taut strings—erroneously without the necessary holders to put the tension forces on the strings. He thought that when there was an EM disturbance, it was a "plucking" or transverse vibration of these "taut strings." Maxwell also believed in Faraday's material lines of force, and set out to capture them in his electrodynamic theory. He did so by simply assuming the lines (tubes) of force and their transverse "string wave" vibration. This is equivalent to assuming that the electromagnetic vacuum itself is composed of material taut strings, and that additional EM fields are just additional taut material strings.

TRANSVERSE FIELD COMPONENT

The modeled component of the electromagnetic field (as in a moving EM wave in vacuum) that is oriented at right angles to the line of motion.

TRANSVERSE WAVE

A wave where the medium is undergoing repetitive lateral translations, as a lateral wave in a taut string.

The EM wave is vacuum is erroneously modeled as a transverse "string wave," as a relic from Faraday's original belief that EM fields existed in the (assumed) material ether as physical taut strings. He thus believed that EM disturbances were the disturbances of "pluckings" of these taut strings. Maxwell accepted Faraday's physical lines of force and constructed his electrodynamics mode to specifically include the material ether, the physical "taut strings" lines of force notion, and Faraday's "string waves" as the electromagnetic vibrations in the ether. This discards half the energy, half the phenomena, half the wave, and Newton's third law causative EM mechanism.

TUNNELING

In quantum mechanics, a phenomenon where a particle penetrates and crosses a small region where the opposing potential is greater than the particle's available energy.

The phenomenon is thought to be impossible according to classical physics, but occurs nonetheless. Further, the speed of transit through the "tunneling" separation can be superluminal. Tunneling of music between two points has been measured to occur at more than four times the speed of light.

A more extended type of tunneling is the travel of longitudinal EM waves infolded inside the normal EM potentials, fields, and waves. Indeed, this is a more fundamental electrodynamics, and it can be shown that interferometry of this "internal" electrodynamics creates the external electrodynamics by a form of longitudinal EM wave interferometry. E.g., see M.W. Evans, P.K. Anastasovski, T.E. Bearden et al., "On Whittaker's Representation of the Electromagnetic Entity in Vacuo, Part V: The Production of Transverse Fields and Energy by Scalar Interferometry," **Journal of New Energy**, 4(3), Special Issue, Winter 1999, p. 76-78.

UNCONSCIOUS MIND

To be added.

UNIFIED FIELD THEORY (ENGINEERABLE)

A unified theory of the four forces of physics—the electromagnetic, gravitational, strong, and weak forces —that is not just an intellectual model but which is also engineerable on the laboratory bench and in actual physical systems using higher symmetry O(3) electrodynamics.

That's a mouth-filling phrase (yes, we sometimes write awkward phrases unintentionally; it's amazing how reasonable such things sound when you're laboring along at 3:00 a.m. and bleary-eyed as a wet toadstool!)

UNIFIED FIELD THEORY OF MIND AND MATTER

To be added.

UNITARITY

Principle that all probabilities sum to unity.

UNITARY Q_E

Fixed or unit charge q of the electron.

This notion is held only because the q is not decomposed into its component elements, but treated as if it were an indivisible unit. That is in error! The mass of a fundamental particle at rest is quantized, and the massless charge (self-potential) of the particle is discretized as a function of the background potential (virtual particle flux density) in which it is embedded or to which it is exposed. In our view the definition of a charge q is $q \equiv m_q \phi_q$. The *electrical charge* should be taken to be the massless ϕ_q component. The definition of charge q_e of an electron is rigorously given by the identity $q_e \equiv m_e \phi_e$. The *electrical charge* of the electron should be taken to be the massless ϕ_e component.

If a charge (say, an electron) is placed in an additional potential ϕ_1, then the total massless charge of the electron (i.e., its virtual vacuum flux exchange with mass me) is $(\phi_e+\phi_1)$. As can be seen, the massless charge of the electron (its virtual flux activity) has now changed. The electron is then said to *be collecting and to have collected* excess energy (which may be either positive or negative, depending upon the sign of ϕ_1.). Further, either ϕ_e or ϕ_1 or both can be internally and deterministically *dimensioned* (structured in Stoney-Whittaker-Ziolkowski fashion). When its massless charge (its own potential ϕ_e) is so dimensioned, then the dimensioned electron is said to contain or transport a *vacuum engine*.

VACUUM ENGINE

Particle view: Deterministic internal pattern or template deliberately created in the virtual flux of a scalar potential.

It can also be created in, and transported by, the two scalar potentials that comprise a static or dynamic force field, or a moving EM wave in the vacuum. It can also be created in the local vacuum, in which case it has a "charge-up" creation time and a "discharge time," exhibiting a sort of "time constant" very much like a capacitor charging and discharging. In the wave view, the vacuum engine is a deterministic internal pattern or template deliberately created in the Stoney-Whittaker-Ziolkowski internal biwaves and wave products comprising the scalar potential. Again, it can be implanted in the vacuum or in an EM signal as a carrier. The self-energy (scalar potential) portion of any electric charge or magnetic charge can also be a "carrier" that is conditioned (*dimensioned*) with a vacuum potential. The process or act of conditioning any of the carriers with vacuum engines is called *dimensioning* that carrier. Russian energetics refers to the vacuum engines of a dimensioned carrier as the *information content of the field*.

VACUUM FLUX EXCHANGE

The virtual particle interaction between the active vacuum and a charged particle.

The charged particle is an asymmetry in this flux exchange interaction, and extracts and gates some of the vacuum energy as a Poynting **S**-flow. In turn, this S-flow transports and creates in space the **E** field and the scalar potential f associated with the charged particle. An electrically charged particle is thus a little Poynting energy generator, a source of potential, and a source of **E**-field. It is a little electrical dynamo, a little free energy generator. It is already an open system in disequilibrium with its environment—the fierce vacuum flux. Its self-energy (potential) and its "fields," plus its Poynting energy flow, are the result of its asymmetry in the vacuum flux exchange.

VACUUM'S VIRTUAL PARTICLE FLUX

In the particle viewpoint, the quantum mechanical vacuum identically is a virtual particle flux.

Present physics, however, is prone to refer to the vacuum as (an implied emptiness) containing a virtual particle flux. Energy, vacuum, spacetime, virtual particle flux, and dynamic geometry are all synonyms.

VECTOR

In mathematics, an entity completely characterized by a magnitude and a direction.

VECTOR POTENTIAL

In electrical engineering: "Potential postulated in electromagnetic field theory."

Space differentiation (*curl*) of the vector potential yields the field. Magnetic vector potential is due to electric currents, while electric vector potential is assumed to be due to a flow of magnetic charges." [**Chambers Science and Technology Dictionary**, Peter M. B. Walker (Ed.), Chambers Cambridge, 1988, p. 947.

Note that the foregoing is not yet a definition, saying only that it is a postulated potential, then giving some characteristics. Informally, in my view the vector potential is just sort of an ordinary scalar potential, every point of which is in motion in something like a swirling fashion. The magnetic vector potential **A** is most common. There doesn't seem to really be a definition of **A**; the equation $\mathbf{B} = \nabla\times\mathbf{A}$ is usually (erroneously!) said to "define" the **A**. So we are left with the question $\mathbf{A} \equiv$????, since no equation is a definition of anything.

Electrodynamicists have no difficulty in calculating the direction and magnitude of **A**, and in using it, but so far as I can find there is still no real definition. As an ad hoc definition I consider the **A**-potential to be identically a virtual photon flux of vacuum that is moving as an ensemble along the direction of the **A**-vector. Inputs for a more rigorous definition of the form $\mathbf{A} \equiv$ (x**)** would be most welcome!

At any rate, the **A** is known to be quite real and an independent "field" of nature, because when the curl operator is removed from operating on **A**, the **B**-field is zeroed but the *curl-free* **A**-field can still remain and interfere with the fields of charged particles and magnetic poles to cause real effects in physical systems, including at a distance. This latter is known as the Aharonov-Bohm effect.

VECTOR FIELD

In ordinary theory, the assigning of a magnitude and a direction (that is, a vector) to each point in a region of space.

The entire set of vectors and their spatial points is called a vector field.

VECTOR ZERO

See discussion under *zero vector*.

VIRTUAL ANTIPHOTONS

An antiphoton that spontaneously appears and disappears, so swiftly that it cannot be individually observed.

VIRTUAL PARTICLE

A fleeting quantum particle that spontaneously appears and disappears, so swiftly that it cannot be individually observed, so that it exists only temporarily.

The virtual particle does not satisfy the usual relation between energy, momentum, and mass because it is underneath the Heisenberg uncertainty principle. The virtual particle can have any amount of energy momentarily, so long as the product of its energy and the time interval of its existence is less than the uncertainty principle's minimum magnitude.

Nonetheless, the interactions of large numbers of virtual particles with a mass or charge can combine to generate real observable effects. In quantum field theory, all forces of nature are caused by the interaction of the forced mass entity with virtual particles. Interaction of a mass with virtual photons, e.g., is projected to cause all mechanical and electromagnetic forces.

VIRTUAL PARTICLE FLUX EXCHANGE

Interaction with or exchange of, a flux of virtual particles.

Interaction of a mass with virtual particles most often consists of the mass absorbing the virtual particles and re-emitting them.

VIRTUAL PHOTON FLUX (VPF)

A flux of virtual photons.

(Hey, how's *that* for a tautology!) First, see definition and discussion under *flux*. For electromagnetics, the vacuum can often be modeled as a flux of virtual photons. One gets the virtual charges also, since the photon is considered to also consist of a positron-electron pair. That is, the photon is continually separating into a positron-electron pair, which then annihilate each other to form additional photon(s), etc.

VIRTUAL PHOTON FLUX EXCHANGE

The mutual exchange of virtual photons, as between the vacuum and a charged mass, or between two colliding masses.

The emitted photons from one mass are absorbed in the other mass and re-radiated.

VIRTUAL PHOTON FLUX OF VACUUM

The vacuum identically is a flux of virtual particles.

For most electromagnetic cases, it can just be modeled as identically a flux of virtual photons.

VIRTUAL PHOTONS

Photons which spontaneously appear and disappear in the vacuum so quickly that they cannot be individually observed.

VIRTUAL POSITRONS

Positive electrons (positrons) which spontaneously appear and disappear in the vacuum so quickly that they cannot be individually observed.

WHITTAKER, E. T.

Well-known mathematical physicist, who dramatically extended Stoney's earlier work of 1897-8 and authored two papers in 1903 and 1904 giving the basic theory of scalar electromagnetics (Russian energetics, not including the quantum potential portion).

The 1903 paper is E.T. Whittaker, “On the Partial Differential Equations of Mathematical Physics,” **Mathematische Annalen**, Vol. 57, 1903, p. 333-355.

The 1904 paper is E.T. Whittaker, “On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions,” **Proc. Lond. Math. Soc**., Series 2, Vol. 1, 1904, p. 367-372. The paper was published in 1904 and orally delivered in 1903.

WHITTAKER'S DECOMPOSITION OF THE SCALAR POTENTIAL

Decomposition of the scalar potential into a harmonic set of bidirectional longitudinal EM phase conjugate wavepairs.

In his paper “On the Partial Differential Equations of Mathematical Physics,” **Mathematische Annalen**, Vol. 57, 1903, p. 333-355, Whittaker showed that the scalar EM potential can be decomposed into a harmonic series of bidirectional EM wavepairs. In each pair, one wave is the phase conjugate of the other, and exists in the time domain. However, this phase conjugate wave has been considered as having been detected by intercepting charge as a 3-space EM wave travelling in a reversed direction. Hence from a detectable viewpoint, the Whittaker decomposition yields bidirectional longitudinal EM waves in 3-space, as has been pointed out by several electrodynamicists (e.g., Barrett).

However, the present author considered the difference between the phase conjugate wave as it exists prior to interaction with the assumed intercepting unit point charge, and the detected 3-space wave after the detecting charge is assumed. By applying the Whittaker decomposition and also considering the nature of the EM wave in spacetime *prior to interception by a unit point charge*, this led to the discovery of a new and more primary 4-symmetry in EM energy flow, once 3-symmetry is broken, that exists automatically between the time domain (complex plane) and 3-space.

Thus because a dipole (or a charge treated as a set of composite dipoles) breaks 3-symmetry (as is well-known in particle physics), the more general 4-symmetry results automatically when the nature of the potential between the ends of the dipole(s) is considered. This yields the fundamental mechanism by which EM energy is extracted from the vacuum (from the complex plane or the time domain) and output in 3-space from a "source charge" or a "source dipole". In short, it yields the giant negentropy mechanism when the unaccounted Heaviside energy flow component from a charge or dipole is considered as well as the intercepted tiny Poynting energy flow component. See T. E. Bearden, "Giant Negentropy from the Common Dipole", **Journal of New Energy**, 5(1), Summer 2000, p. 11-23; also on http://www. cheniere.org.

In his second paper, “On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions,” **Proc. Lond. Math. Soc**., Series 2, Vol. 1, 1904, p. 367-372, Whittaker showed that the interference of two such scalar potentials can and does create all the field energy, patterns, and functions of classical electromagnetics.

Whittaker's second paper initiated what today is loosely referred to as *superpotential theory*. For an excellent overview discussion of superpotentials and related things, see Melba Phillips, “Classical Electrodynamics,” in **Principles of Electrodynamics and Relativity, Vol. IV of Encyclopedia of Physics**, edited by S. Flugge, Springer-Verlag, 1962.

WORK

The changing of the form of energy.

WORK, EXTERNAL

The changing of the form of the external energy of a body or system.

WORK, INTERNAL

The changing of the form of the internal energy of a body or system.

WORK-ENERGY THEOREM

To be added.

ZERO POINT ENERGY

The minimum energy of a system due to its quantum fluctuations, resulting from its incessant virtual particle activity. Quantum mechanically, no system of interest (including even spacetime itself) can have zero energy.

The zero-point energy of the vacuum is the lowest energy vacuum state, with fluctuations taken into account. Even at low energies, quantum fluctuations continually arise, and result in an incessant, extremely rapid, and violent "jittering" of the energy momentarily present. The minimum energy due to these quantum fluctuations is called the *zero-point energy.*

ZERO VECTOR

(1) A vector having no length (no magnitude) or specific direction.

(2) Absence of any or all finite vectors.

(3) Resultant of a system of multiple, finite vectors whose vector sum has no specific direction.

Note that the second definition differs drastically from the first. That is, we cannot say that a vector resultant zero has no infolded magnitude, if we consider its components, all of whom have magnitude. See the discussion under "zero." In vector analysis, the zero vector axiom states that any vector v plus a zero vector is equal to a zero vector plus v. Note that, being an axiom, this is not proven, but just assumed. We very much disagree with that blanket axiom; it reduces vector analysis to a highly special single case, where all zero vector systems are to be considered equal, and totally "inactive." In the real world that need not be true at all. There are an infinite number of different zero vector resultant systems, and so zero vectors may differ, if their infolded component "substructure" is considered. In the real world, things that are vectors very often have energy. The energy is infolded and hidden, so that it represents not only a local curvature of spacetime, but also a structured, deterministic set (a *template*) of curvatures of local spacetime. Therefore this zero vector system is actually a *vacuum engine*. Any mass system placed in such a potential, will be acted upon in its parts by that local vacuum engine. Further, the zero vector resultant system is a "potential," since it does contain "collected internal energy." This potential is obviously an artificial potential, since it is deterministically structured internally.

So between zero vector resultant systems, the "infolded, hidden energies" differ dramatically in

(i) total infolded and trapped (collected) energy,

(ii) specific internal action patterns (templates),

(iii) general relativistic effects, and

(iv) type of vacuum engine. Accordingly, the actions the zero-vector system induces in an exposed mass may be designed in advanced. This is vacuum engineering. This is spacetime engineering.

The problem is the *vector algebra itself*. In the abstract algebra, a "vector space" is regarded as an inert thing, where the only actants are the overall net nonzero vectors, and there is no interaction between an overt vector and a covert set o f vectors. The vector space is not allowed to have an internal realm, stress, hidden engines, or to interact with the vectors representing the physical system. Consequently, for over a century electrodynamicists—thinking primarily of translation—have routinely discarded such "zero vector systems" as if they represented the total absence of any finite vector. *This they do, in the unsuitable assumptions of the vector algebra*. This they do not do, in the real world.

The common practice in electrical physics of replacing a zero-summed system of nonzero vectors with a vector zero of "complete absence of vectors" is incomplete, and such did not exist in Maxwell's original *quaternion* theory. This present practice should be changed; it has reduced the topology of electromagnetics far too much, and gutted the most important parts of the theory insofar as an extended electromagnetics is concerned. The vector zero should be replaced with a special organized vector zero system and a scalar potential. The interactions of the "hidden" vectors should be incorporated. By failing to do this, physics excludes the ability to engineer electrogravitation, spacetime, the virtual state, local general relativity, free energy, effects at a distance, and the probabilities of the states propagated by the Schrödinger equation. It also excludes unification of all forces.

In the new view, a zero vector may be a system of nonzero vectors that vectorially sum or multiply to zero for translation purposes, but the components may still exist "inside" and dynamically function inside the zero-resultant envelope. This substructure can act on nonlinear or resonant systems. Any or all components may be time varying, or none of them may be. The zero vector system may thus be a dynamic vacuum engine. In addition, such a vector zero system is considered to be also a scalar stress potential, whose magnitude is equal to the sum of the absolute values of the perpendicular components. In addition, a separate type of stress potential may be included for the magnitude of the absolute values of the swirl components (torques). Other associated potentials may be included for the system, particularly if the system is in multiple dimensions, if it consists of more than one type of virtual particle flux, if several fluxes intercommute, etc. Such a system can also be designed and created to deterministically interact with and on the life force itself, the mind, thought, and personality, but that is beyond the scope of this discussion.

ZERO-VECTOR-SUMMATION SURFACE

A surface or assumed spatial surface in which vectors under consideration interact to sum to a vector zero resultant.

ZERO-VECTOR-SUMMATION SYSTEMS

Zero summations of real, nonzero vectors, so that the real vectors are still present but do not cause translation of exposed mass or charges.

With respect to observing/detecting process that depend upon charge translation, the vectors are said to be hidden and infolded —i.e., with respect to detection by translation. See discussion under *zero vector*.

ZIOLKOWSKI, RICHARD

To be added.

Return to top of page

The "Porthole" Concept with technical background

Amplifying the cellular regenerative
(healing) system of the body for
treatment and healing
of mass casualties

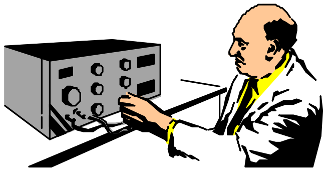

Outline of the presentation

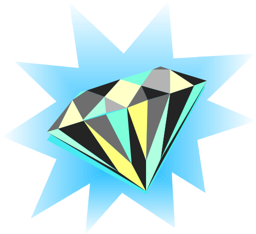

- Mechanism for deep EM exchange of a body with its active EM environment
- Becker's epochal work and its ramifications
- Kaznacheyev's startling results and ramifications
- Weaponization of Kaznacheyev's findings
- Importance of time-energy and the time-domain
- Mechanisms for medical treatment and healing

Outline of the presentation (2)

- Prioré's revolutionary results and their ramifications.
- Proposed new mechanism for cancer promotion.
- Porthole concept: The 2-minute shortcut.
- Terrorist biological warfare capabilities.
- Summary and conclusion.
- Budgetary and Program package.

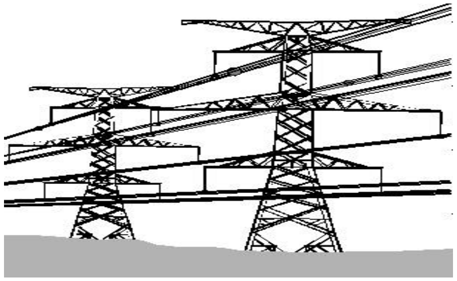

Mechanism for the body's deep EM exchange with its active EM environment

And some ramifications

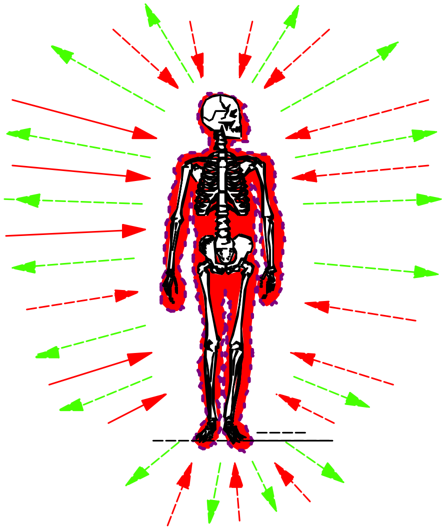

The body continually receives and retransmits EM energy

- The body may be considered as a dielectric.
- Every part of the dielectric participates in the absorption and emission of each photon to and from any point on the surface.*
- Mechanical force effects are also electrical in nature and exchange similarly.

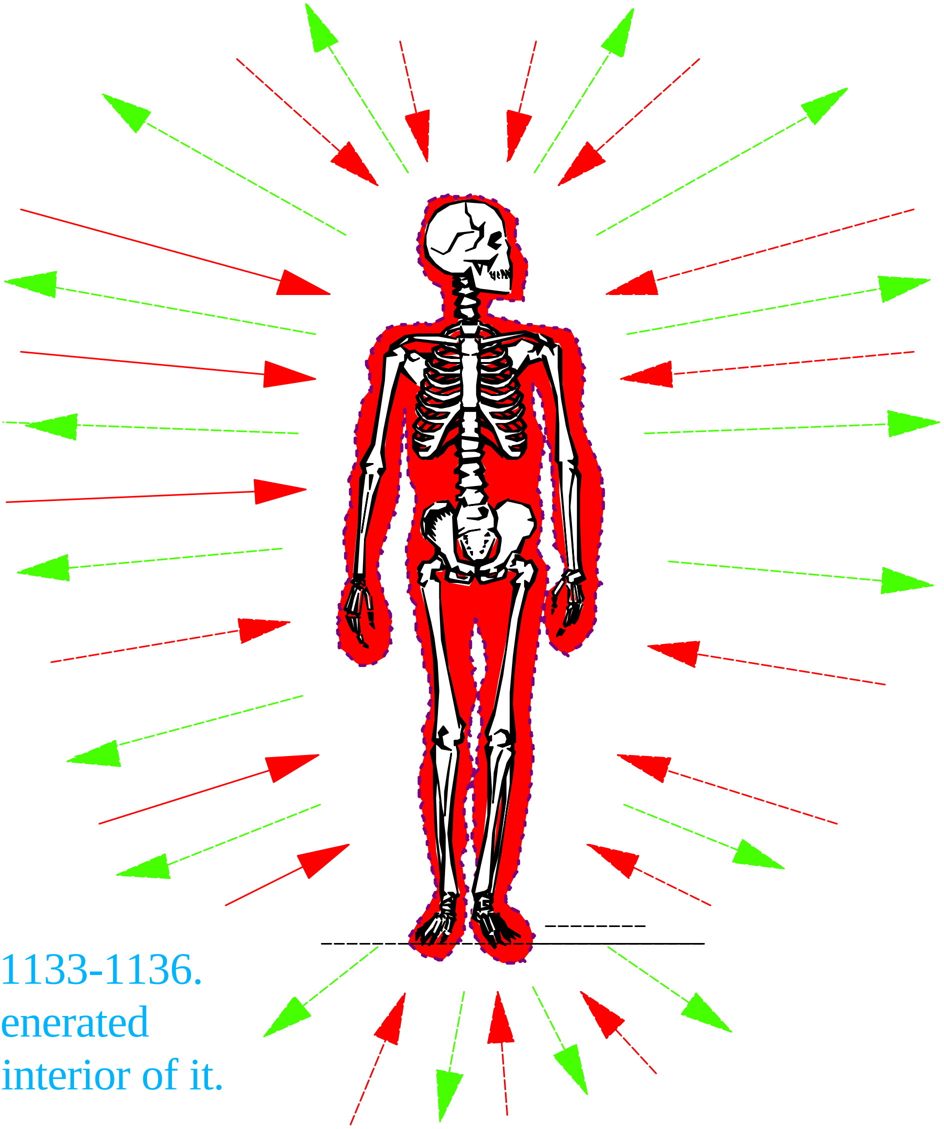

* Reali, G. C., "Reflection from dielectric materials," American Journal of Physics, 50(12), Dec. 1982, p. 1133-1136. The reflected field from a dielectric material is not generated just at its surface but comes from everywhere in the interior of it.

Ramifications:

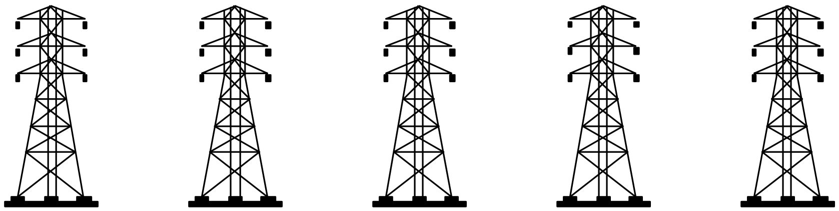

- There is an EM "dielectric transmission path" connecting every part of every cell to every part of the surface of the body.
- All electrical processes in the body, including deep within the cell and its nucleus, participate in the absorption and emission of every photon to and from the body's outer surface (and every mechanical force* experience).
- The EM emission energy of the body is a conglomerate mix of fractions of all processes and functions ongoing in the body or affecting it, including in every cell.
- This includes all electromagnetic, mechanical, chemical, and environmental effects upon and in the body and every tiniest part of it, and provides an extended definition of "stress".

* At base, all normal mechanical forces are generated by electromagnetic forces.

Ramifications (2)

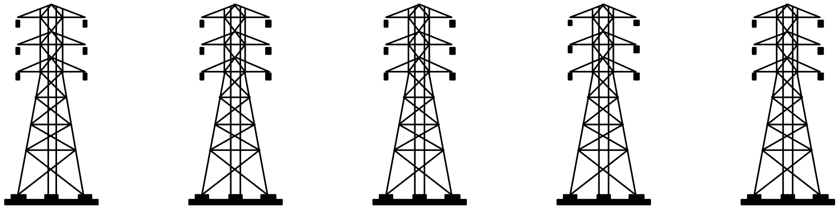

- The reaction of each photon absorbed on any point of the outer surface of the body, connects through the dielectric transmission path to every part of the body, including to every part of every cell*.
- Every emission from the body is participated in by every part of the body, including every part of every cell.
- The body's emission "changes" its environment, adding EM radiation. Some of the internal induced changes (excited states) in the body decay by this external emission. Some do not, but must be otherwise dealt with internally by the body systems.
- The body's EM absorption allows the environment to change or affect every function, operation, and part of the body, by adding EM radiation. All are continually being affected and deviated, both helpfully and harmfully, by these deeply induced EM interactions.
- The body's reaction (healing) must continually readjust and correct deviations from normalcy, in every part of every cell.

* In quantum physics, part of the photon is localized and part is nonlocalized, reaching even across the universe.

Ramifications (3)

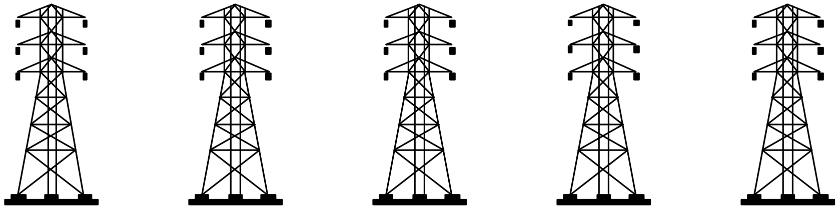

- The sum total of all the impinging external EM radiation upon the body, plus mechanical "special EM" radiation, thus affects and changes the body and all its processes, participating in them.
- That impinging EM radiation can be manipulated to either harm or heal the body and any or all of its cells.
- The body must continually overcome these externally-induced EM changes in its cells and processes, to maintain normalcy. Some EM changes are restored by the subsequent dielectric emission process, relieving the previously-induced deviant EM excitations in its internal processes. Some are not.
- The poorly studied *cellular regenerative system* performs the remainder of the restorative function, which is the fundamental "healing" function of the body.*

*The cellular regenerative system was mostly studied by Becker and a few others. See R. O.Becker, and David G. Murray, "The electrical control system regulating fracture healing in amphibians," Clinical Orthopaedics and Related Research, No. 73, Nov.-Dec. 1970, p. 169-198.

Becker's epochal work

And its ramifications

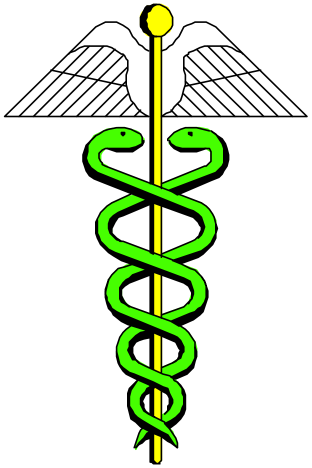

Becker's bone fracture healing

- Tiny DC currents (picoamperes)
- Pulsed DC current can be utilized
- Pulsed magnetic fields may be utilized

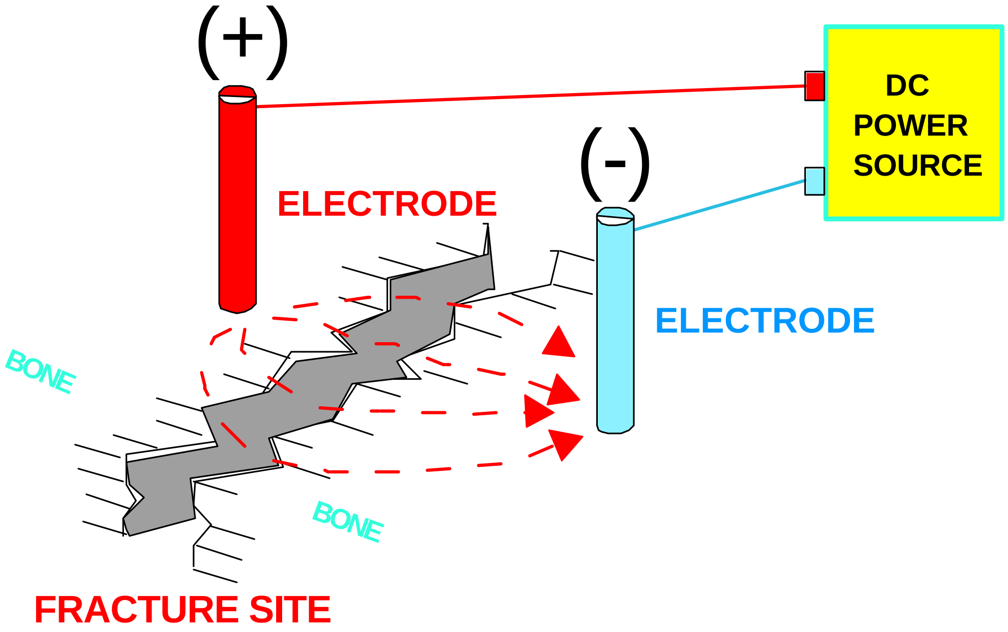
(+)
(-)
DC
POWER
SOURCE
ELECTRODE
ELECTRODE
BONE
BONE
FRACTURE SITE

RED BLOOD CELL DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

Becker's theoretical DC control system involved with response to injury

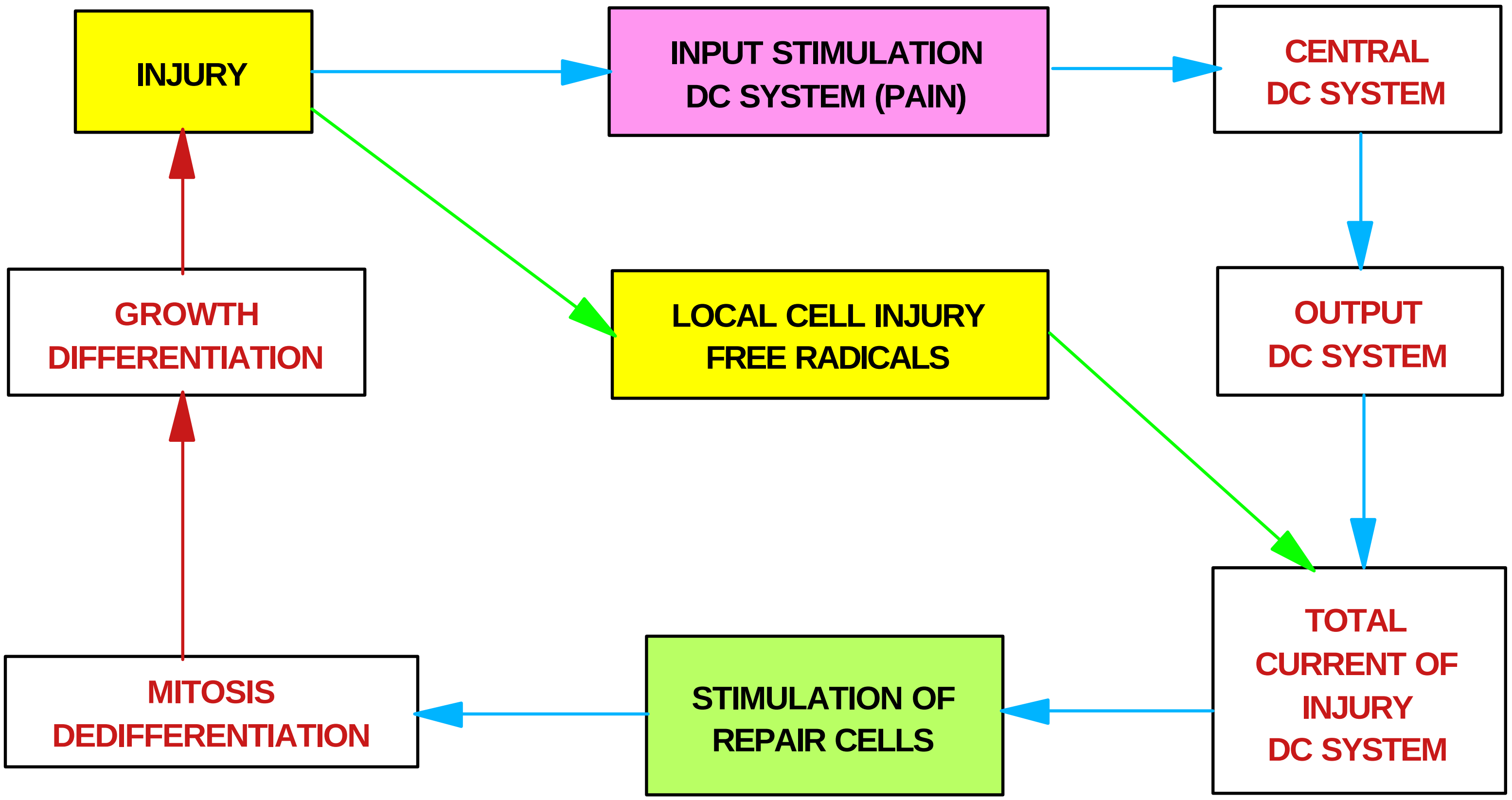
INJURY

INPUT STIMULATION DC SYSTEM (PAIN)

CENTRAL DC SYSTEM

GROWTH DIFFERENTIATION

LOCAL CELL INJURY FREE RADICALS

OUTPUT DC SYSTEM

TOTAL CURRENT OF INJURY DC SYSTEM

MITOSIS DEDIFFERENTIATION

STIMULATION OF REPAIR CELLS

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.

Becker's proposed control system governing regeneration*

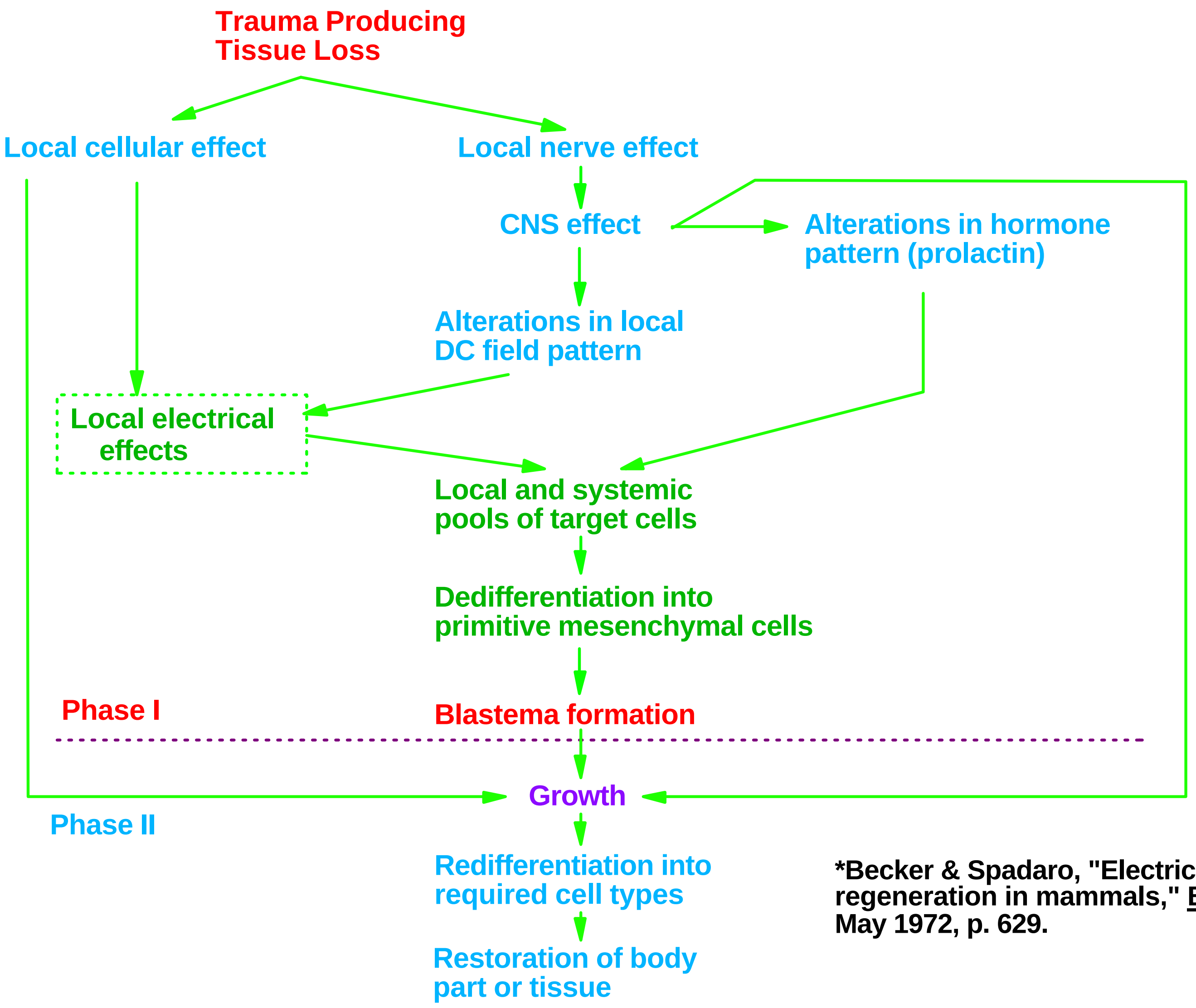

Trauma Producing Tissue Loss

Local cellular effect

Local nerve effect

CNS effect

Alterations in hormone pattern (prolactin)

Alterations in local DC field pattern

Local electrical effects

Local and systemic pools of target cells

Dedifferentiation into primitive mesenchymal cells

Phase I

Blastema formation

Growth

Phase II

Redifferentiation into required cell types

Restoration of body part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bull. N. Y. Acad. Med., 48(4), May 1972, p. 629.

Extending Becker's work

- Becker had only the archaic classical electrodynamics available to him. That EM is grossly inadequate.
  - Insufficient group symmetry to model the process.
  - Already eliminates the "infolded" longitudinal wave EM that structurally and dynamically comprises all "normal" EM potentials, fields, and waves.
  - It is this internal LW EM that is manipulated and used by the cellular regenerative system.
- Nonlinear phase conjugate optics was not yet developed when Becker did his seminal work.
- Successful higher symmetry electrodynamics models -- such as O(3) -- have been developed and are available.

A sad commentary

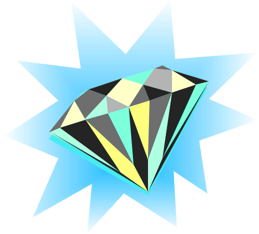

- Becker was nominated for the Nobel Prize, but he was hounded, his funds were withdrawn, and he was forced to retire early.
- His main "sin" was having the courage to testify against the harmful effects of unrestricted powerline radiation and electronic smog.
- Powerful interests then crushed him, set up their own well-funded institutes, and hired scientists who then predictably found that powerline radiation was no problem.
- Such research is so tainted that recently several important journals have now required the authors of submitted papers to state what their affiliated companies do, and what "company massaging" of their research occurred.
- From a higher symmetry EM view, it is obvious that the dielectric pathway and quantum electrodynamics already show a significant problem due to such radiation, particularly with respect to long-term effects.
- This is particularly significant since "noise" -- the mere presence of more "hash" -- appreciably amplifies the dielectric transmission effect. So the major factor becomes EM smog *signals density*, not signal power.

Kaznacheyev's startling results

And its ramifications

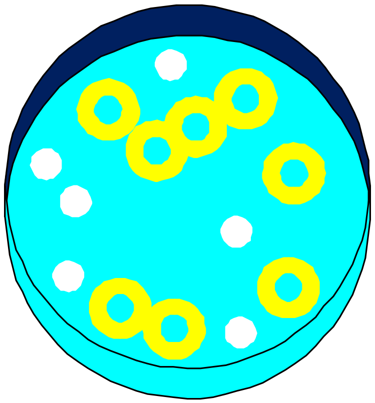

Proof that the cellular condition is radiated from groups of cells

- It follows that a diseased, damaged, or infected cell culture will and does emit its exact internal EM condition, hence the disease or damage "generatrix form" itself (in the internal structuring of the EM radiations).
- Further, these "state" emissions can couple into other targeted cells to produce disease and disorder in them.
- This was clearly proven in some 15,000 Russian experiments by Kaznacheyev.
- Kaznacheyev demonstrated induction of cellular disease and disorder between EM-coupled but otherwise environmentally shielded cell cultures
- Similar experiments have been replicated in the West by Reid *et al*., and by Popp *et al*.

Kaznacheyev's induction of cellular disease and disorder

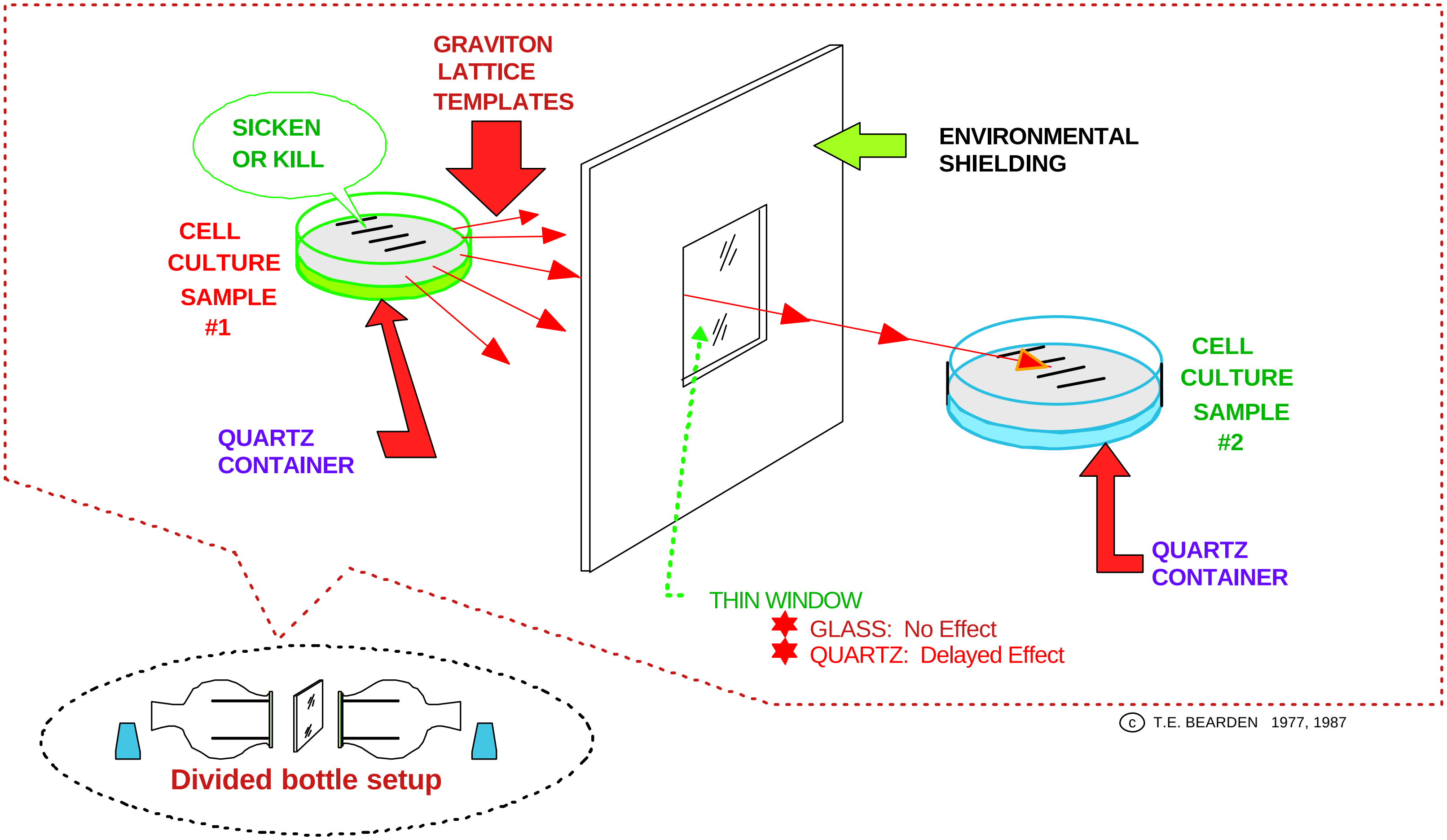

GRAVITON
LATTICE
TEMPLATES

SICKEN
OR KILL

CELL
CULTURE
SAMPLE
#1

QUARTZ
CONTAINER

ENVIRONMENTAL
SHIELDING

CELL
CULTURE
SAMPLE
#2

QUARTZ
CONTAINER

THIN WINDOW
✸ GLASS: No Effect
✸ QUARTZ: Delayed Effect

Divided bottle setup

ⓒ T.E. BEARDEN 1977, 1987

Note: Minimum lattice is one harmonic interval: IR to UV is such a minimum G-lattice. Consider particularly the dielectric pathway in the emitting diseased cells and in the receiving targeted healthy cells.

Another surprising feature of Kaznacheyev's experiments

- The experiments do not work if the targeted cells are in normal light, such as sunlight*.
- The reason is that the normal light bandwidth occupies a single harmonic interval between ultraviolet and infrared.
- Hence its difference frequencies also fill such an interval. For a set of n frequencies, the number *d* of difference frequencies is $d >> n$.
- Thus the visible light spectrum represents "jamming" of specific internal EM signal inputs through the dielectric pathway into the body, turning much of the environmental signals into harmless warmth.

* It has also been shown that if bacteria are killed in the "dark" by UV, then 24 hours later placed in sunlight, a substantial fraction of the "dead" bacteria will revive.

Ramifications of Kaznacheyev's experimental results

- At least one harmonic interval is necessary for the effect to be evidenced in the target cells.
- Interestingly, if we assume the body dielectric to be isotropically nonlinear (to first order):
  - Velocities of the actual transmitted frequencies depend upon the particular point on the wave amplitude.
  - The transmitted frequencies overshoot, interfere, breakup, etc. The difference frequency does not.
  - The "difference frequency" is transmitted through the nonlinear dielectric medium as if it were a sine wave passing through a linear medium*.
- To our knowledge, this direct and deep communication of electronic "hash" difference frequencies in dielectric human bodies has not been investigated in the West.

* Owen Flynn, "Parametric arrays: A new concept for sonar," Electronic Warfare Magazine, June 1977, p. 107-112.

Ramifications of Kaznacheyev's experimental results (2)

- A heterodyne signal -- at the difference frequency between an input signal and a reference signal -- can be enhanced by adding noise*.
- Thus the signal of the disorder in the cellular pattern emitted from diseased cells, received by normal cells, can be amplified electronically and rather easily.
- Powerline radiation (electronic smog) thus carries its own amplification mechanism. Eventually the amplification overcomes any squelching by sunlight, etc.
- The Russians promptly (as early as the late 1950s) weaponized and tested these and similar effects.

* Dykman, M. I. et al., "Noise-enhanced heterodyning in bistable systems," Physical Review E, 49(3), Mar. 1994, p. 1935-1942

Weaponization of Kaznacheyev's findings

And its ramifications

"Microwave" radiation of the U.S. Embassy in Moscow.

Former U.S. Embassy in Moscow.

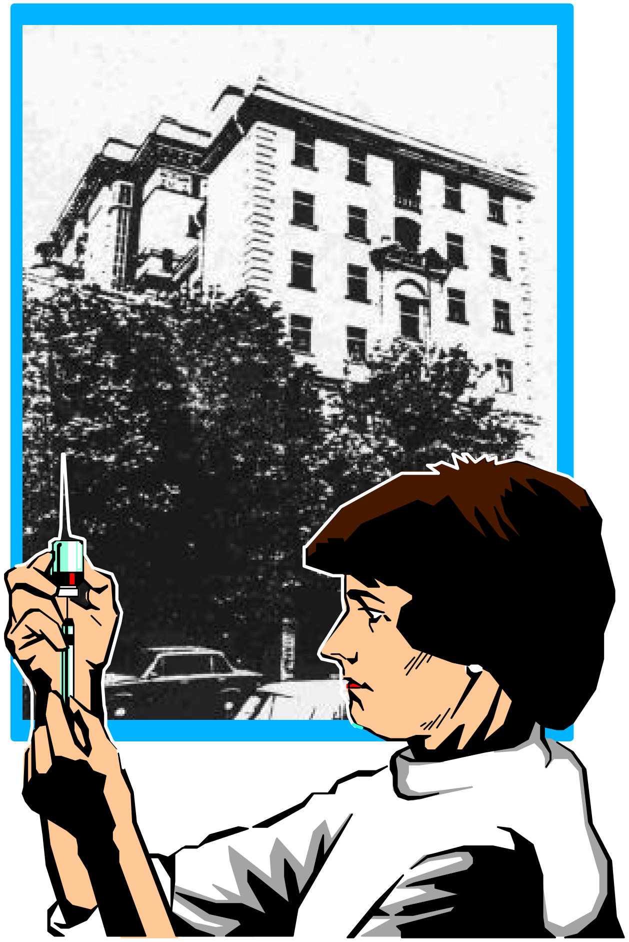

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
  - U.S. Ambassador to USSR
  - U.S. President
  - NSA, CIA, DIA, NSC, etc.
  - Top consulting scientists
  - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero pot'l gradient) areas!
- Four U.S. Presidents requested Soviets cease
  - Cut from 18 watts/sq cm to 2
  - Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

Ramifications of the microwave radiation of the U.S. Embassy

- The cellular disorder pattern in the EM radiation is carried by the field-free scalar potential.
- Since the disorder pattern is a "conglomerate", it must be carried by an internal EM structure existing inside the scalar potential itself.
- Whittaker decomposed the scalar potential into the appropriate internal longitudinal EM biwave structure in 1903*.

* E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," Mathematische Annalen, Vol. 57, 1903, p. 333-355

The importance of time as energy, and the time-domain

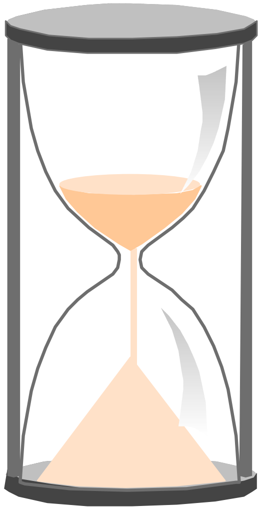

Time as energy

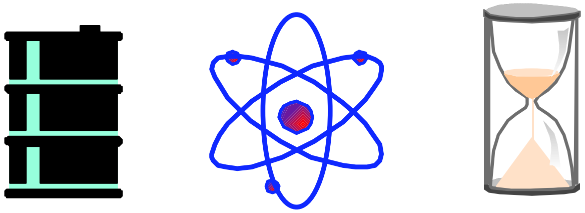

- In physics, the fundamental units one uses in his model are arbitrary.
  - A valid model can be made using only one unit.
  - It is already done in one branch of physics, using length as the single fundamental unit.
- Make a model with a single unit, the joule.
  - All other entities become functions of the joule.
  - We are familiar with mass as highly compressed EM energy, by the factor c^2.
  - It turns out that time is also highly compressed EM energy, by the factor c^2.
  - 1 sec. $\approx 9 \times 10^{16}$ joules.

How to see that "time is compressed spatial energy"

- Take some spatial EM energy and compress it by c^2
- Place it in 3-space, and it is *mass*.
- Place it on the time axis, and it is *time*.

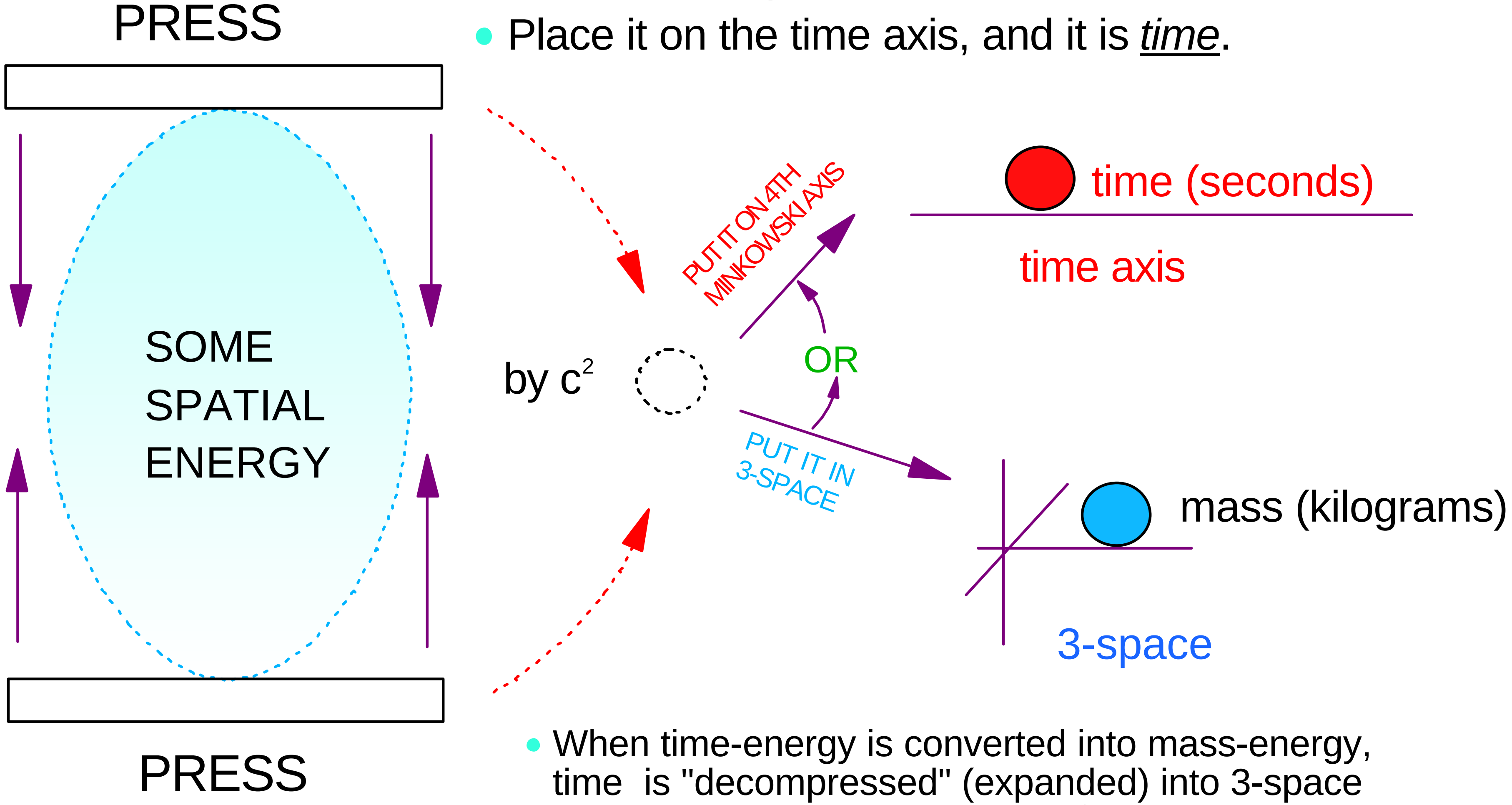
PRESS
SOME SPATIAL ENERGY
PRESS
by c^2
PUT IT ON 4TH MINKOWSKI AXIS
OR
PUT IT IN 3-SPACE
time (seconds)
time axis
mass (kilograms)
3-space

- When time-energy is converted into mass-energy, time is "decompressed" (expanded) into 3-space EM energy and 1 sec. $\approx 9 \times 10^{16}$ joules.

Time as EM energy in the time domain, with a density the same as mass-energy

- Bearden* reinterpreted (corrected) the 1903 Whittaker decomposition of the potential in 2000.
- The reinterpretation is consistent with broken symmetry in particle physics, for which Lee and Yang received the Nobel Prize in 1957.
- It is also powerfully supported by quantum field theory, notably by Mandl and Shaw in 1984**.
- Whittaker's pair is a combined time-polarized (scalar) EM wave and a 3-space longitudinal EM wave.

* T. E. "Giant Negentropy from the Common Dipole," Journal of New Energy, 5(1), Summer 2000, p. 11-23.

** F. Mandl and G. Shaw, Quantum Field Theory, Wiley, 1984, Chapter 5.

All EM energy in 3-space freely comes from the time domain

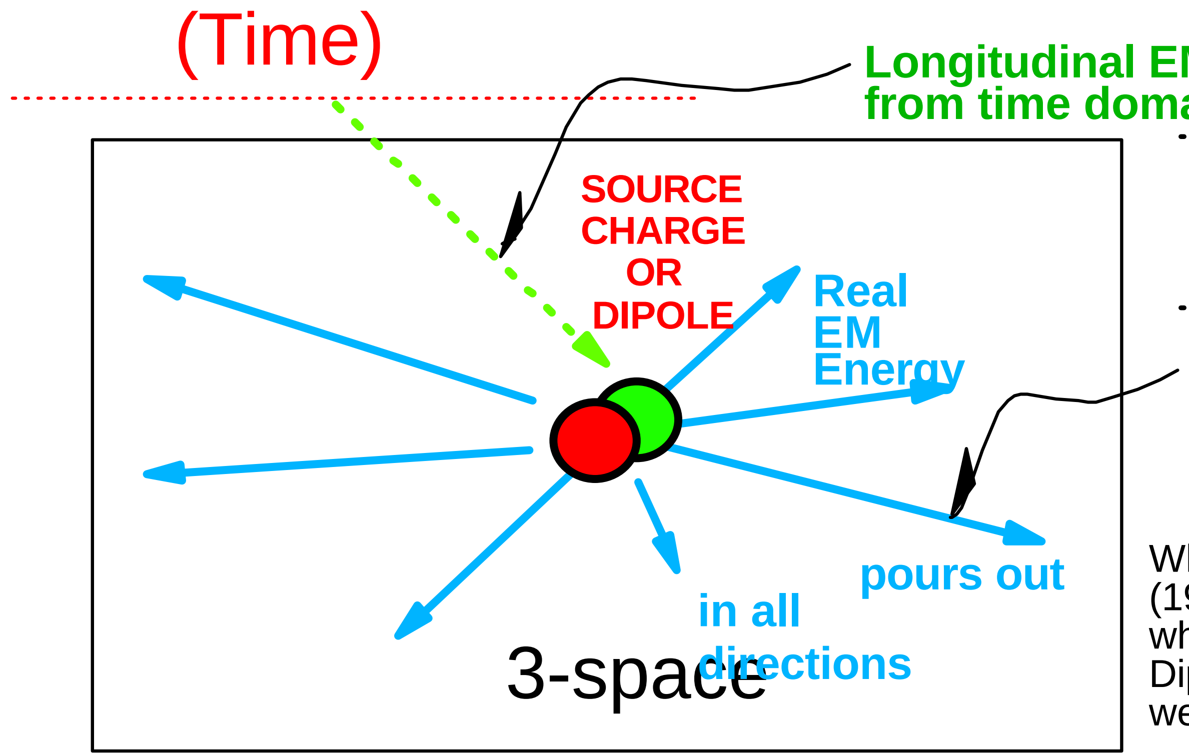

Longitudinal EM wave incoming from time domain and absorbed

Charge's 720º spin transforms time-energy into 3-space energy

Longitudinal EM waves emitted in all directions in 3-space

Whittaker, Math. Ann., 57, 333 (1903) shows this rigorously, when properly reinterpreted. Dipole's broken 3-symmetry is well-known in particle physics

Note: Whittaker (and others) interpreted the phase conjugate half set of LWs after interaction with the charges of the dipole, and as a 3-space *effect* rather than the time-domain *cause*. This fundamental non sequitur was just repeated since then, until corrected by Bearden to be consistent with broken symmetry and quantum field theory.

Strong support from quantum field theory

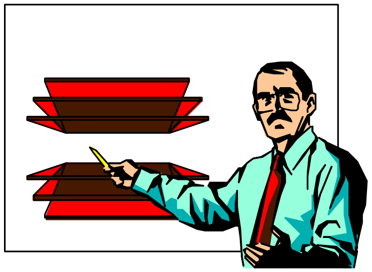

- Quantum field theory recognizes four photon polarizations:
  - Energy along x-, y-, z-, or t- axis.
  - Polarized along x- and/or y-axis, the photon is a *transverse* photon.
  - Polarized along z-axis (along its line of motion in 3-space), the photon is a *longitudinal* photon.
  - Polarized along the time-axis, the photon is a *time-polarized* or *scalar* photon.
- The individual longitudinal or scalar photon is not observable*.
- The combination of a longitudinal photon and a scalar photon is observable as the instantaneous scalar potential*.

* F. Mandl and G. Shaw, Quantum Field Theory, Wiley, 1984, Chapter 5.

Mechanism generating the flow of a mass through time

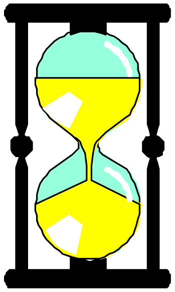

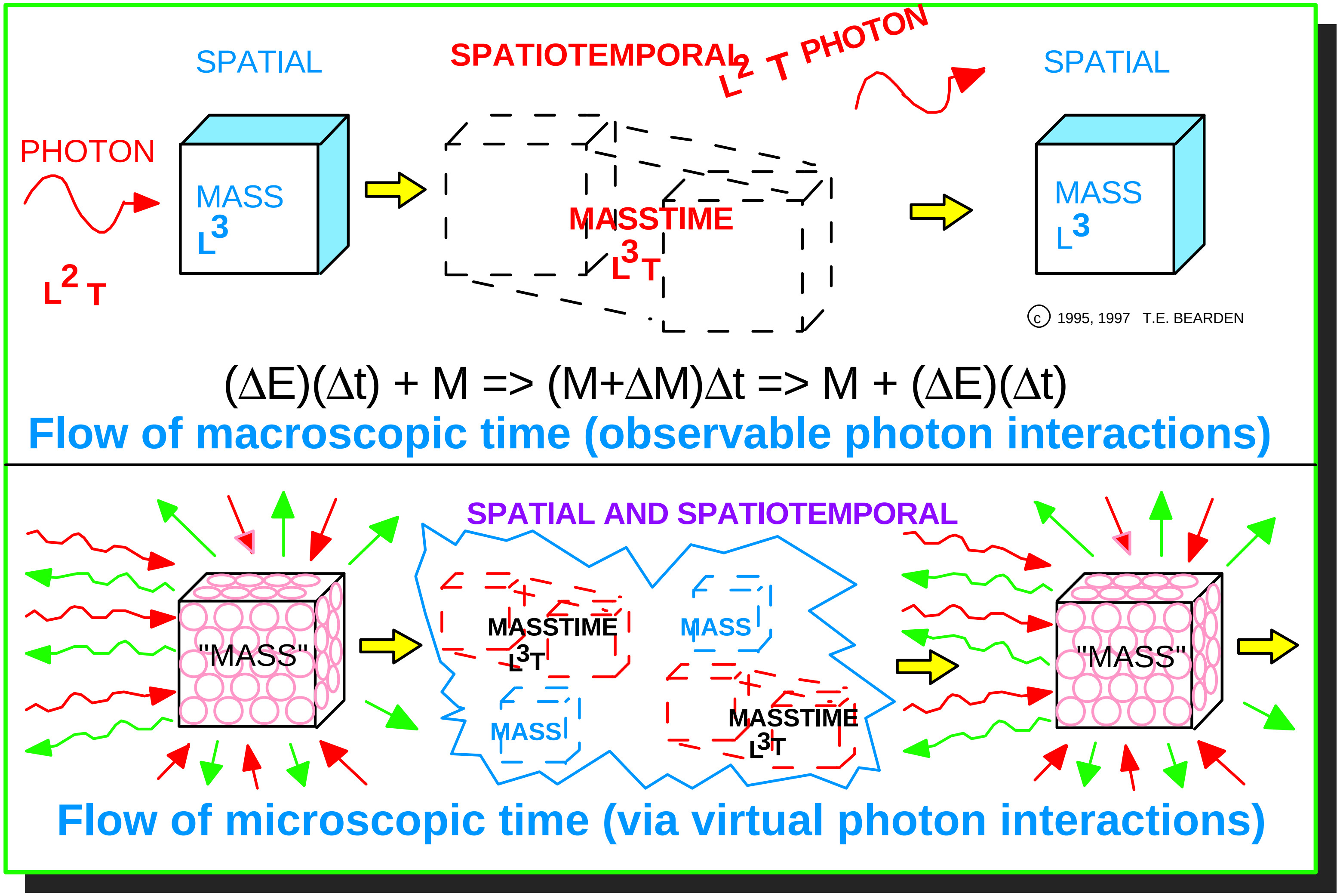

SPATIAL

SPATIOTEMPORAL

L^2T PHOTON

SPATIAL

PHOTON

MASS L^3

MASSTIME L^3T

MASS L^3

L^2T

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$$(\Delta E)(\Delta t) + M => (M+\Delta M)\Delta t => M + (\Delta E)(\Delta t)$$

Flow of macroscopic time (observable photon interactions)

SPATIAL AND SPATIOTEMPORAL

"MASS"

MASSTIME L^3T

MASS

MASS

MASSTIME L^3T

"MASS"

Flow of microscopic time (via virtual photon interactions)

Mechanism is engineerable

Pumping a mass in the time-domain will time-reverse it back to an earlier state

- The reinterpreted biwave EM structure of the scalar potential means that time-reversal (phase conjugation by pumping in the time-domain) can be utilized to time-reverse a targeted cell (its mass-energy) in its entirety, including its genetics.
- Becker's bone fracture experiments showed it:
  - Weak scalar potential across the fracture site.
  - LWs in 3-space and time-energy waves in time
  - Red blood cells entered, dedifferentiated by shucking their hemoglobin and growing a nucleus, which is dedifferentiation (time-reversal of the cell and its mass-energy back to a previous physical state).

Principle for time-reversing a time-pumped mass

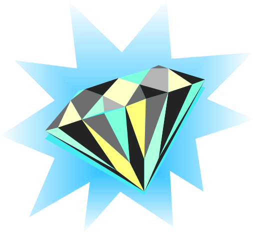

- Becker's cells then redifferentiated and changed -- first to primitive cartilage cells, then to primitive bone cells which were deposited in the fracture, healing it with new bone growth.
- This shows "time-forwarding" (redifferentiation) of the cell also.
- Becker actually showed that the *time-domain pumping* of the cells (by the time-polarized EM waves of Whittaker's reinterpreted wavepairs comprising the scalar potential), and the time-pumping of their mass-energy, operated to continuously and steadily *remove the delta between that cell's present condition and its former "normal" cellular physical condition in that area*.
- This is the long-sought secret of stem-cell research.
- Phase conjugate optics had not been born at the time. Without realizing its full nature, Becker demonstrated the body's own internal mechanism for healing, and the fundamental mechanism for time-reversing a physical mass, whether living or inert.

Mechanisms for use in medical treatment and healing

And ramifications

Successive deep penetration reactions of the cellular dielectric

- Change after change affects the cell and all of its parts, including from the external environment.
- Each successive change affects primarily the internal "LW EM structures and dynamics" comprising the ordinary potentials, fields, and waves.
- Thus in positive time the internal EM structurings produce successive "overlaid layers of change" -- so to speak -- in the internal EM structuring and dynamics of a cell in the body. These layers contain the "delta" from normal state.

Successive deep penetration reactions of the cellular dielectric (2)

- During time reversal, highest layer deltas are successively "peeled away" by the interaction of the mass-energy with the time-domain pumping.
- The result is to return the cell directly back to successive physical states, in the case of a single disease or disorder.
  - A cancer cell is returned to a normal cell prior to its "promotion".
  - An HIV-infected cell would be returned to its normal unaffected condition, free of HIV-induced genetic change.
  - For injuries and damage, the existing "delta" in each successive state-layer is steadily reduced to zero.
- This process thus can involve both cellular differentiation and dedifferentiation, as shown by Becker and by Prioré.

Engines (vacuum engines, spacetime curvature engines)

- Following Whittaker* as reinterpreted**, all normal EM fields, potentials, and waves decompose into sets of longitudinal EM waves (LWs) and their dynamics.
- Since these LWs and their dynamics are dynamics in the local energy density of spacetime (ST), they constitute *ST curvatures*.
- Hence they are general relativity infolded inside electrodynamics.
- By manipulating and changing these LWs, one manipulates and changes spacetime curvatures and their dynamics.
- The result is a unified field model where one directly controls and engineers a set of ST curvatures by use of higher group symmetry electrodynamics.
- Controlled patterns of local curvatures of ST are called "vacuum engines" or "spacetime curvature engines" -- or just "engines".

* E.T. Whittaker, Math. Ann., 57, 333-355 (1903); Proc. Lond. Math. Soc., Series 2, 1, 1367-372 (1904).

** T. E. Bearden, J. New Energy, 5(1), 11-23 (2000).

Pumping with EM time-polarized waves forms *amplified* antiengines

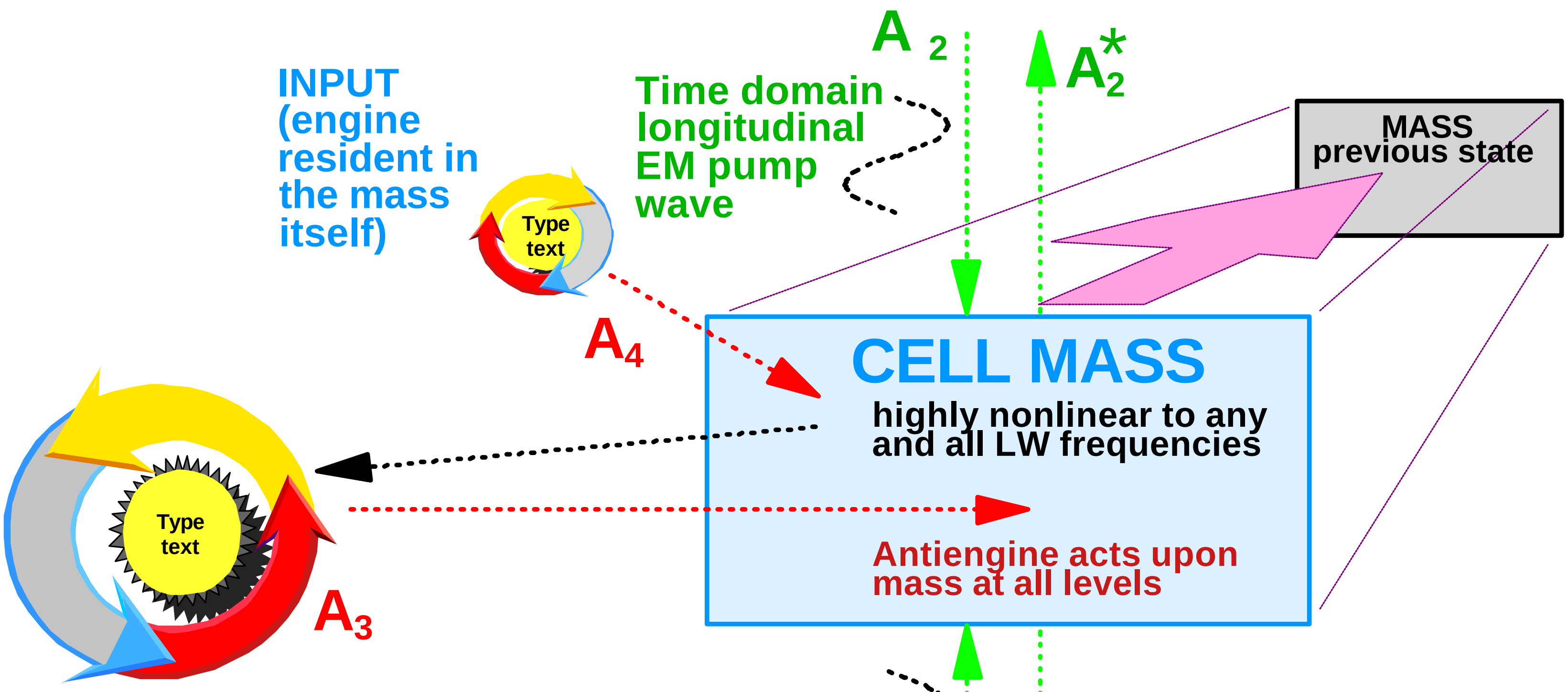

INPUT (engine resident in the mass itself)

Type text

A_4

Time domain longitudinal EM pump wave

A_2

A_2^*

MASS previous state

CELL MASS

highly nonlinear to any and all LW frequencies

Antiengine acts upon mass at all levels

Type text

A_3

AN AMPLIFIED VACUUM (SPACETIME) ANTIENGINE IS FORMED AND ACTS ON THE MASS, TIME-REVERSING IT AND ALL ITS COMPONENTS NO MATTER HOW SMALL

Time domain longitudinal EM pump wave

A_1

A_1^*

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A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

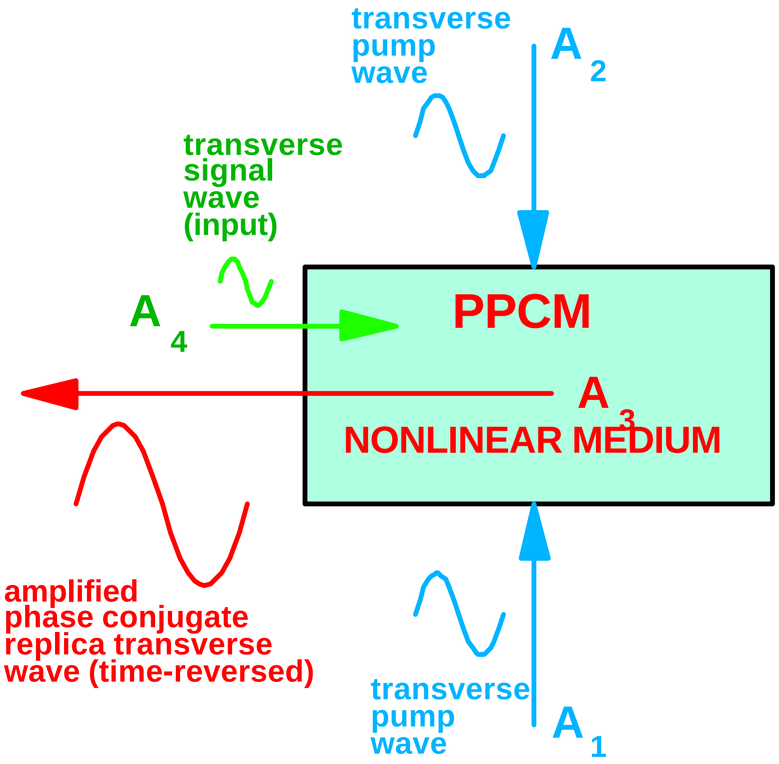
transverse pump wave
A 2
transverse signal wave (input)
A 4
PPCM
A 3
NONLINEAR MEDIUM
amplified phase conjugate replica transverse wave (time-reversed)
transverse pump wave
A 1

a. Pumping with transverse EM waves produces a time-reversed *wave*.

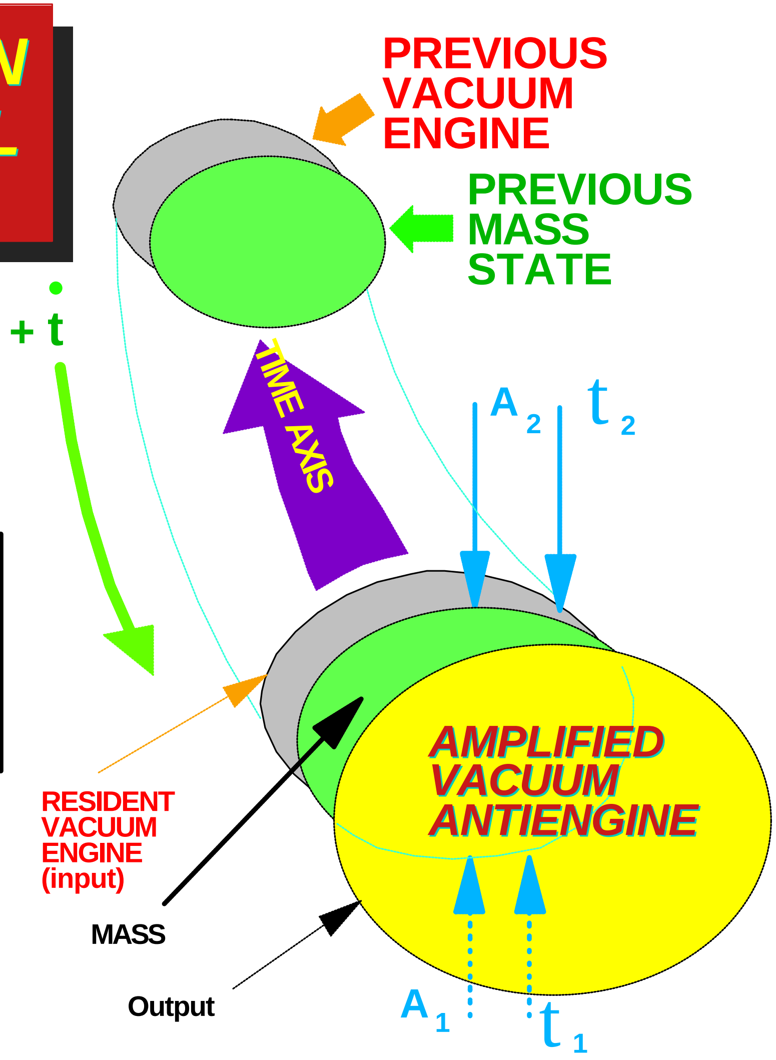
PREVIOUS VACUUM ENGINE
PREVIOUS MASS STATE
+ t
TIME AXIS
A 2
t 2
AMPLIFIED VACUUM ANTIENGINE
RESIDENT VACUUM ENGINE (input)
MASS
Output
A 1
t 1

b. Pumping with longitudinal EM waves A_1 and A_2 time-reverses *the mass itself*.

Time-reversal of a mass to a new physical state not in its past

- Original engine A'
- New engine B' added
- Time-pumping moves to new "past" that is determined by (A'+B')

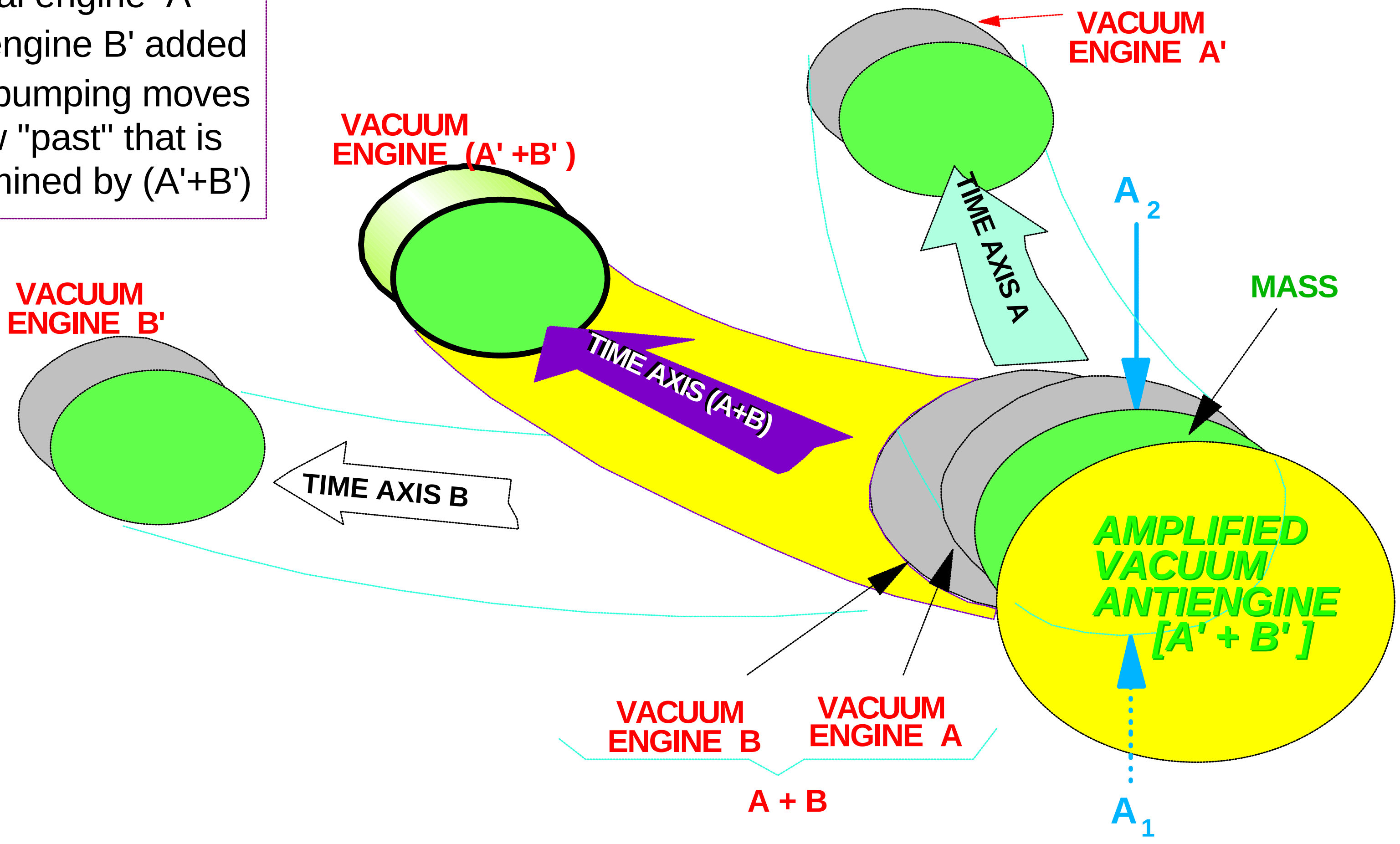
VACUUM ENGINE A'
VACUUM ENGINE (A' +B')
VACUUM ENGINE B'
TIME AXIS A
TIME AXIS (A+B)
TIME AXIS B
A_2
MASS
AMPLIFIED VACUUM ANTIENGINE [A' + B']
VACUUM ENGINE B
VACUUM ENGINE A
A + B
A_1

Extended general relativity principle

- All levels of energy structures and all levels of time structures mold spacetime geometry.
- The "pattern" is called a *template* for a vacuum engine (spacetime curvature engine).
- Spatial and temporal structurings of the engine act upon any exposed mass at al levels.
- This produces a template of forces, for precise translations and stresses within the mass at all levels. The forces exist in both time and 3-space.

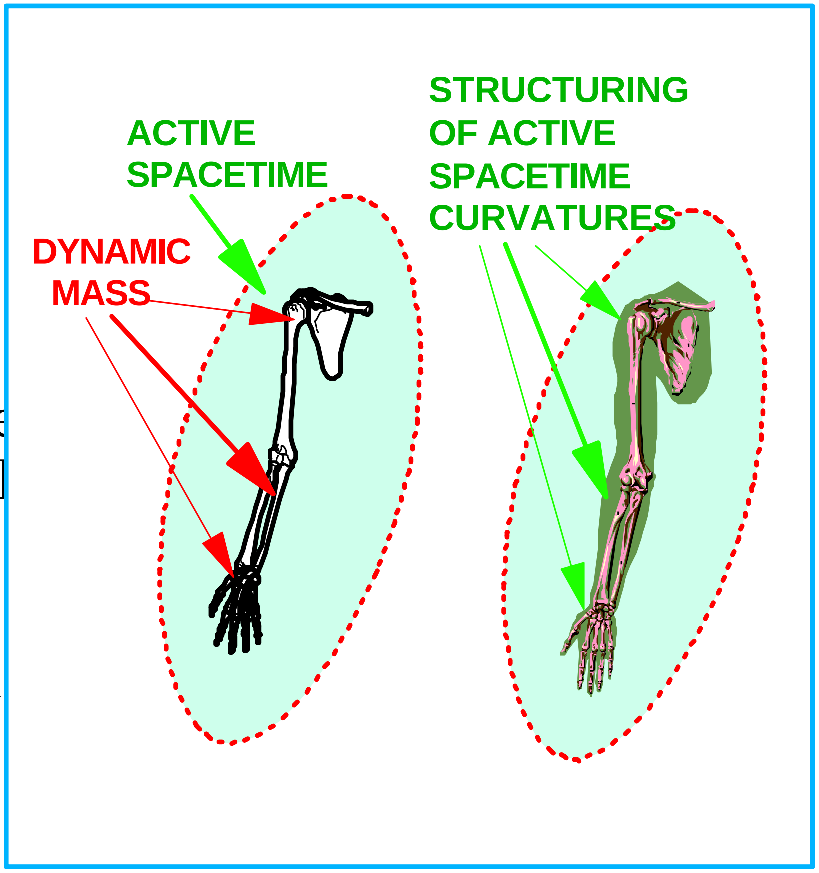
ACTIVE SPACETIME
STRUCTURING OF ACTIVE SPACETIME CURVATURES
DYNAMIC MASS

Engines: Working spacetime demons

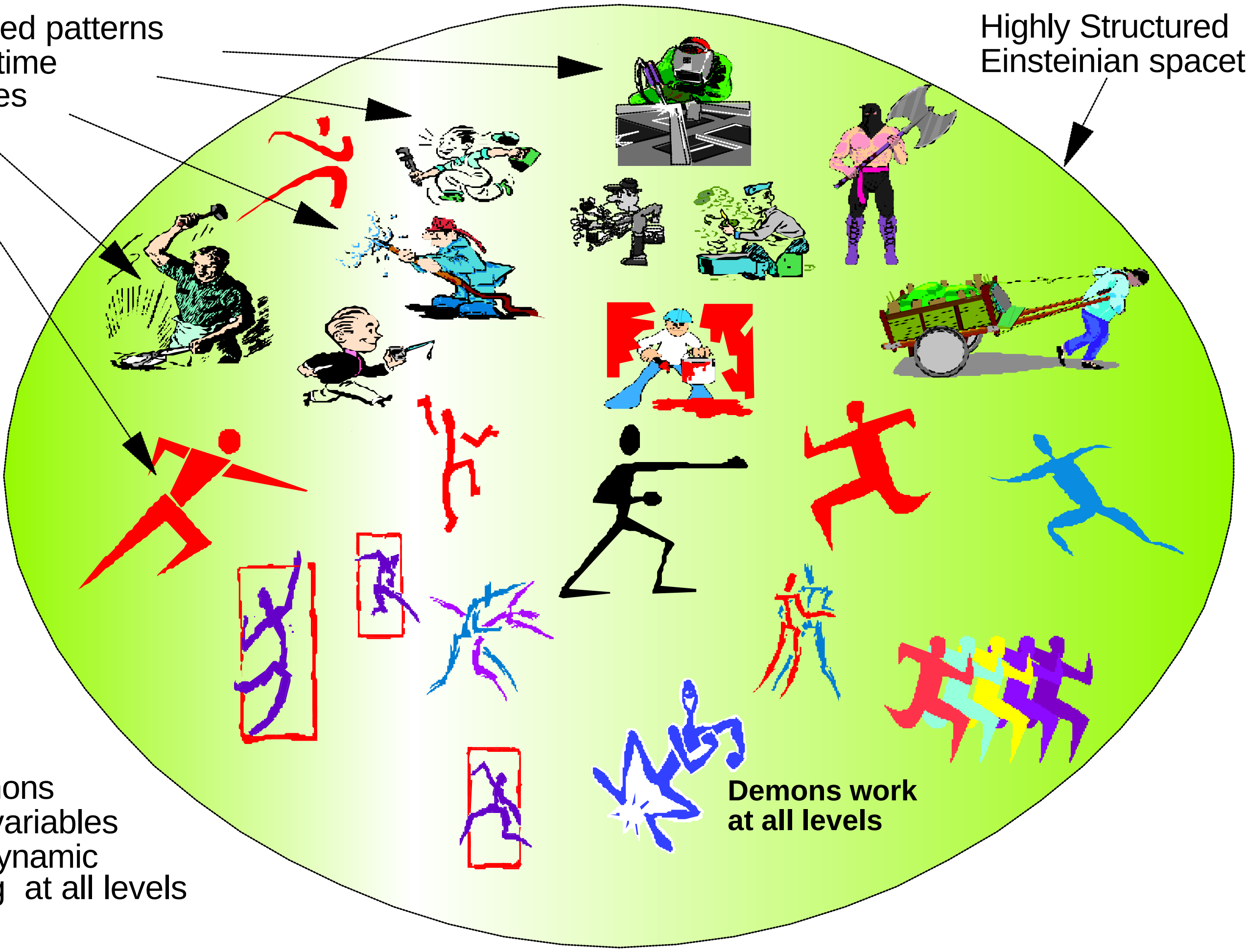

Internested patterns
of spacetime
curvatures

Highly Structured
Einsteinian spacetime

Maxwellian Demons
are EM hidden variables
organized into dynamic
structures acting at all levels

**Demons work
at all levels**

Signal vs. vacuum engine

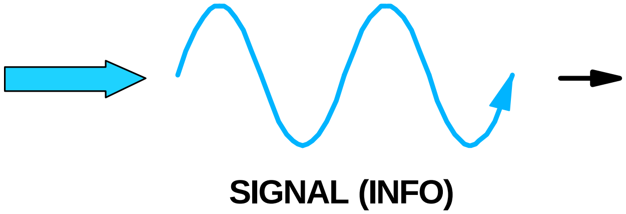

- ★ Information received
- ★ Any overt physical action must be taken by cell itself
- ★ Cell must furnish the energy for any action it takes
- ★ Passes from outside to in

A. Cell must do the action itself; vacuum energy exchange is passive. Energy or fuel for doing the action must be added to cell externally.

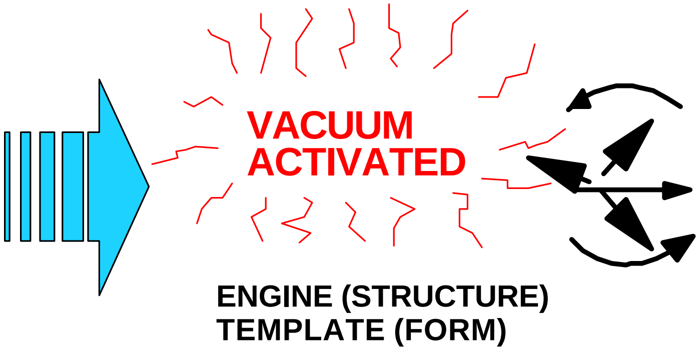

- ★ Information itself acts
- ★ Local spacetime curved, with internal subcurvatures
- ★ Produces template of forces in local spacetime (ST)
- ★ Arises from within local ST
- ★ Acts on and changes all parts of cell, including its genetics

B. Cell is acted upon; vacuum energy exchange does the specific action. No energy or fuel for doing the action need be added to cell externally.

Unified field theory requires modeling and use of supersystem

Three components interact with each other:

- System and its dynamics
- Local active vacuum and its dynamics
- Local curvatures of spacetime and their dynamics.

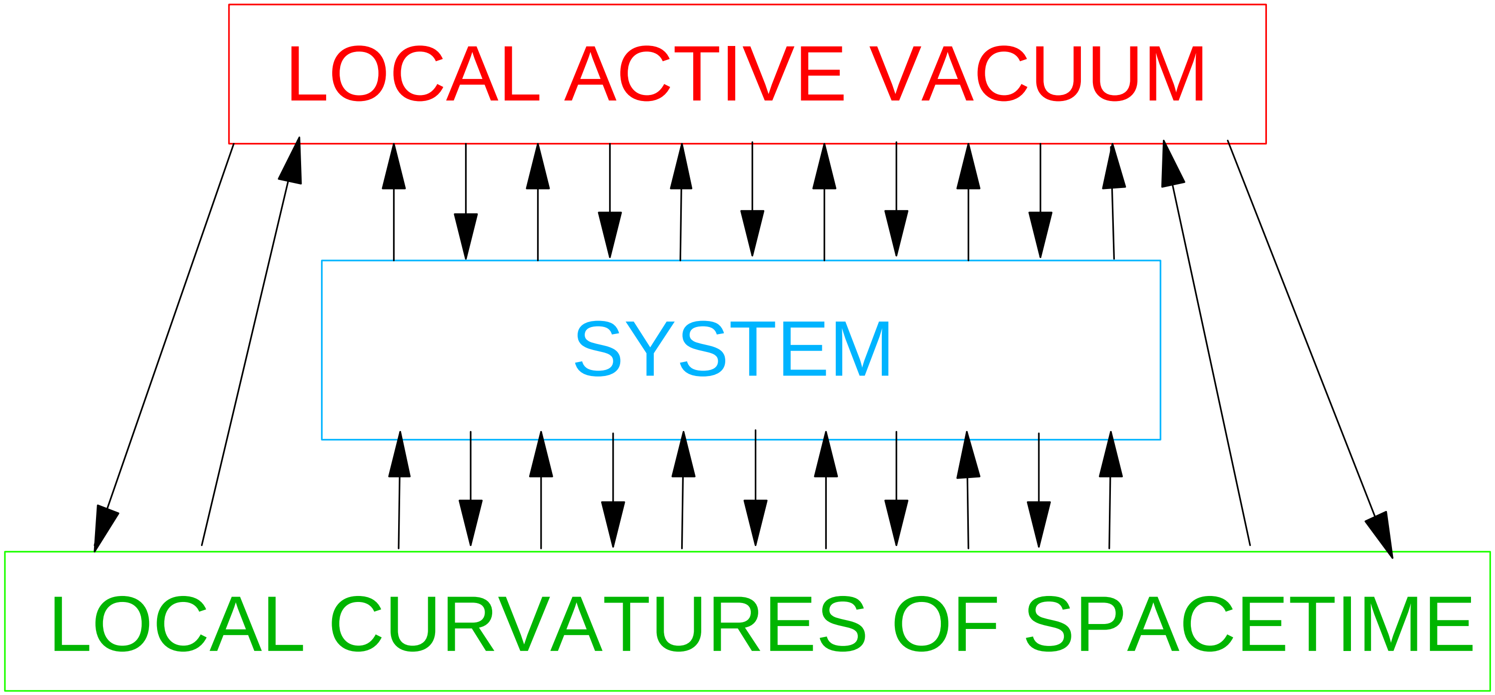

LOCAL ACTIVE VACUUM

SYSTEM

LOCAL CURVATURES OF SPACETIME

Classical EM kills the supersystem, prevents supersystem engineering

- Assumes flat local spacetime
- Assumes inert vacuum

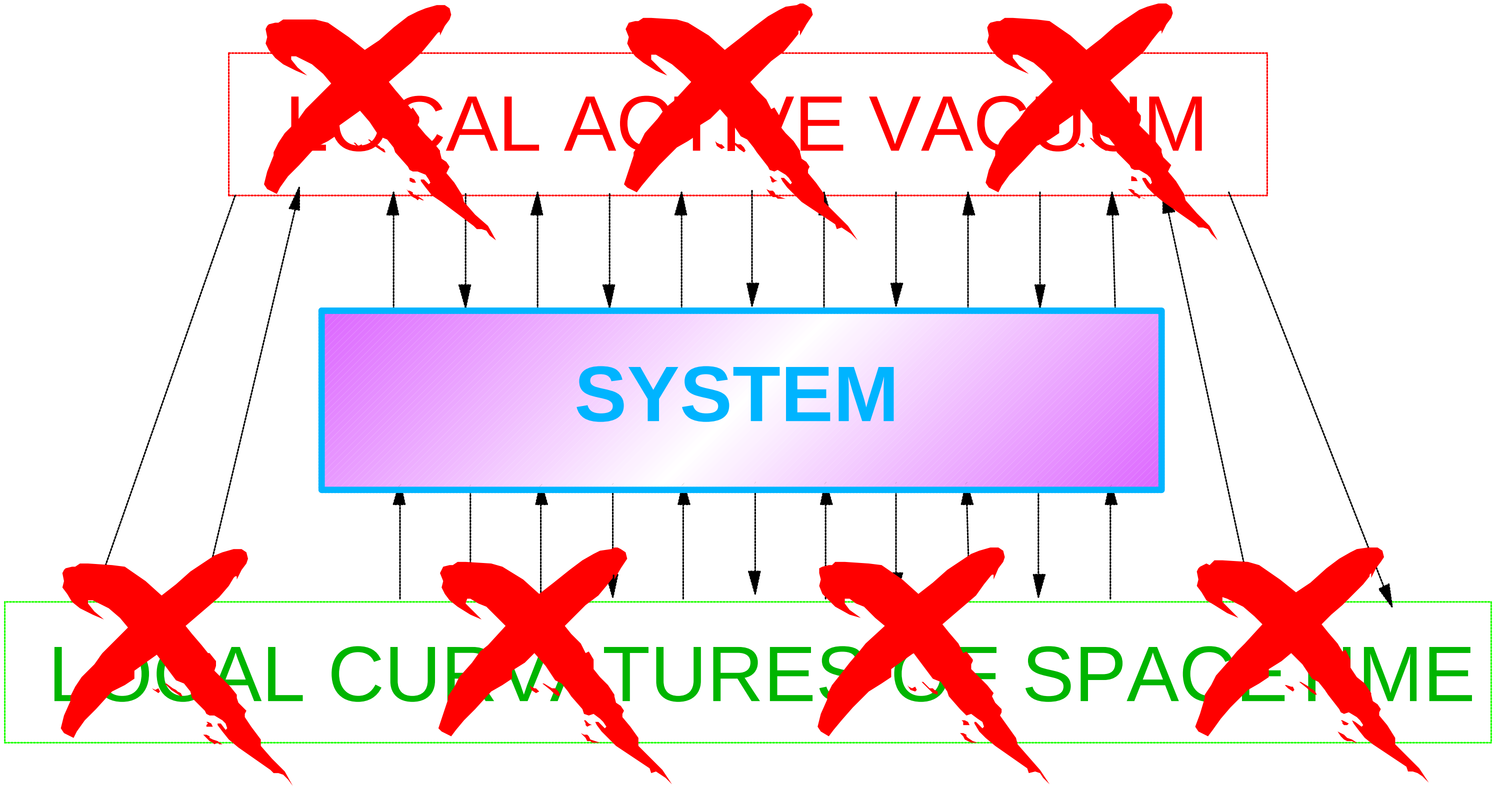
LOCAL ACTIVE VACUUM
SYSTEM
LOCAL CURVATURES OF SPACETIME

Malignant teratoma exhibits both time-reversal and fast-forwarding

- A teratoma cell is a tumor cell that has reverted to stem cells, then proceeds to differentiate toward new kinds of normal cells.
- May produce hair, skin, muscle, heart, bone, and other type cells.
- Sometimes present at birth.
- Demonstrates both "time-reversal" and "time-forwarding".
- The missing key is the engine function(s).

Miller-Fox-Urey biogenesis experiments

- Engines of and from all life forms ever on earth or in the universe exist in the ambient vacuum potential.
- The Miller-Fox-Urey experiments were not in a "sterile" environment.
- Heat (IR) and UV constitute (1) a harmonic interval with a difference frequency, and (2) amplifying by the process previously shown.
- These experiments "kindled" previously living forms from the available gases etc. by amplifying the ancient living engines from their virtual state to the observable state, so that the masses were molded into the physical states of their templates.

Biogenesis Experiments

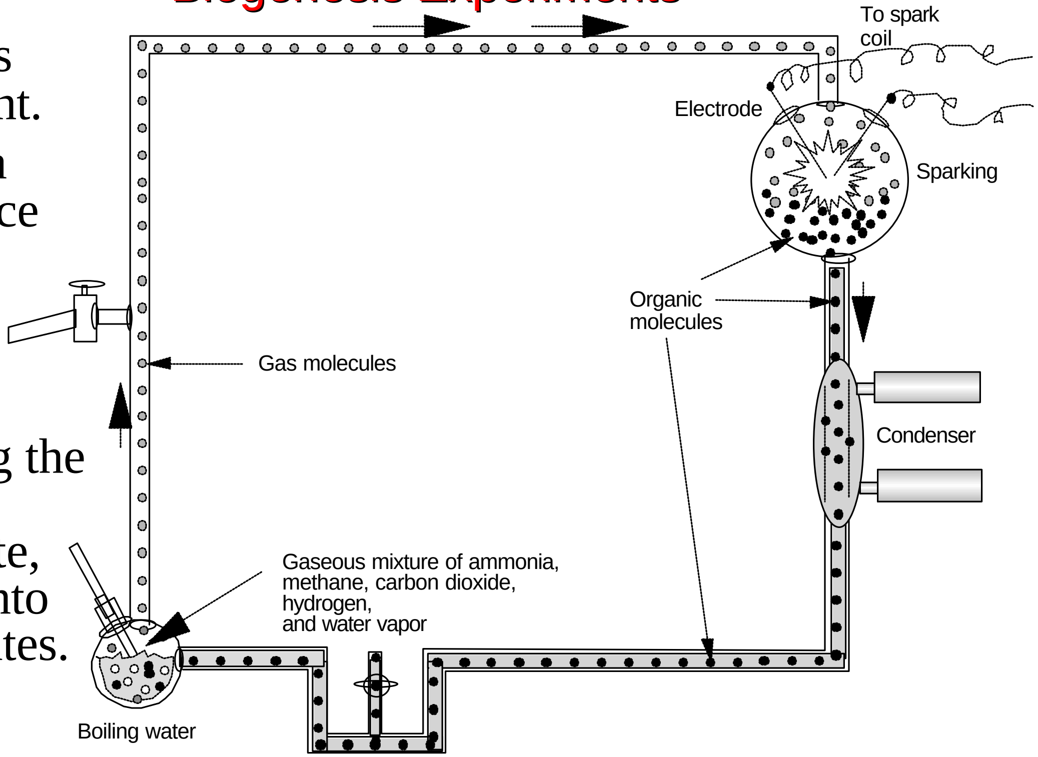
To spark coil
Electrode
Sparking
Organic molecules
Gas molecules
Condenser
Gaseous mixture of ammonia, methane, carbon dioxide, hydrogen, and water vapor
Boiling water

Cloning to produce stem cells

- Human DNA can be inserted in an animal cell, and the cell chemically tricked into proceeding as if fertilized.
- Formation, increase, and growth of stem cells begins and continues.

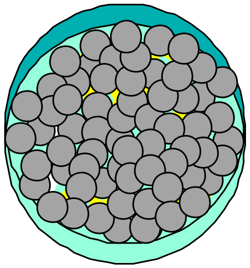

- The "engine" carried by the human DNA is changing the matter available into human cells.
- readily demonstrated experimentally.

Regeneration in a strain of rat with part of its immune system missing

- In mammals, the immune system plays a role in reducing the regeneration capability, compared to that of more primitive systems.
- In a strain of rat where that "suppressive" part of the immune system is missing, the regenerative capability is dramatically increased.
  - Can regrow cut away sections of tail.
  - Regrows plug cut out of ear.
  - Reconnects severed optic nerve.
  - Partially restores severed spinal cord.

- The suppressive "delta" engine of the immune system, operating simultaneously with the underlying primitive regenerative engine, sums to the modern much-reduced regenerative engine in the mammal.

An observation for the future

- When the science of engines is developed, physicians will be able to tailor these engine combinations to restore severed human spines, regrow severed limbs, etc.
- They will also be able to direct the body's "normal growth" to reduce and direct birth defects, genetic defects, etc.

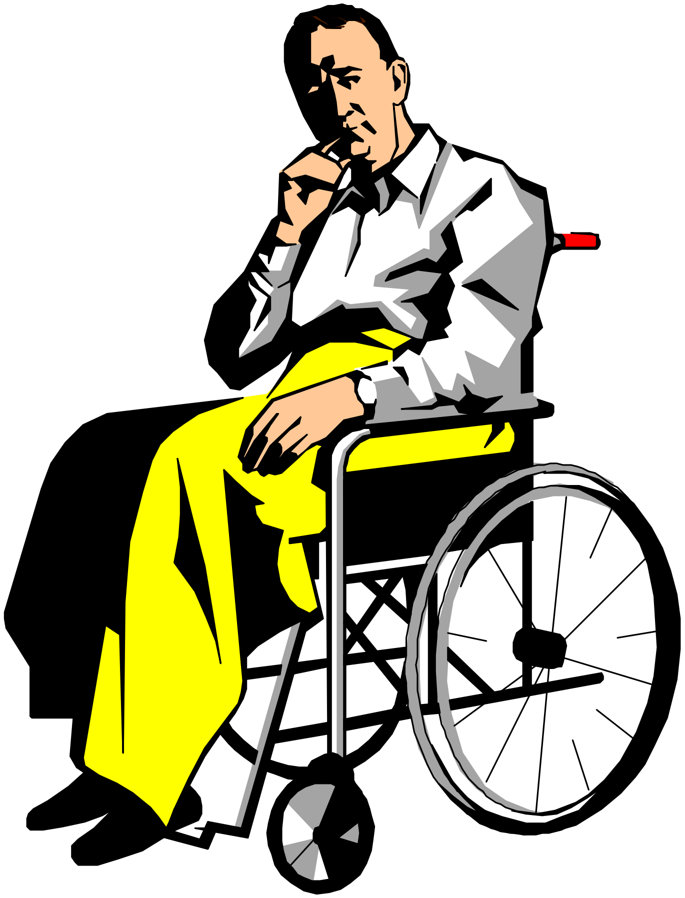

Biochemistry and EM models

- Medical scientists analyze such things as teratomas in terms of biochemistry and the biochemical model.
- An assembly of charges and charge distributions, with their associated fields and potentials, drives all chemistry at base level.
- The charge assembly and its dynamics involves a corresponding assembly of spacetime curvatures and their dynamics. These are *the cause that is driving the charge assembly and its dynamics, and therefore the chemistry*..
  - In unified field theory (such as that of Sachs) and O(3) electrodynamics.
  - Not in classical U(1) EM theory or quantum electrodynamics.
- Conventionally a causative EM field in space is "defined" as the *diversion from* that spatial field by and after its interaction with charge).
  The "definition" substitutes the effect for the cause, a non sequitur.
- This is a known major flaw, pointed out in one fashion or another by many physicists such as Wheeler and Nobelist Feynman.
- Classical EM theory is a 137-year-old model, seriously flawed. These flaws emerge in biochemistry and medical science.

Necessary EM corrections*

- Many of the corrections necessary in electrodynamics modeling either have been done or are underway.
- Higher symmetry, non-Abelian electrodynamics models have long been developed in particle physics.
- The new approach extends these models to also incorporate general relativity, thus producing a unified field theory*.
- In the new approach, spacetime curvature engines are perfectly natural and understandable, and can be directly modeled and engineered by advanced theorists.
- In short, the theory is sufficiently advanced and robust that technology and engineering can now advance.
- This will be a great leap forward for biochemistry and medical science, particularly in therapeutic methods.

* Sachs's unified field theory implemented by O(3) electrodynamics presently is the most suitable to use. Numerical methods are required.

Prioré's revolutionary results in lab animals

And its ramifications

Prioré (right) makes a point to Chaban-Delmas, Mayor of Bordeaux

- Many of the Prioré team's experiments were done in Bordeaux.
- Antoine Prioré patents:
  - "Apparatus for producing radiations penetrating living cells," U.S. Patent No. 3,368,155, Feb. 6, 1968.
  - "Method of producing radiations for penetrating living cells," U.S. Patent No. 3,280,816, Oct. 25, 1966.
  - "Procede et dispositif de production de rayonnements utilisables notamment pour le traitement de cellules vivantes," [Procedure and Assemblage for Production of Radiation Especially Serviceable for the Treatment of Living Cells], Republique Francais Brevet d'Invention P.V. No. 899.414, No. 1,342,772, Oct. 7, 1963.

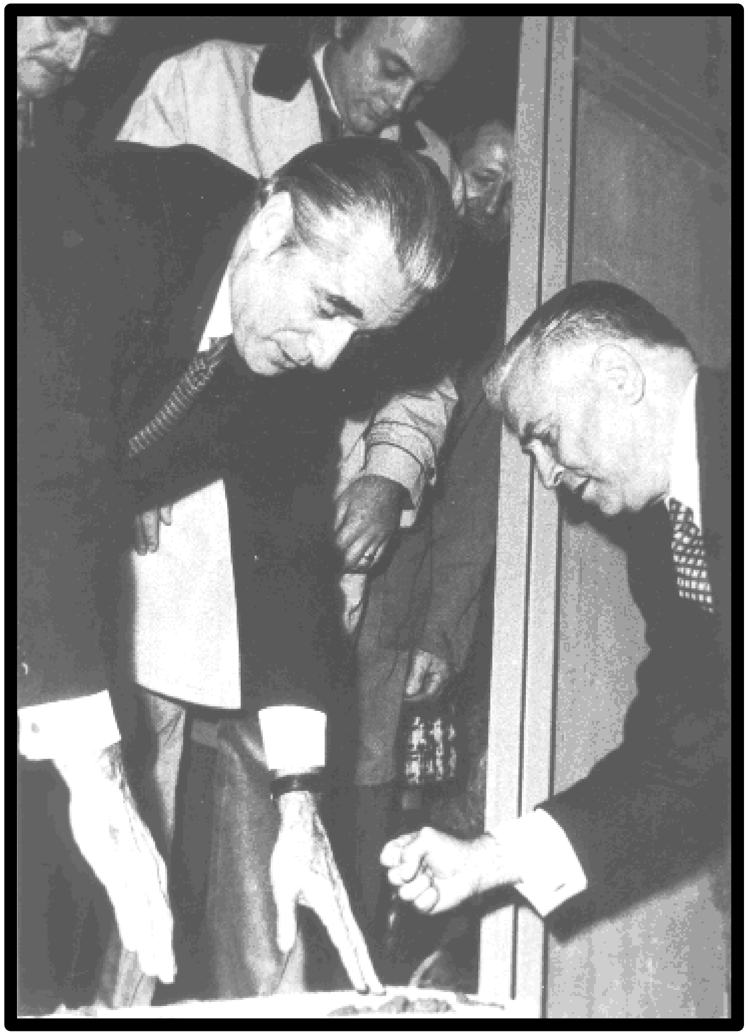

Block diagram of Prioré's method

Time-reversing the cells back to normal state

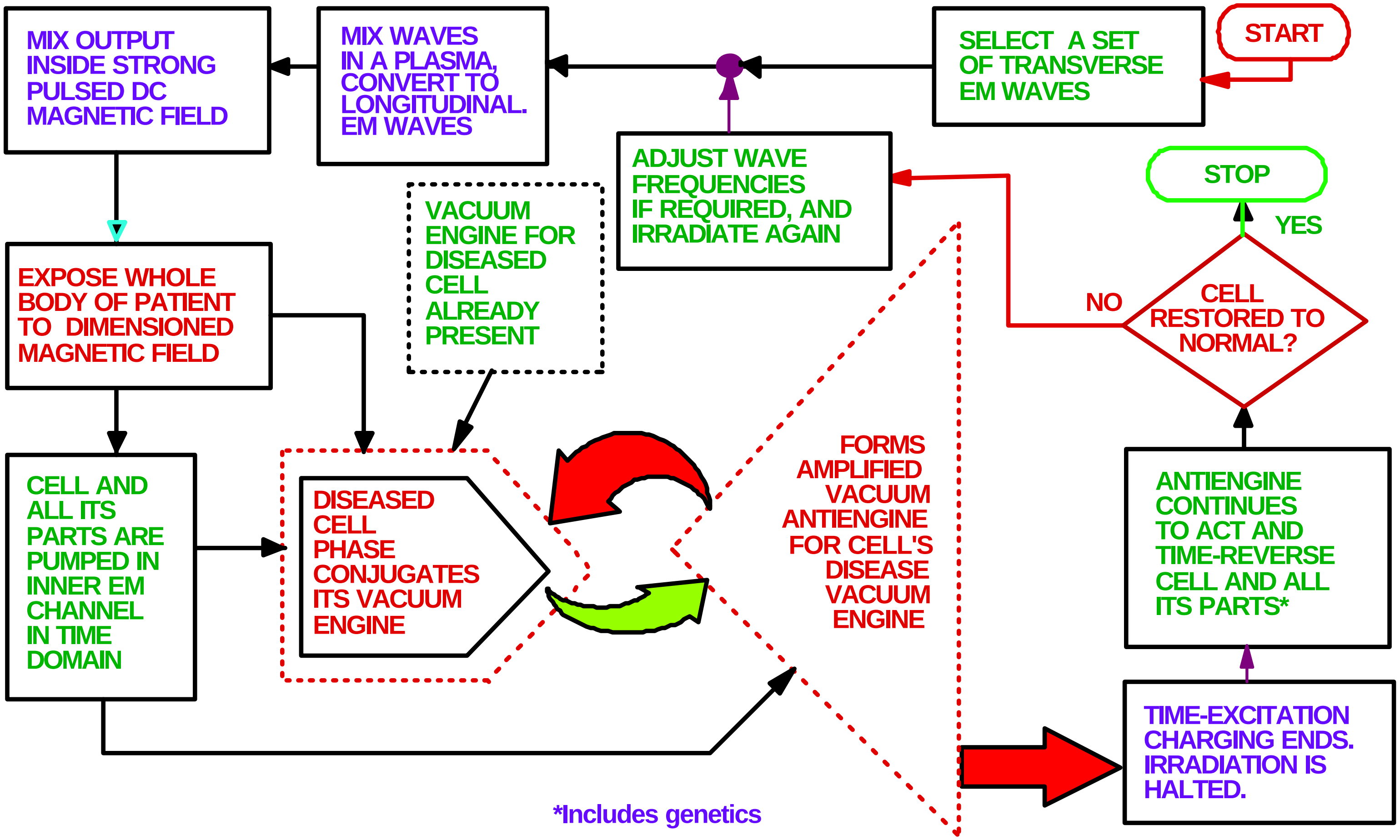

START

SELECT A SET OF TRANSVERSE EM WAVES

MIX WAVES IN A PLASMA, CONVERT TO LONGITUDINAL. EM WAVES

MIX OUTPUT INSIDE STRONG PULSED DC MAGNETIC FIELD

EXPOSE WHOLE BODY OF PATIENT TO DIMENSIONED MAGNETIC FIELD

CELL AND ALL ITS PARTS ARE PUMPED IN INNER EM CHANNEL IN TIME DOMAIN

VACUUM ENGINE FOR DISEASED CELL ALREADY PRESENT

DISEASED CELL PHASE CONJUGATES ITS VACUUM ENGINE

FORMS AMPLIFIED VACUUM ANTIENGINE FOR CELL'S DISEASE VACUUM ENGINE

TIME-EXCITATION CHARGING ENDS. IRRADIATION IS HALTED.

ANTIENGINE CONTINUES TO ACT AND TIME-REVERSE CELL AND ALL ITS PARTS*

CELL RESTORED TO NORMAL?

YES

STOP

NO

ADJUST WAVE FREQUENCIES IF REQUIRED, AND IRRADIATE AGAIN

*Includes genetics

In Laboratory Animals:

Prioré Team Cured

- **Terminal malignant tumors**
- **Clogged arteries (atheriosclerosis)**
- **Suppressed Immune Systems**
- **Infectious trypanosomas**
- ***Results were presented to French Academy of Science by Robert Courrier, Director of the Biology Section of the Academy***

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- ***No one understood the mechanism!***

Some peculiar results by the Prioré team

- Once a rat is cured of a particular disease:
  - A single drop of blood from the cured rat, injected into another rat stricken with same disorder, would result in the injected rat getting well slowly.
  - This ability to transfer immunity and healing in the extracted drop of blood gradually decayed over a period of a few weeks.
- Showed that even the fields and potentials in the blood had been altered internally, in the treated animal.
- Showed that the injected animal's cellular regenerative system possessed the ability to also time-domain pump over the entire body, everywhere reducing the delta between that injected drop of blood now the rat's own, and the rest of the blood in its body.

Proof of cellular time-reversal

- Pautrizel compared identical treatment of immature rats with immature immune systems, and mature rats with mature immune systems.
- Treatment restored the damaged mature system back to full mature functioning, and it promptly recognized and dispatched the pathogens.
- Treatment restored the damaged immature system back to full immature functioning, unable to cope, and the pathogens promptly reinfected and killed the immature rat.
- The lesson: The body is indeed returned to a previous physical state. The pathogens themselves are not killed by the treatment, but by restoring the ability of the immune system to recognize and destroy them.
- Only the *previous ability* of the immune system is restored by the process.

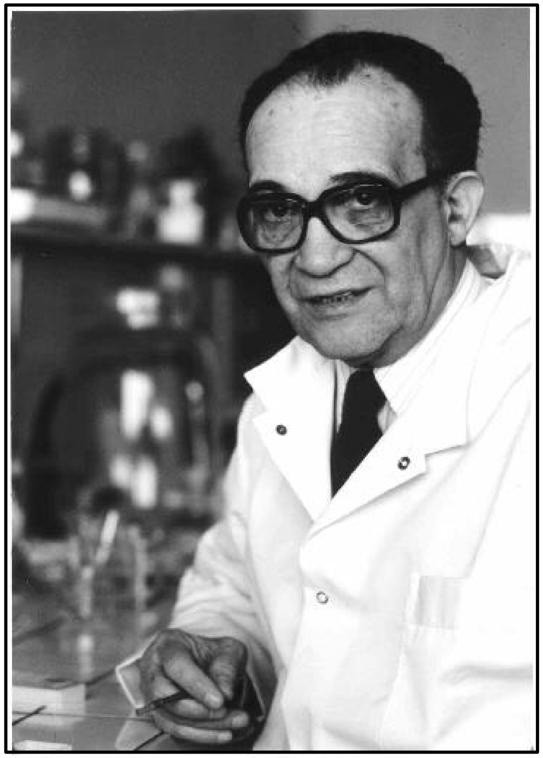

PROF. RAYMOND PAUTRIZEL
(Renowned Parasitologist)

Disadvantages of Prioré method

- Large plasma tube and facility required.
  - 3-stories high building bay if to treat humans.
  - Long irradiation time (2-3 hours).
  - Slow, numerous experimental adjustments.
- Fundamental mechanism was unknown.
  - Phase conjugate optics not yet born in West.
  - No higher symmetry EM modeling used.
  - Prioré thought it was a result of ionization.
  - Importance of difference frequency unknown.
  - Body dielectric transmission path unknown.

3-Story high Prioré device for treating humans

- At the end of the project, Prioré had developed a large unit to treat humans.
- A few were treated.
- Cures replicated what had been done in lab animals
- The massive size of the unit and long treatment time (hours) made the process bulky and very inconvenient -- and also expensive

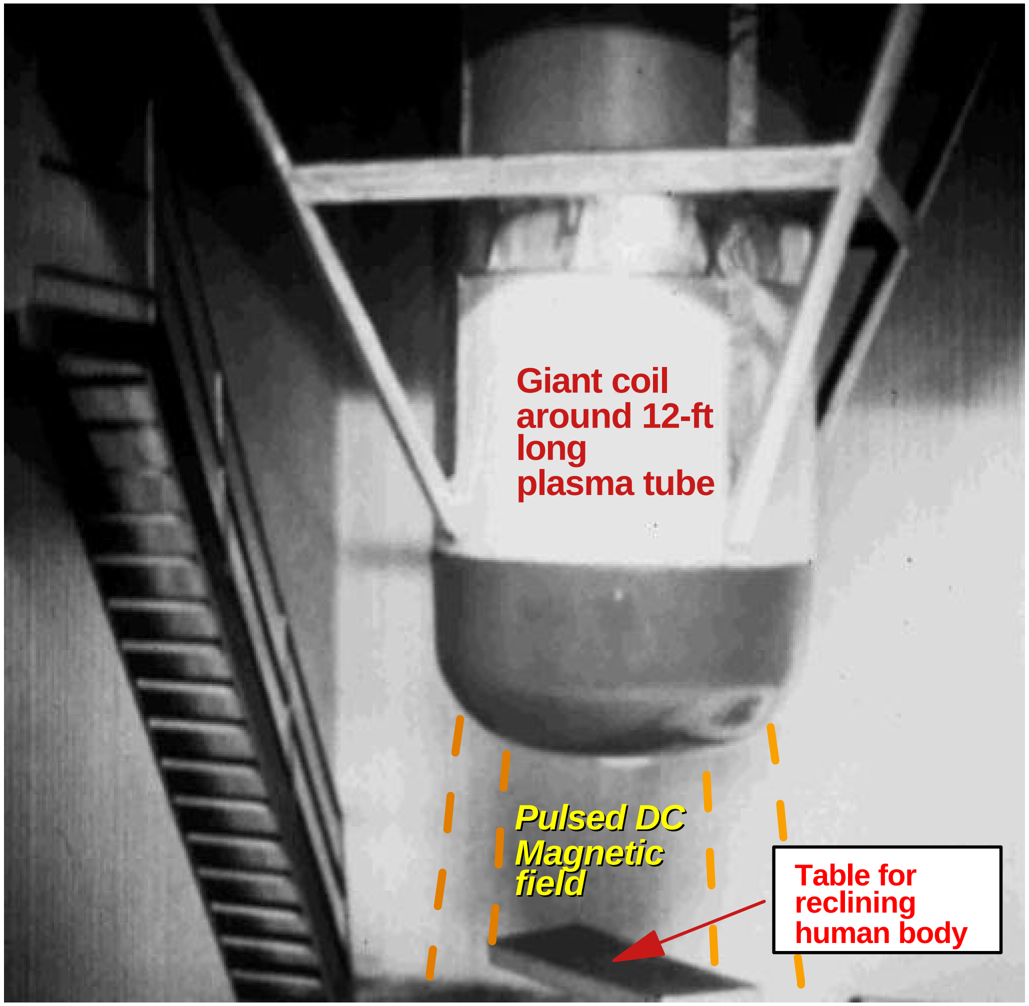
Giant coil around 12-ft long plasma tube
Pulsed DC Magnetic field
Table for reclining human body

17-foot Prioré plasma tube

Used in large machine (3-stories high) to treat a limited number of human patients

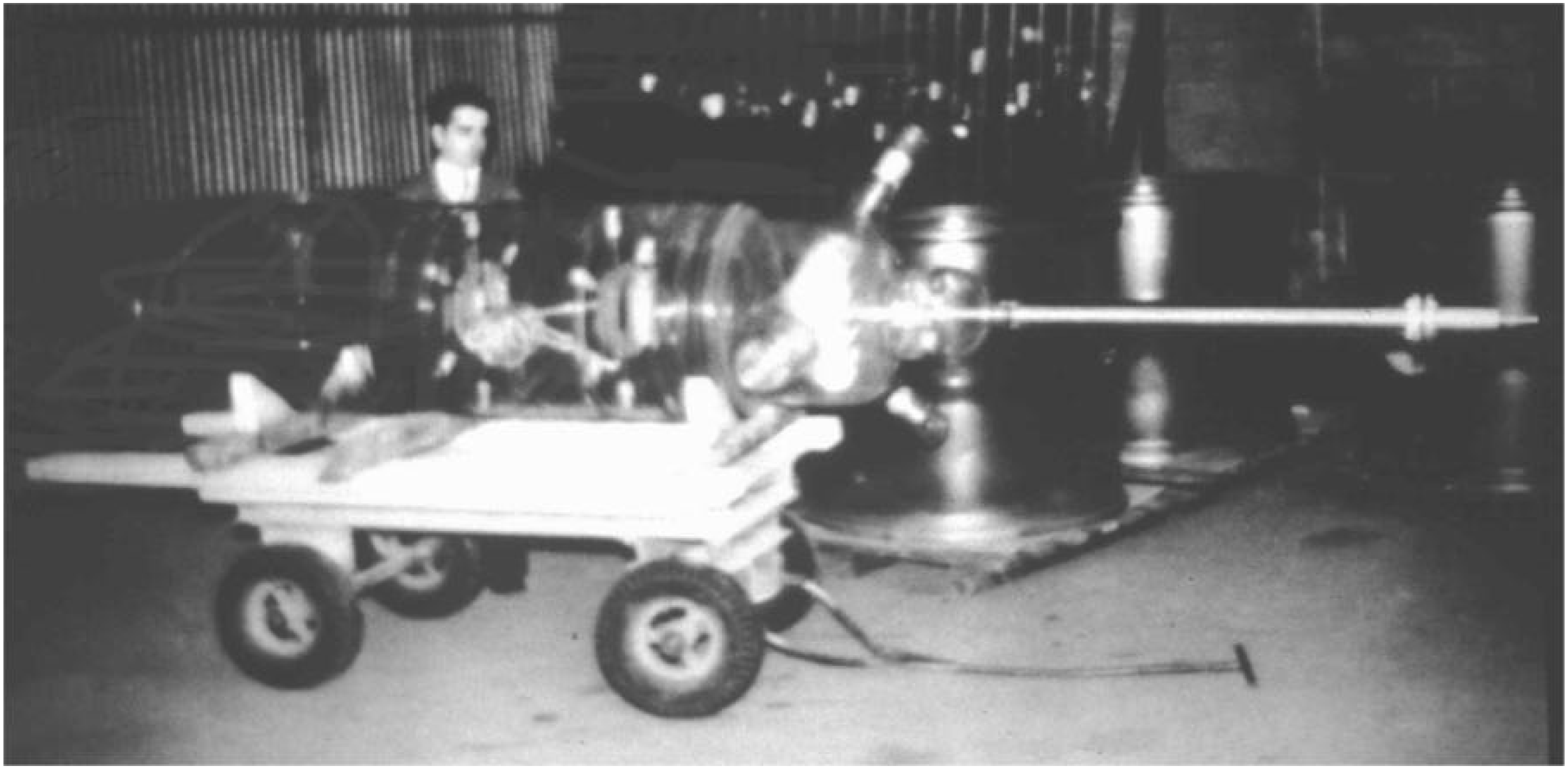

A proposed new mechanism for cancer promotion

And its ramifications

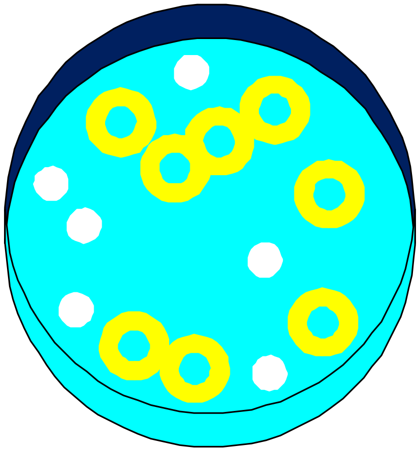

Remarks on cancer from a new perspective

- Two stages: cellular damage and promotion of the damaged cell to a tumorous cell. Promotion presently is poorly understood if at all.
- A master cellular control system (MCS) (studied by Popp et al.) controls both the immune system and the cellular regenerative system, as well as normal functions of the cells.
- The "past history" of ancestral development of aerobic cells and higher multicell aerobic bodies on planet Earth, resides in the "internested engine layers" in every tiniest part of the entire body dielectric, and in all cells.

Remarks on cancer from a new perspective (2)

- Faced with cell damage (such as sustained hypoxia) it cannot handle, the MCS continues to "peel the layers" in taking actions related to ever more distant pasts.
- Faced with continuing hypoxia, e.g., the MCS eventually reaches ancestral layers -- with an engine -- it forces the damaged cells to start moving back toward the original primeval anaerobic form.
- The first step backward is *separation from central growth control*, freeing the cell to multiply independently. At the same time, genetic changes in the cell are forced and produced, starting it back toward becoming an anaerobe.
- These actions comprise the *promotion process*.

The promotion process via engines

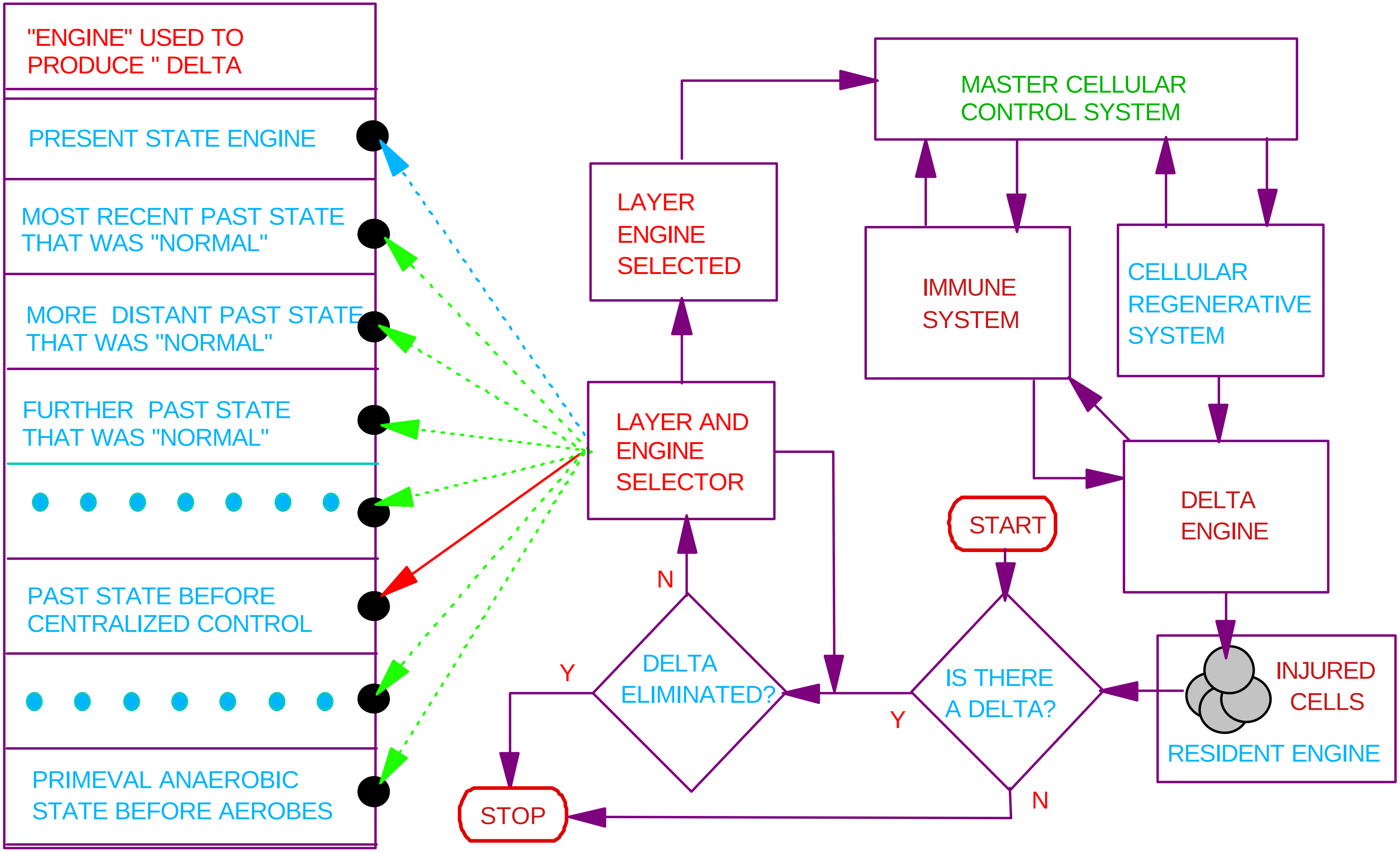

"ENGINE" USED TO PRODUCE " DELTA

PRESENT STATE ENGINE

MOST RECENT PAST STATE THAT WAS "NORMAL"

MORE DISTANT PAST STATE THAT WAS "NORMAL"

FURTHER PAST STATE THAT WAS "NORMAL"

PAST STATE BEFORE CENTRALIZED CONTROL

PRIMEVAL ANAEROBIC STATE BEFORE AEROBES

LAYER ENGINE SELECTED

LAYER AND ENGINE SELECTOR

MASTER CELLULAR CONTROL SYSTEM

IMMUNE SYSTEM

CELLULAR REGENERATIVE SYSTEM

DELTA ENGINE

START

IS THERE A DELTA?

DELTA ELIMINATED?

STOP

INJURED CELLS

RESIDENT ENGINE

Evolution of aerobic systems

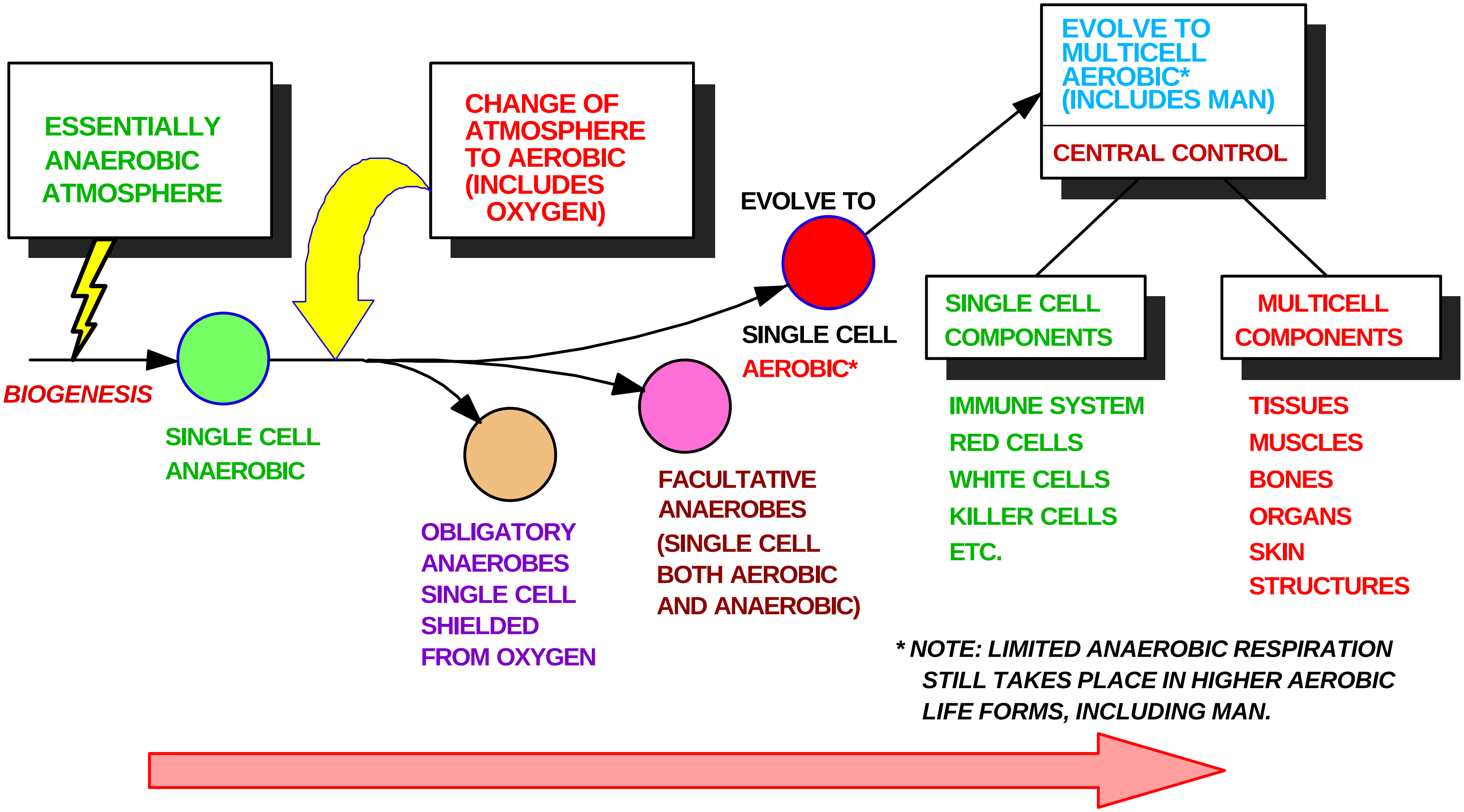

ESSENTIALLY
ANAEROBIC
ATMOSPHERE

CHANGE OF
ATMOSPHERE
TO AEROBIC
(INCLUDES
OXYGEN)

BIOGENESIS

SINGLE CELL
ANAEROBIC

OBLIGATORY
ANAEROBES
SINGLE CELL
SHIELDED
FROM OXYGEN

FACULTATIVE
ANAEROBES
(SINGLE CELL
BOTH AEROBIC
AND ANAEROBIC)

EVOLVE TO

SINGLE CELL
AEROBIC*

EVOLVE TO
MULTICELL
AEROBIC*
(INCLUDES MAN)

CENTRAL CONTROL

SINGLE CELL
COMPONENTS

- IMMUNE SYSTEM
- RED CELLS
- WHITE CELLS
- KILLER CELLS
- ETC.

MULTICELL
COMPONENTS

- TISSUES
- MUSCLES
- BONES
- ORGANS
- SKIN
- STRUCTURES

** NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.*

EVOLUTIONARY TIME

First step in self-promotion of cancer due to hypoxia

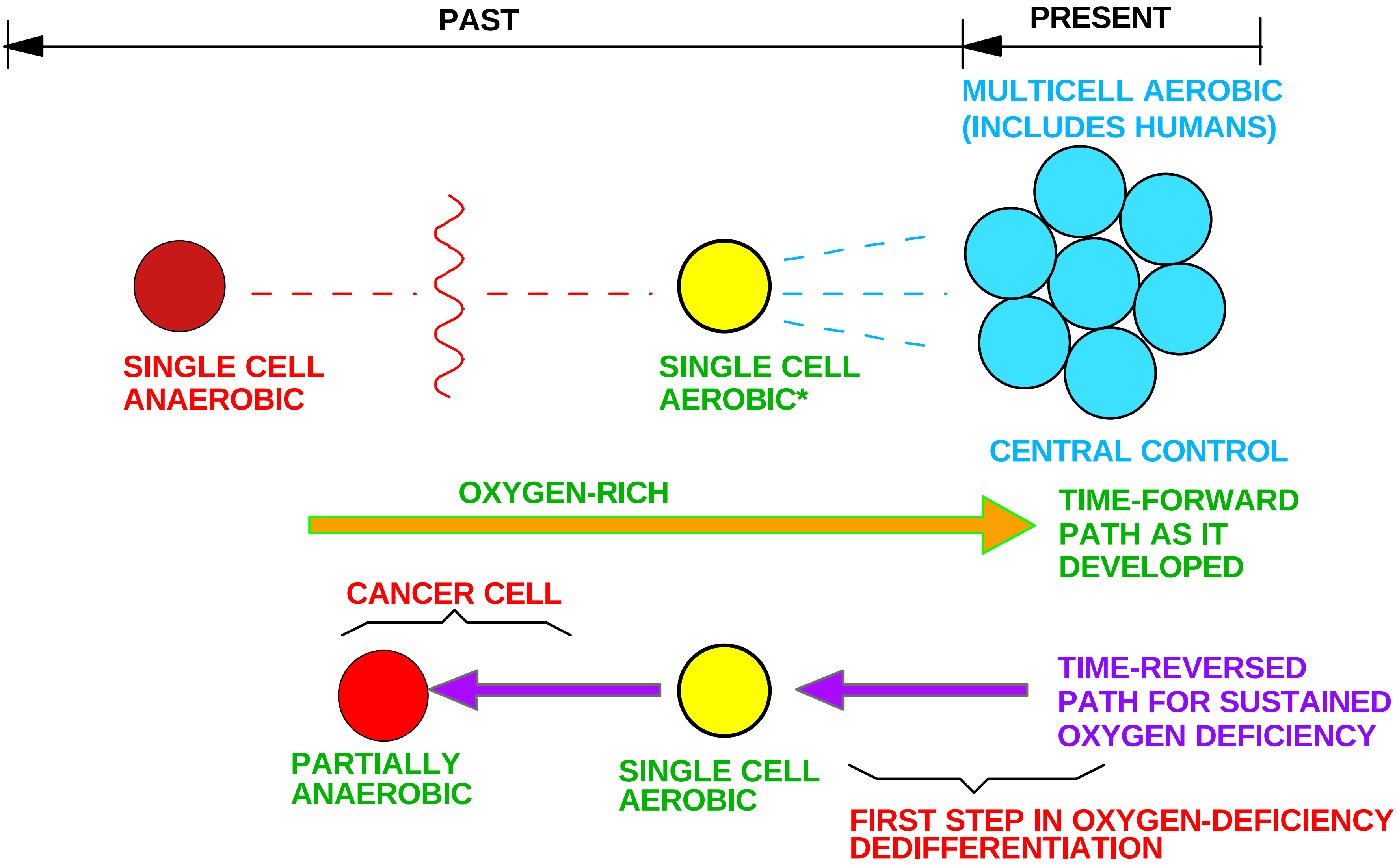

PAST

PRESENT

MULTICELL AEROBIC
(INCLUDES HUMANS)

SINGLE CELL
ANAEROBIC

SINGLE CELL
AEROBIC*

CENTRAL CONTROL

OXYGEN-RICH

TIME-FORWARD
PATH AS IT
DEVELOPED

CANCER CELL

TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY

PARTIALLY
ANAEROBIC

SINGLE CELL
AEROBIC

FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION

Block diagram of the cellular regenerative system

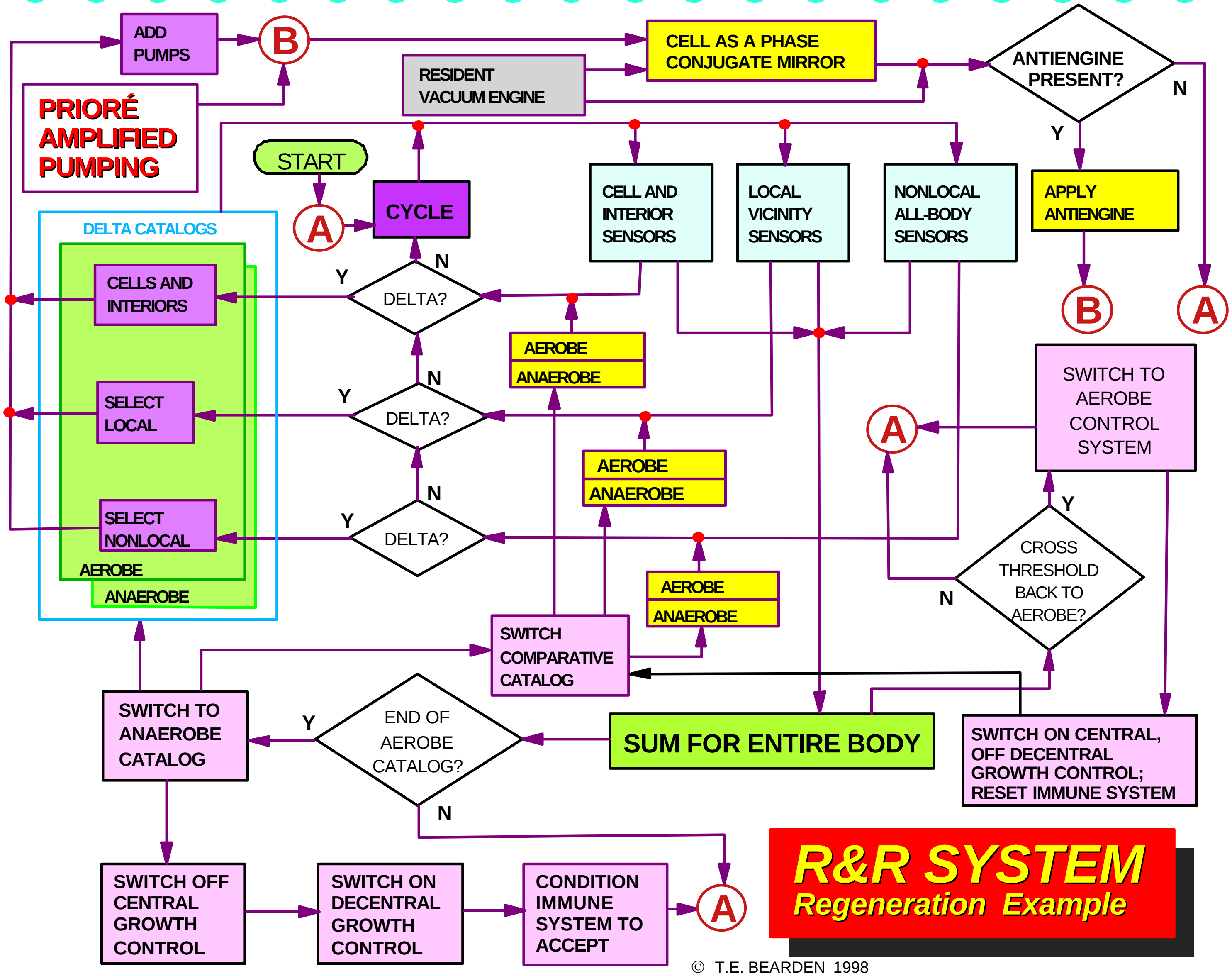

ADD PUMPS

B

PRIORÉ AMPLIFIED PUMPING

RESIDENT VACUUM ENGINE

CELL AS A PHASE CONJUGATE MIRROR

ANTIENGINE PRESENT?

N

Y

APPLY ANTIENGINE

B

A

START

A

CYCLE

CELL AND INTERIOR SENSORS

LOCAL VICINITY SENSORS

NONLOCAL ALL-BODY SENSORS

DELTA CATALOGS

CELLS AND INTERIORS

SELECT LOCAL

SELECT NONLOCAL

AEROBE

ANAEROBE

Y

DELTA?

N

Y

DELTA?

N

Y

DELTA?

N

AEROBE

ANAEROBE

AEROBE

ANAEROBE

AEROBE

ANAEROBE

SWITCH TO AEROBE CONTROL SYSTEM

A

Y

CROSS THRESHOLD BACK TO AEROBE?

N

SWITCH COMPARATIVE CATALOG

SWITCH TO ANAEROBE CATALOG

Y

END OF AEROBE CATALOG?

N

SUM FOR ENTIRE BODY

SWITCH ON CENTRAL, OFF DECENTRAL GROWTH CONTROL; RESET IMMUNE SYSTEM

SWITCH OFF CENTRAL GROWTH CONTROL

SWITCH ON DECENTRAL GROWTH CONTROL

CONDITION IMMUNE SYSTEM TO ACCEPT

A

R&R SYSTEM

Regeneration Example

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Bombshell: Amplified EM healing

- A unified field theory approach and use of supersystem analysis has broken the basic mechanism for healing itself.
  - The Sachs unified field theory applies and has been partially fitted.
  - Evans-Vigier O(3) electrodynamics can properly model it, including both the internal and external electrodynamics and effects of engines.
  - Direct engineering development is now possible.
- Experimental proof of the results obtainable already exists in the literature.
- A medical revolution is in the offing.

Potential Medical Applications

- Non-traumatic cancer treatment
  - *Cure cancers and leukemias of all types*
  - *Remove pre-cancerous state*
  - *Restore system*
- Treat and cure Infectious diseases
- Cure AIDS and restore immune systems
- Defense against biological warfare
  - *Virulent diseases from unknown agents*
  - *Treat, cure prior to symptoms developing*
  - *Both civil populace and armed forces*
- *Dramatically lower health costs*
- *Rejuvenate the aged*

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To treat and save mass casualties: What is urgently needed now:

- A small, portable, relatively inexpensive treatment unit, not requiring plasmas etc.
- Treatment in 2 to 5 minutes rather than 2-hours.
- Simple treatment application, almost anywhere.
- Effective in advanced stages as well as prior to emergence of symptoms.
- Effectiveness against a wide array of illnesses.
- Use is easy, high school student can be trained in 30 minutes.
- Crash program to develop, flood down through emergency systems in great quantities.

The Solution:

- Two blankets have antennas in them.
- Uses the "porthole" concept (discussed shortly)
- Eliminates plasma tube mixing etc.
- Computer-controlled complex signal structure.

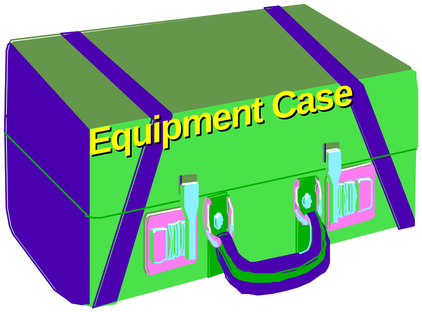
Equipment Case

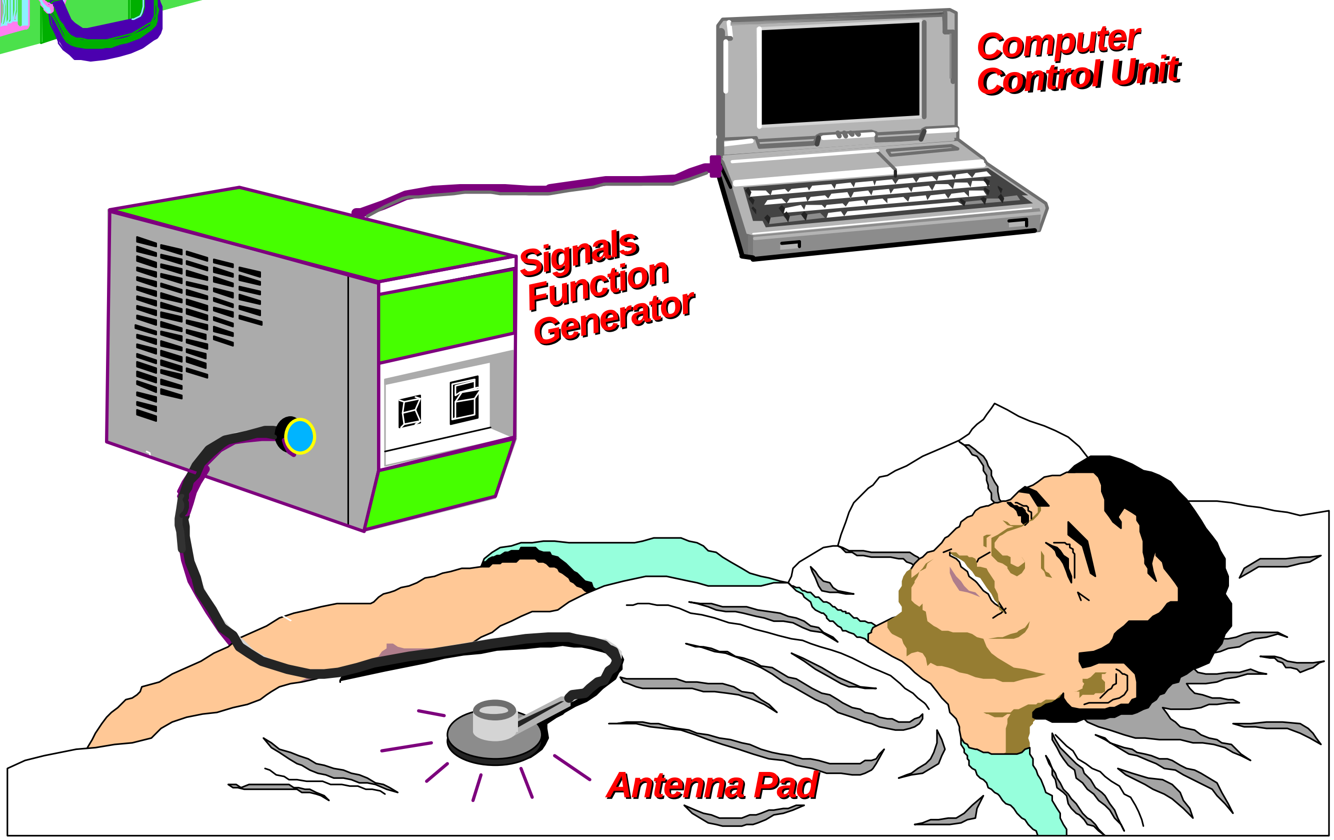
Computer
Control Unit
Signals
Function
Generator
Antenna Pad

The Porthole concept:

The two-minute treatment shortcut

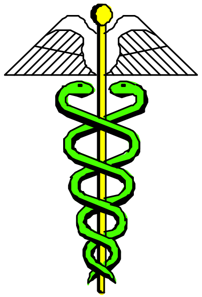

How the porthole concept works

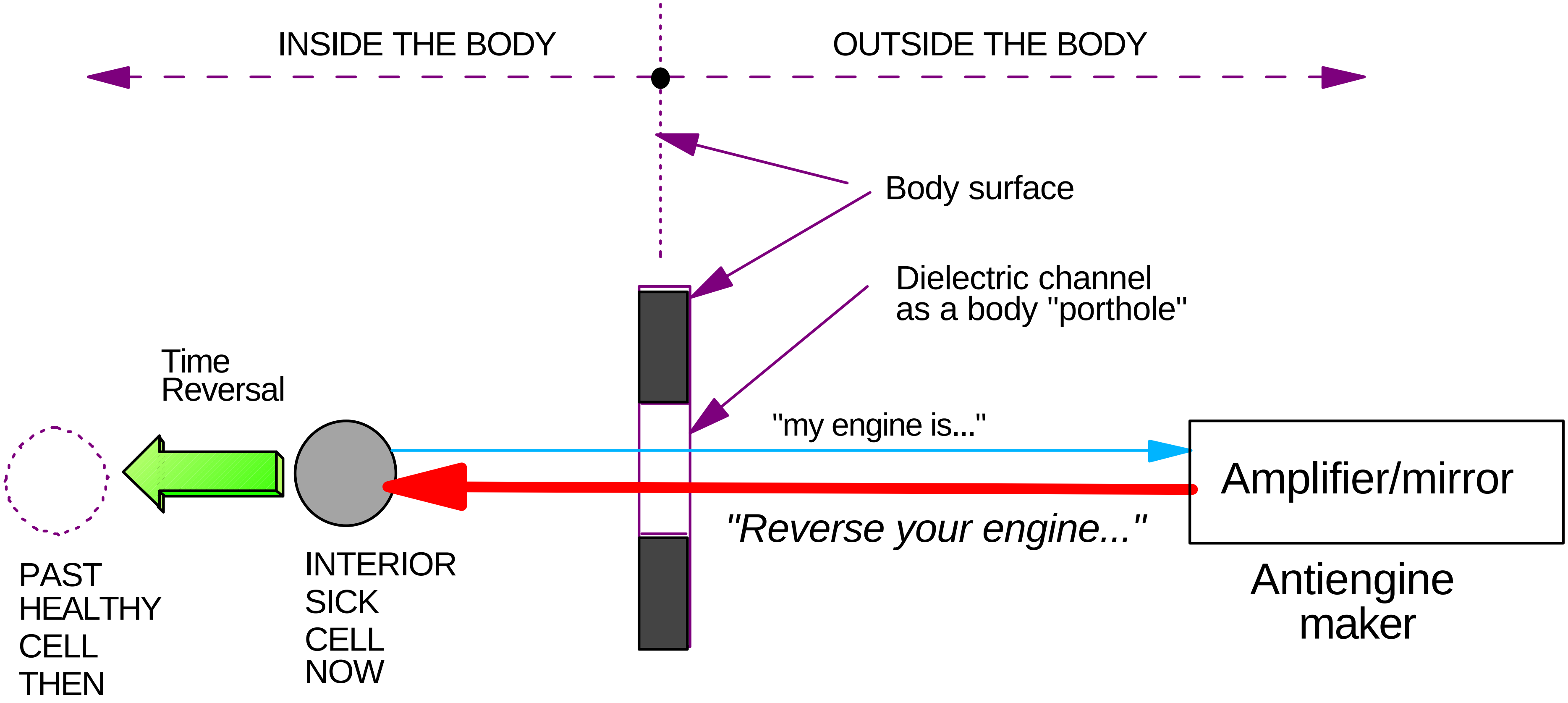

INSIDE THE BODY

OUTSIDE THE BODY

Body surface

Dielectric channel
as a body "porthole"

Time
Reversal

"my engine is..."

Amplifier/mirror

"Reverse your engine..."

PAST
HEALTHY
CELL
THEN

INTERIOR
SICK
CELL
NOW

Antiengine
maker

Porthole concept: An analogy of the dielectric path and inner-outer functional connections

- Imagine perfectly reversible dynamic light processes inside a large "cruise ship", that are also perfect phase conjugate mirrors
- Each process receives, absorbs, and emits light continuously
- Light escaping through the portholes is a composite from all the dynamic processes ongoing inside
- If we record and amplify the escaping light, then force it back through the portholes, it reverses all the internal processes
- The processes revert back, slowly, to a previous ongoing process state
- We cease radiation, and the processes reverse and move forward again

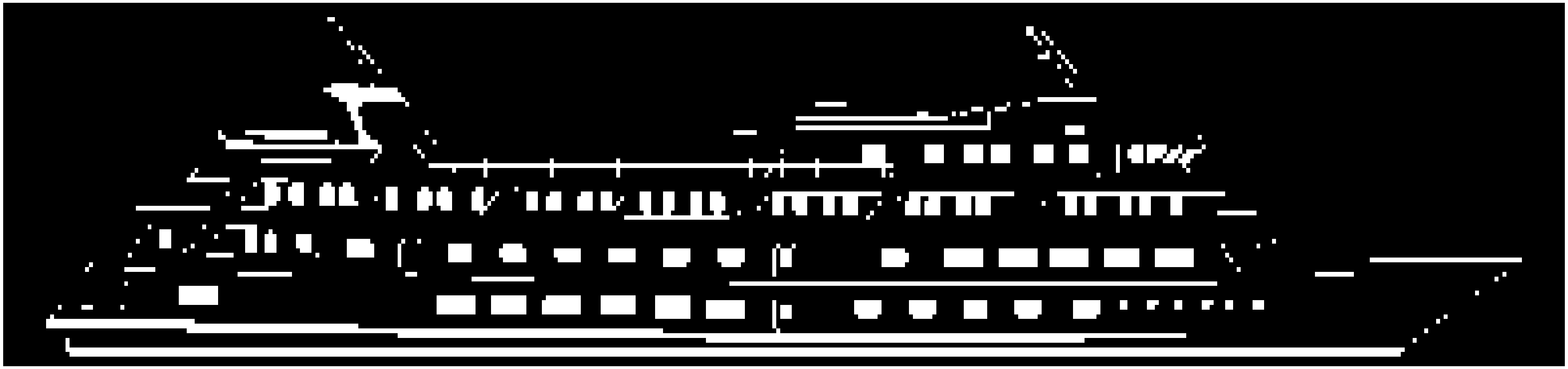

Porthole concept: The discovery

- The processes themselves, *in their own "frame"*, are never actually "reversed". Instead, the frame's motion through time is reversed.
  - Each to itself moves normally -- just receiving, absorbing, and radiating light, regardless of "whatever light" is interacting
  - This is due to a peculiarity of the photon and photon interaction
- Photon interaction creates observed physical reality, including the "frame" and the seeming "passage of a mass through time"
  - The photon is its own antiparticle, which is just a photon traveling in the opposite direction
  - So in this case we can use "light" to precisely time reverse (to the observer) the frame and the apparent operations (to the observer)
- When we cease irradiation, after a decay period to remove the reversed excitation, all functions are now seen to be moving forward normally in observer forward time, but from a previous physical state or condition

Using the porthole concept: Research

- The body's own emitted dense, broadband signals are recorded across a broad bandwidth
  - These signals are amplified, then rebroadcast precisely back into the body
  - This returns an amplified "reversed" signal set back through the dielectric path, invoking and applying the porthole concept in all processes
- The returning photons produce time-charging but in reversed frame direction
  - Tremendous potential energy is absorbed in highly compressed "time-energy" form in seconds
  - This "time-potential" slowly drains off as the body processes and cells reverse back to a previous state

Research using the porthole concept

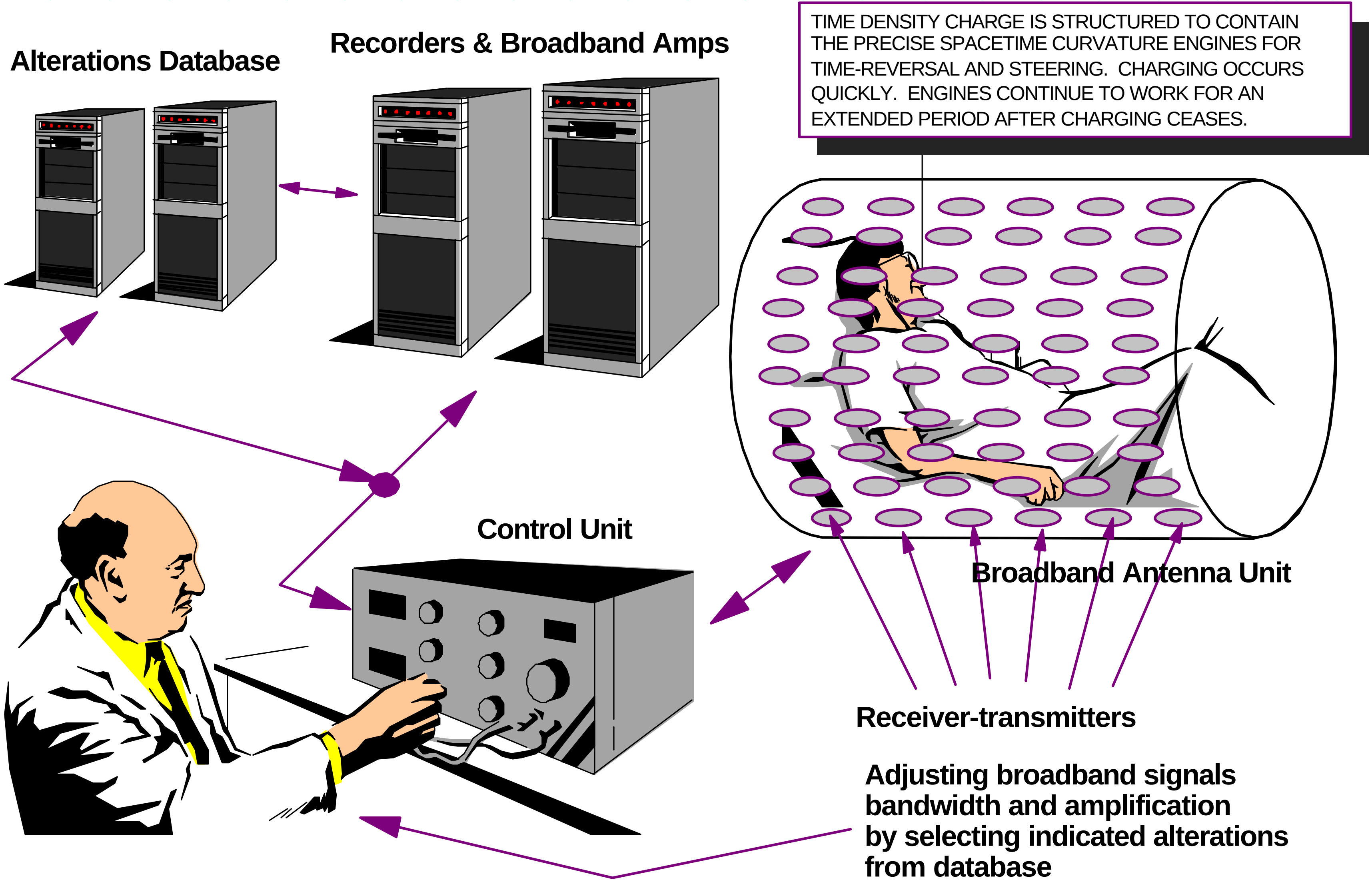

TIME DENSITY CHARGE IS STRUCTURED TO CONTAIN THE PRECISE SPACETIME CURVATURE ENGINES FOR TIME-REVERSAL AND STEERING. CHARGING OCCURS QUICKLY. ENGINES CONTINUE TO WORK FOR AN EXTENDED PERIOD AFTER CHARGING CEASES.

Alterations Database

Recorders & Broadband Amps

Control Unit

Broadband Antenna Unit

Receiver-transmitters

Adjusting broadband signals
bandwidth and amplification
by selecting indicated alterations
from database

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Portable unit then developed for rapid treatment of mass BW casualties

- Two blankets have antennas in them.
- Uses the "porthole" concept (discussed shortly)
- Eliminates plasma tube mixing etc.
- Computer-controlled complex signal structure.
- Irradiation for 2 minutes.

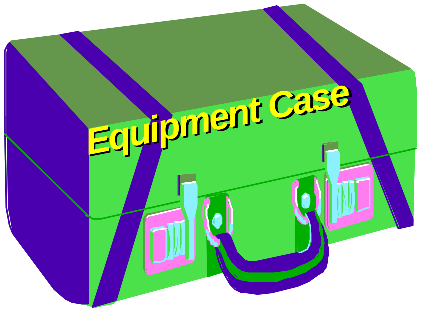
Equipment Case

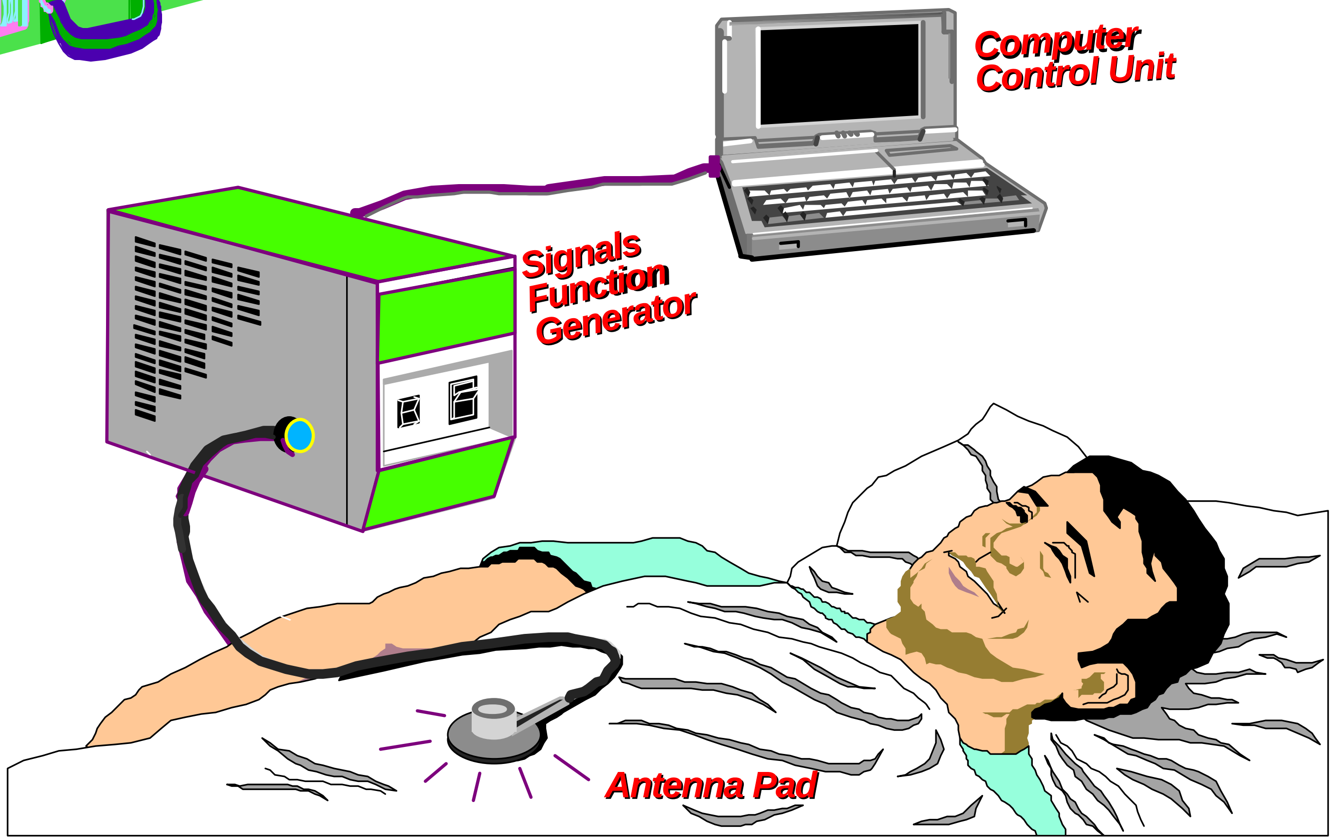
Computer Control Unit
Signals Function Generator
Antenna Pad

Training to use the unit

- High school student level, 30 minutes.
- Patient lies on one blanket, other covers him.
- Set the prescribed standard signal sets from listing.
- Computer-controlled generator produces the signal.
- Irradiation for 2 minutes, uncover patient, bring in another.
- Unit can be self-powering from vacuum energy (MEG*).

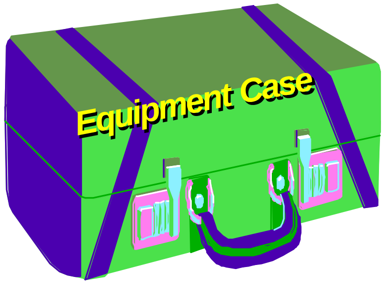
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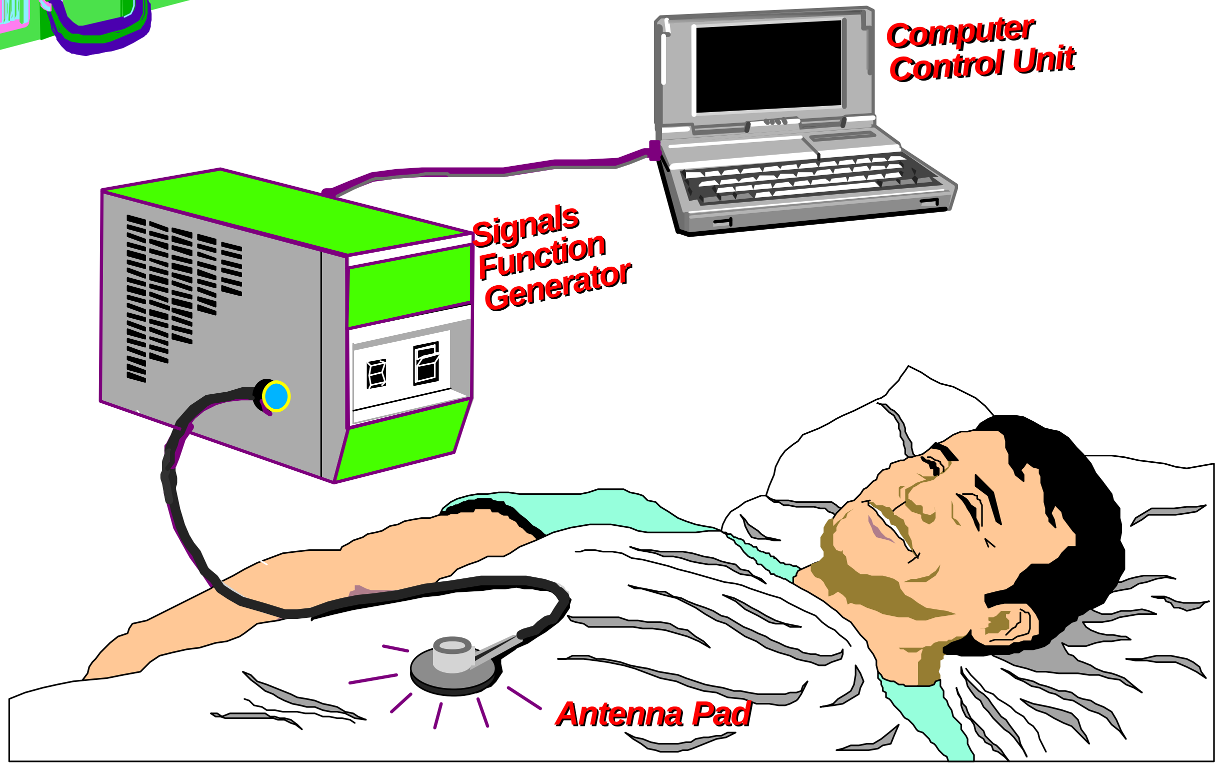
Computer
Control Unit
Signals
Function
Generator
Antenna Pad

Additional advantages

- Can be developed in a crash program in 2-3 years.
- After sunk costs, projected cost per unit in mass production is less than $100,000
- Can be produced by the thousands
- Then flooded down through
  - Fire stations and police stations
  - Red cross units, hospitals, clinics
  - Emergency action teams and armed forces
- Large numbers of operators easily produced
- Emergency training could be watching a 15 minute film, then performing one graded practice run
- First generation equipment can save some 70% of the coming mass casualties from anthrax etc.

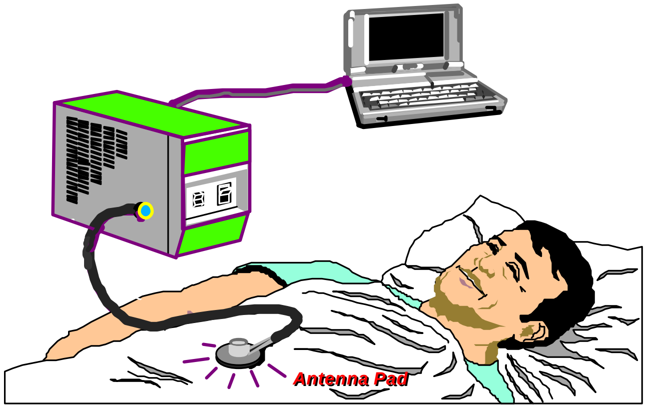

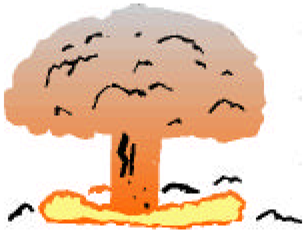

Terrorist BW warfare capabilities against the United States

The growing threat

Mass Casualty Problem: Aerial Anthrax Spray on Washington, D.C.

- **One terrorist, one light aircraft with spray tank**
- **100 kilograms of anthrax**
- **Flies over greater metropolitan Washington, D.C.**
- **Calm night**
- ***1-3 million casualties result****
- ***Most of those stricken will die***
- **Presently little can be done to save the stricken civilians**
- ***Attacks on several population centers might produce some 10 million or more casualties***

***Per OTA Report to Congress, 1993**

For decades, infiltration of terrorist teams into the U.S.

- From several foreign nations, not just Bin Laden in Afghanistan
- Several thousand Cuban guerillas, from training camps in Southern Mexico
- Russian Spetznaz teams
- Nuclear warheads (up to 80 KT)
- Biological warfare agents
- Yakuza in oriental populations in our cities
  - Yakuza manufactures Russian energetics weapons in their own facilities in Japan
  - Possesses the new EM weapons referred to by Secretary of Defense Cohen in 1997
- We are now in a very long, hard war and will suffer millions of casualties in our cities. It may last for decades.

Defense Secretary Cohen*

(Involvement of secret superweapons)

"Others [terrorists] are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves… So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations…It's real, and that's the reason why we have to intensify our [counterterrorism] efforts."

* Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.

Some typical BW agents

- Smallpox, including different strain developed by Russia (some sold to terrorists)
- Anthrax
  - Over 400 known locations around the Earth have cultures
  - Difficult to decontaminate
- Bubonic Plague
- Botulism toxin
- Tularemia (rabbit fever)
- Hemorrhagic fevers, such as Ebola

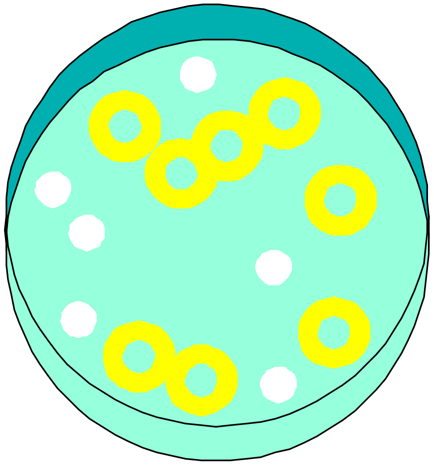

Anthrax

- OTA study: Some 200 pounds released in a spray, on calm night over Washington, D.C. could result in up to 3 million casualties
- Symptoms usually in 2-10 days
  - Sometimes as long as 7 weeks
  - Flu-like symptoms

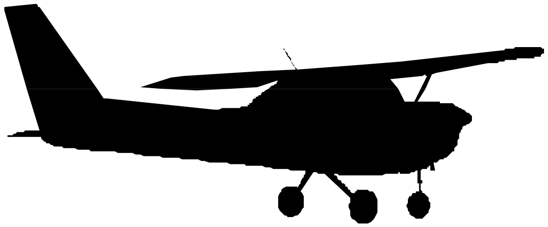

- Then 1-3 days later, shock and breathing problems cause death in up to 100%
- Antibiotics given early (before symptoms) can prevent infected persons from becoming ill
- Limited vaccine, reserved for military

Smallpox

- More than 500 million people killed in the 20th century before "eradicated" in 1977. Vaccination ceased in 1980.
- Russians kept it, developed new strains, sold to terrorists
- Symptoms in about 12 days: fever, headache, nausea. Rash similar to chickenpox then appears.
- Rash turns into hard blisters. *Highly contagious*, kills one-third of its victims.
- No cure. About 12 million doses of vaccine left.
- If smallpox is unleashed in any major city on earth, it will eventually kill 2 billion, or about 1/3 of the human species -- unless a radical new cure is found and utilized.

Bubonic Plague: Historically the most feared (Black Death)

- From 1980-1994, 18,739 cases in 20 countries.
- Symptoms occur in 1-6 days after inhaling the pneumonic form.

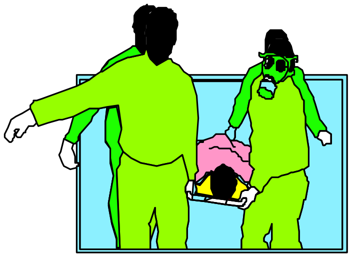

- High fever, cough, labored breathing lead to respiratory failure and death.
- It is contagious.
- Rapid use of antibiotics can be effective.
- Vaccine not currently produced in the U.S.

Botulism toxin (a nerve toxin)

- Single most poisonous BW substance known.
  - Typically borne in food, contacted by eating.
  - Could be developed as aerosol weapon.
- Symptoms in 24-36 hours; blurred vision and difficulty swallowing, speaking.
- Paralyzes muscles, leading to respiratory failure and death.
- Centers for Disease Control and Prevention maintain a botulism antitoxin supply.

Tularemia

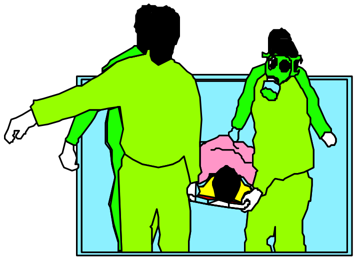

- U.S. studied its weapon potential in 1950s and 1960s.
- Symptoms appear in 3-5 days, including fever, chills, headache, and weakness
- Inflammation and hemorrhaging of the airways can lead to death.
- Without antibiotics, one-third die. Can be 90% if breathed in, in aerosol form.
- Vaccine developed and under review by FDA.

Hemorrhagic fevers, such as Ebola

- E.g., origin of Ebola is unknown. Probably transmitted to humans by animals, to begin a breakout.
- Symptoms in 3-5 days, include fever, aching muscles, diarrhea.
- Hemorrhaging of fluids out of tissues and orifices.
- From 30 to 90 percent die, depending on specific fever type.
- Some of these fevers respond to antiviral drugs.
- The drugs are in short supply.
- Presently *containment* is the primary goal.

A factor the U.S. does not know

(Secret involvement of clandestine superweapons)

- Three nations (not the U.S.) developed quantum potential weapons using Bohm's hidden variable theory of quantum mechanics.
- Can induce disease engines in matter or bodies at a distance.
- Have developed "spreading" of immune systems in a targeted populace (cleverly tested in Gulf War against U.S. troops).
  - Cocktail mix of disease engines for 2 dozen different diseases
  - Targeted area's human immune systems react to these engines when they are still in virtual state, just below quantum threshold.
  - Spread immune system's resources thus "thinned" across response to two dozen shadow diseases at once.
- Hit with a terrorist BW attack, the spread immune systems are overwhelmed much more easily and quickly.
  - Yield (casualties) of the attack is increased by factor of 3-5.
  - Spreading of U.S. immune systems has been accomplished and is still being maintained.

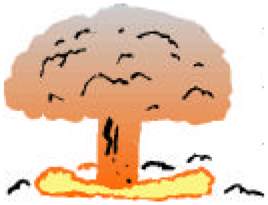

Summary and conclusion

The new war

A new Pearl Harbor: Strike on the World Trade Center in NYC

- The North Tower has already been struck and is burning.
- A second jetliner is about to strike the South Tower.

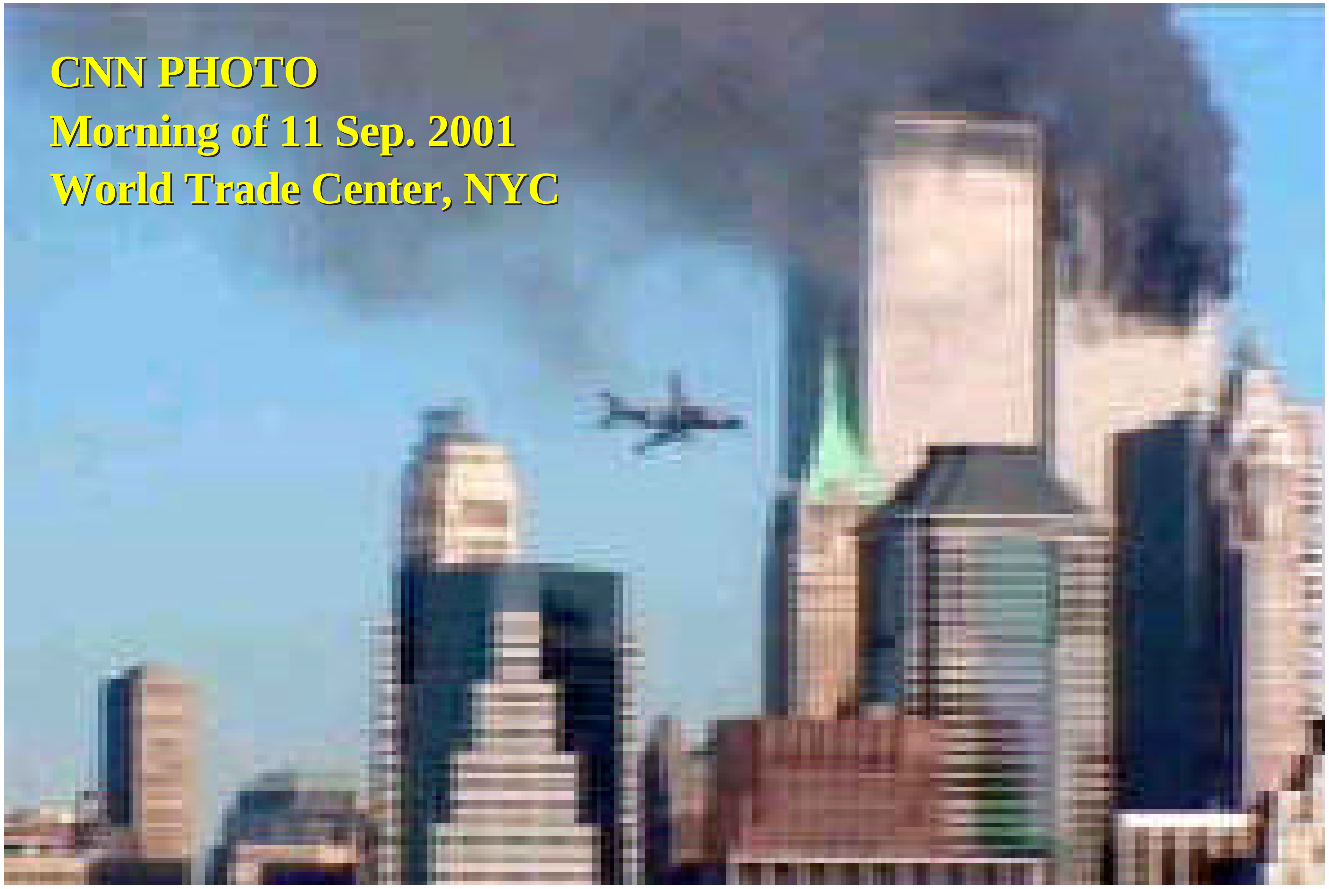

CNN PHOTO
Morning of 11 Sep. 2001
World Trade Center, NYC

Fireball From Impact on South Tower

- The two buildings held some 50,000 occupants
- Evacuation was underway after the first strike
- More than 6,000 persons were killed
- This is more than were killed in the Dec. 7, 1941 strike on Pearl Harbor

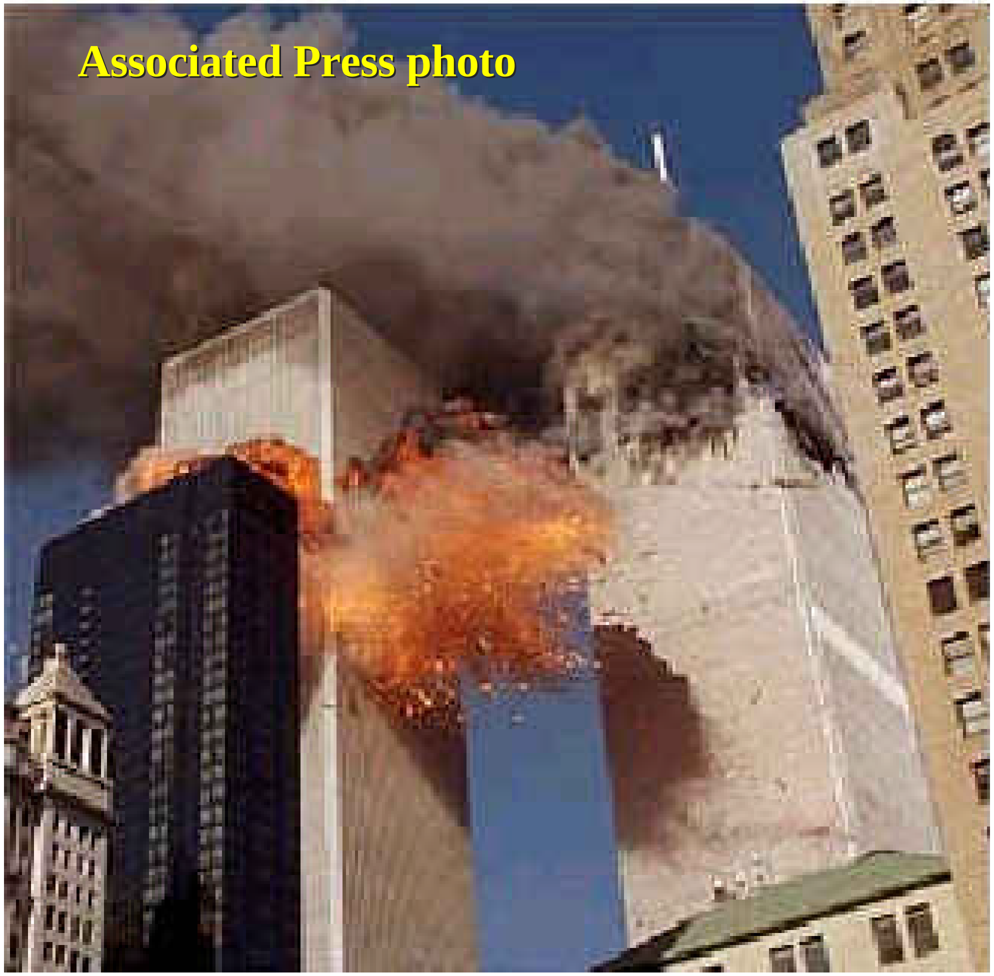
Associated Press photo

Collapse of the South Tower

- The first tower to collapse was the South Tower
- It is still uncertain just how many people were caught inside and killed
- This is a half million tons of debris, falling from the New York skyview.

Photo from CNN

Collapse of the North Tower begins

- The North Tower then collapsed
- This was another half-million tons of debris falling from the NYC skyview

Collapse of North Tower finishes

- Collapse of the North Tower killed many rescue workers, fire-men, and policemen
- At this writing, the total casualties are still unknown

Photos from CNN

Next began the recovery efforts

- Recovery operations will require months
- At this writing, the total casualties are still unknown
- The damage was done by two civilian jetliner "bombs"

The Pentagon was hit on the same day

- Hundreds were killed the same day when another jetliner struck the Pentagon.
- Yet another jetliner, possibly headed for the White House, crashed enroute when the passengers attacked the suicide terrorist hijackers.

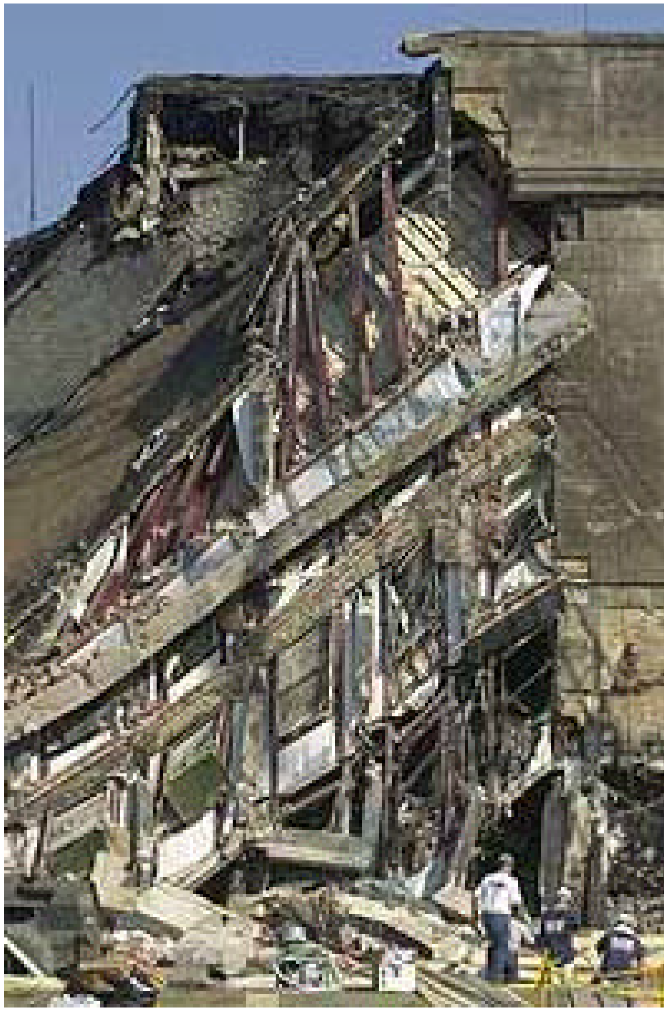

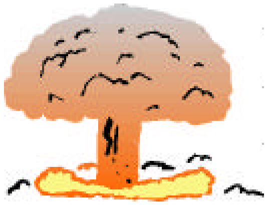

A sobering thought

- Nuclear weapons are already smuggled into the U.S., as are BW agents such as anthrax, smallpox, etc.
- Had a 40-80kT weapon been exploded in New York and one in Washington, millions would have perished and both cities would have been devastated
- There would have been no recovery of those cities for many decades

Present Status of the WMD Threat to the United States

- **Many foreign nations are hostile to the U.S. and sponsor terrorists**
- **Some 25 nations have WMD or are acquiring them**
  - **BW agents and weapons**
  - **Chemical agents and weapons**
  - **Nuclear materials and weapons**
- **Thousands of students and émigrés**
- **Infiltrated teams, BW, other WMD already**
- **Castro guerrillas infiltrated over the years**
- **Can do unacceptable damage to U.S. now**
- ***May reach knockout capability***

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***Per OTA Report to Congress, 1993**

The U.S. is terribly unprepared

- Limited medical supplies, antibiotics, vaccines
- Insufficient facilities, emergency teams
- No civilian shelters (much less BW-filtered)
- Not enough doctors, nurses, masks, etc.
- Present treatment methods woefully inadequate
- Triage will apply
  - First treat those most likely to recover
  - Others (showing symptoms, or advanced) are just set aside to die
- Other attacks are a matter of *when*, not *if*.

Conclusion

- As several cities are struck, millions of U.S. civilian casualties will result. Devastation will be enormous.
- We shall eventually lose more American lives than in all the rest of our wars to date.
- Present medical therapeutic science is totally inadequate to do the job. It cannot save us.

- At some point, when we are sufficiently damaged, the Spetznaz or other terrorists may detonate nuclear weapons in our cities, with appalling carnage.
- A combined superweapon technology and terrorist groups will then destroy the remaining populace.
- On its present course, the inadequacy of Western medicine may doom us.

A difficult truth to consider

- In any strategic strike, the first phase is to get the strategic weapons (weapons of mass destruction) delivered to their distant targets.
- That has already been done.
- Eerily, the first phase of World War III has already been accomplished.
- It was already accomplished before the Sept. 11, 2001 strike on New York and Washington. That was the new "Pearl Harbor", and only the opening round. It already killed more Americans than died at Pearl Harbor on Dec. 7, 1941.
- Unless we improve our medical therapy quickly and dramatically, we will lose -- particularly when the hidden energetics weapons and outside terrorist sponsorship by hostile nations are factored in.

A personal perspective

- There now exists an overwhelming, immediate moral imperative to get this development program done at the utmost speed humanly possible.
- The sheer survival of the United States and Western civilization depends upon it.
- Officialdom is aware that the KGB/Russians have long planned to finish the U.S., after initial nuclear exchanges, by fierce and massive BW strikes.
- It appears that the plan has changed to let the terrorists do the main work, while augmenting U.S. casualty levels by energetics weapons.

China is also involved

- China has declared South China Sea the territorial waters of China
- China will eventually take Taiwan
  - Has massed missile artillery trained on Taiwan
  - Recently held invasion practice on an island near Taiwan
- Recently deployed fearsome EMP weapons utilizing negative energy rather than positive energy (Dirac sea theory)
  - Extinguishes all electron currents
  - Duds electrical and electron systems instantly
  - Instant death to struck bodies
  - Instant kill of missiles, aircraft, electronics in nuclear warheads
  - Ultimate "death ray"; can be made small or large
- Recent 2-carrier U.S. task force maneuvered in South China Sea to caution China
  - The new Chinese EMP weapon was trained on that task force
  - Could have destroyed it within minutes

Final thoughts

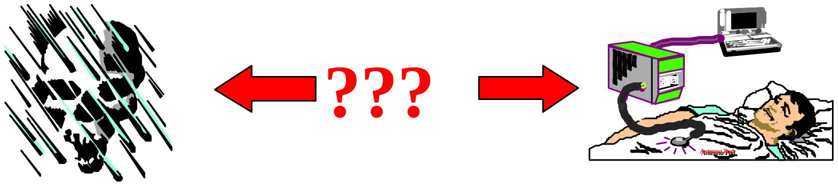

- This is one of the great turning points in history.
- The development program is eminently doable. That it works has been experimentally demonstrated. The long-vexing puzzle of the active mechanism has been solved.
- Our scientific community bitterly opposes any use of electromagnetics -- even an advanced, higher symmetry electrodynamics -- for medical treatment.
- A consortium of the scientific community, the large pharmaceuticals, FDA, and the AMA will oppose this project even while the U.S. is being destroyed wholesale.
- It can only be done in the private sector, and there will likely be no funding unless by philanthropists.

Continuation

Business plan, development program, budget breakdown, proposed schedule etc. go here.

Weapons Slides

The Tom Bearden Website

Help support the research

"Others [terrorists] are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves… So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations…It's real, and that's the reason why we have to intensify our [counterterrorism] efforts." *

Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.

Slides
(covers period up to 1999)

- The Coming Strategic Attack on the United States
- Outline
- Loss of two separate A-10 Warthogs in 1997
- Typical ABM Defenses (Widely Deployed by mid-70s)

- Launch Phase Anti-Missile System
- Launch Phase Anti-Bomber System
- HC-130s Engines Quit, Aircraft Crashes
  Nov. 22, 1996
- 1996 Actions by this analyst
- Additional Information Exists: Not Analyzed, Not Integrated in Briefing
- Kill of Arrow DC-8, Gander AFB, Dec. 12, 1985
- Satellite Photos of Plumes in Soviet Arctic Since 1974
  See "Fer de Lance" for additional information
- Aum Shinrikyo ("Supreme Truth" Cult), Shoko Asahara, Leader

  Aum Shinrikyo - Anatomy of a Dangerous Cult
- Ashkhabad Problem and Its Solution
- Strange Characteristics of Iran Quake, Sep. 1978
- Iran Earthquake, September 1978
- Situation Now (Assessment)
- Situation Now (Assessment 2)
- Aspects of Strong Local Asymmetry
- Mass Casualty Problem: Aerial Anthrax

Spray on Washington, D.C.

- Present Status of the WMD Threat to the United States
- Some Present Problems in the U.S. WMD Defense Capabilities
- Internal Terrorist Threat with Weapons of Mass Destruction: Now & Future
- Attempt to Ban Energetics Weapons Worldwide
- Brezhnev's Schedule
- Large glowing Tesla globe witnessed in Red China by hundreds
- Cold Explosion -- 9 April 1984 Near Kurils, and formation and growth of spherical shell (globe)
  Sequence of Events
- Cold Explosion -- 9 April 1984 Near Kurils, and formation and growth of spherical shell (globe)
  What They Were
- Cold Explosion -- 9 April 1984 Near Kurils (Plus additional weapons effects)
- Countering Insane MAD Systems:
  Find Loophole, Exploit It
- Next Generation Counter to Both Sane and Insane MAD systems
- Simultaneous Dudding of Nuclear Weapons Worldwide

- Simultaneous Dudding of Nuclear Weapons Worldwide
- Operation Divine Wind II
- Advanced EMBW Applications
- EM Biological Warfare (EMBW)
- Microwave Radiation of U.S. Embassy in Moscow
- Pentagon EMI Studies, 1989
- EM Missile Practice (6 slides)
- Subdivisions of Soviet Energetics Program
- Communism's Goal
- Manuilsky's Goal vs. Status Today (Dec. 1996)
- Professor Hellman, German Scientist Released from Work in Soviet Union
- Hemispheres and Globes of Light (4 slides)
- How Could Such Superweapons Ever Be Concealed?
- Soviets Easily Concealed These Superweapons for Four Decades
- Microscope-type, laser-like interferometer for inducing quick α-decay in samples of otherwise longer-lived isotopes
- Longitudinal Wave Interferometry: Endothermic

- Longitudinal Wave Interferometry: Exothermic
- U.S. Air Attack on Libya, April 1986
- Lightning Wall
  circa 1959-1960
- Lisitsyn's Report: Brain Code Broken
- Large Longitudinal Wave Interferometer (LWI) Accident
- Large Longitudinal Wave Interferometer (LWI) Accident
- Use of Hidden Information Content of the Field Can Provide Action-At-A-Distance
- Two Types of Mutual Assured Destruction (MAD) System
- Psychoenergetics Weapons Teams Mentally Disable All Personnel
- Strikes Against Special Ship and Energetics Weapons Sites
- "Mindsnapper" Attack on Special Ships and Energetics Weapons Sites
- How Much Off Guard Are We?
  (7 Slides)
- Possible Targets: 1995-9 Escalation Phase
- Propagation of Weapon Effects
- Yugoslav Earthquake, Followed by Cold Explosion
  April 15th, 1979

- Countering an Insane QP Weapon
- Gulf War Disease: KGB QP Weapon Induced ST Curvature Engines for a Cocktail of Diseases
- Self-Targeting in Inner EM Channel Can Produce a Quantum Potential
- Mechanism for Producing a Quantum Potential
- Major Principles for Use of Quantum Potential Weapons
- Major Principles for Use of Quantum Potential Weapons (2)
- Instantaneous Communication by a Quantum Potential
- Participants in a quantum potential share a common multiply-connected spacetime (MCST)
- Quake in Tangshan, China
  28 July, 1976
- Exchanging Earthquakes
- Instant Communication by a Quantum Potential
- Westerners Do Not React to Slow Threats
- Characterizing a Given Risk or Risk Factor
- Technical Risk Management
- Aum Shinrikyo's Sarin Facility

- In Scalar Beam Interference Zone
- Physicist Schappeller Auralaz Munster, Austria
- Initial Soviet Plan for Cold War, After WWII
- Josef Stalin: Absolute Dictator
- Exploding any Resistance by Operational Scientists
- Significant Soviet Statements
- Captain Svoboda Dives Headlong to Her Death
- T-polarized Beam Projector
- Possible Tests (1)
- Possible Tests (2)
- Possible Tests (3)
- Possible Tests (4)
- Mushroom Cloud Rising From Sea
- Launches from Cape Canaveral and Vandenberg AFB Provided Practice Targets of Opportunity
- The sinking U.S.S. Thresher, with her controls jammed, implodes when she reaches crush depth
- Embodiment of an instrument array sufficient to discriminate when time-density charging has occurred, and that transduction

of time-charge decay has occurred.

- Time-Polarized EM Wave Interferometer Creating Space-Time Curvature Engines in a Distant Interference Zone
- Transmutation of Radioactive Nuclei at a Distance
- Transmutation of Radioactive Nuclei
- Typical Tesla Shield, Northern Route of Japan
- A Curious Tide in Human Affairs
- Large Scalar EM Interferometer (LASI) Accident Near Urals, 1958
- The Superpower Paradox: Asymmetric Cheap WMD Strategic Strike and Destruction
- The KGB/Yakuza-Aum War Plan
- Why Western Science is Ignorant of KGB Energetics
- Transmutation of Radioactive Nuclei at a Distance
- TheYakuza
- Yugoslav Earthquake, Followed by Cold Explosion
  April 15, 1979

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* Note that the Secretary did not speak the words in square blocks; these were added by the writers later,

probably to "soften the tone" of the Secretary's information release. So the Secretary confirmed that some nations of the world -- not just some ragged terrorists, as the writers tried to imply for spin control -- do possess novel electromagnetic weapons and are using them to induce earthquakes, engineer the weather and climate, and trigger volcanic eruptions.

THE COMING STRATEGIC ATTACK ON THE UNITED STATES

By an AUM/Yakuza/KGB/Communist Coalition Using Energetics SuperWeapons

T.E. Bearden, LTC
U.S. Army (Retired)
M.S. Nuclear Eng.
Fellow Emeritus, AIAS

With Technical Background and History of Energetics Weapons

Partial support by the Association of Distinguished American Scientists is gratefully acknowledged.d

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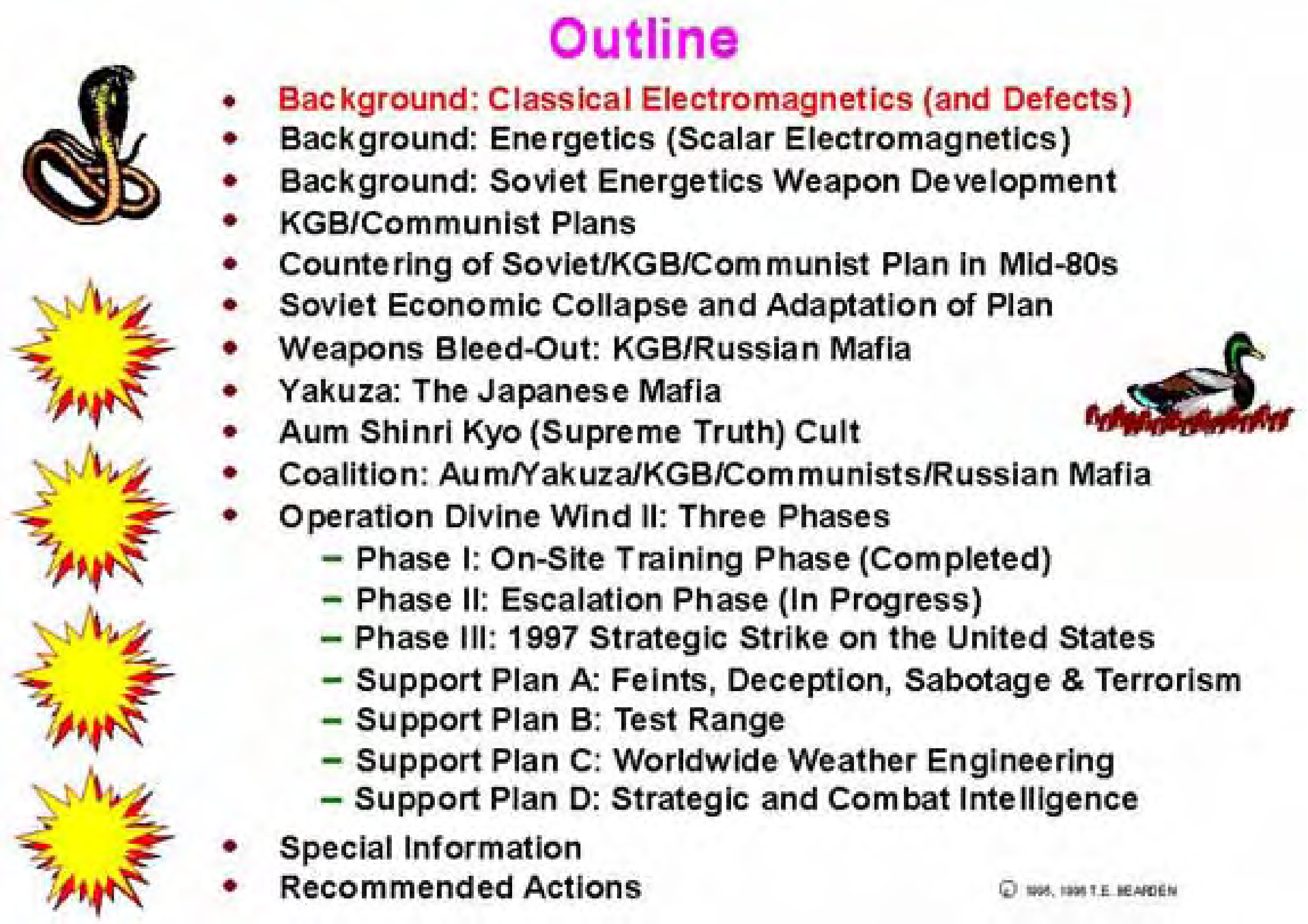

Outline

- Background: Classical Electromagnetics (and Defects)
- Background: Energetics (Scalar Electromagnetics)
- Background: Soviet Energetics Weapon Development
- KGB/Communist Plans
- Countering of Soviet/KGB/Communist Plan in Mid-80s
- Soviet Economic Collapse and Adaptation of Plan
- Weapons Bleed-Out: KGB/Russian Mafia
- Yakuza: The Japanese Mafia
- Aum Shinri Kyo (Supreme Truth) Cult
- Coalition: Aum/Yakuza/KGB/Communists/Russian Mafia
- Operation Divine Wind II: Three Phases
  - Phase I: On-Site Training Phase (Completed)
  - Phase II: Escalation Phase (In Progress)
  - Phase III: 1997 Strategic Strike on the United States
  - Support Plan A: Feints, Deception, Sabotage & Terrorism
  - Support Plan B: Test Range
  - Support Plan C: Worldwide Weather Engineering
  - Support Plan D: Strategic and Combat Intelligence
- Special Information
- Recommended Actions

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The Tom Bearden Website

Help support the research

Loss of two separate A-10 Warthogs in 1997

- A-10 Mysterious Flyaway and Crash - April 2, 1997
- Death of Second A-10 Pilot - May 27, 1997
- Captain Button's Mysterious Flyaway and Eventual Crash
- Death of Second A-10 Pilot - May 27, 1997

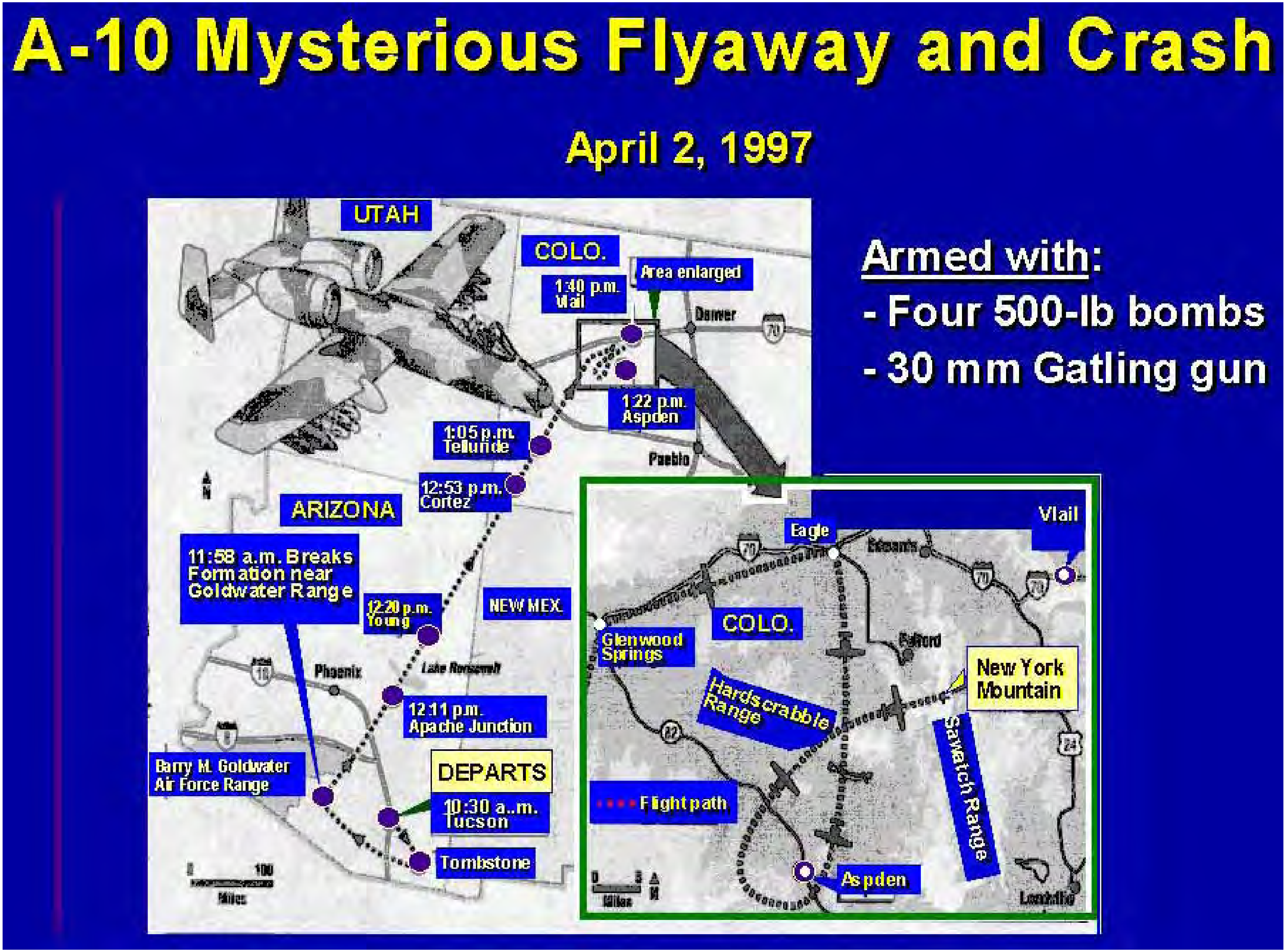

A-10 Mysterious Flyaway and Crash

April 2, 1997

UTAH
COLO.
Area enlarged
1:40 p.m. Vail
Denver
70
1:22 p.m. Aspden
1:05 p.m. Telluride
Pueblo
12:53 p.m. Cortez
ARIZONA
11:58 a.m. Breaks Formation near Goldwater Range
12:20 p.m. Young
NEW MEX.
10
Phoenix
Lake Roosevelt
12:11 p.m. Apache Junction
8
Barry M. Goldwater Air Force Range
DEPARTS
10:30 a.m. Tucson
Tombstone
0 100
Miles
Eagle
Edwards
Vail
70
COLO.
Glenwood Springs
Gilford
Hardscrabble Range
New York Mountain
82
Sawatch Range
24
Flight path
Aspden
0 5
Miles
N
Leadville

Armed with:

- Four 500-lb bombs
- 30 mm Gatling gun

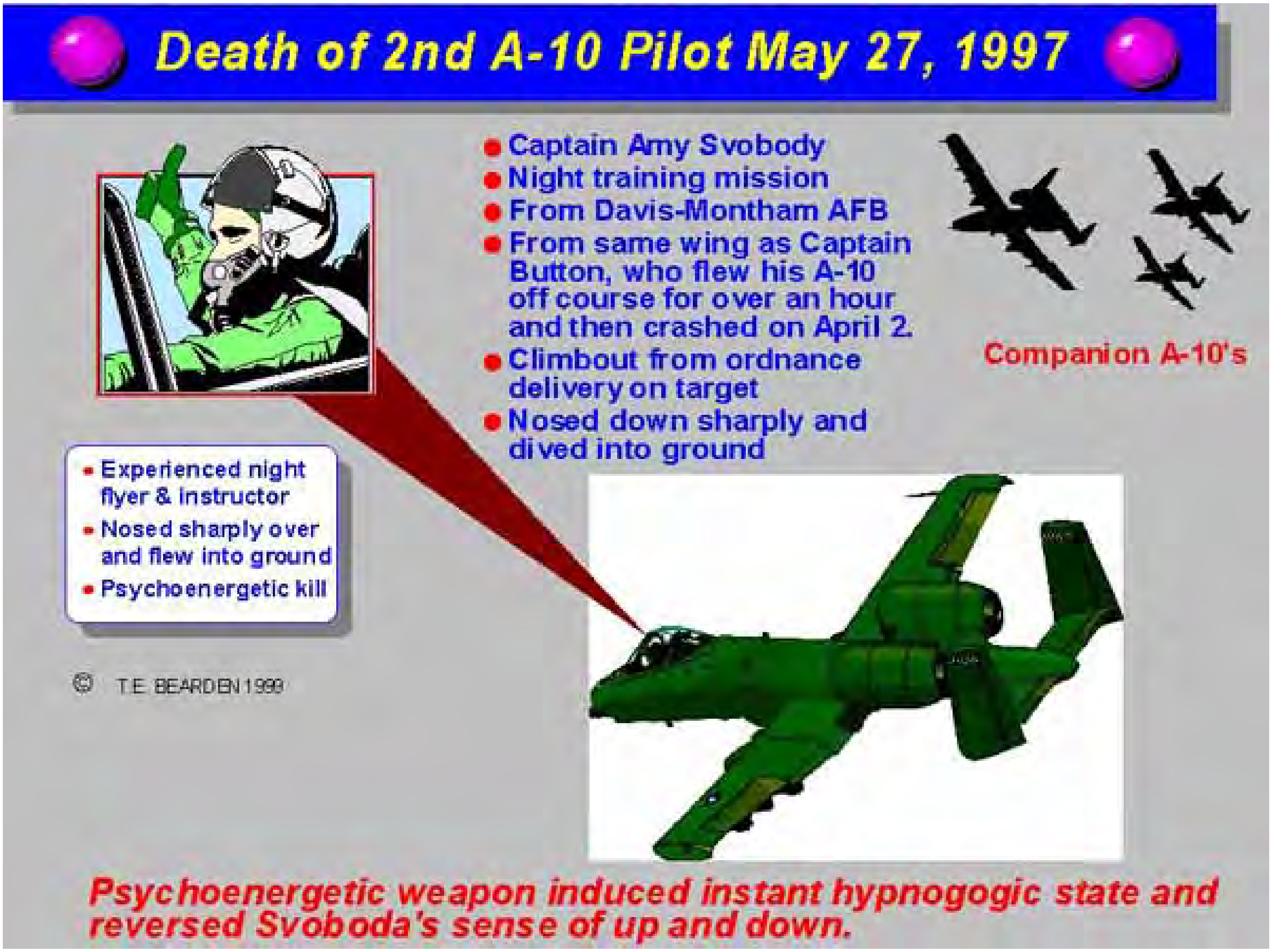

Death of 2nd A-10 Pilot May 27, 1997

- Captain Amy Svobody
- Night training mission
- From Davis-Montham AFB
- From same wing as Captain Button, who flew his A-10 off course for over an hour and then crashed on April 2.
- Climbout from ordnance delivery on target
- Nosed down sharply and dived into ground

Companion A-10's

- Experienced night flyer & instructor
- Nosed sharply over and flew into ground
- Psychoenergetic kill

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Psychoenergetic weapon induced instant hypnogogic state and reversed Svoboda's sense of up and down.

A-10 Mysterious Flyaway and Crash

April 2, 1997

Armed with:

- Four 500-lb bombs
- 30 mm Gatling gun

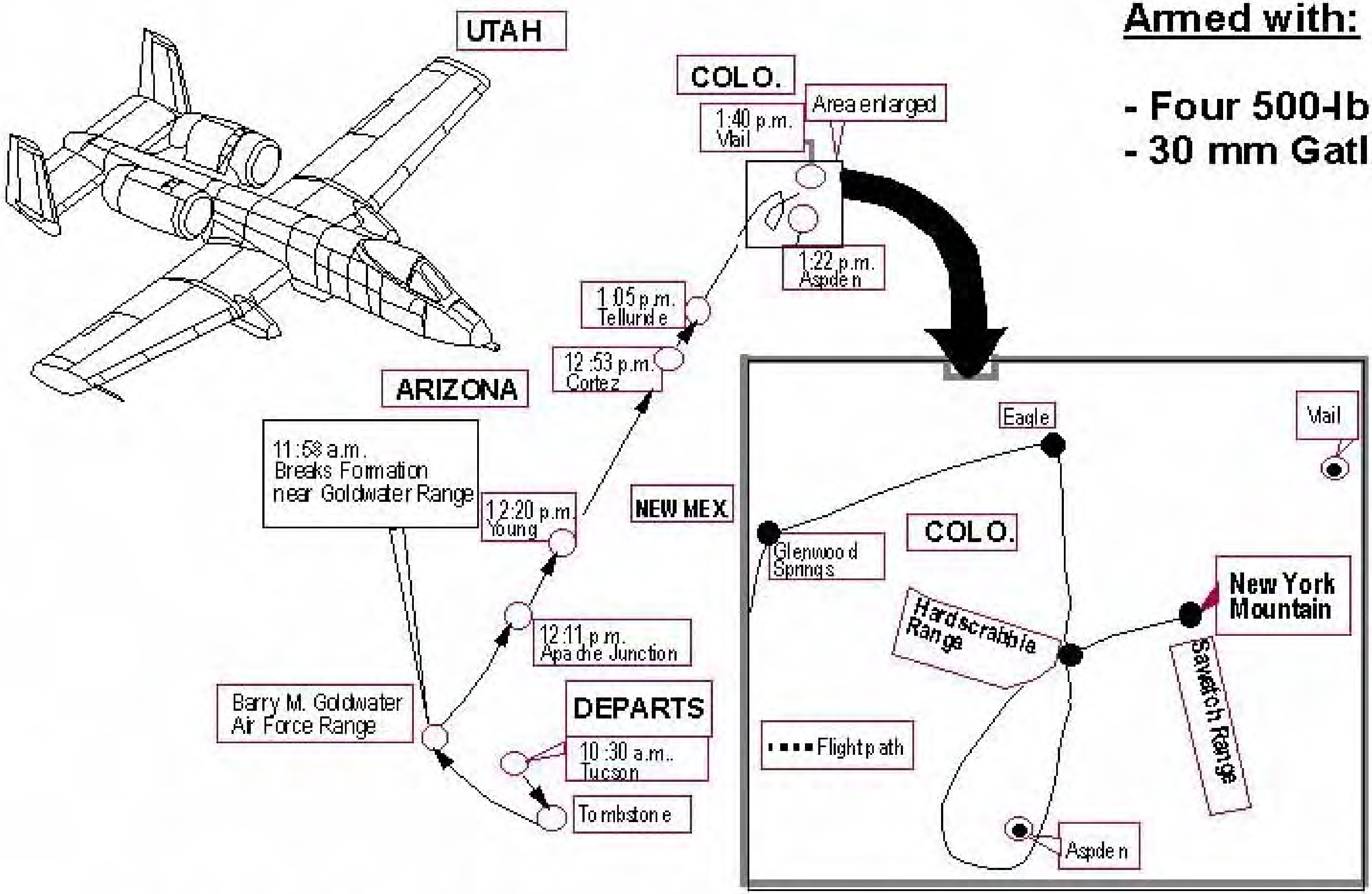
UTAH
COLO.
Area enlarged
1:40 p.m. Vail
1:22 p.m. Aspden
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ARIZONA
11:58 a.m. Breaks Formation near Goldwater Range
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Barry M. Goldwater Air Force Range
DEPARTS
10:30 a.m. Tucson
Tombstone
Eagle
Vail
Glenwood Springs
COLO.
Hardscrabble Range
New York Mountain
Sawatch Range
Flight path
Aspden

Figure 14a. Captain Button's mysterious flyaway and eventual crash.

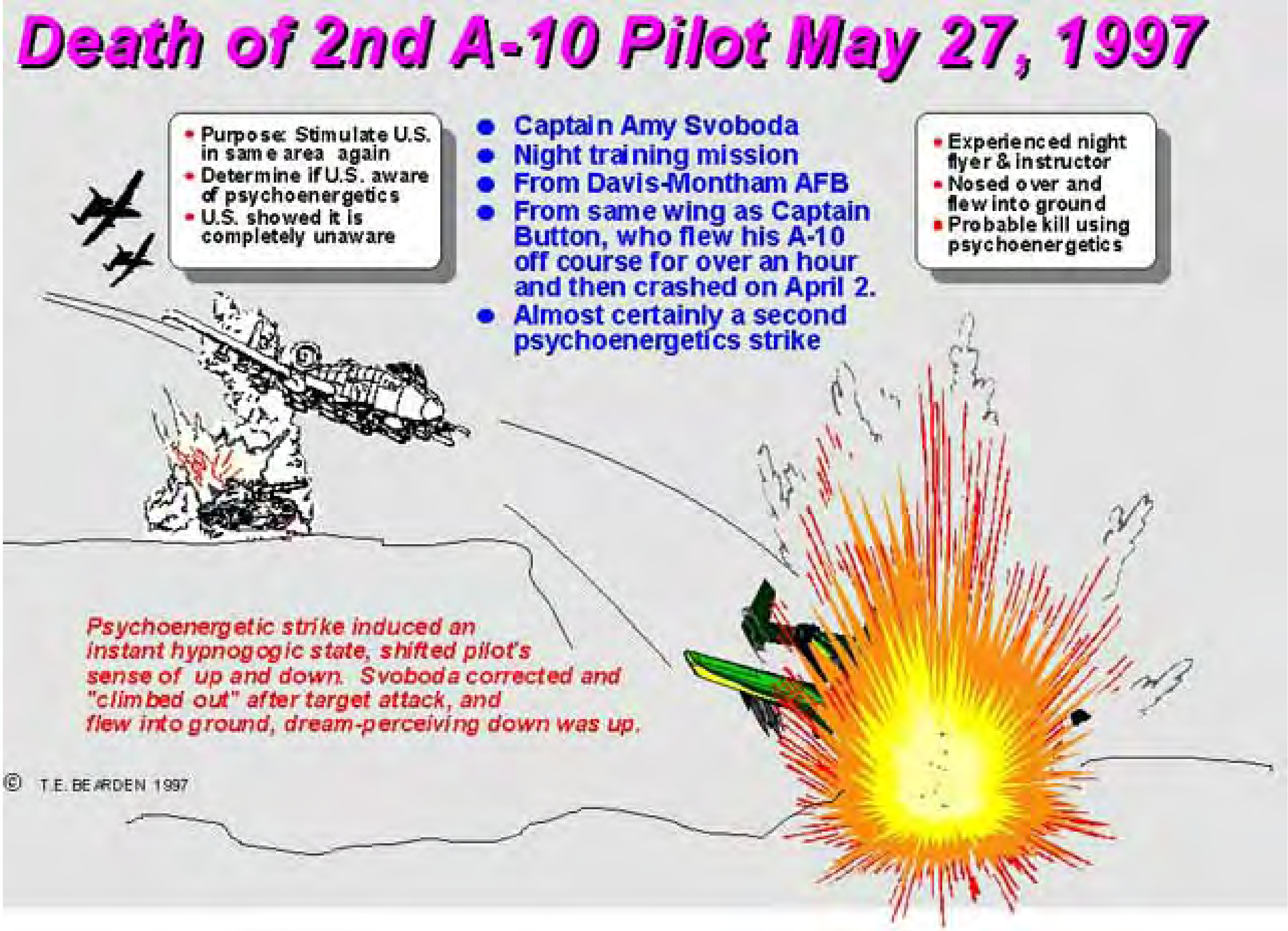

Death of 2nd A-10 Pilot May 27, 1997

- Purpose: Stimulate U.S. in same area again
- Determine if U.S. aware of psychoenergetics
- U.S. showed it is completely unaware

- Captain Amy Svoboda
- Night training mission
- From Davis-Montham AFB
- From same wing as Captain Button, who flew his A-10 off course for over an hour and then crashed on April 2.
- Almost certainly a second psychoenergetics strike

- Experienced night flyer & instructor
- Nosed over and flew into ground
- Probable kill using psychoenergetics

Psychoenergetic strike induced an instant hypnogogic state, shifted pilot's sense of up and down. Svoboda corrected and "climbed out" after target attack, and flew into ground, dream-perceiving down was up.

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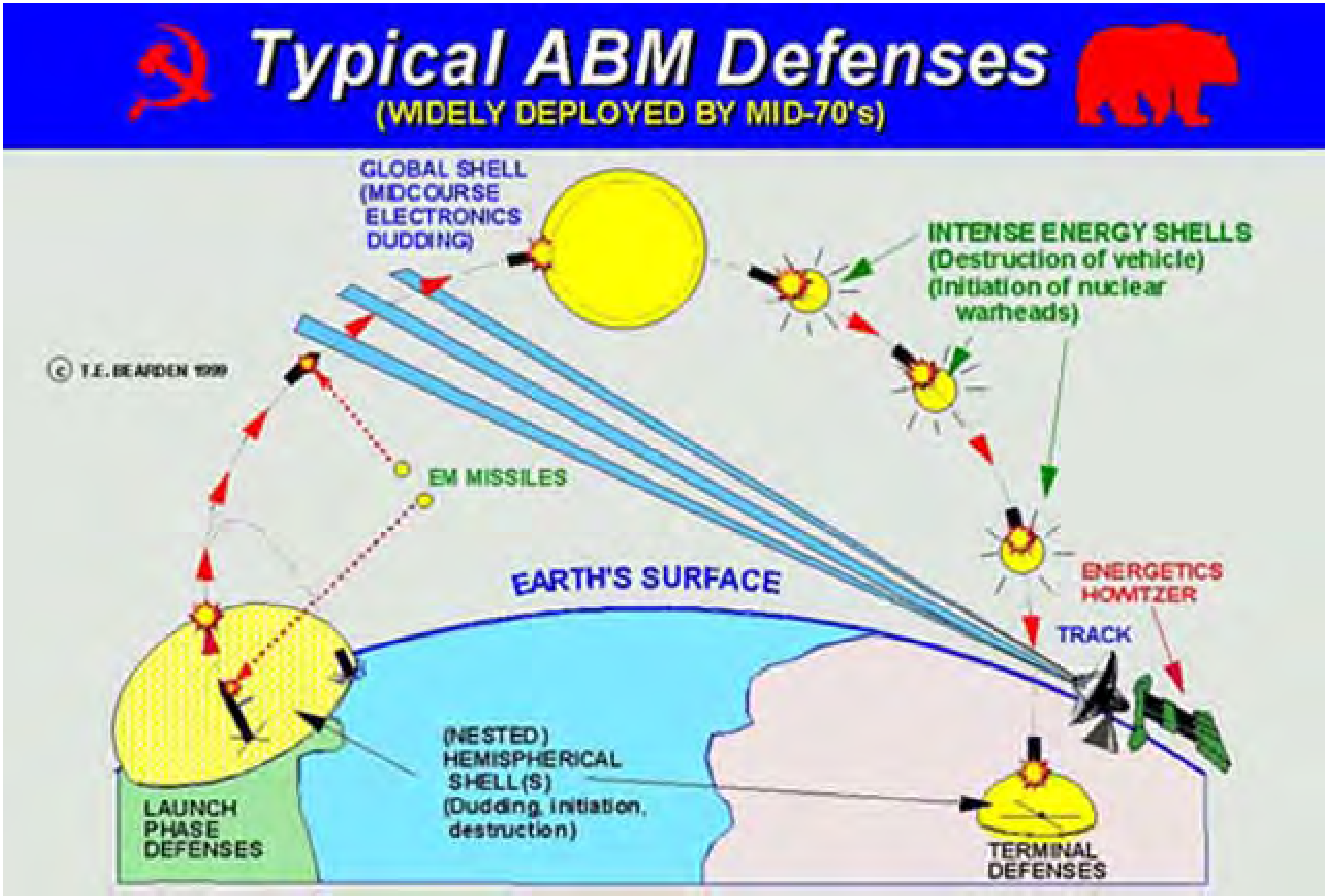
Typical ABM Defenses
(WIDELY DEPLOYED BY MID-70's)
GLOBAL SHELL (MIDCOURSE ELECTRONICS DUDDING)
INTENSE ENERGY SHELLS (Destruction of vehicle) (Initiation of nuclear warheads)
© T.E. BEARDEN 1999
EM MISSILES
EARTH'S SURFACE
ENERGETICS HOWITZER
TRACK
LAUNCH PHASE DEFENSES
(NESTED) HEMISPHERICAL SHELL(S) (Dudding, initiation, destruction)
TERMINAL DEFENSES

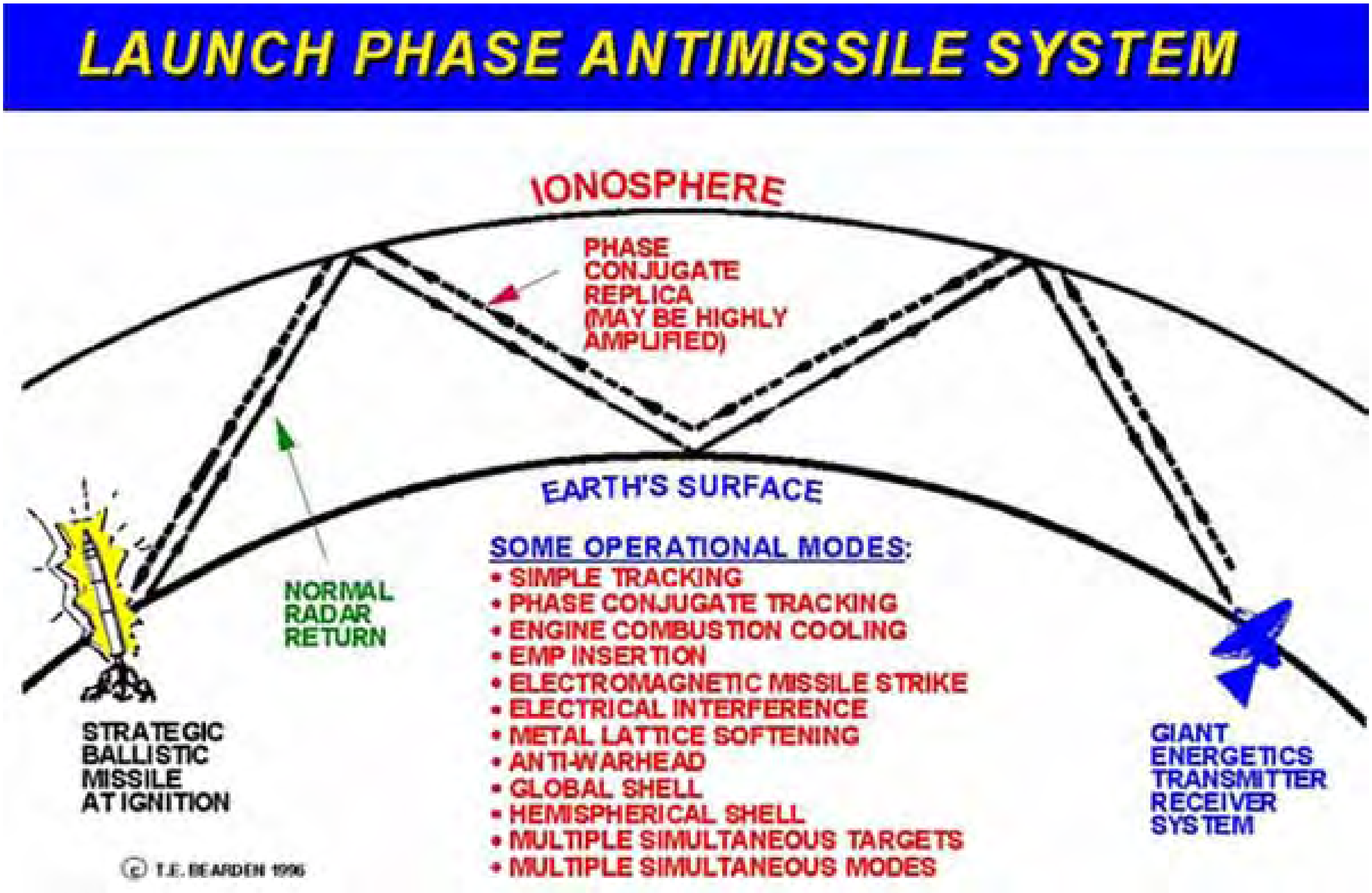

LAUNCH PHASE ANTIMISSILE SYSTEM

IONOSPHERE
PHASE CONJUGATE REPLICA (MAY BE HIGHLY AMPLIFIED)
EARTH'S SURFACE
NORMAL RADAR RETURN
STRATEGIC BALLISTIC MISSILE AT IGNITION
GIANT ENERGETICS TRANSMITTER RECEIVER SYSTEM

SOME OPERATIONAL MODES:
- SIMPLE TRACKING
- PHASE CONJUGATE TRACKING
- ENGINE COMBUSTION COOLING
- EMP INSERTION
- ELECTROMAGNETIC MISSILE STRIKE
- ELECTRICAL INTERFERENCE
- METAL LATTICE SOFTENING
- ANTI-WARHEAD
- GLOBAL SHELL
- HEMISPHERICAL SHELL
- MULTIPLE SIMULTANEOUS TARGETS
- MULTIPLE SIMULTANEOUS MODES

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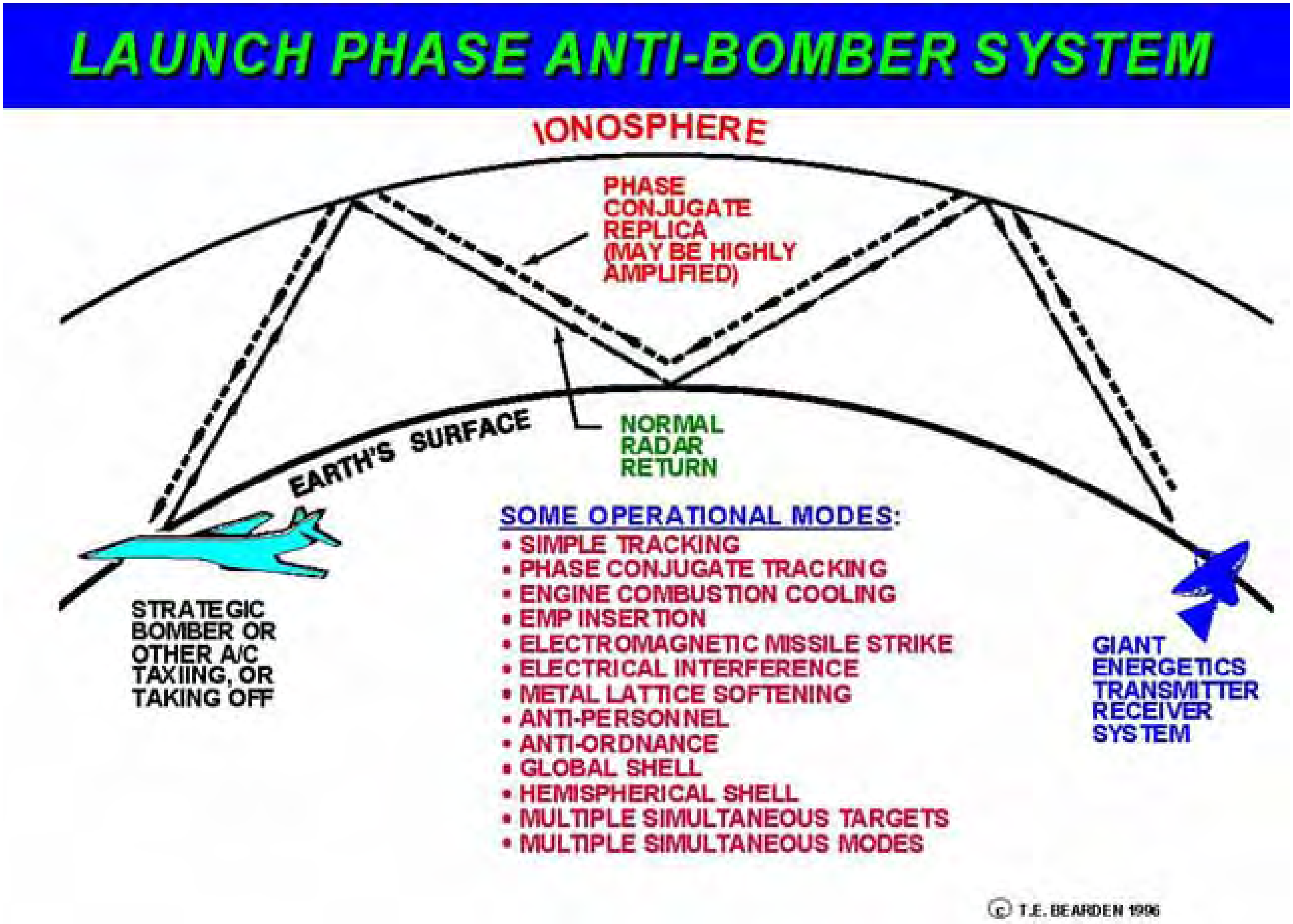

LAUNCH PHASE ANTI-BOMBER SYSTEM

IONOSPHERE
PHASE CONJUGATE REPLICA (MAY BE HIGHLY AMPLIFIED)
NORMAL RADAR RETURN
EARTH'S SURFACE
STRATEGIC BOMBER OR OTHER A/C TAXIING, OR TAKING OFF
GIANT ENERGETICS TRANSMITTER RECEIVER SYSTEM

SOME OPERATIONAL MODES:

- SIMPLE TRACKING
- PHASE CONJUGATE TRACKING
- ENGINE COMBUSTION COOLING
- EMP INSERTION
- ELECTROMAGNETIC MISSILE STRIKE
- ELECTRICAL INTERFERENCE
- METAL LATTICE SOFTENING
- ANTI-PERSONNEL
- ANTI-ORDNANCE
- GLOBAL SHELL
- HEMISPHERICAL SHELL
- MULTIPLE SIMULTANEOUS TARGETS
- MULTIPLE SIMULTANEOUS MODES

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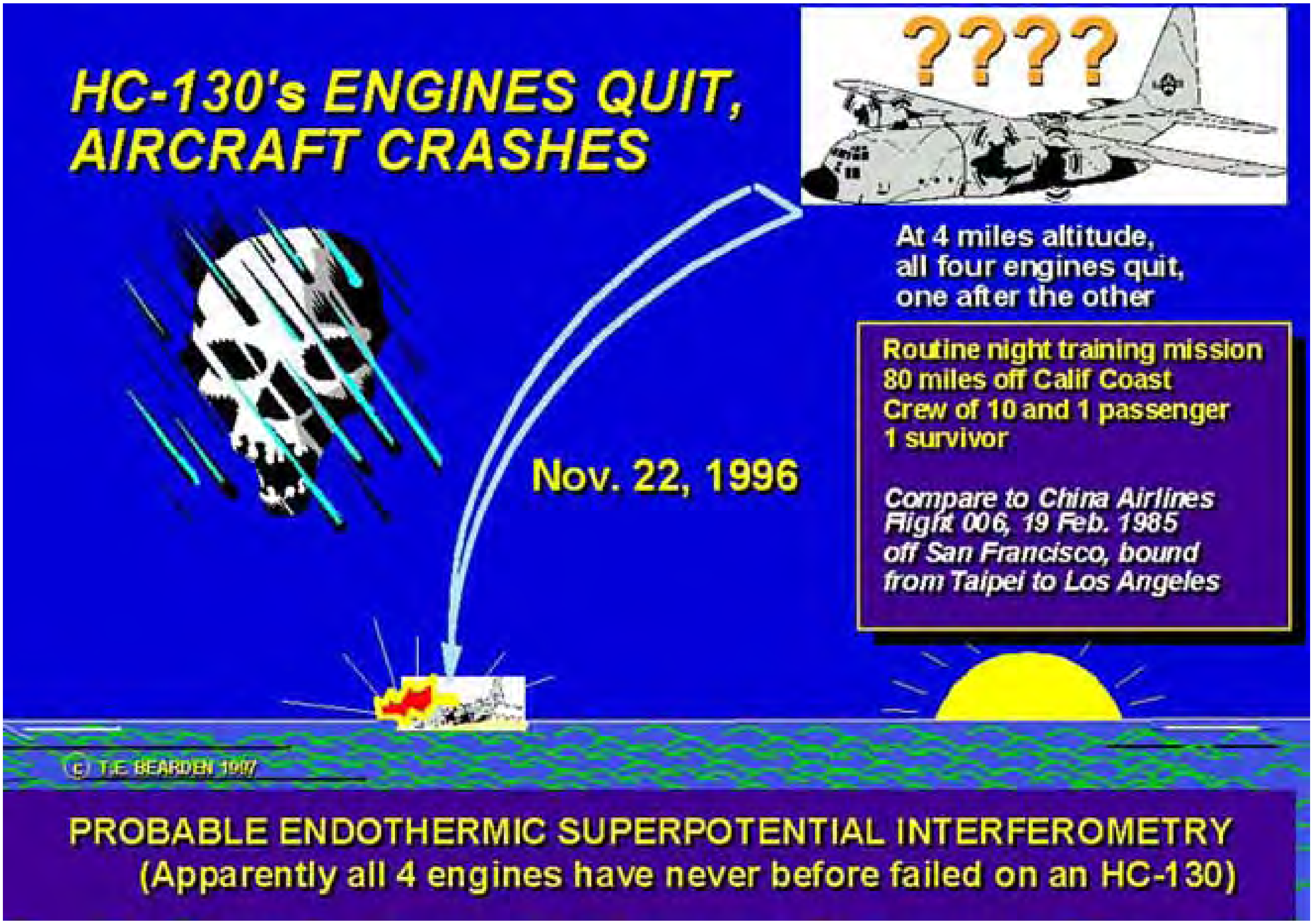

HC-130's ENGINES QUIT, AIRCRAFT CRASHES

At 4 miles altitude,
all four engines quit,
one after the other

Routine night training mission
80 miles off Calif Coast
Crew of 10 and 1 passenger
1 survivor

Compare to China Airlines
Flight 006, 19 Feb. 1985
off San Francisco, bound
from Taipei to Los Angeles

Nov. 22, 1996

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PROBABLE ENDOTHERMIC SUPERPOTENTIAL INTERFEROMETRY
(Apparently all 4 engines have never before failed on an HC-130)

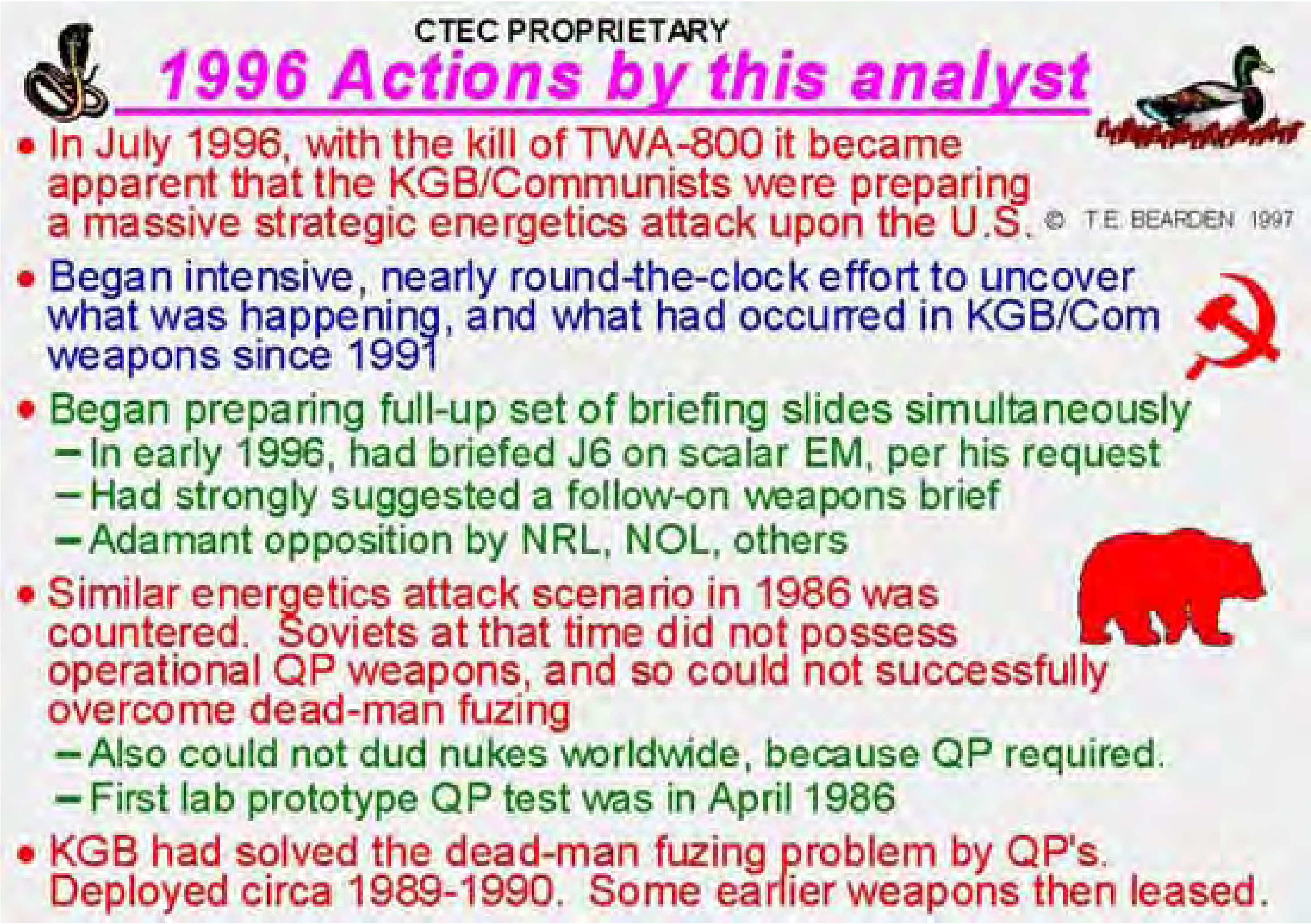

CTEC PROPRIETARY

1996 Actions by this analyst

- In July 1996, with the kill of TWA-800 it became apparent that the KGB/Communists were preparing a massive strategic energetics attack upon the U.S.

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- Began intensive, nearly round-the-clock effort to uncover what was happening, and what had occurred in KGB/Com weapons since 1991
- Began preparing full-up set of briefing slides simultaneously
  - In early 1996, had briefed J6 on scalar EM, per his request
  - Had strongly suggested a follow-on weapons brief
  - Adamant opposition by NRL, NOL, others
- Similar energetics attack scenario in 1986 was countered. Soviets at that time did not possess operational QP weapons, and so could not successfully overcome dead-man fuzing
  - Also could not dud nukes worldwide, because QP required.
  - First lab prototype QP test was in April 1986
- KGB had solved the dead-man fuzing problem by QP's. Deployed circa 1989-1990. Some earlier weapons then leased.

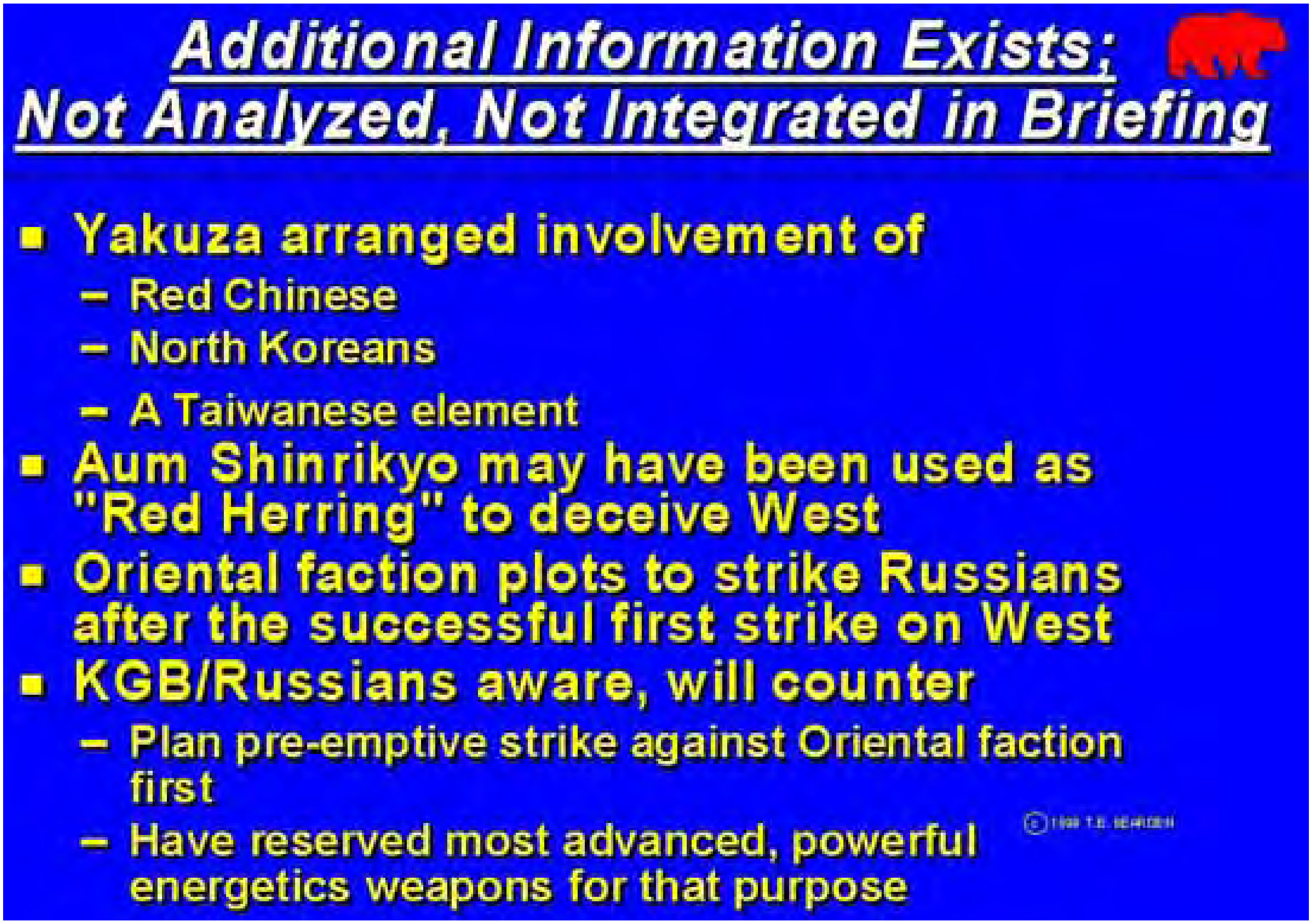

Additional Information Exists; Not Analyzed, Not Integrated in Briefing

- Yakuza arranged involvement of
  - Red Chinese
  - North Koreans
  - A Taiwanese element
- Aum Shinrikyo may have been used as "Red Herring" to deceive West
- Oriental faction plots to strike Russians after the successful first strike on West
- KGB/Russians aware, will counter
  - Plan pre-emptive strike against Oriental faction first
  - Have reserved most advanced, powerful energetics weapons for that purpose

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The Tom Bearden Website

Help support the research

Kill of Arrow DC-8, Gander AFB, Dec. 12, 1985

- Slide 1
- Slide 2
- Slide 3
- Slide 4
- Slide 5
- Slide 6

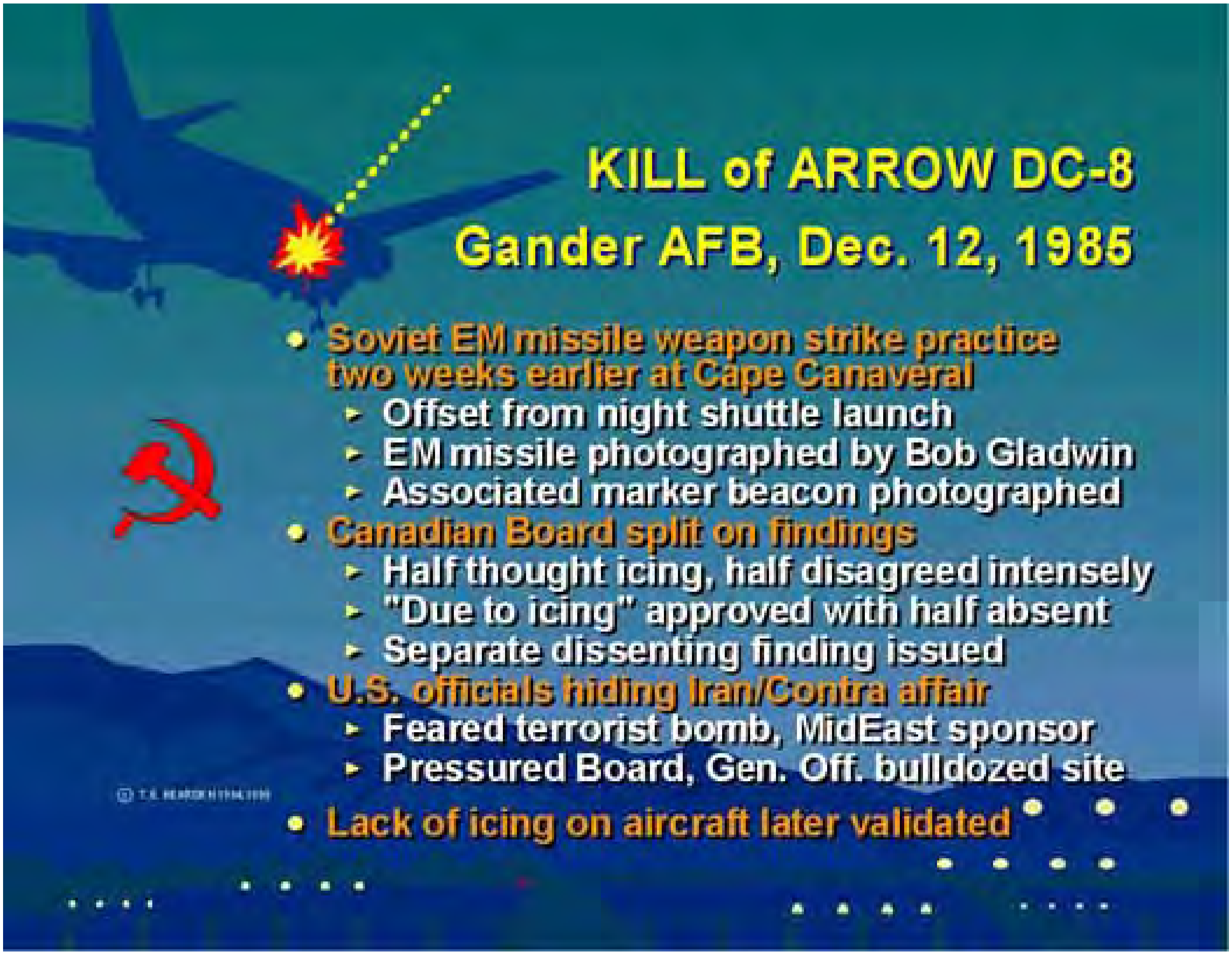

KILL of ARROW DC-8

Gander AFB, Dec. 12, 1985

- Soviet EM missile weapon strike practice two weeks earlier at Cape Canaveral
  - Offset from night shuttle launch
  - EM missile photographed by Bob Gladwin
  - Associated marker beacon photographed
- Canadian Board split on findings
  - Half thought icing, half disagreed intensely
  - "Due to icing" approved with half absent
  - Separate dissenting finding issued
- U.S. officials hiding Iran/Contra affair
  - Feared terrorist bomb, MidEast sponsor
  - Pressured Board, Gen. Off. bulldozed site
- Lack of icing on aircraft later validated

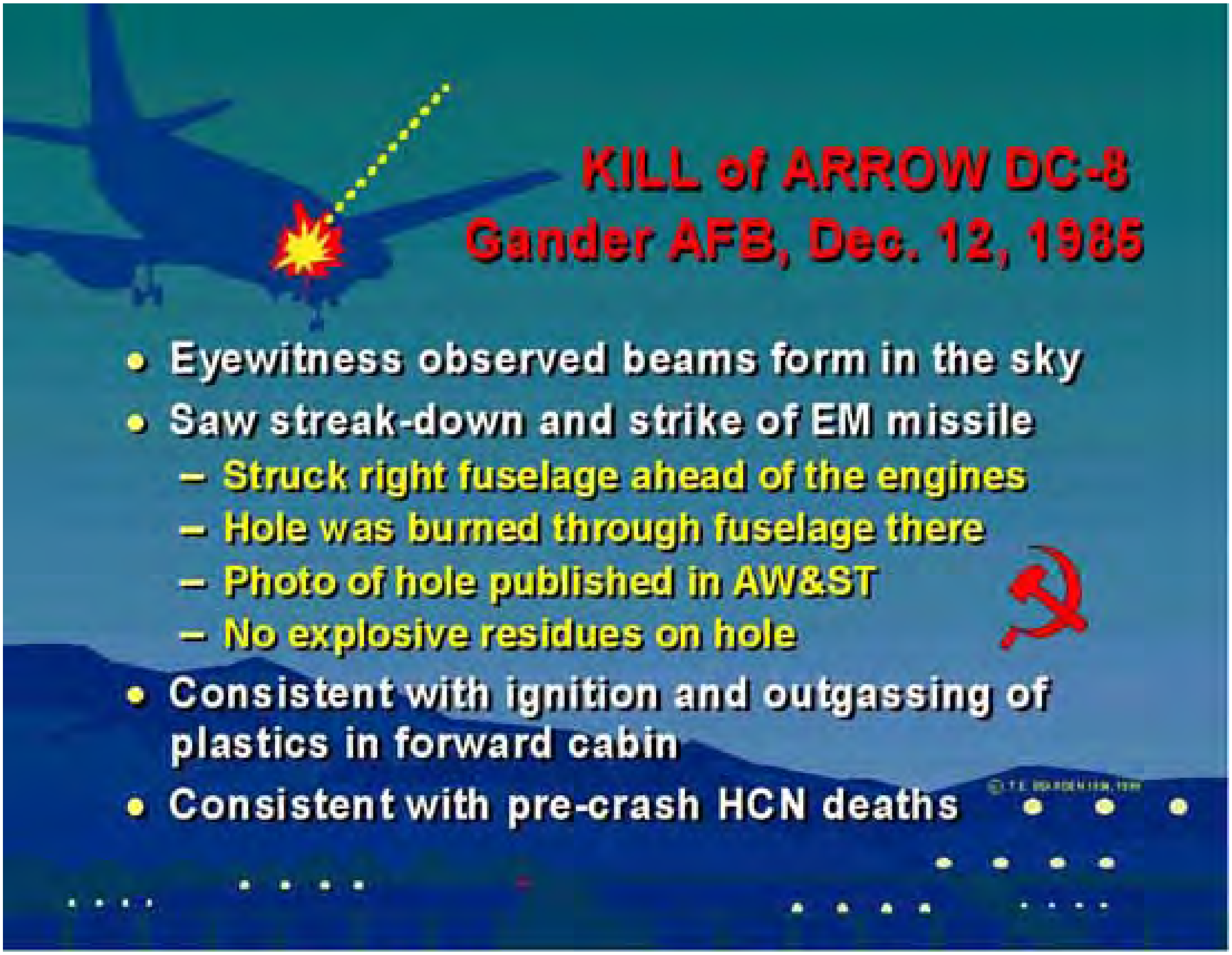

KILL of ARROW DC-8
Gander AFB, Dec. 12, 1985

- Eyewitness observed beams form in the sky
- Saw streak-down and strike of EM missile
  - Struck right fuselage ahead of the engines
  - Hole was burned through fuselage there
  - Photo of hole published in AW&ST
  - No explosive residues on hole
- Consistent with ignition and outgassing of plastics in forward cabin
- Consistent with pre-crash HCN deaths

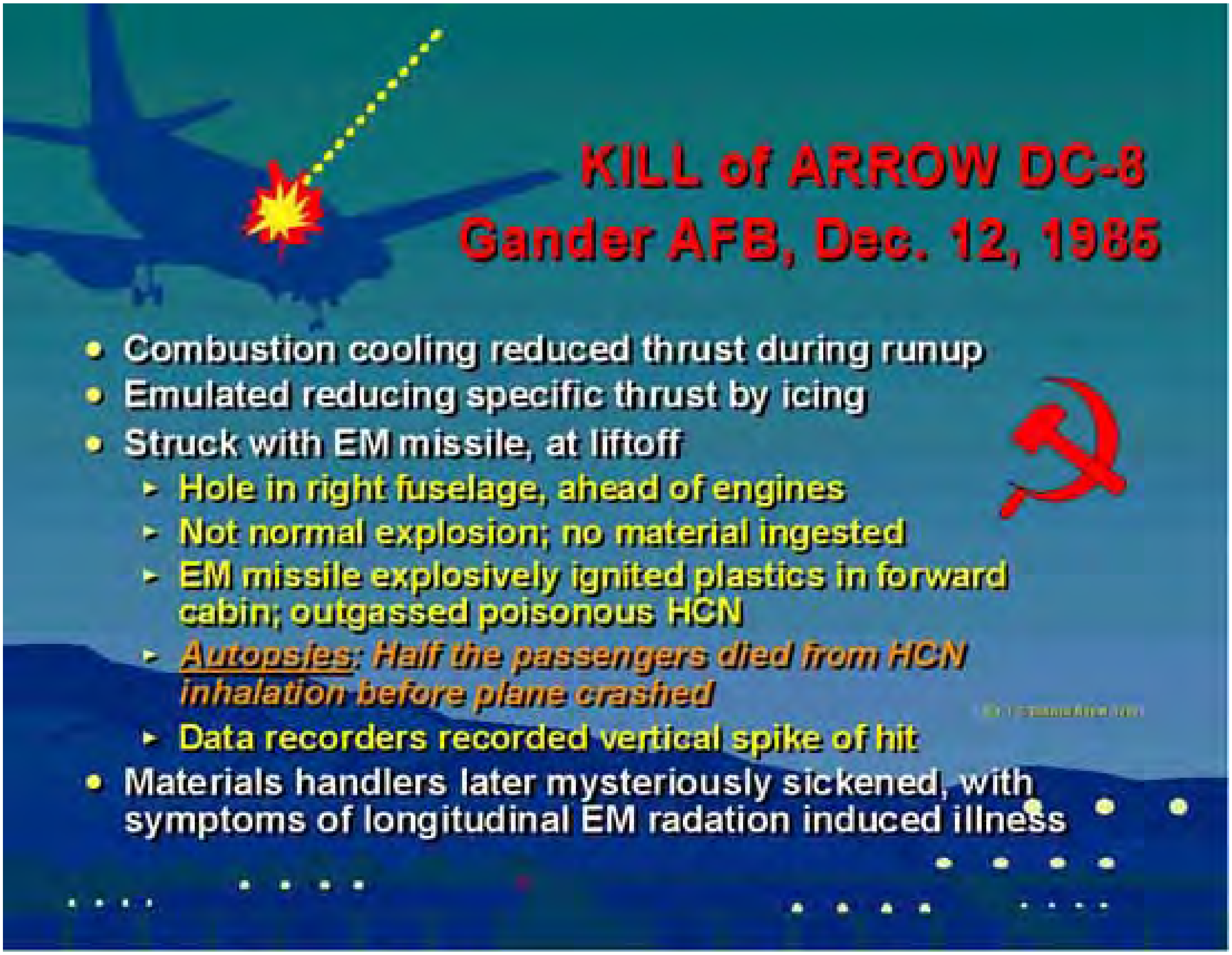

KILL of ARROW DC-8
Gander AFB, Dec. 12, 1985

- Combustion cooling reduced thrust during runup
- Emulated reducing specific thrust by icing
- Struck with EM missile, at liftoff
  - Hole in right fuselage, ahead of engines
  - Not normal explosion; no material ingested
  - EM missile explosively ignited plastics in forward cabin; outgassed poisonous HCN
  - *Autopsies: Half the passengers died from HCN inhalation before plane crashed*
  - Data recorders recorded vertical spike of hit
- Materials handlers later mysteriously sickened, with symptoms of longitudinal EM radation induced illness

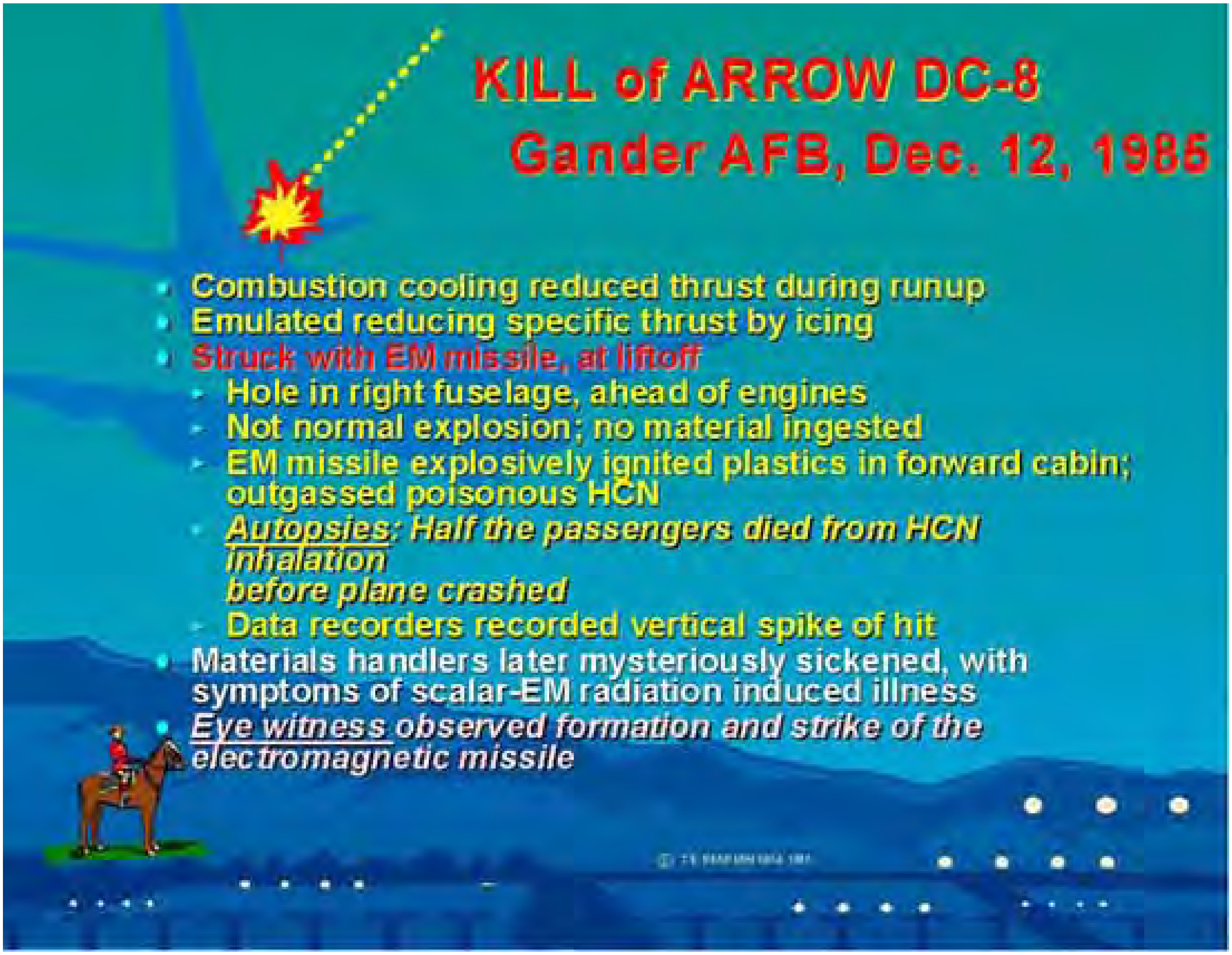

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  - ***Autopsies**: Half the passengers died from HCN inhalation before plane crashed*
  - Data recorders recorded vertical spike of hit
- Materials handlers later mysteriously sickened, with symptoms of scalar-EM radiation induced illness
- *Eye witness observed formation and strike of the electromagnetic missile*

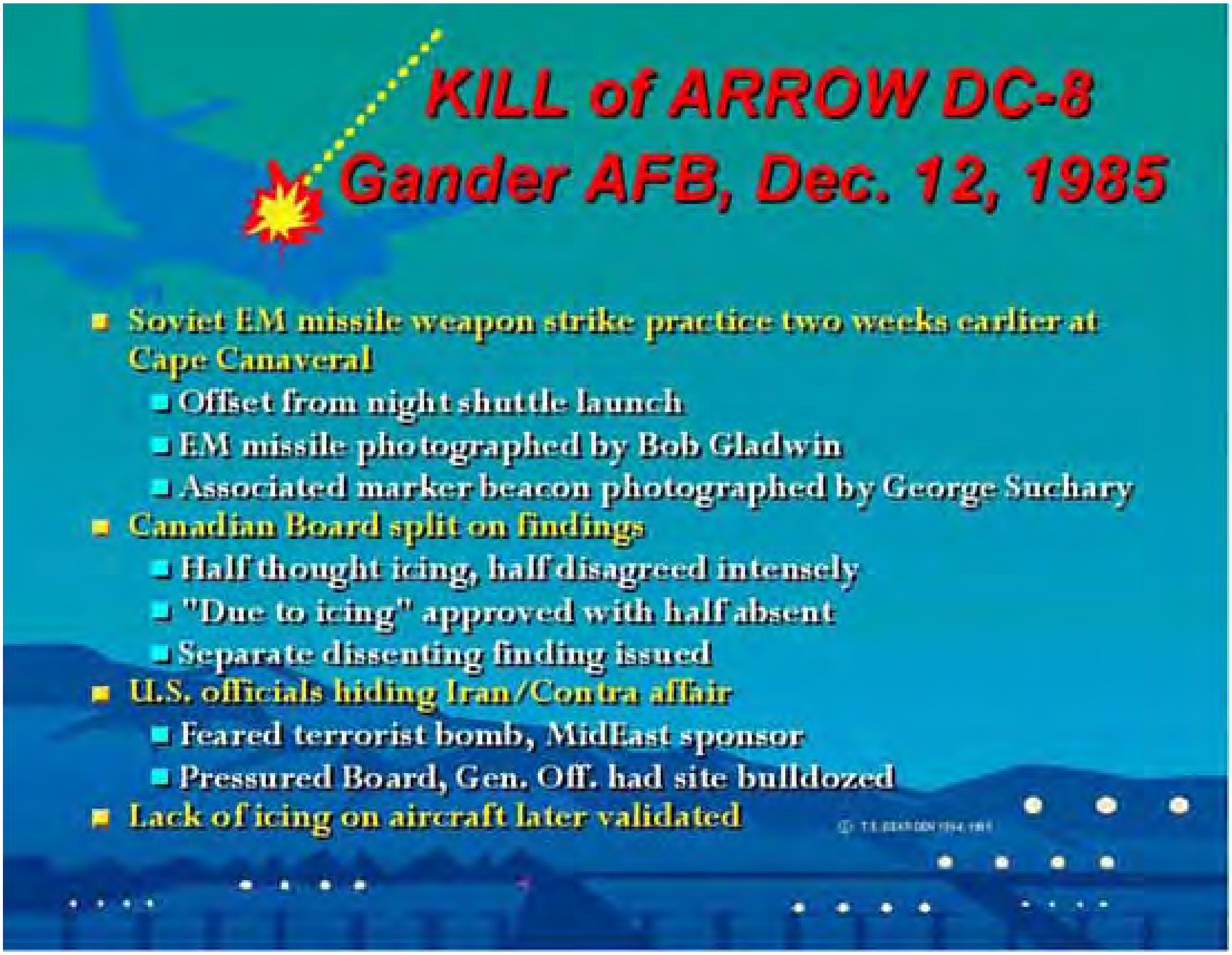

KILL of ARROW DC-8
Gander AFB, Dec. 12, 1985

- Soviet EM missile weapon strike practice two weeks earlier at Cape Canaveral
  - Offset from night shuttle launch
  - EM missile photographed by Bob Gladwin
  - Associated marker beacon photographed by George Suchary
- Canadian Board split on findings
  - Half thought icing, half disagreed intensely
  - "Due to icing" approved with half absent
  - Separate dissenting finding issued
- U.S. officials hiding Iran/Contra affair
  - Feared terrorist bomb, MidEast sponsor
  - Pressured Board, Gen. Off. had site bulldozed
- Lack of icing on aircraft later validated

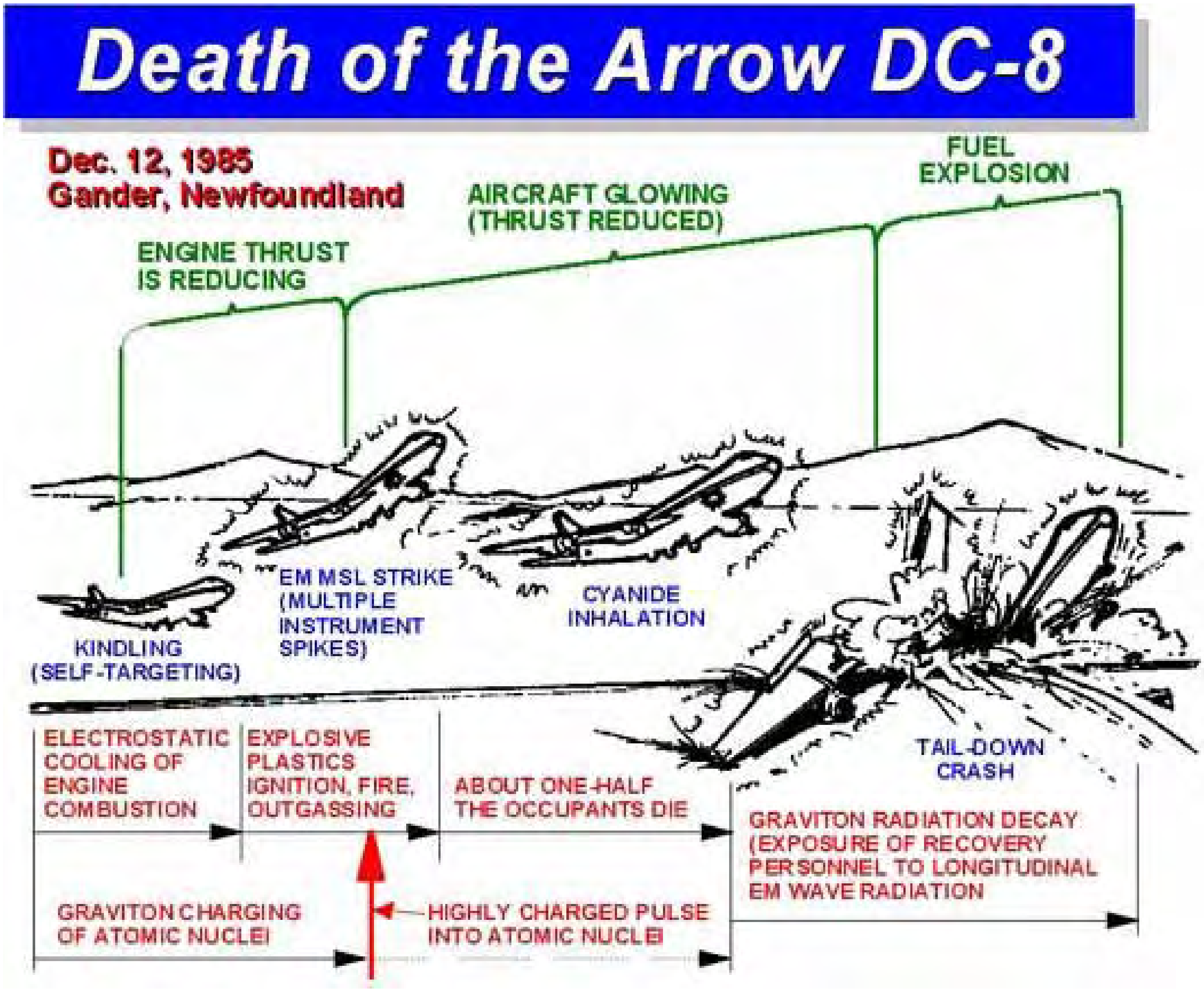
Death of the Arrow DC-8
Dec. 12, 1985
Gander, Newfoundland
ENGINE THRUST
IS REDUCING
AIRCRAFT GLOWING
(THRUST REDUCED)
FUEL
EXPLOSION
KINDLING
(SELF-TARGETING)
EM MSL STRIKE
(MULTIPLE
INSTRUMENT
SPIKES)
CYANIDE
INHALATION
TAIL-DOWN
CRASH
ELECTROSTATIC
COOLING OF
ENGINE
COMBUSTION
EXPLOSIVE
PLASTICS
IGNITION, FIRE,
OUTGASSING
ABOUT ONE-HALF
THE OCCUPANTS DIE
GRAVITON RADIATION DECAY
(EXPOSURE OF RECOVERY
PERSONNEL TO LONGITUDINAL
EM WAVE RADIATION
GRAVITON CHARGING
OF ATOMIC NUCLEI
HIGHLY CHARGED PULSE
INTO ATOMIC NUCLEI

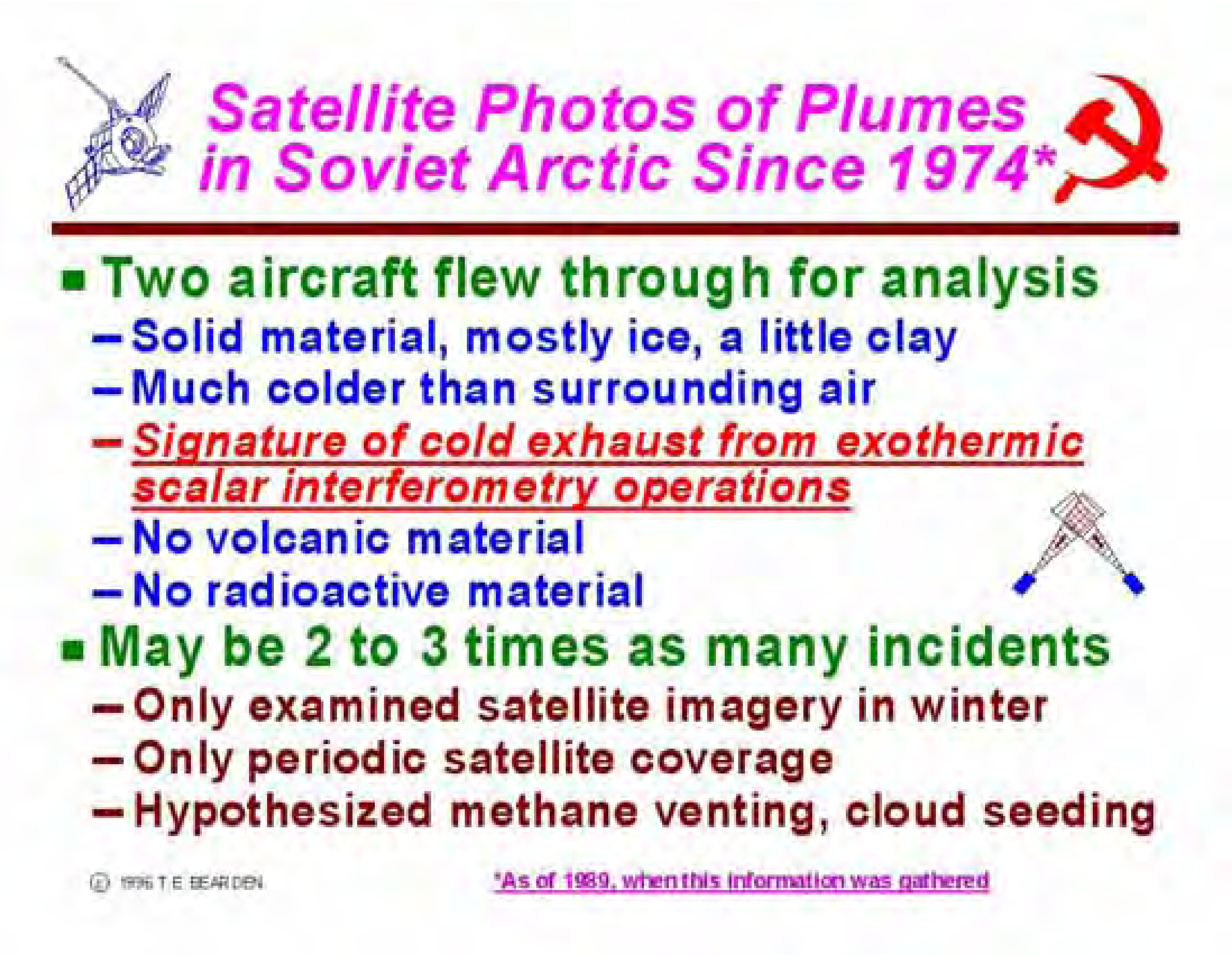

Satellite Photos of Plumes in Soviet Arctic Since 1974*

- Two aircraft flew through for analysis
  - Solid material, mostly ice, a little clay
  - Much colder than surrounding air
  - *Signature of cold exhaust from exothermic scalar interferometry operations*
  - No volcanic material
  - No radioactive material
- May be 2 to 3 times as many incidents
  - Only examined satellite imagery in winter
  - Only periodic satellite coverage
  - Hypothesized methane venting, cloud seeding

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*As of 1989, when this information was gathered

AUM SHINRIKYO

("SUPREME TRUTH" CULT)

Shoko Asahara, Leader

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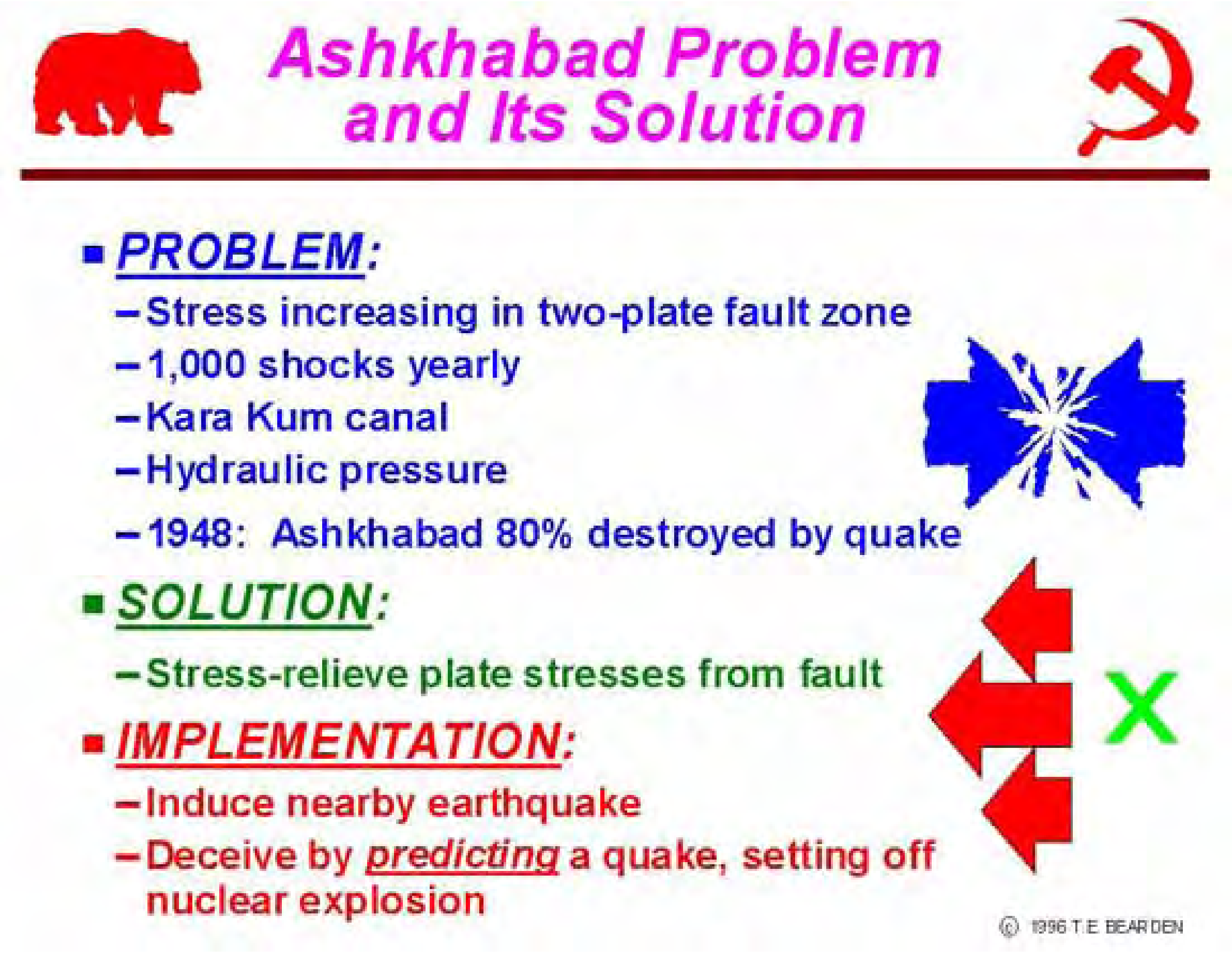

Ashkhabad Problem and Its Solution

- ***PROBLEM:***
  - Stress increasing in two-plate fault zone
  - 1,000 shocks yearly
  - Kara Kum canal
  - Hydraulic pressure
  - 1948: Ashkhabad 80% destroyed by quake
- ***SOLUTION:***
  - Stress-relieve plate stresses from fault
- ***IMPLEMENTATION:***
  - Induce nearby earthquake
  - Deceive by *predicting* a quake, setting off nuclear explosion

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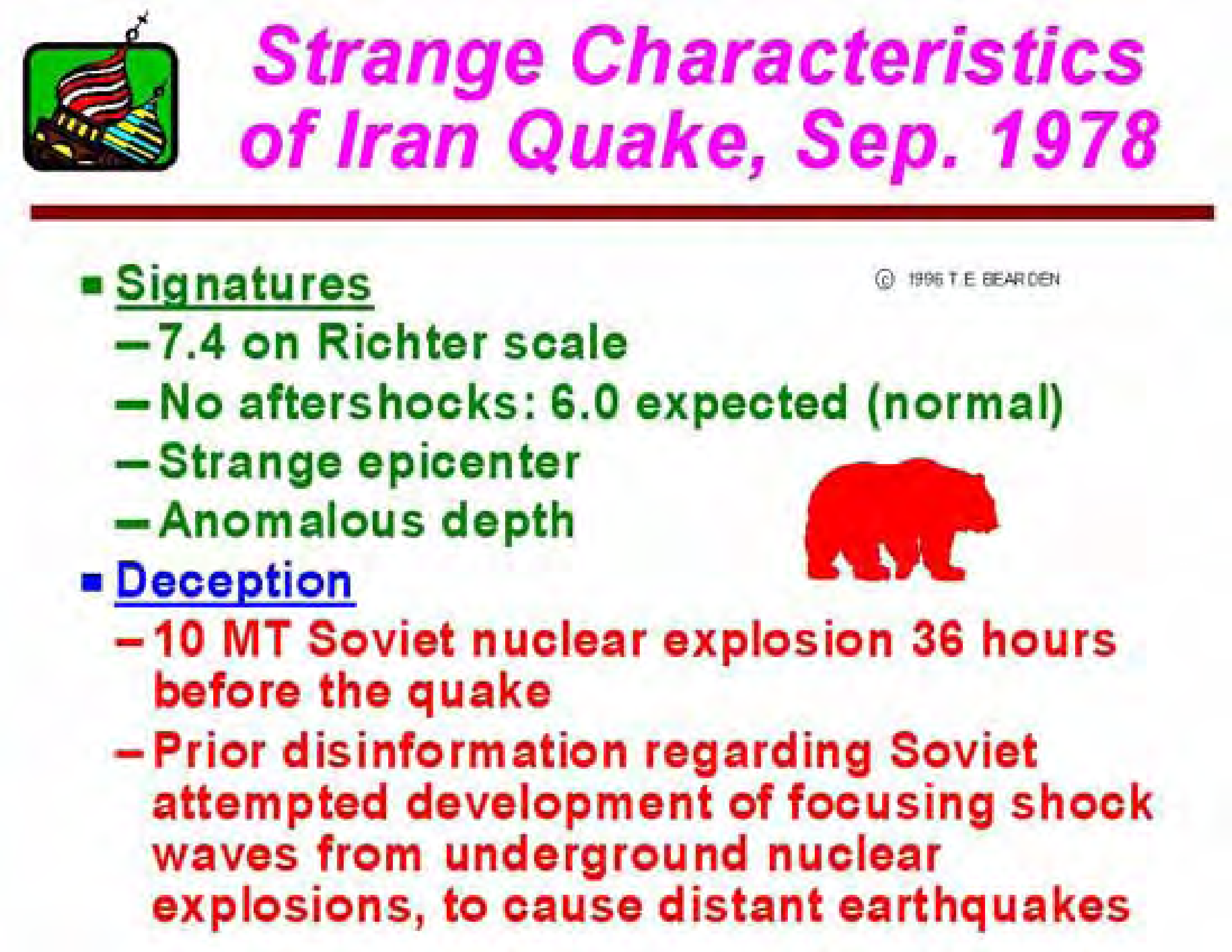

Strange Characteristics of Iran Quake, Sep. 1978

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- **Signatures**
  - 7.4 on Richter scale
  - No aftershocks: 6.0 expected (normal)
  - Strange epicenter
  - Anomalous depth
- **Deception**
  - 10 MT Soviet nuclear explosion 36 hours before the quake
  - Prior disinformation regarding Soviet attempted development of focusing shock waves from underground nuclear explosions, to cause distant earthquakes

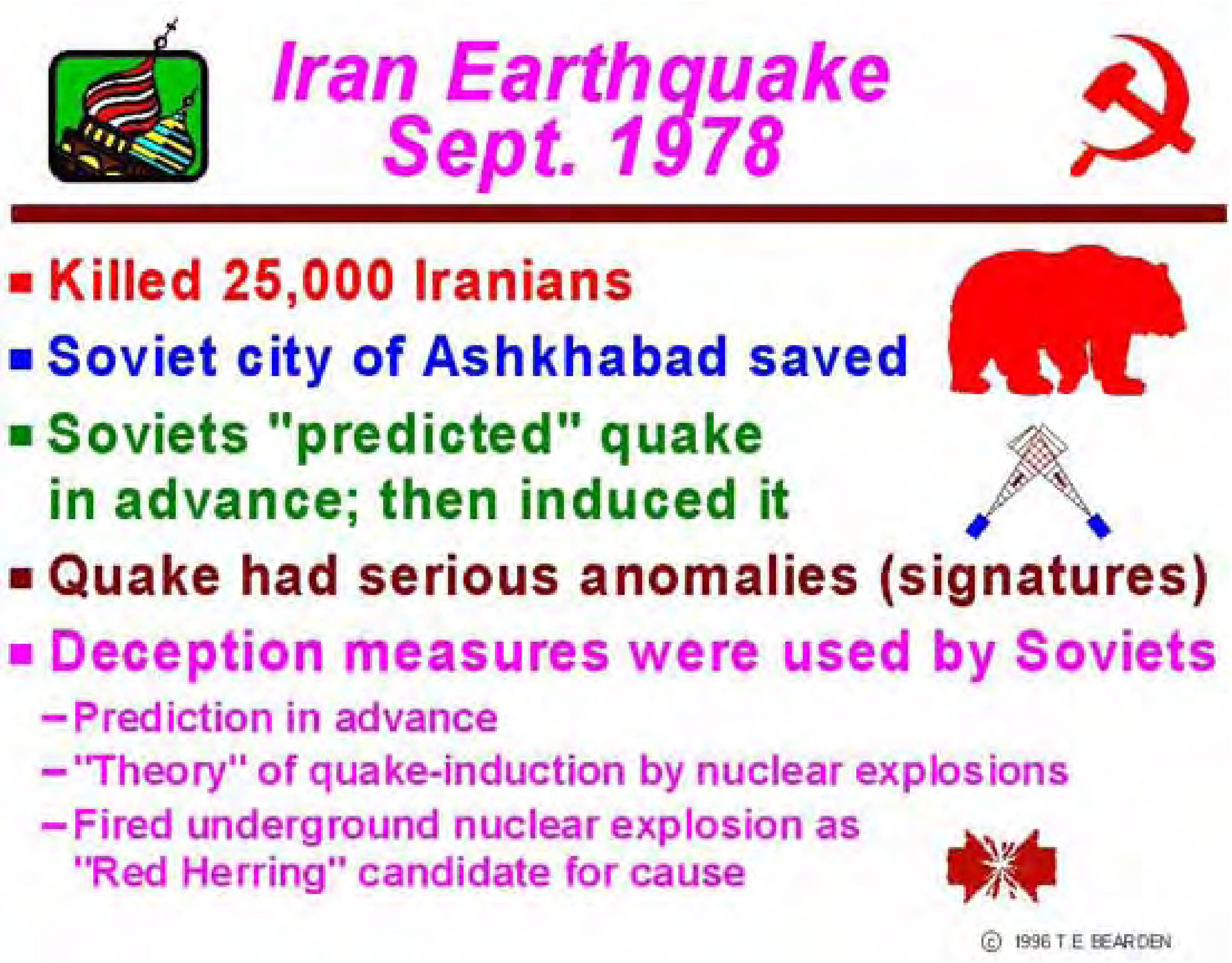

Iran Earthquake Sept. 1978

- Killed 25,000 Iranians
- Soviet city of Ashkhabad saved
- Soviets "predicted" quake in advance; then induced it
- Quake had serious anomalies (signatures)
- Deception measures were used by Soviets
  - Prediction in advance
  - "Theory" of quake-induction by nuclear explosions
  - Fired underground nuclear explosion as "Red Herring" candidate for cause

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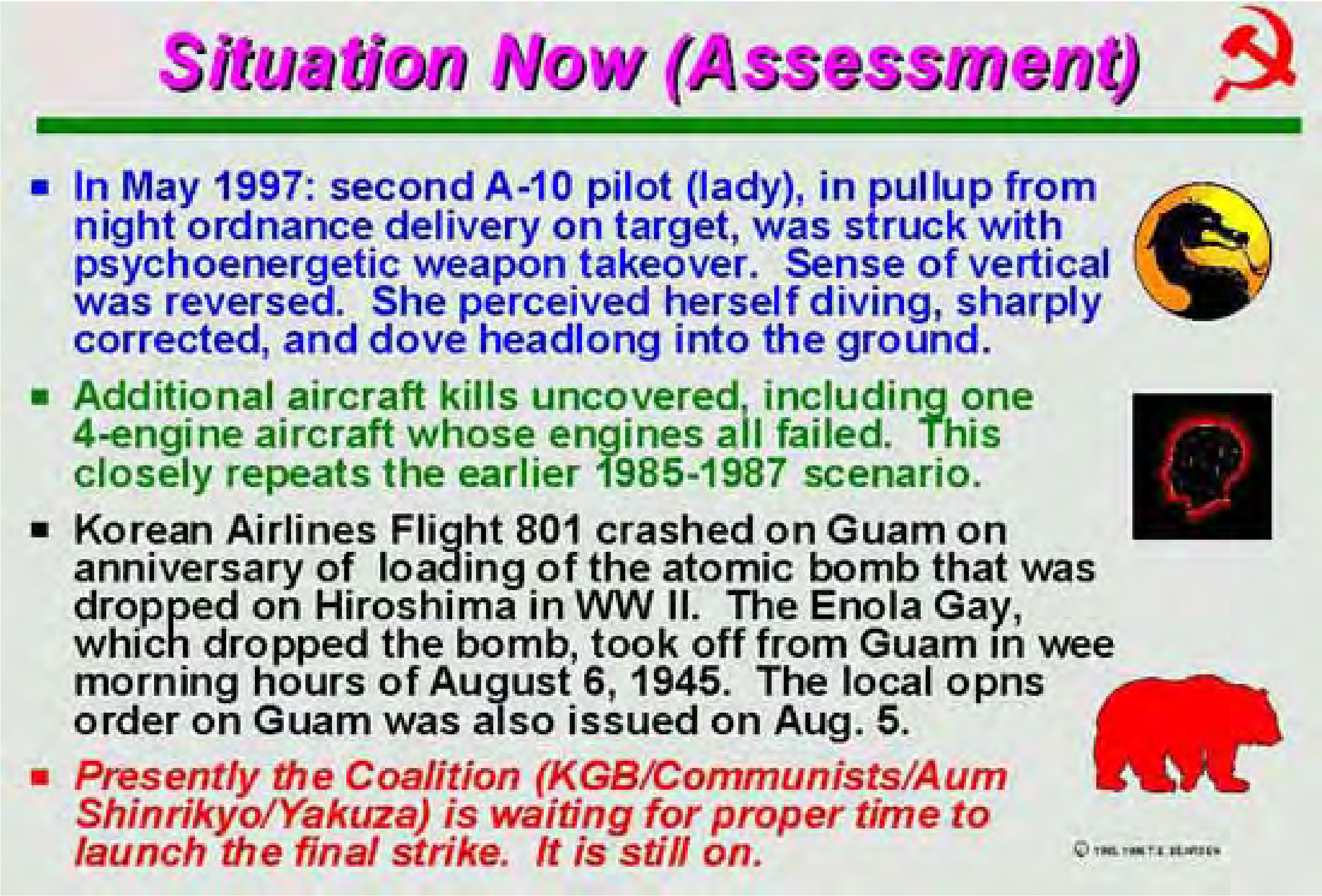

Situation Now (Assessment)

- In May 1997: second A-10 pilot (lady), in pullup from night ordnance delivery on target, was struck with psychoenergetic weapon takeover. Sense of vertical was reversed. She perceived herself diving, sharply corrected, and dove headlong into the ground.
- Additional aircraft kills uncovered, including one 4-engine aircraft whose engines all failed. This closely repeats the earlier 1985-1987 scenario.
- Korean Airlines Flight 801 crashed on Guam on anniversary of loading of the atomic bomb that was dropped on Hiroshima in WW II. The Enola Gay, which dropped the bomb, took off from Guam in wee morning hours of August 6, 1945. The local opns order on Guam was also issued on Aug. 5.
- *Presently the Coalition (KGB/Communists/Aum Shinrikyo/Yakuza) is waiting for proper time to launch the final strike. It is still on.*

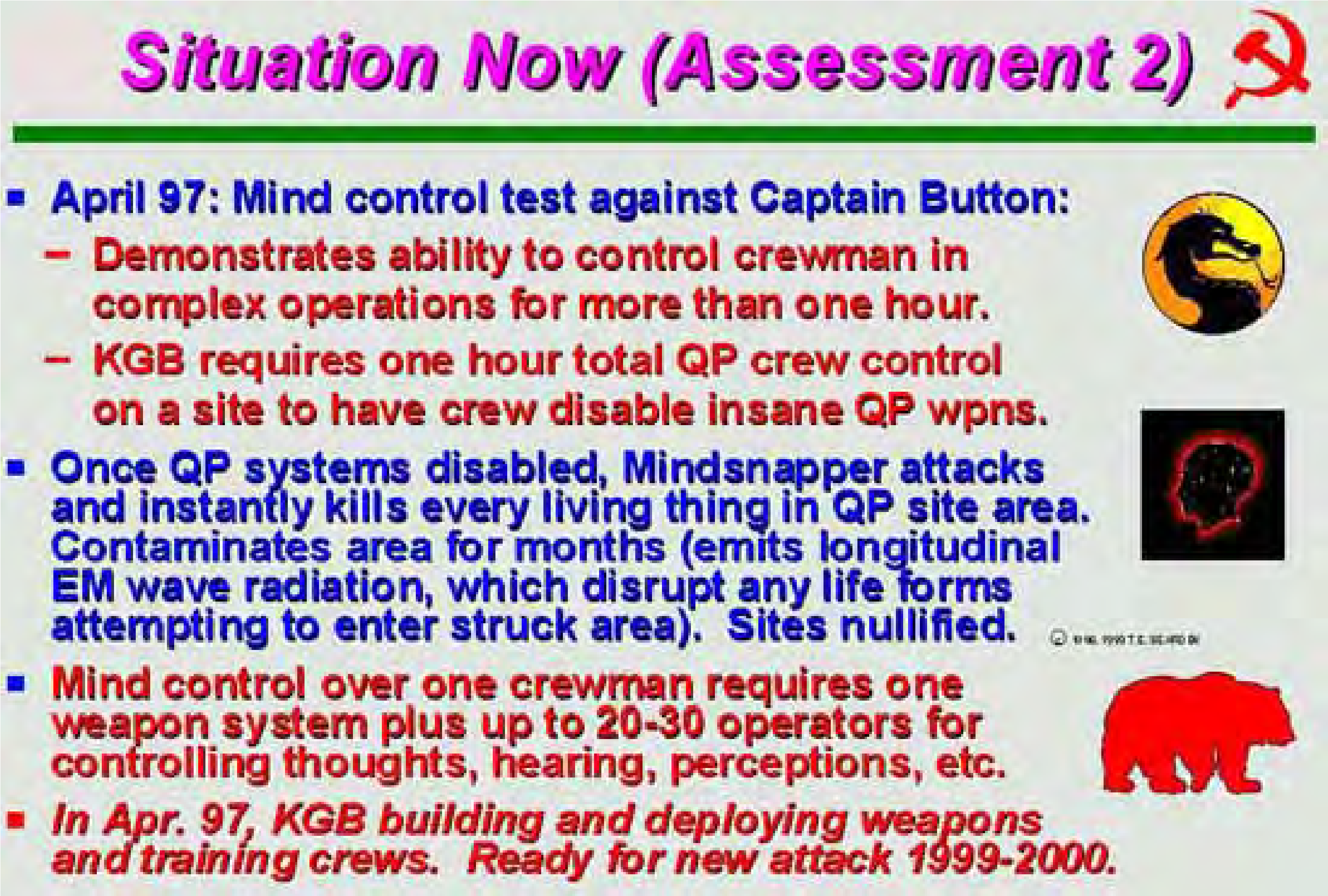

Situation Now (Assessment 2)

- April 97: Mind control test against Captain Button:
  - Demonstrates ability to control crewman in complex operations for more than one hour.
  - KGB requires one hour total QP crew control on a site to have crew disable insane QP wpns.
- Once QP systems disabled, Mindsnapper attacks and instantly kills every living thing in QP site area. Contaminates area for months (emits longitudinal EM wave radiation, which disrupt any life forms attempting to enter struck area). Sites nullified.
- Mind control over one crewman requires one weapon system plus up to 20-30 operators for controlling thoughts, hearing, perceptions, etc.
- *In Apr. 97, KGB building and deploying weapons and training crews. Ready for new attack 1999-2000.*

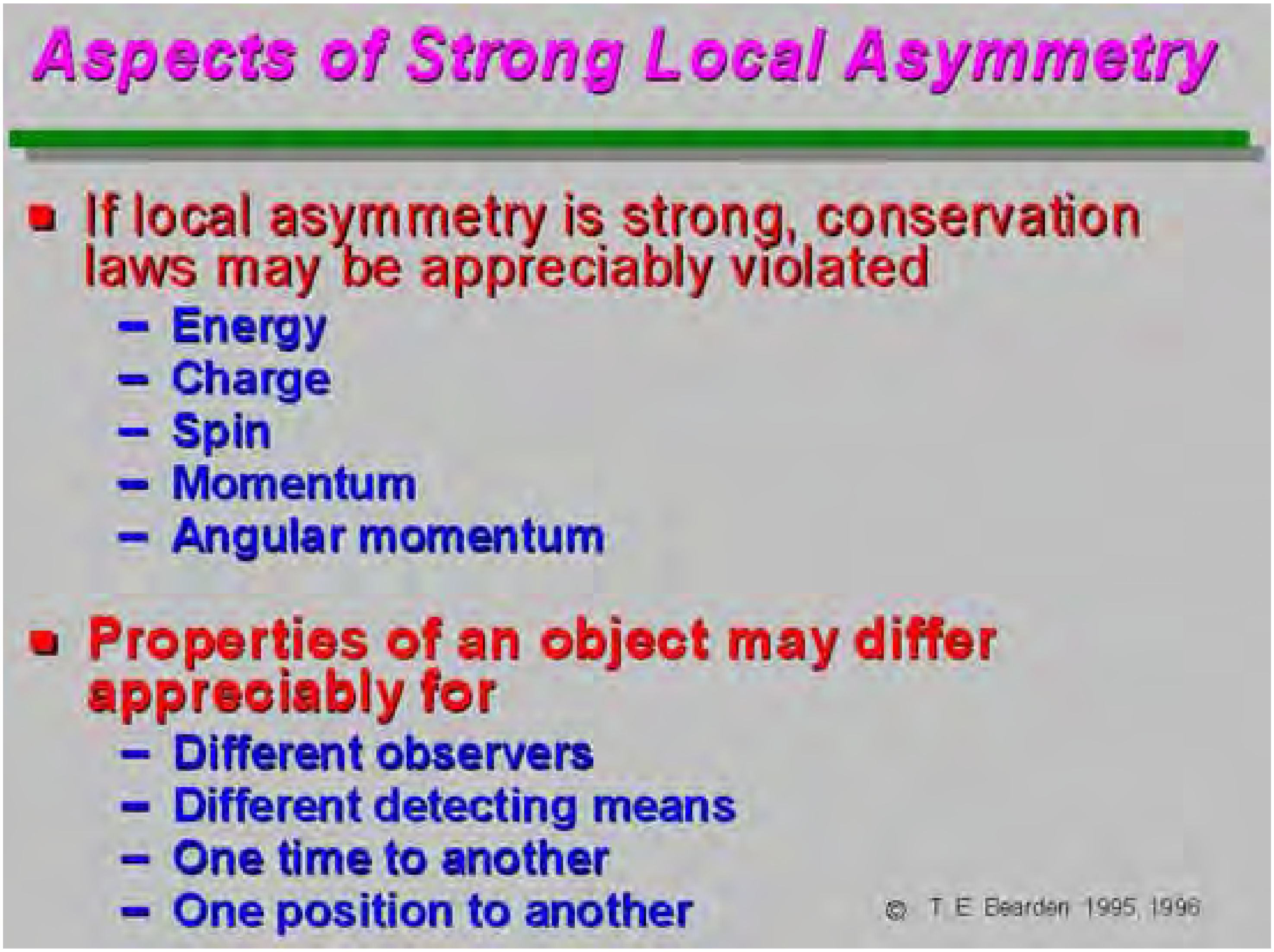

Aspects of Strong Local Asymmetry

- If local asymmetry is strong, conservation laws may be appreciably violated
    - Energy
    - Charge
    - Spin
    - Momentum
    - Angular momentum
- Properties of an object may differ appreciably for
    - Different observers
    - Different detecting means
    - One time to another
    - One position to another

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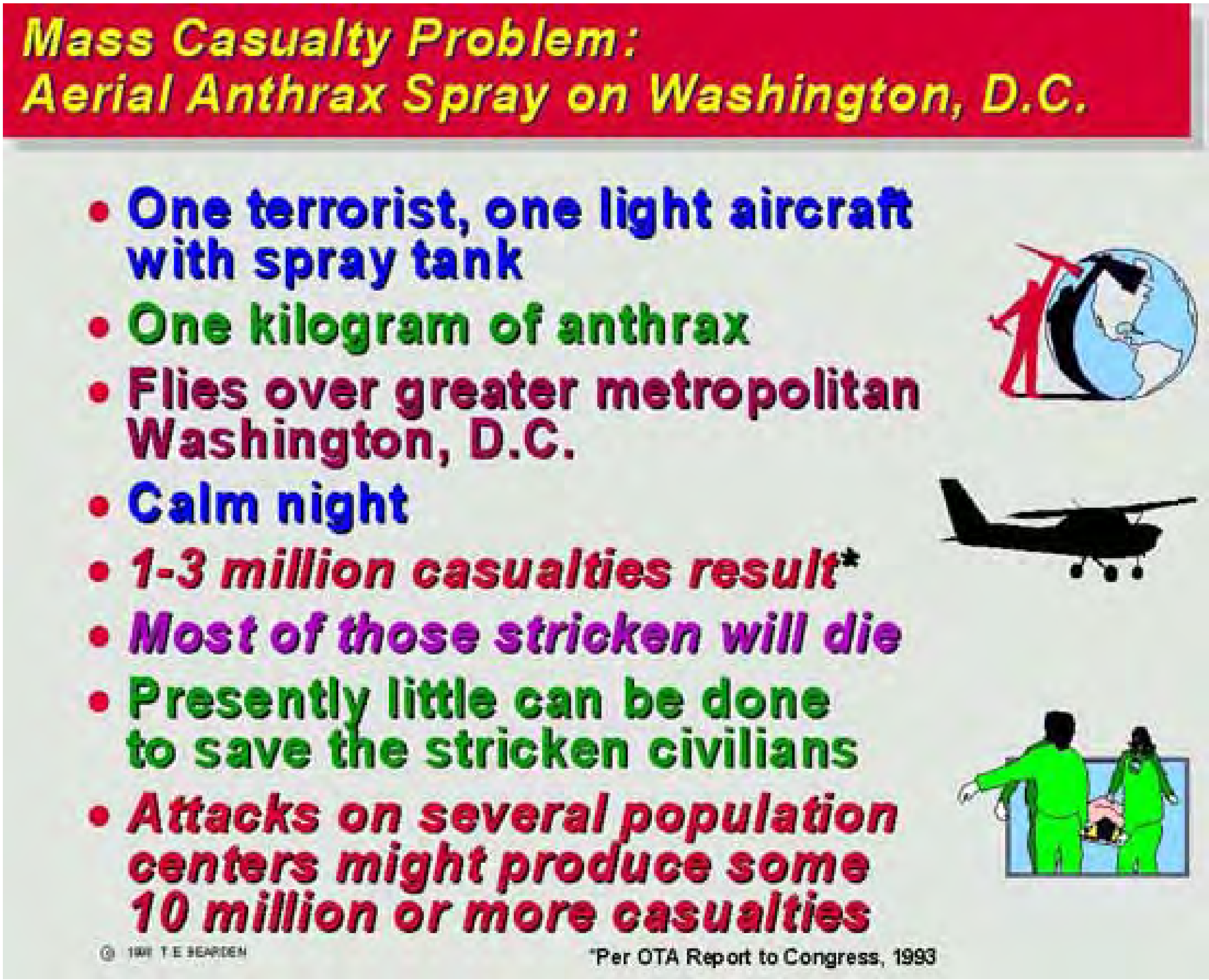

Mass Casualty Problem:
Aerial Anthrax Spray on Washington, D.C.

- One terrorist, one light aircraft with spray tank
- One kilogram of anthrax
- Flies over greater metropolitan Washington, D.C.
- Calm night
- *1-3 million casualties result**
- *Most of those stricken will die*
- Presently little can be done to save the stricken civilians
- *Attacks on several population centers might produce some 10 million or more casualties*

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*Per OTA Report to Congress, 1993

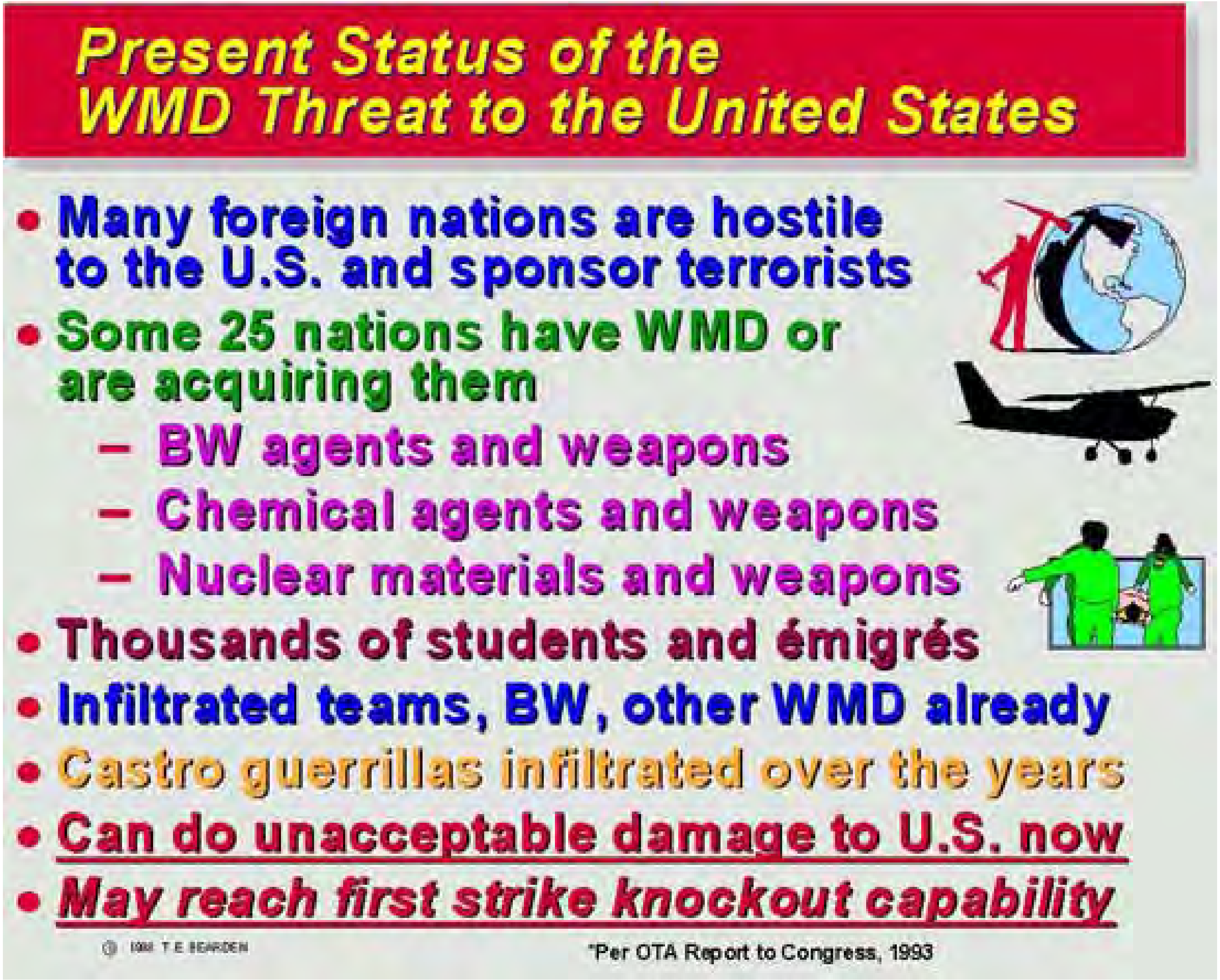

Present Status of the WMD Threat to the United States

- **Many foreign nations are hostile to the U.S. and sponsor terrorists**
- **Some 25 nations have WMD or are acquiring them**
  - **BW agents and weapons**
  - **Chemical agents and weapons**
  - **Nuclear materials and weapons**
- **Thousands of students and émigrés**
- **Infiltrated teams, BW, other WMD already**
- **Castro guerrillas infiltrated over the years**
- **Can do unacceptable damage to U.S. now**
- ***May reach first strike knockout capability***

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*Per OTA Report to Congress, 1993

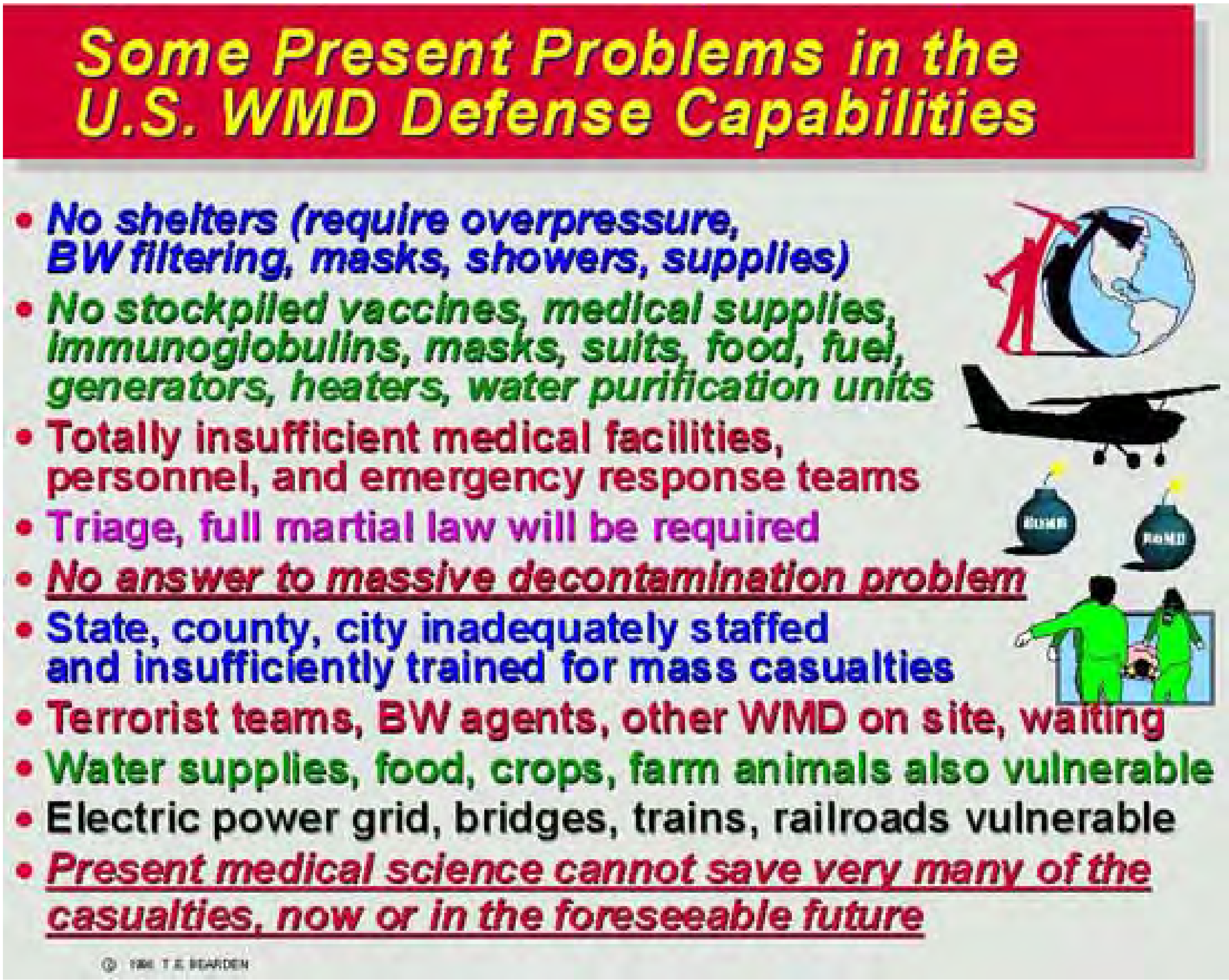

Some Present Problems in the U.S. WMD Defense Capabilities

- *No shelters (require overpressure, BW filtering, masks, showers, supplies)*
- *No stockpiled vaccines, medical supplies, immunoglobulins, masks, suits, food, fuel, generators, heaters, water purification units*
- Totally insufficient medical facilities, personnel, and emergency response teams
- Triage, full martial law will be required
- *No answer to massive decontamination problem*
- State, county, city inadequately staffed and insufficiently trained for mass casualties
- Terrorist teams, BW agents, other WMD on site, waiting
- Water supplies, food, crops, farm animals also vulnerable
- Electric power grid, bridges, trains, railroads vulnerable
- *Present medical science cannot save very many of the casualties, now or in the foreseeable future*

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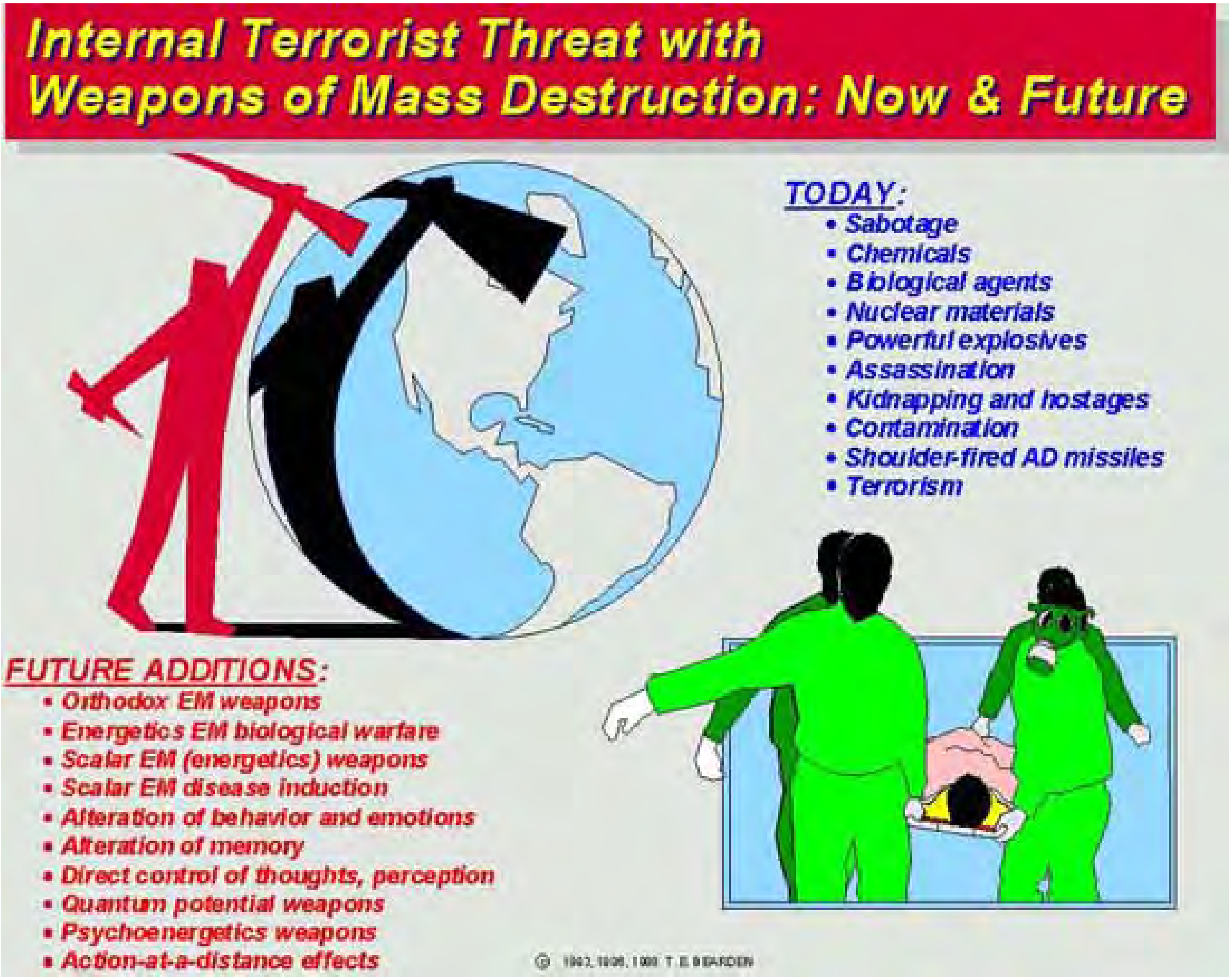

Internal Terrorist Threat with Weapons of Mass Destruction: Now & Future

TODAY:

- *Sabotage*
- *Chemicals*
- *Biological agents*
- *Nuclear materials*
- *Powerful explosives*
- *Assassination*
- *Kidnapping and hostages*
- *Contamination*
- *Shoulder-fired AD missiles*
- *Terrorism*

FUTURE ADDITIONS:

- *Orthodox EM weapons*
- *Energetics EM biological warfare*
- *Scalar EM (energetics) weapons*
- *Scalar EM disease induction*
- *Alteration of behavior and emotions*
- *Alteration of memory*
- *Direct control of thoughts, perception*
- *Quantum potential weapons*
- *Psychoenergetics weapons*
- *Action-at-a-distance effects*

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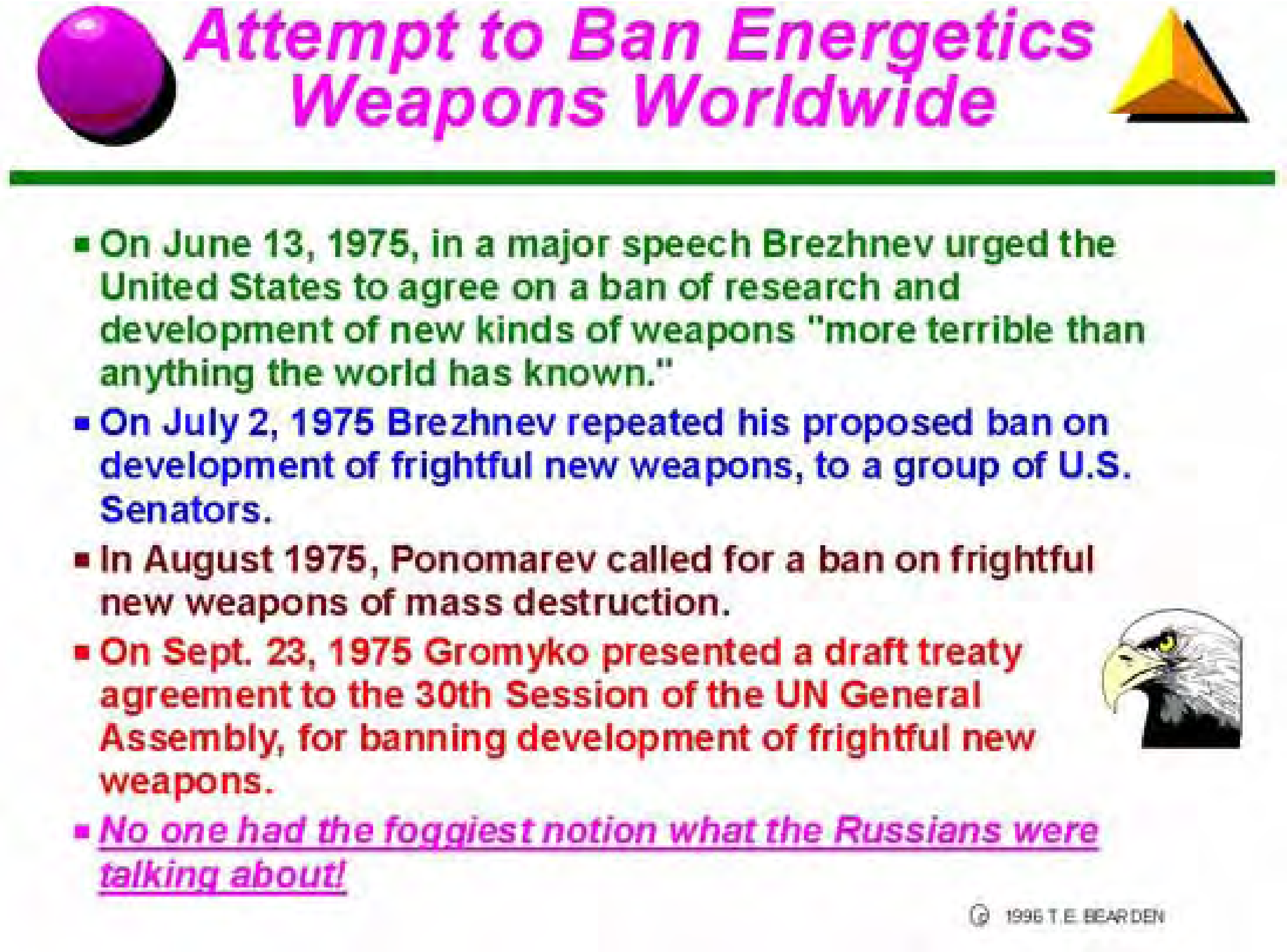

Attempt to Ban Energetics Weapons Worldwide

- On June 13, 1975, in a major speech Brezhnev urged the United States to agree on a ban of research and development of new kinds of weapons "more terrible than anything the world has known."
- On July 2, 1975 Brezhnev repeated his proposed ban on development of frightful new weapons, to a group of U.S. Senators.
- In August 1975, Ponomarev called for a ban on frightful new weapons of mass destruction.
- On Sept. 23, 1975 Gromyko presented a draft treaty agreement to the 30th Session of the UN General Assembly, for banning development of frightful new weapons.
- *No one had the foggiest notion what the Russians were talking about!*

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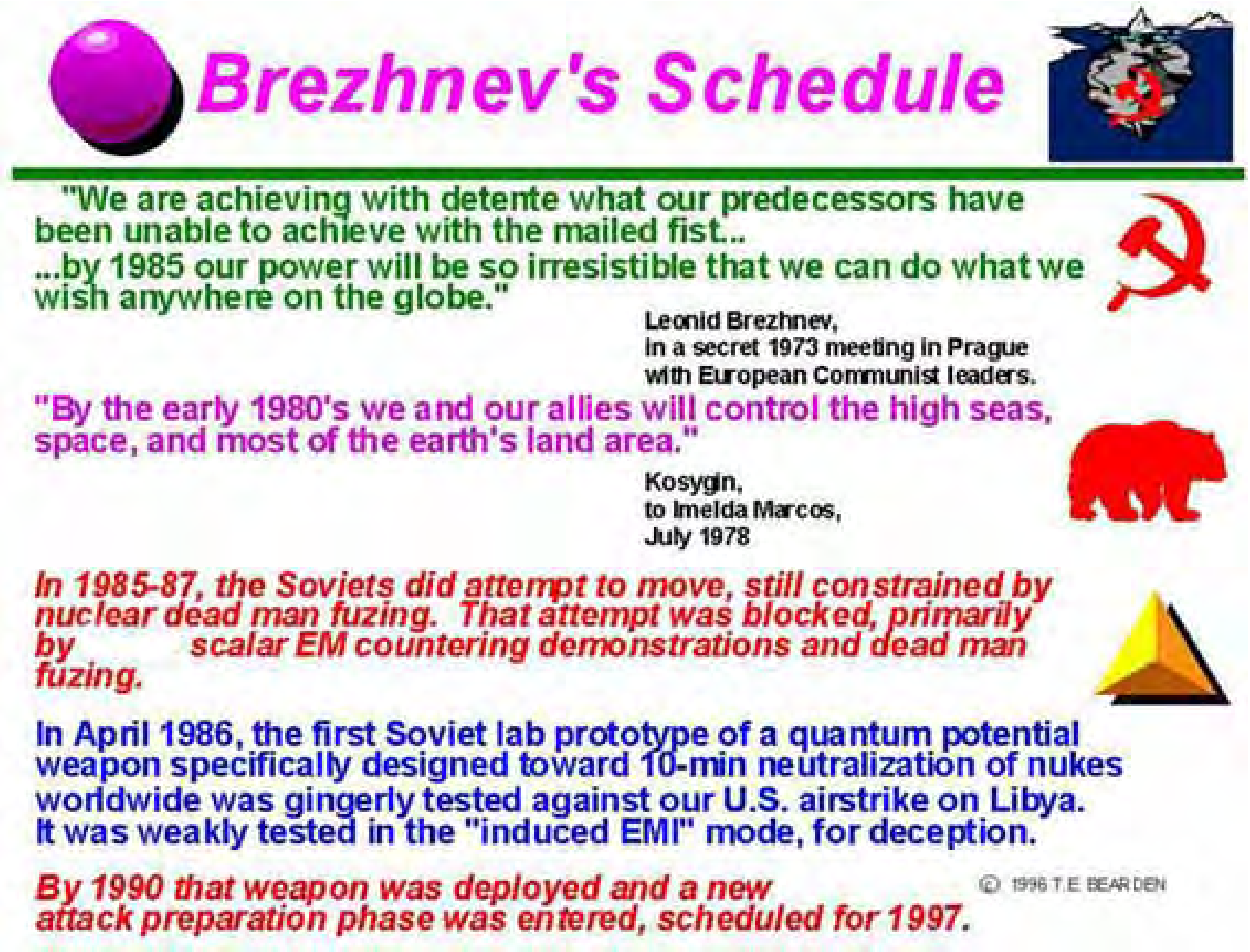

Brezhnev's Schedule

"We are achieving with detente what our predecessors have been unable to achieve with the mailed fist..
...by 1985 our power will be so irresistible that we can do what we wish anywhere on the globe."

Leonid Brezhnev,
in a secret 1973 meeting in Prague
with European Communist leaders.

"By the early 1980's we and our allies will control the high seas, space, and most of the earth's land area."

Kosygin,
to Imelda Marcos,
July 1978

In 1985-87, the Soviets did attempt to move, still constrained by nuclear dead man fuzing. That attempt was blocked, primarily by scalar EM countering demonstrations and dead man fuzing.

In April 1986, the first Soviet lab prototype of a quantum potential weapon specifically designed toward 10-min neutralization of nukes worldwide was gingerly tested against our U.S. airstrike on Libya. It was weakly tested in the "induced EMI" mode, for deception.

By 1990 that weapon was deployed and a new attack preparation phase was entered, scheduled for 1997.

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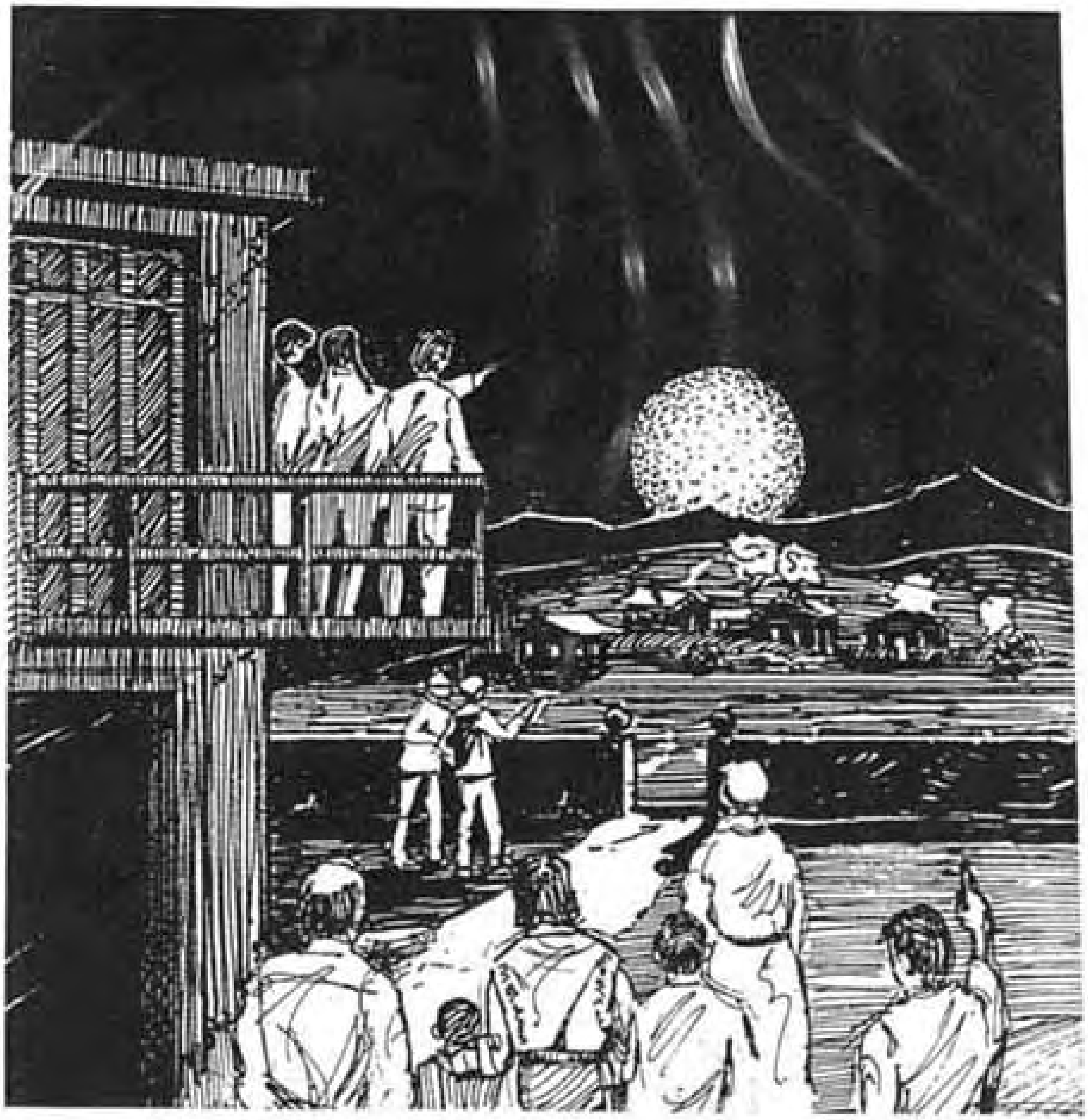

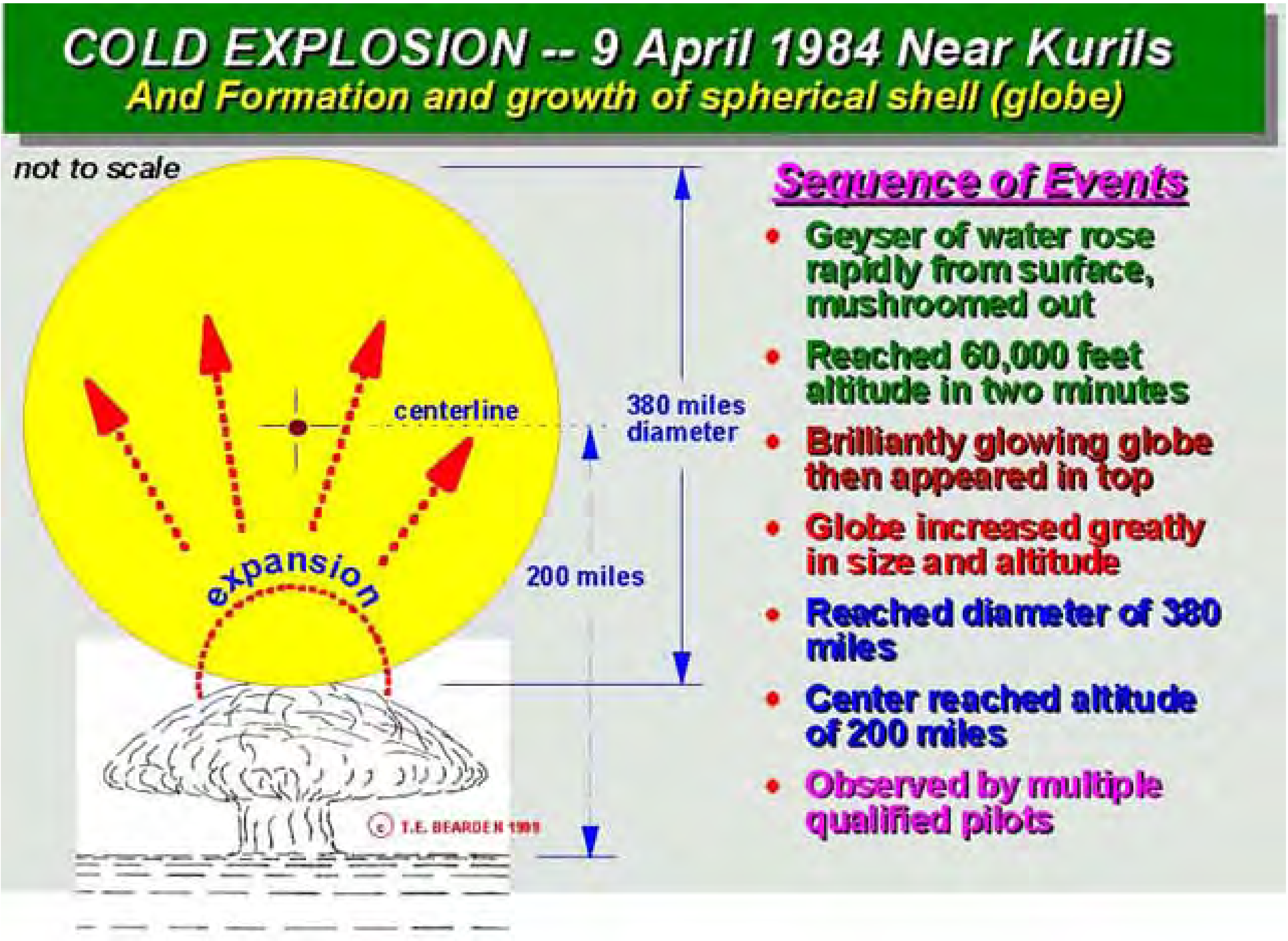

COLD EXPLOSION -- 9 April 1984 Near Kurils

And Formation and growth of spherical shell (globe)

not to scale

centerline
380 miles diameter
200 miles
expansion
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Sequence of Events

- Geyser of water rose rapidly from surface, mushroomed out
- Reached 60,000 feet altitude in two minutes
- Brilliantly glowing globe then appeared in top
- Globe increased greatly in size and altitude
- Reached diameter of 380 miles
- Center reached altitude of 200 miles
- Observed by multiple qualified pilots

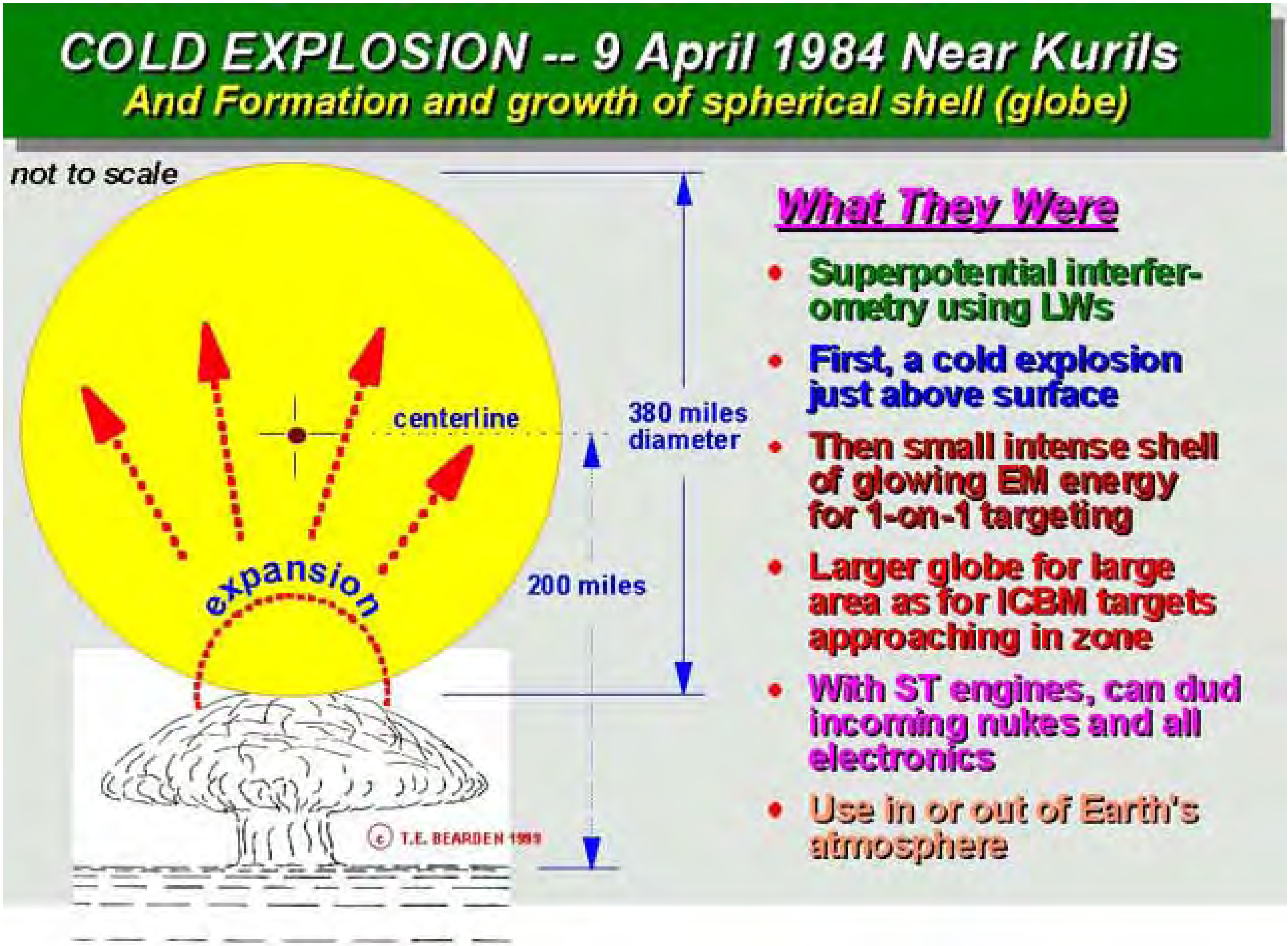

COLD EXPLOSION -- 9 April 1984 Near Kurils

And Formation and growth of spherical shell (globe)

not to scale
centerline
380 miles
diameter
200 miles
expansion
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What They Were

- Superpotential interferometry using LWs
- First, a cold explosion just above surface
- Then small intense shell of glowing EM energy for 1-on-1 targeting
- Larger globe for large area as for ICBM targets approaching in zone
- With ST engines, can dud incoming nukes and all electronics
- Use in or out of Earth's atmosphere

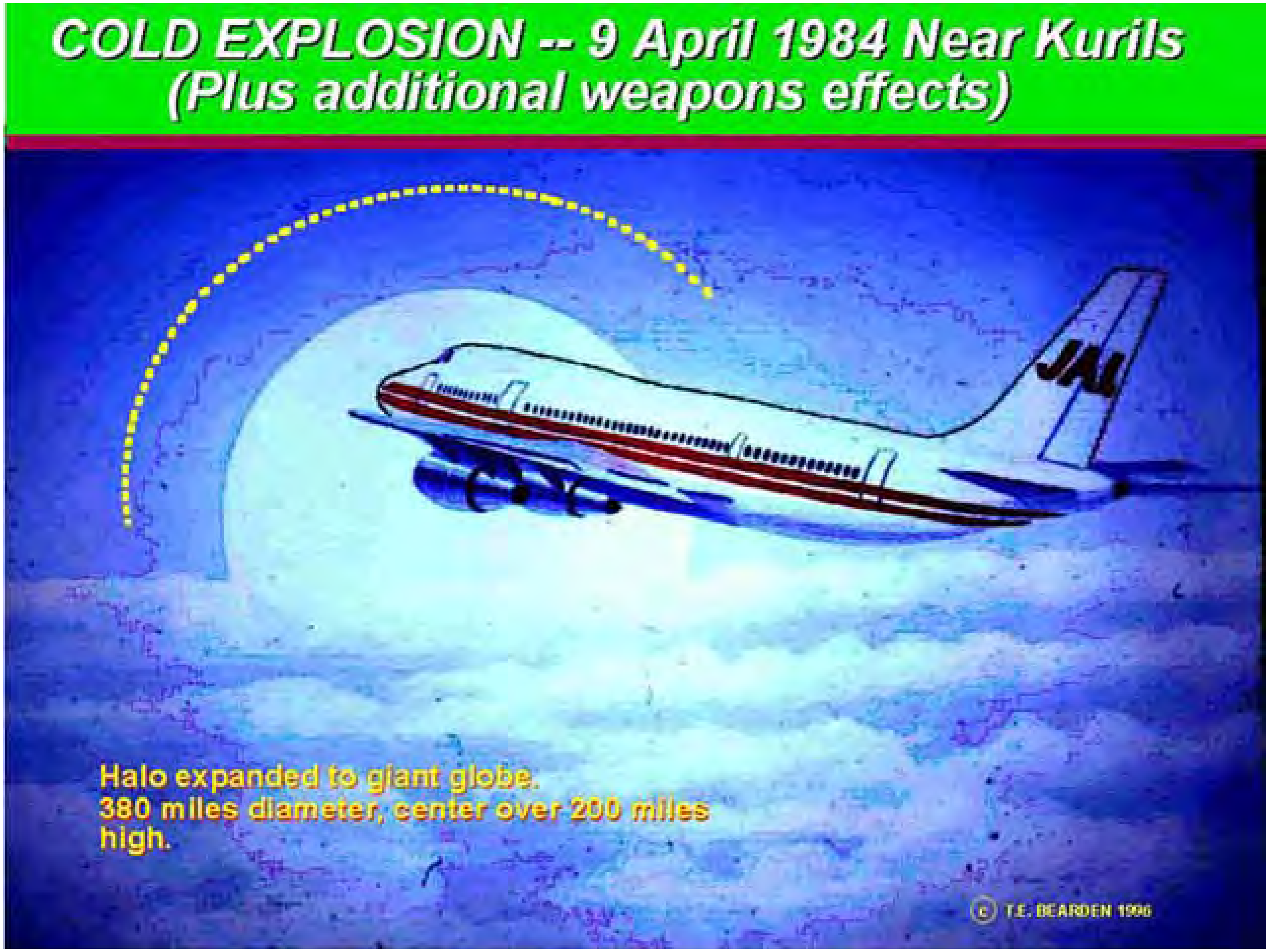

COLD EXPLOSION -- 9 April 1984 Near Kurils
(Plus additional weapons effects)

Halo expanded to giant globe.
380 miles diameter, center over 200 miles high.

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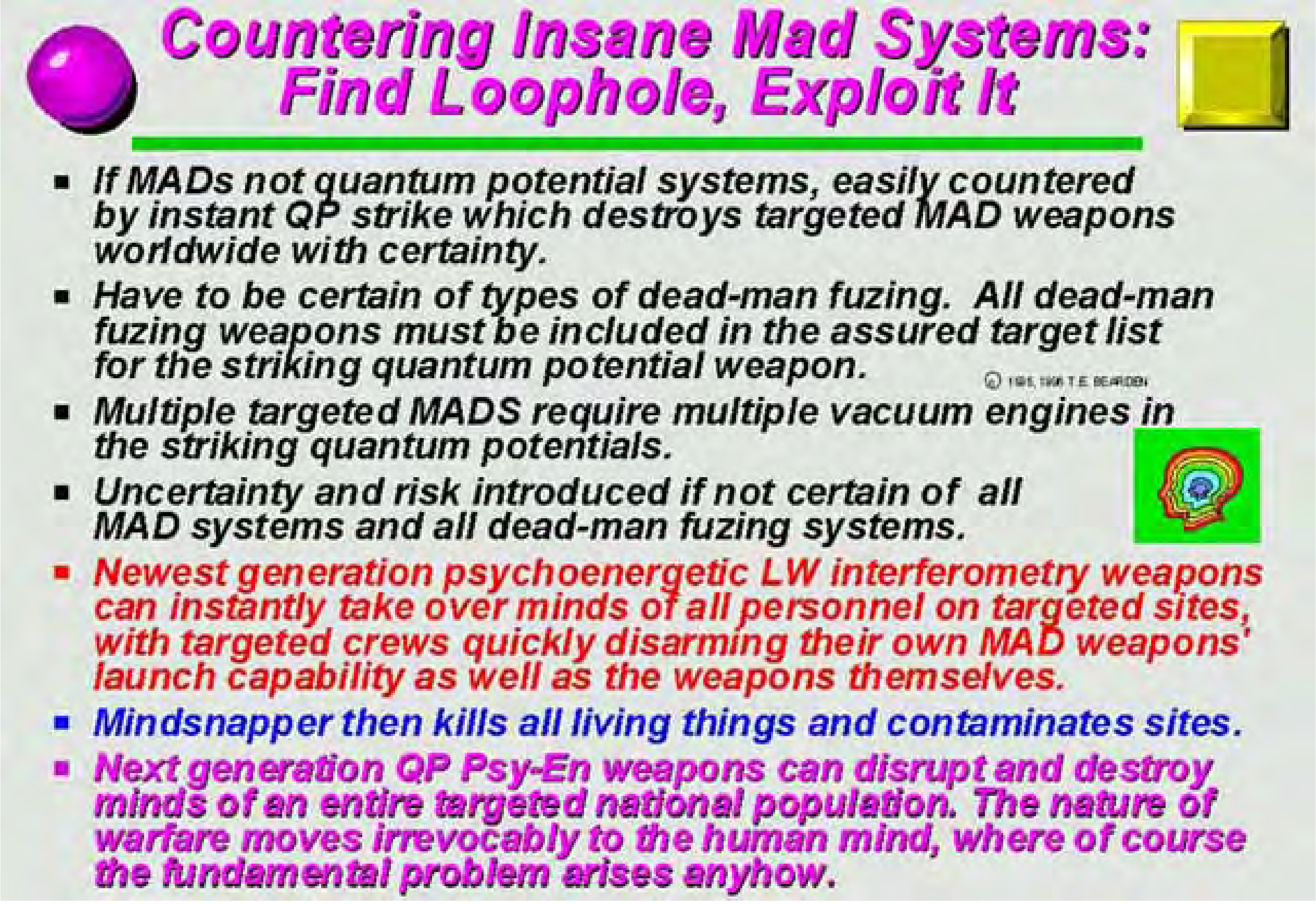

Countering Insane Mad Systems: Find Loophole, Exploit It

- *If MADs not quantum potential systems, easily countered by instant QP strike which destroys targeted MAD weapons worldwide with certainty.*
- *Have to be certain of types of dead-man fuzing. All dead-man fuzing weapons must be included in the assured target list for the striking quantum potential weapon.*
- *Multiple targeted MADS require multiple vacuum engines in the striking quantum potentials.*
- *Uncertainty and risk introduced if not certain of all MAD systems and all dead-man fuzing systems.*
- *Newest generation psychoenergetic LW interferometry weapons can instantly take over minds of all personnel on targeted sites, with targeted crews quickly disarming their own MAD weapons' launch capability as well as the weapons themselves.*
- *Mindsnapper then kills all living things and contaminates sites.*
- *Next generation QP Psy-En weapons can disrupt and destroy minds of an entire targeted national population. The nature of warfare moves irrevocably to the human mind, where of course the fundamental problem arises anyhow.*

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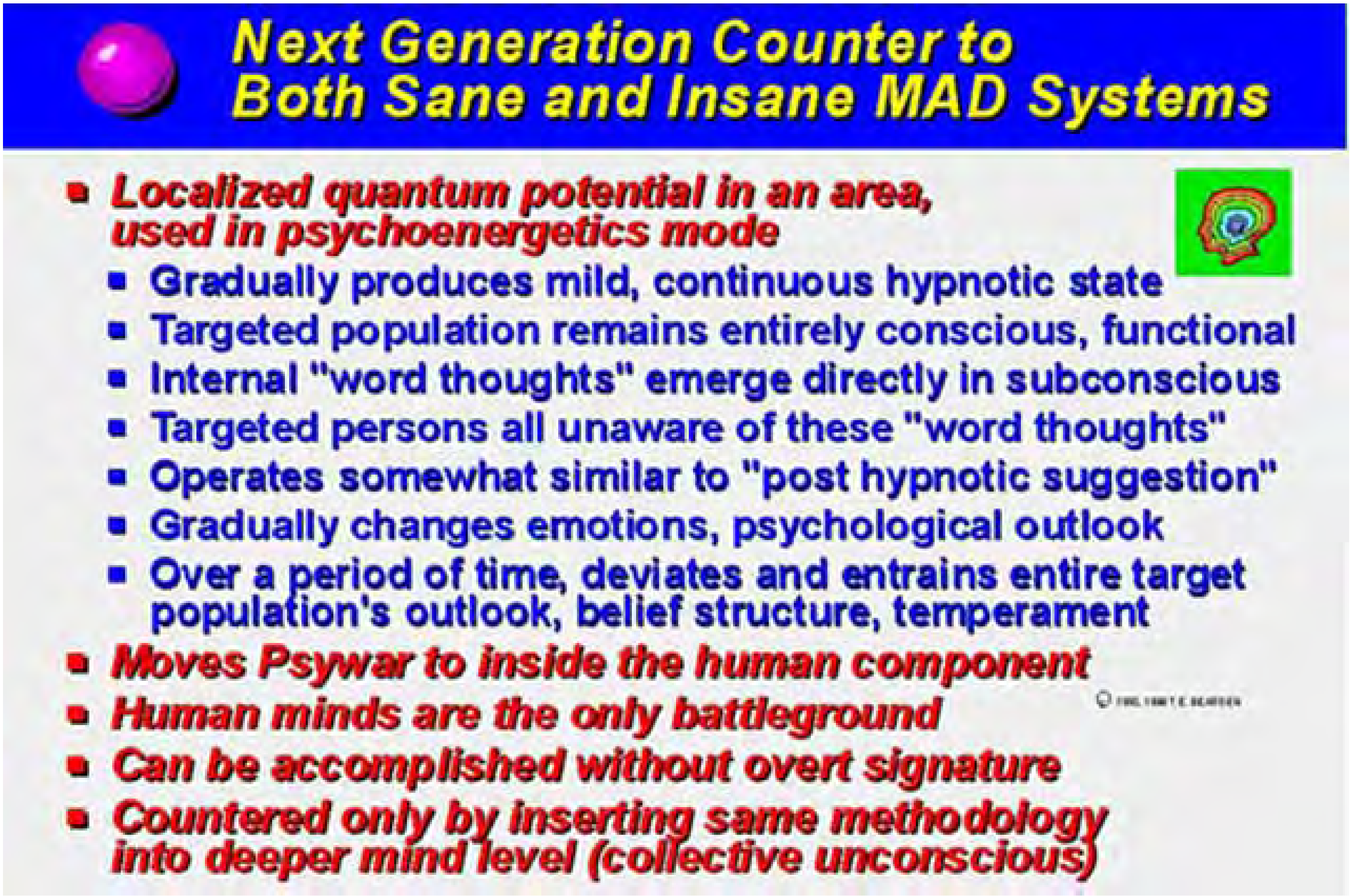

Next Generation Counter to Both Sane and Insane MAD Systems

- ***Localized quantum potential in an area, used in psychoenergetics mode***
  - **Gradually produces mild, continuous hypnotic state**
  - **Targeted population remains entirely conscious, functional**
  - **Internal "word thoughts" emerge directly in subconscious**
  - **Targeted persons all unaware of these "word thoughts"**
  - **Operates somewhat similar to "post hypnotic suggestion"**
  - **Gradually changes emotions, psychological outlook**
  - **Over a period of time, deviates and entrains entire target population's outlook, belief structure, temperament**
- ***Moves Psywar to inside the human component***
- ***Human minds are the only battleground***
- ***Can be accomplished without overt signature***
- ***Countered only by inserting same methodology into deeper mind level (collective unconscious)***

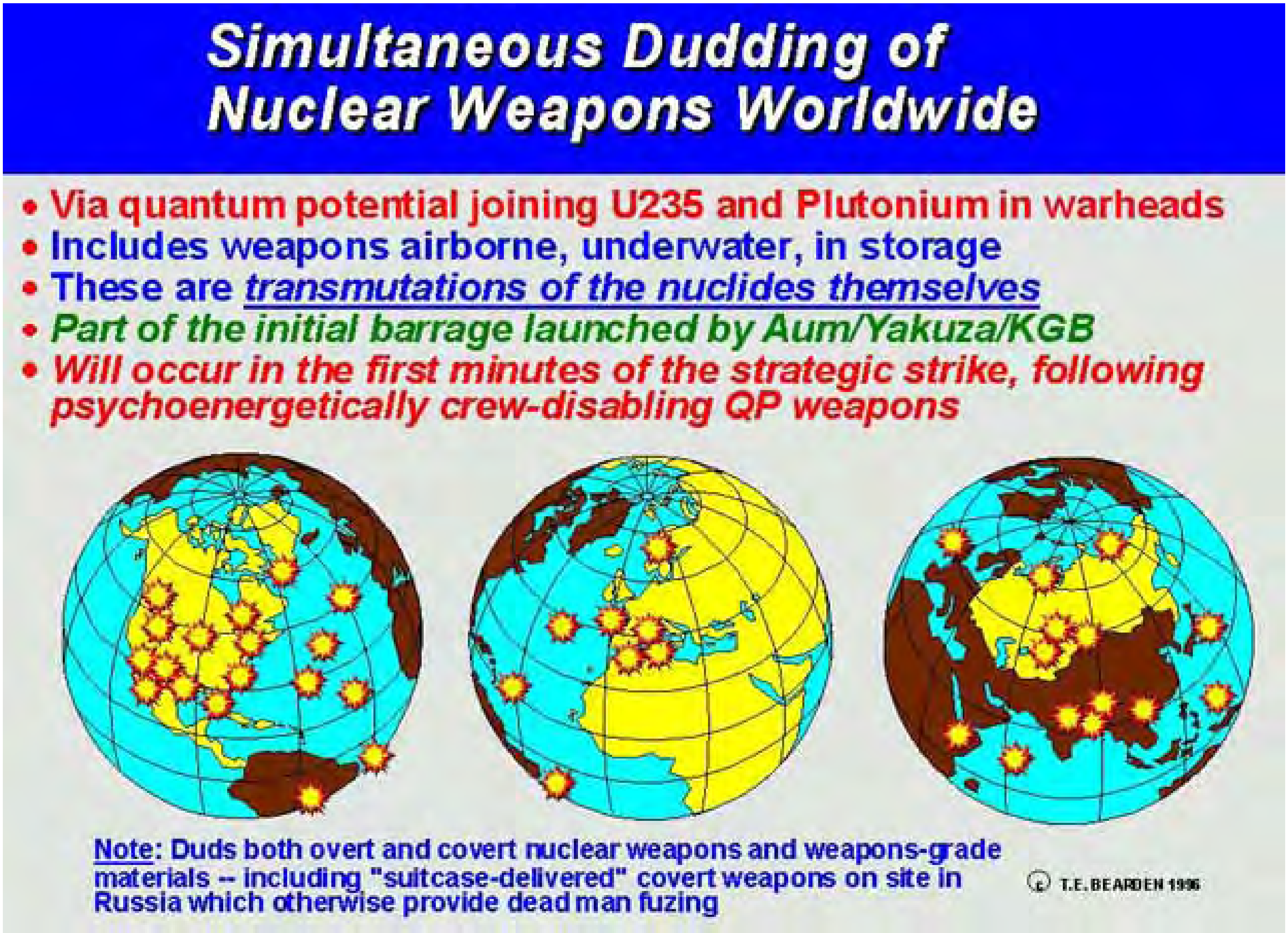

Simultaneous Dudding of Nuclear Weapons Worldwide

- Via quantum potential joining U235 and Plutonium in warheads
- Includes weapons airborne, underwater, in storage
- These are *transmutations of the nuclides themselves*
- *Part of the initial barrage launched by Aum/Yakuza/KGB*
- *Will occur in the first minutes of the strategic strike, following psychoenergetically crew-disabling QP weapons*

Note: Duds both overt and covert nuclear weapons and weapons-grade materials -- including "suitcase-delivered" covert weapons on site in Russia which otherwise provide dead man fuzing

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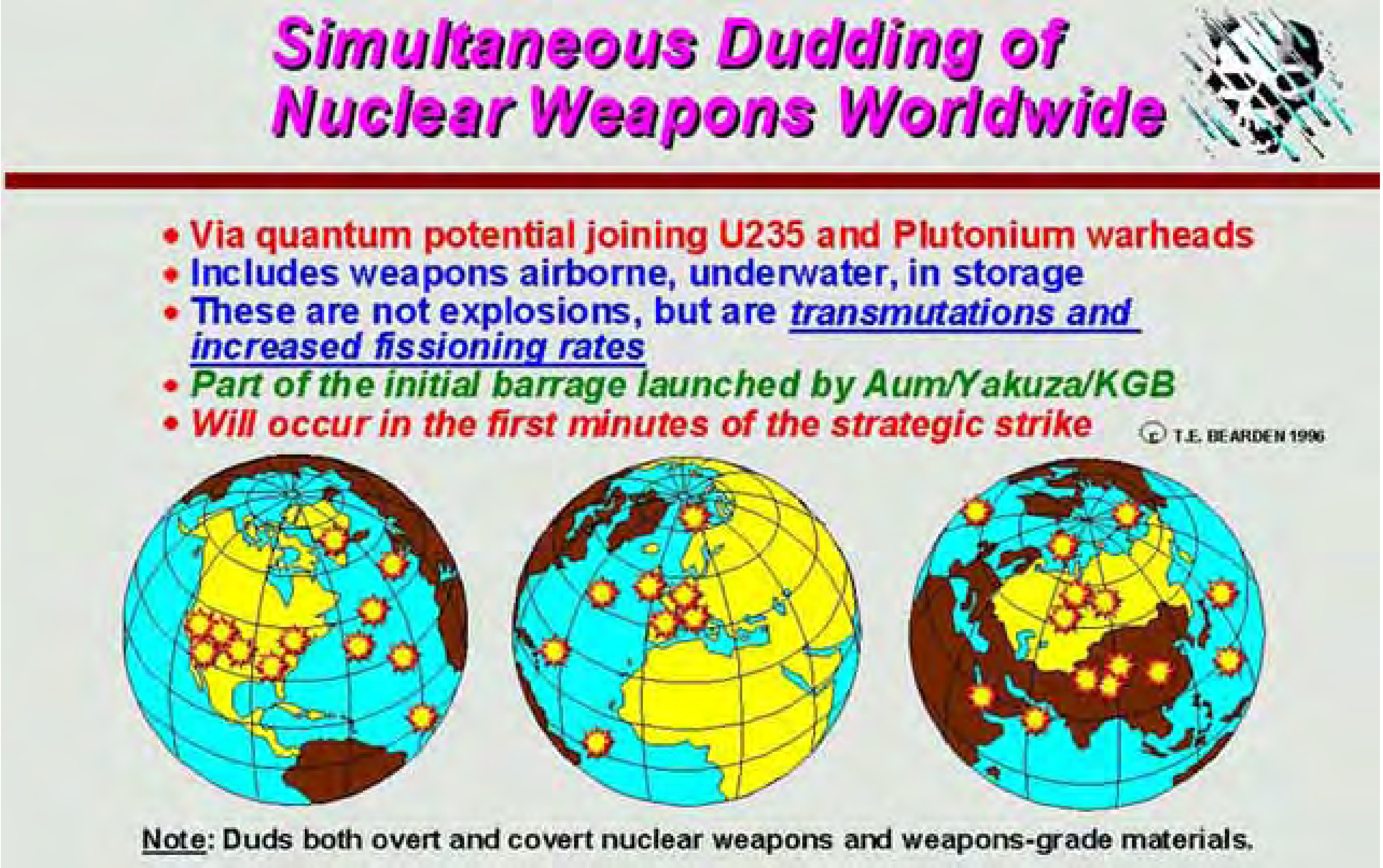

Simultaneous Dudding of Nuclear Weapons Worldwide

- Via quantum potential joining U235 and Plutonium warheads
- Includes weapons airborne, underwater, in storage
- These are not explosions, but are *transmutations and increased fissioning rates*
- *Part of the initial barrage launched by Aum/Yakuza/KGB*
- *Will occur in the first minutes of the strategic strike*

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Note: Duds both overt and covert nuclear weapons and weapons-grade materials.

The Tom Bearden Website

Help support the research

Operation Divine Wind II

Slide 1

Slide 2

Slide 3

Slide 4

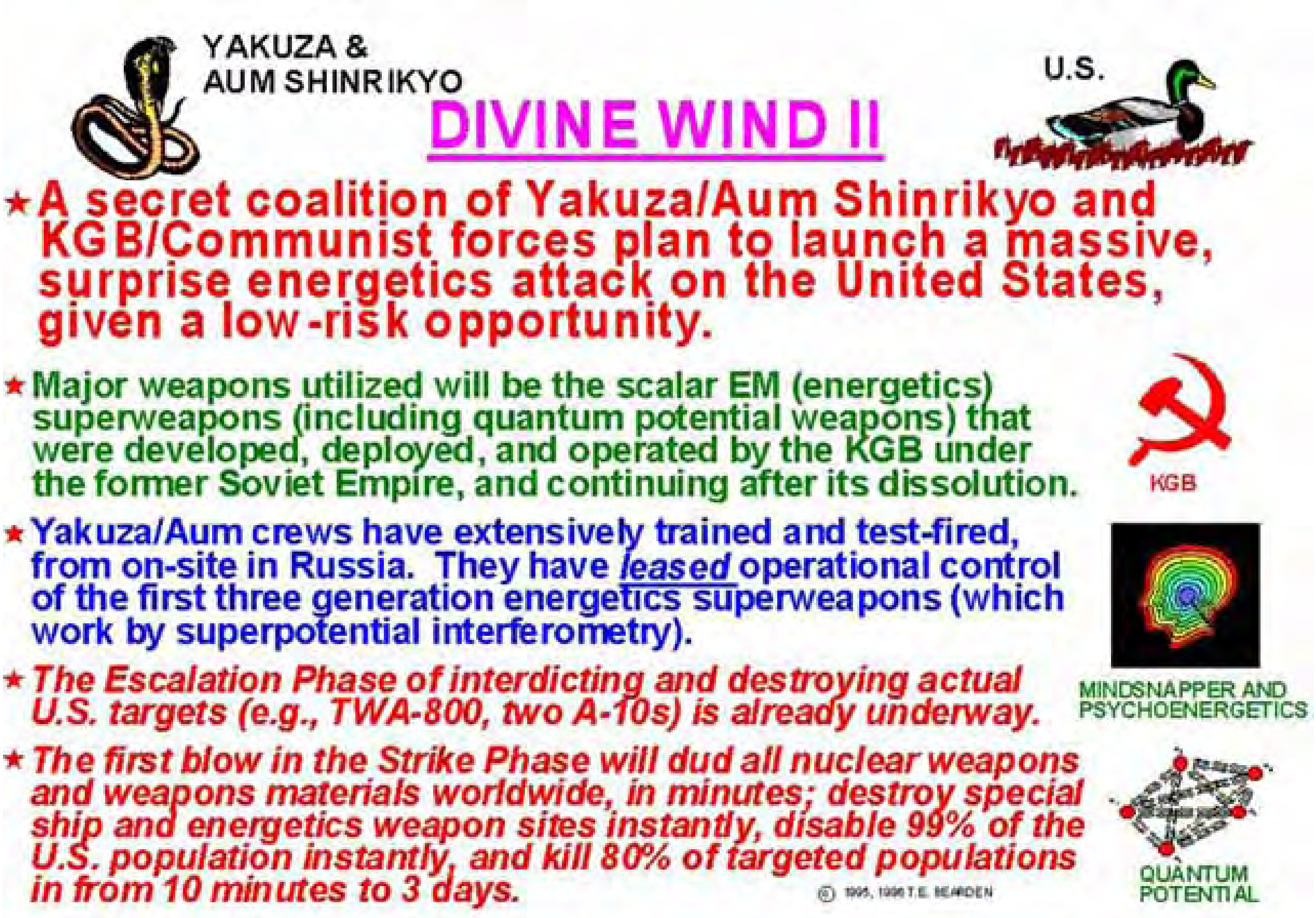

YAKUZA &
AUM SHINRIKYO

U.S.

DIVINE WIND II

- **A secret coalition of Yakuza/Aum Shinrikyo and KGB/Communist forces plan to launch a massive, surprise energetics attack on the United States, given a low-risk opportunity.**
- Major weapons utilized will be the scalar EM (energetics) superweapons (including quantum potential weapons) that were developed, deployed, and operated by the KGB under the former Soviet Empire, and continuing after its dissolution.
- Yakuza/Aum crews have extensively trained and test-fired, from on-site in Russia. They have *leased* operational control of the first three generation energetics superweapons (which work by superpotential interferometry).
- *The Escalation Phase of interdicting and destroying actual U.S. targets (e.g., TWA-800, two A-10s) is already underway.*
- *The first blow in the Strike Phase will dud all nuclear weapons and weapons materials worldwide, in minutes; destroy special ship and energetics weapon sites instantly, disable 99% of the U.S. population instantly, and kill 80% of targeted populations in from 10 minutes to 3 days.*

KGB

MINDSNAPPER AND
PSYCHOENERGETICS

QUANTUM
POTENTIAL

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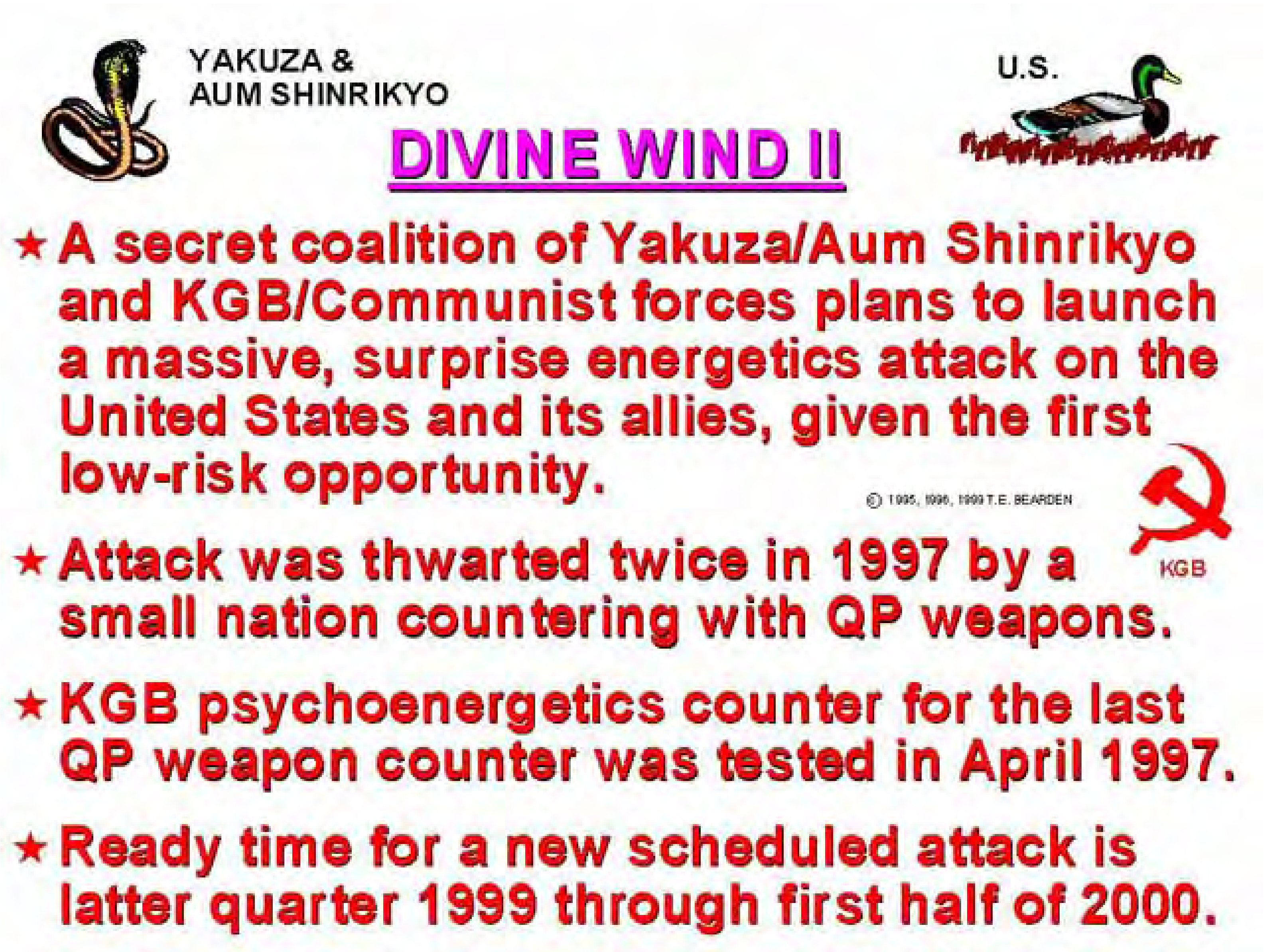

YAKUZA &
AUM SHINRIKYO

U.S.

DIVINE WIND II

- ★ A secret coalition of Yakuza/Aum Shinrikyo and KGB/Communist forces plans to launch a massive, surprise energetics attack on the United States and its allies, given the first low-risk opportunity.

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KGB

- ★ Attack was thwarted twice in 1997 by a small nation countering with QP weapons.
- ★ KGB psychoenergetics counter for the last QP weapon counter was tested in April 1997.
- ★ Ready time for a new scheduled attack is latter quarter 1999 through first half of 2000.

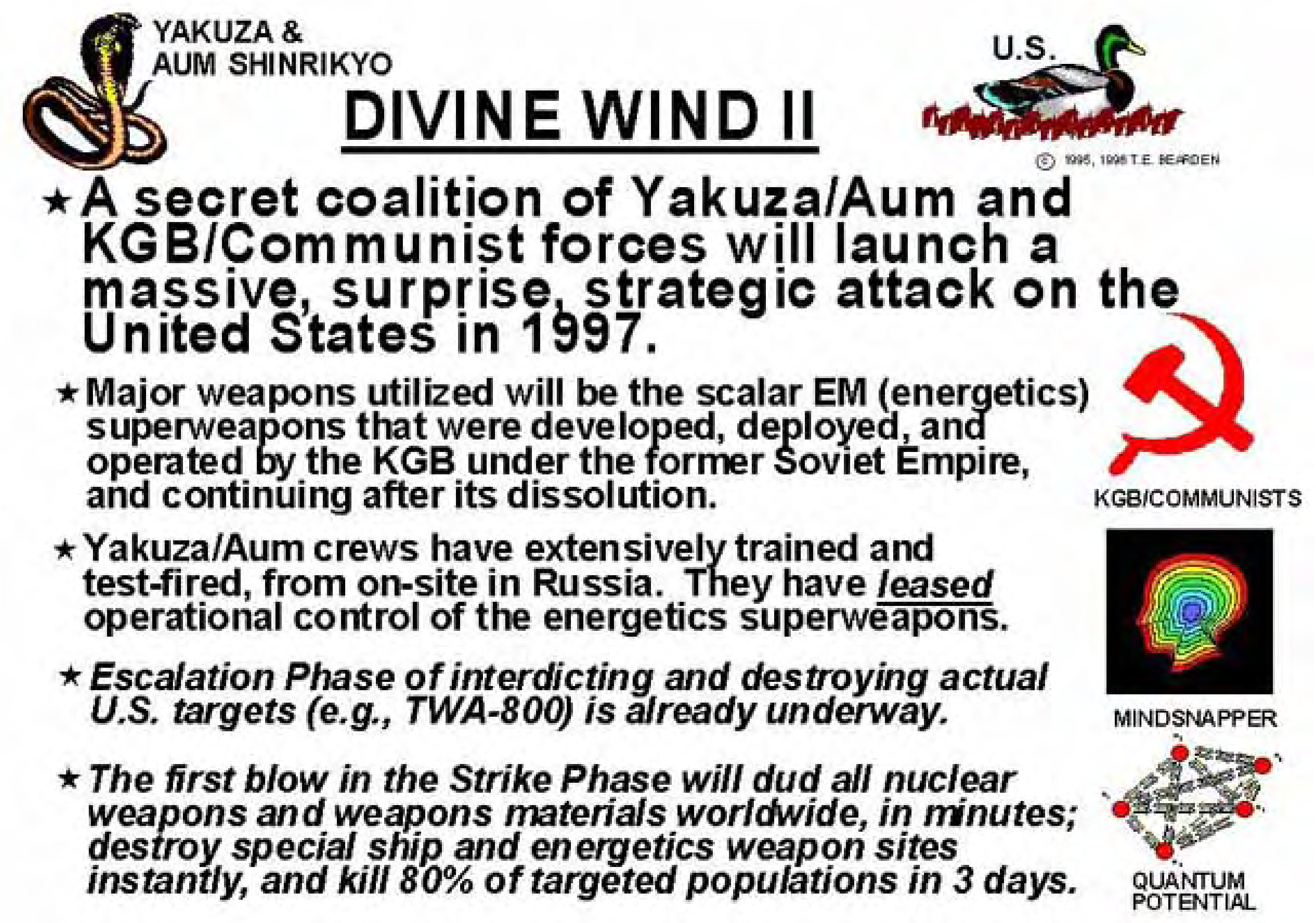

YAKUZA &
AUM SHINRIKYO

U.S.

DIVINE WIND II

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- **A secret coalition of Yakuza/Aum and KGB/Communist forces will launch a massive, surprise, strategic attack on the United States in 1997.**

- Major weapons utilized will be the scalar EM (energetics) superweapons that were developed, deployed, and operated by the KGB under the former Soviet Empire, and continuing after its dissolution.

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KGB/COMMUNISTS

MINDSNAPPER

QUANTUM
POTENTIAL

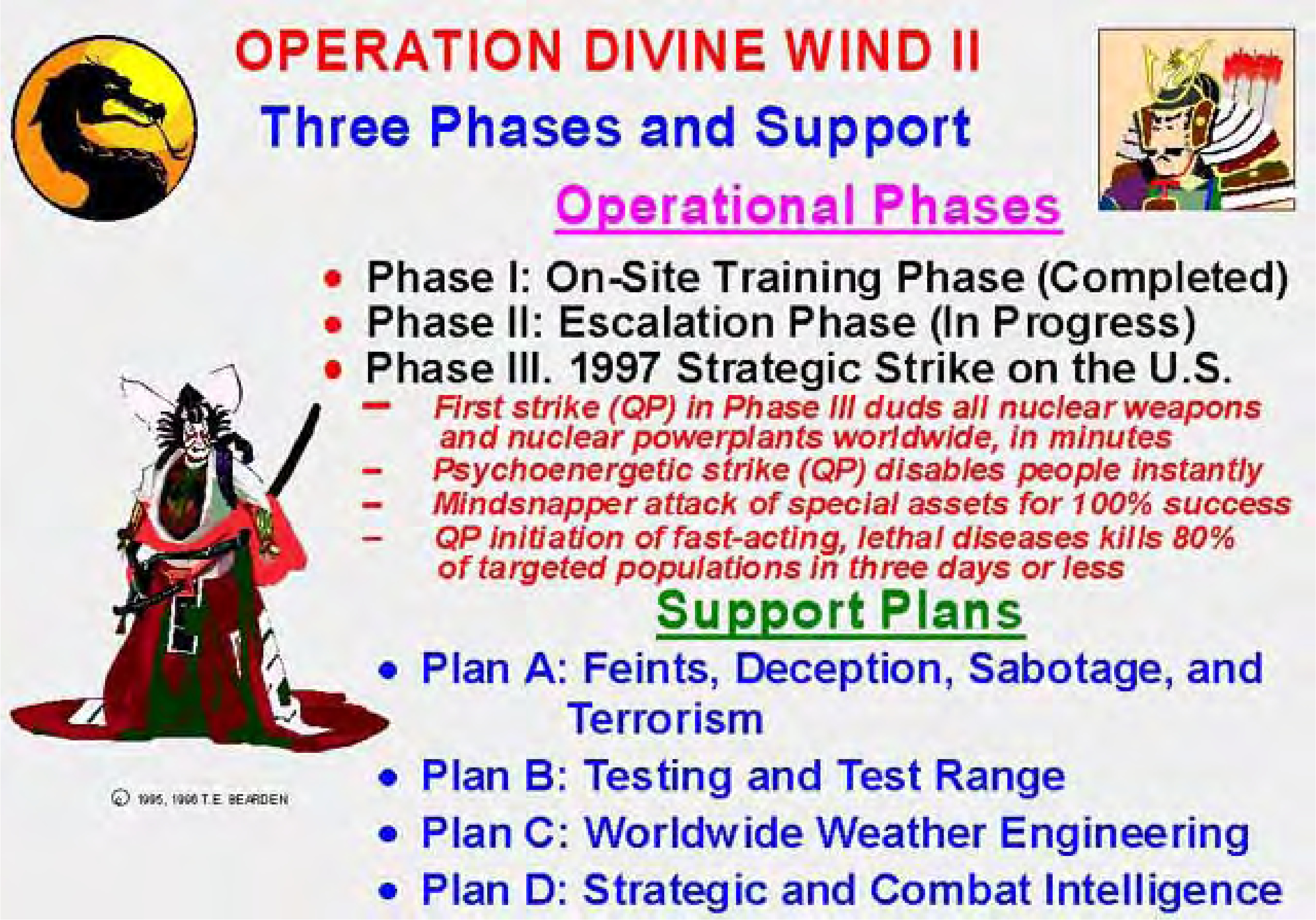

OPERATION DIVINE WIND II

Three Phases and Support

Operational Phases

- Phase I: On-Site Training Phase (Completed)
- Phase II: Escalation Phase (In Progress)
- Phase III. 1997 Strategic Strike on the U.S.
  - *First strike (QP) in Phase III duds all nuclear weapons and nuclear powerplants worldwide, in minutes*
  - *Psychoenergetic strike (QP) disables people instantly*
  - *Mindsnapper attack of special assets for 100% success*
  - *QP initiation of fast-acting, lethal diseases kills 80% of targeted populations in three days or less*

Support Plans

- Plan A: Feints, Deception, Sabotage, and Terrorism
- Plan B: Testing and Test Range
- Plan C: Worldwide Weather Engineering
- Plan D: Strategic and Combat Intelligence

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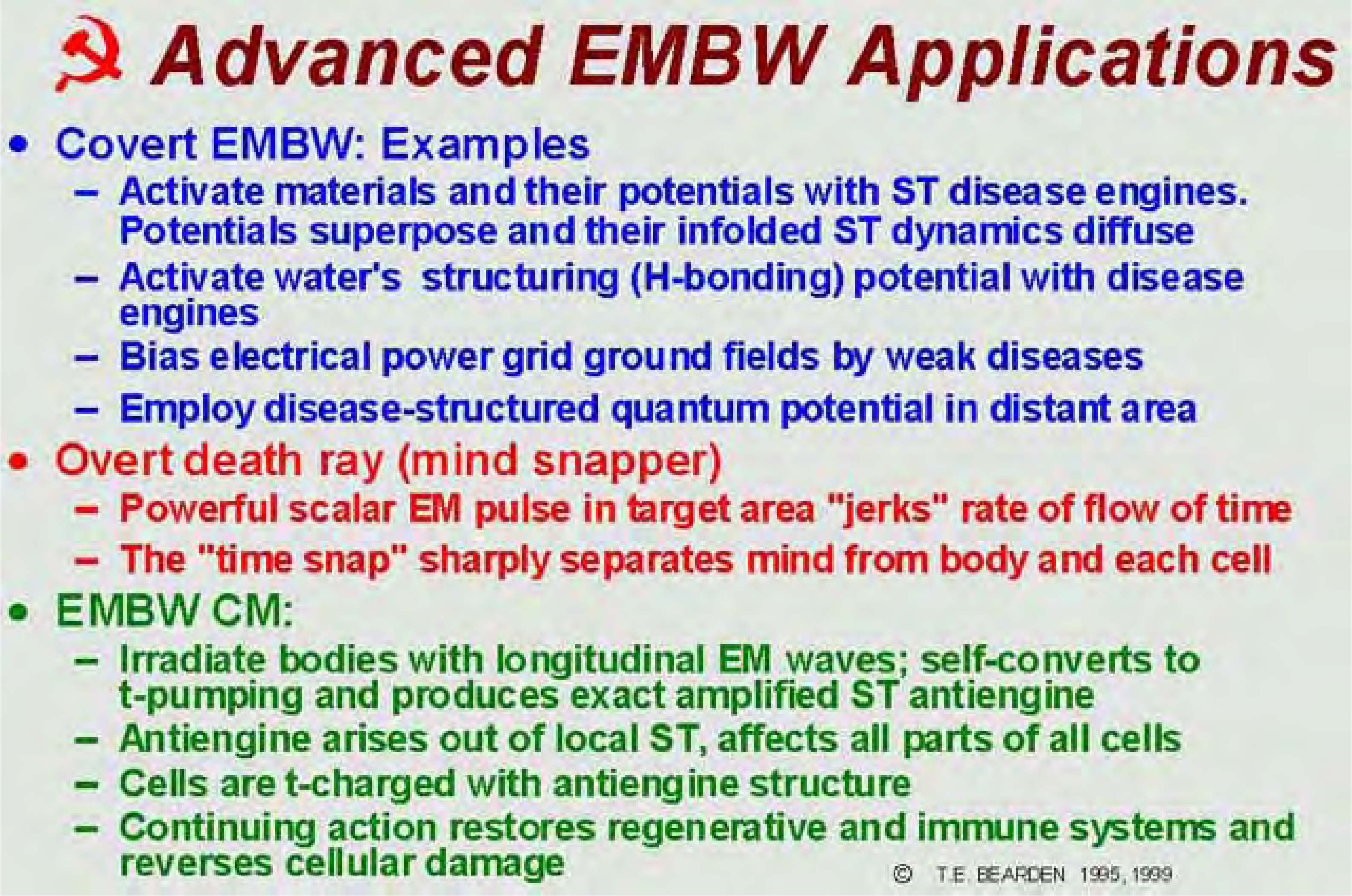

Advanced EMBW Applications

- Covert EMBW: Examples
  - Activate materials and their potentials with ST disease engines. Potentials superpose and their infolded ST dynamics diffuse
  - Activate water's structuring (H-bonding) potential with disease engines
  - Bias electrical power grid ground fields by weak diseases
  - Employ disease-structured quantum potential in distant area
- Overt death ray (mind snapper)
  - Powerful scalar EM pulse in target area "jerks" rate of flow of time
  - The "time snap" sharply separates mind from body and each cell
- EMBW CM:
  - Irradiate bodies with longitudinal EM waves; self-converts to t-pumping and produces exact amplified ST antiengine
  - Antiengine arises out of local ST, affects all parts of all cells
  - Cells are t-charged with antiengine structure
  - Continuing action restores regenerative and immune systems and reverses cellular damage

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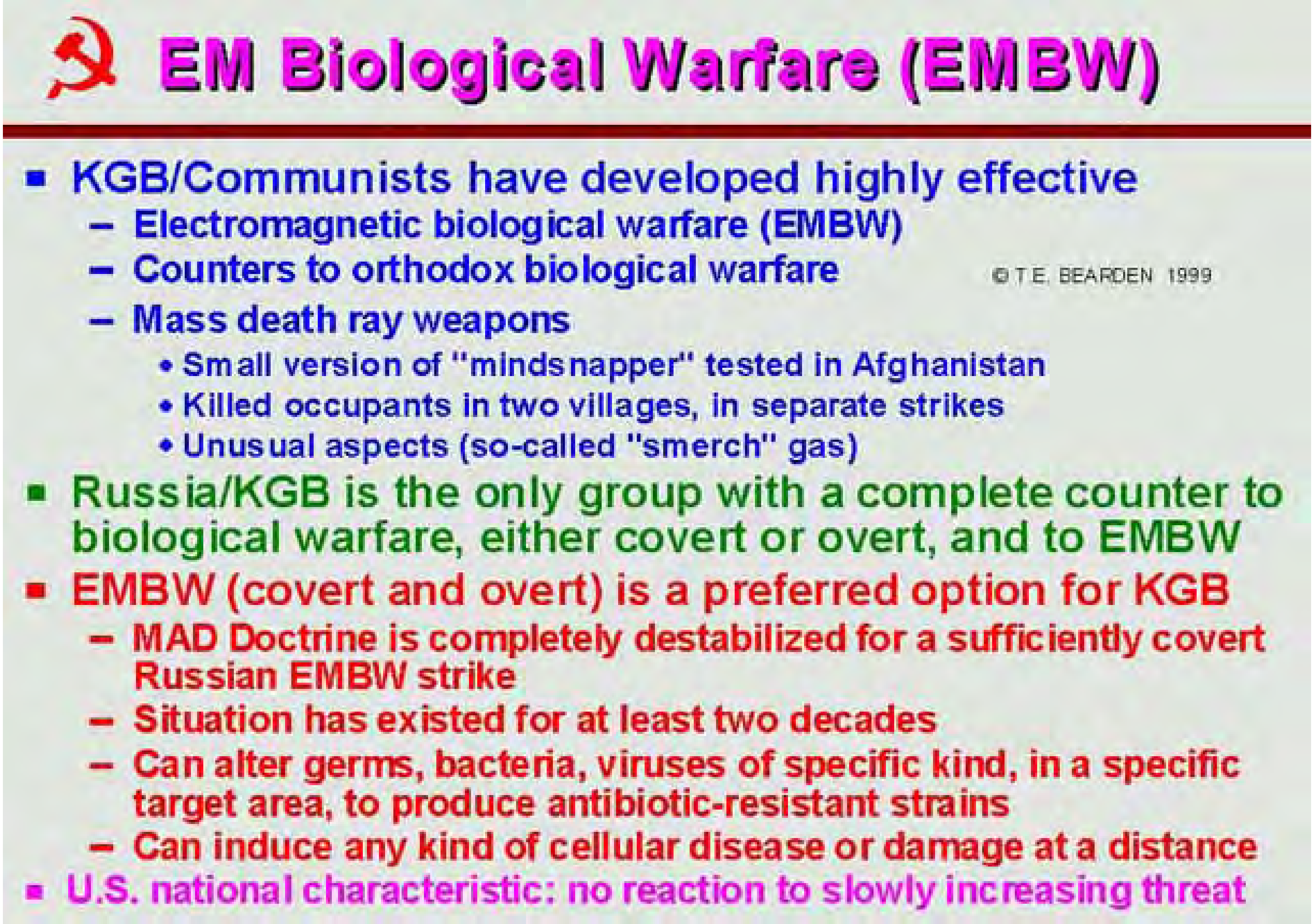

EM Biological Warfare (EMBW)

- KGB/Communists have developed highly effective
  - Electromagnetic biological warfare (EMBW)
  - Counters to orthodox biological warfare
  - Mass death ray weapons
    - Small version of "mindsnapper" tested in Afghanistan
    - Killed occupants in two villages, in separate strikes
    - Unusual aspects (so-called "smerch" gas)
- Russia/KGB is the only group with a complete counter to biological warfare, either covert or overt, and to EMBW
- EMBW (covert and overt) is a preferred option for KGB
  - MAD Doctrine is completely destabilized for a sufficiently covert Russian EMBW strike
  - Situation has existed for at least two decades
  - Can alter germs, bacteria, viruses of specific kind, in a specific target area, to produce antibiotic-resistant strains
  - Can induce any kind of cellular disease or damage at a distance
- U.S. national characteristic: no reaction to slowly increasing threat

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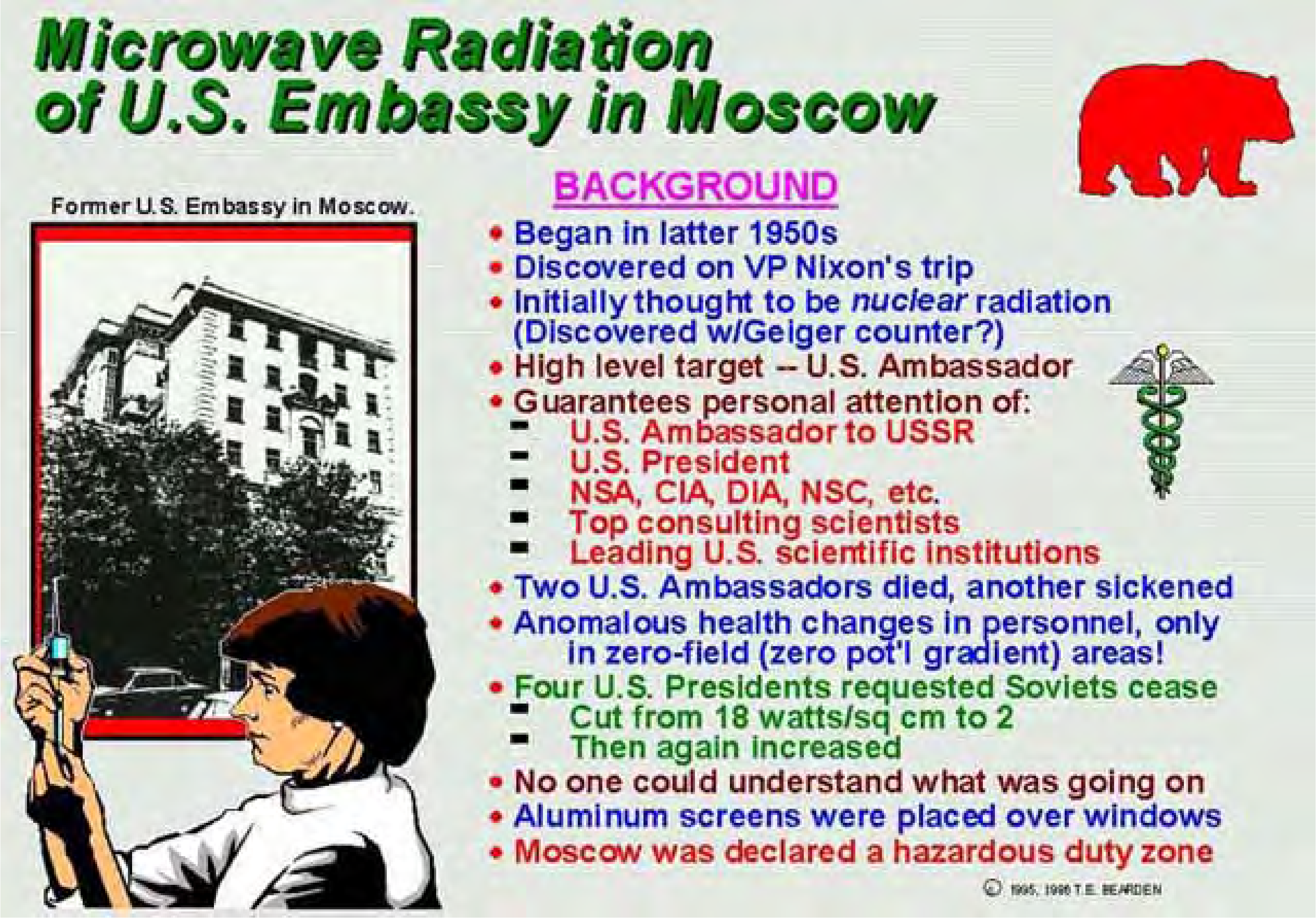

Microwave Radiation of U.S. Embassy in Moscow

Former U.S. Embassy in Moscow.

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter?)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
  - U.S. Ambassador to USSR
  - U.S. President
  - NSA, CIA, DIA, NSC, etc.
  - Top consulting scientists
  - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero pot'l gradient) areas!
- Four U.S. Presidents requested Soviets cease
  - Cut from 18 watts/sq cm to 2
  - Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

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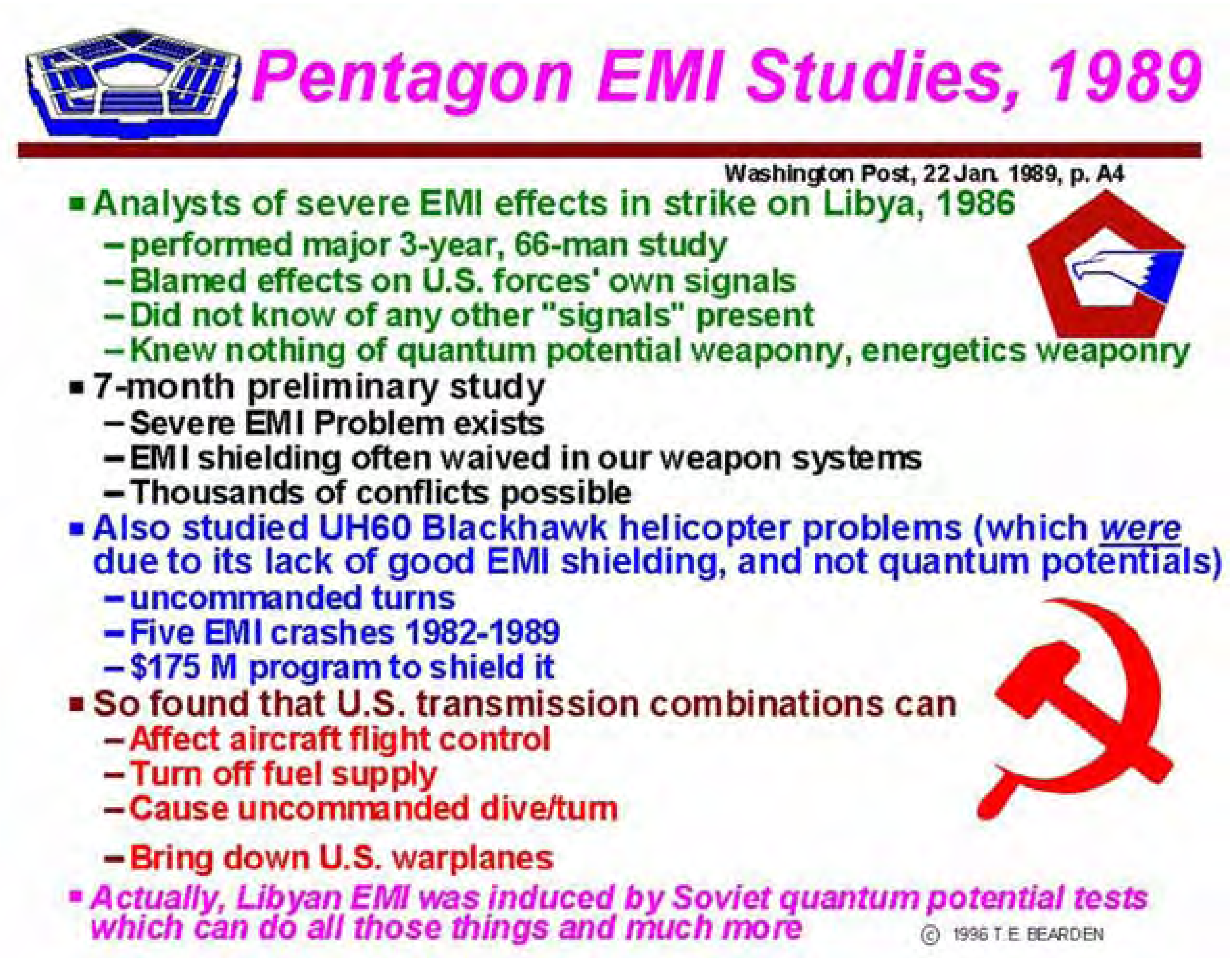

Pentagon EMI Studies, 1989

Washington Post, 22 Jan. 1989, p. A4

- Analysts of severe EMI effects in strike on Libya, 1986
  - performed major 3-year, 66-man study
  - Blamed effects on U.S. forces' own signals
  - Did not know of any other "signals" present
  - Knew nothing of quantum potential weaponry, energetics weaponry
- 7-month preliminary study
  - Severe EMI Problem exists
  - EMI shielding often waived in our weapon systems
  - Thousands of conflicts possible
- Also studied UH60 Blackhawk helicopter problems (which *were* due to its lack of good EMI shielding, and not quantum potentials)
  - uncommanded turns
  - Five EMI crashes 1982-1989
  - $175 M program to shield it
- So found that U.S. transmission combinations can
  - Affect aircraft flight control
  - Turn off fuel supply
  - Cause uncommanded dive/turn
  - Bring down U.S. warplanes
- *Actually, Libyan EMI was induced by Soviet quantum potential tests which can do all those things and much more*

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The Tom Bearden Website

Help support the research

EM Missile Practice

- EM Missile Practice
  Latter Sept. - Early Nov. 1996
  Melbourne, Australia
- Deception: Using EM Missile to Reinforce Notion of SAM Attack
  Saturday evening, Nov. 16, 1996
- Intelligence Probe: Insuring U.S. Still Unaware of Energetics Weaponry
  Thursday, December 12th, 1996
- EM Missile Strike, Offset from Night Shuttle Launch, Cape Canaveral, Florida
  The Smoking Gun in November 1985
- Distant Operator Onsite in Russia Slew Away Registration Point
  Marker Beacon over Night Shuttle Launch, 26 November, 1985
- EM Missile Practice and Deception
  November 17, 1996

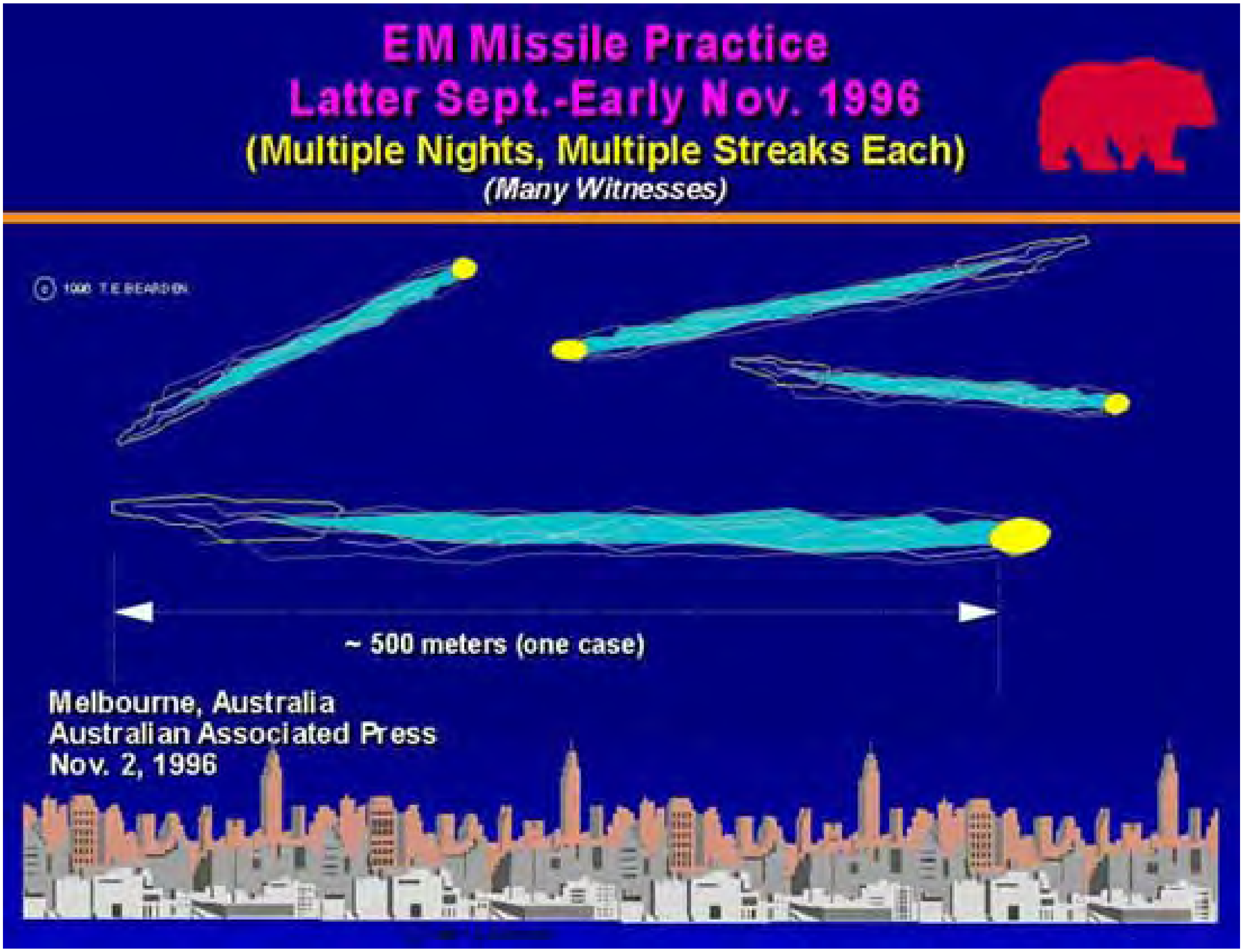

EM Missile Practice
Latter Sept.-Early Nov. 1996

(Multiple Nights, Multiple Streaks Each)

(Many Witnesses)

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Melbourne, Australia
Australian Associated Press
Nov. 2, 1996

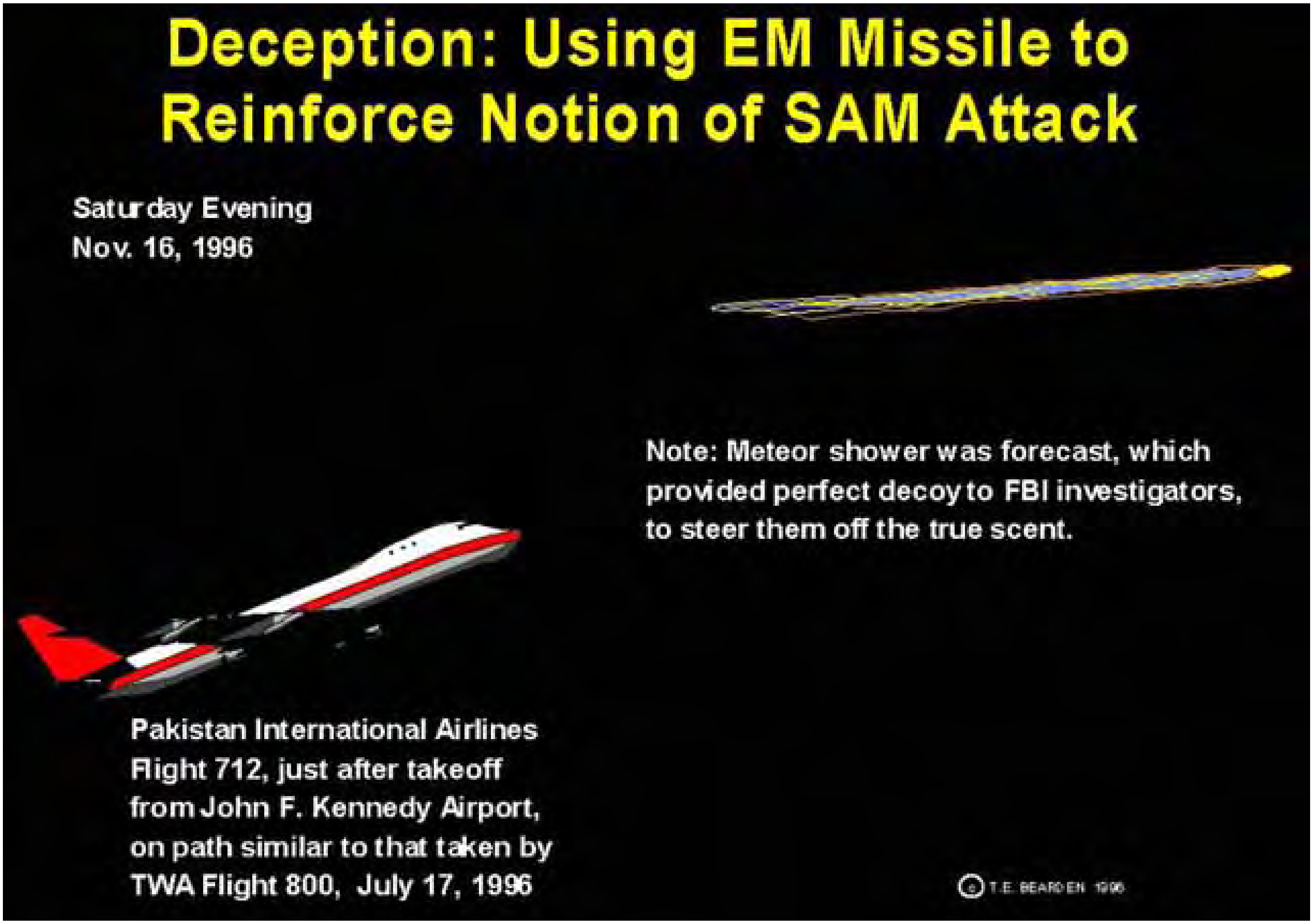

Deception: Using EM Missile to Reinforce Notion of SAM Attack

Saturday Evening
Nov. 16, 1996

Note: Meteor shower was forecast, which provided perfect decoy to FBI investigators, to steer them off the true scent.

Pakistan International Airlines Flight 712, just after takeoff from John F. Kennedy Airport, on path similar to that taken by TWA Flight 800, July 17, 1996

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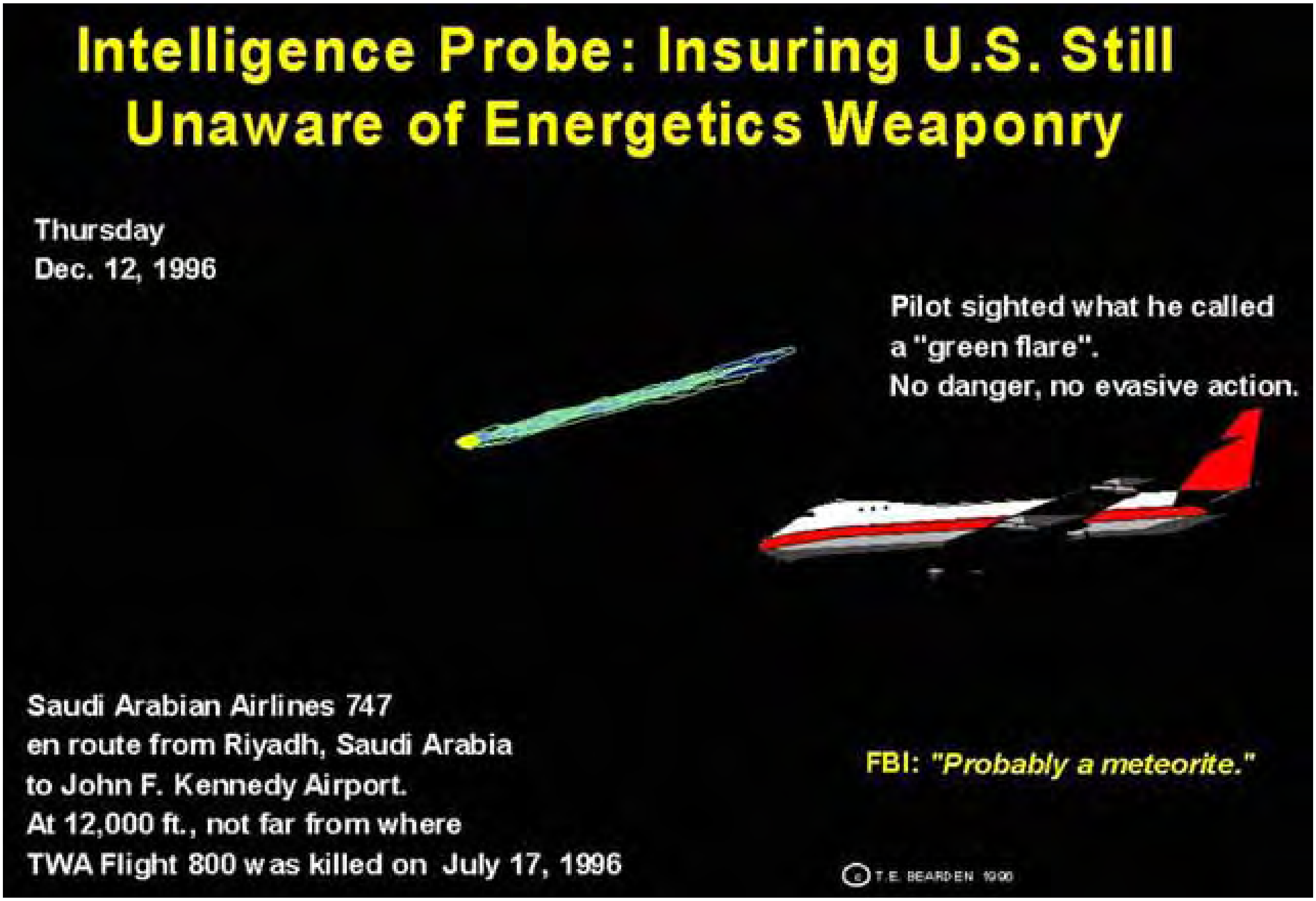

Intelligence Probe: Insuring U.S. Still Unaware of Energetics Weaponry

Thursday
Dec. 12, 1996

Pilot sighted what he called
a "green flare".
No danger, no evasive action.

Saudi Arabian Airlines 747
en route from Riyadh, Saudi Arabia
to John F. Kennedy Airport.
At 12,000 ft., not far from where
TWA Flight 800 was killed on July 17, 1996

FBI: *"Probably a meteorite."*

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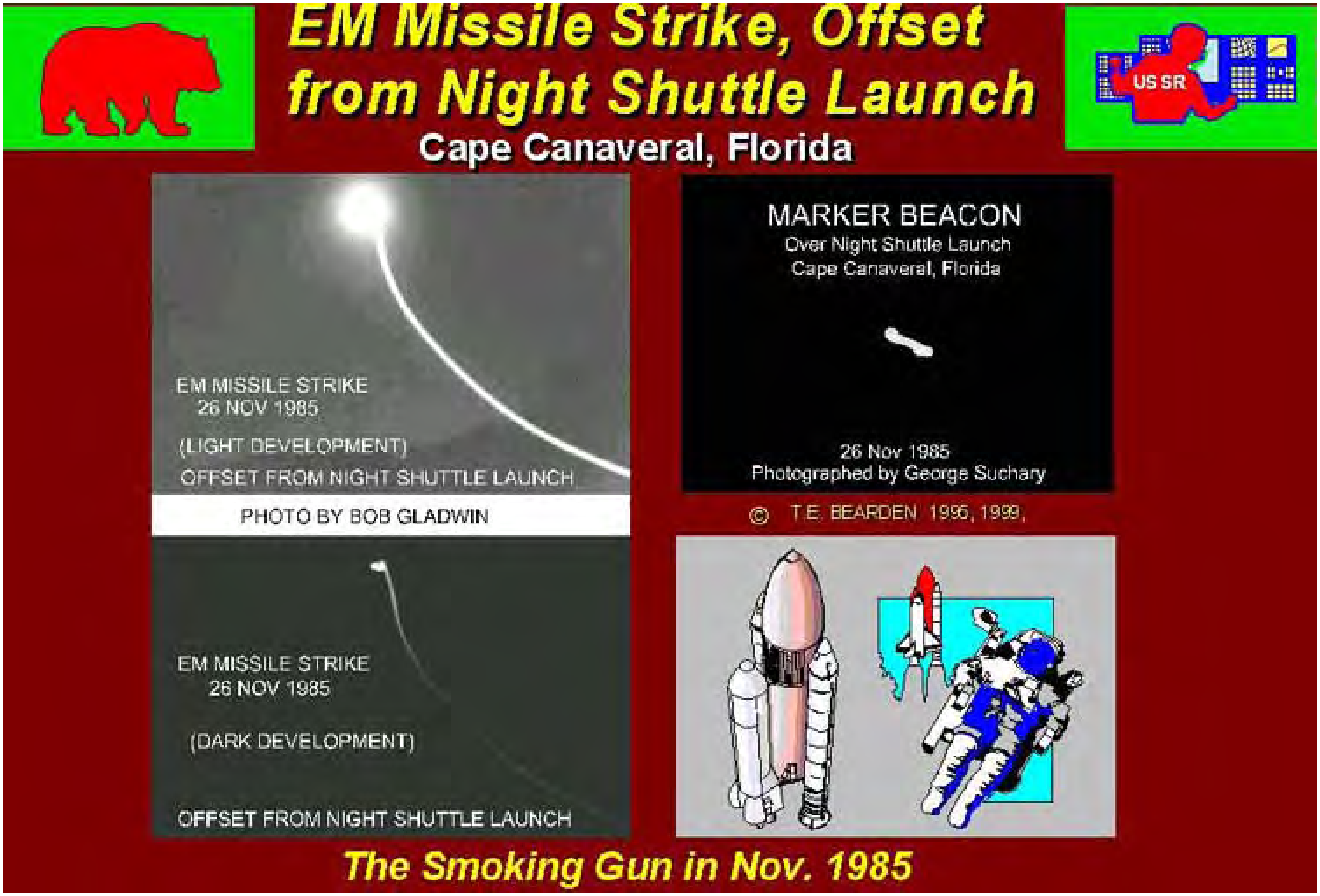

EM Missile Strike, Offset from Night Shuttle Launch

Cape Canaveral, Florida

EM MISSILE STRIKE
26 NOV 1985

(LIGHT DEVELOPMENT)
OFFSET FROM NIGHT SHUTTLE LAUNCH

PHOTO BY BOB GLADWIN

MARKER BEACON
Over Night Shuttle Launch
Cape Canaveral, Florida

26 Nov 1985
Photographed by George Suchary

© T.E. BEARDEN 1996, 1999,

EM MISSILE STRIKE
26 NOV 1985

(DARK DEVELOPMENT)

OFFSET FROM NIGHT SHUTTLE LAUNCH

The Smoking Gun in Nov. 1985

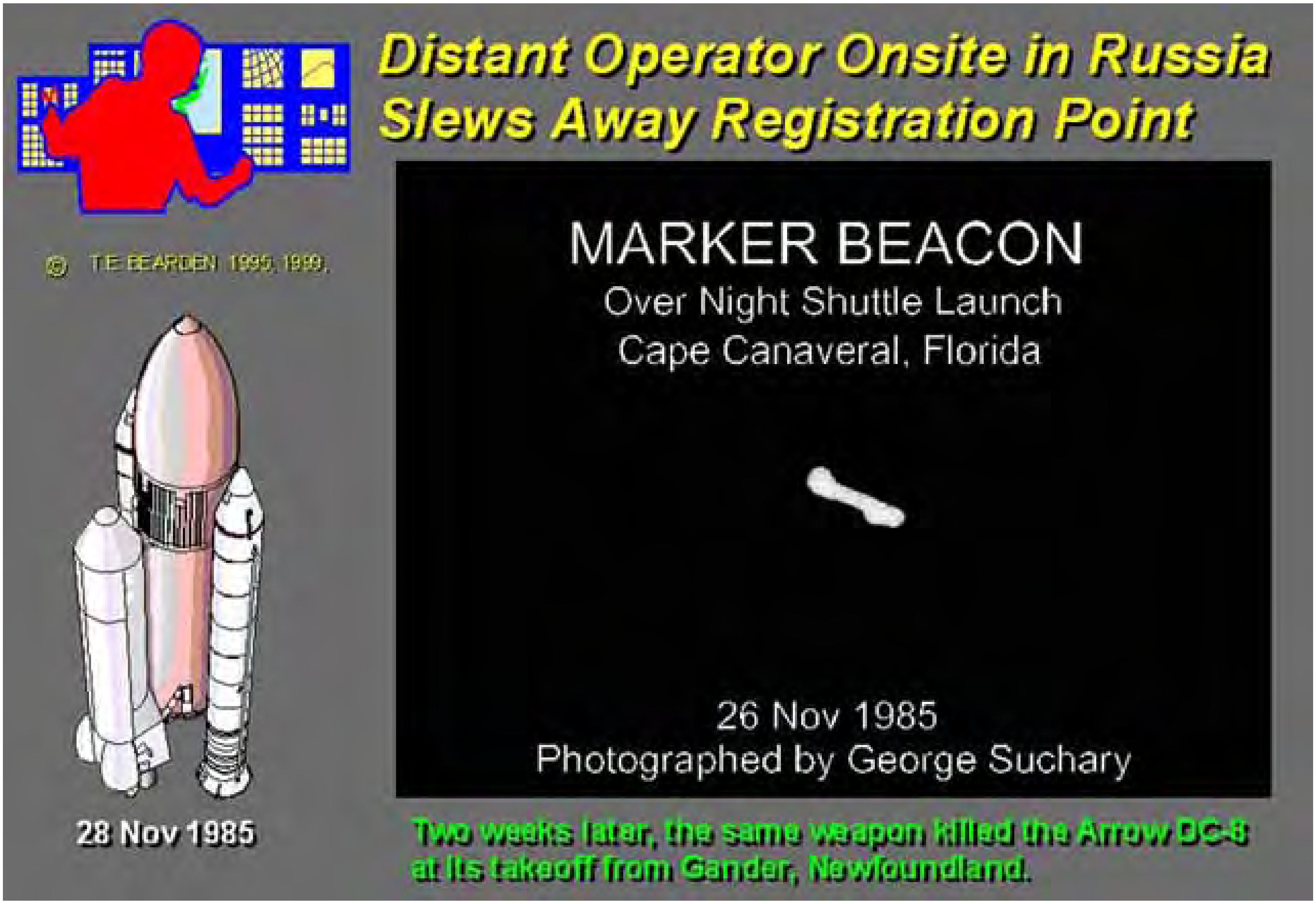

Distant Operator Onsite in Russia Slews Away Registration Point

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MARKER BEACON

Over Night Shuttle Launch
Cape Canaveral, Florida

26 Nov 1985
Photographed by George Suchary

28 Nov 1985

Two weeks later, the same weapon killed the Arrow DC-8 at its takeoff from Gander, Newfoundland.

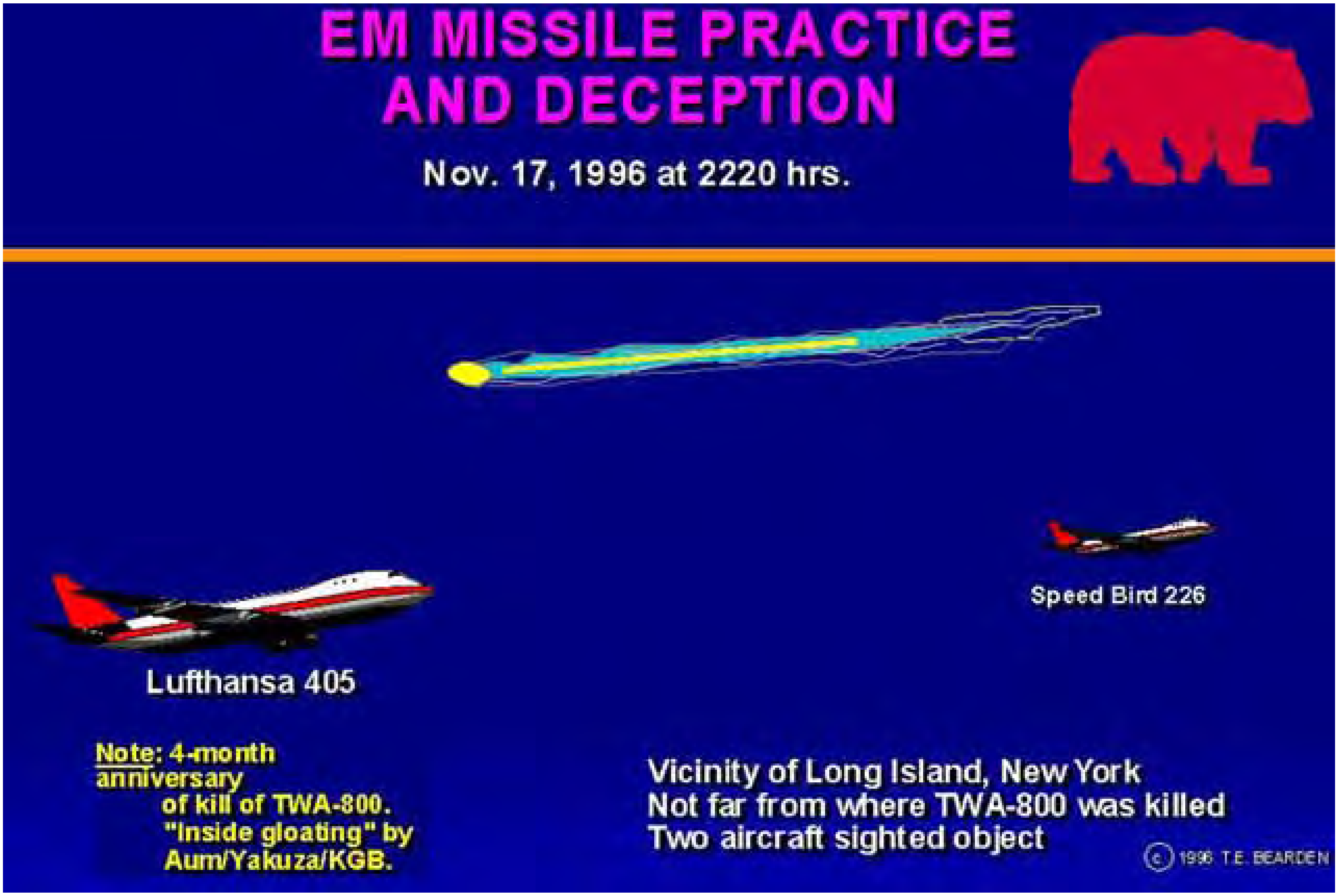

EM MISSILE PRACTICE AND DECEPTION

Nov. 17, 1996 at 2220 hrs.

Speed Bird 226

Lufthansa 405

Note: 4-month
anniversary
of kill of TWA-800.
"Inside gloating" by
Aum/Yakuza/KGB.

Vicinity of Long Island, New York
Not far from where TWA-800 was killed
Two aircraft sighted object

ⓒ 1996 T.E. BEARDEN

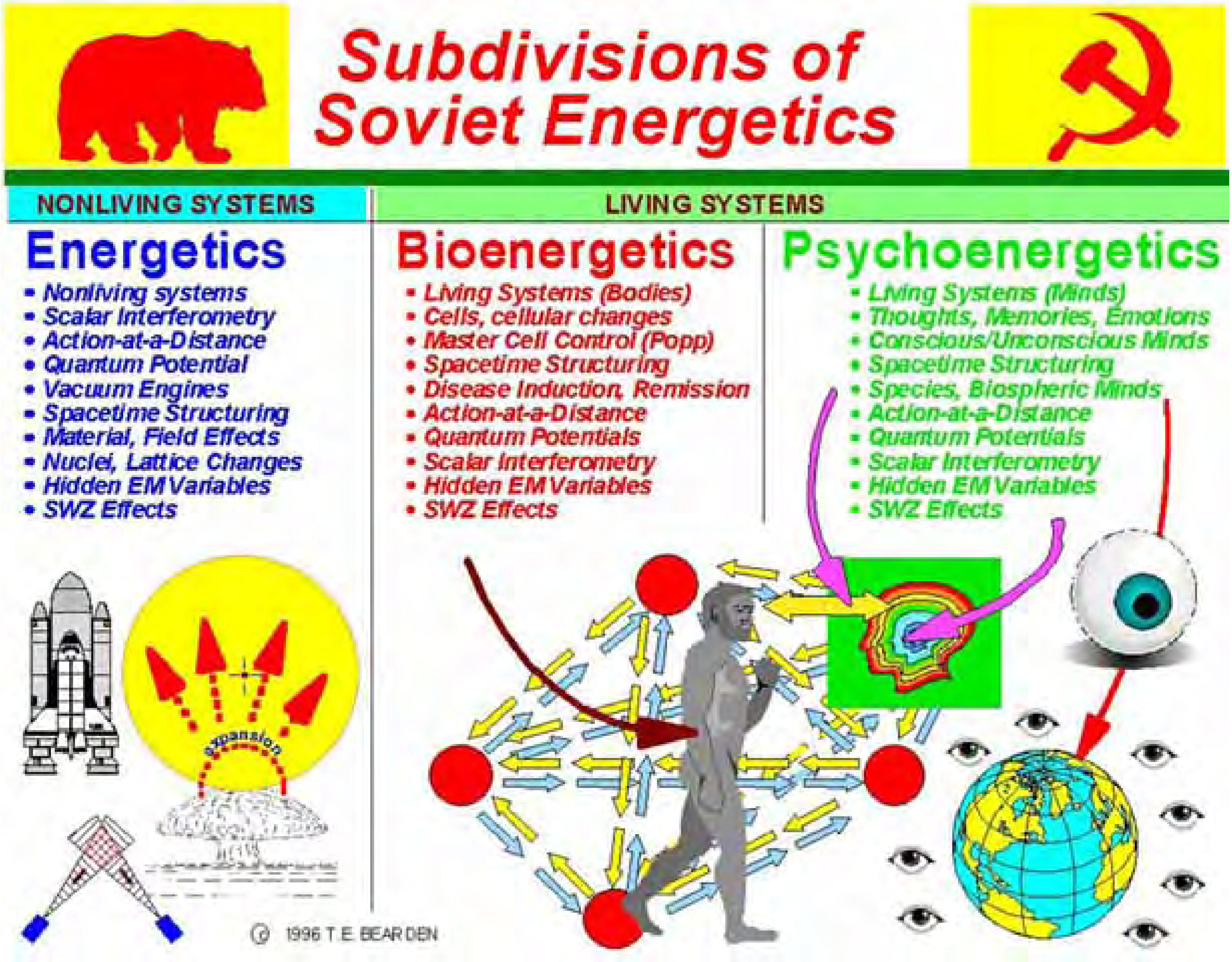

Subdivisions of Soviet Energetics

NONLIVING SYSTEMS

LIVING SYSTEMS

Energetics

- Nonliving systems
- Scalar Interferometry
- Action-at-a-Distance
- Quantum Potential
- Vacuum Engines
- Spacetime Structuring
- Material, Field Effects
- Nuclei, Lattice Changes
- Hidden EM Variables
- SWZ Effects

Bioenergetics

- Living Systems (Bodies)
- Cells, cellular changes
- Master Cell Control (Popp)
- Spacetime Structuring
- Disease Induction, Remission
- Action-at-a-Distance
- Quantum Potentials
- Scalar Interferometry
- Hidden EM Variables
- SWZ Effects

Psychoenergetics

- Living Systems (Minds)
- Thoughts, Memories, Emotions
- Conscious/Unconscious Minds
- Spacetime Structuring
- Species, Biospheric Minds
- Action-at-a-Distance
- Quantum Potentials
- Scalar Interferometry
- Hidden EM Variables
- SWZ Effects

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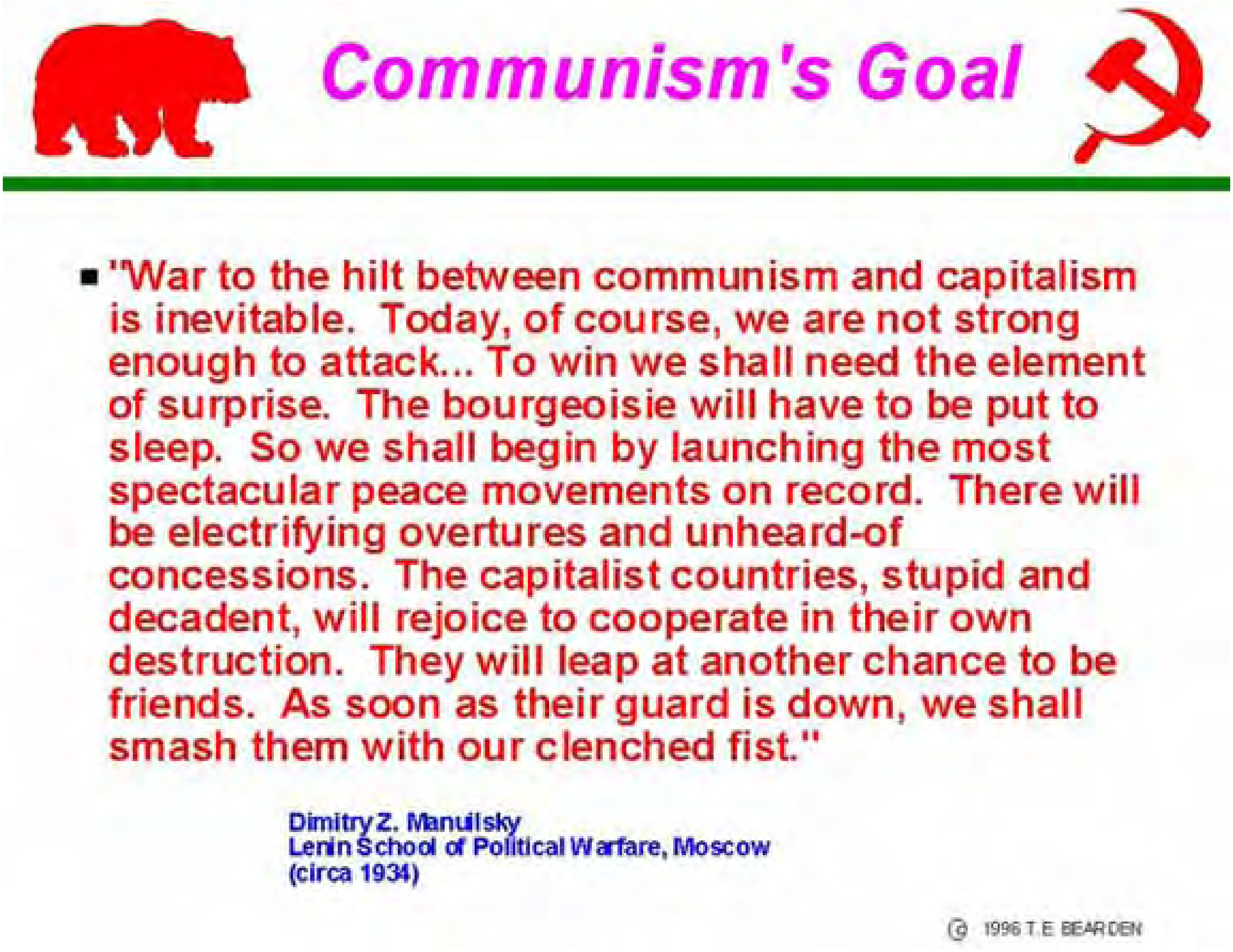

Communism's Goal

- "War to the hilt between communism and capitalism is inevitable. Today, of course, we are not strong enough to attack... To win we shall need the element of surprise. The bourgeoisie will have to be put to sleep. So we shall begin by launching the most spectacular peace movements on record. There will be electrifying overtures and unheard-of concessions. The capitalist countries, stupid and decadent, will rejoice to cooperate in their own destruction. They will leap at another chance to be friends. As soon as their guard is down, we shall smash them with our clenched fist."

Dimitry Z. Manuilsky
Lenin School of Political Warfare, Moscow
(circa 1934)

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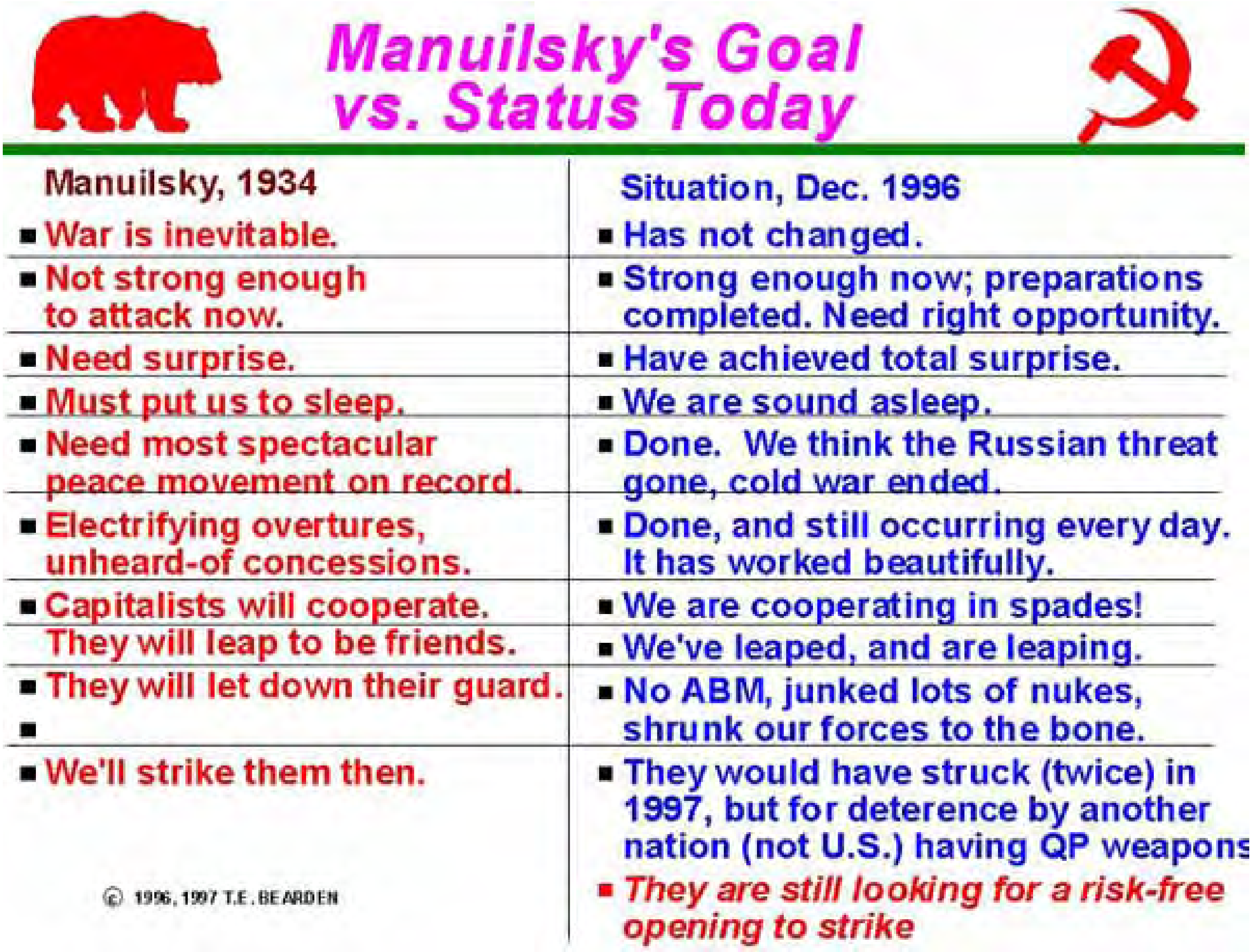

Manuilsky's Goal vs. Status Today

Manuilsky, 1934	Situation, Dec. 1996
■ War is inevitable.	■ Has not changed.
■ Not strong enough to attack now.	■ Strong enough now; preparations completed. Need right opportunity.
■ Need surprise.	■ Have achieved total surprise.
■ Must put us to sleep.	■ We are sound asleep.
■ Need most spectacular peace movement on record.	■ Done. We think the Russian threat gone, cold war ended.
■ Electrifying overtures, unheard-of concessions.	■ Done, and still occurring every day. It has worked beautifully.
■ Capitalists will cooperate.	■ We are cooperating in spades!
They will leap to be friends.	■ We've leaped, and are leaping.
■ They will let down their guard. ■	■ No ABM, junked lots of nukes, shrunk our forces to the bone.
■ We'll strike them then.	■ They would have struck (twice) in 1997, but for deterence by another nation (not U.S.) having QP weapons ■ *They are still looking for a risk-free opening to strike*

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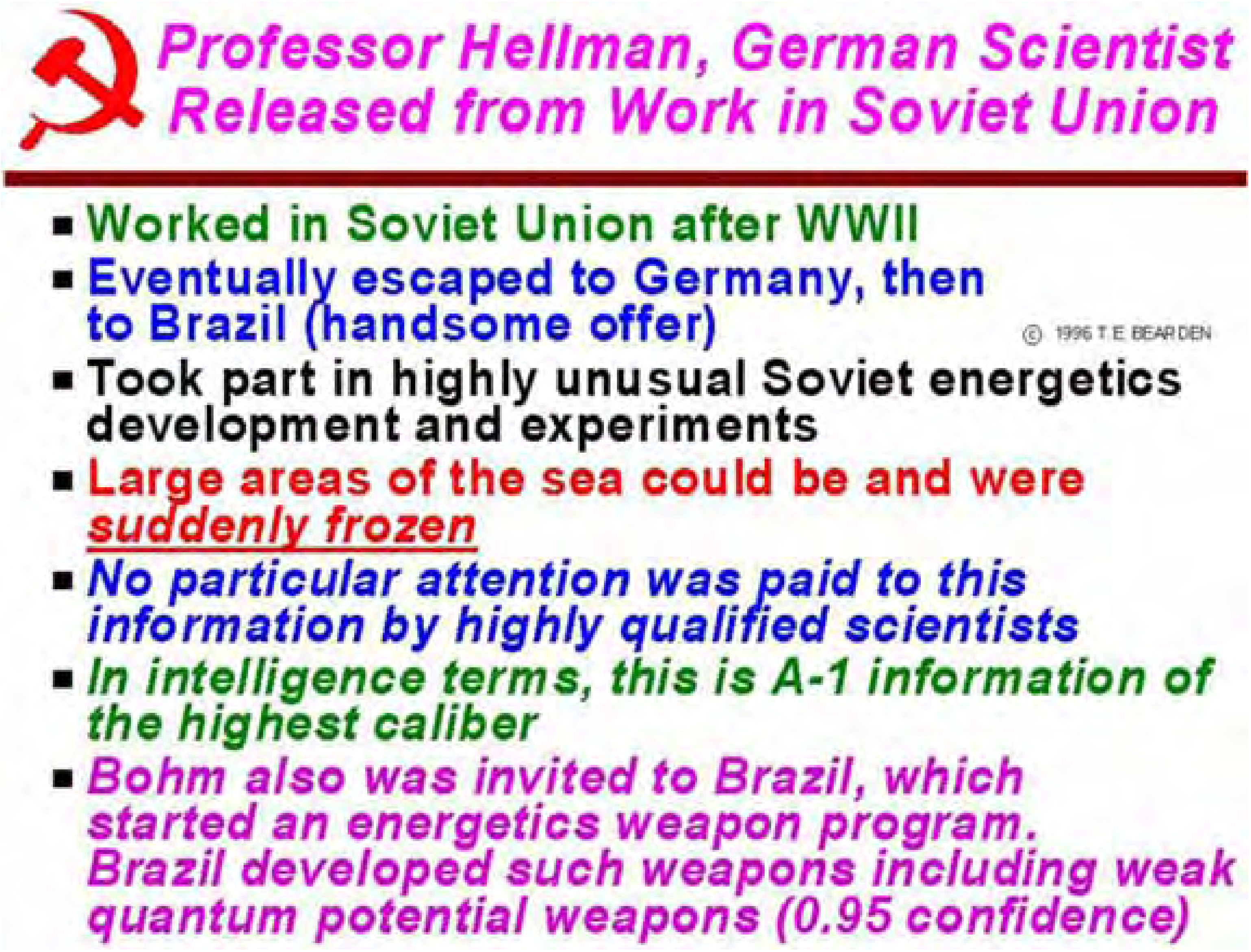

Professor Hellman, German Scientist Released from Work in Soviet Union

- Worked in Soviet Union after WWII
- Eventually escaped to Germany, then to Brazil (handsome offer)
- Took part in highly unusual Soviet energetics development and experiments
- Large areas of the sea could be and were *suddenly frozen*
- *No particular attention was paid to this information by highly qualified scientists*
- *In intelligence terms, this is A-1 information of the highest caliber*
- *Bohm also was invited to Brazil, which started an energetics weapon program. Brazil developed such weapons including weak quantum potential weapons (0.95 confidence)*

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Hemispheres of Light

- March 20th, 1969
  Caribbean and Western North Atlantic
- Hemisphere and Globes, 1977
  24 March, 1977
- Virgin Islands Incident
  August 1969
- Typical Shield Test, Northern Route to Japan
  June, 1982

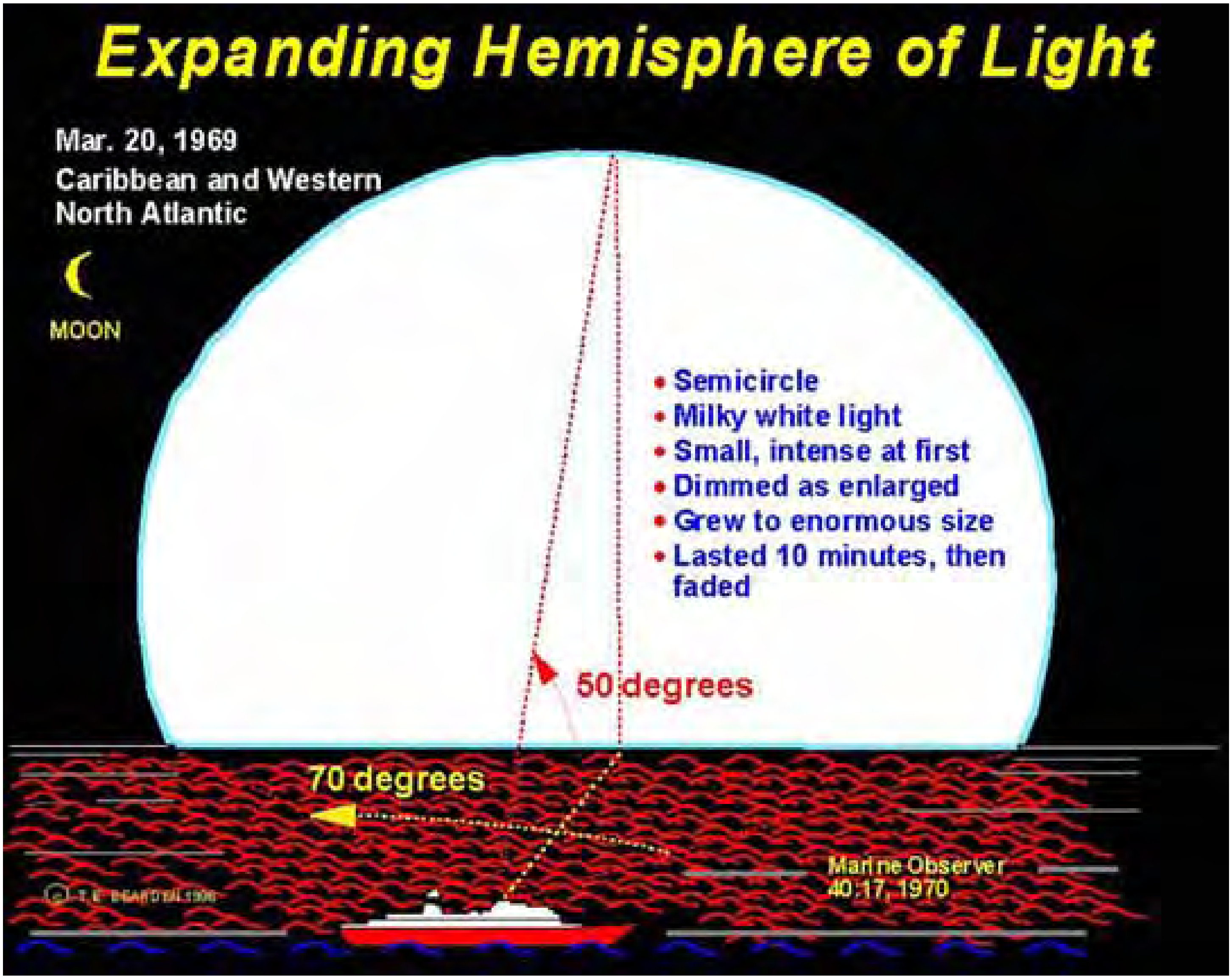

Expanding Hemisphere of Light

Mar. 20, 1969
Caribbean and Western
North Atlantic

- Semicircle
- Milky white light
- Small, intense at first
- Dimmed as enlarged
- Grew to enormous size
- Lasted 10 minutes, then faded

MOON
50 degrees
70 degrees
Marine Observer
40:17, 1970

© T. E. BEARDEN [illegible]

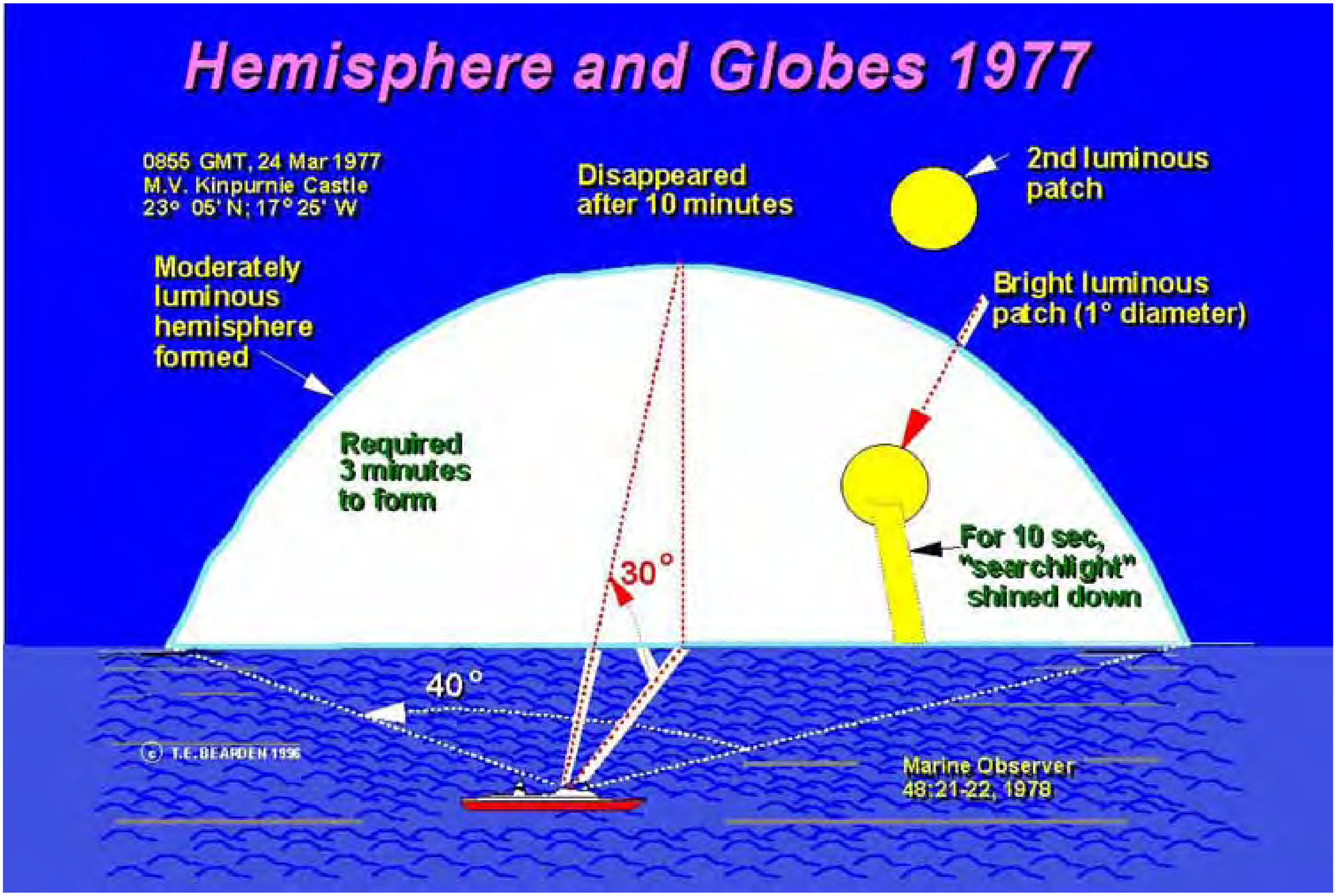
Hemisphere and Globes 1977
0855 GMT, 24 Mar 1977
M.V. Kinpurnie Castle
23° 05' N; 17° 25' W
Disappeared after 10 minutes
2nd luminous patch
Moderately luminous hemisphere formed
Bright luminous patch (1° diameter)
Required 3 minutes to form
For 10 sec, "searchlight" shined down
30°
40°
© T.E. BEARDEN 1996
Marine Observer 48:21-22, 1978

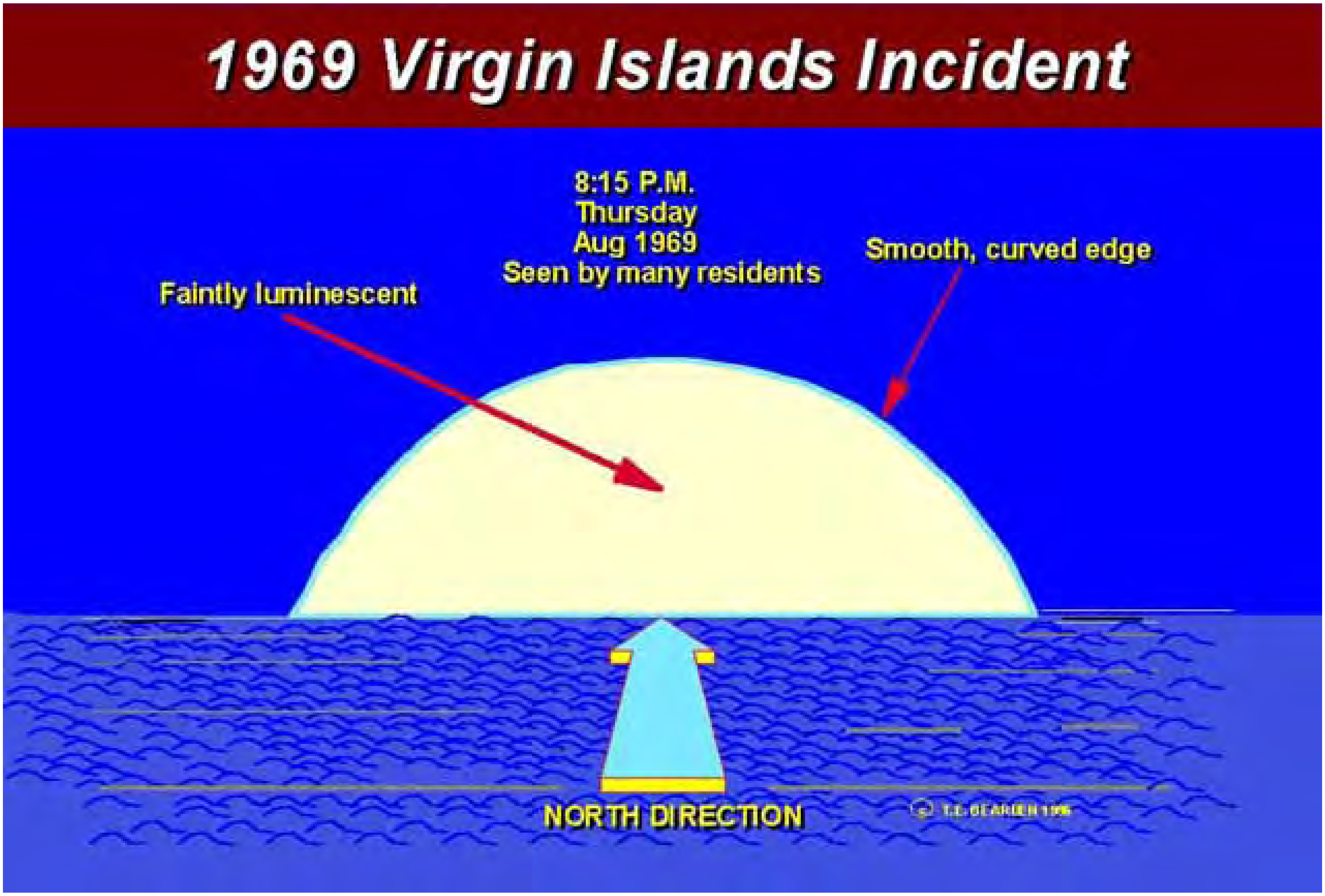

1969 Virgin Islands Incident

8:15 P.M.
Thursday
Aug 1969
Seen by many residents

Faintly luminescent

Smooth, curved edge

NORTH DIRECTION

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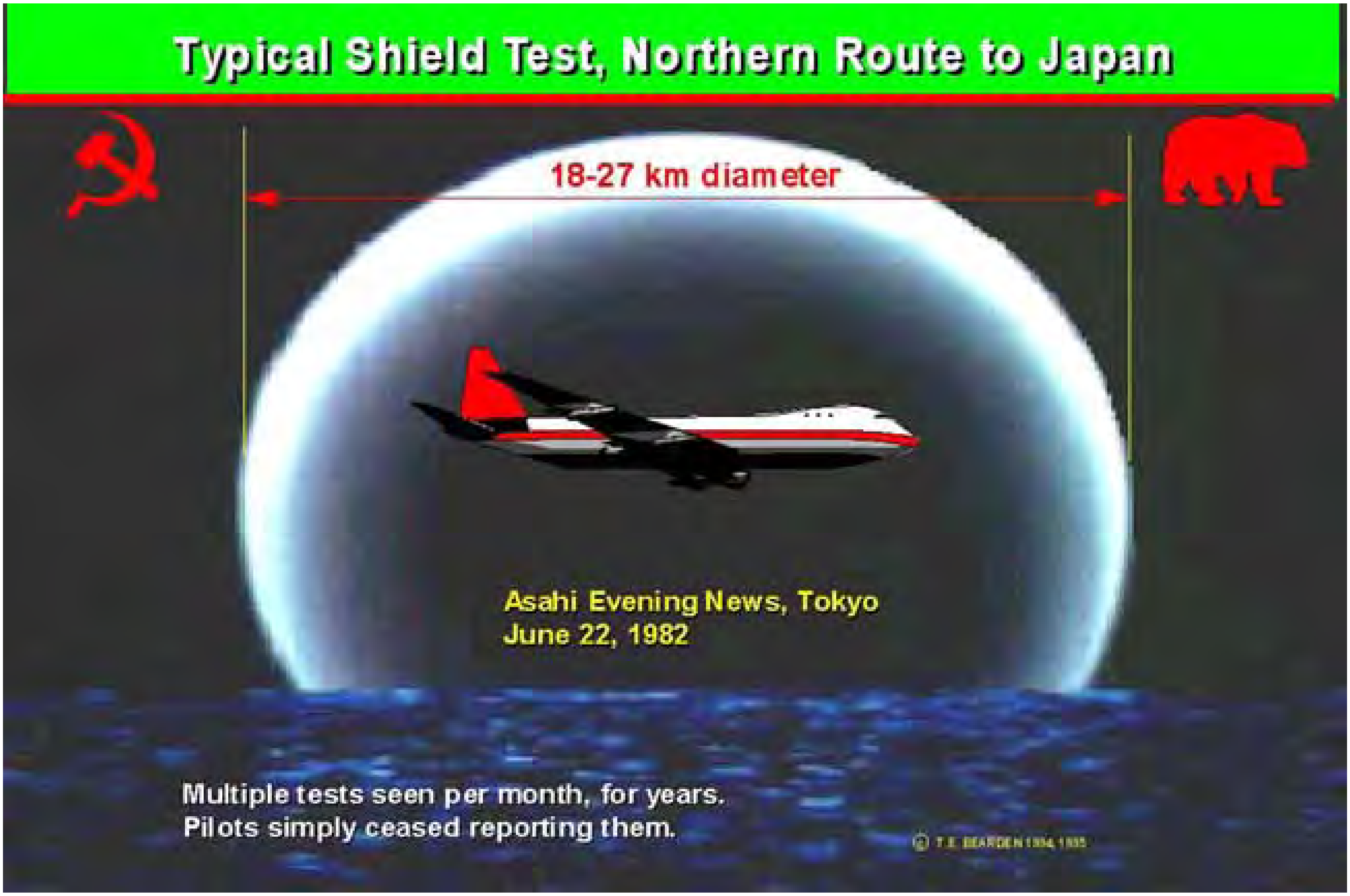

Typical Shield Test, Northern Route to Japan

Asahi Evening News, Tokyo
June 22, 1982

Multiple tests seen per month, for years.
Pilots simply ceased reporting them.

© T.E. BEARDEN 1994, 1995

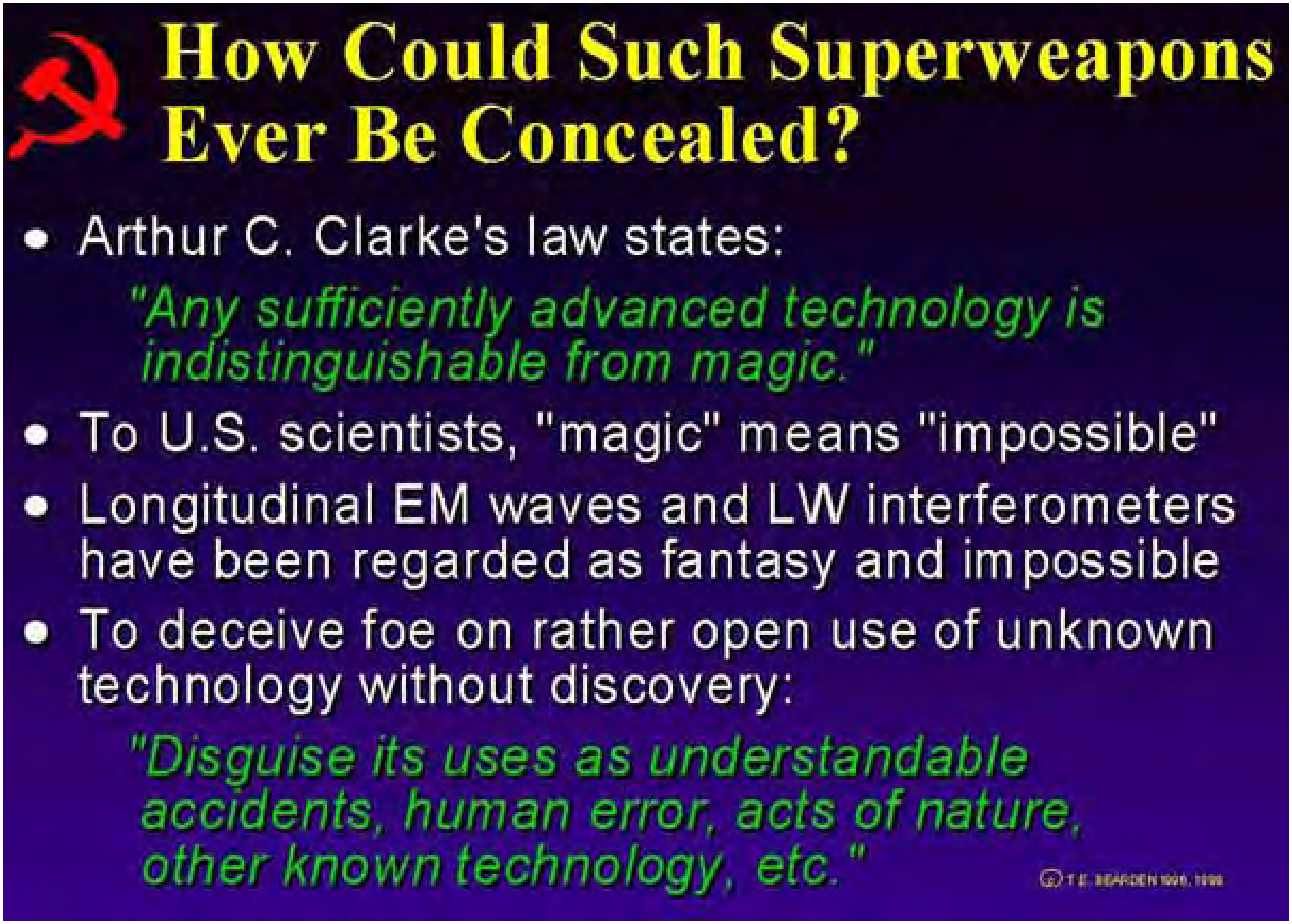

How Could Such Superweapons Ever Be Concealed?

- Arthur C. Clarke's law states:

  "Any sufficiently advanced technology is indistinguishable from magic."
- To U.S. scientists, "magic" means "impossible"
- Longitudinal EM waves and LW interferometers have been regarded as fantasy and impossible
- To deceive foe on rather open use of unknown technology without discovery:

  "Disguise its uses as understandable accidents, human error, acts of nature, other known technology, etc."

© T.E. BEARDEN [illegible]

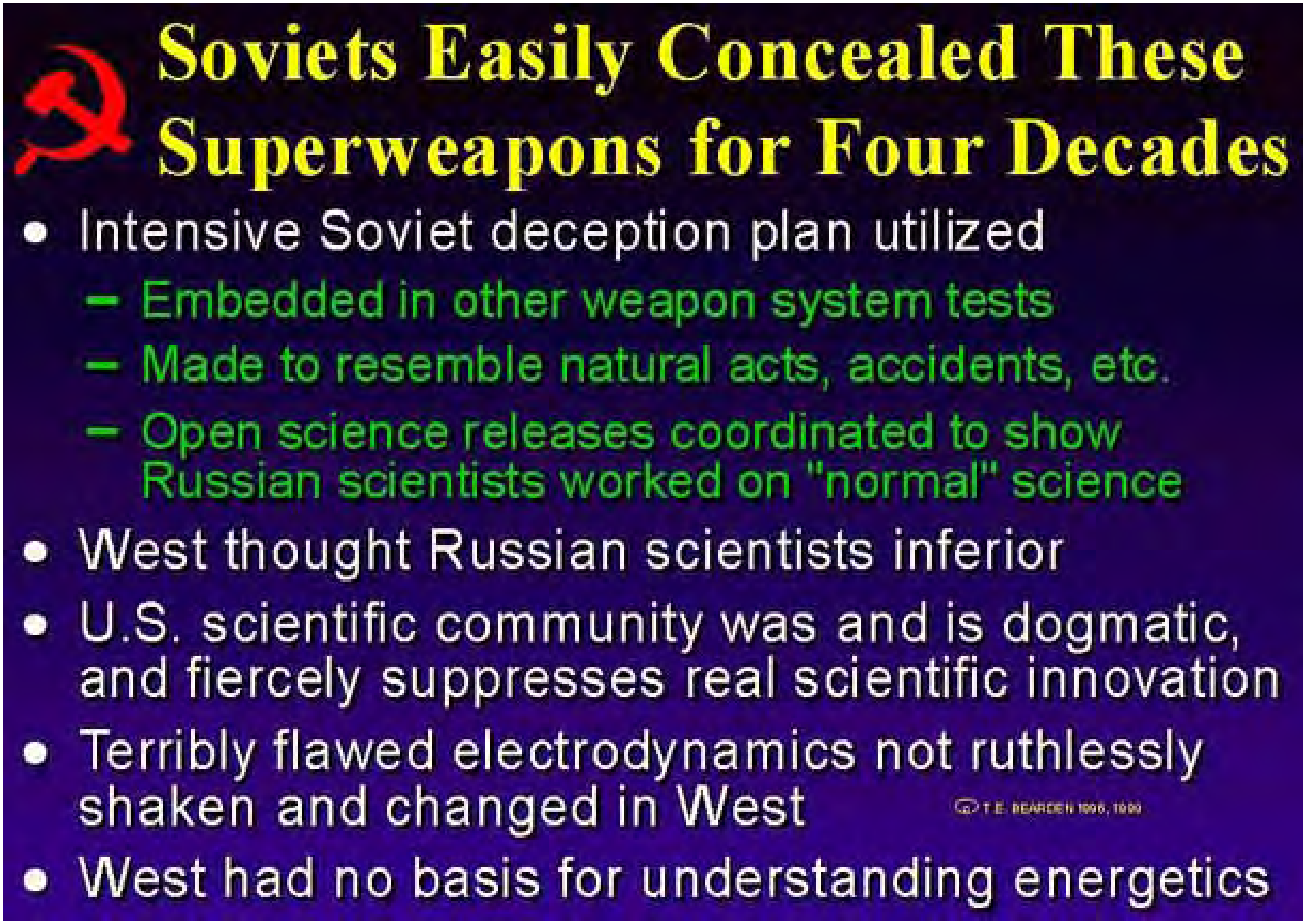

Soviets Easily Concealed These Superweapons for Four Decades

- Intensive Soviet deception plan utilized
  - Embedded in other weapon system tests
  - Made to resemble natural acts, accidents, etc.
  - Open science releases coordinated to show Russian scientists worked on "normal" science
- West thought Russian scientists inferior
- U.S. scientific community was and is dogmatic, and fiercely suppresses real scientific innovation
- Terribly flawed electrodynamics not ruthlessly shaken and changed in West
- West had no basis for understanding energetics

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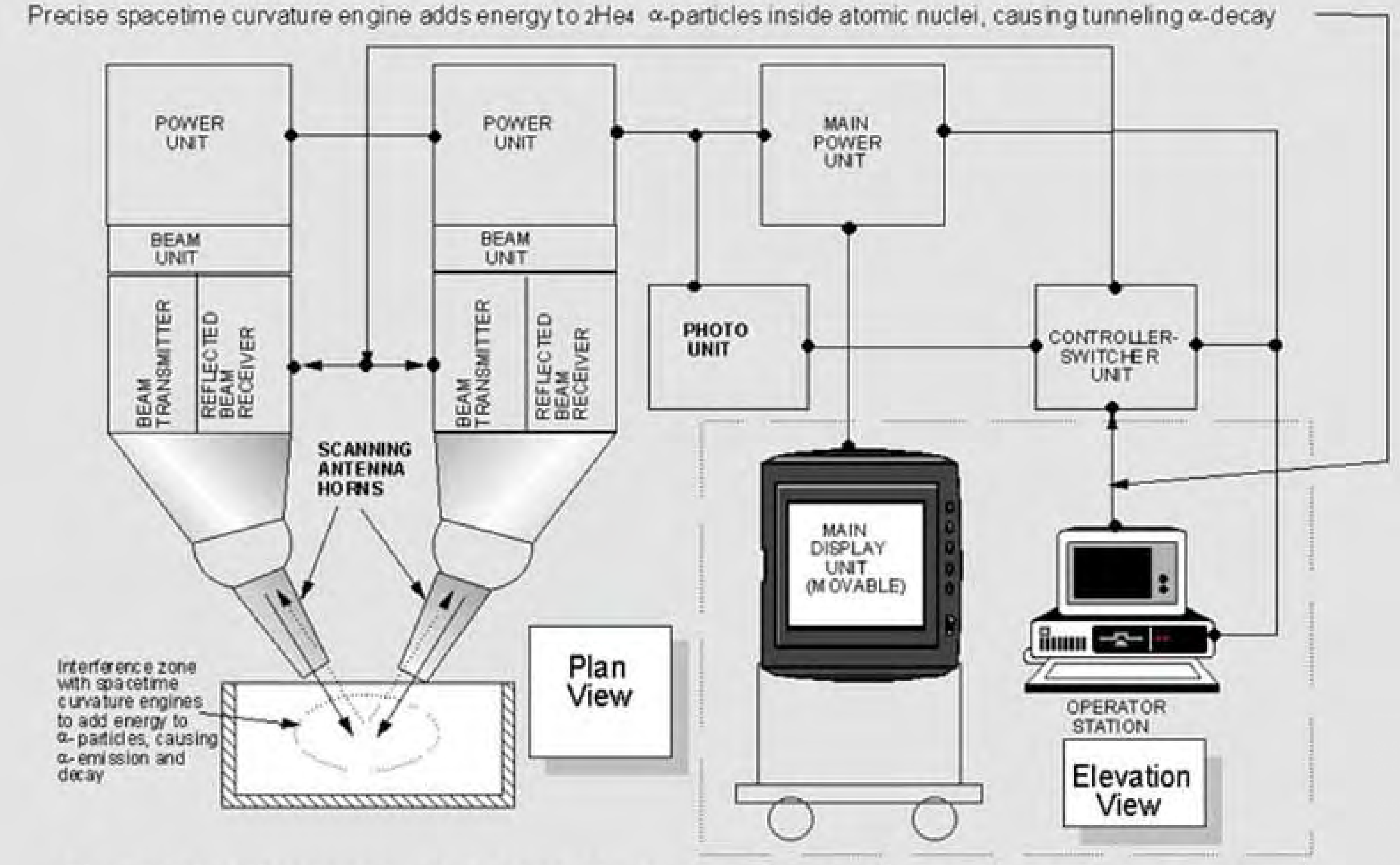
Precise spacetime curvature engine adds energy to ${}_2\text{He}_4$ α-particles inside atomic nuclei, causing tunneling α-decay
POWER UNIT
POWER UNIT
MAIN POWER UNIT
BEAM UNIT
BEAM UNIT
BEAM TRANSMITTER
REFLECTED BEAM RECEIVER
BEAM TRANSMITTER
REFLECTED BEAM RECEIVER
PHOTO UNIT
CONTROLLER-SWITCHER UNIT
SCANNING ANTENNA HORNS
MAIN DISPLAY UNIT (MOVABLE)
Interference zone with spacetime curvature engines to add energy to α-particles, causing α-emission and decay
Plan View
OPERATOR STATION
Elevation View

Figure 26. Microscope-type, laser-like interferometer for inducing quick α-decay in samples of otherwise longer-lived isotopes.

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Longitudinal EM Wave Interferometry: Endothermic

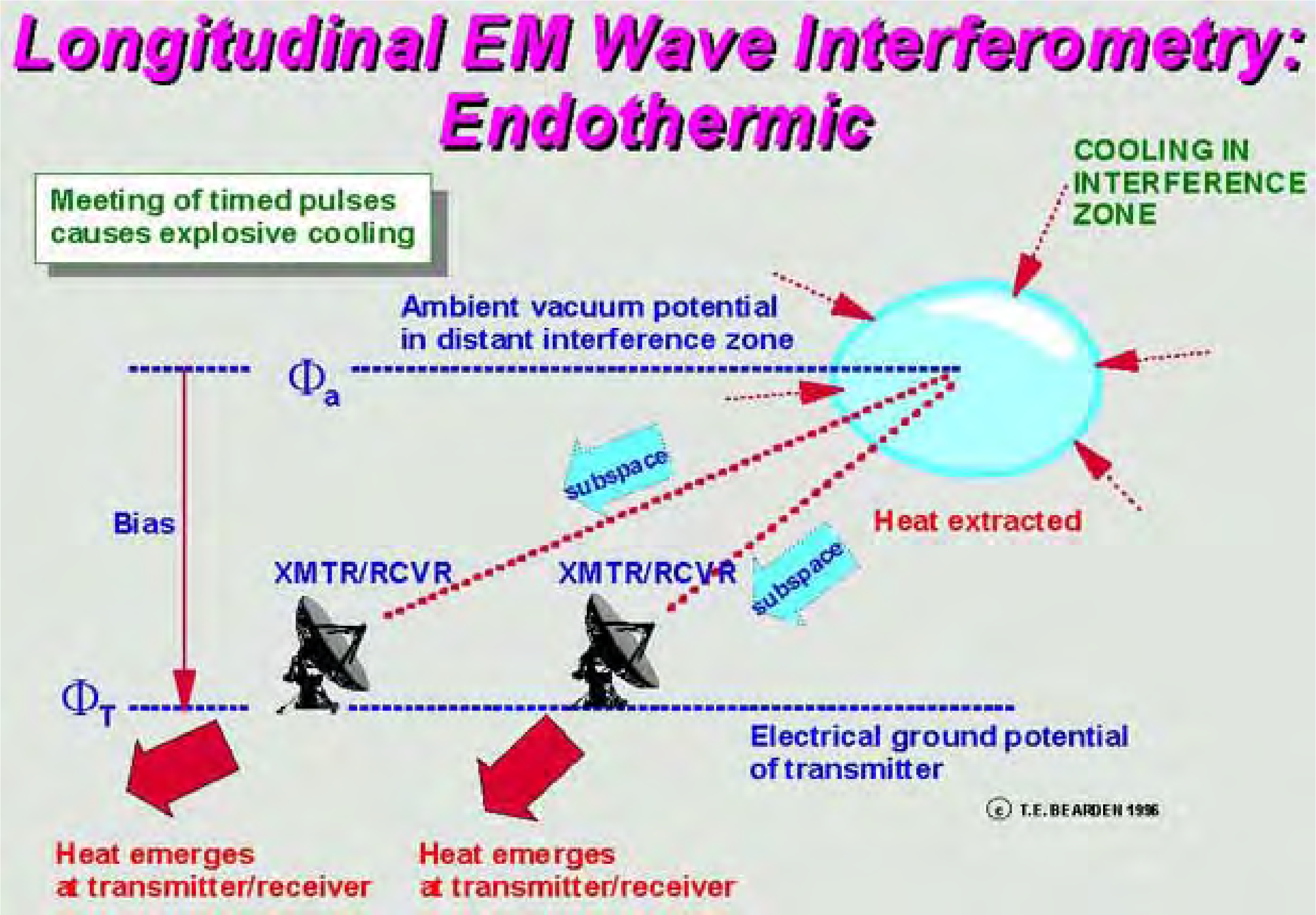

Meeting of timed pulses causes explosive cooling

COOLING IN INTERFERENCE ZONE

Ambient vacuum potential in distant interference zone

Φ_a

Bias

subspace

subspace

Heat extracted

XMTR/RCVR

XMTR/RCVR

Φ_T

Electrical ground potential of transmitter

ⓒ T.E.BEARDEN 1996

Heat emerges at transmitter/receiver

Heat emerges at transmitter/receiver

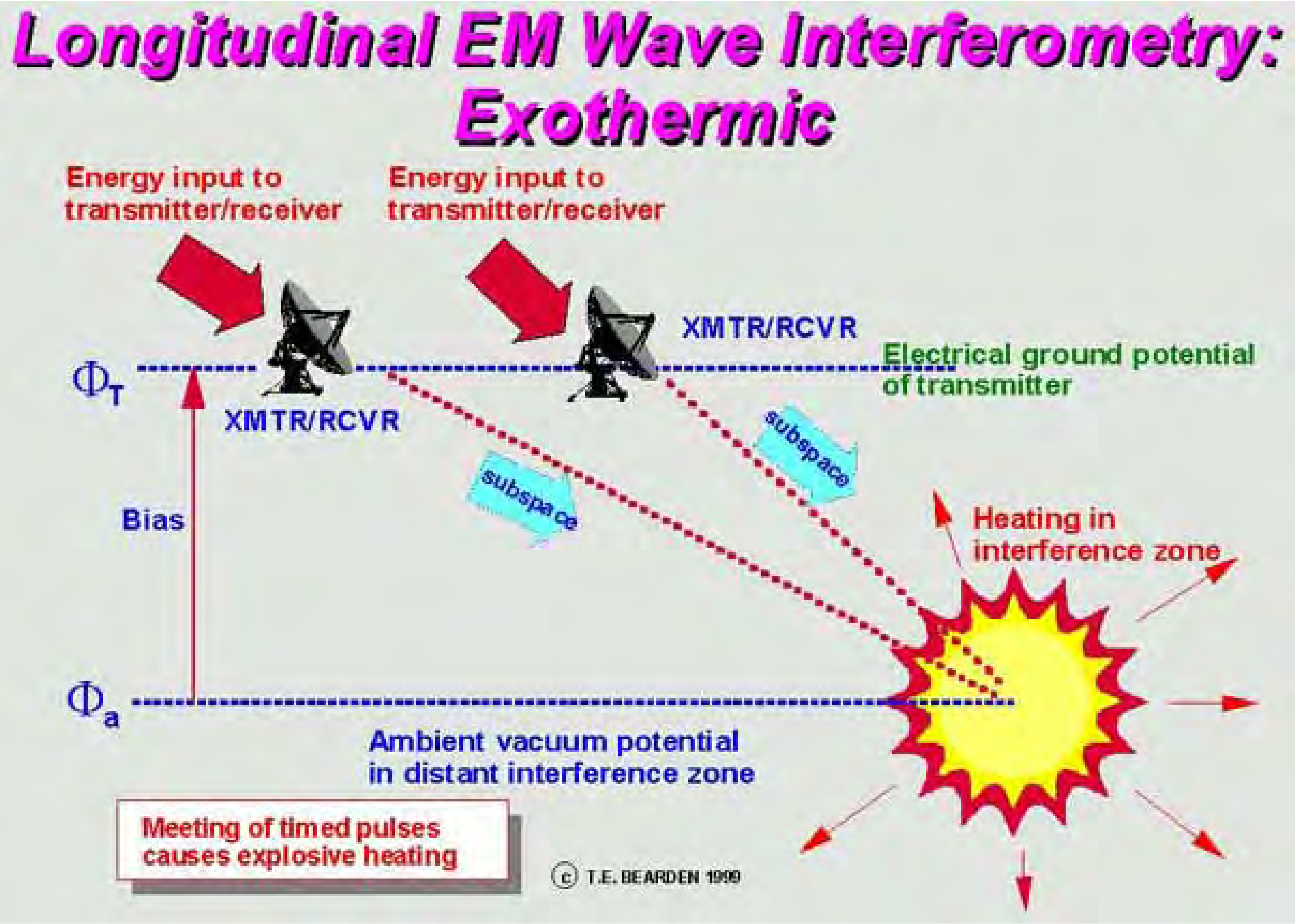

Longitudinal EM Wave Interferometry: Exothermic

Energy input to transmitter/receiver

Energy input to transmitter/receiver

XMTR/RCVR

Φ_T

Electrical ground potential of transmitter

XMTR/RCVR

subspace

subspace

Bias

Heating in interference zone

Φ_a

Ambient vacuum potential in distant interference zone

Meeting of timed pulses causes explosive heating

ⓒ T.E. BEARDEN 1999

The Tom Bearden Website

Help support the research

U.S. Air Attack on Libya
April 1986

- Slide 1
- Slide 2
- "Washington Post" Article
  January 22, 1989

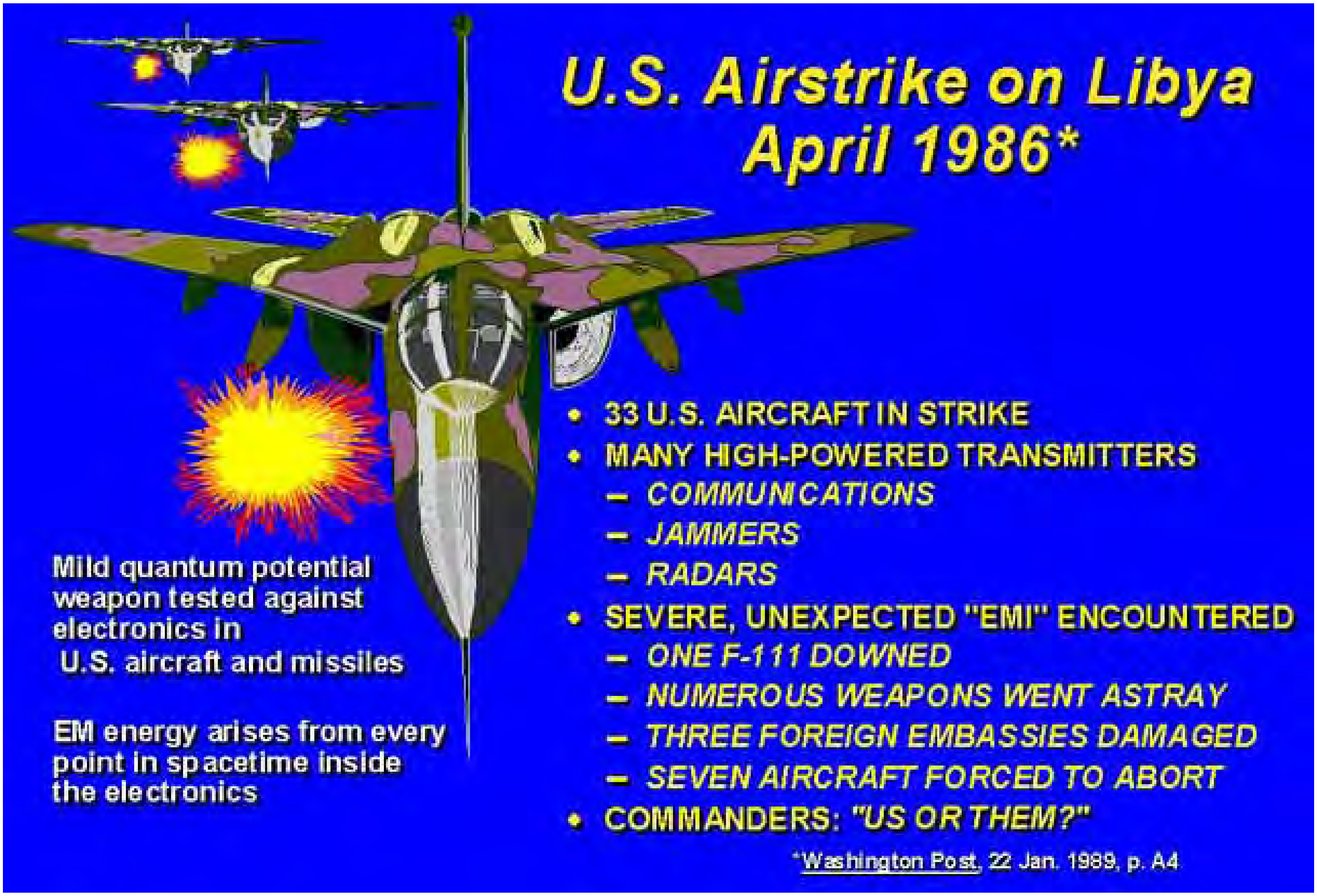

U.S. Airstrike on Libya April 1986*

- 33 U.S. AIRCRAFT IN STRIKE
- MANY HIGH-POWERED TRANSMITTERS
  - *COMMUNICATIONS*
  - *JAMMERS*
  - *RADARS*
- SEVERE, UNEXPECTED "EMI" ENCOUNTERED
  - *ONE F-111 DOWNED*
  - *NUMEROUS WEAPONS WENT ASTRAY*
  - *THREE FOREIGN EMBASSIES DAMAGED*
  - *SEVEN AIRCRAFT FORCED TO ABORT*
- COMMANDERS: *"US OR THEM?"*

*Washington Post, 22 Jan. 1989, p. A4

Mild quantum potential weapon tested against electronics in U.S. aircraft and missiles

EM energy arises from every point in spacetime inside the electronics

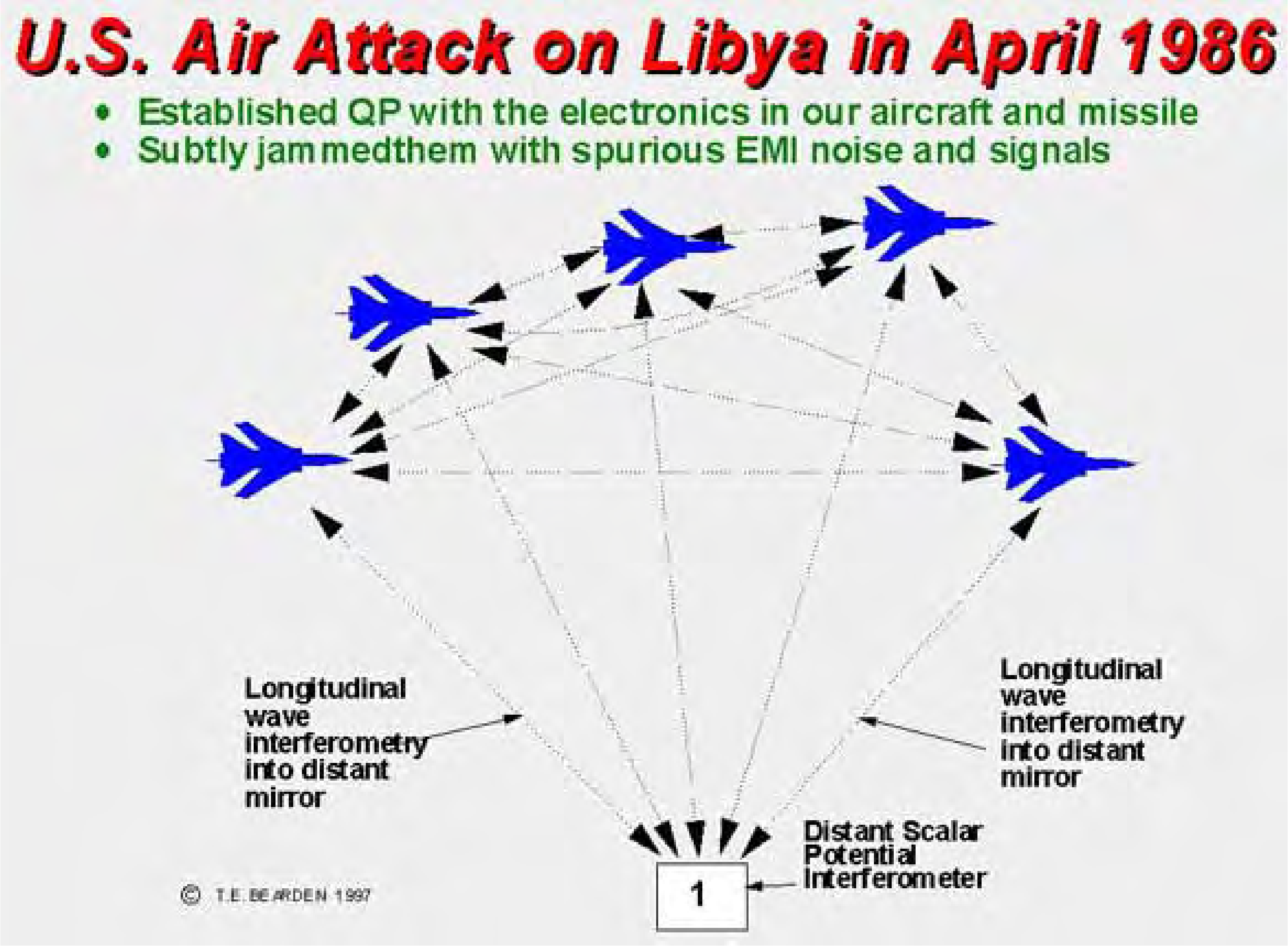

U.S. Air Attack on Libya in April 1986

- Established QP with the electronics in our aircraft and missile
- Subtly jammedthem with spurious EMI noise and signals

Longitudinal wave interferometry into distant mirror
Longitudinal wave interferometry into distant mirror
Distant Scalar Potential Interferometer
1

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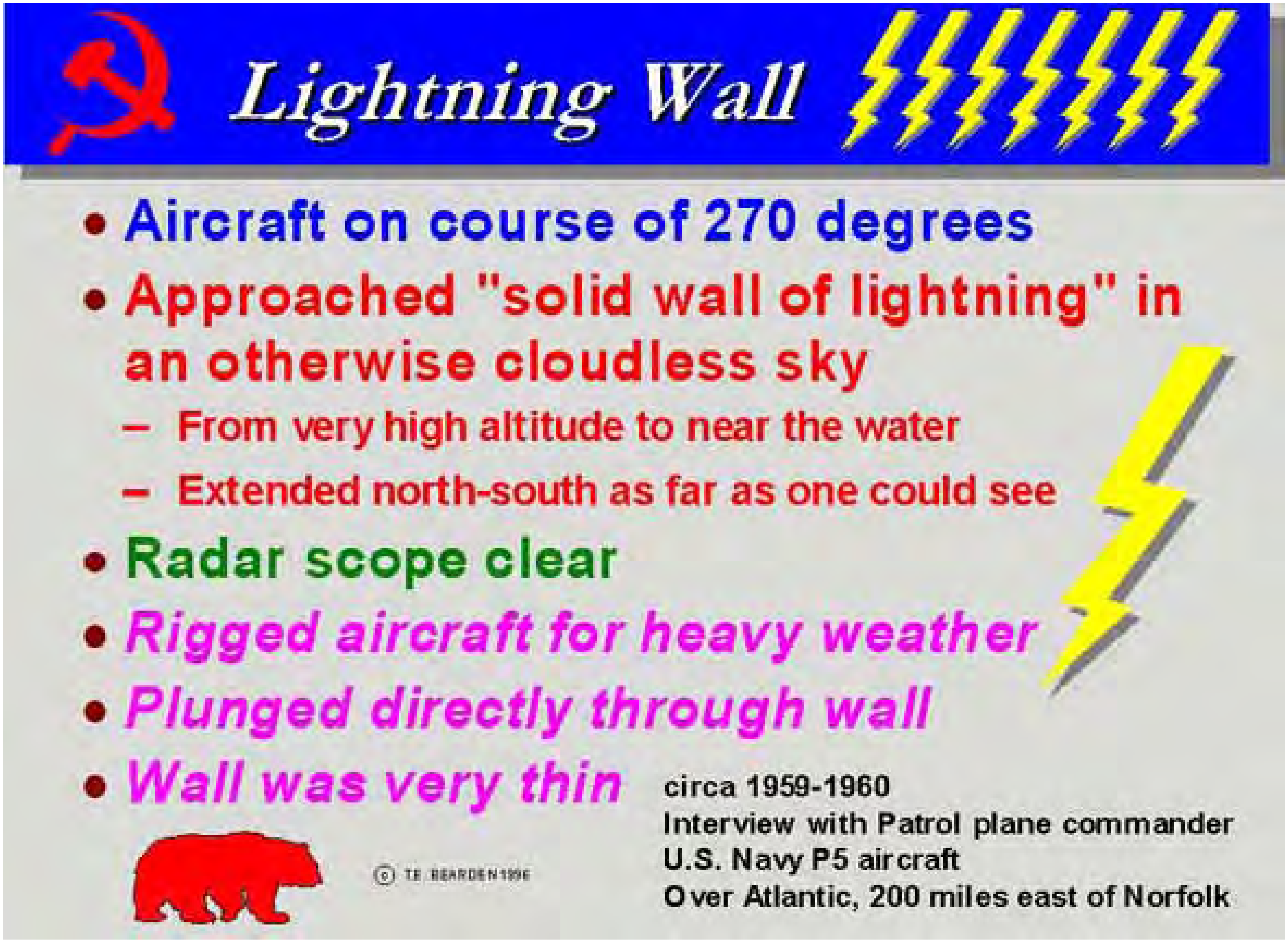

Lightning Wall

- Aircraft on course of 270 degrees
- Approached "solid wall of lightning" in an otherwise cloudless sky
  - From very high altitude to near the water
  - Extended north-south as far as one could see
- Radar scope clear
- *Rigged aircraft for heavy weather*
- *Plunged directly through wall*
- *Wall was very thin*

circa 1959-1960
Interview with Patrol plane commander
U.S. Navy P5 aircraft
Over Atlantic, 200 miles east of Norfolk

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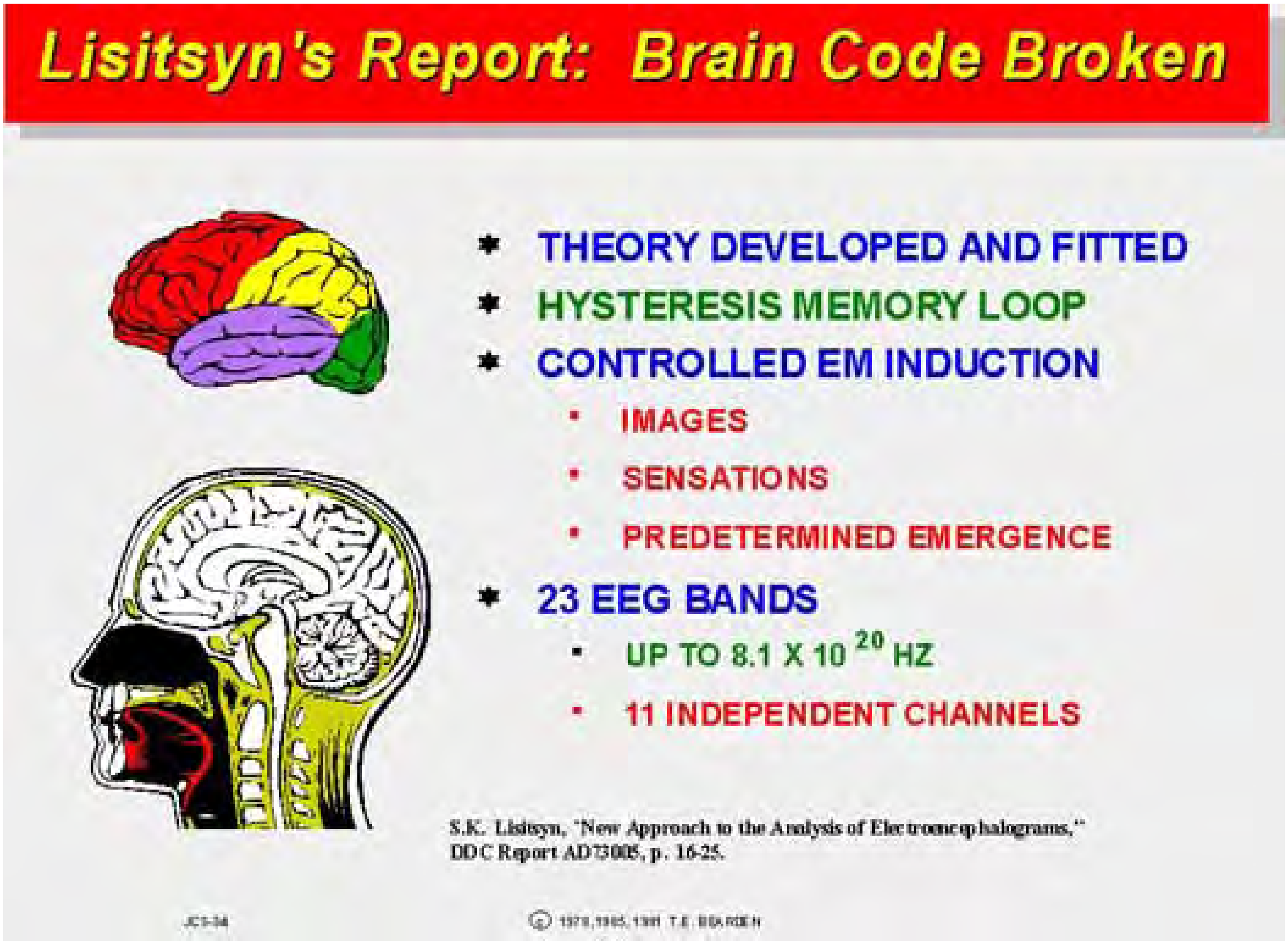

Lisitsyn's Report: Brain Code Broken

- THEORY DEVELOPED AND FITTED
- HYSTERESIS MEMORY LOOP
- CONTROLLED EM INDUCTION
  - IMAGES
  - SENSATIONS
  - PREDETERMINED EMERGENCE
- 23 EEG BANDS
  - UP TO 8.1×10^{20} HZ
  - 11 INDEPENDENT CHANNELS

S.K. Lisitsyn, "New Approach to the Analysis of Electroencephalograms," DDC Report AD73005, p. 16-25.

JCS-34

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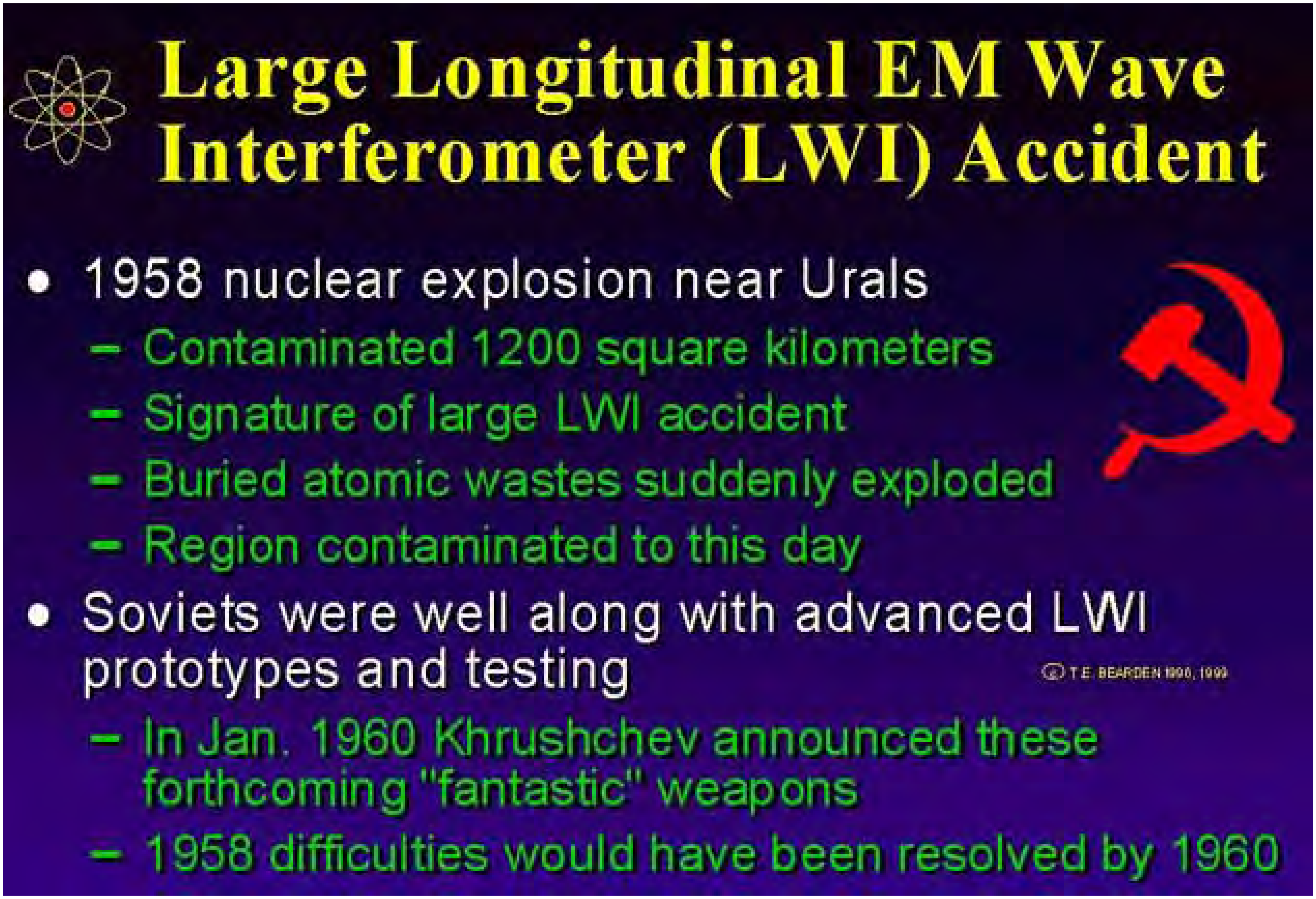

Large Longitudinal EM Wave Interferometer (LWI) Accident

- 1958 nuclear explosion near Urals
  - Contaminated 1200 square kilometers
  - Signature of large LWI accident
  - Buried atomic wastes suddenly exploded
  - Region contaminated to this day
- Soviets were well along with advanced LWI prototypes and testing
  - In Jan. 1960 Khrushchev announced these forthcoming "fantastic" weapons
  - 1958 difficulties would have been resolved by 1960

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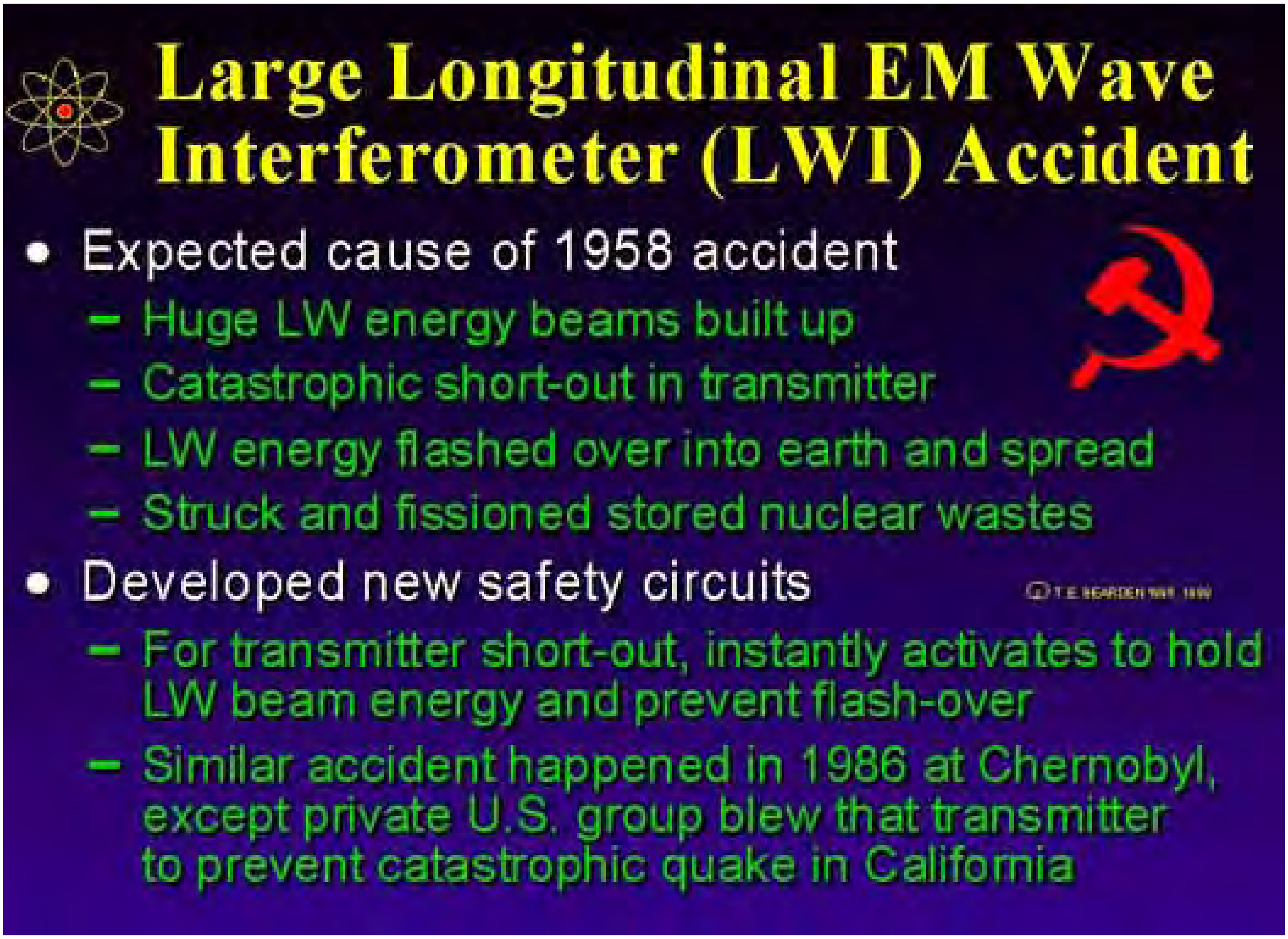

Large Longitudinal EM Wave Interferometer (LWI) Accident

- Expected cause of 1958 accident
  - Huge LW energy beams built up
  - Catastrophic short-out in transmitter
  - LW energy flashed over into earth and spread
  - Struck and fissioned stored nuclear wastes
- Developed new safety circuits
  - For transmitter short-out, instantly activates to hold LW beam energy and prevent flash-over
  - Similar accident happened in 1986 at Chernobyl, except private U.S. group blew that transmitter to prevent catastrophic quake in California

© T.E. BEARDEN [illegible]

(Use of Hidden Information Content of the Field)
(Can Provide Action-at-a-Distance)

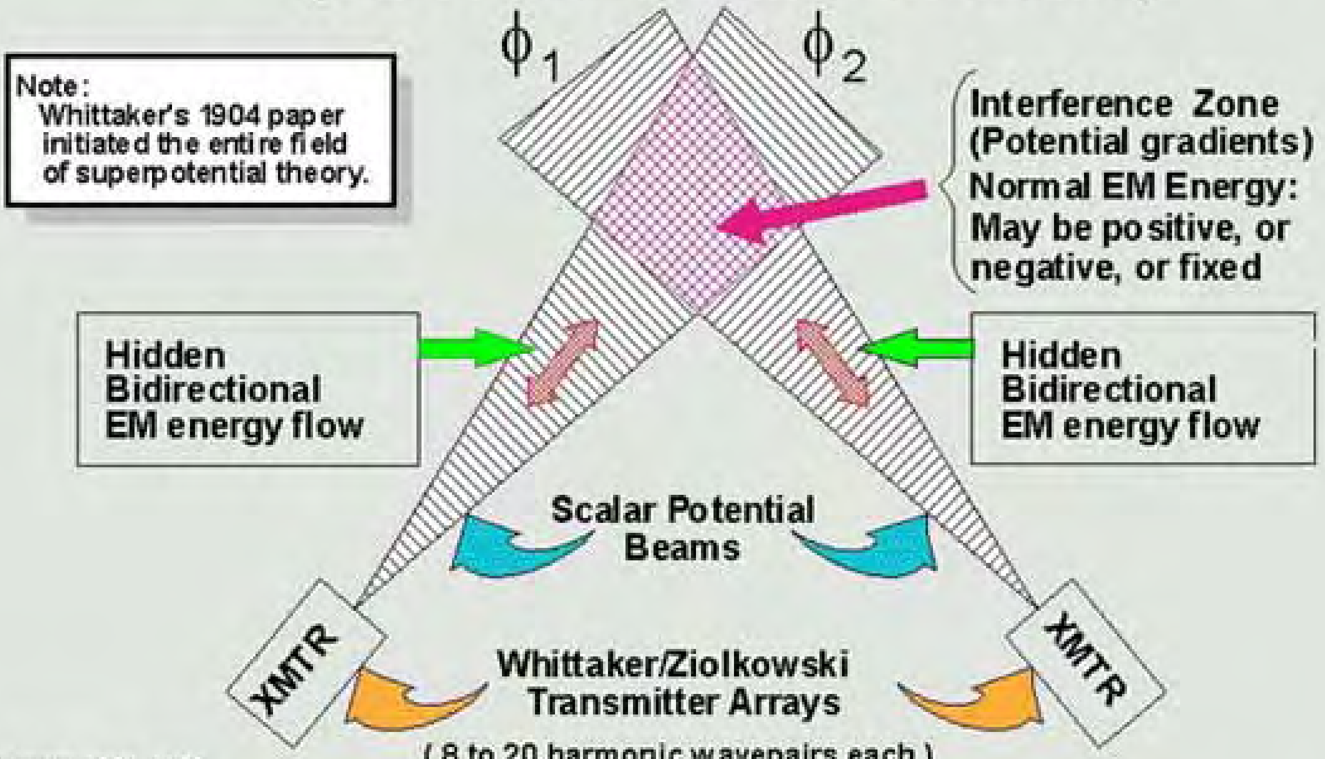
ϕ_1
ϕ_2
Note:
Whittaker's 1904 paper initiated the entire field of superpotential theory.
Interference Zone (Potential gradients)
Normal EM Energy: May be positive, or negative, or fixed
Hidden Bidirectional EM energy flow
Hidden Bidirectional EM energy flow
Scalar Potential Beams
XMTR
XMTR
Whittaker/Ziolkowski Transmitter Arrays
(8 to 20 harmonic wavepairs each)

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Figure 5. Scalar potential interferometry (between the two sets of bidirectional longitudinal EM wavepair functions) produces all EM force fields and waves.

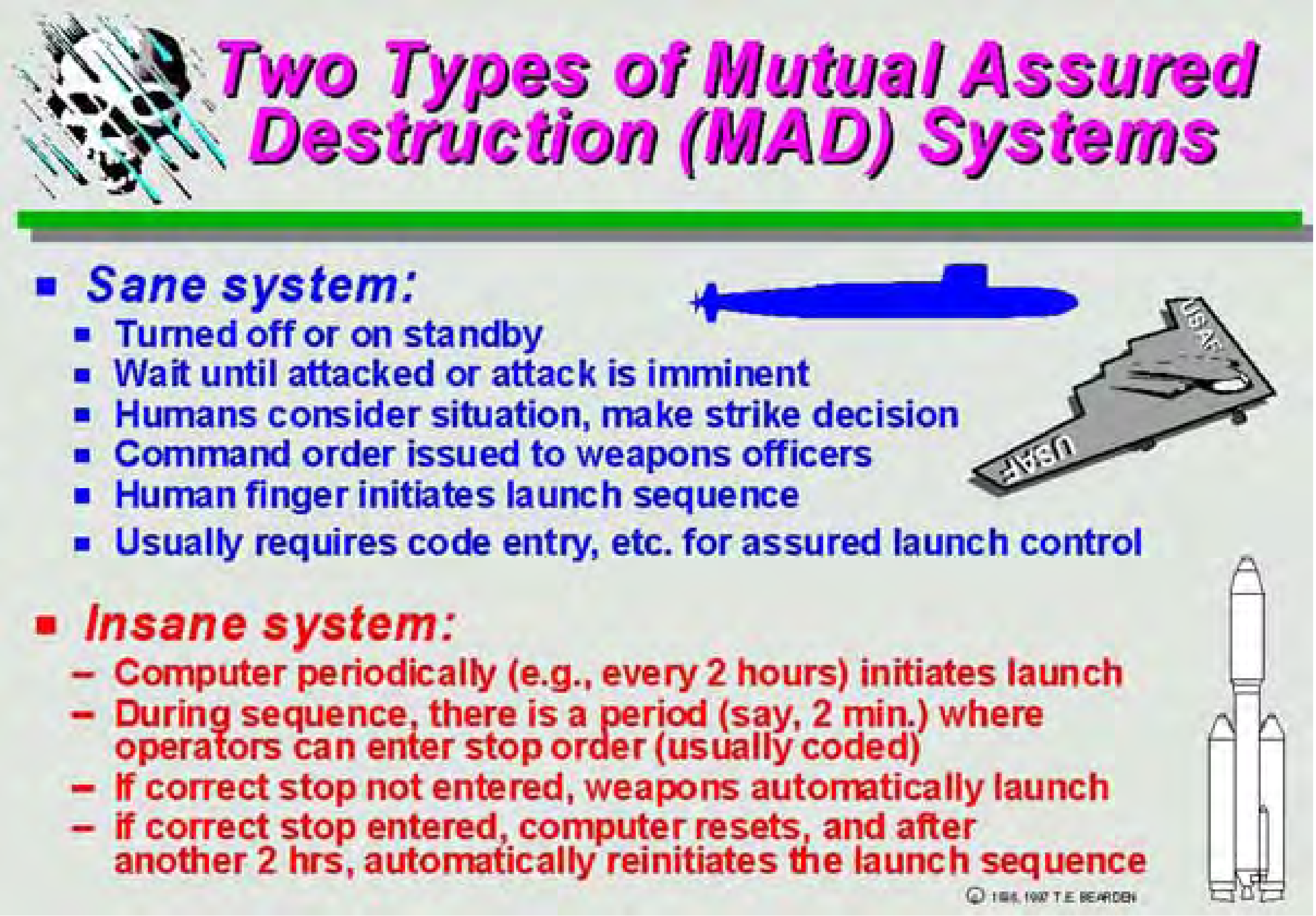

Two Types of Mutual Assured Destruction (MAD) Systems

- ***Sane system:***
  - Turned off or on standby
  - Wait until attacked or attack is imminent
  - Humans consider situation, make strike decision
  - Command order issued to weapons officers
  - Human finger initiates launch sequence
  - Usually requires code entry, etc. for assured launch control
- ***Insane system:***
  - Computer periodically (e.g., every 2 hours) initiates launch
  - During sequence, there is a period (say, 2 min.) where operators can enter stop order (usually coded)
  - If correct stop not entered, weapons automatically launch
  - If correct stop entered, computer resets, and after another 2 hrs, automatically reinitiates the launch sequence

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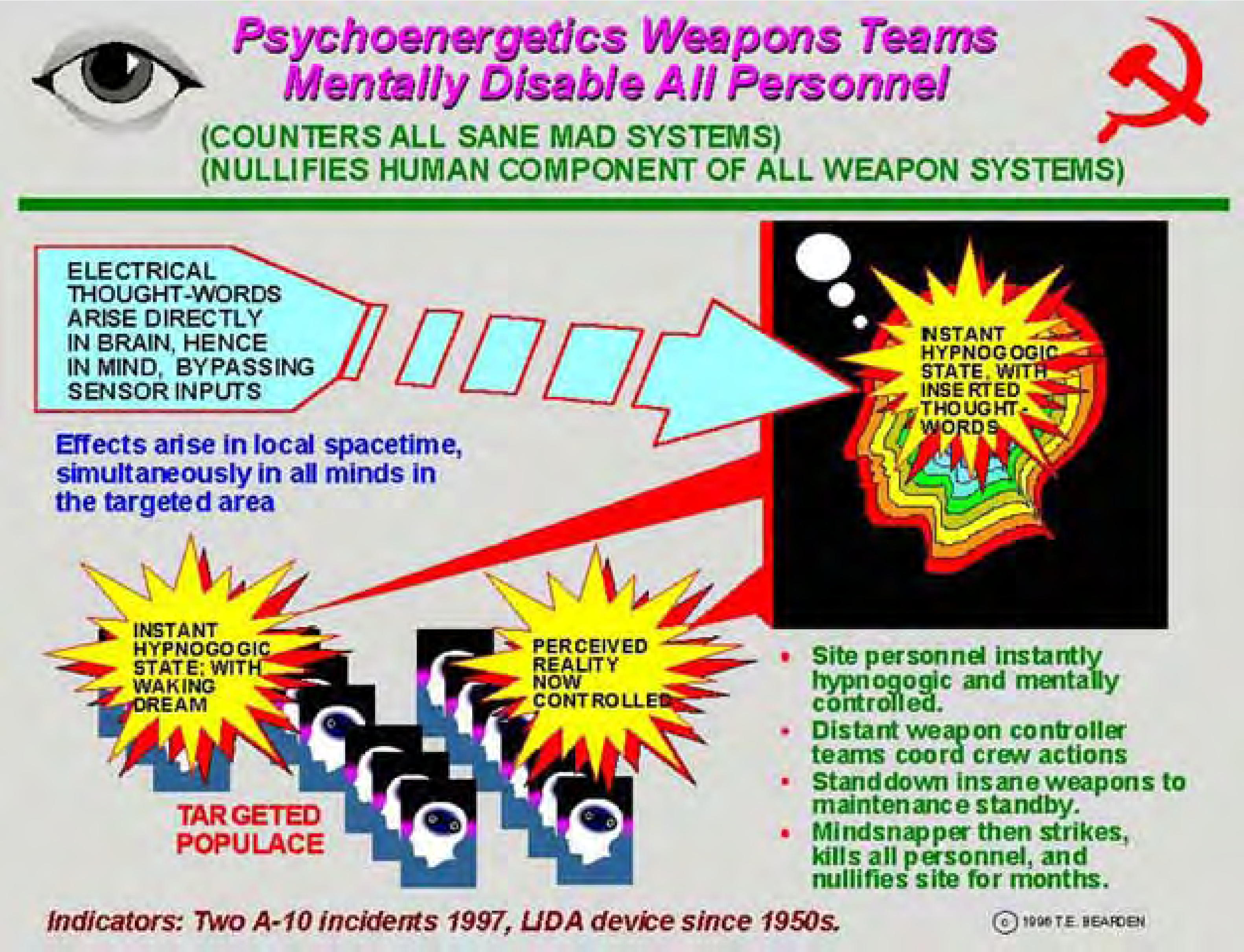

Psychoenergetics Weapons Teams Mentally Disable All Personnel

(COUNTERS ALL SANE MAD SYSTEMS)
(NULLIFIES HUMAN COMPONENT OF ALL WEAPON SYSTEMS)

ELECTRICAL THOUGHT-WORDS ARISE DIRECTLY IN BRAIN, HENCE IN MIND, BYPASSING SENSOR INPUTS

INSTANT HYPNOGOGIC STATE, WITH INSERTED THOUGHT-WORDS

Effects arise in local spacetime, simultaneously in all minds in the targeted area

INSTANT HYPNOGOGIC STATE: WITH WAKING DREAM

PERCEIVED REALITY NOW CONTROLLED

TARGETED POPULACE

- Site personnel instantly hypnogogic and mentally controlled.
- Distant weapon controller teams coord crew actions
- Standdown insane weapons to maintenance standby.
- Mindsnapper then strikes, kills all personnel, and nullifies site for months.

Indicators: Two A-10 incidents 1997, LIDA device since 1950s.

(c) 1998 T.E. BEARDEN

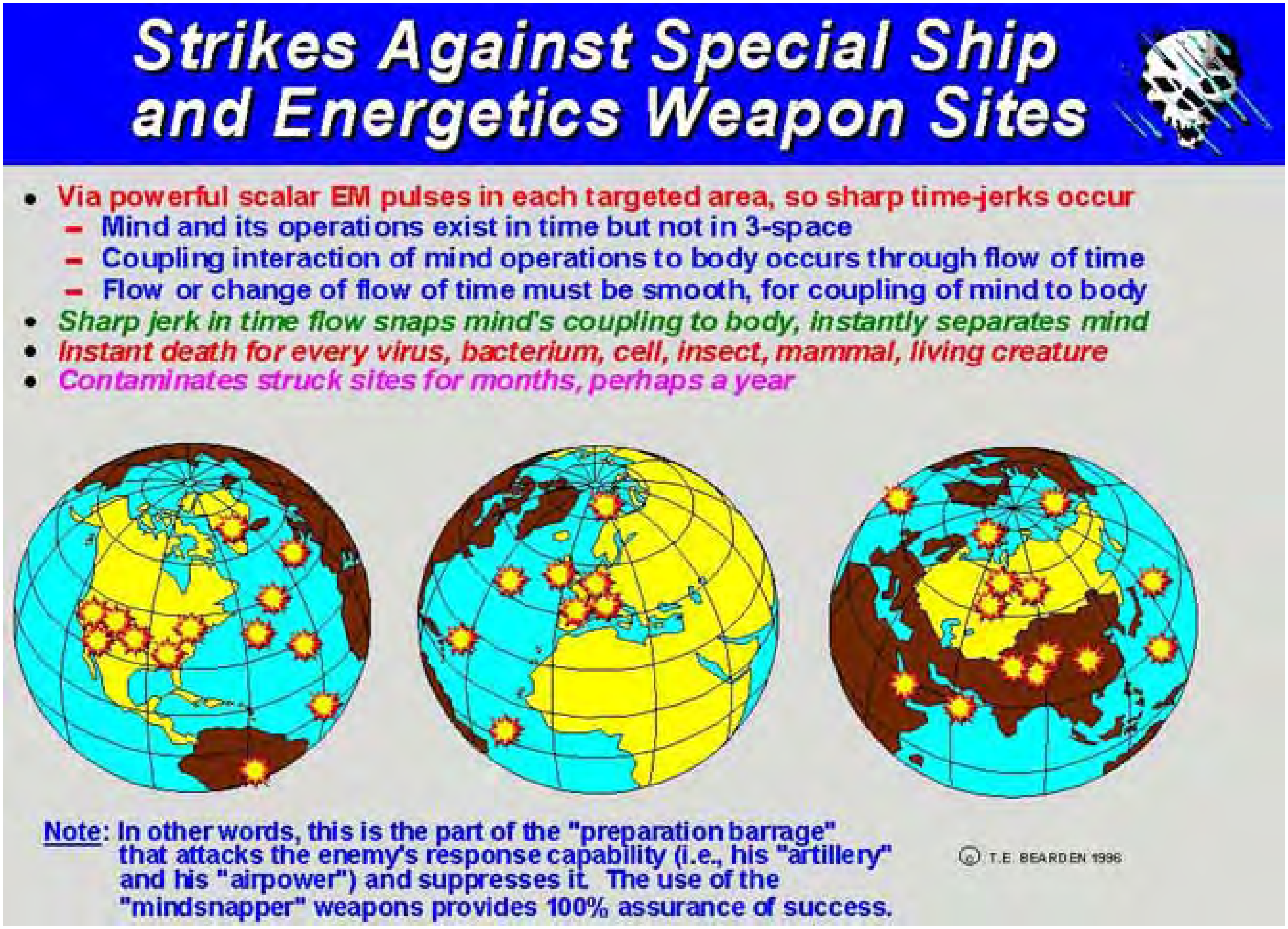

Strikes Against Special Ship and Energetics Weapon Sites

- Via powerful scalar EM pulses in each targeted area, so sharp time-jerks occur
  - Mind and its operations exist in time but not in 3-space
  - Coupling interaction of mind operations to body occurs through flow of time
  - Flow or change of flow of time must be smooth, for coupling of mind to body
- *Sharp jerk in time flow snaps mind's coupling to body, instantly separates mind*
- *Instant death for every virus, bacterium, cell, insect, mammal, living creature*
- *Contaminates struck sites for months, perhaps a year*

Note: In other words, this is the part of the "preparation barrage" that attacks the enemy's response capability (i.e., his "artillery" and his "airpower") and suppresses it. The use of the "mindsnapper" weapons provides 100% assurance of success.

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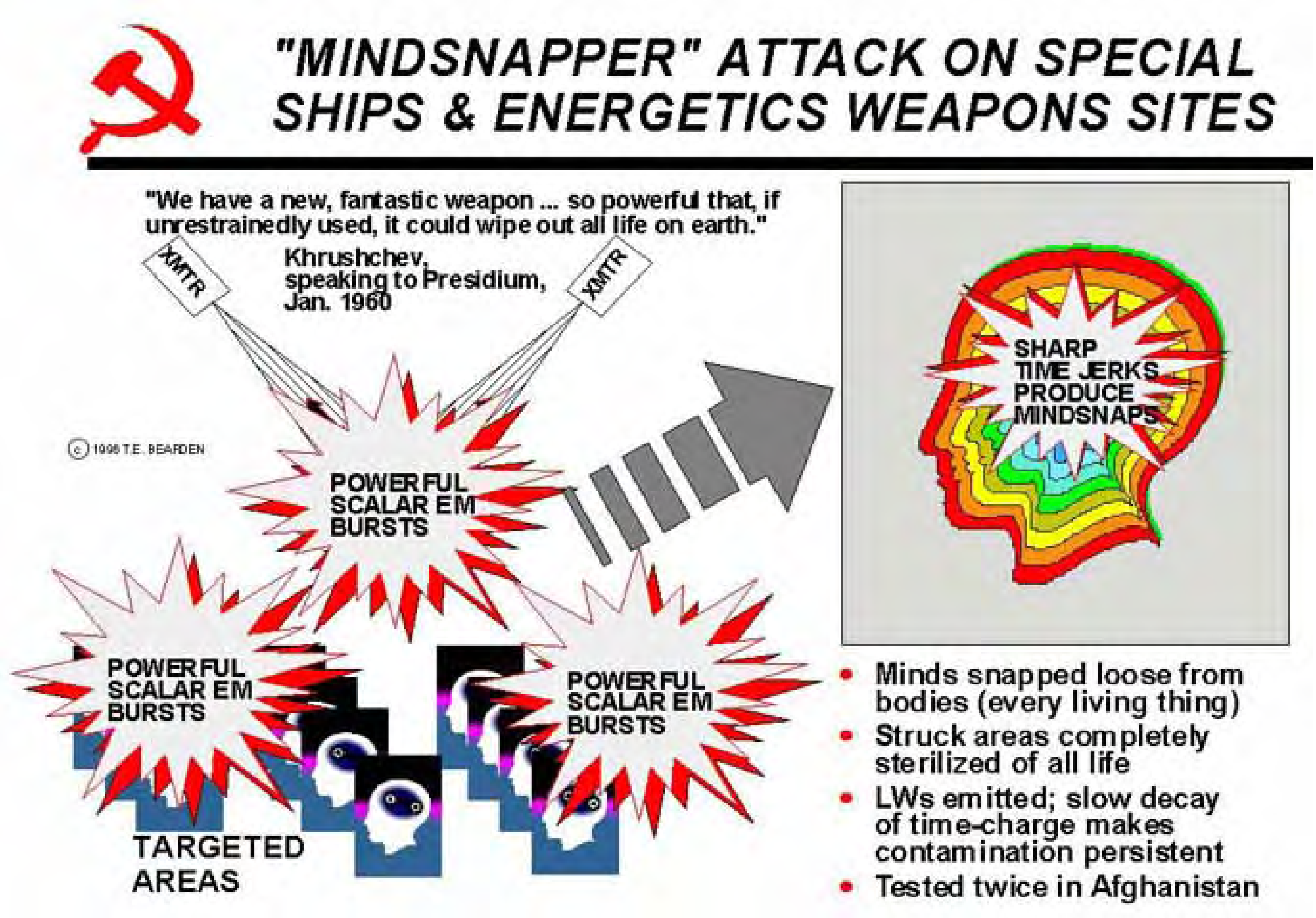

"MINDSNAPPER" ATTACK ON SPECIAL SHIPS & ENERGETICS WEAPONS SITES

"We have a new, fantastic weapon ... so powerful that, if unrestrainedly used, it could wipe out all life on earth."

Khrushchev,
speaking to Presidium,
Jan. 1960

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XMTR
XMTR
POWERFUL SCALAR EM BURSTS
POWERFUL SCALAR EM BURSTS
POWERFUL SCALAR EM BURSTS
TARGETED AREAS
SHARP TIME JERKS PRODUCE MINDSNAPS

- Minds snapped loose from bodies (every living thing)
- Struck areas completely sterilized of all life
- LWs emitted; slow decay of time-charge makes contamination persistent
- Tested twice in Afghanistan

How Much Off Guard Are We?

- Slide 1
- Slide 2
- Slide 3
- Slide 4
- Slide 5
- Slide 6
- Slide 7

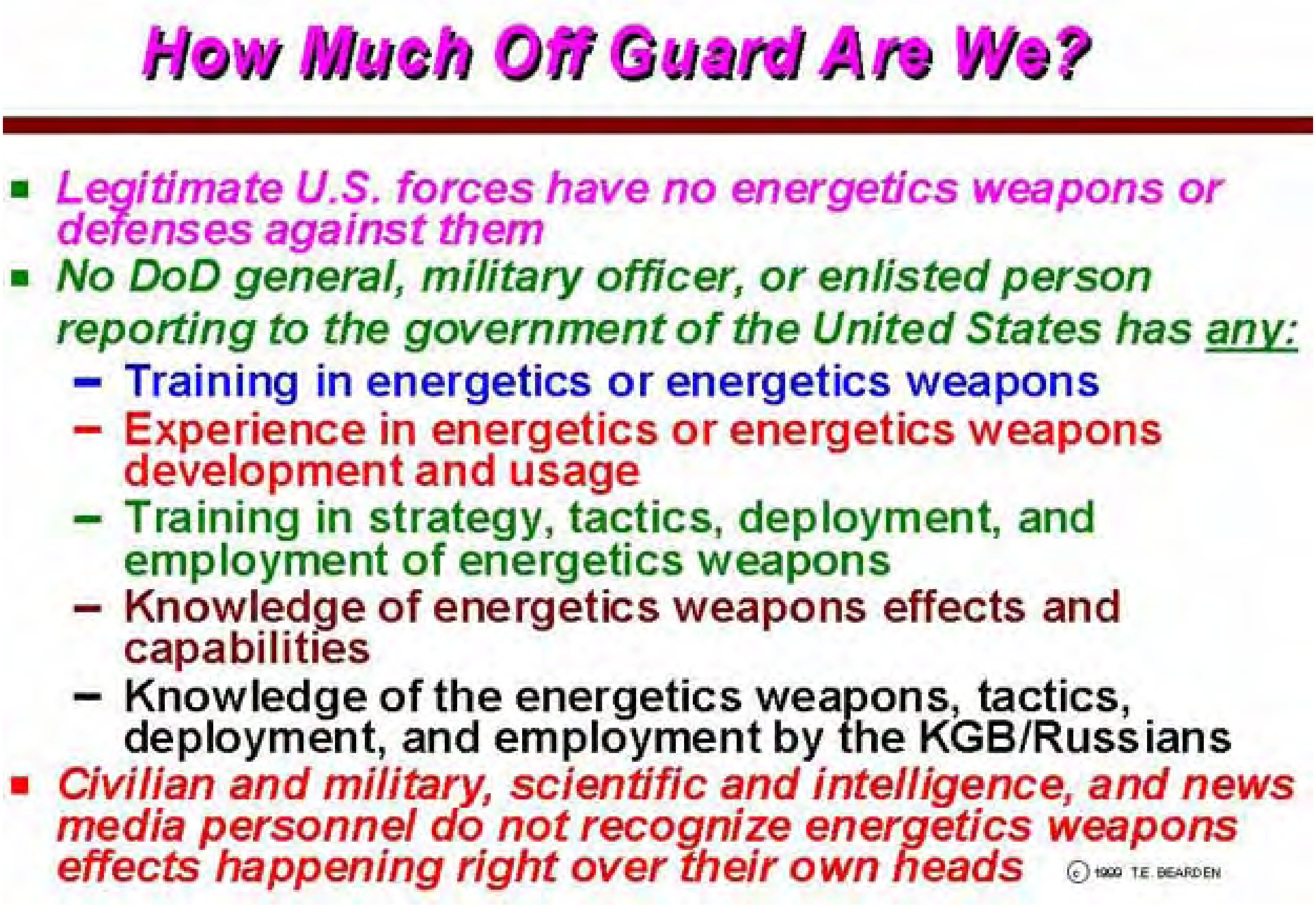

How Much Off Guard Are We?

- *Legitimate U.S. forces have no energetics weapons or defenses against them*
- *No DoD general, military officer, or enlisted person reporting to the government of the United States has any:*
  - Training in energetics or energetics weapons
  - Experience in energetics or energetics weapons development and usage
  - Training in strategy, tactics, deployment, and employment of energetics weapons
  - Knowledge of energetics weapons effects and capabilities
  - Knowledge of the energetics weapons, tactics, deployment, and employment by the KGB/Russians
- *Civilian and military, scientific and intelligence, and news media personnel do not recognize energetics weapons effects happening right over their own heads*

ⓒ 1999 T.E. BEARDEN

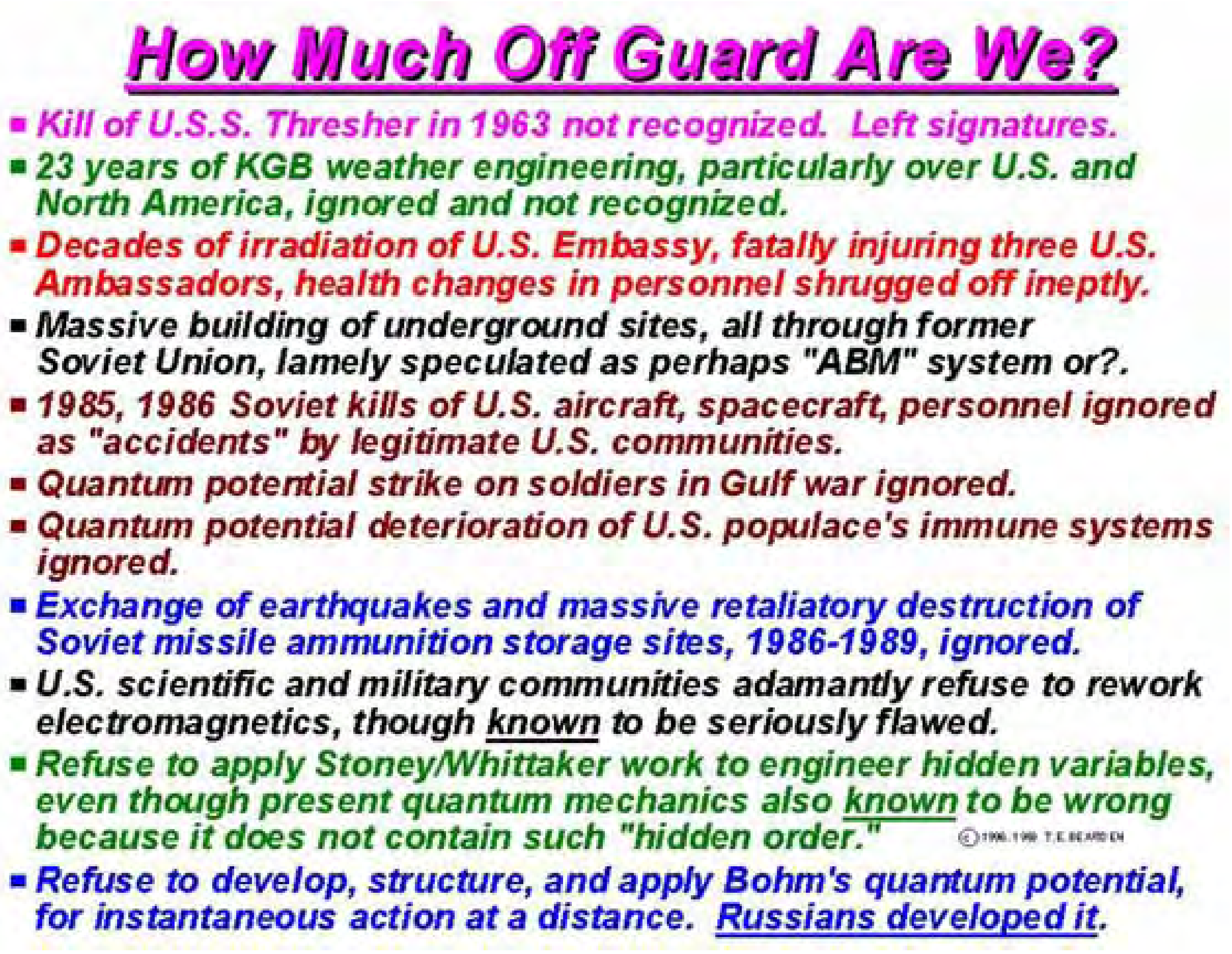

How Much Off Guard Are We?

- *Kill of U.S.S. Thresher in 1963 not recognized. Left signatures.*
- *23 years of KGB weather engineering, particularly over U.S. and North America, ignored and not recognized.*
- *Decades of irradiation of U.S. Embassy, fatally injuring three U.S. Ambassadors, health changes in personnel shrugged off ineptly.*
- *Massive building of underground sites, all through former Soviet Union, lamely speculated as perhaps "ABM" system or?.*
- *1985, 1986 Soviet kills of U.S. aircraft, spacecraft, personnel ignored as "accidents" by legitimate U.S. communities.*
- *Quantum potential strike on soldiers in Gulf war ignored.*
- *Quantum potential deterioration of U.S. populace's immune systems ignored.*
- *Exchange of earthquakes and massive retaliatory destruction of Soviet missile ammunition storage sites, 1986-1989, ignored.*
- *U.S. scientific and military communities adamantly refuse to rework electromagnetics, though known to be seriously flawed.*
- *Refuse to apply Stoney/Whittaker work to engineer hidden variables, even though present quantum mechanics also known to be wrong because it does not contain such "hidden order."*
- *Refuse to develop, structure, and apply Bohm's quantum potential, for instantaneous action at a distance. Russians developed it.*

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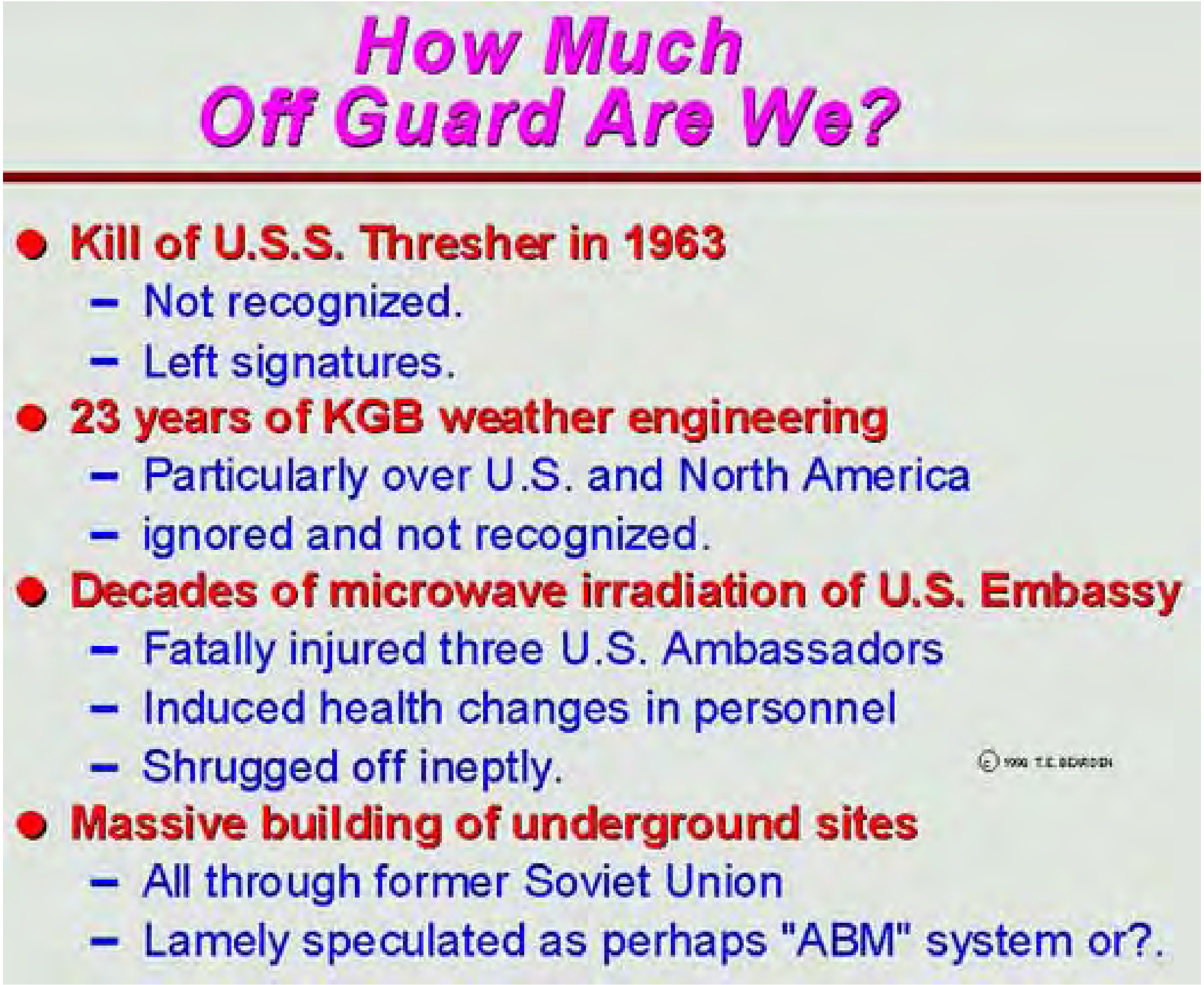

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  - Not recognized.
  - Left signatures.
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  - Particularly over U.S. and North America
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  - Fatally injured three U.S. Ambassadors
  - Induced health changes in personnel
  - Shrugged off ineptly.
- **Massive building of underground sites**
  - All through former Soviet Union
  - Lamely speculated as perhaps "ABM" system or?.

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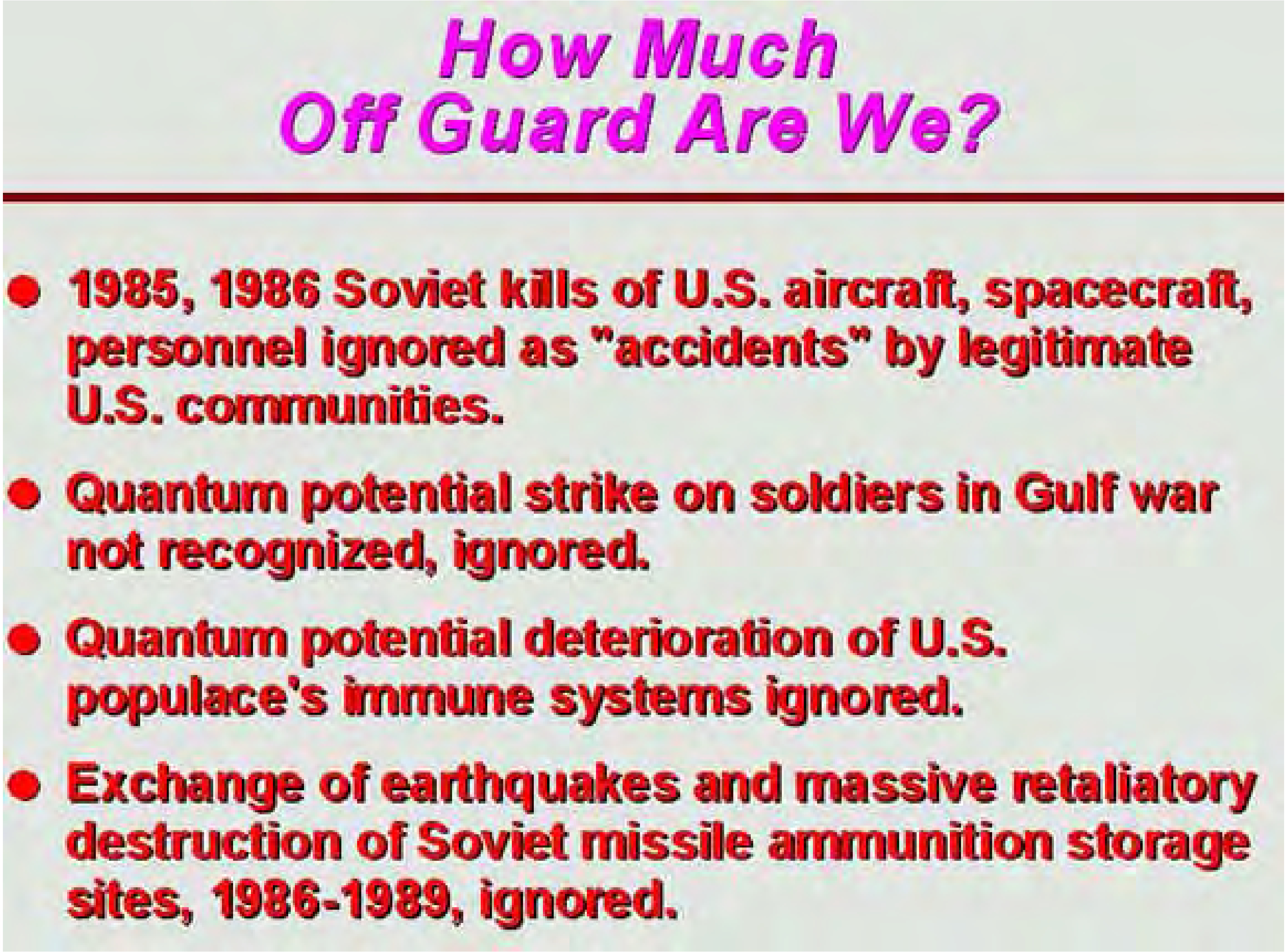

How Much
Off Guard Are We?

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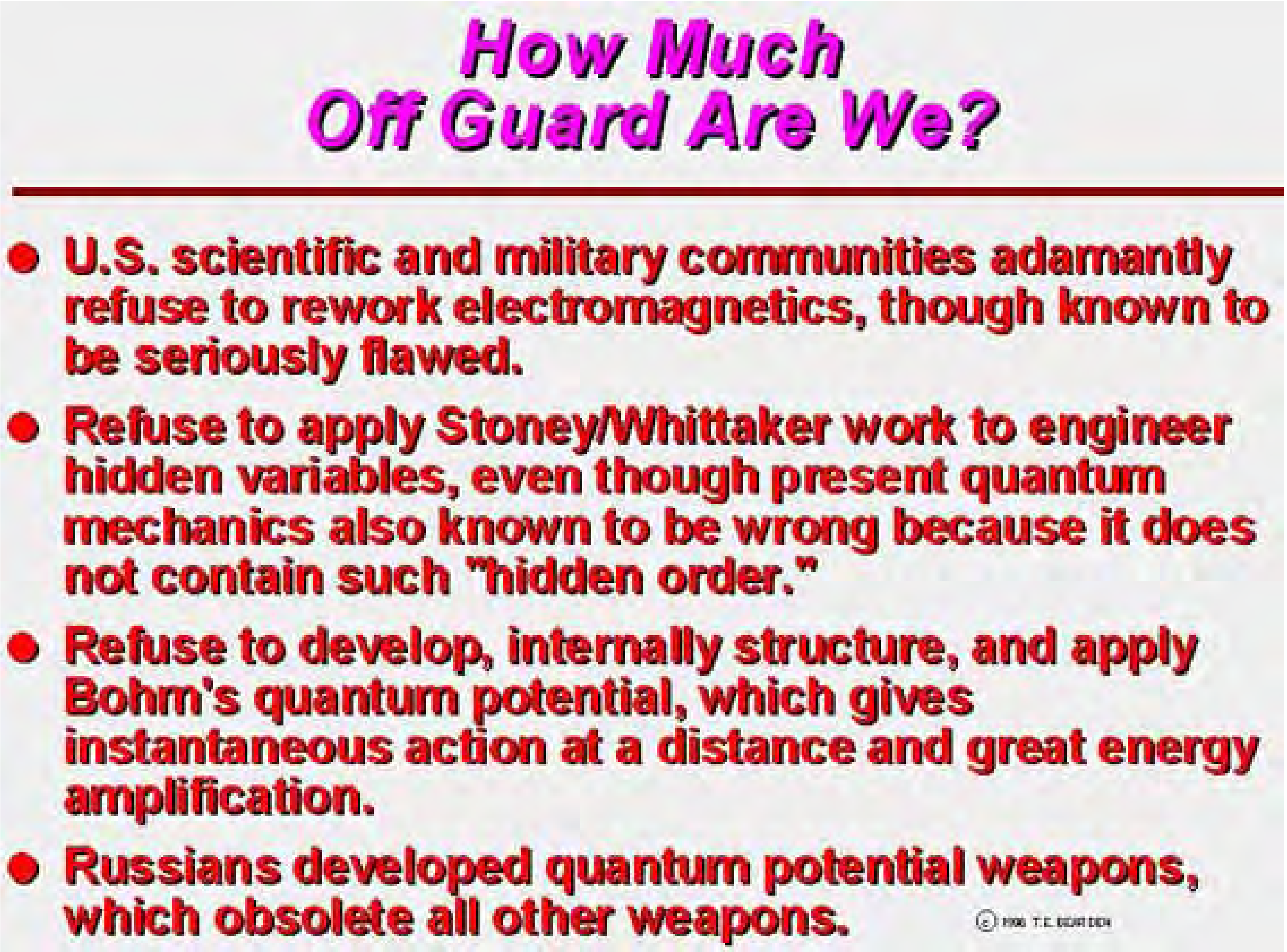

How Much Off Guard Are We?

- U.S. scientific and military communities adamantly refuse to rework electromagnetics, though known to be seriously flawed.
- Refuse to apply Stoney/Whittaker work to engineer hidden variables, even though present quantum mechanics also known to be wrong because it does not contain such "hidden order."
- Refuse to develop, internally structure, and apply Bohm's quantum potential, which gives instantaneous action at a distance and great energy amplification.
- Russians developed quantum potential weapons, which obsolete all other weapons.

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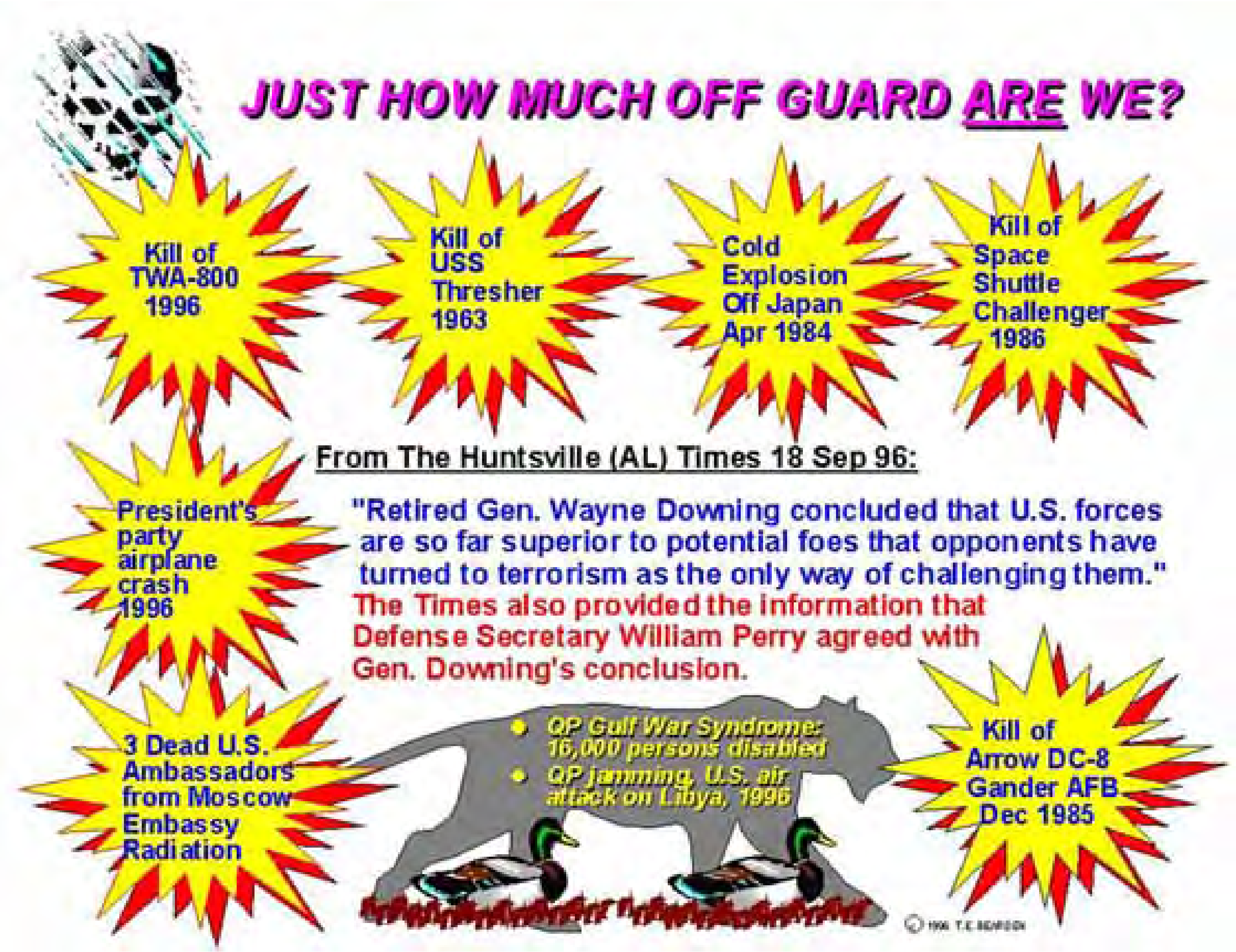

JUST HOW MUCH OFF GUARD ARE WE?

Kill of
TWA-800
1996

Kill of
USS
Thresher
1963

Cold
Explosion
Off Japan
Apr 1984

Kill of
Space
Shuttle
Challenger
1986

President's
party
airplane
crash
1996

From The Huntsville (AL) Times 18 Sep 96:

"Retired Gen. Wayne Downing concluded that U.S. forces are so far superior to potential foes that opponents have turned to terrorism as the only way of challenging them."

The Times also provided the information that Defense Secretary William Perry agreed with Gen. Downing's conclusion.

3 Dead U.S.
Ambassadors
from Moscow
Embassy
Radiation

- *QP Gulf War Syndrome: 16,000 persons disabled*
- *QP jamming, U.S. air attack on Libya, 1996*

Kill of
Arrow DC-8
Gander AFB
Dec 1985

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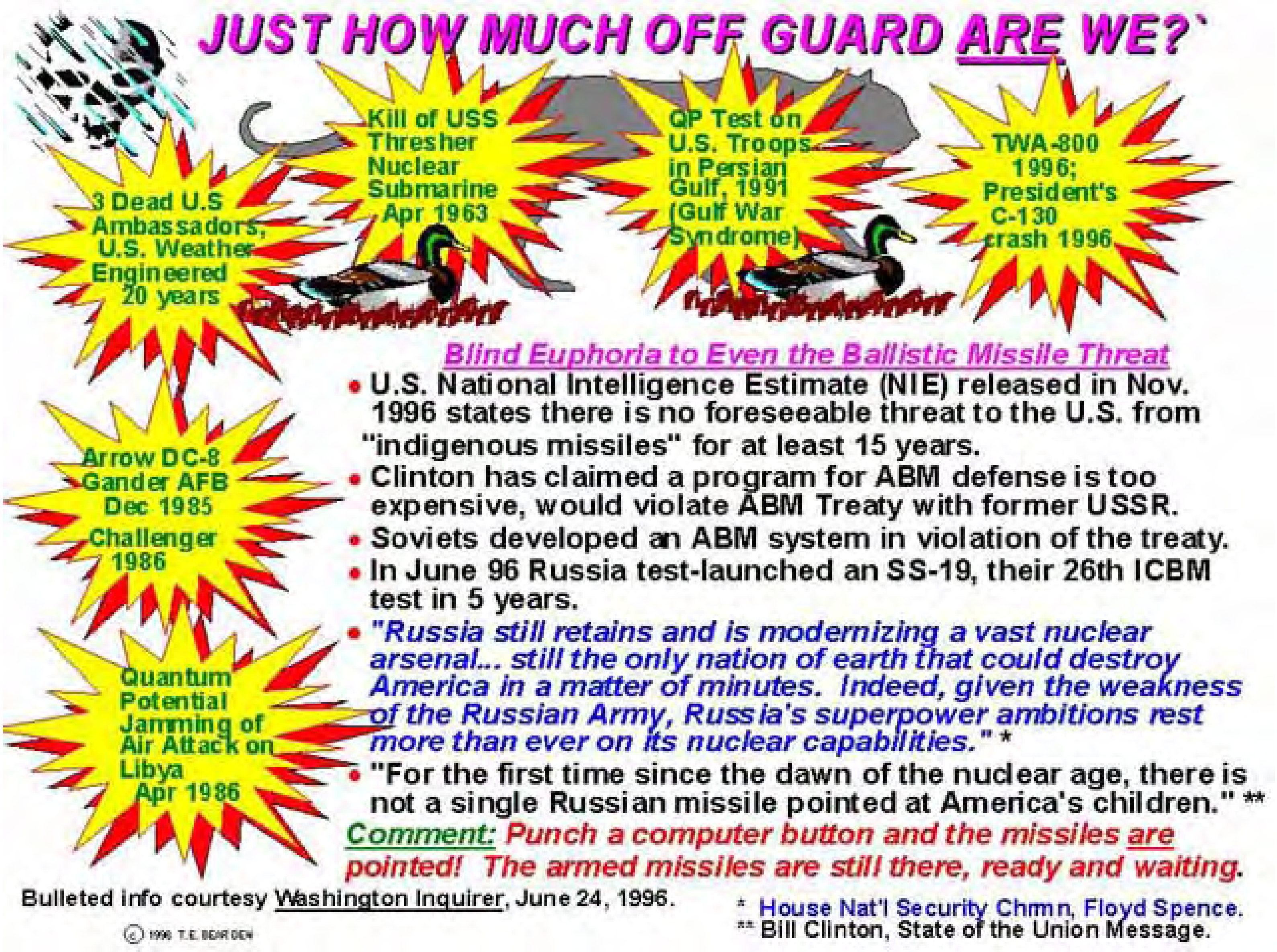

JUST HOW MUCH OFF GUARD ARE WE?`

3 Dead U.S Ambassadors, U.S. Weather Engineered 20 years

Kill of USS Thresher Nuclear Submarine Apr 1963

QP Test on U.S. Troops in Persian Gulf, 1991 (Gulf War Syndrome)

TWA-800 1996; President's C-130 crash 1996

Arrow DC-8 Gander AFB Dec 1985

Challenger 1986

Quantum Potential Jamming of Air Attack on Libya Apr 1986

Blind Euphoria to Even the Ballistic Missile Threat

- U.S. National Intelligence Estimate (NIE) released in Nov. 1996 states there is no foreseeable threat to the U.S. from "indigenous missiles" for at least 15 years.
- Clinton has claimed a program for ABM defense is too expensive, would violate ABM Treaty with former USSR.
- Soviets developed an ABM system in violation of the treaty.
- In June 96 Russia test-launched an SS-19, their 26th ICBM test in 5 years.
- *"Russia still retains and is modernizing a vast nuclear arsenal... still the only nation of earth that could destroy America in a matter of minutes. Indeed, given the weakness of the Russian Army, Russia's superpower ambitions rest more than ever on its nuclear capabilities."* *
- "For the first time since the dawn of the nuclear age, there is not a single Russian missile pointed at America's children." **

Comment: Punch a computer button and the missiles are pointed! The armed missiles are still there, ready and waiting.

Bulleted info courtesy Washington Inquirer, June 24, 1996.

* House Nat'l Security Chmn, Floyd Spence.
** Bill Clinton, State of the Union Message.

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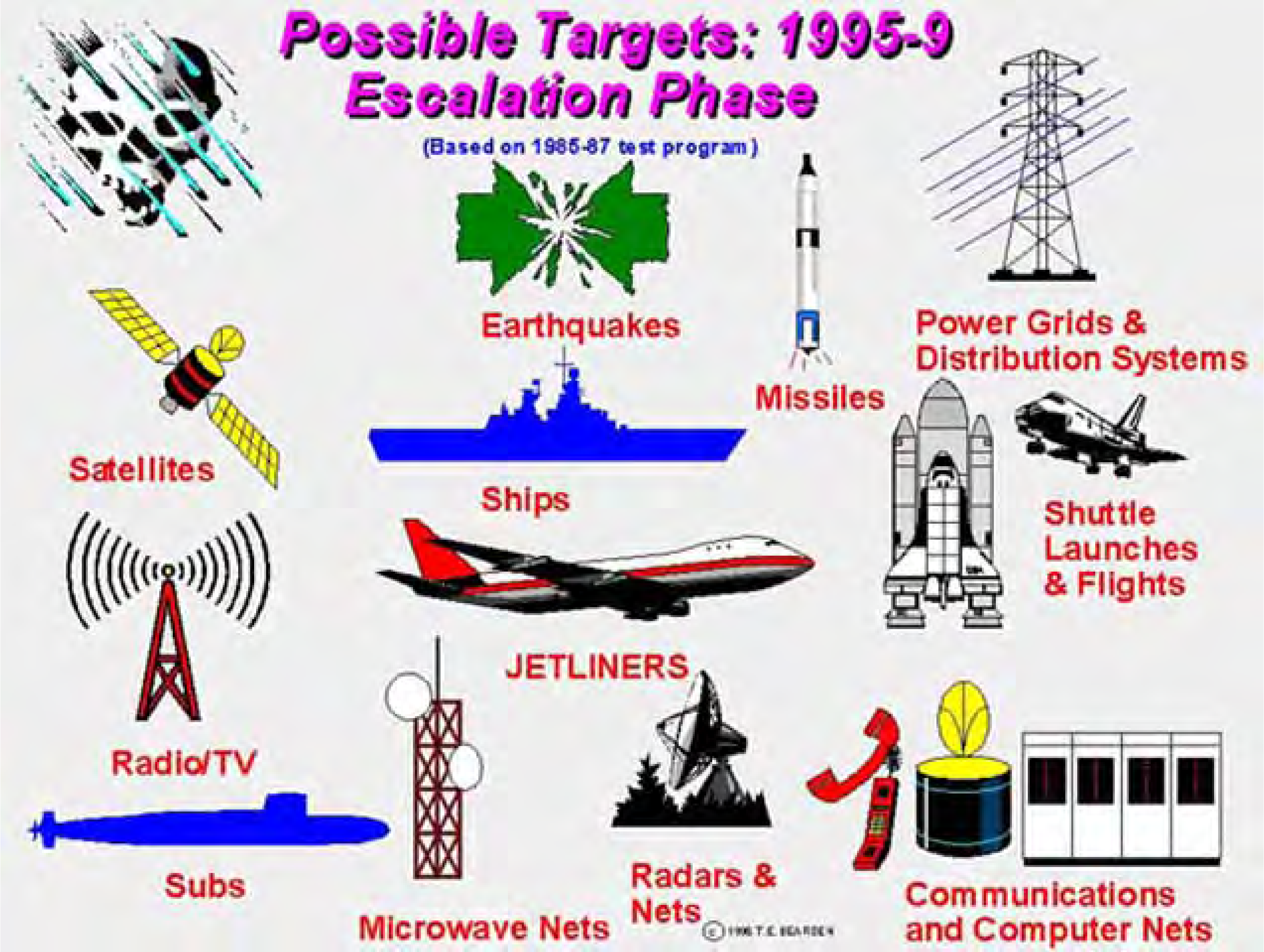
Possible Targets: 1995-9
Escalation Phase
(Based on 1985-87 test program)
Earthquakes
Missiles
Power Grids &
Distribution Systems
Satellites
Ships
Shuttle
Launches
& Flights
JETLINERS
Radio/TV
Subs
Microwave Nets
Radars &
Nets
© 1996 T.E. BEARDEN
Communications
and Computer Nets

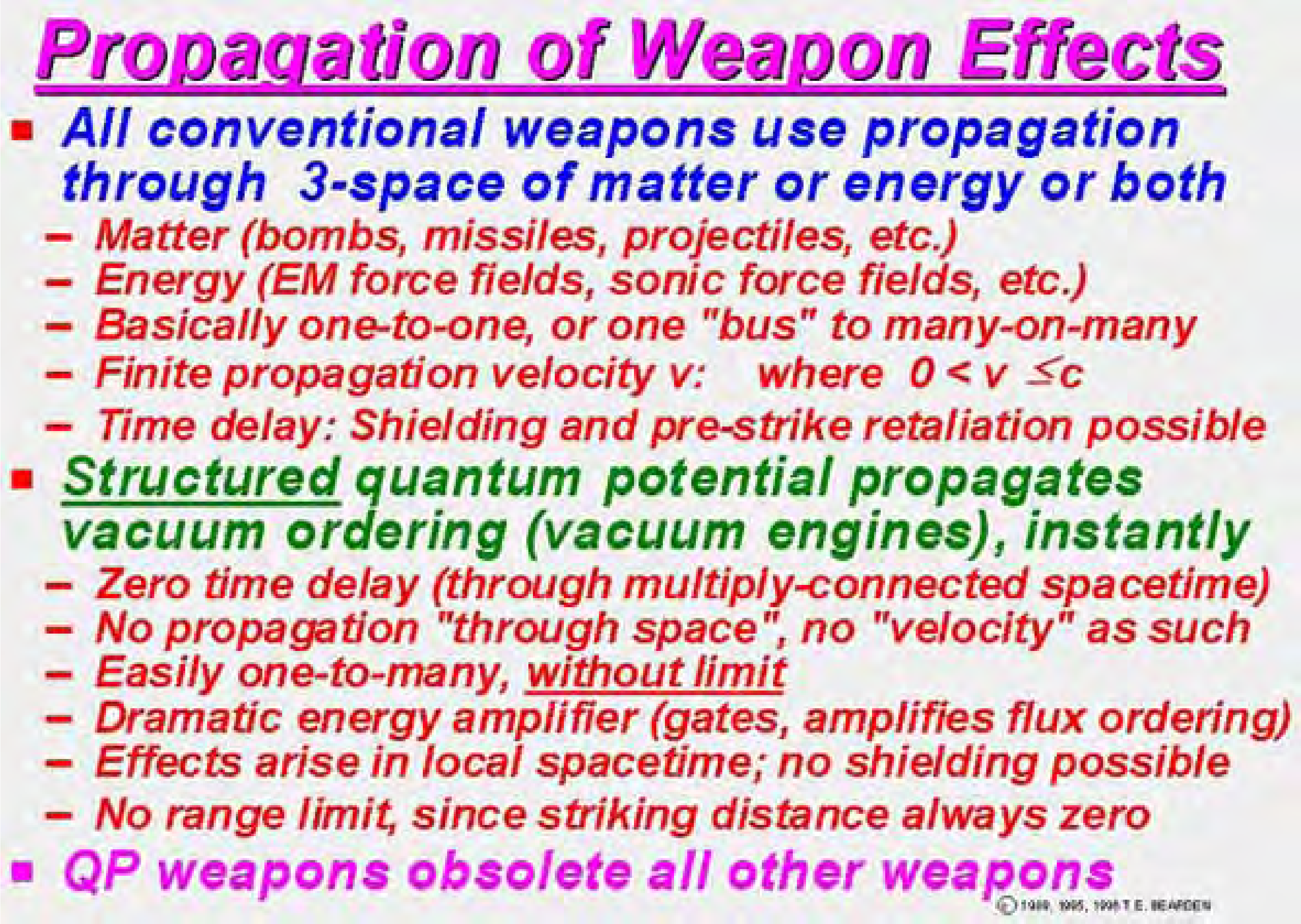

Propagation of Weapon Effects

- All conventional weapons use propagation through 3-space of matter or energy or both
  - Matter (bombs, missiles, projectiles, etc.)
  - Energy (EM force fields, sonic force fields, etc.)
  - Basically one-to-one, or one "bus" to many-on-many
  - Finite propagation velocity v: where $0 < v \leq c$
  - Time delay: Shielding and pre-strike retaliation possible
- Structured quantum potential propagates vacuum ordering (vacuum engines), instantly
  - Zero time delay (through multiply-connected spacetime)
  - No propagation "through space", no "velocity" as such
  - Easily one-to-many, without limit
  - Dramatic energy amplifier (gates, amplifies flux ordering)
  - Effects arise in local spacetime; no shielding possible
  - No range limit, since striking distance always zero
- QP weapons obsolete all other weapons

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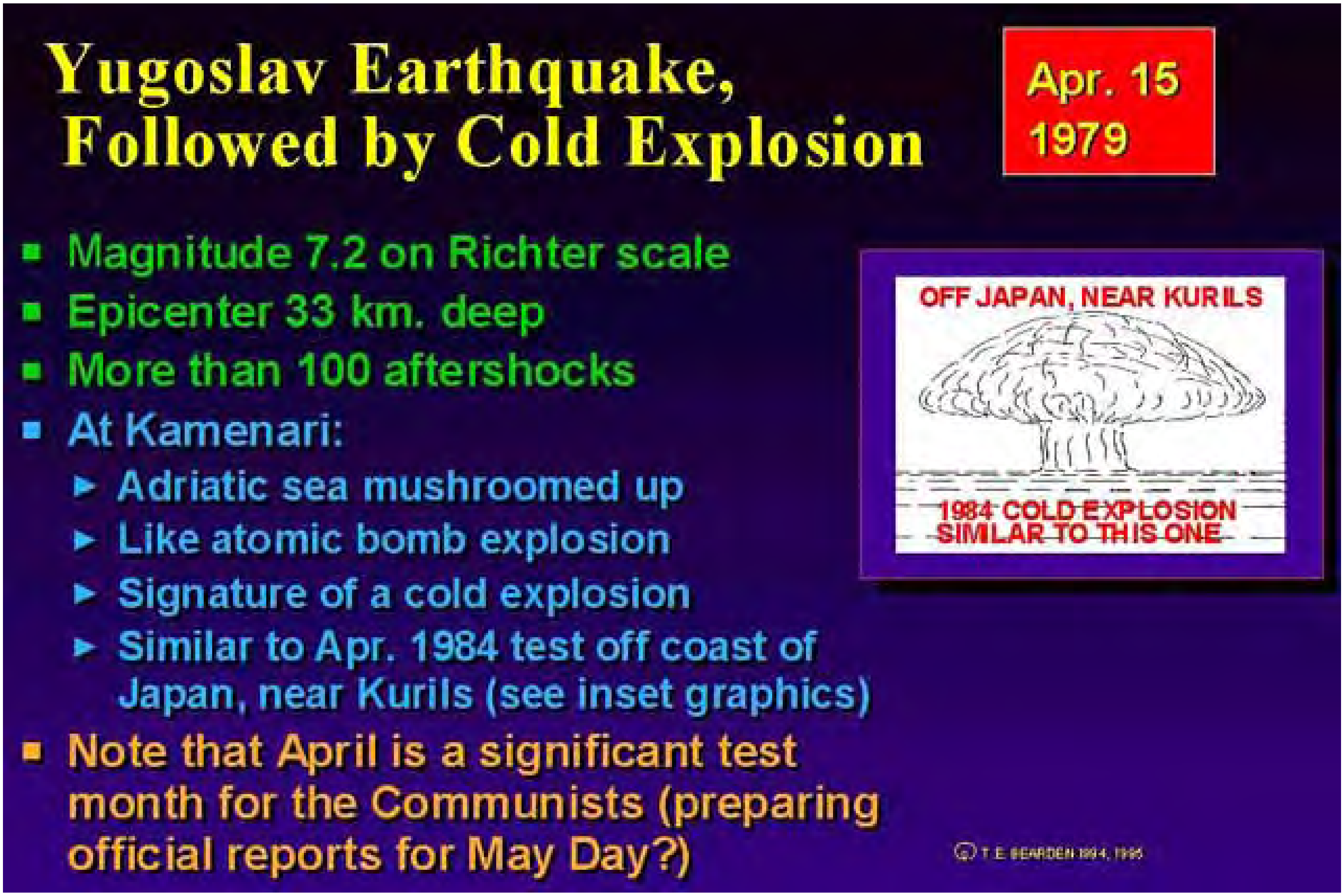

Yugoslav Earthquake, Followed by Cold Explosion

Apr. 15
1979

- Magnitude 7.2 on Richter scale
- Epicenter 33 km. deep
- More than 100 aftershocks
- At Kamenari:
  - Adriatic sea mushroomed up
  - Like atomic bomb explosion
  - Signature of a cold explosion
  - Similar to Apr. 1984 test off coast of Japan, near Kurils (see inset graphics)
- Note that April is a significant test month for the Communists (preparing official reports for May Day?)

OFF JAPAN, NEAR KURILS

1984 COLD EXPLOSION
SIMILAR TO THIS ONE

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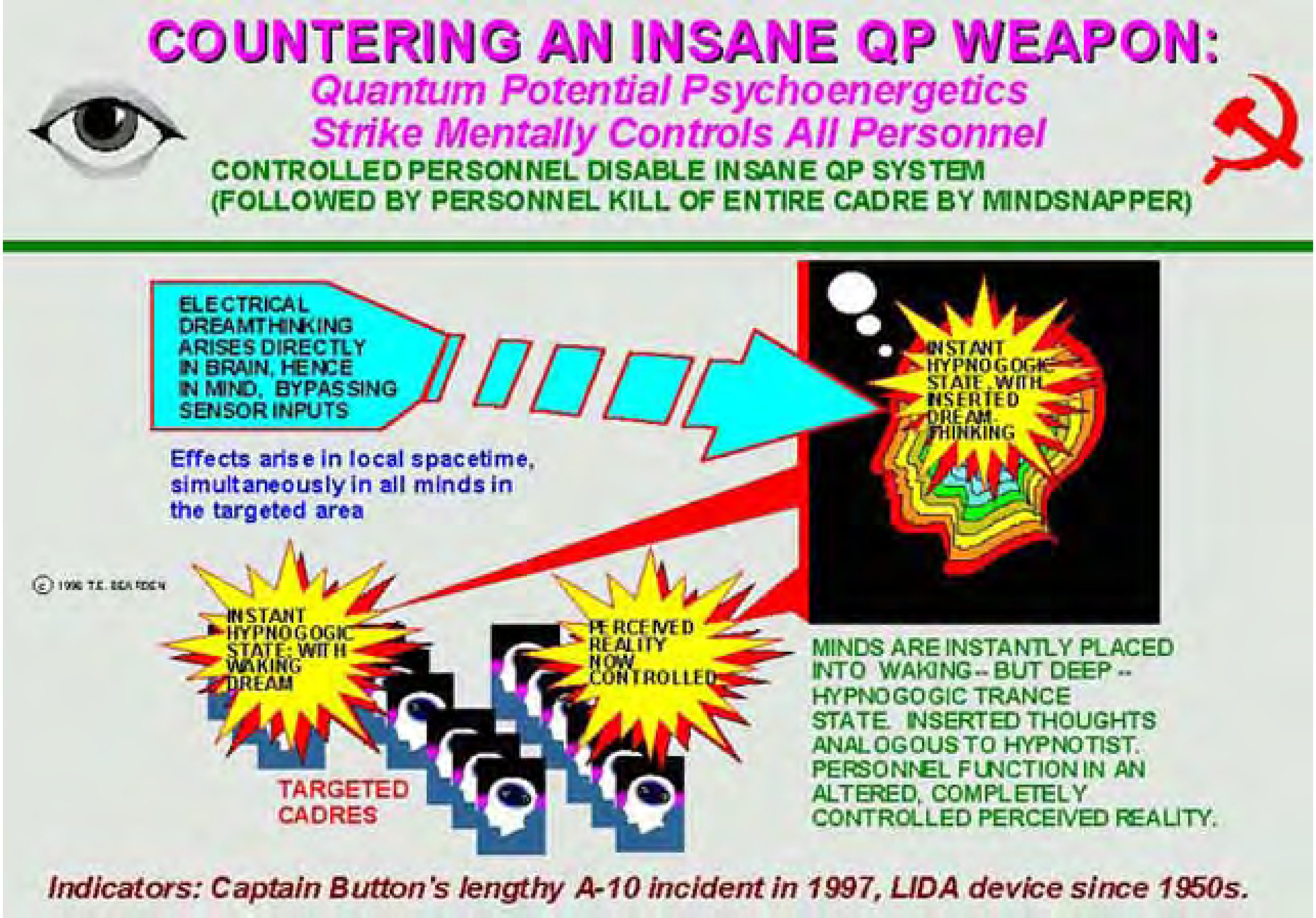

COUNTERING AN INSANE QP WEAPON:

Quantum Potential Psychoenergetics Strike Mentally Controls All Personnel

CONTROLLED PERSONNEL DISABLE INSANE QP SYSTEM
(FOLLOWED BY PERSONNEL KILL OF ENTIRE CADRE BY MINDSNAPPER)

ELECTRICAL DREAMTHINKING ARISES DIRECTLY IN BRAIN, HENCE IN MIND, BYPASSING SENSOR INPUTS

Effects arise in local spacetime, simultaneously in all minds in the targeted area

INSTANT HYPNOGOGIC STATE, WITH INSERTED DREAM THINKING

INSTANT HYPNOGOGIC STATE: WITH WAKING DREAM

PERCEIVED REALITY NOW CONTROLLED

TARGETED CADRES

MINDS ARE INSTANTLY PLACED INTO WAKING-- BUT DEEP -- HYPNOGOGIC TRANCE STATE. INSERTED THOUGHTS ANALOGOUS TO HYPNOTIST. PERSONNEL FUNCTION IN AN ALTERED, COMPLETELY CONTROLLED PERCEIVED REALITY.

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Indicators: Captain Button's lengthy A-10 incident in 1997, LIDA device since 1950s.

Gulf War Disease: KGB QP Weapon Induced ST Curvature Engines for a Cocktail of Diseases

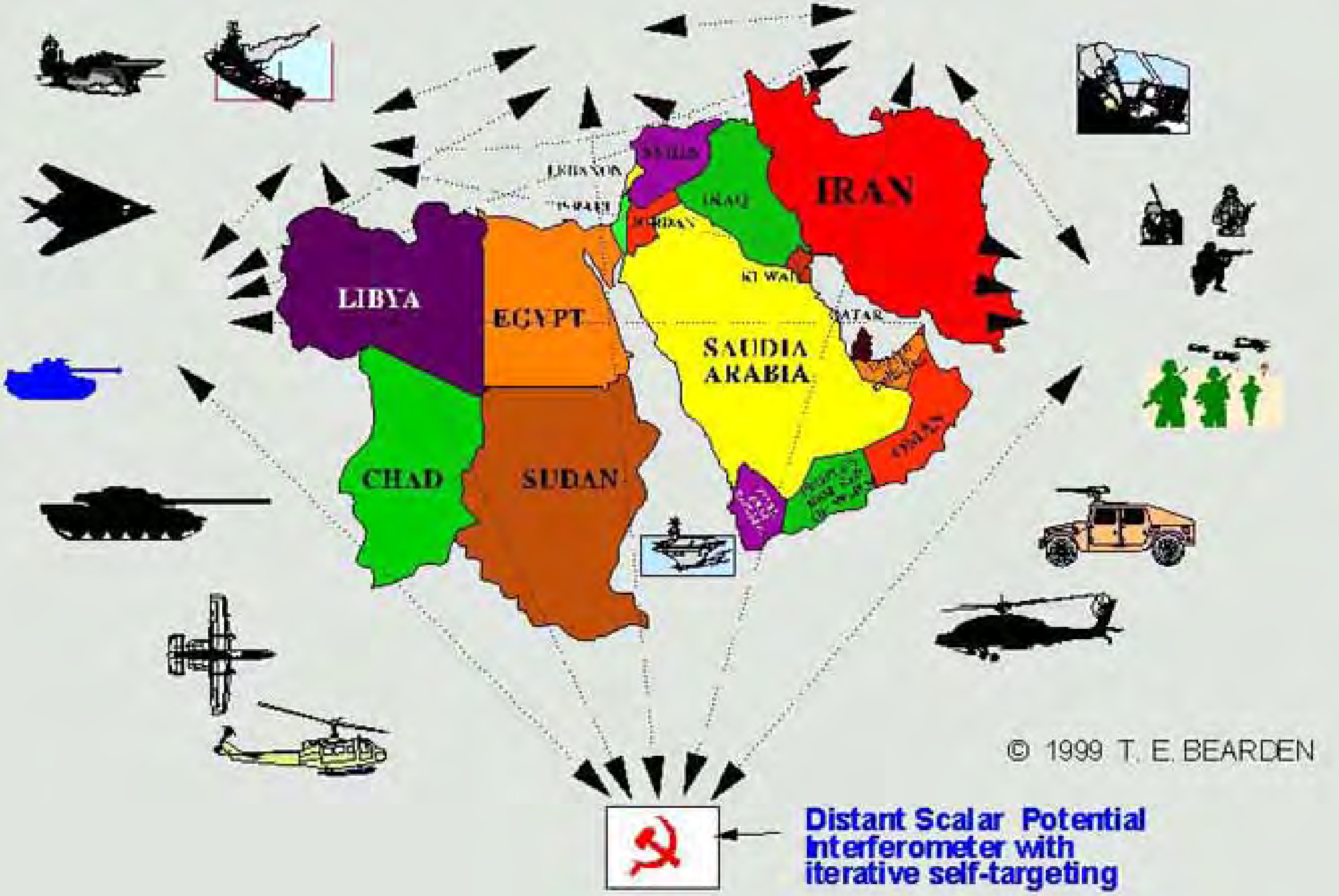
LEBANON
SYRIA
ISRAEL
JORDAN
IRAQ
IRAN
KUWAIT
QATAR
LIBYA
EGYPT
SAUDIA ARABIA
OMAN
CHAD
SUDAN

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Distant Scalar Potential Interferometer with iterative self-targeting

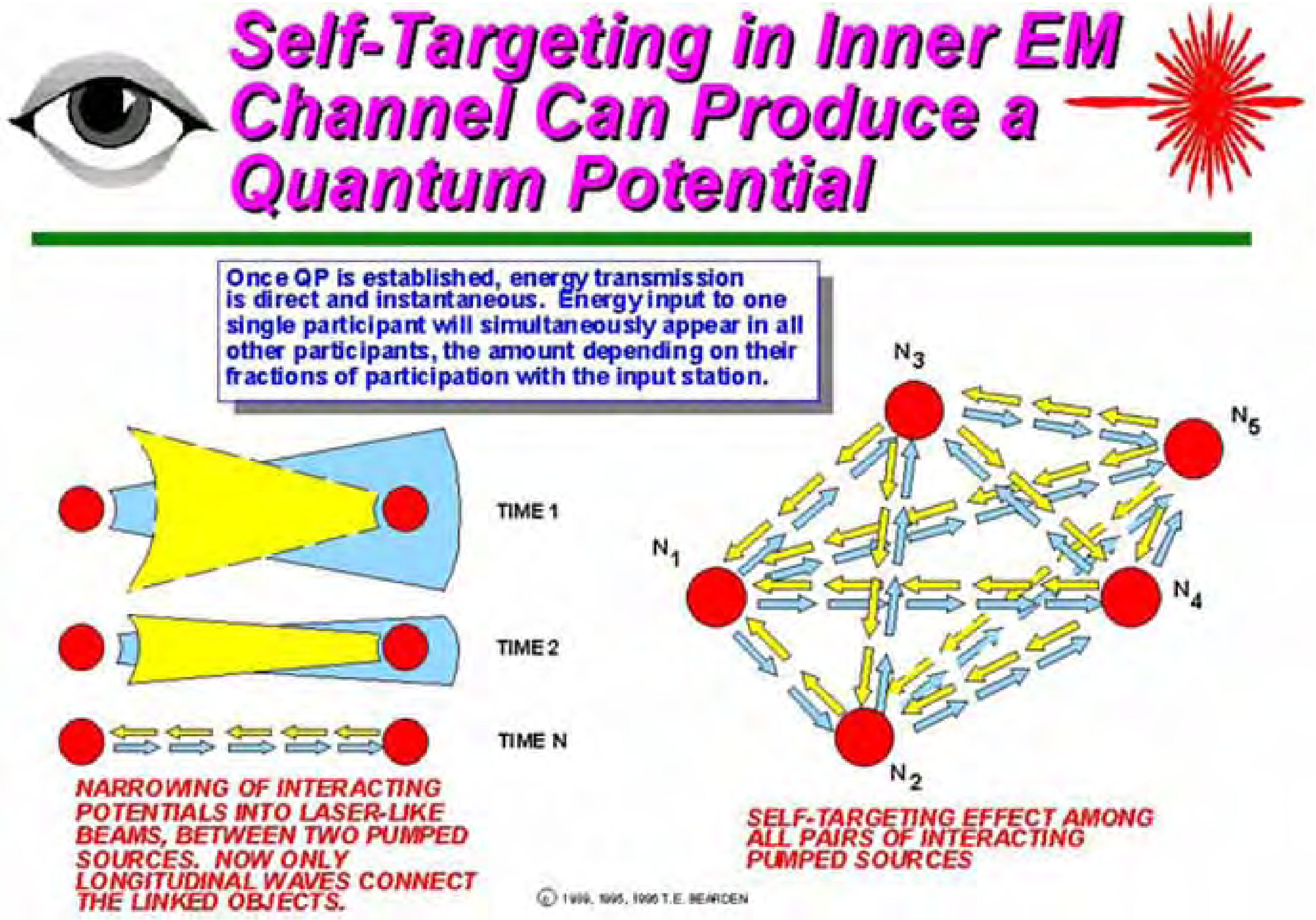

Self-Targeting in Inner EM Channel Can Produce a Quantum Potential

Once QP is established, energy transmission is direct and instantaneous. Energy input to one single participant will simultaneously appear in all other participants, the amount depending on their fractions of participation with the input station.

NARROWING OF INTERACTING POTENTIALS INTO LASER-LIKE BEAMS, BETWEEN TWO PUMPED SOURCES. NOW ONLY LONGITUDINAL WAVES CONNECT THE LINKED OBJECTS.

SELF-TARGETING EFFECT AMONG ALL PAIRS OF INTERACTING PUMPED SOURCES

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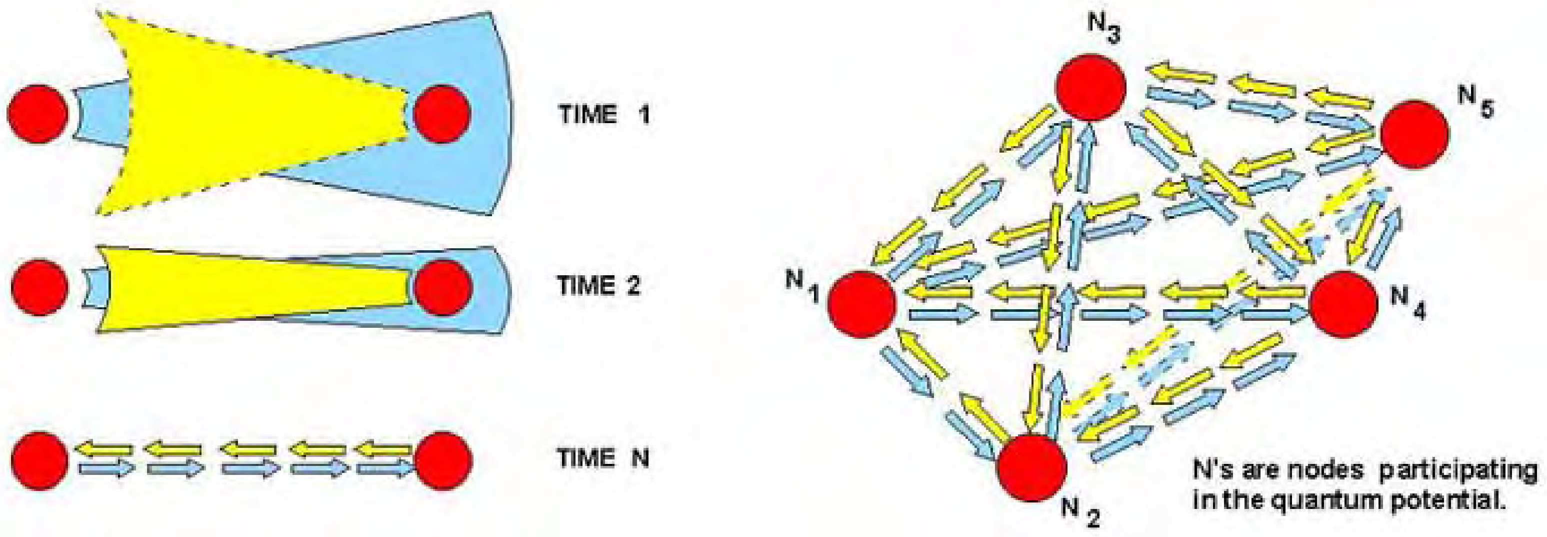

a. Iterative retroreflection between any pair of nodes narrows the interconnecting potentials to a laser-like, bidirectional beam. Iterative phase conjugate reflection provides self-targeting.

b. The quantum potential exists as narrow, laser-like beams between participating nodes, even when the nodes are widely separated. The beam space is multiply-connected; transmission is instantaneous.

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Consider the hidden Stoney/Whittaker bidirectional EM waves that comprise the potential from each source node. If these nodes have sufficient intersymmetry of dynamic material form, then self-targeting occurs between the two nodes of any nodal pair. By iterative phase conjugate reflection, the scattering is narrowed into interconnecting wavepairs, in laser-like beams, between each two nodes. Thus the interconnecting potentials narrow into laser-like, bidirectional beams. The Coulomb gauge may apply, and a quantum potential may be formed.

Figure 30. Mechanism for generating a quantum potential, by iterative self-targeting induced into a system of multiple scattering nodes. Once a QP is established, spatial separation has little or no effect.

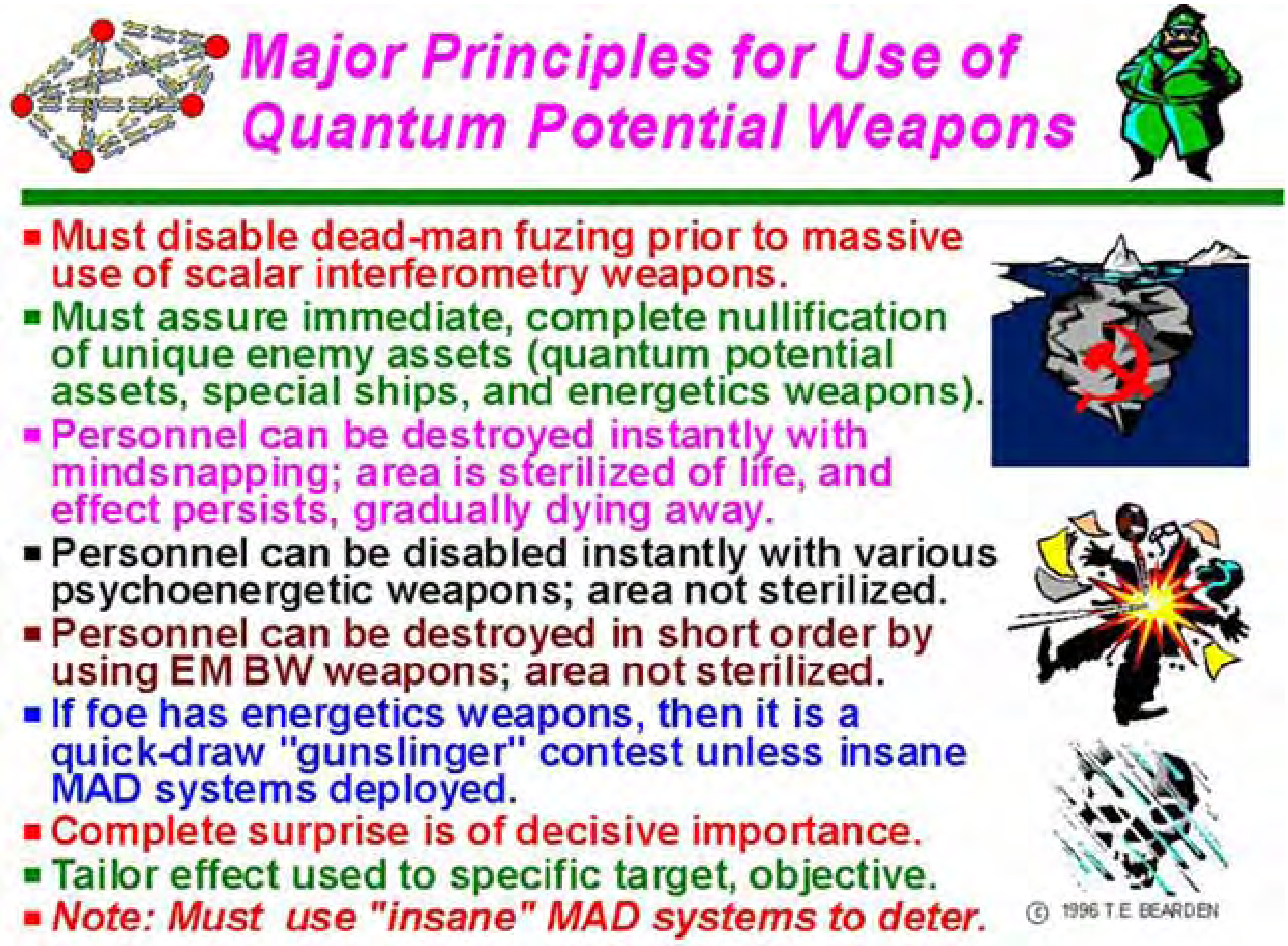

Major Principles for Use of Quantum Potential Weapons

- Must disable dead-man fuzing prior to massive use of scalar interferometry weapons.
- Must assure immediate, complete nullification of unique enemy assets (quantum potential assets, special ships, and energetics weapons).
- Personnel can be destroyed instantly with mindsnapping; area is sterilized of life, and effect persists, gradually dying away.
- Personnel can be disabled instantly with various psychoenergetic weapons; area not sterilized.
- Personnel can be destroyed in short order by using EM BW weapons; area not sterilized.
- If foe has energetics weapons, then it is a quick-draw "gunslinger" contest unless insane MAD systems deployed.
- Complete surprise is of decisive importance.
- Tailor effect used to specific target, objective.
- *Note: Must use "insane" MAD systems to deter.*

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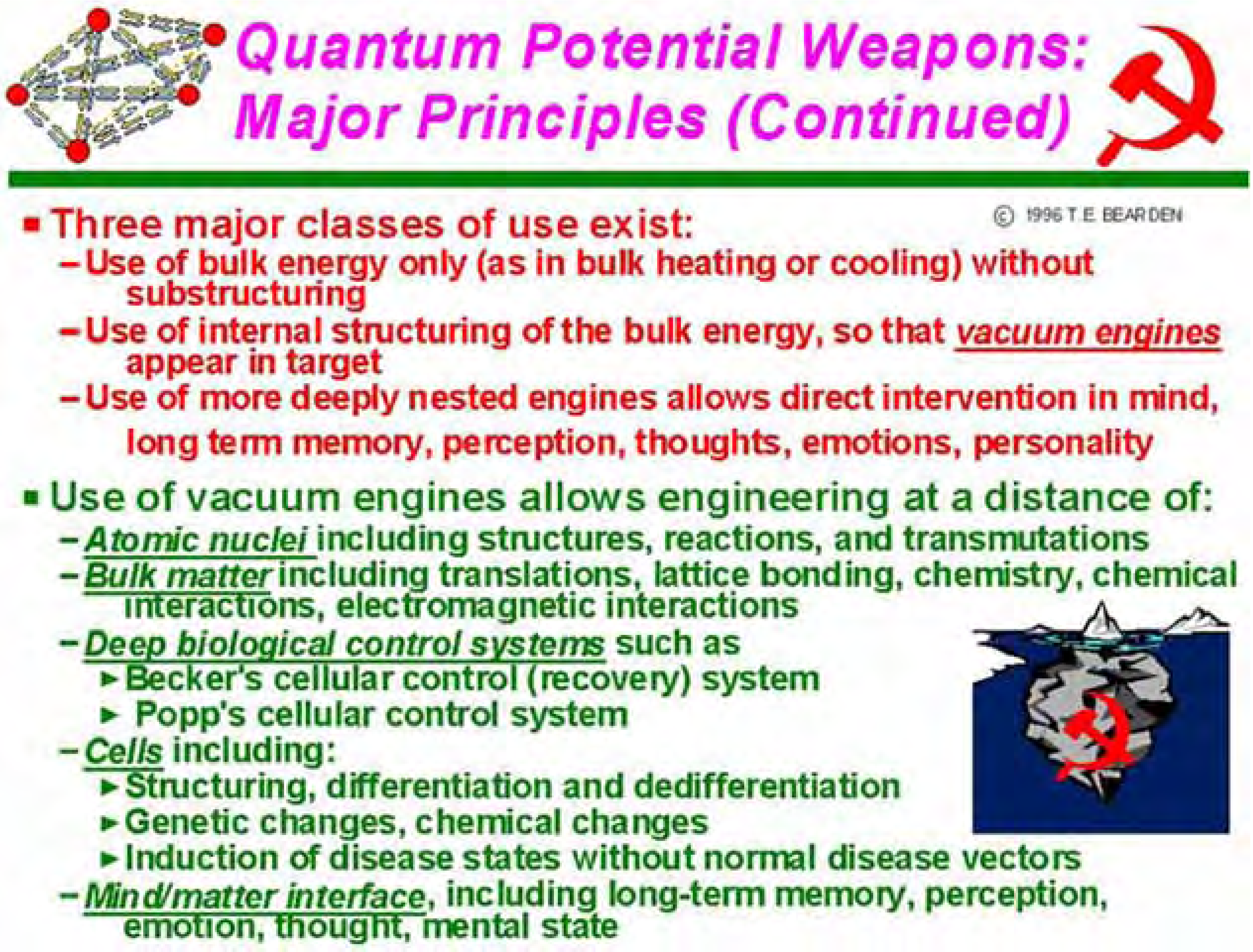

Quantum Potential Weapons: Major Principles (Continued)

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- Three major classes of use exist:
  - Use of bulk energy only (as in bulk heating or cooling) without substructuring
  - Use of internal structuring of the bulk energy, so that *vacuum engines* appear in target
  - Use of more deeply nested engines allows direct intervention in mind, long term memory, perception, thoughts, emotions, personality
- Use of vacuum engines allows engineering at a distance of:
  - *Atomic nuclei* including structures, reactions, and transmutations
  - *Bulk matter* including translations, lattice bonding, chemistry, chemical interactions, electromagnetic interactions
  - *Deep biological control systems* such as
    - Becker's cellular control (recovery) system
    - Popp's cellular control system
  - *Cells* including:
    - Structuring, differentiation and dedifferentiation
    - Genetic changes, chemical changes
    - Induction of disease states without normal disease vectors
  - *Mind/matter interface*, including long-term memory, perception, emotion, thought, mental state

Instantaneous Communication by a Quantum Potential

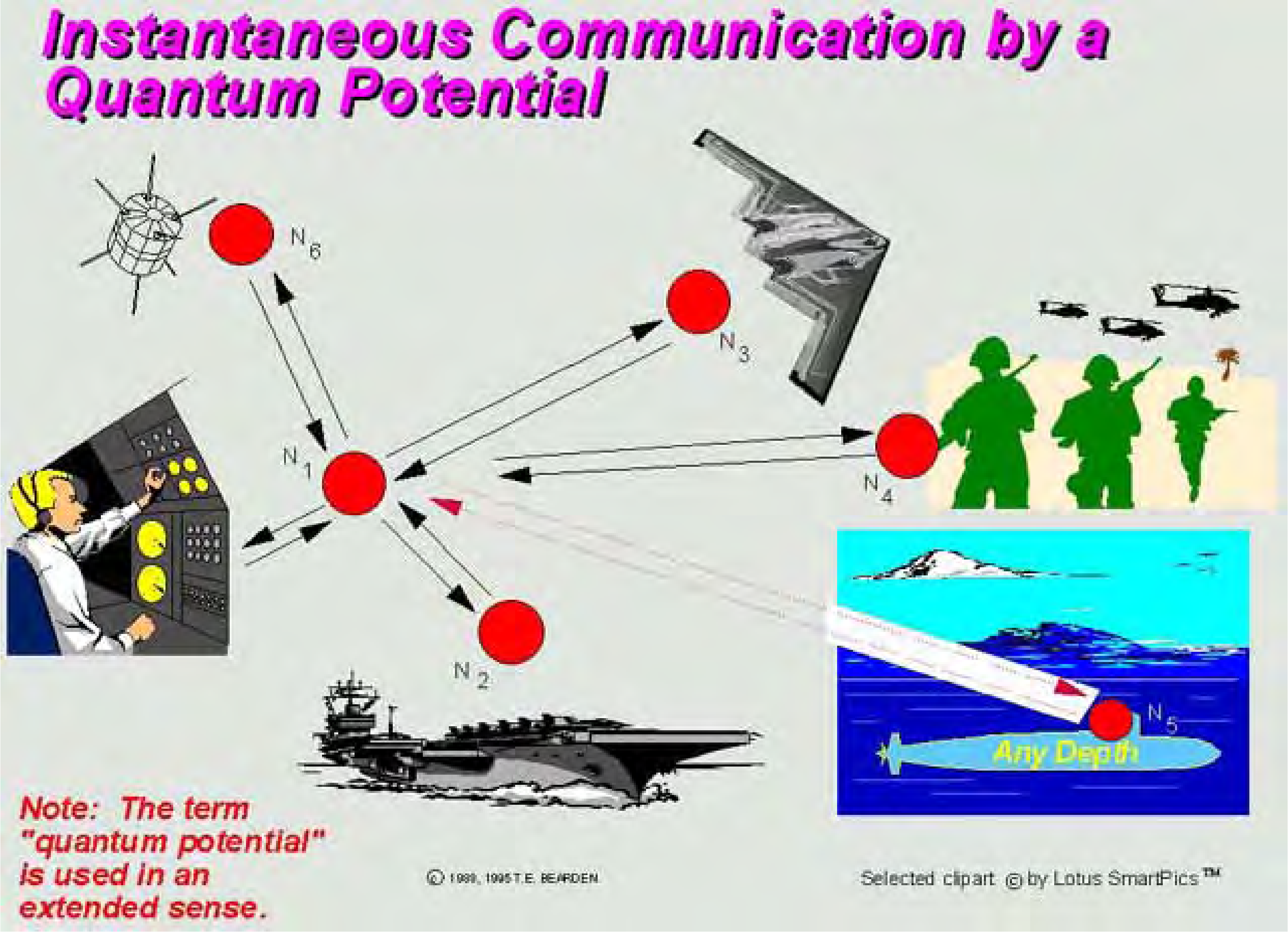

Note: The term "quantum potential" is used in an extended sense.

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Selected clipart © by Lotus SmartPics™

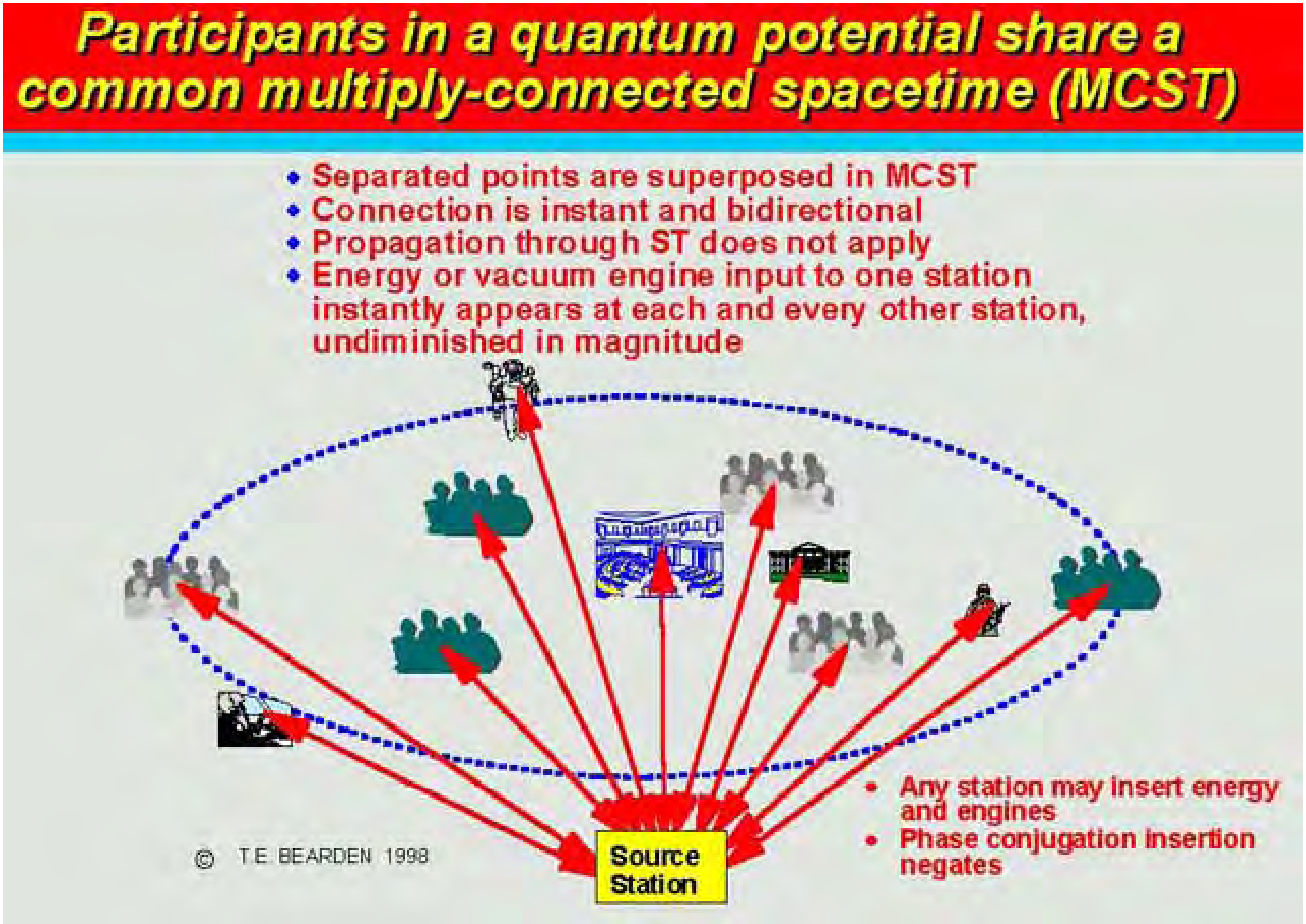

Participants in a quantum potential share a common multiply-connected spacetime (MCST)

- Separated points are superposed in MCST
- Connection is instant and bidirectional
- Propagation through ST does not apply
- Energy or vacuum engine input to one station instantly appears at each and every other station, undiminished in magnitude

- Any station may insert energy and engines
- Phase conjugation insertion negates

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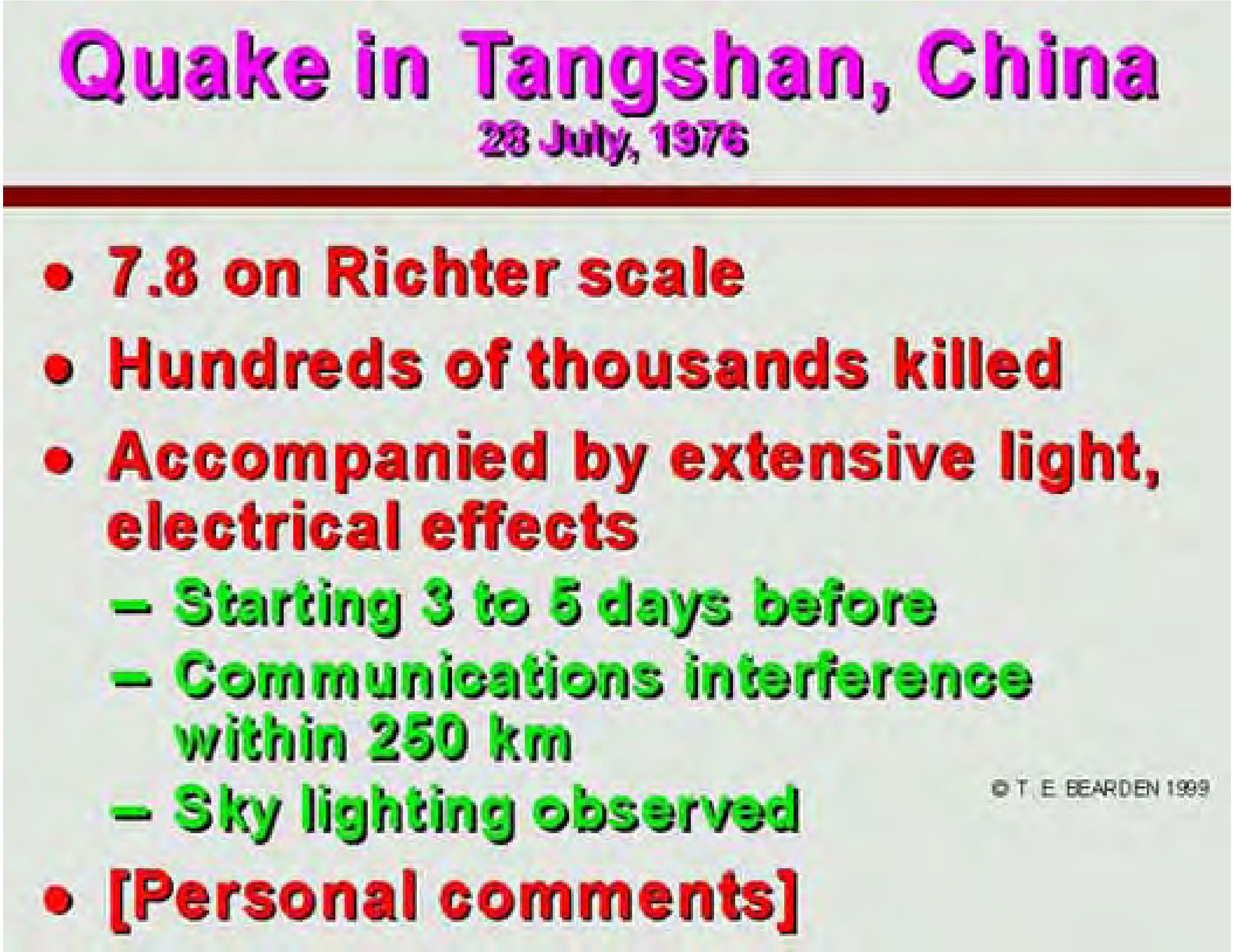

Quake in Tangshan, China

28 July, 1976

- 7.8 on Richter scale
- Hundreds of thousands killed
- Accompanied by extensive light, electrical effects
  - Starting 3 to 5 days before
  - Communications interference within 250 km
  - Sky lighting observed
- [Personal comments]

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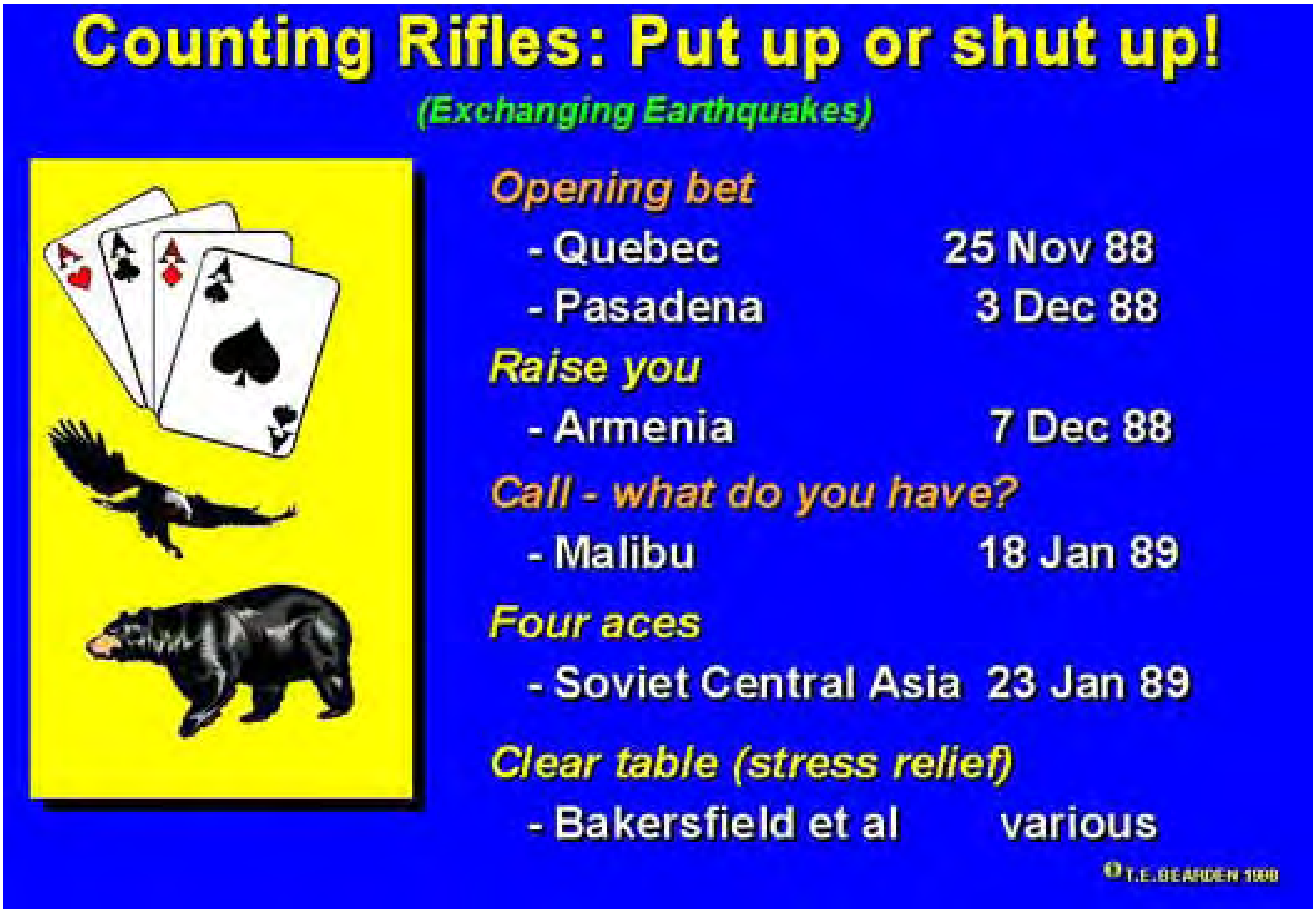

Counting Rifles: Put up or shut up!

(Exchanging Earthquakes)

Opening bet

- Quebec 25 Nov 88
- Pasadena 3 Dec 88

Raise you

- Armenia 7 Dec 88

Call - what do you have?

- Malibu 18 Jan 89

Four aces

- Soviet Central Asia 23 Jan 89

Clear table (stress relief)

- Bakersfield et al various

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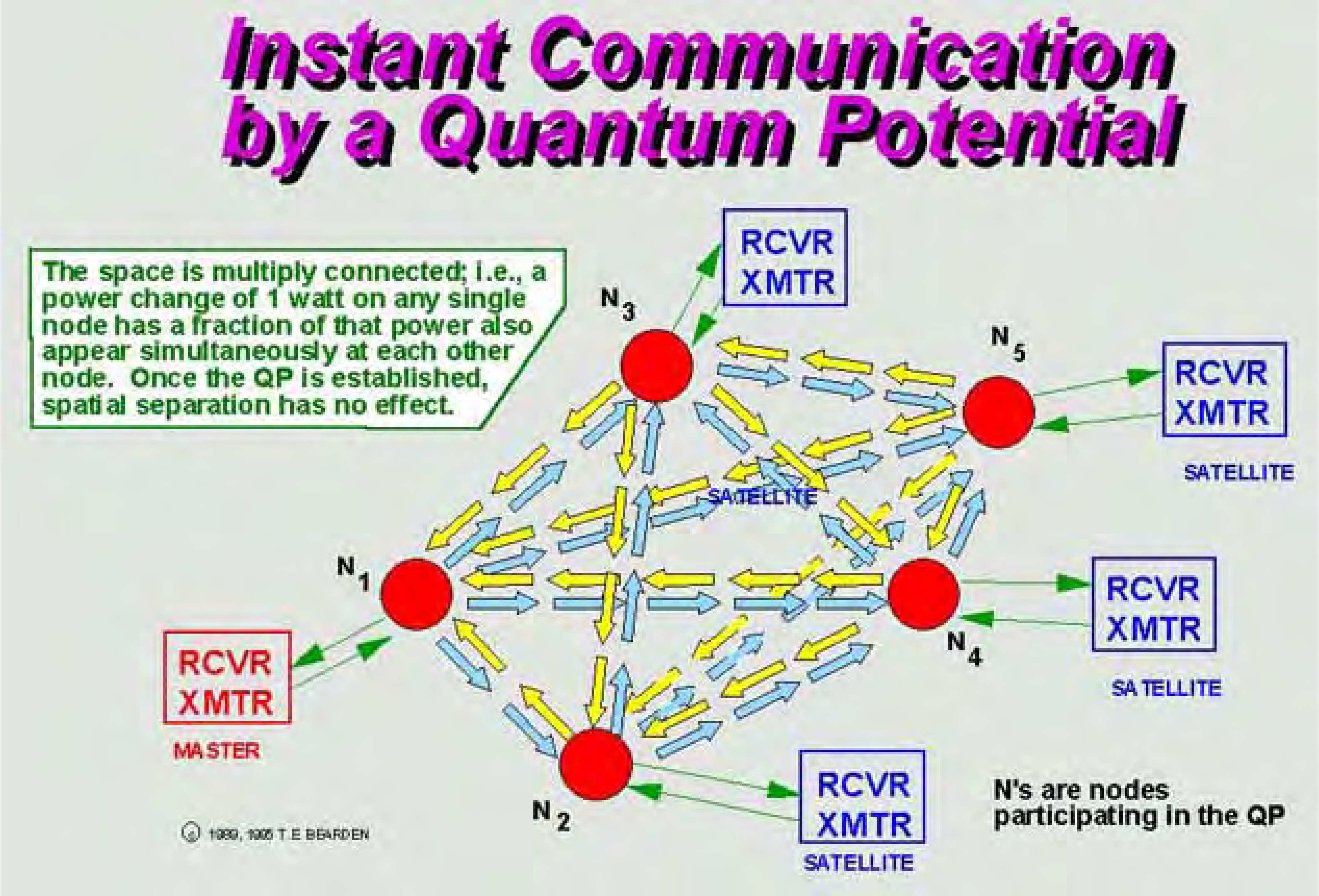

Instant Communication by a Quantum Potential

The space is multiply connected; i.e., a power change of 1 watt on any single node has a fraction of that power also appear simultaneously at each other node. Once the QP is established, spatial separation has no effect.

RCVR
XMTR
N_3
N_5
RCVR
XMTR
SATELLITE
SATELLITE
N_1
RCVR
XMTR
N_4
RCVR
XMTR
MASTER
SATELLITE
N_2
RCVR
XMTR
SATELLITE

N's are nodes participating in the QP

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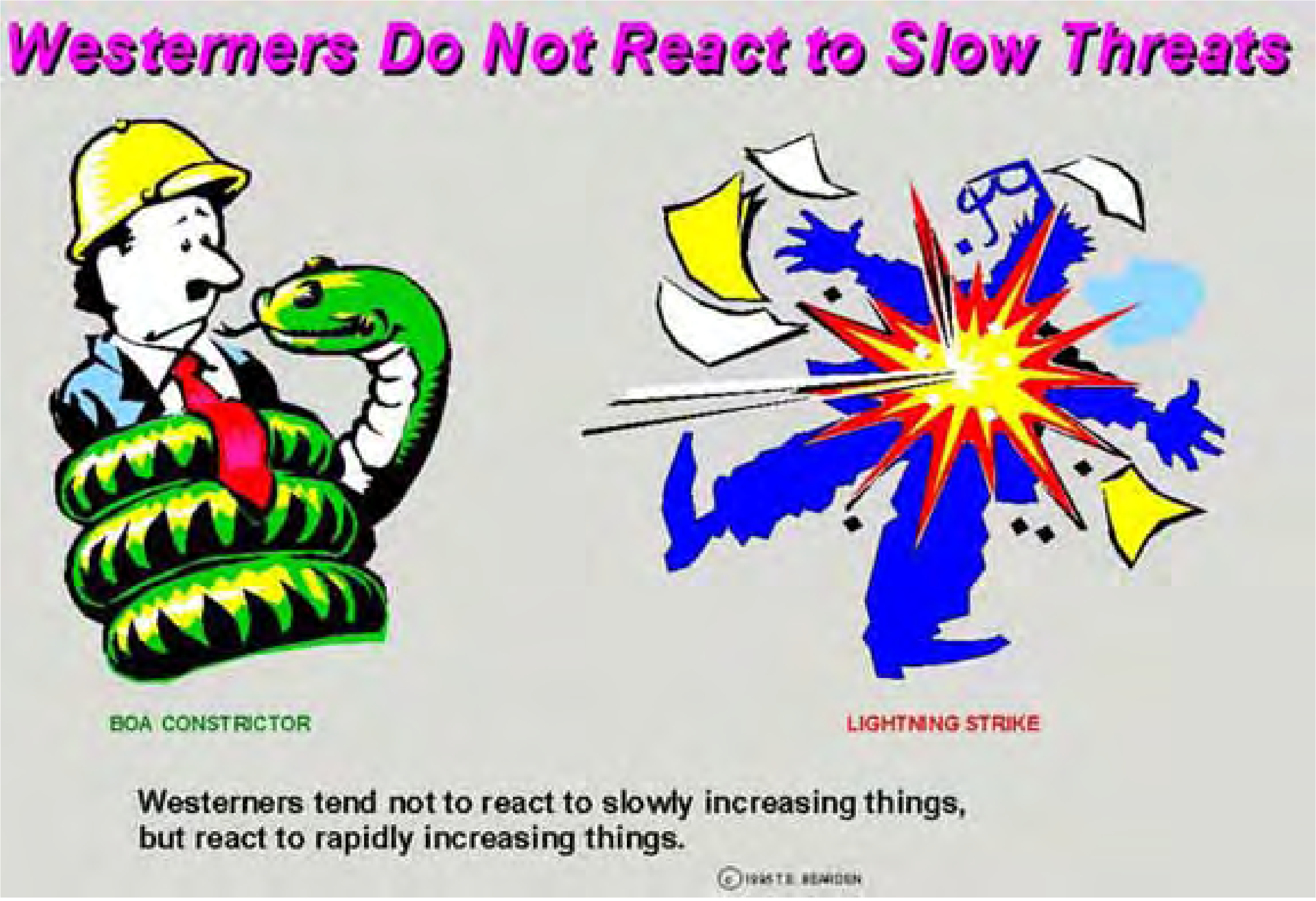

Westerners Do Not React to Slow Threats

BOA CONSTRICTOR
LIGHTNING STRIKE

Westerners tend not to react to slowly increasing things,
but react to rapidly increasing things.

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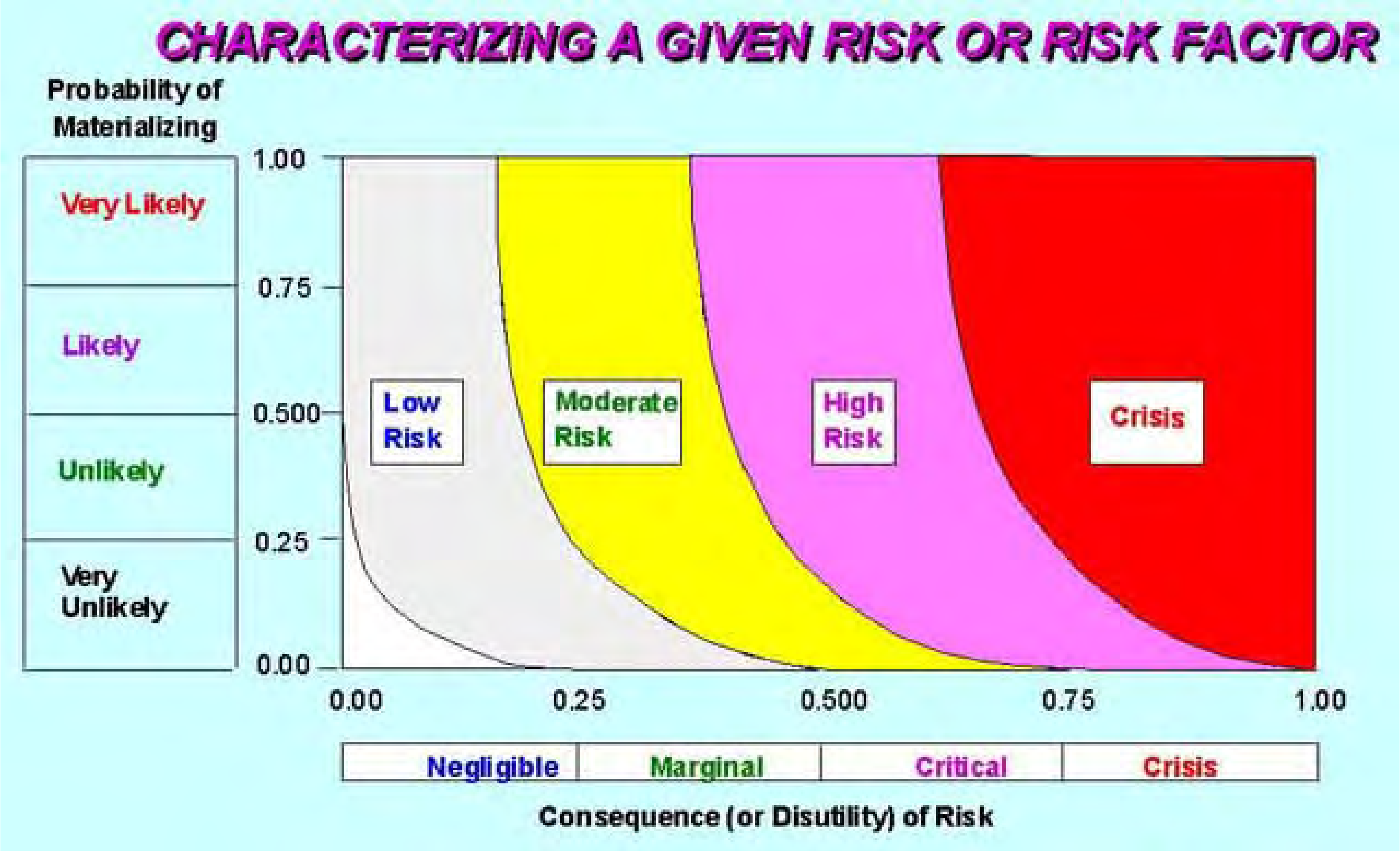
CHARACTERIZING A GIVEN RISK OR RISK FACTOR
Probability of Materializing
Very Likely
Likely
Unlikely
Very Unlikely
1.00
0.75
0.500
0.25
0.00
Low Risk
Moderate Risk
High Risk
Crisis
0.00
0.25
0.500
0.75
1.00
Negligible
Marginal
Critical
Crisis
Consequence (or Disutility) of Risk

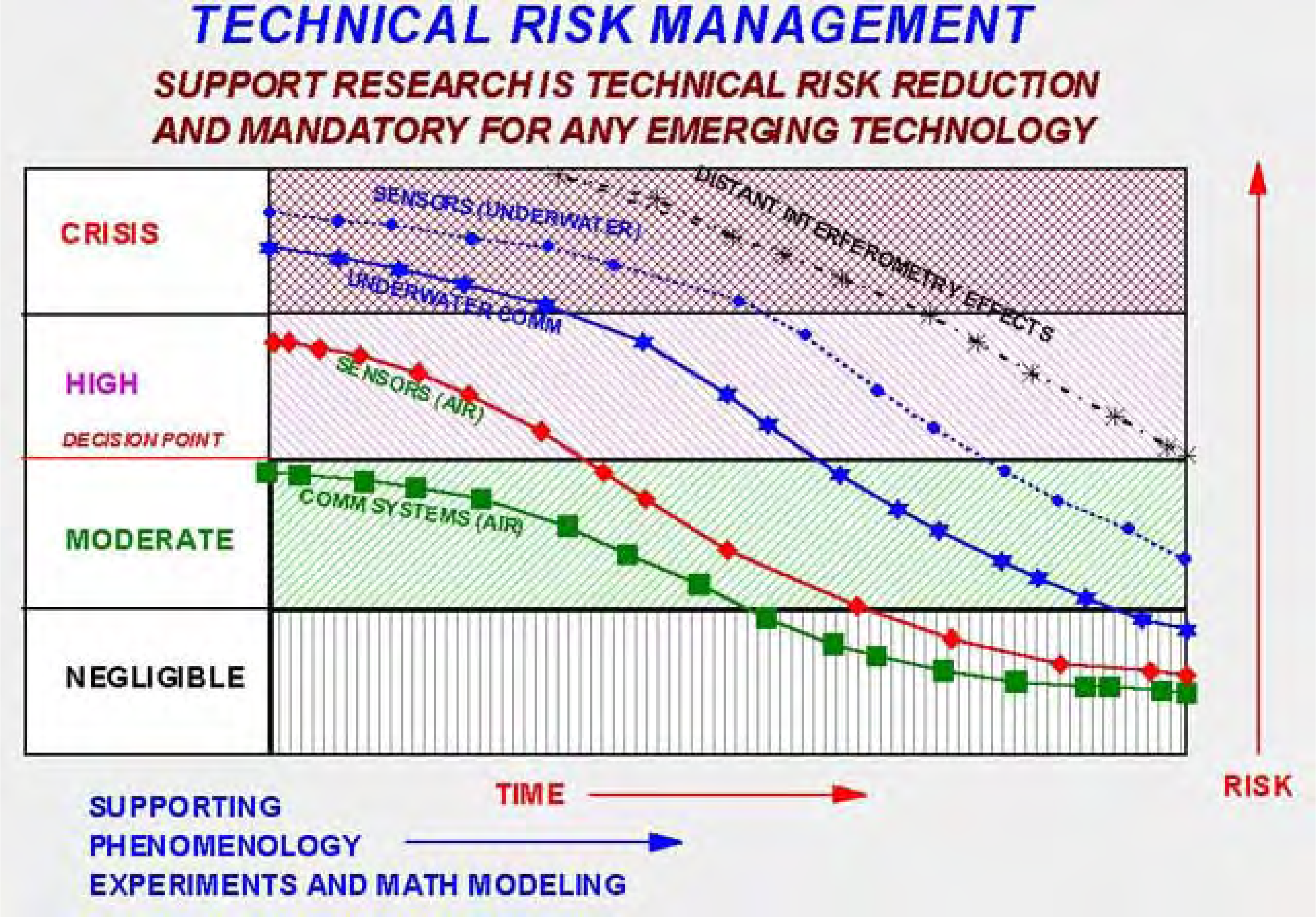

TECHNICAL RISK MANAGEMENT

SUPPORT RESEARCH IS TECHNICAL RISK REDUCTION AND MANDATORY FOR ANY EMERGING TECHNOLOGY

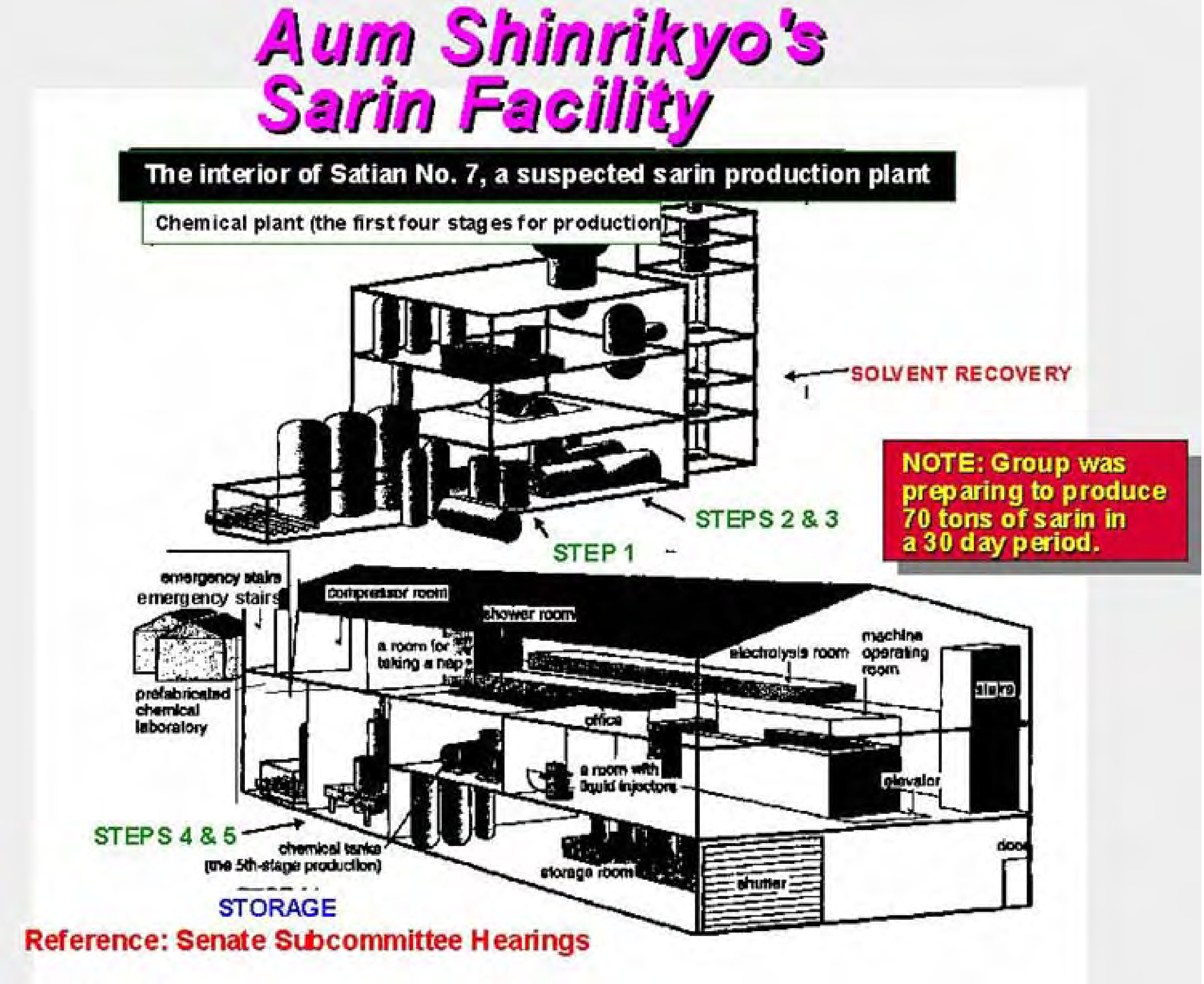

Aum Shinrikyo's Sarin Facility

The interior of Satian No. 7, a suspected sarin production plant

Chemical plant (the first four stages for production)

SOLVENT RECOVERY
STEPS 2 & 3
STEP 1
emergency stairs
emergency stairs
compressor room
shower room
a room for taking a nap
electrolysis room
machine operating room
stairs
prefabricated chemical laboratory
office
a room with liquid injectors
elevator
STEPS 4 & 5
chemical tanks (the 5th-stage production)
storage room
shutter
door
STORAGE

NOTE: Group was preparing to produce 70 tons of sarin in a 30 day period.

Reference: Senate Subcommittee Hearings

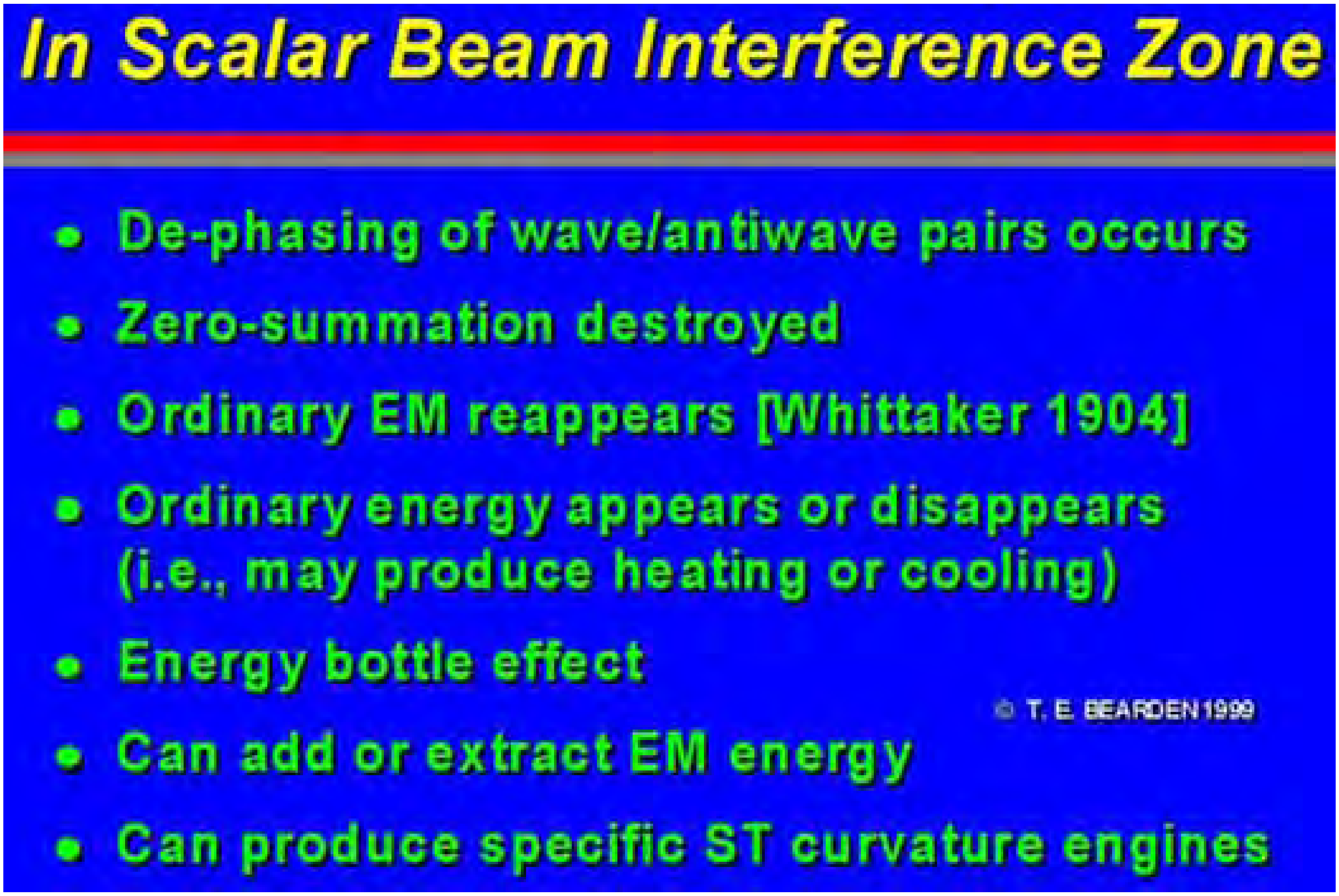

In Scalar Beam Interference Zone

- De-phasing of wave/antiwave pairs occurs
- Zero-summation destroyed
- Ordinary EM reappears [Whittaker 1904]
- Ordinary energy appears or disappears (i.e., may produce heating or cooling)
- Energy bottle effect
- Can add or extract EM energy
- Can produce specific ST curvature engines

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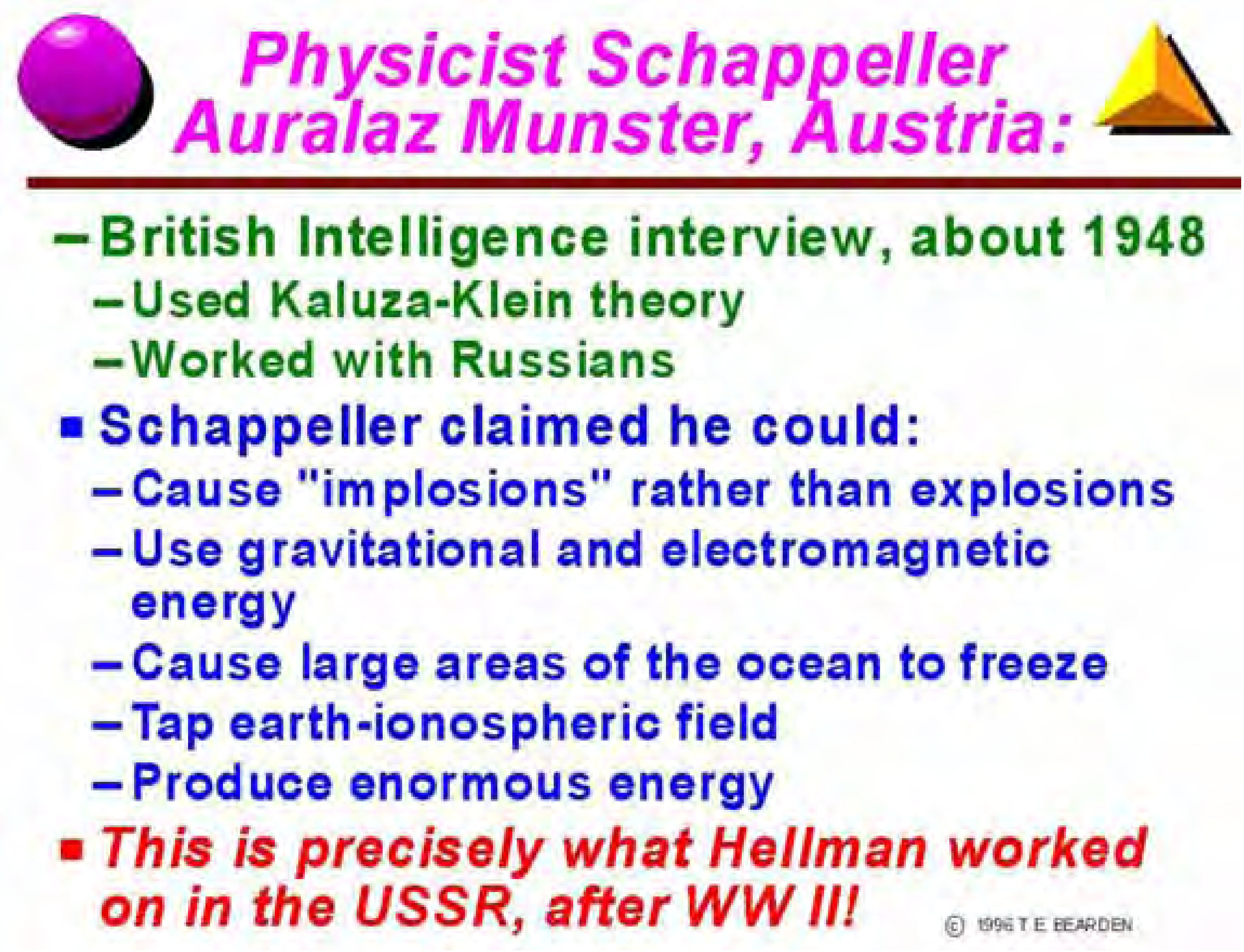

Physicist Schappeller Auralaz Munster, Austria:

- British Intelligence interview, about 1948
  - Used Kaluza-Klein theory
  - Worked with Russians
- Schappeller claimed he could:
  - Cause "implosions" rather than explosions
  - Use gravitational and electromagnetic energy
  - Cause large areas of the ocean to freeze
  - Tap earth-ionospheric field
  - Produce enormous energy
- *This is precisely what Hellman worked on in the USSR, after WW II!*

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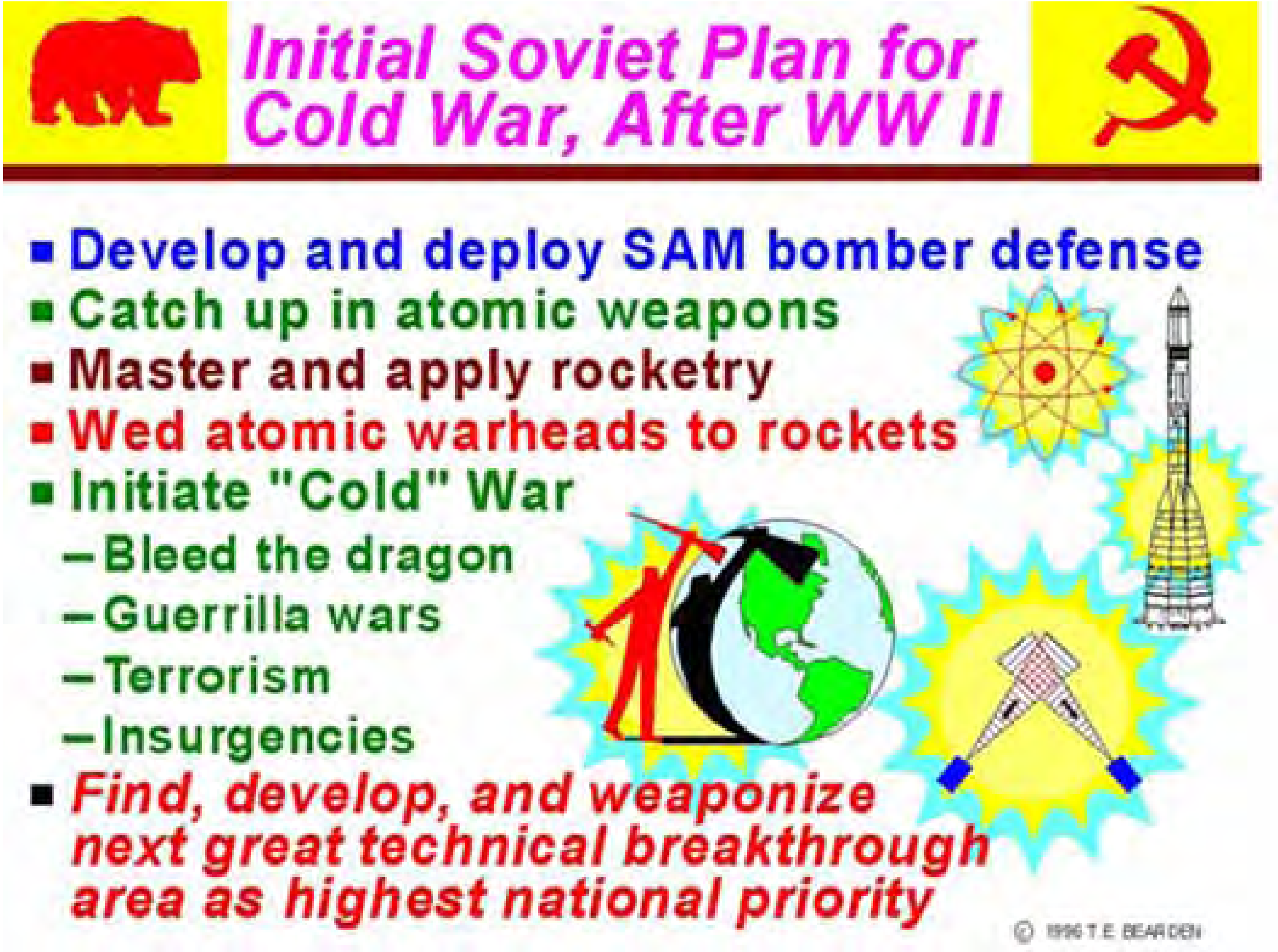

Initial Soviet Plan for Cold War, After WW II

- Develop and deploy SAM bomber defense
- Catch up in atomic weapons
- Master and apply rocketry
- Wed atomic warheads to rockets
- Initiate "Cold" War
  - Bleed the dragon
  - Guerrilla wars
  - Terrorism
  - Insurgencies
- *Find, develop, and weaponize next great technical breakthrough area as highest national priority*

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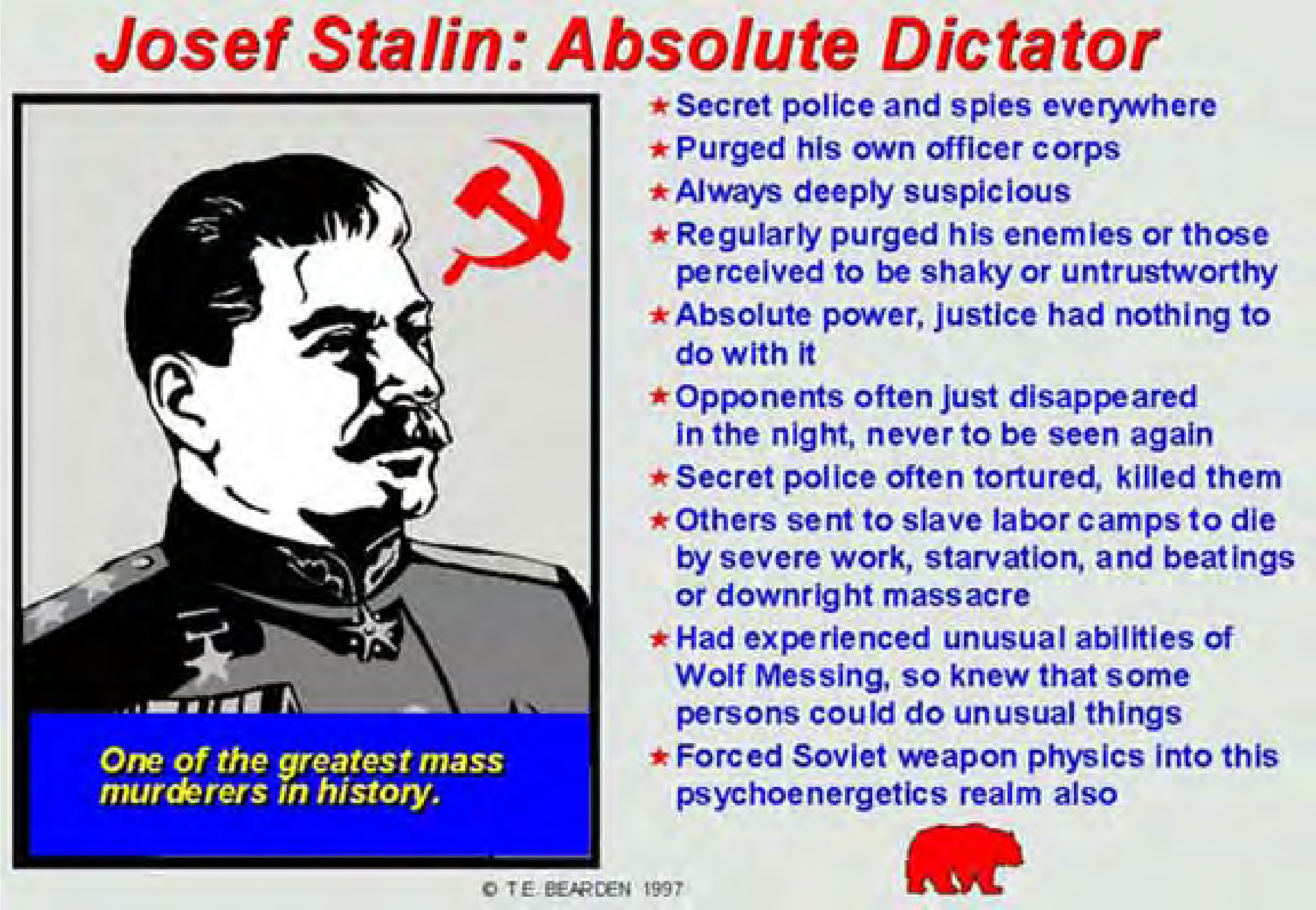

Josef Stalin: Absolute Dictator

- Secret police and spies everywhere
- Purged his own officer corps
- Always deeply suspicious
- Regularly purged his enemies or those perceived to be shaky or untrustworthy
- Absolute power, justice had nothing to do with it
- Opponents often just disappeared in the night, never to be seen again
- Secret police often tortured, killed them
- Others sent to slave labor camps to die by severe work, starvation, and beatings or downright massacre
- Had experienced unusual abilities of Wolf Messing, so knew that some persons could do unusual things
- Forced Soviet weapon physics into this psychoenergetics realm also

One of the greatest mass murderers in history.

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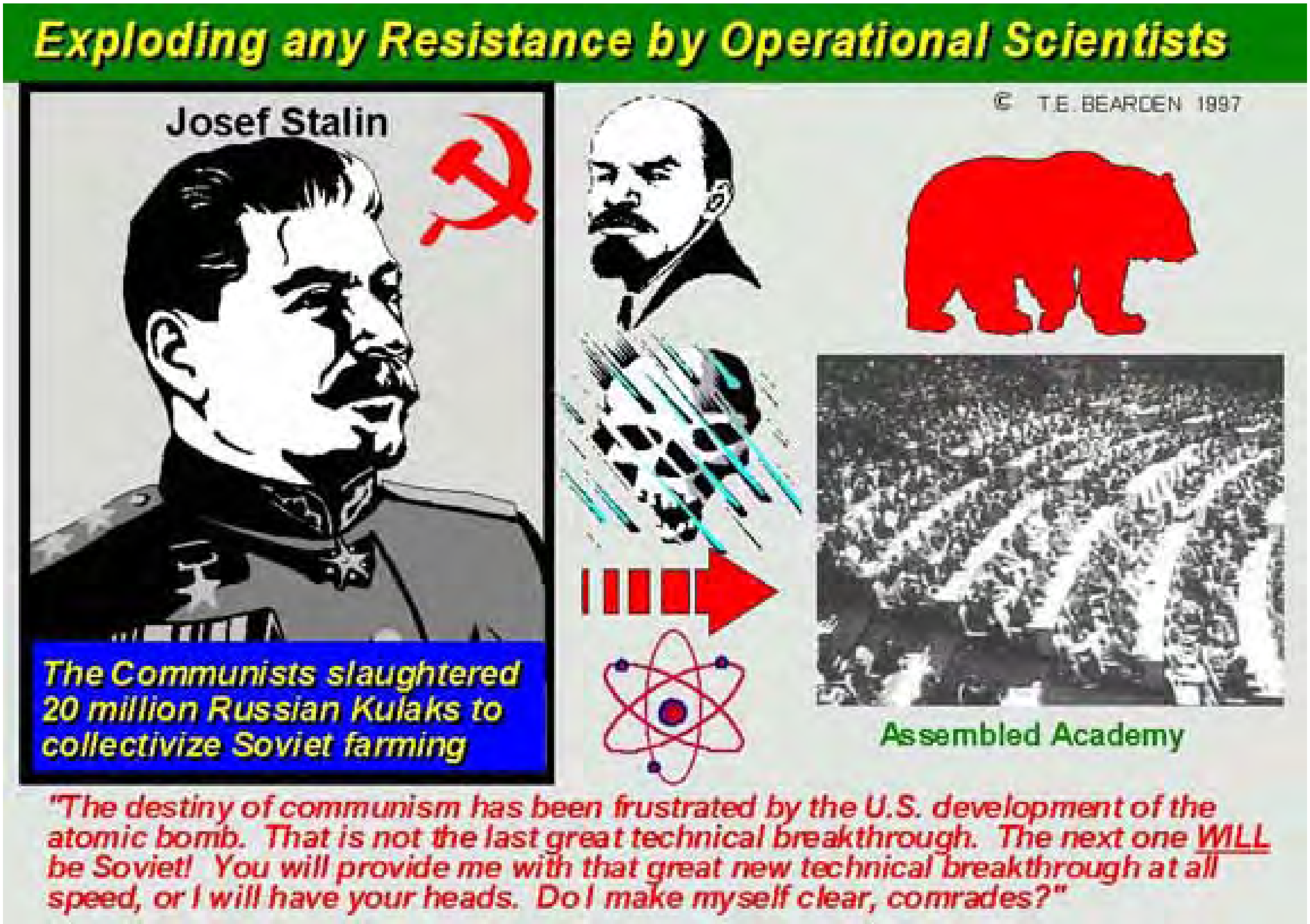

Exploding any Resistance by Operational Scientists

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Josef Stalin

The Communists slaughtered 20 million Russian Kulaks to collectivize Soviet farming

Assembled Academy

"The destiny of communism has been frustrated by the U.S. development of the atomic bomb. That is not the last great technical breakthrough. The next one WILL be Soviet! You will provide me with that great new technical breakthrough at all speed, or I will have your heads. Do I make myself clear, comrades?"

Significant Soviet Statements

- "In the final revolution, it does not matter if three-quarters of the earth is destroyed, so long as the other quarter emerges communist." *[Lenin]*
- "If a means of total neutralization of foreign missiles is to be found, it can only come from a group of new principles in physics, called energetics." *[Nobelian Petr Kapitsa, to Nikita Khrushchev, in answer to Khrushchev's demand for a 100% method of defense against long range missile attack.]*
- "We will bury you." *[Khrushchev, to Nixon, Kitchen Debate*]
- "We have a new weapon, just within the portfolio of our scientists, so to speak, which is so powerful that, if unrestrainedly used, it could wipe out all life on earth. It is a *fantastic* weapon." *[Khrushchev, speaking to the Presidium, Jan. 1960]*

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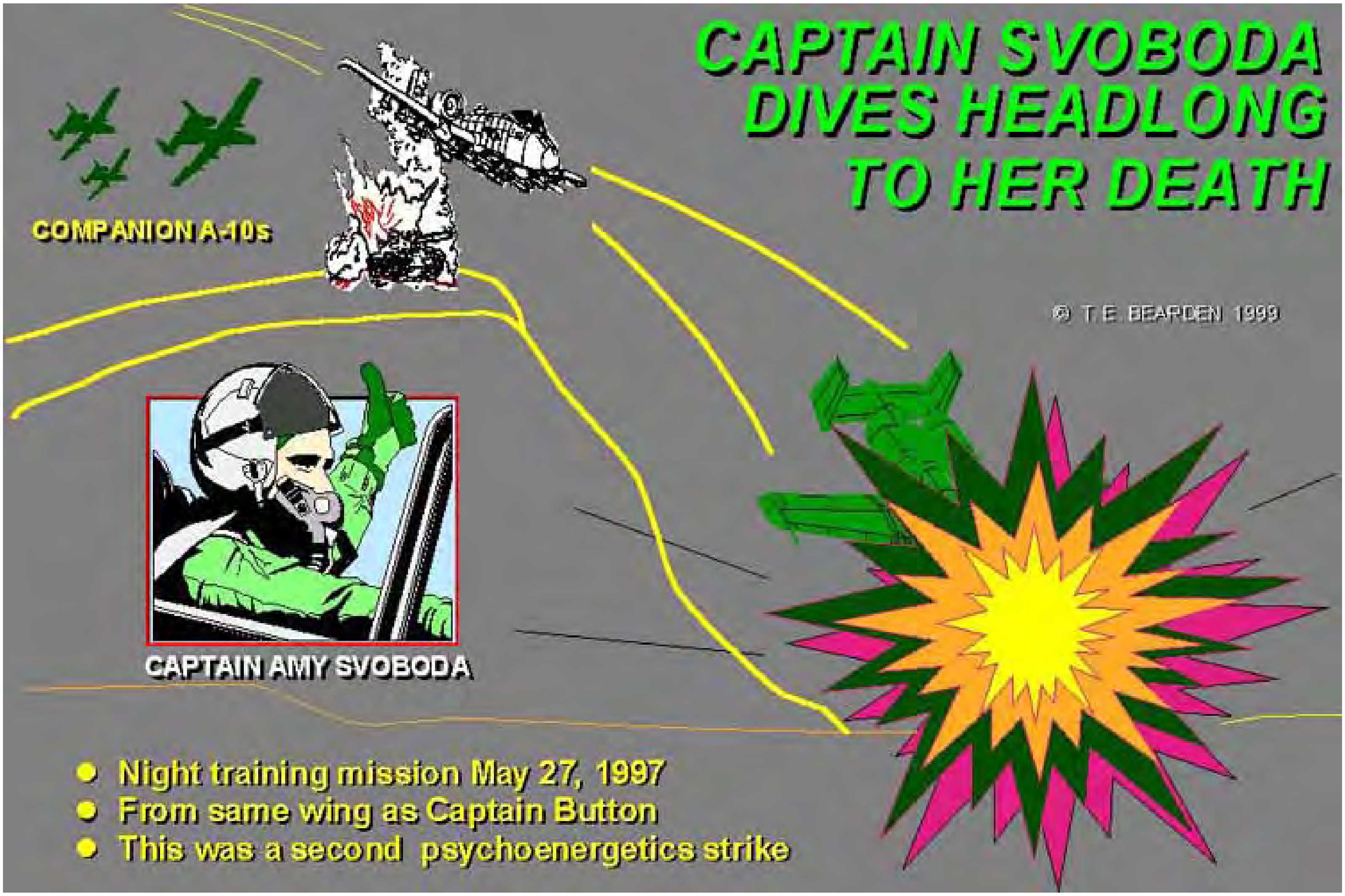

CAPTAIN SVOBODA DIVES HEADLONG TO HER DEATH

COMPANION A-10s
CAPTAIN AMY SVOBODA

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- Night training mission May 27, 1997
- From same wing as Captain Button
- This was a second psychoenergetics strike

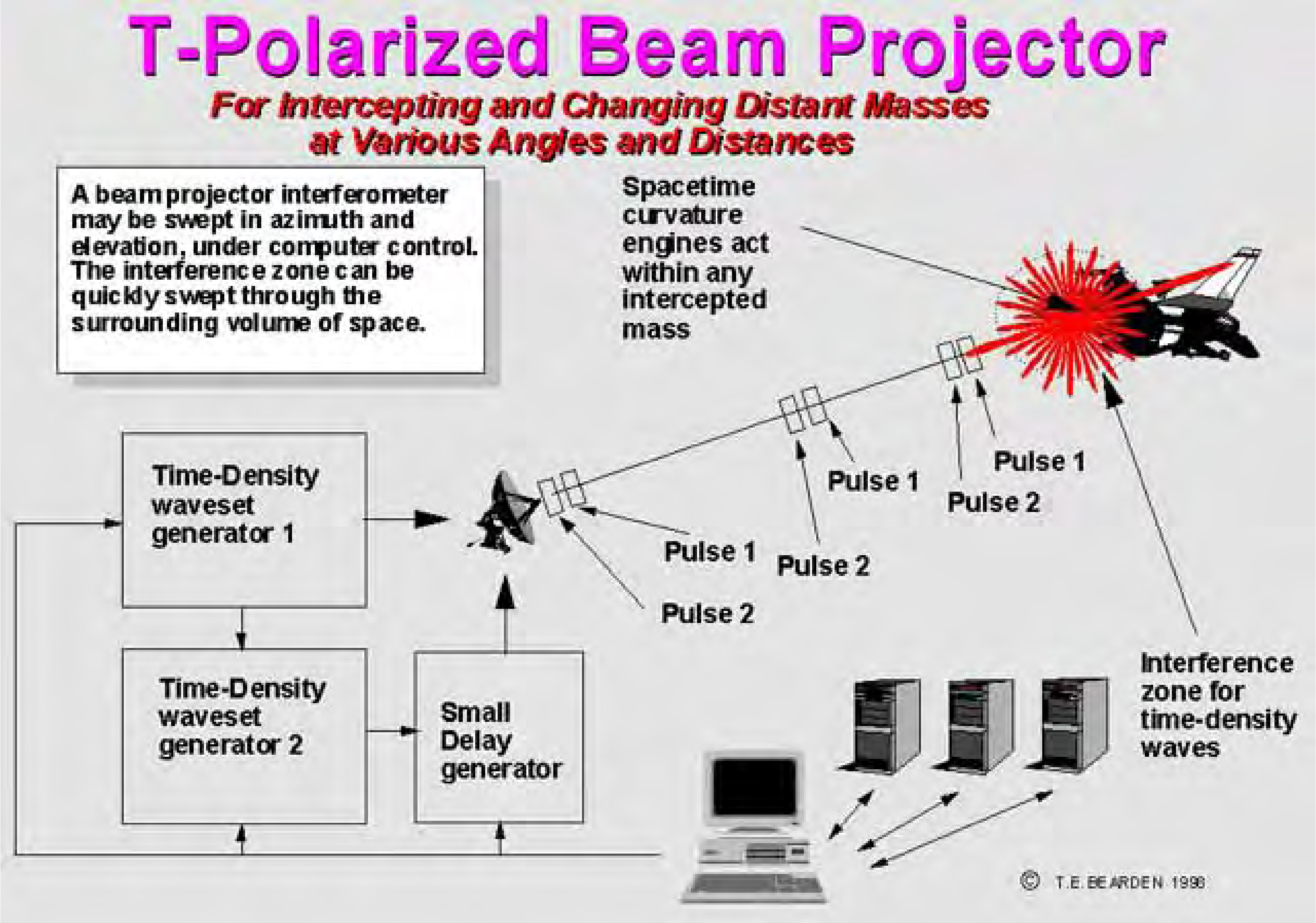

T-Polarized Beam Projector

For Intercepting and Changing Distant Masses at Various Angles and Distances

A beam projector interferometer may be swept in azimuth and elevation, under computer control. The interference zone can be quickly swept through the surrounding volume of space.

Spacetime curvature engines act within any intercepted mass
Time-Density waveset generator 1
Time-Density waveset generator 2
Small Delay generator
Pulse 1
Pulse 2
Pulse 1
Pulse 2
Pulse 1
Pulse 2
Interference zone for time-density waves
© T.E. BEARDEN 1996

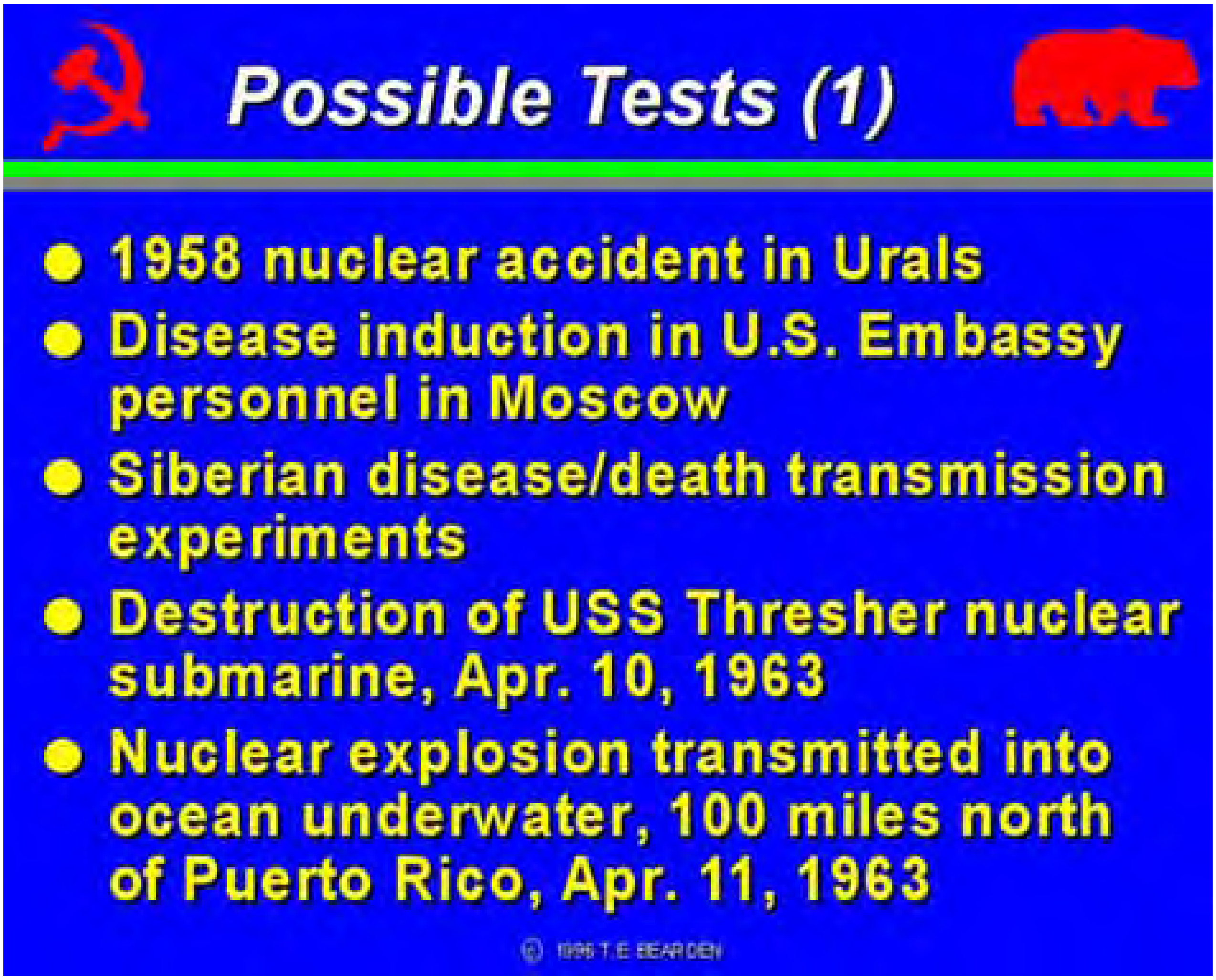

Possible Tests (1)

- 1958 nuclear accident in Urals
- Disease induction in U.S. Embassy personnel in Moscow
- Siberian disease/death transmission experiments
- Destruction of USS Thresher nuclear submarine, Apr. 10, 1963
- Nuclear explosion transmitted into ocean underwater, 100 miles north of Puerto Rico, Apr. 11, 1963

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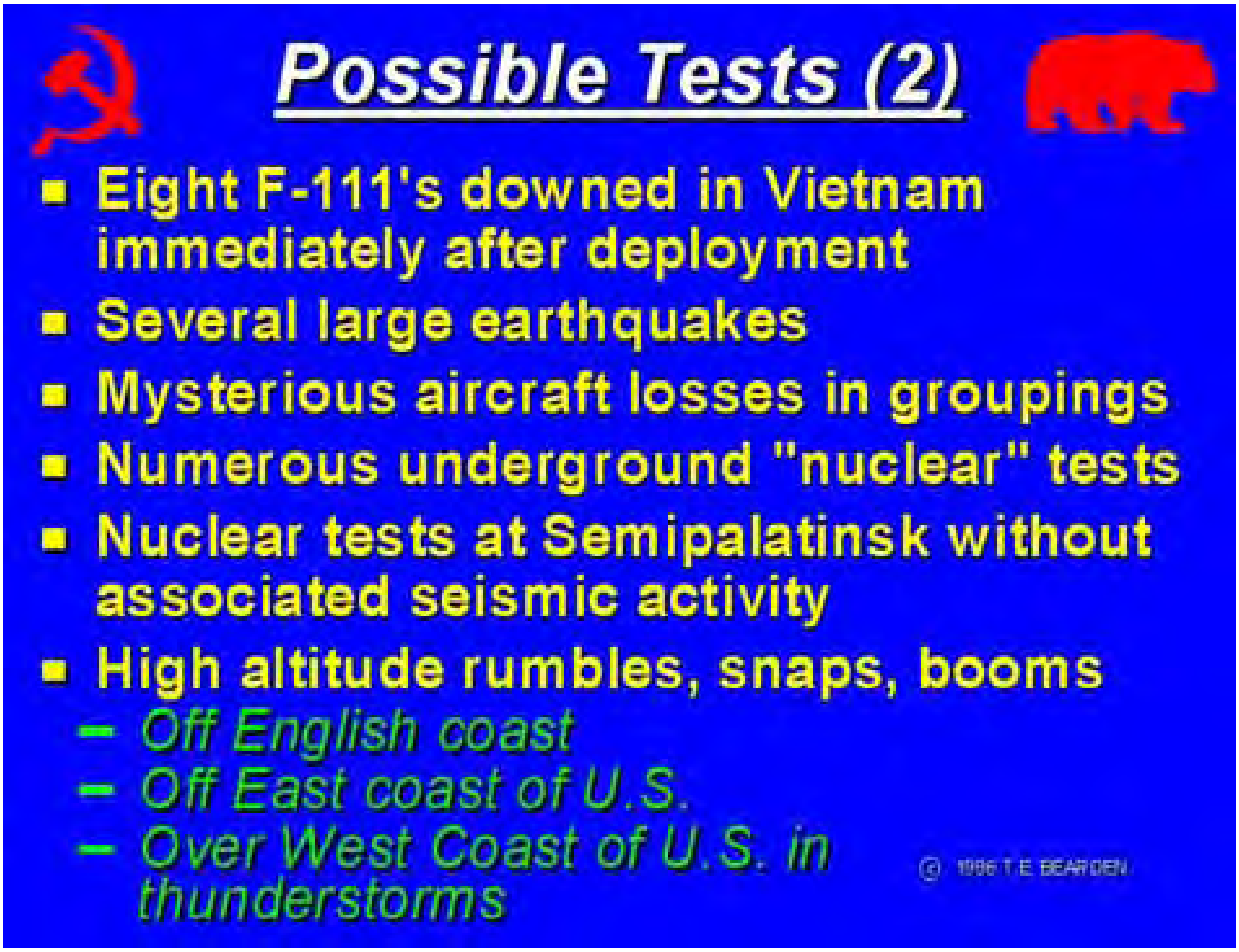

Possible Tests (2)

- Eight F-111's downed in Vietnam immediately after deployment
- Several large earthquakes
- Mysterious aircraft losses in groupings
- Numerous underground "nuclear" tests
- Nuclear tests at Semipalatinsk without associated seismic activity
- High altitude rumbles, snaps, booms
  - *Off English coast*
  - *Off East coast of U.S.*
  - *Over West Coast of U.S. in thunderstorms*

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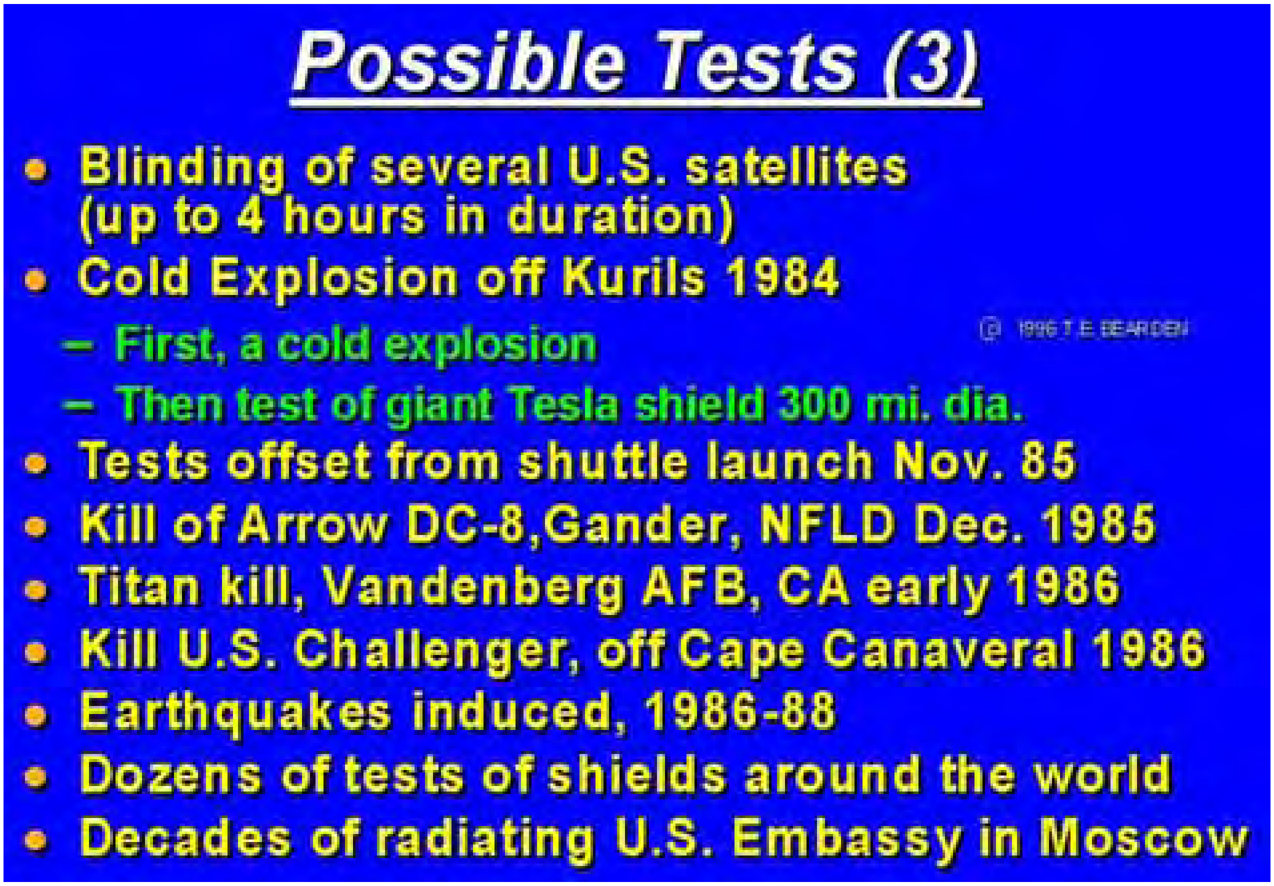

Possible Tests (3)

- Blinding of several U.S. satellites (up to 4 hours in duration)
- Cold Explosion off Kurils 1984
  - First, a cold explosion
  - Then test of giant Tesla shield 300 mi. dia.
- Tests offset from shuttle launch Nov. 85
- Kill of Arrow DC-8,Gander, NFLD Dec. 1985
- Titan kill, Vandenberg AFB, CA early 1986
- Kill U.S. Challenger, off Cape Canaveral 1986
- Earthquakes induced, 1986-88
- Dozens of tests of shields around the world
- Decades of radiating U.S. Embassy in Moscow

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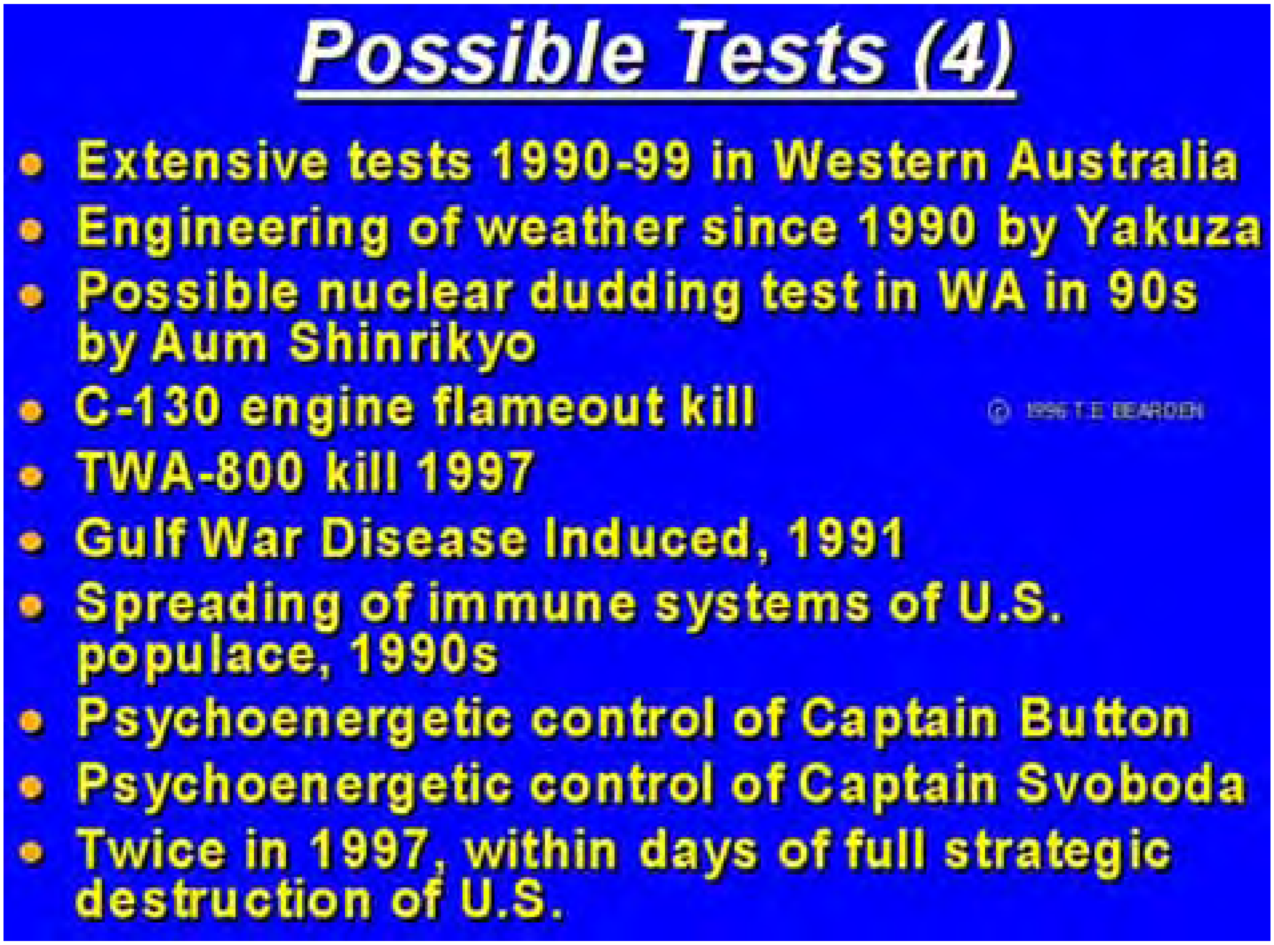

Possible Tests (4)

- Extensive tests 1990-99 in Western Australia
- Engineering of weather since 1990 by Yakuza
- Possible nuclear dudding test in WA in 90s by Aum Shinrikyo
- C-130 engine flameout kill
- TWA-800 kill 1997
- Gulf War Disease Induced, 1991
- Spreading of immune systems of U.S. populace, 1990s
- Psychoenergetic control of Captain Button
- Psychoenergetic control of Captain Svoboda
- Twice in 1997, within days of full strategic destruction of U.S.

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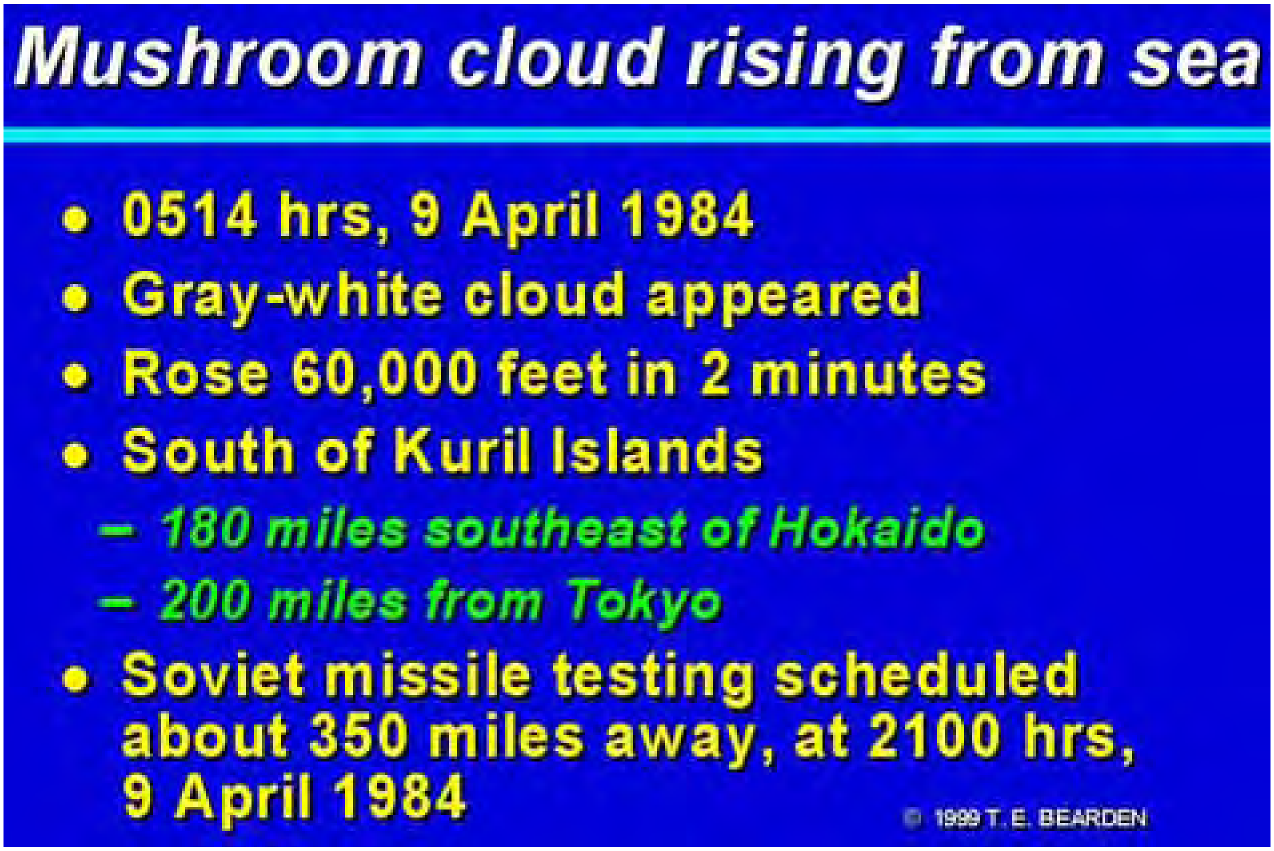

Mushroom cloud rising from sea

- 0514 hrs, 9 April 1984
- Gray-white cloud appeared
- Rose 60,000 feet in 2 minutes
- South of Kuril Islands
  - *180 miles southeast of Hokaido*
  - *200 miles from Tokyo*
- Soviet missile testing scheduled about 350 miles away, at 2100 hrs, 9 April 1984

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Launches from Cape Canaveral and Vandenberg AFB Provided Practice Targets of Opportunity

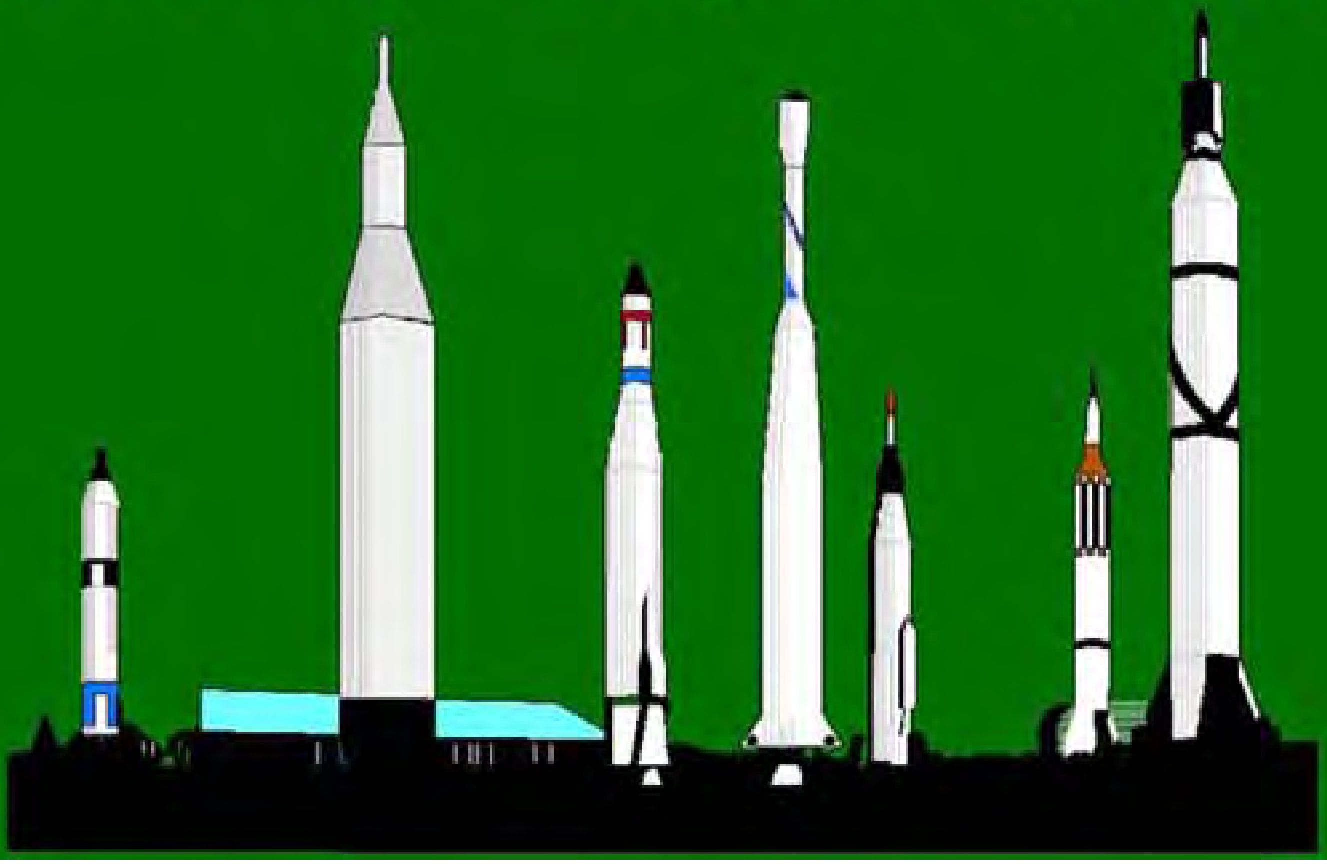

The sinking U.S.S. Thresher, with her controls jammed, implodes when she reaches crush depth

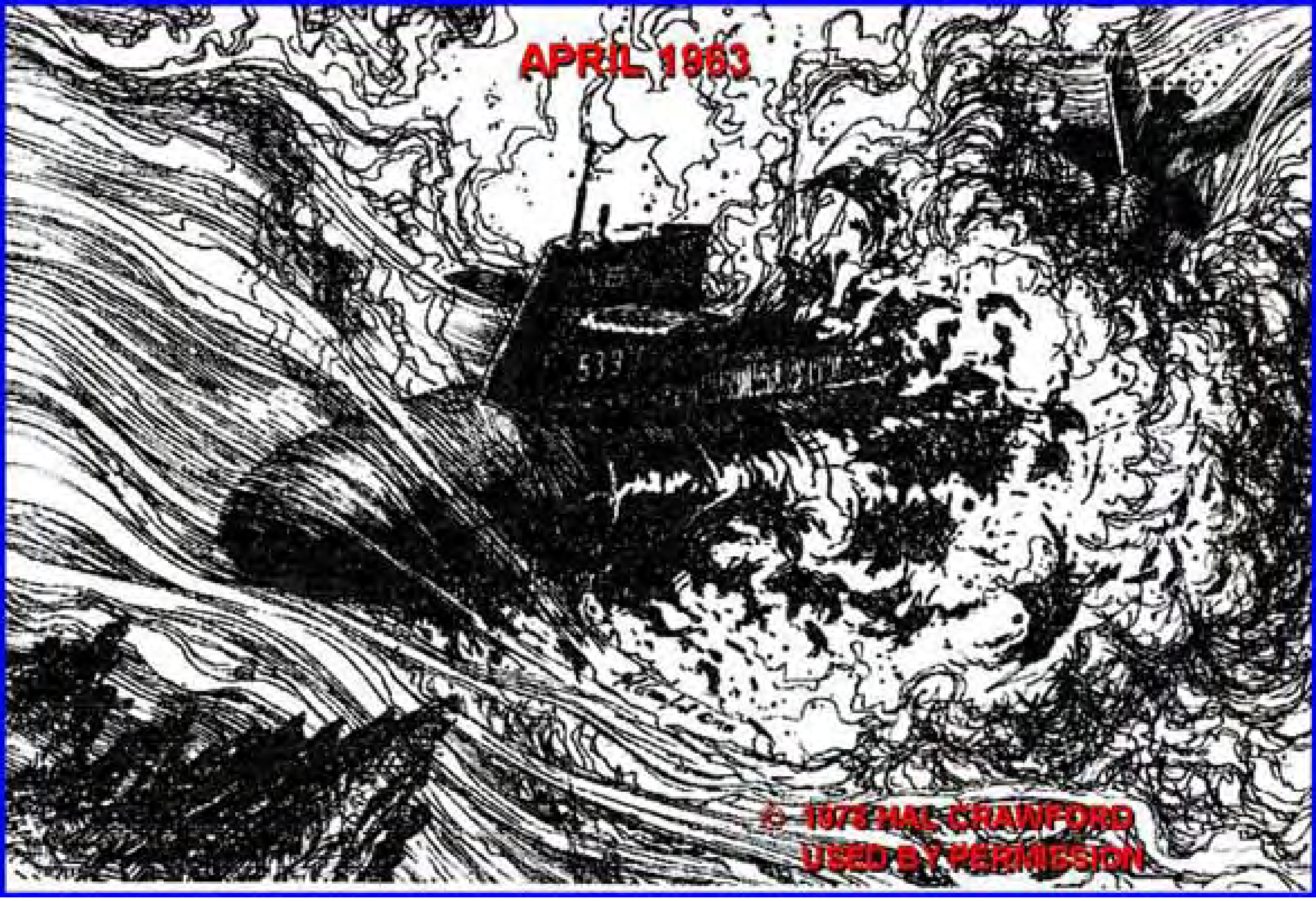

APRIL 1963

© 1978 HAL CRAWFORD
USED BY PERMISSION

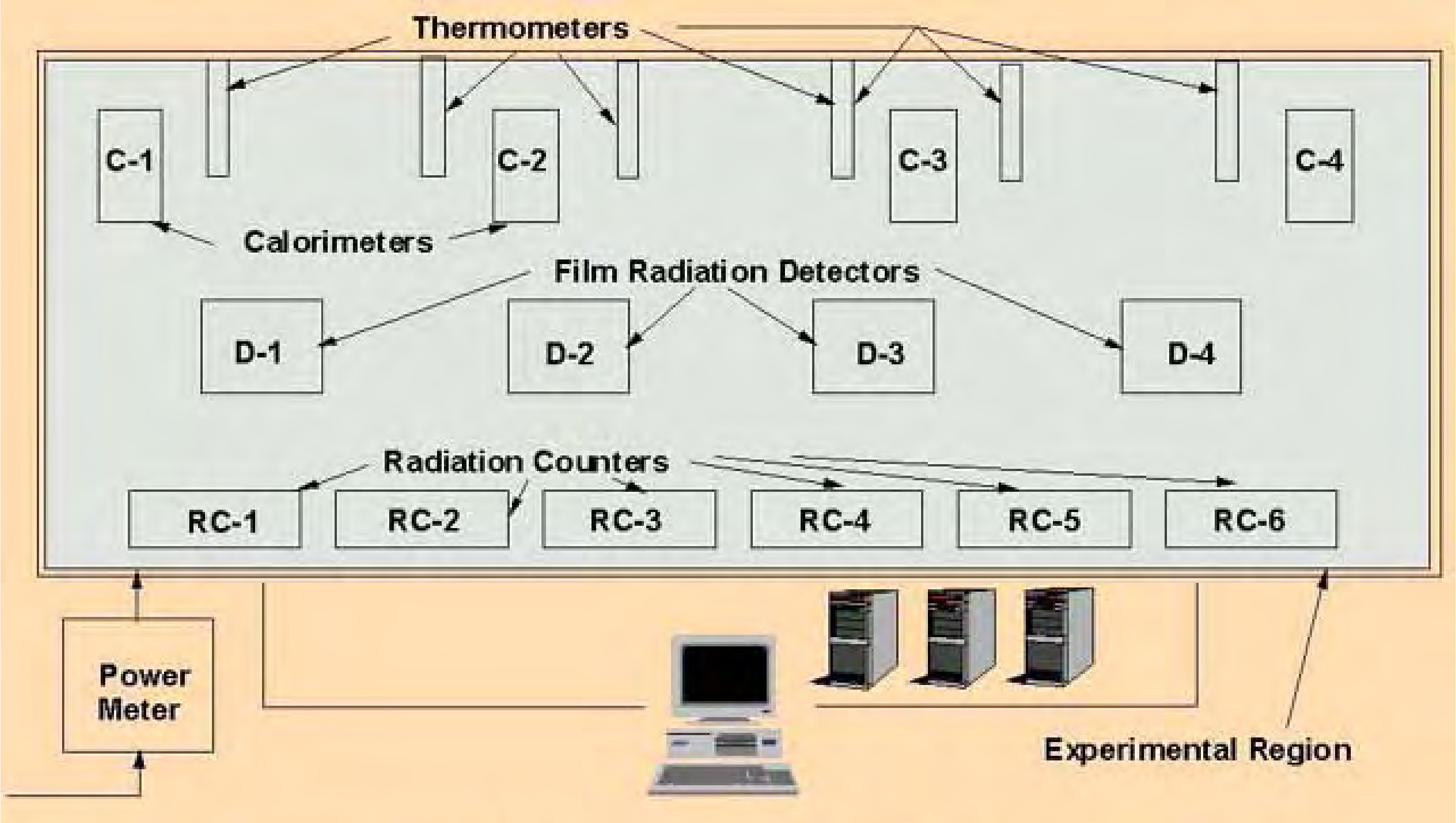
Thermometers
C-1
C-2
C-3
C-4
Calorimeters
Film Radiation Detectors
D-1
D-2
D-3
D-4
Radiation Counters
RC-1
RC-2
RC-3
RC-4
RC-5
RC-6
Power Meter
Experimental Region

Figure 32. Embodiment of an instrumental array sufficient to discriminate when time-density charging has occurred, and that transduction of time-charge decay is occurring.

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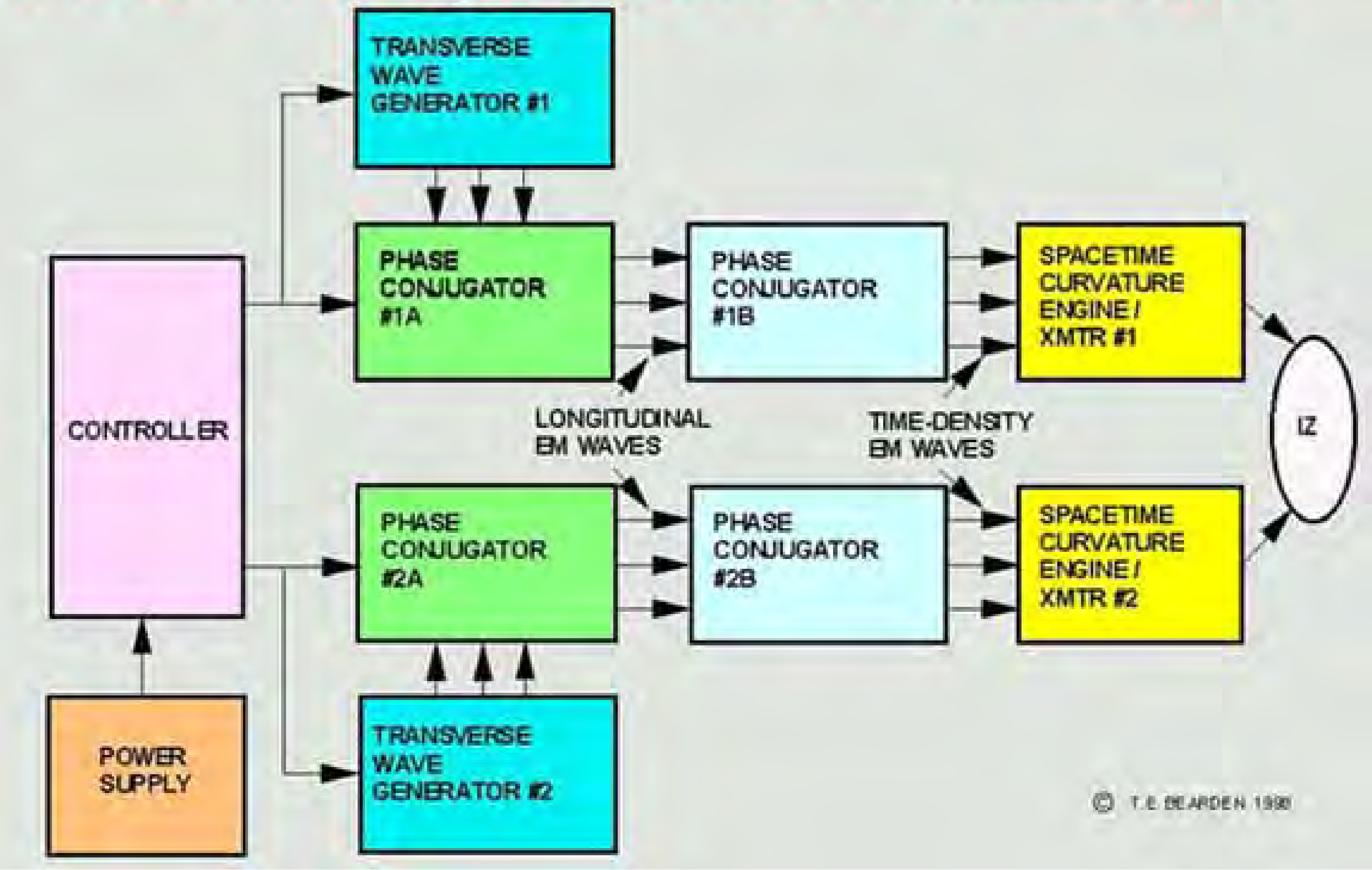

Time-Polarized EM Wave interferometer Creating Space-Time Curvature Engines in a Distant Interference Zone

TRANSVERSE WAVE GENERATOR #1
PHASE CONJUGATOR #1A
PHASE CONJUGATOR #1B
SPACETIME CURVATURE ENGINE / XMTR #1
CONTROLLER
LONGITUDINAL EM WAVES
TIME-DENSITY EM WAVES
IZ
PHASE CONJUGATOR #2A
PHASE CONJUGATOR #2B
SPACETIME CURVATURE ENGINE / XMTR #2
POWER SUPPLY
TRANSVERSE WAVE GENERATOR #2
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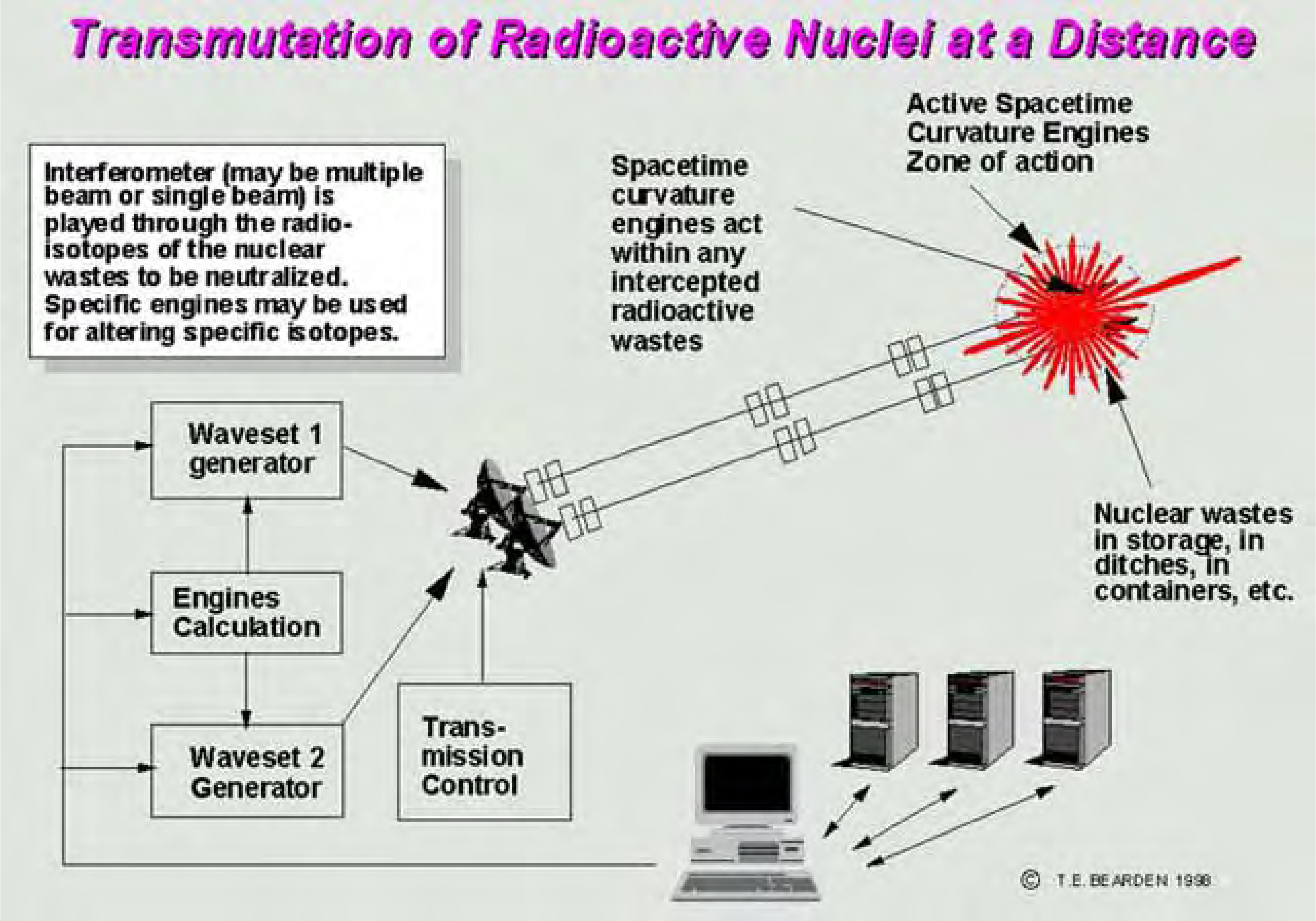

Transmutation of Radioactive Nuclei at a Distance

Interferometer (may be multiple beam or single beam) is played through the radioisotopes of the nuclear wastes to be neutralized. Specific engines may be used for altering specific isotopes.

Active Spacetime Curvature Engines Zone of action
Spacetime curvature engines act within any intercepted radioactive wastes
Waveset 1 generator
Engines Calculation
Waveset 2 Generator
Trans-mission Control
Nuclear wastes in storage, in ditches, in containers, etc.
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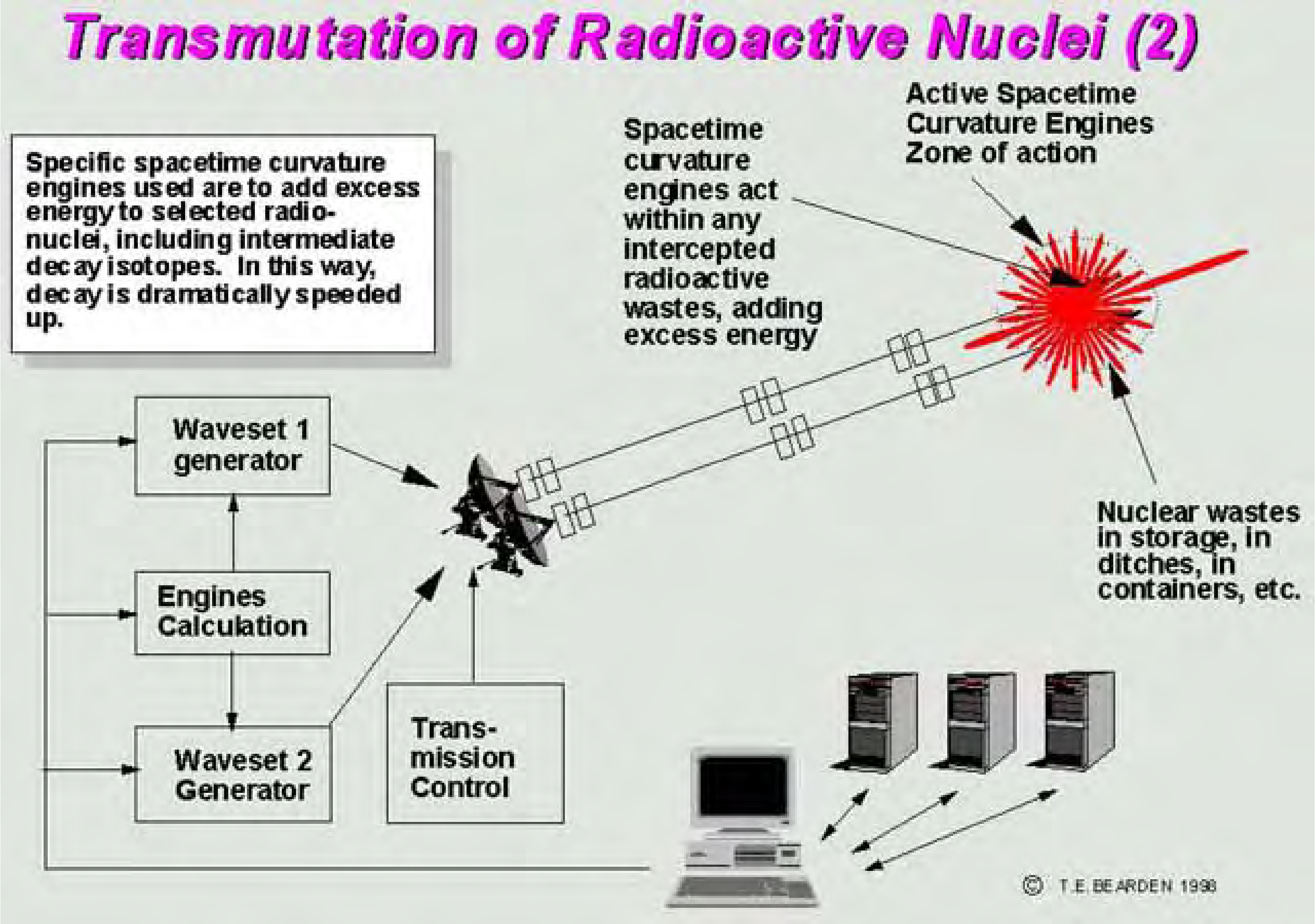

Transmutation of Radioactive Nuclei (2)

Specific spacetime curvature engines used are to add excess energy to selected radio-nuclei, including intermediate decay isotopes. In this way, decay is dramatically speeded up.

Spacetime curvature engines act within any intercepted radioactive wastes, adding excess energy

Active Spacetime Curvature Engines Zone of action

Nuclear wastes in storage, in ditches, in containers, etc.

Waveset 1 generator

Engines Calculation

Waveset 2 Generator

Trans-mission Control

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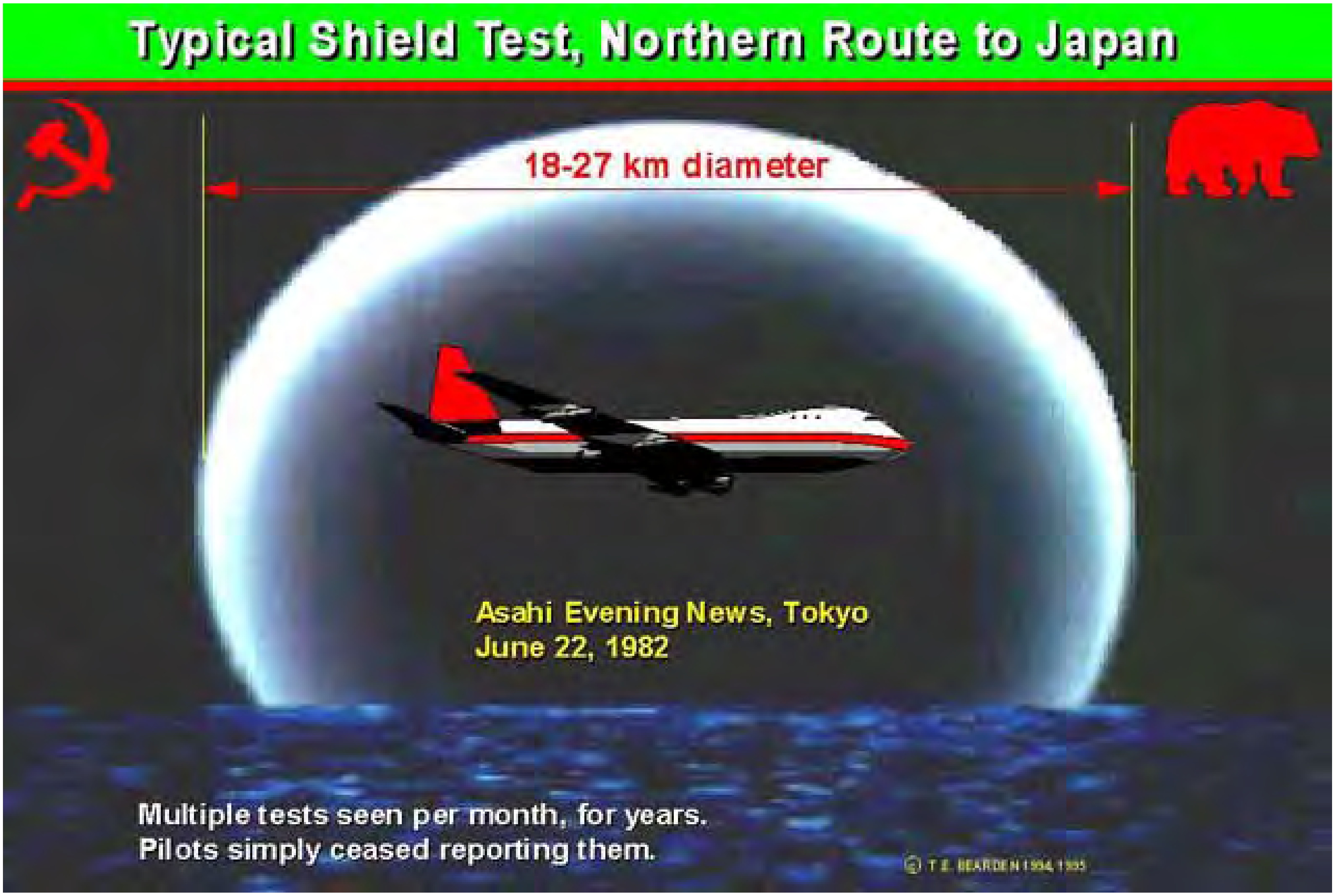

Typical Shield Test, Northern Route to Japan

Asahi Evening News, Tokyo
June 22, 1982

Multiple tests seen per month, for years.
Pilots simply ceased reporting them.

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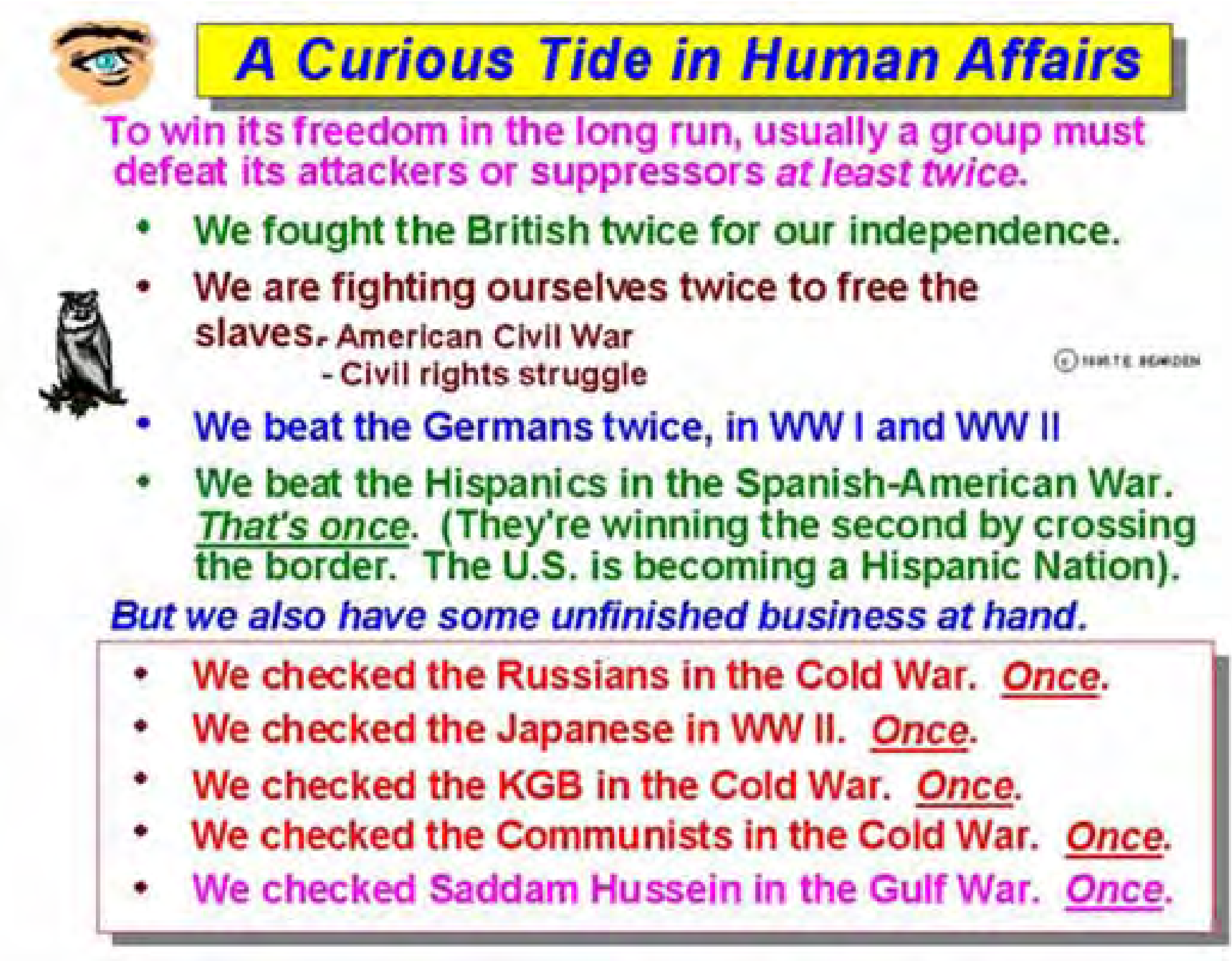

A Curious Tide in Human Affairs

To win its freedom in the long run, usually a group must defeat its attackers or suppressors *at least twice*.

- We fought the British twice for our independence.
- We are fighting ourselves twice to free the slaves. - American Civil War
  - Civil rights struggle
- We beat the Germans twice, in WW I and WW II
- We beat the Hispanics in the Spanish-American War. *That's once*. (They're winning the second by crossing the border. The U.S. is becoming a Hispanic Nation).

But we also have some unfinished business at hand.

- We checked the Russians in the Cold War. *Once*.
- We checked the Japanese in WW II. *Once*.
- We checked the KGB in the Cold War. *Once*.
- We checked the Communists in the Cold War. *Once*.
- We checked Saddam Hussein in the Gulf War. *Once*.

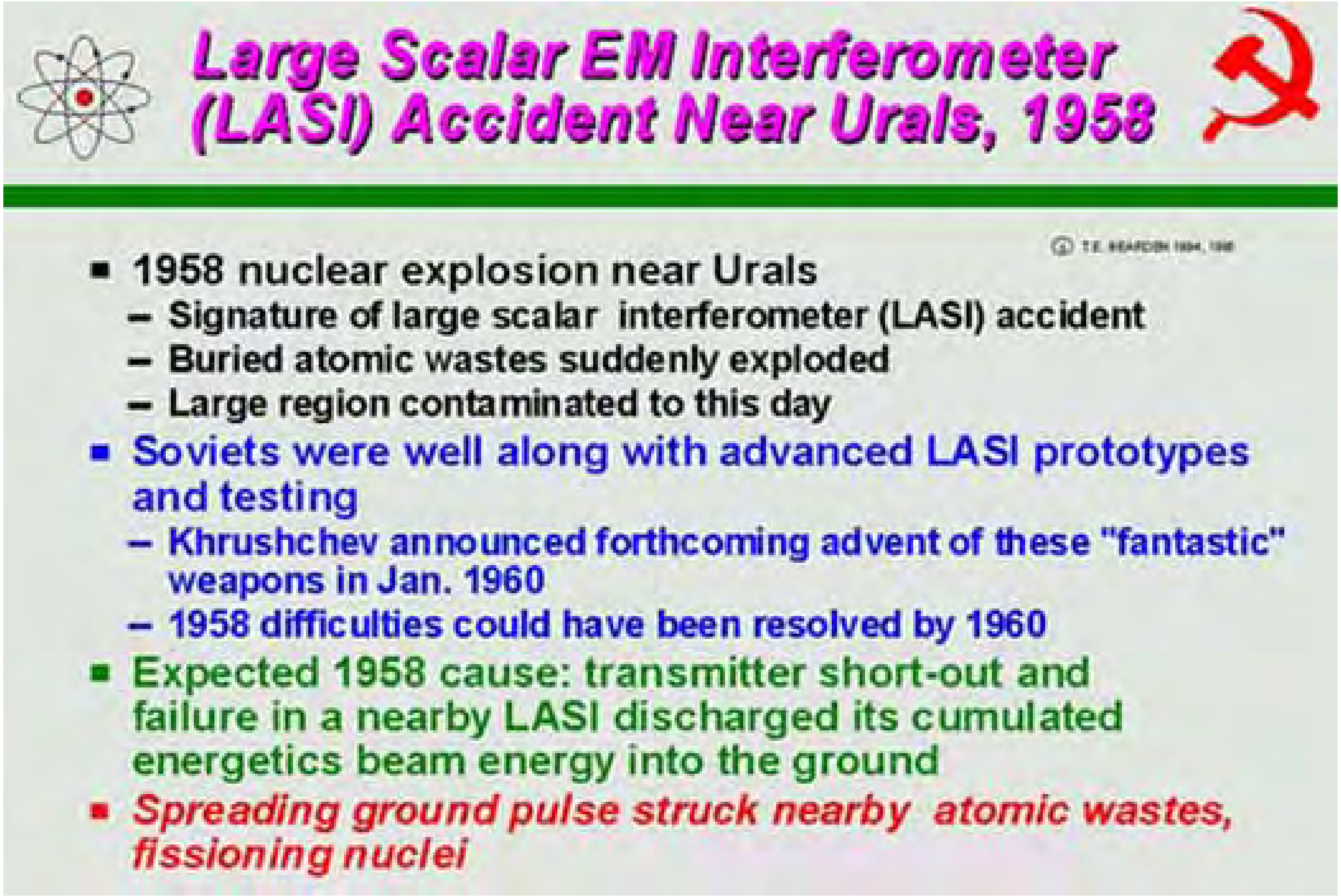

Large Scalar EM Interferometer (LASI) Accident Near Urals, 1958

- 1958 nuclear explosion near Urals
  - Signature of large scalar interferometer (LASI) accident
  - Buried atomic wastes suddenly exploded
  - Large region contaminated to this day
- Soviets were well along with advanced LASI prototypes and testing
  - Khrushchev announced forthcoming advent of these "fantastic" weapons in Jan. 1960
  - 1958 difficulties could have been resolved by 1960
- Expected 1958 cause: transmitter short-out and failure in a nearby LASI discharged its cumulated energetics beam energy into the ground
- *Spreading ground pulse struck nearby atomic wastes, fissioning nuclei*

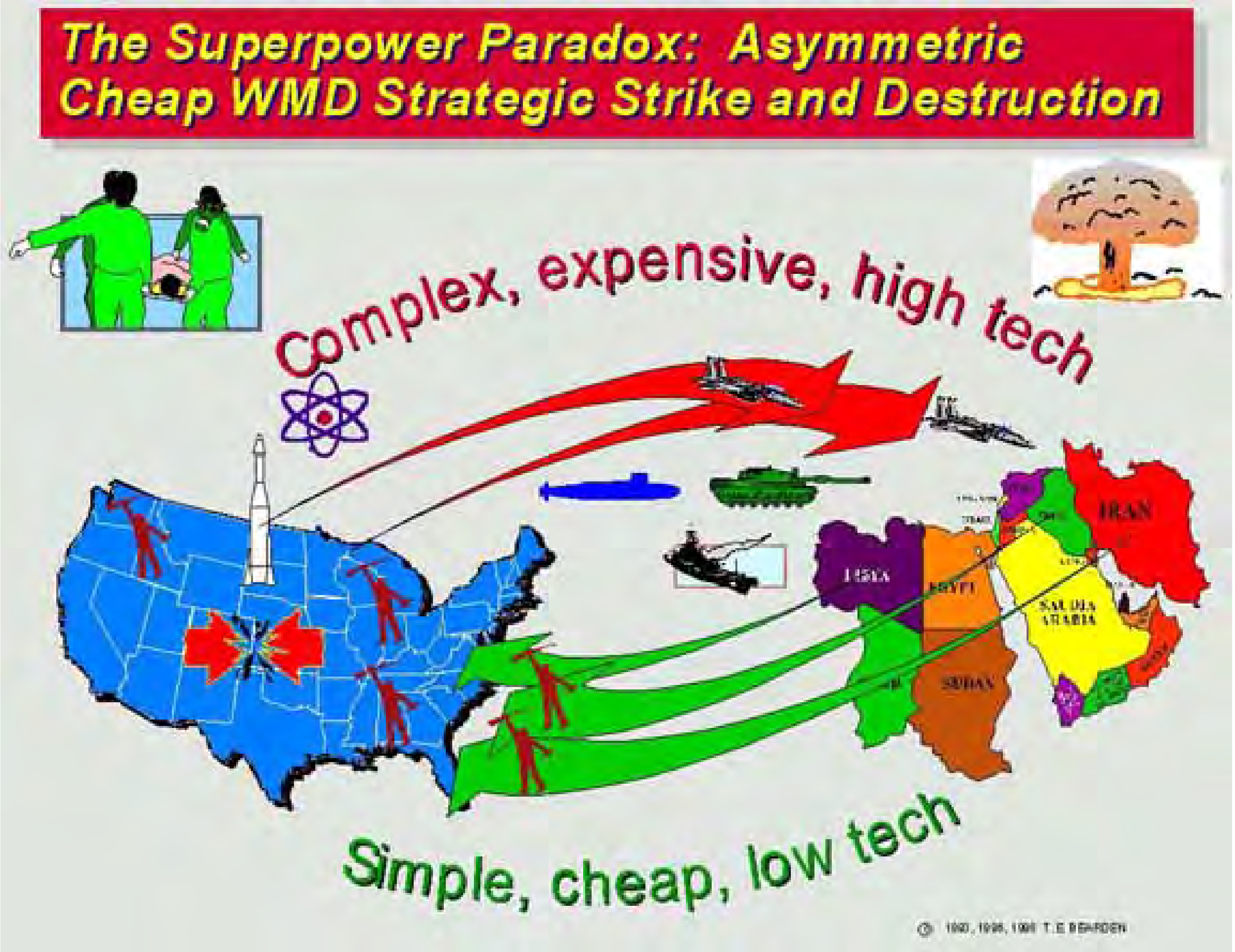

The Superpower Paradox: Asymmetric Cheap WMD Strategic Strike and Destruction

Complex, expensive, high tech
LIBYA
EGYPT
SUDAN
SAUDI ARABIA
IRAN
Simple, cheap, low tech

© [illegible], [illegible], [illegible] T. E. BEARDEN

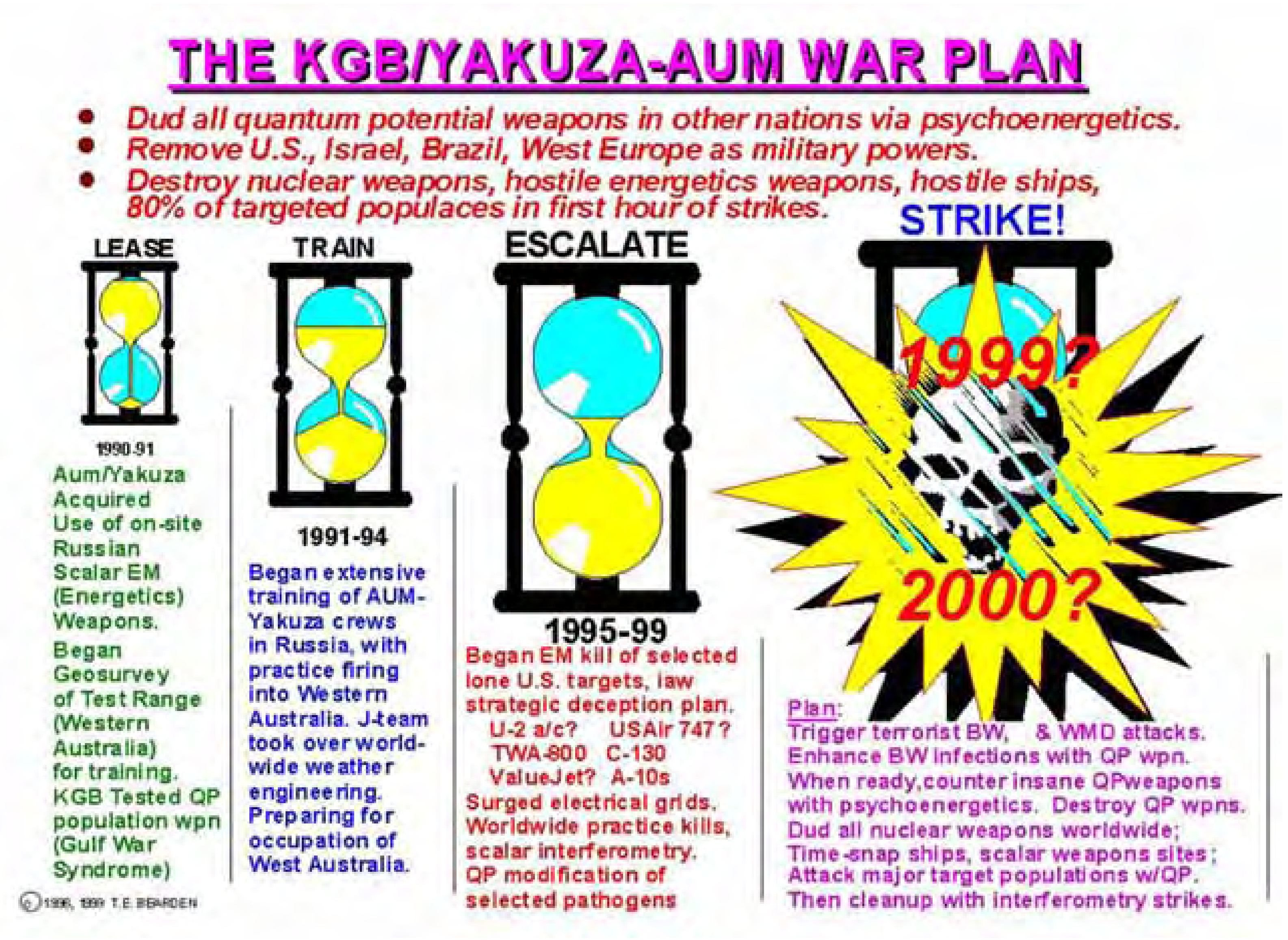

THE KGB/YAKUZA-AUM WAR PLAN

- *Dud all quantum potential weapons in other nations via psychoenergetics.*
- *Remove U.S., Israel, Brazil, West Europe as military powers.*
- *Destroy nuclear weapons, hostile energetics weapons, hostile ships, 80% of targeted populaces in first hour of strikes.*

LEASE

1990-91

Aum/Yakuza Acquired Use of on-site Russian Scalar EM (Energetics) Weapons.

Began Geosurvey of Test Range (Western Australia) for training.

KGB Tested QP population wpn (Gulf War Syndrome)

TRAIN

1991-94

Began extensive training of AUM-Yakuza crews in Russia, with practice firing into Western Australia. J-team took over worldwide weather engineering. Preparing for occupation of West Australia.

ESCALATE

1995-99

Began EM kill of selected lone U.S. targets, law strategic deception plan.
U-2 a/c? USAir 747 ?
TWA-800 C-130
ValueJet? A-10s
Surged electrical grids.
Worldwide practice kills, scalar interferometry.
QP modification of selected pathogens

STRIKE!

1999?

2000?

Plan:
Trigger terrorist BW, & WMD attacks.
Enhance BW infections with QP wpn.
When ready, counter insane QPweapons with psychoenergetics. Destroy QP wpns.
Dud all nuclear weapons worldwide;
Time-snap ships, scalar weapons sites;
Attack major target populations w/QP.
Then cleanup with interferometry strikes.

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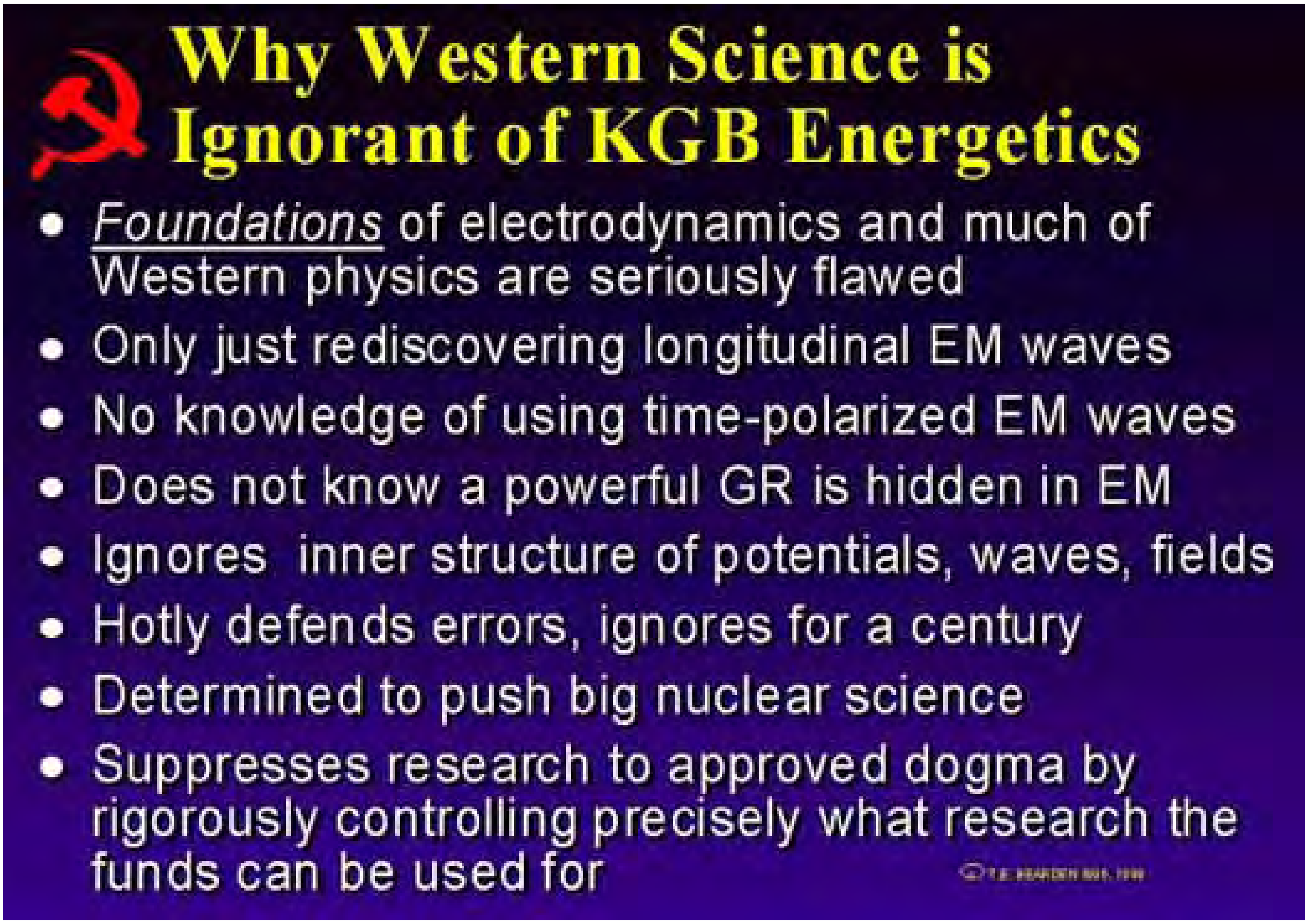

Why Western Science is Ignorant of KGB Energetics

- *Foundations* of electrodynamics and much of Western physics are seriously flawed
- Only just rediscovering longitudinal EM waves
- No knowledge of using time-polarized EM waves
- Does not know a powerful GR is hidden in EM
- Ignores inner structure of potentials, waves, fields
- Hotly defends errors, ignores for a century
- Determined to push big nuclear science
- Suppresses research to approved dogma by rigorously controlling precisely what research the funds can be used for

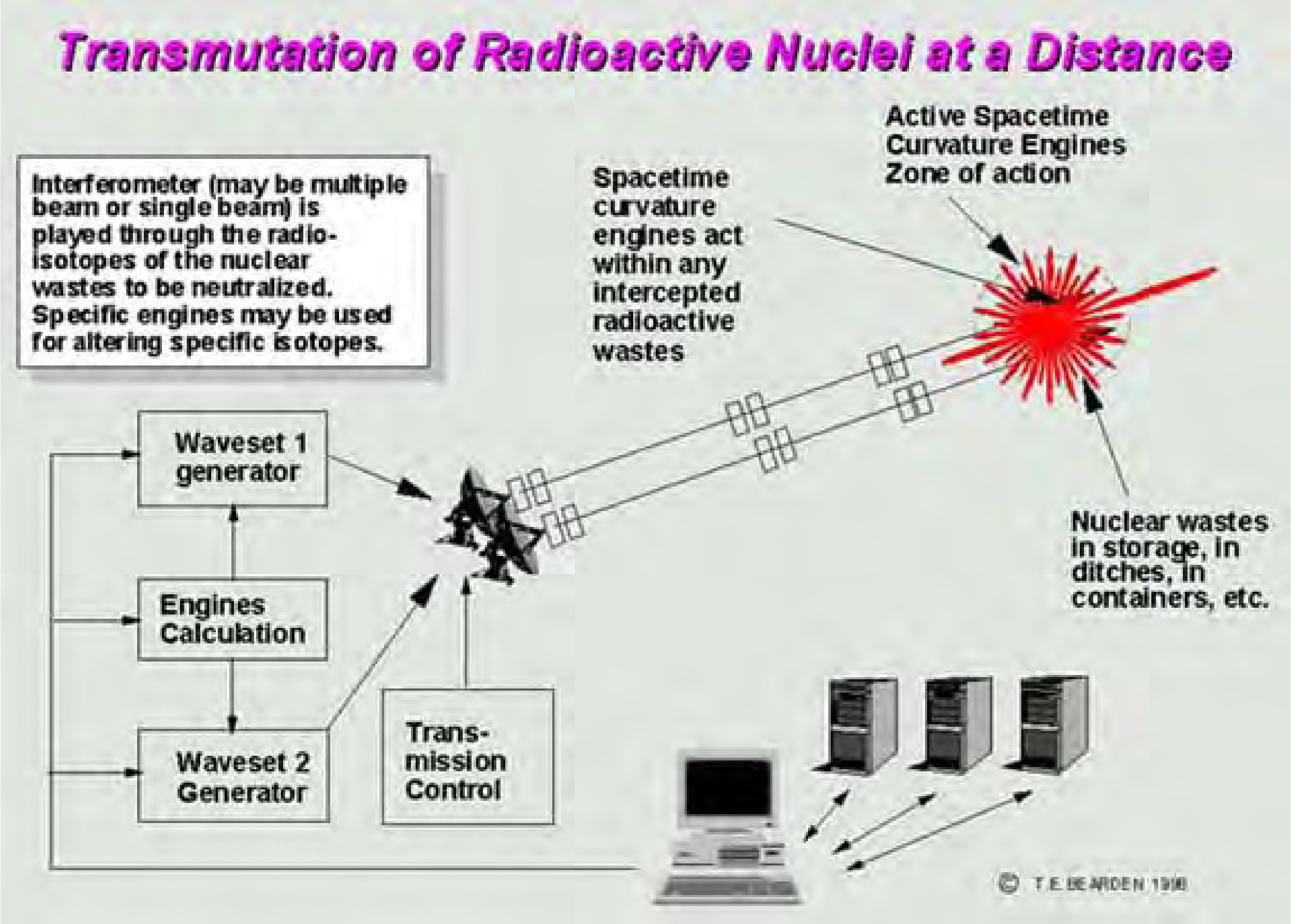

Transmutation of Radioactive Nuclei at a Distance

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Spacetime curvature engines act within any intercepted radioactive wastes

Active Spacetime Curvature Engines Zone of action

Nuclear wastes in storage, in ditches, in containers, etc.

Waveset 1 generator

Engines Calculation

Waveset 2 Generator

Trans-mission Control

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THE YAKUZA

(JAPANESE MAFIA)

To do business with Japan is to do business with the Yakuza

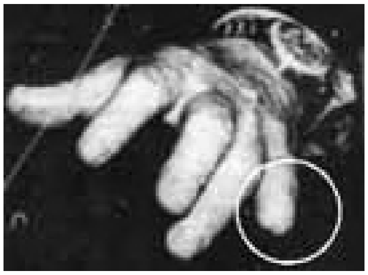

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The Last Samurai, Defending Bushido

- **3 Major Yakuza Groups, In Coalition.**
- **Penetrate Japanese Government.**
- **Open Offices, Signs on Street.**
- **Public Romanticizes Yakuza as Last Japanese Samurai**
- **In Large High-Tech Corporations.**
- **In Control of Japanese Banks.**
- **Japanese Real-Estate Rip-off.**
- **$500 - 1,000 Billion per Year Income.**
- **Rapidly Spreading in U.S.**
- **Uniting Mafia Groups Worldwide.**
- **Coalition with Aum Shinrikyo.**
- **Leased Russian Energetics Weapons.**
- **Crews On-site in Russia, Trained.**
- **Practice Firings into Western Australia for Three Years. (Dozens of Shots per Month)**
- **Now in Escalation Phase, Killing U.S. Targets.**
- **All-out Strike on U.S. ready 1999-2000.**
- **Now held in check by KGB, dead-man fuzed by small nation friendly to U. S.**

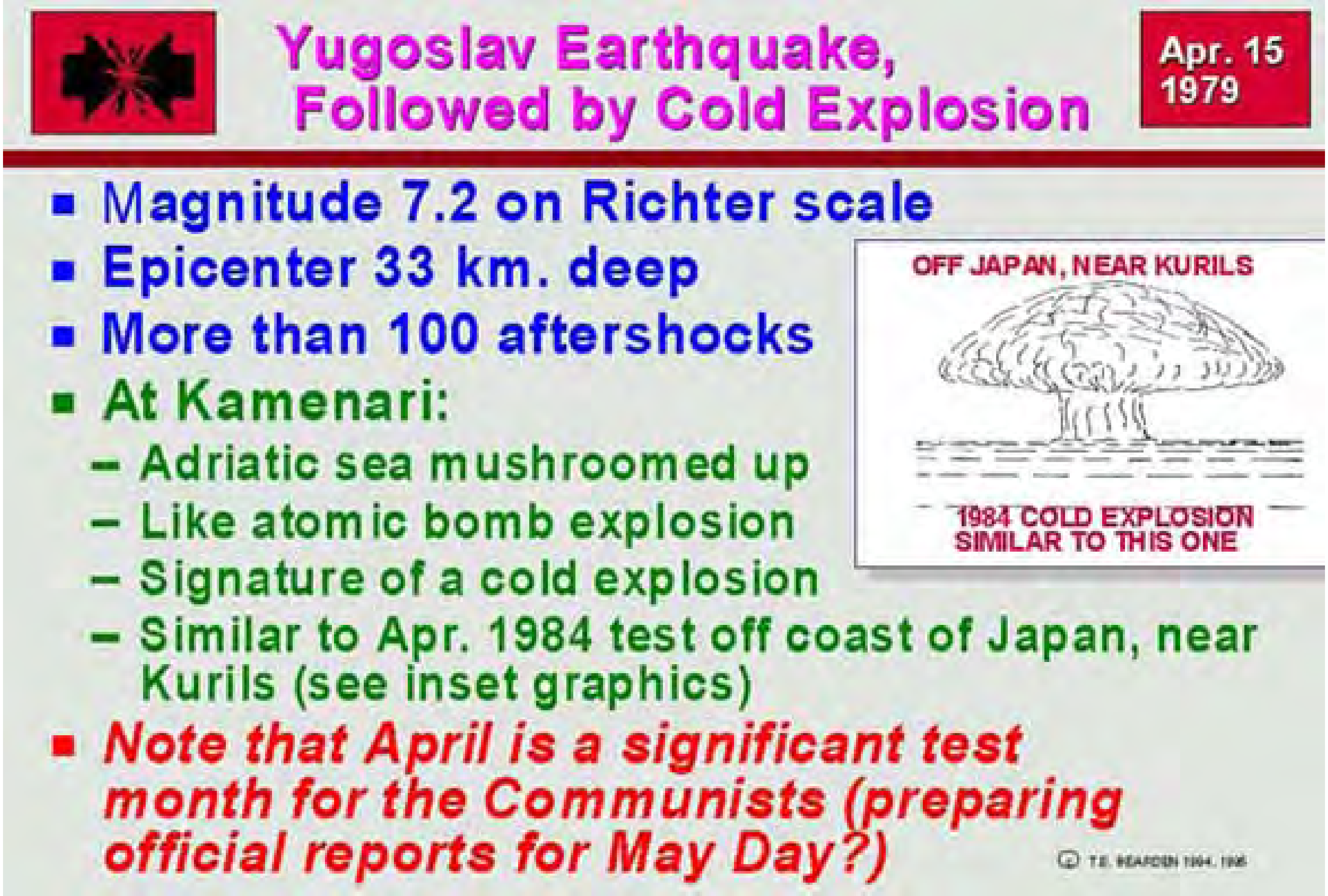

Yugoslav Earthquake, Followed by Cold Explosion

Apr. 15
1979

- Magnitude 7.2 on Richter scale
- Epicenter 33 km. deep
- More than 100 aftershocks
- At Kamenari:
  - Adriatic sea mushroomed up
  - Like atomic bomb explosion
  - Signature of a cold explosion
  - Similar to Apr. 1984 test off coast of Japan, near Kurils (see inset graphics)
- *Note that April is a significant test month for the Communists (preparing official reports for May Day?)*

OFF JAPAN, NEAR KURILS

1984 COLD EXPLOSION
SIMILAR TO THIS ONE

© T.E. BEARDEN 1994, 1996

SCALAR WEAPONS

UNDERSTANDING THESE MAKES IT EASIER TO UNDERSTAND THE NATURE OF THE AETHERS. WE'LL START WITH TOM BEARDEN'S FACTUAL INFO ABOUT THE RESULTS OF THE RUSSIAN'S SCALAR WEAPONS PROGRAM

http://www.cheniere.org/books/ferdelance/intro.htm

THE RUSSIANS USED SCALAR WEAPONS TO BLOW UP THE CHALLENGER SPACE SHUTTLE, A NUMBER OF OTHER LAUNCH VEHICLES, VARIOUS JET AIRPLANES, MODIFY THE WEATHER AND KILL UNTOLD NUMBERS OF BIRDS & FISH, WHICH HAS HAPPENED AGAIN RECENTLY. HAARP DEVICES CAN DO THIS.

SIMPLY PUT: A SCALAR WEAPON IS A FIGURE 8 WAVE FORM THAT IS NOT IN HARMONY WITH AN AMBIENT AETHER, IF POWERFUL ENOUGH THE SCALAR WEAPON CHANGES THE SIZE OF THE BACKGROUND SCREEN AETHER, WHICH THEN NO LONGER SUPPORTS THE MANIFESTATION OF MATTER, WHICH DESTABILIZES AND EXPLODES.

THE REASON WE ARE NOT ALL SPEAKING RUSSIAN IS BECAUSE THE MOST UNSTABLE MATTER IS IN NUCLEAR WARHEADS - DESTROYING THE ENTIRE WORLD IS NOT WINNING A WAR. PROVIDED, OF COURSE, THAT YOU LIVE ON THAT WORLD - THERE IS EXCELLENT EVIDENCE THAT A SCALAR WEAPON WAS USED TO DESTROY THE BIG BEAUTIFUL PLANET WHERE THE ASTEROID BELT IS NOW. THAT'S IN THE BOOK "COSMIC WAR".

GIGGLE, LAUGHING MY ASS OFF AT THIS ONE FROM BEARDEN:

It has also become fashionable in the West to believe that all the laws of physics are already discovered. We assume we already know all of them. While we have been pridefully crowing this tune, the Soviets have been steadily discovering new laws in secret, as well as new ways to circumvent the old laws.

THE SAD PART IS THAT IT HASN'T CHANGED - WESTERN SCIENTISTS ARE IDIOTS WHO ARE LEADING THE WORLD INTO DESTRUCTION. OR SITTING BACK AND WATCHING THE DESTRUCTION, WRINGING THEIR HANDS AND SAYING THAT FUKUSHIMA RADIATION WILL BE WITH US FOR 1000s OF YEARS. B.S. THERE ARE A NUMBER OF ENERGETIC WAYS TO CANCEL RADIATION INSTANTLY.

BEARDEN TAUGHT ME ABOUT SCALAR ENERGY - BUT, THEN HE HAS STARTED PARROTING LAME STREAM PHYSICS - PROBABLY TO KEEP HIS HEAD FROM BEING SEPARATED FROM HIS BODY BY OUR CONTROLLERS.

SCALAR WEAPONS ARE DESCRIBED IN A NUT SHELL ABOVE. BUT, WE'LL EXPAND IT A LITTLE - THE SIMPLE FACT THAT THEY WORK IS PROOF THAT THE AETHERS IS THE BACKGROUND SCREEN THAT SUPPORTS THE MANIFESTATION OF MATTER, WHICH IS ALL DIVINE I.E. MADE FROM IMAGES.

THE AETHERS PROGRESS IN SIZE ACCORDING TO THE FIBONACCI SERIES, BECAUSE EVERYTHING FROM THE QUANTUM TO THE COSMOS MANIFESTS ACCORDING TO THE FIBONACCI SERIES - ITS ALL FRACTAL I.E. A RECURRING MATHEMATICAL PATTERN, THAT IS PERFECT THROUGHOUT CREATION. HERE'S THE PROOF - OUR ENTIRE GALAXY IS IN PERFECT HARMONY WITH ONE NUMBER = RIDICULOUSLY AMAZING

http://blog.hasslberger.com/docs/PERFECTION.pdf

THUS, IF YOU CHANGE THE BACKGROUND SCREEN, THEN MATTER HAS TO CHANGE = THE RESULT OF USING A SCALAR WEAPON.

THE PRECISE WAY THE WEAPON WORKS IS TO IMPOSE A MAN MADE SCALAR WAVE ON AN AREA OF SPACE. GIVEN ENOUGH POWER TO THE SCALAR WAVE, IT WILL CAUSE THE AETHER IN THAT AREA TO MATCH ITS SIZE (LIKE ATTRACTS LIKE). WE ARE TALKING UNBELIEVABLY SIMPLE.

YOU CAN MAKE ONE YOURSELF - AMAZINGLY THE REQUIRED WINDINGS OF A SCALAR PRODUCING COIL CAN BE USED AS A WEAPON OR FOR HEALING - ITS CALLED A RADIONIC WITNESS WELL WHEN USED FOR HEALING.

TO MAKE A WITNESS WELL ONE WINDS INSULATED WIRE AROUND A GAP IN SPACE I.E. THE CENTER OF A TORROID. THE WIRE IS WOUND TO THE LEFT AND TO THE RIGHT. THE MORE WINDINGS THE MORE POWERFUL. AND, OF COURSE, THE POWER OF THE WAVE IS A FUNCTION OF THE POWER OF THE DC ELECTRICITY USED TO ACTIVATE THE DOUBLE WOUND COIL. SUCH A COIL PRODUCES A FIGURE 8 WAVE THAT IS THE SIZE OF THE CENTER OF THE COIL. IF THAT SIZE HAPPENS TO BE THE SIZE OF AN AMBIENT AETHER, YOU'RE NOT GOING TO HAVE A WEAPON.

IF YOU MAKE SUCH A COIL FOR HEALING, POWER IS NOT REQUIRED, IT AUTOMATICALLY CONNECTS WITH THE AETHERS IN A POSITIVE WAY.

IF YOU MAKE IT AS A WEAPON ADD LOTS OF POWER AND BE A LONG WAYS AWAY, WHEN YOU TURN IT ON. THE DESTRUCTIVE EFFECT IS INSTANTANEOUS - I'VE SEEN IT, WE BUILT ONE.

SCALAR WAVES ARE ALSO REFERRED TO AS PHASE CONJUGATED WAVES, MEANING TWO SINE WAVES THAT ARE 180 DEGREES OUT OF PHASE FROM ONE ANOTHER. (WESTERN LAME STREAM IDIOTS SAY THAT THOSE TWO WAVES CANCEL ONE ANOTHER.)

ONE SINE WAVE IS SAID TO RUN IN TIME FORWARD AND THE OTHER IN TIME REVERSE. AND THERE ARE A NUMBER OF EFFECTS THAT PROVE THIS. ONE EXAMPLE: DON BRANDT (ONE OF BEARDEN'S PROTEGEES) USED A SCALAR WAVE TO REGROW A LEG ON A CAT (A KID HAD SHOT IT OFF WITH A .22), WHEN DON FINISHED, THE CAT HAD ITS LEG BACK AND ALL OF THE CLOCKS WITHIN FIVE MILES WERE 15 MINUTES BEHIND TIME - THAT WAS THE LAST TIME HE PLAYED WITH THAT.

IN 2-D THERE IS NO LINEAL TIME.

BOTTOM LINE: SCALAR WEAPONS PROVE THE NATURE OF THE AETHER AS THE BACKGROUND SCREEN - IF THAT WAS NOT SO, THEN SCALAR WEAPONS WOULD NOT WORK.

ALSO, SCALAR WAVES THAT ARE IN HARMONY WITH AN AMBIENT AETHER ARE VERY BENEFICIAL AND USEFUL - A BEE'S HONEYCOMB IS AN EXCELLENT EXAMPLE. DITTO GRAPHENE.

LOVE AND BLESSINGS

PS: THERE HAVE BEEN A NUMBER OF HUMAN "CIVILIZATIONS" IN THIS SOLAR SYSTEM AND ON THIS PLANET. OUR CONTROLLERS LIKE US TO BE STUPID, BECAUSE IT SEEMS THAT WHEN EVER WE MAKE GREAT TECHNOLOGICAL ADVANCES OR SPIRITUAL ADVANCES, THEN THEY WIPE US OUT. WE ARE AN ENTERTAINMENT SLAVE SPECIE.

THIS LAYS OUT HOW OUR DREAMS / ANUs ARE SHARED WITH OTHERS AND THAT JESUS' ENERGY IS FOUNDATIONAL
http://blog.hasslberger.com/docs/GOLDFISH_JESUS_REVELATIONS.pdf

THIS IS FUNNY AND SHOWS THAT THE EARTH IS THE BEST ENTERTAINMENT SYSTEM IN ALL OF GOD'S CREATION:
http://blog.hasslberger.com/docs/EARTH_WINS.pdf

OH - THE CHEMTRAILS WILL KILL JUST ABOUT EVERY LIVING THING ON THE FACE OF THIS PLANET, IF WE DON'T START MEDITATING AND BUILDING ORGONE DEVICES, WHICH HAS TO BE DONE EVEN IF THEY STOP SPRAYING BECAUSE THE EFFECTS OF THE CHEMTRAILS CAN AND WILL CARRY ON, EVEN IF THE SPRAYING STOPPED.

Scalar Wars

The Brave New World of Scalar Electromagnetics

by Bill Morgan

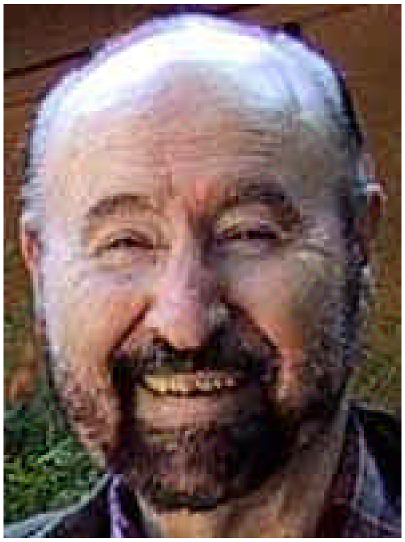

For the past six months I have been undergoing the greatest **paradigm shift** I have ever had to go through. It has rattled my nerves and shaken my bones. This intense adjustment of my "world" has come about by studying the information given by Col. Tom Bearden at his website Cheniere. The new knowledge there has necessitated a total revision of my ideas about physical reality, the world we live in, and the future of humanity. This paradigm shifting even actually made me dizzy on certain days as I tried to absorb and digest Bearden's vast amount of information. I am not a scientist at all, just a layman, and I have little comprehension of the math and high physics of this new science called "**Scalar Electromagnetics**." But there is a great deal of information at Cheniere which needs to become common knowledge as fast as possible, for the sake of the survival of life on earth. To that end I have put together this small primer of Bearden's ideas, as a kind of "beginner's guide" to his website. (I have tried to underline certain words and phrases which are part of the new "jargon" of talking about these "new" phenomena. Also I have taken the liberty of bolding certain words and phrases to help them stick in the mind).

(Note: Throughout "**EM**" means "**electromagnetic**," and "**LW**" means "**longitudinal wave**")

This article has six sections:

New Waves 2. Tapping the Waves 3. Weaponization 4. Healing 5. Psychoenergetics 6. As It Stands

1. New waves discovered

Longitudinal EM energy fills vacuum of space, the time domain of spacetime, time as compressed energy, E=tc2, waves of time, phase conjugate wave pairs.

"Electric power is everywhere present in unlimited quantities and can drive the world's machinery without the need of coal, oil, gas, or any other of the common fuels." Nikola Tesla

"At any point and at any time, one can freely and inexpensively extract enormous EM energy flows directly from the active vacuum itself." Tom Bearden

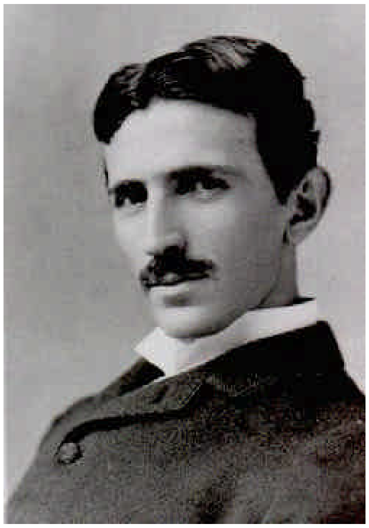

I guess the first thing to try to comprehend is that a "new" kind of electromagnetic (EM) wave has been discovered in the empty vacuum of space called “longitudinal” waves, which, when engineered, can be an inexhaustible supply of energy in great magnitude at any place in the universe. The word "new" is in quotes because the discovery really goes back to **Nikola Tesla** and his discovery of what he called "radiant energy." It is also not "new" because the Russians (KGB) have been working on this technology for over 30 years and have **weaponized** these "new" longitudinal scalar waves to a great degree.

These are the very weapons **Nikita Khrushchev** spoke of in January, 1960.

> "By 1957-8 the Soviets had progressed to the point of a giant scalar EM accident in the Urals which exploded nearby atomic wastes, devastating the area. They had also progressed to development of great new superweapons using their new energetics - weapons to which Khrushchev referred in 1960 when he informed the Soviet Presidium of a new, fantastic weapon in development, a weapon so powerful that it could wipe out all life on earth if unrestrainedly employed.'" Tom Bearden

After over 30 years of development, and extensive testing around the globe, these new scalar electromagnetic weapons are up and running and ready to go. Tom Bearden, at his website Cheniere, discusses the history of these new scalar electromagnetic weapons in his paper "Historical Background of Scalar EM Weapons."

Some Immediate Implications

> The implications of successful engineering of the longitudinal waves are enormous, and will change the world as we know it, one way or another. Among other things, these discoveries mean that:
>
> 1. The **solutions to the energy crisis and the "oil problem" are in hand**. These oil wars are unnecessary. There is endless energy available freely from the domain of time.

2. **Unbelievably powerful weapons** are not only possible, but are already operating in several nations. The many powers of these weapons are unprecedented and mind-boggling.

3. The **cure of diseases such as cancer and AIDS**, in fact nearly any disease, has become possible within a few years of sufficient funding. Everyone can be made healthy and stay healthy.

4. **Mind control on a mass scale** has now become possible, and the machines to do it are already in place in certain nations. It has become possible to mentally enslave whole populations with the twist of a few dials.

So the layman will need to understand that there is a new kind of electromagnetic energy that is altogether different from what he knows, e.g. radio, TV, cell phones, etc. The ordinary EM waves that we have known about are called transverse EM waves, to distinguish them from the new longitudinal EM waves. These scalar waves do not actually exist in our "material" world, but exist only in the vacuum of empty space, or the time domain. And we must keep in mind that this vacuum of space we speak of exists all through everything. Even our bodies are mostly empty space between atoms and molecules. So the gateway to this seething ocean of energy can be there at every point in the universe. This seething ocean of energy is all around us and all through us.

Emptiness is Full

This amazing discovery announces that the "emptiness" of empty space is in fact not empty, but a great ocean of seething energy!

Col. Bearden refers to this ocean of energy as being of the "time domain." It seems like something from Star Trek but this is where scalar electromagnetics has come to. And where it is going may be beyond anything Star Trek could have dreamed of.

We live in a 3-dimensional world, which physics calls "3-space." But there is also spacetime, or 4-space, or the "4th dimension." Then suddenly comes this amazing new knowledge that time itself is actually compressed energy. And it is energy which is compressed by exactly the same factor by which matter is considered compressed energy: the speed-of-light-squared!

So we have a new companion to the famous E=mc2. It is now paired with E=tc2 (where t is actually "delta-t," or change in time). Or (amaze your family and friends and) say:

"E equals em-cee-squared"

and

"E equals delta-tee-cee-squared"

It has a nice ring to it, like some freedom bell announcing a new era.

And as the atomic bomb released the compressed energy in matter, so can we now unleash the tremendous energy that is compressed into time itself. It gives a completely new meaning to the term "time bomb."

Some New Terminology of Scalar Electromagnetics

A new science, several new names

> "Those [Russian] weapon scientists resurrected an old term from the history of electrodynamics, called "energetics". That is their approach to a unified field theory, where everything is based on "energetics". This model as its foundations uses a very similar approach to that "single fundamental unit" model, where energy is the unit. If one makes the energy EM in nature, then one has the Russian energetics approach. This unified approach gathers everything in, including all energy actions and relations in inert matter (the first branch of energetics, called by the same name), all field and matter interactions in living matter (the second branch of energetics, called "bioenergetics"), and all mind operations and mind-matter interactions (the third branch of energetics, called "psychoenergetics"). [ed: sometimes also called "psychotronics" by the Russians]

Rick Andersen in an article called "What is Scalar Electromagnetics?" describes the new science this way:

> "Scalar EM is the brainchild of Lt. Col. (retired) Thomas E. Bearden, a systems analyst and wargames specialist who has been advocating a view of electromagnetics which is based on the notion of a vast, unseen background of scalar energies (as opposed to vector energies) which underlie all physical reality.
>
> "If Bearden is correct in his Scalar EM theory, then we can build devices which would enable us to alter gravity, time, inertia, and the apparent mass of an object. This of course has ENORMOUS implications for military applications, space-vehicle drives, time-travel, teleportation, paranormal phenomena, and just about every other area one can think of." http://twm.co.nz/Beard_scalem.html

> "Time-energy, time-currents, and time-structuring play the dominant role in electromagnetics. Time-as-energy eventually becomes engineerable, as easily as is spatial energy now. We are always dealing with spacetime and with spacetime curvature."
>
> Bearden: http://www.cheniere.org/techpapers/Vision%202000%20paper.doc

The scalar energy discovered in the vacuum of space is sometimes called "zero-point" energy. Thomas Valone explains how this term came about.

What does "Zero Point" mean?

"Boyer traces the historical “creation of the vacuum” as proceeding in stages in parallel with the historical development of ideas about the vacuum. To paraphrase, he says that in the 17th century, it was thought that a totally empty volume of space could be created by simply removing all matter and, in particular, all gases. That was our first concept of the vacuum. Just get rid of all the gas. Late in the 19th century, it became apparent that the region still contained thermal radiation. But it seemed that the radiation might be eliminated by cooling. So the second concept of getting a real vacuum is to cool it down to zero temperature. Just go all the way to absolute zero. Then we’ve got a real vacuum. Right? Well, since then, both theory and experiment have shown that there is a non-thermal radiation in the vacuum and that it persists even if the temperature could be lowered to absolute zero. Therefore, it was simply called the “zero point” radiation. "Thomas Valone http://www.seaspower.com/InsideZeroPoint.htm

> "**For our very survival, it is absolutely imperative that informed citizens be aware of this dramatic change, which is just now starting. The powerful new science and engineering must be controlled and used for humanity's benefit, not its detriment. Else it will eventually be let loose unrestrainedly, to destroy all life on earth - a possibility indicated by Nikita Khrushchev in 1960**." - Bearden
>
> http://www.cheniere.org/explore%20articles/priore1/p4.jpg

2. Tapping the waves

Endless free energy, Tesla's radiant energy, the dipole as the gateway to the energy of the void, MEG in one year, Bedini, Yakuza, etc. End of Oil, geopolitical chaos, rogue groups

Move Over G.E. & Big Oil, Energy is Everywhere!

Third-world nations set to rise

> "Certain powerful interests did not wish the extended electromagnetics to be discovered or taught. That, after all, would lead to free energy and loss of economic control of the citizens. That was precisely why Nikola Tesla had already been suppressed ... Today it is still being suppressed by the orthodox establishment."
> http://www.cheniere.org/books/ferdelance/s25.htm

The vast seething ocean of energy of the vacuum, the longitudinal scalar EM waves of the time domain, can now be tapped and "transduced" into ordinary (transverse) EM energy in our 3-Space world. The process can be compared to putting a paddlewheel into a river. The energy acquired is free, since the river is there flowing whether we tap it or not. And it is a mighty river, and is not diminished by our paddlewheel.

This means that a permanent solution to the "energy crisis" is at hand, if only those who hold it so secret would give it up to humankind.

It means our species' insane use of oil is no longer necessary. We can make automobiles that need no fuel at all. We can build motors that power themselves. It means that unlimited electrical power can be available for free anywhere in the world. Every house and even shack can have its own power supply.

Of course there is the cost of the equipment at first, but the energy flow is free for the presumably very long life (no moving parts) of the generator. It will probably take decades to shift over to scalar power.

But the ability to tap the scalar (longitudinal) EM waves of the vacuum (which exists everywhere) also means that unbelievably powerful weapons can be, and already have been developed. In fact these weapons are so dangerous that the fear engendered becomes a psychological obstacle to the grasping of the facts.

I struggled with this myself for months, and even though Tom Bearden had completely convinced me already, it is hard to accept the fact that for everyone on earth the "worst that might happen" has suddenly gotten much worse. It takes time to deal with that, to realize it and get over it.

Indeed, the possibilities of these new weapons, which are tapping the huge energies of time, are so terrifying it is natural for the mind to simply say: "I don't want to hear about that."

And the government, likewise, pretends these weapons do not exist and tries to keep it secret from the people. Because most people would indeed be truly alarmed to know the actual situation. Col. Tom Bearden has decided that the people need to know the truth anyway. As a People on a Planet we must face this now, and ban the use of scalar weapons in war or in mass mind control. The current deployment of these weapons is a world emergency which we must all face.

The physics and mathematics of the longitudinal waves and the time domain are clearly beyond the layman, but I recommend scanning through them anyway just to get a sense of the wonder and the elegance of it all and some of the exotic terms which are used. Two of the most important papers by Col. Bearden are:

Giant Negentropy from the Common Dipole

The Final Secret of Free Energy.

Despite the complexity of the science involved, Bearden sums up the essential secret of it all in a few words.

> "There is no problem at all in extracting all the energy one wishes from the active vacuum, anywhere in the universe, at any time. Just make a dipole.

> The problem is in (1) catching some of that freely gushing EM energy in a circuit containing a load, and (2) dissipating the caught and collected EM energy in that load to power it, without using half the caught energy to destroy the source dipole's).
>
> That is the ONLY real energy problem on the planet, and always has been."
>
> http://www.cheniere.org/correspondence/022502.htm

A dipole could be a battery, which is polarized into negative and positive. Or the terminals of a generator. Or any magnet with its two poles. Or an atom with its positive and negative charges. Or the earth's magnetic field, the sun, and all heavenly bodies. Even a galaxy must be some kind of mega-dipole. Wherever there is a dipole there is already immense scalar EM energy ushering out of and back into the vacuum. And there have already been demonstrated a number of diverse methods for tapping that energy as it flows. (John Bedini, Edwin Gray, Bruce de Palma, and others). Bearden provides what he calls a "partial list" on his website.

> "In other words, nature then gladly gives us as much EM energy flow as we need, indefinitely — just for paying a tiny little bit initially to "make the little dipole." After that, we never have to pay anything again, and nature will happily keep on pouring out that 3-flow of EM energy for us. This is the giant negentropy mechanism I uncovered, performed in the simplest way imaginable: just make an ordinary little dipole."
>
> Bearden http://www.cheniere.org/techpapers/Unnecessary%20Energy%20Crisis.doc

How to Buy a Free Energy Machine

Answer: Just wait one more year! 2003. Then get off the Grid!

Perhaps the most eagerly awaited event now is the marketing of Bearden's Motionless Electromagnetic Generator (MEG) scheduled to begin in about a year's time. This is when the proof will hit the fan. Many people have said to me, when talking about free energy, "I'll believe it when I can go to the store and buy one." Hopefully in a year's time they will be able to order their own MEG. And then they will believe, because it works and is working.

Says Bearden: "I will admit that the chief scientist of an important experimental group in a large company was rather stunned at the type of output we were able to obtain. The MEG may look like just a transformer, but it is not. It is a completely different breed of cat."

(Bearden : http://www.cheniere.org/correspondence/011202.htm)

Soon the cat will be fully out of the bag. The first MEG units will supply 2.5 kilowatts of free electricity. Forever. Units can be connected together to double or triple the wattage. After that gets going, 10 kilowatt generators are planned. Energy will flow freely from the time domain indefinitely, and there are no moving parts to wear out. This manufacturing project is a heroic effort and will change the world as we know it. For once people are in possession of such devices there can be no further denial from anyone, including the government and/or "secret-government."

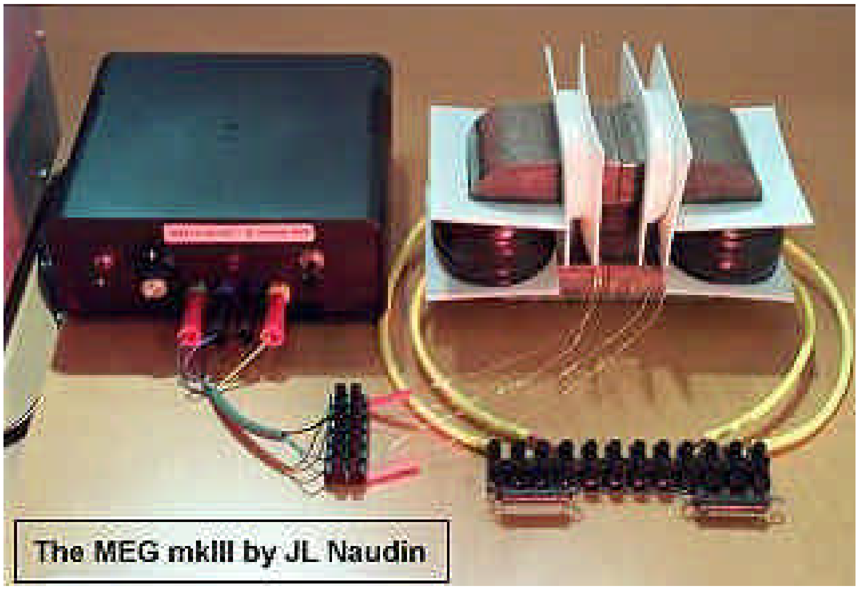

The Motionless Electromagnetic Generator

(Successfully replicated here by J. L. Naudin)

The physics of how the MEG works is explained in the paper "The Motionless Electromagnetic Generator: Extracting Energy from a Permanent Magnet with Energy Replenishment from the Active Vacuum."

The device was successfully replicated by J.L. Naudin in France, and others, like Steve Utne, are also working on their own models. But Magnetic Energy Limited's MEG is actually scheduled for production soon and looks to be the first commercially available free-energy generator in history!

I imagine it will not take long for tinkerers to put them into their electric cars and make the first fuelless automobiles since Tesla's unheralded (and unheeded) experiments. Or for builders to begin building houses powered by MEG's. Houses which will never see electric bills. How can they ever make enough of these to meet the demand that will suddenly be there? Bearden is right, it needs to be an all-out crash program of the government on the order of the Manhattan Project.

I must include here that Bearden is quick to point out that he is not himself the inventor of the MEG, but is a partner and advisor in bringing it to the public market through Magnetic Energy Limited, Inc. I must also admit that I am praying for the success of this venture, and the ending of the absurd and criminal withholding of this technology from the people by the black-ops military-industrial people. This secrecy has cost the planet over 30 years of unnecessary pollution.

The first units off the assembly line, which is being set up in a "friendly" unnamed nation, will usher the public at last into the new era of scalar electromagnetics.

As of December, 2001, the situation with the MEG was described by Bearden in a letter.

> "What we presently have with the MEG is a successful laboratory experiment. At least a year's very hard research will have to be done before we will be ready to put a commercial power supply into production.
>
> "Consequently, we have made an agreement with a foreign partner (the National Materials Science Lab of the National Academy of Sciences of a friendly foreign nation) to do that year's research. At the same time, we are trying to make an agreement with one or more large financial partners here in the U.S."
>
> Bearden http://www.cheniere.org/correspondence/121901.htm
>
> "So we are hopeful that we will be able to start introducing units on the market about a year from now. Quite simply, we will either succeed or we will fail. But we will give it our very best effort."
>
> Bearden http://www.cheniere.org/correspondence/012202a.htm

Bearden has given another technical explanation of how the MEG works here in a letter.

Motionless Electromagnetic Generator patented, 3-26-2002

Click here to read the patent

"In Magnetic Energy Limited, all business discussions and arrangements are taken care of by Dr. Lee Kenny, Managing Partner. There are five of us who are co-inventors of the MEG, and two of the others are really the principal inventors." Bearden http://www.cheniere.org/megstatus.htm

Free Energy has been Suppressed

Secret Government Aware of Free Energy

> "In this world of contemporary times, all the agencies, CIA, FBI, KGB, NSA, Electric Power Research Institute, DARPA, Brookings Institution, Henry Kissinger, Edward Teller, et al., all are aware of [free-energy researcher Bruce] De Palma and his ideas.
>
> "Because these individuals and institutions are employed by the ruling elite to forecast the future and satisfy present needs and demands, it is clear that free energy is a threat to the world order constructed by business and the mindset of those who want to own the world.
>
> "Free energy represents Man's aspirations and dreams of freedom and equality, uniform division of resources and the ability to choose one's own future.
>
> "The fact that free energy is suppressed speaks to the greed and self-interest of a ruling elite which, even in the face of an emergency of global starvation, resource depletion and environmental pollution, will not give one inch if it means loss of control. This is an

> attitude of paranoid delusion and fantasy which can only arise from the alienation of a class of elitists who, through their money, are completely insulated from the reality of the day to day fight for existence of the common man."
>
> http://depalma.pair.com/Absurdity/Absurdity07/ProblemOfFreeEnergy.html

Bearden describes one case of suppression when the Yakuza killed the Kawai engine in his very presence in Huntsville, Alabama.

> "That night a jet arrived from Los Angeles, with a Yakuza on board. The next morning Kawai no longer controlled his company, his invention, or his own fate. The Kawai party was in fear and trembling. The Yakuza coldly dissolved the agreement, they packed up the two Kawai engines we had, and left. And that was that."

So it is not only governments who are keeping this revolutionary technology from seeing the light of day. The Yakuza? KGB? The Aum Shinrikyo cult? Our "leaders" need to be honest about what is going on, otherwise they look foolish, acting out a kind of "Alice In Wonderland" script before the public, a script that has become completely unbelievable.

Concerning the criminal withholding of this scalar technology by the military black-budget people, and the cover-up of the actual situation regarding scalar weapons throughout the world, Tom has this to say:

> "The high government officials of the United States of America grossly violated our constitution and their sworn oaths of office. Our constitution specifically charges the government of the United States to defend the people of the United States. That means our officials are specifically charged with defending our people. Yet they deliberately agreed not to do so, and they deliberately sacrificed us in advance.
>
> "They committed treason of the highest kind, by deliberately surrendering us to total destruction anytime the big balloon goes up."
>
> Bearden http://www.cheniere.org/books/ferdelance/s75.htm

Energy Crisis Solved

One of the "must read" documents at Cheniere is "The Unnecessary Energy Crisis: How to Solve It Quickly," especially since the "oil wars," which Bearden has foreseen for decades, have now already begun.

Here are some clips from that Document:

> "To avoid the impending collapse of the world economy and/or the destruction of civilization and the biosphere, we must quickly replace much of the "electrical energy from oil" heart of the crisis at great speed, and simultaneously replace a significant part of the "transportation using oil products" factor also.

> "The technical basis for that solution and part of the prototype technology required, are now at hand. We discuss that solution in this paper."

And although the solution to the energy problem and the oil wars may be at hand, Bearden suggests there is still an urgent rush that needs to be made to save human civilization from collapse.

> "Once the technology hardware solutions are ready for mass production, even with a massive worldwide deployment effort some five years are required to deploy the new systems sufficiently to contain the problem of world economic collapse. This means that, by the end of 2003, those hardware technology solutions must have been completed, and the production replacement power systems must be ready to roll off the assembly lines en masse.
>
> "The 2003 date appears to be the critical "point of no return" for the survival of civilization as we have known it.
>
> "Reaching that point, say, in 2005 will not solve the crisis in time, and the collapse of the world economy as well as the destruction of civilization and the biosphere will still almost certainly occur, even with the solutions in hand."
>
> "The good news is that we now know how to easily initiate continuous and powerful "electromagnetic winds" from the vacuum at will. Once initiated, each free EM energy wind flows continuously so long as the simple initiator is not deliberately destroyed."

On page 9 he explains the concept of the dipole, and how there is already huge scalar energy flowing in the time domain around any dipole. Hold a magnet or a battery in your hand and you hold a stress in time and a beautiful flowing loop of longitudinal waves!

Bearden decries the scientific community in the West for being unable to let go of their dogma long enough to see that the greatest discovery in human history lies at their feet, but for their stubborn ignorance.

> "The present energy crisis then is due totally to that "conspiracy of ignorance" we referred to, that is maintained by the scientific community, and that has been maintained by it for more than 100 years.
>
> "This is the real situation that the environmentalists must become aware of, if they are to see the correct path into which their energies and efforts should be directed — to solve both the energy crisis and the problem of gigantic pollution of the biosphere. "As far as anyone in the legislative branch of government ever understanding the profundity of the discovery and engineering of scalar waves, Tom Bearden says they are at a great disadvantage in doing so.
>
> "The nontechnical person — e.g., a Senator or a Congressperson — is operating under a distinct disadvantage. If he or she takes the stance that much better electrical power systems can readily be achieved, he or she is in fact opposing almost the entire set of University, Government Technical, Power Company, Battery Company, and Organized

> Science communities. Further, in most cases his technical advisors are themselves from one or the other of those communities, and likely to go back into that community or those communities when the Senator or Congressperson leaves office, or even before. So the Congress and the non-technical government community at large operate at a great disadvantage...Bearden National Emergency Declaration is Needed
>
> "The Government Non-Technical community (the Senate and the Congress, in particular) are in far better shape than the Government Technical community, to appreciate the world implications of the pending economic disaster. I am hopeful that both the environmentalists and the Government Non-Technical community will rapidly unite in a common goal to get this vacuum energy program launched, under a National Emergency declaration. If so, then they can solve the energy crisis and the pending economic crisis, in fairly short order, and permanently."
>
> unnecessary_energy_crisis.htm#congress_disadvantage

In the conclusion of his paper The Unnecessary Energy Crisis: How to Solve It Quickly Bearden again states the urgency of replacing our centralized power grids with highly dispersed and local taps on the freely flowing energy of the active vacuum. Given the abilities of the Tesla howitzers, the power grids of all nations are sitting ducks.

> "Personally, the present author regards the increasing energy crisis as the greatest strategic threat to the United States in its entire history. I will do anything within my power to help prevent what I perceive to be the looming economic collapse of the Western world, preceded or accompanied by a sudden, explosive, all-out and continuing exchange of the WMD arsenals of most of the world.
>
> ...In the name of all humanity, let us begin! Else by the time this first decade of the new millennium ends, much of humanity may not remain to see the second decade."

---

3. Weaponization

Scalar interferometry, Tesla howitzer, Tesla dome, heat/cold, dudding, 10 nations have them, dead-man fusing & Insane Systems, scalar strategy, earthquakes and weather wars, solar storms, mind attacks, leased to Yakuza, many examples of testing, quantum potential weapons.

> "Indeed, Soviet energetics weapons are now capable of destroying both our triad shield, our homeland, our armed forces in the field, and our population, quickly and efficiently. We have a new "gap" of monumental proportions: not a missile gap, not a submarine or bomber gap, and not even a particle beam or laser gap. We have a scalar electromagnetics or electrogravitation gap." Bearden http://www.cheniere.org/books/ferdelance/intro.htm

"**We have a new weapon, just within the portfolio of our scientists, so to speak, which is so powerful that,**

if unrestrainedly used, it could wipe out all life on earth. It is a fantastic weapon." Khrushchev, to the Presidium, Jan. 1960

> "We've totally missed the most incredible "secret superweapons" development program of all times, and the worldwide testing of the weapons themselves.
>
> "Hiroshima and Nagasaki should serve as object lessons in the price of ignorance of such technological breakthroughs.
>
> "History does repeat itself. But this time it's not we Americans who got the great new superweapon first."
>
> Bearden http://www.cheniere.org/books/ferdelance/s75.htm

Warfare has been changed forever by the development of these scalar energy longitudinal wave howitzers. To get a basic understanding of scalar waves is to have the imagination suddenly run wild as all the implications and possibilities regarding warfare fall into place. One realizes with a certain horror that the world has totally changed, and that there are some very fearsome possibilities. Remember, the power for these weapons comes from the time domain, longitudinal EM waves in the vacuum of empty space, and the power is tremendous and mind-boggling. Being able to blast away at any target from a distant control booth is something that has never happened before. This is incredible power to be in control of and it divides the history of weaponry into "before" and "after." And the destructive power of these weapons is delivered instantaneously to the target from the local vacuum at the place of the target.

From an interview:

> Questioner: "Are you saying that real energy can be transmitted faster than the speed of light?"
>
> Bearden: "Yes. But hyperspatially. Not through 3-space, but "around" it. Again, this means that it's possible to produce energetic changes in a distant system at a distant place, without transmitting energy "through space" in the normal sense. You transmit "around" space, so to speak, and directly in time or through a higher dimension, depending on the model you're using to understand this. Further, the speed of the internal EM energy transmission is not limited to the speed of light."
>
> http://twm.co.nz/beard_interview.htm

Here are some initial considerations about scalar weapons and scalar wars

1. Tesla Howitzer 2. Tesla Domes 3. Rogue groups 4. WW III 5. Russian "UFOs?"

3a. The Tesla Howitzer and its modes of action

Source: Tom Bearden's weapons slides and Fer-de-Lance Briefing

For one thing there is no delivery of any thing to any place. Bombs are obsolete. So are the planes to get them there. No helicopters necessary. All current nuclear devices are rendered nearly useless by electronic "dudding." All distant-destruction can be done from a control room, and to any point on earth. The destructive power of "men" has just increased by orders of magnitude. The new weapons could even cause storms on the sun! Thus there is great urgency to make these new facts public and known, with the hope that all nations would come together to ban the use of scalar weapons.

Two scalar antennae together along with the computers to control them, make up a scalar interferometer, and according to Col. Bearden the Russians have hundreds of such installations already. These interferometers are called "Tesla Howitzers." They can deliver a giant blast of energy to the distant target site, true "action-at-a-distance".

The first howitzer mode is called the "exothermic" mode of operation because immense EM energy blasts outward at the target site. The blast of a scalar howitzer can be of near nuclear level in destructiveness, and can be repeated easily, at that place, or nearby, or anywhere.

The howitzer can use a lesser exothermic power setting and simply destroy all electronics in the target area. Thus they can render our nuclear missiles inoperable as they sit in their silos by "frying" the electronic circuits that guide them. They can bring down any airplane, anywhere in the world, at any time. Any person anywhere, if their exact position is known, can be assassinated without a shot being fired.

The howitzers can also bring down power grids anywhere in the world, at any time. Thus they could bring Wall Street to an instant halt by disabling all its electronics. Even this one little easy tweak of the howitzer could cripple the U.S. economy in a single day. No wonder the "leaders" don't want you to know! This is a new era we are in. The discovery and development of scalar interferometry has put us in a new world, whether we like it or not. Anyone could be expected to go into denial, the befuddled senators and congressmen included. But we have to wake up.

In a second howitzer mode called the "endothermic" mode, the howitzer sucks energy out of the target area, essentially creating a blast of cold at the distant target. It is even capable of freezing parts of the ocean. Bearden gives a number of cases where these "cold explosions" have been witnessed, mostly by airline pilots. April 9, 1984: 1 2 3) A huge mushroom cloud of mostly water is seen rising miles into the sky from out of the ocean, an awesome sight.

In the endothermic mode the sucked-out energy must go somewhere, so it is vented out at some other chosen spot on the earth. These endothermic plumes have been photographed by satellite.

> "The exhaust in the left picture is about 150 miles long, and is nearly horizontal (about 1.5 degrees above the horizontal). It is entirely consistent with the continuous exhaust from a "dumping transfer" scalar EM howitzer in the continuous exothermic mode. (The primary howitzer, of course, was activated in the endothermic mode.)" Bearden More Plumes

By using both of these heat (exothermic) and cold (endothermic) modes together the weather can be altered anywhere. Warm the air over here, cool it down over there, put a curl in the jet stream, dissipate clouds, create clouds, whip up a tornado. Bearden speaks about using the endothermic howitzer mode as a weapon of war:

"Cold explosions can be used to freeze tanks, personnel, and equipment. The equipment and tanks thaw out. The personnel thaw out too, but they are dead when they do." Bearden, Fer-de-Lance

(This endothermic mode of the howitzers makes me think that there might one day be a cure for the problem of global warming after all. Could not a big device, situated in space or on the moon, be able to vent a great deal of excess heat outside the atmosphere into space, thus functioning as a kind of planetary thermostat?)

While the United States has experimented with electomagnetic weapons using ordinary transverse EM waves, the longitudinal [LW] weaponized waves are truly of another order altogether.

For one thing they do not have to travel through space, for they come from the time domain, which is everywhere. The energy of the blast, the heat or light or whatever, comes from the vacuum of space at the location of the target itself. This is astonishing. The weapons actually just trigger the release of immense energy from the vacuum at the target location.

> "... it is possible to focus the potential for the effects of a weapon through spacetime itself, in a manner so that mass and energy do not "travel through space" from the transmitter to the target at all. Instead, ripples and patterns in the fabric of spacetime itself are manipulated to meet and interfere in and at the local spacetime of some distant target. There interference of these ripple patterns creates the desired energetic effect (hence the term energetics) directly in and through the target itself, emerging from the very spacetime (vacuum) in which the target is imbedded at its distant location." Bearden Fer-de-Lance

The big Tesla howitzers are aimed at their targets by using a worldwide electromagnetic pattern called the "Woodpecker Grid," begun by the Russians in 1976.

You can hear the Woodpecker signal here: http://www.cheniere.org/misc/woodpeckersound.htm

The woodpecker grid is just that, a grid of EM waves which provide a channel for the LW waves to any point on earth. Computers use the woodpecker grid information to hone down the aiming of the howitzers to a pinpoint location on earth. (For that matter, it could be under the earth, in space, or under the sea).

A third howitzer mode is what Col. Bearden calls "Mindsnapper" mode. This is a truly frightening mode which affects the electromagnetic mind-body connection. Being mind-snapped at a low level would cause you to lose consciousness. Being mind-snapped at a slightly higher power would "entrain" all minds in the target area into a kind of hypnogogic trance, a state in which they would all be highly susceptible to suggestions and orders.

Being mind-snapped at high level would so disrupt the mind-body connection that everyone in the target area would fall down, instantly dead. Not only that, everything around you and inside you would be killed, so that your sterilized body would not rot for quite a long time.

The Mindsnapper can be used for a small area, or to kill an entire population. In fact, using the scalar waves to affect the human mind has become a new field in its own right, and has been dubbed "psychoenergetics." (This is discussed below in section 5).

Bearden describes the use of the howitzer in mind-snapping mode against people, to cause unconsciousness or death:

> "From a military viewpoint, these scalar EM weapons are really quite all-around weapons.
>
> "For example, they are very lethal against personnel.
>
> "Set in the "high intensity pulse mode," one blast and a person's nervous system is destroyed instantly. Total, instantaneous death results. One can blast away at entire groups of infantrymen, for example. It's the peak power that's important, not the average power. So the weapon doesn't require too much battery power.
>
> "Set on a lower intensity pulse mode, one zap can simply knock out a person, rendering him instantly unconscious. Quite useful if one needs prisoners to interrogate. Also very silent, which is useful in operations employing stealth and surprise." Bearden http://www.cheniere.org/books/ferdelance/s80.htm
>
> "Those hit by the scalar EM weapon, however, have a most peculiar death mode.
>
> "Death comes-instantly and totally. There is no convulsion, no response. The entire nervous system is destroyed instantly. Every living cell in the body is killed instantly, including all bacteria, germs, etc.
>
> "A body hit with this thing falls like a limp rag and lies where it falls. It doesn't decay in even 30-45 days. In a macabre fashion, it's been reduced to something like food irradiated with nuclear radiation; everything is killed, so the material is preserved for an extended period before any decay can set in."
>
> Bearden http://www.cheniere.org/books/ferdelance/s81.htm

He goes on to say that the same "bazooka-sized scalar EM pulse weapon" can also be used to knock out a tank with one shot (or pulse). So tank warfare is obsolete. Helicopters? Bearden points out: "... if he's attacked by a helicopter or a fixed-wing aircraft, he can bring the same weapon to bear on it. He can knock down a chopper or a jet. With one shot."

Obituary for Tank Warfare

Tanks useless against portable LW weapons

> "For example, suppose one attacks a tank. [with an LW weapon] With scalar EM pulse, the personnel die instantly. Total personnel kill is achieved.
>
> All electronic systems of the tank are dudded. Total systems kill is achieved. The ammunition in the tank explodes. Total kill is achieved.
>
> The fuel explodes. This is another total kill mechanism.
>
> That tank has been killed totally, by a variety of mechanisms, all simultaneously.
>
> That's a k-kill in any analyst's book.
>
> And don't worry about retrieval and repair. That tank is finished permanently.
>
> Even the most modern tank is just as vulnerable as the most obsolete."
>
> Bearden http://www.cheniere.org/books/ferdelance/s88.htm

One begins to get the idea how profoundly the conventional means of warfare have been obsoleted. All the usual weapons of war have been rendered nearly useless! And Star Trek's "Phaser," with its "stun" and "kill" modes is here at last.

Although it is the weapons aspect of scalar electromagnetic which has received the most developmental effort, Bearden points out that a great many other amazing things that may be accomplished in this new field of science. Beam me up Scotty!

> "Superluminal communications systems, hyperspace drive, and materialization and dematerialization are all hypothetically possible, using scalar electromagnetics. As the technology develops, we should see the development of many of the systems long thought impossible except in science- fiction."
>
> Bearden http://www.cheniere.org/books/ferdelance/s15.htm

Bearden describes a huge test of the Russian scalar weapons systems which occurred in 1985, a test that went completely unnoticed by western scientists:

> "Just before May 1, 1985 the Soviet Union performed a "full-up" operational test of their entire strategic scalar EM weapons complex. This test was detected and monitored periodically by Frank Golden. Some 27 of these giant Soviet "power taps" were locked into the molten core of the earth, producing forced (entrained) scalar resonance of the entire planet on 54 controlled frequencies under our very feet. The remainder of the scalar frequency spectrum was ablaze with literally hundreds of Soviet scalar transmitters: probably the entire strategic scalar command and control system to

> underwater submarines, higher command centers, distant commands, etc. was activated in the giant exercise.
>
> "For several days, the system was exercised on a mind-boggling scale, apparently as part of the Soviet Union's highly accentuated 40th anniversary celebration of the end of World War II.
>
> "Ironically, not a single U.S. intelligence agency, laboratory, or scientist detected this monstrous exercise for the new Soviet leader, Gorbachev. Not a one of them had a detector for scalar EM radiation, and not a one of them officially believes the exercise ever happened."
>
> Bearden http://www.cheniere.org/books/ferdelance/s38.htm
>
> "The Woodpecker grid/howitzer weapon system can be placed over the ocean and used against cruise missiles, naval surface-to-air and surface-to-surface missiles, submarine-launched ballistic and cruise missiles, etc. Placed over a carrier task force, it can also take care of the aircraft launched by the carrier as fast as they are launched. It can also handily take care of the missiles launched by guided-missile cruisers of the accompanying task force."
>
> (Bearden http://www.cheniere.org/books/ferdelance/s65.htm)

The whole series of the Fer-de-Lance briefing slides and comments is a "must read" for anyone wanting to be aware of the actual state of things in this world right now. It is a new world and it takes some getting used to. Fer-de-Lance speaks clearly, for the layman, of the way things stand.

What is it like to operate these Tesla Howitzers? Col. Bearden gives us an idea in his "Fer-de-Lance" briefing, Slides 66-71.

Who needs armies anymore? A entire war can be fought and won by a handful of men sitting in a comfortable control booth! The scalar electromagnetics revolution has made all previous forms of warfare nearly obsolete.

Why haven't the Russians used the scalar weapons yet?

Bearden gives his thoughts on this in "Fer-de-Lance." The power of these weapons is so great that an accident or war could wipe out all life on earth, and even affect the sun.

> "As can be appreciated, this entire concept [MAD] is now totally obsoleted by the Soviet possession of scalar EM weapons.
>
> 'The "mutual assured destruction" capability -- or MAD concept as it was so aptly named! -- is no longer mutual. And for two reasons: (1) the Soviet surprise attack could destroy essentially all our Triad forces wherever they are, in the first attack. (2) Even if a very small number of our strategic forces survive, the puny strike we could attempt to launch could be repeatedly decimated from launch to terminal phase.

> 'The restraint on the Soviets is not because of our Triad forces. The restraint is twofold: (1) a second nation has scalar EM weapons, and would undoubtedly unleash them upon the Soviet Union with great violence if such a massive world-wide destruction of U.S. forces occurred or was threatened (is it really "accidental" that six major Soviet missile ammunition storage sites mysteriously exploded within seven months?); (2) the closed-loop scalar radiation exchange system of Earth-Sun could be inadvertently "tweaked" in the feedback loop from Earth to Sun, so that a large solar scalar resonance was stimulated. In that case the Sun could emit a mighty resonant "burp" that would simply wipe out all life on Earth in a fiery shower.
>
> 'The "terror" in the "balance of terror" between nations has just increased by many, many orders of magnitude.
>
> 'The biblical prophecy that the Earth will be wiped out by "fire and brimstone from heaven" is very near fulfillment now.
>
> 'Put another way, the pucker factor -- even on the Russians who may contemplate unleashing Armageddon -- is higher than any Western strategic analyst has ever imagined, even in his wildest nightmares.
>
> 'Truly these weapons are "more frightening than the mind of man has imagined," as Brezhnev put it in 1975.
>
> 'The frightening scalar EM weapons can be used, but only very, very gingerly indeed. If a slight mistake is made, everybody loses everything."
>
> Bearden http://www.cheniere.org/books/ferdelance/s74.htm

But the Russians (KGB) are not the worst of it. Bearden claims that some of the scalar weapons have been leased to the Yakuza for about a billion a year, and that only the KGB is holding the Yakuza in check from making a full-scale all out scalar attack on the west.

U.S. Defense Secretary William Cohen

Warns about eco-terrorism using scalar electromagnetic weapons

> "Others [terrorists] are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves... So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations...It's real, and that's the reason why we have to intensify our [counter terrorism] efforts." - Defense Secretary William Cohen, 1997
>
> In a letter to a writer named "Russell" Bearden says,
>
> "In short, Russell, the Secretary of Defense of the United States confirmed that there are indeed novel kinds of EM weapons, right now and have been for some time, which have been and are being used to (1) initiate earthquakes, (2) engineer the weather and climate,

> and (3) initiate the eruption of volcanoes. We wrote about those exact uses of the weaponry decades ago. Several nations now have such weapons. Three of them (two on one side and the other on a hostile side) are even firing practice shots into Western Australia, as a convenient test range."
>
> http://www.earthchangestv.com/ufo/0209gandor.htm

Tesla Howitzers in Weather mode

How to Make Weather

> "Engineering the weather is duck soup; they tested that over the U.S. in 1967, and entered upon continuing operations over North America on July 4, 1976 as a grim kind of KGB "Bicentennial Gift" to the United States. Here's how it is done with several interferometers.
>
> "First, the interferometers can deliberately make "high pressure areas" (cool the air so it shrinks and its "footprint" pressure on the ground increases because its density increases) and "low pressure areas" (heat the air so that expands and its "footprint" pressure on the ground decreases because its density decreases). Well, if one makes the highs and lows where one wishes them, and judiciously and somewhat slowly moves them along a given path, these highs and lows will entrain the jet streams and thus "steer" the weather.
>
> "So if you wish a very cold snap or attack, go up into Canada and start these actions to steer down some streams that bring some very frigid air. Establish other highs and lows judiciously to "block" or "slow" other jet streams and flows as desired. In this way, one can pull the "large cold air masses coming down from Canada" deep into the southern U.S. at will. They do it regularly. If you wish an ice storm, add an additional current of warm moist air you bring up (steer up by using artificial highs and lows) from the ocean. Where they meet, you will get freezing rain, then sleet, then severe icing accumulating. This type of attack does rather large damage to the struck area."
>
> http://www.earthchangestv.com/ufo/0209gandor.htm

Whole websites have now sprung up showing weather radar anomalies which may well be indications of scalar weather engineering. One list of over 500 images is here. Cheniere has its own collection here.

In another section at Cheniere are many photos of cloud anomalies which reveal the underlying grid along which the clouds are forming or un-forming. Bearden relates a startling incident in these clandestine ongoing "weather wars."

> "During the spring of 1986, abnormally strong Soviet weather engineering occurred over the U. S., causing a drastic drought in the southeastern U.S. This drought was broken by a colleague who used an extremely powerful scalar EM device to redirect jetstreams. A most unusual and unique signature of the "blocking" against the Soviet scalar EM actions

resulted: Two huge circulations developed in the atmosphere, clearly showed as two adjacent giant "holes" in the swirling cloud cover over the middle and eastern U.S.

"Between these two giant holes, the cloud circulations formed a stream of clouds, moving to the south, looking very: much like a giant vertical "bar" of a huge "Y-shaped" cloud flow.* Several national weathermen commented on this unusual pattern, which had not been observed before. The pattern continued, day after day, as the blocking continued."

* On the weather maps.

http://www.cheniere.org/books/analysis/history.htm

Tesla Howitzers in Earthquake mode

How to Make an Earthquake

"Here's how you initiate a very large earthquake with such weapons. Take a convenient fault zone of set of them. Focus the interferometry on the fault zone, in the "diverging" mode, and deposit EM energy there in the rocks on both sides, increasing (slowly) the stress in the rocks by the reverse piezoelectric effect (deposit excess energy, get crystal mechanical movements).

"Do it slowly, and the stress will build up to large pressures well-above a plate slip minimum energy required. At some point, the rocks yield and one or both sides "slip" and move rather sharply, giving a very large earthquake in that zone.

"Do the same thing down in the earth (remember, LWs easily penetrate right through the earth and ocean at will, and so the "interference zone" focus can be inside the earth or beneath the ocean, at will.

"Anyway, focus this thing down to where the active part of the volcano is still slumbering, down where the hole in the plate has been made. Keep increasing the deposition of energy in the magma itself, and eventually the increasing pressure from deep within that volcano, underground, will cause an eruption. Build the energy slow, and the eruption will likely be much larger."

http://www.earthchangestv.com/ufo/0209gandor.htm

Yugoslav Earthquake, Followed by Cold Explosion

Strange Characteristics of Iran Quake, Sep. 1978

Tesla Howitzers in Tesla's "Big Eye" mode

How to make a Big Eye in the Sky

By using longitudinal wave interferometry in a weakly endothermic mode a new kind of "radar" is now possible, one which can look right through the earth and oceans. Because the endothermic mode extracts energy from the distant target, a pattern of the target area can be scanned for in the returned energy.

> "Thus the receiver produces a representation of the energy extracted from various locations within the distant endothermic zone. By displaying the received signals on an appropriately scanned screen, a representation of the distant scene in the intersection zone can be created. Indeed this is a special kind of "microwave interferometry," and -- with modern techniques -- the imagery obtained might be surprisingly good. With development, it might even become as good as the image presently obtained by side-looking acquisition radars.
>
> "Interestingly enough, since scalar EM beams will easily penetrate the earth or the ocean, one can also look beneath the earth or beneath the ocean with this type of scanning scalar interferometer.
>
> "The importance of this capability to strategic and tactical reconnaissance is obvious. Camouflage, cover, and concealment have no effect on such a system. One can easily look inside buildings and into underground facilities. With a small system such as this, the U.S. Marines at Khe Sahn would have had little difficulty locating the tunnels continually dug under the perimeter by the Viet Cong. And targets under jungle canopies are directly visible."
>
> Bearden http://www.cheniere.org/books/ferdelance/s42.htm

Tesla Howitzers can destroy all life on earth

How to Make a Storm on the Sun!!

(Just make a big mistake with your Tesla howitzers)

The deepest dangers of the use of scalar weapons are frighteningly pointed out by Bearden here where he considers that the sun, earth and moon (actually the whole solar system) is a delicately balanced arrangement of scalar (longitudinal) EM radiation. There is a scalar connection between the earth and the sun, which are both giant dipoles gushing energy in the time domain. Big scalar events on the earth could alter this balance causing true catastrophe.

"Indeed, a solar response could be stimulated so that the Sun would violently belch and destroy our biosphere, among other effects."

Unrestrained scalar warfare could cause huge solar storms? To realize that human activity could actually affect the sun itself is truly mind boggling.

Bearden goes on to say:

> "Accordingly, use of huge scalar EM weapons is a double-edged sword. Unless carefully employed, use of the weapons could cause a terrible backlash to the user as well as the victim, and even accidentally cause the destruction of the earth itself. It is not accidental

that in 1960 Khrushchev stated that his new fantastic weapon could -- if unrestrainedly used -- destroy all life on earth.

"This appalling backlash potential is apparently what prompted Brezhnev in 1975 to make so strong an effort to get agreement to outlaw the development of "new weapons of mass destruction" more frightful than the mind of man had even dreamed of. Gromyko even introduced such a draft agreement into the proceedings of the United Nations. The first article of the draft agreement indicated that the nature of the weapons referred to would be negotiated. Sadly, the entire Western world did not even know what the Russians were talking about."

http://www.cheniere.org/books/ferdelance/s24.htm

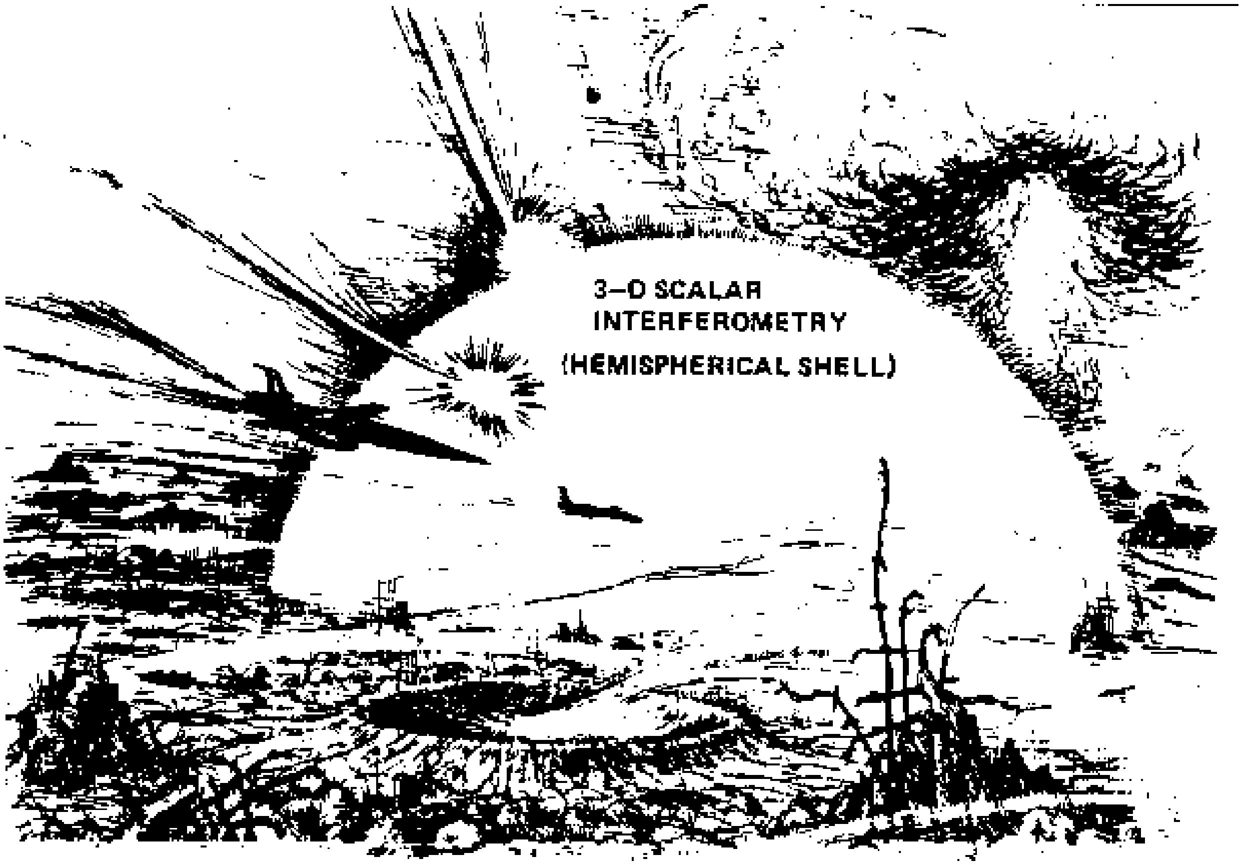

3b. Tesla domes provide near-perfect defense shield.

(Slide from Cheniere.org)

The Tesla howitzers can be used in a nearly impregnable defensive mode whereby they throw up a dome (**Tesla Dome**) or a sphere (**Tesla Globe**) of highly powerful electromagnetic energy, enough to "dud" or destroy missiles which try to penetrate them. Once again, this energy is not going through space from the howitzer, but being made to emerge from the local vacuum at the location of the shell. KGB tests of these domes have been witnessed by airline pilots around the world. Bearden gives many examples of the Tesla domes being sighted around the world in his briefing paper "Fer-de-Lance." (Russian dome test, another globe incident, yet another globe test). These giant electromagnetic domes can be hundreds of miles across, or narrowed down more to total impermeability.

> "Such a shell may be several hundred miles in diameter at the base. The enormous energy required to form such a defense shell is obtained by a "scalar power tap" into the molten core of the earth itself, as previously explained. In late April/early May of 1985, 27 such "power taps" were placed in the earth by the Soviets. If each tap is capable of powering four to six large scalar EM weapons, then the Soviet strategic scalar EM arsenal contains over 100 monstrous superweapons capable of generating exothermic explosions, endothermic explosions, engineering the weather, locating and destroying underwater submarines, detecting and destroying ballistic missiles shortly after launch, detecting and destroying long range strategic bombers as soon as they are airborne, etc."
>
> http://www.cheniere.org/books/ferdelance/s52.htm

By using nested domes one can protect the domed area even against nuclear radiation itself. Tesla globes can be used to hit airborne targets by simply placing a globe of any chosen size in the flight path of the incoming missile. It does double duty because the missile hits it going in, and then the rubble hits it again going out the other side.

While the U.S. persists in its useless boondoggle "missile defense system" by shooting a missile with a missile (missiles which would already have been "dudded" by the Tesla howitzers), between the domes and the globes the Russians (KGB) have in hand (operational) a nearly perfect missile defense system. Someone should ask the Secretary of Defense if the U.S. Tesla domes are in place. And over which cities? How powerful are our American Tesla domes?

Bearden cites a number of examples of these domes being tested around the world:

March 20, 1969 | March 24, 1977 | August 17, 1980 | June 17, 1966 | June 18, 1982 | June 22, 1976

In a slide from the Fer-de-Lance briefing it is shown how the "woodpecker grid" itself also acts as a sensor, detecting any missile launch anywhere, and how the howitzers can respond instantly by delivering a blast to exactly the right coordinates, right along the channels of that same grid which is feeding the location information about the missile launch. This certainly beats "trying to hit a bullet with a bullet." Especially since YOUR bullet would probably be instantly inoperable in a real scalar war situation.

3c. Rogue Groups in the government

Bearden fears that these scalar electromagnetic secrets may have fallen into the hands of what he called secret "rogue groups" within the labyrinthine depths of the black-ops special-access domain of the secret government. "In the extreme, such a deep black program can even become a "captured" program," he says, "which is totally in the hands of rogues and no longer reports to or is bound by the dictates of the parent government."

> "They have their own agendas. And being rogue groups, they may well bring in unethical, immoral tricks: assassination, bribery, entrapment, disinformation, plausible deniability, etc. A certain percentage of a highly secret rogue group will wind up using all these things and more. It's a human characteristic, the old primate dominance game. Only now disguised and hidden under deep classification. ...
>
> "In highly classified groups, these groups are greatly enabled to joust more widely, unethically, and immorally because it is so deeply hidden. So very deep classification evokes the growth and intensity of rogue groups. It's the old 'Power corrupts, and absolute power corrupts absolutely' routine. ... Due to loose formation of rogue groups inside such programs, they may have dual or triple purposes, may not operate under very much legitimate government control at all, and may operate specifically for the purposes of the rogue group or groups that have gained control."
>
> "The involvement of at least some rogue groups, some being "cowboys" who operate well outside all laws and ethics, could also result in such things as assassinations, clandestine testing on individuals without their consent, etc. In short, it could account for what seems to be actually occurring. "
>
> http://www.cheniere.org/explore%20articles/mind%20control3/p05.htm

3d. World War III has already begun

Because it is now possible to cripple the power grids and electronics of any nation, that nation could be reduced to economic ruin without ever firing an actual "shot." Without electricity Wall Street cannot operate. Without electricity you quickly need martial law. One no longer needs to wage a conventional war anymore at all. There are now lots of new ways to bring any nation to its knees.

> "We are at war, whether we like it or not. And we are going to have strategic strikes on an unparalleled scale for us. Pearl Harbor was nothing compared to what is coming down, once we consider the "augmentation" and such.
>
> "When that factor is considered, then it's a totally new ball game on replacing the power system. There isn't going to be much choice; the old one is going to be destroyed or so badly crippled that it will collapse the U.S. economy in a way we have not seen since 1929. Of course, in such a case hitting us, we will be under martial law, the works, everywhere. For one thing, it's the only way you can keep the cities from imploding from within, by the criminal element, looting, robbing, killing, etc. Simply wait and see; it's on the way."

> Although Bearden has for years decried the "scalar-gap," and chided the military for falling so far behind the Russian KGB in the field of scalar electromagnetics, recent statements indicate that things may at last have changed somewhat.
>
> "In the new war, the first phase of WW III has already been completed. Hence President Bush's recognition that this is a total war, and has to be taken to the enemy no matter where he may be hiding or in what sanctuary or in what foreign nation. This is an entirely different war than anything the U.S. has ever fought in its history. And before it is over, it is going to kill more Americans than have died in all the previous wars in our history. The news media and the public have not yet recognized that awful situation and predicament. Most are already thinking that, well, we won in Afghanistan so it's just about over. Instead, it has only just begun.
>
> "Anyway, that's a brief uptake on some of the weapon situation today. Some 10 nations or more now have LWIs, and five have the QPs. I'm still working on how many have the appalling negative EMP weapons, but would estimate 6 or 7 nations have them in one stage or the other, either deployed or in at least advanced development. And in my estimation, the Yakuza will have them within three to five years if they have to build them themselves, and quicker if they can buy them from the Russians, Chinese, or???"
>
> Bearden http://www.cheniere.org/correspondence/030202a.htm

When he was asked the question '**Does the government listen to Tom Bearden?**" Bearden said:

> "Let me speak carefully. I am very satisfied with how I've been listened to in the quarters where the rubber meets the road. The West is no longer defenseless, not by any means. Cannot amplify it further than that."
>
> http://www.cheniere.org/correspondence/030202a.htm

Bearden has briefed the government a number of times and the Cheniere website contains a great number of his graphic military briefing slides.

3e. Are the Russians making "UFOs?"

Scalar electromagnetics engineering opens the possibility of antigravity vehicles and "hyperspace travel." In other words we can now make our own UFO's! Of such scalar-powered antigravity vehicles, which have now become possible, Bearden has this to say:

> "We might expect to see such vehicles glowing. Their various surface features and mechanisms might appear to be glowing or revolving lights, etc.
>
> "They could exhibit incredible "aerodynamic performance," seemingly in the atmosphere. Actually they would not be moving "through" the atmosphere at all, but through a higher space outside each particle of atmosphere.

> "They could seem to materialize and dematerialize.
>
> "They could seem to plunge into the ocean or rise out of it.
>
> "They could even seem to operate under the ocean or inside the earth itself.
>
> "Such anomalous vehicle performances have been seen all over the world, particularly since a few years after WWII.
>
> "It appears that one or more nations of Earth are operating such vehicles now in great secrecy. Our own "government" may even be one of these.
>
> "If so, it isn't our true "government/government." Instead, it's the "control group/government." It's government at the operational level, but at higher level it belongs to certain control groups who have penetrated our government's vitals and taken over all such projects."
>
> Bearden http://www.cheniere.org/books/ferdelance/slide32.htm

In an excellent article on her Earthfiles website, Linda Moulton Howe reports on the utter bafflement of Norwegian scientists over mysterious lights appearing in the valley of Hessdalen, Norway.

She writes of the research there: "The results can be broken down into two groups: 95% are thermal plasmas and 5% are unidentified solid objects. The plasmas emit long wave radio frequencies and strangely, their temperatures do not vary with change in size or brightness." She quotes the scientists' research summary:

> "1) most of the luminous phenomenon is a thermal plasma;
>
> 2) the light-balls are not single objects but are constituted of many small components which are vibrating around a common barycenter;
>
> 3) the light-balls are able to eject smaller light-balls;
>
> 4) the light-balls change shape all the time;
>
> 5) the luminosity increase of the light balls is due to the increase of the radiating area. But the cause, and the physical mechanism with which radiation is emitted, is currently unknown."

This would almost certainly seem to be another example of the testing of the scalar howitzers. It is baffling because, as Bearden points out repeatedly, Western scientists have limited knowledge of the scalar electromagnetic principles by which the howitzers operate. The Hessdalen scientists were completely baffled as to where the energy of these plasma balls was coming from.

Ms. Howe interviews Massimo Teodorani, Ph.D., Astrophysicist, who released the report on the 2001 Hessdalen sightings. The scientist speaks of the baffling phenomenon observed.

> "I don't know how it is possible that Nature is spontaneously able to do that. Anyway, we deduce that the plasma is trapped inside a sort of magnetic cage and the magnetic cage closes around the plasma and keeps it fixed in some way, prevents it from expanding. But where does it come from? We don't know."

By what we have been considering here, we can recognize the signatures of scalar electromagnetic engineering. If it is a Tesla howitzer, then the energy for the plasma balls is coming from the vacuum of spacetime at the very location of the balls themselves, triggered by scalar interferometers aimed through the woodpecker grid.

These kind of balls can be used as marker beacons giving feedback for precision aiming of the howitzers. The energy of the marker beacon can be read back into the computers giving precise location information for pinpoint aiming. The target area can be very small, or widened out.

There is a little movie of one of the Hessdalen plasma balls here. It would seem to be a clear documentation of a scalar howitzer marker-beacon. How many other current "UFO" sightings are actually the witnessing of Tesla howitzer tests?

In fact there are a great many anomalous events of the past few decades which might very well be explained by the Russian testing of their longitudinal electromagnetic weapons. It would seem that the mysterious appearance of crop circles around the world could be accomplished by feeding a precise mathematical graphic pattern into the computerized aiming software and change the very molecular structure of the crops themselves along the lines of that pattern. The

stalks fall over from the localized effect of the longitudinal waves. A plasma ball tracing patterns? Are they slyly sending a message to see if we are "getting it" yet?

The "Cambridge Angel" - Made by Russian scalar plasma balls?

Also see: [Interview with Tom Bearden]

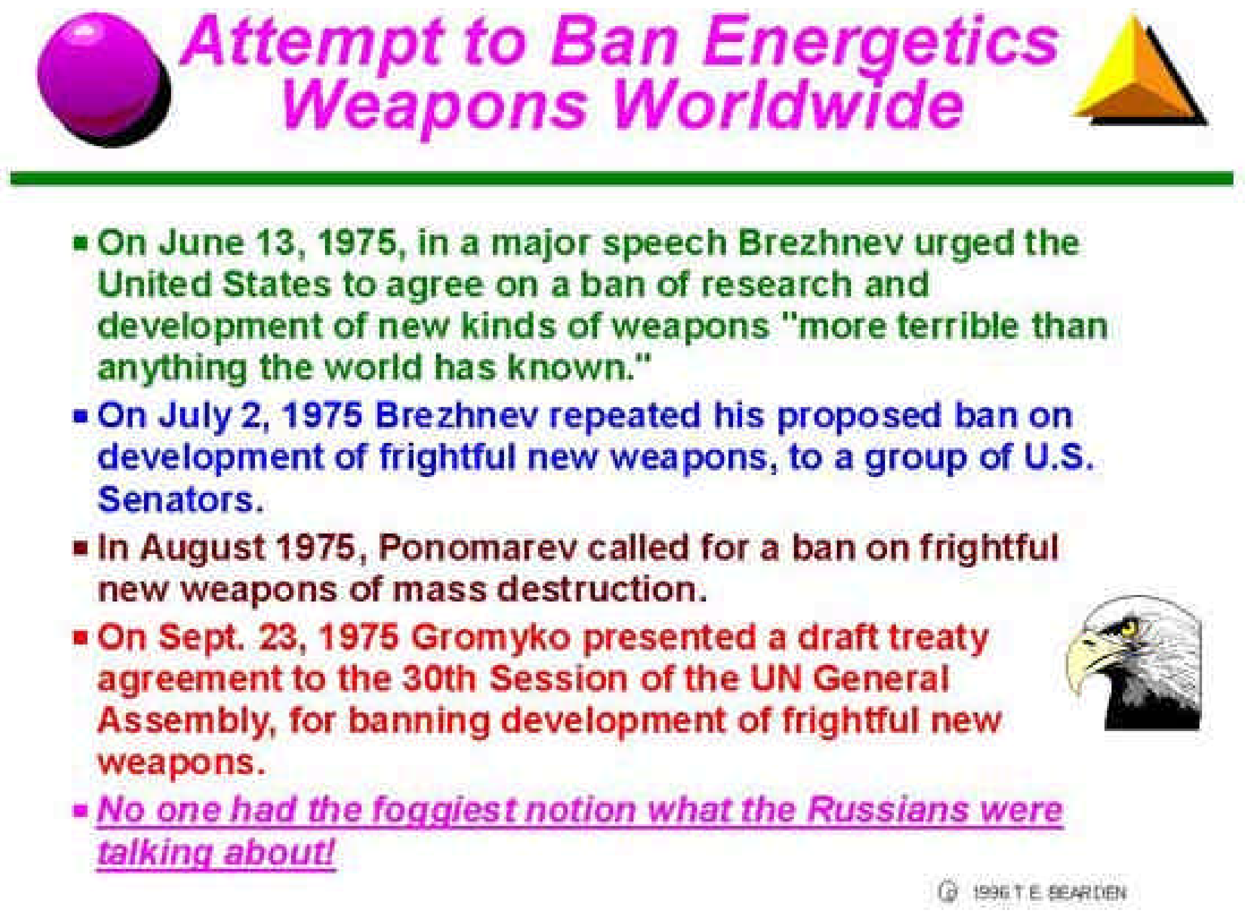

Attempt to Ban Energetics Weapons Worldwide

- On June 13, 1975, in a major speech Brezhnev urged the United States to agree on a ban of research and development of new kinds of weapons "more terrible than anything the world has known."
- On July 2, 1975 Brezhnev repeated his proposed ban on development of frightful new weapons, to a group of U.S. Senators.
- In August 1975, Ponomarev called for a ban on frightful new weapons of mass destruction.
- On Sept. 23, 1975 Gromyko presented a draft treaty agreement to the 30th Session of the UN General Assembly, for banning development of frightful new weapons.
- *No one had the foggiest notion what the Russians were talking about!*

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(Slide from Cheniere.org)

4. Healing powers of longitudinal waves

Healing via longitudinal waves, time reversal of cells (de-differentiation), Priore's machine, Bearden's proposed "blanket" version, using the electric power grid for healing waves or for broadcasting disease patterns. Scalar Biowar.

The good news!

> "Any sort of disease whatsoever - physical or mental - will be rapidly curable, simply and cheaply. It will be possible to reverse aging and rejuvenate the person. It will be possible to regrow limbs and straighten misshapen spines - and directly remove the causes of mental diseases and cure them as well. Lifespan will be staggeringly increased, without 'old age's debilitation.' AIDS, cancer, leukemia, and genetic diseases will be completely conquered. The potential for a true golden era is upon us, for all humanity."
>
> Bearden- http://twm.co.nz/beard_interview.htm

Proof of the healing powers of longitudinal waves from the vacuum is seen in the work of Antoine Priore who produced longitudinal scalar waves using a gigantic glass tube filled with plasma. He himself did not understand why it worked or how it cured cancer in animals.

> "The Priore team cured terminal tumors, trypanosomias, and other dread diseases in laboratory animals in France, in the 1960s and 1970s, under rigorous scientific protocols by eminent scientists. The Priore project was funded by the French Government to the tune of several millions of dollars (equivalent).
> http://www.explorepub.com/articles/energetics.html
>
> ". . . Prioré's machines concretely demonstrated a nearly 100% cure of all kinds of terminal cancers and leukemias, in thousands of rigorous laboratory tests with animals. These results were shown to medical scientists as early as 1960." http://www.cheniere.org/priore/index.html

Bearden has stated that the longitudinal EM waves can have a healing effect because they always come in pairs called "phase conjugate pairs" and one of the pair is time-reversed. This enables engineering of the waves to "pump" the cells of the body (with waves from the time domain) and actually time-reverse the cells back to a previous healthy condition. The scalar cure of cancer does not involve killing the cancer cells but rather pumping them with time energy into a previous condition. I know, this seems miraculous, and is it not?

Priore and his giant plasma tube

This healing power in the longitudinal waves of the time domain is a mind-boggling thing to face. It took me months to get through it, and to suffer the fact that the cure for cancer and AIDS was right there, in this new scalar electromagnetics technology, and that it has been kept back from the people for so many decades now.

Bearden has a great deal to say about the work of Priore, who himself did not understand why his machine worked. Priore did not know about the longitudinal scalar waves of the time domain. In fact, Tom Bearden has supplied, at last, the missing explanation as to how that big giant two-story glass tube consistently cured cancer in animals.

"**The medical implications are enormous**. By just reversing the damaged cells back to a previous physical state, this gives a physics mechanism for controlled cellular dedifferentiation, in biology terms. Physicians will time-reverse diseased, damaged or aged cells back to an earlier healthy condition, including all the cellular genetics. Normal cells are just reversed to a slightly younger condition."

> "We believe this mechanism explains the revolutionary but baffling electromagnetic cures achieved by a team of outstanding French scientists in the 1960s and early 70s, working with inventor Antoine Prioré. In lab animals, cures were achieved for terminal tumors, infectious diseases such as trypanosomiasis, and atheriosclerosis. In addition, deliberately suppressed immune systems were dramatically restored.
>
> "We hypothesize that this is the long-sought mechanism of how the living body heals itself. In short, the body's cellular control system induces cellular reversal by weak time-domain pumping of the damaged cells and the affected area. The cellular regeneration system performs all healing of cellular damage in the body; the immune system heals nothing, not even its own damaged cells) .
>
> "For the first time medical science can develop as a science of healing rather than a science of intervention. And it will develop as a science of unlimited healing, since no pathogen can resist action by curved spacetime engines." Bearden
>
> http://www.cheniere.org/techpapers/Vision%202000%20paper.doc

See Priore's machine   See Slides of how it works.

Bearden has extended the Priore work, with the previously missing knowledge now in place, and designed a revised system (for irradiating the body with longitudinal waves) which gets rid of Priore's giant glass plasma tube and uses instead an antenna unit which surrounds the body. He has also provided the missing explanation of how it works. There is an article from "Explore" magazine, Part I and Part II.

In fact, Bearden has presented to the U.S. government a plan to use a portable version of a Scalar Healing Blanket where wire channels in the blanket act as a scalar antenna, which can both send and receive scalar electromagnetic waves. A two minute treatment of the waves is sufficient to restore the body to its earlier healthy condition. Thus even thousands could be treated easily and quickly in a biowar mass attack situation.

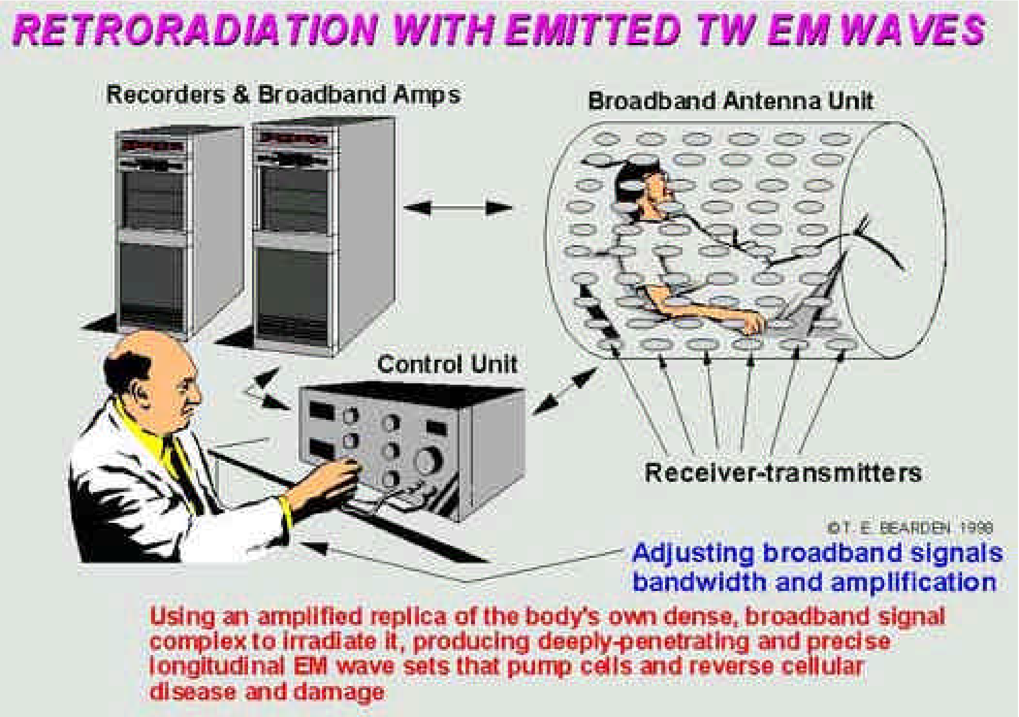
RETRORADIATION WITH EMITTED TW EM WAVES
Recorders & Broadband Amps
Broadband Antenna Unit
Control Unit
Receiver-transmitters
© T. E. BEARDEN 1998
Adjusting broadband signals bandwidth and amplification
Using an amplified replica of the body's own dense, broadband signal complex to irradiate it, producing deeply-penetrating and precise longitudinal EM wave sets that pump cells and reverse cellular disease and damage

"To defend against things like anthrax attacks on our civilian population centers, we also have recommended to the U.S. Government the crash development of small, portable treatment machines—using similar "antiengine-forming" and cellular reversing "porthole technology". [See Figure 13 on previous page]. Such portable machines could be developed cheaply and quickly, and present government facilities could be used to massively attack the correlate database production problem. "The portable treatment units could be cranked out by the hundreds of thousands and flooded down through emergency response agencies such as the police forces, the National Guard, emergency hospitals,

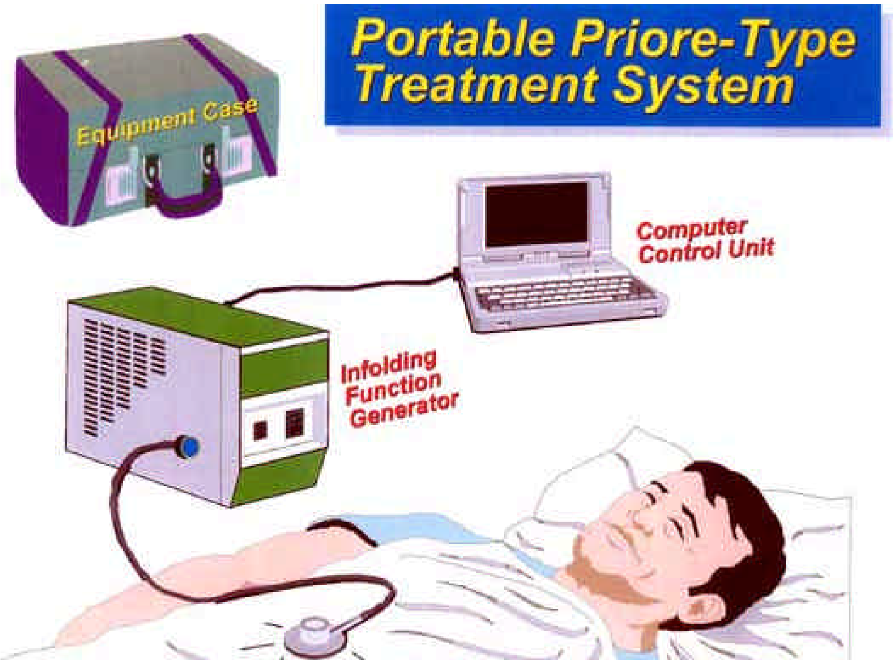
Portable Priore-Type Treatment System
Equipment Case
Computer Control Unit
Infolding Function Generator

> emergency response teams, etc."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p04.htm

The Scalar Healing Blanket would fit into large suitcase. It has three basic parts, the longitudinal wave generator, a laptop computer, and the antenna-blanket. The plan was a stroke of Bearden's genius, but unfortunately it fell on befuddled government ears. "Unfortunately, so far the DOD [Dept. of Defense] doesn't even understand what the heck we're talking about!"

Article "**Healing with Energy**": http://www.explorepub.com/articles/energetics.html

> "We tried very hard in 1998 to call attention to the extreme national need for the most urgent possible development of a portable computer-controlled treatment device based on the experimentally proven Prioré methodology, but extended to a much simpler and far more rapid method of treatment.
>
> "Quick development of this technology could lead to a suitcase size device, capable of treating a patient in less than one minute, and stopping the symptoms and disease progress cold, then reversing it. Three "less than a minute" treatments one week apart would be required for complete cure. As an added advantage, partial reversal of aging in older patients would also be accomplished as a bonus, in addition to time-reversing the damaged and diseased cells...
>
> "The method proposed to the DoD in 1998 used normal EM in a peculiar way to force the body itself to make its own time-polarized EM waves, and pump every part of its cells -- including the genetics -- in the time domain.
>
> "Quite simply, we are going to be struck this way (QP spreading the immune systems of the populace plus professional smallpox, anthrax, etc. BW attacks on our population centers) and by other means we've spoken of in other papers and briefings."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

The Dark Side of the Force:
Creating and broadcasting disease

Speaking of the scalar wave induction of disease by longitudinal wave patterns Bearden refers to work by French scientist Kervran Russian scientist Kaznacheyev, who proved that any disease could be transmitted electromagnetically.

> "It works this way: the Kaznacheyev experiments (and others) demonstrated that any cellular disease or disorder can be initiated into cells at a distance, by electromagnetic means (albeit unusual EM in nature). The decades of microwave radiation of the U.S. Embassy in Moscow, was an ongoing set of "stimuli" to ping the U.S. system and, by its response, ascertain how far along (or if it was "along") in its knowledge of such weapons. The radiation was responsible for many health changes in personnel and for the eventual deaths of three U.S. Ambassadors."

> Bearden http://www.cheniere.org/correspondence/021702a.htm

In a letter he writes,

> "Yes, the Kaznacheyev experiments were quite real; 15,000 or so in military research institutes in Siberia. As with so many other novel areas investigated and developed by the Soviets, most U.S. investigators just assumed normal EM, which is not what the Kaznacheyev experiments involved, and not what was carrying disease induction patterns from one cell culture to another in rigorous lab tests."

How to "Broadcast" Diseases

Longitudinal EM Biowars

Bearden explains how the new quantum potential weapons can be used to induce disease-at-a-distance in a population, or to "spread" the immune system so thin that a conventional bio-attack would be greatly potentiated. By "broadcasting" virtual disease patterns over a population, the immune system is so overloaded by the presence of the "shadow" diseases that its effectiveness is thinned out.

> "In short, alter the internal wavestructure, and one creates a curved spacetime 'engine' that acts on mass in any fashion one chooses to design -- including initiate diseases . . . Now visualize one of these 'vacuum engines' or 'spacetime curvature engines' that acts on mass to generate the exact effects produced by anthrax. (Or any other disease one wishes) . . . Call the virtual state of a disease engine the disease pattern in the "shadow" state, just prior to becoming observable. . . .
>
> "And the master cellular control system responds to "coming events that cast their shadows before". In short, it responds to the upper level of the "shadow state" of a disease, still in the virtual state! (Hey, virtual particles are real, virtual photons are real, virtual ST curvatures are real --- just very fleeting, only for another to immediately arise). The exchange of virtual particles is known to generate all forces in physics anyway! . . .
>
> "So the cellular control system responds to "shadow state" disease patterns. Enter a QP weapon application. Place a quantum potential weapon "area" on the United States, so that the entire populace is in it. The slowly introduce and bring up in the shadow state, the necrotizing fasciitis disease engine. At some point, the cellular control systems will react, and order the immune system into action. In other words, immune system resources will be committed against this "immediately coming" enemy. Bring it on up a little, but still just in the shadow state. Voila! Humans form a bell-shaped distribution curve. And even if the structure of the QP fluctuates a little, fluctuating a bit stronger and a bit weaker, etc. A few of those targeted bodies will now actually develop necrotizing fasciitis. So far, just like the U.S. Embassy targeting, except a different "carrier".
>
> "But now there is an exact signature that this is what is doing it, and not normal vector carriers of disease and contact or exposure infection. The few cases of necrotizing fasciitis that break out will be most puzzling. They will be randomly scattered across the

> entire nation, and so few that the vector carrier and contact or exposure explanation completely fails."
>
> "And that one happened, right here in the U.S., not so long ago. Check it out.
>
> "So carefully adjust the patterns for, say, 12 major terrible diseases, to that "adjusted and desired shadow state level". Now add all 12 patterns into the internal structure of the quantum potential. Now it has 12 shadow state disease engines in it.
>
> "Place that one on a populace. The cellular control systems order the immune systems into action, and they now have to commit their finite resources to 12 different areas. This greatly thins the response an immune system can make to any one of those 12 disease patterns! In short, it "spreads" the capabilities of the immune system, which can be galvanized to great effort, but only can perform a small bit against each area.
>
> "Suppose one of those "galvanized" areas in the targeted populace's immune systems is anthrax. And suppose the bad guys now hit one or more of those cities with a professional anthrax attack. A former OTA study showed that a professional anthrax aerial spray attack against Washington D.C., dispensing 100 kilograms of anthrax spores in the spray, will account for 1 to 3 million casualties. And that's in an "unthinned" set of immune systems. In the "thinned" set, one can at least double or triple, and even up to five times, that estimate. So conservatively, now there would be from 2 to 6 million casualties. And even mild anthrax spray attacks in other "thinned" cities would also be amplified.
>
> "That one is being set up, or already set up, right now. There are other such "augmentation" setups also under way.
>
> "So the weapons alluded to by the SecDef in 1997 are already being employed. WW III has already begun, and our populace (and our scientific community) is blissfully unaware of it."
>
> http://www.cheniere.org/correspondence/021702a.htm

Most of us can remember the strange outbreaks of the so-called "flesh eating disease." It seemed to break out here and there randomly with no known cause. Bearden believes this was a test of the newer quantum potential weapons which go even beyond the capabilities of the Tesla howitzers.

> "The Kaznacheyev "disease induction by novel electrodynamics" work is also the basis for the spacetime curvature engines (not EM signals!) carried by quantum potential EM biological weapons for distant induction of diseases etc. into the population of an entire nation or area, such as the U.S.
>
> "This quantum potential disease induction weapon -- capable of attacking an entire population of a nation or area -- has been tested several times in the U.S. at very low levels, in the shadow state only (we explain shortly) and it has a most peculiar signature. E.g., one test used necrotizing fasciitis (flesh-rotting disease) engines.

> "The disease 'engine' was deliberately kept down in the 'shadow state' (virtual state, just below the observable state) so that only a tiny bit of the populace with depressed thresholds would "breach the observable threshold' due to the population forming a bell-shaped curve as to the threshold level. The major signature of the test was that the cases of the disease broke out totally statistically and randomly, spread all over, without any 'disease vector' in between.
>
> "In short, it was not spread in any manner required by normal deterministic disease vectoring, but was a totally random set of occurrences. Several other diseases were also tested this way in the American populace, with precisely the same signature."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

"Apparently one planned use of such an augmented clandestine BW weapon will be smallpox, e.g. As you know, the Russians did develop smallpox for biological warfare, and even developed a new strain against which previous vaccination is ineffective.

> "The vast numbers of expected casualties, coupled with immune system spreading, are absolutely irresistible to the Russian mind. You can count on it that they have seen that the smallpox is already on site here, in the U.S. and in the hands of professional terrorist teams. Of course, the Russians/KGB will protest they have nothing to do with that! Yet likely the KGB will have flatly arranged it or at least assisted it. The capability for mass destruction of the nation is so lucrative and easy to achieve in advance, that they would never be able to resist doing it."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

Bearden believes the Gulf War Syndrome involved the use of scalar technology to induce a disease state, as he stated in a 1997 interview:

> "I'll say this flatly, and I won't answer any further questions about it; the Gulf War Syndrome was induced... It was induced with this stuff. All the rest... was contributing factors that everybody's talking about... There are some deeper signatures, if you look into it very deeply, that show you exactly how it was done and the fact that it was induced. It was a test. It was a test of a very special kind of weapon I have not talked about yet. Anyway you can use it to create diseases."
>
> Bearden http://twm.co.nz/beard_weapon.htm

Besides using the woodpecker grid to target a population, the entire electrical grids of nations can be used as "channels" for disease patterns to be broadcast to all people near that grid. Your own house wiring can become an antenna, broadcasting these "shadow" patterns of disease, weakening your immune system.

And here one faces the frustrating fact that the same power grids could be set to channel patterns which would keep the entire population healthy, rejuvenated, continuously bathing in the time-reversing old-age-defying energy of the spacetime vacuum. We have no idea yet of how long the human life span could be increased with this new technology. People might be able to live two centuries given full humane development of this technology.

5. Psychoenergetics

Mental entrainment, inducing hypnogogic trance, mind control, broadcasting thoughts and feelings, the Ant World, education via EM [LW] mental download, the "Feelies," revolution in spirituality, "enlightenment machine?" Scalar churches?

Psychoenergetics is simply using the scalar interferometers to manipulate and engineer the human psyche. To me it is the most mind-boggling and frightening aspect of longitudinal wave engineering.

The mind is electromagnetic in nature, and itself of the time-domain. It is not observable in 3-space. There is no thing you can point to that is the mind. As Bearden says**, "The mind is time-like**."

The longitudinal scalar EM waves are also of the time-domain. By overlaying certain infolded patterns (oscillations in time) on the longitudinal waves, a thought or feeling may be made to arise in a person or persons who are in the **interference zone** (where the wave beams cross).

The person will not notice anything, feeling that this thought or idea is his or her own idea. The longitudinal wave pattern might be a wave of panic or fear that spontaneously sweeps over you, perhaps inexplicably. It could even be in the form of a sudden intense patriotism. It could be explicit words and phrases, which everyone would think they had thought of by themselves. Or it could be rage and hatred, angry and violent. On the other hand It could also be a continuous sense of docility and placidity. This is the brave new world of psychoenergetics and the coming "Mind Wars."

Scalar Psychoenergetics in its most primitive form simply "entrains" all minds in the target area into a deep hypnogogic trance. In this state of mind people would be suddenly extremely suggestible, and would likely believe anything they are told, and would obey any orders given. Talk about winning the hearts and minds of the American People!

Tom Bearden makes me think of **Paul Revere**, who heroically conveyed important warnings for the sake of the new nation. But the words of the famous phrase have now strangely and curiously mutated into the once-inconceivable: "**One if by land, Two if by mind**."

Indeed one strategy in a Mind War would be to simply take over the minds of the "leaders" of the enemy nation. The targeted leader would not be aware that anything was amiss, although he might begin to make unexpected changes in policy.

And are, in fact, any of our "leaders" already having secret thoughts that are not their own? Who knows? Frighteningly, we can no longer be sure. The new sciences of scalar electromagnetics and psychoenergetics are even now plunging humanity into a sudden science-fiction-like world beyond anything in humanity's previous imaginings.

> "The Russians reached the point in the mid 1990s that they could take over control of a person's mind, with modified longitudinal EM waves including some time-polarized EM waves, and with a team of specialists (estimate 25-30 per transmitter, and one transmitter and team per controlled person)." Bearden http://www.cheniere.org/misc/time.htm

In a slide Bearden illustrates how a Scalar War would involve a psychoenergetics attack on the operators of the enemy scalar installation, entraining their minds into hypnogogic trance and getting them to shut down their systems.

And ultimately psychoenergetic warfare goes to the very heart of human identity itself. For if my thoughts might no longer be "mine," then who and what am I? Can my very sense of being "me" be hijacked by some nefarious psychoenergetic scheme? Will the "secret government" eventually dictate directly into your mind how you feel about yourself? Or what you think you are? Or what you should do?

How Does Longitudinal EM Mind Control Work?

The physics of scalar psychoenergetics as expounded by Col. Bearden seems even more arcane and over-my-head than that of extracting energy from the vacuum. I can't understand it, but I look through it anyway. Each time another tiny understanding might occur, or a term might fall into place. I know the mathematics is forever beyond me.

One paper to begin with is “Mind Control and EM Wave Polarization Transductions” This is such serious stuff that Bearden includes a strong warning about misuse of this knowledge. Psychoenergetics weapons can mentally maim and physically kill.

Warning!

(From "Mind Control and EM Wave Polarization Transductions")

> "This article refers to experimental research techniques which can be detrimental or lethal in the hands of any but highly skilled, qualified experimental scientists proceeding under proper laboratory safety procedures. The purpose of this article is strictly for information to properly qualified and authorized scientists in certified laboratories. We do not propose or condone any use of these procedures for nonapproved practice of medicine without a license. Neither the publisher nor the author are responsible for accidents or outcomes in the use of these experimental procedures and techniques. Any researcher who performs these procedures and experiments is acting on his or her own volition, and is solely responsible for insuring safety, qualifications, and legality of the acts and their results. We neither suggest nor condone unauthorized experimentation on human subjects. Such is a criminal violation of the constitutional rights of the subject under Federal and State laws, and is both illegal and immoral."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control1/p01.htm

After the serious warning comes the description of the paper. This is heady stuff for the layman.

> "Calling full attention to the special note above, in this paper we present a high-level overview of the novel electromagnetic nature of mind operations, mind and body coupling, and intent - the induction of physical 3-space EM energy changes into the brain and nervous system, and into every cell of the body, from the mind's time-like coherent operations. We summarize the time-polarized electrodynamics used to engineer and affect mind operations and the mind-body coupling loop. Transaction mechanisms whereby differing EM wave polarization's can be transformed one-into-the-other are presented."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control1/p01.htm

I will leave it to the technically astute to try to understand the mechanisms of operation which are described in scientific language. But there are tidbits for the layman. Here he speaks of the difficulty Western scientists have in opening up to the "immaterial" (longitudinal wave) nature of the human mind.

Western Science Remains Largely Materialistic

> "Ironically, most Western scientists are materialists and consider "mind" as a mystical and nonscientific concept. They tend to consider mind operations and functions either to be simply "meat computer" operations and functions, or at best to be very weak ordinary transverse-wave EM operations and functions in the brain and nervous system. This serious self-limitation exists because in the body we measure only weak TW [transverse wave] EM operations and functions correlated to biological behavior and brain operations. We simply do not know how to measure "mind operations" directly.
>
> "With no mind measurements possible and no instruments, it is understandable that Western science considers only the physical side of the mind-matter interface.
>
> "Presently our scientists do not measure the longitudinally-polarized EM wave operations and functions in the body and around it in nature. Few of them are aware that a maelstrom of such LW [longitudinal wave] functions exist in the body and in all of nature in general."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control1/p05.htm

Western methods of influencing the mind with EM waves have only used transverse waves, not the longitudinal waves of the vacuum. If only transverse waves are used one pretty well has to hit the target mind with a sledgehammer of waves.

Western Science knows only transverse EM waves

Brute Forcing Time Functions versus Fine Control Methods

> "Ironically, Western mind control researchers using transverse EM waves for mind control research, are using a brute force method of evoking and using vacuum engines

> (spacetime curvature engines) and a special form of general relativity, although they do not appear to realize it.
>
> "While KGB scientists also use TW EM "brute force" TW waves when necessary, they do "imprint" or "activate" those waves with the desired internal LW and time-polarized EM wave and photon structures required to directly perform the mind engineering desired... Bearden
>
> "These "fitted brute-force models" certainly can be very powerful, and certainly can produce the exact results shown in the experimental verifications of the fittings. However, they do not of themselves allow sophisticated design for example of the necessary time-polarized wave assemblies for engineering the entire human collective unconscious simultaneously, or for engineering the entire collective unconscious of all species on Earth (i.e., Gail's collective unconscious), or even for precisely engineering the memory and knowledge base of an individual.
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control1/p09.htm

The seemingly magical operations of psychoenergetics, sometimes called "psychotronics," cannot be achieved with ordinary transverse EM wave energy. But they are possible with longitudinal scalar waves because the mind itself is scalar in nature.

> "We note that all mind operations are time-like, i.e., they are comprised as scalar EM photon functions and scalar EM wave functions. Thus the mind is a very special kind of electromagnetic system, existing in the time domain..."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control1/p08.htm

The engineering of the mind can only be accomplished with the waves of time.

The course of psychoenergetics development necessitates the building of a vast database of settings and patterns which bring about given mental and/or emotional states. A kind of "gnome" of the psyche. Bearden describes the process of the decoding of this "gnome."

> "Now the scientists would perform many phenomenology experiments, making one little change at a time and profusely recording the data. Each time, they would establish the physical change(s) that occur in the body and/or the mental and emotional changes that occur in the mind for each spectral reinsertion back through the "ship's portholes". They would simply but painstakingly (over some years) build up an extensive database of those individual correlates.
>
> "In these experiments, the experimenters will eventually be able to provoke any body or mind change they wish. Strong emotion. Intense pain. Intense pleasure. Painful thoughts. Images. Memories. Perceptions. Dreams. Visions. Memory losses. Memory changes. Personality changes. Etc. The "delta" in the emission spectrum (the changes from zero reference spectrum) represent the precise totality of all mental, physical, organic, chemical, etc. changes and interactions."

> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p01.htm
>
> "A second stage in the research would be to test the correlates and porthole insertions upon a statistically significant cross section of ordinary people, and/or specialized populations (such as toughened soldiers). The program would evolve a highly complex, very effective, ever-improving science and technology of mind and behavior control and engineering mechanisms, complete with finished database and developed applications equipment."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p02.htm

Summing up his paper Bearden speculates on what the actual situation the science of psychoenergetics probably is. The intense secrecy with which this knowledge has been kept from the public has led to the current farce of the "government" pretending it all does not exist, and this secrecy may have now put us at great risk.

> "The implication is that in the West one or more highly classified, sustained, heavily funded developments in advanced mind control programs, probably exists and probably has existed for some time. Due to loose formation of rogue groups inside such programs, they may have dual or triple purposes, may not operate under very much legitimate government control at all, and may operate specifically for the purposes of the rogue group or groups that have gained control.
>
> "In a nutshell, that's what may be going on in the clandestine mind control projects in several Western governments. The involvement of at least some rogue groups, some being "cowboys" who operate well outside all laws and ethics, could also result in such things as assassinations, clandestine testing on individuals without their consent, etc. In short, it could account for what seems to be actually occurring. As also is "usual" in such a mess, one or more of the rogue groups eventually may become very powerful because their secret weapons are very powerful. They may become confident, thinking they have the "best in the world." They may actually believe they are ahead of the Russians..."
>
> "Remember that, in every large and powerful human organization, the basis for rogue groups is power and secrecy. They are always seeking to increase their power, control, influence, prestige, etc. Nothing else. Patriotism and mission are—to rogue groups—often just idle words. They have their own agendas. And being rogue groups, they may well bring in unethical, immoral tricks: assassination, bribery, entrapment, disinformation, plausible deniability, etc. A certain percentage of a highly secret rogue group will wind up using all these things and more. It's a human characteristic, the old primate dominance game. Only now disguised and hidden under deep classification."
>
> "The Russians, with their additional knowledge of the actual mechanisms in the transforms, will be much more advanced than the West, because their fundamental psychoenergetics science is far more advanced, so long as we continue to use the old U(l) electrodynamics. Further, the Russians have decades of use of longitudinal interferometry beams to reach right through the earth and ocean and produce stringent EM effects at a distance. So they will also be able to do the same things here in "mind control" with LW [longitudinal wave] interferometers, through intervening mass."

> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p05.htm

Bearden cites two examples where he believes the Russian KGB tested the psychoenergetics capabilities of their scalar interferometers. One was the case of Captain Button in his A-10 "Warthog" aircraft on April 2, 1997.

> "Over Arizona, Captain Button was thrown into a hypnogogic state, and his perceptions instantly altered and controlled. In his instant "dream-waking" state, everything seemed perfectly normal. His sense of direction was altered a bit more than 90 degrees, so he simply corrected and turned and "flew toward the range", actually flying off course by more than 90 degrees and ignoring radio contacts. He flew right on out of Arizona."
>
> "At one point he circled, probably thinking he was over the range, and he probably dropped his ordnance there. Then he "flew on back toward home," as he thought in his waking dream state, until his fuel ran out and he crashed and died in the explosion—dream-thinking until he died that everything was normal. All the while, his sense of the passage of time was altered. To him, in his dream-thinking, dream-acting state, everything was normal and nothing untoward had happened. So the distant KGB transmitters and associated psychoenergetics team controlled him for over an hour. "Indeed, that was the exact purpose of the test: demonstrate control (at a great distance) of a skilled person performing highly skilled tasks."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p06.htm

The paper "Mind Control and EM Wave Polarization Transductions" ends with the most chilling and frightening possibility of all: the psychoenergetic engineering of the human species as a whole.

The Ant World

The Final Race for Direct Mind Control of the Entire Human Species

> "The KGB psychoenergetics weapons scientists—because of their direct measurements and detections (and use) of t-polarized waves and LWs [longitudinal waves] for decades—also understand that Jung's collective unconscious mind (of the entire human species) also has its own time-like operations and correlates, which one measures also when using t-polarization measurements and sorting it all out. The collective unconscious mind operations are buried several levels deeper inside the recursive Whittaker structuring inside the EM fields, waves, and potentials. "The KGB scientists also know that something very like Gaia — a collective unconscious mind for all species on earth — also exists, and they are striving to be able to sort out and measure that one as well. The Gaia operations are buried even deeper in the recursive structuring inside the EM fields, waves, and potentials.""Actually, from day one, the Russian mind control scientists have had their eventual goal set upon this "deeper area of mind and possible mind control" of the entire human species.
>
> "I am convinced that the KGB psychoenergetics scientists understand this deeper area. If they can learn to directly engineer the collective human species unconscious, they can

> then convert the human species easily into a sort of "ant" society, modeled along ideal Communism lines, except of course with an excluded "hierarchy at the top" running everything. The "ant society" — communist style — is still a variation of feudalism (all systems tend to feudalism or some form thereof). "The KGB psychoenergetics weapon scientists are seriously pressing on toward that very goal. In my opinion they are not very far from it right now...
>
> "Some versions of Russian mind control devices were used on Russian soldiers in the Afghan War to condition them for performance of merciless acts." 13
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p07.htm

More about "The Ant World"

Whether it is the Russians planning an "ant world" society or rogue U.S. black-ops groups withholding a great boon from human race, the secrecy on all sides around has allowed largely criminal elements to take over this technology while leaving the civilized elements in the dark. Openness and the spreading of this knowledge among good and decent people is essential, and for that we will have to overcome our frightened denial.

> "Meanwhile, rogue groups amongst Western clandestine mind control researchers will probably arise if they have not already done so. They will likely seek to increase their personal control and further isolate the programs from orthodox government review and from government and legislative control. They may even divert the research into highly illegal and unethical means, because it furthers their own rogue agendas. That is how clandestine U.S. government research can sometimes go sour, unless great care is exercised by the oversight committees in the House and the Senate.
>
> "Sometimes when rogue groups do gain control and total secrecy of a given new technological area, then what appears to be "U.S. government operations" do start to encompass a criminal and unethical operations, hidden usually beneath the deep veil of high classification. Also, if it's "scientific," no one is ever brought to justice, even if the "evil science actions" are uncovered and publicly revealed."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p08.htm

Like the huge energy of the Tesla howitzers, the ability to engineer the mind with longitudinal waveforms is a seeming "magical" thing which can be used for good or ill. Bearden envisions that further developments will allow something like the "downloading" of knowledge via scalar interferometry. Everyone could be highly educated, and quickly and easily.

In the conclusion of the paper "Mind Control and EM Wave Polarization Transductions" Bearden makes a plea to the nations of the world regarding the use of psychoenergetic engineering.

> "Let us hope this great new area, already off to a bad start, can be bridled and steered in the direction helping and healing people, rather than killing or abusing them. The excesses in its bad use are a potent threat to all nations on earth.

"Yet it can revolutionize medical science, education, communication, and psychology. We foresee the day -- perhaps 30 years hence -- when education will be accomplished by directly loading the software into the mind. Then in three weeks one will "load" a doctorate, say, in physics. In three more weeks on will also load a doctorate in chemistry. Another three weeks, in electrical engineering. Another three weeks, an MD And so on. When that happens then truly everyone on earth can be educated. Freedom from ignorance may well be another great freedom that is legally recognized. There will be no impoverished large groups lacking the education to find decent, productive jobs.

"We urge all nations to use the principles involved: not for human abuse, but for healing, educating, uplifting, and life-expanding of every person on earth. If we do, we shall all have a far brighter future. Then we shall check what has started out to be the Sword of Damocles and turn it into the golden Millennium."

Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p08.htm

(Perhaps after so many frightening topics a slight break is in order here to consider the lighter side of psychoenergetics. For example, what will be the ultimate impact on the entertainment industry?)

The Feelies at Last!

Psychoenergetics will be able to bring about at last, for better or for worse, Aldous Huxley's fanciful idea in his novel "Brave New World," an entertainment format which he called "The Feelies." Those were something you went to, like going to the movies, but you would experience all the actual feelings themselves, as if the depicted events were actually happening to you. Although our "leaders" seem too dim to grasp what is going on in the world of scalar electromagnetics, it should not take some young Hollywood genius too long to understand that The Feelies are now possible, and that the immense megabucks of potential profit more than justify heavy investment in bringing it to market.

One can imagine that first "Feelie" theater, "The Huxley" perhaps, a large comfortable area surrounded by nine giant screens (not just one screen!), which become 3D if you put on your headset. And The Huxley is fitted with the finest sound, and oh, by the way, a modest sized scalar interferometer with computer. And there are one or more new tracks now recorded on the film next to the sound track. These are the digital patterns of thoughts, feelings, and ideas to be fed into the theater's interferometer. And these thoughts and feelings and ideas will be felt by the audience as if they were their own thoughts and ideas. It is an entirely new art form. Psychevision.

As important (and no doubt famous) as the actors would be the "feelers," those from whose minds the feelings were lifted in the original programming of the Feelie tracks. Because, for example, Brad Pitt might be a good and handsome actor, but can he really feel it? Like the dubbing of foreign language films, it might be necessary to dub the "emotional track" using a deeper and more profound person's feelings, thoughts and ideas.

It might even be engineered so that if you sat on one side of the theater you would feel like the hero, and on the other side you would feel exactly like the bad guy! What would that lead to?

We have all cried at a movie some time, most people have, though they might not want to admit it. But this would be deep sobbing and a flood of tears, if the director so desired it. You would feel it at your core. Or, take a big chase scene, you would be terrified. They are breathing down your neck! You would be gripped by panic.

For that matter, the whole genre of Horror-Feelie would be too much for many people to take. Do I really want to feel that an actual vampire is tearing at my throat with his fangs?

A Religious Feelie would make you feel the exaltation of a saint at his prayers, or give you the definite feeling that you are Christ suffering on the cross. All the pain could be there too. The stickiness of the blood. The very feeling itself: "Why hast thou forsaken me?" Who among us could come up that despair for scanning? Had this been developed a bit earlier we might watch a documentary of, say, Mother Theresa, containing her own actual deep sense of compassion, which we would feel arising in us as our own.

Then again, a Psychedelic Feelie could induce an LSD-like state and simply blow the audience's minds.

Even in its simplest most primitive mode, the hypnogogic trance induction with its increased suggestibility, would completely alter the experience of even ordinary current movie going.

6. As it Stands - 2002

"Anyway, it's presently a "Mexican stand-off" with the various parties maneuvering with check and countercheck. That is the real "balance of terror" that is held by such a fragile balance."

"You can see the implications if such weapons fall into the hands of the radical terrorists. Ordinary positive energy EMP shooters can be made fairly readily and cheaply from nearly just Radio Shack parts or surplus parts. It just takes some know-how... When and if the Yakuza [Japanese mafia] gets those (and they will, it's just a question of time), you can begin to appreciate some of the turns this present terrorism and our war on it will take."

Bearden http://www.cheniere.org/correspondence/021702a.htm

The very thought of the building of one of these howitzers by "some lone-nut gunman" from Radio Shack parts makes one realize how serious it is for humanity to face the crisis it has come to.

Once again, as at the dawn of the nuclear era, humanity finds itself at the crossroads of Heaven and Hell. As a species, we must stop and consider. And there is at least one real difference between this visit to the crossroads and the last: this time there is a very real possibility of a true "earthly heaven" on the Heaven side.

The poor nations could come to a good life. Disease could be largely eliminated. Fossil fuel pollution could end. Global warming could be solved, and the weather could be managed in a humane way, bringing water where there is drought, and sunny skies where there is flood. Scalar interferometry would be there to avert any possible hits by asteroids or comets. Mars could be colonized and terraformed. Everyone would be highly educated through psychoenergetic downloading of knowledge. And the wisdom of the wise could be realized directly through scalar connection to their minds and hearts.

These stunning sudden possibilities give me pause to think: if our species has reached this crossroads in such a short span of centuries, then surely other species in this vast universe have passed this way before and long ago. And of those who chose the path to "planetary heaven," what is their life like now? It might be good if some of them were with us now, to guide us through this last struggle over this pesky old good-and-evil problem. It is our last chance to choose the path which benefits the whole species, and not just some elite group or faction.

The Disclosure Project

One person working tirelessly to bring to bring these technologies into the open is Dr. Stephen Greer of the Disclosure Project, which is calling for congressional hearings into the issues of UFOs and the free energy technology that was, perhaps in part, reverse-engineered from them.

> "Once abundant and nearly free energy is available in impoverished areas for agriculture, transportation, construction, manufacturing and electrification, there is no limit to what humanity can achieve. It is ridiculous — obscene even — that mind-boggling poverty and famine exists in the world while we sit on classified technologies that could completely reverse this situation. "So why not release these technologies? Because the social, economic and geo-political order of the world would be greatly altered. Every deep insider with whom I have met has emphasized that this would be the greatest change in known human history. The matter is so highly classified not because it is so silly, but because its implications are so profound and far reaching. By nature, those who control such projects do not like change. And here we are talking about the biggest economic, technological, social and geo-political change in known human history. Hence, the status quo is maintained, even as our civilization hurtles towards oblivion...
>
> "With the types of weapons currently in the covert arsenal — weapons more fearsome even than thermonuclear devices — there is no possibility of a survivable conflict. Yet in the darkness of secrecy, actions have been taken on behalf of every human that may

> endanger our future. Only a full, honest disclosure will correct this situation. It is not possible for me to convey in words the urgency of this."
>
> Dr. Stephen Greer http://www.disclosureproject.org/ES-DisclosureImplications-2.htm

Greer and his team have assembled hundreds of witnesses, many of whom are military or ex-military, who are ready to testify to congressional hearings what they know about the covert black projects which have kept free-energy and antigravity propulsion technology secret from the people.

Greer points out the need to regulate these technologies so they are limited to peaceful uses, but this is of course difficult when the government simply chooses to pretend they do not exist. In the meantime, as the President and the Defense Department continue the charade of war-as-usual, those scalar (longitudinal wave) installations which DO exist continue to fall into ever more sinister hands. And there is no reporter in the press brave enough to ask, "Mr. Secretary of Defense, what steps are you taking to defend our MINDS from attack by the big Russian longitudinal interferometers?"

Longitudinal Interferometers are Proliferating

In a later statement Bearden reveals that in fact the Yakuza [Japanese mafia] has already leased some of the interferometers with a nearly $1 billion "down payment:"

> "After the collapse of the Soviet Union's economy, lots of things got available for lease or purchase that would never have been under the old system. That happened in the resulting economic chaos. The Russian Mafia rose to prominence, as did some wheeling and dealing entrepreneurs who played both ends against the middle.
>
> "In that atmosphere, and in the need for money, the KGB allowed leasing of the earlier longitudinal EM wave interferometers to a consortium of the Yakuza and Aum Shinrikyo. They did this only after they had tested and deployed their great new quantum potential weapons. That class of weapon is the dominant weapon on earth. Five nations now have it: Brazil, Russia (KGB), China, and two nations friendly to the U.S. The deal to lease many of the earlier LWIs [longitudinal wave interferometers] to the Japanese Yakuza and Aum Shinrikyo was consummated at the end of 1989, with a down payment of $900 million in gold bullion as "up front" money. I don't know what the lease per year was and is, but probably something like a billion dollars a year. So the rogue Japanese acquired longitudinal EM weapons and that technical know-how. In fact, the Yakuza is producing certain kinds of those in its own facilities in Japan now."
>
> Bearden http://www.cheniere.org/correspondence/030202a.htm

Personally, I am a little uncomfortable with the knowledge that the Japanese mafia may now be able to insert things into my mind. I'd like to sleep at night knowing that my dreams are my own, such as they may be, and not some weird fantastic visions cooked up by a criminal organization. This is a world emergency.

And in Bearden's analysis, it all comes back to the issue of energy. It is the energy crisis which is now provoking the current "oil wars," since oil production has hit the "Hubbert Peak" and will decline. And the electrical power grids must be replaced with scalar power as fast as possible, for these grids are now totally vulnerable to any possessor of longitudinal interferometers. They can all be wiped out in minutes. By anyone who possesses or controls a Tesla howitzer.

> "Anyway, in my personal view, we should have a national Manhattan Project right now, to develop decentralized electrical power systems taking their energy from the vacuum . . . The MEG is real and so are several other systems invented by private inventors and colleagues. All these efforts should be massively funded and massively and quickly developed. The survival of this nation is going to depend upon it. . . . There are many other facets, but the major point is that our scientific apparatus and the public are still unaware of what a desperate struggle we have entered, since it was thrust upon us. 9-11 was a wake-up call. It was certainly bad enough, and one grieves for those lost American lives. But I fear the worst is yet to come, and it is coming at us like a runaway train hurtling right down the track at us."
>
> Bearden http://www.cheniere.org/correspondence/021702a.htm
>
> "The electromagnetic weapons mentioned by the Secretary of Defense in April 1997 are in terrorist hands also, including the Yakuza and Aum Shinrikyo. That rogue group leased those earlier weapons on site in Russia, from the KGB, at the end of 1989. The SecDef stated that such weapons were being used to initiate earthquakes, initiate volcanoes into eruption, and control and engineer the weather. Quite true. And presently there is a truly massive set of weather engineering operations going on over North America, from that rogue Japanese group manning the weapons in Russia. Some 10 nations of the world now have the type of longitudinal EM wave interferometer weapons (which are what the SecDef was most probably referring to). There are other even more fearsome weapons, possessed by five nations. So a great deal of the state of the world is not covered in the news at all, and will not be . . .
>
> "We have been in an undeclared war of an eerie kind for some decades. That war seems now to have started to heat up also. The destructive capability of some of these weapons is awesome, and far greater than nuclear."
>
> Bearden http://www.cheniere.org/correspondence/021702a.htm
>
> "In that sense, the first phase of WW III is already completed. Now we are only waiting for Phase II.
>
> "It is against that backdrop that I think one must "analyze" such things as how fast we will be replacing the power grid (it's going to go anyway, and catastrophically, the terrorists will see to that). And everything we have is critically dependent upon energy, from the economy to jobs to mobility, to the millions of trucks that transport our goods every day, etc.
>
> "As far as I am concerned, we are already late in declaring a great national emergency in energy, because of the coming destruction of the present energy infrastructure. The

> scientific community should lead, follow, or get out of the way. The emergency is not in seeking "alternative but conventional" systems. It is in developing "energy from the vacuum" on an emergency, crash basis.
>
> "Unfortunately, everywhere I look I just see business as usual. Most Americans (and news media) seem to think, hey, Afghanistan is finished except for a bit of cleanup, and it's just about over).
>
> "It isn't. It has only just begun."
>
> Bearden http://www.cheniere.org/correspondence/021702a.htm

Beyond the Howitzers: Quantum Potential Weapons

Do not use EM propagation through space

As more and more nations acquire the scalar interferometers, Bearden speculates on the next generation of longitudinal weapons called "quantum potential" [QP] weapons.

> "The quantum potential weapons are presently only held by three nations: Russia (in the hands of the KGB, which is now know by its new name), Brazil, and the "friendly little nation." Red China may be working on them, but is just at the beginning...
>
> "The QP weapons have been highly reserved by the Russians. However, the complete extent of their capabilities is still being figured out...
>
> "The quantum potential weaponry (possessed by only three nations) is supreme, because it uses multiply connected spacetime, and DOES NOT involve propagation of EM energy through space as does the longitudinal EM wave interferometers.
>
> Bearden http://www.cheniere.org/misc/qp.htm
>
> "The operational deployment of full-scale strategic QP weapons on site in Russia occurred at the end of 1989, which is when the formal weapons first went operational. These weapons are not in the inventory of the regular Russian armed forces, but all research and development, manufacturing, deployment, an manning and employment is under the ruthless control of the KGB. Shortly thereafter (within weeks), the KGB leased many of their earlier longitudinal EM wave interferometer (LWI) weapons to a rogue Japanese group comprised of the Aum Shinrikyo and Yakuza."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

In another paper, "Time Polarization - Significance and Weaponization," Bearden tells the story of how a KGB longitudinal wave attack was averted by the longitudinal weapons of a "friendly small nation."

So as it stands, it is precarious. Not until the people demand an end of what author Jim Marrs has dubbed the "Rule by Secrecy," can the people's representatives tackle the big problems of a worldwide ban on Scalar Wars and the shifting over to an essentially oil-free economy.

Latest Update from Tom Bearden - March 2002

The whole situation is changing so fast that when I asked Tom to look over this article he mentioned the seeming contradiction when some of the above statements are taken together. At different times the information he has is updated so one has to keep a kind of running track. He was kind enough to clear up the confusion here with the situation as it stands as of March, 2002.

> "We knew of three nations having the QP weapons for some time. Then we found out last year that five nations had it. So that explains my using the figure "three" first (which represented what I knew at the time). Later I found out about the other two nations. China, e.g., only deployed its QP weapon this past year. So that explains the apparent contradiction between me using "five" in later papers and "three" in earlier ones. It was the best information I had at that time. Might mention that so the reader will understand the apparent discrepancy." Tom Bearden

Emptiness is Full of Energy

"The Tao is an empty vessel;
it is used, but never filled.
Oh, unfathomable source
of ten thousand things!

"Oh, hidden deep but ever present!
I do not know from whence it comes.
It is the forefather of the gods."

Lao Tzu -Tao te Ching

Afterward

Because of the extreme seriousness of the topics brought forward in this article, I asked Tom Bearden to look it over to make sure I had not gotten anything too terribly wrong or mixed up. I did not want to pass on any misunderstanding of my own. I felt a little nervous writing to an eminent scientist, and hoped I had not presumed upon his time.

But Tom was so kind as to answer immediately, and to my relief I had not gotten anything too terribly wrong. Here is his letter, in which he clears up a misunderstanding, and reports on his current health treatment, and gives a call to the young grad students to turn themselves loose in the whole new field of scalar electromagnetics and free energy.

Subject: RE: Article on Tom Bearden and "Scalar Wars"
Date: Fri, 22 Mar 2002 22:54:01 -0600

Bill,

Well, I must say I'm astounded at your persistence and hard work in congealing all that together. My compliments on a hard job quite well done.

Couple tiny things: In the area mentioning Kervran and Kaznacheyev: Kervran was French; Kaznacheyev was and is Russian. Little typo of "spredding" the immune system. Should be "spreading".

We knew of three nations having the QP weapons for some time. Then we found out last year that five nations had it. So that explains my using the figure "three" first (which represented what I knew at the time). Later I found out about the other two nations. China, e.g., only deployed its QP weapon this past year. So that explains the apparent contradiction between me using "five" in later papers and "three" in earlier ones. It was the best information I had at that time. Might mention that so the reader will understand the apparent discrepancy.

Otherwise, it's pretty accurate.

Just now I'm letting the weapons take care of themselves; have to, as I will be recovering now for nearly a year from now after the heart attack last year and discovering that I had contracted mycoplasia (the BW modified kind) in Canada in 1968. Finally got a test which confirmed the chronic mycoplasia (which I had for 33 years!). The stuff burrows inside one's red corpuscles, then draws nutrients from the hemoglobin, hardening it and reducing its ability to take on oxygen (by as much as 50% or more). The resulting symptom is loss of endurance (which I had for that 33 years) -- the so-called "chronic fatigue syndrome".

Many of the Gulf War Veterans who are sick also have it, though they apparently have other complicating factors as well. A very high percentage of persons with chronic fatigue syndrome also have mycoplasia. The treatment for the long-standing mycoplasma infection of that nature is to stay on antibiotics for a year. The only time the mycoplasma is vulnerable is when one wears out a red cell in normal usage, and the body makes a new red cell to replace it. The mycoplasma comes out of the dying cell to infect the new replacement cell, so it is exposed and vulnerable at that specific time and that time only. The antibiotics kills it at that time. Hence the necessity to stay on antibiotics for such a long time so it is continuously in your bloodstream (I've already been on antibiotics for over two months, and have at least 10 more months to go). We also take a little medical oxygen every day.

Another symptom of the mycoplasma infection is the association of runaway fibrillation of the heart. To stop that, there are pills one takes, and they stop it. But they also further reduce the volume of blood pumped by the heart, so that this projects one right back into the hypoxia, dizzy, loss of balance, etc. Catch 22 situation; the fibrillation will build and cause heart attack, stroke, etc. if not stopped, and if stopped it puts you back in the hypoxia which can cause many things! With the conventional treatment, you're damned if you do and damned if you don't. Hence the need for a little extra medical oxygen, so you can take the "heart clamp" pill and stop the fibrillation, but also augment the oxygen enough to continue to survive without a stroke or some such. Interestingly, it's very difficult to even obtain a mycoplasma test, and Medicare fights you tooth and nail over paying for the oxygen. Either they will pay for it or I'll pay for it myself; it is absolutely necessary.

After a heart attack, one is treated in the heart clinic by specialists who are very caring and excellent practitioners, but know nothing of mycoplasma infection, so not consider it even a part of "heart disease", and who are rather puzzled when one has no clogging of the arteries, has the right count of red corpuscles (largely nonfunctional, of course, but there), pumps the right amount of blood, etc. So they identify and treat only the runaway fibrillation, do not prescribe the oxygen -- and essentially place you on a regime as best they know, but one that is guaranteed to kill or maim you or turn you into a totally disabled person or human vegetable via stroke, paralysis, etc. Fortunately my family doctor will prescribe the oxygen anyway, though I may have to pay for it myself. Whatever works!

However, I'm slowly improving little by little, working as much as I'm able to and trying to finish my book: Energy from the Vacuum: Concepts and Principles, and get it to the publisher for publication later this year. Hopefully the book will turn all the interested young grad students and post-docs loose in the free-energy area. They will not have to spend 30 agonizing years to get to where I am, and where a few others are, but can simply start here and go forward. Since speed to develop energy from the vacuum is of the essence because of the world situation, I'm moving on it as fast as I am physically able to.

Meanwhile, working with the AIAS (Alpha Foundation's Institute for Advanced Study), the AIAS (15 authors) has now gotten about 20 scientific papers published in leading journals (Foundations of Physics, Foundations of Physics Letters, Physical Scripta, Optik, etc.) dealing with electromagnetic energy from the vacuum. Several more are either approved for publication or in the review process also. So slowly we are getting it into the mainstream scientific literature. Hopefully it will be in time, but it's cutting it close.

Very best wishes,

Tom Bearden

Late update

Massive display of longitudinal interferometers?

UFO Fleet Taped Over Bedhampton, England

Is this sighting a case of the testing of all the Russian (KGB) longitudinal interferometers at once? And coordinating their targeting through the woodpecker grid to a common place, as an exercise in making a massive scalar attack upon a given region? Was this a confluence of Russian Tesla howitzer marker-beacons?

Bedhampton, England - March 22, 2002 - Video Frames by: Anthony Woods

Certainly for a massive all-out scalar attack you would want coordinated movements of the target areas of many howitzers at once, for you could then just cut a bloody swath across a wide area, all the howitzer blasts marching across the land in a kind of scalar version of the "scorched-earth policy." All in a line, blasting, and heat, and mind waves. Or you might want to put the blasts all in the same place for a truly horrendous destruction. And on top of that biowar on citizens whose immune systems have been weakened with the quantum potential weapons. This is the latest version of Armageddon.

And should any madmen gain control of these weapons, any rogue group at all, and should they have some agenda to radically depopulate the world, to simply kill by the billion, the means will be in their hands to do so.

Update: MEG patent granted

Motionless Electromagnetic Generator Patent Granted

This message is from Jean-Louis Naudin, the French scientist who successfully replicated the Motionless Electromagnetic Generator (MEG) in France. He announces the granting of the patent to the MEG Builder's group at Yahoo.

----- Original Message -----

From: jnaudin509@aol.com
To: jlnlabs@yahoogroups.com
Sent: Tuesday, March 26, 2002 2:20 PM
Subject: [jlnlabs] (Info) GOOD NEWS : The Tom Bearden's MEG IS PATENTED

Dear ALL,

GOOD NEWS !!!!

The Motionless Electromagnetic Generator from Tom Bearden is now PATENTED US 6362718 granted on March 26, 2002

US Patent 6,362,718 :
Motionless Electromagnetic Generator (MEG)

Abstract: An electromagnetic generator without moving parts includes a permanent magnet and a magnetic core including first and second magnetic paths. A first input coil and a first output coil extend around portions of the first magnetic path, while a second input coil and a second output coil extend around portions of the second magnetic path. The input coils are alternatively pulsed to provide induced current pulses in the output coils. Driving electrical current through each of the input coils reduces a level of flux from the permanent magnet within the magnet path around which the input coil extends. In an alternative embodiment of an electromagnetic generator, the magnetic core includes annular spaced-apart plates, with posts and permanent magnets extending in an alternating fashion between the plates. An output coil extends around each of these posts. Input coils extending around portions of the plates are pulsed to cause the induction of current within the output coils.

Inventors: Patrick; Stephen L. (2511 Woodview Dr. SE., Huntsville, AL 35801); Bearden; Thomas E. (2211 Cove Rd., Huntsville, AL 35801); Hayes; James C. (16026 Deaton Dr. SE., Huntsville, AL 35803); Moore; Kenneth D. (1704 Montdale Rd., Huntsville, FL 35801); Kenny; James L. (925 Tascosa Dr., Huntsville, AL 35802)

Appl. No.: 656313
Filed: September 6, 2000

For some technical info see my web site at : http://jnaudin.free.fr/html/meg.htm

Best Regards
Jean-Louis Naudin
Email: JNaudin509@aol.com
Main Web site : http://jlnlabs.org
Site France : http://jlnlabs.multimania.com

Click here to view patent # 6,362,718

Patent Story on Rense.com:

Rense.com

MEG Scalar Energy Device
Patented - Production Starts Next Year

From Bill Morgan
wmorgan@nycap.rr.com
3-28-2

Patent was granted on March 26, 2002 for "The Motionless Magnetic Generator," (MEG) US Patent 6,362,718, which is likely to become the first commercially available free energy device in history in about one year from now. The machine will provide free electricity from the vacuum, for the life of the device, which should be a very long life since it has no moving parts. You can see a picture of scientist Jean-Louis Naudin's MEG replication model at: http://jnaudin.free.fr/html/meg.htm.

It has strong magnets, coils, and a controller unit with the electronics. Naudin made the announcement to the MEG-builder's Yahoo group. The announcement has significance since the patent office has always been skeptical of devices which seem to "get-something-for-nothing." But according to the new science of scalar electromagnetics, the MEG does not break the law of conservation of energy. It's just that the energy is conserved in the fourth dimension, time, and not our 3-space world.

The MEG provides electrical energy by tapping the longitudinal electromagnetic (EM) waves which exist in almost infinite abundance in the vacuum of space. This ocean of energy which permeates everything is sometimes called the "zero point" energy, since it remains there even at absolute zero temperature.

Four inventors are listed: Stephen L. Patrick, Thomas E. Bearden, James C. Hayes, Kenneth D. Moore.

Tom Bearden has explained the operation of the MEG on his website Cheniere.org, and also speaks about the new fearful weapons that can and have been made using the same "longitudinal waves" of the vacuum.

The complicated physics of how the MEG works is explained in the paper "The Motionless Electromagnetic Generator: Extracting Energy from a Permanent Magnet with Energy Replenishment from the Active Vacuum," which can be found at Tom Bearden's website:

cheniere.org.(http://www.help4all.de/energy/MEGpaper.pdf)

The first MEG units to be produced for sale will output 2.5 kilowatts of free electricity. Forever. They should be in production about a year from now. Facilities for manufacturing the device are being set up in an unnamed "friendly nation."

This free electricity will flow indefinitely, without much, or any maintenance. The units may be hooked together to provide more wattage, so four of them would provide 10 kilowatts. After some production experience units will be made which output 10 kilowatts each. With a couple of those units a house could get off the electrical grid.

Tom Bearden, one of the inventors has said "I will admit that the chief scientist of an important experimental group in a large company was rather stunned at the type of output we were able to obtain. The MEG may look like just a transformer, but it is not. It is a completely different breed of cat." This cat, it would seem, is out of the bag now.

The ordinary EM waves we are familiar with are called "transverse" waves, to distinguish them from the new "longitudinal" EM waves of the vacuum. Bearden has explained in depth on his website cheniere.org that wherever there is a dipole (battery, generator, magnet) there is an unseen flow of longitudinal EM waves in that local vacuum, the only problem is in tapping that energy and "transducing" it to electricity. Bearden says that the problem with all the electrical circuits we have is that they are two-wire circuits, a loop by which half the energy goes back to destroy the dipole. In the MEG that closed loop is never made. So the dipole is not being destroyed.

Patents are not granted on devices which do not work, so in a sense this announcement proclaims a new era. The MEG device itself proclaims and proves that energy is abundantly available everywhere, for free. We only have to build the devices to tap it. MEG type devices could be put into a car with an electric engine to make a truly fuel-less automobile. Electricity can be available in very remote places. People will be able to get off our very terrorist-vulnerable power grids. In an era of terrorism a highly dispersed power system would be most desirable rather than our centralized systems.

What is somewhat astonishing to me is the discovery by Bearden et. al. that time itself is actually compressed energy, and that this free energy is actually coming from the time domain, the ocean of longitudinal EM waves which fill the empty vacuum of spacetime. In fact, time is energy compressed by the same factor that matter is compressed energy: the speed-of-light squared. Thus there is a new companion to Einstein's E=mc2. Can you say "E equals delta-tee-cee-squared?" The "tee" is time and delta-tee is change in time.

A company has been set up to manufacture the MEG called Magnetic Energy Limited.

The ramifications of free energy are enormous. The oil wars are not necessary. If we threw as much money at this technology as we are spending on the oil wars we would be free of the need for oil in less than a decade. With fuel-less cars air pollution will be greatly lessened. Third world nations can raise their standard of living eventually. And the energy is free. And it never runs out.

I have put together a kind of "Bearden for Beginners" article which explains some of the basic concepts of the current state of scalar technology.

http://www.prahlad.org/pub/bearden/scalar_wars.htm

The granting of the MEG patent is the herald of the new era of scalar electromagnetics, and the free energy which flows forever and never runs out.

Bill Morgan
wmorgan@nycap.rr.com

Do the magnets run down after a while?

Further developments: Tom Bearden clears up a question

When the MEG patent was released many questioned the patent language which seemed to imply that permanent magnets of the MEG would "wear out" after awhile. I myself wondered about the same thing so I put the question to Tom, and here is his reply.

> Dear Bill,
>
> Thanks for the kind words; much appreciated.
>
> I'm not up to going on radio or TV, and won't be for quite some time. Still suffering from hypoxia, though very slowly improving, and will still be on antibiotics for 10 more months at least (maybe longer).
>
> Obviously an extensive dialog developed between the Patent office and our patent attorneys. As best I can understand it, the Patent office accepts the fact that a permanent magnet produces and emits energy, or has a history of accepting it. They do not appear to be at all cognizant of the broken symmetry of opposite charges, and hence of a dipole. So in their opinion (which seems to be vague), the magnet has to use itself up very gradually, or some such. So some rewrites were essentially required by the Patent office.
>
> All I can say is that a magnet is a very durable thing, so long as you don't heat it up too much or shock it to much. Certainly one will make a good 20 years, and of course there are plenty of magnets that have been around awhile longer.
>
> That said, in our earliest experiments we did "measure" some such effect, or so we thought, until we found that a particular instrument was bad and giving erroneous readings. So with a new instrument, we have not observed since then any such readings.
>
> Out of all that fuzziness came the inclusion of "using up the magnets gradually". So far as we are aware (after correcting those early readings on a defective instrument), we have seen no such measurements or effects since then at all. Nonetheless, just in case there is some very small effect in that respect, at least it's in there.
>
> Actually, as you are aware, capacitors and solid state components are the major concerns for failure, and any system does require maintenance, both periodic and whenever malfunction or failure occurs. The MEG is no different from any other device in that respect, so of course it will have a component failure rate and maintenance required from time to time, just as any other electromagnetic device. But without moving parts, it can be ruggedized and made very durable indeed.
>
> Please give Jeff Rense my regrets, and I do admire his work and his show. He's laying it in there.
>
> The depth of the scientific mindset against COP>1.0 is inexplicable, particularly when physics itself already has COP>1.0 validated experiments (such as Bohren's experiment,

which outputs 18 times as much as one inputs by Poynting calculations), and it works every time. Any competent university optics lab can perform the experiment. Also, even the conventional texts admit that a charged capacitor or electret laid on a permanent magnet, so that the E of the cap or electret and the H of the magnet are at right angles, is a "free energy machine". That silly thing will just sit there and pour out Poynting energy S = EXH indefinitely. Years and years and years. If you wait just a single year, that silly thing has changed the energy density of a volume of space a light year in radius, reaching out well beyond the solar system. Now that's a WHALE of a lot of EM energy that beast poured out in that year, and it will still be going strong and pouring it out at a steady rate. The charges and dipoles in original matter in the universe have been pouring out EM energy in that fashion for some 14 billion years, give or take a billion or so. It's also easy to see that, prior to Lorentz's ARBITRARY symmetrical regauging of the Maxwell-Heaviside equations, those equations prescribe both EM systems in equilibrium with their active environment, and EM systems not in equilibrium with it. The latter systems are permitted by the thermodynamics of open disequilibrium systems to perform five magic functions: (1) self-order, (2) self-oscillate or self-rotate, (3) output more energy than the operator inputs (the active environment inputs the rest of it), (4) power itself and its load (the active environment inputs all the energy, like a windmill), and (5) exhibit negentropy. That is a well-established thermodynamics. Lorentz arbitrarily discarded all such open disequilibrium EM systems in order to get simpler equations having analytical solutions and not requiring numerical methods. So he simply scrapped all the really interesting and challenging EM systems in Maxwell's theory. ARBITRARILY!

That our scientific establishment continues to teach only that "half" of the theory, and not point out the rest to the young students, and not fund research into developing such systems that take energy from the vacuum, is simply inexplicable. It's a matter of total dogma, not science at all.

But hopefully it is changing a little bit. At least now we cite chapter and verse when these things were done, and what they are, and the young grad students and post docs can go check the papers and make up their own minds.

That is the real hope of the future: that we get a generation of young fellows, with excellent skills, who now know where all the skeletons got hidden in the closet, and understand that the electrical engineering model arbitrarily assumes an inert vacuum environment (falsified for more than a half century in particle physics) and a local flat spacetime (falsified for nearly a century by general relativity).

Once they know that past history, and go read into what broken symmetry of opposite charges means for a dipole and for all dipolar EM circuits, they will set to and change that more than a century of error. In that case, we shall have numerous solutions to the energy crisis rather quickly, popping up all over.

Good thing. It will certainly displace some great energy barons, but it will also free the populace. One can extract all the EM energy from the vacuum one wishes, anywhere, anytime, with ridiculous ease. One can produce that "electrical wind of energy" at will, by making a simple dipole and then letting it alone. The only energy problem is in how to then intercept some of that energy flow and "catch" it in a circuit, discharge it in a load to power it, and not use half the "caught" energy to kill that dipole that is gushing out the extracted EM energy from the vacuum.

Very best wishes,

Tom Bearden

END

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/2011/03/26/9501797_Teslas_Scalar_Waves_Replicated_by_Steve_Jackson/
You are here: PureEnergySystems.com > News > March 26, 2011

Tesla's Scalar Fields Still Beaming On!

The superluminal (faster than light) scalar or longitudinal waves Nikola Tesla used to magnify and wirelessly transmit power are not just a thing of the past. IEEE engineer, Steve Jackson, discusses and demonstrates how they can be utilized today, and he is open sourcing it here!

by Hank Mills
Pure Energy Systems News

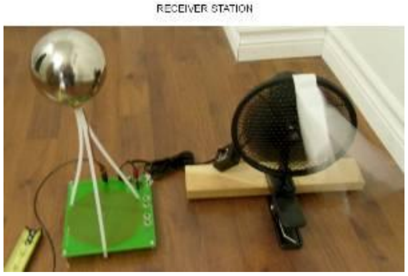

Nikola Tesla is the father of the modern age. His inventions of radio, remote controlled devices, alternating current, and induction motors (among many others), paved the way for modern civilization. Yet other of his inventions barely saw the light of day, despite their tremendous potential.

Such a severely under utilized technology is his wireless energy transmission techniques. By producing scalar (longitudinal) waves, he could achieve superluminal (faster than light) communication, send signals through any material including Faraday cages, and wirelessly beam power to receivers. Researchers like Steve Jackson provide hope that by open sourcing Tesla's work, scalar wave transmission can proliferate and positively benefit the world.

Last Thursday, March 24, 2011, Steve Jackson held a presentation and demonstration of a scalar wave transmitter and receiver at a local IEEE meeting at McMaster University in Ontario, Canada. During the talk he gave an overview of Tesla's life, his inventions, and a plethora of information on his wireless power transmission technology. Afterwards, he demonstrated a small electric fan attached to a scalar wave receiver powered by a transmitter over twenty feet away. Tesla's technology is alive today!

Furthermore, he has approached us at PES Network to open source his design. You can download his PowerPoint presentation here. We'll be uploading to

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our PESNetwork YouTube account a video of his presentation to the IEEE in a couple of days. It's in process of being transmitted, but will take a while, as it is 3+ Gb. We're expecting to get instructions from Steve on Monday, and we'll be posting a PESWiki page to organize all this material to streamline the presentation.

Take a look at the following video that shows a small boat powered by scalar waves many feet from a transmitter.

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Demonstration of Tesla's Wireless Power Transmission System duplicated at the Tesla Tech Conference, July 2007.

Scalar Wave Properties

You might be wondering what in the world is a scalar wave! It's actually pretty simple. Unlike a transverse wave (like an ordinary radio or light wave) a scalar wave's amplitude does not fluctuate up and down. Instead, try to visualize it more like a vibration of electric potential expanding and contracting in the direction of propagation.

Scalar waves are also often called "Tesla Waves" or "Longitudinal Waves." All of these terms refer to the same type of wave which oscillates in the direction of propagation instead of perpendicular to the direction of movement. These waves have many unique properties which have been tested and confirmed repeatedly.

1) They are capable of penetrating any solid object including Faraday Cages. You can put a transmitter in a box of thick metal and a receiver outside of the box will receive the scalar wave frequency you are pulsing. The potential here is for a transmitter that can penetrate any obstacle or perhaps communicate directly through the Earth from one side of the globe to the other.

2) They are capable of superluminal travel. These waves are claimed not to be electromagnetic, but composed of pure potential energy. Due to this, the speed of light limit does not apply to them. The propagation speed of a scalar wave has been measured as faster than the speed of light and thought by some researchers to be potentially of infinite velocity. (Perhaps SETI - The Search for Extraterrestrial Intelligence - needs a different kind of receiver in order to pick up signals from elsewhere in the universe! Why would advanced ET civilizations even bother using slow transverse waves for interstellar communications?)

3) They are capable of transmitting power. It can then be put to use powering motors, lights, vehicles, etc.

4) A scalar transmitter can wirelessly send power to a receiver through any obstacle. For example, as mentioned above, you can setup a transmitter, put it in a Faraday Cage or a metal box, and a

receiver can receive power far away.

5) During the process of transmission and reception they can magnify power. You can input a certain quantity of power into a scalar wave transmitter and yet the receiver can receive several times the power.

6) Transmitters and receivers can communicate.

7) A conventional transverse wave transmitter cannot sense if a receiver has "tuned in." However, in a scalar system the transmitter and receiver interact because they are in a state of resonance.

As you can see Scalar Waves hold many potential applications for communication, energy, and other applications. To mimic a commercial for a popular brand of cell phone, "Scalar Waves do what Transverse waves don't." They are fast, penetrating, connected, and can broadcast magnified power. These waves are begging to be utilized!

Recipes for Scalar Waves

Nikola Tesla's most famous scalar wave transmitter was his Wardenclyffe tower on Long Island, NY. Prior to that, at the height of his amazing inventive career, he had a lab in Colorado Springs, Colorado. He was able to beam power to receivers miles away that were used to illuminate neon tubes. A great deal is known about his tower, transmitters, and receivers. It is all detailed in his patents. This allows for present day replications!

From examination of Tesla's patents, researchers have learned that perhaps the most critical component of a scalar wave system is the antenna. It is composed of a flat "pancake coil" composed of both a primary and a secondary winding. The coil is connected to a spherical metallic resonator that helps transmit and receive scalar waves.

A particularly good source for information about scalar wave systems is the website of German scientist, author, and researcher, Konstantin Meyl. He has published a series of books that describe scalar wave systems, detail their components, and discuss their operation. His books also dive into the science and physics of scalar waves, among other fascinating topics.

In fact, he offers scalar wave kits for sale on his site. They include all the components needed for a complete system, arrive in an aluminum suitcase that can serve in the same manner as a Faraday cage for your experiments, and come with a book detailing the kit. These kits have been used by experimenters to prove to themselves and others the existence of scalar waves and their unique properties.

Take a look at the following video to see Konstantin demonstrating a scalar wave transmitter and receiver. The same device in the following video is for sale right now on the internet from his website.

M
eyl shows Tesla's longitudinal electricity transmission in Washington DC at a Tesla,m meeting in 2003!

Even NASA is paying attention to scalar waves to some degree. The paper titled, "Advanced Energetics for Aeronautical Applications: Volume II" by David S. Alexander offers a review of scalar wave (longitudinal wave) research. It mentions the work of Konstantine Meyl and others in the field. Interestingly, the paper also discusses how Dr. James Clerk Maxwell's original equations specifically allowed for scalar or longitudinal waves. Only many years later did short sighted scientists who did not care to deal with Maxwell's complex equations based in "quaternions" mathematics arbitrarily discard longitudinal waves. Due to this, many mainstream scientists doubt their existence despite their history and the mountain of evidence which proves they are very, very real.

Opening Tesla's Technology

Steve Jackson's goal is to open source Tesla's wireless power transmission technology. This is very possible to do, due to the simple nature of the parts and components required. During his talk he published a list of components required to build a system. This same information can be found in the books of Konstantin Meyl and elsewhere on the internet.

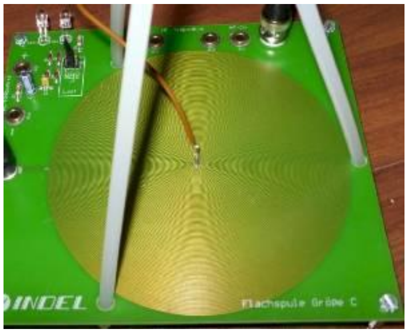

By open sourcing this technology, ordinary individuals could prove to themselves, friends, associates, co-workers, and others that Tesla's technology worked as claimed. Not only does it work, but can be replicated and used for practical applications today. All unique properties of scalar waves could be harnessed and developed to revolutionize our society.

When Steve releases plans, drawings, and other information, probably next week, we will add them to a project page at PESWiki.com. We'll add a link from this page when it is ready.

Earth Changes and the Future

In his books and lectures, Konstantin Meyl has compared superluminal scalar waves to the neutrino, which is also thought by some to travel faster than light. Neutrinos bombard the Earth in all directions, but the majority of them arrive from the central star of our solar system. Due to the fact that approximately half of the neutrinos are absorbed as they pass through the Earth, it is thought they may interact with the core and inner layers of our planet.

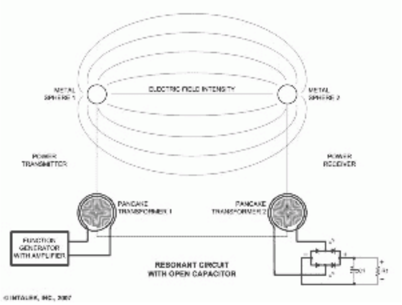

Circuit diagram used by Steve comes from Intalek.com, Figure 3.

Some researchers suggest solar phenomenon can produce variations in neutron emissions which may trigger "earth changes" on our planet. This was depicted in the blockbuster movie, 2012, as the cause for the crust disruptions from the mantle heat-up from increased solar activity. Hence, studying and understanding the nature of scalar waves may increase our chance of survival during chaotic periods in the future. Perhaps by understanding them we could eventually learn how to constructively utilize them to stabilize our planet during periods of solar fluctuations, sun spots, flares, etc.

Perhaps with the use of scalar wave technology, earthquakes, volcanic eruptions, or other natural disasters could be prevented or detected ahead of time. Even a one hour warning before an earthquake, such as the one that recent devastated Japan, could save thousands of lives. Although all kinds of unique technologies are possible with scalar waves, at a minimum we need to understand how neutrinos and scalar waves interact without planet. Not doing so could result in needless death and suffering.

Lets get moving!

To not harness scalar wave technology for the benefit of mankind would be tragic. Our civilization is facing adversity in countless forms. Hunger, disease, pollution, poverty, and war threaten our future and the future of our children. Scalar waves exist, they are useful, and the information to build devices that generate and receive them is available to everyone. To better understand our universe, to ensure the continuation of our civilization, and to honor Nikola Tesla we should do our best to support the open sourcing of this technology.

Videos

On March 30, Steve conveyed the following YouTube links showing his presentation to the local IEEE on March 24.

#1 Slide 1 https://www.youtube.com/watch?v=qs-2s85lO6o
#2 Slide 20 https://www.youtube.com/watch?v=s4kvJpUgGKI
#3 Slide 39 https://www.youtube.com/watch?v=4YXPa73NNsA
#4 Slide 57 https://www.youtube.com/watch?v=LqhRDY56CqU
#5 Slide 81 https://www.youtube.com/watch?v=e1Ht5OVyI5Q
#6 Slide 93 https://www.youtube.com/watch?v=JuehDylES_A

Replication Instruction should be done tomorrow.

Contact

Steve can be reached by email at steve.jackson@ieee.org

# # #

This story is also posted at *BeforeItsNews*.

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Comments

Feel free to view/post comments down below. The following came in by other means.

Not Scalar "Wave"

On March 27, 2011, 1:45 pm, Karl Palsness wrote:

You should read about Scalar .. it is a "Scalar FIELD" there should be no such thing as a "Scalar wave"; and there is a "Longitudinal Wave", instead of scalar wave. Scalar waves just don't exist according to the word scalar meaning size. A Tesla coil has a scalar field around it...and emits a longitudinal wave....

A Tesla-era dictionary defined it as:

> **Scalar** -- In physics, a quantity which has magnitude, or magnitude and sign only, without direction, such as density, mass, energy, etc., as distinguished from a vector quantity.

and

> **longitudinal wave**: A "pressure" type of wave, similar to sound, in which the vibrations are along the direction of travel of the wave. Hence, a wave composed of alternating densifications and rarefactions, where we focus upon the longitudinal component of the changes.

* * * *

Longitudinal Waves (L.M.D.)s

On April 02, 2011 12:29 AM MST, Dr. Eng. Roberto Handwerker <info {at} deltaavalon.com> wrote:

Dear Sirs,

this mail is a reply to a number of e-mail messages I got from [...], subsequently from Dr. K. Meyl and from Mr. S. Jackson about longitudinal waves ("L.M.D.s").

The matter "L.M.D"s. is not new at all but there is still too much discussion around it from different point of views, i.e. mathematics/physics calculus and electrical devices; this has slowly but definitely led to a total chaos even on the Web, resulting in misunderstanding and disbelief, which doesn't help anybody;

therefore, the best approach for an engineer is to be very straight and careful especially when someone talks about Nikola Tesla and theories about aether and L.M.D.s., still not accepted by the "Academic World" who is as happy to hear such arguments as could be "a sailboat in a forest" so to speak and who brings in turn only useless negative criticism and hectic hysterism instead of helping clarify.

This is why I prefer to proceed "step by step" scientifically replicating some Tesla apparatus and demonstrating his experiments, which is of course not easy because he was the Mozart of the art.

I will present a book about the above and will very soon attend a Meeting in Italy to talk about L.M.D.s and show some working devices to public: it is always a pleasure to demonstrate FACTS and WORKING DEVICES rather than only showing some slides and theoretically discuss matters as "Lorenz gauge vs. Coulomb gauge", "quaternions vs. vectors", "T.E.M. vs. L.M.D." etc. etc. Only facts count, observation of Nature and research: math must consequently follow, as always.

It is therefore more useful instead to bring something new to L.M.D.s tech and to the understanding of Tesla, like for instance my "Tesla power wireless" system with the "small car-demo" shown in my following vids on You Tube (& others under "HorizonDelta"): https://www.youtube.com/watch?v=0BGFF4ltEv and https://www.youtube.com/watch?v=dvZH3RCdeVw

also a tech e-book "Longitudinal dielectric waves in a Tesla coil and quaternionic Maxwell's equations" can be found on my Website for download:

https://www.deltaavalon.com/immagini/L.M.D. waves in a Tesla Coil revised.pdf

I hope the above helped positive discussion and knowledge.

Regards

Dr. Eng. Roberto Handwerker
DELTA Ingegneria

* * * *

The Laplace Operator

On March 31, 2011 2:06 PM MST, Konstantin Meyl wrote:

Subject: Re: About Scalar Field and an Italian Book

There is one comment, making clear, where the problem is localized:

Karl Palsness wrote:

> "You should read about Scalar .. it is a "Scalar FIELD" there should be no such thing as a "Scalar wave"; and there is a "Longitudinal Wave", instead of scalar wave. Scalar waves just don't exist according to the word scalar meaning size. A Tesla coil has a scalar field around it...and emits a longitudinal wave..."

If a scientist is using an expression, he first has to define, what the meaning is. This is what I do in my books, but in America, nobody seems to read my writings. I explain that the scalar wave is nearly the opposite of a scalar field. The expression is more than 200 years old and in mathematics exactly explained by the field equation of Laplace.

The Laplace Operator (describing the distribution of a wave in space) may be separated in 2 parts: grad div - curl curl. The second part is explaining the EM wave, a transverse wave, while the first part gives a scalar wave: The div applied on a vector is scalar! This is why scalar particles or vortices as part of the wave equation are propagating as a scalar wave. But they are propagating in the direction of a field vector and by this the wave is longitudinal and has a direction. In mathematics it is known, that the grad applied on a scalar is a vector again. This is why the scalar wave is propagating in one direction, not in a scalar way, as Karl Palsness wants the scalar wave to do. So he has to read the literature first before he is spreading nonsense in the world wide web.

My opinion about the education in the states is not the best. Lets help to improve it.

* * * *

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  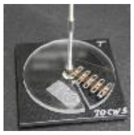
  Jackson's Wireless Aetheric Power Transmission Open Source Project - To facilitate the replication of these plans, as well as to characterize, optimize, improve, and come up with the zillion applications that can come from it, including: 1) harnessing aetheric energy, 2) superluminal communication, 3) wireless transmission of power through any barrier, 4) anti-gravity capabilities, and 5) creating defensive shields to make conventional war obsolete. (*PESWiki*; April 21, 2011)

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  Tesla Coils: Unleash the Aether - Nikola Tesla's most significant contribution was not AC power, radio, or the induction motor, but what we call the Tesla Coil - a tool which allows for the power of the aether to be unleashed and harnessed. Now being launched through an open source project. (*PESN* and *BeforeItsNews*; April 19, 2011)

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  Tesla's Scalar Field Still Beaming On! - The superluminal (faster than light) scalar or longitudinal waves Nikola Tesla used to magnify and wirelessly transmit power are not just a thing of the past. IEEE engineer, Steve Jackson, discusses and demonstrates how they can be utilized today, and he is open sourcing it here! (*PESN*; March 26, 2011)

See also

Resources at *PESWiki.com*

- **Directory:Konstantin Meyl**
- **Directory:Wireless_Transmission_of_Electricity**
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Page composed by Sterling D. Allan March 26, 2011
Last updated September 04, 2012

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"It is harder to crack a prejudice than an atom." // "I'd rather be an optimist and a fool than a pessimist and right." -- Albert Einstein

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First, it is ridiculed;
Second, it is violently opposed; and
Third, it is accepted as self-evident.
-- *Arthur Schopenhauer (1788-1860)*

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-- *Rabbi Shlomo Riskin, (Feb. 1998)*

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The Tom Bearden Website

Subject: RE: Missing Reference Slide
Date: Mon, 9 Jul 2001 11:58:04 -0500

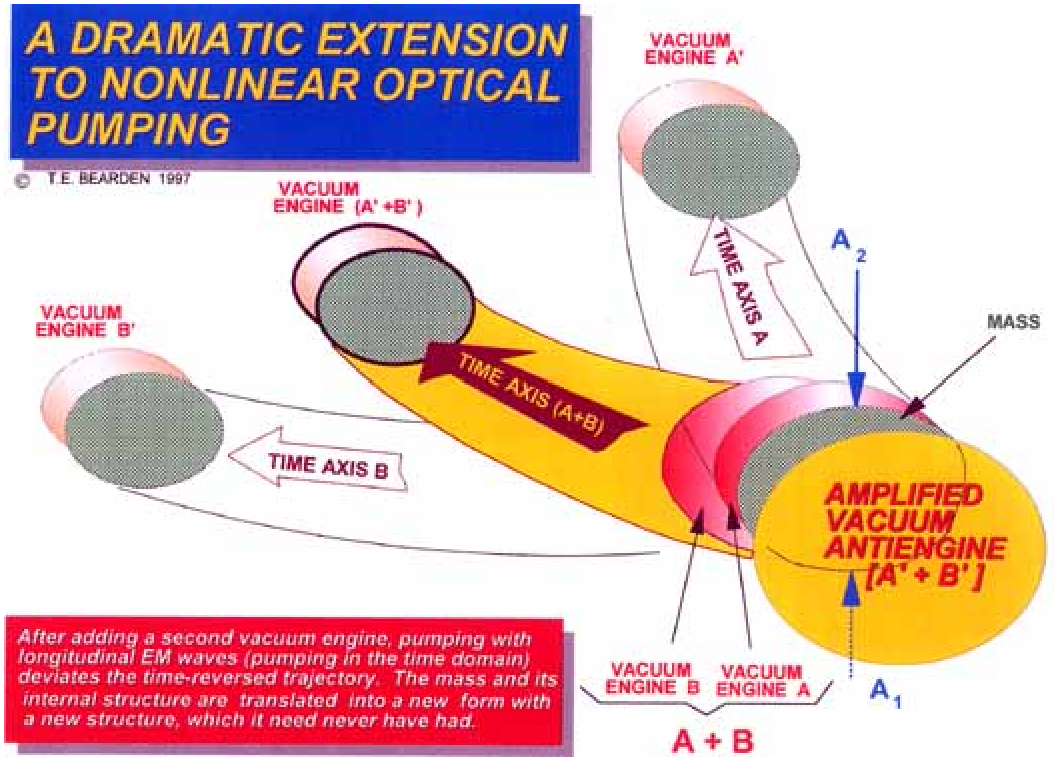

A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

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After adding a second vacuum engine, pumping with longitudinal EM waves (pumping in the time domain) deviates the time-reversed trajectory. The mass and its internal structure are translated into a new form with a new structure, which it need never have had.

Yes, that is the slide. It works this way: When you time-reverse a cell, you effectively create a major anti-engine for the cell's exact "engine" (exact set of spacetime curvatures at all levels). Because of the precise one-to-one correspondence, this antiengine then "backs the cell up" along the original time-path it took in its physical functioning and changes, back to a precise earlier condition where the disease or disorder was not present. For a cancer cell, e.g., this backs the cell up past where it was originally "promoted" from a stressed or damaged cell to a tumor cell. That makes it into a "damaged cell". The antiengine continues to act, backing it up further into the state before the damage or disorder occurred. That then constitutes "healing" of that cell in a rigorous sense.

The cloning methods etc. used, do violence to the cell in the process. At the cellular level, damaging it or any part of it in the process changes the resident spacetime curvature engine set, to include the damage. You then "clone" a cell with an imperfect resident engine. The cloned cell then interacts with a large variety of phenomenology, continually altering various subcomponents of its resident engine by taking on additional subengines or changing some of its former subengines. Somewhere later, that festering "delta" in the resident engine -- after sufficient interactions with other environmentally-induced engines, will undergo interactions that "add" two deltas so something detrimental to the organism. At that point, physical damage to the cell erupts in "anomalous" fashion. Actually it erupts by perfectly normal fashion, once the internal engines and their interactions are understood.

This would appear to pose a problem anytime you *artificially* change the subengines of an organism, as in the case of genetically modified food. The small physical damage associated with splicing the genetics has associated with it the injection of such an artificial engine. The interactions of future environmental engines with the spliced genetic organism or plant then remains to be seen. Not all interactions would appear to happen in the limited test time usually allotted for testing the "effects". Anyway, that was the intention.

E.g., Pautrizel demonstrated that immature rats, having immature immune systems, would be restored by the Priore process back to the same immature immune system. The Priore process did not destroy the parasites themselves, but depended upon restoring the immune system back to its first ability to recognize the pathogen and go after it. Priore did not directly "kill" anything! In that case, the pathogens simply re-infected the immature rats, because their immature immune systems could not adequately protect them. It would be the intention of the research, in later generation equipment, to be able to design a specific "extra engine" and introduce it to the pumping, in addition to the "resident engine" in the subject to be treated. That "extra input engine" would accordingly generate a specific "extra antiengine" component in the total antiengine produced. When sufficient research and development maturity has been reached to be able to design such desired "extra engines" to cause the exact, desired extra antiengine to be produced, then the "extra antiengine" technique can be used, e.g., to time-reverse Pautrizel's immature infected rat back to an infected rat with a now-matured immune system. In that case, the rat's stronger immune system would make short work of the pathogen, just as analogously infected mature rats did.

To correct birth defects, etc., obviously one would have to change the actual time-path backwards, to a "state" that the body did not have physically, but which its genetics had before the damage. I foresee that eventually, after some years of development, the process would mature until it could regrow severed limbs, or correct dwarfism, etc. Of course that would be fourth or fifth generation, but it is definitely possible, given sufficient development.

Cheers,

Tom

AD 763210

QUITON/PERCEPTRON PHYSICS: A THEORY OF EXISTENCE, PERCEPTION, AND PHYSICAL PHENOMENA

by

Thomas E. Bearden

March 1973

Approved for public release; distribution unlimited.

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ABSTRACT

A fundamental answer is attempted to the questions of being, time, space, existence, perception, and physical phenomena. Mass, empty space, reality, gravitational attraction, continuity, discontinuity, and relativity are among the "things" and "nonthings" for which relationships and explanations are provided.

Perception is defined as detection by a mass of change to itself and as a differentiating process. Perceived physical phenomena are revealed to be first derivatives of ultimate reality, and outputs of the physical perceiving device call the "perceptron." Using the operation of the physical perception process on action, the units of which are energy times time, an entirely different view is generated of both reality and the Heisenberg uncertainty principle. When superposition is imposed as a condition, the Heisenberg uncertainty principle is revealed to be a quantized statement. A concept of the absolute value of a dimensional molecule is advanced.

A reality model is constructed of an action continuum and a nonaction continuum separated by an operational threshold whose magnitude is given by an uncertainty principle. Perception is modeled as a process which switches atomic quanta of action and nonaction back and forth across the threshold. Mass is explained as perceptron switch activity rate, and a mass definition equation is generated. One kilogram mass is shown to represent 17.053 x 10^{50} perceptron switches per second. From the model, Newton's laws of motion and gravity can be generated directly from the concept of the interaction of mass with space itself, space being taken as a massless fluid, or ether, composed of tiny nonaction particles called "quitons." Einstein's postulates of special relativity are also shown to follow from the model, and a statement of the equivalence principle is shown to be consistent with the model.

The concept of "lineception" as a causal chain of perceptron operations is advanced. "Inception" is developed as a noncausal modulation of lineception and as a distinguishing feature of a living system. The possibility is raised that inception could provide an explanation of the noncausal, statistical, ultramicroscopic universe and yet require large ensembles of ultramicroscopic events to conform to causality. Inception is shown to lead to karma. Perception is shown to be causal and to generate causality itself.

Some elementary philosophical implications of quiton/perceptron theory are pointed out and briefly discussed.

I. INTRODUCTION

The unsolved problems of physics stem from the unclear nature of the physical perception of change, and their resolution lies in the analysis of perception as a physical process. The unsolved problems of metaphysics stem from the same source, and can be resolved by the same perception analysis.

Specifically, a physical detection system can detect changes to itself and nothing else. These detected internal changes are thus what a detector "sees" or "observes" or "perceives" as changes to its external environment, i. e., as its physical phenomena. Thus a mass, being itself a physical detecting system, must detect only changes to itself, and these perceived changes to itself constitute its observed physical phenomena. For that reason, these perceived changes are obviously entirely relative to (i. e., are part of) the perceiver (observer); more precisely, they are entirely relative to and part of the perceiver's mass, which is the detector that is doing the perceiving.

Since only changes are perceived by a mass, then mass's perception must be a differentiating process. Ergo, perceived physical phenomena are first derivatives of a higher, or more fundamental, reality. The nature of that higher reality is by definition unperceivable (perception differentiates or fragments it), and it involves the quantity "action."[1] Action itself is not perceivable; change of action is perceivable since perception differentiates action. If superposition is placed on the Heisenberg uncertainty principle as a required condition, then the uncertainty principle contradicts itself for all except integral or zero multiples of a quantum of action. Correction of the uncertainty principle by imposing superposition as a condition provides a statement of the basic operation of perception -- the detection by a mass of change to itself.

All mental perception of a human being regarding physical phenomena is received (i. e., is inputted to the mind) from a physical sensory apparatus whose primary ingredient is mass. Thus we may describe the perceptive mind as consisting of sensory outputs of mass perceptions; that is, the input to mental perception must be the output of mass perception, and this interface within the mind may be referred to as the "perceptive mind."

From the above foundation, a comprehensive theory of perception can be constructed, and a most unusual model of "reality" emerges. A variety of unsolved questions are then resolved by the model. The resolutions include, among other things, 1) derivation of the postulates of relativity; 2) definition of the nature of time and space; 3) the explanation of gravity; 4) the generation of causality itself; 5) resolution of the wave theory of light with the quantum theory of light; 6) the explanation of why ultramicroscopic phenomena are statistical yet large ensembles of ultramicroscopic phenomena are causal; and 7) validation of Mach's principle and the equivalence principle. A totally new and precise definition of mass and of being itself are also two unexpected results. The problems of metaphysics are also answered: metaphysics is elevated to an exact science without any tinge of dogma, and physics and metaphysics are united.

---

[1] Planck's constant, Heisenberg's uncertainty principle, the principle of least action, the energy of a photon, etc., are derived from action and perception's differentiation of action.

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II. EXISTENCE, PERCEPTION, OBSERVATION AND PHYSICAL PHENOMENA

We first define perception[1] as detection by a mass of change[2] to itself, and state that it is an operation performed by that mass. The physical apparatus that accomplishes this perception is termed a "perceptron," which thus may be an electron, an atom, or the sensory apparatus of a living being.

A change detector does not detect the state of its input, but rather detects changes in that state. So in this sense a change detector can be regarded as a state differentiator. Therefore a perceptron differentiates, i. e., it perceives changes in its input and generates outputs in accordance. When its input is constant it will have no output. Thus zero output of a perceptron does not necessarily mean zero input.

What is to be fed into the perceptron's input section exists; i. e., existence (ultimate reality)[3] is defined as what is to be fed into the perceptron's input. The output of the perceptron is that which is perceived, or what we ordinarily call "physical phenomena."[4] Since the perceptron differentiates its input state, then physical phenomena are first derivatives of ultimate reality, which precisely accounts for the sharp separation between observable and nonobservable, i. e., between macroscopic and microscopic.

Any change in a perceptron's input section must involve both time change, Δt, and energy change, ΔE. So we may assume their product, $\Delta E \Delta t$, has always occurred in a perceptron's input whenever it produces an output. The output will be a derivative of the input, e. g.,

$$\frac{\Delta E \Delta t}{\Delta t} = \Delta E \tag{1}$$

and

$$\frac{\Delta E \Delta t}{\Delta E} = \Delta t \, , \tag{2}$$

where in each case the constant of proportionality has been ignored.

---

[1] We differentiate between perception and realization. Perception is entirely a physical process, and causal. Realization is a mental process and is not restricted to causal relationships.

[2] Reflecting, one notes that mass can only change in a nonmass manner. It cannot "change" without involving space and time, both of which are "nonmass." Therefore a mass change must be composed of both mass and nonmass.

[3] "Ultimate" in that it is higher or more fundamental than perceived reality.

[4] Changes to mass and only changes to mass constitute physical phenomena. Changes to one mass constitute "its" perceived physical phenomena, or its physical universe.

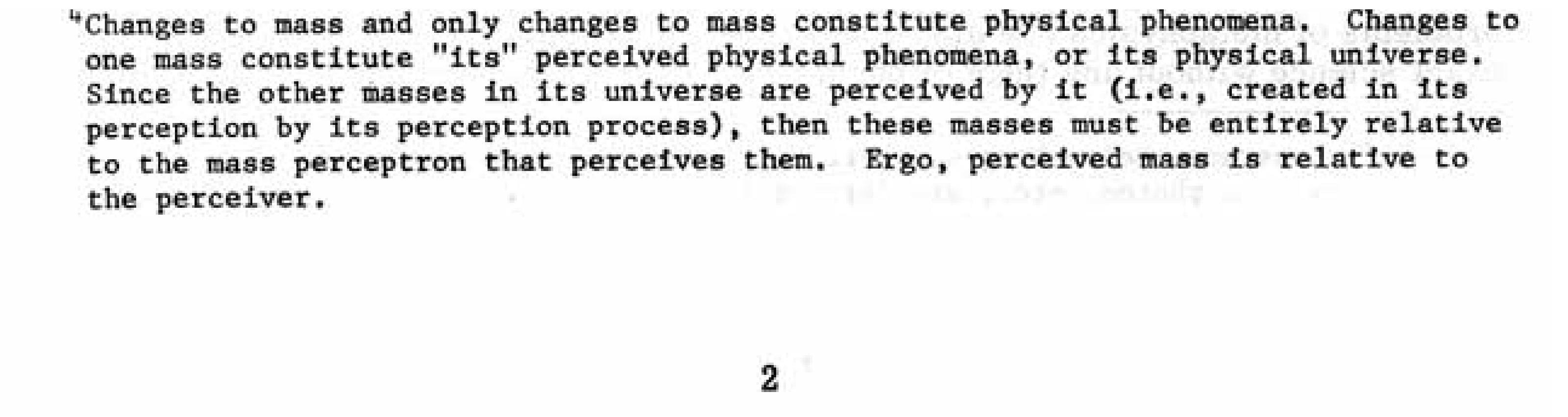

"Changes to mass and only changes to mass constitute physical phenomena. Changes to one mass constitute "its" perceived physical phenomena, or its physical universe. Since the other masses in its universe are perceived by it (i.e., created in its perception by its perception process), then these masses must be entirely relative to the mass perceptron that perceives them. Ergo, perceived mass is relative to the perceiver.

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Any detector has an operational input threshold, i.e., a minimum discernible signal. The Heisenberg uncertainty principle states the requirement for such energy-time changes:

$$\Delta E \Delta t \geqslant \hbar/2 \,. \tag{3}$$

Its smallest value, or

$$\Delta E \Delta t = \hbar/2 \,, \tag{4}$$

is then the input threshold for a physical perceptron to operate and produce an output.[1] Letting $k = \hbar/2$, we can write this simply as

$$\Delta E \Delta t = k \,. \tag{5}$$

Since existence has been defined as that which is fed into the perceptron's input, then that existence exists whether or not the perceptron operates, and the case[2] where

$$\Delta E \Delta t < k \,, \tag{6}$$

also exists (i.e., can be present in the input of a perceptron) but cannot be perceived or detected (i.e., the perceptron will not operate and produce an output).

At this point we diverge to remark that the product of energy and time is a quantity called "action," and the units of action are

$$A \equiv \frac{ML^2}{T} \tag{7}$$

Thus the input state to a perceptron is composed of an action continuum,[3] and the perceptron differentiates action quanta to produce physical phenomena.

---

[1] We acknowledge additional uncertainty statements but for simplicity will use only one in this paper.

[2] Equation (6) exists and it is proper to write it down and search out its ramifications. Equation (3) is a limiting condition which applies only to mass. But since our physical experience must involve nonmass (e.g., photons, space, time, being), then nonmass considerations must be examined. A good beginning is to consider the entire field of nonmass possibility, i.e., that field of nonmatter changes defined by (6), which includes the entire subquantum domain. So we legitimately examine two conditions: Eq. (3) must define (or apply as a condition to) the mass phenomena (change, quantized) system, and (6) must define (or apply to) the nonmass phenomena (subquantum) system.

[3] We exactly define continuity as the failure to perceive difference (change), and

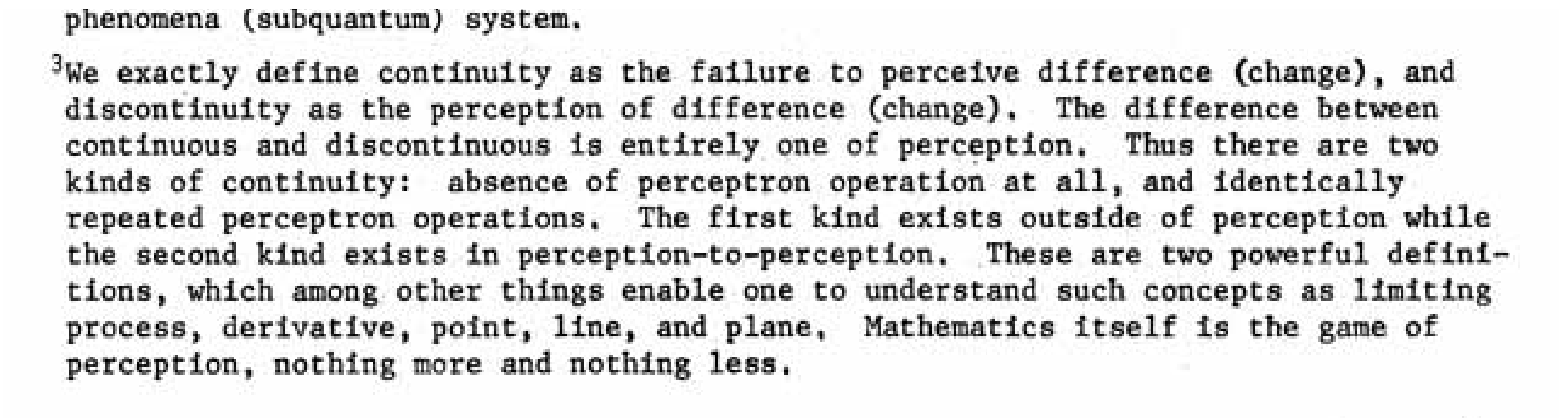

phenomena (subquantum) system.

[3] We exactly define continuity as the failure to perceive difference (change), and discontinuity as the perception of difference (change). The difference between continuous and discontinuous is entirely one of perception. Thus there are two kinds of continuity: absence of perceptron operation at all, and identically repeated perceptron operations. The first kind exists outside of perception while the second kind exists in perception-to-perception. These are two powerful definitions, which among other things enable one to understand such concepts as limiting process, derivative, point, line, and plane. Mathematics itself is the game of perception, nothing more and nothing less.

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When a large quantity of action is to be fed into a perfect perceptron, the input process cannot occur instantaneously; a Δt must be outputted (created)[1] by the perceptron for each operation. Thus perception processes steps or quanta of exactly k size, and exactly k size only. Inputs of less than k size are simply collected[2] until the aggregate is equal to k, then differentiated to produce an output. We must therefore rewrite the Heisenberg uncertainty principle as

$$\Delta A = nk \qquad , n = \pm 0, 1, 2, \ldots \quad , \tag{8}$$

where the plus and minus signs are necessary since action only has to change about some constant level in the perceptron input, and this change may be either additive or reductive (this quantum statement is actually the basis for quantum physics).[3] Thus, from the viewpoint of a perceptron, its output universe of physical phenomena is constructed by successive granular differentiation of unit operations, each of size k, but it detects no time lapse (creates no Δt) between operations.

When differentiated by a perceptron, an action atom may be regarded as being "chopped up" (the word "differentiated" literally means separated or torn apart):

$$\frac{\Delta E \Delta t}{n} = \frac{k}{n} \quad \bar{A} , \qquad n = 2, 3, 4, \ldots \quad , \tag{9}$$

where the bar over the A indicates nonaction, or action atoms which have been broken into bits.

Thus we now conceive of an action continuum of action atoms and a nonaction continuum[4] of bits of action atoms. The two continua coexist and the perceptron

---

[1] Or "extracted from an action quantum $\Delta E \Delta t$," which means exactly the same as "created." Einstein's treatment of simultaneity showed that it was operational, but if simultaneity itself is operationally created then both time and length must also be operationally created.

[2] This is not a simple discontinuous operation, since no time flow exists (Δt is not being outputted) during this collection process. We have to think of the process discontinuously, but the stepwise process is actually continuous (in time), or discontinuous, or both.

[3] Since ΔE may be positive or negative, we may state the uncertainty principle as $|\Delta E \Delta t| \geqslant k$, or as $\Delta A = nk$, $|n| \geqslant 1$. Consider the two cases $\Delta A > 0$, $n = 1$, and $\Delta A < 0$, $-1 < n < -2$. Superimposing them would give $|\Delta A| < k$, which violates the uncertainty principle. Thus, assuming superposition must hold, the uncertainty principle can be made to violate itself for all except integral values of n, and it follows that the Heisenberg uncertainty principle must be written as a quantized statement.

[4] The separation into two continua is artificial, but is necessary to allow us to perceive perceptron operation with our brain perceptron mind. There is absolutely

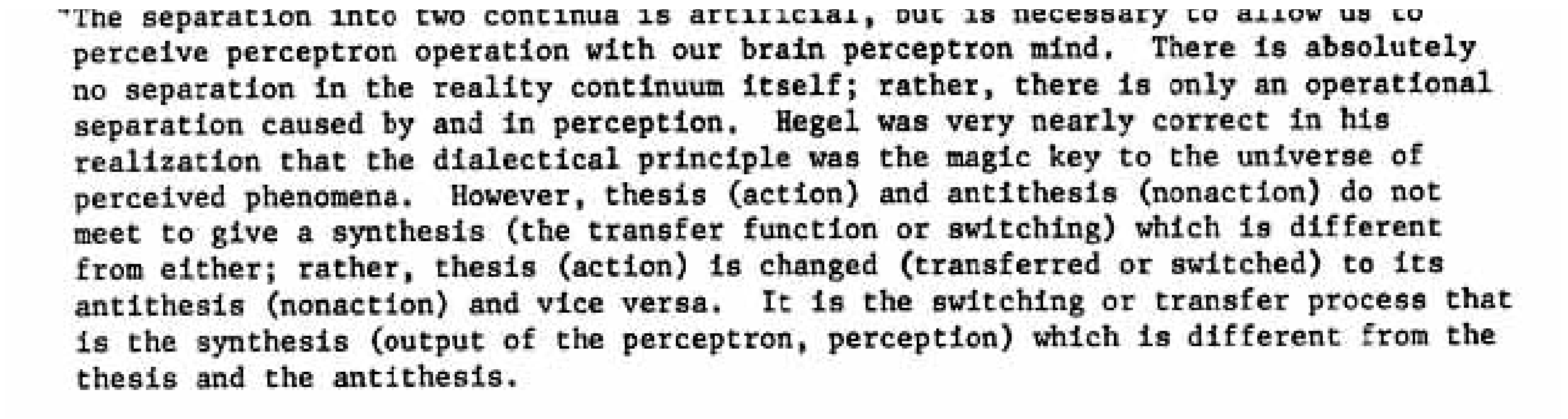

"The separation into two continua is artificial, but is necessary to allow us to perceive perceptron operation with our brain perceptron mind. There is absolutely no separation in the reality continuum itself; rather, there is only an operational separation caused by and in perception. Hegel was very nearly correct in his realization that the dialectical principle was the magic key to the universe of perceived phenomena. However, thesis (action) and antithesis (nonaction) do not meet to give a synthesis (the transfer function or switching) which is different from either; rather, thesis (action) is changed (transferred or switched) to its antithesis (nonaction) and vice versa. It is the switching or transfer process that is the synthesis (output of the perceptron, perception) which is different from the thesis and the antithesis.

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operates, or moves, in them. Only action quanta of exactly k size can be processed by the operating perceptron to give outputs which we know as physical phenomena. Such phenomena (events) consist of aggregates of extremely large numbers of perceptron operations. Action atoms will be referred to simply as "action atoms." The very smallest bits or fragments[1] of action atoms will be referred to as "quitons" and the symbol "q" used for one quiton. For convenience, we shall regard the "magnitude"[2] of q to be very much less than k, or

$$q \ll k \,. \tag{10}$$

The perceptron's process of collecting quitons to form action atoms will be termed "fusion," which is an additive change to the constant action continuum. "Fission" will be the term for the perceptron's process of breaking up action atoms into aggregates of quitons, where the size of each aggregate is less than k; fission is a reductive change to the constant action continuum. The term "switching" will be used to refer to either fission or fusion, or both.[3]

Fission and fusion are merely transfers or switches across the k-threshold separating the action and nonaction continua, and may be represented by either of the diagrams shown in Fig. 1.

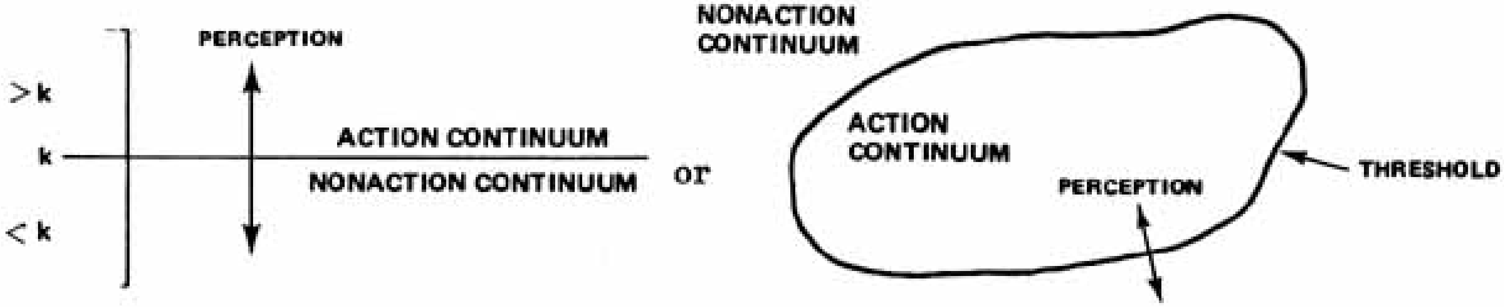

Fig. 1. Continua of the Universe

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[1] These are actually nonthings and not bits or pieces at all, but since we can only perceive or think of things, we will model them as things. The difficulty is in the nature of thought, not in the nature of reality.

[2] The perceivable magnitude of a quiton is zero, i.e., it is not perceivable.

[3] And, in fact, switching can also refer to the transfer of Δt into ΔL, i.e., the creation of space from time or vice versa. Separation (relation) is composed of ΔL and Δt, and we know from relativity that when relativistic (perceived) ΔL is changed, then relativistic (perceived) Δt is also changed. When time dilates, length contracts; and when time shrinks, length expands. Therefore the statement that length and time are intertransferrable is valid: one kind of separation can be transferred into another kind of separation just as one kind of energy can be changed into another kind of energy. Since this transfer itself is an operation, then there is a rate (i.e., a constant) of transfer. This constant is actually a parameter, since by special relativity it can vary as a function of the mass changes themselves. And since we are dealing with mass changes (perception), then the rate of transfer constitutes a rate of mass change (rate of perception). Since perception is finite

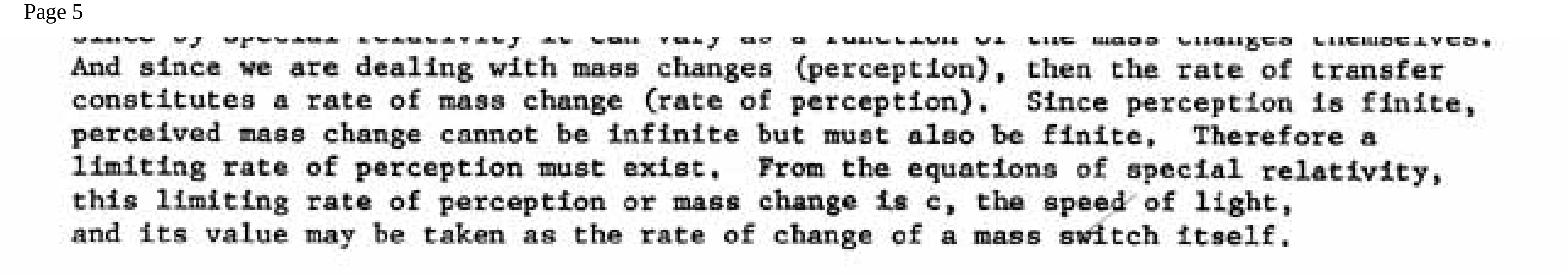

since by special relativity it can vary as a function of the mass changes themselves. And since we are dealing with mass changes (perception), then the rate of transfer constitutes a rate of mass change (rate of perception). Since perception is finite, perceived mass change cannot be infinite but must also be finite. Therefore a limiting rate of perception must exist. From the equations of special relativity, this limiting rate of perception or mass change is c, the speed of light, and its value may be taken as the rate of change of a mass switch itself.

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We now examine the expression for energy of a photon:

$$E = hf \tag{11}$$

Considering fission of an action atom as a chopping of that atom, the process can be expressed by:[1]

$$\begin{bmatrix}\text{Minimum}\\ \text{time rate of}\\ \text{change of action}\end{bmatrix} = \begin{bmatrix}\text{Energy}\\ \text{Transferred}\end{bmatrix} \simeq \begin{bmatrix}\text{atom of}\\ \text{action}\end{bmatrix} \begin{bmatrix}\text{cuts or chops}\\ \text{per second}\end{bmatrix}, \tag{12}$$

or

$$\frac{\Delta A}{\Delta t} = \Delta E = C_1 kf , \tag{13}$$

where C_1 is a constant of proportionality. According to Eq. (1), the energy perceived to be expended (transferred to quiton disturbances) in fissioning of an action atom ought to be proportional to the speed of the chopping action. Neglecting constants of proportionality, Eq. (13) is simply[2]

$$\Delta E = hf , \tag{14}$$

where the Δ symbol is deliberately added to show that it is a transfer process. The equation works in reverse for fusion of quitons into action atoms, i. e., the energy ΔE transferred to each action atom assembled is proportional to its rate of assembly.

We can now represent a perceptron as shown in Fig. 2, which corresponds precisely to the two-pronged arrows shown in the diagrams of Fig. 1. A perceptron has two channels, fission and fusion, in which switching transfers between action and nonaction are involved.

By Eq. (2), one of the outputs of a perceptron is Δt. Since perception creates its own time interval, it only has its kind of time, i. e., positive time, to deal with. Thus only positive time is perceived, and what we think of as positive time flow is merely the successive Δt's created by perception.[3]

---

[1] Note how admirably the view of tearing apart or differentiating the action atom describes the result. The smaller the Δt torn from $(\Delta E\ \Delta t)$ (or the quicker the separation), the larger the ΔE left (produced), i.e., the more energetic the separation. The atom of action is a quantum of action and one integral piece; the ΔE and Δt, however, are not necessarily of individually fixed size.

ΔE and Δt, however, are not necessarily of individually fixed size.

[2] Action atoms can occur in more than one size (see note 1 on p. 3).

[3] This explains why we sense existence as if we were the point of contact of a pointer moving along a time line. In effect, perceptron time advances one time slice at a time, where the slice is of Δt thickness. Thus all physical phenomena occur in minute granular sequences.

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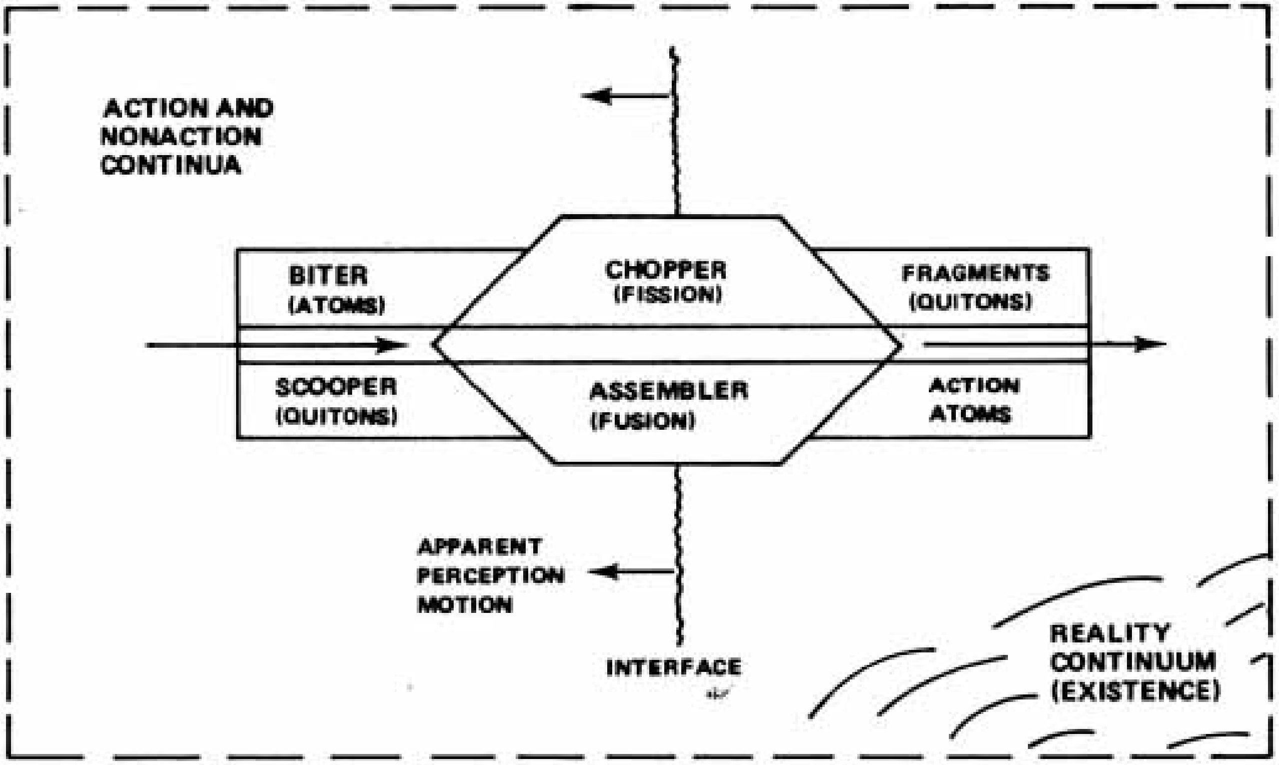
ACTION AND NONACTION CONTINUA
BITER (ATOMS)
CHOPPER (FISSION)
FRAGMENTS (QUITONS)
SCOOPER (QUITONS)
ASSEMBLER (FUSION)
ACTION ATOMS
APPARENT PERCEPTION MOTION
INTERFACE
REALITY CONTINUUM (EXISTENCE)

Fig. 2. The Fundamental Perceptron Switch

The existence of a negative time flow can be postulated by a simple symmetry analogy, but this postulated negative time, by definition, cannot be a perceptron output. We use the term "reflection" to denote a postulated operation in negative time[1] symmetrical to perception which operates only in positive time. Reflection is essential to the explanation of electric charge and charge effects,[2] but these will not be discussed here. Figures 3, 4, and 5 summarize the concepts of reflection, perception, and positive and negative time.

We now introduce the concept of absolute value of a dimensional molecule.[3] To illustrate, if we know that F = Ma, we will state that

$$|F| \equiv |Ma| \equiv |M| \times |a| = M\ |a| \quad , \tag{15}$$

where the last expression is true because of the nondivisibility of the unit ΔL and

---

[1] Modern theorists such as Feynman, Wheeler, and Dirac of necessity incorporate negative time operation into their theories involving action-at-a-distance.

[2] The quiton/perceptron theory can and does explain what "charge" is, why like charges repel and unlike charges attract, etc. It predicts the force of attraction or repulsion to be proportional to Q_1Q_2/R^2.

[3] Although perceptron output bits may vary in magnitude from operation to operation,

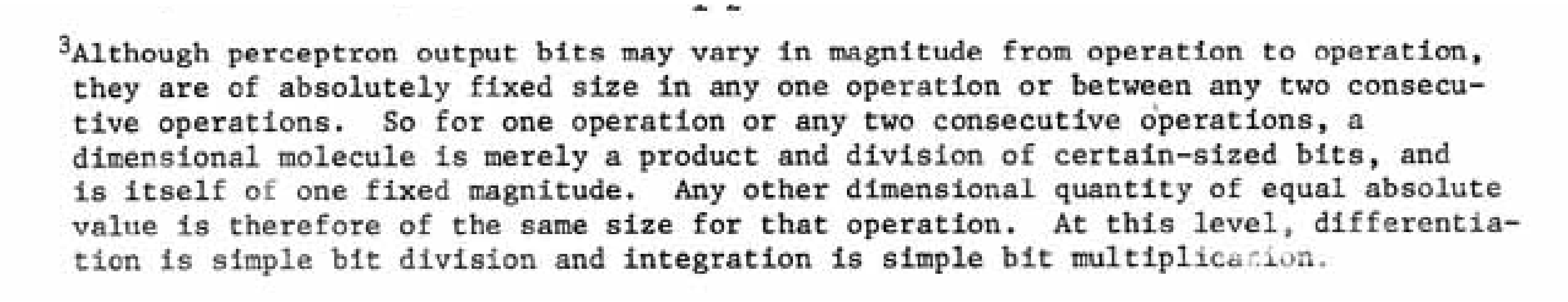

[3] Although perceptron output bits may vary in magnitude from operation to operation, they are of absolutely fixed size in any one operation or between any two consecutive operations. So for one operation or any two consecutive operations, a dimensional molecule is merely a product and division of certain-sized bits, and is itself of one fixed magnitude. Any other dimensional quantity of equal absolute value is therefore of the same size for that operation. At this level, differentiation is simple bit division and integration is simple bit multiplication.

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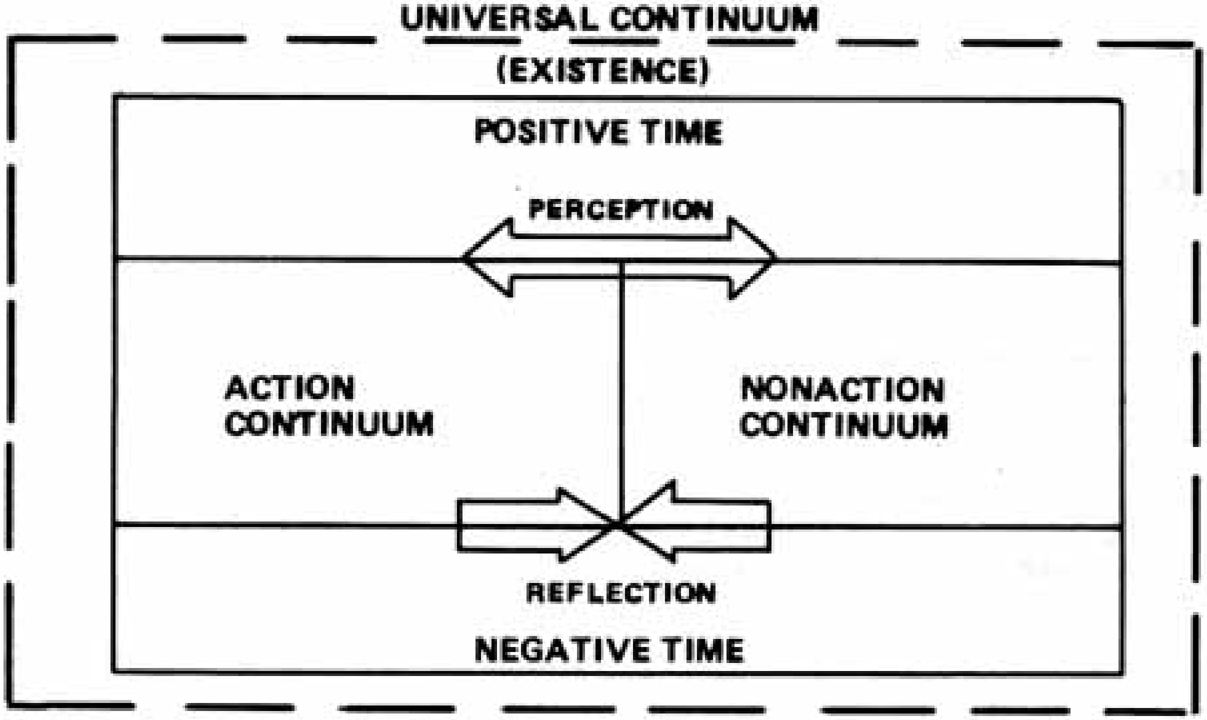
UNIVERSAL CONTINUUM
(EXISTENCE)
POSITIVE TIME
PERCEPTION
ACTION
CONTINUUM
NONACTION
CONTINUUM
REFLECTION
NEGATIVE TIME

Fig. 3. The Continua (Complete Model)

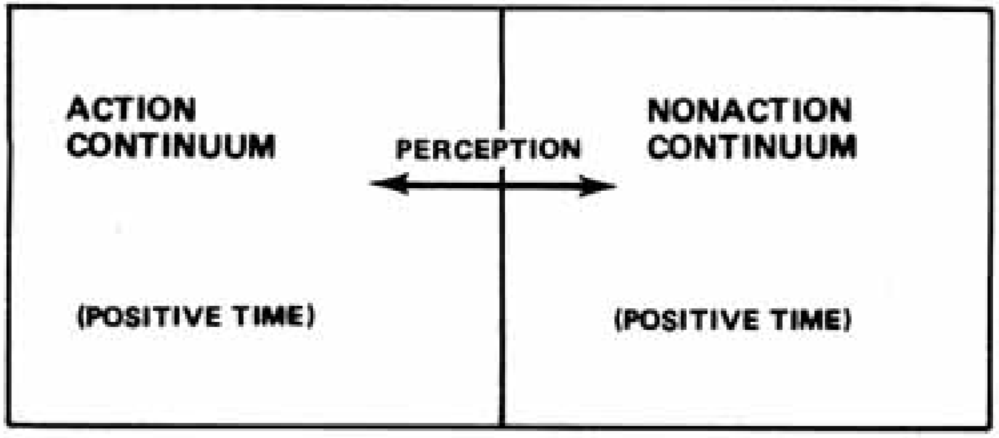
ACTION
CONTINUUM
PERCEPTION
NONACTION
CONTINUUM
(POSITIVE TIME)
(POSITIVE TIME)

Fig. 4. The Positive Time Continua --
Model in Which Perception Acts

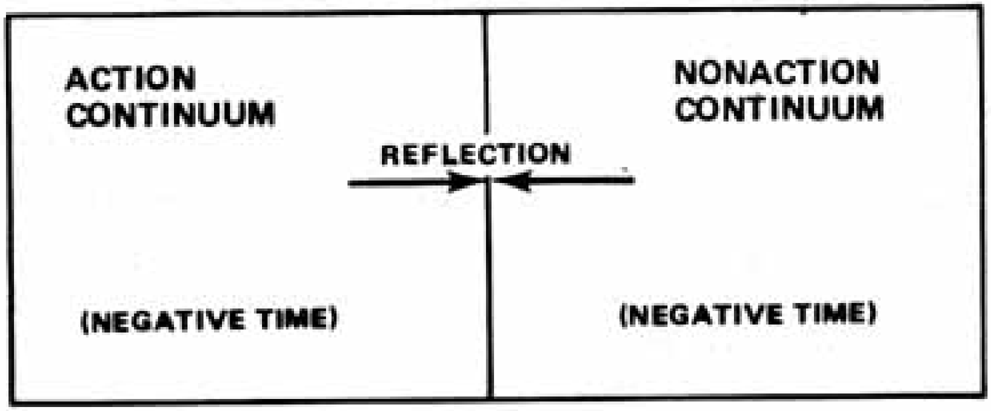
ACTION CONTINUUM
NONACTION CONTINUUM
REFLECTION
(NEGATIVE TIME)
(NEGATIVE TIME)

Fig. 5. The Negative Time Continua -- Model in Which Perception Does Not Act

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Δt quanta outputted by one perceptron operation. The absolute value signs must be added to any dimensional molecule which can take on either positive or negative values. Dimensionally,

$$M_0 = |E| \ , \tag{16}$$

where M_0 is rest mass and requires no absolute value sign since a quantity of rest mass is only positive. Actually, since perceptron operation only outputs quanta, then the perceptron outputs ΔE and ΔM_0, or

$$\Delta M_0 = \left|\Delta E\right| \ , \tag{17}$$

and repetition rate allows perception of M_0 as a positive quantity. Then,

$$\frac{\Delta A}{\Delta M} \longrightarrow \frac{\Delta(L^2)}{\Delta t} \ . \tag{18}$$

The perceptron expression of the right-hand side of (18) will be[1]

$$\frac{\Delta(L^2)}{\Delta t} \longrightarrow \frac{\Delta L \Delta L}{\Delta t} \longrightarrow \Delta L\,(V) \ , \tag{19}$$

and then we have

$$\Delta E \Delta t(V/V) \longrightarrow \frac{\Delta E(V \Delta t)}{V} \longrightarrow \Delta P(\Delta t)(\Delta L/\Delta t) \longrightarrow \Delta P \Delta L \ , \tag{20}$$

which must be another statement of the minimum condition of the Heisenberg uncertainty principle, or

$$k = \Delta P \Delta L \ . \tag{21}$$

It follows that

$$\Delta P \Delta L = nk, \qquad n = \pm 0, \pm 1, \pm 2, \ldots \tag{21a}$$

To consider why constant velocity yields special relativity, from $E = ML^2/T^2$ and Eq. (16), we can write

$$M = \left|\frac{ML^2}{T^2}\right| = M\left|\frac{L^2}{T^2}\right| \ . \tag{22}$$

Dividing out the M gives

$$1 = \left|\frac{L^2}{T^2}\right| = \left|\frac{L}{T}\right| = \frac{|L|}{|T|} = |V| \ . \qquad (23)$$

---

[1] Obviously $\Delta(L^2) = 2L\Delta L + (\Delta L)^2$, but the units of $2L\Delta L$ are $\Delta L\Delta L$.

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So velocity is a dimensionless quantity in the absolute dimensional sense, i.e., in the perceptron operational sense, and "the laws of physics apply equally well for all observers as long as they are moving with constant velocities" (Einstein's postulate). When the perceptron process is applied to a system of objects whose relative velocities are constant, the inputs to perception always differ by a constant value and the differentiated outputs of perception do not differ, i.e., the differential of $f(x) + C_1$ is identical to the differential of $f(x)$.[1]

Observation is related to perception as shown in Fig. 6. An observer observes only perceptron outputs[2] -- never ultimate reality -- from his sensory apparatuses.

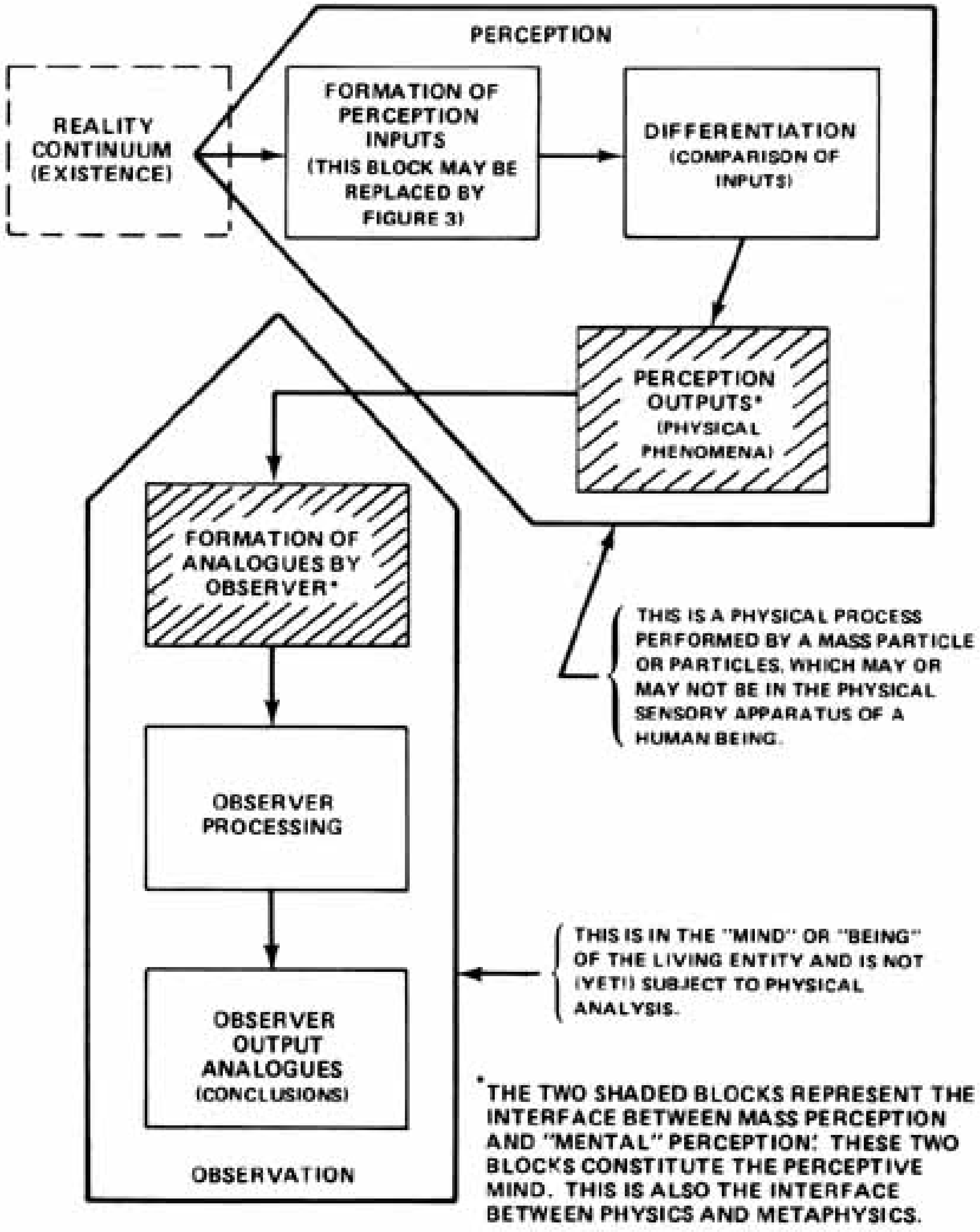
PERCEPTION
REALITY CONTINUUM (EXISTENCE)
FORMATION OF PERCEPTION INPUTS (THIS BLOCK MAY BE REPLACED BY FIGURE 3)
DIFFERENTIATION (COMPARISON OF INPUTS)
PERCEPTION OUTPUTS* (PHYSICAL PHENOMENA)
FORMATION OF ANALOGUES BY OBSERVER*
OBSERVER PROCESSING
OBSERVER OUTPUT ANALOGUES (CONCLUSIONS)
OBSERVATION

THIS IS A PHYSICAL PROCESS PERFORMED BY A MASS PARTICLE OR PARTICLES, WHICH MAY OR MAY NOT BE IN THE PHYSICAL SENSORY APPARATUS OF A HUMAN BEING.

THIS IS IN THE "MIND" OR "BEING" OF THE LIVING ENTITY AND IS NOT (YET!) SUBJECT TO PHYSICAL ANALYSIS.

*THE TWO SHADED BLOCKS REPRESENT THE INTERFACE BETWEEN MASS PERCEPTION AND "MENTAL" PERCEPTION: THESE TWO BLOCKS CONSTITUTE THE PERCEPTIVE MIND. THIS IS ALSO THE INTERFACE BETWEEN PHYSICS AND METAPHYSICS.

Fig. 6. Overall Relationships

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[1] Einstein's treatments of simultaneity and special relativity may be regarded as

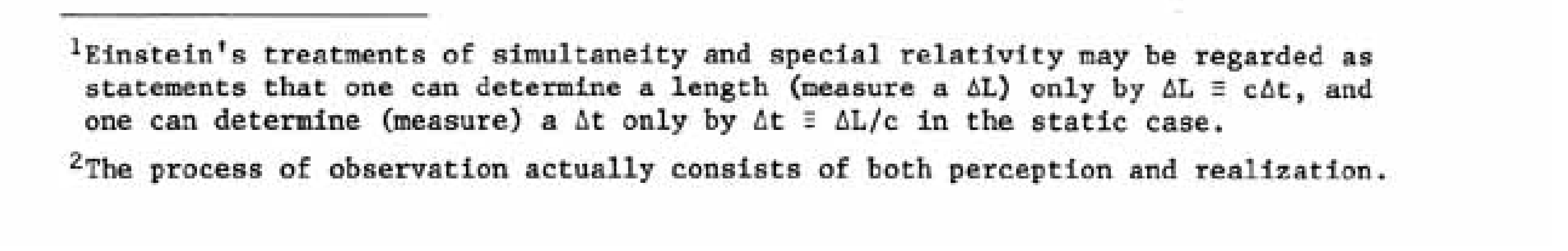

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[1] Einstein's treatments of simultaneity and special relativity may be regarded as statements that one can determine a length (measure a ΔL) only by $\Delta L \equiv c\Delta t$, and one can determine (measure) a Δt only by $\Delta t \equiv \Delta L/c$ in the static case.

[2] The process of observation actually consists of both perception and realization.

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III. MASS AND SPACE

The nonaction continuum may be further visualized as a sea or gas of small, unperceivable particles, i. e., of quitons and aggregates of quitons which are less than k in magnitude. Since mass is a perceived quantity and a quiton cannot be perceived, a quiton or aggregate of less than k magnitude has zero mass.

Since fission and fusion both constitute perceptron switching, we may explain mass by visualizing a changing pile of quiton bundles, each of k size, in which the total rate of switching activity is what we call the "mass"[1] of the pile. Thus the mass is equal to the sum of the absolute values of the fission and fusion activities:

$$M \equiv \left|\frac{\Delta A_i}{\Delta t}\right| + \left|\frac{\Delta A_o}{\Delta t}\right| \simeq \left|\dot{n}_i + \dot{n}_o\right| \quad k \ , \tag{24}$$

or

$$M \simeq \left|\dot{n}_i + \dot{n}_o\right| \qquad \text{sw/sec}, \tag{25}$$

where[2]

Δt = perceptron operation time (one operation)

M = perceived mass of the pile

ΔA_i = action created from fu~~z~~sing quitons into action atoms

ΔA_o = action lost from fissioning action atoms into quitons

$\dot{n}_i$ = number of k-sized bundles per second fused into atoms

$\dot{n}_o$ = number of atoms per second fissioned into quitons

sw/sec = one perceptron operation per second.

---

[1] If ΔE is time rate of change of action, and if the absolute dimensional value of rest mass and rest mass energy are the same, then mass must also be a time rate of change of action. One kilogram mass equals $17.053\text{x}10^{50}$ sw/sec.

[2] The switch concept is necessary to explain charge and charge effects. The switching occurs between the positive (perception outputted) and negative (reflection outputted) time streams. Three types of switches exist, two of which are charge switches and all of which are mass switches. Switching may also be regarded as change of Δt into ΔL. For a mass switch, the limiting value of the conversion parameter b in (ΔL = bΔt) is c, the speed of light. However, the

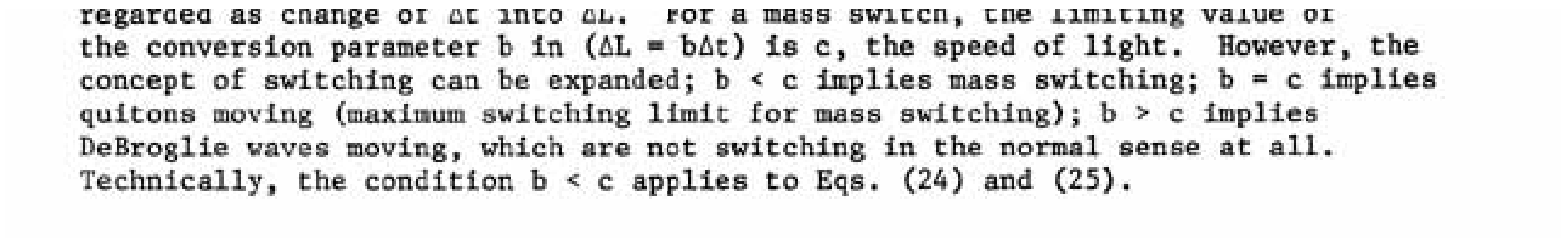

regarded as change of Δt into ΔL. For a mass switch, the limiting value of the conversion parameter b in ($\Delta L = b\Delta t$) is c, the speed of light. However, the concept of switching can be expanded; $b < c$ implies mass switching; $b = c$ implies quitons moving (maximum switching limit for mass switching); $b > c$ implies DeBroglie waves moving, which are not switching in the normal sense at all. Technically, the condition $b < c$ applies to Eqs. (24) and (25).

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The use of the mass definition equation can be illustrated by a simple example. First,

$$k \equiv h/2 = 0.527 \times 10^{-34} \text{ joule-sec} \tag{26}$$

$$1 \text{ kg mass} = 8.987 \times 10^{16} \text{ joules ,} \tag{27}$$

so

$$1 \text{ kg mass} = \frac{8.987 \times 10^{16} \text{ joules}}{0.527 \times 10^{-34} \text{ joule-sec/switch}} \tag{28}$$

$$1 \text{ kg mass} = 17.053 \times 10^{50} \text{ switches/sec.} \tag{29}$$

For a mass that does not accelerate, switches must occur in couplets. This would require, for example, that angular momentum be quantized in quanta of 2k magnitude, since two switches would process two action atoms -- one in and one out of the mass action pile. Since

$$2k = h/2\pi \ , \tag{30}$$

then angular momentum should be quantized in $h/2\pi$ quanta, which indeed it is: from the Bohr theory of the hydrogen atom,[1]

$$mvr = \frac{nh}{2\pi} \qquad , \ n = 0, 1, 2, \ldots \ , \tag{31}$$

and the change permitted is thus

$$\Delta(mvr) = \frac{nh}{2\pi} \qquad , \ n = 0, \ \pm 1, \pm 2, \pm 3, \ldots \tag{32}$$

What we normally think of as empty space is sometimes described as the absence of mass and energy, existing in time.[2] Empty space can be defined by

$$\frac{\Delta A}{\Delta t} = 0; \qquad \frac{\Delta \bar{A}}{\Delta t} = 0 \ , \tag{33}$$

which merely state that no perceptron output is occurring. Thus empty space exists only as defined by a perceptron and is merely the total absence of perception. While these equations rule out fission and fusion, they do not rule out the static presence of large numbers of quitons and quiton aggregates each of which is less than k in size (a quiton may be viewed as a quantum of space or a quantum of ether).

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[1] Beiser, Concepts of Modern Physics, McGraw Hill, 1963.

[2] Actually there is no time connected with the existence of space; the time is connected only with our perception of change; that is, space is a product of perception, or the nonoperation of perception, and is related to a mass perceptron. Similarly, space itself has no length -- length is relative between two masses. That is why both length and time can change, and why a specific length and a specific time can

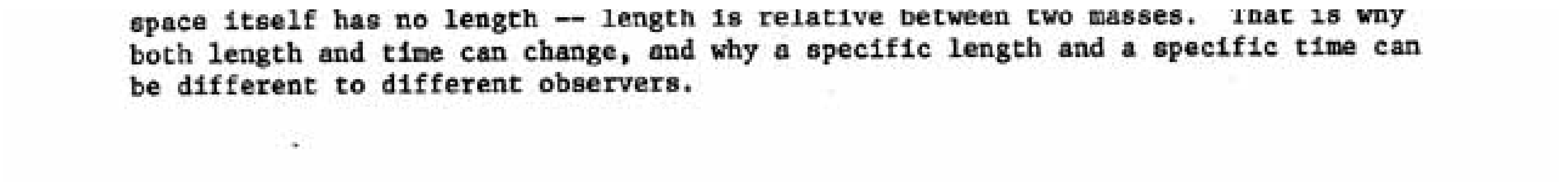

space itself has no length -- length is relative between two masses. That is why both length and time can change, and why a specific length and a specific time can be different to different observers.

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A massless quiton cannot individually generate any drag resistance against matter in the Newtonian sense. So a mass object moving along at a constant velocity will just push a stream of massless quitons ahead of it. In effect, the mass "bulldozer" is pushing its own medium along with it, and this requires no force.[1] Therefore, empty space (i. e., the zero output condition of one's mass perceptron) is filled with (has added to it) streams and streams of quitons moving ahead of other objects (perceived by one's perceptron) from all over the universe (perceived by one's perceptron). These quiton streams may be regarded as quiton pulses or quiton waves[2] in one's own static-relative quiton pond. The static-relative quiton pond of a mass will be called its "q-space" or "space" (more commonly referred to as the mass's inertial frame of reference).

When impinging on a perceptron's mass, these disturbances are being collected into k-sized quanta and switched into action atoms. The switching produces outputs that reveal the presences of the disturbing masses. The situation for a perceived mass is described in Fig. 7. Note that a fusion pileup is shown in front of the perceived object due to the object's motion, and a fission pileup is shown at the rear (switching is actually distributed throughout). Additional switching is occurring in the pileups and constitutes increase in mass. So one's mass perceptron perceives the moving object's mass as having increased. The relative velocity of the object with respect to one's perceptron determines the additional collection rate of quitons, and hence the additional switching rate, occurring for the object in one's perceptron q-space. The perceived increase in the moving body's mass is a function of the increased collection rate, which is a function of both the initial mass switch size M_0 and the velocity V, or

$$M = f(V,\ M_0)\ . \tag{34}$$

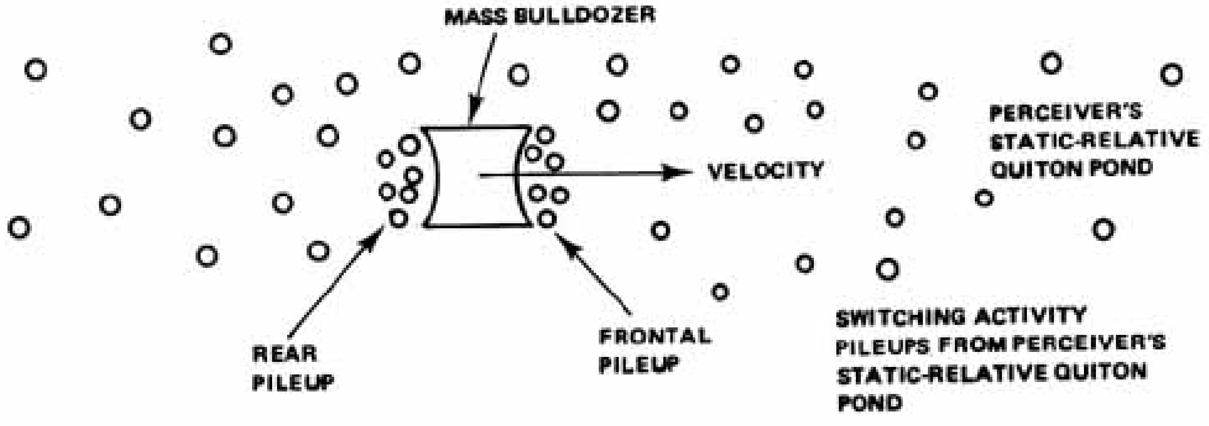
MASS BULLDOZER
VELOCITY
PERCEIVER'S STATIC-RELATIVE QUITON POND
REAR PILEUP
FRONTAL PILEUP
SWITCHING ACTIVITY PILEUPS FROM PERCEIVER'S STATIC-RELATIVE QUITON POND

Fig. 7. Increased Perceiver Switching Due to Perceived Velocity

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[1] More precisely, it requires no resultant (unbalanced) force. Both fission and fusion create forces; however, these forces are opposing, and so when fission rate equals fusion rate the resultant force is zero.

[2] These pulses or waves are not in themselves perceived, so one can equally well consider them bunches of particles or waves. The difficulty lies with the perceptron mind, not with the disturbances.

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If the perceiver shifts "his view" to the object, he would at the same time shift his perceptron to it and so would then see the same sort of effect existing on his vacated mass. The pileup is relative to the perceiver and is occurring in the perceiver's perceptron itself.[1] So material objects do not just move through an ether, they carry their own q-space ethers right along with them.[2] And all they can detect is the disturbances in that q-space that produces switching transfers in and out of the action and nonaction continua.

We now wish to know the standard medium velocity at which wave disturbances move in the q-space. The question is, what has zero mass, is unperceivable, and yet can move through the perceiver's empty space ether[3] at some standard velocity? Photons satisfy all these requirements. Photons themselves cannot be perceived -- only their interactions can; and photons move in free space at the velocity c, the speed of light. Thus c is the quiton medium's wave velocity[4] and quiton disturbances move in a q-space at the velocity c. They move only in a q-space and in nothing else, since movement (velocity) is defined as $\Delta L/\Delta t$, and both ΔL and Δt exist only to the perceptron that created them. Therefore, velocity of a perceived object is absolutely relative to the perceiver since it is part of the perceiver's mass's perception. At this point, Einstein's postulate that "the speed of light is the same for every observer" can be seen to follow directly from the quiton/perceptron model.

But a difference exists between the speed of light in q-space and the speed of light in a medium. Simply speaking, when light travels in a medium the quiton waves (photons) are perceived to interact with particles (get switched by other switches) continually. In each imposed interaction switching perceived, another Δt occurs in the perceiver's perceptron. Thus more Δt's occur, and the photon is perceived to take longer in traveling through the medium than through free q-space; that is, the perceiver's perceptron (in which the medium itself exists) creates more time output in the case of light traveling through a perceived medium than light traveling through unperceived free q-space.

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[1] This point is emphasized. The mass's mass does not increase as perceived by itself; its mass does increase as seen by the perceiver. This fact alone is sufficient to establish that the increase in mass is subjective, not objective (although these two terms are usually misused). That is what the term "relative" means, i.e., relative to the subject. Note that the perceiver is always the subject. The fact that the effect occurs only to the perceiver should indicate that it is the perceiver's perception process which is causing the effect.

[2] Thus one can have one space moving through another space.

[3] From Einstein's Theory of Relativity by Max Born, p. 224: "Einstein in later years proposed calling empty space equipped with gravitational and electromagnetic fields the 'ether,' whereby, however, this word is not to denote a substance with its traditional attributes. Thus in the 'ether,' there are to be no determinable points, and it is meaningless to speak of motion relative to the 'ether.' Such a use of the word 'ether' is of course quite admissible, and when once it has been sanctioned by usage in this way, probably quite convenient." The use of "ether" here is quite close to Einstein's proposal; however, in our usage it is meaningful to speak of "perceived motion of a perceived object" in the q-space ether of the perceiver. Otherwise, there can be no observation and no observer, which are of course necessary

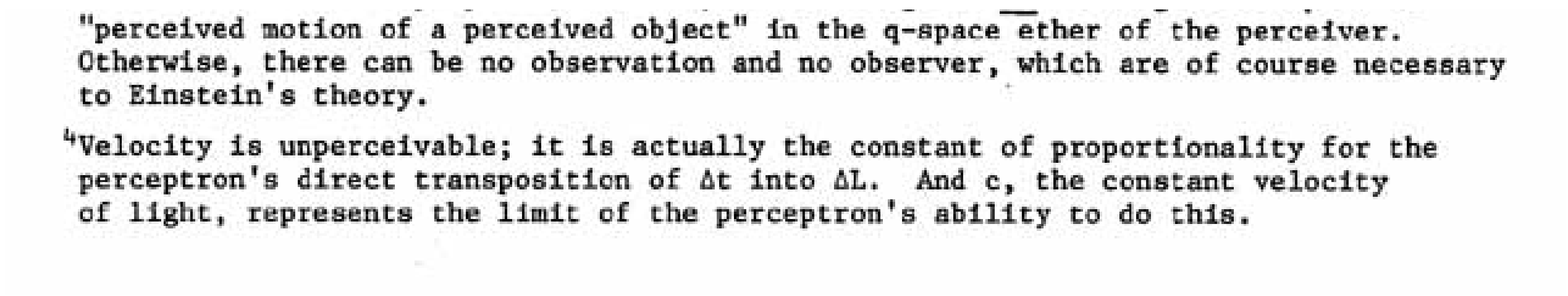

"perceived motion of a perceived object" in the q-space ether of the perceiver. Otherwise, there can be no observation and no observer, which are of course necessary to Einstein's theory.

[4] Velocity is unperceivable; it is actually the constant of proportionality for the perceptron's direct transposition of Δt into ΔL. And c, the constant velocity of light, represents the limit of the perceptron's ability to do this.

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It should be noted, but will not be pursued further here, that electromagnetic waves in space are merely quiton wave disturbances[1] moving in a perceptron's q-space. The energy being transmitted is the "energy equivalence" of the nonaction quiton aggregates that were chopped up from action atoms. When these fissioned aggregates are again collected in some perceptron, then $\overline{\Delta E}$ is recovered as ΔE, or perhaps as $\underline{\Delta M}$.

In passing, we note that hidden in the principle of complementarity is the fact that wave and particle are operationally excluded, i. e., separated by an operation. A wave by definition is operational (dynamic). The most elementary idea involved in the concept of a particle is that it is nonoperational; i. e., it doesn't have to move, or change, or function, or be dynamic to exist. Obviously that which is operational differs from (is separated from) that which is nonoperational, but such separation itself is differentiation which is an operation. Therefore, wave (operation) and particle (nonoperation) are operationally separated. The only "mystery" in complementarity is that one must stop (interfere with) an operational entity to have a nonoperational entity, and one must start (interfere with) a nonoperational entity to have an operational entity. Depending upon the conditions imposed upon it, an entity can be either operational or nonoperational. For example, the operation of superposition must be imposed upon DeBroglie waves before they can constitute a particle. It then follows that the particle's velocity must in fact be the velocity of the superimposed group, i. e., the wave packet's velocity. By the same reasoning it follows that one cannot measure a particle's exact position (which is a static or nonoperational entity) and its exact momentum (which is a moving or operational entity) at the same time. The same is true for the particle's exact time position (nonoperational) and its exact kinetic energy (operational). Thus uncertainty principles, complementarity, and the relationship of DeBroglie wave velocity to wave packet velocity all involve the one fundamental concept that an operational entity is separated from a nonoperational entity by an operation. The changing is separated from the unchanging by a change; i. e., the changing is operationally derived from the unchanging, or perceived reality is derived from unperceived reality.

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[1] Photons are aggregates of quitons; quiton aggregate behavior is particulate. Behavior from the standpoint of individual quitons is wave-like. This explains the dual behavior of light and reconciles its wave and quantum aspects.

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IV. IMPACT ON PHYSICS

A. MICHELSON-MORLEY EXPERIMENT

The Michelson-Morley experiment was conducted in the Michelson/Morley/earth q-space. The Michelson/Morley/earth perceptron(s) would perceive the speed of light to be the same in all directions, i.e., any fringe shift observed should have been a result of experimental uncertainty only. The experiment did not prove there was no ether; it did prove there was no perceivable ether[1] through which the earth was moving. The results admitted of a static-relative ether if it is unperceived. Perception is a process, and if the process does not occur then perception does not occur. Since by definition the q-space of a perceptron does not cause the perceptron to operate, then the q-space is unperceived by the perceptron.

More careful examination of observation reveals the following facts: A perceived mass has a constant mass when not moving with respect to the perceiver. When it is moving through the space frame or the ether of the perceiver with a constant velocity v, its perceived mass is again constant but is now perceived to be greater than was its rest mass. From whence came the extra mass?

The extra mass effect is only to the perceiver. The only possible sources for the extra mass in perception are the original rest mass M_0 and the empty space of the perceiver's space-frame (i.e., the interaction of perceived mass with unperceived space). Space does not drag, in the conventional Newtonian sense, against a moving body that is not accelerating. And space is unperceivable; therefore it can be visualized as a massless fluid. Thus the increase in perceived mass (which is a change) must come from the perceived mass's increase in velocity in perceiver space (because velocity is all that was changed), and it must involve the physical operation of the perceiver's physical perceiving mechanism. A perceived mass does exert resistance (drag) called "inertia" whenever it is accelerated in the perceiver's space-frame. This resistance is a force. Perceived force is equal to perceived mass times perceived acceleration through the perceiver's space.[2]

---

[1] Is not space an unperceivable ether? An extract from Einstein's Theory of Relativity by Max Born, p. 223, states: "If each of two observers who are moving relative to each other can assert with equal right that he is at rest in the ether, there can be no ether. Thus, the extreme development of the ether theory leads to its dissolution as a fundamental concept." The conclusion that there can be no ether does not logically follow. Each observer can assert that he is at rest in an ether (space), and these spaces can be intermoving. That is precisely what a "moving frame of reference" is: one space moving through another. Today we retain the (or more correctly, an) ether concept, but call it "space" or "inertial frame of reference" or "frame." The conclusion should have been that there can be no single "stable ether," but that there can be many.

[2] Newton's law, $F = ma$,* to date has been used in a half sense, i.e., that the acceleration of a perceived mass through the perceiver's unperceived q-space generates force. If this is true, and relativity holds, then the acceleration of any other unperceived q-space, through a perceived mass, also generates force; through one perceived mass in a perceiver's q-space, the q-spaces of all other perceived accelerating masses are accelerating and thereby generating forces on it. By this "other half" of Newton's law and by relativity, Mach's principle (that inertia of a mass is derived from the

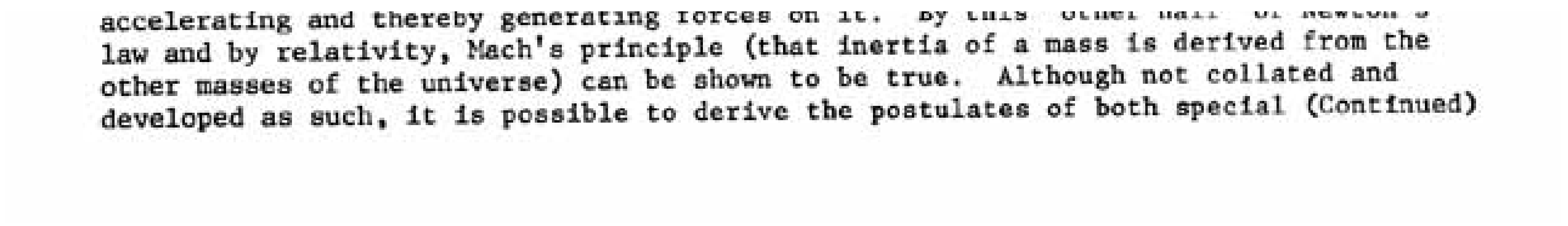

accelerating and thereby generating forces on it. By this "other half" of Newton's law and by relativity, Mach's principle (that inertia of a mass is derived from the other masses of the universe) can be shown to be true. Although not collated and developed as such, it is possible to derive the postulates of both special (Continued)

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This equation states that a perceived accelerating mass must react with the perceiver's q-space, and in fact this interaction may be taken as the basic mechanism that creates force itself. Again the perceiver's physical perception mechanism is the causative agent.

A quite logical conclusion at this point is that the perceiving mechanism perceives (produces) additional perceived mass from the interaction of perceived rest mass with perceived mass-motion (velocity) through its unperceived space.[1] Also, the perceiving mechanism produces perceived inertial drag from the interaction of perceived mass with the mass's perceived acceleration through its unperceived space.

The concept of "ether" should not be rejected while the concept of "space" is retained, since the latter is actually an unperceivable ether. Rather, the concepts of mass, perception, and ether-space should be tailored to fit the perceived phenomena. Quiton/perceptron theory (perception theory) is a deliberate transfer function model specifically tailored to fit these criteria.

B. GRAVITATIONAL ATTRACTION

Newton's law of universal gravitation can be generated, in both effect and form, from quiton/perceptron theory.

A perceptron's q-space is filled with streams and streams of quiton disturbances moving ahead of its perceived moving objects from all over its universe. Thus there exists a flux of quitons at any point in its space, and this flux is isotropic to the first approximation: because of the vast interstellar distances between disturbing masses, the flux gradient in the relatively local neighborhood of any perceiver point is essentially zero. The quiton disturbance flux can be represented as shown in Fig. 8. A quiton flux stream switching pressure P_1 is exerted on M_1 and a switching pressure P_2 is exerted on mass M_2. In any one flux stream line in this shadowed zone, the pressure against either of the two bodies is reduced in proportion to the amount of switching flux subtracted from that flux line by the other body. The total reduction of switch pressure in the shadowed zone is therefore proportional to the product of the two masses M_1 and M_2, considering the effects to be mutually independent.

(Footnote 2 continued from preceding page) and general relativity from quiton/perceptron theory, and the steps essential to that derivation are contained in this paper.

*[More precisely, $F = d/dt\ (mv) = ma + v\ dm/dt$. From the second term, increase or decrease in mass of a moving object also produces a force. This second force component may not be too important except in microscopic phenomena, but for fast microscopic changes in mass (e.g., in the nucleus) it could generate significant forces. Also note that the velocities of all other spaces (i.e., velocities of the q-spaces of all other moving objects) in the perceiving mass's universe interact with its perceived mass change rates, according to the second term of Newton's law, relativistic form.]

[1] A disagreement has long existed over whether a "nonthing" exists if it cannot be observed. The argument is illogical; e.g., if a photon itself cannot be perceived

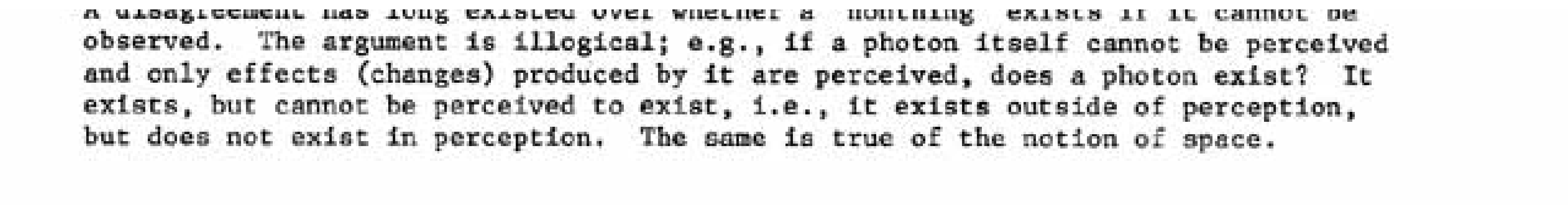

A disagreement has long existed over whether a "nothing" exists if it cannot be observed. The argument is illogical; e.g., if a photon itself cannot be perceived and only effects (changes) produced by it are perceived, does a photon exist? It exists, but cannot be perceived to exist, i.e., it exists outside of perception, but does not exist in perception. The same is true of the notion of space.

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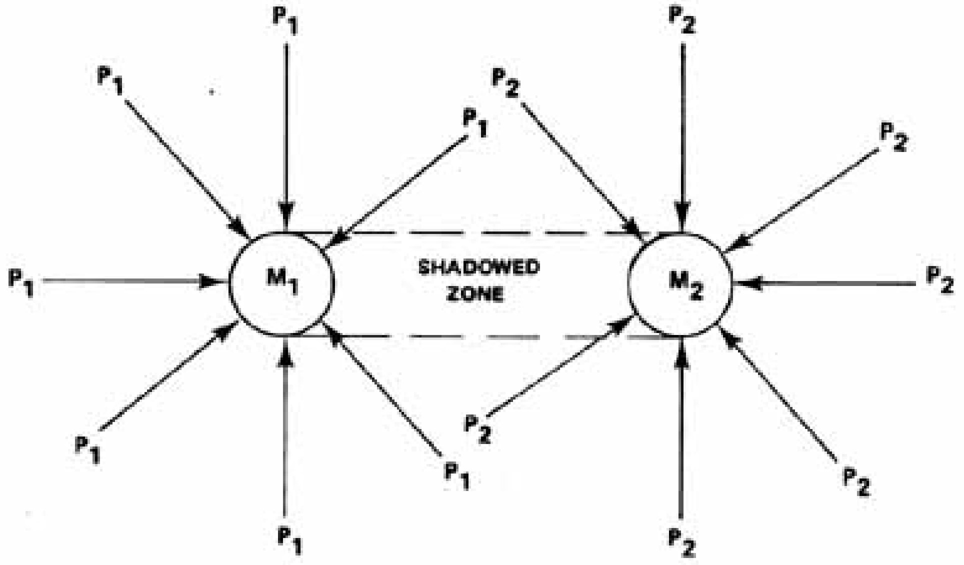

Fig. 8. Gravitational Attraction of Masses

From purely geometrical considerations, a shielding factor is also present due to the solid angle that is shadowed about any mass point. This effect is proportional to $1/R^2$ by usual solid angle considerations. Putting these two factors together, the attraction of mass should therefore be proportional to M_1M_2/R^2, or

$$F = K \frac{M_1M_2}{R^2} \tag{35}$$

which is the expression for Newton's universal law of gravitational force, and this force is driving the two masses together.[1] By merely extending the basic statement by superposition of the effects of every perceived mass-pair in the perceptron's universe, one obtains the attraction of mass[2] for the universe.

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[1] It is not accidental that electric, magnetic, and gravitational field forces all obey "inverse square of the distance" laws, since these forces are derived from analogous switching operations.

[2] Attraction of mass implies an effect derivable from the presence of mass only. Mass is a switching rate. Therefore attraction of mass must be derived from switching only. Now a massless fluid generates no drag against a constant velocity mass, but switching is a negative quiton acceleration which does generate force. So switching generates drag, but constant velocity does not. This accounts for the error long made in considering the "mass shadowing" explanation of gravitational attraction to suffer from a serious defect of implied retardation force due to velocity through an ether-flux (see, for example, the Feynman Lectures on Physics, Vol. 1, p. 7-9). Velocity of an ether flux through a body merely affects the mass of the body; it does not generate force. Acceleration of an ether flux through a body generates a resultant force on that body. In Feynman's example of an orbital body, let us assume perfect circular motion with constant speed. Since the speed of the ether flux is always constant, the mass is always constant. Since the component of acceleration tangential to the circle is zero, there is no force generated tangentially to the orbit. But since there is a constant radially outward acceleration of flux through the orbital body, then there is a constant radial force outwards that is generated, and this force is called the "centrifugal force," i.e., the "center-fleeing" force.

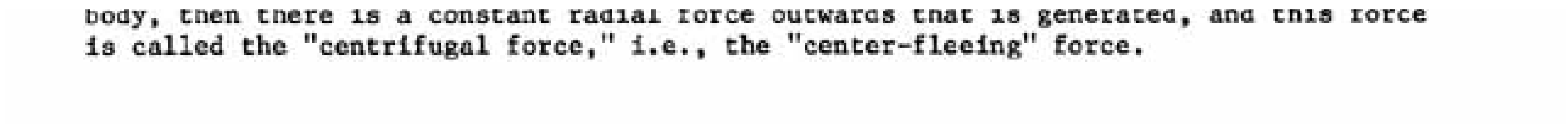

body, then there is a constant radial force outwards that is generated, and this force is called the "centrifugal force," i.e., the "center-fleeing" force.

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It should be noted that for extremely small masses at extremely close distances, or for extremely short times, turbulence and interference effects can form in the shadowed zone of Fig. 8 and superposition may no longer hold.

C. NEWTON'S THIRD LAW OF MOTION

One of the recognized ways of stating Newton's third law of motion is: "To every action force there is an opposite and equal reaction force." This law follows from quiton/perceptron theory, as can be shown by examining two colliding bodies. It should be stressed that these two bodies, and all changes related to them, exist as changes in the output of the perceiver's perceptron. It must always be borne in mind that these changes, or physical phenomena, exist as outputs of the perceiver's mass perceptron.[1,2]

Figure 9 shows perceived bodies M_1 and M_2 in constant velocity motion just before collision. A deliberate choice was made of a case where the momenta of the two bodies were not equal, so that the initial switching rates for the two masses were different. In the example, $M_1V_1 > M_2V_2$. The mass switching drag of each body is again represented by small circles. Each body has the same size roll in front as in the rear, so its switch pressure forces are balanced. Figure 10 shows the collision.

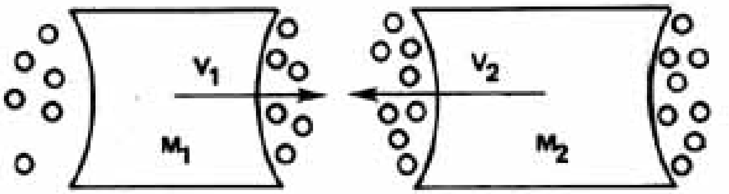

Fig. 9. Two Bodies Before Collision

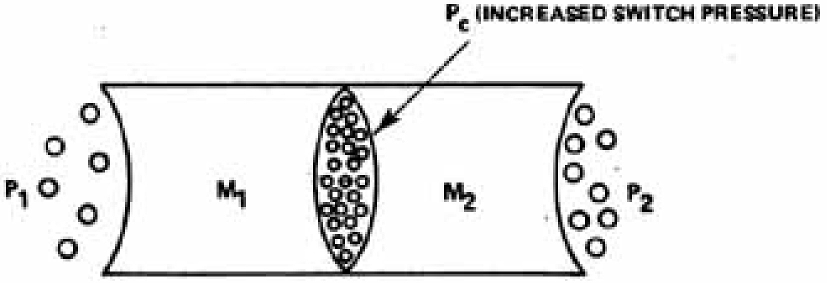

Fig. 10. Two Bodies at Moment of Collision

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[1] We consider the question: "If a tree falls in a forest and there is no ear to hear it, is there a sound created?" A tree is a perceived tree, a forest is a perceived forest, and a fall is a perceived change. Their presence or existence implies a perceiver and perception; thus they imply that a "sound" change would be perceived, since they imply a perceiver to perceive it. If, however, by "no ear to hear it" we mean "no perceiver present at all," then the question as posed contains a self-contradiction: with no perceiver, there can be no perceived tree, perceived forest, perceived fall, or perceived sound.

[2] The manner of searching for quiton/perceptron causal explanation of a physical

or perceived sound.

[2] The manner of searching for quiton/perceptron causal explanation of a physical phenomenon is to ask, "What would the perceptron have to do to generate the phenomenon?".

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There is an almost instantaneous switch pressure increase in the contact zone between the colliding bodies, and consequently there is a switch pressure differential across each body as shown in Fig. 11.

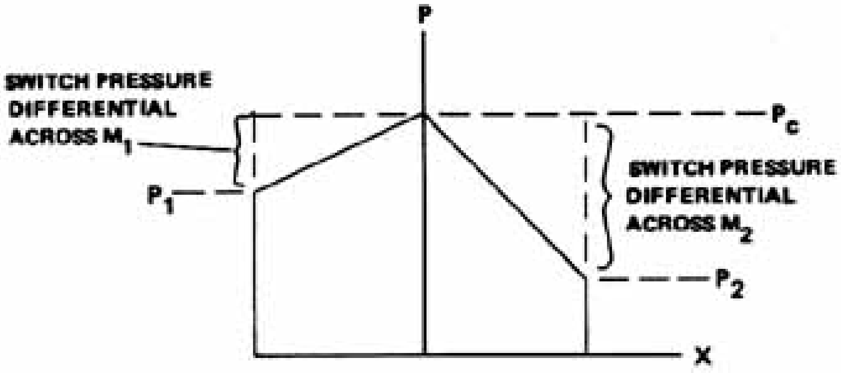
P
SWITCH PRESSURE DIFFERENTIAL ACROSS M_1
P_1
P_c
SWITCH PRESSURE DIFFERENTIAL ACROSS M_2
P_2
X

Fig. 11. Switch Pressure Relationships at Collision

In the figure, the contact pressure P_c is exerted against each body, so that the pressure forces on the two bodies act in opposite directions. But for any two colliding bodies, the contact areas, one against the other, are the same. This common contact area will be called A_c. Since $P \equiv F/A$, then

$$|F_1| = |F_2| = P_c A_c \ . \tag{36}$$

But since the pressure forces on the two bodies are being exerted in opposite directions, then

$$\vec{F}_1 = -\vec{F}_2 \ , \tag{37}$$

which is Newton's third law of motion.

D. NEWTON'S SECOND LAW OF MOTION

Neglecting constants of proportionality, Newton's second law of motion may be stated in the most general sense as

$$F = \frac{d(mv)}{dt} \ . \tag{38}$$

The first step in deriving this law is to examine a point mass which is perceived moving with velocity $\vec{V}$, as shown in figure 12.

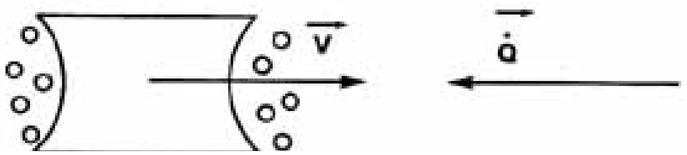

Fig. 12. Moving Point Mass

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An increased rate of quiton switching activity exists along the axis containing the velocity vector $\vec{V}$. We will call this increased quiton activity a vectorial "current" $\vec{\dot{Q}}$, and define its direction as contrary to the velocity vector. The mass is perceived to be moving against the current vector, and

$$\vec{\dot{Q}} \ \alpha \ -\vec{V} \ . \tag{39}$$

When the current $\vec{\dot{Q}}$ is steady, i.e., when

$$\vec{\dot{Q}}_{in} = \vec{\dot{Q}}_{out} \quad , \tag{40}$$

then the switching activity, and hence the mass and the energy, are constant. Therefore, from $v = \pm\sqrt{2E/m}$, the velocity remains constant.

If $\vec{\dot{Q}}_{out}$ suddenly increases, then

$$\vec{\dot{Q}}_{in} < \vec{\dot{Q}}_{out} \quad , \tag{41}$$

which can be represented as in Fig. 13.

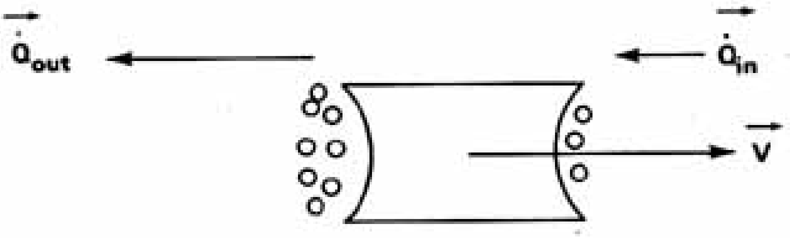

Fig. 13. Difference in Quiton Current

From Eq. (39),

$$\vec{\dot{Q}} = -k_1\vec{V} \ . \tag{42}$$

At any time in a quiton current, the switch pressure force exerted against the mass can be represented as

$$F = P_cA_c \quad , \tag{43}$$

where P_c is the switch pressure and A_c is the area of contact. However, since the area of contact A_c, or the drag area, is the mass switch rate itself, then (neglecting constraints of proportionality)

$$A_c \sim M' \tag{44}$$

$$A_c \alpha M' \quad , \tag{44}$$

where M' is the switch rate at the point of switch pressure application. We will next examine the switch pressure forces before and after one perceptron operation

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(i. e., across the smallest possible time interval Δt used by the perceptron itself in perceiving a change). When there is any difference in the pressure forces against the body front and body rear, this difference is the resultant force $\vec{R}$, or

$$\vec{R} = \left[(P_c A_c)_{in} - (P_c A_c)_{out}\right] \vec{q} \quad , \tag{45}$$

where $\vec{q}$ is a unit vector whose direction is given by the direction of $\vec{\dot{Q}}_{in} - \vec{\dot{Q}}_{out}$. Now, from Eq. (44),

$$\vec{R} = \left[(M' P_c)_{in} - (M' P_c)_{out}\right] \vec{q} \quad . \tag{46}$$

Since $P_c \ \alpha \ \dot{Q}$ and $\vec{\dot{Q}} \ \alpha \ (-\vec{V})$, then (neglecting constants of proportionality)

$$\vec{R} = - \left[(M'\vec{\dot{Q}})_{in} - (\overrightarrow{M'\dot{Q}})_{out}\right] \quad , \tag{47}$$

which from Eq. (39) gives

$$\vec{R} = (M'\vec{V})_{in} - (M'\vec{V})_{out} \tag{48}$$

or

$$\vec{R} = K_4 \Delta(M'\vec{V}) \quad . \tag{49}$$

However, this has happened in the smallest possible time Δt, and since by definition

$$\Delta(M'\vec{V})_{min\ \Delta t} = (\dot{\overrightarrow{M'V}}) \quad , \tag{50}$$

then

$$\vec{R} = k_4(\dot{\overrightarrow{M'V}}) = k_4 \frac{d}{dt}(M'\vec{V}) \quad , \tag{51}$$

which is Newton's second law of motion, relativistic form. Acceleration of a body is caused by a difference in mass switch rate (i. e., a switch rate gradient)[1] induced across it by transfer of momentum from another moving body or by induction from a field such as an electrostatic field or a magnetic field.

E. NEWTON'S FIRST LAW OF MOTION

Newton's first law, that "a body at rest or in uniform motion will remain at rest or in uniform motion unless some external force is applied to it," can be derived from the same type of considerations used to develop the second law. Obviously, if

$$\vec{\ddot{Q}} = 0 \quad , \tag{52}$$

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[1] Switching can be thought of as transfer of Δt into ΔL. An increased switch rate represents an increased rate of transfer resulting in a higher value for the ratio

[1] Switching can be thought of as transfer of Δt into ΔL. An increased switch rate represents an increased rate of transfer resulting in a higher value for the ratio of ΔL to Δt being outputted. Since the ratio $\Delta L/\Delta t$ is defined as v, an increase in this ratio increases the velocity, and thus acceleration occurs.

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then

$$\vec{R} = 0 \tag{53}$$

and

$$\vec{a} = 0 \quad , \tag{54}$$

in which case the body at rest will not move and the body in uniform motion will remain so, by the definition of acceleration. Every perceptron repetition will output the identical value for V as the preceeding repetition, and that is why the first law holds.

F. IDENTITY OF LENGTH AND TIME

From $E = Mc^2$, we have

$$c^2 = E/M = 9 \times 10^{16} \text{ joules/kg} \tag{55}$$

$$c^2 \Leftrightarrow 9 \times 10^{16} \text{ joules/kg} \times 1/17.053 \text{ kg sec/sw} \tag{56}$$

$$c^2 \Leftrightarrow 0.527 \times 10^{-34} \text{ joule-sec/sw} \tag{57}$$

$$c^2 \Leftrightarrow \text{k/mass switch} \ . \tag{58}$$

Thus

$$c^2 = (3 \times 10^8)^2 \text{ m}^2/\text{sec}^2 \Leftrightarrow \frac{\text{k}}{\text{mass switch}} = \text{one sw opn} \tag{59}$$

$$\text{one sw opn} \Rightarrow (3 \times 10^8)^2 \text{ m}^2/\text{sec}^2 \tag{60}$$

$$\Rightarrow 3 \times 10^8 \text{ m/sec} \tag{61}$$

$$\Rightarrow 1 \text{ sec} = 3 \times 10^8 \text{ meters} \ . \tag{62}$$

Length and time are thus synonymous,[1] and c is the constant of proportionality (more precisely, the identical ratio for transposing Δt into ΔL will be maintained for each perceptron operation). Therefore, a perceptron actually outputs only one thing which may be taken to be either Δt or ΔL (it actually outputs only change that abnormal (turbulent) switching can deviate from this limitation. Thus "time warping," "time travel," "hyperspace travel," and the interplanetary drive may indeed be possible. Since at least one of these effects of turbulence in switching (that of DeBroglie wave velocity exceeding the speed of light) is theoretically accepted, the problem of turbulent switching should be well worth the theorist's attention and effort.

---

[1] By "synonymous" we mean that Δt and ΔL are intertransposable by perception operation. The term c is the velocity (rate of change) of switching itself, i.e., the speed at which quitons themselves can move, since quitons are being switched by mass. Therefore c ought indeed to be the wave velocity at which quitons move, and thus represents the maximum ΔL obtainable from Δt by mass in normal switching. The possibility exists that abnormal (turbulent) switching can deviate from this limitation. Thus "time warping," "time travel," "hyperspace travel," and the interplanetary drive may indeed

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itself, which is perceived and thought of as ΔL and Δt). All other dimensions, quantities, and dimensional molecules are but bit division or bit multiplication. This seems to be consistent with some of the latest conclusions from general relativity theory.

In passing we note that there is no separation without relation, and there is no relation without separation. Therefore

$$\text{relation} \Leftrightarrow \text{separation.} \tag{63}$$

Also, there is no operation without separation, and there is no separation without operation. Therefore

$$\text{operation} \Leftrightarrow \text{separation.} \tag{64}$$

It follows that

$$\text{operation} \Leftrightarrow \text{separation} \Leftrightarrow \text{relation.} \tag{65}$$

We note a difference between free space and a Cartesian space (inertial reference frame). In a Cartesian space or inertial reference frame a definite length is considered to have been established for each and every point in that frame. But such a definite length to each point is rigorously operational by statement (65) above, i. e., such a length is defined by an operation. Specifically, it is defined by the operation of a mass perceptron (or an understood mass perceptron) at the origin of the frame. Such a frame is linear if the identical type of perceptron operation has defined the length to each point. If the type of defining operation varies, then the frame so defined is nonlinear; i. e., its space is said to be curved or distorted.

In one perceptron, its length defining operation and its mass defining operation can interfere or react one with the other. This type of interference or interaction is the direct interaction of frame space (length) with mass and it is the fundamental generating mechanism of force. All forces are so generated (see again the inset footnote on p. 17). And in fact a perceived moving force does work in the direction of its perceived movement rather than in the force's perceived direction precisely because of the moving operational length's interaction (interference) with the operationally generated force. This interference interaction is between operations in the same perceptron and generates what is called work.

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V. ELEMENTARY PHILOSOPHICAL IMPLICATIONS

Every scientific treatise is filled with forms of the words "one" and "be," yet none attempt to define these metaphysical terms. Ontologists and metaphysicians have uncovered many problems connected with these two words, but no real solutions. In addition, the historical preoccupation of metaphysics with dogmatic religious beliefs contributed strongly to its disfavor, since scientists were required to exert considerable effort to establish the scientific (observational) method as a legitimate criterion for the judgment of physical truth. Consequently, both science and philosophy today are constructed on quite undefined foundations, primarily because of the failure to recognize the relationship of perception operation to reality, which recognition is a prerequisite to the synthesis of physics and metaphysics. One therefore must comprehend the concepts of be (exist),[1] thing (perception), and one (thing) from the viewpoint of the relation between perception and ultimate reality.

A. EXISTENCE, THING, AND ONE

Existence has been defined here as "what is to be fed into the perceptron's input." In the situation where all operation of the perceptron has ceased, what can be said to exist in the input? First, what exists is a continuum: it has no limit, interface, dimension, time, velocity, change, space, place, or discontinuity since these are all derived from perceptron operations and the perceptron is not operating. What exists is continuity only, with no discontinuity.[2] To comprehend this, we must examine the thought process itself more closely, realizing that "to think" is "to perceive thoughts."

What is a "thing?" Further, what is "one" -- one "thing," one "anything?" A thing is first a perceived thing: it resulted from the output of a perceptron operation, in which one input bite and one output occurred. This output is characterized by the the fact that it is one, and the absence of one (i.e., zero) is the absence of output.[3] Figure 14 shows these relationships. The perceptron operation created the separation between the inside and the outside by creating a ΔL and a Δt, that is what the delta symbol means. Thus the operation of the perceptron determines the basic nature of one itself, and any one necessarily requires that a perceptron operation has occurred. In fact, the perceptron itself is a result of perceptron operations. Thus indeed all is relative. A perceptron exists and is able to function because it perceives other perceptrons to exist and function. Thus perceptrons are mutually created derivatives of reality

---

[1] Being is undifferentiated; that is its total definition. It cannot be perceived, since perception differentiates. It is continuity only, without any discontinuity, which is unperceivable. The preoccupation of being with causality (perception) is technically called "inception," the influencing of perception. In Zen philosophy this is technically "attachment to the world of illusion (change);" the literal meaning of "incarnation."

[2] This concept is unperceivable, by the definition of perception, which accounts for its difficulty. To be a "perceived one" implies limit (finiteness); oneness itself, without a bound or limit to make it a one (perceived), cannot be perceived. This is the primary limitation of the human mind (i.e., of perceptive thinking)--being, continuity, and oneness themselves imply absence of perception (differentiation) and are therefore unperceivable.

[3] Thus Boolean algebra describes the most basic operation, and is applicable to the

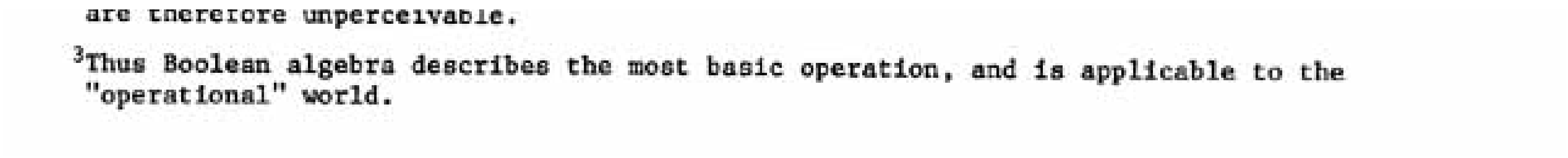

are therefore unperceivable.

[3] Thus Boolean algebra describes the most basic operation, and is applicable to the "operational" world.

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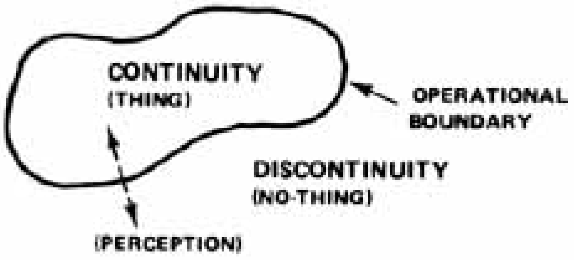

Fig. 14. Nature of One

which drive themselves and each other. Note that the preceding sentence itself is a perception.

So in the fullest sense, Gautama Buddha was indeed correct to state that the world of phenomena (changes) is an "illusion," relative only to itself (i.e., to perceptrons).[1] Einstein, expressing this idea in the language of mathematics, produced the theory of relativity and inaugurated a new physics. Buddha and Einstein spoke in different technical languages, but both expressed the same idea. The only difference is that in science we have assumed that our observations themselves are real and perfect. They are real, but not perfect in that they represent only changes in ultimate reality. Thus observational science alone can never reveal ultimate reality.

Another approach may aid in the comprehension of the nature of one. What is meant by the statement "he is the man?" Reflecting, one realizes that what is meant is that the perceived thing HE is exactly the same perceived thing THE MAN, and this identity exists now (during this one Δt perceptron time slice). There is no part of HE that is discontinuous from THE MAN, or vice versa. The different forms of the verb "be" attempt to express continuity without discontinuity, or unlimited oneness which is a state and not a thing. However, we do use the verb "be"[2] to relate continuity between different time slices. "He is the man" is related in the present time slice; "he was the man" means that HE in the NOW slice is identical to THE MAN in a past slice; etc.

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[1] The reader interested in Zen will find complete agreement between this paper and Zen precepts, and will find the paper of some assistance in comprehending the unperceivable (unthinkable) Zen realizations. In Zen, for example, the aim is to comprehend at once the totality of reality, directly, escaping beyond the limiting fetters of perceptive thought. Now if it is actually possible to do this, and if some unusual men have done it, then their enigmatic writings should contain the wisdom of their experience, and should correspond to ultimate reality itself. Since ostensibly their insight is obtained by other-than-logic and other-than-perceptive means, then their statements should appear illogical and unperceivable.* Thus the "sound of one hand clapping" and other illogical concepts are used in Zen as a meditative means of driving the student beyond logical perception (certainly the sound of one hand clapping cannot be perceived or thought) to realization. But if the Zen experience is actually valid, then reality itself must be pure Zen (i.e., unperceivable), and so it would appear to be. We note that for each component part of all, the opposite part must exist. So all can be regarded as the complete set of all possible opposites or contradictions.

*(However, this most assuredly does not imply that every statement that is illogical and unperceivable is of value!)

[2] It should be stressed again that being is defined as undifferentiated (unseparated,

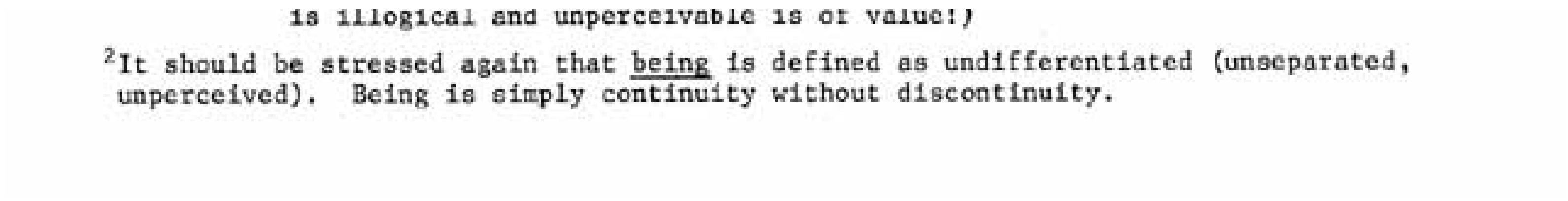

is illogical and unperceivable is of value!)

[2] It should be stressed again that being is defined as undifferentiated (unseparated, unperceived). Being is simply continuity without discontinuity.

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B. REALITY, ULTIMATE REALITY, BEING, AND ULTIMATE BEING

Actually one should be quite careful in using these terms. What does one get when one differentiates reality? One gets another reality, but not the primary or ultimate reality. For example, assume that length and time are real. When one time-differentiates length, one obtains velocity, which of course is real also but quite different from either length or time. However, velocity is always operationally related to the two first (assumed) reals length and time, because differentiation is an operation. So what is meant by "ultimate reality" is that state (or essence, or whatever name one prefers) that is not differentiated. Since "being" (continuity with no discontinuity) is defined as "that which is not differentiated," then the ultimate reality is pure being.

But all perceivables are differentials of ultimate reality. When one differentiates being, one gets pieces (differentials) of being which themselves are beings, but they have been perceived (differentiated) from a more primary or higher being. Therefore any being that one perceives has been differentiated (separated) by perception,[1] which explains why human beings, for example, consider themselves separate or individual (one). They are separate only in their individual perceptions. Thus "beings" by its plural nature always implies fragments (differentials) of a higher being (of singular nature). There can be many such integral levels: starting with one function, one can integrate it, then the resulting function can be integrated, etc., as long as we are speaking of definite integrals between two limits. When we reach a state that has no pieces or limits, the process is finished. That state is being in the ultimate sense, i.e., ultimate being.

One perceives these integral levels directly in nature, i.e., in the perceived phenomenological world. Living molecules (tiny beings) of RNA, DNA, etc., integrate together into a cell (a higher level being). Cells then integrate into a still higher being (man, animal, plant), which is the level on which man finds himself. But since man is perceivable and there are more men than one, it follows directly that men are capable of being integrated into a still higher being,[2] and the only word we have at present to describe such an ultimate being is "God." It is not at all accidental, therefore, that the ultimate being cannot be directly perceived by man, since by the definition of perception the ultimate being cannot be perceived by a lower order being such as man (i.e., since perception differentiates, or separates, then only differentials of being, or separate beings, are perceivable).

The avatar Jesus, having no technical concept for the derivative available in the language of the day, used the analogy of the father-son relationship, the son being the derivative of the father in this sense. Thus he referred to himself as the "Son of Man" (the derivative of all mankind or of integrated mankind) and also as the "Son of God" (the derivative of the integral of man). He continually referred to the ultimate being as "Father." It is little wonder that he was not understood then, and has not been understood for almost twenty centuries.

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[1] Thus not only are physical objects relative to the perceiver's perception, but so are the perceived beings. Ergo the entire perceived universe, both living and non-living, is related to perception, and in fact perception and creation are abstractly

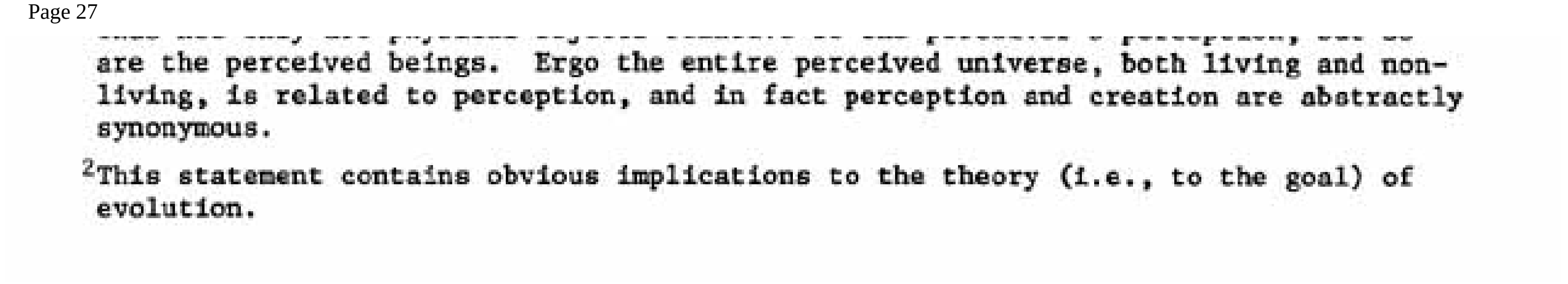

are the perceived beings. Ergo the entire perceived universe, both living and non-living, is related to perception, and in fact perception and creation are abstractly synonymous.

[2] This statement contains obvious implications to the theory (i.e., to the goal) of evolution.

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VI. CAUSALITY AND ITS MODIFICATION

A little closer look at perception can be obtained by viewing it from the causal standpoint.[1] All that perception really creates is Δt and ΔL (which are the same, ignoring constants of proportionality), and the perception we normally think of is point perception, where a point is one switching operation. The perception point may be thought of as following a line path which we will call "lineception" (Fig. 15). Physical phenomena as seen by one perceptron constitute this lineception; or rather, it constitutes the physical phenomena that are perceived or observed by the perceptron. Any point-based perceptron system, such as human perception, will accordingly perceive the universe of physical phenomena as if the perceiving system were a pointer moving along a lineception.[2]

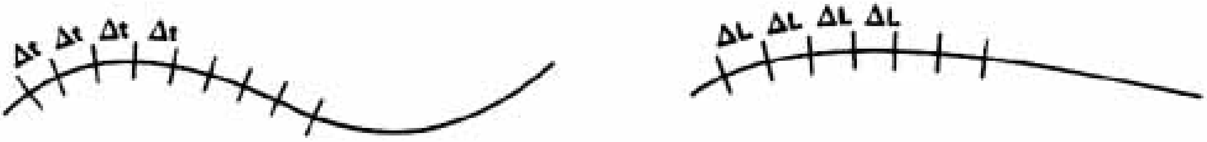

Fig. 15. Lineception (One Connected to One)

For each perception there is a reflection, so there exists (but by definition cannot be perceived) a similar line-path, or "lineflection" as shown in Fig. 16.

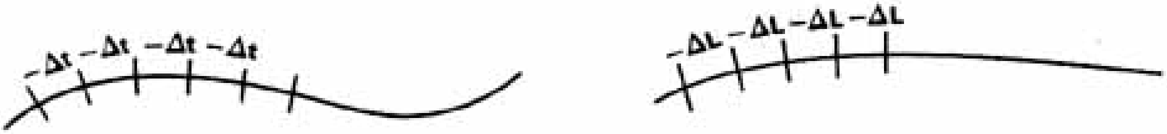

Fig. 16. Lineflection (One Connected to One)

that perception generates causality is completely consistent with our initially assumed definition of causality as the set of all causes.

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[1] Perception is identical to causality itself, i.e., perception can be said to generate causality. The causal view is that causes inputted to a situation operate to produce, or output or create, effects. According to its inputs, the perceptron generates causal outputs. An adequate theory of perception should be able to explain all causal (perceived) phenomena. We might define causality as the set of all causes. Then the answer to the question, "What causes causality itself?" is causality itself; i.e., since it is the set of all causes, causality must contain its own cause. Causality must therefore be closed or circular. The entire causal world must then be purely relative to itself (closed). Closer attention to causal operation yields the following: We perceive something change (in time or in space), then the situation changes so that we perceive new changes emerge (occur later, or separately). Thus the line of perception by its own unperceived operation connects the perceived cause (change) to the perceived effect (change), i.e., perception generates causality. Since perception itself is causal, then causality truly causes itself. This indeed is closed or circular--causality generates perception (perception is causal) and perception generates causality (causality is perceptive). Thus the idea that perception generates causality is completely consistent with our initially assumed definition of causality as the set of all causes.

[2] A "frame" or "coordinate system" is a point-centered perceptron system centered about the "understood perceptron" at the origin.

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The ultimate reality, or existence, contains all, all-at-once (ultimate reality is allness, or oneness). At each operation of the perceptron, the exact amount of Δt and ΔL, and their relationship, put out by a perceptron is a function of its input quiton disturbances. A great number, in fact perhaps an infinite number, of different input states are possible, i. e., exist in all, all-at-once (ultimate reality). So an equally large number of output states are possible (exist ultimately),[1] but one particular input condition results in one particular output condition. We can represent the all possible lineceptions existing as "multiception" (Fig. 17). From this figure, a lineception can be seen to be one particular path through multiception. The corresponding multiflection could, of course, be illustrated in similar manner but with negative components.

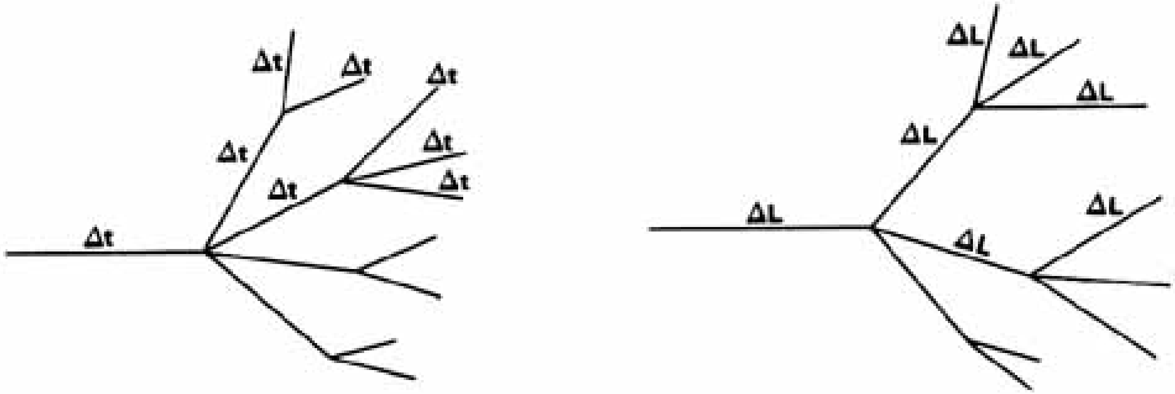

Fig. 17. Multiception (One Connected to Many)

One could immediately apply statistics to the concept along the lines illustrated by Fig. 18.

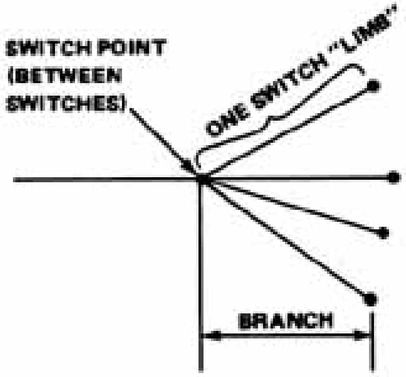

Fig. 18. One Branch

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[1] It is stressed that these multiceptions exist, which is not at all the same limited statement as "exist now," but much more comprehensive; e.g., all possible numbers must exist in zero, else, given the number A, there is no justification for the axiom that $A + (-A) = 0$. The "absence of number" means precisely the "absence of all possible

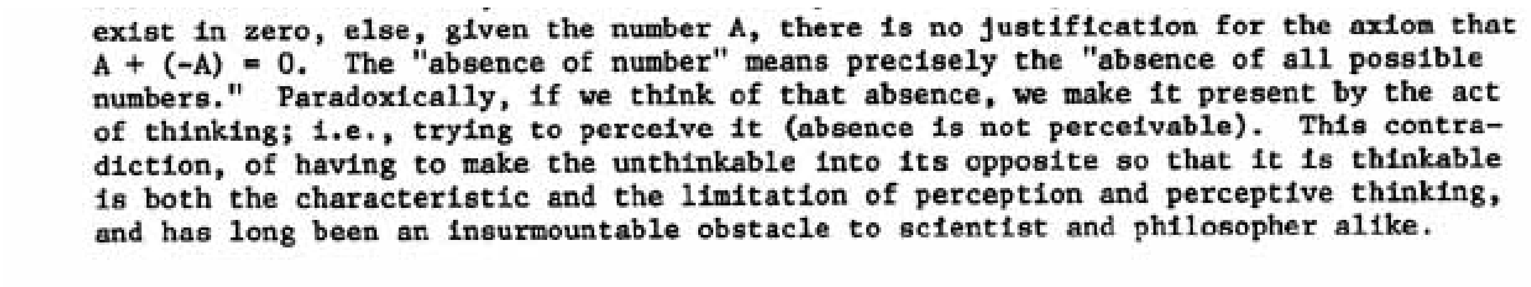

exist in zero, else, given the number A, there is no justification for the axiom that A + (-A) = 0. The "absence of number" means precisely the "absence of all possible numbers." Paradoxically, if we think of that absence, we make it present by the act of thinking; i.e., trying to perceive it (absence is not perceivable). This contradiction, of having to make the unthinkable into its opposite so that it is thinkable is both the characteristic and the limitation of perception and perceptive thinking, and has long been an insurmountable obstacle to scientist and philosopher alike.

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At each switch point, the perceptron is faced with the branch of possibilities ahead, which all exist in multiception but only one of which exists in one perception, or lineception.[1] A certain set of limbs in the branch must have a perception probability equalling 1, and thus each of the limbs has some finite probability.[2] The input conditions to the perceptron then determine which limb is selected for the next switching operation; and, of course, the input conditions are the results of other related perceptrons' operations (relativity). The statistics will not be pursued further here.

For an absolutely mechanistic world, the entire process is automatic according to quite rigidly fixed rules. A system of perceptrons that behave this way shall be referred to as "mechanically switched." What we call "non-living systems" are mechanically switched systems. But what we call a "living system" is able to arbitrarily select the limb taken, to some extent at least,[3] i. e., the fact that a living system is able to choose its behavior within certain limits, directly implies that it must be able to deflect its lineception from a mechanically switched lineception. The only way it can possibly do this is to influence the switching operation of the perceptron. But since the output of one switching operation is a mechanistic function of the inputs, then the only way a life system can affect the perceptron switching operation is by affecting the input to some extent. How could it possibly do this?

In our crude model, the nonaction continuum is composed of action atom fragments, or quitons. But such non-things are massless by definition (they are not being switched and the absence of switching defines masslessness), and we can think of the nonaction continuum as a massless fluid or ether or empty space, since these terms are all synonymous. All that is implied by these terms is that the fluid is composed of massless elements, which merely means they are not being switched. They are capable of being switched, of course, but switching is not being done. The main point is that force, in the conventional sense, is not required to move a massless fluid, so the input fluid to a perceptron can possibly be interfered with by some nonphysical means requiring zero force. The being portion of a life system can apparently do this to some extent.

Since the switch time of a perceptron is on the order of 10^{-21} seconds, then even an incredibly tiny quiton input variation to a perceptron will result in

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[1] It is stressed that all possibilities exist and are real, but do not exist in perception. Perception is the only difference between unperceived reality and perceived reality.

[2] Which leads to an unusual view of "probability." A perceptron operation is already finished when one perception is complete; that is why "the past is always gone, the present has just occurred, and the future is never here." Perceptron operation continually creates the perceptron's universe as it operates, including all changes, time, space, etc.). Thus, at the conclusion of any one perceptron operation, a multitude of lineception steps can exist for the next operation. However, although possibly quite large, the number of next steps available must be finite to be causal (perceivable). It is the process of perception that makes probability finite. Perception is finite; nonperception is infinite.

[3] The only alternative conclusion is that the living system is unable to deliberately

Perception is finite; nonperception is infinite.

[3] The only alternative conclusion is that the living system is unable to deliberately modify its behavior and its behavior is purely mechanical. But since this implies that all behavior is absolutely programmed and predictable, which is obviously false, this alternative is not valid and the original conclusion stands.

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noticeably altered lineception after one second of such variation. So it is quite reasonable to presume the futility of trying to measure such infinitesmal influence as is brought to bear on one single perceptron operation. However, the total influence can obviously be detected after being accumulated by a very large number of perceptron operations, and for living systems it is. So while we have not proved the mechanism of life-system manipulation of lineception, we have shown a logical progression from an assumed mechanism to a result that is universally verified by countless observations (i. e., all living systems are observed to manipulate causality, which manipulation is, after all, the definition of behavior). Since no other mechanism has been proposed, to the author's knowledge, that would reasonably explain the observed phenomenon of life-system manipulation of lineception, it is logical to accept as true the assumed mechanism -- a life system can exert an incredibly tiny influence on perceptron inputs,[1] i. e., on the ether or on empty space.[2,3]

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[1] This tiny influence is the basis of the realization process. To comprehend the noncausal, the individual observer usually wrestles diligently with the problem, repeatedly attempting to perceive it causally. In each such attempt, the tiny influence of inception on perceptron inputs is exerted. Over an ensemble of such attempts, the perceptron causal output can be modified, i.e., modulated noncausally to give what are now slightly noncausal perceived outputs. Presence of a required fit or required output pattern in the perceptive mind allows the output to be examined (compared) against the required output, i.e., it allows the selection of the proper noncausally modulated causal transfer function. When the outputs match, one then has a breakthrough or realization which matches the real world pattern but which cannot be directly perceived causally. However, since the mental file of the perceptive mind has now filed the proper transfer function, the individual has assimilated the information and understands it, being able to recall the noncausally modulated causal transfer function at will. Thus in Zen, the ultimate example of realization is described as "enlightenment." Phrases such as "direct perception of reality," "direct experience of ultimate reality," or "direct realization of all-being" are also used in trying to portray the nonperceivable realization. Conventional science hides the entire process behind vague terms, such as "creative thinking," which actually only conceal the fact that we do not know what it is, or how it is accomplished.

Note that such "creative realization" can cover either purely causal or noncausally modulated perception, the difference being merely whether the inputs are incepted in a normal manner comparable to causal phenomena, or in another manner. Realization is derived only from inception. Since the observed phenomena of physics already appear to be noncausal (statistical) in the ultramicroscopic region while ensembles of these yet appear to be causal, then the physicist is already confronted with the necessity of changing causality but at the same time retaining causality. The implications to the observation process itself must be examined, and they remove the dichotomy between physics and metaphysics when pursued.

[2] The Hieronymus effect is an example of this in reverse. It generates an effect on living nervous systems that is not the result of electric, magnetic, or gravitational fields, and is not caused by matter in motion. For that matter, a polygraph has been used to clearly measure a response of plants to human thoughts alone, and such an effect is not presently explainable within the body of physics theory. "Firewalking" is another unexplainable phenomenon from the standpoint of present physics theory as is acupuncture.

[3] All psi phenomena derive from this effect (inception) together with turbulent

is acupuncture.

[3] All psi phenomena derive from this effect (inception) together with turbulent switching. A straightforward theory of psi phenomena (and of such things as fire-walking and acupuncture, for that matter) can conceivably be generated from the quiton/perceptron theory.

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Of course the most efficient development of manipulation of lineception (i.e., the widest response) by a life system would necessitate a control system approach; i.e., life system direct manipulation of only a very small control valve or control mechanism, which in turn controls the input to a much larger mechanistic (deterministic) servo amplifier. Systems like this are universally observed in life systems. Thus the great bulk of a life system's manipulation of lineception is servomechanistic: the actual direct influence of life (being) on matter (perceptron switching) is so microscopic as to be immeasurable at its operating level, and only its macroscopic effects become measurable. For that reason the scientist has never been able to isolate the mechanism of life's manipulation of lineception, nor is he likely to be able to do so in the foreseeable future.[1]

Life's manipulation of lineception will be denoted by the term "inception," and can be thought of as a modulation (partial change or additive change) of the lineception carrier. Ordinary physical phenomena are macroscopic ensembles of lineceptions, where the deterministic (mechanistic) law holds absolutely but in a relative manner (ensemble to ensemble) which is fixed cause-and-effect, or causality, from the viewpoint of perception. Since inception is a modulation of lineception, then living behavioral phenomena should be superimposed as envelopes on causal lineceptions, or causal lineception ensembles, and, indeed, they are universally observed to be so superimposed.[2]

Absolute or ultimate reality, however, can be thought of in one respect as all multiceptions and all multiflections, all-at-once, which is timeless (i.e., which is both all-possible-times and zero time simultaneously or identically).[3] Along any one lineception, causality applies; yet since a very large number of changes to that lineception are available in just one multiception branch, then quite a large

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[1] This latter statement, of course, is subject to challenge.

[2] Since all matter is, it contains being. Another intriguing possibility exists: that there are two types of inceptive systems, or two magnitude directions that inception takes. The first type would produce inception with difficulty, and its inception would only be apparent at the macroscopic level; the second type would produce inception with ease, its inception would be apparent only at the microscopic level. The first type would correspond to what we call "living systems," while the second would correspond to what we call "inert systems." Living systems' inception would be observable to human senses and human instruments, while inert system's inception would not. A second and remarkable consequence would be, that in the extreme microscopic case, inception would dominate and this scale would appear to be absolutely statistical (individually unpredictable), which apparently is true (i.e., degree of causality represents degree of restraint of inception). This would modify causality (for individual events) at the ultramicroscopic level, but at higher levels causality would still apply due to the karma effect on perceived ensembles. It is significant that at present the universe of matter seems to behave in precisely this fashion. To summarize, perception is causal -- it generates causality. Inception, being noncausal, must be below the perception threshold. Aggregates of inception (noncausal) that equal or exceed the perception threshold become causal (are processed by perception) and generate causal karma.

[3] Since every perceived ΔT has an unperceived complement $-\Delta T$ which exists in reflec-

[3] Since every perceived ΔT has an unperceived complement $-\Delta T$ which exists in reflection, then the sum total of all times in absolute existence, which includes both perception and reflection, equals zero time.

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number of inceptions are available to be applied to that one lineception by an organism to change or direct the lineception. Herein is the explanation of karma. Since every inception made by an organism (or by a submicroscopic particle of being for the second case, see note 2, p. 32) changes its entire lineception, it also changes its entire perceived or relative universe, which is the only universe it knows or senses. And since causal feedbacks from this perceived universe[1] occur to the organism's perceptron (which itself is part of that perceived universe), then the effects of the organism's actions indeed return precisely to it. So, "as a man soweth, that shall he also reap" is quite true.[2]

It is now possible to formulate some conclusive statements:

1. One perceptron follows a lineception path, mechanically basing its output on its inputs, and this operation establishes causality to perception repetition, i.e., to lineception.

2. Ordinary physical phenomena are merely ensembles of related lineceptions, and are perceived to be absolutely deterministic (obey only cause-and-effect.

3. Living phenomena exhibit the effects (selective behavior) of inception (modulations impressed on lineception) which occasionally diverts one lineception from its deterministic lineception limb to another multiception limb, resulting in a changed (modulated) lineception.

4. Ultimate, or absolute, reality may be thought of as the sum-total of all multiceptions and multiflections.

5. "God" is all-being, which is all multiflection and multiception at once, which is both no time at all and forever and all forevers as well.

6. "God's will" is lineception and its accompanying lineflection.

7. "Man's will" or "free will" is inception, the modulation of lineception (and unknowingly its accompanying lineflection). Inception, however, imposes a feedback on the inceptor since a precise feedback, from the inception changes to perception, occurs to the perceptron of the perceiver. This feedback resulting from inception is karma.

8. The law of cause and effect (causality) exists in perceived nonmodulated phenomena (ensembles of lineceptions).

9. Causality is affected (modulated) by living systems, but applies to each choice once made. The causal feedback from inception is karma.

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[1] "Perceived" must be accented: the nonperceived universe is not causal, since by definition causality invokes a perceiver and the perception process.

[2] Collective karma of any ordered group such as a species must exist in like manner. On the submicroscopic level, "karma of ensembles" means that the statistics of

[2] Collective karma of any ordered group such as a species must exist in like manner. On the submicroscopic level, "karma of ensembles" means that the statistics of lineceptions and inceptions still lead to causal relationships in the perceived collective phenomena.

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10. Neither causality or karma applies in ultimate reality, although all causality lineceptions and their reflections, and all modulations (inceptions) and the karma reflections of those inceptions, are included in ultimate reality.

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VII. CLOSING REMARKS

The quiton/perceptron approach appears to offer a most extensive area for further investigation, and it is hoped that the physicists will interest themselves in the concept. It offers explanations for the problems long posed by ontology, and unifies the bases of science and metaphysics.

We state categorically that the theory explains what electric charge is, why like charges repel, and why unlike charges attract. In addition, since all phenomena are perceptron outputs, the theory indicates that multiple effects which are very close in time or distance will interfere with each other due to turbulent switching; i. e., conservation of mass/energy holds only as long as no switch interference exists. Turbulent switching can possibly disrupt all known physical laws. Unexpectedly strong forces, such as nuclear force, might in fact result from this effect. Other implications include possibility of travel faster than the speed of light (deBroglie waves do this now) and of travel back and forth in "time."

Since both laboratory instruments and human sensory apparatuses are perceptrons and differentiate reality, investigations of physical phenomena should include the laws of the perceptron as well as the laws of the perceived phenomena.

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13. ABSTRACT

A fundamental answer is attempted to the question of being, time, space, existence, perception, and physical phenomena. Mass, empty space, reality, gravitational attraction, continuity, discontinuity, and relativity are among the "things" and "nonthings" for which relationships and explanations are provided.

Perception is defined as detection by a mass of change to itself and as a differentiating process. Perceived physical phenomena are revealed to be first derivatives of ultimate reality, and outputs of the physical perceiving device called the ✓ "perceptron." Using the operation of the physical perception process on action, the units of which are energy times time, an entirely different view is generated of both reality and the Heisenberg uncertainty principle. When superposition is imposed as a condition, the Heisenberg uncertainty principle is revealed to be a quantized statement. A concept of the absolute value of a dimensional molecule is advanced.

A reality model is constructed of an action continuum and a nonaction continuum separated by an operational threshold whose magnitude is given by an uncertainty principle. Perception is modeled as a process which switches atomic quanta of action and nonaction back and forth across the threshold. Mass is explained as perceptron switch activity rate, and a mass definition equation is generated. One kilogram mass is shown to represent 17.053×10^{50} perceptron switches per second. From the model, Newton's laws of motion and gravity can be generated directly from the concept of the interaction of mass with space itself, space being taken as a massless fluid, or ether, composed of tiny nonaction particles called "quitons." Einstein's postulates of

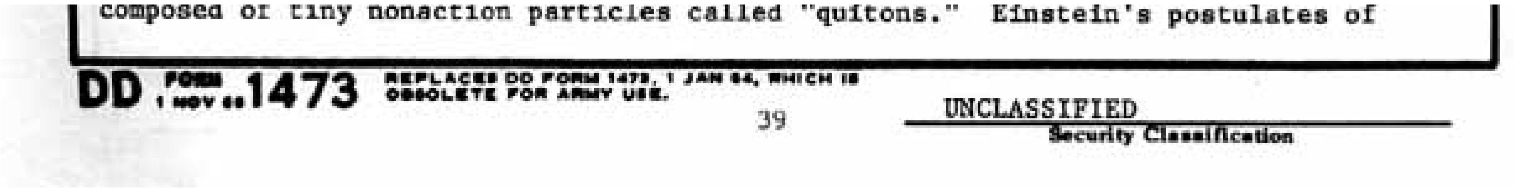

composed of tiny nonaction particles called "quitons." Einstein's postulates of

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	ROLE	WT	ROLE	WT	ROLE	WT
causality perception perceptron quiton quiton/perceptron theory gravitation mass reality metaphysics being existence space time photon action action quantum quantum observation relativity Karma complementarity physical phenomena Mach's principle Newton's laws inertia Debroglie wave Einstein's postulates Michelson-Morley experiment ontology Heisenberg Uncertainty Principle superposition equivalence principle simultaneity inertial frame						

ABSTRACT (Continued)
special relativity are also shown to follow from the model, and a statement of the equivalence principle is shown to be consistent with the model.

The concept of "lineception" as a causal chain of perceptron operations is advanced. "Inception" is developed as a noncausal modulation of lineception and as a distinguishing feature of a living system. The possibility is raised that inception could provide an explanation of the noncausal, statistical, ultramicroscopic universe and yet require large ensembles of ultramicroscopic events to conform to causality. Inception is shown to lead to karma. Perception is shown to be causal and to generate causality itself.

Some elementary philosophical implications of quiton/perceptron theory are pointed out and briefly discussed.

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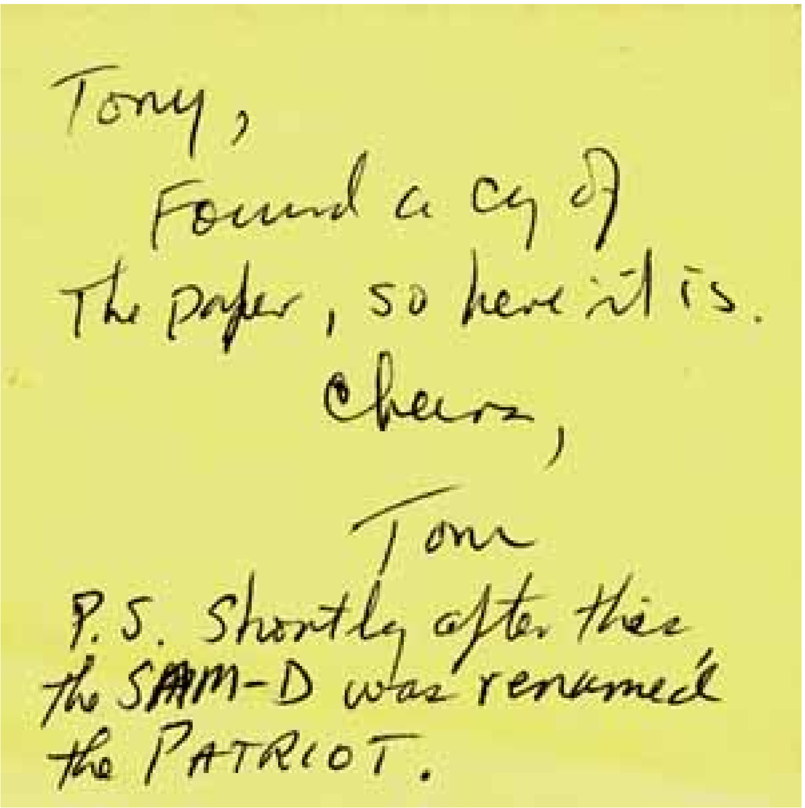

Tony,

Found a cy of
The paper, so here it is.

Cheers,

Tom

P.S. Shortly after this
the SAM-D was renamed
the PATRIOT.

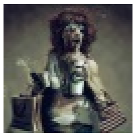

SCALAR WEAPONS: Read It and Weep

- Posted by Ms MoD on July 27, 2011 at 4:42 in HAARP
- View Discussions

This is a REALLY long paper but it is broken down into categories so you can easily skip to sections of interest to you. I found this after reading Twelve Things You Should Know About Scalar Weapons which was posted by FDF in April and is a MUCH SHORTER overview of scalar technology by the same author. I highly recommend it but wanted to post the longer version here as well which you can download in the PDF attached. Topics in the paper are listed below -MoD

SCALAR WEAPONS: Read It and Weep

By C Verismo

1. THE DISCOVERY OF SCALAR WAVES
2. BEAM WEAPONS OF A CENTURY AGO
3. THE CONTINUATION OF TESLA'S SCALAR WAVE TECHNOLOGY
4. TESLA'S CROSSED SCALAR BEAMS
5. RUSSIA'S 'WOODPECKER' SCALAR WAVE TRANSMITTERS
6. THE 1930s
7. THE 1940s
8. THE 1950s
9. THE 1960s
10. THE 1970s
11. THE 1980s
12. THE 1990s
13. THE PRESENT
WHAT CAN BE DONE WITH SCALAR TECHNOLOGY?
14. MIND READING, MASS HYPNOTISM AND SYNTHETIC TELEPATHY
15. DISEASE INDUCTION
16. DISABLING SATELLITES
17. IN THE AIR
18. WEATHER ENGINEERING
19. EARTHQUAKES
20. SEA ATTACKS
21. TESLA SHIELDS AND GLOBES
22. GROUND ATTACKS
23 OBLITERATING INDIVIDUALS
24. PORTABLE SCALAR BAZOOKAS
25. RADAR INVISIBILITY
26. SUMMARY OF A WAR THAT COULD OCCUR
27. RUSSIAN UFOs ATTACKED THE US SHUTTLE PROGRAM FROM THE BEGINNING
28. HOW DID RUSSIA GET UFOs?
29 FORMER BOLSHEVIKS RUNNING AMERICA
30 REPLICAS USED FOR THE LANDINGS, AFTER ORIGINALS SHOT DOWN
31. CLOAKED RUSSIAN UFOS ABOVE USA

32. ALL U.S. SATELLITES SHOT DOWN BY RUSSIA UNTIL 1981
33. LIES, LIES AND LIES
34. FRICTION WITH THE JAPANESE
35. ENTERPRISE SHUTTLE DETERMINED TO SPY ON RUSSIA
36. RUSSIA INTENSIFIES ATTACKS
37. TRYING AGAIN TO GET UP INTO SPACE. THIRD TIME LUCKY?
38. BOLD ATTACKS ON AMERICA
39. THE STRUGGLE AT THE TOP FOR POWER
40. THE STEALTH PLANE COMES TO THE RESCUE
41. PHANTOM AGAINST THE COSMOSPHERE
42. THE EXPECTED GENOCIDE
43. PLANS FOILED TO DESTROY RUSSIA'S MILITARY ARSENAL
44. BRAZIL
45. INDIA
46. JAPAN
47. KOBE 'EARTHQUAKE'
48. CHINA
49. OKLAHOMA FBI BUILDING 'BOMBING'
50. WHO ELSE HAS UFOs?

Full paper in PDF below…

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Views: 459

Attachments:

- SCALAR WEAPONS - Read It and Weep.pdf, 494 KB

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Replies to This Discussion

Permalink Reply by Jenny on July 27, 2011 at 6:22
HAARP Patents (Assigned to APTI, Inc. Los Angeles, CA, Washington, DC)

U.S. Patent 4686605: Method And Apparatus For Altering A Region In The Earth’s Atmosphere, Ionosphere, And/Or Magnetosphere Issued: Aug. 11, 1987 Filed: Jan. 10, 1985
http://www.freepatentsonline.com/4686605.pdf

U.S. Patent 5038664: Method For Producing A Shell Of Relativistic Particles At An Altitude Above The Earth’s Surface ~ Issued: Aug. 13, 1991 Filed: Jan. 10, 1985
http://www.freepatentsonline.com/5038664.pdf

U.S. Patent 4712155: Method And Apparatus For Creating An Artificial Electron Cyclotron Heating

Region Of Plasma ~ Issued: Dec. 8, 1987 Filed: Jan. 28, 1985
http://www.freepatentsonline.com/4712155.pdf

U.S. Patent 5068669: Power Beaming System ~ Issued: Nov. 26, 1991 Filed: Sep. 1, 1988
http://www.freepatentsonline.com/5068669.pdf

U.S. Patent 5218374: Power Beaming System With Printer Circuit Radiating Elements Having Resonating Cavities ~ Issued: June 8, 1993 Filed: Oct. 10, 1989
http://www.freepatentsonline.com/5218374.pdf

U.S. Patent 5293176: Folded Cross Grid Dipole Antenna Element ~ Issued: Mar. 8, 1994 Filed: Nov. 18, 1991
http://www.freepatentsonline.com/5218374.pdf

U.S. Patent 5202689: Lightweight Focusing Reflector For Space ~ Issued: Apr. 13, 1993
http://www.freepatentsonline.com/5202689.pdf
Filed: Aug. 23, 1991

U.S. Patent 5041834: Artificial Ionospheric Mirror Composed Of A Plasma Layer Which Can Be Tilted ~ Issued: Aug. 20, 1991 Filed: May. 17, 1990
http://www.freepatentsonline.com/5041834.pdf

U.S. Patent 4999637: Creation Of Artificial Ionization Clouds Above The Earth ~ Issued: Mar. 12, 1991 Filed: May. 14, 1987
http://www.freepatentsonline.com/4999637.pdf

U.S. Patent 4954709: High Resolution Directional Gamma Ray Detector ~ Issued: Sep. 4, 1990 Filed: Aug. 16, 1989
http://www.freepatentsonline.com/4954709.pdf

U.S. Patent 4817495: Defense System For Discriminating Between Objects In Space ~ Issued: Apr. 4, 1989 Filed: Jul. 7, 1986
http://www.freepatentsonline.com/4817495.pdf

U.S. Patent 4873928: Nuclear-Sized Explosions Without Radiation ~ Issued: Oct. 17, 1989 Filed: June 15, 1987
http://www.freepatentsonline.com/4873928.pdf

Still think that HAARP is just another wacky fictional conspiracy? The above listed patents should be enough to convince any intelligent person that HAARP is real and is now actively modifying our weather and triggering earthquakes. For those who are still not convinced, look to the United States Congress for proof. In order for HAARP to get funding the people who first created HAARP needed funding. That funding was made possible by the US government. If you were to look at Congressional records you would find documents that states just one of the many official purposes of HAARP – for penetrating the earth with signals bounced off of the ionosphere. Congress was informed by people in the High Frequency Active Auroral Research Program that the bounced signals would be used to look inside the planet to a depth of many kilometers in order to locate underground munitions, minerals and tunnels. If you bounced the known earthquake signature signal (2.5 Hz) for a sustained period of time an earthquake could triggered many kilometers inside Earth’s crust. The U.S. Senate actually set aside $15 million dollars in 1996 (Clinton and Al Gore Administration) to develop this ability alone — earth-penetrating-tomography.

Update April 21, 2011

Under pressure from the International community the HAARP website is up again. No data is available from April 7 to April 12, 2011. Data before and after shows the signature frequency of an earthquake (2.5Hz) being transmitted. Also shows energy spikes which indicates active weather modification. Now that the website is up again you can view the data for the Japan earthquake at http://137.229.36.30/cgi-bin/scmag/disp ... i?20110311. From the magnetometer induction data you can see 2.5Hz (earthquake inducing frequency) being broadcasted and recorded for several days before the 9.0 magnitude earthquake. To see what a normal (no HAARP broadcasting) day looks like view the magnetometer charts for the days of March 15, 16 and 17 – March 16, 2011 http://137.229.36.30/cgi-bin/scmag/disp ... 0316&Bx=on. No earthquake inducing broadcast was detected from March 15 to March 27, 2011. On March 28, 2011 a low powered broadcast was detected from approximately 12:00 am to 3:00 am. Broadcasting resumed on April 2, 2011. April 6, 2011 shows you what the magnetometer charts looks like when a solar storm blasts Earth. No data is available from April 7, 2011 to April 13, 2011 – a shutdown. Starting on April 15, 2011 and ending approximately 10:00 am April 16, 2011 the earthquake inducing frequency of 2.5Hz was detected being broadcasted.
Short URL: http://presscore.ca/2011/?p=2261

- ▶ Reply
-

Permalink Reply by Jenny on July 27, 2011 at 6:23
WOW MoD! What a paper! I need like a year to get through it all but it sure is awesome to have it all in one place! Excellent!

- ▶ Reply
-

Permalink Reply by Ms MoD on October 26, 2012 at 6:38

Boeing Tests Microwave Missile That Can Knock Out All Electronics (CHAMP)
Huffington Post UK | By Michael Rundle 24/10/2012

Boeing is testing a missile which can destroy electronics in a wide area with little or no physical damage.

The 'Champ' (Counter-electronics High-powered Advanced Missile Project) may "one day change warfare", Boeing said.

"This technology marks a new era in modern-day warfare," said Keith Coleman, CHAMP program manager for Boeing Phantom Works.

"In the near future, this technology may be used to render an enemy’s electronic and data systems useless even before the first troops or aircraft arrive".

The missile was tested on 16 October, when the high-powered microwaves were fired at a two storey building built especially for the job.

The missile would, if successful, take out rows of personal computers which were turned on to gauge the effect of the blast.

The result?

"Seconds later the PC monitors went dark and cheers erupted in the conference room. CHAMP had successfully knocked out the computer and electrical systems in the target building. Even the television cameras set up to record the test were knocked off line without collateral damage."

Seven targets were hit in the one-hour test, and all were successfully disabled.

There is a long way to go before the microwave can be placed into a missile and used to disable targets without loss of life, but the team is hopeful it could prove to be a milestone in non-lethal warfare.

"Today we turned science fiction into science fact," Coleman said.

http://www.huffingtonpost.co.uk/2012/10/24/boeing-tests-microwave-m...

- ▶ Reply
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Permalink Reply by Ms MoD on August 3, 2013 at 11:01

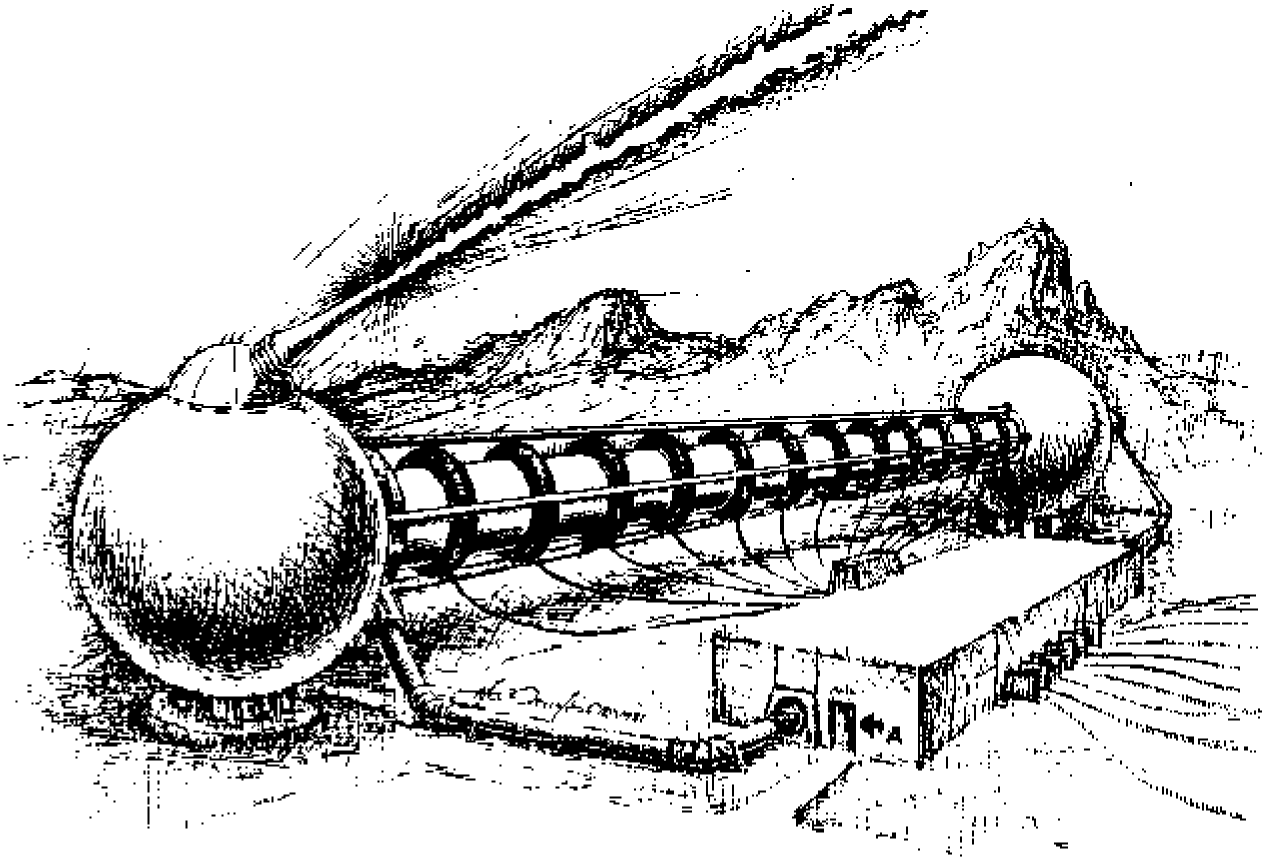

Scalar Potential Interferometer

Figure 6. Multimode Tesla Weapon

In the 1930's Tesla announced other bizarre and terrible weapons: a death ray, a weapon to destroy hundreds or even thousands of aircraft at hundreds of miles range, and his ultimate weapon to end all war -- the Tesla shield, which nothing could penetrate. However, by this time no one any longer paid any real attention to the forgotten great genius. Tesla died in 1943 without ever revealing the secret of these great weapons and inventions.

Unfortunately, today in 1981 the Soviet Union has long since discovered and weaponized the Tesla scalar wave effects. Here we only have time to detail the most powerful of these frightening Tesla weapons -- which Brezhnev undoubtedly was referring to in 1975 when the Soviet side at the SALT talks suddenly suggested limiting the development of new weapons "more frightening than the mind of man had imagined." One of these weapons is the Tesla howitzer recently completed at the Saryshagan missile range and presently considered to be either a high-energy laser or a particle beam weapon, (See Aviation Week & Space Technology, July 28, 1980, p. 48 for an artist's conception.)

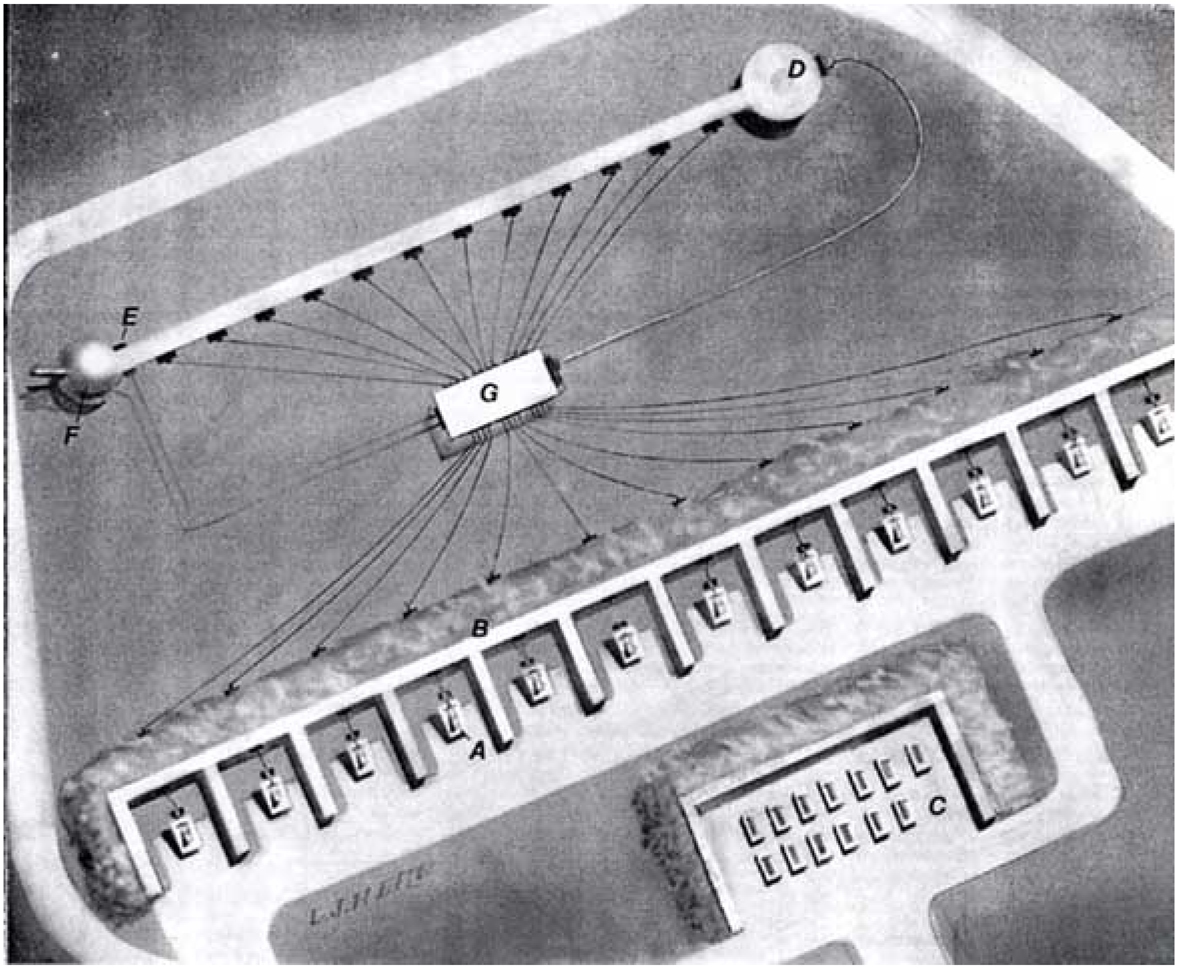

Aviation Week & Space Technology July 28, 1980

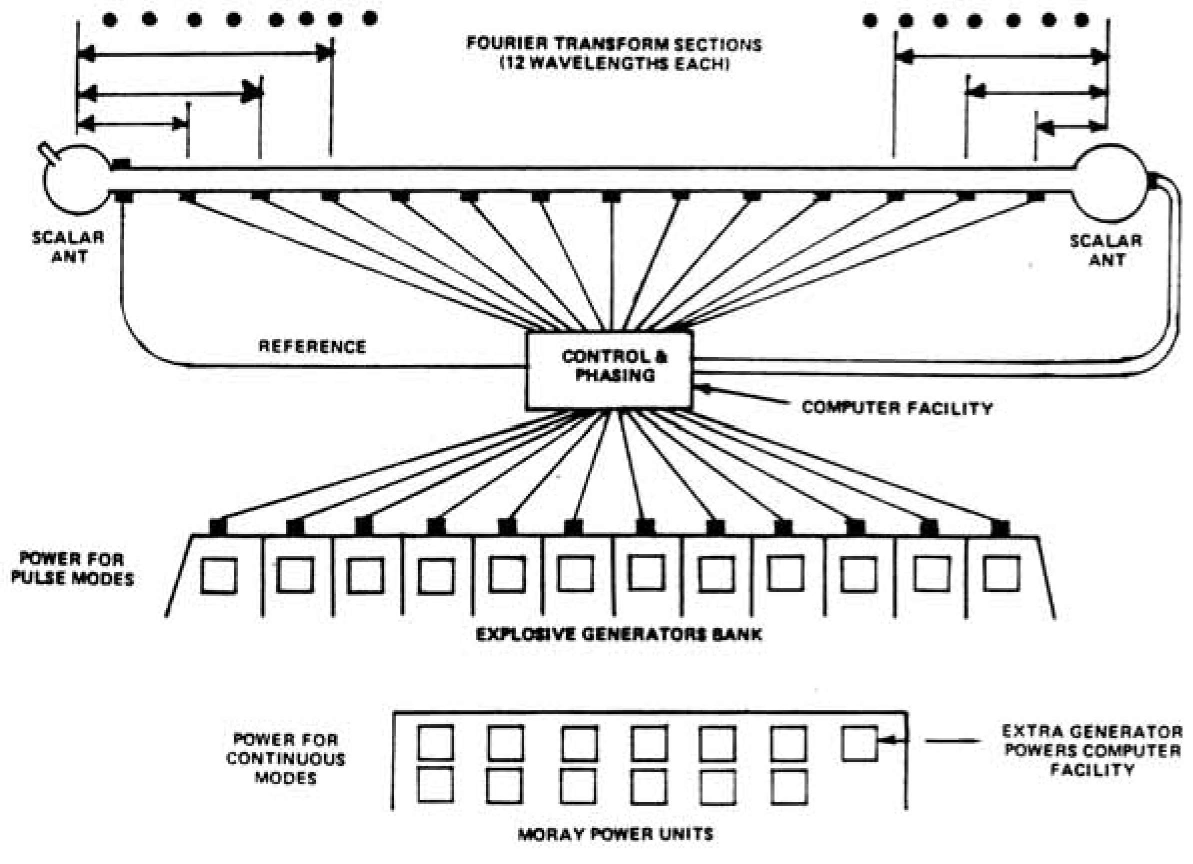
FOURIER TRANSFORM SECTIONS
(12 WAVELENGTHS EACH)
SCALAR ANT
SCALAR ANT
REFERENCE
CONTROL & PHASING
COMPUTER FACILITY
POWER FOR PULSE MODES
EXPLOSIVE GENERATORS BANK
POWER FOR CONTINUOUS MODES
EXTRA GENERATOR POWERS COMPUTER FACILITY
MORAY POWER UNITS

Figure 7. Tesla Weapons at Saryshagan

The Saryshagan howitzer actually is a huge Tesla scalar interferometer with four modes of operation. One continuous mode is the Tesla shield, which places a thin, impenetrable hemispherical shell of energy over a large defended area. The 3-dimensional shell is created by interfering two Fourier-expansion, 3-dimensional scalar hemispherical patterns in space so they pair-couple into a dome-like shell of intense, ordinary electromagnetic energy. The air molecules and atoms in the shell are totally ionized and thus highly excited, giving off intense, glowing light. Anything physical which hits the shell receives an enormous discharge of electrical energy and is instantly vaporized -- it goes pfft! like a bug hitting one of the electrical bug killers now so much in vogue.

If several of these hemispherical shells are concentrically stacked, even the gamma radiation and EMP from a high altitude nuclear explosion above the stack cannot penetrate all the shells due to repetitive absorption and reradiation, and scattering in the layered plasmas.

In the continuous shield mode, the Tesla interferometer is fed by a bank of Moray free energy generators, so that enormous energy is available in the shield. A diagram of the Saryshagan-type Tesla howitzer is shown in figure 7. Hal Crawford's fine drawing of the interferometer end of the Tesla howitzer is shown in figure 6. Hal's exceptional rendition of the Tesla shield produced by the howitzer is shown in figure 8.

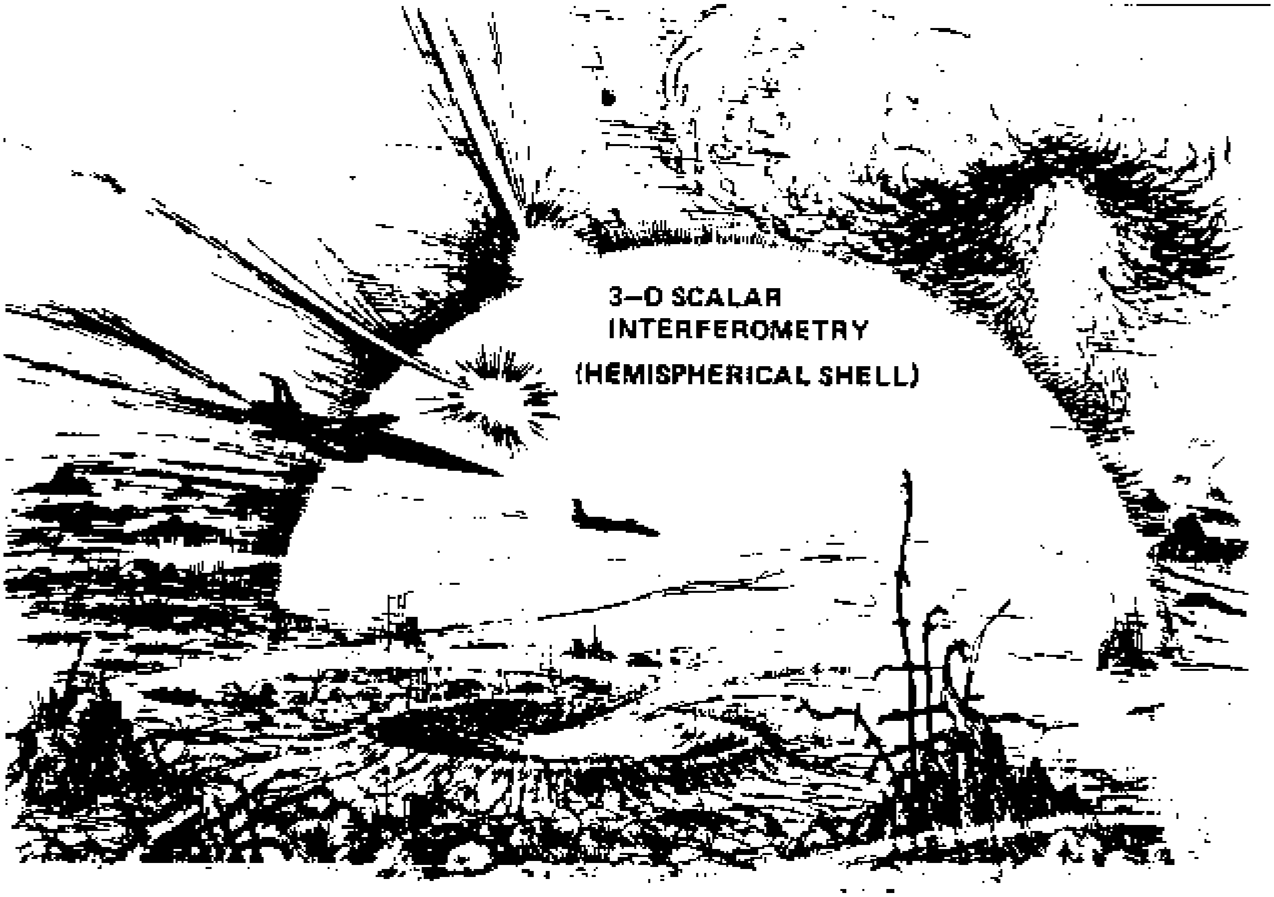

Figure 8. The Tesla Shield

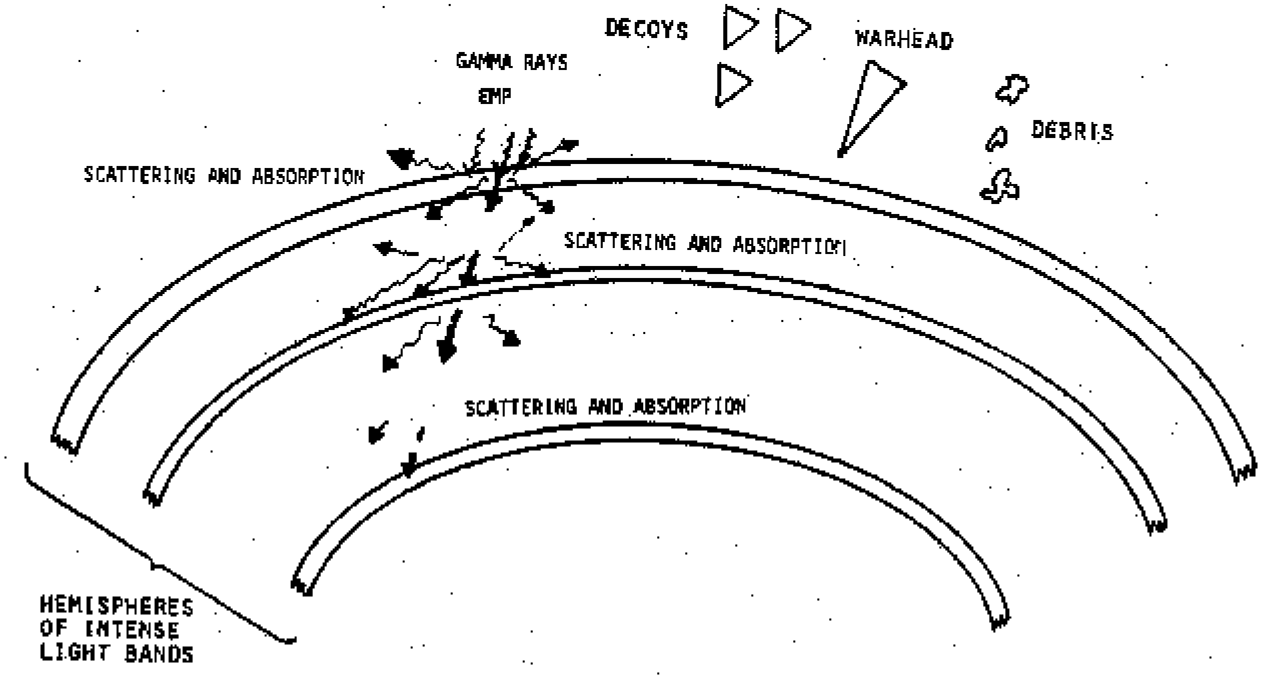
DECOYS
WARHEAD
GAMMA RAYS
EMP
DEBRIS
SCATTERING AND ABSORPTION
SCATTERING AND ABSORPTION
SCATTERING AND ABSORPTION
HEMISPHERES OF INTENSE LIGHT BANDS

Figure 9. Tesla Terminal Area Defense System

In the pulse mode, a single intense 3-dimensional scalar phi-field pulse form is fired, using two truncated Fourier transforms, each involving several frequencies, to provide the proper 3-dimensional shape (Figure 10). This is why two scalar antennas separated by a baseline are required. After a time delay calculated for the particular target, a second and faster pulse form of the same shape is fired from the interferometer antennas. The second pulse overtakes the first, catching it over the target zone and pair-coupling with it to instantly form a violent EMP of ordinary vector (Hertzian) electromagnetic energy. There is thus no vector transmission loss between the howitzer and the burst. Further, the coupling time is extremely short, and the energy will appear sharply in an "electromagnetic pulse (EMP)" strikingly similar to the 2-pulsed EMP of a nuclear weapon.

This type weapon is what actually caused the mysterious flashes off the southwest coast of Africa, picked up in 1979 and 1980 by Vela satellites. The second flash, e.g., was in the infrared only, with no visible spectrum. Nuclear flashes do not do that, and neither does superlightning, meteorite strikes, meteors, etc. In addition, one of the scientists at the Arecibo Ionospheric Observatory observed a gravitational wave disturbance -- signature of the truncated Fourier pattern and the time-squeezing effect of the Tesla potential wave -- traveling toward the vicinity of the explosion.

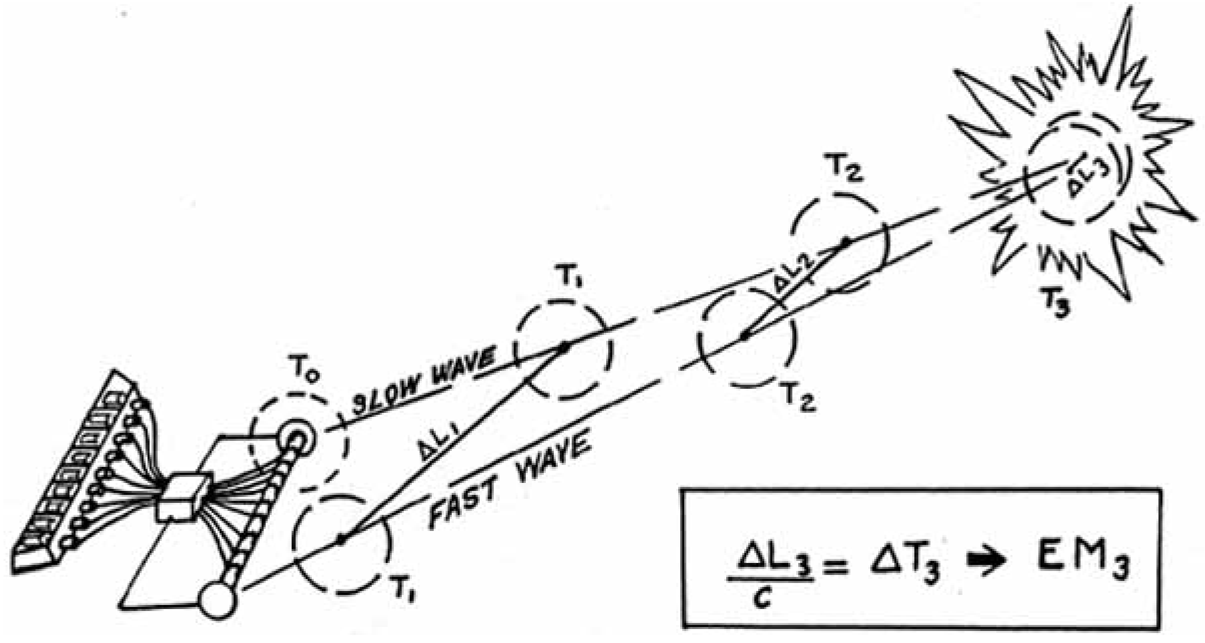
T₀
SLOW WAVE
T₁
ΔL₁
FAST WAVE
T₁
T₂
ΔL₂
T₂
ΔL₃
T₃
$\frac{\Delta L_3}{c} = \Delta T_3 \rightarrow EM_3$

TESLA HOWITZER
(SCALAR INTERFEROMETER)

Figure 10. "Nuclear" Flashes off the Coast of Africa

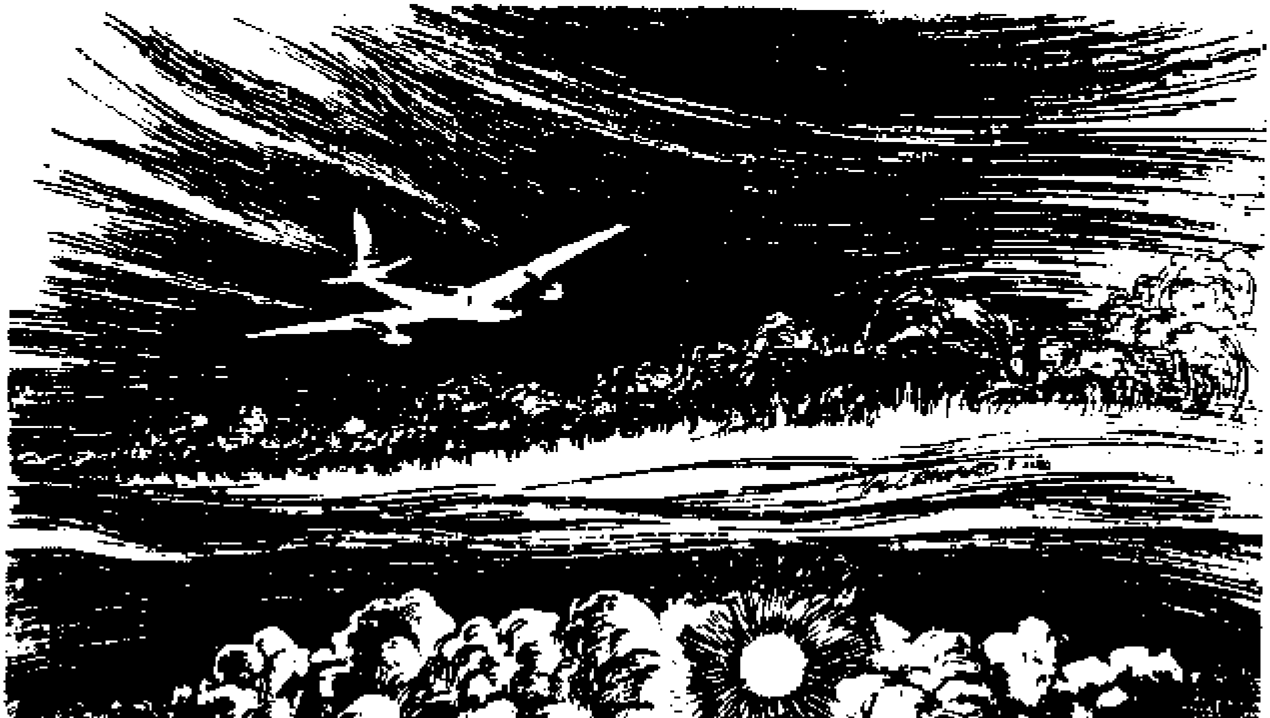

Lithuania - 10 Sep 1976 - British European Airways Flight #831 between Moscow and London

CIA Report Released under FOIA

Figure 11. Continuous Tesla Fireball

The pulse mode may be fed from either Moray generators or -- if the Moray generators have suffered their anomalous "all fail" malfunction -- ordinary explosive generators. Thus the Tesla howitzer can always function in the pulse mode, but it will be limited in power if the Moray generators fail.

In the continuous mode, two continuous scalar waves are emitted -- one faster than the other -- and they pair-couple into vector energy at the region where they approach an in-phase condition. In this mode, the energy in the distant "ball" or geometric region would appear continuously and be sustained -- and this is Tesla's secret of wireless transmission of energy at a distance without any losses. It is also the secret of a "continuous fireball" weapon capable of destroying hundreds of aircraft or missiles at a distance. An example of a Soviet test of this mode of operation is shown in figure 11.

Witness to a super weapon?

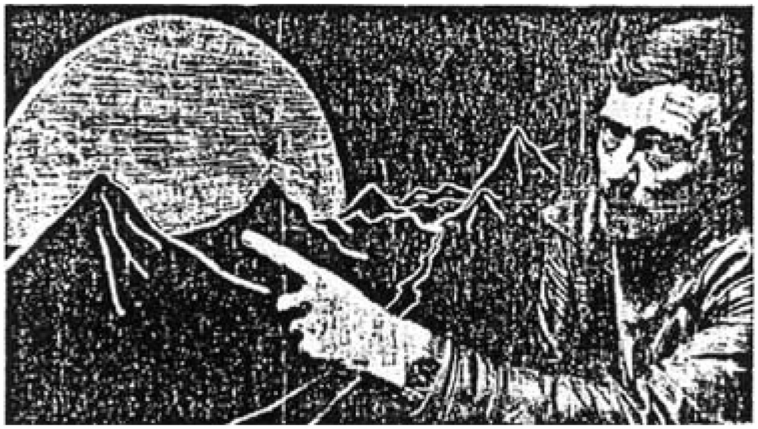

Nick Downie describes the strange lurid glow that flared silently over the Hindu Kush

THE SUNDAY TIMES, 17 AUGUST 1980

(Multiple incidents in Sept., 1979)

TEHERAN, IRAN 17 JUNE 1966

SEEN FROM NEAR MEHRABAD AIRPORT

OBSERVED 4-5 MINUTES

SEEN BY 2 AIRCRAFT

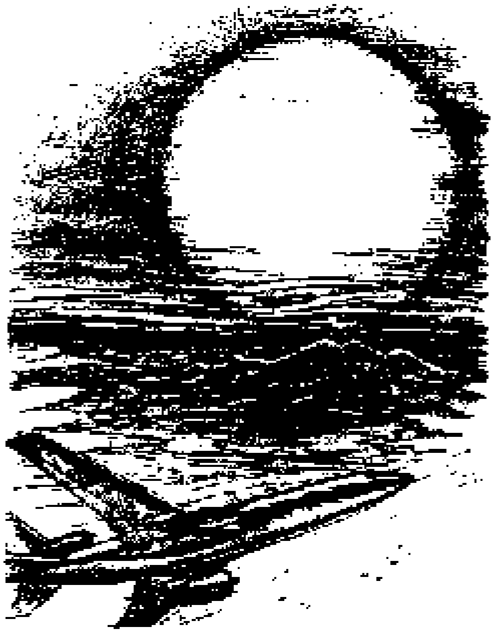

CIA REPORT RELEASED UNDER FOIA

Figure 12. Tesla EMP Globe

The volume of the Tesla fireball can be vastly expanded to yield a globe which will not vaporize physical vehicles but will deliver an EMP to them to dud their electronics. A test of this mode is shown in figure 12. (See also Gwynne Roberts, "Witness to a Super Weapon?", the London Sunday Times, 17 August 1980 for several other tests of this mode at Saryshagan, seen from Afghanistan by British TV cameraman and former War Correspondent Nick Downie.)

If the Moray generators fail anomalously, then a continuous mode limited in power and range could conceivably be sustained by powering the interferometer from more conventional power-sources such as advanced magnetohydrodynamic generators.

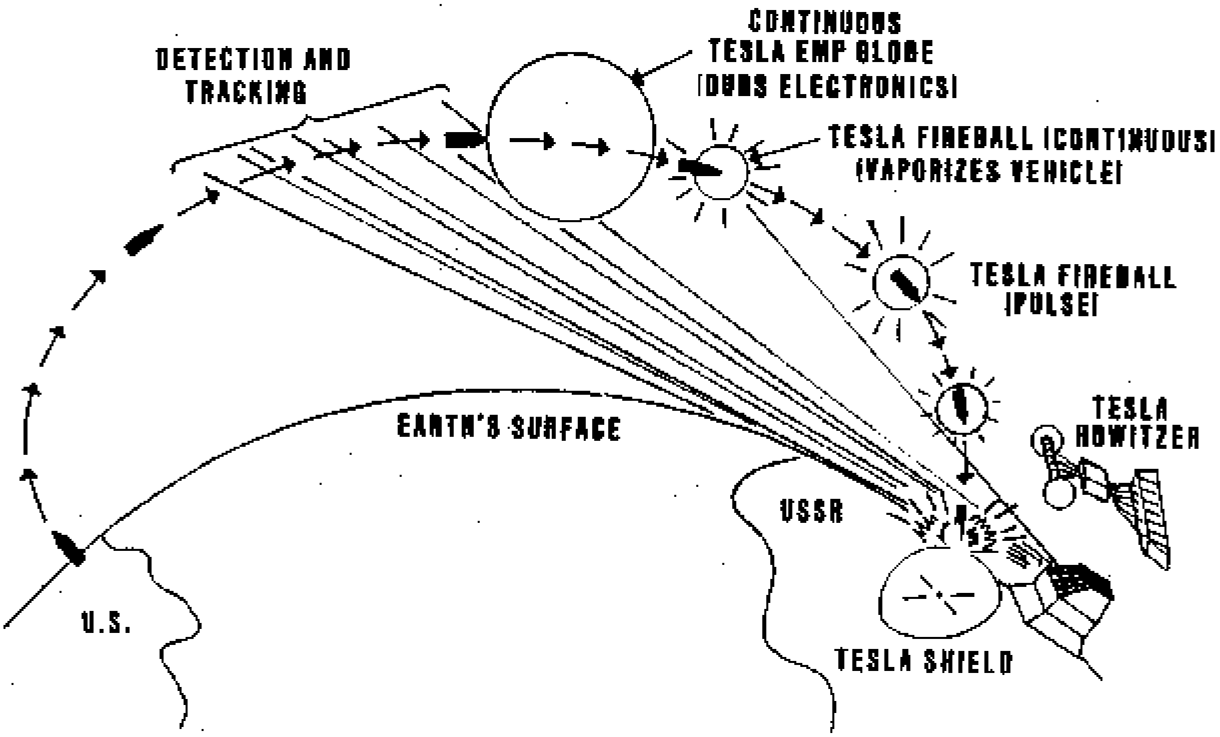
CONTINUOUS
TESLA EMP GLOBE
(DUDS ELECTRONICS)
DETECTION AND
TRACKING
TESLA FIREBALL (CONTINUOUS)
(VAPORIZES VEHICLE)
TESLA FIREBALL
(PULSE)
TESLA
HOWITZER
EARTH'S SURFACE
USSR
U.S.
TESLA SHIELD

Figure 13. Tesla ABM Defenses

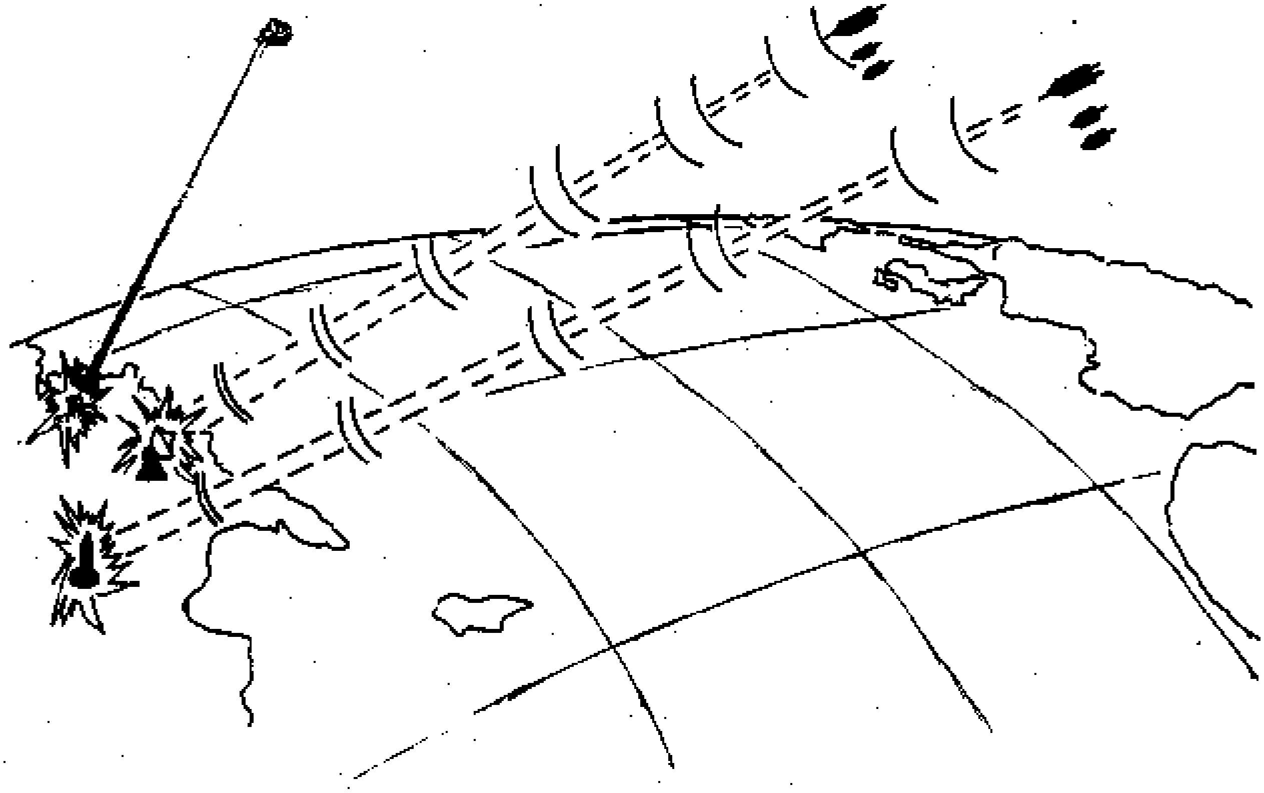

Figure 14. Moray/Tesla Technology: Star Wars Now

Typical strategic ABM uses of Tesla weapons are shown in figure 13. In addition, of course, smaller Tesla howitzer systems for anti-tactical ballistic missile defense of tactical troops and installations could be constituted of more conventional field missile systems using paired or triplet radars, of conventional external appearance, in a scalar interferometer mode.

With Moray generators as power sources and multiply deployed reentry vehicles with scalar antennas and transmitters, ICBM reentry systems now can become long range "blasters" of the target areas, from thousands of kilometers distance (figure 14). Literally, "Star Wars" is liberated by the Tesla technology. And in air attack, jammers and ECM aircraft now become "Tesla blasters." With the Tesla technology, emitters become primary fighting components of stunning power.

The potential peaceful implications of Tesla waves are also enormous. By utilizing the "time squeeze" effect, one can get antigravity, materialization and dematerialization, transmutation, and mindboggling medical benefits. One can also get subluminal and superluminal communication, see through the earth and through the ocean, etc. The new view of phi-field also provides a unified field theory, higher orders of reality, and a new super-relativity, but detailing these possibilities must wait for another book.

With two cerebral brain halves, the human being also has a Tesla scalar interferometer between his ears. And since the brain and nervous system processes avalanche discharges, it can produce (and detect) scalar Tesla waves to at least a limited degree. Thus a human can sometimes produce anomalous spatiotemporal effects at a distance and through time. This provides an exact mechanism for psychokinesis, levitation, psychic healing, telepathy, precognition, postcognition, remote viewing, etc. It also provides a reason why an individual can detect a "stick" on a radionics or Hieronymus machine (which processes scalar waves), when ordinary detectors detect nothing. Unfortunately there is not room to develop the implications of this human Tesla interferometry in detail, for that must wait for yet another book, presently in its initial stages, that Hal Crawford and I are writing.

Table 5. Orders of Reality

- **PHOTONS ARE**
  > **PAIR-COUPLED SCALARS**
  > **VELOCITY-LIMITED TO C**
  > **CARRIERS OF T**

- **PHOTON INTERACTION**
  > **IS UBIQUITOUS**
  > **PRODUCES $\dot{T}$ = C**
  > **YIELDS 1st ORDER REALITY**

- **SCALAR O WAVES**
  > **NOT VELOCITY-LIMITED**
  > **YIELD HIGHER ORDER REALITIES**

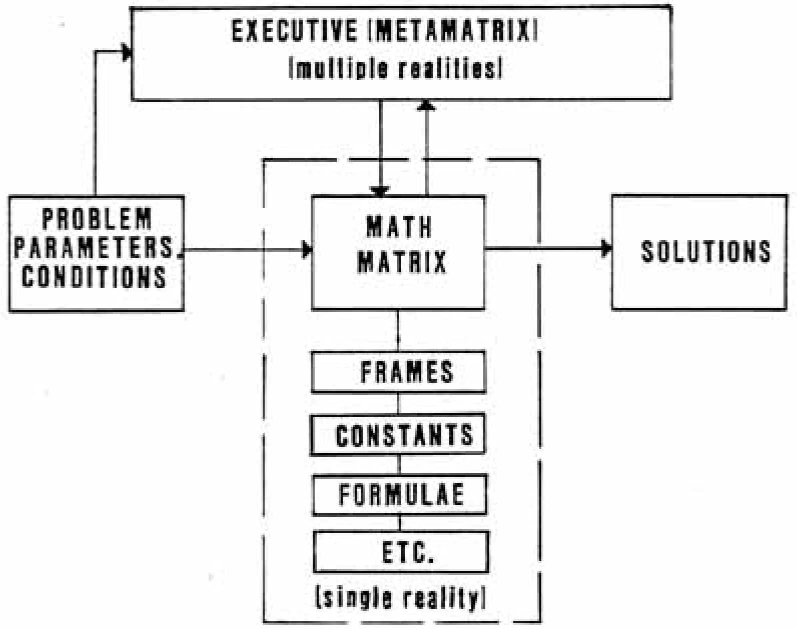

Figure 15. Implications of Tesla Potential

At the July 1981 U.S. Psychotronics Association's Annual Conference in Dayton, Ohio, I presented the first rough paper on the Tesla secret and scalar interferometry. A videotape of the presentation was made and will shortly be available. I am also scheduled to make a special presentation at the Alternate Energy Conference in Toronto, Canada in latter October, 1981. A professional, videotaped two-hour presentation on this subject is also being prepared. Wide distribution of the material through the international underground physics and technology network has already been made. This time, God willing, Tesla's secret will not be suppressed for another 80 years!

And perhaps it is not yet too late. The material has cost me (now) some 16 years of agonizing labor and nearly $100,000 of my own personal funds. No orthodox university, scientific group, foundation, or governmental agency would support such an effort, either financially or otherwise. Indeed, most ordinary journals will not even accept material on such matters. Nonetheless, the area is of overwhelming importance and I truly believe Tesla's lost secret will shortly affect the lives of every human being on earth.

Perhaps with the free and open release of Tesla's secret, the scientific and governmental bureaucracies will be. shocked awake from their slumber, and we can develop defenses before Armageddon occurs. Perhaps there is hope after all -- for even Brezhnev, in his strange July, 1975 proposal to the SALT talks, seemed to reveal a perception that a turning point in war and weaponry may have been reached, and that human imagination is incapable of dealing with the ability to totally engineer reality itself. Having tested the weapons, the Soviets must be aware that the ill-provoked oscillation of timeflow affects the minds and thoughts -- and the very lifestreams and even the collective species unconsciousnesses -- of all lifeforms on earth. They must know that these weapons are two-edged swords, and that the backlash from their use can be far more terrible to the user than was the original effect to his victim.

If we can avoid the Apocalypse, the fantastic secret of Nikola Tesla can be employed to cure and elevate man, not kill him. Tesla's discovery can eventually remove every conceivable external human limitation. If we humans ourselves can elevate our consciousness to properly utilize the Tesla electromagnetics, then Nikola Tesla -- who gave us the electrical twentieth century in the first place -- may yet give us a fantastic new future more shining and glorious than all the great scientists and sages have imagined.

References

http://www.cheniere.org/books/part1/teslaweapons.htm

- ▶ Reply
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Permalink Reply by rose on August 4, 2013 at 10:54

yeah this ones from deep in the archives Greg - I would love to see that article!!!

- ▶ Reply
-

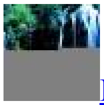Permalink Reply by deanna munson on August 4, 2013 at 18:16

what if these weapons work in conjunction with cell towers and smartgrid/wifi relays? i just read this and it blew me away how the dangers this is being purposely ignored http://www.stayonthetruth.com/electromagnetic-fields---killing-fiel... "

November 14 1996, Omnipoint, New York City's first digital cellular provider, did open for business, broadcasting from thousands of antennae newly erected on the rooftops of apartment buildings. According to the health authorities, an early flu hit New York City - but not Boston, and not Philadelphia - on about 15 November. The flu was severe and ran a prolonged course, often dragging on for months instead of the usual two weeks.

At Christmas time, the Cellular Phone Task Force placed a small classified ad in a free weekly newspaper. It read: 'If you have been ill since 11/15/96 with any of the following: eye pain, insomnia, dry lips, swollen throat, pressure or pain in the chest, headaches, dizziness, nausea, shakiness, other aches and pains, or flu that won't go away, you may be a victim of a new microwave system blanketing the city. We need to hear from you.' And we did hear from them. Hundreds called, men, women, whites, blacks, Asians, Latinos, doctors, lawyers, teachers, stockbrokers, airline stewards, computer operators. Most had woken up suddenly in mid-November, thinking they were having a stroke or a heart attack or a nervous breakdown, and were relieved to know they were not alone and not crazy.

Later, I analysed weekly mortality statistics, which the Centres for Disease Control publish for122 US cities. Each of dozens of cities recorded a 10-25 per cent increase in mortality, lasting two to three months, beginning on the day in 1996 or 1997 on which that city's first digital cell phone network began commercial service." we already know these agendas are being forced everywhere.no one is even noticing how even though everyone is already "connected" they are still erecting more and more towers and infastructure,by force in the case of smartmeters.wired in connections now cost over double what wifi does.they just put up another tower here on my block,disguised as a flipping pine tree.cant block the effects when it comes from literally all sides

- ▶ Reply
-

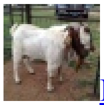Permalink Reply by Rhonda Reichel on August 6, 2013 at 6:15

Scalar weapons makes all the billions we spend on war obsolete.....what a racket

- ▶ Reply
-

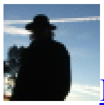

Permalink Reply by steve on August 9, 2013 at 6:43
having read a few pages, it looks like a weapon of distraction to me. The physics is in the realm of the tooth fairy, and the history has the ring of recent manufacture

- ▶ Reply
-

Permalink Reply by rose on August 9, 2013 at 12:24

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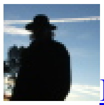

Permalink Reply by steve on August 9, 2013 at 16:03
plus, Tom Beardon is nothing but a fear merchant.

- ▶ Reply
-

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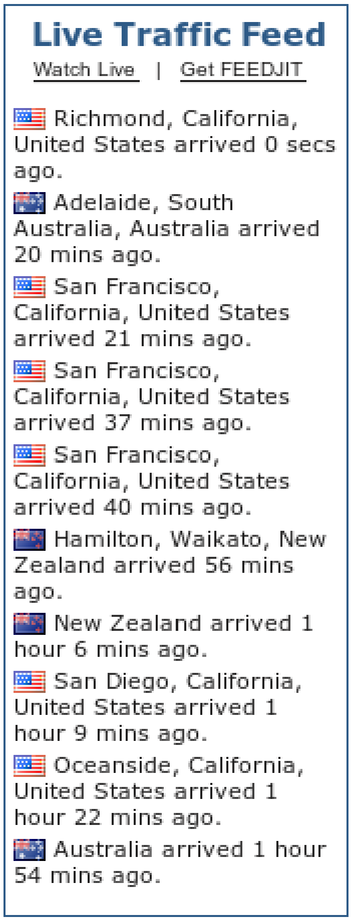

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Foundations of Electro-Magnetism

Slide Series

- Major Points of Presentation
- Chung's Carbon Filament Negative Resistor
- Aharanov-Bohm Effect
- Absorption and emission reactions (1)
- Absorption and emission reactions (2)
- Anti-engine for cell's deviation reverses cell back to normal
- Asymmetric regauging produces excess force, which can be used to do work on the system
- Asymmetric regauging produces excess force, which can be used to do work on the regauging system
- Becker's bone fracture healing experiments
- Becker's theoretical control system governing regeneration
- Becker's theoretical DC control system involved with response to injury
- Geometrical Distortion of Poynting Energy Flow
- Cosmic Bootstrap: Before the Big Bang
- Bridging Enables COP > 1

- Aspects of Strong Local Symmetry
- Other Aspects of Strong Local Symmetry
- Bunge on the Status of Electrodynamics
- Bunge on the Status of Electrodynamics and Physics
- Bunge on the Status of Classical and Quantum Physics
- Fractions of BW Casualties Surviving
- First Step in Self-Promotion of Cancer Due to Hypoxia
- Differentiation and Dedifferentiation Timelines
- Evolution of Cells on Earth
- A Charged Particle q is a Coupled System of m and Ø
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (1)
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (2)
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (3)
- A Charged Particle is a Coupled System
- The Anomalies in Navy Electrolyte Experiments at China Lake
- Chung's Carbon Filament Negative Resistor

- Typical circuit has about 10^{-13} energy collection efficiency
- Classical View of EM
- Curved Spacetime acts as source or sink
- Chronic Disease Puzzling
- Cancer Characteristics
- Solving a Cancer Enigma
- Cancer: Characteristics
- Nonlinear Optics Distortion Correction Theorem
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (1)
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (2)
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (3)
- In Time-Reversed Zone: Nuclear reactions are biased
- In Time-Reversed Zone: Dynamics may be reversed
- Time-Reversed Zone: Significant only after time-density charging
- A New Conservation of Energy Law
- Questions on Carcinogens and EM

Radiation

- AS DEFINED, fields and potentials only exist in and on charged matter
- Serious flaws and errors in classical EM theory
- Electrodynamicists' Reaction to Removal of the Material Ether
- Reaction to Loss of Material Ether (1)
- Reaction to Loss of Material Ether (2)
- Some EM waves in Spacetime
- Air Medium Disturbances Generated When Air is Perturbed by a Plucked Taut String
- Launching a Spacetime Perturbation ("EM Wave") from a Wire Antenna
- Phase Conjugate Wavepairs Produce New Waves
- Scalar Electromagnetics (Energetics) View of EM (1)
- Scalar Electromagnetics (Energetics) View of EM (2)

- Scalar Electromagnetics (Energetics) View of EM (3)
- Extended General Relativity Principle
- Extension of Work-Energy Theorem
- 34 Flaws in Classical EM Theory
- MTW's General Relativity Principle
- Use of General Relativity (GR) in Particle Physics
- The Missing Infolded Electrodynamics
- Infolded Engines: Excluded by Present Physics
- Mass curves and structures spacetime; ST curvatures change and structure mass (1)
- Mass curves and structures spacetime; ST curvatures change and structure mass (2)
- At Infinite Velocity: Each Is Every Other
- Lisitsyn's Report: Brain Code Broken
- Lorentz Closed Surface Integration
- Lorentz's physically insignificant energy flow can be collected and utilized
- Lorentz surface integration of the Poynting vector around a closed surface
- Longitudinal EM Photon Interaction with Charge
- Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass.

- Pumping with Longitudinal EM waves Time-reverses the Mass
- Maxwell's Quaternion Theory
- Maxwellian Systems before and after Regauging
- Maxwell's four equations reduce to: Page 1
- Maxwell's four equations reduce to: Page 2
- More to come

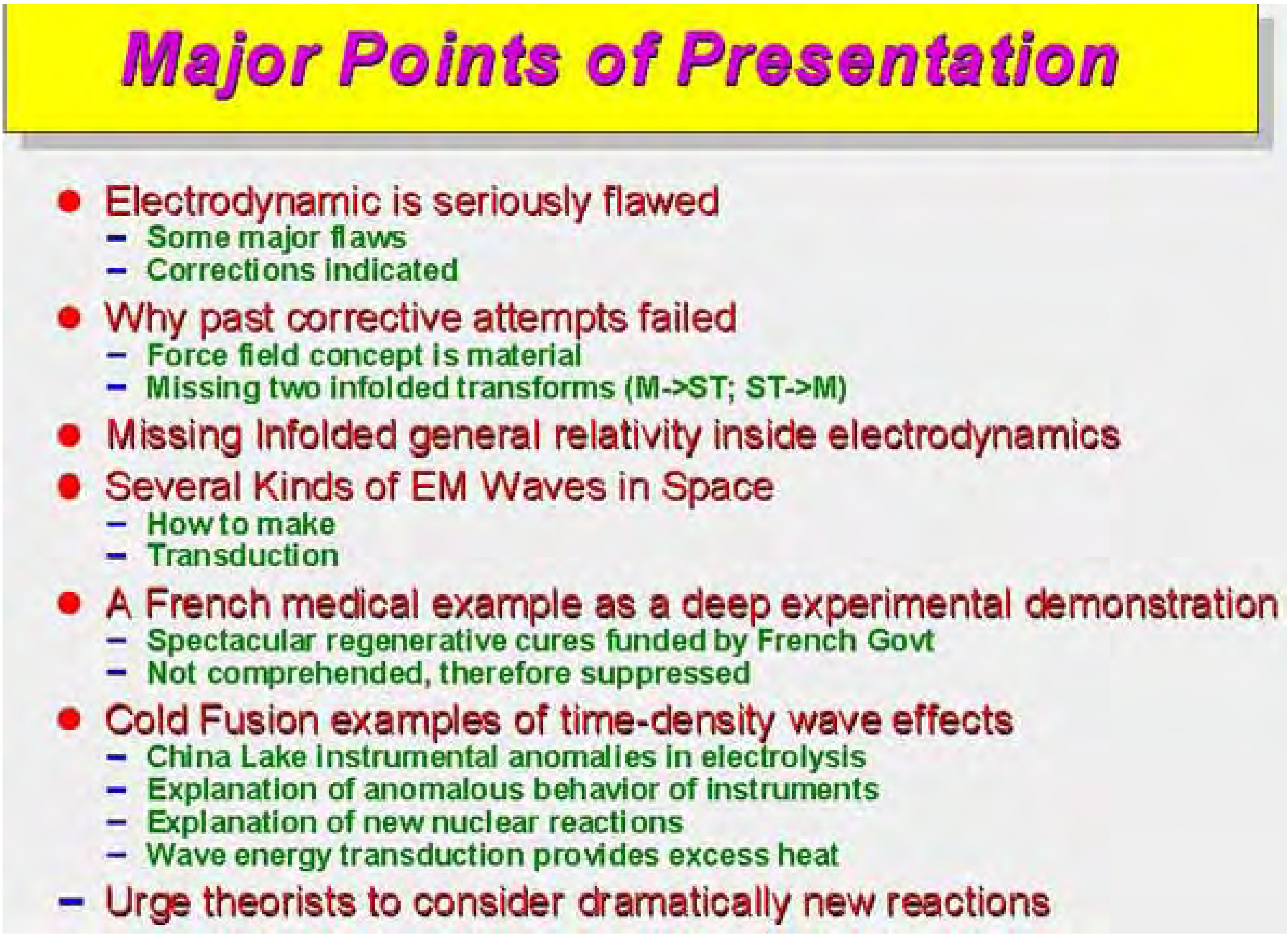

Major Points of Presentation

- Electrodynamic is seriously flawed
  - Some major flaws
  - Corrections indicated
- Why past corrective attempts failed
  - Force field concept is material
  - Missing two infolded transforms (M->ST; ST->M)
- Missing infolded general relativity inside electrodynamics
- Several Kinds of EM Waves in Space
  - How to make
  - Transduction
- A French medical example as a deep experimental demonstration
  - Spectacular regenerative cures funded by French Govt
  - Not comprehended, therefore suppressed
- Cold Fusion examples of time-density wave effects
  - China Lake instrumental anomalies in electrolysis
  - Explanation of anomalous behavior of instruments
  - Explanation of new nuclear reactions
  - Wave energy transduction provides excess heat
- Urge theorists to consider dramatically new reactions

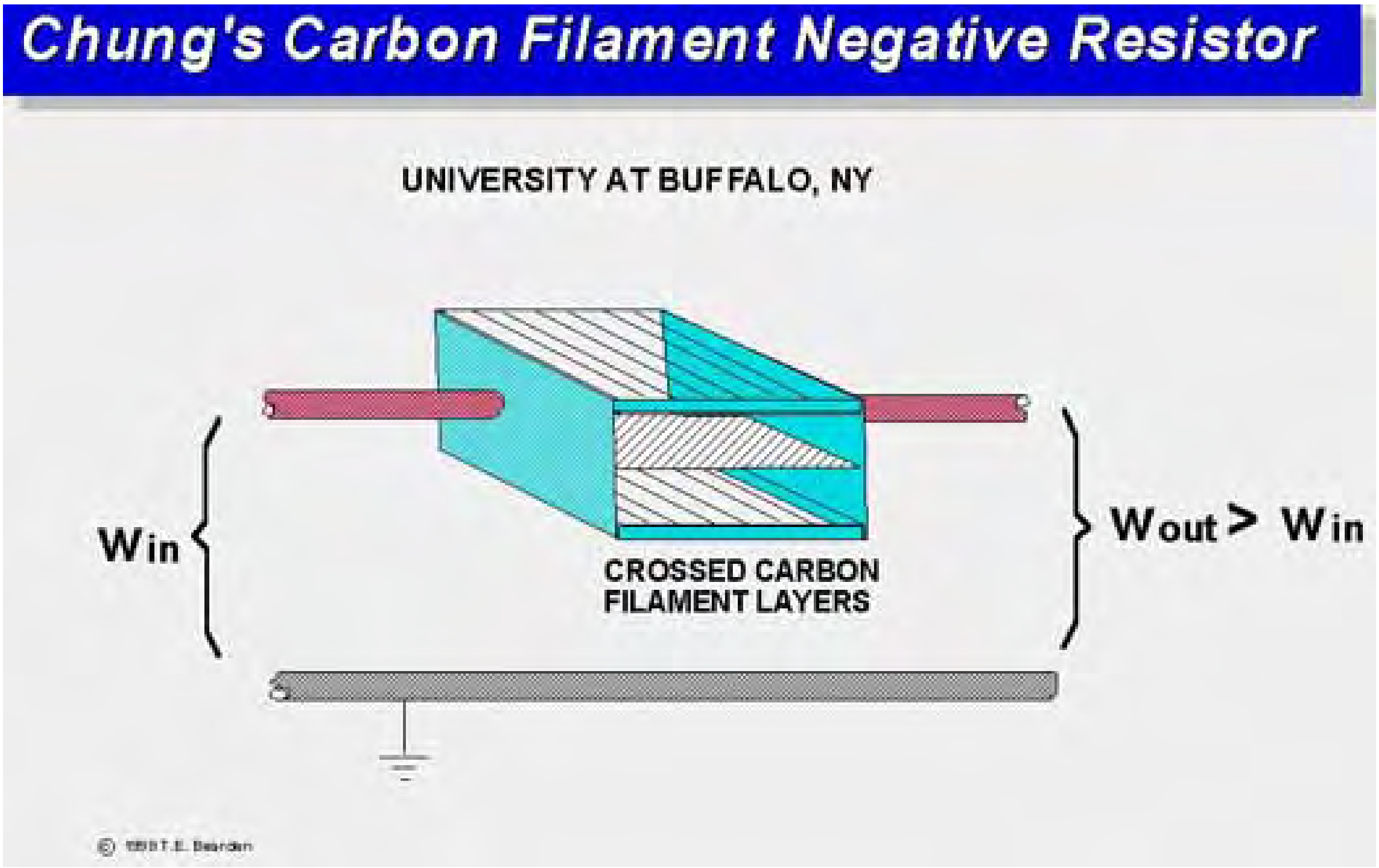

Chung's Carbon Filament Negative Resistor

UNIVERSITY AT BUFFALO, NY

Win
CROSSED CARBON FILAMENT LAYERS
Wout > Win

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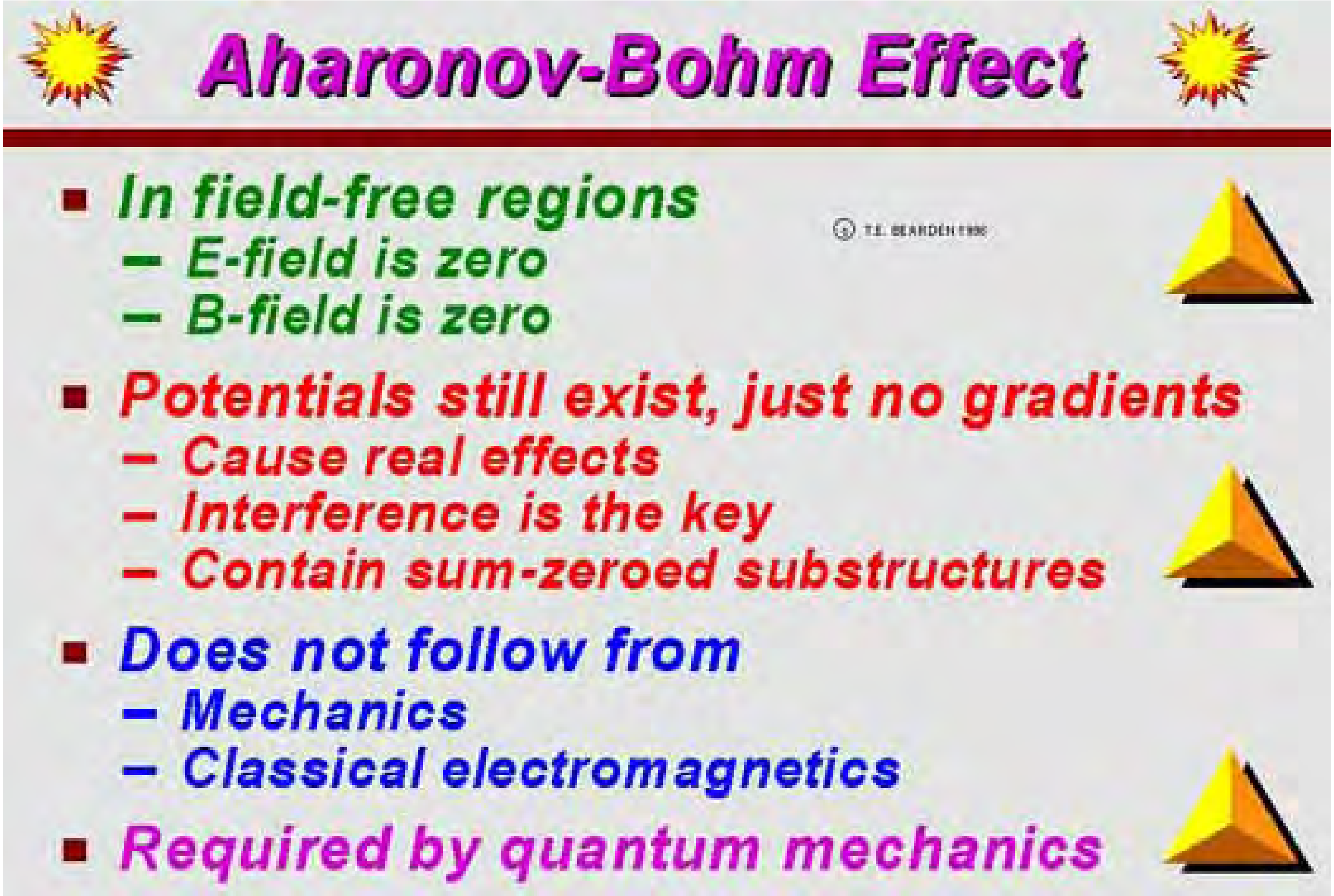

Aharonov-Bohm Effect

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- In field-free regions
  - E-field is zero
  - B-field is zero
- Potentials still exist, just no gradients
  - Cause real effects
  - Interference is the key
  - Contain sum-zeroed substructures
- Does not follow from
  - Mechanics
  - Classical electromagnetics
- Required by quantum mechanics

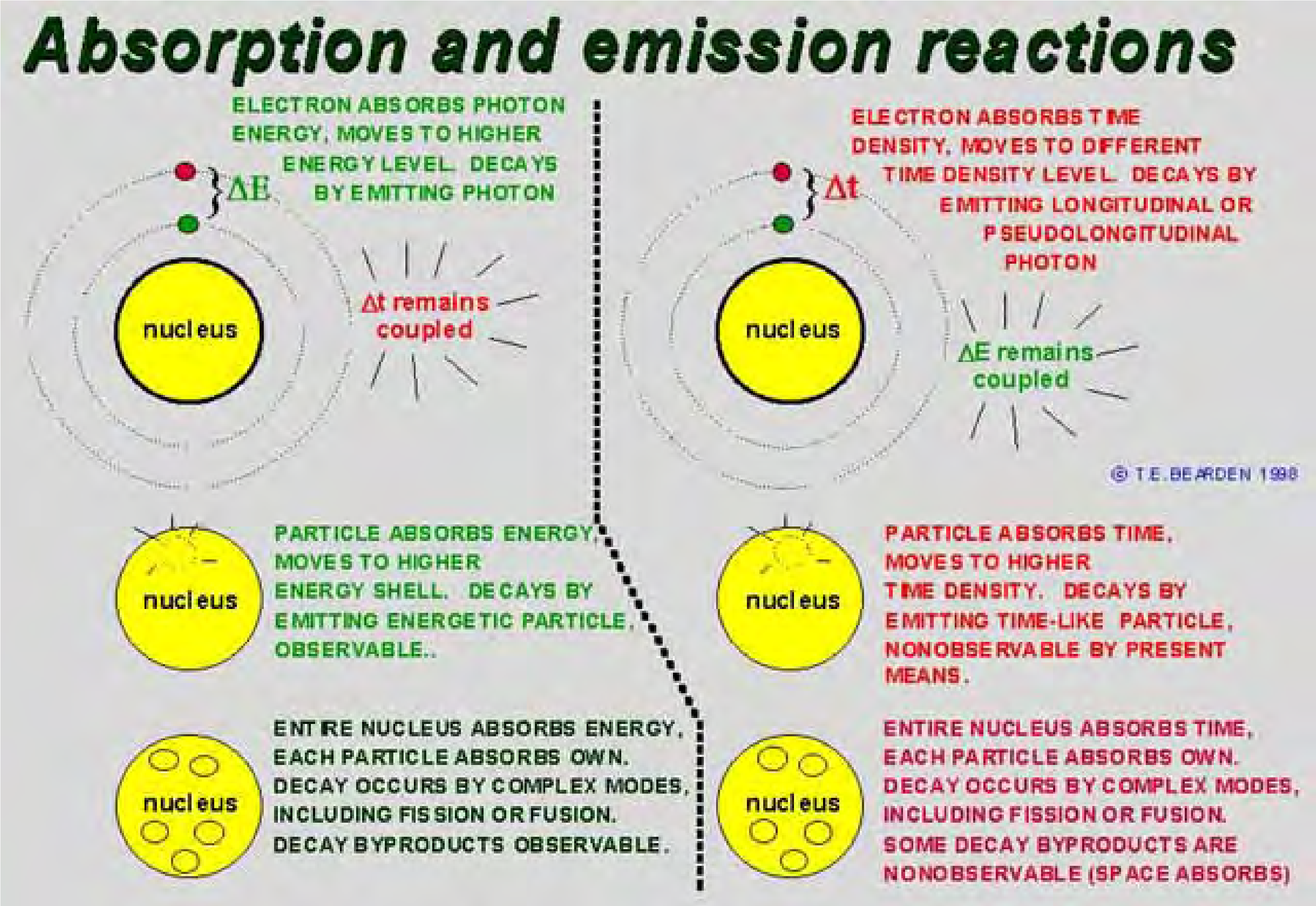

Absorption and emission reactions

ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON

ELECTRON ABSORBS TIME DENSITY, MOVES TO DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTON

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PARTICLE ABSORBS ENERGY, MOVES TO HIGHER ENERGY SHELL. DECAYS BY EMITTING ENERGETIC PARTICLE. OBSERVABLE..

PARTICLE ABSORBS TIME, MOVES TO HIGHER TIME DENSITY. DECAYS BY EMITTING TIME-LIKE PARTICLE, NONOBSERVABLE BY PRESENT MEANS.

ENTIRE NUCLEUS ABSORBS ENERGY, EACH PARTICLE ABSORBS OWN. DECAY OCCURS BY COMPLEX MODES, INCLUDING FISSION OR FUSION. DECAY BYPRODUCTS OBSERVABLE.

ENTIRE NUCLEUS ABSORBS TIME, EACH PARTICLE ABSORBS OWN. DECAY OCCURS BY COMPLEX MODES, INCLUDING FISSION OR FUSION. SOME DECAY BYPRODUCTS ARE NONOBSERVABLE (SPACE ABSORBS)

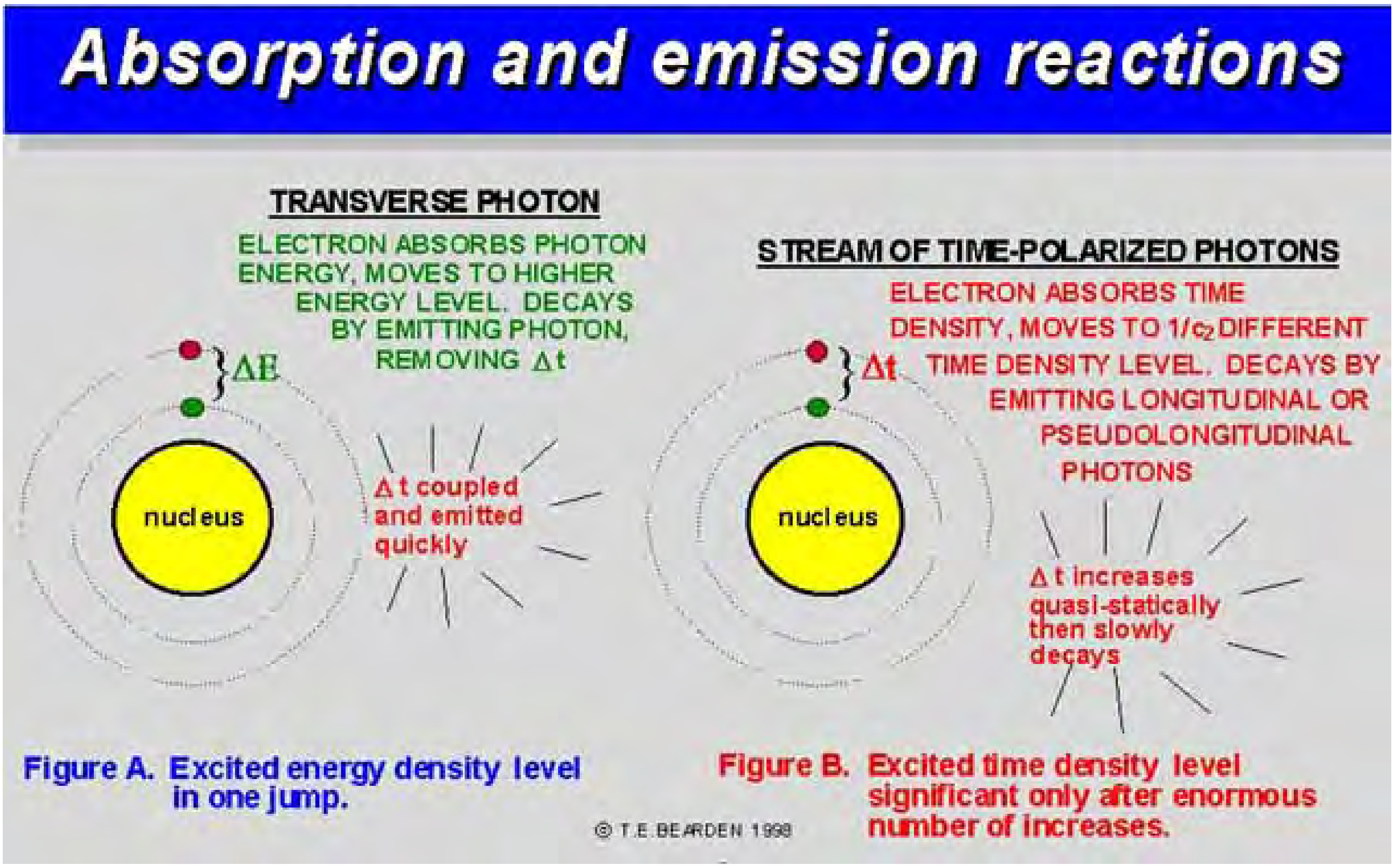

Absorption and emission reactions

TRANSVERSE PHOTON

ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON, REMOVING Δt

Δt coupled and emitted quickly

STREAM OF TIME-POLARIZED PHOTONS

ELECTRON ABSORBS TIME DENSITY, MOVES TO 1/c_2 DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTONS

Δt increases quasi-statically then slowly decays

Figure A. Excited energy density level in one jump.

Figure B. Excited time density level significant only after enormous number of increases.

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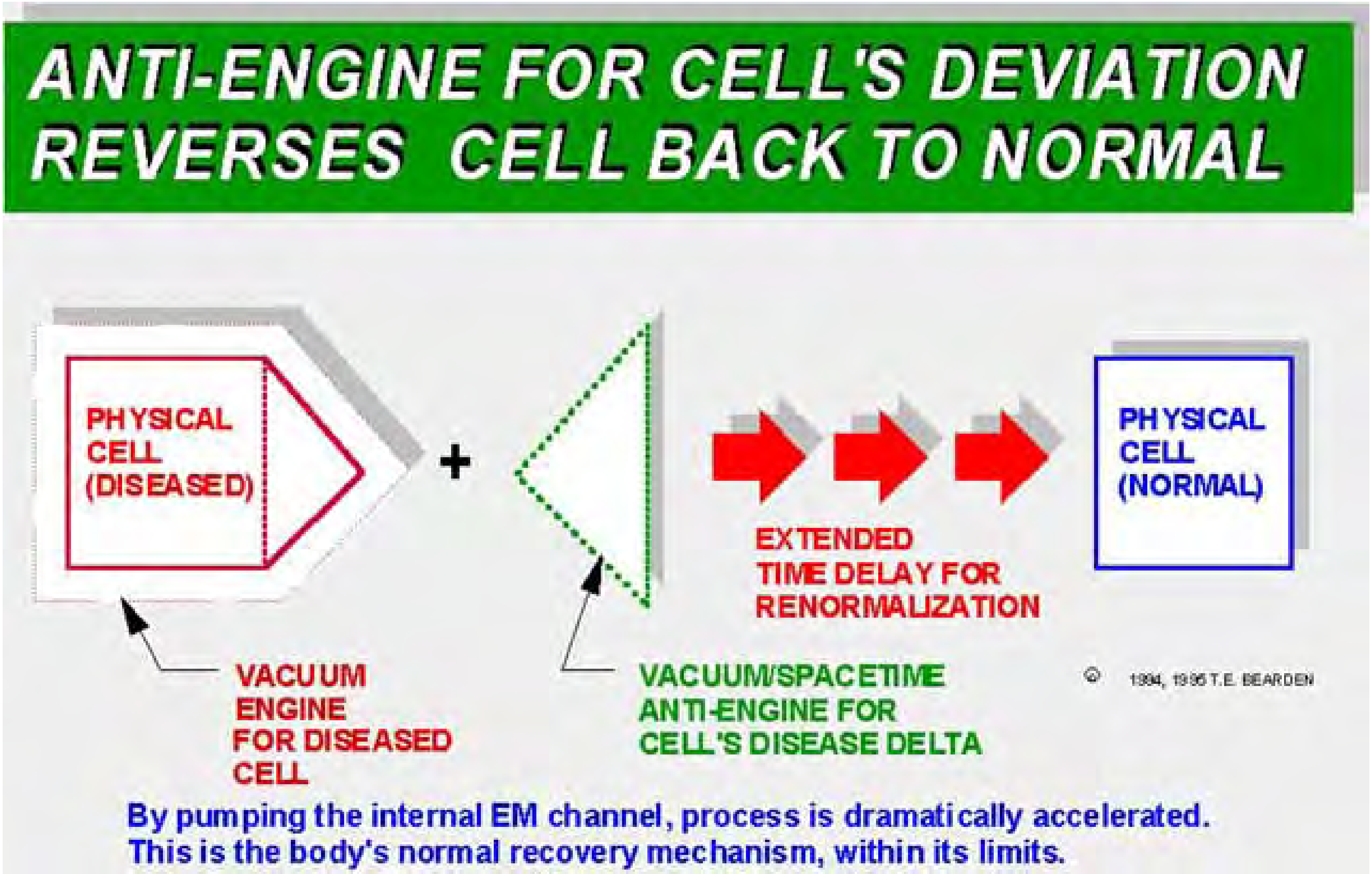

ANTI-ENGINE FOR CELL'S DEVIATION REVERSES CELL BACK TO NORMAL

PHYSICAL CELL (DISEASED)

+

EXTENDED TIME DELAY FOR RENORMALIZATION

PHYSICAL CELL (NORMAL)

VACUUM ENGINE FOR DISEASED CELL

VACUUM/SPACETIME ANTI-ENGINE FOR CELL'S DISEASE DELTA

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By pumping the internal EM channel, process is dramatically accelerated.
This is the body's normal recovery mechanism, within its limits.

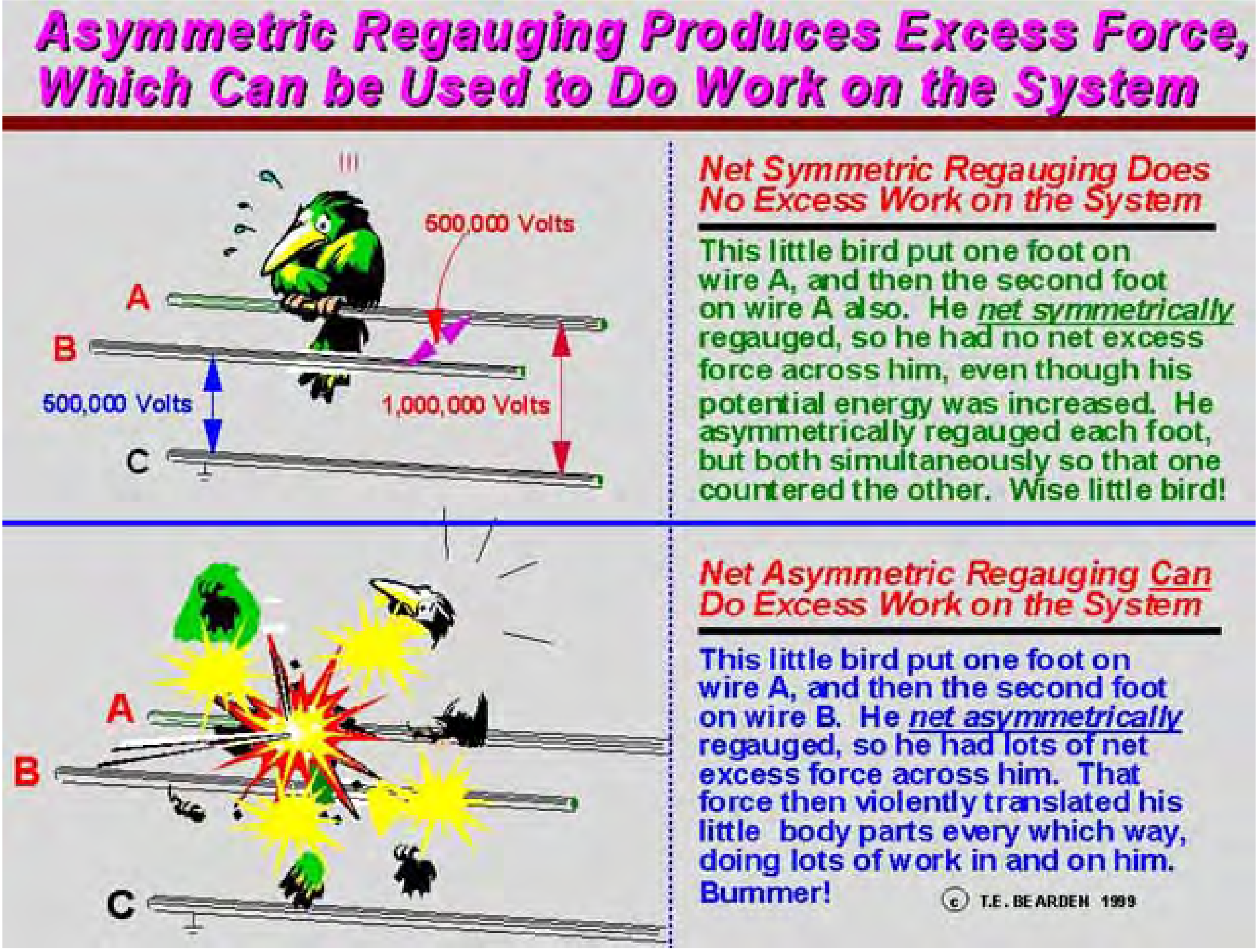

Asymmetric Regauging Produces Excess Force, Which Can be Used to Do Work on the System

Net Symmetric Regauging Does No Excess Work on the System

This little bird put one foot on wire A, and then the second foot on wire A also. He *net symmetrically* regauged, so he had no net excess force across him, even though his potential energy was increased. He asymmetrically regauged each foot, but both simultaneously so that one countered the other. Wise little bird!

Net Asymmetric Regauging Can Do Excess Work on the System

This little bird put one foot on wire A, and then the second foot on wire B. He *net asymmetrically* regauged, so he had lots of net excess force across him. That force then violently translated his little body parts every which way, doing lots of work in and on him. Bummer!

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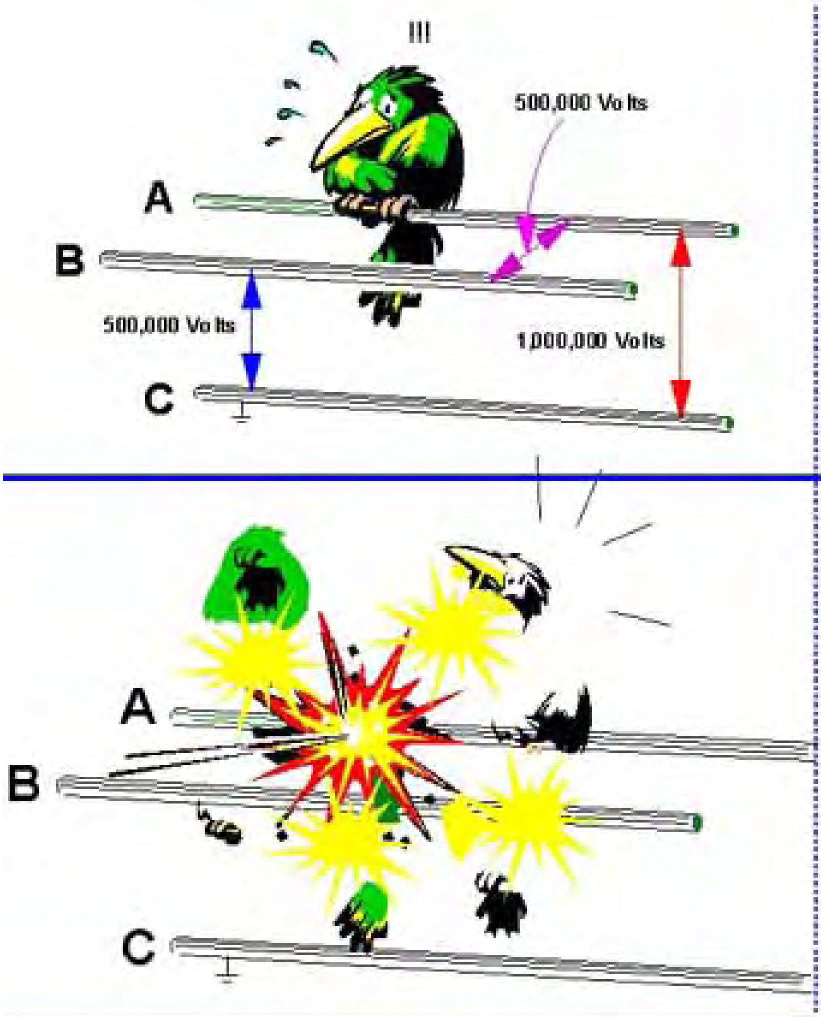

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Ⓒ T.E. BEARDEN 1996

Figure 32. Asymmetric regauging produces excess force, which can be used to do work on the regauging system.

Selected clipart © by Lotus SmartPics™

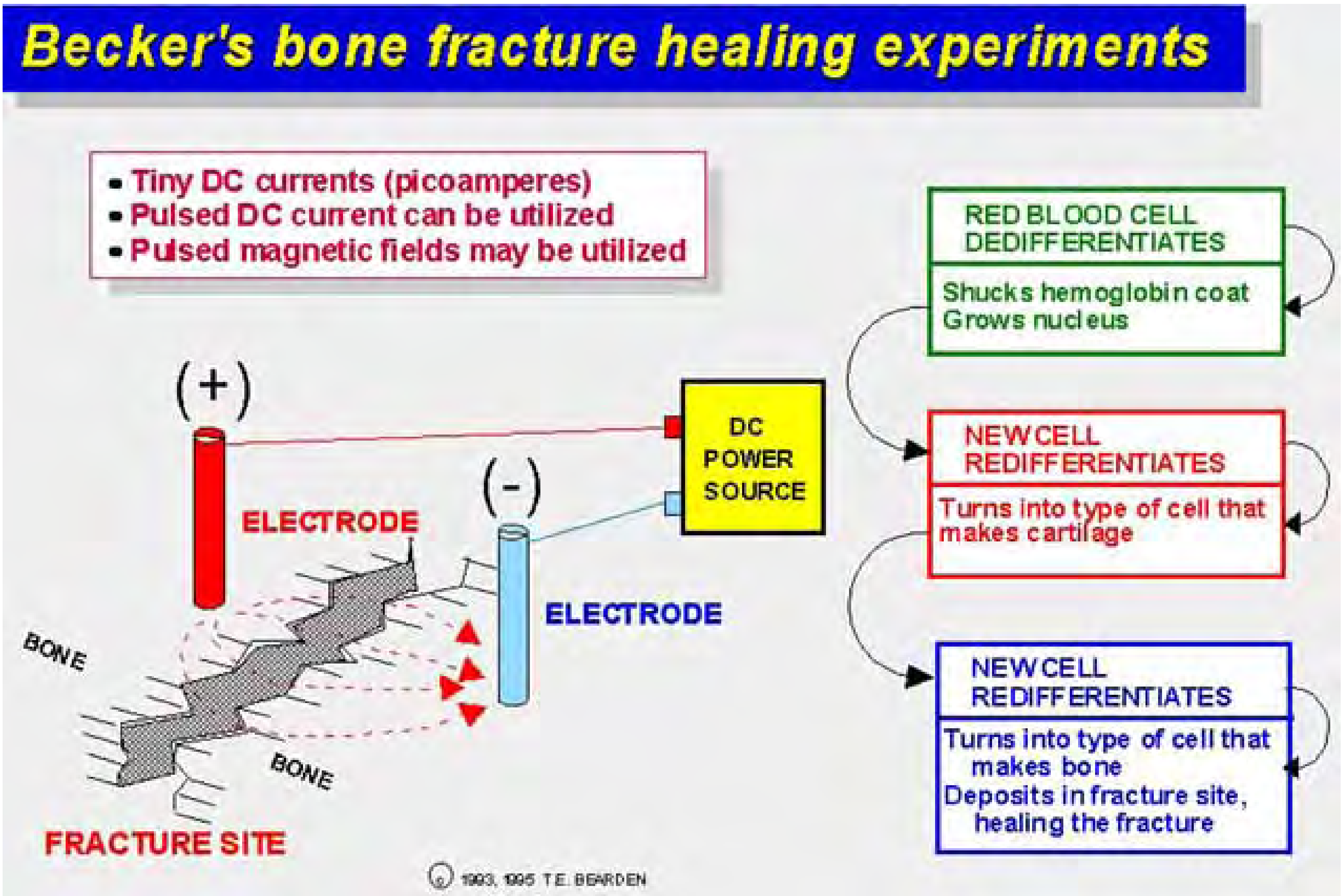

Becker's bone fracture healing experiments

- Tiny DC currents (picoamperes)
- Pulsed DC current can be utilized
- Pulsed magnetic fields may be utilized

(+)
ELECTRODE
(-)
ELECTRODE
DC POWER SOURCE
BONE
BONE
FRACTURE SITE

RED BLOOD CELL DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

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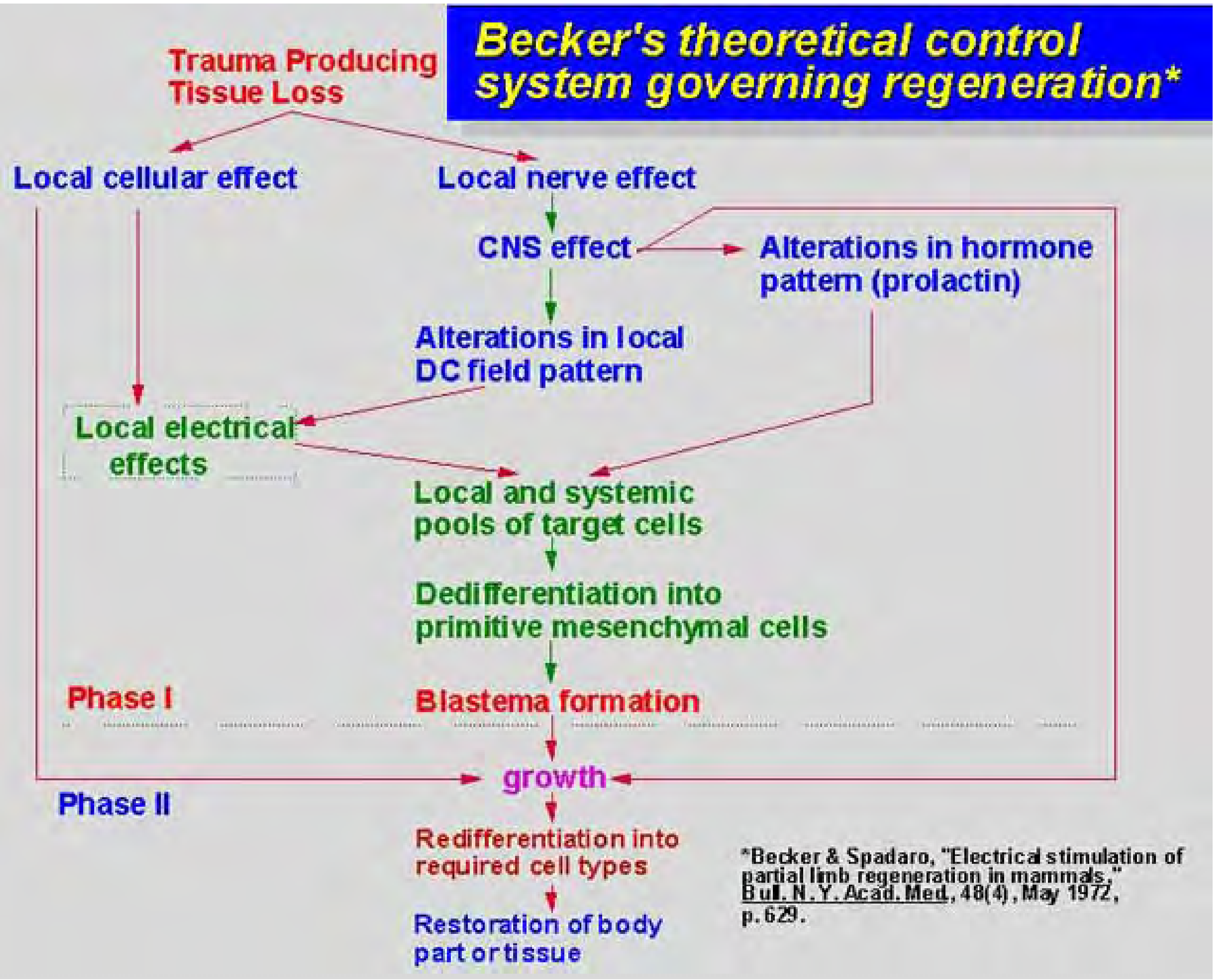

Becker's theoretical control system governing regeneration*

Trauma Producing Tissue Loss

Local cellular effect

Local nerve effect

CNS effect

Alterations in hormone pattern (prolactin)

Alterations in local DC field pattern

Local electrical effects

Local and systemic pools of target cells

Dedifferentiation into primitive mesenchymal cells

Phase I

Blastema formation

growth

Phase II

Redifferentiation into required cell types

Restoration of body part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bul. N.Y. Acad. Med., 48(4), May 1972, p. 629.

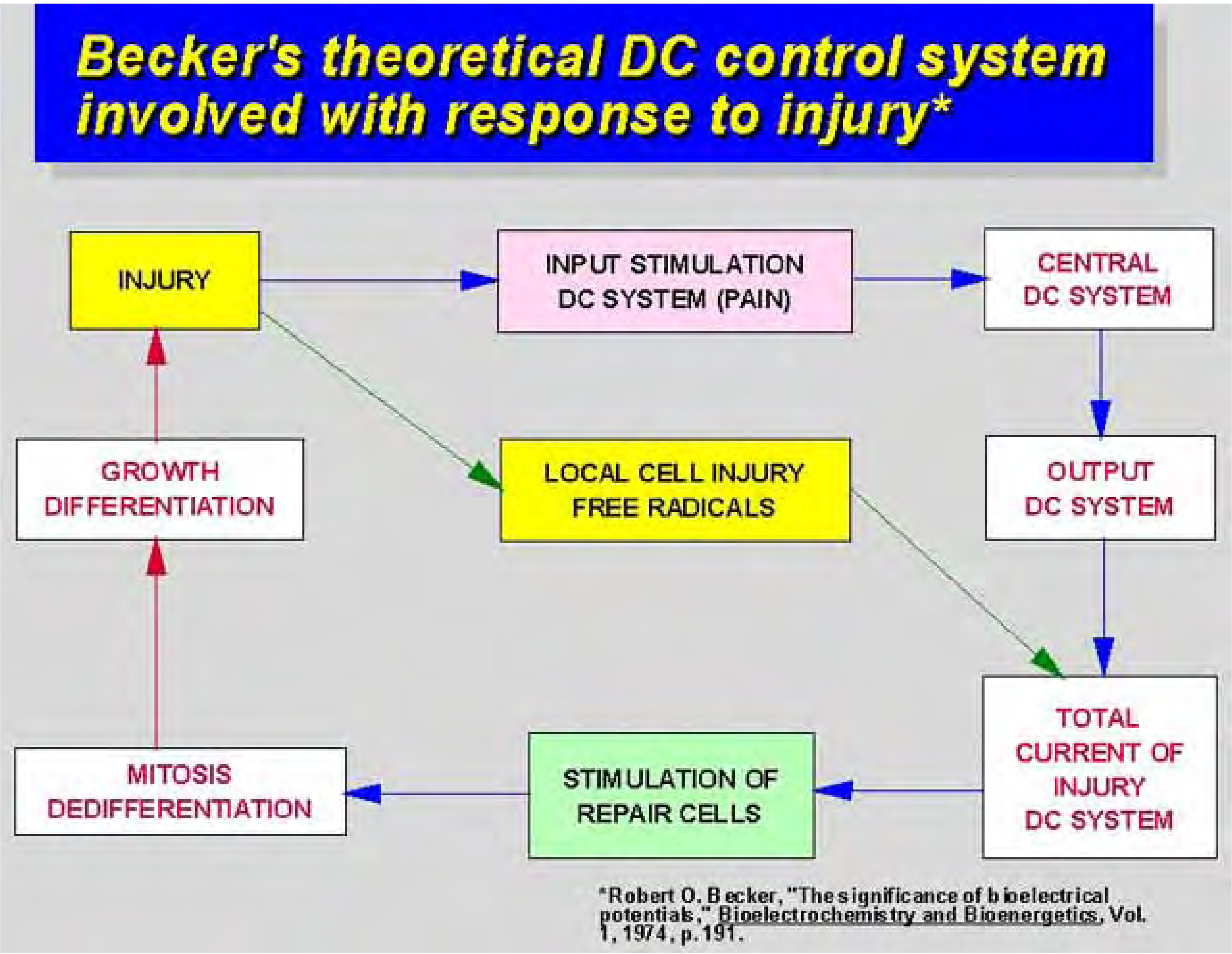

Becker's theoretical DC control system involved with response to injury*

INJURY

INPUT STIMULATION DC SYSTEM (PAIN)

CENTRAL DC SYSTEM

OUTPUT DC SYSTEM

TOTAL CURRENT OF INJURY DC SYSTEM

LOCAL CELL INJURY FREE RADICALS

STIMULATION OF REPAIR CELLS

MITOSIS DEDIFFERENTIATION

GROWTH DIFFERENTIATION

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.

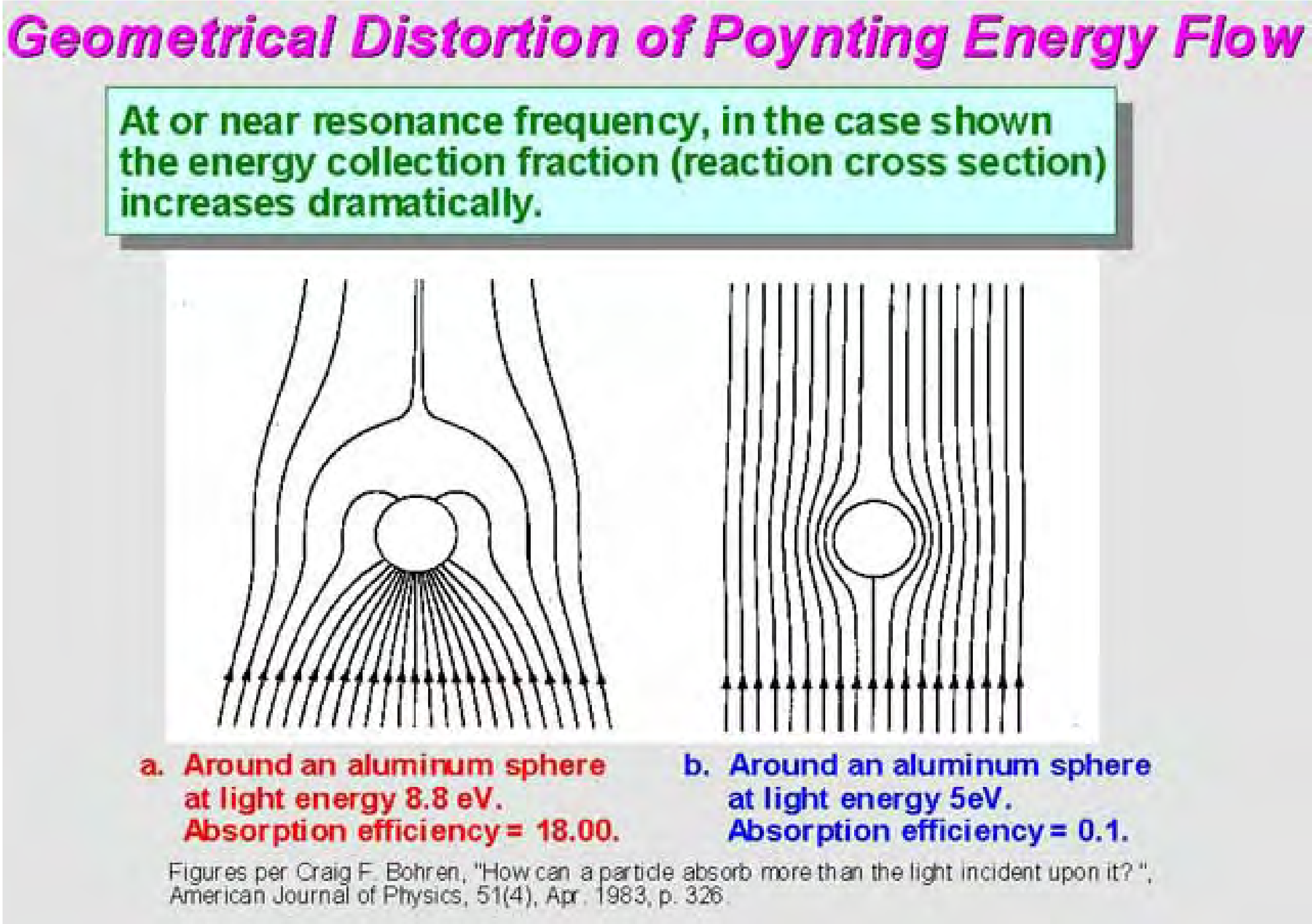

Geometrical Distortion of Poynting Energy Flow

At or near resonance frequency, in the case shown the energy collection fraction (reaction cross section) increases dramatically.

a. Around an aluminum sphere at light energy 8.8 eV. Absorption efficiency = 18.00.

b. Around an aluminum sphere at light energy 5eV. Absorption efficiency = 0.1.

Figures per Craig F. Bohren, "How can a particle absorb more than the light incident upon it? ", American Journal of Physics, 51(4), Apr. 1983, p. 326.

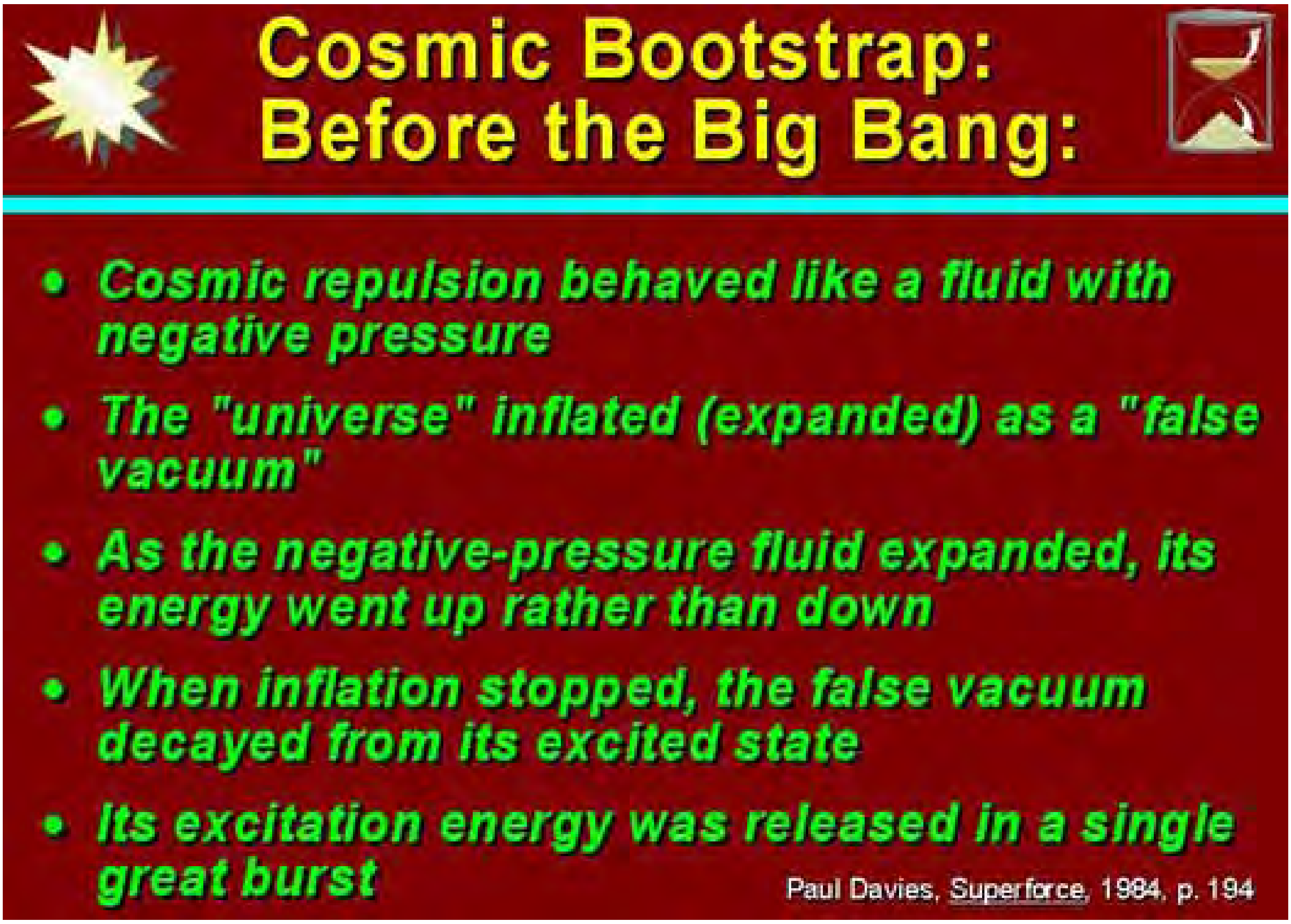

Cosmic Bootstrap: Before the Big Bang:

- Cosmic repulsion behaved like a fluid with negative pressure
- The "universe" inflated (expanded) as a "false vacuum"
- As the negative-pressure fluid expanded, its energy went up rather than down
- When inflation stopped, the false vacuum decayed from its excited state
- Its excitation energy was released in a single great burst

Paul Davies, Superforce, 1984, p. 194

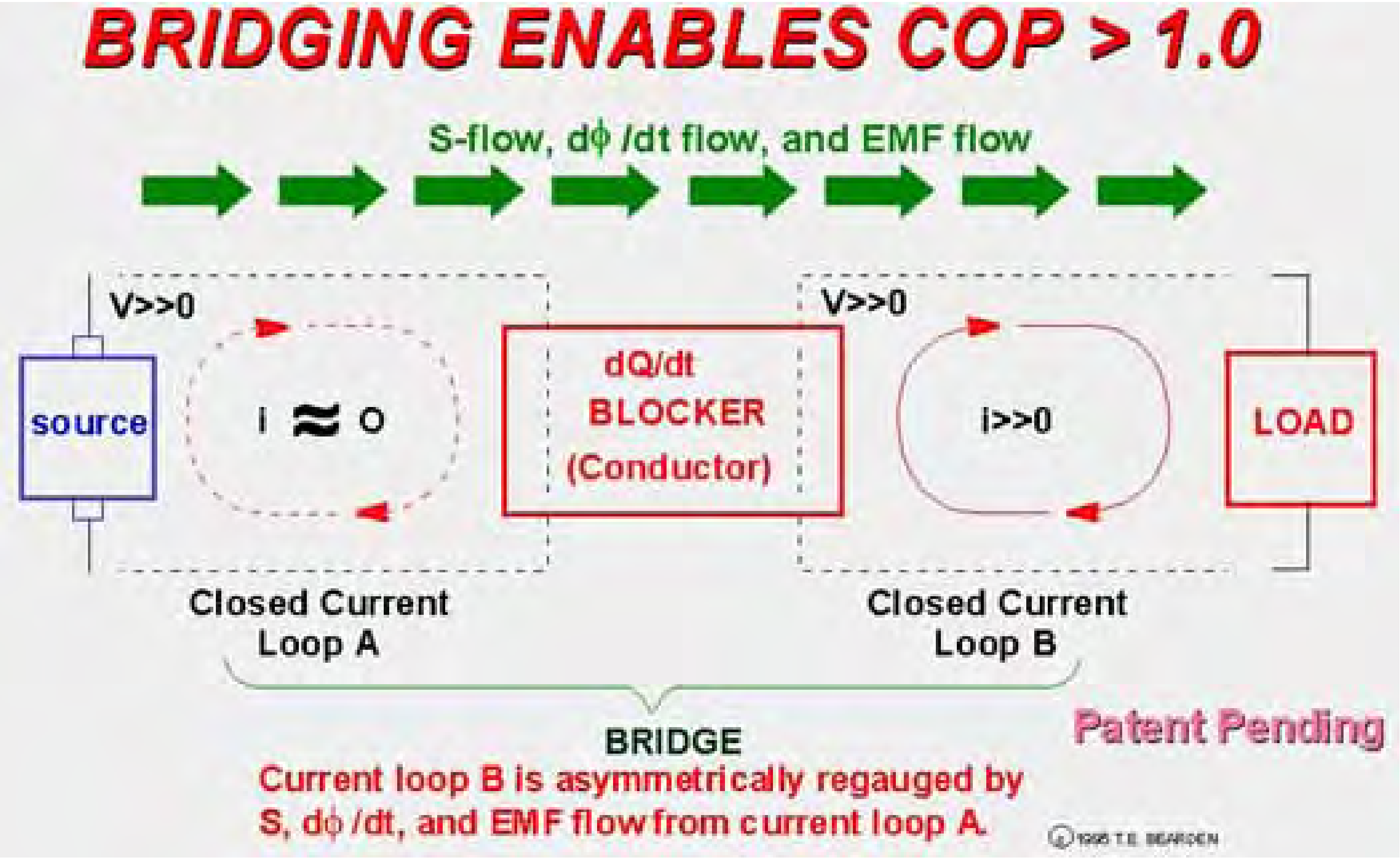

BRIDGING ENABLES COP > 1.0

S-flow, dϕ /dt flow, and EMF flow
V>>0
source
i ≈ o
dQ/dt
BLOCKER
(Conductor)
V>>0
i>>0
LOAD
Closed Current
Loop A
Closed Current
Loop B

BRIDGE

Current loop B is asymmetrically regauged by S, dϕ /dt, and EMF flow from current loop A.

Patent Pending

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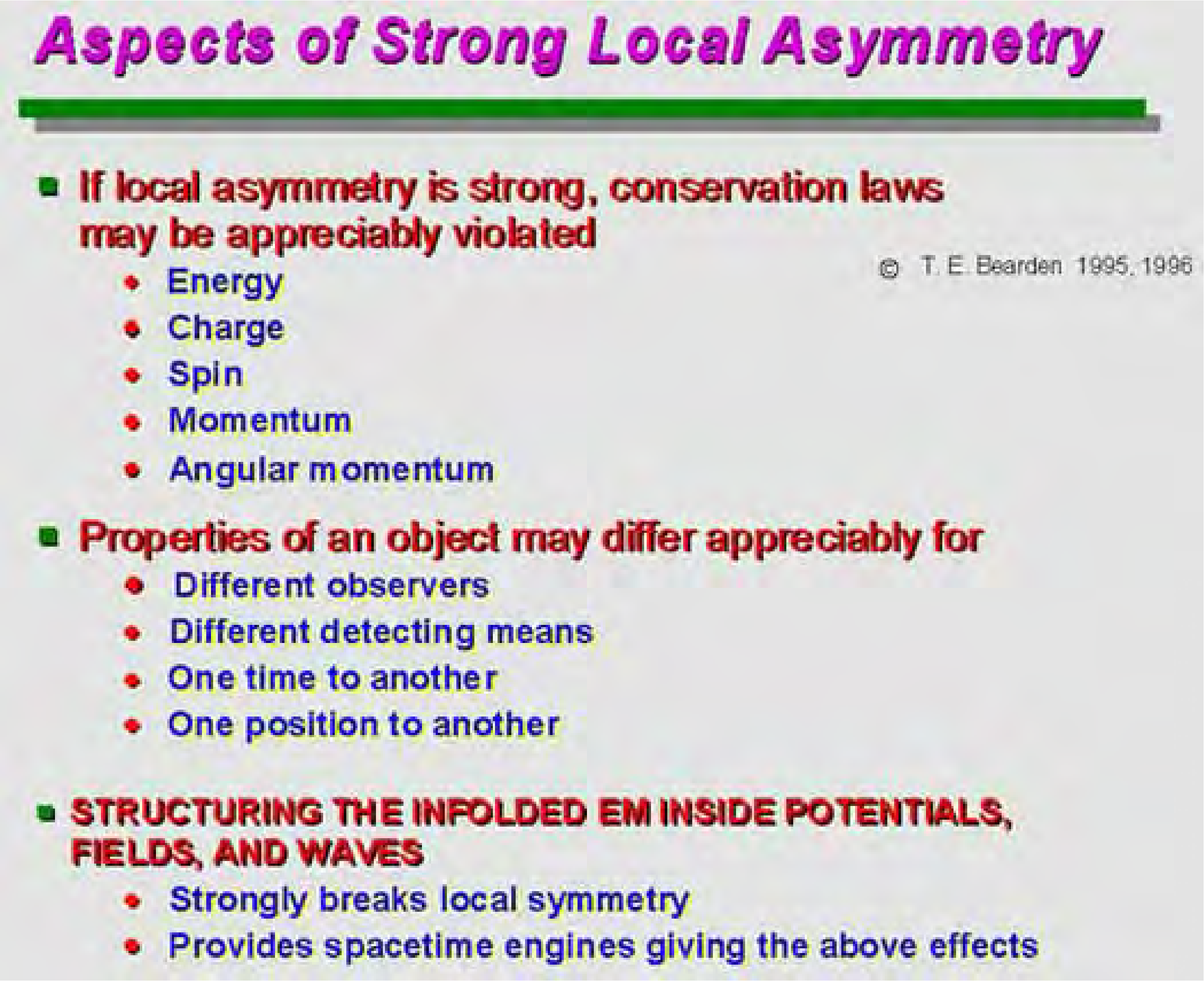

Aspects of Strong Local Asymmetry

- If local asymmetry is strong, conservation laws may be appreciably violated
  - Energy
  - Charge
  - Spin
  - Momentum
  - Angular momentum

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- Properties of an object may differ appreciably for
  - Different observers
  - Different detecting means
  - One time to another
  - One position to another
- STRUCTURING THE INFOLDED EM INSIDE POTENTIALS, FIELDS, AND WAVES
  - Strongly breaks local symmetry
  - Provides spacetime engines giving the above effects

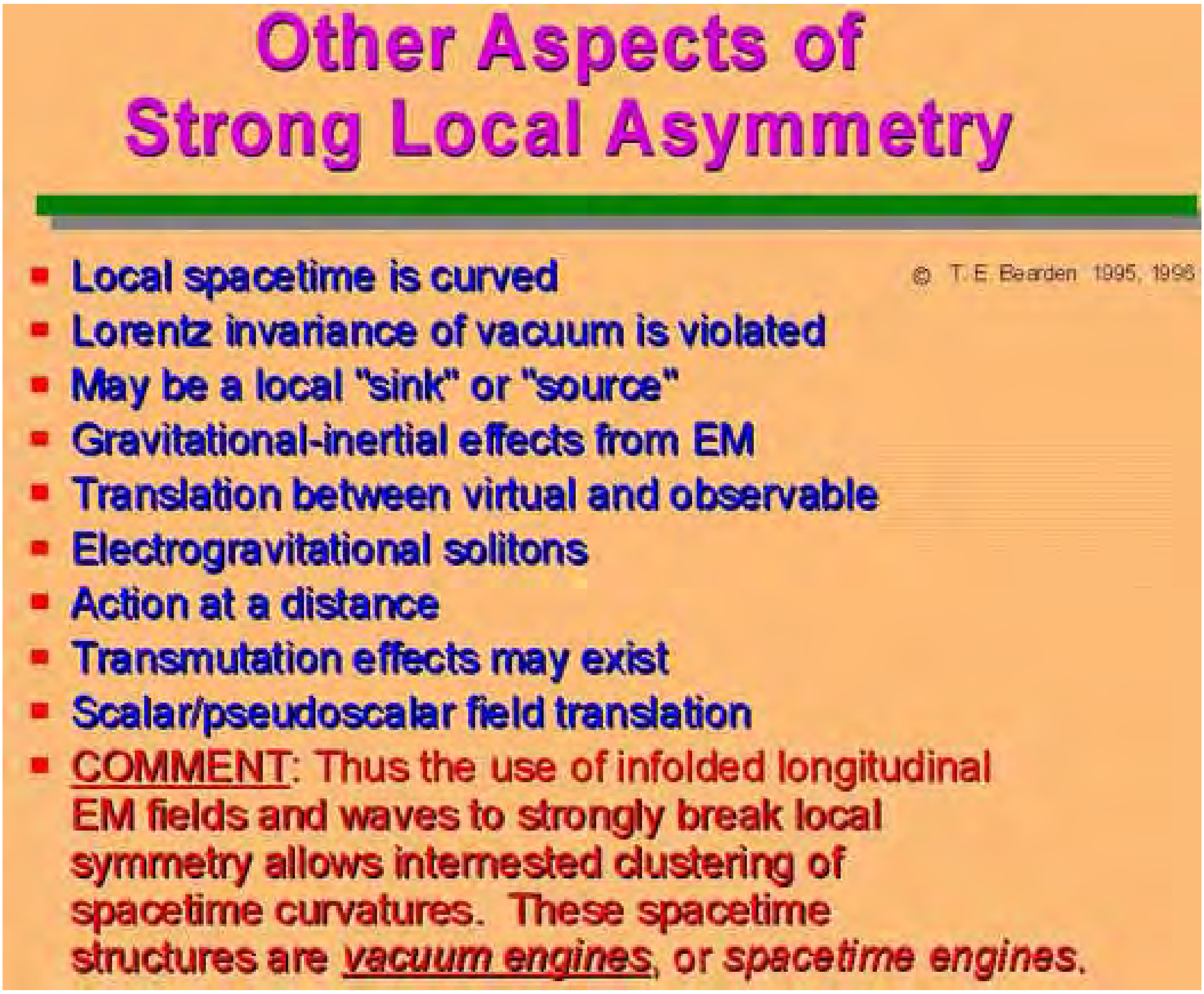

Other Aspects of Strong Local Asymmetry

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- Local spacetime is curved
- Lorentz invariance of vacuum is violated
- May be a local "sink" or "source"
- Gravitational-inertial effects from EM
- Translation between virtual and observable
- Electrogravitational solitons
- Action at a distance
- Transmutation effects may exist
- Scalar/pseudoscalar field translation
- COMMENT: Thus the use of infolded longitudinal EM fields and waves to strongly break local symmetry allows internested clustering of spacetime curvatures. These spacetime structures are *vacuum engines*, or *spacetime engines*.

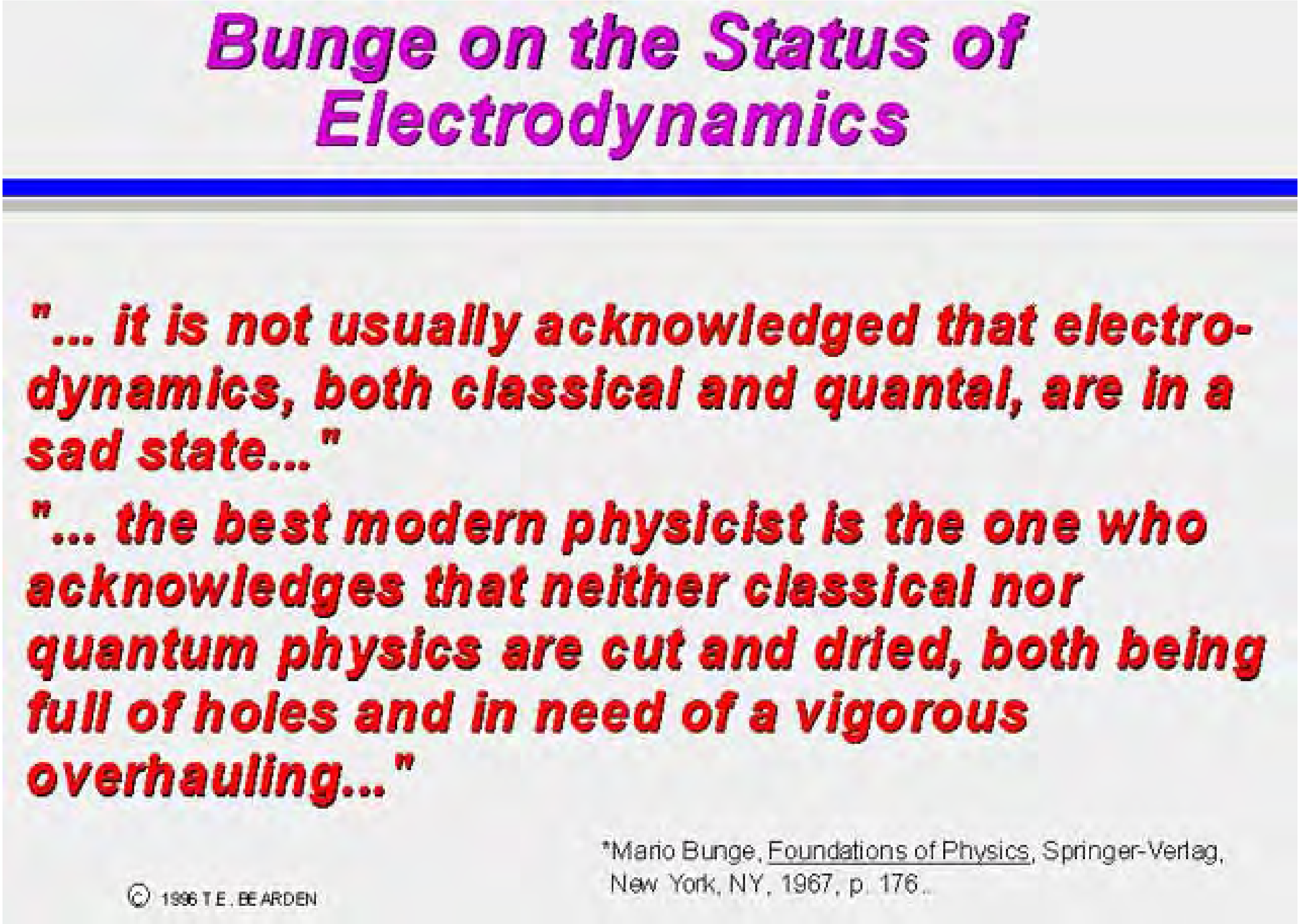

Bunge on the Status of Electrodynamics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state..."

"... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling..."

*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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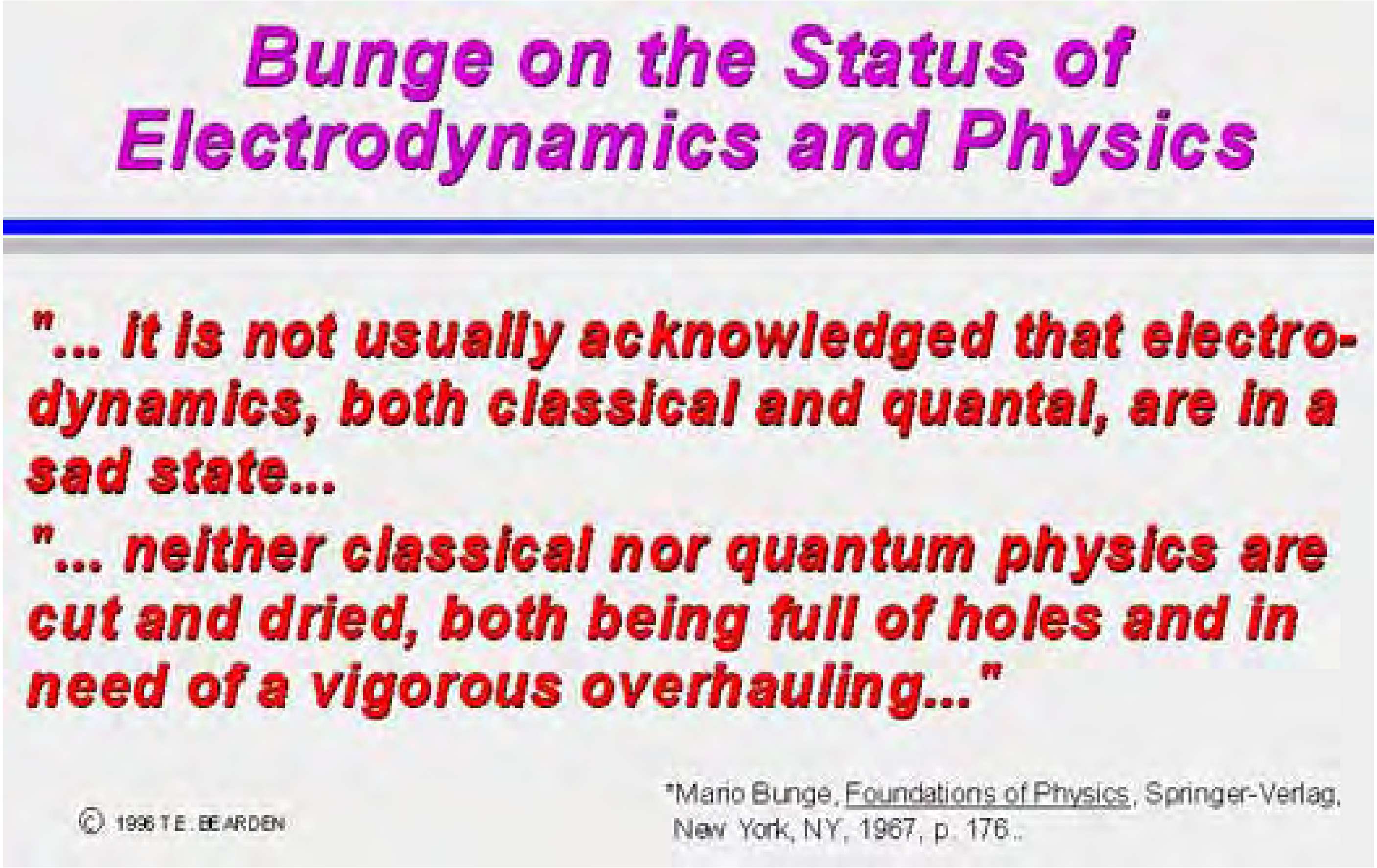

Bunge on the Status of Electrodynamics and Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state...

"... neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling..."

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*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

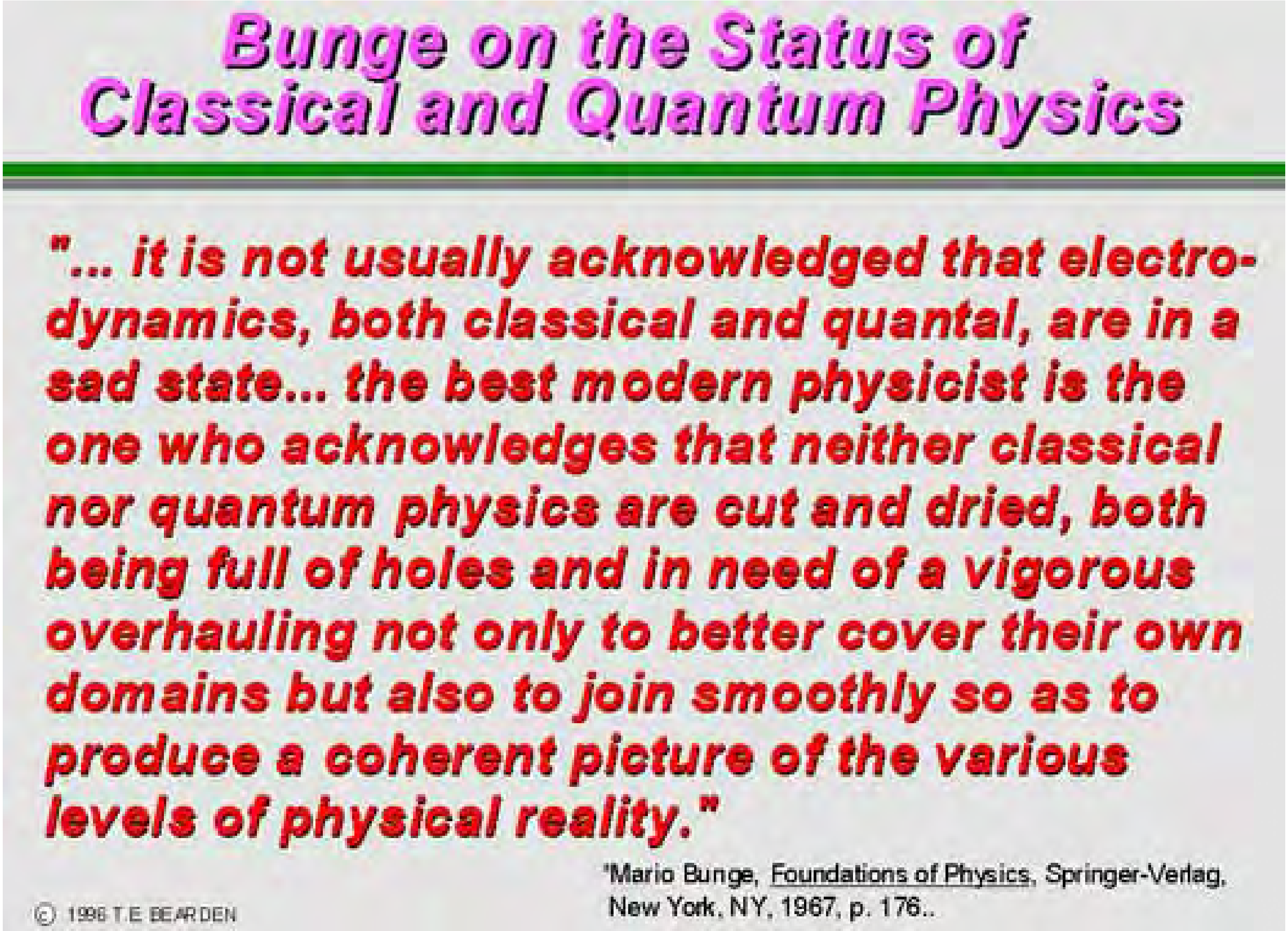

Bunge on the Status of Classical and Quantum Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling not only to better cover their own domains but also to join smoothly so as to produce a coherent picture of the various levels of physical reality."

'Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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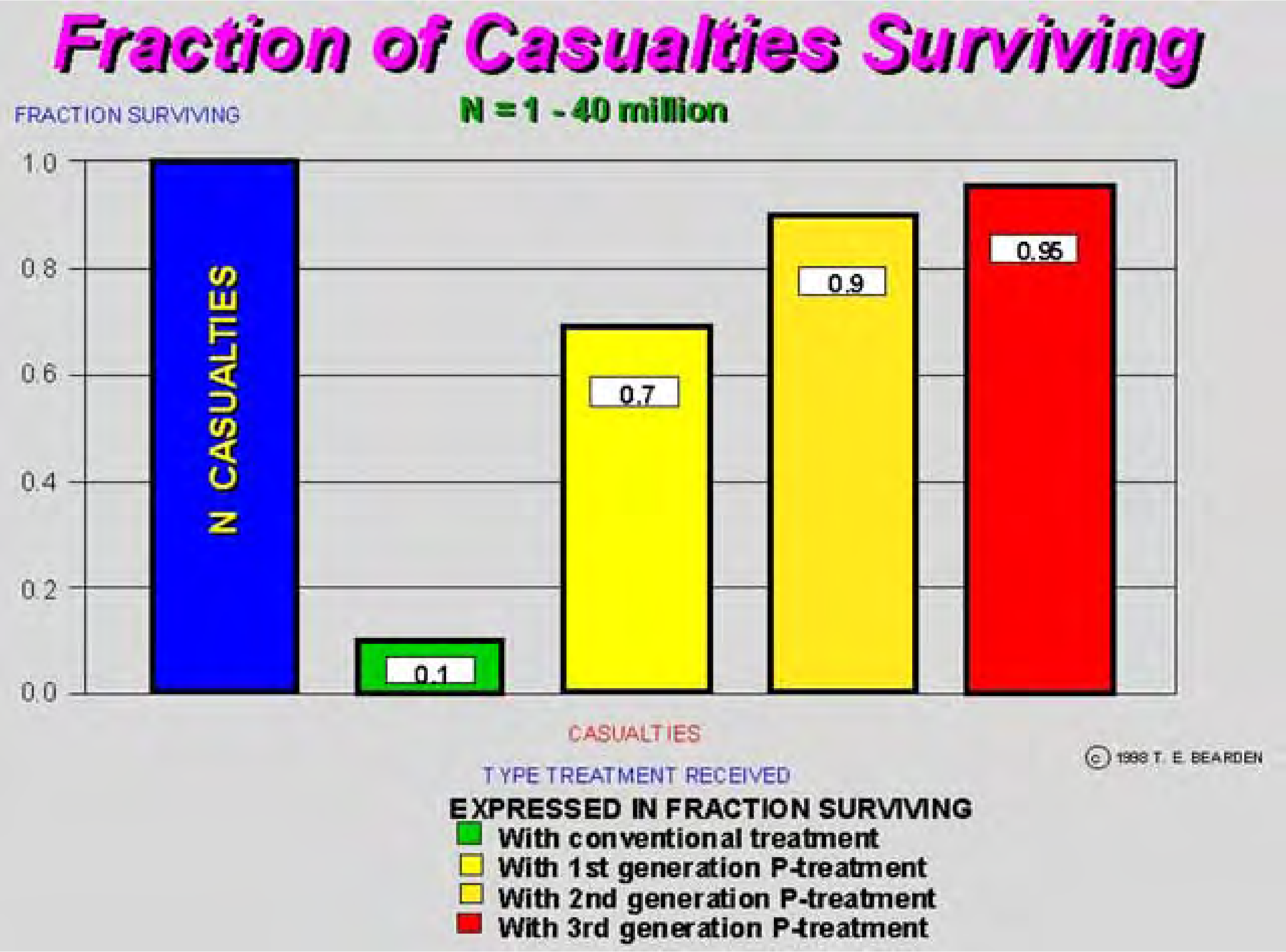
Fraction of Casualties Surviving
N = 1 - 40 million
FRACTION SURVIVING
1.0
0.8
0.6
0.4
0.2
0.0
N CASUALTIES
0.1
0.7
0.9
0.95
CASUALTIES
TYPE TREATMENT RECEIVED
© 1998 T. E. BEARDEN
EXPRESSED IN FRACTION SURVIVING
🟩 With conventional treatment
🟨 With 1st generation P-treatment
🟨 With 2nd generation P-treatment
🟥 With 3rd generation P-treatment

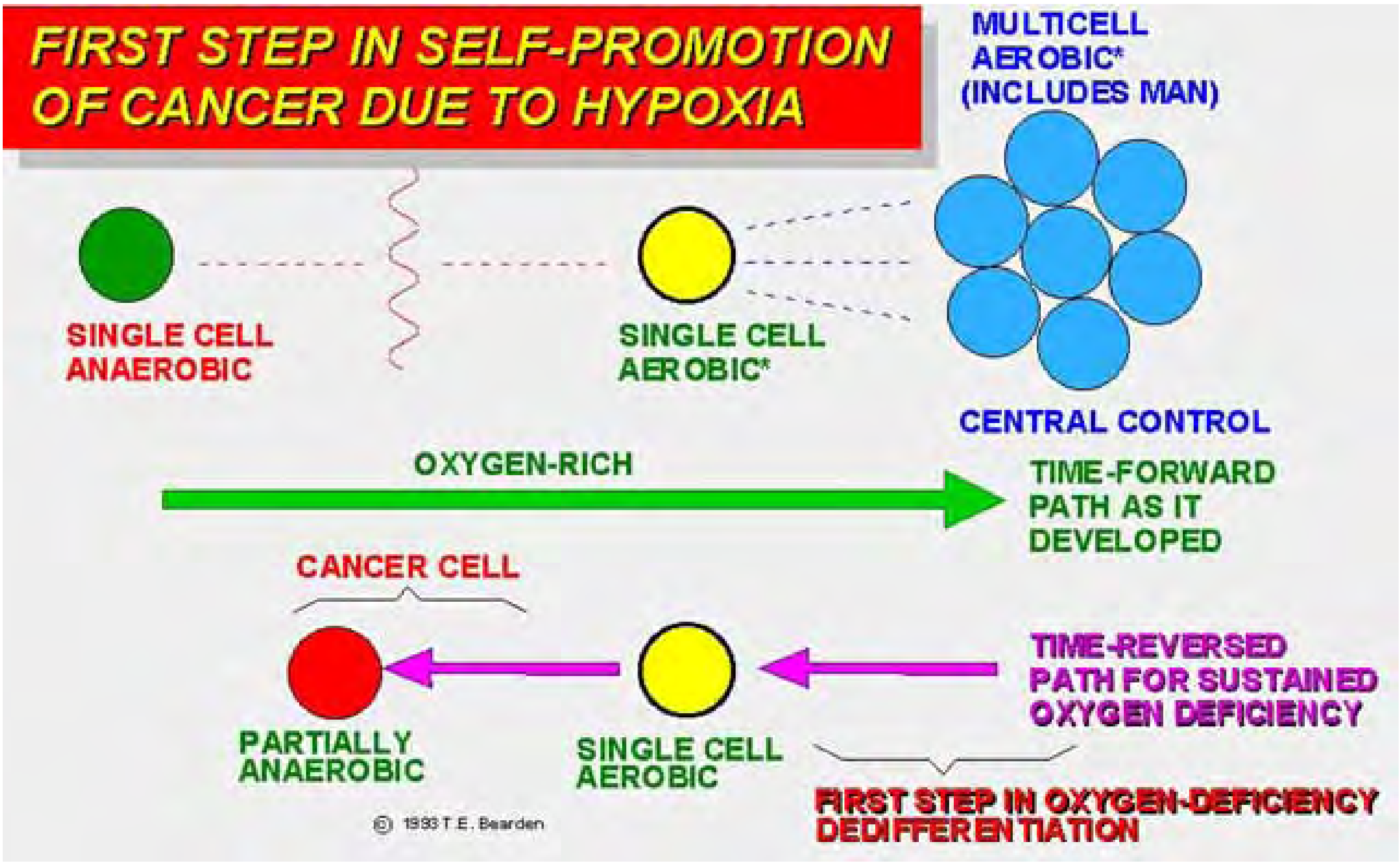

FIRST STEP IN SELF-PROMOTION OF CANCER DUE TO HYPOXIA

MULTICELL
AEROBIC*
(INCLUDES MAN)

SINGLE CELL
ANAEROBIC

SINGLE CELL
AEROBIC*

CENTRAL CONTROL

OXYGEN-RICH

TIME-FORWARD
PATH AS IT
DEVELOPED

CANCER CELL

TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY

PARTIALLY
ANAEROBIC

SINGLE CELL
AEROBIC

FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION

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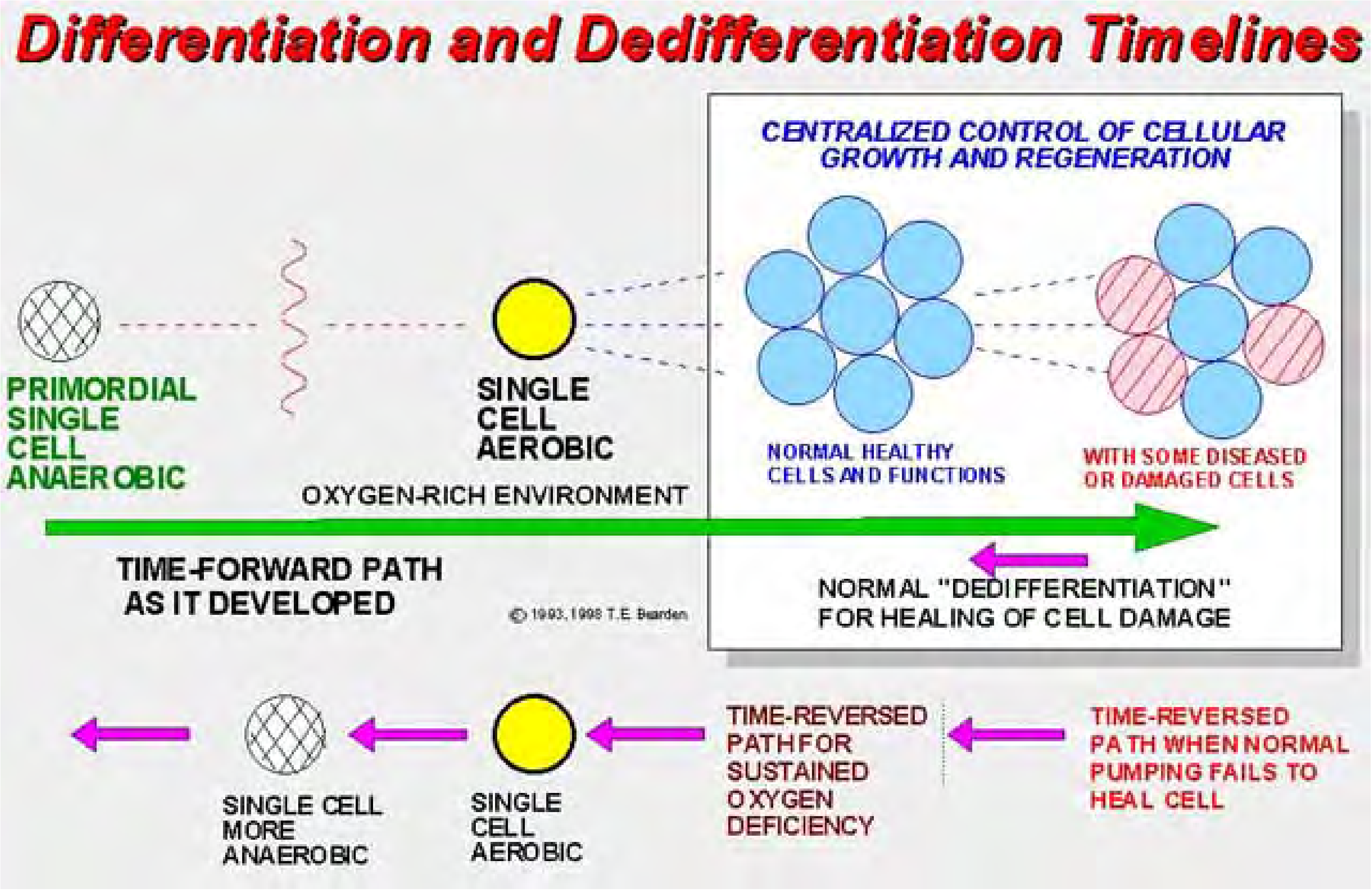
Differentiation and Dedifferentiation Timelines
CENTRALIZED CONTROL OF CELLULAR GROWTH AND REGENERATION
PRIMORDIAL SINGLE CELL ANAEROBIC
SINGLE CELL AEROBIC
NORMAL HEALTHY CELLS AND FUNCTIONS
WITH SOME DISEASED OR DAMAGED CELLS
OXYGEN-RICH ENVIRONMENT
TIME-FORWARD PATH AS IT DEVELOPED
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NORMAL "DEDIFFERENTIATION" FOR HEALING OF CELL DAMAGE
SINGLE CELL MORE ANAEROBIC
SINGLE CELL AEROBIC
TIME-REVERSED PATH FOR SUSTAINED OXYGEN DEFICIENCY
TIME-REVERSED PATH WHEN NORMAL PUMPING FAILS TO HEAL CELL

Evolution of Cells on Earth

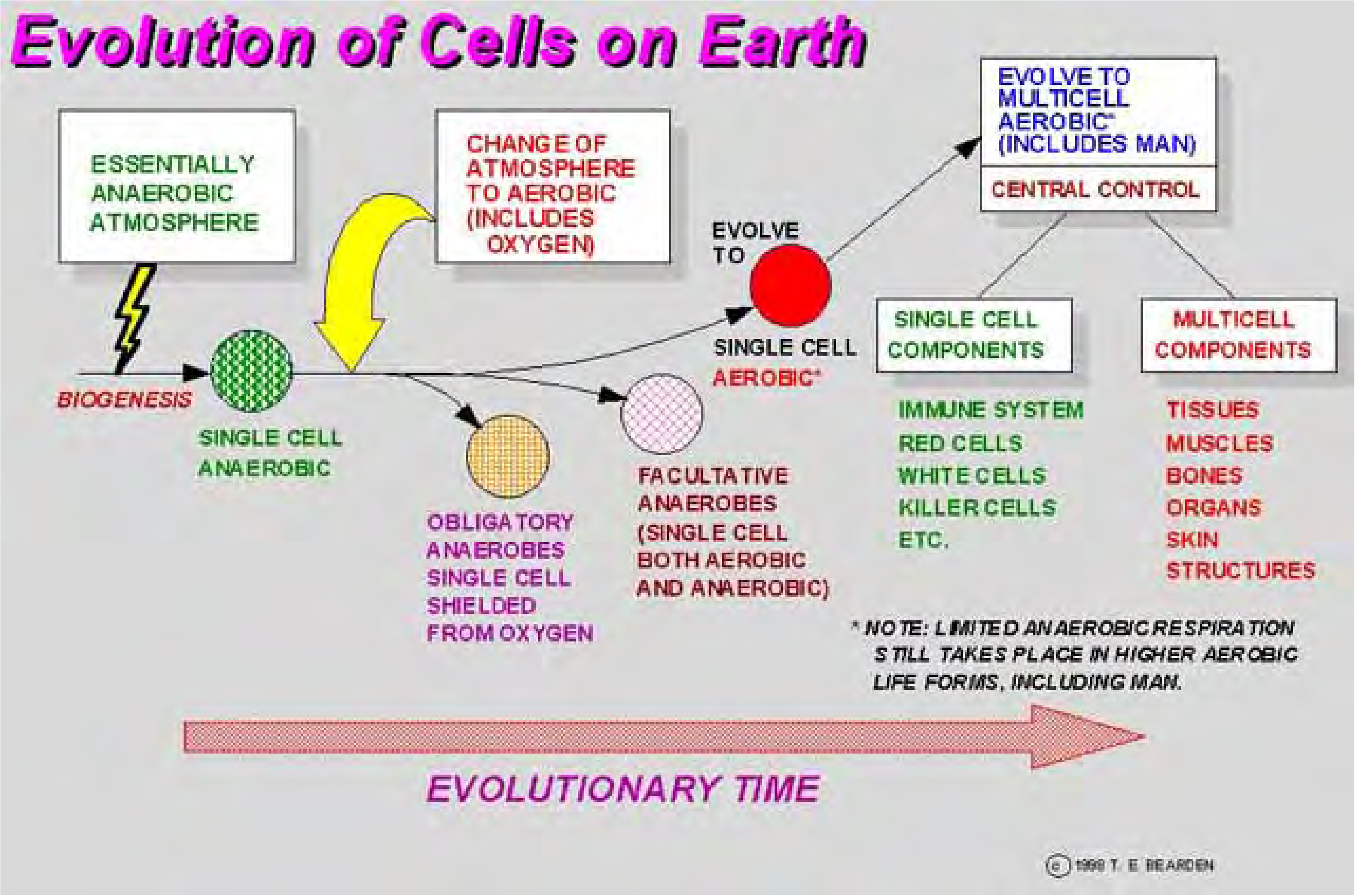
ESSENTIALLY ANAEROBIC ATMOSPHERE
CHANGE OF ATMOSPHERE TO AEROBIC (INCLUDES OXYGEN)
EVOLVE TO MULTICELL AEROBIC* (INCLUDES MAN)
CENTRAL CONTROL
EVOLVE TO
BIOGENESIS
SINGLE CELL ANAEROBIC
SINGLE CELL AEROBIC*
OBLIGATORY ANAEROBES SINGLE CELL SHIELDED FROM OXYGEN
FACULTATIVE ANAEROBES (SINGLE CELL BOTH AEROBIC AND ANAEROBIC)
SINGLE CELL COMPONENTS
IMMUNE SYSTEM
RED CELLS
WHITE CELLS
KILLER CELLS
ETC.
MULTICELL COMPONENTS
TISSUES
MUSCLES
BONES
ORGANS
SKIN
STRUCTURES
EVOLUTIONARY TIME

* NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.

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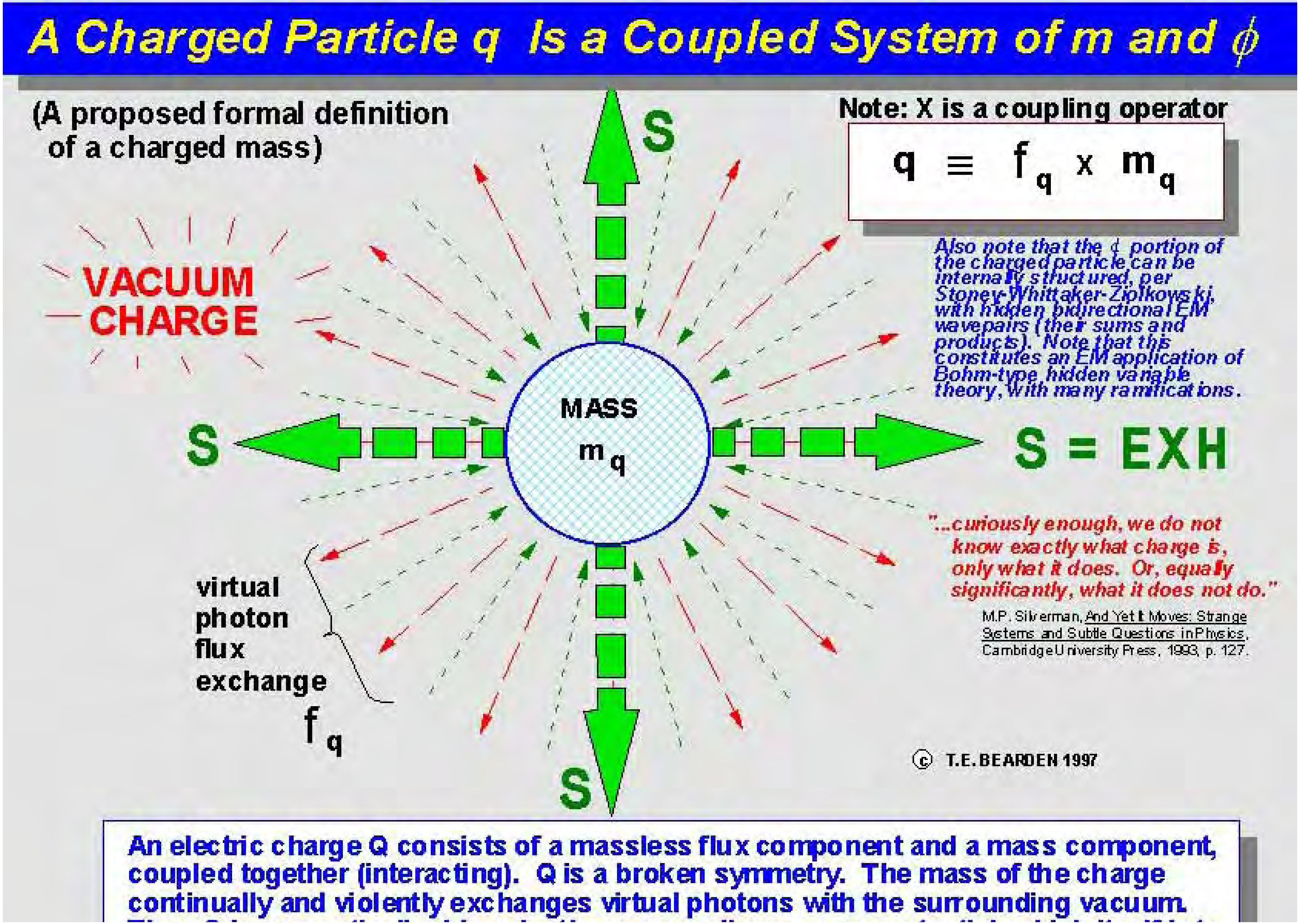

A Charged Particle q Is a Coupled System of m and ϕ

(A proposed formal definition of a charged mass)

Note: X is a coupling operator

$$q \equiv f_q \times m_q$$

Also note that the ϕ portion of the charged particle can be internally structured, per Stoney-Whittaker-Ziolkowski, with hidden bidirectional EM wavepairs (their sums and products). Note that this constitutes an EM application of Bohm-type hidden variable theory, with many ramifications.

VACUUM CHARGE

"...curiously enough, we do not know exactly what charge is, only what it does. Or, equally significantly, what it does not do."

M.P. Silverman, And Yet It Moves: Strange Systems and Subtle Questions in Physics, Cambridge University Press, 1993, p. 127.

virtual photon flux exchange f_q

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An electric charge Q consists of a massless flux component and a mass component, coupled together (interacting). Q is a broken symmetry. The mass of the charge continually and violently exchanges virtual photons with the surrounding vacuum.

Thus Q is energetically driven by the surrounding vacuum potential, which itself is to first order just a violent virtual photon flux.

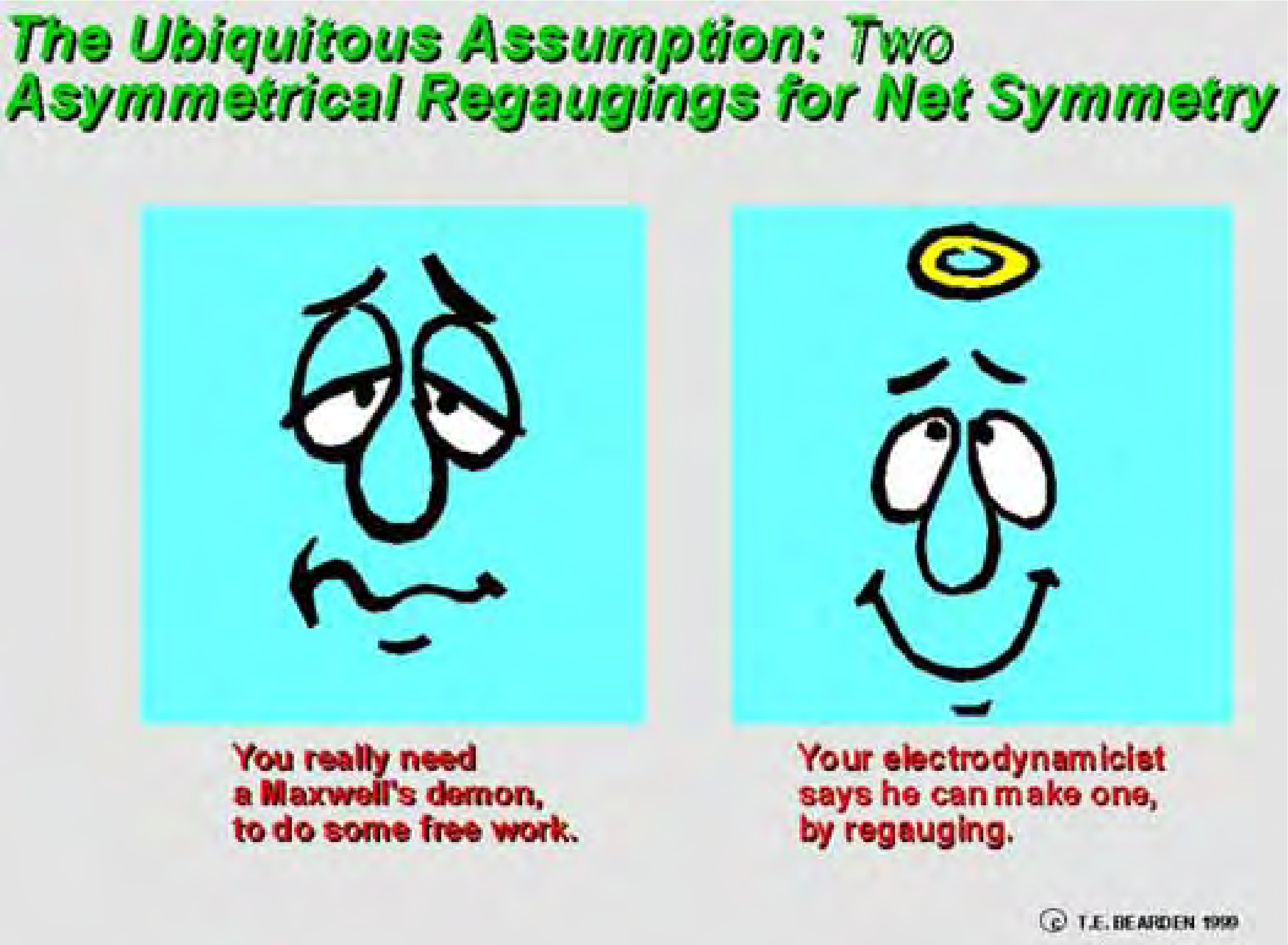

The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry

You really need
a Maxwell's demon,
to do some free work.

Your electrodynamicist
says he can make one,
by regauging.

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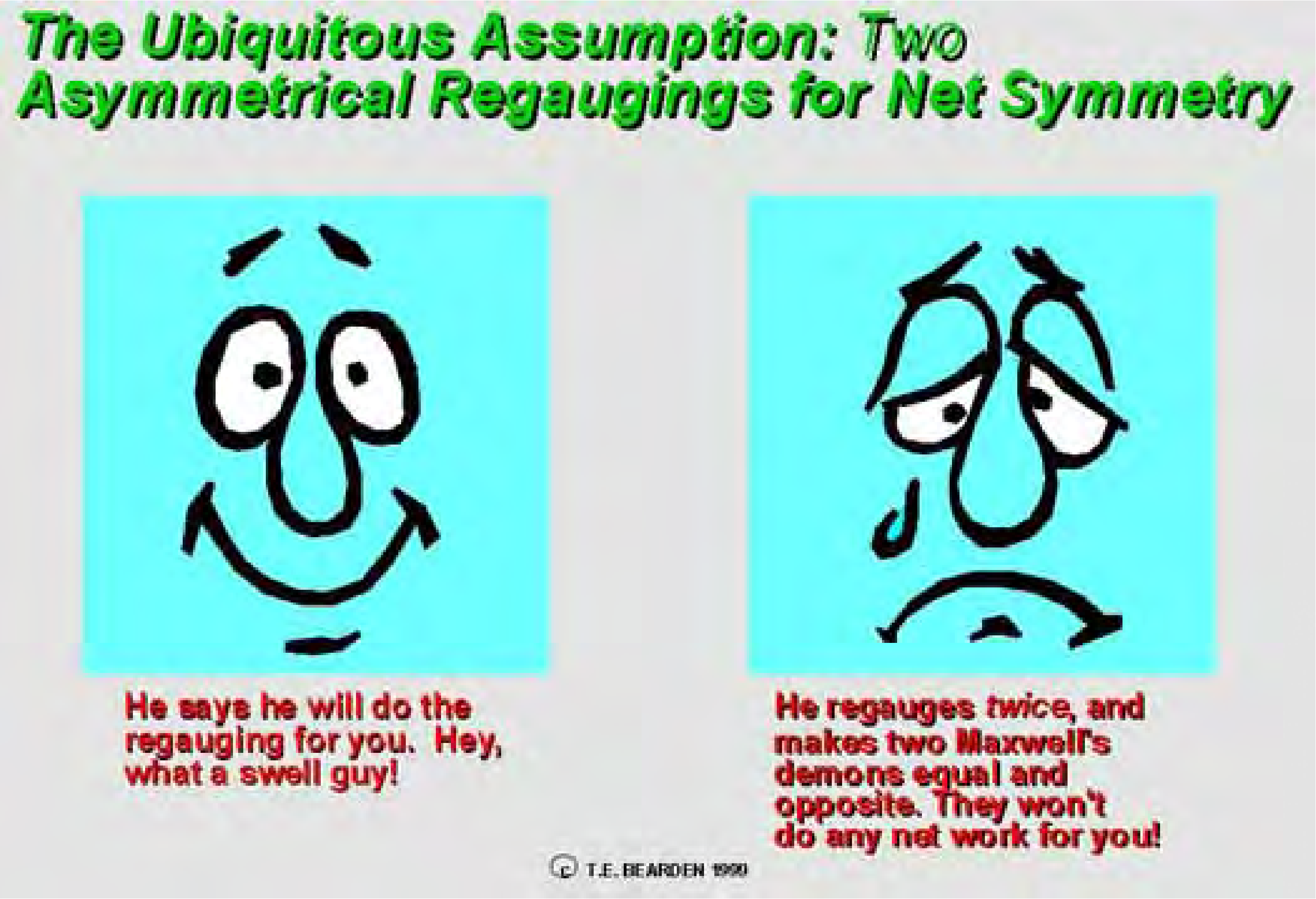

The Ubiquitous Assumption: *Two* Asymmetrical Regaugings for Net Symmetry

He says he will do the regauging for you. Hey, what a swell guy!

He regauges *twice*, and makes two Maxwell's demons equal and opposite. They won't do any net work for you!

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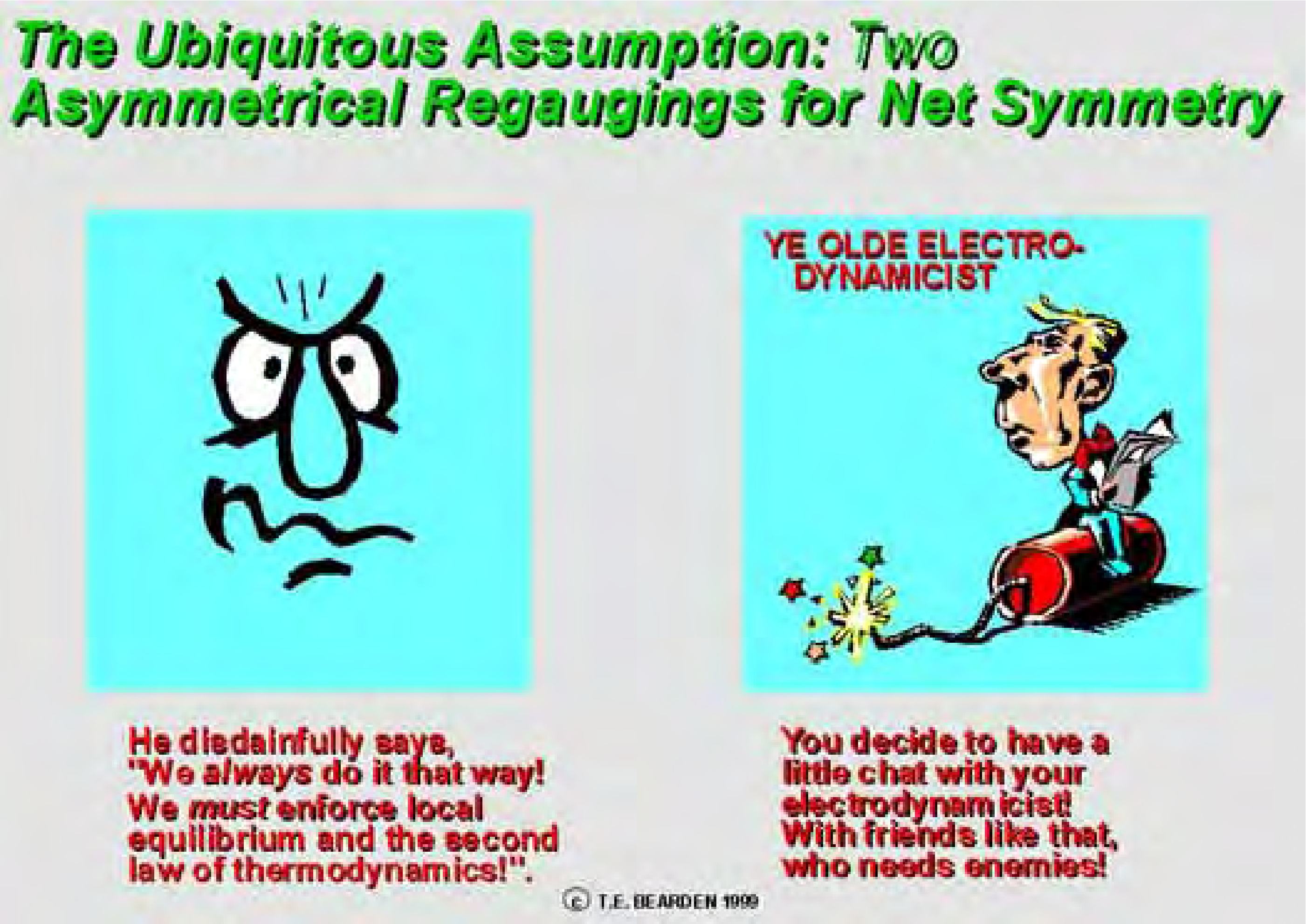

The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry

YE OLDE ELECTRO-
DYNAMICIST

He disdainfully says,
"We *always* do it that way!
We *must* enforce local
equilibrium and the second
law of thermodynamics!".

You decide to have a
little chat with your
electrodynamicist!
With friends like that,
who needs enemies!

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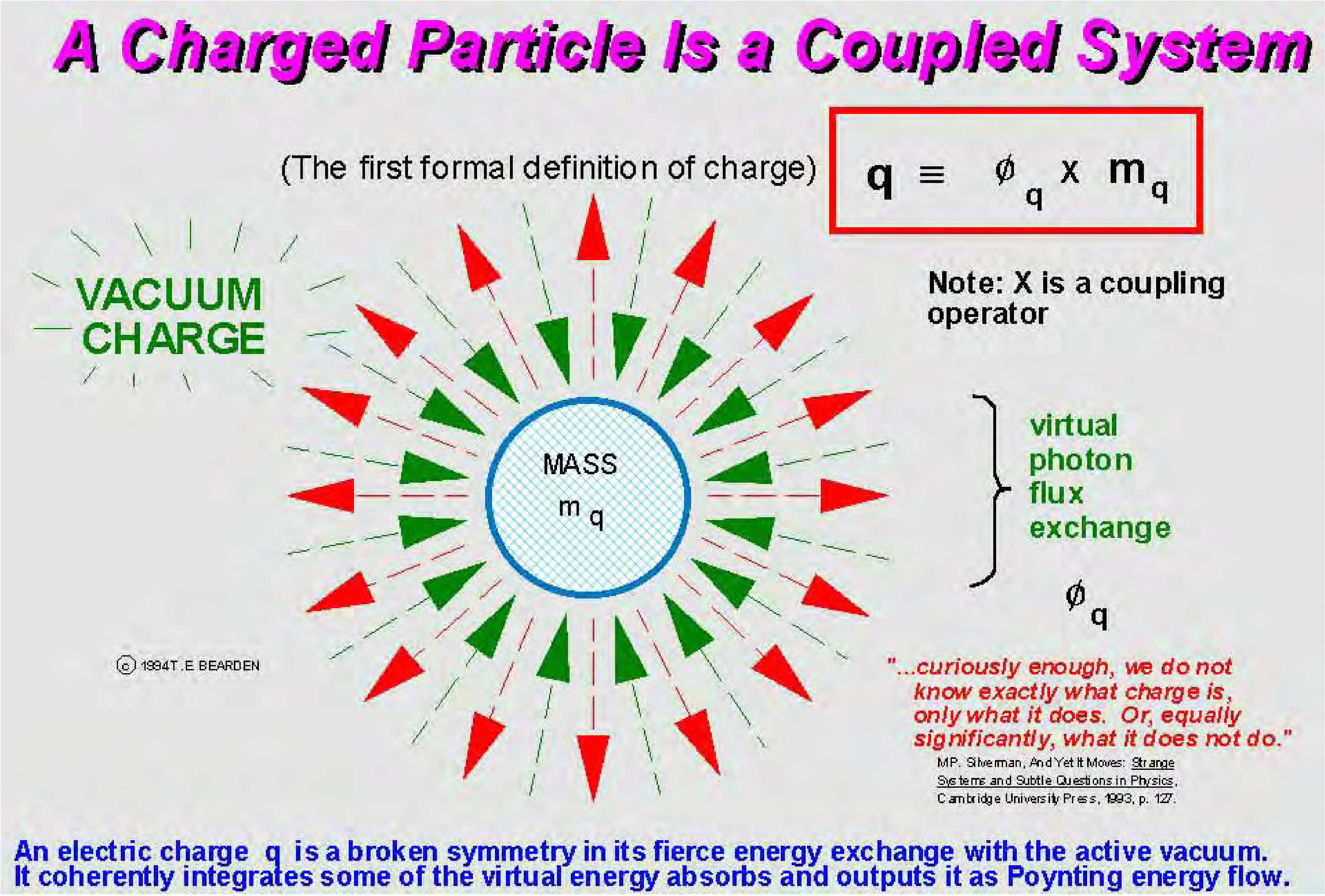

A Charged Particle Is a Coupled System

(The first formal definition of charge)

$$q \equiv \phi_q \text{ x } m_q$$

Note: X is a coupling operator

virtual
photon
flux
exchange

ϕ_q

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"...curiously enough, we do not know exactly what charge is, only what it does. Or, equally significantly, what it does not do."

M.P. Silverman, And Yet It Moves: Strange Systems and Subtle Questions in Physics, Cambridge University Press, 1993, p. 127.

An electric charge q is a broken symmetry in its fierce energy exchange with the active vacuum. It coherently integrates some of the virtual energy absorbs and outputs it as Poynting energy flow.

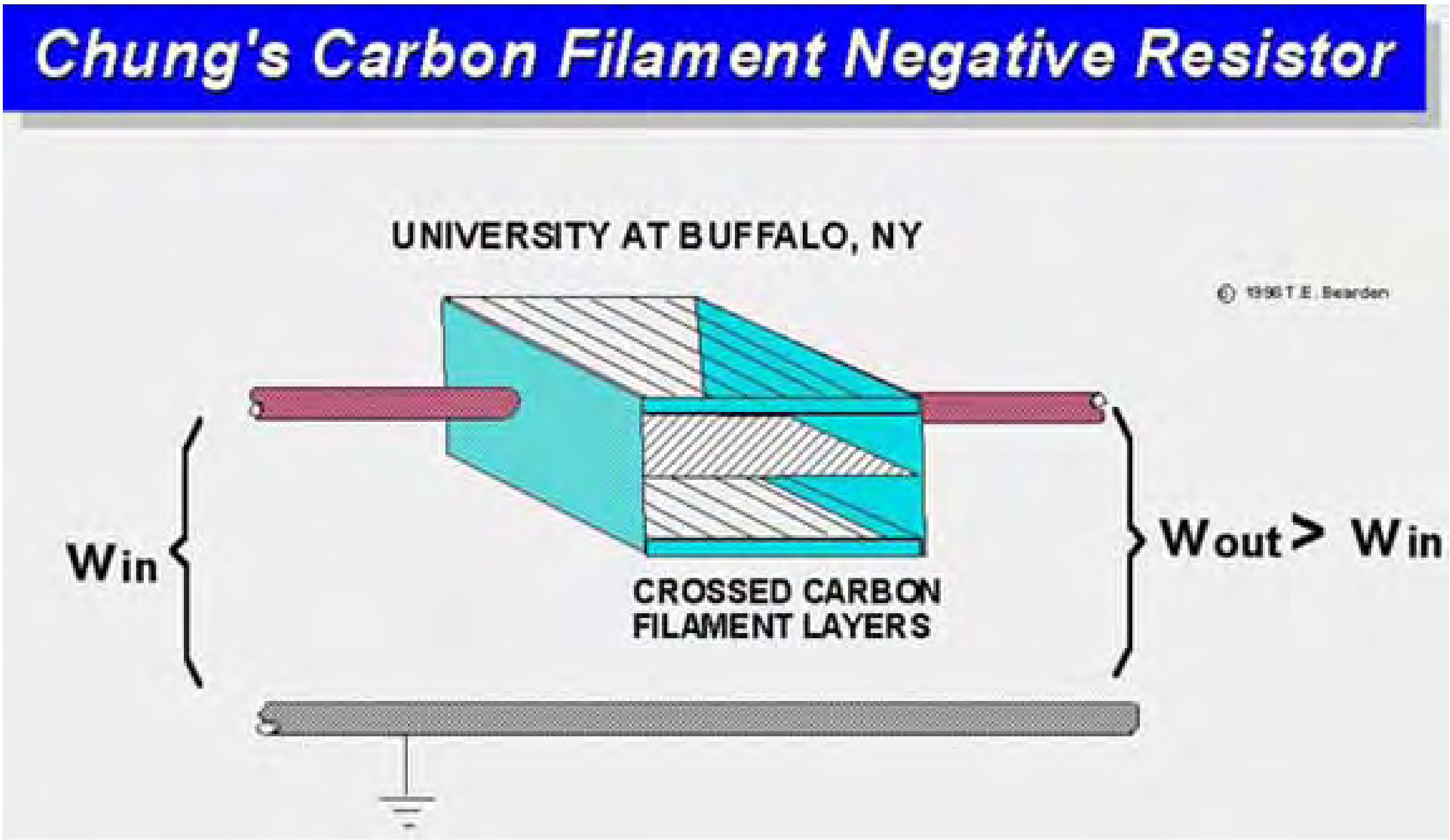
Chung's Carbon Filament Negative Resistor
UNIVERSITY AT BUFFALO, NY
© 1996 T.E. Bearden
Win
Wout > Win
CROSSED CARBON
FILAMENT LAYERS

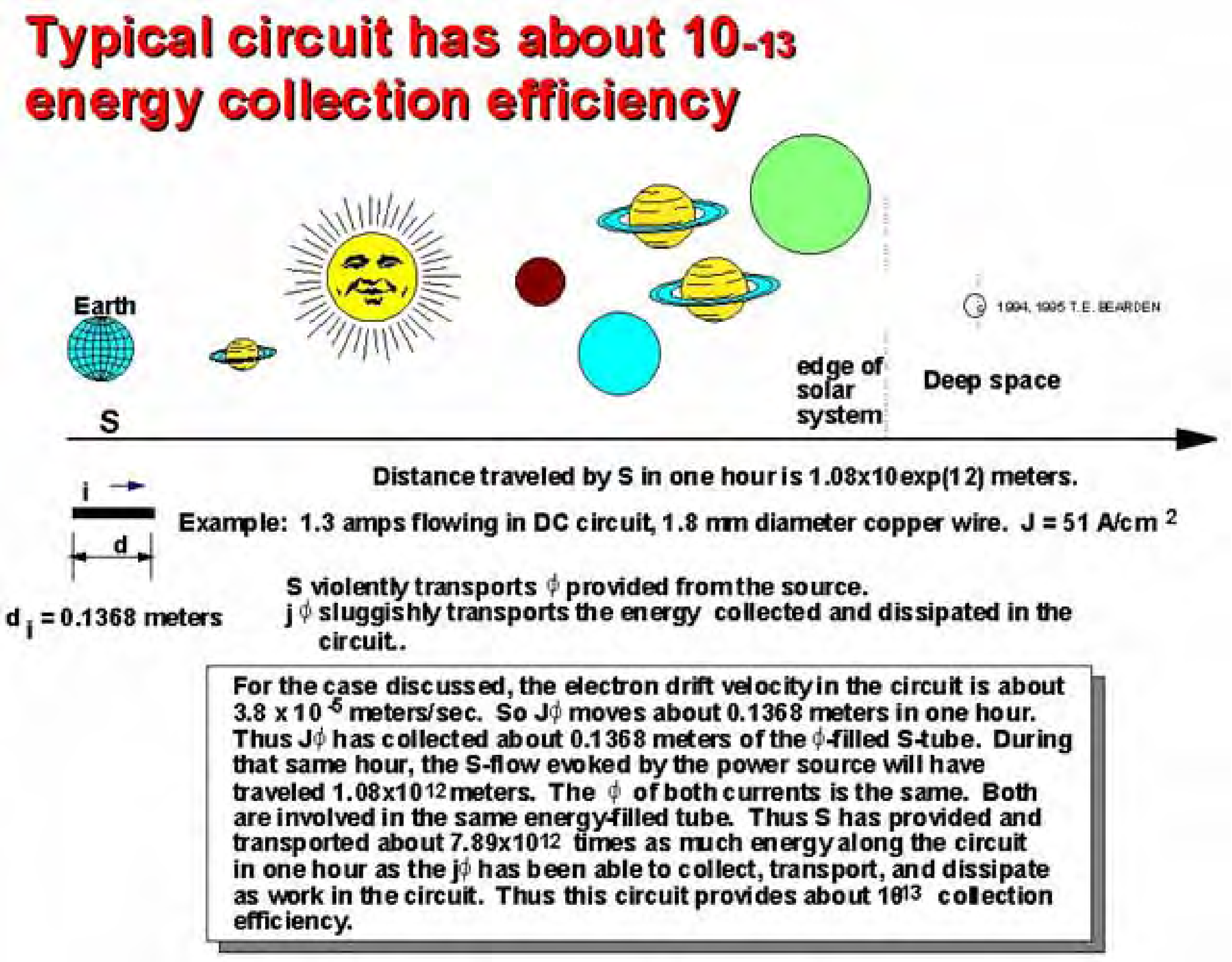

Typical circuit has about 10^{-13} energy collection efficiency

Distance traveled by S in one hour is 1.08x10exp(12) meters.

Example: 1.3 amps flowing in DC circuit, 1.8 mm diameter copper wire. $J = 51\ A/cm^2$

$d_i = 0.1368$ meters

S violently transports ϕ provided from the source.
$j\phi$ sluggishly transports the energy collected and dissipated in the circuit..

For the case discussed, the electron drift velocity in the circuit is about 3.8×10^{-5} meters/sec. So $J\phi$ moves about 0.1368 meters in one hour. Thus $J\phi$ has collected about 0.1368 meters of the ϕ-filled S-tube. During that same hour, the S-flow evoked by the power source will have traveled 1.08×10^{12} meters. The ϕ of both currents is the same. Both are involved in the same energy-filled tube. Thus S has provided and transported about 7.89×10^{12} times as much energy along the circuit in one hour as the $j\phi$ has been able to collect, transport, and dissipate as work in the circuit. Thus this circuit provides about 10^{-13} collection efficiency.

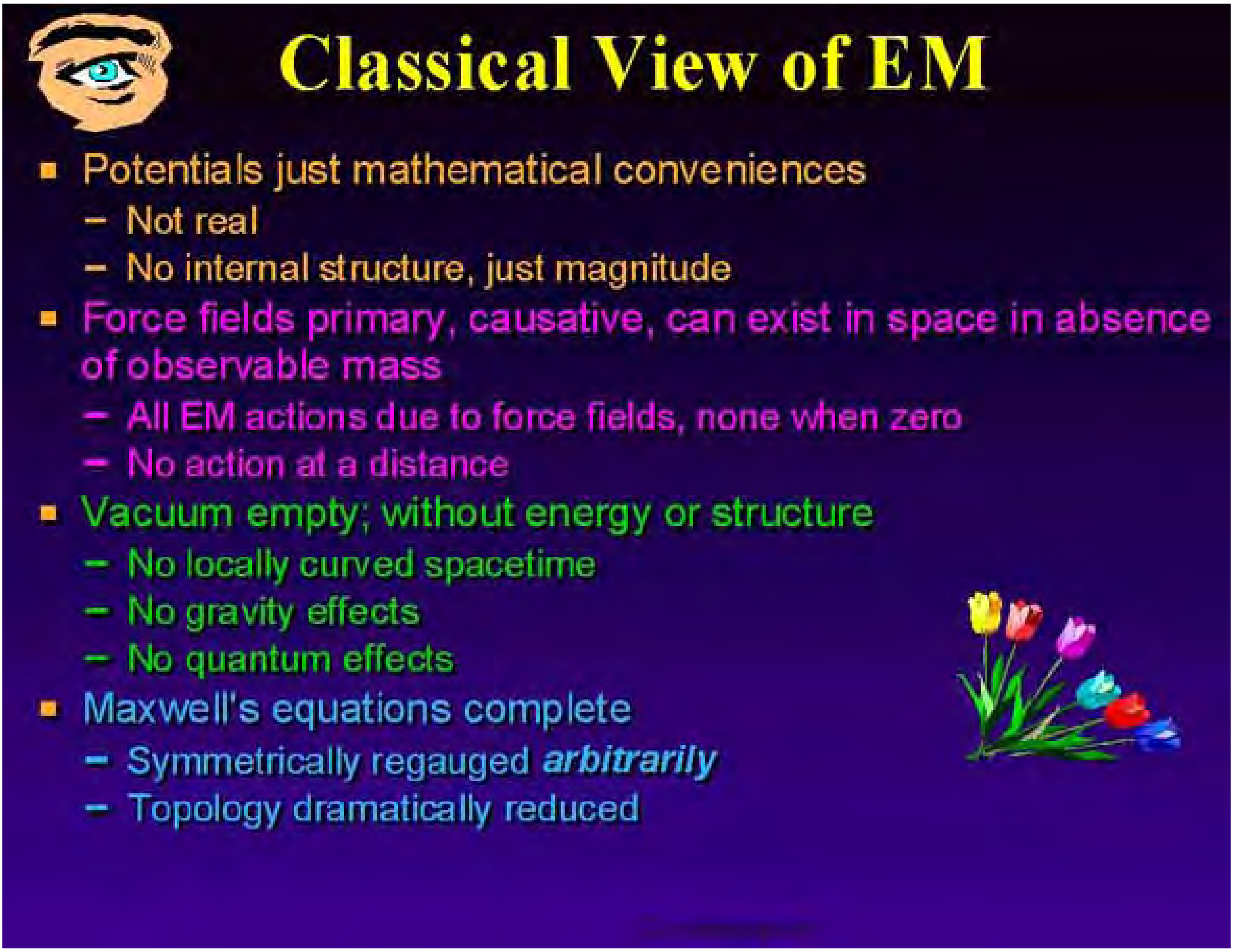

Classical View of EM

- Potentials just mathematical conveniences
  - Not real
  - No internal structure, just magnitude
- Force fields primary, causative, can exist in space in absence of observable mass
  - All EM actions due to force fields, none when zero
  - No action at a distance
- Vacuum empty; without energy or structure
  - No locally curved spacetime
  - No gravity effects
  - No quantum effects
- Maxwell's equations complete
  - Symmetrically regauged ***arbitrarily***
  - Topology dramatically reduced

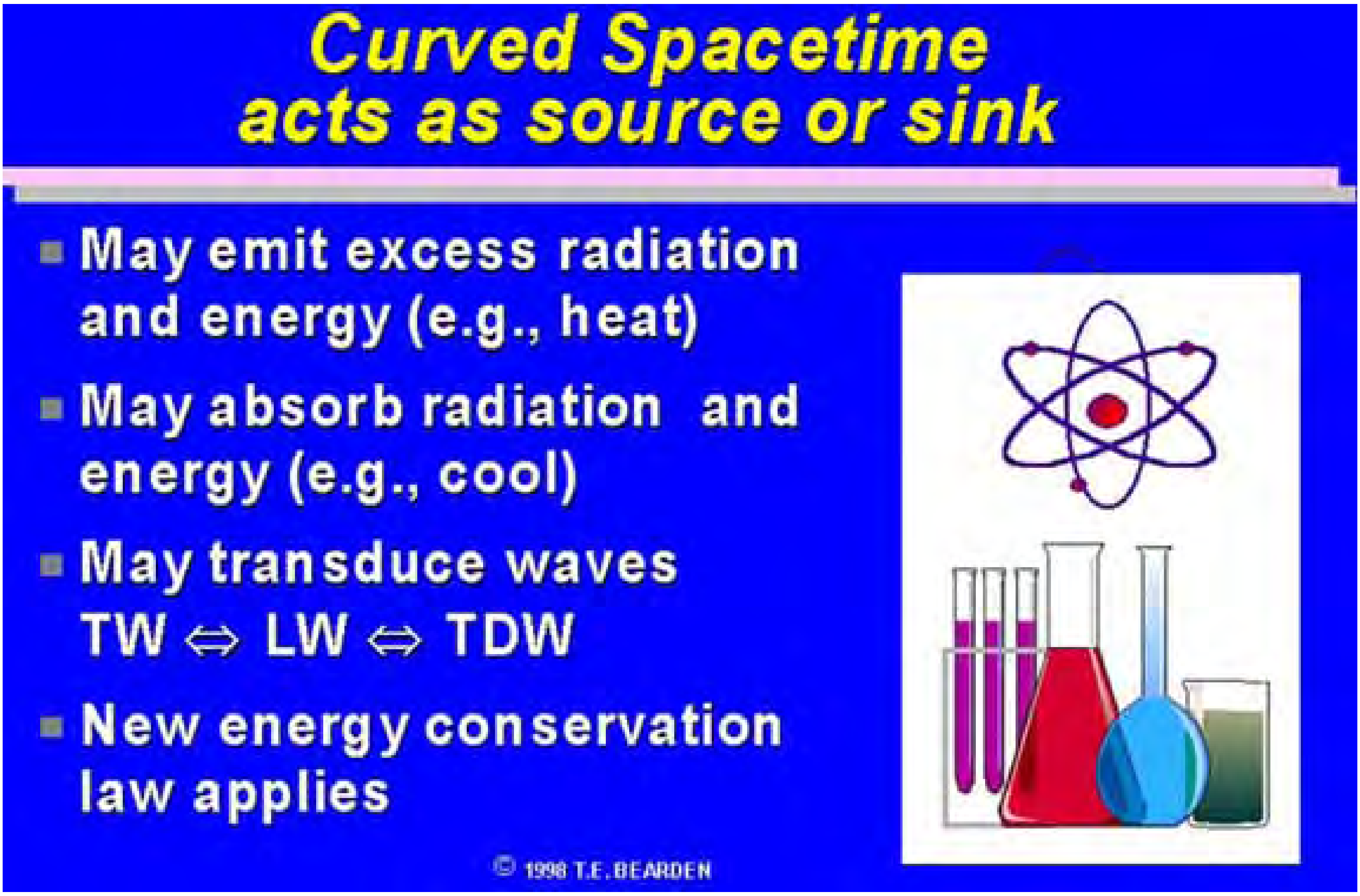

Curved Spacetime acts as source or sink

- May emit excess radiation and energy (e.g., heat)
- May absorb radiation and energy (e.g., cool)
- May transduce waves TW ⇔ LW ⇔ TDW
- New energy conservation law applies

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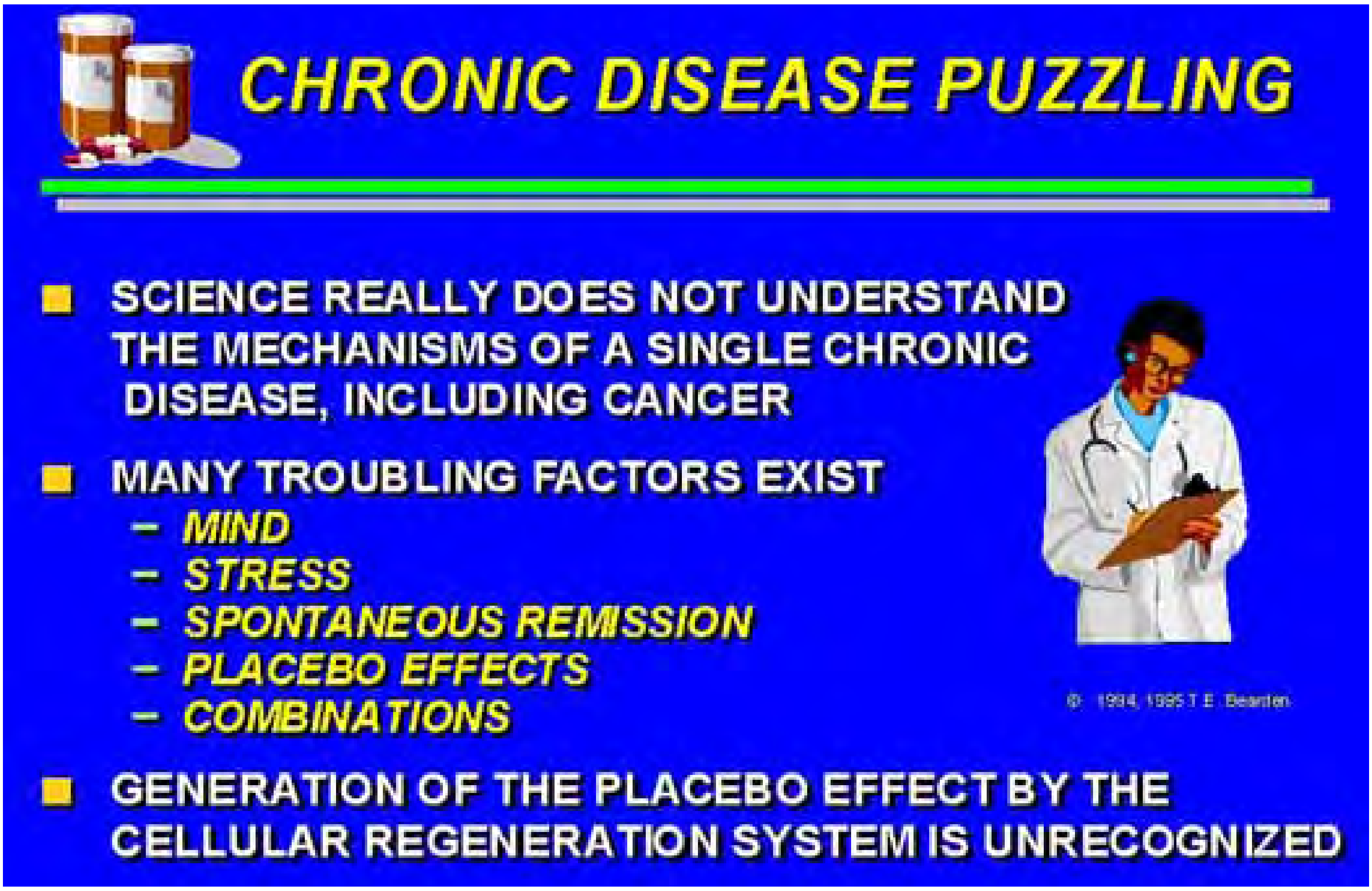

CHRONIC DISEASE PUZZLING

- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
- MANY TROUBLING FACTORS EXIST
  - *MIND*
  - *STRESS*
  - *SPONTANEOUS REMISSION*
  - *PLACEBO EFFECTS*
  - *COMBINATIONS*
- GENERATION OF THE PLACEBO EFFECT BY THE CELLULAR REGENERATION SYSTEM IS UNRECOGNIZED

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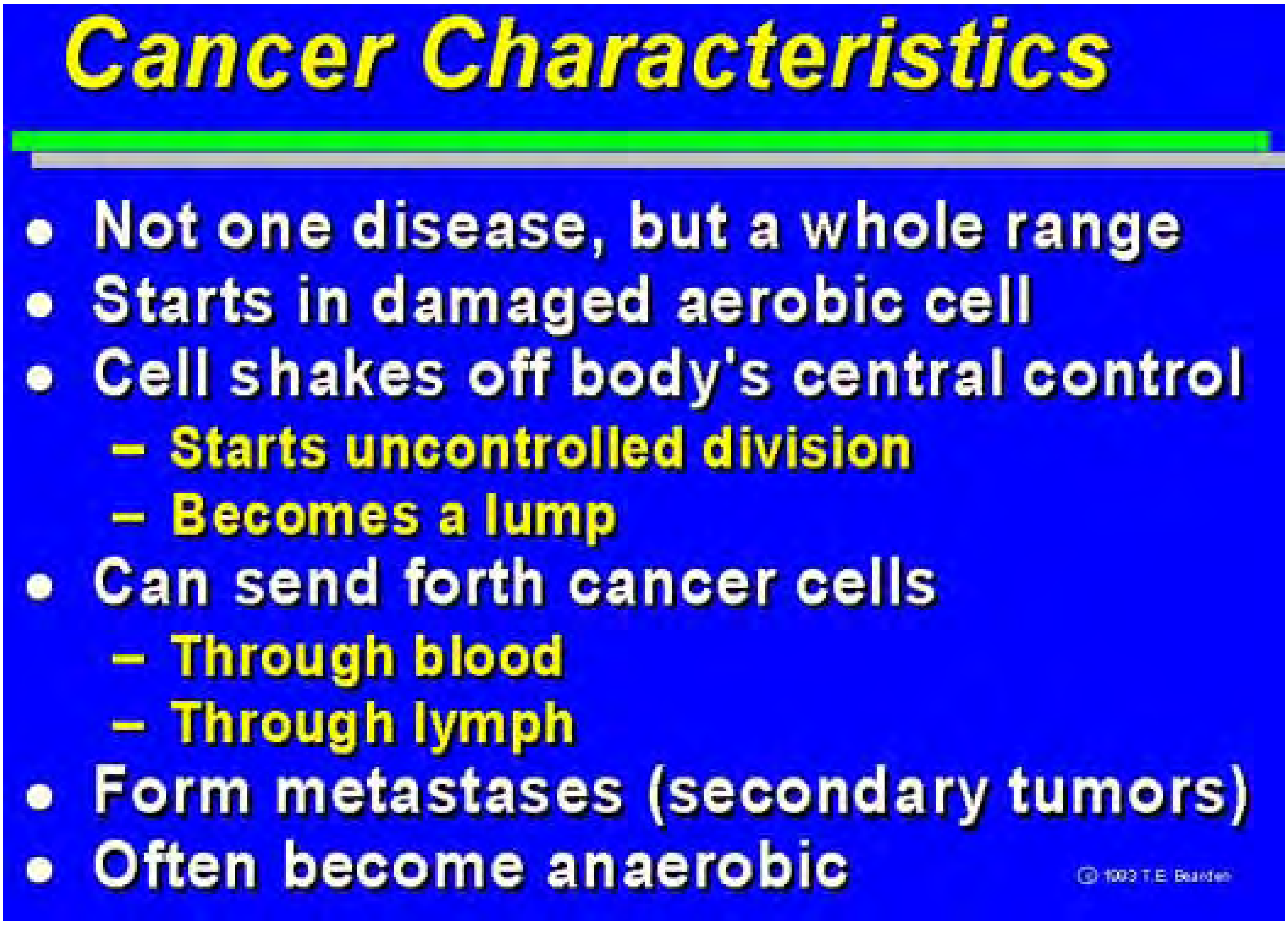

Cancer Characteristics

- Not one disease, but a whole range
- Starts in damaged aerobic cell
- Cell shakes off body's central control
  - Starts uncontrolled division
  - Becomes a lump
- Can send forth cancer cells
  - Through blood
  - Through lymph
- Form metastases (secondary tumors)
- Often become anaerobic

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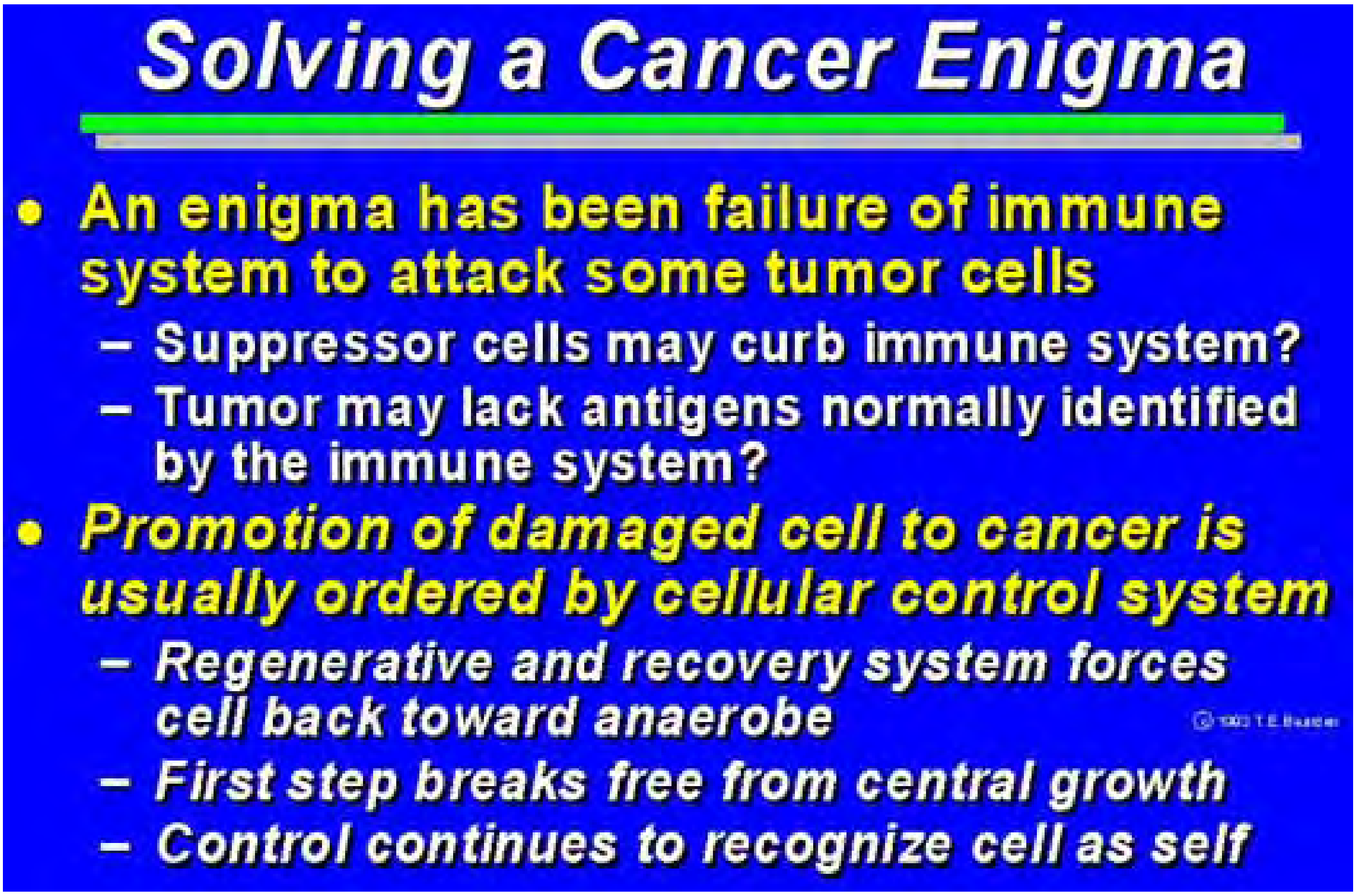

Solving a Cancer Enigma

- An enigma has been failure of immune system to attack some tumor cells
  - Suppressor cells may curb immune system?
  - Tumor may lack antigens normally identified by the immune system?
- *Promotion of damaged cell to cancer is usually ordered by cellular control system*
  - *Regenerative and recovery system forces cell back toward anaerobe*
  - *First step breaks free from central growth*
  - *Control continues to recognize cell as self*

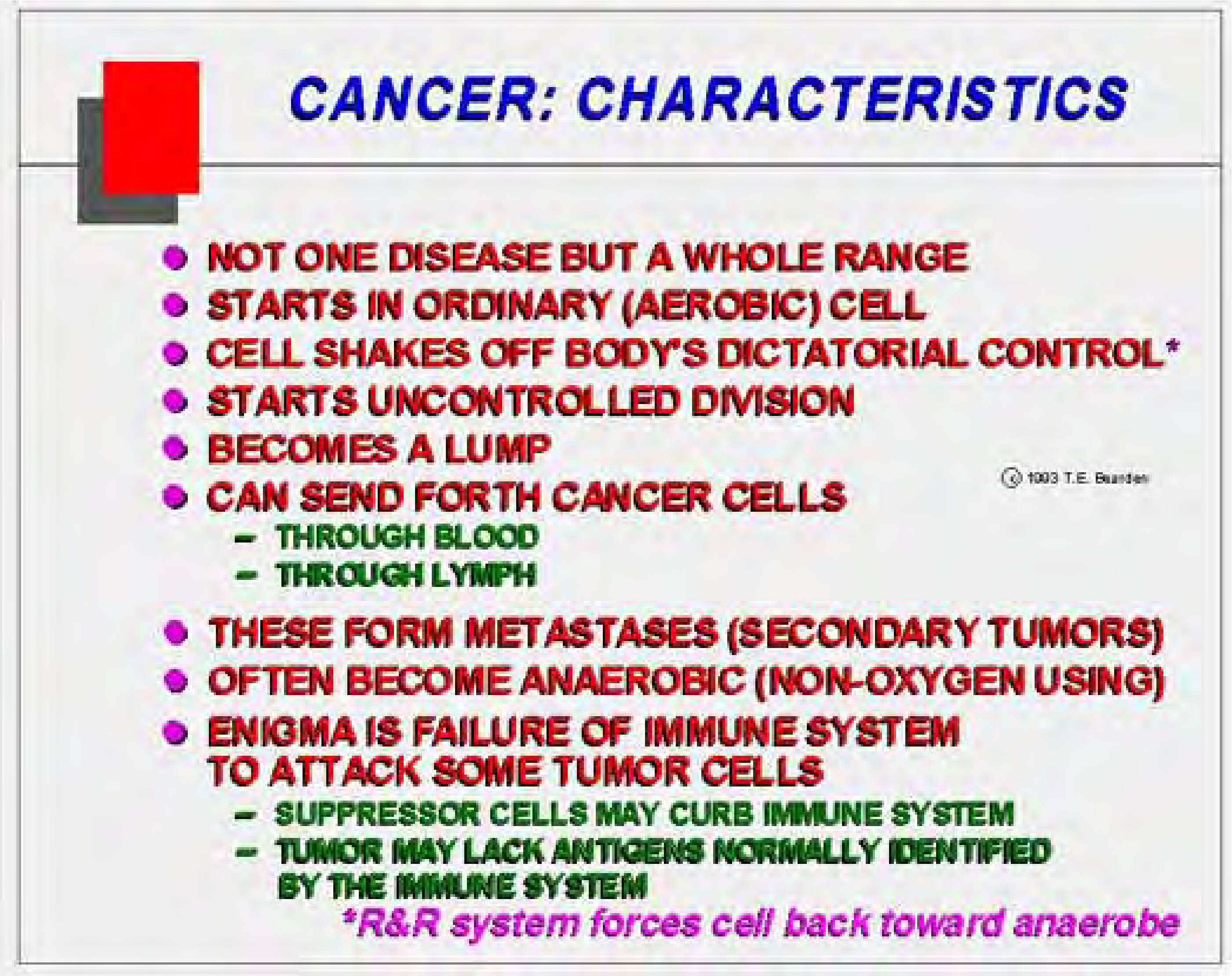

CANCER: CHARACTERISTICS

- NOT ONE DISEASE BUT A WHOLE RANGE
- STARTS IN ORDINARY (AEROBIC) CELL
- CELL SHAKES OFF BODY'S DICTATORIAL CONTROL*
- STARTS UNCONTROLLED DIVISION
- BECOMES A LUMP
- CAN SEND FORTH CANCER CELLS
  - THROUGH BLOOD
  - THROUGH LYMPH
- THESE FORM METASTASES (SECONDARY TUMORS)
- OFTEN BECOME ANAEROBIC (NON-OXYGEN USING)
- ENIGMA IS FAILURE OF IMMUNE SYSTEM TO ATTACK SOME TUMOR CELLS
  - SUPPRESSOR CELLS MAY CURB IMMUNE SYSTEM
  - TUMOR MAY LACK ANTIGENS NORMALLY IDENTIFIED BY THE IMMUNE SYSTEM

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*R&R system forces cell back toward anaerobe

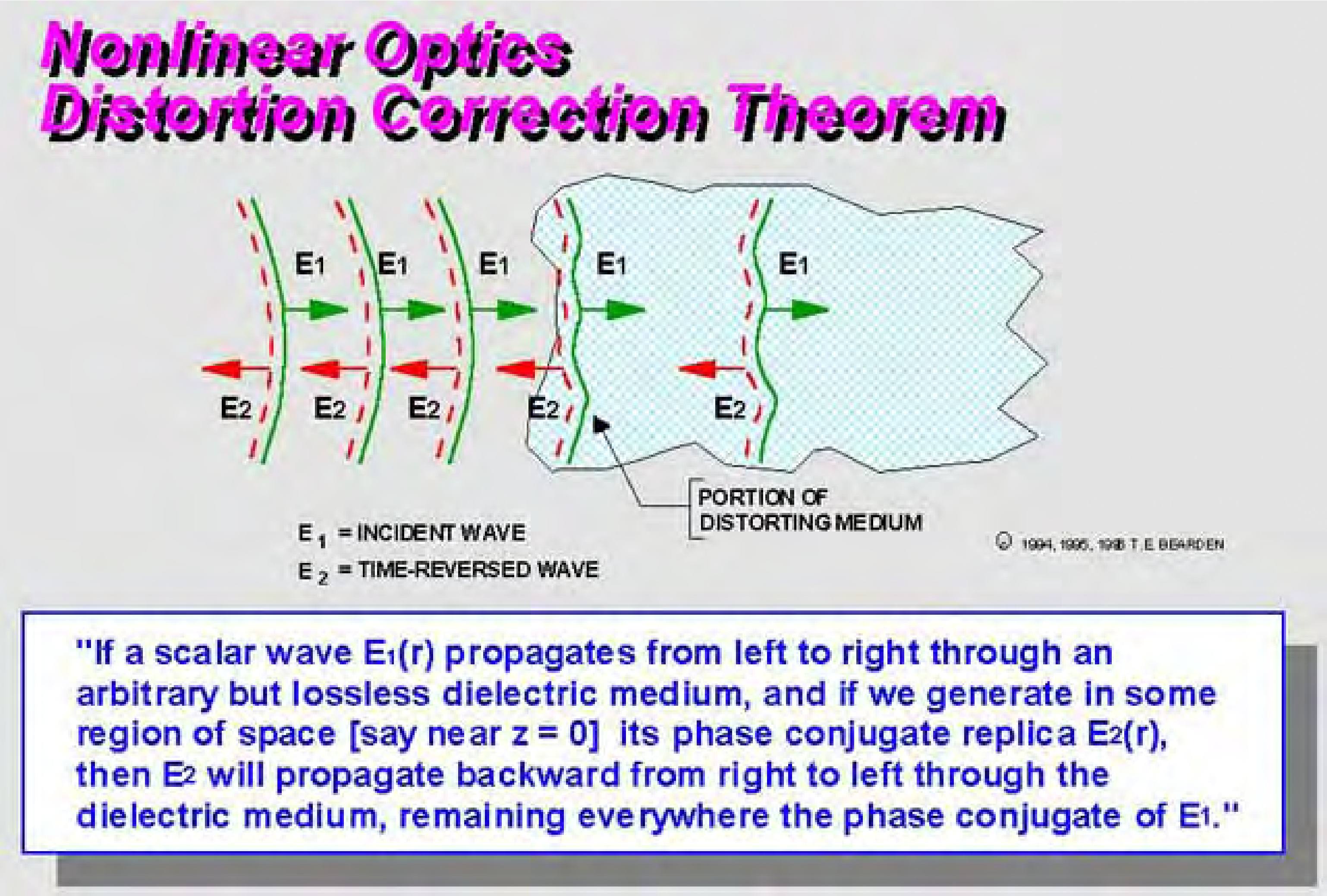

Nonlinear Optics
Distortion Correction Theorem

E_1 = INCIDENT WAVE

E_2 = TIME-REVERSED WAVE

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"If a scalar wave $E_1(r)$ propagates from left to right through an arbitrary but lossless dielectric medium, and if we generate in some region of space [say near z = 0] its phase conjugate replica $E_2(r)$, then E_2 will propagate backward from right to left through the dielectric medium, remaining everywhere the phase conjugate of E_1."

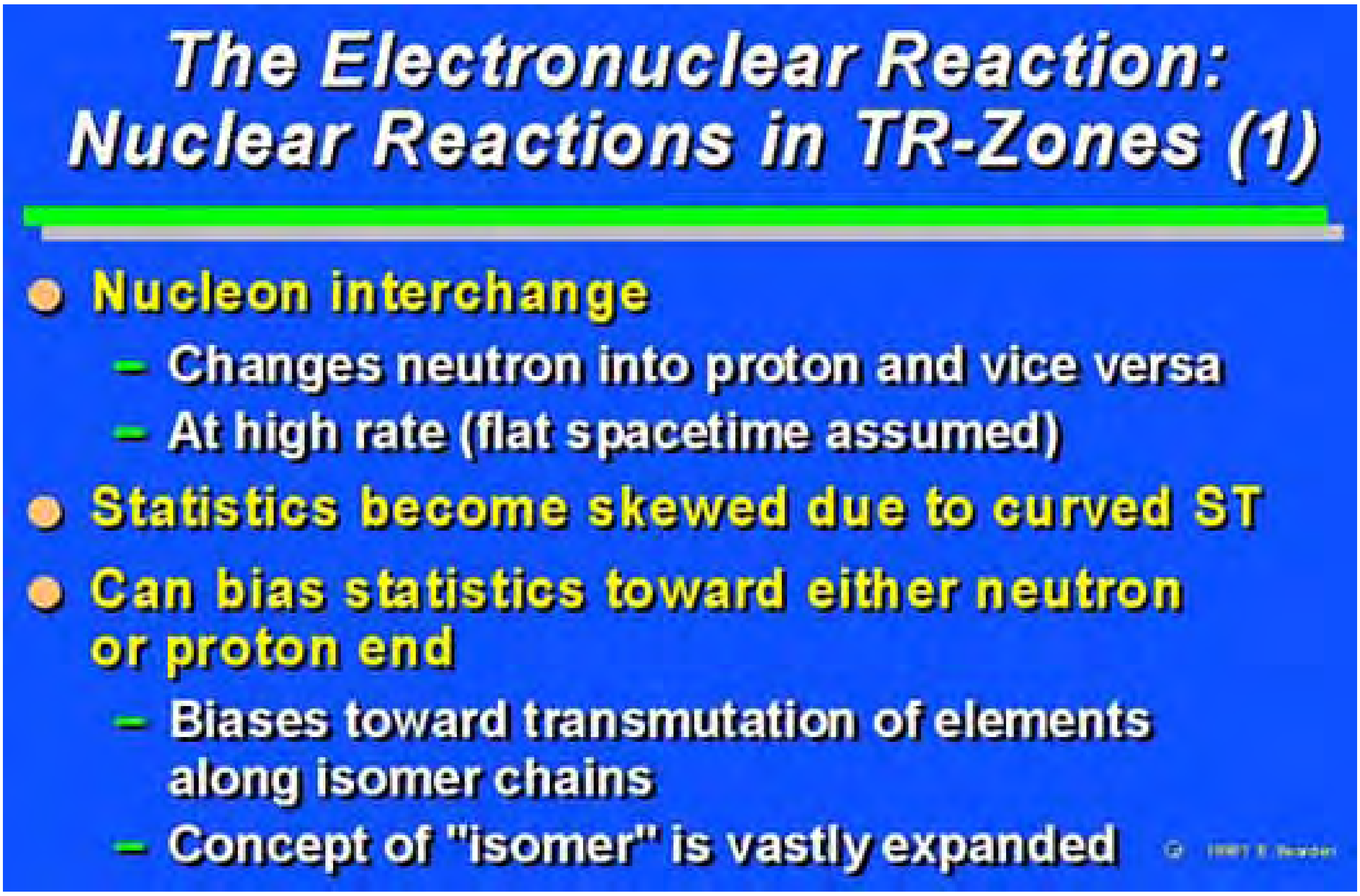

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (1)

- **Nucleon interchange**
  - Changes neutron into proton and vice versa
  - At high rate (flat spacetime assumed)
- **Statistics become skewed due to curved ST**
- **Can bias statistics toward either neutron or proton end**
  - Biases toward transmutation of elements along isomer chains
  - Concept of "isomer" is vastly expanded

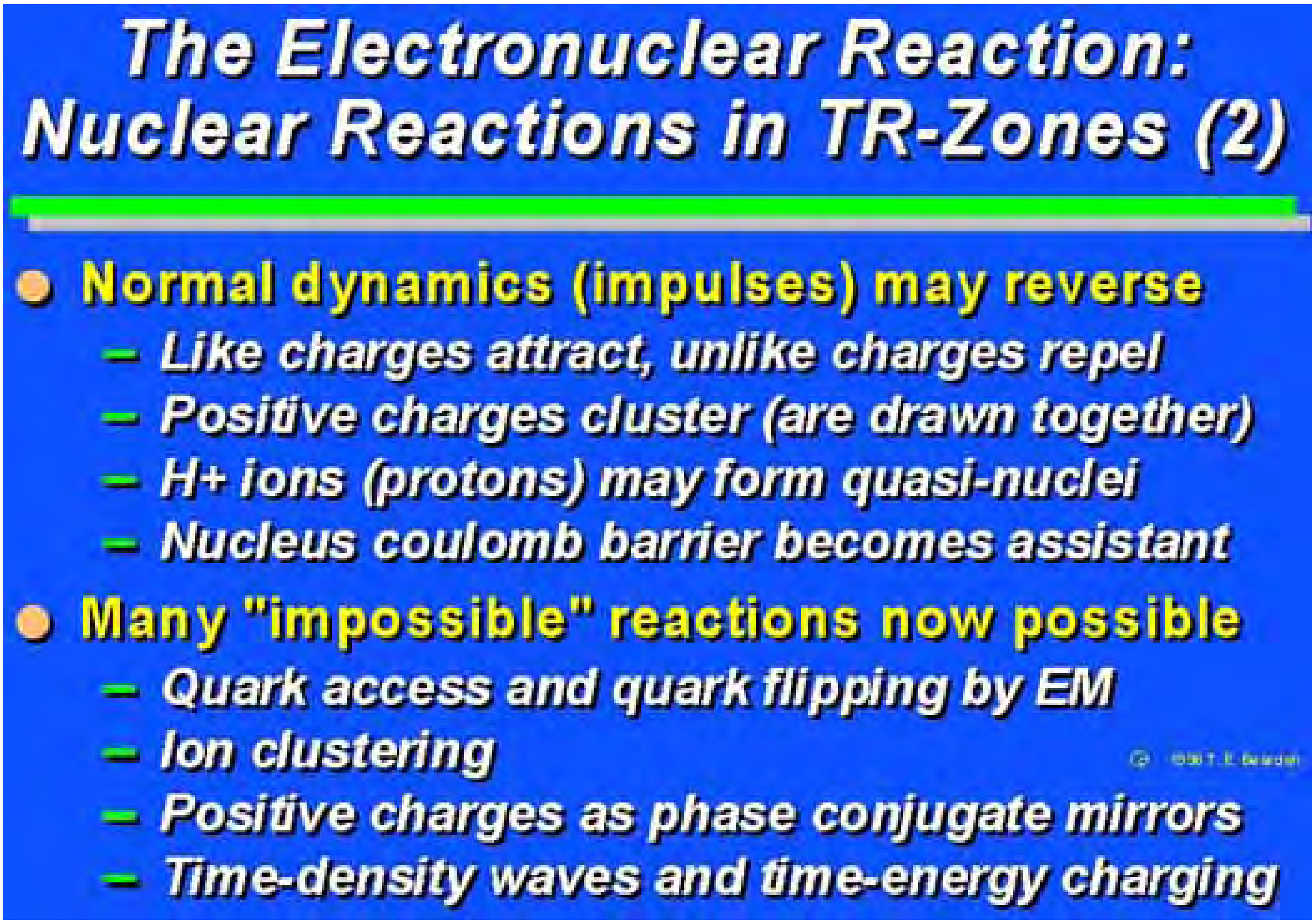

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (2)

- **Normal dynamics (impulses) may reverse**
  - *Like charges attract, unlike charges repel*
  - *Positive charges cluster (are drawn together)*
  - *H+ ions (protons) may form quasi-nuclei*
  - *Nucleus coulomb barrier becomes assistant*
- **Many "impossible" reactions now possible**
  - *Quark access and quark flipping by EM*
  - *Ion clustering*
  - *Positive charges as phase conjugate mirrors*
  - *Time-density waves and time-energy charging*

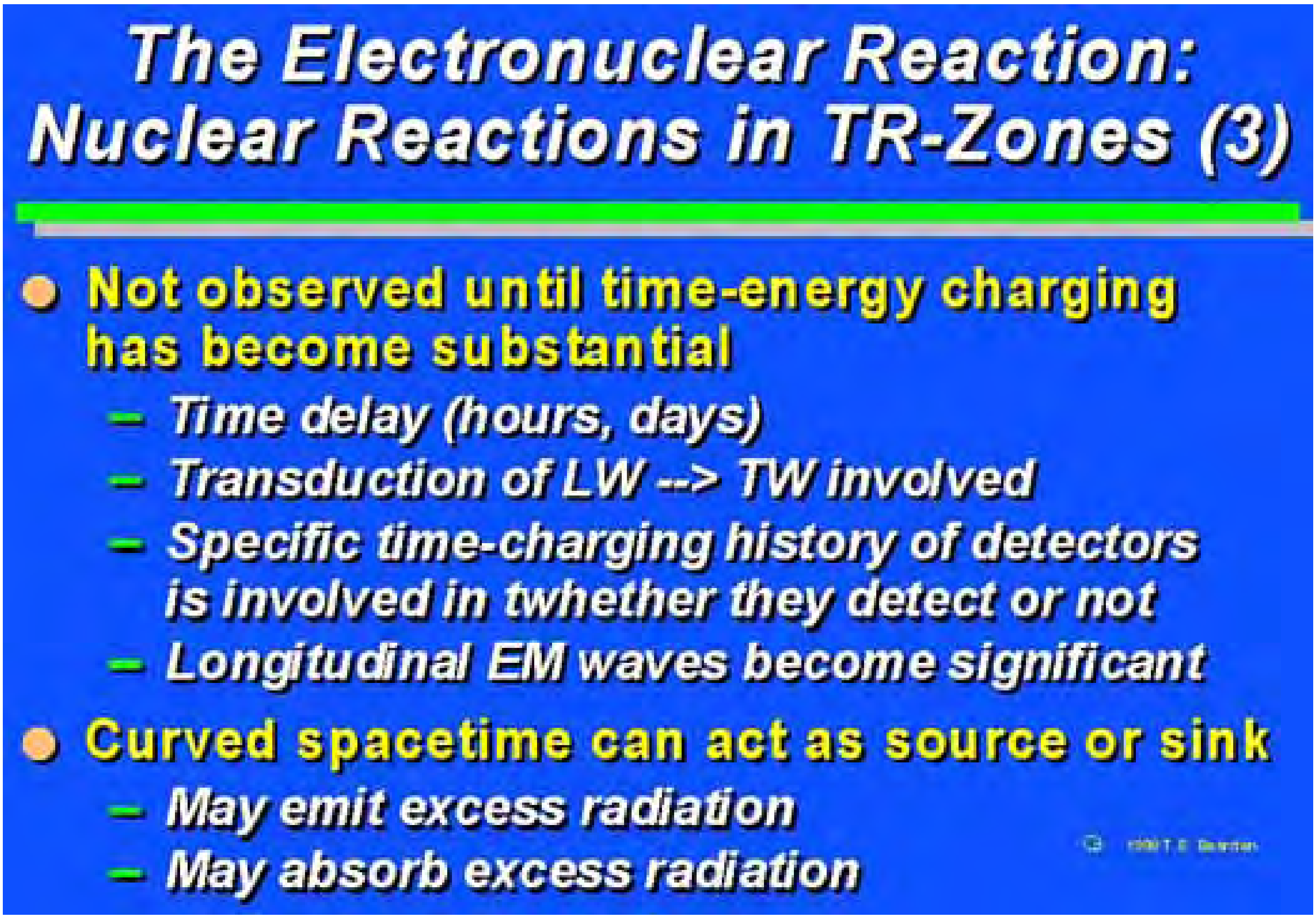

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (3)

- **Not observed until time-energy charging has become substantial**
  - *Time delay (hours, days)*
  - *Transduction of LW --> TW involved*
  - *Specific time-charging history of detectors is involved in twhether they detect or not*
  - *Longitudinal EM waves become significant*
- **Curved spacetime can act as source or sink**
  - *May emit excess radiation*
  - *May absorb excess radiation*

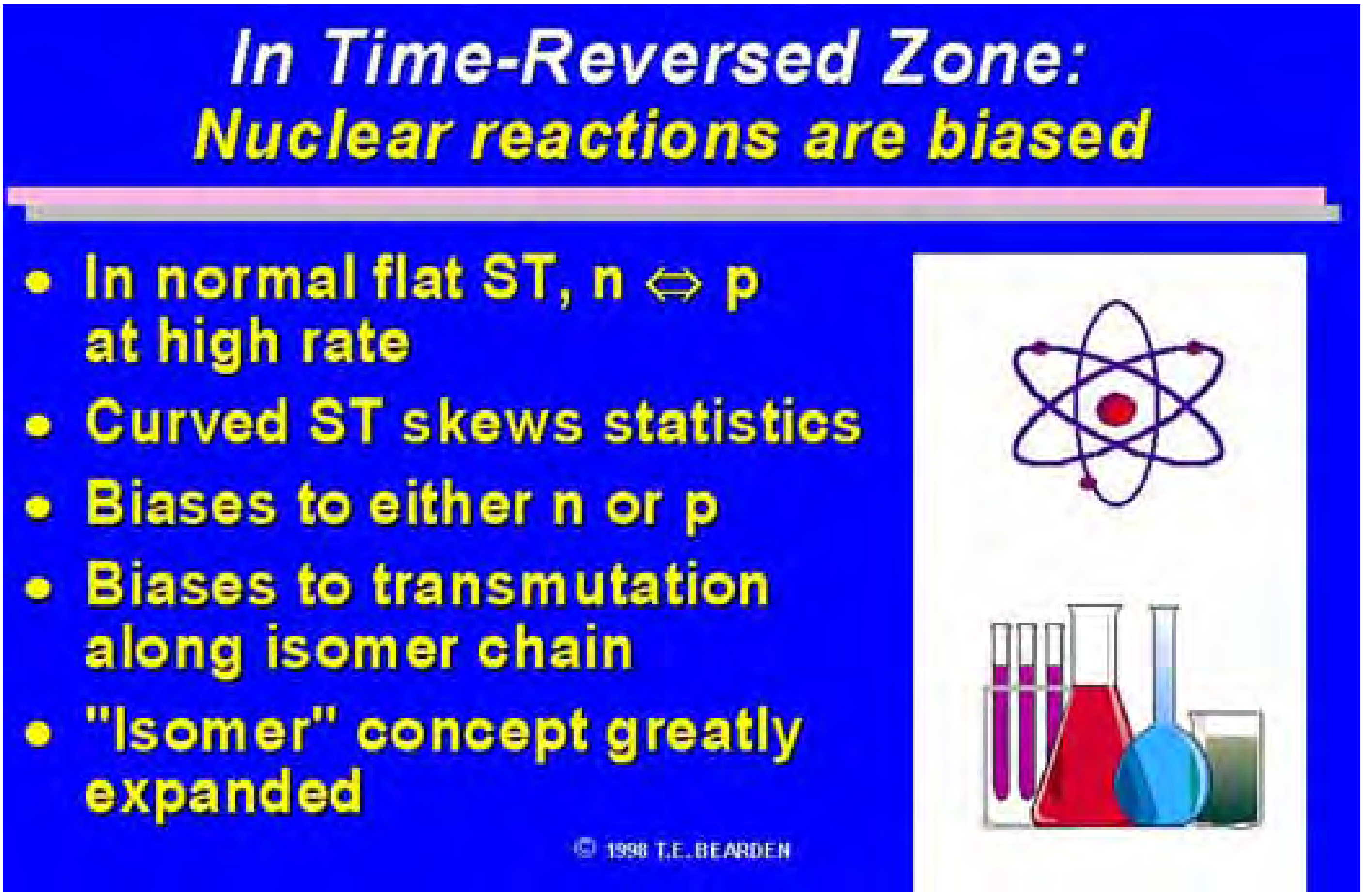

In Time-Reversed Zone:
Nuclear reactions are biased

- In normal flat ST, n ⇔ p at high rate
- Curved ST skews statistics
- Biases to either n or p
- Biases to transmutation along isomer chain
- "Isomer" concept greatly expanded

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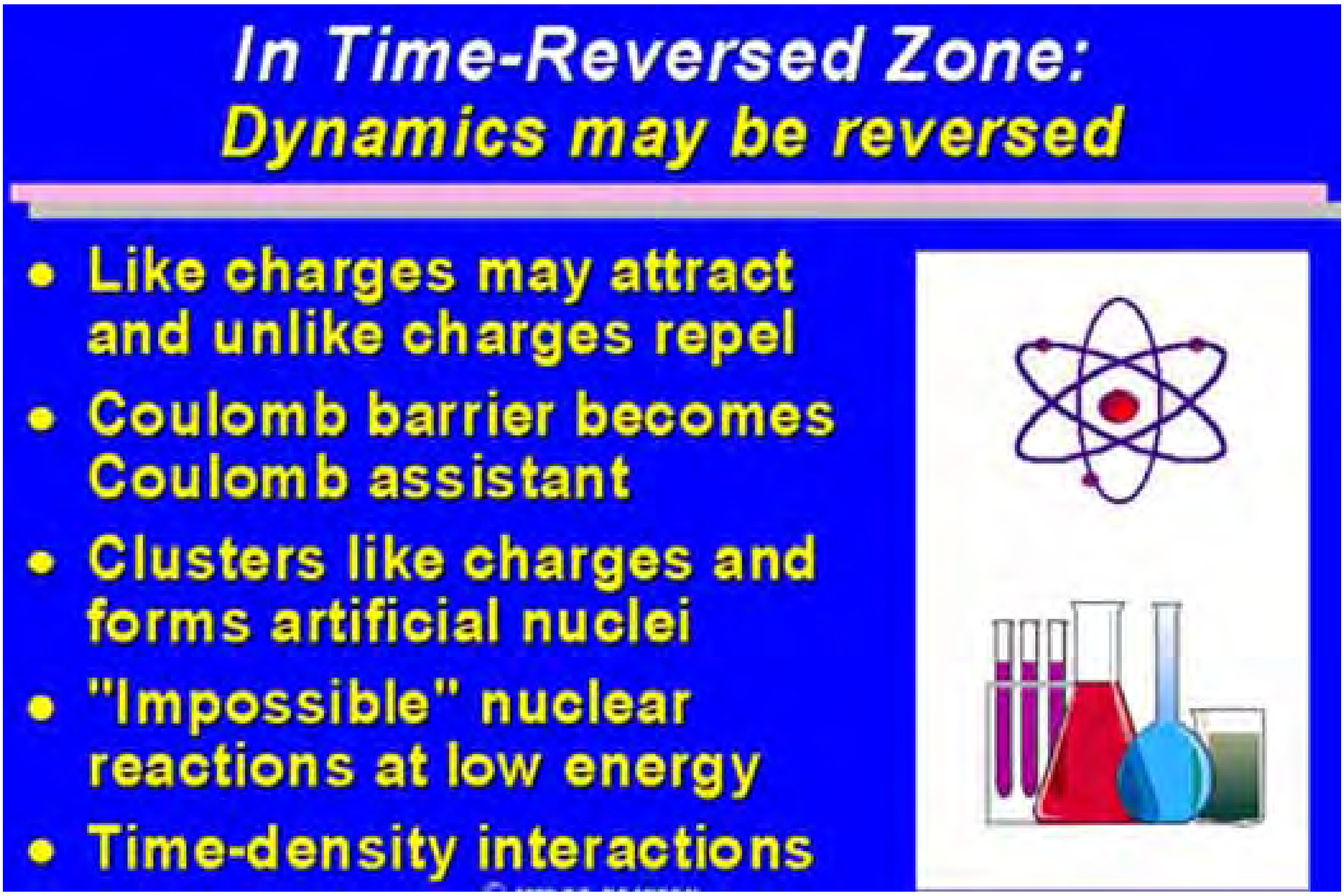

In Time-Reversed Zone:
Dynamics may be reversed

- Like charges may attract and unlike charges repel
- Coulomb barrier becomes Coulomb assistant
- Clusters like charges and forms artificial nuclei
- "Impossible" nuclear reactions at low energy
- Time-density interactions

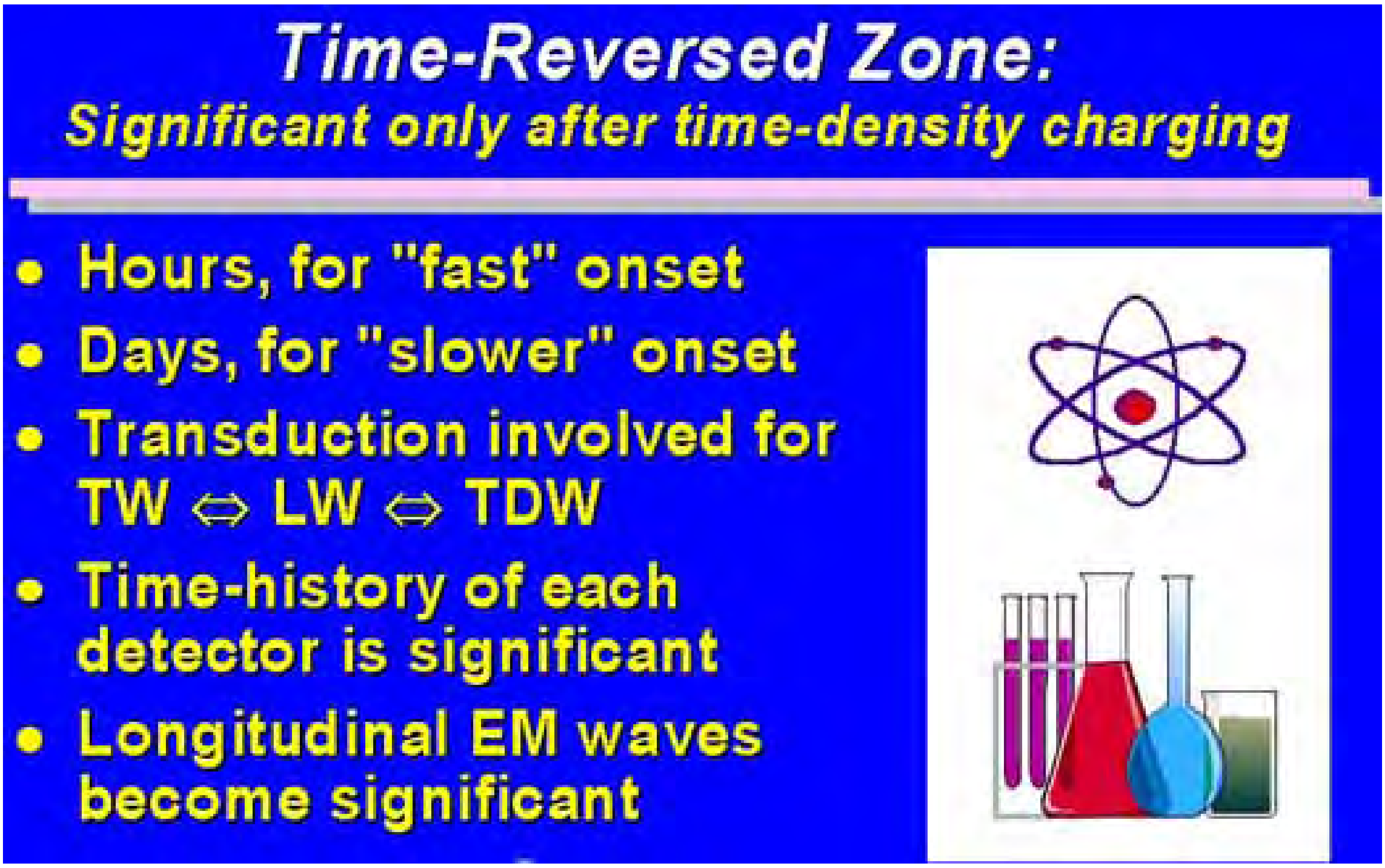

Time-Reversed Zone:

Significant only after time-density charging

- Hours, for "fast" onset
- Days, for "slower" onset
- Transduction involved for TW ⇔ LW ⇔ TDW
- Time-history of each detector is significant
- Longitudinal EM waves become significant

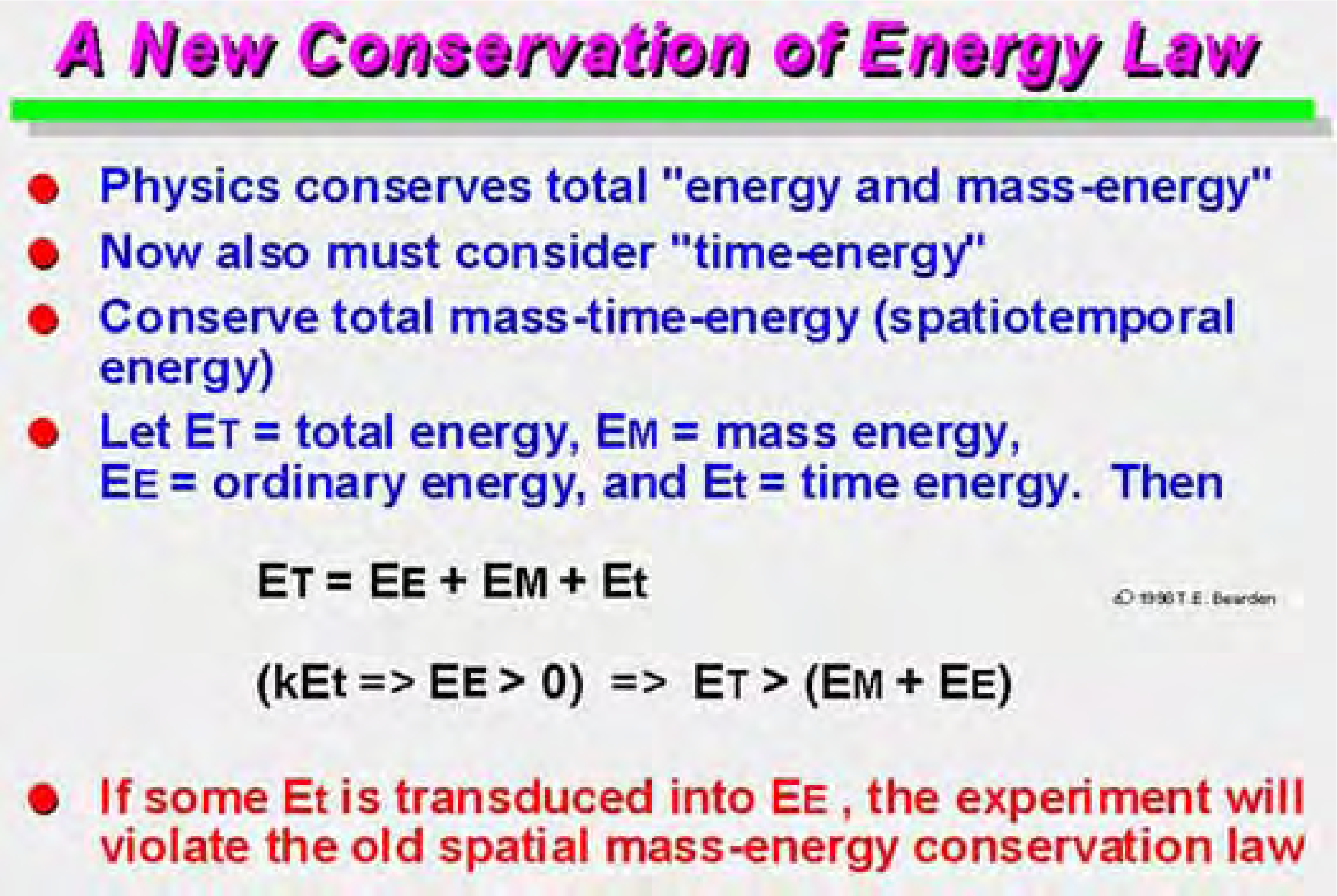

A New Conservation of Energy Law

- Physics conserves total "energy and mass-energy"
- Now also must consider "time-energy"
- Conserve total mass-time-energy (spatiotemporal energy)
- Let E_T = total energy, E_M = mass energy, E_E = ordinary energy, and E_t = time energy. Then

$$E_T = E_E + E_M + E_t$$

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$$(kE_t \Rightarrow E_E > 0) \quad \Rightarrow \quad E_T > (E_M + E_E)$$

- If some E_t is transduced into E_E, the experiment will violate the old spatial mass-energy conservation law

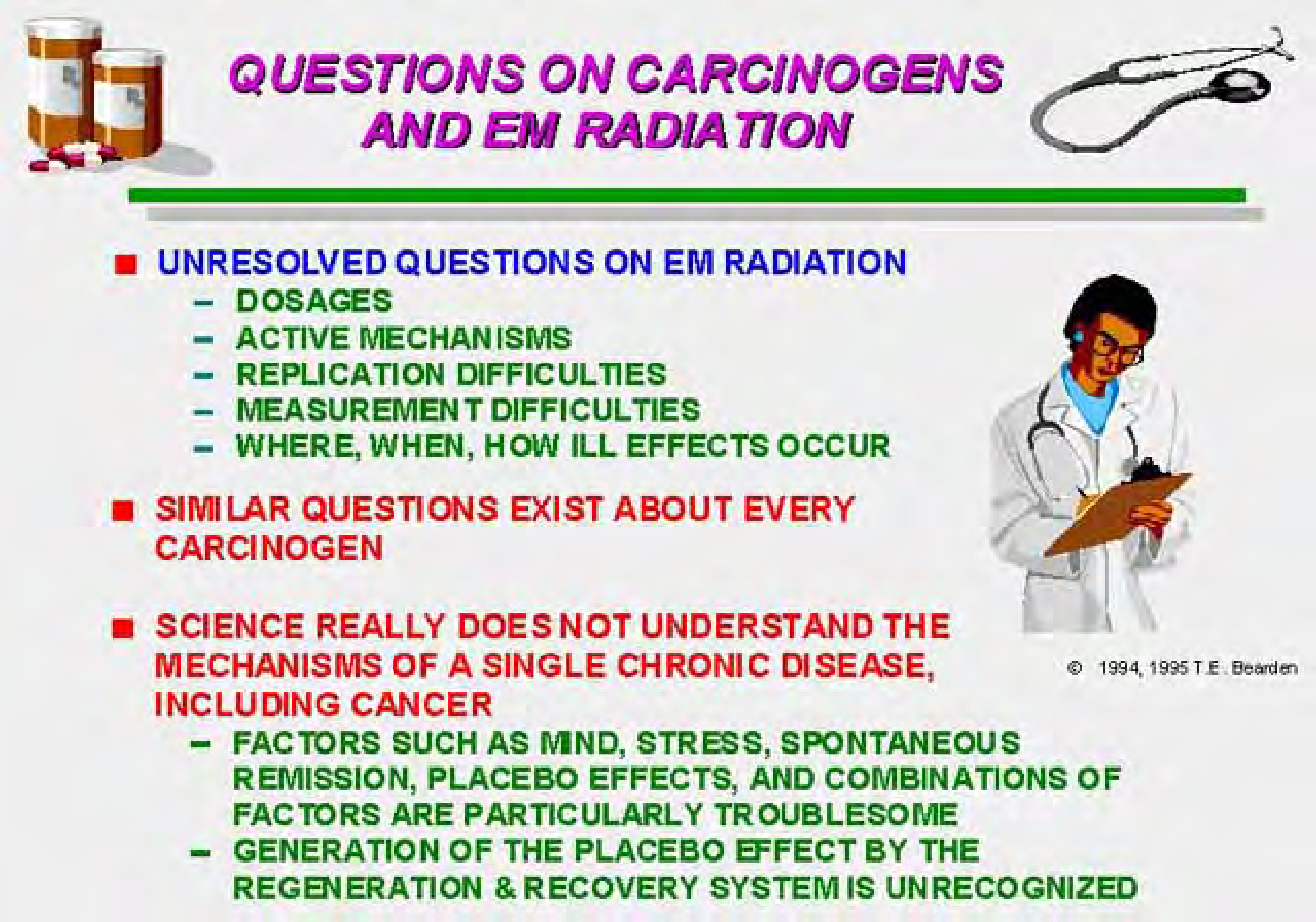

QUESTIONS ON CARCINOGENS AND EM RADIATION

- UNRESOLVED QUESTIONS ON EM RADIATION
  - DOSAGES
  - ACTIVE MECHANISMS
  - REPLICATION DIFFICULTIES
  - MEASUREMENT DIFFICULTIES
  - WHERE, WHEN, HOW ILL EFFECTS OCCUR
- SIMILAR QUESTIONS EXIST ABOUT EVERY CARCINOGEN
- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
  - FACTORS SUCH AS MIND, STRESS, SPONTANEOUS REMISSION, PLACEBO EFFECTS, AND COMBINATIONS OF FACTORS ARE PARTICULARLY TROUBLESOME
  - GENERATION OF THE PLACEBO EFFECT BY THE REGENERATION & RECOVERY SYSTEM IS UNRECOGNIZED

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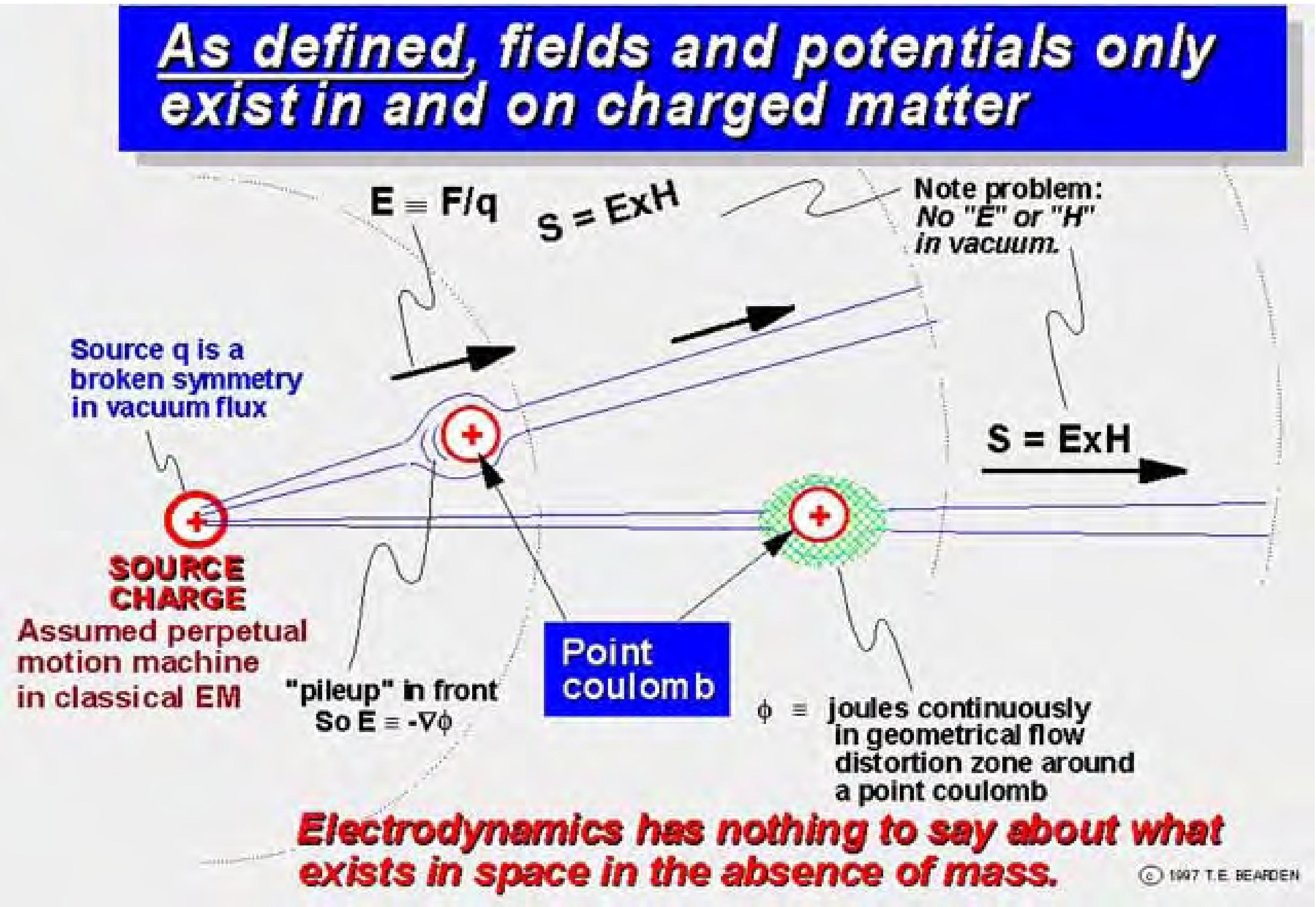

As defined, fields and potentials only exist in and on charged matter

$E \equiv F/q$

$S = E \times H$

Note problem:
No "E" or "H" in vacuum.

Source q is a broken symmetry in vacuum flux

$S = E \times H$

SOURCE CHARGE

Assumed perpetual motion machine in classical EM

"pileup" in front
So $E \equiv -\nabla\phi$

Point coulomb

$\phi \equiv$ joules continuously in geometrical flow distortion zone around a point coulomb

Electrodynamics has nothing to say about what exists in space in the absence of mass.

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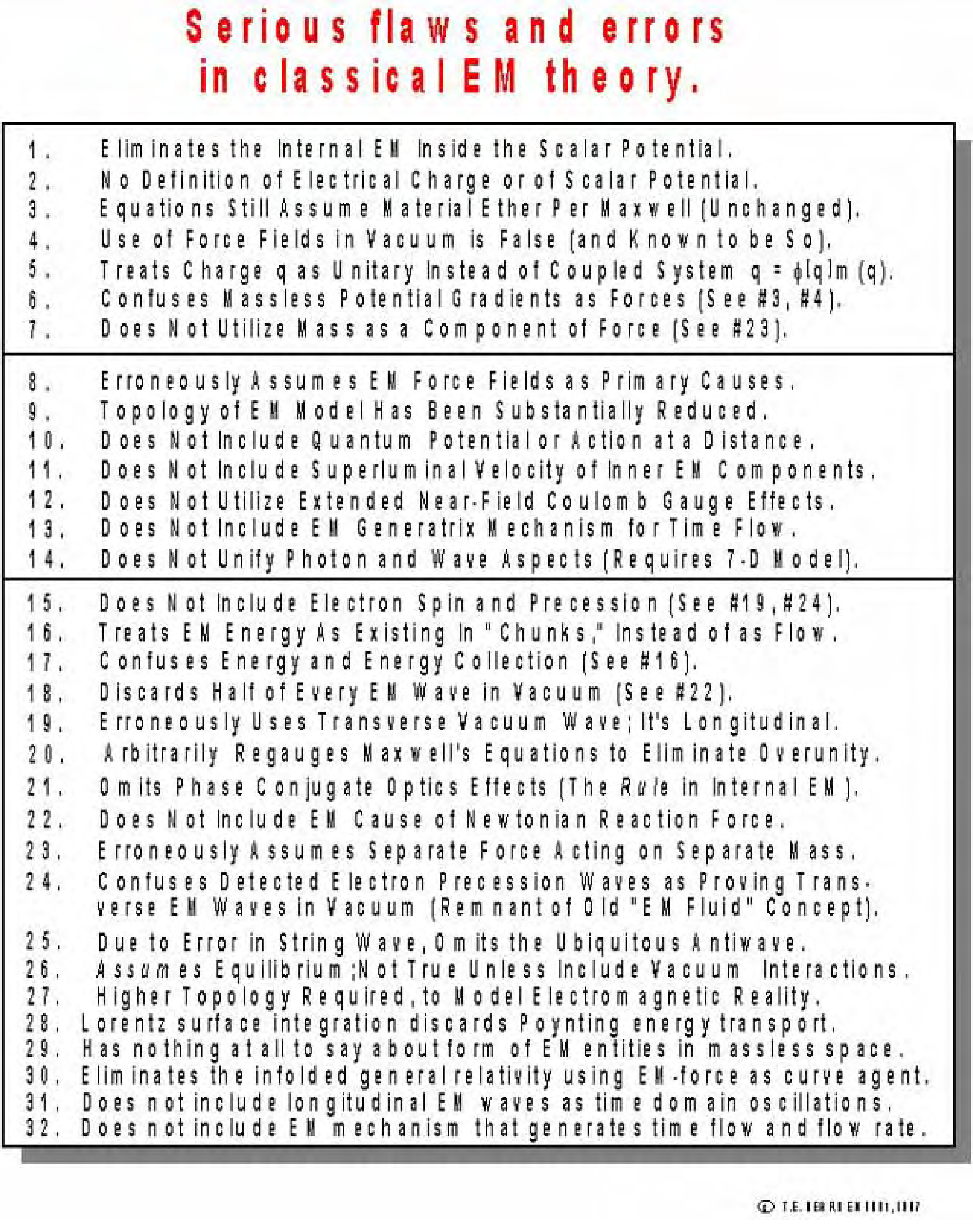

Serious flaws and errors in classical EM theory.

1. Eliminates the Internal EM Inside the Scalar Potential.
2. No Definition of Electrical Charge or of Scalar Potential.
3. Equations Still Assume Material Ether Per Maxwell (Unchanged).
4. Use of Force Fields in Vacuum is False (and Known to be So).
5. Treats Charge q as Unitary Instead of Coupled System $q = \phi[q]m(q)$.
6. Confuses Massless Potential Gradients as Forces (See #3, #4).
7. Does Not Utilize Mass as a Component of Force (See #23).

8. Erroneously Assumes EM Force Fields as Primary Causes.
9. Topology of EM Model Has Been Substantially Reduced.
10. Does Not Include Quantum Potential or Action at a Distance.
11. Does Not Include Superluminal Velocity of Inner EM Components.
12. Does Not Utilize Extended Near-Field Coulomb Gauge Effects.
13. Does Not Include EM Generatrix Mechanism for Time Flow.
14. Does Not Unify Photon and Wave Aspects (Requires 7-D Model).

15. Does Not Include Electron Spin and Precession (See #19, #24).
16. Treats EM Energy As Existing In "Chunks," Instead of as Flow.
17. Confuses Energy and Energy Collection (See #16).
18. Discards Half of Every EM Wave in Vacuum (See #22).
19. Erroneously Uses Transverse Vacuum Wave; It's Longitudinal.
20. Arbitrarily Regauges Maxwell's Equations to Eliminate Overunity.
21. Omits Phase Conjugate Optics Effects (The *Rule* in Internal EM).
22. Does Not Include EM Cause of Newtonian Reaction Force.
23. Erroneously Assumes Separate Force Acting on Separate Mass.
24. Confuses Detected Electron Precession Waves as Proving Transverse EM Waves in Vacuum (Remnant of Old "EM Fluid" Concept).
25. Due to Error in String Wave, Omits the Ubiquitous Antiwave.
26. *Assumes* Equilibrium; Not True Unless Include Vacuum Interactions.
27. Higher Topology Required, to Model Electromagnetic Reality.
28. Lorentz surface integration discards Poynting energy transport.
29. Has nothing at all to say about form of EM entities in massless space.
30. Eliminates the infolded general relativity using EM-force as curve agent.
31. Does not include longitudinal EM waves as time domain oscillations.
32. Does not include EM mechanism that generates time flow and flow rate.

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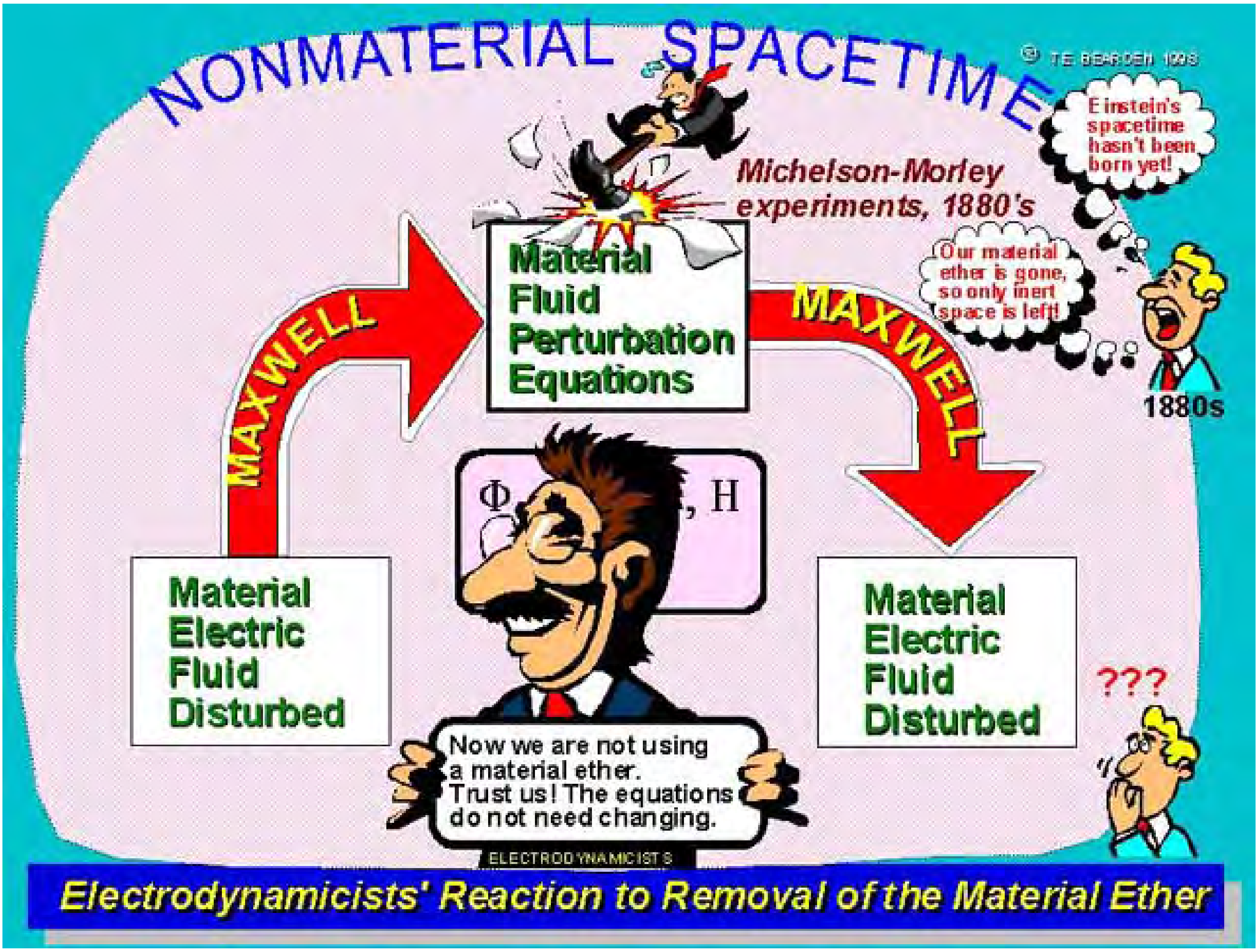
NONMATERIAL SPACETIME
© T.E. BEARDEN 1998
Einstein's spacetime hasn't been born yet!
Michelson-Morley experiments, 1880's
Our material ether is gone, so only inert space is left!
1880s
MAXWELL
Material Fluid Perturbation Equations
MAXWELL
Φ
, H
Material Electric Fluid Disturbed
Material Electric Fluid Disturbed
???
Now we are not using a material ether. Trust us! The equations do not need changing.
ELECTRODYNAMICISTS

Electrodynamicists' Reaction to Removal of the Material Ether

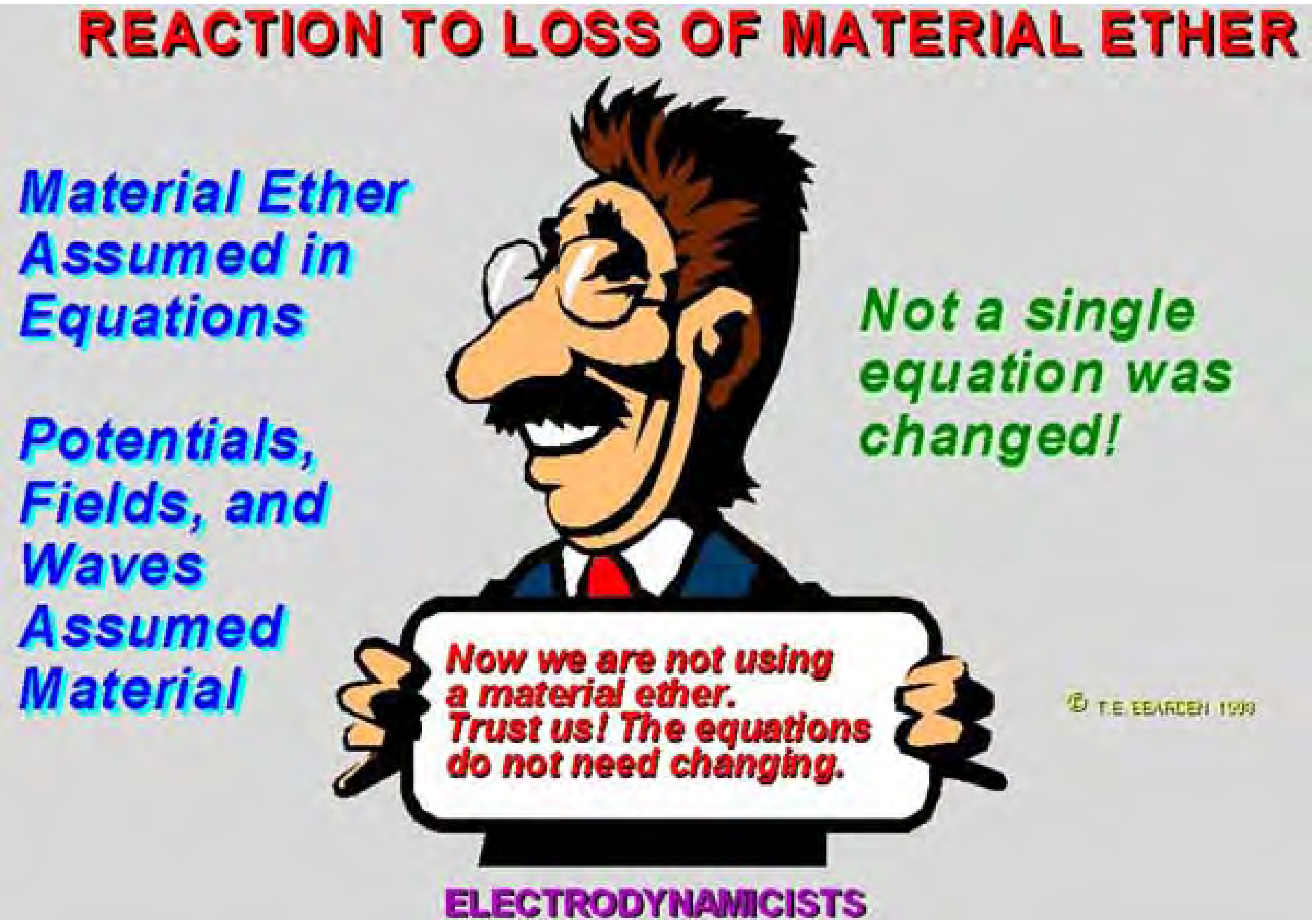

REACTION TO LOSS OF MATERIAL ETHER

Material Ether
Assumed in
Equations

Potentials,
Fields, and
Waves
Assumed
Material

Not a single
equation was
changed!

Now we are not using
a material ether.
Trust us! The equations
do not need changing.

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ELECTRODYNAMICISTS

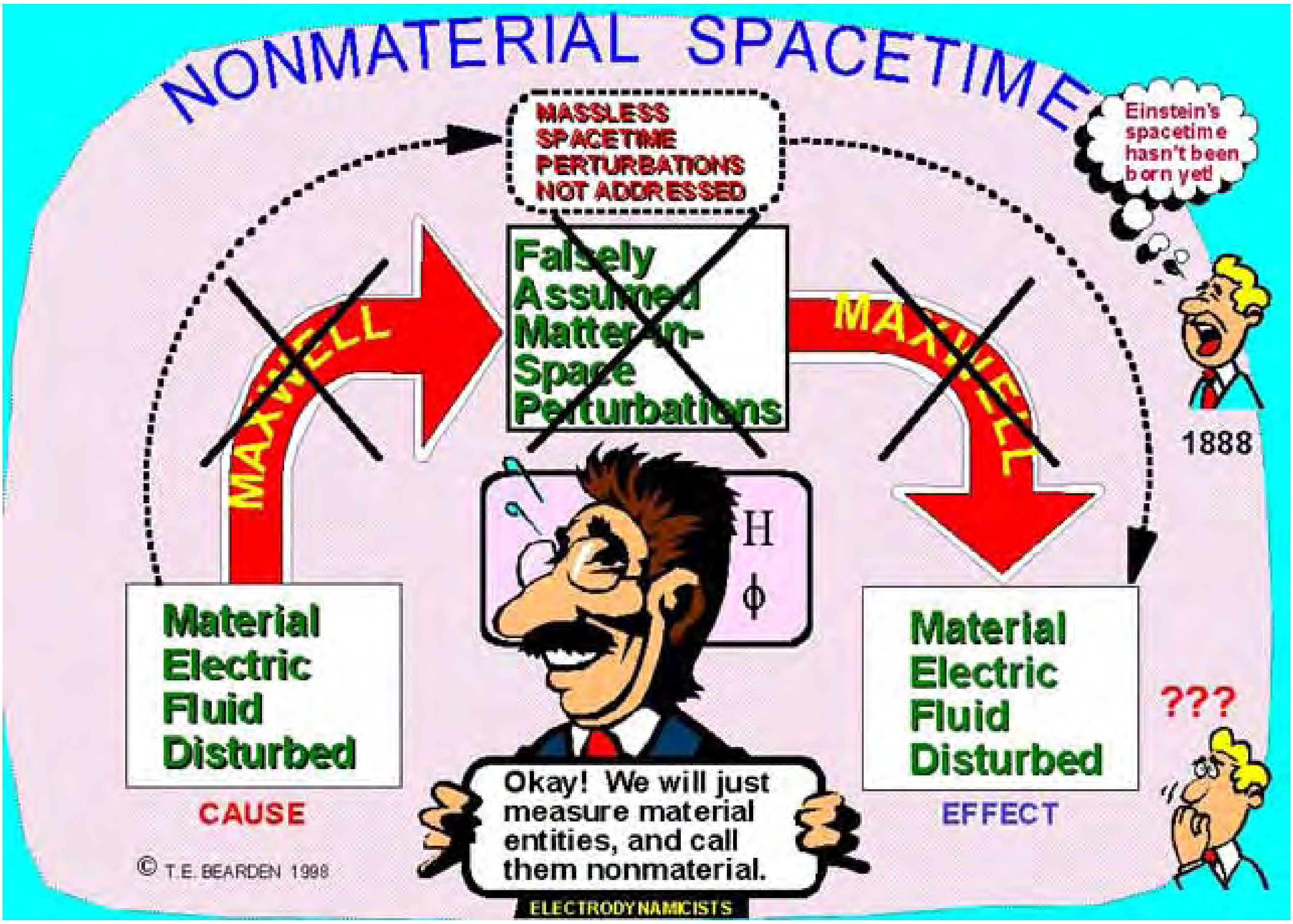
NONMATERIAL SPACETIME
MASSLESS SPACETIME PERTURBATIONS NOT ADDRESSED
Einstein's spacetime hasn't been born yet!
~~MAXWELL~~
~~Falsely Assumed Matter-in-Space Perturbations~~
~~MAXWELL~~
1888
H
ϕ
Material Electric Fluid Disturbed
CAUSE
Material Electric Fluid Disturbed
EFFECT
???
Okay! We will just measure material entities, and call them nonmaterial.
ELECTRODYNAMICISTS
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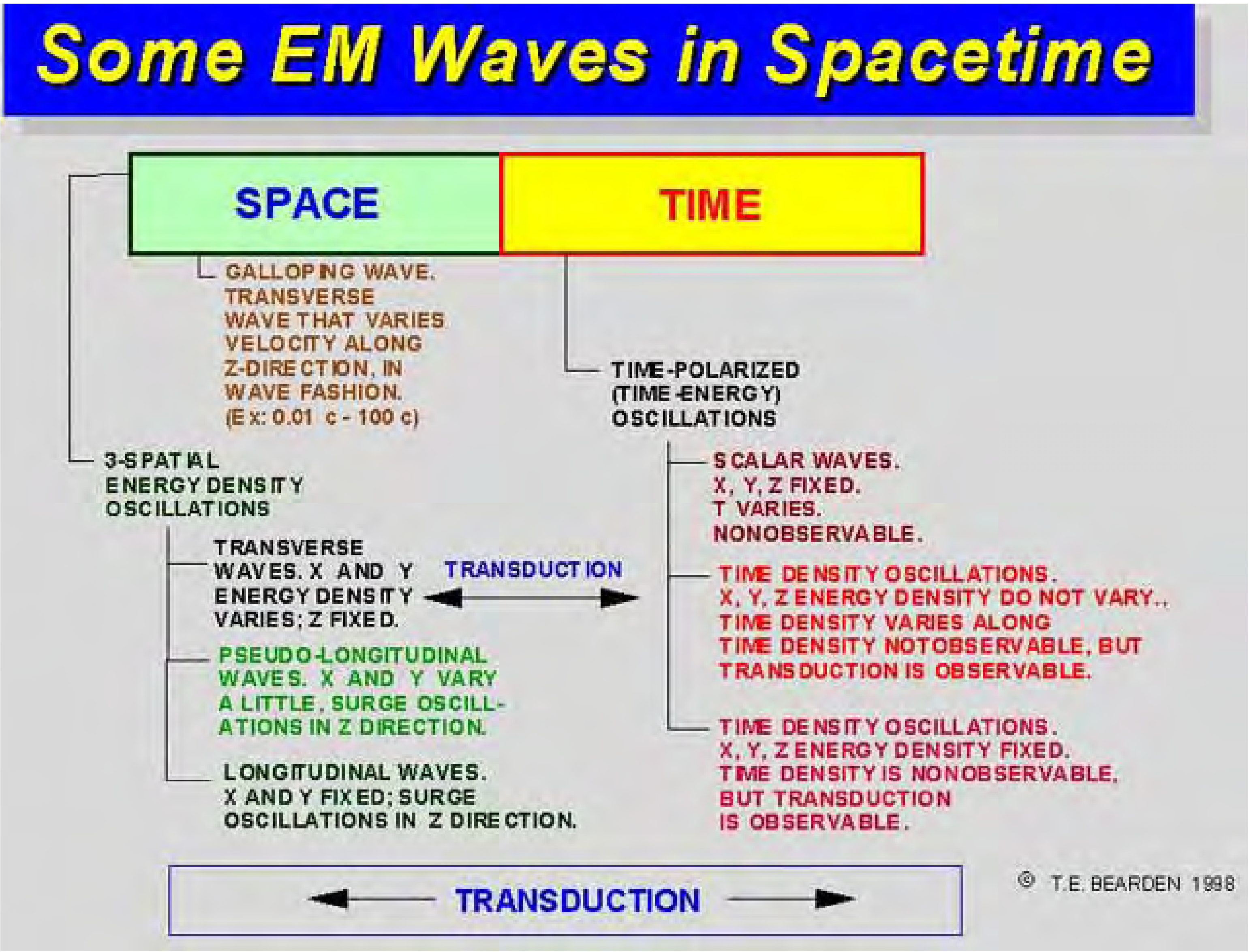

Some EM Waves in Spacetime

SPACE

TIME

GALLOPING WAVE. TRANSVERSE WAVE THAT VARIES VELOCITY ALONG Z-DIRECTION, IN WAVE FASHION. (Ex: 0.01 c - 100 c)

TIME-POLARIZED (TIME-ENERGY) OSCILLATIONS

3-SPATIAL ENERGY DENSITY OSCILLATIONS

SCALAR WAVES. X, Y, Z FIXED. T VARIES. NONOBSERVABLE.

TRANSVERSE WAVES. X AND Y ENERGY DENSITY VARIES; Z FIXED.

TRANSDUCTION

TIME DENSITY OSCILLATIONS. X, Y, Z ENERGY DENSITY DO NOT VARY.. TIME DENSITY VARIES ALONG TIME DENSITY NOTOBSERVABLE, BUT TRANSDUCTION IS OBSERVABLE.

PSEUDO-LONGITUDINAL WAVES. X AND Y VARY A LITTLE, SURGE OSCILLATIONS IN Z DIRECTION.

LONGITUDINAL WAVES. X AND Y FIXED; SURGE OSCILLATIONS IN Z DIRECTION.

TIME DENSITY OSCILLATIONS. X, Y, Z ENERGY DENSITY FIXED. TIME DENSITY IS NONOBSERVABLE, BUT TRANSDUCTION IS OBSERVABLE.

TRANSDUCTION

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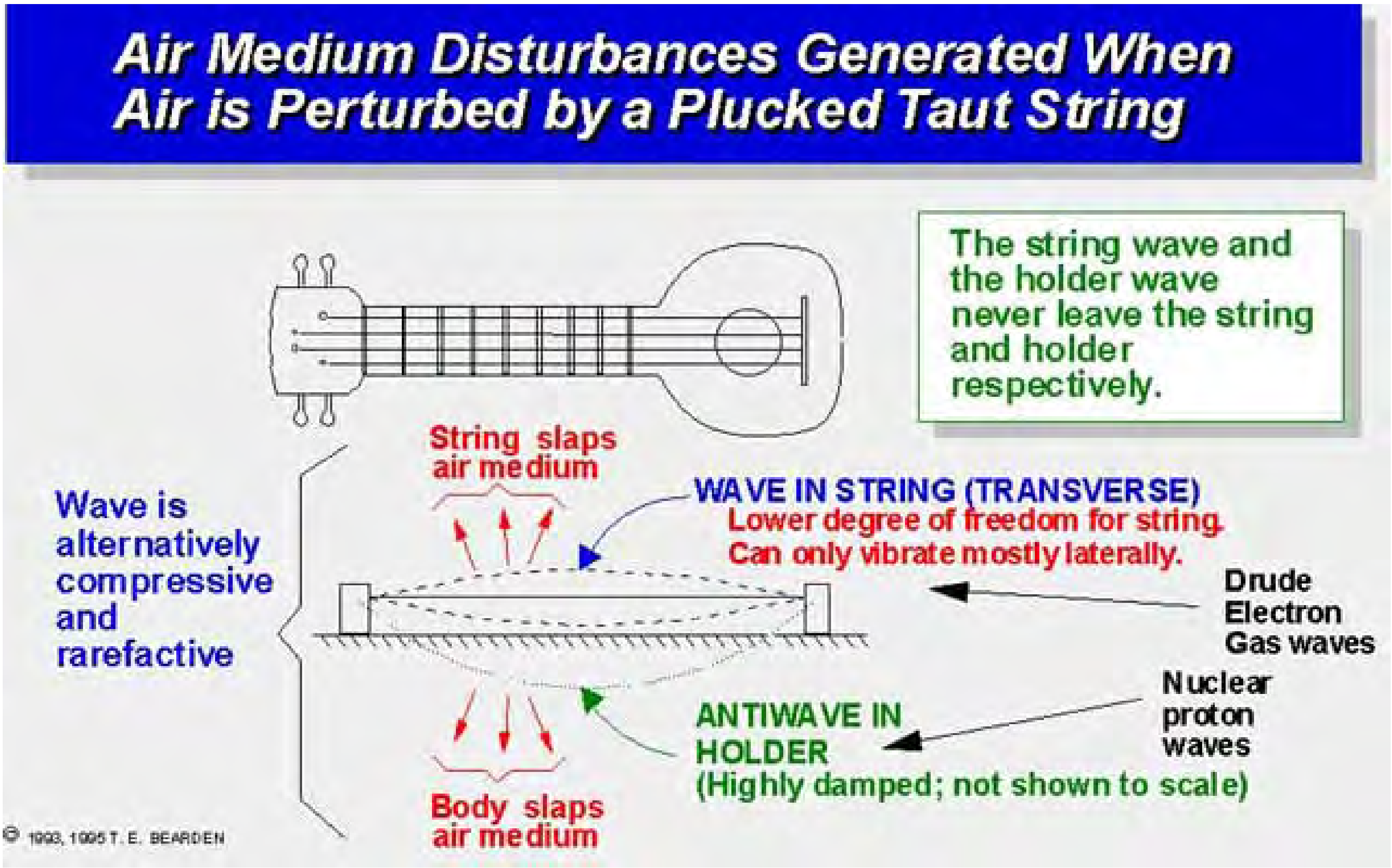

Air Medium Disturbances Generated When Air is Perturbed by a Plucked Taut String

The string wave and the holder wave never leave the string and holder respectively.

String slaps air medium

WAVE IN STRING (TRANSVERSE)

Lower degree of freedom for string.
Can only vibrate mostly laterally.

Drude Electron Gas waves

Wave is alternatively compressive and rarefactive

Nuclear proton waves

ANTIWAVE IN HOLDER
(Highly damped; not shown to scale)

Body slaps air medium

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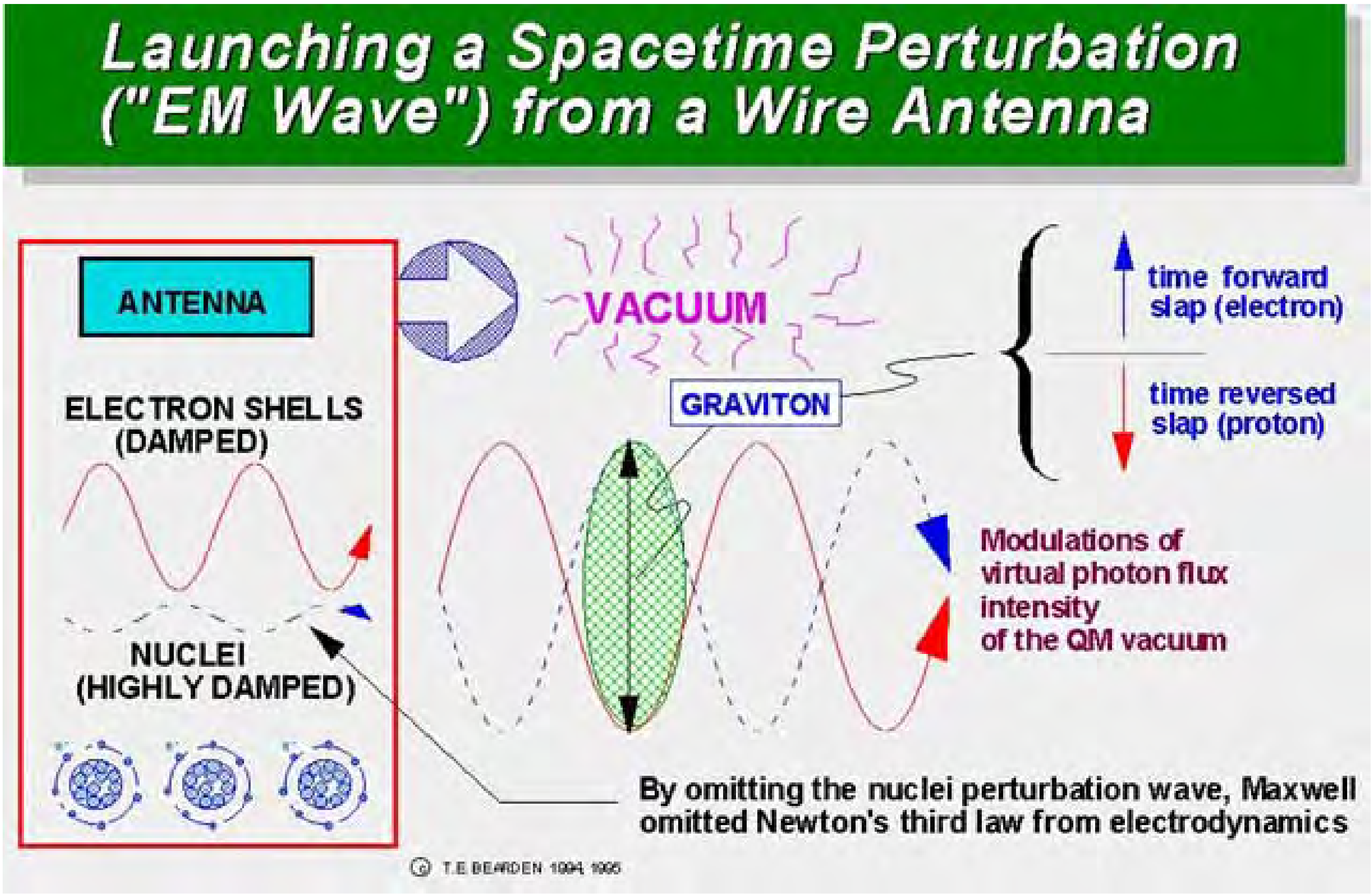

Launching a Spacetime Perturbation ("EM Wave") from a Wire Antenna

ANTENNA
ELECTRON SHELLS (DAMPED)
NUCLEI (HIGHLY DAMPED)
VACUUM
GRAVITON
time forward slap (electron)
time reversed slap (proton)
Modulations of virtual photon flux intensity of the QM vacuum

By omitting the nuclei perturbation wave, Maxwell omitted Newton's third law from electrodynamics

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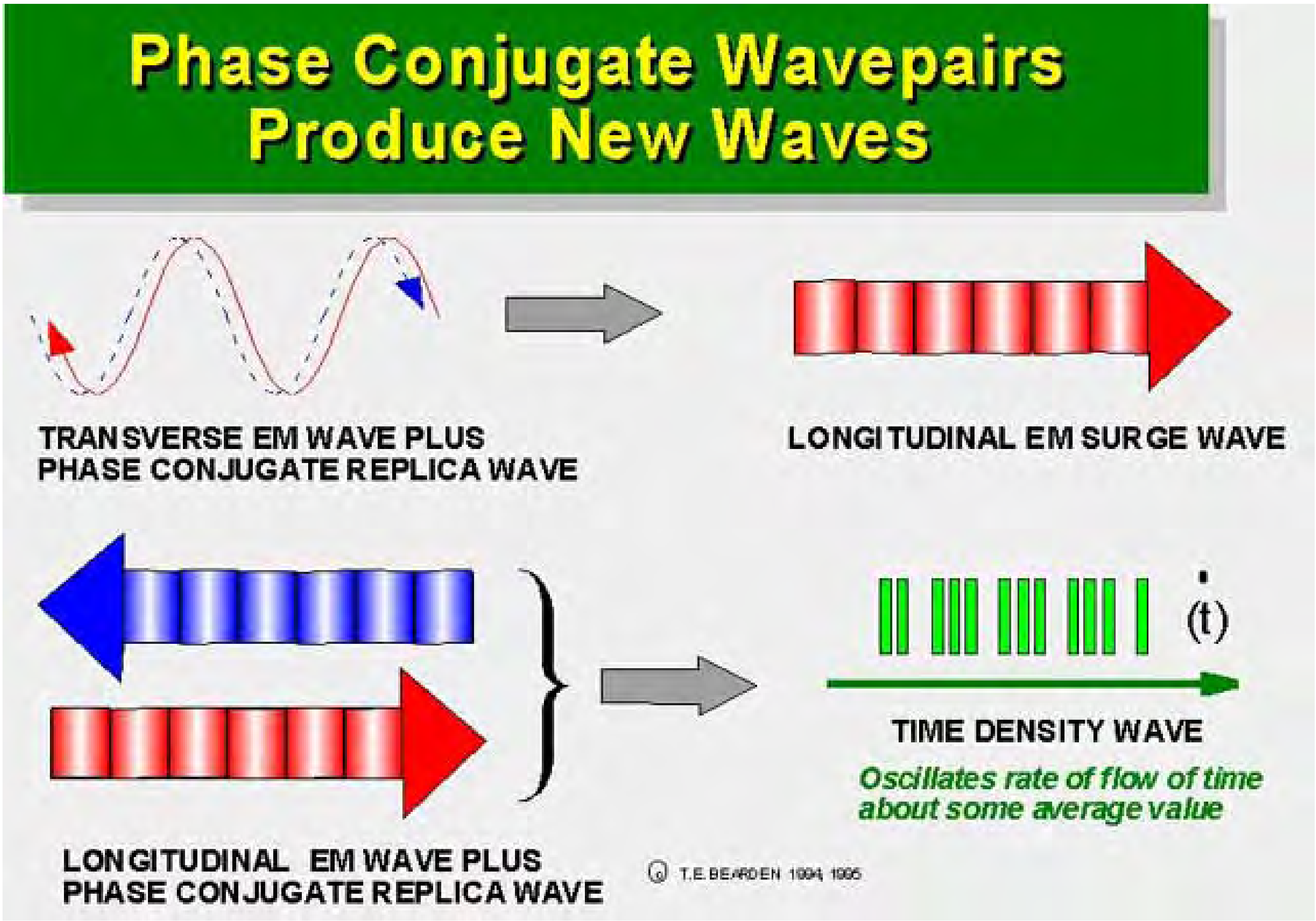

Phase Conjugate Wavepairs Produce New Waves

TRANSVERSE EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE

LONGITUDINAL EM SURGE WAVE

LONGITUDINAL EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE

TIME DENSITY WAVE

Oscillates rate of flow of time about some average value

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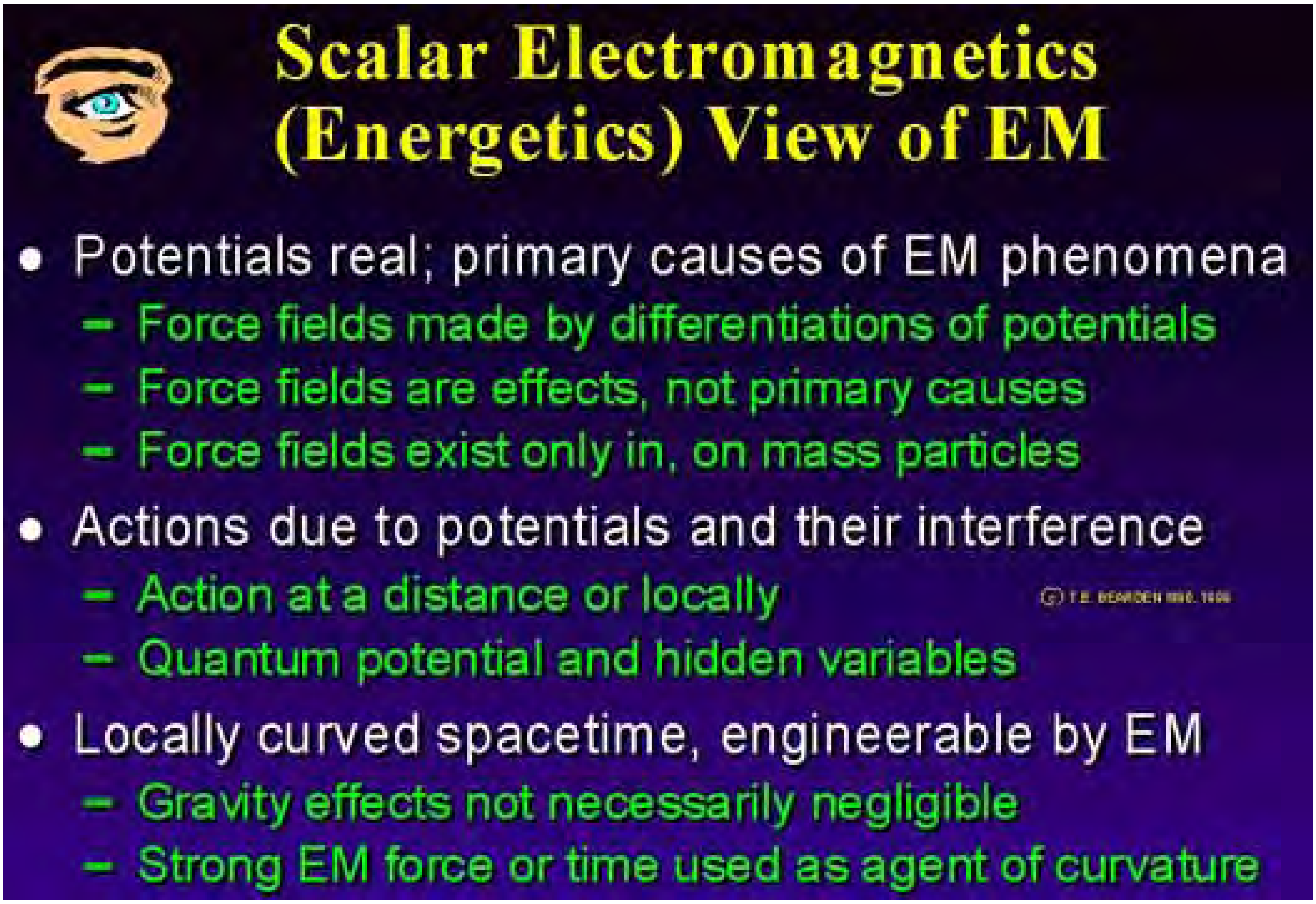

Scalar Electromagnetics (Energetics) View of EM

- Potentials real; primary causes of EM phenomena
  - Force fields made by differentiations of potentials
  - Force fields are effects, not primary causes
  - Force fields exist only in, on mass particles
- Actions due to potentials and their interference
  - Action at a distance or locally
  - Quantum potential and hidden variables
- Locally curved spacetime, engineerable by EM
  - Gravity effects not necessarily negligible
  - Strong EM force or time used as agent of curvature

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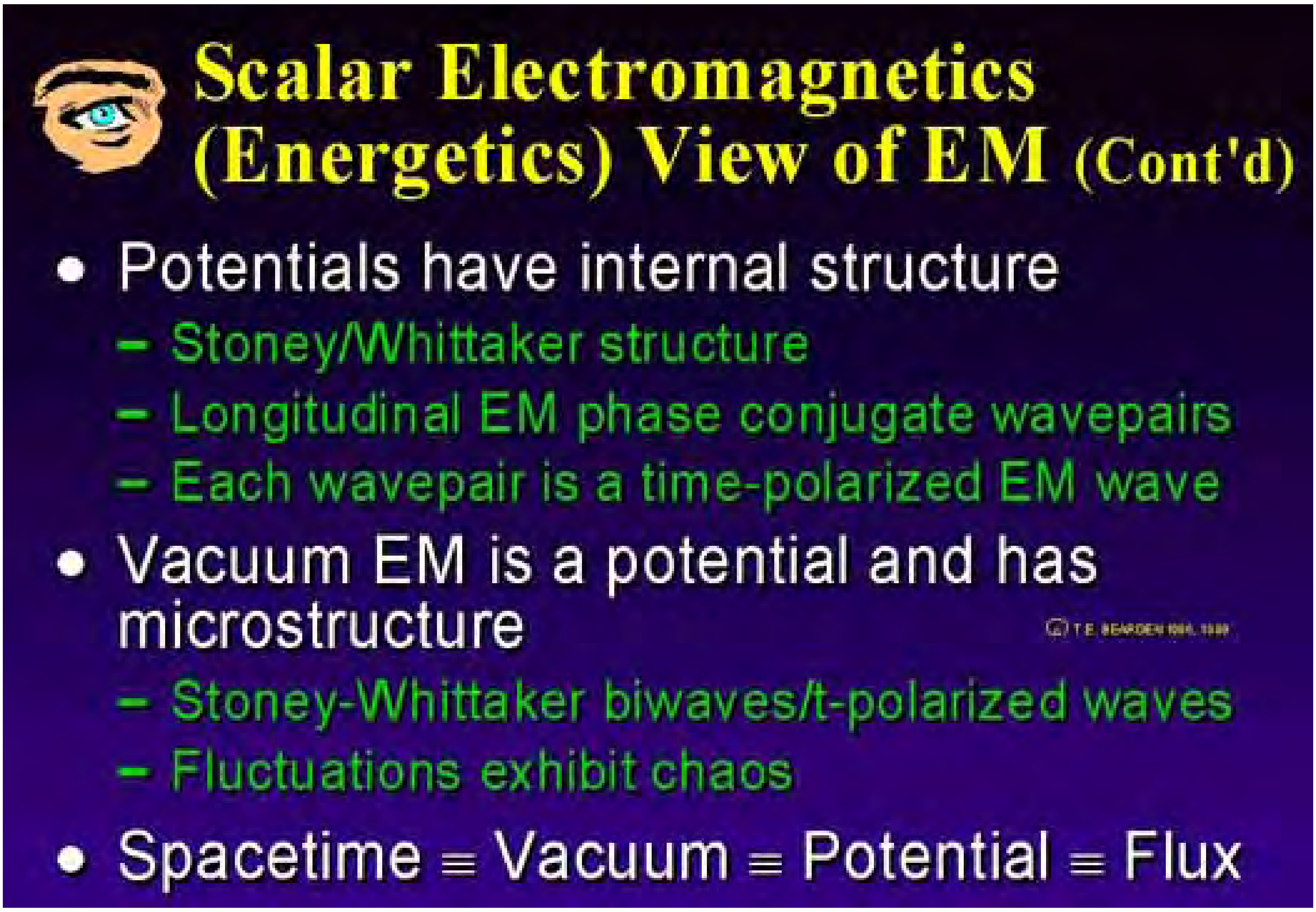

Scalar Electromagnetics (Energetics) View of EM (Cont'd)

- Potentials have internal structure
  - Stoney/Whittaker structure
  - Longitudinal EM phase conjugate wavepairs
  - Each wavepair is a time-polarized EM wave
- Vacuum EM is a potential and has microstructure
  - Stoney-Whittaker biwaves/t-polarized waves
  - Fluctuations exhibit chaos
- Spacetime ≡ Vacuum ≡ Potential ≡ Flux

© T.E. BEARDEN [illegible]

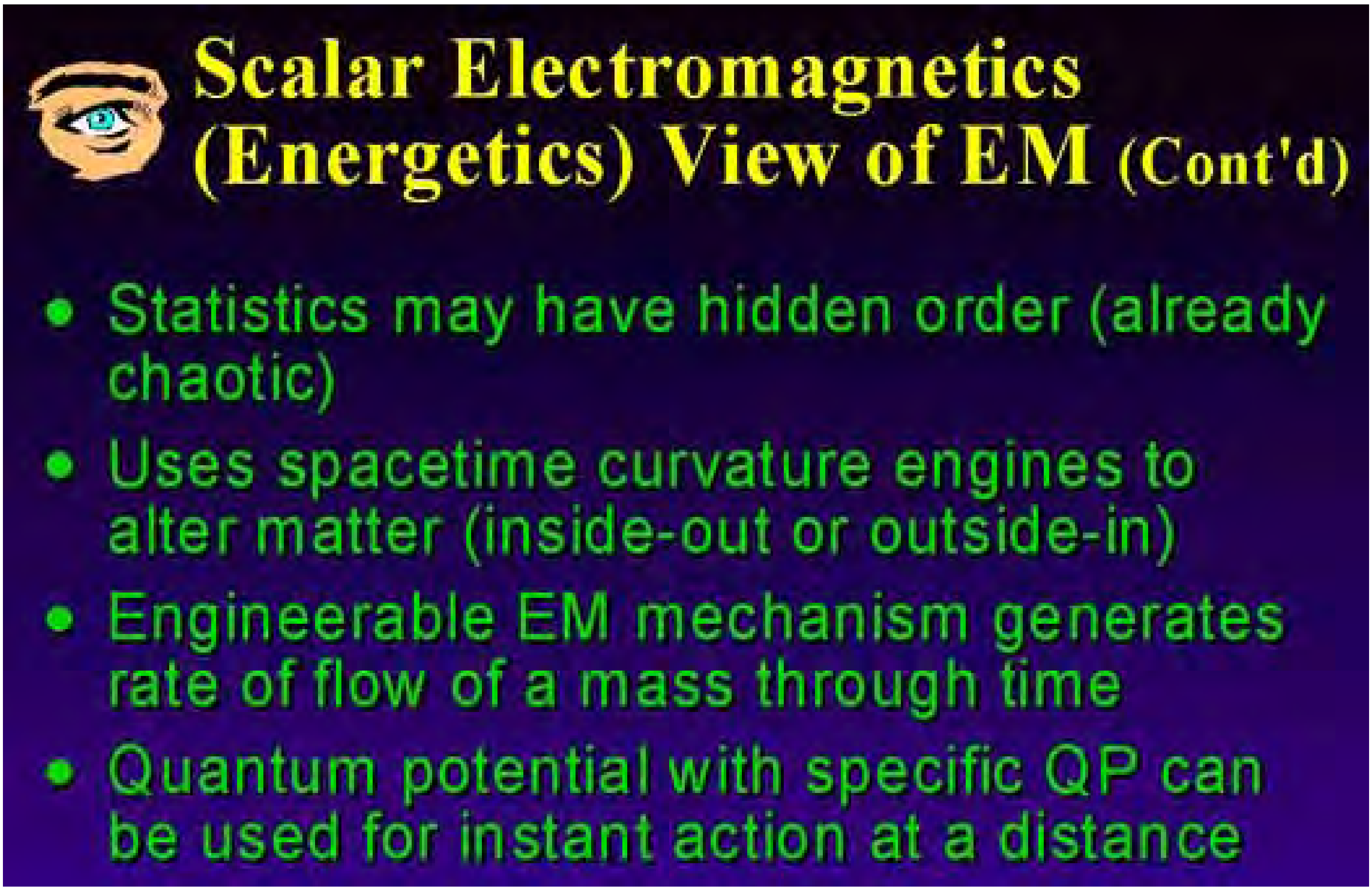

Scalar Electromagnetics (Energetics) View of EM (Cont'd)

- Statistics may have hidden order (already chaotic)
- Uses spacetime curvature engines to alter matter (inside-out or outside-in)
- Engineerable EM mechanism generates rate of flow of a mass through time
- Quantum potential with specific QP can be used for instant action at a distance

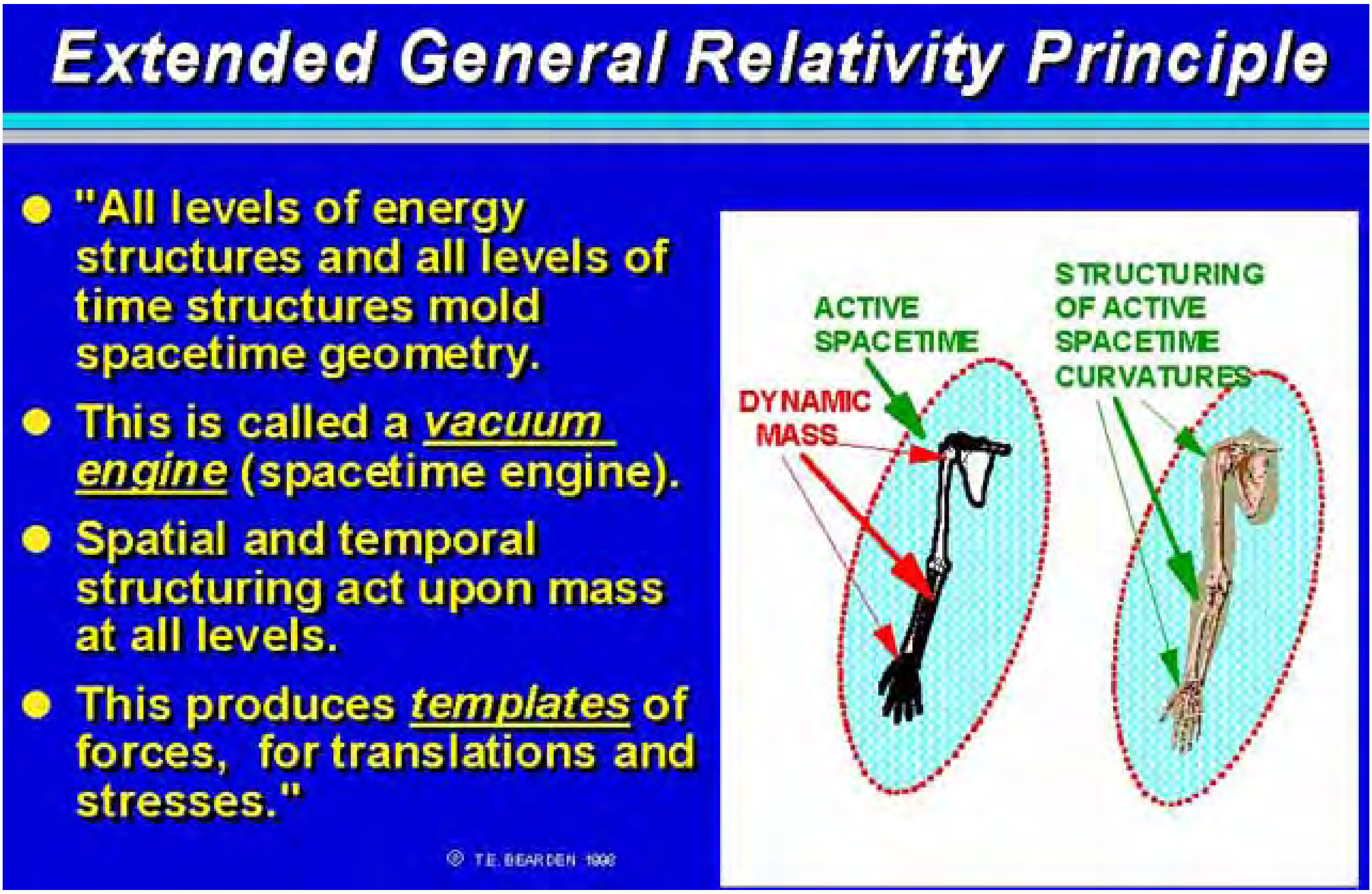

Extended General Relativity Principle

- "All levels of energy structures and all levels of time structures mold spacetime geometry.
- This is called a *vacuum engine* (spacetime engine).
- Spatial and temporal structuring act upon mass at all levels.
- This produces *templates* of forces, for translations and stresses."

ACTIVE SPACETIME
DYNAMIC MASS
STRUCTURING OF ACTIVE SPACETIME CURVATURES

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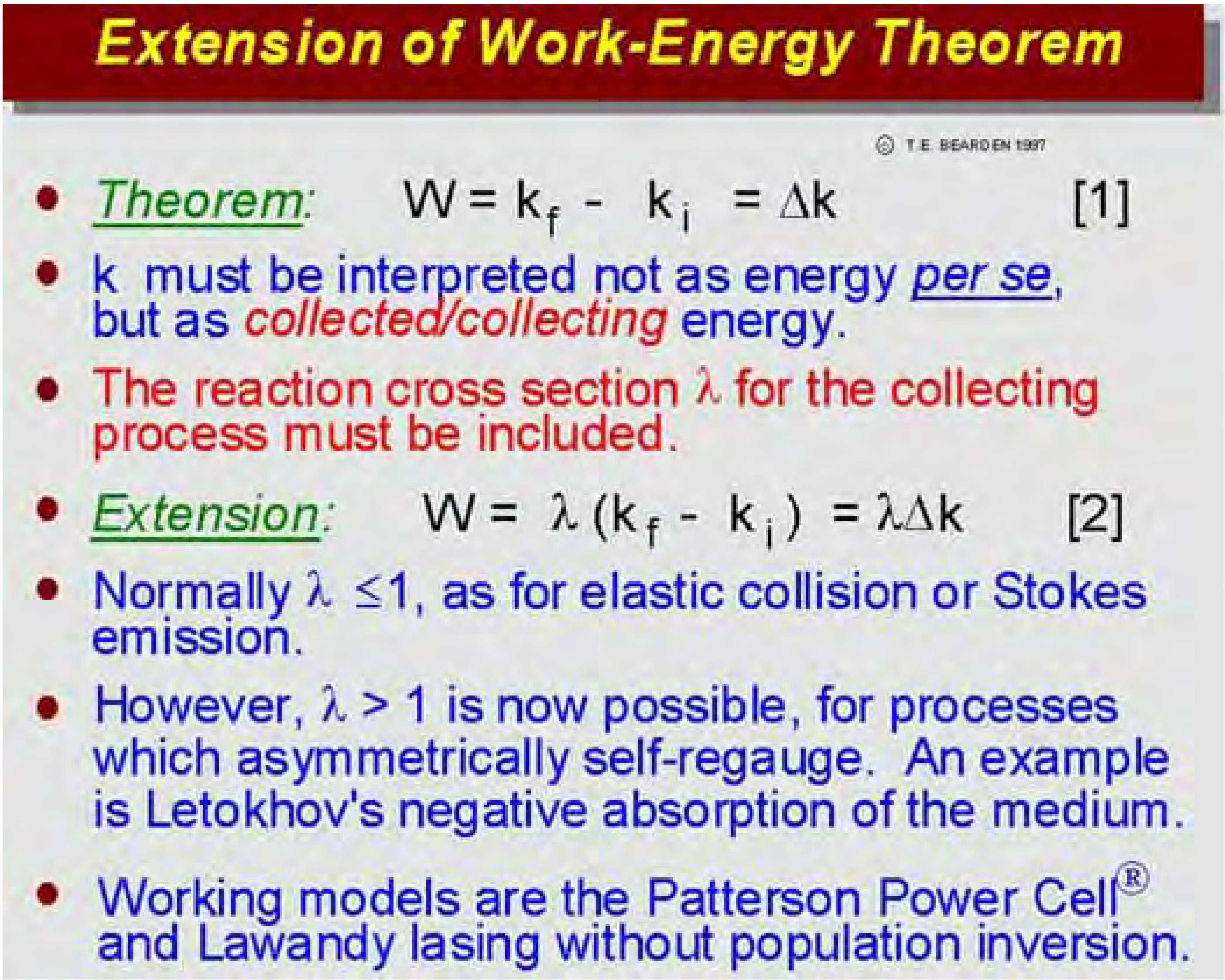

Extension of Work-Energy Theorem

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- *Theorem*: $W = k_f - k_i = \Delta k$ [1]
- k must be interpreted not as energy *per se*, but as *collected/collecting* energy.
- The reaction cross section λ for the collecting process must be included.
- *Extension*: $W = \lambda (k_f - k_i) = \lambda \Delta k$ [2]
- Normally $\lambda \leq 1$, as for elastic collision or Stokes emission.
- However, $\lambda > 1$ is now possible, for processes which asymmetrically self-regauge. An example is Letokhov's negative absorption of the medium.
- Working models are the Patterson Power Cell® and Lawandy lasing without population inversion.

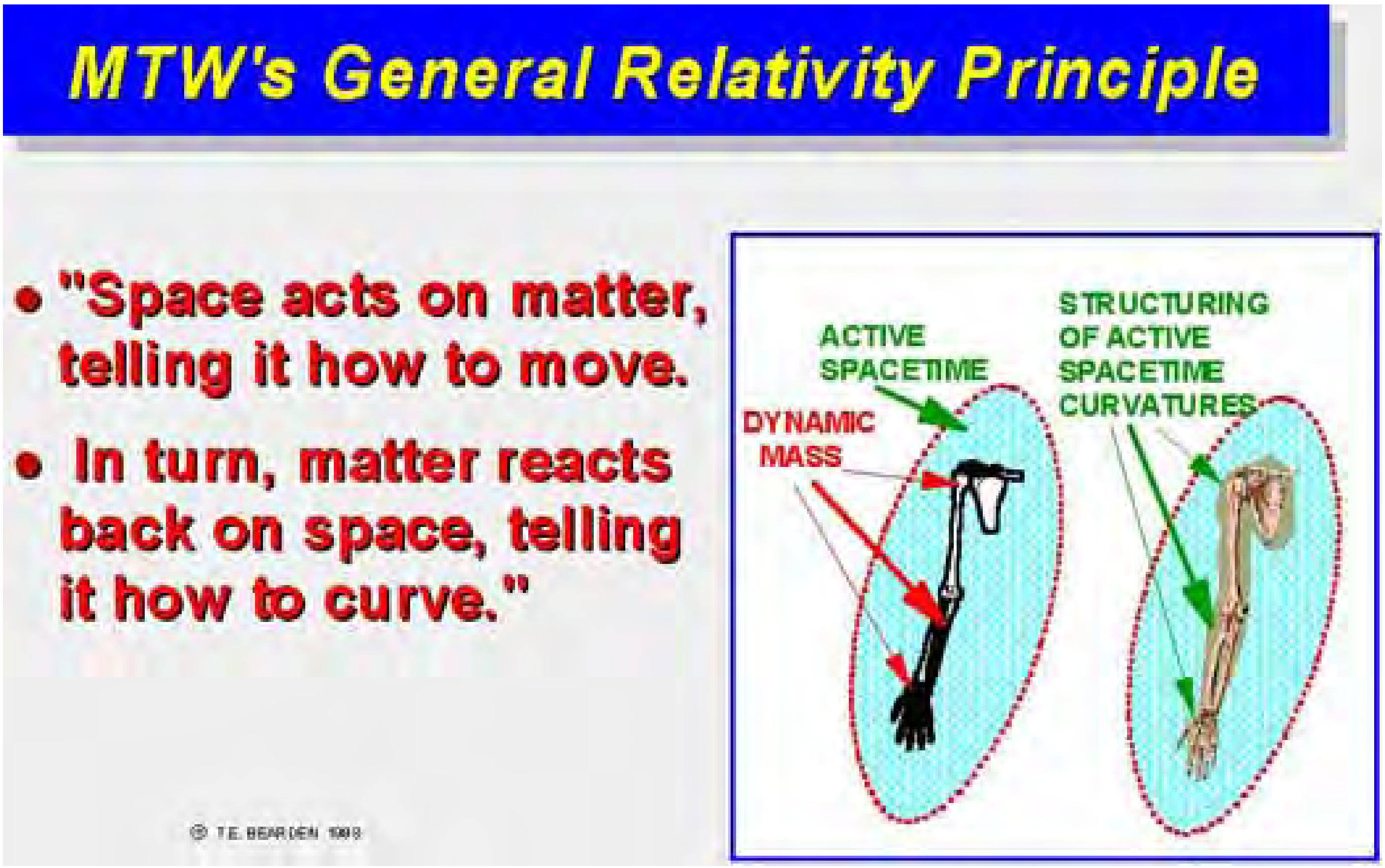

MTW's General Relativity Principle

- "Space acts on matter, telling it how to move.
- In turn, matter reacts back on space, telling it how to curve."

ACTIVE SPACETIME
STRUCTURING OF ACTIVE SPACETIME CURVATURES
DYNAMIC MASS

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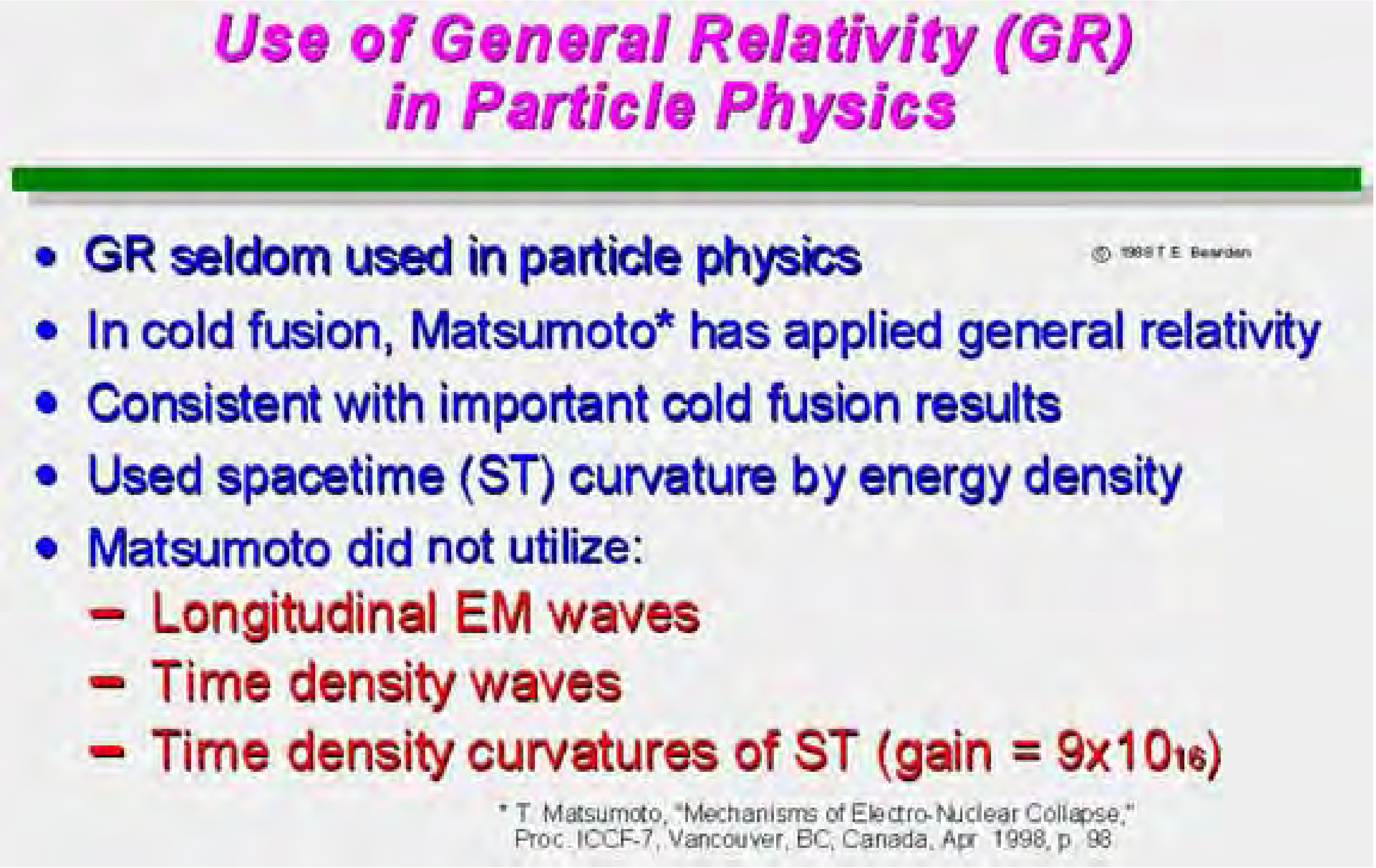

Use of General Relativity (GR) in Particle Physics

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- GR seldom used in particle physics
- In cold fusion, Matsumoto* has applied general relativity
- Consistent with important cold fusion results
- Used spacetime (ST) curvature by energy density
- Matsumoto did not utilize:
  - Longitudinal EM waves
  - Time density waves
  - Time density curvatures of ST (gain = $9x10^{16}$)

* T. Matsumoto, "Mechanisms of Electro-Nuclear Collapse," Proc. ICCF-7, Vancouver, BC, Canada, Apr. 1998, p. 98

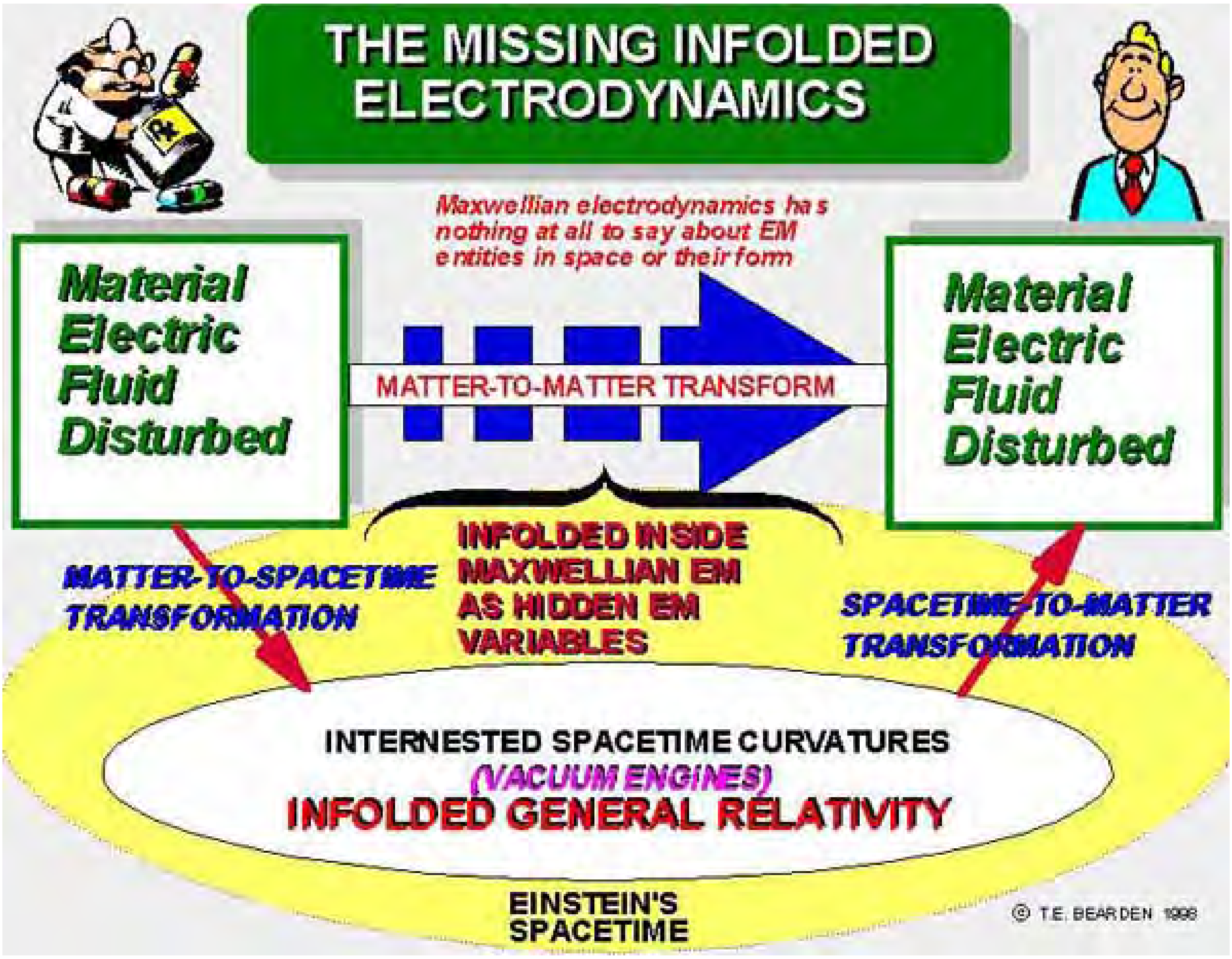

THE MISSING INFOLDED ELECTRODYNAMICS

Maxwellian electrodynamics has nothing at all to say about EM entities in space or their form

Material Electric Fluid Disturbed

MATTER-TO-MATTER TRANSFORM

Material Electric Fluid Disturbed

MATTER-TO-SPACETIME TRANSFORMATION

INFOLDED INSIDE MAXWELLIAN EM AS HIDDEN EM VARIABLES

SPACETIME-TO-MATTER TRANSFORMATION

INTERNESTED SPACETIME CURVATURES

(VACUUM ENGINES)

INFOLDED GENERAL RELATIVITY

EINSTEIN'S SPACETIME

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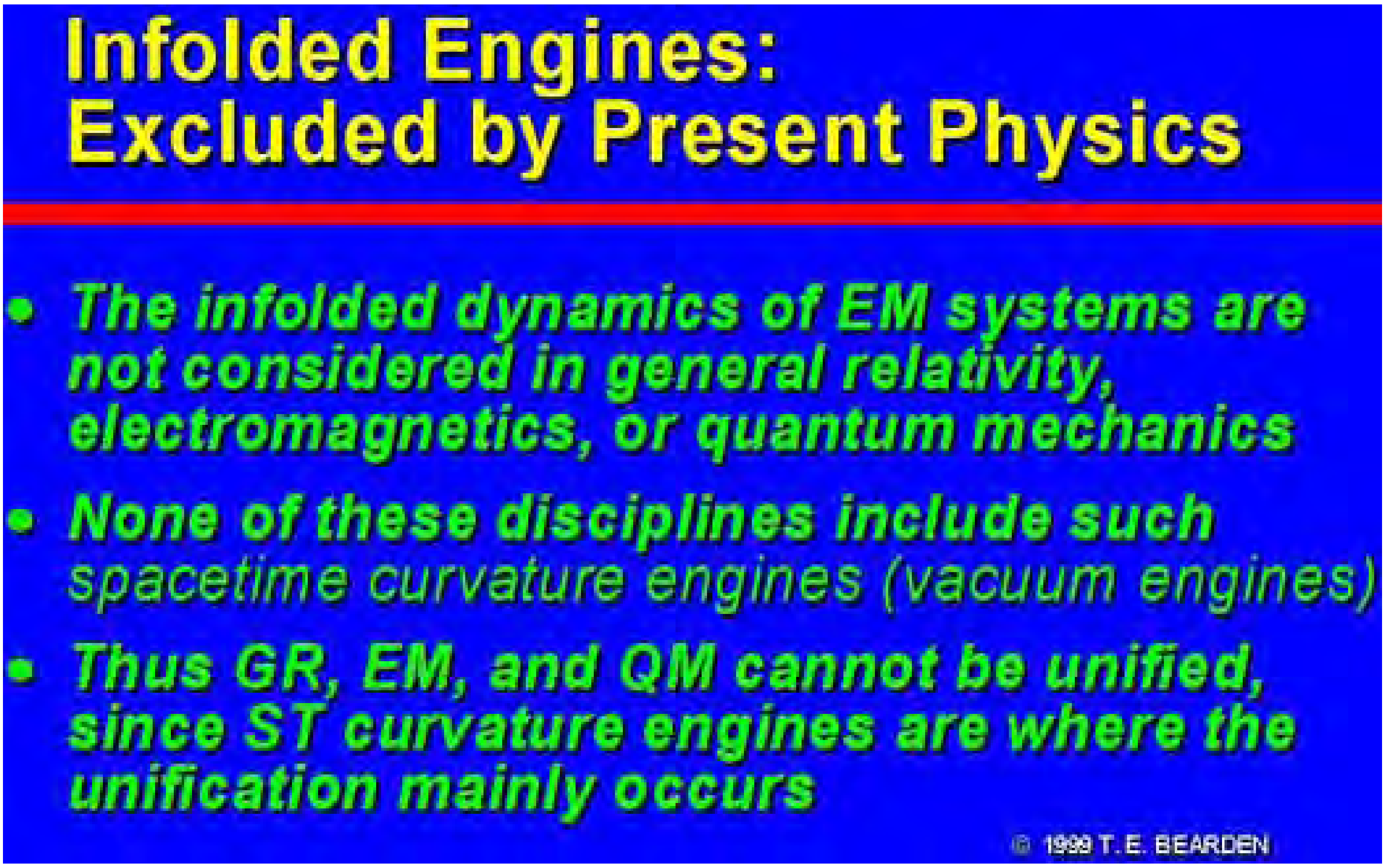

Infolded Engines: Excluded by Present Physics

- *The infolded dynamics of EM systems are not considered in general relativity, electromagnetics, or quantum mechanics*
- *None of these disciplines include such spacetime curvature engines (vacuum engines)*
- *Thus GR, EM, and QM cannot be unified, since ST curvature engines are where the unification mainly occurs*

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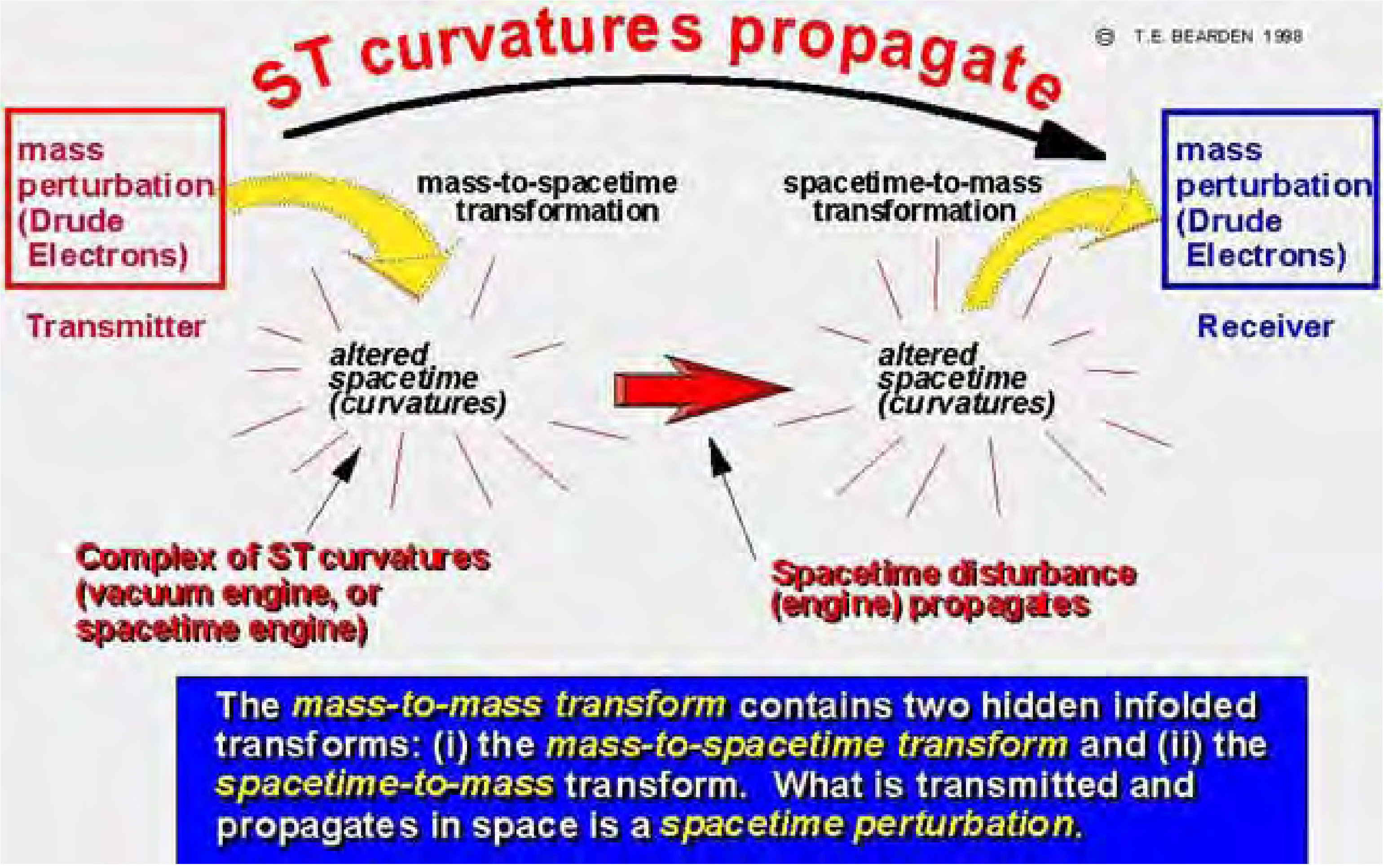

ST curvatures propagate

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mass perturbation (Drude Electrons)

Transmitter

mass-to-spacetime transformation

altered spacetime (curvatures)

spacetime-to-mass transformation

altered spacetime (curvatures)

mass perturbation (Drude Electrons)

Receiver

Complex of ST curvatures (vacuum engine, or spacetime engine)

Spacetime disturbance (engine) propagates

The *mass-to-mass transform* contains two hidden infolded transforms: (i) the *mass-to-spacetime transform* and (ii) the *spacetime-to-mass* transform. What is transmitted and propagates in space is a *spacetime perturbation.*

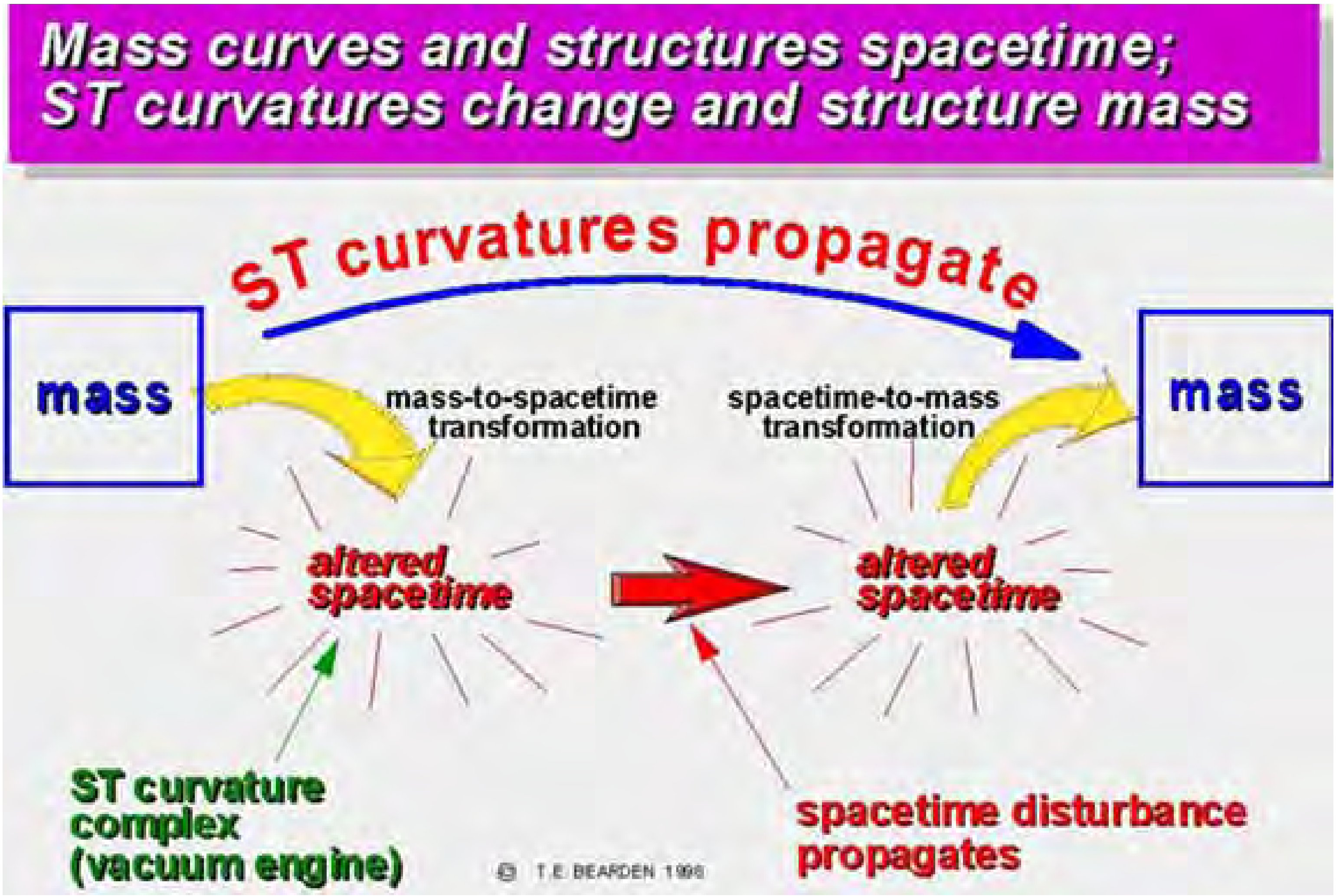

Mass curves and structures spacetime; ST curvatures change and structure mass

ST curvatures propagate

mass

mass-to-spacetime transformation

spacetime-to-mass transformation

mass

altered spacetime

altered spacetime

ST curvature complex (vacuum engine)

spacetime disturbance propagates

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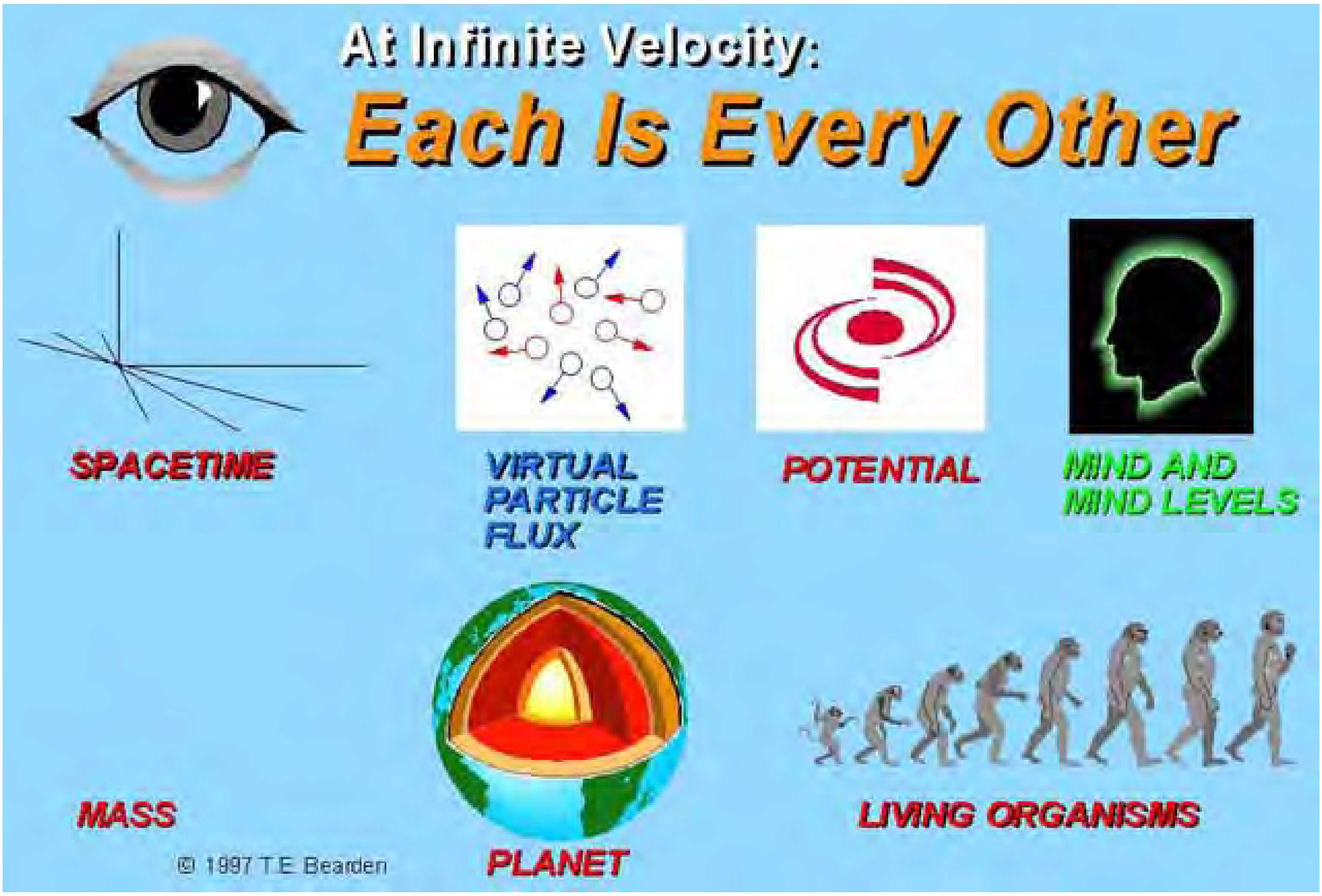

At Infinite Velocity:

Each Is Every Other

SPACETIME

VIRTUAL PARTICLE FLUX

POTENTIAL

MIND AND MIND LEVELS

MASS

PLANET

LIVING ORGANISMS

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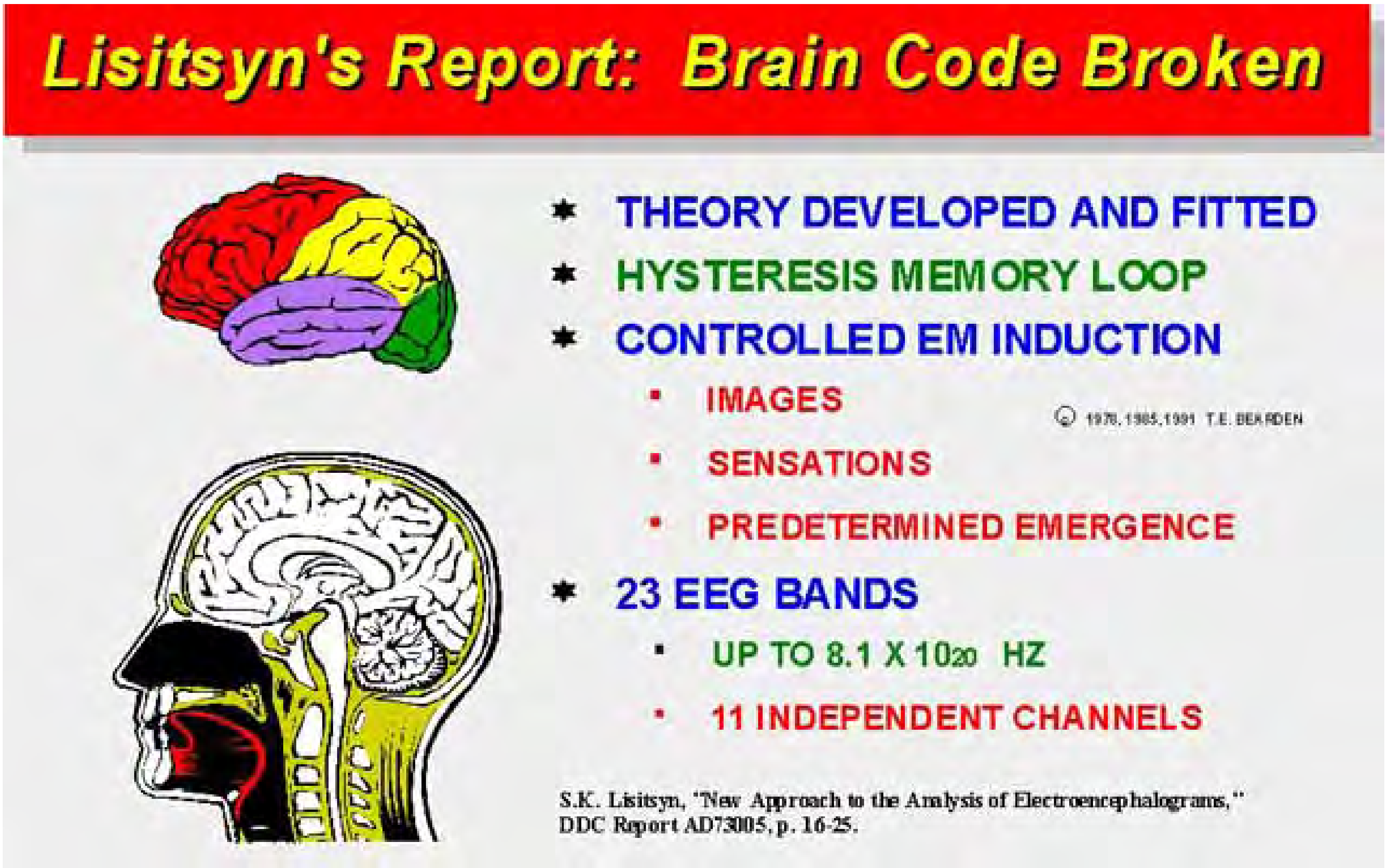

Lisitsyn's Report: Brain Code Broken

- THEORY DEVELOPED AND FITTED
- HYSTERESIS MEMORY LOOP
- CONTROLLED EM INDUCTION
  - IMAGES
  - SENSATIONS
  - PREDETERMINED EMERGENCE
- 23 EEG BANDS
  - UP TO 8.1 X 10^{20} HZ
  - 11 INDEPENDENT CHANNELS

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S.K. Lisitsyn, "New Approach to the Analysis of Electroencephalograms," DDC Report AD73005, p. 16-25.

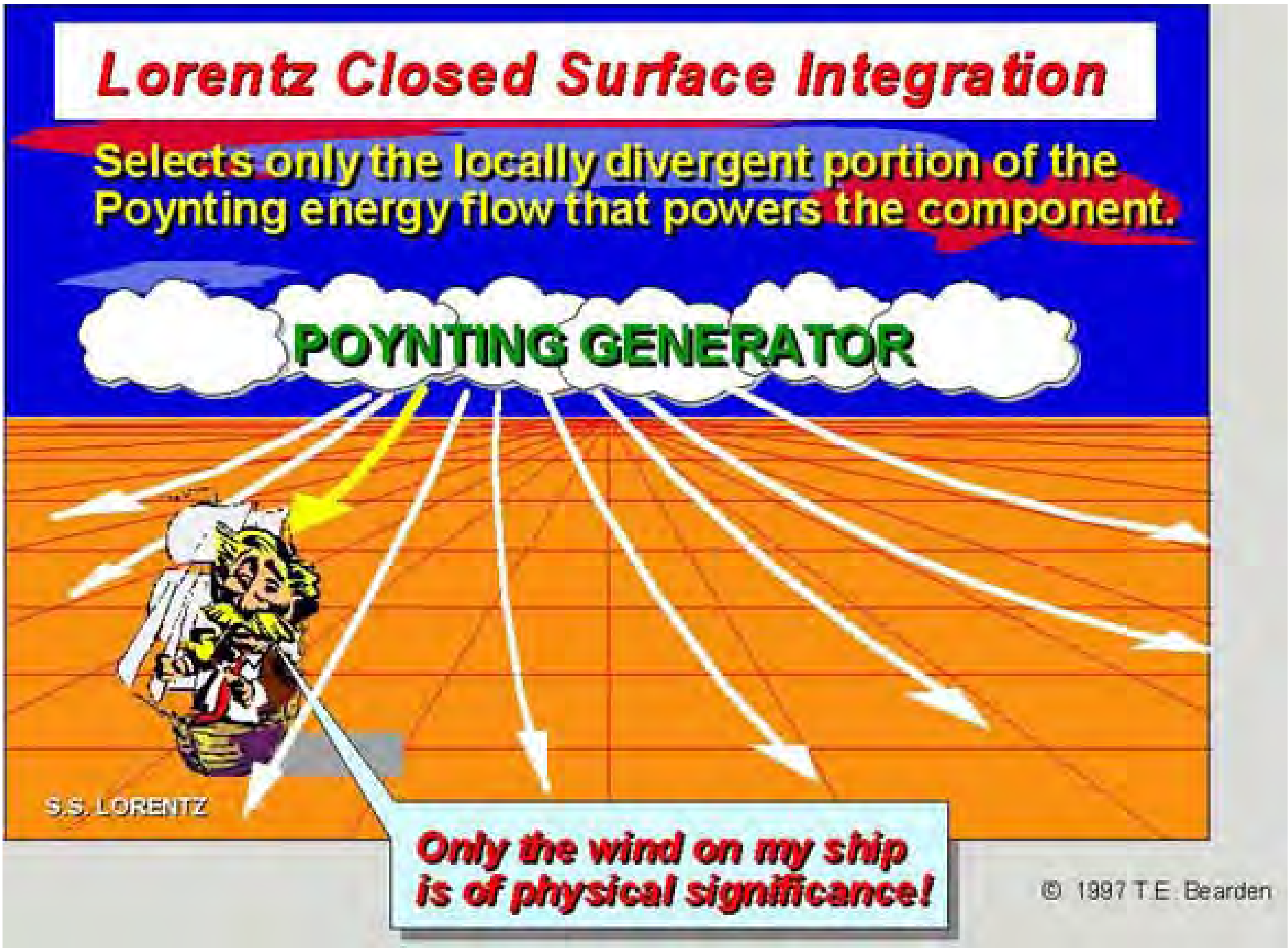

Lorentz Closed Surface Integration

Selects only the locally divergent portion of the Poynting energy flow that powers the component.

Only the wind on my ship is of physical significance!

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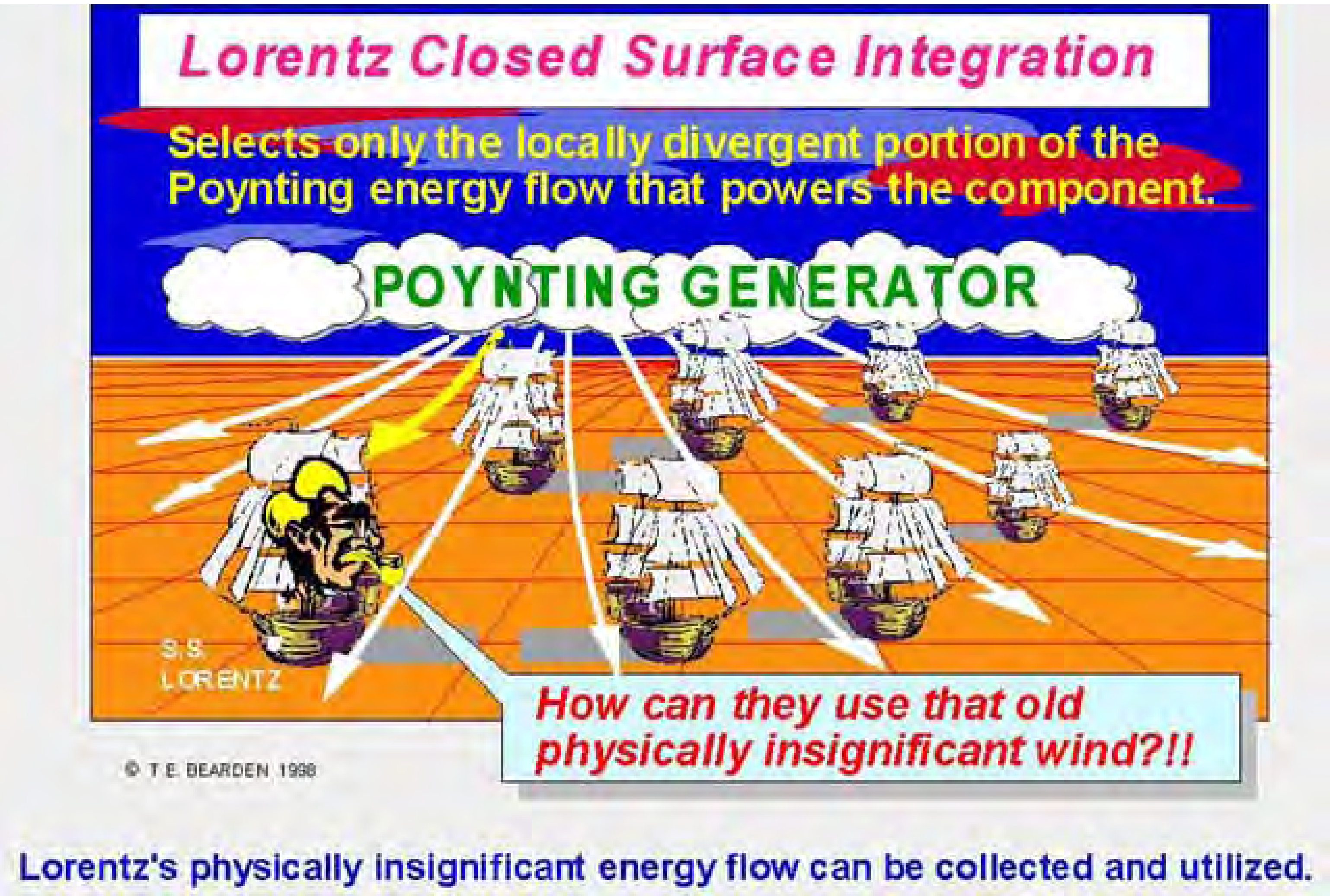

Lorentz Closed Surface Integration

Selects only the locally divergent portion of the Poynting energy flow that powers the component.

How can they use that old physically insignificant wind?!!

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Lorentz's physically insignificant energy flow can be collected and utilized.

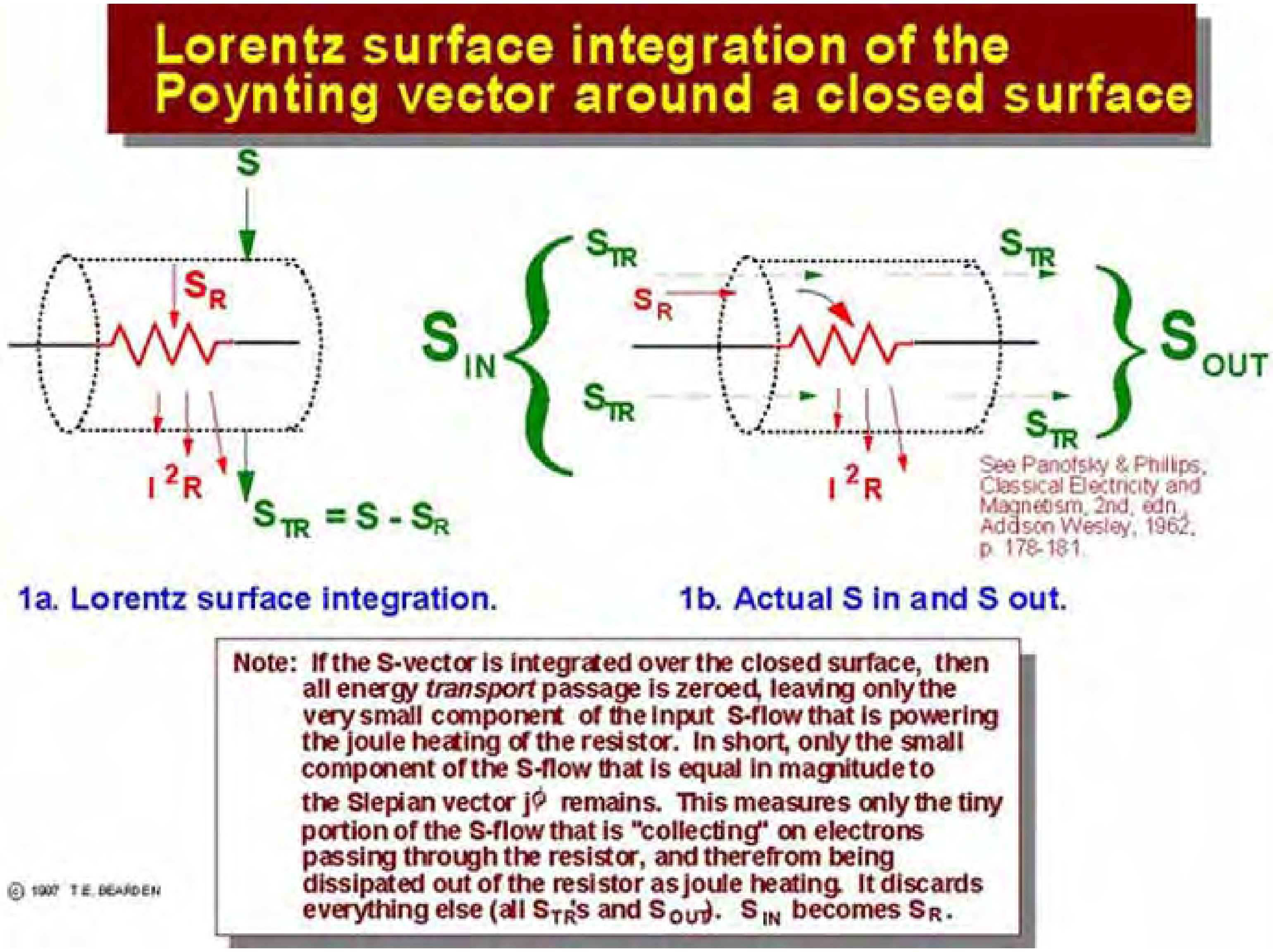

Lorentz surface integration of the Poynting vector around a closed surface

See Panofsky & Phillips, Classical Electricity and Magnetism, 2nd, edn., Addison Wesley, 1962, p. 178-181.

1a. Lorentz surface integration.

1b. Actual S in and S out.

Note: If the S-vector is integrated over the closed surface, then all energy *transport* passage is zeroed, leaving only the very small component of the input S-flow that is powering the joule heating of the resistor. In short, only the small component of the S-flow that is equal in magnitude to the Slepian vector $j\phi$ remains. This measures only the tiny portion of the S-flow that is "collecting" on electrons passing through the resistor, and therefrom being dissipated out of the resistor as joule heating. It discards everything else (all S_{TR}'s and S_{OUT}). S_{IN} becomes S_R.

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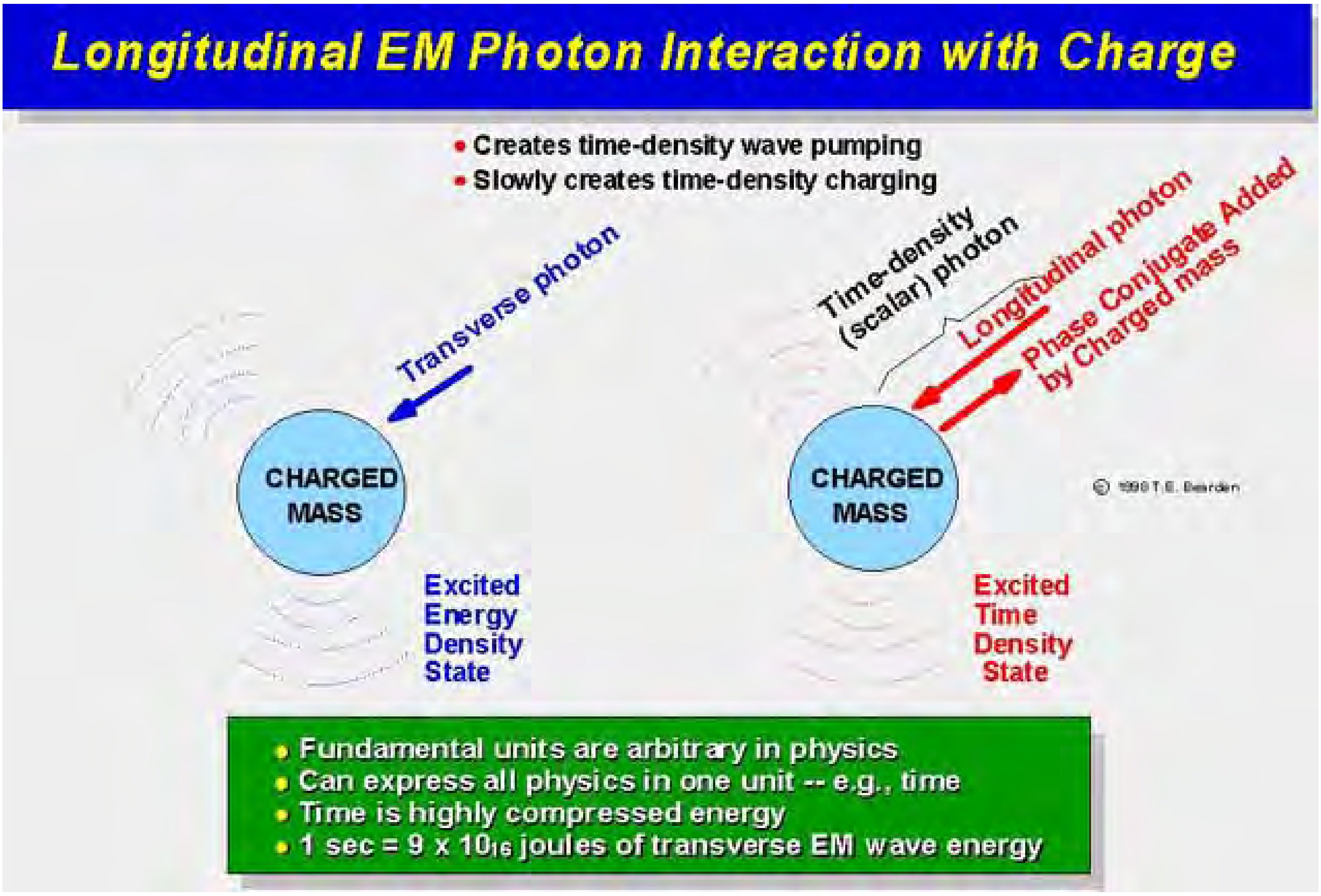

Longitudinal EM Photon Interaction with Charge

- Creates time-density wave pumping
- Slowly creates time-density charging

Transverse photon

CHARGED MASS

Excited Energy Density State

Time-density (scalar) photon

Longitudinal photon

Phase Conjugate Added by Charged mass

CHARGED MASS

Excited Time Density State

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- Fundamental units are arbitrary in physics
- Can express all physics in one unit -- e.g., time
- Time is highly compressed energy
- 1 sec = 9 x 10_{16} joules of transverse EM wave energy

Figure 1-8. Infolded biwave composition of a scalar potential.

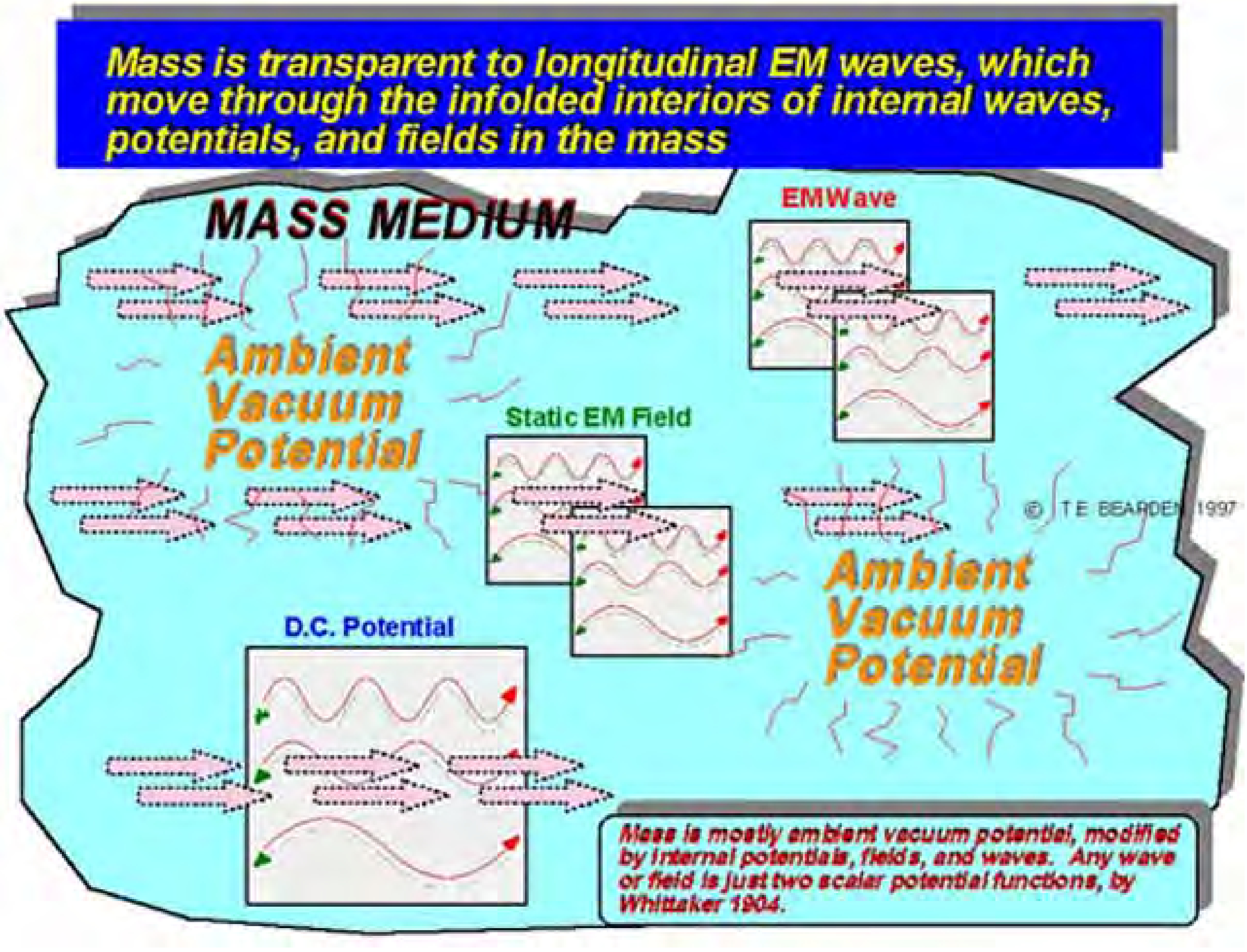

Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass

Mass is mostly ambient vacuum potential, modified by internal potentials, fields, and waves. Any wave or field is just two scalar potential functions, by Whittaker 1904.

MASS MEDIUM
Ambient Vacuum Potential
EMWave
Static EM Field
© T.E. BEARDEN 1997
Ambient Vacuum Potential
D.C. Potential

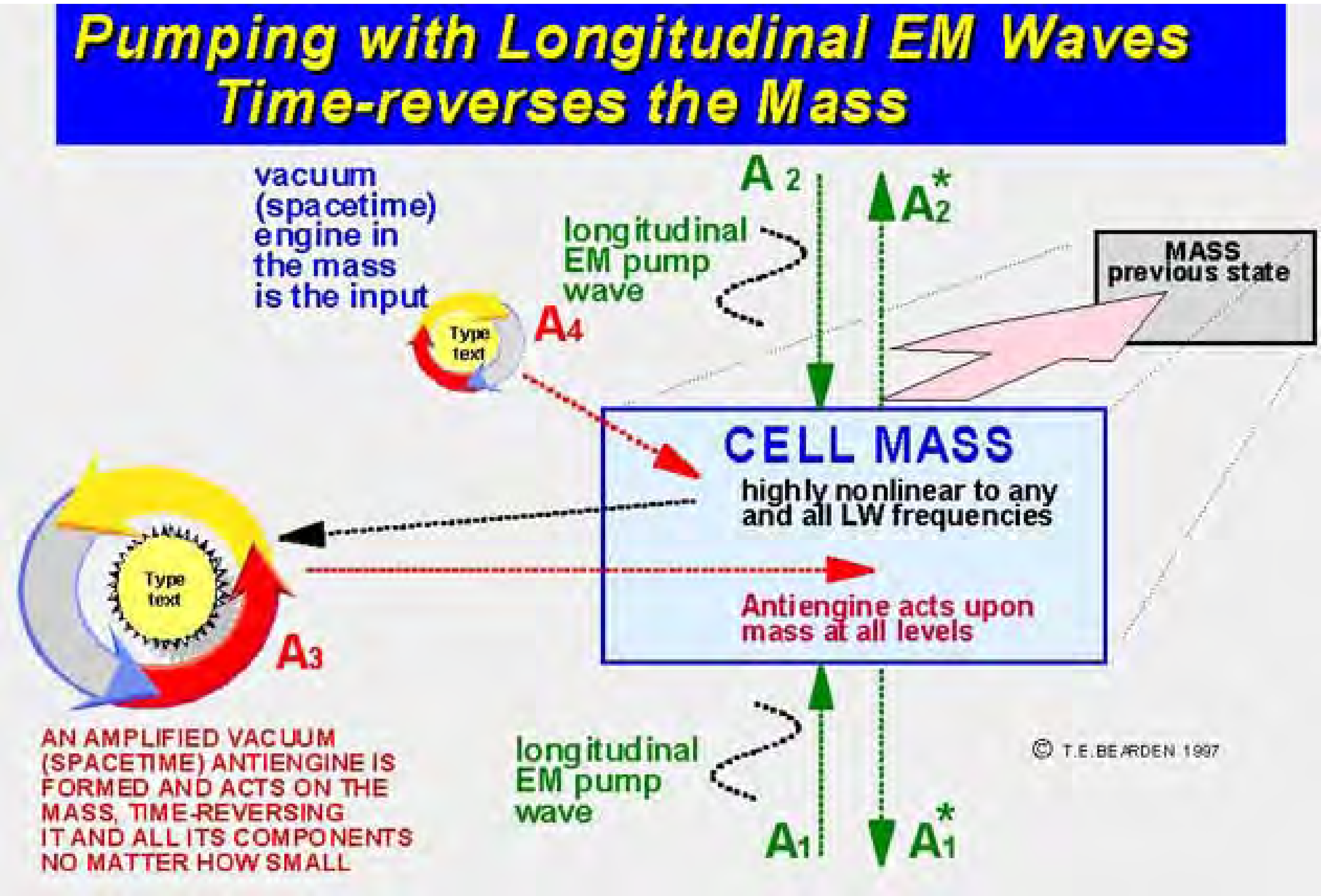

Pumping with Longitudinal EM Waves Time-reverses the Mass

vacuum (spacetime) engine in the mass is the input

longitudinal EM pump wave

MASS previous state

CELL MASS

highly nonlinear to any and all LW frequencies

Antiengine acts upon mass at all levels

AN AMPLIFIED VACUUM (SPACETIME) ANTIENGINE IS FORMED AND ACTS ON THE MASS, TIME-REVERSING IT AND ALL ITS COMPONENTS NO MATTER HOW SMALL

longitudinal EM pump wave

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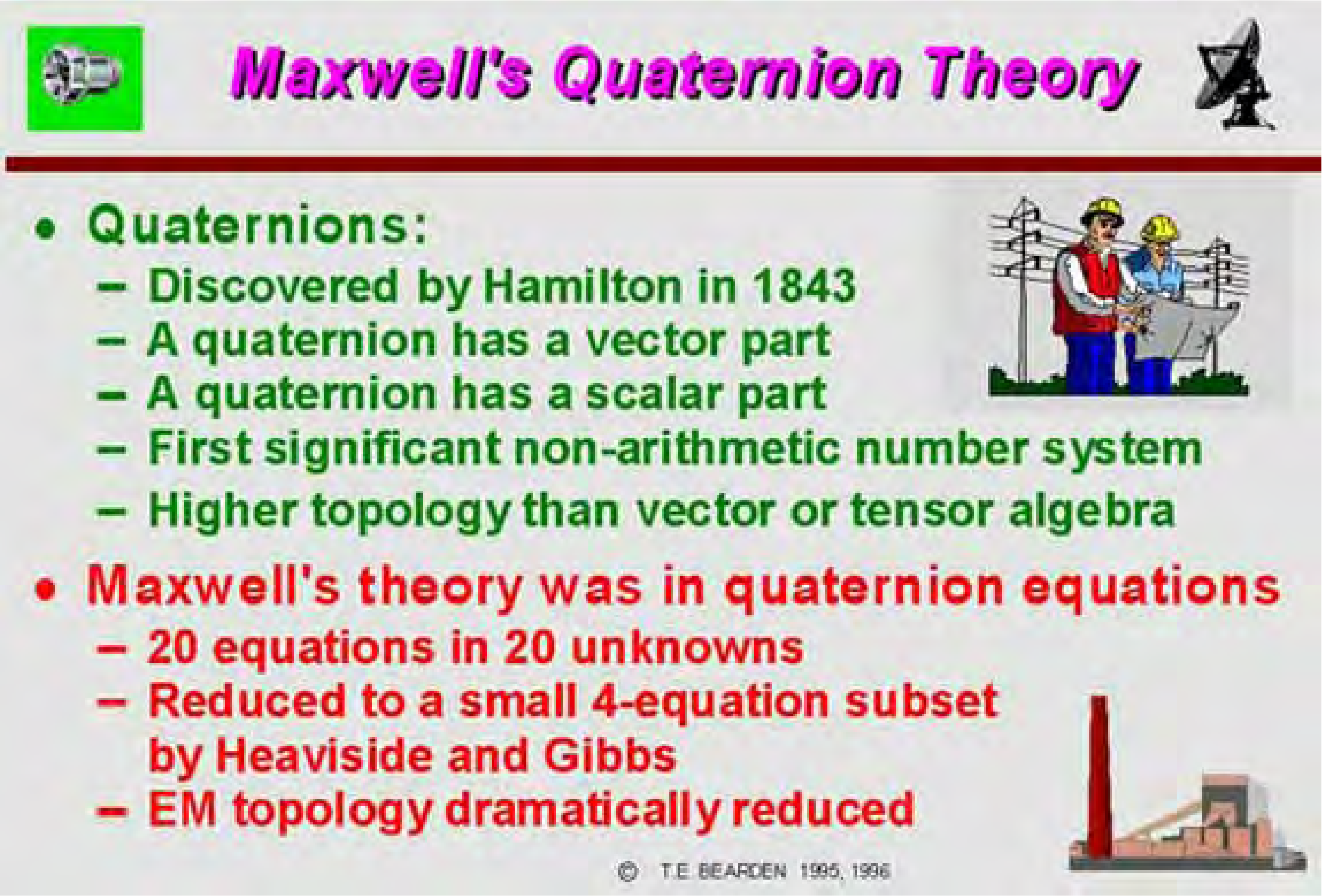

Maxwell's Quaternion Theory

- Quaternions:
  - Discovered by Hamilton in 1843
  - A quaternion has a vector part
  - A quaternion has a scalar part
  - First significant non-arithmetic number system
  - Higher topology than vector or tensor algebra
- Maxwell's theory was in quaternion equations
  - 20 equations in 20 unknowns
  - Reduced to a small 4-equation subset by Heaviside and Gibbs
  - EM topology dramatically reduced

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Maxwellian Systems
Before regauging, after symmetrical regauging, and after asymmetrical regauging

Note: Any system must first break equilibrium in its vacuum exchange, before it can energize Drude electrons and "power" the load. Asymmetric regauging is always utilized. Powering loads and losses is a symmetry-restoring operation.

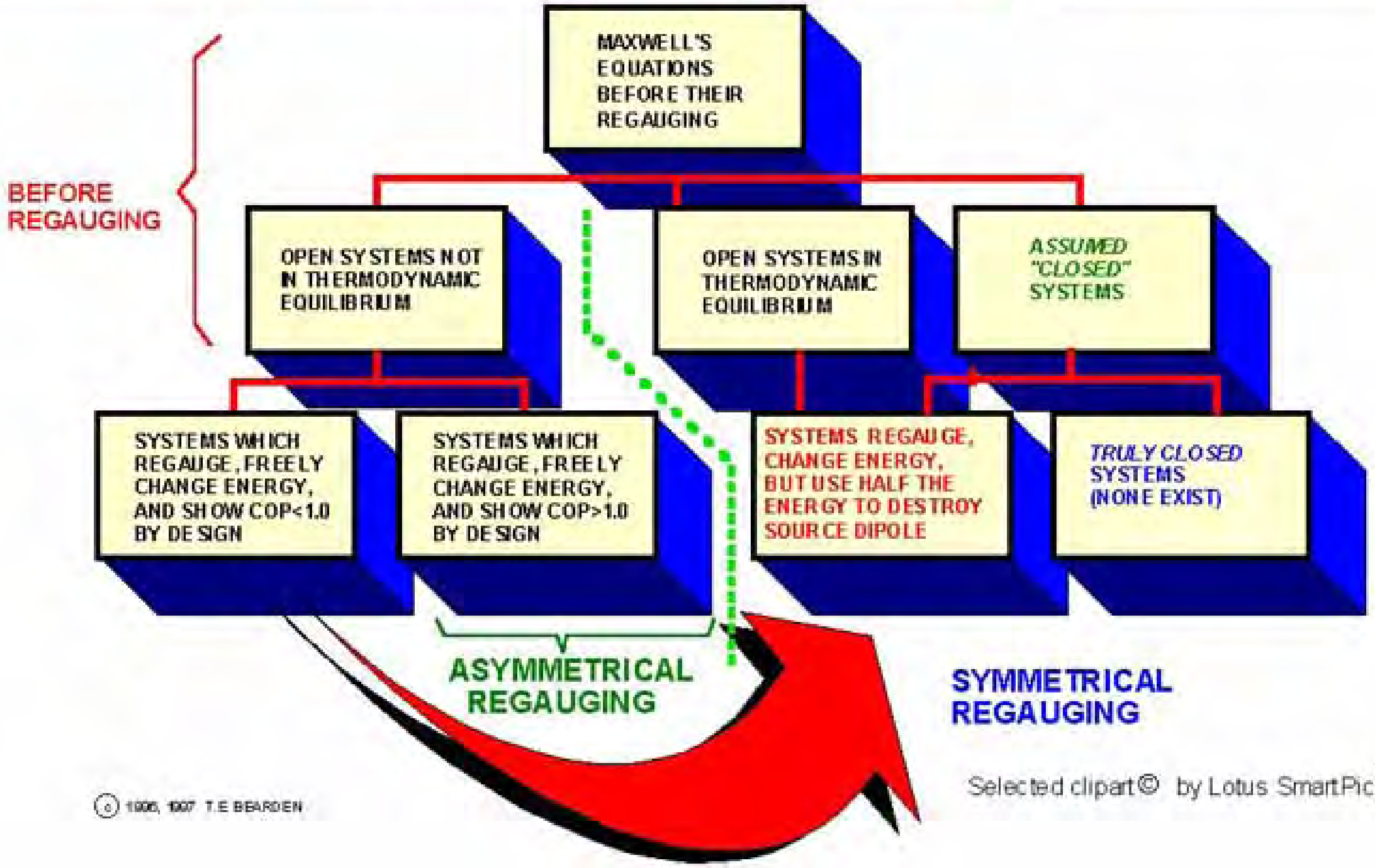

BEFORE REGAUGING

MAXWELL'S EQUATIONS BEFORE THEIR REGAUGING

OPEN SYSTEMS NOT IN THERMODYNAMIC EQUILIBRIUM

OPEN SYSTEMS IN THERMODYNAMIC EQUILIBRIUM

ASSUMED "CLOSED" SYSTEMS

SYSTEMS WHICH REGAUGE, FREELY CHANGE ENERGY, AND SHOW COP<1.0 BY DESIGN

SYSTEMS WHICH REGAUGE, FREELY CHANGE ENERGY, AND SHOW COP>1.0 BY DESIGN

SYSTEMS REGAUGE, CHANGE ENERGY, BUT USE HALF THE ENERGY TO DESTROY SOURCE DIPOLE

TRULY CLOSED SYSTEMS (NONE EXIST)

ASYMMETRICAL REGAUGING

SYMMETRICAL REGAUGING

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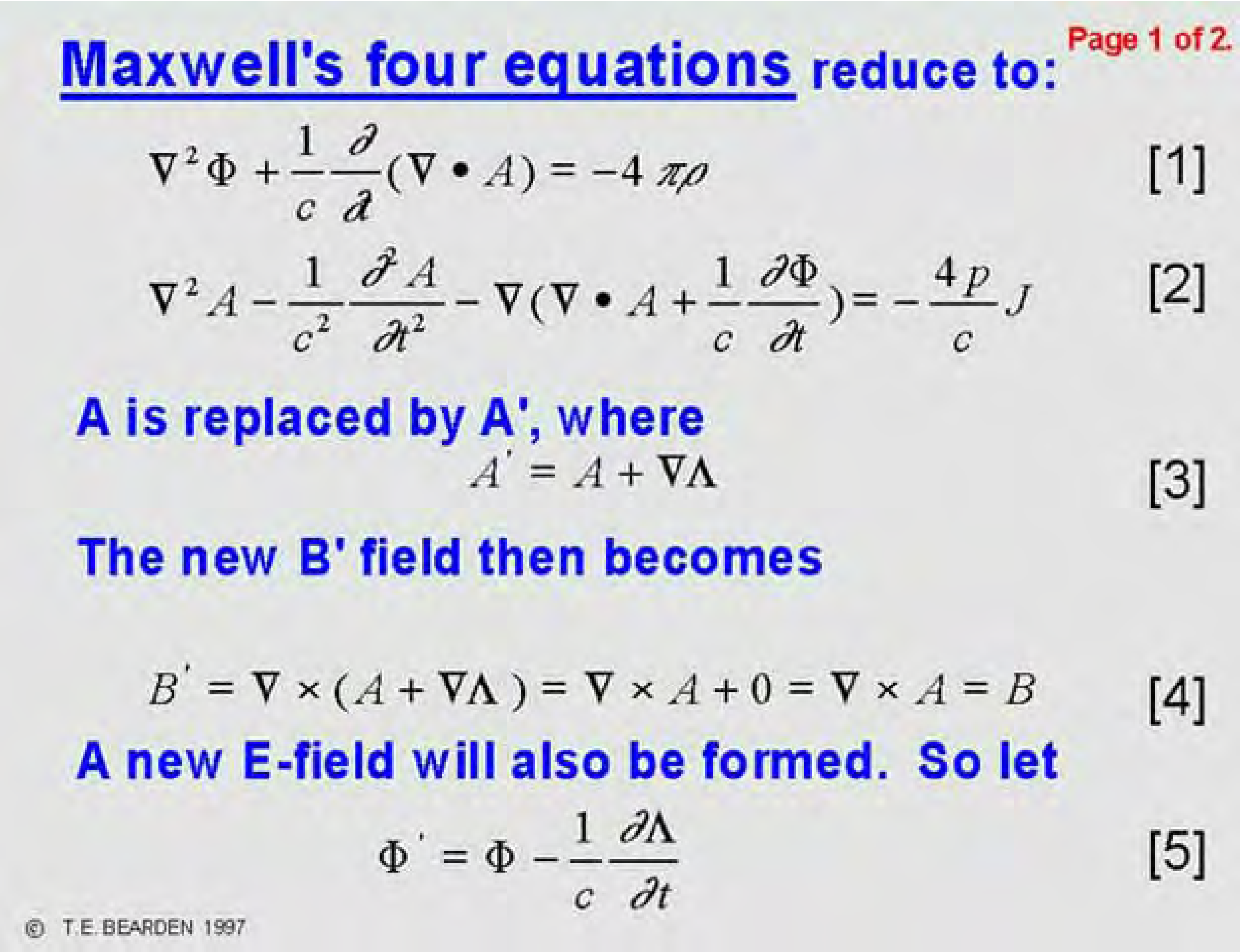

Page 1 of 2.

Maxwell's four equations reduce to:

$$\nabla^2 \Phi + \frac{1}{c}\frac{\partial}{\partial t}(\nabla \bullet A) = -4\pi\rho \qquad [1]$$

$$\nabla^2 A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} - \nabla(\nabla \bullet A + \frac{1}{c}\frac{\partial \Phi}{\partial t}) = -\frac{4p}{c}J \qquad [2]$$

A is replaced by A', where

$$A' = A + \nabla\Lambda \qquad [3]$$

The new B' field then becomes

$$B' = \nabla \times (A + \nabla\Lambda) = \nabla \times A + 0 = \nabla \times A = B \qquad [4]$$

A new E-field will also be formed. So let

$$\Phi' = \Phi - \frac{1}{c}\frac{\partial \Lambda}{\partial t} \qquad [5]$$

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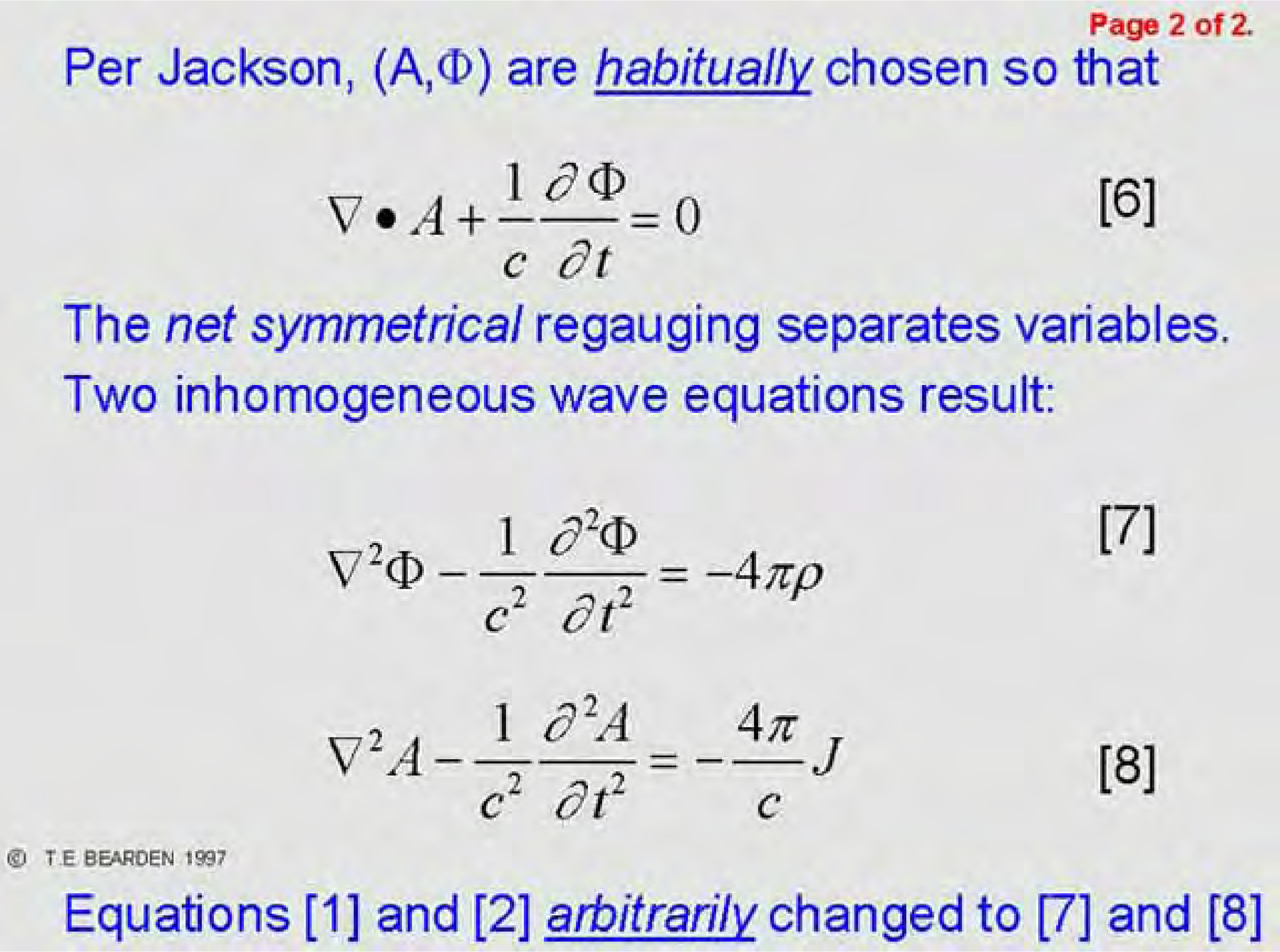

Per Jackson, (A,Φ) are *habitually* chosen so that

$$\nabla \bullet A + \frac{1}{c}\frac{\partial \Phi}{\partial t} = 0 \qquad [6]$$

The *net symmetrical* regauging separates variables.

Two inhomogeneous wave equations result:

$$\nabla^2 \Phi - \frac{1}{c^2}\frac{\partial^2 \Phi}{\partial t^2} = -4\pi\rho \qquad [7]$$

$$\nabla^2 A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} = -\frac{4\pi}{c} J \qquad [8]$$

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Equations [1] and [2] *arbitrarily* changed to [7] and [8]

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CHASING THE WILD DRAGON

Foundations of a New Science

By T.E. Bearden
November 12, 1995

It is a pleasure to accept the offer of John and Larry to write a column in their new InterNet magazine. Theirs is a great venture, and with the energy and knowledge they bring to the task, one can be confident of their success in making this a very interesting and informative publication.

There is a new “rebel” science slowly being born, with most of the work being done outside the universities and orthodox scientific community. In the months ahead it will be my job to try to acquaint you with the gist of what’s going on, and what all the excitement is about.

This first article is deliberately just introductory, and its purpose is to interest you in the unusual fields we are going to be covering in more scientific detail, in future columns. We will also be listing a variety of references from the technical literature, which bear upon the various points addressed.

In this first article a little of my own background experience [note 1] is given, so you can decide whether you will be interested in what we have to say!

The real purpose of the column will just be to *present information* that you may not be able to readily obtain any other way. We will not argue or debate with skeptics; nothing productive is to be gained by that. If the information we present is useful to you, then our purpose has been accomplished. If it isn’t of use to you, then just file it in the old wastebasket. Also, from time to time I may answer a generic question, constructed from multiple queries. Individual responses to correspondence cannot be provided.

The work toward a new breakthrough science is going on in a broad spectrum of “fields,” most of which are not yet recognized by academia as even constituting legitimate areas of scientific endeavor (Table 1).
Some of the major areas involved are:

- theoretical and experimental research in overunity electrical machines,
- free energy research of other kinds, such as devices utilizing thermodynamics phase changes,
- rapidly advancing efforts in cold fusion,

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- direct engineering of quantum change via a new kind of "hidden" electrodynamic variables,
- the direct engineering of the vacuum's virtual photon flux exchange with matter,
- action at a distance, including the deliberate formation and usage of quantum potentials,
- direct engineering of the local curvature of spacetime (yes, the direct engineering of general relativity, using the new hidden kind of electrodynamics),
- use of the new "hidden" electromagnetics to engineer body cells including the reversal of diseased cells, genetics and all, back to a previous healthy state (cellular dedifferentiation, in biophysical terms, or cellular phase conjugation, in physics terminology),
- research toward the direct engineering of the mind, including both the conscious and unconscious minds, long-term memory, and the personality itself, and
- a ruthless re-examination (and correction where necessary and possible) of the definitions, concepts, and postulates that present physics is founded upon.

Each of these "major areas" as yet has no single "experts" in the sense that individuals exist who possess a "mastery" of the given area. As an example, in spite of multiple researchers and decades of vigorous research, no one is really an "overall expert" in the overunity electrical power systems field. The "field" itself is still struggling to be born and is not recognized at all by orthodoxy; in fact, many orthodox scientists bitterly resent one even attempting to work in this area. There is as yet no cohesive single "theory" of overunity electrical or magnetic machines, although our own group is making rapid progress in that respect. But there is still no universal agreement amongst even the researchers themselves. Literally the field is still being discovered.

This "groping dimly toward a new field" should not be too surprising. After all, the early electromagnetics researchers went through the same tortuous, agonizing kind of development. They were playing with cat fur, glass rods, and pith balls for quite an extended period before understanding progressed to the point where Maxwell could mathematically tie together and model the results of the experimenters such as Faraday and others. It has taken a century and a half for modern electromagnetics and electronics to reach its own present development. It is going to take another decade or so before the overunity researchers can overturn several ill-founded parts of the present electromagnetics and get the emerging field onto a solid foundations footing and into a solid theoretical position.

In the effort to produce a theoretical model of electromagnetics, Maxwell and his predecessors performed a magnificent work. Yet they also made very serious errors (Table 2), which persist to this day. [note 2] Let us list just a few of the more blatant errors in classical EM theory today:

First, Franklin guessed wrong on which way electrical current flowed in a circuit. There is no definition at all of electrical charge in all of physics, and there is no acceptable definition of potential (that is, there is no rigorous definition of just good old "voltage.") There are no "fields of force" in the vacuum; there are just potential gradients __ because the vacuum is just one vast potential (virtual particle flux) in the first place. Force fields actually occur only in and of the matter in a material system. The primary causative agents of electromagnetics are not the so-called "force fields' at all, but are the potentials __ as is well-known in quantum mechanics. [note 3] Maxwell assumed a material ether in his equations. The Michelson-Morley experiment destroyed the material ether, but the Maxwell equations have never been changed accordingly. The electron was not yet discovered when the Maxwell equations were written; the theory does not address electron spin. Maxwell was already dead some two decades when Barus' 1898 paper [note 4] was published, pointing out the strange "backwards-traveling" wave (i.e., time-reversed wave) solution to the wave equation. In addition, Heaviside and Gibbs had already produced their vector truncation __ this truncated theory is the modern so-called "Maxwell's equations" that universities teach today __ of Maxwell's theory.

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in a higher topology (quaternion algebra), and involves some 20 quaternion equations. Heaviside and Gibbs created vector algebra, and seriously curtailed Maxwell's theory when they "translated" it into the much lower topology of vectors and some four equations. The later addition of tensors as the basis mathematics did not restore the lost topology provided by the quaternion model. [note 6]

For the EM wave, Maxwell simply assumed the transverse EM wave that had come from the much earlier derivation of the familiar wave equation from the old "plucked taut string" notions. [note 7] Yet when one closely examines and corrects some of the erroneous *assumptions* [note 8] made for the actual mathematical derivation of this "taut string" transverse wave, one finds (Figure 1) that an equal-energy second antiphased transverse "antiwave" is actually produced by the instrument and added to the "plucked string's" transverse wave disturbance of the air medium, to produce a longitudinal wave of compression and rarefaction in the air itself. The "transverse string wave" in fact never leaves the string. The string wave is not the wave that is launched into the medium.

A similar electromagnetic situation exists. In a whip antenna (Figure 2), the Drude electron gas in the conductor does exhibit a transverse "string-type" EM wave of electron precession. However, at the same time, by Newton's third law (which Maxwell neglected because at the time the atom was regarded as just a blob with no internal structure) the positively charged, phase conjugated atomic nuclei have equal energy, highly damped transverse recoil waves created in them. Further, these "nuclei-recoil" waves are phase conjugate replicas of the electron gas waves. The total disturbance that is launched into the vacuum from the whip antenna is (a) the normal transverse disturbance of the virtual photon flux of vacuum caused by the electron gas wave, and (b) the coupled equal-energy transverse antiwave caused by the nuclei-recoil via Newton's third law. The amplitude of the material antiwaves of nuclei vibration are highly damped because of the massiveness of the nuclei; however, they are of equal energy to the electron wave. But when launched into the same vacuum, the two equal-energy wave disturbances experience equal damping because they are in the same medium. Hence the wave and antiwave are (a) locked together in the vacuum, and (b) of equal energy, and (3) of equal amplitude once launched into the vacuum. What results is a vacuum EM wave of rarefaction (reduction in intensity) and compression (increase in intensity) of the virtual photon flux of vacuum __ just exactly like what is launched into the surrounding gaseous air medium from the "plucked taut string" and perturbed body of a physical instrument. The EM wave in vacuum is a longitudinal wave directly analogous to a sound wave __ just as Nikola Tesla stated. [note 9]

The vacuum may be considered a scalar potential, in which case it has an internal biwave structure (Figure 3). Interference of two potentials __ i.e., the hidden interference (Figure 4) of their internal wave structures __ in fact already creates all EM fields and waves.

When the incoming longitudinal "biwave" from the vacuum strikes the atoms of the receiving antenna, each atom may be considered a dynamic assembly of multiple dipoles, where each dipole consists of one of the electrons in the electron shells and one of the positive charges in the nucleus. The receiving dipole in the interacting atom splits the two waves apart again (Figure 5). The negatively charged end of the dipole is time-forward, and the positively charged end is time-reversed. Hence the separated normal-wave-half of the biwave interacts with the electron, to give again the familiar transverse "electron precession" wave that we detect with our "electron wiggle-detecting" instruments (Figure 6). This detected electron precession wave is what all our textbooks prescribe erroneously as the vacuum wave! The separated time-reversed-wave-half of the incoming vacuum wave is split off and interacts with the positive end of the receiving atomic dipole, in the time-reversed atomic nucleus, thus generating Newton's third law reaction force to provide the recoil of the nucleus. Present physics has ignored this second wave altogether, because of the serious error in the original derivation of the wave equation from plucked strings. Thus

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would appear to violate Newtonian third law reaction. Phase conjugate mirrors already do just exactly this when they emit a phase conjugate replica wave. They direct the antiwave outside and away from the atom instead of inwards into the nucleus. So they do not recoil, no matter how powerful a phase conjugate replica wave they emit.

Finally, we can also show that the EM wave in vacuum is longitudinal, by yet another approach. The electrons in the electron gas in a conductor are spinning, and they are severely constrained longitudinally to be able to move only very, very slowly down the wire. So when perturbed, they act as gyroscopes, and precess at right angles to the perturbing force. The fact that the gyroelectrons in a wire move radially almost entirely, and only “slip” down the wire very slowly with a “drift” velocity, already proves conclusively that the incoming vacuum disturbance was longitudinal. The precession of a gyro is at right angles to the perturbing force. Therefore rigorously the vacuum EM waves are longitudinal, because the gyroelectrons moved transversely. The present assumption of the transverse EM wave in vacuum contradicts the entire theory of gyroscopes! [note 10] There are many other errors in classical EM that we will point out in future articles; this should give the reader a flavor of what is in store for him in future articles.

So there are no truly satisfactory “experts” in any of the 14 fields. Yet there is still something to be said for having some years of experience in one or more of the areas. I have had the good fortune or misfortune, depending upon one’s viewpoint, to be involved in various of those 14 activities for some 30 years or more, and am active in several of the areas now. My colleagues and I are particularly active in researching overunity electrical devices (see Figure 8), to include the effects of controlled chaotic oscillators, charge-blocking oscillators, and oscillators driven by in-shuttled (bridged) Poynting field energy density flow ExH. Parametric oscillation is known to have yielded overunity electrical machines and was fully reported by Russian researchers in the Russian and French technical journals in the mid 1930s. [note 11] We will further cite that little-known work in future articles. Also, we are working mightily upon true negative resistors (Figure 9), wherein the resistor scavenges some of the disorganized energy from the vacuum’s energetic exchange with the charges in the system, organizes and collects it, and then outputs that collected energy flow into the external circuit. Such a resistor acts as a power source. Kron, perhaps the greatest of the electrical machinery scientists, is known to have produced such true negative resistors.

I have also proposed a theoretical explanation of the Priore device (Figure 10) in France which in laboratory animals demonstrated remarkable cures of terminal tumors, cured trypanosomias, reversed atheriosclerosis, and restored suppressed immune systems. The Priore work was not anecdotal, but was performed under rigorous scientific protocols, working under the auspices of renowned French scientists such as Courrier and Pautrizel. The work is properly reported in numerous papers in the French medical literature. [note 12] The results were certainly achieved, but neither Priore himself nor the scientists of the day could understand the mechanism involved. The deciphering of that causative technical mechanism utilized by the Priore group required 10 years of intense effort. The results have now been published in the journal Explore! and are there for anyone to read. [note 13]
Presently my CTEC colleagues and I have filed three patent applications and a continuation, on various methods for overunity processes and apparatuses, room temperature superconductivity, Poynting generators, etc.

As an example, we took exactly the opposite approach to room temperature superconductivity as has been taken by all the orthodox researchers to date. What exactly is sought, after all, for superconductivity (SC) in a section of an electrical circuit? Well, one has some electrons on one side of that SC section that are transporting excess potential, as given by the Slepian vector J*. [note 14] What is desired is to get some electrons on the other side of the SC section that also are transporting the same amount of excess energy in the form of J*. You can do that in two ways: (1) you can flow the electron carriers through the SC section, carrying their J*, or (2) you can block the J and flow the * itself across as the Poynting flow S. [note 15] Nondivergent Poynting flow flows along an equipotential, which is

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fanblades to a crawl) and massive correlation of the electrons and of the electron-to-lattice interactions is necessary if one is to get the electrons through there without excess collisions that shake off some of the excess * from J*, as scattered photons (heat) or as a change of form of the energy (as in straining the dielectric of a capacitor to convert electrical energy to mechanical strain energy via the piezoelectric effect.)

Our approach is exactly the opposite (Figure 11) and Figure 12). Why not just *stop* the flow of excited electron carriers on one side of the SC section, and continue the nondiverging flow of the Poynting field energy density S across that section at room temperature? Then the cryogenics is not needed at all. After all, circuits already work that way anyhow __ except standard practice is to nullify the process by letting current be driven around the sourcing current loop and back through the back EMF of the primary source. A quantum well (or several other methods) can be used to trap the "sourcing" electrons in the conductor just prior to entering the SC section. The "receiving" electrons on the other side of the SC section, however, must be in their own dq/dt-isolated current loop.

Normal sources do not furnish electrons and current to a circuit anyway. Sources just furnish Poynting flow S and EMF. [note 16] In the receiving current loop, the EMF appears automatically once the S-flow flows in and is "locked on to" by the receiving electrons. Given q**, you will immediately have J* if the electrons are free to move in the conducting circuit (see Figure 13). Further, you have eliminated all the loss terms from the standard Poynting equation for energy losses. So all the energy flow S just flows across the SC section, without any current or Cooper pairs flowing through that SC section. The SC section has become a "bridge" which (1) strips off the Poynting field energy density flow S from the electron current dq/dt on the sourcing side of the SC/bridge section, by simply reducing the dq/dt to zero; and (2) continues to pass the S-flow across the dq/dt-blocked SC/bridge section to the other side (Figure 14). The excess S-flow (and EMF) pours into the receiving dq/dt-isolated current loop, exciting the electrons therein to produce dq/dt and J*. *Any closed current loop is self-powered, once it receives S and EMF. It furnishes its own electrons; it only requires excess energy and EMF.* [note 17]

So our approach gives room temperature superconductivity in a very straightforward manner, once you discover how to block the current dq/dt in a conductor. Blocking it in an insulator is not sufficient, because that drops the potential and stops the S-flow and the equipotential * (the EMF). However, a degenerate semiconductor such as the Fogal chip can be used, as can several other processes for blocking dq/dt in a conductor. We will discuss these in a future article.

Another advantage of this approach to room temperature superconductivity is that now one can also have permissible overunity coefficient of performance. Now the load can be placed in its own S-receiving, isolated current loop. With the sourcing current loop furnishing only S and not dq/dt, the load is still powered normally in its own closed dq/dt current loop, but none of the load current is passed back through the back EMF of the primary source in the sourcing circuit.

This principle — that at least a substantial portion of the load current must not pass back through the primary source — is the primary principle required for a permissible overunity electrical machine (Figure 15). A permissible overunity electrical machine is one which produces more power in the load than you have to put into the machine to run it.

Obviously, the laws of physics and thermodynamics require such an overunity machine to be an open system that extracts and utilizes excess energy from an external source. In the case outlined, we extract the excess energy directly from the vacuum in the form of S-flow; essentially we convert our primary source to a Poynting generator rather than a "power" (energy flow loss rate) generator. The resulting9. overunity machine accomplishes both room temperature superconductivity and also overunity coefficient of performance (Figure 16). It does not violate the

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a dipolar source, as in the simple two-wire circuit, all we are doing with the conductors is providing waveguides for the extracted S-flows from the vacuum to flow along (it flows outside the conductors) without loss. In effect, each lead is simply extending the pole (i.e., the terminal) to which it is connected.

My associates and I are also working on several other inventions at present, including two more patent applications to be filed in the near future. One of those is in the field of overunity power systems, while the other is in an entirely different, highly proprietary nuclear effort. I will address all these areas in future columns, and those columns will have real “meat” in them.

Present “big science” proclaims that overunity electrical machines are impossible. The reader should understand that the U.S. Patent and Trademarks Office is never going to grant a patent for an overunity electrical machine unless the machine is independently tested and replicated, and unless it is certified by scientists of impeccable credentials. This is as it should be. Legitimate free energy researchers accept that dictum. Eventually the stuff has to work on the bench in order to be validated. On the other hand, free energy researchers also point out that one must not demand of us the next 100 years of national research by a hundred major laboratories immediately! This is still a shoestring operation, because all conventional sources of research funds are denied to the serious overunity researcher (with the single exception of occasional personal funding of a researcher by a private individual). In other words, we demand at least the same kind of consideration that the orthodox nuclear fusion community has enjoyed. Billions of dollars have been poured into that sinkhole, and not a single controlled fusion power unit is working anywhere in the world after decades of work at enormous expense to the taxpayers.

So we overunity researchers deserve at least a decade or two of our own, to try to accomplish overunity electrical system development. We also painfully point out that “Big Science” will not fund a single overunity researcher, for specific overunity purpose, no matter what his credentials or capability. In fact, “Big Science” is part of the problem, because it fervently seeks to prevent any legitimate research in overunity. To carry out its suppression campaign. it resorts to vilification, character assassination, libel, and slander of the overunity researchers themselves __ again, regardless of their qualifications or legitimate scientific procedures. [note 21]

Indeed, orthodoxy has a black record with respect to energy. When Mayer advanced the conservation of energy law, orthodoxy hounded him unmercifully. He was universally ridiculed as the very epitome of a fool. He lost his job and suffered a nervous breakdown. Then years later toward the end of his life, scientists came to accept the conservation of energy as a most useful tool that dramatically simplified much of their analyses. So then science began to laud Mayer. There are a thousand other such examples; suffice it to say that “big science” is a bureaucracy and a “bell-shaped distribution curve” just like any other large group of people. Some scientists are near-angels. Others are near-devils. The vast majority are neither, but are just ordinary persons doing a special kind of job. In the scientific bureaucracy, however, the manipulative scientists scurry, slash, and manipulate their way toward the top. So the leadership of any big bureaucracy __ including the scientific bureaucracy __ is always rife with such near-scalawags and power-hungry individuals. Scientists are not exceptions to the same human weaknesses that we all evidence. If you really want to see jealousy, backbiting, and fierce “back-room dealing” and power-struggling, just get into a university research environment! But because the “power merchants” of any bureaucracy always fiercely resist any challenge to their position or superiority, big science has always fiercely resisted anything truly revolutionary. And today they also enlist the power of the state to enforce their dictums. We will devote one of our future columns to pointing out some glaring examples of persecution of independent researchers by big science. It is an area that all unorthodox researchers should be well-aware of. The world of science does not run by sweet reason and lofty

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to the U.S. Patent and Trademarks Office. Anyone with a modicum of knowledge of modern physics already knows that there does not exist a single closed system in the universe, anywhere. In particular, every physical system is continuously “open” to the violent exchange of energy with the surrounding vacuum. It’s just that most systems are in local equilibrium in these flow exchanges, except for minuscule gating accomplished for such things as the Lamb shift, etc.

By analogy it’s something like this. The free energy researcher is standing by the banks of a mighty, rushing river with breathtaking falls, turbulent areas, etc. Big Science is begrudgingly admitting that, yes, there is a river there, but it is an insane delusion to think that you can tap that energy. The free energy researcher is saying that, well, if I can build a gating sluice a little distance upstream, perhaps I can divert a small portion of the river’s flow downstream to my waterwheel, and power my mill. The orthodox scientist then vilifies the free energy researcher for even having such a heretical thought. In fact, says the orthodox researcher, any fool can see that the laws of nature force the river’s flow to stay firmly in its banks, because it is a closed system, and Moses brought that law down off the mountain with him on a special stone tablet. Then he adds all the other smug remarks such as, “If it could be done, then we at MIT and Harvard and Caltech would already have done it!” So until the orthodox scientist develops a little less dogma and a little more common sense, and learns the difference between a scientific discussion and a dogfight, the free energy researcher can hardly communicate with him.

The goal of the legitimate free energy researcher is to find a way to break the local equilibrium of this universal energy exchange, and gate a tiny bit of it up into the external circuit as excess electrical energy (Figure 17). Then he must collect the excess energy, and shuttle it from the “gating and collecting circuit” over to a dq/dt-closed current loop containing the load. He must also prevent the load current, or most of it, from passing back through the primary source against its back EMF, because if it does that, he will destroy the separation of charges in the dipolar source, killing the dipole and extinguishing the “excess energy gating.” In other words he must find a way to process and transport the energy flow across dq/dt-blocked bridges between the source’s closed dq/dt-current loop and the load’s closed dq/dt-current loop. Ruthlessly it is an energy transport S-flow problem, not a J* energy transport problem. If he uses J* in his sourcing current loop, he automatically drives the current dq/dt back through the back EMF of his source and kills it. If he does not drive dq/dt back through the source, the source will furnish S-flow for an indefinite period! Every battery and generator we have ever built is already a “free energy” machine in that it already involves broken local symmetry in the vacuum energy exchange. We have just not realized how to use our power sources purely as Poynting S-flow sources.

So we must treat an electrical system as an open system with broken local symmetry (Table 3) in the vacuum flux exchange, so that the system extracts (gates) excess energy from an external source. In this case the source is the system’s flux exchange with the vacuum. This approach is no more mysterious or bizarre than putting a waterwheel in a river, or a windmill in a wind, or a bank of solar cells out in the sunshine. The universal “free source of energy” that the overunity researcher seeks to tap is the violent exchange of virtual photons between the electrical charges of the system and the surrounding quantum mechanical vacuum (Figure 18). In quantum physics this powerful, energetic exchange of the vacuum with electrical matter is now proven both experimentally and theoretically. It is already accepted in quantum physics that the vacuum is filled with electromagnetic energy. The researcher doesn’t have to prove it anymore; he just has to find out how to properly use it. The artesian well is already there; we just have to learn how to collect and use the flowing water without dynamiting the well!

The remaining objection orthodox scientists usually raise against the notion of extracting vacuum energy has been

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density of the exchange causing the Lamb shift is greater than the surface energy density of the sun. Different physicists have made various theoretical estimates of the energy density of this seething vacuum. A conservative ballpark figure is something on the order of 1090 grams per cubic centimeter, expressed in mass units.

It has also been my good fortune to know and work closely with several other free energy researchers. I was a colleague of Floyd ("Sparky") Sweet (recently deceased) for about seven years; Sparky held a Master's degree in EE from MIT and had years of experience with General Electric and other firms. He was a highly skilled researcher who invented the solid state vacuum triode amplifier (Figure 19), a unit which produced 500 watts of output and a coefficient of performance of 1,500,000. I personally tested the machine, activated the magnets on one occasion, and understand how it all worked. [note 24] The paper [note 25] I co-authored in 1991 with Floyd is still the only paper in the orthodox engineering literature that reports (a) successful overunity functioning of a solid state magnetic device, and (b) a successful antigravity experiment on the laboratory bench, reducing the weight of an object by 90%. [note 26]

We stress again that a legitimate overunity electrical machine must be an open system, receiving excess electrical energy from the surrounding vacuum. As such, it must operate in a higher topology than normal electrical machines (Figure 20).

My good friend Frank Golden has long been a close colleague. Years ago Frank developed a motor that produced overunity efficiency, but then to our astonishment we found (courtesy of Bill Tiller, [note 27] with whom we were working at the time) that its operation depended upon a 5-year-long conditioning (structuring) of the local ambient potential in order to work. Previously we had been entirely unaware that one can sometimes condition the local vacuum and the local matter in the area with a particular dynamic form. Given the local conditioning, a motor with that form will then work in that vicinity, but not necessarily elsewhere at an appreciable distance away. We now understand the mechanism for such "conditioning of the vacuum." We also now know what to do if an overunity machine is actually a machine of that type (many of them are not). In other words, we know how to convert it to a machine that will work anywhere, anytime. We will be addressing such little-known things in future articles.

John Bedini is also a close friend and colleague; John built several experimental motors (both electrical and magnetic) in the overunity area, and performed successful trans-mutation experiments. John is a recognized genius in high-end sound amplifier development. Many audiophiles worldwide still swear that the Bedini amplifier is the best and sweetest-sounding audio amplifier ever built. One of John's battery-powered electrical motors (Figure 21), for example, ran continuously off its battery for about five years, and kept the battery charged. When you realize that such a small electric motor is only about 35% efficient, then you realize that about 65% of the energy flowing out of the battery was being dissipated in the motor as heat, core losses, etc. So the unit was continuously performing work for that five years. [note 28] The 1/8 hp motor represented a load in which the continuous rate of work being done (the rate of energy dissipation) was about 0.08 hp. We will have more to say on this motor and its technical process in a future article.

Bill Fogal is a close colleague; Bill has patented the world's first dq/dt-blocking semiconductor, [note 29] which partially blocks the normal current while continuing to pass the flow of voltage (Table 4). I have written a proprietary technical explanation of the Fogal semiconductor, which utilizes an extremely little-known feature called the "overpotential." The overpotential part of the theory is experimentally proven and theoretically explained in an obscure part of electrochemistry, by a few chemists who specialize in electrode effects. J. O'M. Bockris is probably the leading world expert in overpotential theory; he authored the textbook on it. [note 30]

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because we did not have the proper instruments available. E.g., all our oscilloscopes were "hard grounded" to building ground, and we needed to make “floating differential ground” measurements in order to settle things once and for all. McLain and Wooten have filed for a patent, and multiple tests with excellent equipment have indeed indicated overunity. What happens next remains to be seen. I suspect that the two inventors may simply accept foreign capital investment and go offshore.

Howard Johnson is also a respected colleague, whom I very much admire. (See Figure 23). Howard has continued to work quietly and patiently upon his patented permanent magnet motor, [note 31] including patenting various magnetic gates, etc. that are necessary to make such a motor work in a rotary configuration. [note 32] Howard employs a two-particle theory of magnetism; i.e., each magnetic flux line is envisioned as having a particle traveling from the north pole to the south pole, and also a particle traveling from the south pole to the north pole. The particles are spinning; the forward-time particle spins in one direction, and the antiparticle spins in the other direction. Howard then slightly separates the two particle flows. [note 33] In other words, Johnson splits the flux lines themselves, into two different pieces. When so separated, the component lines are now curls, so their paths curve. The paths of the two “curl particles” are different; one curls in one direction and the other curls in the opposite direction. Further, a predominance of one form of curl particle gives a “time-forward” aspect, while a predominance of the other form of curl particle gives a “time-reversed” aspect. Johnson is thus able to employ a deeper kind of magnetism than the textbooks presently contain. He demonstrates that a “spin-altered” magnetic assembly exhibiting (to a compass or other such detector) a north polarity can attract another unaltered magnetic assembly exhibiting a north polarity. In short, he can make a north pole attract a north pole. We will give you further insight into Johnson’s two-particle theory in a future article. [note 34] We will also explain how and why the physicists missed that antiparticle in the magnetic field’s flux lines, and thereby failed to advance the theory of magnetism to a deeper level. Make no mistake, one day when the new theory is done, Johnson may well be awarded a Nobel Prize for his epochal discovery of a deeper structure of magnetism.

Bits and pieces of the new science approach are just now beginning to spill into a few conventional journals and symposia. For some time a few of the rebels spearheading this new science have been doing something that the University scientists should have been doing all along. The rebels have been meticulously examining the concepts, postulates, and definitions that the present scientific models are founded upon, to reveal serious foundations errors. Corrections for some of these errors have been discovered and made. [note 35] Others are still problems yet to be resolved. Yet slow progress is being made, and a “flip-over” of the old science is likely to occur within the next decade if not sooner. By then the new concepts will have become “solid” enough to allow producing an engineering mathematical model. Also the supporting experiments will have become solid enough to justify the new concepts and the model.

In this first article I wanted to introduce the 14 major areas. We will be discussing these areas in some technical detail in the future. We’ll also include current major news items of development in these areas, for the interested lay reader. I’ll particularly try to give you the benefit of extensive reference citations painfully gathered over the last 30 years. The articles will be targeted toward both the serious researcher and the interested, educated layman.

So that’s the agenda for the months ahead. We hope you find this information and the approach of direct interest and use.

Again, it’s a privilege to be aboard. And we invite you to hang on in the future; it’s going to be a wild but exciting ride. We really are going to chase this wild dragon with great vigor.

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Scalar Wave Technology

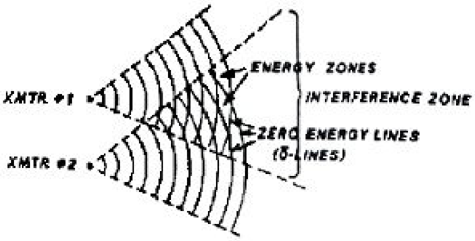

Scalar Wave Detection

Warren York
Scalar Wave Researcher

Originally published: **ExtraOrdinary Science (Volume 1, Issue 4; Oct/Nov/Dec 1989)**

WARNING: Do not attempt electrical construction on any of the equipment, coils or devices described here unless you are fully qualified. In some cases LETHAL voltages and charges are required. Also be advised that improper use, application and physical methods may cause psychological tramuma or permanent physical and neurological damage when near the vicinity of such equipment. This information is being provided as a point of interest to our readers... the publisher and author disclaim any responsibility in the use or misuse of this information.

Introduction

All of this talk so far on scalar waves and scalar technology has no purpose in the scientific community until something can be detected, observed and duplicated. The original seedlings and thoughts which led to Lt. Col. Bearden's scalar theories were developed out of observation. If not by Lt. Col. Bearden himself, then by others from many noncorrelated paths.

I already have given a small sample list of such observers from Nikola Tesla to the latest, Moray King. I have just read a newly released book by Moray entitled ***Tapping the Zero Point Energy***. I also recommend highly for others interested in scalar technology to obtain copies of Bearden's works and books from the new release of ***Excalibur Briefings*** to ***AIDS--Biological Warfare***. The two books and papers will fill in the much needed base work on understanding scalar technology and can be obtained through the High Energy Catalog.

I also understand that a new book is in the making which is a rebuttal entitled something along the lines of *Anti-Scalar*. All of this is healthy in any development process, for without pros and cons, the sorting of correct data to trash data cannot be accomplished. On the other hand, I would like to point out that any conclusions should be supported by actual tests and not just by armchair theory.

Anybody can debate from the armchair but to have any meaning to back up their statements, one must present tests where one gets his or her hands dirty. That is to say that until I had reactions and observed actual phenomena occurring, all the theories were no more than that--just theories. This is what I hope to accomplish here with these articles on scalar technology. I feel this is a true new technology and deserves some serious consideration.

If I had not gotten my hands dirty and followed through on others' experiments from other observers then I would never have been convinced that something extraordinary was taking place. Even though my senses told me I was wasting my time I set out on the monotonous task of duplicating others's work and notes of observation. This is what I hope some of you will do and start to help unfold and unleash this hidden knowledge called scalar -- zero point energy -- stress energy and even radionics. Itis true indeed that it has many names over the years, but now we can at least have hope of defining its true limits and abilities.

The detection methods I will present here are not confirmed by myself or corresponding researchers as of yet due to development is still in progress. In one method I can only accept the word of the researcher as to his results. Until I or others duplicate results it remains a possible process and approach in detection.

My own detection came in the form of two experiments which were reproductions of another author's work based on this technology. When I had reproducible results I knew there was more to scalar than just theory. The process is now underway in developing a reliable instrument or means of detection that others can use. Up to this point most of scalar observations have been uncertain and always with the person or operator being part of the circuit. Nobody could remove the person at this point to bring scalar under true observation conditions. Due to a simple observation in Mr. George Meek's work in electro-voice phenomena (EVP), where my first breakthrough was established, this now seems a possibility. The personal element was still included in the circuit but unlike radionics or Hieronymus devices, could be reproduced by anybody once special conditions were met. A co-researcher has hit upon a method which was initially observed by Nikola Tesla and shows promise of another breakthrough in removing the personal element.

I will now discuss my initial breakthrough to scalar detection which will help you follow my thinking on what is needed and just what we are looking for in scalar detection. Scalar properties are the dictating key elements in this approach. I will then describe a possible detection method of another researcher and finally what I feel will be a unique approach with an instrument currently under construction by Mr. Russell Clift, a co-researcher/inventor, and myself. Do not feel you have to adhere to these techniques for they are only a guideline and starting point to spring from in your own approach to this subject. They are not established yet and will most likely be altered many times before their completion.

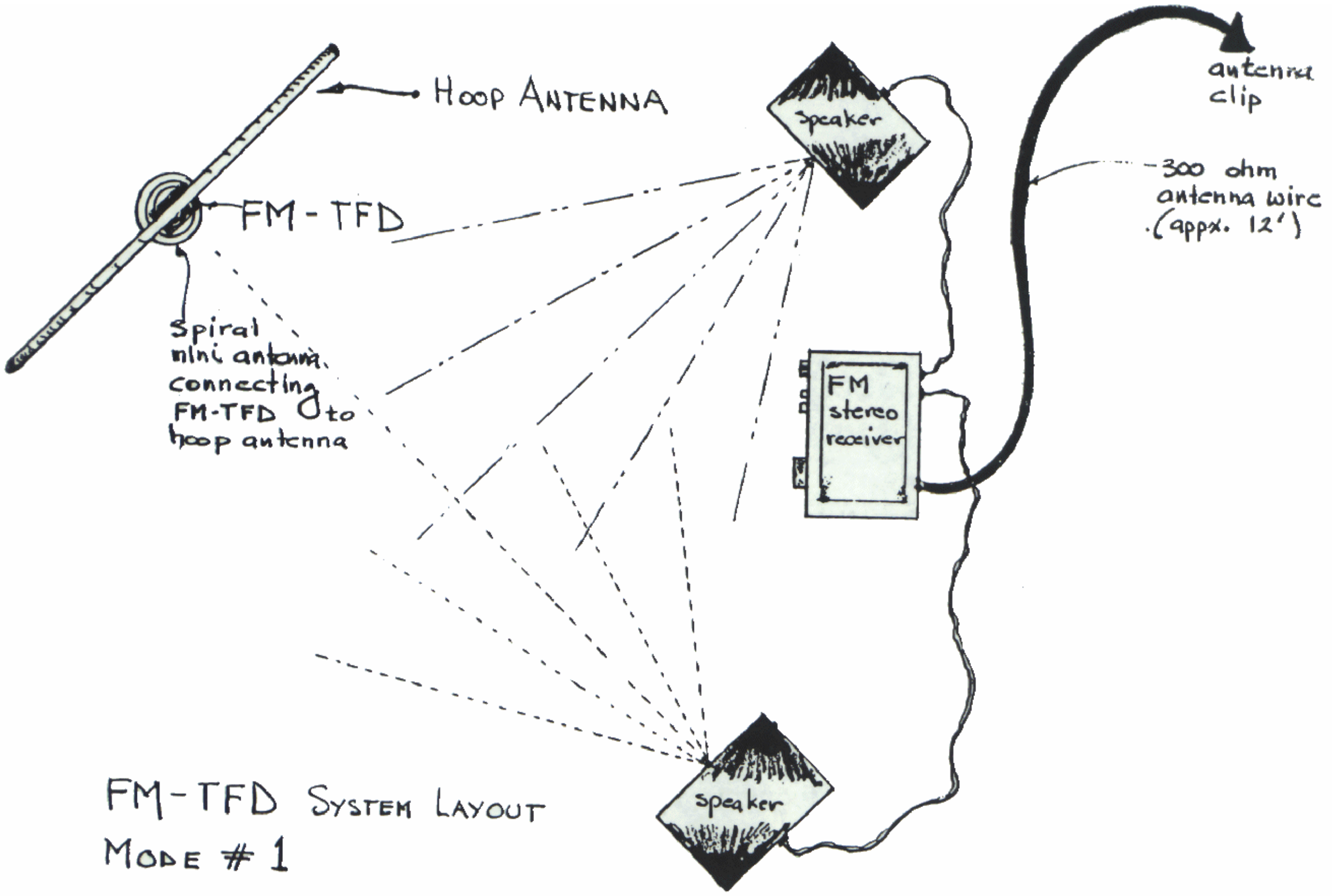

Figure 1. **System Layout for FM-TFD [Mode 1]**

As in all unknowns there are always unforeseen dangers involved and one should always use extreme caution and behave professionally in all approaches with any experimenting. Madame Curi and the XRay research is a good example. They paid dearly for their progress in X-Ray development with their lives. Scalar and its properties can be just as deadly as it is fascinating. I hope you read the seriousness in my tone for no matter how science fictionish scalar may sound to you now, I assure you the reality of actuallity can end up staring you in the face.

Breakthrough Event

Several years ago a Mr. George Meek presented me with construction planes and notes to a device he called Mark V. [Figure 1] Mr. Meek had been researching a phenomenon better known as EVP, or electro-voice phenomena. [Figure 2]

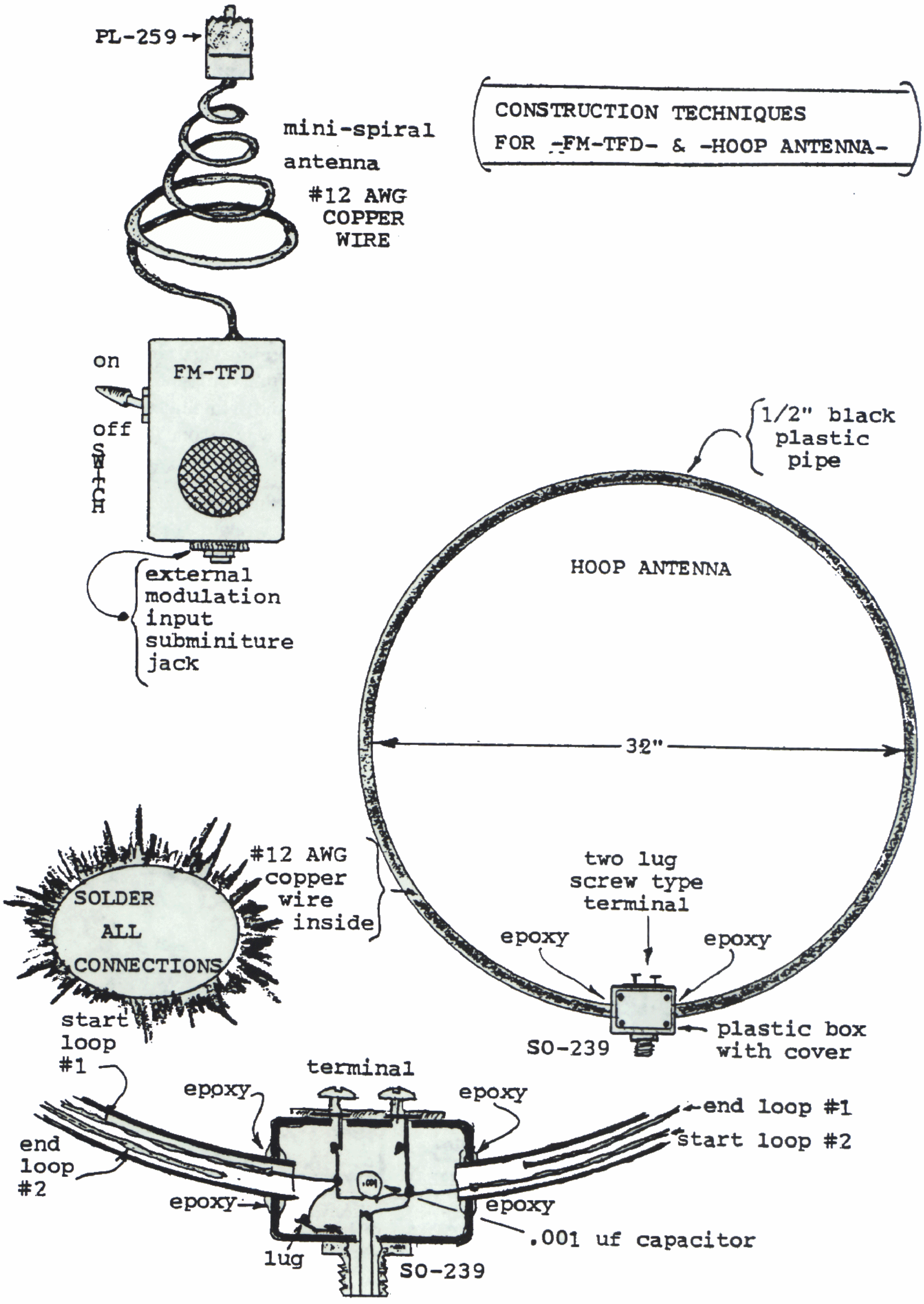
CONSTRUCTION TECHNIQUES
FOR -FM-TFD- & -HOOP ANTENNA-
PL-259
mini-spiral
antenna
#12 AWG
COPPER
WIRE
on
FM-TFD
off
SWITCH
external
modulation
input
subminiture
jack
1/2" black
plastic
pipe
HOOP ANTENNA
32"
SOLDER
ALL
CONNECTIONS
#12 AWG
copper
wire
inside
two lug
screw type
terminal
epoxy
epoxy
SO-239
plastic box
with cover
start
loop
#1
end
loop
#2
terminal
epoxy
epoxy
end loop #1
start loop #2
epoxy
epoxy
.001
.001 uf capacitor
lug
SO-239

Figure 2.

Figure 2. **Construction Techniques for FM TFD & Hoop Antenna**

I would like to take a second here and answer a letter from one of **Extraordinary Science**'s subscribers printed in our last issue. Mr. Jeff King from New Zealand had written to the effect if perhaps I could cover what relationship scalar technology has in reference to EVP. [Figure 3] Well here it is, for this was the first reproducible effect dealing with scalar energy [interference pattems] [Figure 4] that I could verify really took place. My second breakthrough was also in the EVP area but I will not be able to go into it at this time due to available space to cover what must be covered now.

In short, Mr. Meek claimed to have a fantastic breakthrough of his own in the communications field of EVP. His claims were a recorded two-way conversation with another dimension. ***ZAP!*** Right here one would stop and feel that Mr. Meek and his researchers needed psychological help as I am sure some of you feel about me at this point. I contacted Mr. Meek and he flew down to El Paso so we could talk in person. He brought me two audio tapes of which one surely did have what appeared two-way communication in real time.

Up to this point all EVP claims were after the fact type of events. That is, the voices always appeared on blank tape after the operator had run the tape recorder for a period of time. No audible sounds were heard during the initial recording, only after playback of the tape--sort of the same thing being done now with channeling, but the person is still part of the circuit. Not all voices were understandable or clear enough to be real voice prints or just random white noise perhaps forming what almost sounds like words. In other cases, the words and even statements were definitely clear and of intelligent source. Well, Mr. Meek's tape went way beyond this to a two-way real time conversation.

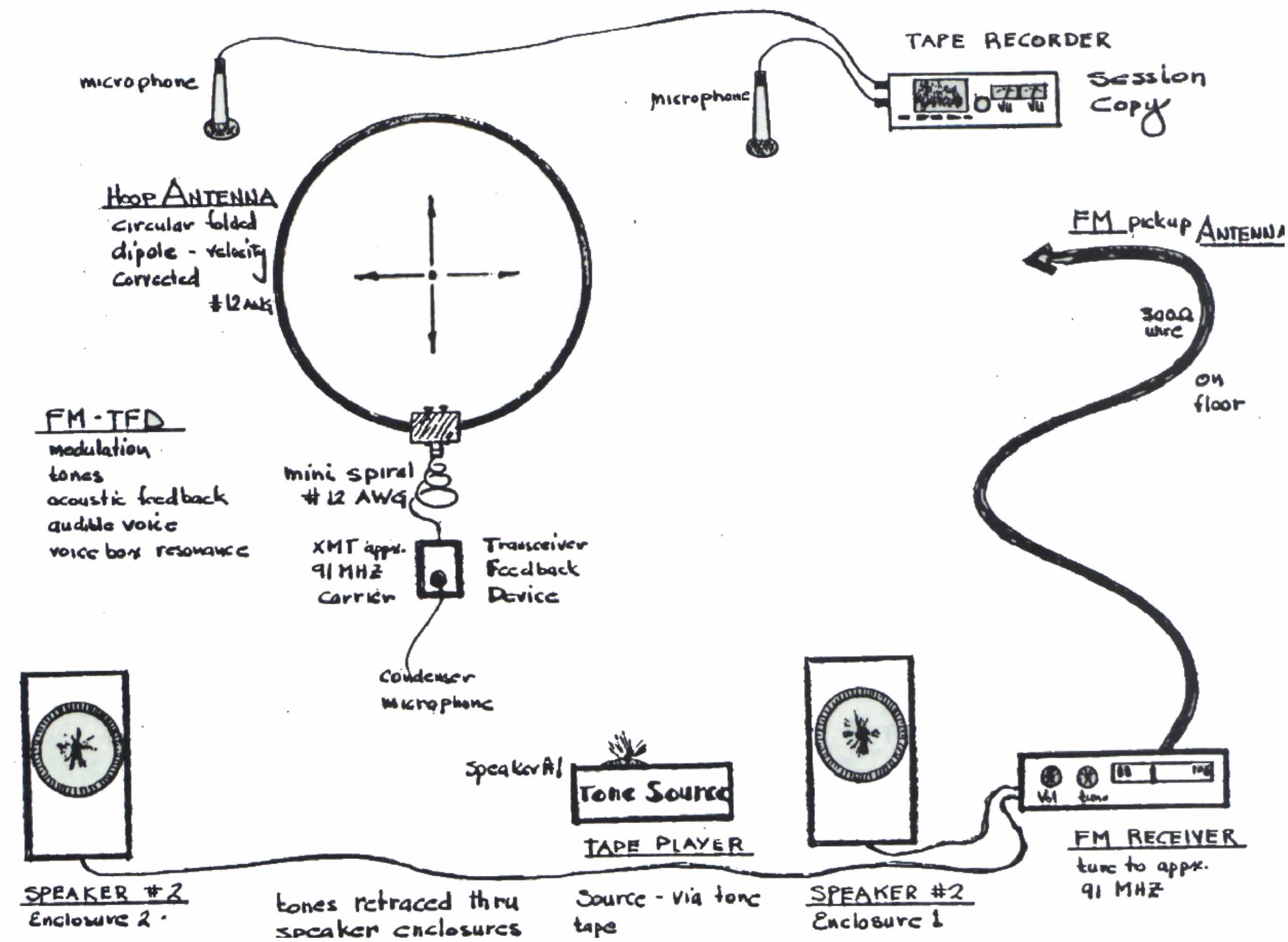
microphone
microphone
TAPE RECORDER
Session Copy
HOOP ANTENNA
circular folded dipole - velocity corrected
#12 AWG
FM pickup ANTENN
300Ω wire
on floor
FM-TFD
modulation
tones
acoustic feedback
audible voice
voice box resonance
mini spiral #12 AWG
XMT appx. 91 MHZ Carrier
Transceiver Feedback Device
Condenser microphone
Speaker #1
Tone Source
TAPE PLAYER
Vol
tune
FM RECEIVER
tune to appx. 91 MHZ
SPEAKER #2
Enclosure 2
tones retraced thru speaker enclosures
Source - via tone tape
SPEAKER #2
Enclosure 1

Figure 3. **Mode 2 Communications Setup**

Fascinated by these claims I wanted to know more on how such a process worked. This is where he presented me with the second tape. It consisted of thirteen mixed electronic tones. No, there is no magical number in why thirteen tones were used only that they were needed to create interference patterns. These tones with an acoustical feedback and RF transmission with a Smith coil produced a unique interference pattern [scalar-RF and acoustical stress field].

I followed the notes and set out to reproduce this fantastic claim. At one point in the notes was one observation statement:

The system seems capable of feeding back changes in emotional states.

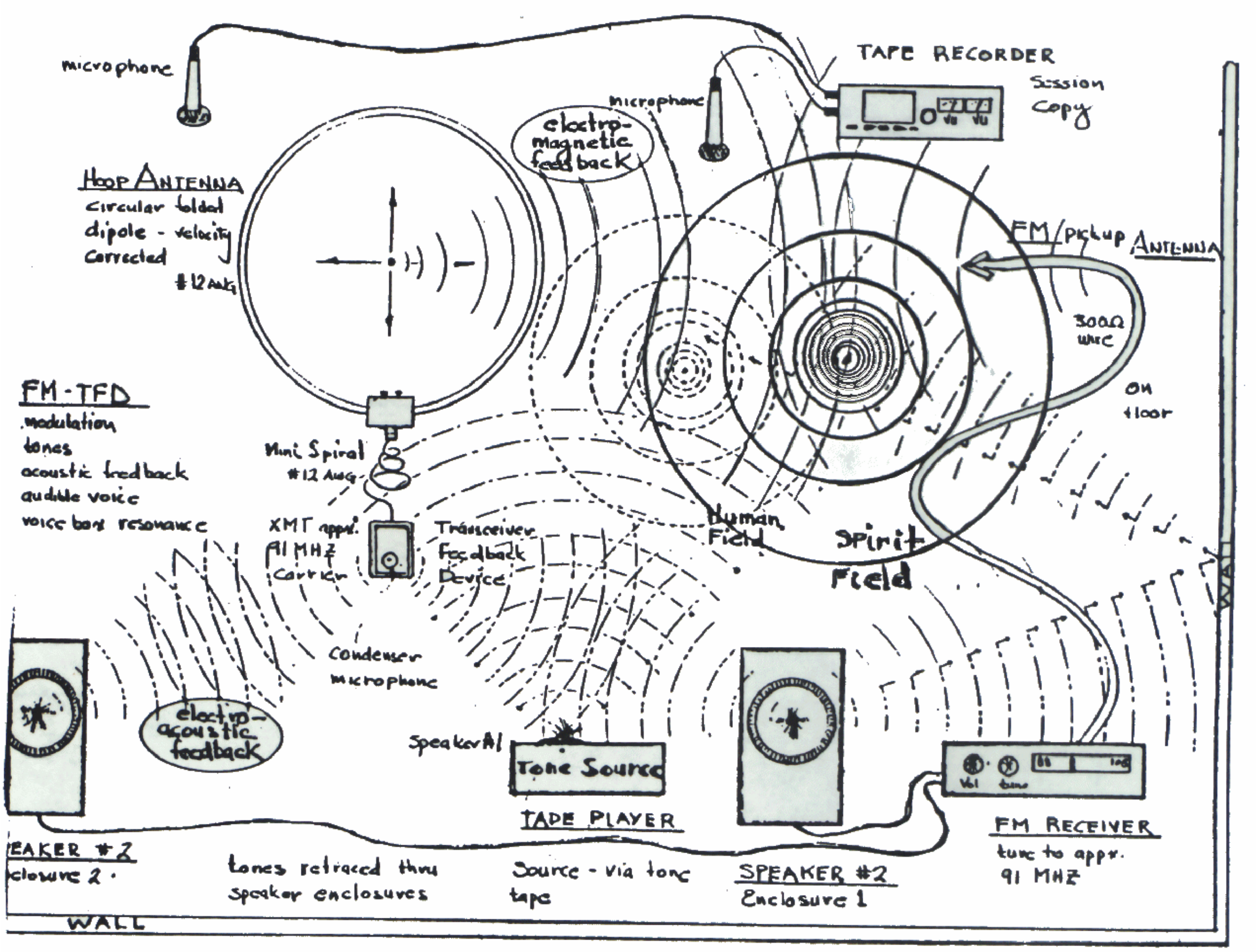
microphone
TAPE RECORDER
Session Copy
microphone
electro-magnetic feedback
HOOP ANTENNA
circular folded dipole - velocity corrected
#12 Awg
FM-TFD
.modulation
tones
acoustic feedback
audible voice
voice box resonance
Mini Spiral
#12 Awg
XMT appr. 91 MHZ carrier
Transceiver Feedback Device
Human Field
Spirit Field
FM/pickup ANTENNA
300Ω wire
on floor
Condenser microphone
electro-acoustic feedback
Speaker #1
Tone Source
TAPE PLAYER
Vol
tune
FM RECEIVER
tune to appr. 91 MHZ
EAKER #2
closure 2
tones retraced thru speaker enclosures
Source - via tone tape
SPEAKER #2
Enclosure 1
WALL

Figure 4. **Mode 2 Communications Interference Pattern**

I stopped there and to my amazement found the observation to be true. I was able to control an avalanche effect in a balanced tone of a set of acoustical and RF frequencies with only my own concentration -- no doppler effect or movement or contacts to my body in any way. I taped this effect and it is available to those who wish to observe the level of control of an electrical circuit with shear stress energy from a human.

This observation is equal to Nikola Tesla's observation of his plasma globe and tensing a fist. He found the plasma trail would rotate in relation with the tension or muscle pressure produced. I will cover this process in a moment for the plasma approach in construction a scalar indicator seems to be ideal due to its extreme sensitivity that up until now has been the human or personal element.

Bedini Version ---- Dea/Faretto Scalar Detector

In this version of an electromagnetic scalar detector you will see that a coil is suspended in a magnetic field within a shielded case. [Figure 5] It is not indicated but I am sure the coil should be wound as a scalar coil. See "Construction of a Scalar Coil," **ExtraOrdinary Science**, Vol.I, Issue 3, page 16. The shielding is so all that known EMF fields will be run to ground and not affect the sensor within the case. As you know, one of the properties of scalar energy is that it cannot be shielded. All known EMF will be stopped from entering the case except gravity fields and scalar energy.

I am not saying that gravity fields or scalar fields are EMF, but only that the formula to each have a basic root in the EMF part of the spectrum. A generated scalar pulse or field will cut past the case shielding and affect the atoms of the scalar coil within the magnetic field which in tum will be coupled to the op amp. Any change or effect will then be displayed on the scope indicating a pulse or field of some kind has gotten past the system's shielding and to the sensor. You should see a change in the display around 6AM when the sun comes up and there is a slight gravity shift. [1,2]

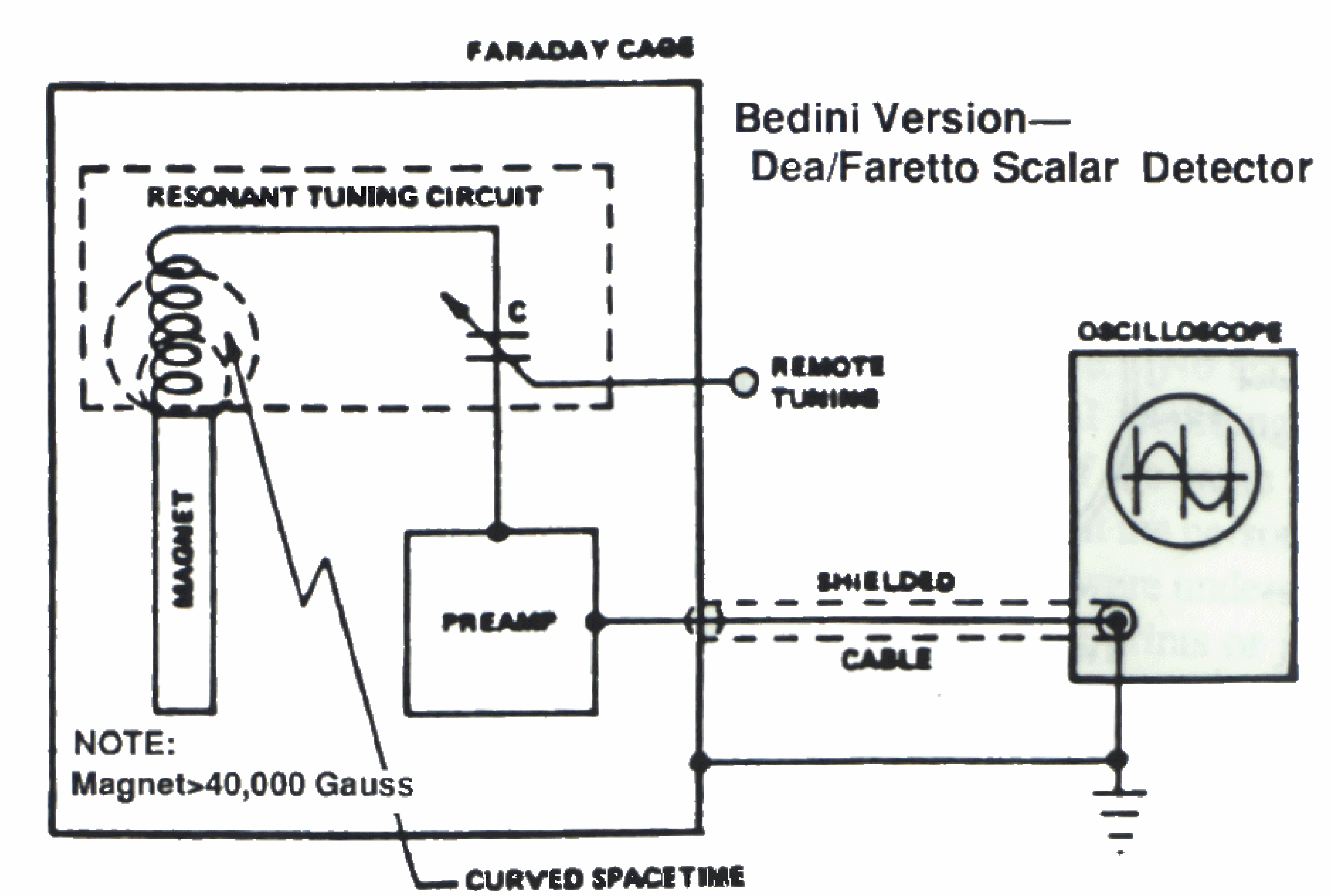
FARADAY CAGE
Bedini Version—
Dea/Faretto Scalar Detector
RESONANT TUNING CIRCUIT
C
REMOTE
TUNING
OSCILLOSCOPE
MAGNET
PREAMP
SHIELDED
CABLE
NOTE:
Magnet>40,000 Gauss
CURVED SPACETIME

Figure 5. **Bedini Version of Dea/Faretto Detector**

Plasma Scalar Detector

This is the method which is under construction by Russell Clift and myself. At the time of this printing the construction is not far enough to give any details or results as to this approach. [See Figure 6] This is based on the same construction of Nikola Tesla's experiment.[3] Figure 7 is for experiments with various voltages and ion currents. Figure 8 is a simple multiplier for the AC supply shown in Figure 6.

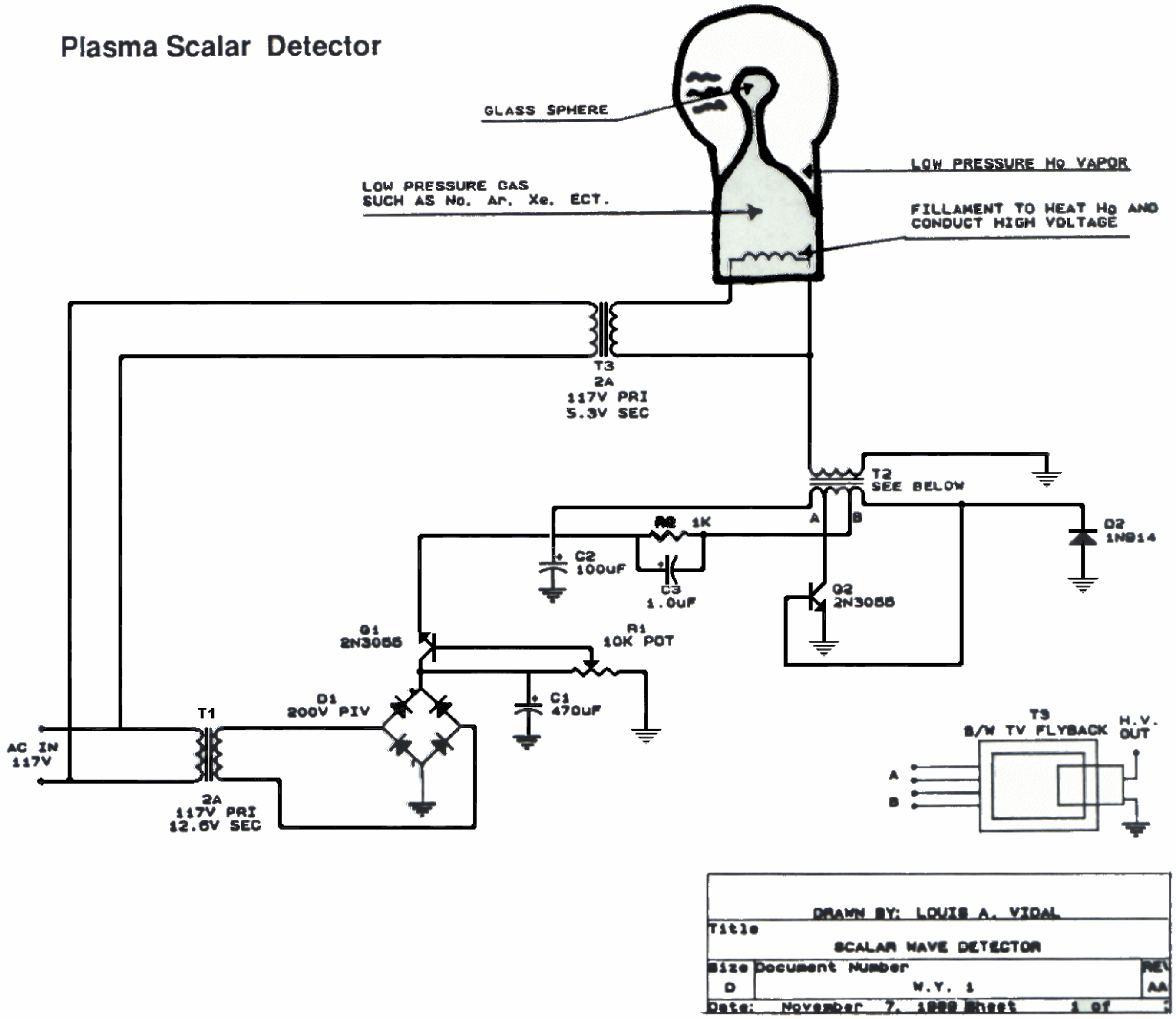
Plasma Scalar Detector
GLASS SPHERE
LOW PRESSURE Hg VAPOR
LOW PRESSURE GAS
SUCH AS Ne. Ar. Xe. ECT.
FILLAMENT TO HEAT Hg AND
CONDUCT HIGH VOLTAGE
T3
2A
117V PRI
5.3V SEC
T2
SEE BELOW
A
B
R2 1K
C2
100uF
C3
1.0uF
Q2
2N3055
D2
1N914
Q1
2N3055
R1
10K POT
D1
200V PIV
C1
470uF
T1
AC IN
117V
2A
117V PRI
12.6V SEC
T3
B/W TV FLYBACK
H.V.
OUT
A
B
DRAWN BY: LOUIS A. VIDAL
Title
SCALAR WAVE DETECTOR
Size
Document Number
REV
D
W.Y. 1
AA
Date: November 7, 1999 Sheet 1 of

Figure 6. Plasma Scalar Detector

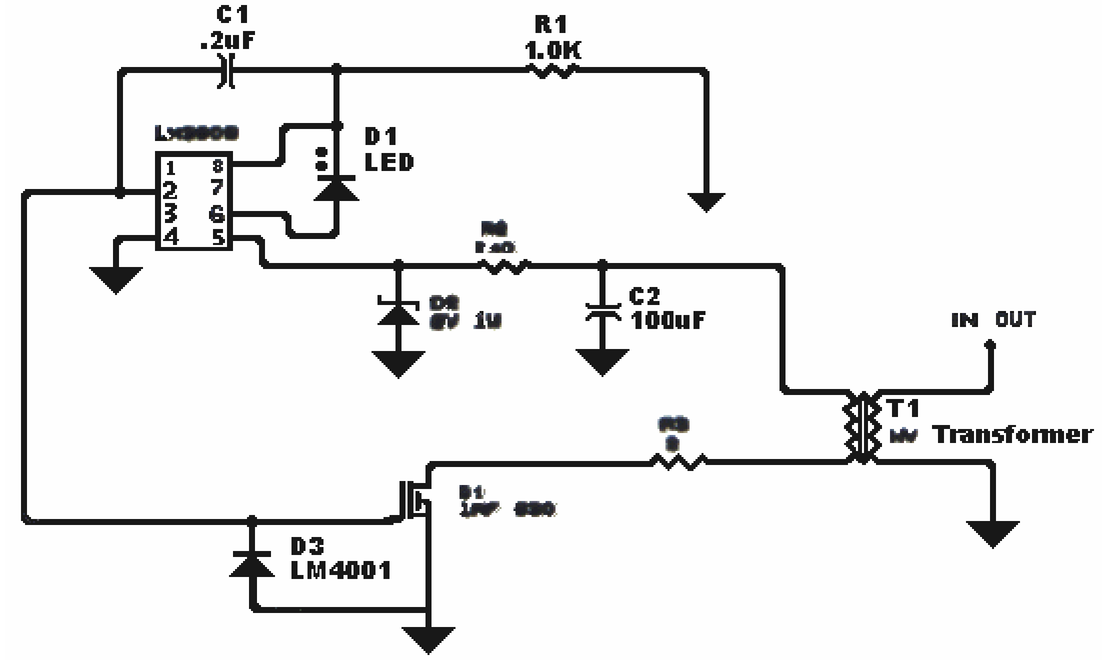
C1
.2uF
R1
1.0K
D1
LED
1
2
3
4
8
7
6
5
C2
100uF
IN OUT
T1
Transformer
D3
LM4001

Figure 7. Power Supply

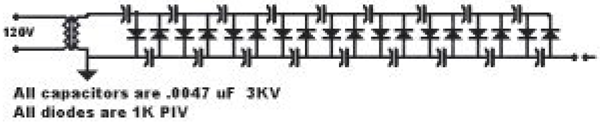

Figure 8. **Voltage Multiplier**

I know I have just touched upon this subject so far but I hope I have given some of you starting points in your own research and findings. I will welcome any and all papers or works you may do in the scalar field and submit your work for publication here for others to read and gain from. Will be looking forward to your replies in the new year. Thank you for your interest.___***WRY***

References

1. Michael Polonyi, "Electrodynamics, Inertia and Gravitation: A Unifying Approach," **Speculations in Science and Technology**, Vol. 10, No. 2, page 145, 1987.

2. Gregory Hodowanec, "Gravitational Impulses," **Electronics Experimenters Handbook**, January 1989, page 114.

Thomas Cummerford Martin, **Inventions. Researches and Writings of Nikola Tesla**, page 226 to page 228.

HUNTSVILLE EDITION

The Southeast's Oldest E-Zine!

Chasing the Wild Dragon Tables and Figures

By Tom Bearden

Figures

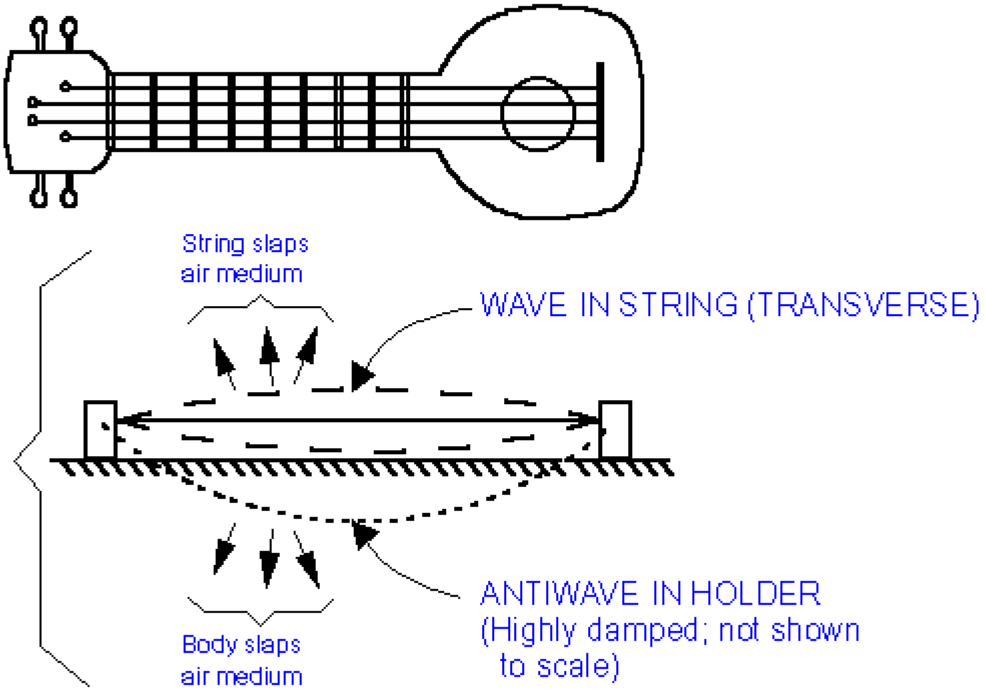
String slaps
air medium
WAVE IN STRING (TRANSVERSE)
Higher
degree of
freedom for
air medium
oscillation;
wave is
alternately
compressive
and rarefactive.
ANTIWAVE IN HOLDER
(Highly damped; not shown
to scale)
Body slaps
air medium

Figure 1. Air medium disturbances generated by plucked string.

Two waves are created, both slapping the air medium at the same time, but in opposite directions. A disturbed medium oscillates according to its own degrees of freedom. The air has more degrees of freedom than the string. A wave of compression and rarefaction is created in the air medium.

D-1-F 1

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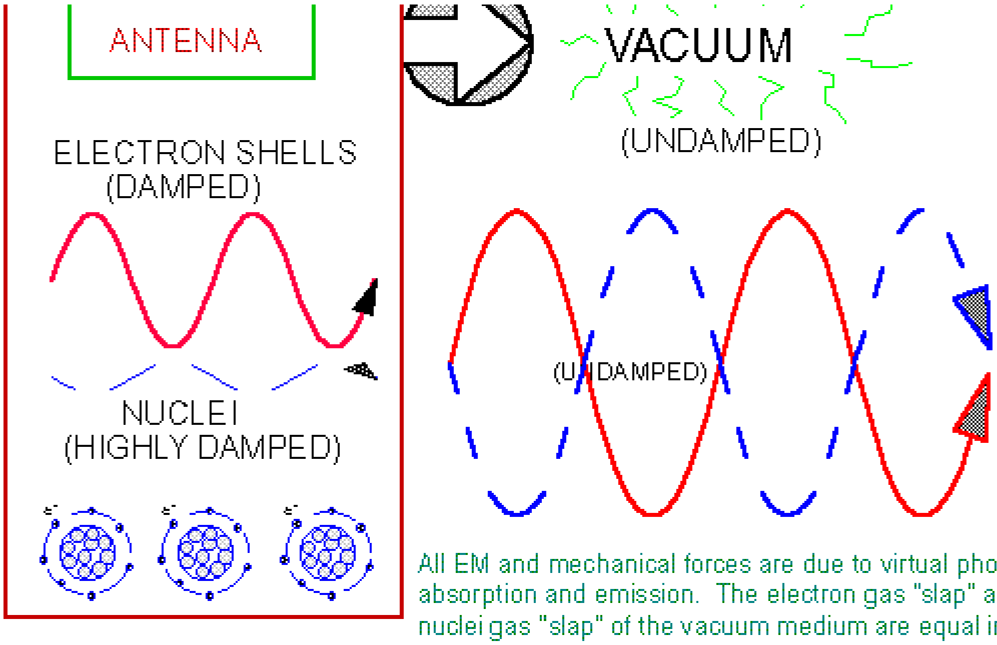
ANTENNA
ELECTRON SHELLS
(DAMPED)
NUCLEI
(HIGHLY DAMPED)
VACUUM
(UNDAMPED)
(UNDAMPED)

All EM and mechanical forces are due to virtual photon absorption and emission. The electron gas "slap" and the nuclei gas "slap" of the vacuum medium are equal in energy. Hence they inject equal numbers of virtual photons into the vacuum, creating equal and opposite vacuum disturbances. This gives a vacuum wave of alternating compression and rarefaction. This vacuum EM wave is similar to a sound wave, which is modeled longitudinally.

Figure 2. Launching an EM wave from a wire antenna.

D-1-F2

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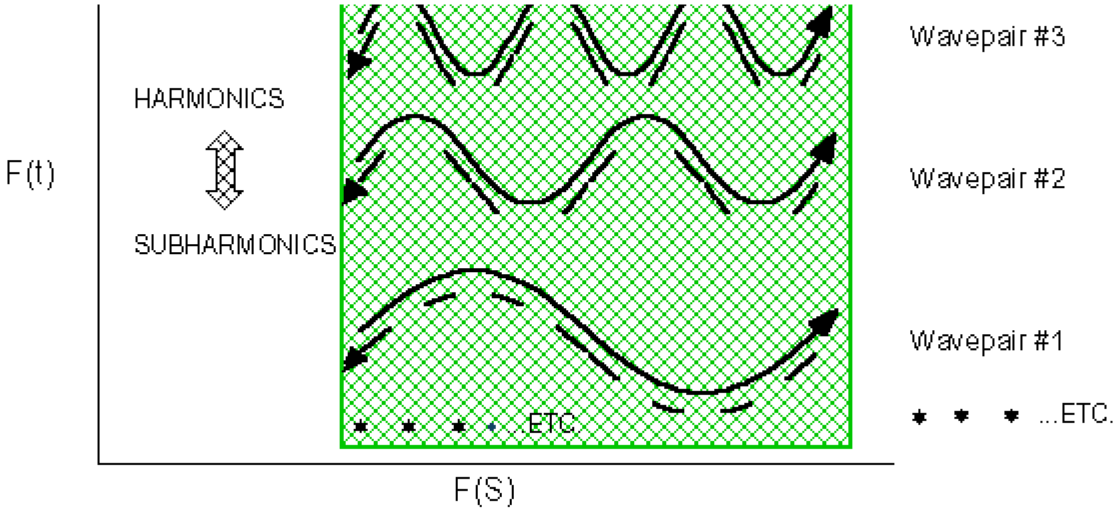

Figure 3. Internal Wave Structure of the scalar potential.

A harmonic set if wavepairs, where in each wavepair the two waves superpose spatially, but travel in opposite directions. The two waves in each pair are true phase conjugates and time-reversals of each other. Thus they comprise a coupled wave and antiwave. The photons must also be coupled into photon/antiphoton pairs, by a strong application of the distortion correction theorem of nonlinear optics.
Each wavepair is a standing electrogravitational wave.

D-1-F3

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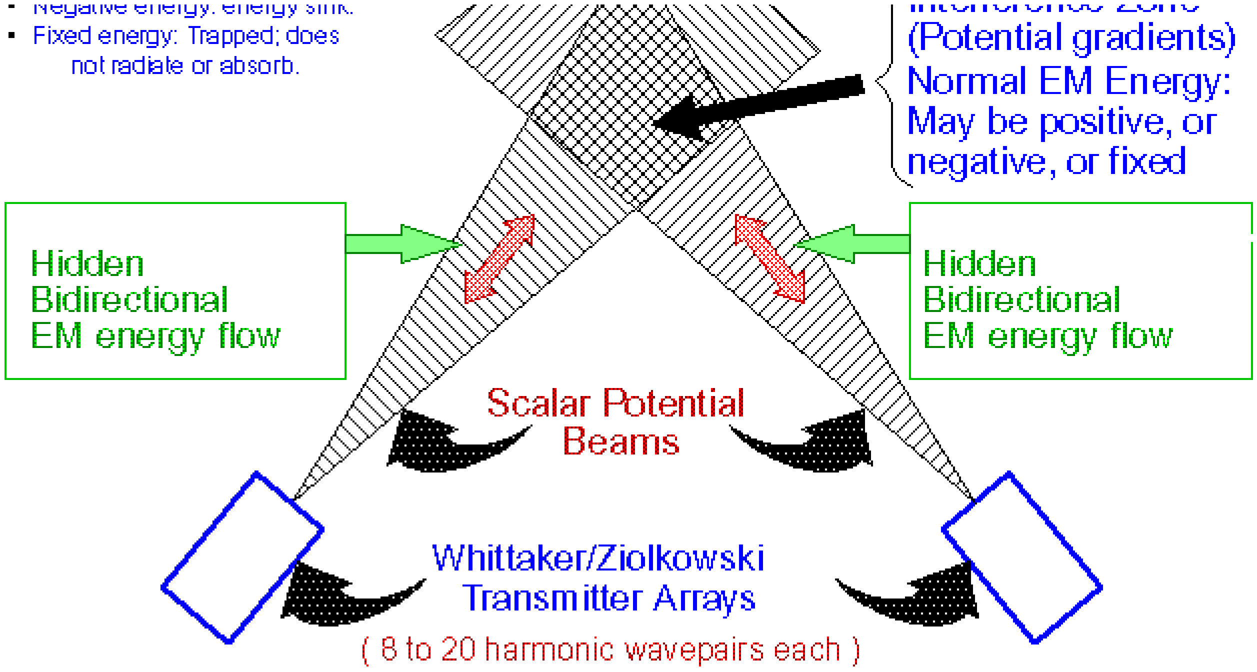
Negative energy: energy sink.
Fixed energy: Trapped; does not radiate or absorb.
Interference Zone
(Potential gradients)
Normal EM Energy:
May be positive, or negative, or fixed
Hidden Bidirectional EM energy flow
Hidden Bidirectional EM energy flow
Scalar Potential Beams
Whittaker/Ziolkowski Transmitter Arrays
(8 to 20 harmonic wavepairs each)

Figure 4. Scalar potential interferometry provides action-at-a-distance. It already creates normal EM fields and waves.

D-1-F4

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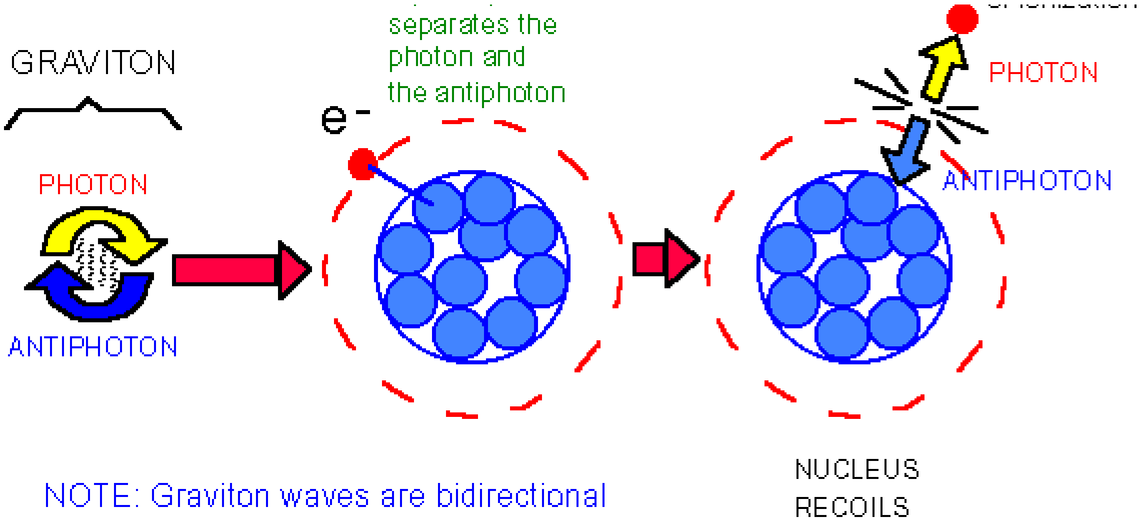
GRAVITON
PHOTON
ANTIPHOTON
separates the
photon and
the antiphoton
e -
PHOTON
ANTIPHOTON
NUCLEUS
RECOILS

NOTE: Graviton waves are bidirectional
phase waves of photon/antiphoton
coupling and uncoupling in the vacuum.

The atom is an assembly of dynamic dipoles.

A dipole splits the graviton into a photon and an antiphoton.
The photon interacts with the electron, producing the action.
The antiphoton interacts with the nucleus, producing the reaction.

Figure 5. Graviton interaction with matter produces the photon interaction and Newton's third law reaction.

D-1-F5

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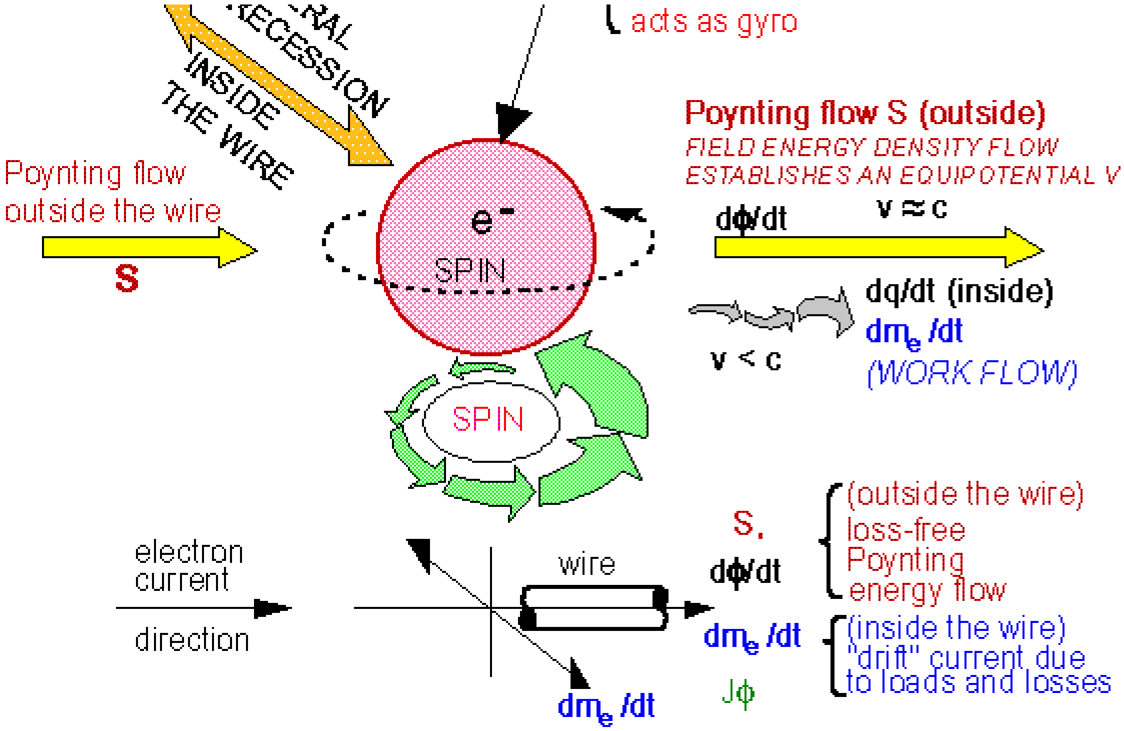

-RAL
RECESSION
INSIDE
THE WIRE
acts as gyro
Poynting flow S (outside)
FIELD ENERGY DENSITY FLOW
ESTABLISHES AN EQUIPOTENTIAL V
Poynting flow
outside the wire
S
e⁻
SPIN
dφ/dt
v ≈ c
dq/dt (inside)
dmₑ /dt
(WORK FLOW)
v < c
SPIN
electron
current
direction
wire
S,
dφ/dt
(outside the wire)
loss-free
Poynting
energy flow
dmₑ /dt
(inside the wire)
"drift" current due
to loads and losses
Jφ
dmₑ /dt

Figure 6. Currents in and along a conductor, with electron precession.

D-1-F6

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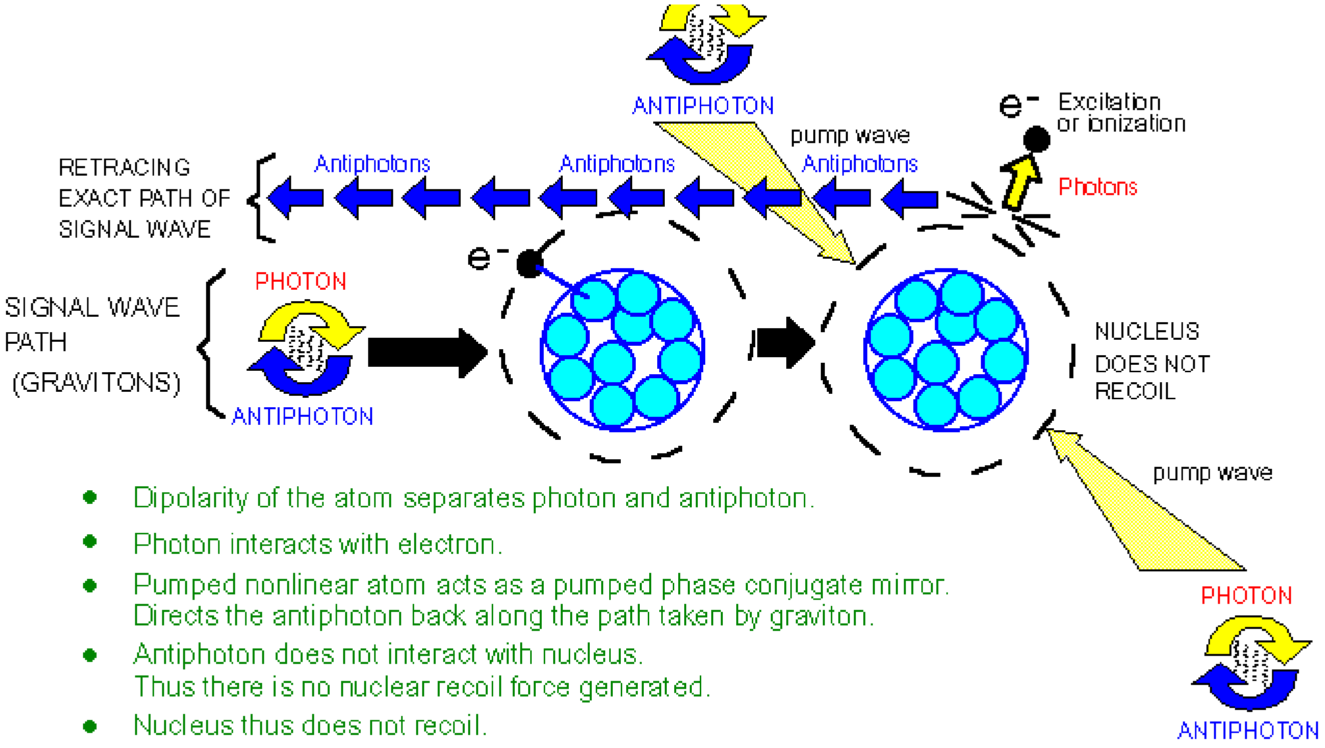
ANTIPHOTON
pump wave
e⁻ Excitation or ionization
RETRACING EXACT PATH OF SIGNAL WAVE
Antiphotons
Antiphotons
Antiphotons
Photons
e⁻
SIGNAL WAVE PATH (GRAVITONS)
PHOTON
ANTIPHOTON
NUCLEUS DOES NOT RECOIL
pump wave
PHOTON
ANTIPHOTON

- Dipolarity of the atom separates photon and antiphoton.
- Photon interacts with electron.
- Pumped nonlinear atom acts as a pumped phase conjugate mirror. Directs the antiphoton back along the path taken by graviton.
- Antiphoton does not interact with nucleus. Thus there is no nuclear recoil force generated.
- Nucleus thus does not recoil.
- Not a violation of Newton's third law, once one understands the mechanism that generates third law reaction. In the absence of the generating mechanism, there is no third law recoil. In EM field theory, the "missing antiwave" has necessitated third law omission.

Figure 7. Emission of antiphoton; nucleus does not recoil. Atom acts as a pumped phase conjugate mirror.

D-1-F7

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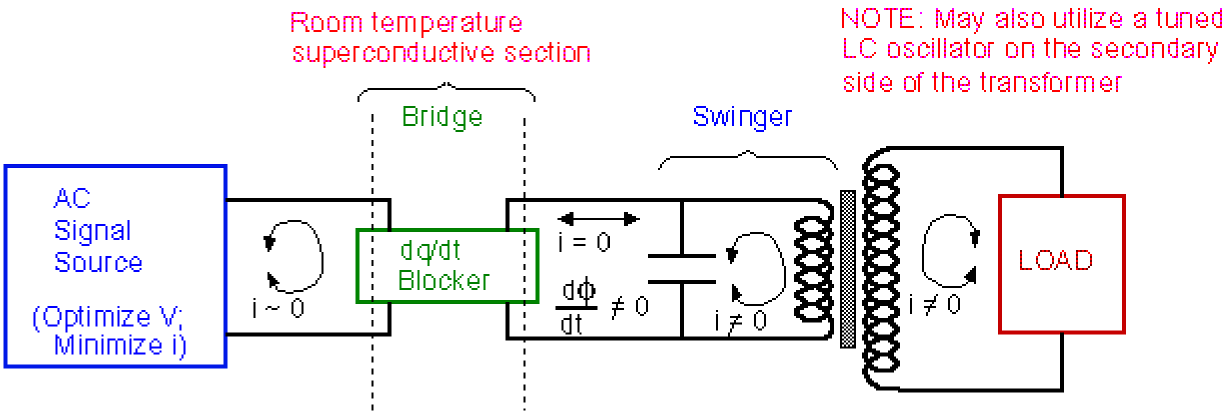
Room temperature
superconductive section
NOTE: May also utilize a tuned
LC oscillator on the secondary
side of the transformer
Bridge
Swinger
AC
Signal
Source
(Optimize V;
Minimize i)
i ~ 0
dq/dt
Blocker
i = 0
$\frac{d\phi}{dt} \neq 0$
i ≠ 0
i ≠ 0
LOAD

Patent Pending

Figure 8. dq/dt-free driving a swinger by S-flow.

Poynting energy flow S with its accompanying potential V is shuttled from the source to a tuned LC oscillator in resonance at the driving frequency or slightly below. The LC oscillator is driven by S-flow and dV/dt flow alone. The swinger furnishes its own free electrons, which receive S and EMF from the bridge, thereby producing dq/dt.

D-1-F8

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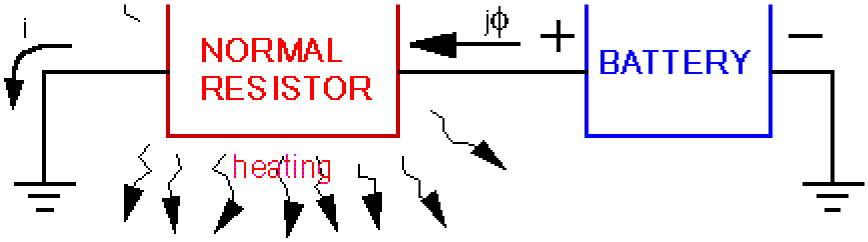

Figure 9a. Normal resistor receives ordered energy and scatters it.

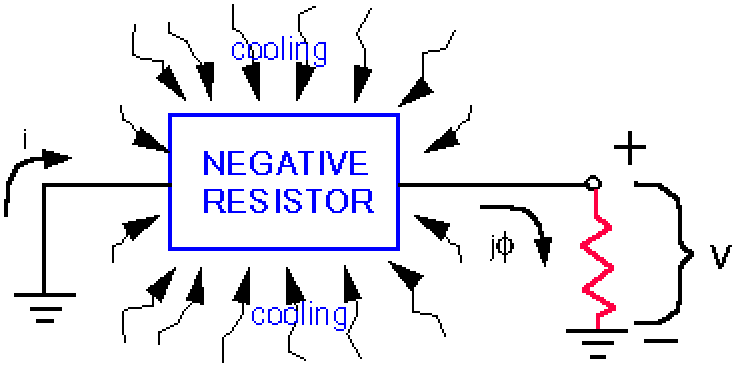

Figure 9b. Negative resistor receives, concentrates, and reorders scattered energy.

Figure 9. Normal resistor versus a negative resistor.

D-1-F9

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Some 17 signals were fed into a rotating plasma, which added phase conjugates to them. This infolded 17 wavepairs, each pair a coupled wave/antiwave, thereby forming a scalar potential with an artificial Whittaker pump wave internal structure. This infolded pump wave complex was modulated onto a powerful, rippling magnetic field, guaranteeing penetration even into the atomic nuclei. A specific, amplified antiengine for the exact cellular disease state was generated, reversing the diseased cells back to a previous healthy state.

Figure 10. Priore's laboratory apparatus for cellular reversal.

D-1-F10

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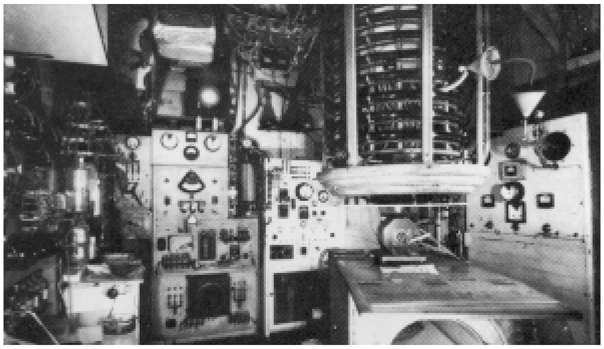

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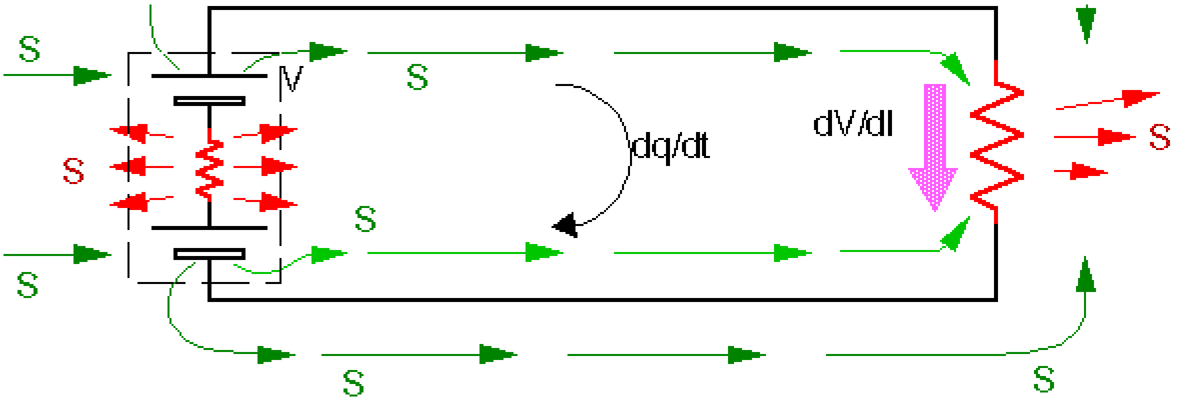

Note: EM texts err in showing the battery "gate" as the source of energy.

Figure 11. Poynting S-flow along a simple circuit.

From particle physics, any electric charge is a broken symmetry in the vacuum's virtual particle flux. Any dipole is thus two locally broken symmetries. Thus the dipole acts as a gate/source, driven by the fierce vacuum flux. So a dipole already "extracts" and gates EM energy flow, directly from the seething vacuum.

Every battery and generator is already a "free energy" source of extracted and gated EM energy from the vacuum.

D-1-F11

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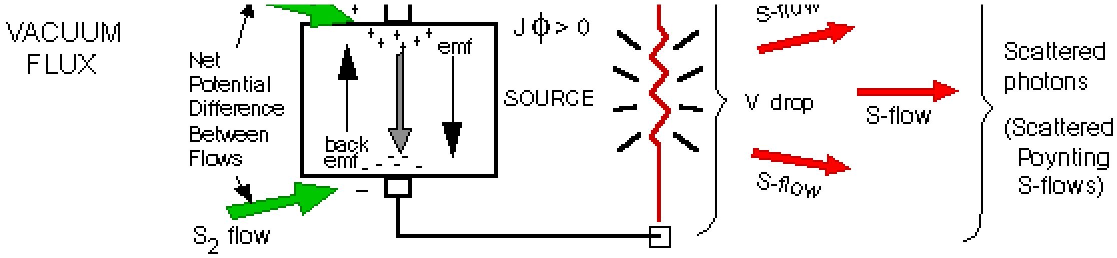
VACUUM FLUX
Net Potential Difference Between Flows
S₂ flow
emf
back emf
SOURCE
Jϕ > 0
S-flow
V drop
S-flow
S-flow
Scattered photons
(Scattered Poynting S-flows)

Figure 12a. Normal current flow; $J\phi$ is the electron transport of energy, while S is the speed-of-light Poynting energy flow.

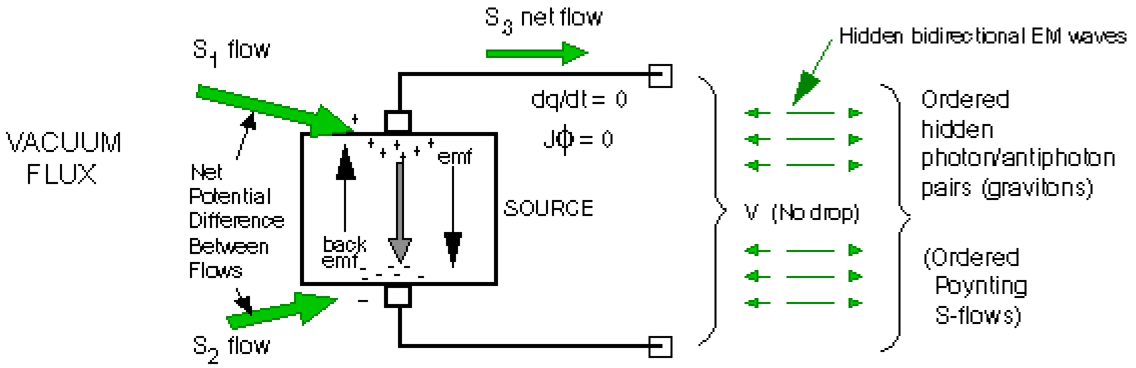
S₁ flow
S₃ net flow
Hidden bidirectional EM waves
VACUUM FLUX
Net Potential Difference Between Flows
emf
back emf
dq/dt = 0
Jϕ = 0
SOURCE
V (No drop)
Ordered hidden photon/antiphoton pairs (gravitons)
(Ordered Poynting S-flows)
S₂ flow

Figure 12b. In a conductor with dq/dt blocked; S-flow and hidden Whittaker-wave flow continue.

Figure 12. Overt and covert field energy density flows.

D-1-F12

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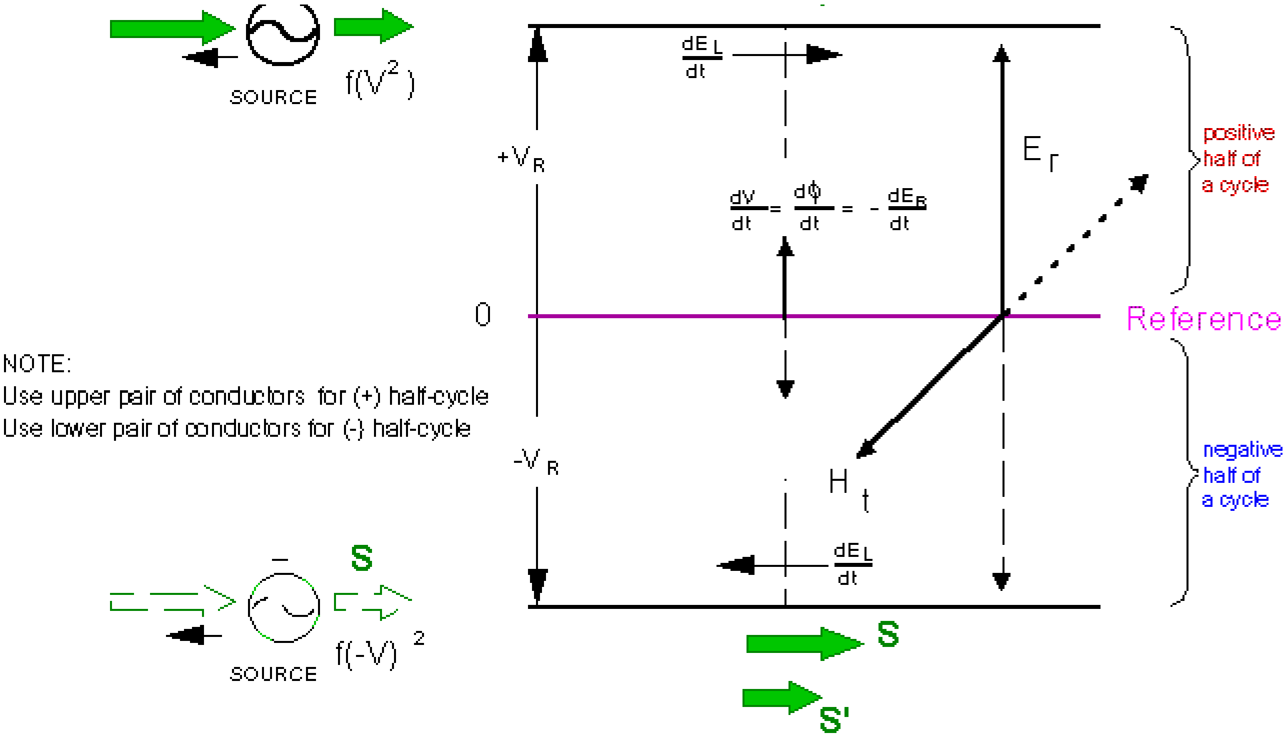
SOURCE
f(V²)
+V_R
0
-V_R
dE_L/dt
dV/dt = dϕ/dt = - dE_B/dt
E_r
positive half of a cycle
Reference
negative half of a cycle
H_t
NOTE:
Use upper pair of conductors for (+) half-cycle
Use lower pair of conductors for (-) half-cycle
S
SOURCE
f(-V)²
S
S'

Figure 13. Poynting vector currents S and S' versus massless displacement currents.

D-1-F13

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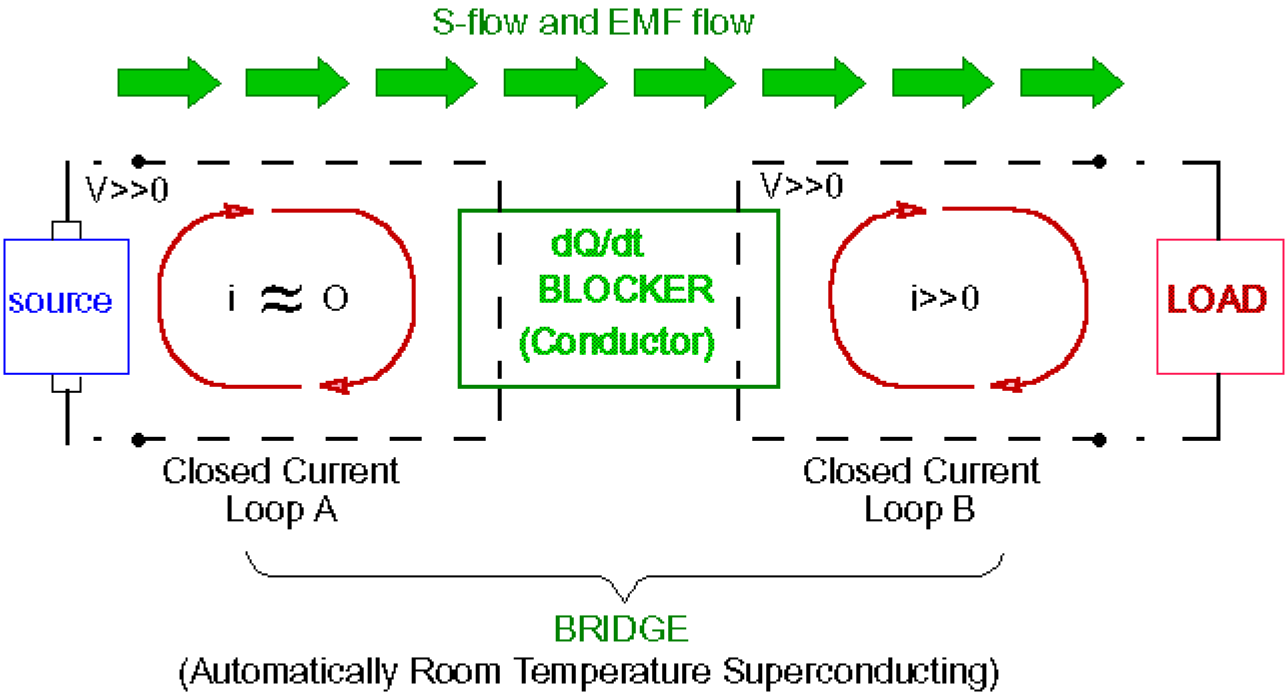
S-flow and EMF flow
V>>0
source
i ≈ 0
dQ/dt
BLOCKER
(Conductor)
V>>0
i>>0
LOAD
Closed Current Loop A
Closed Current Loop B
BRIDGE
(Automatically Room Temperature Superconducting)

Figure 14. Bridging to enable room temperature superconductivity.

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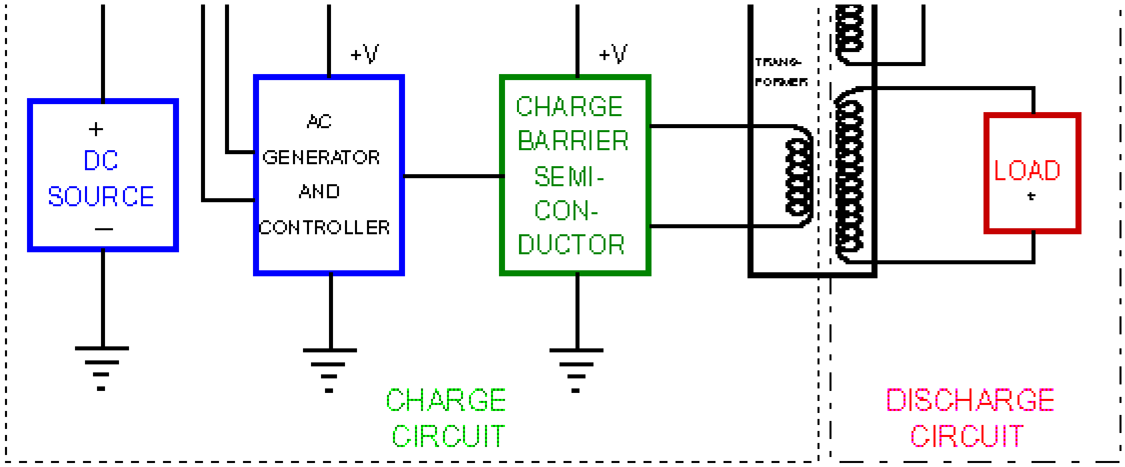
+V
+V
TRANS-
FORMER
+
DC
SOURCE
—
AC
GENERATOR
AND
CONTROLLER
CHARGE
BARRIER
SEMI-
CON-
DUCTOR
LOAD
*
CHARGE
CIRCUIT
DISCHARGE
CIRCUIT

Patent Pending

* NOTE:

DISCHARGE CIRCUIT AND LOAD GROUND
MUST BE ISOLATED FROM THE
CHARGE CIRCUIT GROUND.
FEEDBACK LOOP MUST BE RIGIDLY CLAMPED AND LIMITED.

Figure 15. Use of Fogal semiconductor for overunity (closed system).

D-1-F15

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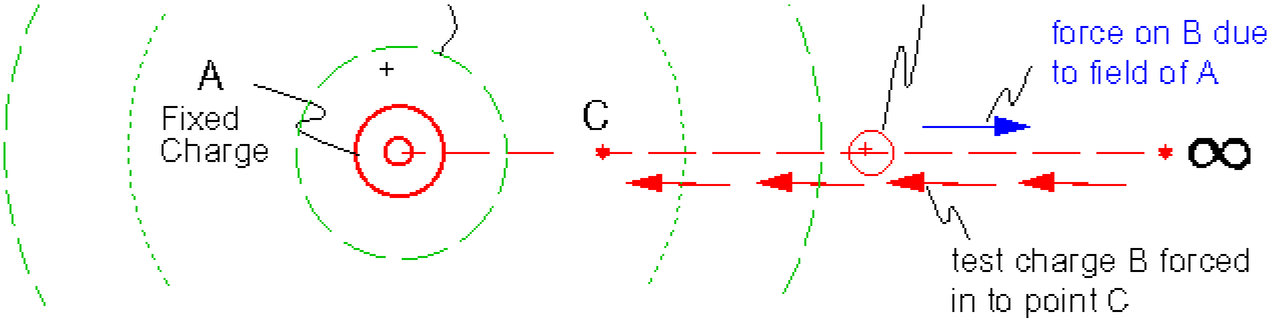
A
Fixed
Charge
+
C
∞
force on B due
to field of A
test charge B forced
in to point C

Figure 16a. Magnitude of the scalar potential is determined by work required to push in a unit charge from infinity; e.g., against a repelling like charge. If test charge is released, work will be performed upon it to translate it back toward infinity

Figure 16a. Process for overunity coefficient of performance.

D-1-F16A

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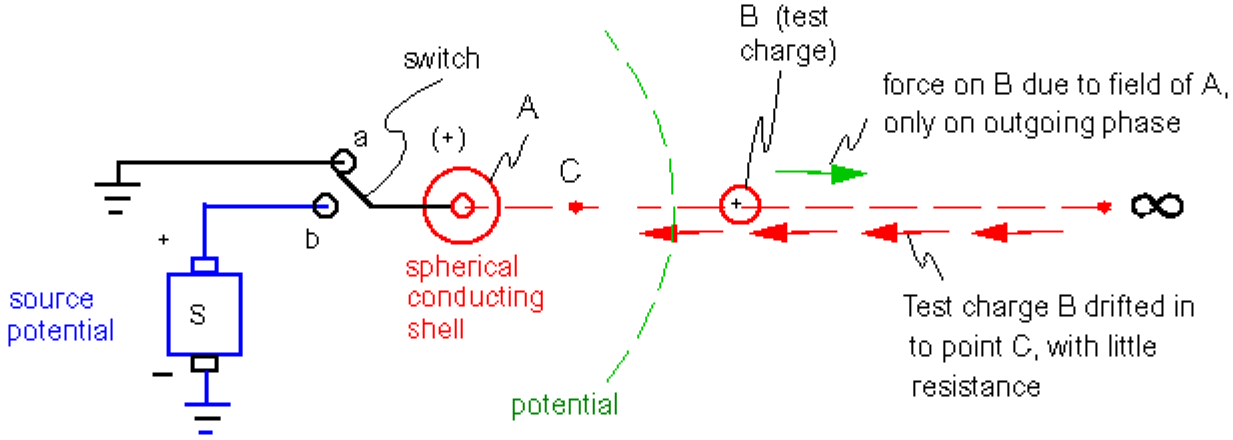
switch
a
(+)
A
C
B (test
charge)
force on B due to field of A,
only on outgoing phase
∞
b
+
S
−
source
potential
spherical
conducting
shell
potential
Test charge B drifted in
to point C, with little
resistance

Assumptions: Capacitance of A very small; charge B large, power-free switching

Switch potential off, drift in test charge B, switch potential back on. Can now get free work from repelled test charge B. Get much more free work if A is at a high potential, and charge B is large.

Figure 16 b. Demonstration of overunity efficiency

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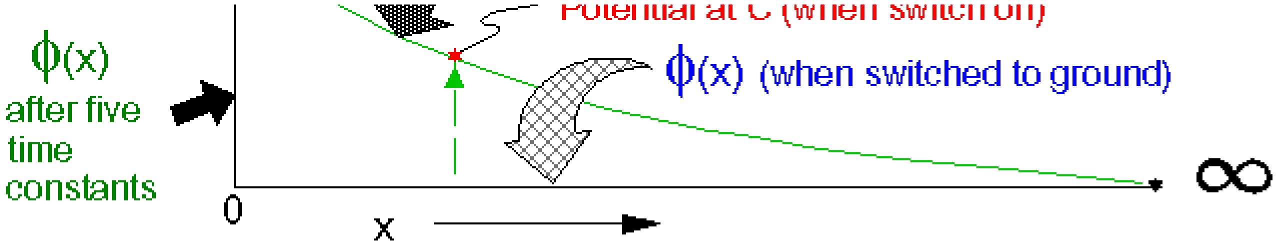

Ideally, switching the potential, rather than flowing charges, requires only minuscule overhead energy dissipation

Figure 16c. Potential to which test charge is exposed.

D-1-F16C

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Open system receiving excess energy from an external source

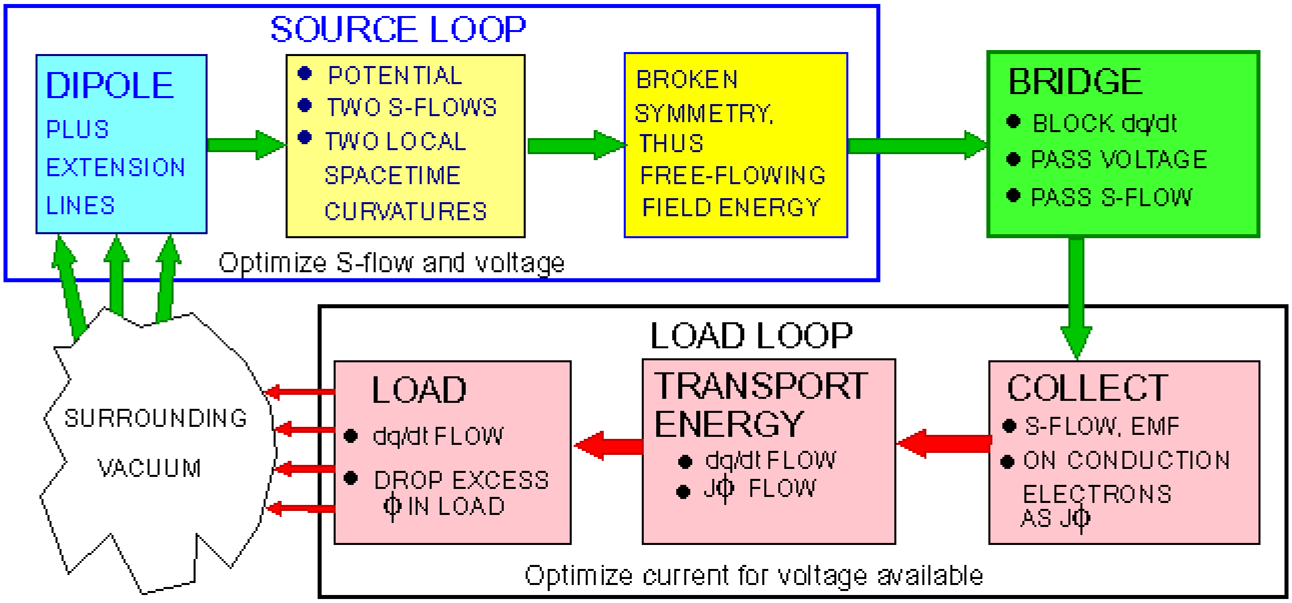
SOURCE LOOP
DIPOLE
PLUS
EXTENSION
LINES
● POTENTIAL
● TWO S-FLOWS
● TWO LOCAL SPACETIME CURVATURES
BROKEN SYMMETRY, THUS FREE-FLOWING FIELD ENERGY
Optimize S-flow and voltage
BRIDGE
● BLOCK dq/dt
● PASS VOLTAGE
● PASS S-FLOW
LOAD LOOP
SURROUNDING VACUUM
LOAD
● dq/dt FLOW
● DROP EXCESS ϕ IN LOAD
TRANSPORT ENERGY
● dq/dt FLOW
● $J\phi$ FLOW
COLLECT
● S-FLOW, EMF
● ON CONDUCTION ELECTRONS AS $J\phi$
Optimize current for voltage available

Figure 17. Operation of an overunity electrical power system.

D-1-F 17

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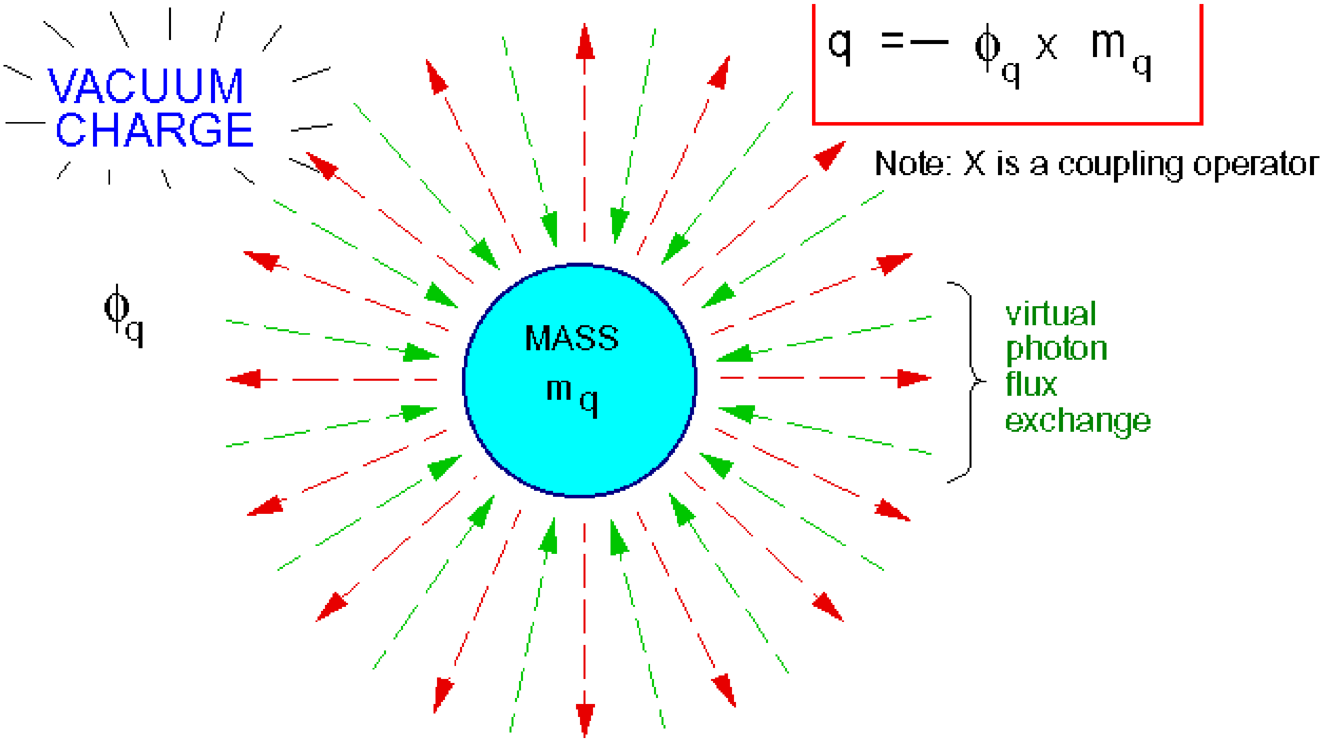
VACUUM CHARGE
$q = - \phi_q \times m_q$
Note: X is a coupling operator
ϕ_q
MASS
m_q
virtual photon flux exchange

Figure 18. An electric charge q is a broken symmetry. It continuously and violently exchanges energy with the vacuum.

D-1-F 18

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Dawn of The E-BOMB

For the wired world, the allure and the danger of high-power microwave weapons are both very real

By Michael Abrams

In these media-fueled times, when war is a television spectacle and wiping out large numbers of civilians is generally frowned upon, the perfect weapon would literally stop an enemy in his tracks, yet harm neither hide nor hair. Such a weapon might shut down telecommunications networks, disrupt power supplies, and fry an adversary's countless computers and electronic gadgets, yet still leave buildings, bridges, and highways intact. It would strike with precision, in an instant, and leave behind no trace of where it came from.

In fact, it almost certainly is already here, in the form of high-power microwave (HPM) weapons. As their name suggests, HPMs generate an intense "blast" of electromagnetic waves in the microwave frequency band (hundreds of megahertz to tens of gigahertz) that is strong enough to overload electrical circuitry. Most types of matter are transparent to microwaves, but metallic conductors, like those found in metal-oxide semiconductor (MOS), metal-semiconductor, and bipolar devices, strongly absorb them, which in turn heats the material.

An HPM weapon can induce currents large enough to melt circuitry. But even less intense bursts can temporarily disrupt electrical equipment or permanently damage ICs, causing them to fail minutes, days, or even weeks later. People caught in the burst of a microwave weapon would, by contrast, be untouched and might not even know they'd been hit. (There is, however, an effort to build a microwave weapon for controlling crowds; a person subjected to it definitely feels pain and is forced to retreat.)

"HPM sources are maturing, and one day, in the very near future, they will help revolutionize how U.S. soldiers fight wars," says Edl Schamiloglu, a professor of electrical and computer engineering at the University of New Mexico in Albuquerque and one of the leading researchers in this burgeoning field.

The fact that we seldom hear about HPM weapons only adds to their exoticism. Last spring, stories leaked to the press suggested that the Pentagon, after decades of research, had finally deployed such a device in Iraq. And when news footage showed a U.S. bomb destroying an Iraqi TV station, many informed onlookers suspected it was an electromagnetic "e-bomb."

"I saw the detonation, and then I saw the burst—which wasn't much. If they took the station out with that blast, I strongly suspect that we used Iraq as a proving ground" for HPMs, says Howard Seguine, an expert on emerging weapons technology with Decisive Analytics Corp., in Arlington, Va.

But while the U.S. military proudly paraded assorted new war-making technology during its conquest of Iraq, from unmanned combat aerial vehicles to a new satellite-based tracking network, it remained tight-lipped about this "mother of all weapons." Asked at a 5 March news briefing to confirm the rumor, General Tommy Franks, head of U.S. forces during the war, would only say, "I can't talk to you about that because I don't know anything about it."

Military secrecy is nothing new, of course. What is known about microwave weapons is that the U.S. military has actively pursued them since the 1940s, when scientists first

CHIP SIMONS

Microwave weapons researcher Edl Schamiloglu sits in front of the Pulserad-110A accelerator, which his lab at the University of New Mexico uses to produce single 100-nanosecond pulses of electron beams, each pulse emitting hundreds of megawatts of power.

observed the powerful electromagnetic shock wave that accompanied atmospheric nuclear detonations, suggesting a new class of destructiveness. While much of the work on HPMs remains classified, the Pentagon has also recently sponsored a number of U.S. university laboratories to work out the basic principles of microwave weapons, including reliable and compact nonnuclear ways of generating microwave pulses.

Many of those results are being published in the open literature [see To Probe Further, p. 30]. In fact, all you need is a reasonable grasp of physics and electrical engineering to appreciate the ingeniousness of microwave weapons. Anyone with a technical bent could probably also build a crude e-bomb in their garage, a thought that security-minded folks find rather troubling.

How they work

From the military's perspective, HPM weapons, also known as radiofrequency weapons, have many things going for them: their blast travels at the speed of light, they can be fired without any visible emanation, and they are unaffected by gravity or atmospheric conditions. The weapons come in two flavors: ultrawideband and narrowband. Think of the former as a flashbulb, and the latter as a laser; while a flashbulb illuminates across much of the visible spectrum (and into the infrared), a laser sends out a focused beam at a single frequency.

Like the flashbulb, ultrawideband weapons radiate over a broad frequency range, but with a relatively low energy (up to tens of joules per pulse). Their nanoseconds-long burst produces a shock that indiscriminately disrupts or destroys any unshielded electronic components within their reach. The bomb's destructiveness depends on the strength of the ultrawideband source, the altitude at which it is initiated, and its distance from the target [see "E-Bomb Anatomy," p. 29].

Narrowband weapons, by contrast, emit at a single frequency or closely clustered frequencies at very high power (from hundreds up to a thousand kilojoules per pulse), and some can be fired hundreds of times a second, making an almost continuous beam. These pulses can be directed at specific targets—say, a command and control complex positioned on the roof of a hospital in a densely populated neighborhood—and tuned to specific frequencies. Technologically more sophisticated than ultrawideband sources, they are far more difficult to develop, but are reusable and potentially of much greater use to the U.S. military.

Both versions wreak the same kind of havoc on just about any kind of unprotected electronic equipment. Particularly vulnerable is commercial computer equipment; anything in excess of just tens of volts can punch through gates in MOS and metal-semiconductor devices, effectively destroying the device, explains Carlo Kopp, a visiting research fellow in military strategy at the Strategic and Defense Studies Centre in Canberra, Australia, and a computer scientist who lectures at Monash University in Melbourne. The higher the circuitry's density, the more vulnerable it is, because less energy is required to overload and destroy the transistors. HPMs also produce standing waves in electrical grid wiring and telephone and communications wiring, entering through cables, antennas, and even ventilation grills. They can immobilize vehicles with electronic ignition and control systems, too.

"Since the frequency is high, this permits parasitic or stray capacitances to couple energy via paths in the circuit that may not be protected against overvoltage," Kopp explains.

The e-bomb

You could deliver an e-bomb in a number of ways: cruise missile, unmanned aerial vehicle, or aerial bomb. Whether ultrawideband or narrowband, the e-bomb consists of both a microwave source and a power source [again, see diagram, p. 29]. Ultrawideband e-bombs aim to create an electromagnetic pulse like that accompanying a nuclear detonation, except that the nuclear material is replaced with a conventional, chemical explosive. The microwave source typically relies on an extremely fast switching device, according to Kopp, who has written widely on weaponizing HPM technology. Narrowband e-bombs might use a virtual cathode oscillator (vircator) tube or a variant of a magnetron. Though termed narrowband, they don't have the high coherency seen in signal-carrying applications, Kopp says.

It takes gigawatts of power to feed an e-bomb's microwave source. For that, the flux compression generator, or FCG, is a good choice, says Kopp. Invented by Clarence ("Max") Fowler at Los Alamos National Laboratory after World War II as a byproduct of research into atomic bomb detonators, FCGs are conceptually simple. The best-known type consists of an explosive-packed copper cylinder surrounded by a helical current-carrying coil. Upon detonation, the explosion flares out the cylinder, short-circuiting the coil and progressively reducing the number of turns in the coil, thus compressing the magnetic flux. Large FCGs have produced tens of gigawatts, and they can be cascaded—connected end to end—so that the output from one stage feeds the next.

Despite its simplicity, an FCG-powered e-bomb is probably too difficult for the average terrorist to build on the cheap. For one thing, to test the assembled apparatus, you have to blow it up. For weapons researchers, the e-bomb poses other problems. The strength of the shock wave dissipates rapidly as it moves out from the explosion. To knock out an electrical power substation, for example, the weapon has to strike within about a hundred meters. "Like all microwave radiation, the effect follows an inverse square law with increasing distance," Kopp notes. Though the explosion needed to force out the current can be fairly small, it keeps the munition from being fully nonlethal and nondetectable. Also, anything that's been hardened or shielded against an electromagnetic pulse from a nuclear bomb will probably emerge unscathed.

Focused like a laser

The type of narrowband HPM weapons that the U.S. military is looking at offers everything that e-bombs do not. They're nonlethal, reuseable, and tunable, and they can be fired from miles away. Like a laser, the focused beam disperses only slightly over great distances. With a frequency range that is between about 1 and 10 GHz, they can penetrate even electronics shielded against a nuclear detonation. The deepest bunkers with the thickest concrete walls are not safe from such a beam if they have even a single unprotected wire reaching the surface.

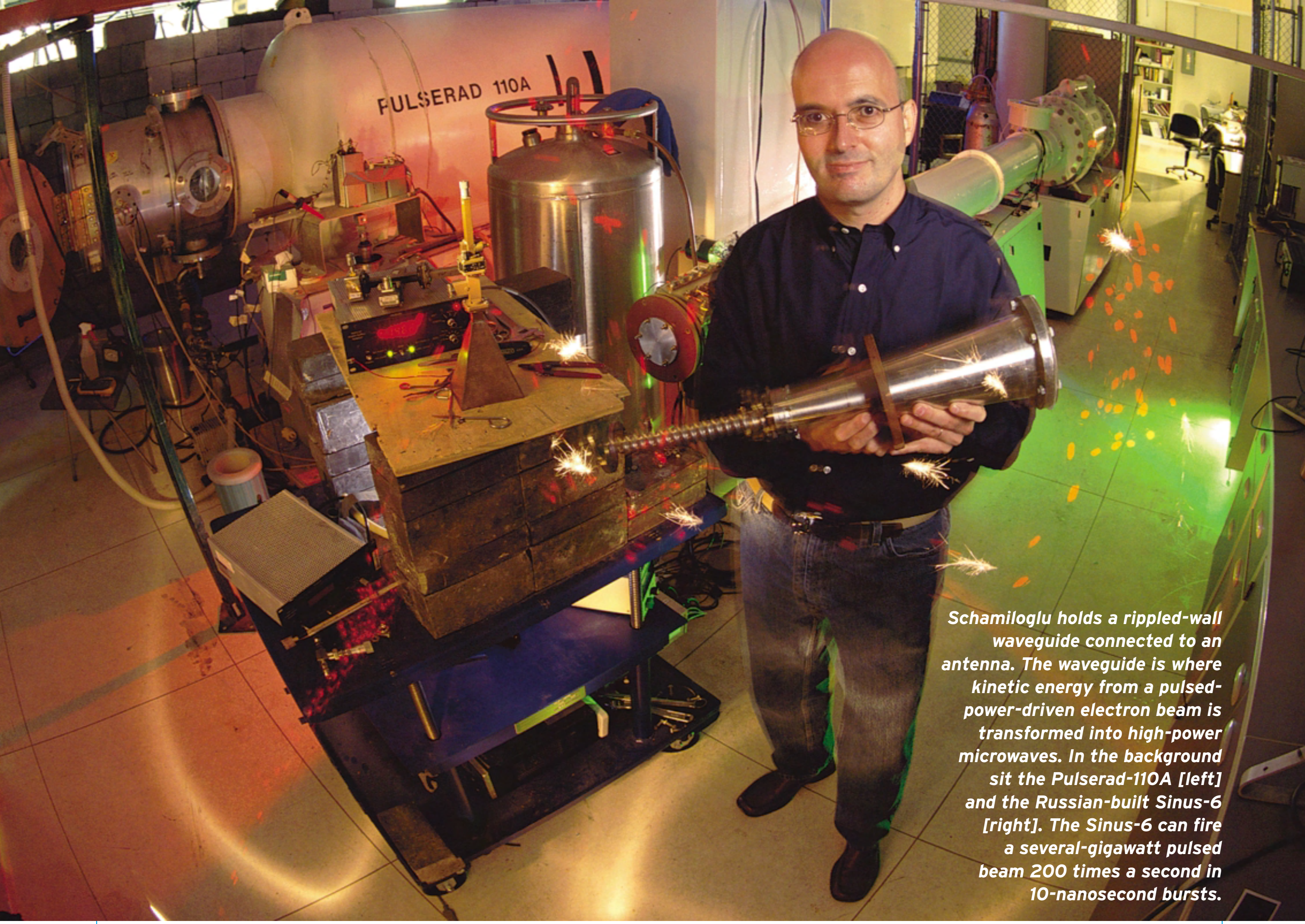

Schamiloglu holds a rippled-wall waveguide connected to an antenna. The waveguide is where kinetic energy from a pulsed-power-driven electron beam is transformed into high-power microwaves. In the background sit the Pulserad-110A [left] and the Russian-built Sinus-6 [right]. The Sinus-6 can fire a several-gigawatt pulsed beam 200 times a second in 10-nanosecond bursts.

CHIP SIMONS

A microwave beam is created much like a laser beam. Between the batteries (or other power source) and the beam sit three elements: capacitors that turn the stored energy into an electron beam of nanosecond bursts, a microwave source that converts the electron beam into focused, high-frequency electromagnetic waves, and an antenna that points and shoots the beam.

Kirtland Air Force Base, in Albuquerque, N.M., is considered the epicenter of the Pentagon's research on pulsed-power electromagnetic weapons. There, its premier pulsed-power system, the Shiva Star, is housed behind meter-thick walls [see photo, p. 28]. An Air Force spokesperson refused to comment on what goes on in their pulsed-power programs, but a fact sheet on the Web site of Kirtland's Directed Energy Directorate describes the Shiva Star as capable of producing "120 thousand volts and 10 million amps for down to one millionth of a second to produce a power flow equivalent to a terawatt."

The Kirtland machine isn't used to investigate HPM weapons per se, and its massive size makes it clearly impractical for delivering microwave beams to any spots of real military interest. Indeed, one big push in microwave weapons has been toward portability. "Back in the 1960s and 1970s, the attitude was, 'Yeah, we can do it—but we need Hoover Dam as our power supply,' " says Seguine. But just as batteries for cellphones and laptops have shrunk and gained capacity, so have sources for microwave weapons.

In the 1990s, the U.S. Air Force Office of Scientific Research set up a five-year Multidisciplinary University Research Initiative (MURI) program to explore microwave sources. One of those funded was the University of New Mexico's Schamiloglu, whose lab is located just a few kilometers down the road from where the Shiva Star sits behind tightly locked doors. Thanks in large part to his and his colleagues' efforts, the fundamental capabilities and limitations of high-power microwave sources are now better understood and appreciated.

Amidst the lead bricks and clutter in Schamiloglu's basement lab lies his masterwork: the Sinus-6. "A lot of laboratories come up with very cute names for these devices," Schamiloglu notes with a smile. "We never did." With a huge cylinder at one end connected to the long microwave source, the Sinus-6 looks like a giant torch lying on its side [see photo, above]. The big cylinder contains a Tesla transformer, whose two coils vibrate in resonance and amplify the incoming voltage "with nearly 100-percent efficiency," Schamiloglu says. Once the pulse has been transformed into an electron beam, it is guided by a strong axial magnetic field through the long tube that will turn it into microwaves.

The Sinus-6 can fire a several-gigawatt pulsed beam 200 times a second in 10-nanosecond bursts. "It has to be pulsed power because what you're after is high peak power," says Schamiloglu. "The power in the microwaves is going to depend on the electric field squared, so if you generate very large power, then the electric field is going to be big."

How big? To drive the Sinus-6's beam continuously for an entire second, you'd need to supply about 25 gigajoules—"the entire output of a typical coal-fired electrical plant for 10 full seconds," Schamiloglu says. Another reason for pulsed rather than continuous power is to avoid a problem at the output end: the air around the antenna would heat to a plasma that in turn would interfere with a continuous beam at these power levels.

The key to reaching gigawatts of power is dumping all the energy in one gigantic, nearly instantaneous pulse. A pressurized gas switch prevents the Tesla transformer from prematurely dumping as it builds up for the next pulse. The switch is filled with highly compressed and nonconducting nitrogen gas. When the transformer coils reach 700 kV, the nitrogen gas breaks down, and the pulse leaps through to the electron-beam diode.

The U.S. Air Force's Shiva Star is a pulsed-power system used to simulate the effects of nuclear weapons.

"Once you've fired the switch, it conducts, it generates a pulse," says Schamiloglu. "It conducts because you've made a plasma channel out of the gas. Then you have to wait for that plasma to recombine and form a neutral gas again. A typical time scale for this thing to recombine and fizzle out and be a neutral gas again is probably on the order of milliseconds."

Among the best candidates for supplying microwaves is the backward wave oscillator; it has the advantage of being tunable (plus or minus 20 percent) and producing output in the 4–10-GHz range. To turn the kinetic energy from the Sinus-6's electron beam into high-power microwaves, the oscillator uses a rippled-wall waveguide, also called a slow-wave structure [see photo, p. 27].

The structure sets up standing electromagnetic waves in such a way that energy is rapidly transferred to them from the incoming beam of relativistic electrons from the Sinus-6. This growing energy initially propagates in the opposite direction of the beam's movement—hence the device's name—and is then reflected forward and radiated in the form of high-power microwaves. Backward wave oscillators, by the way, are also being tested as a way to push giant sails into outer space, to detect space debris, and to clear minefields.

Being able to tune an HPM weapon comes in handy when a particular target proves invulnerable to a particular frequency. "Experience has shown that if the frequency is slightly altered, measurable effects are discerned," Schamiloglu notes. People used to believe that varying the frequency of HPMs wasn't practical, but Schamiloglu and his students proved them wrong.

Coincidence and curiosity led to their discovery. Schamiloglu first acquired the Sinus-6 from Russian researchers in the early 1990s. (The Soviet Union once boasted a sophisticated program to develop microwave weapons; after its collapse, parts of that legacy were put up for sale, to the delight of researchers like Schamiloglu.) But once the apparatus was assembled in his New Mexico lab, he couldn't get it to operate as promised, so Russian colleagues flew over to help.

"One of them took the RF structure [the rippled-wall waveguide] and started hammering on the thing," Schamiloglu recalls. When they tried it again, everything worked. "I was baffled why manhandling this RF structure—ramming it in—could affect the power so much," says Schamiloglu. So he started a series of experiments in which he slightly displaced the backward wave oscillator by increments. With a little experimentation assisted by computer simulations, his team found that the frequency could be adjusted by changing the distance between the diode and the microwave source. The result is that the backward wave oscillator is now one of the few pulsed-power HPM sources that can be tuned.

Smaller is better

One disadvantage of this oscillator, however, is that it needs an external magnetic field to create the microwave beam, a major hurdle to making the whole system smaller. The size of the Sinus-6 and attendant equipment in Schamiloglu's basement suggests that the U.S. military is nowhere near fielding a narrowband HPM weapon. "When I first started working on high-power narrowband sources, we joked that you can do more damage dropping this equipment on someone than you can by using it," he recalls. "People know how to make microwave sources in the laboratory. The challenge is to take this and package it into an autonomous platform and have it function at the same parameter levels."

Schamiloglu is now hard at work under a new MURI program to study the possibilities of making a compact pulsed-power source. Current narrowband generators are typically several meters long, batteries not included. Schamiloglu and his colleagues are studying how to incorporate novel ceramics into pulsed-power systems, which they believe will allow the length of such sources to be halved. The trick is identifying materials with a high dielectric constant that can also survive the harsh electric fields. "Materials will be an important part in making the next giant leap," he says.

Life in a glass house

Among those agreeing that narrowband HPM weapons will need more refining before they become truly useful to the military is Loren B. Thompson, chief operating officer of the Lexington Institute, a military think tank based in Arlington, Va. He looked

U.S. AIR FORCE

E-Bomb Anatomy

In this hypothetical design for an e-bomb, a two-stage flux compression generator provides gigawatts of power to the virtual cathode oscillator (vircator), which produces the high-power microwaves. The bomb's destructiveness depends on the microwave source and target's vulnerability to electromagnetic attack, among other things, but a 10-GW, 5-GHz HPM device would have a "lethal" footprint 400 to 500 meters across, producing field strengths of several kilovolts per meter. Such an e-bomb would wreak major havoc if detonated over a heavily populated area.

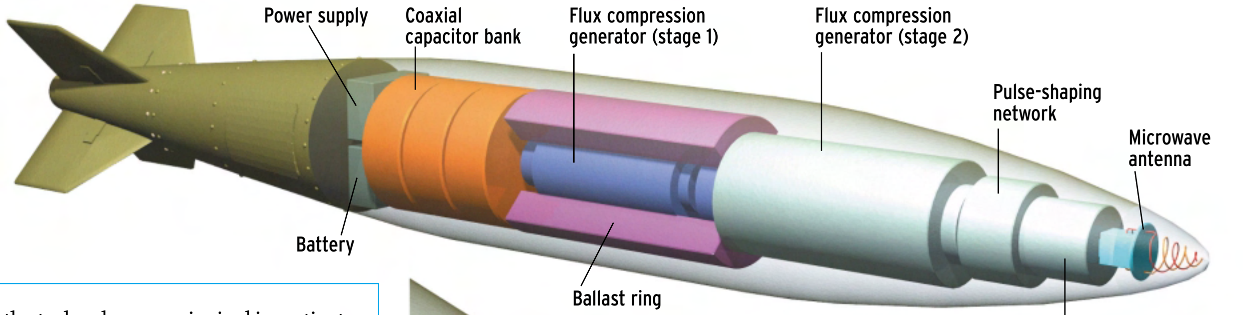
Power supply
Coaxial capacitor bank
Flux compression generator (stage 1)
Flux compression generator (stage 2)
Pulse-shaping network
Microwave antenna
Battery
Ballast ring

Vircator tube

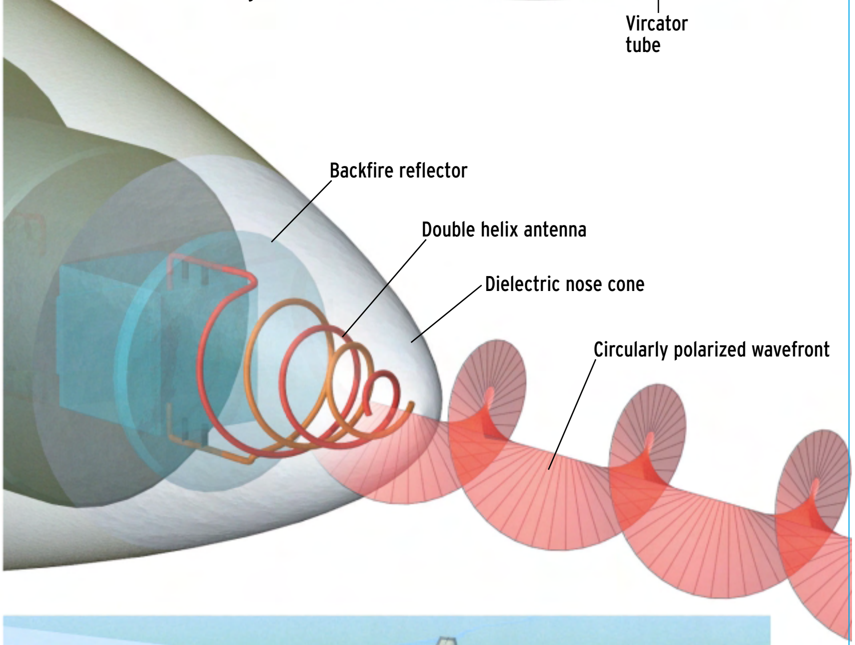
Backfire reflector
Double helix antenna
Dielectric nose cone
Circularly polarized wavefront

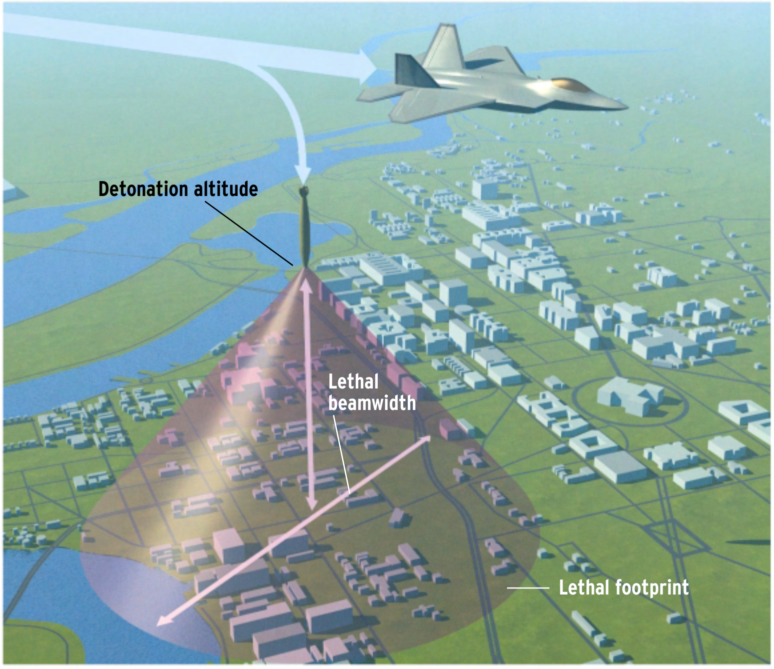
Detonation altitude
Lethal beamwidth
Lethal footprint

ILLUSTRATION: JOHN MACNEILL SOURCE: CARLO KOPP

at the technology as principal investigator of "Directed-Energy Weapons: Technologies, Applications and Implications," a report that the institute put out in February. "We have some fairly rudimentary weapons that we're ready to use," Thompson says. "This is going to be a very important weapons technology, and the basic physical principles are well understood. But the military is having some difficulty in assimilating them."

Thompson's report speaks of a future with satellites delivering missile-debilitating microwaves, unmanned vehicles that fly by and destroy communications systems, and war without civilian casualties. But the fact remains that it's the U.S. military—as well as U.S. financial institutions, PCs, and Game Boys—that will be the most susceptible to such weapons.

"One of the things that happened during the last 10 years—as the Pentagon fell in love with network-centered warfare—is that we purchased a lot of very fragile digital systems off the shelf from commercial sources," Thompson notes. Such moves were taken in the name of cost and efficiency, but the resulting equipment is almost certainly more vulnerable to electromagnetic attack than the vacuum tubes and heavy metal-encased electronics of yesteryear.

"Computers become more vulnerable as the voltage at which they operate becomes smaller," says Victor Granatstein, professor of electrical engineering at the University of Maryland in College Park, who is studying the effects of microwave pulses on integrated electronics. "When our opponent was the

Soviet Union, the electronics were much more robust because they weren't miniaturized. Now they have very thin oxide layers that can easily break down." Wireless networking makes matters worse. Computers and other communications devices now have antennas attached, giving an electromagnetic pulse a direct pathway to its guts.

Meanwhile, the U.S. Navy no longer requires that all its hardware be hardened against nuclear electromagnetic pulses. It deemed that maintaining those standards was too costly and slowed down the integration of new technology. The presumption was that after the Cold War, nobody would be using nuclear bombs, says the Lexington Institute's Thompson. "Whenever I ask the admirals, 'Well, what if someone did use a nuclear bomb?,' I just get this kind of blank I-don't-have-an-answer-for-that sort of look."

Don't Try This at Home

First things first: we do not under any circumstances recommend that you build your own electromagnetic weapon. But if you're hellbent on adding to the mayhem, cheaply and without too much studying, you might try a high-energy radiofrequency, or HERF, gun. As described by engineering student Rostislav Persion on his Web site, Voltage Labs, which is devoted to do-it-yourself electromagnetic weapons, you can make one from a microwave oven.

Before you begin, though, wait until everyone else has left the house. Next, take apart the microwave oven, but don't disconnect any of the components; manufacturers intentionally make this hard to do, so you may end up just breaking the machine. Inside you will find the oven's microwave source: the magnetron. Wrap a tube of sheet metal around it to act as a waveguide. Your power source is the house's ac, so just plug in the oven and point it at your TV. Warning: there's a real possibility that you will burn yourself instead.

For schematics and a demonstration, head to the Web at http://www.voltsamps.com/pages/projects/herf004/. —*M.A.*

In the wrong hands

The scariest part of microwave weapons may be that crude forms of the technology are readily available to anyone right now. "Any nation with a 1950s technology base capable of designing and building nuclear weapons and radars" can build an e-bomb, says military analyst Kopp. Indeed, more than 20 countries now have programs to develop some type of RF weapon.

"The more widespread the technology is, the more likely that people with nefarious purposes will have access. It's just an inescapable fact," says Thompson. "I don't know what we're going to do. Nobody in Washington knows. I imagine that the way the clear thinking starts is with a catastrophe."

Criminals and pranksters have already started exploiting that weakness. In one of the more harmless applications, a Japanese scam artist rigged up a weak microwave generator inside a suitcase to rip off a pachinko parlor. When he placed the suitcase next to one of the machines (which is something like a cross between a slot machine and a pinball machine) and turned it on, the pachinko machine went haywire and disgorged a pile of coins. The perp managed the trick several times before he was caught.

Other press accounts hint at electromagnetic weapons being deployed by Chechen troops, and by an unnamed assailant trying to topple London's futures market [see "Don't Try This at Home," above].

Thankfully, protecting yourself against the microwave-enabled goofballs of the world isn't too difficult. "It is analogous to existing techniques used to trap RF interference inside equipment, except that the higher power levels require special measures," Kopp notes. Rooms or equipment chassis must become electrically sealed Faraday cages, and protective devices must be added wherever cables enter the protected volume. "Optical fibers are very useful in this game."

Such protective measures are a lot cheaper to design in from the beginning than to add on afterward, says Howard Seguine. "The general rule of thumb is that if you do the hardening during the design phase, it increases the cost roughly 1 percent. If you do it afterward, it may cost as much as 30 percent more."

But maybe hardening is a waste of time. Arthur Varanelli, a Raytheon Co. engineer who has helped write several IEEE standards for electromagnetic field measurement, human exposure, and safety, is skeptical that a malicious prankster could exploit the technology.

"Some of this stuff is just so far out there," Varanelli says. "I just don't see people running around with Buck Rogers ray guns. It's great for a science fiction writer, great to prey upon people's fears." He scoffs at the suggestion that a do-it-yourselfer could build a microwave weapon potent enough to do real damage. "People can put tacks in the road. Are we worried about electronic tacks in the air?"

The wide disparity in opinions and the uncertainty about microwave weapons, from Loren Thompson on one end to Arthur Varanelli on the other, are all part of what makes them so powerful, says military analyst John Pike, who is director of GlobalSecurity.org (Alexandria, Va.). "It all depends on the complex interactions between the weapon and the target," he notes. "I can set up a strap-down chicken test that makes [an HPM weapon] look pretty good. But as soon as I start getting into real-world targets, maybe it doesn't work so well."

"Part of the story is we don't know what the story is," Pike says. "These are weapons that by their nature seek the shadows. And unlike cluster bombs or atomic bombs, they aren't going to leave behind unambiguous evidence of their use." ●

To Probe Further

For a detailed technical discussion of high-power microwaves, see *High-Power Microwave Sources and Technologies*, edited by IEEE Fellows Robert J. Barker and Edl Schamiloglu (Wiley–IEEE Press, 2001). Schamiloglu is also coauthor, with James Benford and John Swegle, of the forthcoming *High-Power Microwaves*, 2nd edition (Institute of Physics, 2004).

The truly prepared, or merely paranoid, will want to consult Carlo Kopp's "Hardening Your Computing Assets" at http://www.globalsecurity.org/military/library/report/1997/harden.pdf.

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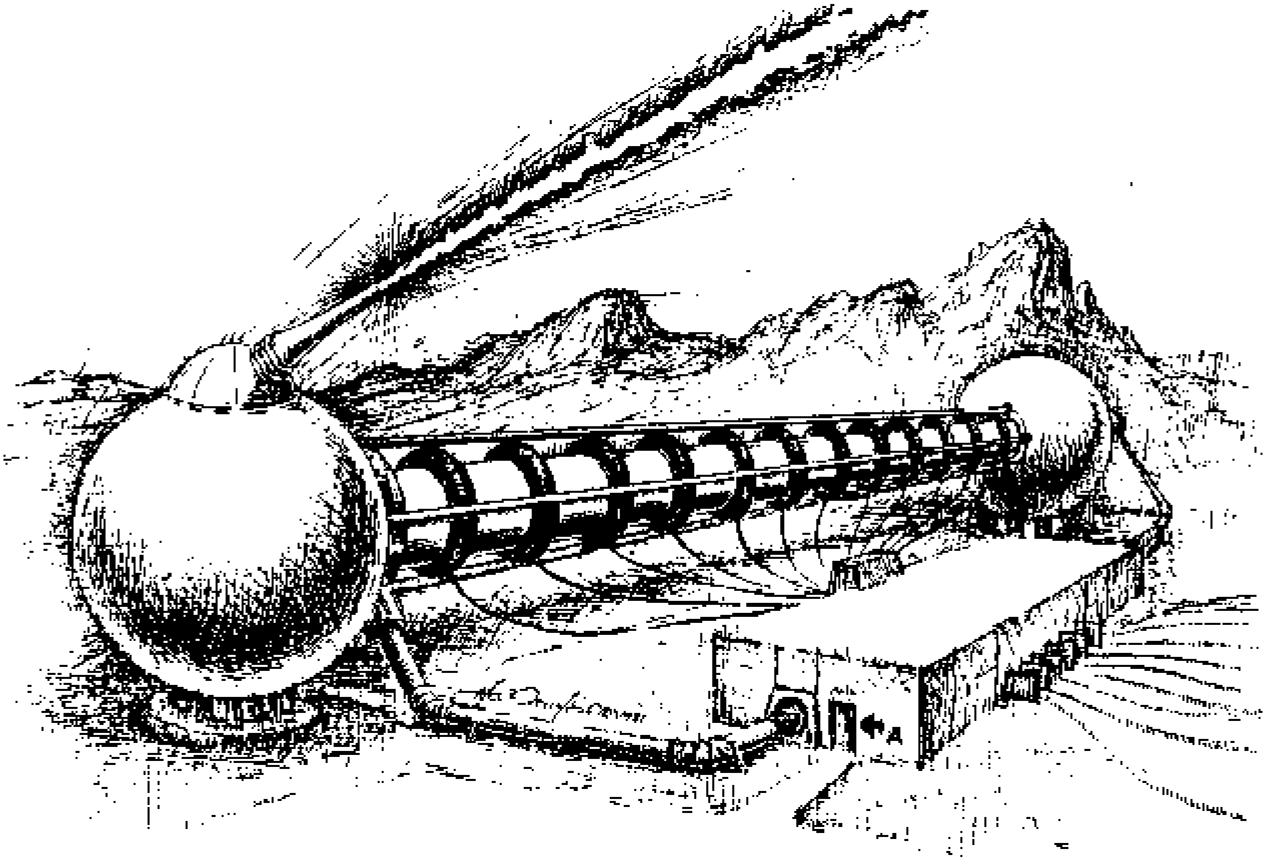

Scalar Potential Interferometer

Figure 6. Multimode Tesla Weapon

In the 1930's Tesla announced other bizarre and terrible weapons: a death ray, a weapon to destroy hundreds or even thousands of aircraft at hundreds of miles range, and his ultimate weapon to end all war -- the Tesla shield, which nothing could penetrate. However, by this time no one any longer paid any real attention to the forgotten great genius. Tesla died in 1943 without ever revealing the secret of these great weapons and inventions.

Unfortunately, today in 1981 the Soviet Union has long since discovered and weaponized the Tesla scalar wave effects. Here we only have time to detail the most powerful of these frightening Tesla weapons -- which Brezhnev undoubtedly was referring to in 1975 when the Soviet side at the SALT talks suddenly suggested limiting the development of new weapons "more frightening than the mind of man had imagined." One of these weapons is the Tesla howitzer recently completed at the Saryshagan missile range and presently considered to be either a high-energy laser or a particle beam weapon, (See Aviation Week & Space Technology, July 28, 1980, p. 48 for an artist's conception.)

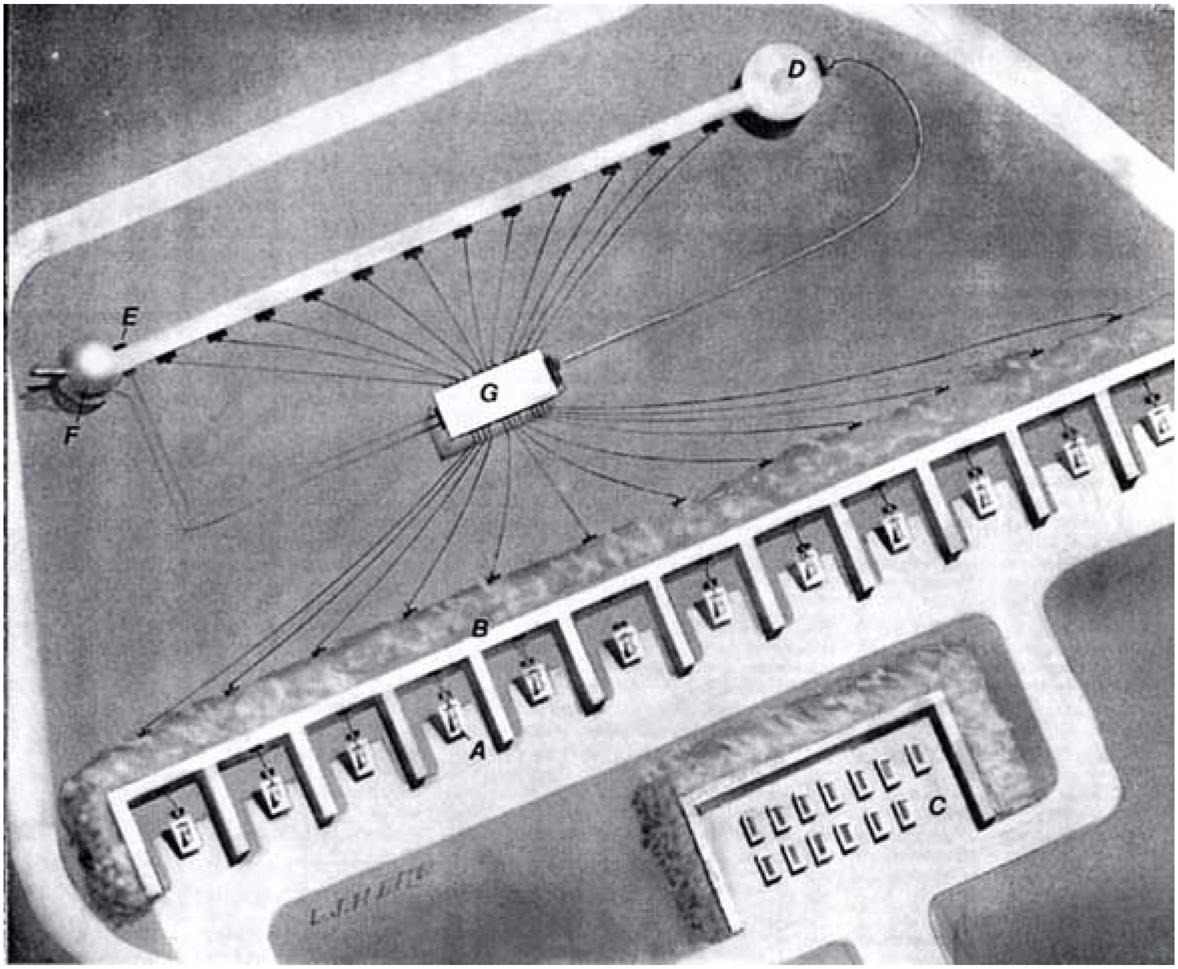

Aviation Week & Space Technology July 28, 1980

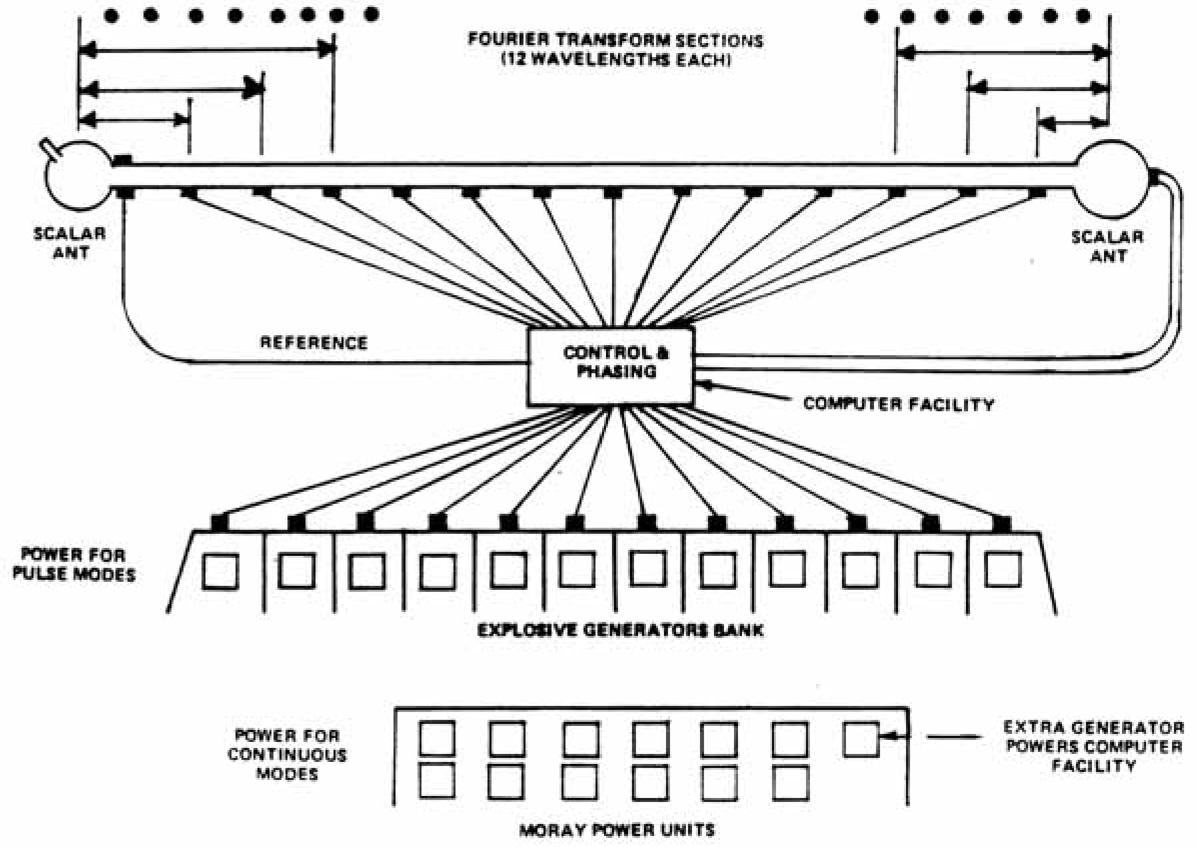
FOURIER TRANSFORM SECTIONS
(12 WAVELENGTHS EACH)
SCALAR ANT
SCALAR ANT
REFERENCE
CONTROL & PHASING
COMPUTER FACILITY
POWER FOR PULSE MODES
EXPLOSIVE GENERATORS BANK
POWER FOR CONTINUOUS MODES
EXTRA GENERATOR POWERS COMPUTER FACILITY
MORAY POWER UNITS

Figure 7. Tesla Weapons at Saryshagan

The Saryshagan howitzer actually is a huge Tesla scalar interferometer with four modes of operation. One continuous mode is the Tesla shield, which places a thin, impenetrable hemispherical shell of energy over a large defended area. The 3-dimensional shell is created by interfering two Fourier-expansion, 3-dimensional scalar hemispherical patterns in space so they pair-couple into a dome-like shell of intense, ordinary electromagnetic energy. The air molecules and atoms in the shell are totally ionized and thus highly excited, giving off intense, glowing light. Anything physical which hits the shell receives an enormous discharge of electrical energy and is instantly vaporized -- it goes pfft! like a bug hitting one of the electrical bug killers now so much in vogue.

If several of these hemispherical shells are concentrically stacked, even the gamma radiation and EMP from a high altitude nuclear explosion above the stack cannot penetrate all the shells due to repetitive absorption and reradiation, and scattering in the layered plasmas.

In the continuous shield mode, the Tesla interferometer is fed by a bank of Moray free energy generators, so that enormous energy is available in the shield. A diagram of the Saryshagan-type Tesla howitzer is shown in figure 7. Hal Crawford's fine drawing of the interferometer end of the Tesla howitzer is shown in figure 6. Hal's exceptional rendition of the Tesla shield produced by the howitzer is shown in figure 8.

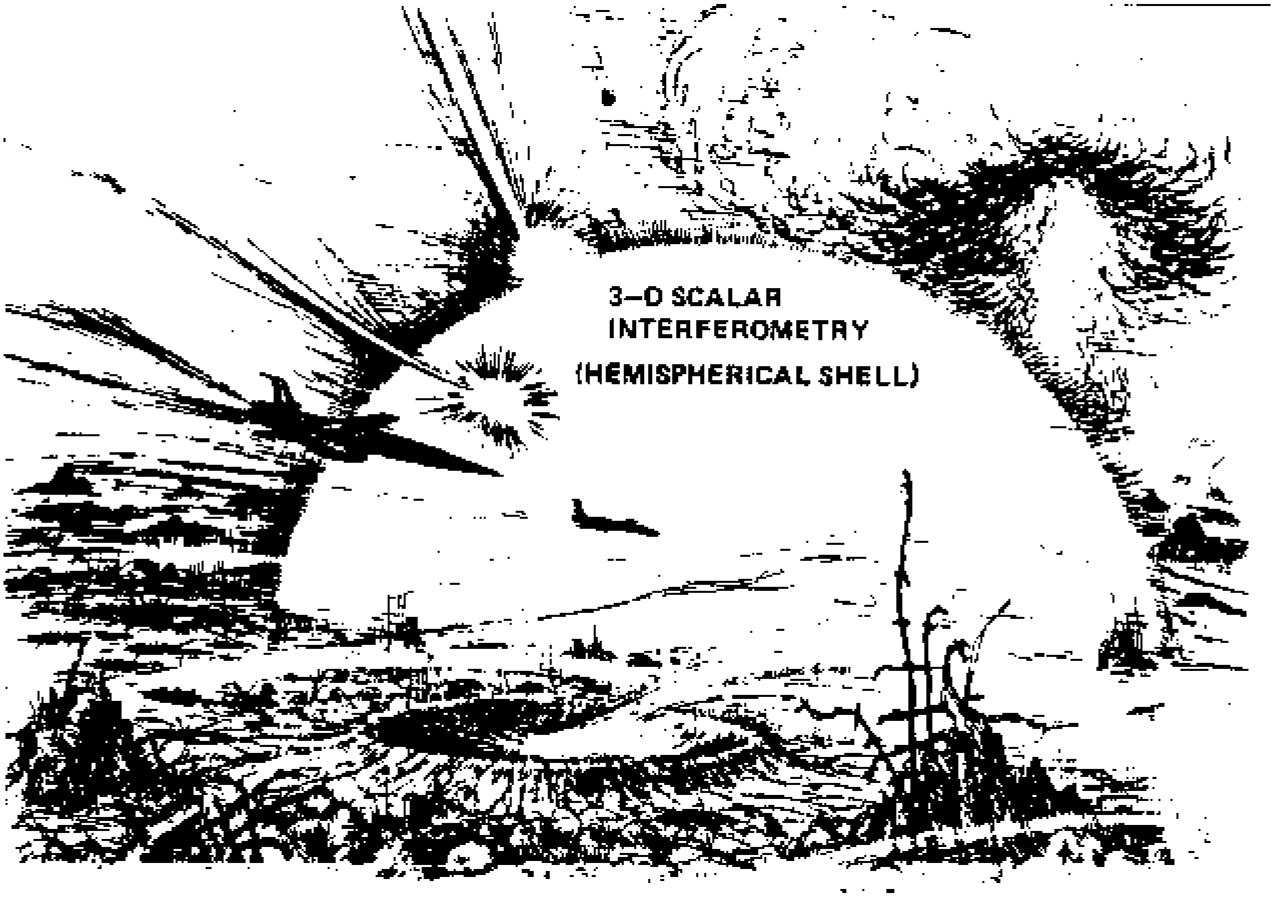
3-D SCALAR
INTERFEROMETRY
(HEMISPHERICAL SHELL)

Figure 8. The Tesla Shield

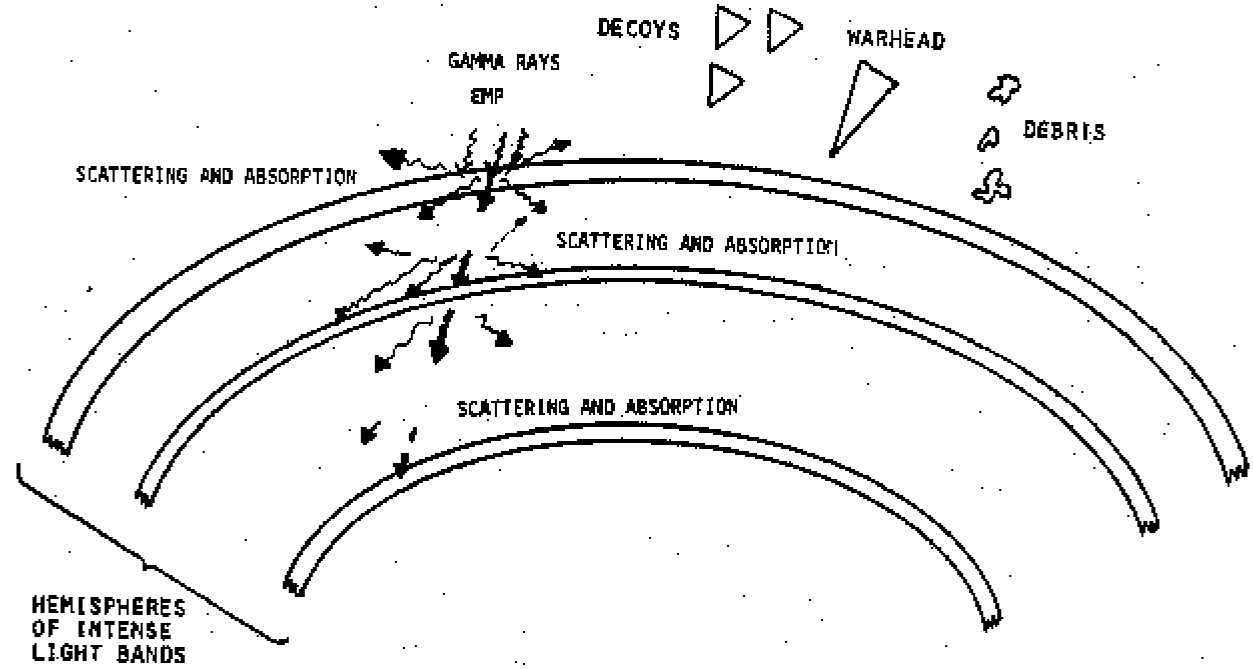
DECOYS
WARHEAD
GAMMA RAYS
EMP
DEBRIS
SCATTERING AND ABSORPTION
SCATTERING AND ABSORPTION
SCATTERING AND ABSORPTION
HEMISPHERES
OF INTENSE
LIGHT BANDS

Figure 9. Tesla Terminal Area Defense System

In the pulse mode, a single intense 3-dimensional scalar phi-field pulse form is fired, using two truncated Fourier transforms, each involving several frequencies, to provide the proper 3-dimensional shape (Figure 10). This is why two scalar antennas separated by a baseline are required. After a time delay calculated for the particular target, a second and faster pulse form of the same shape is fired from the interferometer antennas. The second pulse overtakes the first, catching it over the target zone and pair-coupling with it to instantly form a violent EMP of ordinary vector (Hertzian) electromagnetic energy. There is thus no vector transmission loss between the howitzer and the burst. Further, the coupling time is extremely short, and the energy will appear sharply in an "electromagnetic pulse (EMP)" strikingly similar to the 2-pulsed EMP of a nuclear weapon.

This type weapon is what actually caused the mysterious flashes off the southwest coast of Africa, picked up in 1979 and 1980 by Vela satellites. The second flash, e.g., was in the infrared only, with no visible spectrum. Nuclear flashes do not do that, and neither does superlightning, meteorite strikes, meteors, etc. In addition, one of the scientists at the Arecibo Ionospheric Observatory observed a gravitational wave disturbance -- signature of the truncated Fourier pattern and the time-squeezing effect of the Tesla potential wave -- traveling toward the vicinity of the explosion.

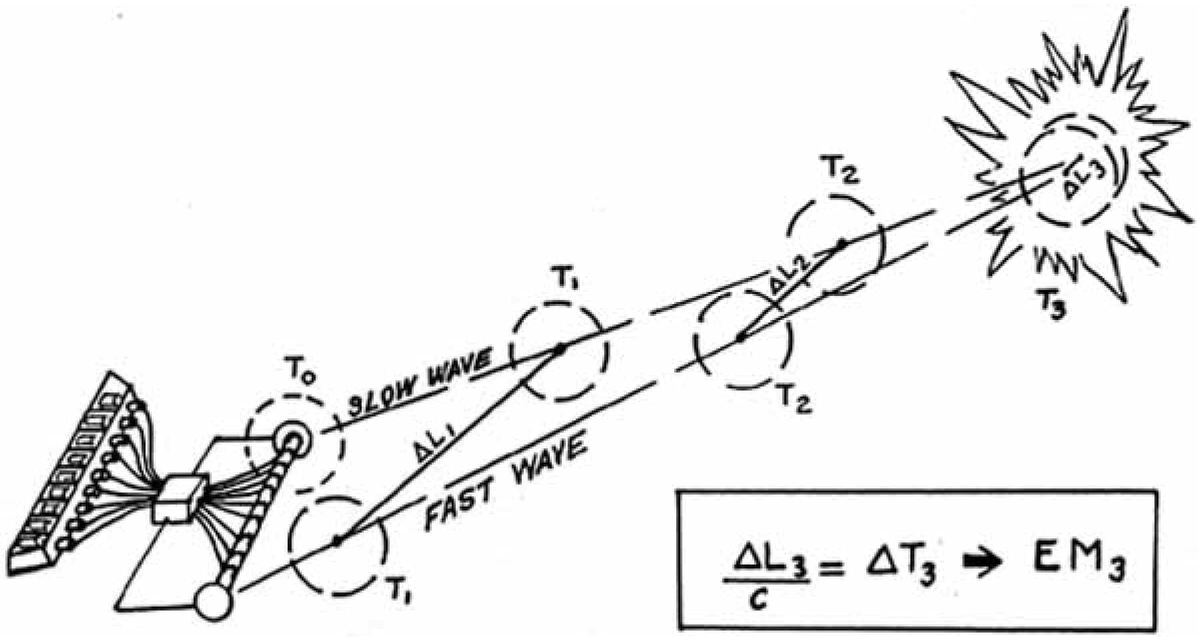

TESLA HOWITZER
(SCALAR INTERFEROMETER)

Figure 10. "Nuclear" Flashes off the Coast of Africa

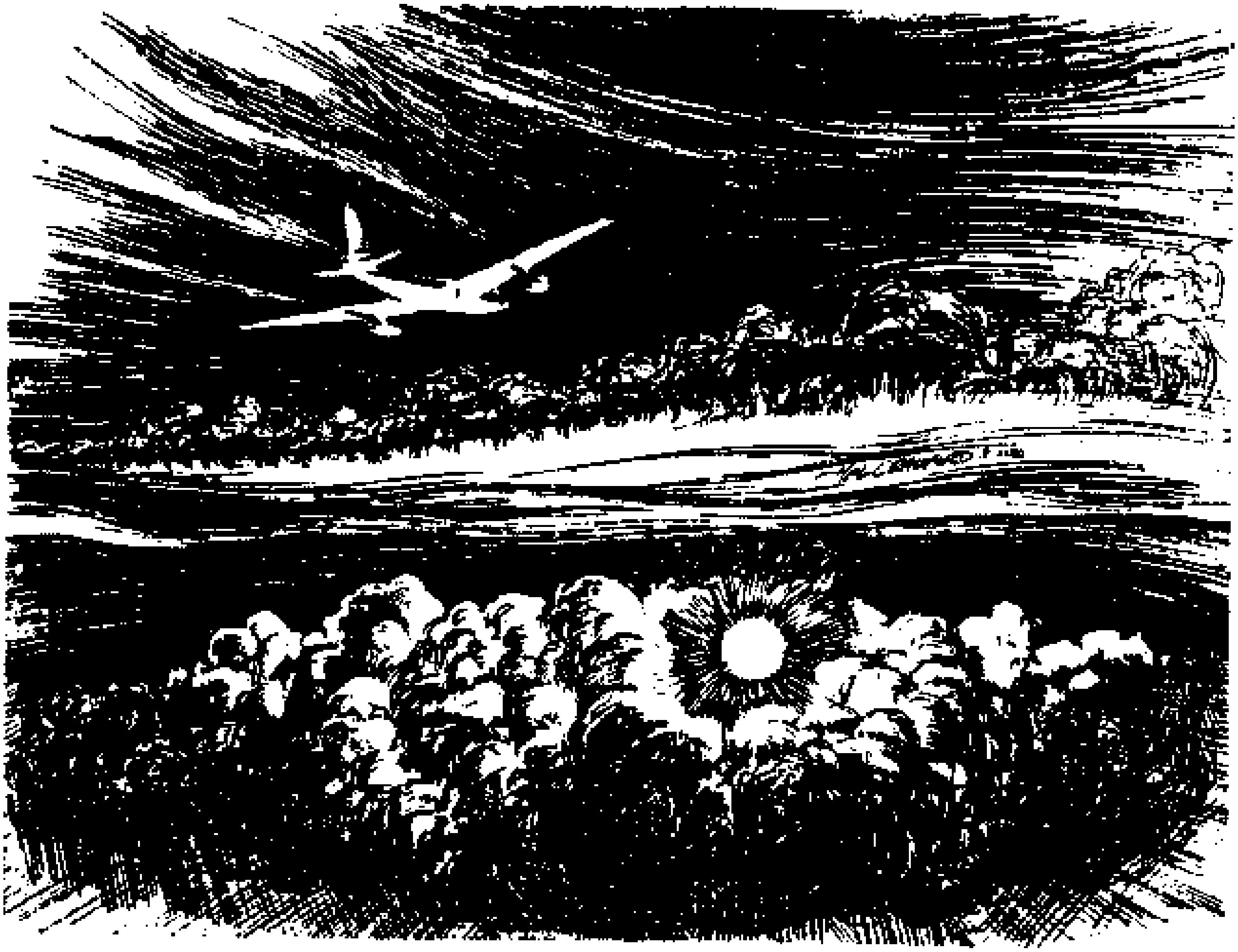

Lithuania - 10 Sep 1976 - British European Airways Flight #831 between Moscow and London

CIA Report Released under FOIA

Figure 11. Continuous Tesla Fireball

The pulse mode may be fed from either Moray generators or -- if the Moray generators have suffered their anomalous "all fail" malfunction -- ordinary explosive generators. Thus the Tesla howitzer can always function in the pulse mode, but it will be limited in power if the Moray generators fail.

In the continuous mode, two continuous scalar waves are emitted -- one faster than the other -- and they pair-couple into vector energy at the region where they approach an in-phase condition. In this mode, the energy in the distant "ball" or geometric region would appear continuously and be sustained -- and this is Tesla's secret of wireless transmission of energy at a distance without any losses. It is also the secret of a "continuous fireball" weapon capable of destroying hundreds of aircraft or missiles at a distance. An example of a Soviet test of this mode of operation is shown in figure 11.

Witness to a super weapon?

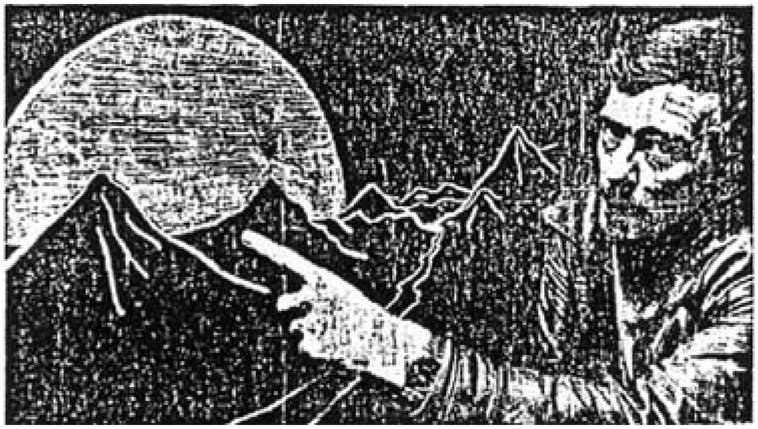

Nick Downie describes the strange lurid glow that flared silently over the Hindu Kush

THE SUNDAY TIMES, 17 AUGUST 1980

(Multiple incidents in Sept., 1979)

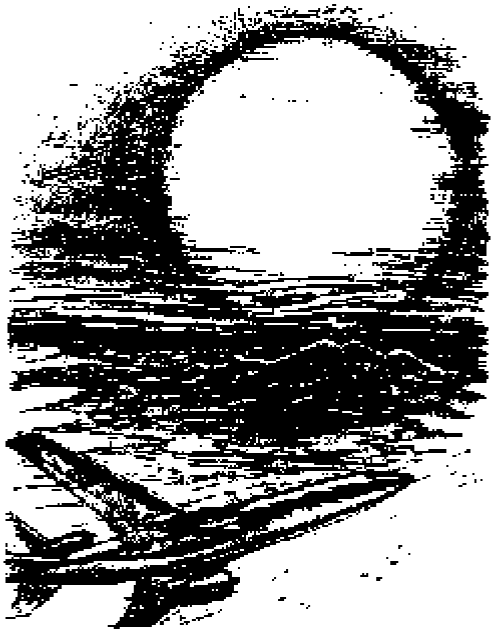

TEHERAN, IRAN 17 JUNE 1966

SEEN FROM NEAR MEHRABAD AIRPORT

OBSERVED 4-5 MINUTES

SEEN BY 2 AIRCRAFT

CIA REPORT RELEASED UNDER FOIA

Figure 12. Tesla EMP Globe

The volume of the Tesla fireball can be vastly expanded to yield a globe which will not vaporize physical vehicles but will deliver an EMP to them to dud their electronics. A test of this mode is shown in figure 12. (See also Gwynne Roberts, "Witness to a Super Weapon?", the London Sunday Times, 17 August 1980 for several other tests of this mode at Saryshagan, seen from Afghanistan by British TV cameraman and former War Correspondent Nick Downie.)

If the Moray generators fail anomalously, then a continuous mode limited in power and range could conceivably be sustained by powering the interferometer from more conventional power-sources such as advanced magnetohydrodynamic generators.

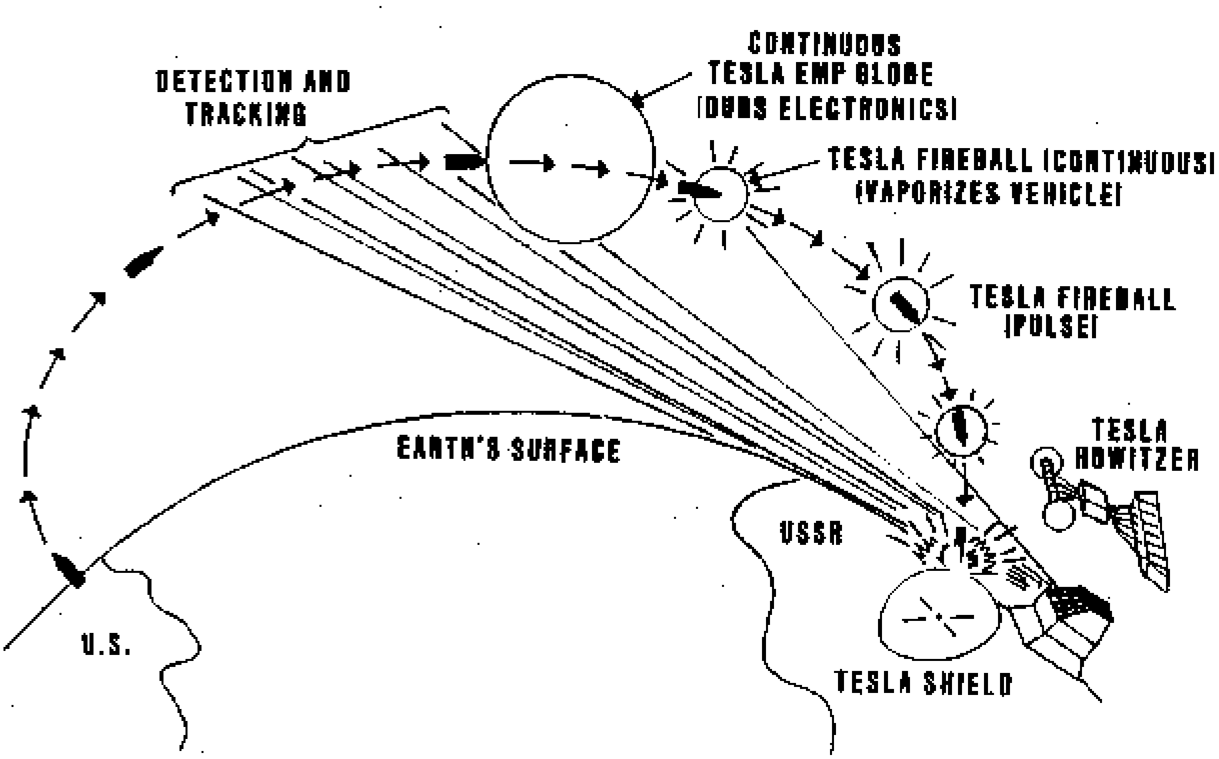
DETECTION AND TRACKING
CONTINUOUS TESLA EMP GLOBE (DUDS ELECTRONICS)
TESLA FIREBALL (CONTINUOUS) (VAPORIZES VEHICLE)
TESLA FIREBALL (PULSE)
TESLA HOWITZER
EARTH'S SURFACE
USSR
U.S.
TESLA SHIELD

Figure 13. Tesla ABM Defenses

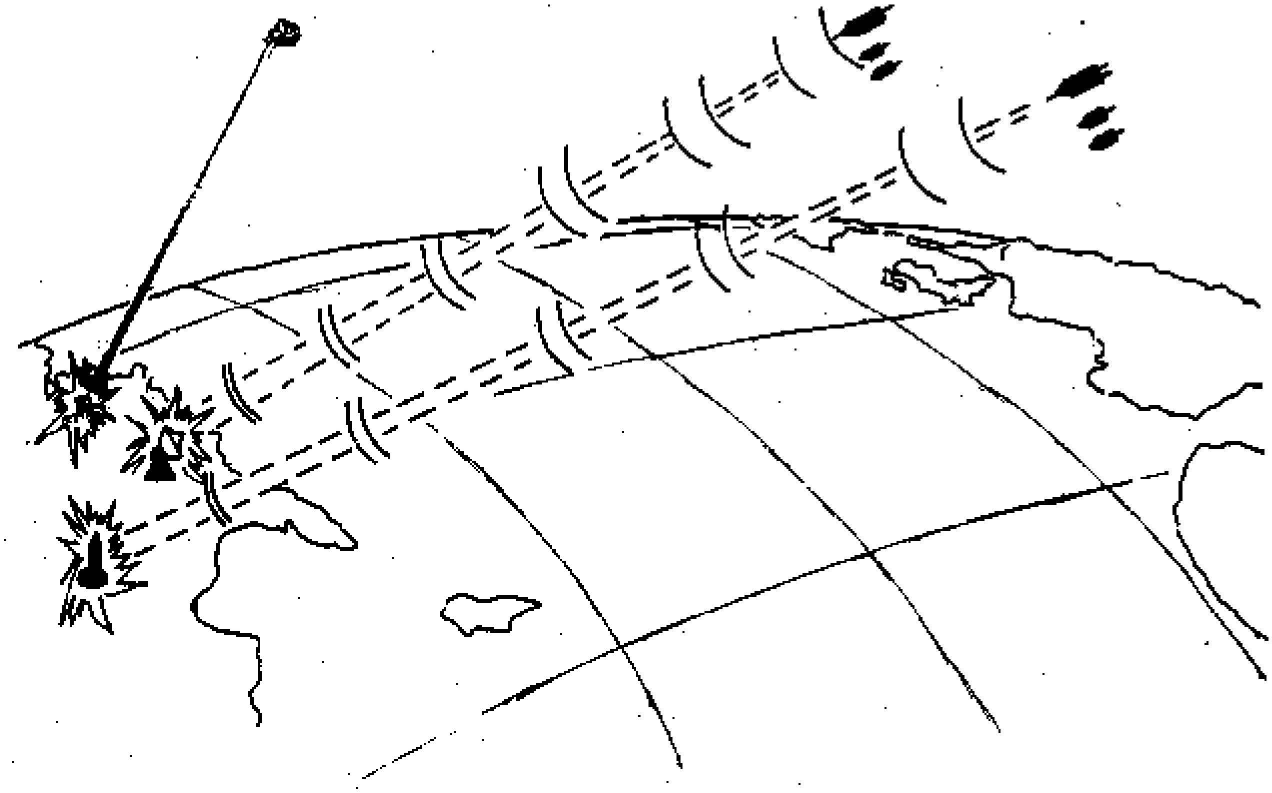

Figure 14. Moray/Tesla Technology: Star Wars Now

Typical strategic ABM uses of Tesla weapons are shown in figure 13. In addition, of course, smaller Tesla howitzer systems for anti-tactical ballistic missile defense of tactical troops and installations could be constituted of more conventional field missile systems using paired or triplet radars, of conventional external appearance, in a scalar interferometer mode.

With Moray generators as power sources and multiply deployed reentry vehicles with scalar antennas and transmitters, ICBM reentry systems now can become long range "blasters" of the target areas, from thousands of kilometers distance (figure 14). Literally, "Star Wars" is liberated by the Tesla technology. And in air attack, jammers and ECM aircraft now become "Tesla blasters." With the Tesla technology, emitters become primary fighting components of stunning power.

The potential peaceful implications of Tesla waves are also enormous. By utilizing the "time squeeze" effect, one can get antigravity, materialization and dematerialization, transmutation, and mindboggling medical benefits. One can also get subluminal and superluminal communication, see through the earth and through the ocean, etc. The new view of phi-field also provides a unified field theory, higher orders of reality, and a new super-relativity, but detailing these possibilities must wait for another book.

With two cerebral brain halves, the human being also has a Tesla scalar interferometer between his ears. And since the brain and nervous system processes avalanche discharges, it can produce (and detect) scalar Tesla waves to at least a limited degree. Thus a human can sometimes produce anomalous spatiotemporal effects at a distance and through time. This provides an exact mechanism for psychokinesis, levitation, psychic healing, telepathy, precognition, postcognition, remote viewing, etc. It also provides a reason why an individual can detect a "stick" on a radionics or Hieronymus machine (which processes scalar waves), when ordinary detectors detect nothing. Unfortunately there is not room to develop the implications of this human Tesla interferometry in detail, for that must wait for yet another book, presently in its initial stages, that Hal Crawford and I are writing.

Table 5. Orders of Reality

- **PHOTONS ARE**
  - **> PAIR-COUPLED SCALARS**
  - **> VELOCITY-LIMITED TO C**
  - **> CARRIERS OF T**

- **PHOTON INTERACTION**
  - **> IS UBIQUITOUS**
  - **> PRODUCES $\dot{T}$ = C**
  - **> YIELDS 1st ORDER REALITY**

- **SCALAR O WAVES**
  - **> NOT VELOCITY-LIMITED**
  - **> YIELD HIGHER ORDER REALITIES**

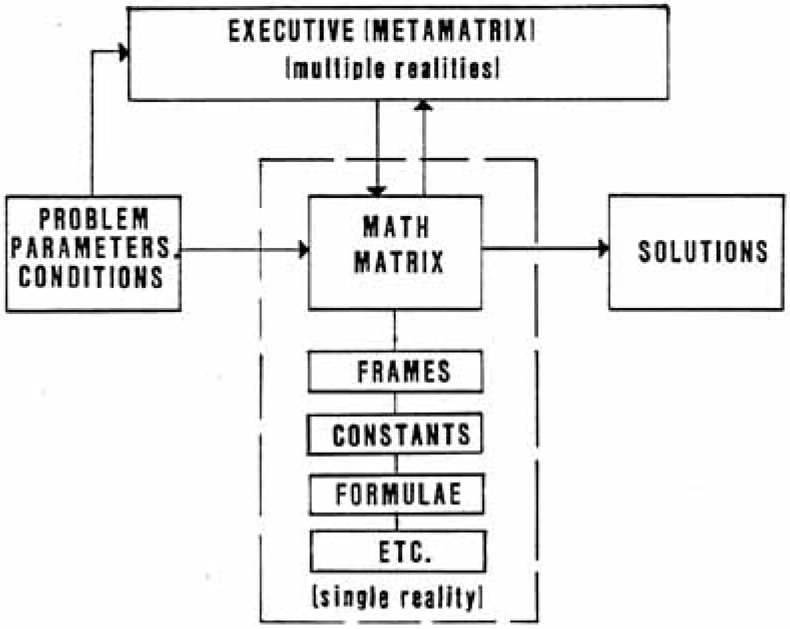

Figure 15. Implications of Tesla Potential

At the July 1981 U.S. Psychotronics Association's Annual Conference in Dayton, Ohio, I presented the first rough paper on the Tesla secret and scalar interferometry. A videotape of the presentation was made and will shortly be available. I am also scheduled to make a special presentation at the Alternate Energy Conference in Toronto, Canada in latter October, 1981. A professional, videotaped two-hour presentation on this subject is also being prepared. Wide distribution of the material through the international underground physics and technology network has already been made. This time, God willing, Tesla's secret will not be suppressed for another 80 years!

And perhaps it is not yet too late. The material has cost me (now) some 16 years of agonizing labor and nearly $100,000 of my own personal funds. No orthodox university, scientific group, foundation, or governmental agency would support such an effort, either financially or otherwise. Indeed, most ordinary journals will not even accept material on such matters. Nonetheless, the area is of overwhelming importance and I truly believe Tesla's lost secret will shortly affect the lives of every human being on earth.

Perhaps with the free and open release of Tesla's secret, the scientific and governmental bureaucracies will be. shocked awake from their slumber, and we can develop defenses before Armageddon occurs. Perhaps there is hope after all -- for even Brezhnev, in his strange July, 1975 proposal to the SALT talks, seemed to reveal a perception that a turning point in war and weaponry may have been reached, and that human imagination is incapable of dealing with the ability to totally engineer reality itself. Having tested the weapons, the Soviets must be aware that the ill-provoked oscillation of timeflow affects the minds and thoughts -- and the very lifestreams and even the collective species unconsciousnesses -- of all lifeforms on earth. They must know that these weapons are two-edged swords, and that the backlash from their use can be far more terrible to the user than was the original effect to his victim.

If we can avoid the Apocalypse, the fantastic secret of Nikola Tesla can be employed to cure and elevate man, not kill him. Tesla's discovery can eventually remove every conceivable external human limitation. If we humans ourselves can elevate our consciousness to properly utilize the Tesla electromagnetics, then Nikola Tesla -- who gave us the electrical twentieth century in the first place -- may yet give us a fantastic new future more shining and glorious than all the great scientists and sages have imagined.

References

The Tom Bearden Website

34 Flaws in Classical EM Theory

Note: If the scientific community had done their job, this Website would probably not be necessary.

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2. SLIDE 2
3. SLIDE 3
4. SLIDE 4
5. SLIDE 5

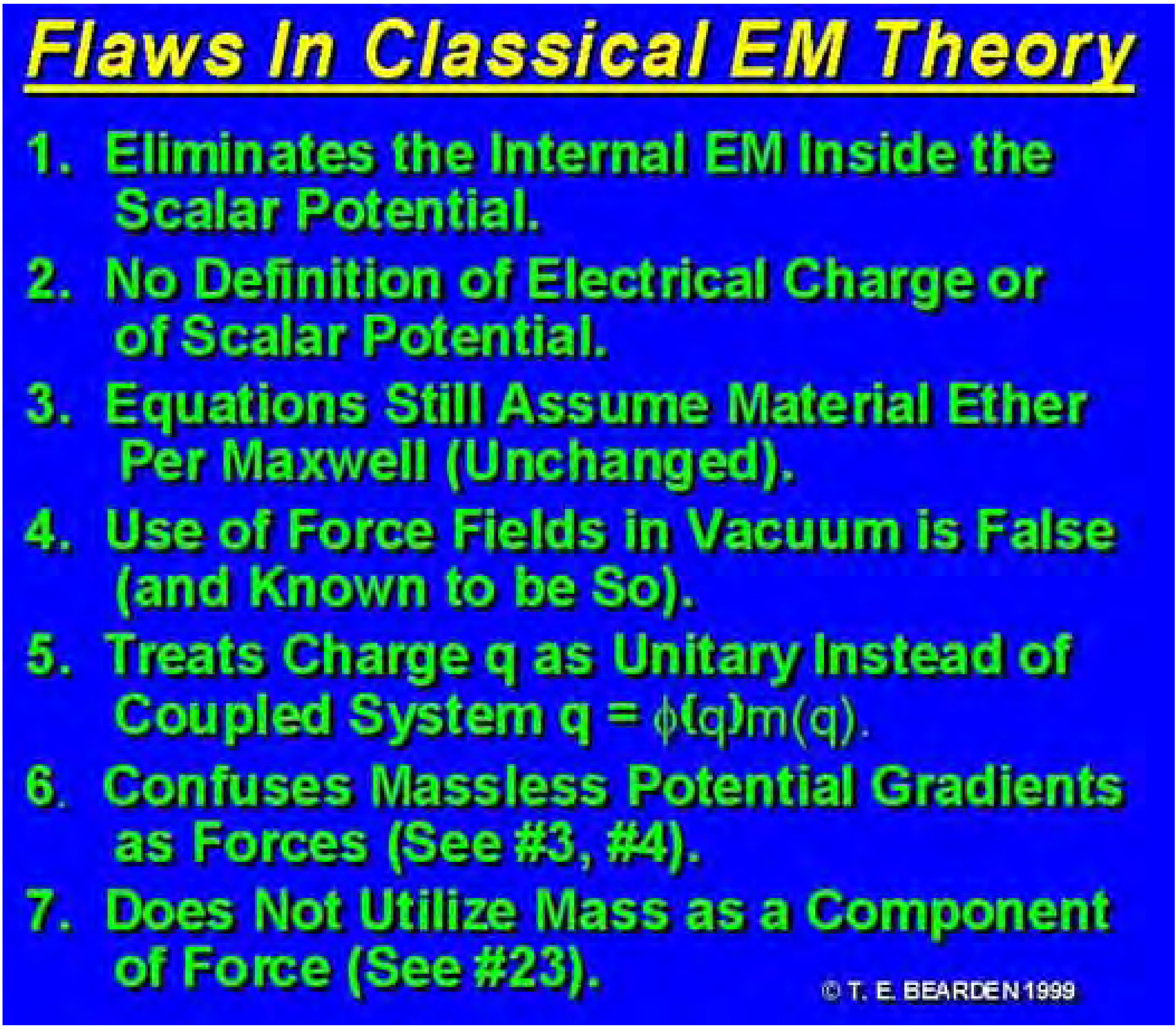

Flaws In Classical EM Theory

1. Eliminates the Internal EM Inside the Scalar Potential.
2. No Definition of Electrical Charge or of Scalar Potential.
3. Equations Still Assume Material Ether Per Maxwell (Unchanged).
4. Use of Force Fields in Vacuum is False (and Known to be So).
5. Treats Charge q as Unitary Instead of Coupled System $q = \phi(q)m(q)$.
6. Confuses Massless Potential Gradients as Forces (See #3, #4).
7. Does Not Utilize Mass as a Component of Force (See #23).

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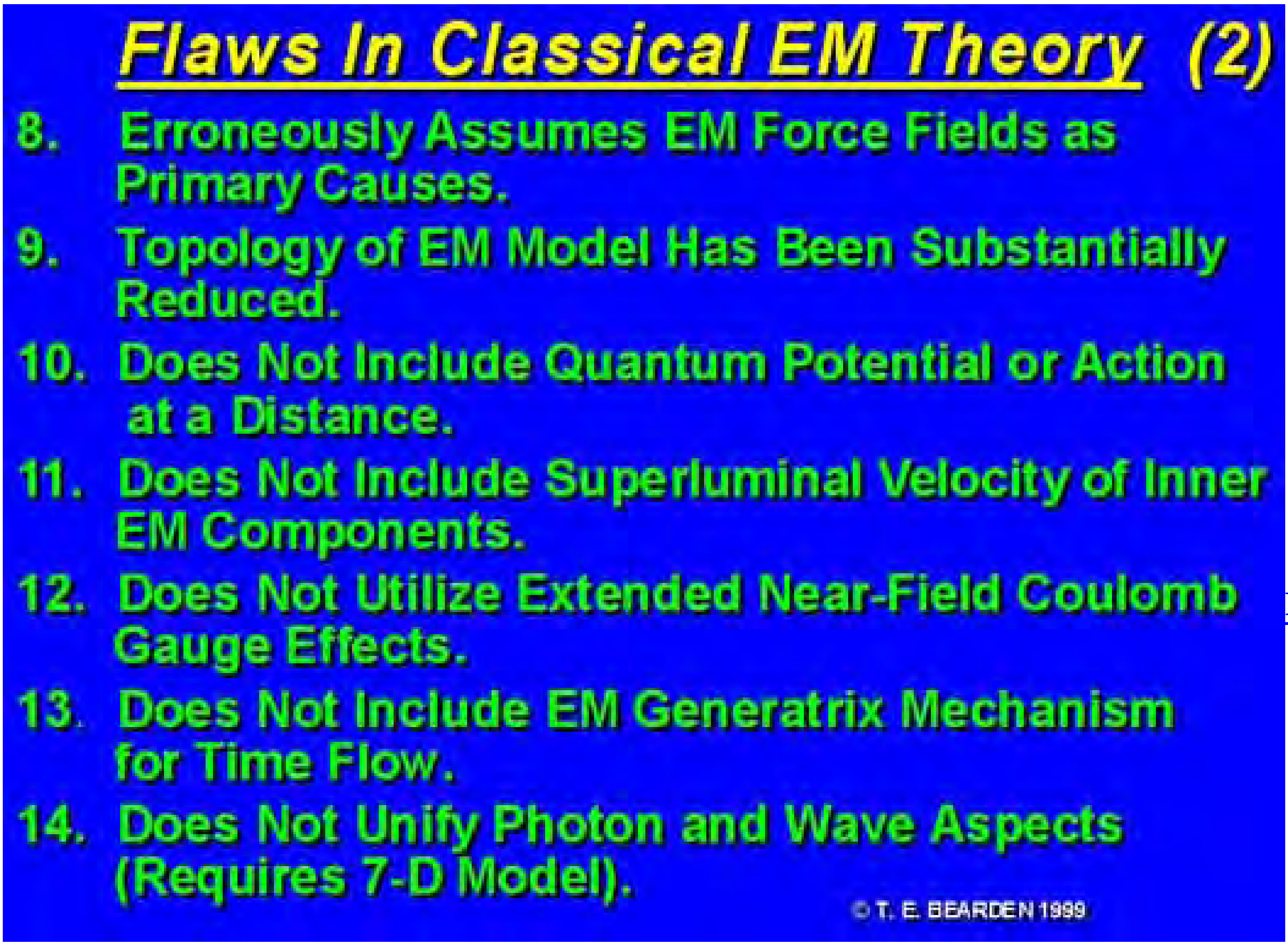

Flaws In Classical EM Theory (2)

8. Erroneously Assumes EM Force Fields as Primary Causes.
9. Topology of EM Model Has Been Substantially Reduced.
10. Does Not Include Quantum Potential or Action at a Distance.
11. Does Not Include Superluminal Velocity of Inner EM Components.
12. Does Not Utilize Extended Near-Field Coulomb Gauge Effects.
13. Does Not Include EM Generatrix Mechanism for Time Flow.
14. Does Not Unify Photon and Wave Aspects (Requires 7-D Model).

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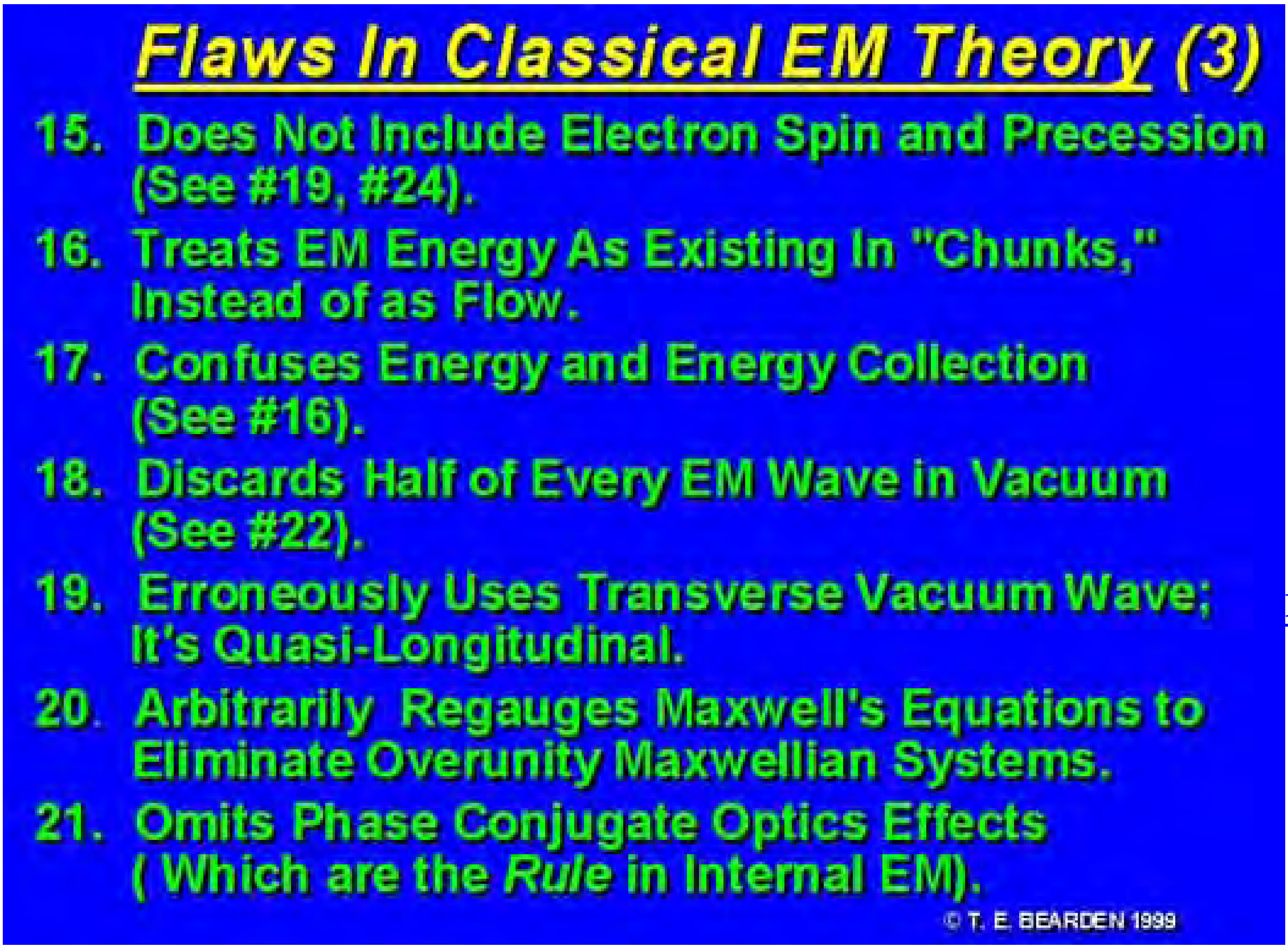

Flaws In Classical EM Theory (3)

15. Does Not Include Electron Spin and Precession (See #19, #24).
16. Treats EM Energy As Existing In "Chunks," Instead of as Flow.
17. Confuses Energy and Energy Collection (See #16).
18. Discards Half of Every EM Wave in Vacuum (See #22).
19. Erroneously Uses Transverse Vacuum Wave; It's Quasi-Longitudinal.
20. Arbitrarily Regauges Maxwell's Equations to Eliminate Overunity Maxwellian Systems.
21. Omits Phase Conjugate Optics Effects (Which are the *Rule* in Internal EM).

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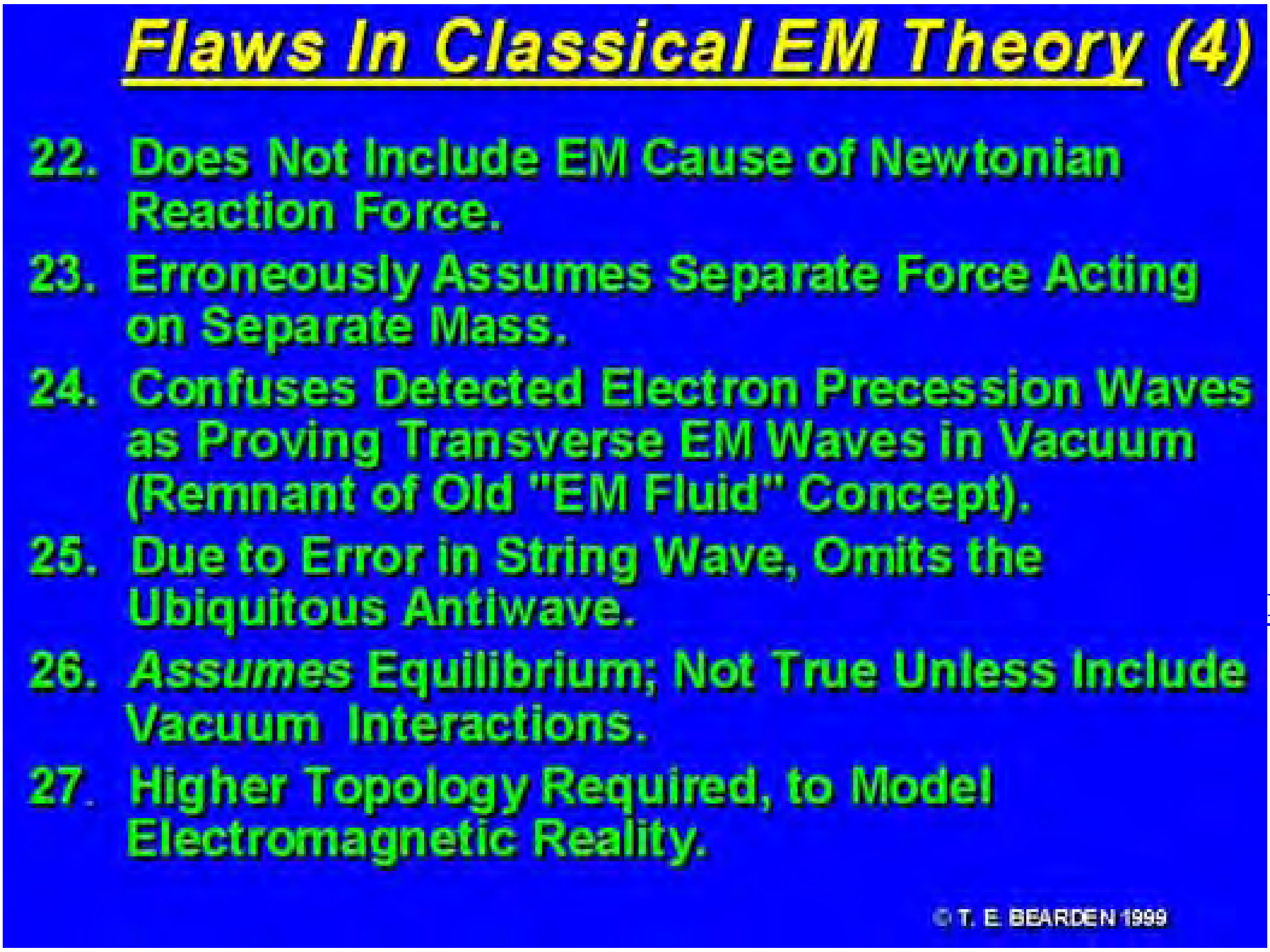

Flaws In Classical EM Theory (4)

22. Does Not Include EM Cause of Newtonian Reaction Force.
23. Erroneously Assumes Separate Force Acting on Separate Mass.
24. Confuses Detected Electron Precession Waves as Proving Transverse EM Waves in Vacuum (Remnant of Old "EM Fluid" Concept).
25. Due to Error in String Wave, Omits the Ubiquitous Antiwave.
26. *Assumes* Equilibrium; Not True Unless Include Vacuum Interactions.
27. Higher Topology Required, to Model Electromagnetic Reality.

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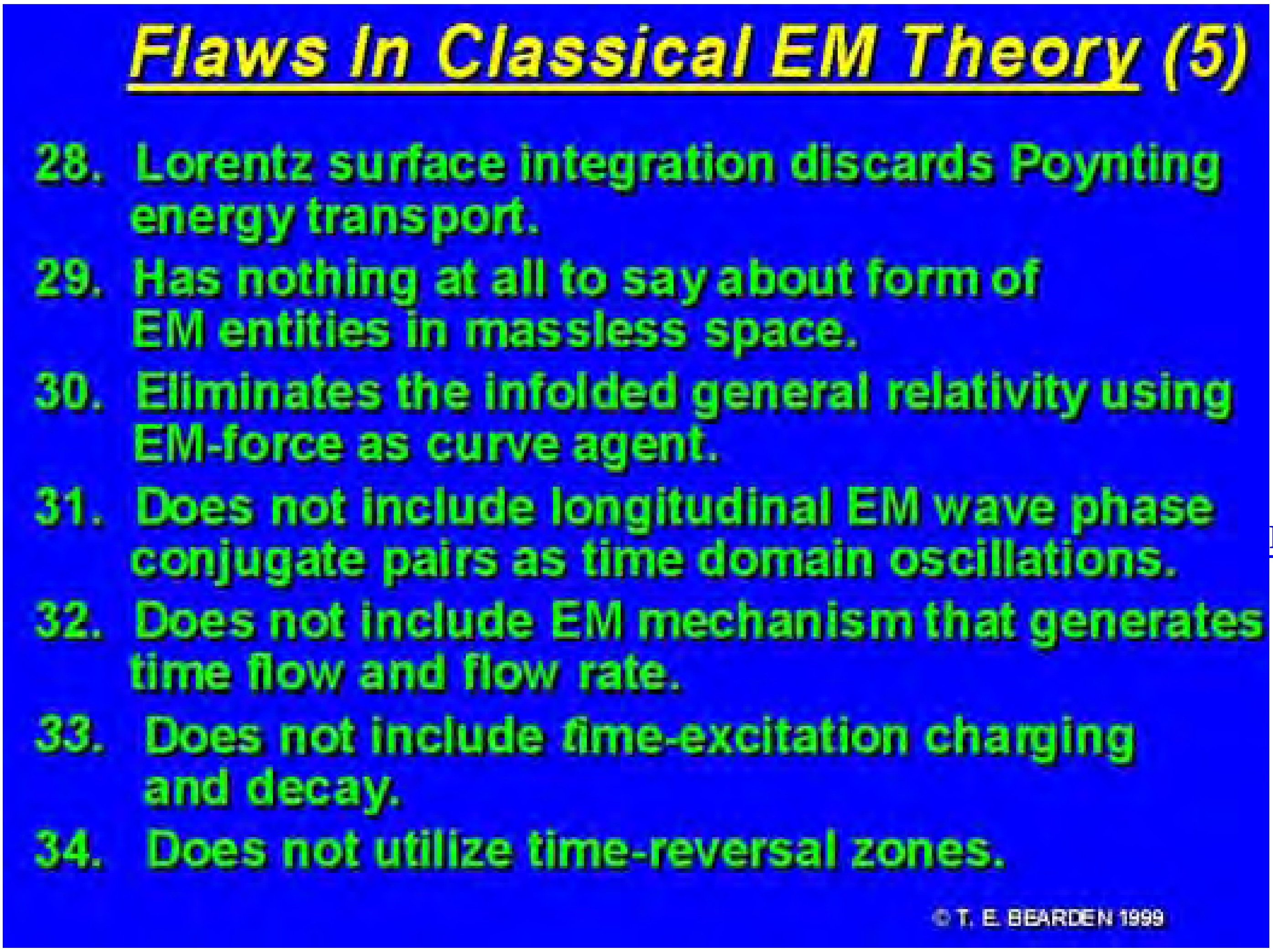

Flaws In Classical EM Theory (5)

28. Lorentz surface integration discards Poynting energy transport.
29. Has nothing at all to say about form of EM entities in massless space.
30. Eliminates the infolded general relativity using EM-force as curve agent.
31. Does not include longitudinal EM wave phase conjugate pairs as time domain oscillations.
32. Does not include EM mechanism that generates time flow and flow rate.
33. Does not include time-excitation charging and decay.
34. Does not utilize time-reversal zones.

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The Tom Bearden Website

Mind Control and EM Wave Polarization Transductions - Part I, II & III

Reprinted from "Explore" magazine, 1999

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- The U.S. approach to mind control

- "Voices in my head"
  Flanagan's neurophone - used to give instructions to diplomats during negotiations, etc.

Mind Control and EM Wave Polarization Transductions, Part 1

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Special Note

This article refers to experimental research techniques which can be detrimental or lethal in the hands of any but highly skilled, qualified experimental scientists proceeding under proper laboratory safety procedures. The purpose of this article is strictly for information to properly qualified and authorized scientists in certified laboratories. We do not propose or condone any use of these procedures for nonapproved practice of medicine without a license. Neither the publisher nor the author are responsible for accidents or outcomes in the use of these experimental pro-cedures and techniques. Any researcher who performs these procedures and experiments is acting on his or her own volition, and is solely responsible for insuring safety, qualifications, and legality of the acts and their results. We neither suggest nor condone unauthorized experimentation on human subjects. Such is a criminal violation of the constitutional rights of the subject under Federal and State laws, and is both illegal and immoral.

Abstract

For some time we have been repeatedly queried about the technical mechanisms and unusual electrodynamics of advanced mind control research, both in the West and abroad. Calling full attention to the special note above, in this paper we present a high-level over-view of the novel electromagnetic nature of mind operations, mind and body coupling, and *intent*•the induction of physical 3-space EM energy changes into the brain and nervous system, and into every cell of the body, from the mind's time-like coherent operations. We summarize the time-polarized electrodynamics used to engineer and affect mind operations and the mind-body coupling loop. Transduction mechanisms whereby differing EM wave polarizations can be transformed one-into-the-other are presented. We give two specific examples of lethal foreign military tests in 1997 of advanced mind control weapons against two military pilots over the central U.S. Some dangers and potential benefits of the emerging mind control technology are pointed out

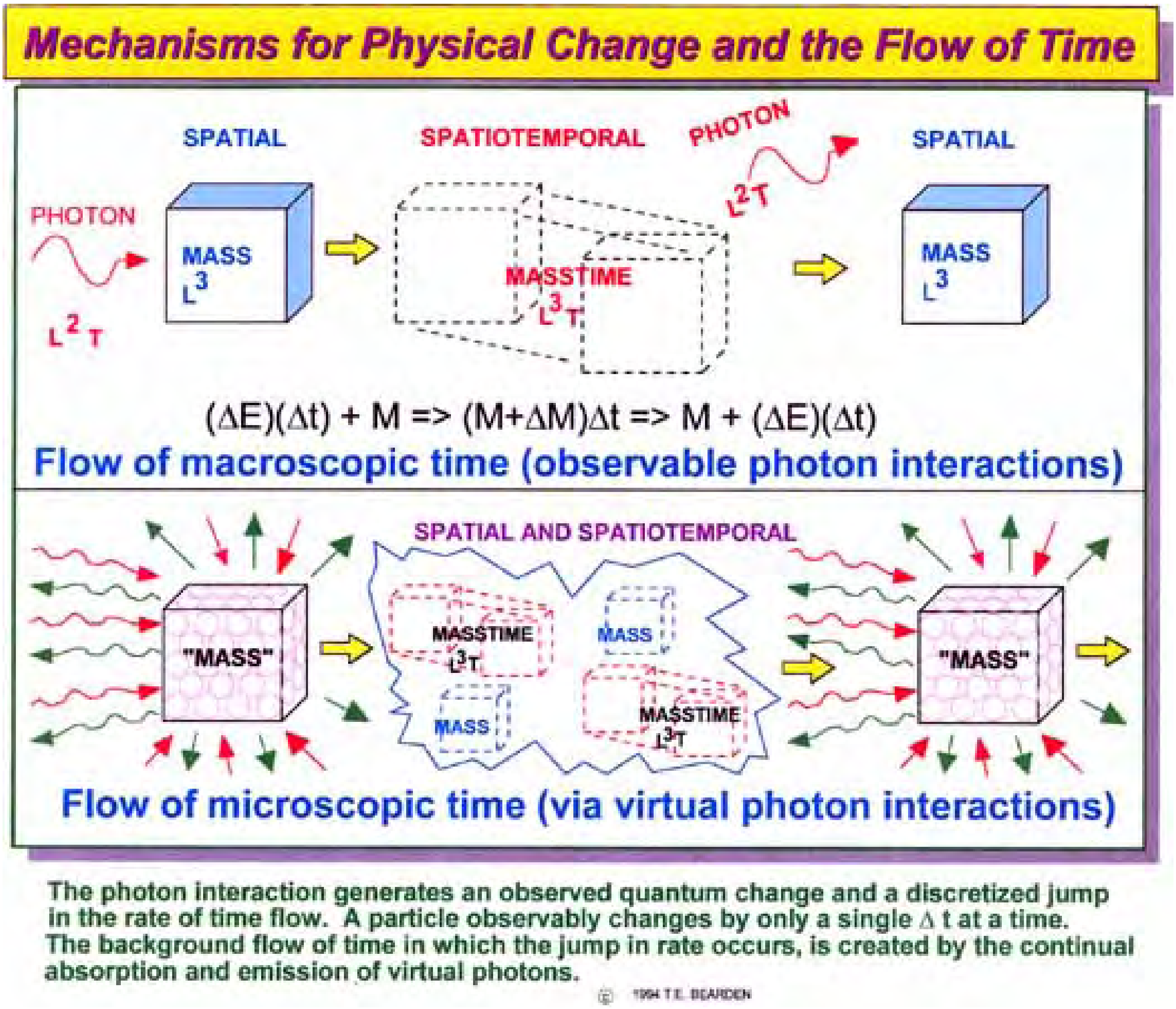
Mechanisms for Physical Change and the Flow of Time
SPATIAL
SPATIOTEMPORAL
PHOTON
SPATIAL
PHOTON
MASS
L^3
L^2T
MASSTIME
L^3T
L^2T
MASS
L^3
SPATIAL AND SPATIOTEMPORAL
"MASS"
MASSTIME
L^3T
MASS
MASS
MASSTIME
L^3T
"MASS"
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$$(\Delta E)(\Delta t) + M \Rightarrow (M+\Delta M)\Delta t \Rightarrow M + (\Delta E)(\Delta t)$$

Flow of macroscopic time (observable photon interactions)

Flow of microscopic time (via virtual photon interactions)

The photon interaction generates an observed quantum change and a discretized jump in the rate of time flow. A particle observably changes by only a single Δt at a time. The background flow of time in which the jump in rate occurs, is created by the continual absorption and emission of virtual photons.

Figure 1. Mechanism that generates a mass's flow through time.

EXPLORE! VOLUME 9, NUMBER 2, 1999

Introduction and Background

In quantum field theory, there are four polarizations of photons.[1] Using 4-space and the z-direction as the direction of propagation, we have x- and y- polarizations where the 3-spatial energy of the photon is oscillating laterally, in the x- or y- direction. These are *transverse polarized* photons, as is any combination of the two. The third polarization is along the z-direction, which is a longitudinal polarization. In other words, the 3-spatial energy of the longitudinal photon cannot oscillate in the x- or y- direction, and so it is oscillating to-and-fro along the line of motion, z-. The fourth polarization occurs when the energy is frozen in all three spatial dimensions x-, y-, and z- and it cannot oscillate in any of those directions. In that case, the photon oscillates its energy in the t- direction, providing the t-polarized photon. We will later discuss how time is actually highly condensed energy.

In Minkowski 4-space, body operations are space-like, and are so treated in conventional materialistic physics. Mind and mind-operations are time-like, not space-like, even though they are totally electromagnetic in nature.[2]

As is well-known, all observation in physics is considered 3-spatial..[3] Mass is a 3-spatial concept, and we detect changes to mass (as, e.g., in the shift of electrons in the circuits of electrical instruments). So one may model the common physical observation mechanism as a *time-differentiating process* which *a priori* discards time-change and retains 3-spatial energy change.[4] That is, Minkowski reality is modeled in the fundamental units of L^3t. Physical observation (via the transverse photon interaction) is the process given by applying the operator $\partial/\partial t$ to L^3t, yielding an L^3 output. Hence mind and mind operations are excluded by the usual physics instruments and observation, which simply exclude the time domain in their outputs and do not "measure" it.

For this reason, physicists have erroneously considered mind to be "metaphysical" and nonreal. Indeed, most physicists to one extent or the other are materialists, and consider the "mind" to be nothing but the operations ongoing in a "meat computer." Nonetheless, in the time-domain the time is absolutely real, and it is completely electrodynamic in nature. There is no metaphysics involved, and the temporal domain—along with mind and mind operations—is simply an erroneously neglected area of physics. In present physics, the notion of mind is comfortably disposed of by imposing the use of the "observer" concept, with out ever specifying that the observer has a consciousness and a mind. Indeed, "observation" is only about what that "observer" perceives. Obviously, one has a dramatically crippled physics if one eliminates that nonobservable called "time." Similarly, one also has a dramatically crippled physics when one eliminates the mechanisms and physics ongoing in those time-like and dynamic "things" such as mind, that occupy time and function in it.

From this viewpoint, Western physics adheres to its 3-spatial measurement foundation only by ignoring the transduction of time-polarized EM changes into detectable longitudinal and transverse EM wave changes. In this aspect, present Western physics is severely self-crippled.

Time is totally electromagnetic and energetic in nature. The flow of time is not a separate external river on which a mass floats along like a boat drifting down the current of a great flowing river. Instead, the flow of time is generated directly on every mass by its total set of photon interactions, both virtual and ob servable. We have previously presented the exact mechanism for the flow of time. *[Figure 1]*

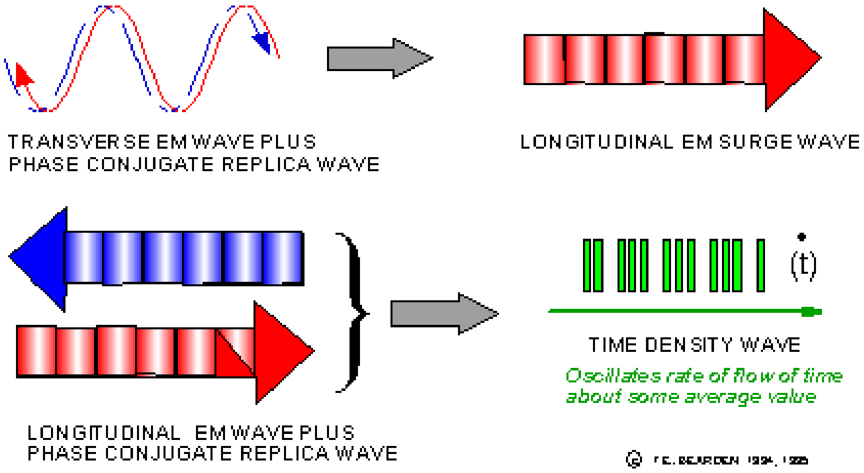
TRANSVERSE EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE
LONGITUDINAL EM SURGE WAVE
LONGITUDINAL EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE
(t)
TIME DENSITY WAVE
Oscillates rate of flow of time
about some average value
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Figure 2. Transduction of EM wave type by successive phase conjugate pairing.

Further, a photon is comprised of angular momentum, therefore of (energy)x(time). It transports both energy and time, not just energy alone. When absorbed by a mass, not only does it "energy-excitation" charge the mass, but also it "time-excitation" charges it, converting the former "mass" to "mass time". Rigorously it is *masstime* that emits a photon, not *mass*. So a mass moves through time in little spurts, by the continual macroscopic addition and subtraction of little Dt components. Further, in being driven through time, mass is continually altered to masstime (a quite different critter from mass), to mass, to masstime, to mass, etc.

In any masstime state, a myriad of tiny virtual photon interactions made of very tiny (DE)(Dt)'s interact with that same mass during that particular larger Dt of the masstime state (m+Dm)(Dt). Hence mass in its alternate masstime state has that state internally structured by its surrounding environment's interactions with it. The masstime state is internally structured energetically in its (DE) component, and also internally structured temporally in its (Dt) component.

A standard charged fundamental particle such as an electron, e.g., is not necessarily identical with another, when the internal structuring of its masstime state is considered. Further, by two papers by Whittaker,[5] interferometry of masstime states with either energy reactions or temporal reactions can yield observable effects and changes due to these neglected "hidden variables" in the electron's masstime alternative states. To engineer the mind and its operations directly, one must perform electrodynamic engineering in the *time* domain, not in the 3-space EM energy density domain. The direct engineering of time-like mind and mind operations—in all levels and all aspects—requires the use of *time-polarized photons and time-polarized EM waves*. This is the rarest form of electrodynamics, almost untouched by Western physicists.

One can either painfully produce such time-polarized photons and EM waves and directly irradiate a target mass with specific assemblies of them, or one can force the mass itself to iteratively transduce ordinary transverse EM waves first into longitudinally-polarized EM waves and then into time-polarized EM waves. Both will be discussed briefly.

In the West, it appears that the present author's discovery of mechanisms for producing time-polarized (scalar) EM waves [see *Figure 2*] and for transducing between wave polarizations has no precedent. [See *Figure 3*]. While scalar (time-polarized) photons are known in the literature,[1] the creation and use of time-polarized EM waves does not seem to appear in the Western physics literature.[6]

Wave transduction or *polarization transductions* are terms used by the author for the process of transforming an EM wave's particular polarization into another polarization type. Such transduction to other than transverse polarization forms is little known in the West. It appears essentially haphazardly in some experiments, usually without any recognition by the experimenters themselves. Significant transduction in experiments will also produce "strange" and unexplained anomalies in the instruments being used for experimental measurements.[7]

So most probably Western mind control researchers have not recognized the methodology and mechanisms[8] for transducing one type of EM wave polarization directly into another.[9] They continue to seek the "mind" in 3-space and hence in the brain, rather than in the time domain. On the other hand, it appears

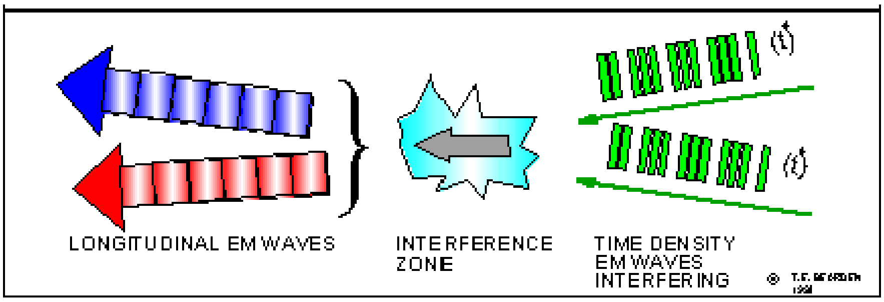

Figure 3. Interference processes for transducing higher EM wave polarizations into lower polarization states.

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that the Russian KGB energetics[10] weapons scientists—particularly those in psychoenergetics[11]—have known and used methods of transducing one wave polarization into another, for at least two decades. It follows that those same scientists have very probably developed mind engineering and mind control via novel time-polarized EM wave means and a dramatically extended electrodynamics of the time-like mind operations.

In the present paper we briefly develop the wave transductions and the basis for mind engineering, including the specialized use of ordinary transverse wave (TW) EM spectra to force internal EM wave transductions and time-domain operations inside irradiated bodies, cells, and tissues. Through the mind-body coupling mechanism, these transductions of transverse EM waves can operate upon the mind and its deepest operations as well as upon the body, every cell, and every part of every cell.

Russian Mind Control Uses Higher EM Wave Polarizations

It is apparent that the KGB psychoenergetics weapons scientists know and use the full extended EM wave polarization range. As a postulation, one would expect our own weapons scientists to know and utilize the orthodox transverse wave (TW) EM for similar research and experimentation. However, in the West scientists are just beginning to realize the importance of a very general (and weaker) type of longitudinal EM wave (LW) polarization, as evidenced by the appearance of dozens of papers on "undistorted progressive waves" (UPWs, which are essentially imperfect LW s with TW residues remaining). The Los Alamos National Laboratory web site has a number of such papers—particularly by Rodrigues[12] and Lu—available for free downloading. UPWs have very interesting characteristics. If they were perfect longitudinal EM waves, they would have infinite energy and infinite speed. Since only imperfect UPWs can be physically made, their speed can vary from slower than the speed of light to faster than the speed of light. Their energy can also vary over a great range.

Another characteristic of UPWs that are reasonably good longitudinal EM waves, is that they pass readily through a large depth of water and mass, including through the ocean and the earth with only small interactions and losses. Yet by interfering two such beams of "high quality" UPWs at a great distance, then in the interference zone ordinary EM energy will rise directly out of local spacetime potential, as essentially shown by Whittaker[13] nearly a century ago. Russian weapon research facilities have weaponized these effects[14] for nearly 50 years, under rigid KGB control and operation. Nonetheless, even if using only ordinary TW waves, Western mind control researchers may get some fairly good results, brute-force-like, by using gross correlates between just the input irradiating TWs and the exhibited behavioral responses of the individual. The net input-output correlations can be determined, even though not taking into account the actual wave polarization transduction mechanisms ongoing inside the irradiated dielectric (or brain, or mind, etc.). However, Western researchers appear to have no knowledge of the exact mechanisms by means of which coherent time-like mind operations of a biological organism couple to the organism's 3-spatial body to provide the mental control loop. They also appear unaware of how the coherent 3-spatial behavior responses of the body couple back to the time-like mind to provide it with a sensory feedback of the body's responses.

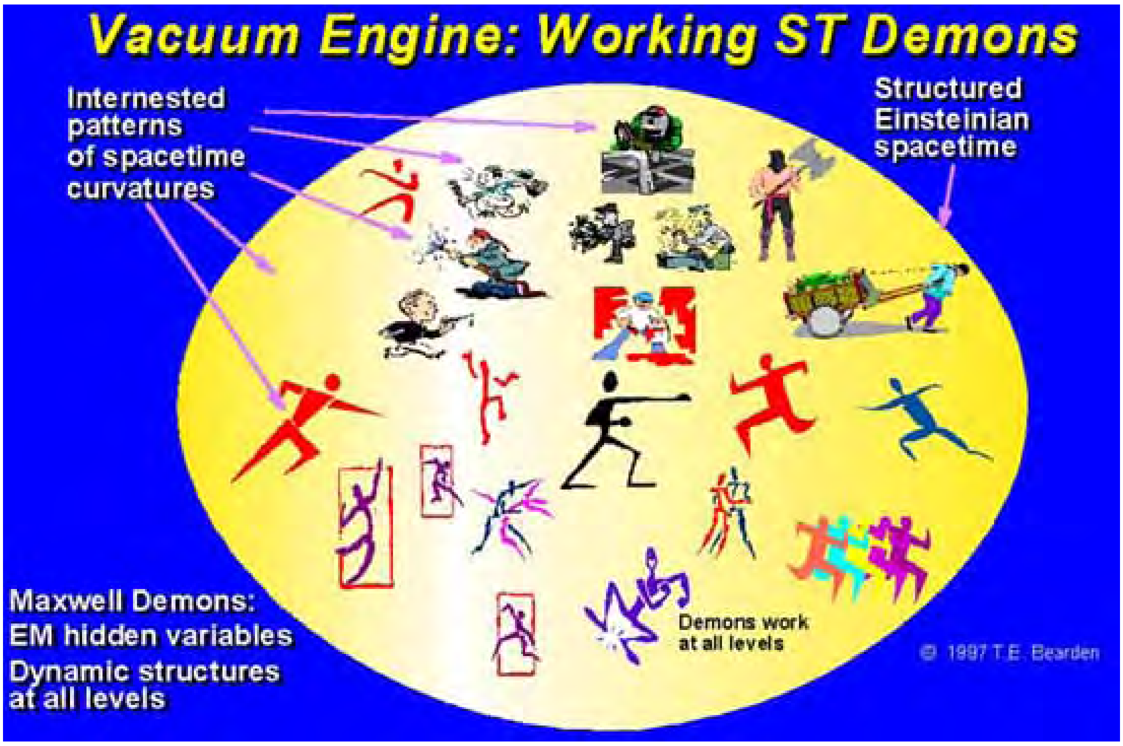

Vacuum Engine: Working ST Demons

Internested patterns of spacetime curvatures

Structured Einsteinian spacetime

Maxwell Demons:
EM hidden variables
Dynamic structures at all levels

Demons work at all levels

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Figure 4. A spacetime curvature engine has myriads of small ST curvature components which act upon mass at all levels.

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General Relativity Aspects

Both these coupling mechanisms can be taken directly from general relativity, if one puts one's mind to it. However, unless the wave polarization transformations are known, it is difficult or impossible to apply the ordinary GR *directly*, since relativists usually concentrate upon spacetime curvature by altering 3-space energy density rather than by altering time-polarized "time-energy" density.

In applied general relativity, spacetime itself is an active medium. One speaks of a change in spacetime as a "spacetime curvature". Any curvature of spacetime in a local region directly performs continuous work upon any mass embedded in that region. Vice versa, any mass (or other concentration of energy) in a local spacetime continuously acts upon that spacetime to "curve" it.

So if one wishes to perform actions upon mass in a distant region, one may generate local curvatures of spacetime in that region, and these curvature "engines" will directly act upon the mass at all levels. *[Figure 4]* This is very different from energy propagation through space from one point to another. Now the "ordinary EM energy and actions" arise from every spatiotemporal point within the mass, at every level, and move upwards (from inside to outside). So we speak of specific forms of "templates" of nested spacetime curvatures formed and utilized to engineer mass "from inside out" as *spacetime curvature engines or vacuum engines*.

Use of vacuum (spacetime curvature) engineering[15] is a far more powerful form of engineering than is provided by energy propagation through space. As an example, it is easy to alter the quarks in a nucleon, using spacetime curvature engines and time-charging decay. Indeed, we have developed the mechanisms for cold fusion and the electronuclear interaction (formation of new nuclides) at feeble energy. An Invention Disclosure[16] on this work has been filed with the U.S. Patent Office, and formal patent applications are in preparation. Some information on these mechanisms and principles has been released[17].

Time as Dense EM Energy and a Strong Spacetime Curvature Agent

The advantage of using the time-polarized "time-energy" for spacetime curvature is that time is ordinary energy compressed by a factor of at least c^2—which, in the MKS system of units, is some 9¥10^{16}. Thus use of time-polarized EM photons and waves as ST curvature agents gives an amplification of 9 ¥10^{16} over the use of transverse-polarized EM waves for that purpose. In turn, the use of the strong EM force in ordinary TW waves as an agent of ST curvature is already a nominal 10^{40} times as strong as is the weak G force used as the agent of ST curvature.

The bottom line is this: For spacetime curvature effects, the use of the t-polarized domain provides amplification of some 9¥10^{56} greater than the weak G-force ST curvature agent usually considered in general relativity[18].

Western Science Remains Largely Materialistic

Ironically, most Western scientists are materialists and consider "mind" as a mystical and nonscientific concept. They tend to consider mind operations and functions either to be simply "meat computer" operations and functions, or at best to be very weak ordinary transverse-wave EM operations and functions in the brain and nervous system.[8] This serious self-limitation exists because in the body we *measure* only weak TW EM operations and functions correlated to biological behavior and brain operations. We simply do not know how to measure "mind operations" directly.

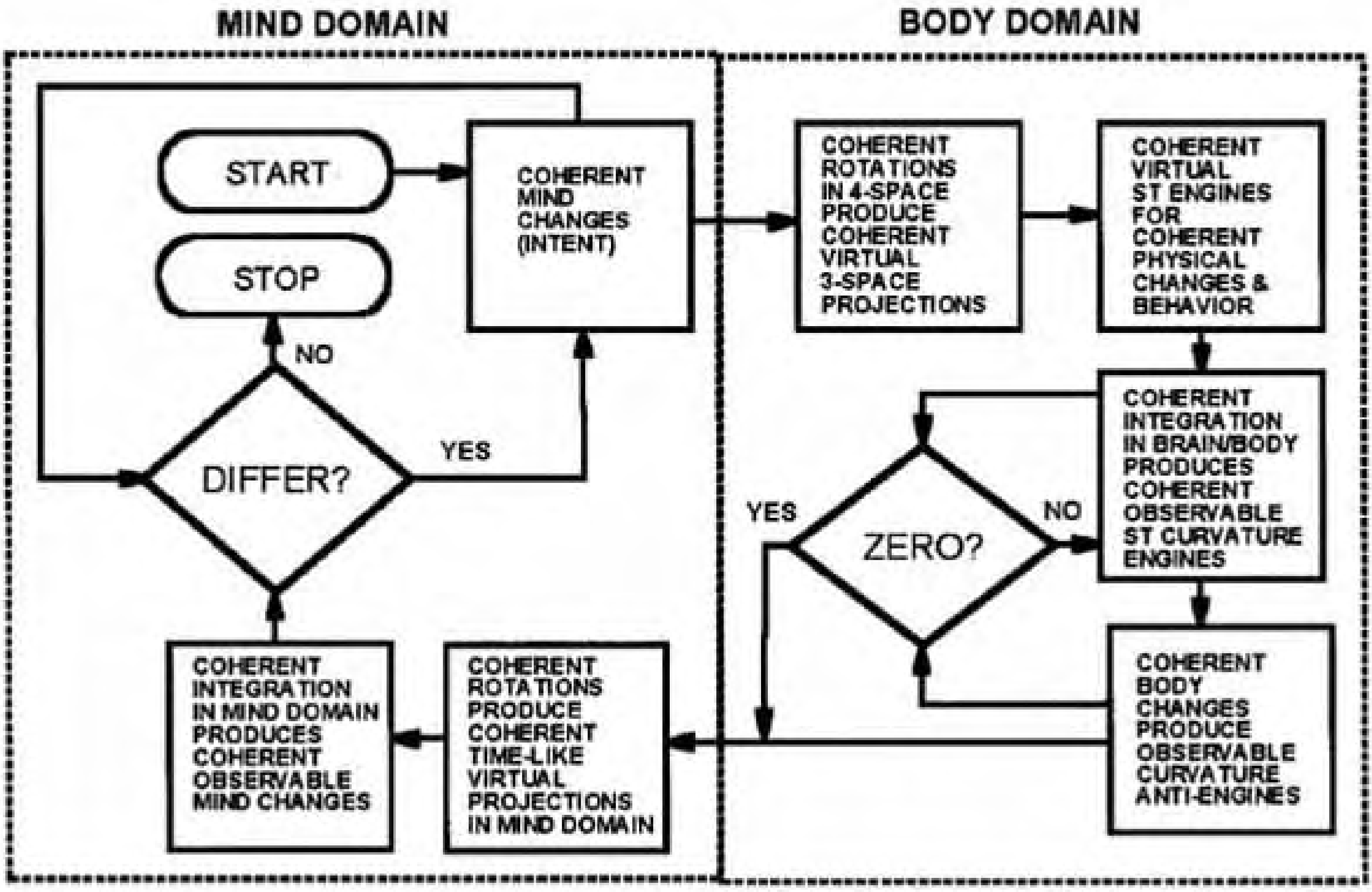
MIND DOMAIN
BODY DOMAIN
START
STOP
COHERENT MIND CHANGES (INTENT)
NO
YES
DIFFER?
COHERENT INTEGRATION IN MIND DOMAIN PRODUCES COHERENT OBSERVABLE MIND CHANGES
COHERENT ROTATIONS PRODUCE COHERENT TIME-LIKE VIRTUAL PROJECTIONS IN MIND DOMAIN
COHERENT ROTATIONS IN 4-SPACE PRODUCE COHERENT VIRTUAL 3-SPACE PROJECTIONS
COHERENT VIRTUAL ST ENGINES FOR COHERENT PHYSICAL CHANGES & BEHAVIOR
COHERENT INTEGRATION IN BRAIN/BODY PRODUCES COHERENT OBSERVABLE ST CURVATURE ENGINES
YES
NO
ZERO?
COHERENT BODY CHANGES PRODUCE OBSERVABLE CURVATURE ANTI-ENGINES

Figure 5. Mind-to body coupling and body-to-mind coupling.

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With no mind measurements possible and no instruments, it is understandable that Western science considers only the physical side of the mind-matter interface.

Presently our scientists do not measure the longitudinally-polarized EM wave operations and functions in the body and around it in nature. Few of them are aware that a maelstrom of such LW functions exist in the body and in all of nature in general. Presently only highly theoretical quantum field theorists seem to even be aware of the existence of scalar (t-polarized) photons, and even they are unaware of t-polarized EM waves. Certainly our scientists do not measure t-polarized EM waves in and around the body and in nature, nor do they make them in the laboratory. Apparently they have not studied such waves and their interactions with matter—living and inert—at all.

But it's even worse. In ignoring the time component transported by photons and EM waves, science has also erroneously omitted half of the excitation charging and excitation decay processes whenever a mass interacts with photons and EM waves. More on that later.

Brute Forcing Time Functions versus Fine Control Methods

Ironically, Western mind control researchers using transverse EM waves for mind control research, are using a brute force method of evoking and using vacuum engines (spacetime curvature engines) and a special form of general relativity, although they do not appear to realize it.

While KGB scientists also use TW EM "brute force" TW waves when necessary, they do "imprint" or "activate" those waves with the desired internal LW and time-polarized EM wave and photon structures required to directly perform the mind engineering desired. They also do not hesitate to use LWs and t-polarized waves overtly. So in blunt terms, Western compared to Russian mind control research is probably like comparing an automobile body shop with a fine surgical ward. Having long ago worked out all those "exact correlates" to the internal "information content of the field" is where the KGB scientists are at least 20 years ahead of the West.

The reason one can get mind and behavior results with the TW electromagnetics, while bypassing the real mechanism which uses t-polarized waves and photons, is due to (1) the very peculiar nature of the EM emission from a dielectric, and (2) what can be done by re-radiating that dielectric with its emitted spectrum, deliberately and very carefully altered in selected parts. We will return to that important feature later.

Polarization and Observability

As we stated, there are four photon polarizations and therefore there must be correspondingly four EM wave polarizations[1] The first three polarizations are the x-, y-, and z- spatial polarizations. The x- and y- polarizations are transverse polarizations and the z-polarization is a longitudinal polarization along the direction of propagation (along the z-axis, by standard notation). Simply put, we may visualize the transverse polarizations as rather like the wiggling of a fish's tail from side to side as the fish moves forward, or a whale's flukes up and down as the whale moves forward, or some combination thereof. We may visualize the longitudinal polarization as a sort of "repetitive accordion effect" along the line of motion of the wave. Usually the z- polarization is neglected in EM wave theory, although in recent years physicists have "rediscovered" longitudinal EM waves and are now intensely researching the use and characteristics of such waves.[12]

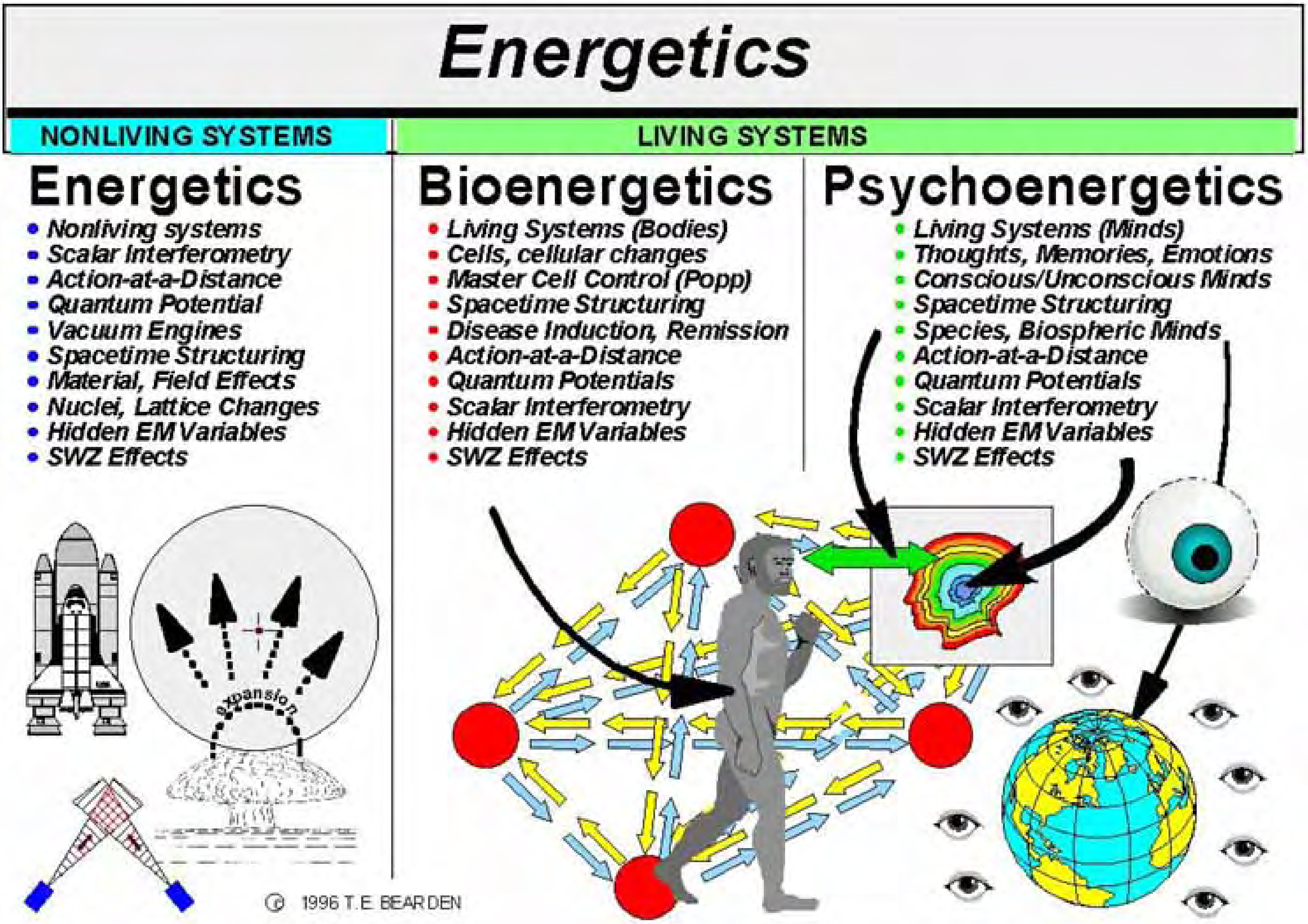

Energetics

NONLIVING SYSTEMS | **LIVING SYSTEMS**

Energetics

- Nonliving systems
- Scalar Interferometry
- Action-at-a-Distance
- Quantum Potential
- Vacuum Engines
- Spacetime Structuring
- Material, Field Effects
- Nuclei, Lattice Changes
- Hidden EM Variables
- SWZ Effects

Bioenergetics

- Living Systems (Bodies)
- Cells, cellular changes
- Master Cell Control (Popp)
- Spacetime Structuring
- Disease Induction, Remission
- Action-at-a-Distance
- Quantum Potentials
- Scalar Interferometry
- Hidden EM Variables
- SWZ Effects

Psychoenergetics

- Living Systems (Minds)
- Thoughts, Memories, Emotions
- Conscious/Unconscious Minds
- Spacetime Structuring
- Species, Biospheric Minds
- Action-at-a-Distance
- Quantum Potentials
- Scalar Interferometry
- Hidden EM Variables
- SWZ Effects

Figure 6. The three divisions of Soviet energetics and their characteristics.

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Unfortunately, in quantum field theory there has been a tendency to regard the t-polarized or "scalar" photon—where the local rate of time is oscillated—as unobservable. Oscillation of the local rate of time produces powerful oscillations of local space-time curvatures, due to the extreme energy density of time. Individually, the t-polarized photon tends to be unobservable. However, a *coherent sequential group* of such t-polarized photons, each individually in the virtual state with respect to the external observer, may simply integrate in its interaction with mass over a short time period into observable change because of the coherent integration of virtual spacetime curvatures into a larger, observable spacetime curvature.

Rotations and Projections in 4-Space

Relativistically, any velocity change in 4-space is a rotation. Any such rotation in the time-domain also creates a tiny projection component into 3-space. Any such rotation in the 3-spatial domain also creates a tiny projection component into the time domain.

Hence a sufficient series of coherent time-domain (mental) changes produces a coherent series of virtual changes in 3-space (the body), thereby coherently integrating into an observable energy change in the body. A sufficient series of coherent 3-spatial energy changes produces a coherent series of virtual changes in the time domain which coherent integrate into an observable time-domain change.

Solution to the Age-Old Philosophical Problem of Intent

This is in fact the solution to the age-old problem of *intent*, or how the nonmaterial (i.e., non-3-spatial and non-observable) mind induces a 3-spatial, observable energy change upon the 3-spatial body. It is also the solution to the problem of *awareness*; i.e., how the mind is aware of itself[19] and of the responses of the body. Together the two form a closed loop coupling of the mind and body. The time delay in the loop together with memory recall for comparison, creates the sense of "persistence" of self in time. This also creates the sense of being a "separate, closed being" (i.e., of separate persistence in time—in the living entity). The sense of "separation of self from an external world" is created by comparing those body-to-mind sensory feedbacks which are not correlated to the mind's previous feed-forward intent.

Time As Energy and Why It Is Very Dense Energy

In addition to the three spatial polarizations of photons and EM waves, there is a very, very useful t-polarization along the time axis. In this polarization, the 3-spatial energy is not oscillating at all. Instead, the time or time-energy is oscillating. Time can be taken to be energy compressed by at least c^2, so it has at least the same energy density as mass. In other words, one second is $9x10^{16}$ joules of time-energy (energy compressed into time). The t-polarized photon or EM wave is called the scalar photon or scalar EM wave, respectively.

To demonstrate why time can be regarded as energy, we need only point out that the choice of fundamental units in any physics model is totally arbitrary. We usually choose these units to ease the mathematical manipulation, ease our understanding, and simplify the ability to visualize or "grasp" the physics. However, if one wishes, one can build all of physics from a single fundamental unit—e.g., energy. In that case, one readily sees that time is a function of energy and only energy. Hence it is perfectly proper to regard time as energy, and to seek out what form the function takes in our normal system of units (say, the MKS system).

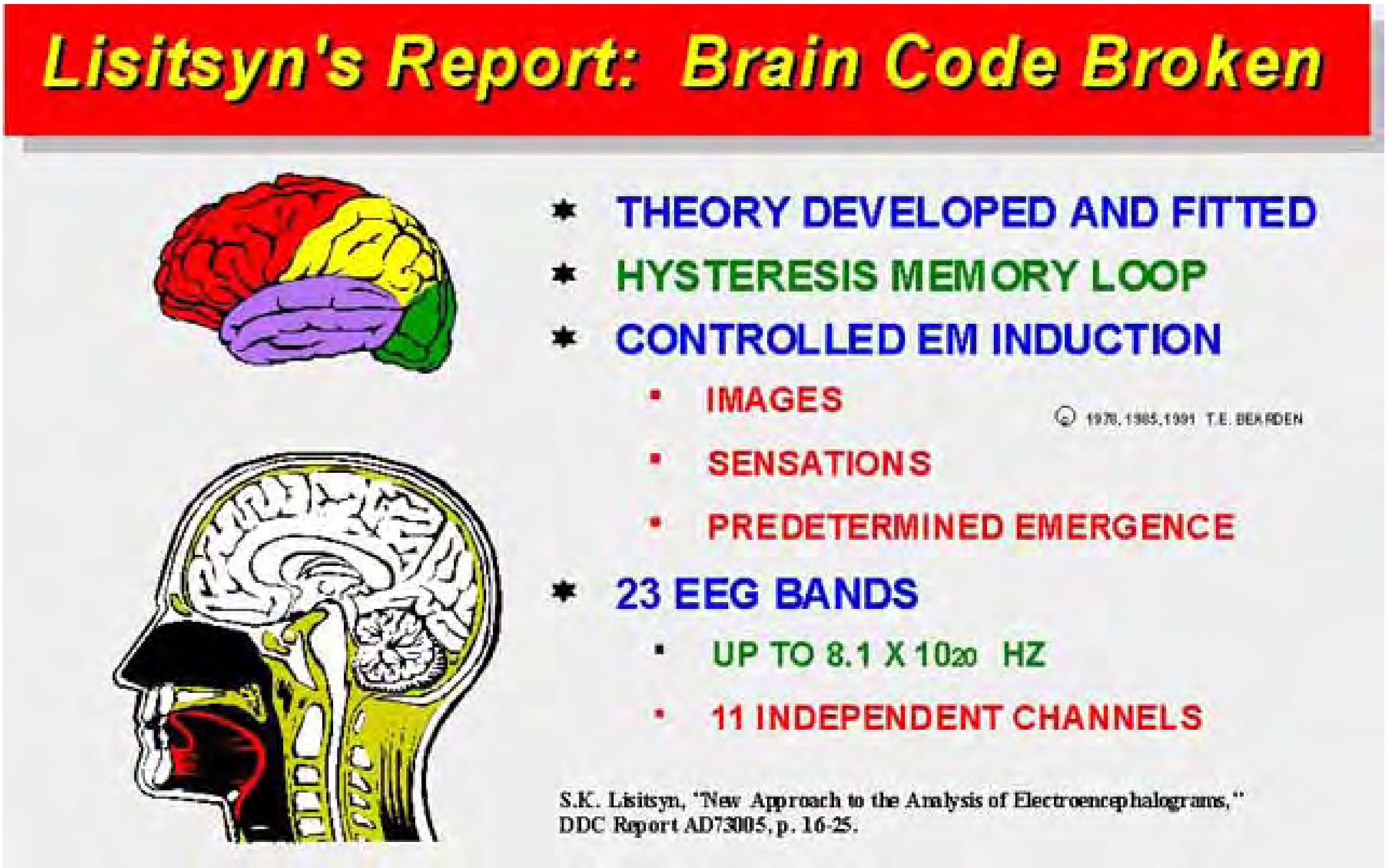

Lisitsyn's Report: Brain Code Broken

- THEORY DEVELOPED AND FITTED
- HYSTERESIS MEMORY LOOP
- CONTROLLED EM INDUCTION
  - IMAGES
  - SENSATIONS
  - PREDETERMINED EMERGENCE
- 23 EEG BANDS
  - UP TO 8.1 X 10^{20} HZ
  - 11 INDEPENDENT CHANNELS

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S.K. Lisitsyn, "New Approach to the Analysis of Electroencephalograms," DDC Report AD73005, p. 16-25.

Figure 7. In the 1960s, Lisitsyn revealed Russian scientists had deciphered the human brain code.

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In that system, it appears that any change in time Δt can be taken as always a function of a corresponding change in energy ΔE, where $\Delta t \leq (\Delta E) \div c^2$ [1] from which it follows that $\Delta E \geq (\Delta t) \times c^2$ [2] For convenience, we take the special case where $\Delta t = (\Delta E) \div c^2$ [3] $\Delta E = (\Delta t) \times c^2$ [4].

Observation as Used in Physics Is Spatial

We note that all mind operations are time-like, i.e., they are comprised as scalar EM photon functions and scalar EM wave functions. Thus the mind is a very special kind of electromagnetic system, existing in the time domain, and thus "lost" by the stripping away of time in the ordinary observation process. Physical observation is essentially a time-differentiating mechanism applied to a 4-spatial change, or in terms of MKS fundamental units L and t, observation θ is $\theta = \partial/\partial t(L^3 t) = L^3$ [5].

Thus, as is well-known in quantum mechanics, physical observation is 3-spatial, and time is not a physical observable, even in theory. Since mind is time-like, it follows that mind is not a physical observable either, since discarding the time dimension also discards the mind. In short, one may also take physical operation as the mechanism that separates mind and body. To observe is to separate. We point out, however, that merely "separating and discarding" the time domain (as in physical observation of a single change) does not eliminate it, nor does it eliminate the single time-like mind change that may be involved in an intentional volition. The time domain certainly remains, even though only the 3-spatial intersection of the 4-spatial Minkowski change is given by physical mechanism and the resulting "outputs". So a series of coherently integrated "mental intent" changes introduced into the human body's overall servo-mechanism provides the continuing input. From there, ordinary physics will generate the resulting actions induced in the body by that servomechanism and its amplifying mechanisms.

Two Coupling Mechanisms Make a Closed Loop

This is the "mind-to-body" coupling mechanism. [See *Figure 5*] It is the mechanism whereby the mind is coupled to the body, and whereby mental intent is able to induce a series of physical inputs into the body servomechanism.

So the body's servomechanism then generates the responses of the body (including everything from chemistry to electrical changes to muscular movements, etc.). These responses are changes in 3-space.

The conscious mind is a *serial processor*, though extremely rapid. It produces the series of coherent intent inputs for volitional behavior.

The unconscious mind is a *massively parallel processor*.[20] It continually produces the vast series of coherent "unconscious intent inputs" for control of all the deeper processes in the body, beyond usual conscious awareness.

However, as the body moves or changes in 3-space, each resulting quantum change in body 3-space is also a slight rotation out of 3-space and toward the time axis. Hence it induces—in the "virtual state" in the time domain—a precisely correlated projection. The body's responses are in general coherent, so a coherent series of virtual state changes in the time-domain (in observation. So we may say *that the time-change remains in the virtual state, with respect to attempted physical observation of a single Minkowski 4-space change.*

Rotation, Coherent Integration, and Intent

Previously we pointed out that any change in a 4-space entity may be regarded as a rotation away from the "trajectory" of the entity. Hence each and every t-polarized change creates a very small projection into 3-space by its rotation slightly away from the time axis. All mind changes in the time-domain actually produce virtual 3-spatial projections in 3-space (in the physical domain). We define "intent" as the continued production of successively coherent mental changes, producing coherent virtual changes in the 3-space body system, with coherent integration of those 3-space virtual changes into observable 3-space energy inputs into the 3-space body system. Successively coherent mind-changes will produce successively coherent 3-space virtual changes. In short, coherent mind-changes will produce coherent integration of those 3-space virtual projections into an observable 3-space change. This is the creation of an ordinary 3-spatial energy change induced upon the 3-space body. In short, this is the mechanism whereby time-like mental intent is able to produce a series of coherent observable quantum changes in the physical body (as in the brain and nervous system).

The Body as a Servomechanism

From the standpoint of control theory, we may consider the body system to be a complex servomechanism system comprised of many subordinate servo systems with feedback and feedforward the mind realm) are created successively. In short, again we have coherent integration, this time in the mind or time domain. This produces "observable" changes in the time-mind domain, which are coherent with the body's 3-spatial changes actually performed. Thus the mind receives feedback directly from the physical movements and changes of the body. This is the manner in which the body is coupled back to the mind.[21]

By comparing the "intent" behavioral move that was "fed forward" into the body, with the return "response" move analog that was "fed back" from the body to the mind, the mind is able to determine errors and differences, and originate additional correctional commands.

Thus the entire mind-body loop is a closed-circuit system of feedforward and feedback, together with corrections. It also has multiple levels of such, infolded in the larger volitional levels. See again *Figure 4*.

This solves the age-old problem of the mechanisms for the mind-body coupling, intent, volition, conscious and unconscious functioning, sense of the external world, sense of the internal world, sense of "being in" the external world, etc.[22]

All This Is Included in Russian Psychoenergetics

This is the highly summarized basis for *psychoenergetics*, the KGB's division of energetics that deals with the mind and body coupling and functions, and direct engineering of (1) the mind-body coupling and (2) the mind operations directly. [See *Figure 6*] The KGB intent, of course, has always been to exploit this science for the degradation, killing, and control of human beings, including all humanity.

The Russians know full well that, if you looping.

Given the input from intent, ordinary servo theory will take it from there. Once a servo has an input, servomechanism theory describes the response of the

produce and utilize scalar EM photons and t-polarized EM waves, you can directly affect and engineer mind and mind operations at any and all levels. Western researchers, who know nothing of how to make

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time-polarized photons and time-polarized EM waves, do not yet know that. Consequently the Russians have developed a highly secret science of *directly* engineering the mind and its operations, including thought, images, perceptions, feelings, emotions, memory, and mind processing. Indeed, Lisitsyn[23] wrote quite specifically of this capability in the 1960s. [See *Figure 7*]

Western clandestine mind control researchers are apparently still slowly and painfully fitting TW EM irradiation correlates to induced or resulting mental and physical behavior responses. They seem unaware of the actual wave transductions occurring inside the body and mind, but are unwittingly inducing those transductions in hidden fashion anyway and in "brute-force input-response fitting" models.

These "fitted brute-force models" certainly can be very powerful, and certainly can produce the exact results shown in the experimental verifications of the fittings. However, they do not of themselves allow sophisticated design—for example—of the necessary time-polarized wave assemblies for engineering the entire human collective unconscious simultaneously, or for engineering the entire collective unconscious of all species on Earth (i.e., Gaia's collective unconscious), or even for precisely engineering the memory and knowledge base of an individual.

This fine research article will be continued in Part II with Russian Methodology, Waves and Wave Transduction, The Cellular Control

spacetime that is highly active. The mind is rooted in the time-domain and projects from that domain into 3-space. The body is rooted in the 3-space domain and projects into the time-domain. To "change" or "function" in one domain is automatically to function in the other. EM and gravitational phenomena are still modeled separately by human scientists, but not by nature.

3. In quantum mechanics, time is not an observable, but merely a parameter.
4. It is convenient to consider mass as a 3-spatial form of condensed energy.
5. E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics, " Mathematische Annalen, Vol. 57, 1903, p. 333-355;— "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions, "Proc. Lond. Math. Soc., Series 2, Vol. I, 1904, p. 367-372.
6. A NERAC document search yielded some 16 good references on t-polarized photons, but not a single reference on t-polarized EM waves.
7. E.g., such previously inexplicable instrument anomalies have accompanied some excellent and rigorous electrolyte experiments at U. S. Navy research facilities at China Lake. For a description, see Melvin H Miles and Benjamin F. Bush, "Radiation measurements at China Lake: Real or Artifacts?", Proc. ICCF - 7 (International Conference on Cold Fusion—7, Vancouver, BC, Canada, Apr. 1998, p. 101. For a brief explanation of the anomalies, see T. E. Bearden, "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves, " Explore!, 8(6), 1998, p. 7-16;— "Toward a Practical Unified Field Theory and a Deep Experimental Example," Proc. INE Symposium, Univ. Utah, Aug. 14-15, 1998.
8. Many U. S. researchers and journalists—and even many scientists—have wrestled with the problems of mind, intent, and mind-body coupling. Enumeration of those efforts would itself require an entire book. For an introduction into that domain, the reader is referred to the very determined exposé by

System, and other matters of interest. ♦

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He is president of the Association of Distinguished American Scientists (ADAS), a life member of the Alabama Academy of Science, Emeritus member of the American Association of Physics Teachers, and has served on the Board of Directors of several associations and corporations. Tom is a guitarist, a retired aikidoist (Sandan, Yoseikan style), is happily married and has two sons and two daughters. He and his wife Doris live in Huntsville, Alabama where Tom is retired from aerospace, continues private research, and serves as a consultant to industry on Scalar

Cheryl Welsh in her very timely book, The 1950's Discovery of the Code of the Brain, May 1988, published on the Internet. Simply employ any Net search engine and search on the name Cheryl Welsh. A connection to the site and to Welsh's book will immediately be found Welsh's important compendium is highly recommended, giving the reader a "birds eye view", so to speak, of how Western scientists think and proceed regarding the subject of mind control by electromagnetic means. Unfortunately all journalists so far researching the area have not been aware that Western electrodynamics itself is seriously flawed, and that the great Russian advances in mind engineering and mind control are a result of their secret but complete revision and correction of Western electrodynamics to provide the basis for energetics. Until Western scientists revise their own decrepit old electrodynamics fouling the textbooks, they will never catch up to the Russian mind control developments springing from intense development programs that did that revision in the late 1940s and early 1950s.
9. An Invention Disclosure on these processes and enhancement embodiments has been filed with the U. S. Patent Office. Formal patent applications are also in preparation.
10. Energetics is a unified science of an extended electrodynamics possessing a hidden infolded general relativity inside the potentials, fields, and waves. It deliberately employs higher polarizations (longitudinal and tempic) of photons and EM waves to engineer action at a distance, use of specific patterns of spacetime curvature created at a distance, and direct engineering of either inert or living bodies. It also encompasses the direct engineering of time-like mind and mind functions. It is divided into three divisions, depending upon the nature of the target. Targeted against inert materials, structures, fields, and waves it is called "energetics. "Against living bodies, their fields, and biochemistry, it is called "bioenergetics." Against the mind and mind functions, it is called "psychoenergetics".
11. Psychoenergetics is that branch of energetics used to directly affect and engineer

electromagnetics processes.

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1. E.g., see Lewis H Ryder, Quantum Field Theory, Cambridge University Press, 2nd Edition, 1996, p. 147+. For an even deeper discussion of photon polarization, see F. Mandl and G. Shaw, Quantum Field Theory, Wiley, 1984, under the heading "Covariant Quantization of the Photon Propagator" in Chapter 5. Mandl and Shaw argue that the longitudinal and scalar polarizations are not directly observable, but only in combination, where they manifest as the "instantaneous" Coulomb (i.e. electrostatic) potential.

2. Nature is unified and not separated into the "separate" disciplines our science has prescribed. Thus the mind is also totally electrogravitational. The mind works not just with EM forms in an inert space, but also with spacetime curvatures in a the mind, memory, perception, thought, emotion, sensation, personality, and other mind functions of a living biological organism. It is usable against a single personal conscious (serial processor) mind and a single personal unconscious (massively parallel) processor mind In theory it is also usable against lungs collective unconscious mind and its functions, as well as the deeper unconscious for all species on Earth (i.e., against Gaia). We are speaking of physics, not metaphysics.

12. W A. Rodrigues Jr.. and J.-Y. Lu, "On the existence of undistorted progressive waves (UPWs) of arbitrary speeds $0 \leq v < \infty$ in nature," Foundations of Physics, 27(3), 1997, p. 435-5•08 A slightly corrected version is downloadable as hep-th/9606171 on the Los Alamos National Laboratory website.

13. E. T. Whittaker, "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions, "Proc. Lond. Math. Soc., Series 2, Vol. I, 1904, p. 367-372. The paper was published in 1904 and orally delivered in 1903.

14. E.g., see T. E. Bearden, Fer-de-Lance, Tesla Book Co., 1986;—AIDS: Biological Warfare, Tesla Book Co., 1988;—Soviet Weather Engineering Over North America, 1-hour videotape, 1985,—Gravitobiology; A New Biophysics, Tesla Book Co., P.O. Box 121873, Chula Vista, CA 91912, 1991,—Energetics of Free Energy Systems and Vacuum Engine

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Therapies, Tara Publishing, Internet node www.tarapublishing.com/books, July 1997; — Energetics: Extensions to Physics and Advanced Technology for Medical and Military Applications, CTEC Proprietary, May 1, 1998, 200+ pages furnished to selected government agencies and key Congressional committee leaders.

15. E.g., see T.D. Lee, Particle Physics and Introduction to Field Theory, Harwood; New York, 1981. On P.383, Nobelist Lee points out that the microstructure of the scalar vacuum field (i.e., of vacuum charge) is not utilized. Particularly see Lee's own attempt to indicate the possibility of using vacuum engineering, in his "Chapter 25; Outlook; Possibility of Vacuum Engineering, " p. 824-828. With wave transductions and use of higher polarization EM waves, there are far better and more powerful ways to do vacuum (spacetime curvature) engineering.

16 T.E. Bearden, "Formation and Use of Time-Reversal Zones, EM Wave Transduction, Time-Density (Scalar) EM Excitation and Decay, and Spacetime curvature Engines to Alter Matter and Convert Time Into Energy," Invention Disclosure Document #446522, Oct. 26, 1998.

17. T.E. Bearden, "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves, "Explore!, 8(6), 1998, p. 7-16; — "Toward a Practical Unified Field Theory and a Deep Experimental Example," Proc. INE Symposium, Univ. Utah, Aug. 14-15, 1998.

18. We have used the enormous energy density of time in our approach to a totally new kind of electronuclear interaction at feeble spatial energy. By use of a time-reversal zone (TRZ) in a fluid; the free H+ ions—which are free protons—can be induced to attract each other so tightly that the edge of the nuclear force region is entered. In that case the protons form a quasi-nucleus. When the TRZ decays back to a time-forward zone (TRZ), this new quasi-nucleus decays by changing quarks in one or more nucleons, thereby producing new nuclides. We point out that means "sense of existing in time".

20. The "unconscious" is totally conscious, just multiply so. The conscious mind can see only "a single slide in the slide projector at a time, " so to speak. When it "looks" at the ongoings and outputs of the unconscious, it "sees" millions of slides in the slide projector simultaneously. Hence it cannot distinguish "one and one only". So it just sees nothing, where by "nothing" we mean "no single distinguishable thing." It therefore is unable to consciously perceive the actions of the unconscious. When the unconscious wishes to communicate with the conscious (because of unresolved conflicts, etc.), it must produce large groupings integrated into "symbolic scenarios". Hence the symbolism of the unconscious, and the basis for therapeutic psychology and psychiatry. A "symbol", after all, is just a thing which can have many different meanings, all folded into one.

21. The mind continually has activities of its own, each of which produces coherent changes in the body to a much smaller degree. The interweaving of these "smaller self-changes" infolded inside the 3-space major intent changes also produces slight body changes, which in turn "project back" into the mind. This huge group of "infolded self-loops" produces the sense of "my body" being "volitionally directed or occupied" simultaneously with the "greater intent" loops which represent "my intentional actions with my body". Further; the body servo continually receives a myriad of inputs from its sensory systems, both from changes inside the body and from incoming changes from the external universe. This interweaving produces the awareness of "being in the external world" by having (i) changes whose feedback do not match mind-intent changes, and (ii) changes whose feedback does match mind-intent changes. This of course applies to both the conscious and unconscious levels. The purpose here is to demonstrate that there exists an actual physics of the living being, the mind as well as the body, and the coupling and interfiinctioning of mind and body.

this is actually a very high energy reaction; however; since the time-energy is used and is very, very dense, the amount of 3-spatial energy that must be used is very small. If this new mechanism holds, it represents a revolution in particle physics.

19. "Self-awareness" refers to be continually "refreshed" by time-delayed coherent feed-back inputs from the body to the mind; where these inputs compare to the recalled memory of the minds inputs to the body. In short, the time-delay coherence creates the sense of "existing in time". Awareness usually

22. The methodology also easily extends to include deeper interlays for the collective human unconscious mind and for Gaia—the collective unconscious mind level for all the species on earth.

23. S. K Lisitsyn, "New Approach to the Analysis of Electroencephalograms, " in Problems of Bionics— (Selected Articles), Defense Documentation Center Report AD 73005, date unknown, p. 16-25. Available through the National Technical Information System (NTIS).

Mind Control and EM Wave Polarization Transductions, Part 2

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This article continues on with T.E. Bearden's article, Part 1 of which was published in Volume 9, #2 of Explore! for the Professional. Because we feel that Col. Bearden's caution below is so very important we are repeating its publication in all parts of this article.

Special Note

This article refers to experimental research techniques which can be detrimental or lethal in the hands of any but highly skilled, qualified experimental scientists proceeding under proper laboratory safety procedures. The purpose of this article is strictly for information to properly qualified and authorized scientists in certified laboratories. We do not propose or condone any use of these procedures for non-approved practice of medicine without a license. Neither the publisher nor the author are responsible for accidents or outcomes in the use of these experimental procedures and techniques. Any researcher who performs these procedures and experiments is acting on his or her own volition, and is solely responsible for insuring safety, qualifications, and legality of the acts and their results. We neither suggest nor condone unauthorized experimentation on human subjects. Such is a criminal violation of the constitutional rights of the subject under Federal and State laws, and is both illegal and immoral.

A Strategic Threat Completely Unrecognized by the West

The Russian methodology leads directly to rather mind-bending, extended capabilities. KGB psychoenergetics scientists seem fixed on an eventual goal of directly engineering Jung's collective human unconscious, thereby converting the entire human species into a sort of "ant" species. In short, they seek to engineer what they regard as "perfect communism and perfect order" directly in the entire species. *Figure 8* indicates the direct connection of every human's conscious and unconscious mind to the collective species unconscious and to Gaia, the collective unconscious for all species on Earth. Since time is internally structured and layered, it follows that time-like mind levels are also internested and layered.

This appears to be a significant strategic threat, *well along in its development*, that our scientific and intelligence communities have completely failed to recognize.

The direct engineering of the entire human collective species is a doable.[1] It is going to be done, whether we like it or not. In that race (which may eventually determine whether or not we retain any personal freedom at all), the "democratic" nations are woefully behind. In fact, the West has not even realized there is such a new kind of "arms race" for dictatorship and control of the "collective species mind" and we have already almost lost it. The West has not yet even developed the overall theory of psychoenergetics.

Waves and Wave Transductions

A pure longitudinal EM wave (LW) would have infinite energy and infinite speed. In practice, one can only approach this perfect LW wave, and one always has transverse residues remaining. Hence the "imperfect" longitudinal EM waves we can make in suitable equipment and techniques, are known as "undistorted progressive waves" (UPWs). The UPWs may have velocity far greater than the speed of light, or less than the speed of light. So the speed v of UPWs can vary as

$$0 < v < \infty \qquad [6]$$

The Russians also know that, when a nearly-pure longitudinal EM wave interacts with matter (it usually doesn't interact very much, and has a low reaction cross section), the mass immediately adds the phase conjugate replica to the interacting LW portion, regardless of frequency, thereby transducing the input LW interactions into scalar (time-polarized) EM interactions.

One transduces from TW to LW to Scalar EM via iterative phase conjugation. One transduces from scalar EM to LW to TW via iterative interferometry. It took the present author 20 years to discover this simple thing; we now have filed an invention disclosure on the process and embodiments for performing it, and will be following with formal patent applications. Let TW = transverse EM wave, LW = longitudinal EM wave, and TDW = time-density EM wave (another name I use for t-polarized or scalar EM waves, since the density of time-energy is what is varying). Let (I) = interfering with, PCR = phase conjugate replica wave with a coupled set of parentheses enclosing the type of wave. The rules for wave type transduction are:

$$\mathrm{TW} + \mathrm{PCR(TW)} \Rightarrow \mathrm{LW} \qquad [7]$$

$$\mathrm{LW} + \mathrm{PCR(LW)} \Rightarrow \mathrm{TDW} \qquad [8]$$

Going the other way, the rules are:

$$\mathrm{TDW\ (I)\ TDW} \Rightarrow \mathrm{LW} \qquad [9]$$

$$\mathrm{LW\ (I)\ LW} \Rightarrow \mathrm{TW} \qquad [10]$$

In EM smog (dense EM signals, even though very weak), there is increased nonlinear multiwave interactions, both interferometric and phase conjugative. So in such EM smog there exists an increased, non-negligible component of LW and TDW irradiation, formed by the above transduction interactions in the irradiated living cells and bodies. This latter part accounts for many of the long term effects which show up in "correlative" studies, but which do not show up in the normal limited-frequencies TW experiments produced by so-called "physical experiments."

The standard EM bioeffects manner of experimenting uses a theoretical model of simple, direct energy deposition by means of absorption in cells and tissues. Now we must utilize an "open system" throughout the body dielectric in which higher polarized EM energy (either LW or t-polarized) travels readily throughout all areas of the body.

EM Bioeffects and Wave Transductions

In the EM bioeffects experiments to date, there has been absolutely zero control of the internal transductions, and there has been no consideration of them. Almost all transductions of TWs into LWs will immediately result into transduction into TDW and time-excitation charging of the cells and all their internal components. These time-excitation charges (excited states of time-charging) will then slowly decay, emitting longitudinal EM waves in the process which travel throughout the body. These emitted LWs interfere with each other and the LW processes in the body, producing low level TW "noise jamming" of the cellular processes and—most especially—of the deep cellular control system of the body. The latter system functions by means of LWs and TDWs. Long-term effects of such "noise jamming" of biochemistry reactions and the control systems of the cells and body, can lead to degenerative diseases such as arthritis, atherosclerosis, Alzheimer's disease, heart disease, cataracts, tumors, leukemia, somewhat accelerated aging, immune system weakening and depressing, etc. As the body's natural defense and regeneration ability weakens, opportunistic infections further add to the degeneration.

It was shown by Whittaker in 1903 that any scalar EM potential is comprised of a harmonic series of bidirectional longitudinal EM wavepairs. [See *Figure 9*] Each longitudinal EM wave pair in the harmonic series is a phase conjugate pair. Unknown to Whittaker, that "LW phase conjugate pair" is actually a time-polarized EM "photon" structure, containing a phase conjugate LW photon substructure. So staid old "voltage" (potential) is comprised of a harmonic series of time-polarized EM waves!

The corresponding "t-polarized photons" are actually spin-4 *supergravitons* comprised of coupled antipairs of LW "photons". Each LW photon is a spin-2 *graviton* comprised of a coupled TW photon-antiphoton pair. Each TW photon and antiphoton in the coupled pair has spin-1. The couplet, being the longitudinal "photon" or graviton, thus has spin-2. And so on.

In 1904, Whittaker showed that any EM field or wave pattern can be decomposed into two scalar potential functions. By applying Whittaker 1903 decomposition to each scalar potential function, any EM field or wave has an enormously rich internal structure, comprised of scalar potential functions in interference. Each scalar potential function is comprised of time-polarized EM waves (made of spin-4 supergravitons). Each time-polarized EM wave is further comprised of bidirectional longitudinal EM wavepairs. Each longitudinal EM wave is further comprised of phase-conjugate pairs of transverse EM waves. Each transverse EM wave is further comprised of two scalar potential functions, each of which is in turn comprised of an infinite harmonic series of time-polarized EM waves, and so on *ad infinitum* and *ad nauseum*. Obviously all EM potentials, fields, and waves have an enormous "internal structure" or internal "information content of the field".

The Cellular Control System Uses t-Polarized EM Photons and Waves

The master cellular control system (MCCS) in the body utilizes these photon-gravitons, their corresponding EM wave polarizations, and transductions between them. By the use of very powerfully condensed gravitons and supergravitons, it is able to utilize small but highly significant direct curvatures of spacetime in precise patterns. In short, it utilizes general relativistic spacetime curvature engines, rather than "EM photon signals", to accomplish its control of the cells and their processes. It does not merely send a "signal" and hope the cell itself acts upon it. Instead, it sends an "engine" which alters the local spacetime in which the cell and all its components are embedded. This "local ST curvature engine" then physically works directly upon the cell and all its parts, to alter the cell according to the specific "template" of the engine.

This is the direct application of the Wheeler's simple statement of general relativity: *Mass (trapped energy) acts upon spacetime to curve it, and curved spacetime acts upon mass to change it.*

Popp's "ordinary photon" study of this cellular control system[2] therefore will detect the coherent ordinary TW photon residues which result from the photon polarization transductions occurring from the actions of the ST curvature engines upon the cells.

Cellular division, biochemical processes, growth and growth control, cell differentiation and dedifferentiation, etc. are all controlled by the MCCS or one of its subsystems, using spacetime curvature engines. The ordinary TW electronic activity our biophysicists detect and correlate are simply the intermediate components of the actual ongoing polarization transductions.

The Cellular Control System Uses EM Time-Energy

One important subsystem of the MCCS controls the immune system's functions, including the deepest and most subtle functioning performed by all elements of the immune system. This system has been rather intensively studied, but since our biophysicists have not possessed the full electrodynamics utilized, only the correlated residue of normal TW EM waves and photons have been recognized and studied. Hence Western biophysics is in its very crude infancy.

Incorporation of the total wave and photon polarizations, together with their transductions, will eventually present a revolution in both biomedicine and biophysics. Unfortunately, presently our entire medical community is very firmly entrenched in only ordinary TW EM polarizations and ordinary biochemistry. Our scientists thus are studying less than 1% of the functioning of the living organism.

As an example, since Western scientists have no knowledge or research into the time-polarized mind domain and mind-body coupling, the mystery of the *placebo effect*—in which the mind has been verified to produce actual physical effects – will indefinitely remain a mystery.[3] As one result of that "crippling" of our medical theory, medical experimenters have to deliberately drive experiments on drug effects, etc. beyond the "mind's own threshold" of physical effect. In short, they have to drive the experimental results over and above the results being accomplished by the placebo effect. They must perform valid placebo control experiments, and subtract the placebo component results from their own experimental results, to determine the "delta" induced purely by the drugs.

The Regenerative Subsystem

Another important subsystem of the MCCS controls the *regenerative system* of the body. The regenerative system has various mechanisms, including growth control, differentiation and dedifferentiation of cells, etc. Becker's portrayal of the regenerative system is shown in *Figure 10*. One of its most important functions is healing and restoring damaged or diseased cells. It does that by a most remarkable process.

This system has been very poorly studied, mostly by Becker[4] *et al.*, although there is still sporadic, ill-funded, and ill-planned research on regenerative effects from time to time.[5] Becker and his colleagues came closest, and—considering the severe limitations of the orthodox U(1) EM model available to them—Becker's work is particularly revolutionary. He demonstrated beyond question that simple DC potentials could generate cellular differentiation and redifferentiation, and produce results at global sites in the body and not just at the local injury sites where the DC potentials were applied.

Becker was nominated for a Nobel Prize for his Herculean efforts and remarkable results. For his trouble he was hounded, his funds were withdrawn, and he was forced to retire at an early age in his 50s. His biggest "heresy" was to bravely point out that power line radiations had deleterious effects upon biological systems, and to testify to it in a series of hearings and court cases where a very powerful electrical power industry essentially ran rough shod over science and the public.

Organized Science Is Highly Politicized and Imperfect

It is not only politicians that are "bought and paid for" by powerful vested financial interests. In organized science, precisely the same arrangement holds true. Scientists are no better or no worse than any other segment of humanity. A surprising percentage will produce the results desired by their benefactors, if provided with cushy jobs, good income, prestige, and secure positions.

It has been said that money is power. It has also been said that power corrupts, and absolute power corrupts absolutely. In the scientific community, as well as in the political community, this "great corruption" by great financial power has been elevated to an art form. Simply examine the funds made available to scientists. There is not enough for all the scientists, so it is fiercely competitive. If the scientist does not get grants (e.g., a would-be professor at a university), he does not bring in extra money to the university. He cannot get his graduate students funded, so his own innovative (read: heretical) research is thwarted. His papers are rejected by the journals, and before long he has no funded position in science. If lucky, he will be employed in the grocery store or the butcher shop.

Every bit of funding available for the scientists to compete for (and apply for grants) already has firmly fixed controls of exactly what research can be done with that money. The "science" that will be applied is already formulated. That and only that can be done. It is a tribute to the dedication and resourcefulness of our working scientists themselves, that anything innovative at all gets done.

One can have a very fine scientific career, tenure as a professor, get one's graduate students funded, get one's papers published in prestigious journals, win awards and achieve stature and prestige, if one just plays the desired game prescribed by the "old boys schools" in control of almost all the scientific funding. Yes, one can permissibly move the decimal point in the present models a bit, and be rewarded handsomely for doing so. But one is damned if one attempts any serious change or overthrow of obsolete scientific models and practices favored by the "system".

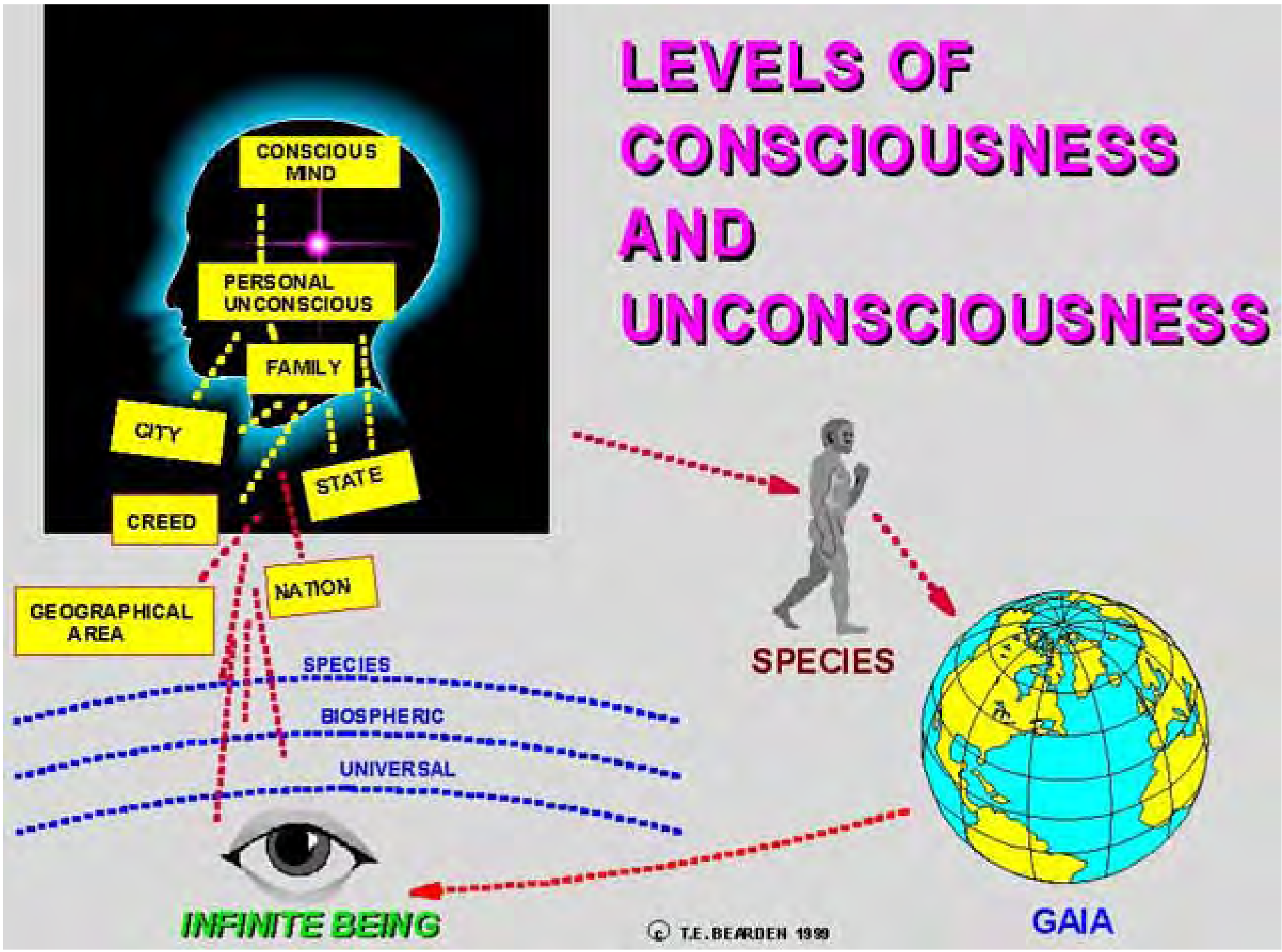

Figure 8. Nested levels of consciousness and unconsciousness. The mind levels contain the "life" and "mind" dynamics.

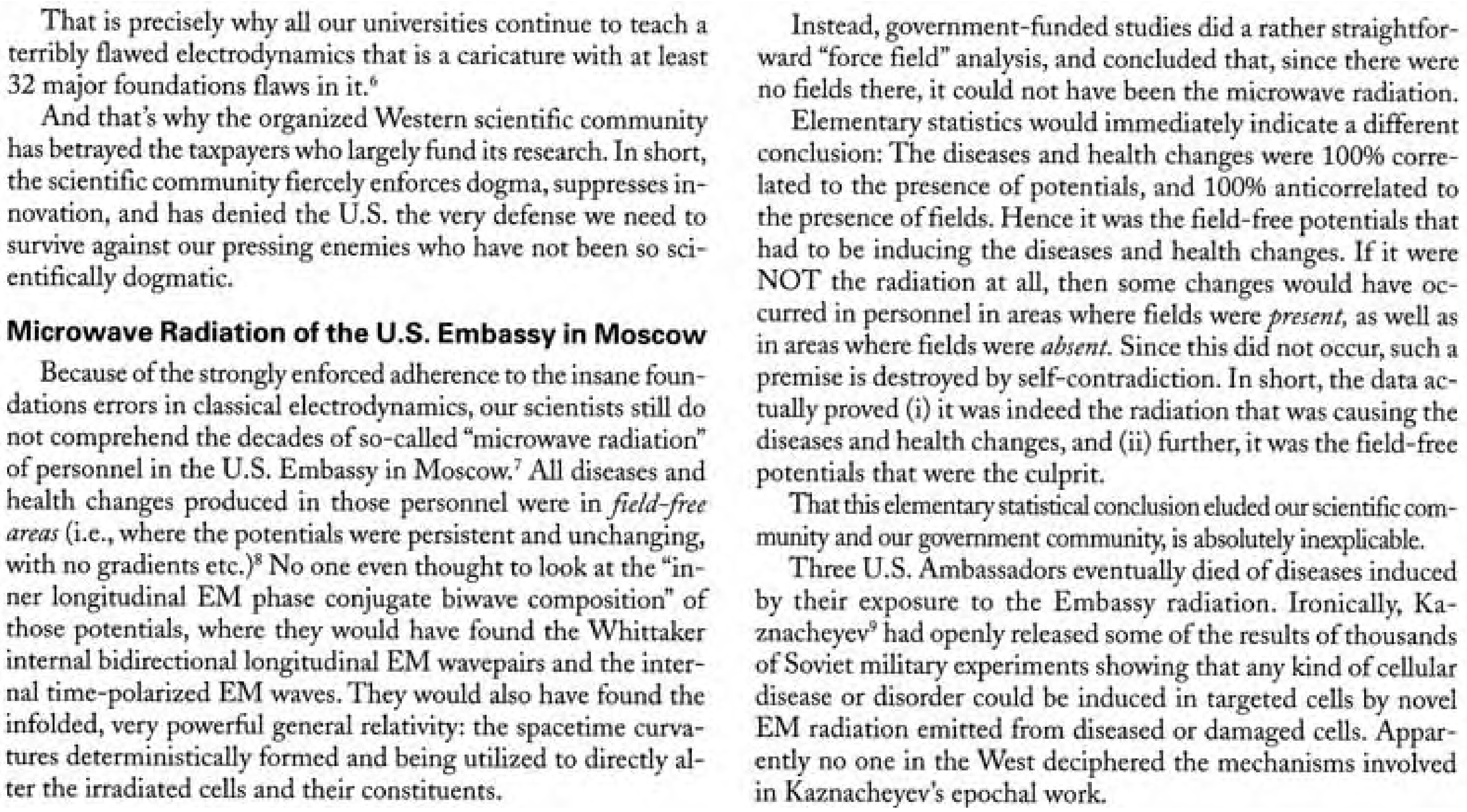

That is precisely why all our universities continue to teach a terribly flawed electrodynamics that is a caricature with at least 32 major foundations flaws in it.[6]

And that's why the organized Western scientific community has betrayed the taxpayers who largely fund its research. In short, the scientific community fiercely enforces dogma, suppresses innovation, and has denied the U.S. the very defense we need to survive against our pressing enemies who have not been so scientifically dogmatic.

Microwave Radiation of the U.S. Embassy in Moscow

Because of the strongly enforced adherence to the insane foundations errors in classical electrodynamics, our scientists still do not comprehend the decades of so-called "microwave radiation" of personnel in the U.S. Embassy in Moscow.[7] All diseases and health changes produced in those personnel were in *field-free areas* (i.e., where the potentials were persistent and unchanging, with no gradients etc.)[8] No one even thought to look at the "inner longitudinal EM phase conjugate biwave composition" of those potentials, where they would have found the Whittaker internal bidirectional longitudinal EM wavepairs and the internal time-polarized EM waves. They would also have found the infolded, very powerful general relativity: the spacetime curvatures deterministically formed and being utilized to directly alter the irradiated cells and their constituents.

Instead, government-funded studies did a rather straightforward "force field" analysis, and concluded that, since there were no fields there, it could not have been the microwave radiation.

Elementary statistics would immediately indicate a different conclusion: The diseases and health changes were 100% correlated to the presence of potentials, and 100% anticorrelated to the presence of fields. Hence it was the field-free potentials that had to be inducing the diseases and health changes. If it were NOT the radiation at all, then some changes would have occurred in personnel in areas where fields were *present*, as well as in areas where fields were *absent*. Since this did not occur, such a premise is destroyed by self-contradiction. In short, the data actually proved (i) it was indeed the radiation that was causing the diseases and health changes, and (ii) further, it was the field-free potentials that were the culprit.

That this elementary statistical conclusion eluded our scientific community and our government community, is absolutely inexplicable.

Three U.S. Ambassadors eventually died of diseases induced by their exposure to the Embassy radiation. Ironically, Kaznacheyev[9] had openly released some of the results of thousands of Soviet military experiments showing that any kind of cellular disease or disorder could be induced in targeted cells by novel EM radiation emitted from diseased or damaged cells. Apparently no one in the West deciphered the mechanisms involved in Kaznacheyev's epochal work.

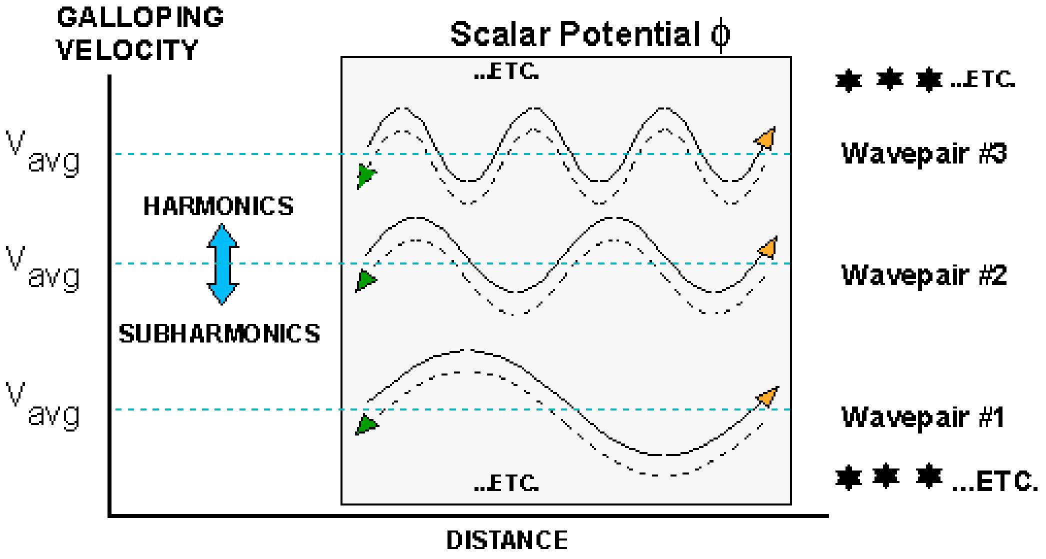

The Structure Is:

- A harmonic set of longitudinal phase conjugate wavepairs.
- In each wavepair the two waves superpose spatially after detection, but travel in opposite directions.
- The convergent wave set is in the imaginary plane, and hence is not observable. It is EM energy incoming to the potential (dipolarity) from the time domain.
- The charge's spin is 720 degrees, 360 in the real plane and 360 in the imaginary plane.
- Hence the charge receives the complex convergent EM energy, transduces it into real EM energy, and emits enormous energy at the speed of light in all directions -- which includes bidirectional pairs in 3-space (after the reaction, being after "observation").
- This produces the fields and potentials from the "source charge or dipole."
- Mandl and Shaw argue that the scalar (time-polarized) photon and longitudinal photon are observable only in similar pairs, which then makes the instantaneous scalar potential. Thus their quantum field theory work strongly supports the "negative resistor" interpretation of the scalar potential and our solution to the source charge and source dipole problem.

Figure 9. Infolded longitudinal biwaves (time-polarized EM waves)

composition of a scalar potential.

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The Present Situation in Western EM Bioeffects Research

Our scientific community has not even *designed physical experiments* to validate long-term EM bioeffects of the kind caused by induced wave transductions and long-term effects inside the absorbing human cells and in the body's regenerative and immune systems. Western science has no knowledge of these technical internal "wave polarization transduction" mechanisms. Yet the basis for such mechanisms has existed in the hard physics literature for decades. Leading EM bioeffects researchers seem totally unaware of small reaction cross sections inside the body cells and tissues for the transduction of transverse EM signals into LW and t-polarized EM signals. Conventional Western researchers have not investigated it, and often will not believe it when it is pointed out to them along with the supporting basis in the literature.

A major part of the mainline "EM bioeffects" community, of course, seems comfortably funded largely by the power industry etc.[11] The record is clear that this dominant, well-funded group has little or no intention of "finding" anything that will question powerline radiation safety and upset their cushy positions.

In fact, leading bioeffects researchers have pointed out this deliberate biasing of EM bioeffects as a research area. Quoting Dr. Andrew A. Marino, one of the great pioneers in the area of EM bioeffects[10] and powerline radiation assessment.[11]

"Neither scientists nor the public can rely on power-industry research or analysis to help decide whether powerline electromagnetic fields affect human health because power-industry research and analysis are radically misleading."

Dr. Marino then gives the specific details to prove it, and he shows specifically how they slant and mangle their experiments and interpretations of the results, to do it. If the major financial interests cannot *scientifically* destroy determined, honest researchers such as Marino and Becker, they do not hesitate to attempt to destroy them in lawsuits.

The "Diffusion Mixmaster" at All Body and Cellular Levels

Every mass and all its particles are in a violent energy exchange with the active vacuum. A human body and every part of it is in a continual exchange of EM energy with its environment(s), including transverse, longitudinal, and t-polarized (scalar) EM energy exchanges. Further, within the dielectric body there is a sort of intensive "diffusion" of special kind, actually due to iterative phase conjugation and iterative interferometry of the dense signals environment impinging upon it. This internal "diffusion" and transduction (iterative multiwave phase conjugation and iterative multiwave interferometry) thoroughly "mixes up and transduces" one type of EM wave or signal into the other, including many of the body's own TW, LW, and TDW signals.

Continual or sustained TDW exposure (irradiation by t-polarized EM waves) charges the body and its particles with time-excitation charging, something which has been erroneously omit-

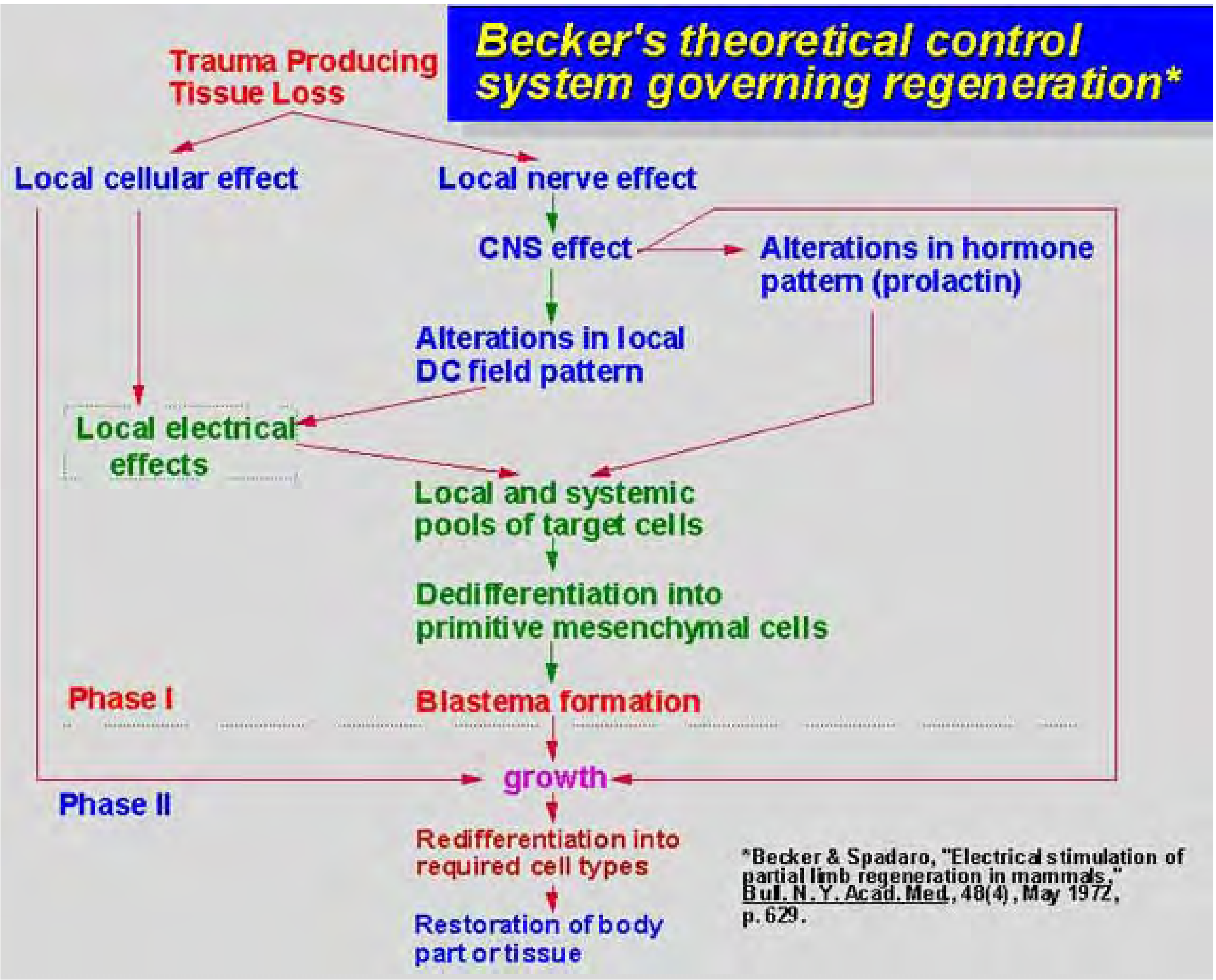

Becker's theoretical control system governing regeneration*

Trauma Producing Tissue Loss
Local cellular effect
Local nerve effect
CNS effect
Alterations in hormone pattern (prolactin)
Alterations in local DC field pattern
Local electrical effects
Local and systemic pools of target cells
Dedifferentiation into primitive mesenchymal cells
Phase I
Blastema formation
growth
Phase II
Redifferentiation into required cell types
Restoration of body part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bull. N.Y. Acad. Med., 48(4), May 1972, p. 629.

Figure 10. Becker's model of the Regenerative system of the body.

ted in physics, but is true nonetheless. Inexplicably, physicists just ignore what happens time-wise when a mass absorbs a photon. We have covered that elsewhere.

So inside the body dielectric, there is a "diffusion mix" correlate of any and every type of the waves, to any or all of the exchanges, plus the additional internal interactions of the body in its TW, LW, and scalar EM wave transductions. There is a one-to-one correspondence to any one of the three types of polarization waves (transverse, longitudinal, and scalar) and everything going on anywhere in the body.

Note that the type of LW we are using is actually made of phase conjugate pairs of transverse EM waves, so its "photons" are made of photon/antiphoton pairs. That is, our longitudinal EM wave has an internal TW structure, and the LW wave is comprised of spin-2 *gravitons*. Our longitudinal EM wave has an internal structure, and it dramatically differs from the LW used by the U.S. scientific community which ignores wave, field, and potential infolded substructures. Our LW (which seems to be what the Russians use) is also a gravitational wave because it is comprised of oscillations in its distributions of spin-2 photon/antiphoton pairs (i.e., *gravitons*).

The type of t-polarized (scalar) EM wave we are using is a phase conjugate coupled pair of the specialized electrogravitational (EG) LWs. The "t-polarized photons" comprising this t-polarized "EM" wave are comprised of spin-4 *supergravitons*. These are, I believe, what the KGB energetics weapons scientists use also. By iteration, we can go into as deep an internal multilevel structuring of EM and EG waves, of any type, via methods shown by Whittaker.[12]

Now let us examine a body as a dielectric, sitting there in its exchange, in relative equilibrium. It turns that every tiniest piece of a dielectric participates in any emission from it[13]—even the emission of a single photon, graviton, or supergraviton. Well, it *would* so participate, due to the special sort of correlated diffusion and interferometry and phase conjugation that we pointed out. Anything that escapes (is re-emitted) from the body, has been through this "diffusion wringer". It has escaped from each and every internal part of the body.

Novel Signatures in Body-Emitted EM Radiation of Any Polarization

A single photon or wave emitted from a dielectric carries in its internally structured time component a *template* of the exact internal time structuring of every part of the dielectric emitting that photon. It carries in its internally structured energy component a *template* of the internal energy structuring of every part of the dielectric emitting it. An emitted EM wave, being a collection of emitted photons and photon structures, thus carries the same internal structuring of both its transported energy and its transported time.[14] Western scientists do not use the internal

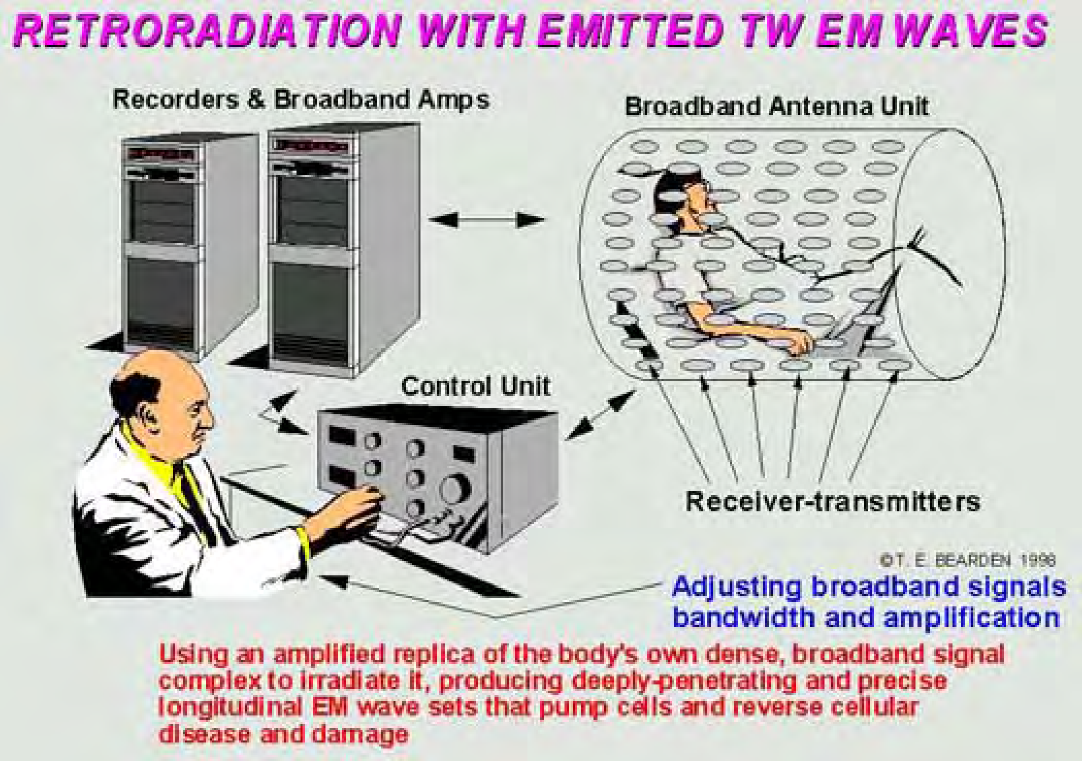

Adjusting broadband signals bandwidth and amplification

Using an amplified replica of the body's own dense, broadband signal complex to irradiate it, producing deeply-penetrating and precise longitudinal EM wave sets that pump cells and reverse cellular disease and damage

Figure 11.

structuring of photons and EM sine waves, have no instruments for that, and so do not know it. The Russians know it,[15,16] use it, and have developed sophisticated instruments for it for the last 30 years or more.

Shortly we will postulate how conventional scientists experimenting with mind and behavior control electromagnetically might utilize an immediate consequence of the fact that the specific emission from a body at any time—whatever type of wave component we look at—is a total correlate to all that body's internal functions, its energy exchanges with its environment, its states, its mental states and conditions, etc.

And we accent that the coherently integrated intent-changes in that body from its coupled mind's operations are also in the substructure of photons and EM waves emitted from the living body into its environment.

How Western Mind Control Scientists Might Proceed

Conventional scientists would ignore scalar photons and waves, determine the TW spectrum, and then slowly and painfully correlate that to the various physical, mental, and emotional things. That's the way they would *have* to do it, since apparently they use only standard electrodynamics. They can in fact do this via brute force, because that emission TW spectrum is of waves escaping from the entire "diffusion machinery" mixmaster in the body dielectric. It does contain all those integrated *mind-intent* 3-space correlates as well as the ordinary body 3-space energy correlates.

Anyhow, in envisioning Western procedures, the test body would be sitting there, in its normal (let's say fairly normal and quiet) EM environment. [See *Figure 11*] Let's assume this body is not sick, but is healthy and normal. Its emissions are a part of its equilibrium condition. It follows that the totality of its TW emissions is correlated to the sum total of everything that interacted with the body, plus its own internal reactions, including from mind-body coupling. Indeed, everything that has ever happened to that entity—physically, mentally, emotionally, etc.—has internal correlates infolded inside the emitted transverse EM wave spectrum.[17]

So first the scientists would simply measure the full environmental TW spectrum down to very tiny levels in all frequency bands possible—everything that is coming in to the body from its environment. They would probably perform the experiments in a triply-shielded Faraday cage, so the external environment outside the cage contributes very little transverse EM wave noise (perhaps some Schumann resonance). Magnetic wave shielding and ELF shielding is something else again, and longitudinal EM wave shielding is in general not possible unless longitudinal EM waves are employed in the shielding. But a "quiet external TW environment" enhances the isolation and measurement of the specific TW signal transforms the Western experimenters would be seeking.

Then they would measure everything likewise that the body is *emitting* when in that environment. That is the "zero reference" or "normal reference" level. They would measure every aspect: frequency, amplitude, phase, wave shape, modulation, etc.

Probable Experimental and Measurement Techniques

Next they would selectively irradiate the body with specific signals, frequencies, waveforms, etc. They would begin by using portions of the same frequencies that are being emitted from the body in the "zero reference" environment. They would insure that the returned signal was of higher amplitude than the usual signal being emitted by the body at that same frequency and type.

They would consider the body dielectric as a "ship with portholes". Light (EM transverse wave energy) coming out of the portholes has originated and adapted from everywhere inside the ship and its operations. When the experimenters reinsert energy through one or more portholes, they are interested in determining precisely which operations inside the ship are affected. So the body physiological functions are also heavily instrumented.

By feeding back in the exact EM pattern and magnitude escaping the body dielectric through a single porthole, one "nullifies" that part of the emission by producing a net equilibrium in that component. This will in turn produce changes elsewhere in the spectrum emission from other portholes, and this can be measured. It will also produce "stress changes" in specific portions of the body dielectric, and in the heavily instrumented body these physiological, chemical, electrical, etc. changes can also be detected. Monitoring of the skin conductance, e.g., indicates the level of stress, and EEG monitoring with sophisticated instrumentation can indicate something of the brain wave states.

In short, the necessary measurements from which to construct specific correlates can be performed, recorded, and later analyzed.

This article will be concluded in Volume 9, #4 with Improving the Methodology, Further Phenomenology Experiments, Rejuvenation and other matters. ◆

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Tom is the leading advocate of scalar potential electromagnetics and the Fogal charge-blocking semiconductor. He is involved in alternate energy devices and scalar electromagnetic system prototypes. He has defined charge q as a coupled system of two components, advanced a mechanism for a vacuum engine, whereby the vacuum's virtual particle flux is organized and used to energetically shape and manipulate matter and energy, and advanced a mechanism for a Bohm-type quantum potential, which theoretically allows the engineering of action at a distance in physical systems.

He is president of the Association of Distinguished American Scientists (ADAS), a life member of the Alabama Academy of Science, Emeritus member of the American Association of Physics Teachers, and has served on the Board of Directors of several associations and corporations. Tom is a guitarist, a retired aikidoist (Sandan, Yoseikan style), is happily married and has two sons and two daughters. He and his wife Doris live in Huntsville, Alabama where Tom is retired from aerospace, continues private research, and serves as a consultant to industry on Scalar electromagnetics processes.

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6. I have one viewgraph which lists those 32 major flaws in electrodynamics. Further, leading theorists (Evans, Crowell, and others) in the Alpha Foundation's Institute for Advanced Study (AIAS)—of which I am a Fellow Emeritus by AIAS's kind tolerance—have added about another very technical and very fundamental dozen or so errors to my own list. A leading foundations scientist with over 500 papers in the literature commented dryly to the AIAS that "I broadly agree. that the transverse plane wave view of vacuum electrodynamics is the biggest blunder of twentieth century science. Faraday visualized that "EM disturbances" surrounding wires, magnets, etc. were simply the transverse plucking of taut strings. As he states in his book, Maxwell—who also firmly believed in the material ether—simply captured Faraday's thinking and assumed that transverse "plucked string" wave disturbance in the material ether. At the time all this was expressed, the electron had not been discovered, the atom had not been discovered, the molecule was a featureless blob, and no one had the slightest notion of an atomic nucleus filled with protons and neutrons. Charge was simply a "certain volume of electric fluid" and everything electromagnetic was expressed in fluid dynamics. As an example, that "material fluid" and "material ether" theory was destroyed in the late 1880s by the Michelson-Morley experiment. All the Maxwell equations assume that material ether to this day; not a single equation was ever changed to eliminate the material ether assumptions during the last 110 years.
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11. Andrew A. Marino, Powerline Electromagnetic Fields and Human Health, http://www.ortho.lsumc.edu/Faculty/Marino/Marino.html. This book is highly recommended. Particularly see "Chapter 5, Blue-Ribbon Committees and Powerline EMF Health Hazards," and "Chapter 6: Power-Industry Science and Powerline EMF Health Hazards." Biophysicist Marino is one of the leaders in the field and has been personally involved in many skirmishes with powerline-dominated studies and findings.
12. E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," Mathematische Annalen, Vol. 57, 1903, p. 333-355; — "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions," Proc. Lond. Math. Soc., Series 2, Vol. 1, 1904, p. 367-372.
13. Reali, G. C., "Reflection from dielectric materials," American Journal of Physics, 50(12), Dec. 1982, p. 1133-1136. The reflected field from a dielectric material is not generated just at its surface but comes from everywhere in the interior of it.
14. Present physics models the EM wave as transporting energy, but erroneously omits that it also transports time. A photon is made of angular momentum, or "energy x time". Since EM waves are made of photons, it follows that they transport both the energy components and the time components making up those photons. An EM wave is a wave of angular momentum, not just a wave of energy.
15. KGB energetics weapons scientists call this internal structuring the "information content of the field." However, the Russians use a good deception plan, which implies that the "information content of the field" is just the normal transverse EM spectral content of EM signals. Appreciable "pertinent" work using that phrase is produced by the open Russian scientific community, thus confusing the issue. Our electrodynamicists seem to buy it hook, line, and sinker. The deception plan also tricks Western scientists into thinking that psychoenergetics is nothing but a Russian version of Western parapsychology. Again, our scientists comfortably accept this with smug satisfaction.
16. Presently the Russians are in a great new version of this deception plan, with the goal of deceiving Western scientists into thinking that the "secret" Russian energetics is based on torsion fields. Consequently they are releasing substantial material on torsion wave theory, including replicable experimental results. The released version of torsion fields has one glaring omission: the time components and structuring. This deception plan is excellent, because the torsion field theory that is released, is indeed "real" and testable. It is also revolutionary, with respect to present Western science. It almost positively assures diverting the attention of much of the Western science community into this highly limited subset of the full Russian torsion theory—effectively diverting the West away from psychoenergetics and the direct use of t-polarized EM waves and fields, torsion or otherwise.
17. We point out that E. T. Whittaker, in "On the Partial Differential Equations of Mathematical Physics," Mathematische Annalen, Vol. 57, 1903, p. 333-355, showed that every scalar potential is comprised of an internal structure of bidirectional longitudinal EM phase conjugate wavepairs in an infinite set of harmonics. Each of those phase conjugate longitudinal EM wavepairs comprises a time-polarized EM wave. So the common potential contains an internal longitudinal EM wave structure that is further organized into an internal time-polarized EM wave structure. The mind-intent correlates and the total mind and emotional experience correlates from fertilization of the egg that led to development of that person, is in the internal substructure of every potential in the living body. In his "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions," Proc. Lond. Math. Soc., Series 2, Vol. 1, 1904, p. 367-372, Whittaker also showed that any EM field or wave is comprised of two scalar potential functions. It follows from Whittaker and Reali that the EM emissions from the living body carry the internal correlates of everything that has been experienced by that person from conception in the womb. Sometimes this deep embedded "hidden information content" can even be accessed in deep hypnosis. I once observed the deep hypnotic regression of a subject back to her prenatal experiences prior to birth, where the subject relived hearing words of rejection by the father, before the subject was born. The occurrence of the incident and the father's words were directly confirmed on the spot by the mother, who was closely observing the session as it occurred. It turned out that this particular rejection of the baby still in the womb had played a major role in subsequent deep psychological problems experienced by that person all her life. To resolve the problem, use of a powerful "simulated" reliving pre-birth experience was conducted with the subject again in the pre-birth state and actively participating, but now with the father figure directly expressing love, acceptance, and cuddling and hugging his daughter. This led to a rather dramatic remission of most of the deep psychological problems within 24 hours.

Mind Control and EM Wave Polarization Transductions, Part 3 of 3

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This outstanding article is the last, Part 3, Part I and 2 of which were published in Volume 9, #2 and #3 of Explore! for the Professional. Because we feel that Col. Bearden's Special Note below is so very important we are repeating its publication in all 3 parts of this article.

Special Note

This article refers to experimental research techniques which can be detrimental or lethal in the hands of any but highly skilled, qualified experimental scientists proceeding under proper laboratory safety procedures. The purpose of this article is strictly for information to properly qualified and authorized scientists in certified laboratories. We do not propose or condone any use of these procedures for nonapproved practice of medicine without a license. Neither the publisher nor the author are responsible for accidents or outcomes in the use of these experimental procedures and techniques. Any researcher who performs these procedures and experiments is acting on his or her own volition, and is solely responsible for insuring safety, qualifications, and legality of the acts and their results. We neither suggest nor condone unauthorized experimentation on human subjects. Such is a criminal violation of the constitutional rights of the subject under Federal and State laws, and achieving many more effects in the targeted bio-organism or groups of them. With Hunt's method, the system as an open dissipative system far from thermodynamic equilibrium in its environment is being measured as such. This more directly allows for determination of the environmental inputs on a much broader range of subsystems, both space-like and time-like. Particularly for mental and emotional correlates to environmental stimuli, such measurements and correlations are essential.

More Comprehensive Phenomenology Experiments

To return: Now the scientists would perform many phenomenology experiments, making one little change at a time and profusely recording the data. Each time, they would establish the physical change(s) that occur in the body and/or the mental and emotional changes that occur in the mind for each spectral reinsertion back through the "ship's portholes". They would simply but painstakingly (over some years) build up an extensive database of those individual correlates.

In these experiments, the experimenters will eventually be able to provoke any body or mind change they wish. Strong emotion. Intense pain. Intense pleasure. Painful thoughts. Images. Memories.

is both illegal and immoral.

Two Ways to Improve the Methodology and Experimental Correlates

We diverge momentarily: If they wish to improve this methodology, they will consider the body dielectric as a nonlinear isotropic medium. Then they will pretend that the spectrum of difference frequencies between each two adjacent waves is the spectrum of "emissions" from the body. They would also use those, as if they were actual emitted spectral signals, instead of the actual signals emitted. That procedure will give superior correlations, but it is more complicated. Part of that is known for underwater sonar,[1] and so our own scientists may or may not have realized it for use in mind and behavior correlate determination with respect to the body dielectric.

Another dramatic improvement in the depth to which the correlates can be constructed, is provided by detecting each porthole output in a two-channel device, where one channel has an adjustable time-delay as utilized by Dr. Valerie Hunt.[2] The two channels—one real-time and one slightly delayed—are then mixed, as by Hunt's method, producing an instrumental measurement of the chaotic part of the functions. Again, this can be measured, recorded, and later analyzed. It adds (i) a completely different kind of thermodynamics in the system measurements, (ii) a dramatically extended set of correlates, (iii) more direct measurement of the time-polarization causative signals, and (iv) an applications technology eventually having many additional degrees of freedom and therefore capable of Perceptions. Dreams. Visions. Memory losses. Memory changes. Personality changes. Etc. The "delta" in the emission spectrum (the changes from zero reference spectrum) represent the precise totality of all mental, physical, organic, chemical, etc. changes and interactions.

A particularly vulnerable aspect of every mammal is the pleasure center in the brain. Experiments have shown that, when this center is stimulated, it is the most addictive experience possible. Rats will forego food, endure electrical shocks, starve, and even die to obtain stimulation of this center. Obviously a device capable of generating signals that evoke direct stimulation of the pleasure center in humans would be a powerful weapon.[3]

Extending the Data Base

See Figure 12. After the researchers have made an "individual porthole signal insertion" correlate database, then they would make a "two, three, four," porthole signal insertion correlate database by inducing selected multiple changes at once. Again they would analyze everything; the program would need one or more supercomputers. It would also require quite a highly qualified multidisciplinary team, extensive facilities, substantial funding, and would be many years in duration. We are describing a decades-long program. But it's a doable.

With sufficient development and performance of such a program, the researchers would have produced (with sufficient testing and analysis, and sufficient retest validation and verification) a database of "specific correlates for a given overall desired physical, mental, or physical and mental delta."

A second stage in the research would be to test the correlates and porthole insertions upon a statistically significant cross section of ordinary people, and/or specialized populations (such as toughened soldiers). The program would evolve a highly complex, very effective, ever-improving science and technology of mind and behavior control and engineering mechanisms, complete with finished database and developed applications equipment.

The Dielectric Body as a Ship With Portholes

Again let us review what the EM transverse wave irradiation from the body dielectric represents. Think of the body dielectric as a sort of "ship", with lots of portholes. When it gets irradiated, certain operations happen internally to that radiation, i.e., certain "processes" and "interactions" occur, which change both the mental and physical states. The output emissions back from the body dielectric, out through the filtering "portholes", will directly correlate to what has happened inside the ship.

It is terribly important to realize that one can use the same frequencies and spectra coming back out of those "portholes" to insert EM signals and waves etc. back in there, and into the deepest processes going on in the body and in the mind (at all levels, including the deep unconscious). times. So it will reach directly into and affect any and every part of the dielectric, as you wish, and in whatever manner you have correlates for.

We filed an invention disclosure[4] on the above correlate and "back-porthole" process for use in directly inducing full and efficient conversion directly to time-density (scalar, or time-polarized) EM waves inside the body/ cells, therefore immediately and directly time-excitation charging the body cells and all their internal components.

Subtracting the Normal Correlates to Obtain the Deltas

A specifically diseased body, e.g., has a specifically tailored change in its "normal" emission spectra, because of the disease condition alteration of its resident spacetime curvature engine. By having a database for the normal emission spectra of the healthy body, one can subtract it from the actual emitted spectra, to obtain the "delta spectrum".

If the correlates have been previously determined by the above mentioned research program, then one may simply introduce an amplified "delta spectrum" into the body, i.e., through the portholes. This will immediately time-excite the cells and their components throughout the body, particularly where that disease does exist. It turns out that the time-excitation charging by that method will "pump" those diseased cells in the time domain. The cells themselves (and all their parts) are highly nonlinear—to time-excitation

Remember, whatever you put back in there, is going back through the "mixmaster" hopper. It will be iteratively phase conjugated and interfered with by everything, countless

charging, they are totally nonlinear. So they will act as rather perfect pumped phase conjugate mirrors, but pumped in the time-energy domain rather than in the spatial

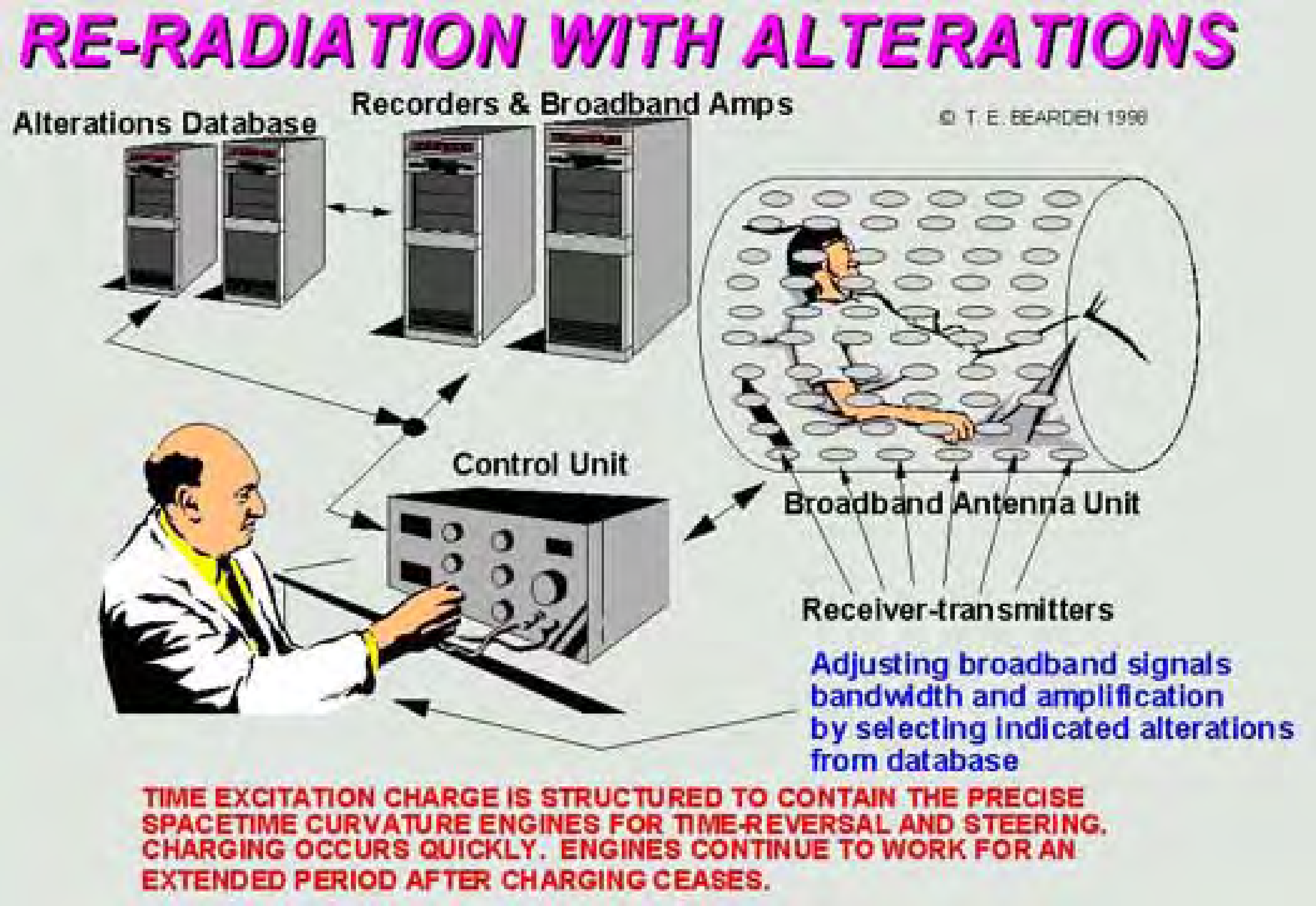
RE-RADIATION WITH ALTERATIONS
Alterations Database
Recorders & Broadband Amps
© T. E. BEARDEN 1998
Control Unit
Broadband Antenna Unit
Receiver-transmitters

Adjusting broadband signals bandwidth and amplification by selecting indicated alterations from database

TIME EXCITATION CHARGE IS STRUCTURED TO CONTAIN THE PRECISE SPACETIME CURVATURE ENGINES FOR TIME-REVERSAL AND STEERING. CHARGING OCCURS QUICKLY. ENGINES CONTINUE TO WORK FOR AN EXTENDED PERIOD AFTER CHARGING CEASES.

Figure 12. Using an amplified replica of the body's own dense, broadband signal complex, containing added alterations, to irradiate the body and produce deeply-penetrating precise time-density charging for cellular time-reversal while steering the time-reversal trajectory to also correct a congenital condition.

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energy domain. This is a dramatic extension to nonlinear phase conjugate optics theory.[5]

General relativity tells us that each specific detail of the mass and energy structure of each cell and all its parts—down to the finest details—is accompanied by a precise set of spacetime curvatures. By reintroducing the same energy as the disease delta TW waves, the affected cells add the phase conjugates, converting the inserted TW signals into longitudinal EM wave signals. The longitudinally-pumped cells again phase conjugate, converting these longitudinal EM waves to time-polarized EM waves, and "charging" the cells and all their parts in the time domain.

Suddenly, at that point the resident spacetime curvature engine—rather than TW or LW EM waves-serves as the "input signal" to the cell-and-its-parts as pumped phase conjugate mirrors (PCMs), pumped in the time domain. An extension to the distortion correction theorem of nonlinear optics results. An exact, amplified antiengine for the diseased cells—i.e., a phase conjugate replica of the resident spacetime curvature engine—is formed. This amplified antiengine overpowers the resident disease engine, powerfully time-reversing the cells and their components back to a previous healthy state. The time-reversal actually occurs over a period of time after the "time excitation charge-up" ceases, say over the next week or two. Usually two to three quick irradiations are required, one week apart, to give a time-reversing period of three to four weeks.

Even though appreciable forces are operating internally upon the cells and all their parts, there is no net translation force upon the cells or any part. E.g., as Pepper[6] states,

"On a more fundamental level, the ideal lossless PCM reverses all the quantum numbers of the incident photon (i. e., linear momentum, angular momentum, etc.). It can be shown that the PCM therefore experiences no linear or angular momentum transfer from the incident photons; hence, the PCM is free from photon radiation pressure and torques."

Note that, in ordinary EM theory, it is precisely translation forces that are engendered upon charged mass by EM fields. This process is quite different. In biological terms, this process dedifferentiates (in physics: time-reverses) the diseased cells and all their components—including the genes—back to an earlier healthy state.

By taking a diseased body and feeding back into it an exact amplified replica of its emitted TW spectrum, one can force the body to "time-excitation charge" all cells and their components immediately, with high efficiency. The human body and every cell and every part of every cell does the necessary "calculation" for the exact antiengine for each part. Since time is extremely condensed spatial EM energy (by a factor of almost 10^{17}), a startling contraction occurs in the radiation time required to time-charge the cells and their components and charged particles. This is a method for instant initiation of time-charging, hence it is extremely rapid. What took Priore several hours of LW irradiation to accomplish in the body,[7] can now be done in seconds with this "thwarting" and spectrum transduction method. In fact, it is an intense stress on the body, and—say—should only

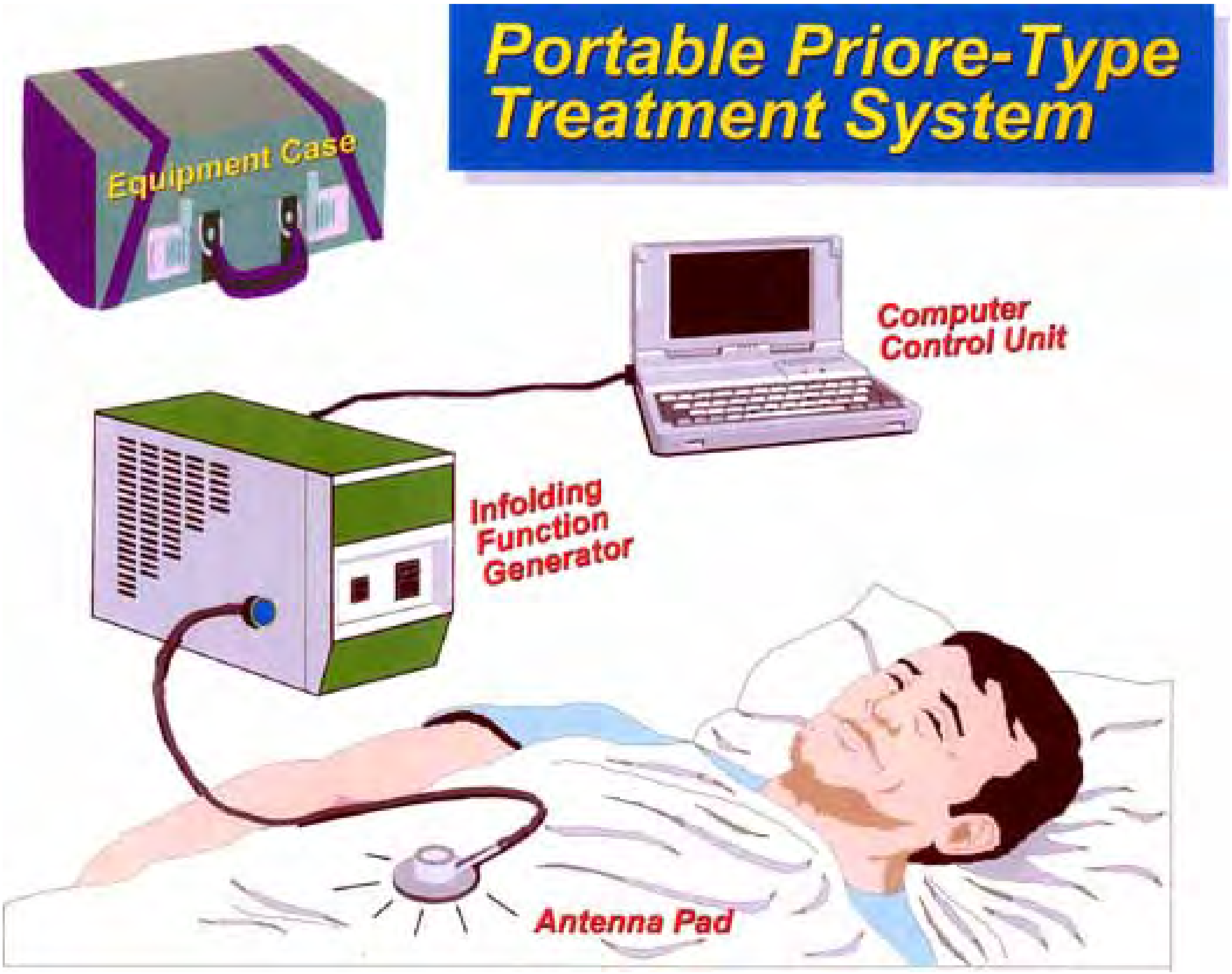
Portable Priore-Type Treatment System
Equipment Case
Computer Control Unit
Infolding Function Generator
Antenna Pad

Figure 13. Portable first-method treatment unit proposed to the Department of Defense. For treating and curing mass casualties from terrorist BW attacks on U.S. population centers.

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be continued for 30 seconds or so. We highly stress that overcharging in this time domain can be detrimental or even lethal if prolonged.

At the end of the very short time-excitation charging time, the body is "time-excitation charged in all its minutest particles". So everything is therefore pumped in the time domain for the next several days after the irradiation is removed, since the time-charge decays very gradually over a period of time. During that decay period, every part of the cell and body acts as a pumped phase conjugate mirror material, pumped in the time domain rather than in the 3-space energy domain. When time-pumped, the mass itself reverses to a previous physical state. This can be used for both nonliving and living masses. Because there is no forcible translation manipulation of the cells and their parts, it can be utilized on living cells in vivo. In the case of diseased cells—e.g., AIDS-it appears that three precisely determined 30-second "AIDS correlate" irradiations a week apart, should be sufficient to completely cure AIDS, including removal of all HIV-genetics changes from every previously infected cell of the body. Also, it would accomplish considerable rejuvenation of the body (making the body younger).

Rejuvenation: Restore the Telomeres and Produce Immortal Cells

Saving Most of the Casualties from Mass Terrorist Attacks

To defend against things like anthrax attacks on our civilian population centers, we also have recommended to the U.S. Government the crash development of small, portable treatment machines—using similar "antiengine-forming" and cellular reversing "porthole technology". [See Figure 13 on previous page]. Such portable machines could be developed cheaply and quickly, and present government facilities could be used to massively attack the correlate database production problem. The portable treatment units could be cranked out by the hundreds of thousands and flooded down through emergency response agencies such as the police forces, the National Guard, emergency hospitals, emergency response teams, etc.

Each device could be used in "assembly line" fashion upon hundreds of sickened patients, in case of a WMD (weapons of mass destruction) attack upon one or more of our cities. The first generation equipment would save probably 70% of the stricken (as from anthrax, etc.). With second generation equipment, one would expect 90% of the stricken casualties could be saved.

Just now, there is a very dim prognosis for all those casualties, using present available treatment capabilities. Time and lack of vaccines defeats just about everything that can be done. Brutally speaking, most of those unfortunate enough to breath in anthrax spores from an

In fact, it is now known that the gradual loss of the telomeres—the natural ends of chromosomes—in a cell's chromosomes is what causes the cell to age. The gradual loss of the telomeres and the resulting shortening of the chromosomes represents a cellular "disease state" or "disorder" state" accompanied by a precise delta in the spacetime curvature engine accompanying every affected (aging) cell.

By determining the correlate for that precise telomere loss in the aging body's emitted radiation spectrum, an effective telomere regeneration process immediately emerges. One simply amplifies that aging "precise telomere reduction" correlate and reradiates the body with it, passing an amplified correlate back into every cell of the body. The cells and all their parts—including the chromosomes—add the phase conjugate replicas, converting the incoming TW EM correlates to longitudinal EM wave correlates. The cells again phase conjugate the LWs and add the phase conjugate replicas, converting the LW correlates to time-polarized EM wave pumping correlates. This latter process time-excitation-charges the aging cells and all their parts, including the genes and chromosomes. The cellular matter itself produces the amplified "aging antiengine" for each and every cell and telomere ending. The result is to again add telomeres, converting the cell back to a younger, more vigorous cell, and reversing the process of aging.

We point out without further elaboration that these methods also introduce direct engineering signals into the body's master cellular control system, including the regenerative subsystem. Hence the body's regenerative subsystem is involved in helping produce the necessary engines and operate upon the short telomere chains to add back telomeres. More specifically, the regenerative subsystem is changed into attack, are going to die. At least 80% of them will expire, in spite of everything the present system can do for them.

Note each device could rapidly treat a whole series patients, one right after the other, merely laying them between "blankets" containing wire antennas, irradiating with the proper correlate spectrum quickly, moving on to the next patient, irradiating quickly (seconds), etc. The entire apparatus could be made to fit in a large suitcase-sized container, and it would be highly portable and controlled by a laptop-sized computer.

Unfortunately, so far the DOD doesn't even understand what the heck we're talking about! The National Institute of Health (NIH) and the National Science Foundation (NSF) are not interested at all. After all, it isn't drugs, vaccines, antibiotics, etc. — which are simply not going to do the job. However, those are what the government and scientific communities are going to finance to the tune of hundreds of millions of dollars. They are then going to lose almost all those mass casualties when the terrorist attacks on our population centers inevitably occur.

Those are Americans. They are going to die. Most of them could be saved. We ought to save them.

For any change in state (physical, chemical, emotional, mental, perceptual), the body dielectric "portholes" change and the output spectrum changes. The delta from zero reference now represents that exact change.

Where Western Mind Control Research Has Probably Arrived

Western mind control researchers probably first established a correlation database of porthole emission correlates to changes in internal states, both physical perfect consonance with the external introduction of the amplified antiengines.

That exact process can be used to rejuvenate the aged population and remedy most of the debilities of growing old. That is how we eventually intend to do it, if we can convince the U.S. government and the U.S. scientific community to perform the necessary research and validation.

and mental. They almost certainly recognize the peculiar participation of every part of the body dielectric in the TW emission spectrum from the body. They will almost certainly have opted for this "porthole" notion of some similar expression of it, and the "thwarting" of these "relaxation and release" emission processes to engender internal physical changes in the body and in the brain-meat-computer, as they see it.

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They probably experimented with different TW EM radiation mixes, to see what the body emission change to, and what states are induced. Undoubtedly they found that the induced states began to correlate with the former emission delta data base. That is, they found out which delta emissions spectra, reversed and amplified and fed back thorough the portholes, produce what internal changes.

Use for healing is the simplest of all. Use for killing or debilitating is more complicated. Of course weapons researchers wish to look only at the killing aspects. That is something they understand. They do not understand healing, for they do not even have the "regenerative" or "healing" mechanism in any of the scientific papers or texts. Becker[8] came closest in this country, and Priore did it in France. Both of those scientists were suppressed and paid a bitter price for their revolutionary and innovative research.

But look at what has been done, by "input-output" correlation research. The scientists will have a database now, that tells what state emerges in the body and in the mind, for what irradiation spectra (frequency, relationships, phases, amplitudes, wave shapes, etc.) one uses. And they did not work out all the wave-to-wave transductions ongoing in the mind and body connection and in the body and in the mind, individually, between TWÛLWÛTDW.

We suspect that this is the course Western mind control researchers will have taken, without even realizing the internal wave transductions occurring. And they would not be concerned with that. They would have what they want, for weapons, mind control, and behavior control. And of the internal "mix" of the dielectric and all its tiniest portions. So Western mind control researchers and rogue groups probably do get good results.

We are not just picking on the U.S. government here! Internal divisive groups exist in all large and powerful groups, and joust for power. In highly classified groups, these groups are greatly enabled to joust more widely, unethically, and immorally because it is so deeply hidden. So very deep classification evokes the growth and intensity of rogue groups. It's the old "Power corrupts, and absolute power corrupts absolutely" routine.

The implication is that in the West one or more highly classified, sustained, heavily funded developments in advanced mind control programs, probably exists and probably has existed for some time. Due to loose formation of rogue groups inside such programs, they may have dual or triple purposes, may not operate under very much legitimate government control at all, and may operate specifically for the purposes of the rogue group or groups that have gained control.

In a nutshell, that's what may be going on in the clandestine mind control projects in several Western governments. The involvement of at least some rogue groups, some being "cowboys" who operate well outside all laws and ethics, could also result in such things as assassinations, clandestine testing on individuals without their consent, etc. In short, it could account for what seems to be actually occurring. As also is "usual" in such a mess, one or more of the rogue groups eventually may become very powerful because their secret weapons are very powerful. They may become confident, thinking they have the "best in the world." They may actually believe they are ahead of the Russians.

they would of course ignore the healing aspects. And they would get results of course, revolutionary results. So they would undoubtedly classify the program very highly, thinking that they had the best of the best.

Rogue Groups May Also Have Arisen to Divert the Purpose of the Projects

And that is where real problems may arise. Every human group has within it competing subgroups, jousting for power. The more highly classified the group and its activities, and the less that is known about it outside its confines, the more strongly and secretly the subgroups can play. So they can emerge as rogue groups pursuing their own agendas, not that of their duly elected governments. In the extreme, such a deep black program can even become a "captured" program, which is totally in the hands of rogues and no longer reports to or is bound by the dictates of the parent government.

It has long been suspected in some quarters that even the US's highly classified research community may be riddled by such rogue groups, and so may be certain highly sensitive parts of the Research and Development community.

Remember that, in every large and powerful human organization, the basis for rogue groups is power and secrecy. They are always seeking to increase their power, control, influence, prestige, etc. Nothing else. Patriotism and mission are—to rogue groups—often just idle words. They have their own agendas. And being rogue groups, they may well bring in unethical, immoral tricks: assassination, bribery, entrapment, disinformation, plausible deniability, etc. A certain percentage of a highly secret rogue group will wind up using all these things and more. It's a

Where the Russians Probably Have Arrived

On the other hand, the Russians will have developed instruments for detecting and isolating the LWs and the scalar waves, in addition to the ordinary mundane instruments for measuring the TWs. So they will have not only the TW correlates, but also the much finer TWÛLWÛTDW (scalar EM wave) correlates. They will understand and employ the use of vacuum engines (spacetime curvature engines) which Western researchers will often invoke but not understand or even be aware that this is what is being invoked. In other words, Western researchers probably just use the old method of "input fi set of functions fi output". That is the standard basis for almost all Western system analysis. With it, one doesn't have to know the exact functions and processes going on in the middle. One just determines a transfer function from a given input to the output that results. Then one catalogs that transfer function. One does that for lots and lots of transfer functions for particularly desirable results, and one has the system analysis. One also has the immediate basis for a rapidly-developed applications technology.

Western scientists are good system analysts. But they have little or no comprehension of what is really going on in that "inside the ship functions" portion, even though they have determined the transform function which acts upon the input to give the "from the portholes" output.

The Russians, with their additional knowledge of the actual mechanisms in the transforms, will be much more advanced than the West, because their fundamental psychoenergetics science is far more advanced, so long as we continue to use human characteristic, the old primate dominance game. Only now disguised and hidden under deep classification.

Nonetheless, the "simplified" TW EM "porthole correlate" approach will yield very positive results, due to the correlation existing with the LW s and scalar portions the old U(l) electrodynamics. Further, the Russians have decades of use of longitudinal interferometry beams to reach right through the earth and ocean and produce stringent EM effects at a distance. So they will also be able to do the same things here in "mind control" with LW interferometers, through intervening mass

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including the earth and ocean. Western mind-control scientists and their rogue groups—assuming they exist as postulated—largely will not be able to do that, and probably won't even recognize Russian testing of psychoenergetics weapons directly in or over Western nations.

Russian Lethal Psychoenergetics Mind Control Tests Over the U. S.

In fact, the KGB tested just such highly advanced mind control weapons over the middle of the United States in 1997 on two occasions. The tests were conducted against Captain Button in his A-10 "Warthog" aircraft on April 2, 1997 [See Figure 14], and upon Captain Svoboda in her A-10 "Warthog" on May 27, 1997. [See Figure 15].

Over Arizona, Captain Button was thrown into a hypnogogic state, and his perceptions instantly altered and controlled. In his instant "dream-waking" state, everything seemed perfectly normal. His sense of direction was altered a bit more than 90 degrees, so he simply corrected and turned and "flew toward the range", actually flying off course by more than 90 degrees and ignoring radio contacts. He flew right on out of Arizona. At one point he circled, probably thinking he was over the range, and he probably dropped his ordnance there. Then he "flew on back toward home," as he thought in his waking dream state, until his fuel ran out and he crashed and died in the explosion—dream-thinking until he died that everything was normal. All the while, his sense of the passage of time was altered. To him, in his dream-thinking, dream-acting state, everything was normal and nothing untoward had happened. So the distant KGB transmitters and associated psychoenergetics team controlled him for over an hour.

Indeed, that was the exact purpose of the test: demonstrate control (at a great distance) of a skilled person performing highly skilled tasks. A secondary purpose was to stimulate the U.S. government, watch its investigation and findings, and ascertain if the U.S. knew of the extent to which Russian KGB mind control weaponry had advanced. Obligingly, we proved to me KGB that we did not understand what had actually happened to Captain Button.

Captain Svoboda was from the same Wing as Captain Button and was its most experienced night fighter A-10 pilot. In fact, she taught other pilots the fine points of night flying combat missions in the A-10. About two months after Captain Button's bizarre flight and death, Svoboda was engaged in night target bombing on the range. Rising from her ordnance drop on me target, Svoboda was suddenly struck and rendered hypnogogic and in a waking-dream state. Her sense of the vertical was instantly reversed. Superb pilot that she was, she immediately dream-perceived she was diving, not climbing out of the delivery. She instantly corrected to "climb out". So in the real world she dived sharply into the ground and her aircraft exploded.

This test demonstrated the instant alteration of a skilled pilot's perception, causing that pilot to inadvertently react promptly in an unintentionally suicidal manner. A secondary purpose of the test was to stimulate the U.S. government system again, to see if the system recognized what had

A-10 Mysterious Flyaway and Crash

April 2, 1997

Armed with:

- Four 500-lb bombs
- 30 mm Gatling gun

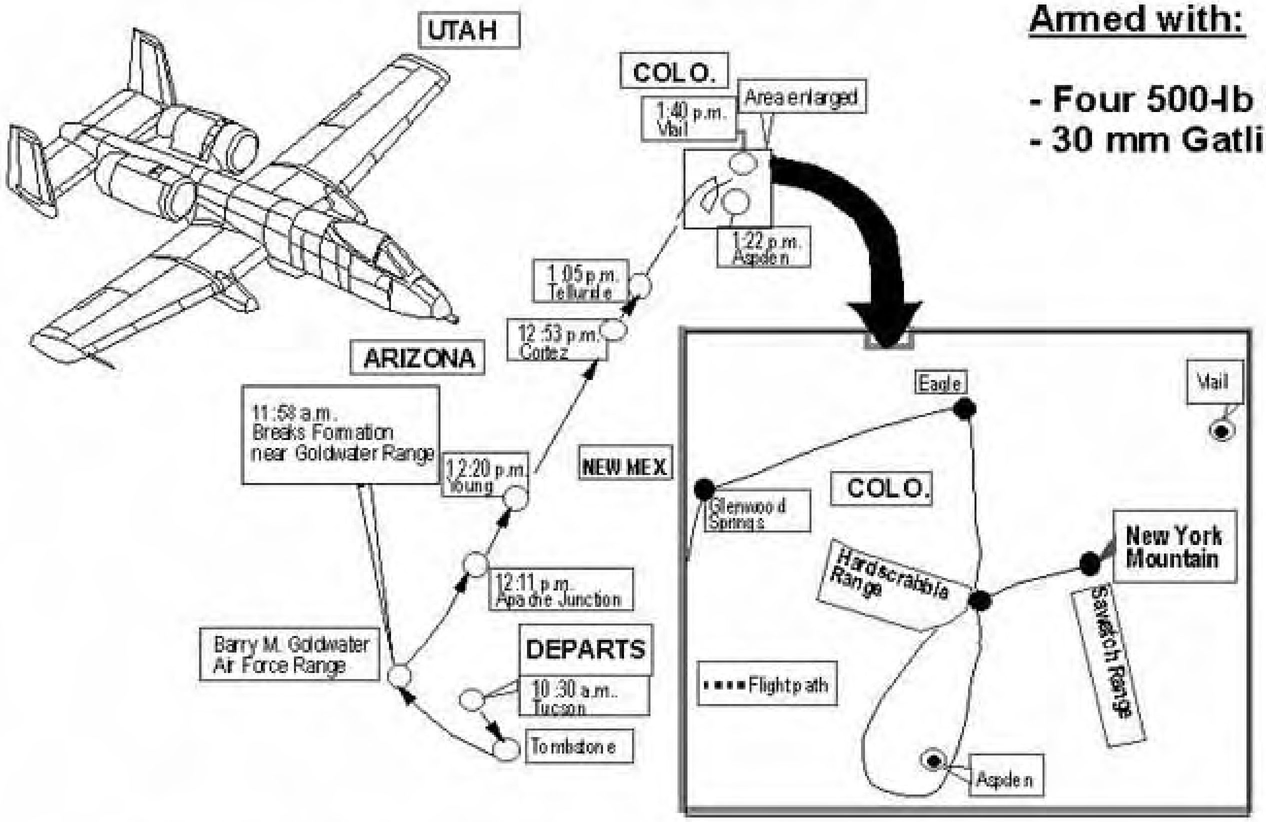
UTAH
COLO.
1:40 p.m. Vail
Area enlarged
1:22 p.m. Aspden
1:05 p.m. Telluride
12:53 p.m. Cortez
ARIZONA
11:58 a.m. Breaks Formation near Goldwater Range
12:20 p.m. Young
NEW MEX
12:11 p.m. Apache Junction
Barry M. Goldwater Air Force Range
DEPARTS
10:30 a.m. Tucson
Tombstone
Eagle
Vail
COLO.
Glenwood Springs
Hardscrabbla Range
New York Mountain
Sawatch Range
Flightpath
Aspden

Figure 14a. Captain Button's mysterious flyaway and eventual crash.

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occurred. Sad to say, it did not and it has not. It was lamely speculated that Svoboda probably looked over her shoulder like a rank greenhorn, and inadvertently dived her aircraft into the ground while looking back at the target. If there was one pilot in the USAF who would have not done that, it was Captain Svoboda. At any rate, the KGB determined that the U.S. scientific, intelligence, and governmental communities did not have the foggiest notion of what had occurred.

In private proprietary communications[9] we have explained further, to proper parties, exactly the reasons for these two tests, and what exactly was being tested, and what is its planned strategic use.

The Final Race for Direct Mind Control of the Entire Human Species

The KGB psychoenergetics weapons scientists—because of their direct measurements and detections (and use) of t-polarized waves and LWs for decades—also understand that Jung's collective unconscious mind (of the entire human species) also has its own time-like operations and correlates, which one measures also when using t-polarization measurements and sorting it all out. The collective unconscious mind operations are buried several levels deeper inside the recursive Whittaker structuring inside the EM fields, waves, and potentials.

The KGB scientists also know that something very like Gaia— a collective unconscious mind for all species on earth—also exists, and they are striving to be able to sort out and measure that one as well. The Gaia operations are buried even deeper in the recursive structuring inside the EM fields, waves, and potentials. If one reads some later books by Kaznacheyev,[10] e.g , this human species unconscious mind aspect and the biosphere unconscious mind aspect emerges loud and clear, if one interpolates between the lines, so to speak. Actually, from day one, the Russian mind control scientists have had their eventual goal set upon this "deeper area of mind and possible mind control" of the entire human species.

I am convinced that the KGB psychoenergetics scientists understand this deeper area. If they can learn to directly engineer the collective human species unconscious, they can then convert the human species easily into a sort of "ant" society, modeled along ideal Communism lines, except of course with an excluded "hierarchy at the top" running everything. The "ant society"—communist style—is still a variation of feudalism (all systems tend to feudalism or some form thereof).

The KGB psychoenergetics weapon scientists are seriously pressing on toward that very goal. In my opinion they are not very far from it right now. It is simply a matter of developing sufficiently complex equipment to be able to directly engineer the time-domain substructuring at sufficiently deep levels. It is a doable, although it is very, very complex and very, very difficult. On the other hand, they have been at it for decades. Even in the 50s the Russians already had the old LIDA device,[11] capable of inducing a catatonic trance-like state in a mammal—either a human or a cat,[12] for example. Some versions of Russian mind control devices were used on Russian soldiers in the

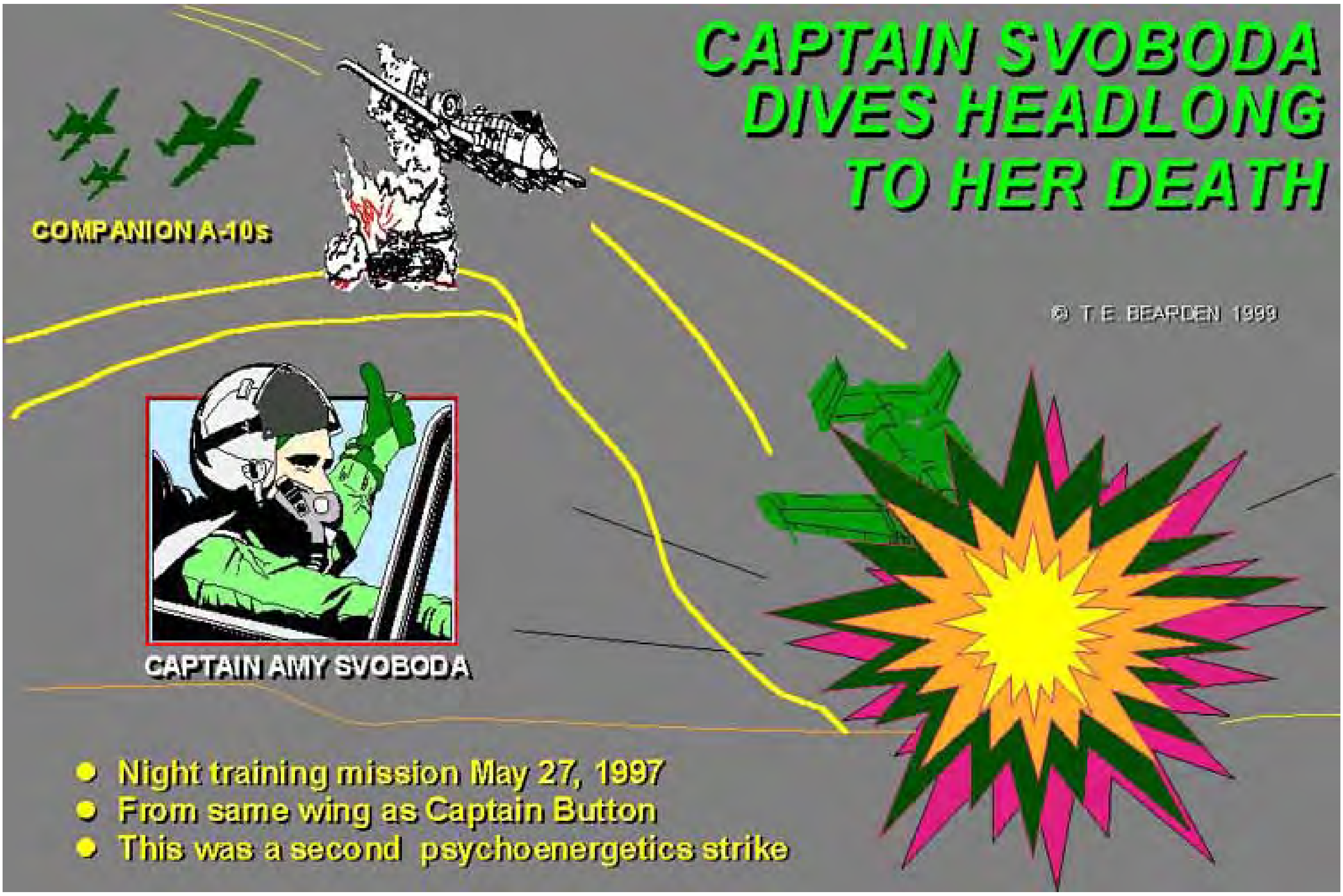
CAPTAIN SVOBODA DIVES HEADLONG TO HER DEATH
COMPANION A-10s
© T. E. BEARDEN 1999
CAPTAIN AMY SVOBODA
● Night training mission May 27, 1997
● From same wing as Captain Button
● This was a second psychoenergetics strike

Figure 15. Captain Svoboda dives headlong to her death.

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Afghan War to condition them for performance of merciless acts.[13]

Potential U.S. Rogue Groups and Two Recent Examples

Meanwhile, rogue groups amongst Western clandestine mind control researchers will probably arise if they have not already done so. They will likely seek to increase their personal control and further isolate the programs from orthodox government review and from government and legislative control. They may even divert the research into highly illegal and unethical means, because it furthers their own rogue agendas. That is how clandestine U.S. government research can sometimes go sour, unless great care is exercised by the oversight committees in the House and the Senate.

Sometimes when rogue groups do gain control and total secrecy of a given new technological area, then what appears to be "U.S. government operations" do start to encompass a criminal and unethical operations, hidden usually beneath the deep veil of high classification. Also, if it's "scientific," no one is ever brought to justice, even if the "evil science actions" are uncovered and publicly revealed.

We Certainly Have Proof of Such Rogue Activity. For Example, Here are Two Prominent Cases:

1. For three decades, scientists from the U.S. government, universities, and civilian contractors secretly

as a result of those ghoulish experiments. So what happened when this gruesome thing was revealed? Again President Clinton publicly apologized! The head of the Executive Branch did not turn the macabre matter over to his Attorney General to prosecute. How many of these scientists were indicted? Not one. How many are going to be indicted? Not one. Suppose again this had been done by a private doctor in his own private clinic. You get the point.

There is Little or No Punishment of Rogue Scientific Groups

Shockingly, the U.S. government at the highest level has directly shown (and these are not all such cases by any means!) that mass crimes against U.S. civilians, perpetrated by portions of the U.S. scientific community in direct conspiracy and in secret, will likely be condoned. The perpetrators will not be indicted, tried, or convicted.

Note the connection of the "rogue groups" thesis to the above incidents. Note how rogue scientific groups got away with it in both these cases. There may be other rogue scientific groups getting away with such things today. They should not be able conspired to treat unsuspecting human patients with whole body nuclear radiation, including some retarded children and cancer patients. Some of those patients—including some of the retarded children—died as a result. These illegal experiments were conducted in great secrecy, and the results were highly classified. Eventually these actions were revealed, and a Presidential investigation committee investigated. These experiments would seem to be little different from the WWII Nazi and Japanese experiments on human prisoners. Are those U.S. scientists who were responsible for those retarded children's' deaths any different from the Nazi scientists and criminals we executed at Nuremberg? So what happened when this terrible thing finally came out into the open? President Clinton publicly apologized! How many of the responsible scientists were indicted for murder? Not one. None is ever going to be. Suppose a doctor here in South Alabama, with his own private clinic, had secretly irradiated those human patients and retarded children with whole body nuclear radiation, over a period of 30 years, resulting in some agonizing deaths. How many state and federal agencies would have come after him with arrest warrants? Probably about 50 or so. Would he have been indicted, tried, convicted, and executed or sent to prison for life? Absolutely! Would the President of the United States have apologized? Not on your life; he would have turned it over to the U.S. Attorney General with a strong directive to to get away with it. But they can.

Perhaps a most startling additional part of those two incidents is that there was no great public outcry from the scientific community, deploring these murders and demanding that the criminal scientists be indicted and tried.

As the old saying goes, "By their silence they have convicted themselves." The organized scientific community, as a community, has shown that it has little or no ethics, and—while deploring any scientific murdering that "gets revealed,"—is not really interested in justice. In short, much of the U.S. scientific community may now have very little ethics left.

We are not talking about normal individual scientists, but the Big Science community. There is a whale of a lot of difference between the two. In the Big Science community, there can be and there are rogue groups. Lots of them. There is deep cover, deep classification. And there is very probably advanced mind control research and testing, be it legal or illegal. Hopefully most of it is legal and constrained. However, some of it is almost certain to be illegal and ill constrained.

Human beings are still human beings. All the good and evil is still there, regardless of the group. The stage settings change, but the cast of characters and the play never change.

It's sad, but 'twas ever thus. Hidden parts of our own governments—and other governments throughout the world—are no different from the old medieval groups, where nobles etc. were always plotting against the king, or using the king's power for their own nefarious end. The rogue groups today are no different from all the scheming and conniving groups that destroyed the Roman Empire. Great empires fall from within, not usually from without!

investigate and prosecute on criminal charges.

2. Again for three decades, scientists from (i) the U.S. Government, (ii) universities, and (iii) civilian contractors conspired to give poor syphilitic blacks in Tuskegee, Alabama a placebo while ostensibly treating them for syphilis. The purpose of the program was to deliberately observe and record the ravages of the disease to its fruition in their wracked bodies. So the scientists deliberately sat there and watched their brains rot and their bodies rot. They kept meticulous notes, of course. It was very scientific. And it was macabre. They "treated" some 400 blacks in the "program." Over 100 blacks died

Conclusion

This concludes our brief portrayal of the probable directions that mind control research has taken, in Russia and in the West. It is a novel and powerful area, and it poses both severe dangers and great benefits to all the peoples of the Earth.

Let us hope this great new area, already off to a bad start, can be bridled and steered in the direction of helping and healing people, rather than killing or abusing them. The excesses in its bad use are a potent threat to all nations on earth. Yet it can revolutionize medical science, education, communication, and psychology. Eventually it can engineer the mind and memory directly, beneficially. We foresee the day—perhaps 30 years hence—when education will be

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accomplished by directly loading the software into the mind. Then in three weeks one will "load" a doctorate, say, in physics. In three more weeks one will also load a doctorate in chemistry. Another three weeks, in electrical engineering. Another three weeks, an M. D. And so on. When that happens, then truly everyone on earth can be educated. Freedom from ignorance may well be another great freedom that is legally recognized. There will be no impoverished large groups lacking the education to find decent, productive jobs.

We urge all nations to use the principles involved: not for human abuse, but for healing, educating, uplifting, and life-expanding of every person on Earth. If we

446955, Oct. 23, 1998, forwarded to US. Patent Office on Nov. 4, 1998.

5. A very good introduction to nonlinear phase conjugate optics is given by David M. Pepper, "Nonlinear Optical Phase Conjugation," Optical Engineering, 21(2), March/April 1982, p. 156-183. Also see David M. Pepper, "Applications of Optical Phase Conjugation," Scientific American, 254(1), Jan. 1986, p. 74-83.

6. Pepper, Optical Engineering, ibid., p. 158.

7. See T.E. Bearden, Energetics of Free Energy Systems and Vacuum Engine Therapies, Tara Publishing, Internet node www.tarapublishing.com/books,July 1997. See also T.E. Bearden, "Energetics Update and Summary, " Part I, Explore, 7 (6), 1997, p. 60-67, Part II, Explore!, 7(7), 1997, p. 53-56; Part III Explore!, 8(1), I997, p. 53-56; Part IV; Explore!, 8(3), 1997, p. 56-63. See also T.E. Bearden, "Vacuum Engines and Priore’s Methodology: The True Science of Energy-Medicine: Parts I and II " Explore!, 6(1), 1995, p. 66-76; 6(2), 1995, p. 50-62.

8. E.g., see R.O. Becker; Charles H. Bachman, and Howard Friedman, The direct current system: A link between the environment and the organism, " New York State Journal of Medicine, Vol. 62,

do, we shall all have a far brighter future. Then we shall check what has started out to be the Sword of Damocles and turn it into the golden Millennium.

We are reminded of a poignant quote from Teilhard de Chardin:

"Someday, after we have mastered the winds, the waves, the tides and gravity, we shall harness for God the energies of love. Then for the second time in the history of the world man will have discovered fire."

May the nations of the world utilize the new mind engineering science to truly free all minds into a common love of, and respect for, their fellow humans of every color, creed, and circumstance. As de Chardin envisioned, may we use the new science to discover a new fire, burning clearer and brighter than anything that has gone before. ♦

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April 15, 1962, p. 1169-1176. See also R. 0. Becker; "The direct current field: A primitive control and communication system related to growth processes, "Proceedings of the XVI International Congress of Zoology, Washington, D.C., VOL.3, 1963, p. 179-183; —"The neutral semiconduction control system and its interaction with applied electrical current and magnetic fields," Proc. 1lth International. Cong. Radiol., Amsterdam, Excerpta Medica Foundation, 1966, Series 105, p. 1753-1759. See particularly Robert O. Becker and David G. Murray, "The electrical control system regulating fracture healing in amphibians," Clinical Orthopaedics and Related Research, Vol. TBD, No. 73, Nov.-Dec. 1970, p. 169-198.

9. Bearden, T.E., Energetics: Extensions to Physics and Advanced Technology for Medical and Military Applications, CTEC Proprietary, May 1, 1998, 200+ page enclosure to CTEC Letter, "Saving the Lives of mass BW Casualties from Terrorist BW Strikes on US. Population Centers," distributed to selected high U.S. Government agencies and Legislative subcommittees, May. 4, 1998.

10. E. g. , Vlail Petrovich Kaznacheyev, V. I. Vernadsky's Study on Biosphere and NooSphere, 1989 [in Russian]. Vernadskys concepts included living matter, biosphere, and human-transformed biosphere (noosphere). Kaznacheyev writes of evolution and

energy, and advanced a mechanism for a Bohm-type quantum potential, which theoretically allows the engineering of action at a distance in physical systems.

He is president of the Association of Distinguished American Scientists (ADAS), a life member of the Alabama Academy of Science, Emeritus member of the American Association of Physics Teachers, and has served on the Board of Directors of several associations and corporations. Tom is a guitarist, a retired aikidoist (Sandan, Yoseikan style), is happily married and has two sons and two daughters. He and his wife Doris live in Huntsville, Alabama where Tom is retired from aerospace, continues private research, and serves as a consultant to industry on Scalar electromagnetics processes.

R E F E R E N C E S

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1. Owen Flynn, "Parametric arrays: A new concept for sonar, "Electronic Warfare Magazine, June 1977, p. 107-112.
2. Valerie Hunt, presentation to the U.S. Psychotronics Associations Annual Symposium, Bergamo Center, Ohio, 1988. Hunt presented epochal work showing chaos—and thus hidden order—in recorded ELF electromagnetic radiation from human bodies. Hunt split the received EM signals into two identical channels, time-delayed one channel by a very slight amount, then recombined (mixed) the nondelayed and delayed signals. The result was that attractors precisely indicative of chaos appeared. This positively proves that human systems produce ordered time-structuring of EM.

organization of the living matter as the biosphere of the earth. Without specifying the exact technical details, Kaznacheyev discusses the gist of much of what is in this present article. The present author has an autographed copy of Kaznacheyevs book referenced above.

11. Rabichev, Lev Yakovlevich; Vladislav Fedorovich Vasiliev; Alexandr Sergeevich Putilin; Tatyana Grigorievna Ilina; Petr Vasilievich Raku; and Leopold Pavlovich Kernitsky, "apparatus for the treatment of neuropsychic and somatic diseases with heat, light, sound; and VHF electromagnetic radiation," U. S. Patent. No. 3,773,049, Nov. 20, 1973. This is the U. S. patent for the LIDA machine, developed by the Russians prior to the Korean War. Additional patents or applications are as follows: Italy, #619,129, March 1961. Germany, #1,183,607, Dec. 1964. Great Britain, #826,766, Jan. 1960.

12. Stefan T. Possony, "Psy-War: Soviet Device Experiment," Defense & Foreign Affairs Daily, 12(104), June 7, 1983, p. 1-2. Reports on Dr. Ross Adey's investigation of the Soviet device called LIDA which is used to bombard human brains with radio waves in the 40-MHz region. Also reports on work by A.S. Davydov of the Ukrainian Academy of Sciences, who discovered how the blood-brain barrier can be penetrated by low-frequency radio waves so that brain cells

3. Years ago, I read an obscure reference to Russian research directly along that line, with successful development of just such a portable device. Unfortunately I lost the reference in a disastrous flood in my basement and have been unable to recover it.
4. T. E. Bearden, "Alteration of Materials by Wideband Multiwave Irradiation Combined with Selective Emission Manipulation," Invention Disclosure Document Number

are affected. See also "Soviet device uses radio waves as tranquilizer, " Associated Press release, Huntsville [Alabama] Times, May 19, 1983. Dr. Ross Adey tested the Soviet LIDA machine on a cat, and in two or three minutes the cat was sitting quietly, almost as though transfixed, and uninterested in its surroundings. The animal remained uninterested in its surroundings for some 20 to 30 minutes after the machine was turned off.

13. "KGB Used PIS to Program Soldiers, "Resonance, No. 30, Mar. 1996, p.29. Quoting: "During the 1970s, the Soviet KGB developed a Psychotronic Influence System (PIS) that was used to turn people into programmable "human weapons." Soldiers fighting in the Afghan conflict were trained using the system which employs a combination of high frequency radio waves and hypnosis. Commands are activated by code words or cyphers. The purpose of PIS was to render regular soldiers and members of the special forces incapable of feeling sympathy.

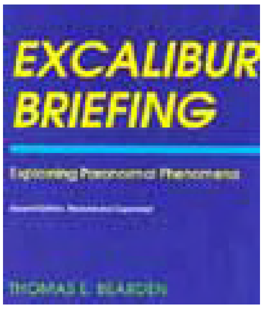
EXCALIBUR
BRIEFING
Explaining Paranormal Phenomena
THOMAS E. BEARDEN

THE NEUROPHONE

Another device that uses the new hyperspatial, virtual state, nested modulation technology (and has done so for seventeen or eighteen years) is Dr. Pat Flanagan's neurophone. With brilliant insight and intuition far beyond that of science at the time, Pat invented and patented the instrument by the time he was seventeen years old. The neurophone is a device that, contrary to all present theory and knowledge, will directly "pump the brain" and reproduce sound and information directly in the brain and mind system, without going through the auditory system at all. A simplified diagram of Pat's improved neurophone is shown in Figure 11.

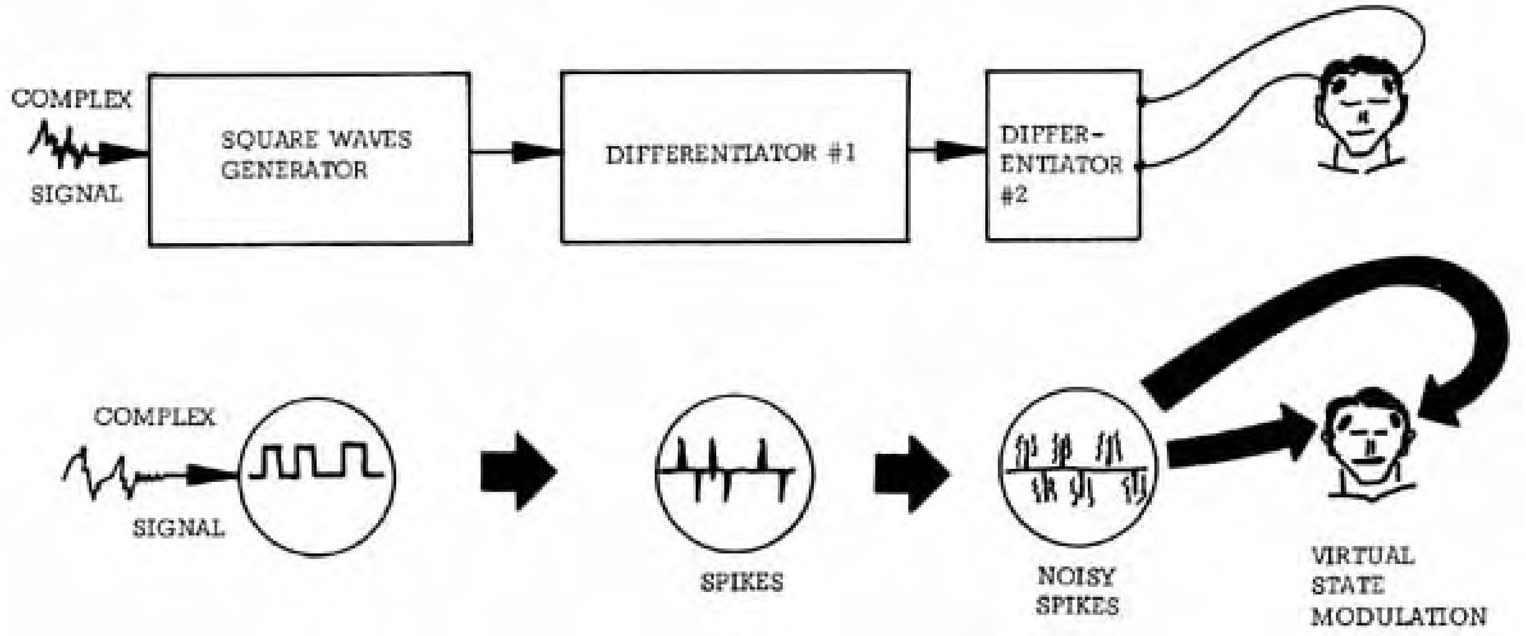
COMPLEX
SIGNAL
SQUARE WAVES GENERATOR
DIFFERENTIATOR #1
DIFFER-ENTIATOR #2
COMPLEX
SIGNAL
SPIKES
NOISY SPIKES
VIRTUAL STATE MODULATION

Figure 11. A simplified diagram of the improved Flanagan neurophone

Briefly, the device takes a complex signal, such as the sound of an orchestra playing a musical interlude, and electrically processes it as shown in the figure. First the signal is passed into a section that clips everything into a series of square waves, remarkably analogous to the sort of clipped waves Lisitsyn confirms are the information carriers of the human brain. Next the square waves are differentiated, yielding a series of sharp spikes (note that these spikes retain the pulse-time content of the clipped signal). These spikes are again differentiated, and since these are finite spikes with real nonzero rise times and decay times rather than theoretical constructs, a series of noisy spikes results from the second differentiator section. From here, the noisy spikes are introduced to special contact electrodes, one of which is normally placed on the forehead, while the other may be placed almost anywhere, including on the foot. Nowhere are any sound waves introduced to the head.

The square-wave clipper section reduces the complex signals, their overtones, and their complex modulations to square waves, retaining the temporal content of the wave mix but not the waves themselves. The first and second differentiators heighten or filter through the temporal content of the higher-order differentiations, that is, they serve as a band pass filter unit to accent the time keying of the neutrinic and mindfield portions or aspects of the signal. When these time spikes are then introduced across the body as pulsed voltages, they are modulated directly on the dendrite firings of the brain and nervous system, providing direct and pulsed modulation of the neutrinic and mindfield component channels of the mind-brain-consciousness-life loop itself. Thus the neurophone directly inputs information into the brain and nervous system, bypassing all the normal sensory systems that lie between the mind-brain loop and the outside environment.

Indeed, a similar development has been reported by two University of Missouri researchers. Dr. Donald York, a neurophysiologist, and Dr. Thomas Jensen, a speech pathologist, have recently reported identifying and decoding twenty-seven words and syllables in specific brain wave patterns and correlating these electroencephalographic patterns with both the spoken word and the silently thought word in about forty subjects. At present, Dr. York and Dr. Jensen are programming a computer with a brain wave vocabulary, to monitor and read the EEG of a stroke victim's brain and help stroke victims who have lost their powers of speech to communicate.

While all such developments can obviously be misused, their potential for assistance to mankind is enormous. Indeed, my own premise that brain linkage is possible and can be used to advance all mankind to the sixth stage of species evolution is slowly being proven. It is within our reach now to develop a multi-channel communications system that will directly link brains, minds, and consciousness into a single functional being; and I have already pointed out that the psychokinetic power of the emergent entity increases exponentially with the number of linked stages. The normal corpus callosum linkage of the two cerebral halves in each human head proves that brains, minds, and beings can be linked and integrated into one.

The Excalibur Briefing details the basic concepts of the theory involved in hyperspace-virtual state engineering, and thus in the engineering of mind-life-consciousness links to multicellular organisms here on earth. Pat Flanagan's neurophone proves that complex information can be implanted directly in the brain and mind, bypassing the normal isolating barriers. Drs. York and Jensen have shown that the brain wave does indeed contain recognizable, decodable information analogues. Lisitsyn has already reported measuring the number of independent channels involved and has documented the importance of the clipped brain waves as opposed to the sine-wave content. If we have the vision, we can still develop a brainlink and rapidly apply it to link sixty to one hundred persons, thereby opening a conscious, multidimensional "eye" for the collective human unconsciousness, gently rousing ZARG into wakefulness, and fulfilling human destiny without undergoing the psychotronic Armageddon planned by the Soviets. The time is short, but it can still be done if the funding, the vision, and the team can be established on a crash priority basis.

SOVIET "WOODPECKER" SIGNALS

But, as I have said, all this can be used for the detriment of mankind as well as for its benefit. Unfortunately, it appears that the Soviet Union has chosen to weaponize the effects on a global scale. A prime example is the "woodpecker" signals emanating from the USSR in the 5-30 megahertz region and interfering with communications around the earth.

These complex woodpecker signals appear to originate from two or three dozen powerful Soviet transmitters, each with a power estimated as high as 40 megawatts (Figure 12).

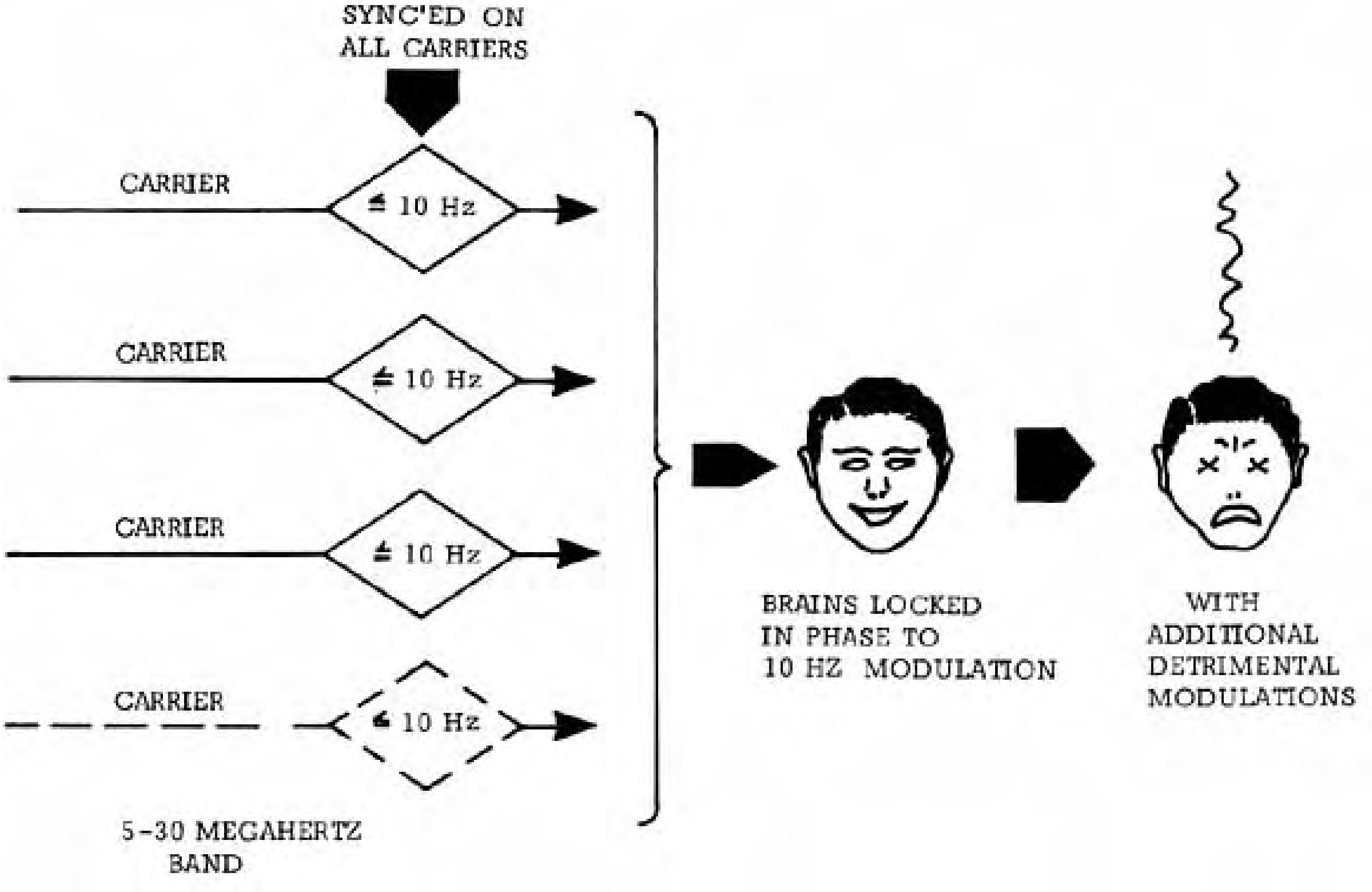

Figure 12. The Soviet "woodpecker" signals

The pioneering experimental measurements of these signals by Dr. Robert Beck and William Bise have shown just how deadly a potential may be possessed by the signals. These measurements have been performed in Eugene and Portland, Oregon; Los Angeles, California; Huntsville, Alabama; and several other locations. They have been particularly significant on the West Coast in and around Eugene, Oregon because of the presence of a direct current transmission line several hundred miles long, which has acted as a long wire antenna, picking up the signals and rebroadcasting them with appreciable gain in the vicinity.

Typically the signals may be found on, say, sixteen different carriers between 10 and 20 megahertz. Twelve of the carriers may appear normal, with normal side-bands, and the other four may have the carrier and both sidebands suppressed but still show the biologically significant modulation (for example, 10 hertz). On all sixteen channels a strong 10 hertz modulation may appear, all perfectly time synchronized and in phase channel-to-channel. The received signal from one of these carriers may be twenty-five to thirty times as strong as the earth's back-ground magnetic field, which is oscillating at approximately 7.0 to 7.5 hertz. Other complex modulation frequencies, many of them changing, are present on the various channels.

Normally, the brainwaves of mammals in an area are gently entrained by the normal oscillations of the earth's magnetic field and are oscillating along at, say, 7.5 hertz. Under continuous radiation from the Soviet woodpecker signals, a percentage (say 30 percent) of the mammalian brains may be captured by the 10 hertz modulation on the overpowering Soviet signals. These captured brains are now in forced oscillation and are riding along in phase with the 10 hertz Soviet modulation. In other words, a certain percentage of the human brains in an area will phase lock to the 10 hertz modulation, and that will effectively lock into those brains the sixteen carrier frequencies with their concomitant frequency mixes and complex signal modulations. If the signals are made much more powerful (for example, by focusing them onto one particular area or increasing the power of the transmitters), then a much higher percentage of brainwave entrainment can be accomplished in the targeted area. By simply adding on the desired modulation patterns, the Soviets can now pump material directly into the mind-brain-consciousness-life loops of the entrained brains. The weapon implications are enormous: raw emotion such as sheer terror or panic can be transmitted; death or disease patterns of all kinds can be transmitted; informational content (thoughts and ideas) can be impressed directly into the captured brains and minds and processed as if originating inside each brain itself. Indeed, as long as the Soviets keep the effects rather gentle, an entire population can be subtly influenced without governmental notice. Certain specific ELF frequencies can rapidly disable or even kill, and for wartime use those frequencies can be directly implanted in the captured brains themselves by the woodpecker signals. It appears that 1984 came a little early, and one can perhaps now understand Brezhnev's strange 1975 proposal to the SAL T negotiations that we should also consider outlawing the development of new weapons more frightful than the mind of man has ever conceived.

The signals also have direct application against strategic targets other than personnel. For example, by incorporating the correct nested modulation pattern, the positron kindling (electron squelching) pattern can be impressed. By beaming through the earth (with a circularly polarized signal or with other complex modulation forms), a beam with a strong neutrinic component, which will squelch electrons and which will interact with great preference for strong voltages or strong magnetic fields, can be directed at a target complex. In the targeted area aircraft and communications systems can be disabled; automobile, truck, and other ignition systems will fail; power transformers and large motors and generators will fail; power transmission systems with their associated high voltages will fail; and so on. Even independent, self-contained emergency power equipment, such as at military installations and strategic missile sites, will fail to operate. Further, to some of these signals, the earth and the sea are as transparent as glass, and so underwater nuclear submarines can be electrically disabled on station before their missiles can be fired, while strategic missile complexes can be electrically disabled before their deadly nuclear missiles can be hurled toward their distant targets. If some submarines and land complexes succeed in firing missiles before being disabled, these missiles can be electrically dudded and scrubbed from the sky over Soviet territory while still far from their intended targets.

So, as stated at the end of *Excalibur,* the players are on stage and in place. The final act begins. One thing is sure - mankind will never be the same again after seeing the play!

VACUUM ENGINES AND PRIORE'S METHODOLOGY: THE TRUE SCIENCE OF ENERGY-MEDICINE

Part I of II

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Photo 1. (to the right) Priore's laboratory. Workbench with animal cage is in the right foreground, under a large overhead assembly to hold the coil for producing the rippling magnetic field.

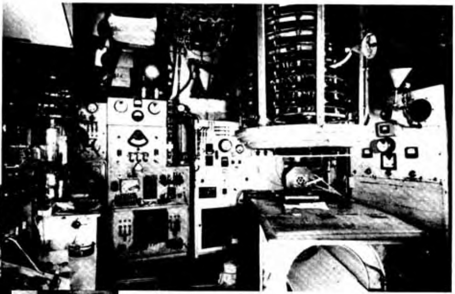

Photo 2. (below) Priore's laboratory. Workbench now has coil installed. The rippling magnetic field descended vertically through the patient. The magnetic field was modulated by the wave/antiwave output of 17 EM waves mixed in a rotating plasma in a giant mixer tube.

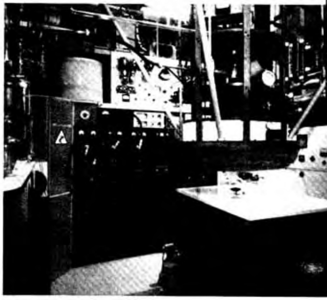

December 1, 1994

Overview

In the late 1960s and early 1970s, Antoine Priore and a team of leading French scientists demonstrated conclusive, total remissions of terminal tumors and infectious diseases in hundreds of laboratory animals. Their research was performed under rigorous scientific protocols and funded by the French Government. The approach employed very complicated mixing of multiple EM signals in a rotating plasma, and modulating the mixed output upon a very strong rippling magnetic field to which the body of the test animal was exposed. Complete remission of the treated diseases was obtained. In addition, the animals' immune systems were also restored to normal. Further, disease-specific antibodies were also created: a single drop of blood drawn from an animal that had been treated and recovered, and injected into the body of a second animal with the same terminal illness, resulted in total remission of the disease in the second animal *and its total recovery.* In the mid-70s Priore's work was suppressed, because of hostility of the oncology community, change of the French Government and loss of further funding, and complete inability of physicists and biological scientists to even hypothesize a mechanism for the curative results.

After a 10-year struggle to discover the Priore mechanism, the present author has proposed a sweeping new explanation for the exact Priore curative mechanism. It represents a totally new kind of medical therapy – one which can dramatically treat and cure a breathtakingly wide variety of diseases. The electrical physics is based on the Stoney, Whittaker, and Ziolkowski decomposition of the scalar EM potential into bidirectional EM wave pairs. Deliberate assembly of such a structure forms a *vacuum engine* of nested curvatures of local spacetime.[1] Priore unwittingly made such a hyperspatially structured vacuum engine, one with the special characteristic that it *time-reversed* (dedifferentiated) diseased cells back to their earlier normal state. The Priore approach not only produces remission of a specific targeted disease, but also fully restores the cells and "factories" of the patient's immune system because they too revert back to their previous healthy condition.[2]

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[1] *In short, Priore found and utilized a method of electromagnetically engineering general relativity in the laboratory – something physicists had not done and have no knowledge of. Neither have they done it overtly today, and neither do they have knowledge of it today.*

[2] *We point out that chemistry is largely driven by charge and charge distribution. The new methodology essentially controls charge and its distribution. Hence it can control and order all the biochemistry.*

Becker et al have shown conclusively that very weak DC currents and pulsed magnetic fields can produce cellular dedifferentiation (change to a previous state) and redifferentiation (change forward to a new state). It follows that transcription (change of the genetics) must also be altered correspondingly. Becker was nominated for a Nobel Prize for his experimental and theoretical demonstration of the mechanism. He also proposed a fundamental electrical control mechanism to account for his revolutionary results.

Kaznacheyev et al have shown that almost any cellular disease or damage can be transferred electromagnetically from one cell culture to another under special conditions. Popp has theoretically and experimentally shown that an electromagnetic master cellular control system exists in the body, as indeed has Becker. Thus it is clear and independently demonstrated that (1) disease can be created or reversed electromagnetically, and (2) the fundamental cellular control system is electromagnetic in nature. We comment that, viewed as physical materials, the cells and their constituents are sufficiently nonlinear that their EM functions, responses, and effects transcend the present classical EM model. A modern addition to nonlinear electromagnetics is the methodology and results of nonlinear phase conjugate optics (NLO). Accordingly, understanding of the higher topology EM/bioeffects functioning requires application and understanding of NLO principles, *regardless of frequency band.*

We also extend the general relativity model by addition of higher topology EM. We incorporate the Stoney/Whittaker/Ziolkowski decomposition of the scalar EM potential into hidden bidirectional waves. This is then applied to structure and engineer the vacuum. The method is also capable of structuring and engineering both mind and matter.

As a case in point, the elements of the new EM bioeffects approach are applied to the Gulf War Syndrome – the strange conglomerate of illnesses and symptoms developed by many Gulf War participants, usually beginning shortly after their arrival back in the United States from the MidEast. Previously unrecognized biological effects of a dense EM signal environment are advanced and their causative mechanisms explained. These new "dense signal environment" bioeffects, coupled with other simultaneous biologically-active suppressants, allow a full explanation of the Gulf War Syndrome and its characteristics. Both normal and anomalous symptoms are explained.

The Priore approach extends and complements Becker's pioneering approach by allowing positive engineering control of dedifferentiation of cells and their redifferentiation. A cancer cell may be regarded as a dedifferentiation or partial dedifferentiation of a normal cell back toward a more primitive or "immature" geological form. In NLO terms, this is a form of phase conjugation (time reversal) of the cell back toward a previous state, or even its *ancestral* cellular form *(see figure 1 below).* By phase conjugating the cancer cell anew and amplifying the process, the diseased cell can quickly be reversed back to a normal cell.

It is possible, using the Priore technique, to phase conjugate cells in the body, including all of them simultaneously if need be. Further, conjugation can be made specific to the type of cell or tissue one desires to affect. One need not "know" the specific disease's "EM signal complex," one must simply "pump the cell correctly" where it and its parts are treated as pumped phase conjugate mirrors (PPCMs). In a higher EM topology, the "diseased-cell-as-a-PPCM" already possesses a special "standing signal wave" input that represents the erroneous *vacuum engine* associated with the change to the specific disease state. Pumping the cell *in this special EM topology* creates the precise, amplified *vacuum anti-engine* in this same special EM topology and renormalizes the cell.

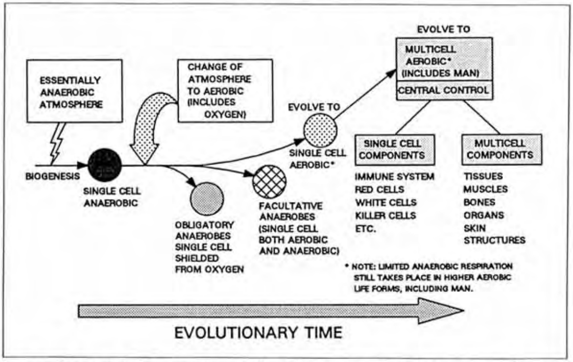
EVOLVE TO
MULTICELL AEROBIC* (INCLUDES MAN)
CENTRAL CONTROL
ESSENTIALLY ANAEROBIC ATMOSPHERE
CHANGE OF ATMOSPHERE TO AEROBIC (INCLUDES OXYGEN)
EVOLVE TO
SINGLE CELL COMPONENTS
MULTICELL COMPONENTS
SINGLE CELL AEROBIC*
BIOGENESIS
SINGLE CELL ANAEROBIC
IMMUNE SYSTEM
RED CELLS
WHITE CELLS
KILLER CELLS
ETC.
TISSUES
MUSCLES
BONES
ORGANS
SKIN
STRUCTURES
FACULTATIVE ANAEROBES (SINGLE CELL BOTH AEROBIC AND ANAEROBIC)
OBLIGATORY ANAEROBES SINGLE CELL SHIELDED FROM OXYGEN
* NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.
EVOLUTIONARY TIME

Figure 1. Cellular path taken in development of aerobic cells and multicellular bio-organisms. Dedifferentiation of a cell or small group of cells back before centralized cell control yields cancer. The body's control system orders the cell to dedifferentiate back toward an anaerobe, breaking its own control.

Because of the special EM topology utilized, direct engineering of both mind and matter are provided by the new approach, which also represents a unification and extension of electromagnetics, quantum mechanics, general relativity, and biology. It should be capable of reversing most physical and mental disorders that assail a biological organism.

INTRODUCTION

In this paper we discuss the present method of utilizing EM energy in science and engineering, and also discuss a radically different second method that is beginning to emerge *(see Table 1 on following page).* The main text is an overview, with technical elaboration in the footnotes.

The first (Type 1) engineering method may be likened to a leaky pipe: We always pour in more energy than the work we get back out. We have to furnish the primary energy used to do the work from an external source. A few of our devices, such as a common heat pump, are open systems extracting and using some excess energy from an external source. These devices may have a coefficient of performance (COP) – work output of the machine divided by work done on the machine to run it – of greater than unity. However, the vast majority of our machines have COPs of less than 1.0. Many of them have COPs of less than 50%, and many have COPs of less than 30%.

As can be seen, Type 1 engineering is very wasteful of energy! In a sense, the present struggle to attain room temperature superconductivity is a struggle to eventually have many more machines that attain a COP approaching 1.0, and so decrease the waste of energy in our

Table 1. Two Ways To Do Engineering.

- *Type 1* Engineering: Vacuum Quiescent, Use External Energy Upon Matter
  - Does not involve mind, thought, life, time streams
  - Time is not an observable
  - Must furnish all the energy
  - Western science uses this method.
- *Type 2* Engineering: Gate and Structure the Vacuum Flux Itself
  - Involves mind, thought, life, time streams
  - Time is an observable
  - Furnish only initial energy, and maintenance
  - Use vacuum's energy (vacuum engines)

Type 1 machines. Vacuum engines allow COPs of far greater than 1.0.

After several decades of painful progress in understanding the nature of the quantum mechanical vacuum, today it is accepted in physics that the vacuum itself is a seething inferno of electromagnetic energy. It is thus a legitimate source of energy, could we but extract and use it. This is now accepted both by leading physicists and by the U.S. Patent Office. Further, as of 1993 it has been clearly shown that, contrary to conventional objections, thermodynamics does not rule out the extraction and utilization of the vacuum's energy as heat and power to operate our engines.[3]

We have now reached one of the great scientific plateaus of history: (1) *The vacuum is energetic, containing an incredible density of electromagnetic energy in a violent flux*; (2) *at least in theory, it is possible to extract energy from the vacuum and utilize it*; and (3) *every particle of mass exists as a nonlinearity in a violent flux of virtual particle energy exchange with the vacuum. In short, every system is an open system, being violently "driven" by the vacuum flux, where normally the "driving flux" is in equilibrium or nearly so.*

This paper briefly describes a great new scientific breakthrough which is approaching as a result of the new understanding of the vacuum energy. This new scientific development will usher in the greatest change to humanity of all time *(see Figure 2)*. It is characterized by the laboratory ability to: (4) Deterministically structure and gate the vacuum's fierce flux of virtual particle energy – even at a distance – and make the vacuum itself an ***engine*** to do any kind of work on an embedded physical system that we choose.[4] (5) Deterministically form a quantum potential, and utilize this potential to achieve essentially instantaneous action at a distance.[5] (6) Engineer the hidden inner structure of any potential; this includes also the potential for the Schroedinger equation, including Bohm's ***quantum potential,*** so that physical reality can actually be engineered prior to the collapse of the wave function and the occurrence of the quantum change. This is engineering and altering an entity in its *pre-reality state.* (7) Engineer and alter the flow of time and the laws of nature in a particular area, including the entire planet or solar system. (8) Simply and cheaply treat and cure essentially every present infectious disease and many other abnormalities. This includes cancer, leukemia, AIDS, malaria, sleeping sickness, arteriosclerosis, etc. – even mental disorders. It also includes reversing the effects of the aging process. (9) Directly engineer, form, create, heal, or modify mind, thought, long-term memory, life, etc.[6] And finally, (10) Directly engineer and alter the species quantum potential, an entire species, and the planetary quantum potential for all species and all living creatures on earth.

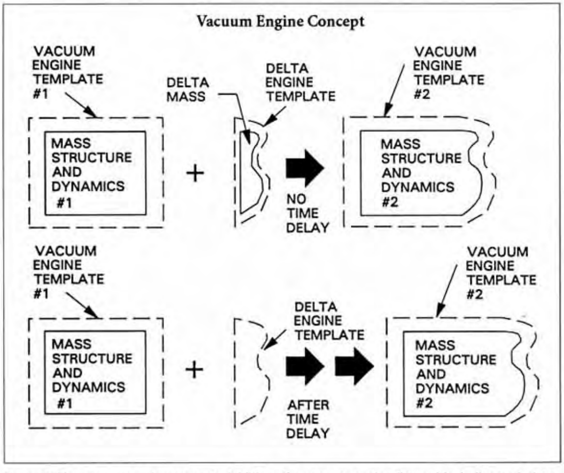
Vacuum Engine Concept
VACUUM ENGINE TEMPLATE #1
DELTA MASS
DELTA ENGINE TEMPLATE
VACUUM ENGINE TEMPLATE #2
MASS STRUCTURE AND DYNAMICS #1
+
NO TIME DELAY
MASS STRUCTURE AND DYNAMICS #2
VACUUM ENGINE TEMPLATE #1
DELTA ENGINE TEMPLATE
VACUUM ENGINE TEMPLATE #2
MASS STRUCTURE AND DYNAMICS #1
+
AFTER TIME DELAY
MASS STRUCTURE AND DYNAMICS #2

Figure 2. The vacuum engine concept. Addition of a vacuum engine (lower block diagram) alters mass and its dynamics after a time delay. Type 1 engineering uses the top level block diagram.

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[3] *Daniel C. Cole and Harold E. Puthoff, "Extracting Energy and Heat from the Vacuum,"* ***Physical Review E,*** *48(2), Aug. 1993, p. 1562-1565.*

[4] *In other words, to perform vacuum engineering, extended from the suggestion of Nobel Laureate T.D. Lee* (***Particle Physics and Introduction to Field Theory,*** *Harwood, New York; Chapter 25: Outlook, "Possibility of Vacuum Engineering," p. 824-828.). Lee recognizes that vacuum engineering can in theory be accomplished, but also that this has never even been tried.*

[5] *For a presentation of the mechanism for creating a quantum potential, see T.E. Bearden,* ***Gravitobiology,*** *Tesla Book Co., Chula Vista, CA, 1991, p. 33-36.*

[6] *The weapons developers are slowly grappling their way toward this new science, which the Russians call energetics. Application to the physical world at large is just referred to as energetics. Application of energetics to mind engineering is called* ***psychoenergetics.*** *Application to the physical body and its structures is called bioenergetics. In the U.S., development of mind and behavior alteration and control is now being dealt with in embryonic fashion under the subject heading of nonlethal warfare.*

This paper is an informal "quick note" to point out the new scientific plateau and introduce the second kind of science and engineering. The new ***vacuum engineering***[7] offers the greatest threat to humanity that has ever existed,[8,9,10] and at the same time offers the greatest promise of benefit.

For our very survival, it is absolutely imperative that informed citizens be aware of this dramatic change, which is just now starting. The powerful new science and engineering must be controlled and used for humanity's benefit, not its detriment. Else it will eventually be let loose unrestrainedly, to destroy all life on earth – a possibility indicated by Nikita Khrushchev in 1960.[11]

THE FIRST KIND OF ENGINEERING (TYPE 1)

First there's the normal way to do engineering (Type 1), which we are all taught as engineers and scientists. Here the vacuum/spacetime itself stays *inert* and out of our way.[12] We ourselves furnish energy into or onto the system we are trying to move or activate, spilling some of this energy all the while, and we struggle until we get the mass to move and the system to operate and perform work.

This "first kind" of engineering is essentially a continual *wrestling match.* Nature herself is the opponent. The engineer furiously struggles with nature, to force her to do the work he wishes to do. *This is the only **overt** kind of engineering presently done on earth.* It is primitive and severely limited in what it can do. In Type 1 engineering, the mind and thought are not affected since the *flow of time connectivity* and the *flow of mind connectivity* are not affected.

THE SECOND KIND OF ENGINEERING (TYPE 2)

Clandestinely, however, the Russians (actually, the KGB) in their secret advanced weapons labs, and three other nations not hostile to the U.S., have also weaponized a second kind of science and engineering, but kept it firmly a secret of the highest order. The second kind of engineering (Type 2) is dramatically different, far more powerful, and essentially unlimited in what it can do. Some of the simpler elements have spilled into the open press. For example *(see Figures 3 & 4 on next page)*, Vlail Kaznacheyev and his colleagues have shown, in thousands of meticulous experiments, that almost any disease or damage to cells can be induced in an isolated cell culture by electromagnetic radiation from the diseased or damaged culture, if a full harmonic interval (infrared to ultraviolet) is open for electromagnetic (photonic) exchange between the cultures.[13] The present author's proposed mechanism for the Priore and Becker results also explains the Kaznacheyev results.[14] It also explains the decades-long Russian induction of health changes and diseases in the microwave radiation of the U.S. Embassy in Moscow.[15]

In Type 2 engineering, the background vacuum/spacetime itself is deliberately altered, structured, and made asymmetrical. One then uses this *struc-*

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[7] *Terminology after Nobel Laureate Lee, ibid., p. 383. Lee points out that the microscopic structure of the scalar vacuum field is not utilized. The particulate flux structure can indeed be engineered, but this has never even been tried by conventional physicists. An excellent coverage of asymmetries and observables is given on p. 181-188. E.g., whenever a symmetry is spontaneously broken, a nonobservable (virtual entity) has become observable. There thus exist vacuum engineering mechanisms for the direct translation between virtual and observable states. Indeed, a whole new vista has opened in physics – some are calling it a "new physics" – due to the discovery that it is possible to directly amplify the virtual state into observable state. E.g., see Serge Haroche and Daniel Kleppner, "Cavity quantum electrodynamics,"* ***Physics Today***, *Jan. 1989, p. 24-30 for an overview. In 1979 the present author foresaw, albeit crudely, the emergence of virtual state engineering by means of a possible hyperspatial (virtual state) amplifier. See T.E. Bearden, "Virtual state engineering and its implications," National Technical Information System, Report AD-A065762, 1979.*

[8] *The Russian weapon engineers model the vacuum as a virtual EM dipole plasma, rather than as a simple particle flux; e.g., see A.V. Chernetski, "Processes in Plasma Systems with Electric Charge Division," Georgi Pleckonov Institute of National Economy, Moscow, 1989 for an introductory theoretical exposition of the basic model with respect to physical energy systems.*

[9] *Use of dipoles focuses immediately upon the hidden electromagnetics. Application of plasma theory then exposes the higher nonlinear EM aspects and the characteristics of a higher topology EM theory. Interestingly, Priore used all the elements fitting this theoretical model, employing a giant plasma-filled tube for multi-signal EM mixing, to produce "hidden EM" vacuum engines.*

[10] *Decades ago, the Russians also applied the virtual EM dipole plasma vacuum to the problem of direct engineering of mind, behavior, and cellular control functions. For the fact that they succeeded in decoding the mind/brain/s operations, see S.K. Lisitsyn, "New approach to the analysis of electroencephalograms," Problems of Bionics* ***(Selected Articles)***, *p. 16-25, National Technical Information System Report AD 730045. See also the various references by Kaznacheyev, sanitized by the Soviet State at the time to prevent revealing the actual primary mechanisms.*

[11] *For a partial discussion of Khrushchev's statement of the impending availability of such new Soviet superweapons, see Max Frankel, "Khrushchev says Soviet will cut forces a third; sees 'Fantastic Weapon'," New York Times, Jan. 15, 1960, p. 1.*

[12] *Technically the vacuum is always highly active, in violent flux exchange with all particles of mass. However, in Type 1 engineering this exchange activity is in equilibrium. So action and reaction are balanced in all directions. With no observable asymmetry, no single net force accumulates for the observer to see, and the vacuum appears to be an "emptiness."*

[13] *See Vlail Kaznacheyev and L.P. Mikhailova,* ***Ultraweak Radiation in Intercellular Interactions,*** *[in Russian], Novosibirsk, 1981. Vlail Kaznacheyev, "Electromagnetic Bioinformation in Intercellular Interactions,"* ***Psi Research***, *1(1), Mar. 1982, p. 47-76 contains an English translation of much of the information referenced in Kaznacheyev's 1981 book. See Vlail Kaznacheyev et al, "Distant intercellular interactions in a system of two tissue cultures," Psychoenergetic Systems, 1(3), Mar. 1976; "Apparent information transfer between two groups of cells,"* ***Psychoenergetic Systems,*** *1(1), Dec. 1974; V.P. Kaznacheyev, "Information function of Ultraweak Light Flows in Biological Systems," in* ***Problems in Biophysics***, *Novosibirsk, 1967, p. 7-18 [in Russian]; V.P. Kaznacheev and A.V. Troftmov, Cosmic Consciousness of* ***Humanity:*** *Problems of New Cosmogony. Elendis-Progress, Tomsk, Russia, 1992.*

[14] *See T.E. Bearden, Gravitobiology, Tesla Book Co., P.O.B. 121873, Chula Vista, CA 91912; 1991. See also Bearden, Cancer and the Unresolved Health Issues in the Biological Effects of EM Fields and Radiation, Tesla Book Company, 1993.*

[15] *The Soviets radiated the U.S. Embassy in Moscow with weak microwave radiation for decades, starting in the early 1950s. Anomalous health changes and diseases were induced in U.S. Embassy personnel. Three Ambassadors eventually died of leukemia-like illnesses of mysterious nature. The results of the Johns Hopkins scientific study of the Embassy radiation problem also provide strong evidence for the explanation, since health changes and diseases only occurred in those areas of the Embassy where the EM force fields from the radiation were zero. In other words, induced health changes occurred only in personnel in those Embassy areas where the potentials from the radiation had zero gradients, so that the potentials were persistent. This 100% correlation to persistent potentials exclusively, is exceptionally strong evidence that the EM radiation was the actual cause. If independent of the EM radiation, health changes would not have precisely correlated to any component of the radiation! The Johns Hopkins scientists were quite competent, but only considered classical EM theory (CEM) in their assessment. CEM assumes that, when the force fields are zero, the electromagnetic actions are zero. That of course has been disproved in quantum mechanics, which has shown theoretically and experimentally that the potentials, not the force fields, are the primary causes of all EM phenomena. [See Y. Aharonov and D. Bohm. (1959) "Significance of Electromagnetic Potentials in the Quantum Theory," Physical Review, Second Series, 115(3), 1959, p. 485-491; Bertram Schwarzschild, "Currents in normal-metal rings exhibit Aharonov-Bohm effect," Physics Today, 39(1), Jan. 1986, p. 17-2.] Even when the force fields are zero, the potentials may remain and provide real changes in charged particle systems by scalar interferometry. Indeed, the force fields do not even exist in vacuum, as CEM assumes. The Johns Hopkins scientists concluded – based on the erroneous CEM model they applied – that since no force fields were present where any of the health changes occurred, the cause could not have been the weak microwave radiation. Had it not been the radiation, some of the health changes would inevitably have occurred where the EM force fields were nonzero. The investigators' results falsified their own study's conclusion, by simple expectation mathematics. Had they known of the SWZ structured potential and its possibilities, they would have realized that by showing 100% correlation to the force-free potentials, they had actually proven that it was indeed the radiation that was the cause, and the force-free potentials component was the actual culprit The team was excellent; its tools failed it. For a complete discussion, see Bearden, Gravitobiology, 1991, p. 27-32.*

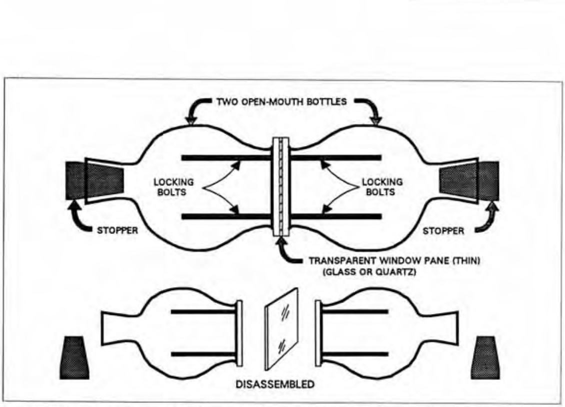
TWO OPEN-MOUTH BOTTLES
LOCKING BOLTS
LOCKING BOLTS
STOPPER
STOPPER
TRANSPARENT WINDOW PANE (THIN) (GLASS OR QUARTZ)
DISASSEMBLED

Figure 3. Kaznacheyev's two-chamber apparatus. A cell culture is divided into two parts. Left ones are damaged or killed. Effect is replicated in right cells through windowglass, but not quartz.

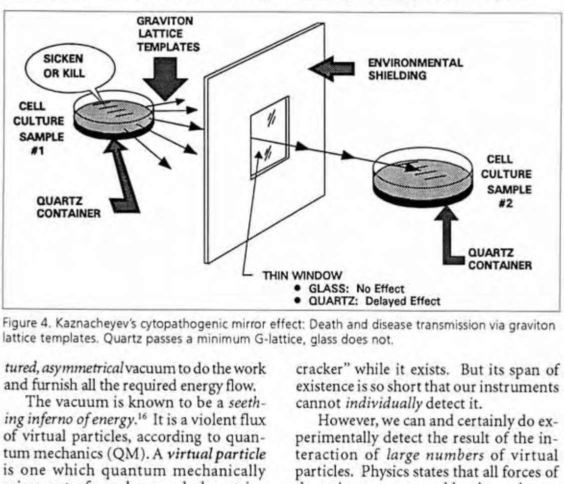
GRAVITON LATTICE TEMPLATES
SICKEN OR KILL
ENVIRONMENTAL SHIELDING
CELL CULTURE SAMPLE #1
CELL CULTURE SAMPLE #2
QUARTZ CONTAINER
QUARTZ CONTAINER
THIN WINDOW
• GLASS: No Effect
• QUARTZ: Delayed Effect

Figure 4. Kaznacheyev's cytopathogenic mirror effect: Death and disease transmission via graviton lattice templates. Quartz passes a minimum G-lattice, glass does not.

tured, asymmetrical vacuum to do the work and furnish all the required energy flow.

The vacuum is known to be a *seething inferno of energy.*[16] It is a violent flux of virtual particles, according to quantum mechanics (QM). A *virtual particle* is one which quantum mechanically arises out of nowhere and almost instantly returns to nowhere. It may be highly energetic and "hotter than a firecracker" while it exists. But its span of existence is so short that our instruments cannot *individually* detect it.

However, we can and certainly do experimentally detect the result of the interaction of *large numbers* of virtual particles. Physics states that all forces of the universe are caused by the exchange of such virtual particles. It is also theoretically and experimentally proven that every particle of mass is in a violent virtual particle flux exchange with the surrounding vacuum. Several experiments directly show this – the Lamb shift for one.[17] The Lamb shift is largely due to fluctuations of the hidden virtual flux exchange with the vacuum, and involves a local energy density far greater than the surface energy density of the sun's surface.

VACUUM ENGINES: ORDERING AND UTILIZING THE VACUUM VIRTUAL PARTICLE FLUX

In Type 2 engineering, one structures and orders the violent virtual particle flows of the fundamental vacuum/spacetime (VST) itself.[18] Accordingly, it alters and orders the vacuum's violent energetic exchange with any mass particles and physical systems in the area. One *oneself* does not input the energy that does the actual work on the material system located in that region of VST. Instead, one only inputs the energy necessary for the *gating and directing* of the VST flux energy in that area. This structuring and gating of the virtual particle flux forms an organized, energetic pattern which I have dubbed a ***vacuum engine*** (after Nobel Laureate Lee's recognition that the vacuum itself could in theory be engineered, but that such had never even been tried).

This ***vacuum engine*** now does the work and furnishes all the working energy. We just have to pay to set up the *gating mechanism and the template* in the beginning, and continue to pay a little bit to sustain them. Literally we have created a stupendous *energy amplifier.*[19] By continuing to expend a little maintenance and steering energy, we can gate and utilize the energies of an enormous engine which can apply incredible energy densities, even at a distance. In principle it can apply anything from a feather's touch up to the explosion of a star. It can be used to engineer anything from a single particle or wave, to the atomic nucleus, to a planet or a sun.[20]

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[16] *For a good overview of the active vacuum, see R. Podolny, Something Called Nothing: Physical Vacuum: What Is It?, translated by Nicholas Weinstein, Mir Publishers, Moscow, 1986, revised from the 1983 Russian edition. See also I.J.R. Aitchison, "Nothing's plenty: The vacuum in modern quantum field theory," Contemporary Physics, 26(4), 1985, p. 333-391; Jack S. Greenberg and Walter Greiner, "Search for the sparking of the vacuum," Physics Today, 35(8), Aug. 1982, p. 24-32; Richard E. Prange and Peter Strance, "The semiconducting vacuum," American Journal of Physics, 52(1), Jan. 1984, p. 19-21; Walter Greiner and Joseph Hamilton, "Is the Vacuum Really Empty?", The American Scientist, 68(2), Mar.-Apr. 1980, p. 154-164; Timothy Boyer, "The Classical Vacuum," Scientific American, Aug. 1985, p. 70. See also important papers by H.E. Puthoff: "Source of vacuum electromagnetic zero-point energy," Phys. Rev. A, 40(9), Nov. 1, 1989, p. 4857-4862; "Gravity as a zero-point fluctuation force," Phys. Rev. A., 39(5), Mar. 1, 1989, p. 2333-2342; and "The Energetic Vacuum: Implications for Energy Research," Speculations in Science and Technology, 13(4), 1990, p. 247-257.*

[17] *W.E. Lamb, Jr. and R.C. Retherford, "Fine structure of the hydrogen atom by a microwave method," Physical Review, Vol. 72, 1947, p. 241-243. Demonstration of the displacement of one of the fine structure electron states of the hydrogen atom by a frequency of about 1060 megacycles played a central role in the development of quantum mechanics, and earned Lamb the Nobel Prize. The observation makes the reality of dynamic vacuum fluctuations inescapably evident.*

[18] *Since the vacuum can be altered, we now must speak of various vacuua, not just one. "A" vacuum, "a" spacetime, and "a" scalar potential are synonymous. "The" ambient vacuum at any local point is a maelstrom of the scalar (hidden multiwave) interferometry of potentials from every charged particle in the universe (adapting Puthoff's Cosmological Feedback Principle). This scalar EM interferometry creates the EM fluctuations of the quantum mechanical vacuum, by Whittaker 1903 & 1904.*

ENGINEERING GENERAL RELATIVITY & NESTING SPACETIME CURVATURES

We actually engineer general relativity (GR) itself, since the Stoney,[21] Whittaker,[22] and Ziolkowski[23] (SWZ) papers point the way to how to do just that *(see figure 5)*. In short, by using the SWZ approach, one is able to utilize electro-magnetics in a new way, to directly form these curvatures of local spacetime. We also *nest* these curvatures to form a ***template*** of structured multiple curvatures; this template constitutes the deliberate format of the vacuum engine *(see figure 6)*.

Indeed, this is a radically different concept of spacetime structure. It is well-known that, whenever one applies a local hidden variable theory, the GR theory of spacetime structure must be radically altered.[24]

We stress that, in Type 2 engineering, one directly extends, applies and engineers general relativity, but by a novel use of electromagnetics. As can be seen, establishment science is not doing that at all, but is doing only Type 1 engineering. Literally anything one wishes can be engineered in the Type 2 fashion, at least in theory, including transmutation of elements, materialization and dematerialization of matter, free energy electrical power sources, and antigravity. However, Type 2 engineering is even more powerful than that. It also is the ultimate form of virtual reality engineering, for it allows the direct engineering of both physical reality and the mind itself.

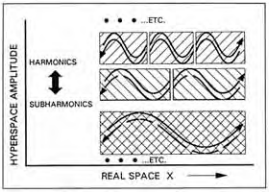

Figure 5. Stoney/Whittaker/Ziolkowski internal EM biwave structure of the scalar EM potential.

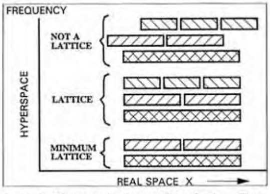

Figure 6. Graviton lattices and nonlattices. Templates require G-lattices. Minimum lattice is one harmonic interval.

MIND, 3-SPACE, HYPERSPACE, MIND FLOW, AND THE FLOW OF TIME

Mind exists in time, but not in our familiar 3-space. Mind does not exist spatially in the same 3-space in which we model physical phenomena.[25] Mind occupies (to the physicist) only one dimension – the time dimension – of Minkowski's 4-space of physical matter. This means that the attachment of mind to matter (in a living biological organism) involves a *mind flow* process, hidden in and occupying the *time flow* process *(see figure 7 below)*.

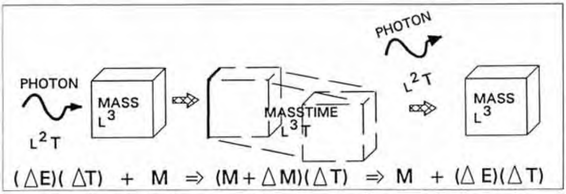
PHOTON
PHOTON
L^2T
MASS
L^3
MASSTIME
L^3T
L^2T
MASS
L^3
$(\triangle E)(\triangle T) + M \Rightarrow (M+\triangle M)(\triangle T) \Rightarrow M + (\triangle E)(\triangle T)$

Figure 7. The photon interaction generates observed quantum change and the discretized flow of time. A particle usually connects to only a single delta T at a time. Every other particle is connected to that small increment of time also, as are all minds.

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[19] *An example of such an actual amplifier was Floyd Sweet's vacuum triode –, a 6-lb., solid-state device containing special coils and two separated barium ferrite magnets. The magnets were specially activated by Sweet's proprietary process so as to powerfully self-oscillate at a chosen ELF frequency, such as 60 Hz. [Such self-oscillation of barium compounds are well-known, but at optical frequencies. Use of a photorefractive magnetic material that is also an insulator allowed Sweet to initiate self-oscillation at ELF frequencies.]. An input sine wave of 10 Volts and 33 microamperes then produced 500 watts of phase conjugate replica EM power, extracted from the self-oscillation energy between the vacuum and the magnets. The amplifier gain (COP) of this open system, self-oscillating, pumped phase conjugate mirror device was some 1,500,000. A successful antigravity test of the device was also performed by Sweet at my urging, and resulted in a controlled reduction of its weight on the laboratory bench by 90%. For as much as could be revealed of the operation and testing of Sweet's proprietary device, see Floyd Sweet and T. E. Bearden, "Utilizing Scalar Electromagnetics to Tap Vacuum Energy," Proceedings of the 26th Intersociety Energy Conversion Engineering Conference (IECEC '91), Boston, Massachusetts, 1991, p. 370-375. Unfortunately nothing can be done with the device – e.g., because of formidable legal entanglements due to the conflicting agreements Sweet made with different financial backers. However, McLain & Wooten have produced a repicable, tested, overunity device & full construction details have been rebuilt on Internet.*

[20] *In the modern geometrical view, all individual field energies come from the conglomerate structure called "gravitational field." Transforming one field energy into another kind may be done by first transforming the initial field energy back into G-field energy, then re-releasing the G-field energy as the desired new type of field energy. Vacuum engines allow control and utilization of this process.*

[21] *G. J. Stoney, "XLVIII. On a Supposed Proof of a Theorem in Wave-motion, To the Editors of the Philosophical Magazine," Philosophical Magazine, 5(43), 1897, p. 368-373.*

[22] *E.T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," Mathematische Annalen, Vol. 57, 1903, p. 333-355; "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions," Proceedings of the London Mathematical Society, Series 2, Vol. 1, 1904, p. 367-372.*

[23] *Richard W. Ziolkowski, "Exact Solutions of the Wave Equation With Complex Source Locations," J. Math. Phys., 26(4), April 1985, p. 861-863. See also Ioannis Besieris, Amr M. Shaarawi, and Richard W. Ziolkowski, "A bidirectional traveling plane wave representation of exact solutions of the scalar wave equation," J. Math. Phys., 30(6), June 1989, p. 1254-1269. See also Michael K. Tippett and Richard W. Ziolkowski, "A bidirectional wave transformation of the cold plasma equations," J. Math._Phys., 32(2), Feb. 1991, p. 488-492.*

[24] *E.g., see Abner Shimony, "Events and processes in the quantum world," in Quantum Concepts in Space and Time, Eds. R. Penrose and C.J. Isham, Clarendon Press, Oxford, 1986, p. 192: "...local hidden variable theories may be possible only if relativity theory is replaced by a radically different theory of spacetime structure." (My comment is that this should not be surprising, since classical electromagnetics, quantum mechanics, and general relativity are in profound contradiction of each other, and cannot be unified as they are, in spite of decades of Herculean efforts by many excellent physicists).*

[25] *We may model a mind as a separate 3-space, and its functional operations as "physical" in that hyperframe. Thus a mind and its operations are hyperspatial and outside physical matter's 3-space. Both mind and matter 3-spaces share a common 4th (time) dimension. So it requires at least seven dimensions to model a living creature, eight to model a species, and nine to model all life on earth. The 4th dimension of the mindworld hyper-4-space coincides with the 4th dimension of the physical world's Minkowski 4-space. A priori, mind/matter engineering operations involve engineering and structuring the time stream. This allows engineering either physical reality or mental reality or both simultaneously.*

Normally, so QM tells us, the observation process destroys time, so that all "observables" are spatial only. So the completion of each observable change in a living mass system momentarily destroys the only connection that the mass had with its associated mind! It vanished in the so-called "collapse of the wave function."[26,27,28] Fortunately, little pieces of time are always being serially added and subtracted by the ubiquitous photon interaction process with every mass. Hence the body's particles of mass are continually being *connected to* and *disconnected from* little serial bits of the time stream, and from corresponding serial bits of the *mindstream* of that individual.

TYPE 2 DISRUPTION OF TIME AND MIND

Type 1 engineering does not disrupt or affect the flowing time stream. Hence it does not disrupt or affect the flowing mindstreams of biological systems in the vicinity.

This is not necessarily true of Type 2 engineering! Type 2 engines of appreciable power can and will disrupt and destroy the body's continual detachment from and reattachment to its mind-stream. Type 2 engines will appreciably disrupt and alter the flowing time stream, and thus disrupt and alter the flowing mindstreams of all life forms in the vicinity. The size of the "vicinity" depends upon the size of the engine.

So to beneficially utilize vacuum engines, we do not strive for control of vast energies. We must use a surgeon's scalpel, so to speak, instead of a giant steam hammer. If one seeks weapons, on the other hand, one will strive for control of much greater vacuum engine energies. The KGB secret laboratories, e.g., have pursued this goal for over four decades. Several generations of Type II weapons have been developed and deployed, all under continued KGB control and operation. These Type 2 weapons could, in the words of Khrushchev's address to the Presidium in January 1960, "*...wipe out all life on earth if unrestrainedly used.*" Now one can easily see how that could happen: ***Any massive use of Type 2 weapons will substantially upset the time stream on earth, including all individual time streams. It will so disrupt all the mind streams of all earth's creatures that their connections to their physical bodies will be instantly broken.*** At least now we know why Brezhnev himself was so frightened of these weapons in 1975.[29]

Another unusual characteristic of Type 2 engineering is the *slowly decaying persistence of any special vacuum engine structure artificially created in the vacuum.* We may analyze this effect in terms of the "ghost forms" of quantum mechanics.[30,31,32]

ENGINEERING THE MIND, ITS OPERATIONS, AND ITS CONTENTS

The vacuum engine affects/curves/structures not only the three *spatial* dimensions of ST, but also the *time* dimension. Hence the vacuum engine approach can be used to engineer not only the observable physical matter (which is 3-spatial), *but also the mind and thought (which are time-like to the external observer).* Literally one can "get into the mind's connection channel" and alter the mind, its contents, and its operations at will by using appropriate vacuum engines.

By appropriately and selectively nesting the spacetime (ST) curvature structuring, one can even reach beyond the

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[26] *Rigorously, the emission of a photon by the living mass destroys its time channel, thus collapsing the wave function and disconnecting the mind. Absorption of another photon immediately thereafter adds an increment of time back to the mass, forming* **masstime** *and reconnecting the time channel and hence the mind channel. Mass does not exist in time per se; masstime does. The temporary disconnection of the time channel by photon emission causes the wave function to collapse; a priori a wave cannot exist without some time available in which to wave! This in fact produces the observable mass from masstime. The problem is that the physicists have ignored the transport by the photon of* Δt *as well as* ΔE. *Thus they have not noticed that the ubiquitous photon interaction with a mass creates the continual addition and subtraction of time increments. This continual coupling and uncoupling of mass to and from the time dimension creates a* ***discretized*** *flow (passage) of time for that mass. This continual connection and disconnection of a mass to and from only a tiny little piece of the time channel is responsible for the past and the future not being observable; "being observable" is simply being connected to a single small* Δt *increment, not all the increments that have gone before or that will follow hence. When one looks at the corner of a room, the 3-spatiality of one's mass instrumentation system is why one can see length, width, and height but not the fourth dimension, time.*

[27] *Since the photon interaction – including the virtual photon interactions – can be engineered, obviously the passage of an object through the discretized timestream can also be engineered, electromagnetically. Not only can a photon, electron, or proton be time-reversed, but also an assemblage of photons, electrons, protons and neutrons can be time-reversed. Among other things, this means that a diseased living physical cell can be time-reversed (dedifferentiated) back to a previous healthy state, as shown by Priore and also by Becker. Kaznacheyev, as does Becker, also shows that healthy living cell can be "time-forwarded" (differentiated) to a new state, if bombarded with the weak vacuum engine templates (graviton lattice structures) for that state. The minimum graviton lattice (ordering of SWZ wavepairs) utilizes one harmonic frequency interval. Thus quartz will pass Kaznacheyev's cytopathogenic effect, since it passes IR to UV – one harmonic interval. Ordinary window glass does not pass a complete harmonic interval, hence cannot pass the minimum graviton lattice and destroys the disease-inducing vacuum engine template.*

[28] *Since the entire area is highly nonlinear, then nonlinear oscillator theory applies. Graviton lattices may therefore be activated harmonically or subharmonically. This means that "optical band" results can be initiated by analogous subharmonic input – e.g., microwaves or even sound waves. G-lattices work like music; one recognizes a C-chord regardless of the octave. In similar manner, vacuum engines (G-lattices) may be shifted by any number of octaves, with initiation of results then being delayed in the responding physical systems, as prescribed by nonlinear oscillator theory.*

[29] *See Christopher S. Wren, "Brezhnev Talk for Accord against 'Terrifying Arms", New York Times, June 14, 1975, p. 1, 11.*

[30] *Since statistically every possible change in the vacuum is constantly and continually occurring in each and every differential volume, no matter how small, then from time to time in that maelstrom any physical (and mental) template we care to visualize appears, exists for a very short but finite time, then disappears, then reappears, etc. Such a continual, untidy characteristic is called a ghost form, and usually downplayed or ignored in the teaching of QM because it is "unpleasant." However, anything and everything – no matter how bizarre and whether living or inert – has a small but nonzero "density of reality" in the vacuum flux. Everything that ever was or will be, and everything that never was and never will be, is also there. The point is, creation of a vacuum engine template for a ghost form adds energy to (activates) that form. Just as a Dirac "ghost form electron" can be lifted from the vacuum by adding energy, so can any other ghost form, be it "living" or "dead." The process is fundamental and not just for electrons. Adding energy to a ghost template, we increase the local energy density of that ghost form in all electrical potentials in the entire area. This structuring of vacuum spacetime extends radially in all directions, tailing off to zero at infinity. When the inputting energy is ceased, the energized/activated form will then gradually decay over a period of time.*

[31] *We may compare the activation, persistence, and decay of the ghost form to an accumulator fed by two inputs, one blue liquid and one yellow liquid, with an outlet pipe on the opposite side. Suppose only the blue pipe is turned on; the tank is filled with blue liquid and blue liquid comes out the outlet. Now we turn on the yellow valve, and yellow liquid also starts entering. Over a period of time, the liquid in the tank will gradually turn green, as will the fluid from the outlet. Now we turn off the yellow valve. Over a period of time, the fluid in the tank will gradually turn back to blue color, as will the outlet liquid. Energizing and decaying ghost template structuring of the vacuum works the same way.*

[32] *For inputs that have raised the ghost template near or above the observable (quantum) threshold, this "decay time" may be quite long. Golden once accidentally charged up his local area with such a local template, in a powerful experiment that lasted about eight hours. Materializations occurred, determined by the thought-form (steady ghost form) inputs from the minds of the unintentional participants. In addition, interference with the timestream occurred, as indicated by all local clocks – mechanical, electrical, pendulum, etc. – going substantially astray. The materializations decayed away in a couple of hours, simply dematerializing back into the virtual state when their average energy density level reduced past the quantum threshold. It required four days for the entire "ghost template" to decay away and for the clocks in the area to fully resume normal operation.*

ordinary 3-space and get directly into the higher dimensional space one may mathematically use to model the mind *(see figure 8)*. One can then directly "engineer" in that *pure mind* arena (in the *mental spacetime*, in the modeling sense). This capability, I believe, was responsible for Brezhnev's vivid fear of these weapons in 1975, and his statement to visiting U.S. senators that, not only must the nations of the earth ban nuclear weapons, but also the development of new weapons of mass destruction *"more frightful than the mind of man has ever imagined."*[33] Gromyko later introduced a draft treaty to that effect to the United Nations the same year, and urged the nations of the world to sign it.[34] Article one of the draft treaty stated that the Russians would identify the type of weapons when negotiations on the treaty started. *No one had the slightest notion what the Russians were referring to.* However, three other nations – not hostile to the U.S. – later did develop some of these Type 2 weapons. The Soviet Union was already engaged in operational testing against U.S. and other targets, with incidents mistaken for "accidents" or "anomalies" by the world's news agencies.[35] During the beginning of the 1980s the three nations began checking the Soviet Union by demonstrating their own use of the weapons against Soviet targets. Again the open press did not recognize the true nature of the incidents involved. At the close of the 1980s the triad *vigorously* "checked" the Soviet Union, clearly demonstrating their ability to devastate the Soviet Union should it attempt to devastate friendly nations.

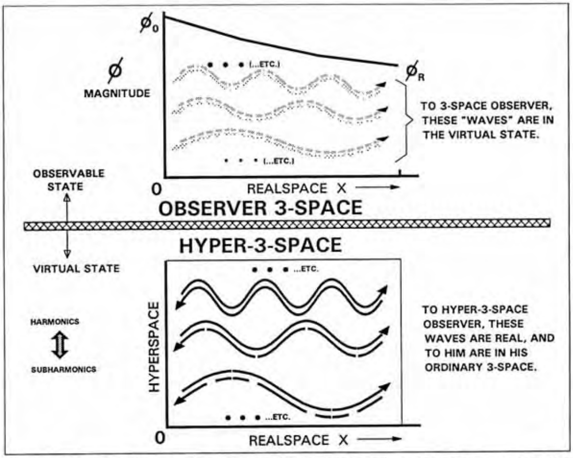

Figure 8. The 7-space EM potential. In observer 3-space (top figure), the potential is composed of a virtual particle flux. In hyper 3-space, the potential is a harmonic series of a SWZ bi-directional EM wavepairs.

So a special case of "deterrence by massive retaliation" came into being in the Type 2 weapons area as well as in the conventional and nuclear areas. Does the reader recall, e.g., the mysterious explosion of several Soviet missile ammunition storage sites in the space of a few months in 1983-84?[36] A single one of these explosions destroyed a third of all the missiles in the entire Soviet Northern Fleet. There were other major incidents whose true nature and cause went unnoticed.

Frustrated in the intent to dominate the world by surreptitious, delicate use of its Type 2 weapons, the economy of the Soviets simply fell apart. The Berlin Wall was torn down and the Soviet Union broke apart into independent regional nations.

In that upheaval of the Soviet Union, however, the KGB remained intact, well-funded, and still firmly in possession and control of the Type 2 superweapons, including development, manufacturing, deployment, manning, and operational employment.[37,38]

WHEELER'S PRINCIPLE AND ITS EXTENSION

Einstein has strongly pointed out the necessity to review foundations *(see table 2)*.

The great physicist Wheeler has a very nice statement on the curvature of spacetime. Briefly, he summarizes the gist of GR as *"Geometry tells mass how to move, and mass tells geometry how to curve."*[39] By "geometry" he is referring to *spacetime*. So we may immediately sub-

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[33] *Wren, 1975, ibid.*

[34] *Prohibition of the Development and Manufacture of New Types of Weapons of Mass Annihilation and of New Systems of Such Weapons, draft treaty introduced by Gromyko at the United Nations' 30th session of the General Assembly, New York, Sept. 23, 1975. The first article provided that the types of these new weapons would be "specified through negotiations on the subject."*

[35] *A long list of these incidents has been published by this author, through the Tesla Book Company. See T.E. Bearden, Soviet Weather Engineering Over North America, 1985; Fer-de-Lance, 1986; AIDS: Biological Warfare, 1988, Analysis of Scalar Electromagnetics, 1990, and Gravitobiology, 1991.*

[36] *See photograph, Jane's Defence Weekly (JDW), 2(3), July 28, 1984, p. 92; see also Mark Daly, "Goa and Goblet SAMs in Severomorsk explosion," JDW, 2(6), Aug. 18, 1984, p. 224; Derek Wood, "Soviets' northern fleet disabled... 'not viable' for six months," JDW, 2(1), July 14, 1984, p. 3; Derek Wood, "Six explosions in the past seven months," JDW, 2(1), July 14, 1984, p. 3; John Moore, "The aftermath of Severomorsk," JDW, 2(6), Aug. 18, 1984, p. 224.*

[37] *To survive as the leader of Russia, Yeltsin of necessity formed a pact with the KGB. KGB support insured that no coup of substance could be mounted against him, and that the KGB would insure his remaining in power. In return, Yeltsin saw that the KGB was well-funded, remained intact, retained all its secret weapons laboratories and secret weapon scientists and manufacturing facilities, and retained and continued to operate all its deployed, operational superweapons. The KGB changed its name and continued business on a less public profile. Publicly it officially turned a "much gentler face" toward the Russian citizenry. But essentially the KGB still controls most of the Russian military officer corps. Through the KGB/military connection the Communist Party can still accomplish a military coup and seize control of the country again, at least for the foreseeable future, when it chooses to do so. The Russian threat has not disappeared; it is simply hibernating.*

[38] *The Communists/Generals in control of the KGB and these superweapons are perfectly capable of turning the unfortunate dissolution into an excursion scenario of their long-planned major concessions offensive prior to ultimately striking the West with a clenched fist and destroying it. The communist aim has not changed one iota since 1917, although the communists have temporarily lost or relinquished control over the Russian civilian populace. For a description of this "29th move of the chess game," see T.E. Bearden, "Glasnost: 29th Move of a 30-Move Chess Game," Raum & Zeit, 1990.*

[39] *W. Misner, K.S. Thorne and J.A. Wheeler. (1973) Gravitation, W.H. Freeman and Co., San Francisco, 1973, p. 408. On p. 5 the principle is stated as "Space acts on matter, telling it how to move. In turn, matter reacts back on space, telling it how to curve." Thus space is already a vacuum engine that acts on matter, and mass-energy acts on space to curve it.*

Table 2. Einstein on Reviewing Foundations

"...the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the eternally problematic character of his concepts, He uses this conceptual material, or, speaking more exactly, these conceptual tools of thought, as something obviously, immutably given; something having an objective value of truth which is hardly even, and in any case not seriously, to be doubted. ...in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them."

Albert Einstein, "Foreword," in Max Jammer, Concepts of Space: The History of the Theories of Space in Physics, Harvard University Press, Cambridge, Massachusetts, 1969, p. xi-xii.

Table 3. Wheeler's Principle and a Corollary

Wheeler

"Geometry tells mass how to move, and mass tells geometry how to curve."

By "geometry" is meant "spacetime." Translating: "Mass tells spacetime how to curve, and curved spacetime tells mass how to move."

Corollary

"Trapped EM energy tells spacetime how to curve. The structuring of that trapped EM energy tells the resulting curved spacetime how to nest its curvatures. This forms a vacuum engine. Its nested curvatures of local spacetime tell mass and energy how to structure and move. By forming vacuum engines deterministically, one may use them to affect, alter, and change local mass, energy, and mind as desired."

stitute synonyms to yield "Mass tells spacetime how to curve, and curved spacetime tells mass how to move."

We further modify and extend this latter statement, replacing mass by its trapped EM energy (this is consistent with general relativity) and adding nesting of such trapped energies. We also allow for altering the timestream, the mind, and the mindstream. With these modifications, a corollary to Wheeler's principle results as follows: *"Trapped EM energy tells spacetime how to curve. The structuring of that trapped EM energy tells the resulting curved spacetime how to nest its curvatures. This forms a* ***vacuum engine****. Its nested curvatures of local spacetime tell mass and energy how to structure and move. By forming vacuum engines deterministically, one may use them to affect, alter, and change local mass, energy, and mind in any manner desired" (see table 3).*

To gain a "feel" for spacetime curvature, one may visualize it as analogous to the variation of local pressure in a gas or fluid.[40] Using the earth's atmosphere as a model, we may precisely create pressure points and areas (lows and highs) throughout, and gradually move them at will. This control of highs and lows will allow control and direction of the atmospheric flows. Theoretically, the entire atmospheric flow of the earth can be steered and controlled, by using such an approach. In short one can directly "steer" the weather worldwide, or over a given continent. Present Russian development allows this weather control process to be done sufficiently to control and steer the great jet streams, with concomitant direct influencing of the weather.[41] *We have not had any truly "normal" weather over the U.S. since 1976.*

TYPE 2 ENGINEERING IS JUST BEYOND THE PRESENT VANGUARD OF SCIENCE

As can be appreciated, Type 2 engineering is beyond vanguard science. The forefront of orthodox science is still where Wheeler's original statement is, and does not apply the SWZ methodology nor nesting of spacetime curvature. Science still does not even try to create vacuum engines and perform vacuum engineering *(see table 4 on page 76)*. Conventional scientists are still very firmly rooted in Type 1 engineering.

In ordinary GR, nowhere does there appear a precise definition of the term "gravitational field."[42] The G-field is just a *conglomerate of loose things*, and – by Sakharov's postulate – not a fundamental field of nature at all.[43] It already follows that, since "gravitation" is "geometry of spacetime," then "curvature" of spacetime is achieved by altering and changing the "conglomerates that comprise G-field" from their ambient conditions. The ability to structure and nest such curvatures also follows in straightforward fashion.[44]

PUMPED PHASE CONJUGATE MIRRORS AND THE PRIORE MECHANISM

The astounding thing is that Antoine Priore, using pure intuition, was able to arrive at an exact process for forming a special kind of beneficial vacuum engine![45]

We know today – but scientists did not know it when most of Priore's work was being done! – that a highly nonlinear material acts as a ***phase conjugate mir-***

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[40] It is actually the variation of the local energy density of the vacuum from its normal value.

[41] See T.E. Bearden, Soviet Weather Engineering Over North America, 1-hr. videotape, 1985. Available through the Tesla Book Co. In the last few years, the Russians have substantially increased their weather engineering capability and activity. Most of the transmissions from this system are now fairly good electrogravitational waves (coupled wave/antiwave pairs), with EM imperfections many dB below signal level. Hundreds of them are utilized when the system is actively employed over the U.S. By applying Whittaker 1904, these signals – invisible to the normal receiver – can be received and displayed.

[42] Misner, Thorne and Wheeler, Gravitation, 1973, p. 399.

[43] A.D. Sakharov, "Vacuum Quantum Fluctuations in Curved Space and the Theory of Gravitation," Soviet Physics Doklady, Vol. 12, 1968, p. 1040-1041 [English translation.] Sakharov's article (in Russian) is in Doklady. Akad. Nauk SSSR, Vol. 177, 1967, p. 70-71.

[44] General relativists already accept the vacuum as containing a 4-momentum-flux river. See Misner, Thorne, and Wheeler, Gravitation, 1973, p. 130-131. They treat the stress energy tensor as a machine (ibid., p. 131). The only difficulty is that they have not realized that, by applying the SWZ approach, much more complicated "vacuum machines" than they have considered can be built and utilized electromagnetically.

[45] See Christopher Bird, "The Case of Antoine Priore and His Therapeutic Machine: A Scandal in the Politics of Science," Explore!, 5(5-6), 1994, p. 97-110 for an excellent summary of the Priore Affair. The Priore group cured terminal tumors, sleeping sickness, and arteriosclerosis in lab animals and restored suppressed immune systems. Eminent, even world-renowned French scientists worked with him. The work was funded by the French government and published in leading French scientific journals. It was suppressed when the French government changed to a leftist government in the mid 70s.

ror[46,47] *(see figures 9 & 10).* In other words, when one puts in a sine wave, e.g., in addition to producing harmonics the nonlinear material will also produce a strange, backward-traveling replica of the input wave. This "backward wave" has been well-known since the early 1970s. It is truly a *time-reversed* wave (Barus wrote the solution much earlier).[48] It will backtrack back through space, over the *exact* path taken by the input wave.[49,50] If the input wave is continuous, this "phase conjugate replica" (PCR) time-reversed wave will precisely appear everywhere in space that the input wave occupies.

The key here is "everywhere in space." It does not matter how tortuous and twisted the route taken by the input wave; the PCR will backtrack it and appear spatially superposed with it. This has been *experimentally* proven many times in nonlinear optics.[51] One concludes that the vacuum has a memory,[52] and the PCR wave can retrace the memory of the path previously taken by its stimulus.

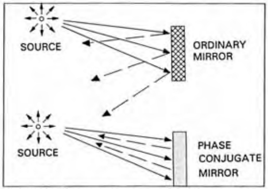

Figure 9. Phase conjugate refection vs. mirror reflection.

Figure 10. Pumped phase conjugate mirror.

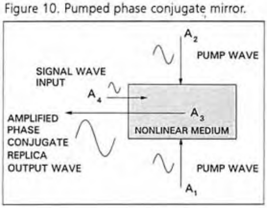

Another nice thing has been discovered and is used in the relatively new nonlinear optics. If one "pumps" the phase conjugate mirror with opposing waves (such as, e.g., bidirectional EM wavepairs), then up to all the energy in the pump waves is absorbed and re-emitted in the "crawfishing" PCR wave.[53] In other words, the stimulated PCM can be made into an amplifier of the time-reversed wave output, just by "pumping" it with the proper bidirectional wavepairs.[54,55]

Anomalous "Bio-Jamming" and Deep Diffusion by EM Smog

Pumping by EM waves or by simultaneously varying EM forces due to opposing streams of photons will produce a much higher probability of 4-wave mixing and multiphoton interactions. Simply put, this probability is a function of the sheer photon/signal density, along the lines pointed out – but not clarified – by

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[46] *Elsewhere we have pointed out that, for the primary EM interactions with a living system, we must employ an electromagnetics of higher topology than the conventional EM (either vector or tensor). Barrett has shown that a higher topology EM will involve and exhibit nonlinear optical functioning without necessarily employing optical materials. See T.W. Barrett, "Tesla's Nonlinear Oscillator-Shuttle-Circuit (OSC) Theory," Annales de la Fondation Louis de Broglie, 16(1), 1991, p. 23-41. Thus if we wish to utilize higher topology EM functioning in and on the body/mind, or just to comprehend such functioning, the nonlinear optical processes will form part of that functioning. We must be familiar with phase conjugate optics functions, regardless of the frequency range we operate within, and we must examine the situation accordingly.*

[47] *In the conventional struggle to elucidate EM effects on biological systems, the failure to realize this higher topology principle has led to experiments that are often difficult or impossible to replicate, primary interactive mechanisms remaining a mystery, and the inability to definitively answer even the simplest question such as "Does power line radiation enhance the emergence of cancer and leukemia, and if so, how and under what circumstances?" Forty years of research by able and determined EM bioeffects scientists have thus failed us, because the model they so stringently apply is grossly in error. What they have thoroughly proved is that their fundamental model is incorrect and inadequate for the intended purpose for which it is being utilized. The solution is not to just continue more experiments in the same vein, but to revise the model itself. We have previously pointed out (Bearden, Cancer and the Unresolved..., 1993, ibid., p. 40) the present EM bioeffects model, the modification areas required, and how to ascertain when the adjusted model is correct.*

[48] *Carl Barus, "A Curious Inversion in the Wave Mechanism of the Electromagnetic Theory of Light," American Journal of Science, Vol. 5, Fourth Series, 1898, p. 343-348 gives the first known solution of Maxwell's equations for a time-reversed or "backwards-traveling" EM wave.*

[49] *According to the well-known "Distortion Correction Theorem" of nonlinear optics. For a precise statement of the theorem, see Amnon Yariv, Optical Electronics, 3rd Edn., Holt, Rinehart and Winston, New York, p. 500-501. See particularly Chapter 16: "Phase Conjugate Optics – Theory and Applications."*

[50] *For the space-borne laser, e.g., the U.S. uses iterative phase conjugation – known as self-targeting – of a booster-reflected laser signal to keep a powerful laser beam locked upon the same spot on a distant missile booster, rising during its launch phase, long enough to burn through the casing and destroy the booster, even 10,000 miles away. The process is known as phase conjugate shooting.*

[51] *A striking example is given by David M. Pepper (1986) "Applications of Optical Phase Conjugation," Scientific American, 254(1), Jan. 1986, p. 75. Possibly the best extant introduction to the subject of nonlinear optical phase conjugation is David M. Pepper, "Nonlinear Optical Phase Conjugation," Optical Engineering, 21(2) March/April 1982, p. 156-183.*

[52] *Without extended discussion we call attention to the importance of this finding with respect to homeopathic medicine and therapy. In fluids, obviously one proceeds from vacuum flux organization and memory upward through matter's organization (and hidden memory), through the individual particles of the nucleus, to the nucleus, to the atom, to the molecule, etc. Between the atom and the molecule levels we encounter hydrogen bonding actions in fluids, which is of great importance to the biochemistry, especially the protein chemistry. It is possible to show that the mind operations and the cellular control operations also SWZ structure the H-bonding activities of the body's aqueous fluid; it can also be shown that any chemical, drug, additive, and EM smog also structures and affects the H-bonding. However, further discussion of these two elements is beyond our scope for this presentation.*

[53] *Note that "pumping" is simply a expansion of the notion of stressing the material. Emission of the amplified PCR wave is a kind of piezoelectric release of the stress energy. The point is that physical stress of a material can be freely tapped and energy continually extracted, if that stress is varying. The McLain/Wooten device uses that principle.*

[54] *To create a normal PCR wave response to an overt EM signal wave input, nonlinear optics uses overt EM pump waves. For the hidden EM signal wave input – i.e., for the hyperspatial vacuum engine as input – one must use "hyperspatial" wave pumping. The "cell as a phase conjugate mirror" must be pumped by hidden (hyperspatial) EM waves inside a scalar EM potential. In the normal case, an amplified, normal EM PCR wave is produced in response to a normal signal wave input and normal pump waves. In the vacuum engine case, an amplified, hyperspatial EM PCR wave complex is produced in response to a hyperspatial signal wave input and hyperspatial pump waves.*

[55] *Note that the amplified PCR wave represents a reorganization and deterministic redirection of stress energy. Hence it is a time-reversed operation, and also a negentropic operation. Since the PPCM operates as an open system not in thermodynamic equilibrium, with input of excess energy in the form of the pumping, negentropic operation is permitted by nonlinear thermodynamics (of a system far from thermodynamic equilibrium) For a lay summary of such thermodynamics, see Gregoire Nicolis, "Physics of far-from-equilibrium systems and self-organization," in Paul Davies, Ed., The New Physics, Cambridge University Press, Cambridge, 1989, p. 316-47. For a more technical presentation, see G. Nicolis and I. Prigogine, (1987), Exploring Complexity, Piper, Munich, 1987. Prigogine received the Nobel Prize for his pioneering work in this field.*

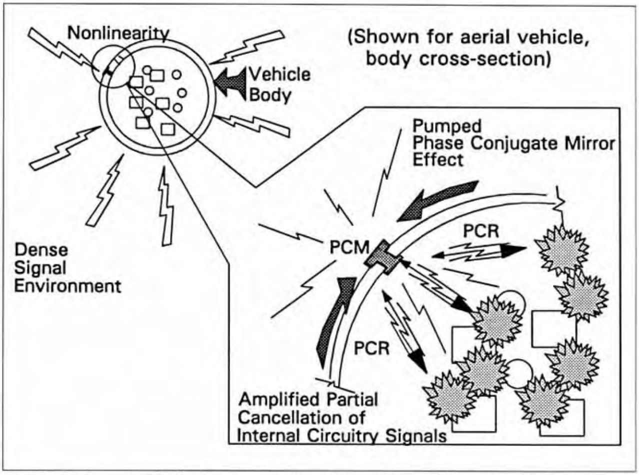
Nonlinearity
(Shown for aerial vehicle, body cross-section)
Vehicle Body
Pumped Phase Conjugate Mirror Effect
PCR
PCM
Dense Signal Environment
PCR
Amplified Partial Cancellation of Internal Circuitry Signals

Figure 11. Single versus multiphoton penetration effects. Phase conjugation effects become of significance, generating PCR signals which couple to and backtrack the cells' and tissues' own signals, this penetrating throughout the body with weak partial cancellation jamming.

Devyatkov et al.[56,57] Thus dense electronic smog – even though it contains only extremely weak signals – increases the nonlinear optics type of interaction. This allows anomalously deep penetration and *diffusion* of special weak EM signals due to the "pumping" aspect of multiphoton interaction. The nonlinear cells and cell parts act as pumped phase conjugate mirrors (PPCMs) when subjected to multiphoton interactions.

Worse, the *signal wave* inputs to the PPCMs are the normal weak EM signals of the body itself. Hence the resulting PCRs from the PPCMs are superposing phase conjugates of the body's normal signals. This results in (1) a "diffusive" effect in the body of the PPCM formations, and (2) formation of very weak "EM cancellation" signals throughout the body, specifically targeted to the body's own control signals, including those to and of the immature immune cells in the bone marrow. In the bone marrow, "*partial-cancellation jamming*" *(see figure 11)* occurs in the normal control and development of the immune system cells as they are created. Slowly errors and degradation damage accumulate with time, including over the years. This cumulative immune system damage combines with other damage effects due to pesticide residues, pollutants, etc. The combined degradation results in long-term cumulative damage to the immune system and its cells. Increasing errors in the immune system's functioning eventually result in appearance of immune system disorders and increasing vulnerability to

Table 4. Mechanism for the Priore Therapy

- Produced Specific SWZ-Structured Scalar Potential
  - -17 EM frequencies mixed in a rotating plasma
  - - Phase conjugates added by the plasma
  - - Formed vacuum engine with hyperspace pump waves
  - - Modulated onto a rippling magnetic field which carried it to every cell and all its parts
  - - Jyperspatial pumping of cells/parts as PPCM's
- PPCM's created amplified anti-engines for disease there
- Anti-engine reversed cells/parts back to normal state
  - - Cells return to control by cellular control system
  - - Restored cellular control system to full functioning
- Scrubbed out the cumulated precancerous state
- Eliminated shadow disease state
- Restored the immune system to high functioning
- No excessive trauma to treated animal

In Part II of this wonderful article, by Mr. Bearden, a few of the topics you can look forward to are; The Gulf War Syndrome, How to Make a Gravitational Wave & Curve Spacetime, Potentials & Gravity and How Priore Made Vacuum Engines.

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[56] *The Russians refer to the hidden EM wave structure of the scalar potential – i.e., to the SWZ structuring and vacuum engine templates – as the information content of the field. Western scientists assume this phrase refers to ordinary spectral analysis and communications, ignoring those statements that the normal EM theory does not apply. Also, Devyatkov et al seem in no great hurry to express their true meaning more clearly. See N.D. Devyatkov (Ed.), Applications of Low-Intensity Millimeter-Wave Radiation in Biology and Medicine, IRE Akad. Nauk. SSR, Moscow, 1985. [in Russian]. See also N.D. Devyatkov, Yu. V. Gulyaev, et al, [Organizing Committee Chairmen], Digest of Papers - International Symposium on Millimeter Waves of Non-thermal Intensity in Medicine, co-sponsored by Research and Development Association "ISTOK" and Research Institute of U.S.S.R. Ministry of Electronic Industry ("ORION"), Moscow, Oct. 3-6, 1991. Collection of 300 papers. [In Russian].*

[57] *However, some leading Western scientists – such as Wheeler, Feynman, and Jaynes – strongly advocate replacing the present erroneous concept of the EM force field existing in spacetime with the notion that what exists there instead is an information storage device containing a summary of what we need to predict the behavior of a charge if there should be one at the point. E.g., see J.A. Wheeler and R.P. Feynman, "Classical electrodynamics in terms of direct interparticle action," Reviews of Modern Physics, Vol. 21, 1949, p. 425-433; E.T. Jaynes, "Probability in quantum theory," in Complexity, Entropy, and the Physics of Information, Ed. W.H. Zurek, Addison-Wesley, Redwood City, CA, 1990, p. 33-55.*

VACUUM ENGINES AND PRIORE'S METHODOLOGY: THE TRUE SCIENCE OF ENERGY-MEDICINE

Part II of II

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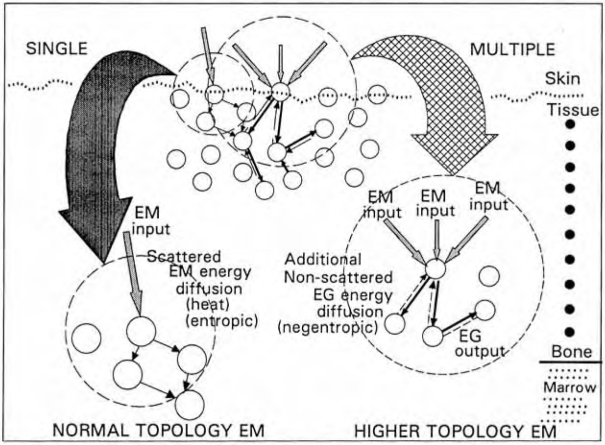

Fig. 12. Single versus multiphoton penetration effects. Phase conjugation effects become of significance, generating PCR signals which couple to and backtrack the cells' and tissues' own signals, thus penetrating throughout the body with weak partial cancellation jamming.

THE GULF WAR SYNDROME

For very dense EM smog environments such as in the recent Gulf War, both the anomalous EM diffusion effect and the partial cancellation jamming effect on humans are dramatically accelerated. Cellular and immune system damage that would require decades of exposure at very low EM smog levels will cumulate in only a few months. In turn, this accelerated malfunctioning of the cellular control system and the immune system enhances the effects of other biological suppressants already present in the body or encountered during the dense signal environment exposure period. These augmented suppressants include the degradation due to the individual's prior lifetime EM smog exposure, attack by unfamiliar disease organisms endemic to the areas, exposure to oil fire smokes and pollutants, exposure to increased UV from solar radiation, and exposure to chemical agents and possibly surreptitious biological warfare agents.[58]

Further, in the haste to protect the troops from possible chemical and biological attack, all soldiers were administered a nerve agent called pyridostigmine bromide; in addition, approximately 150,000 were inoculated with anthrax vaccine, and 8,000 also received experimental botulism toxin shots.[59] Normally for medically-administered agents, the relatively minor suppression effects on the immune systems and body are followed by quick recovery, due to a properly functioning immune system and cellular control system. However, all three of these Gulf War preventive medical treatments do create "small cases of sickness" in the normal body.[60] In other words, a low level of the disease strain *is created* in the patient. Further, even after the apparent "initial recovery," there will now be a much longer dormant "apparently healthy" period during which the *vacuum engine templates for the disease remain, until they have finally decayed away.* In a sustained dense signal environment, this "decay away" period may be dramatically extended or never occur; in fact, the disease may progress from the vacuum-engine state to the low level physical state, then into a fully developed syndrome.

So we introduce the concept of the *relative level of a disease.* First, the disease and/or its vacuum engine templates are in the body. A low level or absence of disease, as we normally think of it, is with respect to the high disease level – the full-up, developed state of the disease. A disease level is "low" because of the ability of the immune system to fight it, overcome it, and reduce it to a "pre-disease" state; and the ability of the cellular control system to eventually rid itself of the disease vacuum engine templates, retaining only antibodies against its re-invasion. When the disease is not physically present according to conventional medical standards, but nonetheless the vacuum templates are present and not yet cleared out, we shall refer to that state as the shadow state of the disease. The cellular control system largely combats this state.[61]

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[58] *Both Senator Riegle's and Senator Rockefeller's May 1994 hearings concluded that all 695,000 troops who served in the Gulf War were also exposed to chemical and biological toxins.*

[59] *Stephen Salgaller, "U.S. Role in Gulf War Illness." Letters, **Science News**, 146(7), Aug. 13, 1994, p. 99.*

[60] *Note that at least one of these three treatments was still quite experimental. Consequently there exists less confidence in stating that its normal side effects are minimal and tolerable.*

[61] *Apparently by being able to phase conjugate with weak amplification, so that it forms anti-engines that usually are stronger than the disease's vacuum engines, gradually reversing the shadow state to normal.*

If the immune system and cellular control system are impaired, a shadow state of the disease can gradually progress to a "low level" of disease, then to a higher level, and become serious or even life threatening. This is true when conventionally the disease is physically absent but its shadow state is still present and cannot be disposed of by the cellular control system, as clearly shown by Kaznacheyev's experiments.[62,63]

We point out, but do not pursue, that the cellular control system also deals with the shadow states of diseases. In the normal state of "free from disease," the cellular control system successfully and continually deals with incident diseases, overcoming them at the shadow state level. Its process for continual disposal of the shadow state residues is hypothesized to be a version of slightly amplified phase conjugation of the vacuum engine's shadow state level.

In the model we are advancing, the disease entry and development occur by successively (1) creating its shadow state and successfully maintaining it in spite of the cellular control system's phase conjugation efforts, (2) breaching the threshold of physical changes, so that at least physical indicators of the struggle by the now-involved immune system appear, (3) progressing until conventional medicine recognizes "low level disease or infection," (4) increasing until conventionally-recognized "developed disease or infection," (5) increasing until the disease is serious and even life-threatening, and (6) increasing until the patient can no longer sustain life and dies. *We note that the best preventative medicine would and should be practiced at the shadow infection level.* The Priore therapeutical approach is capable of doing that.[64]

In the "normal" – if such an adjective can be used! – sustained "weak EM smog" exposure, the shadow state may last for several years or even several decades, prior to sufficiently accumulated degradation of the cellular control system and the immune system to allow the physical emergence of the disease. For much denser EM smog, such as existed in the Gulf War, the shadow incubation process is highly shortened, as is the time to progress from one stage to another higher stage of the disease or disorder condition.

In other words, in a dense but weak EM smog environment, the recovery from "minor diseases" actually administered as part of the initial vaccination and preventive medicine will be substantially altered because of the accelerated damage to the immune system and cellular control system. The control/immune degradation may be fast enough that the disease starts increasing from the shadow state toward higher levels, instead of being reduced and eliminated by the control/immune systems.[65,66]

Consequently, the Gulf War participants were thrust into a unique new situation: The second (shadow state) phase of decay of the "minor diseases" created in the bodies receiving the three preventive medications was interfered with by the EM fog. Because of individual variation in past cumulative damage experience, the individual control/immune systems varied from soldier to soldier. The smog environment varied in density and intensity from place to place, and from time to time. Hence the degree of interference varied from soldier to soldier because of (1) variation of past control/immune degradation, (2) variation of the EM smog exposure, and (3) variation of exposure to other suppressants. A bell-shaped distribution curve of the extent of the *net interference to net control/immune functionality*[67] would result, when the soldiers are taken as a group. That is, some of the participants just had a somewhat longer 2nd phase recovery period; some an extended 2nd phase recovery period; some a sustained, gradual rise in the 2nd phase, toward physical disease but not yet developing the Gulf War Syndrome. Some had a sustained, quicker rise toward actual physical disease instead of a decay, and have had sufficient time to develop the physical disease.

When the additional individual expo-

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[62] *Kaznacheyev, several references, ibid. That is, suppose we have the shadow disease possess only a strength such that the normal cellular control system and immune system could overcome it. If the cellular control system is weakened, the disease progresses across the physical barrier. If the immune system is still strong, it can handle the encroaching disease, but will give physical indicators of its struggle (increased white corpuscles, etc.) If the immune system is also degraded, the disease will progress to low level physical disease, higher level, etc. On the other hand, if the cellular control system is normal but the shadow state of the disease is amplified, the phase conjugation defenses of the cellular control system will be breached and the disease will impel itself into low-level disease, then high level, and then kill the cells, in spite of a normal immune system combatting the breach of the cellular control system. This latter is what Kaznacheyev's experiments showed. It is also what the decades of Soviet weak microwave radiation of the U. S. Embassy in Moscow showed.*

[63] *The discerning reader will note that we are presenting the gist of a new theory of cellular disease.*

[64] *We also point out the electromagnetic biological warfare capability in this area, long since developed by the Russians and under total control of the KGB. The U.S. Embassy radiation, including the health changes and the death of three U.S. Ambassadors, was just to stimulate the U.S. intelligence and scientific communities at the highest levels. By the U.S. electromagnetic response at the Embassy itself, the Soviets could then know for certain whether or not the U.S. was aware of this EM biowar capability, and whether or not it had secretly developed defenses. Our actions assured them we had no such capabilities and no defenses – and were totally unaware of the true nature of the Embassy radiation.*

[65] *Note that the multiplicity of the assault on the control/immune systems augments the resistance and recovery difficulty. E.g., each B-cell lymphocyte can attack only a single antigen – alien property of the surface of an invader. There are about one billion B-cells in the human body, which between them are specific for about a million antigens. As can be seen, the immune system is continually having to develop B-cells with new specificities due to the continual meeting of new strains of antigens. Cumulated damage to this system affects both the body's resistance to diseases it has already acquired specific B-cells for, and its resistance to new strains for which it must make B-cells for new antigens. There is a sort of threshold, at any given time, beyond which the B-cell responses cannot keep pace, and start being overwhelmed. There is also an error tolerance level; when the errors due to deterioration surpass this level. the immune system will often begin attacking the body's own tissues in error. This results in disorders such as arthritis and cartilage and joint deterioration. With sufficient errors, previous immunity abilities also are degraded, so that more ordinary diseases become serious threats.*

[66] *The administering of three "lightly suppressive" treatments closely occurring with the soldier's entry into the Combat Zone thus posed a significantly greater problem than normal to his or her control/immune systems' operations, because the control/immune systems were suddenly degraded and hampered by the suppressive effects of the dense EM signals environment. In other words, the control/immune systems were moderately attacked by the three medical treatments (three enemy light cavalry divisions), and at the same time the entire control/immune system complex was subjected to substantial interference and suppression (the normal friendly) troop divisions were simultaneously placed under fierce and sustained attack throughout the zone. A general whose divisions are already committed in furious combat and under heavy bombardment, as are all his command posts and communications systems, has great difficulty freeing up, reconfiguring, and recommitting some of his committed troops to properly combat three other enemy forces that suddenly have appeared over the horizons from other directions!*

[67] *We may also define this as a disease progression ratio. This ratio should assume a distribution curve. For first-order simplicity, we are assuming a normal distribution.*

sures are factored in, there should have been essentially three broad groups: (1) relatively minor damage sustained, where any overt effects will only begin to appear many years hence if at all, (2) more damage sustained, where overt effects will begin to appear within the next few years, and (3) heavier damage sustained, where overt effects begin to appear either while still in the Gulf Region or within some months or so after returning.

Hence many of the Group 3 veterans of the Gulf war developed anomalous infections and immune system disorders shortly upon their return from such damage-accelerating exposure, resulting in the mysterious "Gulf War Syndrome." Conventional medical science will recognize – and has recognized – the overt phase 3 physical disease syndrome, but its cause and effective treatment remain and will remain medical mysteries. Conventional medical science will entirely fail to recognize Groups 1 and 2 cases, and will label them as due to aging, mental stress, or ordinary rise of diseases.

The syndrome has involved the "anomalous EM smog diffusion" process, as previously explained. It may – and in many cases it will – exhibit certain "signature" differences from normal diseases. The genetics of the victim are affected, and so are altered by induced transcription[68] to carry at least a portion of the "syndrome template." Semen, ova, saliva, and blood will particularly be so affected. A wife may complain that her husband's body fluids are now irritating to her skin, even producing "burning" sensations. Children conceived and born may be borne with the syndrome, or with one or more aspects of it.[69] The syndrome template can be transmitted by exchange of body fluids, so wives may also contract the syndrome and develop the disease from their husbands.[70]

CONVENTIONAL EM BIOEFFECTS KNOWLEDGE IS INSUFFICIENT

Present "EM bioeffects" scientific models contain absolutely no modeling of partially jamming the body's own special EM control system by turning its EM signals partially into G-signals, thereby partially nullifying them. It also contains no modeling of the anomalous EM diffusion process.[71] Thus the conventional medical approaches also do not contain any proper means of accounting the mechanisms for, and results of, long-term exposure to electronic smog and other combined agents and effects. Conventional scientists also have no knowledge of the major degradation mechanisms involved. The conventional medical models specifically are useless when confronted with something such as the Gulf War Syndrome or the decades of Russian microwave radiation of the U.S. Embassy personnel in Moscow. Capable scientists turn to their conventional models for answers, and the models fail them. Therefore present medical science is baffled when faced with such diseases and syndromes.[72] (*See figure 13 on next page*)

HOW TO MAKE A GRAVITATIONAL WAVE AND CURVE SPACETIME

We return now to the fundamentals of Type 2 engineering.

If one superposes an ordinary EM wave with its true phase conjugate replica wave, where the two waves are of equal strength, the *EM forcefield aspects* of the combined wavepair (standing wave) vanish, while the energy-density aspects remain. At every point the E-fields and the B-fields sum to vector zero *forcefield* resultants. The standing wave that results will not cause EM movement of charged particles.

However, the *energy densities* of the two locked (and now "hidden") EM waves remain and add. By standard GR, this "trapped EM density standing wave" must constitute a standing gravitational wave and a standing wave in the local curvature of spacetime!

It follows that, by assembling a harmonic set of such wavepairs, a la Stoney and Whittaker, one can form a region of spacetime such that the energy density is deterministically altered and controlled, and to engineering levels.

Engineering general relativity suddenly became a lot easier! Ironically, present physics only considers primarily the *very weak* ST curvature that can be obtained by the extremely weak gravitational "attraction of mass" G-force. For electrons, e.g., the G-force is only on the order of 10^{-42} times as strong as the electric force. Consequently orthodox GR simply "cannot pack enough trapped G-field energy into the local space" in the laboratory to get measurable effects. Only in the vicinity of a very large mass, such as the sun or a star or a black hole, does the weak G-force reach sufficient strength to yield directly observable, strong effects. Yet by using EM vacuum engines and the SWZ approach, one can obtain readily-measurable GR effects right on the laboratory bench.

> **The conventional medical models specifically are useless when confronted with something such as the Gulf War Syndrome or the decades of Russian microwave radiation of the U.S.**

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[68] *Note that the transcription component may continue to develop in the same "post disease" manner as does the shadow disease of the overall Gulf War Syndrome. The returnee continues to experience EM smog and other control/immune suppressants, though at a lesser level than experienced in the Gulf War environment.*

[69] *Such aspects are highly controversial. A few affected families are reporting such symptoms and aspects, but officially "there is no evidence" for them. However, with the initial appearance of the syndrome, officially veterans who complained of this illness were briefed by these same medical "authorities" that their physical symptoms were stress-related, and that the cause was all in their mind!*

[70] *In a fashion similar to Priore's animal experiments that demonstrated the transfer of curative templates by a single drop of blood. Kaznacheyev showed that disease templates could also be transferred.*

[71] *In fact, EM bioeffects research for decades has used, and continues to use, sheer energy deposition (scattering of EM energy by the tissues – heat by another name!) as a measure of the exposure level. They have not applied nonlinear phase conjugate self-targeting effects at all.*

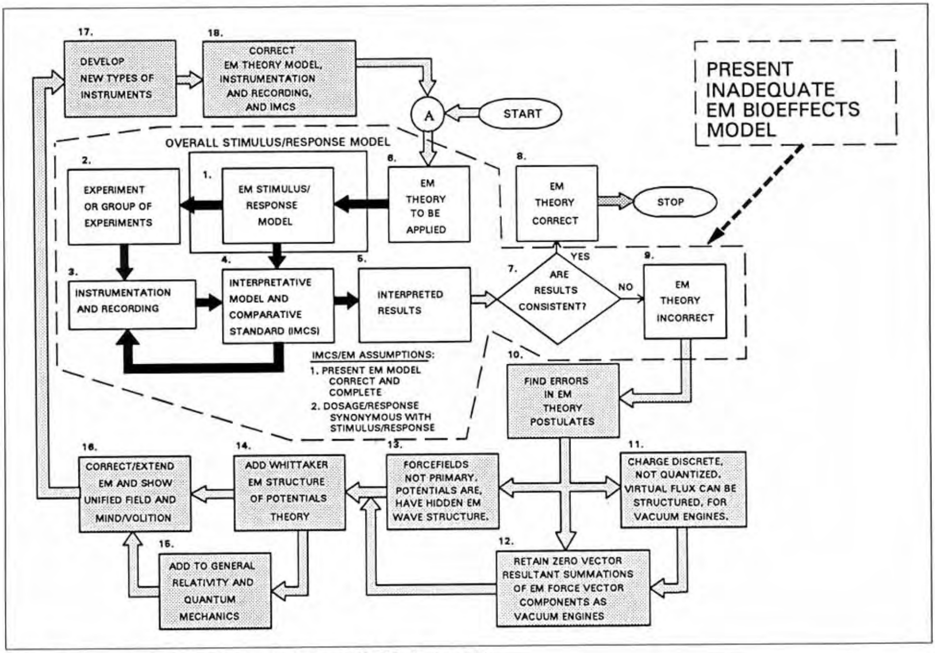
17.
DEVELOP NEW TYPES OF INSTRUMENTS
18.
CORRECT EM THEORY MODEL, INSTRUMENTATION AND RECORDING, AND IMCS
A
START
PRESENT INADEQUATE EM BIOEFFECTS MODEL
OVERALL STIMULUS/RESPONSE MODEL
2.
EXPERIMENT OR GROUP OF EXPERIMENTS
1.
EM STIMULUS/ RESPONSE MODEL
6.
EM THEORY TO BE APPLIED
8.
EM THEORY CORRECT
STOP
3.
INSTRUMENTATION AND RECORDING
4.
INTERPRETATIVE MODEL AND COMPARATIVE STANDARD (IMCS)
5.
INTERPRETED RESULTS
7.
ARE RESULTS CONSISTENT?
YES
NO
9.
EM THEORY INCORRECT
IMCS/EM ASSUMPTIONS:
1. PRESENT EM MODEL CORRECT AND COMPLETE
2. DOSAGE/RESPONSE SYNONYMOUS WITH STIMULUS/RESPONSE
10.
FIND ERRORS IN EM THEORY POSTULATES
16.
CORRECT/EXTEND EM AND SHOW UNIFIED FIELD AND MIND/VOLITION
14.
ADD WHITTAKER EM STRUCTURE OF POTENTIALS THEORY
13.
FORCEFIELDS NOT PRIMARY, POTENTIALS ARE, HAVE HIDDEN EM WAVE STRUCTURE.
11.
CHARGE DISCRETE, NOT QUANTIZED. VIRTUAL FLUX CAN BE STRUCTURED, FOR VACUUM ENGINES.
15.
ADD TO GENERAL RELATIVITY AND QUANTUM MECHANICS
12.
RETAIN ZERO VECTOR RESULTANT SUMMATIONS OF EM FORCE VECTOR COMPONENTS AS VACUUM ENGINES

Fig. 13. Necessary corrections for the present inadequate EM bioeffects model.

POTENTIALS AND GRAVITY

Obviously one can simply add harmonics of such EM "locked in" wavepairs, to produce a standing "constant value potential" pattern of a fixed *excess* energy density of vacuum or a fixed *decrease* in the energy density of vacuum. This harmonic series of bidirectional EM wave pairs – the *sum set* of wavepairs – is precisely what Stoney and Whittaker showed makes an ordinary EM scalar potential. In other words, they showed the actual energy-trapping mechanism, and dramatically altered the view of a scalar potential as being simply an "electrostatic" entity and a scalar field. Instead, it is a *hidden-variable energy flow process.*[73,74,75]

Its external "scalar field" aspect is just its "local energy density" aspect, not its fundamental nature.[76]

As is well-known in GR, all potentials are gravitational because they contain trapped energy. *Any* trapped energy is gravitational, a priori, according to GR. Ziolkowski independently rediscovered the SW decomposition in the 1980s and extended it to also add the product set. Since multiplication of waves is *modulation*, in my opinion Ziolkowski actually wrote the basis for hyperspatial (or subspatial, if one models physics in only 4-dimensions) communication at superluminal velocity, essentially instantaneously anywhere in the universe. (*See figure 14 on opposite page*)

"Paired assembly of an EM wave and its true PCR" was and is the way to turn EM energy directly into gravitational en-

[72] *Just as it is also essentially baffled by many conventional dread diseases such as cancer, leukemia, AIDS, arteriosclerosis, etc. – which indicates that the conventional "models" for those diseases are also seriously deficient.*

[73] *The present preoccupation of physicists with the scalar potential is simply to provide an algorithm for calculating the local energy density – in excess joules per collecting point-coulomb of charge – and erroneously call that the definition of the potential. The magnitude of the energy collection density of the potential at a point is not what the potential* is, *and such is not its definition. Defining how much water can be poured out of a standard bucket, when it is dipped into a flowing river and filled with water, does not define the river!*

[74] *From the particle view, the potential is an ordering in a virtual particle flux of the vacuum. From the wave view, the potential is comprised of an ordered, harmonic series of SWZ bidirectional EM waves, where each wave reaches to the ends of the universe before having a zero energy density. It follows that the energy in each hidden sine wave is infinite, just as it is for any overt theoretical EM sine wave. So any potential – even that of a flashlight battery – already involves an infinite amount of flowing hidden EM energy, being exchanged by the source and the entire universe, flowing in both directions along any radial from the source of the potential. The scalar potential is a flowing, continual exchange of energy between each and every point in the universe and the local source of the potential.*

[75] *Both the wave and particle forms of the potential exist simultaneously. The particle nature exists in Minkowski 4-space. The "hidden SWZ waves" exist in a hyper-4-space whose time dimension is the same as that of Minkowski 4-space. The scalar EM potential actually exists as a 7-dimensional entity. The internal hidden EM flow is not confined to the speed of light in space, because it does not flow "through" 3-space; instead, it flows "around" it.*

[76] *E.g., Whittaker, 1904, ibid. shows us that all of classical electromagnetics can be made by the interference of two scalar fields, which is just a special kind of hyperspatial multiwave interferometry.*

ergy.[77] This is the unification of EM and GR that eluded Einstein all the latter part of his life, and that has continued to elude scientists today. This is the way to "trap" EM energy locally, even though the EM wave energy is flowing at the speed of light or greater. This is the way to change EM energy into gravitational energy.[78] Further, it is engineerable and testable. Remember, physics requires that energy be conserved; however, it can certainly *change its form*. GR already says that it is the trapped energy that is gravitational, not mass per se, and regardless of what kind of energy is trapped. Ultimately Einstein's formula $E = mc^2$ is actually a statement of the trapped EM energy in a mass. However, heretofore no one had the slightest notion as to the actual trapping mechanism. The SWZ work actually shows the trapping mechanism itself and allows the engineering of *electrogravitation*.

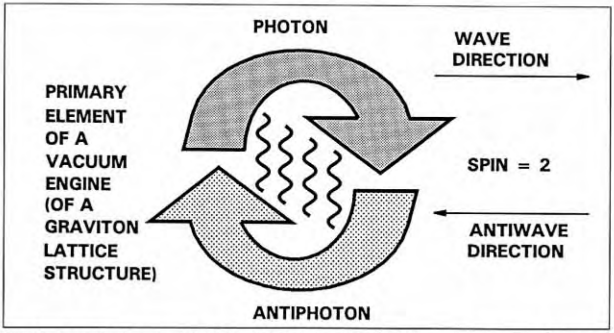
PHOTON
WAVE DIRECTION
PRIMARY ELEMENT OF A VACUUM ENGINE (OF A GRAVITON LATTICE STRUCTURE)
SPIN = 2
ANTIWAVE DIRECTION
ANTIPHOTON

Fig. 14. A graviton is a coupled photon/antiphoton pair. In the bidirectional wavepair of the SWZ internal structure of the scalar potential, photons in the wave continually couple and uncouple as the wave and antiwave pass through each other.

How Did the Revolutionary Stoney/Whittaker Work Go Unnoticed?

Apparently, neither Stoney nor Whittaker realized that their work was pure electrogravitation. *When the referenced papers by Stoney and Whittaker were published, special relativity, general relativity, and quantum mechanics had not even been born yet!* Indeed, there still was not a wide adoption of Heaviside's vector interpretation of Maxwell's fading quaternion theory. Even classical EM was still in its infancy and just getting off to a good start.

In the 1980s Ziolkowski realized that the internal biwaves of a potential could be engineered, but remained primarily focused upon his important work with electromagnetic missiles and focus waves (slugs of EM energy which stay together as they travel, and do not spread out.) Ziolkowski is one of the pioneers in that field.

How Priore Made Vacuum Engines

This "vacuum engine methodology" was and is what Priore's intuition led him to! For the electromagnetic treatment of laboratory animals, his EM therapy device first inputted some 17 or so frequencies into a rotating plasma.[79,80] We know today that such plasmas *phase conjugate* the wave inputs, but that was not known when Priore first did it.

Obviously Priore himself did not understand the actual mechanism, but his brilliant intuition led him to discover how to do it! For many years no one knew how aspirin worked, yet that did not prevent it from being used widely and effectively.

In other words, Priore used the plasma to *unwittingly* add PCRs to each of his waves and form 17 magic SWZ "wavepairs." The entire SWZ wavepair assembly thus made an *artificial potential*, having a "vacuum engine" pumping substructure of hidden bidirectional EM waves. Adjustment of selected frequencies away from their harmonic positions adds multiplications and beat frequency modulations, creating *specific* templates and *specific* vacuum engines. These SWZ waves are hyperspatial; hence they are in the domain of the deep mind's cellular control system. When an abnormal body cell is pumped by these hyperspatial waves, the cell's own hyperspatial vacuum-engine "signal input complex" triggers a specific dedifferentiation anti-engine for that specific abnormal state. By Wheeler's principle, if spacetime curvature is *present in* the material cell, its energy and template are *applied to* the cell and act upon it. With vigorous pumping, the anti-engine is also *amplified* and so the cellular response is more rapid. In other words, the amplified anti-engine fairly quickly overpowers the disease engine and reverses the abnormal cell and all its contents back to their previous *normal* states. (*See figure 15 on the following page*)

Priore's new signal complex came out of the plasma mixing (phase conjugating) tube with SWZ structures of wavepairs, where each pair was composed of two bidirectional (opposing) EM waves. Priore then modulated this output upon a very strong, rippling magnetic field as a carrier, and radiated the body of the patient with that resultant field and its transported hyperspatial SWZ anti-engine components.

Nuclear magnetic resonance guarantees that such a magnetic field with all its modulations will be delivered entirely through the body, penetrating the flesh and bones and even the atomic nuclei themselves. It will certainly penetrate the bone marrow where all the blood cells (which includes most of the immune system's cells) are born! It will penetrate everywhere else also. So all the cells of the immune system will be exposed to the AC magnetic carrier and its impressed hyperspatial biwaves and their modulations.

The body's cells and cell-parts are highly nonlinear, and so they are also *demodulators*. They strip off the SWZ modulations. This puts the amplified vacuum anti-engines directly into and onto the cells, including all the cells of the immune system, and including each and every part of each cell. Small wonder then that the Priore methodology could restore suppressed immune systems! Time-reversing the damaged immune cells and their damaged internal components back to a previous healthy state was one magnificent result. The radiation also delivers the modulations directly into the master potential (the body's quantum potential) that contains its mind, its long-term memories, and its master control system for all cells. Thus not only are the diseased cells and the immune cells affected, but also the *master cellular control system* for all body cells is directly affected.[81]

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[77] *I have previously pointed out that, in a coupled wave/antiwave pair, the photons in the wave and the antiphotons in the superposed phase conjugate replicate wave also pair into photon/antiphoton pairs, which have spin-2 helicity and hence are gravitons. This follows merely from a strong application of the distortion correction theorem. However, it is the fundamental union of EM and G into a single engineerable theory. See Bearden,* ***Gravitobiology,*** *1991, p. 1-9.*

[78] *By Whittaker 1904, we can always interfere two such potential fields and obtain an EM field, even at a distance. Thus we can also readily turn the gravitational (trapped EM) energy back to EM field (untrapped EM) energy.*

[79] *David M. Rorvik, "Do the French Have a Cure for Cancer?"* ***Esquire,*** *July 1975, p. 110-11, 142-149 gives an overview of the Priore Affair and some details of the electromagnetics of the machine.*

[80] *Note the immediate connection to the Russian energetics model, which is directly fashioned after the nature and nonlinear EM functioning of plasmas. Priore was directly applying Soviet energetics, although neither he nor any other Western scientist could have known that.*

In a related work, Becker (*See figure 16 on the following page*) and his colleagues stimulated bone healing in difficult fractures by use of tiny DC currents. They have shown that picoamperes of steady DC current trickled across the fracture site induces bone healing. Becker showed that, surprisingly, red blood cells are dedifferentiated – shucking their hemoglobin and growing a nucleus in the process. These cells redifferentiate into the kind of cells that make cartilage. Then *those* cells redifferentiate anew, into the kind of cells that make bone, and heal the fracture with new bone deposit. Becker also proposed a complete, operational DC control system, staying within the limitations of conventional EM theory.[82,83,84]

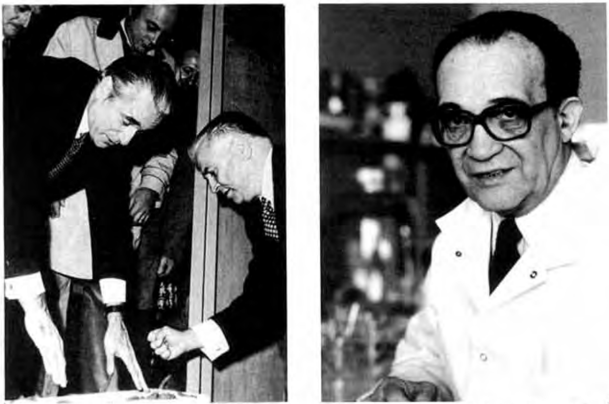

15-A. Priore demonstrates a point to Mr. Chaban-Delmas, Mayor of Bordeaux and a friend and mentor.

15-B. Dr. Raymond Pautrizel, noted immunologist, worked directly with Priore. Dr. Pautrizel is Professor Emeritus, University of Bordeaux, and holder of the first chair in immunology in France.

Dr. Robert Courrier (not shown), head of the Biology Section of the French Academy of Science as well as its Secretaire Perpetuel at the time, was also a noted colleague. He personally presented the astounding results of the Priore Team's experiments to the Academy.

Fig. 15. Priore was supported by notable French political leaders and eminent French scientists were his close scientific colleagues.

A proposed explanation of the fundamental vacuum-engine mechanism for the Priore and Becker effects has previously been given in some detail by Bearden.[85] (*See figure 17 on next page*)

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[81] *We refer to an expanded version of Popp's cellular control system. E.g., see Fritz Albert Popp, "Photon Storage in Biological Systems," in Fritz Albert Popp et al, eds.,* ***Electromagnetic Bio-Information: Proceedings of the Symposium, Marburg, Federal Republic of Germany, Sep. 5, 1977;*** *Urban & Schwarzenberg, Baltimore, 1979, p. 123-149. Popp reports the theoretical and experimental discovery that mitogenetic radiation from cells can be seen as a sort of "waste" from a virtual electromagnetic field with a high coherence. This field has a tendency to become stationary over the whole organism. In addition, it includes the storage of "virtual" coherent photons.* ***Comment:*** *Our substitution of the SWZ hidden wave approach to replace Popp's QM particle approach greatly facilitates understanding and specifying the control system, and materially eases direct engineering of it.*

[82] *E.g., see R.O. Becker, "The direct current field: A primitive control and communication system related to growth processes."* ***Proceedings of the. XVI International. Congress of Zoology****, Washington, D.C., Vol. 3, 1963, p. 179; "The control system governing bone growth in response to mechanical stress."* ***J. Ark. Med. Soc.****, Vol. 62, 1966, p. 404; R.O. Becker and D.G. Murray, "A method for producing cellular dedifferentiation by means of very small electrical currents."* ***Trans. N.Y. Acad. Sci.****, Vol. 29, 1967, p. 606. See particularly Robert O. Becker, "The significance of bioelectric potentials."* ***Bioelectrochemistry and Bioenergetics,*** *Vol. 1, 1974, p. 187-199. Becker proposes that a complete, operational system exists in living organisms, and controls such basic functions as growth, healing, and biological cycles. The system is described in anatomical detail. It functions as a data transmission system in an analog fashion using varying levels of direct current as its signal. The system interlocks physically with the nervous system and is postulated to be its precursor. There are two electrochemical limbs of great significance in the operation of the system. One is between the DC system and the nervous system; the other is between the DC system and all body cells. The concept explains all of the diverse effects reported for the biological effects of applied electrical currents including: electrical anesthesia, electrical growth control, and electroacupuncture. It also furnishes a testable hypothesis for predicting other effects of clinical significance.*

[83] *We comment that the SWZ approach allows control and conditioning – both externally and internally – of both limbs of Becker's proposed DC control system.*

[84] *See also C.W. Hsue, "A DC Voltage is Equivalent to Two Traveling Waves on a Lossless, Nonuniform Transmission Line,"* ***IEEE Microwave and Guided Wave Letters,*** *Vol. 3, 1993, p. 82-84. Hsue shows that the steady DC voltage on a transmission line powering a resistive load, mathematically decomposes into bidirectional EM traveling waves. The bone-healing setup used by Becker et al is precisely of this configuration. The fracture corresponds to the resistive load and the two electrodes on each side correspond to the transmission lines. Hence Becker's team actually employed a form of the Stoney/Whittaker/Ziolkowski harmonic biwave decomposition of the scalar potential, to accomplish hyperspatial pumping and formation of anti-engines of vacuum energy. So this is another application of the same basic "cell-reversing" methodology, as also utilized more extensively by Priore. Becker's brilliant work of course was and is independent and unique, and he was nominated for a Nobel Prize because of his absolutely fundamental work in showing electromagnetic differentiation and dedifferentiation of cells. That he has not been awarded the prize is regrettable and, in my opinion, an injustice.*

[85] *T.E. Bearden, "Mechanism for Long-Term Cumulative Biological Effects of EM Radiation," presented to the 70th Annual Meeting of the Alabama Academy of Science, University of Alabama at Huntsville, March 25, 1993. A digest of this presentation is published by the Tesla Book Company, P.O. Box 121873, Chula Vista, CA 91912 as T.E. Bearden,* ***Cancer and the Unresolved Health Issues in the Biological Effects of EM Fields and Radiation,*** *1993 and includes both text and hard copies of viewgraphs.*

HOW THE PRIORE VACUUM ENGINE REVERSED CELLS TO A PREVIOUS STATE

Taking a GR view, any mass already has its own vacuum engine for its exact form and internal structure and dynamics, in the finest detail. That particularly follows Wheeler's principle; if the mass is there, the appropriate spacetime curvature and dynamic energy structuring is there. If the mass has internal structuring, so does the spacetime curvature: it becomes *nested* curvatures with a precisely correlated template. In short, any mass – living or not – is imbedded in a precise vacuum engine. Any and every change adds a specific delta to this vacuum engine component. Just as a tree has rings for its past years and an onion has layers, the vacuum engine of an object has an exact template for that object's entire past, *as do the mind and its components also.*[86]

So when a normal living cellular mass changes to a diseased state, *a priori* it has added an additional delta vacuum engine (representing the change that resulted in the disease) to its original vacuum engine (which represents the original healthy state of the cell). The cell and all its parts are highly nonlinear and act as phase conjugate mirrors, *including to the higher topology (hyperspatiality) of the vacuum engine. Any living system we isolate and study is at least 7-dimensional.*

Putting all this together, we now can understand the marvelous nature of what Priore did. By exposing the body, treated part, cells, and cell parts to Priore's modulated rippling magnetic field, the "hidden pump waves" carried by that magnetic field are applied to each and every cell and to all its parts, in the exposed area. *In the exposed area, each and every cell and its parts become powerfully pumped phase conjugate mirrors for its hyperspatial vacuum engine complex.*

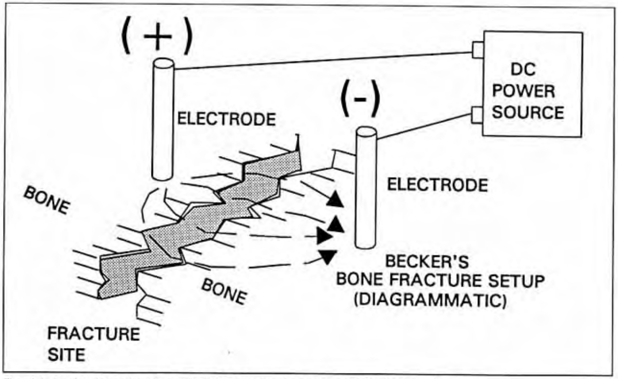

(+)
ELECTRODE
(-)
DC
POWER
SOURCE
ELECTRODE
BONE
BONE
BECKER'S
BONE FRACTURE SETUP
(DIAGRAMMATIC)
FRACTURE
SITE

Fig. 16. Becker's application of tiny DC currents to heal difficult bone fractures.

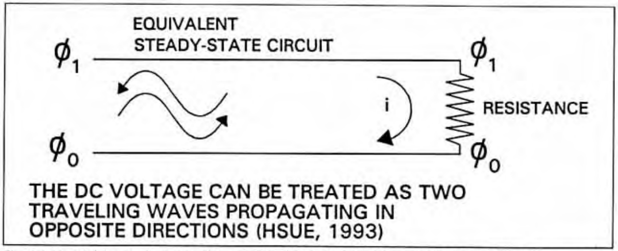

EQUIVALENT
STEADY-STATE CIRCUIT
ϕ_1
ϕ_1
i
RESISTANCE
ϕ_0
ϕ_0
THE DC VOLTAGE CAN BE TREATED AS TWO
TRAVELING WAVES PROPAGATING IN
OPPOSITE DIRECTIONS (HSUE, 1993)

Fig. 17. Hsue's biwave decomposition of DC voltage (as in Becker's application of tiny DC currents to heal difficult bone fractures).

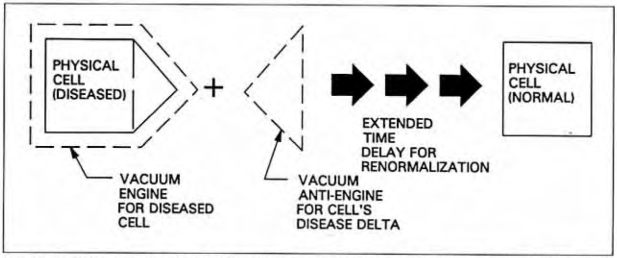

PHYSICAL
CELL
(DISEASED)
+
PHYSICAL
CELL
(NORMAL)
EXTENDED
TIME
DELAY FOR
RENORMALIZATION
VACUUM
ENGINE
FOR DISEASED
CELL
VACUUM
ANTI-ENGINE
FOR CELL'S
DISEASE DELTA

Fig. 18. Applying an anti-engine for the "deviation" of the diseased cell reverses the cell to normal after a time delay.

Extending the language of nonlinear optics, the particular *net* vacuum engine of the diseased cell or part constitutes a "standing input" *hyperspatial signal wave complex*, already input to the hyperspatially pumped phase conjugate mirror cell or cell part. When pumped by "hidden" pump waves, each and every one of those PC mirrors will now originate an *amplified phase conjugate replica of the signal wave complex. Each one will produce a highly amplified, time reversed replica of its specific standing vacuum engine. This includes amplified time reversed replicas of both the "healthy" component of each standing vacuum engine and the "disease delta" component. (See figures 18 above and 19 on following page)*

In other words, every pumped diseased cell and cell part – including the genes and chromosomes – will produce a very powerful, highly amplified, "reverse vacuum engine" (an *anti-engine*) which is fantastically specific and precisely time-reverses the cell and its parts, including the genes and chromosomes as well, back to their *previous normal states.*

---

[86] *If one alters the internal structure (rings) of a tree, one changes the tree. If one alters the internal structures and dynamic functioning of matter, one changes the matter accordingly. If one alters the internal structures and dynamics of the mind, one changes the mind, its contents, and its function ing accordingly, as well as the subsequent behavior exhibited by the altered individual.*

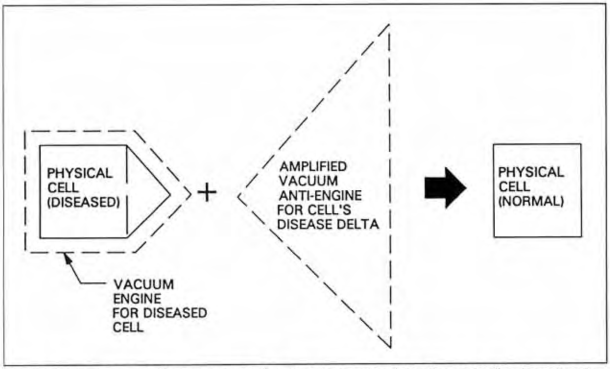
PHYSICAL CELL (DISEASED)
+
AMPLIFIED VACUUM ANTI-ENGINE FOR CELL'S DISEASE DELTA
PHYSICAL CELL (NORMAL)
VACUUM ENGINE FOR DISEASED CELL

Fig. 19. Applying an amplified anti-engine for the "deviation" of the diseased cell reduces the time delay required to reverse it back to normal.

REJUVENATION

Any *normal* cell that is exposed to hyperspatial (Priore-type) pumping just reverts to a *slightly younger* normal state. Note that this allows *rejuvenation*.[87] Priore's earliest experiments that so riveted his attention and set him on the path of discovery, were in fact the abnormal prolongation of the life of fruits! For each class of disease, Priore just had to fiddle with the frequencies until he had the right set of pump waves for the specific "disease delta vacuum engine." This he did by trial and error. So when it is "Priore-pumped," a cancer cell reverses back to a normal cell, as does a precancerous cell as well.

The revolutionary Priore therapy is startling but simple. The diseased cell is analogous to an automobile that has been driven slowly off the road into the rough. Priore's methodology shifts the car into reverse gear, guns the engine, and quickly and precisely backs the car back onto the roadway. It is one of those profoundly beautiful embodiments analogous to Faraday's unipolar generator; it strikes directly to the heart of the fundamental principle. A cell develops damage and disease over a period of time. Simply time-reverse it quickly back to its original healthy state.

AIDS COULD BE QUICKLY CURED THE SAME WAY

Given Priore-pumping, an AIDS-infected cell would revert back to a normal cell, including all its genetics, and including for all of the hundreds of "strains" of AIDS that exist in an advanced AIDS patient. With this ap- proach one could completely reverse and eliminate AIDS whenever a positive reading occurs in the HIV virus test, and prior to the appearance of the actual physical sym- ptoms! If the person just has the antibodies and not the disease, the treatment will still do him absolutely no harm. (It will actually make his cells a "little bit younger and more vigorous," and help his immune system.) If he has both the AIDS antibodies and the infection as well, he will be completely cured and his immune system will be restored to complete vitality.

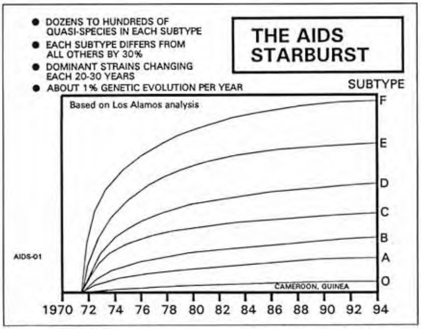

Fig. 20. AIDS is continually changing since the HIV virus is a retrovirus and unstab.

MOST DISEASES COULD BE CURED BY THE NEW THERAPEUTIC MODALITY

Any infectious disease known or unknown can be cured by the same means. The marvelous thing is that one need not know the specific technical pattern for the delta vacuum engine for a specific disease! One just has to *correctly adjust the hidden SWZ pumping frequencies.*

ARTERIOSCLEROSIS

In arteriosclerosis, it has been found that the greatest part of the damage is due to the presence of some rather ordinary viruses, and abnormal cell growth by the body's own cells as a result of triggering by previous viral infection. Cellular reversal (dedifferentiation) gets it all; the viruses and the abnormal cells. Everything reverts to normal, and the body's restored processes quickly "police up" the extra cell growth, using its natural control processes which are now restored to full functioning. *This is how the Priore team was able to so dramatically cure the "clogged arteries" of laboratory animals.*

The Priore approach (pumping of the

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[87] *One should not be surprised that a time-reversal operation upon an entire body leads to reversal of physical aging in that body! But we point out that the time reversal we speak of is not at all the "time travel to the past" so beloved by generations of science fiction writers. For that, one would have to reverse each and every part of the universe simultaneously, except the observer, back to an exact former state, in perfect universal coordination. One would have to pump the entire universe, except for the observer! The observer would then remain as is with no change, while his entire world "went back in time" to a past state. The pumping of the universe would have to stop instantaneously (decay of the false vacuum?), and the universal anti-engine would have to stop operation and decay instantaneously (another big bang, perhaps?). We are not referring to anything such as that! We are referring to the reversal of a single little part of the universe, back to its previous state, which is practical and can be done. Universal time reversal – and hence time travel for the observer – is not practical, at least within our present knowledge and within the time reversal model we are applying. We should point out, however, that time reversal is a legitimate part of physics, and is not science fiction. E.g., for an overview, see Robert G. Sachs,* ***The Physics of Time Reversal,*** *University of Chicago Press, Chicago, Illinois, 1987.*

diseased cell's self-contained vacuum engine to create a very powerful vacuum anti-engine and reverse diseased cells back to normal) is the most powerful therapy for cellular disease ever conceived of. If the cells have ever been normal, they can be reverted to normal.[88] One can also probably regrow lost limbs, etc. but that takes too long to explain here! The methodology should also be able to completely reverse disorders such as Alzheimer's disease, and very probably muscular dystrophy as well. It should even be possible to reverse the physical effects of aging!

MUCH MORE THAN THIS INTRODUCTION HAS BEEN THEORIZED

This is the gist of the mechanism for the Priore therapy's startling success, although it has required some 10 years of very hard work to decipher the mechanics of the process. Along the way, I have also personally discovered and added a great deal more (for example, the quantum potential aspect of a living system and any enclave of living systems, the mechanism to generate a quantum potential, the precise mechanism for Sheldrake's morphogenetic field, the mechanism for directed evolution, the unusual electromagnetic nature of mind and thought, the mechanism for engineering mind and thought, engineering the entire species, and engineering the entire living biosphere), but this much should suffice for now for introductory purposes.

A technical book has been laboriously begun, and hopefully will be finished and published in about a year. Two 2-hour videos are also tentatively being planned. A four-hour technical briefing has already been prepared and presented.

REACTIONS TO THIS VACUUM ENGINE EXPLANATION

In response to numerous queries as to the reactions to this explanation of the Priore mechanism: Reactions tend to be rather good when (1) the technical person is open-minded, in other words, a friendly skeptic, (2) the technical person endures a grueling 2-hour or 4-hour detailed slide presentation I prepared, and (3) sufficient follow-up dialogue is accomplished to answer residual questions. Otherwise, the "mental jump" required of the participant is just too great.[89] Also, perhaps 60-70% of the conventional scientists are absolutely against anything that smacks of "revolutionary." From about half of this contingent the approach may generate disbelief and even overt emotional hostility, just as Priore himself and his associates encountered.[90]

However, some of the sharpest young graduate students readily make the transition, if they interact with me for a long enough period and enough times to understand the physics of the approach. *It did not take me 10 years to decipher an easy thing!* The causative mechanism for Priore's accomplishment is terribly involved and very, very deep. It is slightly beyond the present scientific vanguard, although the bits and pieces necessary to decipher the Priore mechanism are now in the literature. But putting them together has been a bone-crushing, terrible task. Priore was truly a century ahead of the science of his time!

Nonetheless, there is much hope, because the material is slowly taking root in a few sharp young graduate minds. For example, one of the major Eastern Universities would be astonished to know that their sharpest, brightest young PhD candidate – one they already assume will win a Nobel Prize in the future – is a full convert, and thoroughly understands cellular reversal by hidden-variable SWZ pumping, a la Priore. But at my strong urging, he is keeping it a secret until he graduates, and then he will *gradually* begin to filter in some of these ideas. That way he does not initiate his destruction by his peers because of too much energetic advocacy too quickly.

THE PRIORE APPROACH IS URGENTLY NEEDED

We simply must get this Priore therapeutic approach developed, for it is extremely important to all humanity. Our very survival may depend upon it.

Presently all our antibiotics are beginning to fail; the disease organisms are becoming quite resistant. Already our hospitals have strains of diseases that few if any antibiotics will touch. Hundreds of thousands of hospital patients each year are already experiencing complications due to contracting an antibiotic-resistant infection. Probably about 20,000 a year are dying as a result, and the death rate is increasing. In the future, one will have to seriously weigh whether it is better for one's chance of survival to enter the hospital and be treated, or to take one's chances with the disease and not enter the hospital.

With the rising failure of the antibiotics, (*See figure 21 on page 60*) and the rising possession of tailored biological weapons by hostile nations and international terrorists,[91] (*See figure 22 on page 60*) we shall shortly have no defense against an onslaught of pandemics unheard of since the Black Death swept medieval Europe of one third the population. Literally the age of pestilence and dread diseases of Revelations is upon us.[92]

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[88] *They can also be "reversed to normal" even if they have never before been normal. The master cellular control system contains a master blueprint for the normal cell and can make an appropriate template for the specific disease delta vacuum engine, or one can be introduced (e.g., by injection of a drop of blood from a person previously cured of that specific disease; this was in fact demonstrated by the Priore group.). Pumping will then reverse the patient back to normal, as was actually shown by the Priore group. Indeed, the body's own system may be able to use the correct anti-engine template from the drop of blood and cure itself without pumping, as was also shown by the Priore group, if the body itself is reasonably healthy.*

[89] *Simply "dropping it on someone" by mail, for example – as I did to Elizabeth Taylor's foundation and Ross Perot's office – is just too much for a casual reading to grasp. A polite acknowledgment was received from the Taylor foundation, and no acknowledgment at all was received from the Perot camp.*

[90] *As an example, Priore completed the course work for his PhD and submitted his thesis, documenting his formidable and revolutionary work. Because of the ferocity of the oncology establishment toward the Priore team and its accomplishments, the university rejected his thesis. During the two decades or so since then, untold millions have died worldwide from diseases the team cured. These deaths could have been prevented had the Priore work been vigorously pursued and developed by the scientific community.*

[91] *It is not a question of if the international terrorists will use biological weapons against the U.S. civilian populace, but only of when. Astoundingly, often it may even be possible for the terrorists to simply buy their biological warfare agents from us! In a lawsuit by Desert Storm Syndrome victims against certain U.S. companies, one of the companies is alleged to have sold germs – such as anthrax, tularemia, and botulism – to Iraq by mail. These are highly effective biological warfare agents. E.g., a few spray tanks spraying such agents over a large U.S. city complex at night, using an easily obtained light plane to get in a few hours "flying practice," would result in tens or even hundreds of thousands of deaths within days. According to U.S. government-released data, inhaling a few anthrax spores into the lungs has a very high probability of killing the inhaler, unless treatment is started immediately. Even with immediate treatment, many deaths will still occur. A substantial number of nations are now obtaining and producing lethal biological warfare agents – which have been called the "poor man's atomic bomb." Some of the international terrorist groups are also acquiring the biological warfare agents.*

[92] *A good exposition of the rapidly increasing resistant-disease problem is given by Garrett, Laurie,* ***The Coming Plague: Newly Emerging Diseases in World out of Balance,*** *Farrar, Straus and Giroux, New York, 1994.*

In addition, the costs of the present allopathic medicine are rising rapidly and threatening to either bankrupt the nation, or become so expensive that only the wealthy can afford adequate medical care. Even the wealthy could be trapped in the future and denied adequate medical treatment. The Clinton Medicare bill, if approved, would make it a felony to pay a doctor out of one's own pocket, after denial of such treatment by the administrative bureaucracy. It also makes it a felony for the doctor to give the treatment to the disapproved paying person. Thus both the patient and the doctor could be sent to prison, wealthy or not.[93]

CELL CONJUGATION BY VACUUM ANTI-ENGINES IS THE ONLY HOPE

Priore's approach offers an answer to both the age of pestilence and the impending biological warfare strikes against our armed forces and our civilian population.[94,95] By prompt cellular reversal, infection even by totally unknown and modified agents can be quickly voided. Infection by newly adapted, resistant strains of presently known diseases can be quickly conjugated. So the problem of the failing vaccines and antibiotics can be solved quickly, simply, and cheaply. However, the cell-reversing treatment devices and trained, experienced medical staffs must be widely available!

Diseased cell conjugation by EM means is also the only therapy that can largely *eliminate* the debilitating diseases of humanity. Per Wheeler's principle, vacuum engines can mold the *physical matter* of the living body and conditions, operations, and content of the mind, memory, and personality. As the Priore therapy is developed and extended, it will become possible to correct bent spines, mental retardation, mental diseases, genetic defects, physical accidents and disabilities, birth defects, etc. It will be possible to regrow amputated limbs and restore deteriorated cartilage, organs, and joints. It should also be possible to directly remove deep psychiatric problems, heal chemical imbalances, and address and heal such presently difficult disorders as schizophrenia.

The development and application of Type 2 medical engineering can usher in the greatest, most beneficial revolution of all time. As just *one* example, eventually it will be possible to quickly educate students by simply loading the appropriate "software" into their minds and long term memory, in only a few weeks of "sessions." At that point there need no longer be, anywhere in the world, an educationally disadvantaged person.

It can also be used to usher in the most diabolical revolution of all time if we are not careful to (1) be informed of the Type 2 engineering area, including who is developing what, and for exactly what purposes, and (2) rigorously control the development and use of this technology as it progresses. Our legal, political, and scientific leaders – and we common citizens – will have to grapple with the ethics of what is done and to and for whom it is done. Just as one example, the same technology that will allow direct loading of the software in the long-term memory to achieve rapid education, will allow altering or changing any part of the long term memory, including the built-in emotional responses, etc. *Loading software is loading software! What is loaded depends only upon what is in the software.* In theory it is possible not only to alter the learned behavior, memories, emotions, and reactions, but also the genetically "born-in" behavior, emotions, and reactions. The potential for the Type 2 engineering to be used for enslaving and roboticizing humanity should be obvious.

Far more carefully than with any other technology in history, we must ensure that this new one is developed for good, not for evil. To quote an old adage, *the price of freedom is eternal vigilance.* Never before in all of history have those words been more true.

IN CONCLUSION

Pioneers such as Priore, Becker, Kaznacheyev, and Popp have shown us a

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[93] *In fact, under present law all property, homes, bank accounts, and monies of both the patient and the doctor would simply be confiscated – without any legal charge, arrest, or trial – under an absolutely medieval reinterpretation of U.S. law that has again given police at all levels such sweeping and unconstitutional powers. The Clinton Health Care Plan, presently on hold but still alive and sure to be introduced again, is reported to include the establishment of an entire department solely devoted to confiscating assets from patients and doctors who commit such "crimes." Defendants victimized by the present confiscation reinterpretation of law have a slim chance of even forcing the issue into a court. Even if they succeed in getting into court for a hearing, win it and get full "exoneration," the authorities can still keep the property! In the most insane and unjust legal action in all of U.S. history, this law now charges the property itself with having committed the crime, not the erstwhile human defendant. By what means can the "property" defend itself? No one has an answer, for the property is not an individual and has no legal rights for jury protection under the law! U.S. lawyers and judges are actually insisting that this is rational and makes sense. They have already precisely redefined U.S. law into what is specifically required to institute a police state. The police forces who carry out this consfication are themselves awarded a percentage of the "haul." What does the citizen do when the police forces themselves become the robbers by administrative fiat, and there is no court redress possible? Ostensibly passed to counter organized crime and the drug cartel, this law has rapidly been applied directly to the citizenry, and its use is one of the fastest growing "new techniques" by the various levels of law enforcement. In this paper we have deliberately not dwelled upon the political aspect of the already-emerging police state in control of medical treatment. We simply summarize how the bureacratic medical establishment is likely to meet the challenges of the coming plagues and the associate astounding rise in medical costs. In fact the reader will almost certainly see the rise of an iron "state dictatorship" in medicine, as is already emerging in other legal areas.*

In this paper my primary purpose is technical, not political, so we defer detailing the more involved political aspects of the emerging police state (the New World Order – more aptly the New World Feudalism) to other more capable authors and sources. One central thought should remain firmly in mind All political systems and isms tend ultimately to feudalism, which is always the best system for the oligarchy or elite at the top who control and own everything. In any society, there is always an on-going struggle by a fraction of the most powerful to convert the society to special forms of feudalism.

[94] *Some biological agents are very lethal and the associated disease develops at a frightening pace. E.g., the strains of Staphylococcus bacteria that cause necrotizing fascitis and necrotizing myositis – two versions of the "flesh-destroying" disease – are noteworthy examples. Necrotizing is causing inflammation and/or death of tissue, fascitis refers to "sheet" or connective tissue, and myositis refers to muscle tissue. Recently the Quebec separatist leader Lucien Bouchard was suddenly felled by necrotizing myositis, lost a leg, and at this writing is stable and will recover. The disease is usually fatal in 80% of the cases. There is nothing diabolical in his contacting the disease; the bacteria are present from time to time and can enter the body through a nick or otherwise. The disease and the bacteria are known; however, in the past such cases have been relatively rare. The lethality of the disease is augmented by the rapidity of its development. Delayed recognition of the disease may place the patient already beyond the ability of conventional agents to arrest it in time to save him. With the modern hospital and population environment being highly favorable for the more rapid modification and adaptation of disease organisms, even previously rare diseases such as necrotizing fascitis/myositis are ticking time bombs waiting to become resistant to our antibiotics and explode in the dense urban populations.*

[95] *We refer to strikes using biological organisms. We have mentioned but deliberately not dwelled upon the use of electromagnetic induction of lethal cellular diseases at a distance. Such strategic capability to attack a nation and destroy its citizens and soldiers is presently on-line in Russia, under total control by the KGB, not by the conventional Russian military forces.*

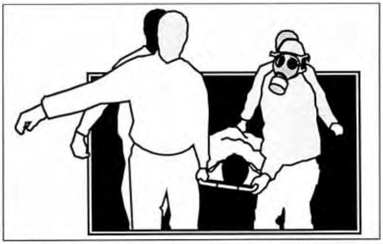

Fig. 21. Present antibiotic therapy is failing as disease organisms adapt.

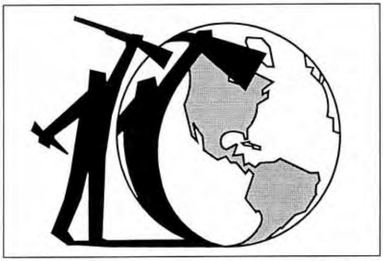

Fig. 22. Terrorists will eventually use biological warfare strikes. Biological warfare is an increasing threat to military forces and the civil populace.

great vision. Having seen it, when one looks at the incredible human suffering throughout the world, and then at the formidable problems of our Type 1 medical science that is struggling so mightily and losing the battle, one is reminded of a phrase by Dante:

> *"Heaven wheels above you*
>
> *Displaying to you her eternal glories*
>
> *And still your eyes are on the ground."*

With every fiber of our being, we exhort the scientific community to lift its eyes from the ground, and develop and apply the Type 2 medical technology as rapidly as humanly possible, for human benefit. Else half of humanity will perish in the coming tide of pestilence. Even the conventional scientists agree that the pestilences are coming, and that conventional approaches are already losing the battle. Long ago Albert Einstein wrote these prophetic words:

"*It would of course be a great step forward if we succeeded in combining the gravitational field and the electromagnetic field into a single structure. Only so could the era in theoretical physics inaugurated by Faraday and Clerk Maxwell be brought to a satisfactory close.*"

Einstein's passionately-sought unification of EM and G has now been accomplished. It has magnificent medical science applications for the benefit of all humankind. Meanwhile, in the orthodox medical journals, the scientists themselves are recognizing the demise of antibiotics and the coming unstoppable plagues. The scientists are redoubling their efforts to apply the present inadequate models, and their efforts are admittedly failing. *If they keep to their present course, the war is already lost!*

In the name of all the bleeding, suffering, and dying peoples of the world, we must do better than that! We can do better than that, if we rapidly redevelop and apply the Priore approach.

We call fervently for a great new "War on Disease" that is empowered, funded, and staffed to perform the task. It can be done in perhaps three years, and perhaps for as little as $60-100 million if we streamline procedures, keep the bureaucracy off the team's necks, and give the team scientists the authority of a War Commander with a mission order to *get on with it.*

What happens next is up to the scientists, the politicians, and the concerned leaders of all the nations of the world. *They simply must not fail us.* They and their families are in the same frying pan as the rest of us. This is not the time for dogma, posturing, arrogance, protecting one's territory, yapping about who's going to control the presently inadequate medicine, yakking about pseudoscience, striving for personal position and power, bowing to the big drug companies and their vested interests, and playing the "Who's to be the big monkey?" game. *We need a new Manhattan Project. We need it now.*

Else we who have
sown the wind
will most certainly reap
the coming whirlwind.

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COMMENT: Lymphosarcoma is a malignant lymphoma (malignant tumor of lymph or lymph-like tissue) that tends to metastasize freely and spread throughout the body. It easily leads to the condition of lymphomatosis, which is the presence of multiple lymphomas in the body, in cluding wide distribution through the various organs, lymph tissue, and tissue resembling lymph tissue. A lymphoblast is a cell giving rise to lymphocytes, the colorless weakly motile cells produced in lymphoid tissue and include the cellular me diators of immunity, constituting some 20 to 30 percent of the leukocytes (white blood cells) of normal human blood. In effect the experimenters have healed a condition that represents a serious leukemia.

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COMMENT: Orchitis is inflammation of a testes. Trypanosomes are protozoan flagellates of genus trypanosoma which infect humans and animals and are responsible for various serious diseases such as Chaga's disease, dourine, nagana, sleeping sickness, and surra. Chaga's disease is marked by prolonged high fever, edema, and enlargement of the spleen,

liver, and lymph nodes. Dourine is a disease favoring horses and asses, marked by inflammation of the genitals, subcutaneous edematous plaques, low-grade fever, progressive paralysis, emaciation, and death. Nagana is a highly fatal disease in/ of domestic animals in tropical Africa marked by fluctuating fever, inappetance, edematous swelling, and sluggishness, and is transmitted by the tsetse fly and possibly by other biting flies. Sleeping sickness is a serious disease that is prevalent in much of tropical Africa; it is marked by fever, protracted lethargy, tremors, and loss of weight, and is transmitted by tsetse flies. Surra is a severe Old World febrile and hemorrhagic disease of domestic animals and is transmitted by biting insects.

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Editorial Note: *We would like to express our appreciation to Mr. Bearden for this wonderful article.*

The Tom Bearden Website

"Dossier Priore"

by Jean-Michel Graille

Photographs

Cover	
Plate 1	The inauguration: the construction of the M 600 had not yet started but, symbolically, the Mayor of Bordeaux starts the smaller machine at close range. (Archives R.P.)
Plate 2	Inaugural scroll.
Plate 3	An information meeting held in Bordeaux. From left to right: Antoine Priore, Robert Courrier, Raymond Pautrizel and Francis Berlureau. (Archives R.P.)
Plate 4	February 1975. Antoine Priore and Professor Pautrizel at the "suspended" base of the M 600, the enormous experimental prototype built by Leroy-Somer. The apparatus would only function for a few days but did make it possible to carry out some experiments with very promising results.
Plate 5	Anne-Nelly Pautrizel. Professor Pautrizel's sister and collaborator, who participated in almost all the experiments with the Priore apparatus since 1968. (Photo J.M.G.)
Plate 6	Pierette Châteaureynaud-Duprat, head of research at C. N.R.S., doctor of science and specialist in grafts, carried out in 1969 and 1970 two series of decisive experiments concerning the proof and the explanation of the biological effectiveness of the Priore Ray.

Plate 7

The Priore machine. The model financed by Pautrizel, the only one which is still likely to function, the one with which patients will be officially looked after as from 1977, is finished in August 1968. In fact, the apparatus is installed all in one place.

Plate 8

1969. Old friends of Priore retrace the road to Floirac. With a monkey-wrench or soldering-iron in hand, they devote all their leisure time to building the new machine for their friend. Here, on the scales, inspector Plantin, of the legal identity service. In coveralls, scarf around his neck, municipal worker M. Léglise.
(Archives R.P.)

Plate 9

A courageous man. Perpetual Secretary of the Academy of Sciences, elder President of the Academy of Medicine, "father" of endocrinology and fertilization, Professor Robert Courrier could have benefited from its prestige and its retirement. At 67, he took all the risks to defend that which he believed in deeply. He has fought now for twenty years. One of the rare photos of him, in the company of Antoine Priore and Professor Pautrizel, taken on 25th March 1970 in the laboratory at Floirac.
(Archives R.P.)

Jean-Michel Graille
DOSSIER PRIORE
Une nouvelle affaire Pasteur?
Denoël

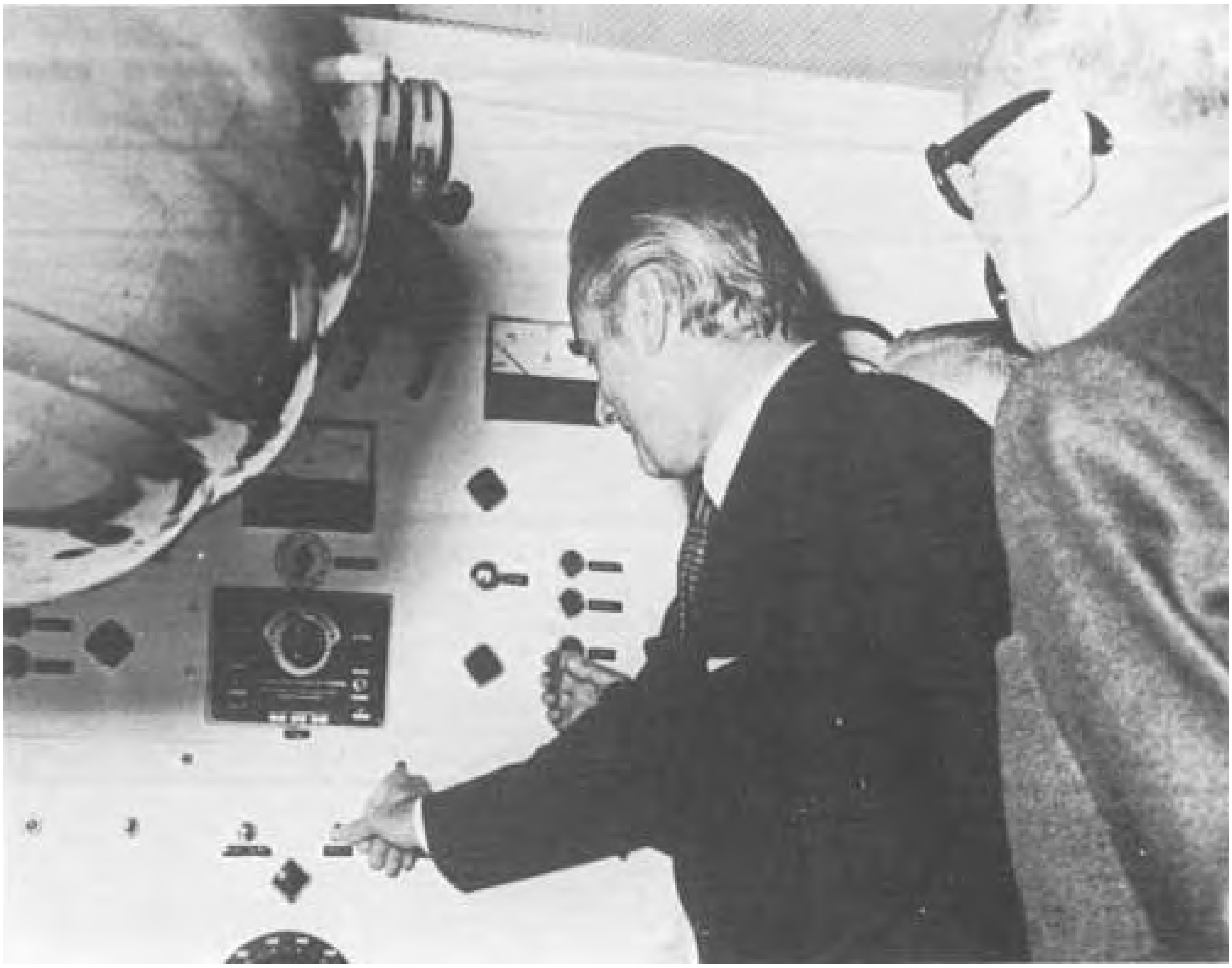

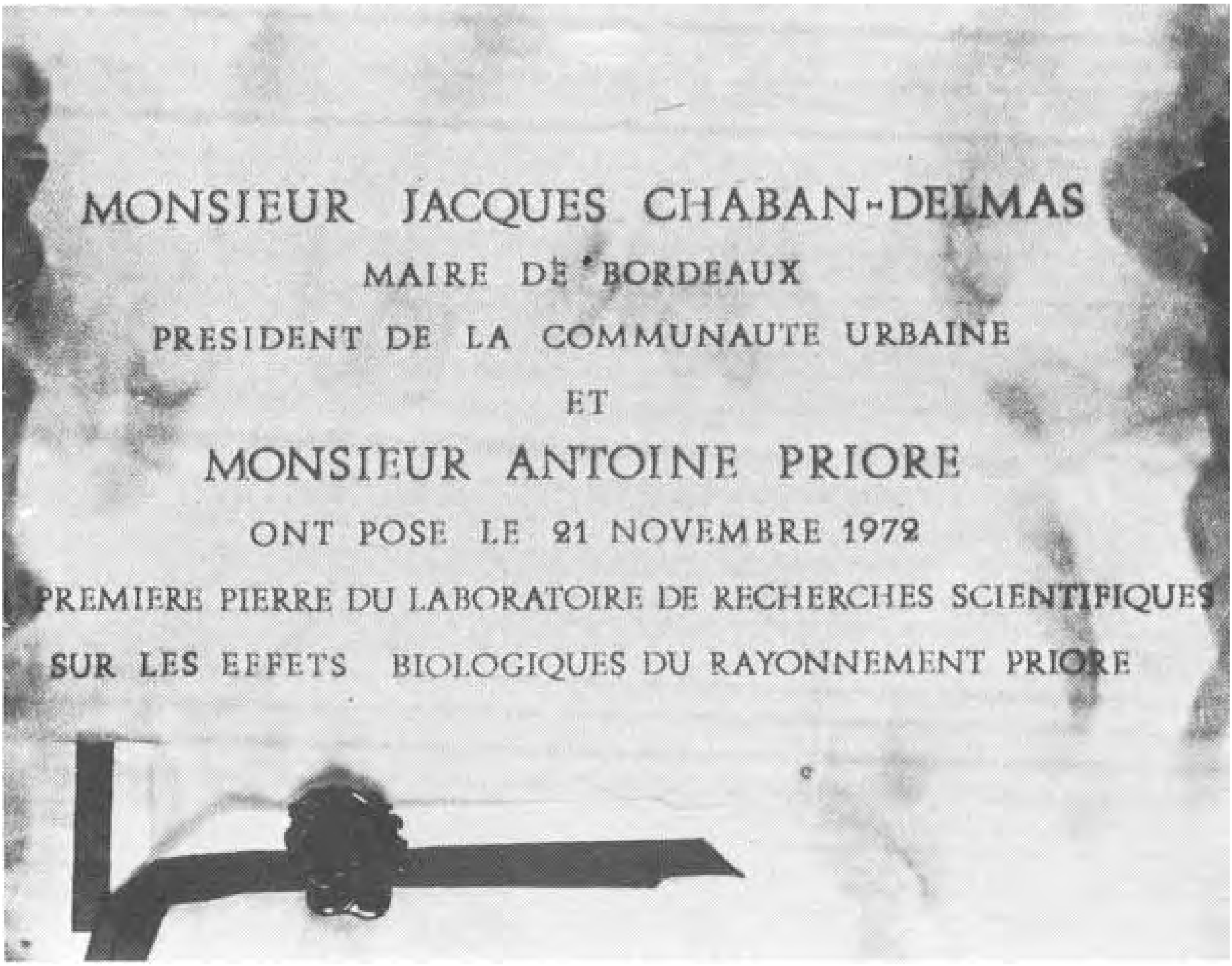

MONSIEUR JACQUES CHABAN-DELMAS
MAIRE DE BORDEAUX
PRESIDENT DE LA COMMUNAUTE URBAINE
ET
MONSIEUR ANTOINE PRIORE
ONT POSE LE 21 NOVEMBRE 1972
PREMIERE PIERRE DU LABORATOIRE DE RECHERCHES SCIENTIFIQUES
SUR LES EFFETS BIOLOGIQUES DU RAYONNEMENT PRIORE

Translation:

JACQUES CHABAN-DELMAS
THE MAYOR OF BORDEAUX
PRESIDENT OF THE URBAN COMMUNITY
AND
ANTOINE PRIORE
HAVE INSTALLED ON THE 21 NOVEMBER 1970
THE FIRST STONE OF THE SCIENTIFIC RESEARCH LABORATORY
FOR THE BIOLOGICAL EFFECTS OF THE PRIORE RAY

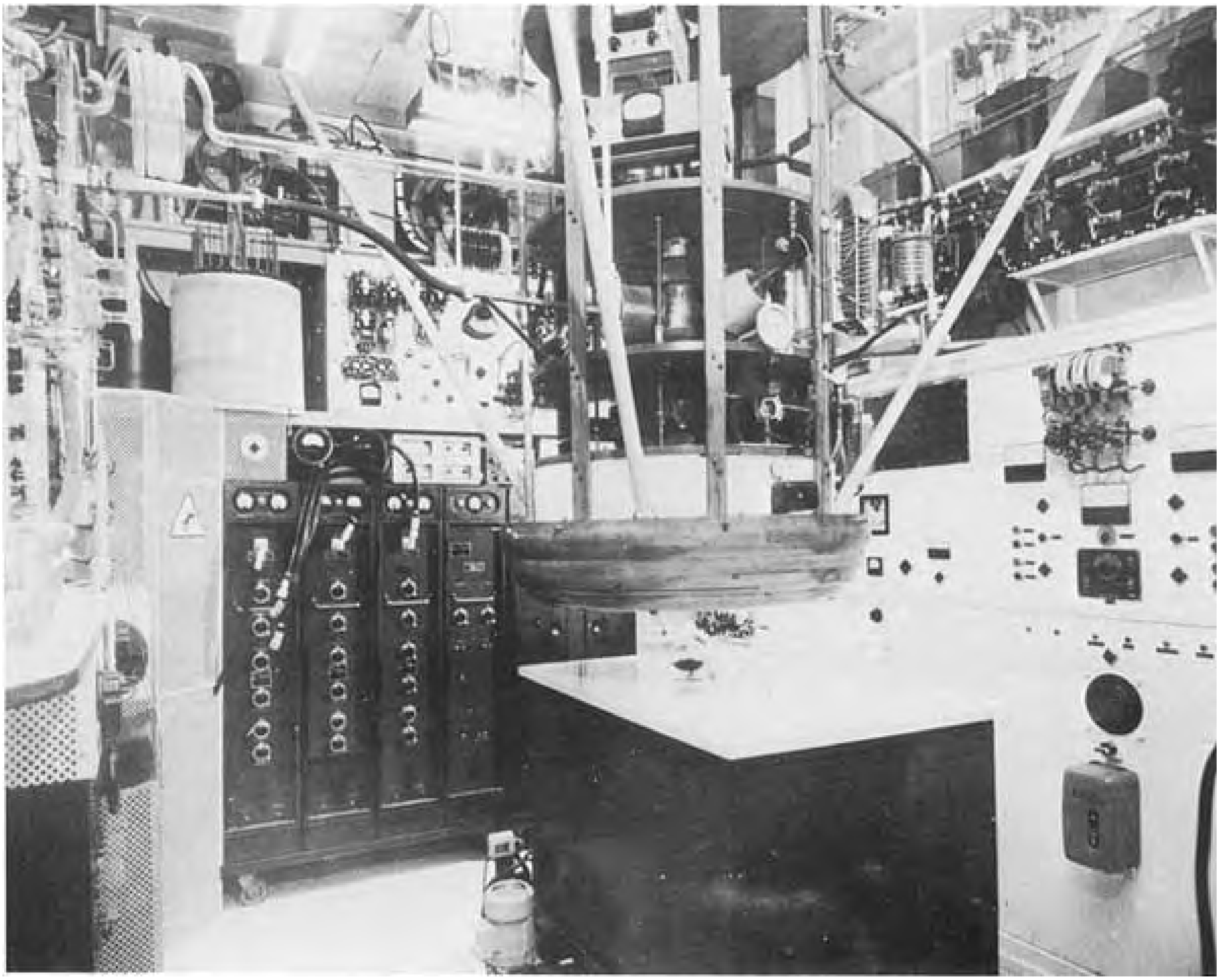

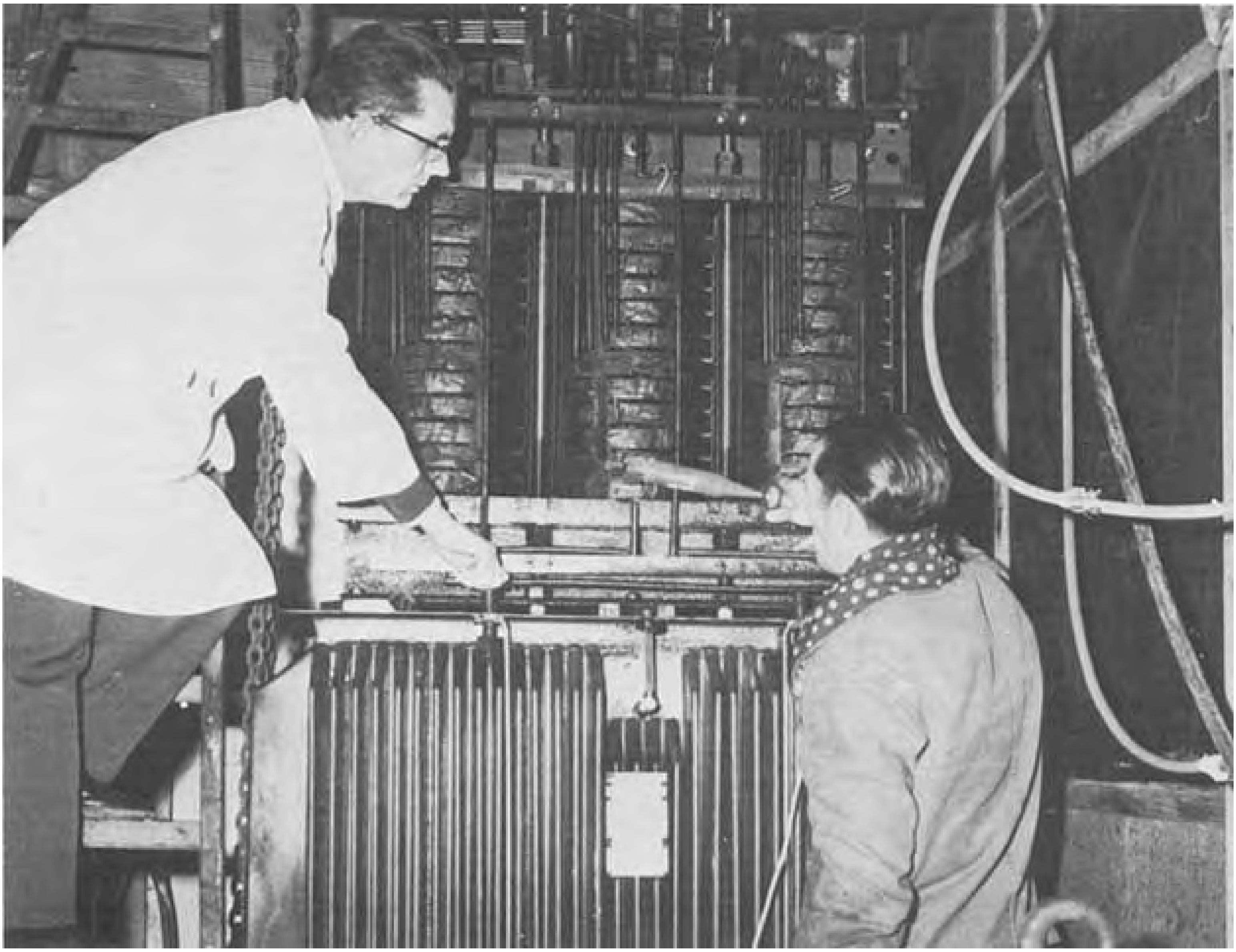

Making Laser Weapons a Reality

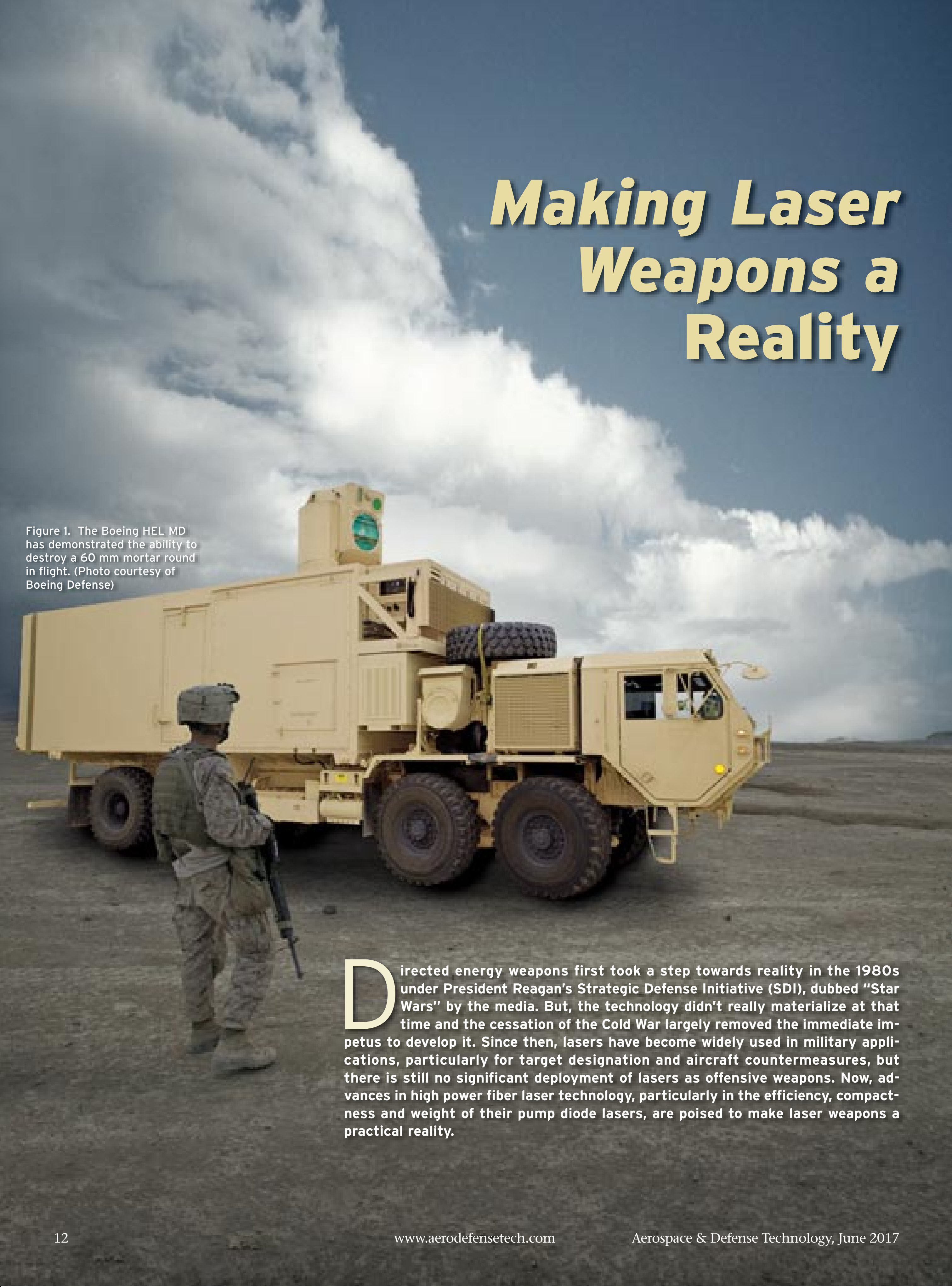

Figure 1. The Boeing HEL MD has demonstrated the ability to destroy a 60 mm mortar round in flight. (Photo courtesy of Boeing Defense)

Directed energy weapons first took a step towards reality in the 1980s under President Reagan's Strategic Defense Initiative (SDI), dubbed "Star Wars" by the media. But, the technology didn't really materialize at that time and the cessation of the Cold War largely removed the immediate impetus to develop it. Since then, lasers have become widely used in military applications, particularly for target designation and aircraft countermeasures, but there is still no significant deployment of lasers as offensive weapons. Now, advances in high power fiber laser technology, particularly in the efficiency, compactness and weight of their pump diode lasers, are poised to make laser weapons a practical reality.

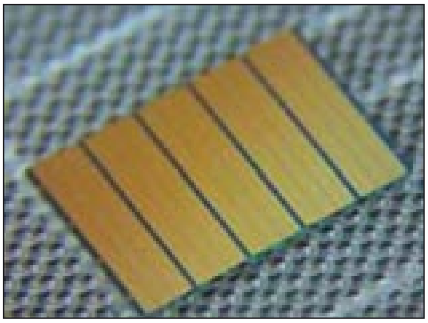

Figure 2. A Coherent | DILAS T-Bar chip contains five emitters, outputs about 50 W, and is 5 mm wide.

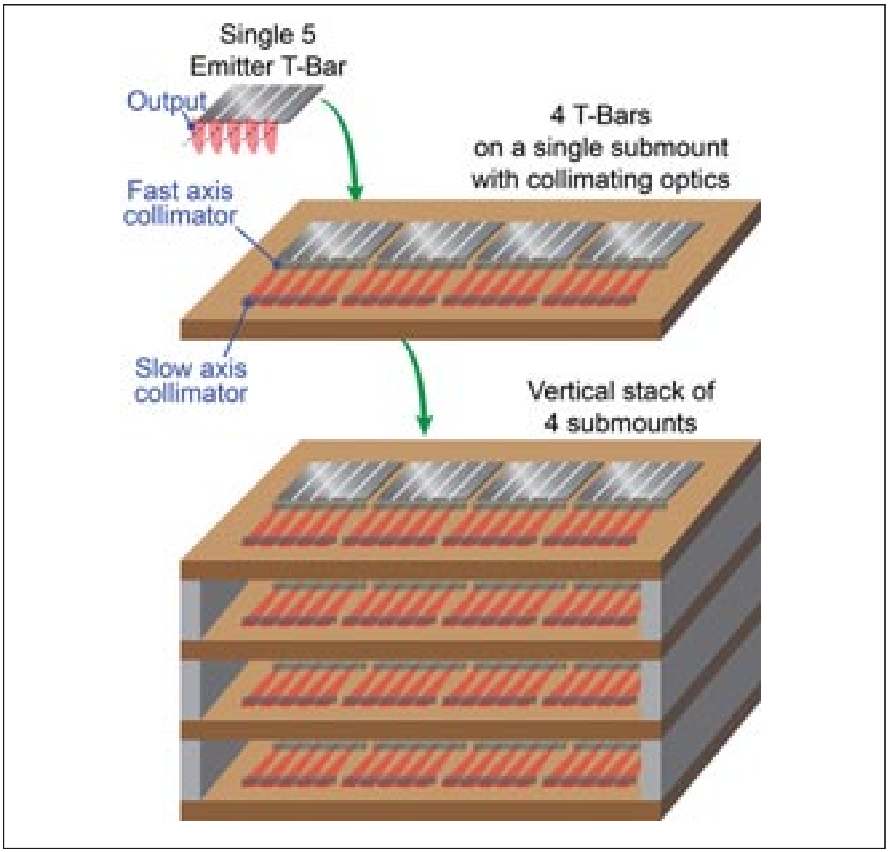

Figure 3. Progression from a single T-Bar die to an 80-emitter stack. The light from all these emitters can be efficiently coupled into a single 225 μm core fiber with a 0.22 NA.

Laser Weapons Overview

The concept behind Reagan's SDI was to protect the United States behind a "missile shield" that would prevent nuclear weapons, delivered via either intercontinental or submarine-launched ballistic missiles, from reaching North America. Part of the SDI was to be lasers, or other directed energy weapons, placed in permanent orbit, which could rapidly knock out a nuclear missile already in flight towards its target. Lasers, in particular, were a promising technology for this application because they can be quickly "charged up" (i.e. be made ready to fire), and their output can reach a fast-moving target nearly instantaneously.

Because these lasers were intended to be deployed primarily in space, or in fixed locations, and used either never (hopefully) or just once, there wasn't much concern about their cost, physical size, weight or operational efficiency. The key goal was simply that they would work when needed, delivering the required knock-out punch.

The offensive laser weaponry under development today is intended to serve almost the exact opposite purpose than the SDI, and therefore has very different goals in terms of its design and functionality. For example, one major laser weapons initiative is for C-RAM (Counter Rocket, Artillery and Mortar). These are systems intended to be deployed in the battlefield to protect troops and equipment from incoming projectiles. Currently, these are envisioned to be single, vehicle mounted lasers, with output powers in the 10 kW to 50 kW range.

Boeing has already successfully prototyped such a system, which they call the High Energy Laser Mobile Demonstrator (HEL MD). This consists of a 10 kW solid state laser installed on an Oshkosh Tactical Military Vehicle, along with all the necessary targeting and control systems. HEL MD has proven the ability to lock on to and destroy a mortar round of about 10 inches in length, traveling at hundreds of miles per hour, from several miles out. The system is also effective against Unmanned Aerial Vehicles (UAVs or drones); in this case, it may be sufficient to damage the drone's navigation and targeting systems, rather than completely destroy it. Similarly, other offensive laser weapons systems are being designed to deliver "swarm defense," that is, to protect a ship or base from attack by a large number of inexpensive drones.

Thus, today's laser weapons are meant to defend against swarms of inexpensive mortar rounds, drones and other projectiles, and are intended to be mounted on platforms which are mobile and self-contained (meaning they may not have ready access to an external source of power). This gives rise to several design imperatives. First, they must deliver a low cost per engagement; it's simply not economically feasible to employ an expensive weapon (such as a missile costing over $100,000) to knock out a drone which costs $1,000, or a mortar round which might cost less than $100. The laser weapon must also be capable of rapid fire so that it can't just be overwhelmed by a large number of simultaneous incoming rounds. Also, rapid fire reduces the number of individual laser weapons systems needed to protect a given number of troops. But, the ability to deliver rapid fire also necessitates that the system be electrically efficient. Otherwise the laser weapon will require access to a large quantity of fuel, which is difficult (and dangerous) to transport into a battlefield. Finally, it's desirable that laser weapons be physically compact, especially for airborne use.

SWaP Optimization

The push to optimize the size, weight and power (called SWaP in military parlance) of field deployed laser weapons has driven a progression in the technology of the gain material used from chemical (e.g. deuterium fluoride), to solid state, and, most recently, to fiber. One reason for this is because fiber lasers offer inherently higher efficiency, in terms of converting input pump energy to usable output, than nearly any other laser type, except diode lasers. However, diode lasers by themselves don't provide the necessary brightness or beam quality, while diode-pumped fiber lasers can. And, beam quality is critical because it determines the distance over which the laser can be focused to a spot size small enough to reach the power density necessary to damage its target.

Fiber lasers offer other advantages in terms of SWaP optimization. Chemical and lamp pumped solid state lasers require a significant overhead in terms of the equipment and power supplies required to run them. In contrast, both solid state (e.g. slab and rod) and fiber lasers can be diode pumped, and diode power supplies and pump modules themselves are electrically efficient and lend themselves to miniaturization. This efficiency, in turn, reduces the cooling requirements, and all its attendant equipment (pumps, heat exchangers, etc.).

But, as laser weapons evolve towards ever higher powers, fiber laser technology becomes increasingly attractive over solid state. Currently, individual fiber lasers can deliver up to about 2 kW of power, but multiple units can be combined to deliver around 10 kW in a single beam with extremely good mode quality. It's a bit more difficult to scale up the power of a solid-state laser, especially while maintaining good mode quality. This is because scaling up and/or increasing the pump power to a traditional solid state laser typically excites higher order modes, and introduces other issues related to thermal lensing.

Of course, there are also challenges to increasing the power of a fiber amplifier. And, because the optical efficiency of their pumping is already so high (~85%), there's not much room for improvement there. So, the focus is on raising the pump power itself, without increasing package size and weight, as well as on methods for low loss beam combining of multiple single mode lasers, all while still maintaining good beam quality.

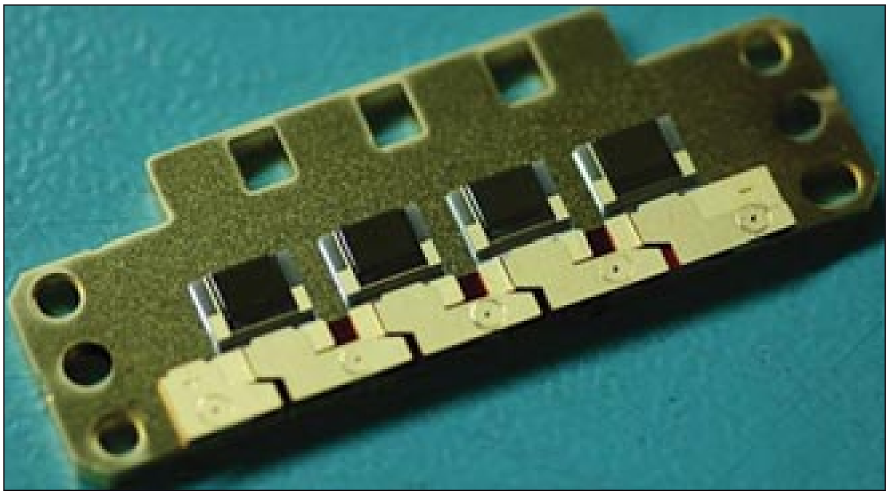

Figure 4. Four T-Bars mounted on a macrochannel cooler with collimating optics.

Pumping Technology Advances

In terms of SWaP optimization of pump diodes for laser weapons, a current benchmark is to achieve a weight to output power ratio of 1 kg/kW. Coherent | DILAS has developed several advances in diode laser technology to reach this goal, and, in fact, is already working on devices that will attain the next level of performance – 0.5 kg for 1 kW of output.

One key to reaching the SWaP benchmark has been the company's introduction of T-Bar (for "tailored" bar) construction, a design approach intended to combine the high total output power of traditional diode laser bars with the relaxed cooling requirements of single emitters. The basic unit of the T-Bar is a diode laser mini-bar having five emitters on a single, 5 mm wide substrate which outputs about 50 W total. In contrast, traditional diode laser bars are usually 10 mm wide, contain at least 19 emitters, and can output over 200 W, depending on the number of emitters and type of heatsink.

For military applications, four of these T-Bar dies are mounted on to a single substrate, yielding a total of 20 emitters. Then, up to four of these substrates are stacked vertically, bringing the total number of individual emitters in this compact assembly to 80, with a total output of about 800 W.

The key optical characteristic of the T-Bar design is that the combination of wide emitter spacing, low divergence and relatively low beam parameter product (in both fast and slow axes) is tailored to enable the light from all 80 of these individual emitters to be efficiently co-linearized and coupled into a single 225 µm core fiber having a numerical aperture of only 0.22. This, in turn, permits highly efficient coupling into the pumping mode volume of the gain fiber. And, this light collection can be accomplished using a relatively simple and compact optical system. This is how output power per unit volume is maximized.

In contrast, the high divergence and poor mode quality of traditional diode laser bars necessitate the use of complex optics for light collection, and still make it impossible to couple all their output into a single, low numerical aperture fiber. Furthermore, high power diode laser bars often suffer from a problem called "smile." This is a sagging or bending alignment error in emitter position along the bar which makes it quite difficult to collimate and co-linearize its output.

Besides the advantage of producing the largest amount of fiber coupled light out in a given system volume, T-Bar construction also offers significantly improved cooling characteristics over traditional bars. In a traditional diode laser bar, the small emitter spacing causes significant thermal crosstalk between the individual emitters, and a very high efficiency cooling system must therefore be employed. This is usually in the form of a so called "microchannel" cooler, in which water is rapidly circulated through channels within the heatsink. But the small bore of the microchannels (tens of microns) makes it easy for them to be clogged by particulates. Thus, the water must be stringently conditioned and filtered, and large, heavy, high pressure pumps must be employed to circulate it rapidly enough to achieve the required level of cooling in these traditional bars.

Furthermore, traditional diode bars are usually placed directly on the heatsink in order to achieve good thermal contact. However, this makes the microchannel cooler part of the electrical circuit, thus necessitating the use of deionized water in order to avoid a short circuit. This imposes yet another requirement that increases cost and complexity.

The larger emitter spacing of the T-Bar largely eliminates this thermal crosstalk, and greatly relaxes the attendant cooling requirement. As a result, Coherent | DILAS has been able to introduce a "macrochannel" cooler. This is a system which uses substantially larger bore channels, thus allowing the use of less stringently filtered tap water, and eliminating the need for high pressure pumping. Also, the reduced cooling requirement enables the laser bar to be placed on a submount, rather than in direct electrical contact with the cooler, which avoids the necessity of using deionized water.

T-Bar construction also delivers better cooling characteristics than single emitter diode lasers. This is because single emitters are typically supplied already packaged. Since the diodes are mounted within the package, there is an extra thermal interface which makes it more difficult to efficiently cool them.

In conclusion, after decades of imagining, offensive laser weapons are nearly ready for deployment on the battlefield. Advances in diode laser pumping technology are proving to be a key enabling factor in this development. And, these military grade pump diode lasers can be constructed using the same automated, high volume fabrication equipment used for industrial product manufacturing, meaning they can be readily delivered at competitive prices.

This article was written by Chris Ebert, Ph.D., Director, Business Development, Coherent | DILAS, (Tucson, AZ). For more information, visit ***http://info.hotims.com/65852-501****.*

The Tom Bearden Website

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from **STAR WARS NOW!**

The Bohm-Aharonov Effect, Scalar Interferometry, and Soviet Weaponization
by Lt. Col. T.E. Bearden (retd.), 1984
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A Sensitive Scalar Wave Detector

Very briefly we present a method of making a very sensitive scalar wave detector so that direct measurement and quantization can be established.

First, we regard one oscillation (one wavelength) of the scalar potential wave as a longitudinal photon. Note that this photon contains a substructure, which may be deliberately determined (when artificially made) or randomized (when naturally made in the idealized case).

For convenience we represent normal linearized vacuum (spacetime) as a horizontal or longitudinal vector (Figure 4), implying the direction of motion of the wave in the laboratory frame. By horizontal position in our diagram, we imply a linear, uncurved spacetime and a non-rotated frame. We represent the longitudinal scalar wave as a horizontal vector, and the usual Hertzian wave as a vertical or "transverse" vector. We visualize a normal detector as detecting only a vertical or "transverse" vector, as we have illustrated in Figure 4.

As can be seen, in a linear, unrotated or uncurved spacetime a pure scalar wave has no vertical component projected upon the laboratory frame vector, so it is not detectable by normal detectors.

To detect the scalar wave, of course we could bend it so that it has a projected vertical component in the laboratory frame (Figure 5). However, this would be an impure wave, not a pure scalar wave, and that is not what we wish.

A better way is to bend or curve spacetime itself in a small region, so that a longitudinal wave that passes through that region now possesses a vertical component with respect to that region (Figure 6). Thus a normal detector there will detect that vertical component. We conduct the detection current out of the "bent spacetime" region to an outside (normal) detector, and we then have a scalar wave detector.

To illustrate, we show conceptually how this has been successfully done. Figure 7 shows the concept. First, we utilize a magnetic pole to provide the infolded energy (potential) to bend or curve spacetime. To reach good sensitivity, we need a pole strength connected with a magnetic field strength of 40,000 Gauss or higher. We utilize a small superconducting magnet, which can reach field strengths of from 40,000 to 80,000 Gauss.

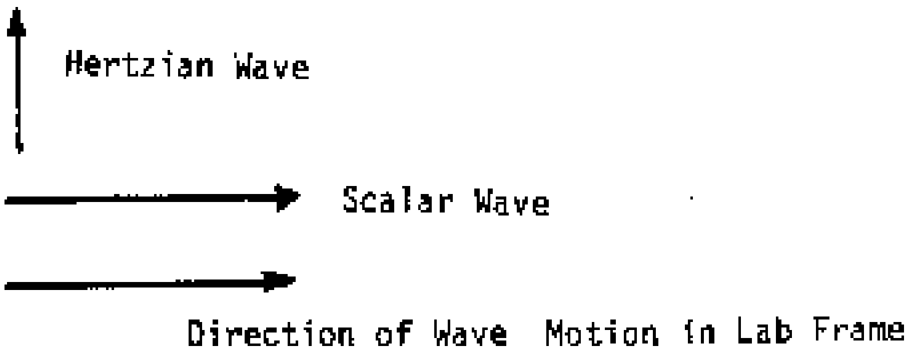
Hertzian Wave
Scalar Wave
Direction of Wave Motion in Lab Frame

Figure 4. Linear, uncurved laboratory frame.

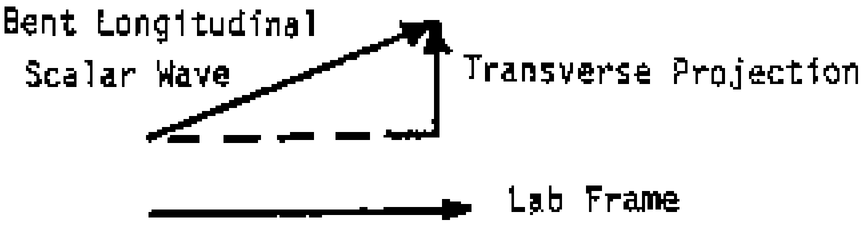
Bent Longitudinal Scalar Wave
Transverse Projection
Lab Frame

Figure 5. Rotating the longitudinal wave produces a transverse component.

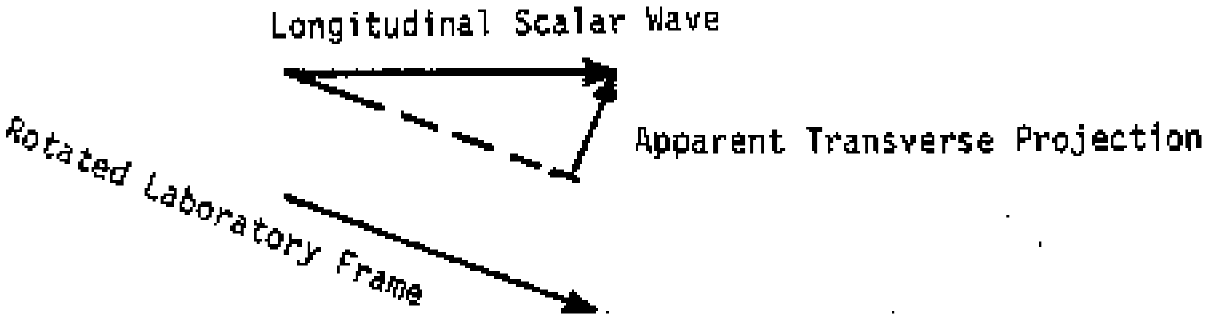
Longitudinal Scalar Wave
Apparent Transverse Projection
Rotated Laboratory Frame

Figure 6. Bending the laboratory spacetime frame produces a transverse component.

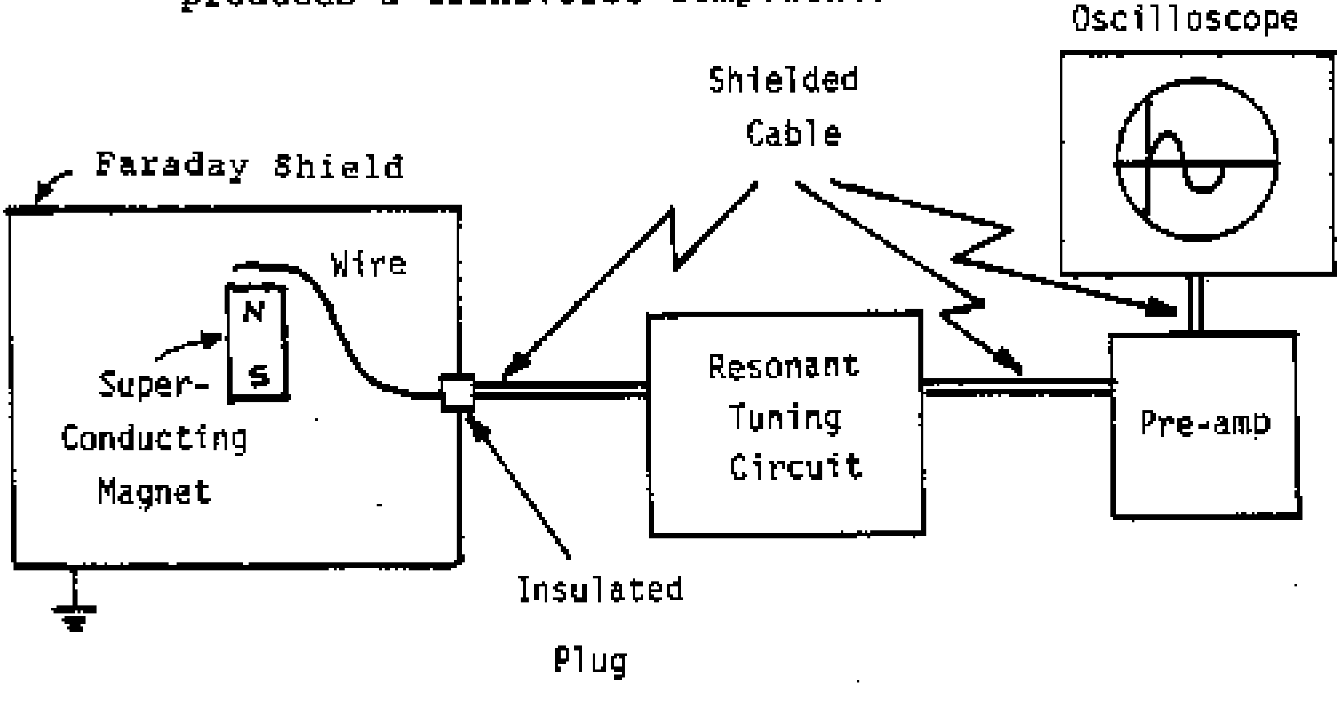
Oscilloscope
Shielded Cable
Faraday Shield
Wire
N
S
Super-Conducting Magnet
Resonant Tuning Circuit
Pre-amp
Insulated Plug

Figure 7. A sensitive scalar wave detector.

Figure 7. A sensitive scalar wave detector.

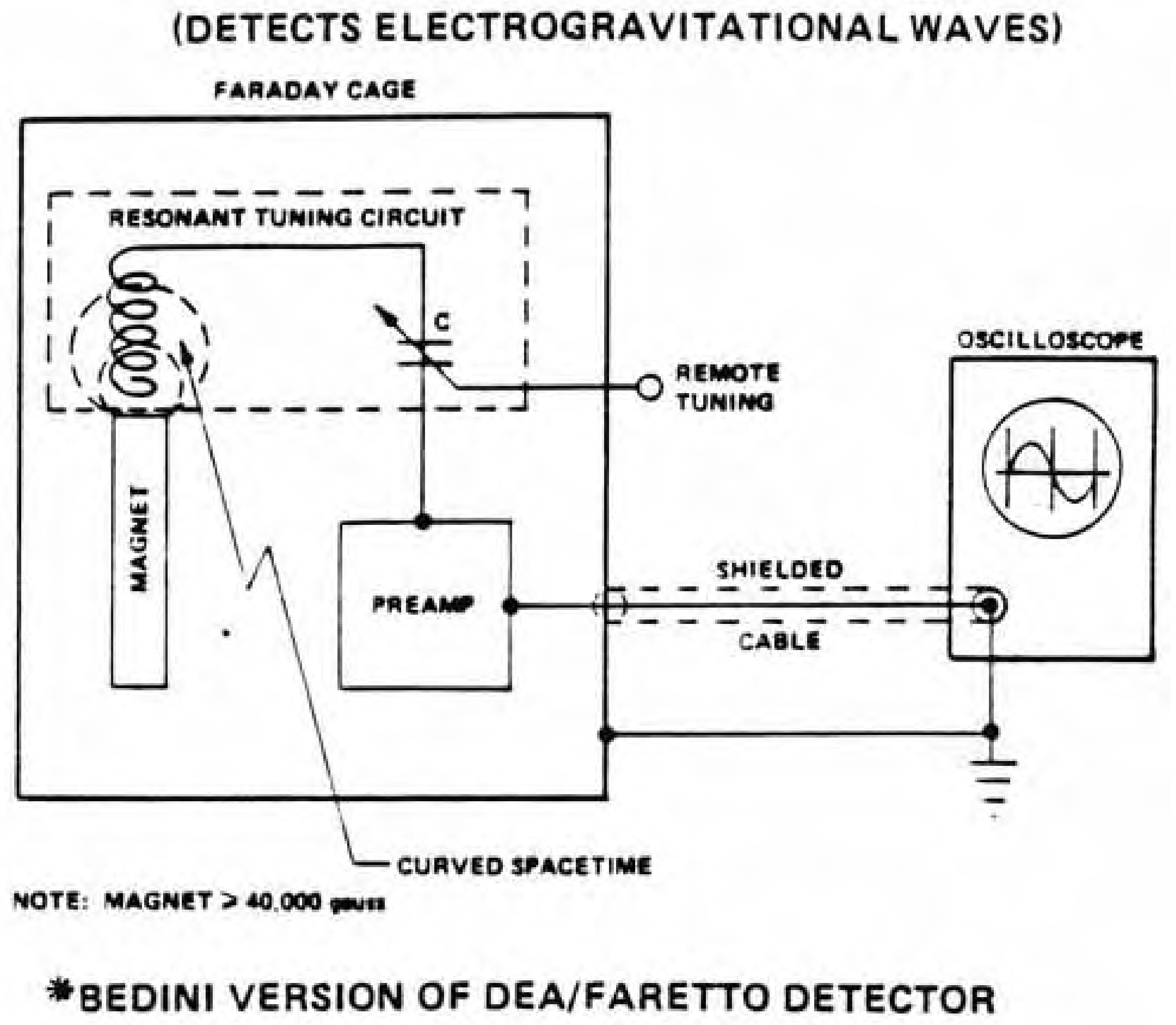
(DETECTS ELECTROGRAVITATIONAL WAVES)
FARADAY CAGE
RESONANT TUNING CIRCUIT
C
MAGNET
PREAMP
REMOTE TUNING
OSCILLOSCOPE
SHIELDED
CABLE
CURVED SPACETIME
NOTE: MAGNET > 40.000 gauss
*BEDINI VERSION OF DEA/FARETTO DETECTOR

Slide 33 - FER DE LANCE

Then to prevent detection of superfluous "normal" radiation, we shield the entire magnet in a grounded Faraday cage, as shown in the figure. Hertzian waves will be grounded in this shield, while scalar waves will readily penetrate it undiminished. In other words, the Faraday cage serves as a "stripper," to strip away the ordinary waves, leaving only the scalar waves to penetrate inside. An ordinary wire lies at the top of the magnetic pole, in proximity to it. The wire runs out of the Faraday cage through an insulated port to a resonant tuning circuit, which is sharply tunable over the range of frequencies we are interested in. A preamp amplifies the output of the tuner, and in turn feeds the input of an oscilloscope or other detector.

With this detector we can select the frequency desired, and detect any passing scalar waves of that frequency. By other variations of amps and preamps, regenerative circuits, etc. we can obtain all the sensitivity desired, and utilize ordinary detection equipment already well-known and highly developed.

Additional Information about detecting Scalar Waves

The Tom Bearden Website

Figure 11. NETWORK OF VIRTUAL TRANSMITTERS

(See Woodpecker Grid)

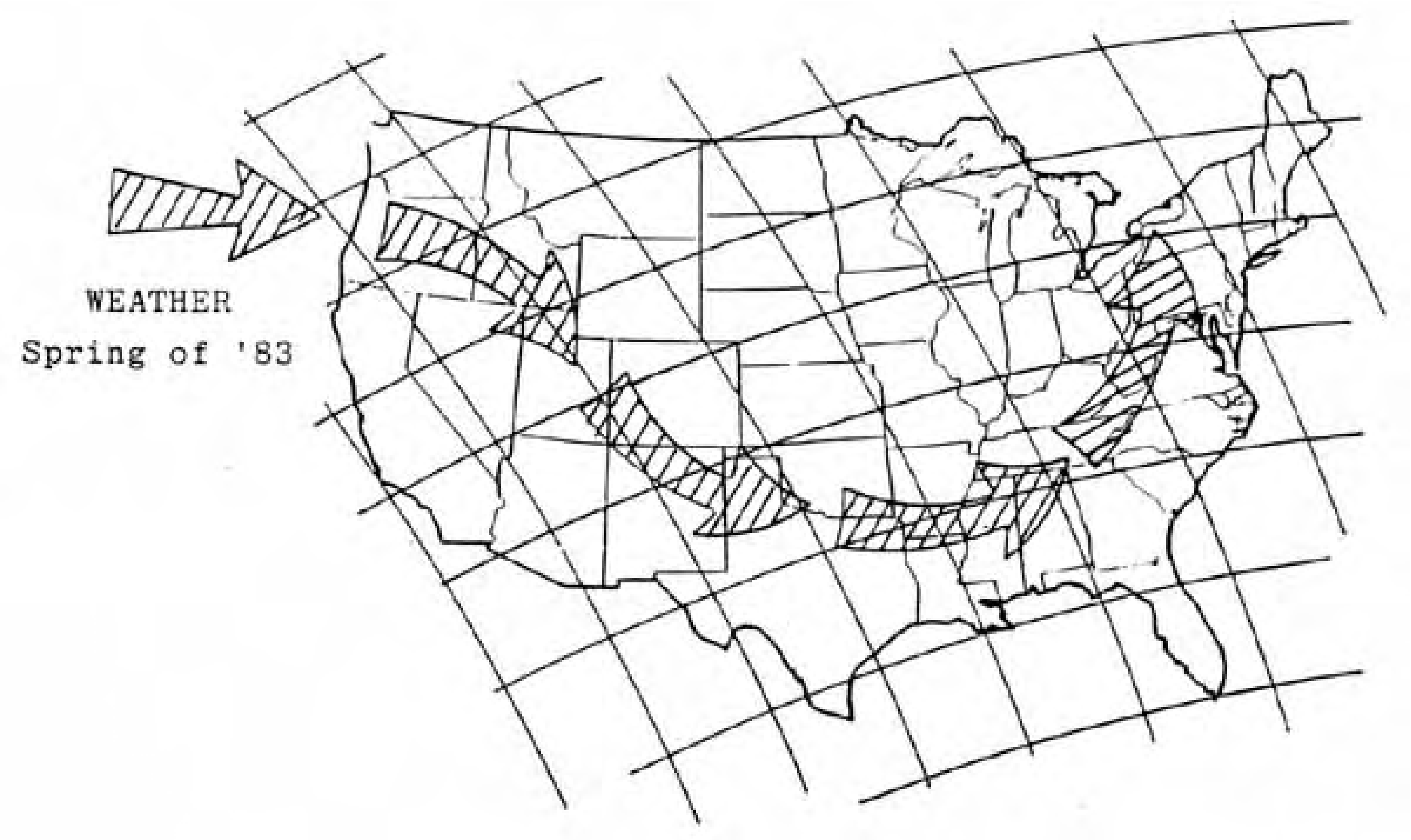

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The Tom Bearden
Website

Figure 12. VIRTUAL TRANSMITTERS IN THE INTERFERENCE GRID

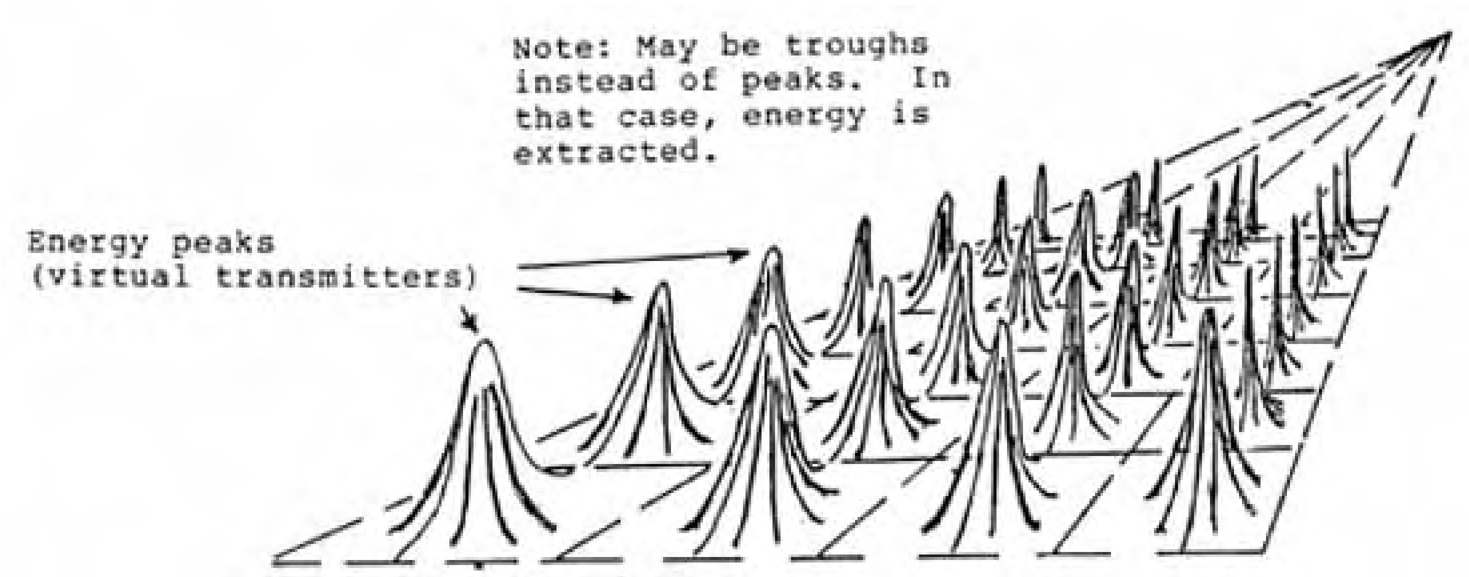
Note: May be troughs instead of peaks. In that case, energy is extracted.
Energy peaks (virtual transmitters)

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The Tom Bearden Website

Figure 13. GIANT RADIAL RELATED TO A VIRTUAL TRANSMITTER

Fall 1983:
Florida
Alabama

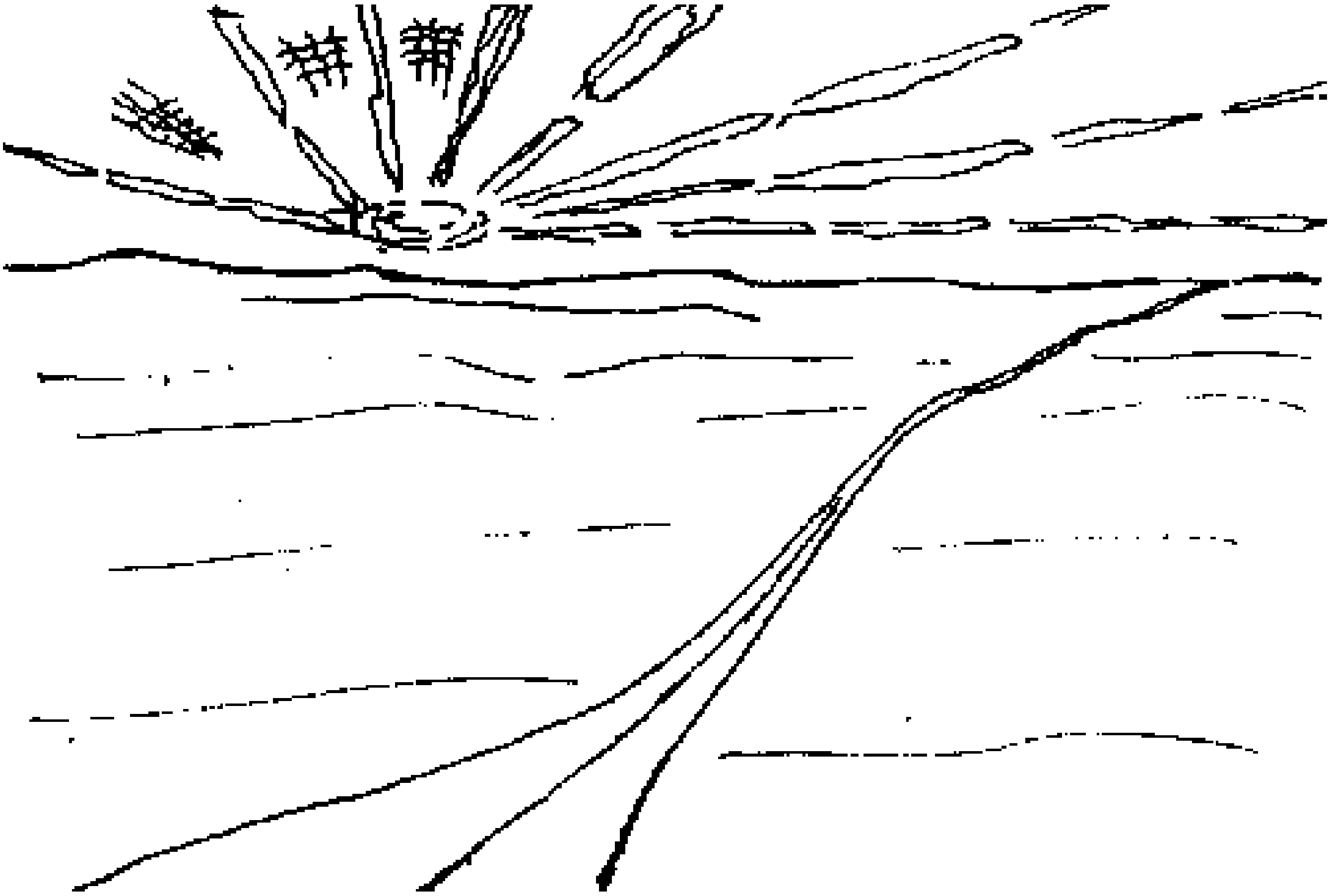

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Figure 14. FORMATION OF A SINGLE GIANT RADIAL

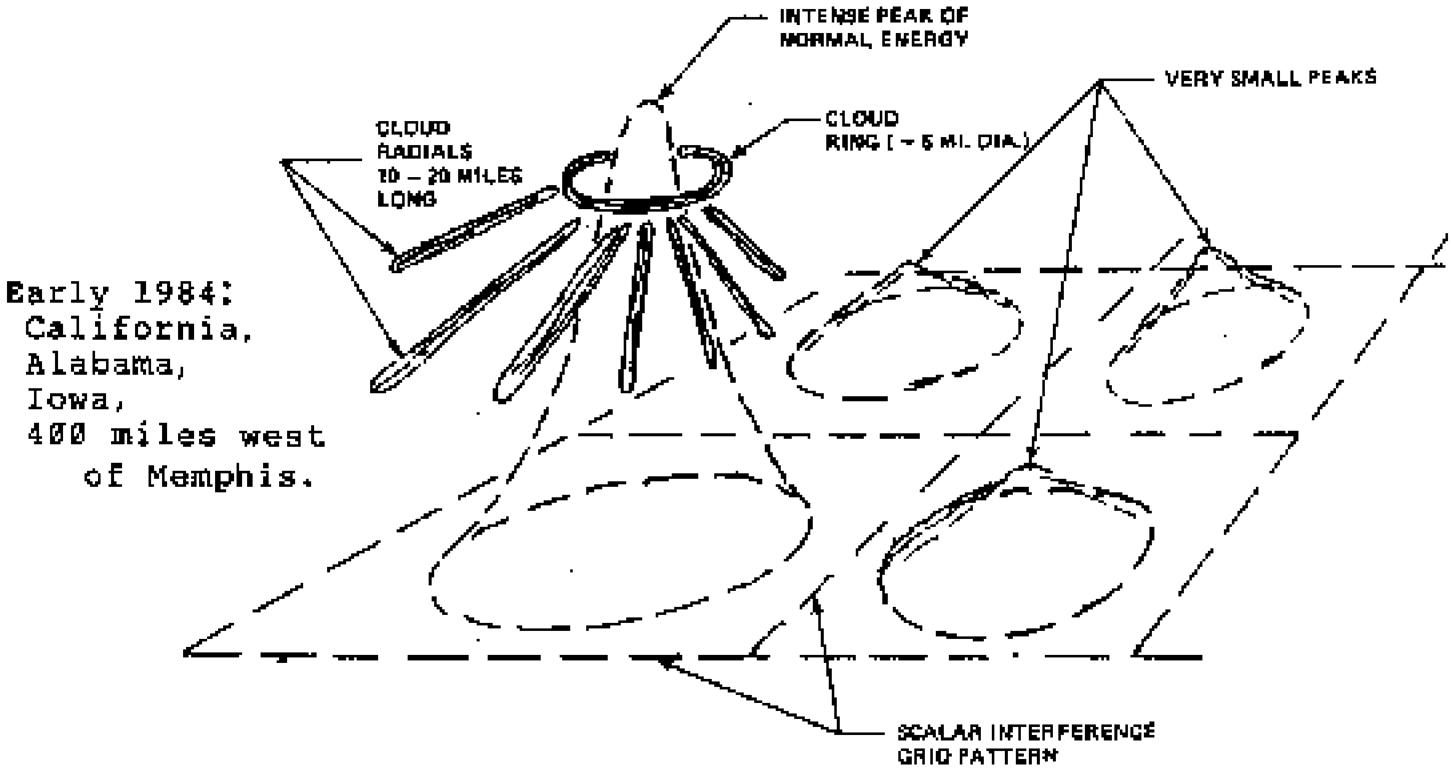
INTENSE PEAK OF NORMAL ENERGY
VERY SMALL PEAKS
CLOUD RADIALS 10 – 20 MILES LONG
CLOUD RING (~5 MI. DIA.)
Early 1984: California, Alabama, Iowa, 400 miles west of Memphis.
SCALAR INTERFERENCE GRID PATTERN

Excerpt P 172
FER DE LANCE

A Briefing on Soviet Scalar Electromagnetic Weapons
by Lt. Col. T.E. Bearden (retd.), 1986
Copyright

2. Continual cloud radials have repeatedly been seen and photographed over Huntsville, Alabama, associated with weather engineering and grid activity. Typical radials seen by this author are shown in Bearden, Soviet Weather Engineering Over North America, 1-hr. v1deotape, 1985. Huntsville is apparently a pivot point or "hinge point" for bending and controlling the jetstream.

3. Spectacular cloud grid patterns have been seen over Huntsville, Alabama and Los Angeles, California. An excellent videoclip of one of the Los Angeles area grids, personally observed and shot by KABC Open Mind talk show host Bill Jenkins, is shown in Bearden, Soviet Weather Engineering Over North America,;1-hr. videotape, 1985. An artist's sketch of an earlier gigantic grid, extending from horizon to horizon in every direction, seen over Huntsville, Alabama by Tom Bearden and Ken Moore, is also shown in the tape. The videotape is available from P.O. Box 1472, Huntsville, AL 35807. Sketches and details of another highly anomalous grid pattern observed in the greater Los Angeles area by engineer Ron Cole are shown in figures 5 and 6.

The reason that clouds of water droplets and/or ice particles detect the scalar interferometry and form signature patterns is simple: Consider each H2O molecule as having two light little hydrogen atoms hanging on to the much heavier oxygen atom. The covalent sharing with the oxygen atom of the electron from each hydrogen atom means that

1. the electrostatic scalar potential between the H ion and the O ion it is bonded to, is rhythmically varying as the electron is shared back and forth,
2. this varying potential contains "electron spin holes" since it is made by the moving electron,
3. two such varying potentials exist since there are two H atoms sharing covalent electrons with the O atom,
4. the two H ions are at an angle of over 100 degrees with respect to each other,
5. the molecule assembly thus constitutes one part (one half, so to speak) of a scalar interferometer with imbedded electron spin holes for electron hooking,
6. Incident scalar waves from outside the system interact with the "half scalar interferometer." This scalar interferometry interaction is coupled to the covalent bonding electron because of the internal spin hole pattern of the molecular half of the interferometer. The coupled electron moves with the sca1ar pattern's changes, causing an observable interaction with and in the electrical structure and ionic potential of the molecule,
7. the weak H to H hydrogen bonding between molecules connects resulting ionic potential changes to the structuring of the entire macroscopic cloud assembly. Thus by scalar interferometry with the H_2O "half interferometers", an incident scalar EM pattern is detected and translated into patterns of E and B force fields. The H_2O molecules then "line up" in accord with the electrical patterns detected.

Thus the clouds form "signature patterns" according to the incident scalar EM radiation patterns. Giant cloud radials in the targeted area are probably due to the type and shape of antennas including the type and shape of the electrical wires establishing the antennas' ground planes -- used by the Soviet Union to project the scalar waves. Note that such "radial" antenna patterns were occasionally used by James Harris Rogers in his underground and undersea scalar EM transmission system.

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The Tom Bearden Website

Figure 15. FORMATION OF A DOUBLE GIANT RADIAL

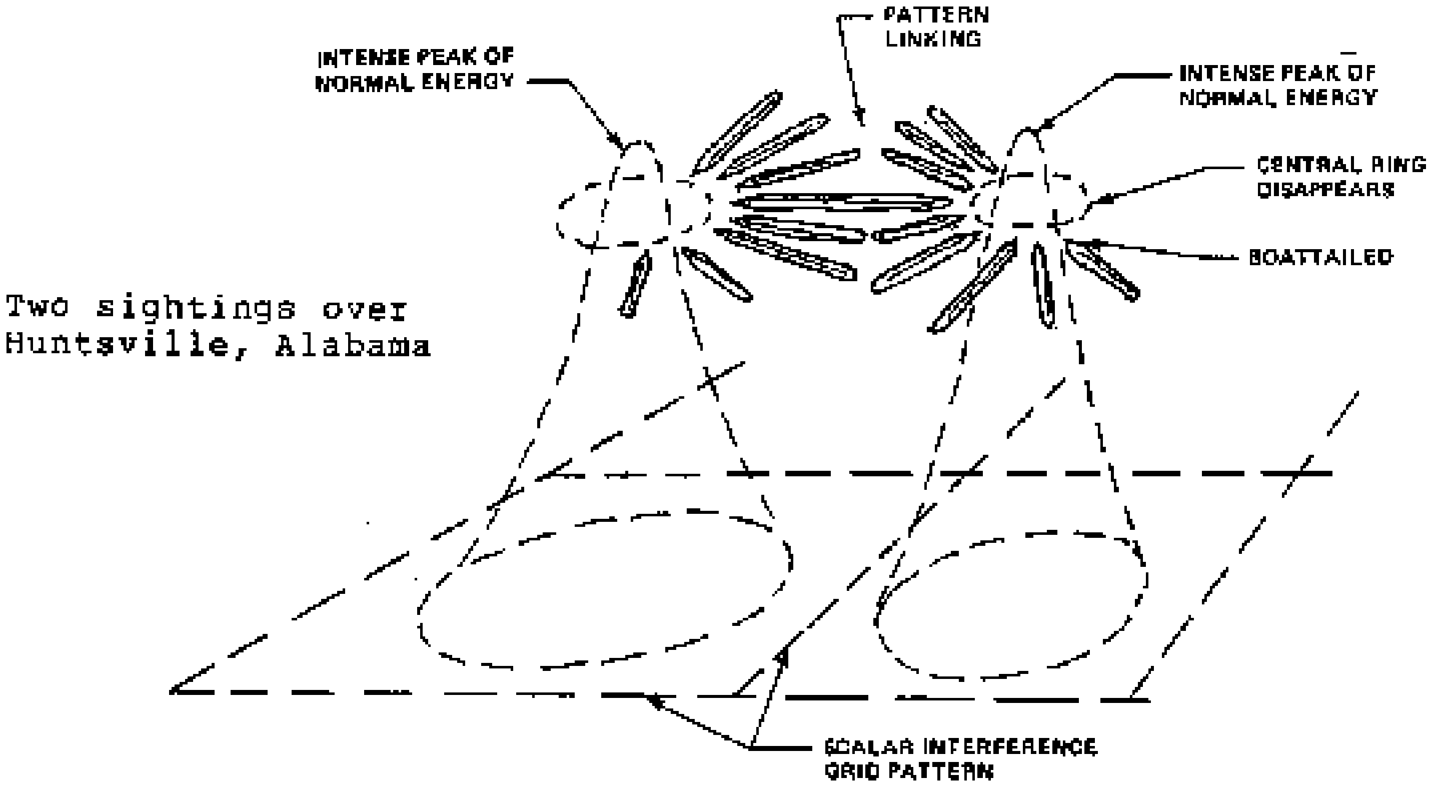
PATTERN LINKING
INTENSE PEAK OF NORMAL ENERGY
INTENSE PEAK OF NORMAL ENERGY
CENTRAL RING DISAPPEARS
BOATTAILED
Two sightings over Huntsville, Alabama
SCALAR INTERFERENCE GRID PATTERN

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Figure 16. DETECTION OF TRANSVERSE AND LONGITUDINAL WAVES

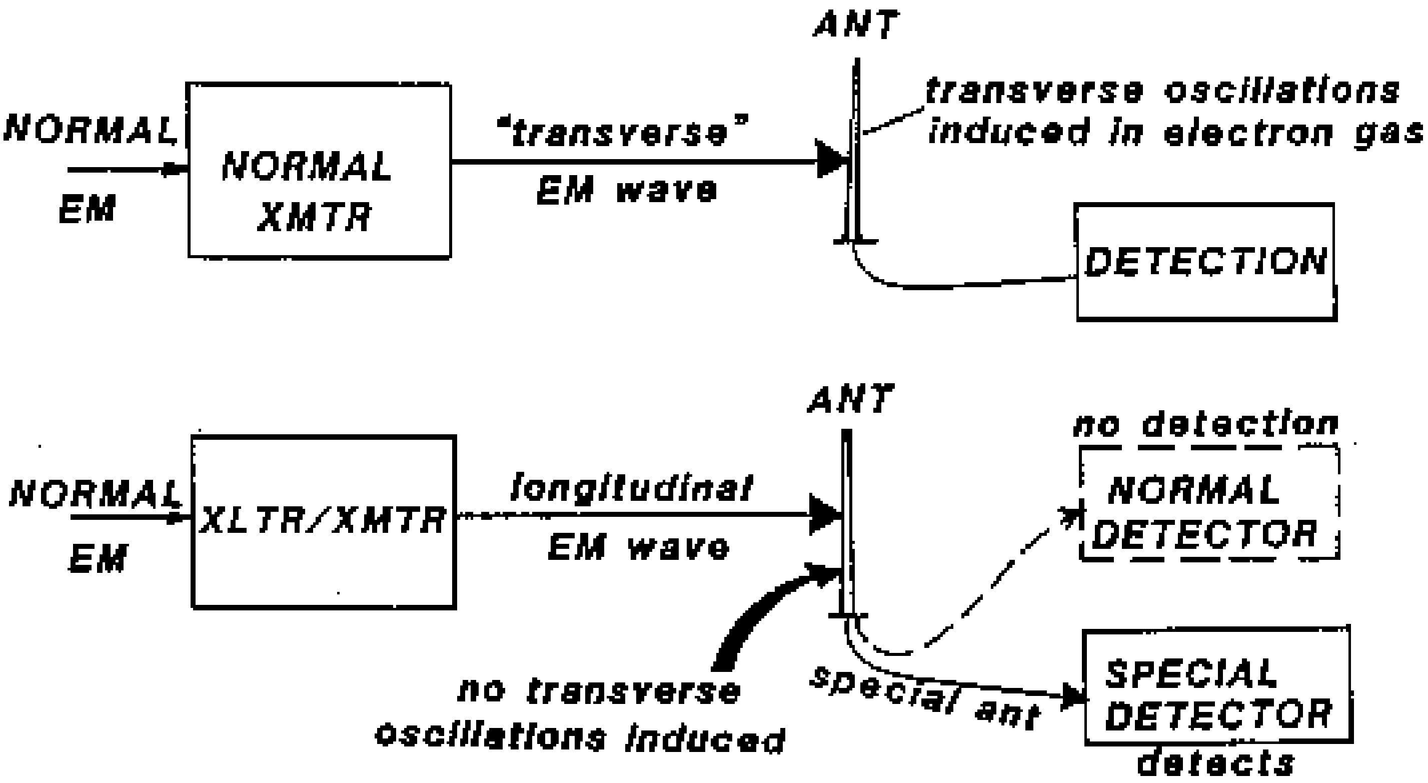
ANT
NORMAL
EM
NORMAL
XMTR
"transverse"
EM wave
transverse oscillations
induced in electron gas
DETECTION
ANT
NORMAL
EM
XLTR/XMTR
longitudinal
EM wave
no detection
NORMAL
DETECTOR
no transverse
oscillations induced
special ant
SPECIAL
DETECTOR
detects

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Defense Department Briefing on Priore Treatment to counter Biological Warfare

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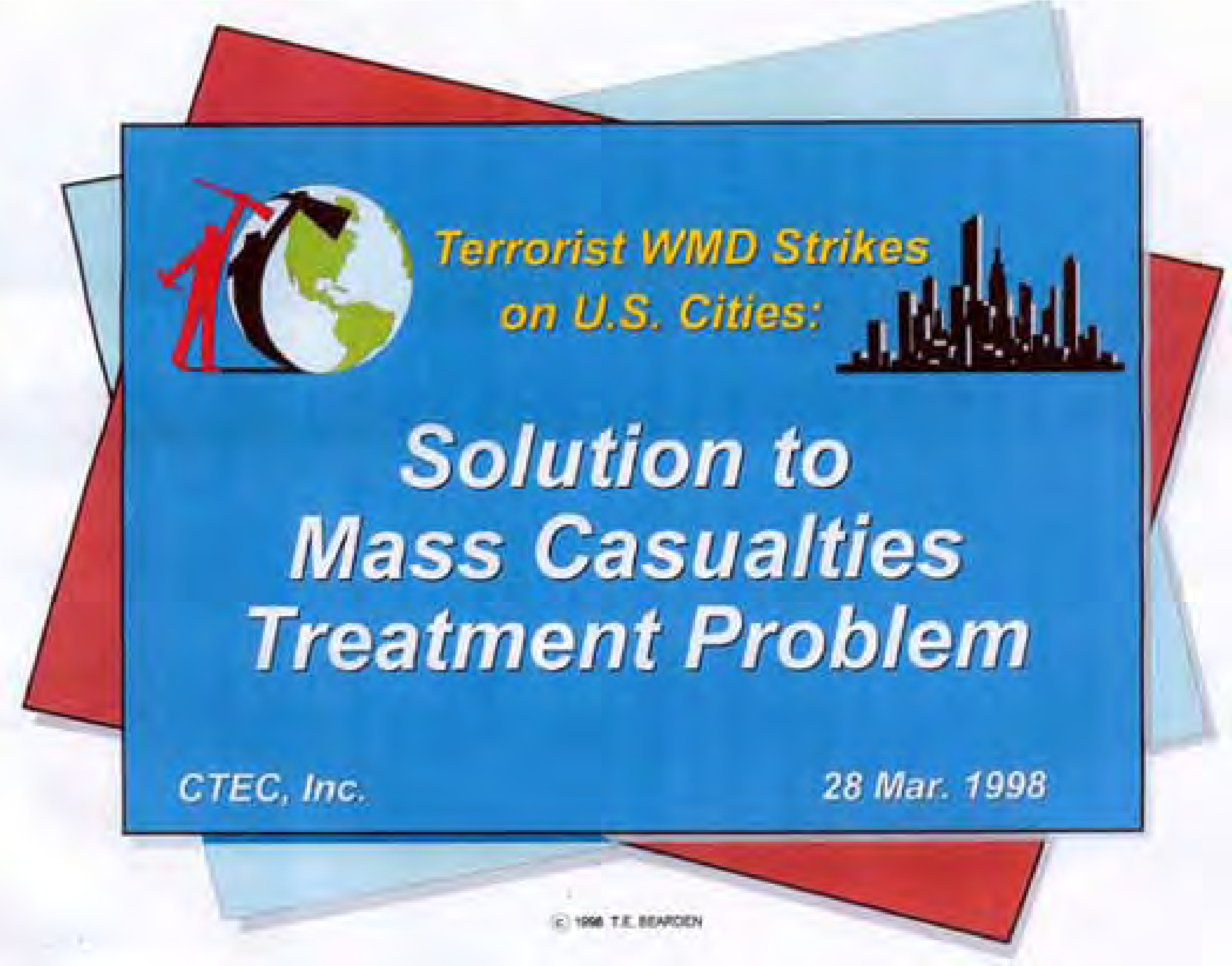

Terrorist WMD Strikes
on U.S. Cities:

Solution to Mass Casualties Treatment Problem

CTEC, Inc.

28 Mar. 1998

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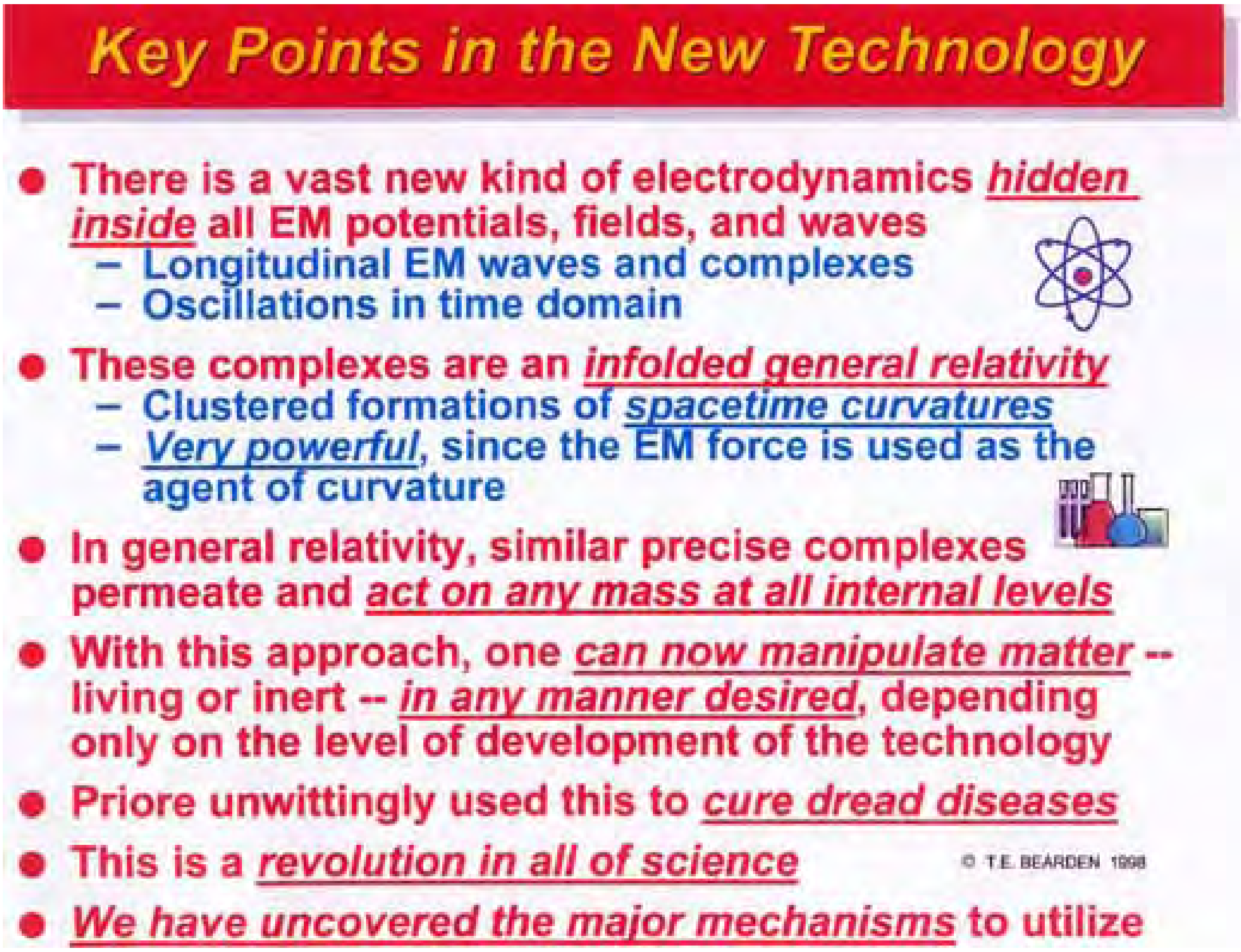

Key Points in the New Technology

- There is a vast new kind of electrodynamics *hidden inside* all EM potentials, fields, and waves
  - Longitudinal EM waves and complexes
  - Oscillations in time domain
- These complexes are an *infolded general relativity*
  - Clustered formations of *spacetime curvatures*
  - *Very powerful*, since the EM force is used as the agent of curvature
- In general relativity, similar precise complexes permeate and *act on any mass at all internal levels*
- With this approach, one *can now manipulate matter* -- living or inert -- *in any manner desired*, depending only on the level of development of the technology
- Priore unwittingly used this to *cure dread diseases*
- This is a *revolution in all of science*
- *We have uncovered the major mechanisms* to utilize

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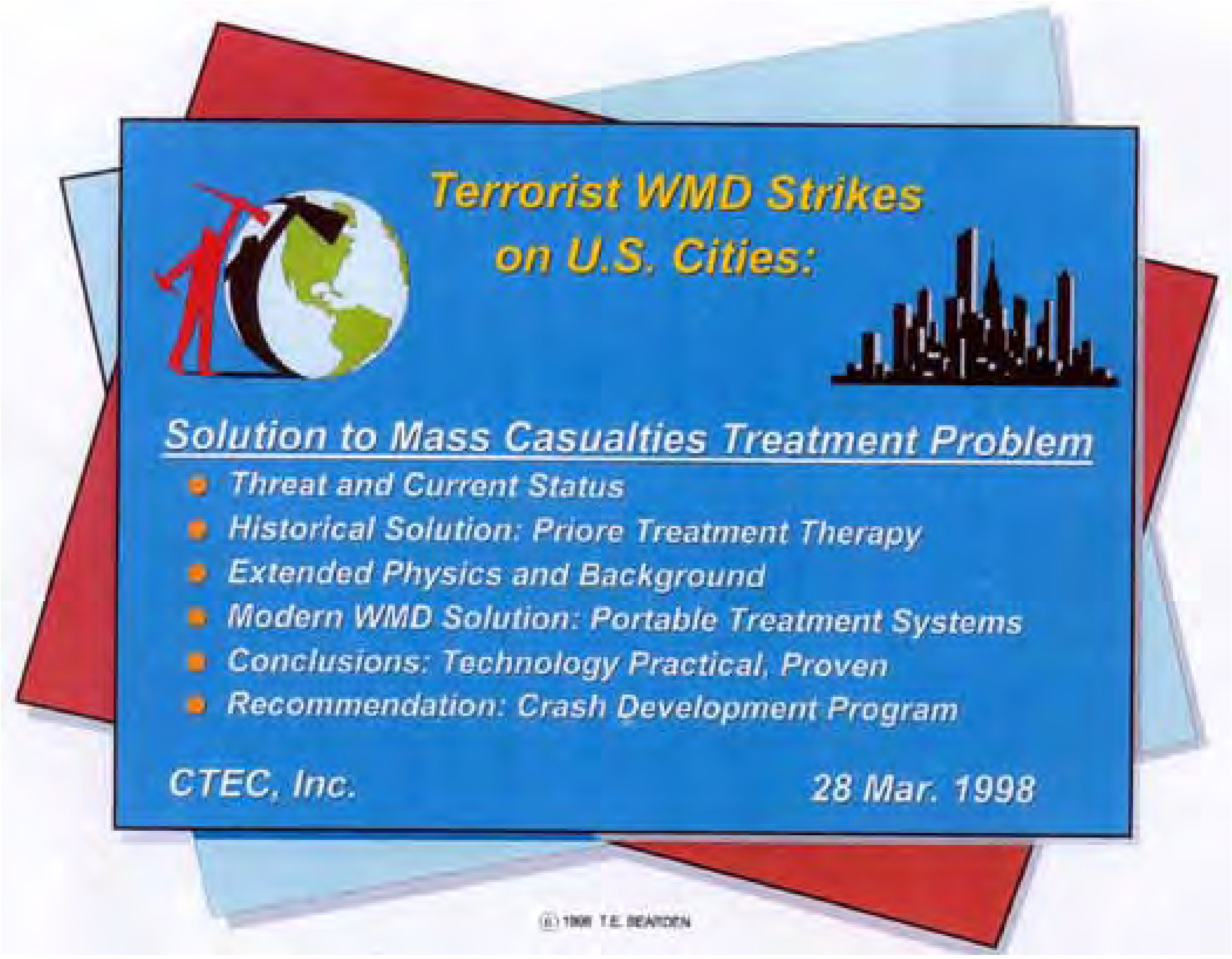

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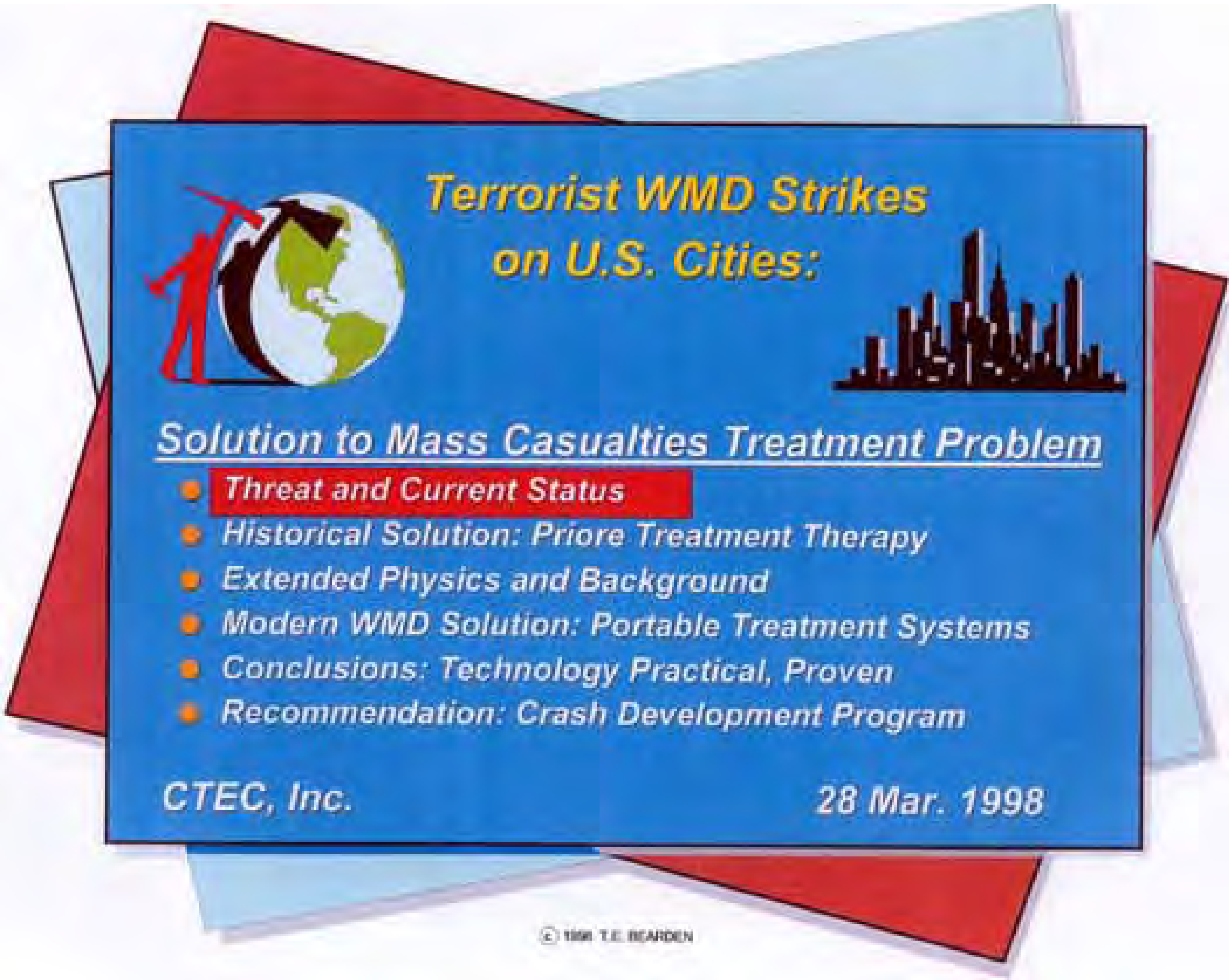

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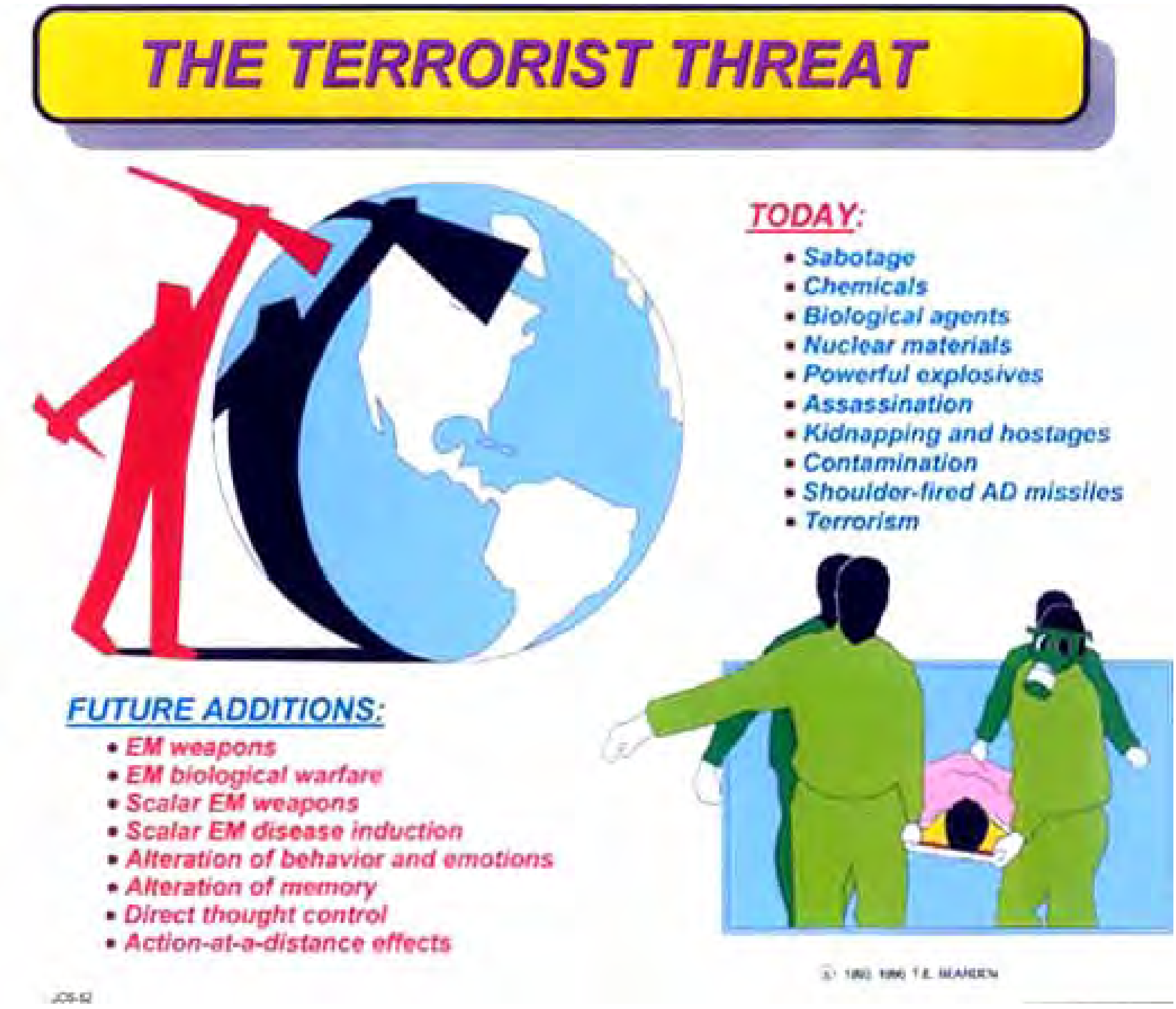

THE TERRORIST THREAT

TODAY:

- Sabotage
- Chemicals
- Biological agents
- Nuclear materials
- Powerful explosives
- Assassination
- Kidnapping and hostages
- Contamination
- Shoulder-fired AD missiles
- Terrorism

FUTURE ADDITIONS:

- EM weapons
- EM biological warfare
- Scalar EM weapons
- Scalar EM disease induction
- Alteration of behavior and emotions
- Alteration of memory
- Direct thought control
- Action-at-a-distance effects

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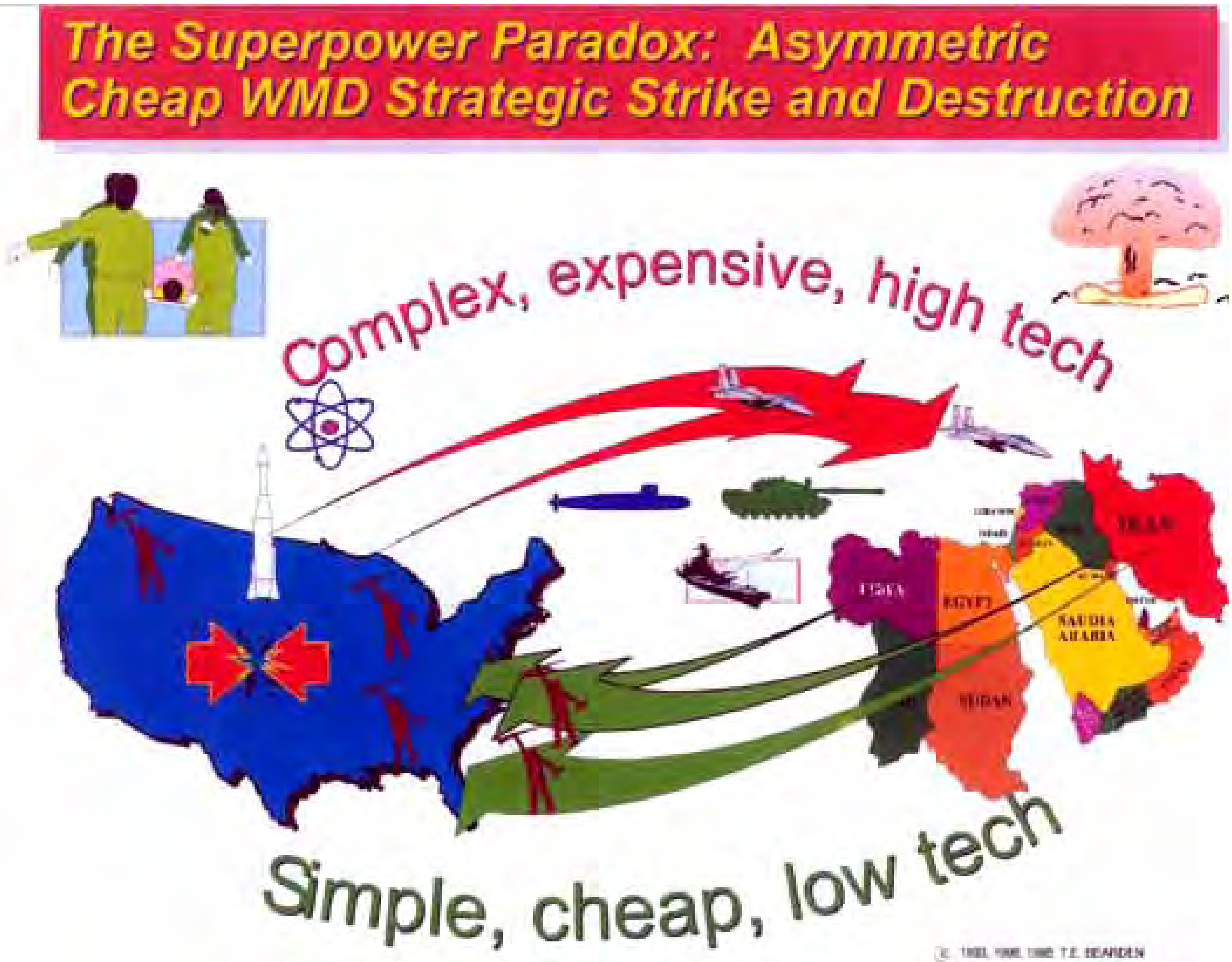

The Superpower Paradox: Asymmetric Cheap WMD Strategic Strike and Destruction

Complex, expensive, high tech

Simple, cheap, low tech

LIBYA
EGYPT
SUDAN
SAUDIA ARABIA
IRAN

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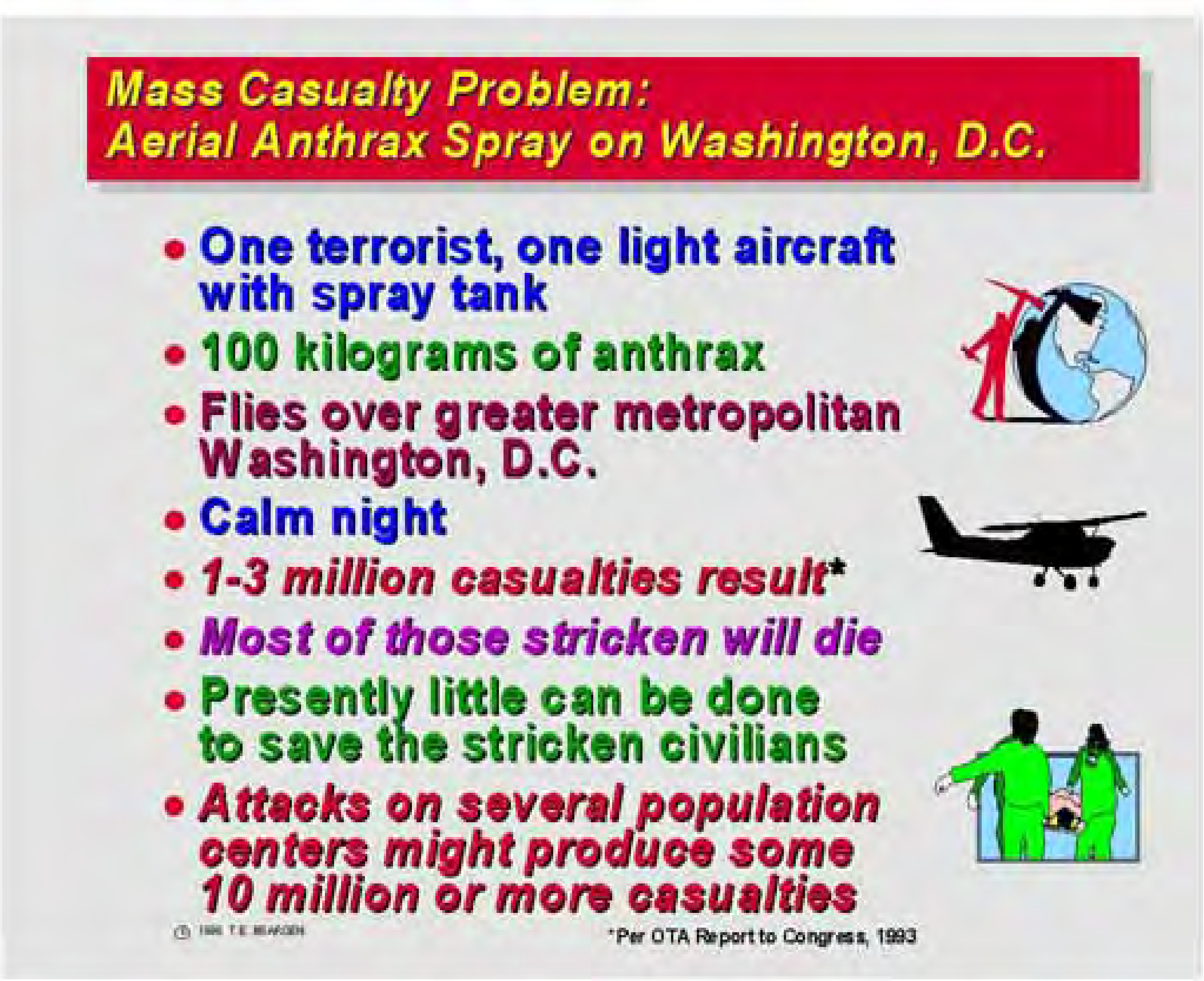

Mass Casualty Problem: Aerial Anthrax Spray on Washington, D.C.

- One terrorist, one light aircraft with spray tank
- 100 kilograms of anthrax
- Flies over greater metropolitan Washington, D.C.
- Calm night
- *1-3 million casualties result**
- *Most of those stricken will die*
- Presently little can be done to save the stricken civilians
- *Attacks on several population centers might produce some 10 million or more casualties*

*Per OTA Report to Congress, 1993

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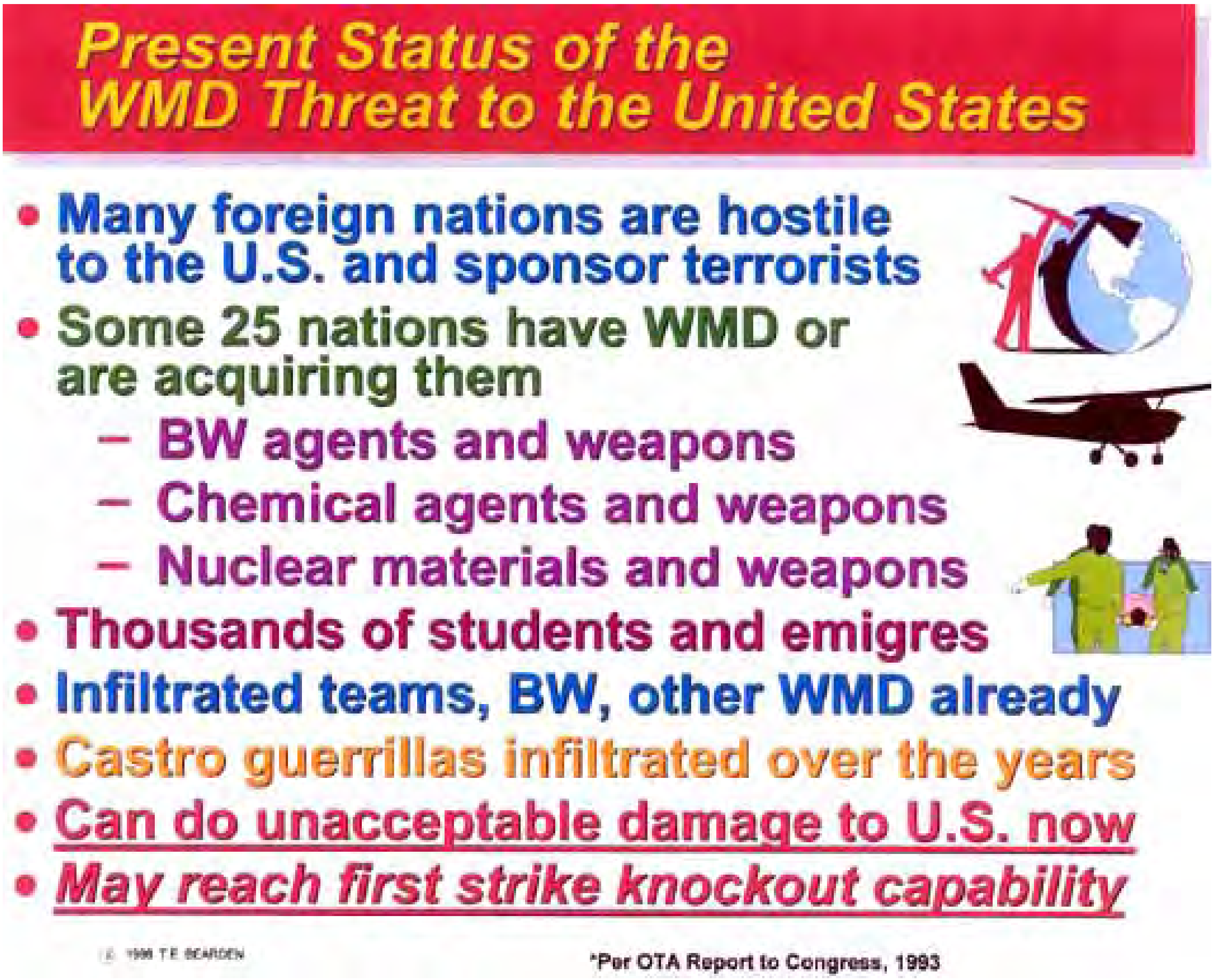

Present Status of the WMD Threat to the United States

- Many foreign nations are hostile to the U.S. and sponsor terrorists
- Some 25 nations have WMD or are acquiring them
  - BW agents and weapons
  - Chemical agents and weapons
  - Nuclear materials and weapons
- Thousands of students and emigres
- Infiltrated teams, BW, other WMD already
- Castro guerrillas infiltrated over the years
- Can do unacceptable damage to U.S. now
- *May reach first strike knockout capability*

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*Per OTA Report to Congress, 1993

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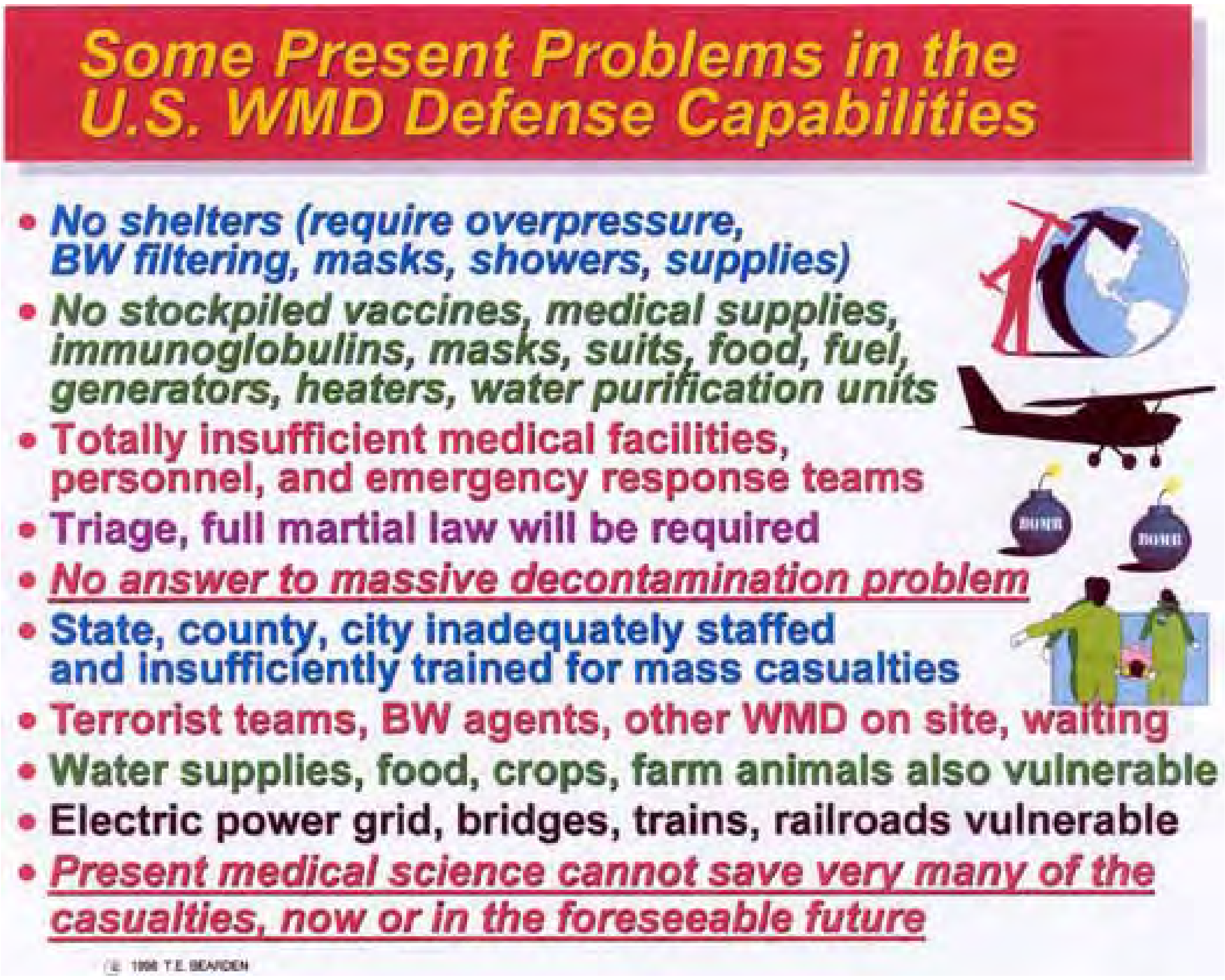

Some Present Problems in the U.S. WMD Defense Capabilities

- *No shelters (require overpressure, BW filtering, masks, showers, supplies)*
- *No stockpiled vaccines, medical supplies, immunoglobulins, masks, suits, food, fuel, generators, heaters, water purification units*
- Totally insufficient medical facilities, personnel, and emergency response teams
- Triage, full martial law will be required
- *No answer to massive decontamination problem*
- State, county, city inadequately staffed and insufficiently trained for mass casualties
- Terrorist teams, BW agents, other WMD on site, waiting
- Water supplies, food, crops, farm animals also vulnerable
- Electric power grid, bridges, trains, railroads vulnerable
- *Present medical science cannot save very many of the casualties, now or in the foreseeable future*

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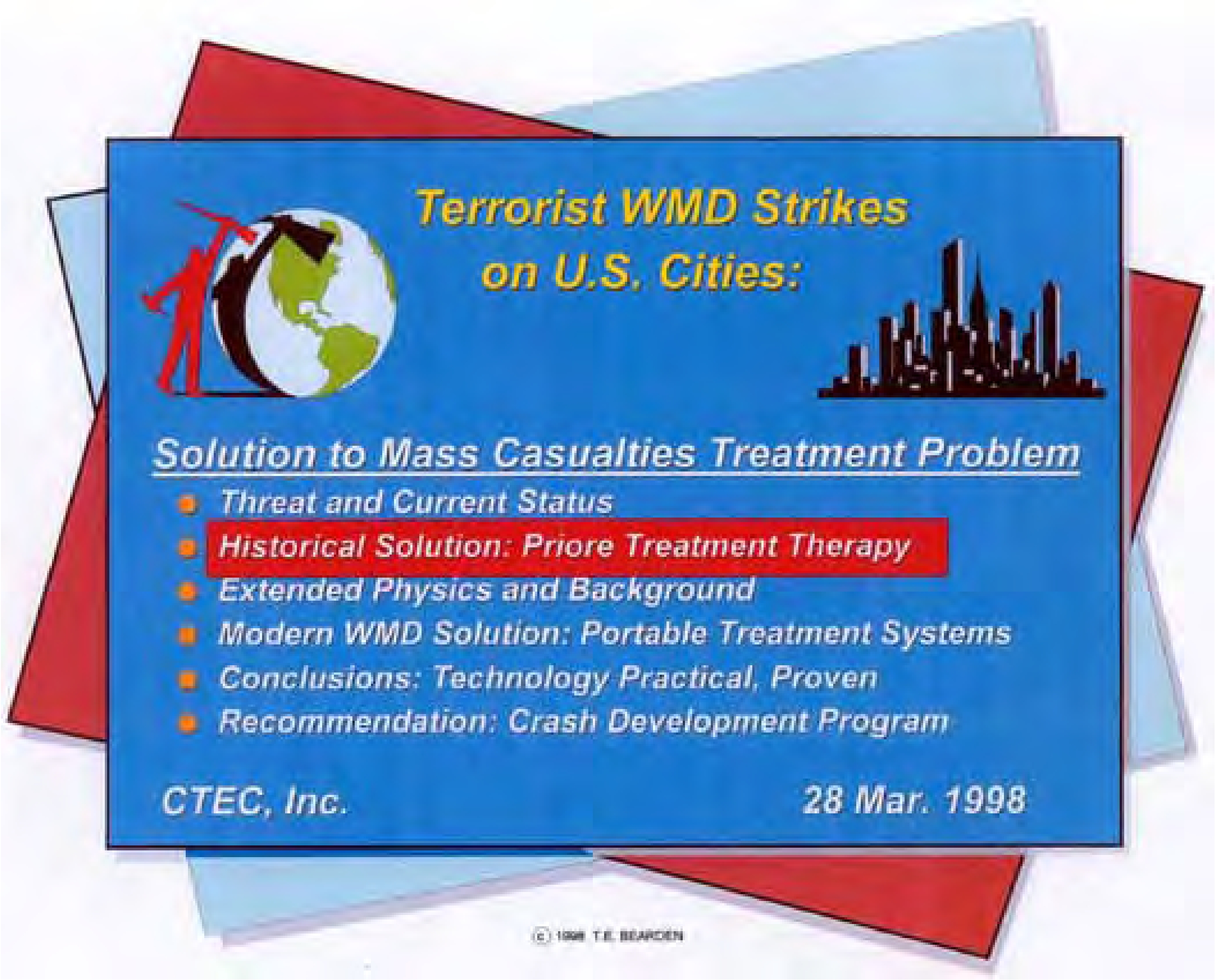

Terrorist WMD Strikes on U.S. Cities:

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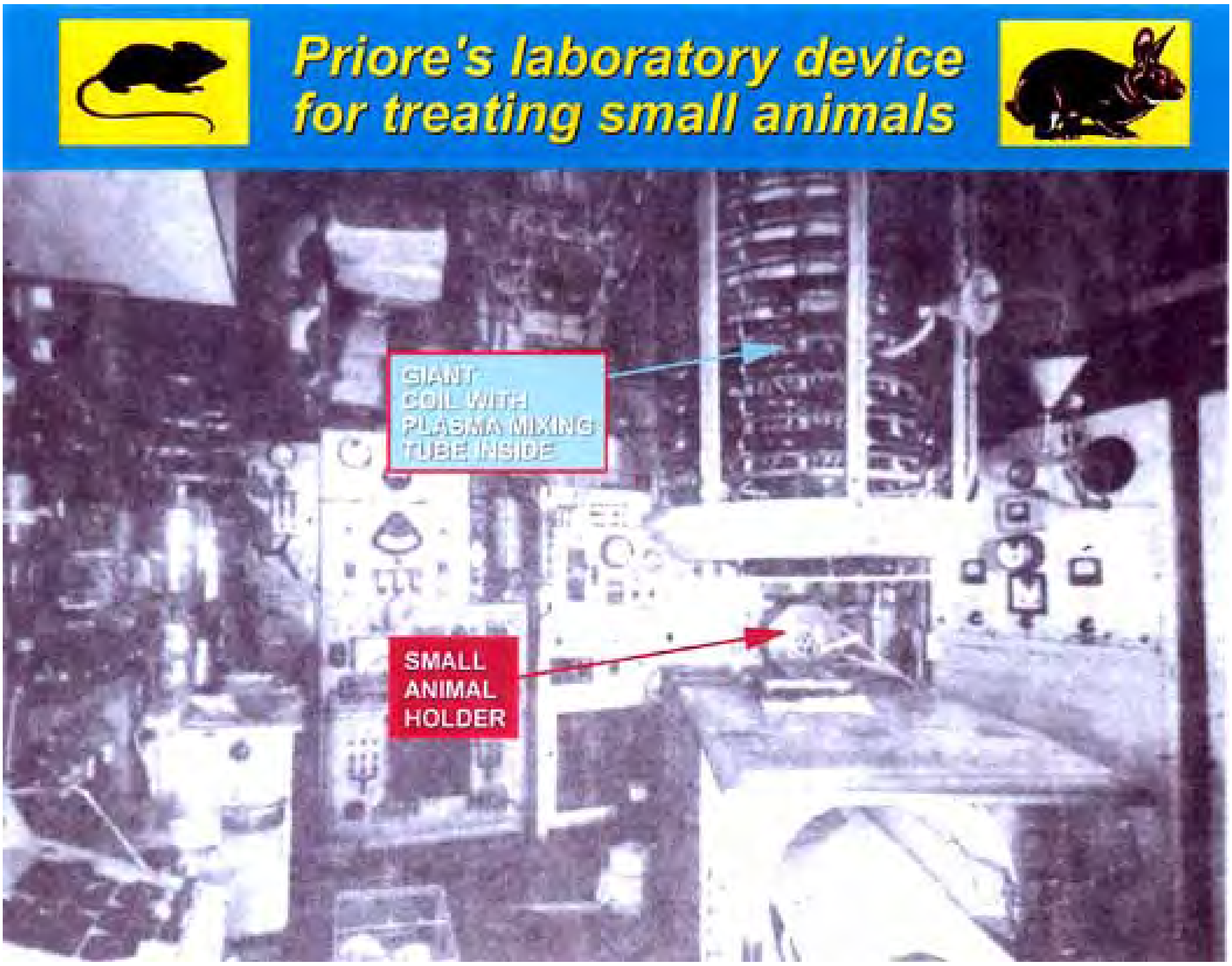

Priore's laboratory device for treating small animals

GIANT COIL WITH PLASMA MIXING TUBE INSIDE
SMALL ANIMAL HOLDER

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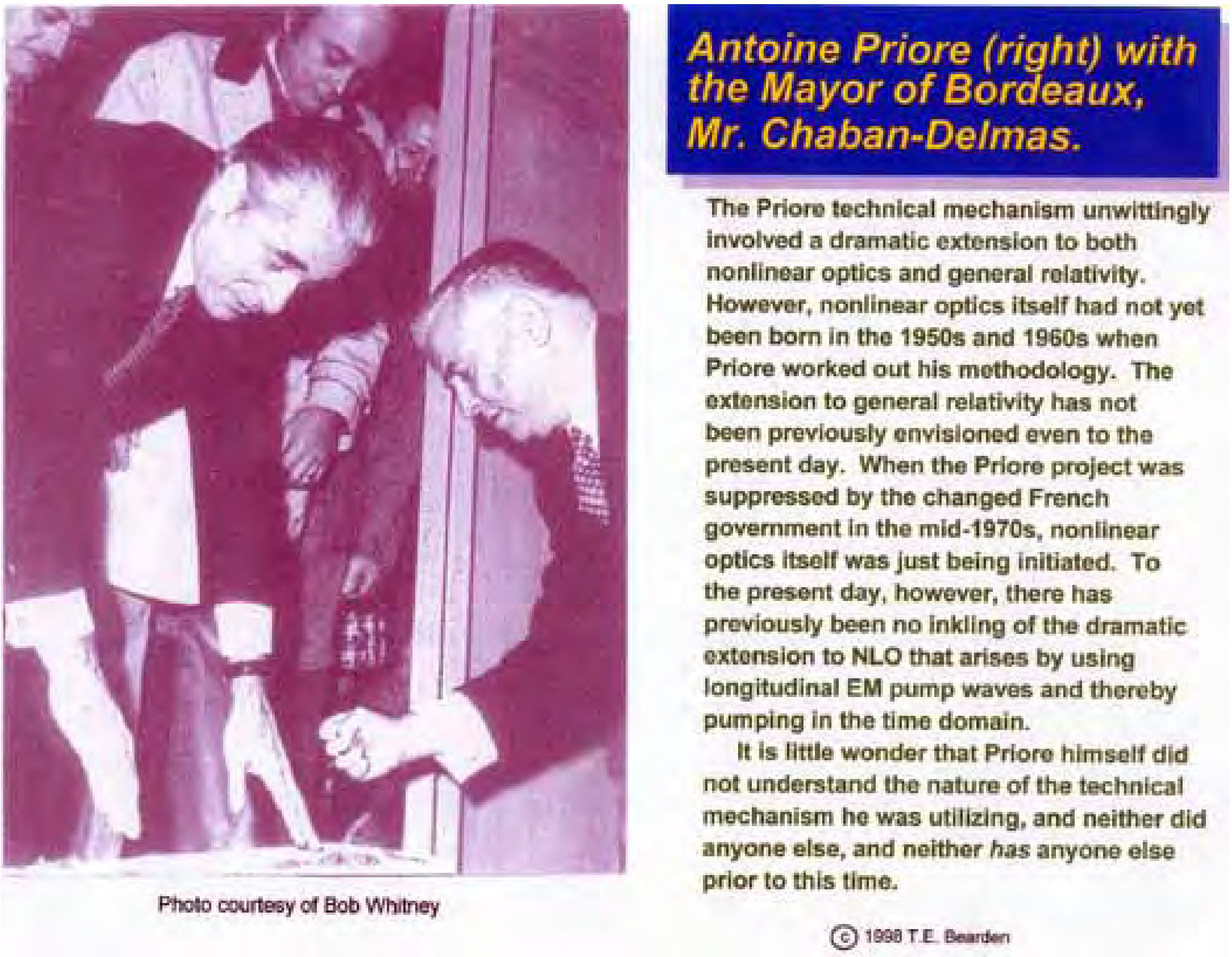

Antoine Priore (right) with the Mayor of Bordeaux, Mr. Chaban-Delmas.

The Priore technical mechanism unwittingly involved a dramatic extension to both nonlinear optics and general relativity. However, nonlinear optics itself had not yet been born in the 1950s and 1960s when Priore worked out his methodology. The extension to general relativity has not been previously envisioned even to the present day. When the Priore project was suppressed by the changed French government in the mid-1970s, nonlinear optics itself was just being initiated. To the present day, however, there has previously been no inkling of the dramatic extension to NLO that arises by using longitudinal EM pump waves and thereby pumping in the time domain.

It is little wonder that Priore himself did not understand the nature of the technical mechanism he was utilizing, and neither did anyone else, and neither *has* anyone else prior to this time.

Photo courtesy of Bob Whitney

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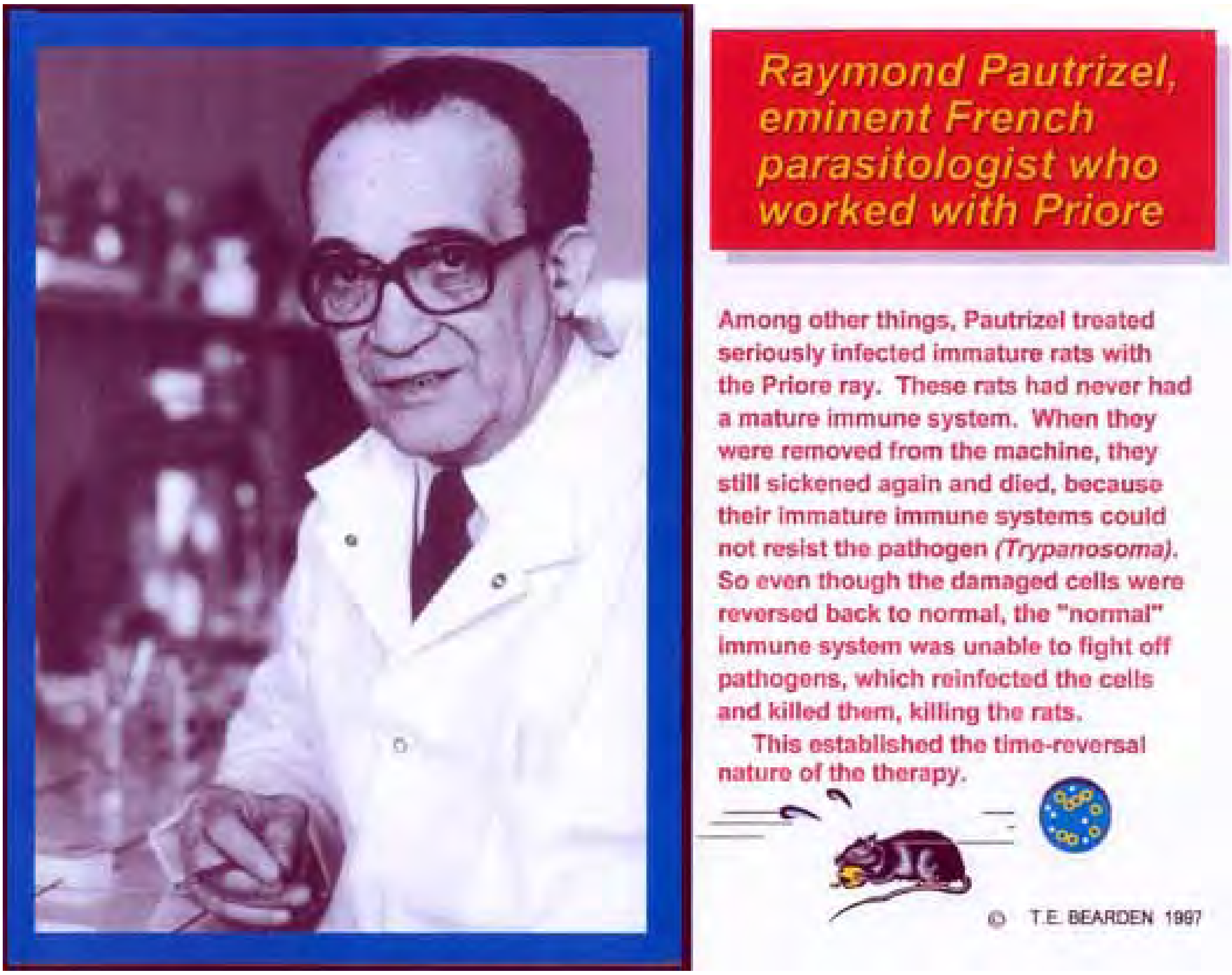

Raymond Pautrizel, eminent French parasitologist who worked with Priore

Among other things, Pautrizel treated seriously infected immature rats with the Priore ray. These rats had never had a mature immune system. When they were removed from the machine, they still sickened again and died, because their immature immune systems could not resist the pathogen *(Trypanosoma)*. So even though the damaged cells were reversed back to normal, the "normal" immune system was unable to fight off pathogens, which reinfected the cells and killed them, killing the rats.

This established the time-reversal nature of the therapy.

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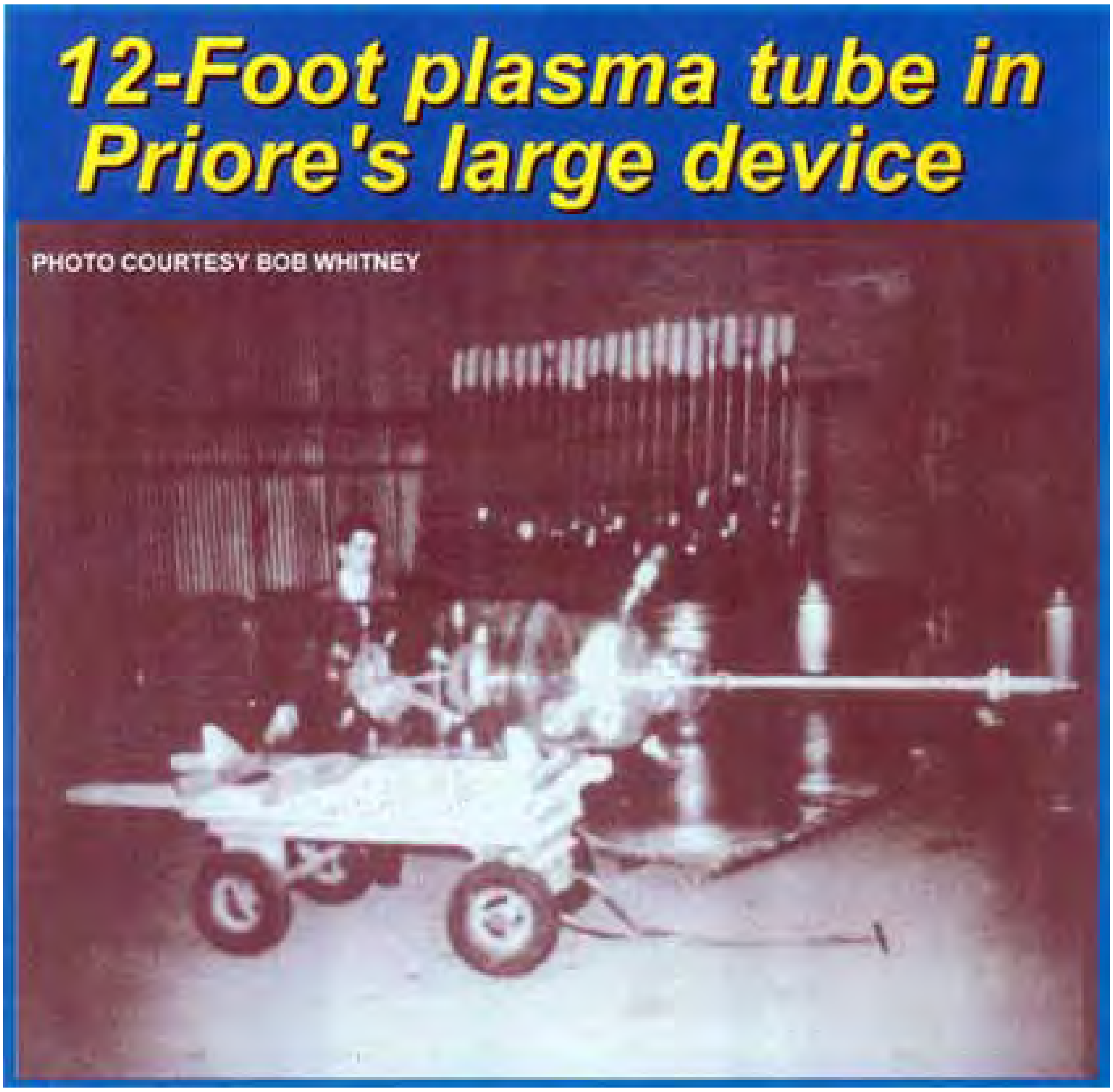

12-Foot plasma tube in Priore's large device

PHOTO COURTESY BOB WHITNEY

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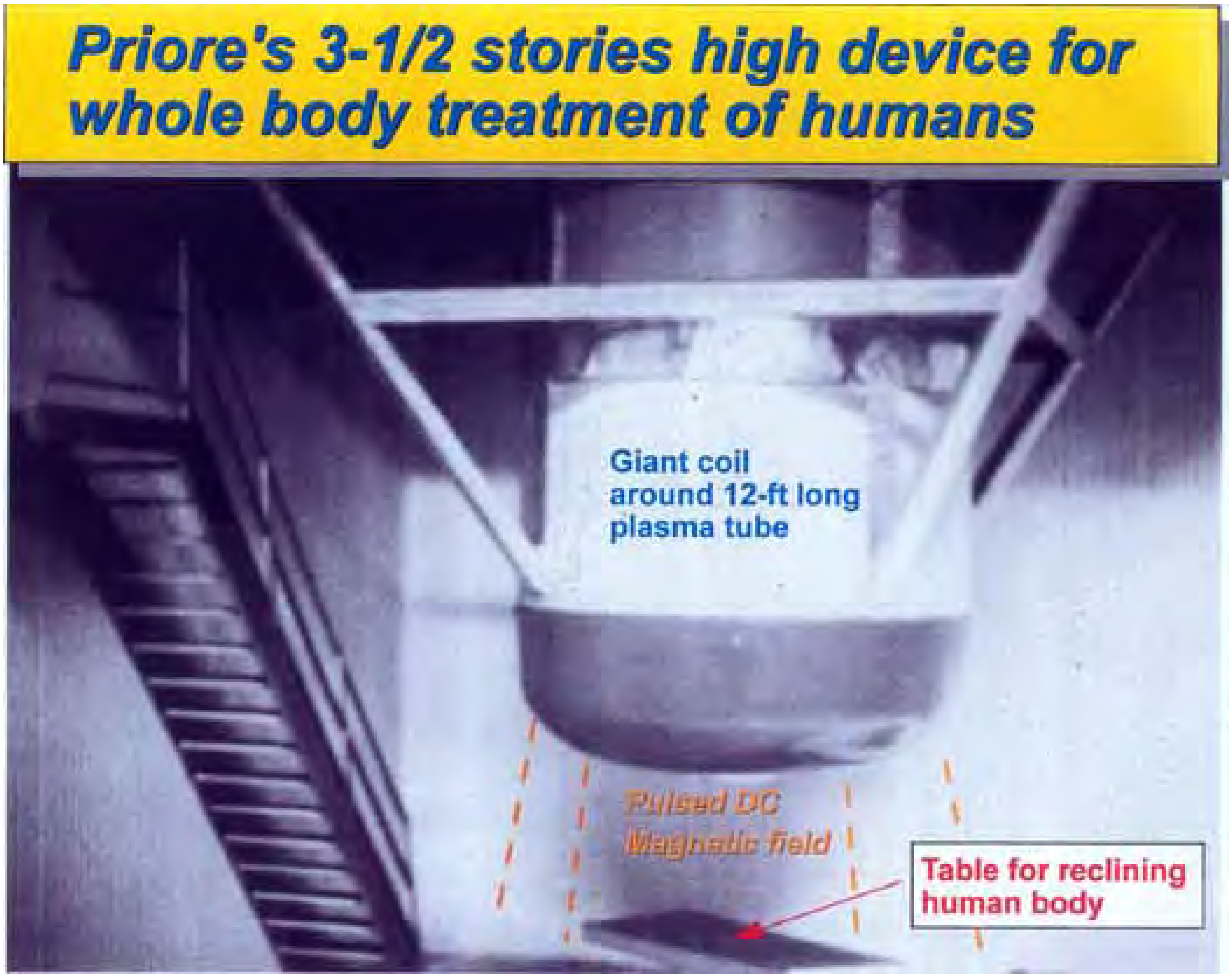

Priore's 3-1/2 stories high device for whole body treatment of humans

Giant coil
around 12-ft long
plasma tube
Pulsed DC
Magnetic field
Table for reclining
human body

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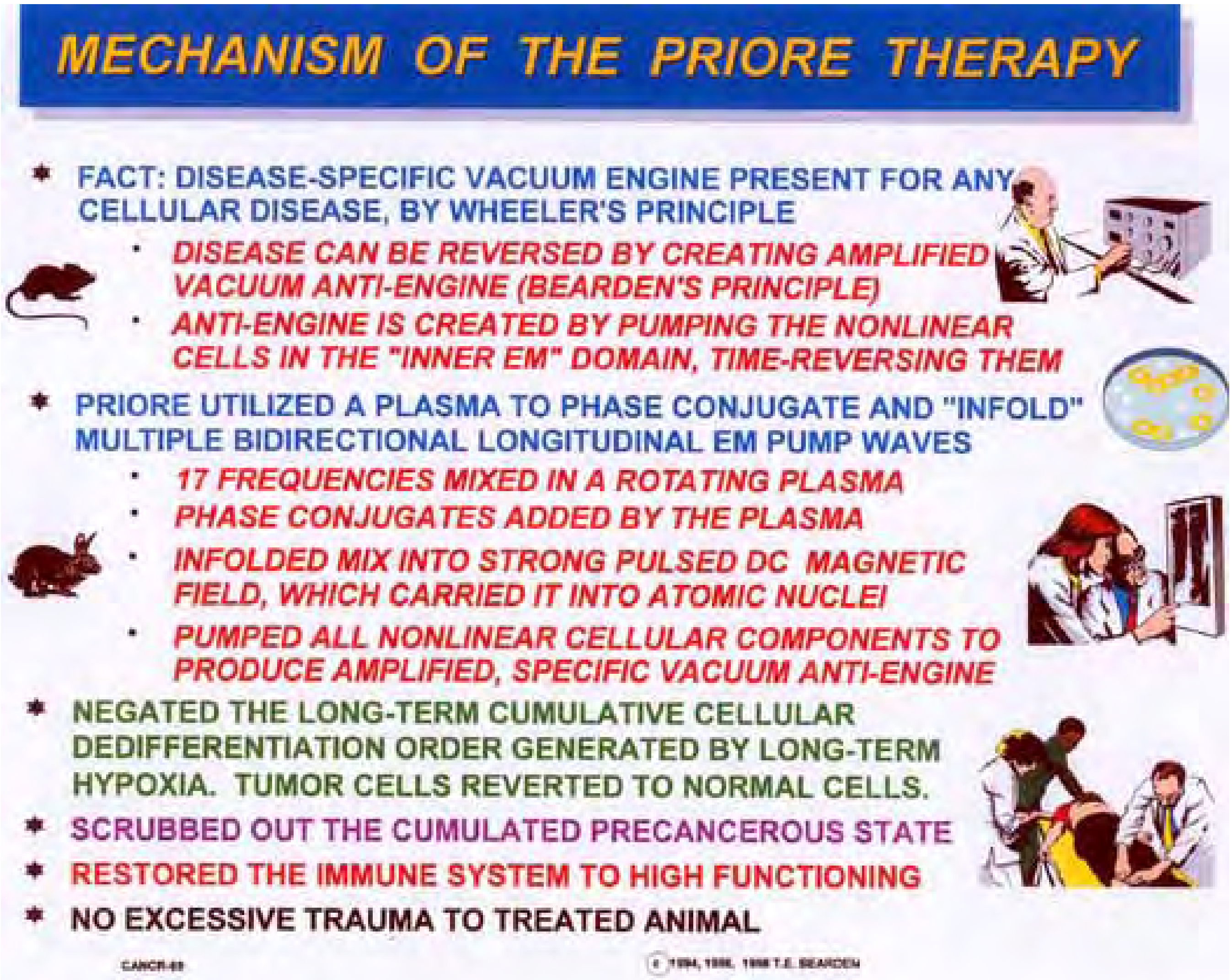

MECHANISM OF THE PRIORE THERAPY

- FACT: DISEASE-SPECIFIC VACUUM ENGINE PRESENT FOR ANY CELLULAR DISEASE, BY WHEELER'S PRINCIPLE
  - *DISEASE CAN BE REVERSED BY CREATING AMPLIFIED VACUUM ANTI-ENGINE (BEARDEN'S PRINCIPLE)*
  - *ANTI-ENGINE IS CREATED BY PUMPING THE NONLINEAR CELLS IN THE "INNER EM" DOMAIN, TIME-REVERSING THEM*
- PRIORE UTILIZED A PLASMA TO PHASE CONJUGATE AND "INFOLD" MULTIPLE BIDIRECTIONAL LONGITUDINAL EM PUMP WAVES
  - *17 FREQUENCIES MIXED IN A ROTATING PLASMA*
  - *PHASE CONJUGATES ADDED BY THE PLASMA*
  - *INFOLDED MIX INTO STRONG PULSED DC MAGNETIC FIELD, WHICH CARRIED IT INTO ATOMIC NUCLEI*
  - *PUMPED ALL NONLINEAR CELLULAR COMPONENTS TO PRODUCE AMPLIFIED, SPECIFIC VACUUM ANTI-ENGINE*
- NEGATED THE LONG-TERM CUMULATIVE CELLULAR DEDIFFERENTIATION ORDER GENERATED BY LONG-TERM HYPOXIA. TUMOR CELLS REVERTED TO NORMAL CELLS.
- SCRUBBED OUT THE CUMULATED PRECANCEROUS STATE
- RESTORED THE IMMUNE SYSTEM TO HIGH FUNCTIONING
- NO EXCESSIVE TRAUMA TO TREATED ANIMAL

CANCR-69

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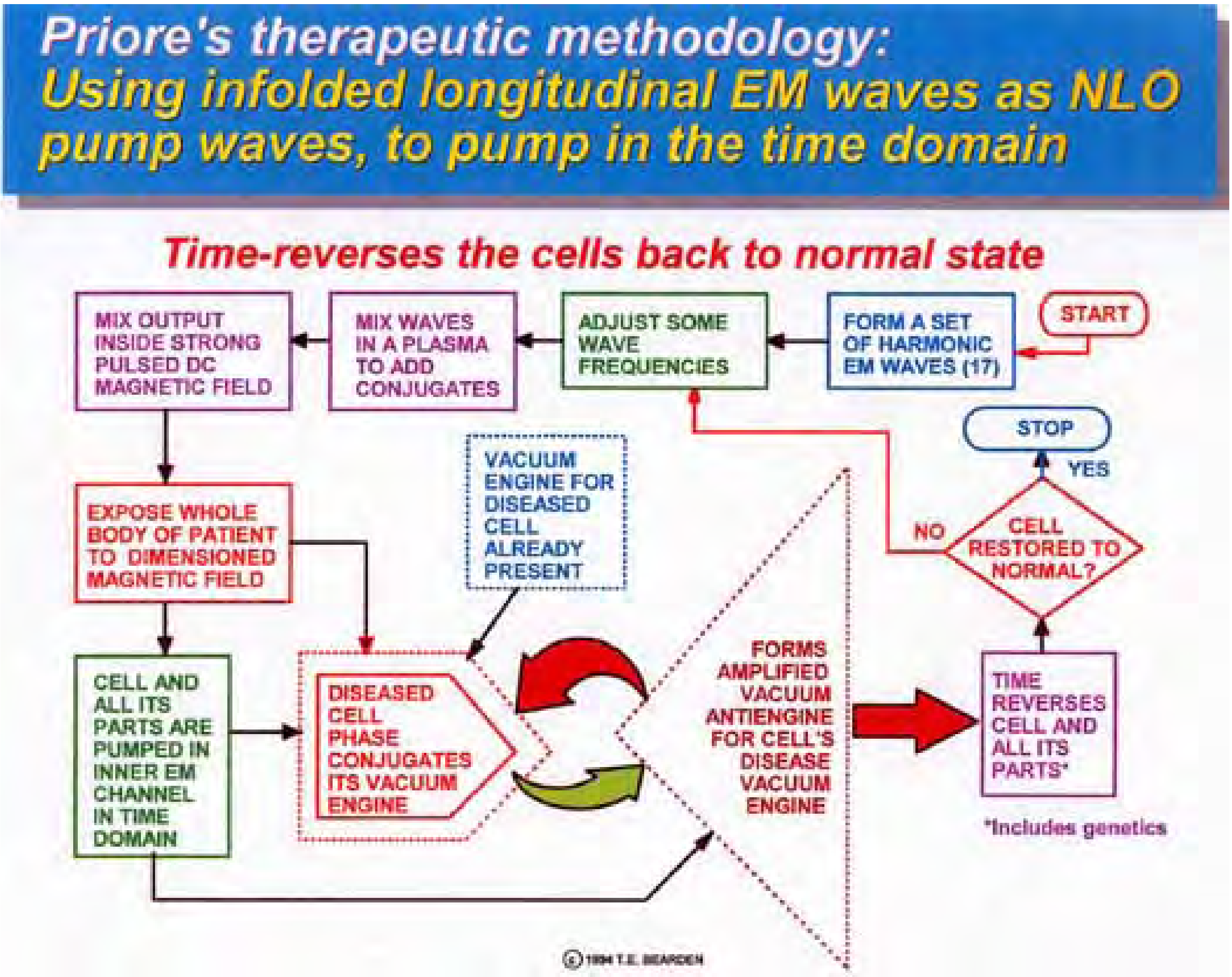

Priore's therapeutic methodology: Using infolded longitudinal EM waves as NLO pump waves, to pump in the time domain

Time-reverses the cells back to normal state

START

FORM A SET OF HARMONIC EM WAVES (17)

ADJUST SOME WAVE FREQUENCIES

MIX WAVES IN A PLASMA TO ADD CONJUGATES

MIX OUTPUT INSIDE STRONG PULSED DC MAGNETIC FIELD

EXPOSE WHOLE BODY OF PATIENT TO DIMENSIONED MAGNETIC FIELD

CELL AND ALL ITS PARTS ARE PUMPED IN INNER EM CHANNEL IN TIME DOMAIN

VACUUM ENGINE FOR DISEASED CELL ALREADY PRESENT

DISEASED CELL PHASE CONJUGATES ITS VACUUM ENGINE

FORMS AMPLIFIED VACUUM ANTIENGINE FOR CELL'S DISEASE VACUUM ENGINE

TIME REVERSES CELL AND ALL ITS PARTS*

CELL RESTORED TO NORMAL?

YES

STOP

NO

*Includes genetics

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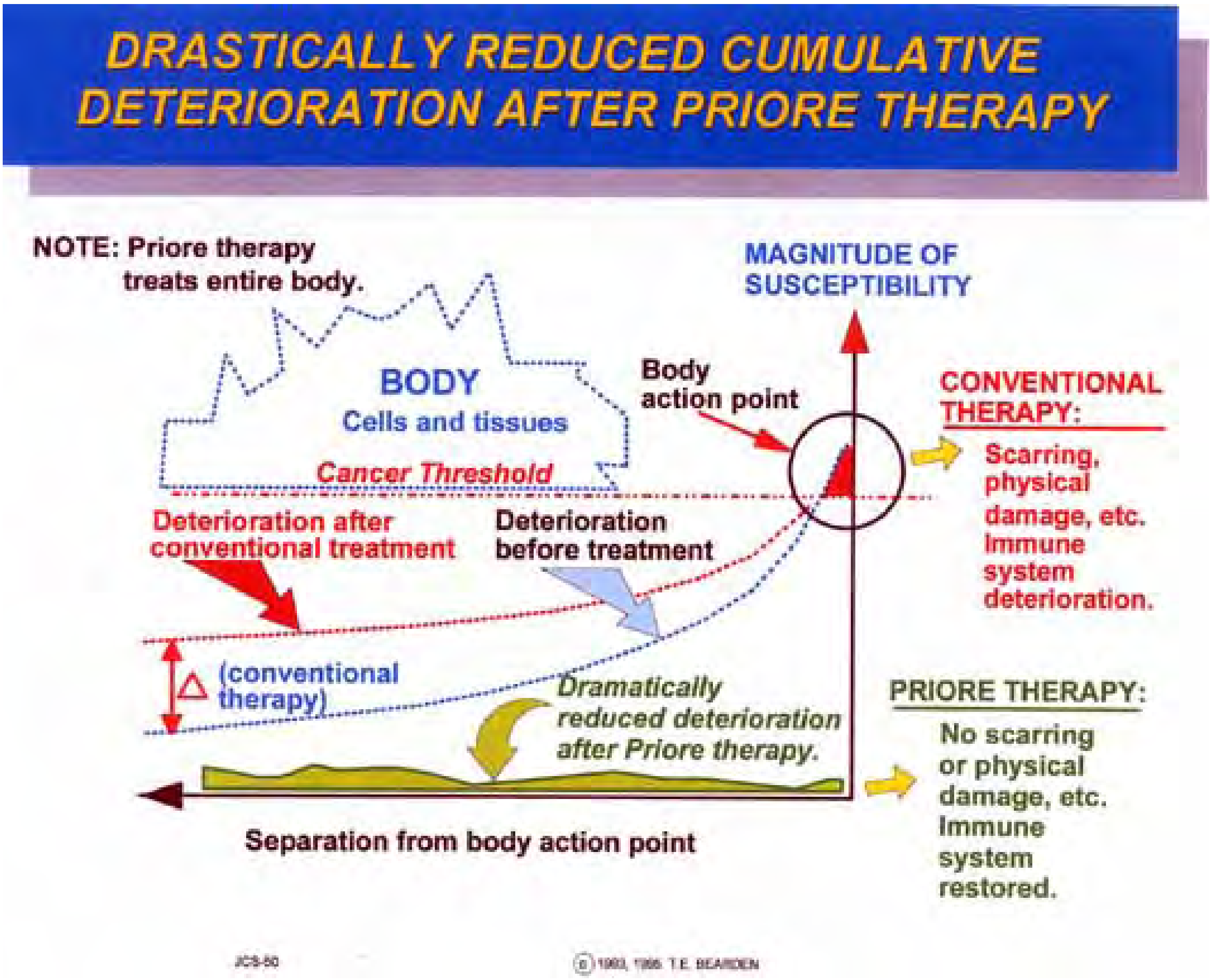

DRASTICALLY REDUCED CUMULATIVE DETERIORATION AFTER PRIORE THERAPY

NOTE: Priore therapy treats entire body.

MAGNITUDE OF SUSCEPTIBILITY

BODY
Cells and tissues

Body action point

Cancer Threshold

CONVENTIONAL THERAPY:
Scarring, physical damage, etc. Immune system deterioration.

Deterioration after conventional treatment

Deterioration before treatment

Δ (conventional therapy)

Dramatically reduced deterioration after Priore therapy.

PRIORE THERAPY:
No scarring or physical damage, etc. Immune system restored.

Separation from body action point

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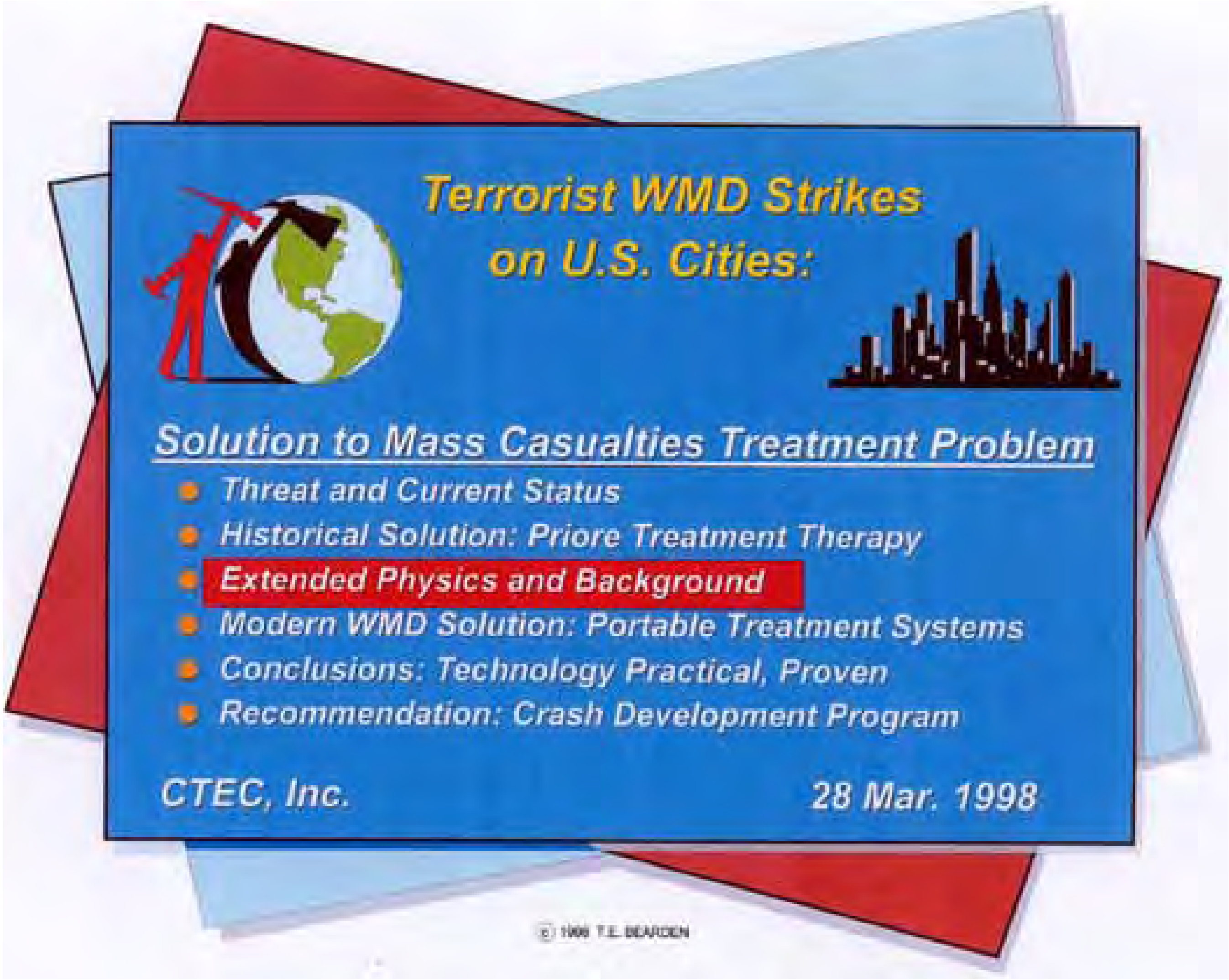

Terrorist WMD Strikes on U.S. Cities:

Solution to Mass Casualties Treatment Problem

- Threat and Current Status
- Historical Solution: Priore Treatment Therapy
- Extended Physics and Background
- Modern WMD Solution: Portable Treatment Systems
- Conclusions: Technology Practical, Proven
- Recommendation: Crash Development Program

CTEC, Inc.

28 Mar. 1998

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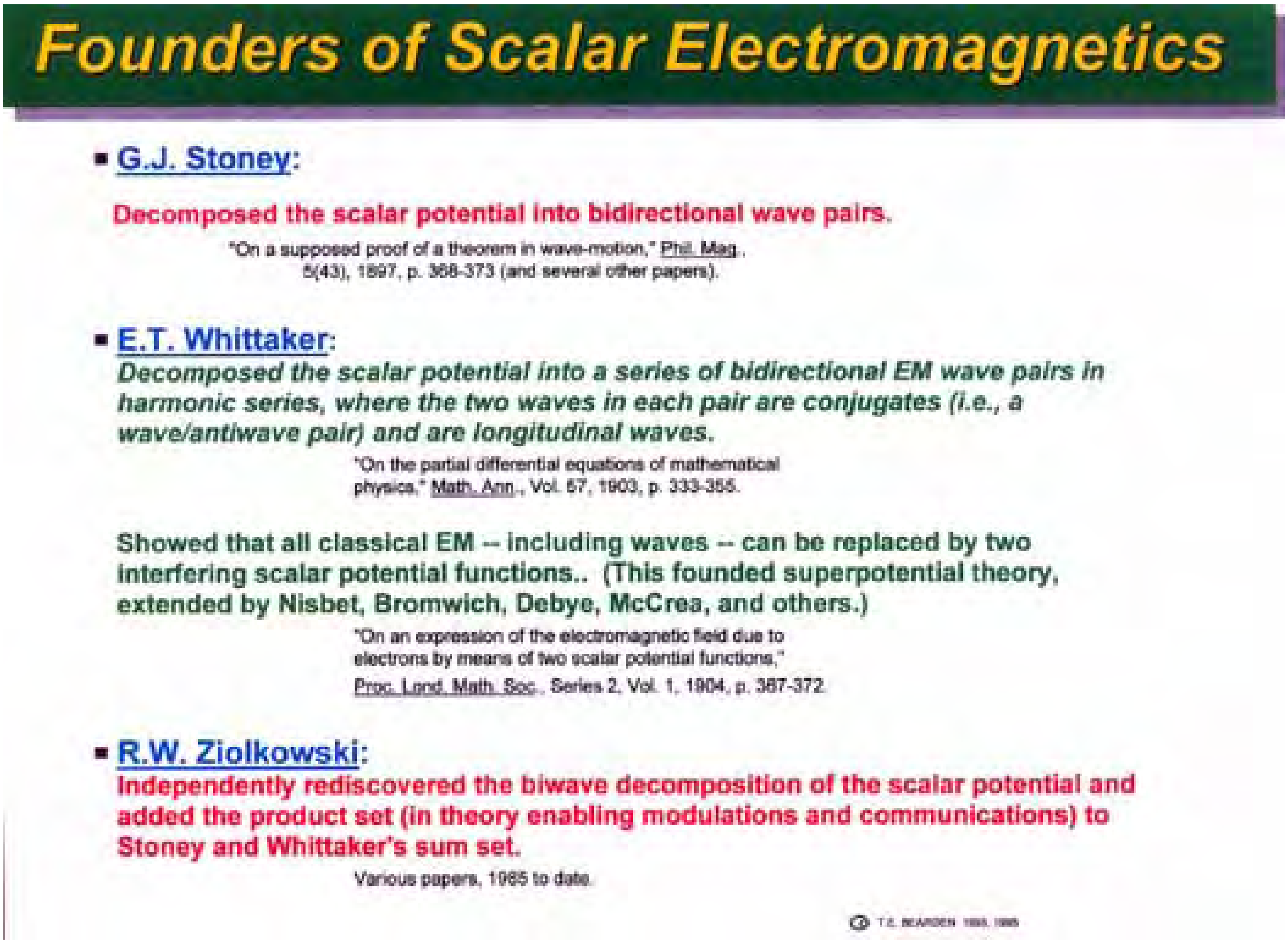

Founders of Scalar Electromagnetics

- **G.J. Stoney:**

Decomposed the scalar potential into bidirectional wave pairs.

"On a supposed proof of a theorem in wave-motion," Phil. Mag., 5(43), 1897, p. 368-373 (and several other papers).

- **E.T. Whittaker:**

Decomposed the scalar potential into a series of bidirectional EM wave pairs in harmonic series, where the two waves in each pair are conjugates (i.e., a wave/antiwave pair) and are longitudinal waves.

"On the partial differential equations of mathematical physics," Math. Ann., Vol. 57, 1903, p. 333-355.

Showed that all classical EM -- including waves -- can be replaced by two interfering scalar potential functions.. (This founded superpotential theory, extended by Nisbet, Bromwich, Debye, McCrea, and others.)

"On an expression of the electromagnetic field due to electrons by means of two scalar potential functions," Proc. Lond. Math. Soc., Series 2, Vol. 1, 1904, p. 367-372.

- **R.W. Ziolkowski:**

Independently rediscovered the biwave decomposition of the scalar potential and added the product set (in theory enabling modulations and communications) to Stoney and Whittaker's sum set.

Various papers, 1985 to date.

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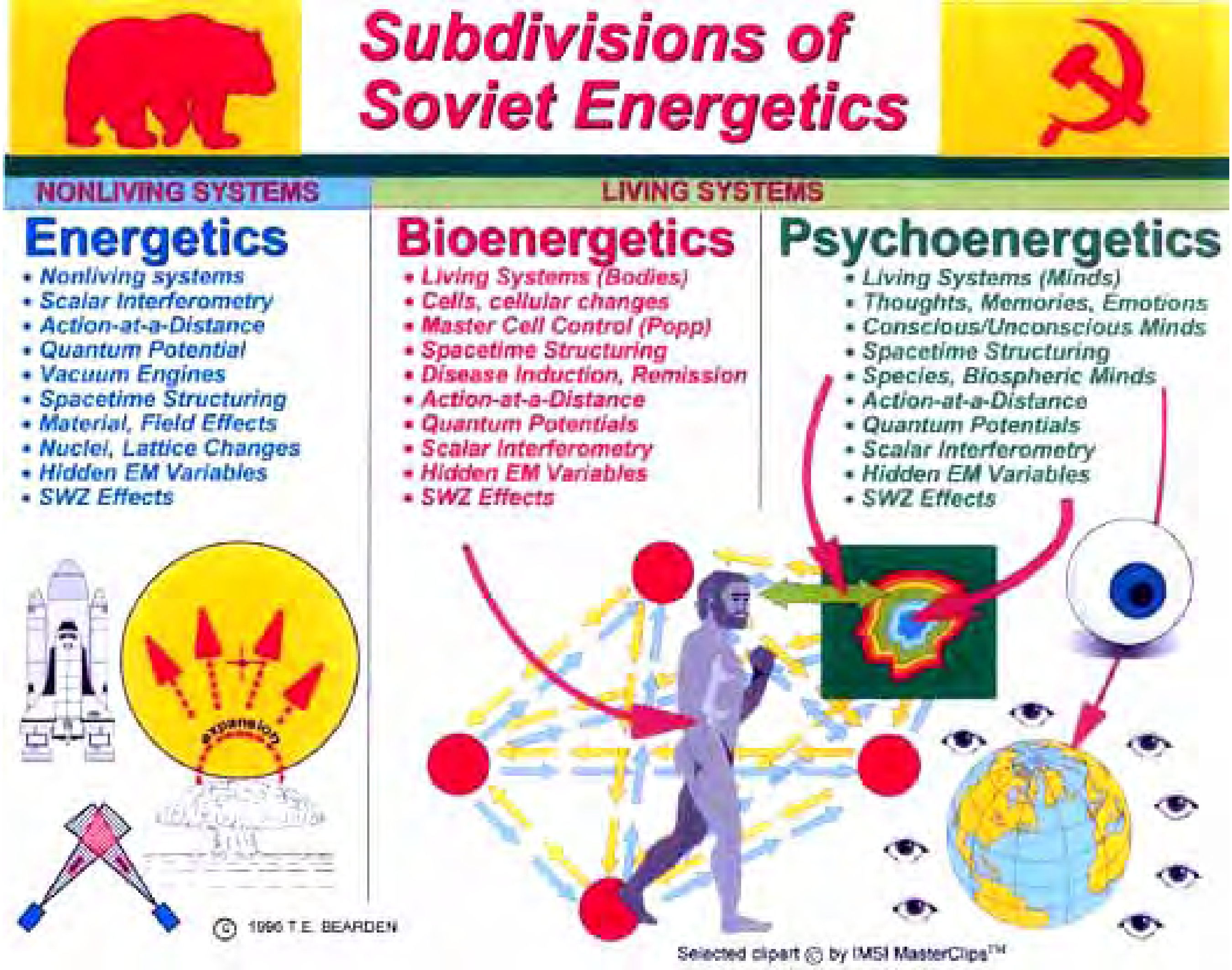

Subdivisions of Soviet Energetics

NONLIVING SYSTEMS

Energetics

- Nonliving systems
- Scalar Interferometry
- Action-at-a-Distance
- Quantum Potential
- Vacuum Engines
- Spacetime Structuring
- Material, Field Effects
- Nuclei, Lattice Changes
- Hidden EM Variables
- SWZ Effects

LIVING SYSTEMS

Bioenergetics

- Living Systems (Bodies)
- Cells, cellular changes
- Master Cell Control (Popp)
- Spacetime Structuring
- Disease Induction, Remission
- Action-at-a-Distance
- Quantum Potentials
- Scalar Interferometry
- Hidden EM Variables
- SWZ Effects

Psychoenergetics

- Living Systems (Minds)
- Thoughts, Memories, Emotions
- Conscious/Unconscious Minds
- Spacetime Structuring
- Species, Biospheric Minds
- Action-at-a-Distance
- Quantum Potentials
- Scalar Interferometry
- Hidden EM Variables
- SWZ Effects

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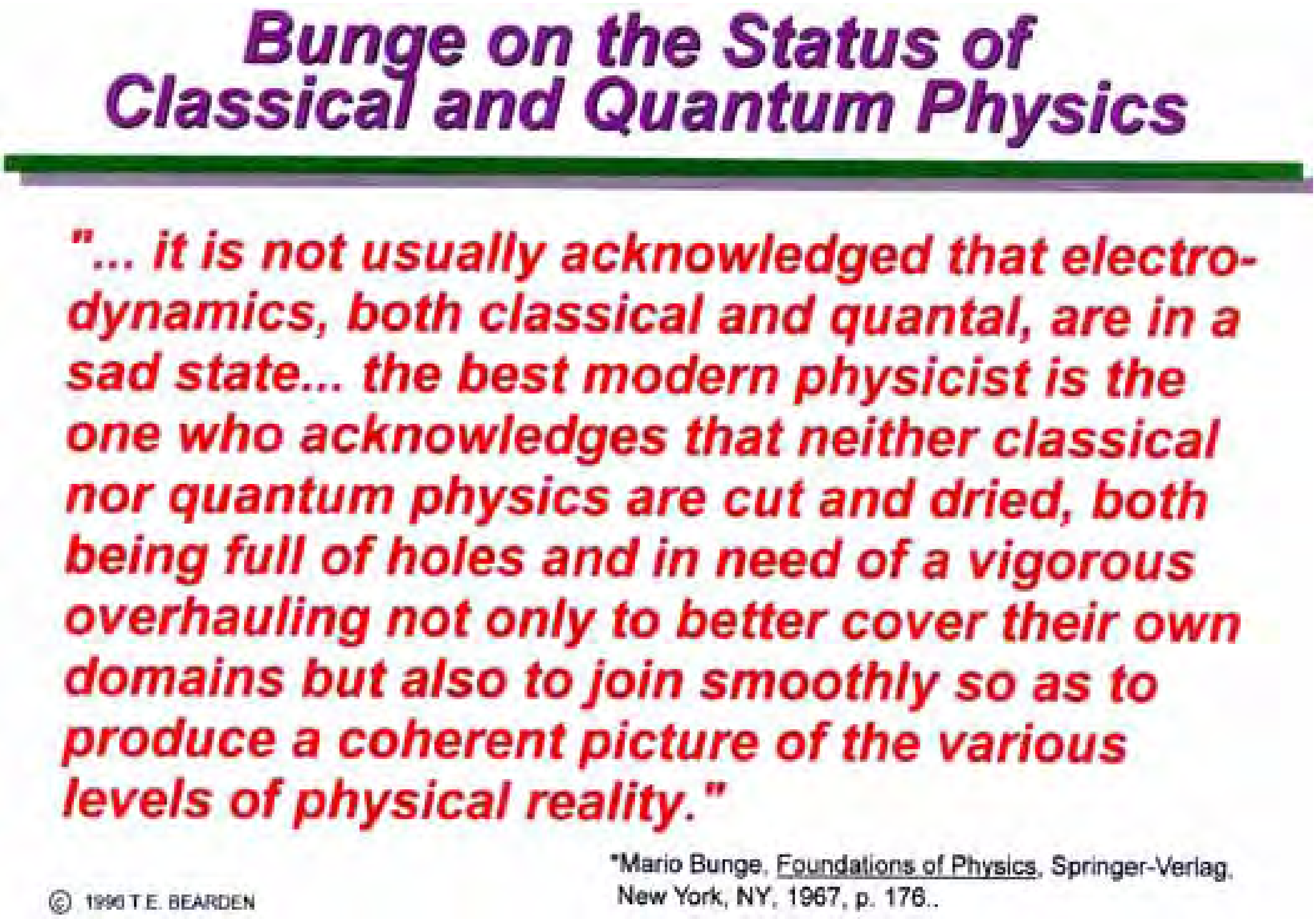

Bunge on the Status of Classical and Quantum Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling not only to better cover their own domains but also to join smoothly so as to produce a coherent picture of the various levels of physical reality."

*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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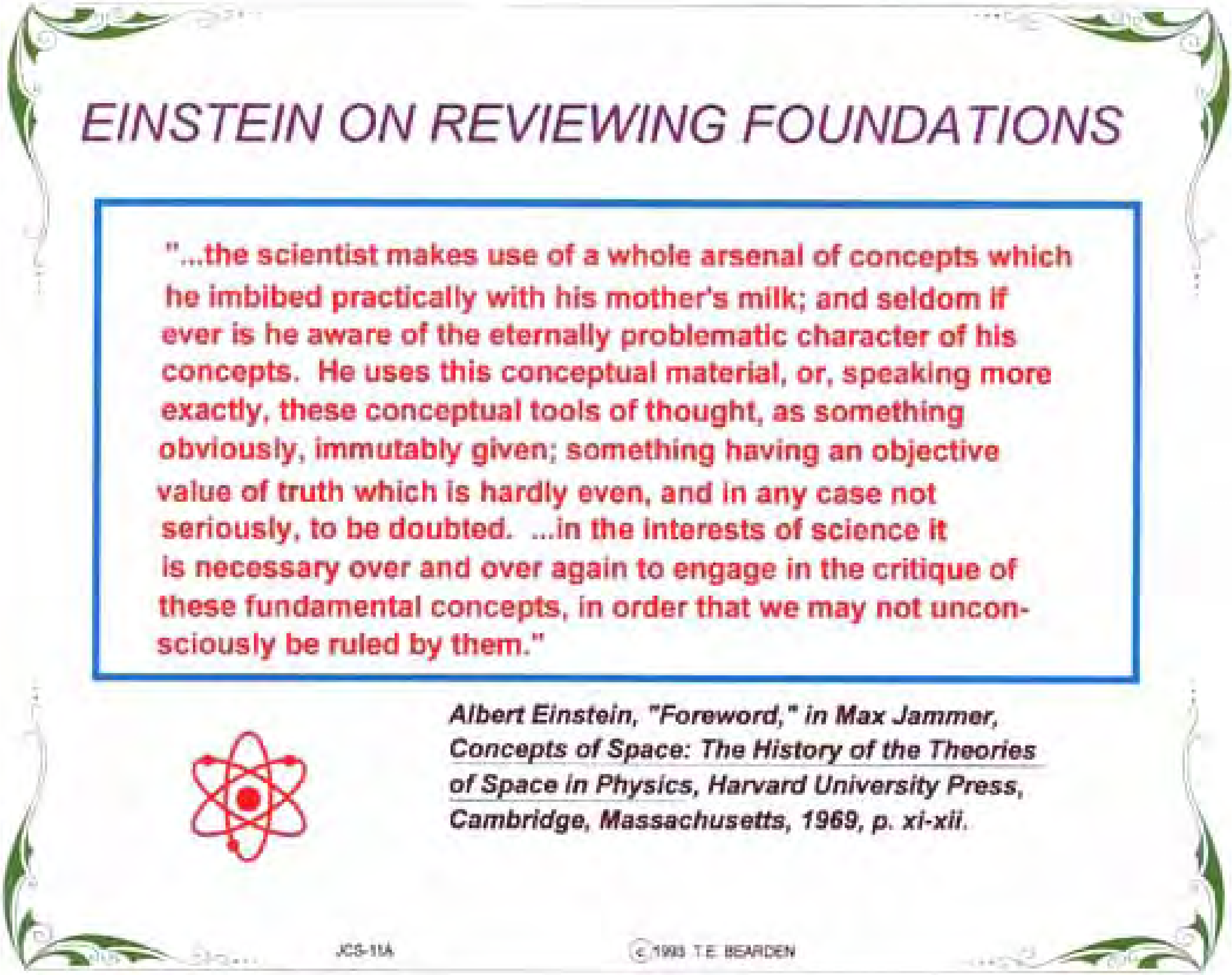

EINSTEIN ON REVIEWING FOUNDATIONS

"...the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the eternally problematic character of his concepts. He uses this conceptual material, or, speaking more exactly, these conceptual tools of thought, as something obviously, immutably given; something having an objective value of truth which is hardly even, and in any case not seriously, to be doubted. ...in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them."

Albert Einstein, "Foreword," in Max Jammer, Concepts of Space: The History of the Theories of Space in Physics, Harvard University Press, Cambridge, Massachusetts, 1969, p. xi-xii.

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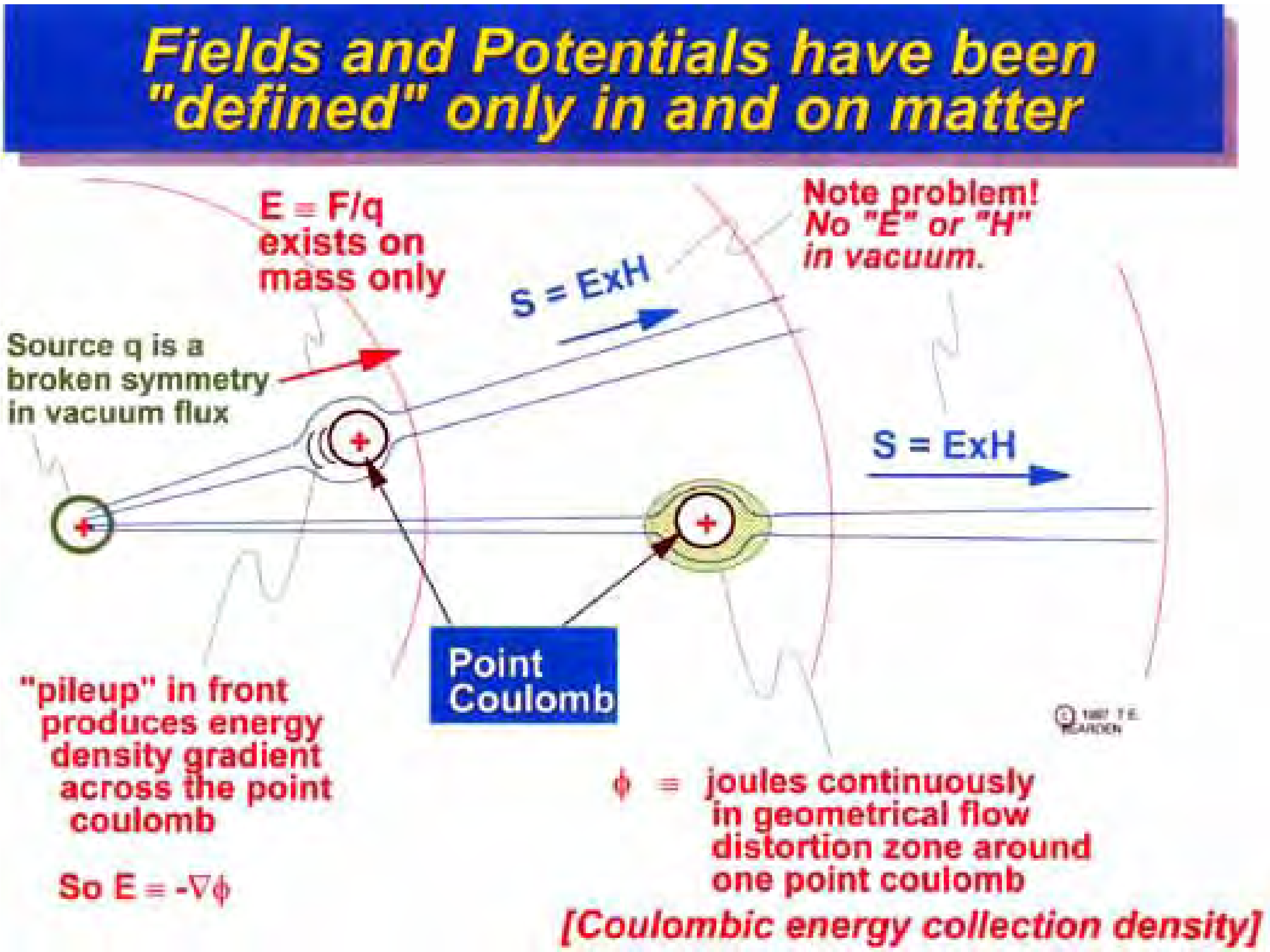

Fields and Potentials have been "defined" only in and on matter

$E \equiv F/q$ exists on mass only

Note problem! *No "E" or "H" in vacuum.*

Source q is a broken symmetry in vacuum flux

$S = E \times H$

$S = E \times H$

Point Coulomb

"pileup" in front produces energy density gradient across the point coulomb

So $E \equiv -\nabla\phi$

ϕ ≡ joules continuously in geometrical flow distortion zone around one point coulomb

[Coulombic energy collection density]

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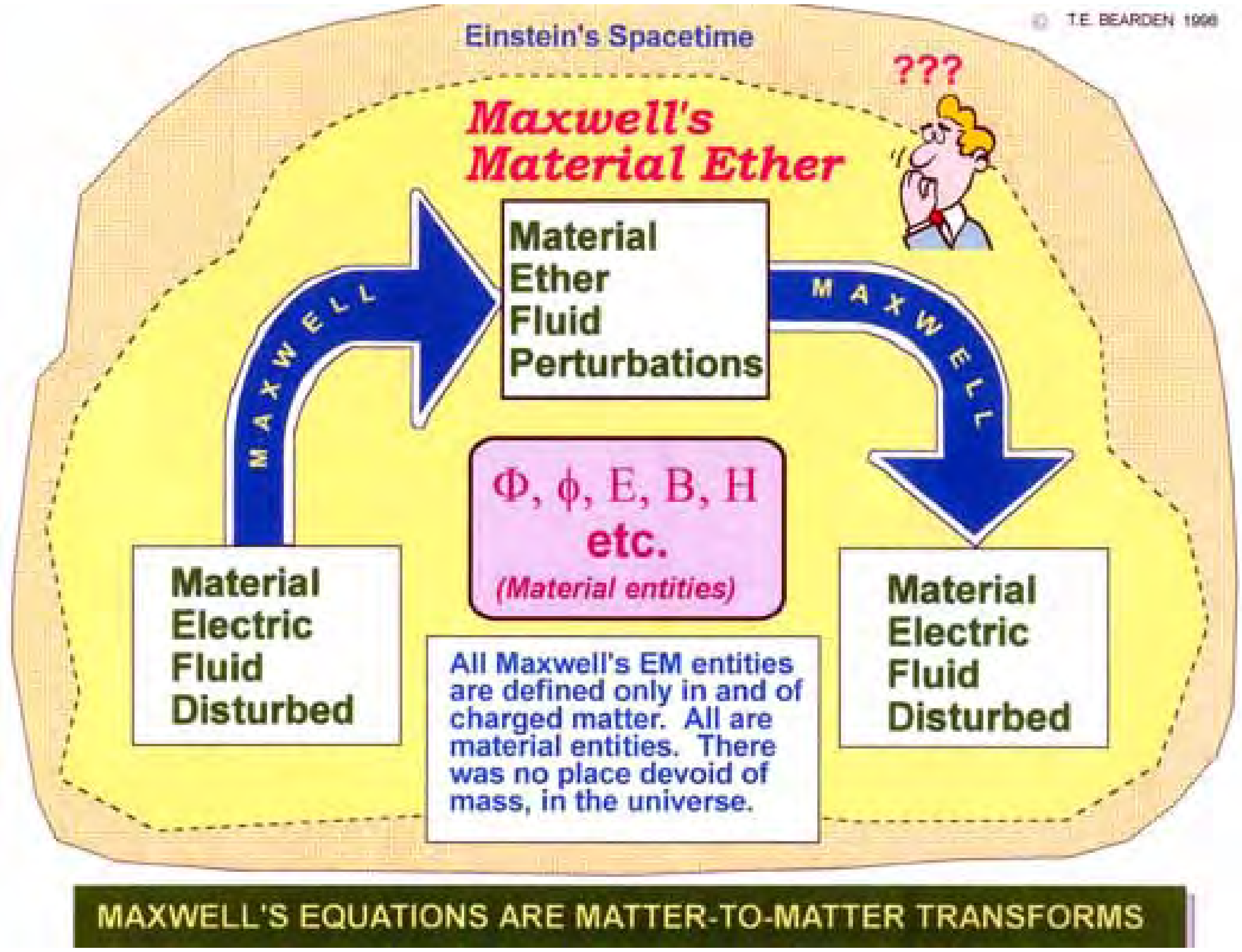

Einstein's Spacetime

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???

Maxwell's Material Ether

Material Ether Fluid Perturbations

Φ, ϕ, E, B, H etc.

(Material entities)

Material Electric Fluid Disturbed

Material Electric Fluid Disturbed

All Maxwell's EM entities are defined only in and of charged matter. All are material entities. There was no place devoid of mass, in the universe.

MAXWELL'S EQUATIONS ARE MATTER-TO-MATTER TRANSFORMS

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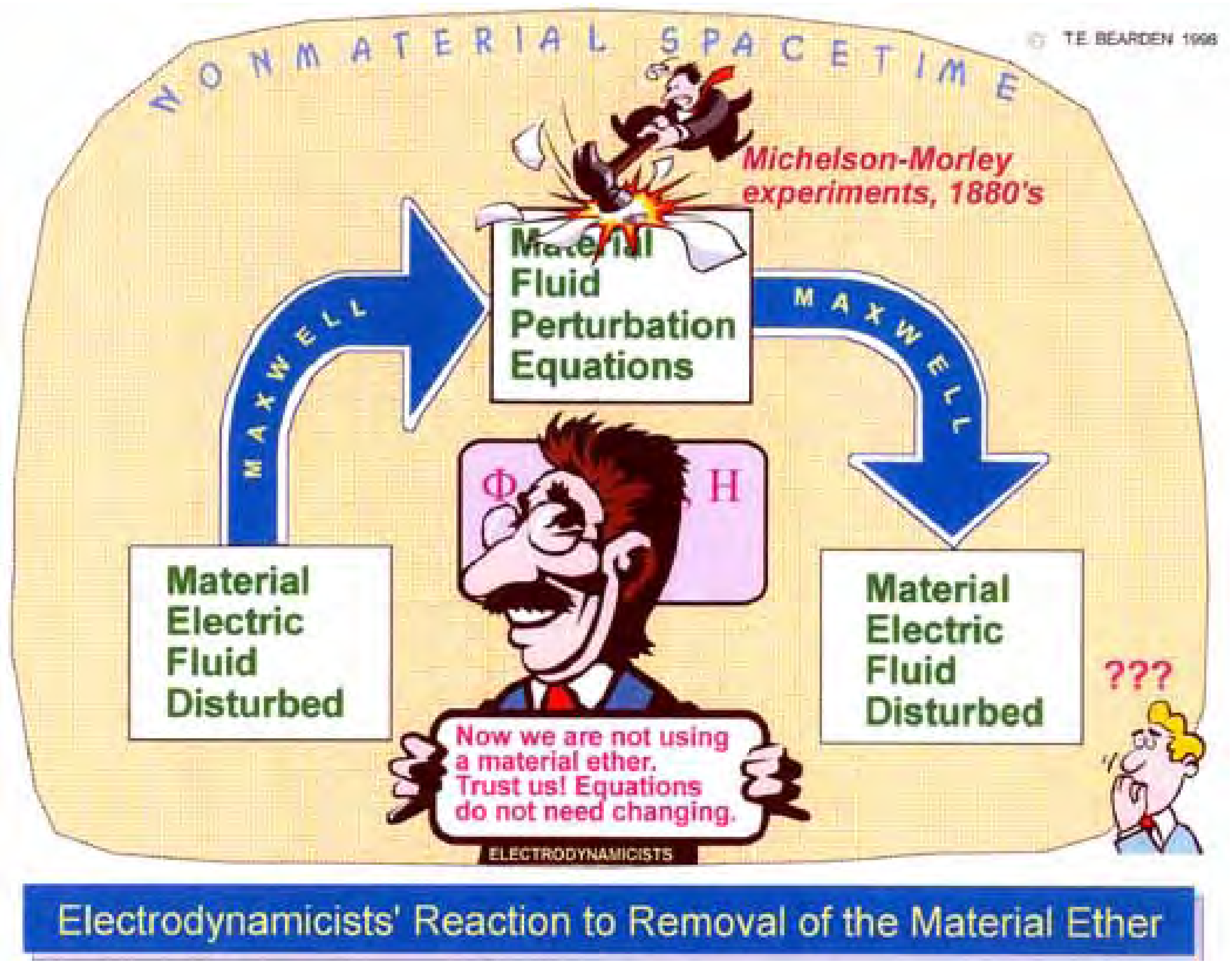

NONMATERIAL SPACETIME

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Michelson-Morley experiments, 1880's

Material Fluid Perturbation Equations

MAXWELL

MAXWELL

Material Electric Fluid Disturbed

Material Electric Fluid Disturbed

Now we are not using a material ether. Trust us! Equations do not need changing.

ELECTRODYNAMICISTS

Electrodynamicists' Reaction to Removal of the Material Ether

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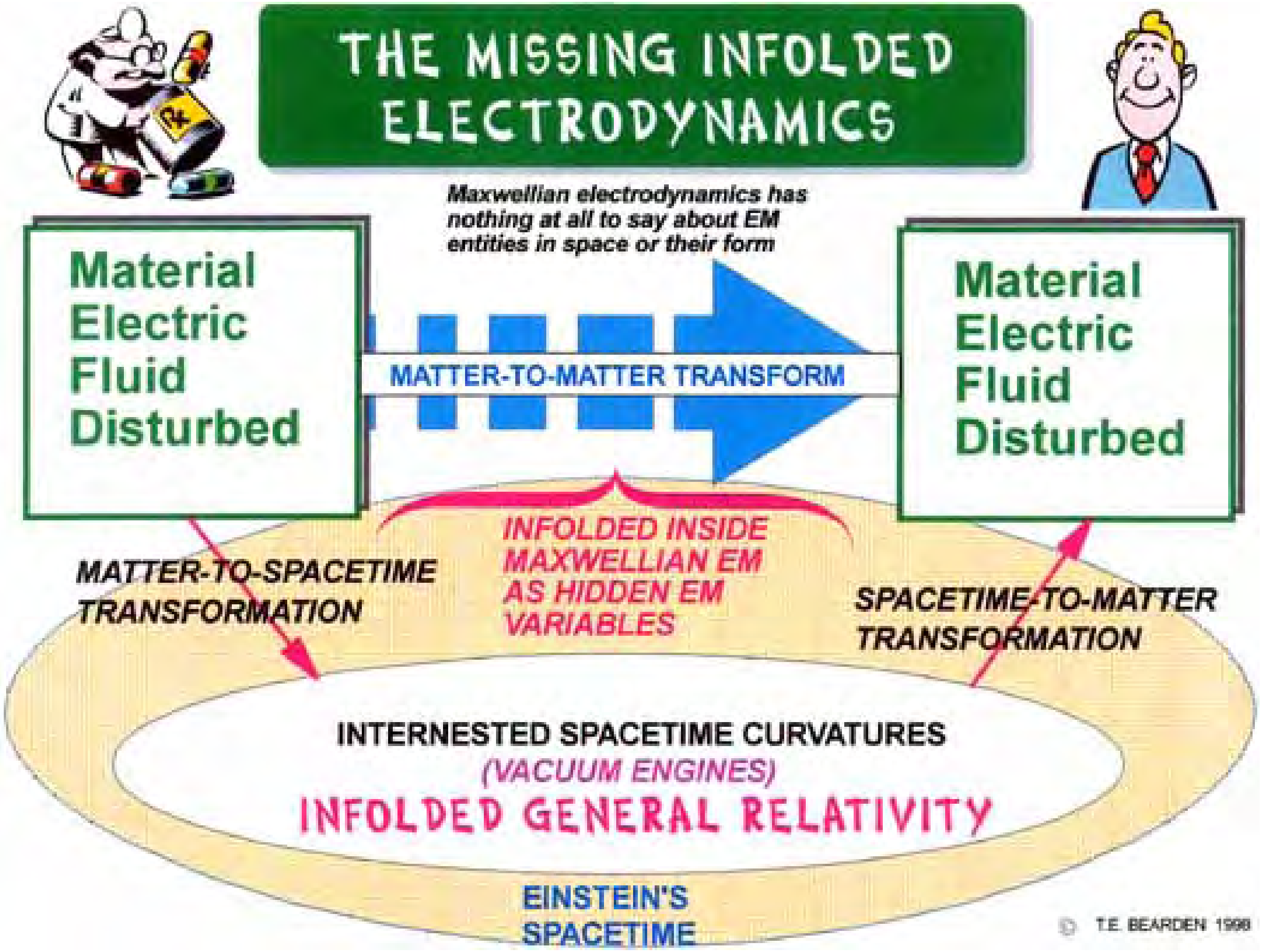

THE MISSING INFOLDED ELECTRODYNAMICS

Maxwellian electrodynamics has nothing at all to say about EM entities in space or their form

Material Electric Fluid Disturbed

MATTER-TO-MATTER TRANSFORM

Material Electric Fluid Disturbed

MATTER-TO-SPACETIME TRANSFORMATION

INFOLDED INSIDE MAXWELLIAN EM AS HIDDEN EM VARIABLES

SPACETIME-TO-MATTER TRANSFORMATION

INTERNESTED SPACETIME CURVATURES

(VACUUM ENGINES)

INFOLDED GENERAL RELATIVITY

EINSTEIN'S SPACETIME

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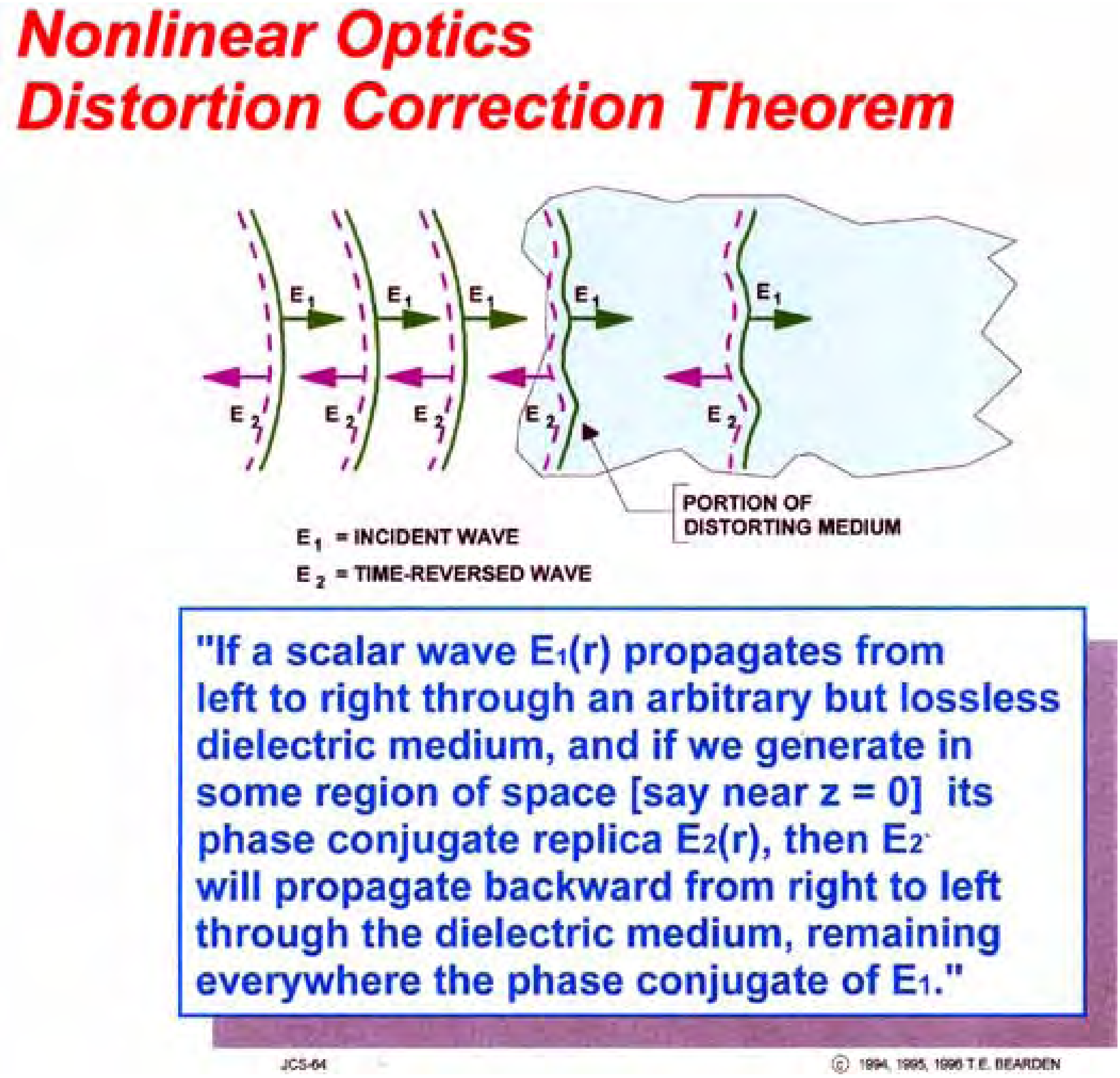

Nonlinear Optics Distortion Correction Theorem

E_1
E_1
E_1
E_1
E_1
E_2
E_2
E_2
E_2
E_2
PORTION OF DISTORTING MEDIUM

E_1 = INCIDENT WAVE

E_2 = TIME-REVERSED WAVE

"If a scalar wave $E_1(r)$ propagates from left to right through an arbitrary but lossless dielectric medium, and if we generate in some region of space [say near z = 0] its phase conjugate replica $E_2(r)$, then E_2 will propagate backward from right to left through the dielectric medium, remaining everywhere the phase conjugate of E_1."

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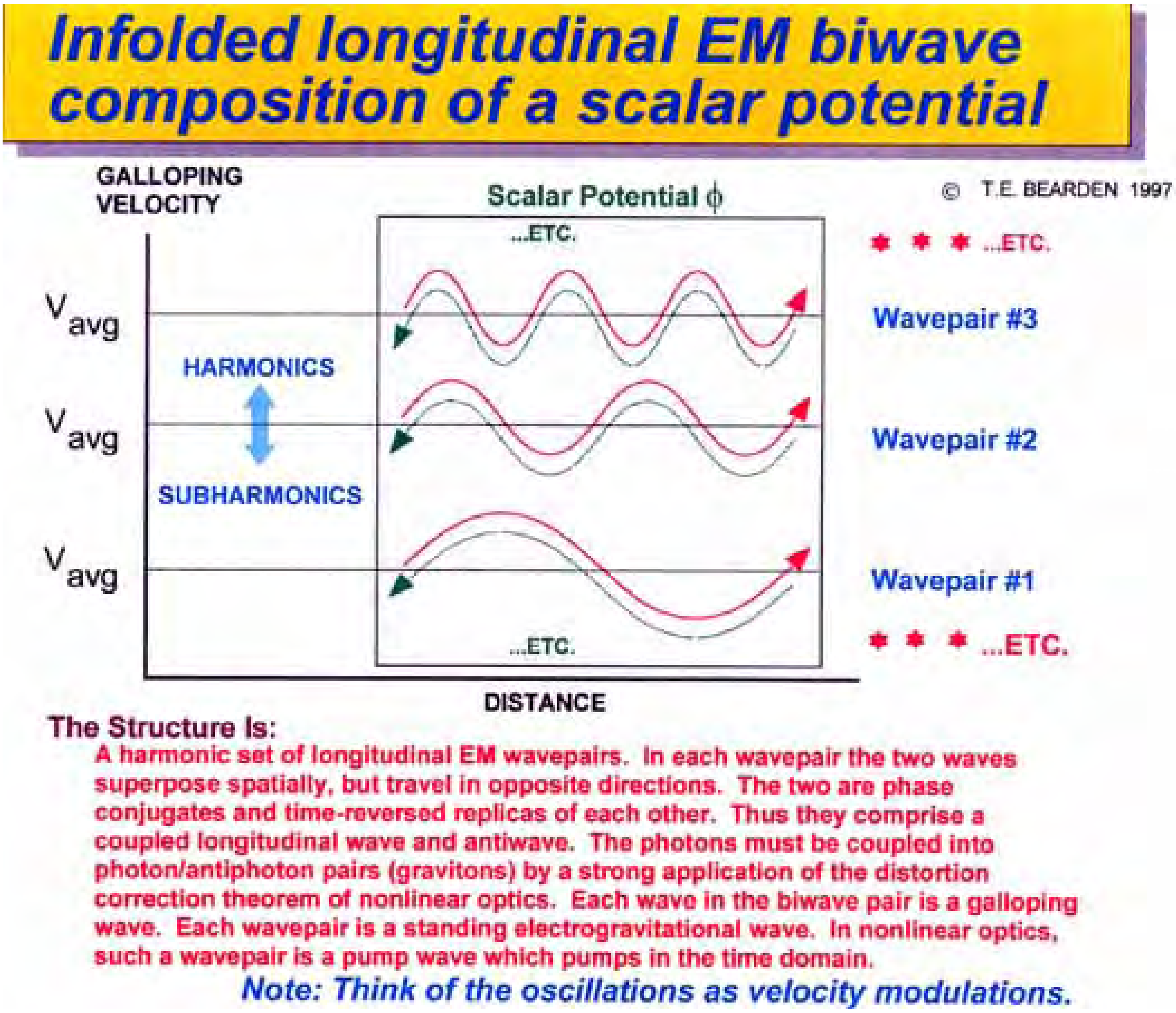

Infolded longitudinal EM biwave composition of a scalar potential

GALLOPING VELOCITY
Scalar Potential ϕ
© T.E. BEARDEN 1997
...ETC.
* * * ...ETC.
V_{avg}
V_{avg}
V_{avg}
HARMONICS
SUBHARMONICS
Wavepair #3
Wavepair #2
Wavepair #1
...ETC.
* * * ...ETC.
DISTANCE

The Structure Is:

A harmonic set of longitudinal EM wavepairs. In each wavepair the two waves superpose spatially, but travel in opposite directions. The two are phase conjugates and time-reversed replicas of each other. Thus they comprise a coupled longitudinal wave and antiwave. The photons must be coupled into photon/antiphoton pairs (gravitons) by a strong application of the distortion correction theorem of nonlinear optics. Each wave in the biwave pair is a galloping wave. Each wavepair is a standing electrogravitational wave. In nonlinear optics, such a wavepair is a pump wave which pumps in the time domain.

Note: Think of the oscillations as velocity modulations.

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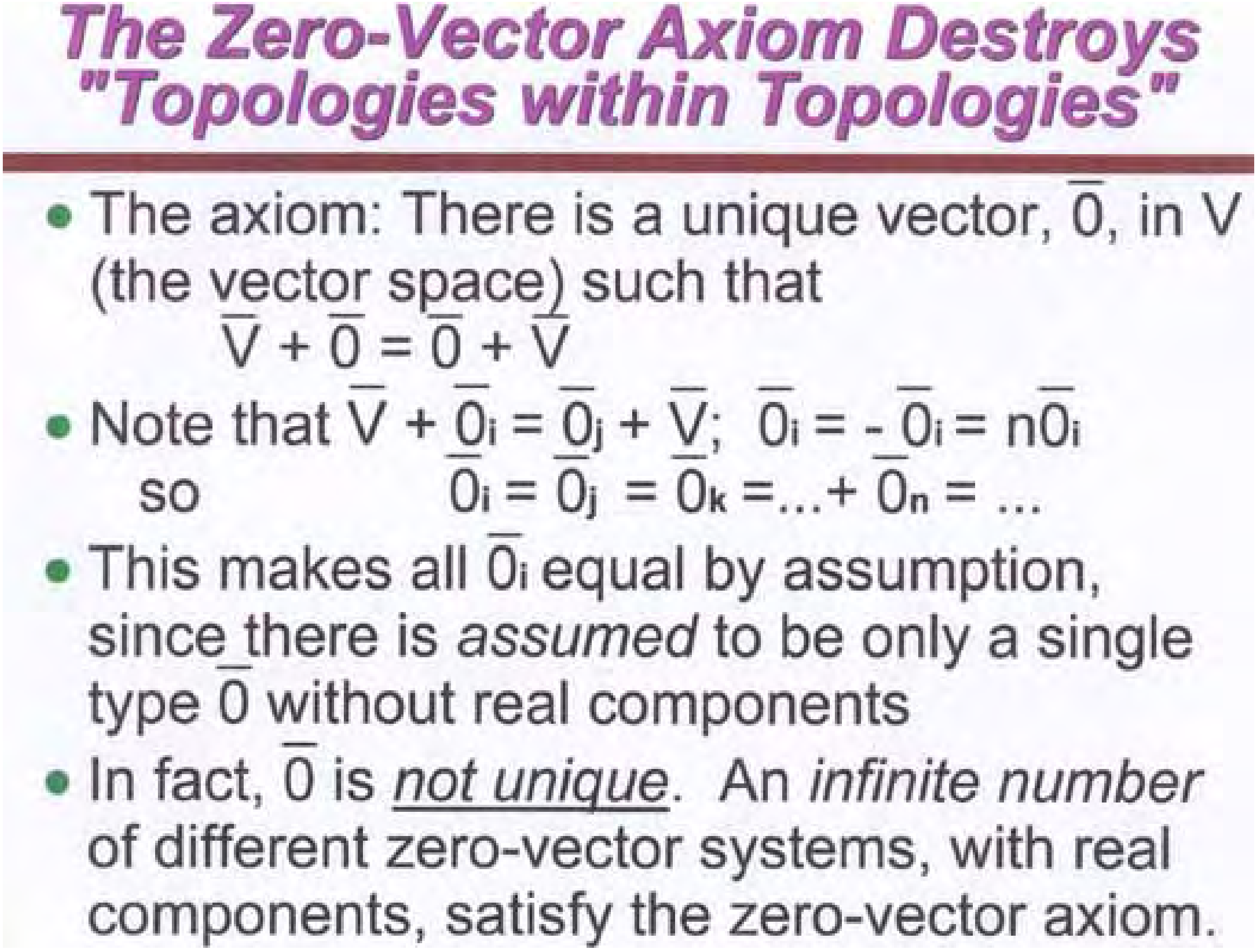

The Zero-Vector Axiom Destroys "Topologies within Topologies"

- The axiom: There is a unique vector, $\overline{0}$, in V (the vector space) such that
  $$\overline{V} + \overline{0} = \overline{0} + \overline{V}$$
- Note that $\overline{V} + \overline{0}_i = \overline{0}_j + \overline{V}$; $\overline{0}_i = -\overline{0}_i = n\overline{0}_i$
  so $\overline{0}_i = \overline{0}_j = \overline{0}_k = \ldots + \overline{0}_n = \ldots$
- This makes all $\overline{0}_i$ equal by assumption, since there is *assumed* to be only a single type $\overline{0}$ without real components
- In fact, $\overline{0}$ is *not unique*. An *infinite number* of different zero-vector systems, with real components, satisfy the zero-vector axiom.

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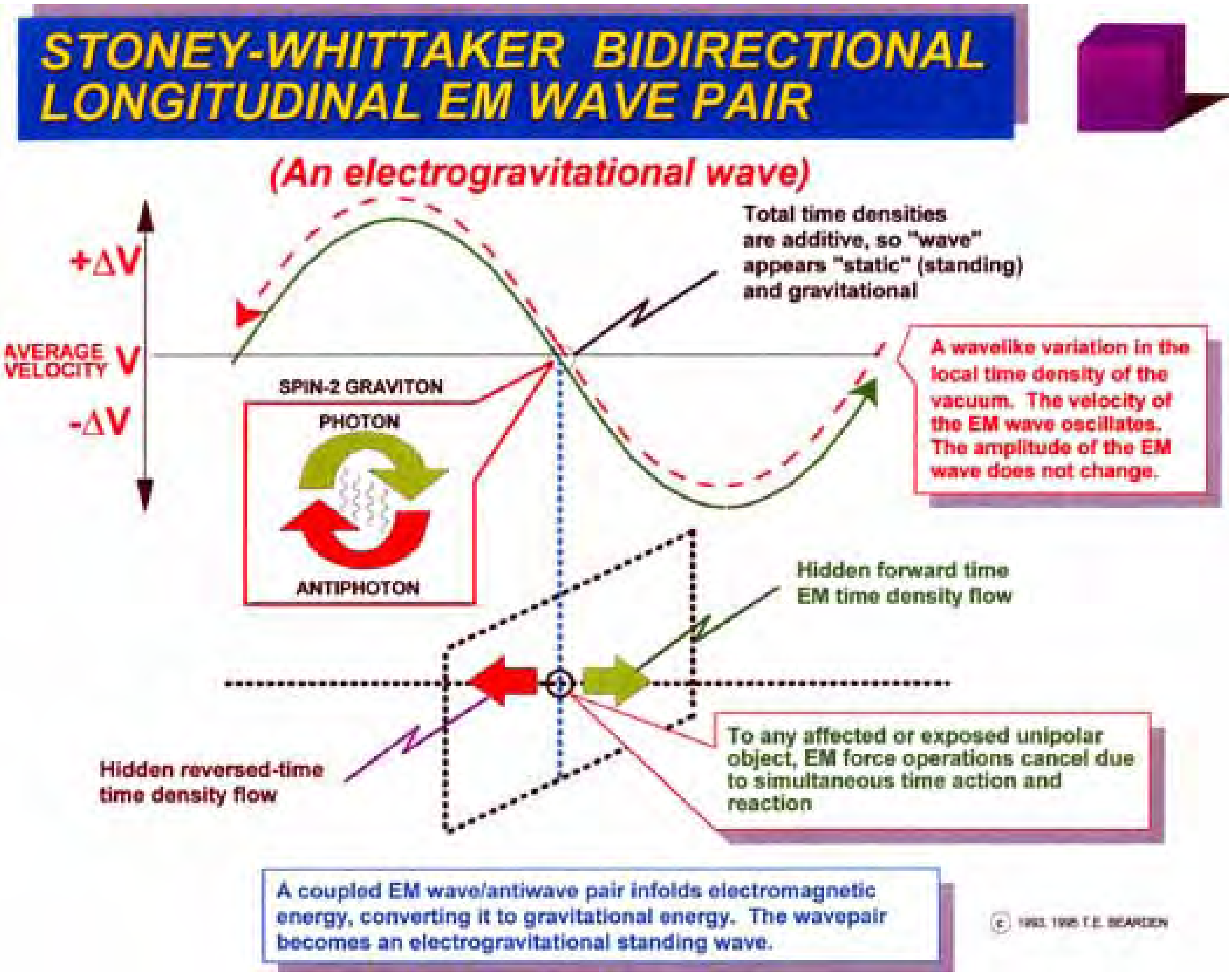

STONEY-WHITTAKER BIDIRECTIONAL LONGITUDINAL EM WAVE PAIR

(An electrogravitational wave)

Total time densities are additive, so "wave" appears "static" (standing) and gravitational

A wavelike variation in the local time density of the vacuum. The velocity of the EM wave oscillates. The amplitude of the EM wave does not change.

Hidden forward time EM time density flow

Hidden reversed-time time density flow

To any affected or exposed unipolar object, EM force operations cancel due to simultaneous time action and reaction

A coupled EM wave/antiwave pair infolds electromagnetic energy, converting it to gravitational energy. The wavepair becomes an electrogravitational standing wave.

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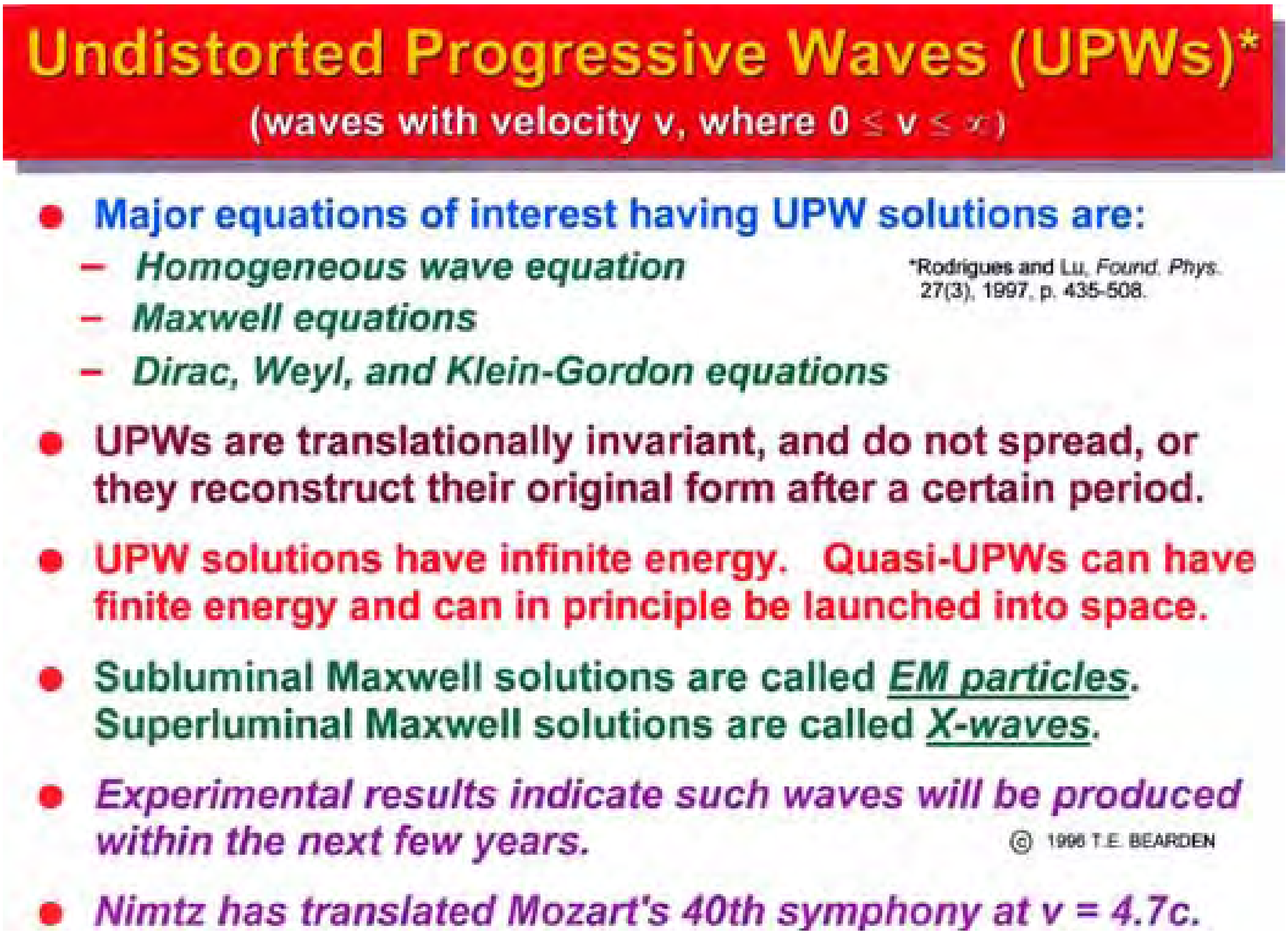

Undistorted Progressive Waves (UPWs)*

(waves with velocity v, where $0 \leq v \leq \infty$)

- Major equations of interest having UPW solutions are:
  - *Homogeneous wave equation*
  - *Maxwell equations*
  - *Dirac, Weyl, and Klein-Gordon equations*
- UPWs are translationally invariant, and do not spread, or they reconstruct their original form after a certain period.
- UPW solutions have infinite energy. Quasi-UPWs can have finite energy and can in principle be launched into space.
- Subluminal Maxwell solutions are called ***EM particles***. Superluminal Maxwell solutions are called ***X-waves***.
- *Experimental results indicate such waves will be produced within the next few years.*
- *Nimtz has translated Mozart's 40th symphony at v = 4.7c.*

*Rodrigues and Lu, *Found. Phys.* 27(3), 1997, p. 435-508.

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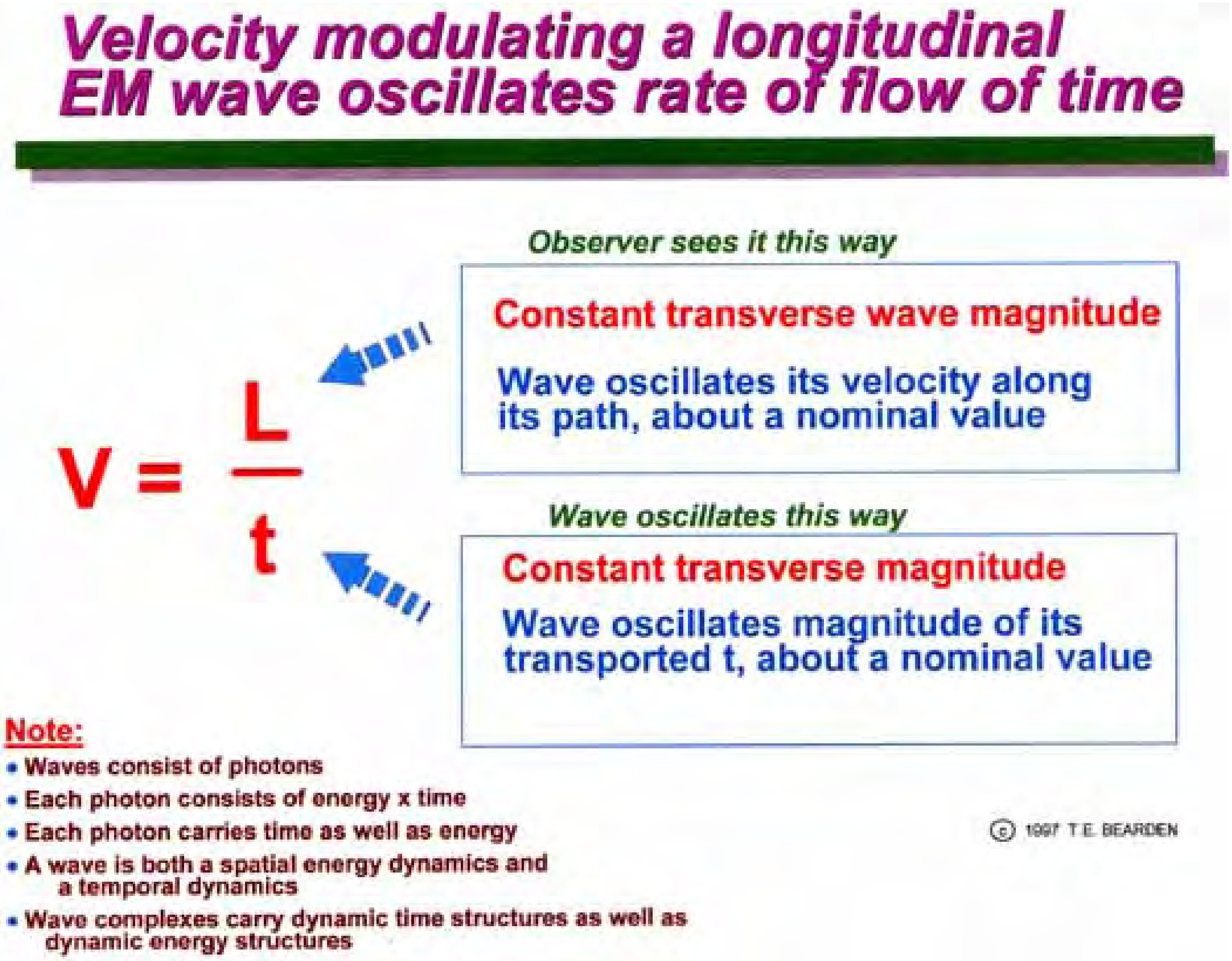

Velocity modulating a longitudinal EM wave oscillates rate of flow of time

$$V = \frac{L}{t}$$

Observer sees it this way

Constant transverse wave magnitude

Wave oscillates its velocity along its path, about a nominal value

Wave oscillates this way

Constant transverse magnitude

Wave oscillates magnitude of its transported t, about a nominal value

Note:

- Waves consist of photons
- Each photon consists of energy x time
- Each photon carries time as well as energy
- A wave is both a spatial energy dynamics and a temporal dynamics
- Wave complexes carry dynamic time structures as well as dynamic energy structures

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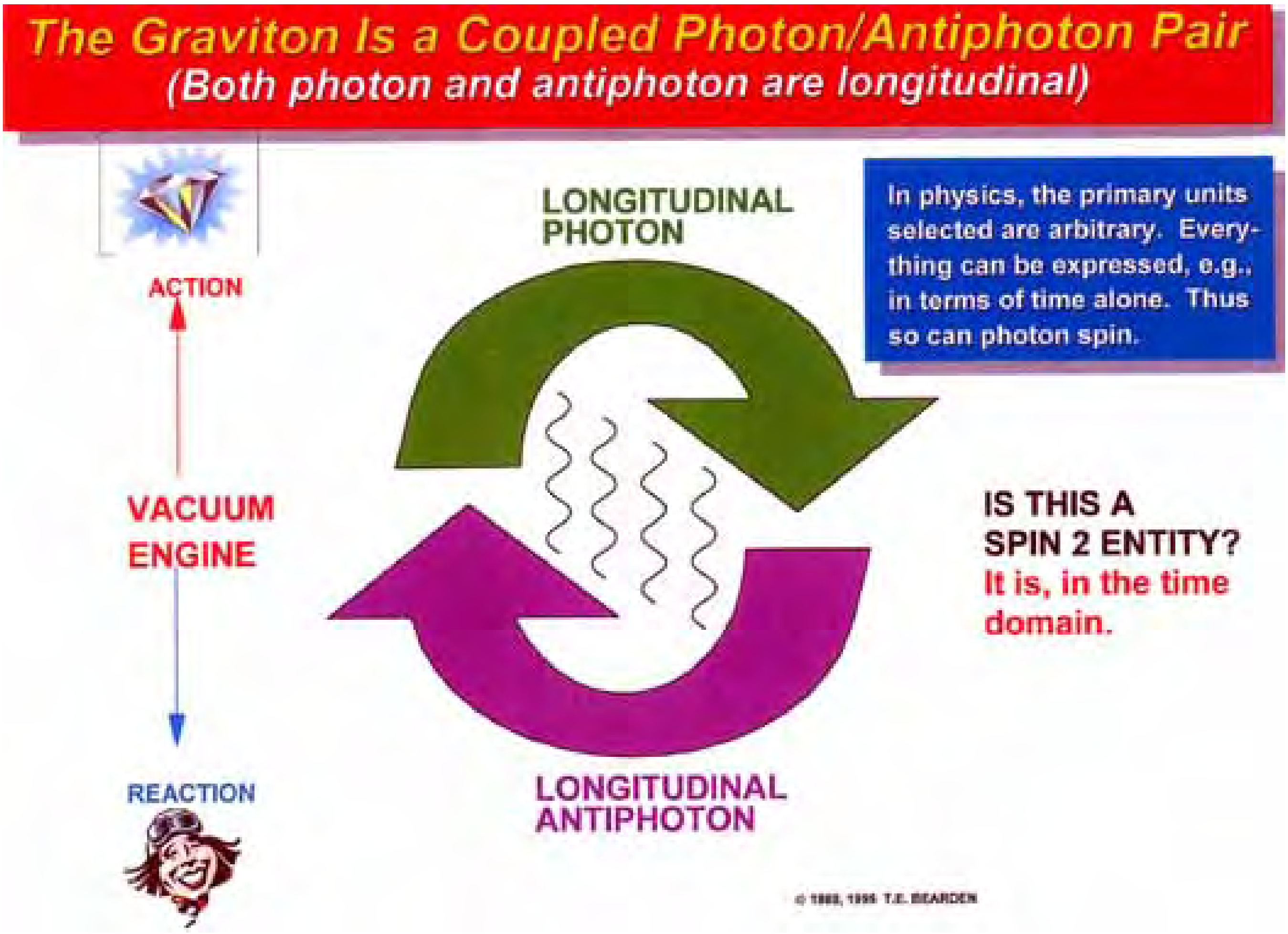

The Graviton Is a Coupled Photon/Antiphoton Pair

(Both photon and antiphoton are longitudinal)

In physics, the primary units selected are arbitrary. Everything can be expressed, e.g., in terms of time alone. Thus so can photon spin.

ACTION
VACUUM ENGINE
REACTION
LONGITUDINAL PHOTON
LONGITUDINAL ANTIPHOTON

IS THIS A SPIN 2 ENTITY?

It is, in the time domain.

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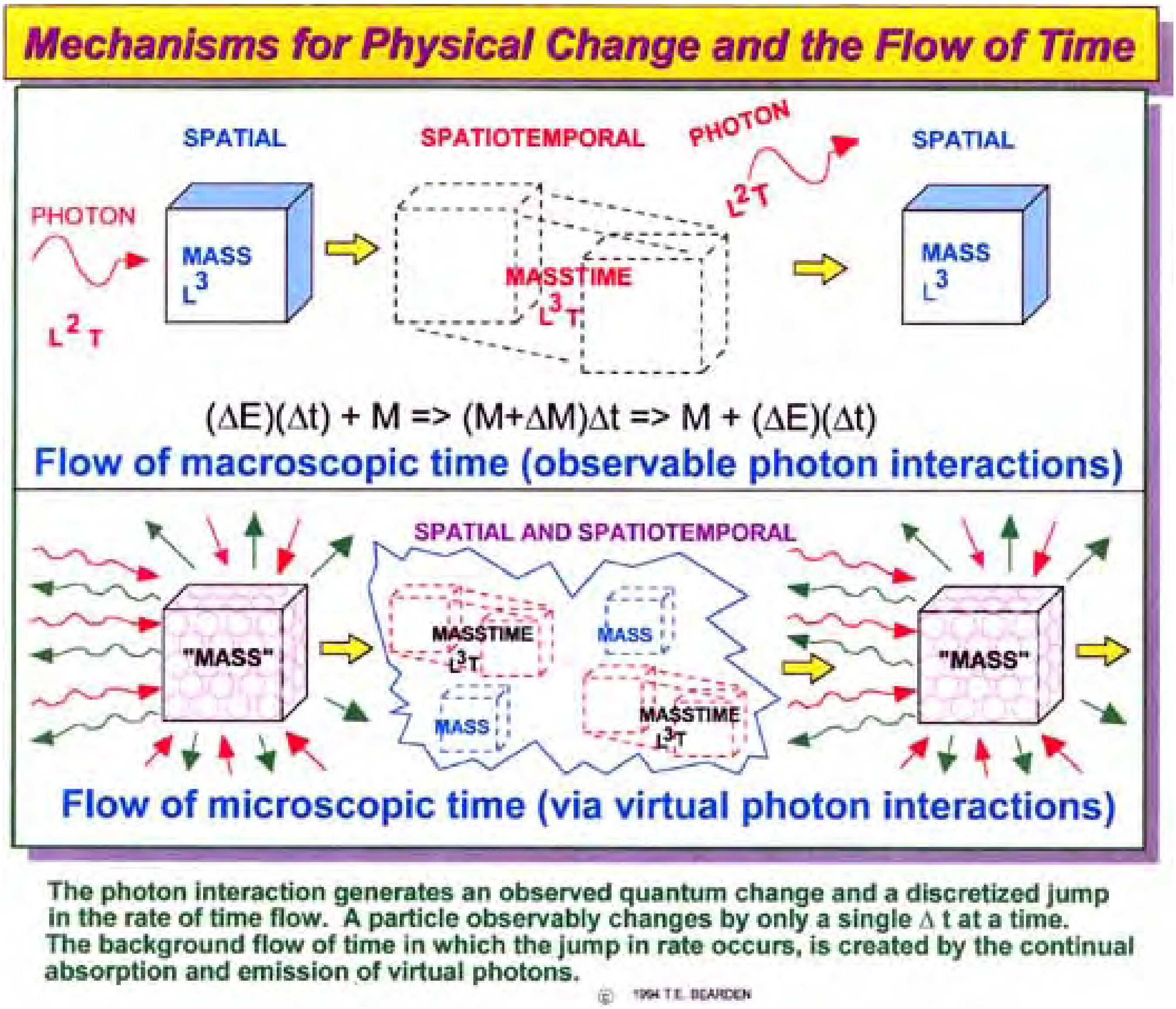

Mechanisms for Physical Change and the Flow of Time

SPATIAL
SPATIOTEMPORAL
PHOTON
SPATIAL
PHOTON
MASS L^3
L^2T
MASSTIME L^3T
L^2T
MASS L^3

$$(\Delta E)(\Delta t) + M \Rightarrow (M+\Delta M)\Delta t \Rightarrow M + (\Delta E)(\Delta t)$$

Flow of macroscopic time (observable photon interactions)

SPATIAL AND SPATIOTEMPORAL
"MASS"
MASSTIME L^3T
MASS
MASS
MASSTIME L^3T
"MASS"

Flow of microscopic time (via virtual photon interactions)

The photon interaction generates an observed quantum change and a discretized jump in the rate of time flow. A particle observably changes by only a single Δ t at a time. The background flow of time in which the jump in rate occurs, is created by the continual absorption and emission of virtual photons.

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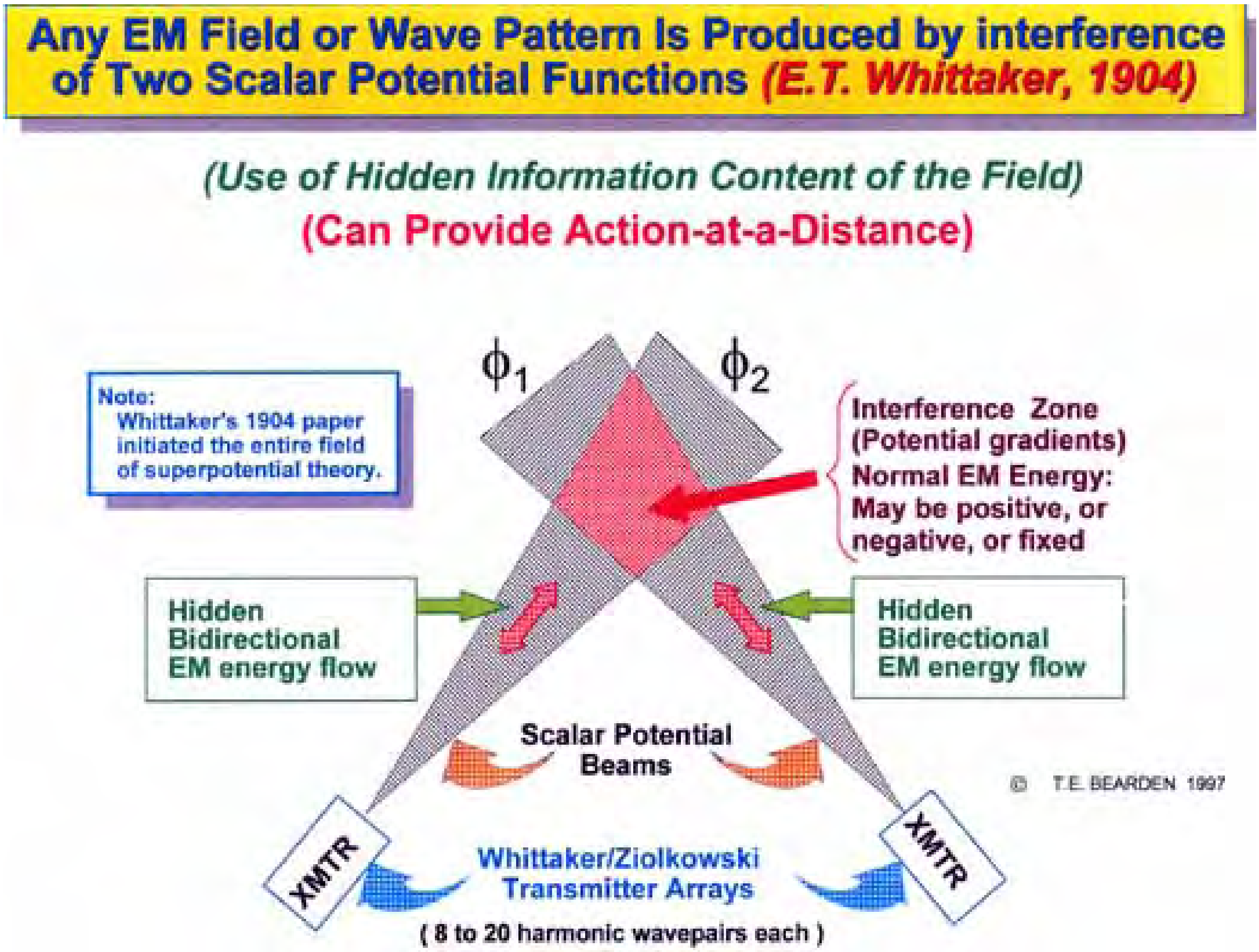

Any EM Field or Wave Pattern Is Produced by interference of Two Scalar Potential Functions *(E.T. Whittaker, 1904)*

(Use of Hidden Information Content of the Field)

(Can Provide Action-at-a-Distance)

Note:
Whittaker's 1904 paper initiated the entire field of superpotential theory.

ϕ_1 ϕ_2

Interference Zone
(Potential gradients)
Normal EM Energy:
May be positive, or
negative, or fixed

Hidden
Bidirectional
EM energy flow

Hidden
Bidirectional
EM energy flow

Scalar Potential
Beams

XMTR

XMTR

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Whittaker/Ziolkowski
Transmitter Arrays

(8 to 20 harmonic wavepairs each)

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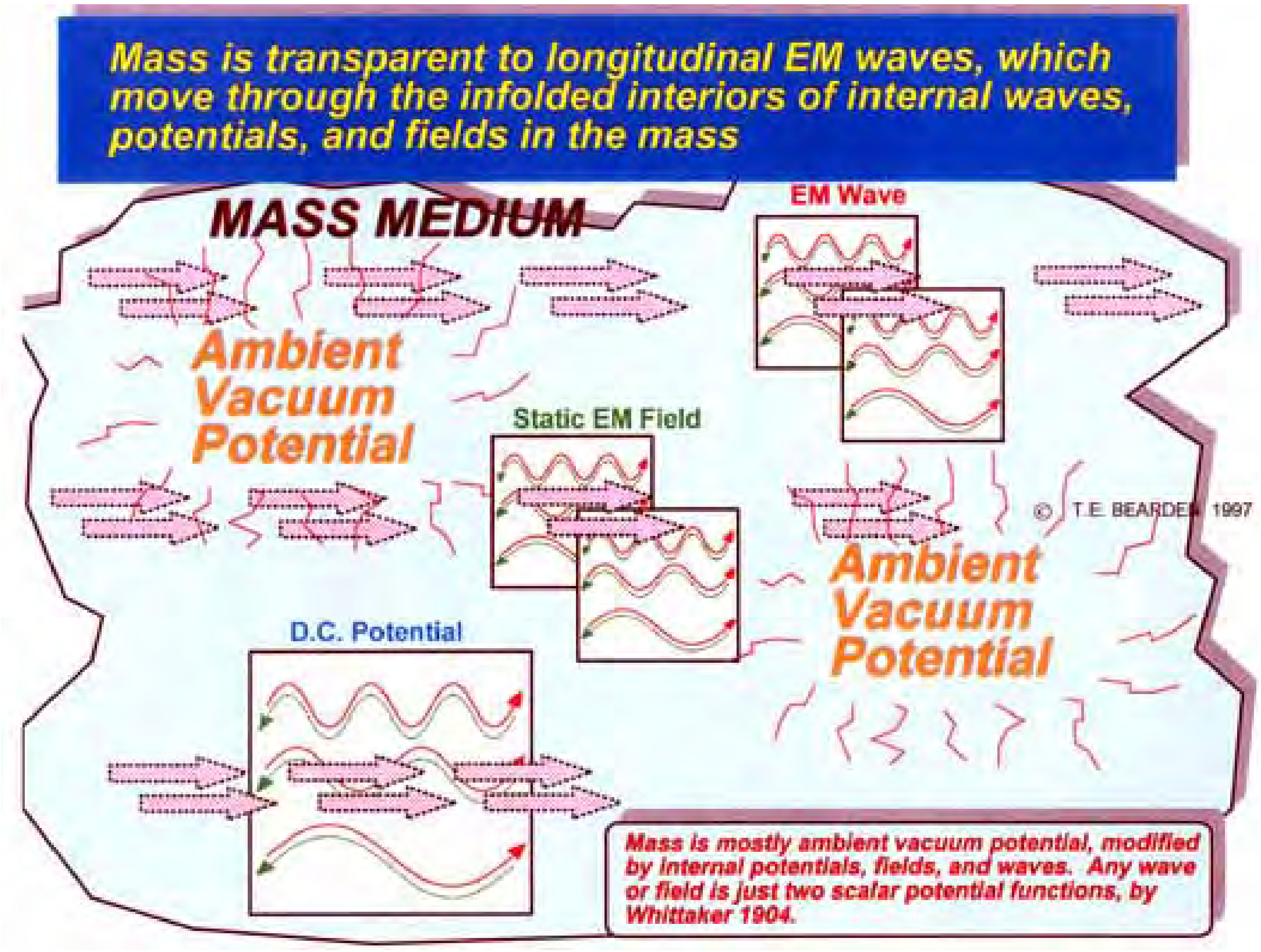

Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass

MASS MEDIUM
Ambient Vacuum Potential
EM Wave
Static EM Field
Ambient Vacuum Potential
© T.E. BEARDEN 1997
D.C. Potential

Mass is mostly ambient vacuum potential, modified by internal potentials, fields, and waves. Any wave or field is just two scalar potential functions, by Whittaker 1904.

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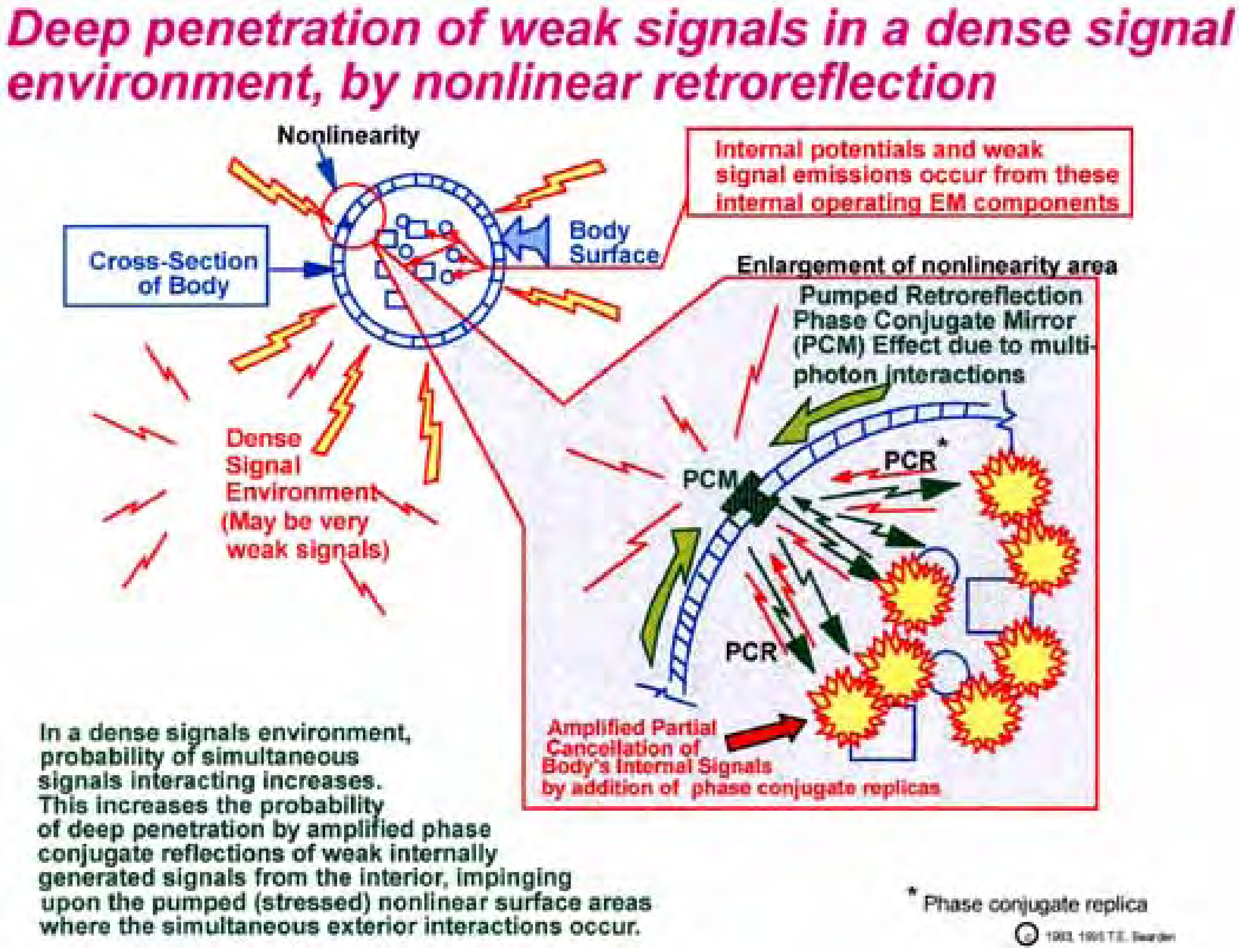

Deep penetration of weak signals in a dense signal environment, by nonlinear retroreflection

Nonlinearity
Internal potentials and weak signal emissions occur from these internal operating EM components
Cross-Section of Body
Body Surface
Enlargement of nonlinearity area
Pumped Retroreflection Phase Conjugate Mirror (PCM) Effect due to multi-photon interactions
Dense Signal Environment (May be very weak signals)
PCM
PCR*
PCR
Amplified Partial Cancellation of Body's Internal Signals by addition of phase conjugate replicas

In a dense signals environment, probability of simultaneous signals interacting increases. This increases the probability of deep penetration by amplified phase conjugate reflections of weak internally generated signals from the interior, impinging upon the pumped (stressed) nonlinear surface areas where the simultaneous exterior interactions occur.

* Phase conjugate replica

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THE IMMUNE SYSTEM

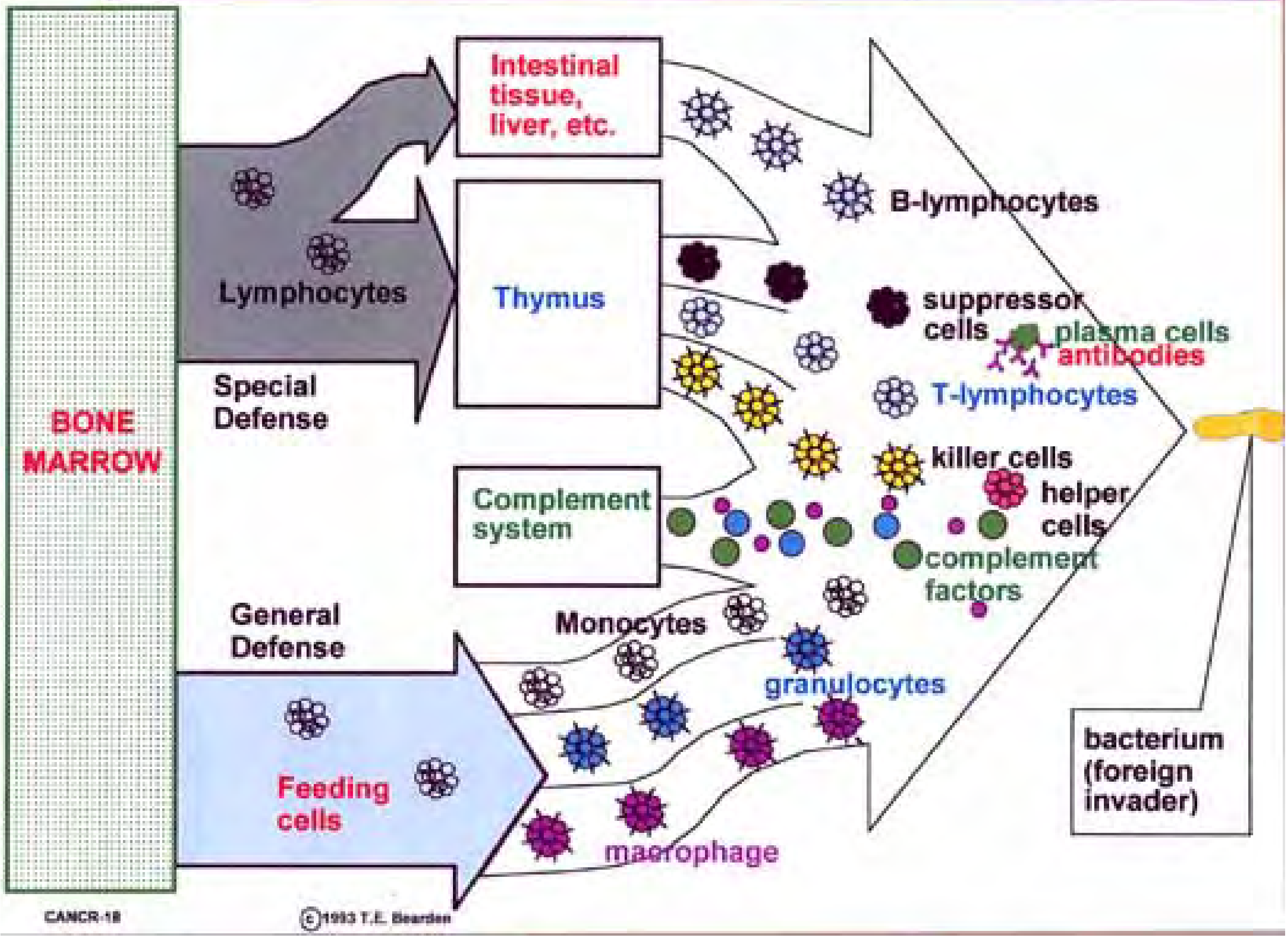
BONE MARROW
Lymphocytes
Special Defense
Intestinal tissue, liver, etc.
Thymus
Complement system
General Defense
Feeding cells
Monocytes
B-lymphocytes
suppressor cells
plasma cells
antibodies
T-lymphocytes
killer cells
helper cells
complement factors
granulocytes
macrophage
bacterium (foreign invader)
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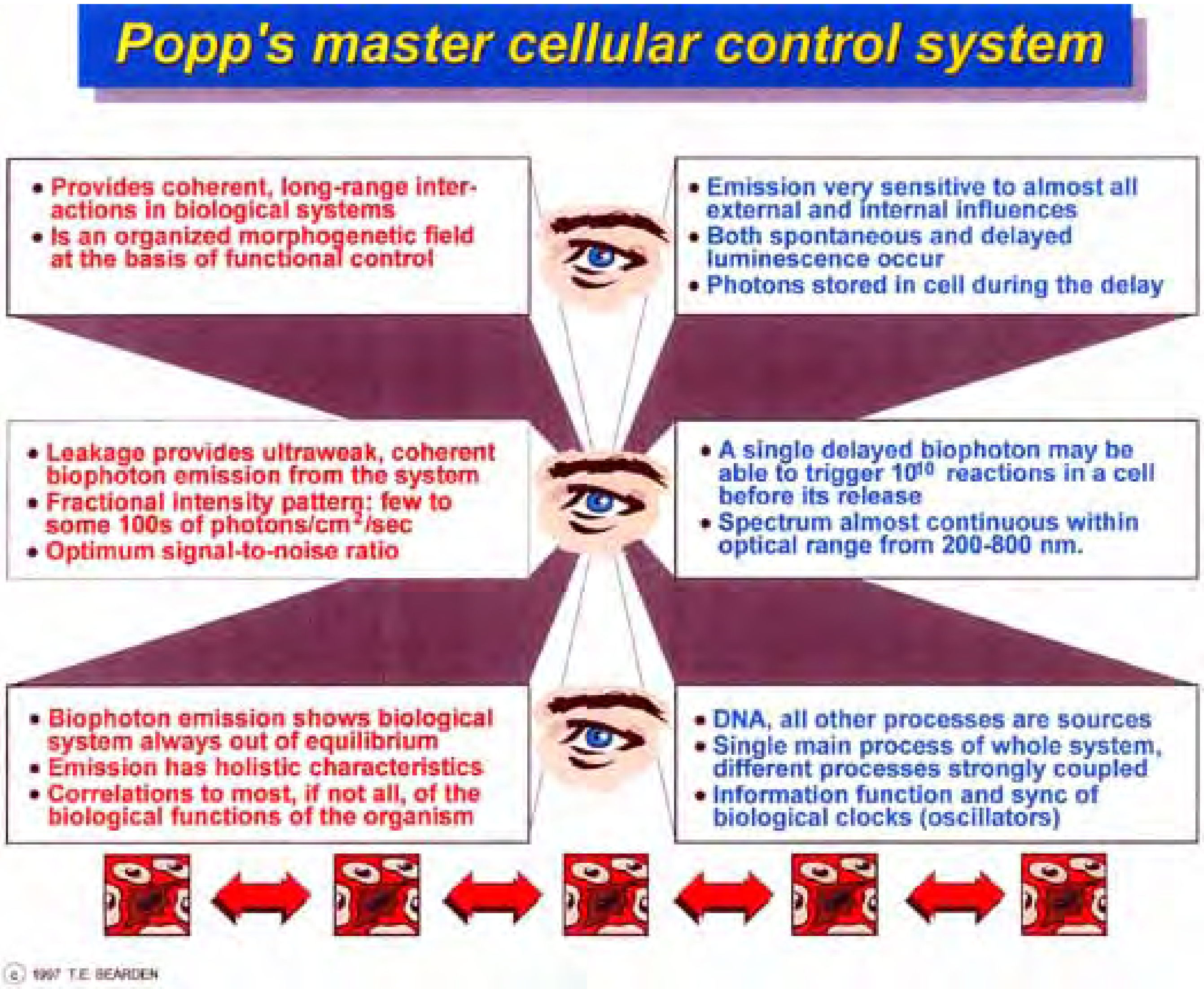

Popp's master cellular control system

- Provides coherent, long-range interactions in biological systems
- Is an organized morphogenetic field at the basis of functional control

- Emission very sensitive to almost all external and internal influences
- Both spontaneous and delayed luminescence occur
- Photons stored in cell during the delay

- Leakage provides ultraweak, coherent biophoton emission from the system
- Fractional intensity pattern: few to some 100s of photons/cm^2/sec
- Optimum signal-to-noise ratio

- A single delayed biophoton may be able to trigger 10^{10} reactions in a cell before its release
- Spectrum almost continuous within optical range from 200-800 nm.

- Biophoton emission shows biological system always out of equilibrium
- Emission has holistic characteristics
- Correlations to most, if not all, of the biological functions of the organism

- DNA, all other processes are sources
- Single main process of whole system, different processes strongly coupled
- Information function and sync of biological clocks (oscillators)

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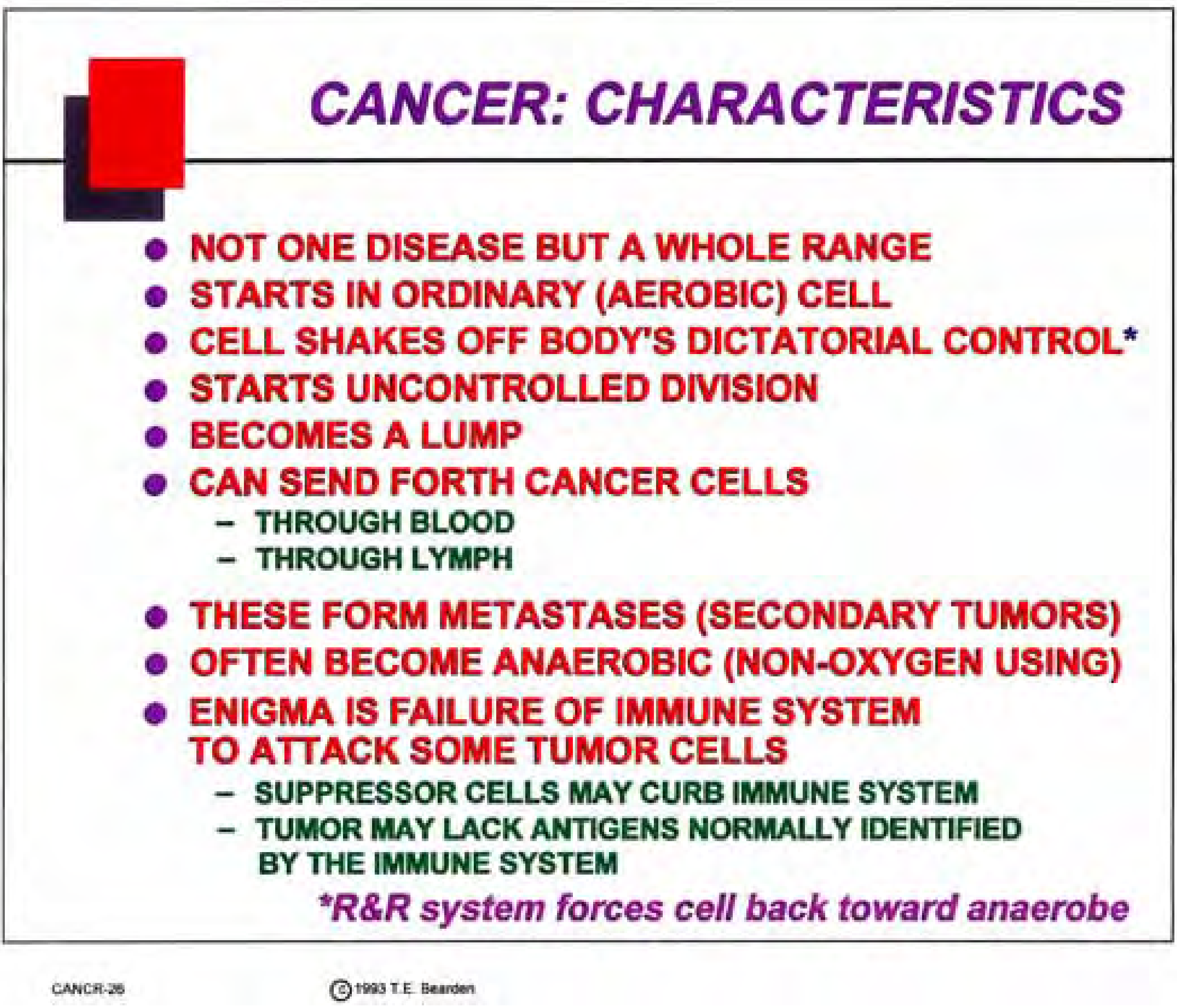

CANCER: CHARACTERISTICS

- NOT ONE DISEASE BUT A WHOLE RANGE
- STARTS IN ORDINARY (AEROBIC) CELL
- CELL SHAKES OFF BODY'S DICTATORIAL CONTROL*
- STARTS UNCONTROLLED DIVISION
- BECOMES A LUMP
- CAN SEND FORTH CANCER CELLS
  - THROUGH BLOOD
  - THROUGH LYMPH
- THESE FORM METASTASES (SECONDARY TUMORS)
- OFTEN BECOME ANAEROBIC (NON-OXYGEN USING)
- ENIGMA IS FAILURE OF IMMUNE SYSTEM TO ATTACK SOME TUMOR CELLS
  - SUPPRESSOR CELLS MAY CURB IMMUNE SYSTEM
  - TUMOR MAY LACK ANTIGENS NORMALLY IDENTIFIED BY THE IMMUNE SYSTEM

**R&R system forces cell back toward anaerobe*

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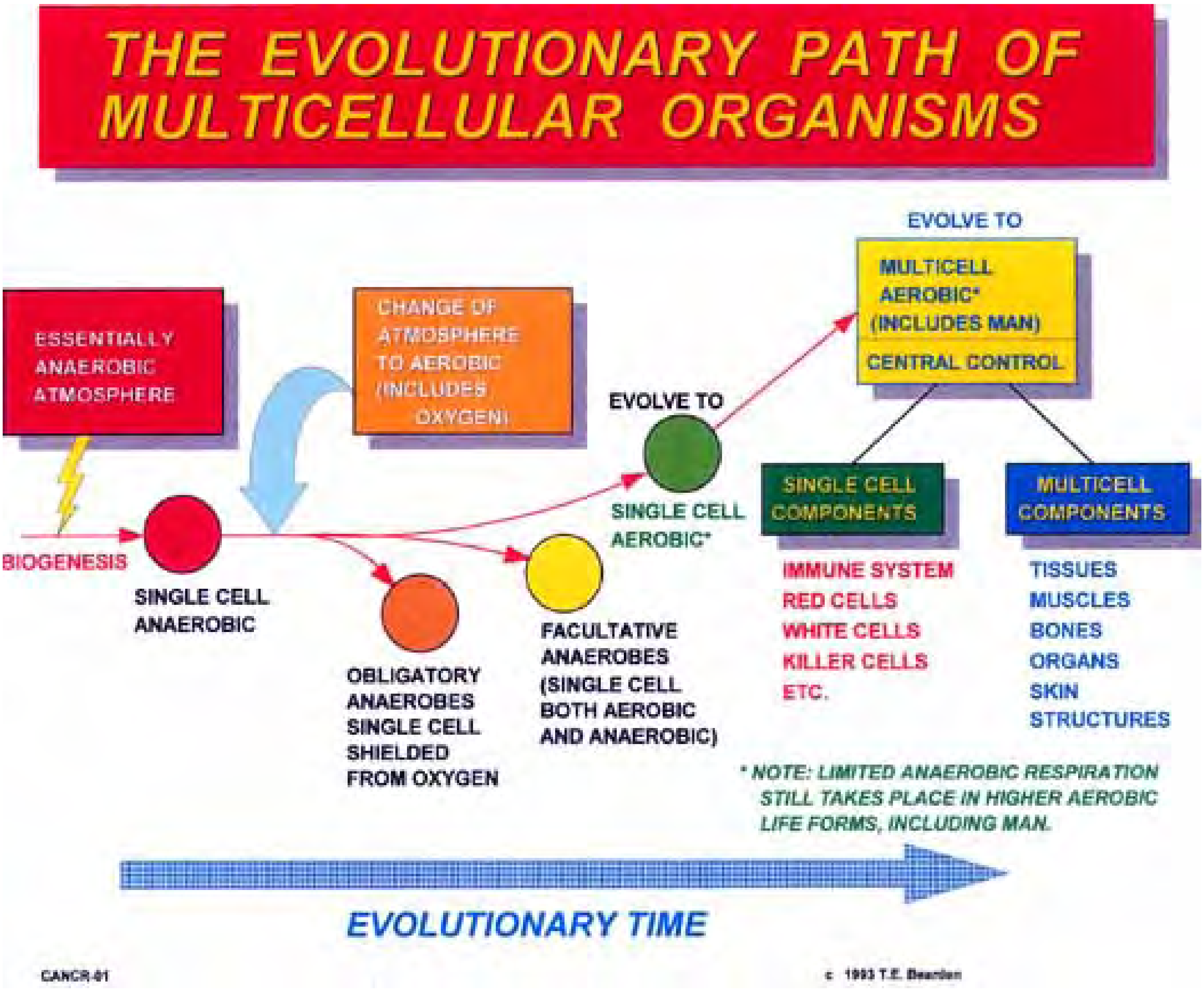

THE EVOLUTIONARY PATH OF MULTICELLULAR ORGANISMS

ESSENTIALLY ANAEROBIC ATMOSPHERE

CHANGE OF ATMOSPHERE TO AEROBIC (INCLUDES OXYGEN)

BIOGENESIS

SINGLE CELL ANAEROBIC

OBLIGATORY ANAEROBES SINGLE CELL SHIELDED FROM OXYGEN

FACULTATIVE ANAEROBES (SINGLE CELL BOTH AEROBIC AND ANAEROBIC)

EVOLVE TO

SINGLE CELL AEROBIC*

EVOLVE TO

MULTICELL AEROBIC* (INCLUDES MAN)

CENTRAL CONTROL

SINGLE CELL COMPONENTS

IMMUNE SYSTEM
RED CELLS
WHITE CELLS
KILLER CELLS
ETC.

MULTICELL COMPONENTS

TISSUES
MUSCLES
BONES
ORGANS
SKIN
STRUCTURES

* NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.

EVOLUTIONARY TIME

CANCR-01

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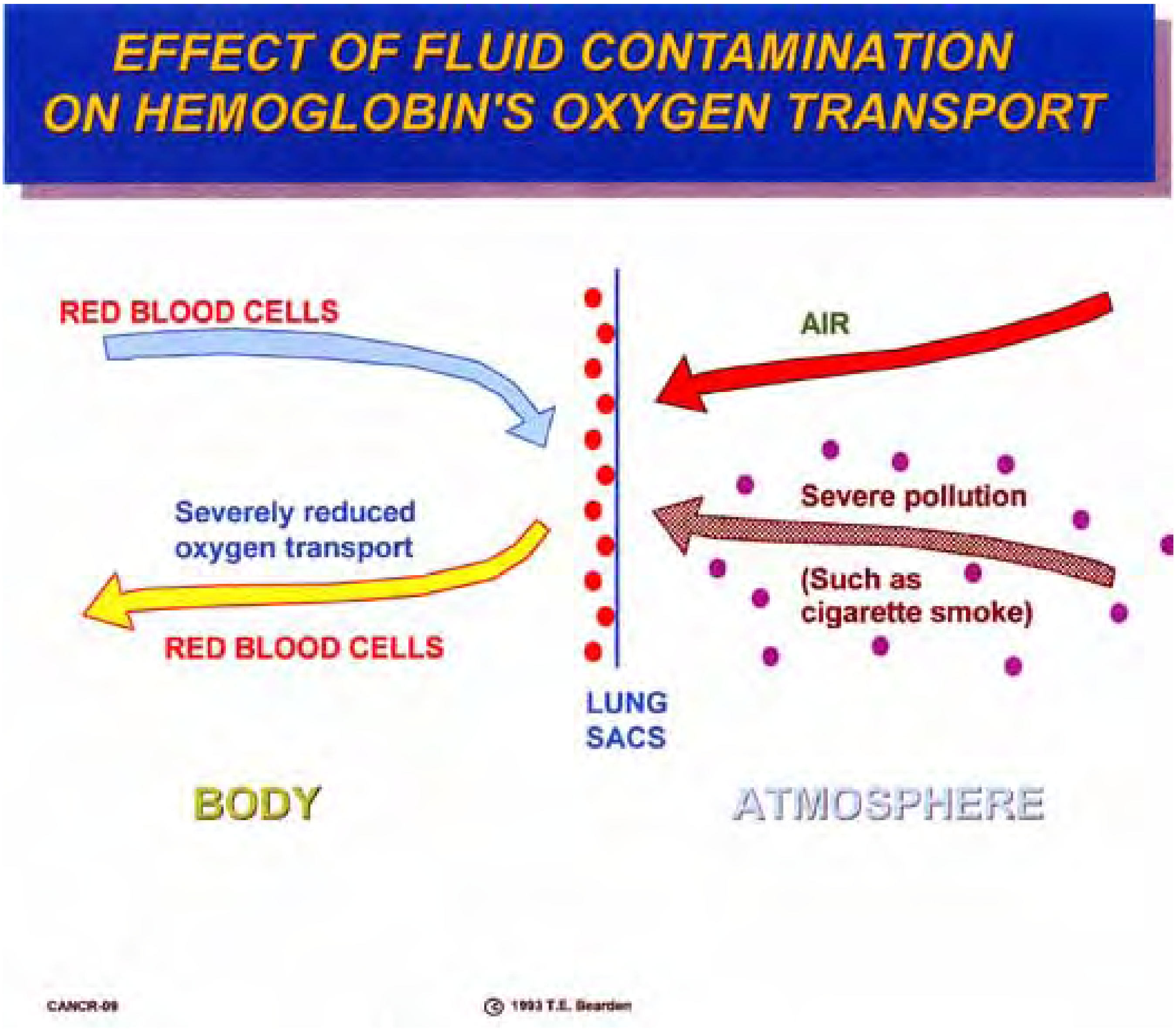

EFFECT OF FLUID CONTAMINATION ON HEMOGLOBIN'S OXYGEN TRANSPORT

RED BLOOD CELLS

AIR

Severe pollution

(Such as cigarette smoke)

Severely reduced oxygen transport

RED BLOOD CELLS

LUNG SACS

BODY

ATMOSPHERE

CANCR-09

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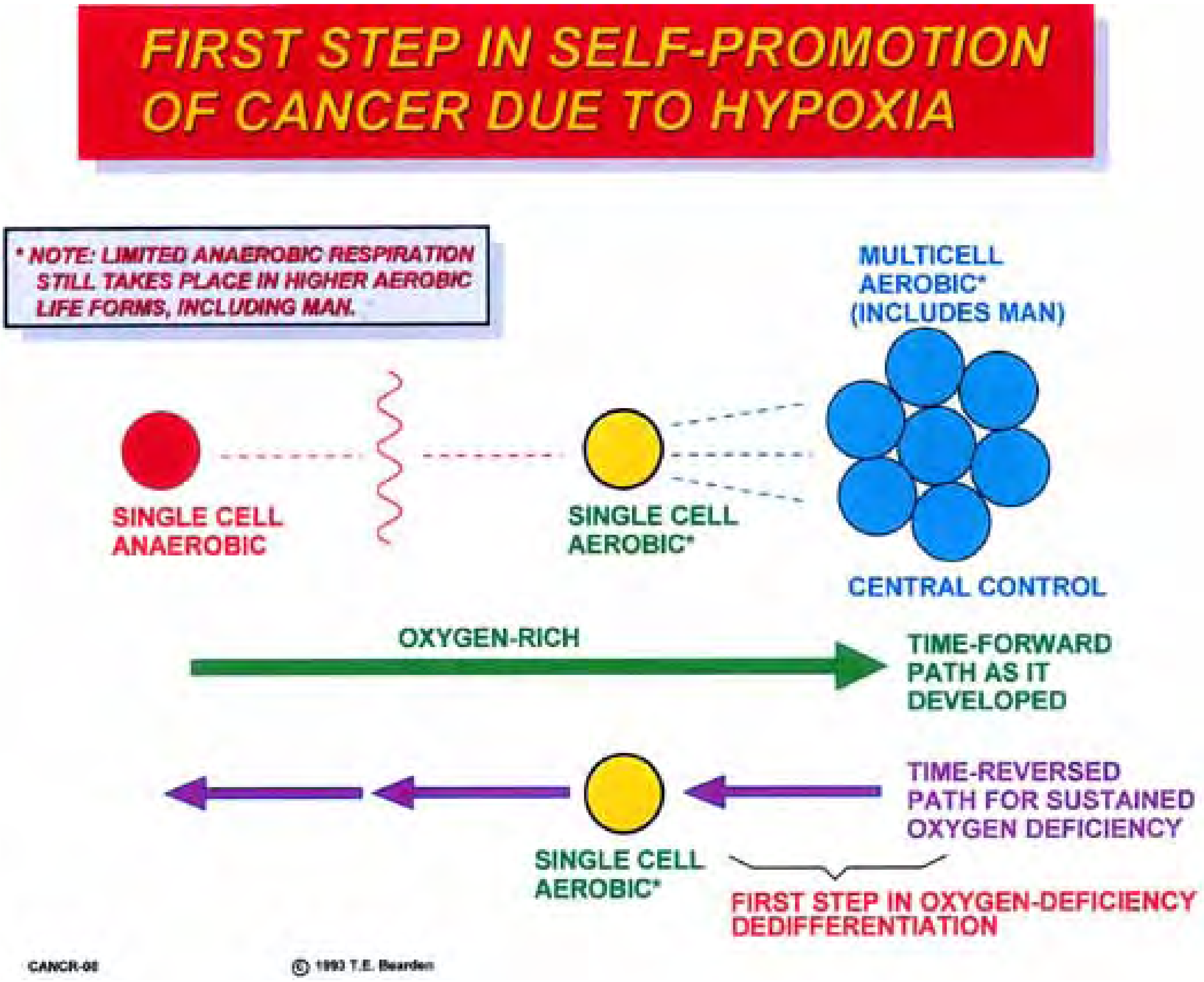

FIRST STEP IN SELF-PROMOTION OF CANCER DUE TO HYPOXIA

* NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.

MULTICELL
AEROBIC*
(INCLUDES MAN)
SINGLE CELL
ANAEROBIC
SINGLE CELL
AEROBIC*
CENTRAL CONTROL
OXYGEN-RICH
TIME-FORWARD
PATH AS IT
DEVELOPED
TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY
SINGLE CELL
AEROBIC*
FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION

CANCR-08

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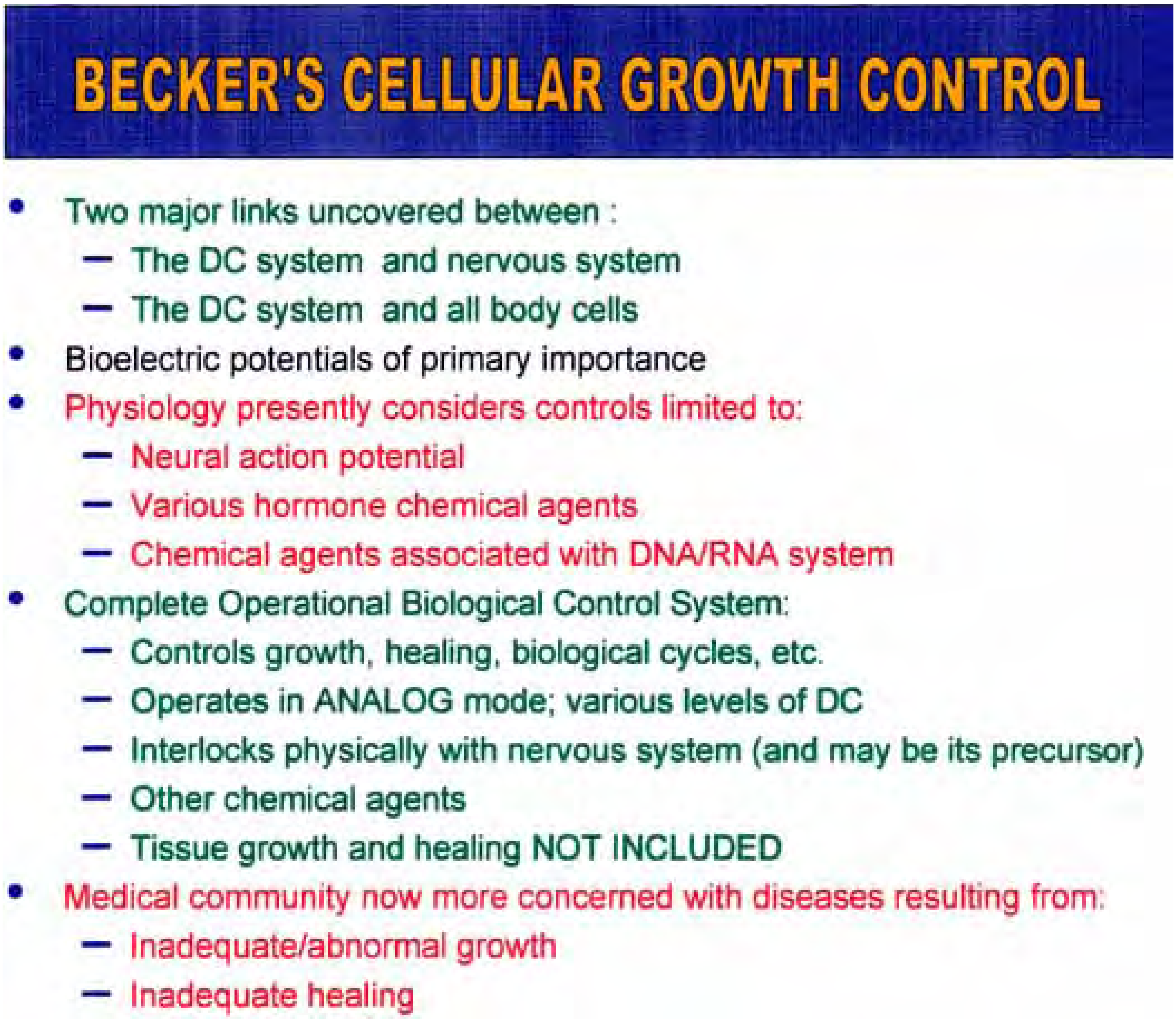

BECKER'S CELLULAR GROWTH CONTROL

- Two major links uncovered between :
  - The DC system and nervous system
  - The DC system and all body cells
- Bioelectric potentials of primary importance
- Physiology presently considers controls limited to:
  - Neural action potential
  - Various hormone chemical agents
  - Chemical agents associated with DNA/RNA system
- Complete Operational Biological Control System:
  - Controls growth, healing, biological cycles, etc.
  - Operates in ANALOG mode; various levels of DC
  - Interlocks physically with nervous system (and may be its precursor)
  - Other chemical agents
  - Tissue growth and healing NOT INCLUDED
- Medical community now more concerned with diseases resulting from:
  - Inadequate/abnormal growth
  - Inadequate healing

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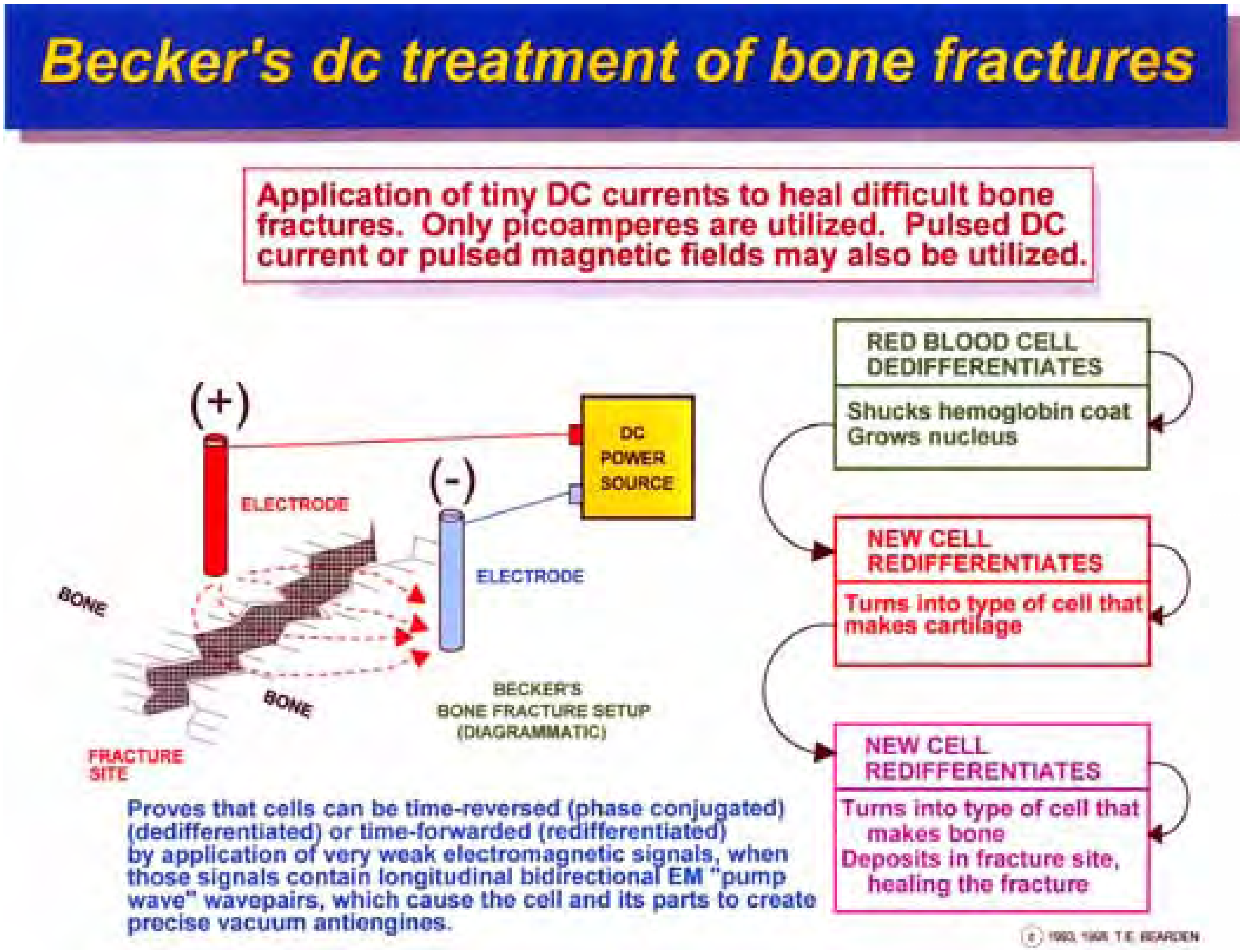

Becker's dc treatment of bone fractures

Application of tiny DC currents to heal difficult bone fractures. Only picoamperes are utilized. Pulsed DC current or pulsed magnetic fields may also be utilized.

(+)

(-)

DC
POWER
SOURCE

ELECTRODE

ELECTRODE

BONE

BONE

FRACTURE
SITE

BECKER'S
BONE FRACTURE SETUP
(DIAGRAMMATIC)

RED BLOOD CELL
DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL
REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL
REDIFFERENTIATES

Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

Proves that cells can be time-reversed (phase conjugated) (dedifferentiated) or time-forwarded (redifferentiated) by application of very weak electromagnetic signals, when those signals contain longitudinal bidirectional EM "pump wave" wavepairs, which cause the cell and its parts to create precise vacuum antiengines.

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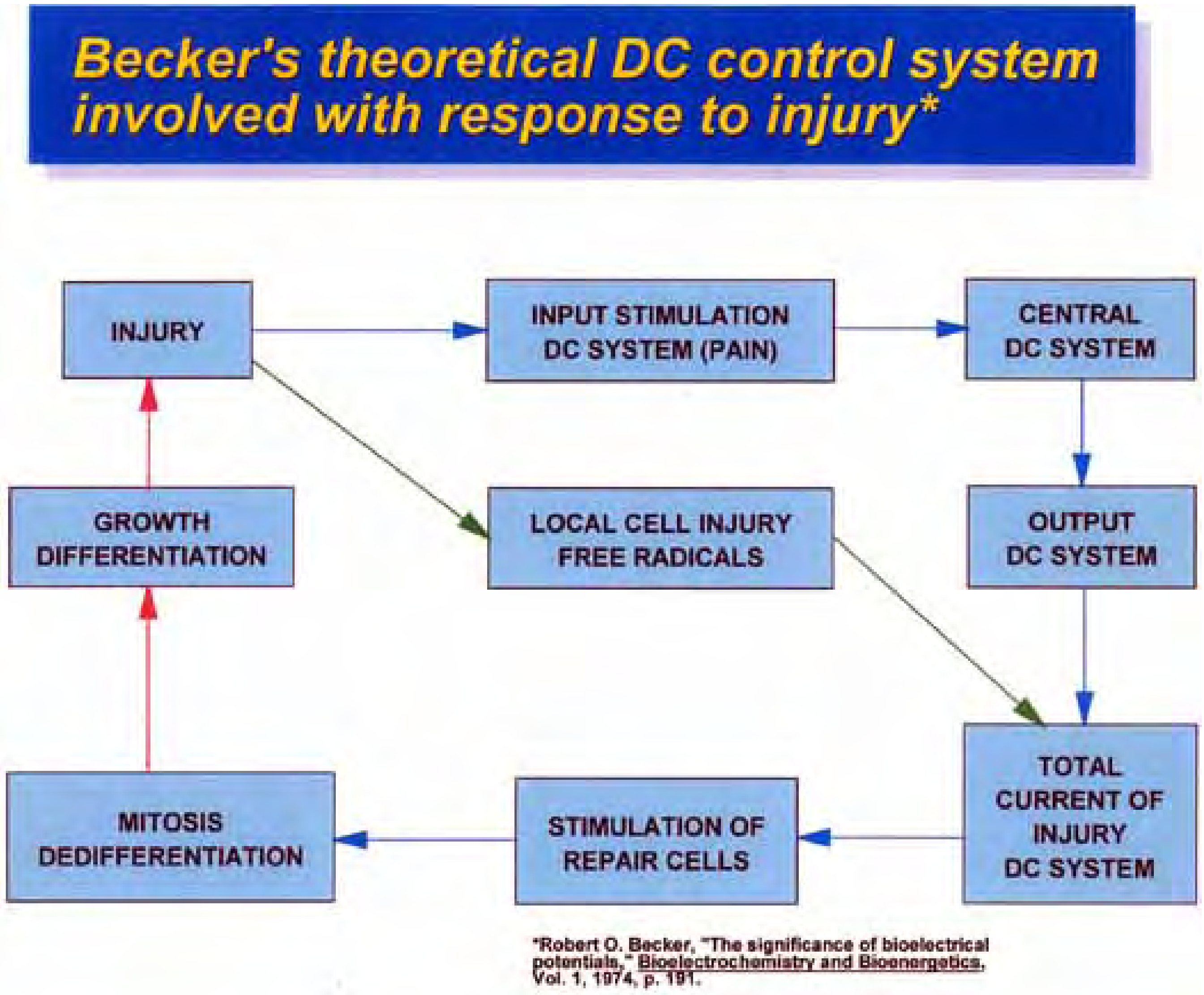

Becker's theoretical DC control system involved with response to injury*

INJURY

INPUT STIMULATION DC SYSTEM (PAIN)

CENTRAL DC SYSTEM

GROWTH DIFFERENTIATION

LOCAL CELL INJURY FREE RADICALS

OUTPUT DC SYSTEM

TOTAL CURRENT OF INJURY DC SYSTEM

STIMULATION OF REPAIR CELLS

MITOSIS DEDIFFERENTIATION

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.

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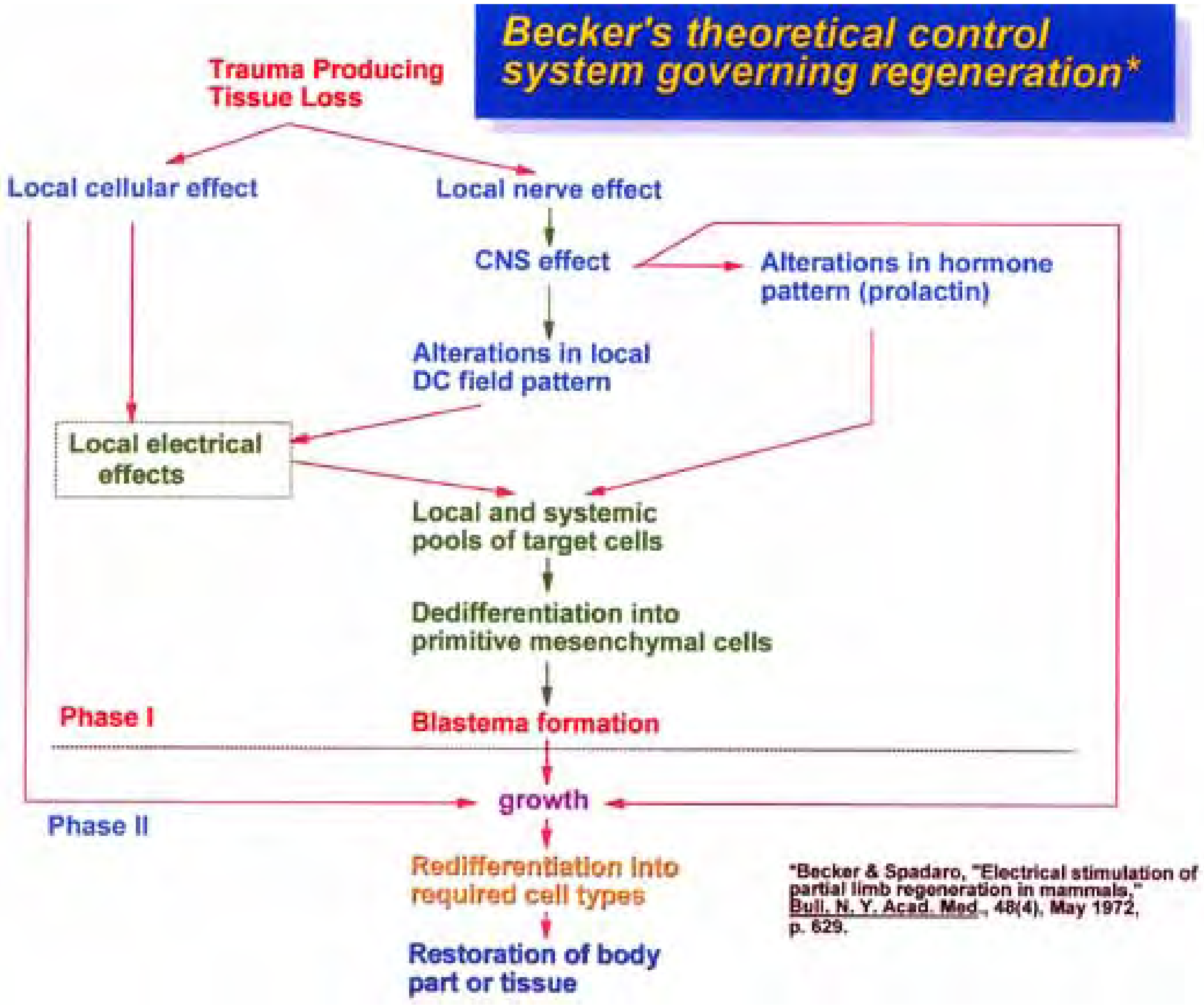

Becker's theoretical control system governing regeneration*

Trauma Producing
Tissue Loss

Local cellular effect

Local nerve effect

CNS effect

Alterations in hormone
pattern (prolactin)

Alterations in local
DC field pattern

Local electrical
effects

Local and systemic
pools of target cells

Dedifferentiation into
primitive mesenchymal cells

Phase I

Blastema formation

growth

Phase II

Redifferentiation into
required cell types

Restoration of body
part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bull. N. Y. Acad. Med., 48(4), May 1972, p. 629.

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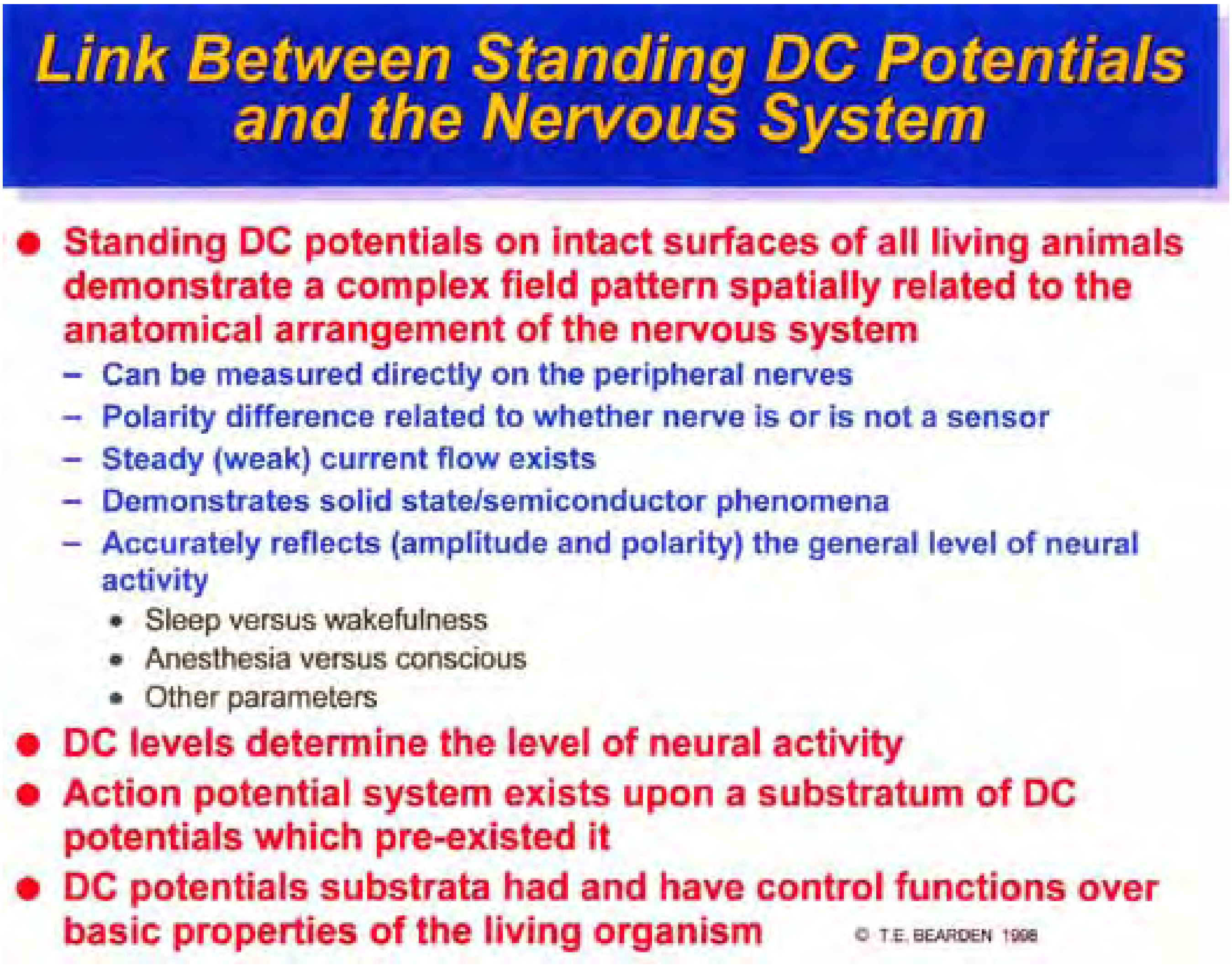

Link Between Standing DC Potentials and the Nervous System

- Standing DC potentials on intact surfaces of all living animals demonstrate a complex field pattern spatially related to the anatomical arrangement of the nervous system
  - Can be measured directly on the peripheral nerves
  - Polarity difference related to whether nerve is or is not a sensor
  - Steady (weak) current flow exists
  - Demonstrates solid state/semiconductor phenomena
  - Accurately reflects (amplitude and polarity) the general level of neural activity
    - Sleep versus wakefulness
    - Anesthesia versus conscious
    - Other parameters
- DC levels determine the level of neural activity
- Action potential system exists upon a substratum of DC potentials which pre-existed it
- DC potentials substrata had and have control functions over basic properties of the living organism

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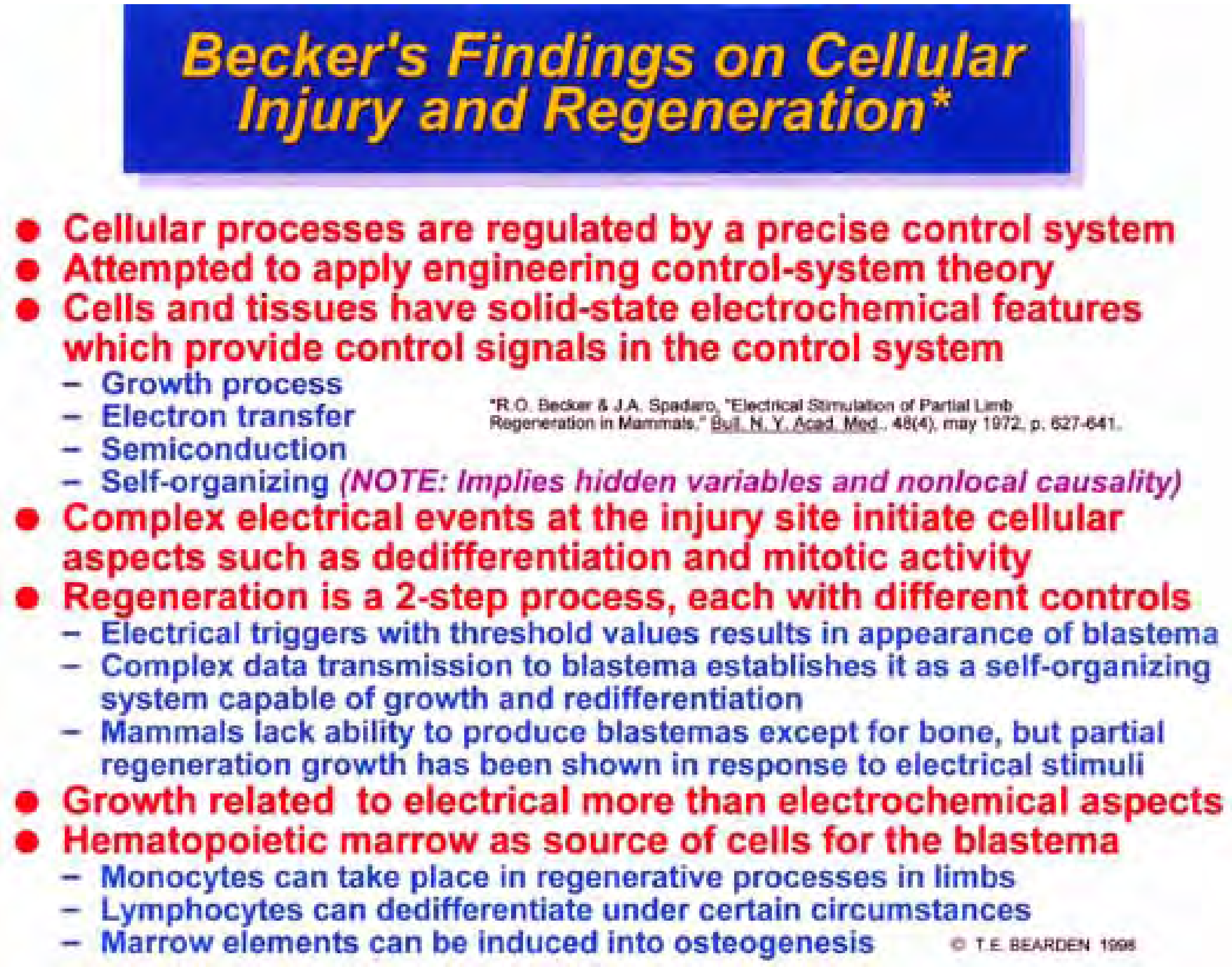

Becker's Findings on Cellular Injury and Regeneration*

- Cellular processes are regulated by a precise control system
- Attempted to apply engineering control-system theory
- Cells and tissues have solid-state electrochemical features which provide control signals in the control system
  - Growth process
  - Electron transfer
  - Semiconduction
  - Self-organizing *(NOTE: Implies hidden variables and nonlocal causality)*
- Complex electrical events at the injury site initiate cellular aspects such as dedifferentiation and mitotic activity
- Regeneration is a 2-step process, each with different controls
  - Electrical triggers with threshold values results in appearance of blastema
  - Complex data transmission to blastema establishes it as a self-organizing system capable of growth and redifferentiation
  - Mammals lack ability to produce blastemas except for bone, but partial regeneration growth has been shown in response to electrical stimuli
- Growth related to electrical more than electrochemical aspects
- Hematopoietic marrow as source of cells for the blastema
  - Monocytes can take place in regenerative processes in limbs
  - Lymphocytes can dedifferentiate under certain circumstances
  - Marrow elements can be induced into osteogenesis

*R.O. Becker & J.A. Spadaro, "Electrical Stimulation of Partial Limb Regeneration in Mammals," Bull. N. Y. Acad. Med., 48(4), may 1972, p. 627-641.

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Corrections For the Present EM Bioeffects Model

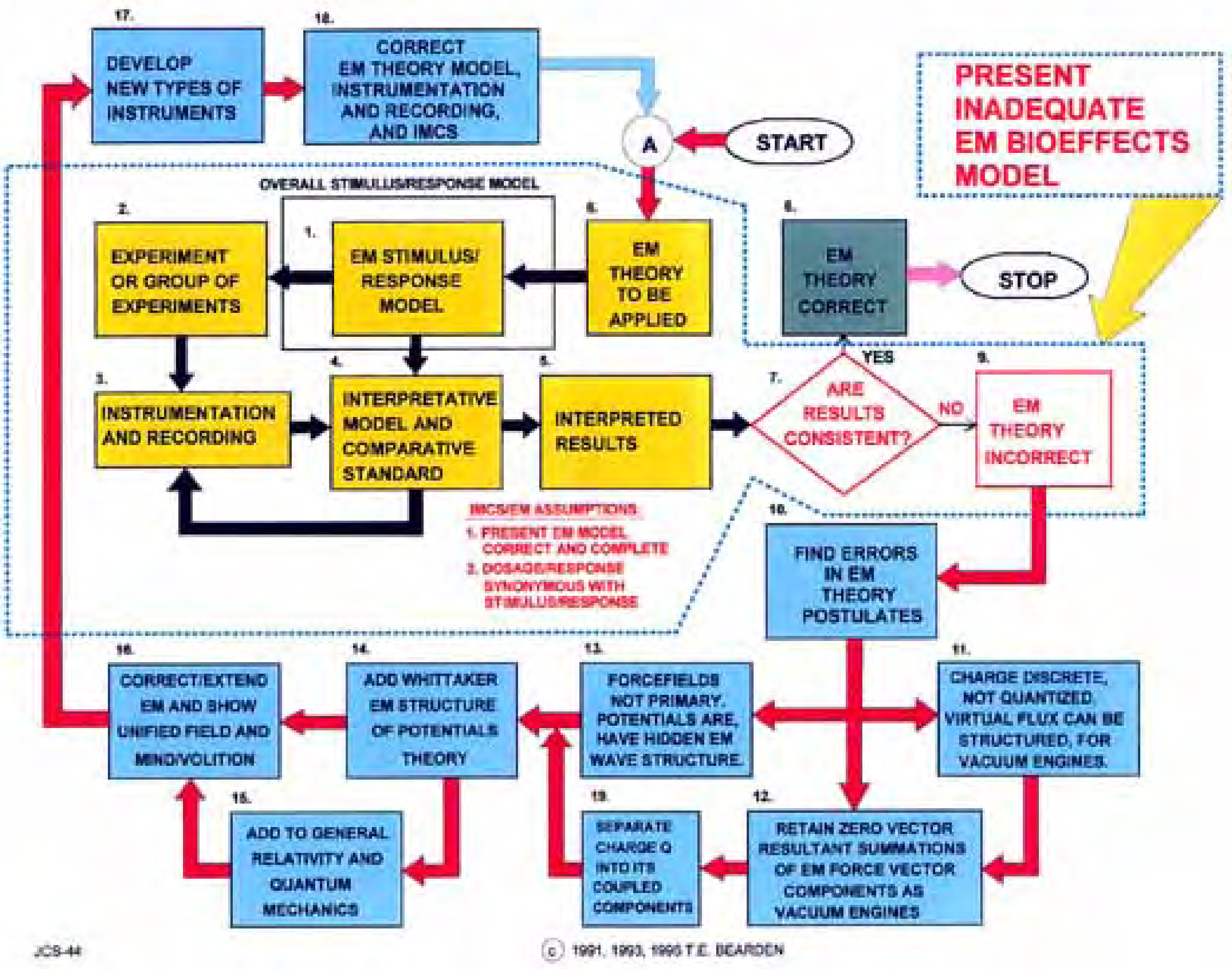

17. DEVELOP NEW TYPES OF INSTRUMENTS

18. CORRECT EM THEORY MODEL, INSTRUMENTATION AND RECORDING, AND IMCS

A

START

PRESENT INADEQUATE EM BIOEFFECTS MODEL

OVERALL STIMULUS/RESPONSE MODEL

2. EXPERIMENT OR GROUP OF EXPERIMENTS

1. EM STIMULUS/ RESPONSE MODEL

6. EM THEORY TO BE APPLIED

8. EM THEORY CORRECT

STOP

3. INSTRUMENTATION AND RECORDING

4. INTERPRETATIVE MODEL AND COMPARATIVE STANDARD

5. INTERPRETED RESULTS

7. ARE RESULTS CONSISTENT?

YES

NO

9. EM THEORY INCORRECT

IMCS/EM ASSUMPTIONS

1. PRESENT EM MODEL CORRECT AND COMPLETE
2. DOSAGE/RESPONSE SYNONYMOUS WITH STIMULUS/RESPONSE

10. FIND ERRORS IN EM THEORY POSTULATES

16. CORRECT/EXTEND EM AND SHOW UNIFIED FIELD AND MIND/VOLITION

14. ADD WHITTAKER EM STRUCTURE OF POTENTIALS THEORY

13. FORCEFIELDS NOT PRIMARY. POTENTIALS ARE, HAVE HIDDEN EM WAVE STRUCTURE.

11. CHARGE DISCRETE, NOT QUANTIZED. VIRTUAL FLUX CAN BE STRUCTURED, FOR VACUUM ENGINES.

15. ADD TO GENERAL RELATIVITY AND QUANTUM MECHANICS

19. SEPARATE CHARGE Q INTO ITS COUPLED COMPONENTS

12. RETAIN ZERO VECTOR RESULTANT SUMMATIONS OF EM FORCE VECTOR COMPONENTS AS VACUUM ENGINES

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R&R SYSTEM
Regeneration Example

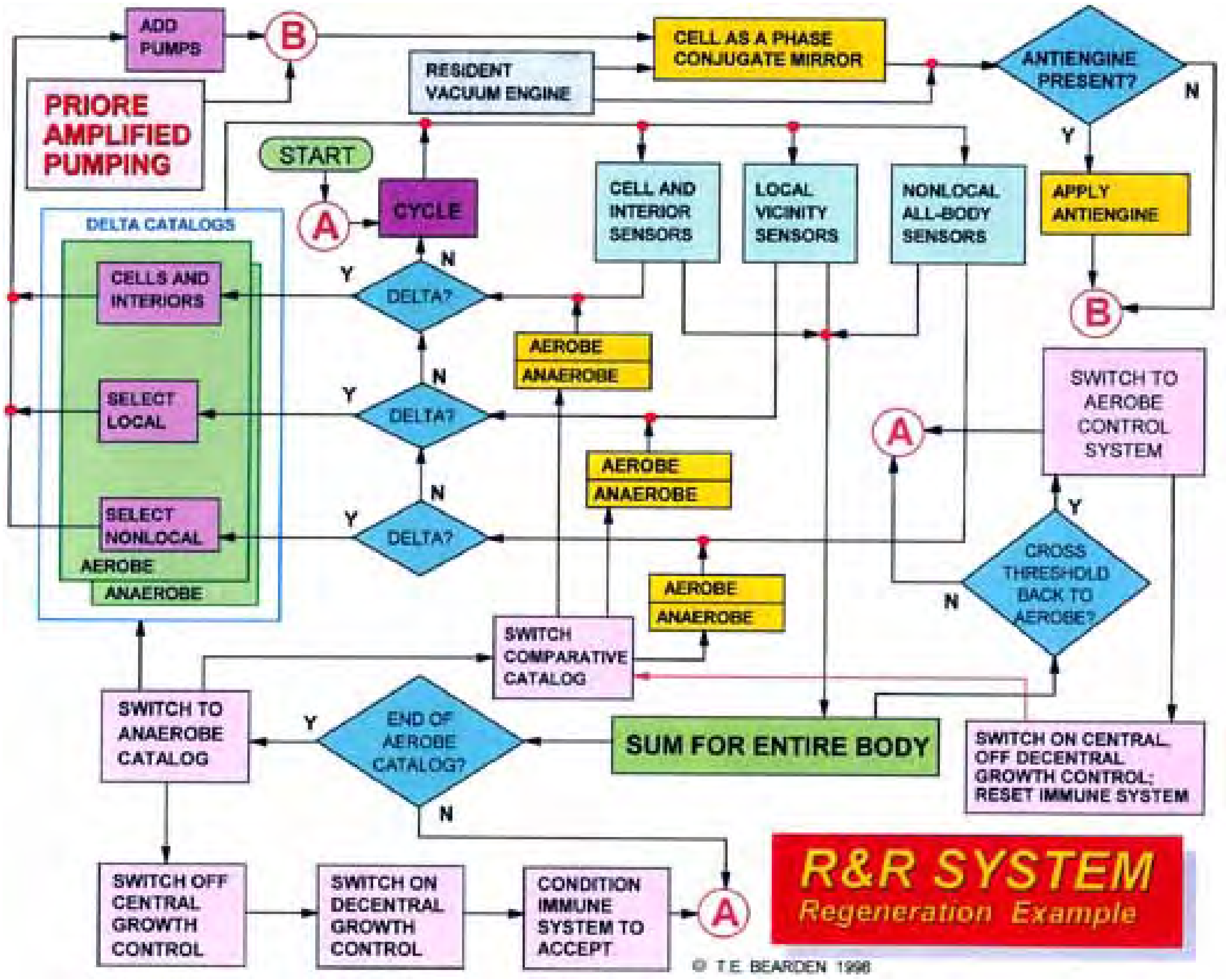

PRIORE AMPLIFIED PUMPING

ADD PUMPS

B

RESIDENT VACUUM ENGINE

CELL AS A PHASE CONJUGATE MIRROR

ANTIENGINE PRESENT?

Y

N

APPLY ANTIENGINE

B

START

A

CYCLE

CELL AND INTERIOR SENSORS

LOCAL VICINITY SENSORS

NONLOCAL ALL-BODY SENSORS

DELTA CATALOGS

CELLS AND INTERIORS

SELECT LOCAL

SELECT NONLOCAL

AEROBE

ANAEROBE

Y

N

DELTA?

Y

N

DELTA?

Y

N

DELTA?

AEROBE

ANAEROBE

AEROBE

ANAEROBE

AEROBE

ANAEROBE

SWITCH TO AEROBE CONTROL SYSTEM

A

Y

CROSS THRESHOLD BACK TO AEROBE?

N

SWITCH COMPARATIVE CATALOG

SWITCH TO ANAEROBE CATALOG

Y

END OF AEROBE CATALOG?

N

SUM FOR ENTIRE BODY

SWITCH ON CENTRAL, OFF DECENTRAL GROWTH CONTROL; RESET IMMUNE SYSTEM

SWITCH OFF CENTRAL GROWTH CONTROL

SWITCH ON DECENTRAL GROWTH CONTROL

CONDITION IMMUNE SYSTEM TO ACCEPT

A

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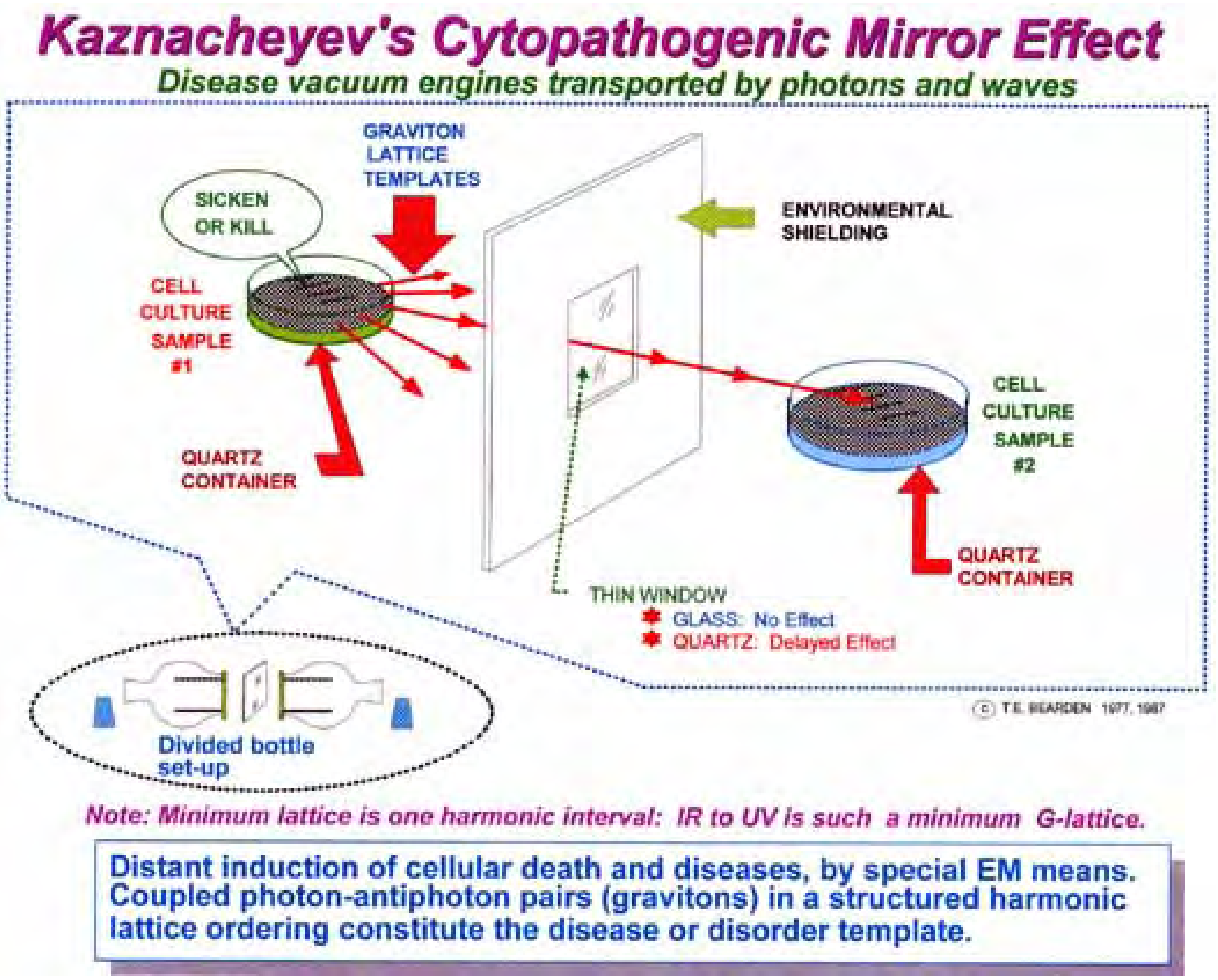

Kaznacheyev's Cytopathogenic Mirror Effect

Disease vacuum engines transported by photons and waves

GRAVITON
LATTICE
TEMPLATES
SICKEN
OR KILL
ENVIRONMENTAL
SHIELDING
CELL
CULTURE
SAMPLE
#1
QUARTZ
CONTAINER
CELL
CULTURE
SAMPLE
#2
QUARTZ
CONTAINER
THIN WINDOW
GLASS: No Effect
QUARTZ: Delayed Effect
Divided bottle
set-up
© T.E. BEARDEN 1977, 1987

Note: Minimum lattice is one harmonic interval: IR to UV is such a minimum G-lattice.

Distant induction of cellular death and diseases, by special EM means. Coupled photon-antiphoton pairs (gravitons) in a structured harmonic lattice ordering constitute the disease or disorder template.

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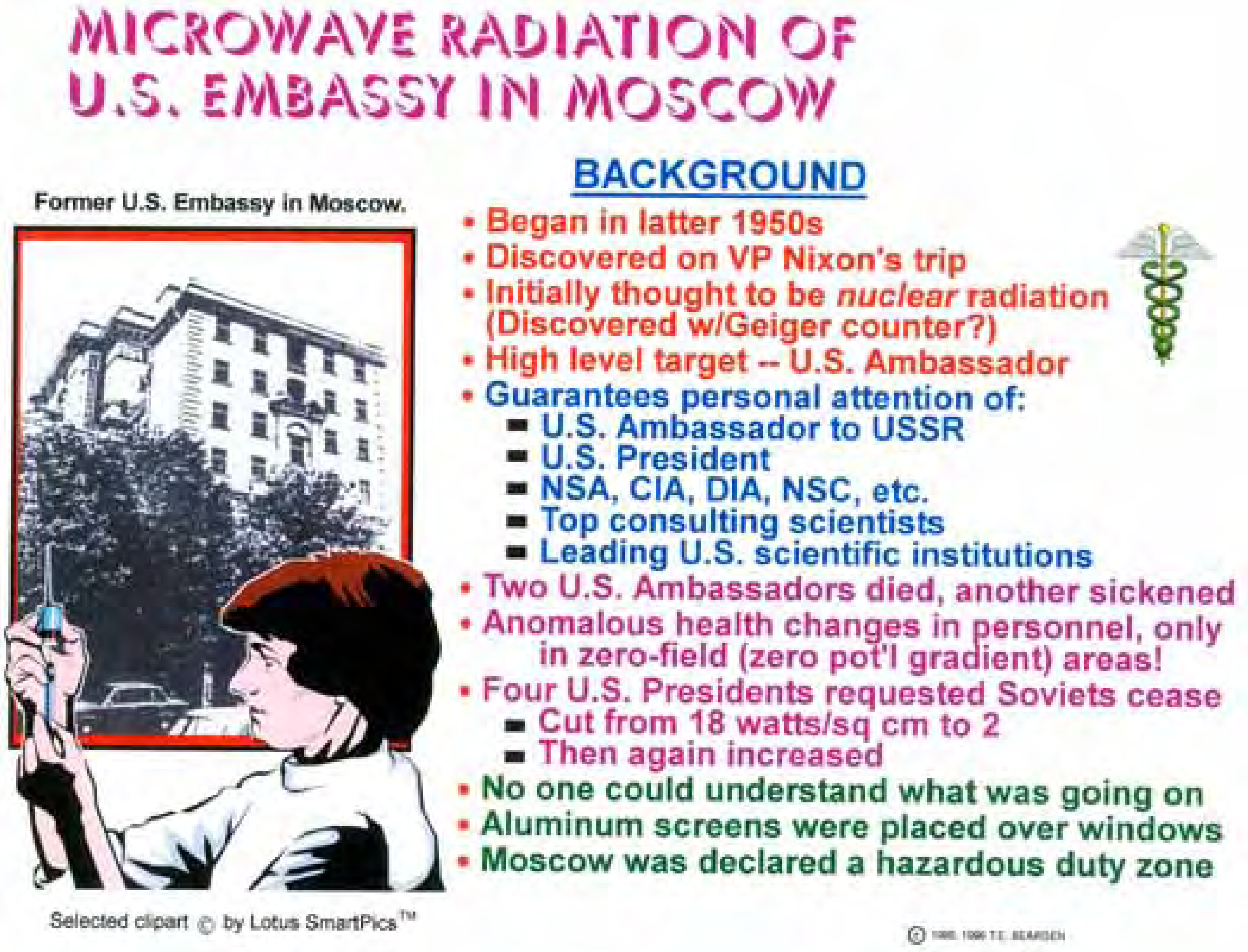

MICROWAVE RADIATION OF U.S. EMBASSY IN MOSCOW

Former U.S. Embassy in Moscow.

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter?)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
  - U.S. Ambassador to USSR
  - U.S. President
  - NSA, CIA, DIA, NSC, etc.
  - Top consulting scientists
  - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero pot'l gradient) areas!
- Four U.S. Presidents requested Soviets cease
  - Cut from 18 watts/sq cm to 2
  - Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

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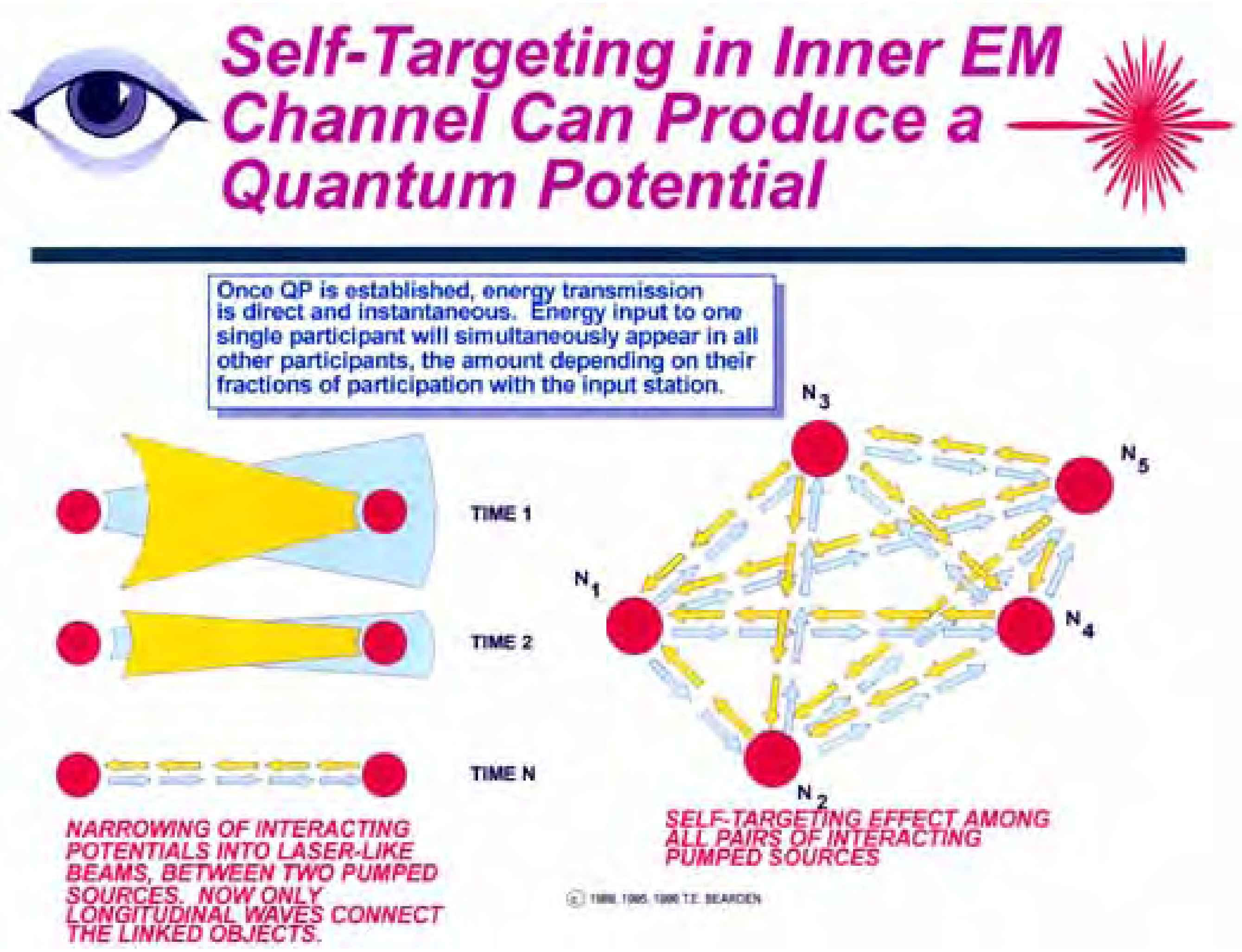

Self-Targeting in Inner EM Channel Can Produce a Quantum Potential

Once QP is established, energy transmission is direct and instantaneous. Energy input to one single participant will simultaneously appear in all other participants, the amount depending on their fractions of participation with the input station.

NARROWING OF INTERACTING POTENTIALS INTO LASER-LIKE BEAMS, BETWEEN TWO PUMPED SOURCES. NOW ONLY LONGITUDINAL WAVES CONNECT THE LINKED OBJECTS.

SELF-TARGETING EFFECT AMONG ALL PAIRS OF INTERACTING PUMPED SOURCES

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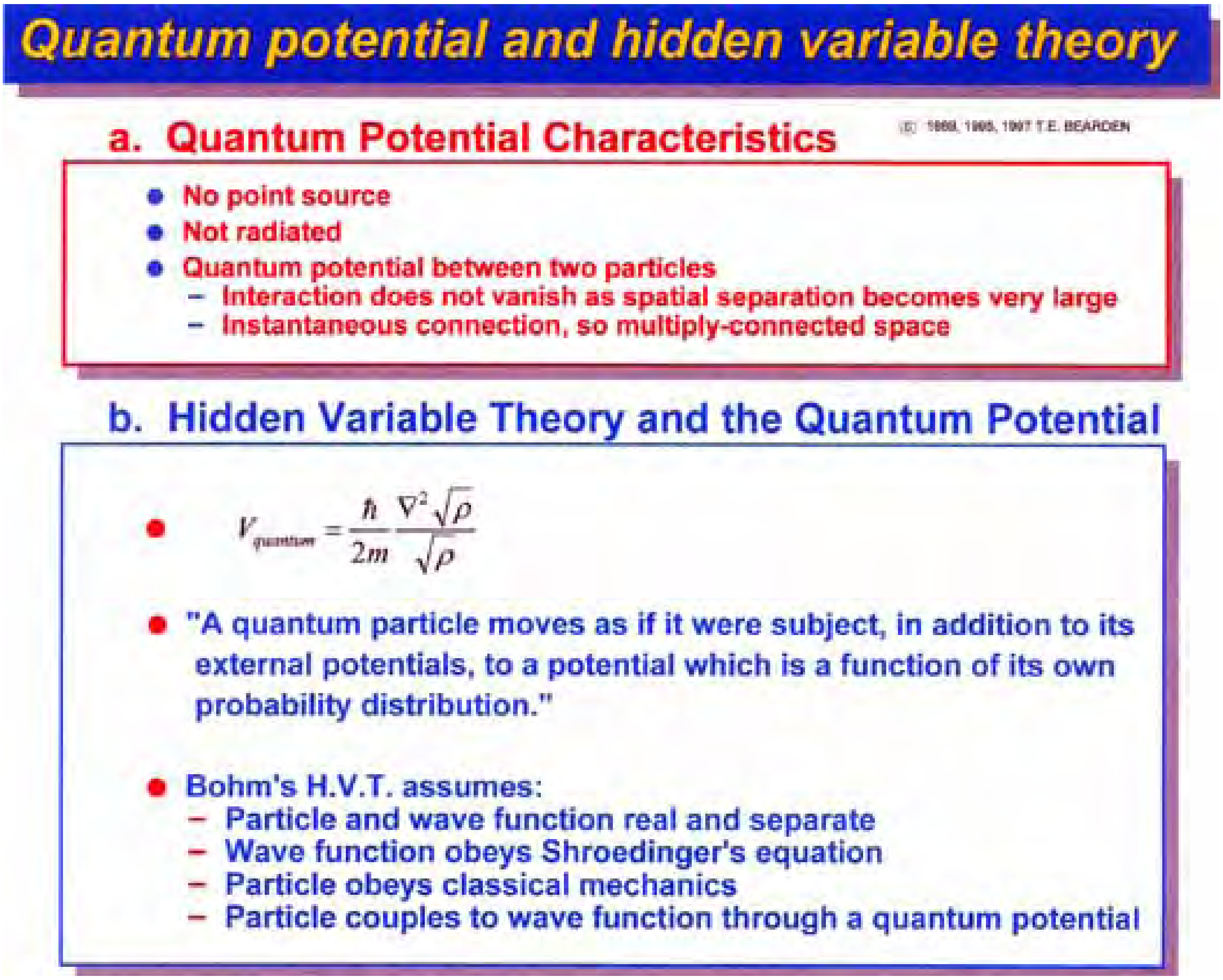

Quantum potential and hidden variable theory

a. Quantum Potential Characteristics

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- No point source
- Not radiated
- Quantum potential between two particles
  - Interaction does not vanish as spatial separation becomes very large
  - Instantaneous connection, so multiply-connected space

b. Hidden Variable Theory and the Quantum Potential

- $V_{quantum} = \frac{\hbar}{2m} \frac{\nabla^2 \sqrt{\rho}}{\sqrt{\rho}}$
- "A quantum particle moves as if it were subject, in addition to its external potentials, to a potential which is a function of its own probability distribution."
- Bohm's H.V.T. assumes:
  - Particle and wave function real and separate
  - Wave function obeys Shroedinger's equation
  - Particle obeys classical mechanics
  - Particle couples to wave function through a quantum potential

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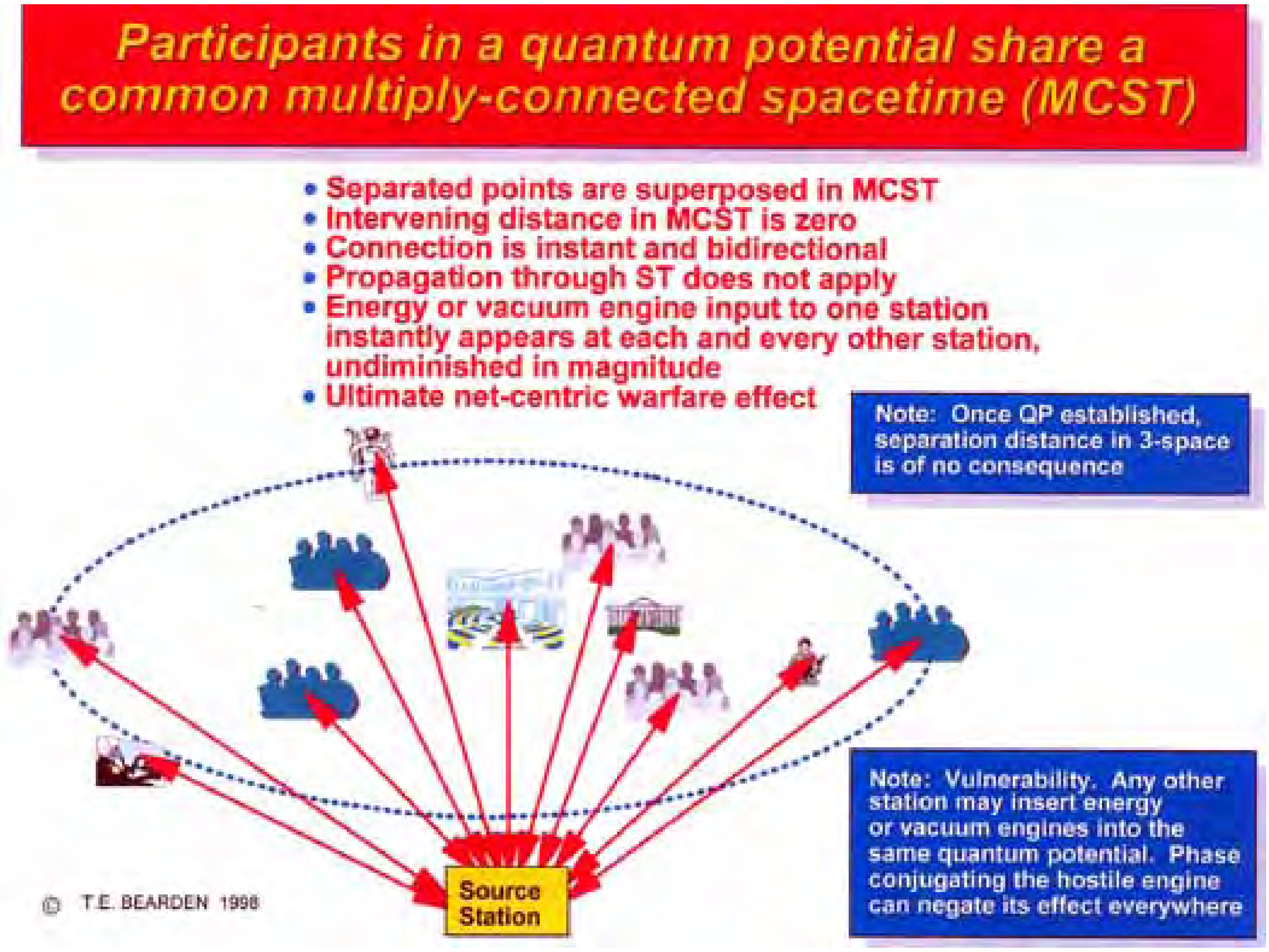

Participants in a quantum potential share a common multiply-connected spacetime (MCST)

- Separated points are superposed in MCST
- Intervening distance in MCST is zero
- Connection is instant and bidirectional
- Propagation through ST does not apply
- Energy or vacuum engine input to one station instantly appears at each and every other station, undiminished in magnitude
- Ultimate net-centric warfare effect

Note: Once QP established, separation distance in 3-space is of no consequence

Note: Vulnerability. Any other station may insert energy or vacuum engines into the same quantum potential. Phase conjugating the hostile engine can negate its effect everywhere

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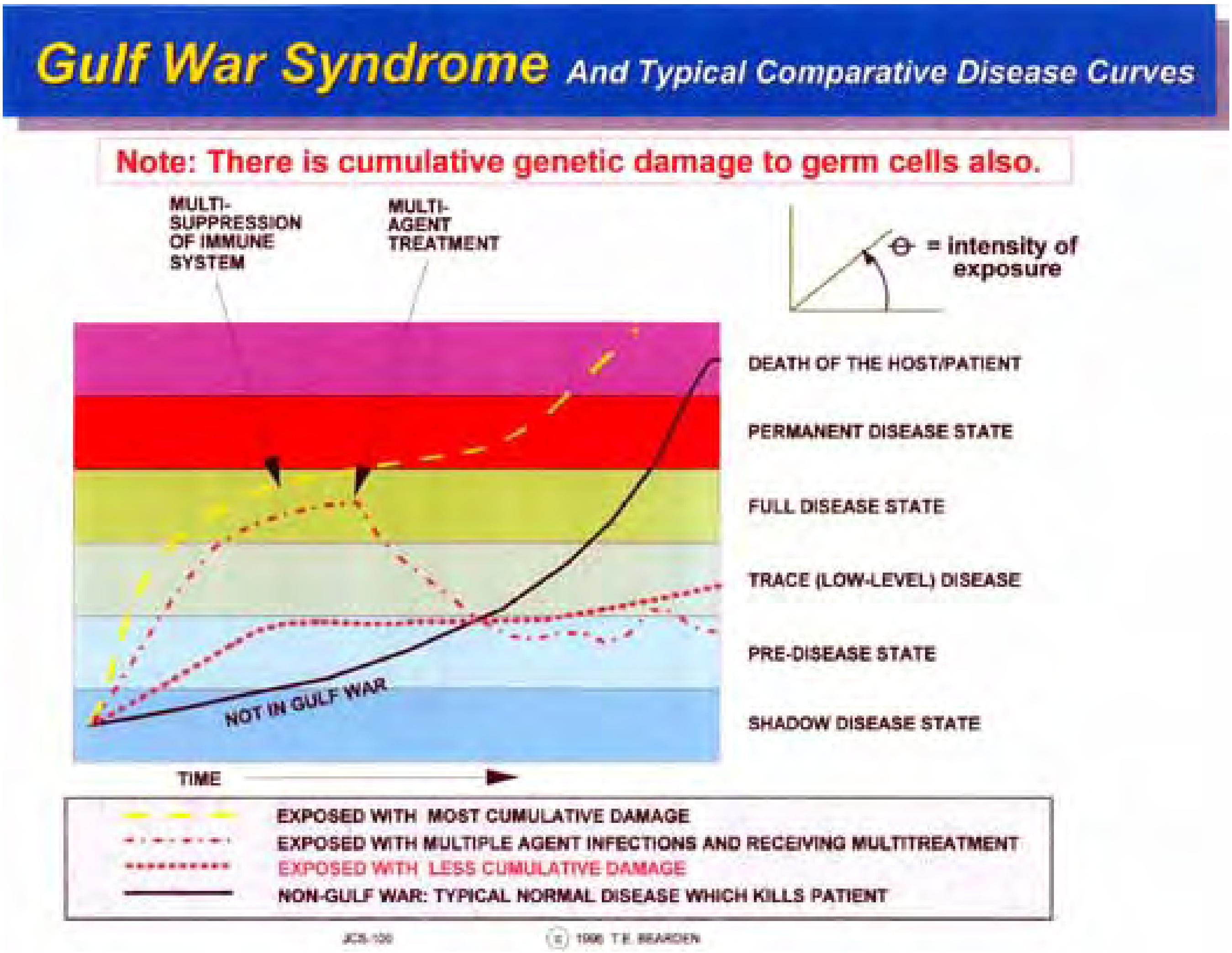

Gulf War Syndrome And Typical Comparative Disease Curves

Note: There is cumulative genetic damage to germ cells also.

— — — EXPOSED WITH MOST CUMULATIVE DAMAGE
-·-·-·-· EXPOSED WITH MULTIPLE AGENT INFECTIONS AND RECEIVING MULTITREATMENT
·········· EXPOSED WITH LESS CUMULATIVE DAMAGE
——— NON-GULF WAR: TYPICAL NORMAL DISEASE WHICH KILLS PATIENT

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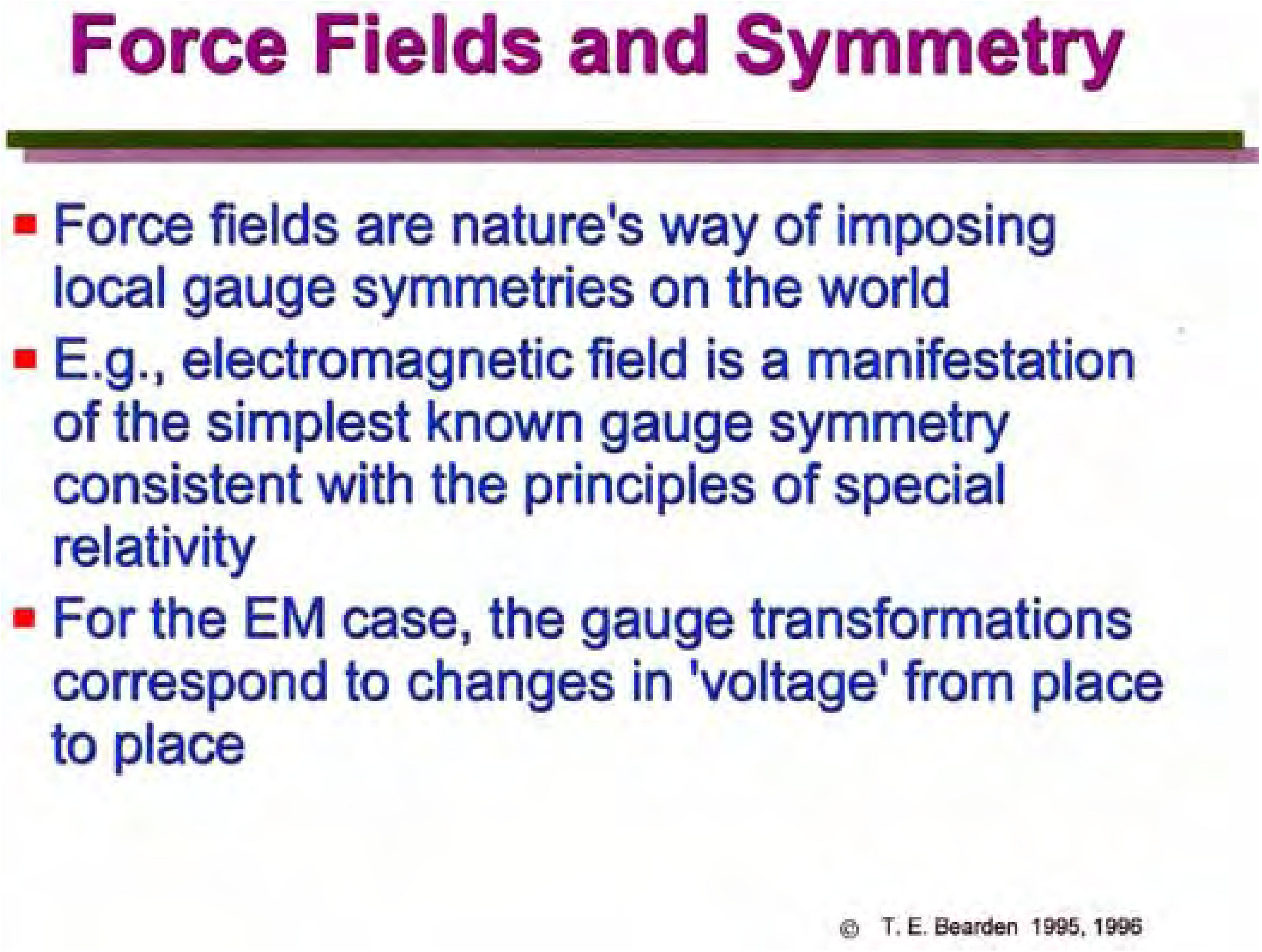

Force Fields and Symmetry

- Force fields are nature's way of imposing local gauge symmetries on the world
- E.g., electromagnetic field is a manifestation of the simplest known gauge symmetry consistent with the principles of special relativity
- For the EM case, the gauge transformations correspond to changes in 'voltage' from place to place

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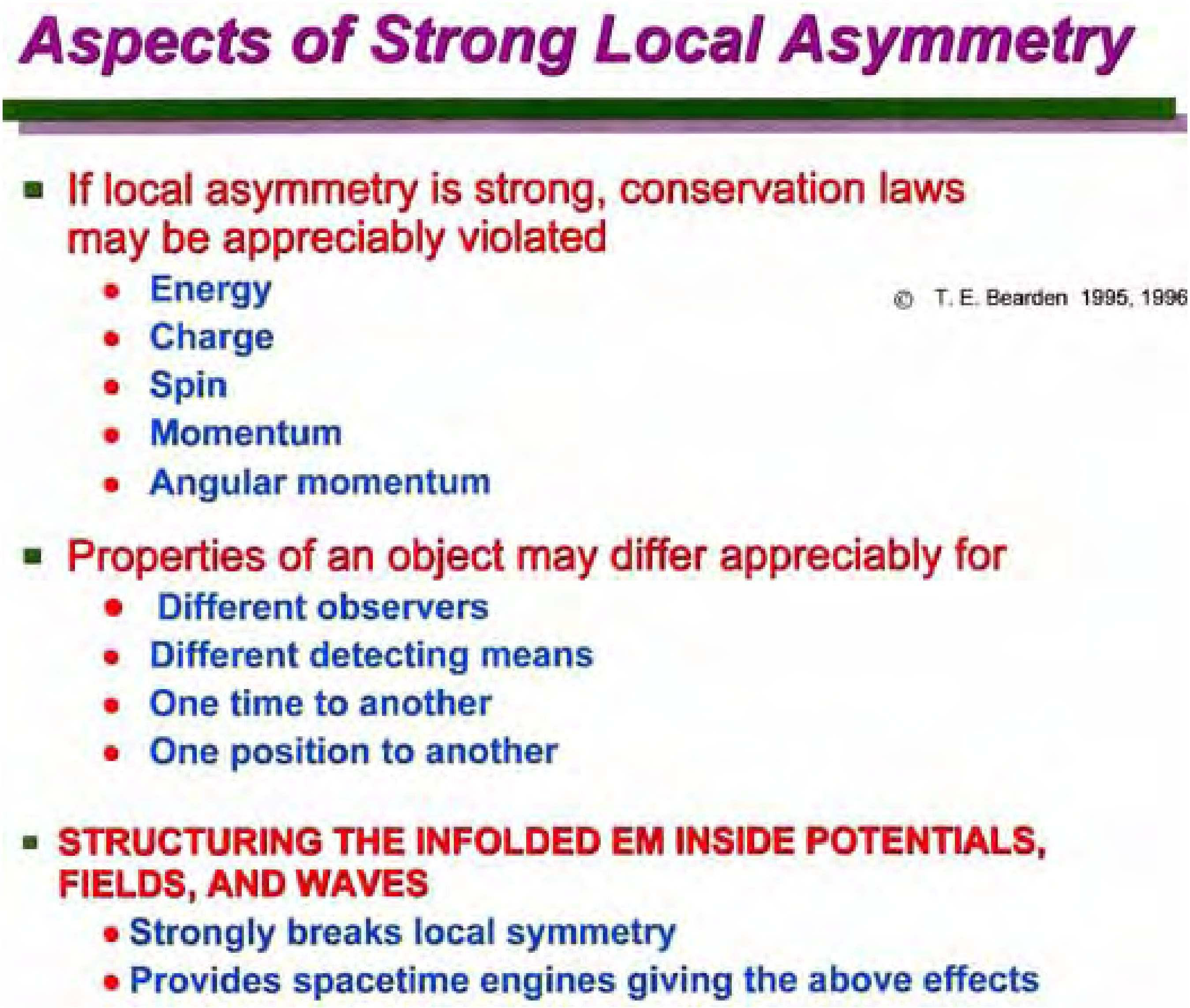

Aspects of Strong Local Asymmetry

- If local asymmetry is strong, conservation laws may be appreciably violated
  - Energy
  - Charge
  - Spin
  - Momentum
  - Angular momentum

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- Properties of an object may differ appreciably for
  - Different observers
  - Different detecting means
  - One time to another
  - One position to another
- STRUCTURING THE INFOLDED EM INSIDE POTENTIALS, FIELDS, AND WAVES
  - Strongly breaks local symmetry
  - Provides spacetime engines giving the above effects

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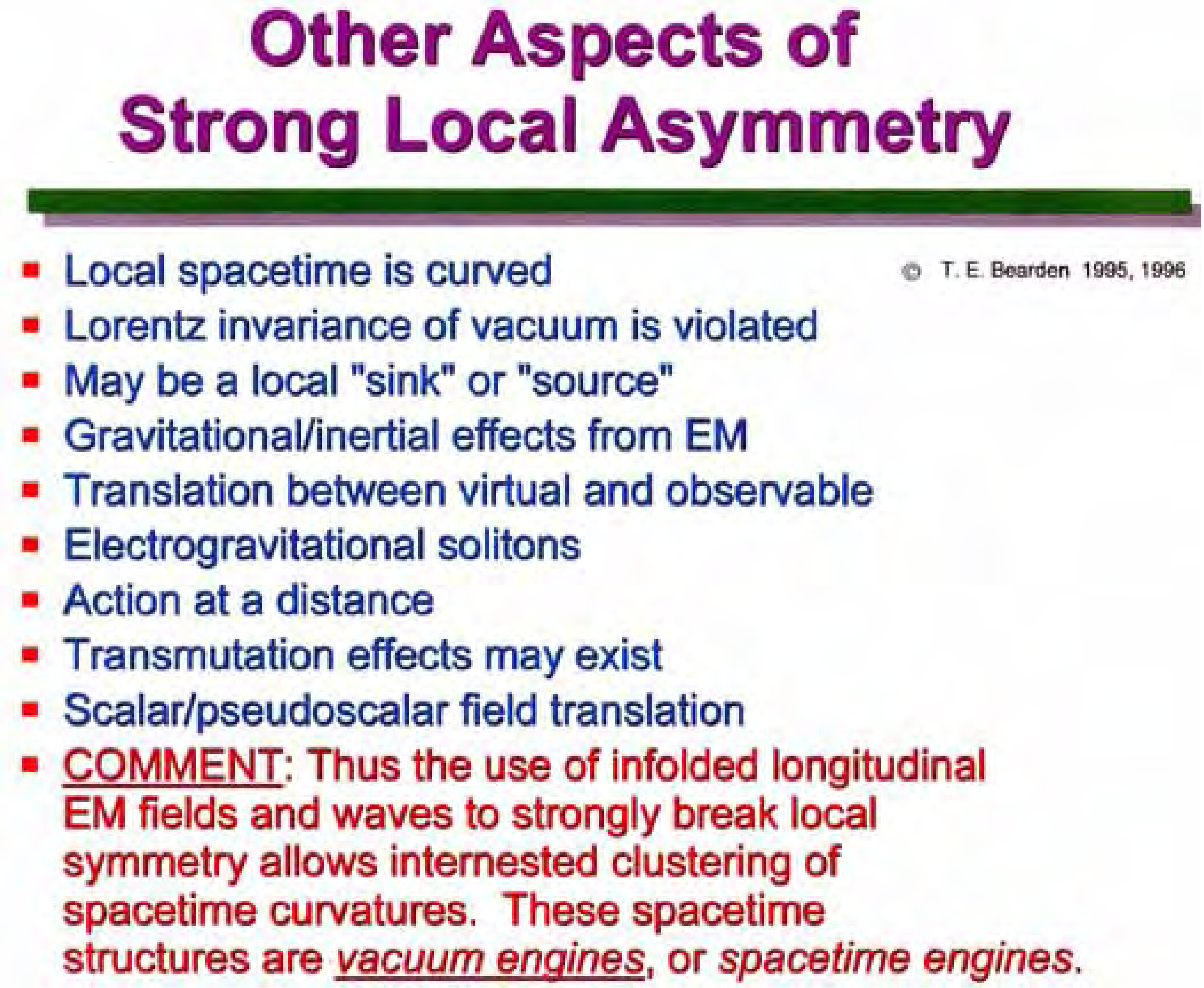

Other Aspects of Strong Local Asymmetry

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- Local spacetime is curved
- Lorentz invariance of vacuum is violated
- May be a local "sink" or "source"
- Gravitational/inertial effects from EM
- Translation between virtual and observable
- Electrogravitational solitons
- Action at a distance
- Transmutation effects may exist
- Scalar/pseudoscalar field translation
- COMMENT: Thus the use of infolded longitudinal EM fields and waves to strongly break local symmetry allows internested clustering of spacetime curvatures. These spacetime structures are *vacuum engines*, or *spacetime engines*.

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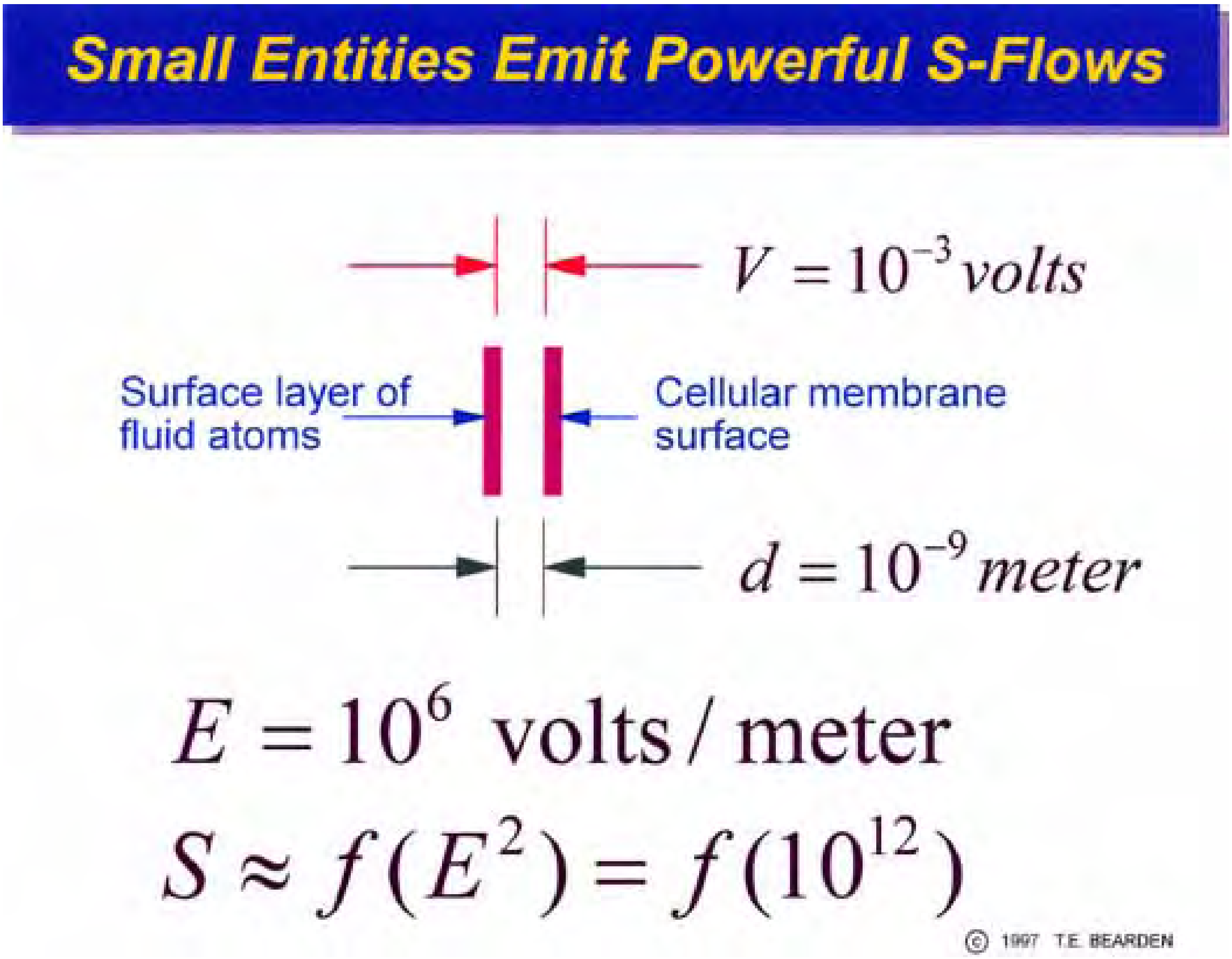

Small Entities Emit Powerful S-Flows

$V = 10^{-3}\,volts$

Surface layer of fluid atoms

Cellular membrane surface

$d = 10^{-9}\,meter$

$$E = 10^{6}\ \text{volts / meter}$$

$$S \approx f(E^{2}) = f(10^{12})$$

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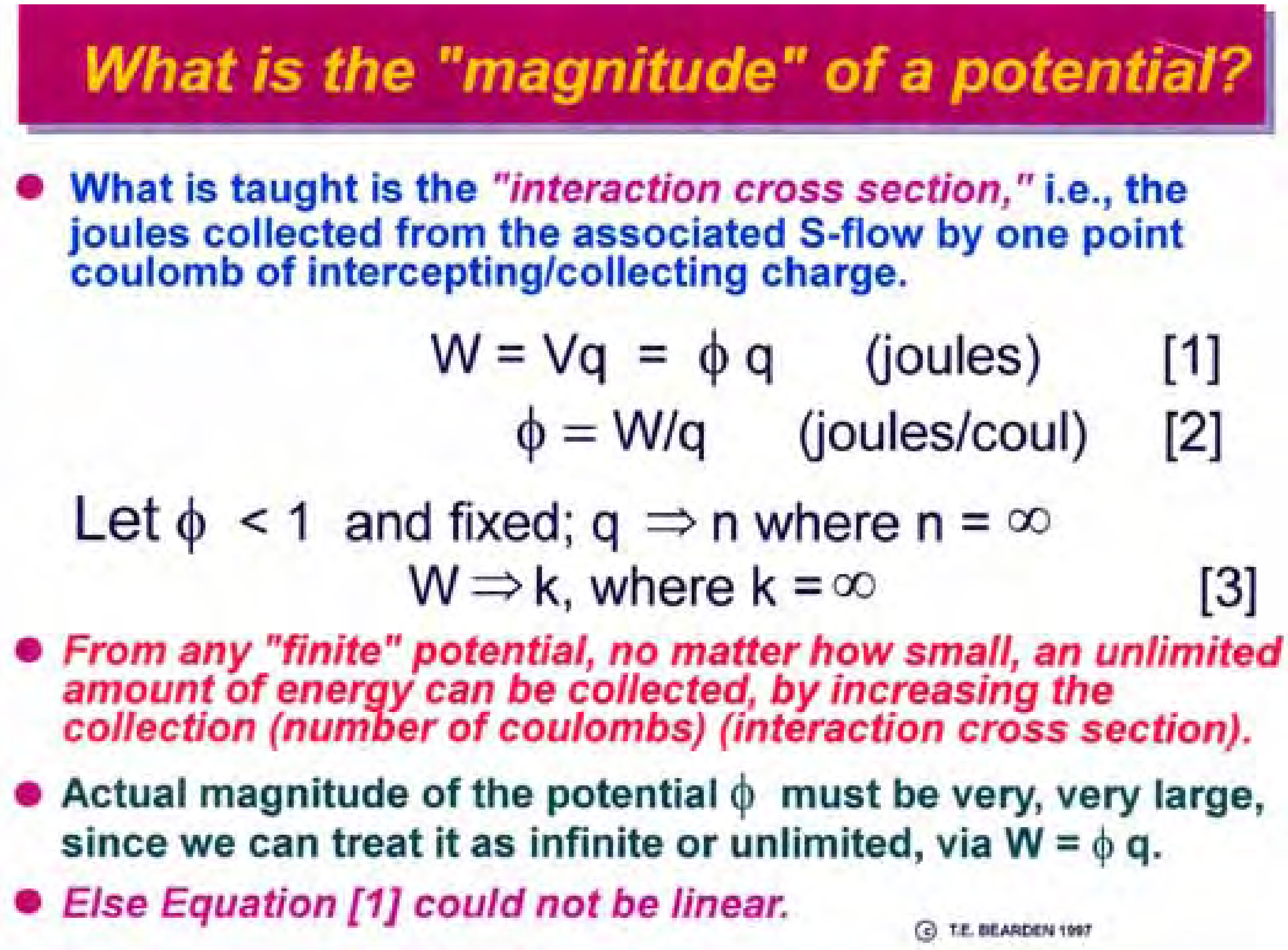

What is the "magnitude" of a potential?

- **What is taught is the *"interaction cross section,"* i.e., the joules collected from the associated S-flow by one point coulomb of intercepting/collecting charge.**

$$W = Vq = \phi q \quad \text{(joules)} \quad [1]$$

$$\phi = W/q \quad \text{(joules/coul)} \quad [2]$$

$$\text{Let } \phi < 1 \text{ and fixed; } q \Rightarrow n \text{ where } n = \infty$$

$$W \Rightarrow k, \text{ where } k = \infty \quad [3]$$

- ***From any "finite" potential, no matter how small, an unlimited amount of energy can be collected, by increasing the collection (number of coulombs) (interaction cross section).***
- **Actual magnitude of the potential ϕ must be very, very large, since we can treat it as infinite or unlimited, via $W = \phi q$.**
- ***Else Equation [1] could not be linear.***

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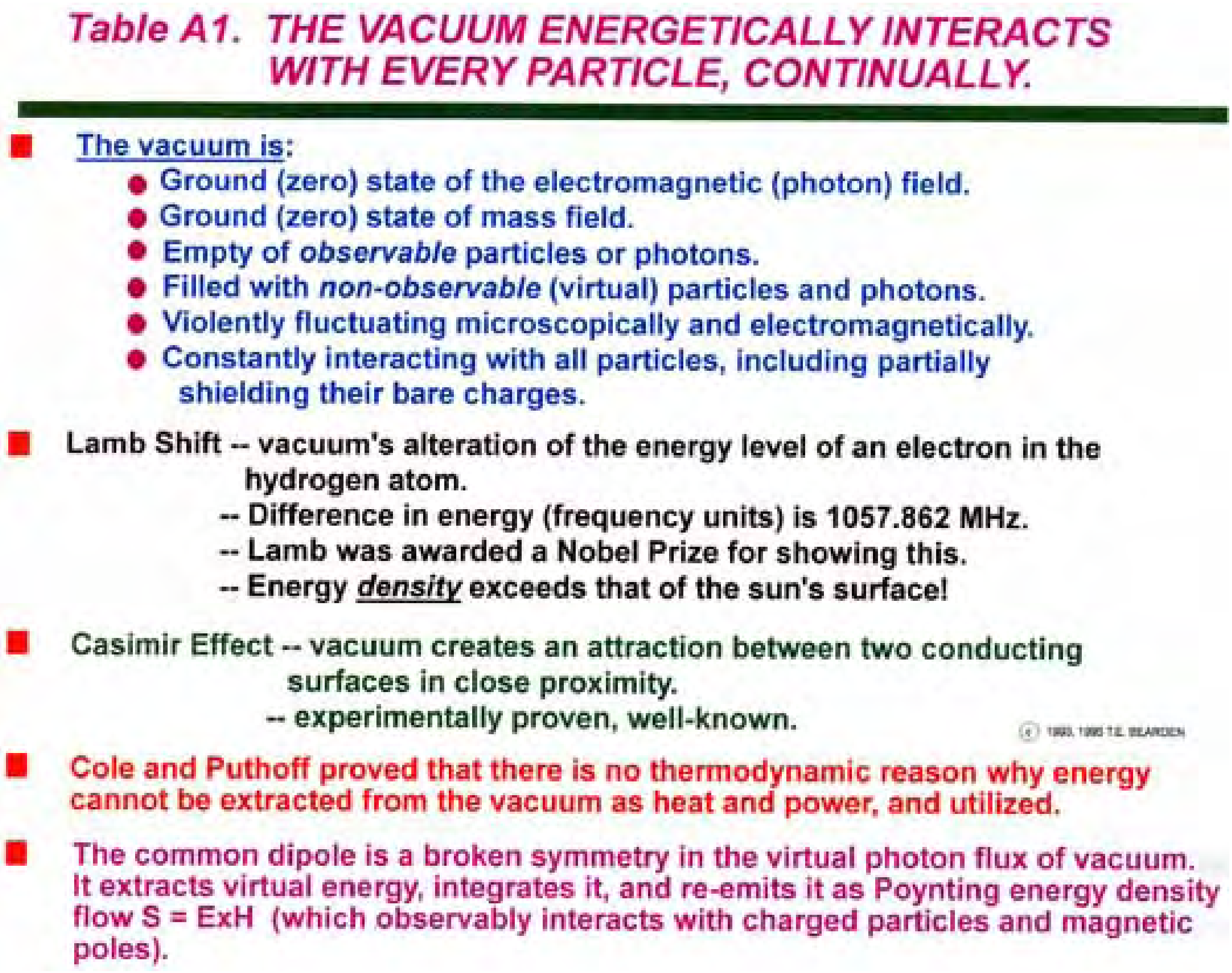

Table A1. THE VACUUM ENERGETICALLY INTERACTS WITH EVERY PARTICLE, CONTINUALLY.

- The vacuum is:
  - Ground (zero) state of the electromagnetic (photon) field.
  - Ground (zero) state of mass field.
  - Empty of *observable* particles or photons.
  - Filled with *non-observable* (virtual) particles and photons.
  - Violently fluctuating microscopically and electromagnetically.
  - Constantly interacting with all particles, including partially shielding their bare charges.
- Lamb Shift -- vacuum's alteration of the energy level of an electron in the hydrogen atom.
  - -- Difference in energy (frequency units) is 1057.862 MHz.
  - -- Lamb was awarded a Nobel Prize for showing this.
  - -- Energy ***density*** exceeds that of the sun's surface!
- Casimir Effect -- vacuum creates an attraction between two conducting surfaces in close proximity.
  - -- experimentally proven, well-known.
- Cole and Puthoff proved that there is no thermodynamic reason why energy cannot be extracted from the vacuum as heat and power, and utilized.
- The common dipole is a broken symmetry in the virtual photon flux of vacuum. It extracts virtual energy, integrates it, and re-emits it as Poynting energy density flow S = ExH (which observably interacts with charged particles and magnetic poles).

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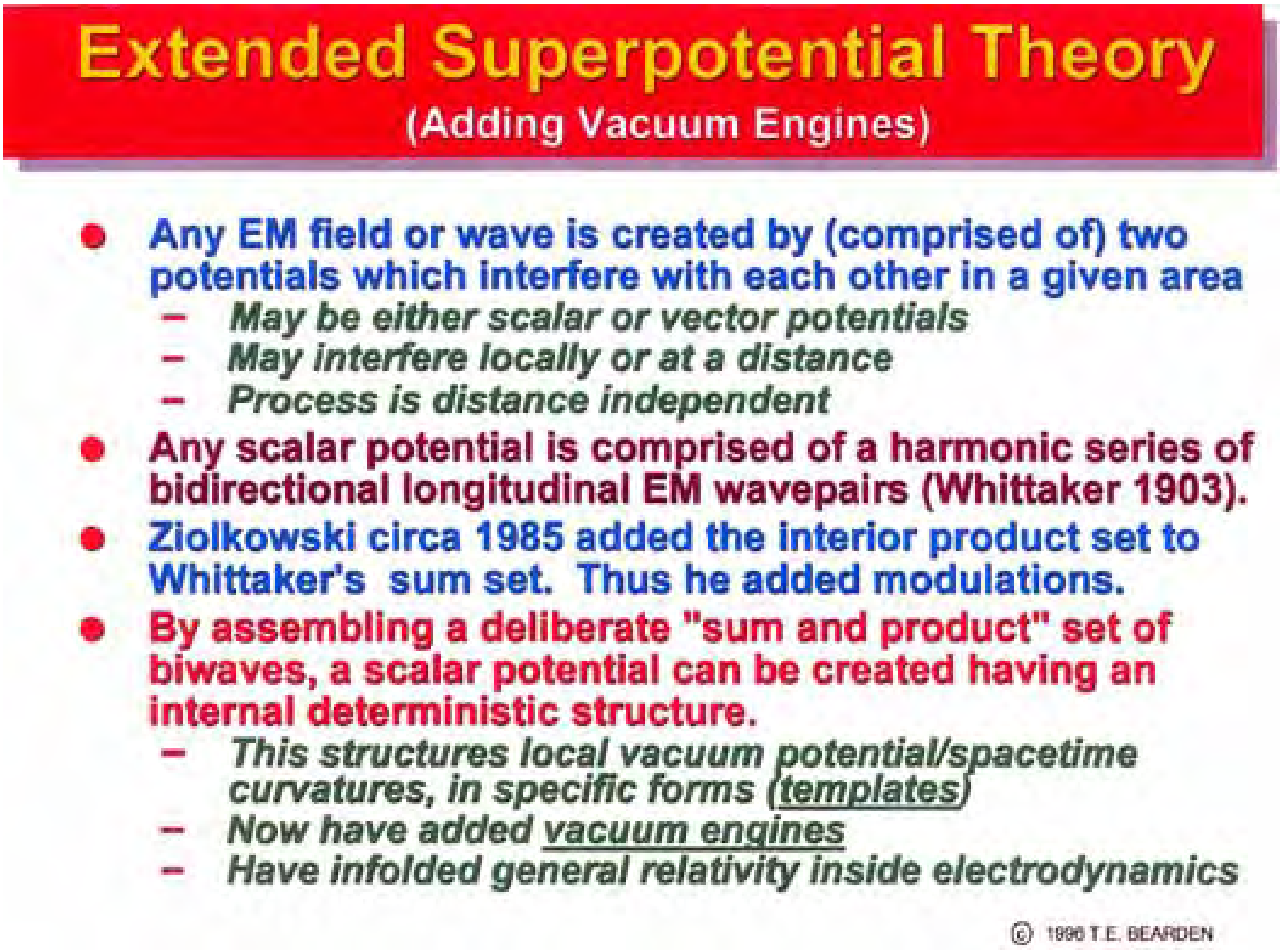

Extended Superpotential Theory

(Adding Vacuum Engines)

- Any EM field or wave is created by (comprised of) two potentials which interfere with each other in a given area
  - *May be either scalar or vector potentials*
  - *May interfere locally or at a distance*
  - *Process is distance independent*
- Any scalar potential is comprised of a harmonic series of bidirectional longitudinal EM wavepairs (Whittaker 1903).
- Ziolkowski circa 1985 added the interior product set to Whittaker's sum set. Thus he added modulations.
- By assembling a deliberate "sum and product" set of biwaves, a scalar potential can be created having an internal deterministic structure.
  - *This structures local vacuum potential/spacetime curvatures, in specific forms (templates)*
  - *Now have added vacuum engines*
  - *Have infolded general relativity inside electrodynamics*

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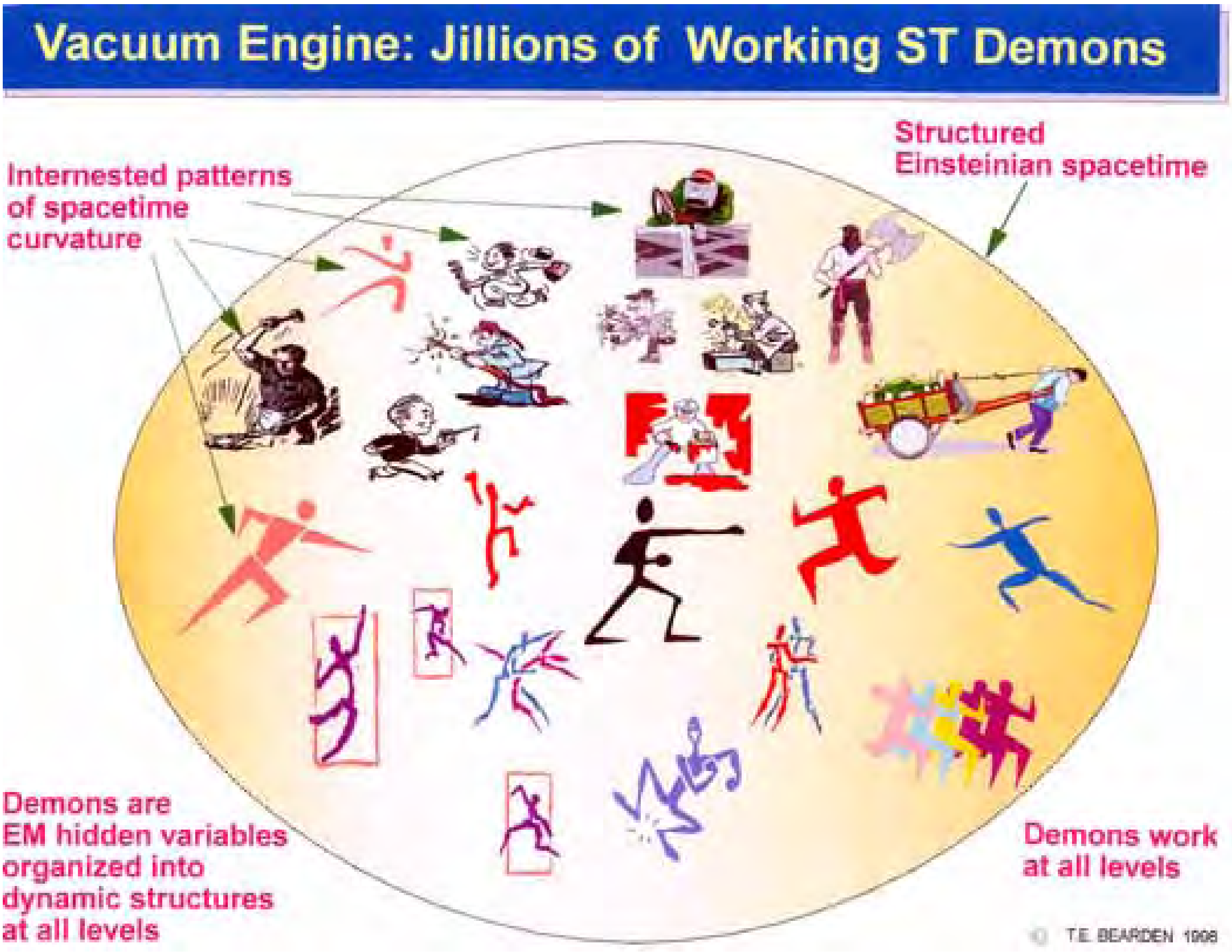

Vacuum Engine: Jillions of Working ST Demons

Internested patterns
of spacetime
curvature

Structured
Einsteinian spacetime

Demons are
EM hidden variables
organized into
dynamic structures
at all levels

Demons work
at all levels

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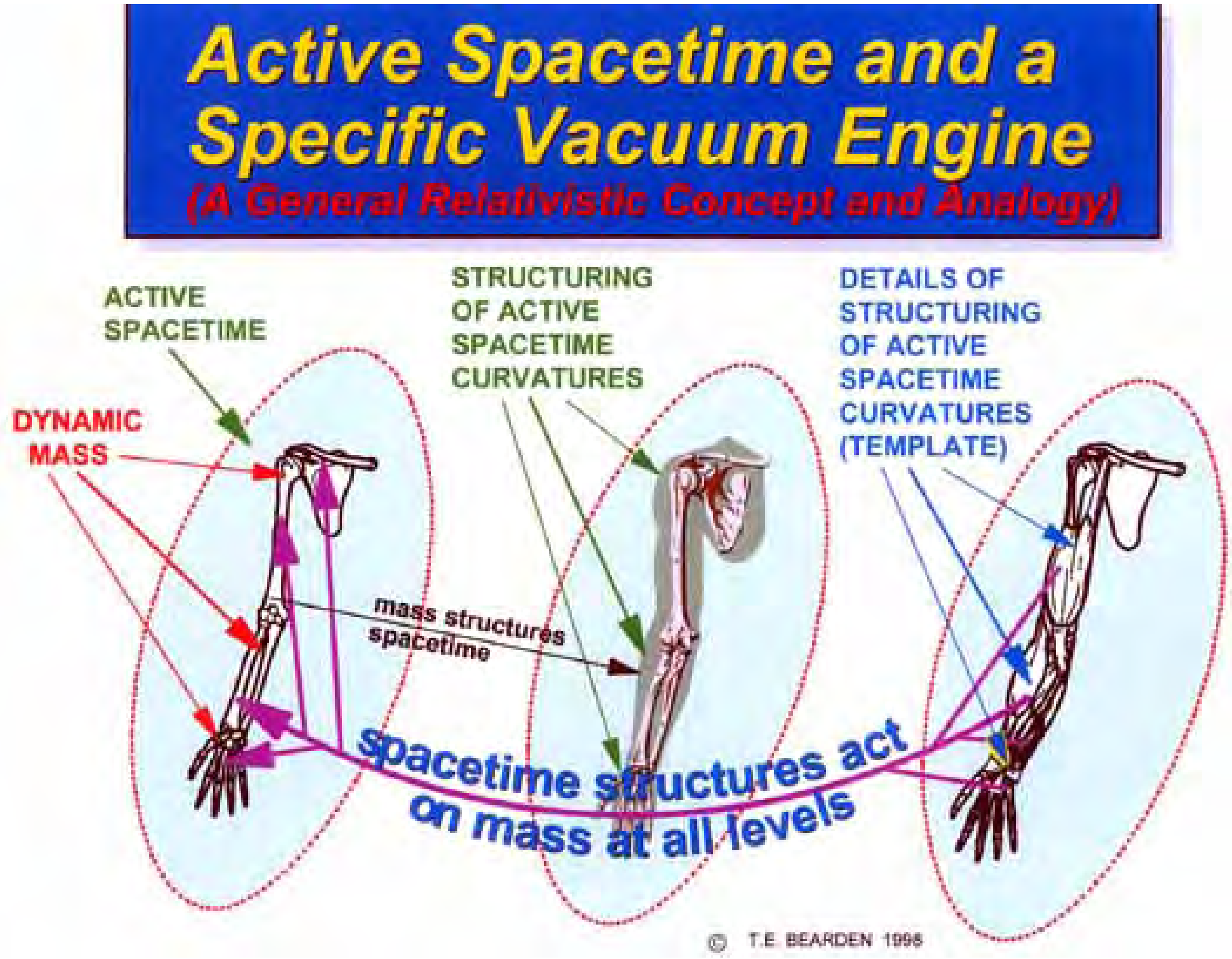

Active Spacetime and a Specific Vacuum Engine

(A General Relativistic Concept and Analogy)

ACTIVE SPACETIME
DYNAMIC MASS
STRUCTURING OF ACTIVE SPACETIME CURVATURES
DETAILS OF STRUCTURING OF ACTIVE SPACETIME CURVATURES (TEMPLATE)
mass structures spacetime
spacetime structures act on mass at all levels

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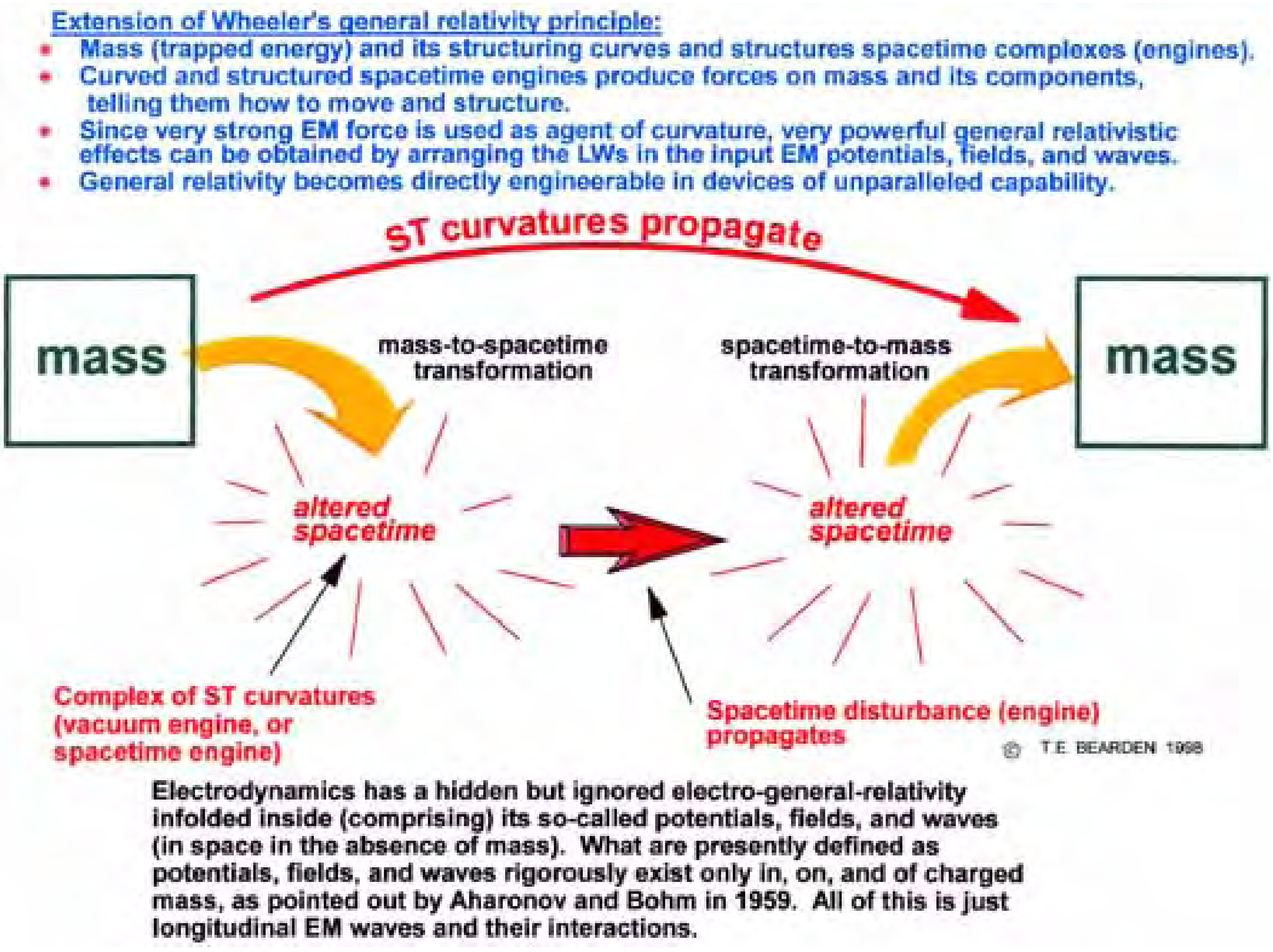

Extension of Wheeler's general relativity principle:

- Mass (trapped energy) and its structuring curves and structures spacetime complexes (engines).
- Curved and structured spacetime engines produce forces on mass and its components, telling them how to move and structure.
- Since very strong EM force is used as agent of curvature, very powerful general relativistic effects can be obtained by arranging the LWs in the input EM potentials, fields, and waves.
- General relativity becomes directly engineerable in devices of unparalleled capability.

ST curvatures propagate
mass
mass-to-spacetime transformation
spacetime-to-mass transformation
mass
altered spacetime
altered spacetime
Complex of ST curvatures (vacuum engine, or spacetime engine)
Spacetime disturbance (engine) propagates
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Electrodynamics has a hidden but ignored electro-general-relativity infolded inside (comprising) its so-called potentials, fields, and waves (in space in the absence of mass). What are presently defined as potentials, fields, and waves rigorously exist only in, on, and of charged mass, as pointed out by Aharonov and Bohm in 1959. All of this is just longitudinal EM waves and their interactions.

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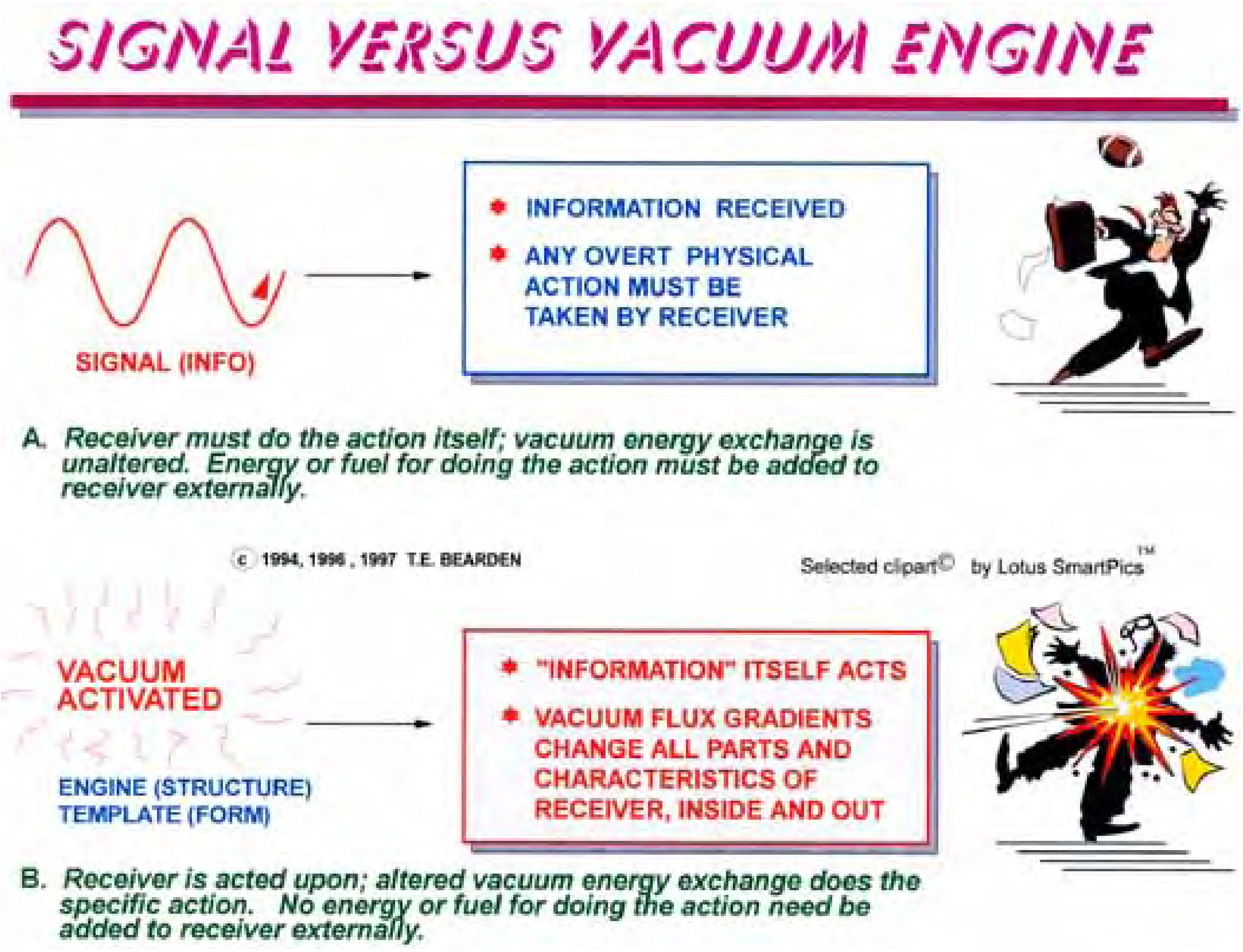

SIGNAL VERSUS VACUUM ENGINE

SIGNAL (INFO)

- INFORMATION RECEIVED
- ANY OVERT PHYSICAL ACTION MUST BE TAKEN BY RECEIVER

A. *Receiver must do the action itself; vacuum energy exchange is unaltered. Energy or fuel for doing the action must be added to receiver externally.*

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VACUUM ACTIVATED

ENGINE (STRUCTURE)
TEMPLATE (FORM)

- "INFORMATION" ITSELF ACTS
- VACUUM FLUX GRADIENTS CHANGE ALL PARTS AND CHARACTERISTICS OF RECEIVER, INSIDE AND OUT

B. *Receiver is acted upon; altered vacuum energy exchange does the specific action. No energy or fuel for doing the action need be added to receiver externally.*

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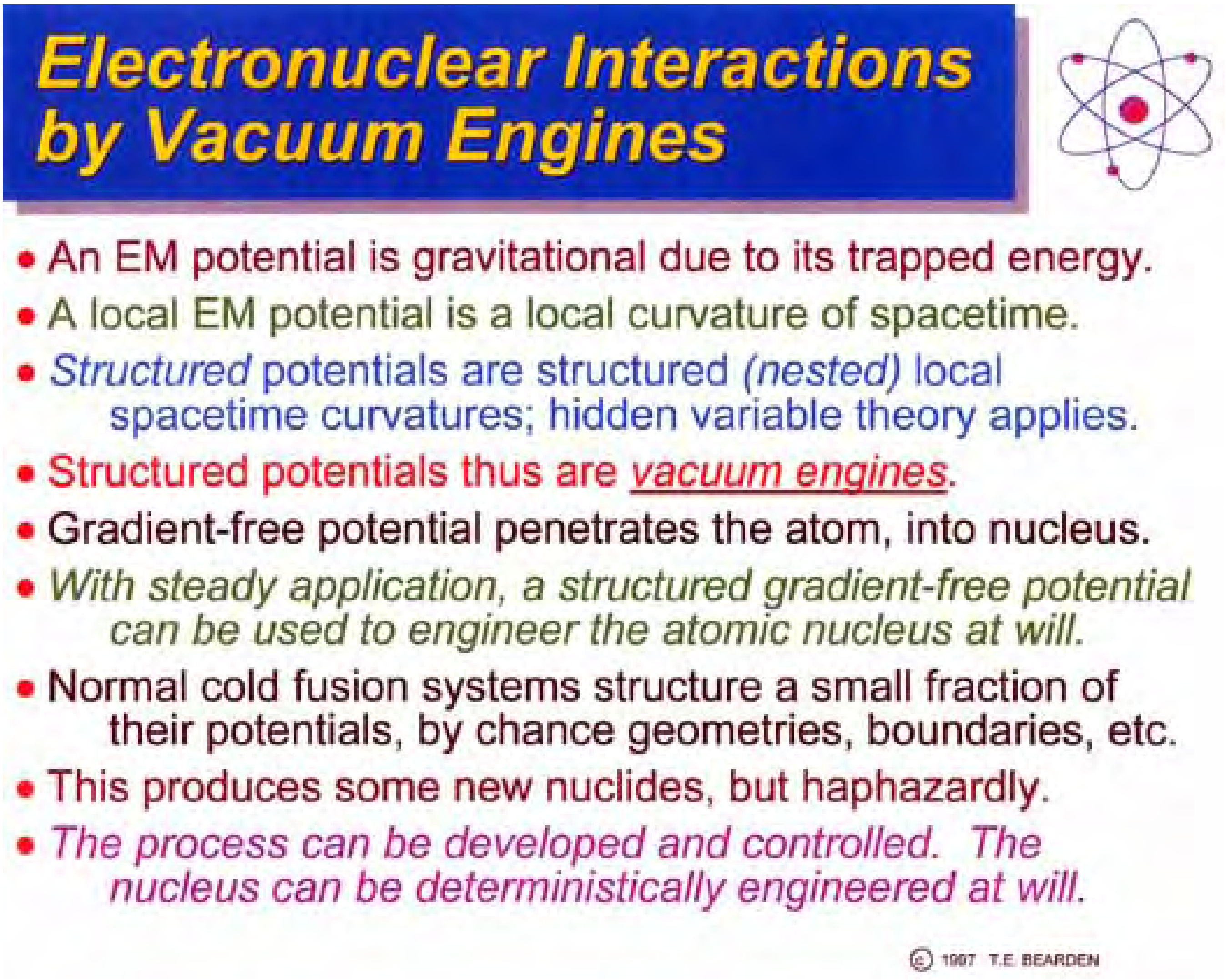

Electronuclear Interactions by Vacuum Engines

- An EM potential is gravitational due to its trapped energy.
- A local EM potential is a local curvature of spacetime.
- *Structured* potentials are structured *(nested)* local spacetime curvatures; hidden variable theory applies.
- Structured potentials thus are *vacuum engines*.
- Gradient-free potential penetrates the atom, into nucleus.
- *With steady application, a structured gradient-free potential can be used to engineer the atomic nucleus at will.*
- Normal cold fusion systems structure a small fraction of their potentials, by chance geometries, boundaries, etc.
- This produces some new nuclides, but haphazardly.
- *The process can be developed and controlled. The nucleus can be deterministically engineered at will.*

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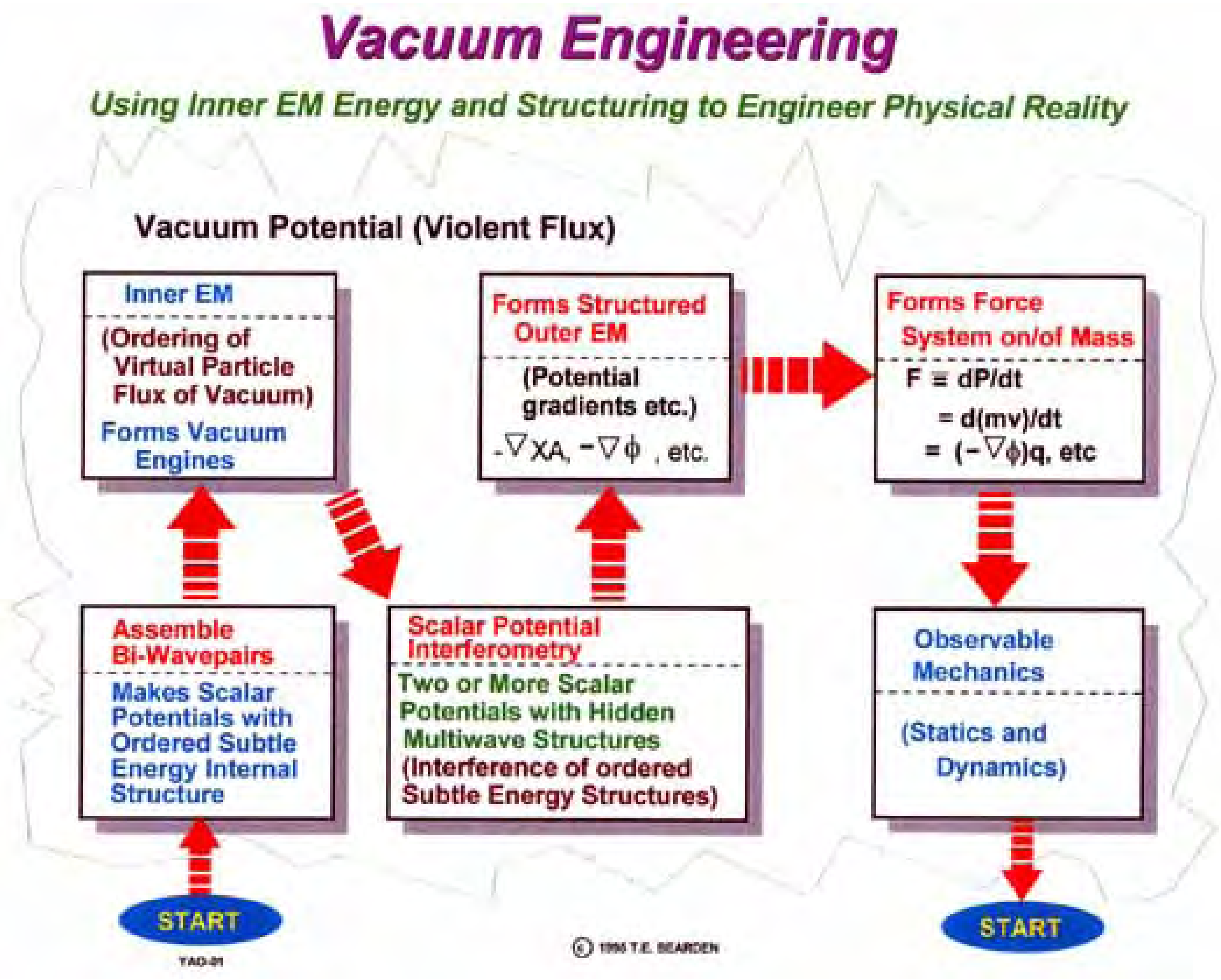

Vacuum Engineering

Using Inner EM Energy and Structuring to Engineer Physical Reality

Vacuum Potential (Violent Flux)

Inner EM

(Ordering of Virtual Particle Flux of Vacuum)

Forms Vacuum Engines

Forms Structured Outer EM

(Potential gradients etc.)

$-\nabla \times A$, $-\nabla \phi$, etc.

Forms Force System on/of Mass

$F \equiv dP/dt$

$= d(mv)/dt$

$= (-\nabla \phi)q$, etc

Assemble Bi-Wavepairs

Makes Scalar Potentials with Ordered Subtle Energy Internal Structure

Scalar Potential Interferometry

Two or More Scalar Potentials with Hidden Multiwave Structures (Interference of ordered Subtle Energy Structures)

Observable Mechanics

(Statics and Dynamics)

START

START

YAO-01

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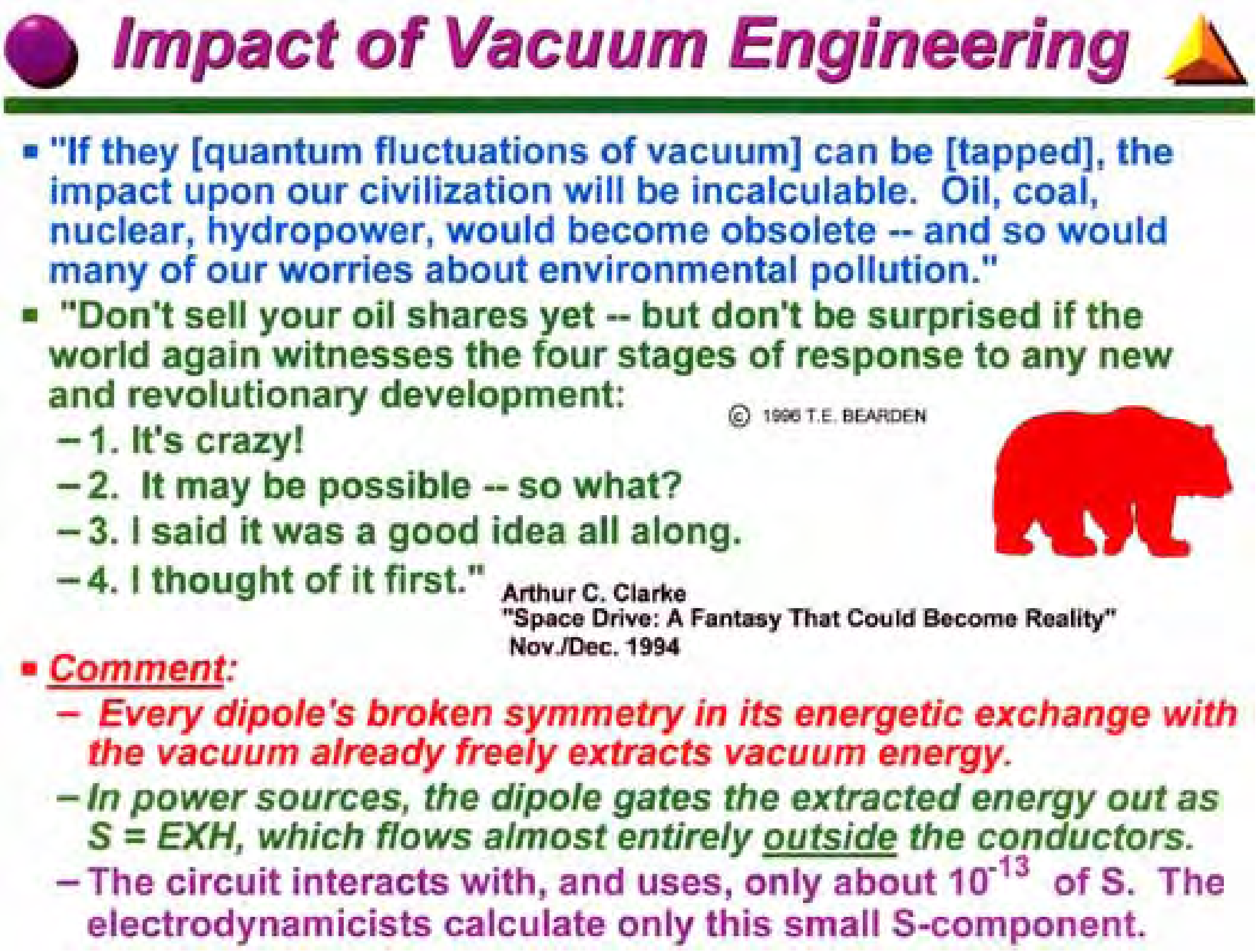

Impact of Vacuum Engineering

- "If they [quantum fluctuations of vacuum] can be [tapped], the impact upon our civilization will be incalculable. Oil, coal, nuclear, hydropower, would become obsolete -- and so would many of our worries about environmental pollution."
- "Don't sell your oil shares yet -- but don't be surprised if the world again witnesses the four stages of response to any new and revolutionary development:
  - 1. It's crazy!
  - 2. It may be possible -- so what?
  - 3. I said it was a good idea all along.
  - 4. I thought of it first."

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Arthur C. Clarke
"Space Drive: A Fantasy That Could Become Reality"
Nov./Dec. 1994

- *Comment:*
  - *Every dipole's broken symmetry in its energetic exchange with the vacuum already freely extracts vacuum energy.*
  - *In power sources, the dipole gates the extracted energy out as $S = E \times H$, which flows almost entirely outside the conductors.*
  - The circuit interacts with, and uses, only about 10^{-13} of S. The electrodynamicists calculate only this small S-component.

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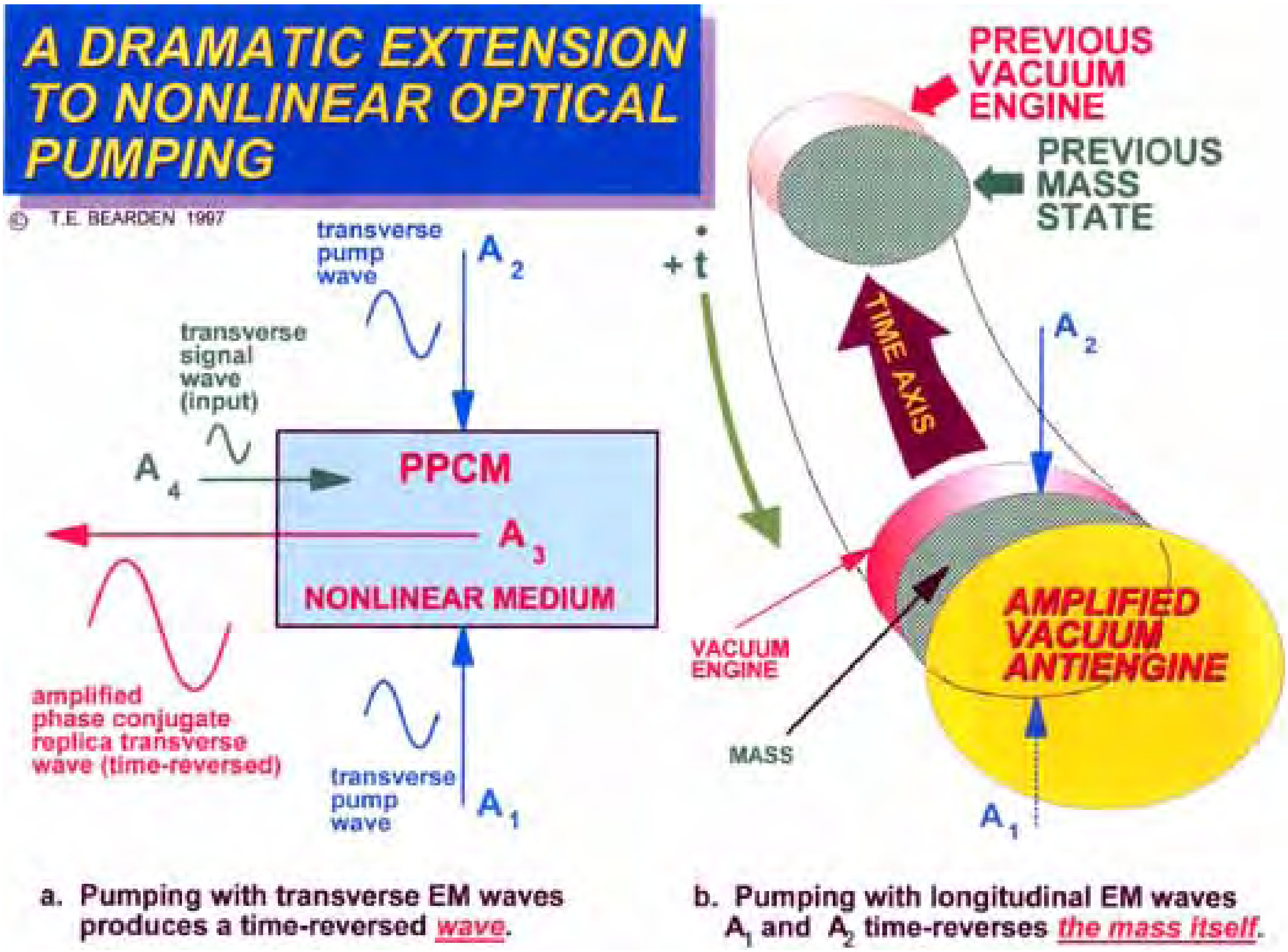

A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

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transverse pump wave
A_2
transverse signal wave (input)
A_4
PPCM
A_3
NONLINEAR MEDIUM
amplified phase conjugate replica transverse wave (time-reversed)
transverse pump wave
A_1
+ t
PREVIOUS VACUUM ENGINE
PREVIOUS MASS STATE
TIME AXIS
A_2
VACUUM ENGINE
AMPLIFIED VACUUM ANTIENGINE
MASS
A_1

a. Pumping with transverse EM waves produces a time-reversed *wave*.

b. Pumping with longitudinal EM waves A_1 and A_2 time-reverses *the mass itself*.

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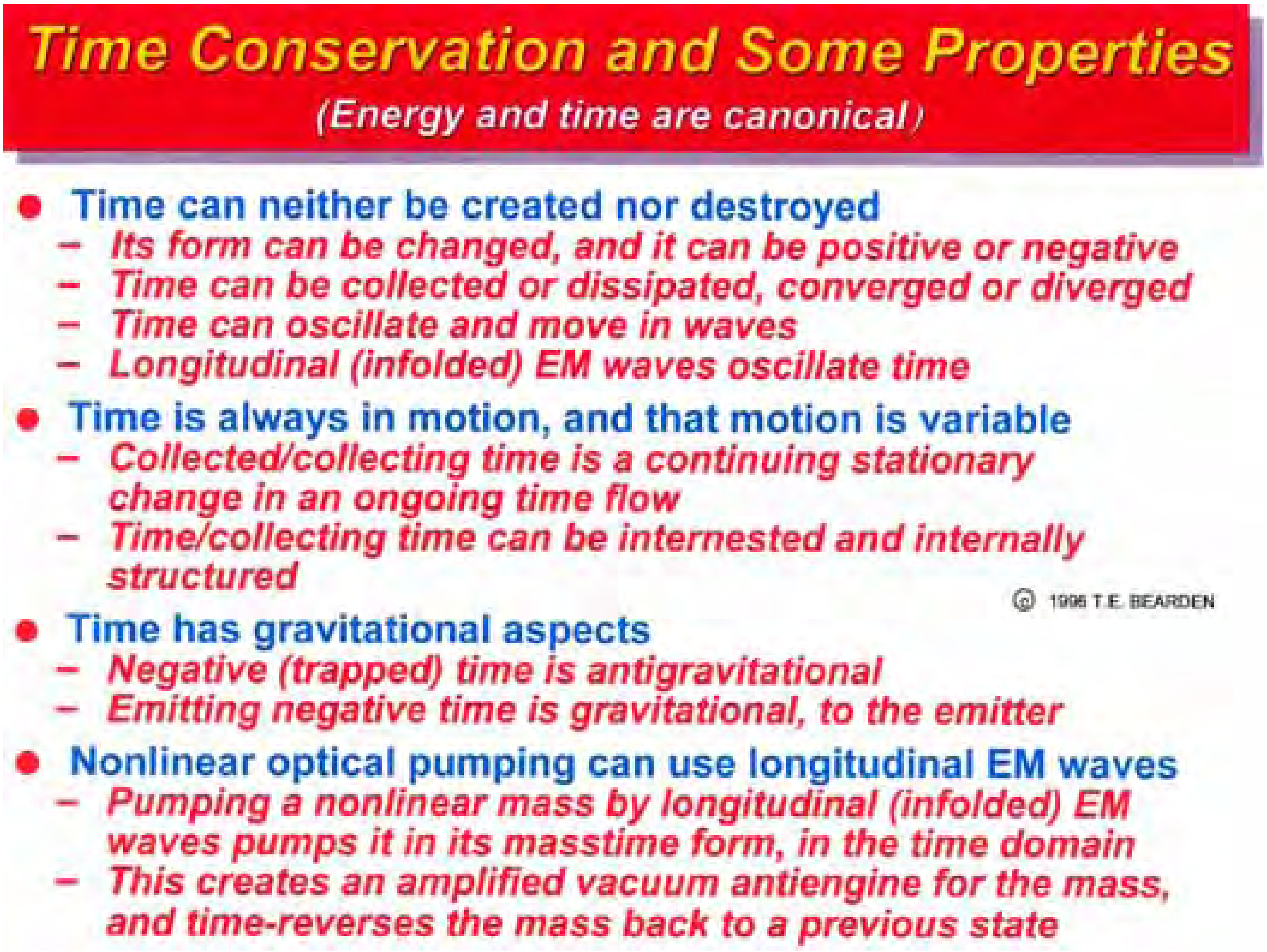

Time Conservation and Some Properties

(Energy and time are canonical)

- Time can neither be created nor destroyed
  - *Its form can be changed, and it can be positive or negative*
  - *Time can be collected or dissipated, converged or diverged*
  - *Time can oscillate and move in waves*
  - *Longitudinal (infolded) EM waves oscillate time*
- Time is always in motion, and that motion is variable
  - *Collected/collecting time is a continuing stationary change in an ongoing time flow*
  - *Time/collecting time can be internested and internally structured*

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- Time has gravitational aspects
  - *Negative (trapped) time is antigravitational*
  - *Emitting negative time is gravitational, to the emitter*
- Nonlinear optical pumping can use longitudinal EM waves
  - *Pumping a nonlinear mass by longitudinal (infolded) EM waves pumps it in its masstime form, in the time domain*
  - *This creates an amplified vacuum antiengine for the mass, and time-reverses the mass back to a previous state*

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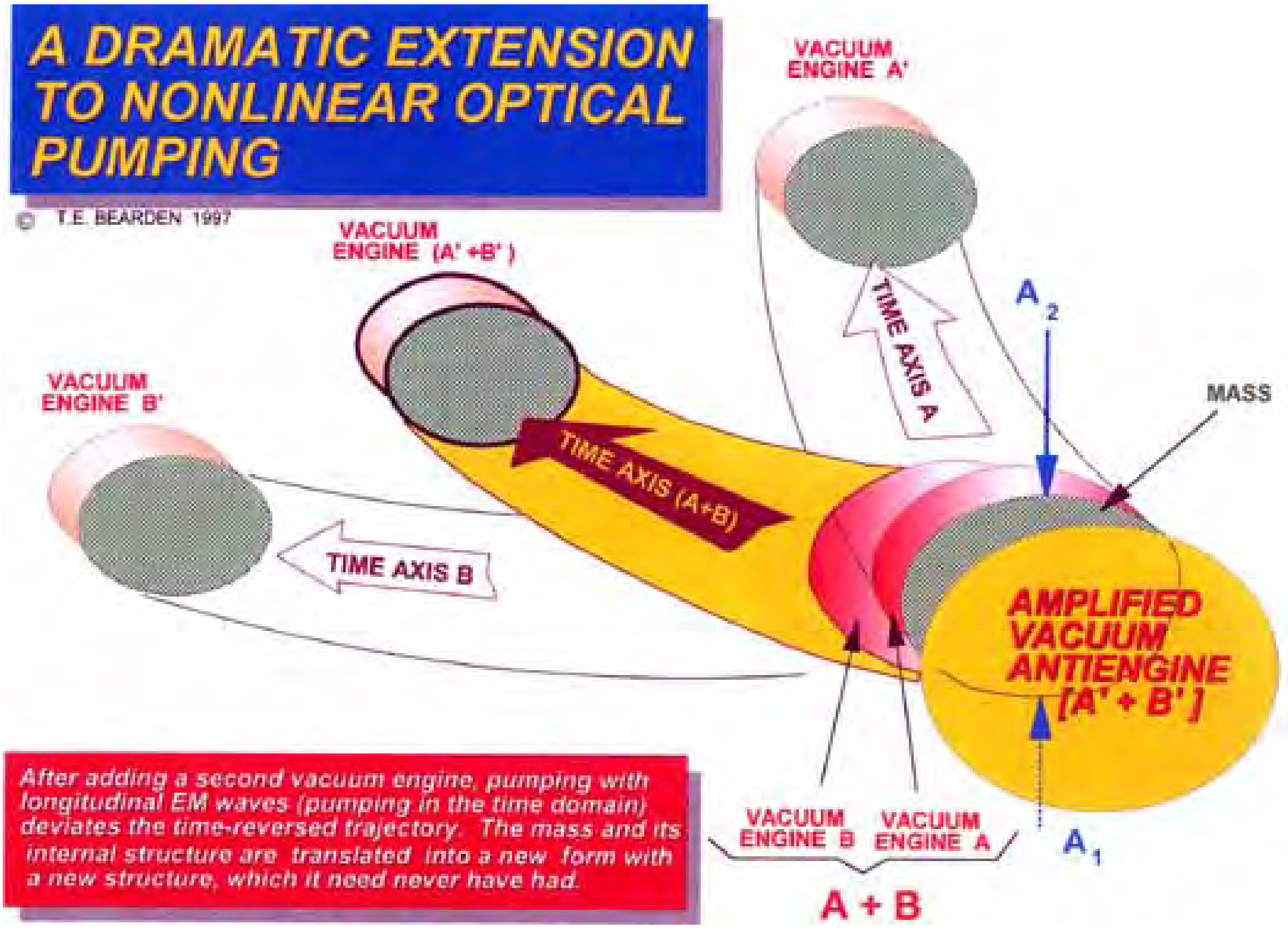

A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

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VACUUM ENGINE A'
VACUUM ENGINE (A' +B')
VACUUM ENGINE B'
TIME AXIS A
A_2
MASS
TIME AXIS (A+B)
TIME AXIS B
AMPLIFIED VACUUM ANTIENGINE [A' + B']
VACUUM ENGINE B
VACUUM ENGINE A
A_1
A + B

After adding a second vacuum engine, pumping with longitudinal EM waves (pumping in the time domain) deviates the time-reversed trajectory. The mass and its internal structure are translated into a new form with a new structure, which it need never have had.

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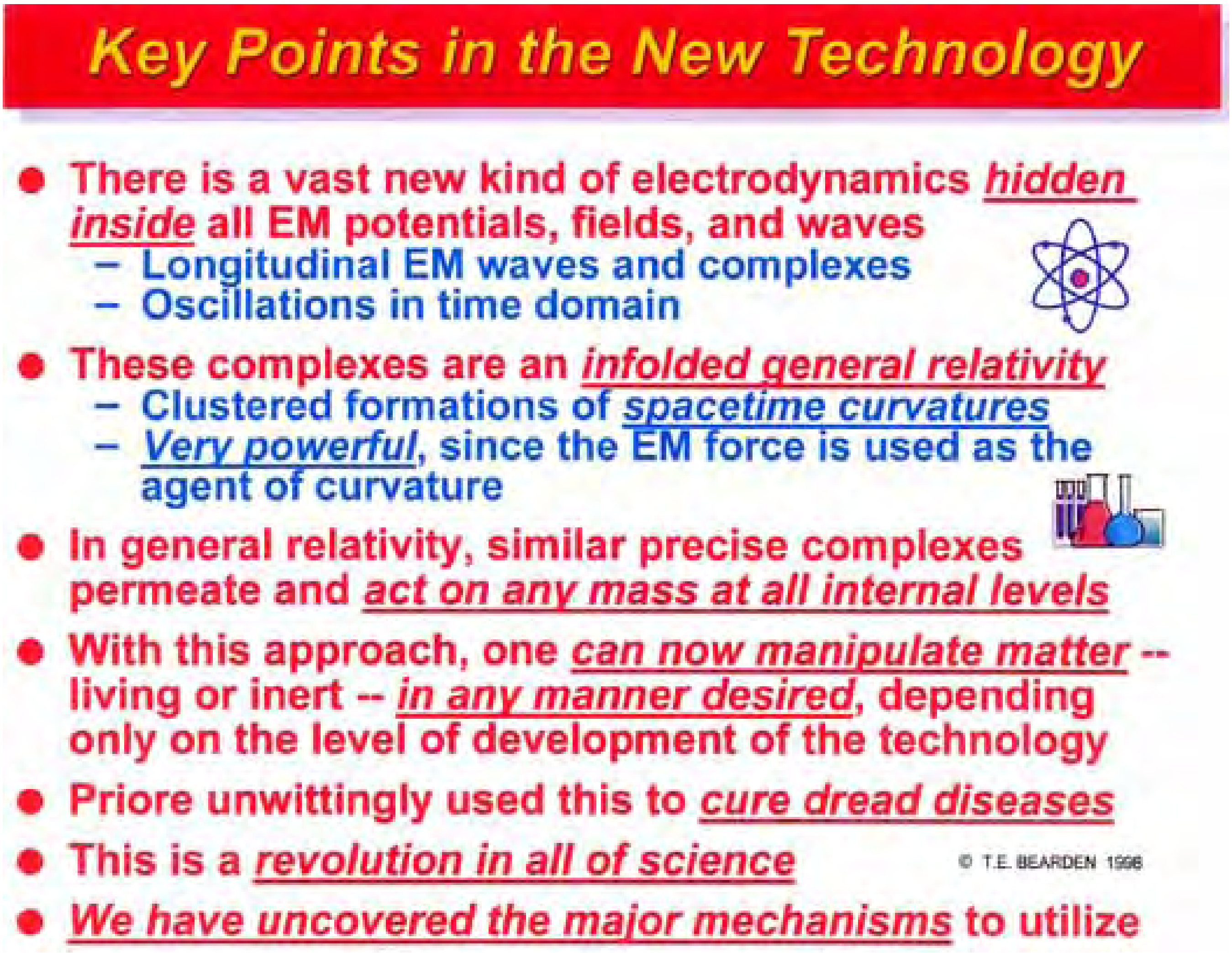

Key Points in the New Technology

- There is a vast new kind of electrodynamics *hidden inside* all EM potentials, fields, and waves
  - Longitudinal EM waves and complexes
  - Oscillations in time domain
- These complexes are an *infolded general relativity*
  - Clustered formations of *spacetime curvatures*
  - *Very powerful*, since the EM force is used as the agent of curvature
- In general relativity, similar precise complexes permeate and *act on any mass at all internal levels*
- With this approach, one *can now manipulate matter* -- living or inert -- *in any manner desired*, depending only on the level of development of the technology
- Priore unwittingly used this to *cure dread diseases*
- This is a *revolution in all of science*
- *We have uncovered the major mechanisms* to utilize

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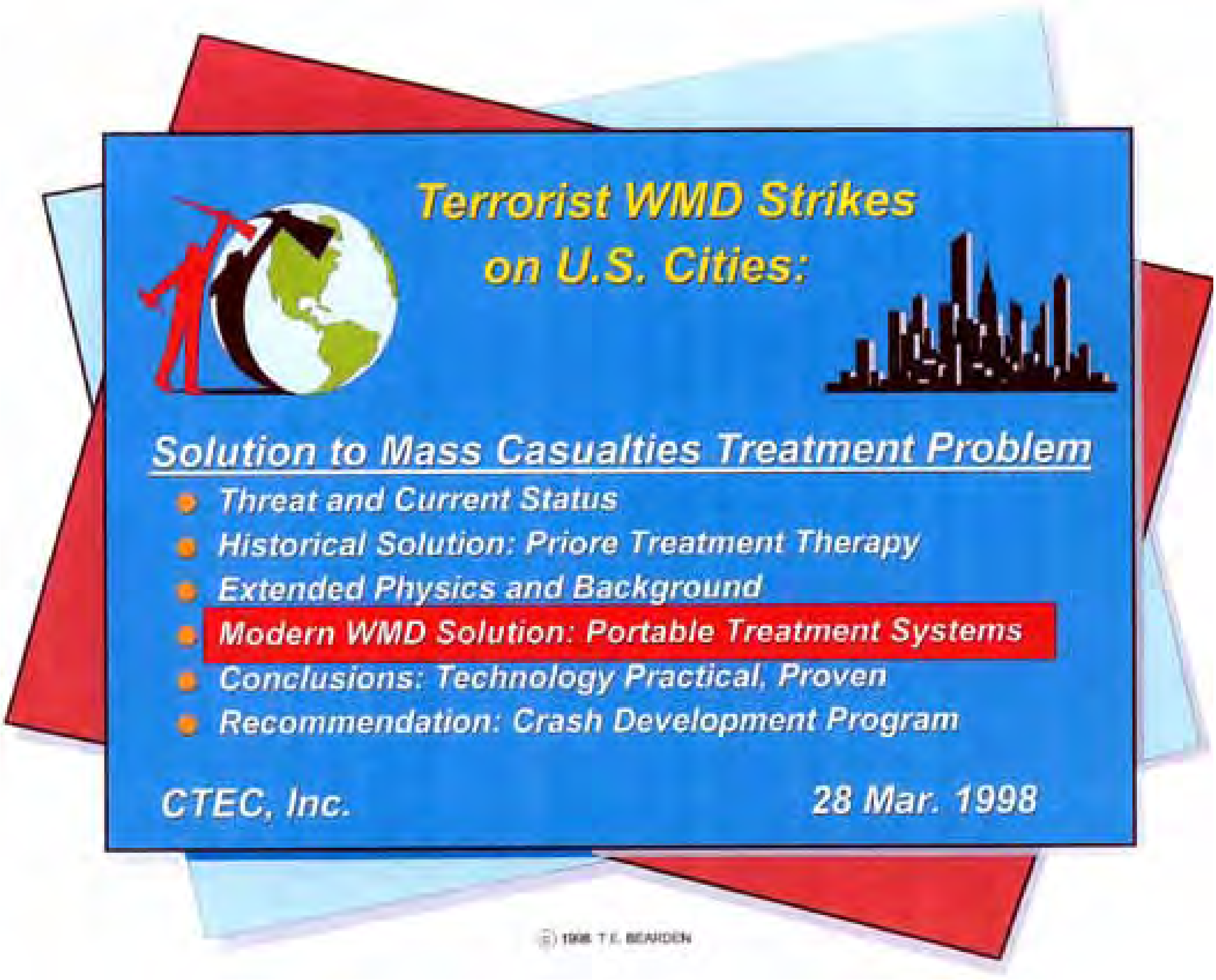

Terrorist WMD Strikes
on U.S. Cities:

Solution to Mass Casualties Treatment Problem

- Threat and Current Status
- Historical Solution: Priore Treatment Therapy
- Extended Physics and Background
- Modern WMD Solution: Portable Treatment Systems
- Conclusions: Technology Practical, Proven
- Recommendation: Crash Development Program

CTEC, Inc. 28 Mar. 1998

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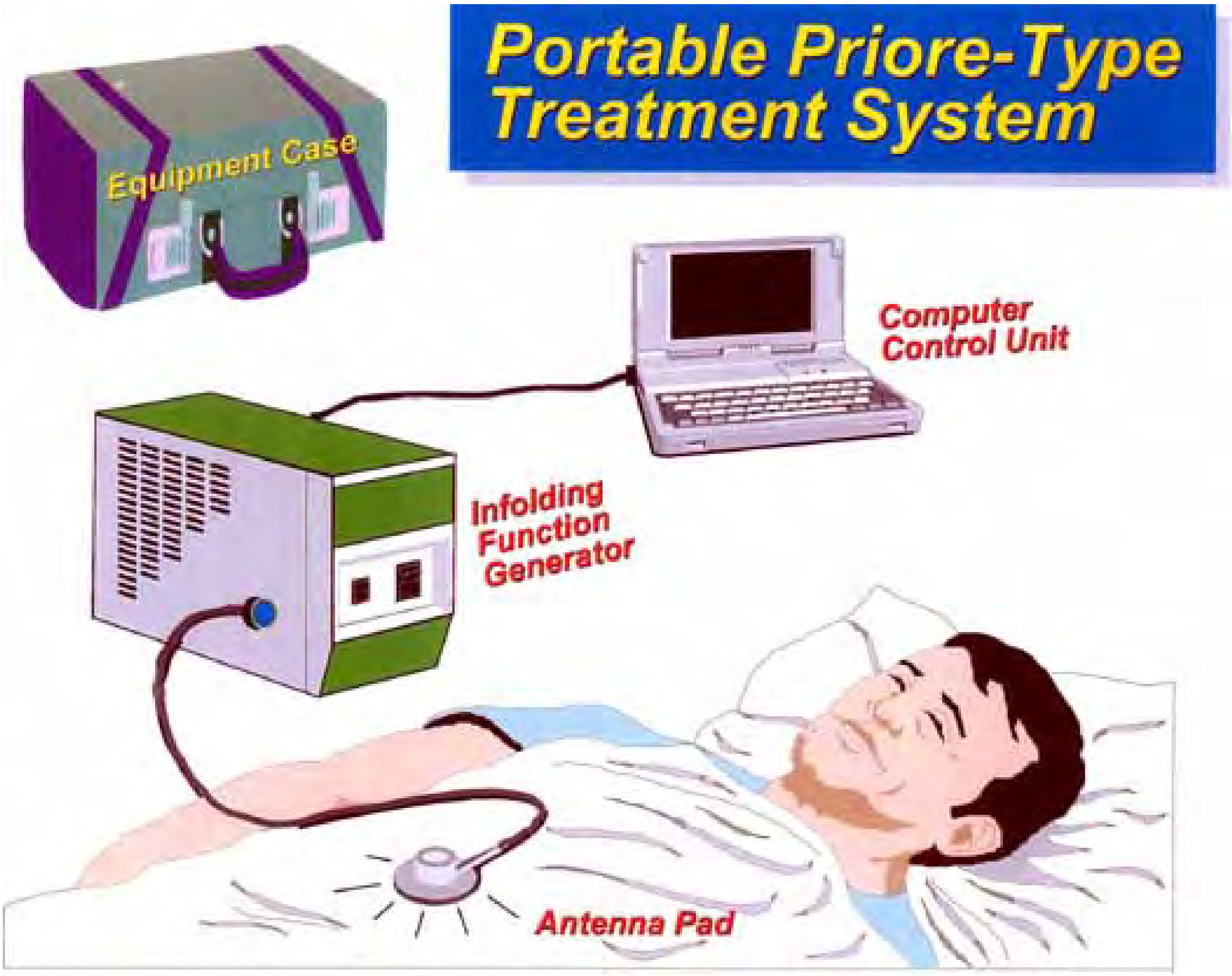

Portable Priore-Type Treatment System

Equipment Case
Computer Control Unit
Infolding Function Generator
Antenna Pad

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Portable System Block Diagram

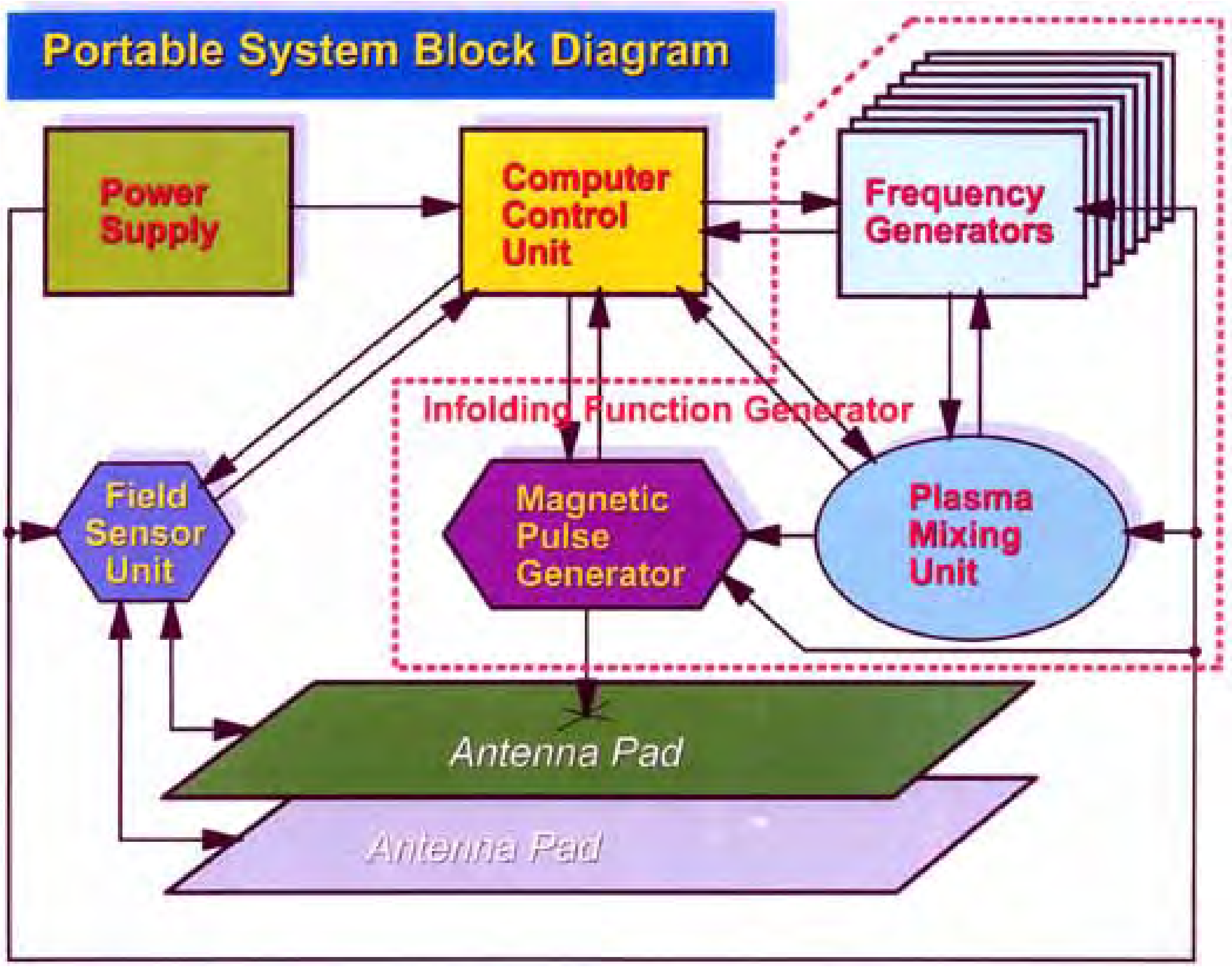
Power Supply
Computer Control Unit
Frequency Generators
Infolding Function Generator
Field Sensor Unit
Magnetic Pulse Generator
Plasma Mixing Unit
Antenna Pad
Antenna Pad

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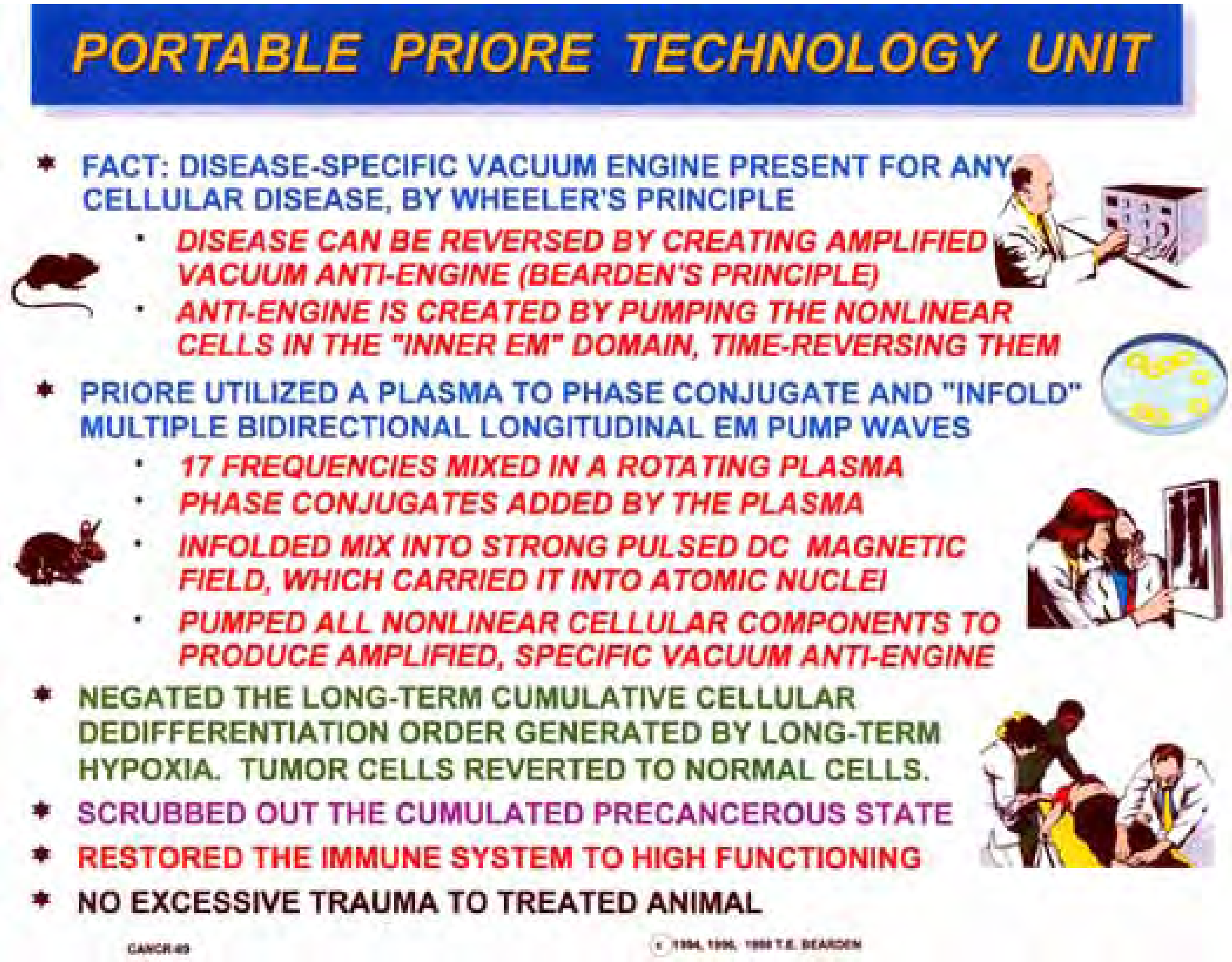

PORTABLE PRIORE TECHNOLOGY UNIT

- FACT: DISEASE-SPECIFIC VACUUM ENGINE PRESENT FOR ANY CELLULAR DISEASE, BY WHEELER'S PRINCIPLE
  - *DISEASE CAN BE REVERSED BY CREATING AMPLIFIED VACUUM ANTI-ENGINE (BEARDEN'S PRINCIPLE)*
  - *ANTI-ENGINE IS CREATED BY PUMPING THE NONLINEAR CELLS IN THE "INNER EM" DOMAIN, TIME-REVERSING THEM*
- PRIORE UTILIZED A PLASMA TO PHASE CONJUGATE AND "INFOLD" MULTIPLE BIDIRECTIONAL LONGITUDINAL EM PUMP WAVES
  - *17 FREQUENCIES MIXED IN A ROTATING PLASMA*
  - *PHASE CONJUGATES ADDED BY THE PLASMA*
  - *INFOLDED MIX INTO STRONG PULSED DC MAGNETIC FIELD, WHICH CARRIED IT INTO ATOMIC NUCLEI*
  - *PUMPED ALL NONLINEAR CELLULAR COMPONENTS TO PRODUCE AMPLIFIED, SPECIFIC VACUUM ANTI-ENGINE*
- NEGATED THE LONG-TERM CUMULATIVE CELLULAR DEDIFFERENTIATION ORDER GENERATED BY LONG-TERM HYPOXIA. TUMOR CELLS REVERTED TO NORMAL CELLS.
- SCRUBBED OUT THE CUMULATED PRECANCEROUS STATE
- RESTORED THE IMMUNE SYSTEM TO HIGH FUNCTIONING
- NO EXCESSIVE TRAUMA TO TREATED ANIMAL

CANCR-69

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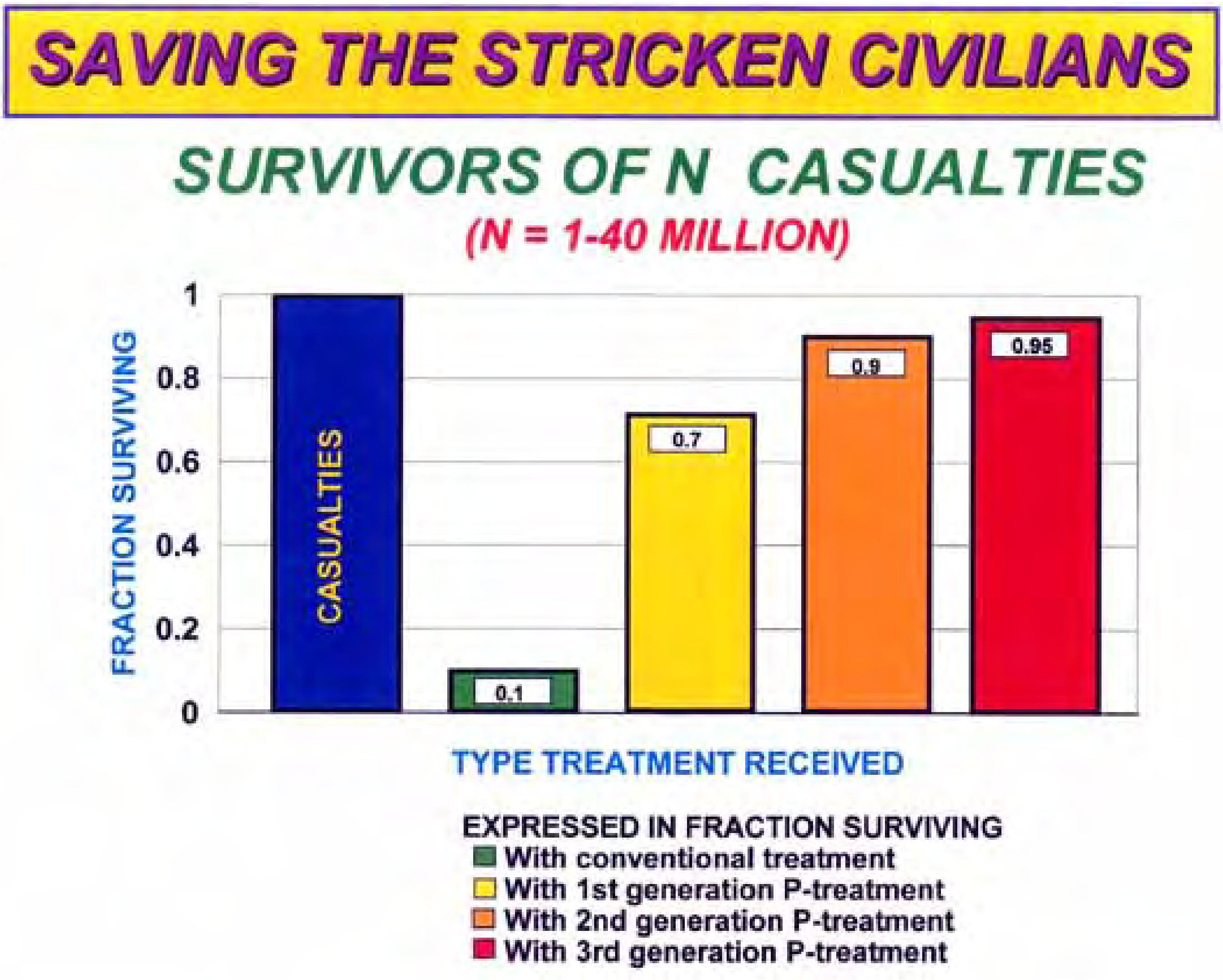

SAVING THE STRICKEN CIVILIANS

SURVIVORS OF N CASUALTIES

(N = 1-40 MILLION)

EXPRESSED IN FRACTION SURVIVING

- 🟩 With conventional treatment
- 🟨 With 1st generation P-treatment
- 🟧 With 2nd generation P-treatment
- 🟥 With 3rd generation P-treatment

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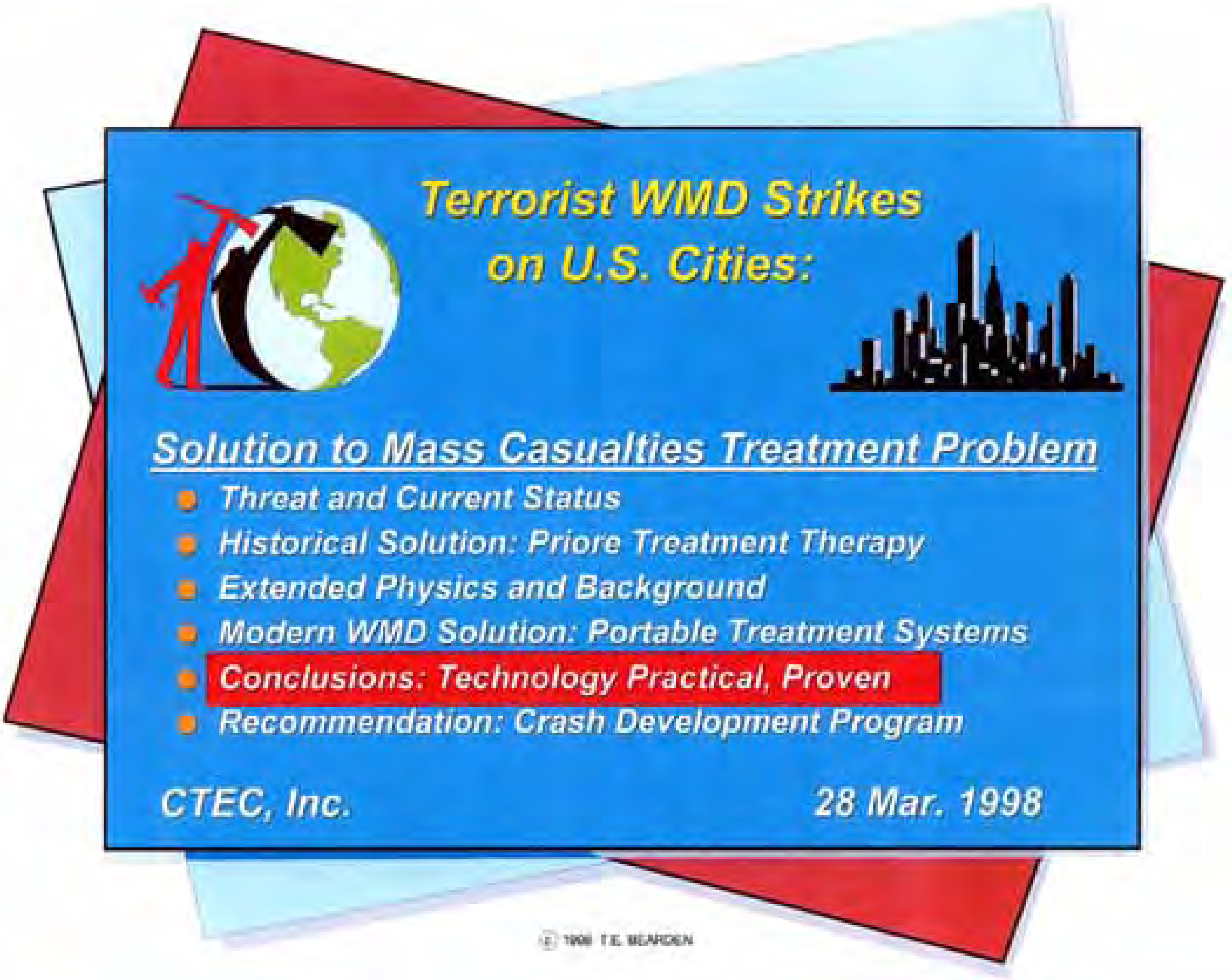

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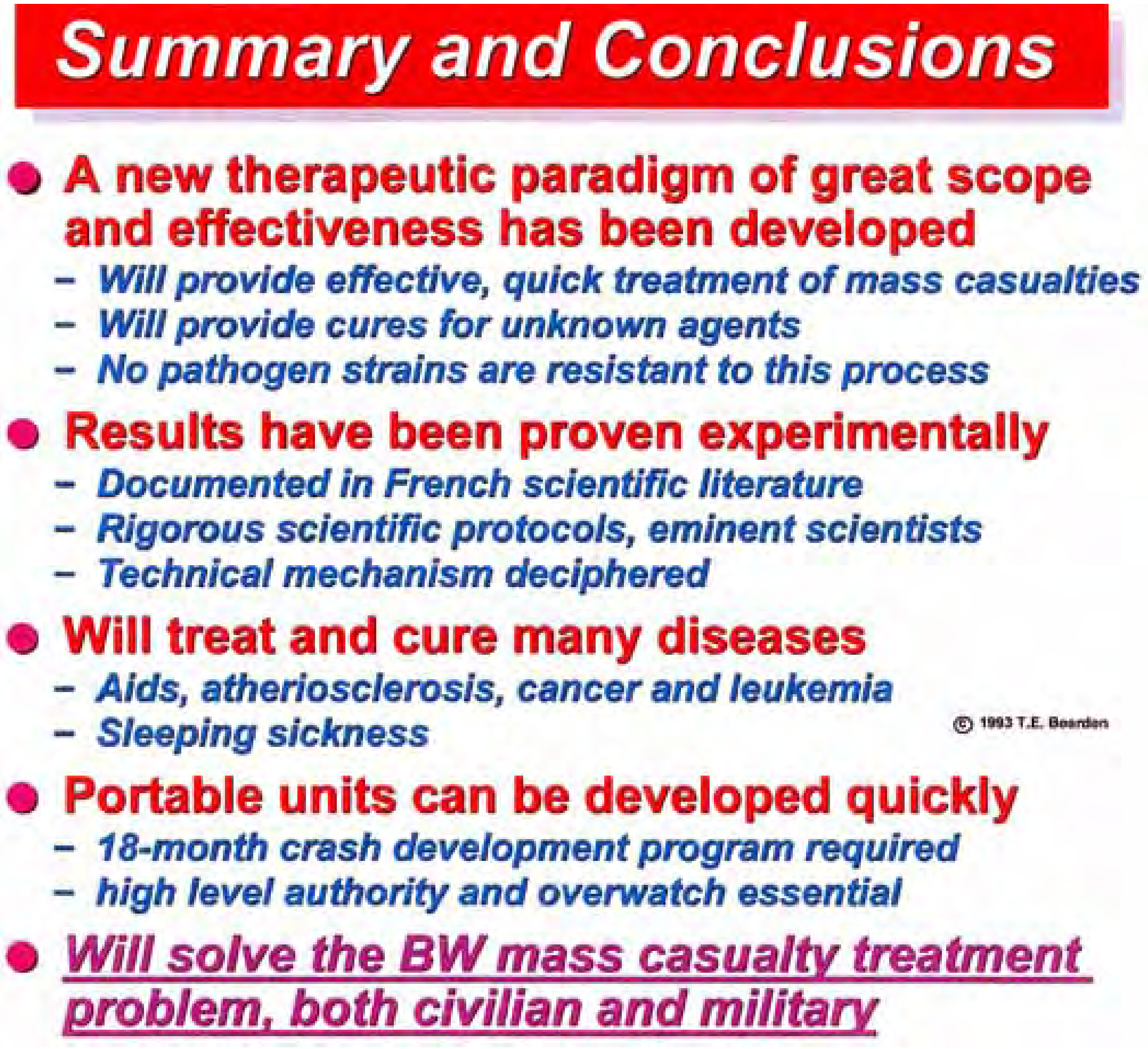

Summary and Conclusions

- A new therapeutic paradigm of great scope and effectiveness has been developed
  - *Will provide effective, quick treatment of mass casualties*
  - *Will provide cures for unknown agents*
  - *No pathogen strains are resistant to this process*
- Results have been proven experimentally
  - *Documented in French scientific literature*
  - *Rigorous scientific protocols, eminent scientists*
  - *Technical mechanism deciphered*
- Will treat and cure many diseases
  - *Aids, atheriosclerosis, cancer and leukemia*
  - *Sleeping sickness*
- Portable units can be developed quickly
  - *18-month crash development program required*
  - *high level authority and overwatch essential*
- ***Will solve the BW mass casualty treatment problem, both civilian and military***

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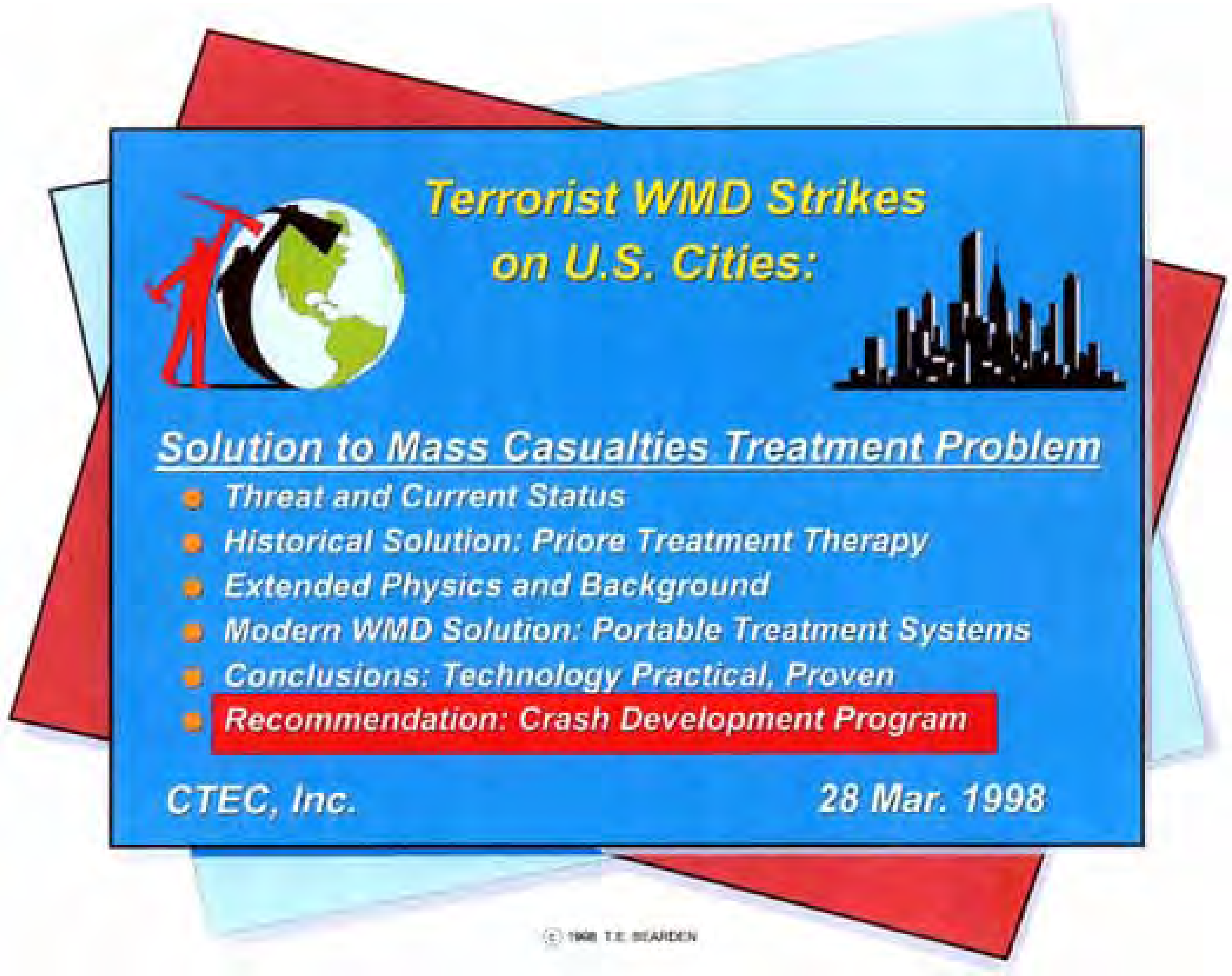

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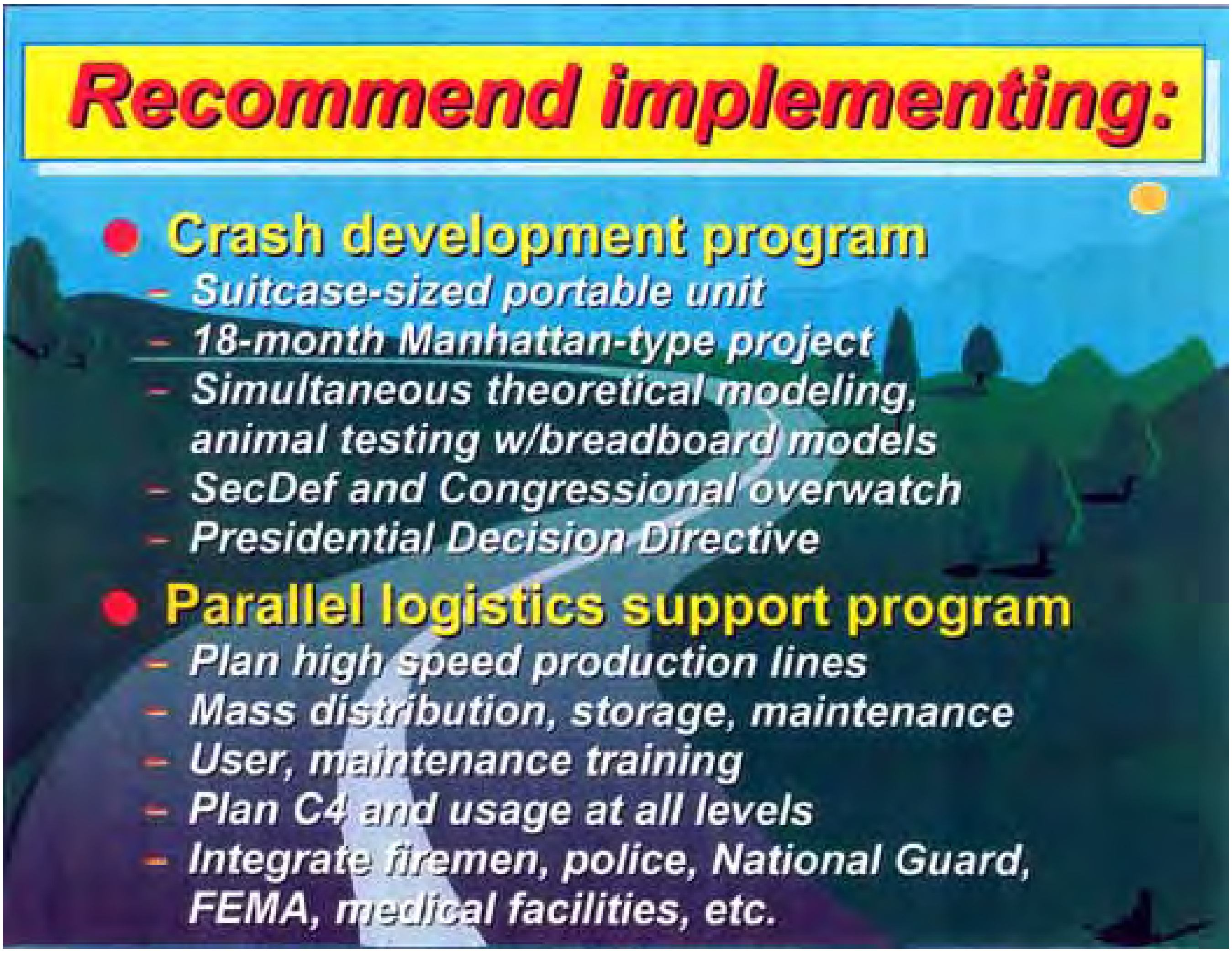

Recommend implementing:

- Crash development program
  - Suitcase-sized portable unit
  - 18-month Manhattan-type project
  - Simultaneous theoretical modeling, animal testing w/breadboard models
  - SecDef and Congressional overwatch
  - Presidential Decision Directive
- Parallel logistics support program
  - Plan high speed production lines
  - Mass distribution, storage, maintenance
  - User, maintenance training
  - Plan C4 and usage at all levels
  - Integrate firemen, police, National Guard, FEMA, medical facilities, etc.

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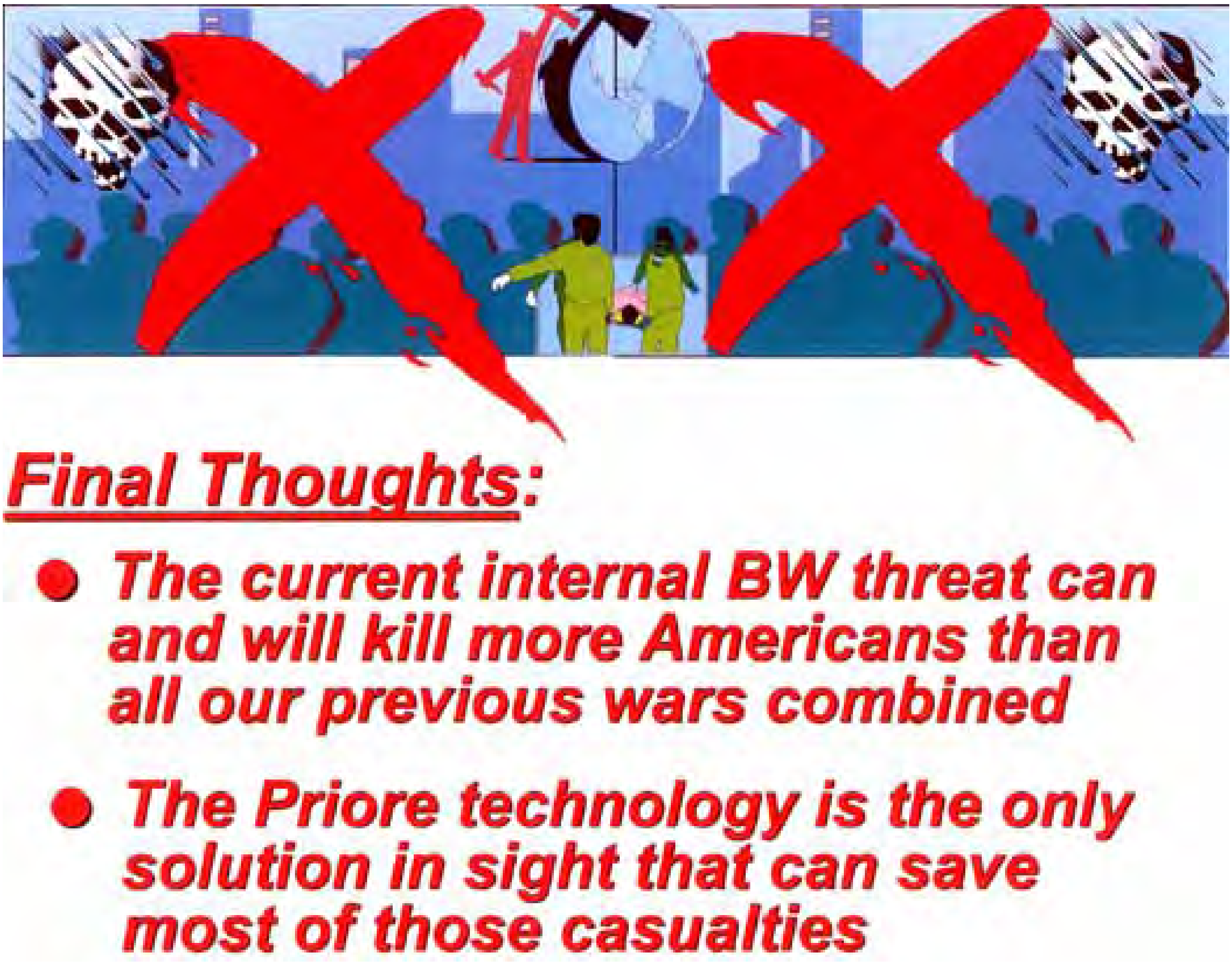

Final Thoughts:

- The current internal BW threat can and will kill more Americans than all our previous wars combined
- The Priore technology is the only solution in sight that can save most of those casualties

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CTEC, Inc.
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CTEC, Inc.

June 24, 1998

Dr. Jane F. Kinsel, Director
Office of Policy Analysis
Department of Health & Human Services
Bathesda, MD 20892

Dear Dr. Kinsel:

Your letter of June 8 is appreciated. However, the entire action package had already gone to the Assistant SecDef and also to Major General Neary in the USAF.

The proof of a revolution in medical treatment was in the package. The basis for it is already demonstrated experimentally in the scientific literature, both in the U.S. and in France. We are speaking of something already proven, but missed by the entire U.S. medical community. Strong words, but true. Let me be specific.

Any cell in the body can be time-reversed (physics term) or dedifferentiated (biology term) back to an earlier state, by pumping (i.e., "squeezing" in simple terms) that cell with longitudinal EM waves as pump waves. There are considerable papers in the French scientific literature showing the experimental results.

Apply that to cancer. We are stating bluntly that all cancerous cells in the body can be "depromoted" back to normal cells easily. Further, the damage previously done to them (such as by sustained hypoxia due to contaminants reducing the oxygen-carrying ability normally given to it by some 60-to-80 surrounding water molecules per red cell and the consequent H-bonding interactions) will also be reversed. The cells can all be returned to healthy, normal cells again, without "killing" or "burning" or "cutting" anything.

With some development of the technology, you can quickly and easily cure every cancer patient in every hospital in the United States.

Now apply it to AIDS. Since you can time-reverse every cell in the body, you can time-reverse the HIV-infected cells – genetics and all – right back to normal cells with normal genetics. Those cells not infected and healthy, will just get a "little younger" again.

So with that small development, you can quickly and easily cure every AIDS patient in every hospital in the United States.

I would have thought that NIH would certainly be interested in such a revolutionary therapy which has already been demonstrated in laboratory experiments. World-renowned French scientists – such as the eminent parasitologist Pautrizel and research PhDs assigned directly by Robert Courrier, head of the Biology Section of the French Academy of Sciences, worked with Prioré in performing those startling experiments that proved what we are saying.

The method was rigorously shown to cure infectious diseases (such as trypanosomiasis), atherosclerosis (which now afflicts millions of Americans), and terminal tumors. It was shown to reverse suppressed immune systems back to normal vigorous functioning.

Please permit me to disagree with you that the examination of such is not the mission of the NIH. To the contrary, it is precisely the NIH which should have some of its very best scientists looking into this.

The action package to DoD was to propose a crash program to develop this methodology in the form of a small, portable unit for treatment of mass casualties resulting from a terrorist BW attack on our cities (now expected in the next few weeks, as you must be aware). The leading Arab terrorist of the world has already promised just this.

We are speaking of several million Americans who are going to die. They are going to die in spite of everything that NIH and its labs can do, even though I know you will make a heroic effort. With NIH present methods, you cannot do very much for those stricken Americans at all. Everything we have in the "normal" kit bag is almost useless against a knowledgeable spray attack of modified smallpox (as you know, the Russian secret BW labs have made and sold tons of that already, to guess who!). Or a spray of tularemia (you are well aware of the extreme lethality of that), or anthrax (easily obtained). It is also common knowledge that these terrorist teams with their BW agents are already on site in this country, waiting for the word to attack. This has now been officially raised to our primary Strategic Threat.

In the face of such looming strikes on the U.S., I simply cannot believe that the NIH does not feel it within their mission to rigorously check out a proposed method for saving perhaps 70% of those coming deaths (first generation equipment), and up to 90% with second generation equipment.

Perhaps you just did not read the package carefully. I urge you to do so.

Else NIH is going to look very, very bad when (1) the strikes do occur, (2) they can't handle them (and they cannot, as you well know), (3) they had within their hands in advance, a proposed methodology that could have been investigated intensely, to save millions of those stricken Americans.

As a staunch supporter of NIH and especially CDC, I have to believe that there is a different attitude there. If NIH is not interested in a previously experimentally demonstrated method of saving millions of Americans, then the only recourse left is the political channel.

I assure you that my critique of electrodynamics is well-founded, as supported by various leading physicists such as Nobelist Feynman (who stated bluntly that the field concept is wrong), Wheeler, Bunge, and so on. It is inexplicable why all our universities are still teaching a 130 year old abridged (Heaviside's) subset of Maxwell's theory, and one that still contains a material ether even though that was falsified 110 years ago!

You already have seen the misuse of this technology by the Russians, in the decades-long radiation of the U.S. Embassy in Moscow. Is it not NIH's mission to understand how they generated all those diseases and health changes? Have you ever looked into Kaznacheyev's experiments showing that ANY cellular disease or disorder can be induced in cells at a distance by purely EM means? Have you looked into what got eliminated from electrodynamics by ignoring the hidden longitudinal EM inside every potential, field, and wave? Do you realize what ignoring that has done to American chemistry, biochemistry, and medical science?"

I would hope that the NIH would at least be interested in its own mission area!

I challenge you bluntly to admit that no one presently understands the primary operation of the human cellular *regenerative* system. That's because its technical principle is not presently in our recognized physics, biochemistry, and medical science – even though it has been in the hard physics literature since 1903-4. Becker's epochal work came closest; since he only had access to the conventional EM model, it failed him. But he at least showed you rigorously that cells can be changed (both differentiated and redifferentiated) all over the map by laughably weak EM – picoamperes of current, which means persistent DC potentials. In the microwave radiation of the U.S. Embassy, all the health changes occurred in regions absent of fields – i.e., absent of bleed-off of the potentials. Hence in regions of stable DC potentials! With 100% correlation of the health changes to persistent, gradient free potentials, and 100% anticorrelation to changing potentials (i.e., fields), our own scientists concluded totally erroneously that it could not have been the EM radiation causing the changes, when their own results had just proven that it was.

Now I ask you: Can NIH explain how it was that the DC potentials caused those health changes? I think not. If it could, it would understand the action package I wrote, and its importance.

This is not a "political" letter. I'm just an ordinary American citizen who has done about 30 years very hard work on this particular area. The work is good enough now to stand on its own merits. The scientific community will eventually accept it, about 50 years from now. But we cannot wait 50 years! Those millions of Americans are going to die, because of the bureaucracy and inaction of our own scientific organizations. Whether they like it or not, the U.S. scientific community is now the forefront of the struggle for this nation to survive. And they are failing us dramatically.

So as a parent who wants his children to live, and his neighbors' children to live, and those millions of soon-to-be stricken Americans to live also, I urge you to at least have someone competent in physics (and knowledgeable that the foundations of physics itself are in woeful shape!) check the work. Has anybody there *read* any of the references to the Prioré work I cited? Does anyone there realize that *there are no EM forcefields in space?* Probably not.

Dr. Kinsel, there is a time for "business as usual" and there is a time to do some serious new work. Those stricken Americans are going to be lying there. Nothing NIH can do is going to stop that. That's a given, and it is not my own estimate. It's the official estimate. And you *know* you presently do not have the tools to do anything really effective about it.

Frankly, I interpret your letter to me as just the normal "spin control" for easy disposition. I would hope that NIH would seriously rethink the situation, get off the "spin control" and "business as usual" posturing, and do something dramatically different for a change.

What have you got to lose? A little time from perhaps two or three of your best scientists.

What have you got to gain? Saving untold millions of American lives. A new, *already partially demonstrated* cure for most dread diseases such as AIDS and cancer – diseases which you presently cannot do very much about in spite of decades of heroic struggle.

Sincerely,

cc: Senator Shelby, Congr. Cramer

T.E. Bearden
President and CEO

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T.E. Bearden, President & CEO
2311 Big Cove Road
Huntsville, AL 35801-1351
(256)533-3682 ph/(256)536-0411 Fax

CTEC, Inc.

May 12, 1998

Dr. Harold Varmus, Director
National Institute of Health
Bathesda, MD 20892
(301) 496-1766

Dear Dr Varmus:

We have recently sent action documents to the Director of Nuclear and Counterproliferation, Office of the DCS, Air and Space Operations, HQ USAF and to the DoD (General Busbee) Assistant Secretary of Defense, as well as several Senate and House committees, which may be of interest to you. For one thing, we give the technical mechanism used to generate the Gulf War Syndrome. The same weaponry is now being used to rapidly induce new strains of certain pathogens worldwide. I urge you to closely read that section of the letter to MG Neary which explains the GWS, why the French did not get it, and why Southern Iraqis got an increase in cancer and leukemia but not GWS. Also explained is how the "microwave radiation" of the U.S. Embassy in Moscow induced diseases for decades, and how we failed to comprehend it because the standard EM model deceived us.

There is a way to treat and quickly cure most diseases, including the mass casualties resulting from a terrorist BW strike on our civilian population centers, our military bases, or our forces in the field. The method is little known, but was scientifically demonstrated in France in the 1960s and early 1970s before cancellation of the Prioré Project when the French Government changed. Eminent French scientists worked on the project, and the results are fully documented in leading French scientific journals. References are listed in a separate attachment.

Previously the Western scientific community has been unable to understand the technical mechanism responsible for such remarkable cures, because of serious foundations flaws in Western physics and electrodynamics. *Foundations* physicists have long been aware our science is flawed, and have pointed out many of these fundamental errors. However, the operational science establishment has not paid attention, even though physicists such as Feynman and Wheeler pointed out that the notion of "force fields in space" was totally wrong.

As a primary example, there is an "infolded" electrodynamics inside all potentials, fields, and waves that is far more primary than the coarse EM that is in our textbooks. It is actually an infolded general relativity, and this is what the Russians have weaponized. This infolded EM-GR has been ignored in the West (but not in Russia) since 1903.

As another example the potentials, fields, and waves of present electrodynamics are rigorously defined – and exist – only in the presence of mass. They do not exist in such form (force fields and oscillating force fields) at all in space, in the absence of mass. Rigorously, Maxwell's equations are mass-to-mass transforms, since Maxwell and everyone at the time assumed the ubiquitous presence of the material ether. In other words, to the founding electrodynamicists, there was no place in all the universe that was devoid of mass. Hence they defined all EM entities as entities containing mass. Even though Michelson-Morley experiments of more than a century ago destroyed that material ether, not a single Maxwellian equation has ever been changed! They still assume the material ether.

Specifically missing from our electrodynamics are two essential transforms: (1) the mass-to-spacetime transform, and (2) the spacetime-to-mass transform. In other words, these two transforms are "infolded" or hidden inside (comprise) the end point extremum case – the mass-to-mass transform actually written by Maxwell.

But these two missing transforms are just general relativity (they correspond precisely to Wheeler's principle of general relativity). So general relativity has always been infolded inside electrodynamics as we know it, but ignored. Further, this is a very powerful general relativity, since it uses the very strong EM force as the agent of spacetime curvature. Hence now one can engineer a powerful general relativity in the laboratory and in practical devices, and even action-at-a-distance, which one cannot do using merely the staid and weak G-force.

It turns out that longitudinal EM waves as shown by E.T. Whittaker in 1903 and 1904 are far more primary than our present EM theory and even our present GR theory. Both EM and GR are directly engineerable using longitudinal EM waves, including subluminal and superluminal EM waves in vacuum, and including action at a distance. One can engineer complexes of spacetime curvatures as desired, which in turn are *spacetime engines* (Wheeler's term). These engines can act upon mass – either living or inert – in any fashion desired, and at any distance desired.

The little-known and poorly understood Regeneration & Recovery (R&R) system – as contrasted to the immune system – utilizes this exact "spacetime engine" methodology to restore damaged or diseased cells, within its limitations – "dedifferentiating" or "time-reversing" them back to normal. The mechanism is fully explained in the attached package. The proposed program applies this fundamental method to greatly amplify the effect. Thus cancer cells can be reversed back to normal cells, HIV-infected cells (HIV-factories) can be reversed back to normal cells (genetics and all), etc. This represents a dramatic and unparalleled new medical therapeutic methodology of extreme power. The same techniques can simply be conjugated one additional time, and used to produce diseases and cellular changes at a distance, including in entire mass populations, as the KGB is doing right now. Specifically, by impressing an extremely weak "cocktail mix" of disease spacetime engines on the U.S. populace, the immune systems are reacting and being "spread thin" across several "shadow state" infectious pathogenic conditions. Thus when an actual terrorist BW attack occurs, the lethality of the strike will be remarkably enhanced because the immune systems will be "thinned" in their ability to fend off this new pathogen. By doing it this way, BW warfare can actually be conducted upon the U.S. without anyone being the wiser.

Our very survival as a nation is threatened by remarkable KGB weapons using this fully documented, extended electrodynamics. Bluntly, unless we take off our scientific blinders and understand Russian energetics weapon science, GWS and the Embassy health changes in Moscow were just a picnic before what is upon us. After two decades of work on the KGB energetics weapon problem, we have fully deciphered the technical mechanisms and what energetics is, as well as citing many of the Russian weapon tests and how they were done. Again, you can see that for yourself in the package.

Now that we understand the technical mechanisms, we are proposing rapid redevelopment of the Prioré process, in portable suitcase-sized units to be mass produced and filtered down into the entire emergency community for mass treatment of lethal infectious diseases resulting from BW strikes. And we are strongly urging the U.S. scientific community to quickly investigate and come to grips with this vast new *biological engineering* mechanism. Our very survival depends on it.

The inclosed documents provide an overview of the process. There is nothing else on the scientific horizon that can save the majority of all those stricken Americans, once the first foreign-sponsored terrorist teams strike our population centers with BW agents.

Sincerely,

Incls: Full package with table of contents

T.E. Bearden
President & CEO

The Tom Bearden Website

Energy, Observations and Comments

---

1. A Conservative Field Requires a Single-Valued Potential
2. Earth-Electrosphere and Earth-Ionosphere Capacitors
3. Earth's Poynting Energy Flow
4. The Hidden Energy Flow around us
5. Electrostatic Fields of the Earth's Electrosphere Capacitor in Fair Weather and Thunderstorms
6. Flow of Current and Energy Into, Through, and Along a Conductor
7. Energy "collected" on a charge
8. Fiber Fuse Effect
9. Impact of Vacuum Engineering
10. Lawandy's Experiment
11. Field may be nonconservative for a multivalued potential
12. The Ostrich Problem - Part 1
13. The Ostrich Problem - Part 2
14. Russia had Overunity Devices in 1930s
15. Energy output of human body
16. A "static" Poynting S-flow free-energy generator
17. Topology and Energy Conservation
18. Block Diagram: Sweet's Vacuum Triode

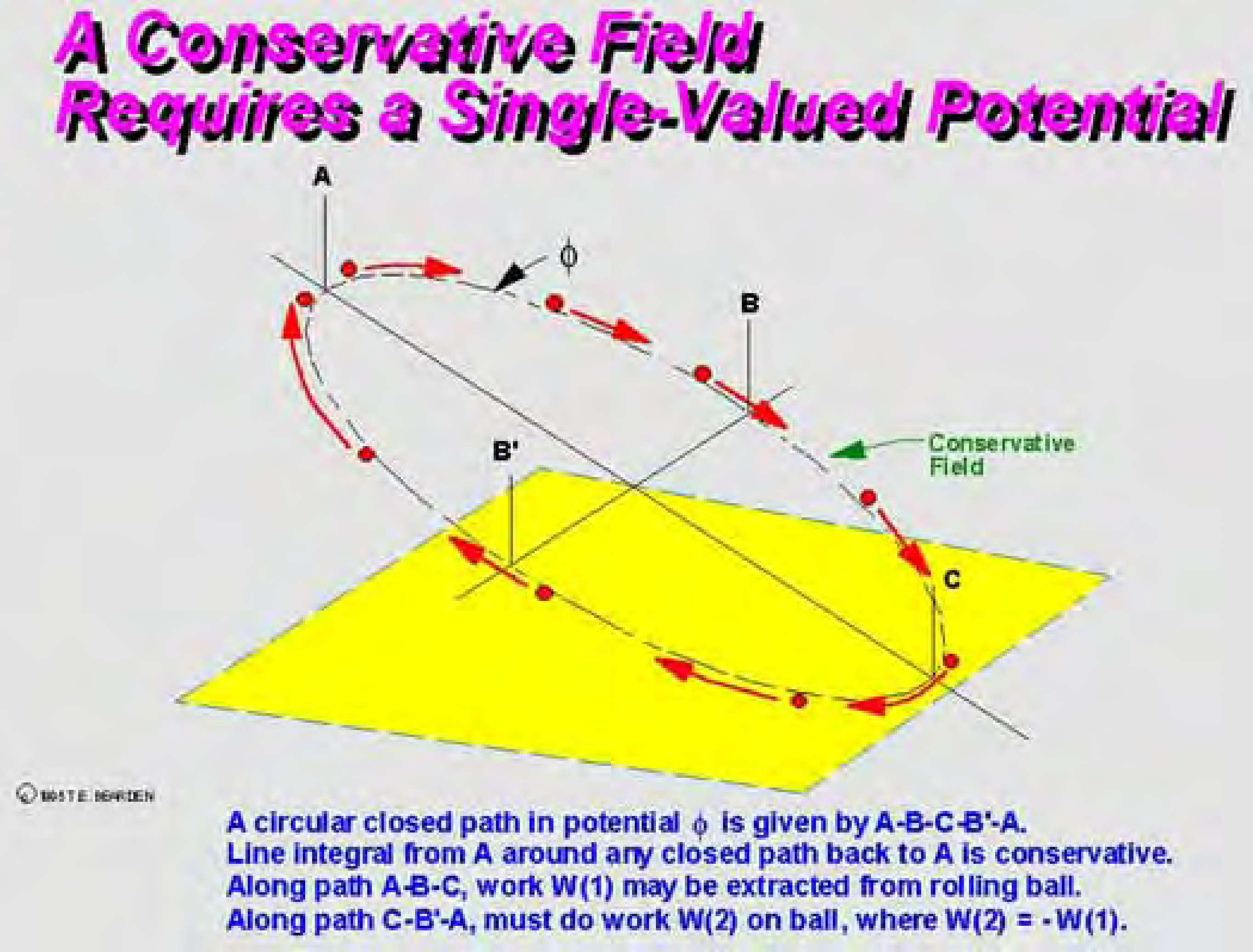

A Conservative Field Requires a Single-Valued Potential

A
ϕ
B
B'
Conservative Field
C
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A circular closed path in potential ϕ is given by A-B-C-B'-A.
Line integral from A around any closed path back to A is conservative.
Along path A-B-C, work W(1) may be extracted from rolling ball.
Along path C-B'-A, must do work W(2) on ball, where W(2) = - W(1).

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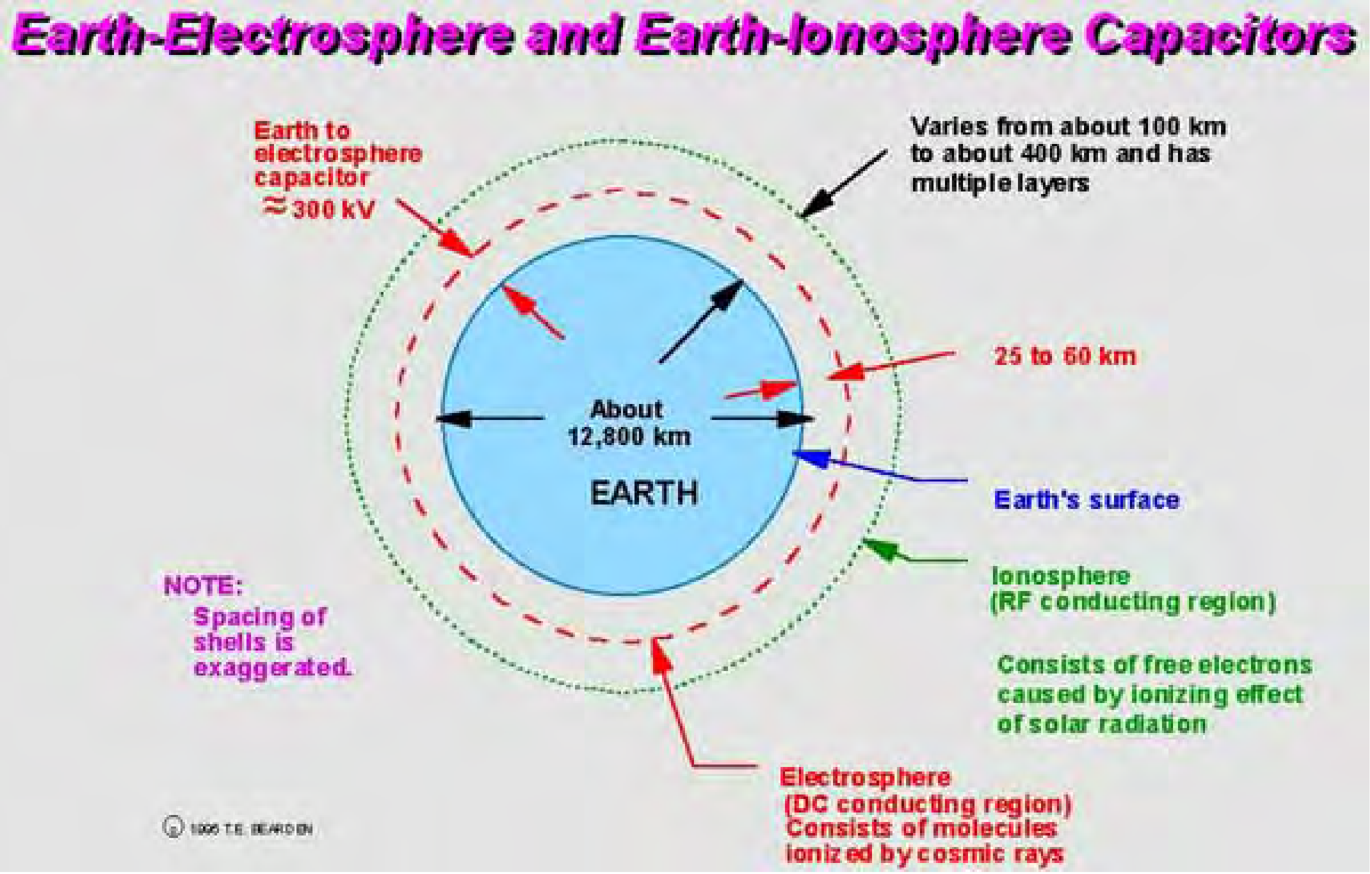

Earth-Electrosphere and Earth-Ionosphere Capacitors

Earth to electrosphere capacitor ≈ 300 kV

Varies from about 100 km to about 400 km and has multiple layers

About 12,800 km

EARTH

25 to 60 km

Earth's surface

Ionosphere (RF conducting region)

Consists of free electrons caused by ionizing effect of solar radiation

NOTE: Spacing of shells is exaggerated.

Electrosphere (DC conducting region) Consists of molecules ionized by cosmic rays

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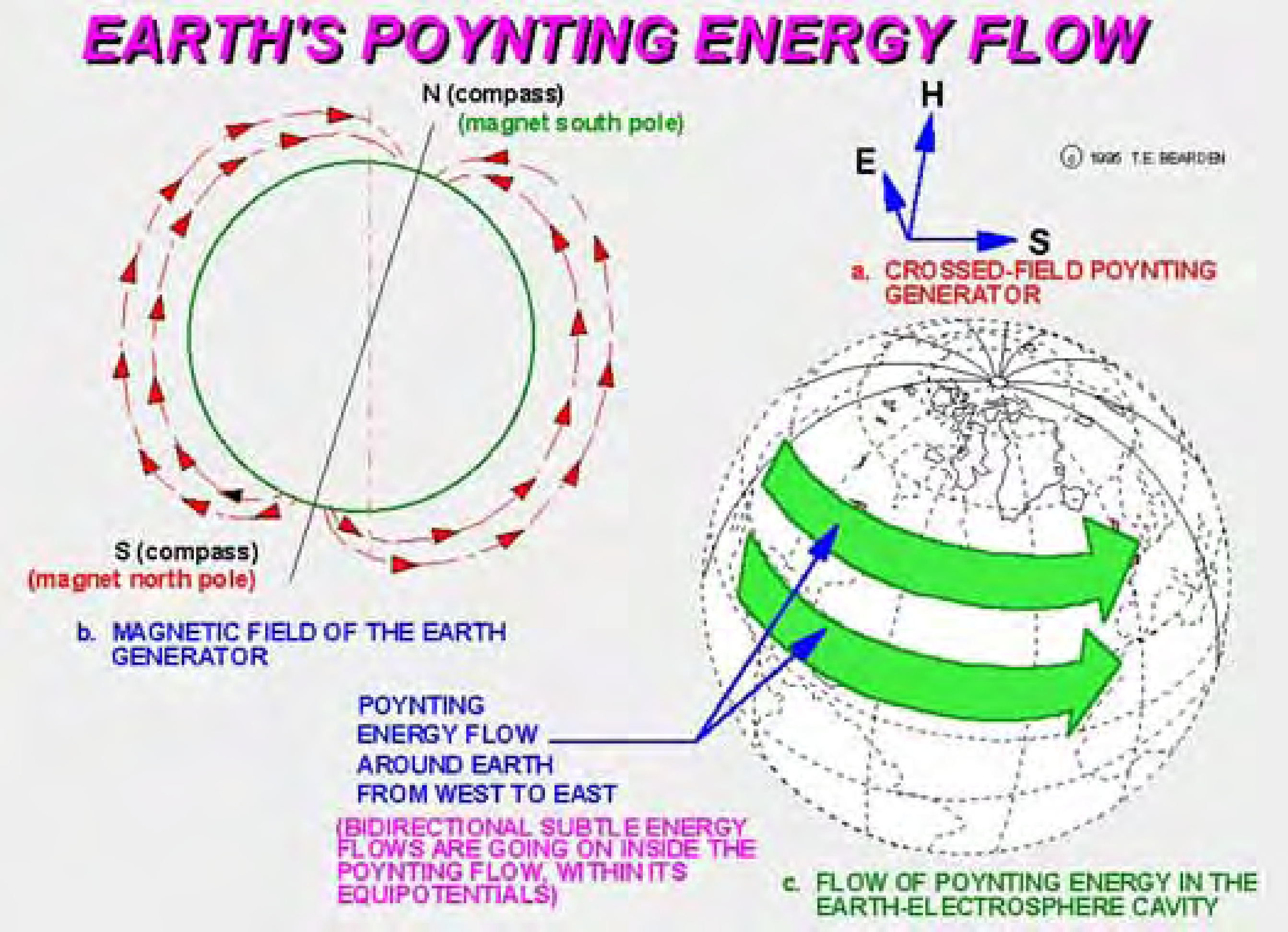

EARTH'S POYNTING ENERGY FLOW

N (compass)
(magnet south pole)
S (compass)
(magnet north pole)
H
E
S
© 1995 T.E. BEARDEN

a. CROSSED-FIELD POYNTING GENERATOR

b. MAGNETIC FIELD OF THE EARTH GENERATOR

POYNTING ENERGY FLOW AROUND EARTH FROM WEST TO EAST

(BIDIRECTIONAL SUBTLE ENERGY FLOWS ARE GOING ON INSIDE THE POYNTING FLOW, WITHIN ITS EQUIPOTENTIALS)

c. FLOW OF POYNTING ENERGY IN THE EARTH-ELECTROSPHERE CAVITY

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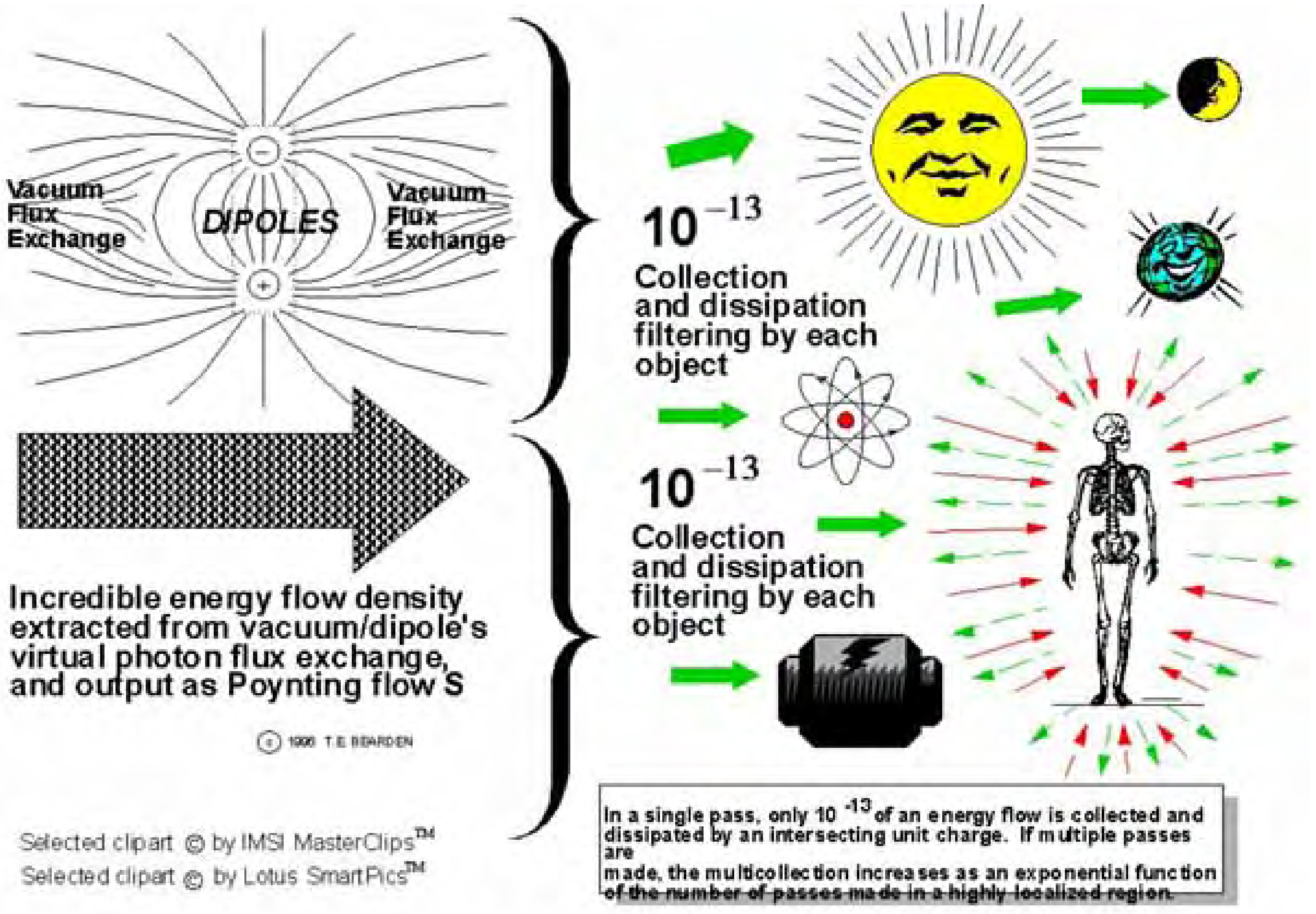
Vacuum Flux Exchange
DIPOLES
Vacuum Flux Exchange
10^{-13}
Collection and dissipation filtering by each object
10^{-13}
Collection and dissipation filtering by each object
© 1996 T.E. BEARDEN
Selected clipart © by IMSI MasterClips™
Selected clipart © by Lotus SmartPics™

Incredible energy flow density extracted from vacuum/dipole's virtual photon flux exchange, and output as Poynting flow S

In a single pass, only 10^{-13} of an energy flow is collected and dissipated by an intersecting unit charge. If multiple passes are made, the multicollection increases as an exponential function of the number of passes made in a highly localized region.

Figure 19. The world of physical matter exists behind a dramatic 10^{-13} filter in a fiery cauldron of fierce and primeval EM energy flow.

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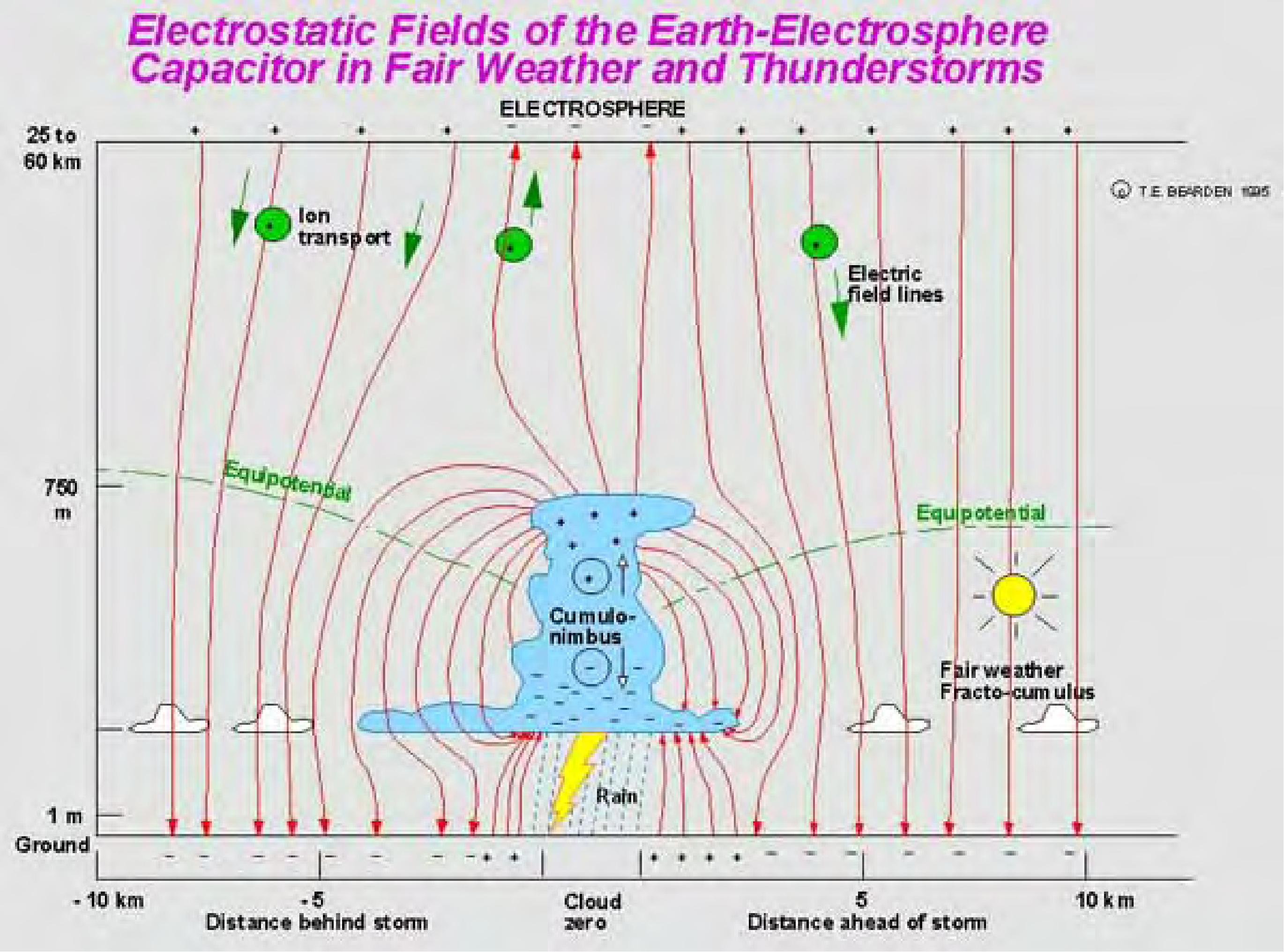

Electrostatic Fields of the Earth-Electrosphere Capacitor in Fair Weather and Thunderstorms

ELECTROSPHERE
25 to 60 km
750 m
1 m
Ground
© T.E. BEARDEN 1995
Ion transport
Electric field lines
Equipotential
Equipotential
Cumulo-nimbus
Fair weather Fracto-cumulus
Rain
- 10 km
- 5
Distance behind storm
Cloud zero
5
Distance ahead of storm
10 km

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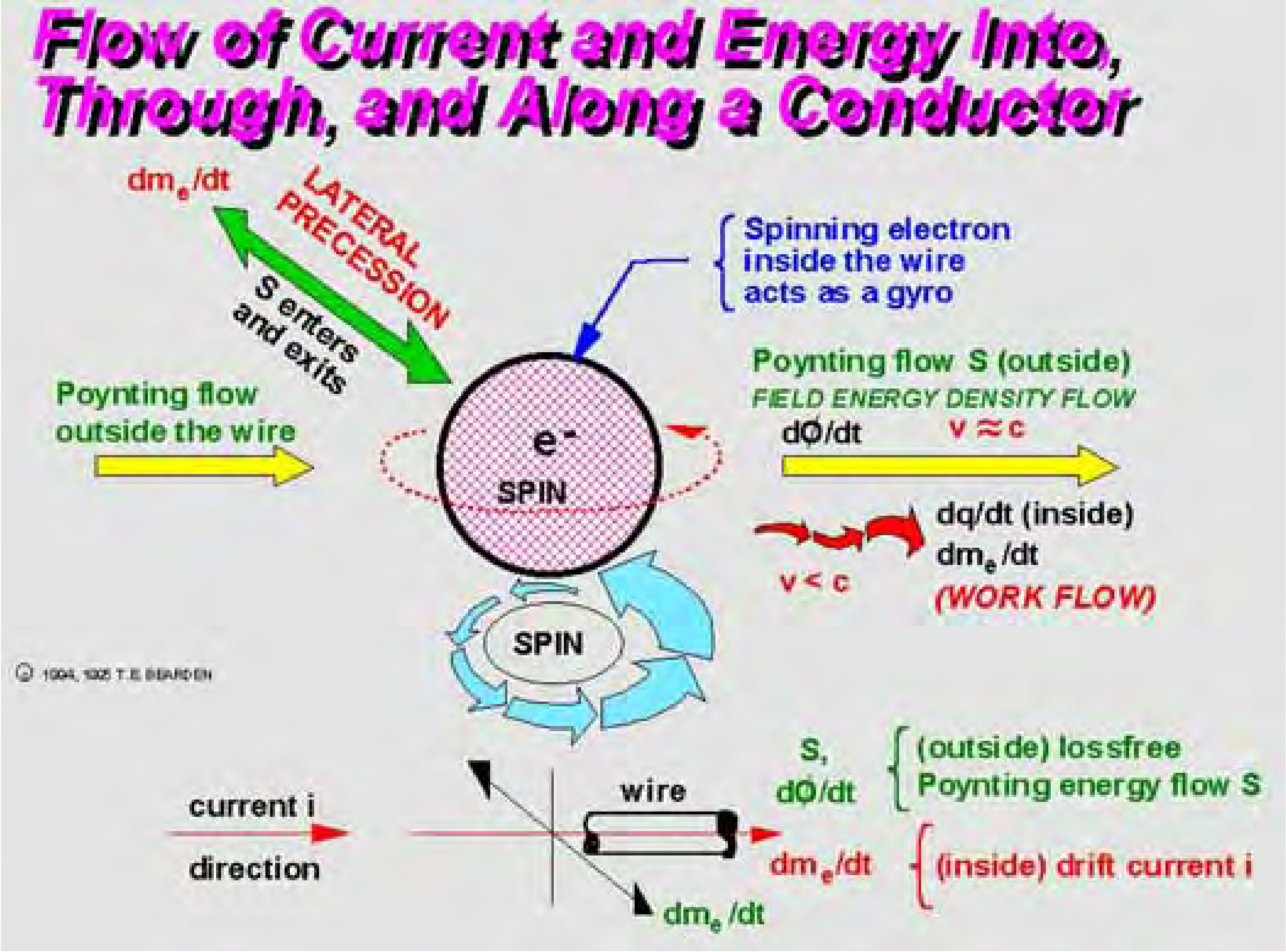

Flow of Current and Energy Into, Through, and Along a Conductor

dm_e/dt

LATERAL PRECESSION

S enters and exits

Spinning electron
inside the wire
acts as a gyro

Poynting flow
outside the wire

e^-

SPIN

SPIN

Poynting flow S (outside)

FIELD ENERGY DENSITY FLOW

$d\phi/dt$ $v \approx c$

dq/dt (inside)

dm_e/dt

$v < c$

(WORK FLOW)

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S, $d\phi/dt$ {(outside) lossfree Poynting energy flow S

current i direction

wire

dm_e/dt {(inside) drift current i

dm_e/dt

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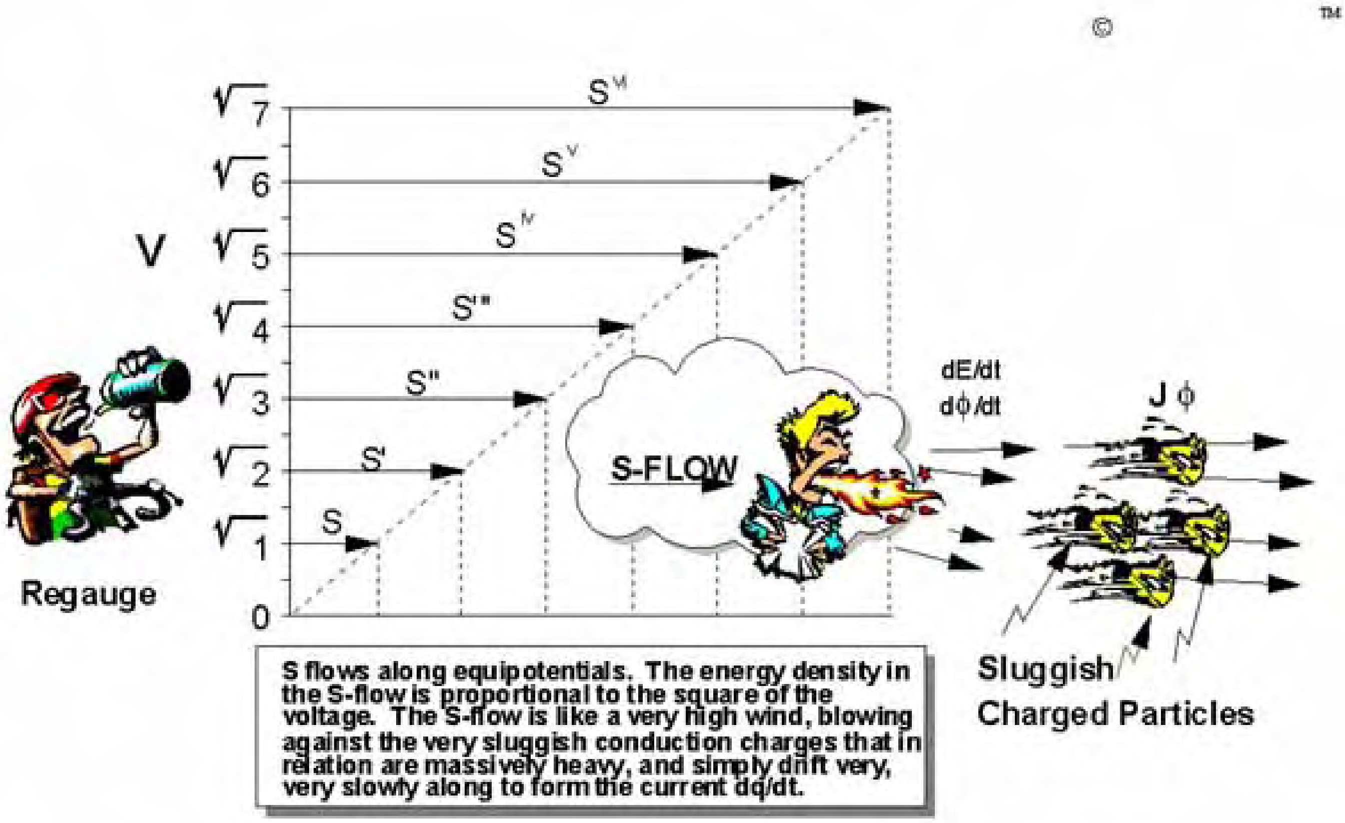
©
™
V
$\sqrt{7}$
$\sqrt{6}$
$\sqrt{5}$
$\sqrt{4}$
$\sqrt{3}$
$\sqrt{2}$
$\sqrt{1}$
0
S^{VI}
S^{V}
S^{IV}
S'''
S''
S'
S
S-FLOW
Regauge
dE/dt
dφ/dt
Jφ
Sluggish
Charged Particles

S flows along equipotentials. The energy density in the S-flow is proportional to the square of the voltage. The S-flow is like a very high wind, blowing against the very sluggish conduction charges that in relation are massively heavy, and simply drift very, very slowly along to form the current dq/dt.

Figure 17. Energy "collected" on a charge depends upon the charge being in a continuous Poynting S-flow. When S ceases, there is no excess energy "collected" on the charge. Energy collection never occurs in chunks, but is always a dynamic, ongoing process.

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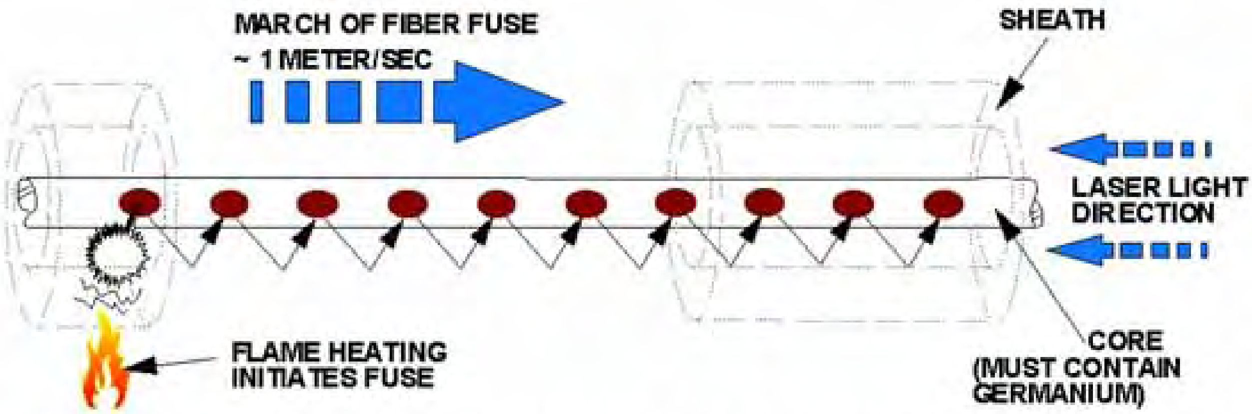
MARCH OF FIBER FUSE
~ 1 METER/SEC
SHEATH
LASER LIGHT DIRECTION
FLAME HEATING INITIATES FUSE
CORE (MUST CONTAIN GERMANIUM)

31A. Fiber fuse destroys core of fiber optics cable of indefinite length, pitting core with holes.

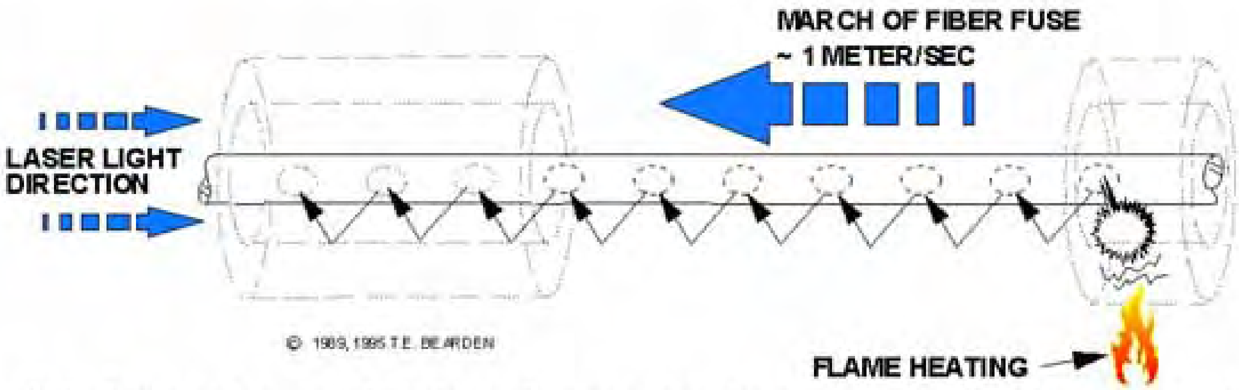
MARCH OF FIBER FUSE
~ 1 METER/SEC
LASER LIGHT DIRECTION
© 1989, 1995 T.E. BEARDEN
FLAME HEATING

31B. Reversed second fiber fuse often *restores* pitted core in cable, filling holes back up.

Figure 31. Fiber fuse effect and its strange anomalies.

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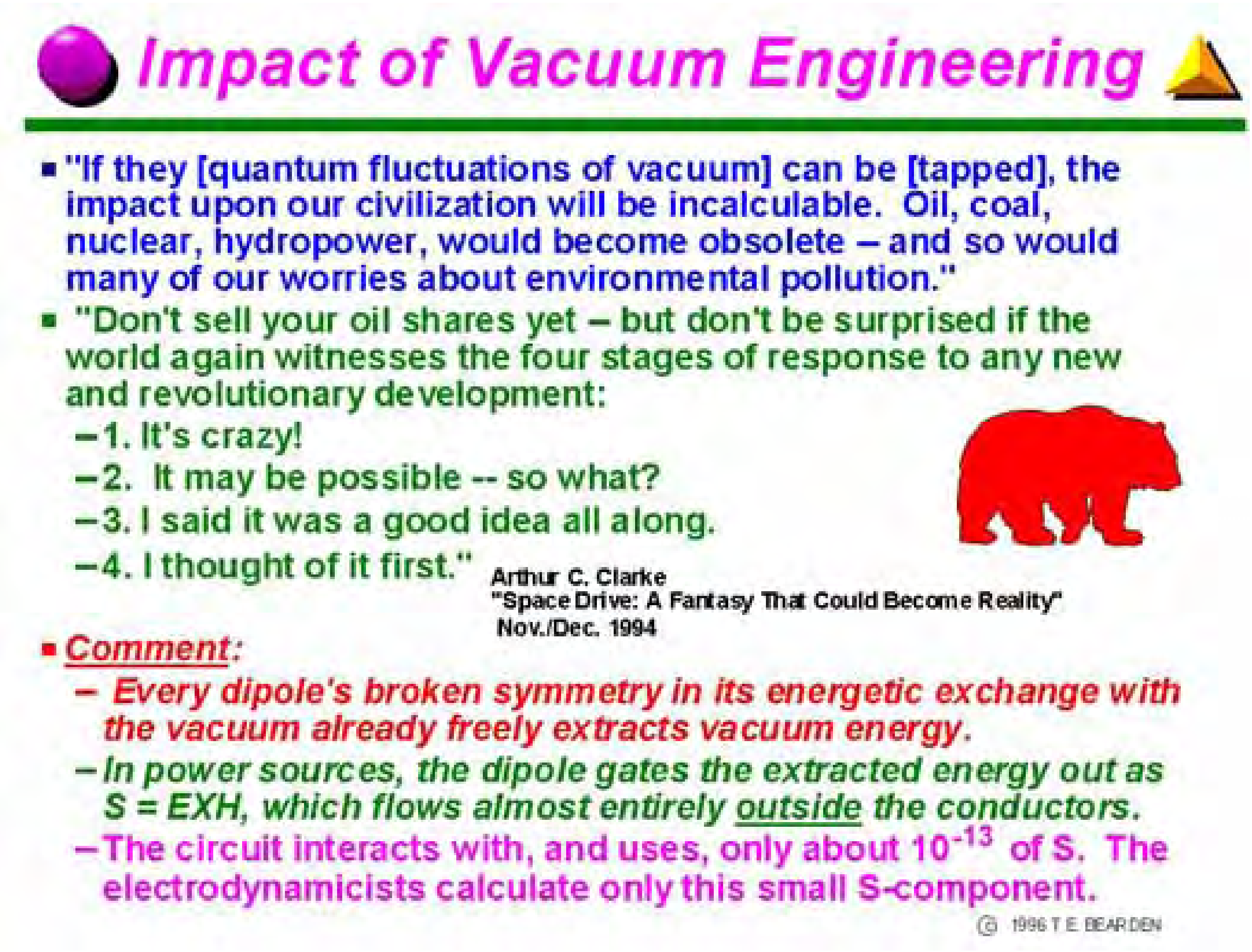

Impact of Vacuum Engineering

- "If they [quantum fluctuations of vacuum] can be [tapped], the impact upon our civilization will be incalculable. Oil, coal, nuclear, hydropower, would become obsolete – and so would many of our worries about environmental pollution."
- "Don't sell your oil shares yet – but don't be surprised if the world again witnesses the four stages of response to any new and revolutionary development:
  - 1. It's crazy!
  - 2. It may be possible -- so what?
  - 3. I said it was a good idea all along.
  - 4. I thought of it first."

Arthur C. Clarke
"Space Drive: A Fantasy That Could Become Reality"
Nov./Dec. 1994

- *Comment:*
  - *Every dipole's broken symmetry in its energetic exchange with the vacuum already freely extracts vacuum energy.*
  - *In power sources, the dipole gates the extracted energy out as S = EXH, which flows almost entirely outside the conductors.*
  - The circuit interacts with, and uses, only about 10^{-13} of S. The electrodynamicists calculate only this small S-component.

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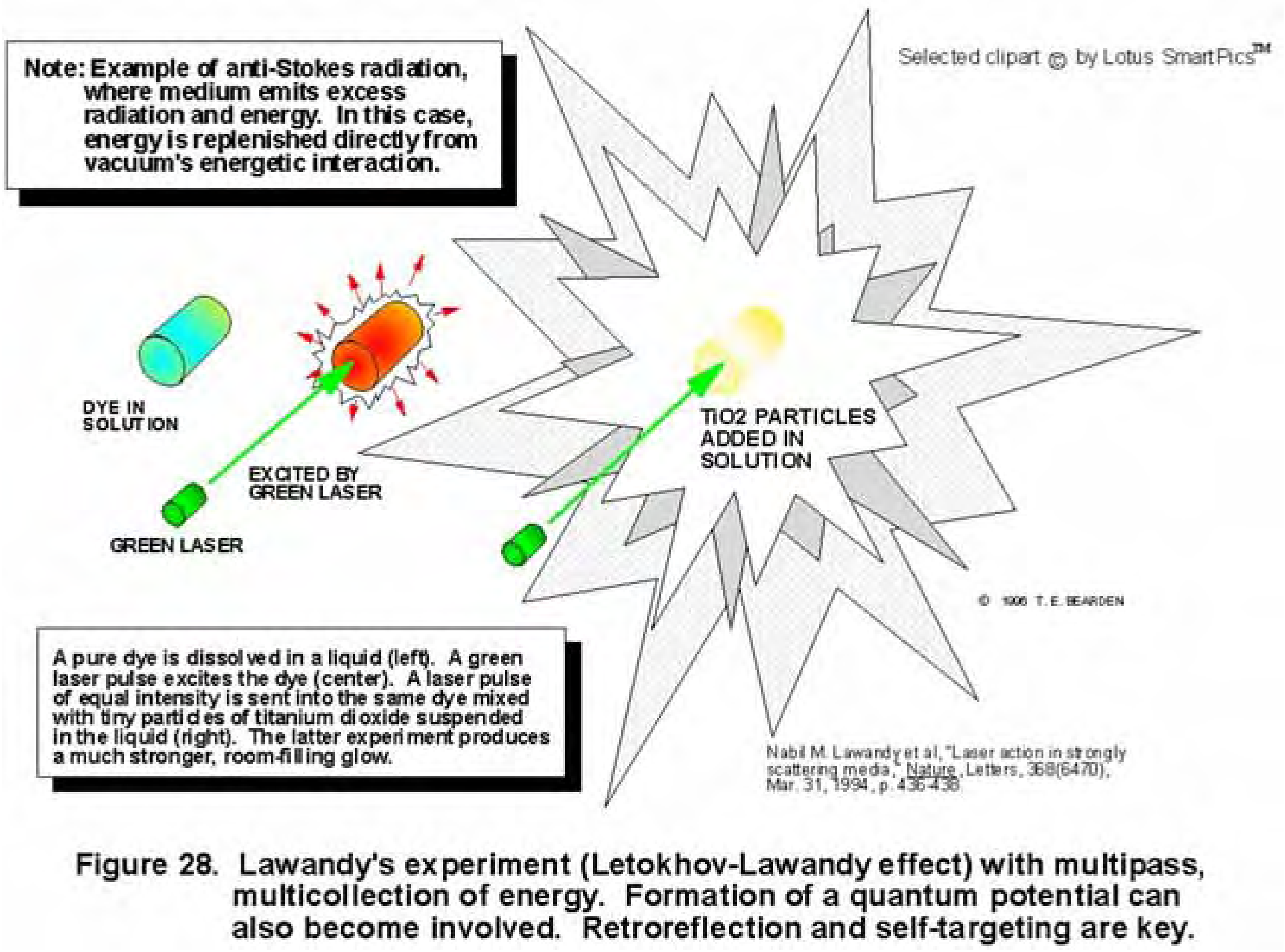

Note: Example of anti-Stokes radiation, where medium emits excess radiation and energy. In this case, energy is replenished directly from vacuum's energetic interaction.

Selected clipart © by Lotus SmartPics™
DYE IN SOLUTION
EXCITED BY GREEN LASER
GREEN LASER
TiO2 PARTICLES ADDED IN SOLUTION
© 1996 T. E. BEARDEN

A pure dye is dissolved in a liquid (left). A green laser pulse excites the dye (center). A laser pulse of equal intensity is sent into the same dye mixed with tiny particles of titanium dioxide suspended in the liquid (right). The latter experiment produces a much stronger, room-filling glow.

Nabil M. Lawandy et al, "Laser action in strongly scattering media," Nature, Letters, 368(6470), Mar. 31, 1994, p. 436-438.

Figure 28. Lawandy's experiment (Letokhov-Lawandy effect) with multipass, multicollection of energy. Formation of a quantum potential can also become involved. Retroreflection and self-targeting are key.

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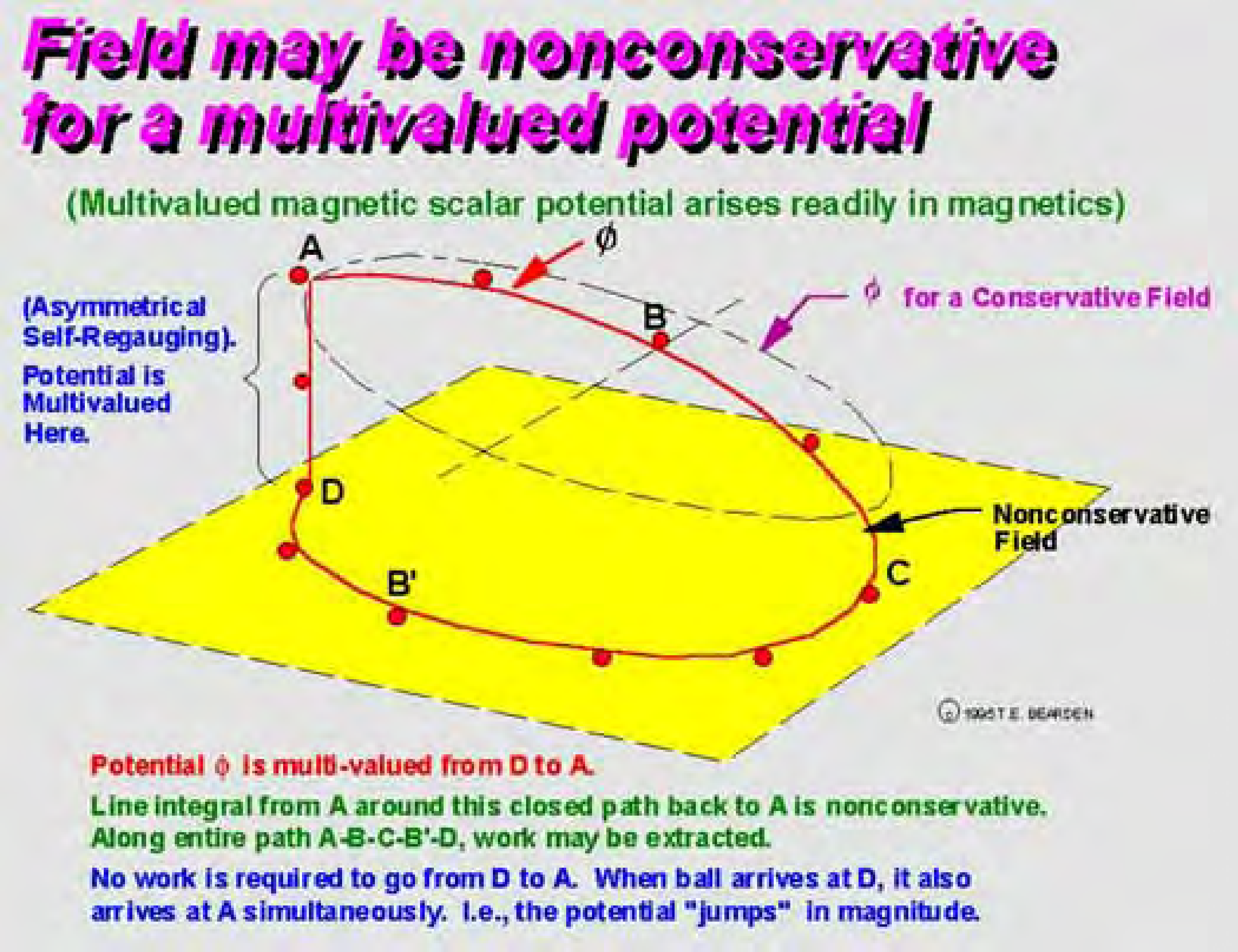

Field may be nonconservative for a multivalued potential

(Multivalued magnetic scalar potential arises readily in magnetics)

(Asymmetrical Self-Regauging). Potential is Multivalued Here.

A
φ
B
φ for a Conservative Field
D
B'
C
Nonconservative Field
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Potential φ is multi-valued from D to A.

Line integral from A around this closed path back to A is nonconservative. Along entire path A-B-C-B'-D, work may be extracted.

No work is required to go from D to A. When ball arrives at D, it also arrives at A simultaneously. I.e., the potential "jumps" in magnitude.

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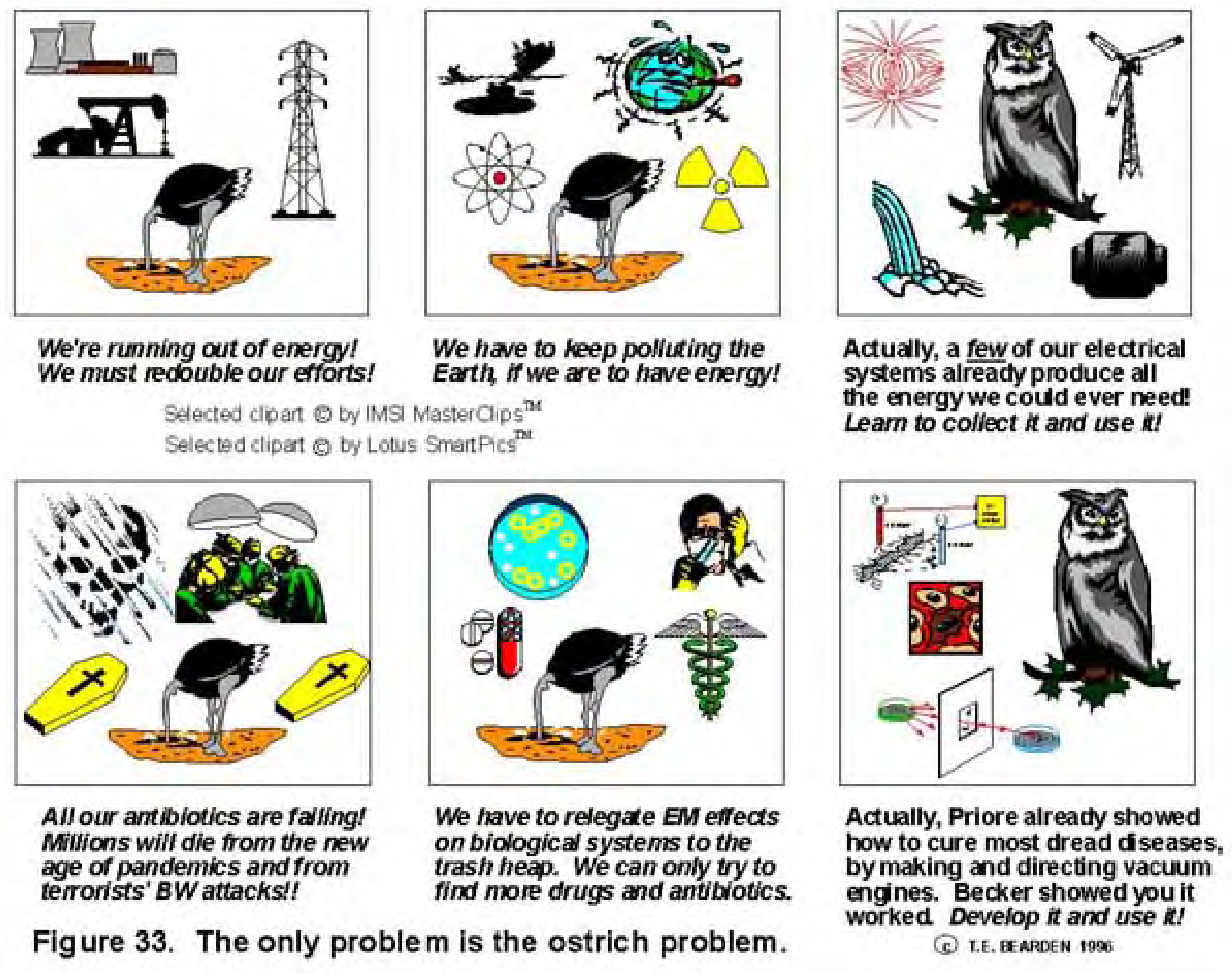

We're running out of energy!
We must redouble our efforts!

We have to keep polluting the
Earth, if we are to have energy!

Actually, a _few_ of our electrical
systems already produce all
the energy we could ever need!
Learn to collect it and use it!

Selected clipart © by IMSI MasterClips™
Selected clipart © by Lotus SmartPics™

All our antibiotics are failing!
Millions will die from the new
age of pandemics and from
terrorists' BW attacks!!

We have to relegate EM effects
on biological systems to the
trash heap. We can only try to
find more drugs and antibiotics.

Actually, Priore already showed
how to cure most dread diseases,
by making and directing vacuum
engines. Becker showed you it
worked. *Develop it and use it!*

Figure 33. The only problem is the ostrich problem.

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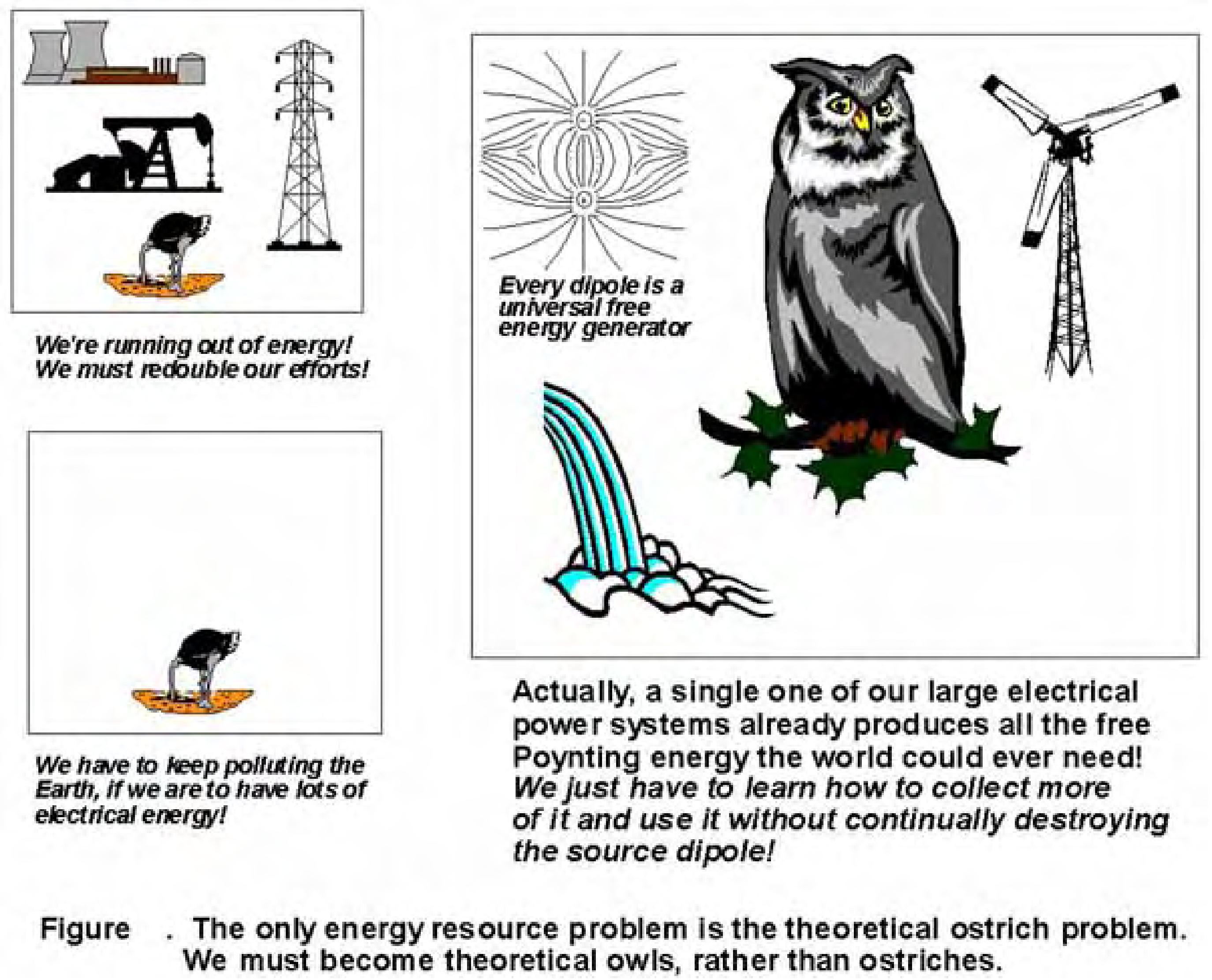

We're running out of energy!
We must redouble our efforts!

We have to keep polluting the Earth, if we are to have lots of electrical energy!

Every dipole is a universal free energy generator

Actually, a single one of our large electrical power systems already produces all the free Poynting energy the world could ever need! *We just have to learn how to collect more of it and use it without continually destroying the source dipole!*

Figure . The only energy resource problem is the theoretical ostrich problem. We must become theoretical owls, rather than ostriches.

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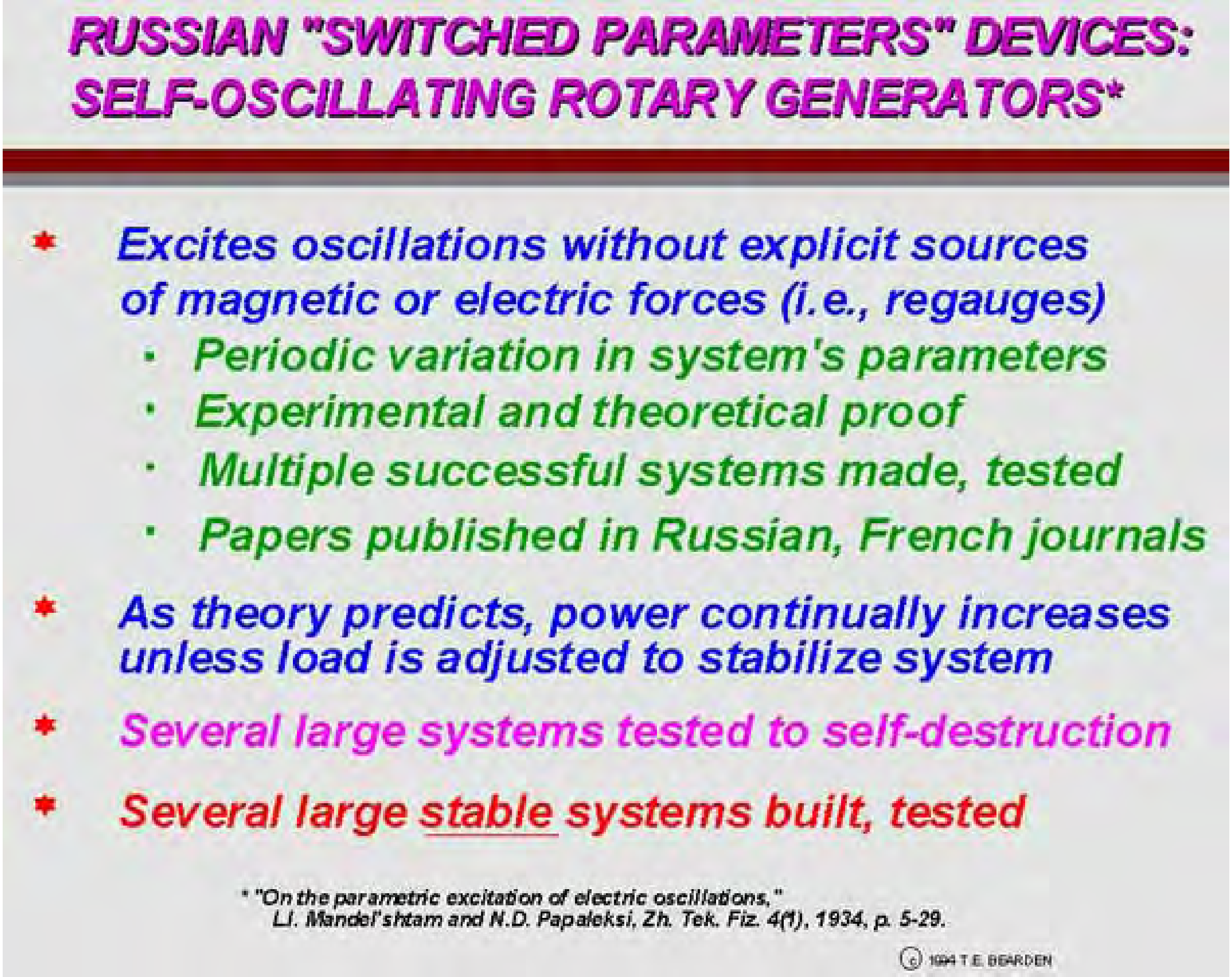

RUSSIAN "SWITCHED PARAMETERS" DEVICES: SELF-OSCILLATING ROTARY GENERATORS*

- Excites oscillations without explicit sources of magnetic or electric forces (i.e., regauges)
  - Periodic variation in system's parameters
  - Experimental and theoretical proof
  - Multiple successful systems made, tested
  - Papers published in Russian, French journals
- As theory predicts, power continually increases unless load is adjusted to stabilize system
- Several large systems tested to self-destruction
- Several large stable systems built, tested

* "On the parametric excitation of electric oscillations," L.I. Mandel'shtam and N.D. Papaleksi, Zh. Tek. Fiz. 4(1), 1934, p. 5-29.

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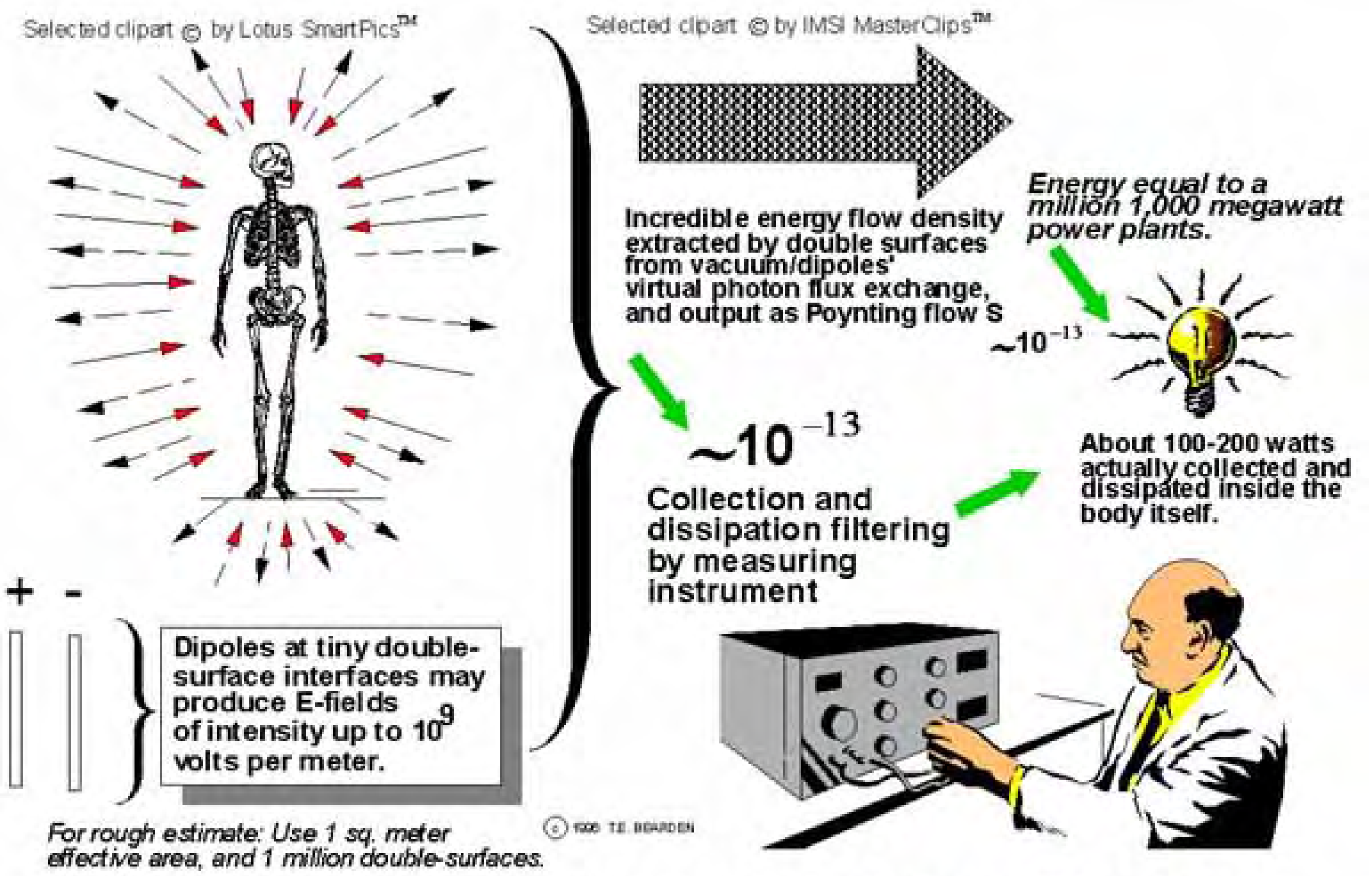
Selected clipart © by Lotus SmartPics™
Selected clipart © by IMSI MasterClips™
+
-
~10^{-13}
© 1996 T.E. BEARDEN

Incredible energy flow density extracted by double surfaces from vacuum/dipoles' virtual photon flux exchange, and output as Poynting flow S

Energy equal to a million 1,000 megawatt power plants.

~10^{-13}

Collection and dissipation filtering by measuring instrument

About 100-200 watts actually collected and dissipated inside the body itself.

Dipoles at tiny double-surface interfaces may produce E-fields of intensity up to 10^9 volts per meter.

For rough estimate: Use 1 sq. meter effective area, and 1 million double-surfaces.

Figure 20. One human body produces more energy flow than all the electrical power loads on earth dissipate. However, only 100-200 watts of its own energy output is collected and dissipated by the body.

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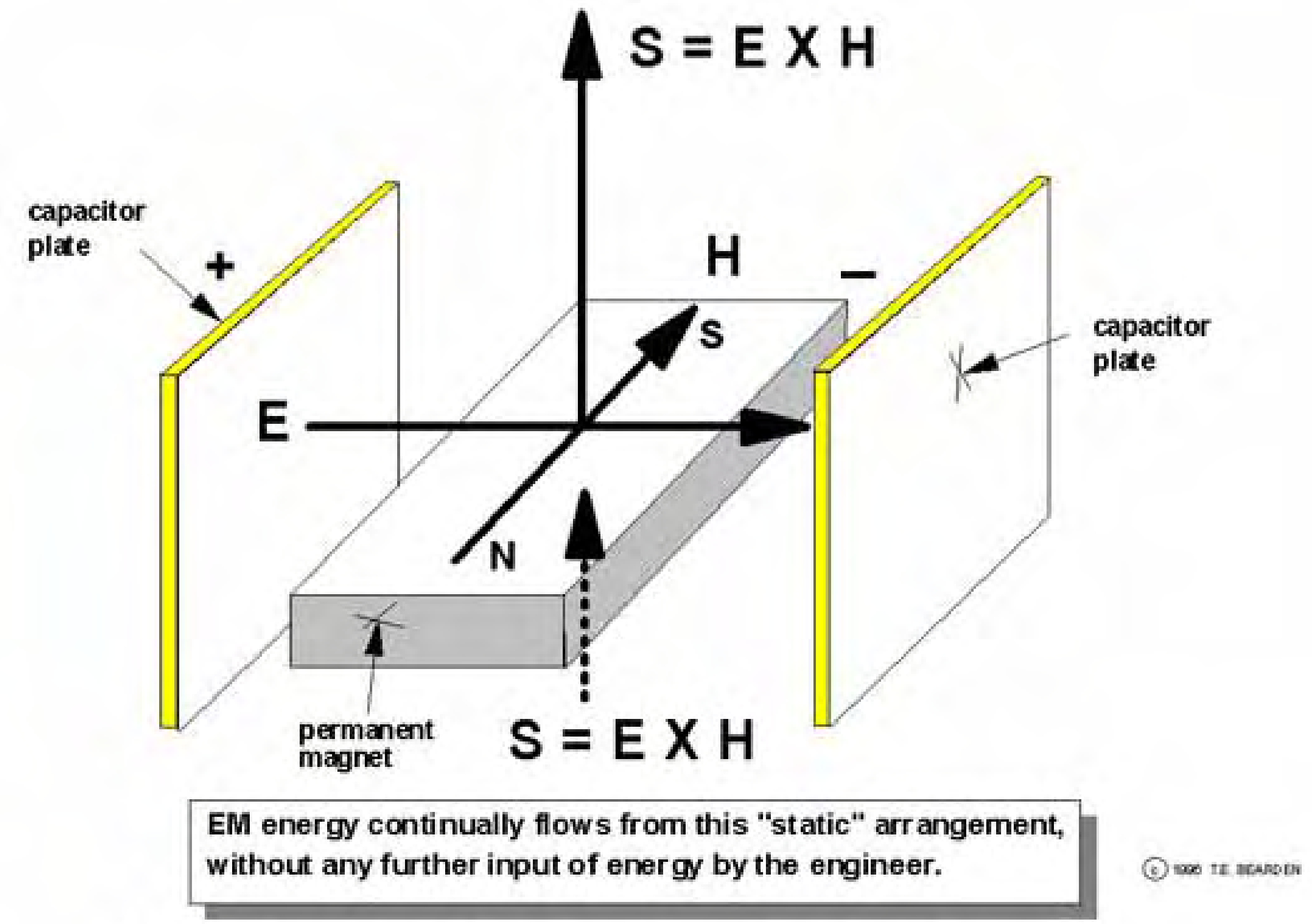
S = E X H
capacitor plate
+
H
–
S
capacitor plate
E
N
permanent magnet
S = E X H

EM energy continually flows from this "static" arrangement, without any further input of energy by the engineer.

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Figure 18. A "static" Poynting S-flow free-energy generator.

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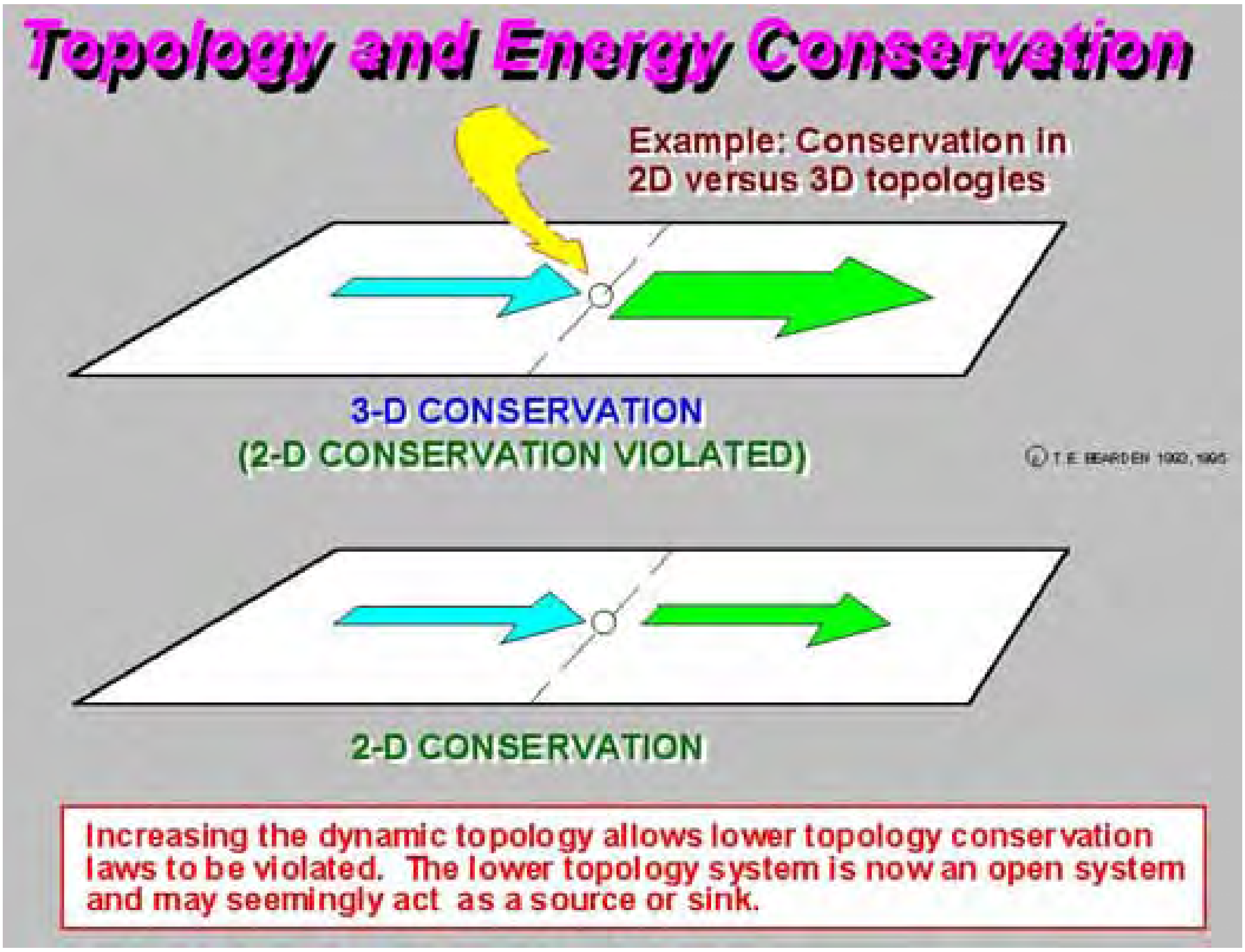

Topology and Energy Conservation

Example: Conservation in
2D versus 3D topologies

3-D CONSERVATION
(2-D CONSERVATION VIOLATED)

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2-D CONSERVATION

Increasing the dynamic topology allows lower topology conservation laws to be violated. The lower topology system is now an open system and may seemingly act as a source or sink.

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Block Diagram: Sweet's Vacuum Triode

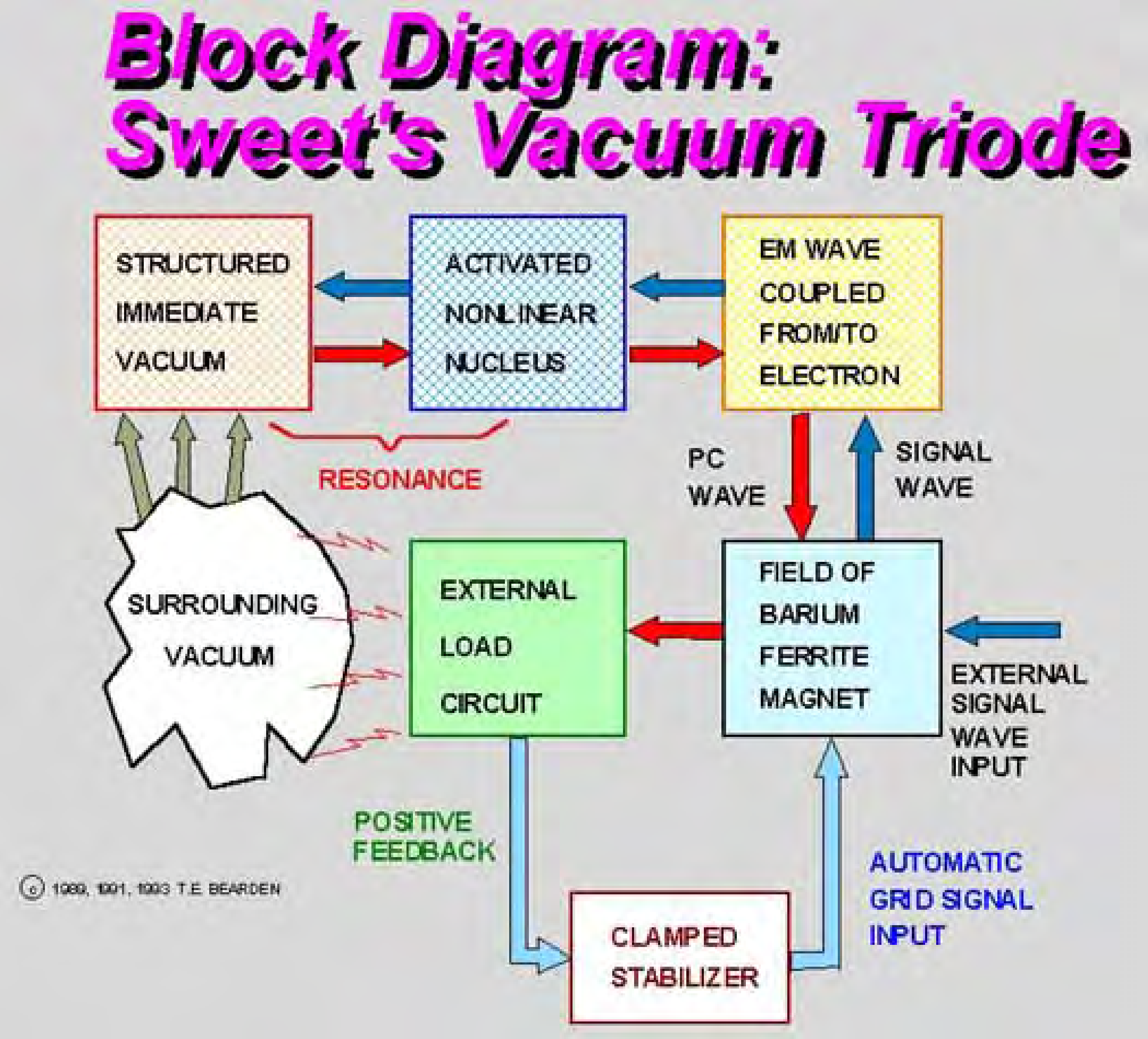
STRUCTURED IMMEDIATE VACUUM
ACTIVATED NONLINEAR NUCLEUS
EM WAVE COUPLED FROM/TO ELECTRON
RESONANCE
PC WAVE
SIGNAL WAVE
SURROUNDING VACUUM
EXTERNAL LOAD CIRCUIT
FIELD OF BARIUM FERRITE MAGNET
EXTERNAL SIGNAL WAVE INPUT
POSITIVE FEEDBACK
AUTOMATIC GRID SIGNAL INPUT
CLAMPED STABILIZER

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The Tom Bearden Website

Help support the research

Foundations of Electro-Magnetism
Slide Series

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- Aharanov-Bohm Effect
- Absorption and emission reactions (1)
- Absorption and emission reactions (2)
- Anti-engine for cell's deviation reverses cell back to normal
- Asymmetric regauging produces excess force, which can be used to do work on the system
- Asymmetric regauging produces excess force, which can be used to do work on the regauging system
- Becker's bone fracture healing experiments
- Becker's theoretical control system governing regeneration
- Becker's theoretical DC control system involved with response to injury
- Geometrical Distortion of Poynting Energy Flow
- Cosmic Bootstrap: Before the Big Bang
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- Aspects of Strong Local Symmetry
- Other Aspects of Strong Local Symmetry
- Bunge on the Status of Electrodynamics
- Bunge on the Status of Electrodynamics and Physics
- Bunge on the Status of Classical and Quantum Physics
- Fractions of BW Casualties Surviving
- First Step in Self-Promotion of Cancer Due to Hypoxia
- Differentiation and Dedifferentiation Timelines
- Evolution of Cells on Earth
- A Charged Particle q is a Coupled System of m and Ø
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (1)
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (2)
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (3)
- A Charged Particle is a Coupled System
- The Anomalies in Navy Electrolyte Experiments at China Lake
- Chung's Carbon Filament Negative Resistor

- Typical circuit has about 10^{-13} energy collection efficiency
- Classical View of EM
- Curved Spacetime acts as source or sink
- Chronic Disease Puzzling
- Cancer Characteristics
- Solving a Cancer Enigma
- Cancer: Characteristics
- Nonlinear Optics Distortion Correction Theorem
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (1)
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (2)
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (3)
- In Time-Reversed Zone: Nuclear reactions are biased
- In Time-Reversed Zone: Dynamics may be reversed
- Time-Reversed Zone: Significant only after time-density charging
- A New Conservation of Energy Law
- Questions on Carcinogens and EM

Radiation

- AS DEFINED, fields and potentials only exist in and on charged matter
- Serious flaws and errors in classical EM theory
- Electrodynamicists' Reaction to Removal of the Material Ether
- Reaction to Loss of Material Ether (1)
- Reaction to Loss of Material Ether (2)
- Some EM waves in Spacetime
- Air Medium Disturbances Generated When Air is Perturbed by a Plucked Taut String
- Launching a Spacetime Perturbation ("EM Wave") from a Wire Antenna
- Phase Conjugate Wavepairs Produce New Waves
- Scalar Electromagnetics (Energetics) View of EM (1)
- Scalar Electromagnetics (Energetics) View of EM (2)

- Scalar Electromagnetics (Energetics) View of EM (3)
- Extended General Relativity Principle
- Extension of Work-Energy Theorem
- 34 Flaws in Classical EM Theory
- MTW's General Relativity Principle
- Use of General Relativity (GR) in Particle Physics
- The Missing Infolded Electrodynamics
- Infolded Engines: Excluded by Present Physics
- Mass curves and structures spacetime; ST curvatures change and structure mass (1)
- Mass curves and structures spacetime; ST curvatures change and structure mass (2)
- At Infinite Velocity: Each Is Every Other
- Lisitsyn's Report: Brain Code Broken
- Lorentz Closed Surface Integration
- Lorentz's physically insignificant energy flow can be collected and utilized
- Lorentz surface integration of the Poynting vector around a closed surface
- Longitudinal EM Photon Interaction with Charge
- Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass.

- Pumping with Longitudinal EM waves Time-reverses the Mass
- Maxwell's Quaternion Theory
- Maxwellian Systems before and after Regauging
- Maxwell's four equations reduce to: Page 1
- Maxwell's four equations reduce to: Page 2
- More to come

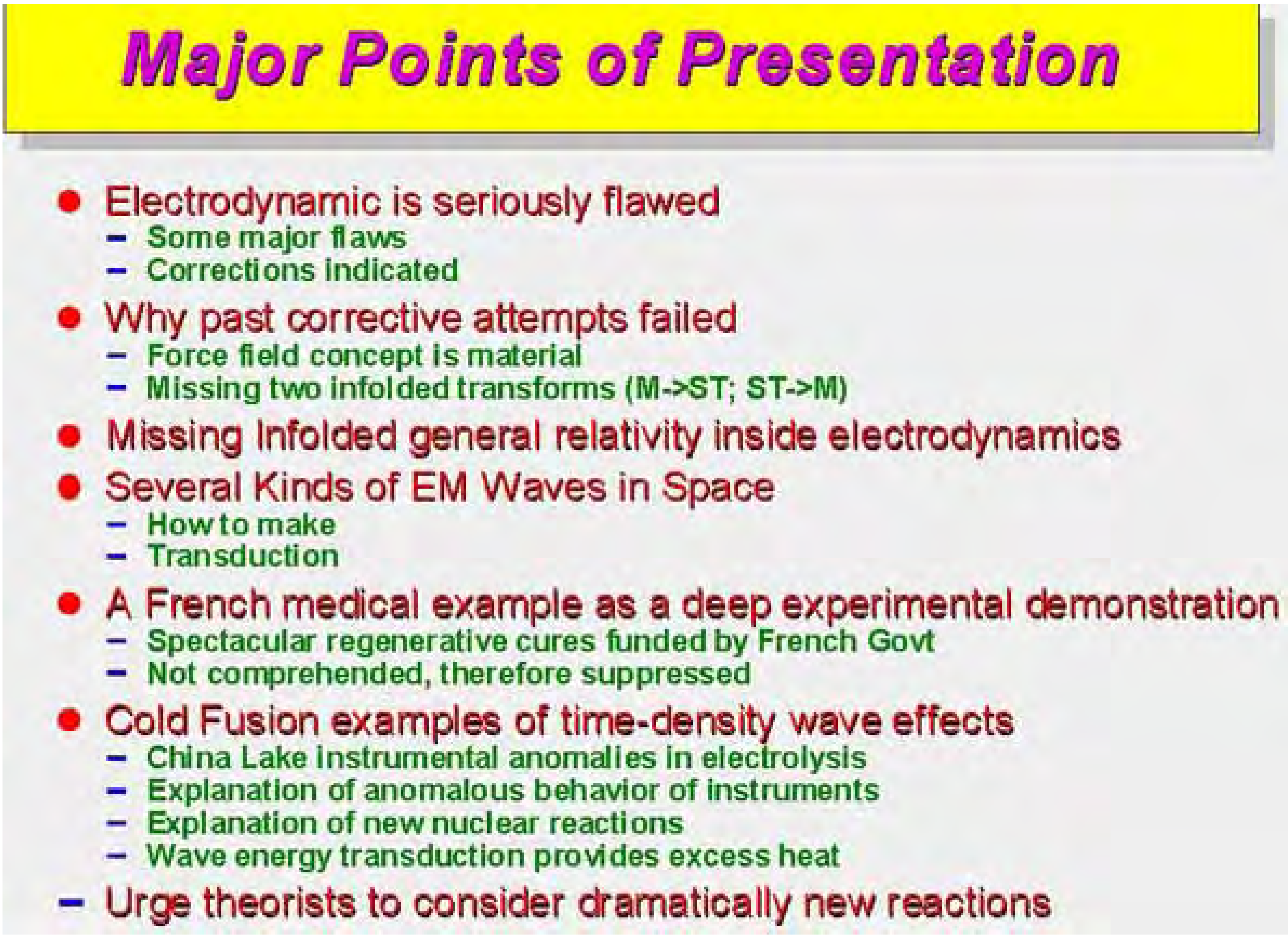

Major Points of Presentation

- Electrodynamic is seriously flawed
  - Some major flaws
  - Corrections indicated
- Why past corrective attempts failed
  - Force field concept is material
  - Missing two infolded transforms (M->ST; ST->M)
- Missing infolded general relativity inside electrodynamics
- Several Kinds of EM Waves in Space
  - How to make
  - Transduction
- A French medical example as a deep experimental demonstration
  - Spectacular regenerative cures funded by French Govt
  - Not comprehended, therefore suppressed
- Cold Fusion examples of time-density wave effects
  - China Lake instrumental anomalies in electrolysis
  - Explanation of anomalous behavior of instruments
  - Explanation of new nuclear reactions
  - Wave energy transduction provides excess heat

– Urge theorists to consider dramatically new reactions

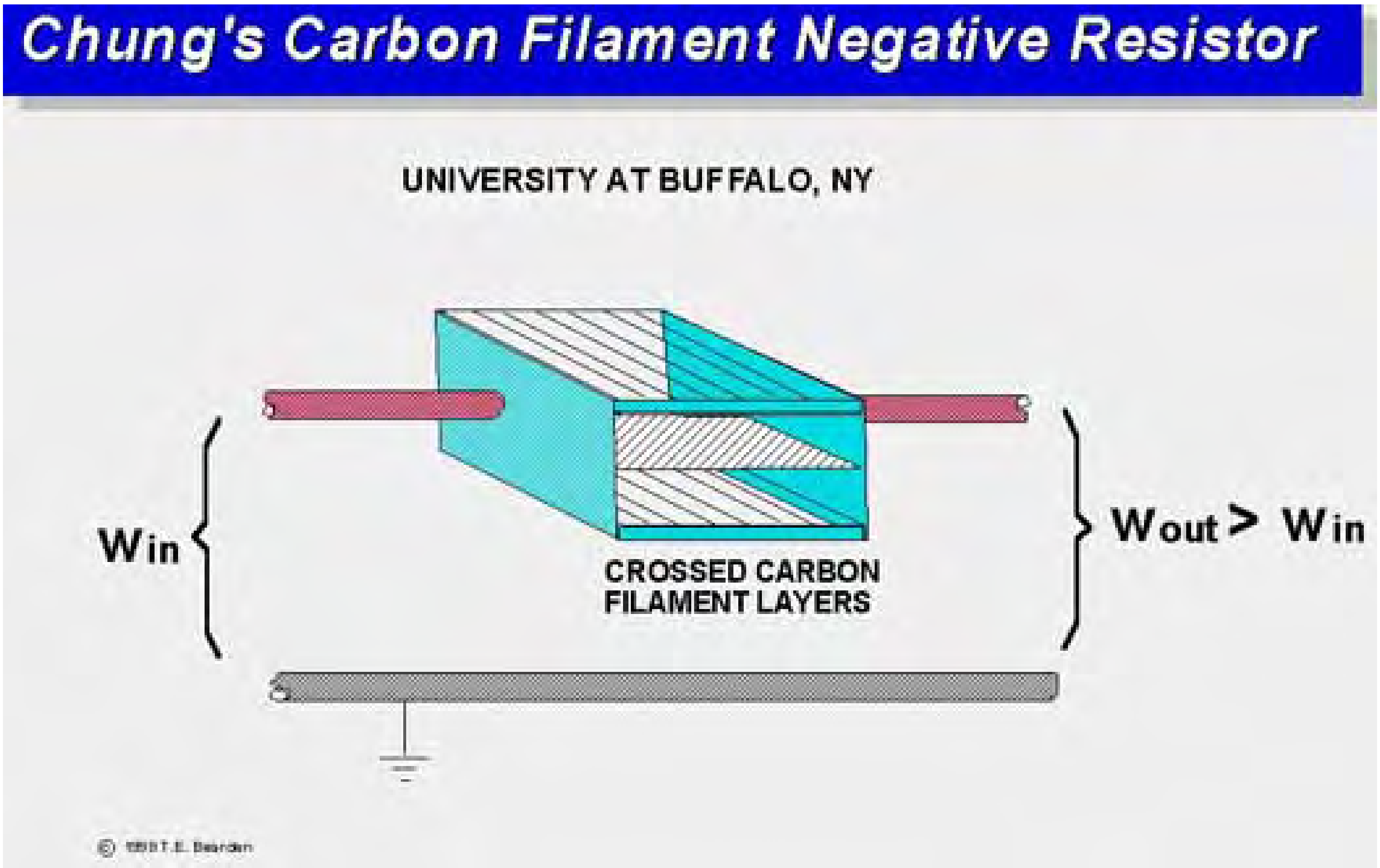

Chung's Carbon Filament Negative Resistor

UNIVERSITY AT BUFFALO, NY

Win
CROSSED CARBON
FILAMENT LAYERS
Wout > Win

© [illegible] T.E. Bearden

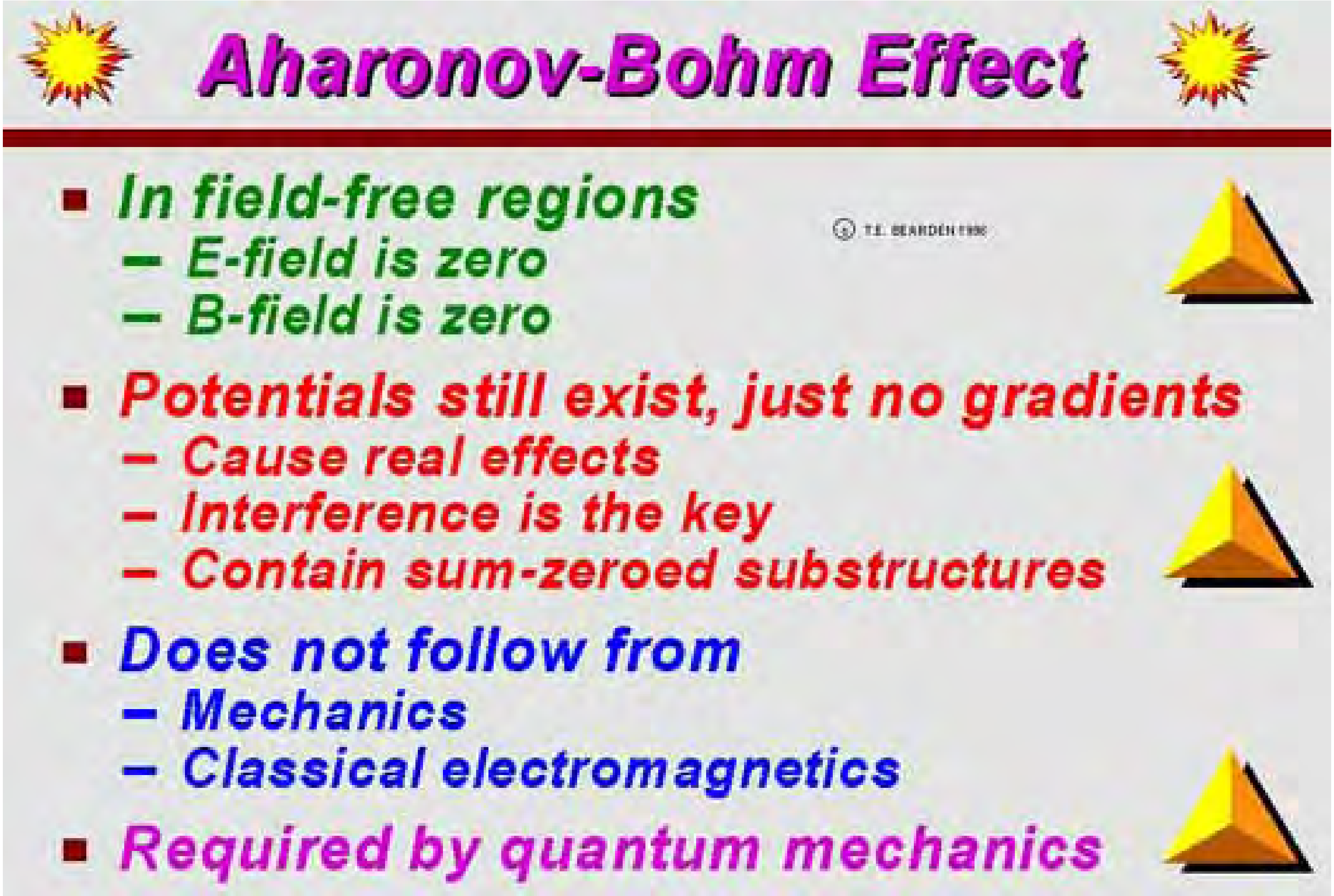

Aharonov-Bohm Effect

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- In field-free regions
  - E-field is zero
  - B-field is zero
- Potentials still exist, just no gradients
  - Cause real effects
  - Interference is the key
  - Contain sum-zeroed substructures
- Does not follow from
  - Mechanics
  - Classical electromagnetics
- Required by quantum mechanics

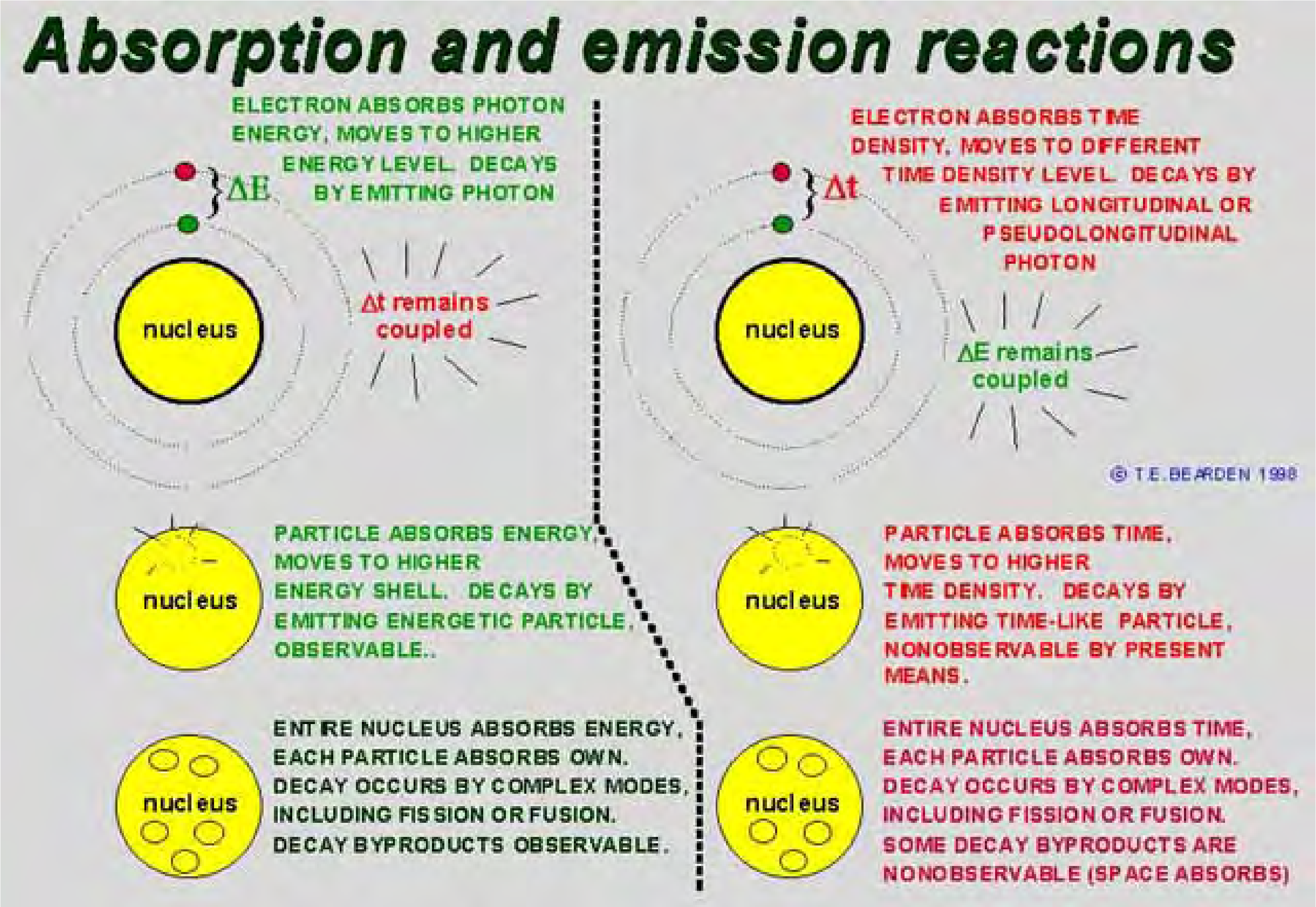

Absorption and emission reactions

ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON

ELECTRON ABSORBS TIME DENSITY, MOVES TO DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTON

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PARTICLE ABSORBS ENERGY, MOVES TO HIGHER ENERGY SHELL. DECAYS BY EMITTING ENERGETIC PARTICLE. OBSERVABLE..

PARTICLE ABSORBS TIME, MOVES TO HIGHER TIME DENSITY. DECAYS BY EMITTING TIME-LIKE PARTICLE, NONOBSERVABLE BY PRESENT MEANS.

ENTIRE NUCLEUS ABSORBS ENERGY, EACH PARTICLE ABSORBS OWN. DECAY OCCURS BY COMPLEX MODES, INCLUDING FISSION OR FUSION. DECAY BYPRODUCTS OBSERVABLE.

ENTIRE NUCLEUS ABSORBS TIME, EACH PARTICLE ABSORBS OWN. DECAY OCCURS BY COMPLEX MODES, INCLUDING FISSION OR FUSION. SOME DECAY BYPRODUCTS ARE NONOBSERVABLE (SPACE ABSORBS)

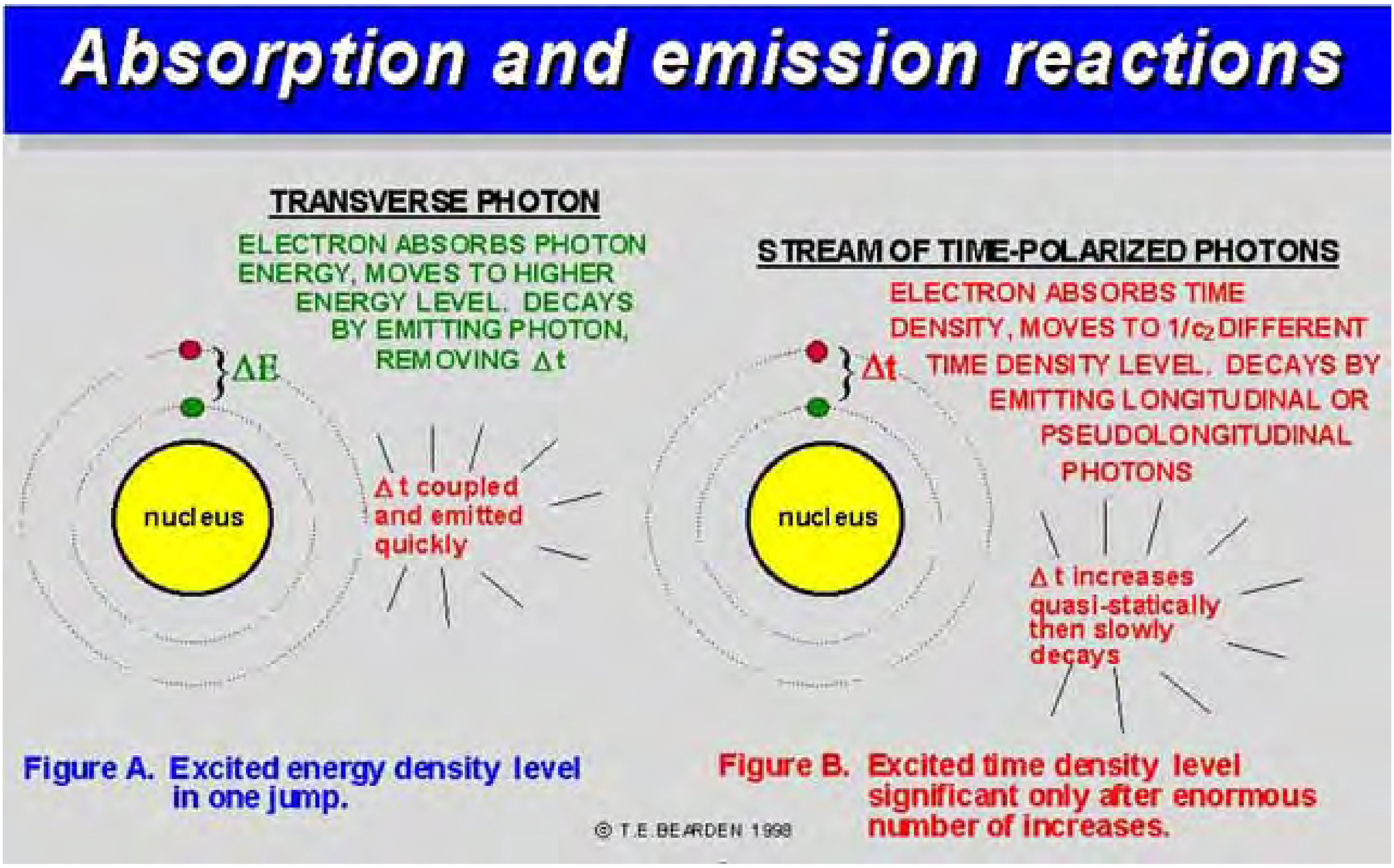

Absorption and emission reactions

TRANSVERSE PHOTON

ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON, REMOVING Δt

ΔE
nucleus
Δt coupled and emitted quickly

STREAM OF TIME-POLARIZED PHOTONS

ELECTRON ABSORBS TIME DENSITY, MOVES TO $1/c_2$ DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTONS

Δt
nucleus
Δt increases quasi-statically then slowly decays

Figure A. Excited energy density level in one jump.

Figure B. Excited time density level significant only after enormous number of increases.

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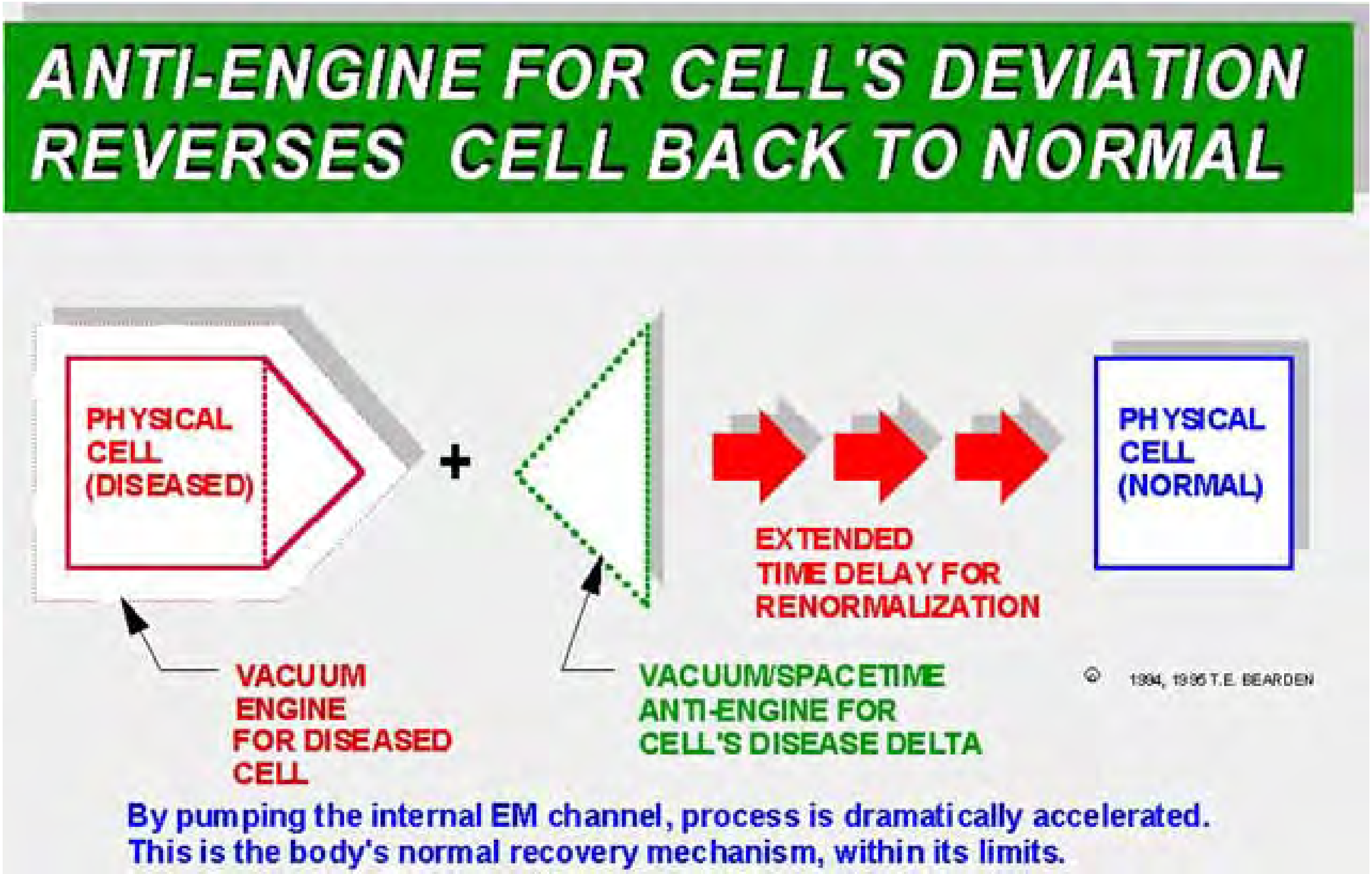

ANTI-ENGINE FOR CELL'S DEVIATION REVERSES CELL BACK TO NORMAL

PHYSICAL
CELL
(DISEASED)

+

EXTENDED
TIME DELAY FOR
RENORMALIZATION

PHYSICAL
CELL
(NORMAL)

VACUUM
ENGINE
FOR DISEASED
CELL

VACUUM/SPACETIME
ANTI-ENGINE FOR
CELL'S DISEASE DELTA

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By pumping the internal EM channel, process is dramatically accelerated.
This is the body's normal recovery mechanism, within its limits.

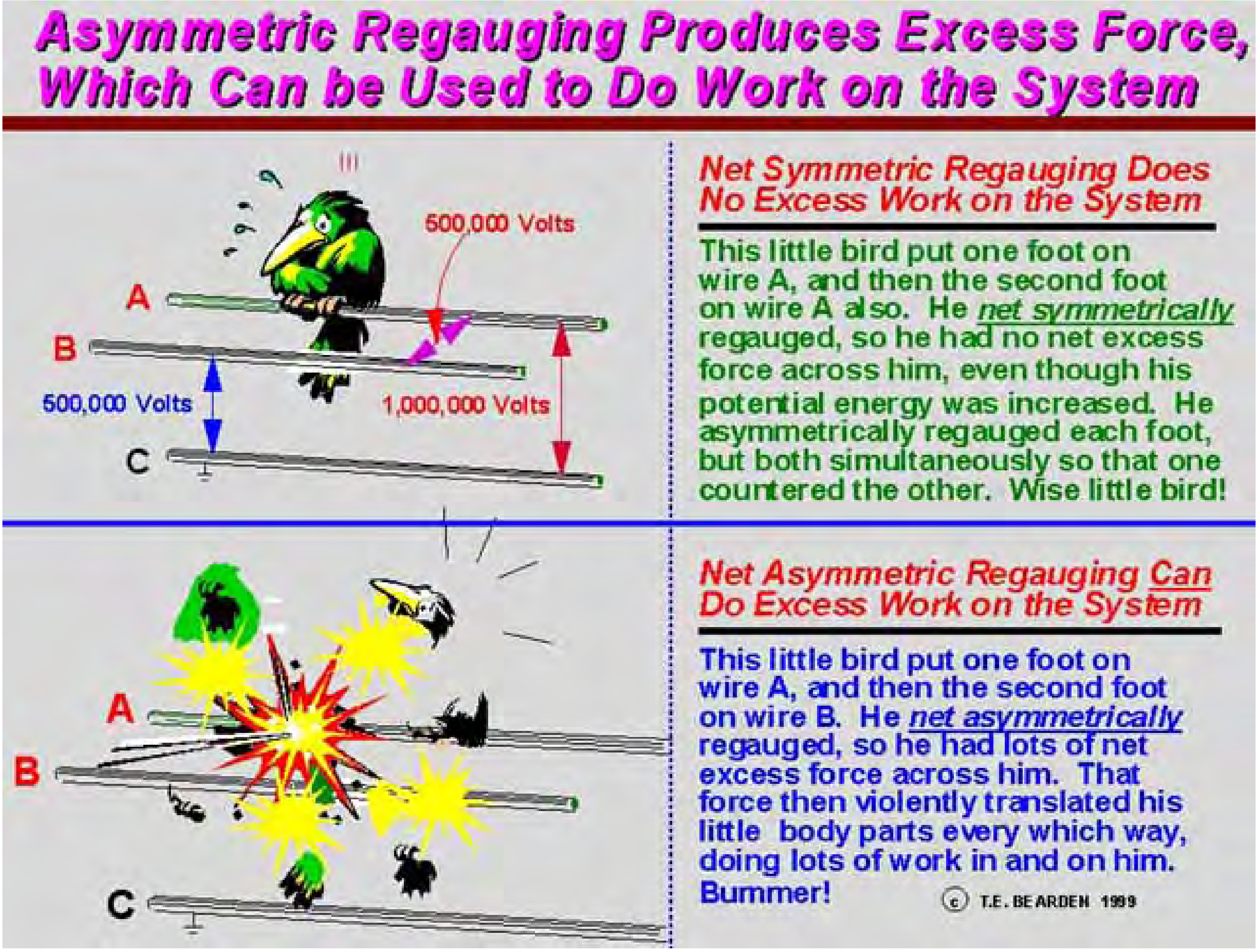

Asymmetric Regauging Produces Excess Force, Which Can be Used to Do Work on the System

Net Symmetric Regauging Does No Excess Work on the System

This little bird put one foot on wire A, and then the second foot on wire A also. He *net symmetrically* regauged, so he had no net excess force across him, even though his potential energy was increased. He asymmetrically regauged each foot, but both simultaneously so that one countered the other. Wise little bird!

Net Asymmetric Regauging Can Do Excess Work on the System

This little bird put one foot on wire A, and then the second foot on wire B. He *net asymmetrically* regauged, so he had lots of net excess force across him. That force then violently translated his little body parts every which way, doing lots of work in and on him. Bummer!

ⓒ T.E. BEARDEN 1999

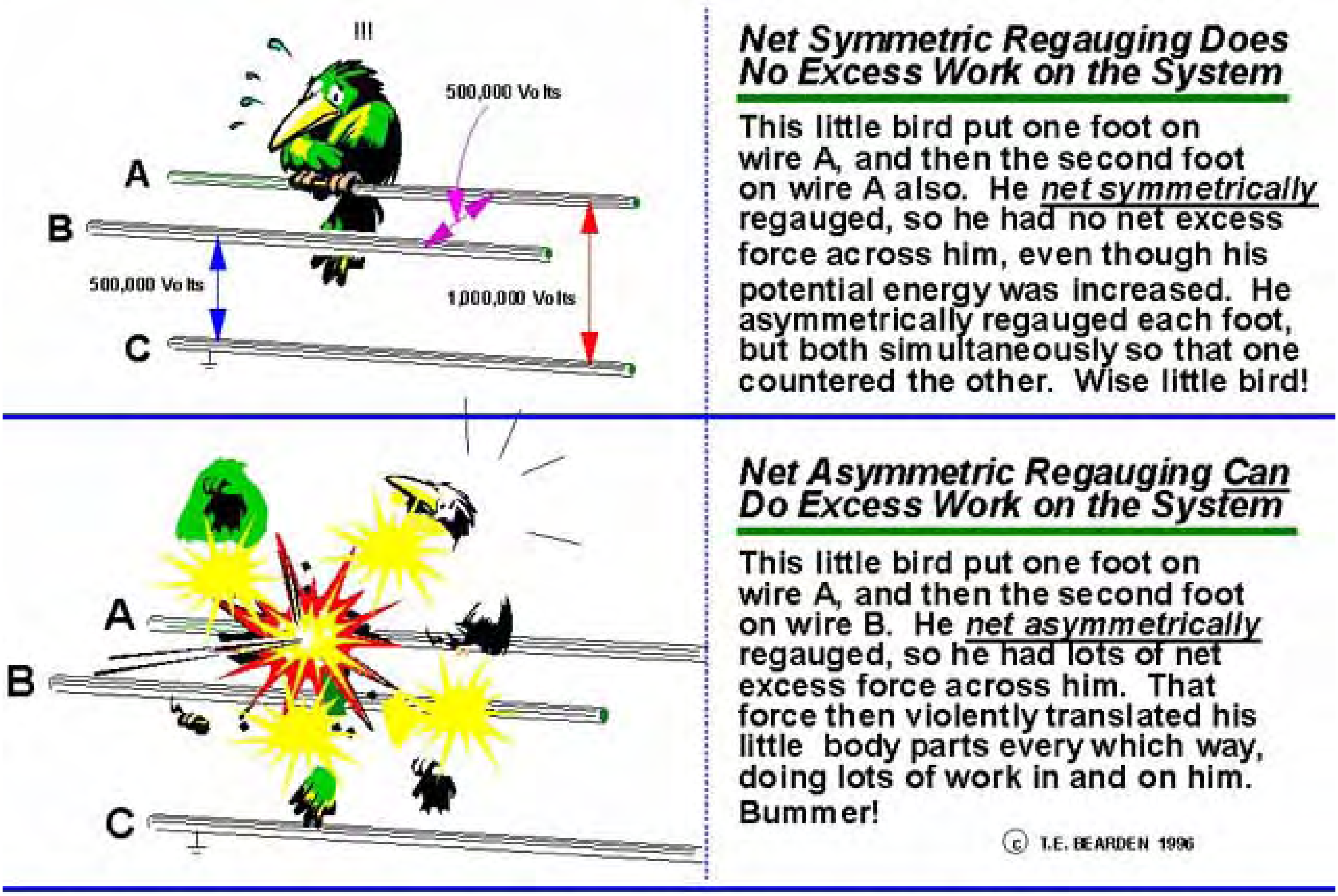

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Net Asymmetric Regauging Can Do Excess Work on the System

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ⓒ T.E. BEARDEN 1996

Figure 32. Asymmetric regauging produces excess force, which can be used to do work on the regauging system.

Selected clipart © by Lotus SmartPics™

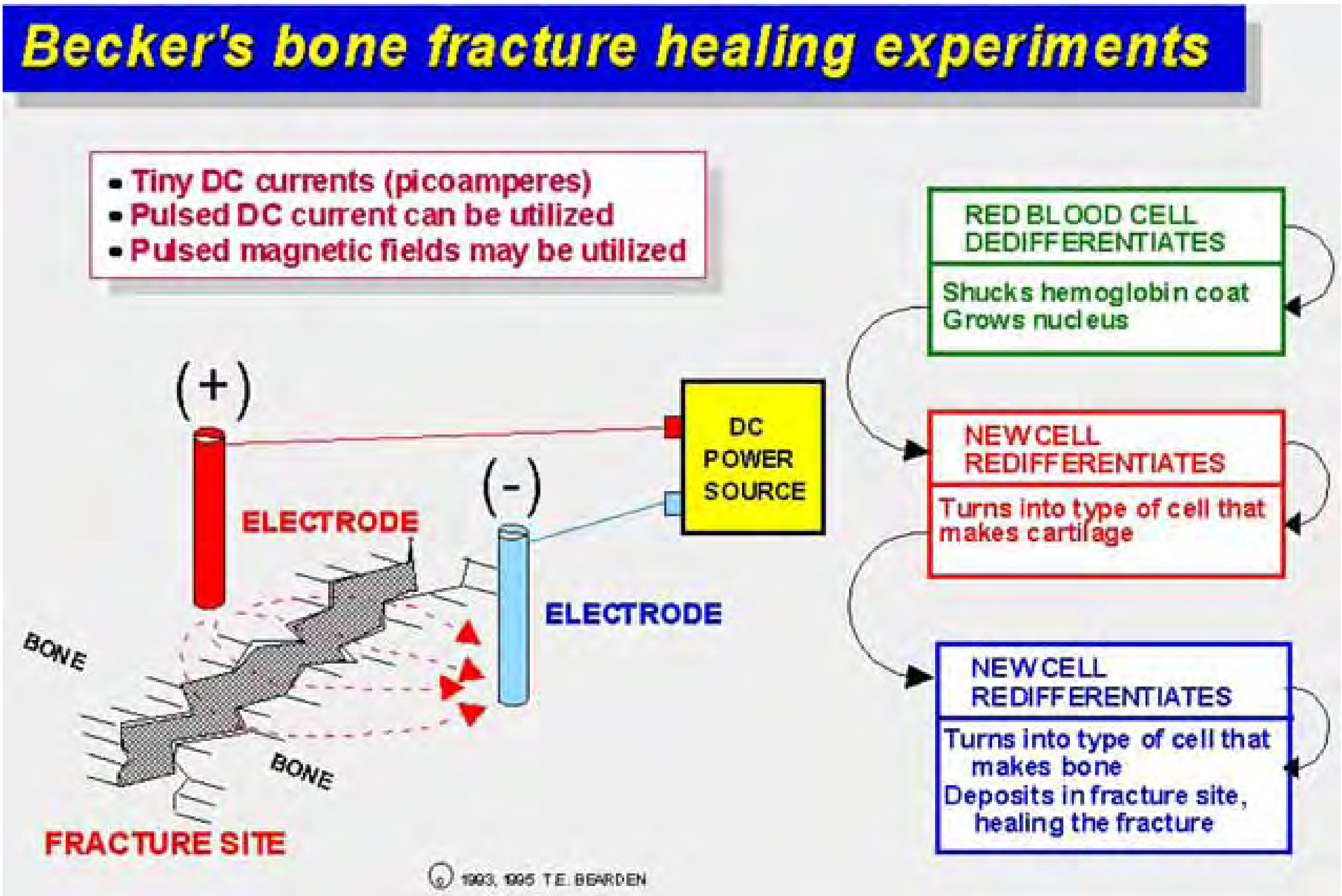

Becker's bone fracture healing experiments

- Tiny DC currents (picoamperes)
- Pulsed DC current can be utilized
- Pulsed magnetic fields may be utilized

(+)
ELECTRODE
(-)
ELECTRODE
DC POWER SOURCE
BONE
BONE
FRACTURE SITE

RED BLOOD CELL DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

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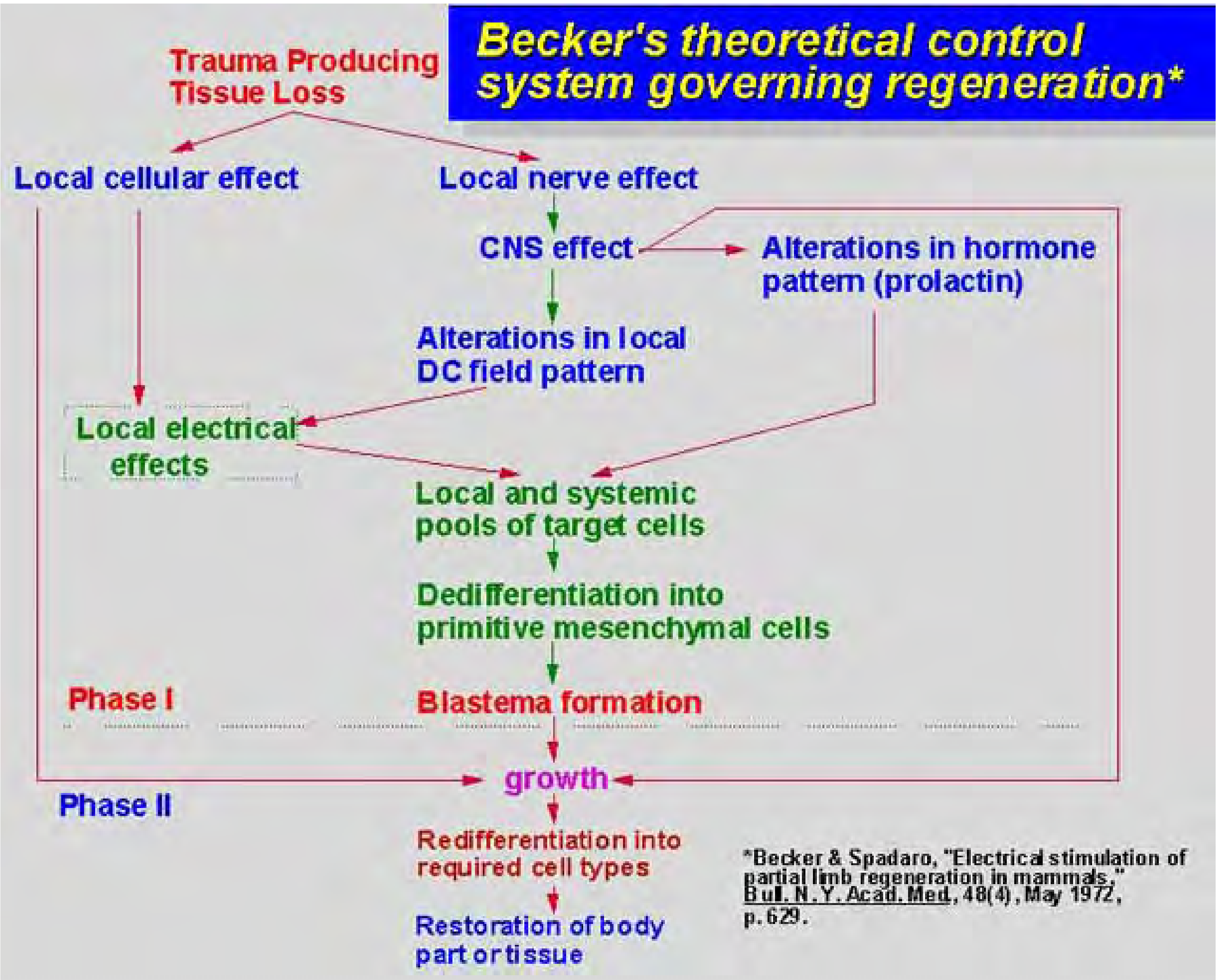

Becker's theoretical control system governing regeneration*

Trauma Producing Tissue Loss

Local cellular effect

Local nerve effect

CNS effect

Alterations in hormone pattern (prolactin)

Alterations in local DC field pattern

Local electrical effects

Local and systemic pools of target cells

Dedifferentiation into primitive mesenchymal cells

Phase I

Blastema formation

growth

Phase II

Redifferentiation into required cell types

Restoration of body part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bul. N.Y. Acad. Med., 48(4), May 1972, p. 629.

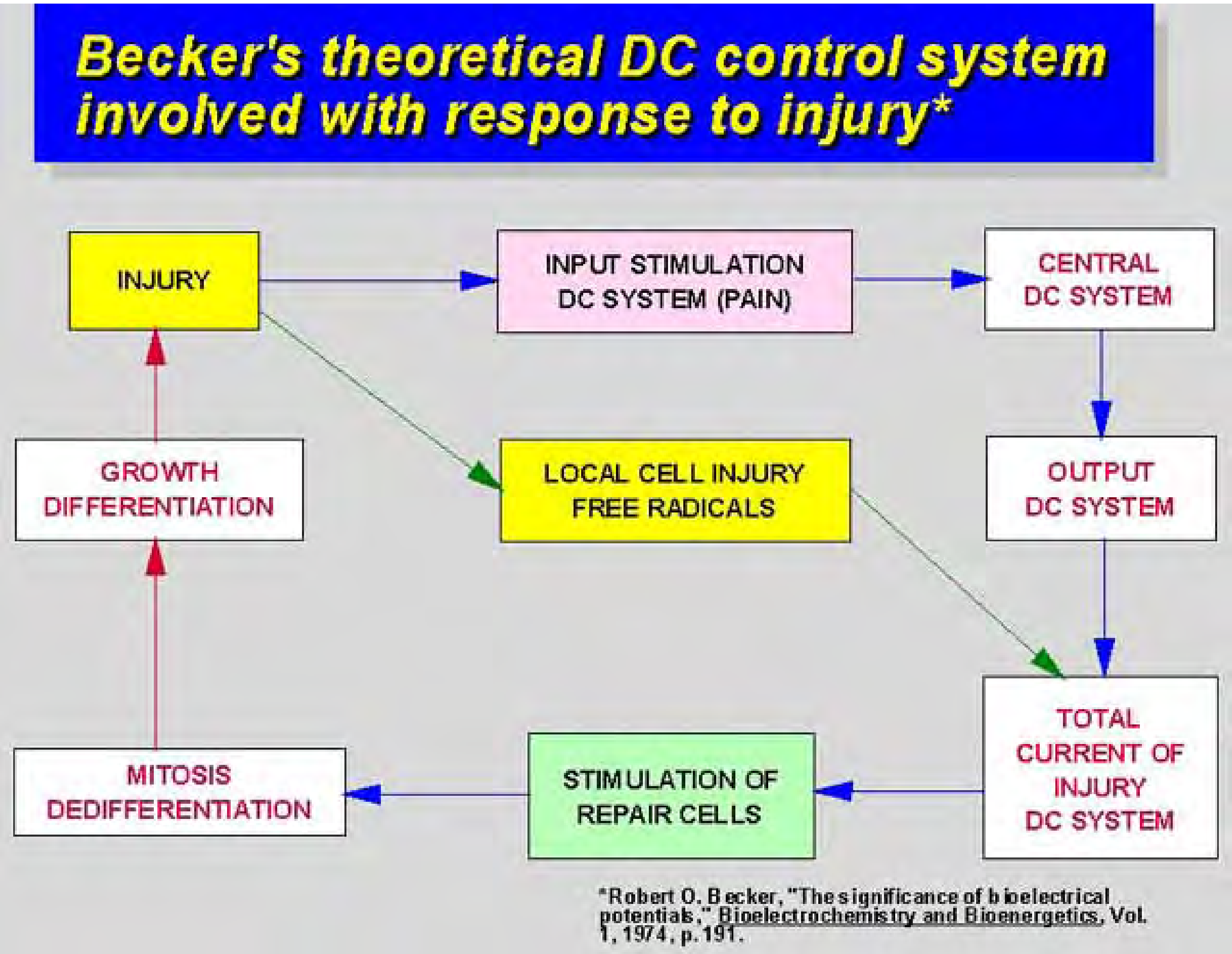

Becker's theoretical DC control system involved with response to injury*

INJURY

INPUT STIMULATION DC SYSTEM (PAIN)

CENTRAL DC SYSTEM

GROWTH DIFFERENTIATION

LOCAL CELL INJURY FREE RADICALS

OUTPUT DC SYSTEM

TOTAL CURRENT OF INJURY DC SYSTEM

STIMULATION OF REPAIR CELLS

MITOSIS DEDIFFERENTIATION

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.

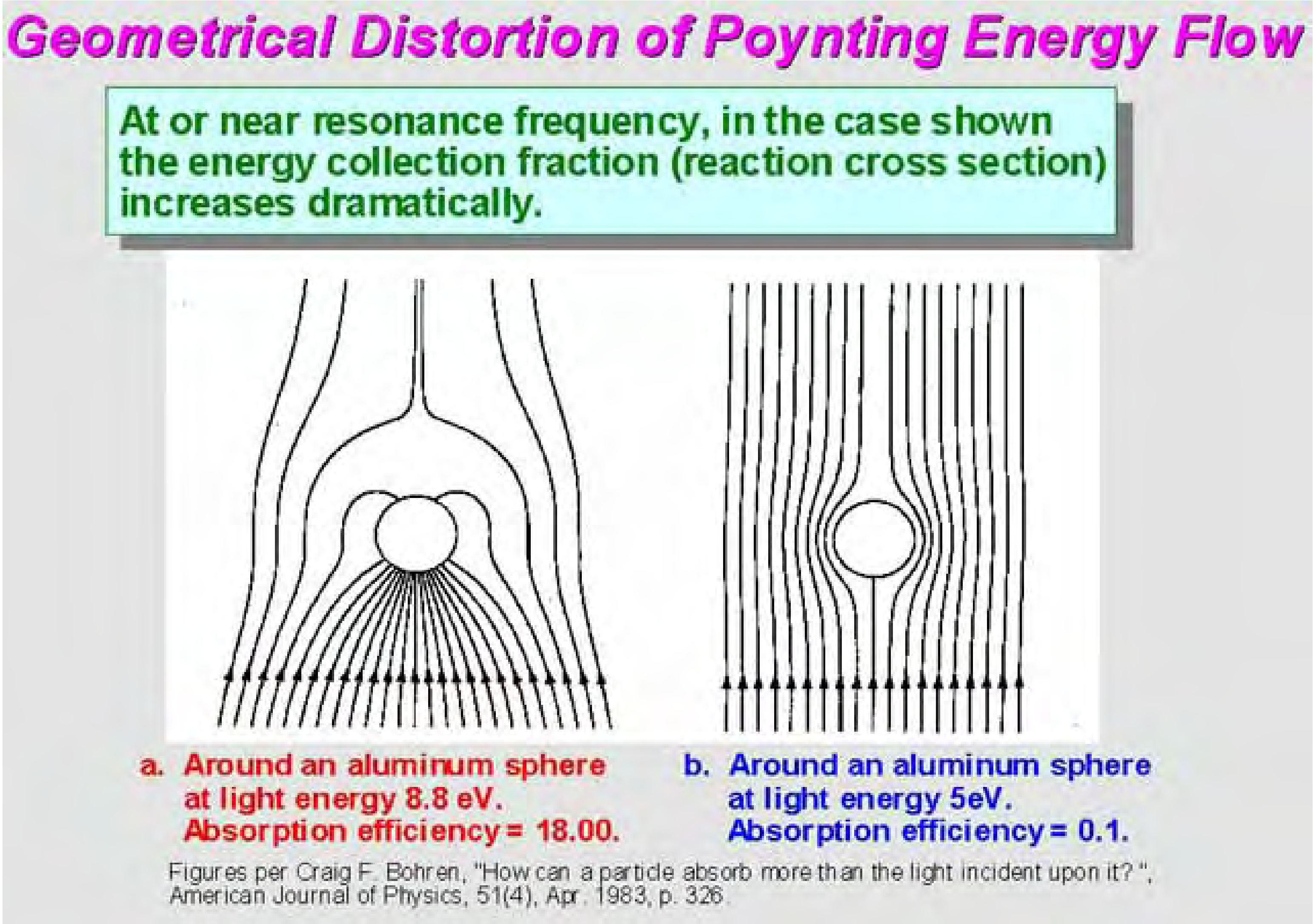

Geometrical Distortion of Poynting Energy Flow

At or near resonance frequency, in the case shown the energy collection fraction (reaction cross section) increases dramatically.

a. Around an aluminum sphere at light energy 8.8 eV. Absorption efficiency = 18.00.

b. Around an aluminum sphere at light energy 5eV. Absorption efficiency = 0.1.

Figures per Craig F. Bohren, "How can a particle absorb more than the light incident upon it? ", American Journal of Physics, 51(4), Apr. 1983, p. 326.

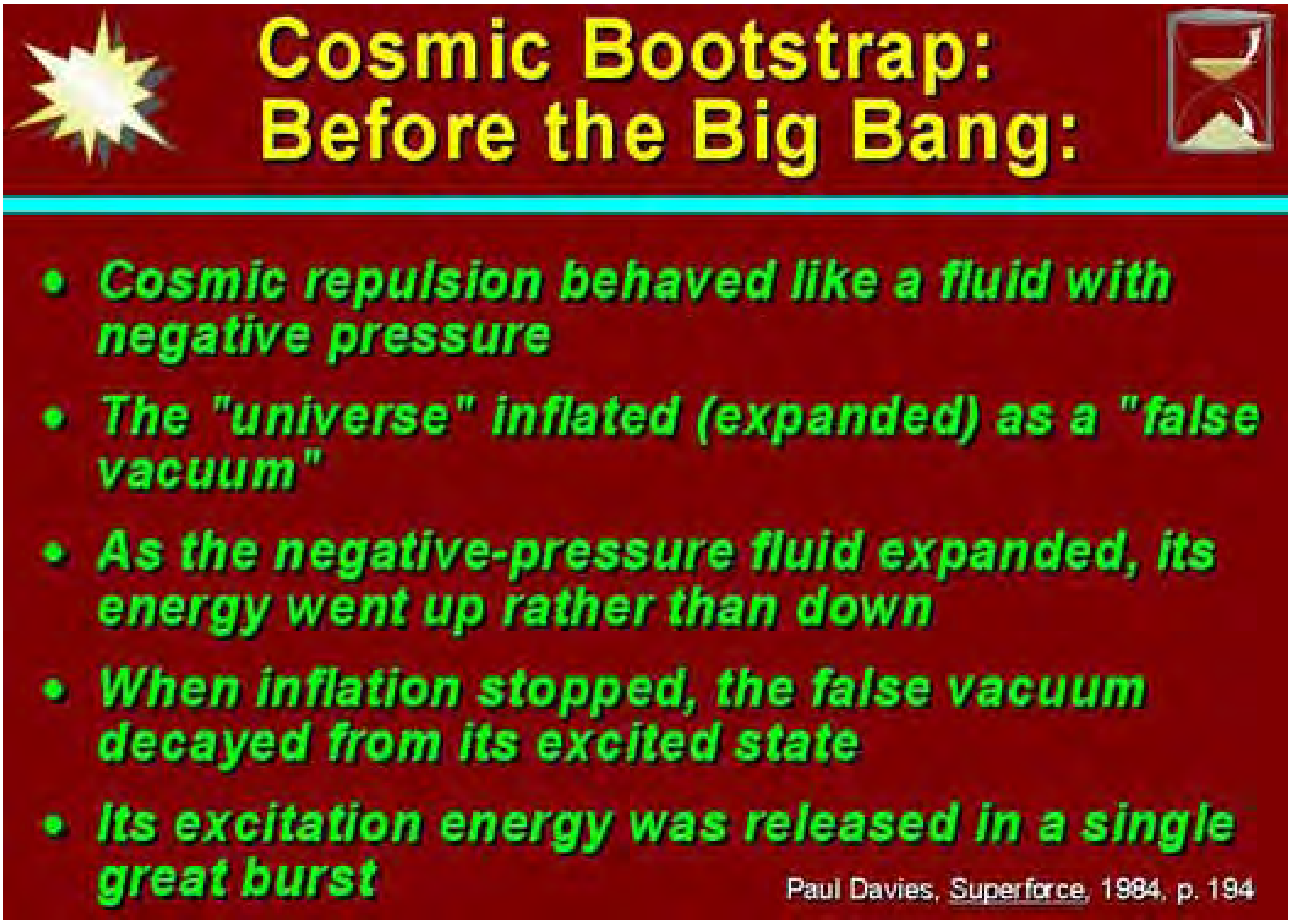

Cosmic Bootstrap: Before the Big Bang:

- *Cosmic repulsion behaved like a fluid with negative pressure*
- *The "universe" inflated (expanded) as a "false vacuum"*
- *As the negative-pressure fluid expanded, its energy went up rather than down*
- *When inflation stopped, the false vacuum decayed from its excited state*
- *Its excitation energy was released in a single great burst*

Paul Davies, Superforce, 1984, p. 194

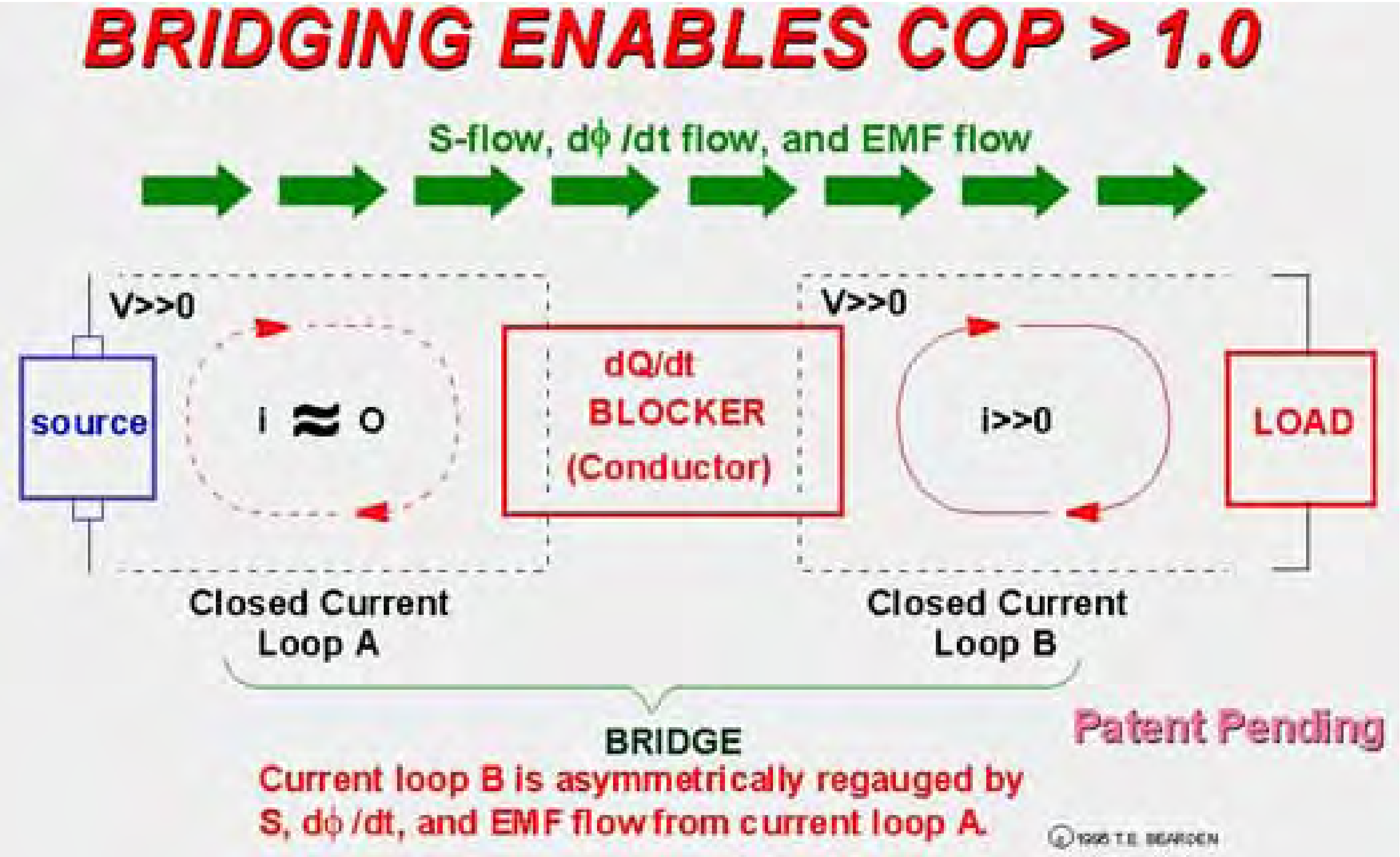

BRIDGING ENABLES COP > 1.0

S-flow, dϕ /dt flow, and EMF flow
V>>0
source
i ≈ 0
dQ/dt
BLOCKER
(Conductor)
V>>0
i>>0
LOAD
Closed Current
Loop A
Closed Current
Loop B
BRIDGE

Current loop B is asymmetrically regauged by S, dϕ /dt, and EMF flow from current loop A.

Patent Pending

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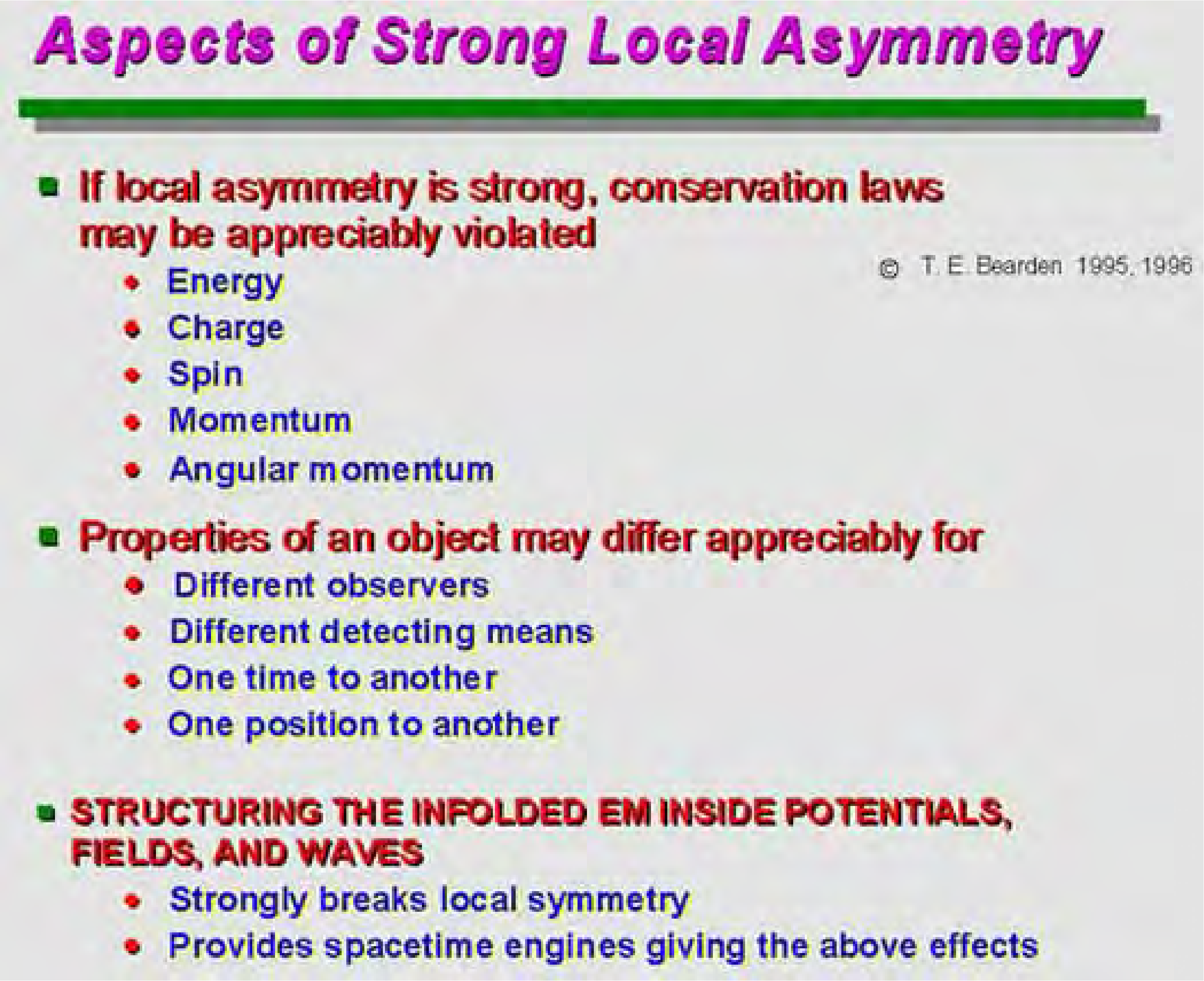

Aspects of Strong Local Asymmetry

- If local asymmetry is strong, conservation laws may be appreciably violated
  - Energy
  - Charge
  - Spin
  - Momentum
  - Angular momentum

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- Properties of an object may differ appreciably for
  - Different observers
  - Different detecting means
  - One time to another
  - One position to another
- STRUCTURING THE INFOLDED EM INSIDE POTENTIALS, FIELDS, AND WAVES
  - Strongly breaks local symmetry
  - Provides spacetime engines giving the above effects

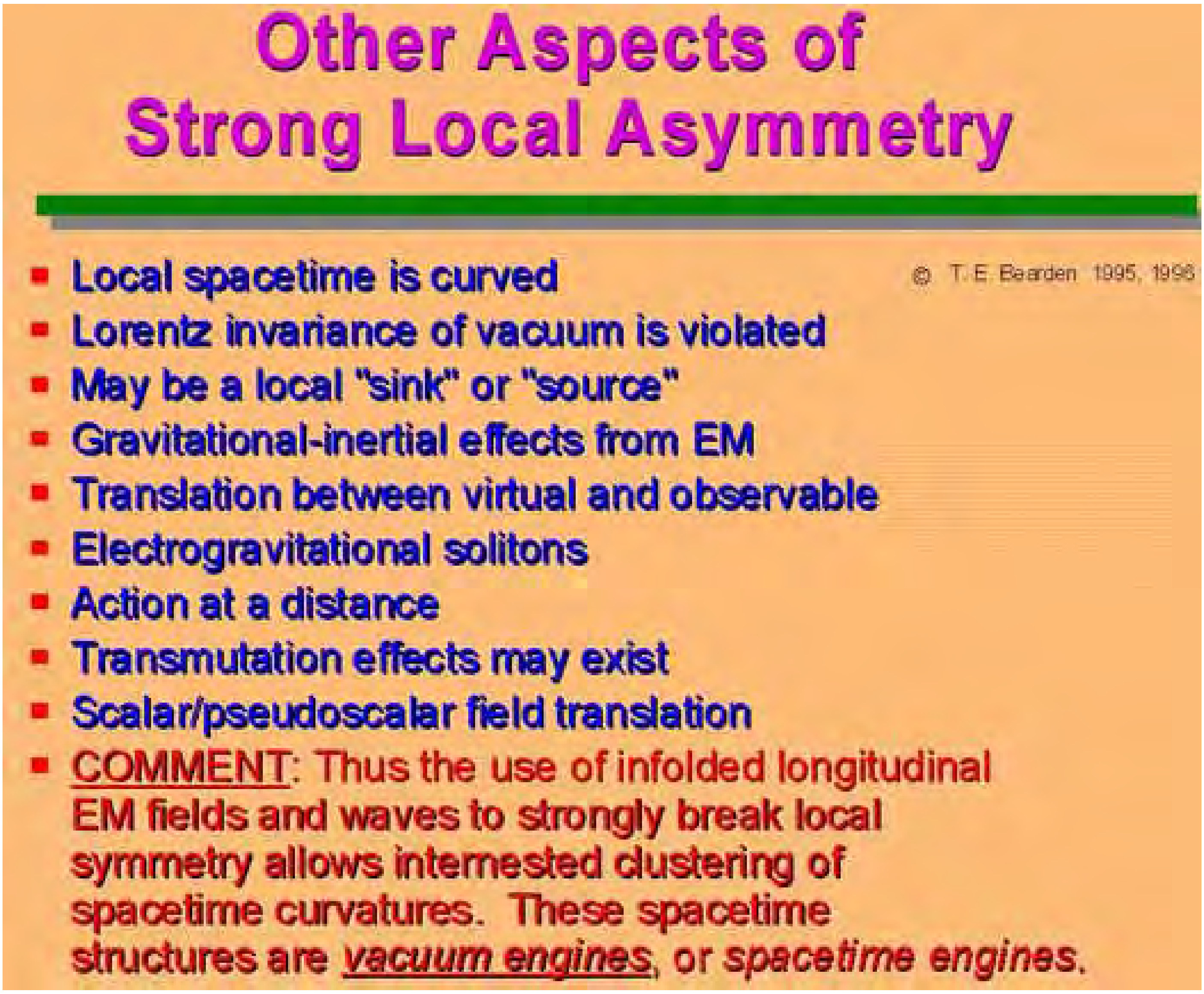

Other Aspects of Strong Local Asymmetry

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- Local spacetime is curved
- Lorentz invariance of vacuum is violated
- May be a local "sink" or "source"
- Gravitational-inertial effects from EM
- Translation between virtual and observable
- Electrogravitational solitons
- Action at a distance
- Transmutation effects may exist
- Scalar/pseudoscalar field translation
- COMMENT: Thus the use of infolded longitudinal EM fields and waves to strongly break local symmetry allows internested clustering of spacetime curvatures. These spacetime structures are *vacuum engines*, or *spacetime engines*.

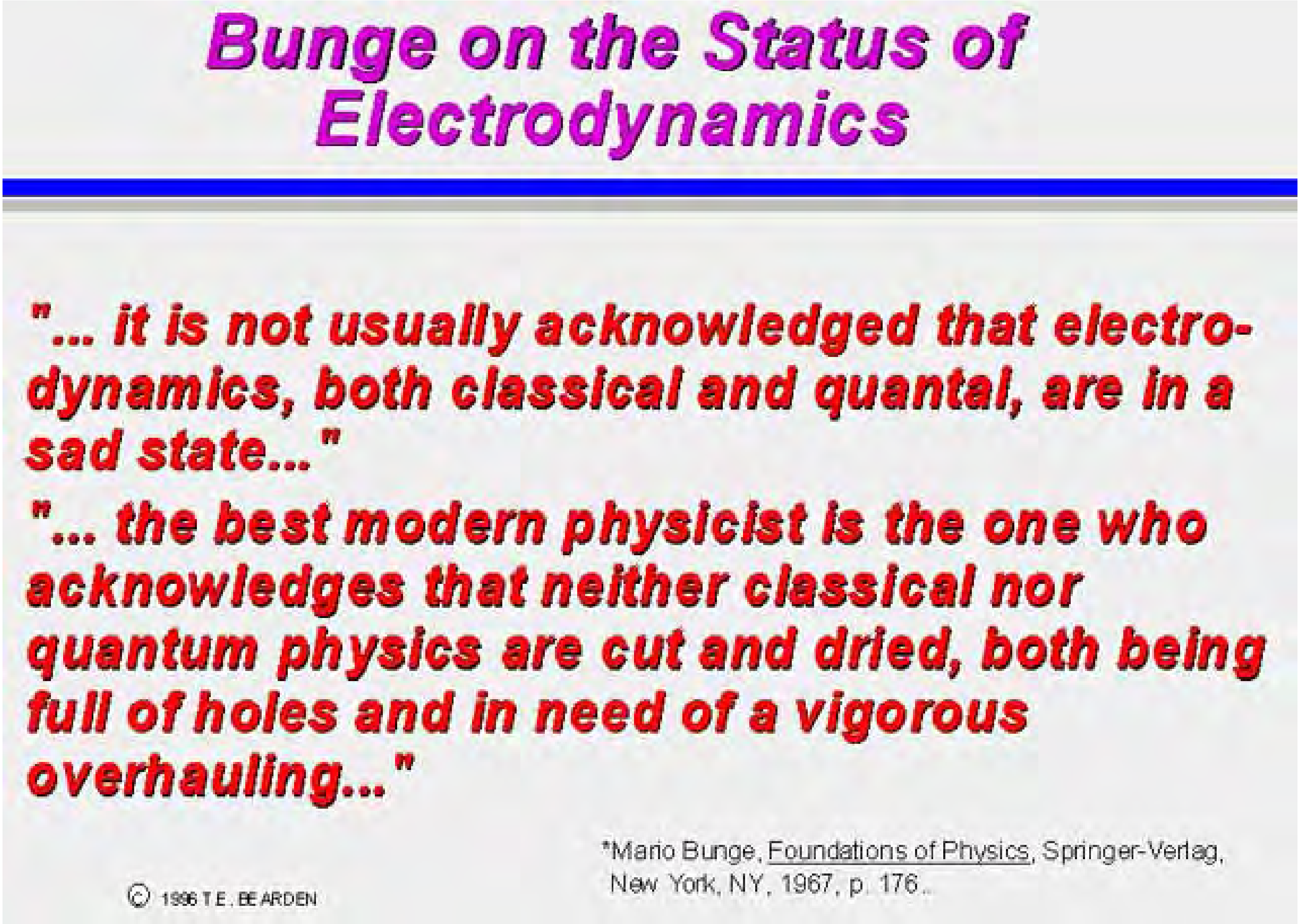

Bunge on the Status of Electrodynamics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state..."

"... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling..."

*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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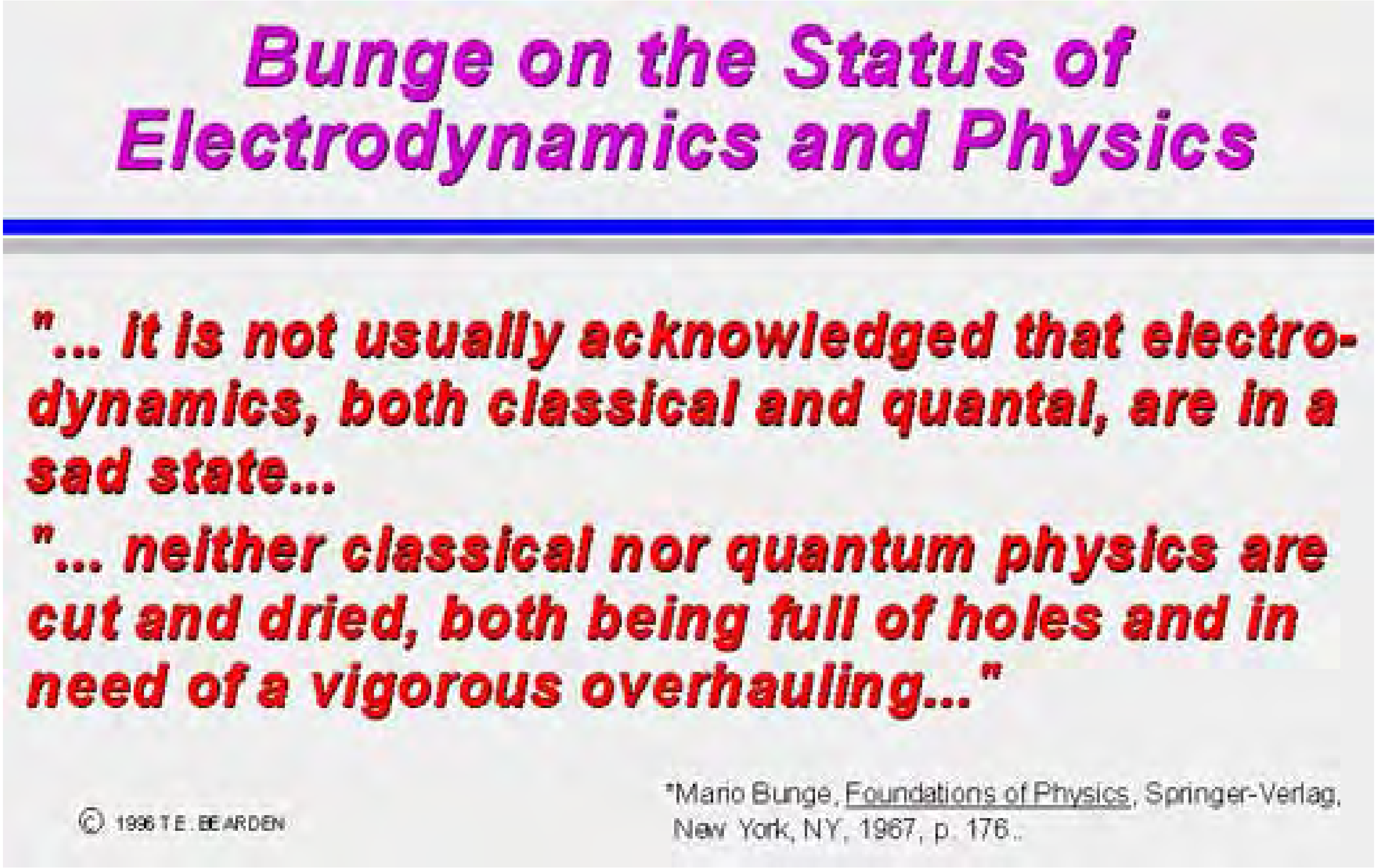

Bunge on the Status of Electrodynamics and Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state...

"... neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling..."

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*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

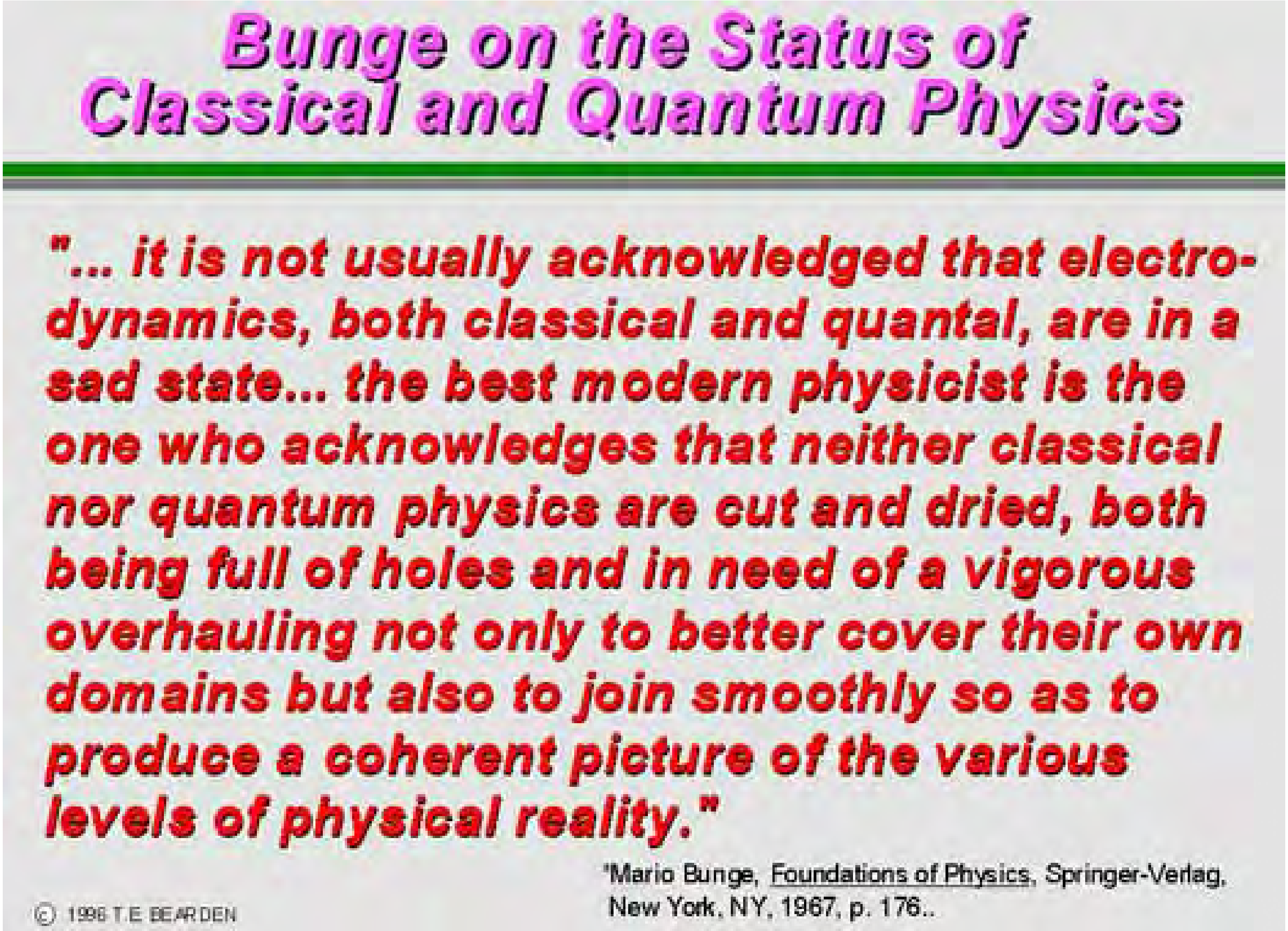

Bunge on the Status of Classical and Quantum Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling not only to better cover their own domains but also to join smoothly so as to produce a coherent picture of the various levels of physical reality."

'Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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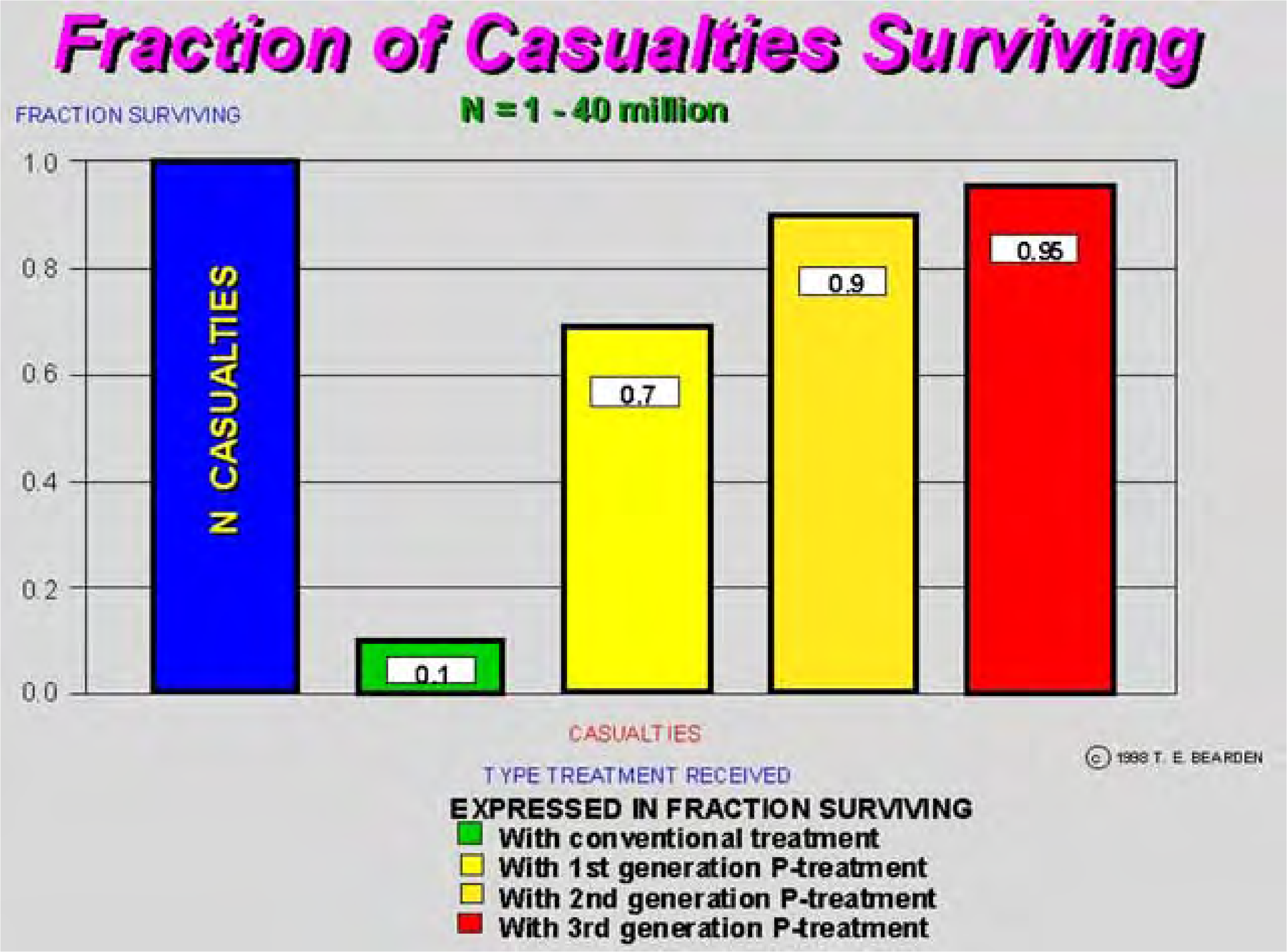
Fraction of Casualties Surviving
FRACTION SURVIVING
N = 1 - 40 million
1.0
0.8
0.6
0.4
0.2
0.0
N CASUALTIES
0.1
0.7
0.9
0.95
CASUALTIES
TYPE TREATMENT RECEIVED
© 1998 T. E. BEARDEN
EXPRESSED IN FRACTION SURVIVING
🟩 With conventional treatment
🟨 With 1st generation P-treatment
🟨 With 2nd generation P-treatment
🟥 With 3rd generation P-treatment

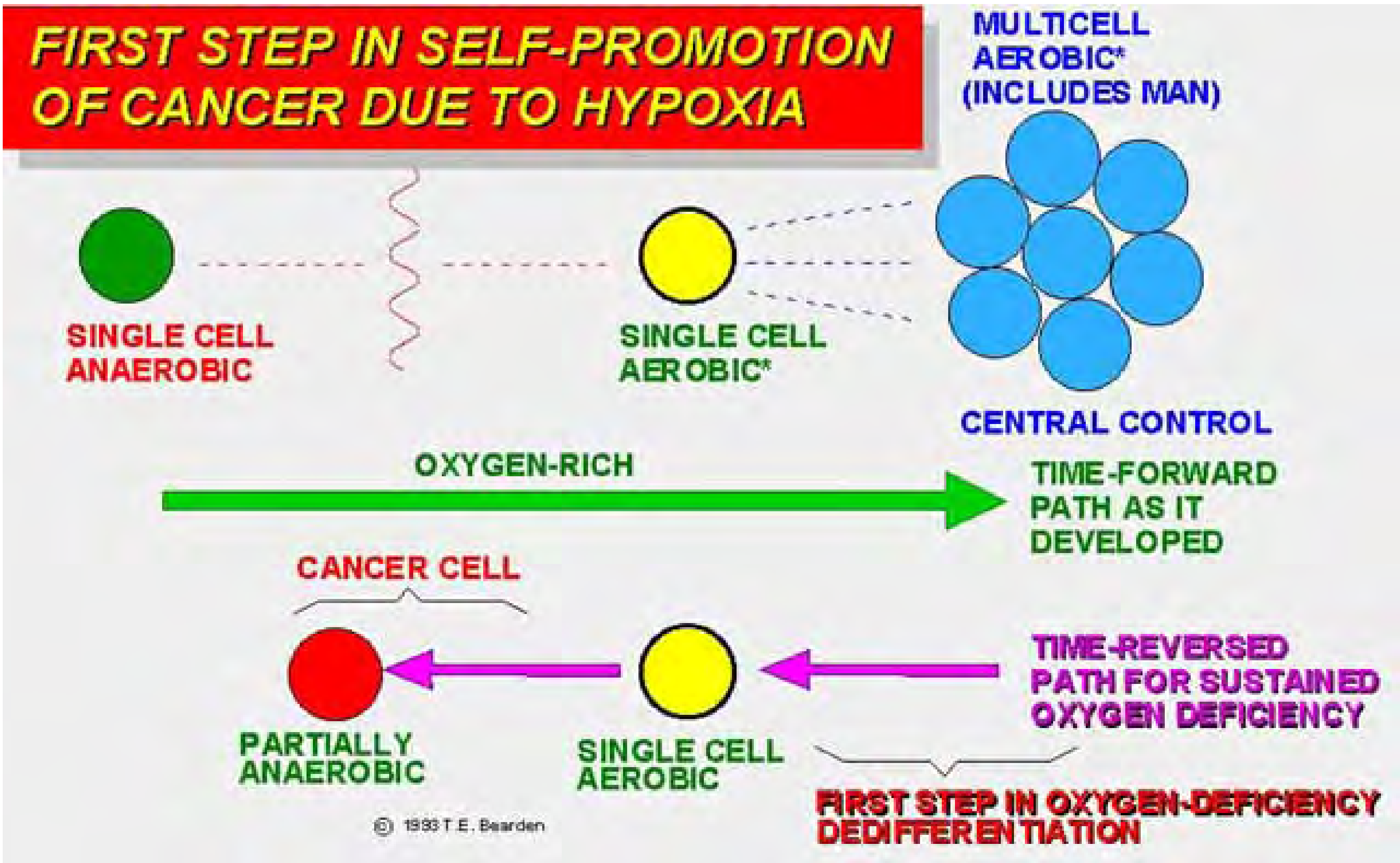

FIRST STEP IN SELF-PROMOTION OF CANCER DUE TO HYPOXIA

MULTICELL
AEROBIC*
(INCLUDES MAN)

SINGLE CELL
ANAEROBIC

SINGLE CELL
AEROBIC*

CENTRAL CONTROL

OXYGEN-RICH

TIME-FORWARD
PATH AS IT
DEVELOPED

CANCER CELL

TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY

PARTIALLY
ANAEROBIC

SINGLE CELL
AEROBIC

FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION

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Differentiation and Dedifferentiation Timelines

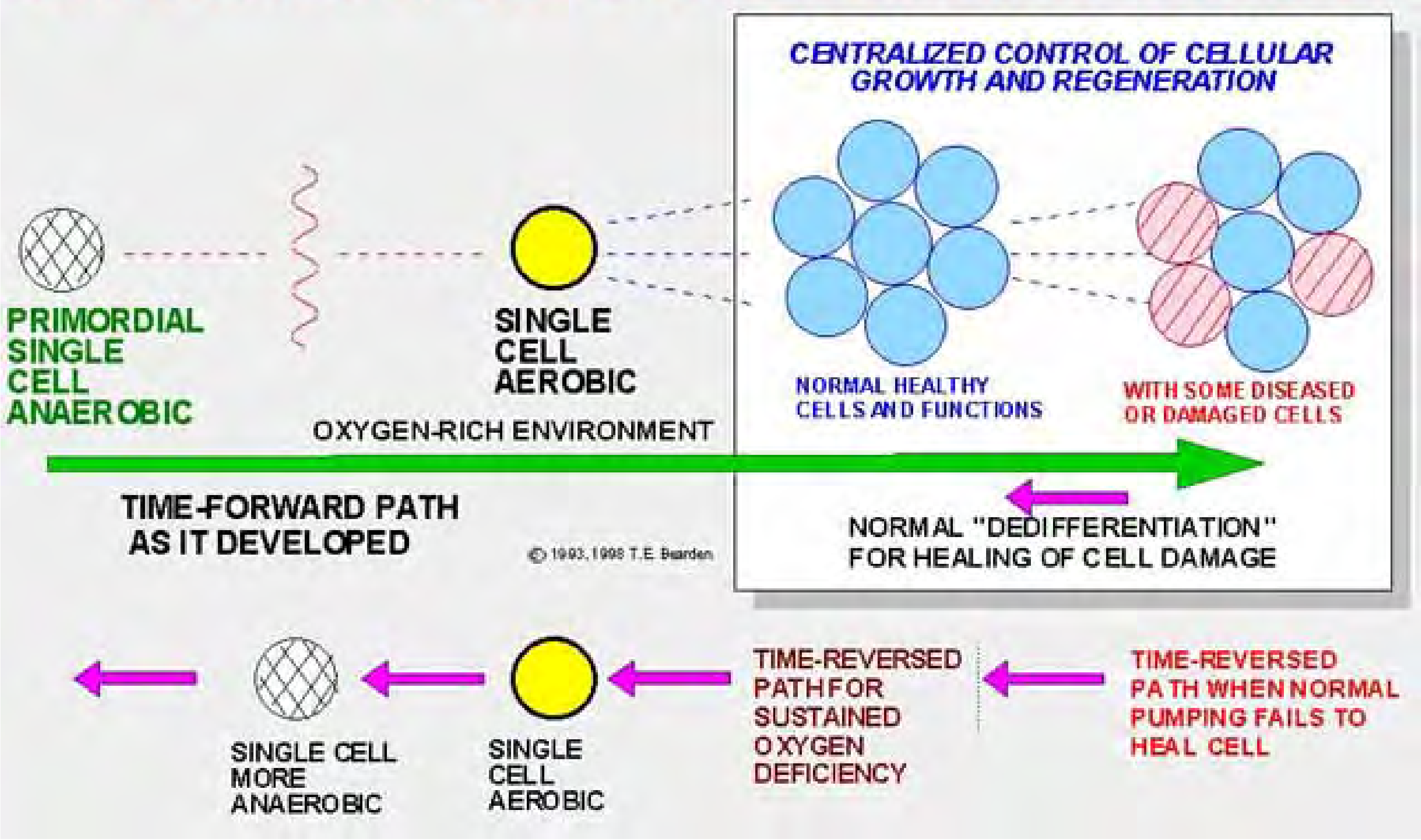
CENTRALIZED CONTROL OF CELLULAR GROWTH AND REGENERATION
PRIMORDIAL SINGLE CELL ANAEROBIC
SINGLE CELL AEROBIC
OXYGEN-RICH ENVIRONMENT
NORMAL HEALTHY CELLS AND FUNCTIONS
WITH SOME DISEASED OR DAMAGED CELLS
TIME-FORWARD PATH AS IT DEVELOPED
© 1993, 1998 T.E. Bearden
NORMAL "DEDIFFERENTIATION" FOR HEALING OF CELL DAMAGE
SINGLE CELL MORE ANAEROBIC
SINGLE CELL AEROBIC
TIME-REVERSED PATH FOR SUSTAINED OXYGEN DEFICIENCY
TIME-REVERSED PATH WHEN NORMAL PUMPING FAILS TO HEAL CELL

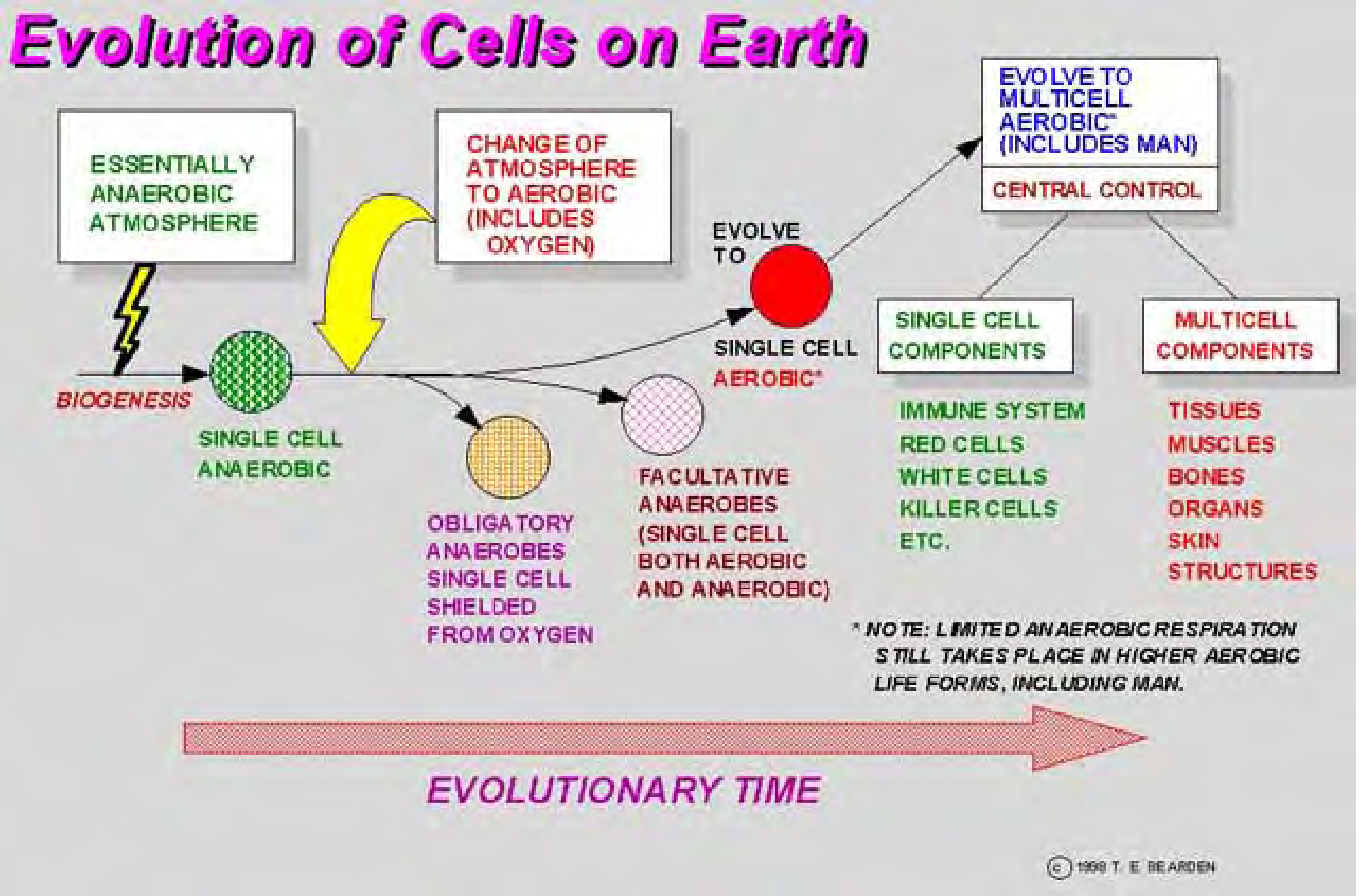

Evolution of Cells on Earth

ESSENTIALLY ANAEROBIC ATMOSPHERE

CHANGE OF ATMOSPHERE TO AEROBIC (INCLUDES OXYGEN)

BIOGENESIS

SINGLE CELL ANAEROBIC

OBLIGATORY ANAEROBES SINGLE CELL SHIELDED FROM OXYGEN

FACULTATIVE ANAEROBES (SINGLE CELL BOTH AEROBIC AND ANAEROBIC)

EVOLVE TO

SINGLE CELL AEROBIC*

EVOLVE TO MULTICELL AEROBIC* (INCLUDES MAN)

CENTRAL CONTROL

SINGLE CELL COMPONENTS

- IMMUNE SYSTEM
- RED CELLS
- WHITE CELLS
- KILLER CELLS
- ETC.

MULTICELL COMPONENTS

- TISSUES
- MUSCLES
- BONES
- ORGANS
- SKIN
- STRUCTURES

** NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.*

EVOLUTIONARY TIME

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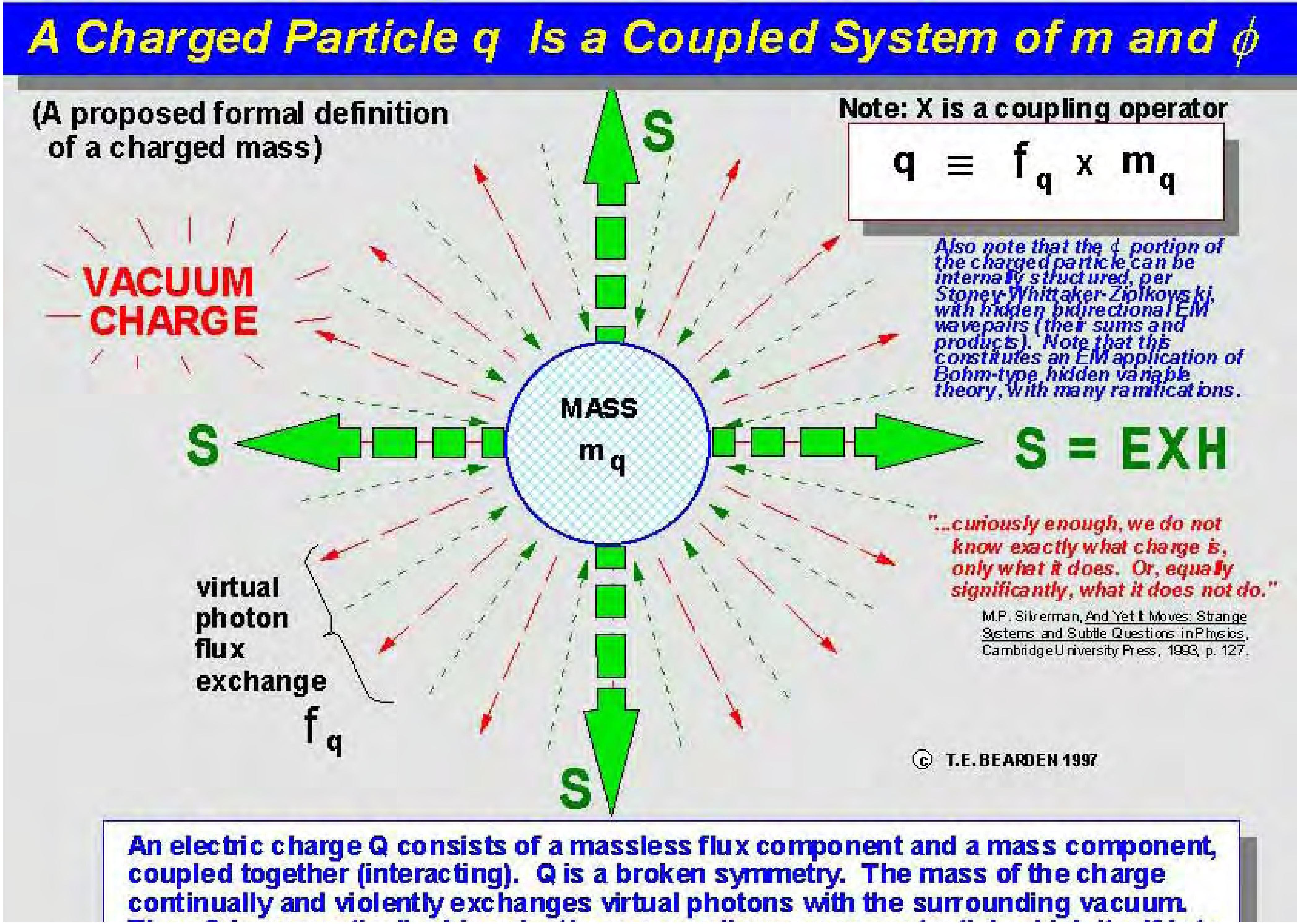

A Charged Particle q Is a Coupled System of m and ϕ

(A proposed formal definition of a charged mass)

Note: X is a coupling operator

$$q \equiv f_q \times m_q$$

Also note that the ϕ portion of the charged particle can be internally structured, per Stoney-Whittaker-Ziolkowski, with hidden bidirectional EM wavepairs (their sums and products). Note that this constitutes an EM application of Bohm-type hidden variable theory, with many ramifications.

$$S = E X H$$

"...curiously enough, we do not know exactly what charge is, only what it does. Or, equally significantly, what it does not do."

M.P. Silverman, And Yet It Moves: Strange Systems and Subtle Questions in Physics, Cambridge University Press, 1993, p. 127.

ⓒ T.E. BEARDEN 1997

An electric charge Q consists of a massless flux component and a mass component, coupled together (interacting). Q is a broken symmetry. The mass of the charge continually and violently exchanges virtual photons with the surrounding vacuum.

Thus Q is energetically driven by the surrounding vacuum potential, which itself is to first order just a violent virtual photon flux.

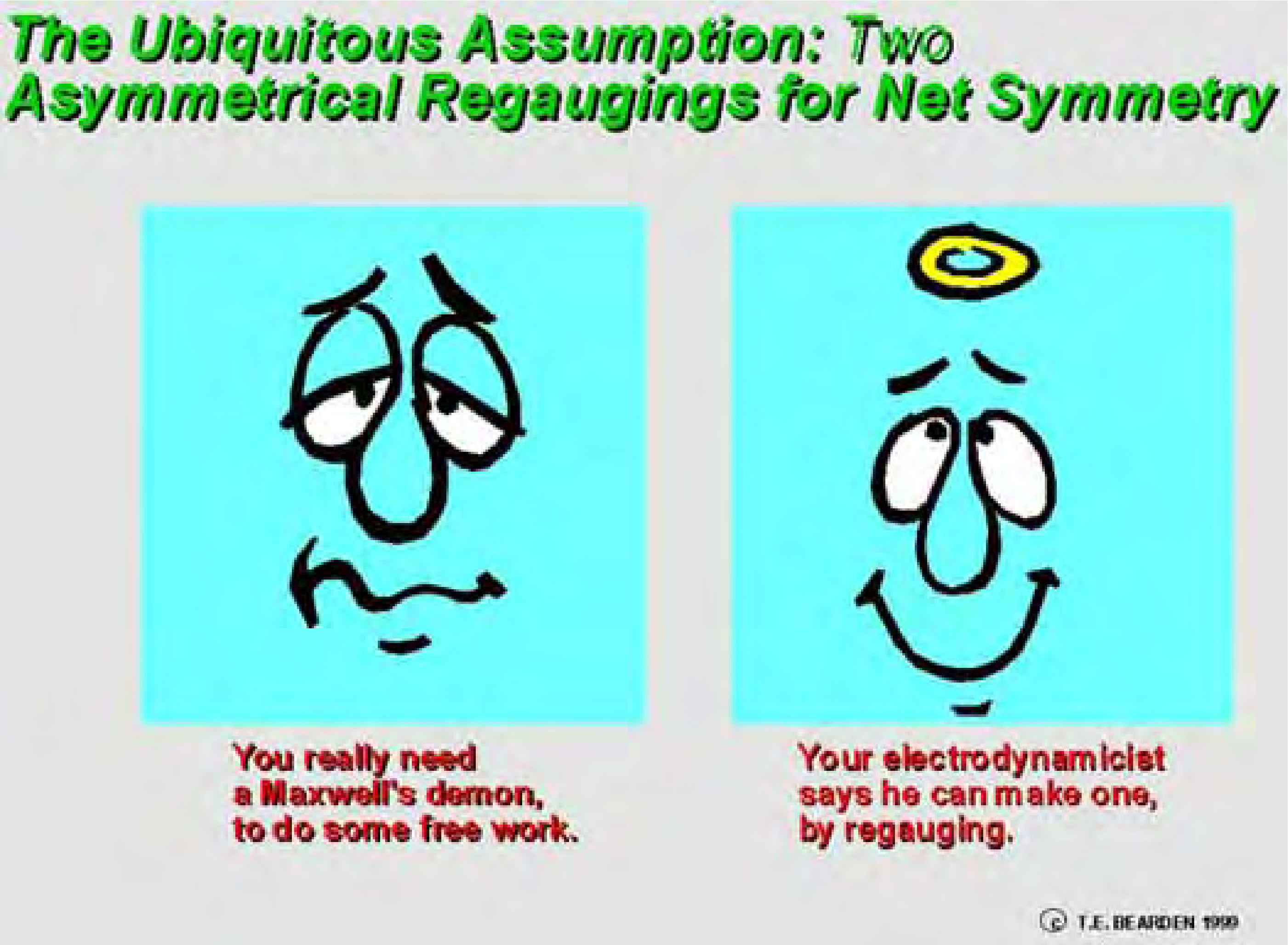

The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry

You really need
a Maxwell's demon,
to do some free work.

Your electrodynamicist
says he can make one,
by regauging.

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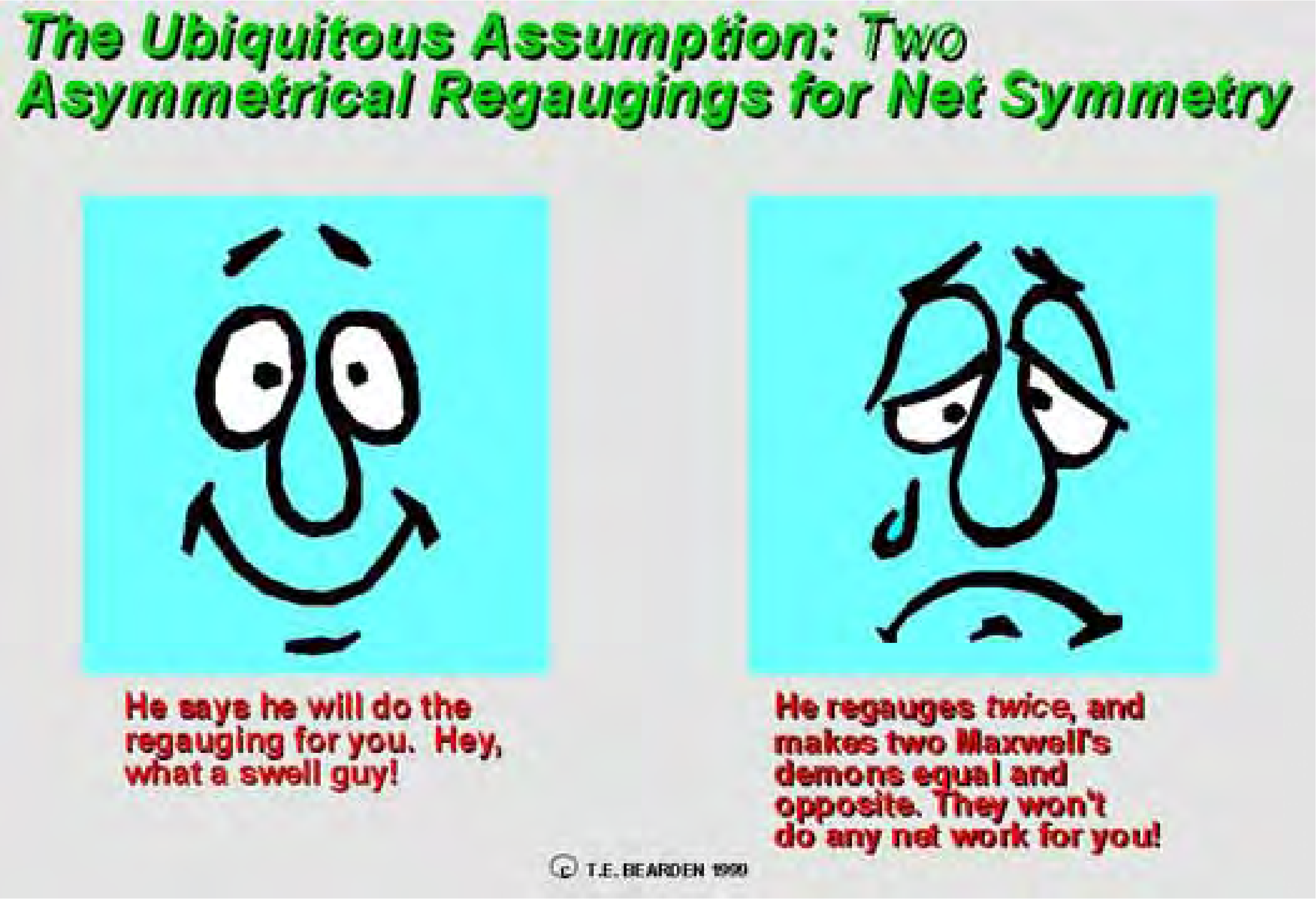

The Ubiquitous Assumption: *Two* Asymmetrical Regaugings for Net Symmetry

He says he will do the regauging for you. Hey, what a swell guy!

He regauges *twice*, and makes two Maxwell's demons equal and opposite. They won't do any net work for you!

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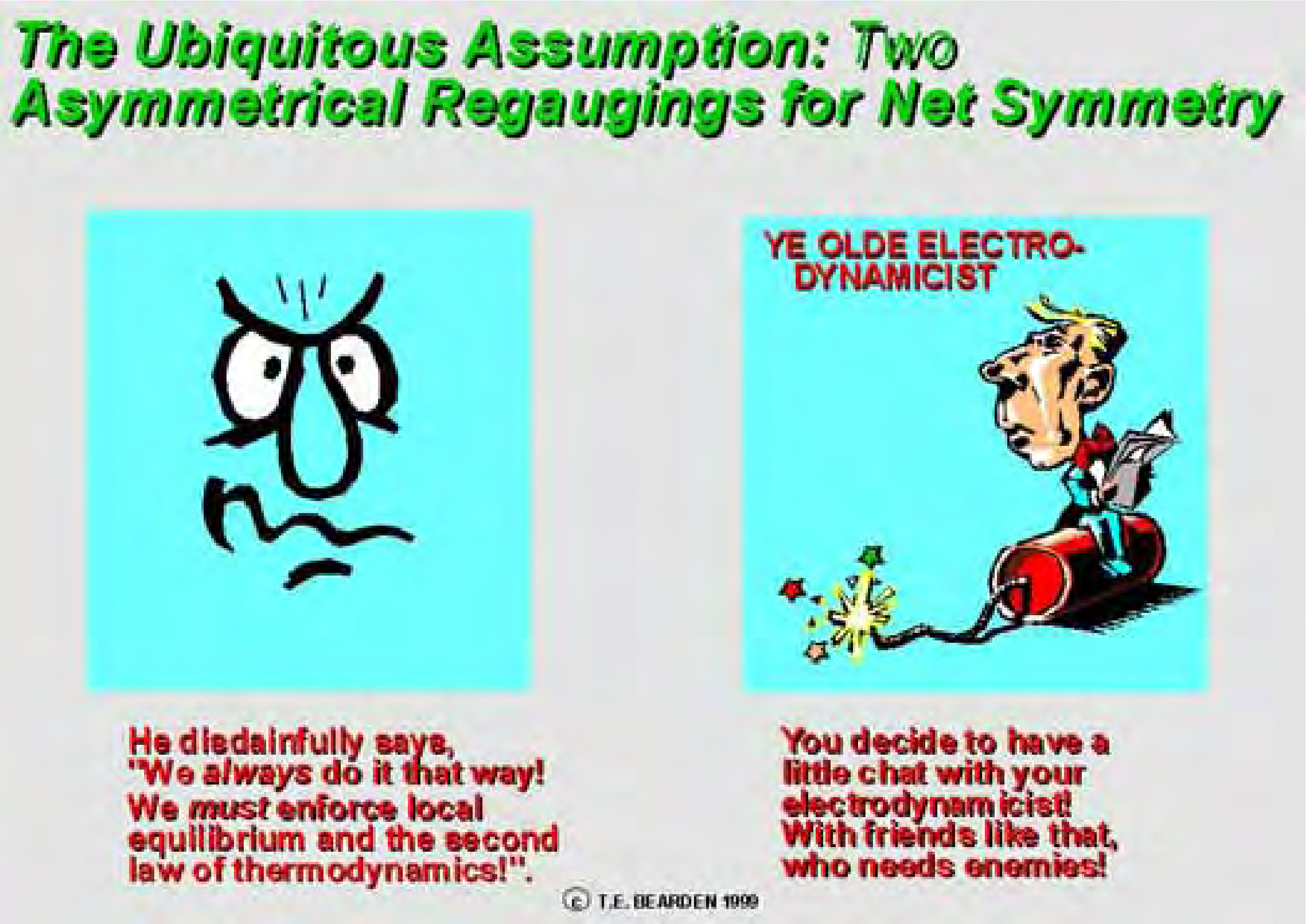

The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry

YE OLDE ELECTRO-
DYNAMICIST

He disdainfully says,
"We *always* do it that way!
We *must* enforce local
equilibrium and the second
law of thermodynamics!".

You decide to have a
little chat with your
electrodynamicist!
With friends like that,
who needs enemies!

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A Charged Particle Is a Coupled System

(The first formal definition of charge)

$$q \equiv \phi_q \text{ x } m_q$$

Note: X is a coupling operator

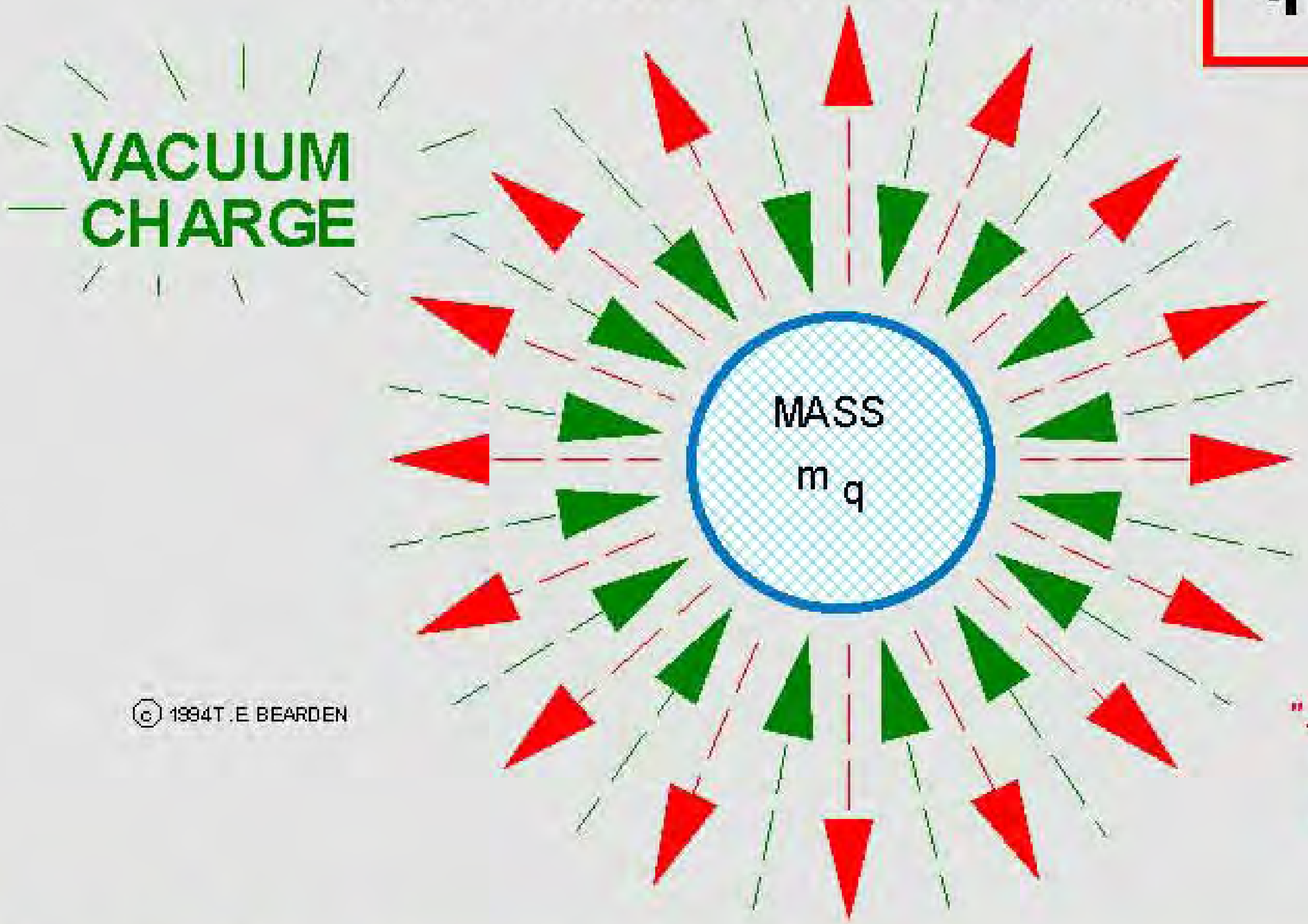

virtual photon flux exchange

ϕ_q

© 1994 T .E BEARDEN

"...curiously enough, we do not know exactly what charge is, only what it does. Or, equally significantly, what it does not do."

M.P. Silverman, And Yet It Moves: Strange Systems and Subtle Questions in Physics, Cambridge University Press, 1993, p. 127.

An electric charge q is a broken symmetry in its fierce energy exchange with the active vacuum. It coherently integrates some of the virtual energy absorbs and outputs it as Poynting energy flow.

Chung's Carbon Filament Negative Resistor

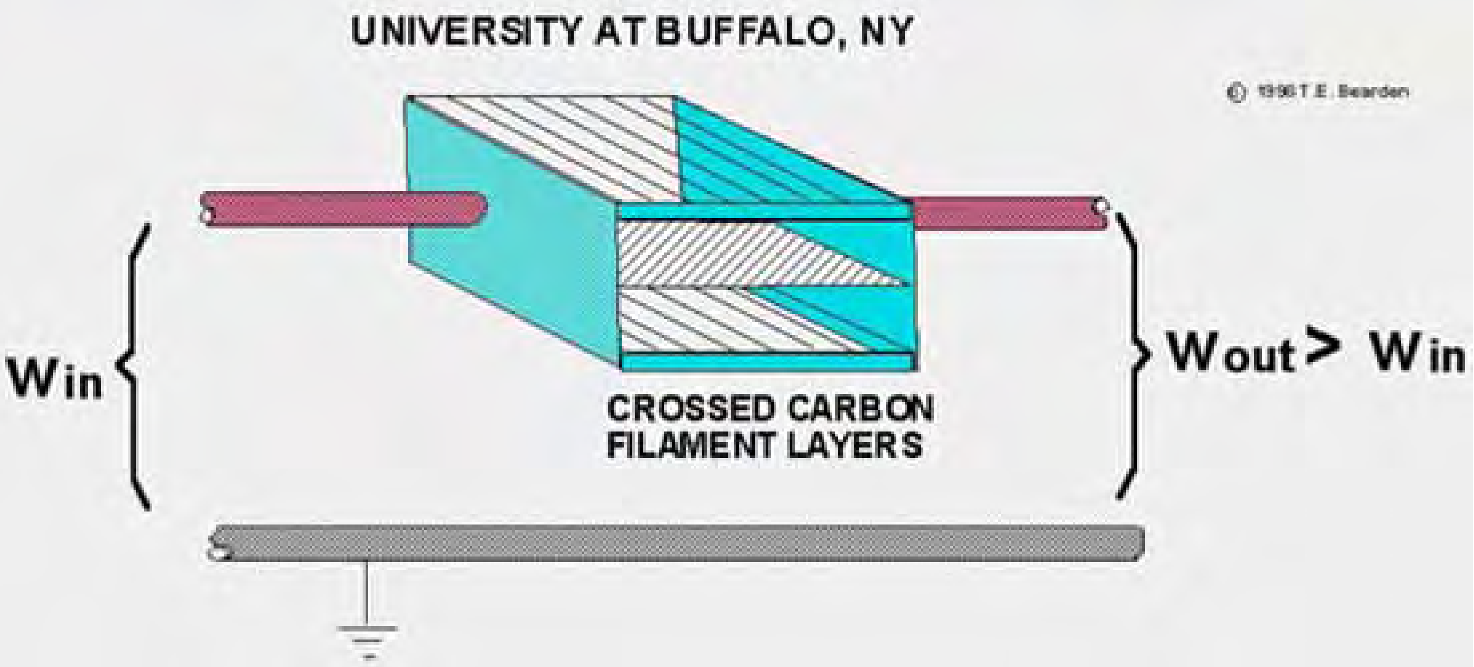
UNIVERSITY AT BUFFALO, NY
© 1996 T.E. Bearden
Win
Wout > Win
CROSSED CARBON
FILAMENT LAYERS

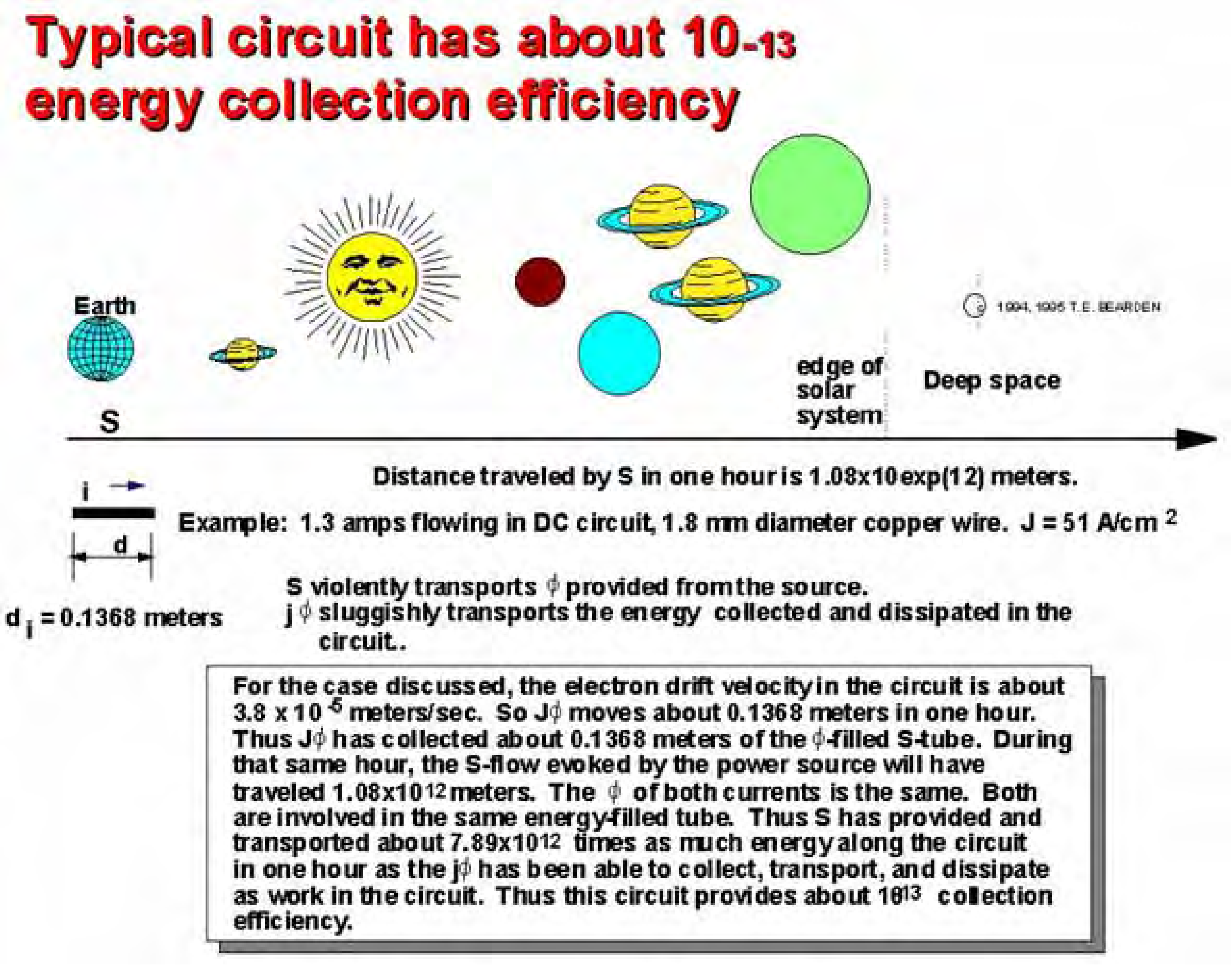

Typical circuit has about 10_{-13} energy collection efficiency

Distance traveled by S in one hour is 1.08x10exp(12) meters.

Example: 1.3 amps flowing in DC circuit, 1.8 mm diameter copper wire. $J = 51\ A/cm^2$

$d_i = 0.1368$ meters

S violently transports ϕ provided from the source.
jϕ sluggishly transports the energy collected and dissipated in the circuit..

For the case discussed, the electron drift velocity in the circuit is about 3.8×10^{-5} meters/sec. So Jϕ moves about 0.1368 meters in one hour. Thus Jϕ has collected about 0.1368 meters of the ϕ-filled S-tube. During that same hour, the S-flow evoked by the power source will have traveled $1.08\text{x}10^{12}$ meters. The ϕ of both currents is the same. Both are involved in the same energy-filled tube. Thus S has provided and transported about $7.89\text{x}10^{12}$ times as much energy along the circuit in one hour as the jϕ has been able to collect, transport, and dissipate as work in the circuit. Thus this circuit provides about 10^{13} collection efficiency.

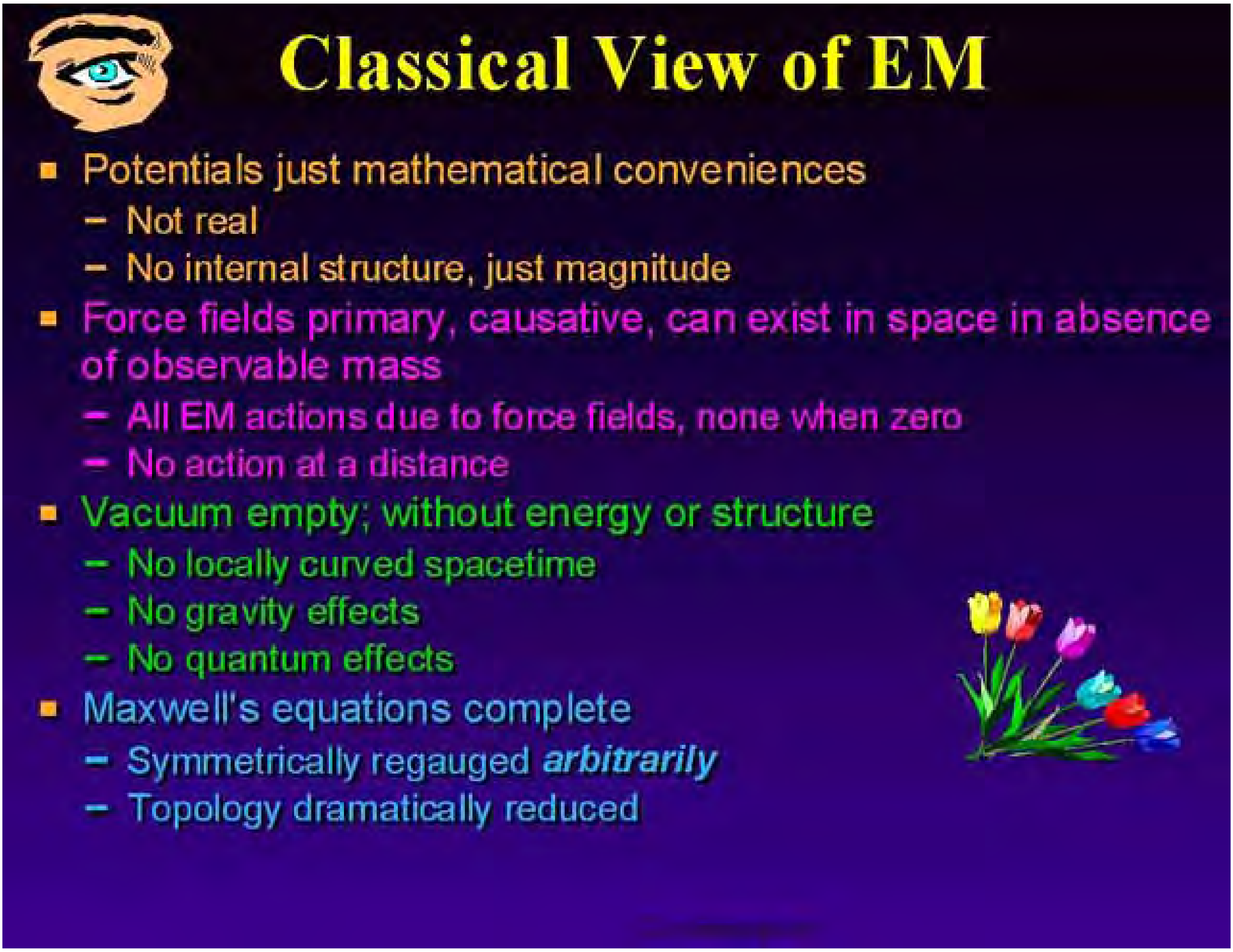

Classical View of EM

- Potentials just mathematical conveniences
  - Not real
  - No internal structure, just magnitude
- Force fields primary, causative, can exist in space in absence of observable mass
  - All EM actions due to force fields, none when zero
  - No action at a distance
- Vacuum empty; without energy or structure
  - No locally curved spacetime
  - No gravity effects
  - No quantum effects
- Maxwell's equations complete
  - Symmetrically regauged ***arbitrarily***
  - Topology dramatically reduced

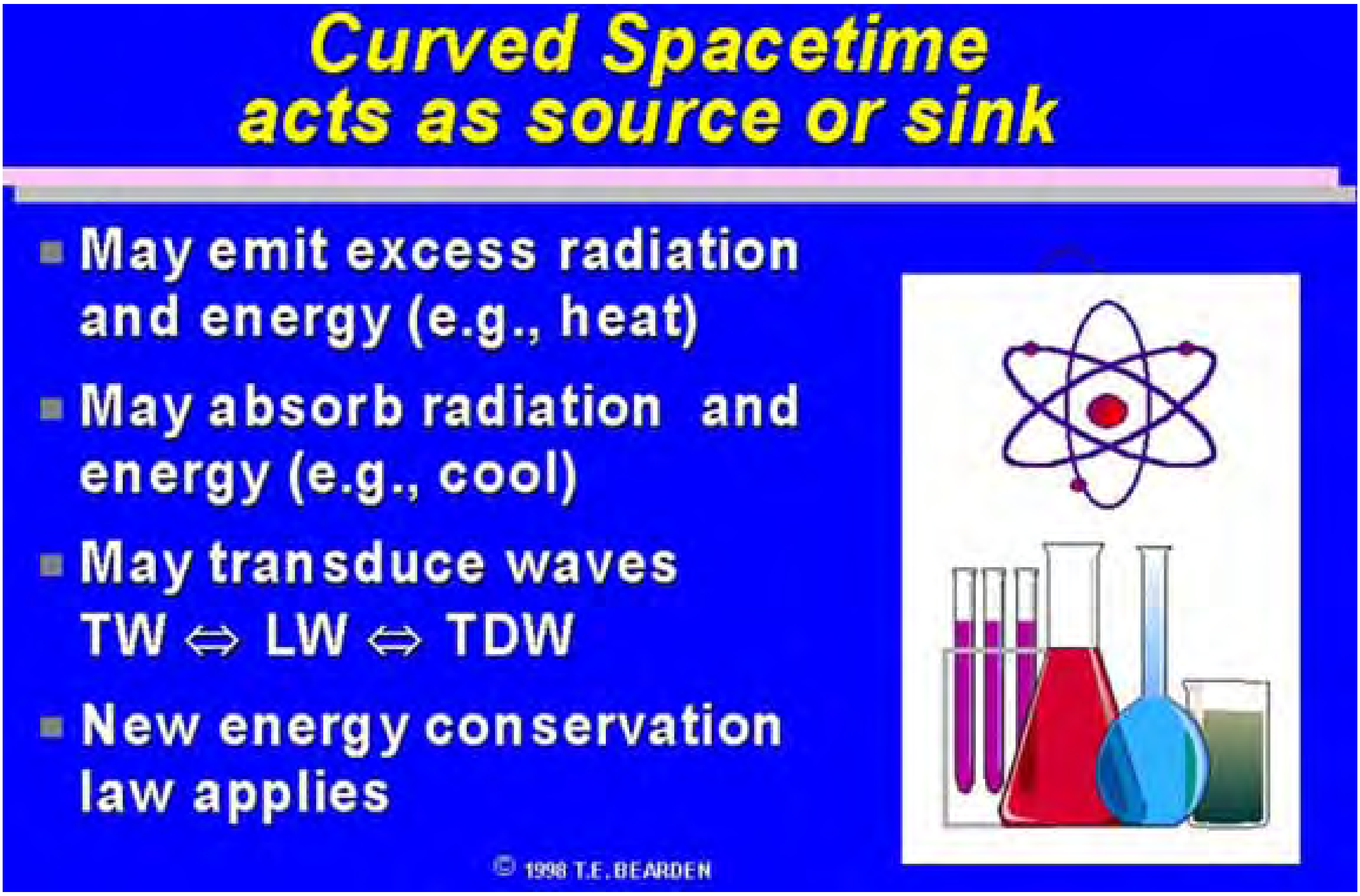

Curved Spacetime acts as source or sink

- May emit excess radiation and energy (e.g., heat)
- May absorb radiation and energy (e.g., cool)
- May transduce waves
  TW ⇔ LW ⇔ TDW
- New energy conservation law applies

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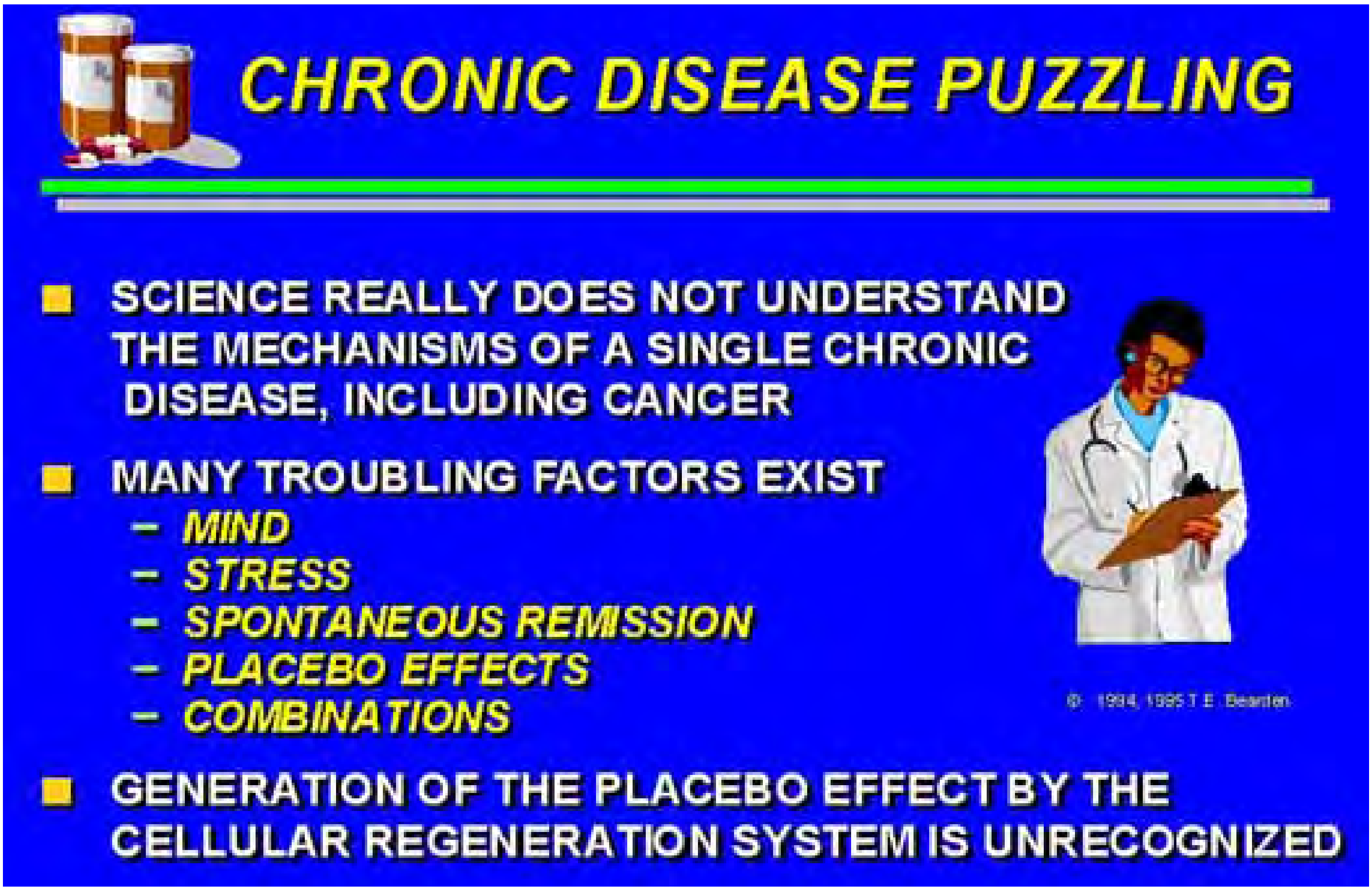

CHRONIC DISEASE PUZZLING

- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
- MANY TROUBLING FACTORS EXIST
  - *MIND*
  - *STRESS*
  - *SPONTANEOUS REMISSION*
  - *PLACEBO EFFECTS*
  - *COMBINATIONS*
- GENERATION OF THE PLACEBO EFFECT BY THE CELLULAR REGENERATION SYSTEM IS UNRECOGNIZED

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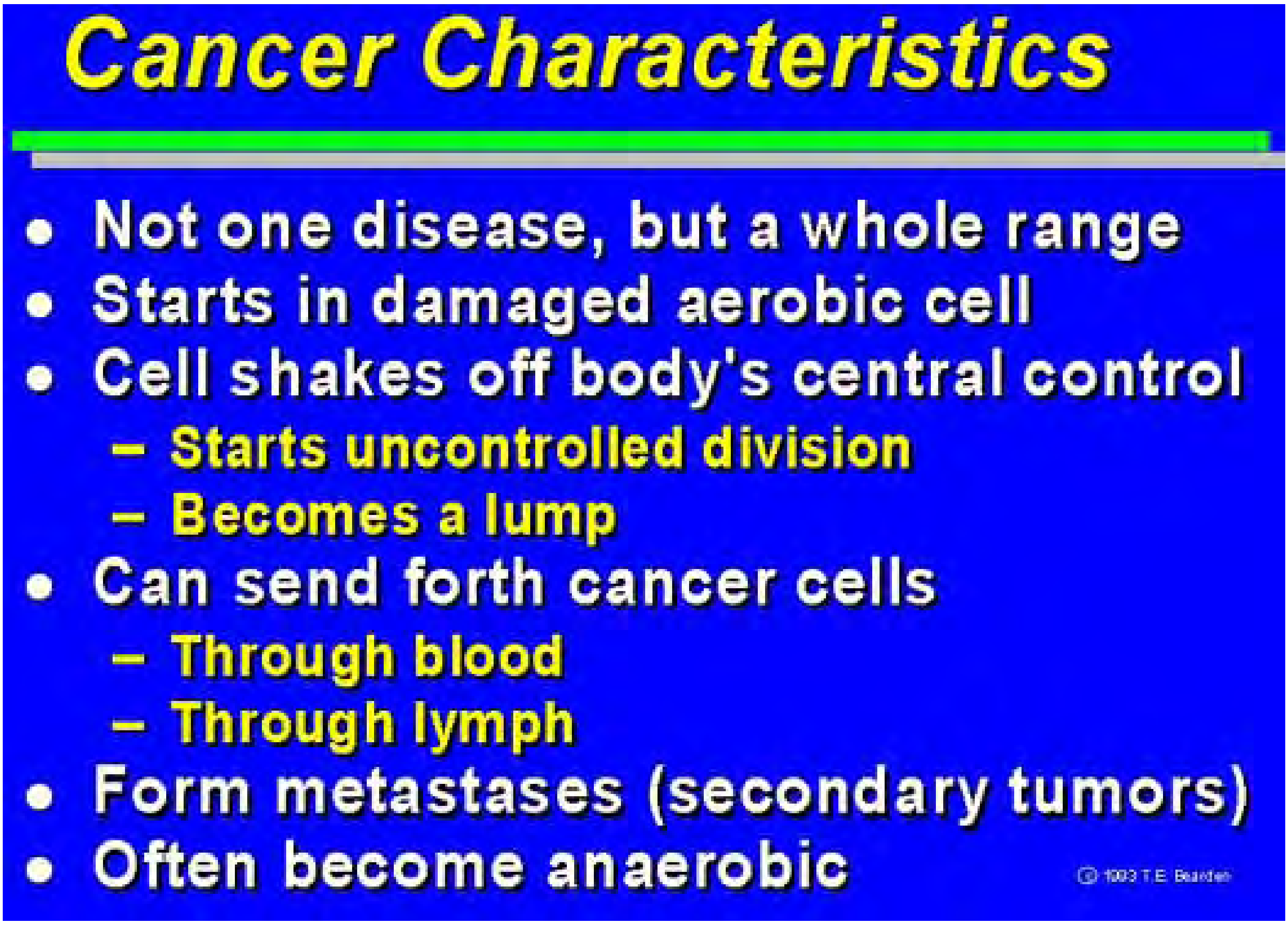

Cancer Characteristics

- Not one disease, but a whole range
- Starts in damaged aerobic cell
- Cell shakes off body's central control
  - Starts uncontrolled division
  - Becomes a lump
- Can send forth cancer cells
  - Through blood
  - Through lymph
- Form metastases (secondary tumors)
- Often become anaerobic

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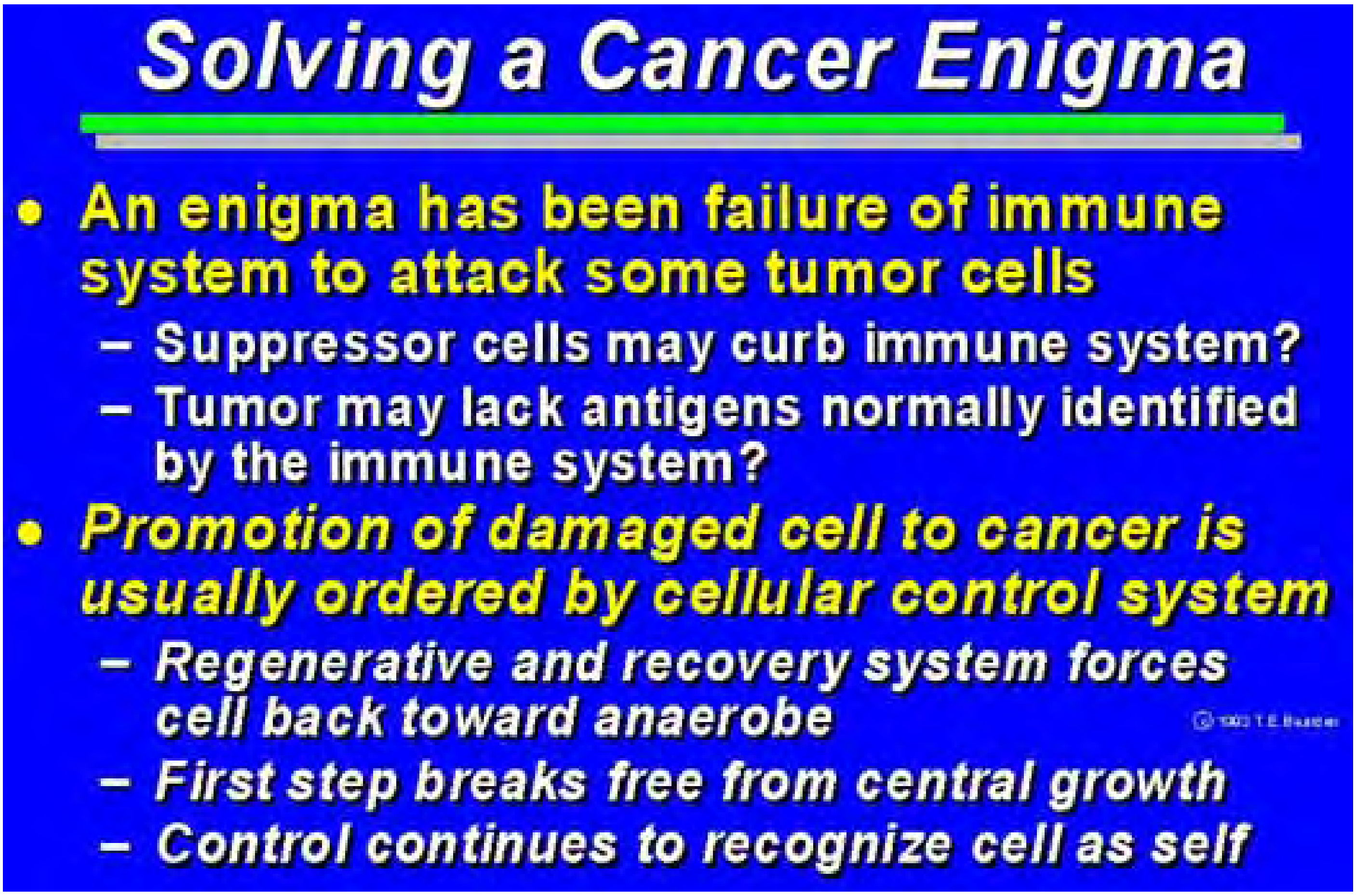

Solving a Cancer Enigma

- An enigma has been failure of immune system to attack some tumor cells
  - Suppressor cells may curb immune system?
  - Tumor may lack antigens normally identified by the immune system?
- *Promotion of damaged cell to cancer is usually ordered by cellular control system*
  - *Regenerative and recovery system forces cell back toward anaerobe*
  - *First step breaks free from central growth*
  - *Control continues to recognize cell as self*

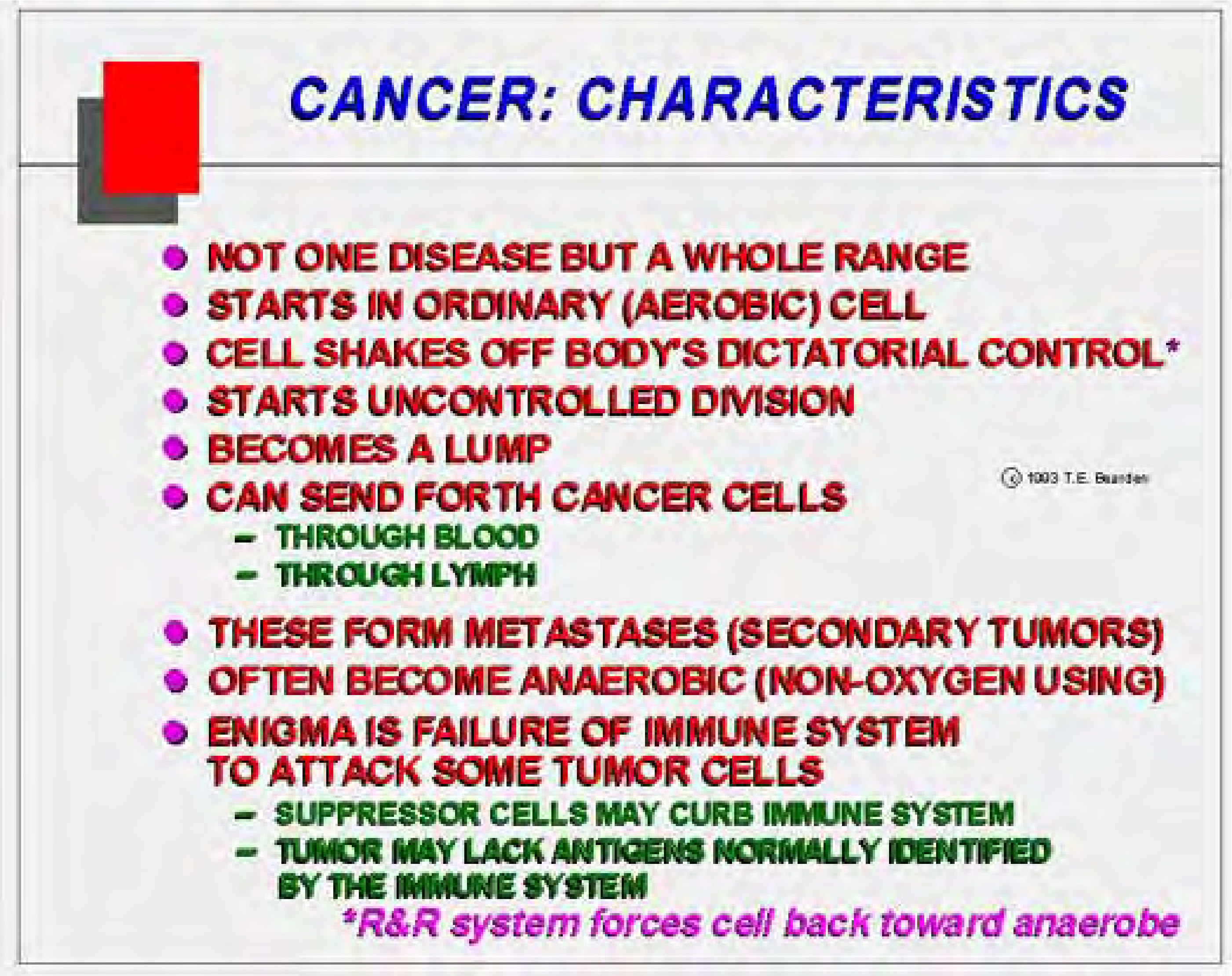

CANCER: CHARACTERISTICS

- NOT ONE DISEASE BUT A WHOLE RANGE
- STARTS IN ORDINARY (AEROBIC) CELL
- CELL SHAKES OFF BODY'S DICTATORIAL CONTROL*
- STARTS UNCONTROLLED DIVISION
- BECOMES A LUMP
- CAN SEND FORTH CANCER CELLS
  - THROUGH BLOOD
  - THROUGH LYMPH
- THESE FORM METASTASES (SECONDARY TUMORS)
- OFTEN BECOME ANAEROBIC (NON-OXYGEN USING)
- ENIGMA IS FAILURE OF IMMUNE SYSTEM TO ATTACK SOME TUMOR CELLS
  - SUPPRESSOR CELLS MAY CURB IMMUNE SYSTEM
  - TUMOR MAY LACK ANTIGENS NORMALLY IDENTIFIED BY THE IMMUNE SYSTEM

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*R&R system forces cell back toward anaerobe

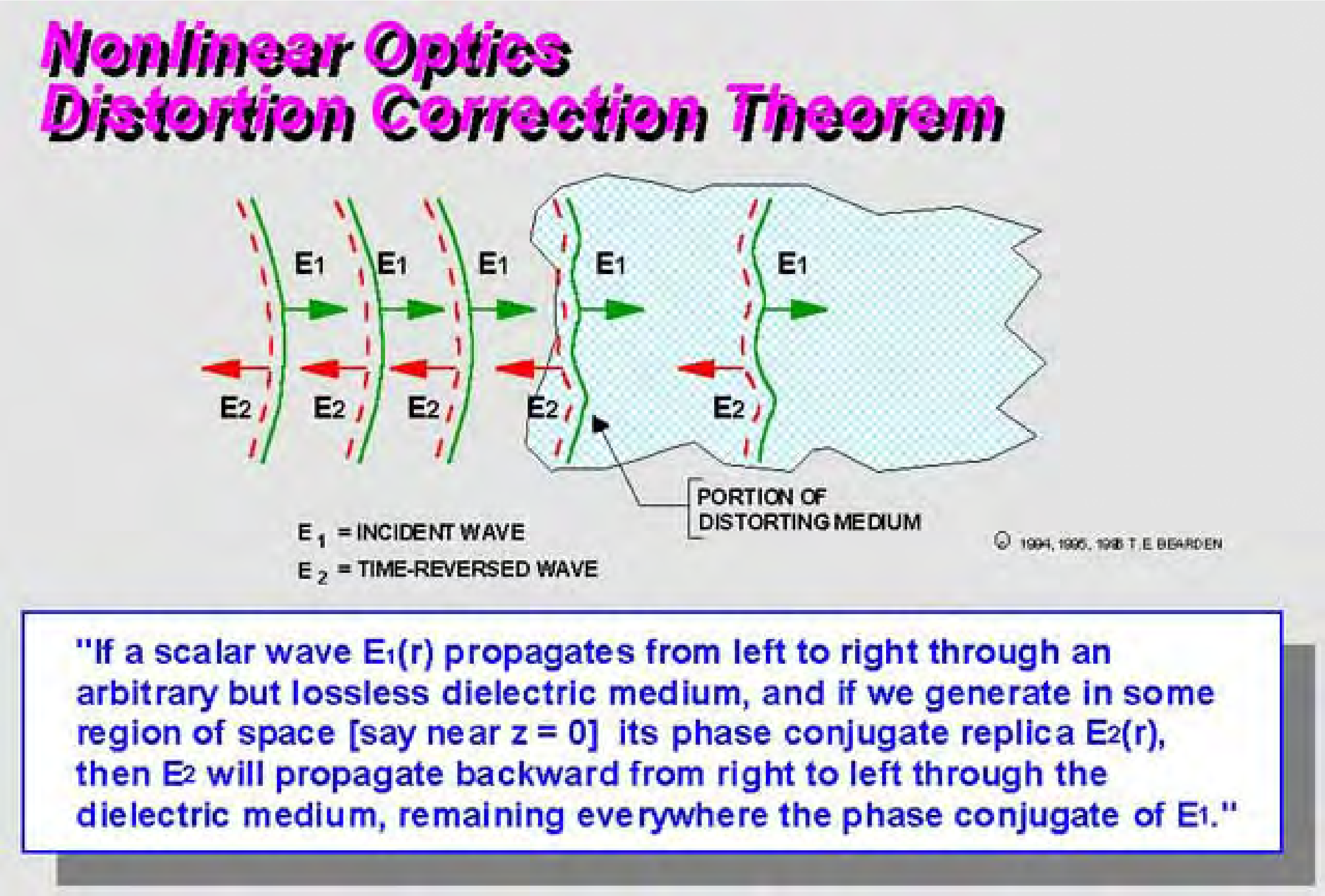

Nonlinear Optics
Distortion Correction Theorem

E_1 = INCIDENT WAVE

E_2 = TIME-REVERSED WAVE

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"If a scalar wave $E_1(r)$ propagates from left to right through an arbitrary but lossless dielectric medium, and if we generate in some region of space [say near $z = 0$] its phase conjugate replica $E_2(r)$, then E_2 will propagate backward from right to left through the dielectric medium, remaining everywhere the phase conjugate of E_1."

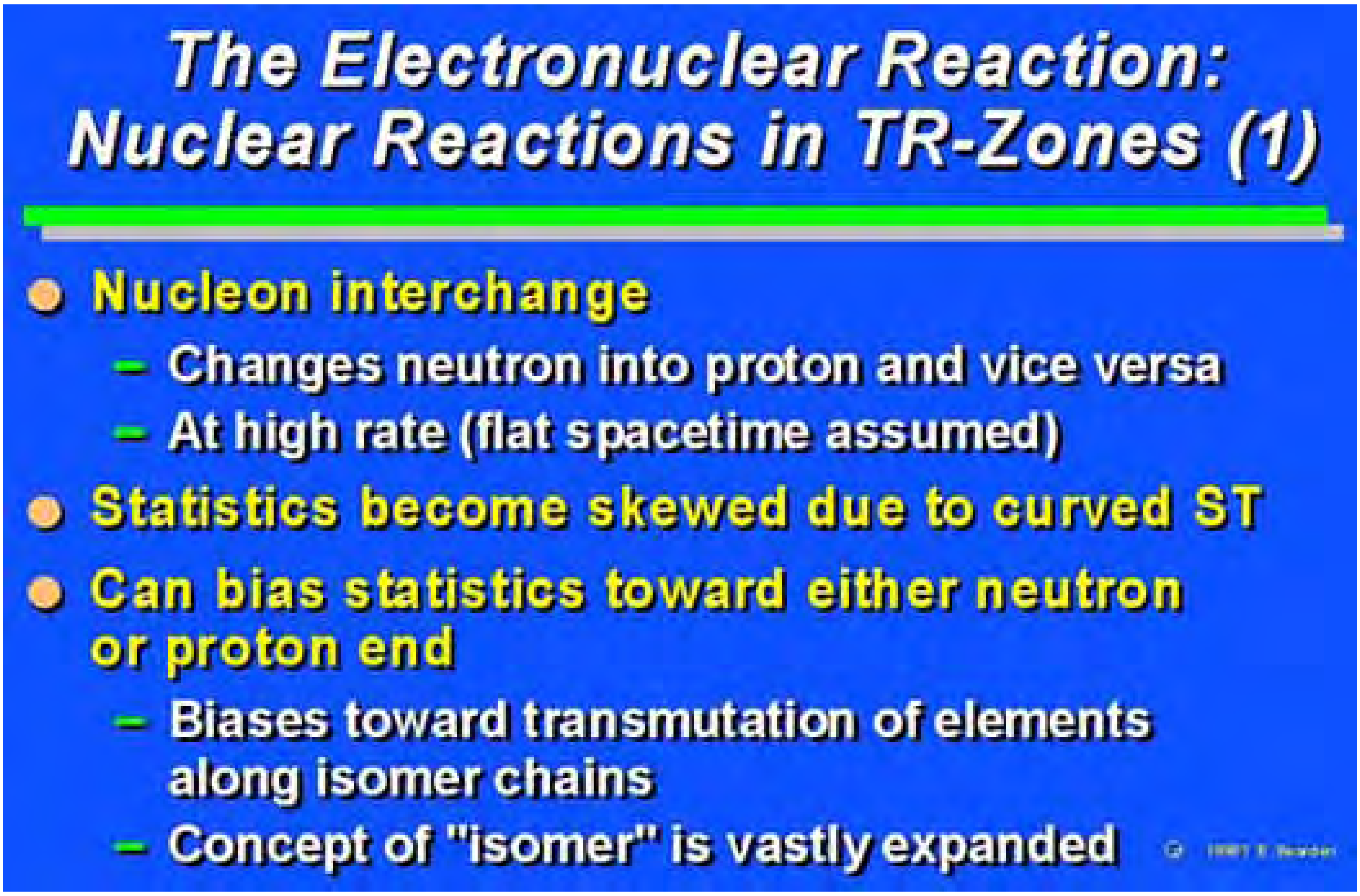

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (1)

- **Nucleon interchange**
  - Changes neutron into proton and vice versa
  - At high rate (flat spacetime assumed)
- **Statistics become skewed due to curved ST**
- **Can bias statistics toward either neutron or proton end**
  - Biases toward transmutation of elements along isomer chains
  - Concept of "isomer" is vastly expanded

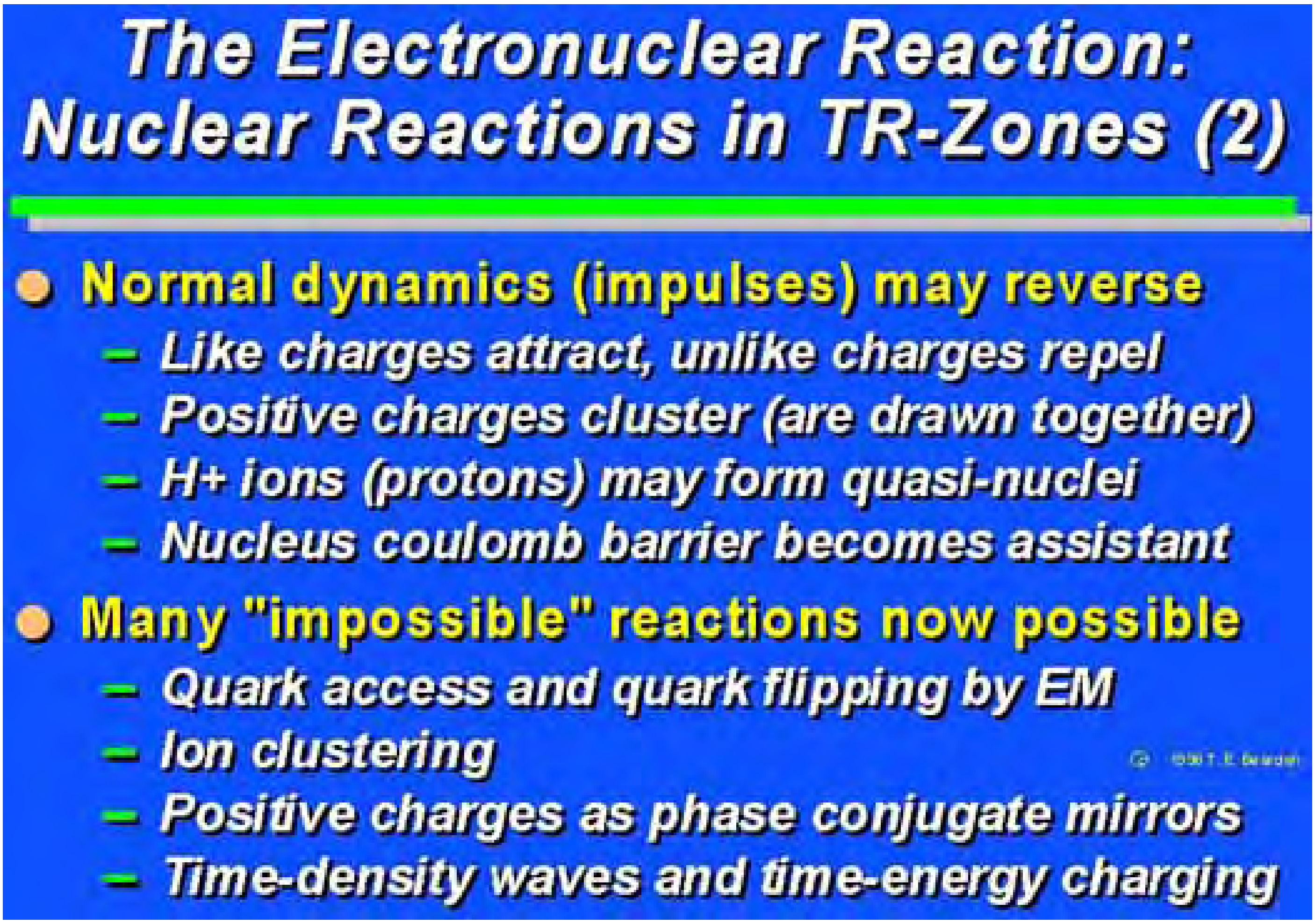

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (2)

- **Normal dynamics (impulses) may reverse**
  - *Like charges attract, unlike charges repel*
  - *Positive charges cluster (are drawn together)*
  - *H+ ions (protons) may form quasi-nuclei*
  - *Nucleus coulomb barrier becomes assistant*
- **Many "impossible" reactions now possible**
  - *Quark access and quark flipping by EM*
  - *Ion clustering*
  - *Positive charges as phase conjugate mirrors*
  - *Time-density waves and time-energy charging*

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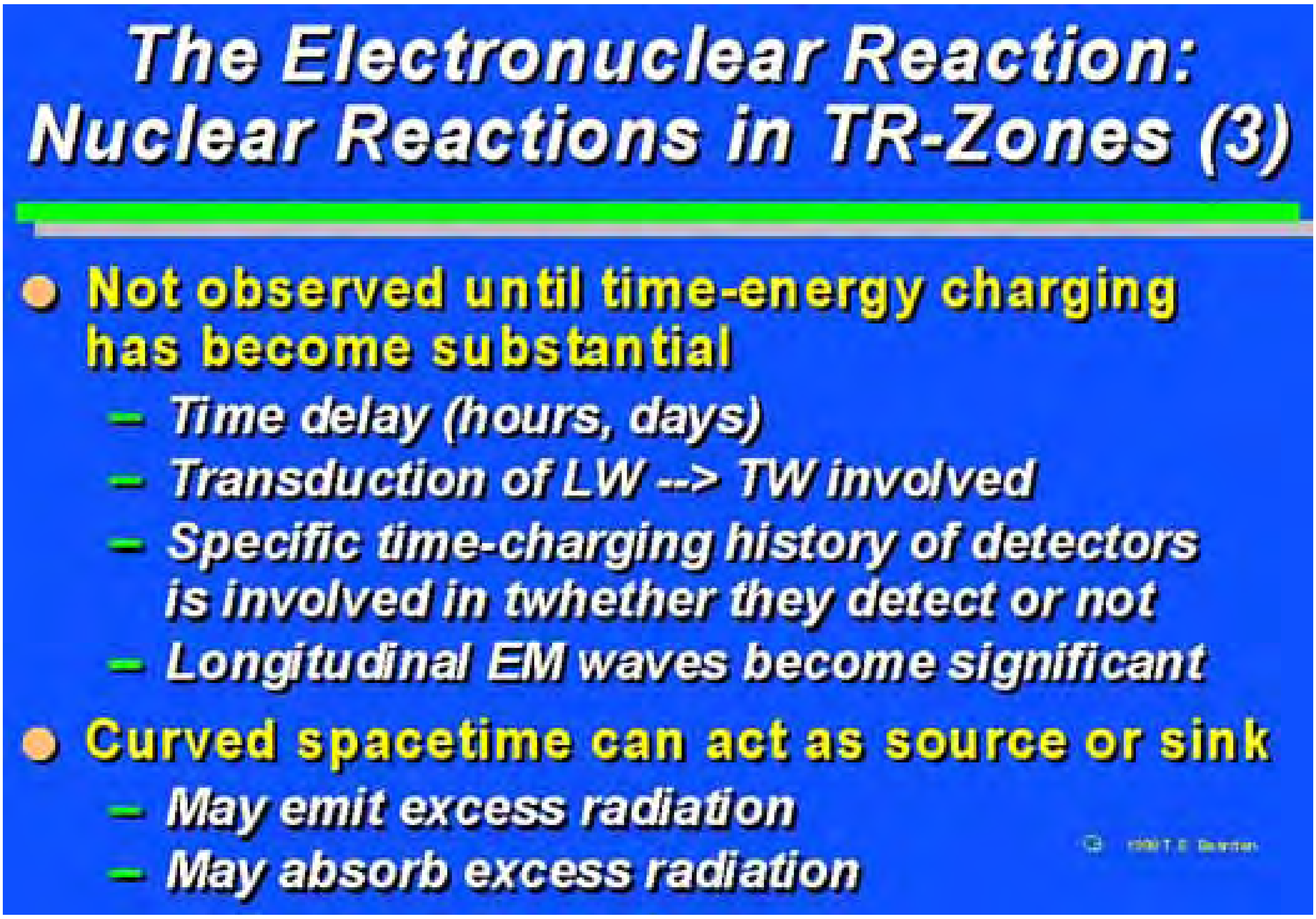

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (3)

- Not observed until time-energy charging has become substantial
  - *Time delay (hours, days)*
  - *Transduction of LW --> TW involved*
  - *Specific time-charging history of detectors is involved in twhether they detect or not*
  - *Longitudinal EM waves become significant*
- Curved spacetime can act as source or sink
  - *May emit excess radiation*
  - *May absorb excess radiation*

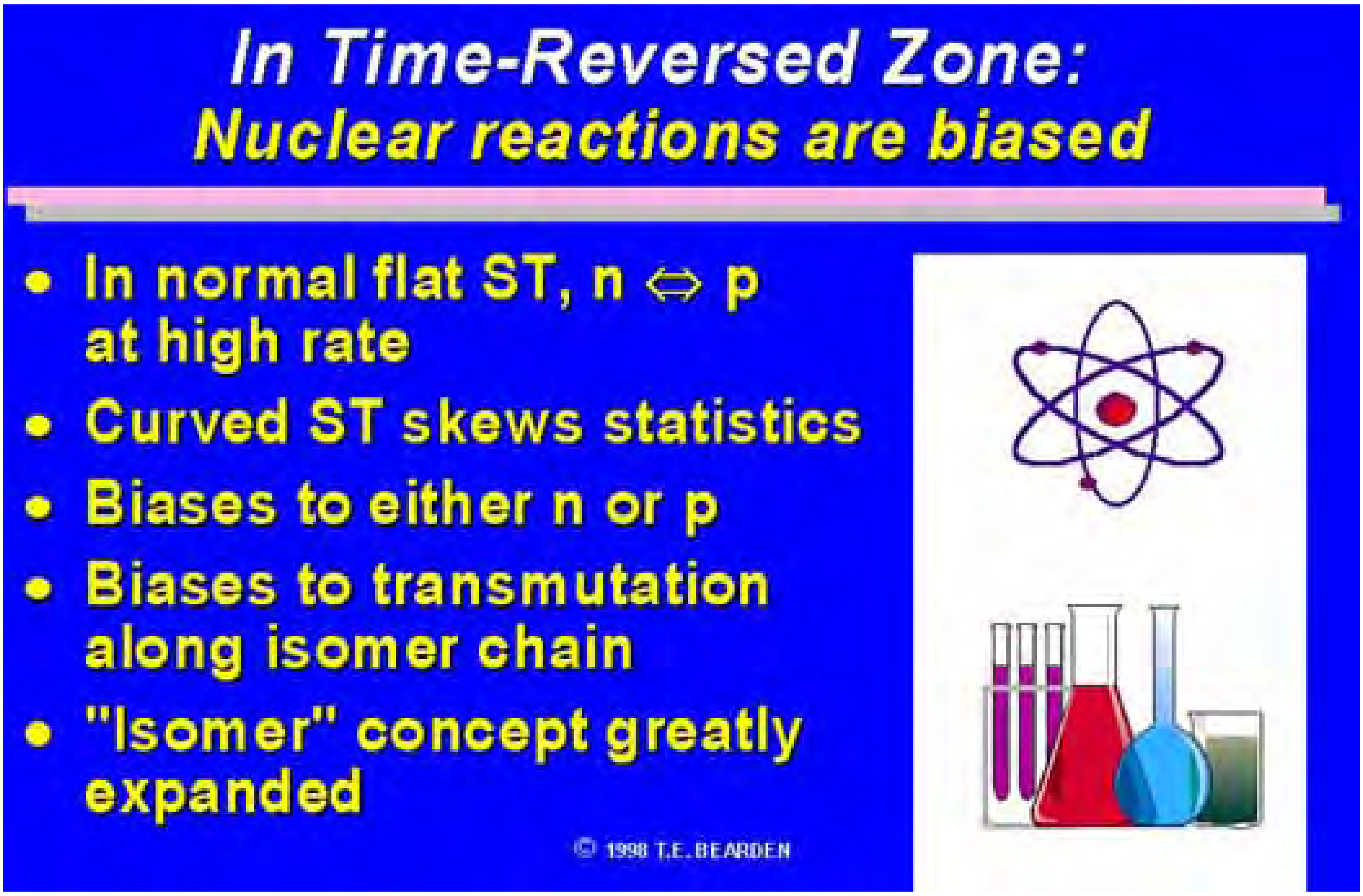

In Time-Reversed Zone:
Nuclear reactions are biased

- In normal flat ST, n ⇔ p at high rate
- Curved ST skews statistics
- Biases to either n or p
- Biases to transmutation along isomer chain
- "Isomer" concept greatly expanded

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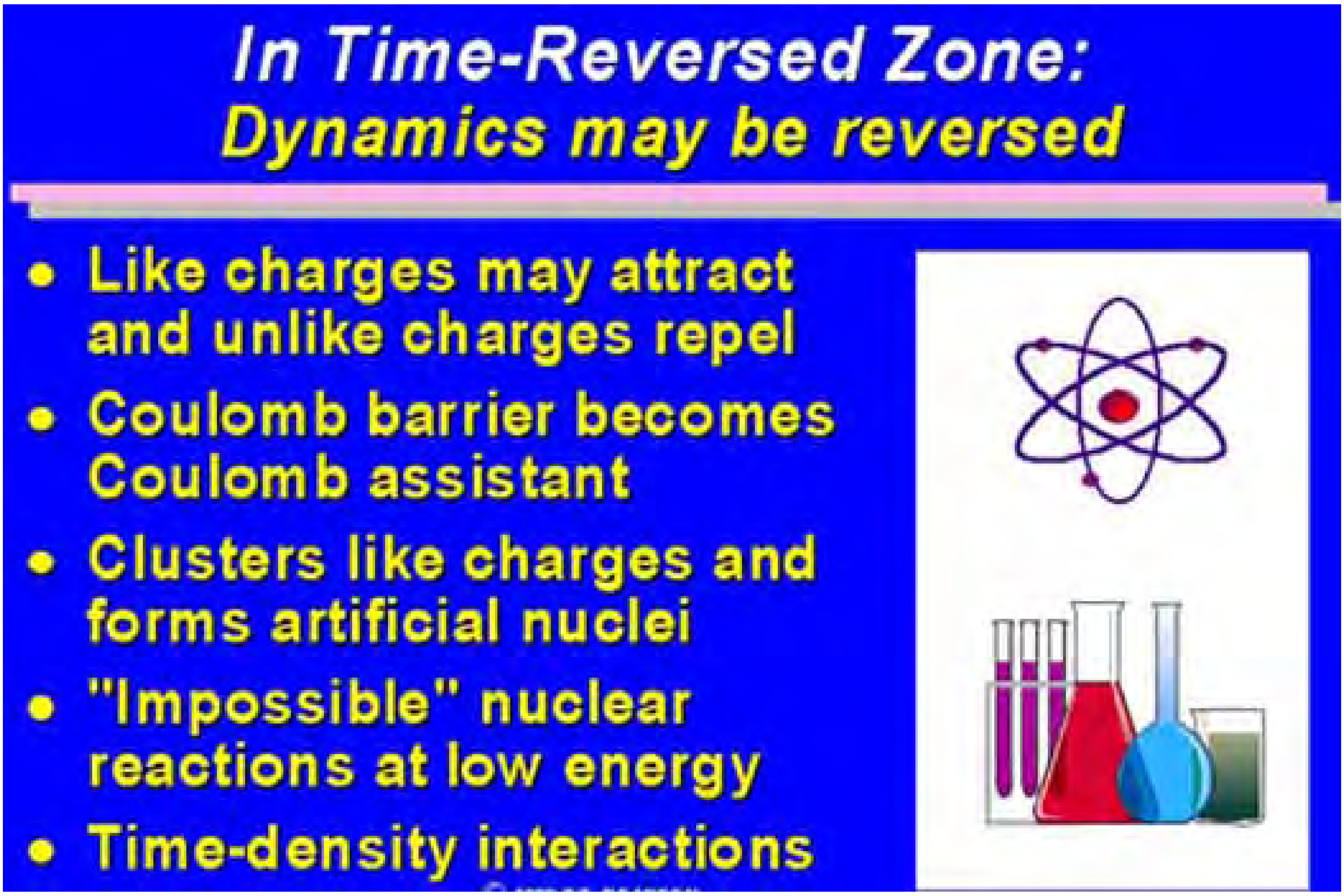

In Time-Reversed Zone:
Dynamics may be reversed

- Like charges may attract and unlike charges repel
- Coulomb barrier becomes Coulomb assistant
- Clusters like charges and forms artificial nuclei
- "Impossible" nuclear reactions at low energy
- Time-density interactions

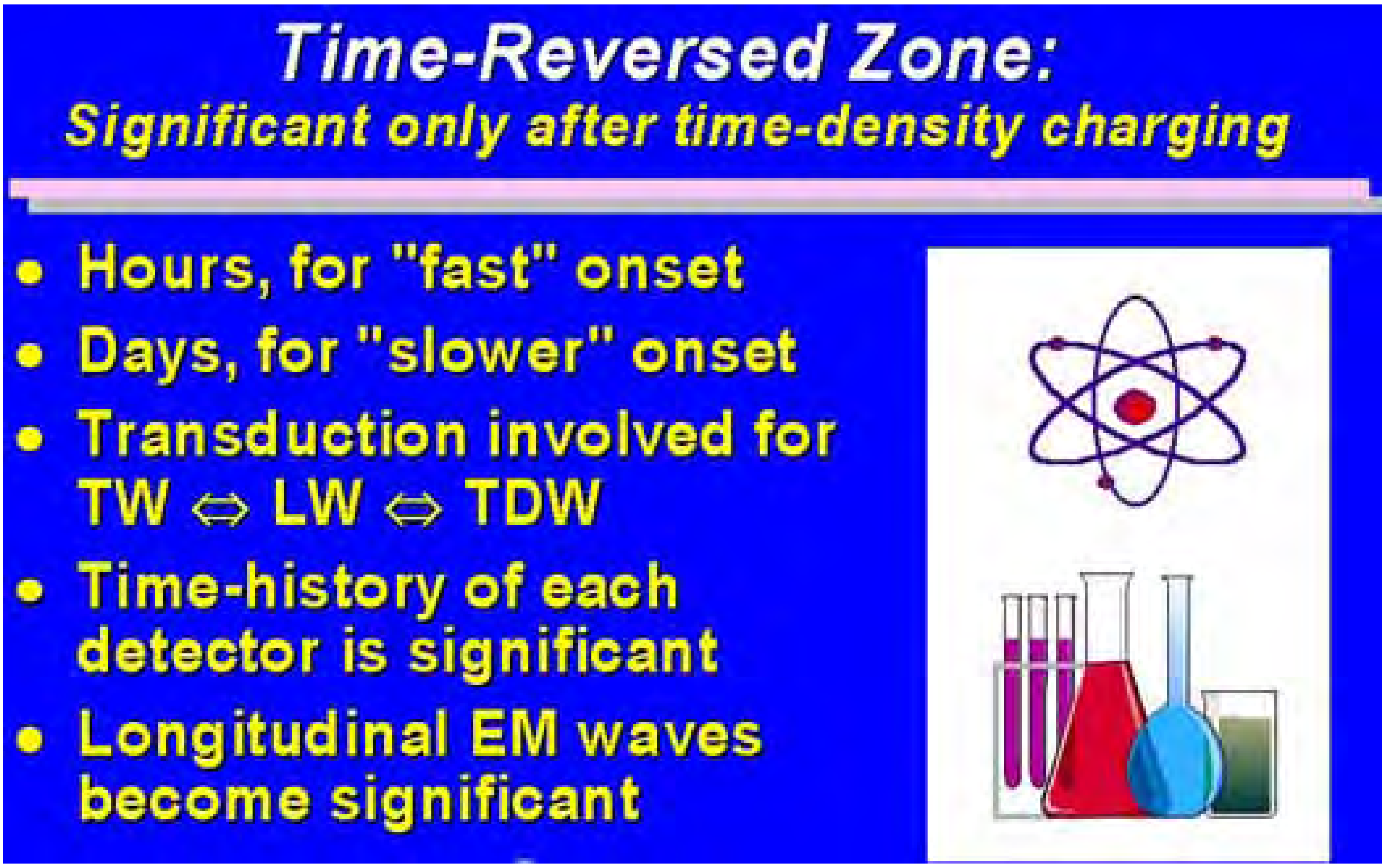

Time-Reversed Zone:

Significant only after time-density charging

- Hours, for "fast" onset
- Days, for "slower" onset
- Transduction involved for TW ⇔ LW ⇔ TDW
- Time-history of each detector is significant
- Longitudinal EM waves become significant

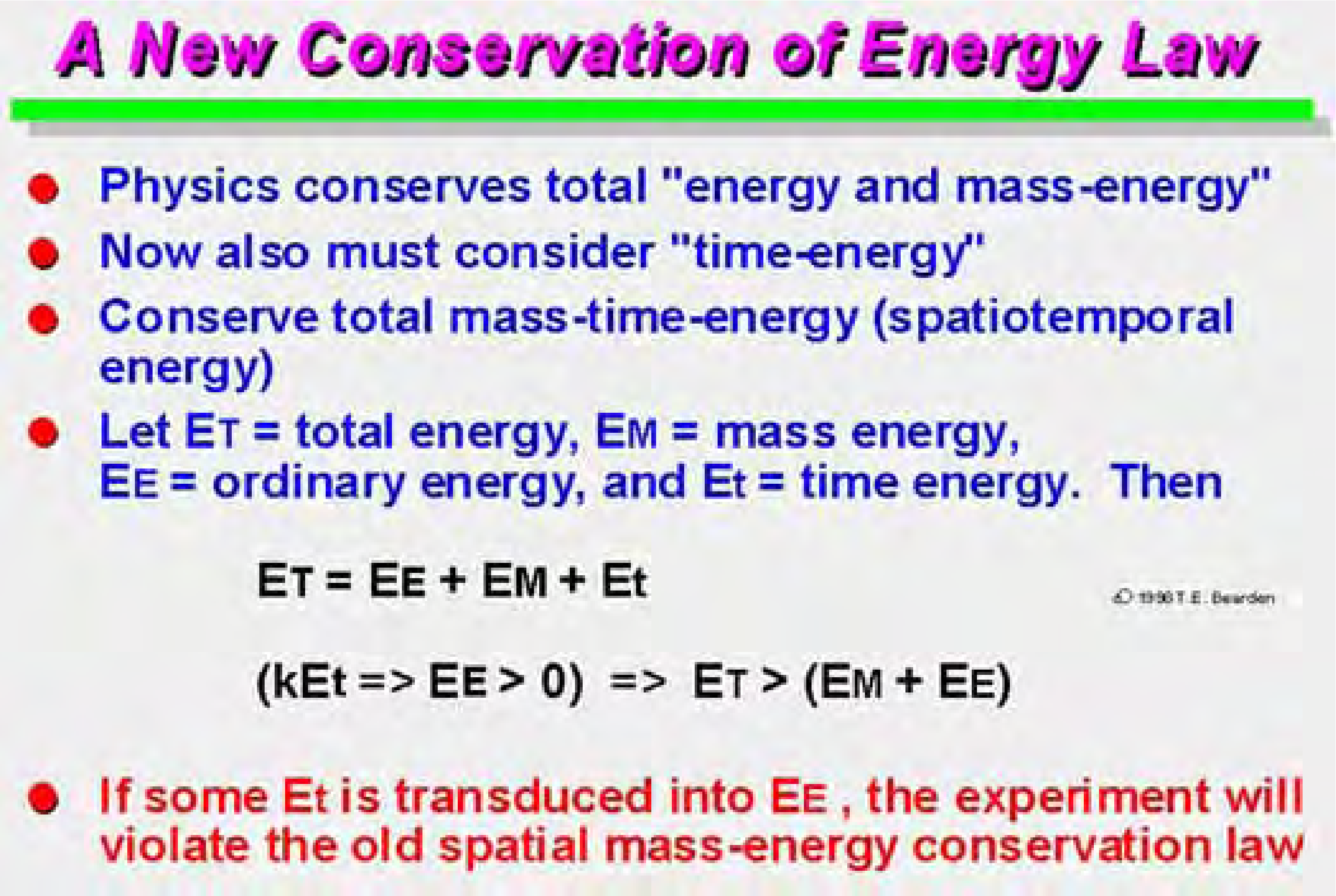

A New Conservation of Energy Law

- Physics conserves total "energy and mass-energy"
- Now also must consider "time-energy"
- Conserve total mass-time-energy (spatiotemporal energy)
- Let E_T = total energy, E_M = mass energy, E_E = ordinary energy, and E_t = time energy. Then

$$E_T = E_E + E_M + E_t$$

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$$(kE_t \Rightarrow E_E > 0) \;\; \Rightarrow \;\; E_T > (E_M + E_E)$$

- If some E_t is transduced into E_E, the experiment will violate the old spatial mass-energy conservation law

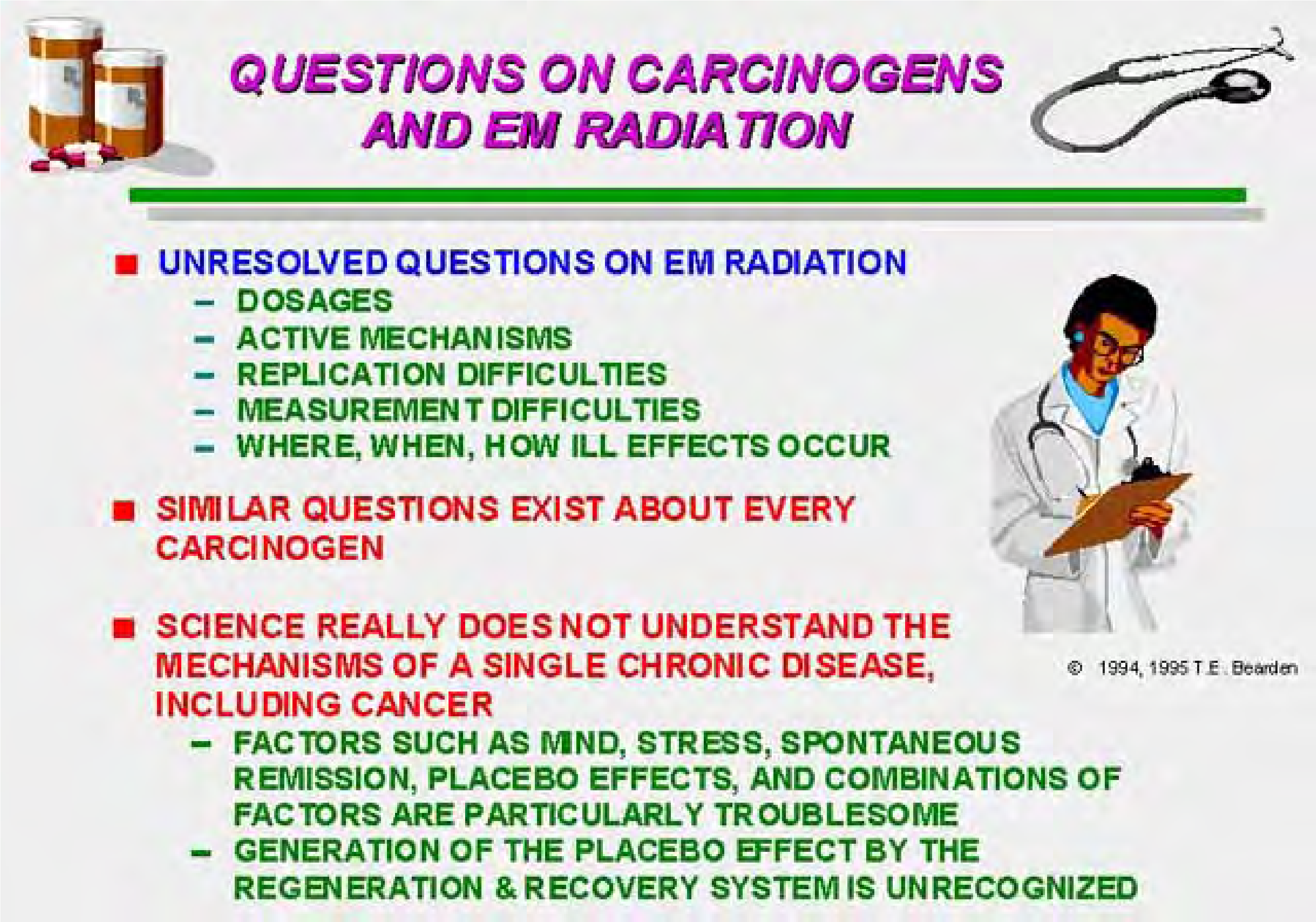

QUESTIONS ON CARCINOGENS AND EM RADIATION

- UNRESOLVED QUESTIONS ON EM RADIATION
  - DOSAGES
  - ACTIVE MECHANISMS
  - REPLICATION DIFFICULTIES
  - MEASUREMENT DIFFICULTIES
  - WHERE, WHEN, HOW ILL EFFECTS OCCUR
- SIMILAR QUESTIONS EXIST ABOUT EVERY CARCINOGEN
- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
  - FACTORS SUCH AS MIND, STRESS, SPONTANEOUS REMISSION, PLACEBO EFFECTS, AND COMBINATIONS OF FACTORS ARE PARTICULARLY TROUBLESOME
  - GENERATION OF THE PLACEBO EFFECT BY THE REGENERATION & RECOVERY SYSTEM IS UNRECOGNIZED

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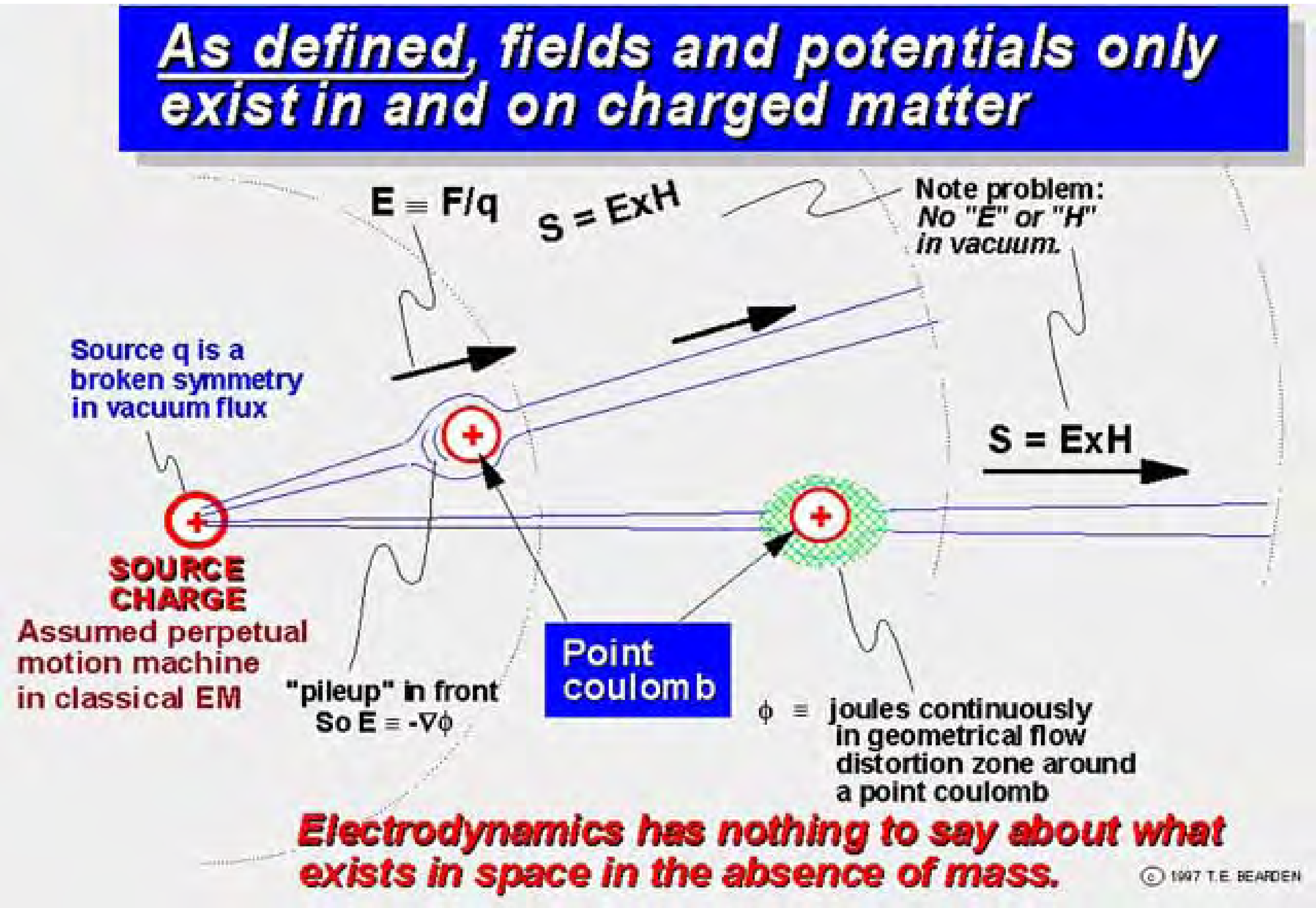

As defined, fields and potentials only exist in and on charged matter

$E \equiv F/q$

$S = E \times H$

Note problem:
No "E" or "H" in vacuum.

Source q is a broken symmetry in vacuum flux

$S = E \times H$

SOURCE CHARGE

Assumed perpetual motion machine in classical EM

"pileup" in front
So $E \equiv -\nabla\phi$

Point coulomb

$\phi \equiv$ joules continuously in geometrical flow distortion zone around a point coulomb

Electrodynamics has nothing to say about what exists in space in the absence of mass.

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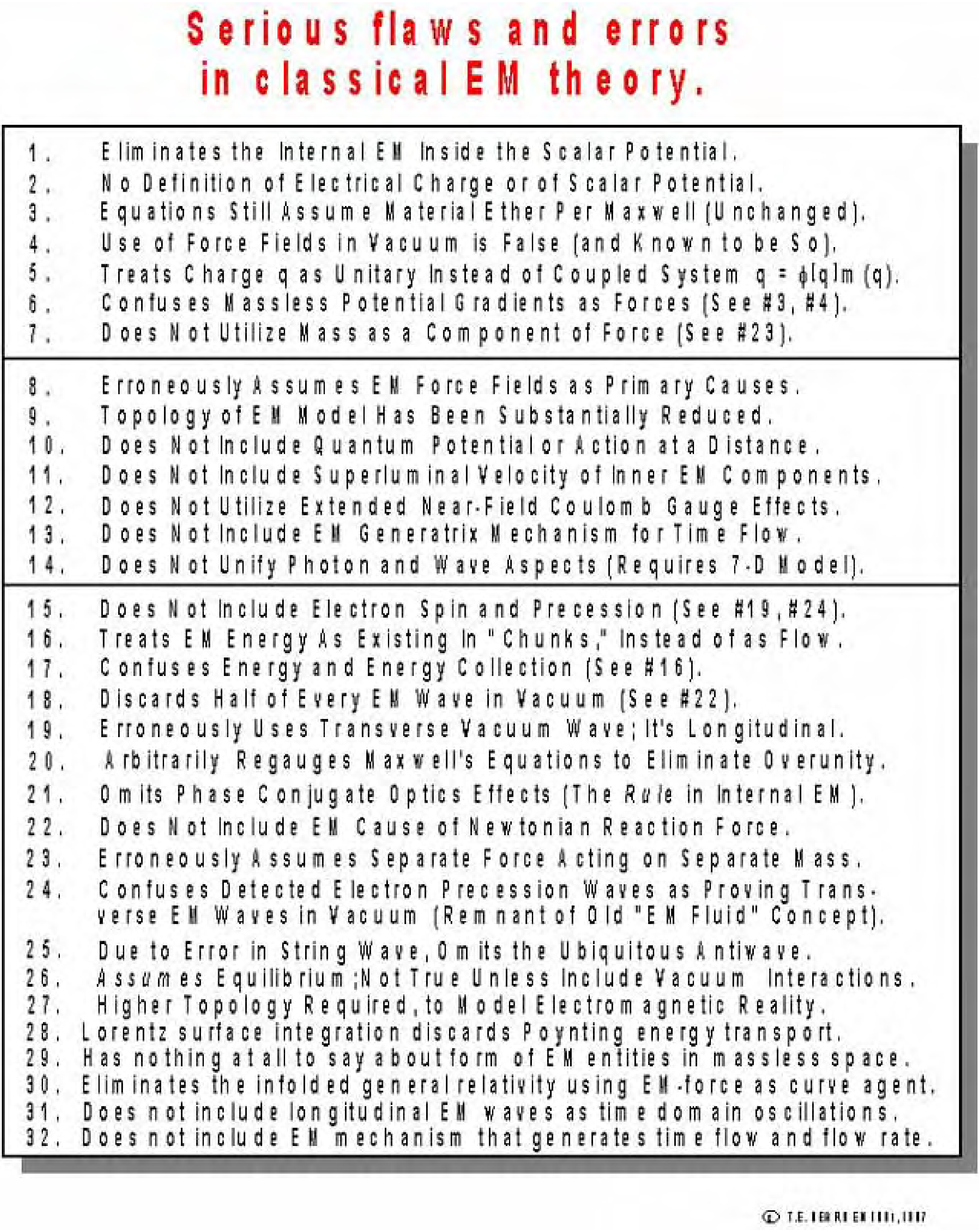

Serious flaws and errors in classical EM theory.

1. Eliminates the Internal EM Inside the Scalar Potential.
2. No Definition of Electrical Charge or of Scalar Potential.
3. Equations Still Assume Material Ether Per Maxwell (Unchanged).
4. Use of Force Fields in Vacuum is False (and Known to be So).
5. Treats Charge q as Unitary Instead of Coupled System $q = \phi[q]m(q)$.
6. Confuses Massless Potential Gradients as Forces (See #3, #4).
7. Does Not Utilize Mass as a Component of Force (See #23).
8. Erroneously Assumes EM Force Fields as Primary Causes.
9. Topology of EM Model Has Been Substantially Reduced.
10. Does Not Include Quantum Potential or Action at a Distance.
11. Does Not Include Superluminal Velocity of Inner EM Components.
12. Does Not Utilize Extended Near-Field Coulomb Gauge Effects.
13. Does Not Include EM Generatrix Mechanism for Time Flow.
14. Does Not Unify Photon and Wave Aspects (Requires 7-D Model).
15. Does Not Include Electron Spin and Precession (See #19, #24).
16. Treats EM Energy As Existing In "Chunks," Instead of as Flow.
17. Confuses Energy and Energy Collection (See #16).
18. Discards Half of Every EM Wave in Vacuum (See #22).
19. Erroneously Uses Transverse Vacuum Wave; It's Longitudinal.
20. Arbitrarily Regauges Maxwell's Equations to Eliminate Overunity.
21. Omits Phase Conjugate Optics Effects (The *Rule* in Internal EM).
22. Does Not Include EM Cause of Newtonian Reaction Force.
23. Erroneously Assumes Separate Force Acting on Separate Mass.
24. Confuses Detected Electron Precession Waves as Proving Transverse EM Waves in Vacuum (Remnant of Old "EM Fluid" Concept).
25. Due to Error in String Wave, Omits the Ubiquitous Antiwave.
26. *Assumes* Equilibrium; Not True Unless Include Vacuum Interactions.
27. Higher Topology Required, to Model Electromagnetic Reality.
28. Lorentz surface integration discards Poynting energy transport.
29. Has nothing at all to say about form of EM entities in massless space.
30. Eliminates the infolded general relativity using EM-force as curve agent.
31. Does not include longitudinal EM waves as time domain oscillations.
32. Does not include EM mechanism that generates time flow and flow rate.

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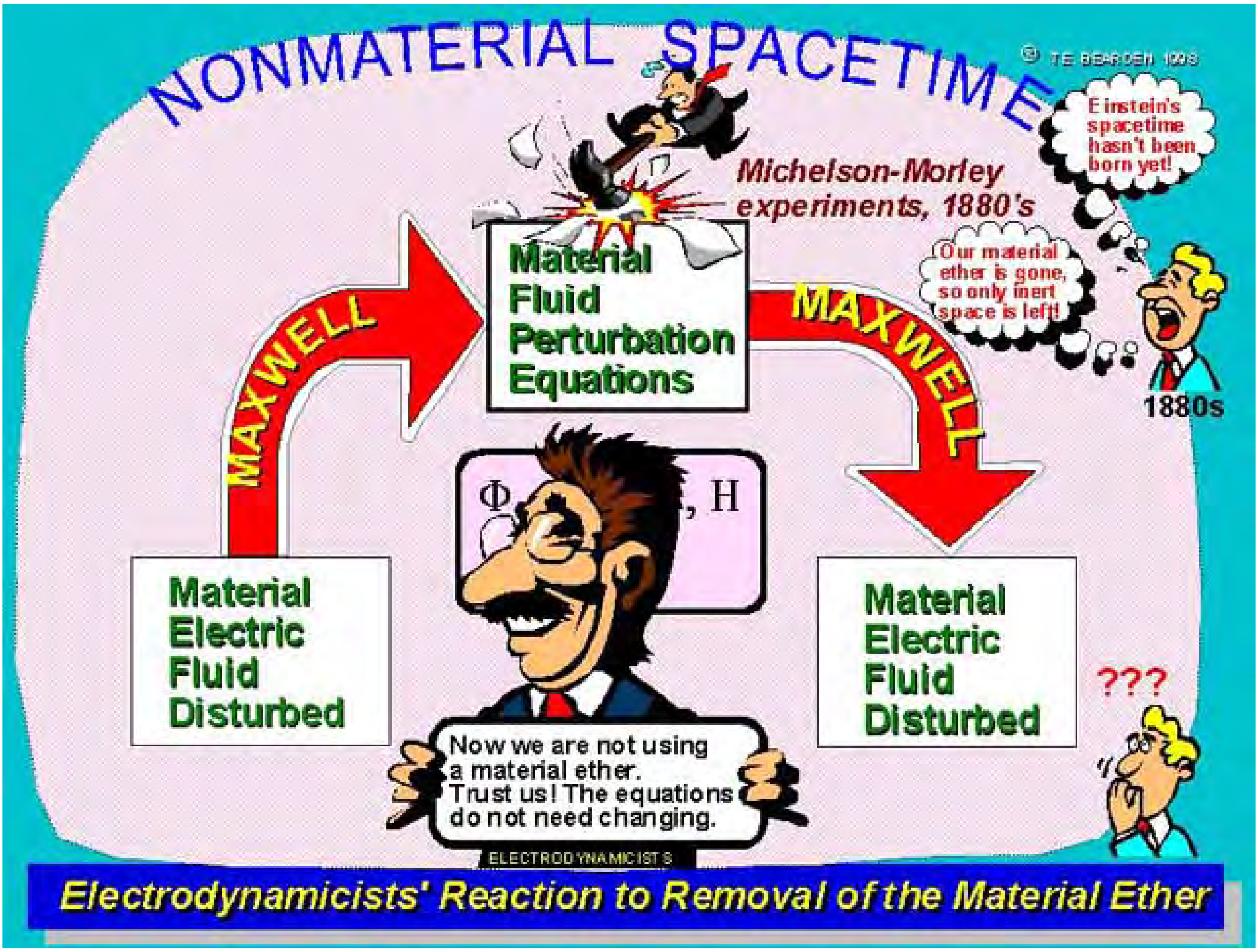
NONMATERIAL SPACETIME
© T.E. BEARDEN 1998
Einstein's spacetime hasn't been born yet!
Michelson-Morley experiments, 1880's
Our material ether is gone, so only inert space is left!
1880s
MAXWELL
Material Fluid Perturbation Equations
MAXWELL
Φ
, H
Material Electric Fluid Disturbed
Material Electric Fluid Disturbed
???
Now we are not using a material ether. Trust us! The equations do not need changing.
ELECTRODYNAMICISTS

Electrodynamicists' Reaction to Removal of the Material Ether

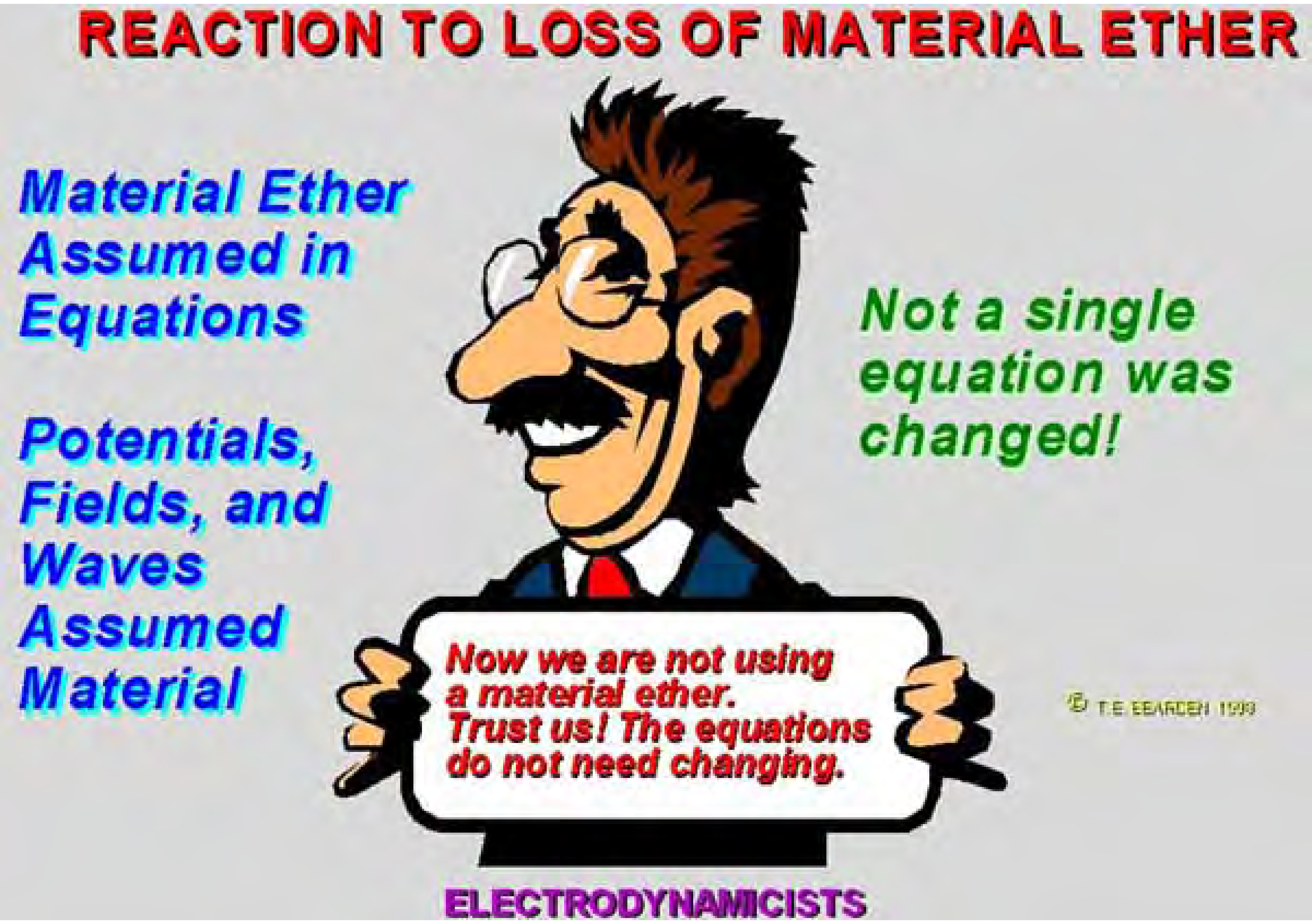

REACTION TO LOSS OF MATERIAL ETHER

Material Ether
Assumed in
Equations

Potentials,
Fields, and
Waves
Assumed
Material

Not a single
equation was
changed!

Now we are not using
a material ether.
Trust us! The equations
do not need changing.

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ELECTRODYNAMICISTS

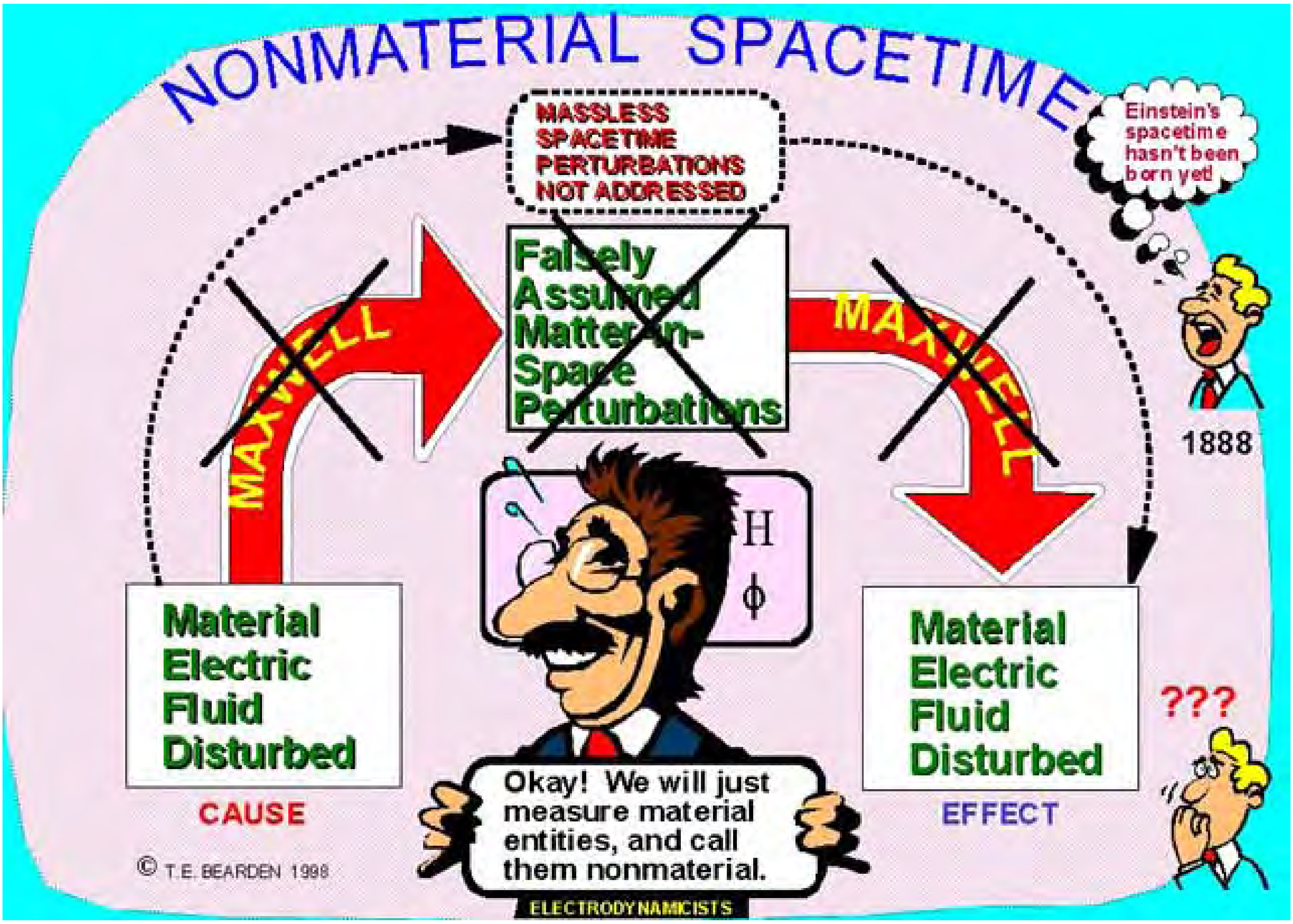
NONMATERIAL SPACETIME
MASSLESS SPACETIME PERTURBATIONS NOT ADDRESSED
Einstein's spacetime hasn't been born yet!
Falsely Assumed Matter-in-Space Perturbations
MAXWELL
MAXWELL
1888
H
ϕ
Material Electric Fluid Disturbed
CAUSE
Material Electric Fluid Disturbed
EFFECT
???
Okay! We will just measure material entities, and call them nonmaterial.
ELECTRODYNAMICISTS
© T.E. BEARDEN 1998

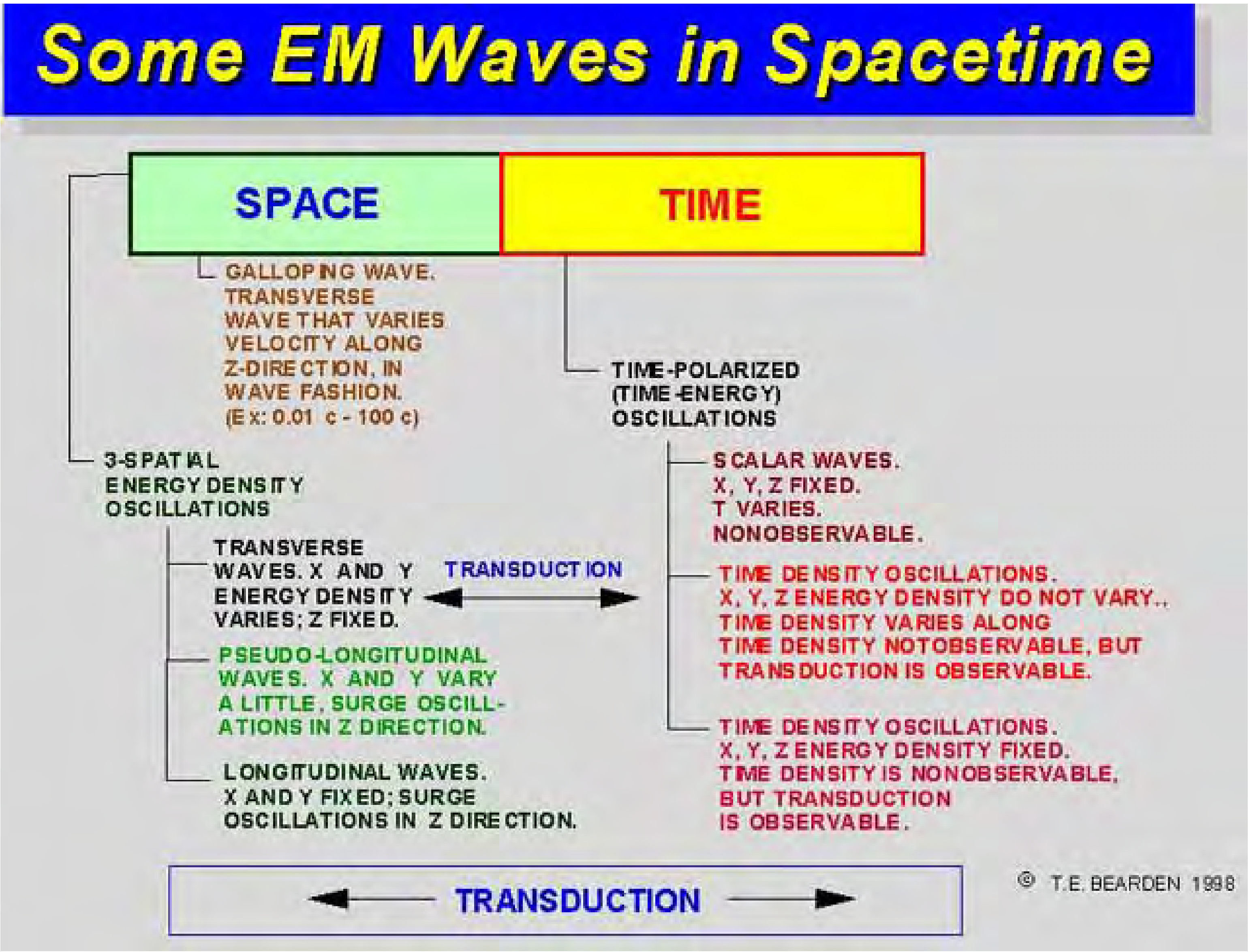

Some EM Waves in Spacetime

SPACE

TIME

GALLOPING WAVE. TRANSVERSE WAVE THAT VARIES VELOCITY ALONG Z-DIRECTION, IN WAVE FASHION. (Ex: 0.01 c - 100 c)

TIME-POLARIZED (TIME-ENERGY) OSCILLATIONS

3-SPATIAL ENERGY DENSITY OSCILLATIONS

SCALAR WAVES. X, Y, Z FIXED. T VARIES. NONOBSERVABLE.

TRANSVERSE WAVES. X AND Y ENERGY DENSITY VARIES; Z FIXED.

TRANSDUCTION

TIME DENSITY OSCILLATIONS. X, Y, Z ENERGY DENSITY DO NOT VARY.. TIME DENSITY VARIES ALONG TIME DENSITY NOTOBSERVABLE, BUT TRANSDUCTION IS OBSERVABLE.

PSEUDO-LONGITUDINAL WAVES. X AND Y VARY A LITTLE, SURGE OSCILLATIONS IN Z DIRECTION.

TIME DENSITY OSCILLATIONS. X, Y, Z ENERGY DENSITY FIXED. TIME DENSITY IS NONOBSERVABLE, BUT TRANSDUCTION IS OBSERVABLE.

LONGITUDINAL WAVES. X AND Y FIXED; SURGE OSCILLATIONS IN Z DIRECTION.

TRANSDUCTION

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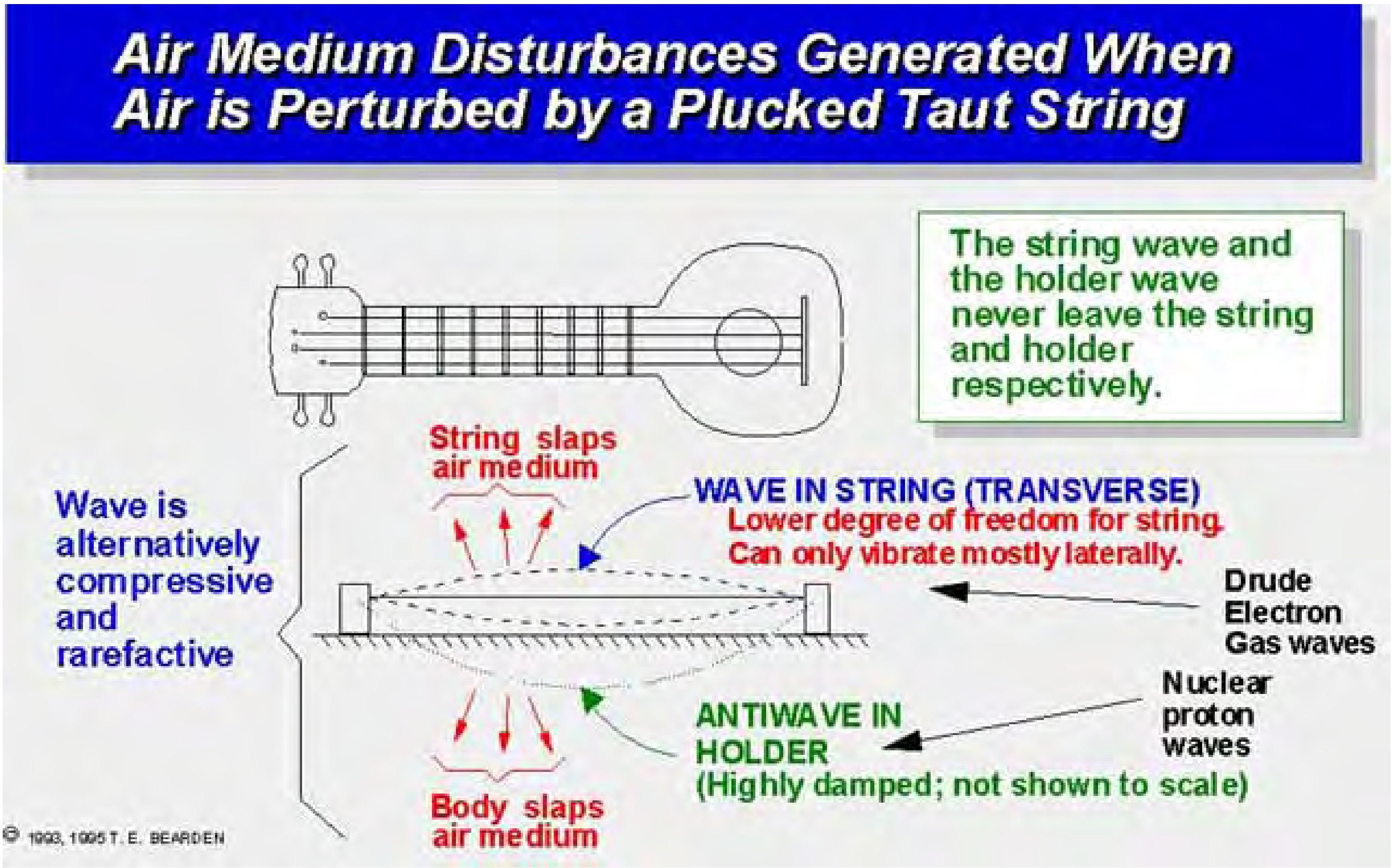

Air Medium Disturbances Generated When Air is Perturbed by a Plucked Taut String

The string wave and the holder wave never leave the string and holder respectively.

String slaps air medium

Wave is alternatively compressive and rarefactive

WAVE IN STRING (TRANSVERSE)

Lower degree of freedom for string. Can only vibrate mostly laterally.

Drude Electron Gas waves

Nuclear proton waves

ANTIWAVE IN HOLDER (Highly damped; not shown to scale)

Body slaps air medium

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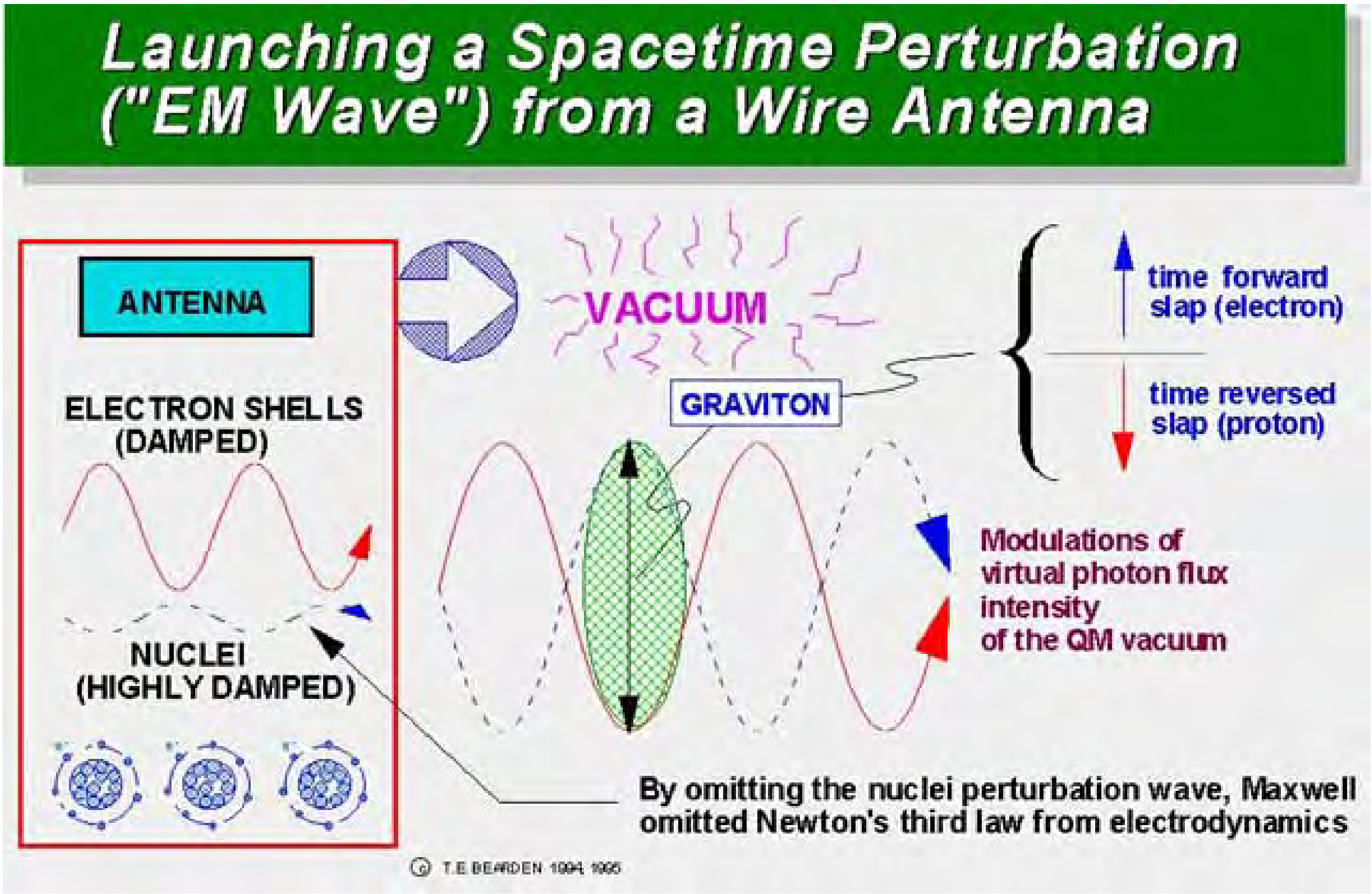

Launching a Spacetime Perturbation ("EM Wave") from a Wire Antenna

ANTENNA
ELECTRON SHELLS (DAMPED)
NUCLEI (HIGHLY DAMPED)
VACUUM
GRAVITON
time forward slap (electron)
time reversed slap (proton)

Modulations of virtual photon flux intensity of the QM vacuum

By omitting the nuclei perturbation wave, Maxwell omitted Newton's third law from electrodynamics

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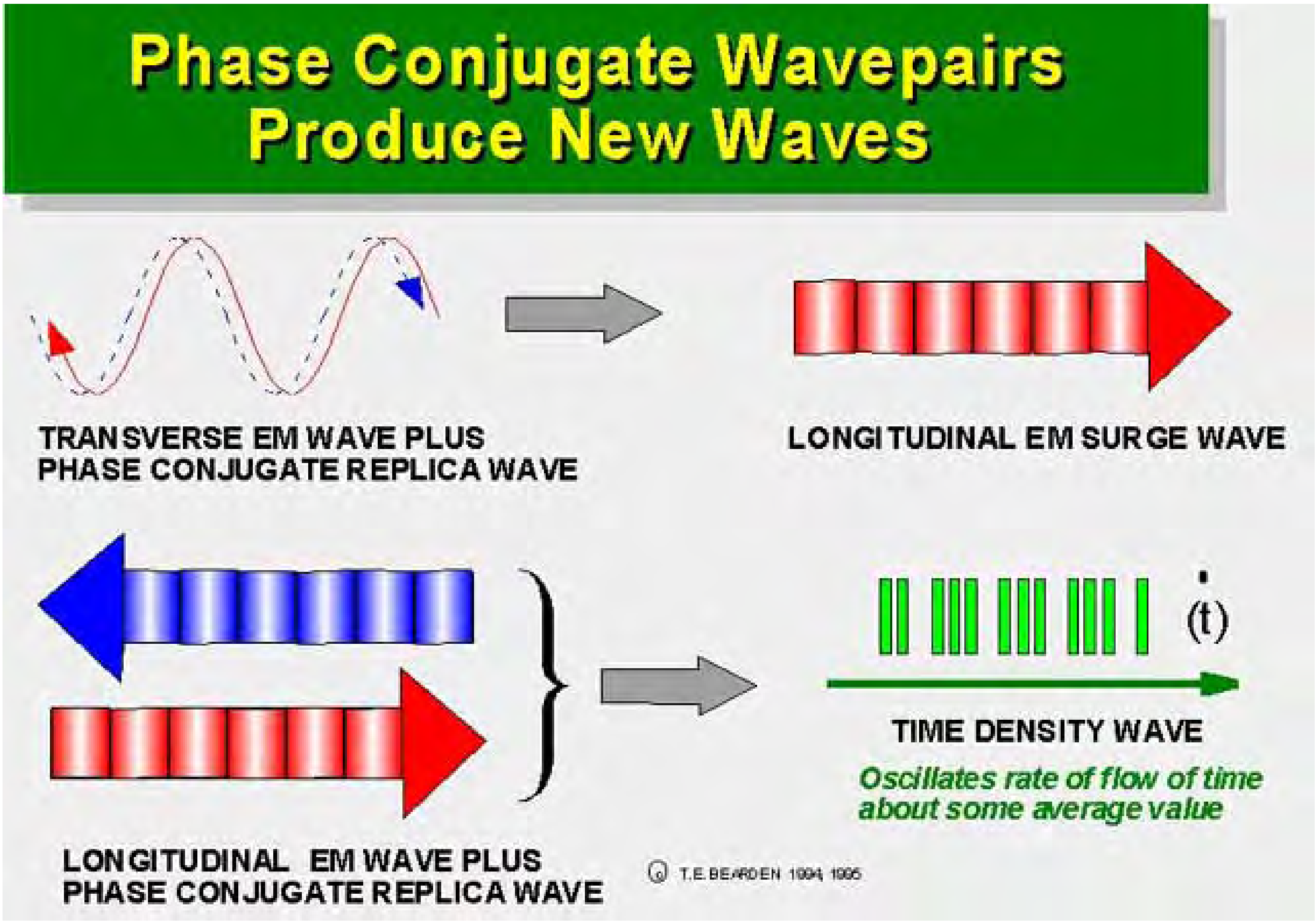

Phase Conjugate Wavepairs Produce New Waves

TRANSVERSE EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE

LONGITUDINAL EM SURGE WAVE

LONGITUDINAL EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE

($\dot{t}$)

TIME DENSITY WAVE

*Oscillates rate of flow of time
about some average value*

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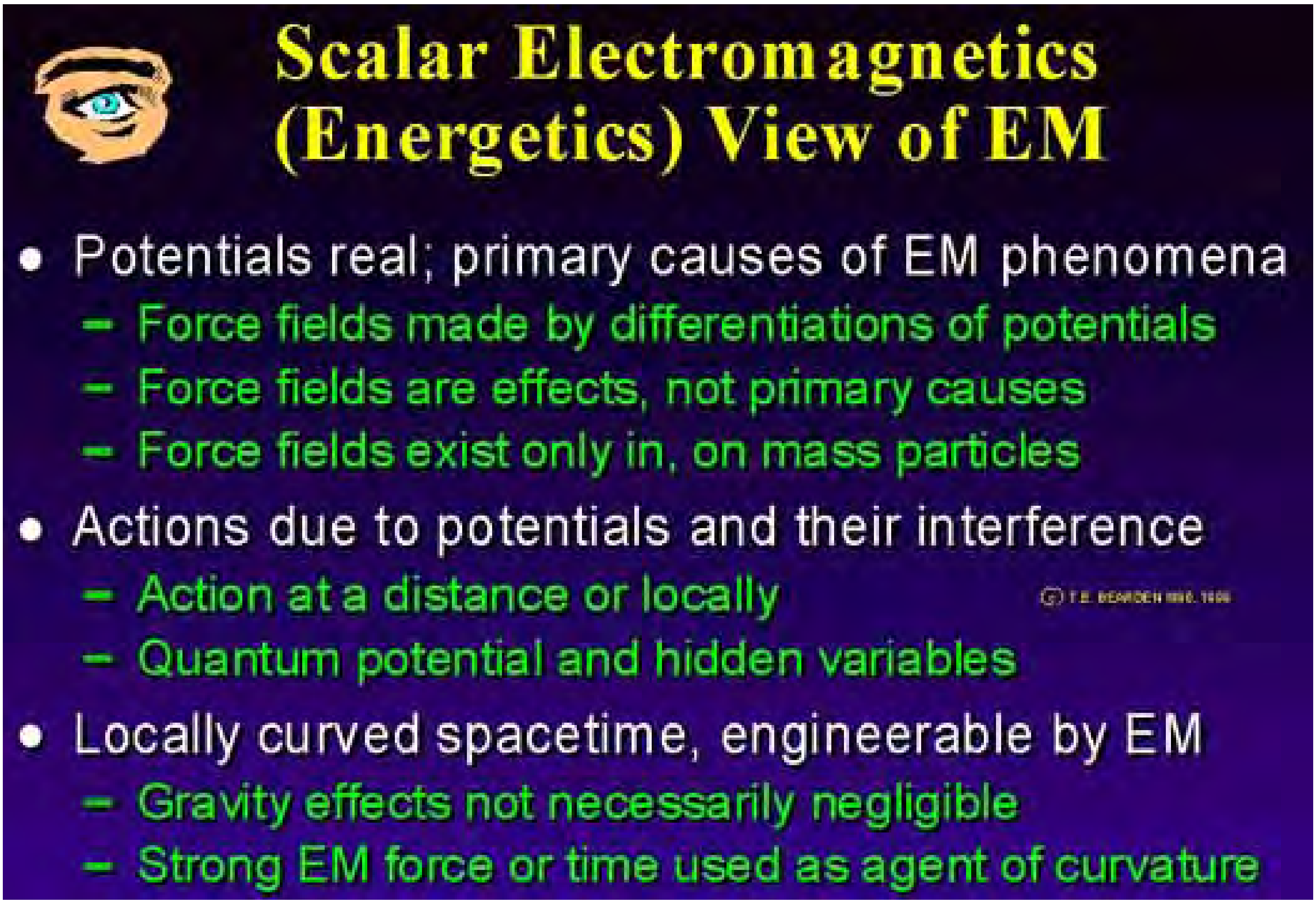

Scalar Electromagnetics (Energetics) View of EM

- Potentials real; primary causes of EM phenomena
  - Force fields made by differentiations of potentials
  - Force fields are effects, not primary causes
  - Force fields exist only in, on mass particles
- Actions due to potentials and their interference
  - Action at a distance or locally
  - Quantum potential and hidden variables
- Locally curved spacetime, engineerable by EM
  - Gravity effects not necessarily negligible
  - Strong EM force or time used as agent of curvature

© T.E. BEARDEN [illegible]

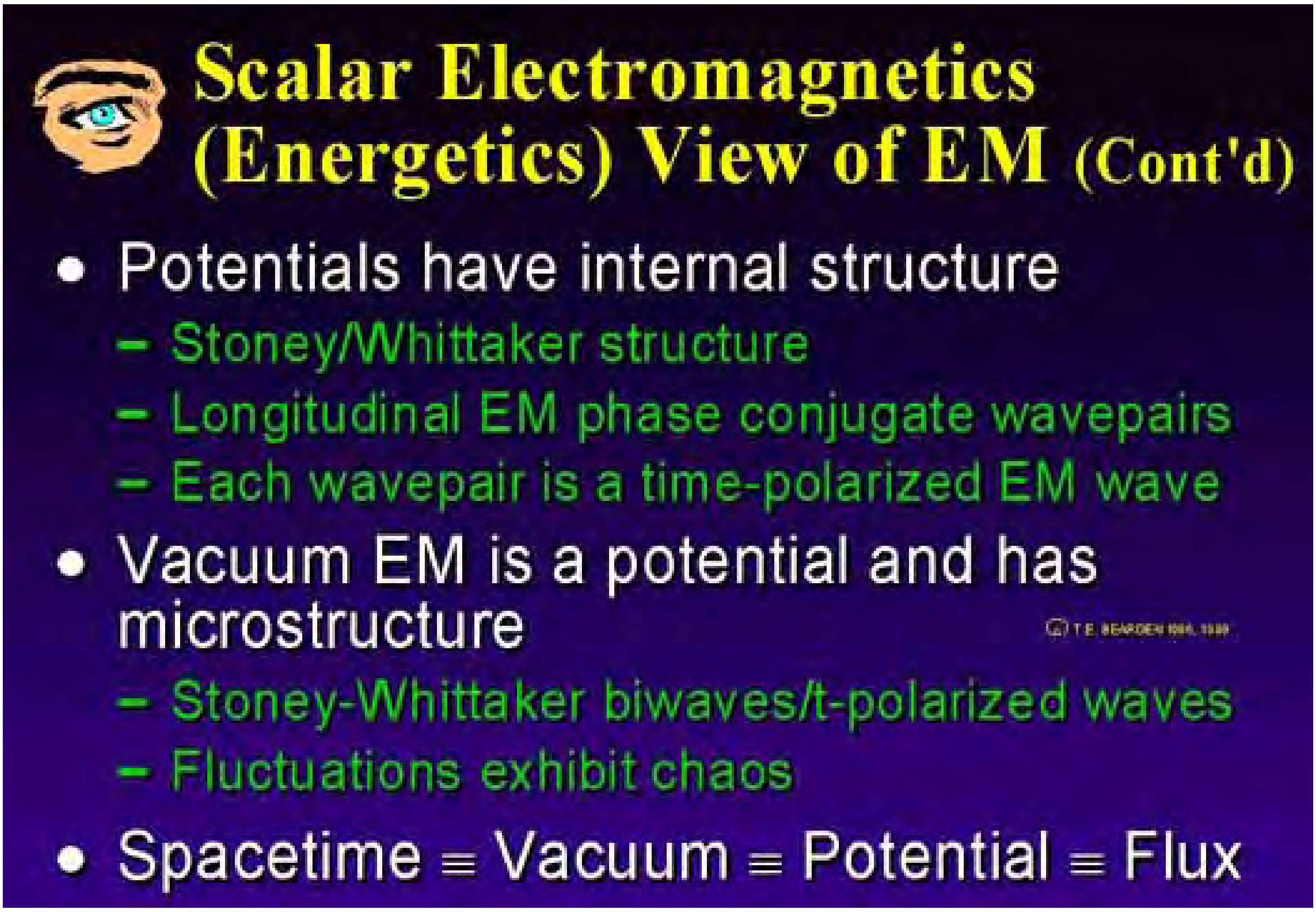

Scalar Electromagnetics (Energetics) View of EM (Cont'd)

- Potentials have internal structure
  - Stoney/Whittaker structure
  - Longitudinal EM phase conjugate wavepairs
  - Each wavepair is a time-polarized EM wave
- Vacuum EM is a potential and has microstructure
  - Stoney-Whittaker biwaves/t-polarized waves
  - Fluctuations exhibit chaos
- Spacetime ≡ Vacuum ≡ Potential ≡ Flux

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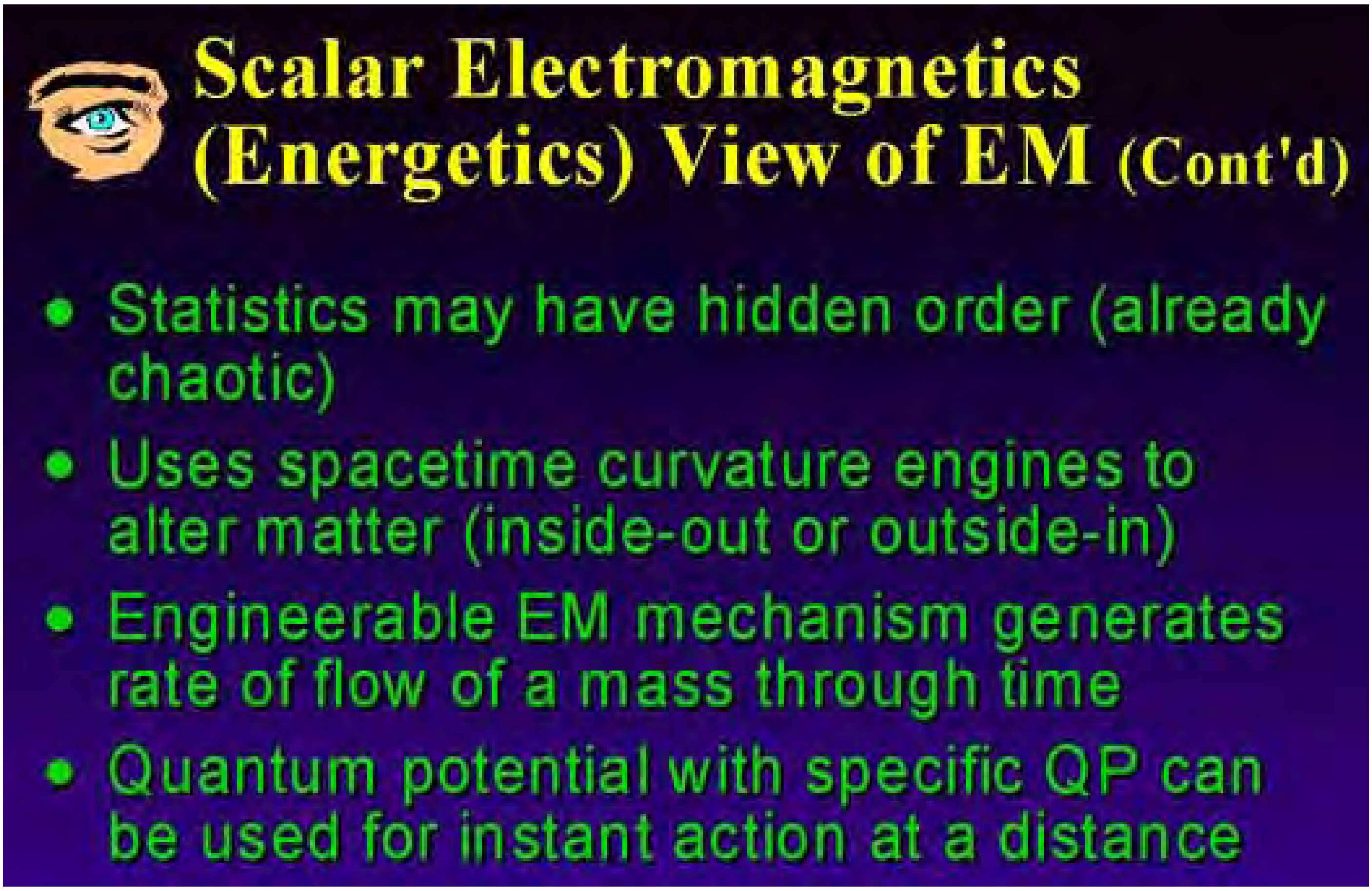

Scalar Electromagnetics (Energetics) View of EM (Cont'd)

- Statistics may have hidden order (already chaotic)
- Uses spacetime curvature engines to alter matter (inside-out or outside-in)
- Engineerable EM mechanism generates rate of flow of a mass through time
- Quantum potential with specific QP can be used for instant action at a distance

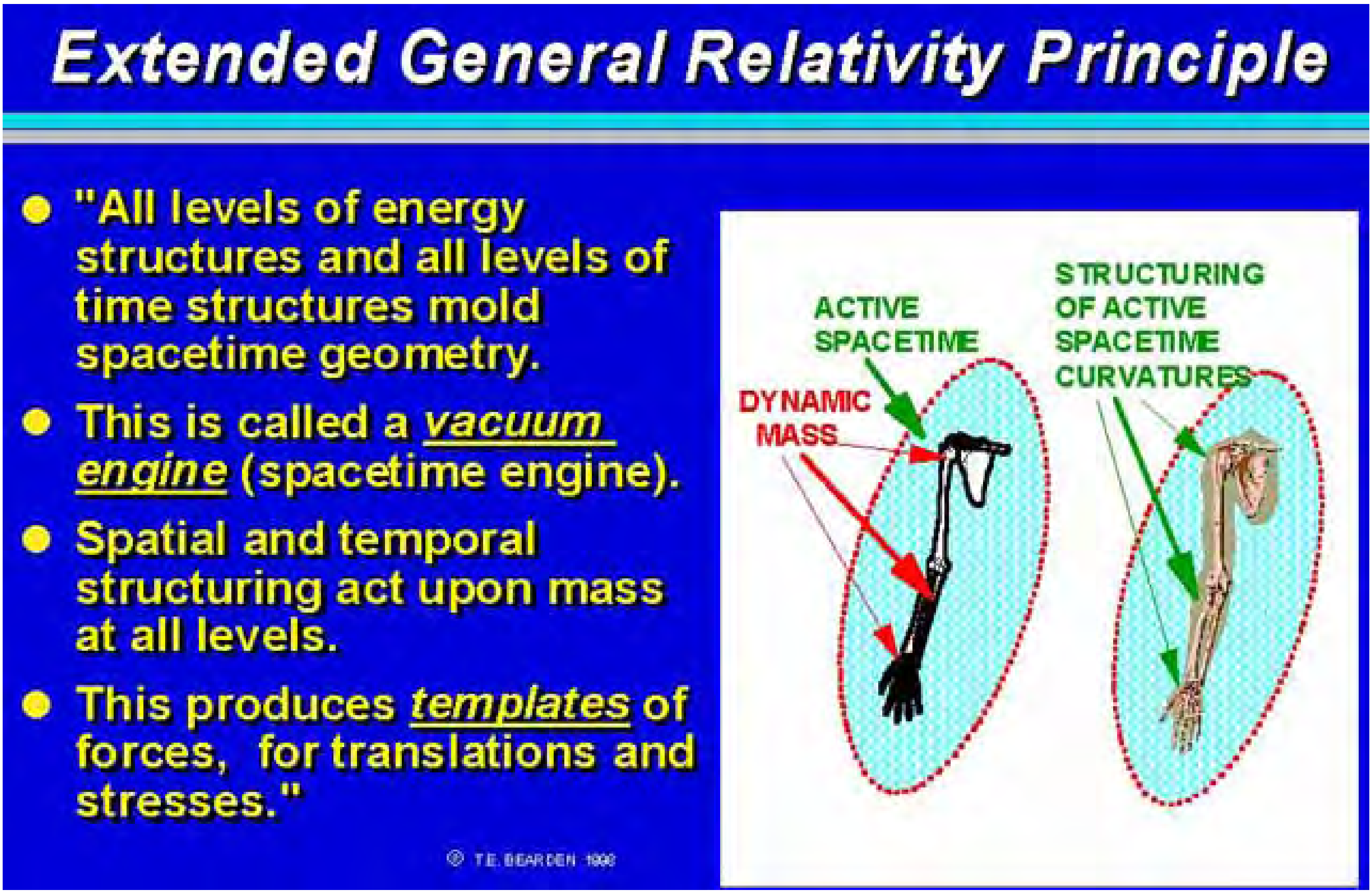

Extended General Relativity Principle

- "All levels of energy structures and all levels of time structures mold spacetime geometry.
- This is called a *vacuum engine* (spacetime engine).
- Spatial and temporal structuring act upon mass at all levels.
- This produces *templates* of forces, for translations and stresses."

ACTIVE SPACETIME
STRUCTURING OF ACTIVE SPACETIME CURVATURES
DYNAMIC MASS

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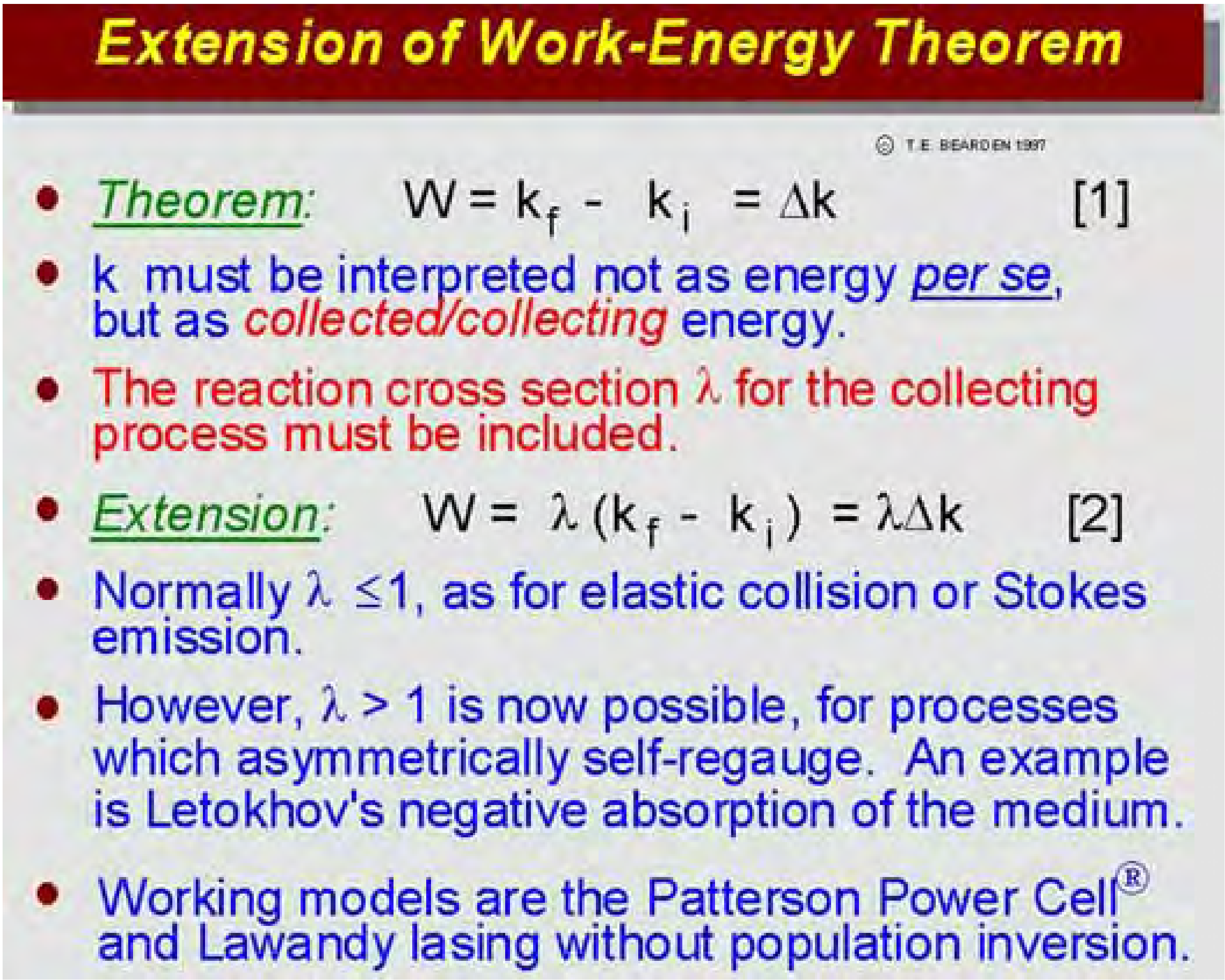

Extension of Work-Energy Theorem

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- *Theorem*: $W = k_f - k_i = \Delta k$ [1]
- k must be interpreted not as energy *per se*, but as *collected/collecting* energy.
- The reaction cross section λ for the collecting process must be included.
- *Extension*: $W = \lambda (k_f - k_i) = \lambda\Delta k$ [2]
- Normally $\lambda \leq 1$, as for elastic collision or Stokes emission.
- However, $\lambda > 1$ is now possible, for processes which asymmetrically self-regauge. An example is Letokhov's negative absorption of the medium.
- Working models are the Patterson Power Cell® and Lawandy lasing without population inversion.

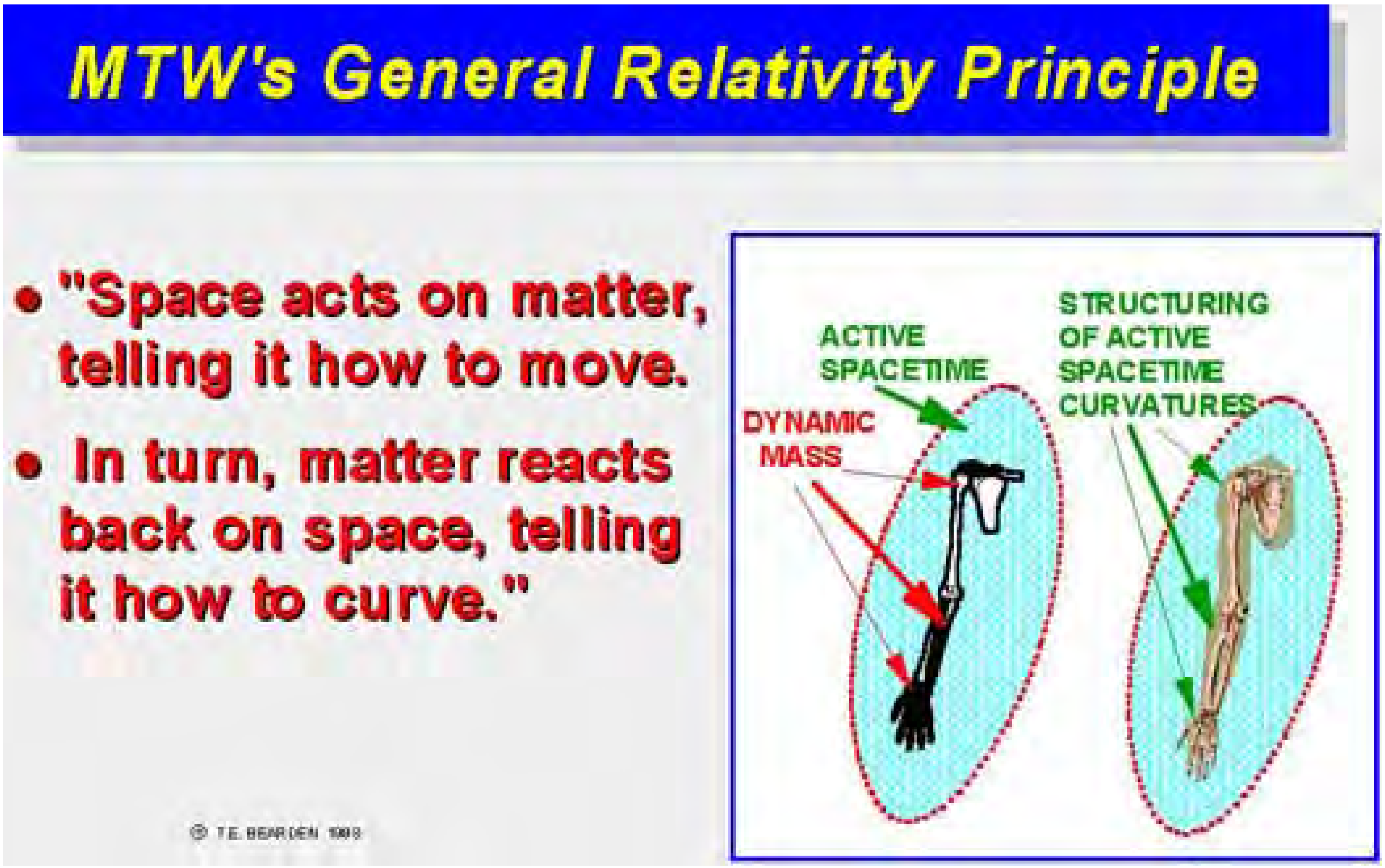

MTW's General Relativity Principle

- "Space acts on matter, telling it how to move.
- In turn, matter reacts back on space, telling it how to curve."

ACTIVE SPACETIME
STRUCTURING OF ACTIVE SPACETIME CURVATURES
DYNAMIC MASS

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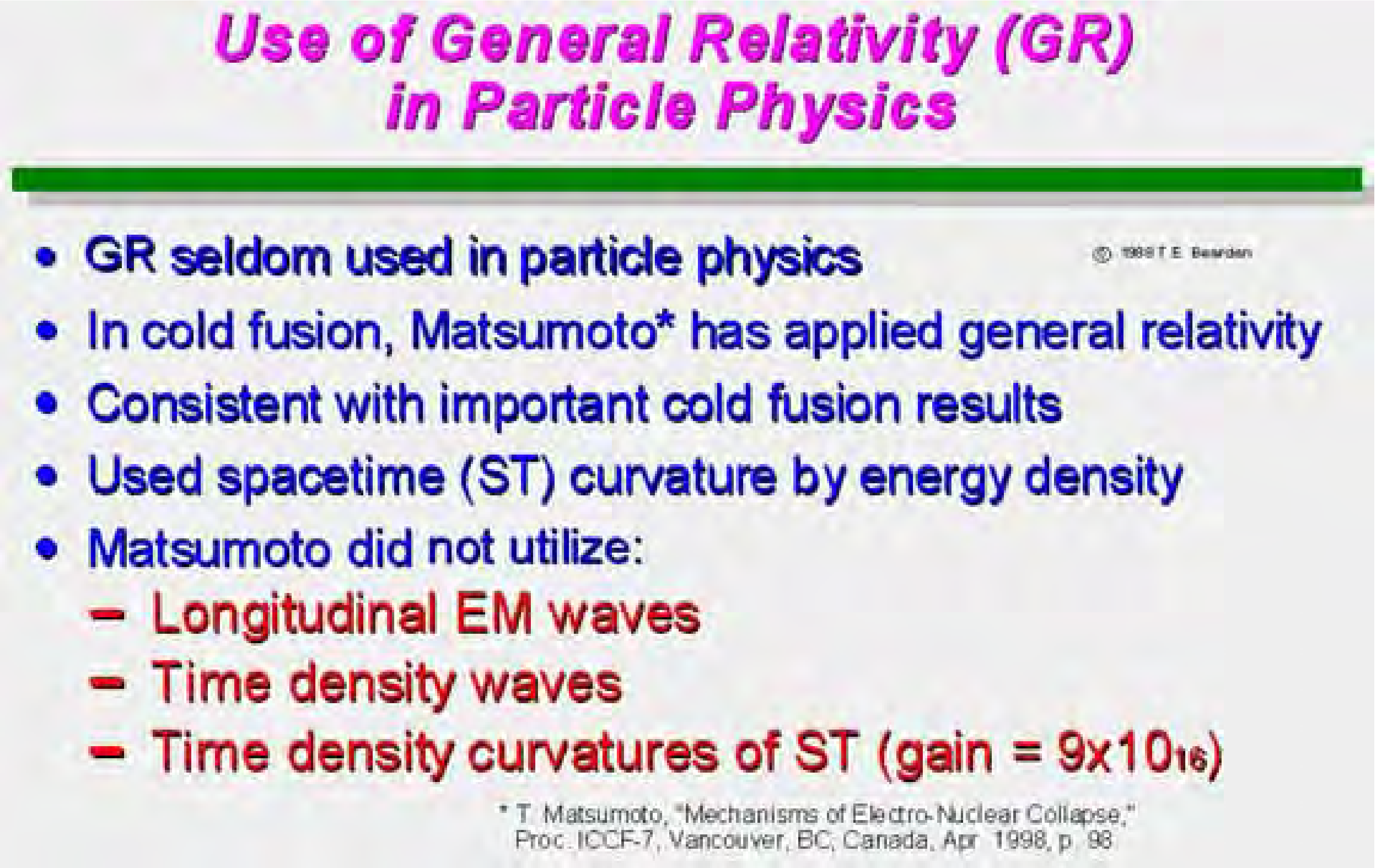

Use of General Relativity (GR) in Particle Physics

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- GR seldom used in particle physics
- In cold fusion, Matsumoto* has applied general relativity
- Consistent with important cold fusion results
- Used spacetime (ST) curvature by energy density
- Matsumoto did not utilize:
  - Longitudinal EM waves
  - Time density waves
  - Time density curvatures of ST (gain = $9x10_{16}$)

* T. Matsumoto, "Mechanisms of Electro-Nuclear Collapse," Proc. ICCF-7, Vancouver, BC, Canada, Apr. 1998, p. 98.

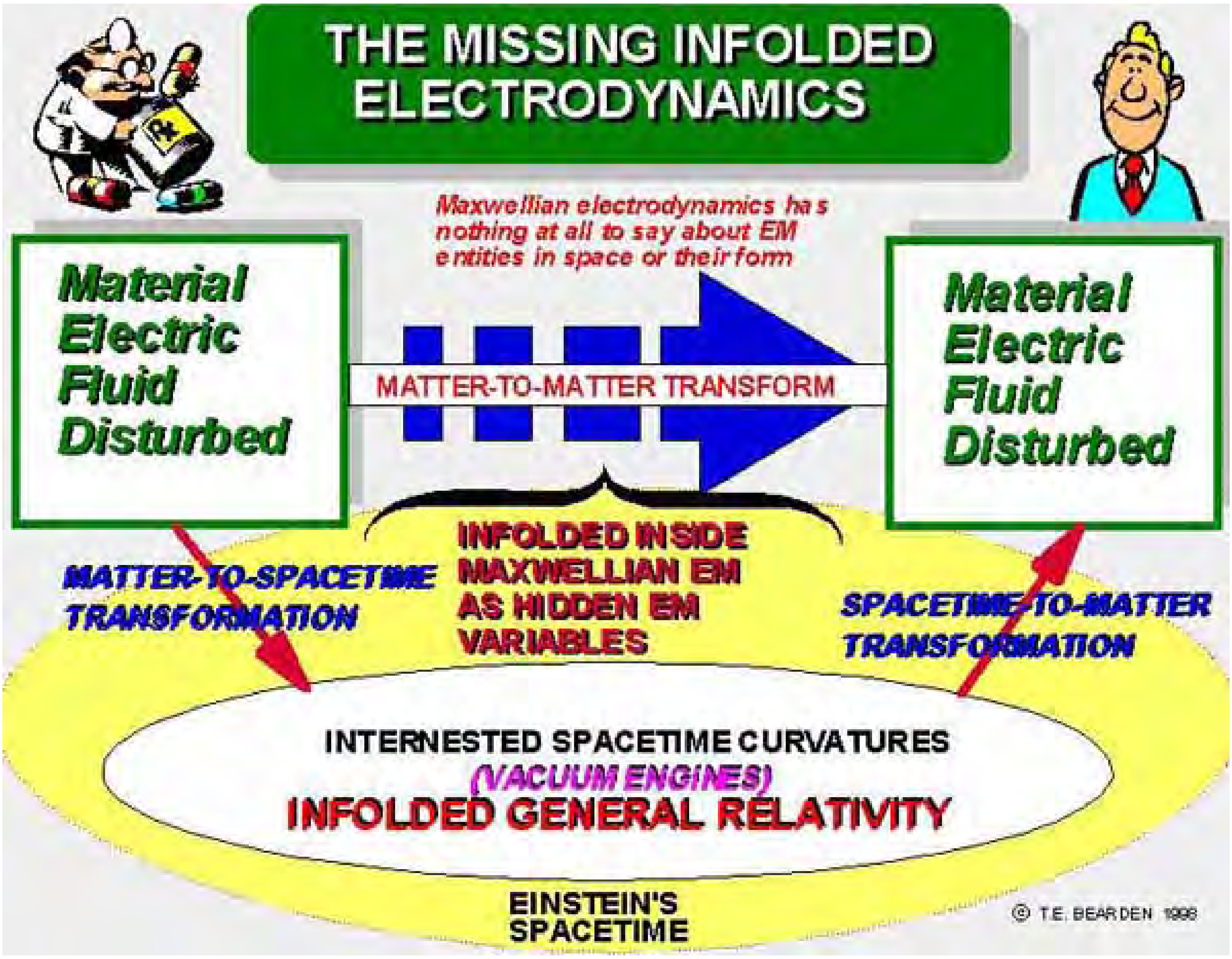

THE MISSING INFOLDED ELECTRODYNAMICS

Material Electric Fluid Disturbed

Maxwellian electrodynamics has nothing at all to say about EM entities in space or their form

MATTER-TO-MATTER TRANSFORM

Material Electric Fluid Disturbed

MATTER-TO-SPACETIME TRANSFORMATION

INFOLDED INSIDE MAXWELLIAN EM AS HIDDEN EM VARIABLES

SPACETIME-TO-MATTER TRANSFORMATION

INTERNESTED SPACETIME CURVATURES

(VACUUM ENGINES)

INFOLDED GENERAL RELATIVITY

EINSTEIN'S SPACETIME

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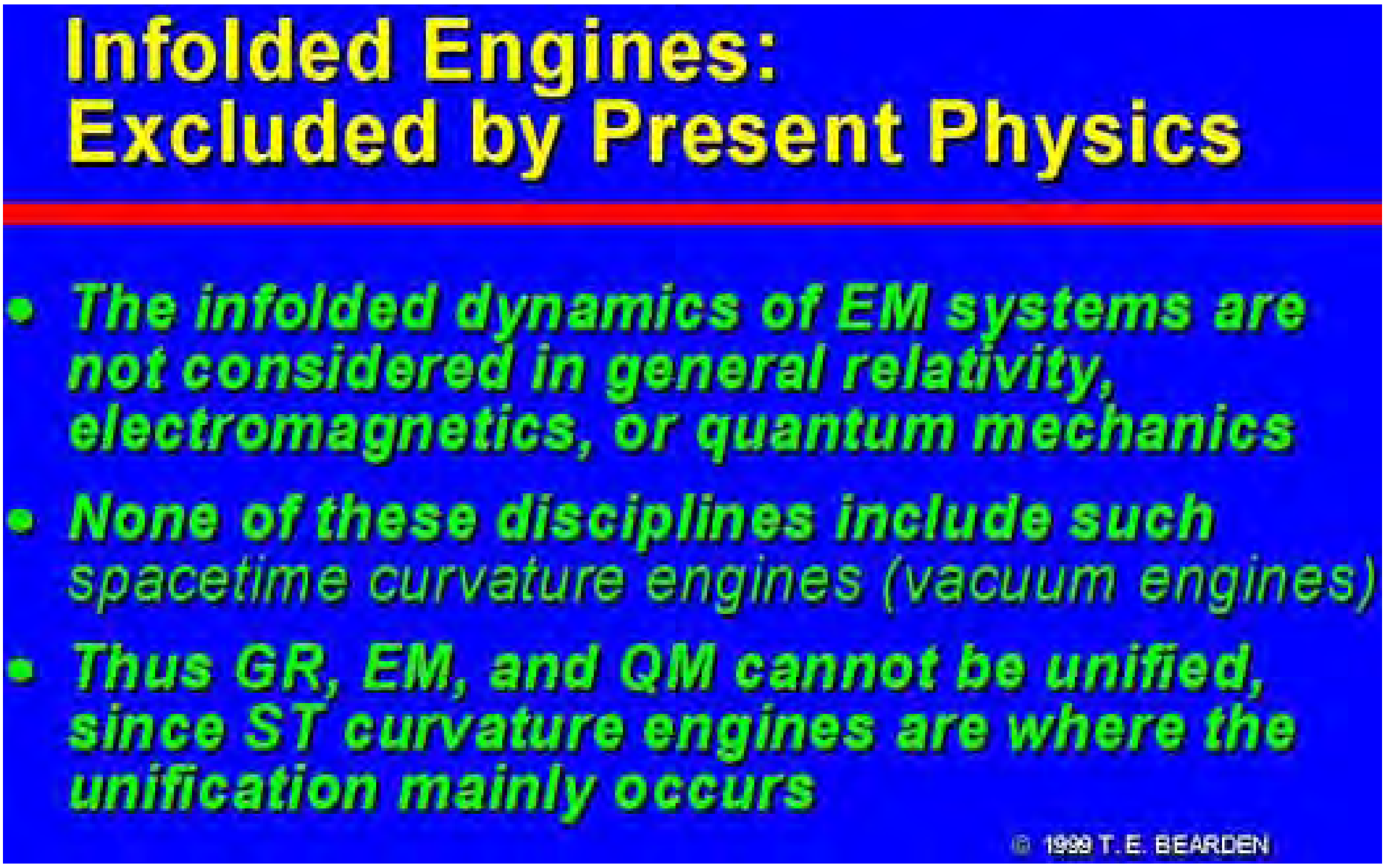

Infolded Engines: Excluded by Present Physics

- *The infolded dynamics of EM systems are not considered in general relativity, electromagnetics, or quantum mechanics*
- *None of these disciplines include such spacetime curvature engines (vacuum engines)*
- *Thus GR, EM, and QM cannot be unified, since ST curvature engines are where the unification mainly occurs*

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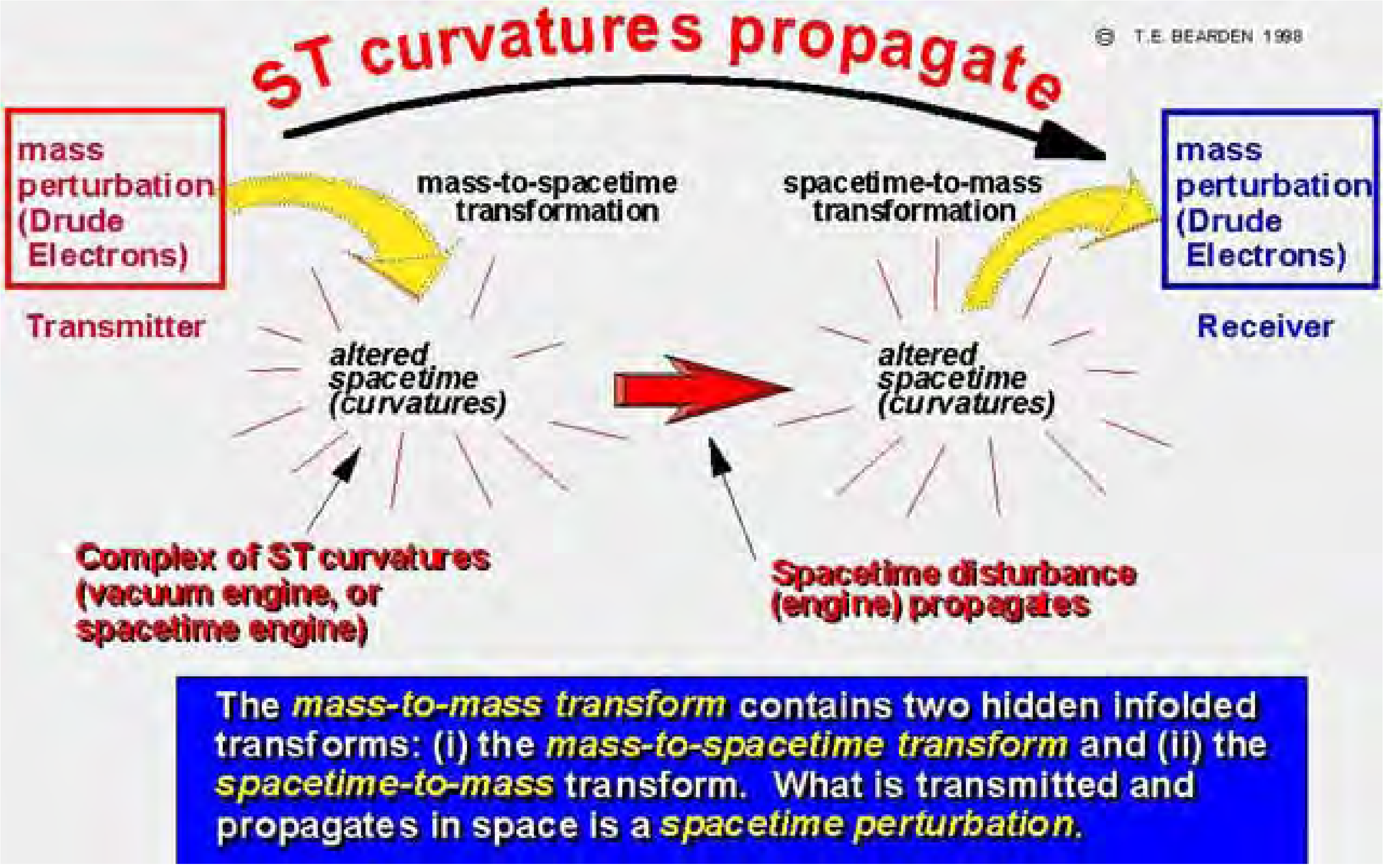

ST curvatures propagate

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mass perturbation (Drude Electrons)

Transmitter

mass-to-spacetime transformation

altered spacetime (curvatures)

Complex of ST curvatures (vacuum engine, or spacetime engine)

spacetime-to-mass transformation

altered spacetime (curvatures)

Spacetime disturbance (engine) propagates

mass perturbation (Drude Electrons)

Receiver

The *mass-to-mass transform* contains two hidden infolded transforms: (i) the *mass-to-spacetime transform* and (ii) the *spacetime-to-mass* transform. What is transmitted and propagates in space is a *spacetime perturbation.*

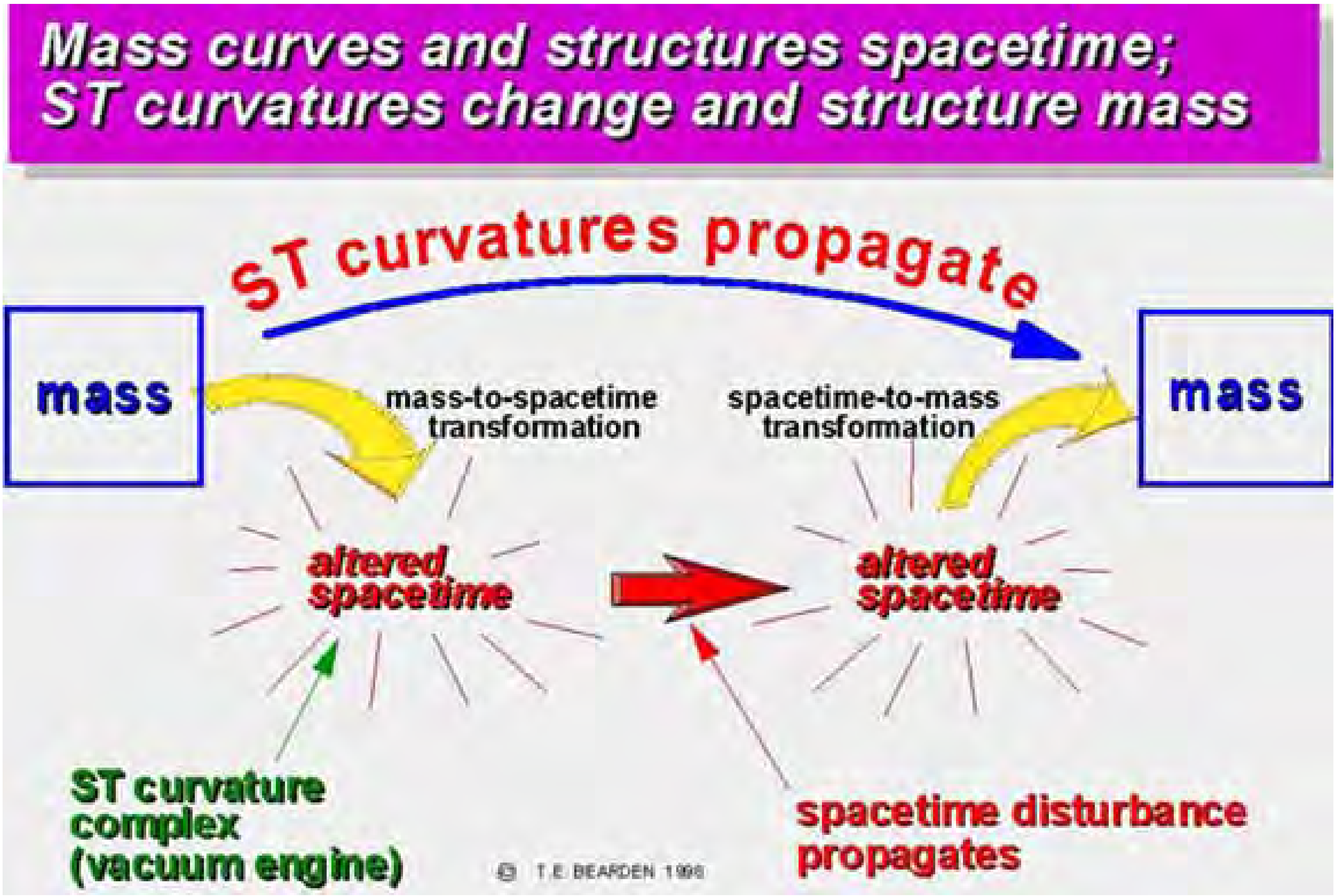

Mass curves and structures spacetime; ST curvatures change and structure mass

ST curvatures propagate

mass

mass-to-spacetime transformation

spacetime-to-mass transformation

mass

altered spacetime

altered spacetime

ST curvature complex (vacuum engine)

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spacetime disturbance propagates

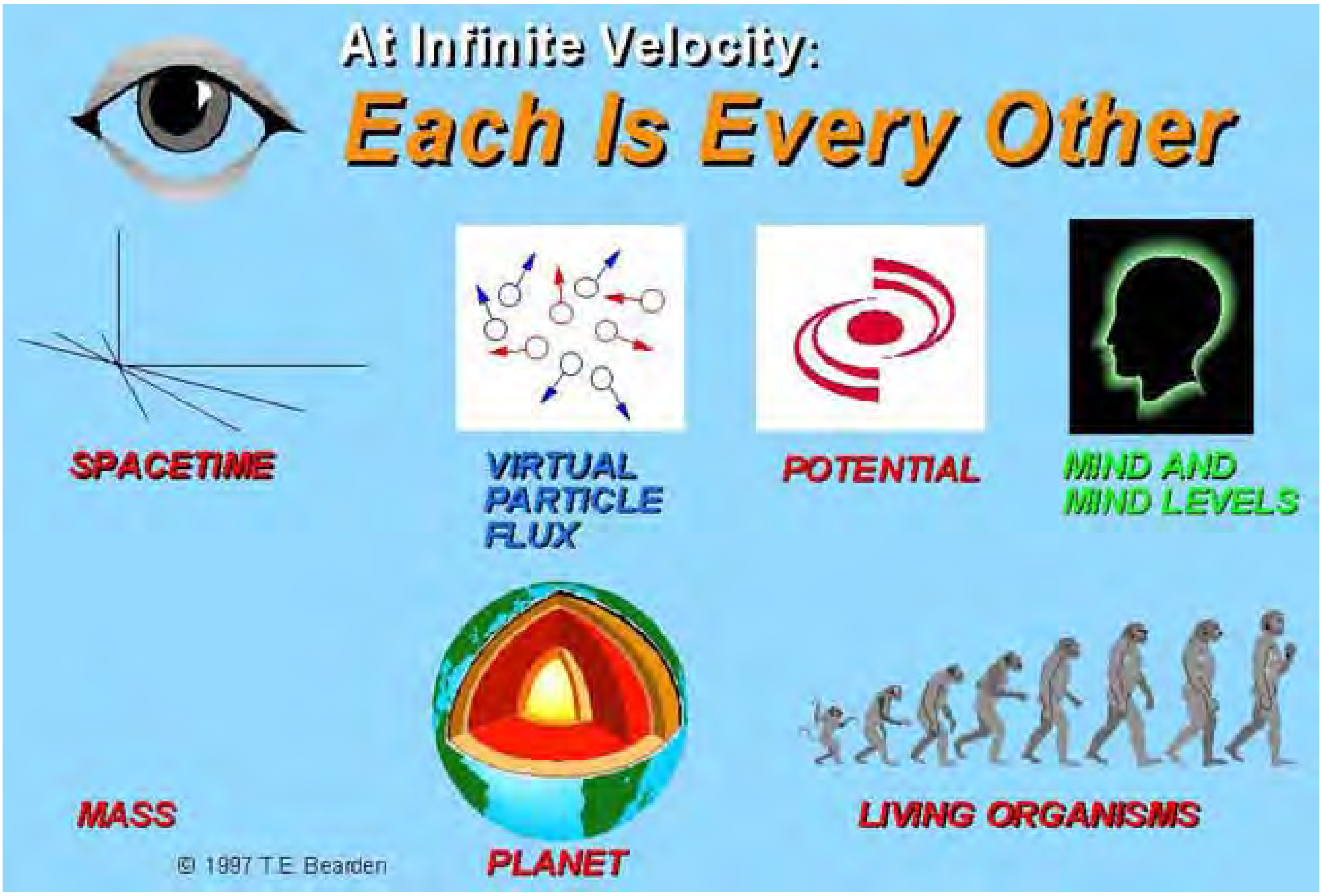

At Infinite Velocity:

Each Is Every Other

SPACETIME

VIRTUAL
PARTICLE
FLUX

POTENTIAL

MIND AND
MIND LEVELS

MASS

PLANET

LIVING ORGANISMS

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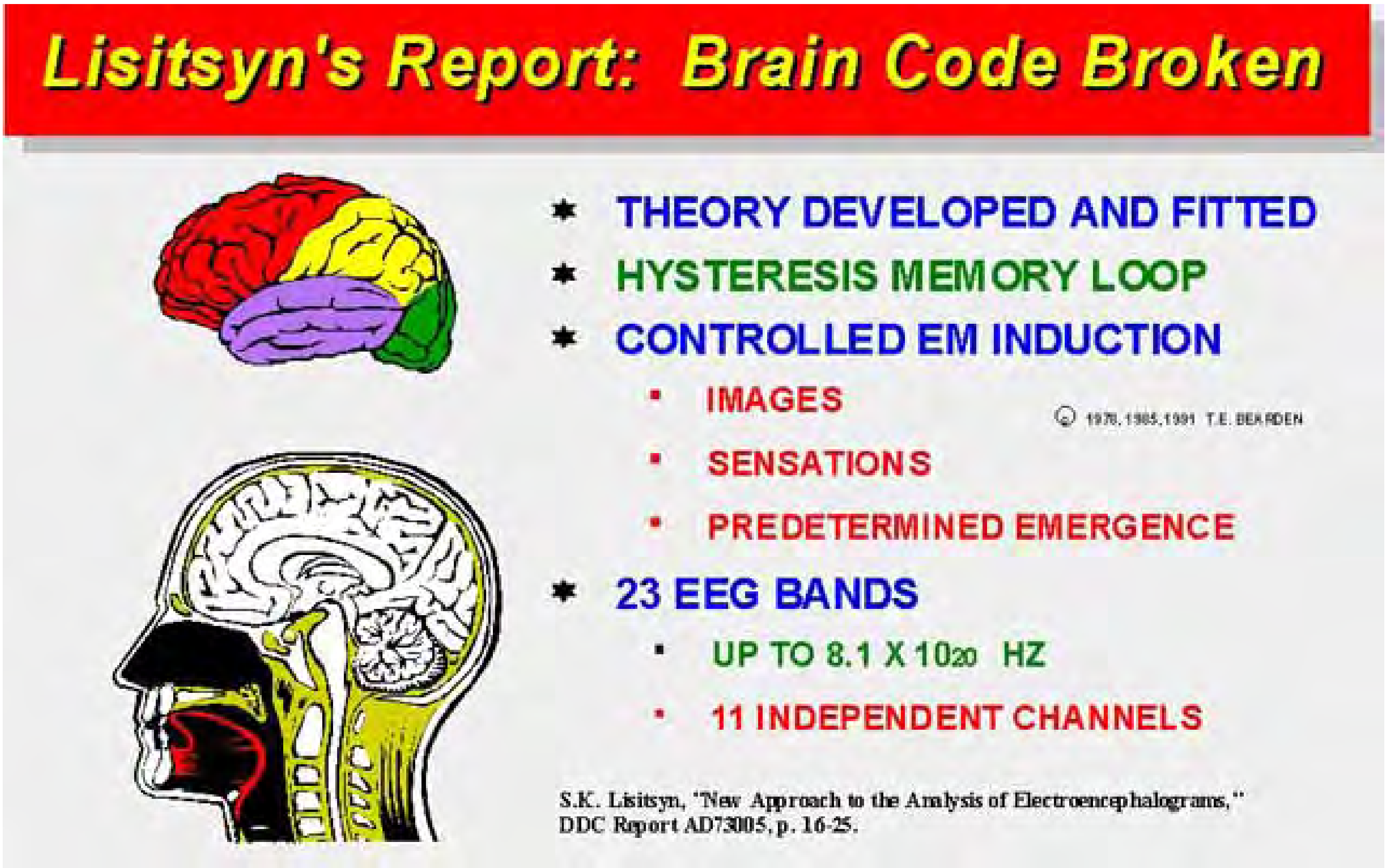

Lisitsyn's Report: Brain Code Broken

- THEORY DEVELOPED AND FITTED
- HYSTERESIS MEMORY LOOP
- CONTROLLED EM INDUCTION
  - IMAGES
  - SENSATIONS
  - PREDETERMINED EMERGENCE
- 23 EEG BANDS
  - UP TO 8.1 X 10^{20} HZ
  - 11 INDEPENDENT CHANNELS

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S.K. Lisitsyn, "New Approach to the Analysis of Electroencephalograms,"
DDC Report AD73005, p. 16-25.

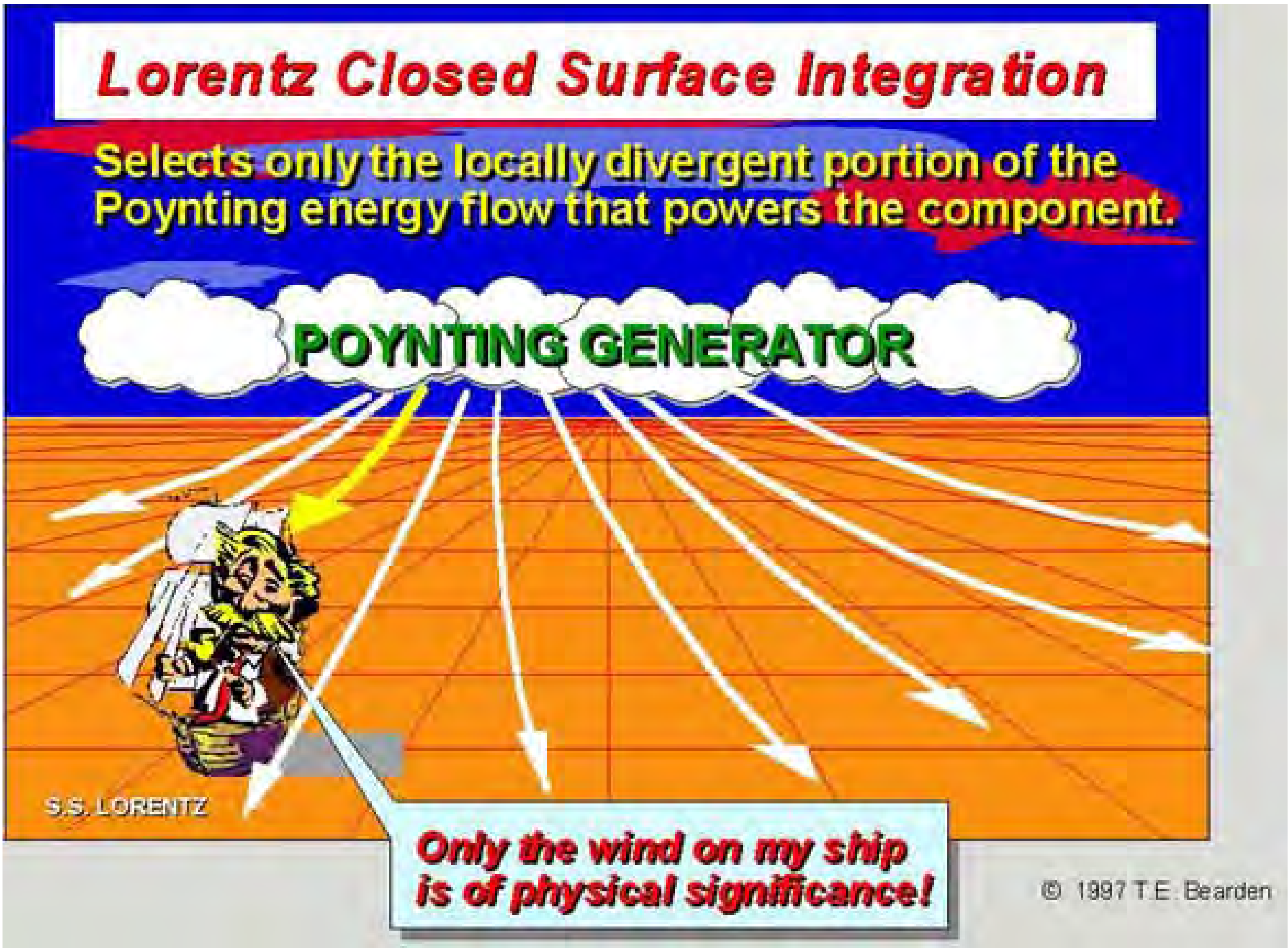

Lorentz Closed Surface Integration

Selects only the locally divergent portion of the Poynting energy flow that powers the component.

POYNTING GENERATOR
S.S. LORENTZ
Only the wind on my ship is of physical significance!

© 1997 T.E. Bearden

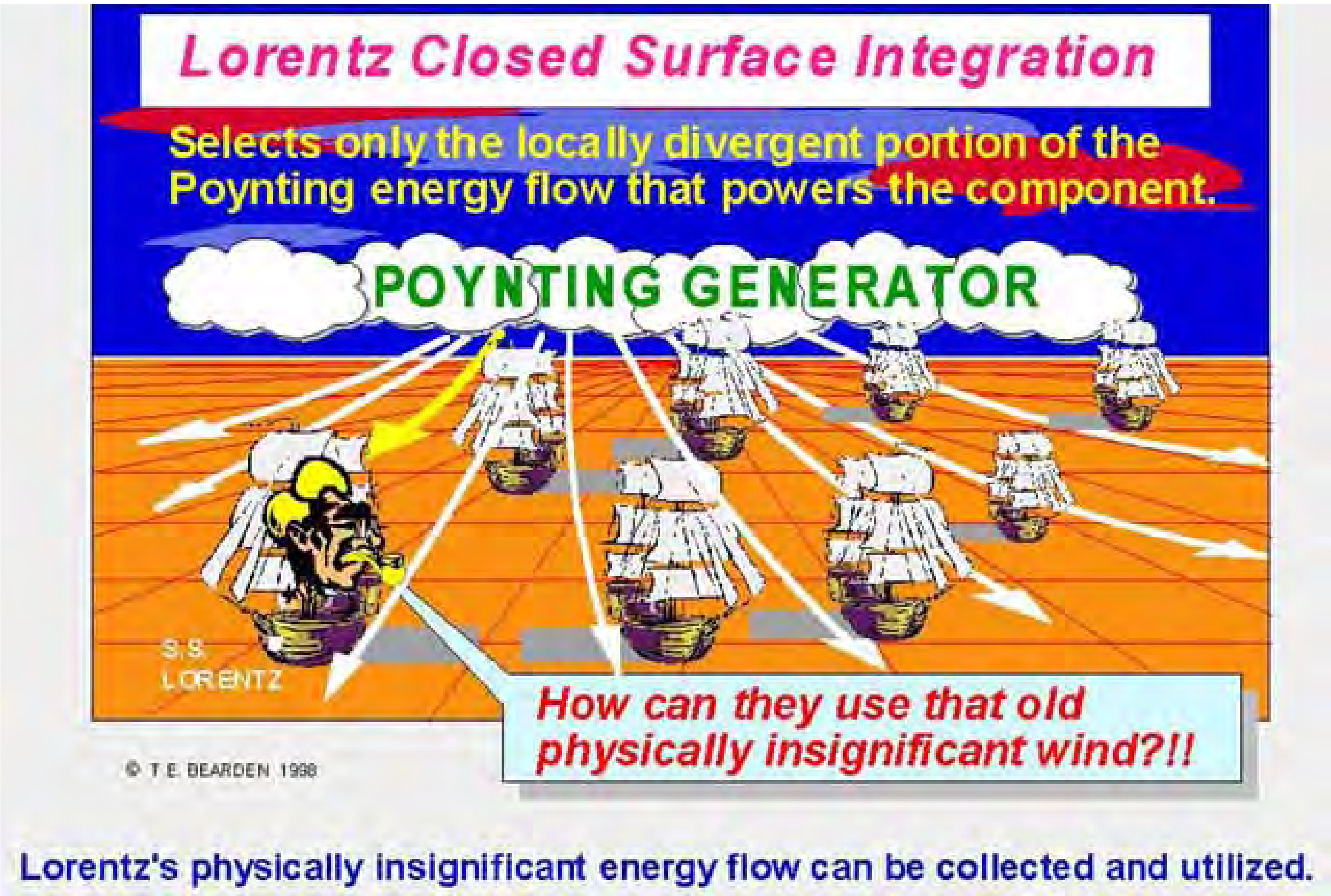

Lorentz Closed Surface Integration

Selects only the locally divergent portion of the Poynting energy flow that powers the component.

How can they use that old physically insignificant wind?!!

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Lorentz's physically insignificant energy flow can be collected and utilized.

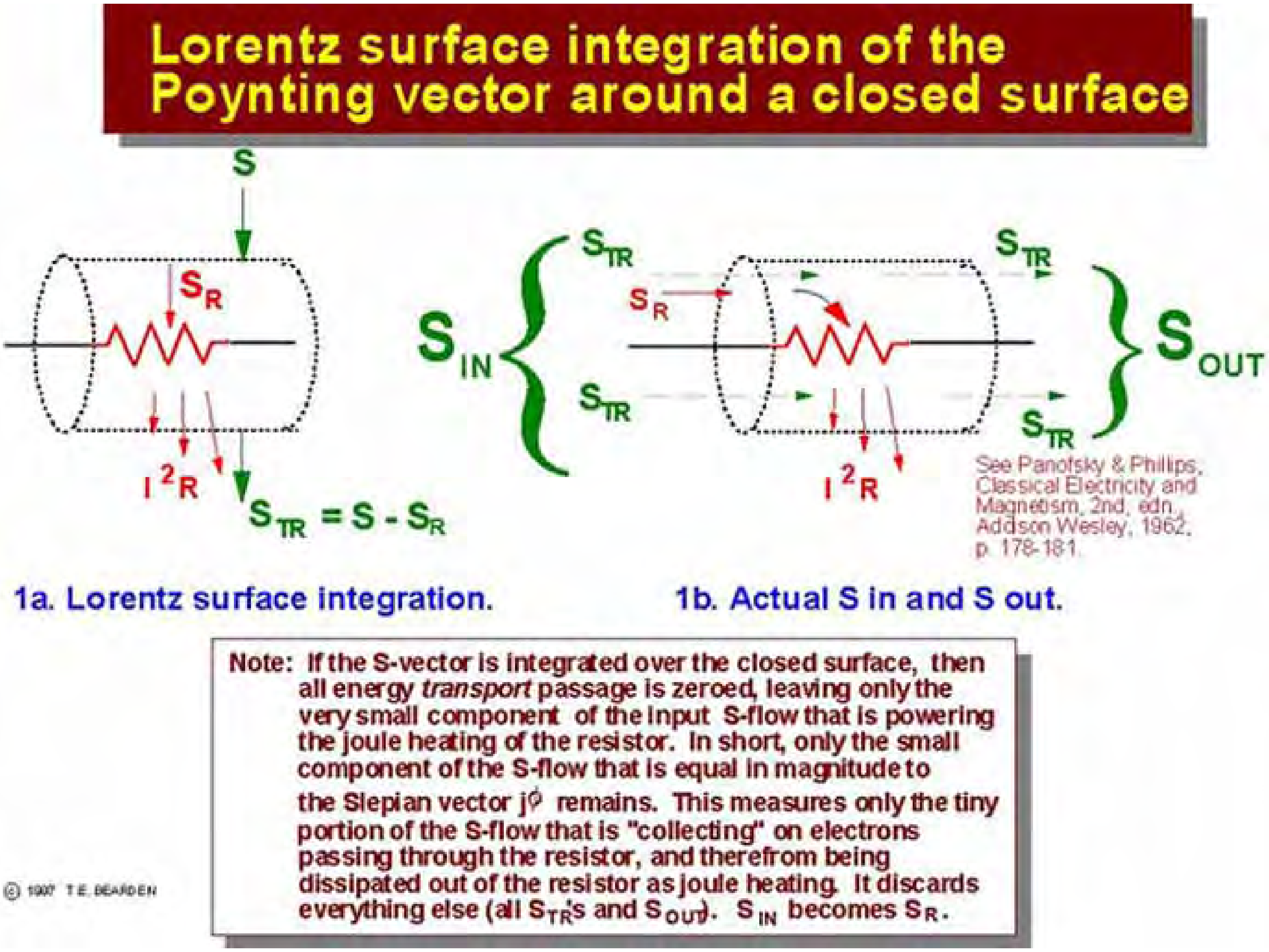

Lorentz surface integration of the Poynting vector around a closed surface

See Panofsky & Phillips, Classical Electricity and Magnetism, 2nd, edn., Addison Wesley, 1962, p. 178-181.

1a. Lorentz surface integration.

1b. Actual S in and S out.

Note: If the S-vector is integrated over the closed surface, then all energy *transport* passage is zeroed, leaving only the very small component of the input S-flow that is powering the joule heating of the resistor. In short, only the small component of the S-flow that is equal in magnitude to the Slepian vector $j\phi$ remains. This measures only the tiny portion of the S-flow that is "collecting" on electrons passing through the resistor, and therefrom being dissipated out of the resistor as joule heating. It discards everything else (all S_{TR}'s and S_{OUT}). S_{IN} becomes S_R.

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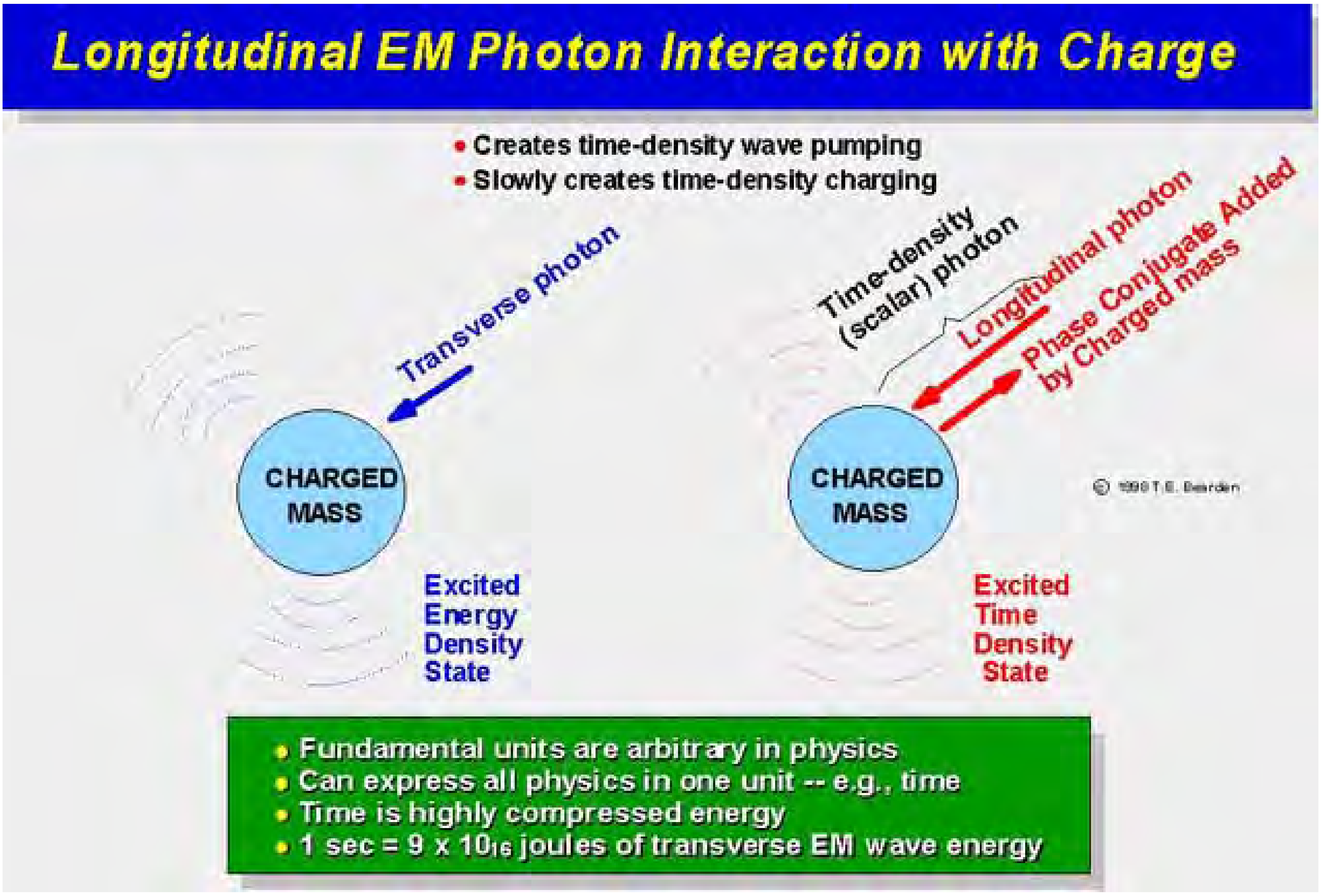

Longitudinal EM Photon Interaction with Charge

- Creates time-density wave pumping
- Slowly creates time-density charging

Transverse photon
CHARGED MASS
Excited Energy Density State
Time-density (scalar) photon
Longitudinal photon
Phase Conjugate Added by Charged mass
CHARGED MASS
Excited Time Density State
© 1990 T.E. Bearden

- Fundamental units are arbitrary in physics
- Can express all physics in one unit -- e.g., time
- Time is highly compressed energy
- 1 sec = 9 x 10_{16} joules of transverse EM wave energy

Figure 1-8. Infolded biwave composition of a scalar potential.

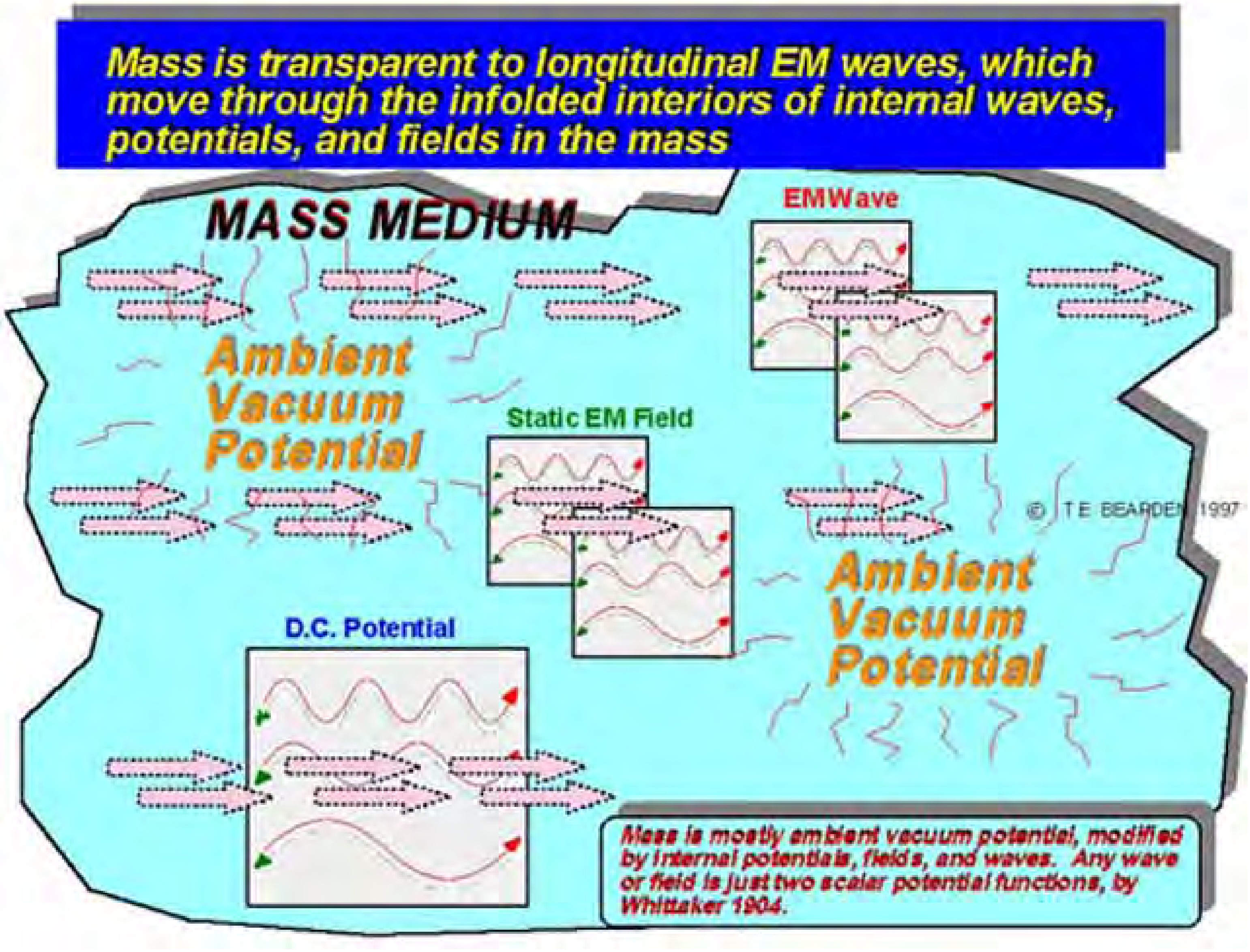

Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass

MASS MEDIUM
Ambient Vacuum Potential
Static EM Field
EMWave
D.C. Potential
© T.E. BEARDEN 1997
Ambient Vacuum Potential

Mass is mostly ambient vacuum potential, modified by internal potentials, fields, and waves. Any wave or field is just two scalar potential functions, by Whittaker 1904.

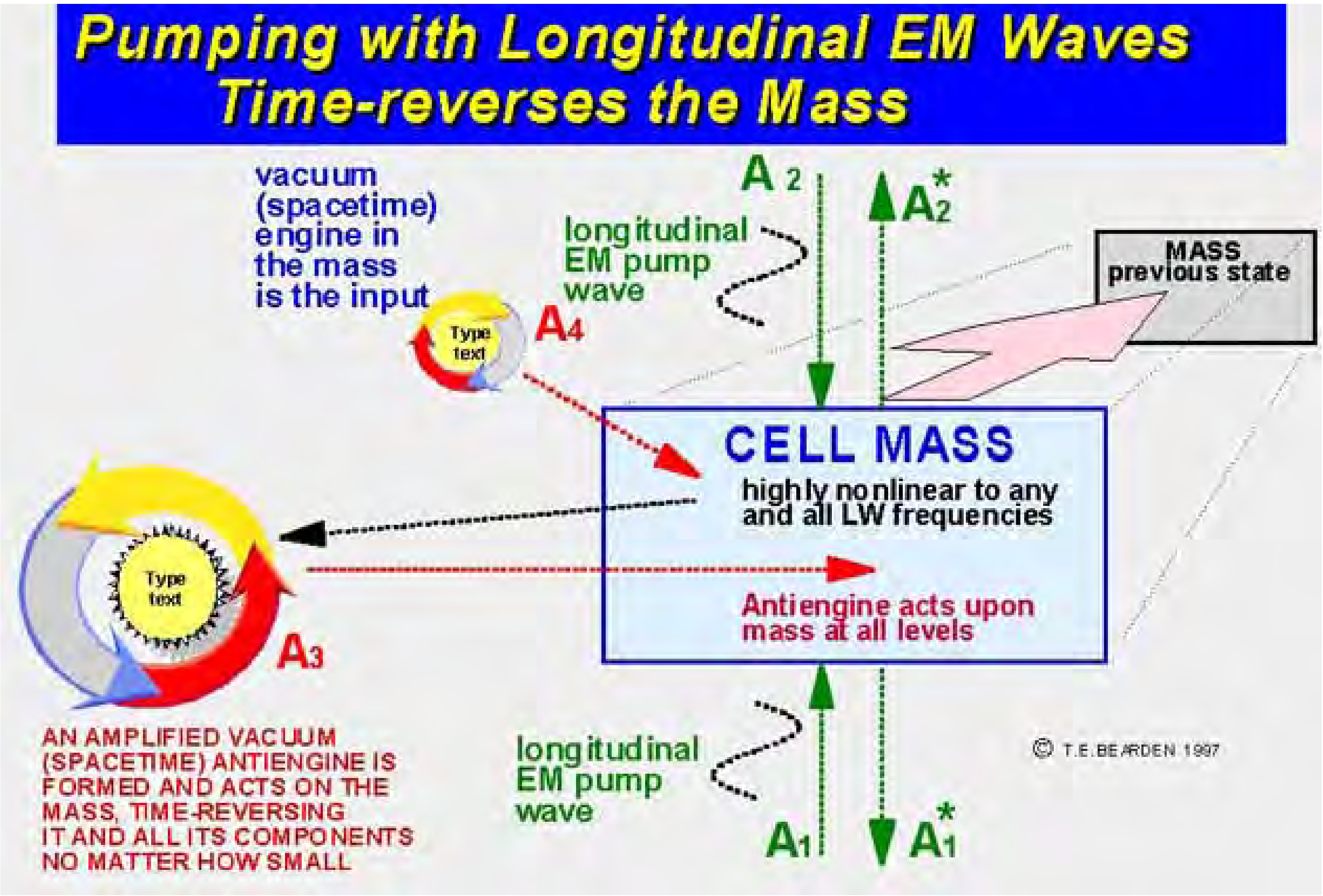

Pumping with Longitudinal EM Waves Time-reverses the Mass

vacuum
(spacetime)
engine in
the mass
is the input

longitudinal
EM pump
wave

CELL MASS

highly nonlinear to any
and all LW frequencies

Antiengine acts upon
mass at all levels

AN AMPLIFIED VACUUM
(SPACETIME) ANTIENGINE IS
FORMED AND ACTS ON THE
MASS, TIME-REVERSING
IT AND ALL ITS COMPONENTS
NO MATTER HOW SMALL

longitudinal
EM pump
wave

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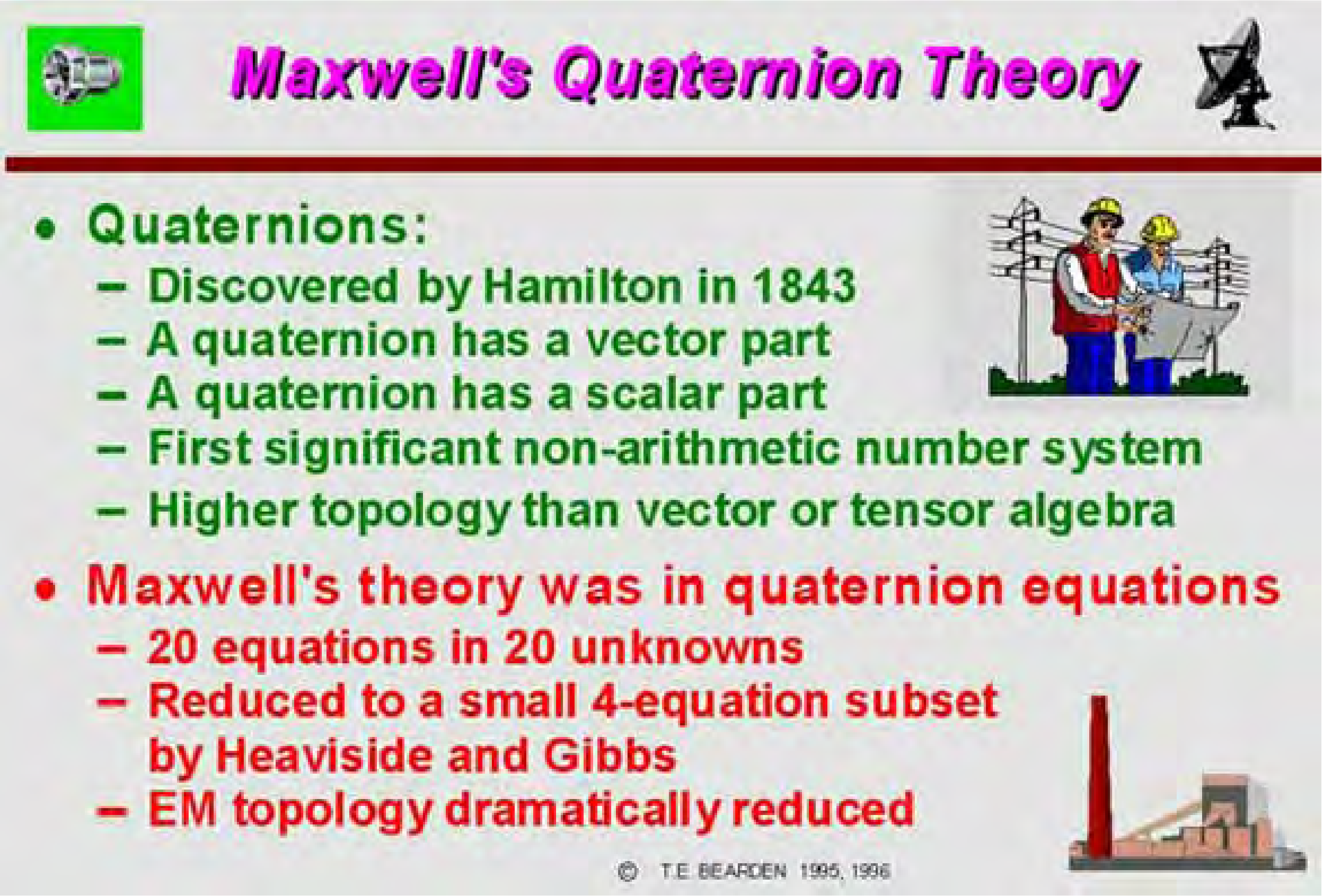

Maxwell's Quaternion Theory

- Quaternions:
  - Discovered by Hamilton in 1843
  - A quaternion has a vector part
  - A quaternion has a scalar part
  - First significant non-arithmetic number system
  - Higher topology than vector or tensor algebra
- Maxwell's theory was in quaternion equations
  - 20 equations in 20 unknowns
  - Reduced to a small 4-equation subset by Heaviside and Gibbs
  - EM topology dramatically reduced

© T.E. BEARDEN 1995, 1996

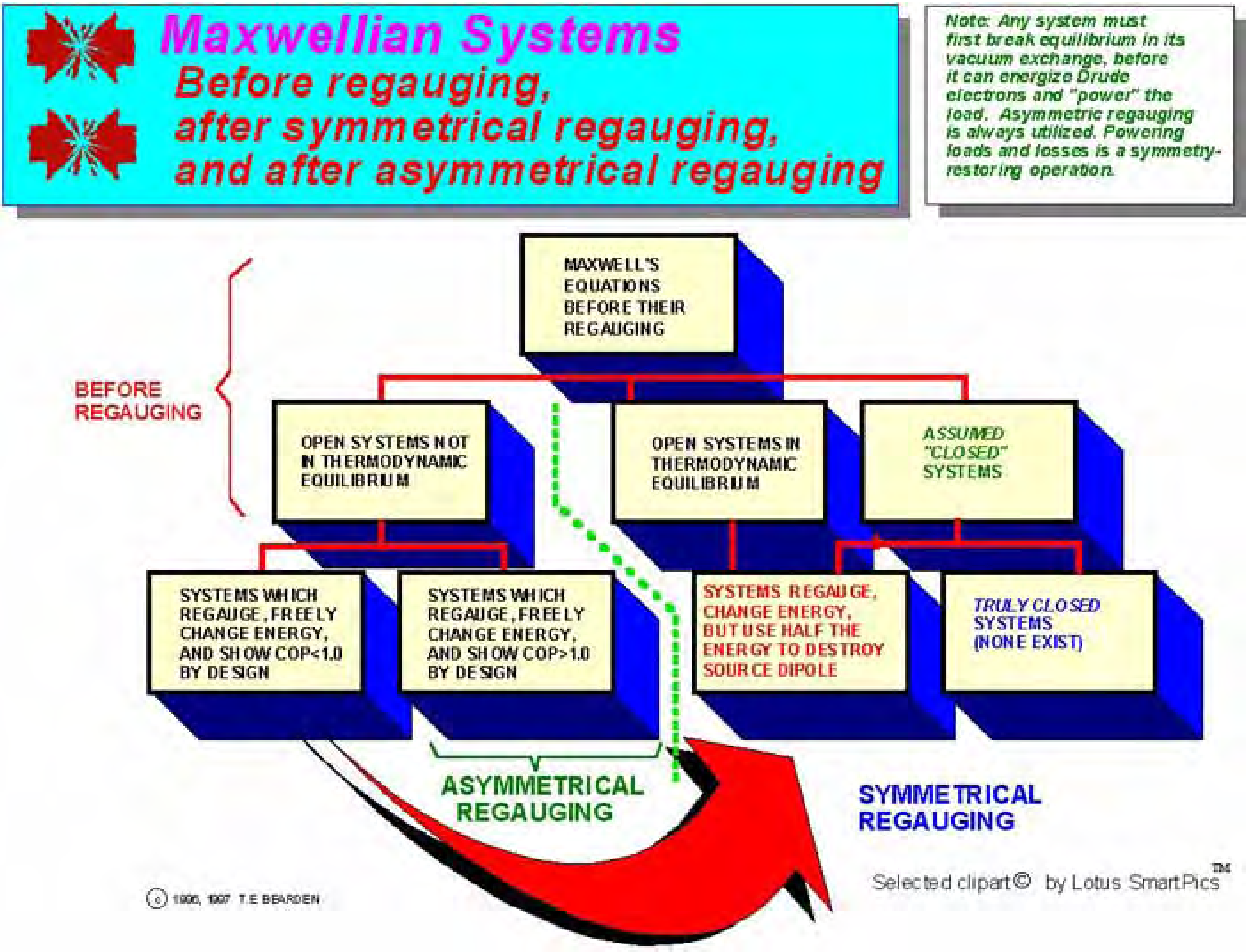

Maxwellian Systems

Before regauging, after symmetrical regauging, and after asymmetrical regauging

Note: Any system must first break equilibrium in its vacuum exchange, before it can energize Drude electrons and "power" the load. Asymmetric regauging is always utilized. Powering loads and losses is a symmetry-restoring operation.

MAXWELL'S EQUATIONS BEFORE THEIR REGAUGING

BEFORE REGAUGING

OPEN SYSTEMS NOT IN THERMODYNAMIC EQUILIBRIUM

OPEN SYSTEMS IN THERMODYNAMIC EQUILIBRIUM

ASSUMED "CLOSED" SYSTEMS

SYSTEMS WHICH REGAUGE, FREELY CHANGE ENERGY, AND SHOW COP<1.0 BY DESIGN

SYSTEMS WHICH REGAUGE, FREELY CHANGE ENERGY, AND SHOW COP>1.0 BY DESIGN

SYSTEMS REGAUGE, CHANGE ENERGY, BUT USE HALF THE ENERGY TO DESTROY SOURCE DIPOLE

TRULY CLOSED SYSTEMS (NONE EXIST)

ASYMMETRICAL REGAUGING

SYMMETRICAL REGAUGING

Selected clipart© by Lotus SmartPics™

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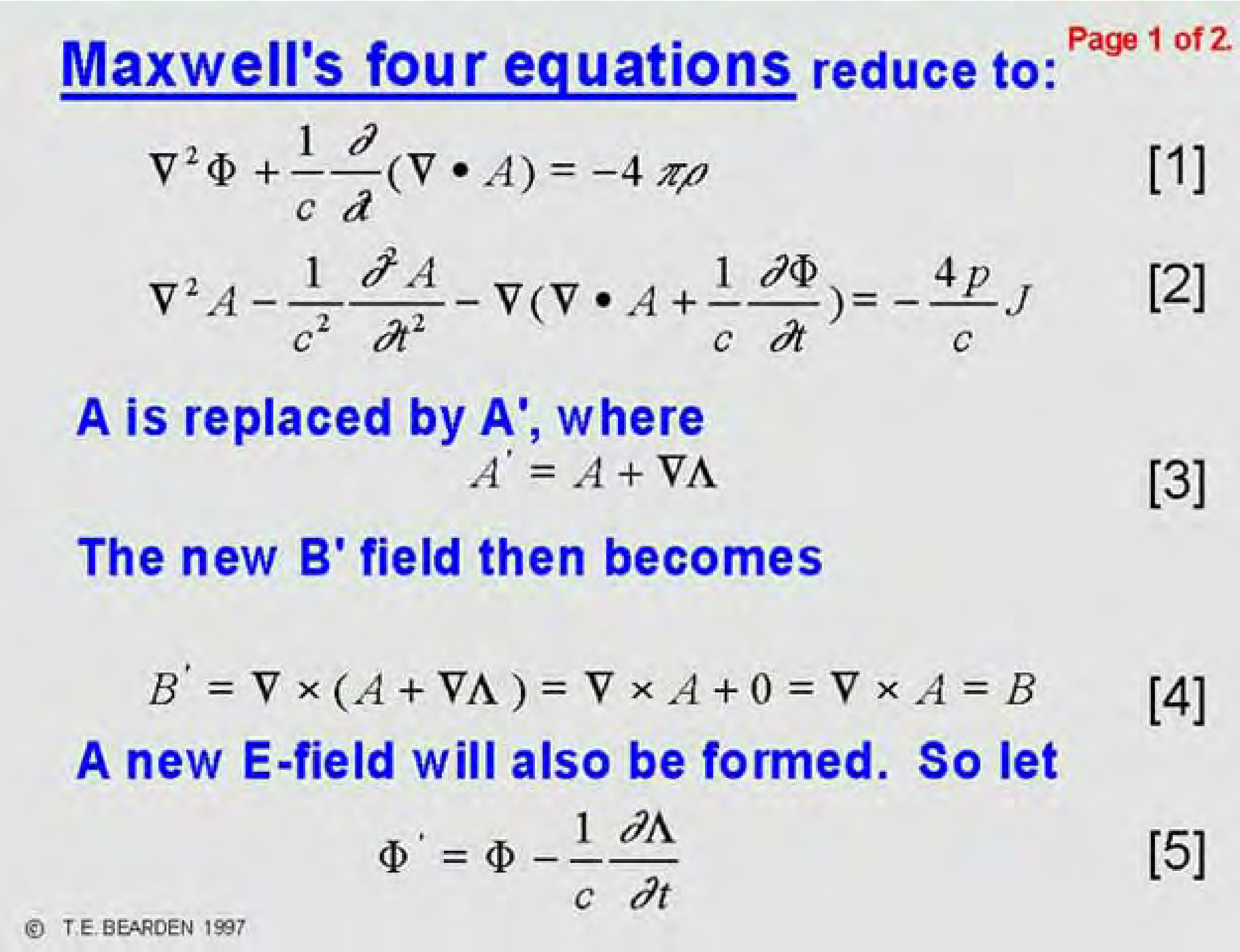

Page 1 of 2.

Maxwell's four equations reduce to:

$$\nabla^2\Phi + \frac{1}{c}\frac{\partial}{\partial t}(\nabla \bullet A) = -4\pi\rho \qquad [1]$$

$$\nabla^2 A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} - \nabla\left(\nabla \bullet A + \frac{1}{c}\frac{\partial\Phi}{\partial t}\right) = -\frac{4p}{c}J \qquad [2]$$

A is replaced by A', where

$$A' = A + \nabla\Lambda \qquad [3]$$

The new B' field then becomes

$$B' = \nabla \times (A + \nabla\Lambda) = \nabla \times A + 0 = \nabla \times A = B \qquad [4]$$

A new E-field will also be formed. So let

$$\Phi' = \Phi - \frac{1}{c}\frac{\partial\Lambda}{\partial t} \qquad [5]$$

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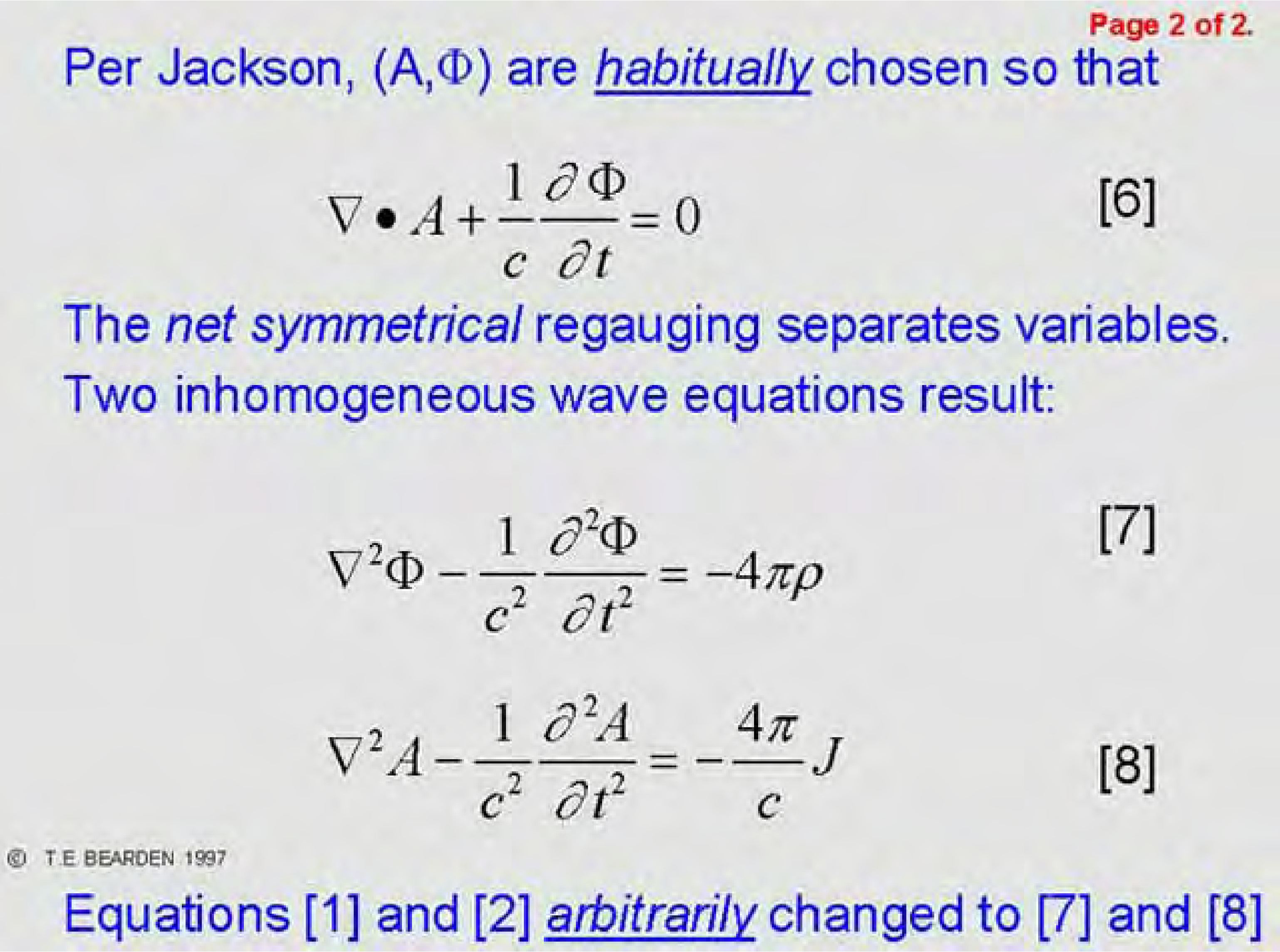

Page 2 of 2.

Per Jackson, (A,Φ) are *habitually* chosen so that

$$\nabla \bullet A + \frac{1}{c}\frac{\partial \Phi}{\partial t} = 0 \qquad [6]$$

The *net symmetrical* regauging separates variables.

Two inhomogeneous wave equations result:

$$\nabla^2 \Phi - \frac{1}{c^2}\frac{\partial^2 \Phi}{\partial t^2} = -4\pi\rho \qquad [7]$$

$$\nabla^2 A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} = -\frac{4\pi}{c}J \qquad [8]$$

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Equations [1] and [2] *arbitrarily* changed to [7] and [8]

The Tom Bearden Website

Life Systems

Toward the Beginning of the End

---

1. Toward the Beginning of the End: Capstone Presentations
2. Toward the Beginning of the End
3. Biospheric Evolution
4. A Living Biological System
5. The Evolutionary Path of Multicellular Organisms
6. To Paraphrase Churchill
7. Directed Evolution: Mechanism for Species Reactive Adaptation
8. Earth's Poynting Energy Flow
9. The Immune System
10. Mind and Matter Interaction
11. Levels of Consciousness and Unconsciousness
12. Access to Mind, Memory and Thought
13. US Intelligence Statement on Soviet Psi Research
14. Mind and Matter Interaction
15. Conscious and Unconscious Minds
16. Velocity is Rotation
17. Species Reactive Adaptation: Directed Evolution
18. Technology's Goal
19. Technology's End
20. Technological Species' Problems

The Tom Bearden
Website

Briefings

One of Tom's first public lectures: World Futures Society 1982
Other panelists included James Beale, Carol Rosin, Barbara Marx Hubbard and Glenn Doman

---

The "Porthole" Concept
Extension of the Priore Method of Healing as applicable to the treatment of biological warfare effects and cellular afflictions such as cancers, AIDS etc.
NEW

Hubbert's Peak: The Impending Oil Crisis, by Professor Kenneth S. Deffeyes
Book Review and Slides

A National Report on America's Energy Crisis
by Energy Secretary Spencer Abraham - March 19, 2001

Commentary and Slide Show (66) by Tom Bearden

A Visual Tour of what they don't want you to know about electrical circuits
10 Trillion Percent of the Current Produced is Wasted!

Weapons Slides

The Missing Infolded Electrodynamics
85 slides

A Brief Technical Background to the Extended Priore Healing Methodology
11 slides

Briefing sent by Tom Bearden to Defense Department, National Institute of Health, USAF, National Science Foundation etc. re extended and improved Priore Treatment to counter mass casualties from Biological Warfare

- Letter to DHHS re adoption of Priore technology
  24 June, 1998
- Letter to NIH re adoption of Priore technology
  12 May, 1998

Towards the Beginning of the End - Lecture in Florida for Capstone Presentations, Sept. 1998

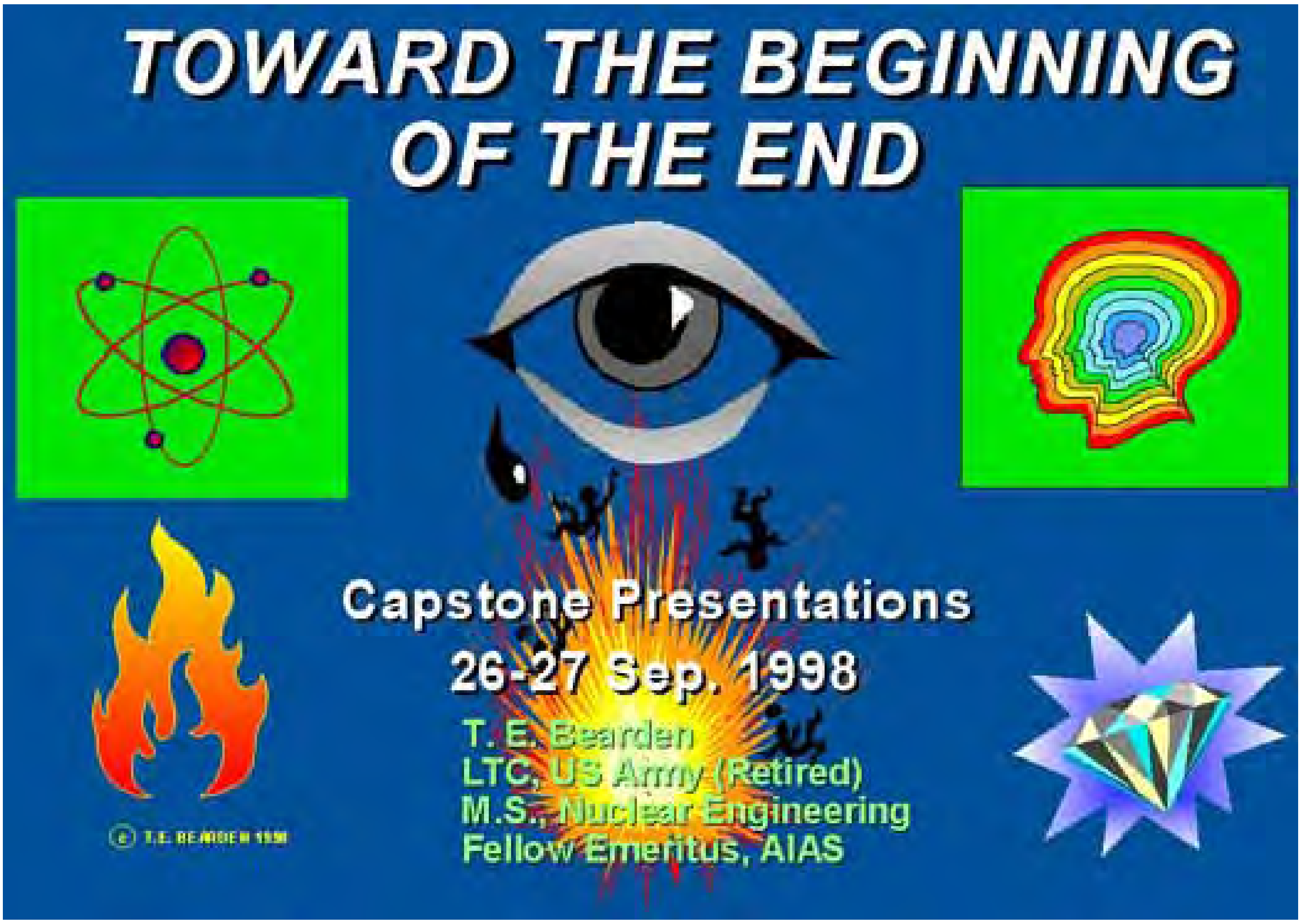

TOWARD THE BEGINNING OF THE END

Capstone Presentations

26-27 Sep. 1998

T. E. Bearden
LTC, US Army (Retired)
M.S., Nuclear Engineering
Fellow Emeritus, AIAS

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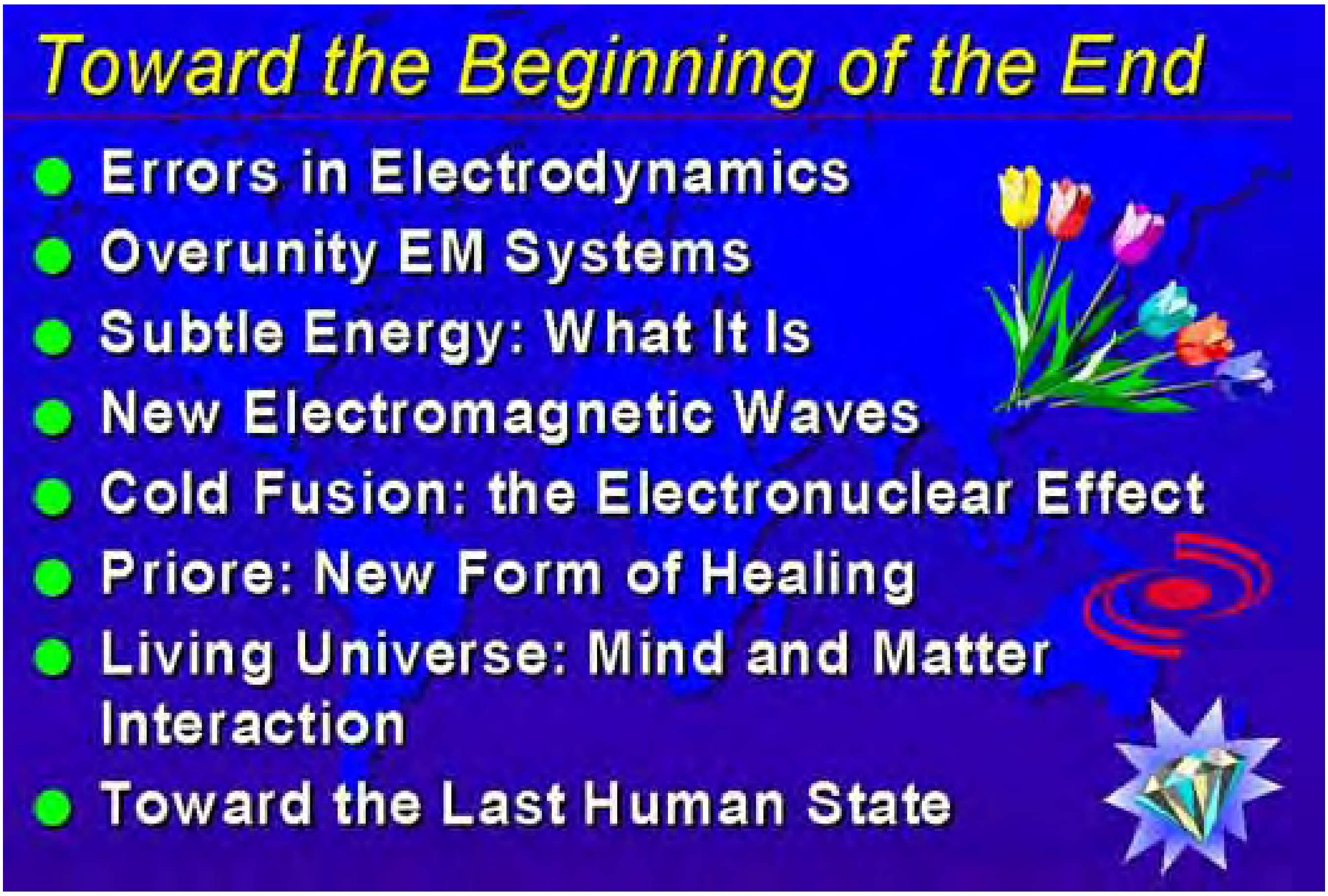

Toward the Beginning of the End

- Errors in Electrodynamics
- Overunity EM Systems
- Subtle Energy: What It Is
- New Electromagnetic Waves
- Cold Fusion: the Electronuclear Effect
- Priore: New Form of Healing
- Living Universe: Mind and Matter Interaction
- Toward the Last Human State

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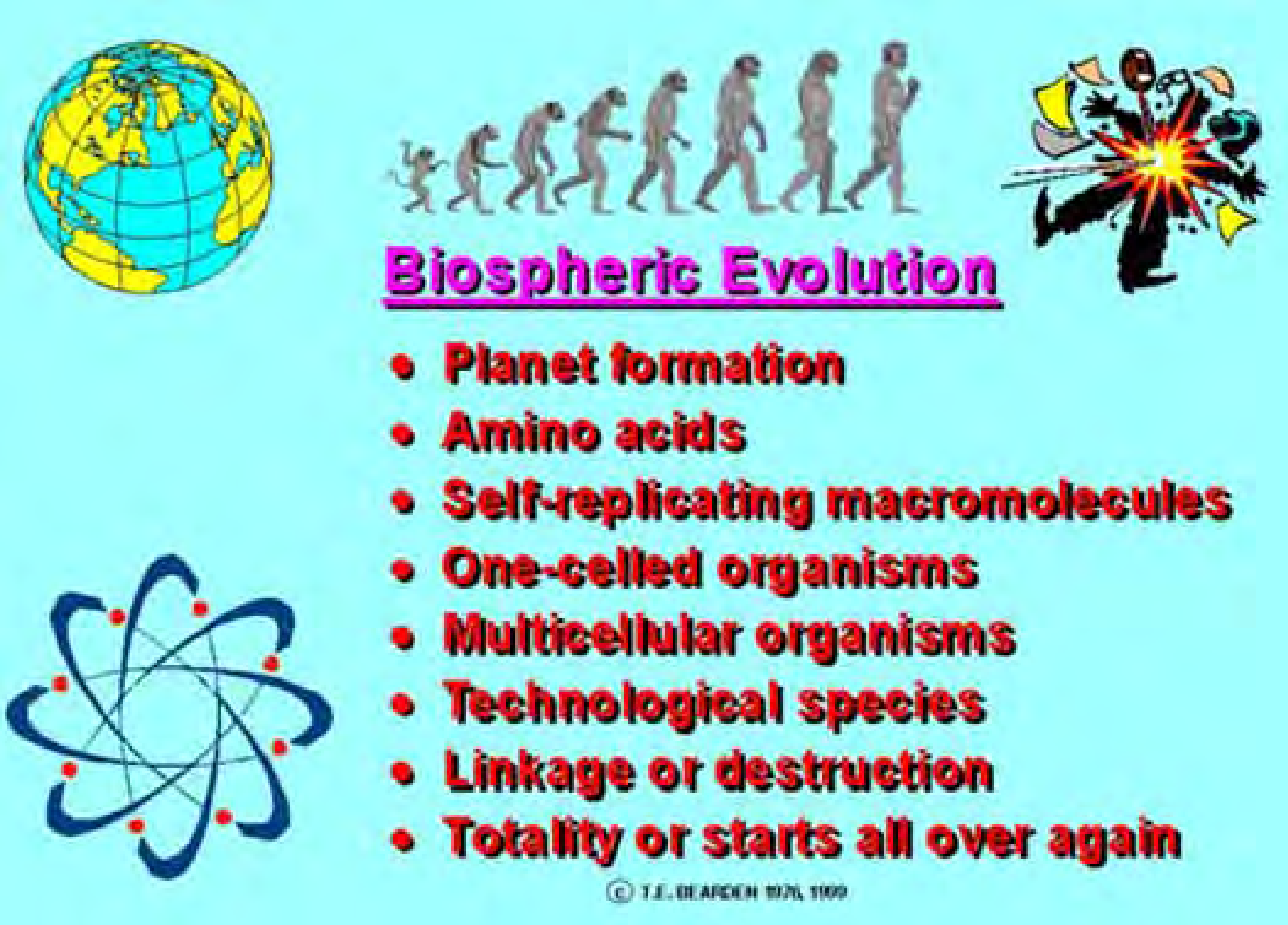

Biospheric Evolution

- Planet formation
- Amino acids
- Self-replicating macromolecules
- One-celled organisms
- Multicellular organisms
- Technological species
- Linkage or destruction
- Totality or starts all over again

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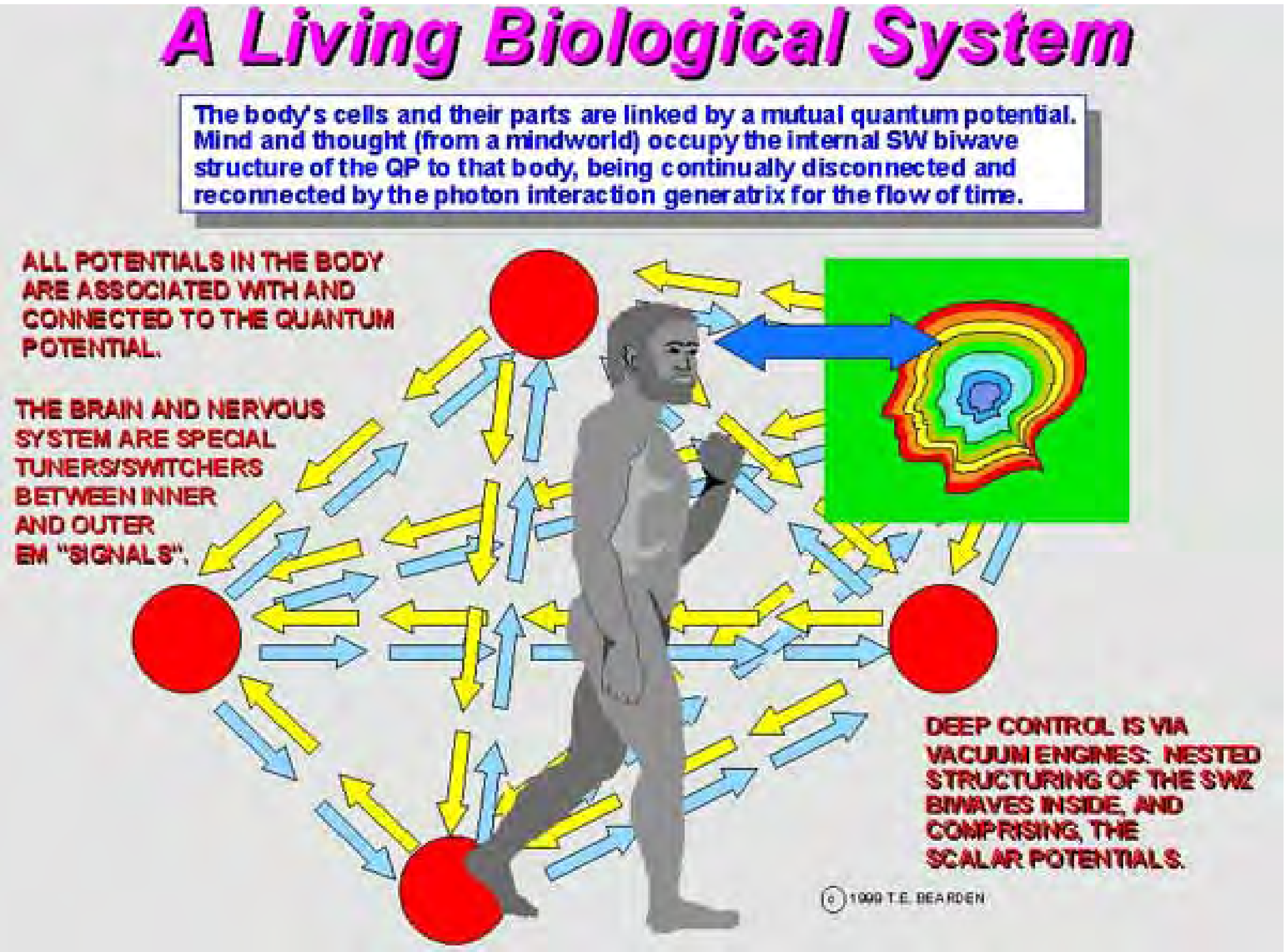

A Living Biological System

The body's cells and their parts are linked by a mutual quantum potential. Mind and thought (from a mindworld) occupy the internal SW biwave structure of the QP to that body, being continually disconnected and reconnected by the photon interaction generatrix for the flow of time.

ALL POTENTIALS IN THE BODY ARE ASSOCIATED WITH AND CONNECTED TO THE QUANTUM POTENTIAL.

THE BRAIN AND NERVOUS SYSTEM ARE SPECIAL TUNERS/SWITCHERS BETWEEN INNER AND OUTER EM "SIGNALS".

DEEP CONTROL IS VIA VACUUM ENGINES: NESTED STRUCTURING OF THE SWZ BIWAVES INSIDE, AND COMPRISING, THE SCALAR POTENTIALS.

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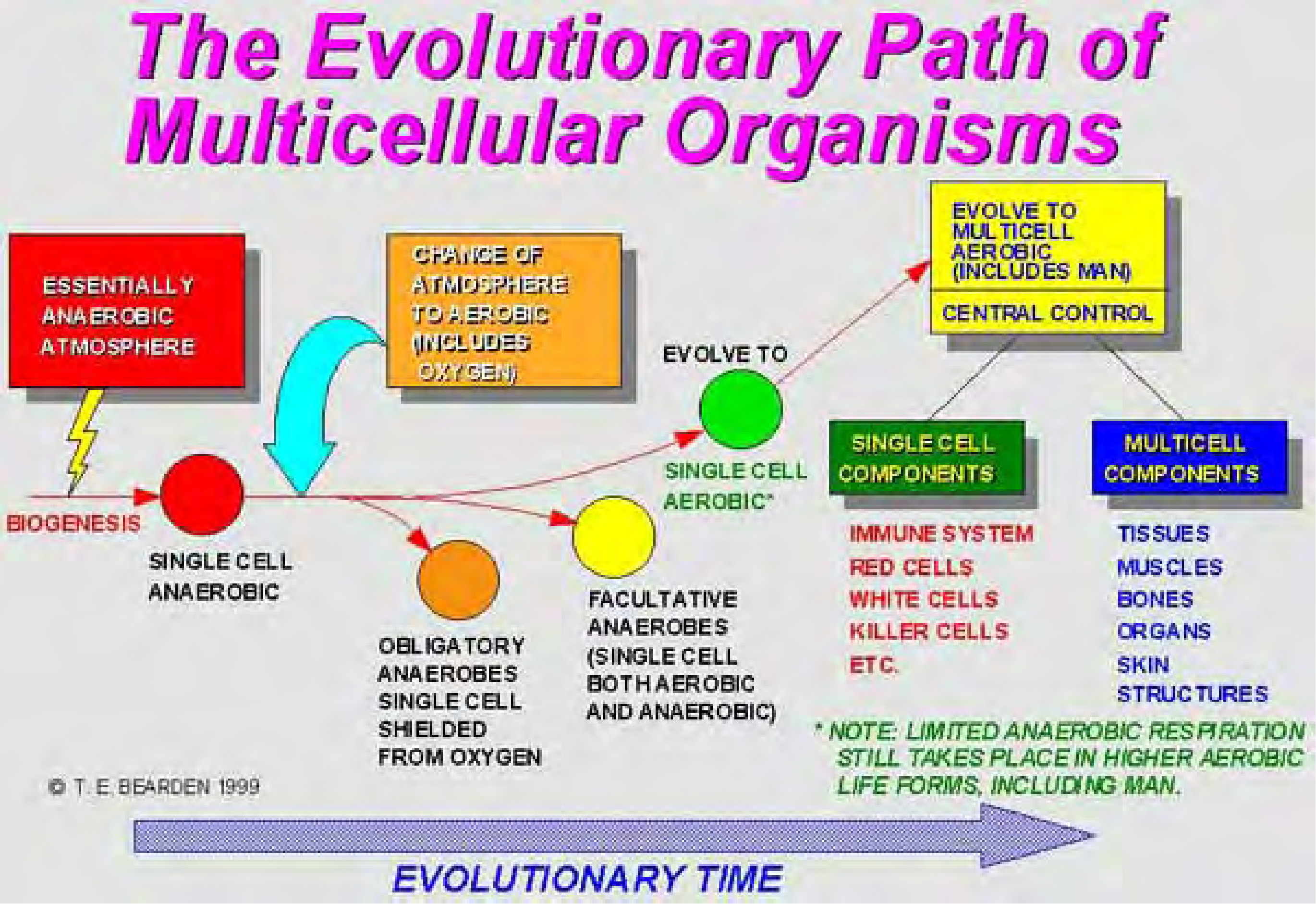

The Evolutionary Path of Multicellular Organisms

ESSENTIALLY ANAEROBIC ATMOSPHERE

CHANGE OF ATMOSPHERE TO AEROBIC (INCLUDES OXYGEN)

EVOLVE TO MULTICELL AEROBIC (INCLUDES MAN)

CENTRAL CONTROL

BIOGENESIS

SINGLE CELL ANAEROBIC

EVOLVE TO

SINGLE CELL AEROBIC*

OBLIGATORY ANAEROBES SINGLE CELL SHIELDED FROM OXYGEN

FACULTATIVE ANAEROBES (SINGLE CELL BOTH AEROBIC AND ANAEROBIC)

SINGLE CELL COMPONENTS

- IMMUNE SYSTEM
- RED CELLS
- WHITE CELLS
- KILLER CELLS
- ETC.

MULTICELL COMPONENTS

- TISSUES
- MUSCLES
- BONES
- ORGANS
- SKIN
- STRUCTURES

** NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.*

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EVOLUTIONARY TIME

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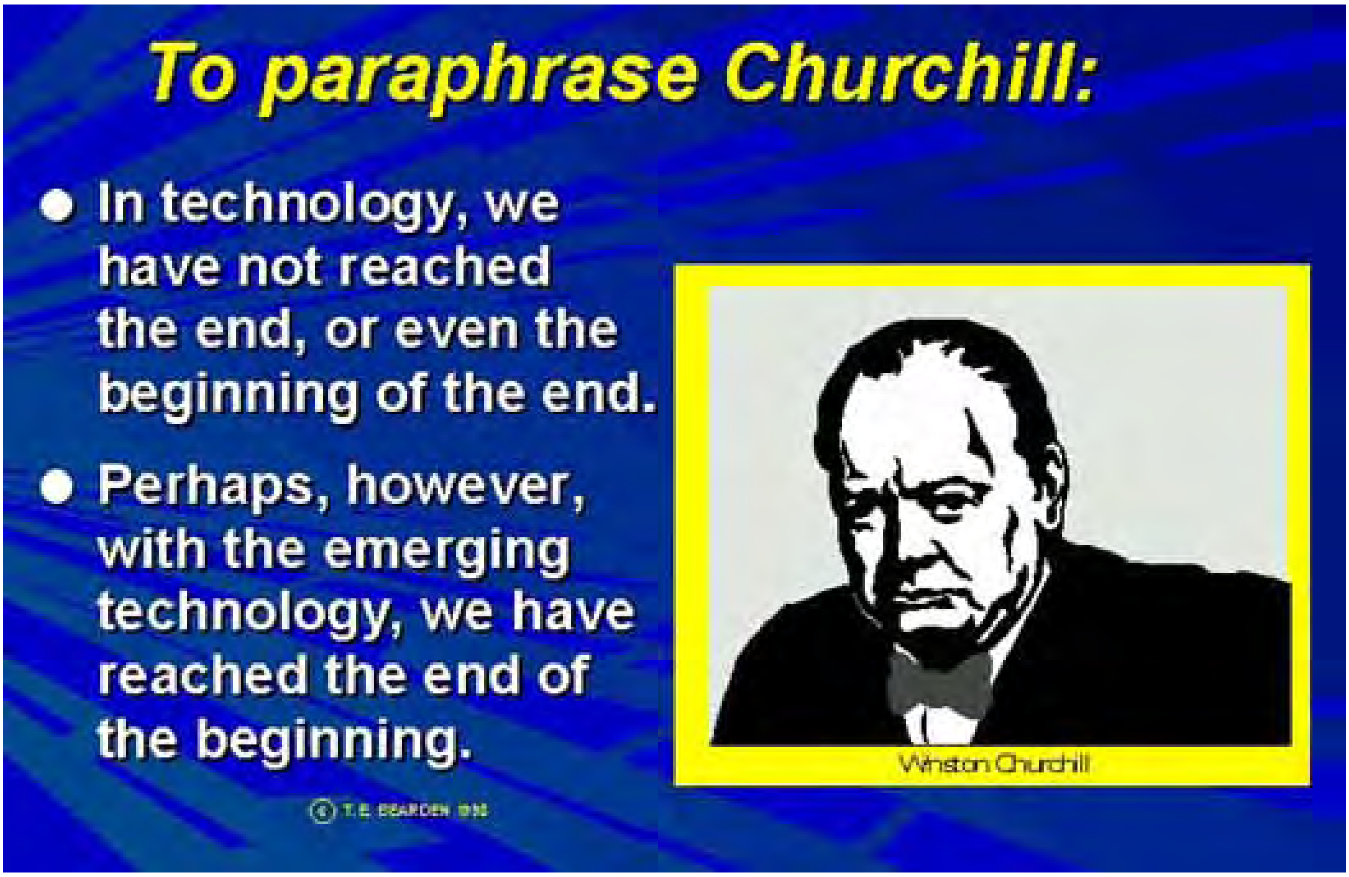

To paraphrase Churchill:

- In technology, we have not reached the end, or even the beginning of the end.
- Perhaps, however, with the emerging technology, we have reached the end of the beginning.

Winston Churchill

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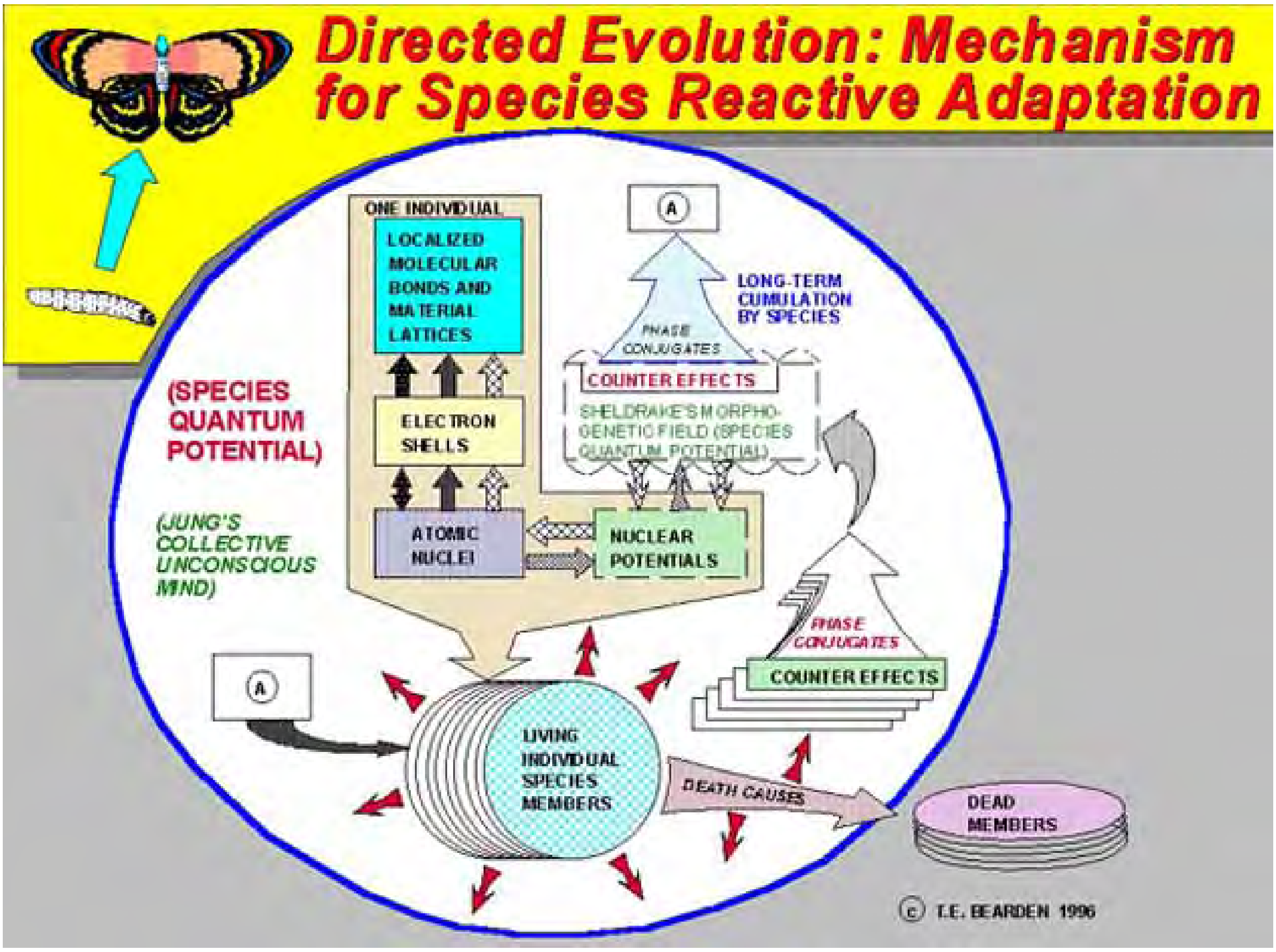

Directed Evolution: Mechanism for Species Reactive Adaptation

ONE INDIVIDUAL

LOCALIZED MOLECULAR BONDS AND MATERIAL LATTICES

ELECTRON SHELLS

ATOMIC NUCLEI

NUCLEAR POTENTIALS

A

LONG-TERM CUMULATION BY SPECIES

PHASE CONJUGATES

COUNTER EFFECTS

SHELDRAKE'S MORPHOGENETIC FIELD (SPECIES QUANTUM POTENTIAL)

(SPECIES QUANTUM POTENTIAL)

(JUNG'S COLLECTIVE UNCONSCIOUS MIND)

A

LIVING INDIVIDUAL SPECIES MEMBERS

PHASE CONJUGATES

COUNTER EFFECTS

DEATH CAUSES

DEAD MEMBERS

ⓒ T.E. BEARDEN 1996

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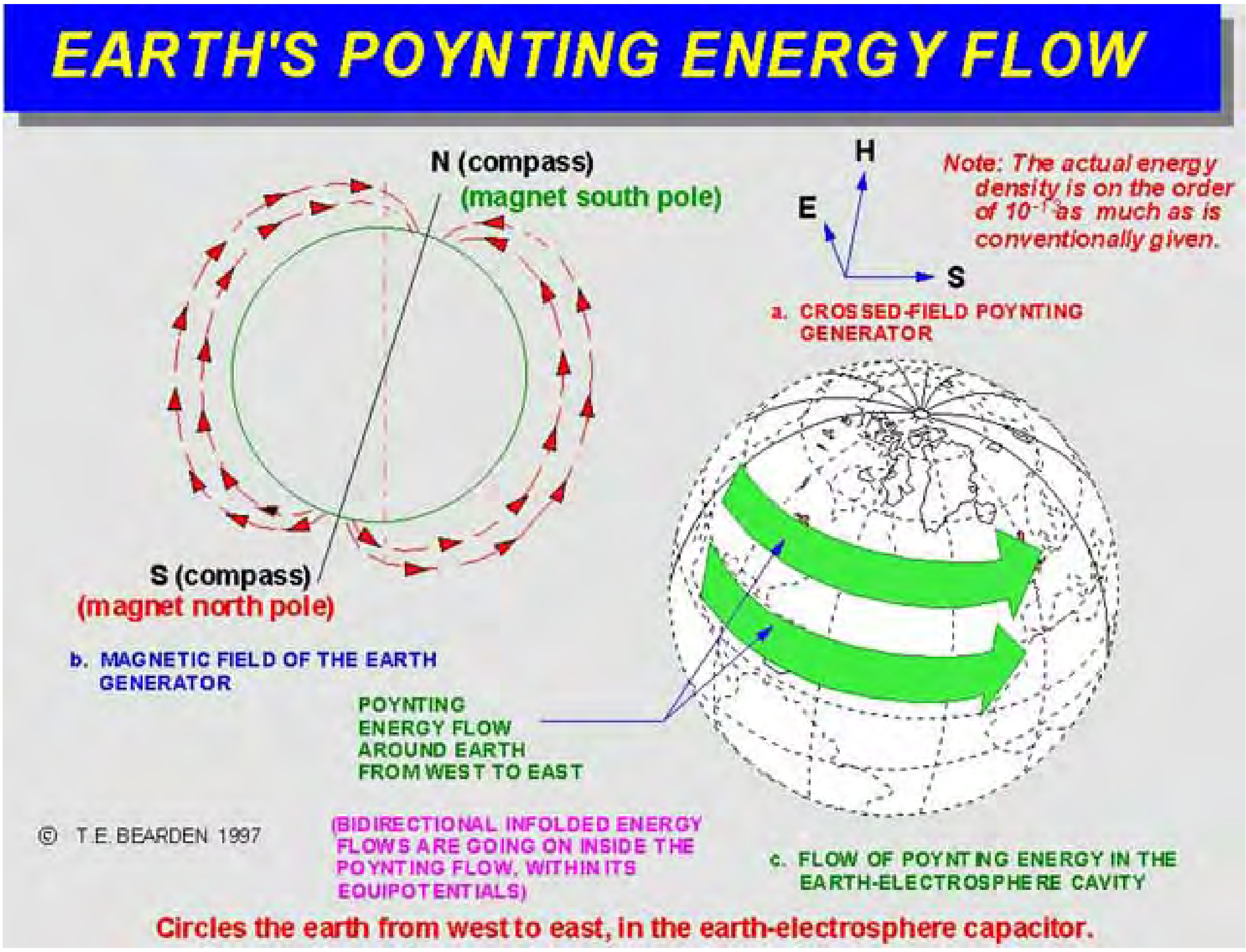

EARTH'S POYNTING ENERGY FLOW

Note: The actual energy density is on the order of 10^{-1} as much as is conventionally given.

a. CROSSED-FIELD POYNTING GENERATOR

b. MAGNETIC FIELD OF THE EARTH GENERATOR

POYNTING ENERGY FLOW AROUND EARTH FROM WEST TO EAST

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(BIDIRECTIONAL INFOLDED ENERGY FLOWS ARE GOING ON INSIDE THE POYNTING FLOW, WITHIN ITS EQUIPOTENTIALS)

c. FLOW OF POYNTING ENERGY IN THE EARTH-ELECTROSPHERE CAVITY

Circles the earth from west to east, in the earth-electrosphere capacitor.

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Note: Should be

10^{13}

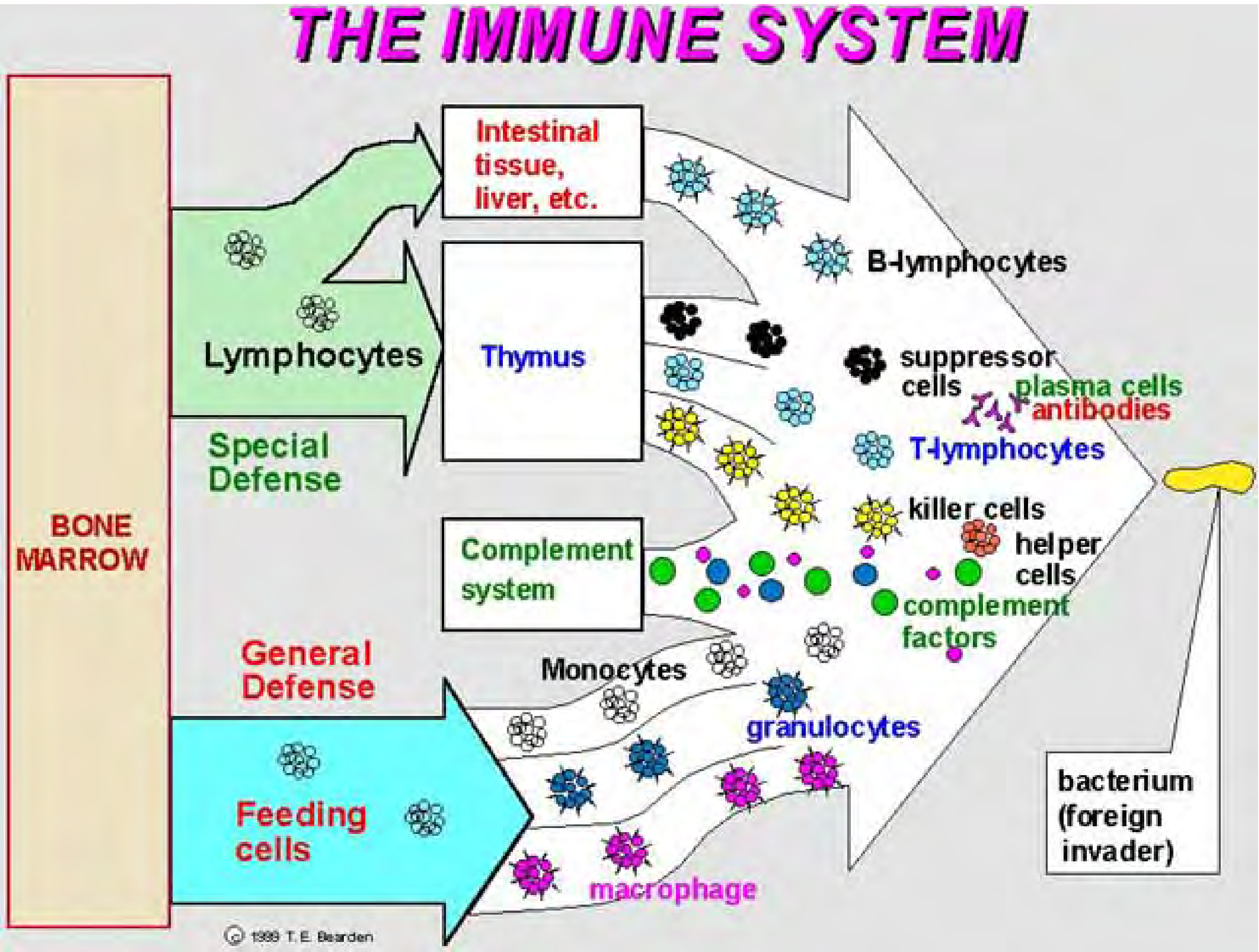
THE IMMUNE SYSTEM
BONE MARROW
Lymphocytes
Special Defense
Intestinal tissue, liver, etc.
Thymus
Complement system
General Defense
Feeding cells
B-lymphocytes
suppressor cells
plasma cells
antibodies
T-lymphocytes
killer cells
helper cells
complement factors
Monocytes
granulocytes
macrophage
bacterium (foreign invader)
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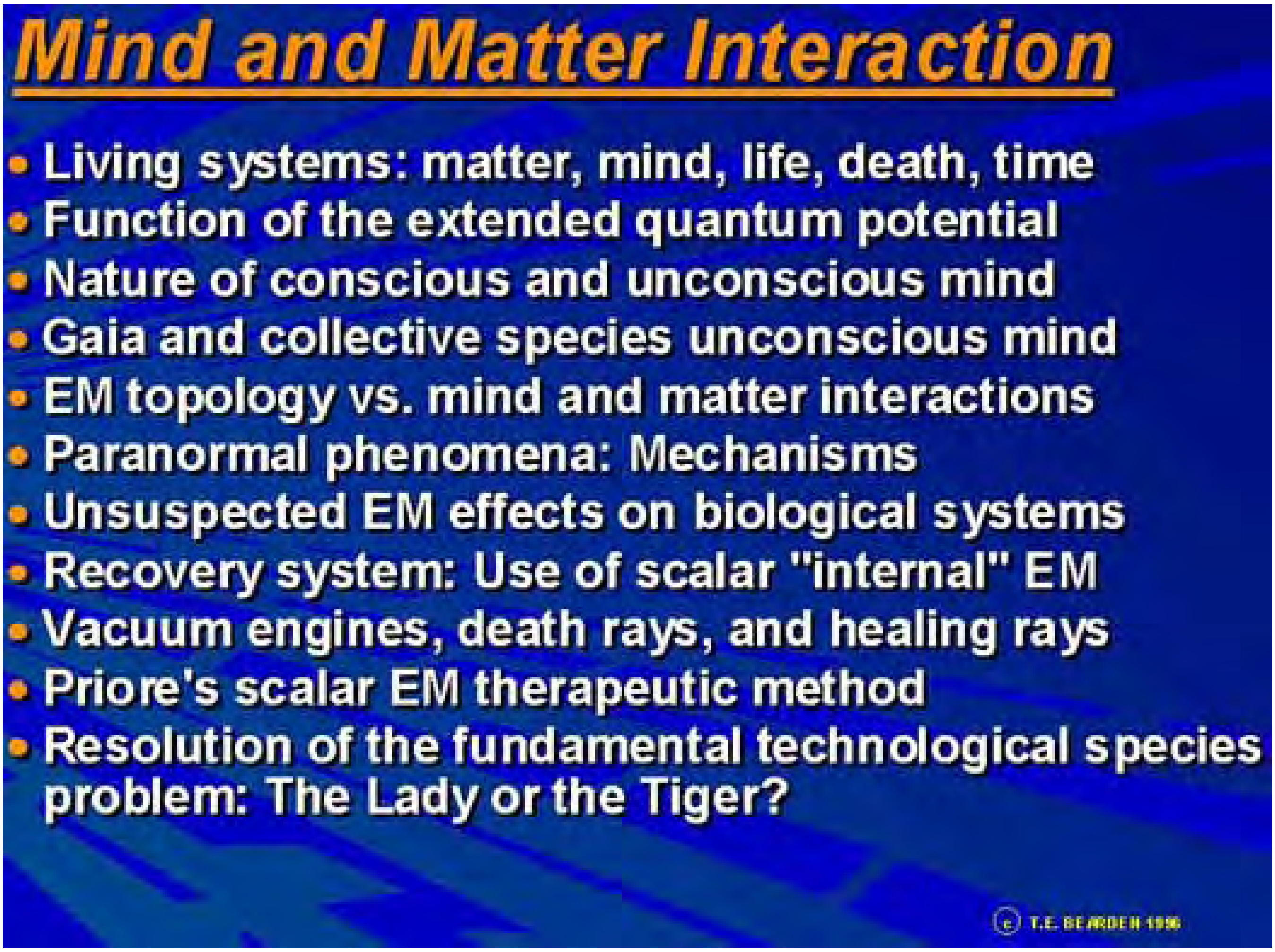

Mind and Matter Interaction

- Living systems: matter, mind, life, death, time
- Function of the extended quantum potential
- Nature of conscious and unconscious mind
- Gaia and collective species unconscious mind
- EM topology vs. mind and matter interactions
- Paranormal phenomena: Mechanisms
- Unsuspected EM effects on biological systems
- Recovery system: Use of scalar "internal" EM
- Vacuum engines, death rays, and healing rays
- Priore's scalar EM therapeutic method
- Resolution of the fundamental technological species problem: The Lady or the Tiger?

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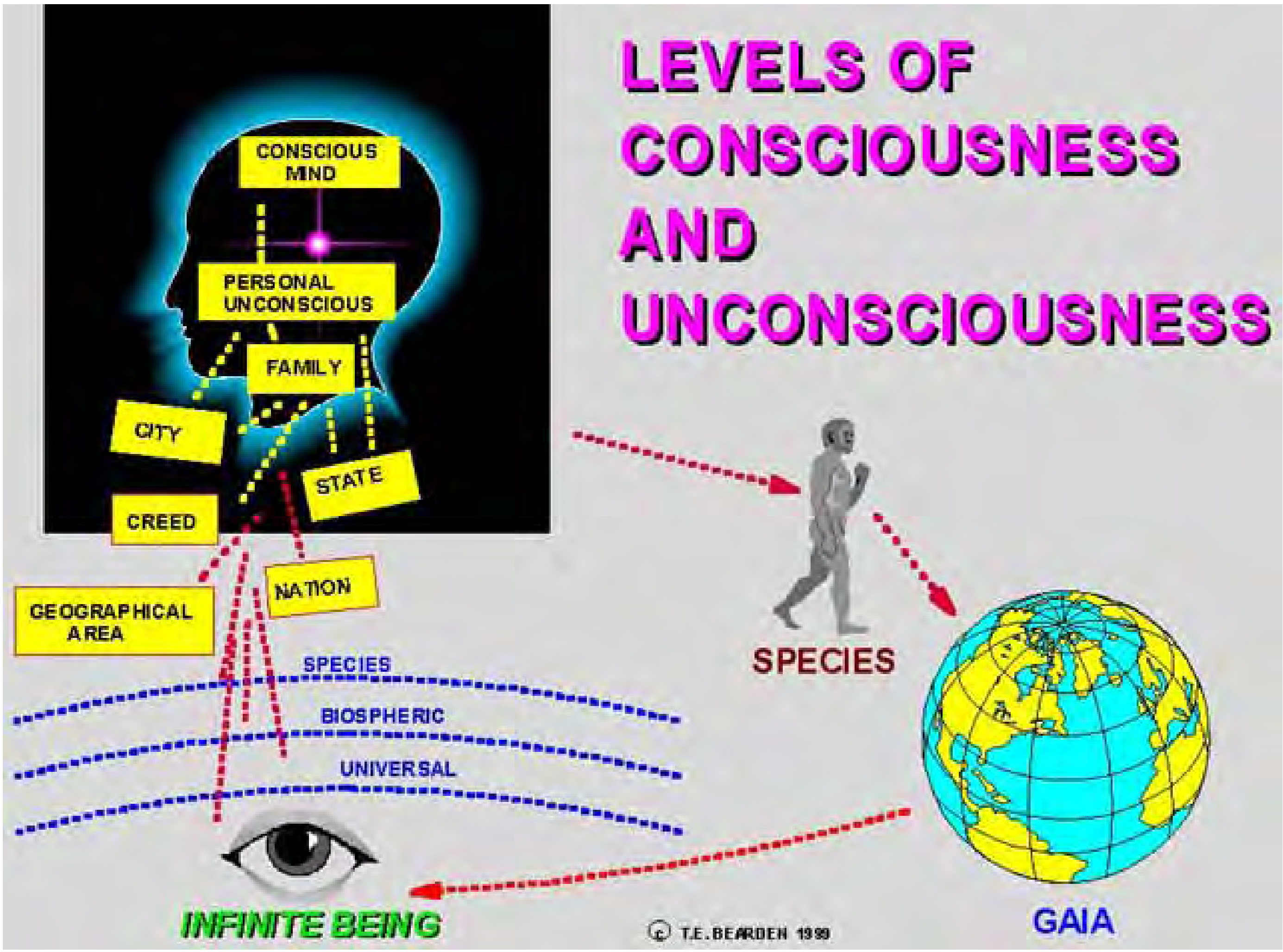

LEVELS OF CONSCIOUSNESS AND UNCONSCIOUSNESS

CONSCIOUS MIND
PERSONAL UNCONSCIOUS
FAMILY
CITY
STATE
CREED
NATION
GEOGRAPHICAL AREA
SPECIES
BIOSPHERIC
UNIVERSAL
INFINITE BEING
SPECIES
GAIA

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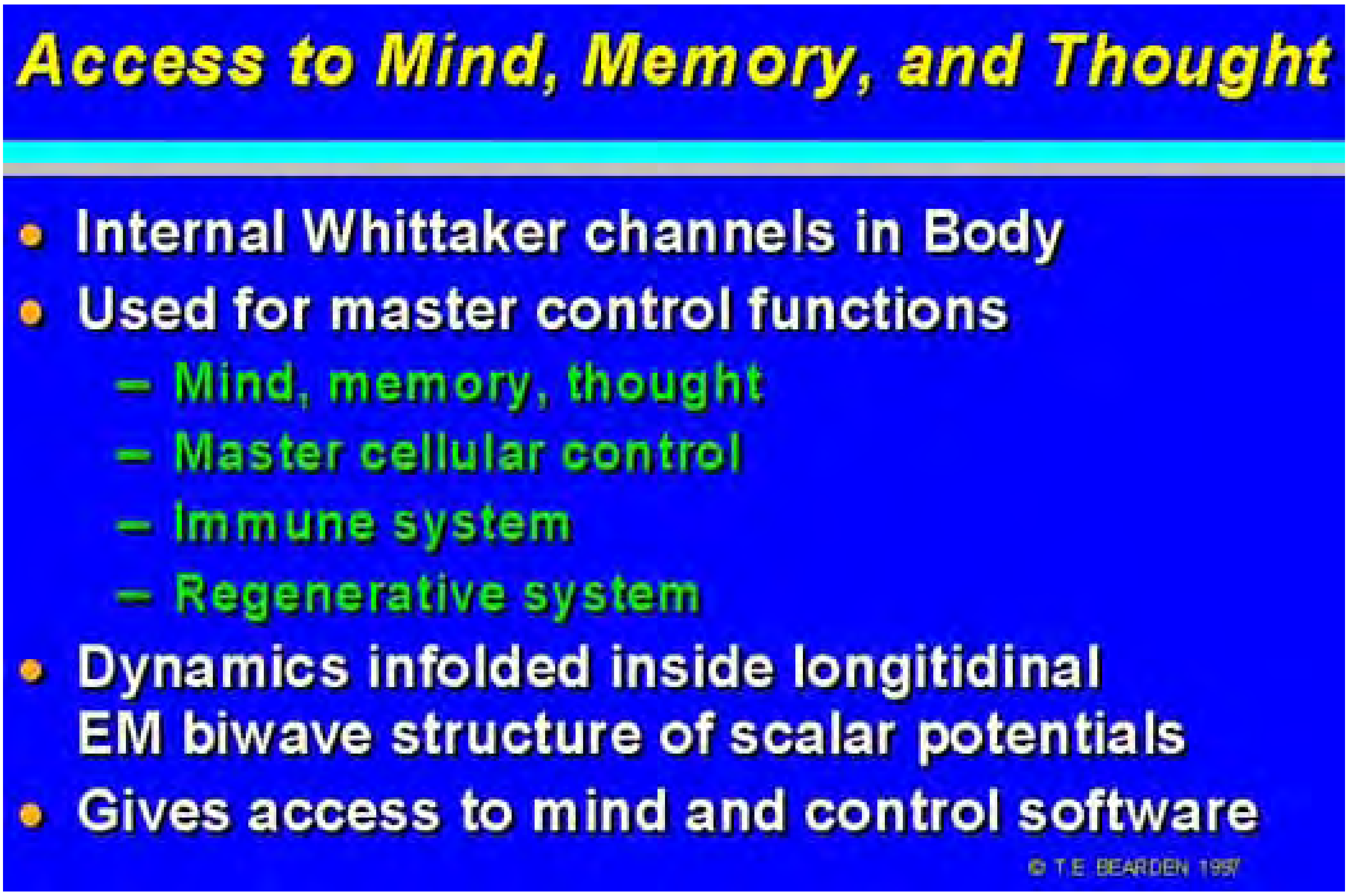

Access to Mind, Memory, and Thought

- Internal Whittaker channels in Body
- Used for master control functions
  - Mind, memory, thought
  - Master cellular control
  - Immune system
  - Regenerative system
- Dynamics infolded inside longitidinal EM biwave structure of scalar potentials
- Gives access to mind and control software

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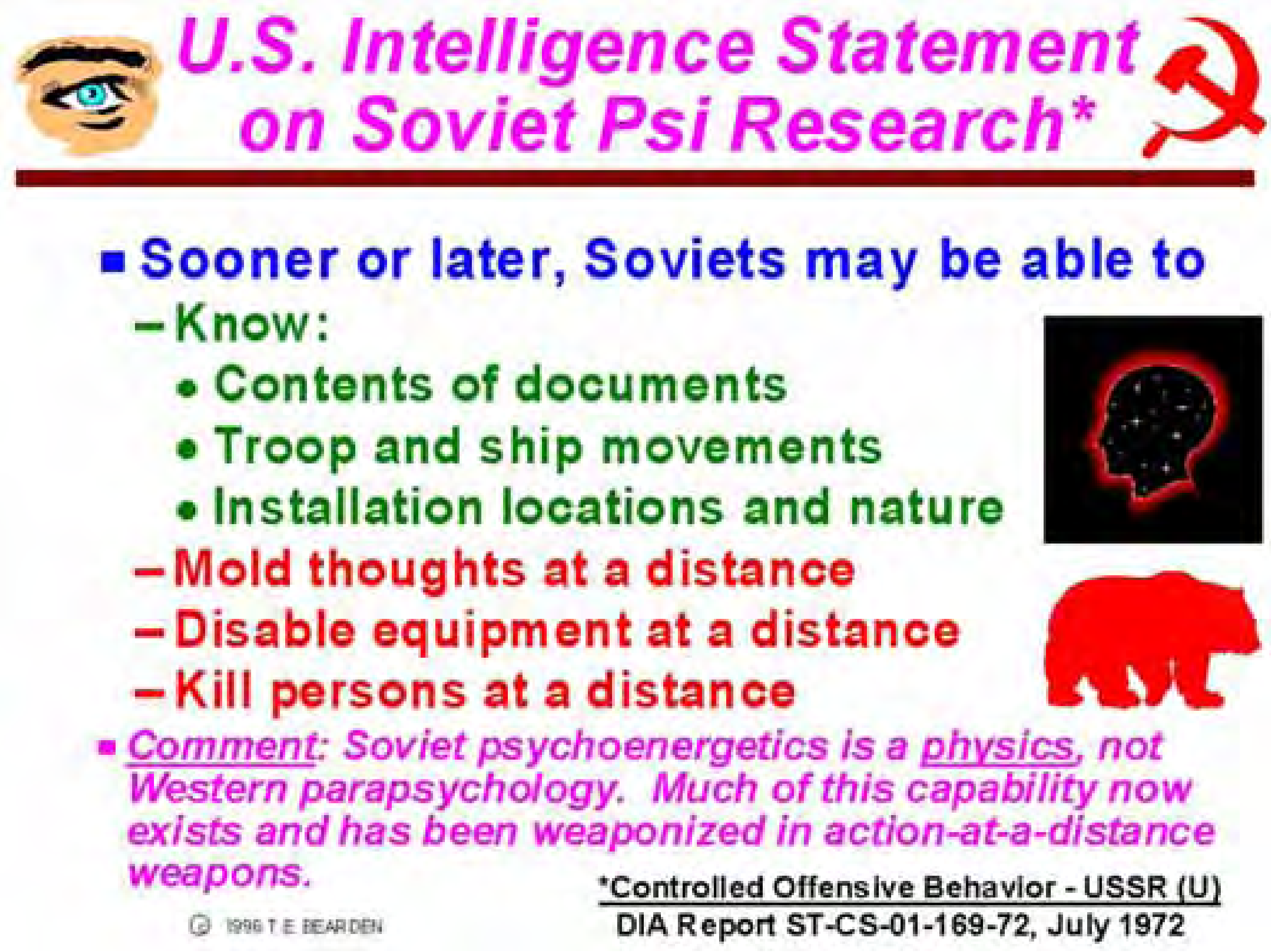

U.S. Intelligence Statement on Soviet Psi Research*

- Sooner or later, Soviets may be able to
  - Know:
    - Contents of documents
    - Troop and ship movements
    - Installation locations and nature
  - Mold thoughts at a distance
  - Disable equipment at a distance
  - Kill persons at a distance
- *Comment: Soviet psychoenergetics is a physics, not Western parapsychology. Much of this capability now exists and has been weaponized in action-at-a-distance weapons.*

*Controlled Offensive Behavior - USSR (U)
DIA Report ST-CS-01-169-72, July 1972

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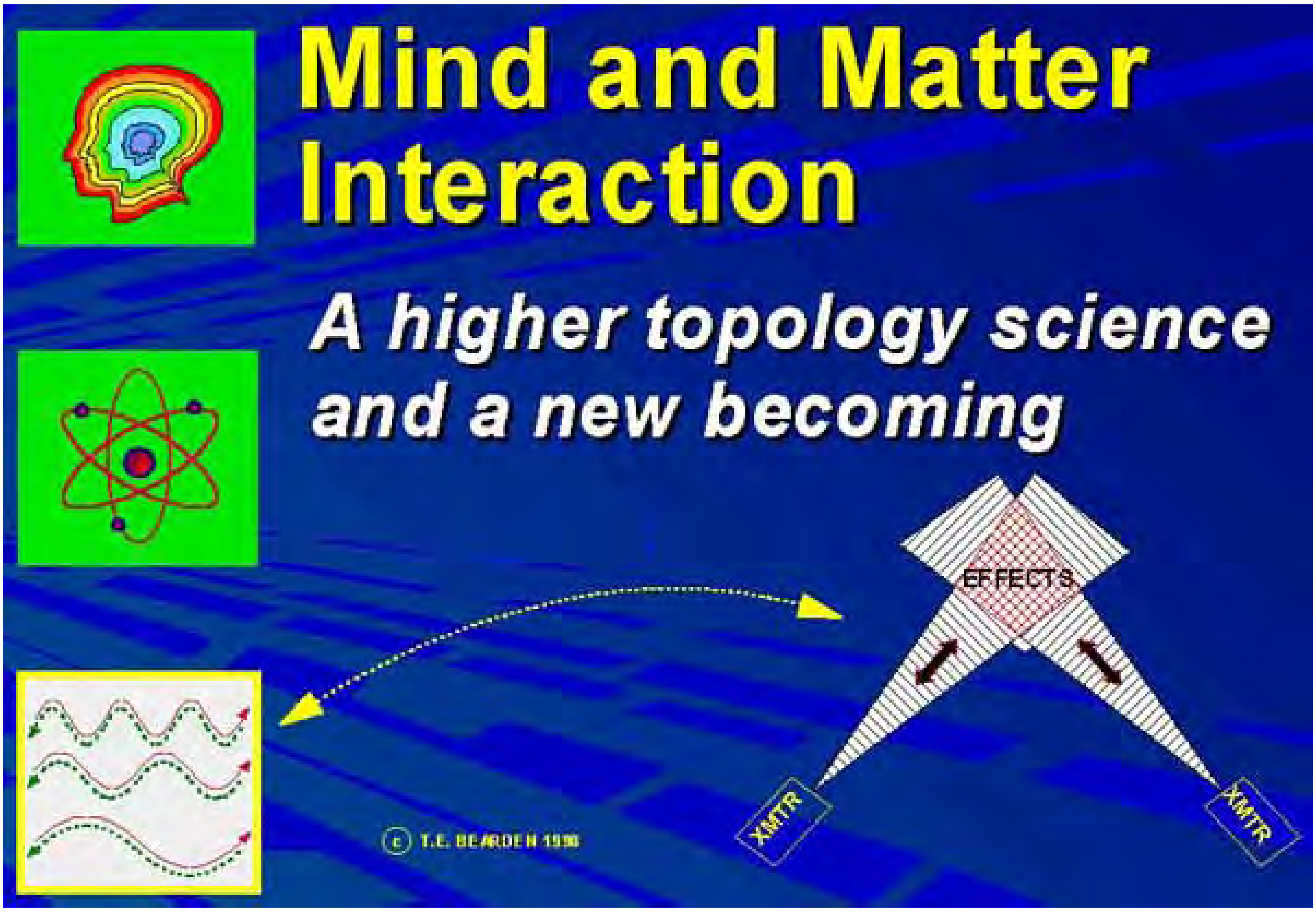

Mind and Matter Interaction

A higher topology science and a new becoming

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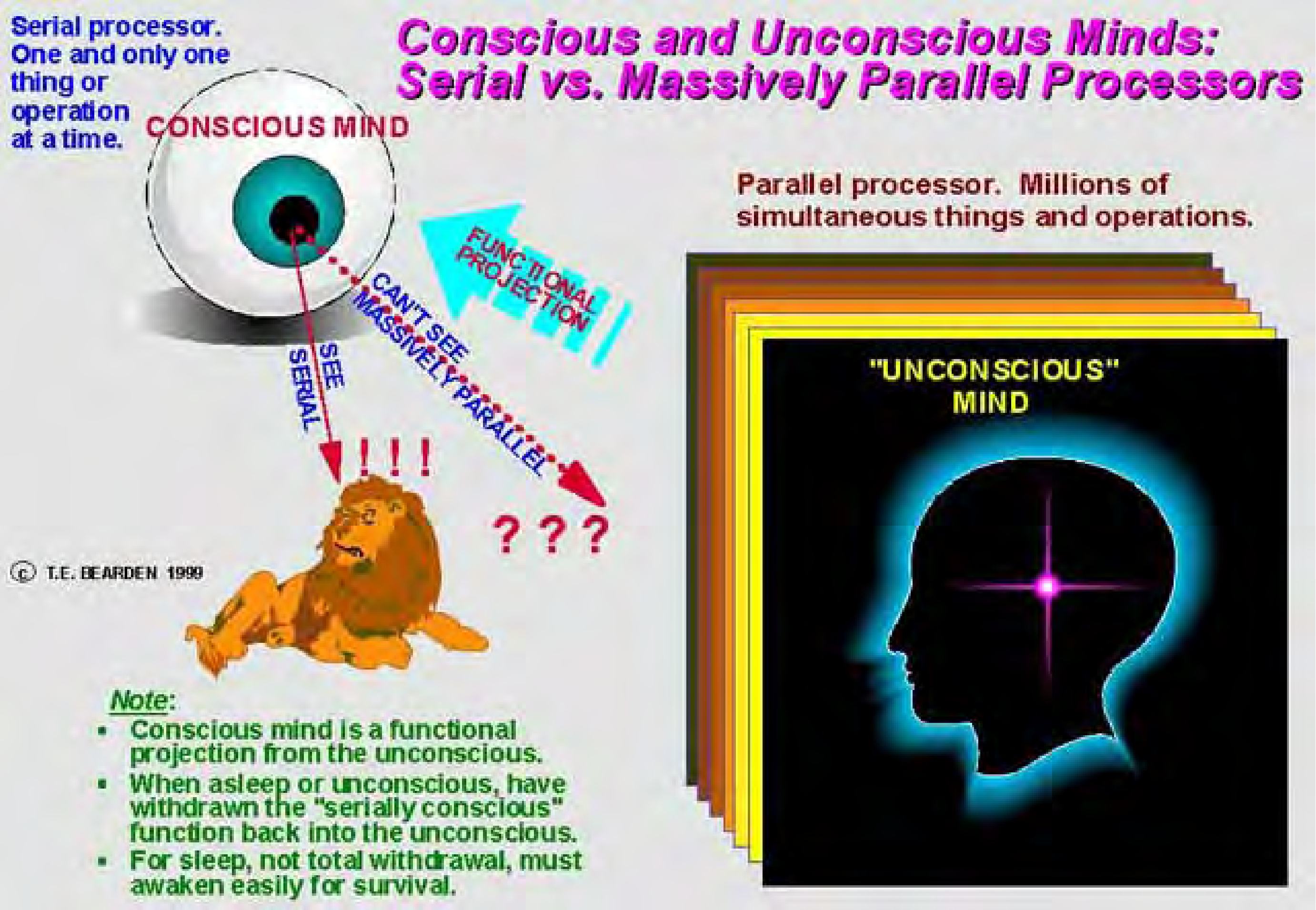

Conscious and Unconscious Minds: Serial vs. Massively Parallel Processors

Serial processor. One and only one thing or operation at a time.

Parallel processor. Millions of simultaneous things and operations.

CONSCIOUS MIND
FUNCTIONAL PROJECTION
CAN'T SEE MASSIVELY PARALLEL
SEE SERIAL
! ! !
? ? ?
"UNCONSCIOUS" MIND

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Note:

- Conscious mind is a functional projection from the unconscious.
- When asleep or unconscious, have withdrawn the "serially conscious" function back into the unconscious.
- For sleep, not total withdrawal, must awaken easily for survival.

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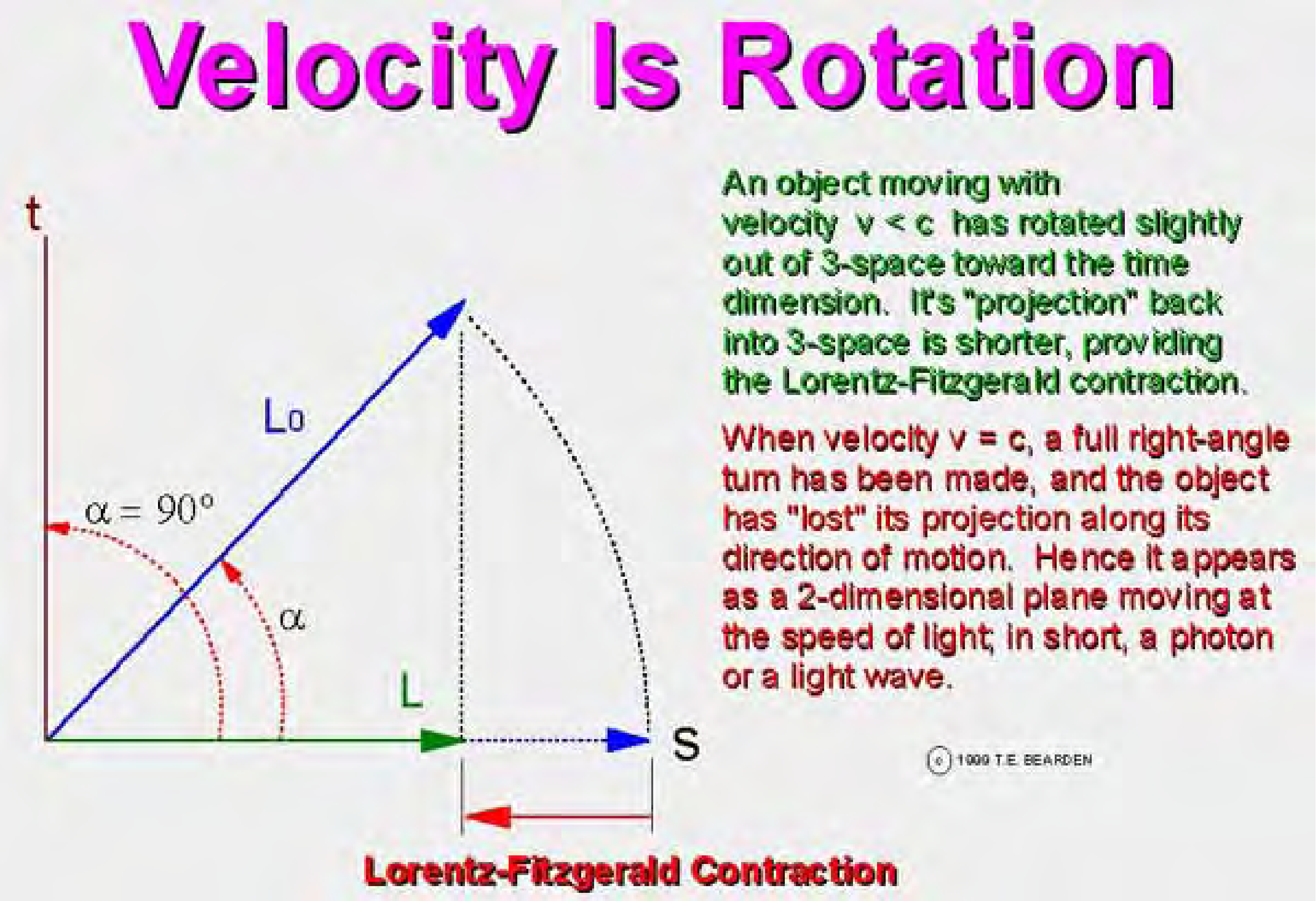

Velocity Is Rotation

An object moving with velocity v < c has rotated slightly out of 3-space toward the time dimension. It's "projection" back into 3-space is shorter, providing the Lorentz-Fitzgerald contraction.

When velocity v = c, a full right-angle turn has been made, and the object has "lost" its projection along its direction of motion. Hence it appears as a 2-dimensional plane moving at the speed of light; in short, a photon or a light wave.

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Lorentz-Fitzgerald Contraction

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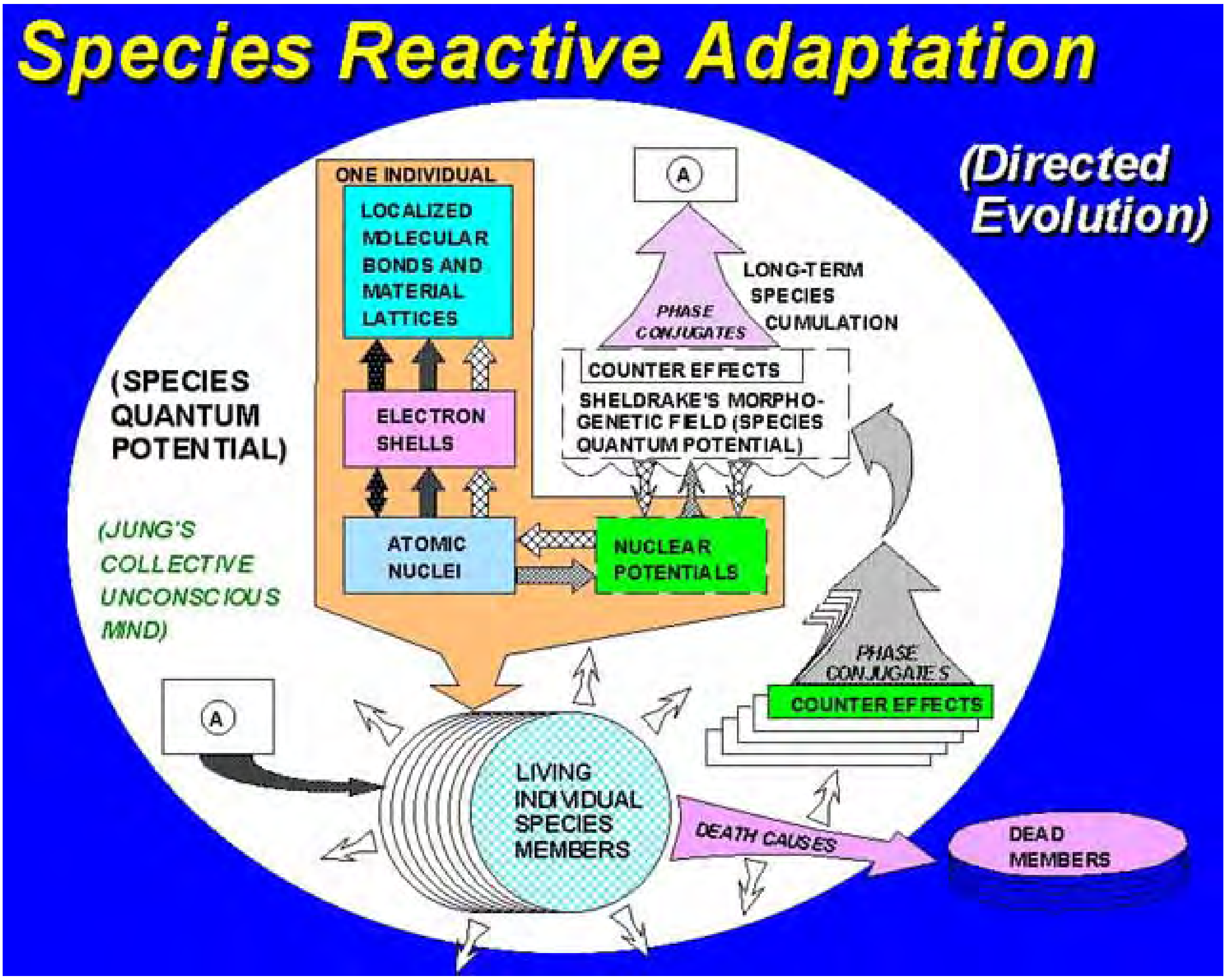

Species Reactive Adaptation

(Directed Evolution)

ONE INDIVIDUAL

LOCALIZED MOLECULAR BONDS AND MATERIAL LATTICES

ELECTRON SHELLS

ATOMIC NUCLEI

NUCLEAR POTENTIALS

(SPECIES QUANTUM POTENTIAL)

(JUNG'S COLLECTIVE UNCONSCIOUS MIND)

A

PHASE CONJUGATES

LONG-TERM SPECIES CUMULATION

COUNTER EFFECTS

SHELDRAKE'S MORPHO-GENETIC FIELD (SPECIES QUANTUM POTENTIAL)

A

PHASE CONJUGATES

COUNTER EFFECTS

LIVING INDIVIDUAL SPECIES MEMBERS

DEATH CAUSES

DEAD MEMBERS

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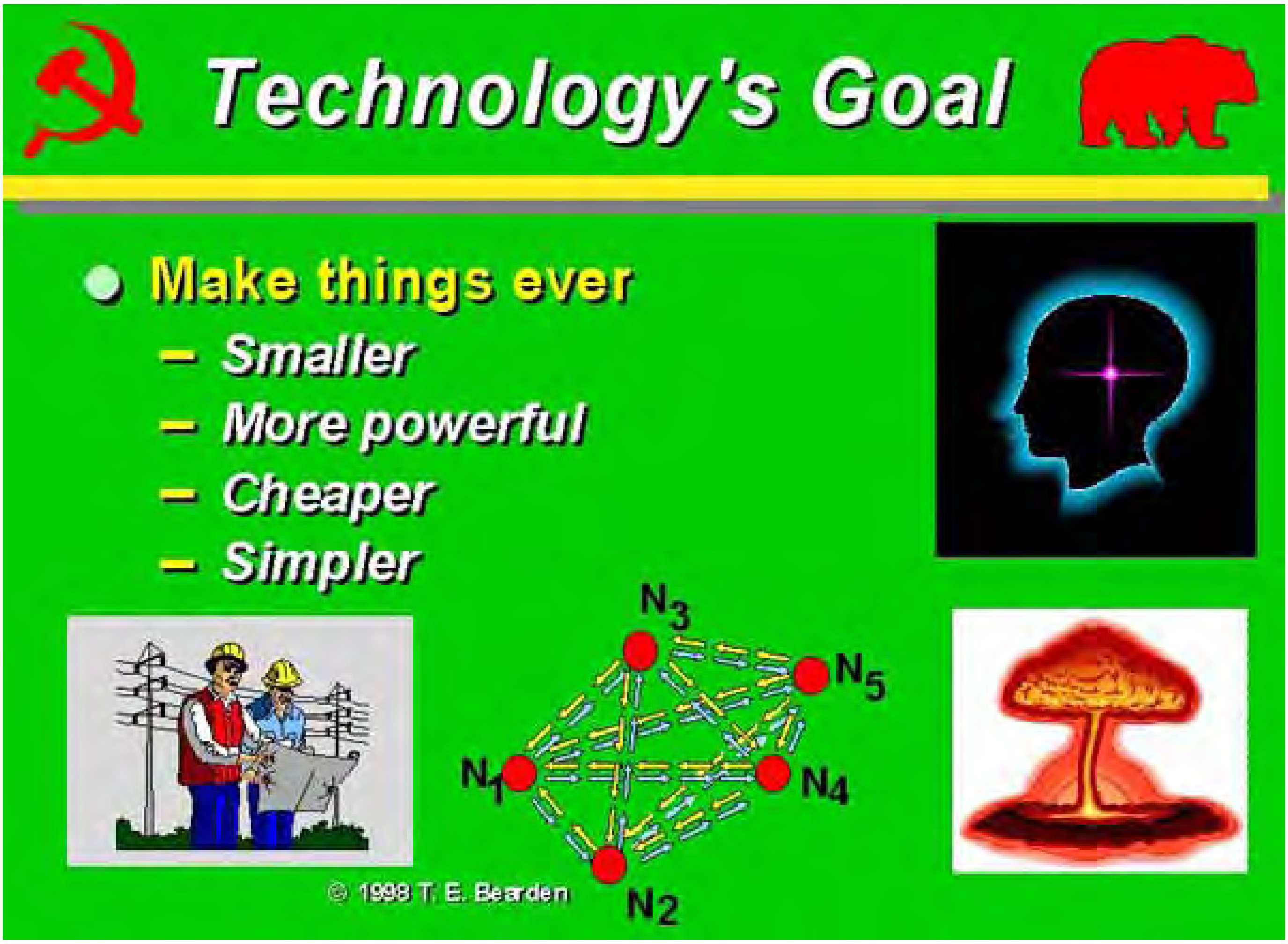

Technology's Goal

- Make things ever
  - Smaller
  - More powerful
  - Cheaper
  - Simpler

N3
N5
N1
N4
N2

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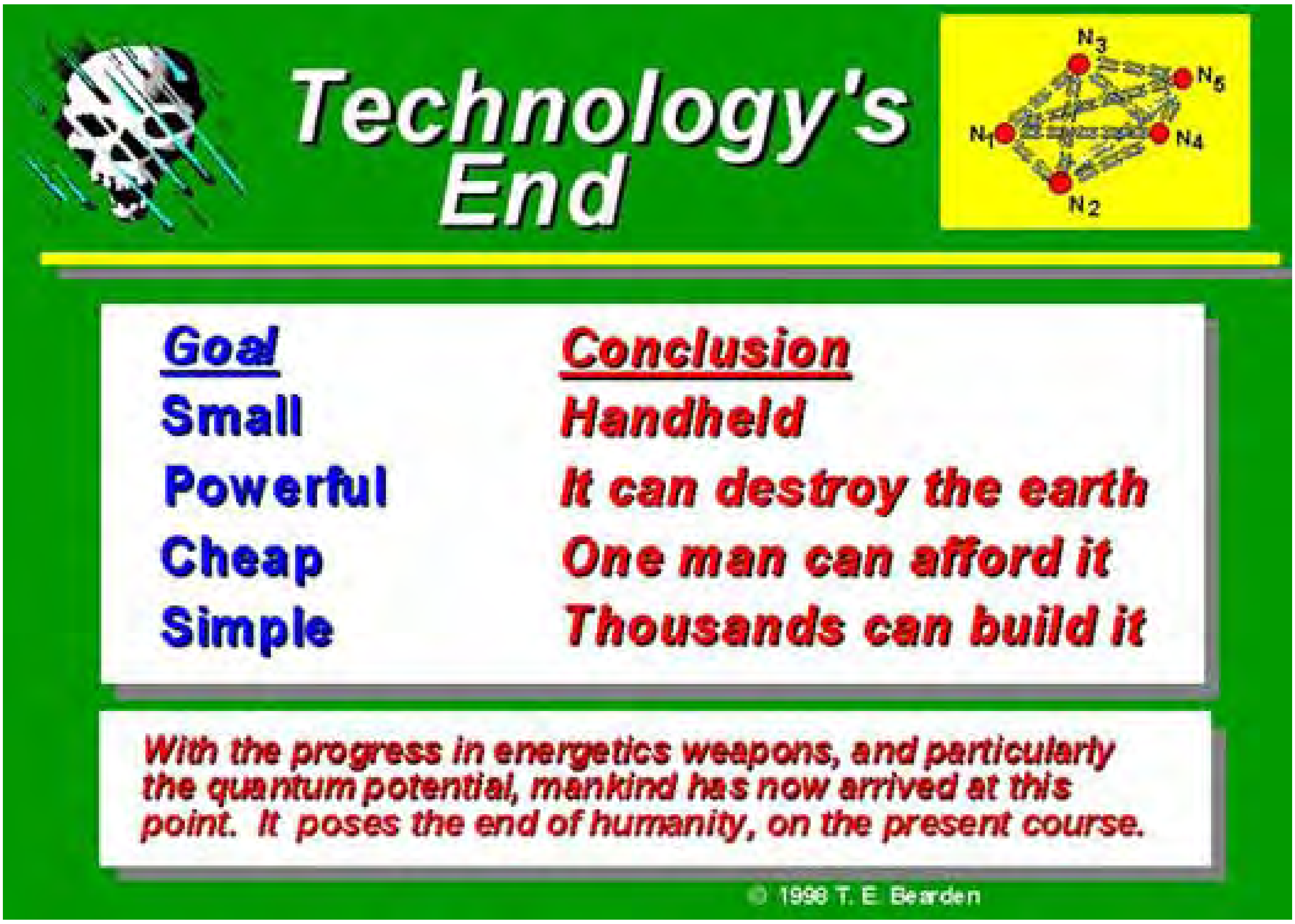
N3
N5
N1
N4
N2

Technology's End

Goal	Conclusion
Small	Handheld
Powerful	It can destroy the earth
Cheap	One man can afford it
Simple	Thousands can build it

With the progress in energetics weapons, and particularly the quantum potential, mankind has now arrived at this point. It poses the end of humanity, on the present course.

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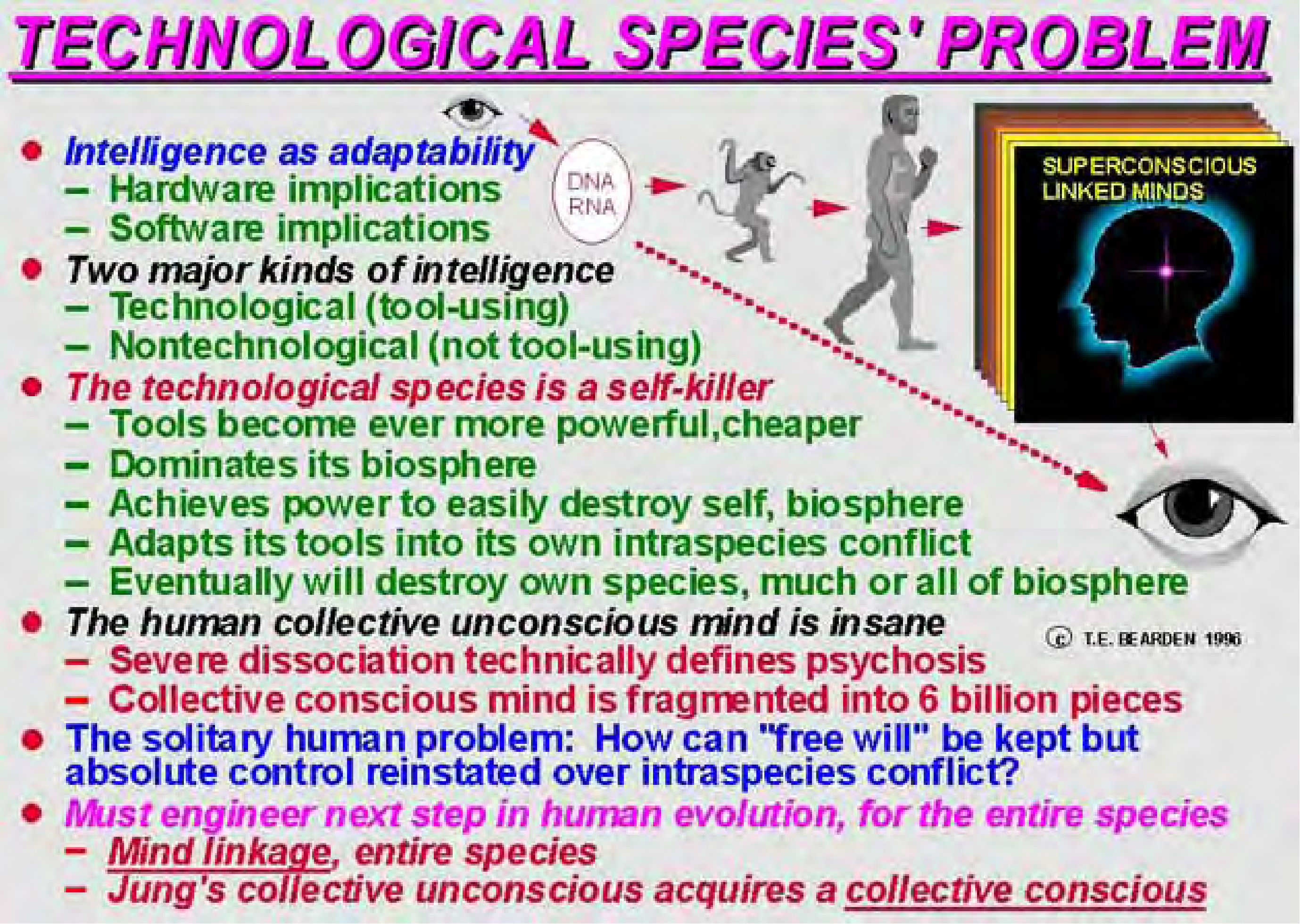
DNA
RNA
SUPERCONSCIOUS
LINKED MINDS

TECHNOLOGICAL SPECIES' PROBLEM

- *Intelligence as adaptability*
  - Hardware implications
  - Software implications
- *Two major kinds of intelligence*
  - Technological (tool-using)
  - Nontechnological (not tool-using)
- *The technological species is a self-killer*
  - Tools become ever more powerful,cheaper
  - Dominates its biosphere
  - Achieves power to easily destroy self, biosphere
  - Adapts its tools into its own intraspecies conflict
  - Eventually will destroy own species, much or all of biosphere
- *The human collective unconscious mind is insane*
  - Severe dissociation technically defines psychosis
  - Collective conscious mind is fragmented into 6 billion pieces
- The solitary human problem: How can "free will" be kept but absolute control reinstated over intraspecies conflict?
- *Must engineer next step in human evolution, for the entire species*
  - *Mind linkage, entire species*
  - *Jung's collective unconscious acquires a collective conscious*

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The Missing Infolded Electrodynamics

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1. The Missing Infolded Electrodynamics
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7. Electrodynamicists React to Removal of Material Ether
8. Reaction to Loss of Material Ether
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17. Time-Polarized (Scalar) EM Wave
18. Mechanism for flow of time
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20. Bridging for Overunity
21. Free Energy Generator
22. Demonstration of Overunity Concept
23. Altered Spacetime Curvatures
24. Interaction of Mass and Spacetime Curvature
25. Composition of Scalar Potential
26. Lorenz Closed Surface Integration
27. How can they use that old physically insignificant wind?!!
28. Vacuum Engines: Spacetime Demons
29. Undistorted Progressive Waves (1)
30. Undistorted Progressive Waves (2)
31. Other Superluminal Waves
32. Becker's Experiments: Healing Bone Fractures
33. Producing a Specific Spacetime Curvature Engine
34. Pumping A Phase Conjugate with Transverse EM

35. Differentiation and Dedifferentiation
36. First Step to Cancer: Hypoxia
37. Longitudinal Photon Interaction with Charge
38. General Relativity in Particle Physics
39. Pepper* on time-reversing mass
40. Pepper* on time-reversing mass (2)
41. Pepper* on time-reversing mass (3)
42. Chung's Negative Resistor
43. China Lake Anomalies
44. Time Reversal (TR) Zone
45. Electronuclear Reactions in TR-Zones (1)
46. Electronuclear Reactions in TR-Zones (2)
47. Electronuclear Reactions in TR-Zones (3)
48. Nuclear Reactions in Time-Reversal Zones
49. Nuclear reactions are biased
50. Dynamics may be reversed
51. Significant only after time-density charging
52. Curved Spacetime as source or sink
53. Anomalous China Lake Phenomena (1)
54. Anomalous China Lake 2
55. Anomalous China Lake 3
56. Anomalous China Lake 4
57. Consistent Anomalies 1
58. Consistent Anomalies 2
59. LW Emission in Electrolysis
60. New Energy Conservation Law
61. Carcinogens & EM Radiation
62. Carcinogens & EM Radiation 1
63. Chronic Disease Puzzle
64. Cancer characteristics
65. Solving Cancer Enigma
66. Cancer Characteristics
67. Portable Prioré Unit
68. Lisitsyn: Brain Code Broken
69. Anti-engine reverses cell
70. Prioré Methodology
71. Prioré Methodology (2)
72. Pumping cell with LW
73. Extension to Nonlinear Optics
74. Time Reversal of Mass to a Form Not in Its Past
75. Cellular R&R System

76. Portable Prioré Treatment System
77. Portable System Block Diagram
78. Absorption and Emission
79. Absorption and Emission (2)
80. EM Waves in Spacetime
81. Cellular Evolution
82. Becker's Regeneration System
83. Becker's Control System Responds to Injury
84. Casualties Surviving Conventional Treatment
85. "Time as fuel" is the future

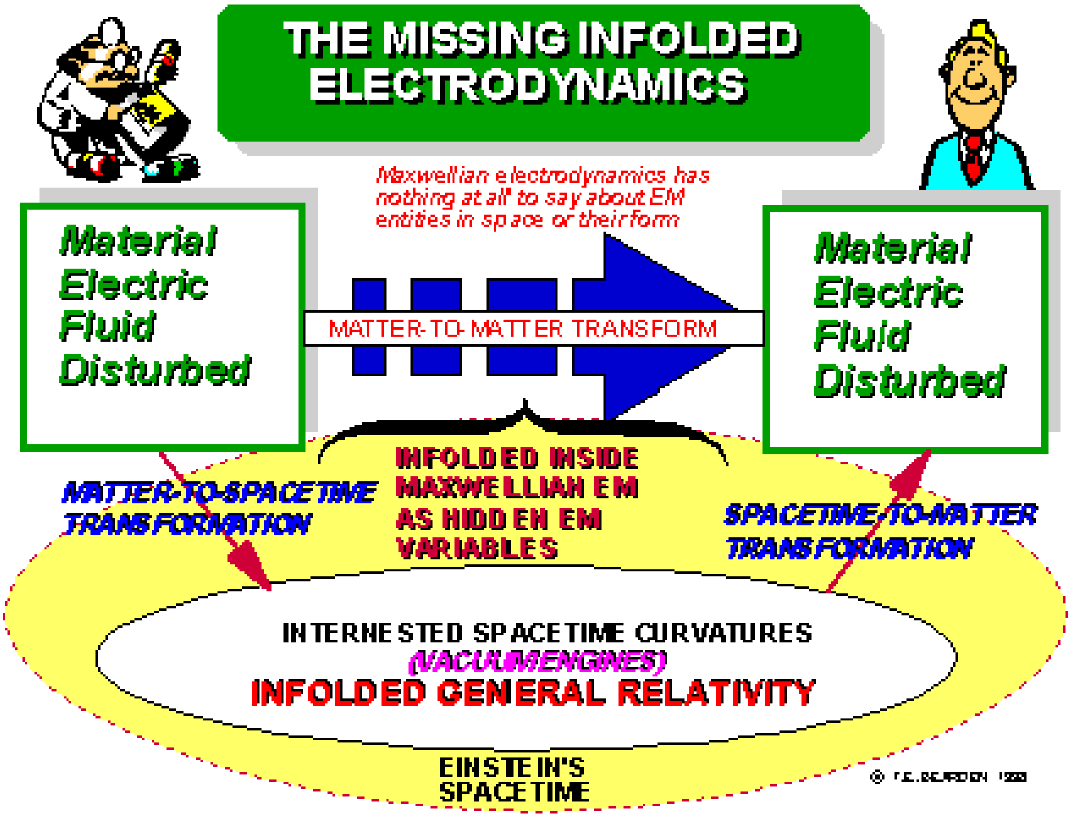
THE MISSING INFOLDED ELECTRODYNAMICS
Maxwellian electrodynamics has nothing at all to say about EM entities in space or their form
Material Electric Fluid Disturbed
MATTER-TO-MATTER TRANSFORM
Material Electric Fluid Disturbed
MATTER-TO-SPACETIME TRANSFORMATION
INFOLDED INSIDE MAXWELLIAN EM AS HIDDEN EM VARIABLES
SPACETIME-TO-MATTER TRANSFORMATION
INTERNESTED SPACETIME CURVATURES
(VACUUM ENGINES)
INFOLDED GENERAL RELATIVITY
EINSTEIN'S SPACETIME
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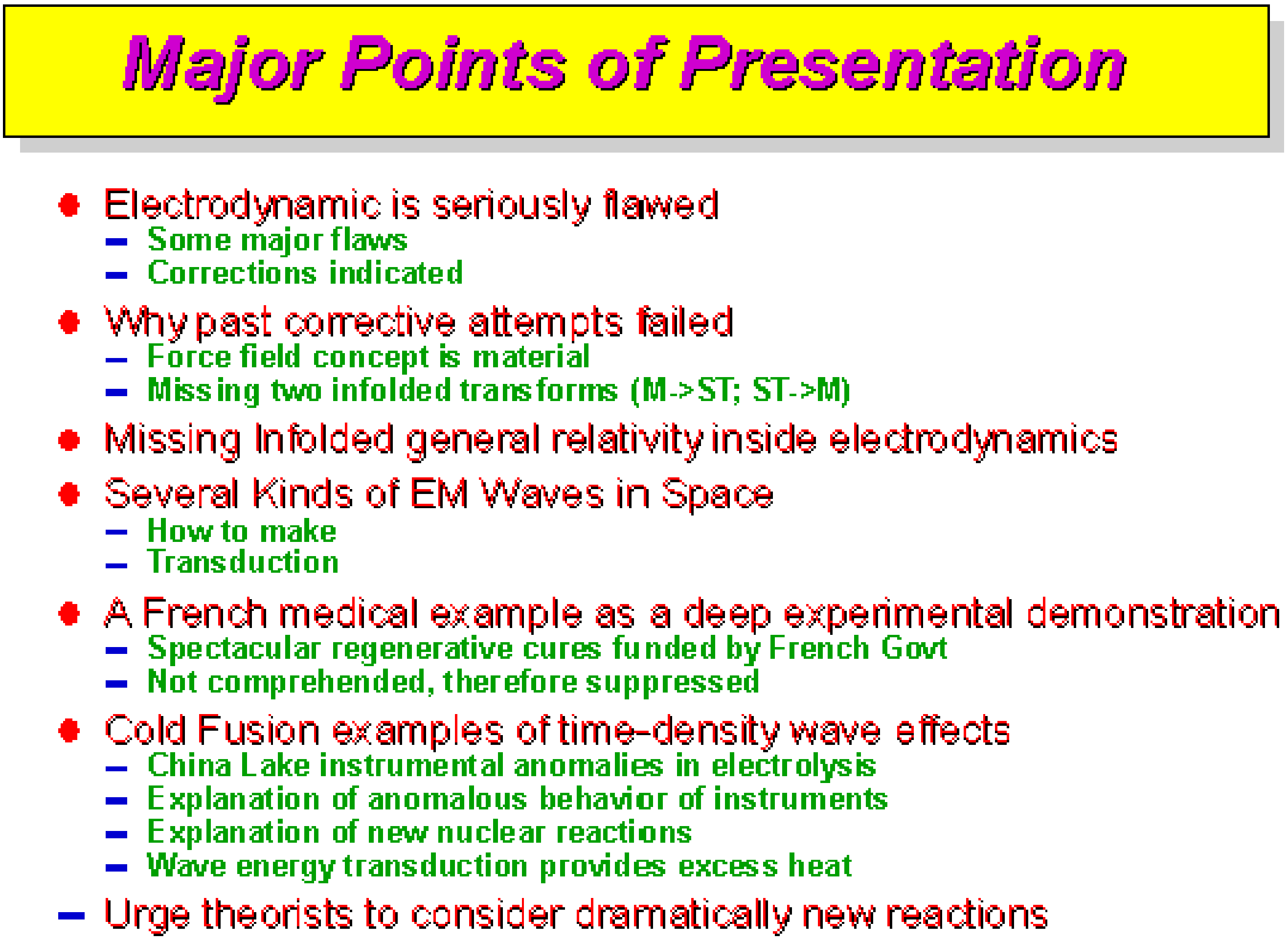

Major Points of Presentation

- Electrodynamic is seriously flawed
  - Some major flaws
  - Corrections indicated
- Why past corrective attempts failed
  - Force field concept is material
  - Missing two infolded transforms (M->ST; ST->M)
- Missing Infolded general relativity inside electrodynamics
- Several Kinds of EM Waves in Space
  - How to make
  - Transduction
- A French medical example as a deep experimental demonstration
  - Spectacular regenerative cures funded by French Govt
  - Not comprehended, therefore suppressed
- Cold Fusion examples of time-density wave effects
  - China Lake instrumental anomalies in electrolysis
  - Explanation of anomalous behavior of instruments
  - Explanation of new nuclear reactions
  - Wave energy transduction provides excess heat
- Urge theorists to consider dramatically new reactions

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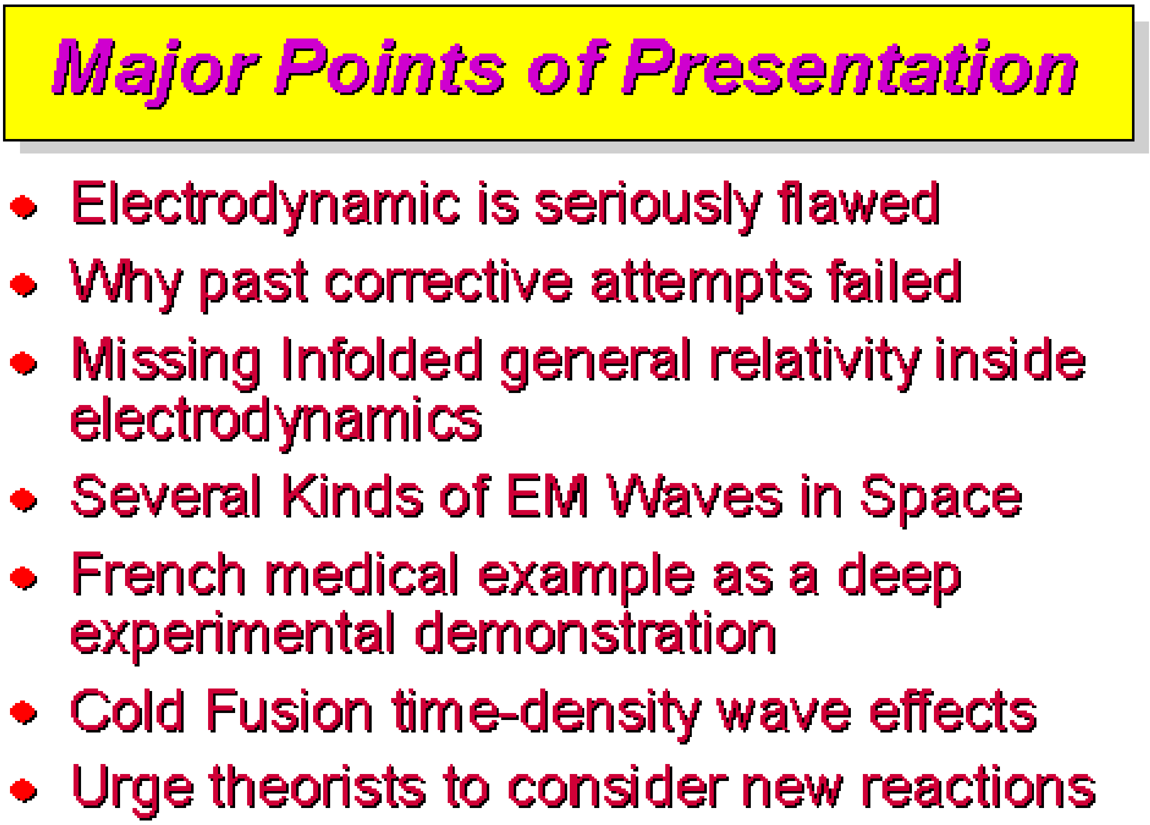

Major Points of Presentation

- Electrodynamic is seriously flawed
- Why past corrective attempts failed
- Missing Infolded general relativity inside electrodynamics
- Several Kinds of EM Waves in Space
- French medical example as a deep experimental demonstration
- Cold Fusion time-density wave effects
- Urge theorists to consider new reactions

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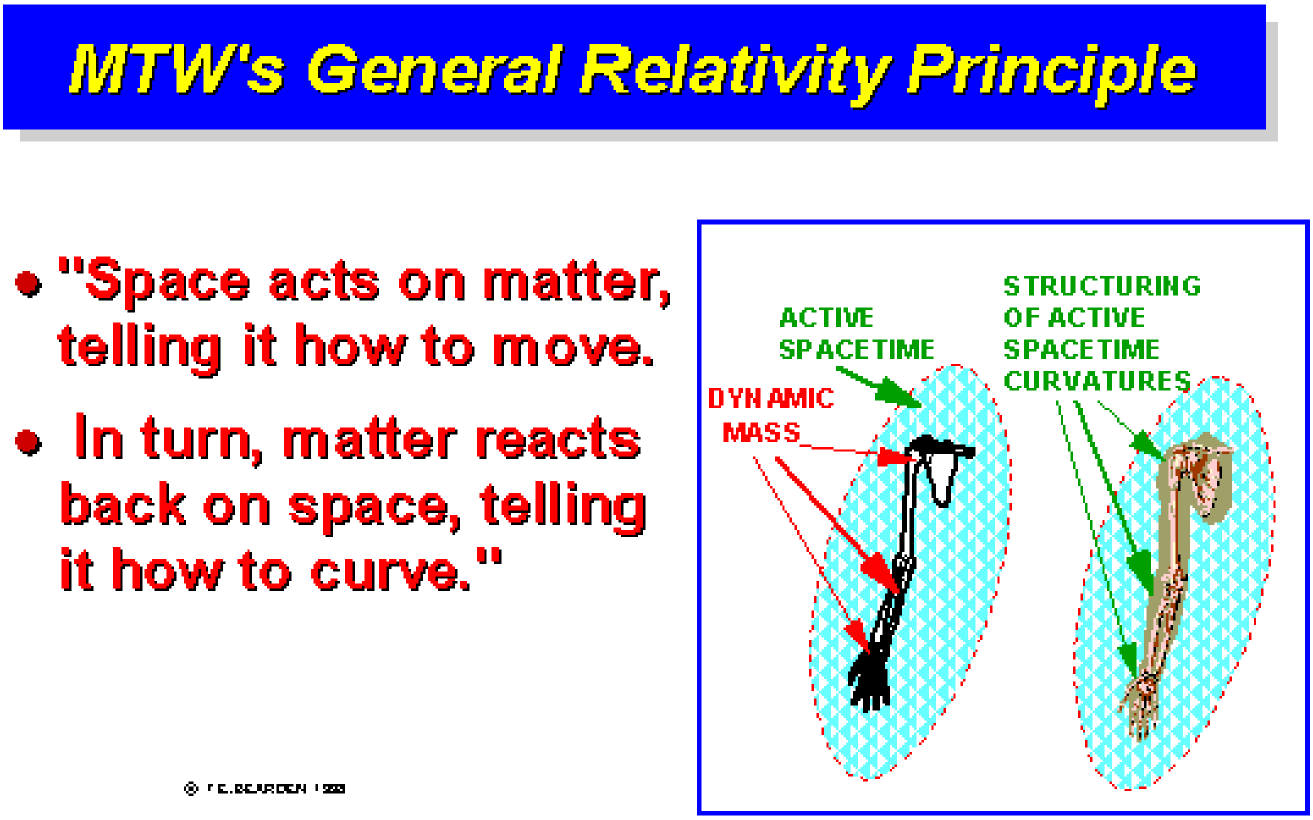

MTW's General Relativity Principle

- "Space acts on matter, telling it how to move.
- In turn, matter reacts back on space, telling it how to curve."

ACTIVE SPACETIME
STRUCTURING OF ACTIVE SPACETIME CURVATURES
DYNAMIC MASS

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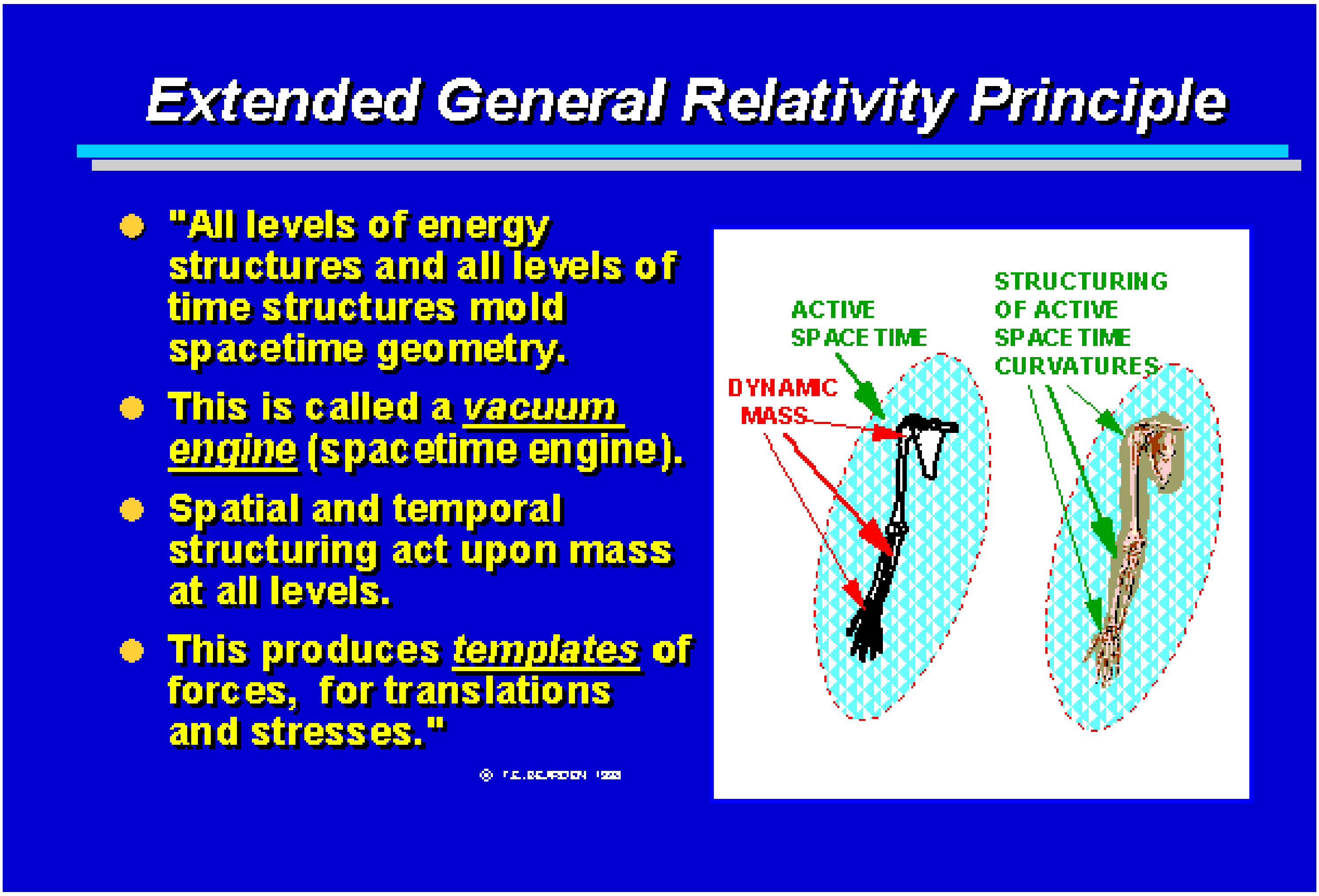

Extended General Relativity Principle

- "All levels of energy structures and all levels of time structures mold spacetime geometry.
- This is called a *vacuum engine* (spacetime engine).
- Spatial and temporal structuring act upon mass at all levels.
- This produces *templates* of forces, for translations and stresses."

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ACTIVE SPACE TIME
DYNAMIC MASS
STRUCTURING OF ACTIVE SPACE TIME CURVATURES

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Active Spacetime and a Specific Vacuum Engine (Spacetime Engine)

(A General Relativistic Concept and Analogy)

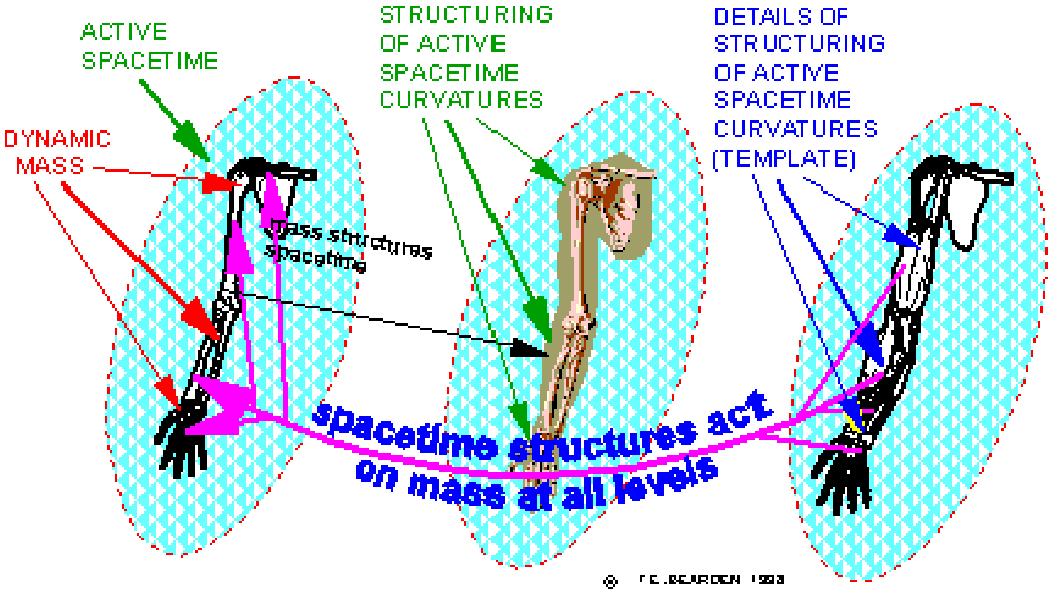
ACTIVE SPACETIME
STRUCTURING OF ACTIVE SPACETIME CURVATURES
DETAILS OF STRUCTURING OF ACTIVE SPACETIME CURVATURES (TEMPLATE)
DYNAMIC MASS
mass structures spacetime
spacetime structures act on mass at all levels
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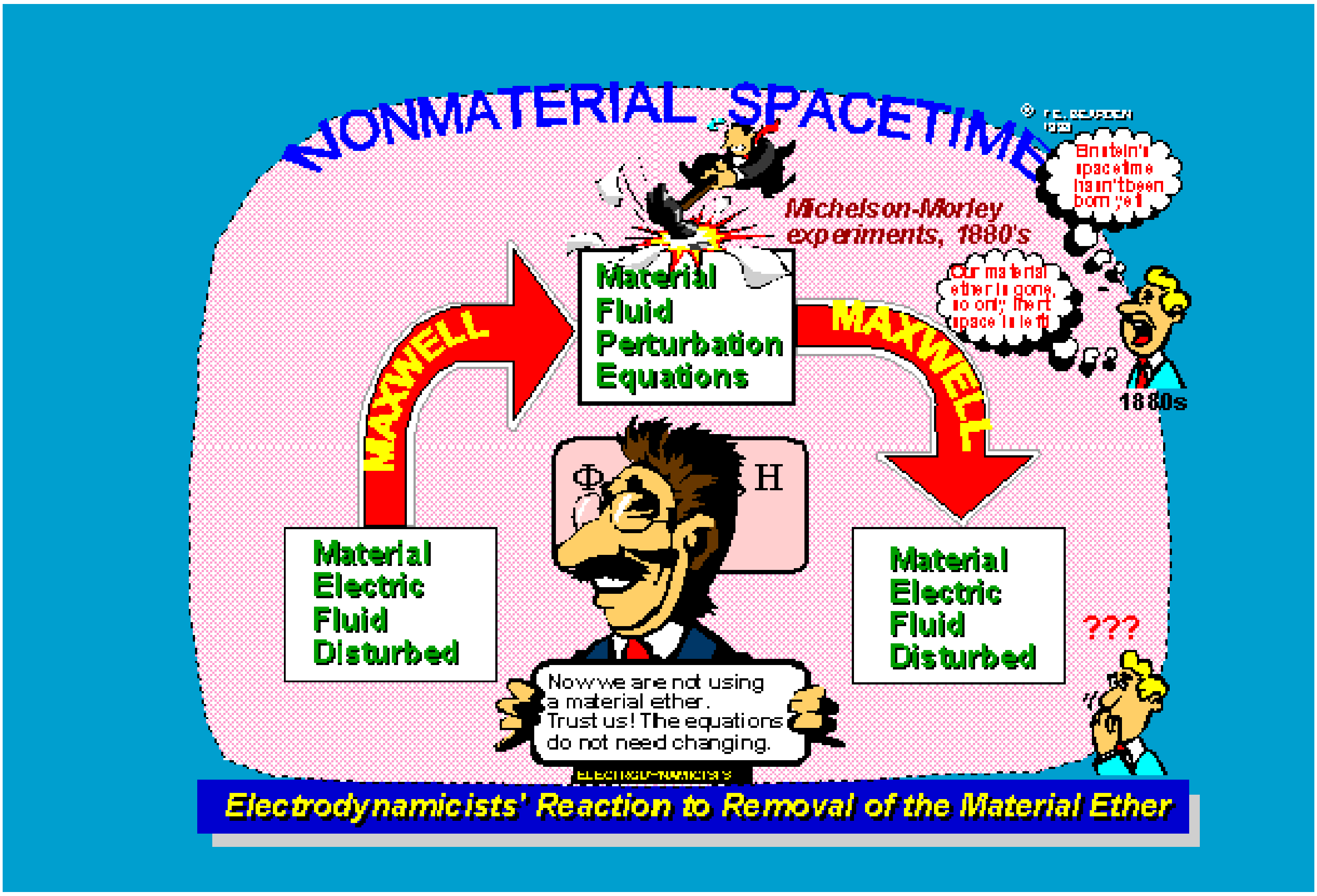
NONMATERIAL SPACETIME
© T.E. BEARDEN
Einstein's spacetime hasn't been born yet!
Michelson-Morley experiments, 1880's
Our material ether is gone, so only inert space is left!
1880s
Material Fluid Perturbation Equations
MAXWELL
MAXWELL
Φ
H
Material Electric Fluid Disturbed
Material Electric Fluid Disturbed
???
Now we are not using a material ether. Trust us! The equations do not need changing.
ELECTRODYNAMICISTS

Electrodynamicists' Reaction to Removal of the Material Ether

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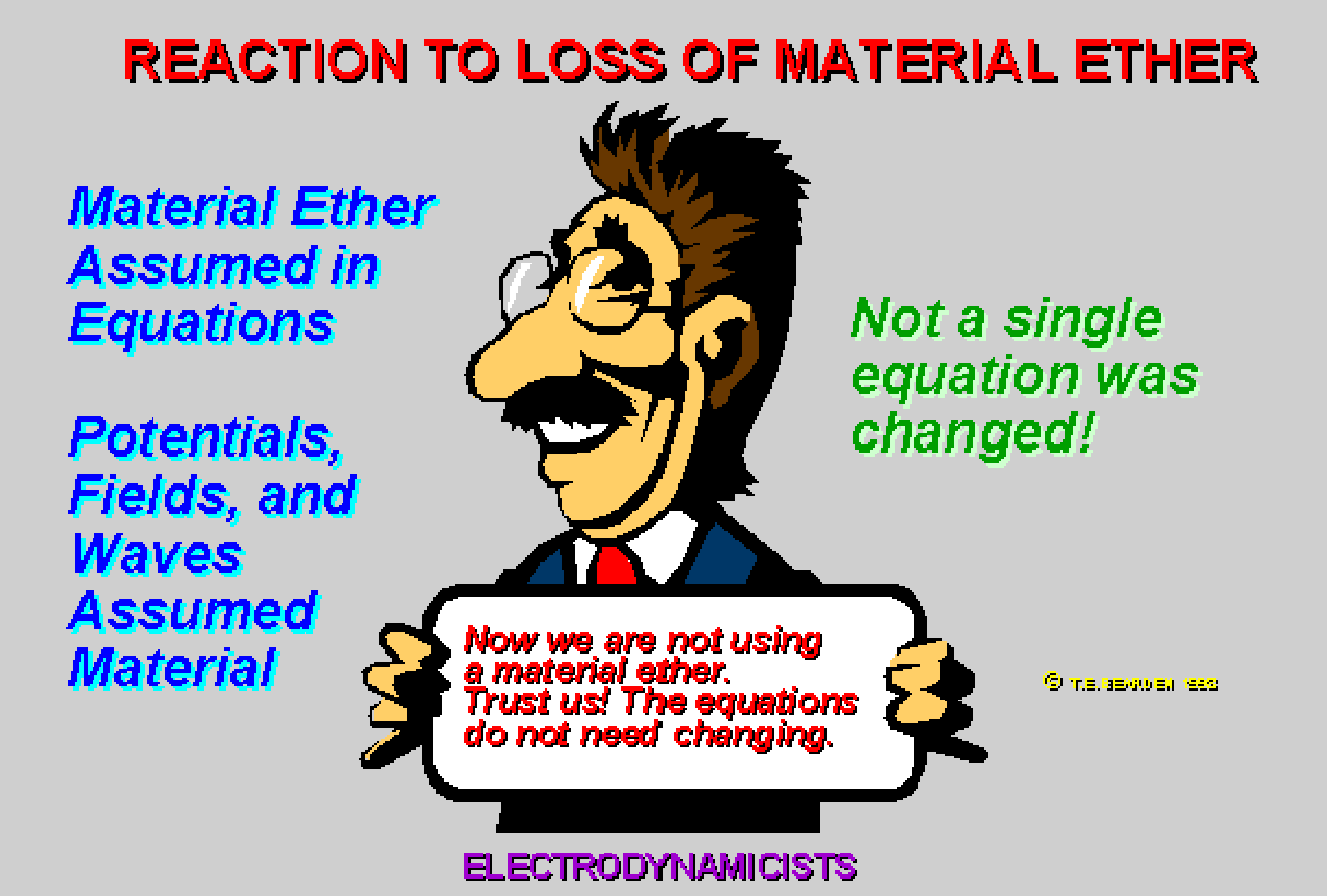

REACTION TO LOSS OF MATERIAL ETHER

Material Ether Assumed in Equations

Potentials, Fields, and Waves Assumed Material

Not a single equation was changed!

Now we are not using a material ether. Trust us! The equations do not need changing.

ELECTRODYNAMICISTS

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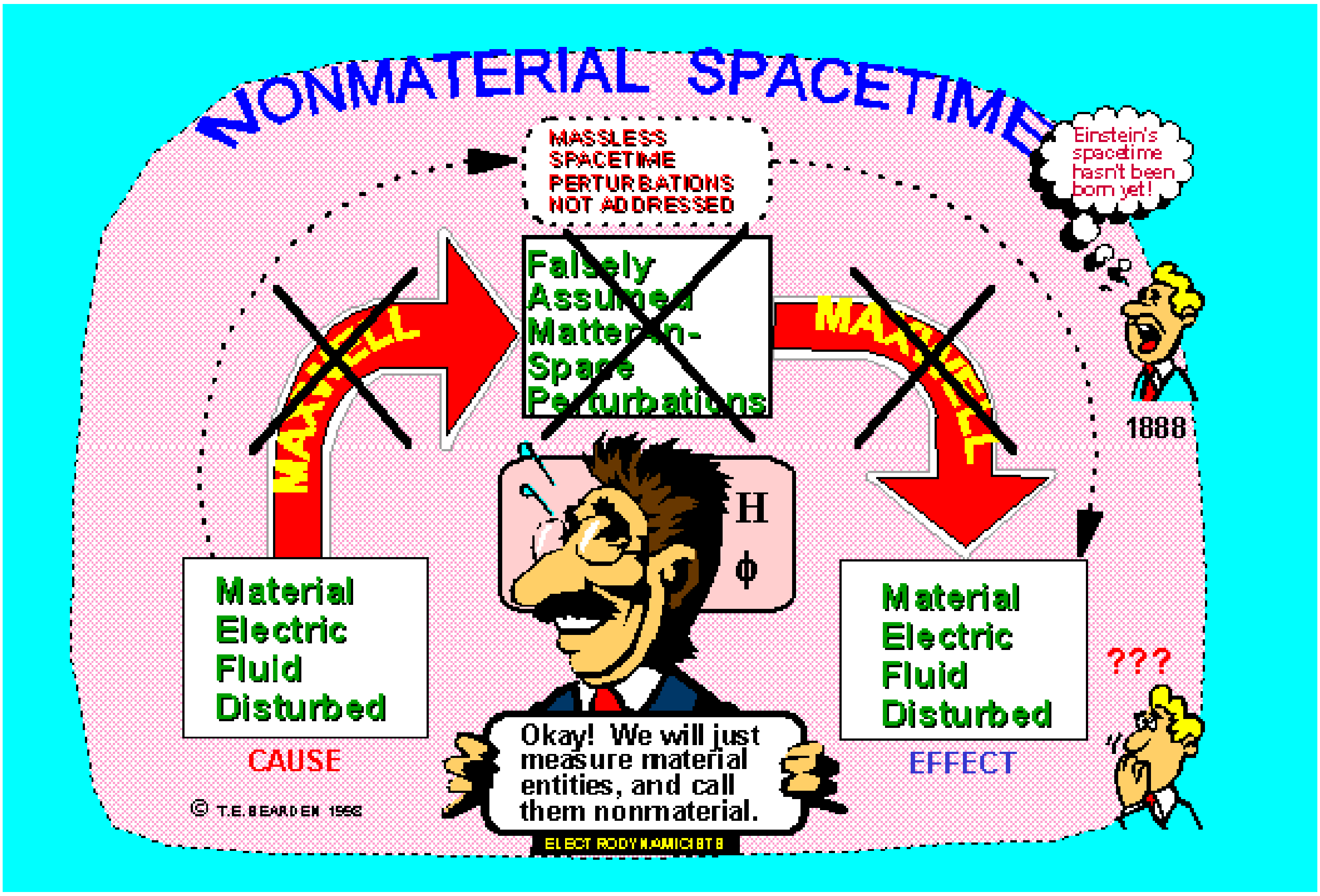
NONMATERIAL SPACETIME
MASSLESS SPACETIME PERTURBATIONS NOT ADDRESSED
Einstein's spacetime hasn't been born yet!
Falsely Assumed Matter-in-Space Perturbations
MAXWELL
MAXWELL
1888
H
ϕ
Material Electric Fluid Disturbed
CAUSE
Material Electric Fluid Disturbed
EFFECT
???
Okay! We will just measure material entities, and call them nonmaterial.
ELECTRODYNAMICISTS
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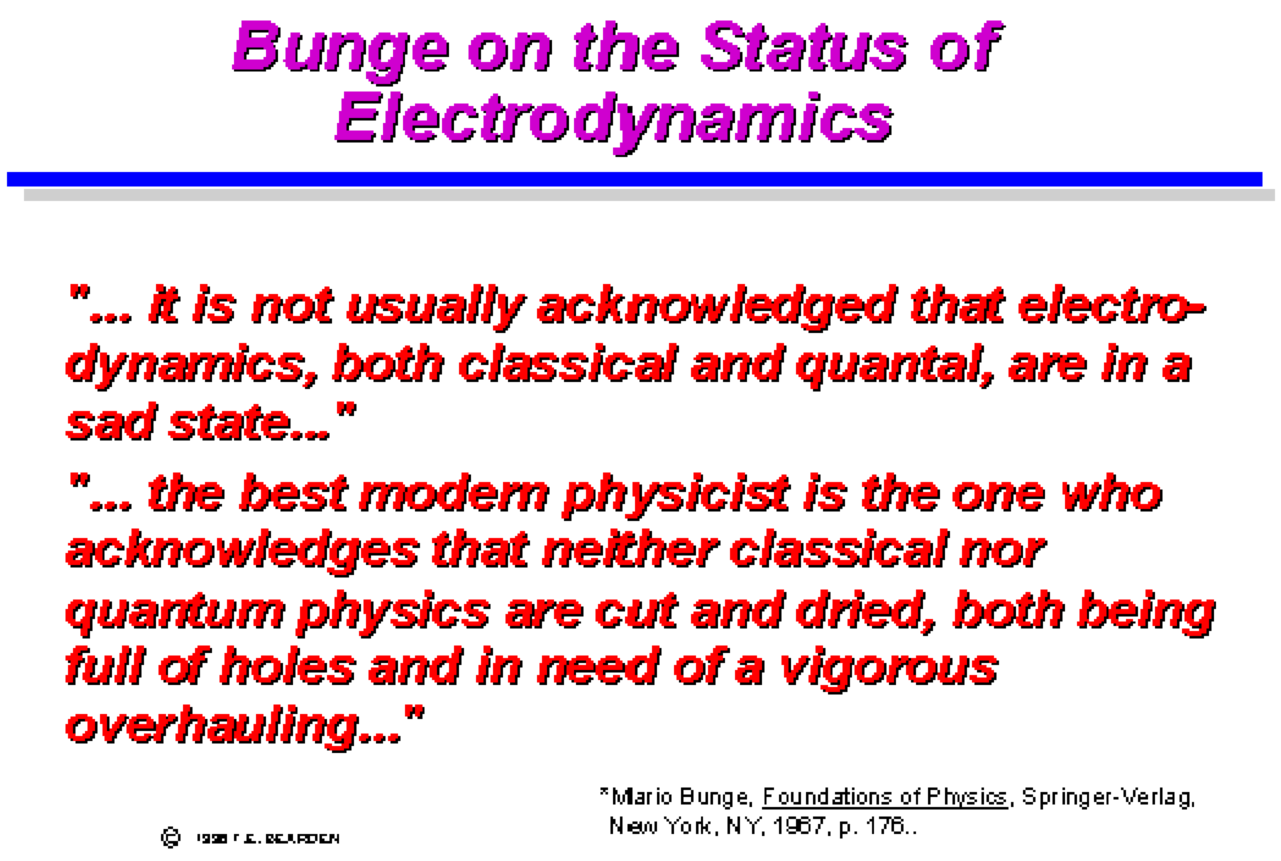

Bunge on the Status of Electrodynamics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state..."

"... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling..."

*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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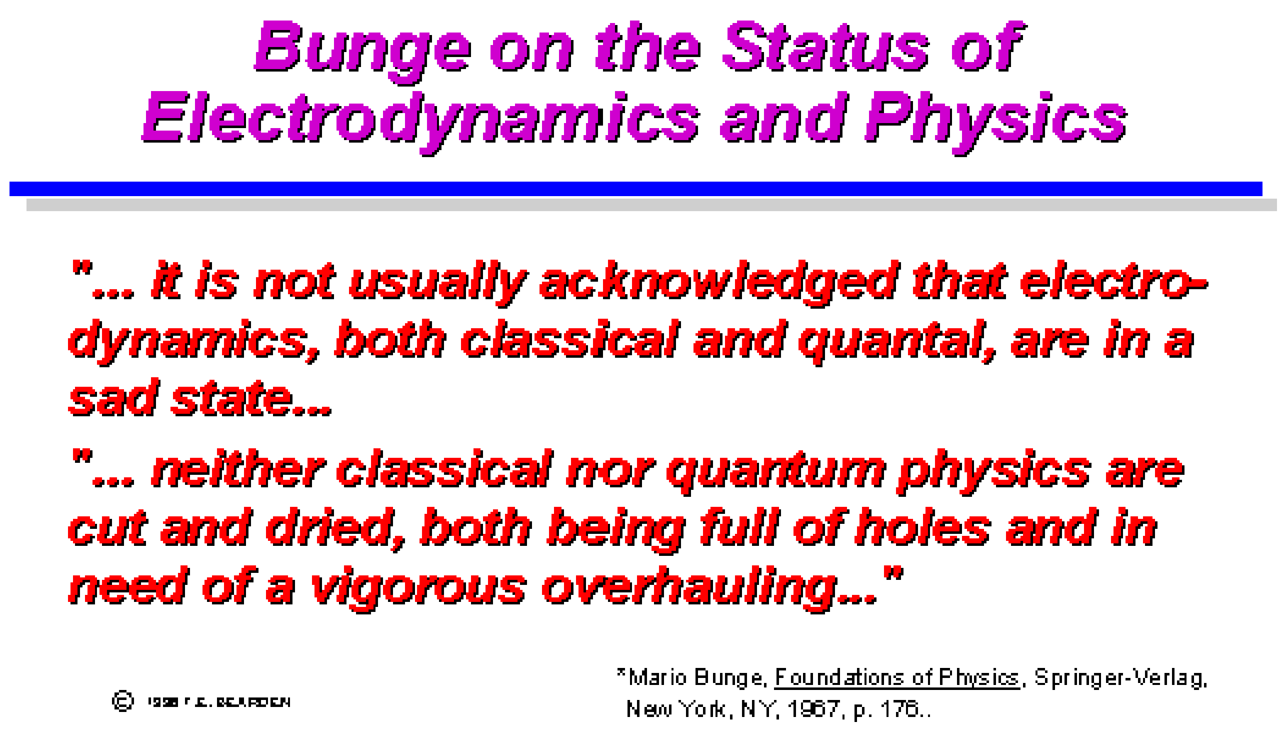

Bunge on the Status of Electrodynamics and Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state...

"... neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling..."

*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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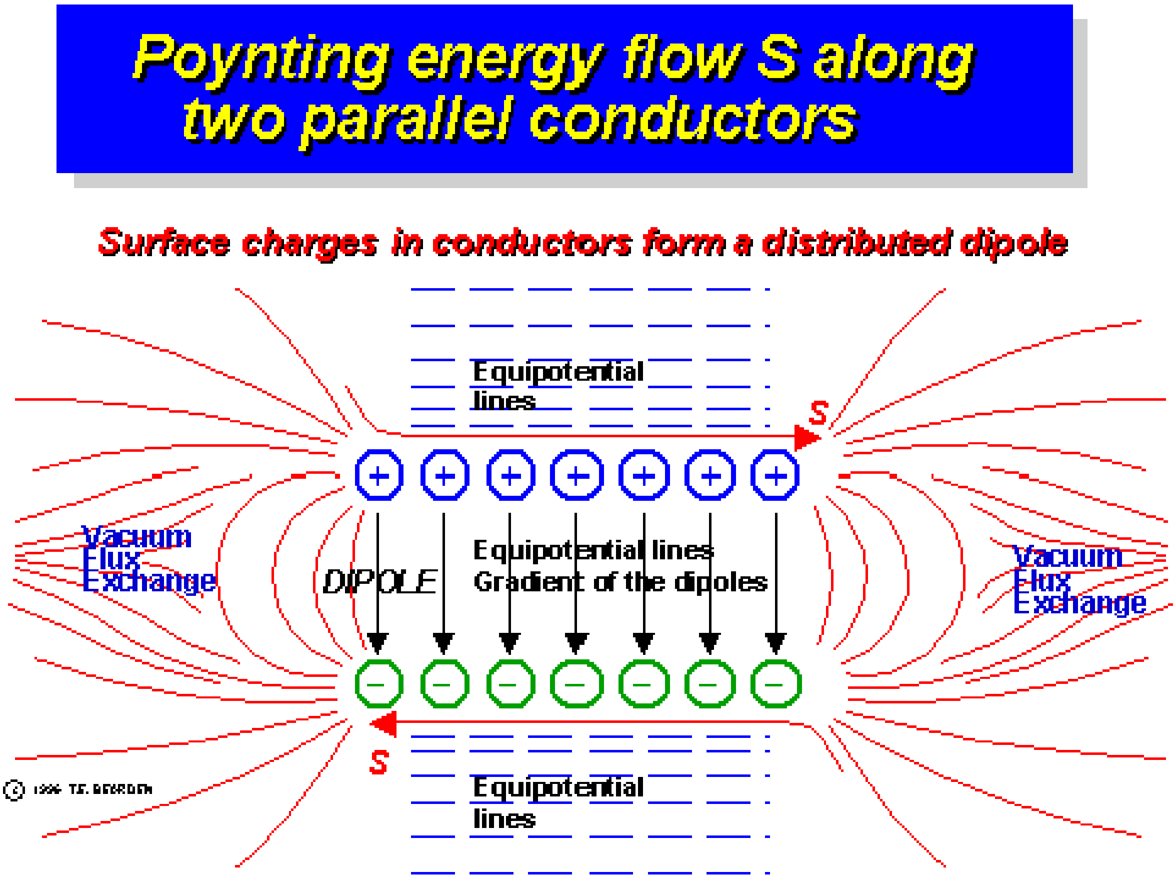

Poynting energy flow S along two parallel conductors

Surface charges in conductors form a distributed dipole

Equipotential lines
S
+
Vacuum Flux Exchange
DIPOLE
Equipotential lines
Gradient of the dipoles
Vacuum Flux Exchange
−
S
Equipotential lines

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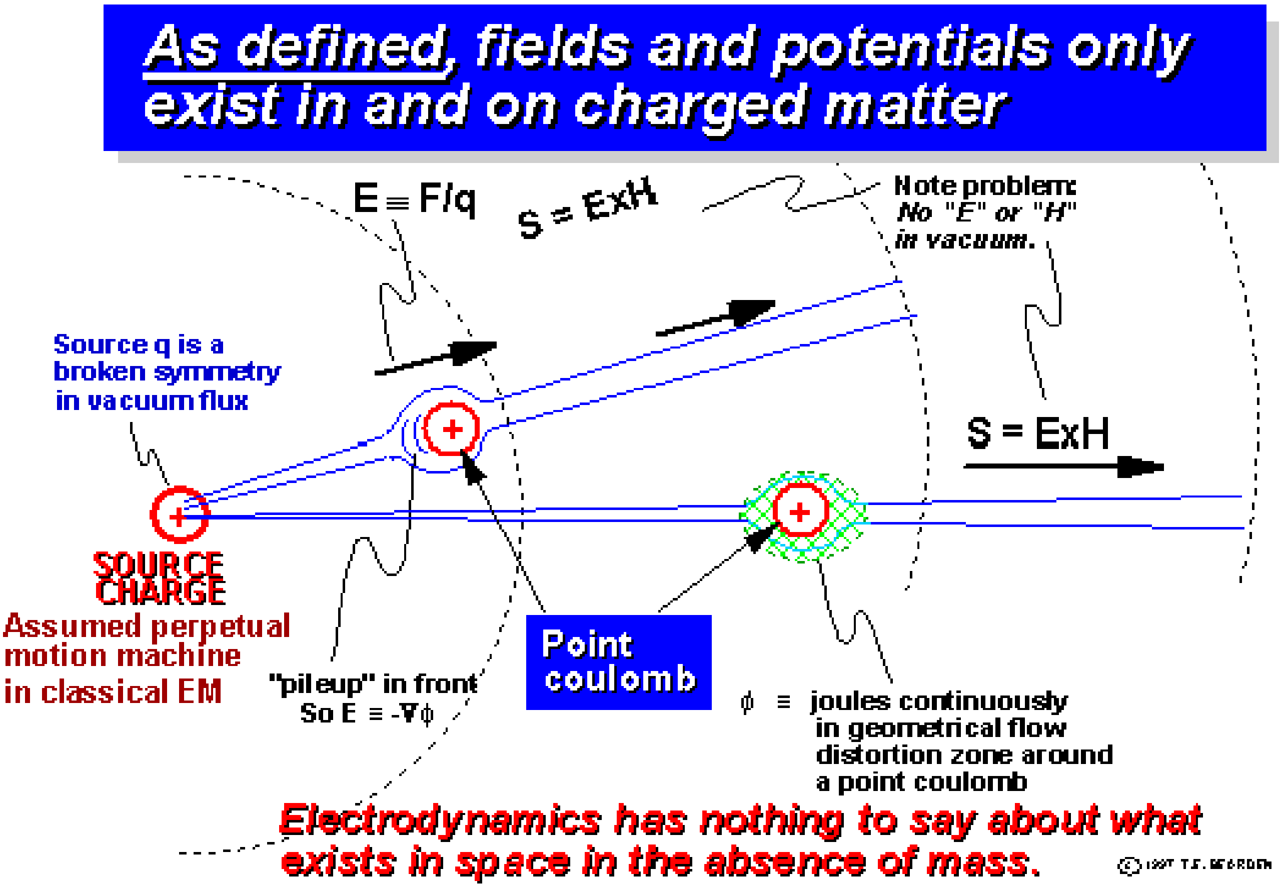

As defined, fields and potentials only exist in and on charged matter

E ≡ F/q
S = ExH
Note problem:
No "E" or "H" in vacuum.
Source q is a broken symmetry in vacuum flux
S = ExH
SOURCE CHARGE
Assumed perpetual motion machine in classical EM
"pileup" in front
So E ≡ -∇ϕ
Point coulomb
ϕ ≡ joules continuously in geometrical flow distortion zone around a point coulomb

Electrodynamics has nothing to say about what exists in space in the absence of mass.

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Air Medium Disturbances Generated When Air is Perturbed by a Plucked Taut String

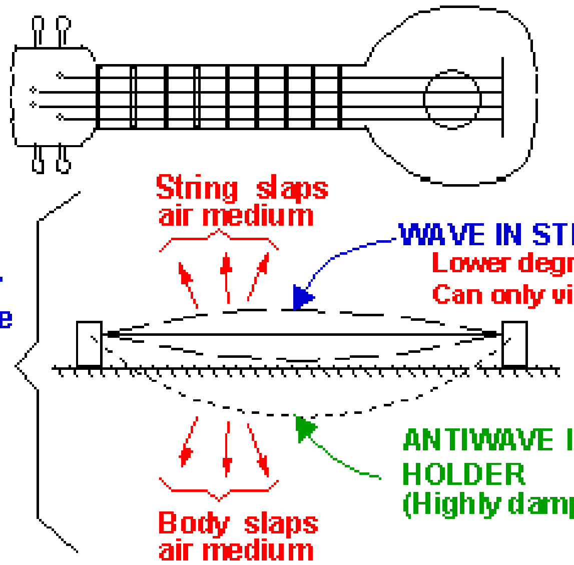

The string wave and
the holder wave
never leave the
string and holder
respectively.

Wave is
alternatively
compressive
and
rarefactive

String slaps
air medium

WAVE IN STRING (TRANSVERSE)
Lower degree of freedom for string.
Can only vibrate mostly laterally.

Drude
Electron
Gas waves

Nuclear
proton
waves

ANTIWAVE IN
HOLDER
(Highly damped; not shown to scale)

Body slaps
air medium

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Launching a Spacetime Perturbation ("EM Wave") from a Wire Antenna

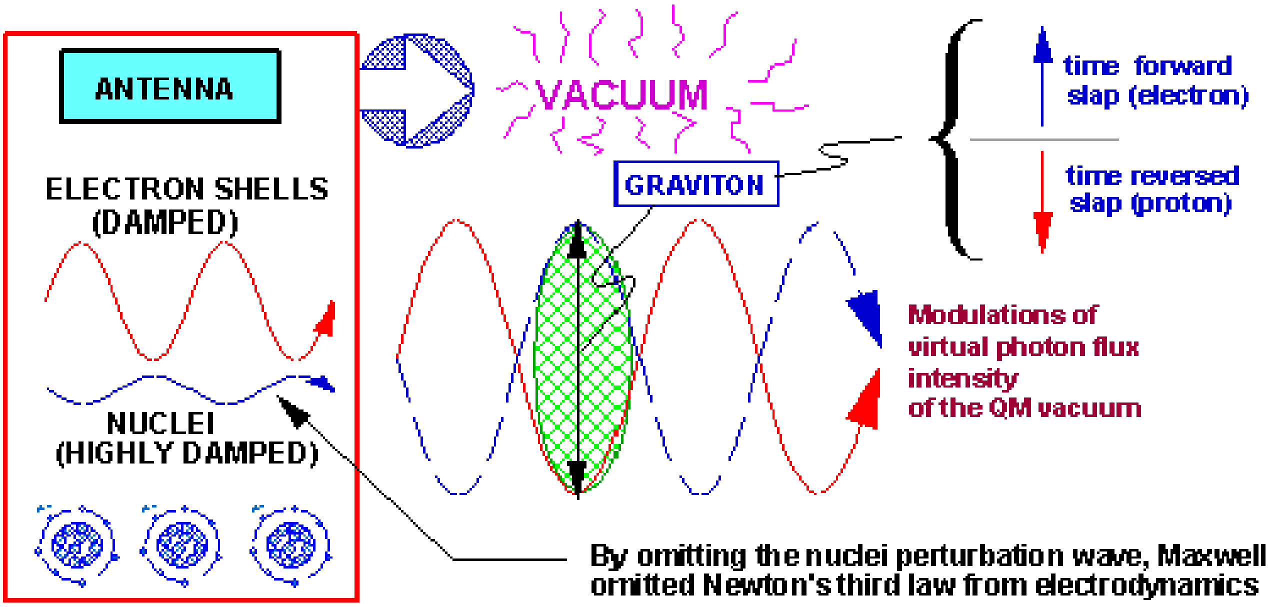
ANTENNA
ELECTRON SHELLS (DAMPED)
NUCLEI (HIGHLY DAMPED)
VACUUM
GRAVITON
time forward slap (electron)
time reversed slap (proton)
Modulations of virtual photon flux intensity of the QM vacuum

By omitting the nuclei perturbation wave, Maxwell omitted Newton's third law from electrodynamics

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Phase Conjugate Wavepairs Produce New Waves

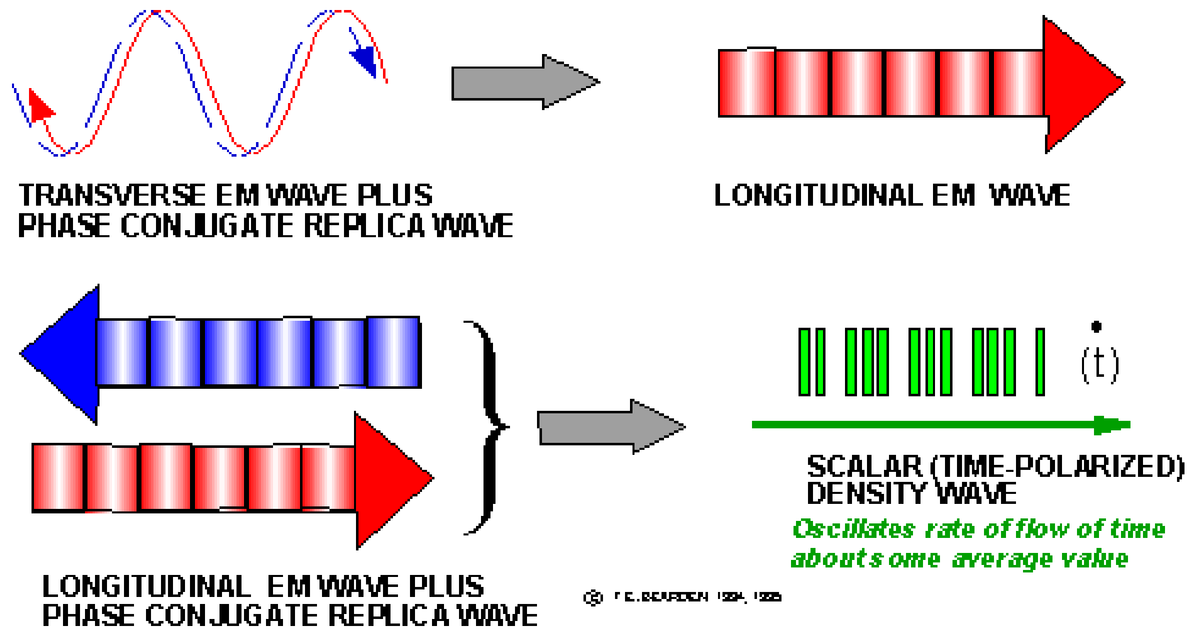
TRANSVERSE EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE
LONGITUDINAL EM WAVE
LONGITUDINAL EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE
(t)
SCALAR (TIME-POLARIZED)
DENSITY WAVE
Oscillates rate of flow of time
about some average value
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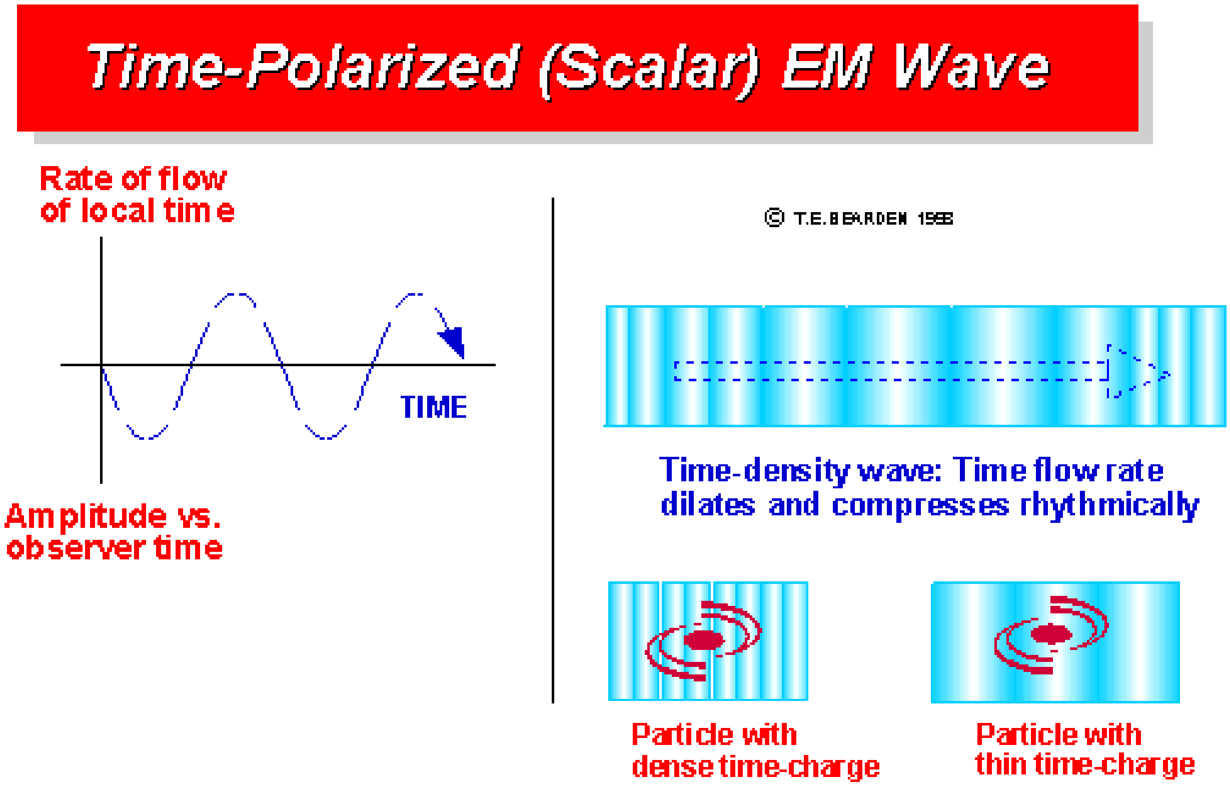

Time-Polarized (Scalar) EM Wave

Rate of flow
of local time
TIME
Amplitude vs.
observer time

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Time-density wave: Time flow rate
dilates and compresses rhythmically

Particle with
dense time-charge

Particle with
thin time-charge

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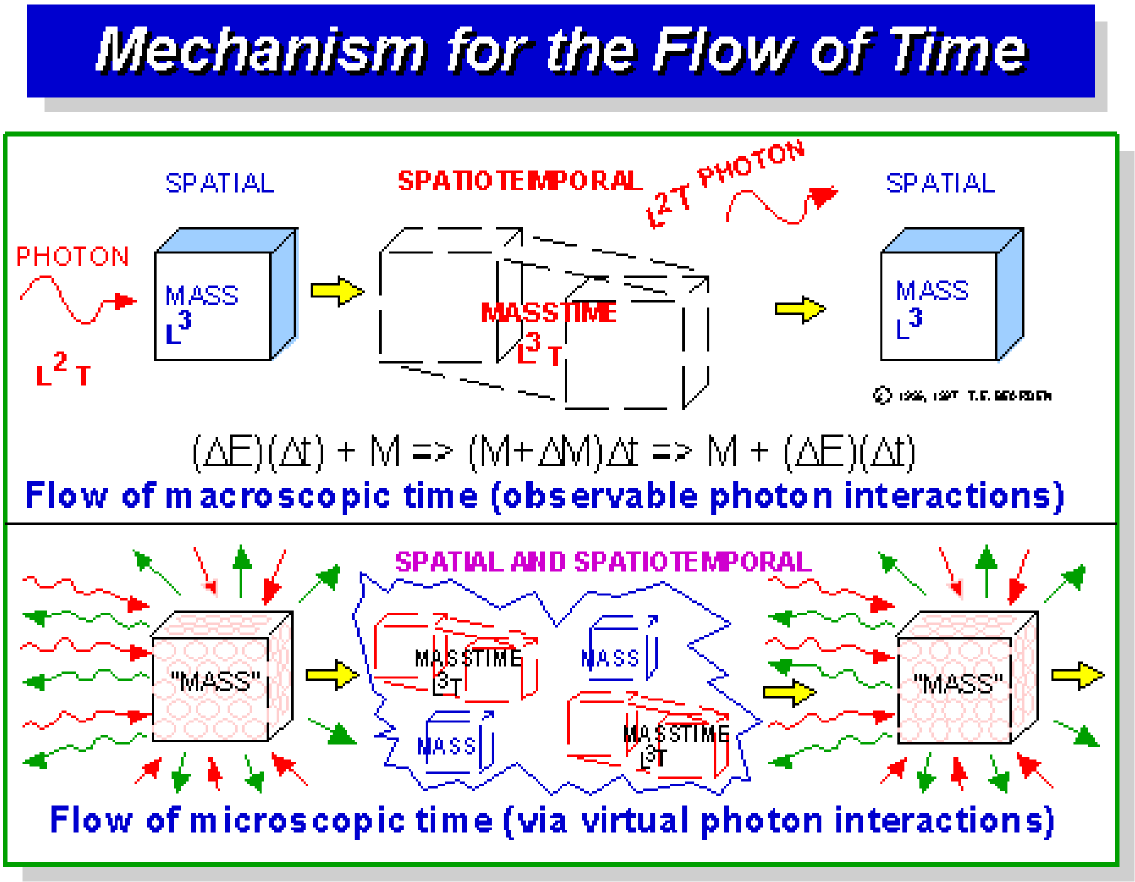

Mechanism for the Flow of Time

SPATIAL
SPATIOTEMPORAL
L^2T PHOTON
SPATIAL
PHOTON
MASS L^3
L^2 T
MASSTIME L^3 T
MASS L^3
SPATIAL AND SPATIOTEMPORAL
"MASS"
MASSTIME L^3T
MASS
MASS
MASSTIME L^3T
"MASS"

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$$(\Delta E)(\Delta t) + M \Rightarrow (M+\Delta M)\Delta t \Rightarrow M + (\Delta E)(\Delta t)$$

Flow of macroscopic time (observable photon interactions)

Flow of microscopic time (via virtual photon interactions)

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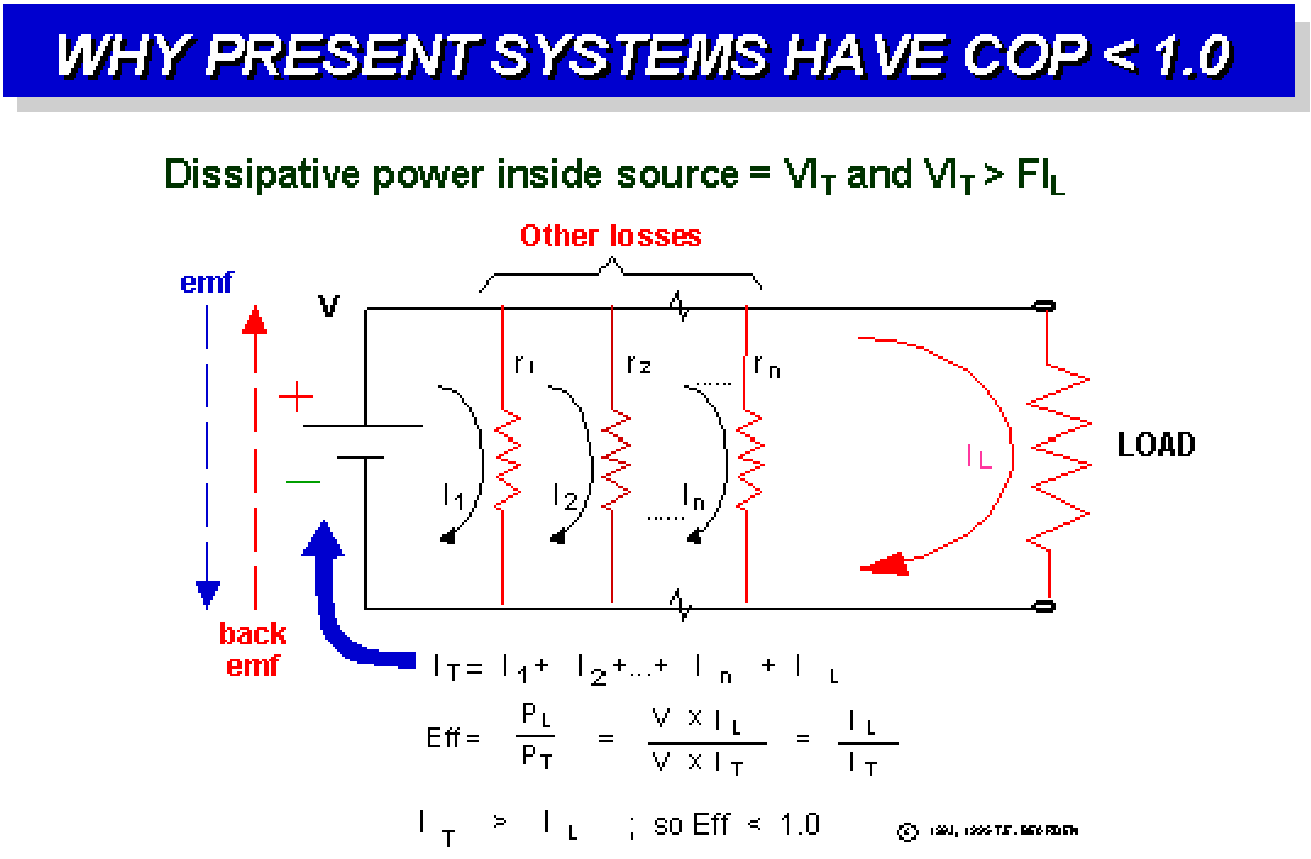

WHY PRESENT SYSTEMS HAVE COP < 1.0

Dissipative power inside source = VI_T and $VI_T > FI_L$

Other losses
emf
V
+
–
back emf
r_1
r_2
r_n
I_1
I_2
I_n
I_L
LOAD

$$I_T = I_1 + I_2 + \ldots + I_n + I_L$$

$$Eff = \frac{P_L}{P_T} = \frac{V \times I_L}{V \times I_T} = \frac{I_L}{I_T}$$

$I_T > I_L$; so Eff < 1.0

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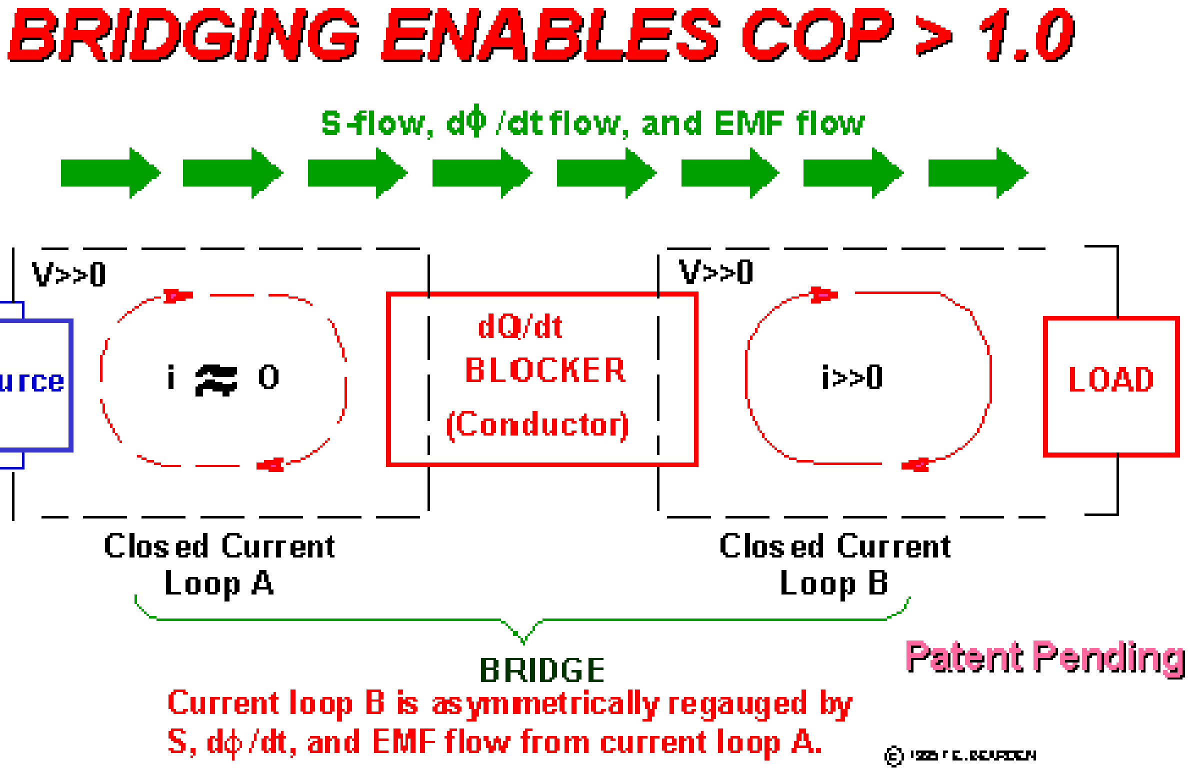

BRIDGING ENABLES COP > 1.0

S-flow, dϕ/dt flow, and EMF flow
V>>0
source
i ≈ 0
Closed Current
Loop A
dQ/dt
BLOCKER
(Conductor)
V>>0
i>>0
LOAD
Closed Current
Loop B
BRIDGE
Patent Pending

Current loop B is asymmetrically regauged by S, dϕ/dt, and EMF flow from current loop A.

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"Static" Poynting free-energy generator

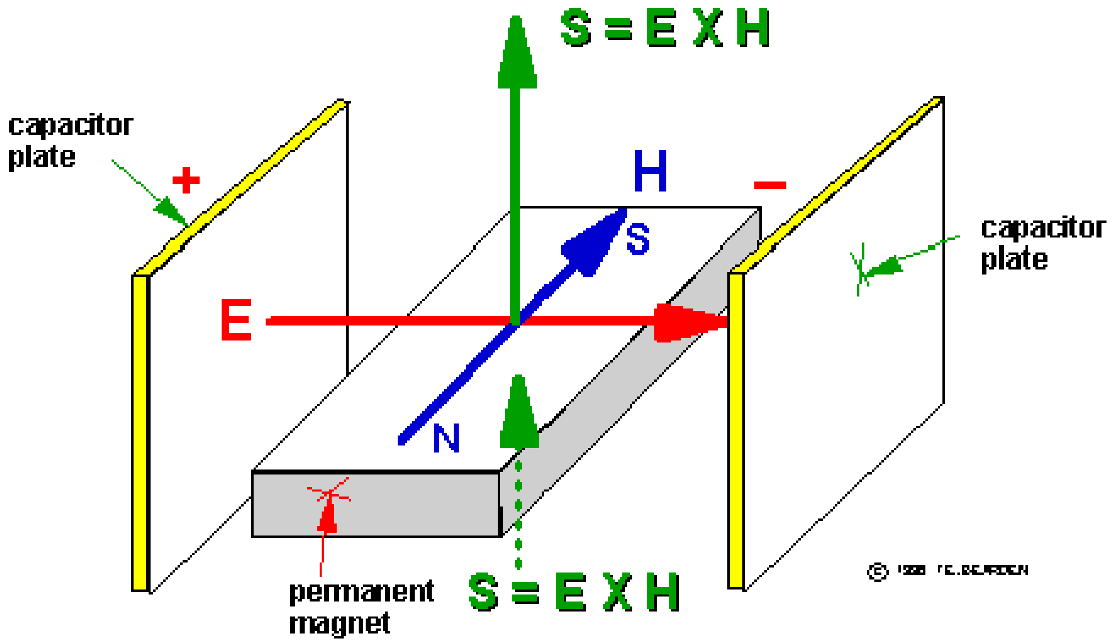
S = E X H
capacitor
plate
+
H
–
S
capacitor
plate
E
N
permanent
magnet
S = E X H
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Demonstration of an Overunity Concept

(By Asymmetrical Self-Regauging)

Patent Pending

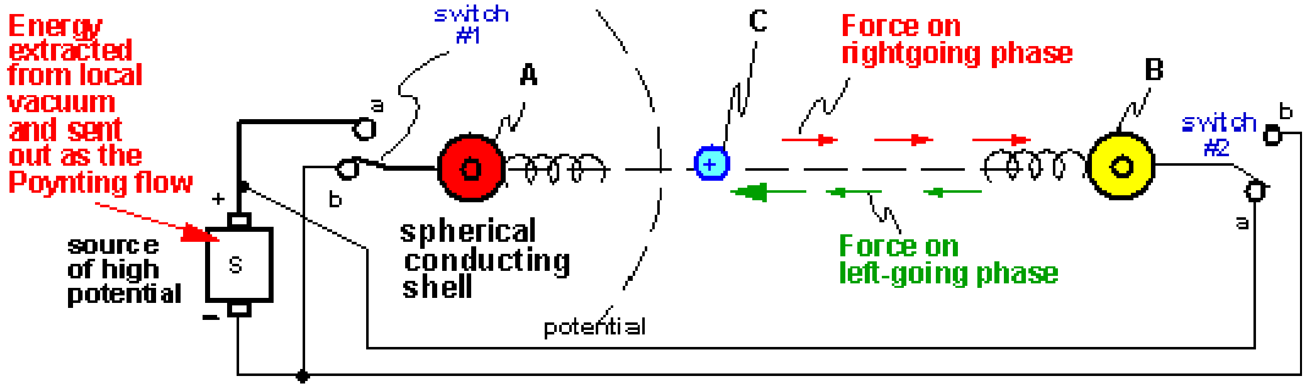
Energy extracted from local vacuum and sent out as the Poynting flow
switch #1
a
b
A
C
Force on rightgoing phase
B
switch #2
b
a
+
S
−
source of high potential
spherical conducting shell
Force on left-going phase
potential

Assumptions: Capacitances of A and B very small; Charge B large, power-free switching

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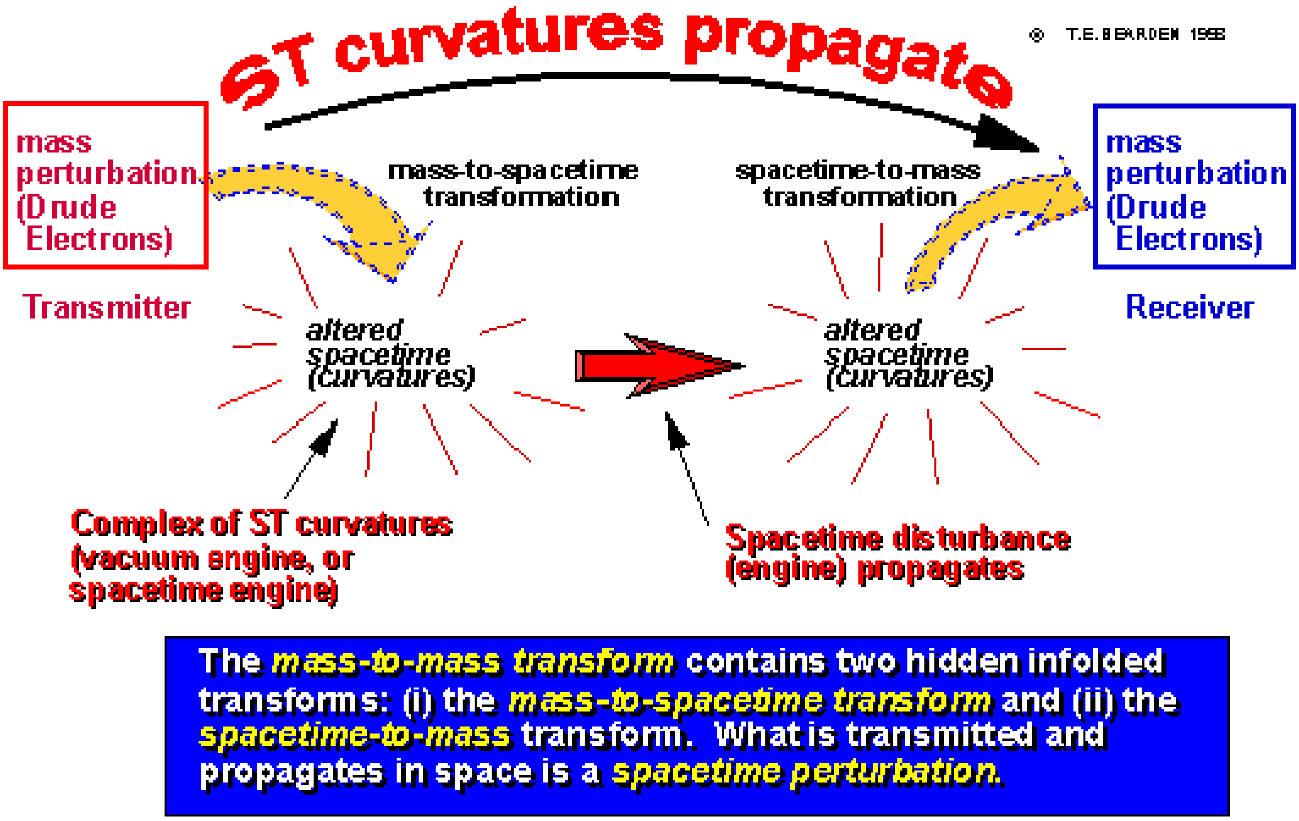
ST curvatures propagate
© T.E.BEARDEN 1993
mass perturbation (Drude Electrons)
Transmitter
mass-to-spacetime transformation
spacetime-to-mass transformation
mass perturbation (Drude Electrons)
Receiver
altered spacetime (curvatures)
altered spacetime (curvatures)
Complex of ST curvatures (vacuum engine, or spacetime engine)
Spacetime disturbance (engine) propagates

The *mass-to-mass transform* contains two hidden infolded transforms: (i) the *mass-to-spacetime transform* and (ii) the *spacetime-to-mass* transform. What is transmitted and propagates in space is a *spacetime perturbation.*

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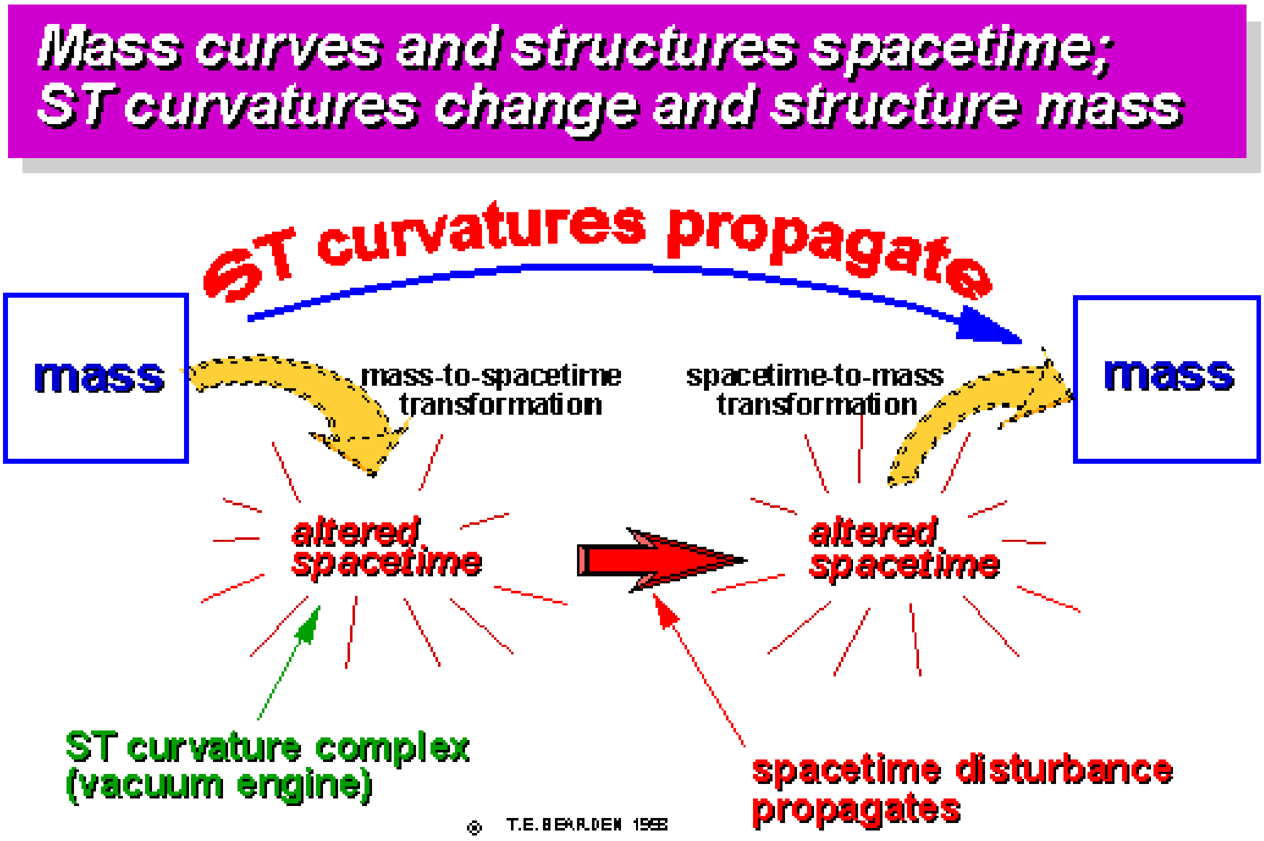

Mass curves and structures spacetime; ST curvatures change and structure mass

ST curvatures propagate
mass
mass-to-spacetime transformation
spacetime-to-mass transformation
mass
altered spacetime
altered spacetime
ST curvature complex (vacuum engine)
spacetime disturbance propagates

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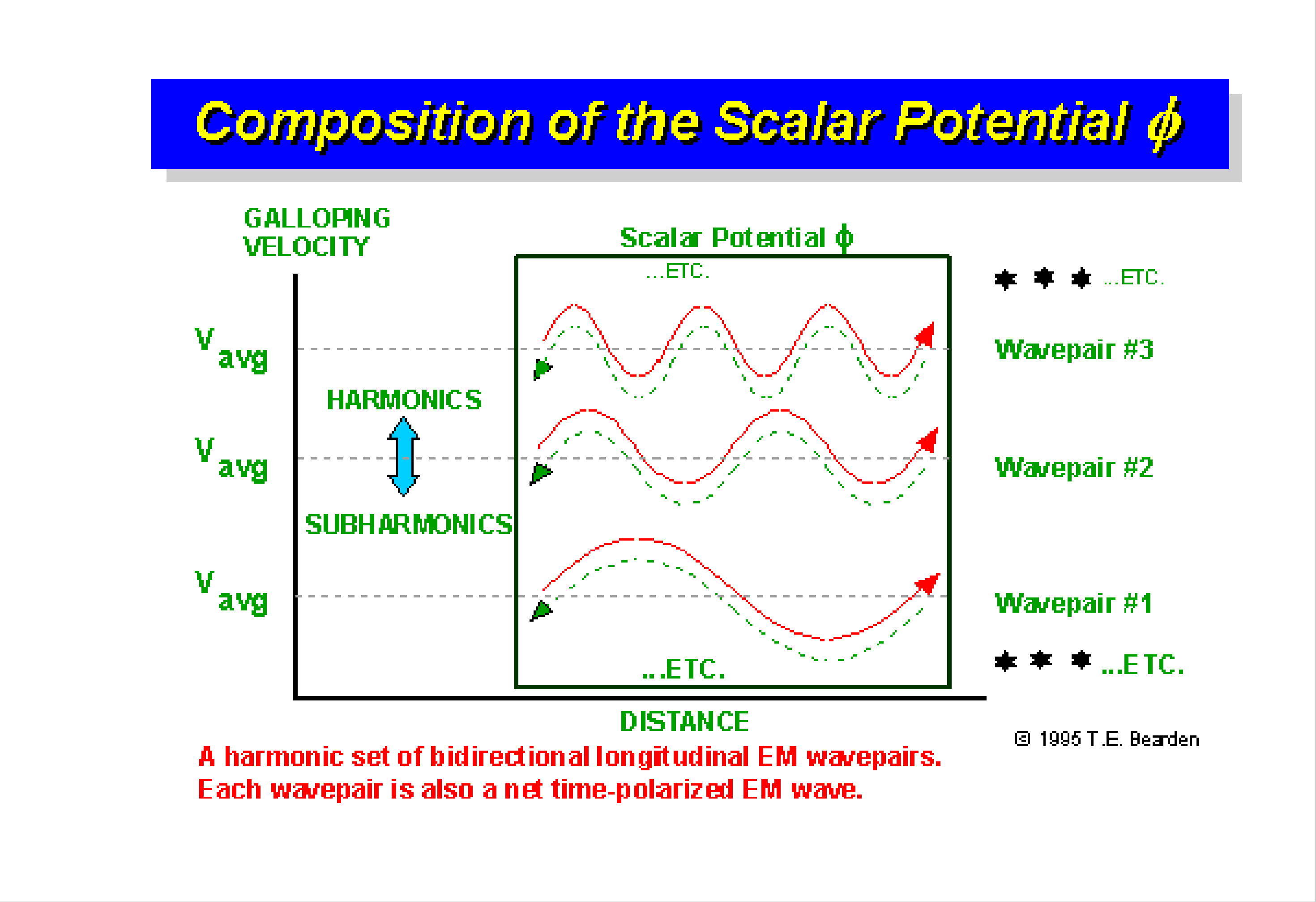

Composition of the Scalar Potential ϕ

GALLOPING VELOCITY
Scalar Potential ϕ
...ETC.
✸ ✸ ✸ ...ETC.
V_{avg}
Wavepair #3
HARMONICS
SUBHARMONICS
V_{avg}
Wavepair #2
V_{avg}
Wavepair #1
...ETC.
✸ ✸ ✸ ...ETC.
DISTANCE

A harmonic set of bidirectional longitudinal EM wavepairs.
Each wavepair is also a net time-polarized EM wave.

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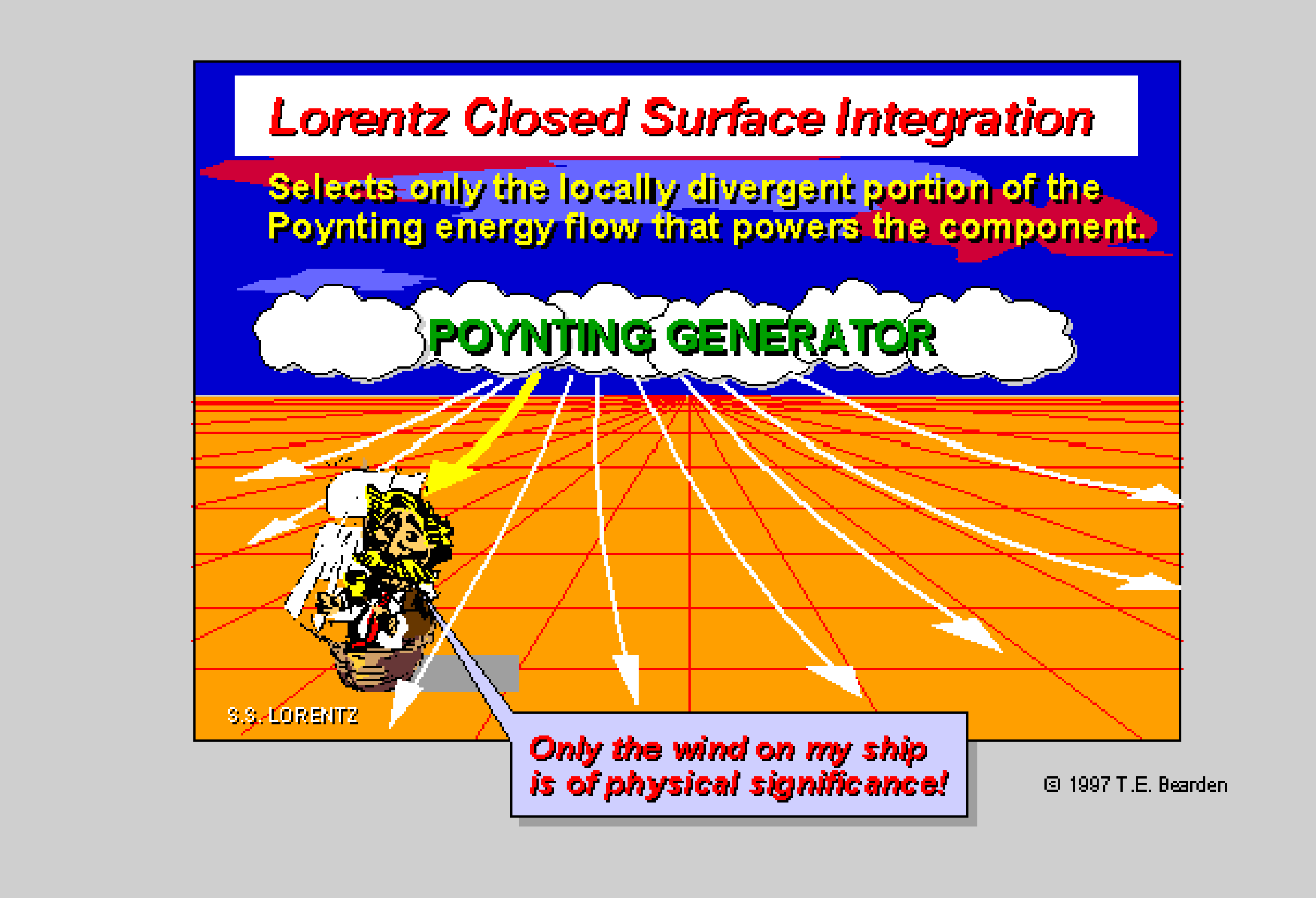

Lorentz Closed Surface Integration

Selects only the locally divergent portion of the Poynting energy flow that powers the component.

Only the wind on my ship is of physical significance!

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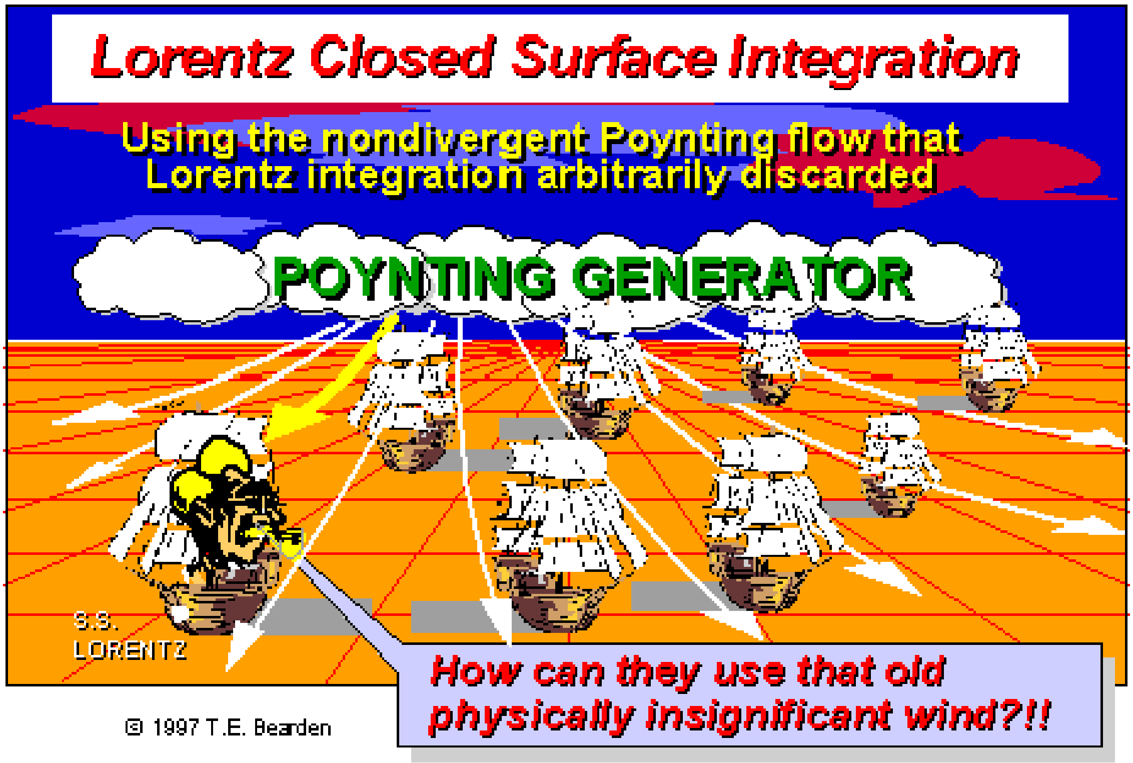

Lorentz Closed Surface Integration

Using the nondivergent Poynting flow that
Lorentz integration arbitrarily discarded

How can they use that old
physically insignificant wind?!!

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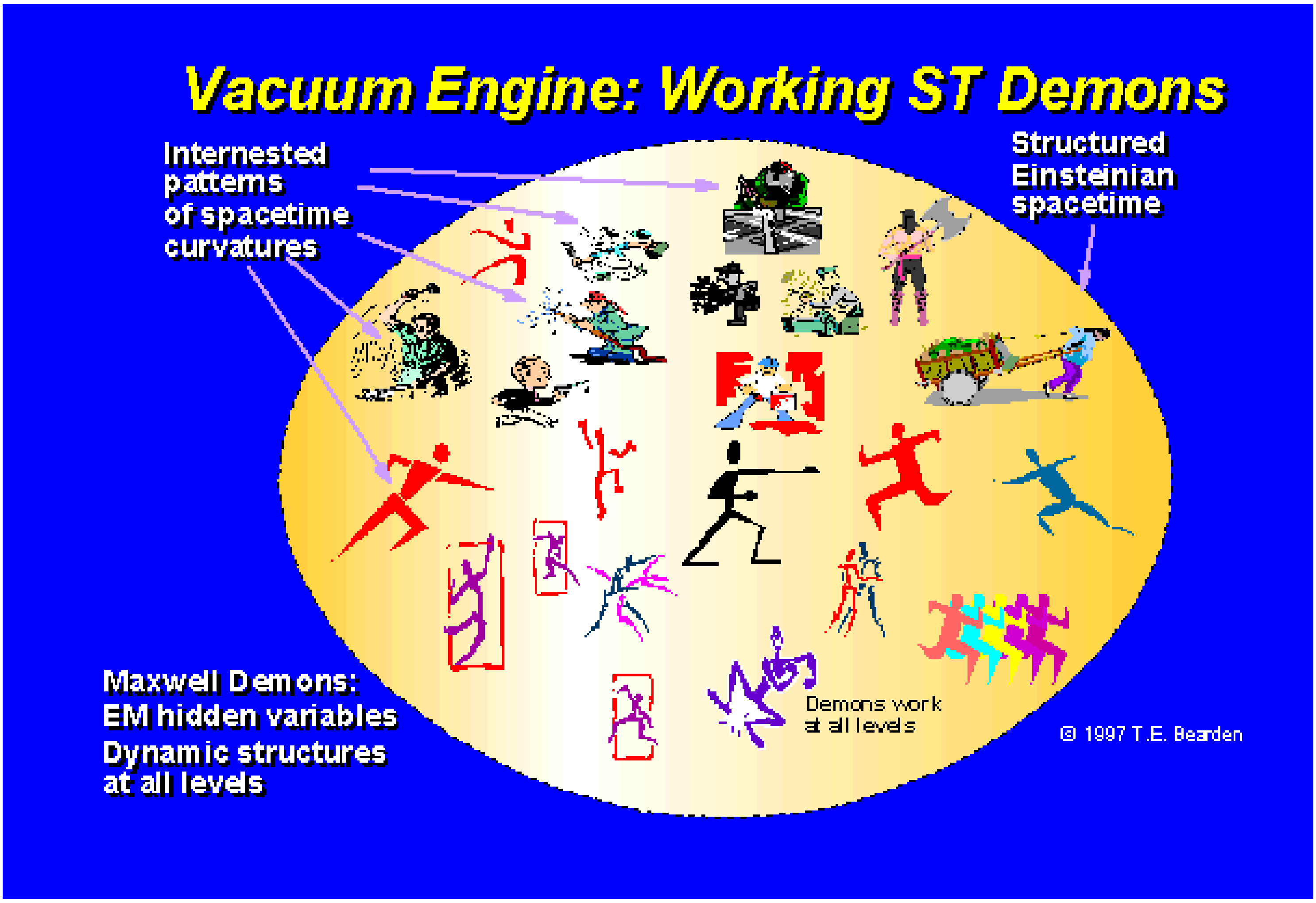

Vacuum Engine: Working ST Demons

Internested patterns of spacetime curvatures

Structured Einsteinian spacetime

Maxwell Demons:
EM hidden variables
Dynamic structures at all levels

Demons work at all levels

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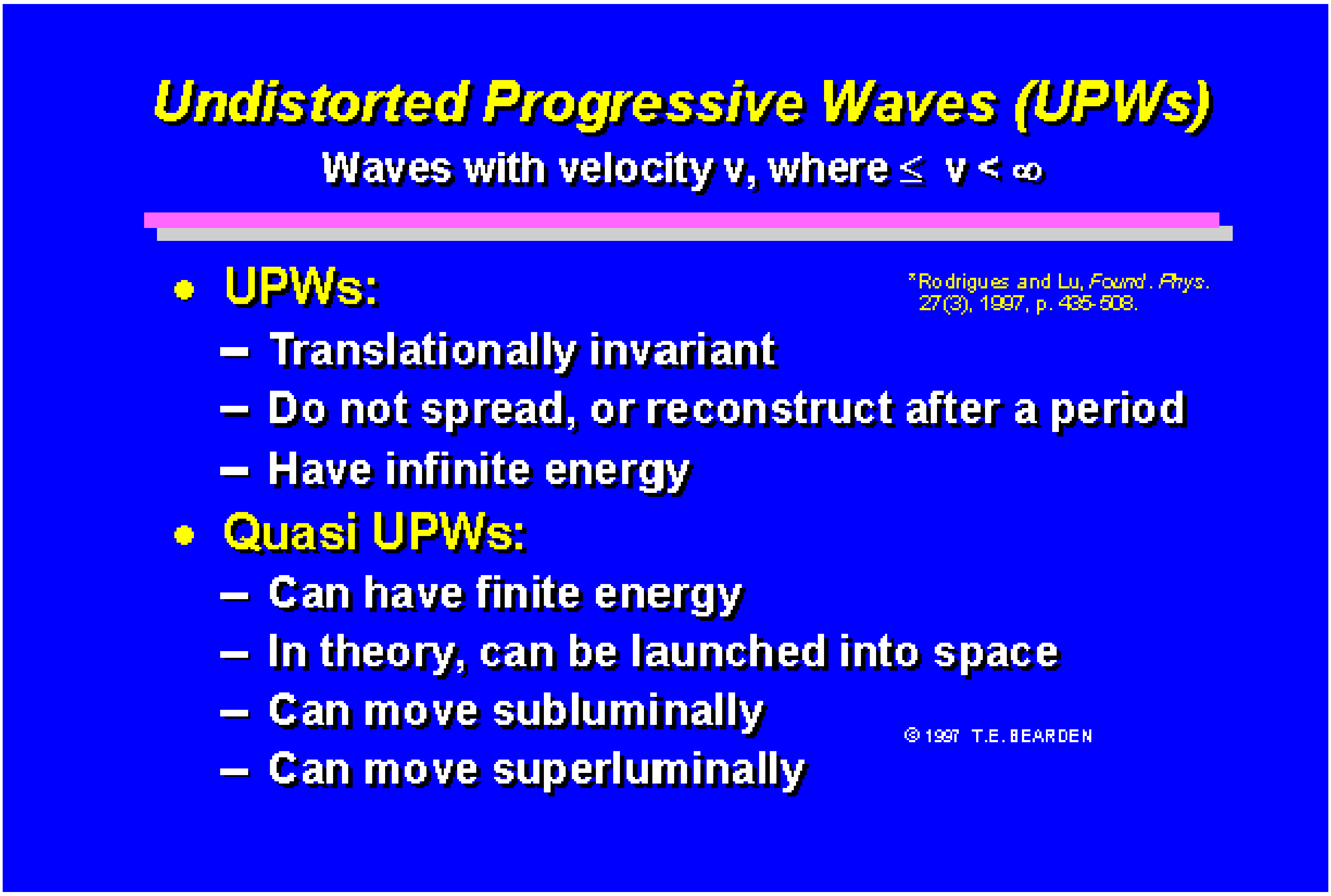

Undistorted Progressive Waves (UPWs)

Waves with velocity v, where $\leq$ v $< \infty$

- **UPWs:**
  - Translationally invariant
  - Do not spread, or reconstruct after a period
  - Have infinite energy
- **Quasi UPWs:**
  - Can have finite energy
  - In theory, can be launched into space
  - Can move subluminally
  - Can move superluminally

*Rodrigues and Lu, *Found. Phys.* 27(3), 1997, p. 435-508.

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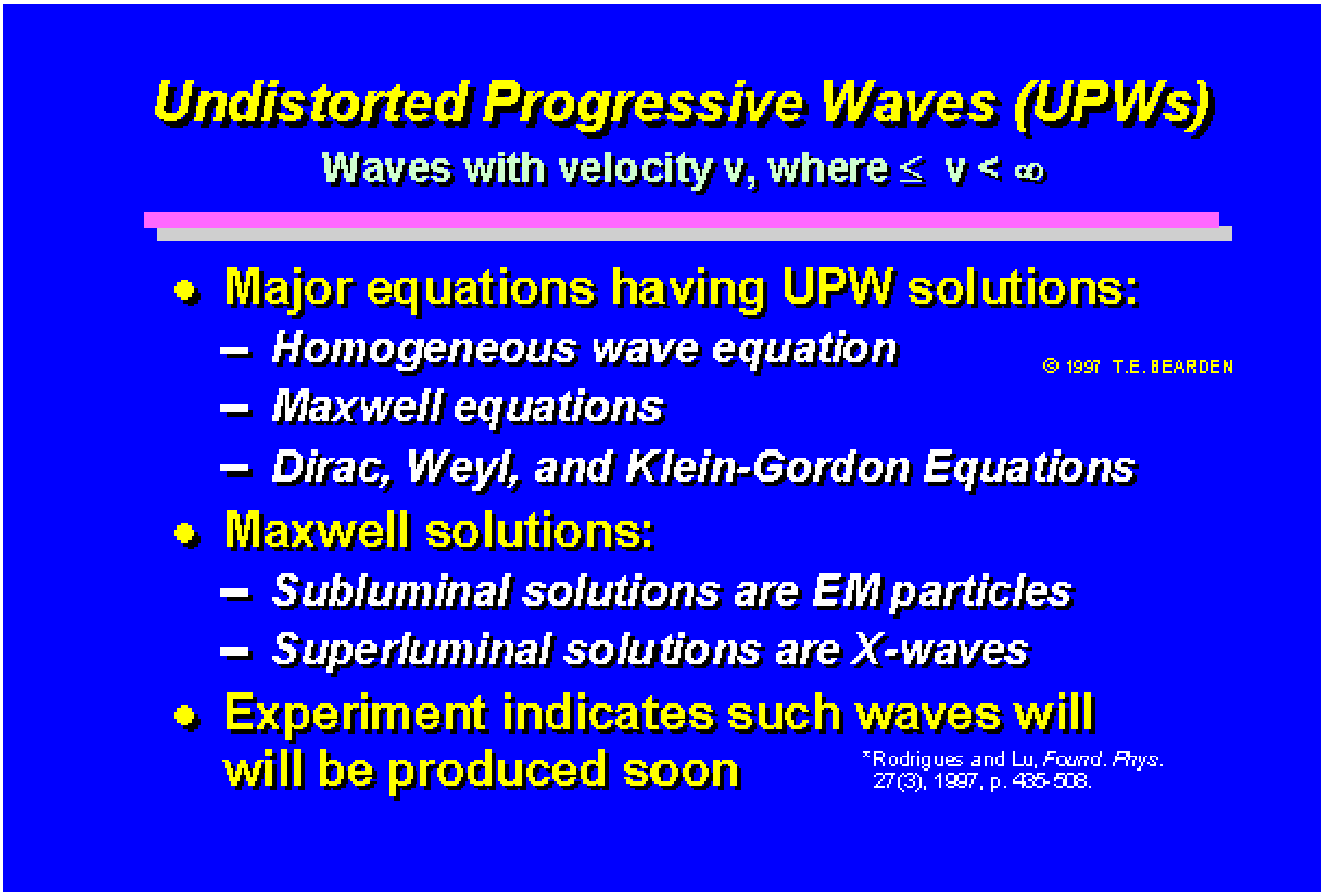

Undistorted Progressive Waves (UPWs)

Waves with velocity v, where $\leq$ v $< \infty$

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- Major equations having UPW solutions:
  - *Homogeneous wave equation*
  - *Maxwell equations*
  - *Dirac, Weyl, and Klein-Gordon Equations*
- Maxwell solutions:
  - *Subluminal solutions are EM particles*
  - *Superluminal solutions are X-waves*
- Experiment indicates such waves will will be produced soon

*Rodrigues and Lu, *Found. Phys.* 27(3), 1997, p. 435-508.

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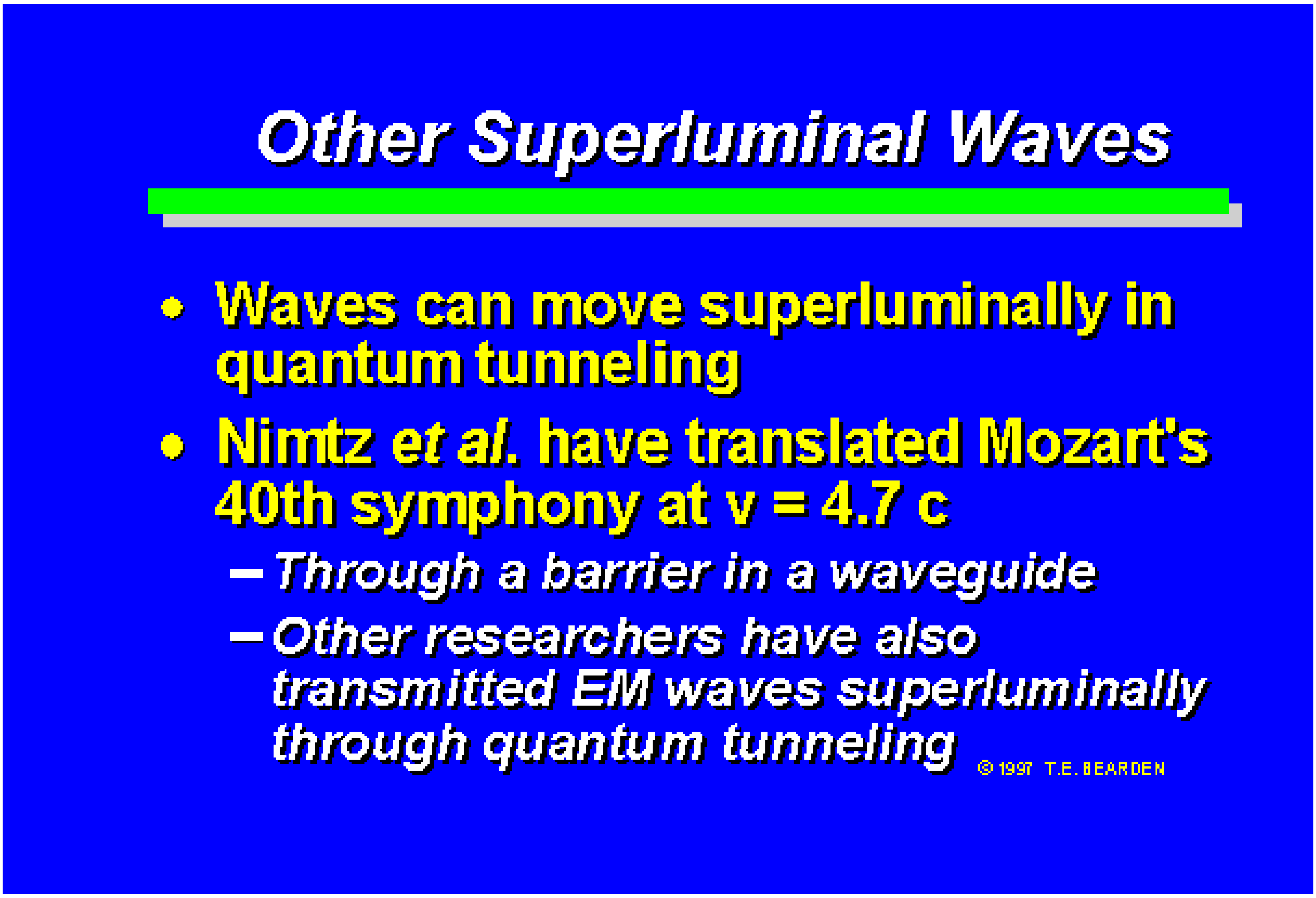

Other Superluminal Waves

- Waves can move superluminally in quantum tunneling
- Nimtz *et al.* have translated Mozart's 40th symphony at v = 4.7 c
  - *Through a barrier in a waveguide*
  - *Other researchers have also transmitted EM waves superluminally through quantum tunneling*

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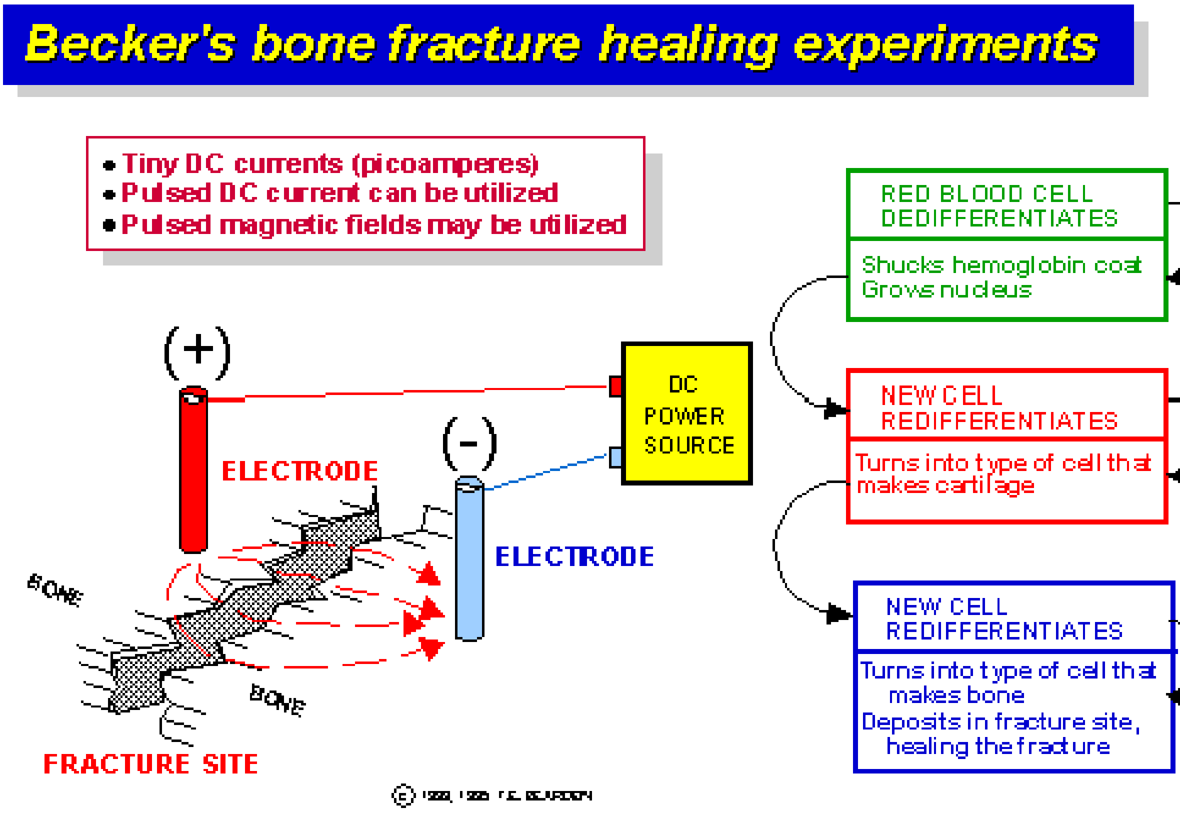

Becker's bone fracture healing experiments

- Tiny DC currents (picoamperes)
- Pulsed DC current can be utilized
- Pulsed magnetic fields may be utilized

RED BLOOD CELL DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes bone

Deposits in fracture site, healing the fracture

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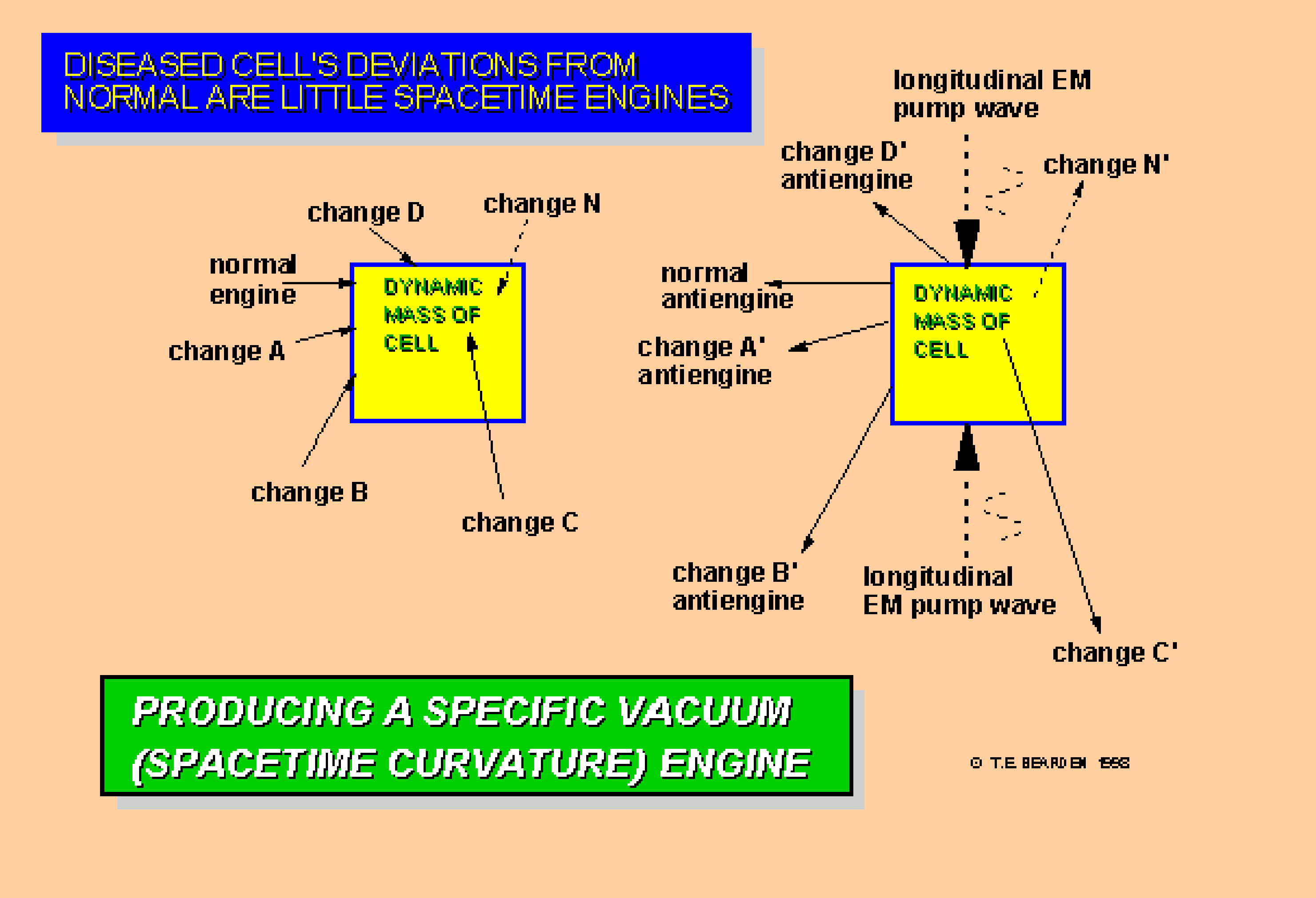

DISEASED CELL'S DEVIATIONS FROM NORMAL ARE LITTLE SPACETIME ENGINES

change D
change N
normal engine
DYNAMIC MASS OF CELL
change A
change B
change C
longitudinal EM pump wave
change D' antiengine
change N'
normal antiengine
DYNAMIC MASS OF CELL
change A' antiengine
change B' antiengine
longitudinal EM pump wave
change C'

PRODUCING A SPECIFIC VACUUM (SPACETIME CURVATURE) ENGINE

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Transverse EM Wave Pumping of PCM

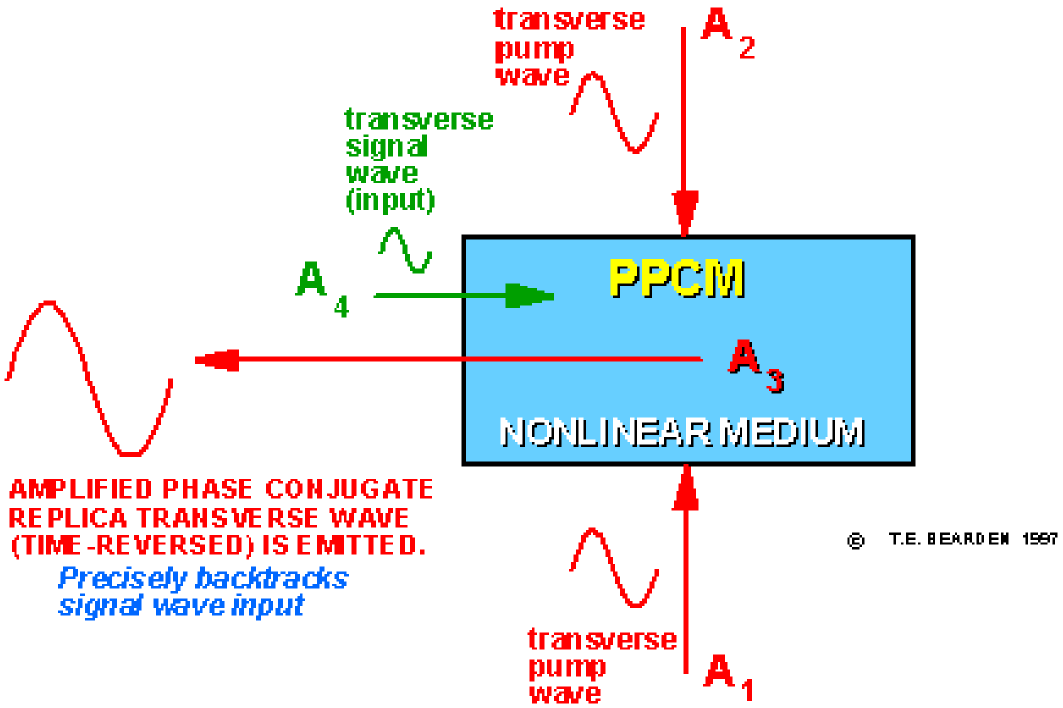
transverse
pump
wave
A 2
transverse
signal
wave
(input)
A 4
PPCM
A 3
NONLINEAR MEDIUM
AMPLIFIED PHASE CONJUGATE
REPLICA TRANSVERSE WAVE
(TIME-REVERSED) IS EMITTED.
Precisely backtracks
signal wave input
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transverse
pump
wave
A 1

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Differentiation and Dedifferentiation Timelines

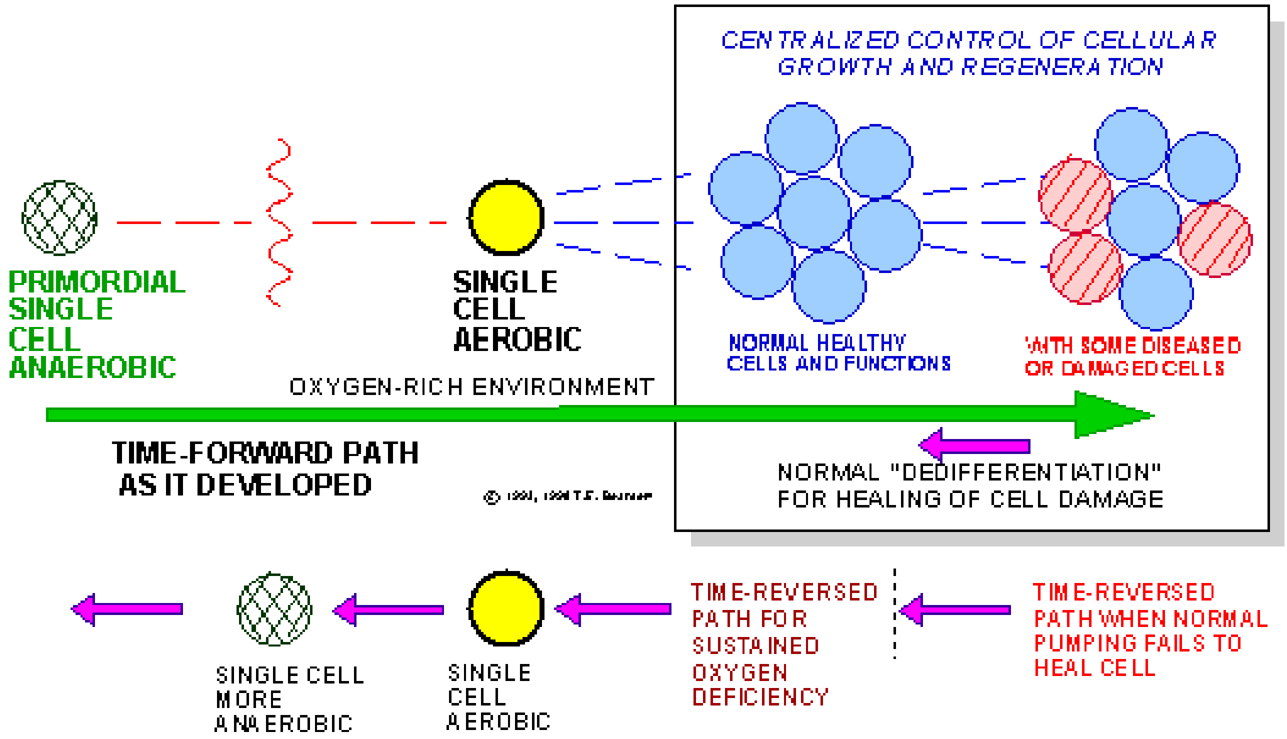
CENTRALIZED CONTROL OF CELLULAR GROWTH AND REGENERATION
PRIMORDIAL SINGLE CELL ANAEROBIC
SINGLE CELL AEROBIC
NORMAL HEALTHY CELLS AND FUNCTIONS
WITH SOME DISEASED OR DAMAGED CELLS
OXYGEN-RICH ENVIRONMENT
TIME-FORWARD PATH AS IT DEVELOPED
NORMAL "DEDIFFERENTIATION" FOR HEALING OF CELL DAMAGE
SINGLE CELL MORE ANAEROBIC
SINGLE CELL AEROBIC
TIME-REVERSED PATH FOR SUSTAINED OXYGEN DEFICIENCY
TIME-REVERSED PATH WHEN NORMAL PUMPING FAILS TO HEAL CELL

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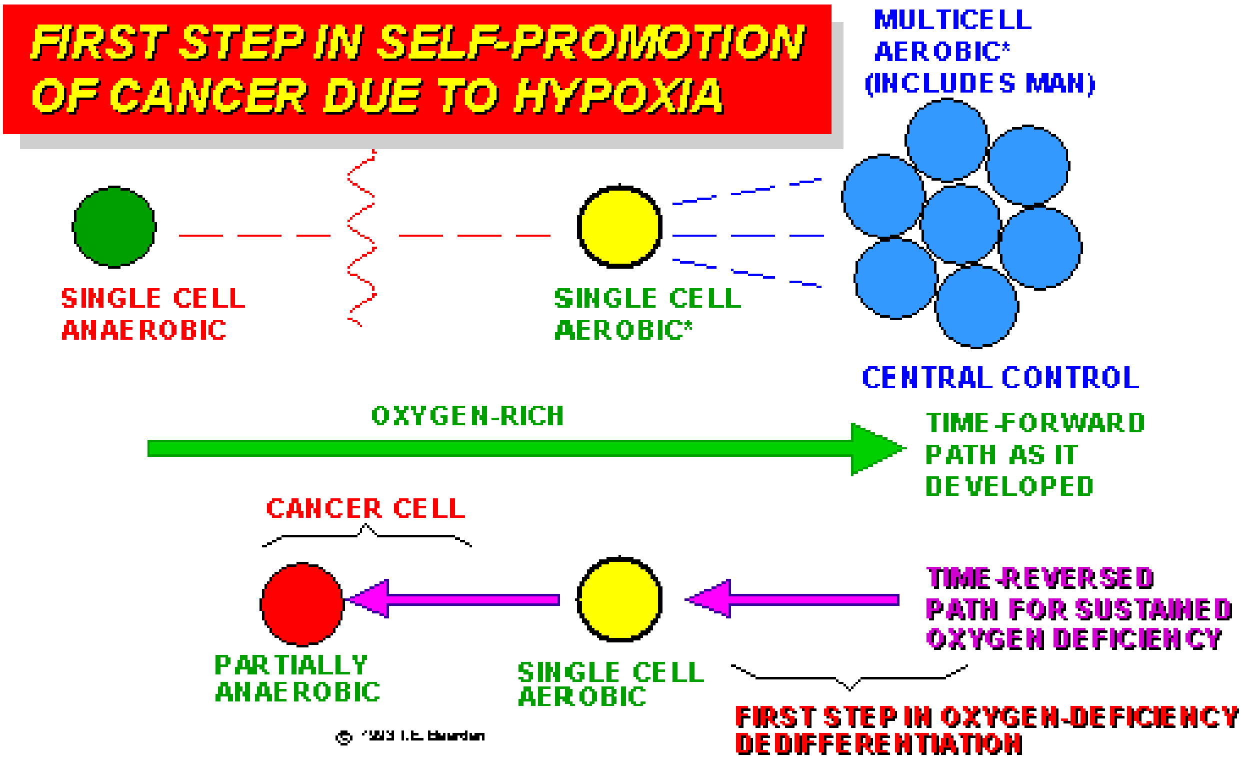
FIRST STEP IN SELF-PROMOTION OF CANCER DUE TO HYPOXIA
MULTICELL
AEROBIC*
(INCLUDES MAN)
SINGLE CELL
ANAEROBIC
SINGLE CELL
AEROBIC*
CENTRAL CONTROL
OXYGEN-RICH
TIME-FORWARD
PATH AS IT
DEVELOPED
CANCER CELL
TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY
PARTIALLY
ANAEROBIC
SINGLE CELL
AEROBIC
FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION
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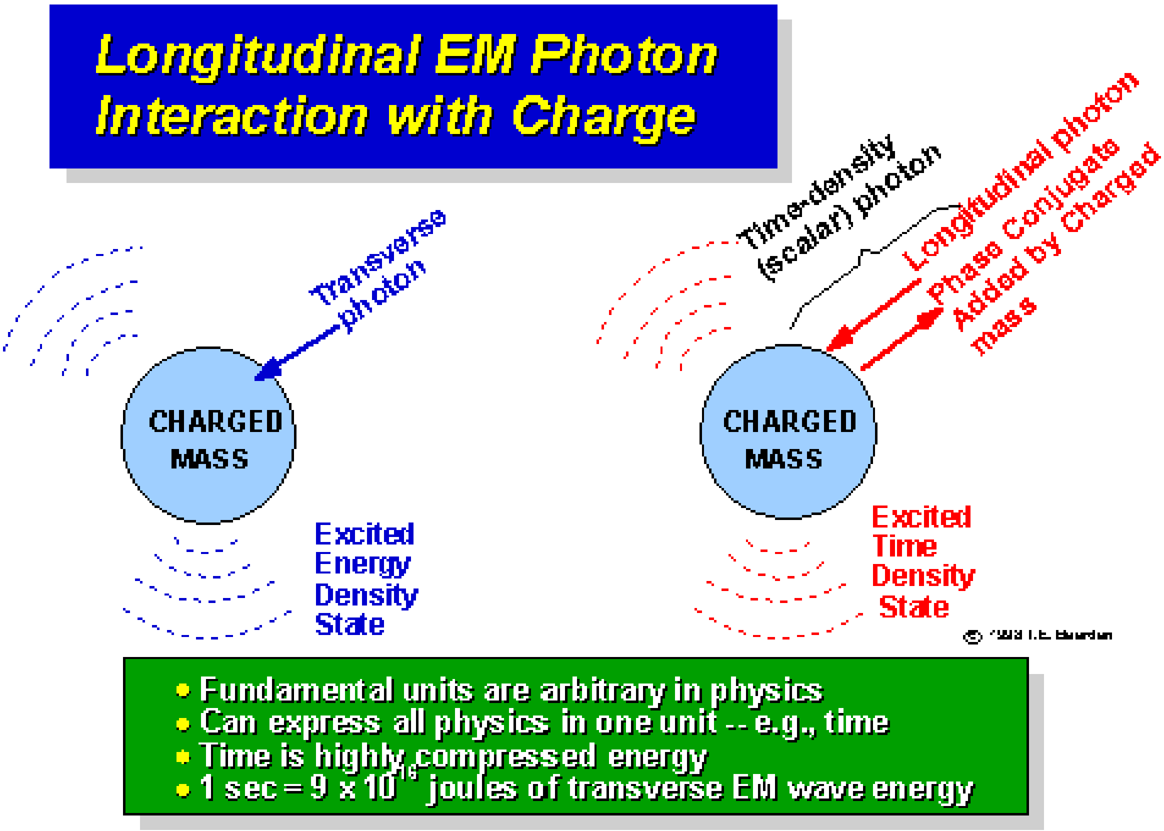

Longitudinal EM Photon Interaction with Charge

Transverse photon
CHARGED MASS
Excited Energy Density State
Time-density (scalar) photon
Longitudinal photon
Phase Conjugate Added by Charged mass
CHARGED MASS
Excited Time Density State
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- Fundamental units are arbitrary in physics
- Can express all physics in one unit -- e.g., time
- Time is highly compressed energy
- 1 sec = 9 x 10^{16} joules of transverse EM wave energy

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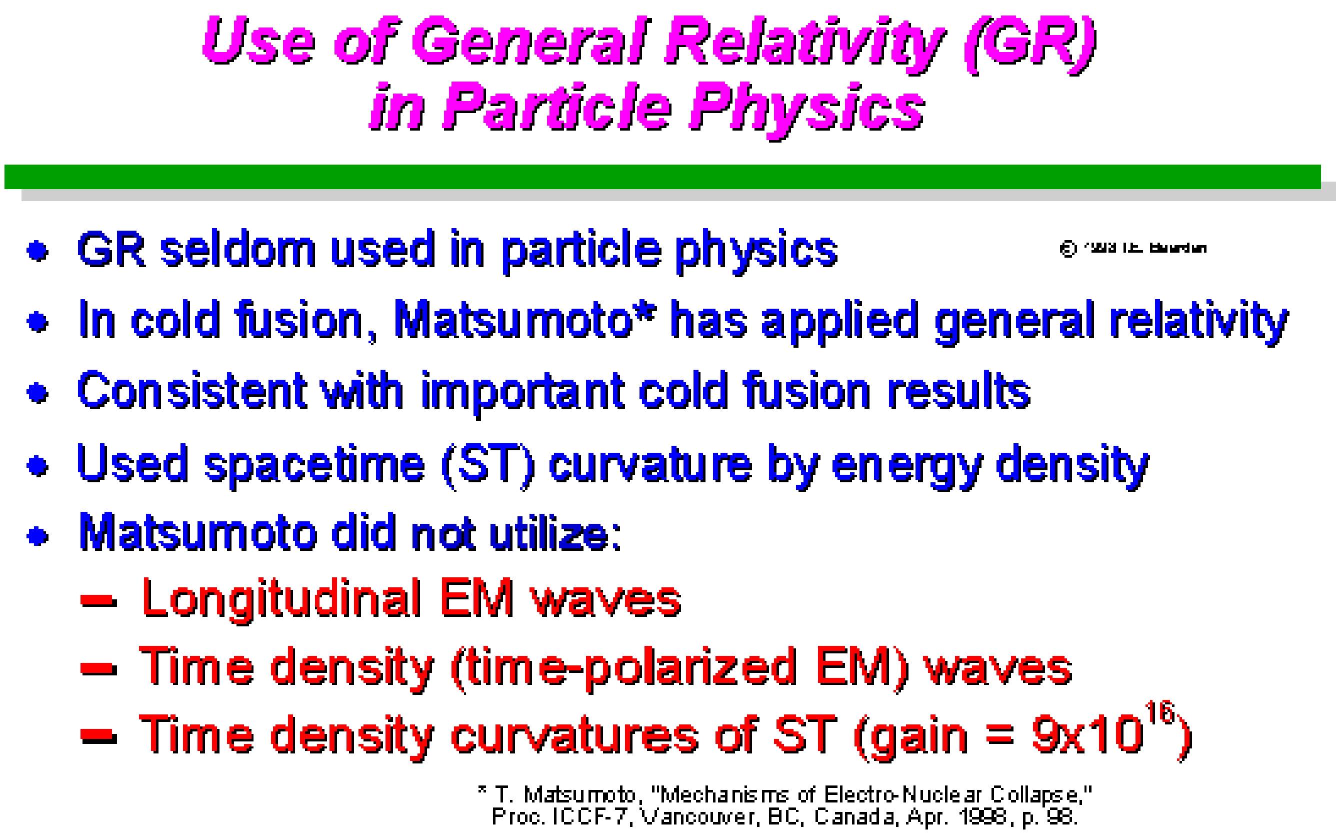

Use of General Relativity (GR) in Particle Physics

- GR seldom used in particle physics
- In cold fusion, Matsumoto* has applied general relativity
- Consistent with important cold fusion results
- Used spacetime (ST) curvature by energy density
- Matsumoto did not utilize:
  - Longitudinal EM waves
  - Time density (time-polarized EM) waves
  - Time density curvatures of ST (gain = $9x10^{16}$)

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* T. Matsumoto, "Mechanisms of Electro-Nuclear Collapse," Proc. ICCF-7, Vancouver, BC, Canada, Apr. 1998, p. 98.

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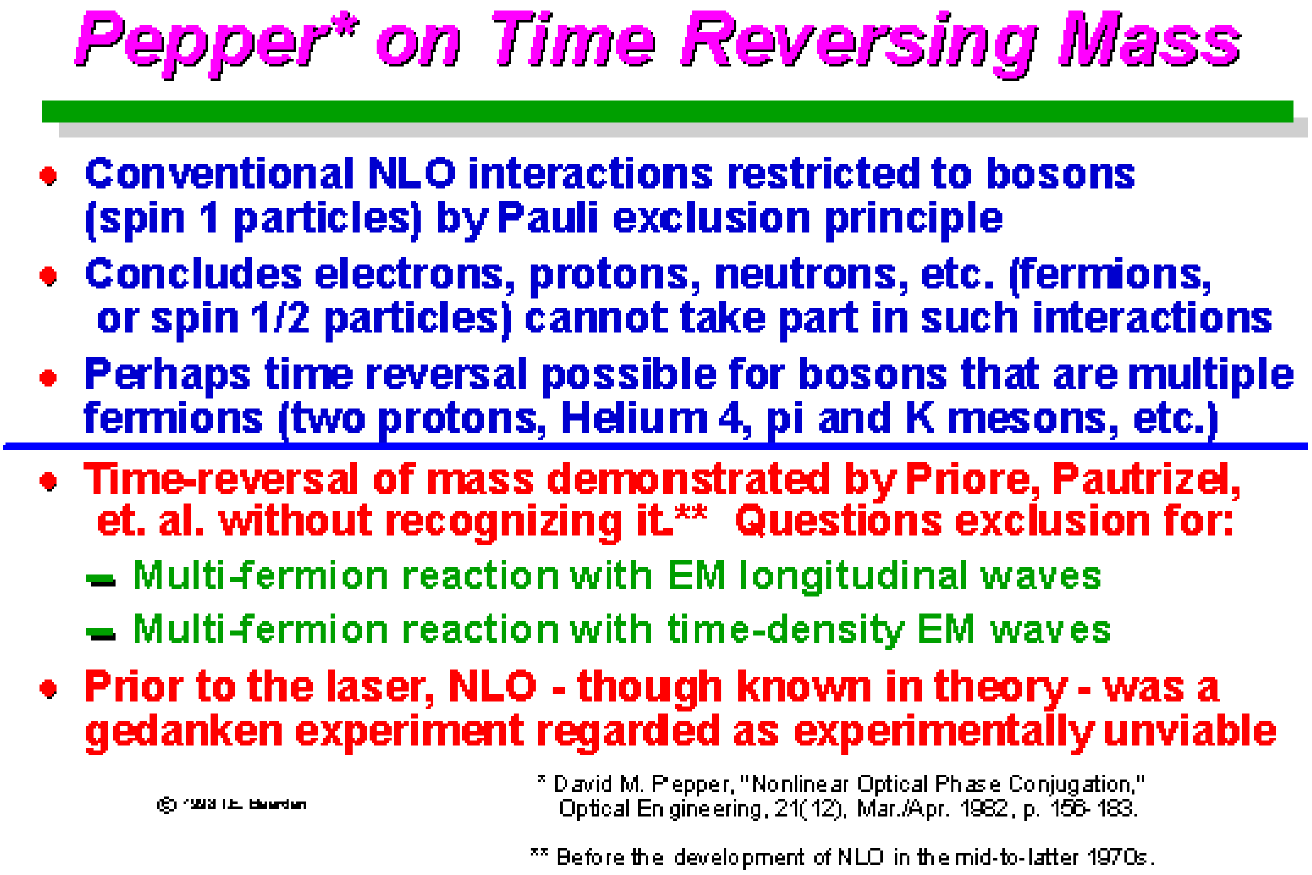

Pepper* on Time Reversing Mass

- Conventional NLO interactions restricted to bosons (spin 1 particles) by Pauli exclusion principle
- Concludes electrons, protons, neutrons, etc. (fermions, or spin 1/2 particles) cannot take part in such interactions
- Perhaps time reversal possible for bosons that are multiple fermions (two protons, Helium 4, pi and K mesons, etc.)

- Time-reversal of mass demonstrated by Priore, Pautrizel, et. al. without recognizing it.** Questions exclusion for:
  - Multi-fermion reaction with EM longitudinal waves
  - Multi-fermion reaction with time-density EM waves
- Prior to the laser, NLO - though known in theory - was a gedanken experiment regarded as experimentally unviable

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* David M. Pepper, "Nonlinear Optical Phase Conjugation," Optical Engineering, 21(12), Mar./Apr. 1982, p. 156-183.

** Before the development of NLO in the mid-to-latter 1970s.

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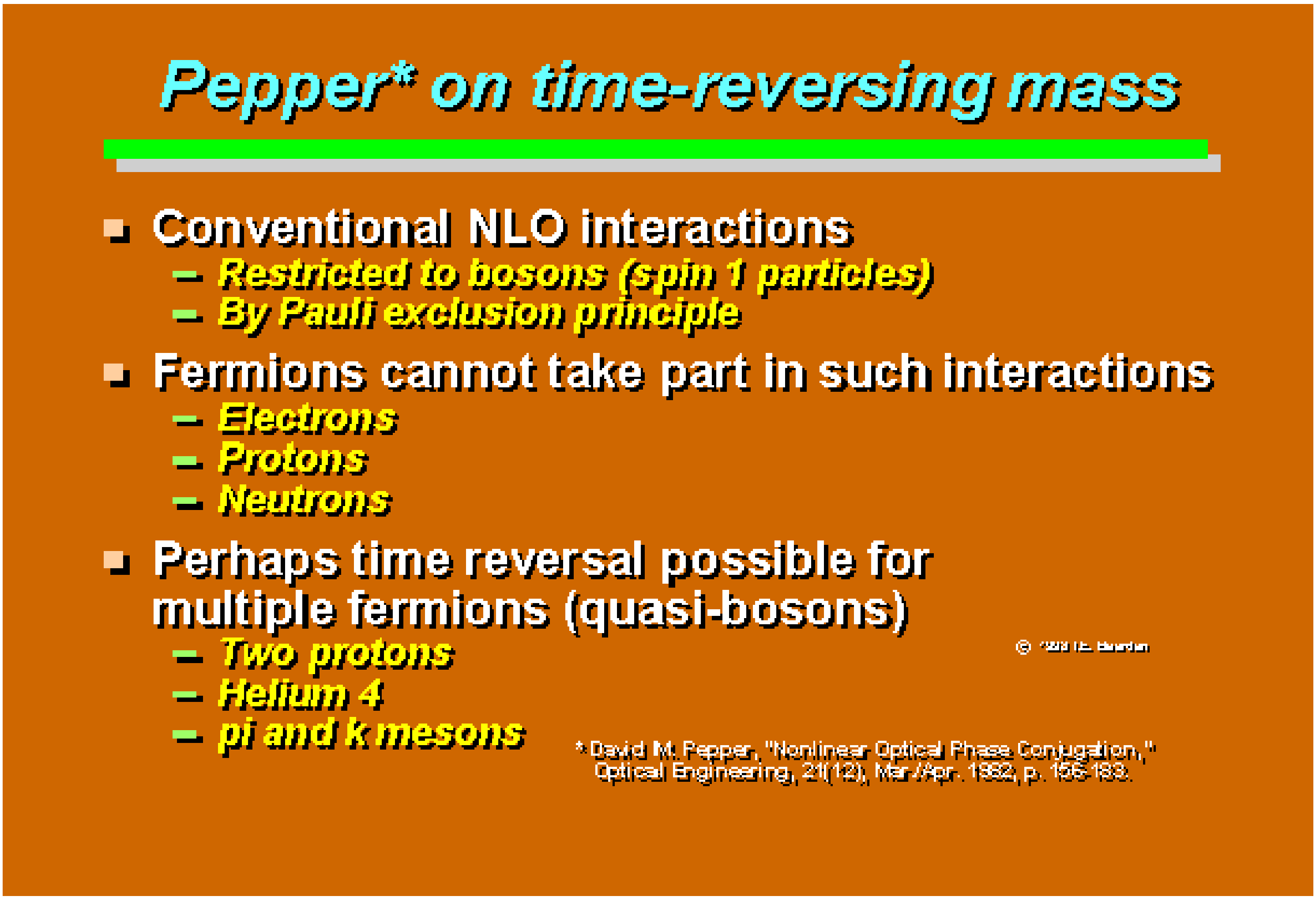

Pepper* on time-reversing mass

- Conventional NLO interactions
  - *Restricted to bosons (spin 1 particles)*
  - *By Pauli exclusion principle*
- Fermions cannot take part in such interactions
  - *Electrons*
  - *Protons*
  - *Neutrons*
- Perhaps time reversal possible for multiple fermions (quasi-bosons)
  - *Two protons*
  - *Helium 4*
  - *pi and k mesons*

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* David M. Pepper, "Nonlinear Optical Phase Conjugation," Optical Engineering, 21(12), Mar./Apr. 1982, p. 156-183.

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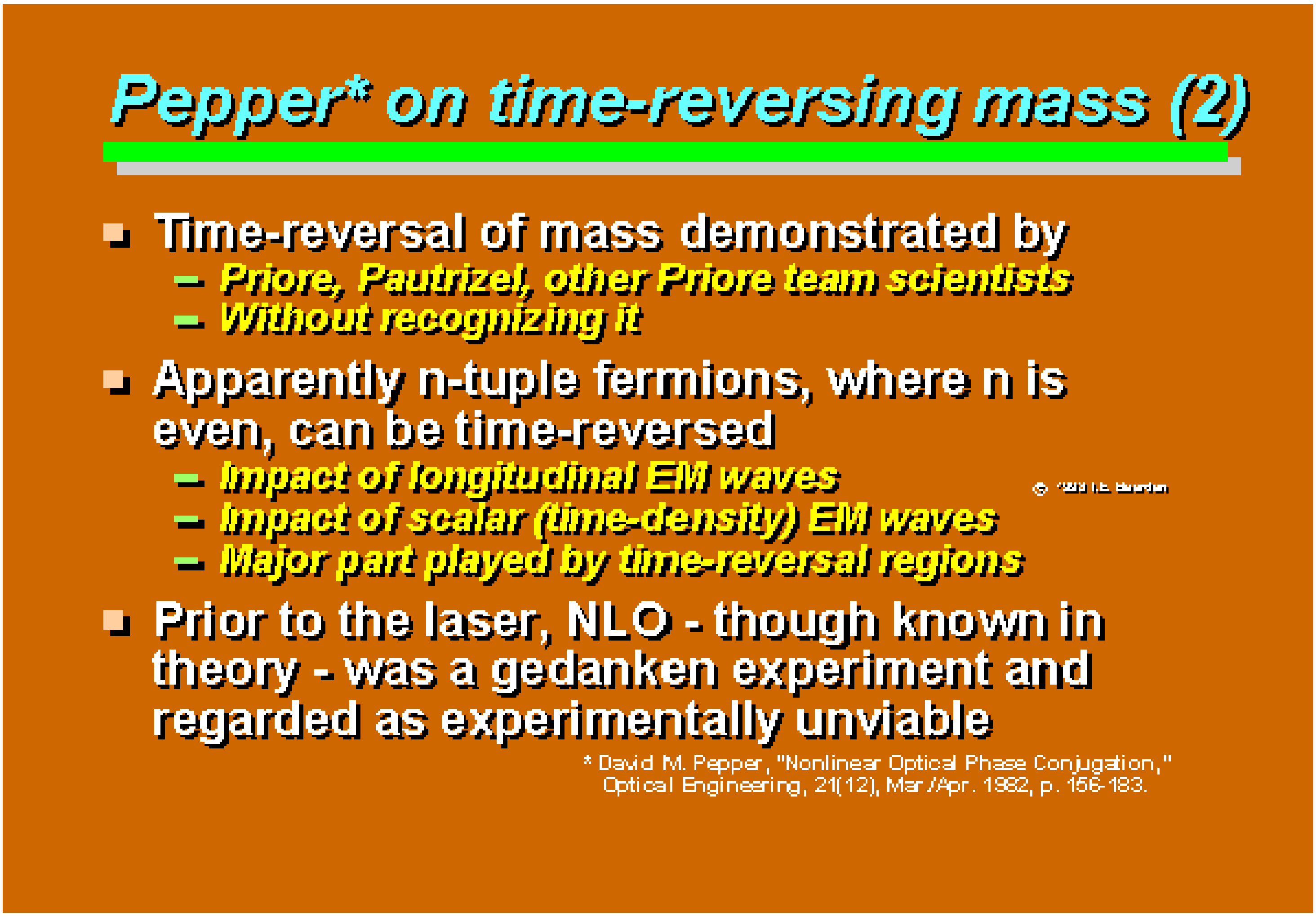

Pepper* on time-reversing mass (2)

- Time-reversal of mass demonstrated by
  - *Priore, Pautrizel, other Priore team scientists*
  - *Without recognizing it*
- Apparently n-tuple fermions, where n is even, can be time-reversed
  - *Impact of longitudinal EM waves*
  - *Impact of scalar (time-density) EM waves*
  - *Major part played by time-reversal regions*
- Prior to the laser, NLO - though known in theory - was a gedanken experiment and regarded as experimentally unviable

* David M. Pepper, "Nonlinear Optical Phase Conjugation," Optical Engineering, 21(12), Mar./Apr. 1982, p. 156-183.

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Chung's Carbon Filament Negative Resistor

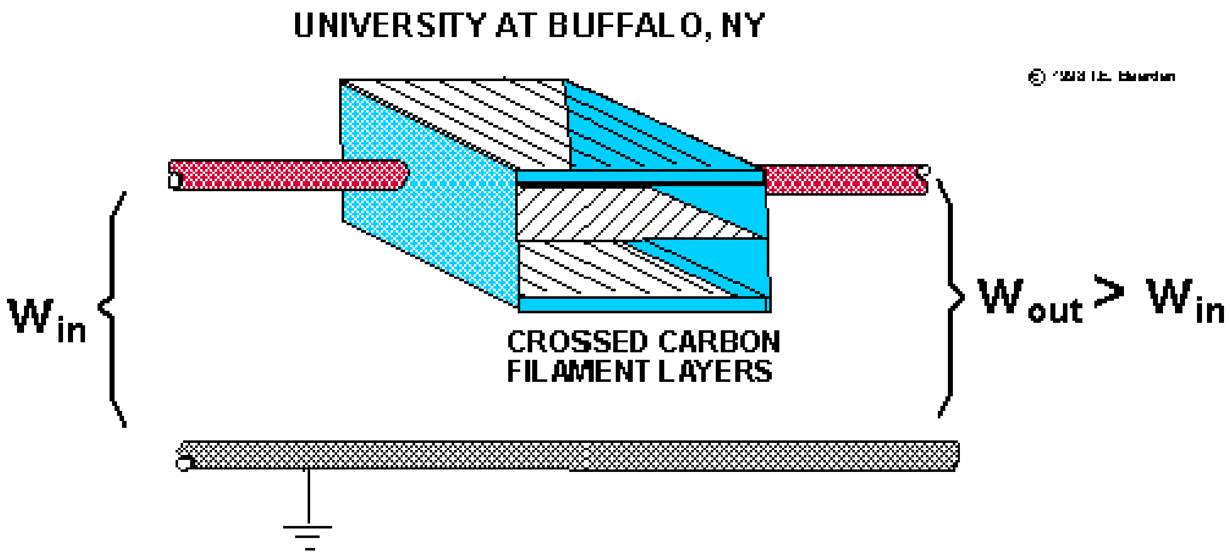
UNIVERSITY AT BUFFALO, NY
© 1993 T.E. Bearden
W_in
CROSSED CARBON
FILAMENT LAYERS
W_out > W_in

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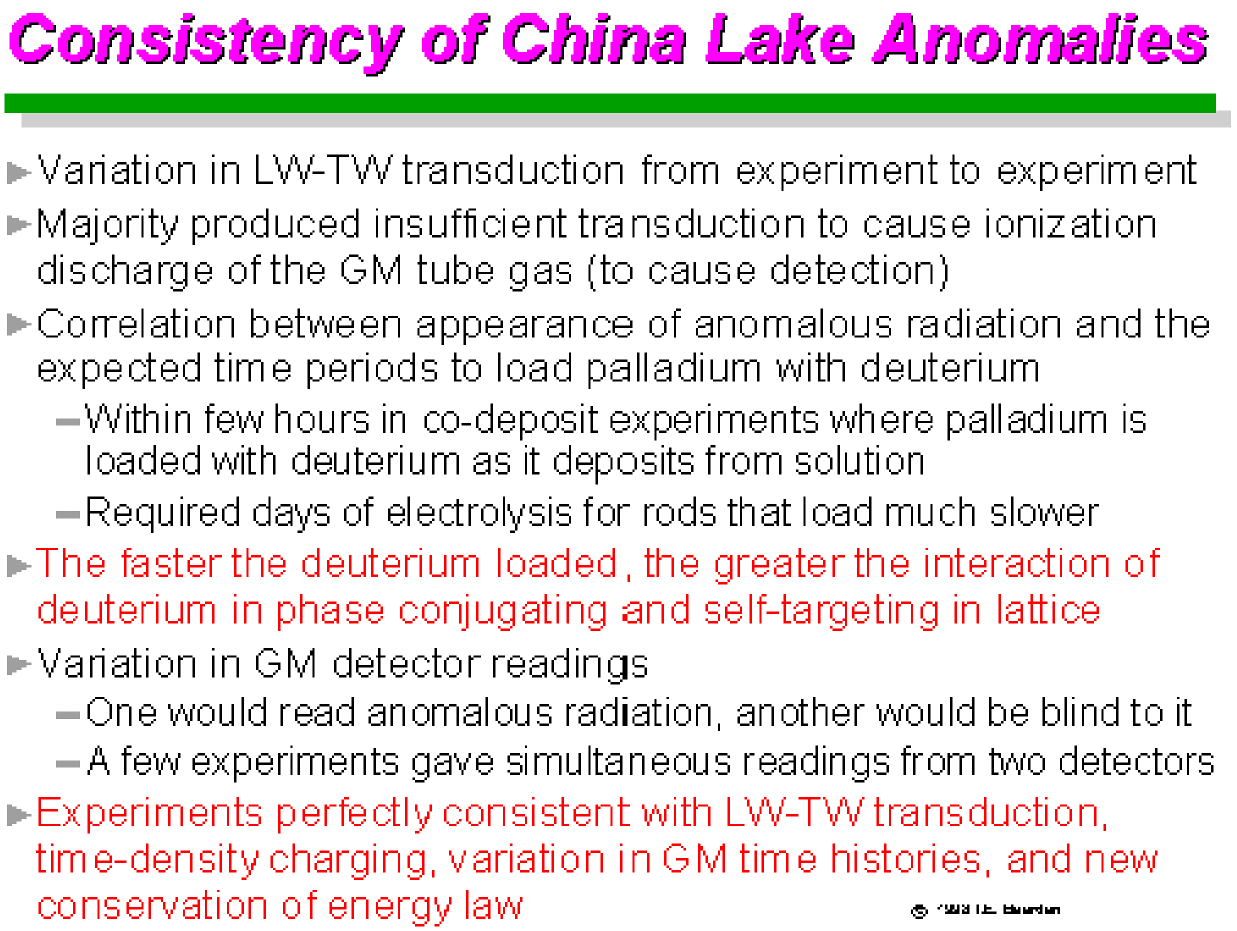

Consistency of China Lake Anomalies

- Variation in LW-TW transduction from experiment to experiment
- Majority produced insufficient transduction to cause ionization discharge of the GM tube gas (to cause detection)
- Correlation between appearance of anomalous radiation and the expected time periods to load palladium with deuterium
  - Within few hours in co-deposit experiments where palladium is loaded with deuterium as it deposits from solution
  - Required days of electrolysis for rods that load much slower
- The faster the deuterium loaded, the greater the interaction of deuterium in phase conjugating and self-targeting in lattice
- Variation in GM detector readings
  - One would read anomalous radiation, another would be blind to it
  - A few experiments gave simultaneous readings from two detectors
- Experiments perfectly consistent with LW-TW transduction, time-density charging, variation in GM time histories, and new conservation of energy law

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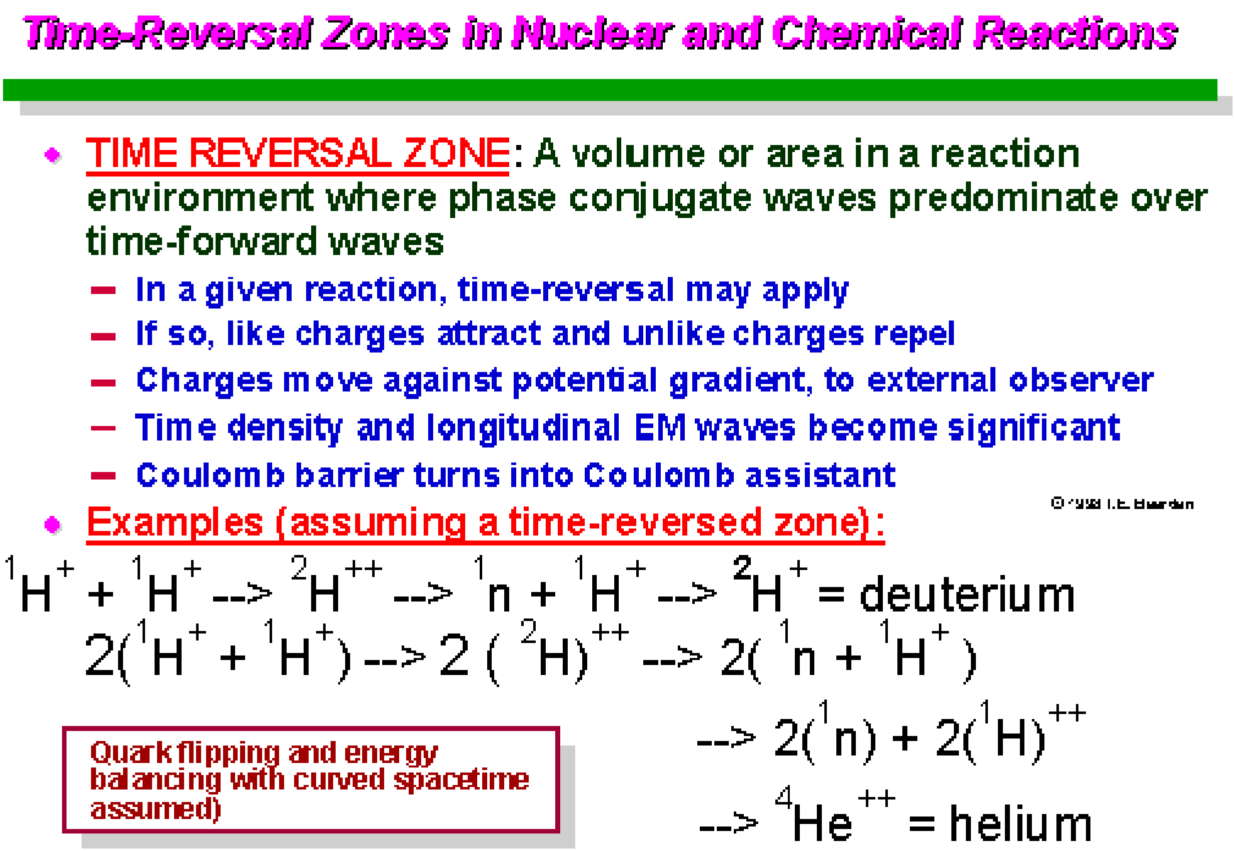

Time-Reversal Zones in Nuclear and Chemical Reactions

- TIME REVERSAL ZONE: A volume or area in a reaction environment where phase conjugate waves predominate over time-forward waves
  - In a given reaction, time-reversal may apply
  - If so, like charges attract and unlike charges repel
  - Charges move against potential gradient, to external observer
  - Time density and longitudinal EM waves become significant
  - Coulomb barrier turns into Coulomb assistant

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- Examples (assuming a time-reversed zone):

$${}^{1}H^{+} + {}^{1}H^{+} \text{-->} {}^{2}H^{++} \text{-->} {}^{1}n + {}^{1}H^{+} \text{-->} {}^{2}H^{+} = \text{deuterium}$$

$$2({}^{1}H^{+} + {}^{1}H^{+}) \text{-->} 2\,({}^{2}H)^{++} \text{-->} 2({}^{1}n + {}^{1}H^{+})$$

$$\text{-->} 2({}^{1}n) + 2({}^{1}H)^{++}$$

$$\text{-->} {}^{4}He^{++} = \text{helium}$$

Quark flipping and energy balancing with curved spacetime assumed)

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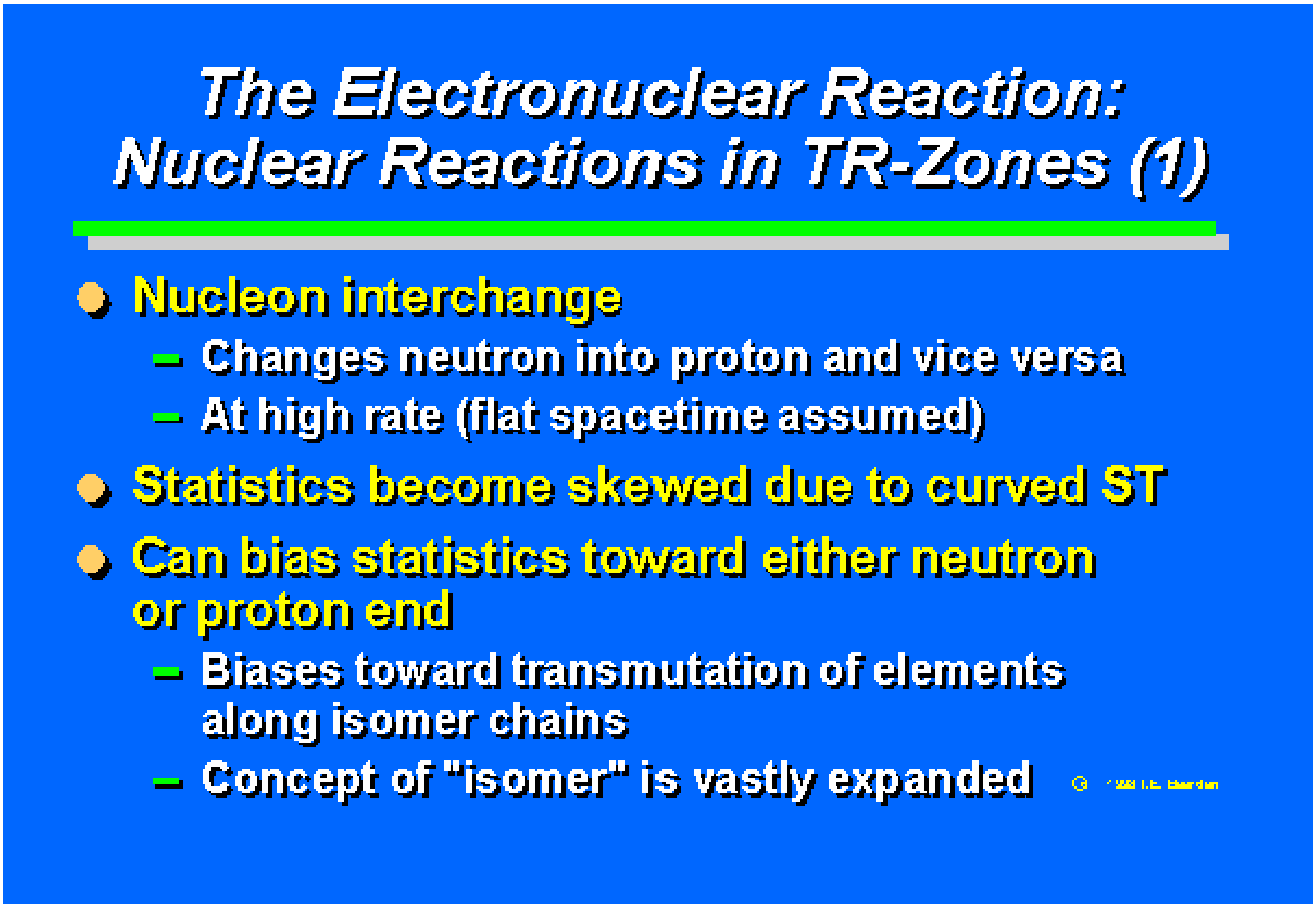

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (1)

- Nucleon interchange
  - Changes neutron into proton and vice versa
  - At high rate (flat spacetime assumed)
- Statistics become skewed due to curved ST
- Can bias statistics toward either neutron or proton end
  - Biases toward transmutation of elements along isomer chains
  - Concept of "isomer" is vastly expanded

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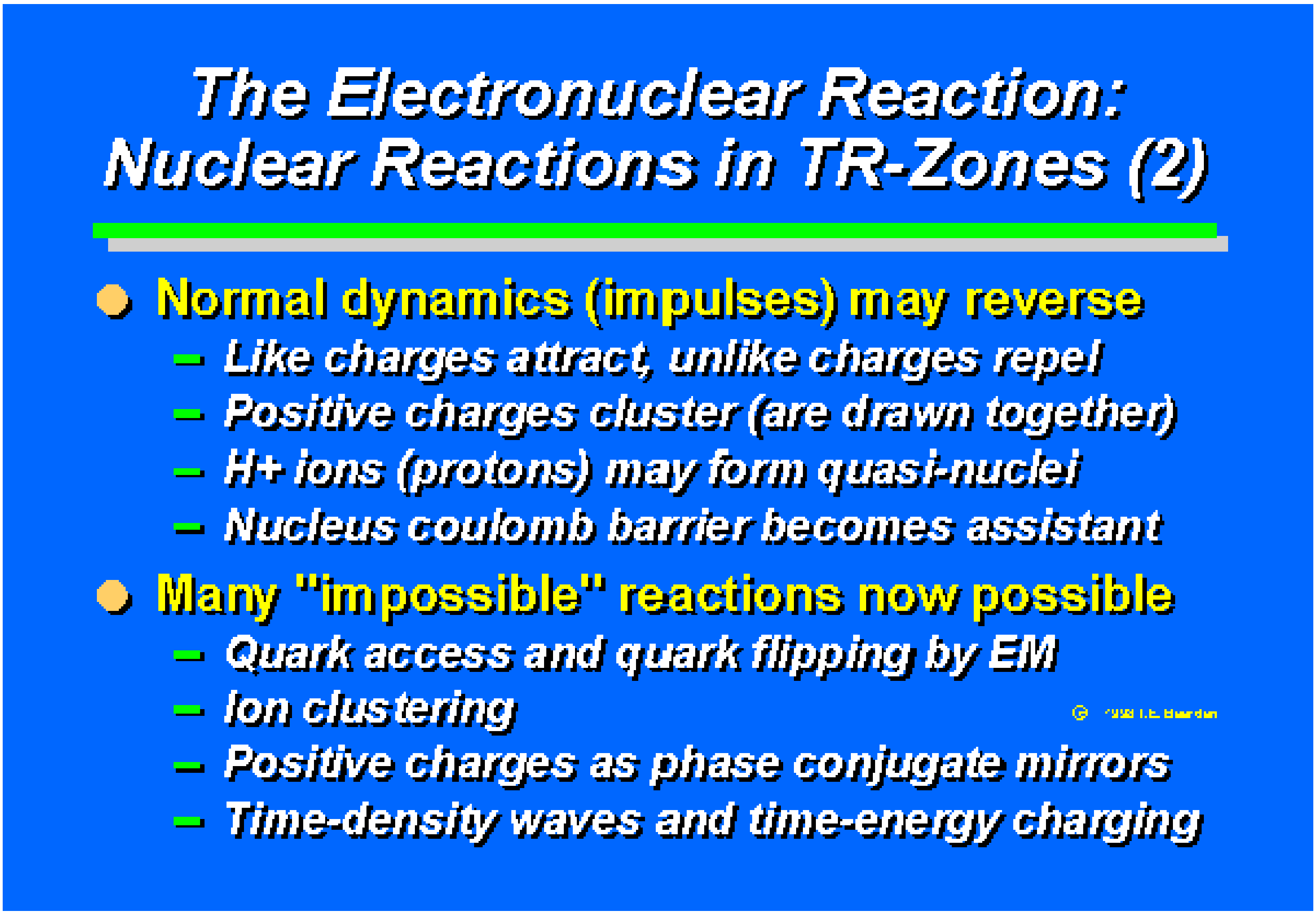

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (2)

- Normal dynamics (impulses) may reverse
  - Like charges attract, unlike charges repel
  - Positive charges cluster (are drawn together)
  - H+ ions (protons) may form quasi-nuclei
  - Nucleus coulomb barrier becomes assistant
- Many "impossible" reactions now possible
  - Quark access and quark flipping by EM
  - Ion clustering
  - Positive charges as phase conjugate mirrors
  - Time-density waves and time-energy charging

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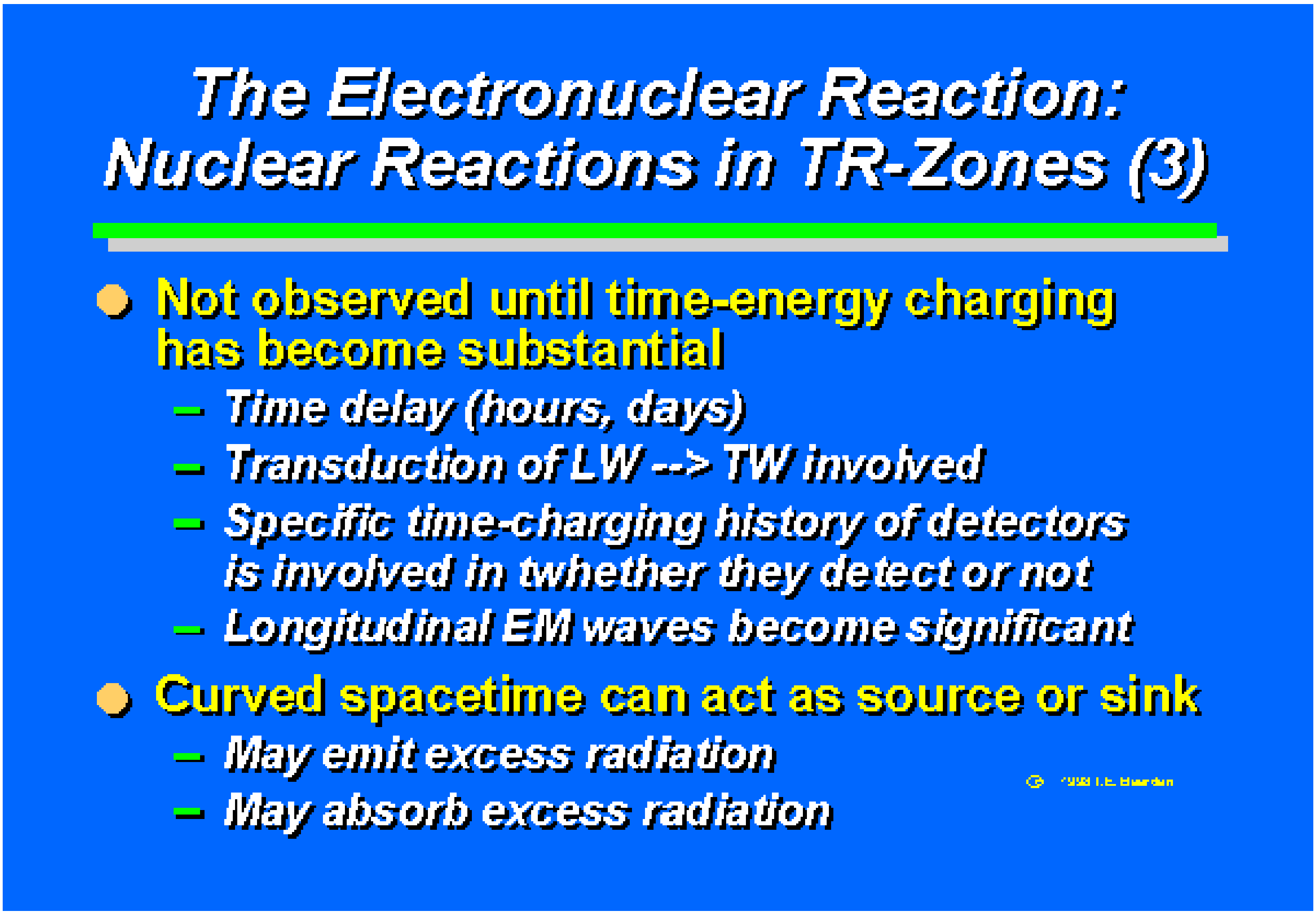

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (3)

- Not observed until time-energy charging has become substantial
  - Time delay (hours, days)
  - Transduction of LW --> TW involved
  - Specific time-charging history of detectors is involved in twhether they detect or not
  - Longitudinal EM waves become significant
- Curved spacetime can act as source or sink
  - May emit excess radiation
  - May absorb excess radiation

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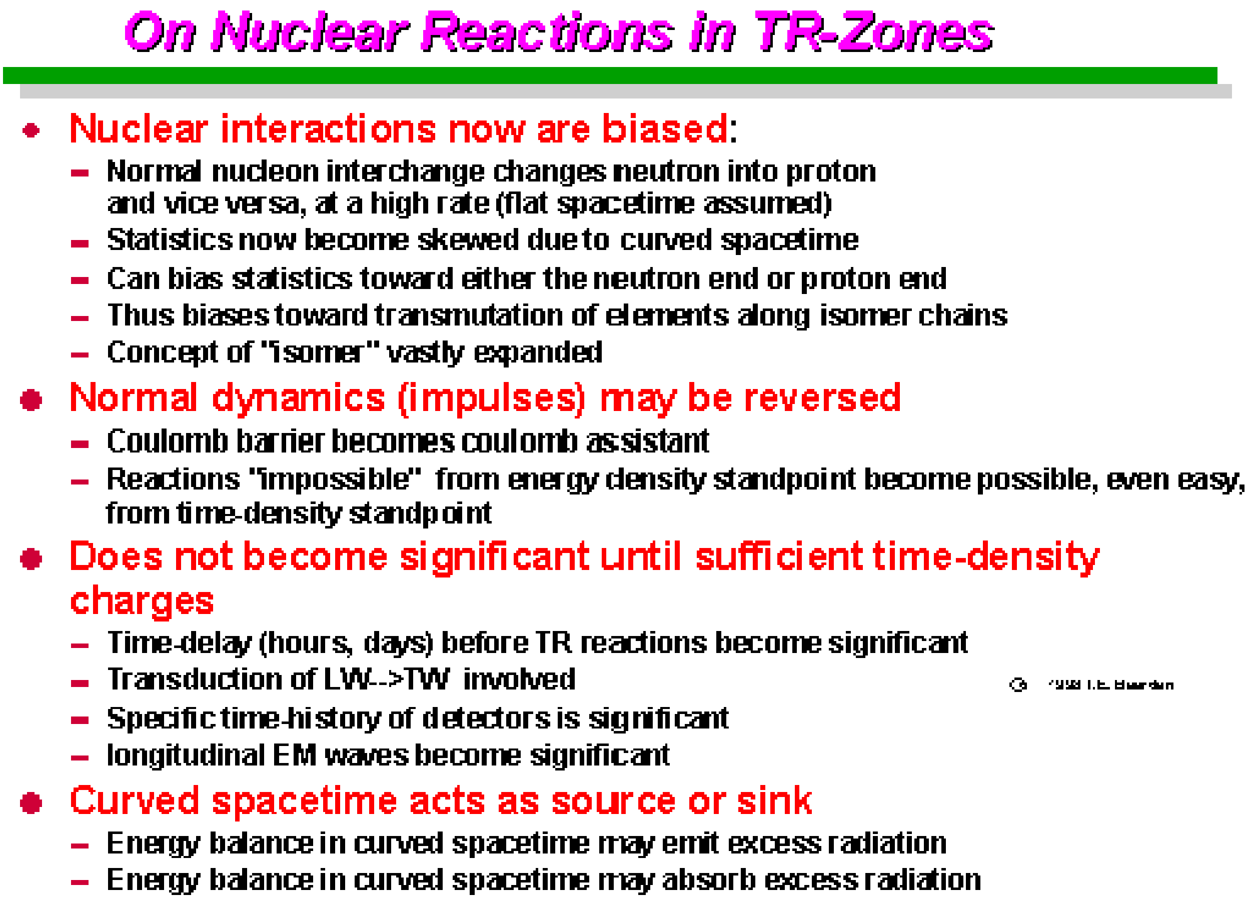

On Nuclear Reactions in TR-Zones

- Nuclear interactions now are biased:
  - Normal nucleon interchange changes neutron into proton and vice versa, at a high rate (flat spacetime assumed)
  - Statistics now become skewed due to curved spacetime
  - Can bias statistics toward either the neutron end or proton end
  - Thus biases toward transmutation of elements along isomer chains
  - Concept of "isomer" vastly expanded
- Normal dynamics (impulses) may be reversed
  - Coulomb barrier becomes coulomb assistant
  - Reactions "impossible" from energy density standpoint become possible, even easy, from time-density standpoint
- Does not become significant until sufficient time-density charges
  - Time-delay (hours, days) before TR reactions become significant
  - Transduction of LW-->TW involved
  - Specific time-history of detectors is significant
  - longitudinal EM waves become significant
- Curved spacetime acts as source or sink
  - Energy balance in curved spacetime may emit excess radiation
  - Energy balance in curved spacetime may absorb excess radiation

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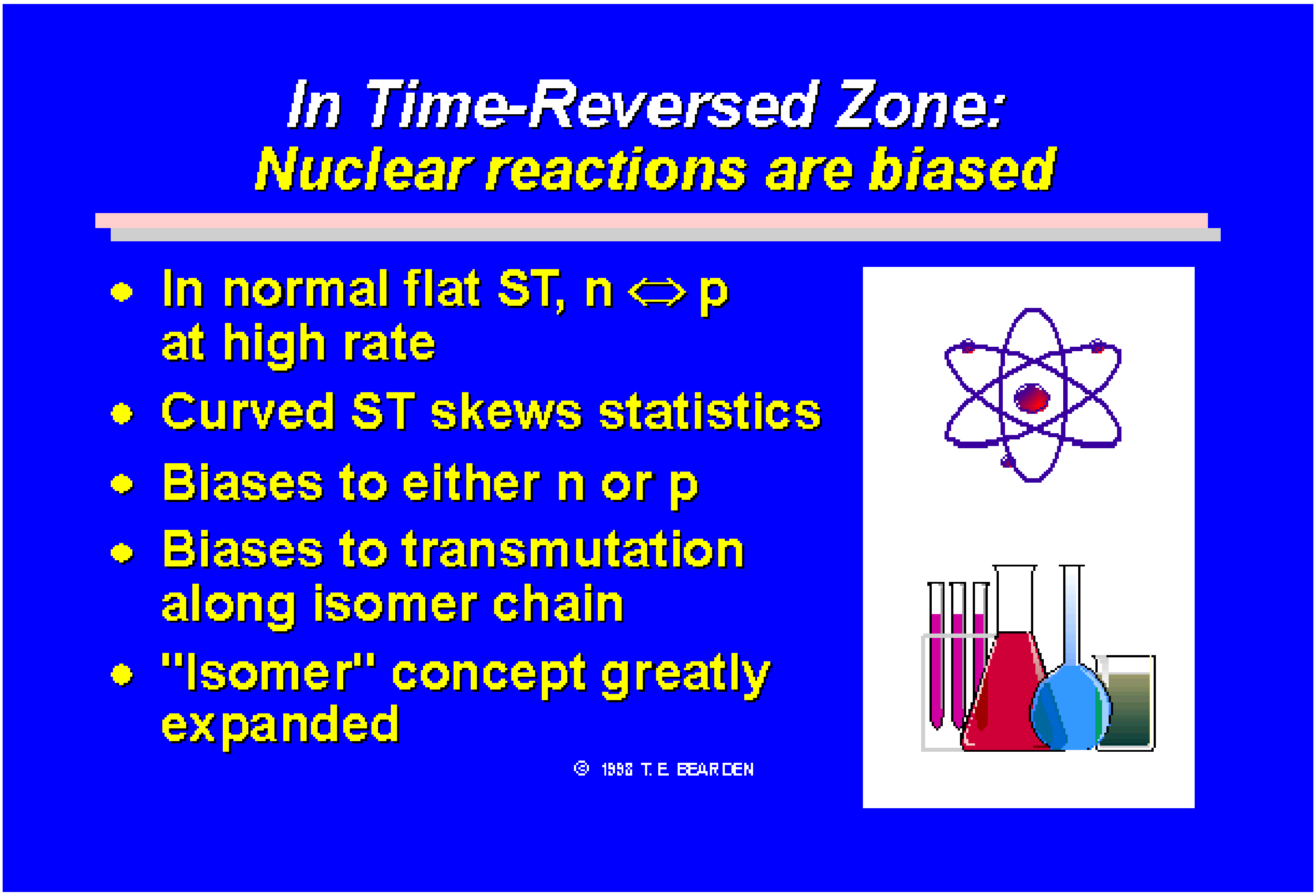

In Time-Reversed Zone:
Nuclear reactions are biased

- In normal flat ST, n ⇔ p at high rate
- Curved ST skews statistics
- Biases to either n or p
- Biases to transmutation along isomer chain
- "Isomer" concept greatly expanded

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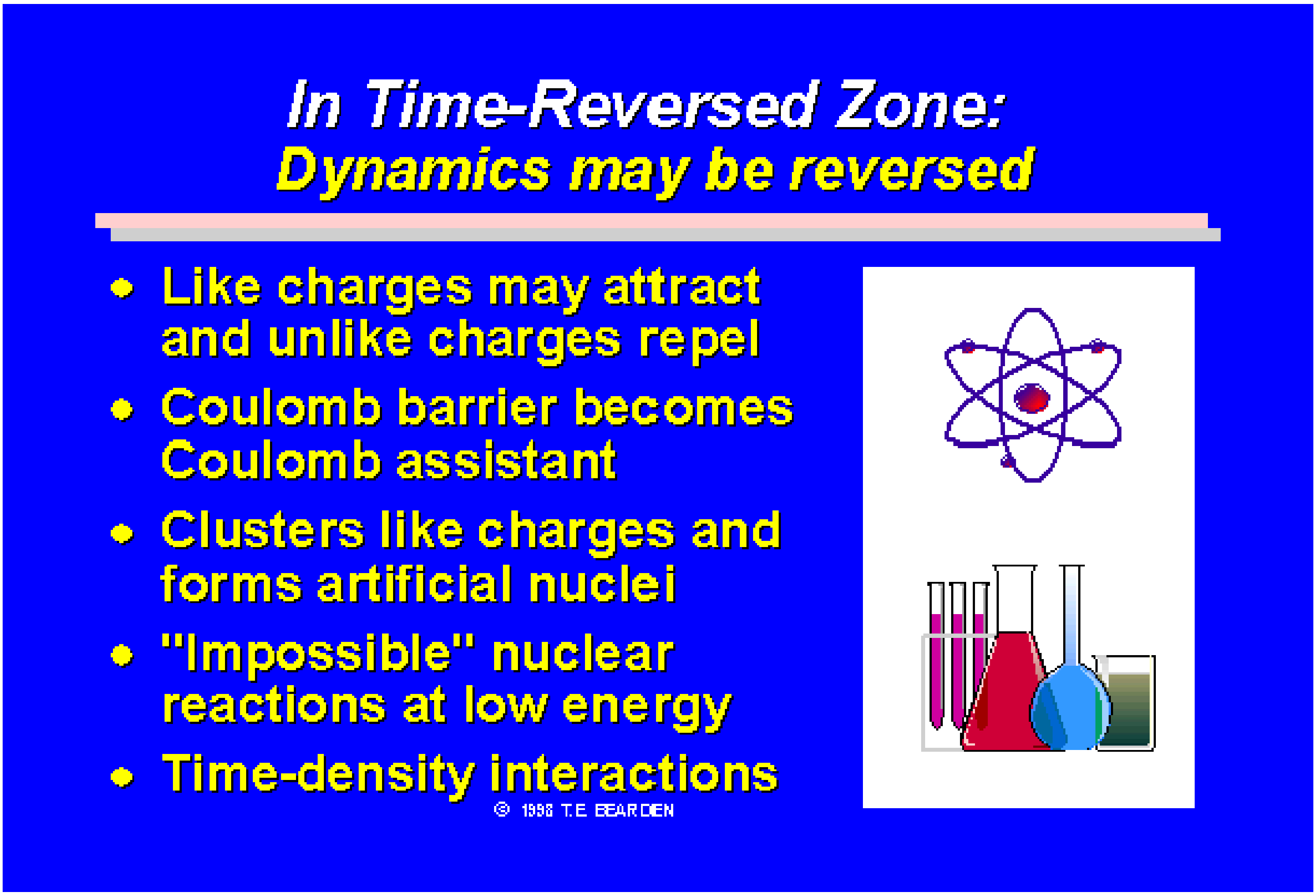

In Time-Reversed Zone:
Dynamics may be reversed

- Like charges may attract and unlike charges repel
- Coulomb barrier becomes Coulomb assistant
- Clusters like charges and forms artificial nuclei
- "Impossible" nuclear reactions at low energy
- Time-density interactions

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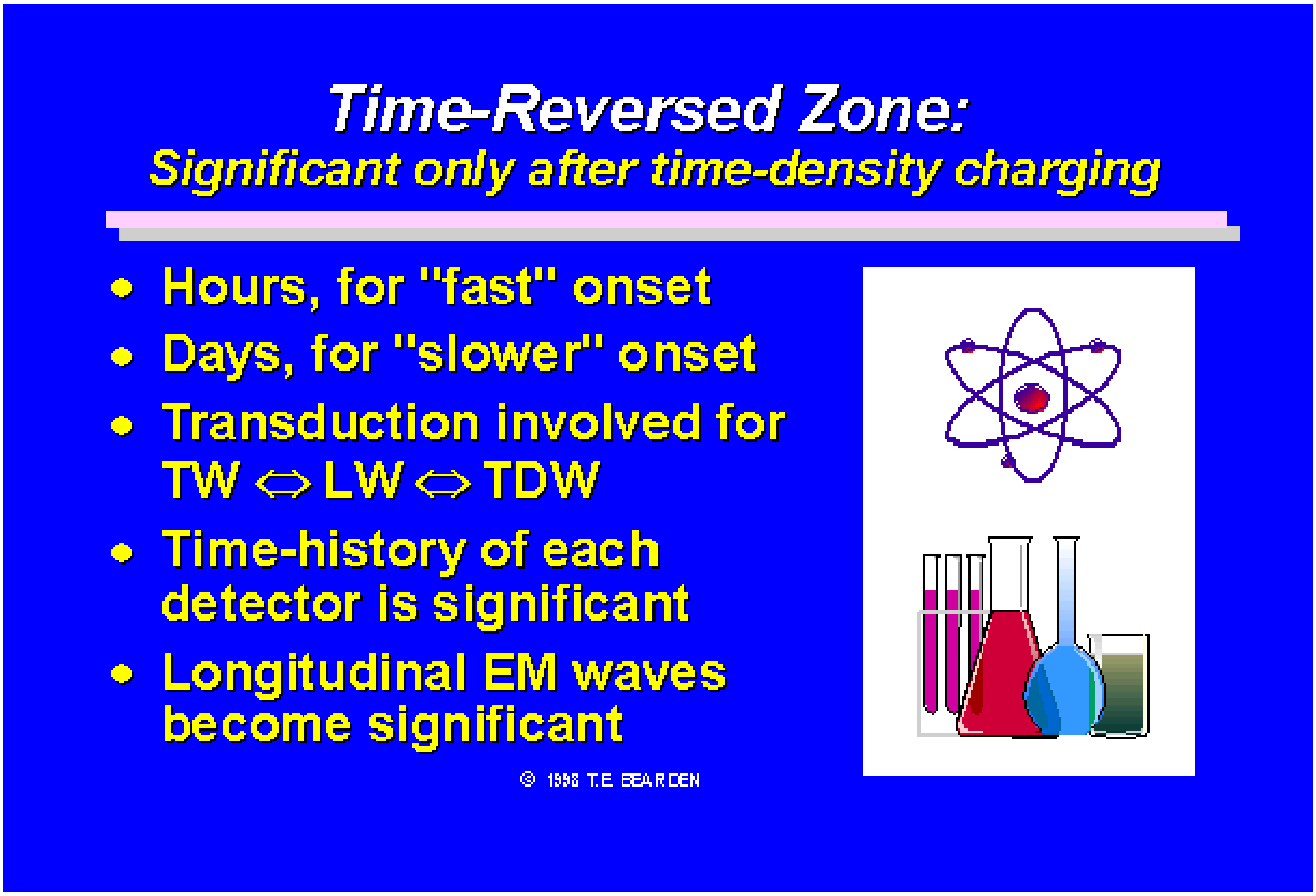

Time-Reversed Zone:
Significant only after time-density charging

- Hours, for "fast" onset
- Days, for "slower" onset
- Transduction involved for TW ⇔ LW ⇔ TDW
- Time-history of each detector is significant
- Longitudinal EM waves become significant

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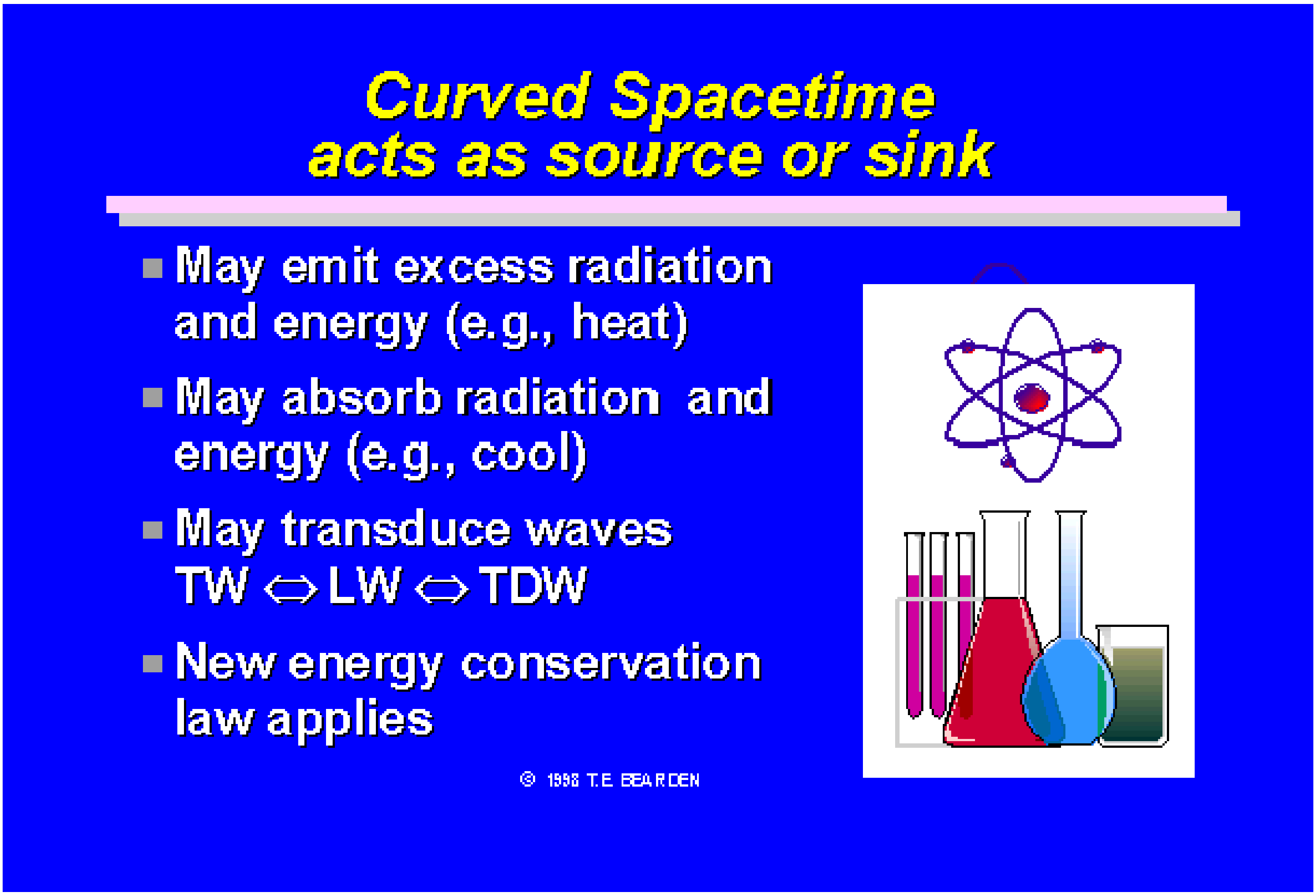

Curved Spacetime acts as source or sink

- May emit excess radiation and energy (e.g., heat)
- May absorb radiation and energy (e.g., cool)
- May transduce waves TW ⇔ LW ⇔ TDW
- New energy conservation law applies

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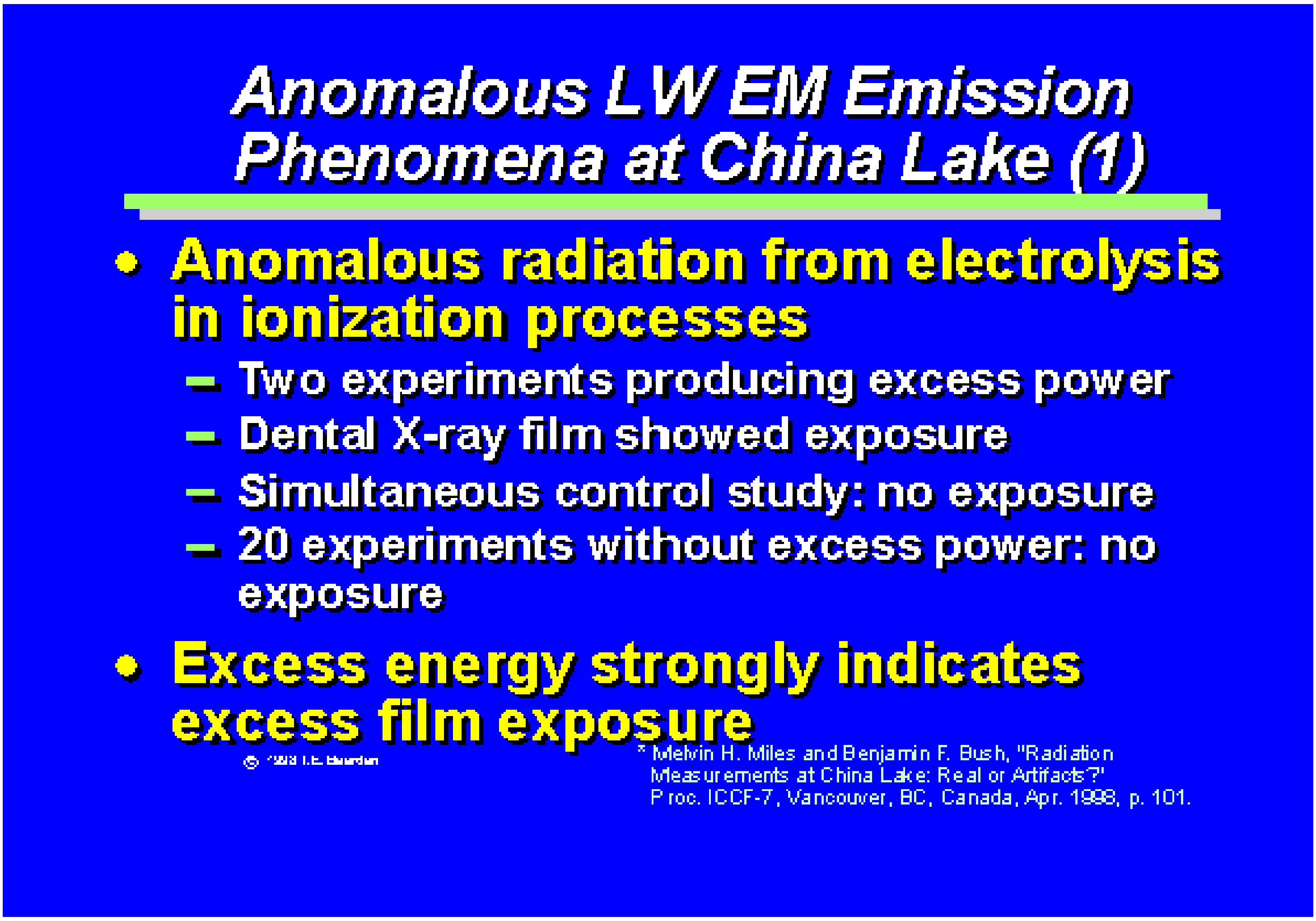

Anomalous LW EM Emission Phenomena at China Lake (1)

- **Anomalous radiation from electrolysis in ionization processes**
  - Two experiments producing excess power
  - Dental X-ray film showed exposure
  - Simultaneous control study: no exposure
  - 20 experiments without excess power: no exposure
- **Excess energy strongly indicates excess film exposure**

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* Melvin H. Miles and Benjamin F. Bush, "Radiation Measurements at China Lake: Real or Artifacts?" Proc. ICCF-7, Vancouver, BC, Canada, Apr. 1998, p. 101.

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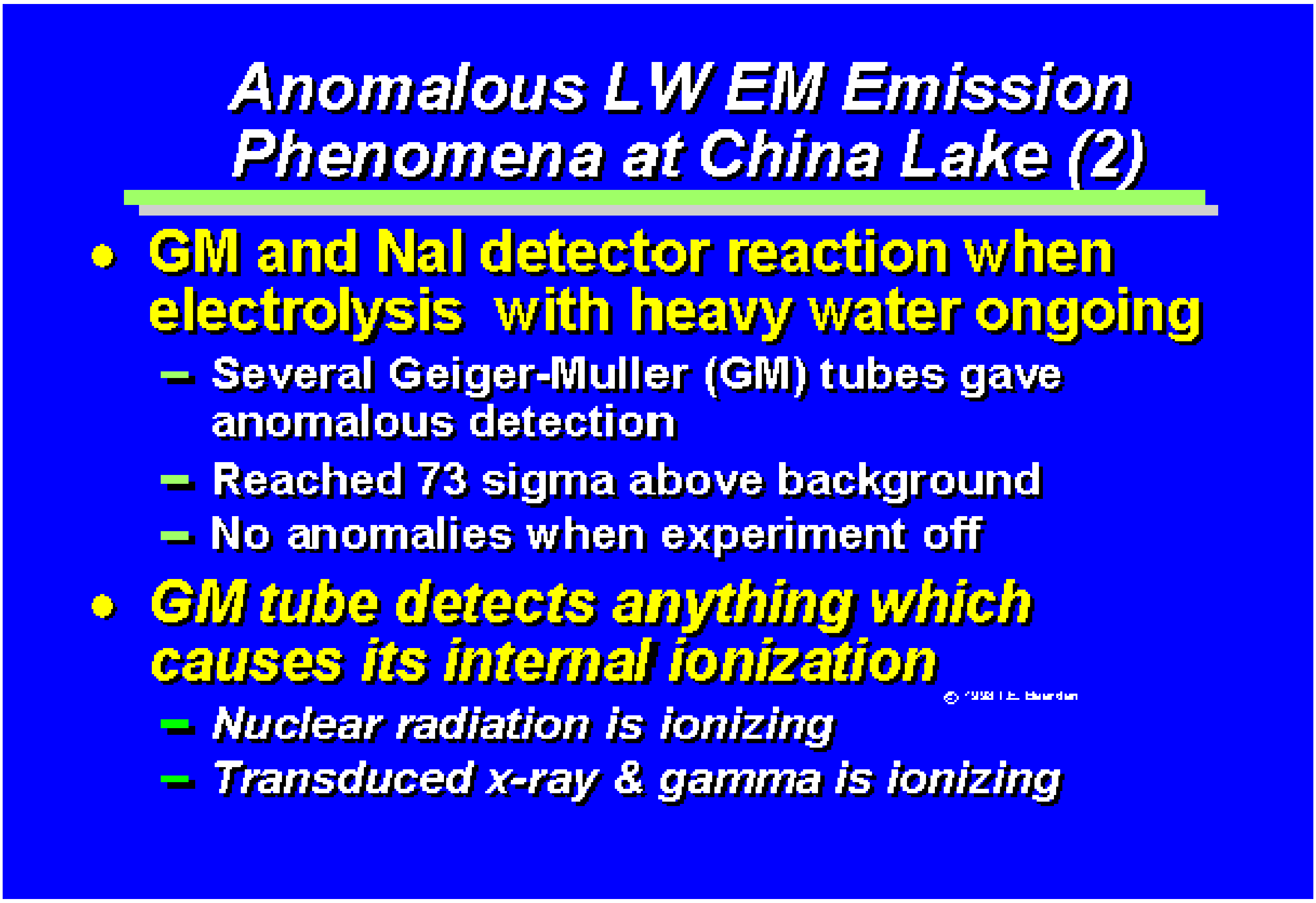

Anomalous LW EM Emission Phenomena at China Lake (2)

- **GM and NaI detector reaction when electrolysis with heavy water ongoing**
  - Several Geiger-Muller (GM) tubes gave anomalous detection
  - Reached 73 sigma above background
  - No anomalies when experiment off
- ***GM tube detects anything which causes its internal ionization***
  - *Nuclear radiation is ionizing*
  - *Transduced x-ray & gamma is ionizing*

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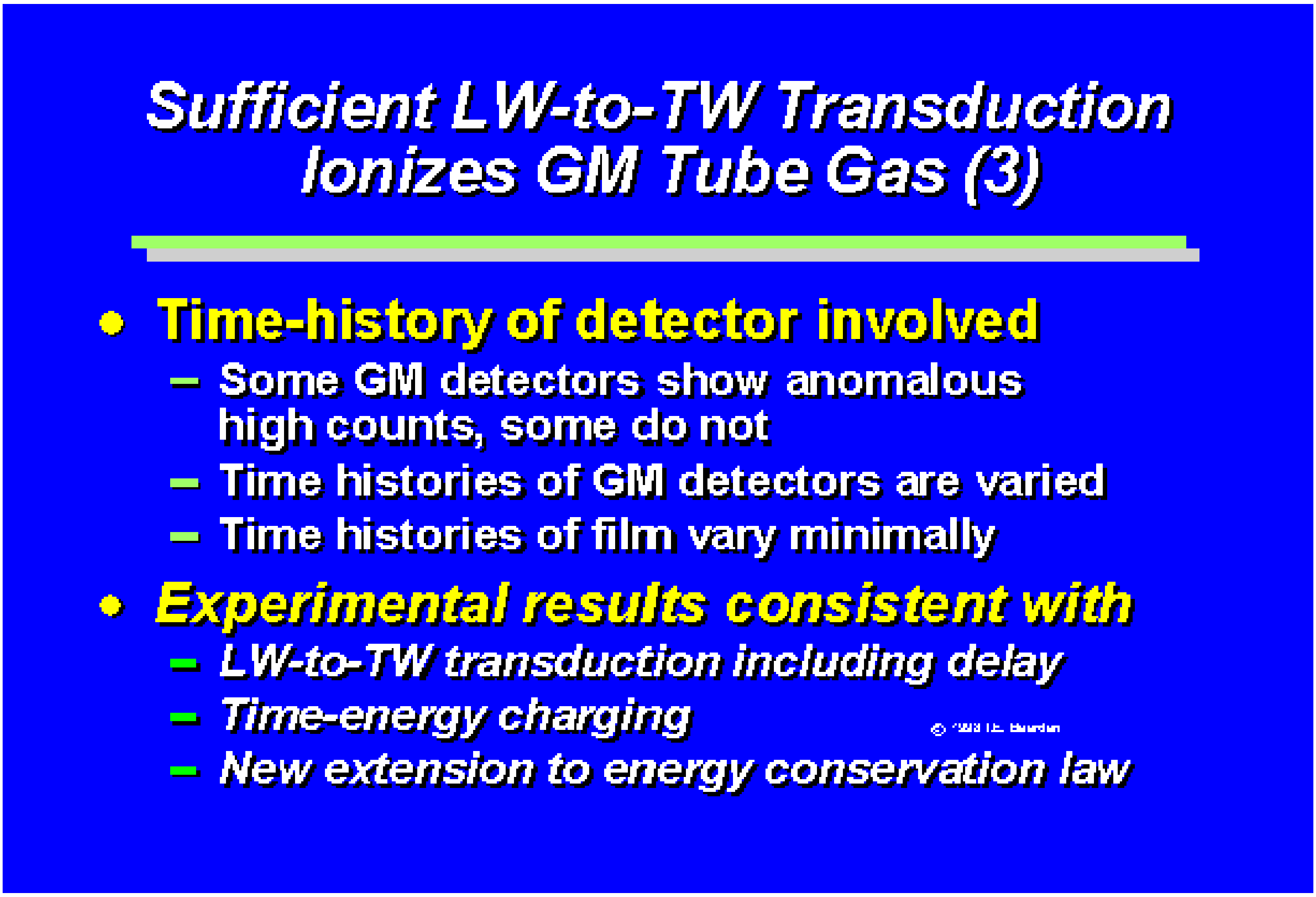

Sufficient LW-to-TW Transduction Ionizes GM Tube Gas (3)

- **Time-history of detector involved**
  - Some GM detectors show anomalous high counts, some do not
  - Time histories of GM detectors are varied
  - Time histories of film vary minimally
- ***Experimental results consistent with***
  - *LW-to-TW transduction including delay*
  - *Time-energy charging*
  - *New extension to energy conservation law*

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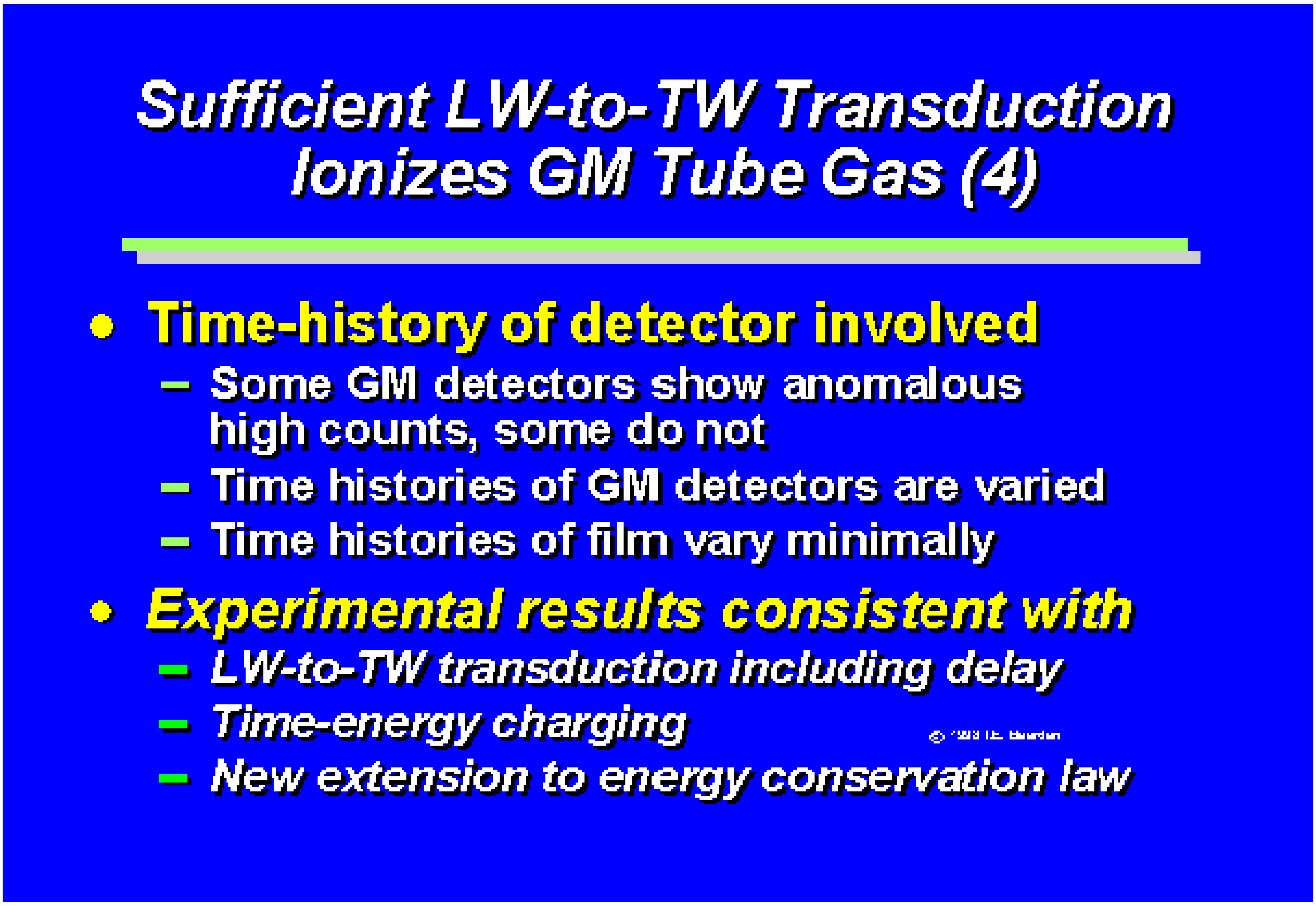

Sufficient LW-to-TW Transduction Ionizes GM Tube Gas (4)

- **Time-history of detector involved**
  - Some GM detectors show anomalous high counts, some do not
  - Time histories of GM detectors are varied
  - Time histories of film vary minimally
- ***Experimental results consistent with***
  - *LW-to-TW transduction including delay*
  - *Time-energy charging*
  - *New extension to energy conservation law*

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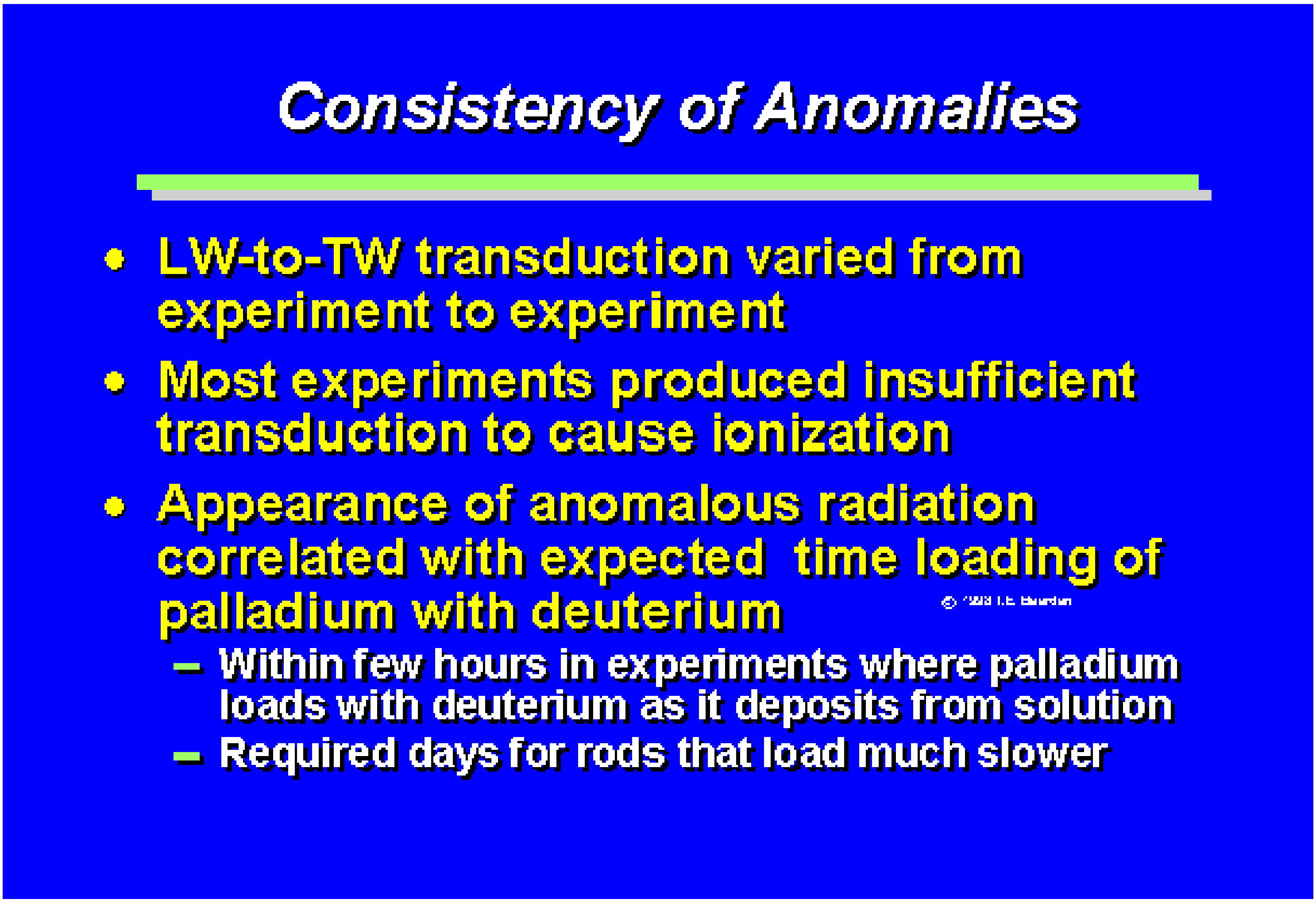

Consistency of Anomalies

- LW-to-TW transduction varied from experiment to experiment
- Most experiments produced insufficient transduction to cause ionization
- Appearance of anomalous radiation correlated with expected time loading of palladium with deuterium
  - Within few hours in experiments where palladium loads with deuterium as it deposits from solution
  - Required days for rods that load much slower

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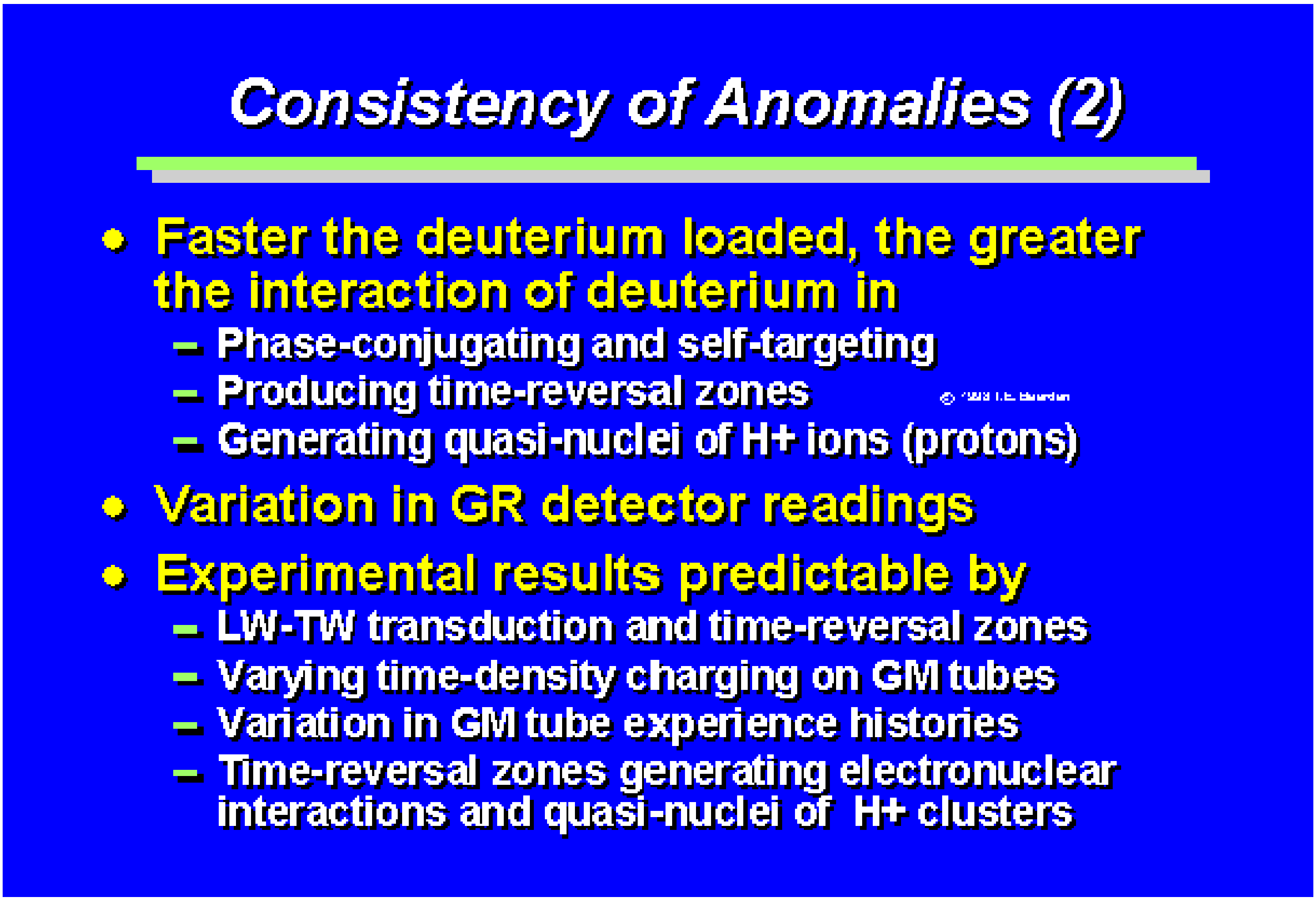

Consistency of Anomalies (2)

- Faster the deuterium loaded, the greater the interaction of deuterium in
  - Phase-conjugating and self-targeting
  - Producing time-reversal zones
  - Generating quasi-nuclei of H+ ions (protons)
- Variation in GR detector readings
- Experimental results predictable by
  - LW-TW transduction and time-reversal zones
  - Varying time-density charging on GM tubes
  - Variation in GM tube experience histories
  - Time-reversal zones generating electronuclear interactions and quasi-nuclei of H+ clusters

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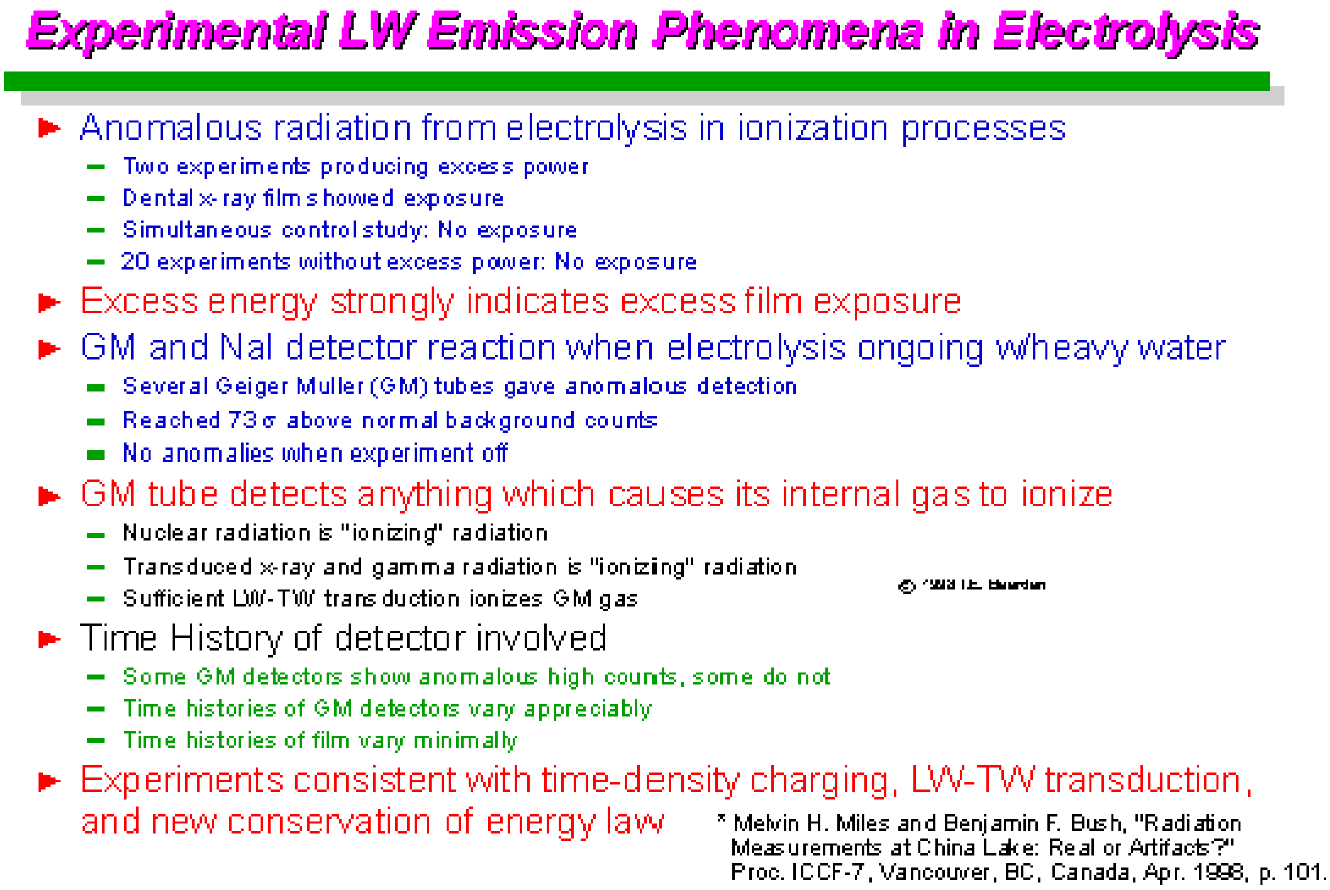

Experimental LW Emission Phenomena in Electrolysis

- Anomalous radiation from electrolysis in ionization processes
  - Two experiments producing excess power
  - Dental x-ray film showed exposure
  - Simultaneous control study: No exposure
  - 20 experiments without excess power: No exposure
- Excess energy strongly indicates excess film exposure
- GM and NaI detector reaction when electrolysis ongoing w/heavy water
  - Several Geiger Muller (GM) tubes gave anomalous detection
  - Reached 73σ above normal background counts
  - No anomalies when experiment off
- GM tube detects anything which causes its internal gas to ionize
  - Nuclear radiation is "ionizing" radiation
  - Transduced x-ray and gamma radiation is "ionizing" radiation
  - Sufficient LW-TW transduction ionizes GM gas
- Time History of detector involved
  - Some GM detectors show anomalous high counts, some do not
  - Time histories of GM detectors vary appreciably
  - Time histories of film vary minimally
- Experiments consistent with time-density charging, LW-TW transduction, and new conservation of energy law

* Melvin H. Miles and Benjamin F. Bush, "Radiation Measurements at China Lake: Real or Artifacts?" Proc. ICCF-7, Vancouver, BC, Canada, Apr. 1998, p. 101.

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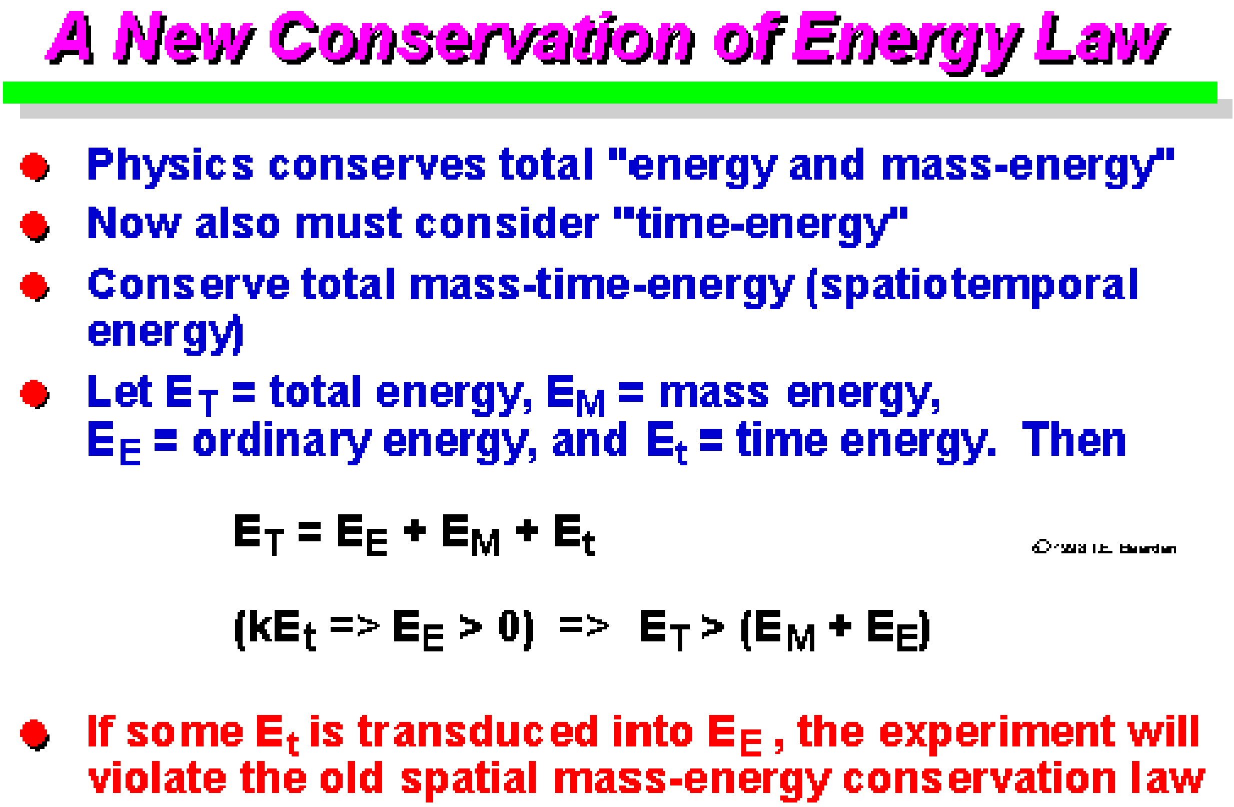

A New Conservation of Energy Law

- Physics conserves total "energy and mass-energy"
- Now also must consider "time-energy"
- Conserve total mass-time-energy (spatiotemporal energy)
- Let E_T = total energy, E_M = mass energy, E_E = ordinary energy, and E_t = time energy. Then

$$E_T = E_E + E_M + E_t$$

$$(kE_t \Rightarrow E_E > 0) \Rightarrow E_T > (E_M + E_E)$$

- If some E_t is transduced into E_E, the experiment will violate the old spatial mass-energy conservation law

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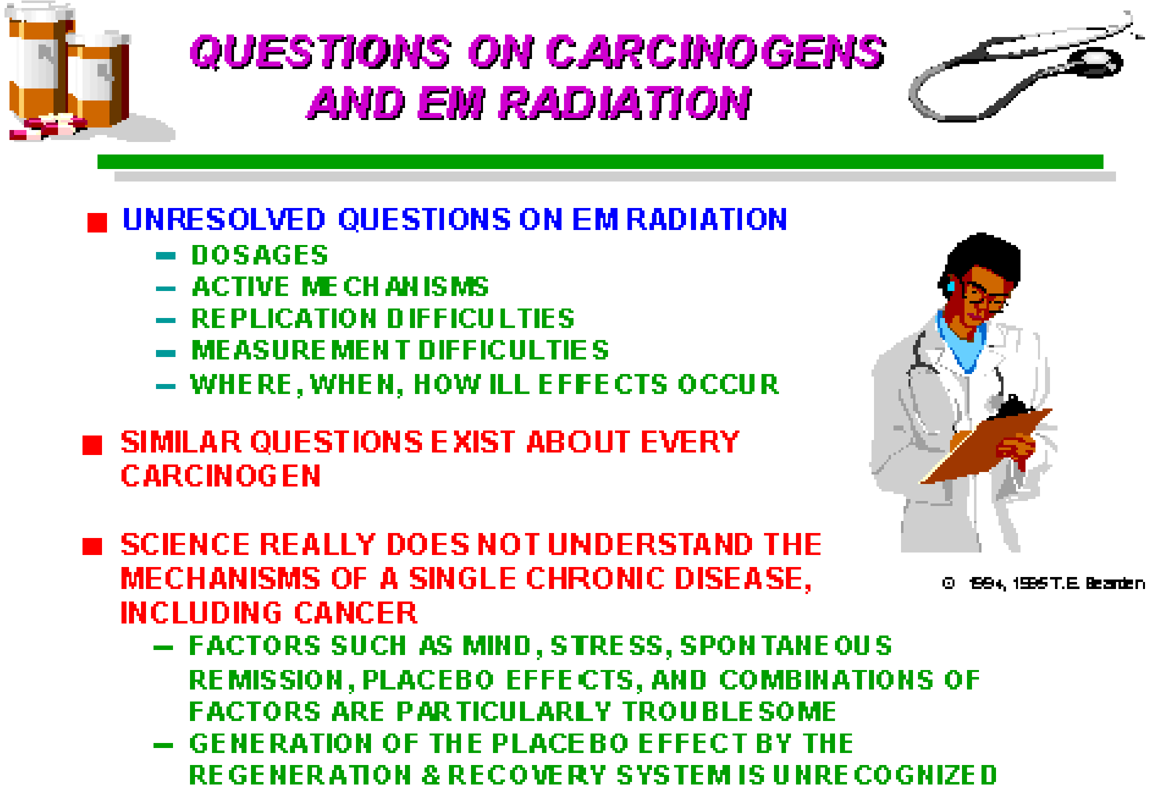

QUESTIONS ON CARCINOGENS AND EM RADIATION

- UNRESOLVED QUESTIONS ON EM RADIATION
  - DOSAGES
  - ACTIVE MECHANISMS
  - REPLICATION DIFFICULTIES
  - MEASUREMENT DIFFICULTIES
  - WHERE, WHEN, HOW ILL EFFECTS OCCUR
- SIMILAR QUESTIONS EXIST ABOUT EVERY CARCINOGEN
- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
  - FACTORS SUCH AS MIND, STRESS, SPONTANEOUS REMISSION, PLACEBO EFFECTS, AND COMBINATIONS OF FACTORS ARE PARTICULARLY TROUBLESOME
  - GENERATION OF THE PLACEBO EFFECT BY THE REGENERATION & RECOVERY SYSTEM IS UNRECOGNIZED

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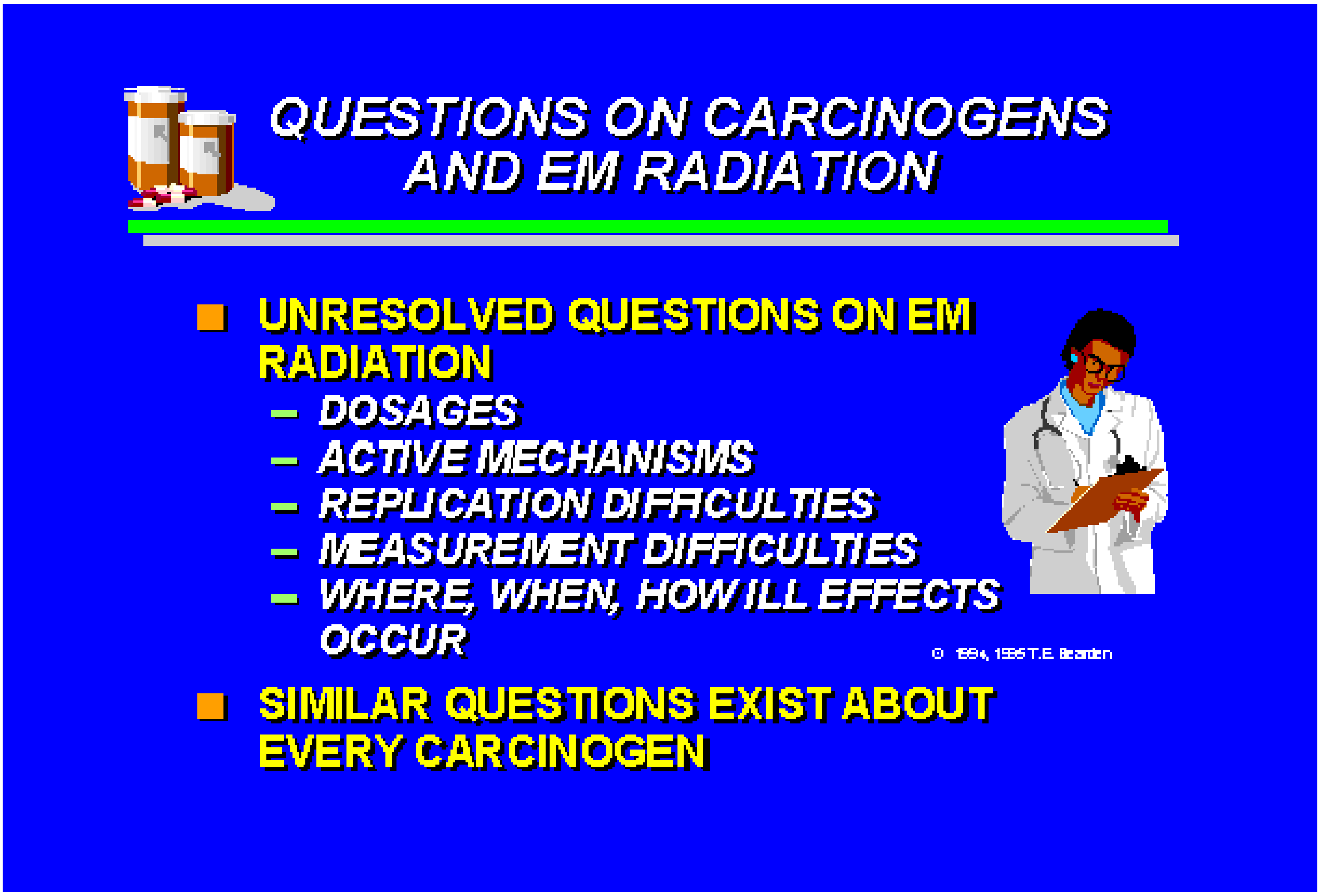

QUESTIONS ON CARCINOGENS AND EM RADIATION

- UNRESOLVED QUESTIONS ON EM RADIATION
  - DOSAGES
  - ACTIVE MECHANISMS
  - REPLICATION DIFFICULTIES
  - MEASUREMENT DIFFICULTIES
  - WHERE, WHEN, HOW ILL EFFECTS OCCUR
- SIMILAR QUESTIONS EXIST ABOUT EVERY CARCINOGEN

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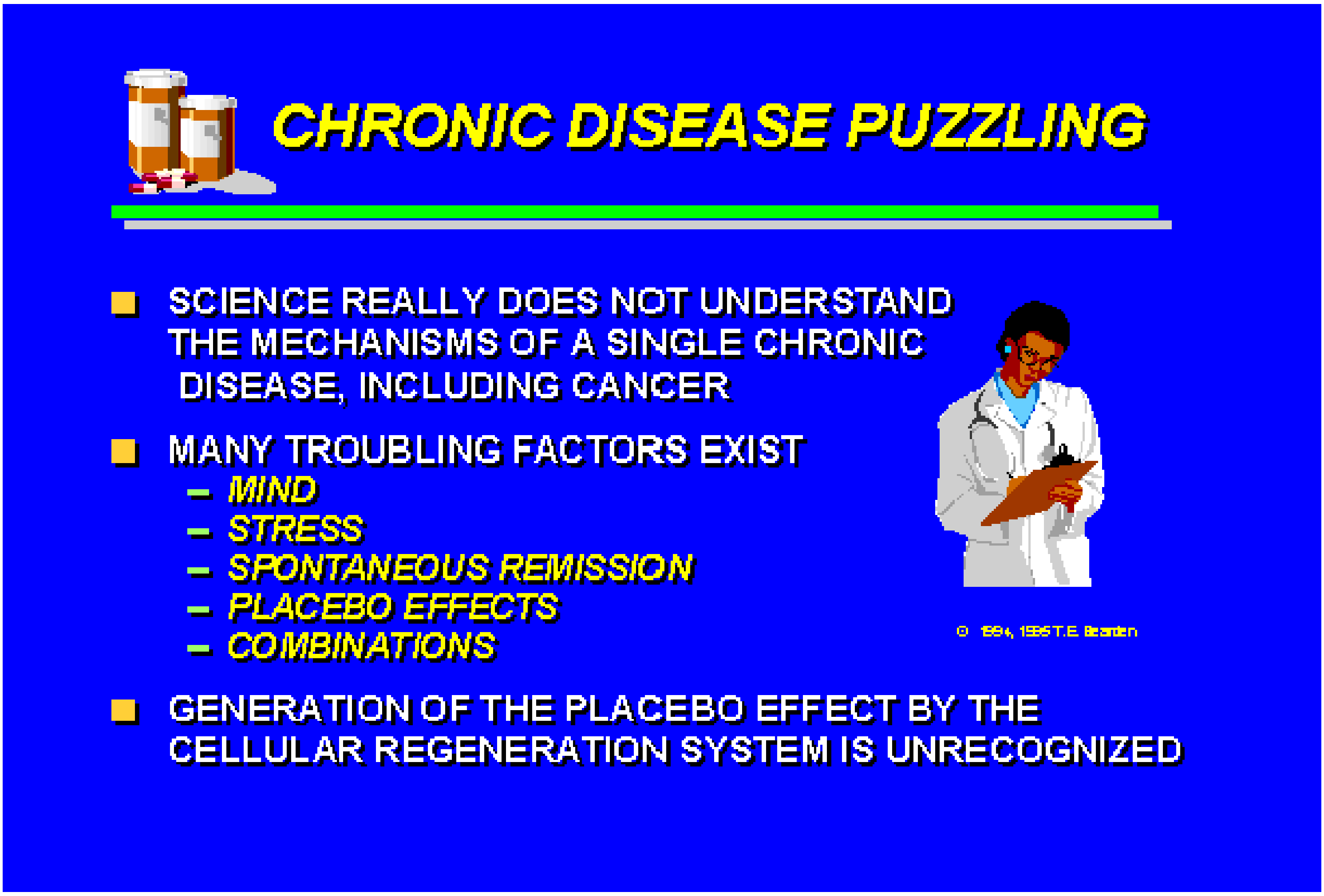

CHRONIC DISEASE PUZZLING

- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
- MANY TROUBLING FACTORS EXIST
  - *MIND*
  - *STRESS*
  - *SPONTANEOUS REMISSION*
  - *PLACEBO EFFECTS*
  - *COMBINATIONS*
- GENERATION OF THE PLACEBO EFFECT BY THE CELLULAR REGENERATION SYSTEM IS UNRECOGNIZED

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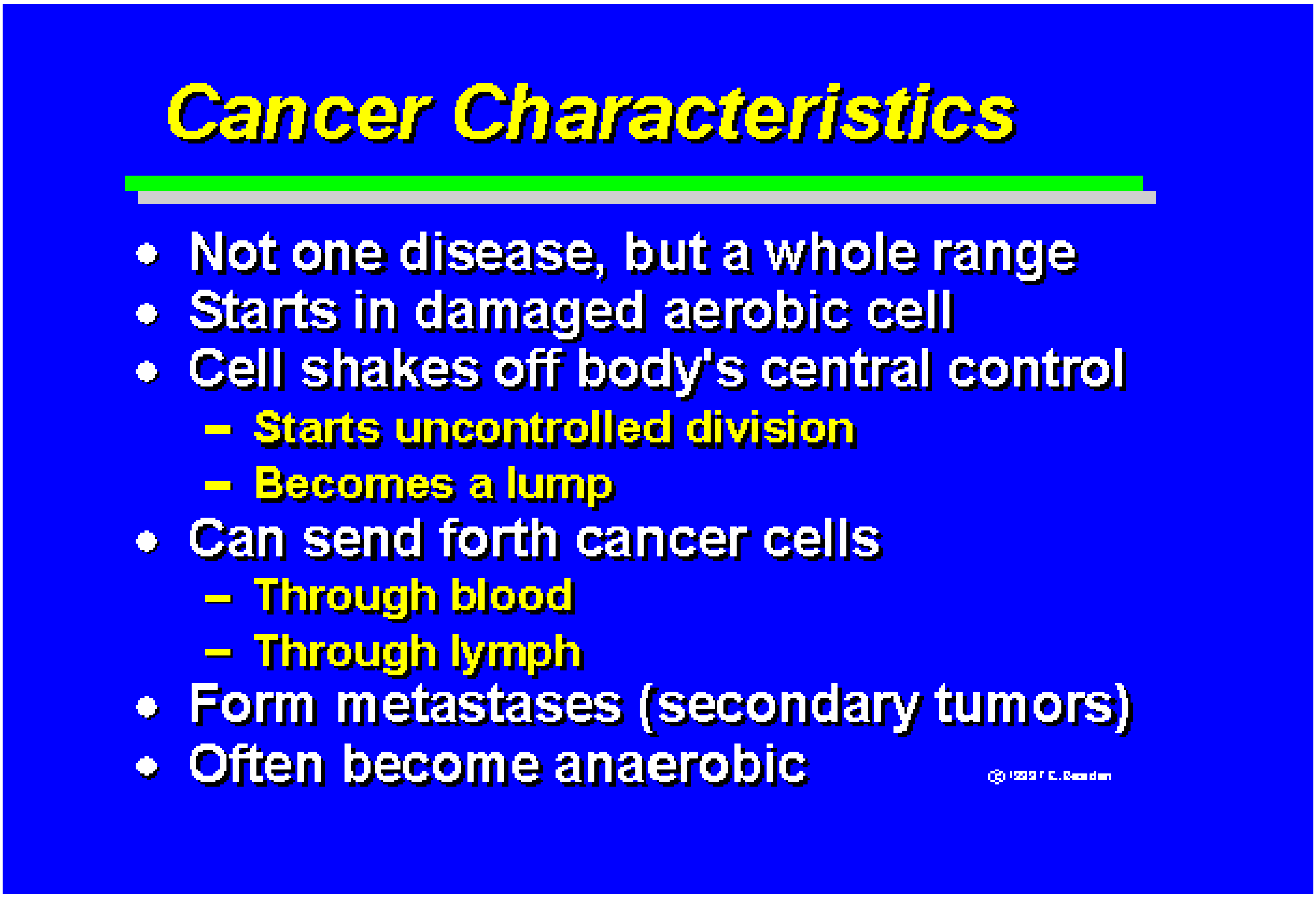

Cancer Characteristics

- Not one disease, but a whole range
- Starts in damaged aerobic cell
- Cell shakes off body's central control
  - Starts uncontrolled division
  - Becomes a lump
- Can send forth cancer cells
  - Through blood
  - Through lymph
- Form metastases (secondary tumors)
- Often become anaerobic

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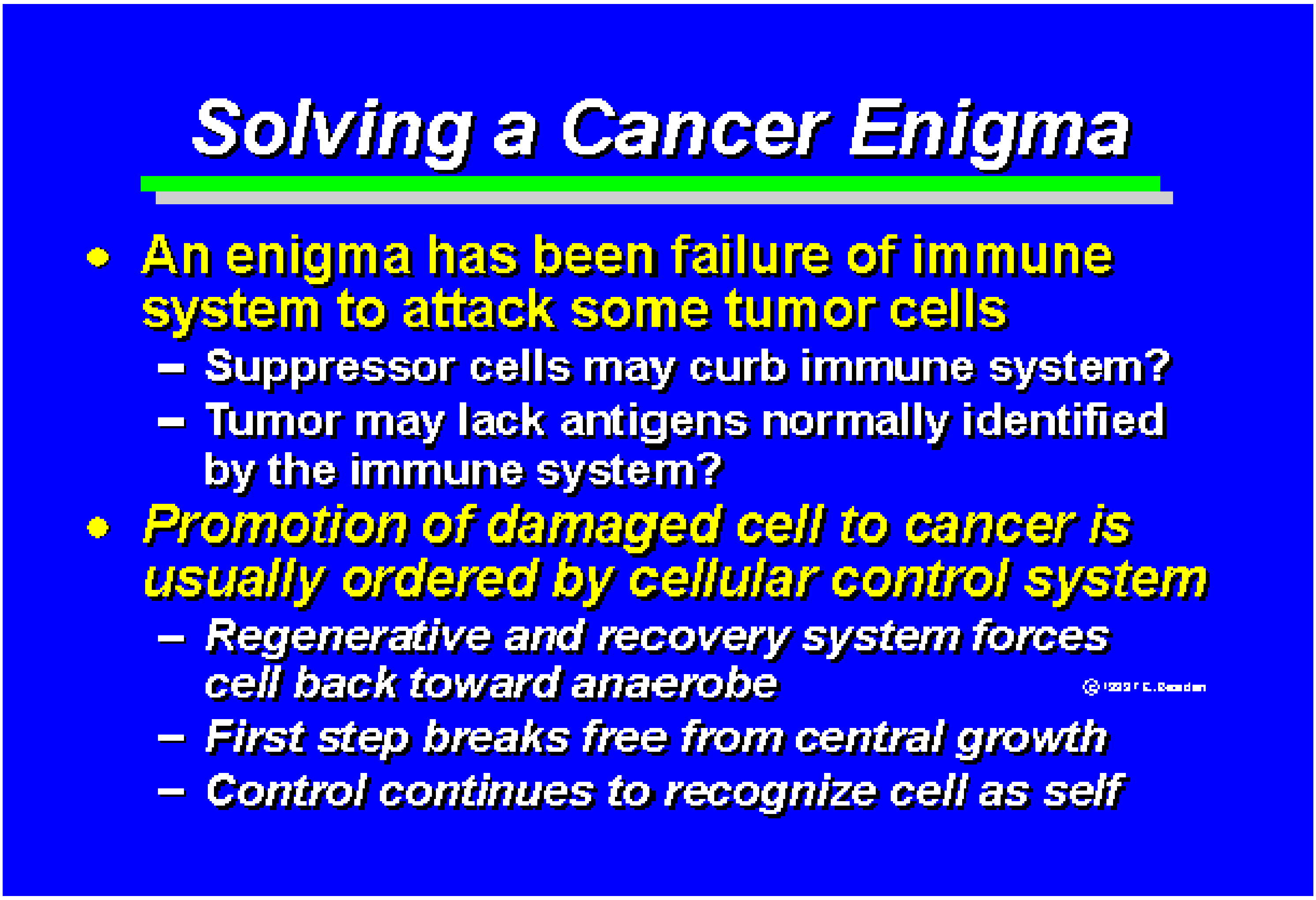

Solving a Cancer Enigma

- An enigma has been failure of immune system to attack some tumor cells
  - Suppressor cells may curb immune system?
  - Tumor may lack antigens normally identified by the immune system?
- *Promotion of damaged cell to cancer is usually ordered by cellular control system*
  - *Regenerative and recovery system forces cell back toward anaerobe*
  - *First step breaks free from central growth*
  - *Control continues to recognize cell as self*

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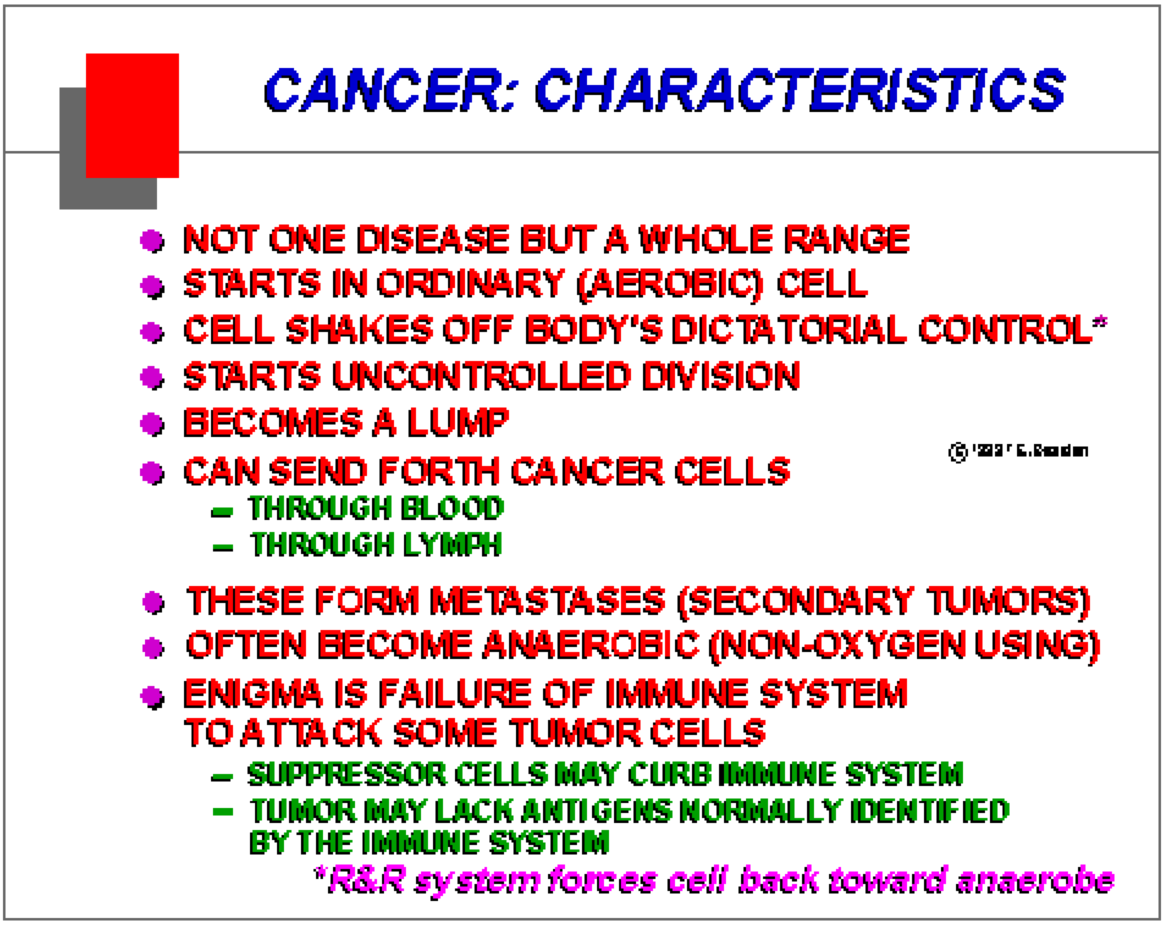

CANCER: CHARACTERISTICS

- NOT ONE DISEASE BUT A WHOLE RANGE
- STARTS IN ORDINARY (AEROBIC) CELL
- CELL SHAKES OFF BODY'S DICTATORIAL CONTROL*
- STARTS UNCONTROLLED DIVISION
- BECOMES A LUMP
- CAN SEND FORTH CANCER CELLS
  - THROUGH BLOOD
  - THROUGH LYMPH
- THESE FORM METASTASES (SECONDARY TUMORS)
- OFTEN BECOME ANAEROBIC (NON-OXYGEN USING)
- ENIGMA IS FAILURE OF IMMUNE SYSTEM TO ATTACK SOME TUMOR CELLS
  - SUPPRESSOR CELLS MAY CURB IMMUNE SYSTEM
  - TUMOR MAY LACK ANTIGENS NORMALLY IDENTIFIED BY THE IMMUNE SYSTEM

R&R system forces cell back toward anaerobe

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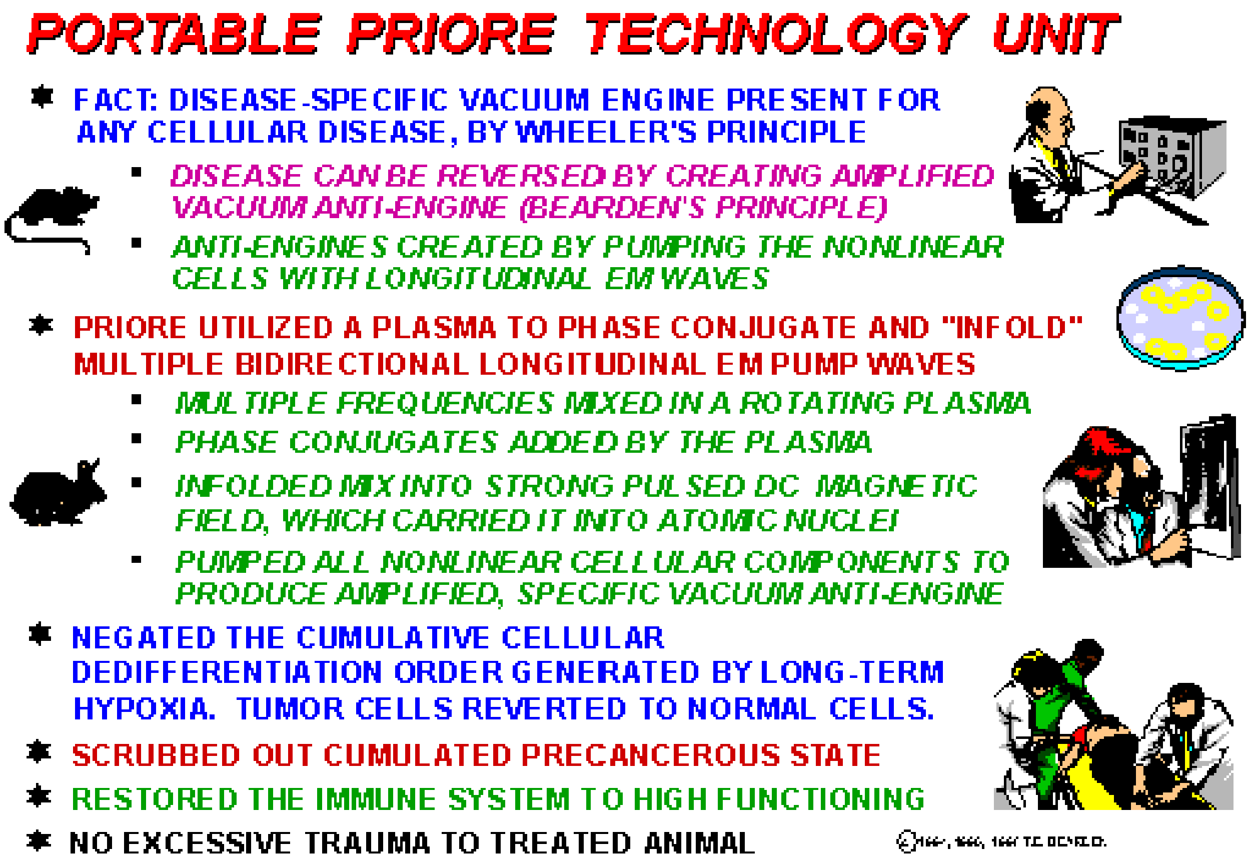

PORTABLE PRIORE TECHNOLOGY UNIT

- FACT: DISEASE-SPECIFIC VACUUM ENGINE PRESENT FOR ANY CELLULAR DISEASE, BY WHEELER'S PRINCIPLE
  - DISEASE CAN BE REVERSED BY CREATING AMPLIFIED VACUUM ANTI-ENGINE (BEARDEN'S PRINCIPLE)
  - ANTI-ENGINES CREATED BY PUMPING THE NONLINEAR CELLS WITH LONGITUDINAL EM WAVES
- PRIORE UTILIZED A PLASMA TO PHASE CONJUGATE AND "INFOLD" MULTIPLE BIDIRECTIONAL LONGITUDINAL EM PUMP WAVES
  - MULTIPLE FREQUENCIES MIXED IN A ROTATING PLASMA
  - PHASE CONJUGATES ADDED BY THE PLASMA
  - INFOLDED MIX INTO STRONG PULSED DC MAGNETIC FIELD, WHICH CARRIED IT INTO ATOMIC NUCLEI
  - PUMPED ALL NONLINEAR CELLULAR COMPONENTS TO PRODUCE AMPLIFIED, SPECIFIC VACUUM ANTI-ENGINE
- NEGATED THE CUMULATIVE CELLULAR DEDIFFERENTIATION ORDER GENERATED BY LONG-TERM HYPOXIA. TUMOR CELLS REVERTED TO NORMAL CELLS.
- SCRUBBED OUT CUMULATED PRECANCEROUS STATE
- RESTORED THE IMMUNE SYSTEM TO HIGH FUNCTIONING
- NO EXCESSIVE TRAUMA TO TREATED ANIMAL

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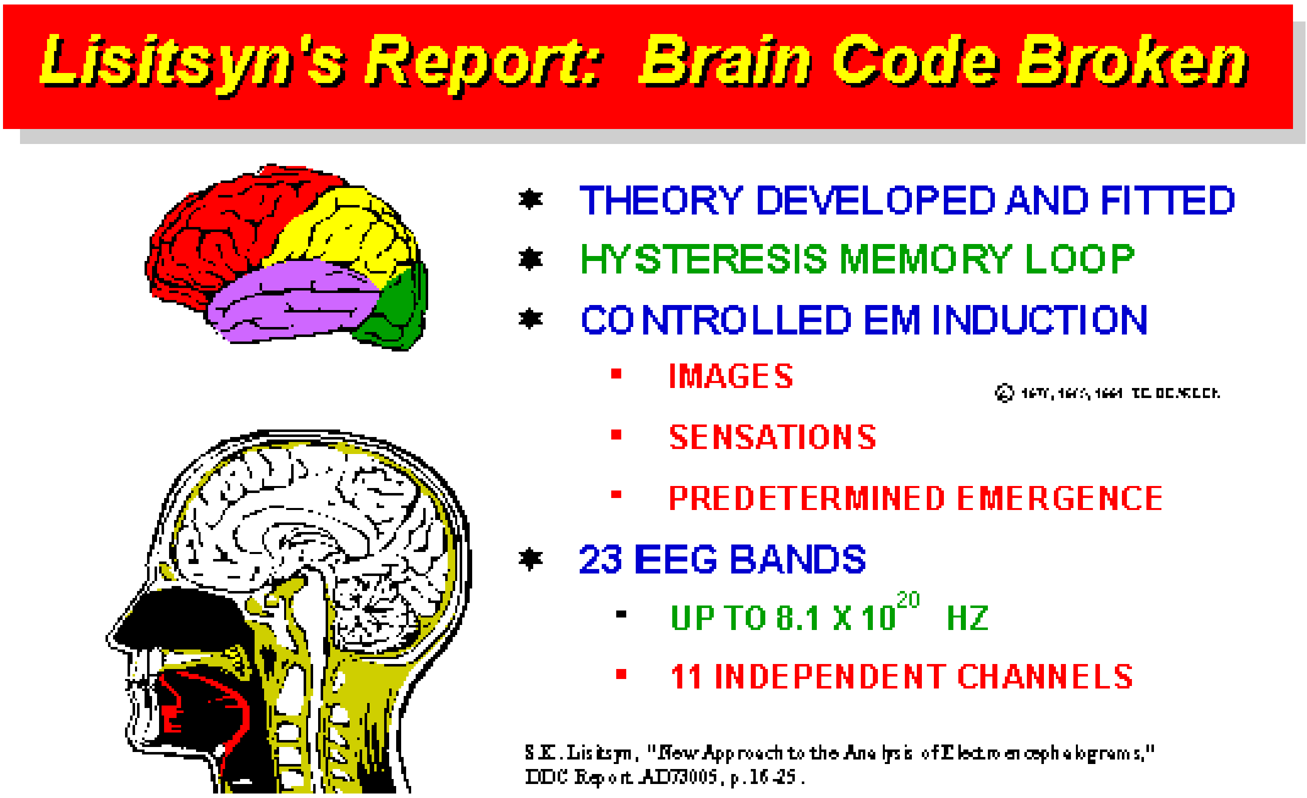

Lisitsyn's Report: Brain Code Broken

- THEORY DEVELOPED AND FITTED
- HYSTERESIS MEMORY LOOP
- CONTROLLED EM INDUCTION
  - IMAGES
  - SENSATIONS
  - PREDETERMINED EMERGENCE
- 23 EEG BANDS
  - UP TO 8.1×10^{20} HZ
  - 11 INDEPENDENT CHANNELS

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S.E. Lisitsyn, "New Approach to the Analysis of Electroencephalograms," DDC Report AD73005, p. 16-25.

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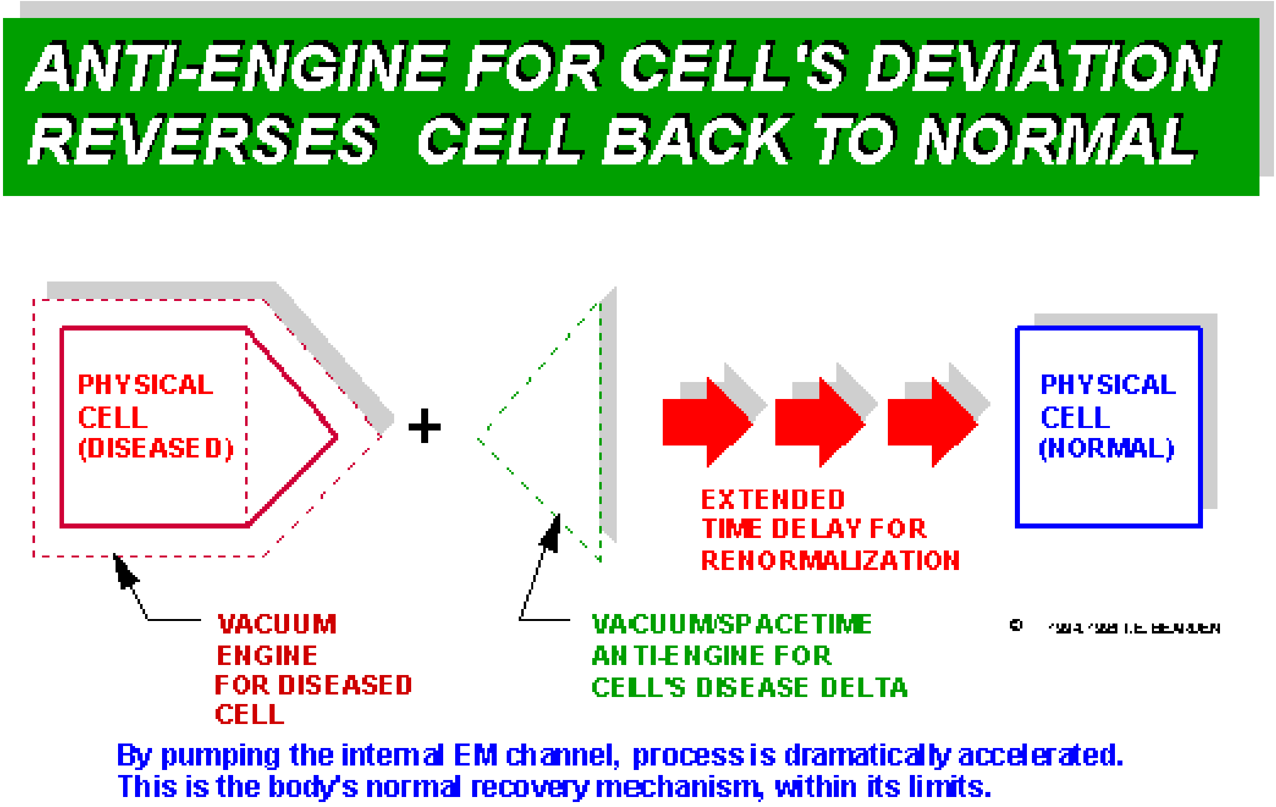

ANTI-ENGINE FOR CELL'S DEVIATION REVERSES CELL BACK TO NORMAL

PHYSICAL
CELL
(DISEASED)
+
EXTENDED
TIME DELAY FOR
RENORMALIZATION
PHYSICAL
CELL
(NORMAL)
VACUUM
ENGINE
FOR DISEASED
CELL
VACUUM/SPACETIME
ANTI-ENGINE FOR
CELL'S DISEASE DELTA

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By pumping the internal EM channel, process is dramatically accelerated.
This is the body's normal recovery mechanism, within its limits.

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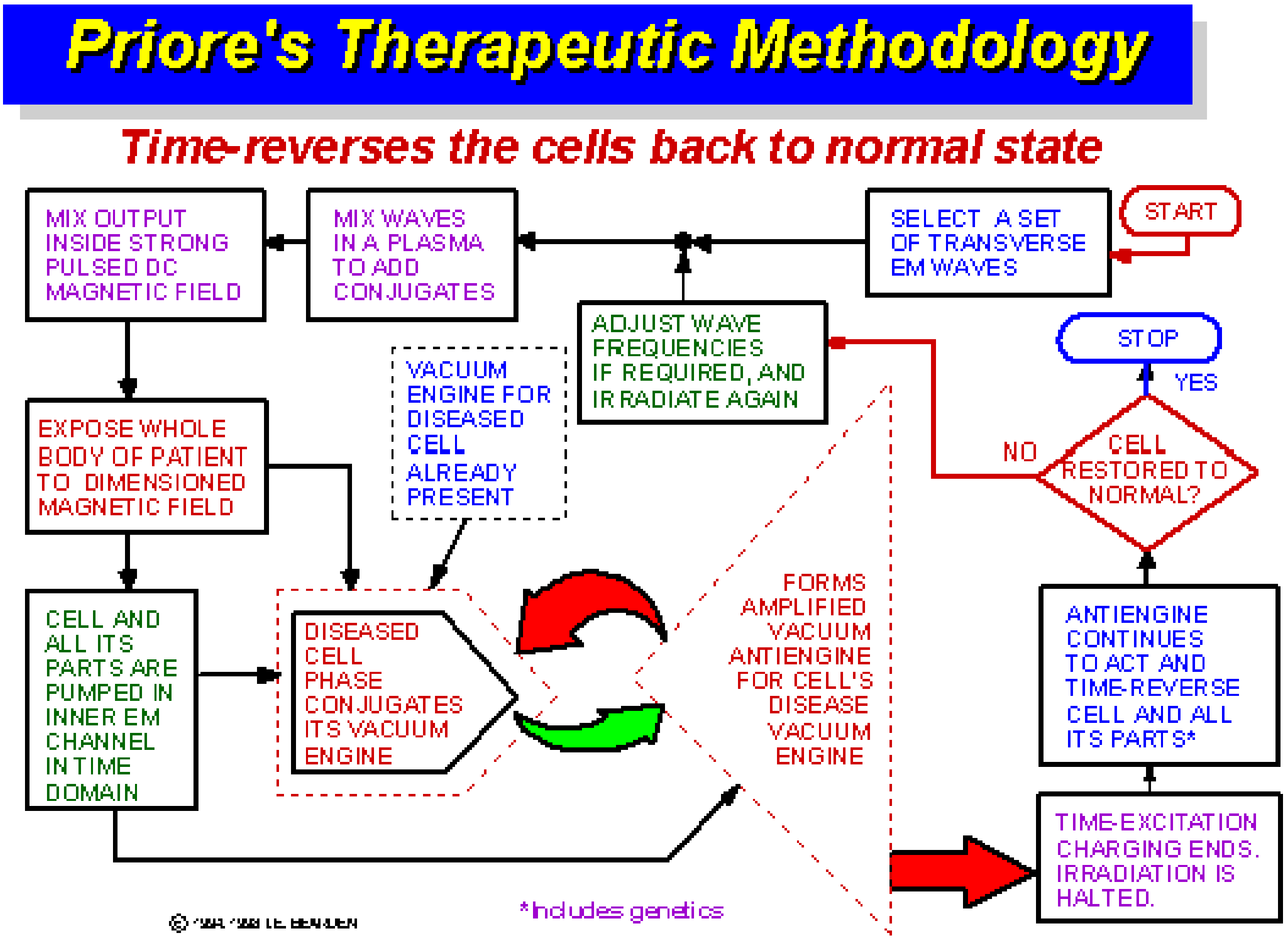
Priore's Therapeutic Methodology
Time-reverses the cells back to normal state
START
SELECT A SET OF TRANSVERSE EM WAVES
MIX WAVES IN A PLASMA TO ADD CONJUGATES
MIX OUTPUT INSIDE STRONG PULSED DC MAGNETIC FIELD
EXPOSE WHOLE BODY OF PATIENT TO DIMENSIONED MAGNETIC FIELD
CELL AND ALL ITS PARTS ARE PUMPED IN INNER EM CHANNEL IN TIME DOMAIN
VACUUM ENGINE FOR DISEASED CELL ALREADY PRESENT
DISEASED CELL PHASE CONJUGATES ITS VACUUM ENGINE
FORMS AMPLIFIED VACUUM ANTIENGINE FOR CELL'S DISEASE VACUUM ENGINE
ADJUST WAVE FREQUENCIES IF REQUIRED, AND IRRADIATE AGAIN
NO
CELL RESTORED TO NORMAL?
YES
STOP
ANTIENGINE CONTINUES TO ACT AND TIME-REVERSE CELL AND ALL ITS PARTS*
TIME-EXCITATION CHARGING ENDS. IRRADIATION IS HALTED.
*Includes genetics

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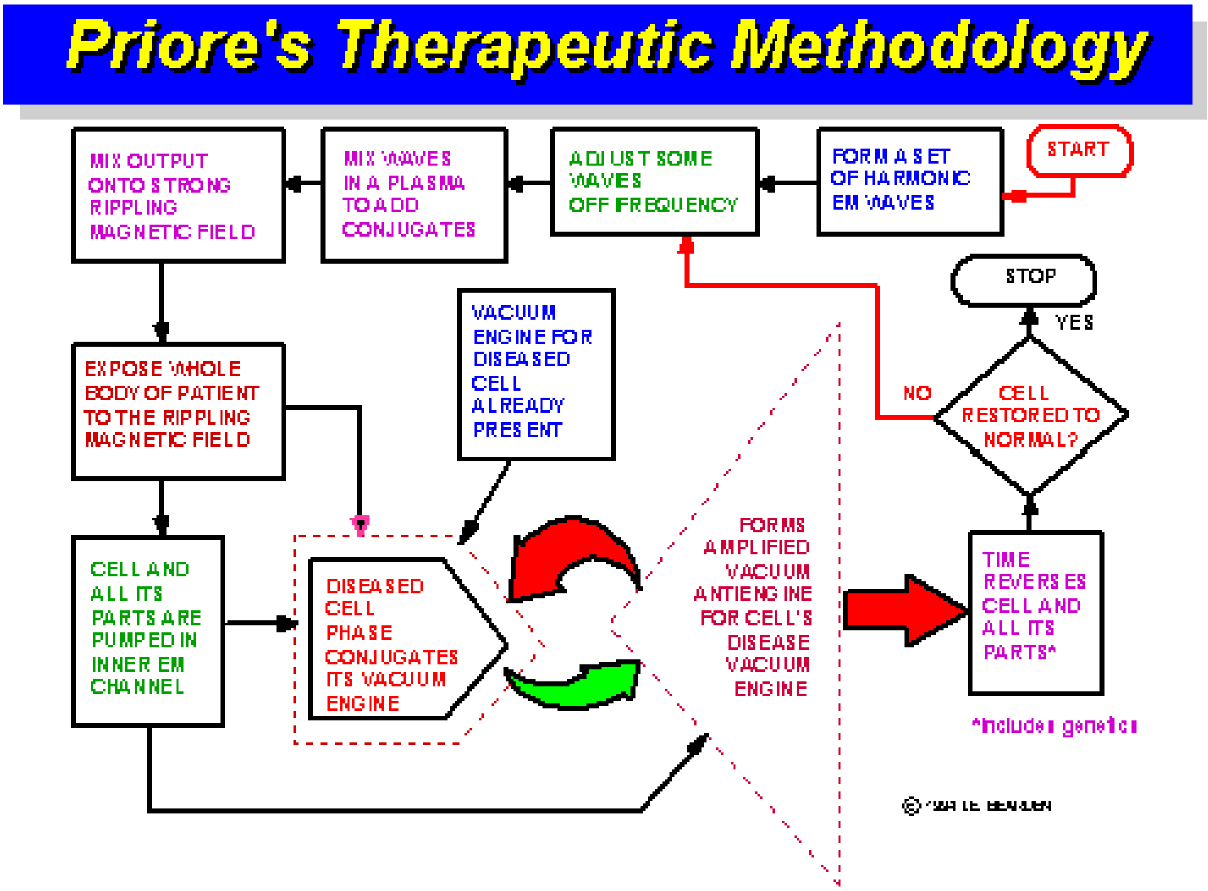
Priore's Therapeutic Methodology
START
FORM A SET OF HARMONIC EM WAVES
ADJUST SOME WAVES OFF FREQUENCY
MIX WAVES IN A PLASMA TO ADD CONJUGATES
MIX OUTPUT ONTO STRONG RIPPLING MAGNETIC FIELD
EXPOSE WHOLE BODY OF PATIENT TO THE RIPPLING MAGNETIC FIELD
CELL AND ALL ITS PARTS ARE PUMPED IN INNER EM CHANNEL
VACUUM ENGINE FOR DISEASED CELL ALREADY PRESENT
DISEASED CELL PHASE CONJUGATES ITS VACUUM ENGINE
FORMS AMPLIFIED VACUUM ANTIENGINE FOR CELL'S DISEASE VACUUM ENGINE
TIME REVERSES CELL AND ALL ITS PARTS*
CELL RESTORED TO NORMAL?
NO
YES
STOP
*Includes genetics
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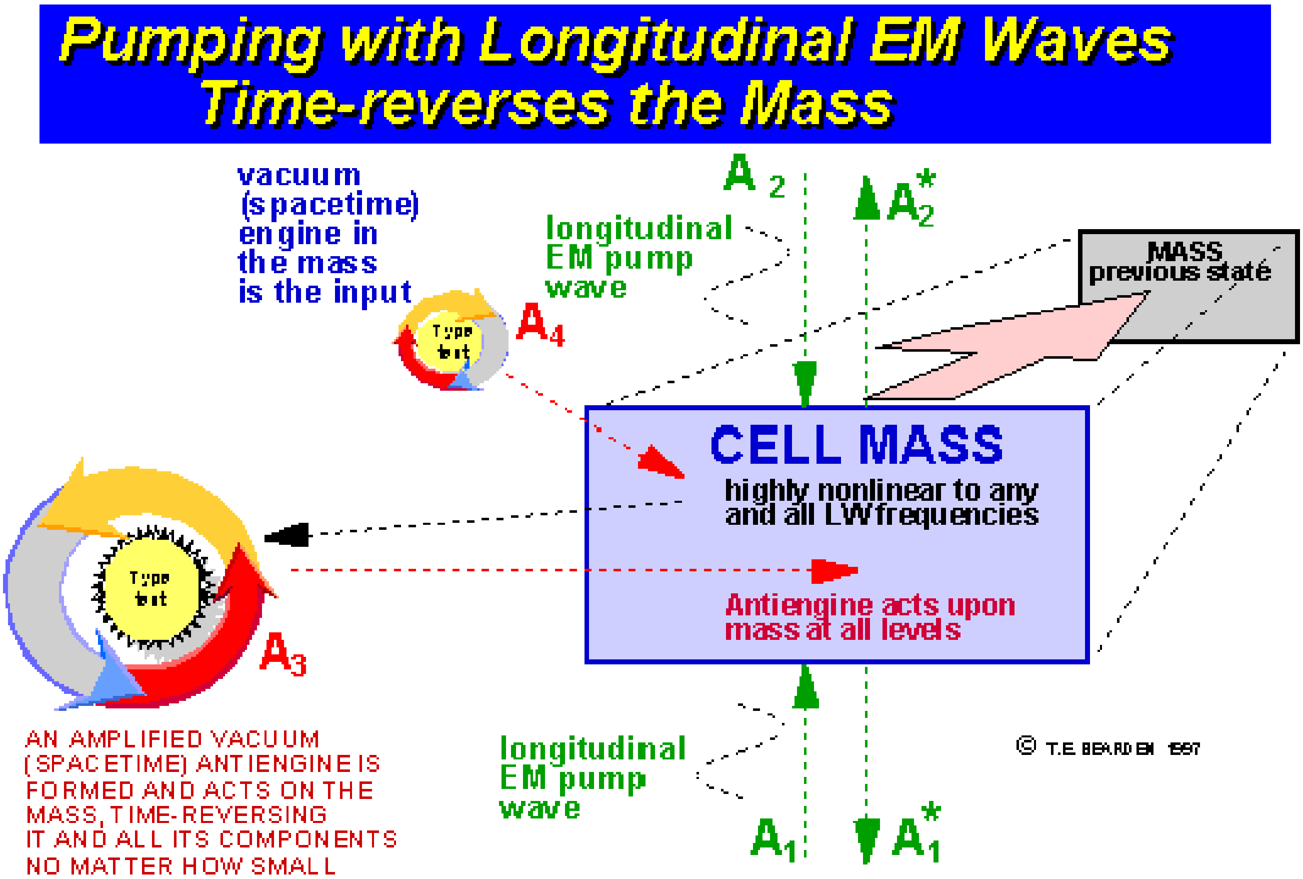
Pumping with Longitudinal EM Waves
Time-reverses the Mass
vacuum
(spacetime)
engine in
the mass
is the input
Type
text
A_4
A_2
A_2^*
longitudinal
EM pump
wave
MASS
previous state
CELL MASS
highly nonlinear to any
and all LW frequencies
Antiengine acts upon
mass at all levels
Type
text
A_3
AN AMPLIFIED VACUUM
(SPACETIME) ANTIENGINE IS
FORMED AND ACTS ON THE
MASS, TIME-REVERSING
IT AND ALL ITS COMPONENTS
NO MATTER HOW SMALL
longitudinal
EM pump
wave
A_1
A_1^*
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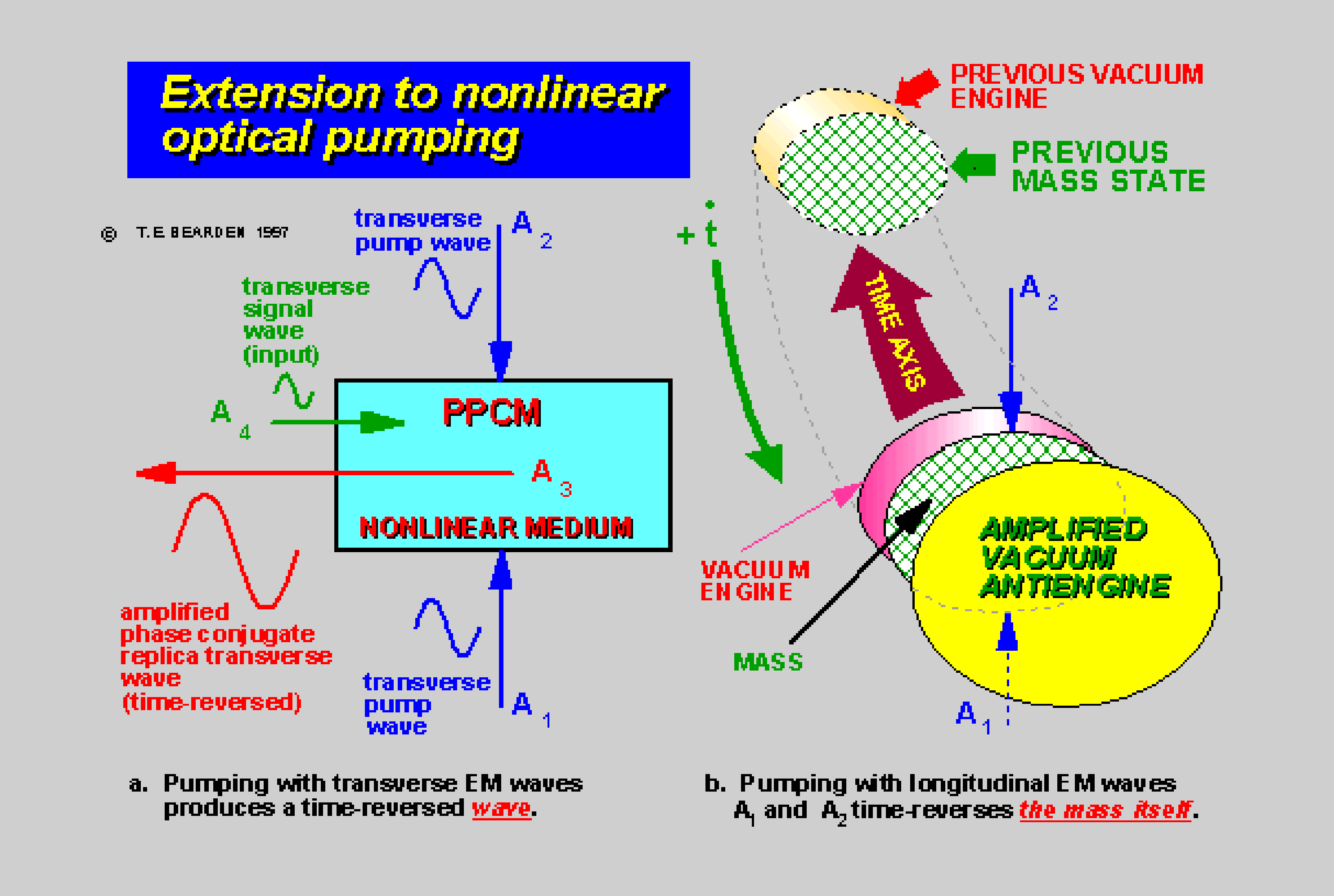

Extension to nonlinear optical pumping

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transverse pump wave
A_2
transverse signal wave (input)
A_4
PPCM
A_3
NONLINEAR MEDIUM
amplified phase conjugate replica transverse wave (time-reversed)
transverse pump wave
A_1
PREVIOUS VACUUM ENGINE
PREVIOUS MASS STATE
+ t
TIME AXIS
A_2
AMPLIFIED VACUUM ANTIENGINE
VACUUM ENGINE
MASS
A_1

a. Pumping with transverse EM waves produces a time-reversed *wave*.

b. Pumping with longitudinal EM waves A_1 and A_2 time-reverses ***the mass itself***.

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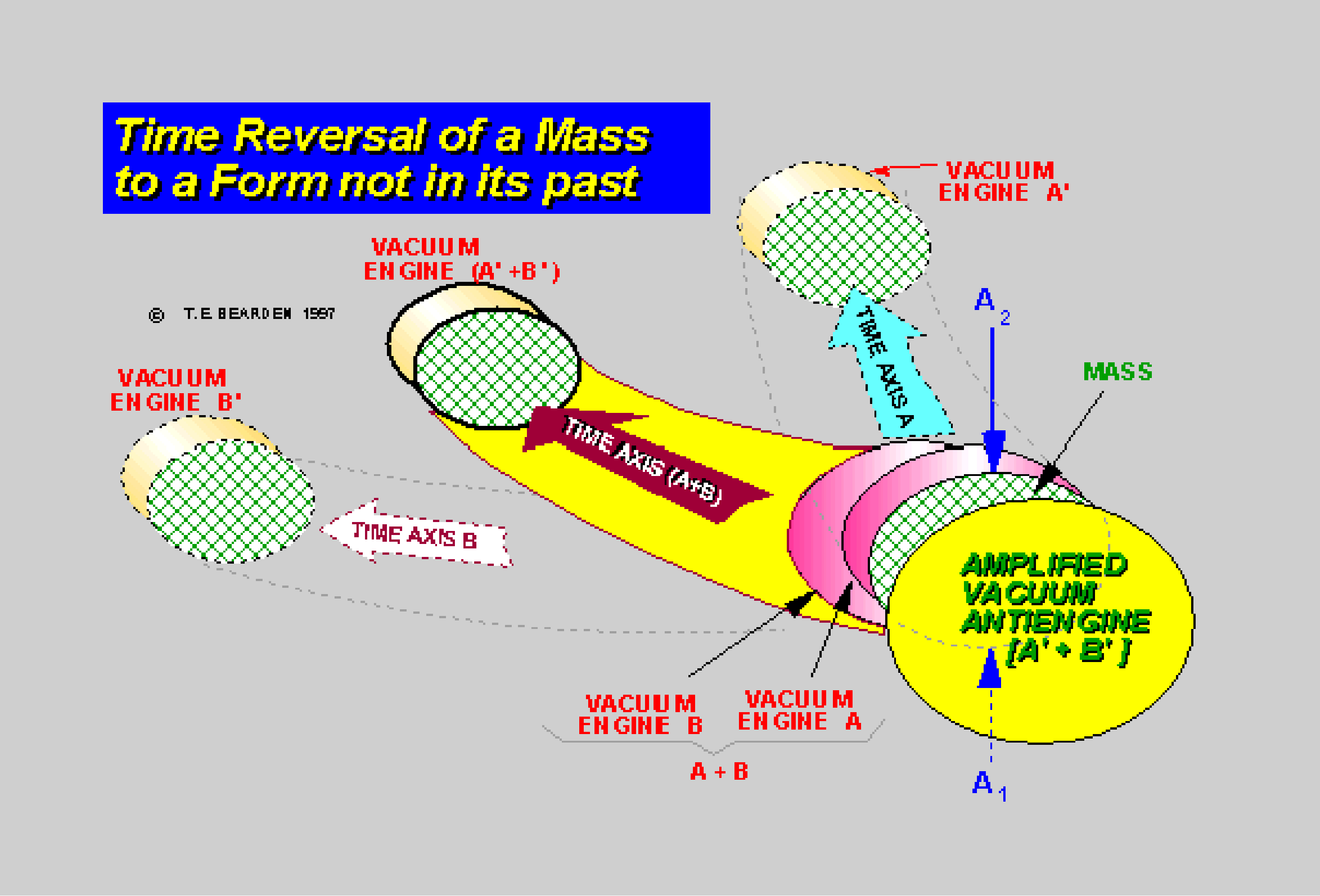

Time Reversal of a Mass to a Form not in its past

VACUUM ENGINE A'
VACUUM ENGINE (A' +B')
© T.E. BEARDEN 1997
VACUUM ENGINE B'
TIME AXIS B
TIME AXIS (A+B)
TIME AXIS A
A 2
MASS
AMPLIFIED VACUUM ANTIENGINE [A' + B']
VACUUM ENGINE B
VACUUM ENGINE A
A + B
A 1

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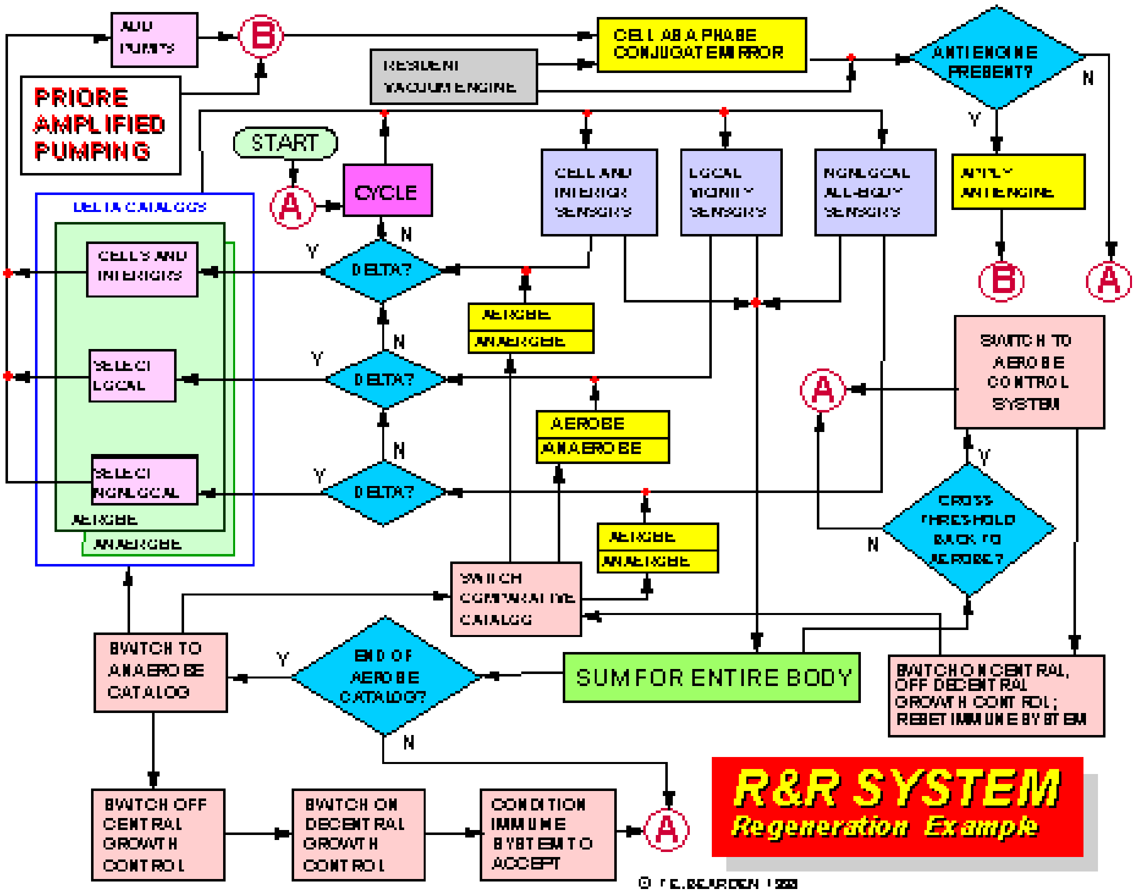
ADD PUMPS
B
CELL AS A PHASE CONJUGATE MIRROR
RESIDENT VACUUM ENGINE
ANTI ENGINE PRESENT?
N
Y
PRIORE AMPLIFIED PUMPING
START
A
CYCLE
CELL AND INTERIOR SENSORS
LOCAL VICINITY SENSORS
NONLOCAL ALL-BODY SENSORS
APPLY ANTI ENGINE
B
A
DELTA CATALOGS
CELLS AND INTERIORS
SELECT LOCAL
SELECT NONLOCAL
AEROBE
ANAEROBE
Y
DELTA?
N
AEROBE
ANAEROBE
Y
DELTA?
N
AEROBE
ANAEROBE
Y
DELTA?
AEROBE
ANAEROBE
SWITCH TO AEROBE CONTROL SYSTEM
A
Y
CROSS THRESHOLD BACK TO AEROBE?
N
SWITCH COMPARATIVE CATALOG
SWITCH TO ANAEROBE CATALOG
Y
END OF AEROBE CATALOG?
N
SUM FOR ENTIRE BODY
SWITCH ON CENTRAL, OFF DECENTRAL GROWTH CONTROL; RESET IMMUNE SYSTEM
SWITCH OFF CENTRAL GROWTH CONTROL
SWITCH ON DECENTRAL GROWTH CONTROL
CONDITION IMMUNE SYSTEM TO ACCEPT
A
R&R SYSTEM
Regeneration Example
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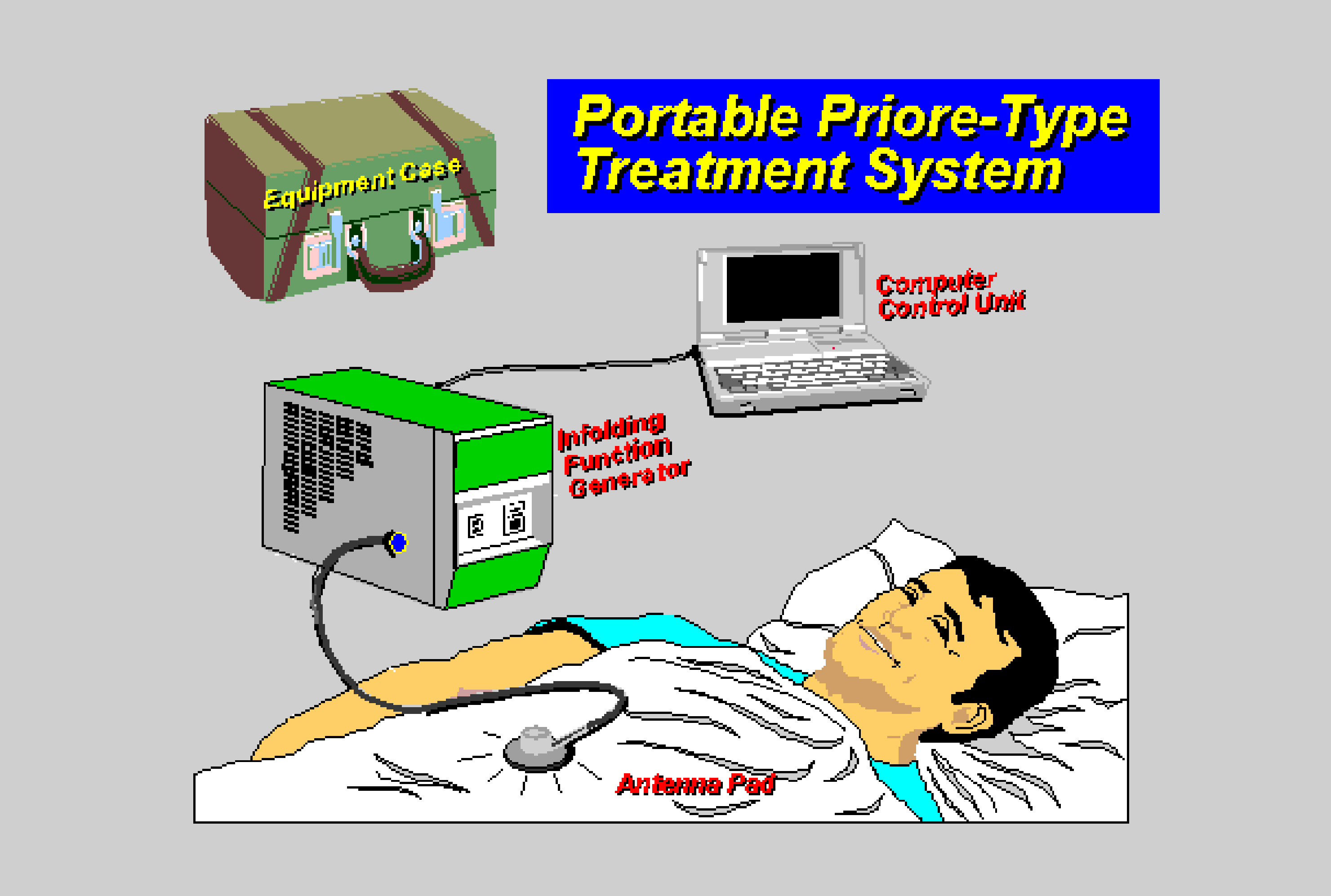
Portable Priore-Type Treatment System
Equipment Case
Computer Control Unit
Infolding Function Generator
Antenna Pad

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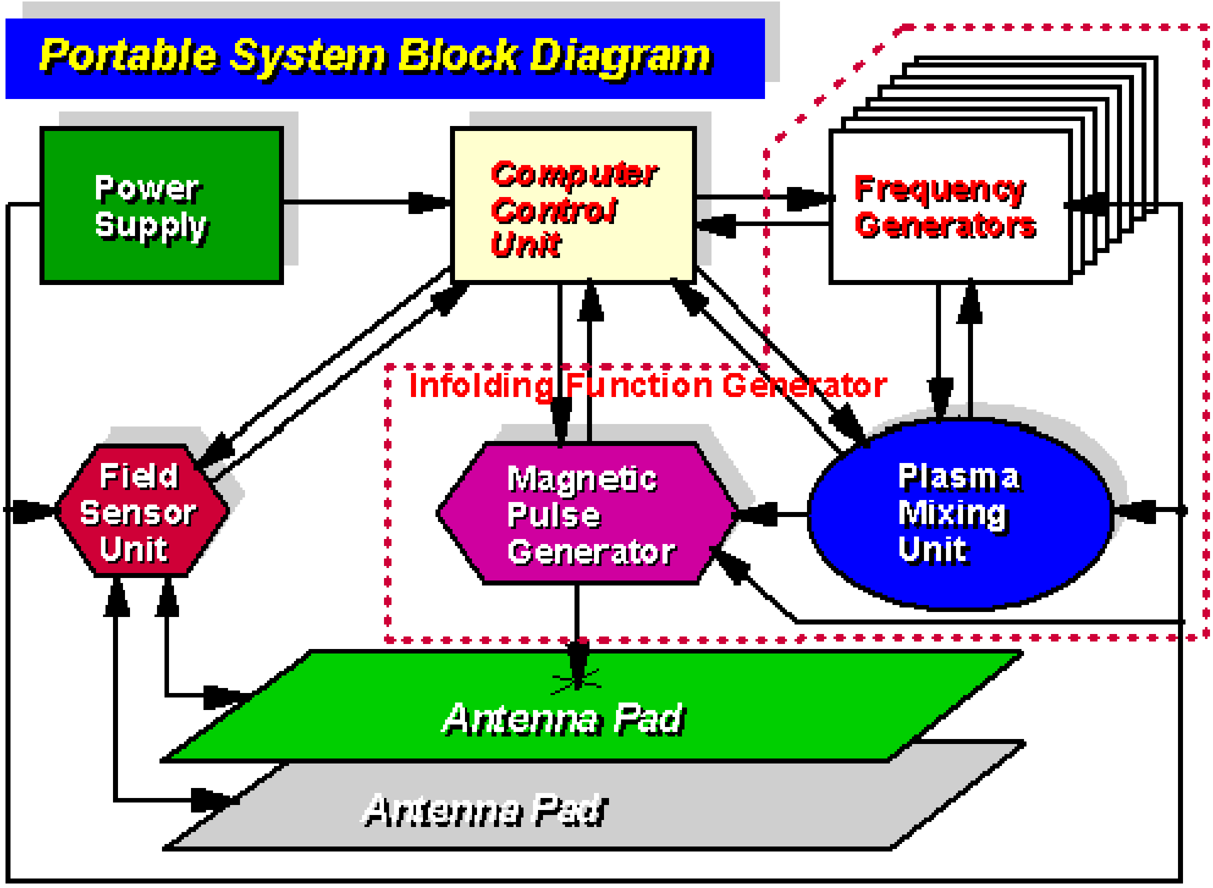
Portable System Block Diagram
Power Supply
Computer Control Unit
Frequency Generators
Infolding Function Generator
Field Sensor Unit
Magnetic Pulse Generator
Plasma Mixing Unit
Antenna Pad
Antenna Pad

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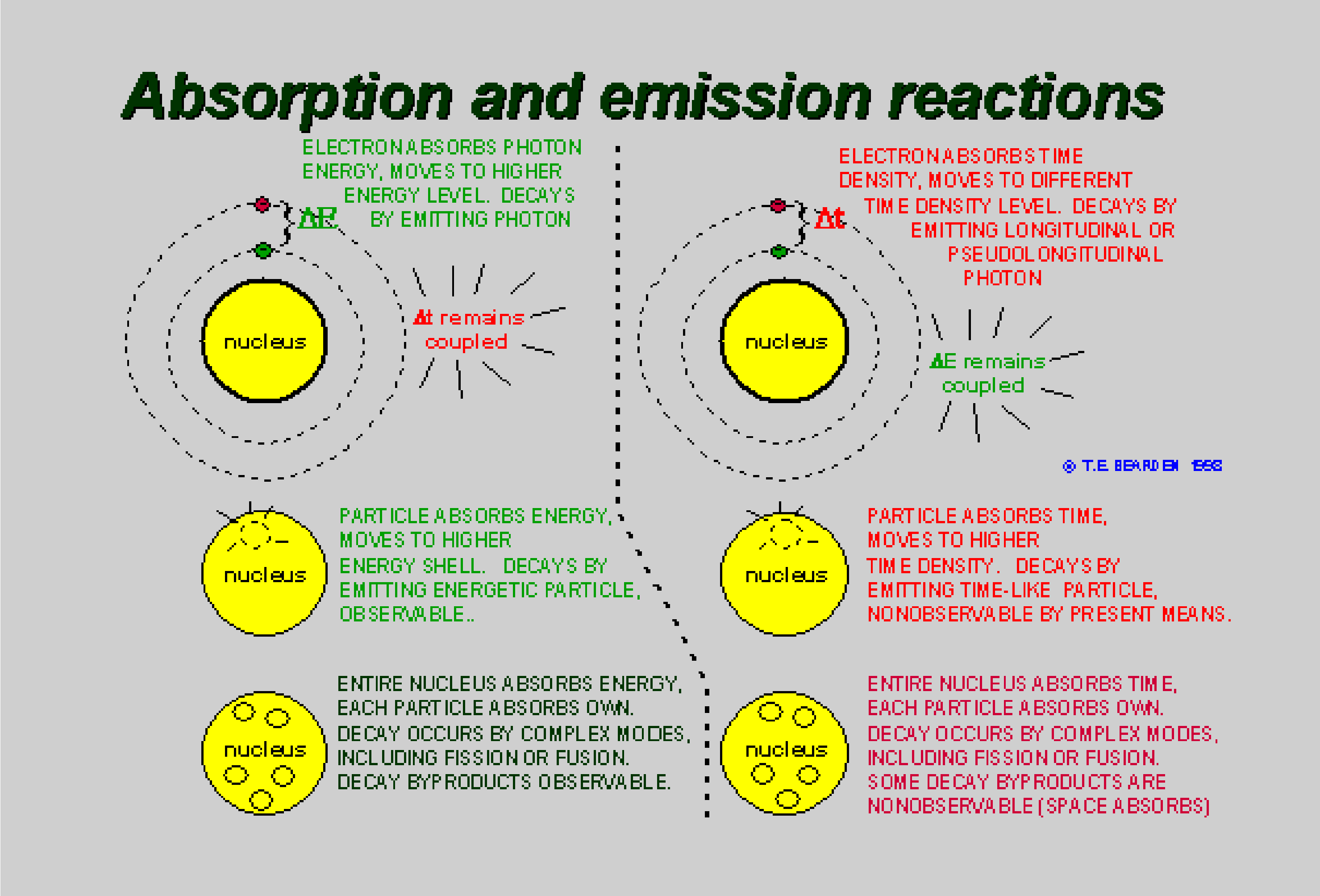

Absorption and emission reactions

ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON

ELECTRON ABSORBS TIME DENSITY, MOVES TO DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTON

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PARTICLE ABSORBS ENERGY, MOVES TO HIGHER ENERGY SHELL. DECAYS BY EMITTING ENERGETIC PARTICLE, OBSERVABLE..

PARTICLE ABSORBS TIME, MOVES TO HIGHER TIME DENSITY. DECAYS BY EMITTING TIME-LIKE PARTICLE, NONOBSERVABLE BY PRESENT MEANS.

ENTIRE NUCLEUS ABSORBS ENERGY, EACH PARTICLE ABSORBS OWN. DECAY OCCURS BY COMPLEX MODES, INCLUDING FISSION OR FUSION. DECAY BYPRODUCTS OBSERVABLE.

ENTIRE NUCLEUS ABSORBS TIME, EACH PARTICLE ABSORBS OWN. DECAY OCCURS BY COMPLEX MODES, INCLUDING FISSION OR FUSION. SOME DECAY BYPRODUCTS ARE NONOBSERVABLE (SPACE ABSORBS)

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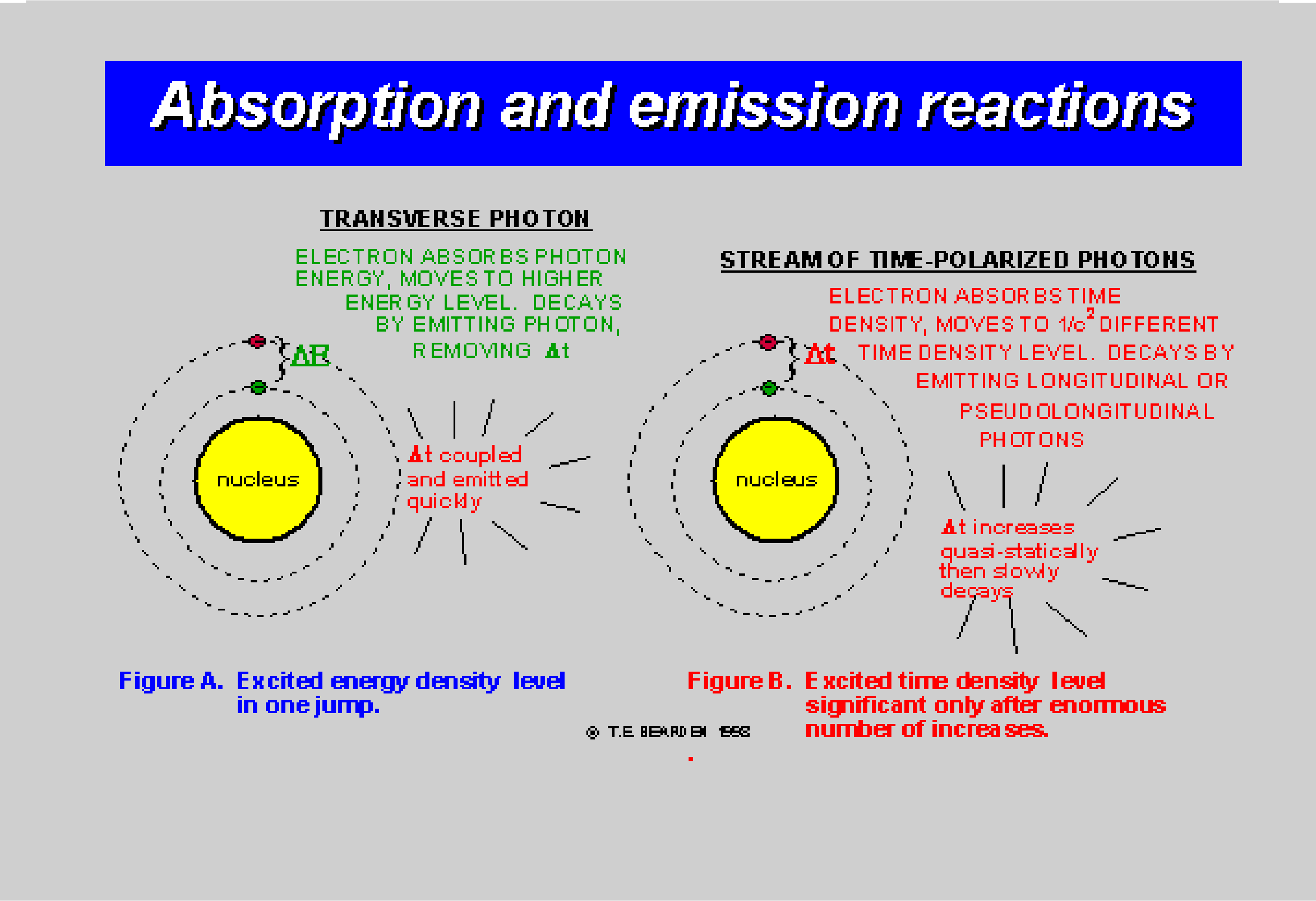

Absorption and emission reactions

TRANSVERSE PHOTON

ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON, REMOVING Δt

ΔE
nucleus
Δt coupled and emitted quickly

STREAM OF TIME-POLARIZED PHOTONS

ELECTRON ABSORBS TIME DENSITY, MOVES TO $1/c^2$ DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTONS

Δt
nucleus
Δt increases quasi-statically then slowly decays

Figure A. Excited energy density level in one jump.

Figure B. Excited time density level significant only after enormous number of increases.

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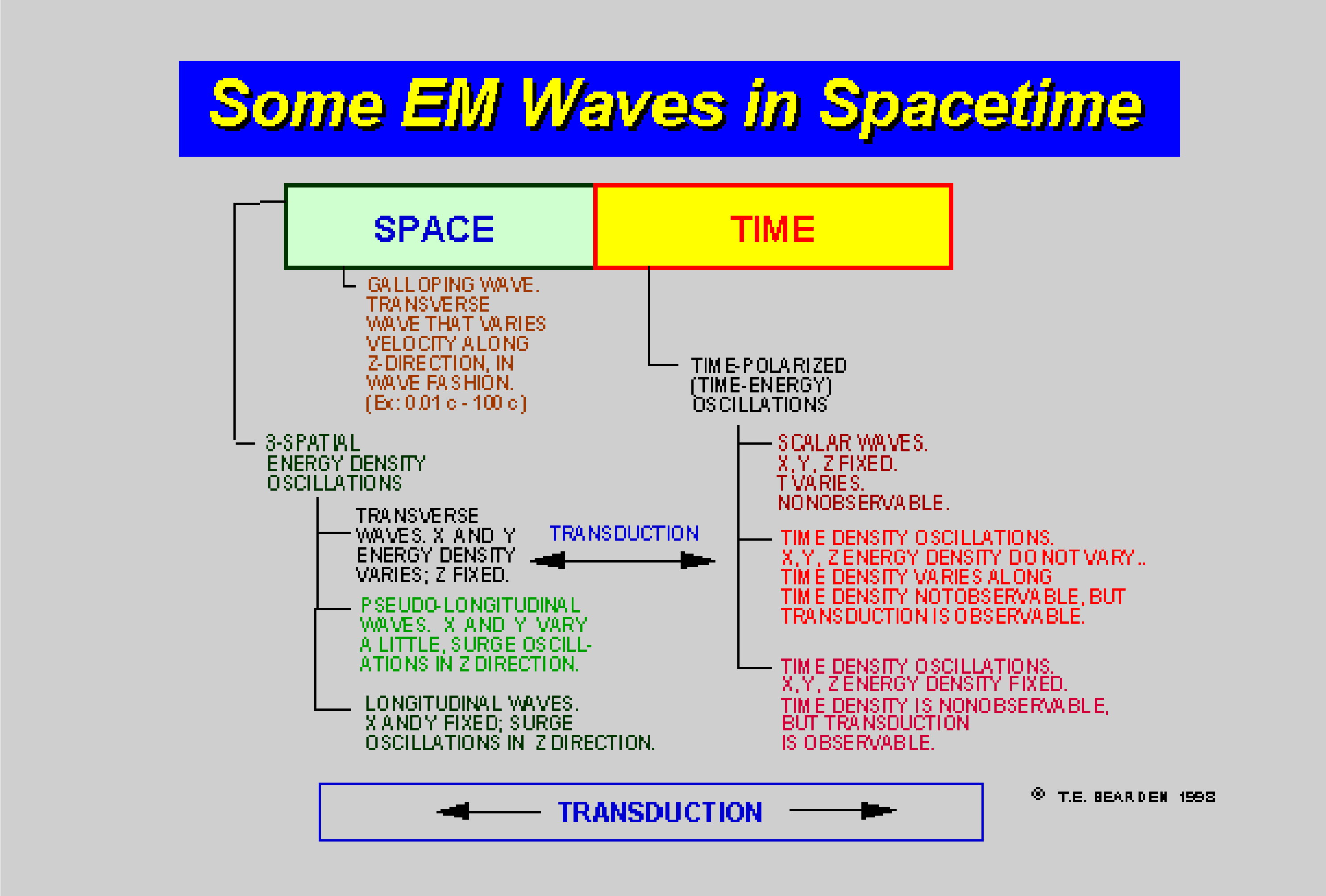

Some EM Waves in Spacetime

SPACE

TIME

GALLOPING WAVE.
TRANSVERSE
WAVE THAT VARIES
VELOCITY ALONG
Z-DIRECTION, IN
WAVE FASHION.
(Ex: 0.01 c - 100 c)

TIME-POLARIZED
(TIME-ENERGY)
OSCILLATIONS

3-SPATIAL
ENERGY DENSITY
OSCILLATIONS

SCALAR WAVES.
X, Y, Z FIXED.
T VARIES.
NONOBSERVABLE.

TRANSVERSE
WAVES. X AND Y
ENERGY DENSITY
VARIES; Z FIXED.

TRANSDUCTION

TIME DENSITY OSCILLATIONS.
X, Y, Z ENERGY DENSITY DO NOT VARY..
TIME DENSITY VARIES ALONG
TIME DENSITY NOT OBSERVABLE, BUT
TRANSDUCTION IS OBSERVABLE.

PSEUDO-LONGITUDINAL
WAVES. X AND Y VARY
A LITTLE, SURGE OSCILL-
ATIONS IN Z DIRECTION.

LONGITUDINAL WAVES.
X AND Y FIXED; SURGE
OSCILLATIONS IN Z DIRECTION.

TIME DENSITY OSCILLATIONS.
X, Y, Z ENERGY DENSITY FIXED.
TIME DENSITY IS NONOBSERVABLE,
BUT TRANSDUCTION
IS OBSERVABLE.

TRANSDUCTION

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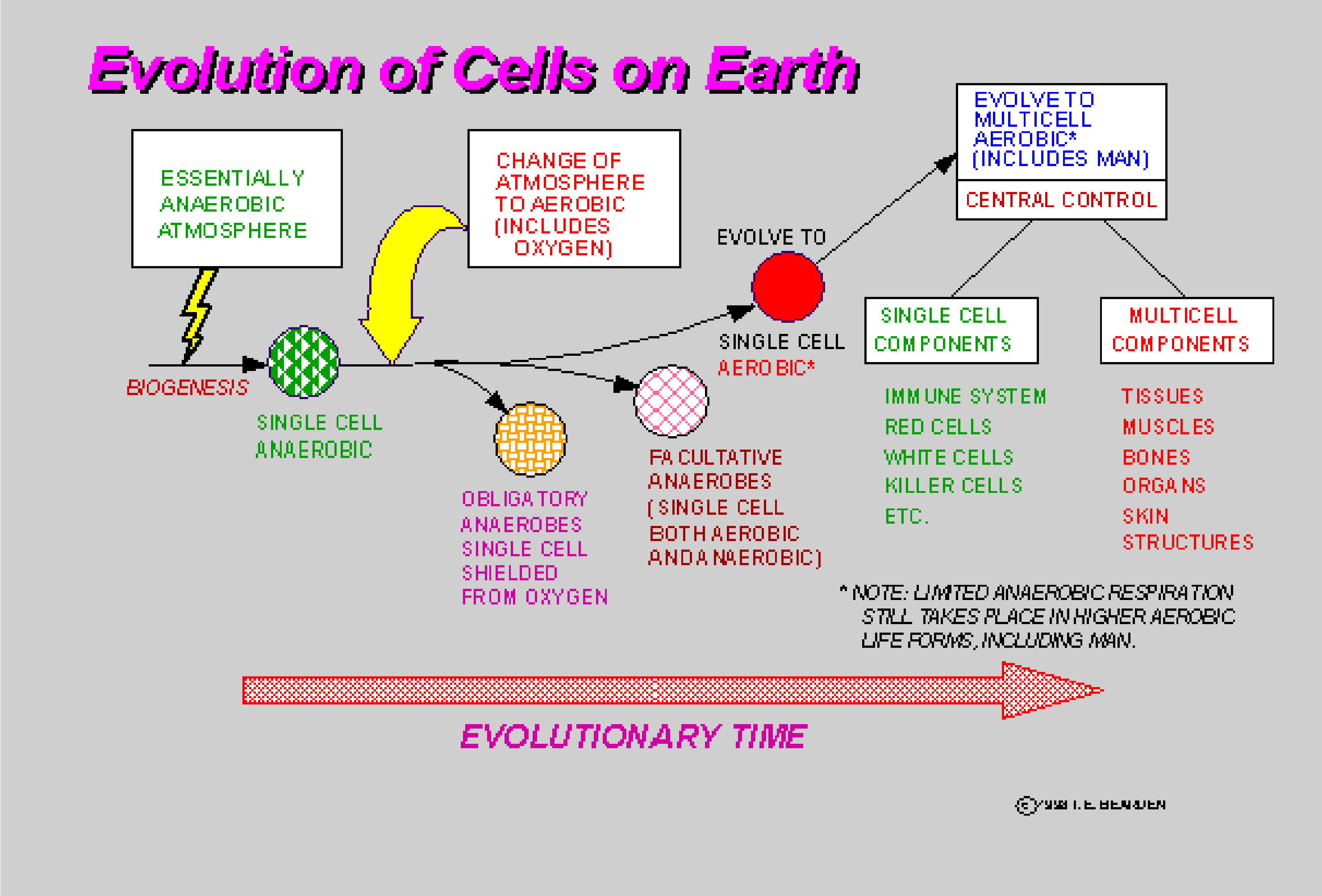

Evolution of Cells on Earth

ESSENTIALLY
ANAEROBIC
ATMOSPHERE

CHANGE OF
ATMOSPHERE
TO AEROBIC
(INCLUDES
OXYGEN)

EVOLVE TO
MULTICELL
AEROBIC*
(INCLUDES MAN)

CENTRAL CONTROL

BIOGENESIS

SINGLE CELL
ANAEROBIC

EVOLVE TO

SINGLE CELL
AEROBIC*

OBLIGATORY
ANAEROBES
SINGLE CELL
SHIELDED
FROM OXYGEN

FACULTATIVE
ANAEROBES
(SINGLE CELL
BOTH AEROBIC
AND ANAEROBIC)

SINGLE CELL
COMPONENTS

IMMUNE SYSTEM
RED CELLS
WHITE CELLS
KILLER CELLS
ETC.

MULTICELL
COMPONENTS

TISSUES
MUSCLES
BONES
ORGANS
SKIN
STRUCTURES

*NOTE: LIMITED ANAEROBIC RESPIRATION
STILL TAKES PLACE IN HIGHER AEROBIC
LIFE FORMS, INCLUDING MAN.

EVOLUTIONARY TIME

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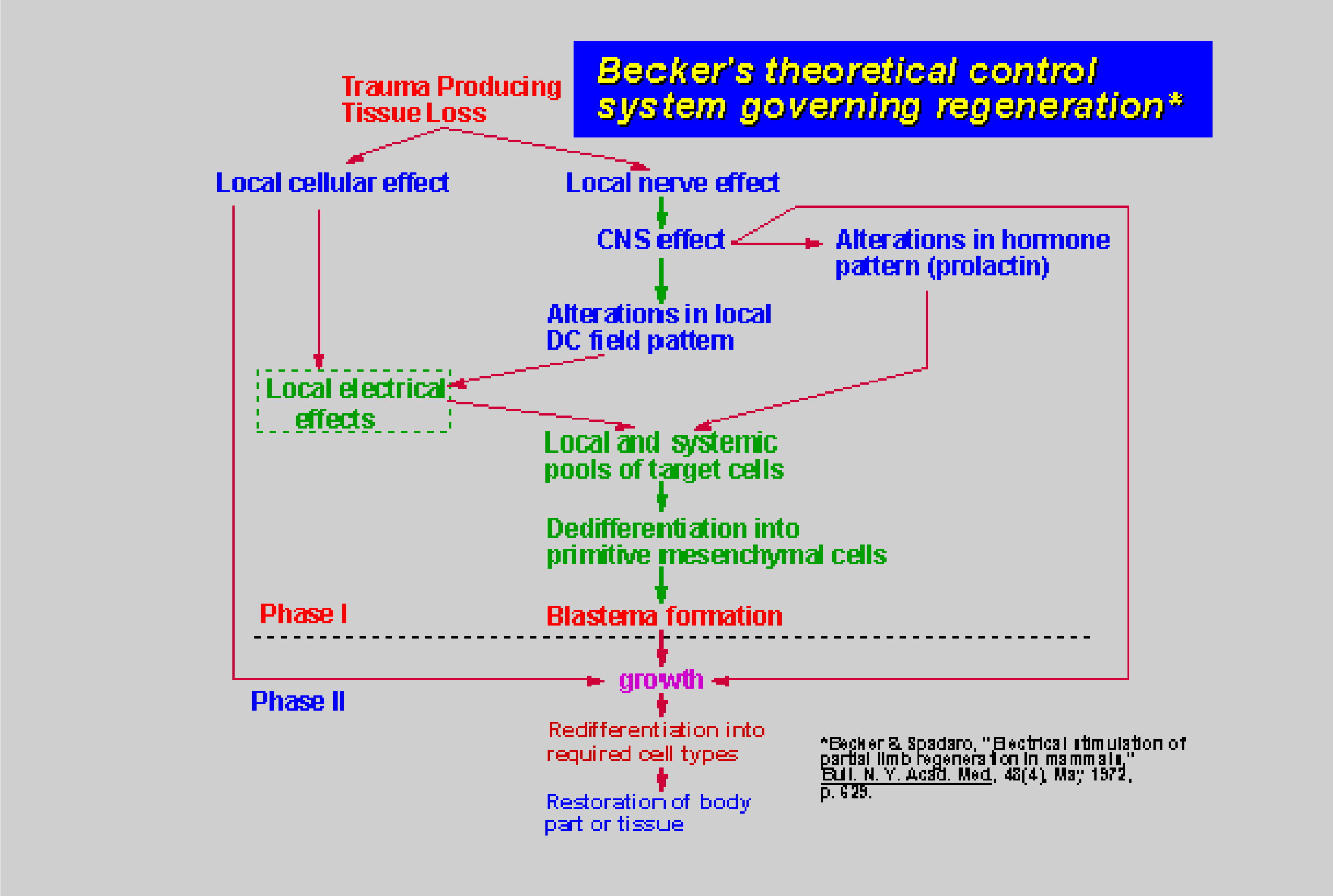

Becker's theoretical control system governing regeneration*

Trauma Producing Tissue Loss

Local cellular effect

Local nerve effect

CNS effect

Alterations in hormone pattern (prolactin)

Alterations in local DC field pattern

Local electrical effects

Local and systemic pools of target cells

Dedifferentiation into primitive mesenchymal cells

Phase I

Blastema formation

growth

Phase II

Redifferentiation into required cell types

Restoration of body part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bull. N. Y. Acad. Med., 48(4), May 1972, p. 625.

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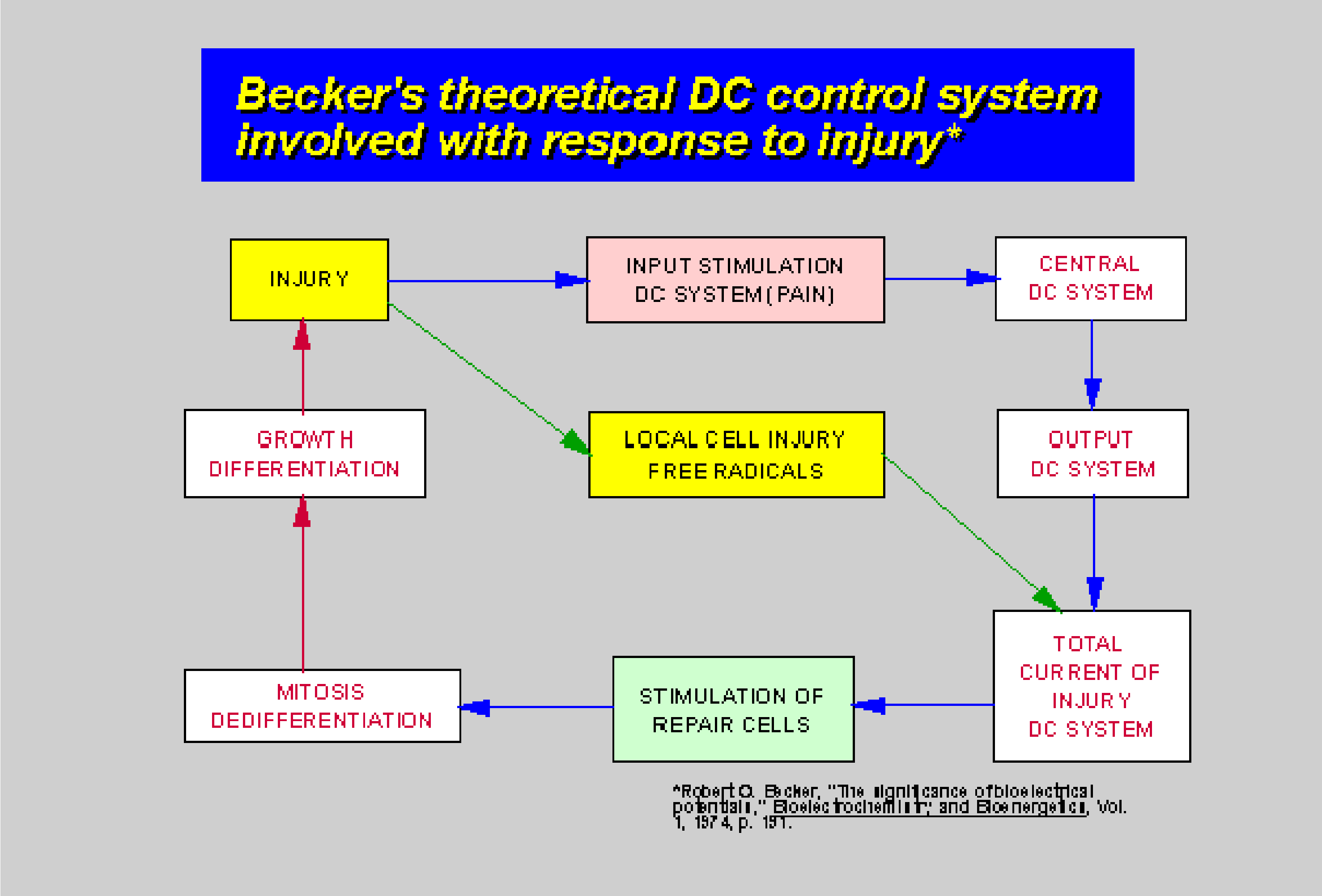

Becker's theoretical DC control system involved with response to injury*

INJURY

INPUT STIMULATION
DC SYSTEM (PAIN)

CENTRAL
DC SYSTEM

GROWTH
DIFFERENTIATION

LOCAL CELL INJURY
FREE RADICALS

OUTPUT
DC SYSTEM

MITOSIS
DEDIFFERENTIATION

STIMULATION OF
REPAIR CELLS

TOTAL
CURRENT OF
INJURY
DC SYSTEM

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.

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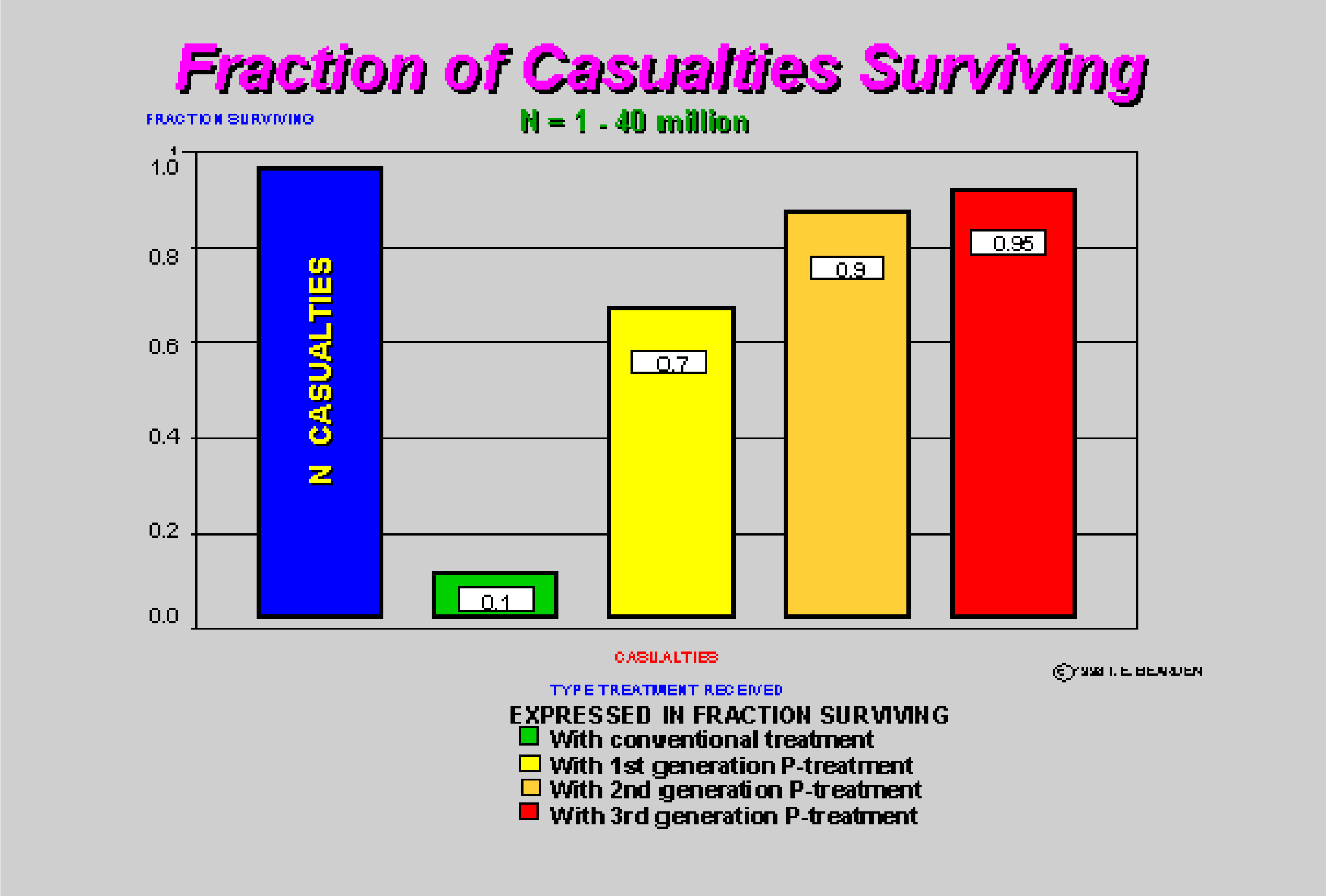

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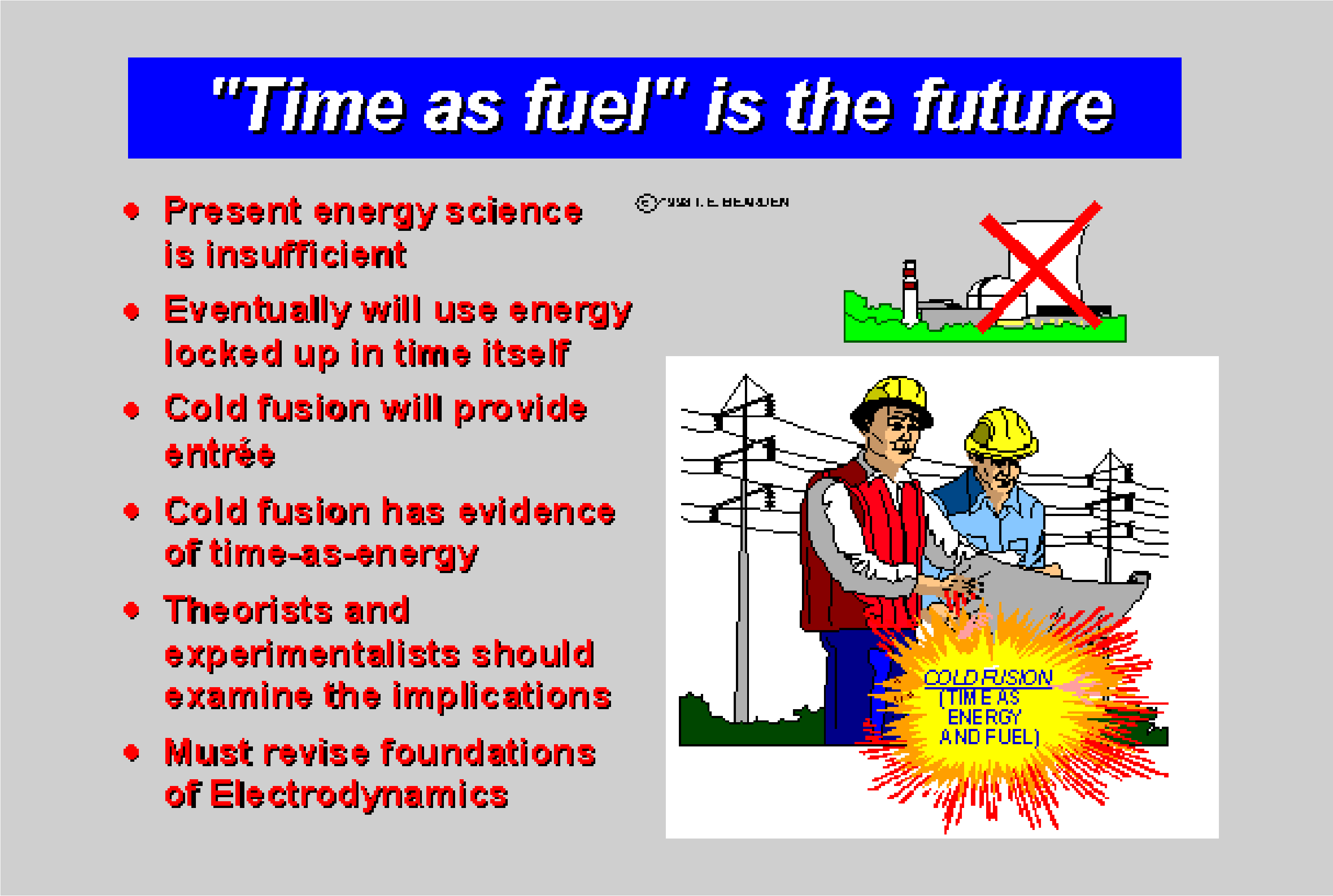

"Time as fuel" is the future

- Present energy science is insufficient
- Eventually will use energy locked up in time itself
- Cold fusion will provide entrée
- Cold fusion has evidence of time-as-energy
- Theorists and experimentalists should examine the implications
- Must revise foundations of Electrodynamics

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COLD FUSION
(TIME AS ENERGY AND FUEL)

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A National Report on America's Energy Crisis

Remarks by U. S. Secretary of Energy Spencer Abraham

U. S. Chamber of Commerce, National Energy Summit March 19, 2001

Opening Remarks

I would like to congratulate the U. S. Chamber of Commerce for convening this two-day National Energy Summit and I appreciate your invitation to participate. As we all know, the topic of energy is as timely as the day's headlines. In just my first eight weeks as Energy Secretary, California has faced almost daily power alerts. Rising natural gas prices have punished consumers with bills that, in some cases, are double or triple last winter's. And forecasts for this summer suggest the possibility of rolling blackouts.

The good news is that America's energy problems can be solved. The bad news is that the situation in California is not isolated, it is not temporary, and it will not fix itself.

America faces a major energy supply crisis over the next two decades. The failure to meet this challenge will threaten our nation's economic prosperity, compromise our national security, and literally alter the way we live our lives.

America has heard these dire warnings before - in fact, they seem to be a recurring theme in our nation's energy discussion, almost since "Colonel" Drake made the first oil strike near Titusville, Pennsylvania in 1859. "The amazing exhibition of oil," advised the State Geologist of Pennsylvania, "[is] a temporary and vanishing phenomenon-one which young men will live to see come to its natural end. " That was in 1885.

Around the same time, John Archbold - who succeeded John D. Rockefeller as head of Standard Oil - joked about the prospects for oil discoveries in Oklahoma: "Are you crazy?" Archbold said. "I'll drink every gallon produced west of the Mississippi. "

I don't know if anyone ever called Mr. Archbold on that pledge. But for whatever reason, in 1914 the U. S. Geological Survey predicted that the U. S. would soon exhaust its available oil supplies. They issued the same warning in 1926. And again in 1939. And in 1949.

All of these warnings have proven false. Despite all these expert predictions, the world has not run out of oil or other resources. And yet here we are, faced with the most serious energy shortage since the days of oil embargoes and gas lines.

My point is, America's current energy supply crisis is not due to some inevitable neo-Malthusian depletion of resources. The United States - and our North American and hemispheric neighbors-are blessed with a rich abundance of natural resources. It's political leadership that has been scarce.

For the past eight years, Washington sat on the sidelines as our nation's energy needs mounted. During the 1990s, the Clinton Administration employed a policy of taxing demand, limiting supply, and ignoring the rapidly expanding needs of the future.

Their energy strategy boiled down to: you can't find it . . . you can't transport it . . . and even if you get it, we don't want you to use it.

Through neglect or complacency or ideology, this approach has led us to the crisis we face today.

The Bush Administration is fully prepared to respond to the broad set of challenges we inherited. But we must be candid with the American people about the magnitude of the problem - which is what I'd like to talk about today.

America's Energy Supply Challenges

Three overriding facts starkly define the challenge of America's energy needs over the next two decades:

First, demand for energy is rising across the board, but particularly for natural gas and electricity;

Second, supplies are being limited by a regulatory structure that, in many respects, has failed to keep pace with advances in technology and an uncertain political environment that often discourages investment in desperately needed facilities;

And third, our energy infrastructure - that network of the generators, transmission lines, refineries and pipelines that convert raw resources into usable fuel - is woefully antiquated and inadequate to meet our future needs.

Unless these challenges are addressed, America's energy supply will be continually at risk . . . our citizens will encounter blackouts and other lifestyle-altering disruptions . . . and our economy will be hobbled by rising energy prices. Let me briefly outline some of the major issues on the horizon:

Oil: Rising Consumption, Accelerating Dependence

In the next 20 years, according to estimates by the Energy Information Administration, America's demand for oil is projected to increase by 33 percent. Yet as consumption surges, U. S. production continues to drop precipitously. We now produce 39 percent less oil than we did in 1970, losing nearly 4 million barrels a day in the process. And unless energy policy is changed, production will slip further - to just 5.1 million barrels per day by 2020 - down from a high of 9. 4 million a day 30 years ago. This widening gap between demand and domestic supply will make us increasingly dependent upon foreign imports. Back in 1973-at the height of the oil crisis - America imported just 36 percent of its oil from abroad.

Today, we import 54 percent. And, if we allow this trend to continue, we will soon be forced to look abroad for some 64 percent of our oil. This will put more power in the hands of foreign suppliers - power they are not reluctant to use, as we just saw when the OPEC cartel decided to reduce oil output by one million barrels a day.

While this administration does not agree with OPEC's decision, that decision demonstrates the importance of increasing America's production of oil. Securing an affordable, reliable and adequate supply of crude is a critical challenge. But it is only half the oil story.

Since 1980, the number of American refineries has been cut in half. There hasn't been a new refinery built in the United States in over 25 years. New regulatory interpretations limit the ability of existing refineries to expand capacity. Add to that regulations that require the production of more than 15 different types of gasoline-and you have a refining industry strained to capacity, leaving us dangerously vulnerable to regional supply disruptions and price spikes.

Refineries are so constrained that when President Clinton made the politically symbolic gesture of releasing 30 million barrels of oil from the Strategic Petroleum Reserve last fall, that oil had to be shipped overseas to be refined.

Natural Gas: Rapidly Rising Demand; Constraints on Supply

Many of the same issues confront the future of natural gas. America's demand for natural gas is projected to rise even more rapidly than oil. If Department of Energy projections are correct, by 2020 Americans will consume 62 percent more natural gas than we do today. More than 9 out of 10 of the announced new electric generating plants will be fired by natural gas.

This approaching wave of new demand begs the question: Do we have an energy policy and a regulatory structure capable of meeting our natural gas needs?

Consider just a few constraints in this market.

Right now, an estimated 40 percent of potential gas resources in the United States are on federal lands that are either closed to exploration or covered by severe restrictions. The last lease sale in the some areas of the Gulf of Mexico was more than a decade ago. New discoveries of natural gas in the United States have fallen for three straight years, creating increasing pressure for more imports.

The notion that we can rely so heavily on natural gas . . . maintain severe restrictions on exploration . . . and still enjoy low prices is a dangerous assumption.

Even if we find the supplies, moving that gas to market will require an additional 38,000 miles of transmission pipeline and 255,000 miles of distribution lines-at an estimated cost of $120-$150 billion.

Today's pipeline system can hardly handle the supplies we know exist. Alaska's Prudhoe Bay, for example, produces about 8 billion cubic feet of natural gas a day - approximately 13 percent of America's daily consumption.

But that gas never reaches the market. Instead, it is just pumped back into the ground, waiting until a pipeline is built to connect the Alaska fields to the U.S./Canada distribution system.

Electricity: Powering the Information Economy

As everyone knows, we also face a real challenge in generating enough electricity to light out homes and run our businesses. Over the next 20 years, the Department of Energy estimates that electricity demand in the United States will increase by 45 percent. That rising growth rate will require the construction of over 1,300 new power plants-about 65 every year.

Yet, the last time we added that much power was 1985.

Furthermore, there is reason to believe that this could turn out to be a conservative estimate. During the 1990s, electricity consumption far outstripped projections, driven by the energy-hungry information economy. Some experts calculate that the demands of the Internet already consume some 8-13 percent of electricity. If demand grows at just the same pace as during the last decade, we'll need nearly 1,900 new plants by 2020-or more than 90 every year-just to keep pace.

Hundreds of new generating plants will place even greater pressure on our already strained and aging power grid. America's network of transmission lines, substations and transformers was built when utilities were tightly regulated monopolies providing service to assigned regions. Interconnections between suppliers were strictly an emergency backup measure to guard against rare service interruptions. The system was simply not designed for long-haul swapping of power in a highly competitive market.

Consumers are already feeling the impact of a transmission systems stressed by rising demand. Transmission bottlenecks contributed to the blackouts that have swept through California and to price spikes in New York City last summer that cost consumers an estimated $100 million.

Coal, Nuclear, and Hydro-Electric Power

Coal has historically been American's number one source for affordable electricity; it currently powers half of America's electricity generators. And at today's recovery rates, our nation has enough coal to keep those plants running for the next 250 years.

Coal generators have already been called upon to make broad reductions in emissions. The Bush Administration supports those efforts-and we will back it up with greater incentives for investment in clean coal technology.

But the administration will not regulate coal out of existence . . . and we will not support measures that will threaten electricity supplies and significantly raise electricity prices. President Bush made the right decision last week not to impose new federal mandates on the emissions of carbon dioxide. If America is to have reliable electricity over the next 20 years, coal must continue to play a major role.

But, coal is not the only energy source facing an uncertain future. There hasn't been a new nuclear power plant permit granted since 1979. Many of the 103 existing nuclear plants are not even expected to file for a renewal of their licenses as they expire over the next 15 years.

Even hydroelectric power generation is expected to fall sharply.

Re-licensing a hydro facility can take a decade or more and cost millions. And now, even though consumers are faced with potential blackouts and chronic electricity shortages in the West, activists and some political leaders want to breach one or more of the four federal dams on the Snake River to help young salmon, on their trek to the sea.

The Dangers of Complacency

What are the dangers of complacency in light of these challenges? How does it all add up for our economy and our citizens?

This nation's last three recessions have all been tied to rising energy prices - and there is strong evidence that the latest crisis is already having a negative effect.

The National Association of Manufacturers estimates that soaring fuel prices between 1999 and 2000 cost the U.S. economy more than $115 billion-shaving a full percentage point off our Gross Domestic Product. A January survey of its 5,500 members reveals that nearly one quarter were forced to curtail operations.

During a two-week period this past January, Californians lost an estimated $2.3 billion in wages, sales and productivity. Layoffs are already hitting workers in the West as companies shift production to states with more reliable energy sources. Then there are the jobs that will never be created.

Intel's CEO Craig Barrett announced that the world's leading chipmaker won't be expanding in California: "As long as California is a Third World country," Barrett said, "we won't build $2 billion manufacturing plants here."

The Food and Agricultural Policy Institute reports that farmers are likely to see their income drop 20 percent over the next two years due to higher energy costs.

Rising energy costs are hitting every family's checkbook, primarily affecting those who can afford it least. Gas bills for many homeowners in the Washington, DC area more than tripled this year. Some residents are reporting that their heating bills are higher than their food bills this winter.

The power crisis isn't just pinching our wallets, it's changing the way we live our lives. In California, power outages have shut down traffic lights, darkened schools and closed businesses. The governor has ordered local police to patrol the streets-not for criminals, but to make sure businesses keep their lights dimmed.

But California is not the only state facing a mismatch between supply and demand. With electricity shortages predicted for New York City and Long Island this summer . . . low capacity margins threatening electricity reliability in the Midwest, Southeast and Northern Plains states . . . and strained refinery capacity in the Midwest, Americans across the nation are feeling the energy squeeze.

The Need For A National Energy Policy

Rising demand . . . tightening supplies . . . an aging power infrastructure . . . a decade of neglect from Washington: These are the trends that define America's emerging energy needs.

President Bush has committed this administration to meeting these challenges - a job that begins with the urgent task of developing and implementing a long-term national energy policy.

To accomplish this, President Bush created an Energy Task Force headed by Vice President Cheney. He has asked us to define a clear strategy - a strategy that will allow environmentally responsible exploration and recovery of our domestic resources . . . enhance our commitment to conservation and energy efficiency . . . and encourage investment in new technology to further the development of renewable energy sources.

I wish I could say that the energy crisis now sweeping the nation has shocked the political system into action. But like other political discussions in recent years, the debate over energy seems as deeply polarized as ever.

On one end of the spectrum, some activists propose what amounts to a "zero tolerance" policy toward exploration and cling to the quixotic idea that new, undiscovered sources will somehow allow us to meet our energy needs. On the other end, some advocates place an almost limitless faith in special tax breaks for this favored activity or subsidies for that preferred industry.

The two extremes in our energy debate are founded on several enduring myths - myths that today conspire to block any true advance toward a rational and stable energy policy in the United States. Here are a few of the more prominent ones.

Myth Number 1: It is impossible to balance energy exploration and environmental protection.

Advances in technology have brought us a long way from the days when wildcatters punched holes in the ground based on the hunch they might hit a gusher. But from a regulatory standpoint, our view of oil and gas exploration hasn't changed much since we saw Jed Clampett strike "black gold" and split for Beverly Hills.

Today, satellites and computers are the tools of choice in the exploration business. Geologists can bounce acoustic and electrical vibrations off the earth's inner depths, gather the resulting mass of data into powerful computers and then create three dimensional and even four dimensional maps of resource fields miles below the surface.

Armed with these pinpoint accurate images, companies employ advanced equipment to drill vertically, horizontally and around corners-allowing us to access supplies from previously unimaginable depths, up to six miles away.

The marriage of oil and gas exploration with cutting-edge technology means fewer rigs, fewer roads and fewer pipelines. Drilling operations that required 65 acres in the 1970s need only 10 acres today. Technological improvements in just the past 15 years have generated success rate increases of 50 percent. America's national energy policy must reflect these staggering advances that have revolutionized the way we develop our resources.

Myth Number 2: All our current problems are due to an energy industry that is engaged in a massive conspiracy to gouge consumers by limiting supply to drive up prices.

This myth has been punctuated by calls for investigations into everything from last summer's Midwest gasoline price spikes, to recent allegations that power generators in the West have been withholding electricity. We have a fair and objective process for judging these claims-and action will be taken when it is merited. Over the past two weeks, for example, the Federal Energy Regulatory Commission ordered power companies to rebate some $124 million to California utilities. Meanwhile, the Federal Trade Commission recently cleared gasoline suppliers of all charges relating to last summer's price increases.

But charges of price gouging largely miss the point. There is no magic source of supply; no hidden pool of energy that can be turned on and off like a faucet. California-and other power-strapped states-will never solve the power crises they confront until they resolve the conflict between demand and supply.

Earlier this year, one company proposed building a $400 million power plant in California that would have provided enough additional electricity to light 600,000 homes in energy-starved Silicon Valley. The company pledged to plant 800 new trees to beautify the area. They proposed cloaking the power station in a brick facade to make it essentially indistinguishable from a high-rent office complex. They even promised to help maintain the local habitat for the endangered bay checkerspoon butterfly.

Their environmentally-sensitive plans won the support of the Sierra Club, the American Lung Association and the NAACP. But city officials voted unanimously -- 11-0 -- to reject the plan. In an editorial, the local paper called this move "Dumb and Dumber."

Meanwhile, further south, plans to build a 550-megawatt gas-fired generator in a Los Angeles suburb were scrapped after residents voted 2:1 against the project. The local mayor added a much-needed dose of reason and maturity to the debate-by launching a hunger strike in opposition to the plant.

In California, workers are being laid off, companies are leaving the state, farmers and small businesses are losing millions, consumers are threatened with rolling blackouts, but local officials reject power plants with little regard for the consequences. Is it really any mystery why there hasn't been a single new power plant built in California in the last decade?

Myth Number 3: The Bush energy plan is focused almost exclusively on opening the Arctic National Wildlife Refuge (ANWR) to exploration-a move that would buy us only about 6 months worth of American consumption while destroying a pristine natural wilderness, not to mention disrupting the breeding ground of the Porcupine Caribou.

Let's separate fact from fiction when it comes to ANWR.

First, according to estimates by the U. S. Geological Survey, ANWR holds between 5. 7 to 16 billion barrels of recoverable reserves-with a mean estimate of 10. 4 billion barrels. And that assumes the use of drilling technology now nearly a decade old. This represents more than 300 times the amount of the oil President Clinton released from the Strategic Petroleum Reserve last fall. And based on December 2000 figures, it would free us from about 54 years of oil imports from Saddam Hussein and Iraq.

Second, exploration would impact only about 2,000 acres out of more than 19 million. To put that in perspective, the massive Arctic National Wildlife Refuge is about the same size as the entire State of South Carolina; the two thousand acres that would be affected is less than half the size of Dulles airport.

And as for the caribou, the herd in the Prudhoe Bay area grew more than 9-fold over the past 20 years to an estimated 28,000 in 2000-seemingly irrefutable evidence that caribou mating and oil exploration can peacefully coexist.

The decision to open a small portion of ANWR should be made on the merits. But it should not be made on the mistaken assumption that opening ANWR will allow us to produce our way to full energy independence.

America first became a net importer of energy in the 1950s - and our economy will continue to depend, in part, on imported oil. However, closing off virtually every available new source of domestic supply, enhances the leverage and power of an oil cartel that cannot be relied on to put America's interests first. While the resources of ANWR won't make us energy independent, they will help increase America's energy security by ensuring a more diverse supply of oil.

Myth Number 4: Government subsidies and tax breaks are the best way to encourage new exploration and production of energy.

This administration will continue to support funding for energy research and development initiatives. But capital is best allocated to its highest uses through the workings of the free market, not manipulations of the tax code. Government regulatory policy should not be aimed at picking winners and losers in any market, including energy. Neither should tax policy.

Myth Number 5: We can forego traditional sources and instead meet rising energy demand by harnessing wind, geothermal, solar and other forms of renewable power.

Excluding hydro-power, renewable sources currently generate about 2 percent of America's electricity. Billions have been invested in developing renewable energy-and will continue to be invested under the Bush Administration. But renewables have yet to overcome the economic advantages of conventional energy sources.

Even with promising advances in research and development, renewables will only provide, according to Energy Information Administration estimates, about 6 percent of our total electricity consumption by 2020. Even if renewables exceed our most optimistic expectations, they would still supply only a fraction of our needs over the next 20 years.

Myth Number 6: Price controls are the answer to today's energy crisis.

Memories are short, aren't they. So let me remind everyone. America imposed price controls on oil and gas in the 1970s. They were an utter failure. They led to shortages and rationing and the idea that America was gripped by malaise.

Let me be clear: The Bush Administration does not support price controls. Price controls on electricity will lead to more blackouts. Price controls on gasoline will lead to gas lines. Price controls will deepen America's energy crisis, because they won't reduce demand, but they will cripple incentives for desperately needed new investments in energy supply.

Charting a New Policy Course

The challenges are formidable . . . the warning signs are obvious . . . but I am optimistic because I know this administration's commitment is equal to the task.

Our national energy policy will be comprehensive. It will reach across every department that touches the energy marketplace-from the Interior Department and the EPA to the Transportation Department and the DOE.

Our national energy policy will be hemispheric. It will be based on the understanding that our policy cannot stand in isolation from our neighbors throughout the Americas.

Our national energy policy will stress the need to diversify America's energy supply. It will be founded on the understanding that diversity of supply means security of supply . . . and that a broad mix of supply options-from coal to windmills, nuclear to natural gas-will help protect consumers against price spikes and supply disruptions.

And our national energy policy will be balanced. It will leapfrog the myths that stifle change-rejecting the notion that there is no middle ground between environmental protection, regardless of the cost and energy exploration, regardless of the impact.

Soon we will deliver our recommendations to President Bush. Later, we will introduce legislation aimed at winning bipartisan support for a national energy policy that matches the magnitude of the challenge. I am hopeful that men and women of good will-from both ends of the political spectrum . . . from environmental organizations to industry groups-will then come together and transcend the stale debate that has characterized energy policy in recent years.

About 150 years ago, America faced a vastly different energy crisis.

Supplies of whale oil were becoming more and more scarce. Few could afford to pay for the luxury of this or other costly methods of illumination. Sure, crude oil was available. In those days it was soaked up with rags, wrung out into small vials, and then sold as a treatment for toothaches . . . until an entrepreneur lined up an investor and a chemist and launched an energy revolution that would light the world.

In America, resources become scarce only when our imagination languishes. By engaging that imagination, I am confident we can meet the challenges of today. If complacency yields to action. If we resolve to strike a rational balance between our energy needs and our environmental concerns. And if a national energy policy becomes an urgent priority.

Thank you.

Report by Energy Secretary Spencer Abraham

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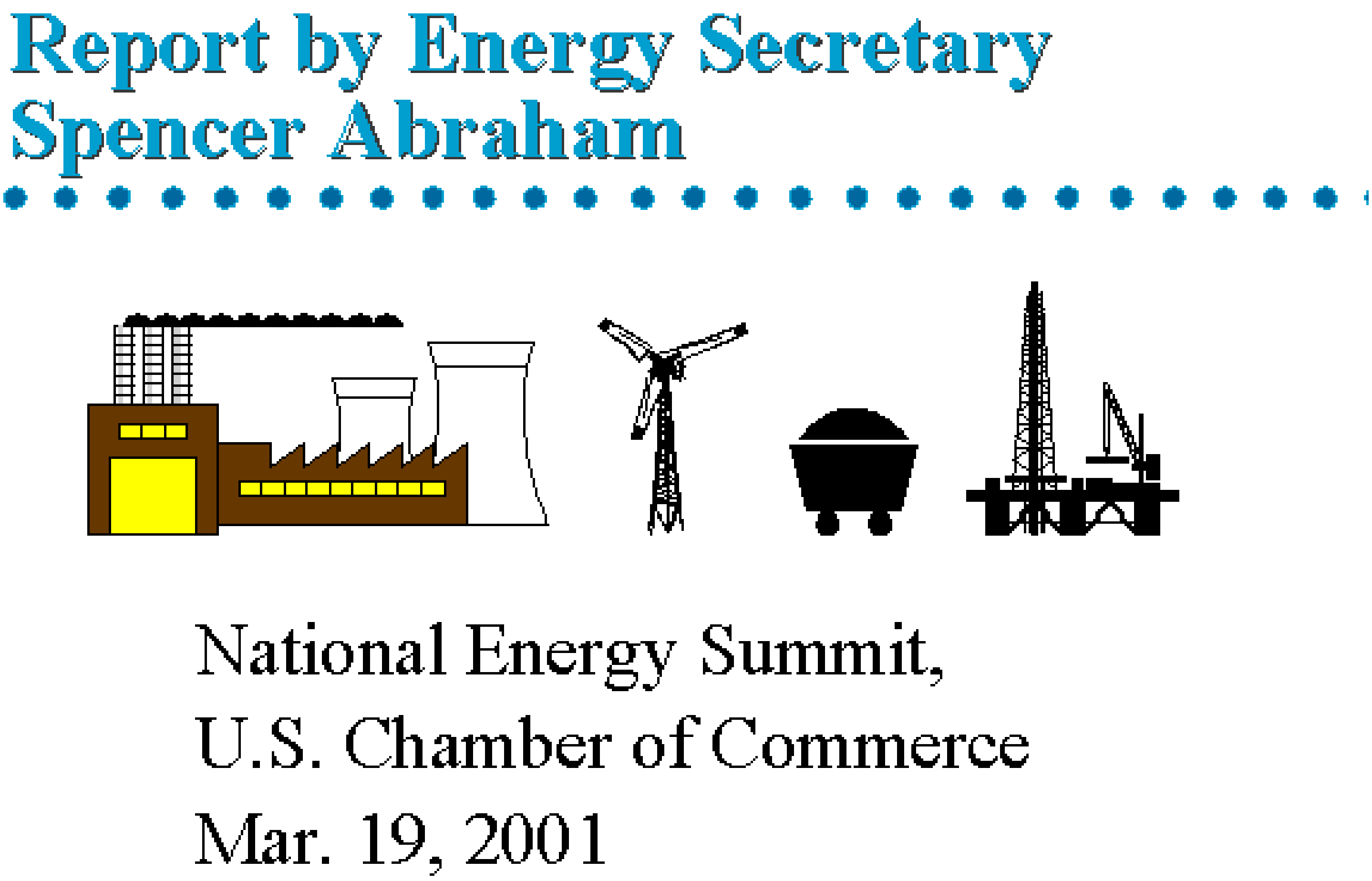

Report by Energy Secretary Spencer Abraham

National Energy Summit,
U.S. Chamber of Commerce
Mar. 19, 2001

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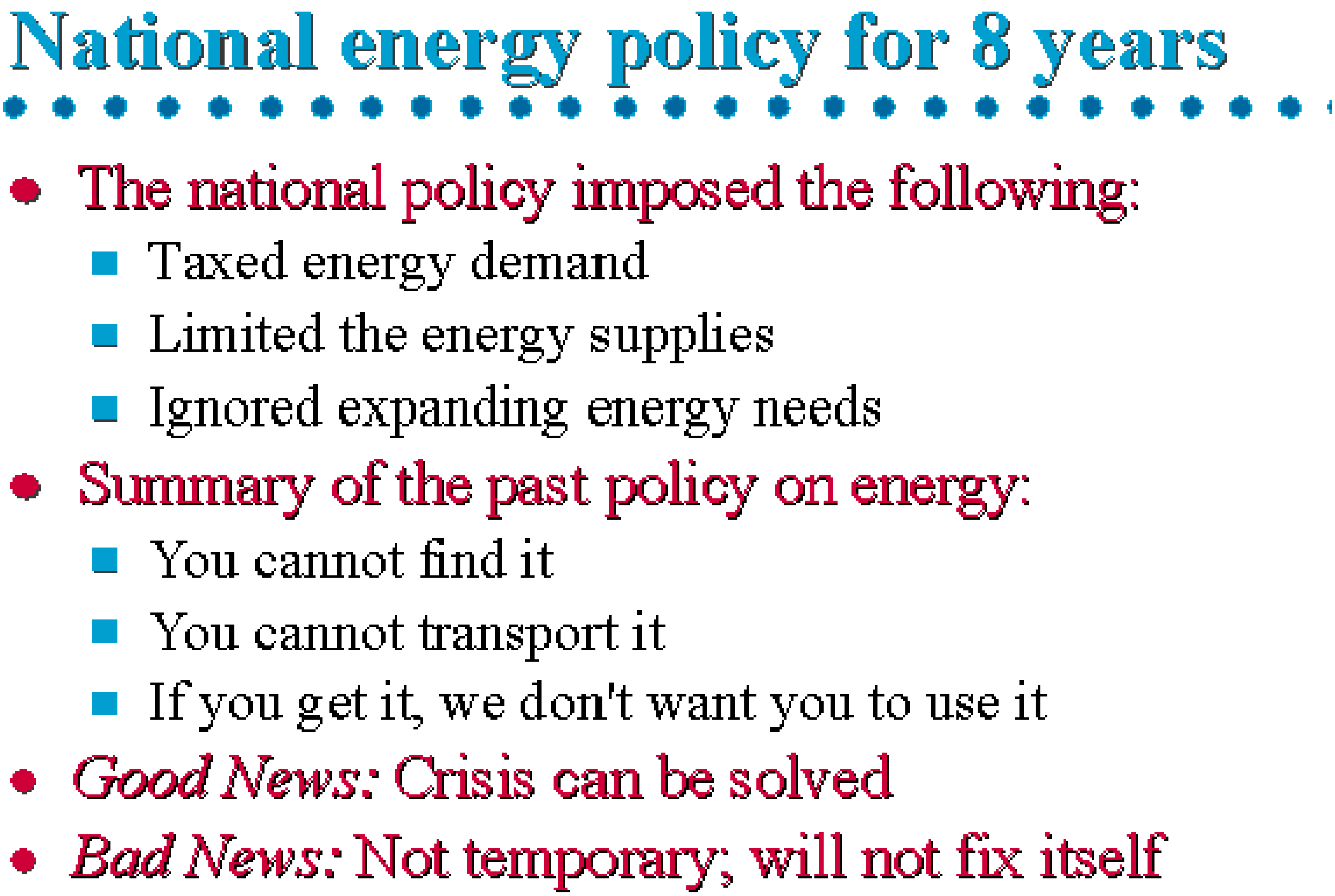

National energy policy for 8 years

- The national policy imposed the following:
  - Taxed energy demand
  - Limited the energy supplies
  - Ignored expanding energy needs
- Summary of the past policy on energy:
  - You cannot find it
  - You cannot transport it
  - If you get it, we don't want you to use it
- *Good News:* Crisis can be solved
- *Bad News:* Not temporary; will not fix itself

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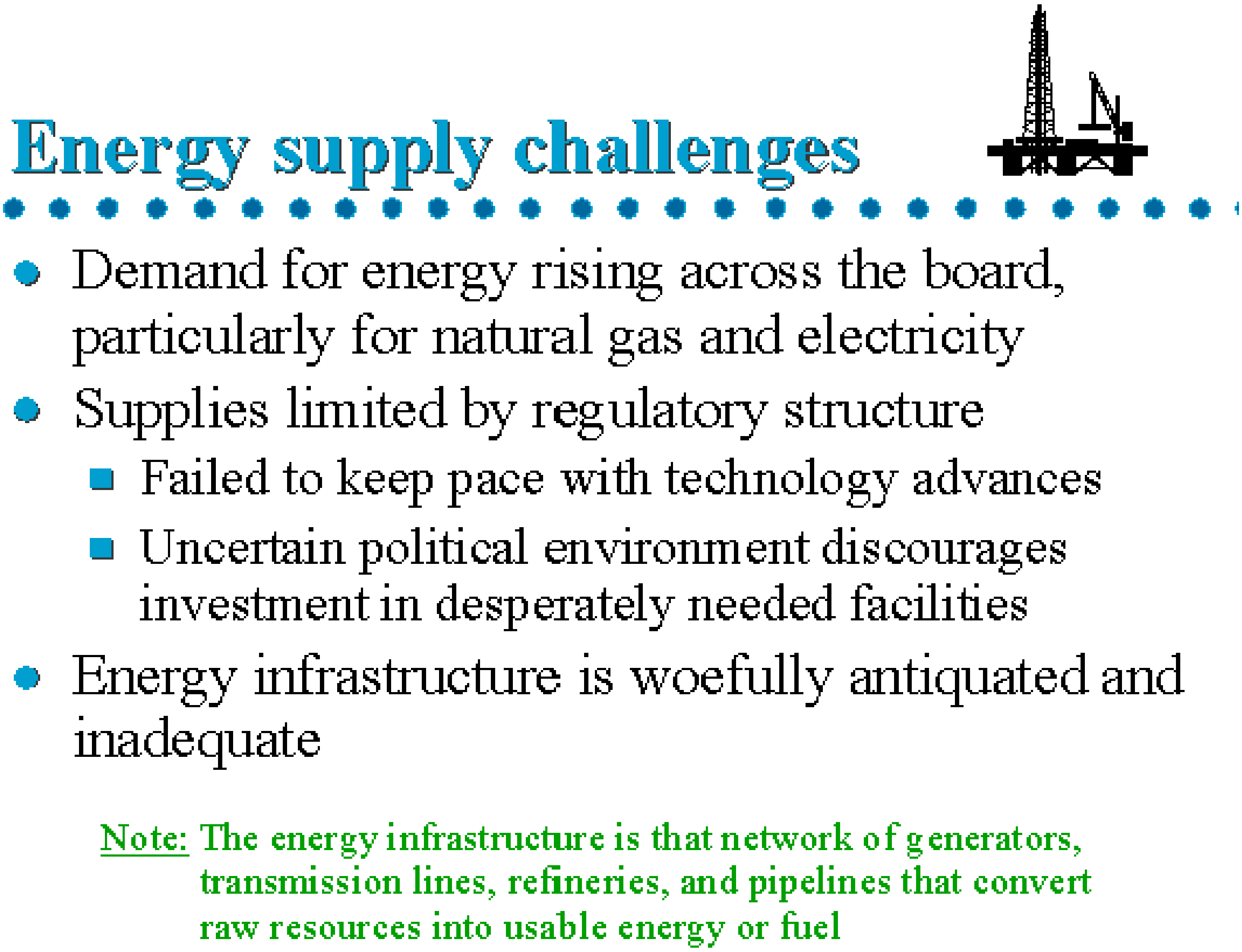

Energy supply challenges

- Demand for energy rising across the board, particularly for natural gas and electricity
- Supplies limited by regulatory structure
  - Failed to keep pace with technology advances
  - Uncertain political environment discourages investment in desperately needed facilities
- Energy infrastructure is woefully antiquated and inadequate

Note: The energy infrastructure is that network of generators, transmission lines, refineries, and pipelines that convert raw resources into usable energy or fuel

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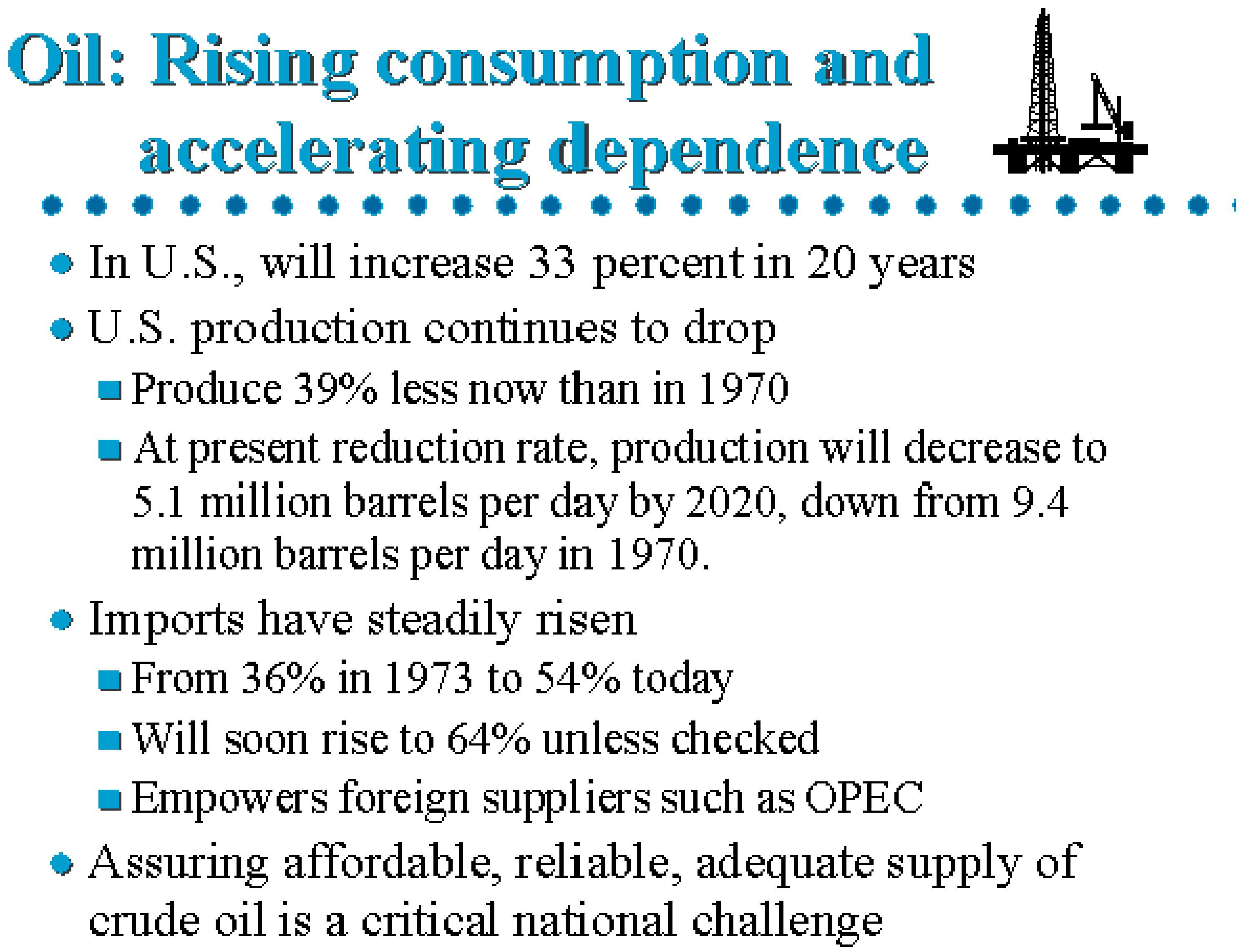

Oil: Rising consumption and accelerating dependence

- In U.S., will increase 33 percent in 20 years
- U.S. production continues to drop
  - Produce 39% less now than in 1970
  - At present reduction rate, production will decrease to 5.1 million barrels per day by 2020, down from 9.4 million barrels per day in 1970.
- Imports have steadily risen
  - From 36% in 1973 to 54% today
  - Will soon rise to 64% unless checked
  - Empowers foreign suppliers such as OPEC
- Assuring affordable, reliable, adequate supply of crude oil is a critical national challenge

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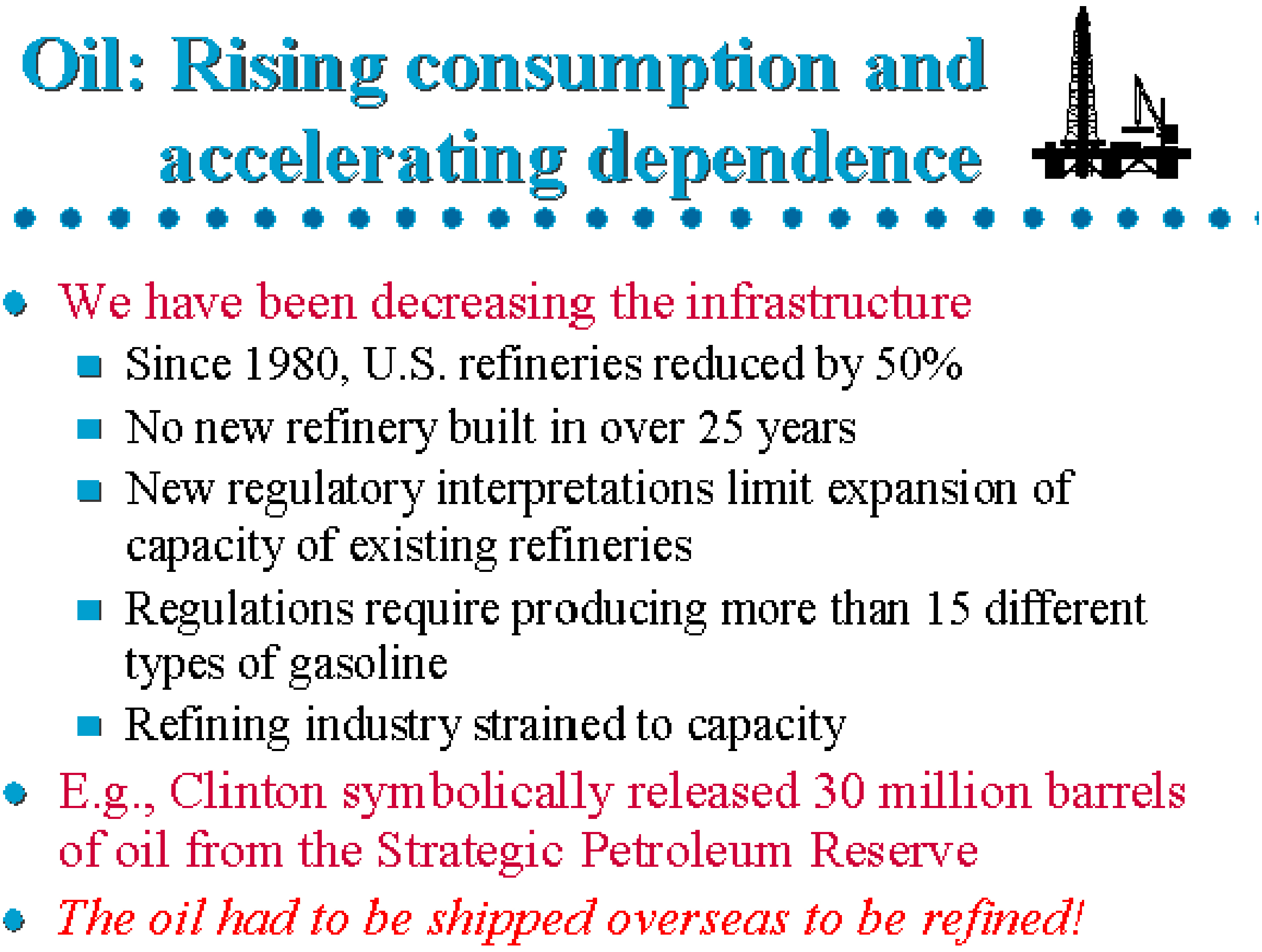

Oil: Rising consumption and accelerating dependence

- We have been decreasing the infrastructure
  - Since 1980, U.S. refineries reduced by 50%
  - No new refinery built in over 25 years
  - New regulatory interpretations limit expansion of capacity of existing refineries
  - Regulations require producing more than 15 different types of gasoline
  - Refining industry strained to capacity
- E.g., Clinton symbolically released 30 million barrels of oil from the Strategic Petroleum Reserve
- *The oil had to be shipped overseas to be refined!*

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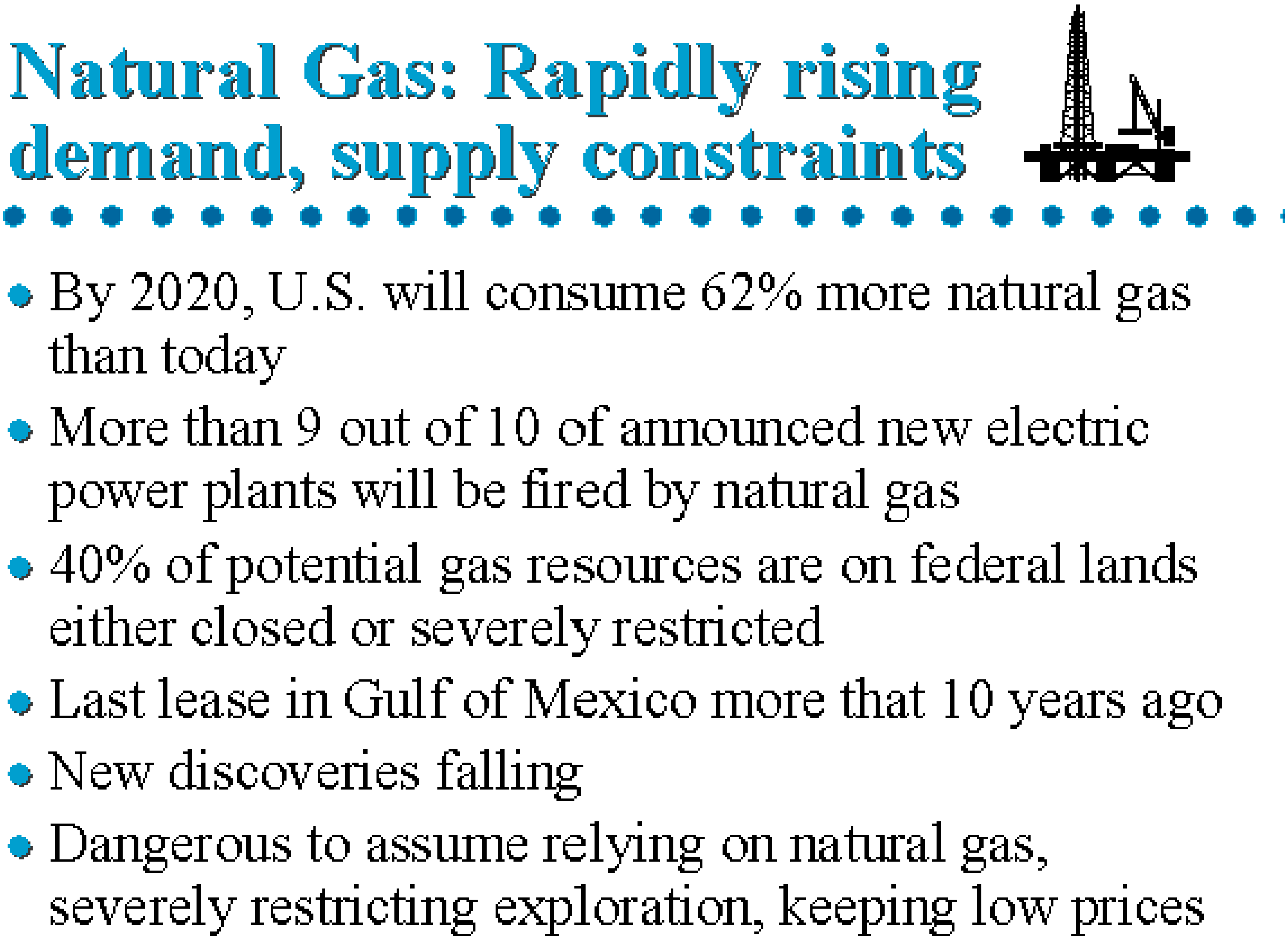

Natural Gas: Rapidly rising demand, supply constraints

- By 2020, U.S. will consume 62% more natural gas than today
- More than 9 out of 10 of announced new electric power plants will be fired by natural gas
- 40% of potential gas resources are on federal lands either closed or severely restricted
- Last lease in Gulf of Mexico more that 10 years ago
- New discoveries falling
- Dangerous to assume relying on natural gas, severely restricting exploration, keeping low prices

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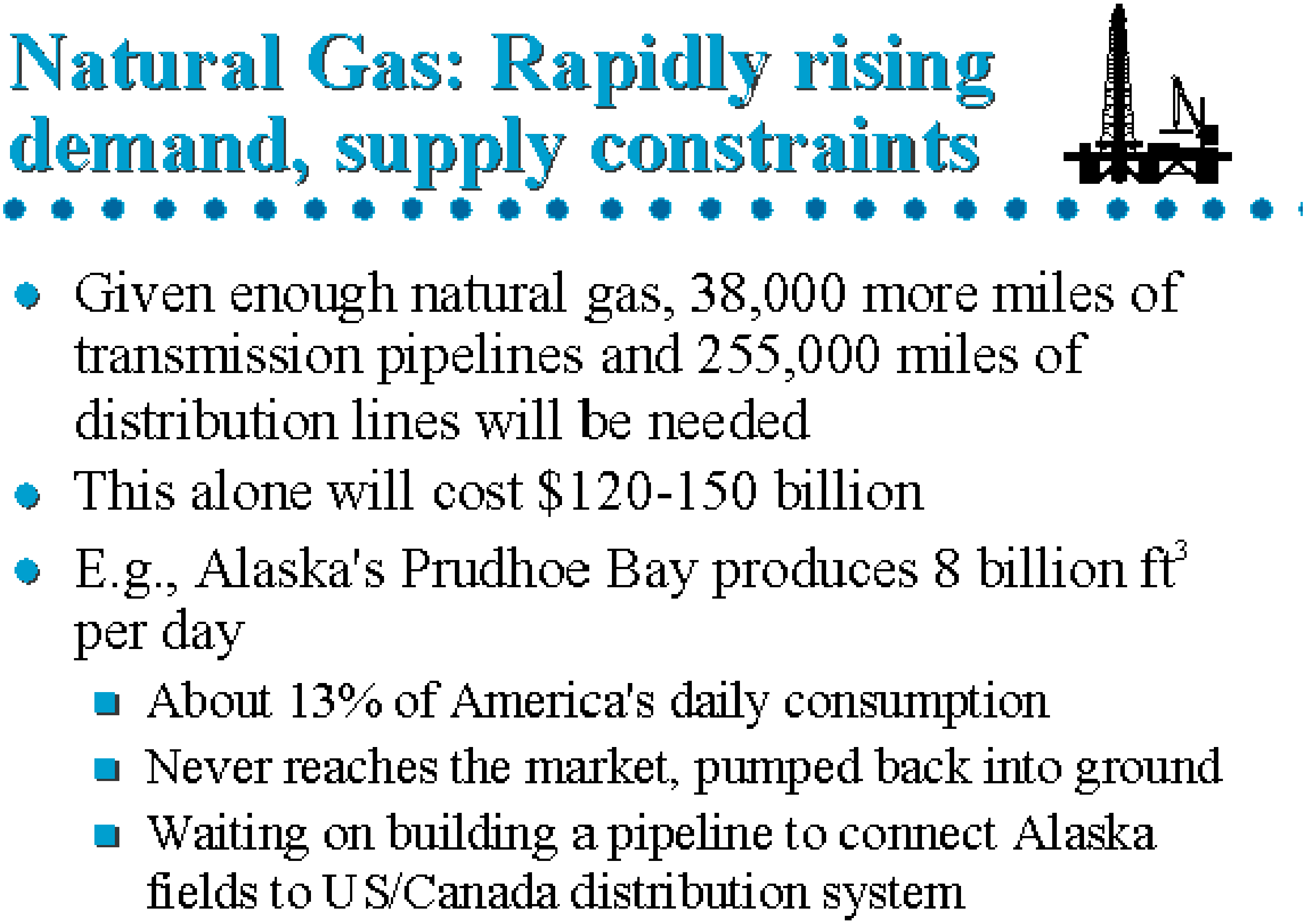

Natural Gas: Rapidly rising demand, supply constraints

- Given enough natural gas, 38,000 more miles of transmission pipelines and 255,000 miles of distribution lines will be needed
- This alone will cost $120-150 billion
- E.g., Alaska's Prudhoe Bay produces 8 billion ft^3 per day
  - About 13% of America's daily consumption
  - Never reaches the market, pumped back into ground
  - Waiting on building a pipeline to connect Alaska fields to US/Canada distribution system

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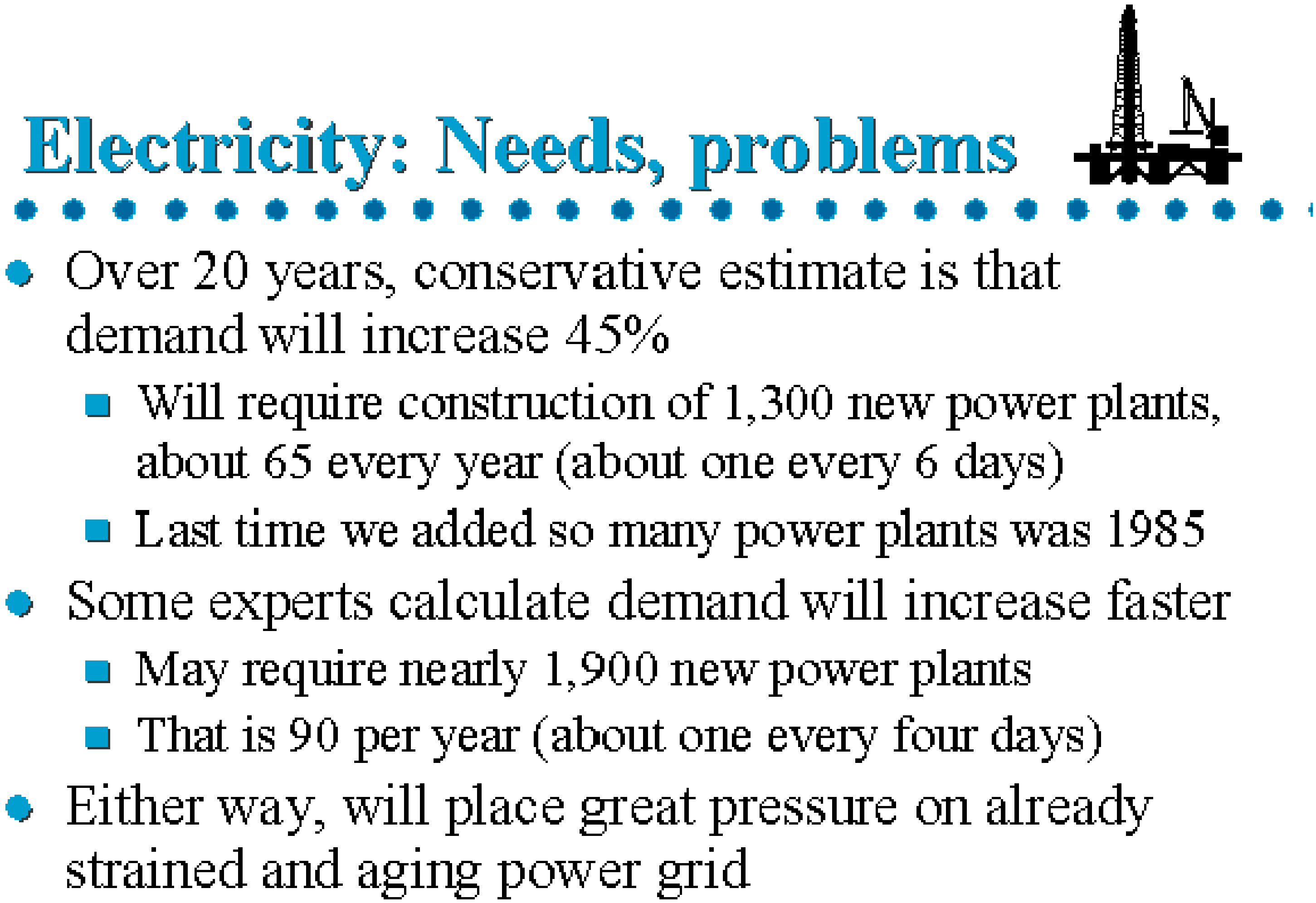

Electricity: Needs, problems

- Over 20 years, conservative estimate is that demand will increase 45%
  - Will require construction of 1,300 new power plants, about 65 every year (about one every 6 days)
  - Last time we added so many power plants was 1985
- Some experts calculate demand will increase faster
  - May require nearly 1,900 new power plants
  - That is 90 per year (about one every four days)
- Either way, will place great pressure on already strained and aging power grid

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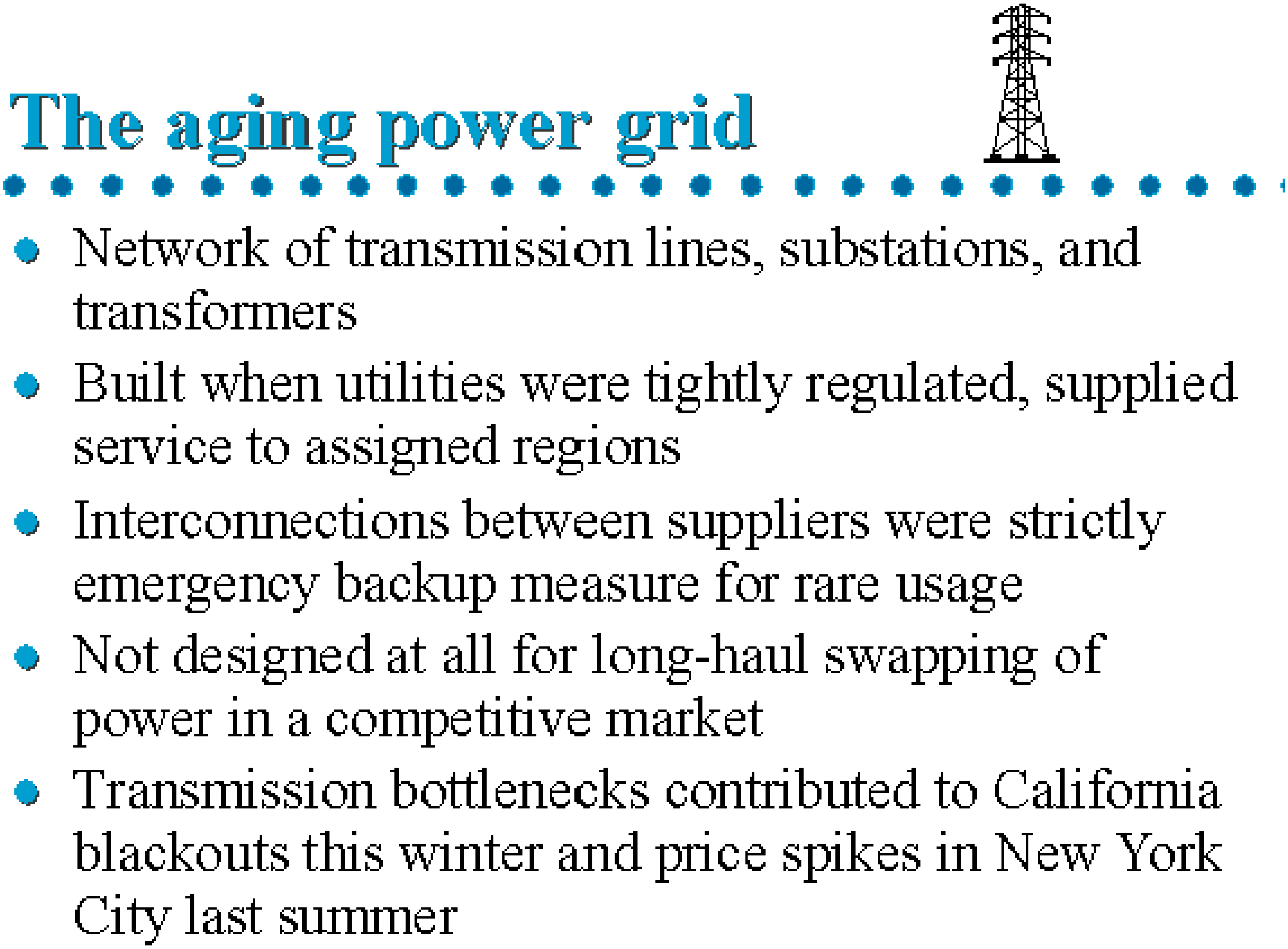

The aging power grid

- Network of transmission lines, substations, and transformers
- Built when utilities were tightly regulated, supplied service to assigned regions
- Interconnections between suppliers were strictly emergency backup measure for rare usage
- Not designed at all for long-haul swapping of power in a competitive market
- Transmission bottlenecks contributed to California blackouts this winter and price spikes in New York City last summer

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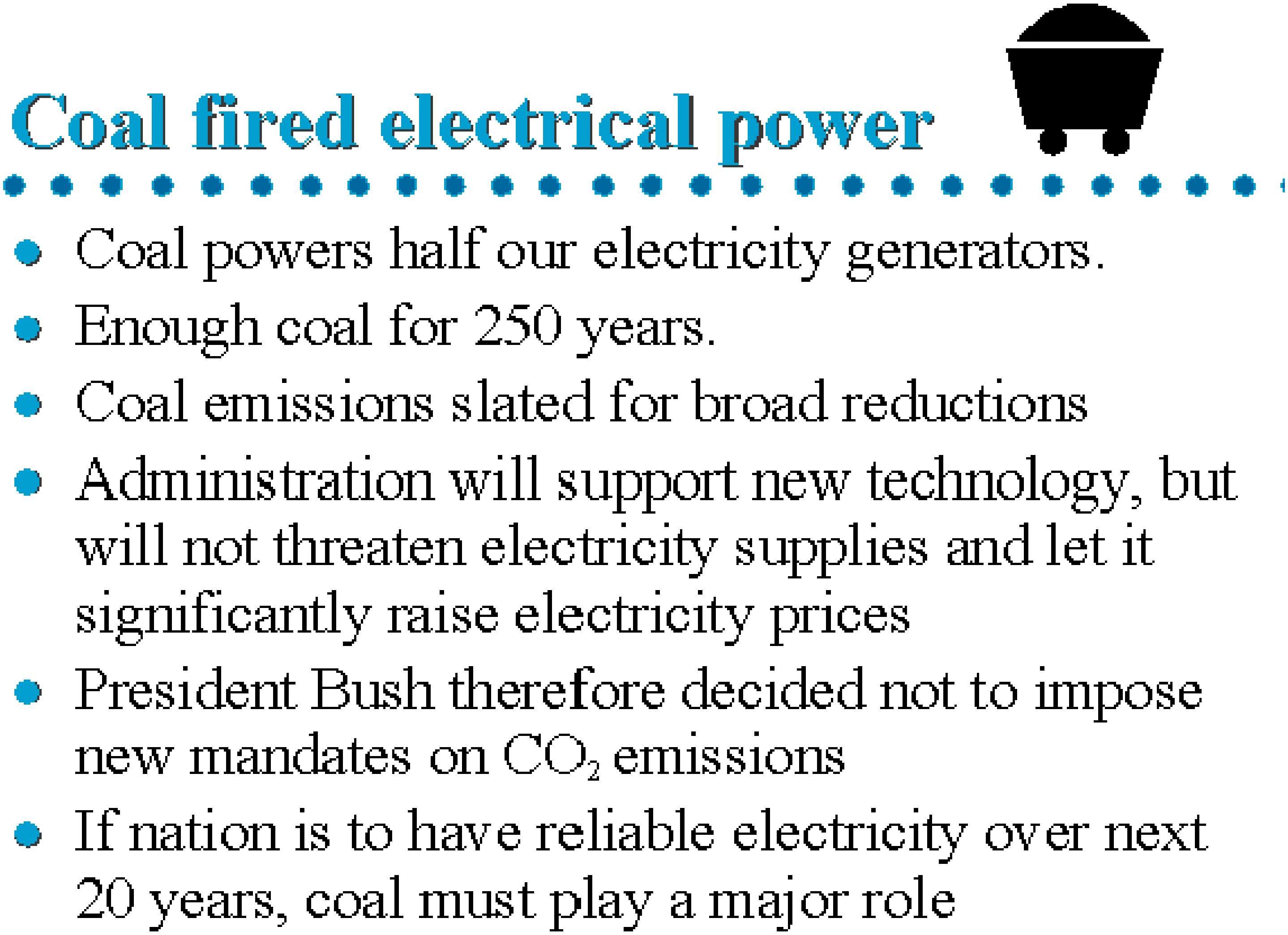

Coal fired electrical power

- Coal powers half our electricity generators.
- Enough coal for 250 years.
- Coal emissions slated for broad reductions
- Administration will support new technology, but will not threaten electricity supplies and let it significantly raise electricity prices
- President Bush therefore decided not to impose new mandates on CO_2 emissions
- If nation is to have reliable electricity over next 20 years, coal must play a major role

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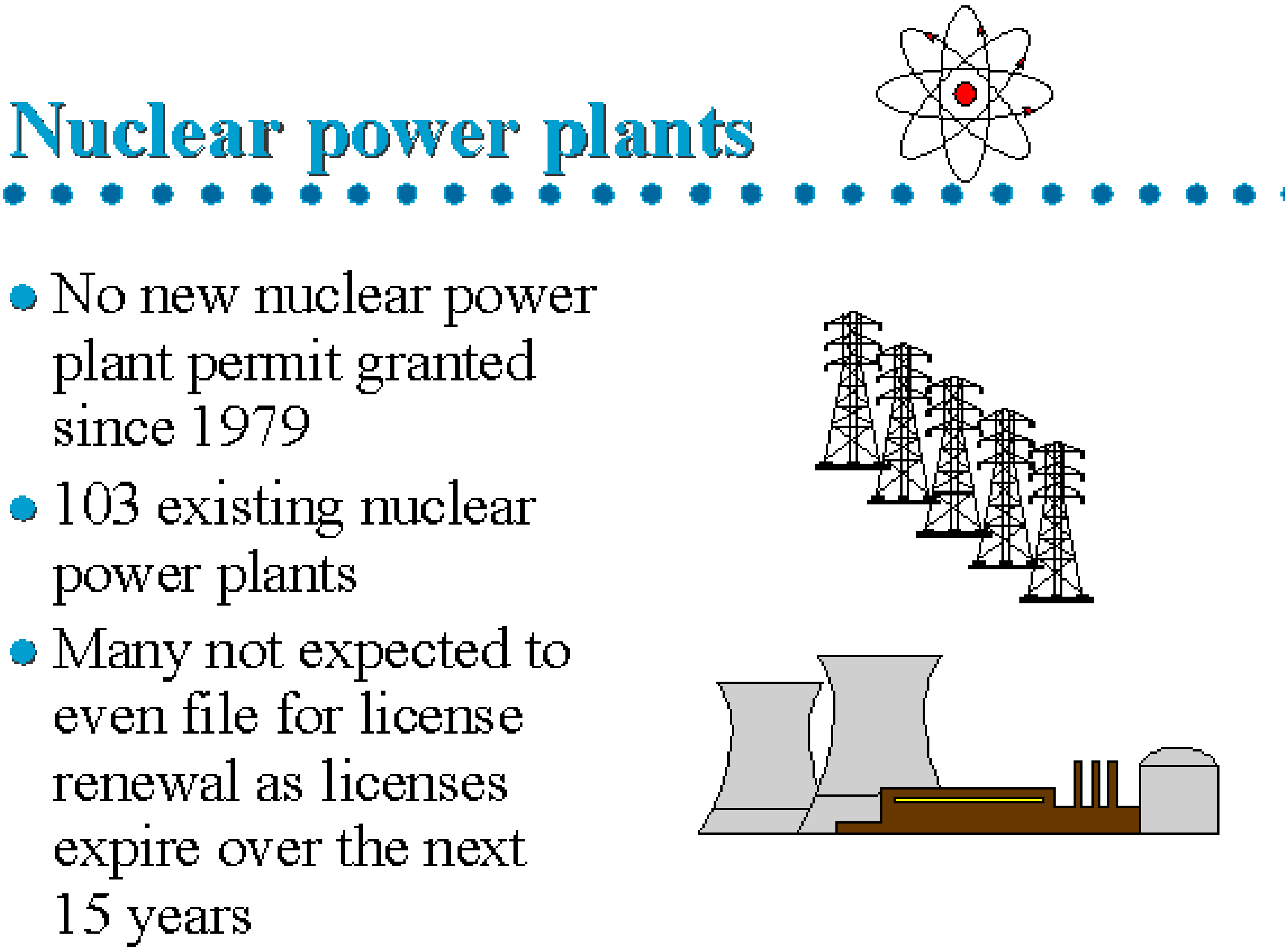

Nuclear power plants

- No new nuclear power plant permit granted since 1979
- 103 existing nuclear power plants
- Many not expected to even file for license renewal as licenses expire over the next 15 years

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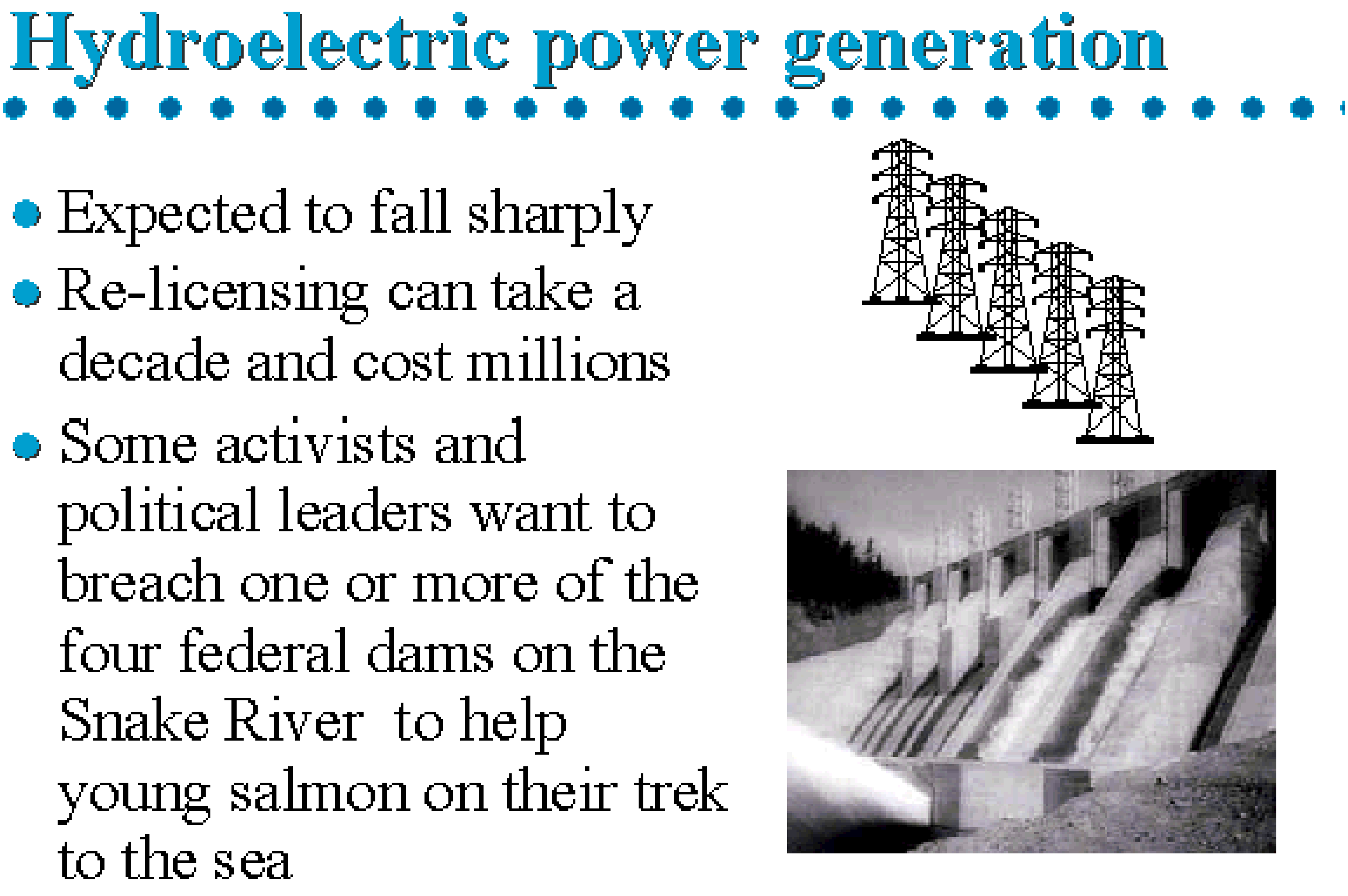

Hydroelectric power generation

- Expected to fall sharply
- Re-licensing can take a decade and cost millions
- Some activists and political leaders want to breach one or more of the four federal dams on the Snake River to help young salmon on their trek to the sea

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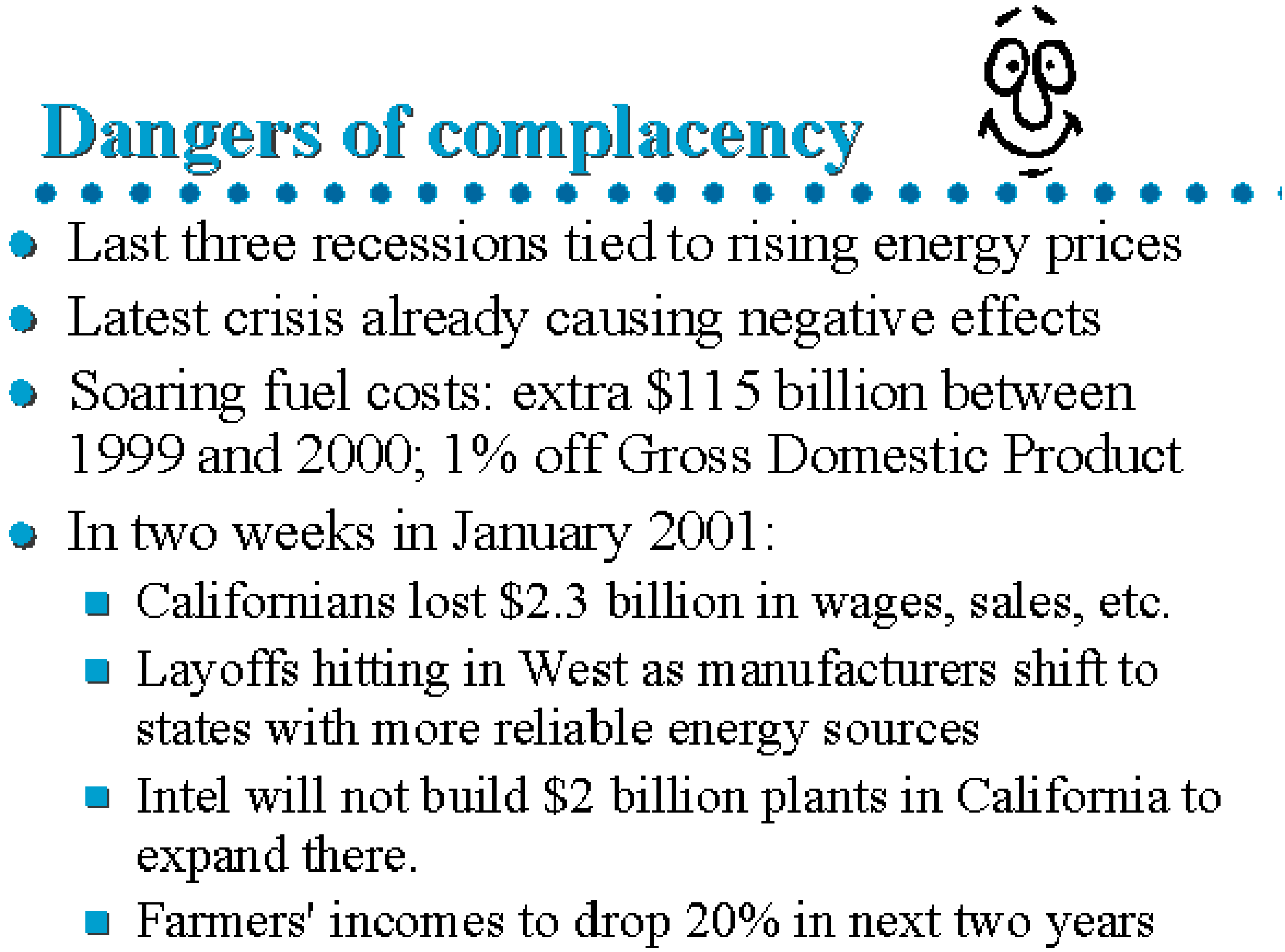

Dangers of complacency

- Last three recessions tied to rising energy prices
- Latest crisis already causing negative effects
- Soaring fuel costs: extra $115 billion between 1999 and 2000; 1% off Gross Domestic Product
- In two weeks in January 2001:
  - Californians lost $2.3 billion in wages, sales, etc.
  - Layoffs hitting in West as manufacturers shift to states with more reliable energy sources
  - Intel will not build $2 billion plants in California to expand there.
  - Farmers' incomes to drop 20% in next two years

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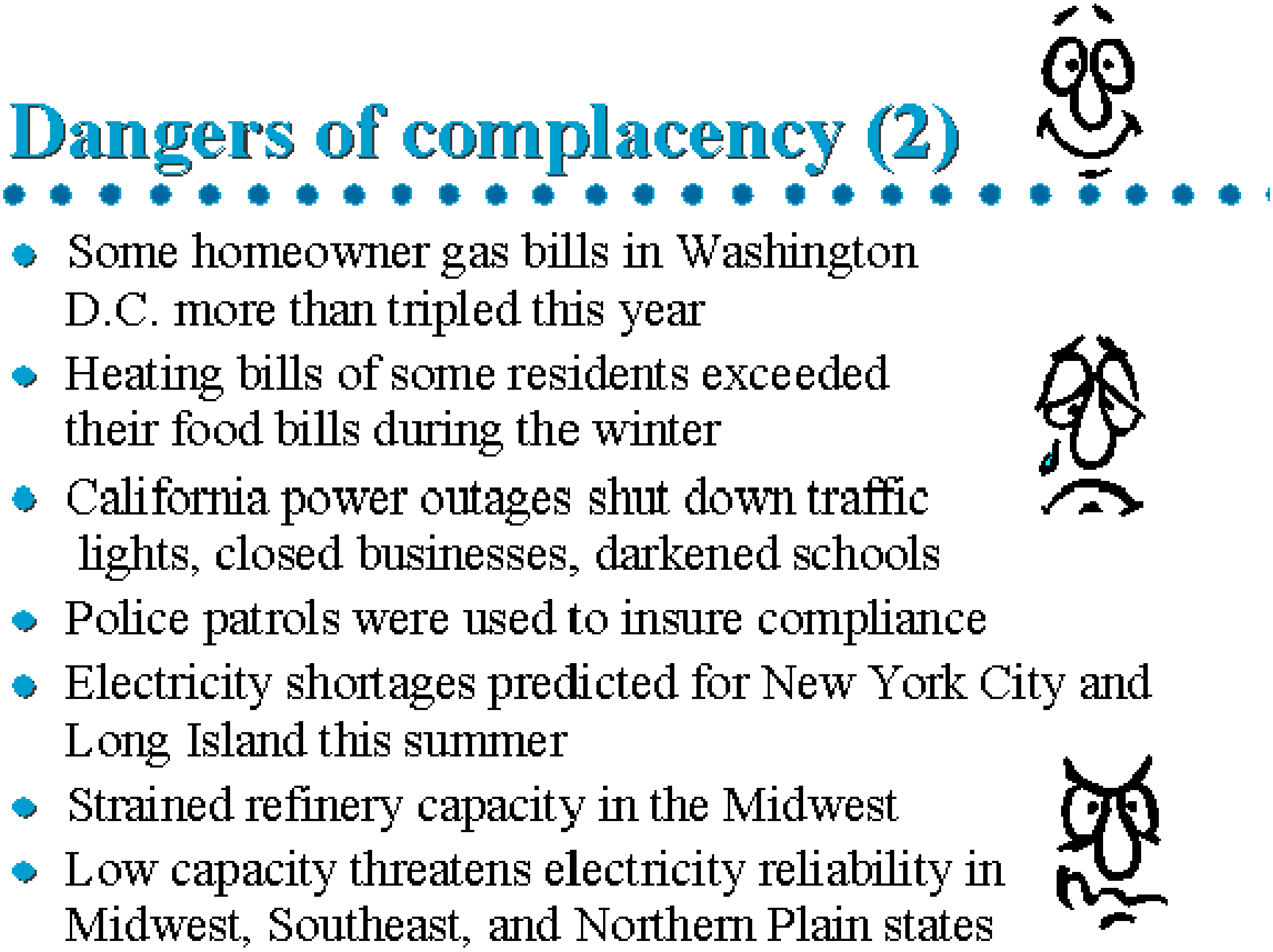

Dangers of complacency (2)

- Some homeowner gas bills in Washington D.C. more than tripled this year
- Heating bills of some residents exceeded their food bills during the winter
- California power outages shut down traffic lights, closed businesses, darkened schools
- Police patrols were used to insure compliance
- Electricity shortages predicted for New York City and Long Island this summer
- Strained refinery capacity in the Midwest
- Low capacity threatens electricity reliability in Midwest, Southeast, and Northern Plain states

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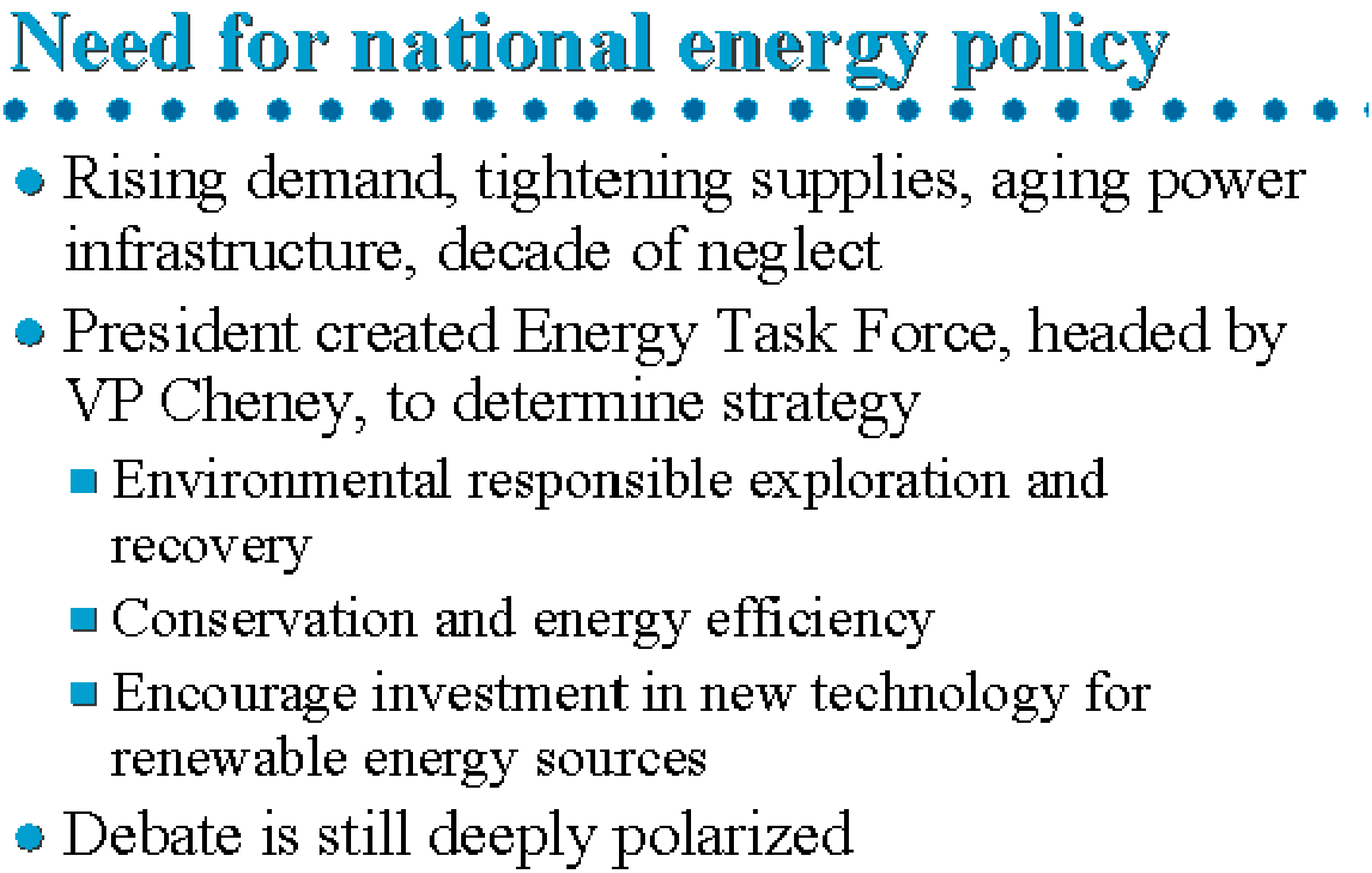

Need for national energy policy

- Rising demand, tightening supplies, aging power infrastructure, decade of neglect
- President created Energy Task Force, headed by VP Cheney, to determine strategy
  - Environmental responsible exploration and recovery
  - Conservation and energy efficiency
  - Encourage investment in new technology for renewable energy sources
- Debate is still deeply polarized

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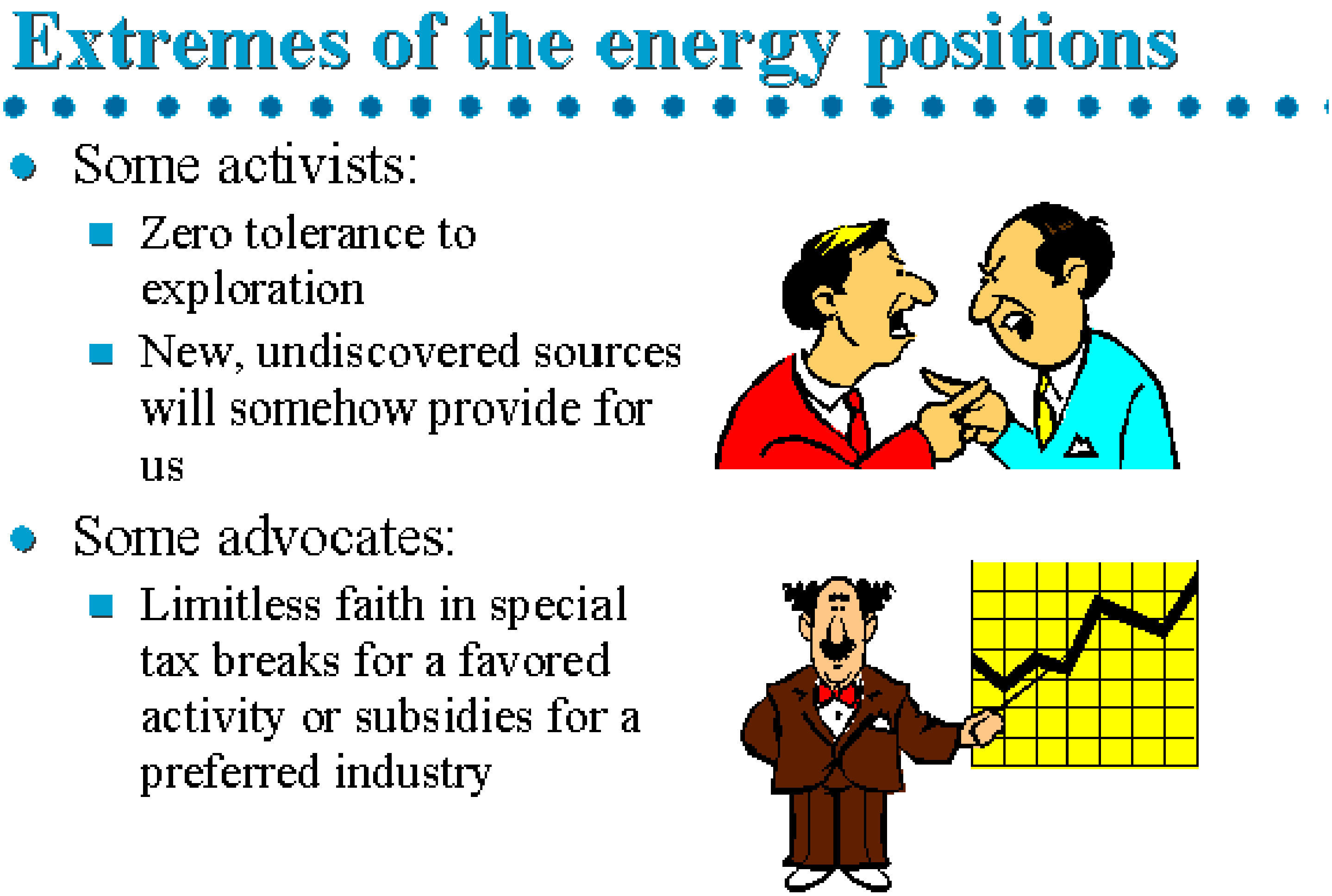

Extremes of the energy positions

- Some activists:
  - Zero tolerance to exploration
  - New, undiscovered sources will somehow provide for us
- Some advocates:
  - Limitless faith in special tax breaks for a favored activity or subsidies for a preferred industry

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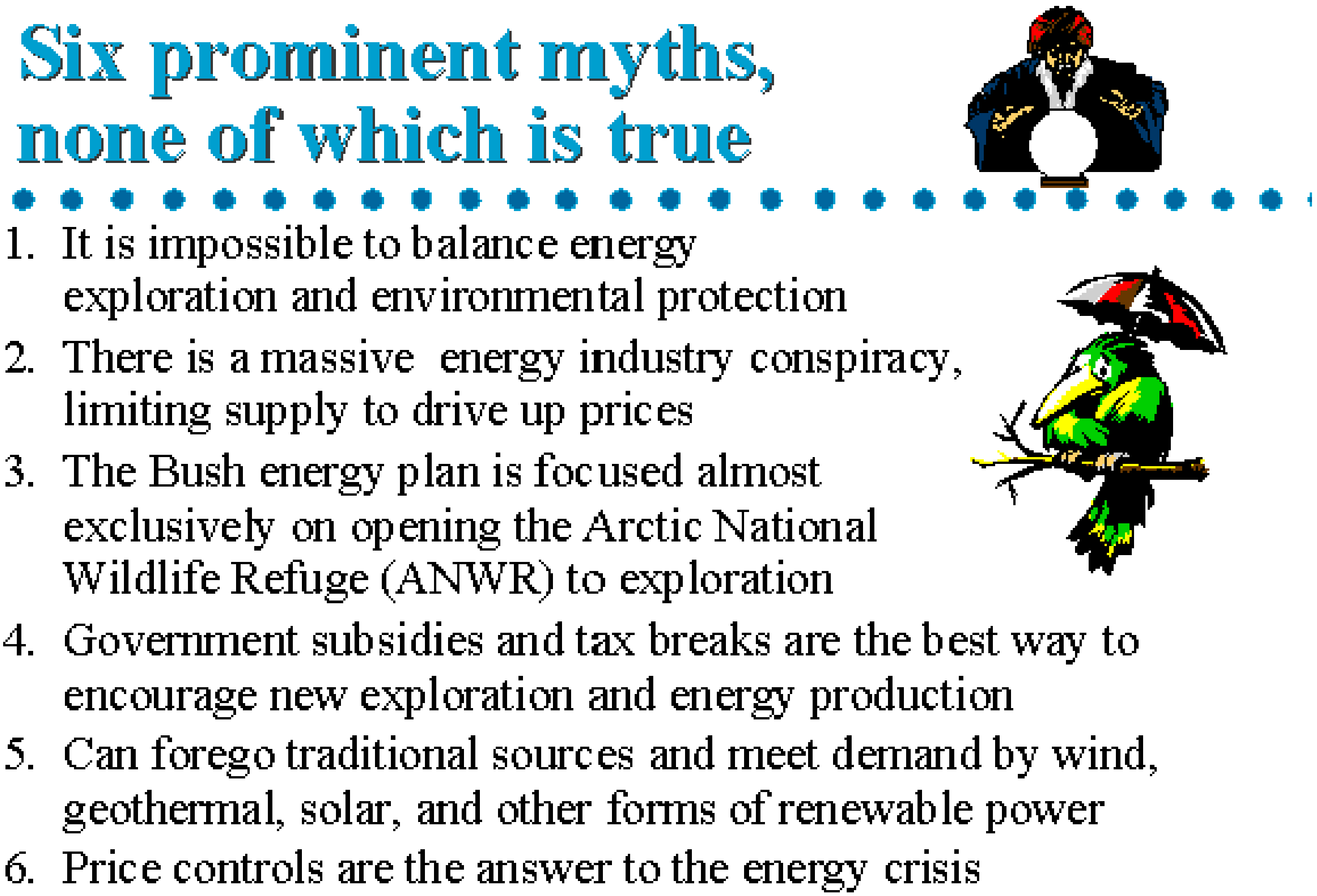

Six prominent myths, none of which is true

1. It is impossible to balance energy exploration and environmental protection
2. There is a massive energy industry conspiracy, limiting supply to drive up prices
3. The Bush energy plan is focused almost exclusively on opening the Arctic National Wildlife Refuge (ANWR) to exploration
4. Government subsidies and tax breaks are the best way to encourage new exploration and energy production
5. Can forego traditional sources and meet demand by wind, geothermal, solar, and other forms of renewable power
6. Price controls are the answer to the energy crisis

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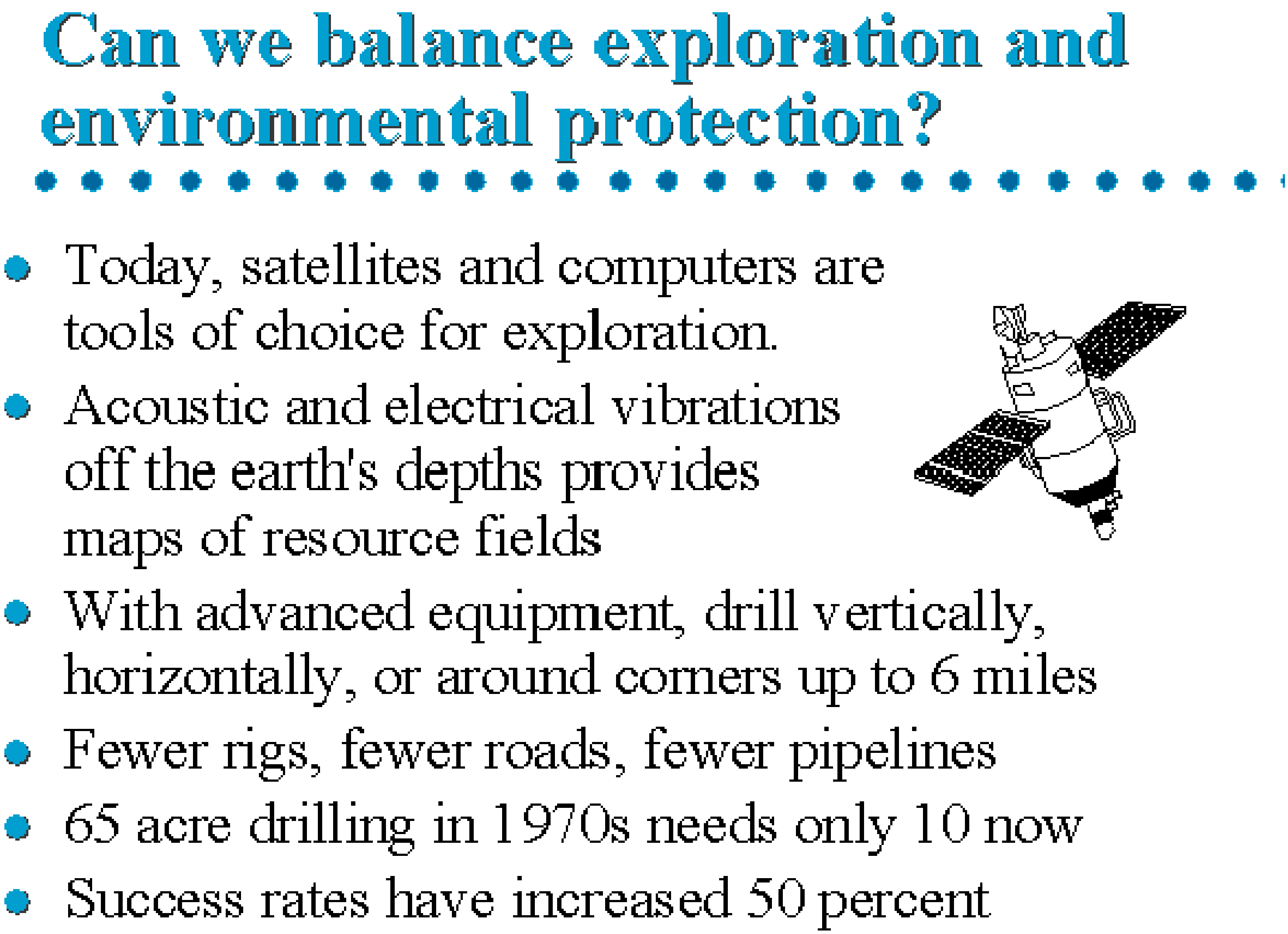

Can we balance exploration and environmental protection?

- Today, satellites and computers are tools of choice for exploration.
- Acoustic and electrical vibrations off the earth's depths provides maps of resource fields
- With advanced equipment, drill vertically, horizontally, or around corners up to 6 miles
- Fewer rigs, fewer roads, fewer pipelines
- 65 acre drilling in 1970s needs only 10 now
- Success rates have increased 50 percent

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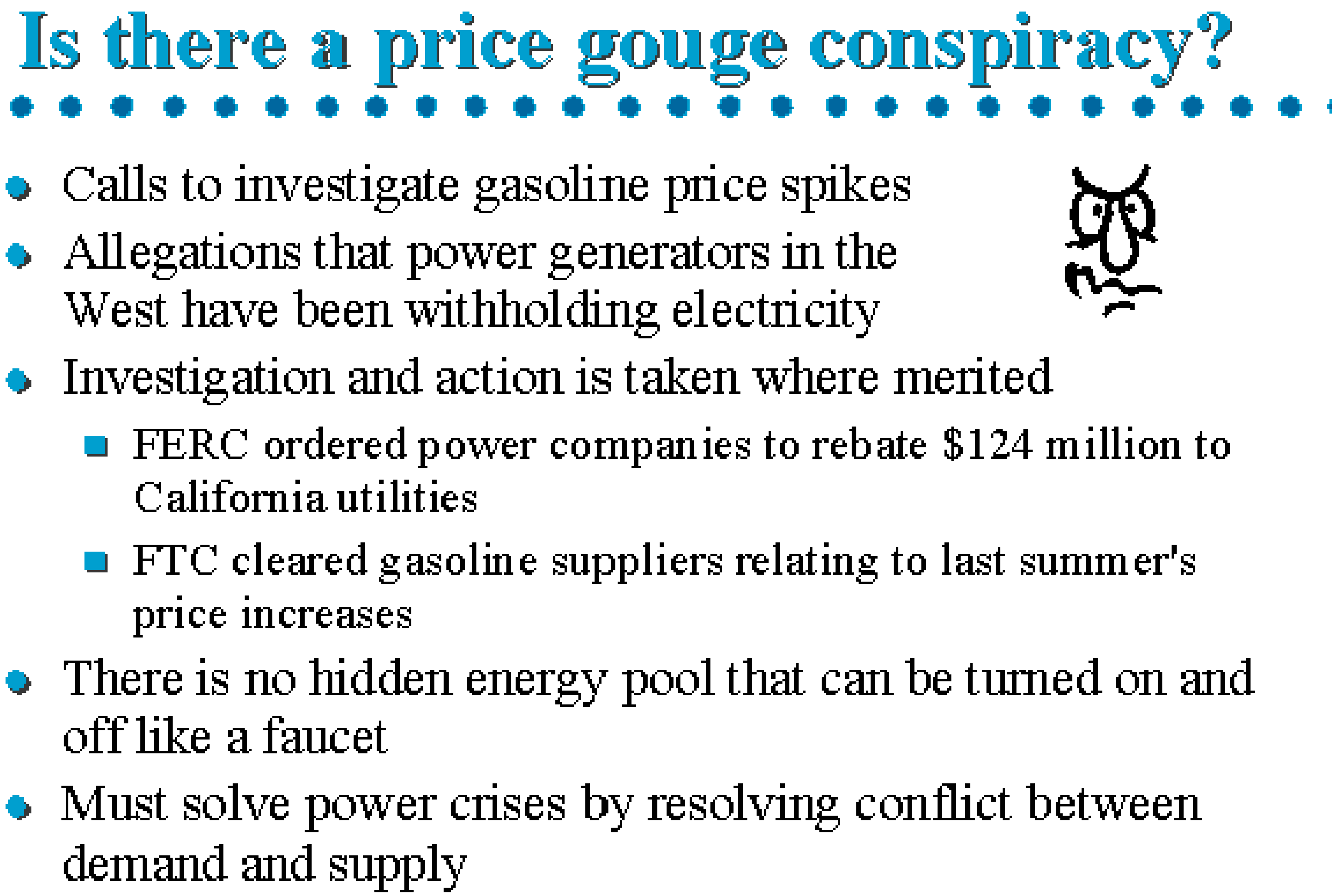

Is there a price gouge conspiracy?

- Calls to investigate gasoline price spikes
- Allegations that power generators in the West have been withholding electricity
- Investigation and action is taken where merited
  - FERC ordered power companies to rebate $124 million to California utilities
  - FTC cleared gasoline suppliers relating to last summer's price increases
- There is no hidden energy pool that can be turned on and off like a faucet
- Must solve power crises by resolving conflict between demand and supply

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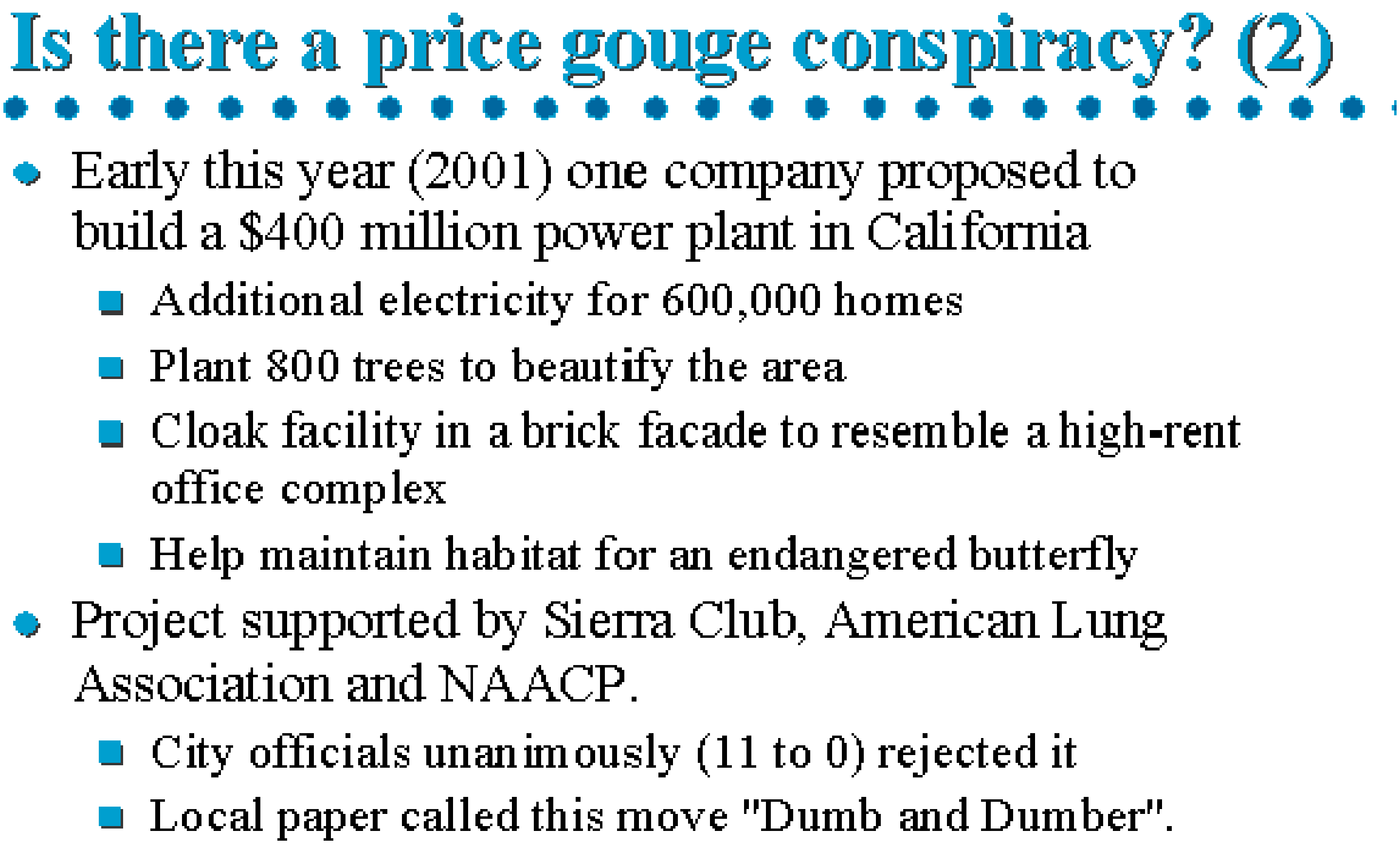

Is there a price gouge conspiracy? (2)

- Early this year (2001) one company proposed to build a $400 million power plant in California
  - Additional electricity for 600,000 homes
  - Plant 800 trees to beautify the area
  - Cloak facility in a brick facade to resemble a high-rent office complex
  - Help maintain habitat for an endangered butterfly
- Project supported by Sierra Club, American Lung Association and NAACP.
  - City officials unanimously (11 to 0) rejected it
  - Local paper called this move "Dumb and Dumber".

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Is there a price gouge conspiracy? (3)

- Plans to build a 550 megawatt gas-fired generator in a Los Angeles suburb were scrapped
- Residents voted 2:1 against the project
- Local mayor launched a hunger strike in opposition to it.
- In California:
  - Workers are being laid off
  - Companies are leaving the state
  - Consumers threatened with rolling blackouts
  - Local officials reject power plants with little regard
- Is it really any mystery why there hasn't been a single new power plant built in California in the last decade?

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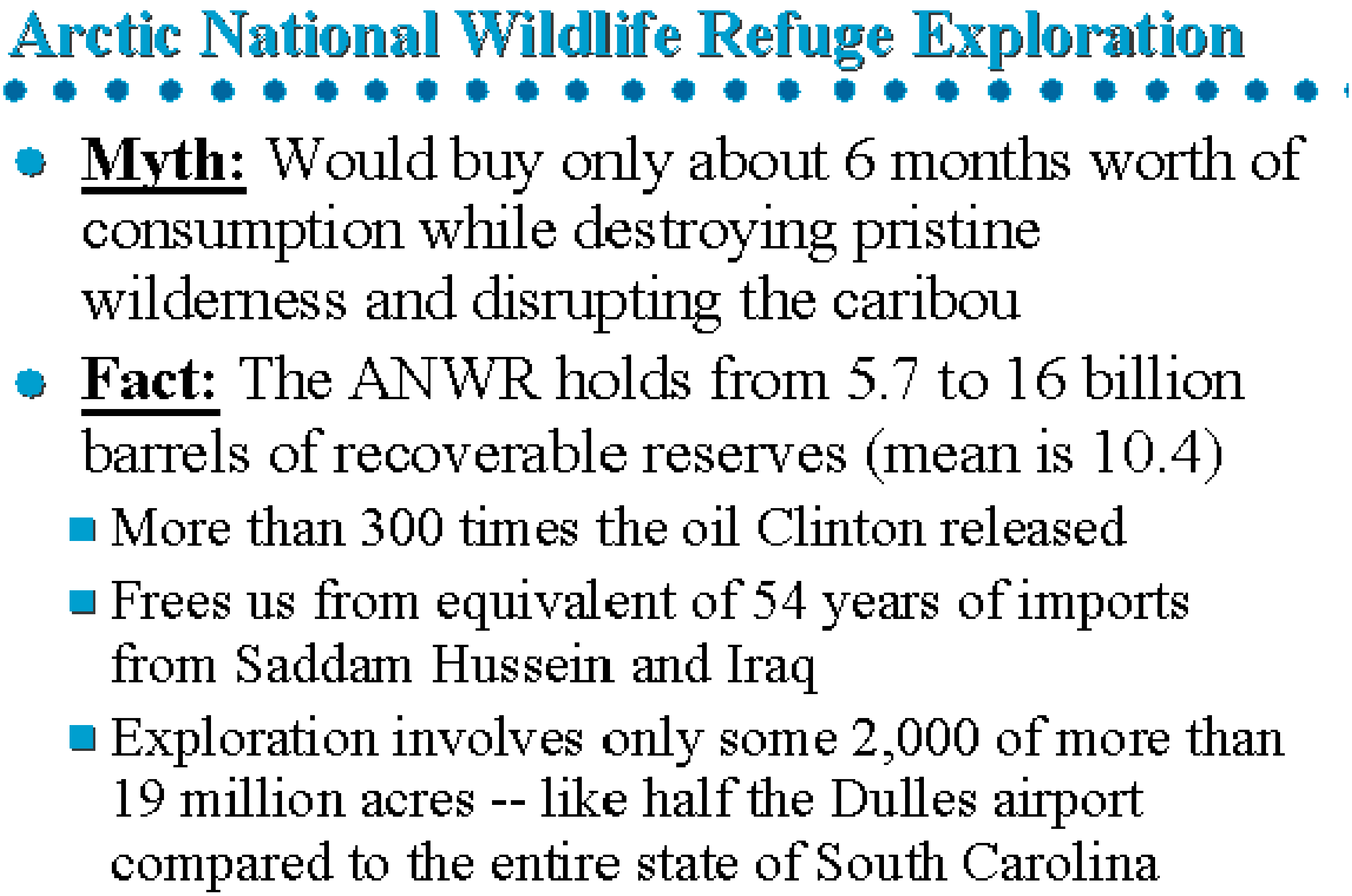

Arctic National Wildlife Refuge Exploration

- **Myth:** Would buy only about 6 months worth of consumption while destroying pristine wilderness and disrupting the caribou
- **Fact:** The ANWR holds from 5.7 to 16 billion barrels of recoverable reserves (mean is 10.4)
  - More than 300 times the oil Clinton released
  - Frees us from equivalent of 54 years of imports from Saddam Hussein and Iraq
  - Exploration involves only some 2,000 of more than 19 million acres -- like half the Dulles airport compared to the entire state of South Carolina

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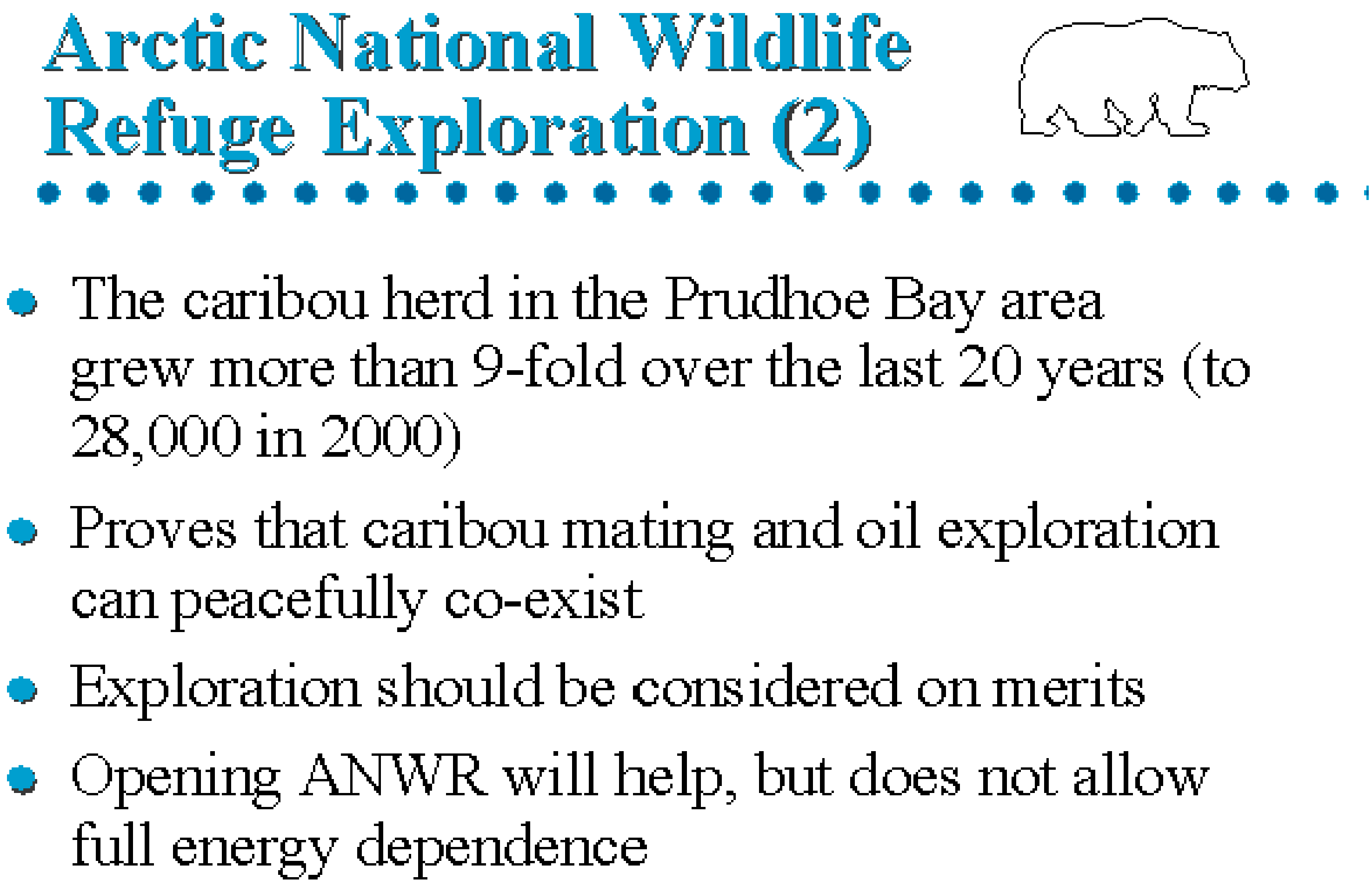

Arctic National Wildlife Refuge Exploration (2)

- The caribou herd in the Prudhoe Bay area grew more than 9-fold over the last 20 years (to 28,000 in 2000)
- Proves that caribou mating and oil exploration can peacefully co-exist
- Exploration should be considered on merits
- Opening ANWR will help, but does not allow full energy dependence

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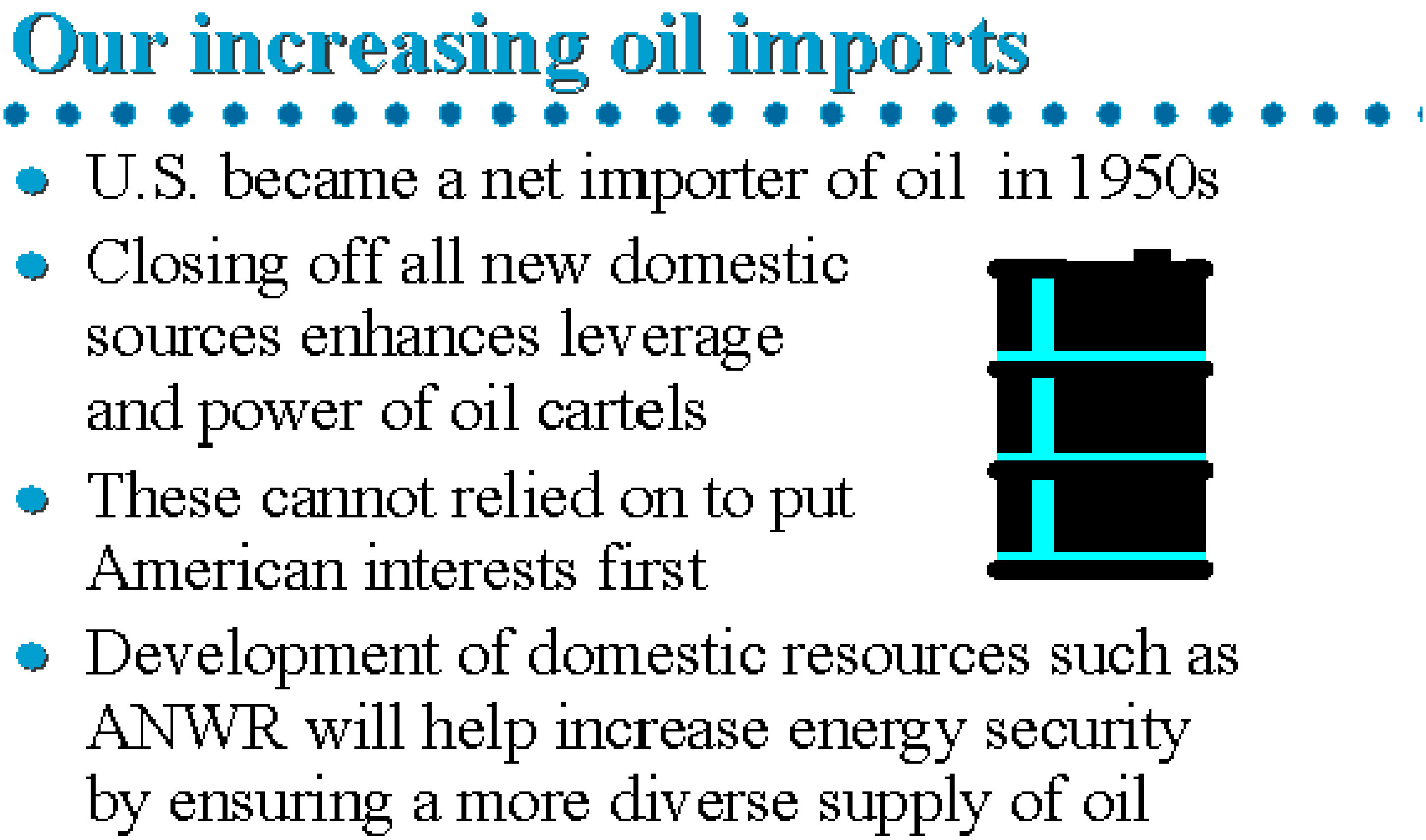

Our increasing oil imports

- U.S. became a net importer of oil in 1950s
- Closing off all new domestic sources enhances leverage and power of oil cartels
- These cannot relied on to put American interests first
- Development of domestic resources such as ANWR will help increase energy security by ensuring a more diverse supply of oil

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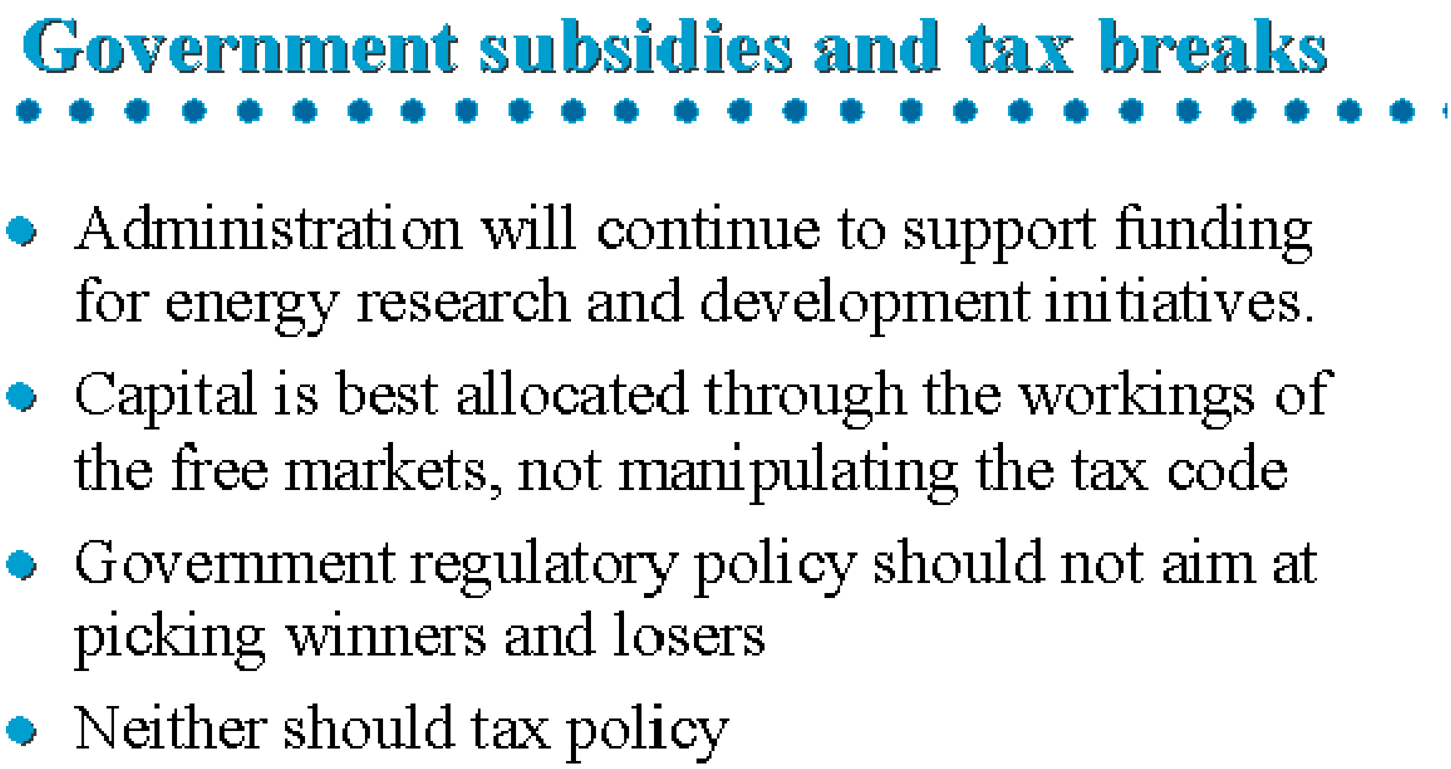

Government subsidies and tax breaks

- Administration will continue to support funding for energy research and development initiatives.
- Capital is best allocated through the workings of the free markets, not manipulating the tax code
- Government regulatory policy should not aim at picking winners and losers
- Neither should tax policy

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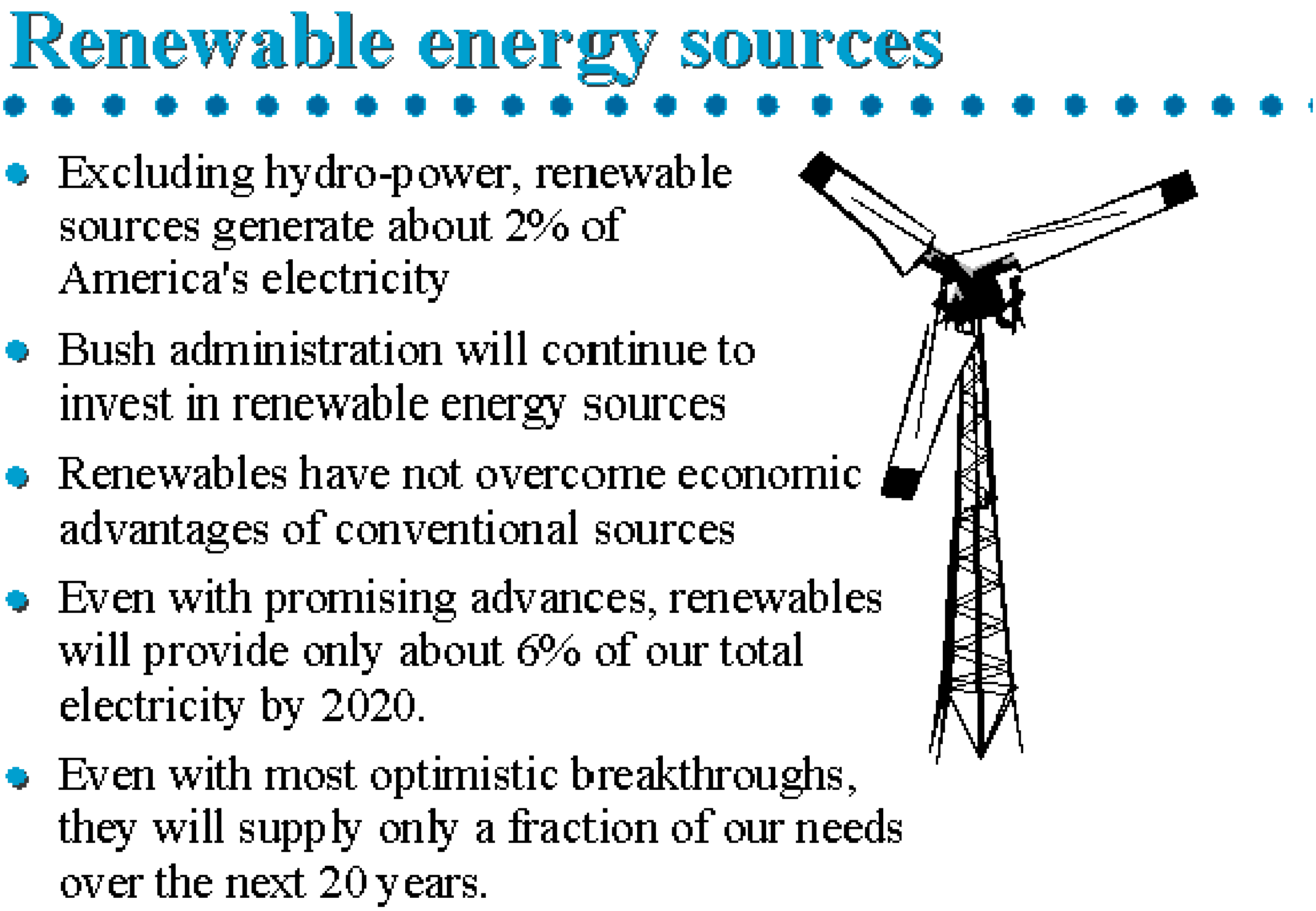

Renewable energy sources

- Excluding hydro-power, renewable sources generate about 2% of America's electricity
- Bush administration will continue to invest in renewable energy sources
- Renewables have not overcome economic advantages of conventional sources
- Even with promising advances, renewables will provide only about 6% of our total electricity by 2020.
- Even with most optimistic breakthroughs, they will supply only a fraction of our needs over the next 20 years.

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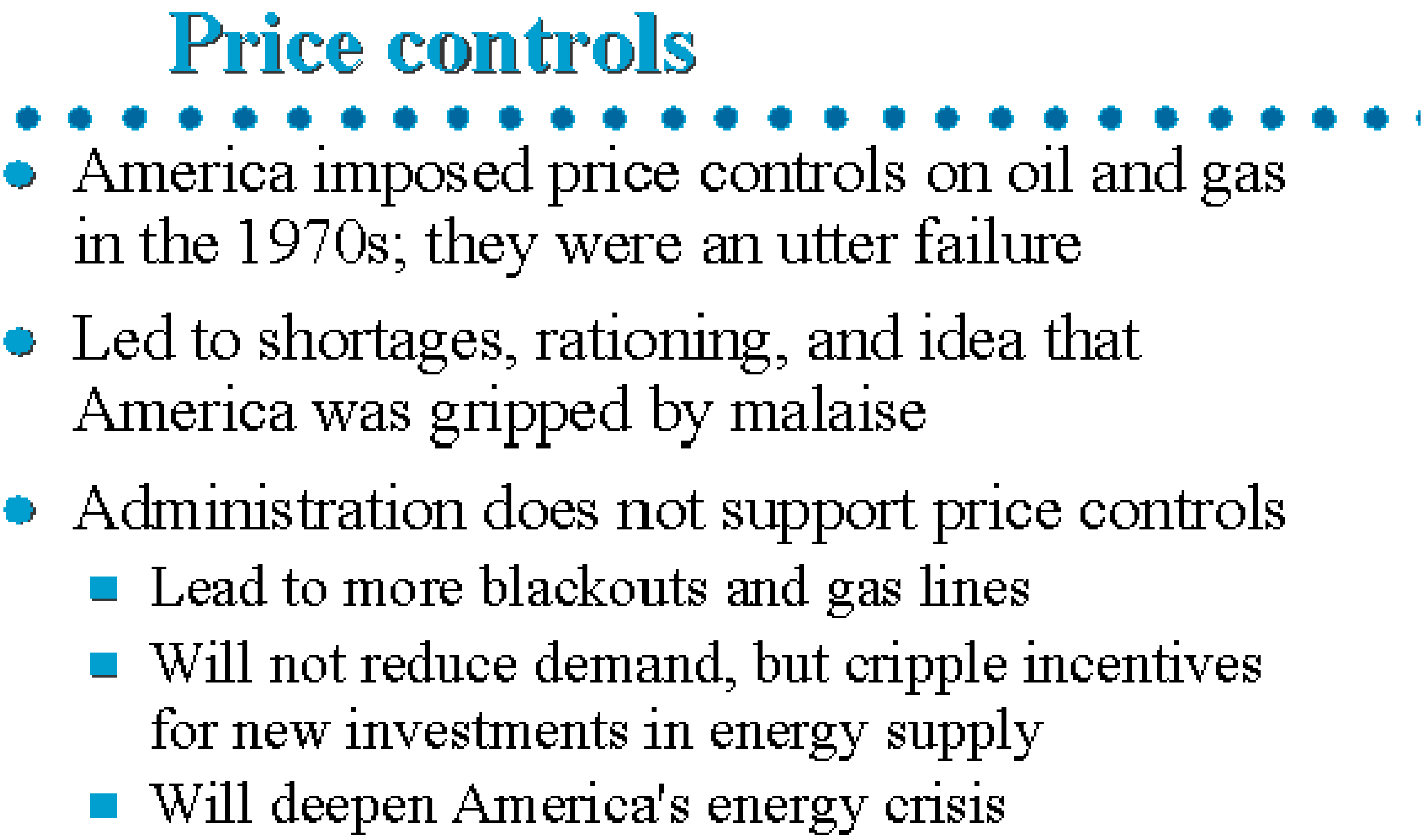

Price controls

- America imposed price controls on oil and gas in the 1970s; they were an utter failure
- Led to shortages, rationing, and idea that America was gripped by malaise
- Administration does not support price controls
  - Lead to more blackouts and gas lines
  - Will not reduce demand, but cripple incentives for new investments in energy supply
  - Will deepen America's energy crisis

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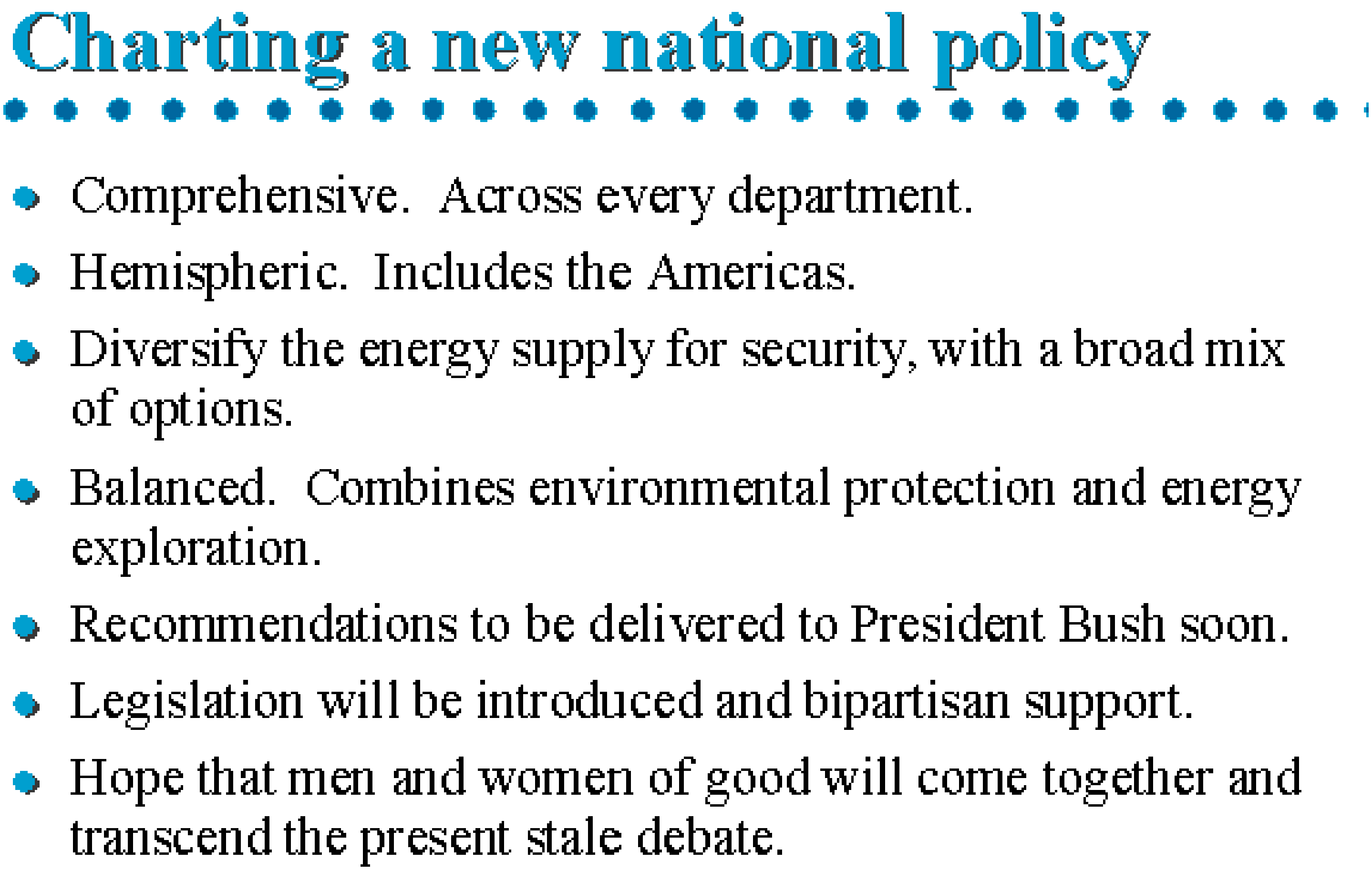

Charting a new national policy

- Comprehensive. Across every department.
- Hemispheric. Includes the Americas.
- Diversify the energy supply for security, with a broad mix of options.
- Balanced. Combines environmental protection and energy exploration.
- Recommendations to be delivered to President Bush soon.
- Legislation will be introduced and bipartisan support.
- Hope that men and women of good will come together and transcend the present stale debate.

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Commentary

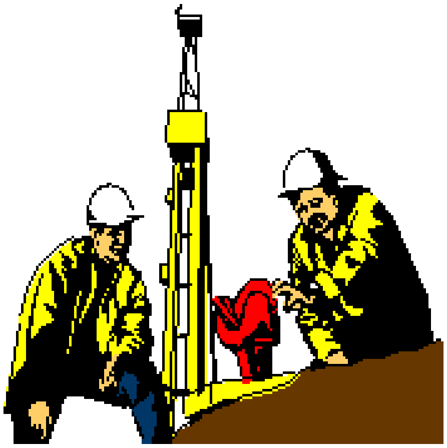

by Tom Bearden, Ph.D.

12 April 2001

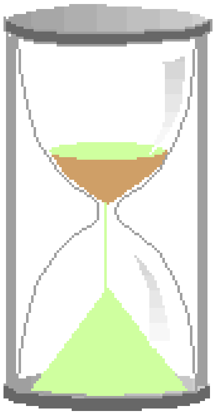

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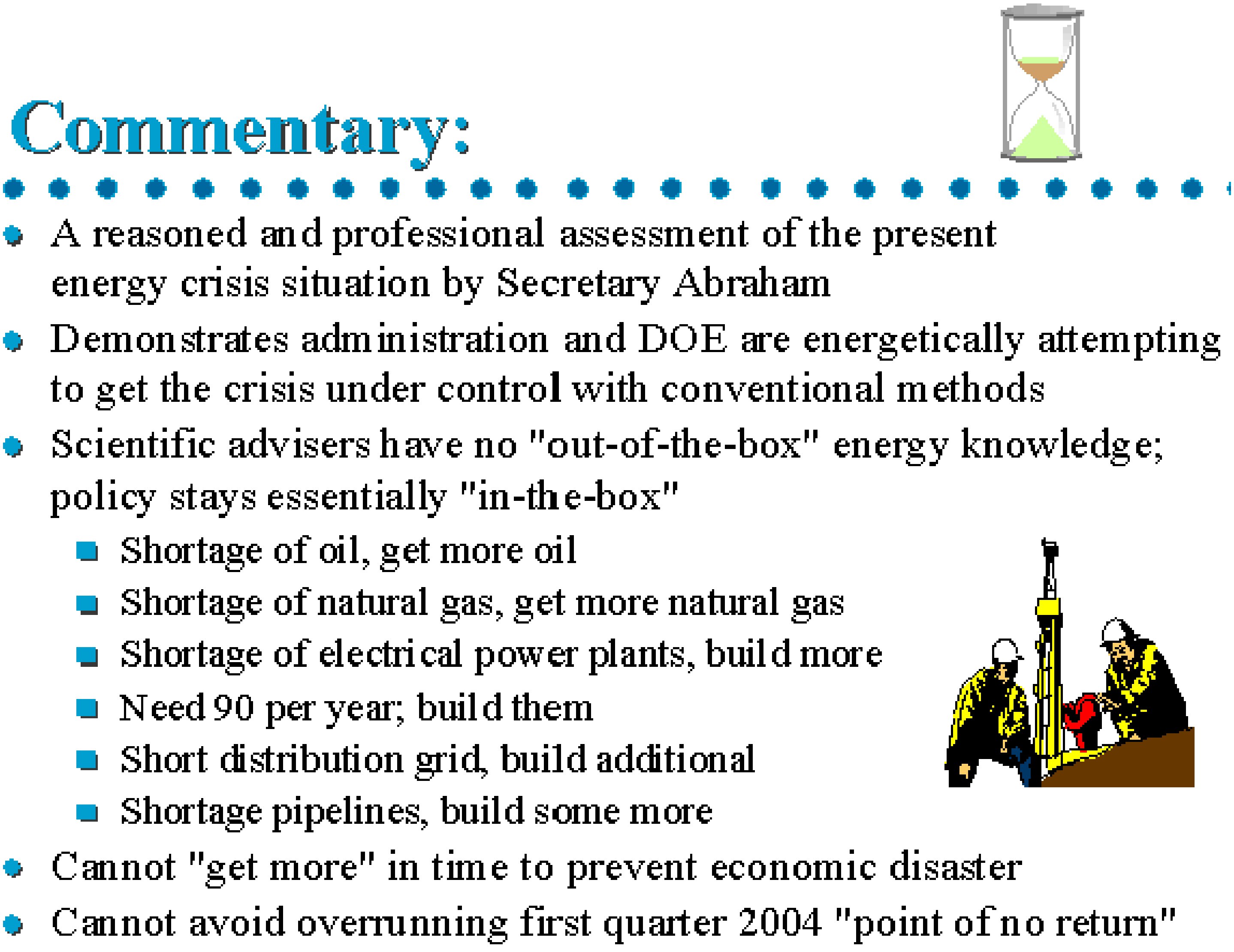

Commentary:

- A reasoned and professional assessment of the present energy crisis situation by Secretary Abraham
- Demonstrates administration and DOE are energetically attempting to get the crisis under control with conventional methods
- Scientific advisers have no "out-of-the-box" energy knowledge; policy stays essentially "in-the-box"
  - Shortage of oil, get more oil
  - Shortage of natural gas, get more natural gas
  - Shortage of electrical power plants, build more
  - Need 90 per year; build them
  - Short distribution grid, build additional
  - Shortage pipelines, build some more
- Cannot "get more" in time to prevent economic disaster
- Cannot avoid overrunning first quarter 2004 "point of no return"

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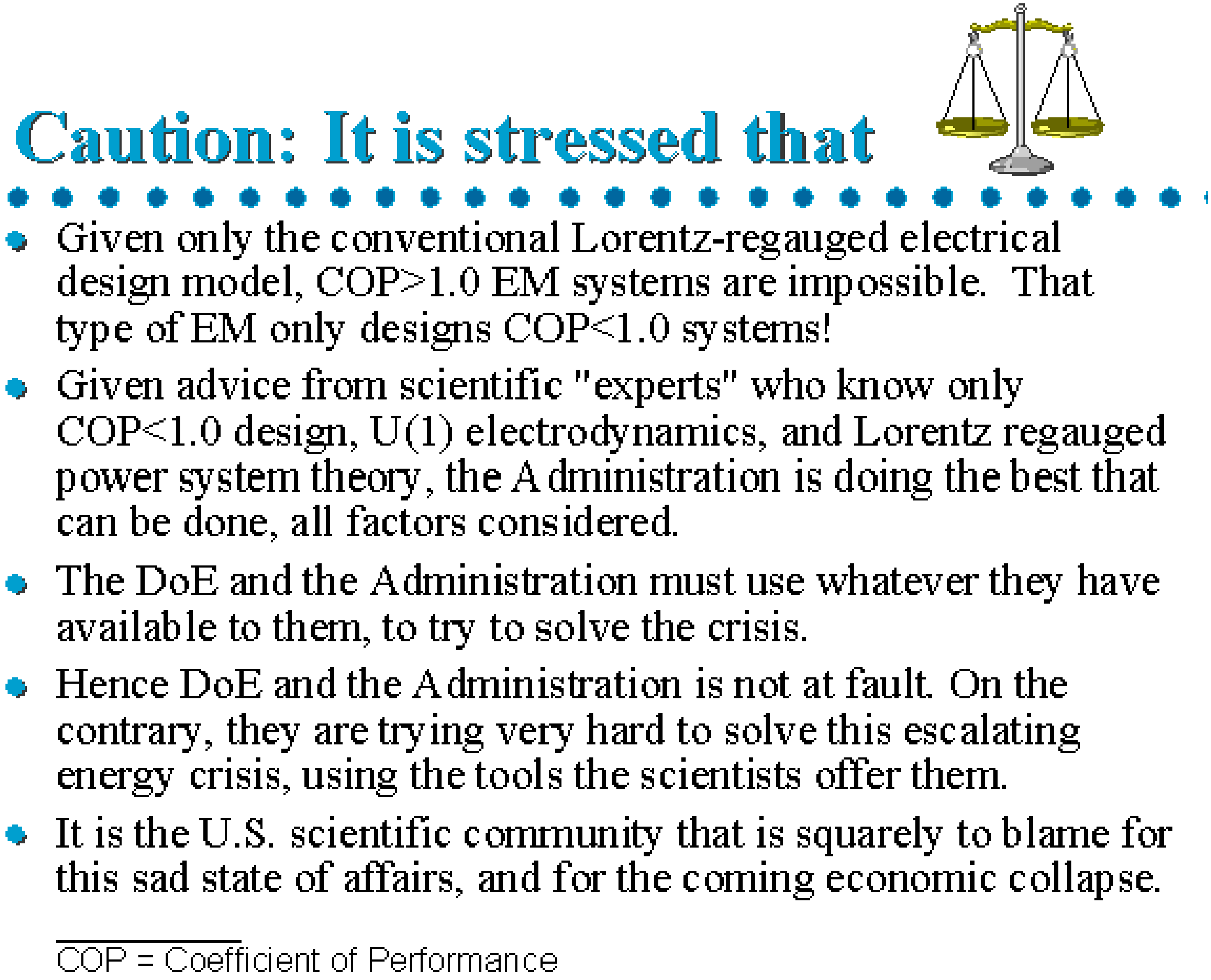

Caution: It is stressed that

- Given only the conventional Lorentz-regauged electrical design model, COP>1.0 EM systems are impossible. That type of EM only designs COP<1.0 systems!
- Given advice from scientific "experts" who know only COP<1.0 design, U(1) electrodynamics, and Lorentz regauged power system theory, the Administration is doing the best that can be done, all factors considered.
- The DoE and the Administration must use whatever they have available to them, to try to solve the crisis.
- Hence DoE and the Administration is not at fault. On the contrary, they are trying very hard to solve this escalating energy crisis, using the tools the scientists offer them.
- It is the U.S. scientific community that is squarely to blame for this sad state of affairs, and for the coming economic collapse.

COP = Coefficient of Performance

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An example of the time problem

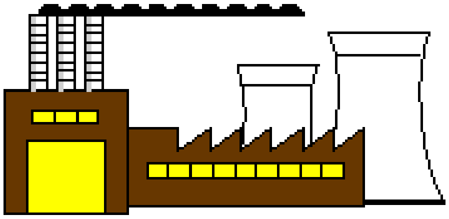

- TVA and Texaco are discussing building a coal gasification 1,500 megawatt power plant.
    - Near Scottsboro, Alabama
    - Construction could begin in 2002.
    - In 3-6 years, begin producing electricity.
    - If 5 years, it will come on line in 2007.
- 90 plants are required per year, beginning now.
- 2007 is about the time that world economies are crumbling, conflicts are raging, and all the arsenals weapons of mass destruction will be unleashed.
- 2007 is about the time civilization will be destroyed, if we continue on the present course.
- With only present solution, can get perhaps 400 to 450 plants ready to come on line, *about the time they are destroyed*

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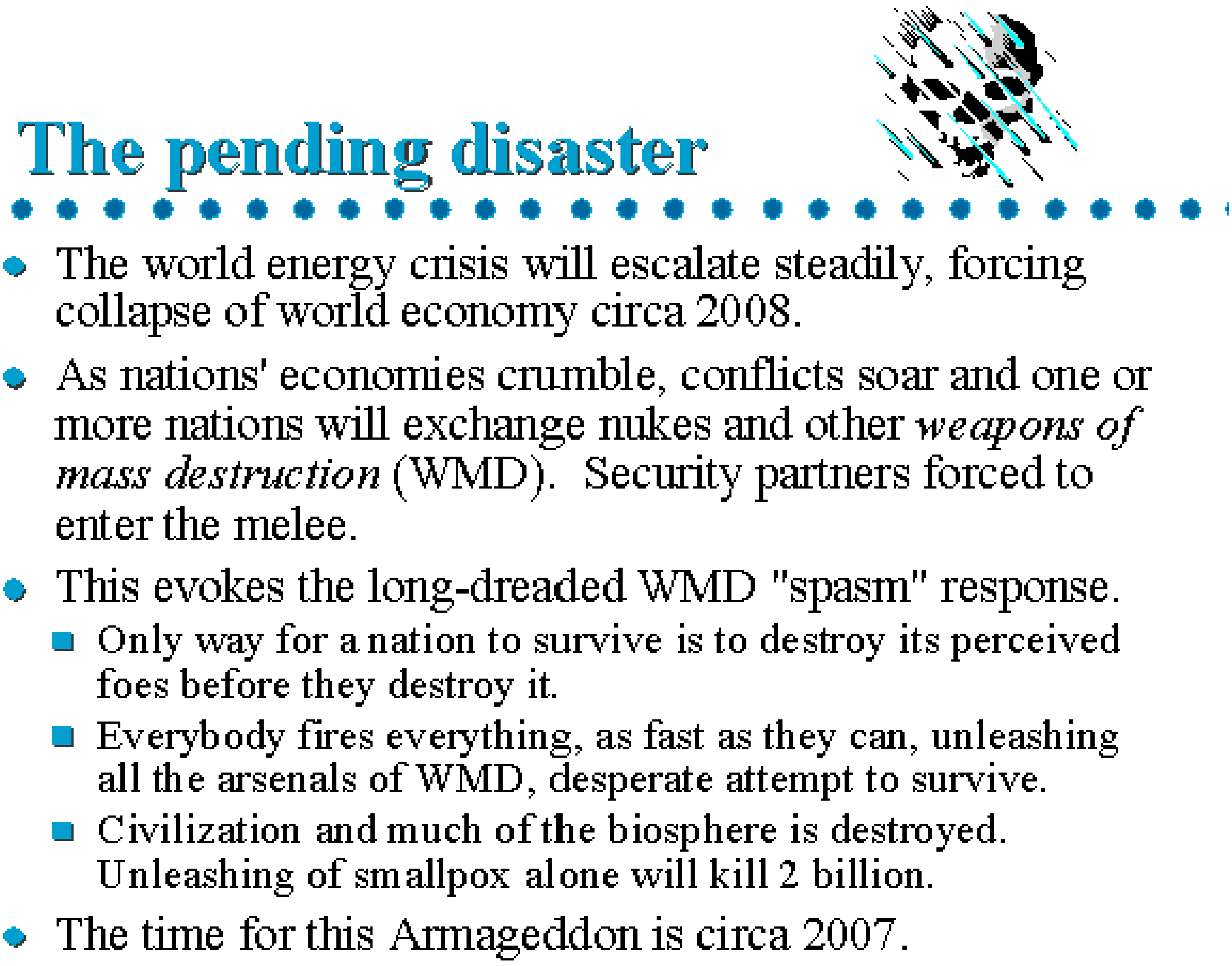

The pending disaster

- The world energy crisis will escalate steadily, forcing collapse of world economy circa 2008.
- As nations' economies crumble, conflicts soar and one or more nations will exchange nukes and other *weapons of mass destruction* (WMD). Security partners forced to enter the melee.
- This evokes the long-dreaded WMD "spasm" response.
  - Only way for a nation to survive is to destroy its perceived foes before they destroy it.
  - Everybody fires everything, as fast as they can, unleashing all the arsenals of WMD, desperate attempt to survive.
  - Civilization and much of the biosphere is destroyed. Unleashing of smallpox alone will kill 2 billion.
- The time for this Armageddon is circa 2007.

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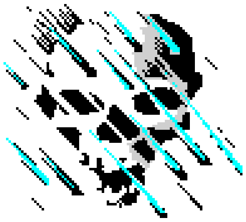

The bottom line:

- Self-powering and COP>1.0 electrical power systems must be rolling off the assembly lines en masse by first quarter 2004. That is the "point of no return".
- Otherwise, the point of no return will be overrun and no solution is possible, by any means, by anyone or by everyone.
- If that deadline is missed, the crisis curves cannot be "damped" in time to prevent world economic collapse.
- It is still doable, but only with a massive national effort of the highest priority. No one recognizes that as yet.
- Meanwhile, the scientific community is doing business as usual. You will have to just push most of it aside.
- We are "fiddling while Rome prepares to explode".

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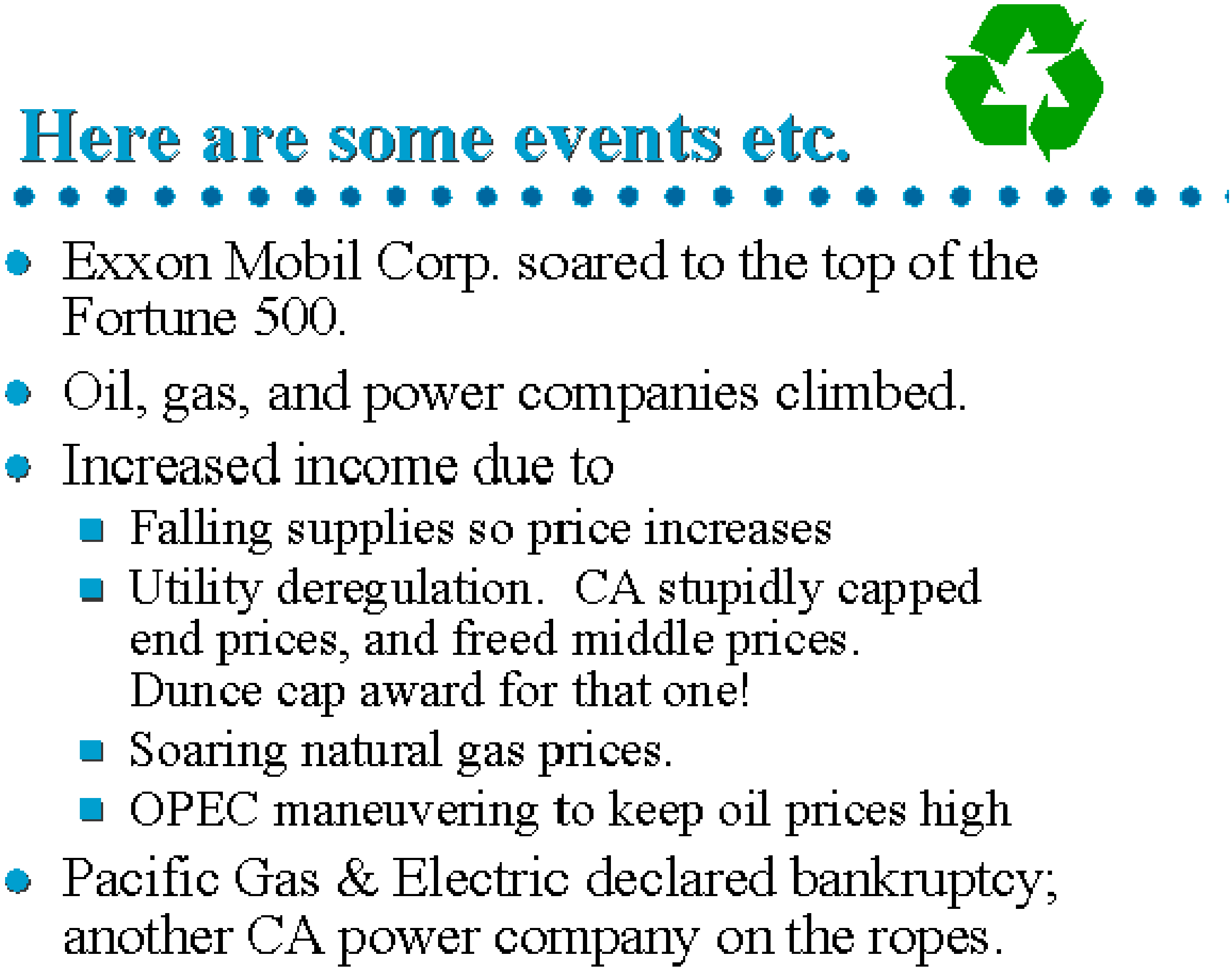

Here are some events etc.

- Exxon Mobil Corp. soared to the top of the Fortune 500.
- Oil, gas, and power companies climbed.
- Increased income due to
  - Falling supplies so price increases
  - Utility deregulation. CA stupidly capped end prices, and freed middle prices. Dunce cap award for that one!
  - Soaring natural gas prices.
  - OPEC maneuvering to keep oil prices high
- Pacific Gas & Electric declared bankruptcy; another CA power company on the ropes.

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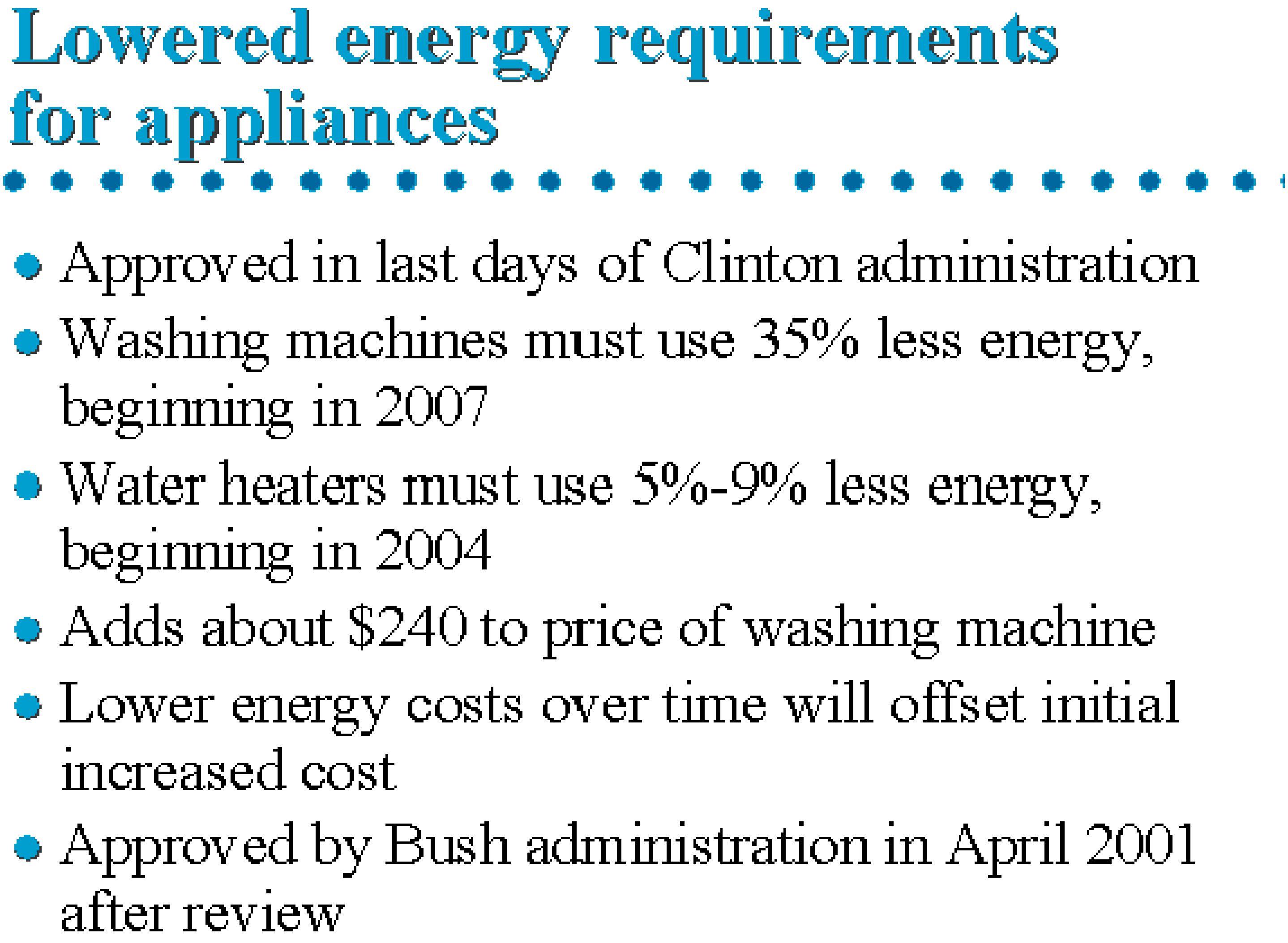

Lowered energy requirements for appliances

- Approved in last days of Clinton administration
- Washing machines must use 35% less energy, beginning in 2007
- Water heaters must use 5%-9% less energy, beginning in 2004
- Adds about $240 to price of washing machine
- Lower energy costs over time will offset initial increased cost
- Approved by Bush administration in April 2001 after review

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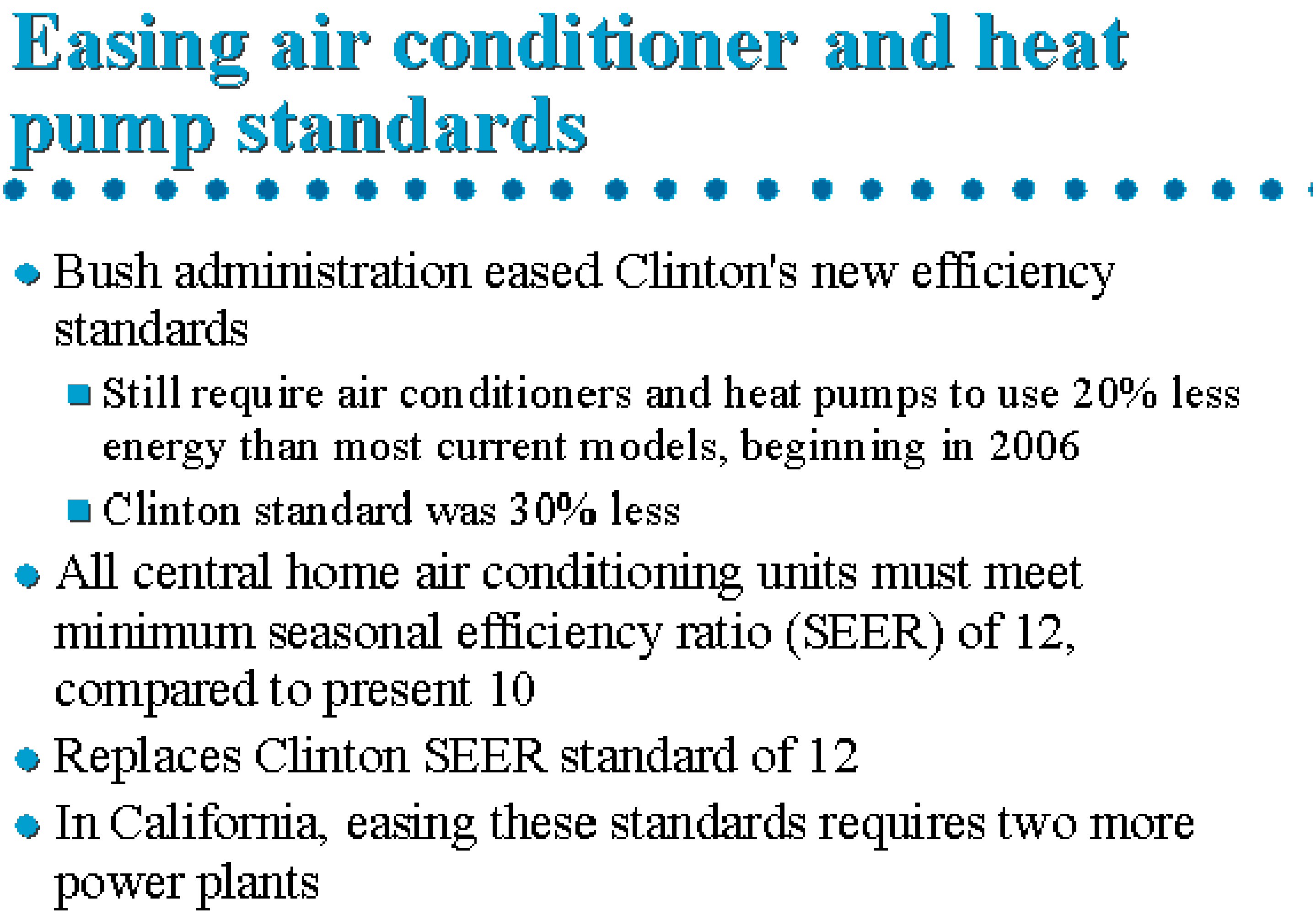

Easing air conditioner and heat pump standards

- Bush administration eased Clinton's new efficiency standards
  - Still require air conditioners and heat pumps to use 20% less energy than most current models, beginning in 2006
  - Clinton standard was 30% less
- All central home air conditioning units must meet minimum seasonal efficiency ratio (SEER) of 12, compared to present 10
- Replaces Clinton SEER standard of 12
- In California, easing these standards requires two more power plants

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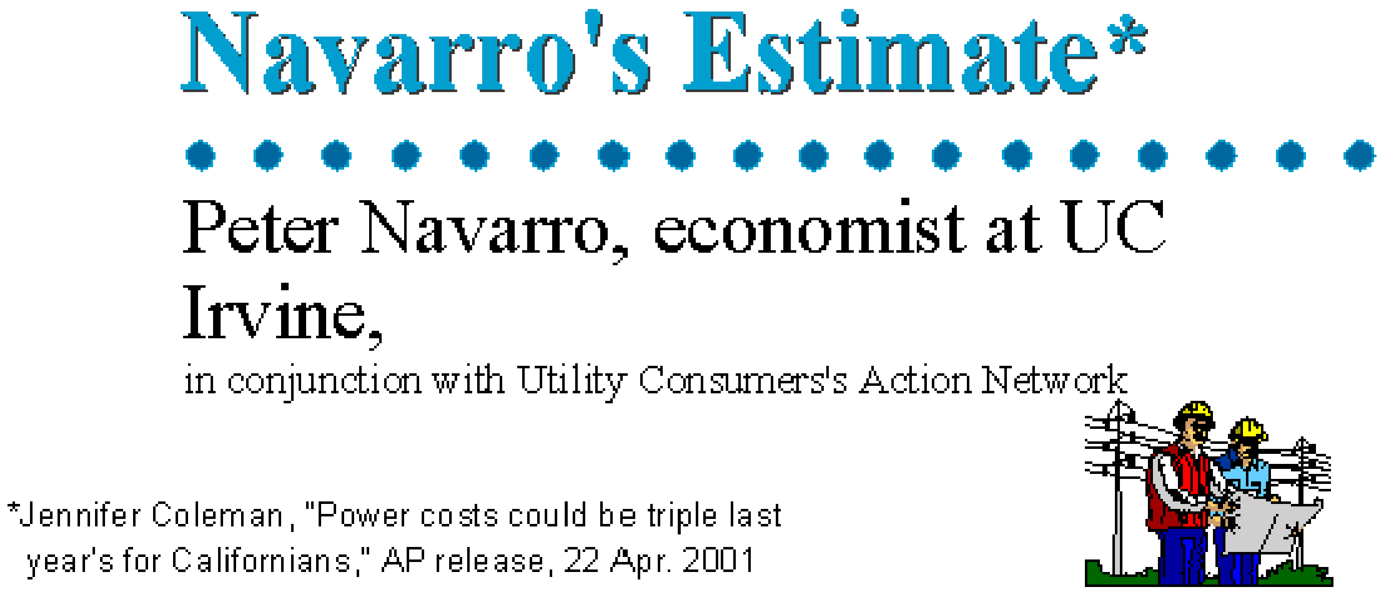

Navarro's Estimate*

Peter Navarro, economist at UC Irvine,

in conjunction with Utility Consumers's Action Network

*Jennifer Coleman, "Power costs could be triple last year's for Californians," AP release, 22 Apr. 2001

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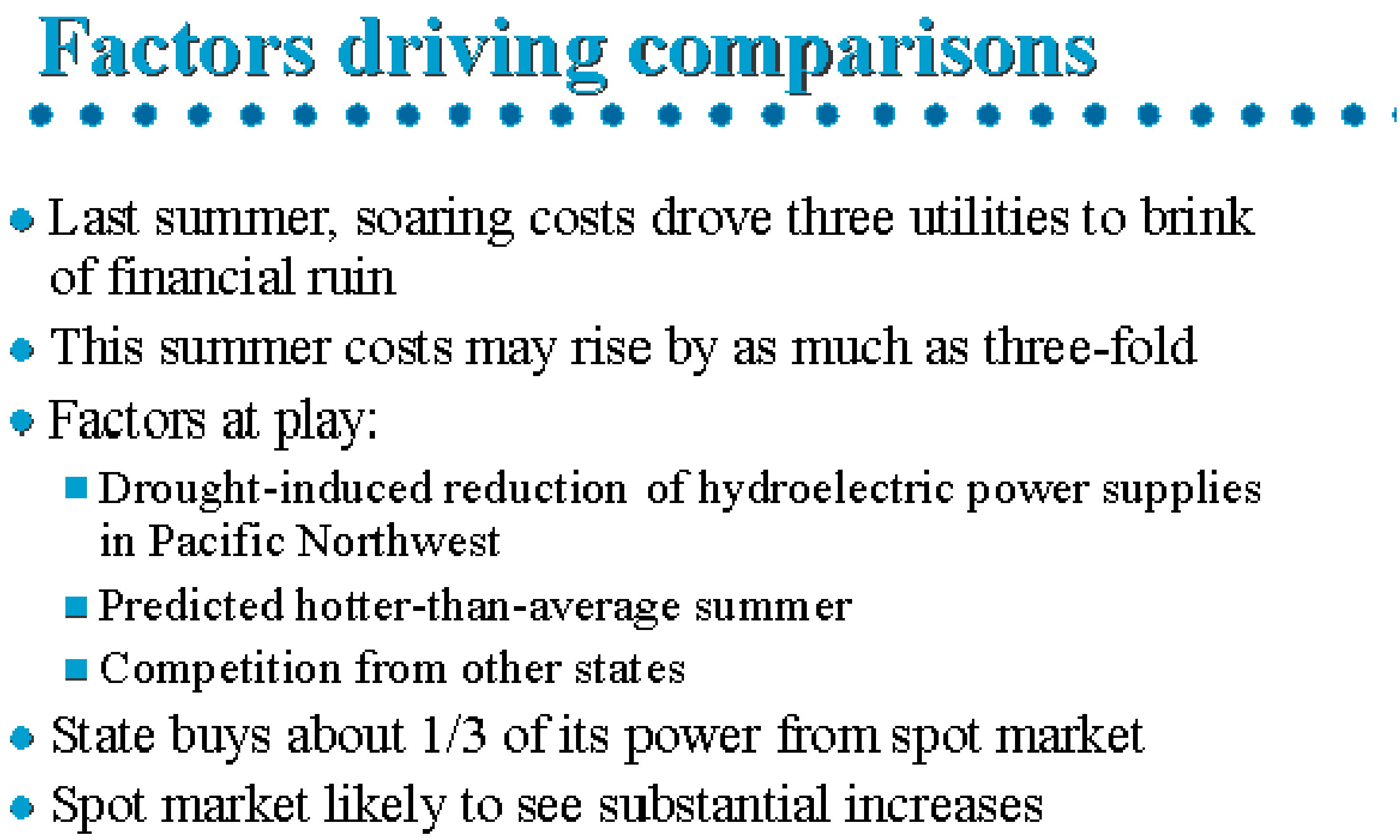

Factors driving comparisons

- Last summer, soaring costs drove three utilities to brink of financial ruin
- This summer costs may rise by as much as three-fold
- Factors at play:
  - Drought-induced reduction of hydroelectric power supplies in Pacific Northwest
  - Predicted hotter-than-average summer
  - Competition from other states
- State buys about 1/3 of its power from spot market
- Spot market likely to see substantial increases

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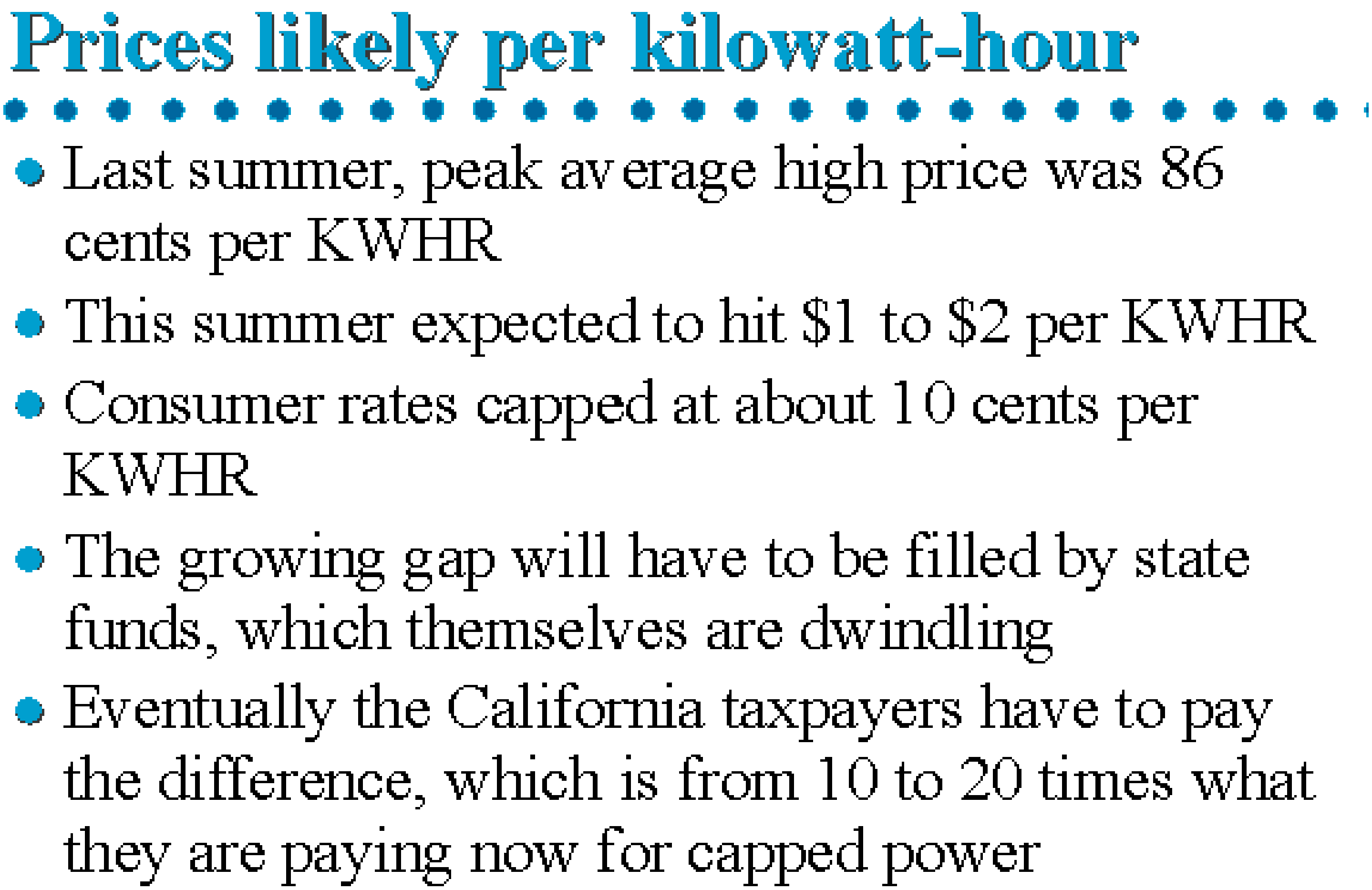

Prices likely per kilowatt-hour

- Last summer, peak average high price was 86 cents per KWHR
- This summer expected to hit $1 to $2 per KWHR
- Consumer rates capped at about 10 cents per KWHR
- The growing gap will have to be filled by state funds, which themselves are dwindling
- Eventually the California taxpayers have to pay the difference, which is from 10 to 20 times what they are paying now for capped power

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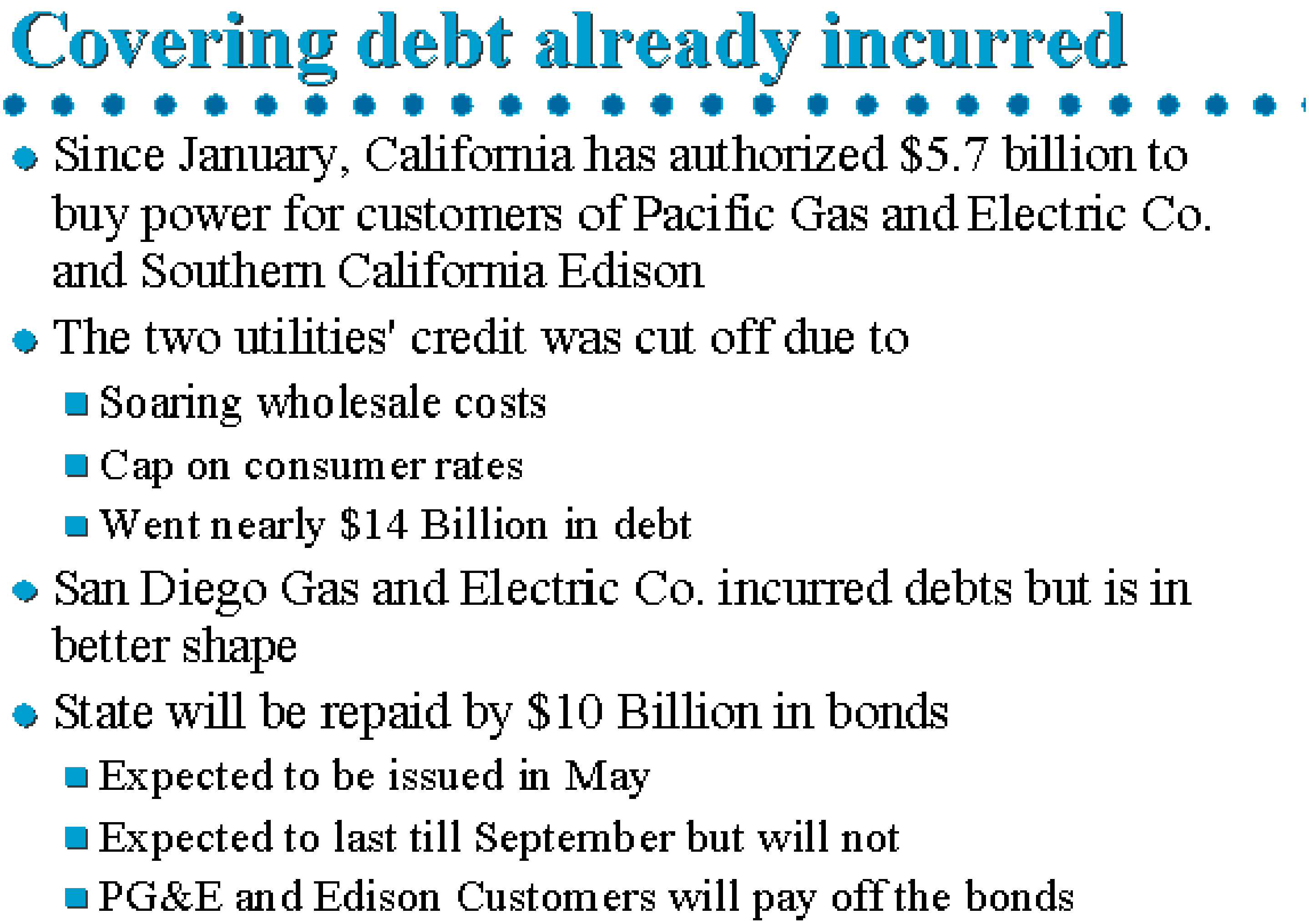

Covering debt already incurred

- Since January, California has authorized $5.7 billion to buy power for customers of Pacific Gas and Electric Co. and Southern California Edison
- The two utilities' credit was cut off due to
  - Soaring wholesale costs
  - Cap on consumer rates
  - Went nearly $14 Billion in debt
- San Diego Gas and Electric Co. incurred debts but is in better shape
- State will be repaid by $10 Billion in bonds
  - Expected to be issued in May
  - Expected to last till September but will not
  - PG&E and Edison Customers will pay off the bonds

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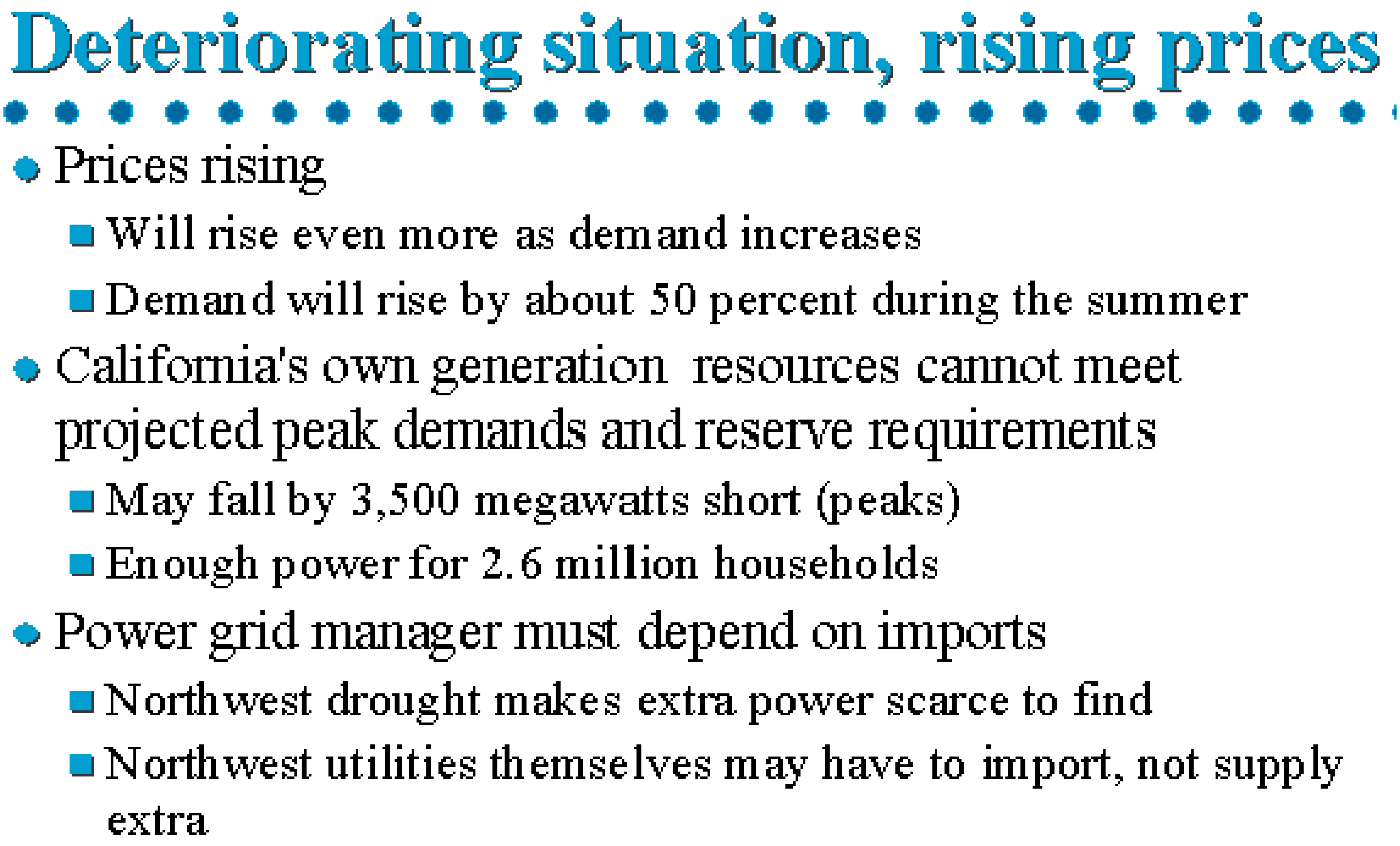

Deteriorating situation, rising prices

- Prices rising
  - Will rise even more as demand increases
  - Demand will rise by about 50 percent during the summer
- California's own generation resources cannot meet projected peak demands and reserve requirements
  - May fall by 3,500 megawatts short (peaks)
  - Enough power for 2.6 million households
- Power grid manager must depend on imports
  - Northwest drought makes extra power scarce to find
  - Northwest utilities themselves may have to import, not supply extra

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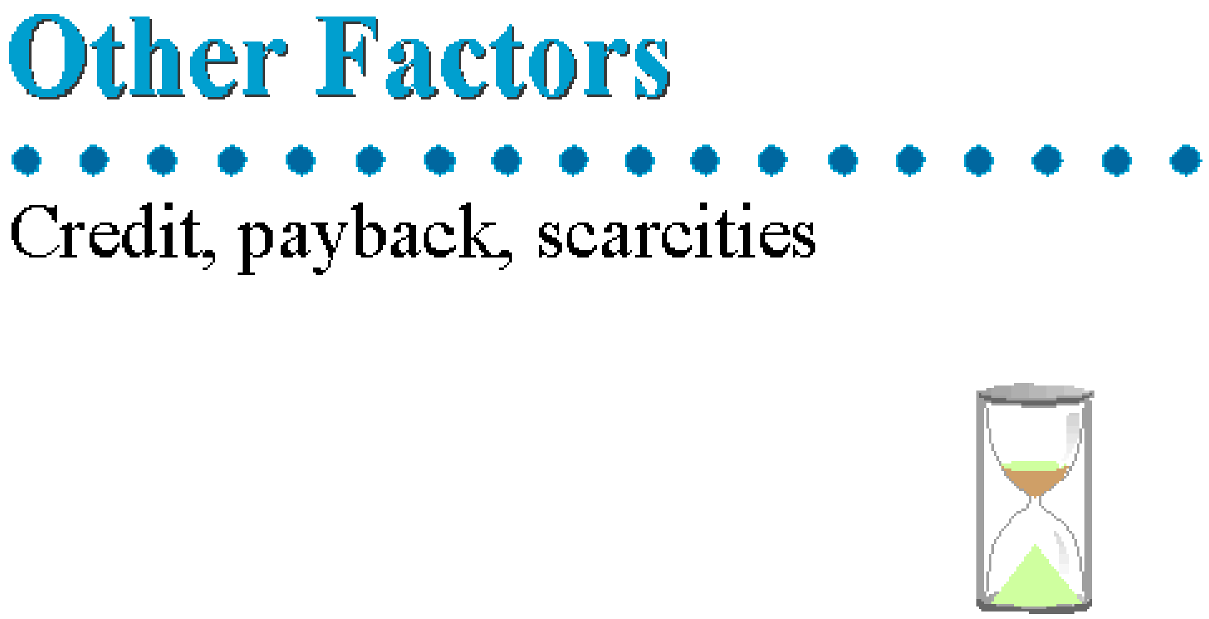

Other Factors

• • • • • • • • • • • • • • • • • •

Credit, payback, scarcities

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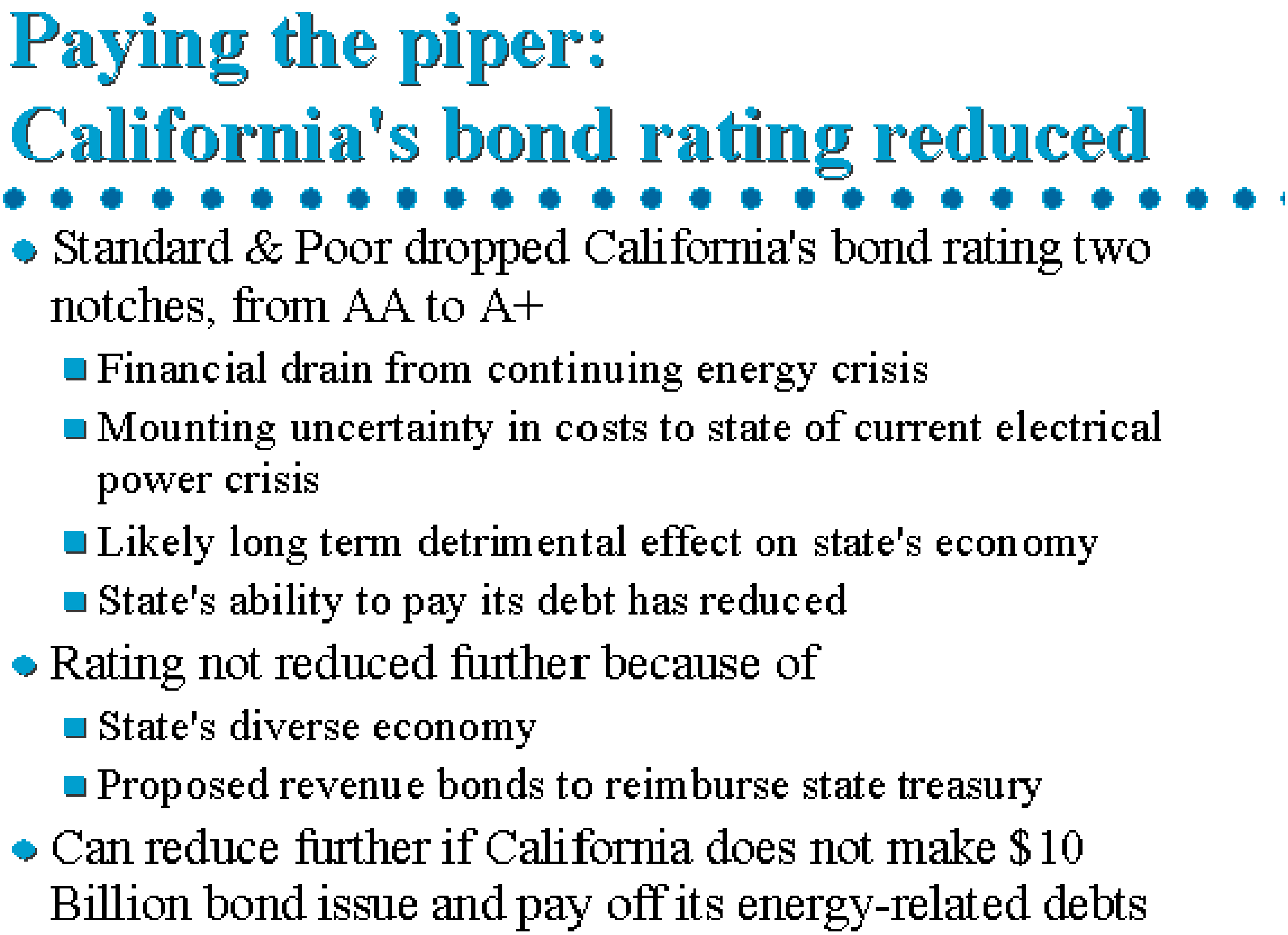

Paying the piper: California's bond rating reduced

- Standard & Poor dropped California's bond rating two notches, from AA to A+
  - Financial drain from continuing energy crisis
  - Mounting uncertainty in costs to state of current electrical power crisis
  - Likely long term detrimental effect on state's economy
  - State's ability to pay its debt has reduced
- Rating not reduced further because of
  - State's diverse economy
  - Proposed revenue bonds to reimburse state treasury
- Can reduce further if California does not make $10 Billion bond issue and pay off its energy-related debts

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Associated Press: Gasoline supplies are critical

- Supplies tightest for mid-April since U.S. government record-keeping began in 1963
- There is a shortage of reformulated gasoline that produces less smog and is required during summer
  - MTBE additive made from methanol, a derivative of natural gas
  - Natural gas prices quadrupled Dec-Jan; MTBE reduced by 1/3
  - California uses more MTBE-treated gasoline than any other state
  - Gas-guzzling SUV sales boomed in 1999 and 2000
- Any kind of refinery snag will be amplified
- Last winter, major refiners had to focus on filling heating oil shortage instead of replenishing gasoline supplies for summer
- Now many forced out of service to take care of maintenance that was put off to deal with the heating oil crisis
- Environmental restrictions make it difficult to build refineries; none constructed in the U.S. for more than 20 years

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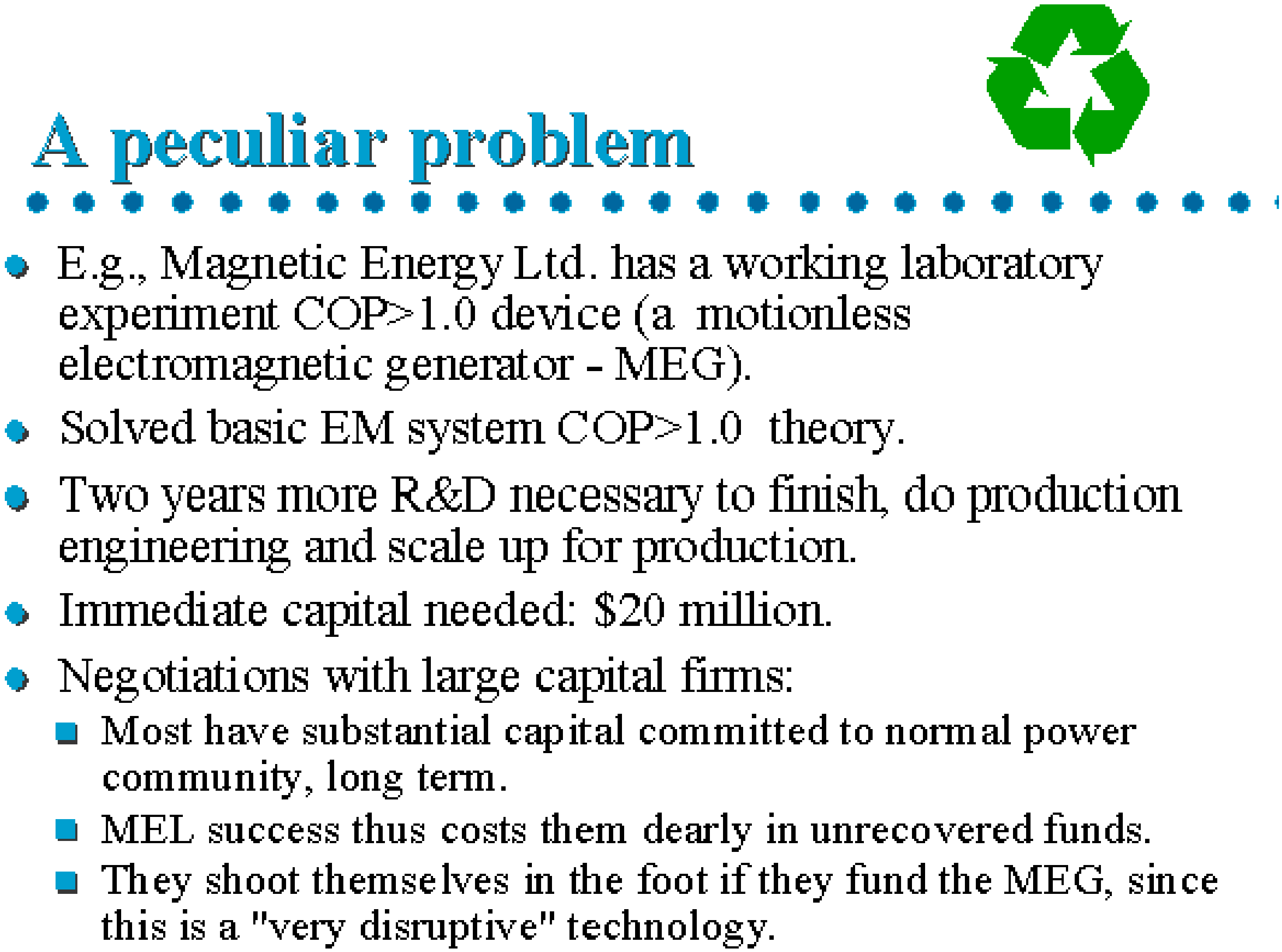

A peculiar problem

- E.g., Magnetic Energy Ltd. has a working laboratory experiment COP>1.0 device (a motionless electromagnetic generator - MEG).
- Solved basic EM system COP>1.0 theory.
- Two years more R&D necessary to finish, do production engineering and scale up for production.
- Immediate capital needed: $20 million.
- Negotiations with large capital firms:
  - Most have substantial capital committed to normal power community, long term.
  - MEL success thus costs them dearly in unrecovered funds.
  - They shoot themselves in the foot if they fund the MEG, since this is a "very disruptive" technology.

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MEG uses the Aharonov-Bohm effect to extract free energy from the vacuum (1)

- The Aharonov-Bohm effect (ABE) is in over 2,000 published physics papers in the hard literature.
- Hundreds of experiments prove it. Physicists themselves would not believe it for 25 years after it was advanced and proven. Now it is universally accepted.
- Free evocation of ABE never appeared for use in power systems, without paying energy to evoke it, until we used ABE in the MEG and *freely* evoked it.
- If the magnetic field **B** of a source is locally confined in a closed path (as in a toroid), the outside local spacetime (ST) where the **B**-field was withdrawn is still curved. Curved ST is energetic. The 3-space energy has been transformed into curl-free magnetic vector potential **A**. But one pays for that **A** around a toroid, since one has to "feed" the toroid.

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MEG uses the Aharonov-Bohm effect to extract free energy from the vacuum (2)

- We uncovered a transformer core material that will *freely* do that **B**-localization of the **B**-flux of a permanent magnet, extracting all the **B**-flux into a closed transformer-like core path.
- The uncurled **A**-potential forms outside the core path as a freely flowing river of energy.
- We pay nothing at all to get the **A**-energy flow going, or to sustain it. That's for free.
- The vacuum energy exchange and locally curved ST sustain that energy flow indefinitely, due to the permanent magnet dipole's broken 3-symmetry.

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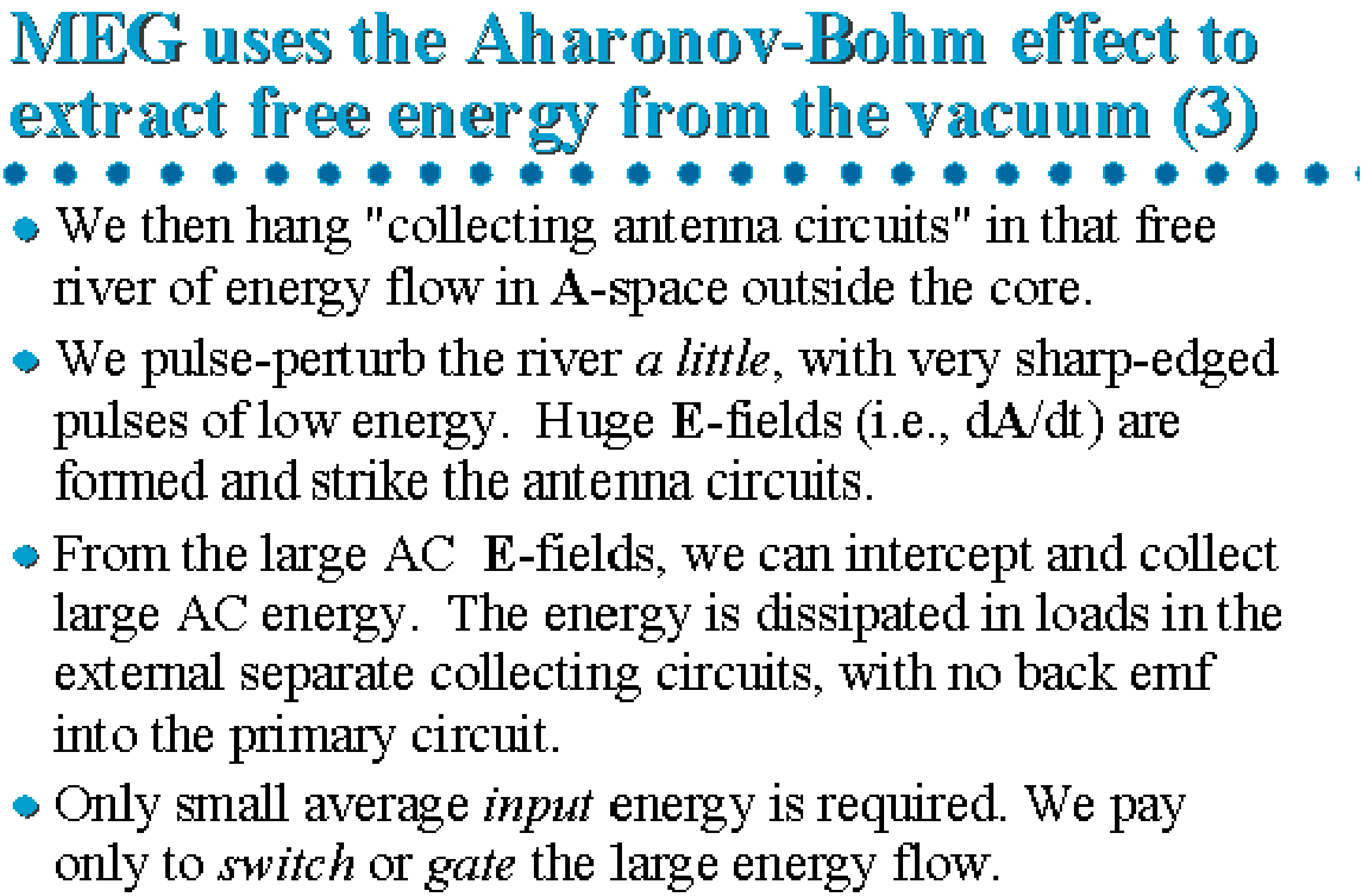

MEG uses the Aharonov-Bohm effect to extract free energy from the vacuum (3)

- We then hang "collecting antenna circuits" in that free river of energy flow in **A**-space outside the core.
- We pulse-perturb the river *a little*, with very sharp-edged pulses of low energy. Huge **E**-fields (i.e., d**A**/dt) are formed and strike the antenna circuits.
- From the large AC **E**-fields, we can intercept and collect large AC energy. The energy is dissipated in loads in the external separate collecting circuits, with no back emf into the primary circuit.
- Only small average *input* energy is required. We pay only to *switch* or *gate* the large energy flow.

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MEG uses the Aharonov-Bohm effect to extract free energy from the vacuum (4)

- By analogy, imagine an old triode vacuum tube.
- Suppose we trick nature into *giving* us the cathode and electron energy flow, for free, really pouring energy out of there continuously.
- Then we only have to put in a grid to switch it, a plate to intercept and catch it, and a plate circuit to dissipate it in a load.
- In the MEG, the permanent magnet and the special core provide the cathode and free flow.
- We provide the "grid" gating, plate "catching," and "plate circuits" with loads that are powered.

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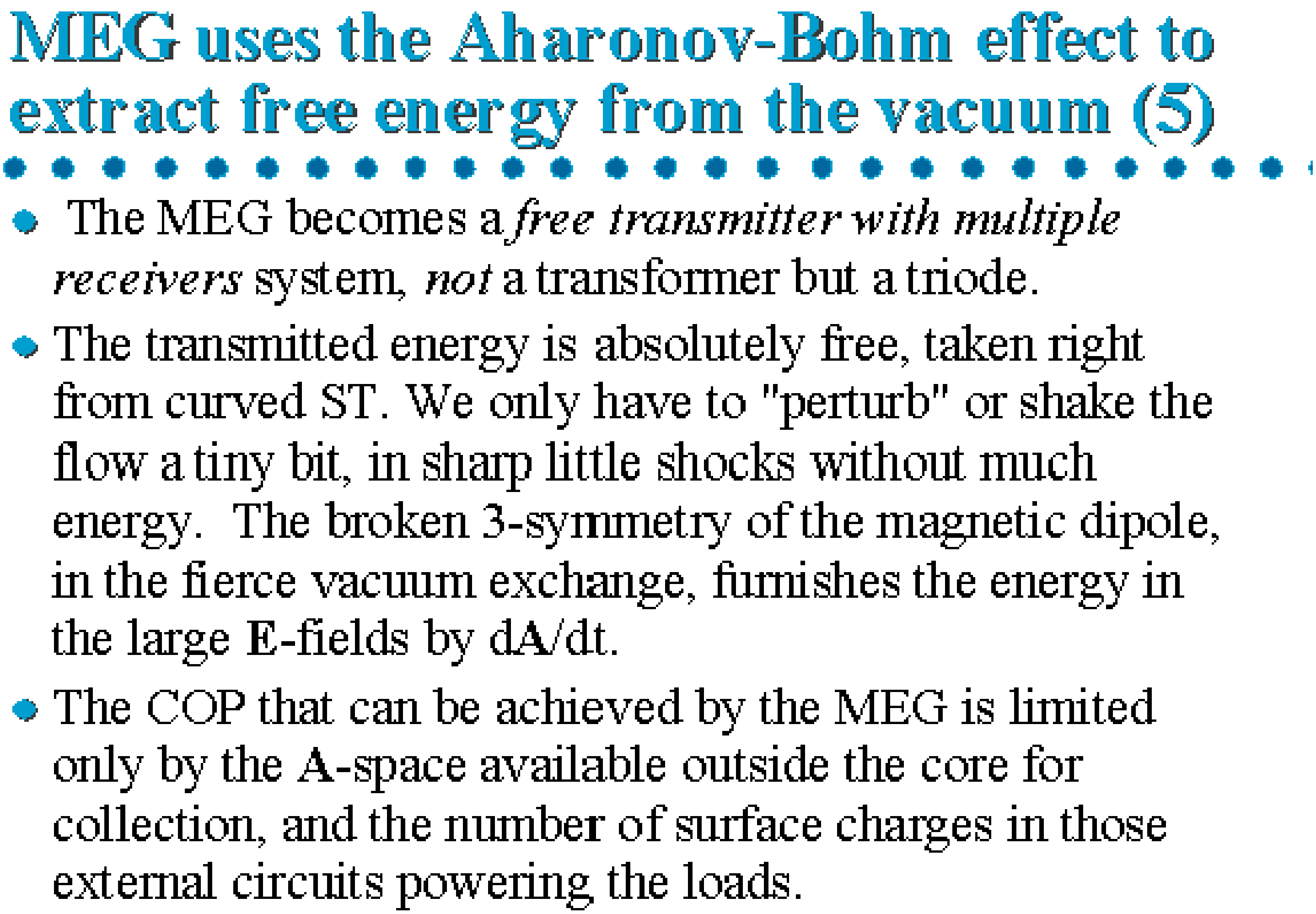

MEG uses the Aharonov-Bohm effect to extract free energy from the vacuum (5)

- The MEG becomes a *free transmitter with multiple receivers* system, *not* a transformer but a triode.
- The transmitted energy is absolutely free, taken right from curved ST. We only have to "perturb" or shake the flow a tiny bit, in sharp little shocks without much energy. The broken 3-symmetry of the magnetic dipole, in the fierce vacuum exchange, furnishes the energy in the large **E**-fields by d**A**/dt.
- The COP that can be achieved by the MEG is limited only by the **A**-space available outside the core for collection, and the number of surface charges in those external circuits powering the loads.

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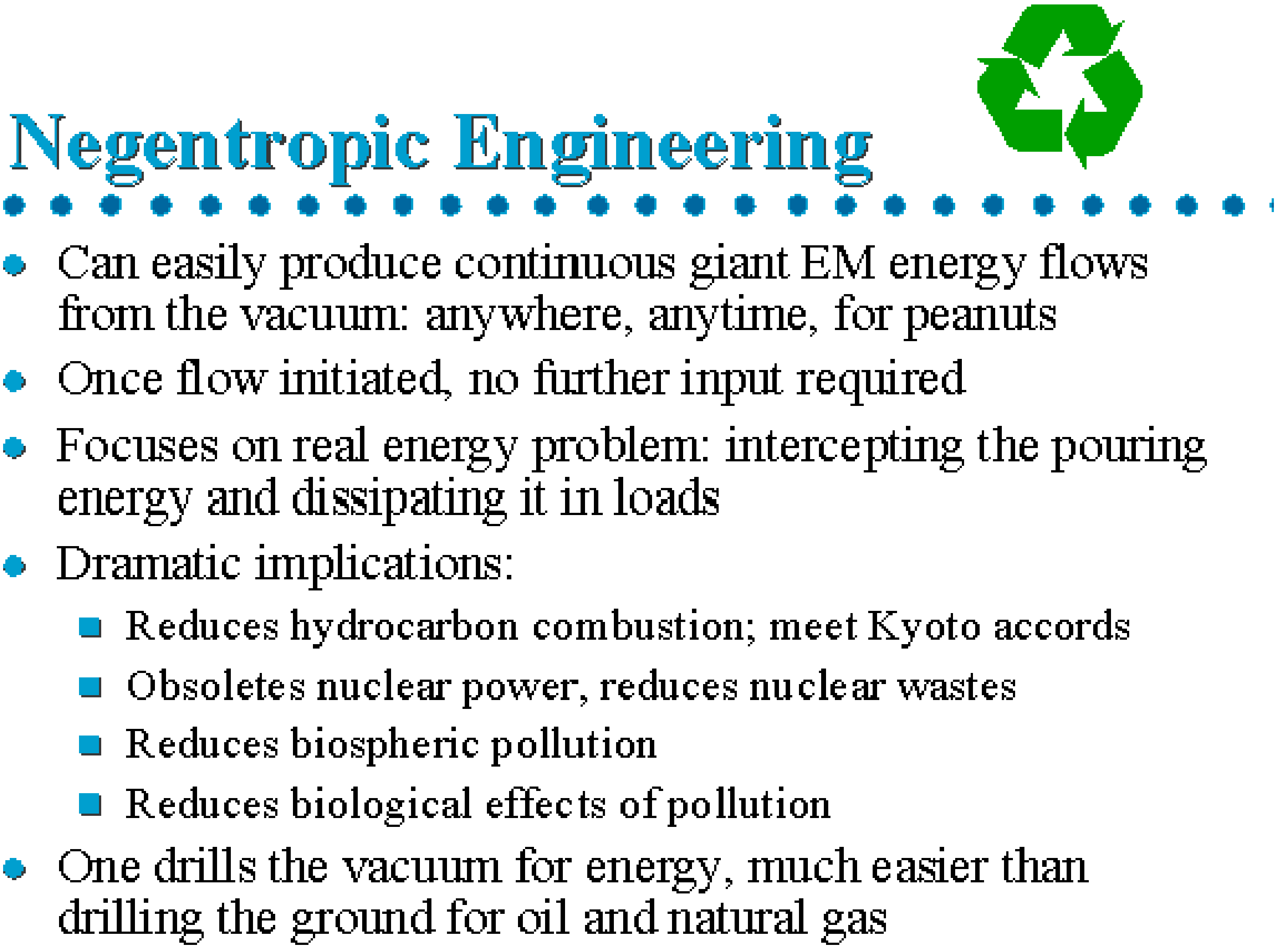

Negentropic Engineering

- Can easily produce continuous giant EM energy flows from the vacuum: anywhere, anytime, for peanuts
- Once flow initiated, no further input required
- Focuses on real energy problem: intercepting the pouring energy and dissipating it in loads
- Dramatic implications:
  - Reduces hydrocarbon combustion; meet Kyoto accords
  - Obsoletes nuclear power, reduces nuclear wastes
  - Reduces biospheric pollution
  - Reduces biological effects of pollution
- One drills the vacuum for energy, much easier than drilling the ground for oil and natural gas

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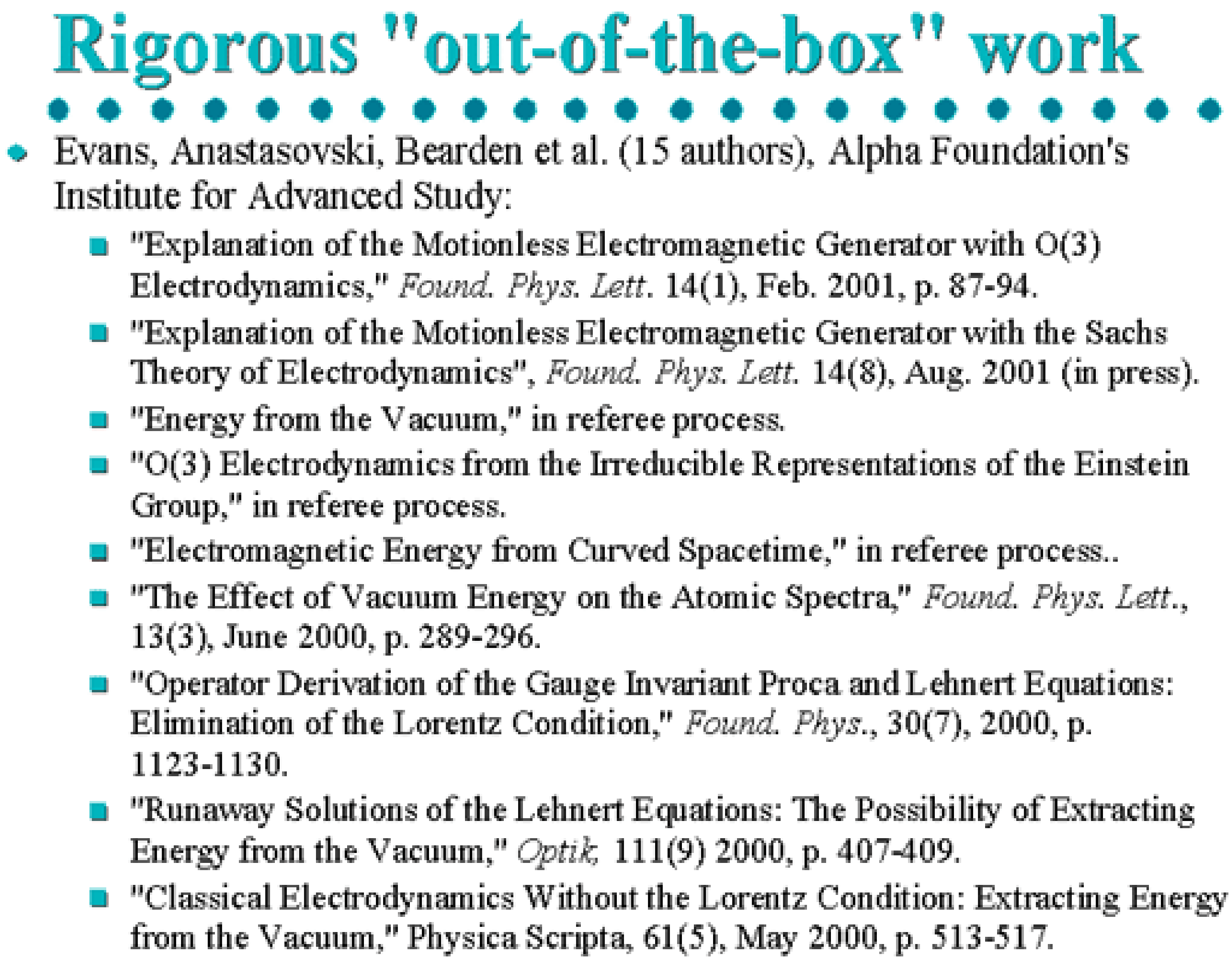

Rigorous "out-of-the-box" work

- Evans, Anastasovski, Bearden et al. (15 authors), Alpha Foundation's Institute for Advanced Study:
  - "Explanation of the Motionless Electromagnetic Generator with O(3) Electrodynamics," *Found. Phys. Lett.* 14(1), Feb. 2001, p. 87-94.
  - "Explanation of the Motionless Electromagnetic Generator with the Sachs Theory of Electrodynamics", *Found. Phys. Lett.* 14(8), Aug. 2001 (in press).
  - "Energy from the Vacuum," in referee process.
  - "O(3) Electrodynamics from the Irreducible Representations of the Einstein Group," in referee process.
  - "Electromagnetic Energy from Curved Spacetime," in referee process..
  - "The Effect of Vacuum Energy on the Atomic Spectra," *Found. Phys. Lett.*, 13(3), June 2000, p. 289-296.
  - "Operator Derivation of the Gauge Invariant Proca and Lehnert Equations: Elimination of the Lorentz Condition," *Found. Phys.*, 30(7), 2000, p. 1123-1130.
  - "Runaway Solutions of the Lehnert Equations: The Possibility of Extracting Energy from the Vacuum," *Optik*, 111(9) 2000, p. 407-409.
  - "Classical Electrodynamics Without the Lorentz Condition: Extracting Energy from the Vacuum," Physica Scripta, 61(5), May 2000, p. 513-517.

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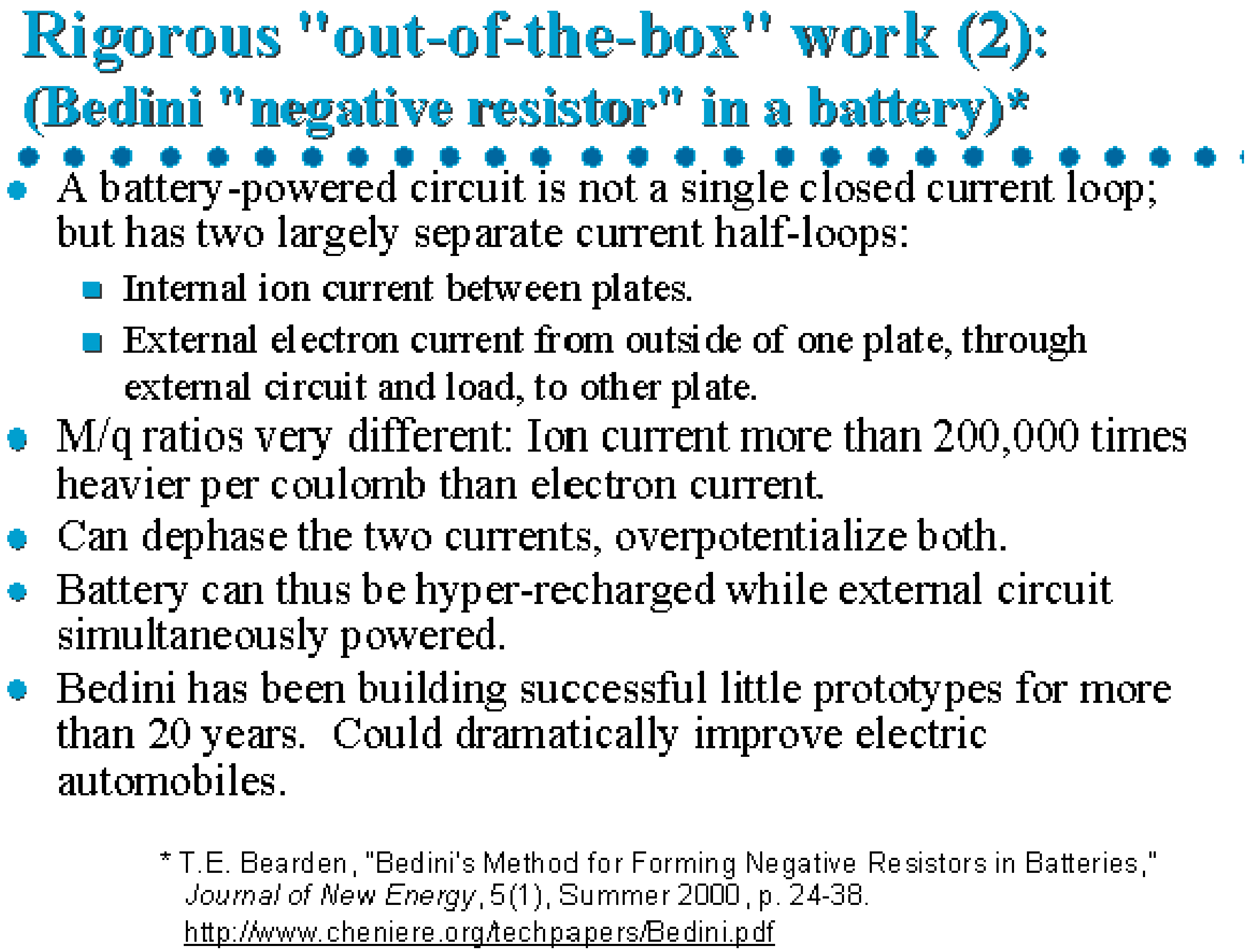

Rigorous "out-of-the-box" work (2): (Bedini "negative resistor" in a battery)*

- A battery-powered circuit is not a single closed current loop; but has two largely separate current half-loops:
    - Internal ion current between plates.
    - External electron current from outside of one plate, through external circuit and load, to other plate.
- M/q ratios very different: Ion current more than 200,000 times heavier per coulomb than electron current.
- Can dephase the two currents, overpotentialize both.
- Battery can thus be hyper-recharged while external circuit simultaneously powered.
- Bedini has been building successful little prototypes for more than 20 years. Could dramatically improve electric automobiles.

* T.E. Bearden, "Bedini's Method for Forming Negative Resistors in Batteries," *Journal of New Energy*, 5(1), Summer 2000, p. 24-38. http://www.cheniere.org/techpapers/Bedini.pdf

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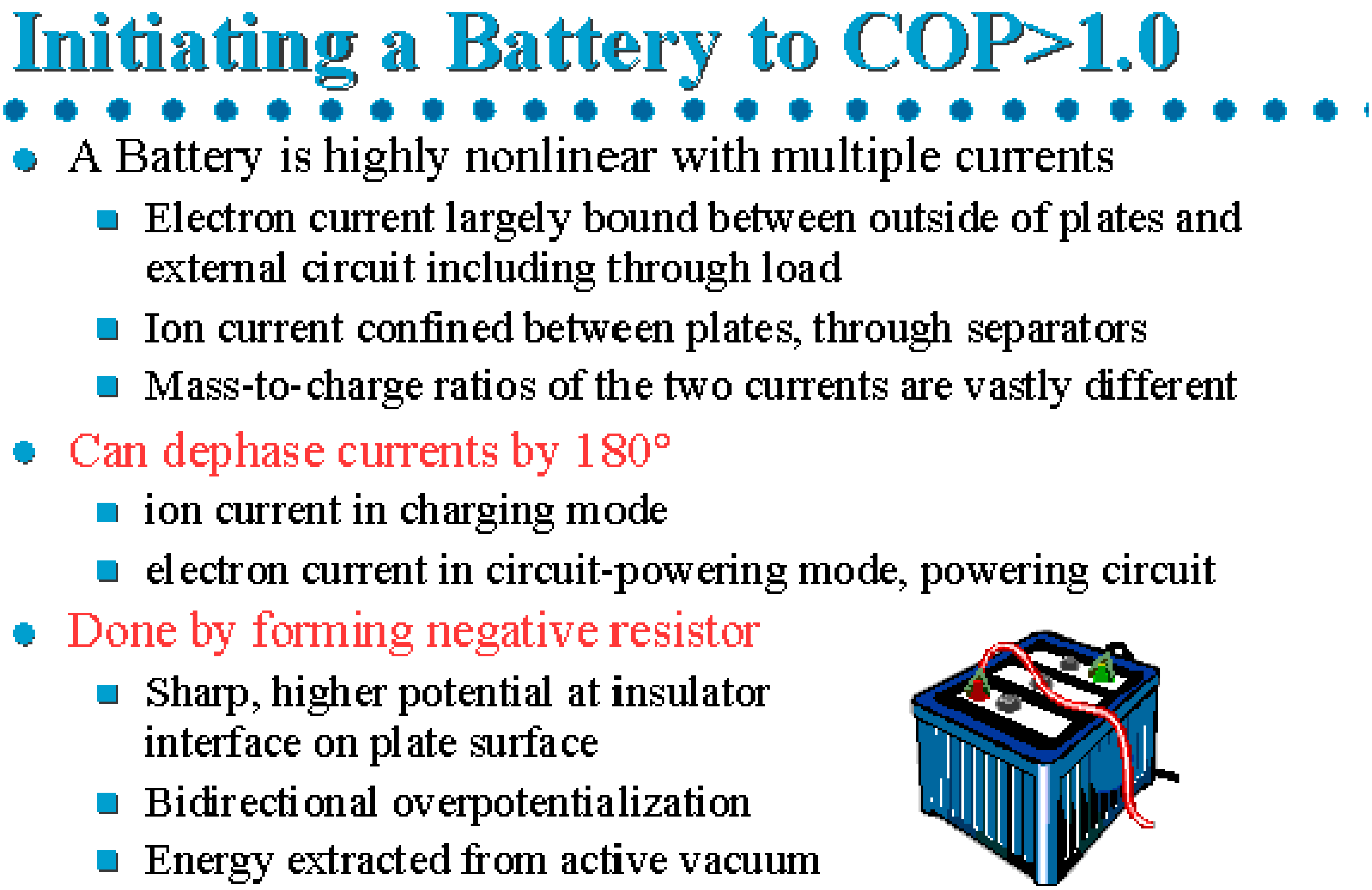

Initiating a Battery to COP>1.0

- A Battery is highly nonlinear with multiple currents
  - Electron current largely bound between outside of plates and external circuit including through load
  - Ion current confined between plates, through separators
  - Mass-to-charge ratios of the two currents are vastly different
- Can dephase currents by 180°
  - ion current in charging mode
  - electron current in circuit-powering mode, powering circuit
- Done by forming negative resistor
  - Sharp, higher potential at insulator interface on plate surface
  - Bidirectional overpotentialization
  - Energy extracted from active vacuum

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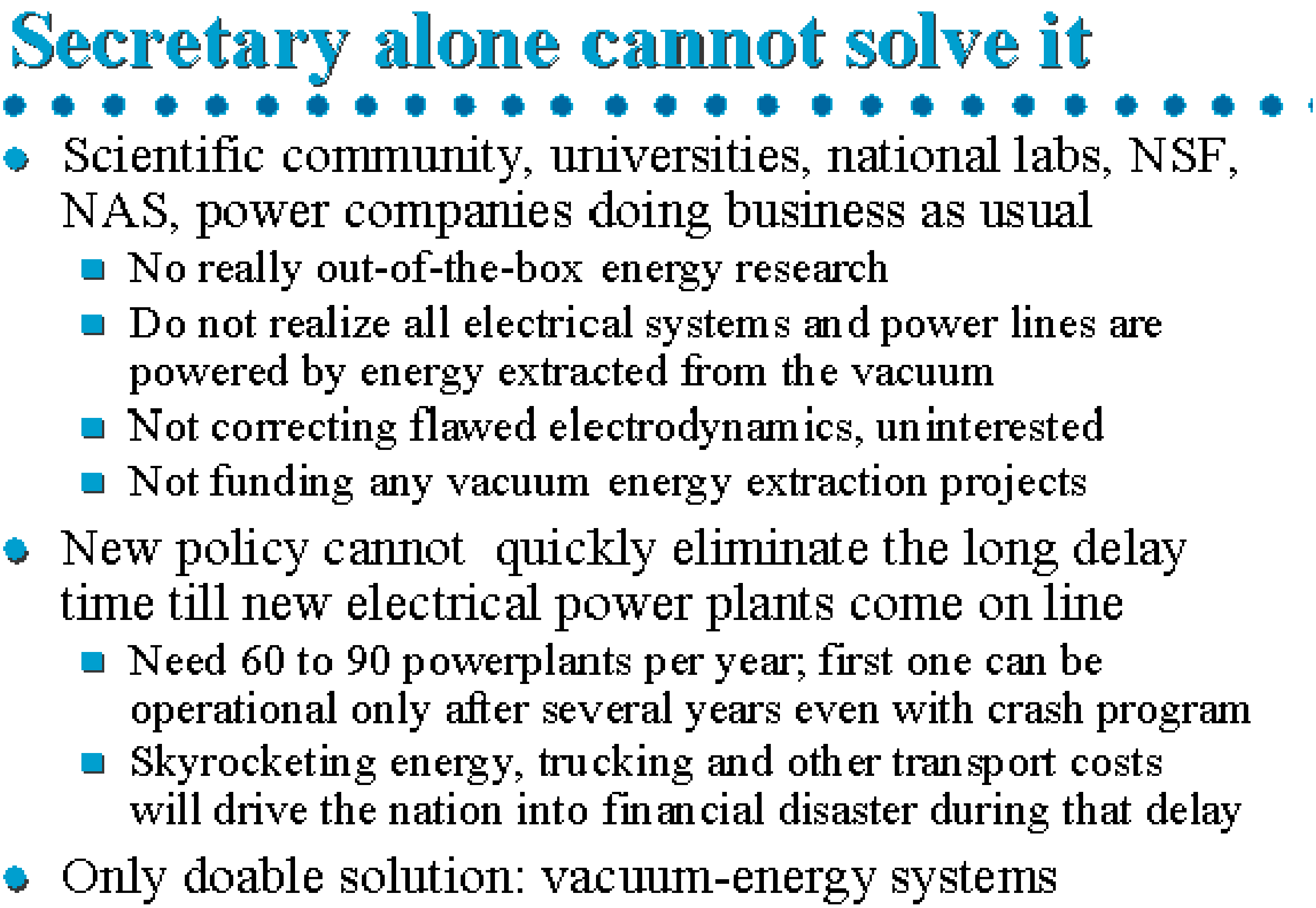

Secretary alone cannot solve it

- Scientific community, universities, national labs, NSF, NAS, power companies doing business as usual
  - No really out-of-the-box energy research
  - Do not realize all electrical systems and power lines are powered by energy extracted from the vacuum
  - Not correcting flawed electrodynamics, uninterested
  - Not funding any vacuum energy extraction projects
- New policy cannot quickly eliminate the long delay time till new electrical power plants come on line
  - Need 60 to 90 powerplants per year; first one can be operational only after several years even with crash program
  - Skyrocketing energy, trucking and other transport costs will drive the nation into financial disaster during that delay
- Only doable solution: vacuum-energy systems

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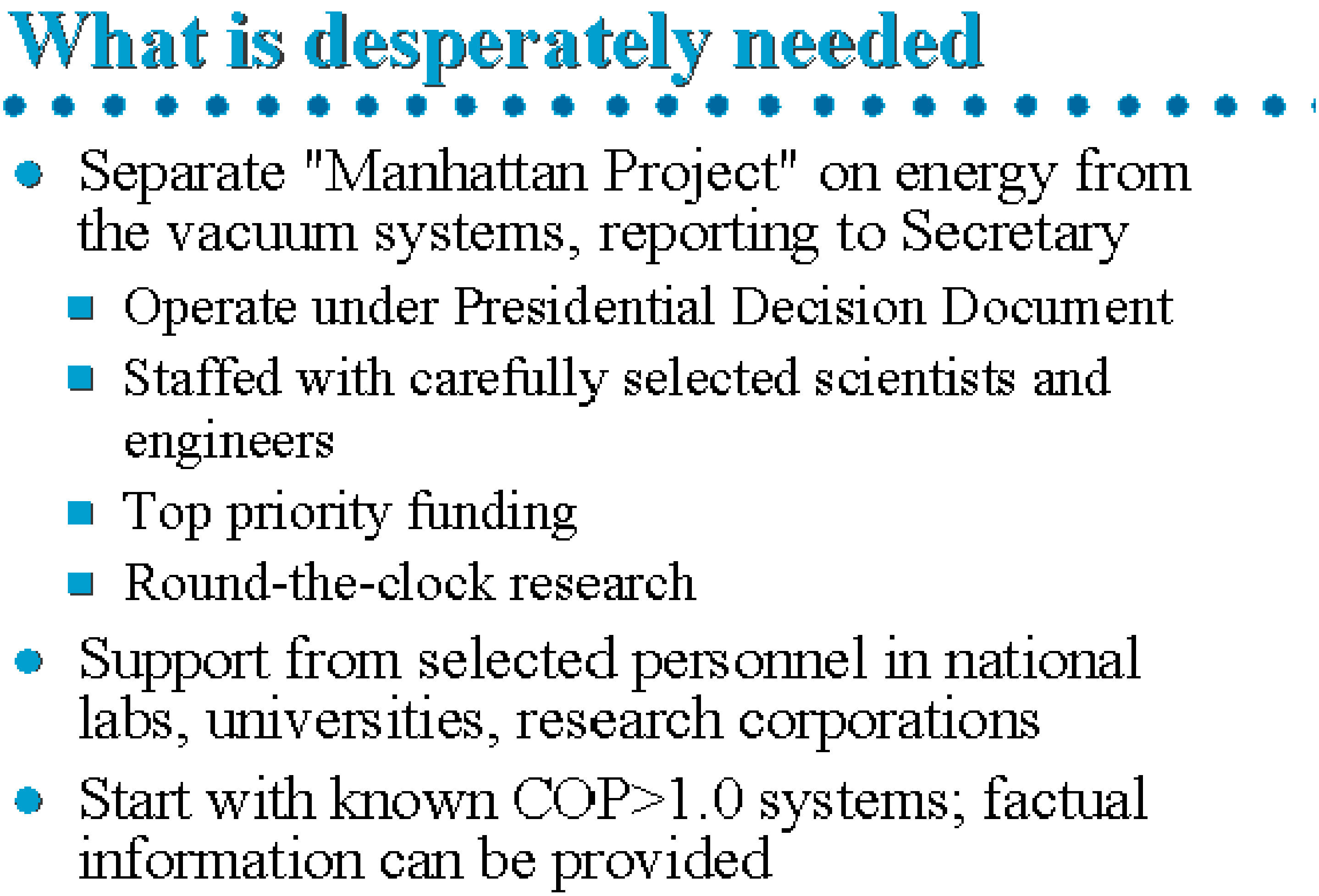

What is desperately needed

- Separate "Manhattan Project" on energy from the vacuum systems, reporting to Secretary
  - Operate under Presidential Decision Document
  - Staffed with carefully selected scientists and engineers
  - Top priority funding
  - Round-the-clock research
- Support from selected personnel in national labs, universities, research corporations
- Start with known COP>1.0 systems; factual information can be provided

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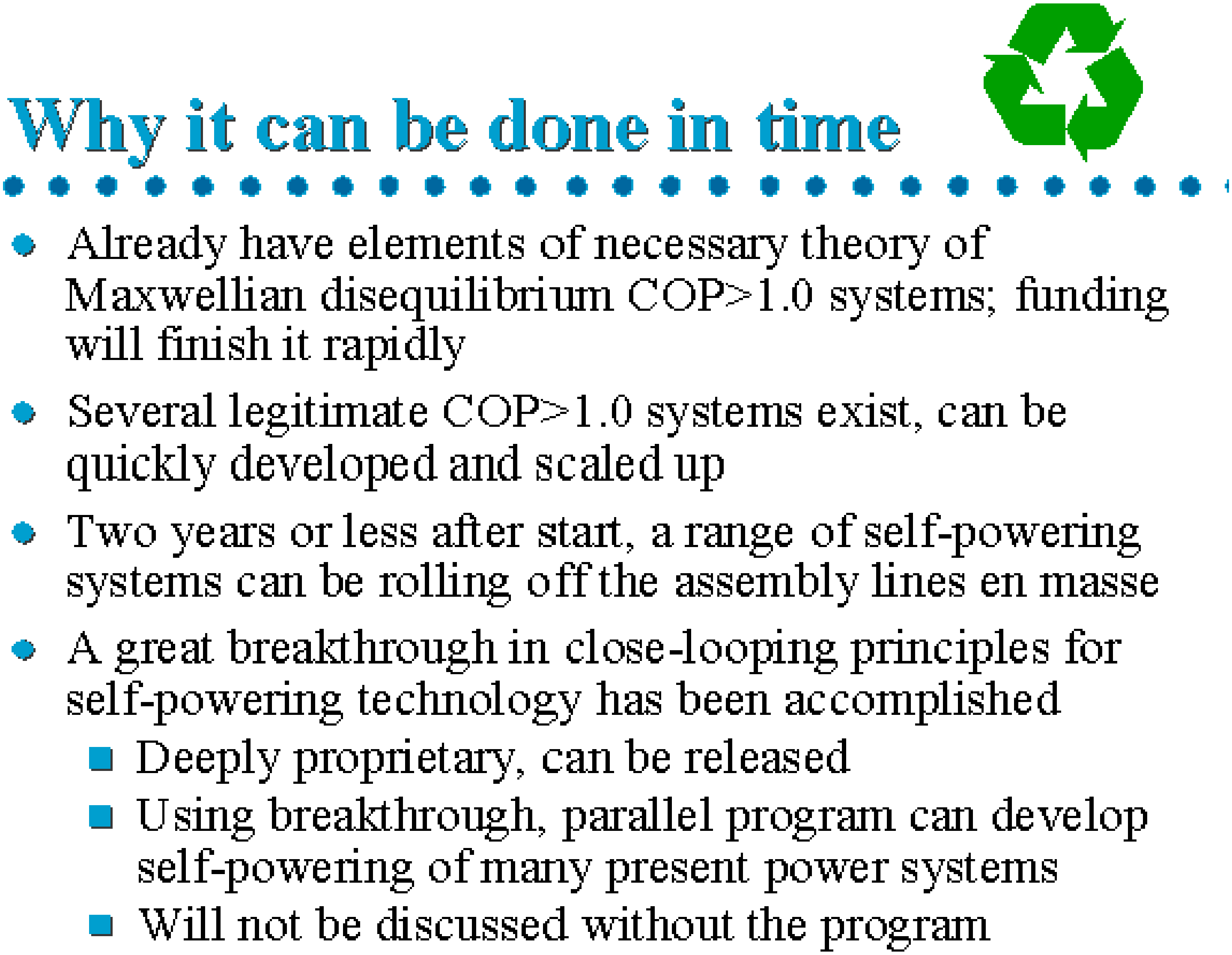

Why it can be done in time

- Already have elements of necessary theory of Maxwellian disequilibrium COP>1.0 systems; funding will finish it rapidly
- Several legitimate COP>1.0 systems exist, can be quickly developed and scaled up
- Two years or less after start, a range of self-powering systems can be rolling off the assembly lines en masse
- A great breakthrough in close-looping principles for self-powering technology has been accomplished
    - Deeply proprietary, can be released
    - Using breakthrough, parallel program can develop self-powering of many present power systems
    - Will not be discussed without the program

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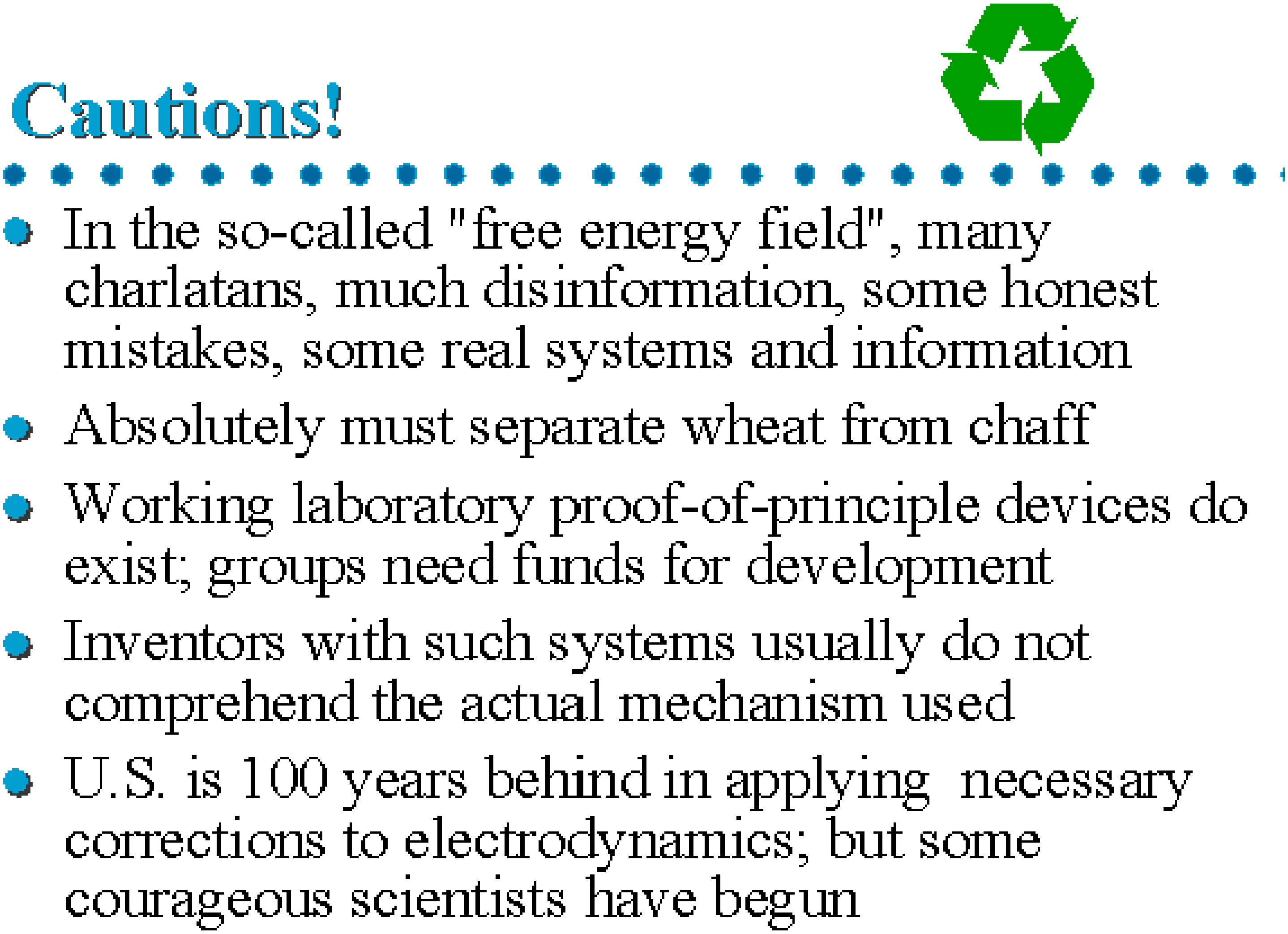

Cautions!

- In the so-called "free energy field", many charlatans, much disinformation, some honest mistakes, some real systems and information
- Absolutely must separate wheat from chaff
- Working laboratory proof-of-principle devices do exist; groups need funds for development
- Inventors with such systems usually do not comprehend the actual mechanism used
- U.S. is 100 years behind in applying necessary corrections to electrodynamics; but some courageous scientists have begun

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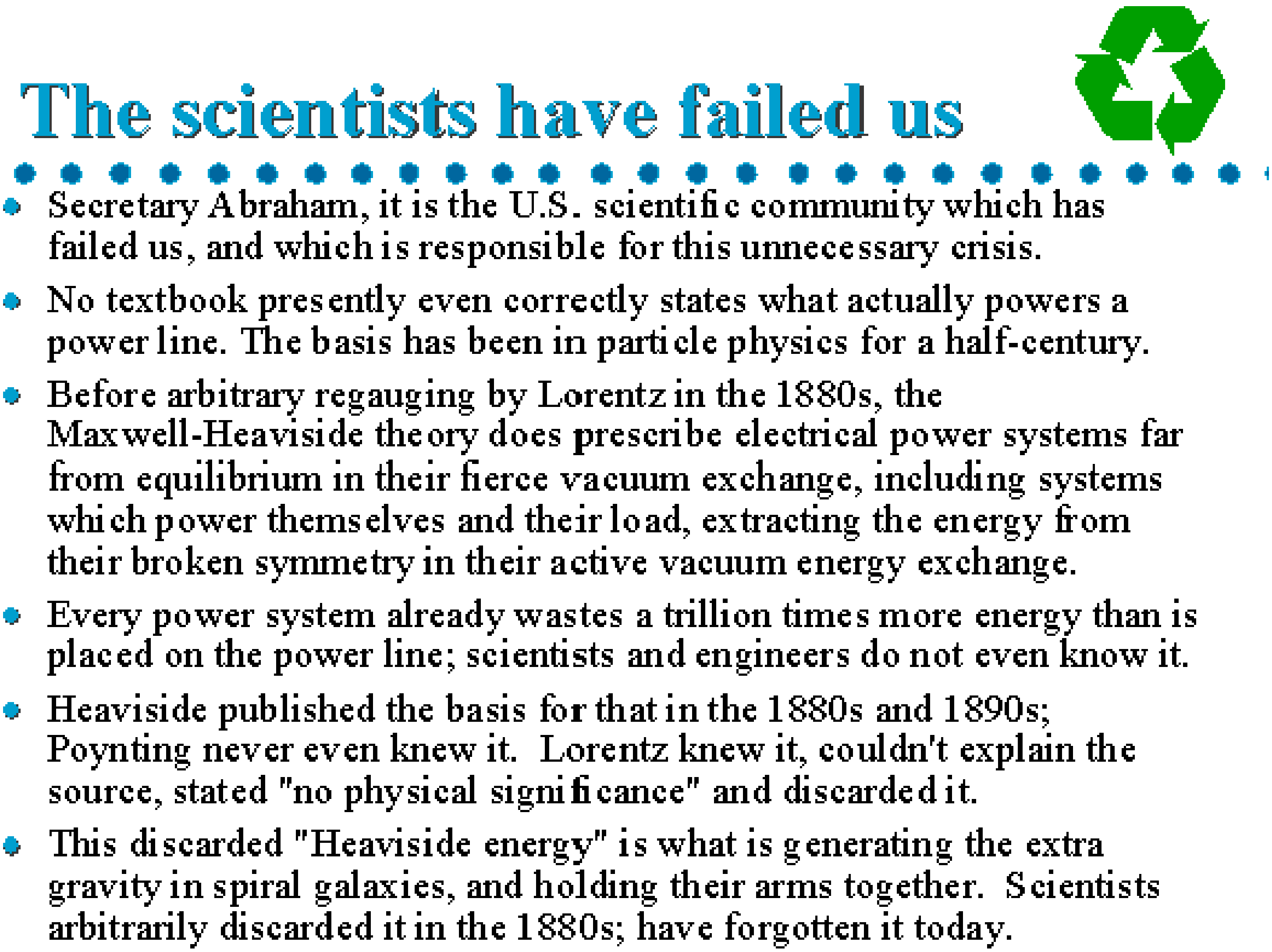

The scientists have failed us

- Secretary Abraham, it is the U.S. scientific community which has failed us, and which is responsible for this unnecessary crisis.
- No textbook presently even correctly states what actually powers a power line. The basis has been in particle physics for a half-century.
- Before arbitrary regauging by Lorentz in the 1880s, the Maxwell-Heaviside theory does prescribe electrical power systems far from equilibrium in their fierce vacuum exchange, including systems which power themselves and their load, extracting the energy from their broken symmetry in their active vacuum energy exchange.
- Every power system already wastes a trillion times more energy than is placed on the power line; scientists and engineers do not even know it.
- Heaviside published the basis for that in the 1880s and 1890s; Poynting never even knew it. Lorentz knew it, couldn't explain the source, stated "no physical significance" and discarded it.
- This discarded "Heaviside energy" is what is generating the extra gravity in spiral galaxies, and holding their arms together. Scientists arbitrarily discarded it in the 1880s; have forgotten it today.

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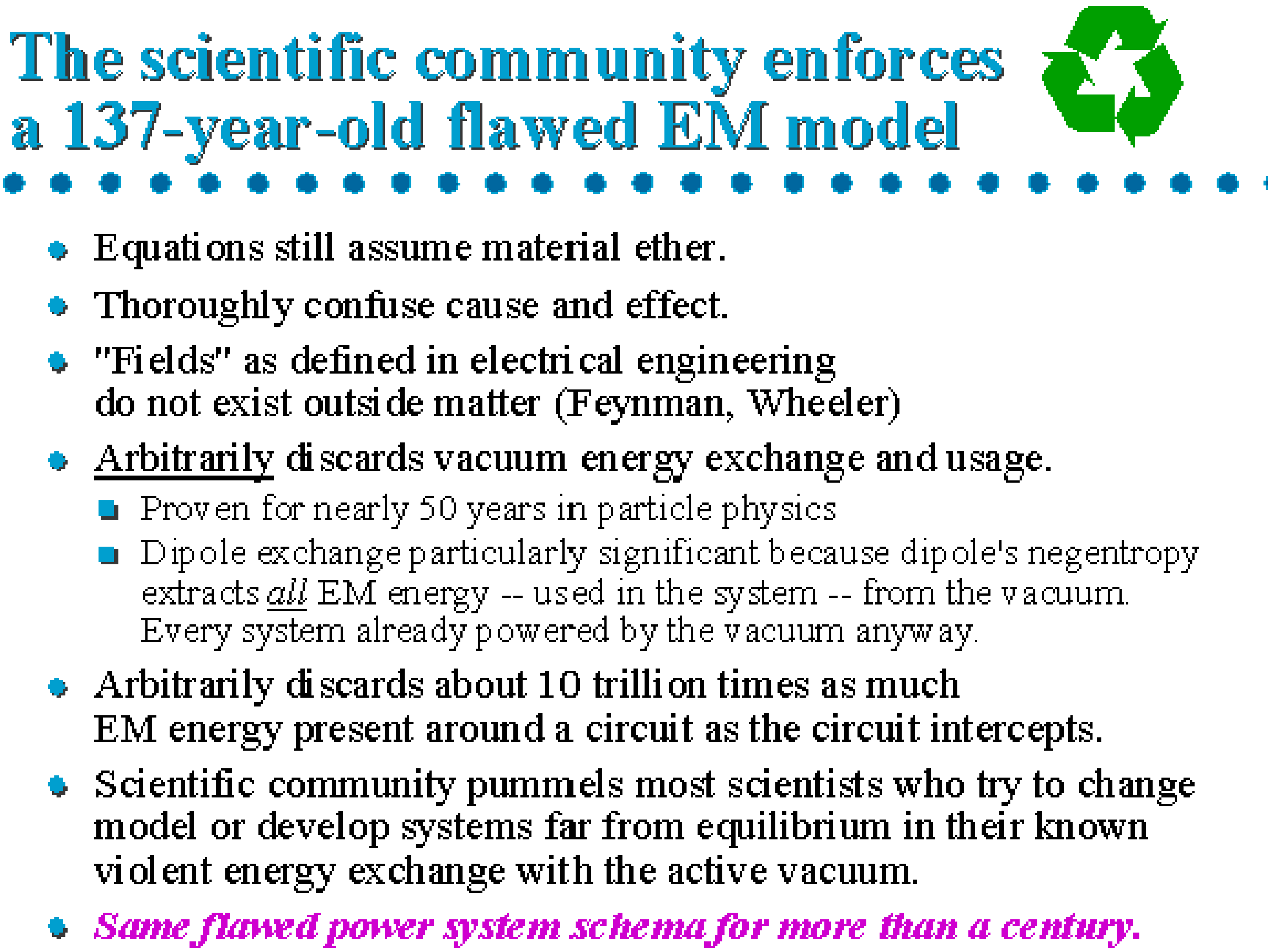

The scientific community enforces a 137-year-old flawed EM model

- Equations still assume material ether.
- Thoroughly confuse cause and effect.
- "Fields" as defined in electrical engineering
  do not exist outside matter (Feynman, Wheeler)
- Arbitrarily discards vacuum energy exchange and usage.
  - Proven for nearly 50 years in particle physics
  - Dipole exchange particularly significant because dipole's negentropy extracts *all* EM energy -- used in the system -- from the vacuum. Every system already powered by the vacuum anyway.
- Arbitrarily discards about 10 trillion times as much
  EM energy present around a circuit as the circuit intercepts.
- Scientific community pummels most scientists who try to change model or develop systems far from equilibrium in their known violent energy exchange with the active vacuum.
- ***Same flawed power system schema for more than a century.***

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All EM 3-space energy freely comes from the time domain*

* T. E. Bearden, "Giant Negentropy of the Common Dipole," Journal of New Energy, 5(1), Summer 2000, p. 11-23. http://www.cheniere.org/techpapers/GiantNegentropy.pdf

Whittaker, Math. Ann., 57, 333 (1903)
shows this rigorously.
Dipole's broken 3-symmetry well-known
in particle physics

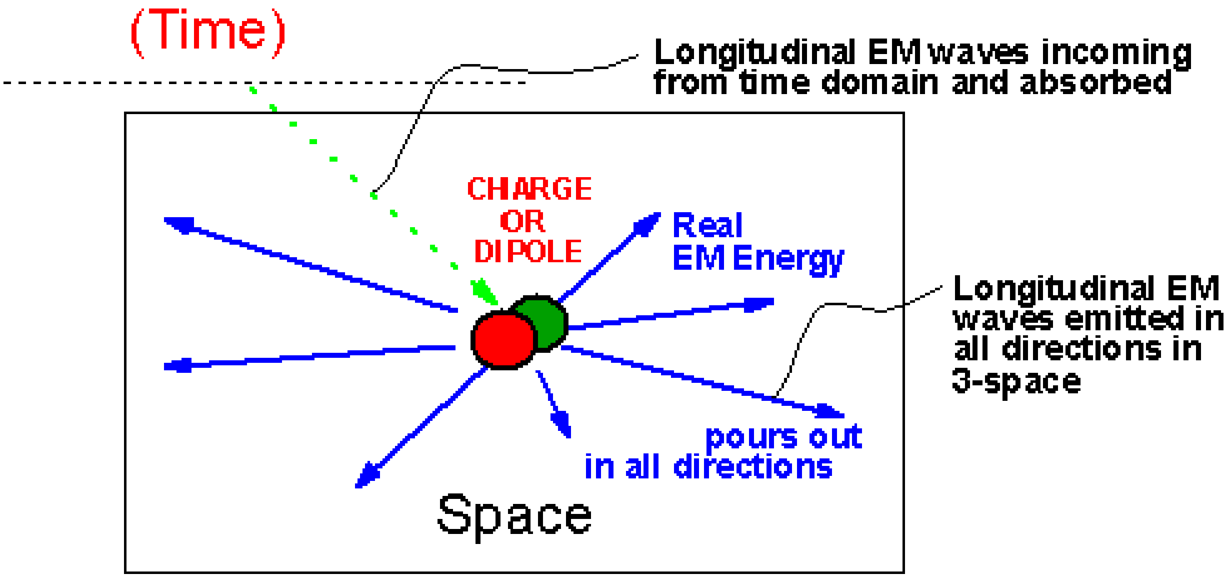

(Time)

Longitudinal EM waves incoming from time domain and absorbed

CHARGE OR DIPOLE

Real EM Energy

Longitudinal EM waves emitted in all directions in 3-space

pours out in all directions

Space

Note: Whittaker (and others) interpreted the phase conjugate half set of LWs after interaction with the charges of the dipole; and as an *effect* rather than the *cause*. This fundamental non sequitur has just been repeated since then. Thus they missed the solution of the source charge and source dipole.

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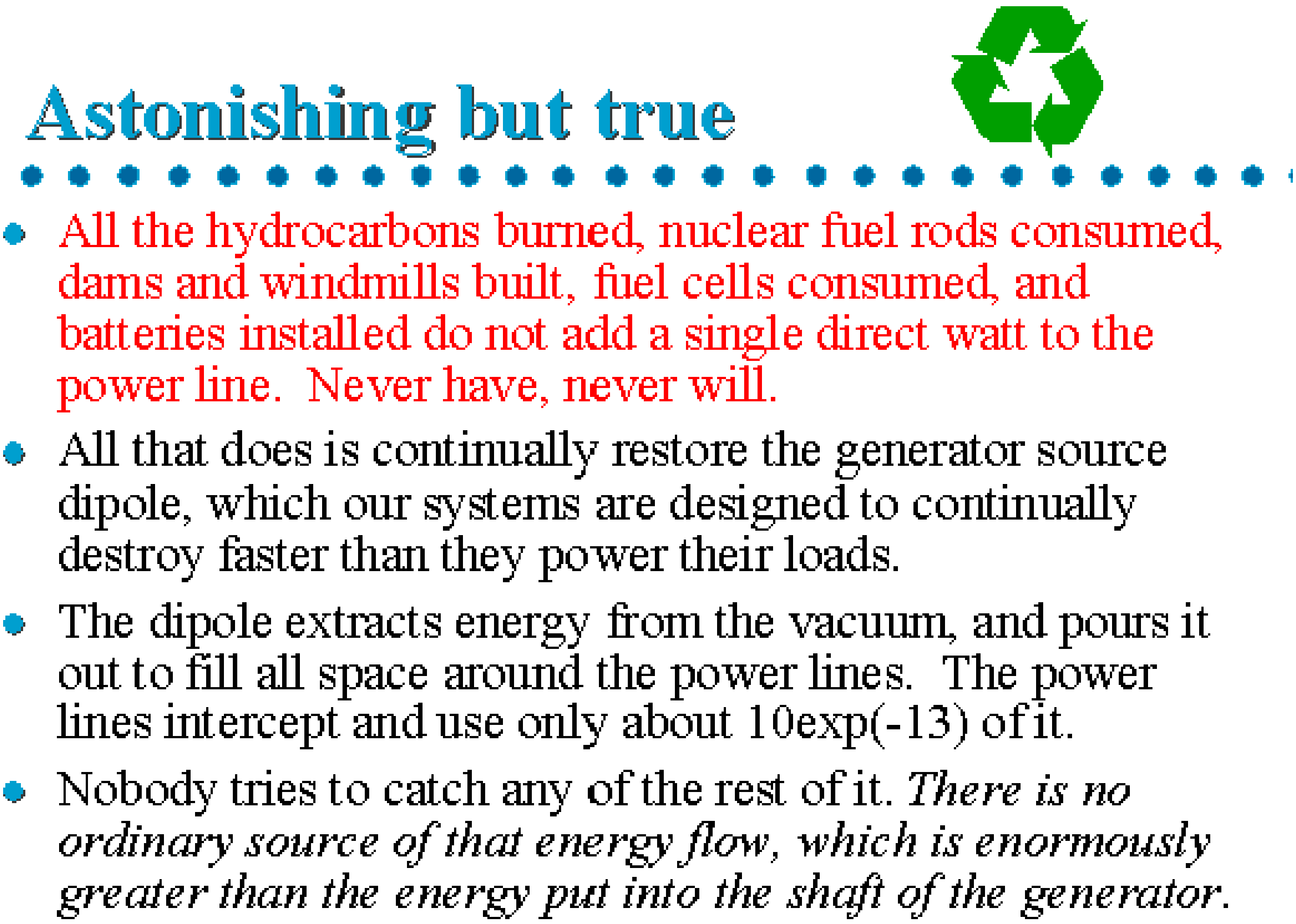

Astonishing but true

- All the hydrocarbons burned, nuclear fuel rods consumed, dams and windmills built, fuel cells consumed, and batteries installed do not add a single direct watt to the power line. Never have, never will.
- All that does is continually restore the generator source dipole, which our systems are designed to continually destroy faster than they power their loads.
- The dipole extracts energy from the vacuum, and pours it out to fill all space around the power lines. The power lines intercept and use only about 10exp(-13) of it.
- Nobody tries to catch any of the rest of it. *There is no ordinary source of that energy flow, which is enormously greater than the energy put into the shaft of the generator.*

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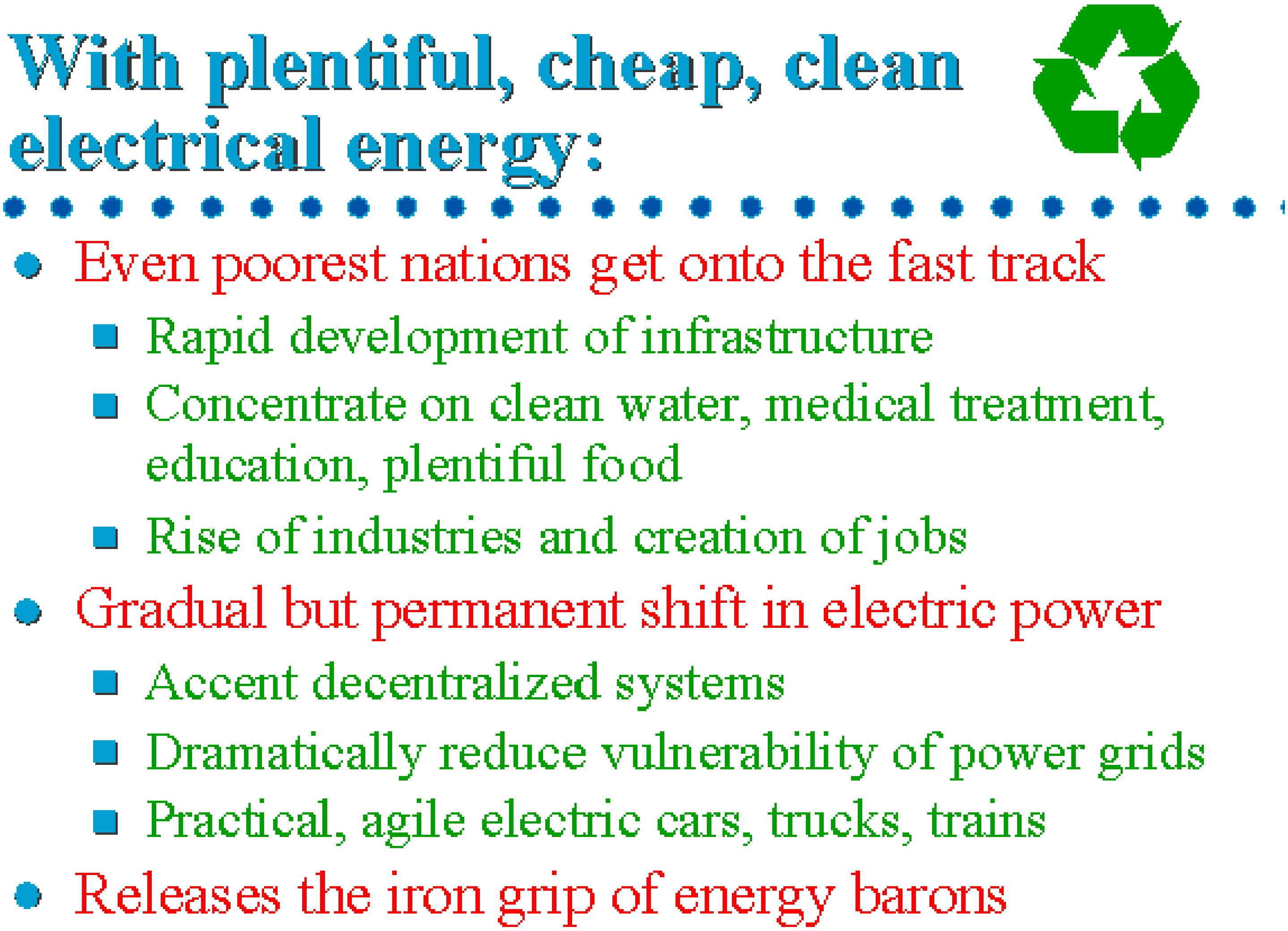

With plentiful, cheap, clean electrical energy:

- Even poorest nations get onto the fast track
  - Rapid development of infrastructure
  - Concentrate on clean water, medical treatment, education, plentiful food
  - Rise of industries and creation of jobs
- Gradual but permanent shift in electric power
  - Accent decentralized systems
  - Dramatically reduce vulnerability of power grids
  - Practical, agile electric cars, trucks, trains
- Releases the iron grip of energy barons

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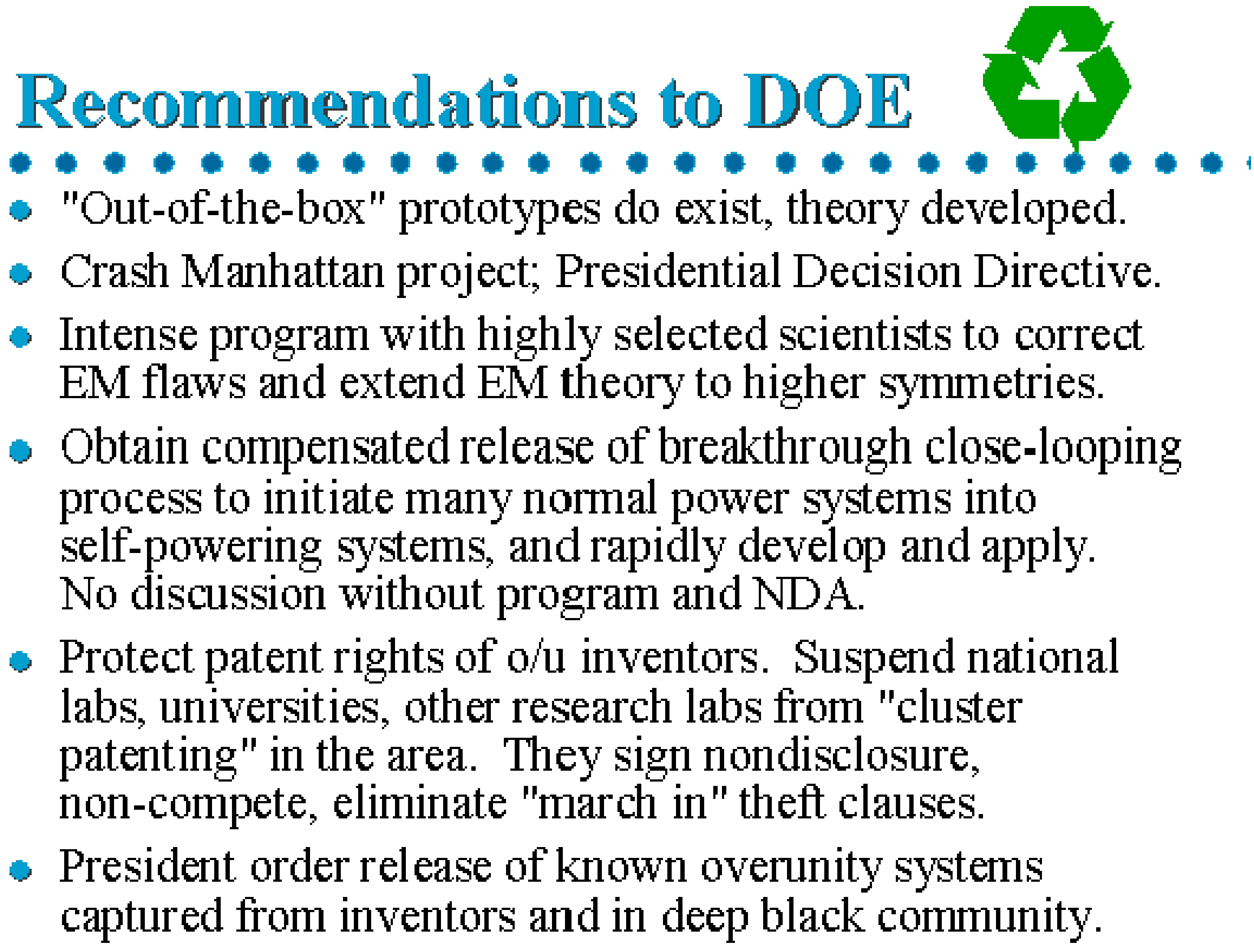

Recommendations to DOE

- "Out-of-the-box" prototypes do exist, theory developed.
- Crash Manhattan project; Presidential Decision Directive.
- Intense program with highly selected scientists to correct EM flaws and extend EM theory to higher symmetries.
- Obtain compensated release of breakthrough close-looping process to initiate many normal power systems into self-powering systems, and rapidly develop and apply. No discussion without program and NDA.
- Protect patent rights of o/u inventors. Suspend national labs, universities, other research labs from "cluster patenting" in the area. They sign nondisclosure, non-compete, eliminate "march in" theft clauses.
- President order release of known overunity systems captured from inventors and in deep black community.

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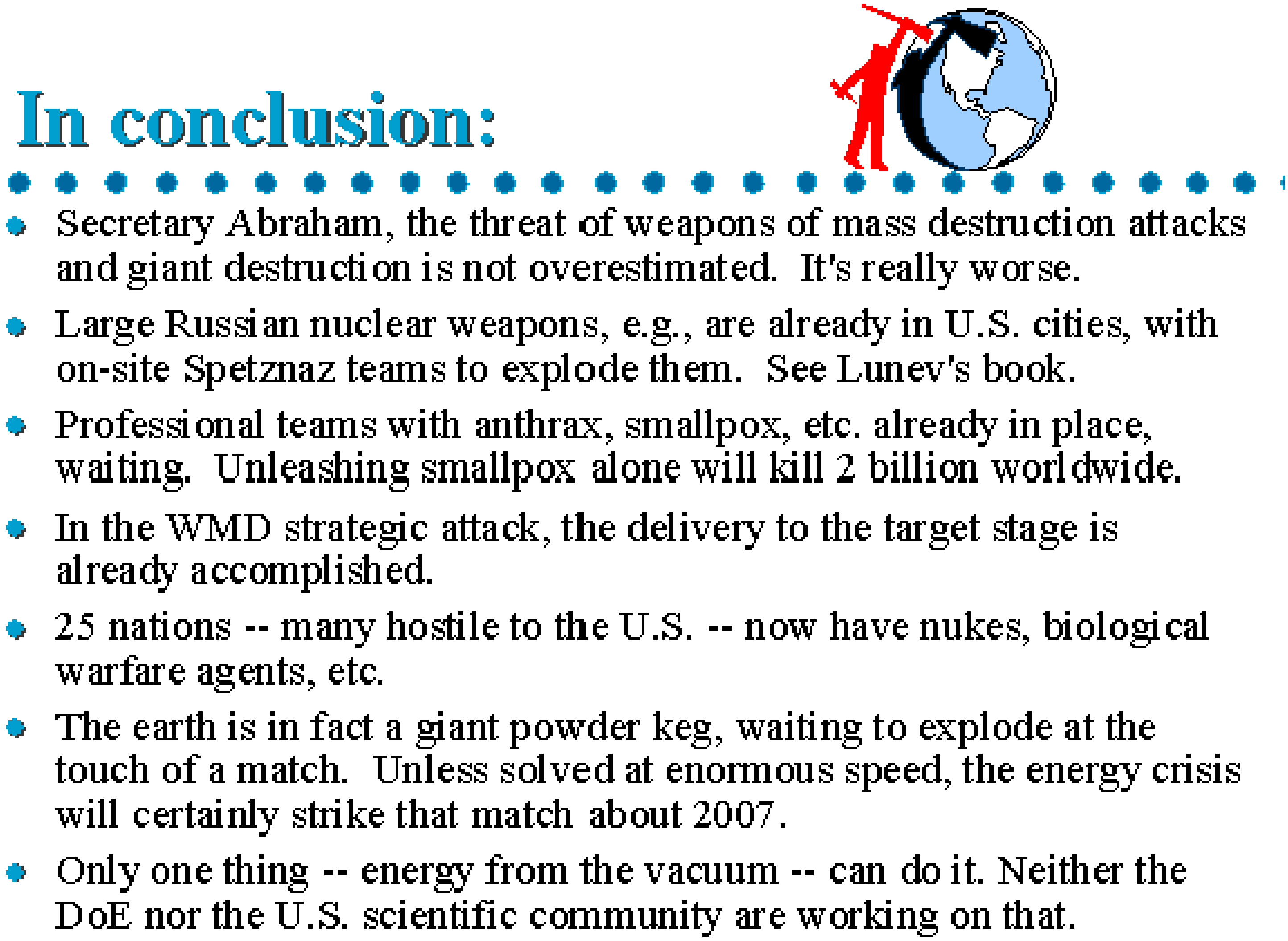

In conclusion:

- Secretary Abraham, the threat of weapons of mass destruction attacks and giant destruction is not overestimated. It's really worse.
- Large Russian nuclear weapons, e.g., are already in U.S. cities, with on-site Spetznaz teams to explode them. See Lunev's book.
- Professional teams with anthrax, smallpox, etc. already in place, waiting. Unleashing smallpox alone will kill 2 billion worldwide.
- In the WMD strategic attack, the delivery to the target stage is already accomplished.
- 25 nations -- many hostile to the U.S. -- now have nukes, biological warfare agents, etc.
- The earth is in fact a giant powder keg, waiting to explode at the touch of a match. Unless solved at enormous speed, the energy crisis will certainly strike that match about 2007.
- Only one thing -- energy from the vacuum -- can do it. Neither the DoE nor the U.S. scientific community are working on that.

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The "Porthole" Concept with technical background

Amplifying the cellular regenerative (healing) system of the body for treatment and healing of mass casualties

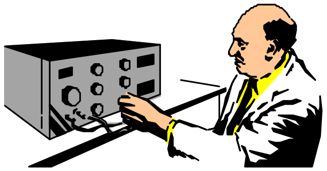

Outline of the presentation

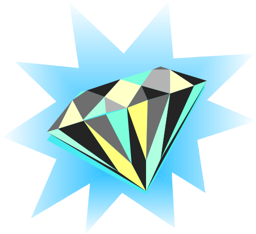

- Mechanism for deep EM exchange of a body with its active EM environment
- Becker's epochal work and its ramifications
- Kaznacheyev's startling results and ramifications
- Weaponization of Kaznacheyev's findings
- Importance of time-energy and the time-domain
- Mechanisms for medical treatment and healing

Outline of the presentation (2)

- Prioré's revolutionary results and their ramifications.
- Proposed new mechanism for cancer promotion.
- Porthole concept: The 2-minute shortcut.
- Terrorist biological warfare capabilities.
- Summary and conclusion.
- Budgetary and Program package.

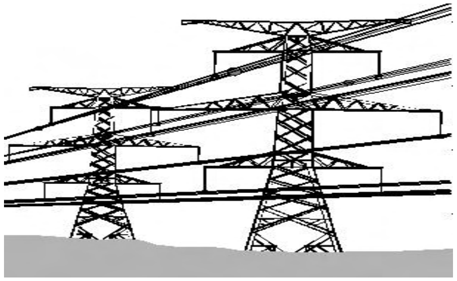

Mechanism for the body's deep EM exchange with its active EM environment

And some ramifications

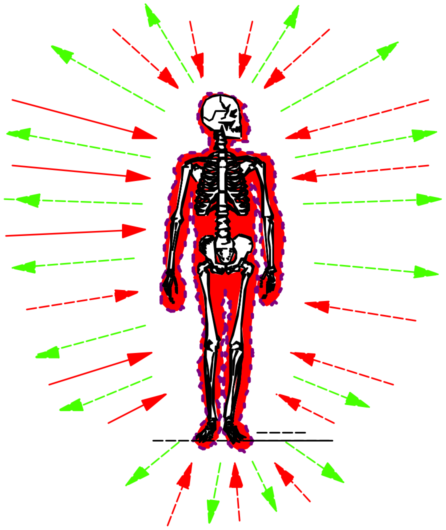

The body continually receives and retransmits EM energy

- The body may be considered as a dielectric.
- Every part of the dielectric participates in the absorption and emission of each photon to and from any point on the surface.*
- Mechanical force effects are also electrical in nature and exchange similarly.

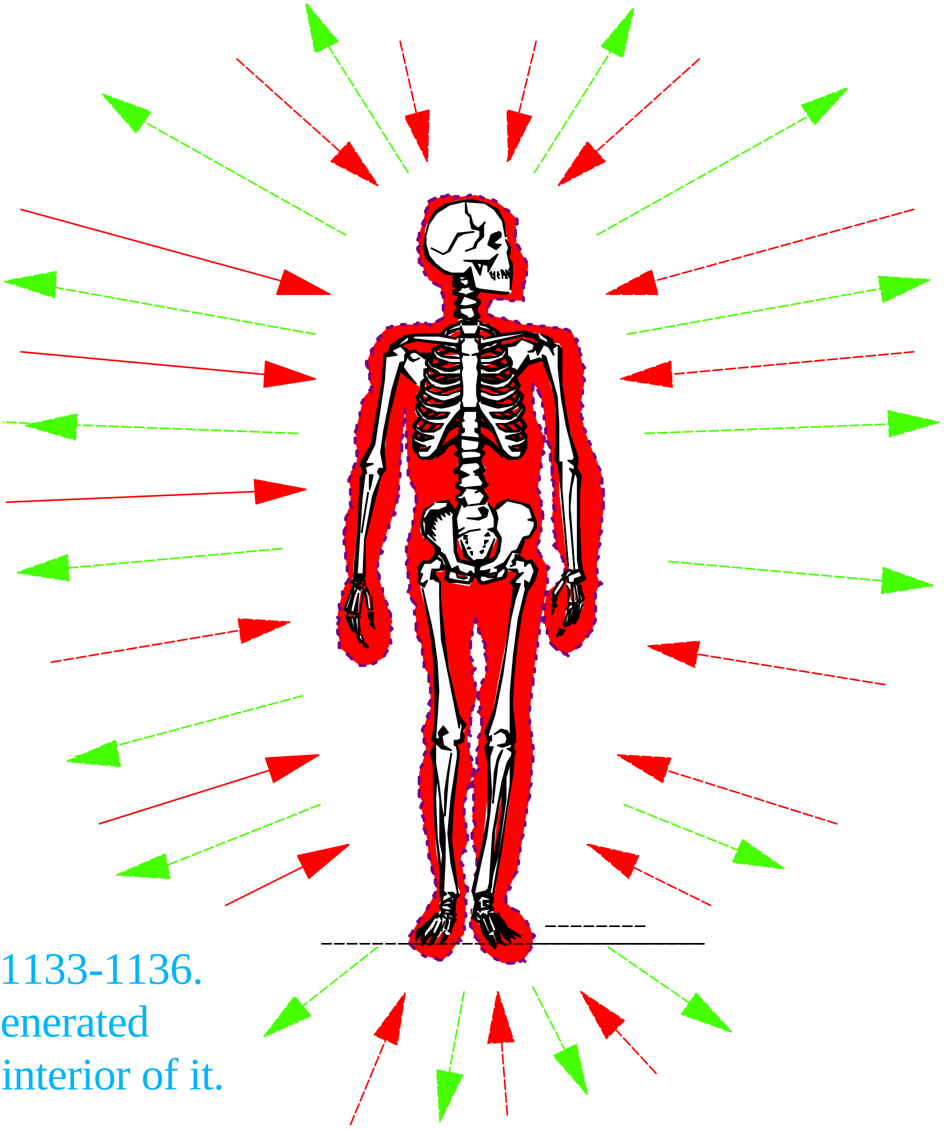

* Reali, G. C., "Reflection from dielectric materials," American Journal of Physics, 50(12), Dec. 1982, p. 1133-1136. The reflected field from a dielectric material is not generated just at its surface but comes from everywhere in the interior of it.

Ramifications:

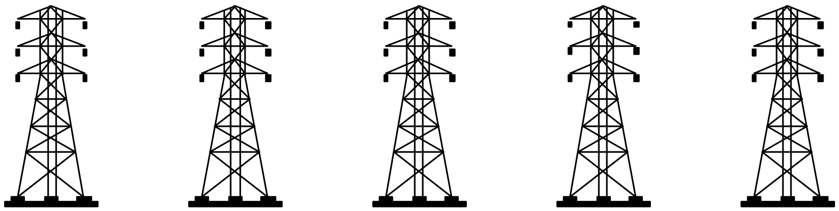

- There is an EM "dielectric transmission path" connecting every part of every cell to every part of the surface of the body.
- All electrical processes in the body, including deep within the cell and its nucleus, participate in the absorption and emission of every photon to and from the body's outer surface (and every mechanical force* experience).
- The EM emission energy of the body is a conglomerate mix of fractions of all processes and functions ongoing in the body or affecting it, including in every cell.
- This includes all electromagnetic, mechanical, chemical, and environmental effects upon and in the body and every tiniest part of it, and provides an extended definition of "stress".

* At base, all normal mechanical forces are generated by electromagnetic forces.

Ramifications (2)

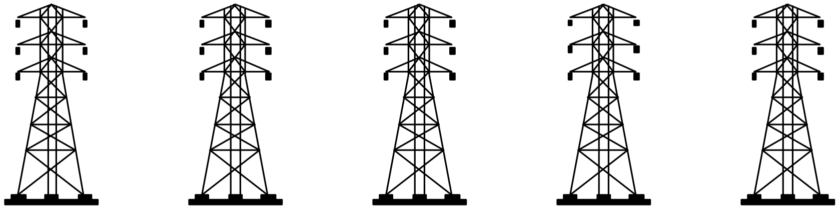

- The reaction of each photon absorbed on any point of the outer surface of the body, connects through the dielectric transmission path to every part of the body, including to every part of every cell*.
- Every emission from the body is participated in by every part of the body, including every part of every cell.
- The body's emission "changes" its environment, adding EM radiation. Some of the internal induced changes (excited states) in the body decay by this external emission. Some do not, but must be otherwise dealt with internally by the body systems.
- The body's EM absorption allows the environment to change or affect every function, operation, and part of the body, by adding EM radiation. All are continually being affected and deviated, both helpfully and harmfully, by these deeply induced EM interactions.
- The body's reaction (healing) must continually readjust and correct deviations from normalcy, in every part of every cell.

* In quantum physics, part of the photon is localized and part is nonlocalized, reaching even across the universe.

Ramifications (3)

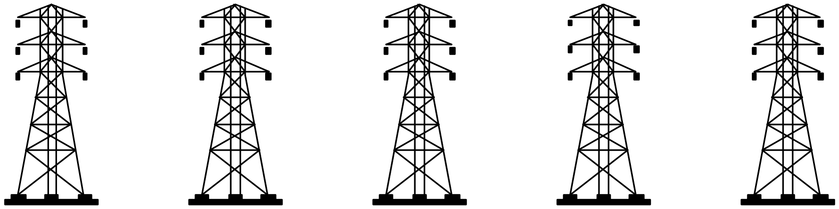

- The sum total of all the impinging external EM radiation upon the body, plus mechanical "special EM" radiation, thus affects and changes the body and all its processes, participating in them.
- That impinging EM radiation can be manipulated to either harm or heal the body and any or all of its cells.
- The body must continually overcome these externally-induced EM changes in its cells and processes, to maintain normalcy. Some EM changes are restored by the subsequent dielectric emission process, relieving the previously-induced deviant EM excitations in its internal processes. Some are not.
- The poorly studied *cellular regenerative system* performs the remainder of the restorative function, which is the fundamental "healing" function of the body.*

*The cellular regenerative system was mostly studied by Becker and a few others. See R. O.Becker, and David G. Murray, "The electrical control system regulating fracture healing in amphibians," Clinical Orthopaedics and Related Research, No. 73, Nov.-Dec. 1970, p. 169-198.

Becker's epochal work

And its ramifications

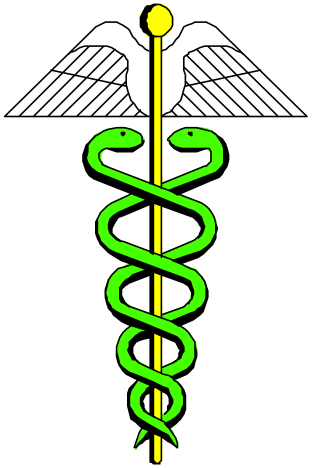

Becker's bone fracture healing

- Tiny DC currents (picoamperes)
- Pulsed DC current can be utilized
- Pulsed magnetic fields may be utilized

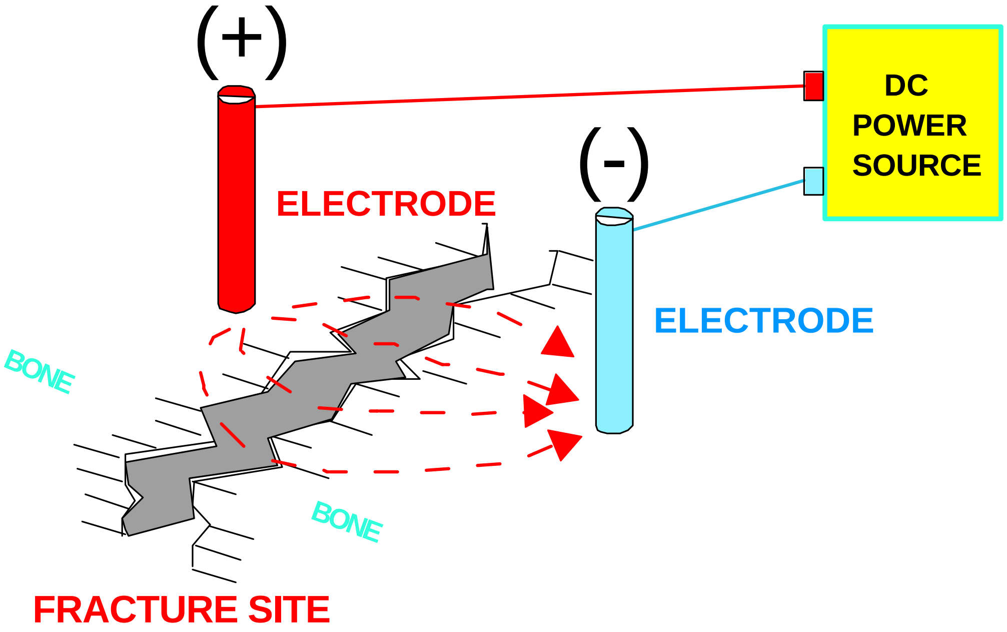
(+)
(-)
DC
POWER
SOURCE
ELECTRODE
ELECTRODE
BONE
BONE
FRACTURE SITE

RED BLOOD CELL DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

Becker's theoretical DC control system involved with response to injury

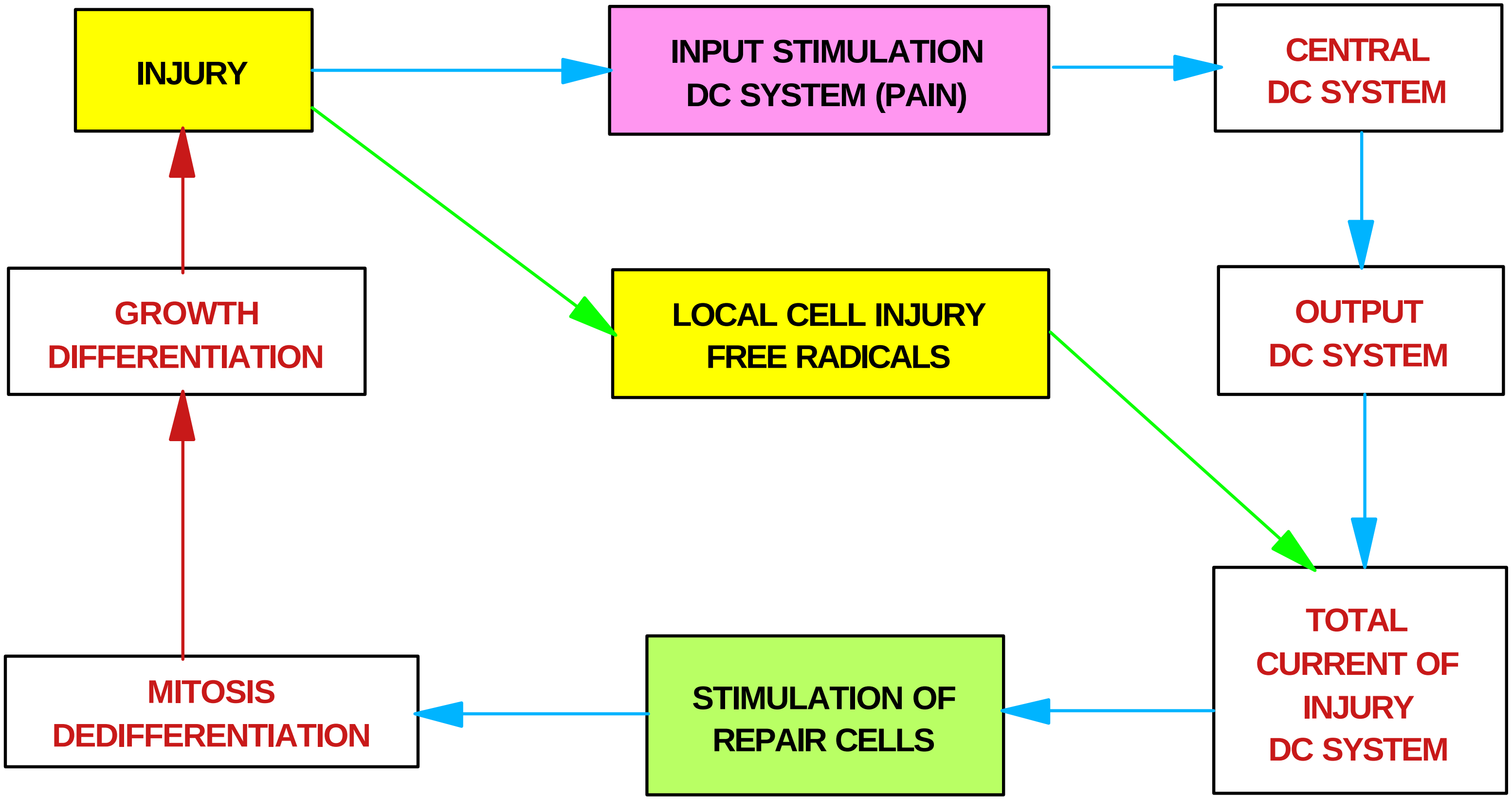

INJURY

INPUT STIMULATION DC SYSTEM (PAIN)

CENTRAL DC SYSTEM

OUTPUT DC SYSTEM

TOTAL CURRENT OF INJURY DC SYSTEM

LOCAL CELL INJURY FREE RADICALS

STIMULATION OF REPAIR CELLS

MITOSIS DEDIFFERENTIATION

GROWTH DIFFERENTIATION

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.

Becker's proposed control system governing regeneration*

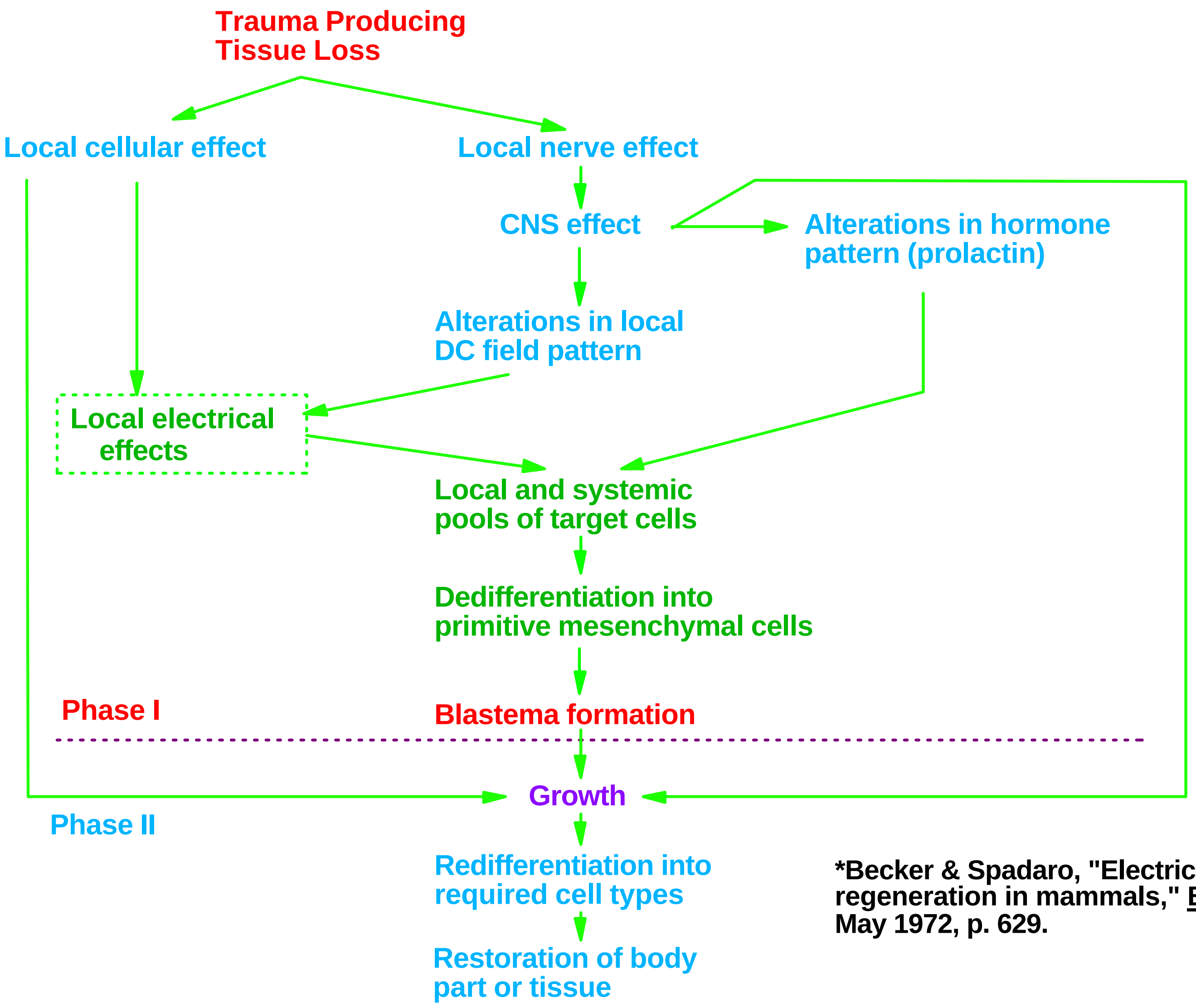

Trauma Producing Tissue Loss

Local cellular effect

Local nerve effect

CNS effect

Alterations in hormone pattern (prolactin)

Alterations in local DC field pattern

Local electrical effects

Local and systemic pools of target cells

Dedifferentiation into primitive mesenchymal cells

Phase I

Blastema formation

Growth

Phase II

Redifferentiation into required cell types

Restoration of body part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bull. N. Y. Acad. Med., 48(4), May 1972, p. 629.

Extending Becker's work

- Becker had only the archaic classical electrodynamics available to him. That EM is grossly inadequate.
  - Insufficient group symmetry to model the process.
  - Already eliminates the "infolded" longitudinal wave EM that structurally and dynamically comprises all "normal" EM potentials, fields, and waves.
  - It is this internal LW EM that is manipulated and used by the cellular regenerative system.
- Nonlinear phase conjugate optics was not yet developed when Becker did his seminal work.
- Successful higher symmetry electrodynamics models -- such as O(3) -- have been developed and are available.

A sad commentary

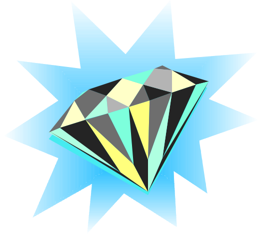

- Becker was nominated for the Nobel Prize, but he was hounded, his funds were withdrawn, and he was forced to retire early.
- His main "sin" was having the courage to testify against the harmful effects of unrestricted powerline radiation and electronic smog.
- Powerful interests then crushed him, set up their own well-funded institutes, and hired scientists who then predictably found that powerline radiation was no problem.
- Such research is so tainted that recently several important journals have now required the authors of submitted papers to state what their affiliated companies do, and what "company massaging" of their research occurred.
- From a higher symmetry EM view, it is obvious that the dielectric pathway and quantum electrodynamics already show a significant problem due to such radiation, particularly with respect to long-term effects.
- This is particularly significant since "noise" -- the mere presence of more "hash" -- appreciably amplifies the dielectric transmission effect. So the major factor becomes EM smog *signals density*, not signal power.

Kaznacheyev's startling results

And its ramifications

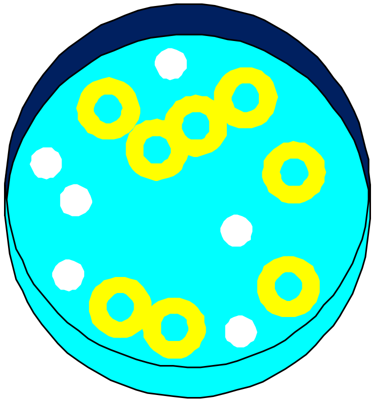

Proof that the cellular condition is radiated from groups of cells

- It follows that a diseased, damaged, or infected cell culture will and does emit its exact internal EM condition, hence the disease or damage "generatrix form" itself (in the internal structuring of the EM radiations).
- Further, these "state" emissions can couple into other targeted cells to produce disease and disorder in them.
- This was clearly proven in some 15,000 Russian experiments by Kaznacheyev.
- Kaznacheyev demonstrated induction of cellular disease and disorder between EM-coupled but otherwise environmentally shielded cell cultures
- Similar experiments have been replicated in the West by Reid *et al*., and by Popp *et al*.

Kaznacheyev's induction of cellular disease and disorder

● ●

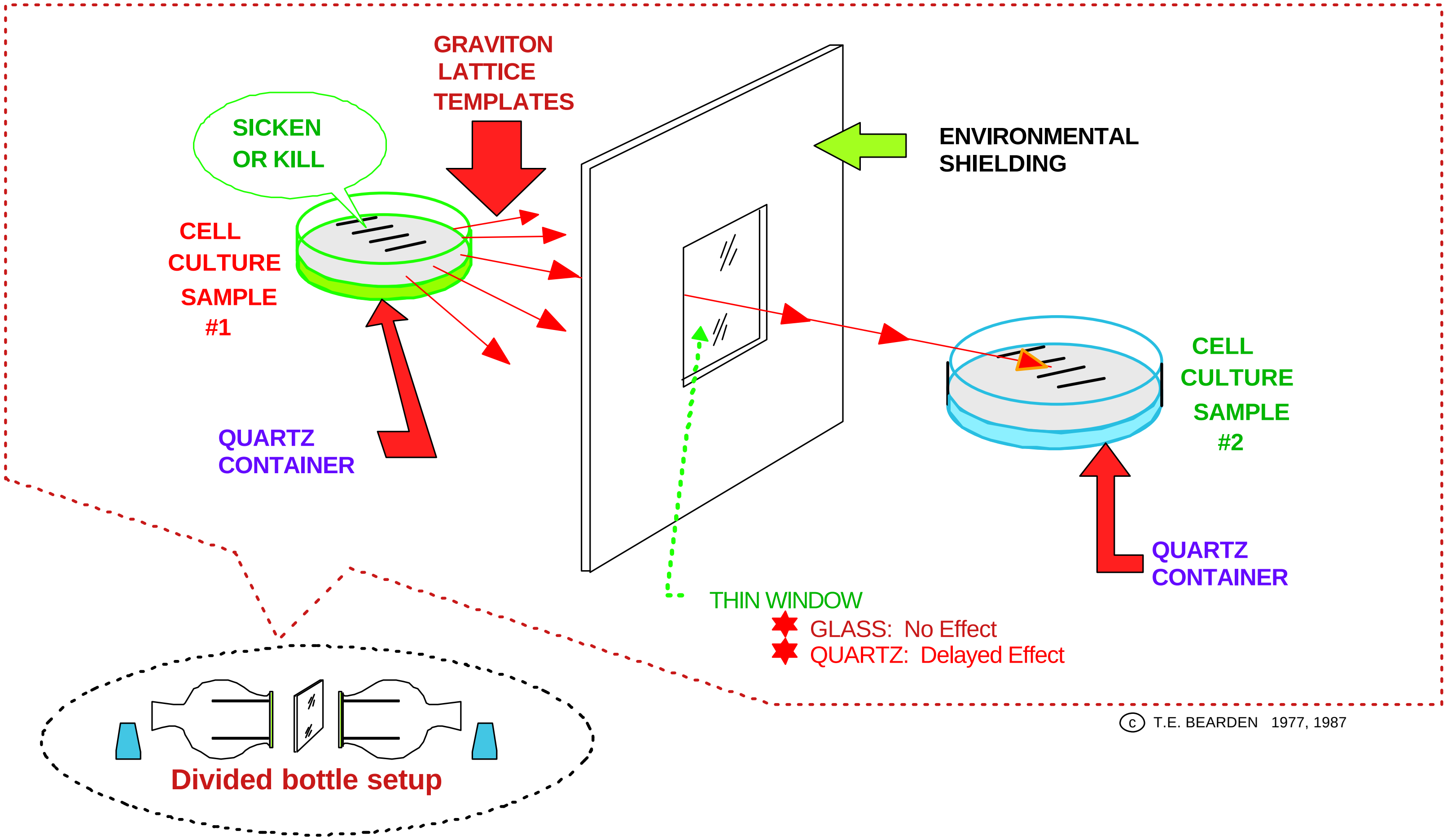

GRAVITON LATTICE TEMPLATES

ENVIRONMENTAL SHIELDING

SICKEN OR KILL

CELL CULTURE SAMPLE #1

QUARTZ CONTAINER

CELL CULTURE SAMPLE #2

QUARTZ CONTAINER

THIN WINDOW

GLASS: No Effect

QUARTZ: Delayed Effect

Divided bottle setup

ⓒ T.E. BEARDEN 1977, 1987

Note: Minimum lattice is one harmonic interval: IR to UV is such a minimum G-lattice. Consider particularly the dielectric pathway in the emitting diseased cells and in the receiving targeted healthy cells.

Another surprising feature of Kaznacheyev's experiments

- The experiments do not work if the targeted cells are in normal light, such as sunlight*.
- The reason is that the normal light bandwidth occupies a single harmonic interval between ultraviolet and infrared.
- Hence its difference frequencies also fill such an interval. For a set of n frequencies, the number *d* of difference frequencies is $d >> n$.
- Thus the visible light spectrum represents "jamming" of specific internal EM signal inputs through the dielectric pathway into the body, turning much of the environmental signals into harmless warmth.

* It has also been shown that if bacteria are killed in the "dark" by UV, then 24 hours later placed in sunlight, a substantial fraction of the "dead" bacteria will revive.

Ramifications of Kaznacheyev's experimental results

- At least one harmonic interval is necessary for the effect to be evidenced in the target cells.
- Interestingly, if we assume the body dielectric to be isotropically nonlinear (to first order):
  - Velocities of the actual transmitted frequencies depend upon the particular point on the wave amplitude.
  - The transmitted frequencies overshoot, interfere, breakup, etc. The difference frequency does not.
  - The "difference frequency" is transmitted through the nonlinear dielectric medium as if it were a sine wave passing through a linear medium*.
- To our knowledge, this direct and deep communication of electronic "hash" difference frequencies in dielectric human bodies has not been investigated in the West.

* Owen Flynn, "Parametric arrays: A new concept for sonar," Electronic Warfare Magazine, June 1977, p. 107-112.

Ramifications of Kaznacheyev's experimental results (2)

- A heterodyne signal -- at the difference frequency between an input signal and a reference signal -- can be enhanced by adding noise*.
- Thus the signal of the disorder in the cellular pattern emitted from diseased cells, received by normal cells, can be amplified electronically and rather easily.
- Powerline radiation (electronic smog) thus carries its own amplification mechanism. Eventually the amplification overcomes any squelching by sunlight, etc.
- The Russians promptly (as early as the late 1950s) weaponized and tested these and similar effects.

* Dykman, M. I. et al., "Noise-enhanced heterodyning in bistable systems," Physical Review E, 49(3), Mar. 1994, p. 1935-1942

Weaponization of Kaznacheyev's findings

And its ramifications

"Microwave" radiation of the U.S. Embassy in Moscow.

Former U.S. Embassy in Moscow.

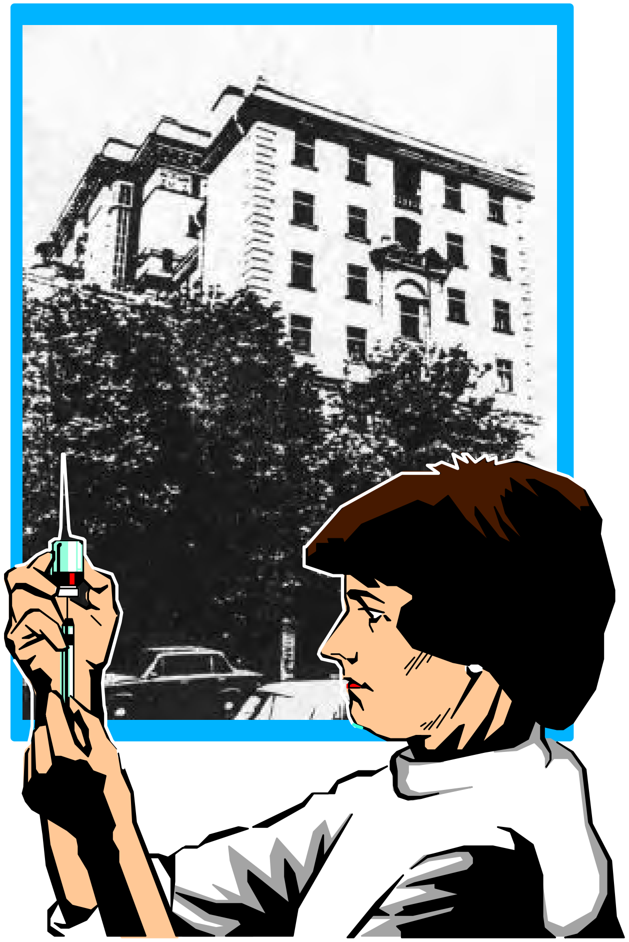

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
  - U.S. Ambassador to USSR
  - U.S. President
  - NSA, CIA, DIA, NSC, etc.
  - Top consulting scientists
  - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero pot'l gradient) areas!
- Four U.S. Presidents requested Soviets cease
  - Cut from 18 watts/sq cm to 2
  - Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

Ramifications of the microwave radiation of the U.S. Embassy

- The cellular disorder pattern in the EM radiation is carried by the field-free scalar potential.
- Since the disorder pattern is a "conglomerate", it must be carried by an internal EM structure existing inside the scalar potential itself.
- Whittaker decomposed the scalar potential into the appropriate internal longitudinal EM biwave structure in 1903*.

* E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," Mathematische Annalen, Vol. 57, 1903, p. 333-355

The importance of time as energy, and the time-domain

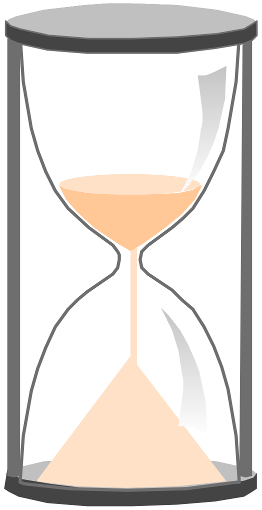

Time as energy

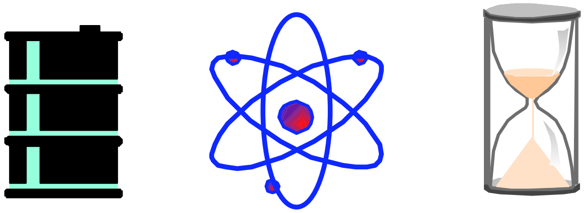

- In physics, the fundamental units one uses in his model are arbitrary.
  - A valid model can be made using only one unit.
  - It is already done in one branch of physics, using length as the single fundamental unit.
- Make a model with a single unit, the joule.
  - All other entities become functions of the joule.
  - We are familiar with mass as highly compressed EM energy, by the factor c^2.
  - It turns out that time is also highly compressed EM energy, by the factor c^2.
  - 1 sec. $\approx 9 \times 10^{16}$ joules.

How to see that "time is compressed spatial energy"

- Take some spatial EM energy and compress it by c^2
- Place it in 3-space, and it is *mass*.
- Place it on the time axis, and it is *time*.

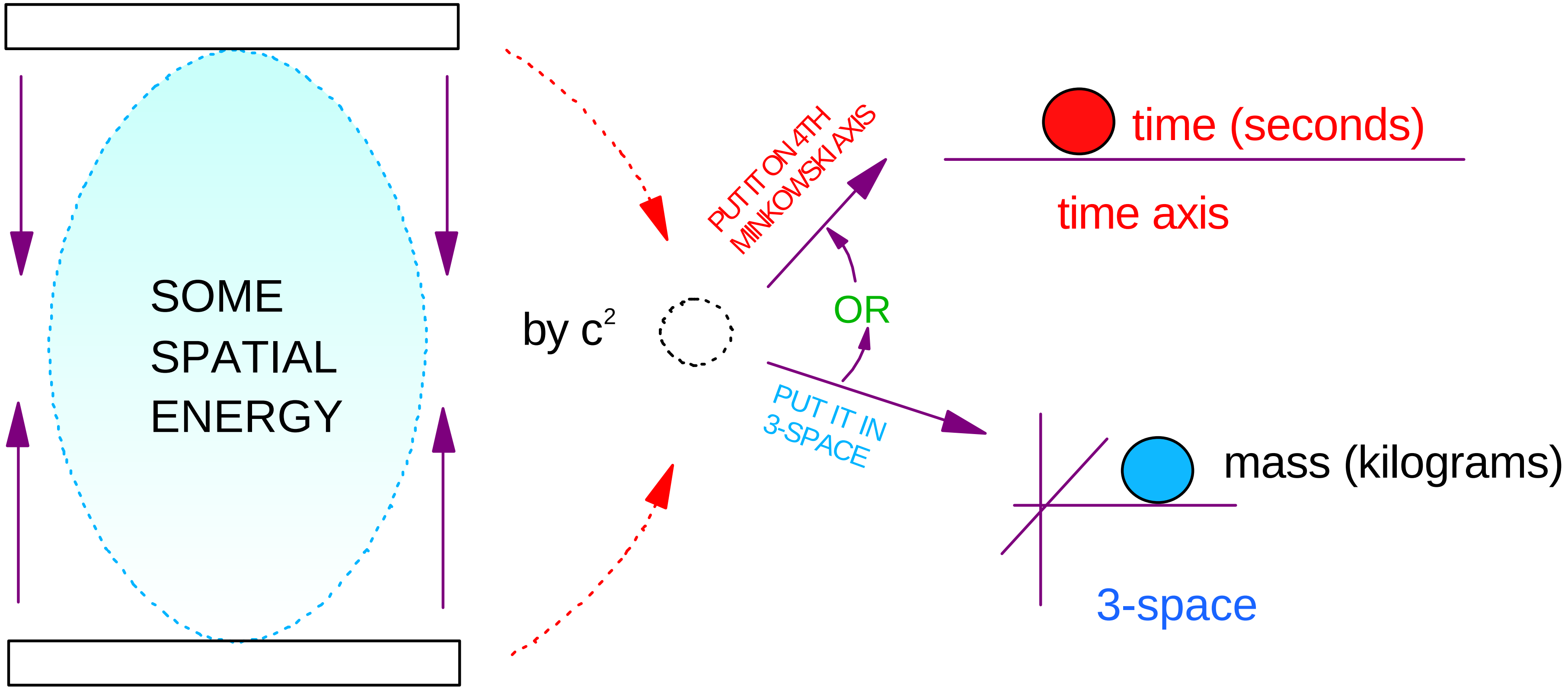

PRESS

SOME
SPATIAL
ENERGY

PRESS

by c^2

PUT IT ON 4TH MINKOWSKI AXIS

OR

PUT IT IN 3-SPACE

time (seconds)

time axis

mass (kilograms)

3-space

- When time-energy is converted into mass-energy, time is "decompressed" (expanded) into 3-space EM energy and 1 sec. $\approx 9 \times 10^{16}$ joules.

Time as EM energy in the time domain, with a density the same as mass-energy

- Bearden* reinterpreted (corrected) the 1903 Whittaker decomposition of the potential in 2000.
- The reinterpretation is consistent with broken symmetry in particle physics, for which Lee and Yang received the Nobel Prize in 1957.
- It is also powerfully supported by quantum field theory, notably by Mandl and Shaw in 1984**.
- Whittaker's pair is a combined time-polarized (scalar) EM wave and a 3-space longitudinal EM wave.

* T. E. "Giant Negentropy from the Common Dipole," Journal of New Energy, 5(1), Summer 2000, p. 11-23.

** F. Mandl and G. Shaw, Quantum Field Theory, Wiley, 1984, Chapter 5.

All EM energy in 3-space freely comes from the time domain

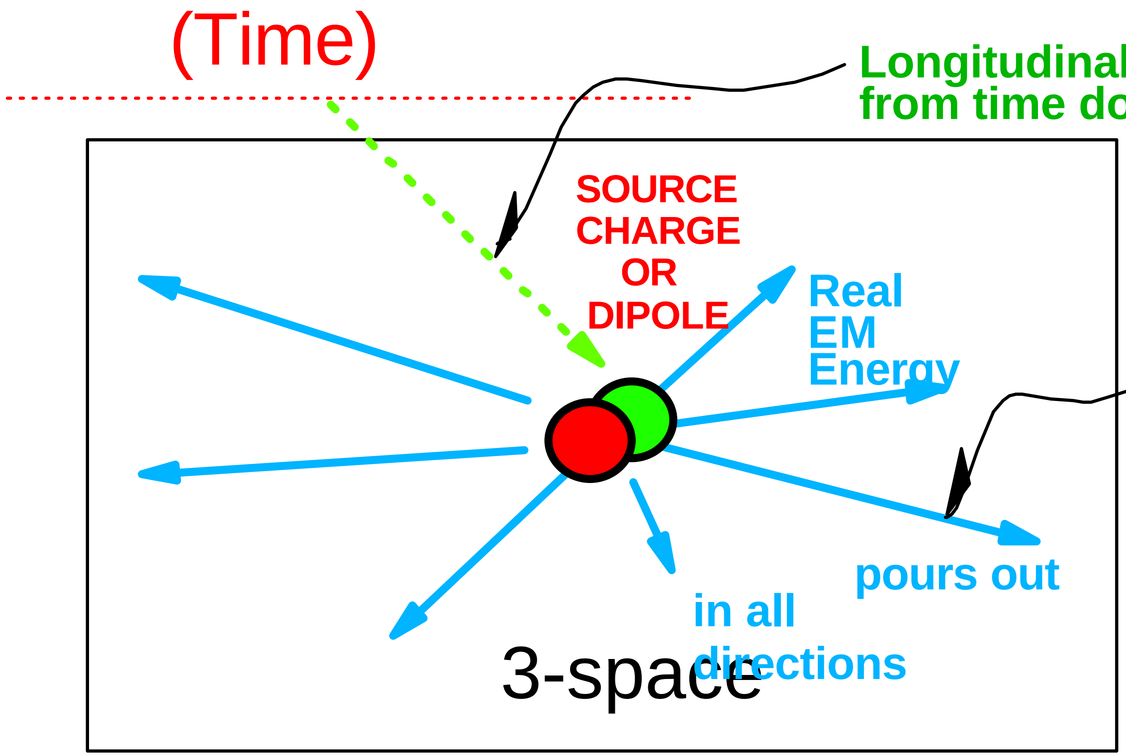

Longitudinal EM wave incoming from time domain and absorbed

Charge's 720º spin transforms time-energy into 3-space energy

Longitudinal EM waves emitted in all directions in 3-space

Whittaker, Math. Ann., 57, 333 (1903) shows this rigorously, when properly reinterpreted. Dipole's broken 3-symmetry is well-known in particle physics

Note: Whittaker (and others) interpreted the phase conjugate half set of LWs after interaction with the charges of the dipole, and as a 3-space *effect* rather than the time-domain *cause*. This fundamental non sequitur was just repeated since then, until corrected by Bearden to be consistent with broken symmetry and quantum field theory.

Strong support from quantum field theory

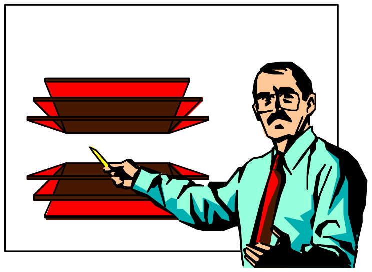

- Quantum field theory recognizes four photon polarizations:
  - Energy along x-, y-, z-, or t- axis.
  - Polarized along x- and/or y-axis, the photon is a *transverse* photon.
  - Polarized along z-axis (along its line of motion in 3-space), the photon is a *longitudinal* photon.
  - Polarized along the time-axis, the photon is a *time-polarized* or *scalar* photon.
- The individual longitudinal or scalar photon is not observable*.
- The combination of a longitudinal photon and a scalar photon is observable as the instantaneous scalar potential*.

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* F. Mandl and G. Shaw, Quantum Field Theory, Wiley, 1984, Chapter 5.

Mechanism generating the flow of a mass through time

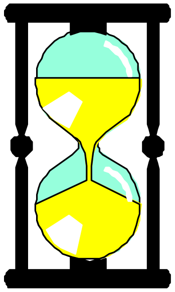

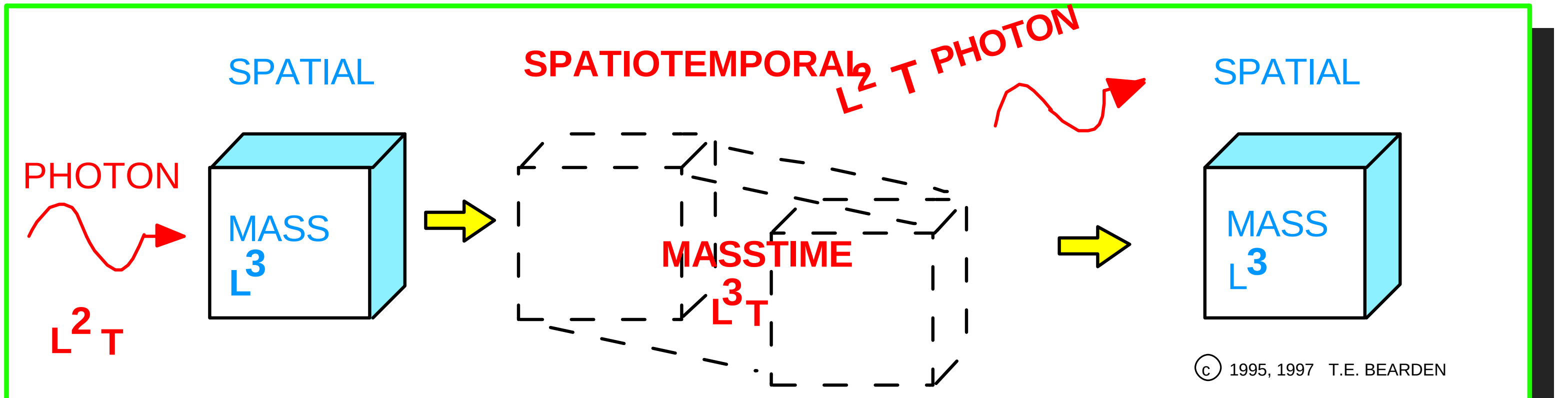
SPATIAL
SPATIOTEMPORAL
L2 T PHOTON
SPATIAL
PHOTON
MASS
L3
MASSTIME
L3T
MASS
L3
L2 T

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$$(\Delta E)(\Delta t) + M \Rightarrow (M+\Delta M)\Delta t \Rightarrow M + (\Delta E)(\Delta t)$$

Flow of macroscopic time (observable photon interactions)

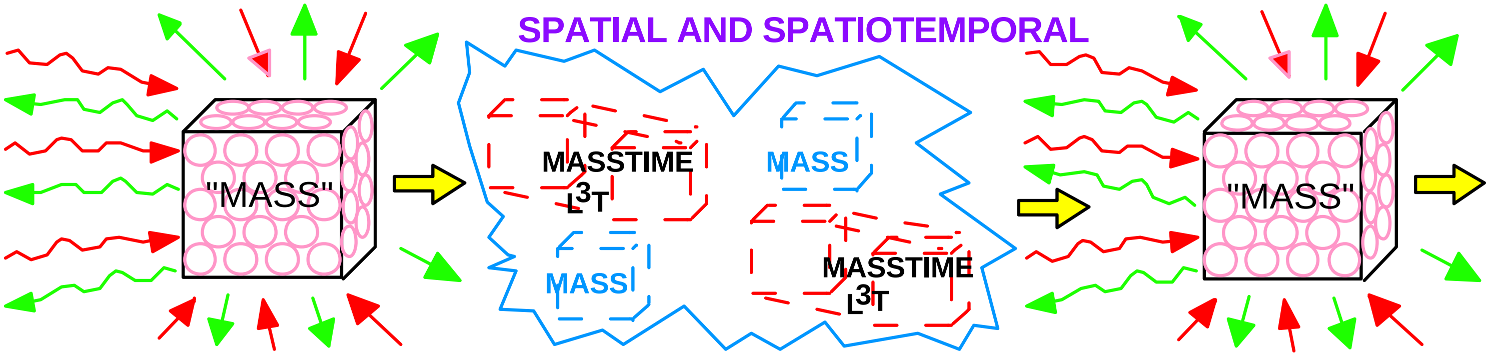
SPATIAL AND SPATIOTEMPORAL
"MASS"
MASSTIME
L3T
MASS
MASS
MASSTIME
L3T
"MASS"

Flow of microscopic time (via virtual photon interactions)

Mechanism is engineerable

Pumping a mass in the time-domain will time-reverse it back to an earlier state

- The reinterpreted biwave EM structure of the scalar potential means that time-reversal (phase conjugation by pumping in the time-domain) can be utilized to time-reverse a targeted cell (its mass-energy) in its entirety, including its genetics.
- Becker's bone fracture experiments showed it:
  - Weak scalar potential across the fracture site.
  - LWs in 3-space and time-energy waves in time
  - Red blood cells entered, dedifferentiated by shucking their hemoglobin and growing a nucleus, which is dedifferentiation (time-reversal of the cell and its mass-energy back to a previous physical state).

Principle for time-reversing a time-pumped mass

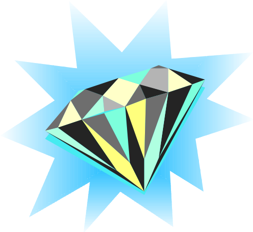

- Becker's cells then redifferentiated and changed -- first to primitive cartilage cells, then to primitive bone cells which were deposited in the fracture, healing it with new bone growth.
- This shows "time-forwarding" (redifferentiation) of the cell also.
- Becker actually showed that the *time-domain pumping* of the cells (by the time-polarized EM waves of Whittaker's reinterpreted wavepairs comprising the scalar potential), and the time-pumping of their mass-energy, operated to continuously and steadily *remove the delta between that cell's present condition and its former "normal" cellular physical condition in that area*.
- This is the long-sought secret of stem-cell research.
- Phase conjugate optics had not been born at the time. Without realizing its full nature, Becker demonstrated the body's own internal mechanism for healing, and the fundamental mechanism for time-reversing a physical mass, whether living or inert.

Mechanisms for use in medical treatment and healing

And ramifications

Successive deep penetration reactions of the cellular dielectric

- Change after change affects the cell and all of its parts, including from the external environment.
- Each successive change affects primarily the internal "LW EM structures and dynamics" comprising the ordinary potentials, fields, and waves.
- Thus in positive time the internal EM structurings produce successive "overlaid layers of change" -- so to speak -- in the internal EM structuring and dynamics of a cell in the body. These layers contain the "delta" from normal state.

Successive deep penetration reactions of the cellular dielectric (2)

- During time reversal, highest layer deltas are successively "peeled away" by the interaction of the mass-energy with the time-domain pumping.
- The result is to return the cell directly back to successive physical states, in the case of a single disease or disorder.
  - A cancer cell is returned to a normal cell prior to its "promotion".
  - An HIV-infected cell would be returned to its normal unaffected condition, free of HIV-induced genetic change.
  - For injuries and damage, the existing "delta" in each successive state-layer is steadily reduced to zero.
- This process thus can involve both cellular differentiation and dedifferentiation, as shown by Becker and by Prioré.

Engines (vacuum engines, spacetime curvature engines)

- Following Whittaker* as reinterpreted**, all normal EM fields, potentials, and waves decompose into sets of longitudinal EM waves (LWs) and their dynamics.
- Since these LWs and their dynamics are dynamics in the local energy density of spacetime (ST), they constitute *ST curvatures*.
- Hence they are general relativity infolded inside electrodynamics.
- By manipulating and changing these LWs, one manipulates and changes spacetime curvatures and their dynamics.
- The result is a unified field model where one directly controls and engineers a set of ST curvatures by use of higher group symmetry electrodynamics.
- Controlled patterns of local curvatures of ST are called "vacuum engines" or "spacetime curvature engines" -- or just "engines".

* E.T. Whittaker, Math. Ann., 57, 333-355 (1903); Proc. Lond. Math. Soc., Series 2, 1, 1367-372 (1904).

** T. E. Bearden, J. New Energy, 5(1), 11-23 (2000).

Pumping with EM time-polarized waves forms *amplified* antiengines

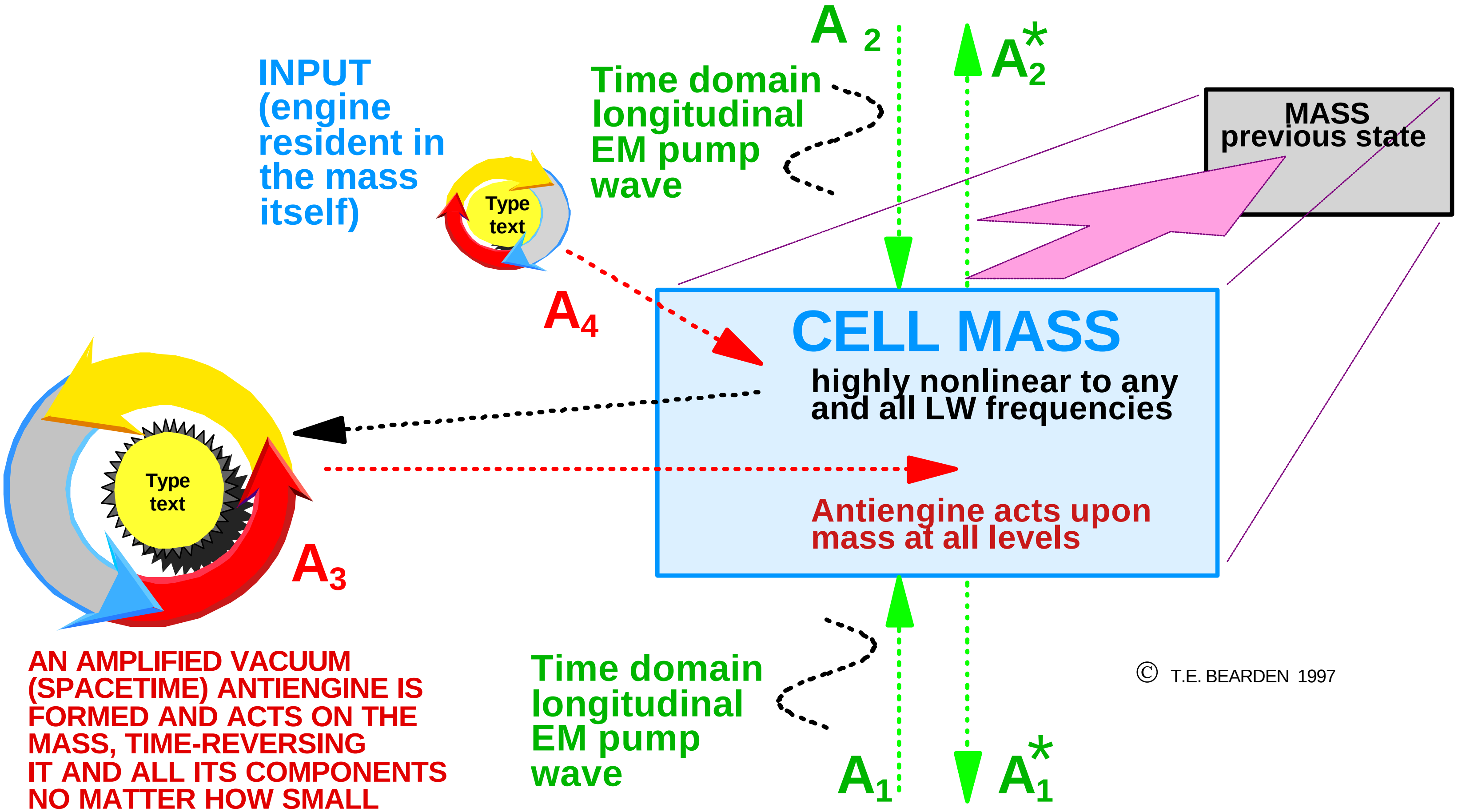

INPUT (engine resident in the mass itself)

Time domain longitudinal EM pump wave

MASS previous state

CELL MASS

highly nonlinear to any and all LW frequencies

Antiengine acts upon mass at all levels

Time domain longitudinal EM pump wave

AN AMPLIFIED VACUUM (SPACETIME) ANTIENGINE IS FORMED AND ACTS ON THE MASS, TIME-REVERSING IT AND ALL ITS COMPONENTS NO MATTER HOW SMALL

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A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

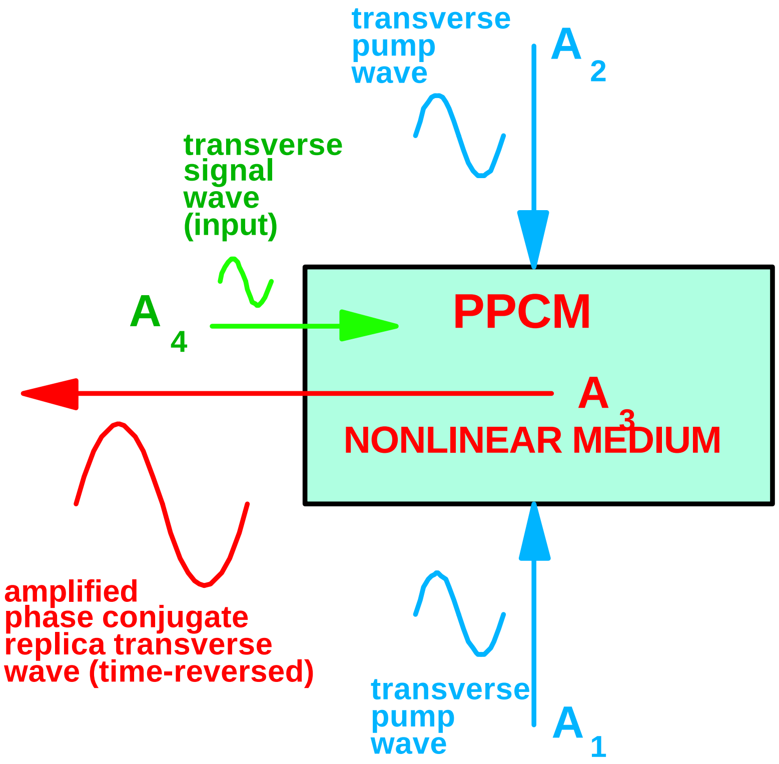
transverse pump wave
A 2
transverse signal wave (input)
A 4
PPCM
A 3
NONLINEAR MEDIUM
amplified phase conjugate replica transverse wave (time-reversed)
transverse pump wave
A 1

a. Pumping with transverse EM waves produces a time-reversed *wave*.

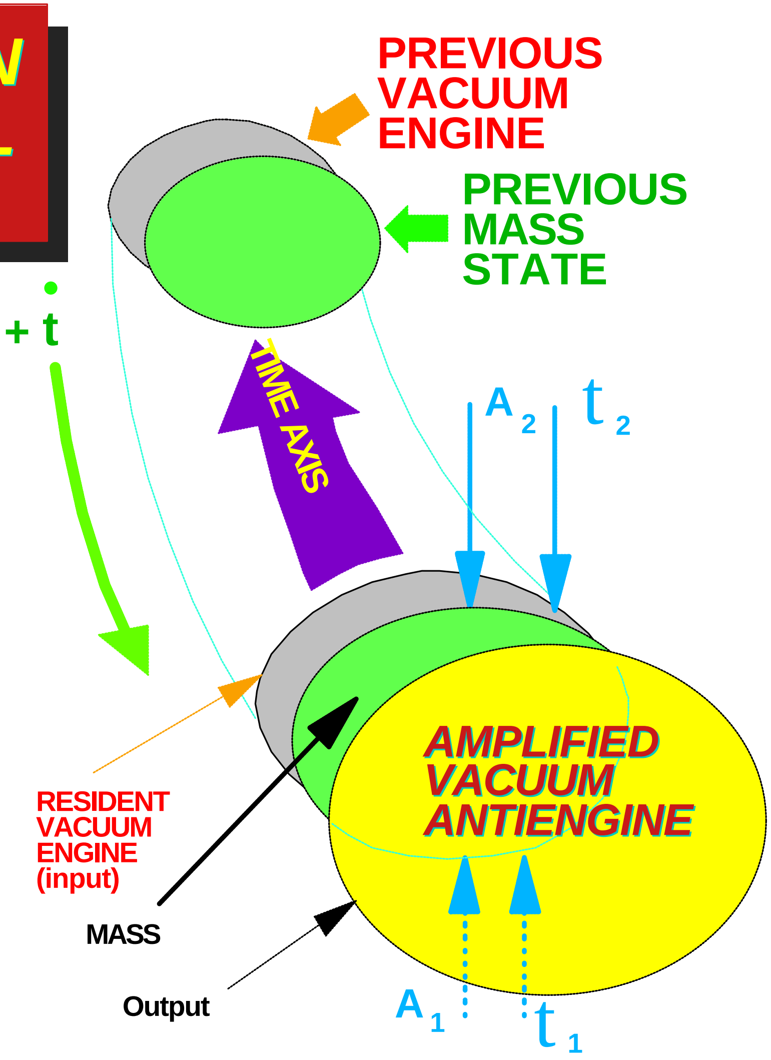
PREVIOUS VACUUM ENGINE
PREVIOUS MASS STATE
+ t
TIME AXIS
A 2
t 2
RESIDENT VACUUM ENGINE (input)
MASS
Output
AMPLIFIED VACUUM ANTIENGINE
A 1
t 1

b. Pumping with longitudinal EM waves A_1 and A_2 time-reverses *the mass itself*.

Time-reversal of a mass to a new physical state not in its past

- Original engine A'
- New engine B' added
- Time-pumping moves to new "past" that is determined by (A'+B')

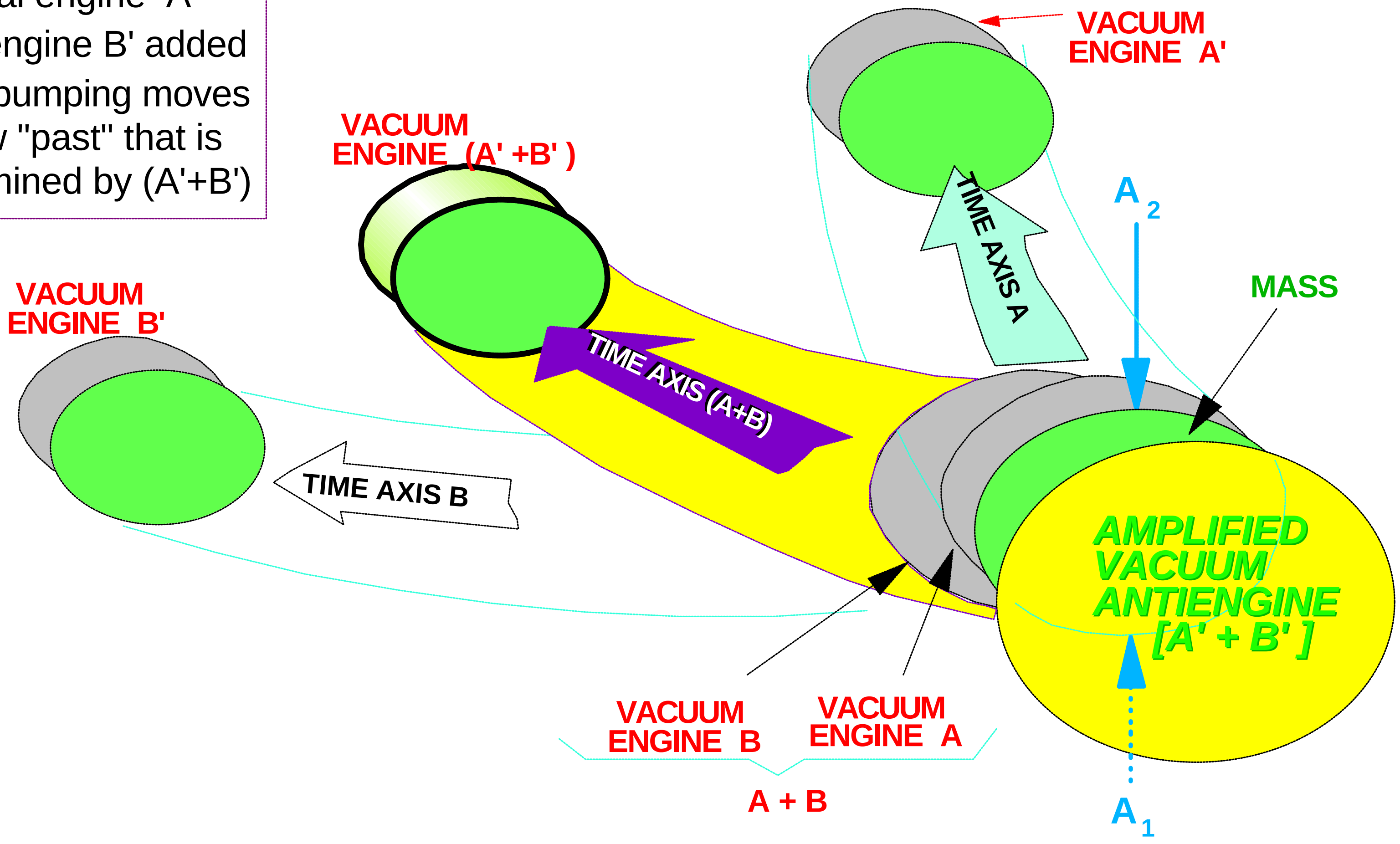
VACUUM ENGINE A'
VACUUM ENGINE (A' +B')
VACUUM ENGINE B'
TIME AXIS A
A_2
MASS
TIME AXIS (A+B)
TIME AXIS B
AMPLIFIED VACUUM ANTIENGINE [A' + B']
VACUUM ENGINE B
VACUUM ENGINE A
A + B
A_1

Extended general relativity principle

- All levels of energy structures and all levels of time structures mold spacetime geometry.
- The "pattern" is called a *template* for a vacuum engine (spacetime curvature engine).
- Spatial and temporal structurings of the engine act upon any exposed mass at al levels.
- This produces a template of forces, for precise translations and stresses within the mass at all levels. The forces exist in both time and 3-space.

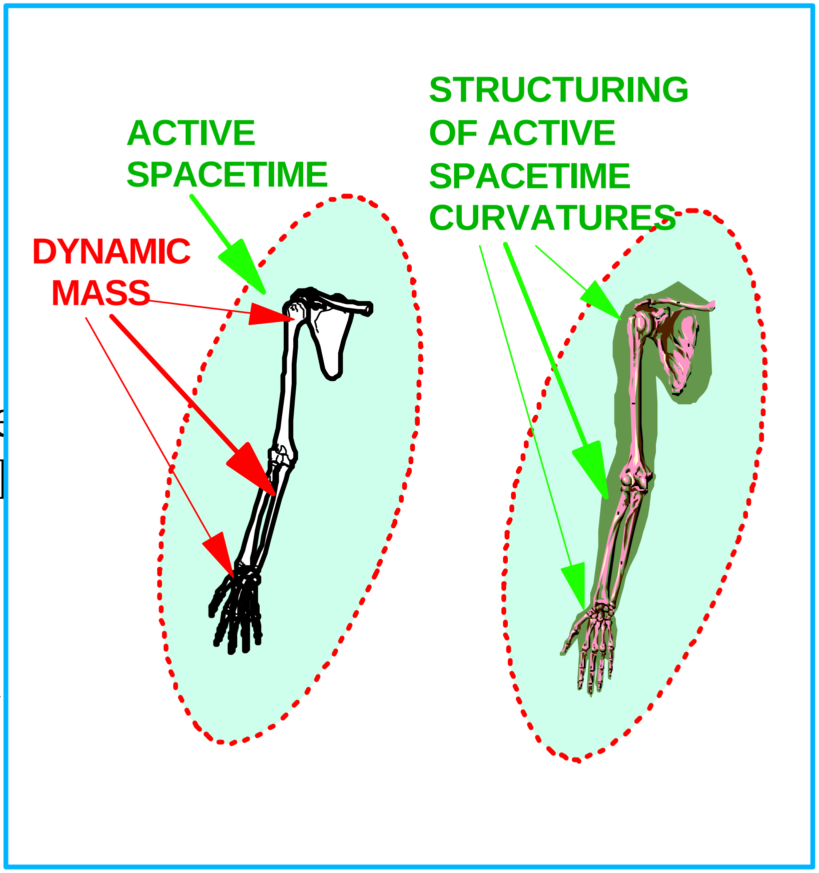
ACTIVE SPACETIME
DYNAMIC MASS
STRUCTURING OF ACTIVE SPACETIME CURVATURES

Engines: Working spacetime demons

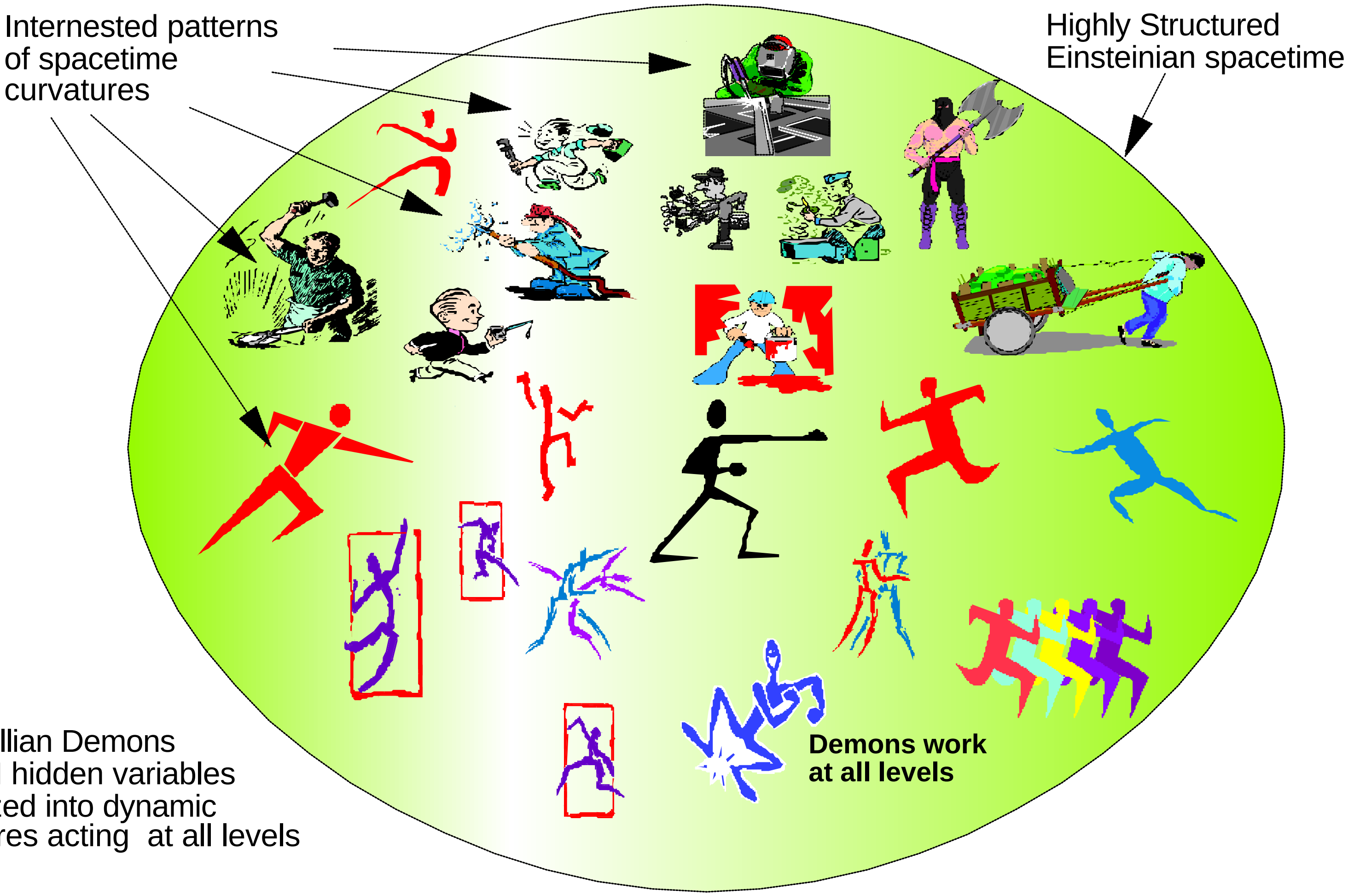

Internested patterns
of spacetime
curvatures

Highly Structured
Einsteinian spacetime

Maxwellian Demons
are EM hidden variables
organized into dynamic
structures acting at all levels

**Demons work
at all levels**

Signal vs. vacuum engine

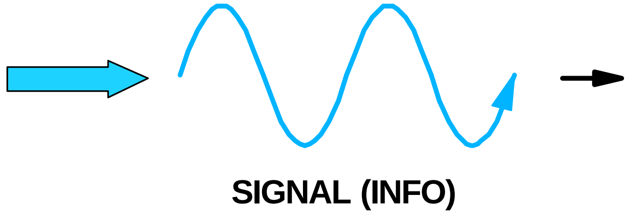

- Information received
- Any overt physical action must be taken by cell itself
- Cell must furnish the energy for any action it takes
- Passes from outside to in

A. Cell must do the action itself; vacuum energy exchange is passive. Energy or fuel for doing the action must be added to cell externally.

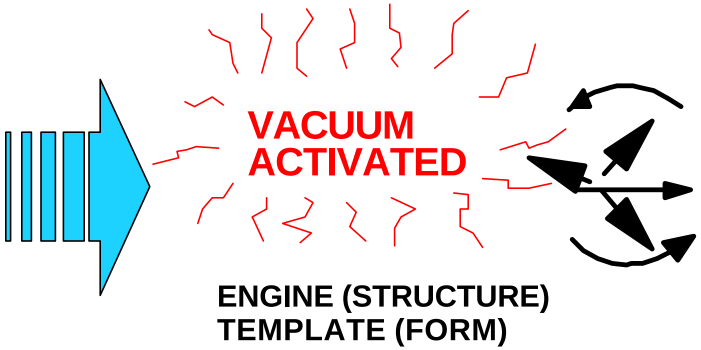

- Information itself acts
- Local spacetime curved, with internal subcurvatures
- Produces template of forces in local spacetime (ST)
- Arises from within local ST
- Acts on and changes all parts of cell, including its genetics

B. Cell is acted upon; vacuum energy exchange does the specific action. No energy or fuel for doing the action need be added to cell externally.

Unified field theory requires modeling and use of supersystem

Three components interact with each other:

- System and its dynamics
- Local active vacuum and its dynamics
- Local curvatures of spacetime and their dynamics.

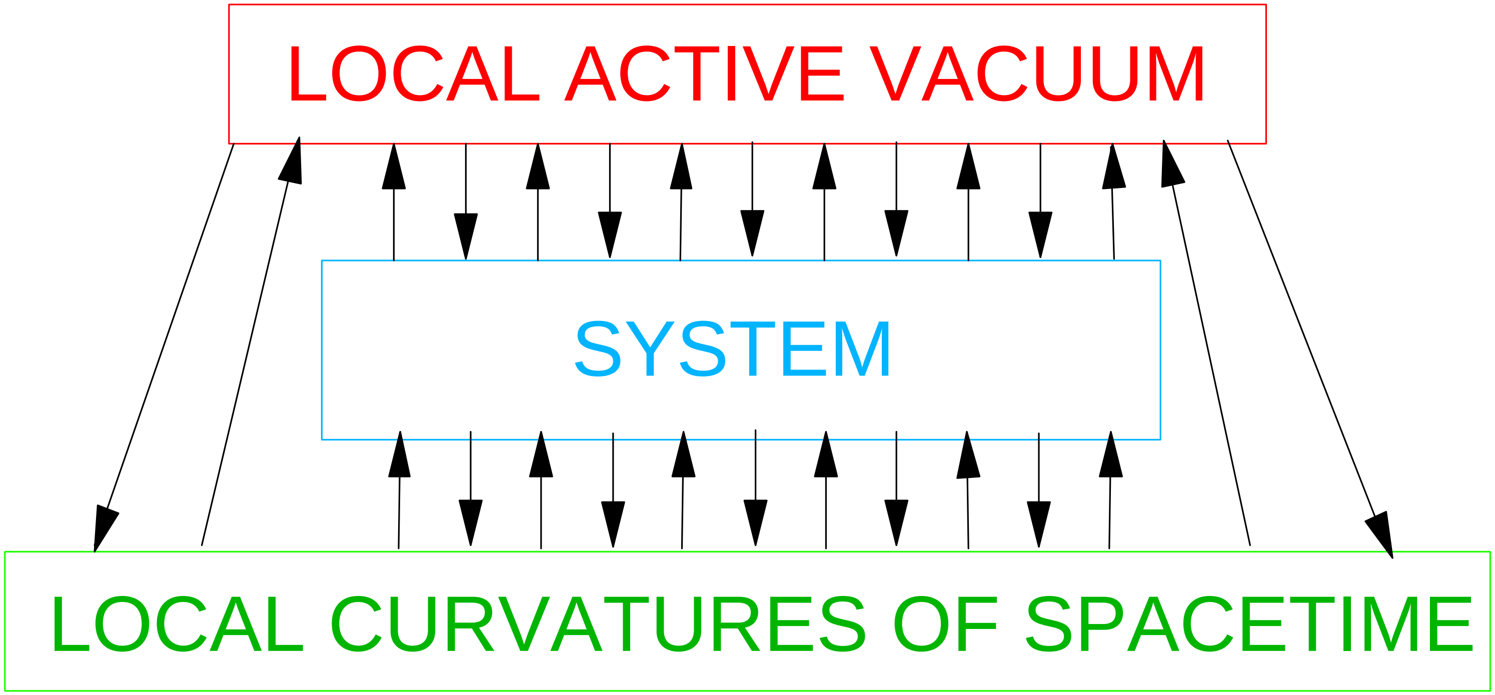
LOCAL ACTIVE VACUUM

SYSTEM

LOCAL CURVATURES OF SPACETIME

Classical EM kills the supersystem, prevents supersystem engineering

- Assumes flat local spacetime
- Assumes inert vacuum

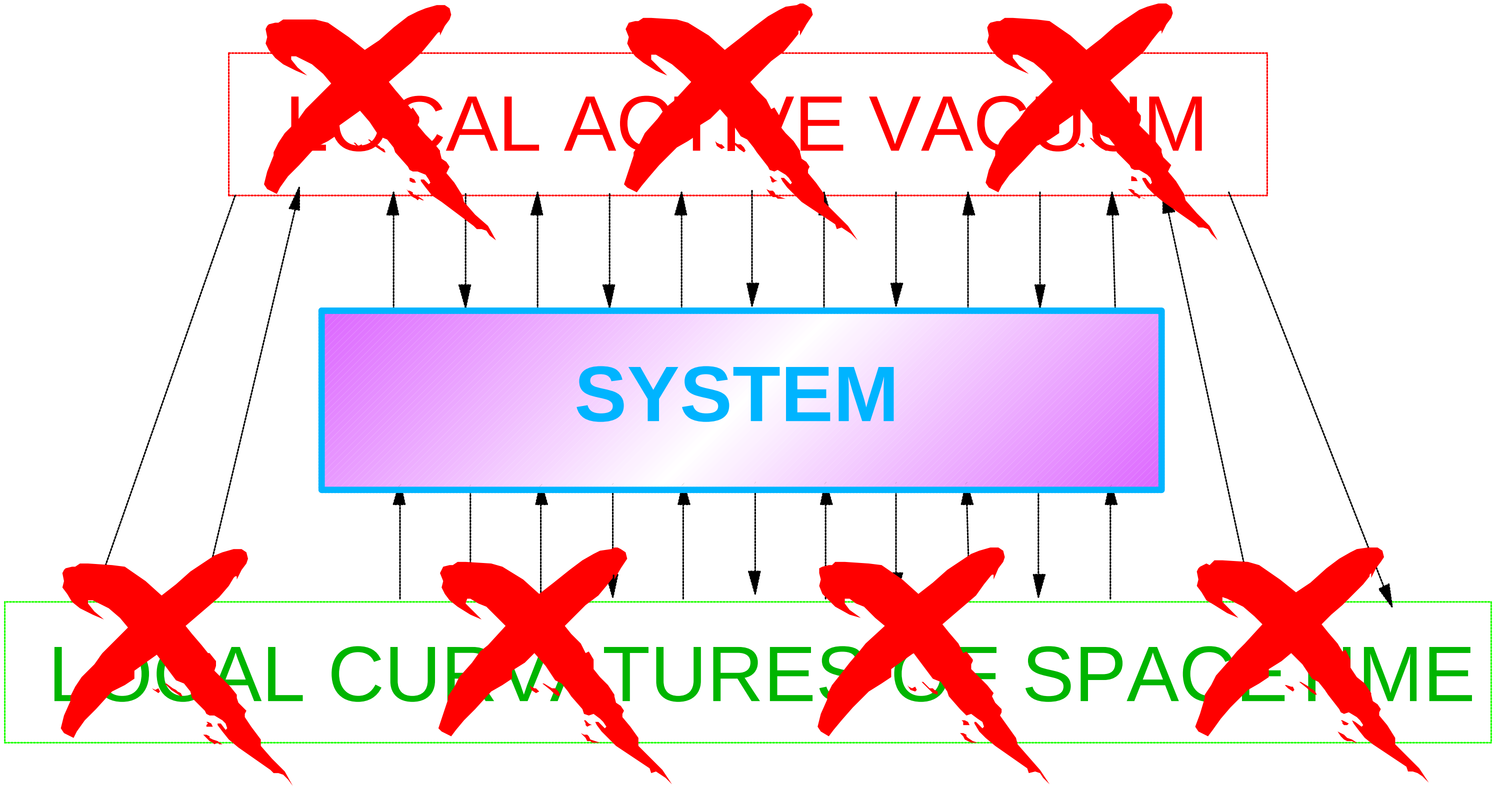

LOCAL ACTIVE VACUUM

SYSTEM

LOCAL CURVATURES OF SPACETIME

Malignant teratoma exhibits both time-reversal and fast-forwarding

- A teratoma cell is a tumor cell that has reverted to stem cells, then proceeds to differentiate toward new kinds of normal cells.
- May produce hair, skin, muscle, heart, bone, and other type cells.
- Sometimes present at birth.
- Demonstrates both "time-reversal" and "time-forwarding".
- The missing key is the engine function(s).

Miller-Fox-Urey biogenesis experiments

- Engines of and from all life forms ever on earth or in the universe exist in the ambient vacuum potential.
- The Miller-Fox-Urey experiments were not in a "sterile" environment.
- Heat (IR) and UV constitute (1) a harmonic interval with a difference frequency, and (2) amplifying by the process previously shown.
- These experiments "kindled" previously living forms from the available gases etc. by amplifying the ancient living engines from their virtual state to the observable state, so that the masses were molded into the physical states of their templates.

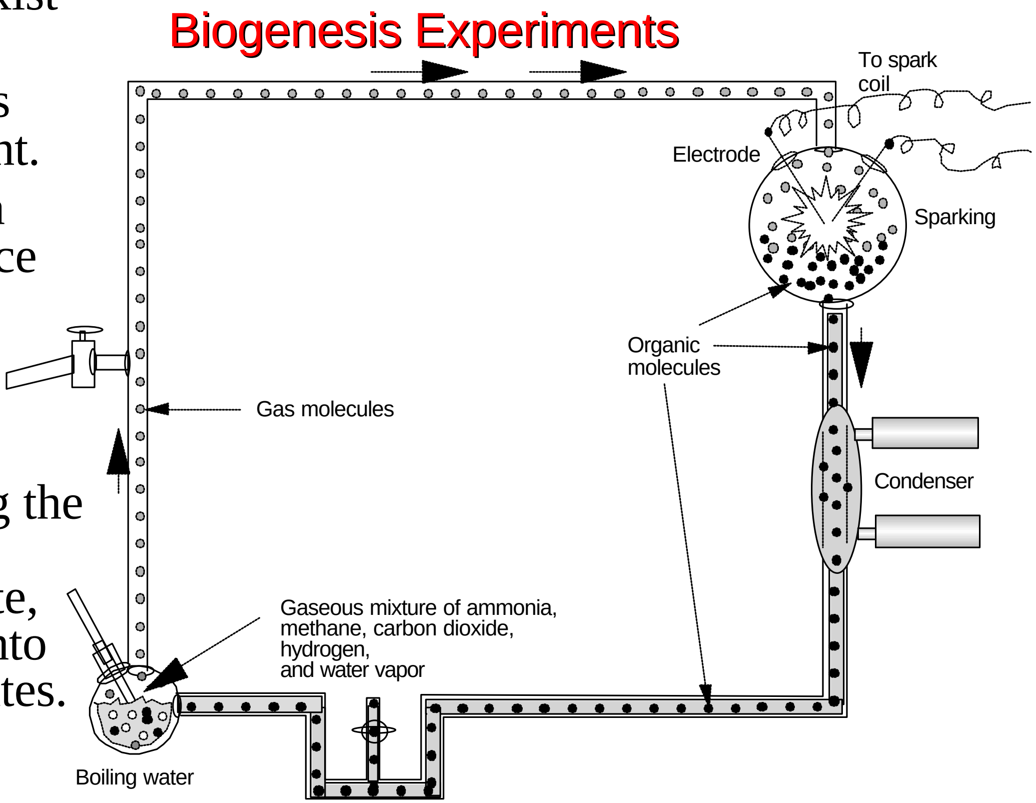
Biogenesis Experiments
To spark coil
Electrode
Sparking
Organic molecules
Gas molecules
Condenser
Gaseous mixture of ammonia, methane, carbon dioxide, hydrogen, and water vapor
Boiling water

Cloning to produce stem cells

- Human DNA can be inserted in an animal cell, and the cell chemically tricked into proceeding as if fertilized.
- Formation, increase, and growth of stem cells begins and continues.

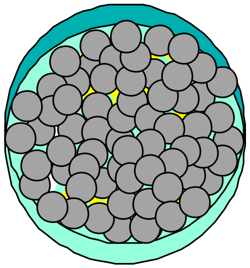

- The "engine" carried by the human DNA is changing the matter available into human cells.
- readily demonstrated experimentally.

Regeneration in a strain of rat with part of its immune system missing

- In mammals, the immune system plays a role in reducing the regeneration capability, compared to that of more primitive systems.
- In a strain of rat where that "suppressive" part of the immune system is missing, the regenerative capability is dramatically increased.
  - Can regrow cut away sections of tail.
  - Regrows plug cut out of ear.
  - Reconnects severed optic nerve.
  - Partially restores severed spinal cord.

- The suppressive "delta" engine of the immune system, operating simultaneously with the underlying primitive regenerative engine, sums to the modern much-reduced regenerative engine in the mammal.

An observation for the future

- When the science of engines is developed, physicians will be able to tailor these engine combinations to restore severed human spines, regrow severed limbs, etc.
- They will also be able to direct the body's "normal growth" to reduce and direct birth defects, genetic defects, etc.

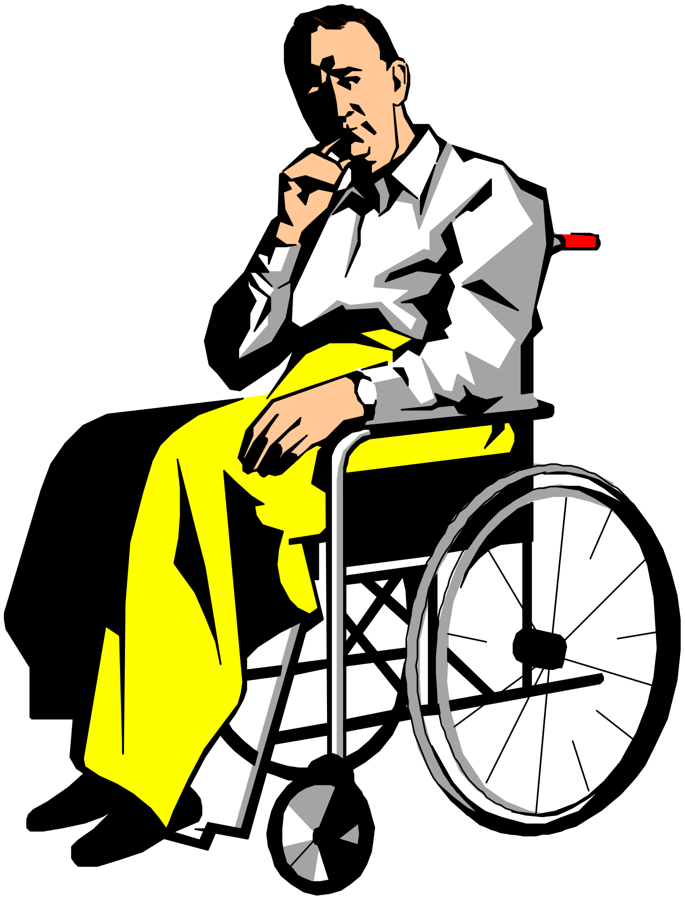

Biochemistry and EM models

- Medical scientists analyze such things as teratomas in terms of biochemistry and the biochemical model.
- An assembly of charges and charge distributions, with their associated fields and potentials, drives all chemistry at base level.
- The charge assembly and its dynamics involves a corresponding assembly of spacetime curvatures and their dynamics. These are *the cause that is driving the charge assembly and its dynamics, and therefore the chemistry*..
  - In unified field theory (such as that of Sachs) and O(3) electrodynamics.
  - Not in classical U(1) EM theory or quantum electrodynamics.
- Conventionally a causative EM field in space is "defined" as the *diversion from* that spatial field by and after its interaction with charge).
  The "definition" substitutes the effect for the cause, a non sequitur.
- This is a known major flaw, pointed out in one fashion or another by many physicists such as Wheeler and Nobelist Feynman.
- Classical EM theory is a 137-year-old model, seriously flawed. These flaws emerge in biochemistry and medical science.

Necessary EM corrections*

- Many of the corrections necessary in electrodynamics modeling either have been done or are underway.
- Higher symmetry, non-Abelian electrodynamics models have long been developed in particle physics.
- The new approach extends these models to also incorporate general relativity, thus producing a unified field theory*.
- In the new approach, spacetime curvature engines are perfectly natural and understandable, and can be directly modeled and engineered by advanced theorists.
- In short, the theory is sufficiently advanced and robust that technology and engineering can now advance.
- This will be a great leap forward for biochemistry and medical science, particularly in therapeutic methods.

* Sachs's unified field theory implemented by O(3) electrodynamics presently is the most suitable to use. Numerical methods are required.

Prioré's revolutionary results in lab animals

And its ramifications

Prioré (right) makes a point to Chaban-Delmas, Mayor of Bordeaux

- Many of the Prioré team's experiments were done in Bordeaux.
- Antoine Prioré patents:
  - "Apparatus for producing radiations penetrating living cells," U.S. Patent No. 3,368,155, Feb. 6, 1968.
  - "Method of producing radiations for penetrating living cells," U.S. Patent No. 3,280,816, Oct. 25, 1966.
  - "Procede et dispositif de production de rayonnements utilisables notamment pour le traitement de cellules vivantes," [Procedure and Assemblage for Production of Radiation Especially Serviceable for the Treatment of Living Cells], Republique Francais Brevet d'Invention P.V. No. 899.414, No. 1,342,772, Oct. 7, 1963.

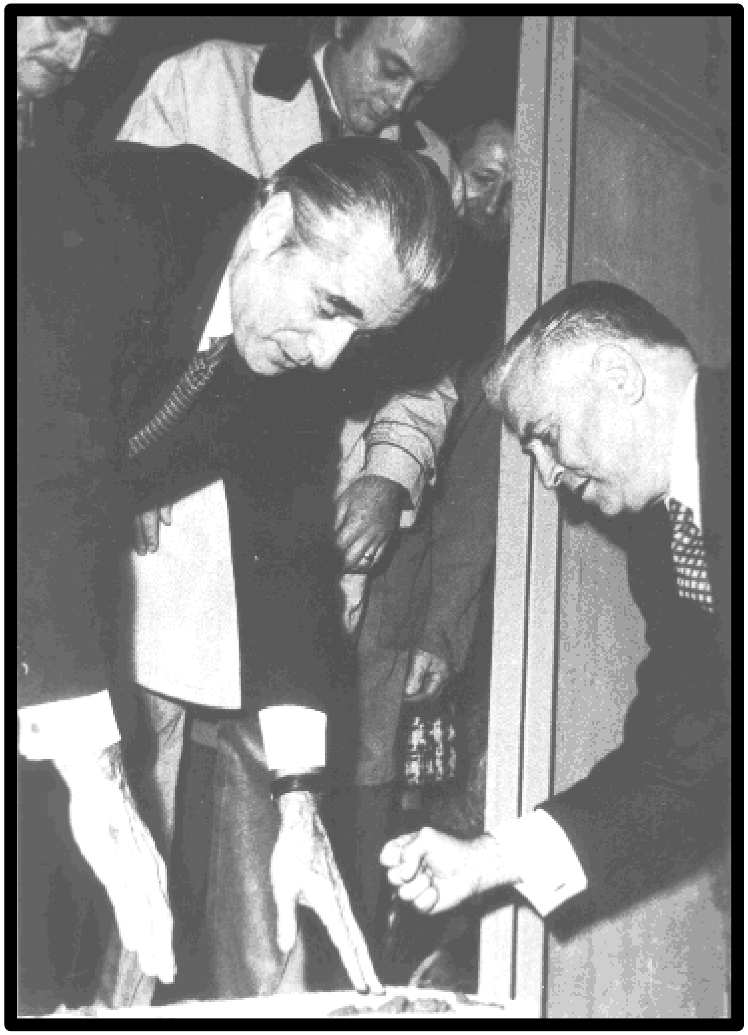

Block diagram of Prioré's method

Time-reversing the cells back to normal state

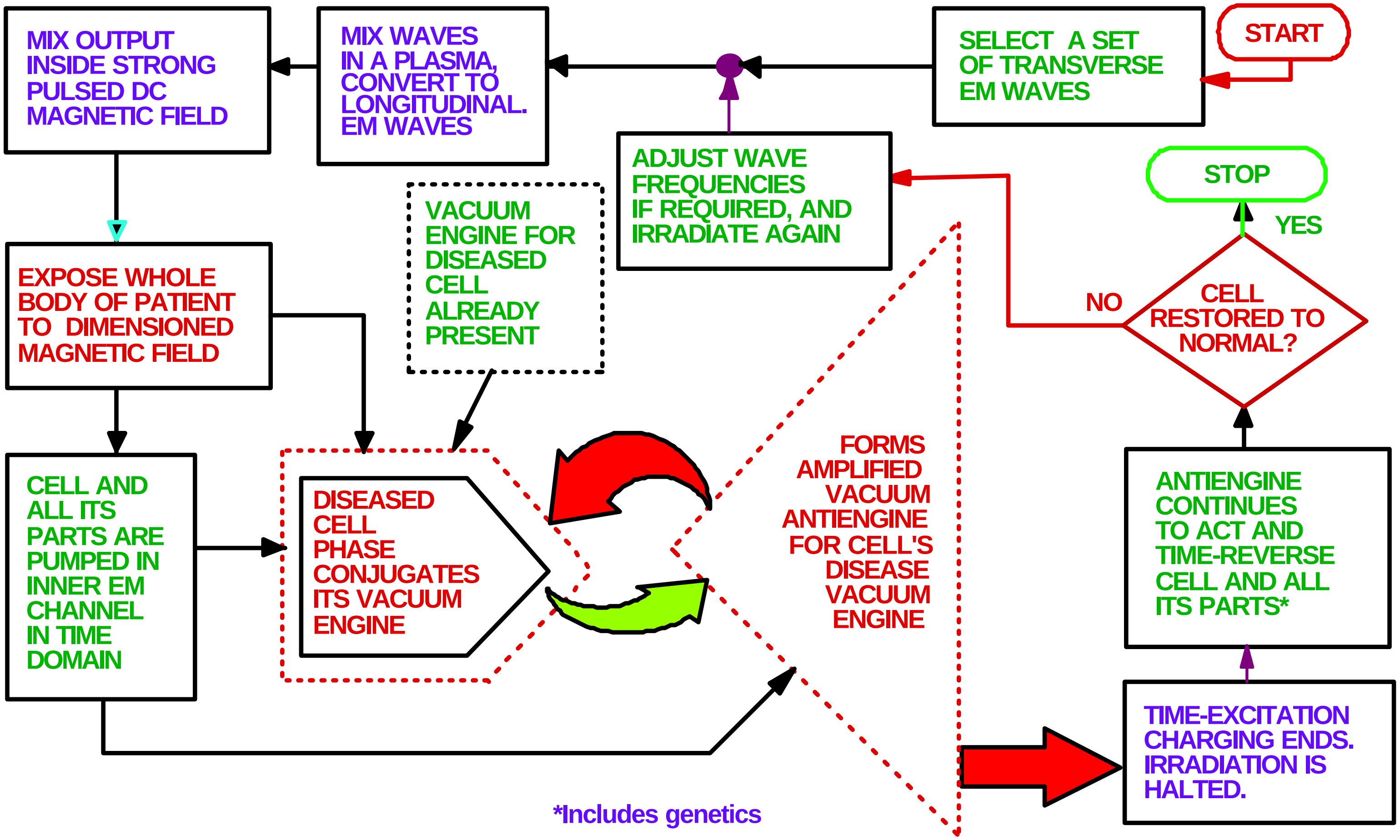

START

SELECT A SET OF TRANSVERSE EM WAVES

MIX WAVES IN A PLASMA, CONVERT TO LONGITUDINAL. EM WAVES

MIX OUTPUT INSIDE STRONG PULSED DC MAGNETIC FIELD

EXPOSE WHOLE BODY OF PATIENT TO DIMENSIONED MAGNETIC FIELD

CELL AND ALL ITS PARTS ARE PUMPED IN INNER EM CHANNEL IN TIME DOMAIN

VACUUM ENGINE FOR DISEASED CELL ALREADY PRESENT

DISEASED CELL PHASE CONJUGATES ITS VACUUM ENGINE

FORMS AMPLIFIED VACUUM ANTIENGINE FOR CELL'S DISEASE VACUUM ENGINE

TIME-EXCITATION CHARGING ENDS. IRRADIATION IS HALTED.

ANTIENGINE CONTINUES TO ACT AND TIME-REVERSE CELL AND ALL ITS PARTS*

CELL RESTORED TO NORMAL?

YES

STOP

NO

ADJUST WAVE FREQUENCIES IF REQUIRED, AND IRRADIATE AGAIN

*Includes genetics

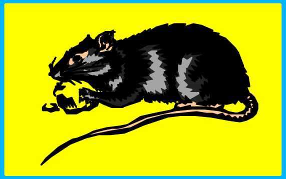

In Laboratory Animals:

Prioré Team Cured

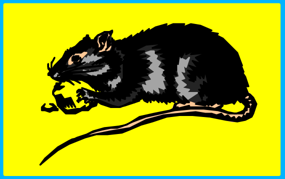

- **Terminal malignant tumors**
- **Clogged arteries (atheriosclerosis)**
- **Suppressed Immune Systems**
- **Infectious trypanosomas**
- ***Results were presented to French Academy of Science by Robert Courrier, Director of the Biology Section of the Academy***

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- ***No one understood the mechanism!***

Some peculiar results by the Prioré team

- Once a rat is cured of a particular disease:
  - A single drop of blood from the cured rat, injected into another rat stricken with same disorder, would result in the injected rat getting well slowly.
  - This ability to transfer immunity and healing in the extracted drop of blood gradually decayed over a period of a few weeks.
- Showed that even the fields and potentials in the blood had been altered internally, in the treated animal.
- Showed that the injected animal's cellular regenerative system possessed the ability to also time-domain pump over the entire body, everywhere reducing the delta between that injected drop of blood now the rat's own, and the rest of the blood in its body.

Proof of cellular time-reversal

- Pautrizel compared identical treatment of immature rats with immature immune systems, and mature rats with mature immune systems.
- Treatment restored the damaged mature system back to full mature functioning, and it promptly recognized and dispatched the pathogens.
- Treatment restored the damaged immature system back to full immature functioning, unable to cope, and the pathogens promptly reinfected and killed the immature rat.
- The lesson: The body is indeed returned to a previous physical state. The pathogens themselves are not killed by the treatment, but by restoring the ability of the immune system to recognize and destroy them.
- Only the *previous ability* of the immune system is restored by the process.

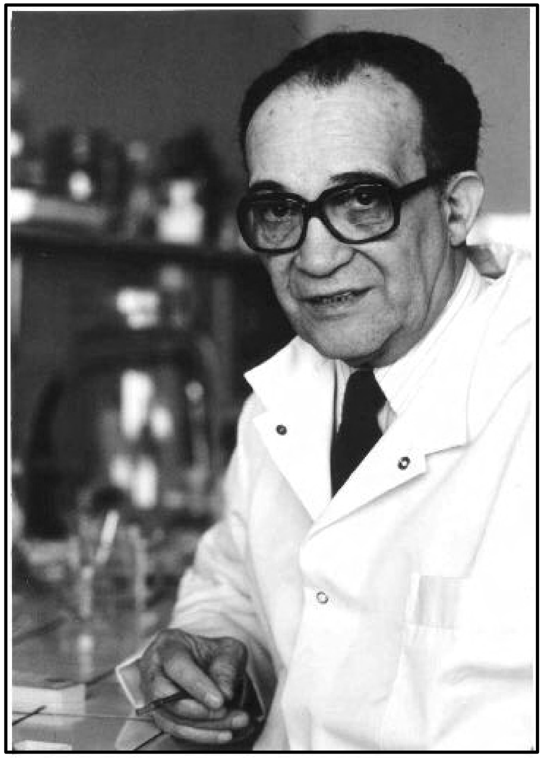

PROF. RAYMOND PAUTRIZEL
(Renowned Parasitologist)

Disadvantages of Prioré method

- Large plasma tube and facility required.
  - 3-stories high building bay if to treat humans.
  - Long irradiation time (2-3 hours).
  - Slow, numerous experimental adjustments.
- Fundamental mechanism was unknown.
  - Phase conjugate optics not yet born in West.
  - No higher symmetry EM modeling used.
  - Prioré thought it was a result of ionization.
  - Importance of difference frequency unknown.
  - Body dielectric transmission path unknown.

3-Story high Prioré device for treating humans

- At the end of the project, Prioré had developed a large unit to treat humans.
- A few were treated.
- Cures replicated what had been done in lab animals
- The massive size of the unit and long treatment time (hours) made the process bulky and very inconvenient -- and also expensive

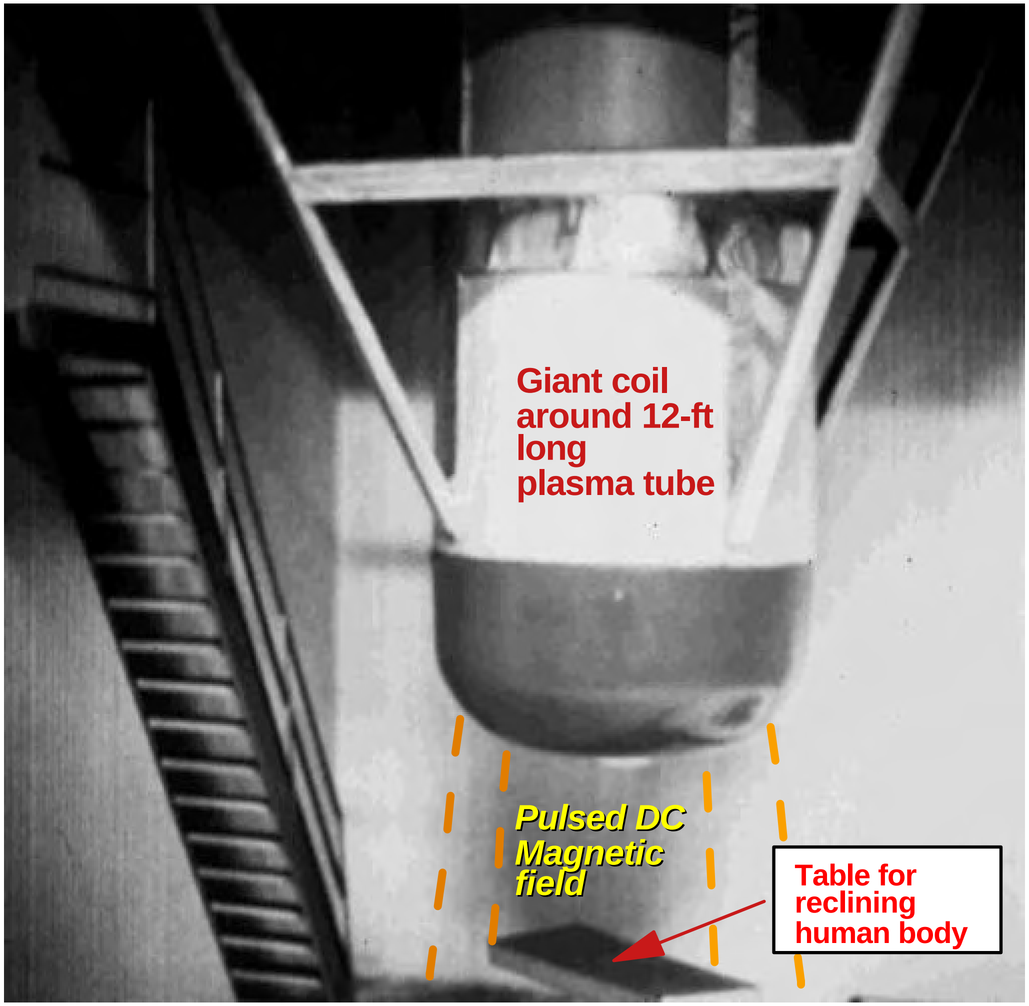
Giant coil around 12-ft long plasma tube
Pulsed DC Magnetic field
Table for reclining human body

17-foot Prioré plasma tube

Used in large machine (3-stories high) to treat a limited number of human patients

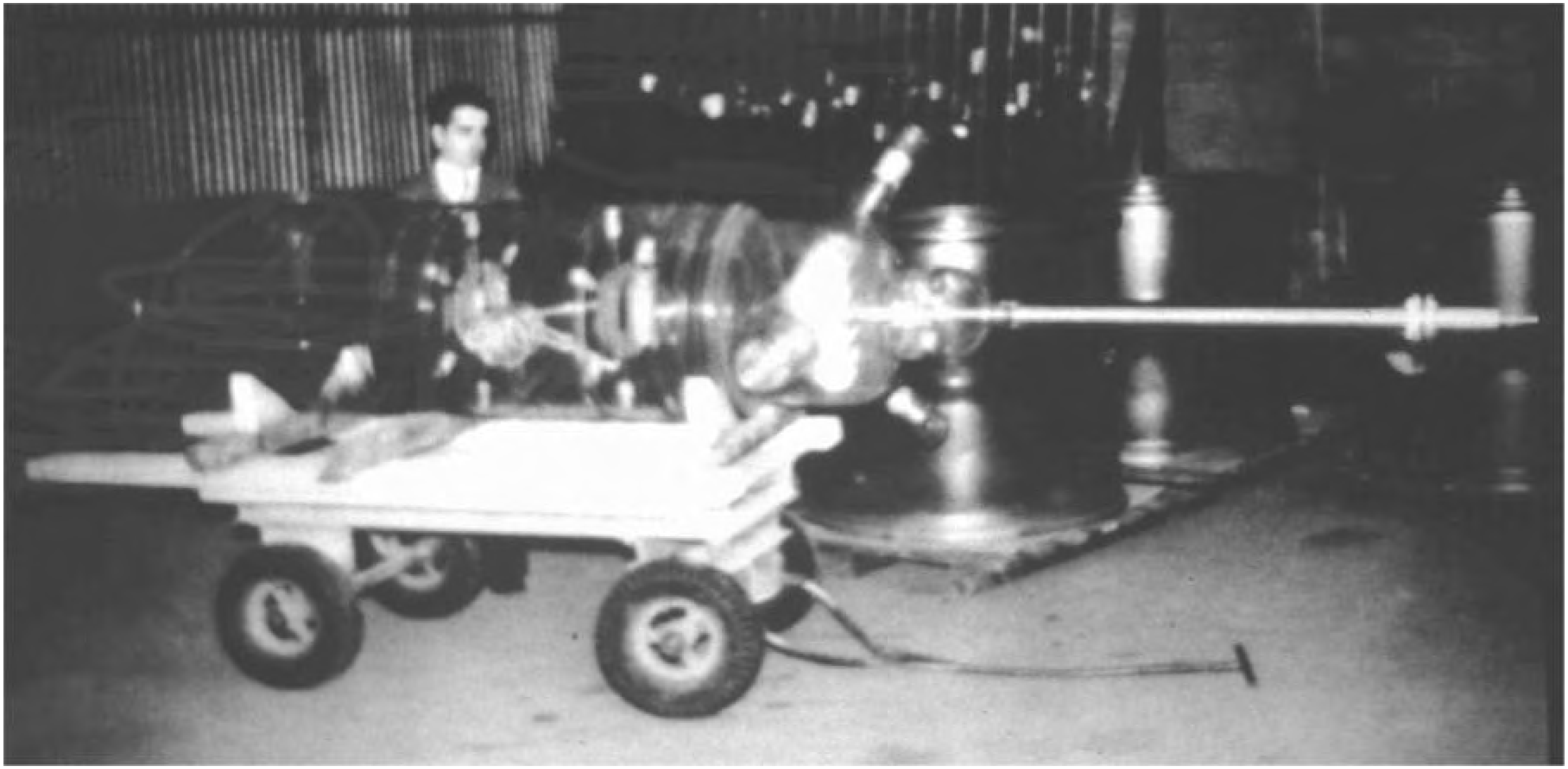

A proposed new mechanism for cancer promotion

And its ramifications

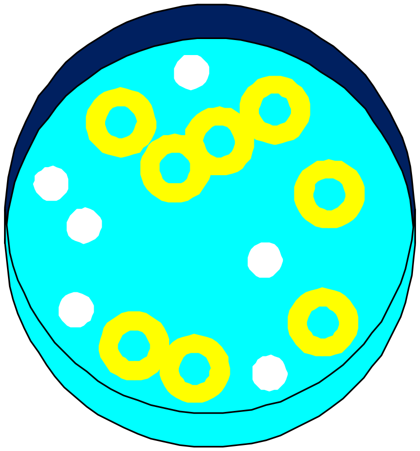

Remarks on cancer from a new perspective

- Two stages: cellular damage and promotion of the damaged cell to a tumorous cell. Promotion presently is poorly understood if at all.
- A master cellular control system (MCS) (studied by Popp et al.) controls both the immune system and the cellular regenerative system, as well as normal functions of the cells.
- The "past history" of ancestral development of aerobic cells and higher multicell aerobic bodies on planet Earth, resides in the "internested engine layers" in every tiniest part of the entire body dielectric, and in all cells.

Remarks on cancer from a new perspective (2)

- Faced with cell damage (such as sustained hypoxia) it cannot handle, the MCS continues to "peel the layers" in taking actions related to ever more distant pasts.
- Faced with continuing hypoxia, e.g., the MCS eventually reaches ancestral layers -- with an engine -- it forces the damaged cells to start moving back toward the original primeval anaerobic form.
- The first step backward is *separation from central growth control*, freeing the cell to multiply independently. At the same time, genetic changes in the cell are forced and produced, starting it back toward becoming an anaerobe.
- These actions comprise the *promotion process*.

The promotion process via engines

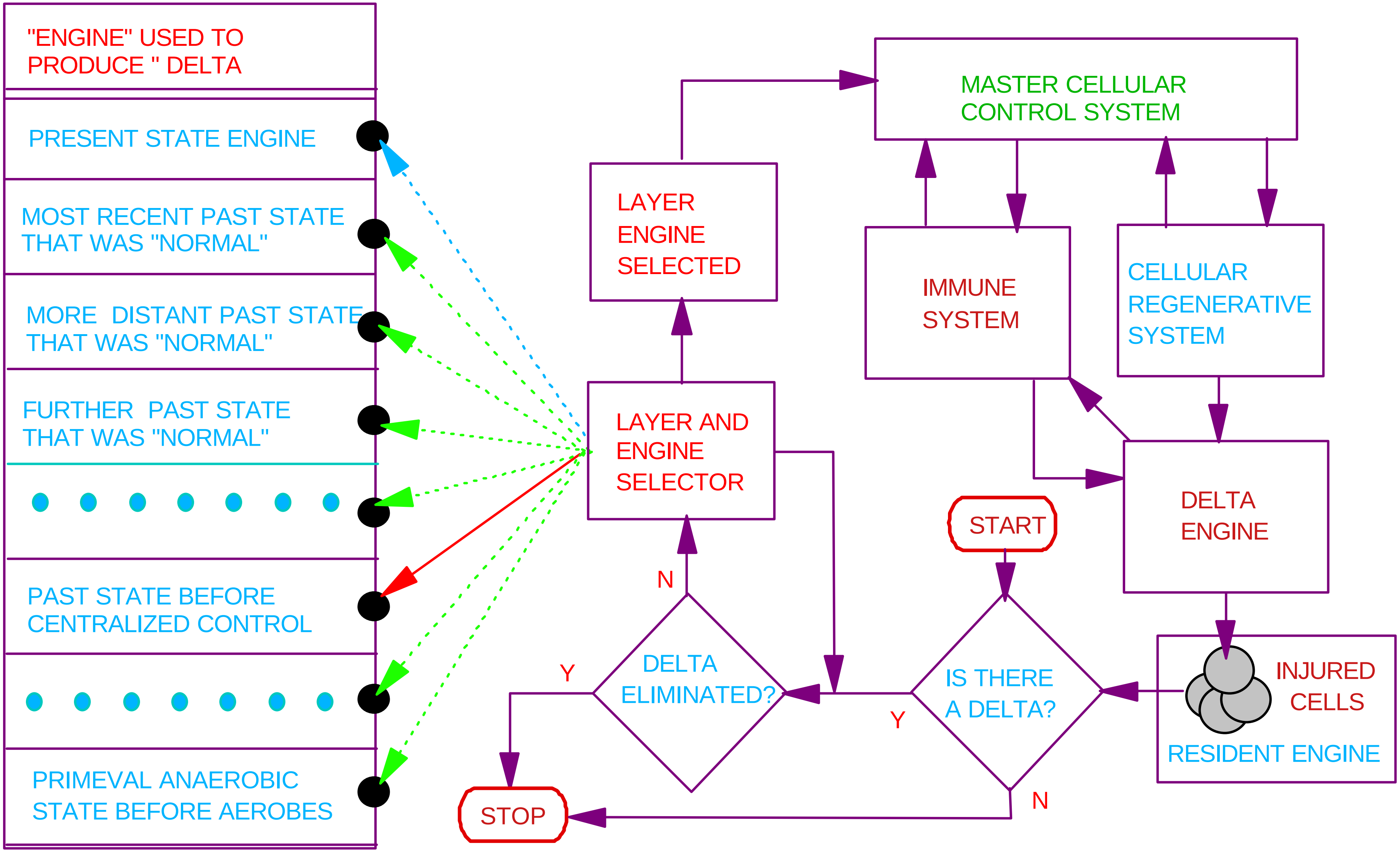

"ENGINE" USED TO PRODUCE " DELTA

PRESENT STATE ENGINE

MOST RECENT PAST STATE THAT WAS "NORMAL"

MORE DISTANT PAST STATE THAT WAS "NORMAL"

FURTHER PAST STATE THAT WAS "NORMAL"

PAST STATE BEFORE CENTRALIZED CONTROL

PRIMEVAL ANAEROBIC STATE BEFORE AEROBES

LAYER ENGINE SELECTED

LAYER AND ENGINE SELECTOR

MASTER CELLULAR CONTROL SYSTEM

IMMUNE SYSTEM

CELLULAR REGENERATIVE SYSTEM

DELTA ENGINE

START

IS THERE A DELTA?

INJURED CELLS

RESIDENT ENGINE

DELTA ELIMINATED?

STOP

Evolution of aerobic systems

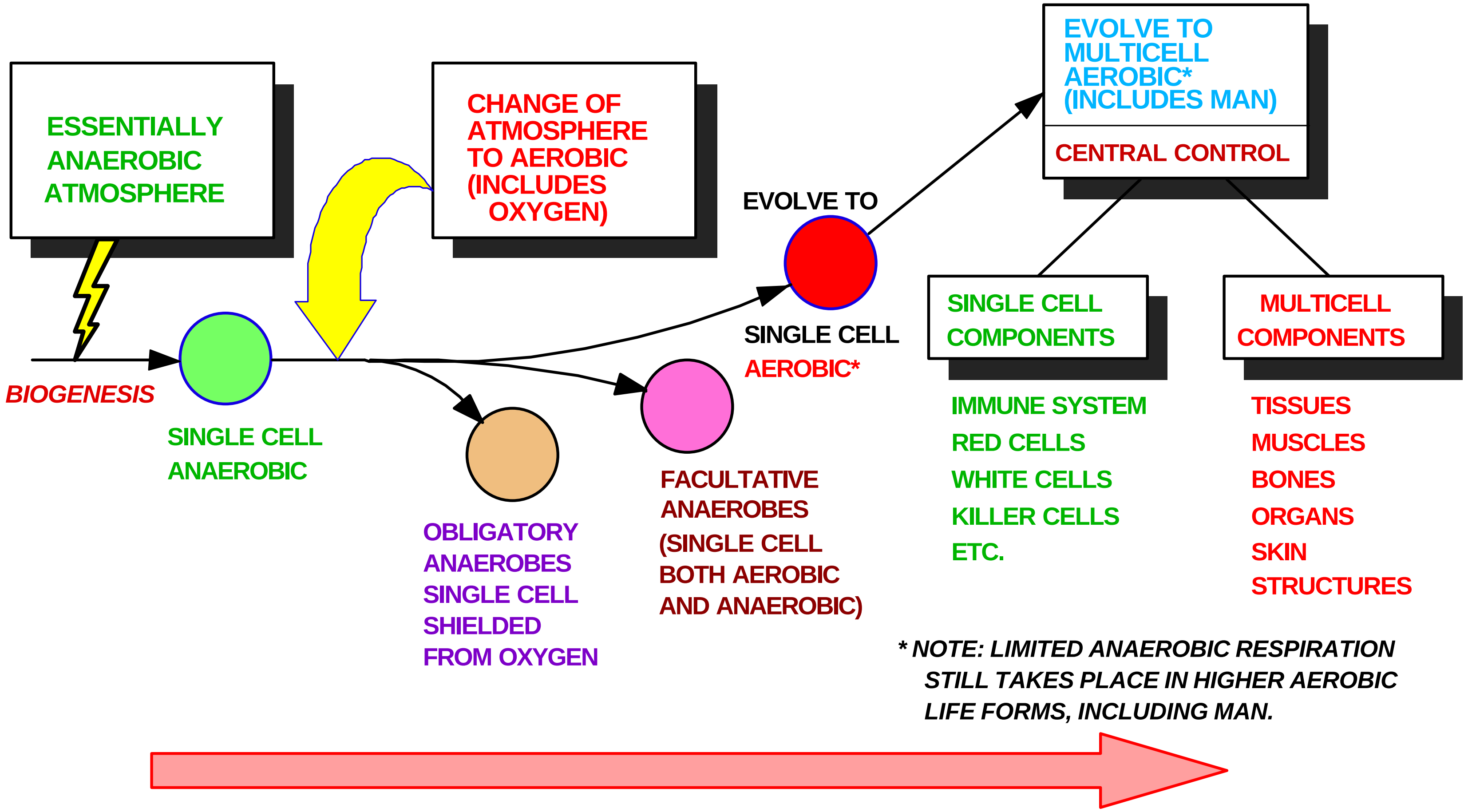

ESSENTIALLY ANAEROBIC ATMOSPHERE

CHANGE OF ATMOSPHERE TO AEROBIC (INCLUDES OXYGEN)

BIOGENESIS

SINGLE CELL ANAEROBIC

OBLIGATORY ANAEROBES SINGLE CELL SHIELDED FROM OXYGEN

FACULTATIVE ANAEROBES (SINGLE CELL BOTH AEROBIC AND ANAEROBIC)

EVOLVE TO

SINGLE CELL AEROBIC*

EVOLVE TO MULTICELL AEROBIC* (INCLUDES MAN)

CENTRAL CONTROL

SINGLE CELL COMPONENTS

- IMMUNE SYSTEM
- RED CELLS
- WHITE CELLS
- KILLER CELLS
- ETC.

MULTICELL COMPONENTS

- TISSUES
- MUSCLES
- BONES
- ORGANS
- SKIN
- STRUCTURES

** NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.*

EVOLUTIONARY TIME

First step in self-promotion of cancer due to hypoxia

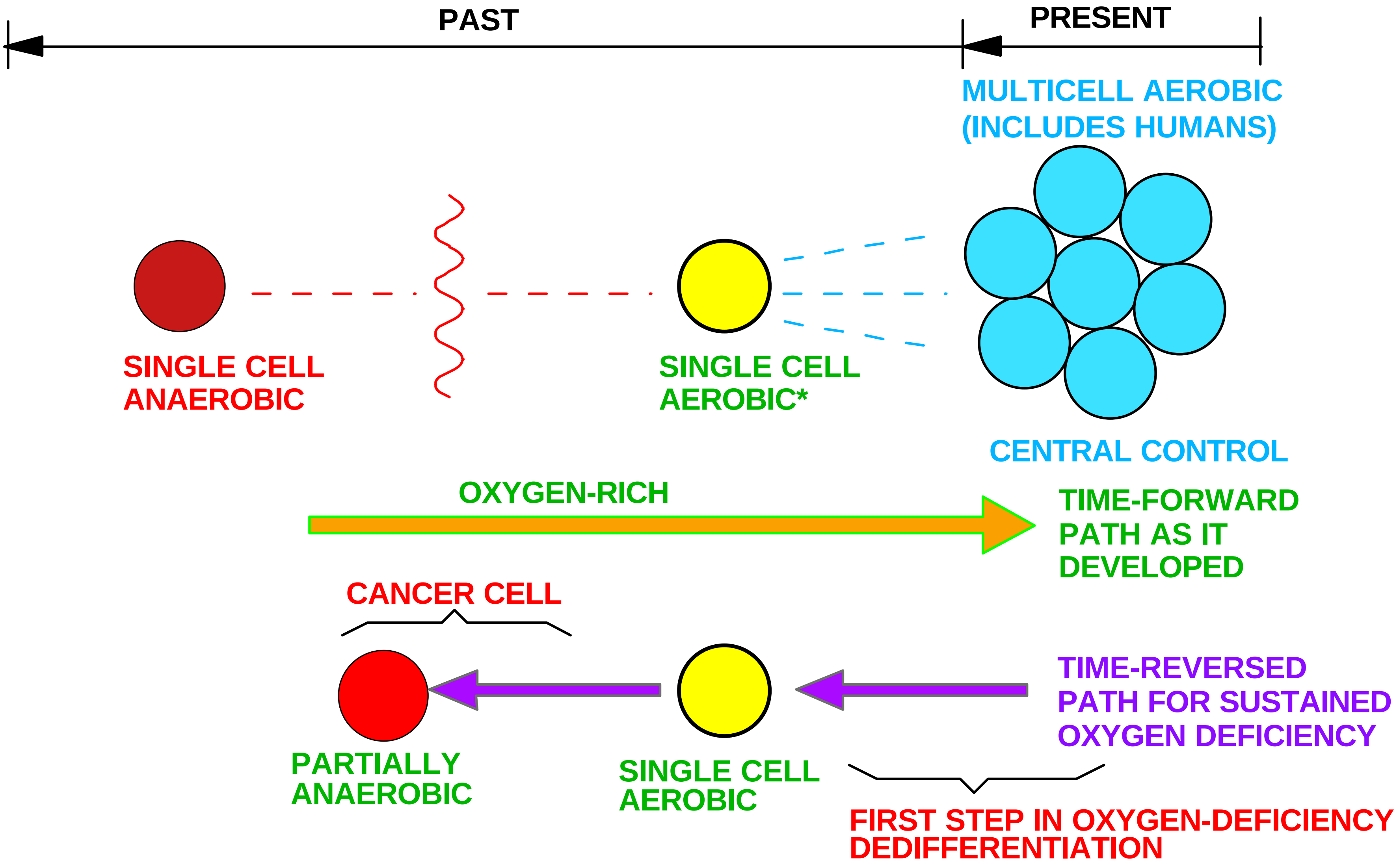

PAST

PRESENT

MULTICELL AEROBIC
(INCLUDES HUMANS)

SINGLE CELL
ANAEROBIC

SINGLE CELL
AEROBIC*

CENTRAL CONTROL

OXYGEN-RICH

TIME-FORWARD
PATH AS IT
DEVELOPED

CANCER CELL

TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY

PARTIALLY
ANAEROBIC

SINGLE CELL
AEROBIC

FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION

Block diagram of the cellular regenerative system

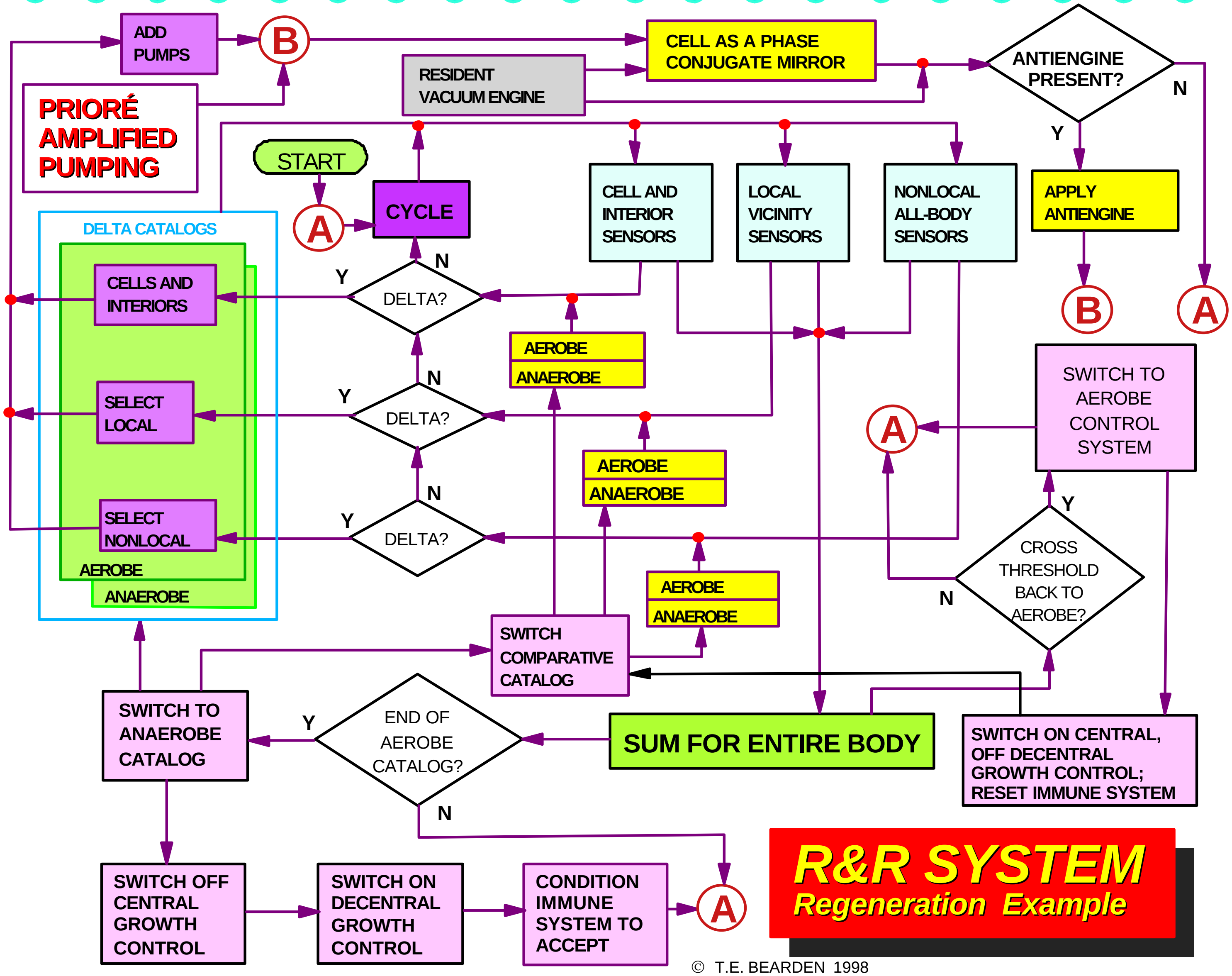

ADD PUMPS

B

CELL AS A PHASE CONJUGATE MIRROR

ANTIENGINE PRESENT?

N

Y

RESIDENT VACUUM ENGINE

PRIORÉ AMPLIFIED PUMPING

START

A

CYCLE

CELL AND INTERIOR SENSORS

LOCAL VICINITY SENSORS

NONLOCAL ALL-BODY SENSORS

APPLY ANTIENGINE

B

A

DELTA CATALOGS

CELLS AND INTERIORS

SELECT LOCAL

SELECT NONLOCAL

AEROBE

ANAEROBE

Y

N

DELTA?

Y

N

DELTA?

Y

N

DELTA?

AEROBE

ANAEROBE

AEROBE

ANAEROBE

AEROBE

ANAEROBE

SWITCH TO AEROBE CONTROL SYSTEM

A

CROSS THRESHOLD BACK TO AEROBE?

Y

N

SWITCH COMPARATIVE CATALOG

SWITCH TO ANAEROBE CATALOG

END OF AEROBE CATALOG?

Y

N

SUM FOR ENTIRE BODY

SWITCH ON CENTRAL, OFF DECENTRAL GROWTH CONTROL; RESET IMMUNE SYSTEM

SWITCH OFF CENTRAL GROWTH CONTROL

SWITCH ON DECENTRAL GROWTH CONTROL

CONDITION IMMUNE SYSTEM TO ACCEPT

A

R&R SYSTEM

Regeneration Example

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Bombshell: Amplified EM healing

- A unified field theory approach and use of supersystem analysis has broken the basic mechanism for healing itself.
  - The Sachs unified field theory applies and has been partially fitted.
  - Evans-Vigier O(3) electrodynamics can properly model it, including both the internal and external electrodynamics and effects of engines.
  - Direct engineering development is now possible.
- Experimental proof of the results obtainable already exists in the literature.
- A medical revolution is in the offing.

Potential Medical Applications

- Non-traumatic cancer treatment
  - *Cure cancers and leukemias of all types*
  - *Remove pre-cancerous state*
  - *Restore system*
- Treat and cure Infectious diseases
- Cure AIDS and restore immune systems
- Defense against biological warfare
  - *Virulent diseases from unknown agents*
  - *Treat, cure prior to symptoms developing*
  - *Both civil populace and armed forces*
- *Dramatically lower health costs*
- *Rejuvenate the aged*

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To treat and save mass casualties: What is urgently needed now:

- A small, portable, relatively inexpensive treatment unit, not requiring plasmas etc.
- Treatment in 2 to 5 minutes rather than 2-hours.
- Simple treatment application, almost anywhere.
- Effective in advanced stages as well as prior to emergence of symptoms.

- Effectiveness against a wide array of illnesses.
- Use is easy, high school student can be trained in 30 minutes.
- Crash program to develop, flood down through emergency systems in great quantities.

The Solution:

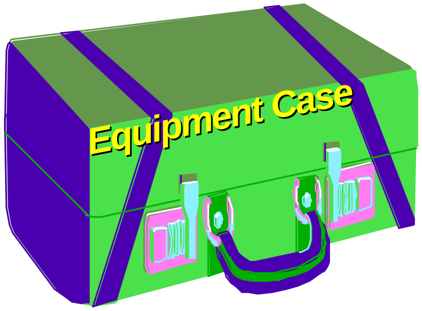
Equipment Case

- Two blankets have antennas in them.
- Uses the "porthole" concept (discussed shortly)
- Eliminates plasma tube mixing etc.
- Computer-controlled complex signal structure.

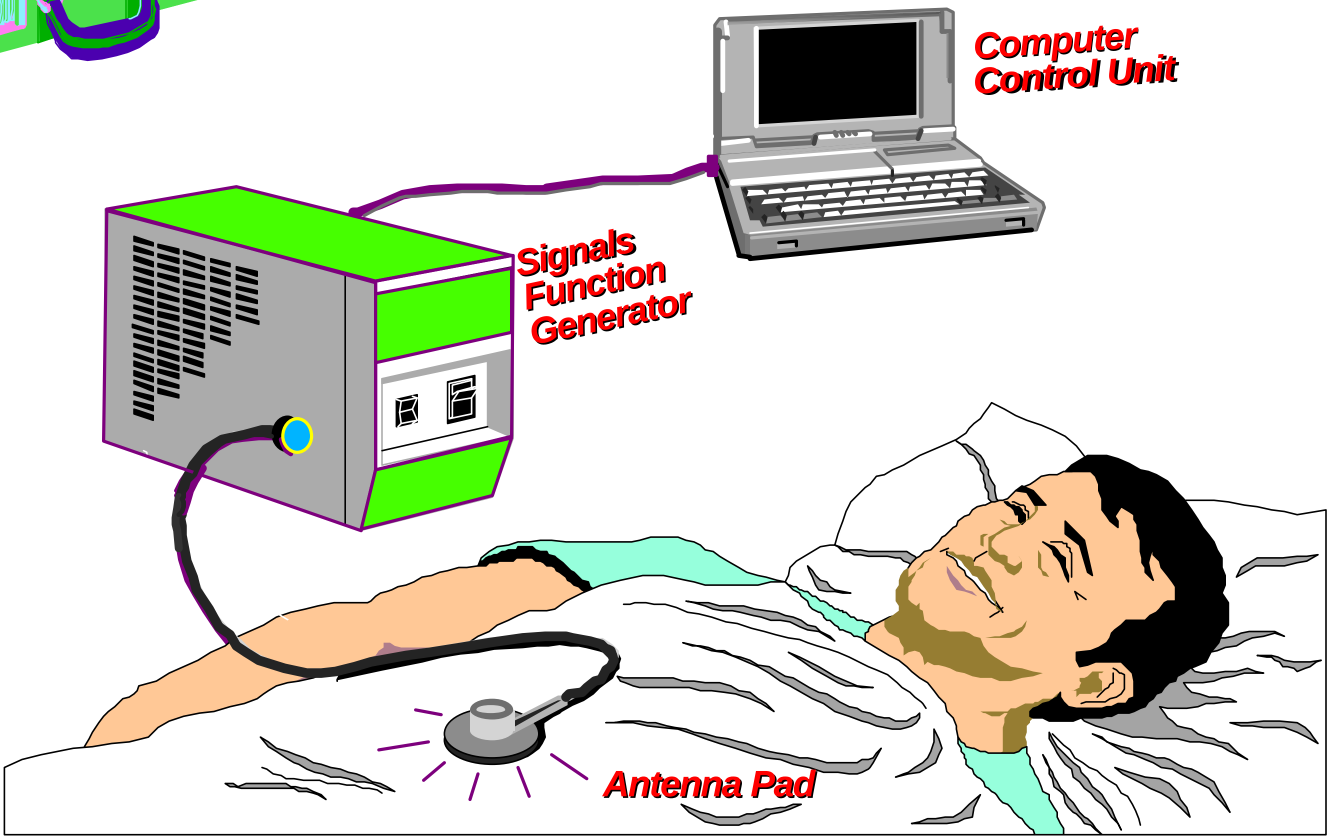
Computer
Control Unit
Signals
Function
Generator
Antenna Pad

The Porthole concept:

The two-minute treatment shortcut

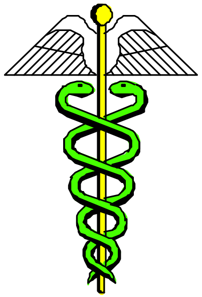

How the porthole concept works

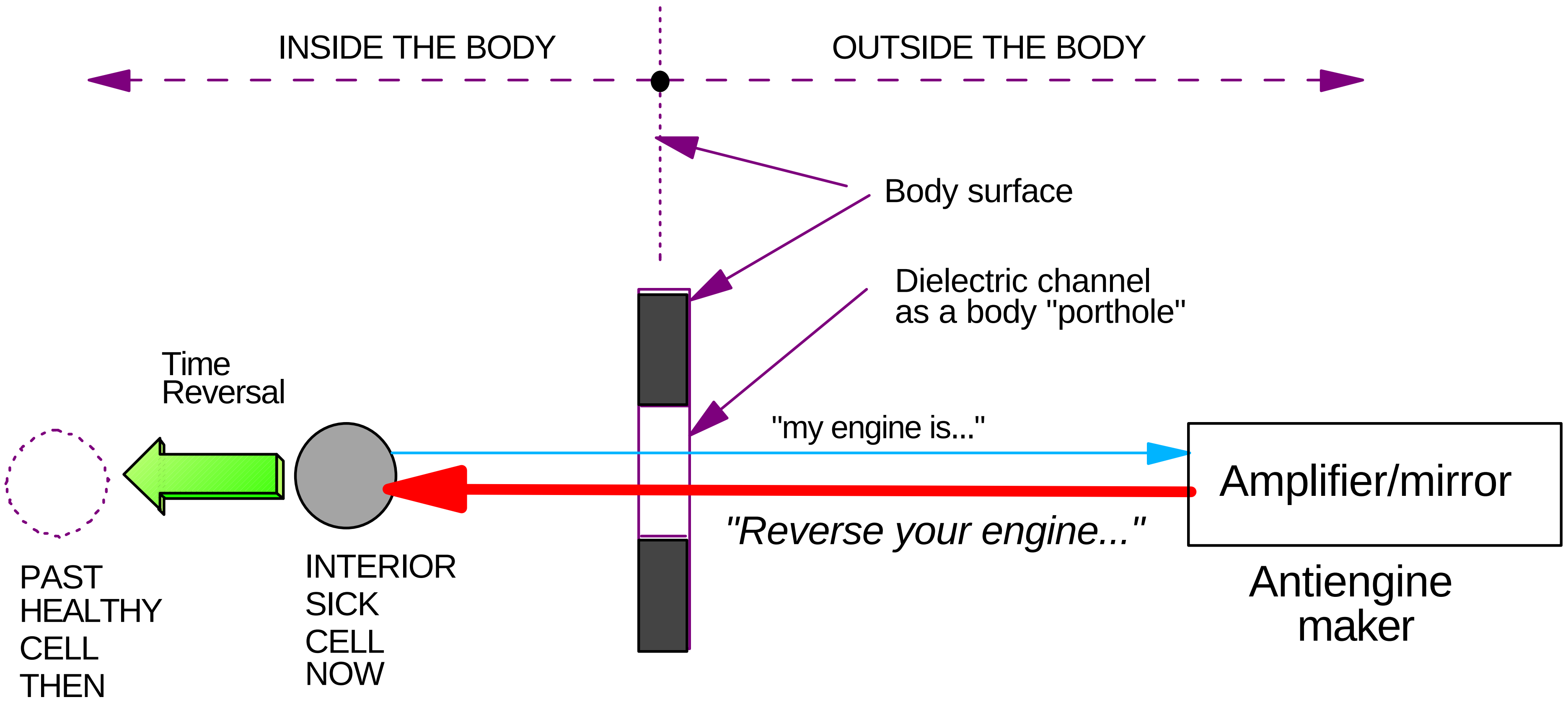
INSIDE THE BODY
OUTSIDE THE BODY
Body surface
Dielectric channel
as a body "porthole"
Time
Reversal
"my engine is..."
Amplifier/mirror
"Reverse your engine..."
PAST
HEALTHY
CELL
THEN
INTERIOR
SICK
CELL
NOW
Antiengine
maker

Porthole concept: An analogy of the dielectric path and inner-outer functional connections

- Imagine perfectly reversible dynamic light processes inside a large "cruise ship", that are also perfect phase conjugate mirrors
- Each process receives, absorbs, and emits light continuously
- Light escaping through the portholes is a composite from all the dynamic processes ongoing inside
- If we record and amplify the escaping light, then force it back through the portholes, it reverses all the internal processes
- The processes revert back, slowly, to a previous ongoing process state
- We cease radiation, and the processes reverse and move forward again

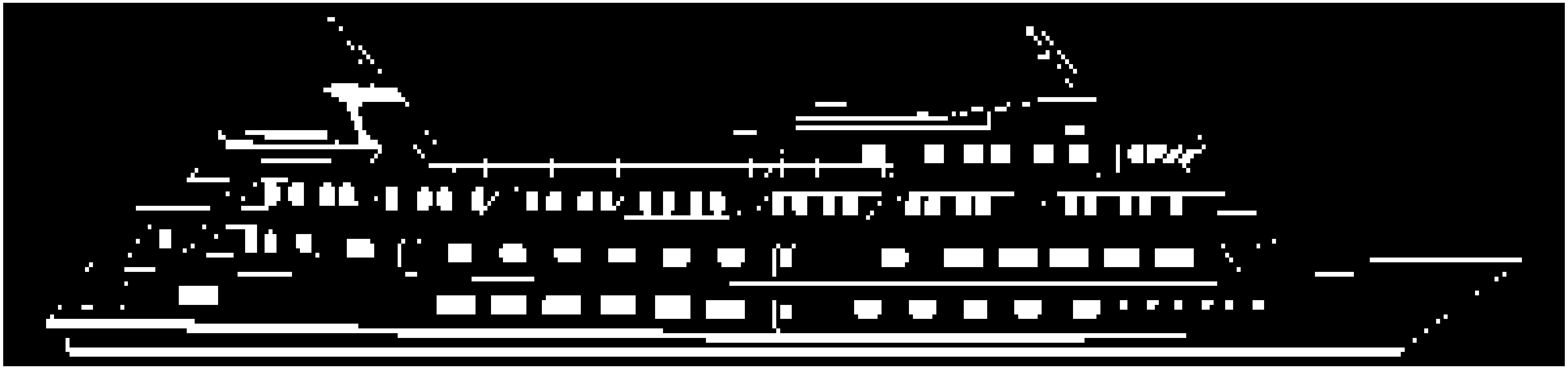

Porthole concept: The discovery

- The processes themselves, *in their own "frame"*, are never actually "reversed". Instead, the frame's motion through time is reversed.
  - Each to itself moves normally -- just receiving, absorbing, and radiating light, regardless of "whatever light" is interacting
  - This is due to a peculiarity of the photon and photon interaction
- Photon interaction creates observed physical reality, including the "frame" and the seeming "passage of a mass through time"
  - The photon is its own antiparticle, which is just a photon traveling in the opposite direction
  - So in this case we can use "light" to precisely time reverse (to the observer) the frame and the apparent operations (to the observer)
- When we cease irradiation, after a decay period to remove the reversed excitation, all functions are now seen to be moving forward normally in observer forward time, but from a previous physical state or condition

Using the porthole concept: Research

- The body's own emitted dense, broadband signals are recorded across a broad bandwidth
  - These signals are amplified, then rebroadcast precisely back into the body
  - This returns an amplified "reversed" signal set back through the dielectric path, invoking and applying the porthole concept in all processes
- The returning photons produce time-charging but in reversed frame direction
  - Tremendous potential energy is absorbed in highly compressed "time-energy" form in seconds
  - This "time-potential" slowly drains off as the body processes and cells reverse back to a previous state

Research using the porthole concept

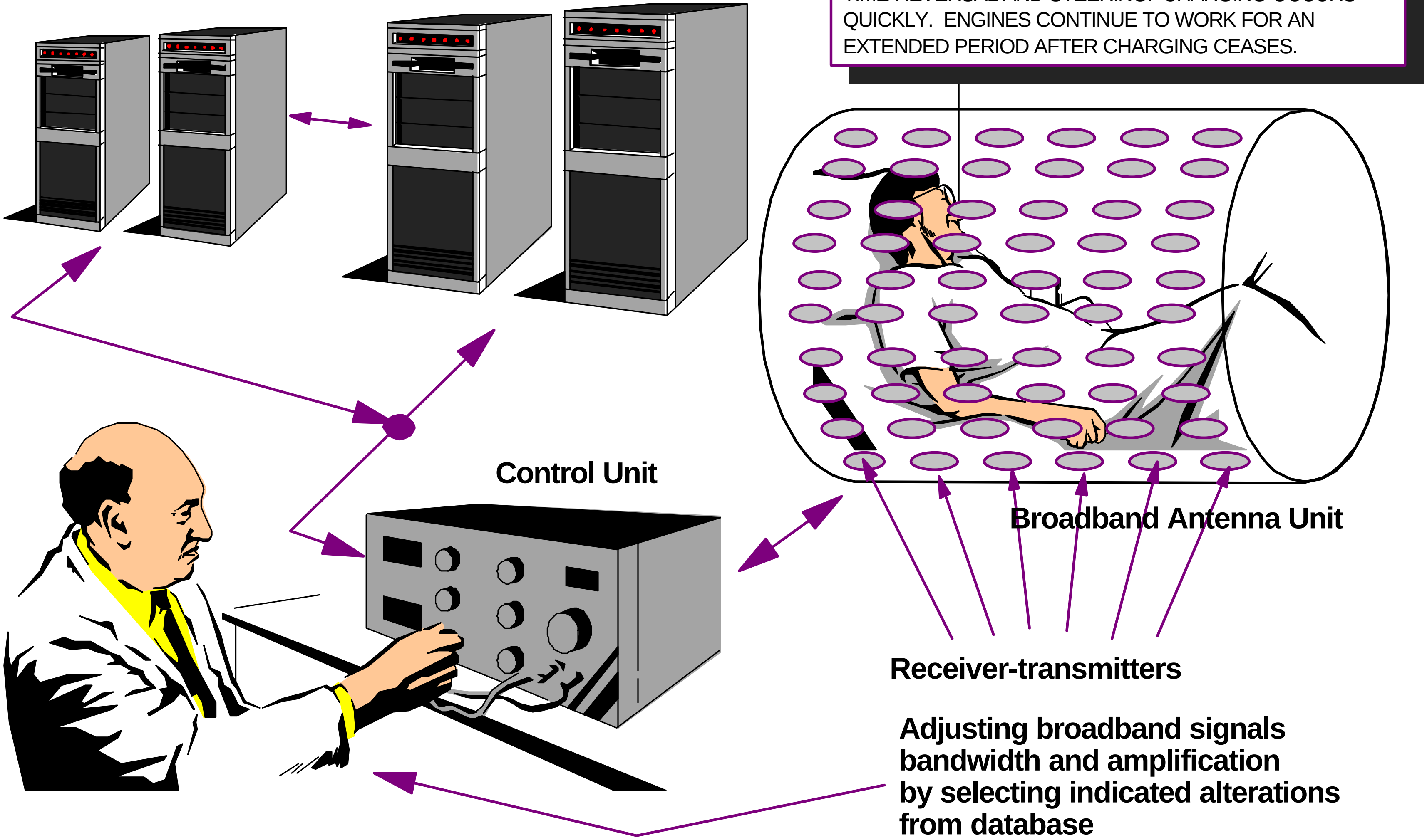

TIME DENSITY CHARGE IS STRUCTURED TO CONTAIN THE PRECISE SPACETIME CURVATURE ENGINES FOR TIME-REVERSAL AND STEERING. CHARGING OCCURS QUICKLY. ENGINES CONTINUE TO WORK FOR AN EXTENDED PERIOD AFTER CHARGING CEASES.

Alterations Database

Recorders & Broadband Amps

Control Unit

Broadband Antenna Unit

Receiver-transmitters

Adjusting broadband signals bandwidth and amplification by selecting indicated alterations from database

© T.E. BEARDEN 1998

Portable unit then developed for rapid treatment of mass BW casualties

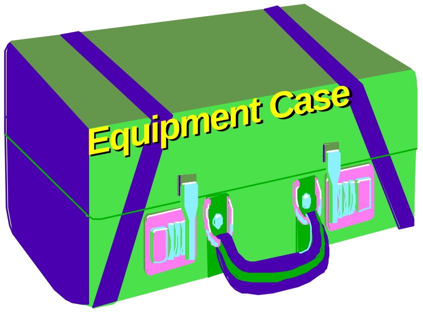
Equipment Case

- Two blankets have antennas in them.
- Uses the "porthole" concept (discussed shortly)
- Eliminates plasma tube mixing etc.
- Computer-controlled complex signal structure.
- Irradiation for 2 minutes.

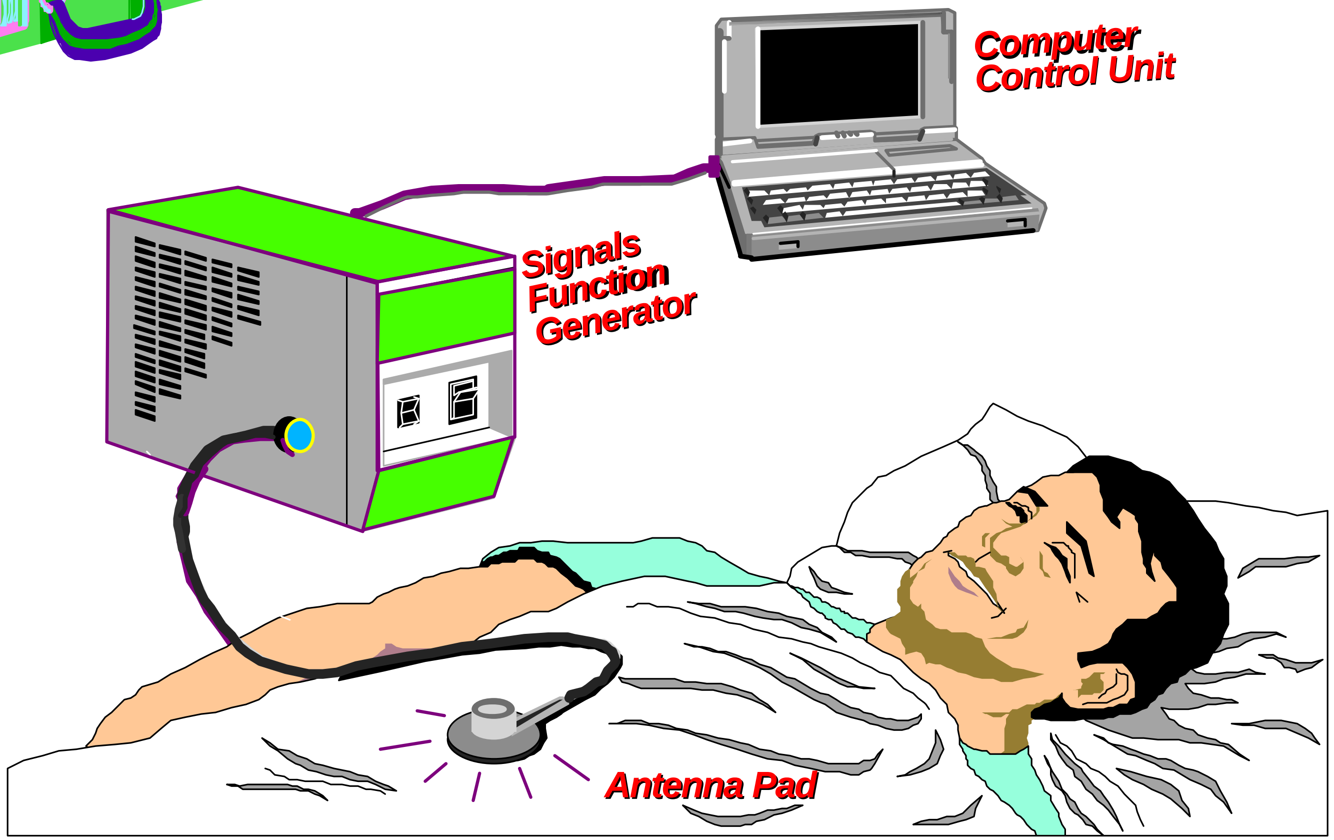
Computer
Control Unit
Signals
Function
Generator
Antenna Pad

Training to use the unit

- High school student level, 30 minutes.
- Patient lies on one blanket, other covers him.
- Set the prescribed standard signal sets from listing.
- Computer-controlled generator produces the signal.
- Irradiation for 2 minutes, uncover patient, bring in another.
- Unit can be self-powering from vacuum energy (MEG*).

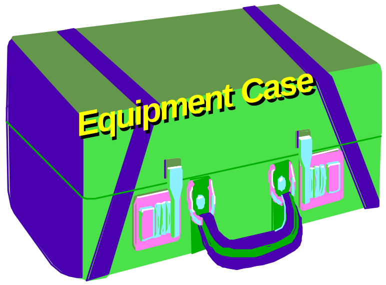
Equipment Case

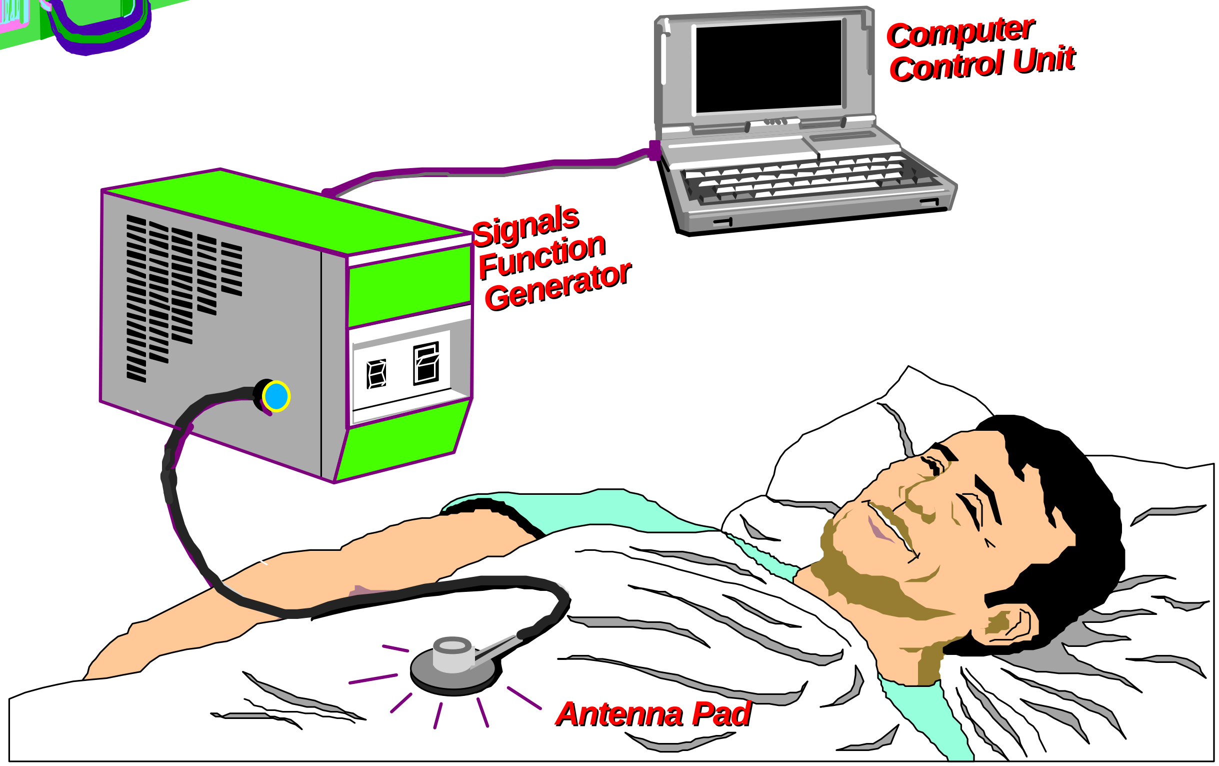
Computer
Control Unit
Signals
Function
Generator
Antenna Pad

Additional advantages

- Can be developed in a crash program in 2-3 years.
- After sunk costs, projected cost per unit in mass production is less than $100,000
- Can be produced by the thousands
- Then flooded down through
  - Fire stations and police stations
  - Red cross units, hospitals, clinics
  - Emergency action teams and armed forces
- Large numbers of operators easily produced
- Emergency training could be watching a 15 minute film, then performing one graded practice run
- First generation equipment can save some 70% of the coming mass casualties from anthrax etc.

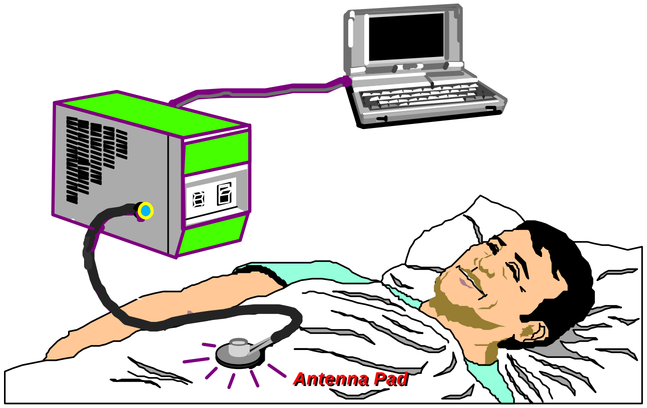

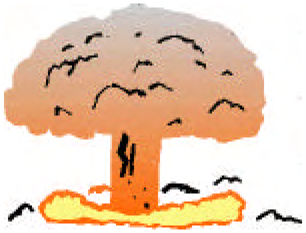

Terrorist BW warfare capabilities against the United States

The growing threat

Mass Casualty Problem: Aerial Anthrax Spray on Washington, D.C.

- **One terrorist, one light aircraft with spray tank**
- **100 kilograms of anthrax**
- **Flies over greater metropolitan Washington, D.C.**
- **Calm night**
- ***1-3 million casualties result****
- ***Most of those stricken will die***
- **Presently little can be done to save the stricken civilians**
- ***Attacks on several population centers might produce some 10 million or more casualties***

***Per OTA Report to Congress, 1993**

For decades, infiltration of terrorist teams into the U.S.

- From several foreign nations, not just Bin Laden in Afghanistan
- Several thousand Cuban guerillas, from training camps in Southern Mexico

- Russian Spetznaz teams
- Nuclear warheads (up to 80 KT)
- Biological warfare agents
- Yakuza in oriental populations in our cities
  - Yakuza manufactures Russian energetics weapons in their own facilities in Japan
  - Possesses the new EM weapons referred to by Secretary of Defense Cohen in 1997
- We are now in a very long, hard war and will suffer millions of casualties in our cities. It may last for decades.

Defense Secretary Cohen*

(Involvement of secret superweapons)

"Others [terrorists] are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves… So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations…It's real, and that's the reason why we have to intensify our [counterterrorism] efforts."

* Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.

Some typical BW agents

- Smallpox, including different strain developed by Russia (some sold to terrorists)
- Anthrax
  - Over 400 known locations around the Earth have cultures
  - Difficult to decontaminate
- Bubonic Plague
- Botulism toxin
- Tularemia (rabbit fever)
- Hemorrhagic fevers, such as Ebola

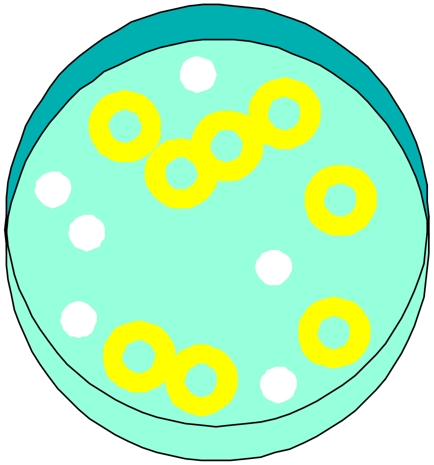

Anthrax

- OTA study: Some 200 pounds released in a spray, on calm night over Washington, D.C. could result in up to 3 million casualties
- Symptoms usually in 2-10 days
  - Sometimes as long as 7 weeks
  - Flu-like symptoms

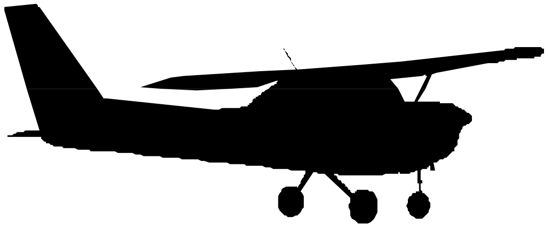

- Then 1-3 days later, shock and breathing problems cause death in up to 100%
- Antibiotics given early (before symptoms) can prevent infected persons from becoming ill
- Limited vaccine, reserved for military

Smallpox

- More than 500 million people killed in the 20th century before "eradicated" in 1977. Vaccination ceased in 1980.
- Russians kept it, developed new strains, sold to terrorists
- Symptoms in about 12 days: fever, headache, nausea. Rash similar to chickenpox then appears.
- Rash turns into hard blisters. *Highly contagious*, kills one-third of its victims.
- No cure. About 12 million doses of vaccine left.
- If smallpox is unleashed in any major city on earth, it will eventually kill 2 billion, or about 1/3 of the human species -- unless a radical new cure is found and utilized.

Bubonic Plague: Historically the most feared (Black Death)

- From 1980-1994, 18,739 cases in 20 countries.
- Symptoms occur in 1-6 days after inhaling the pneumonic form.

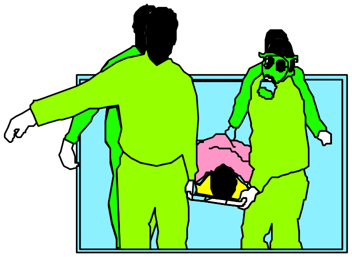

- High fever, cough, labored breathing lead to respiratory failure and death.
- It is contagious.
- Rapid use of antibiotics can be effective.
- Vaccine not currently produced in the U.S.

Botulism toxin (a nerve toxin)

- Single most poisonous BW substance known.
  - Typically borne in food, contacted by eating.
  - Could be developed as aerosol weapon.
- Symptoms in 24-36 hours; blurred vision and difficulty swallowing, speaking.
- Paralyzes muscles, leading to respiratory failure and death.
- Centers for Disease Control and Prevention maintain a botulism antitoxin supply.

Tularemia

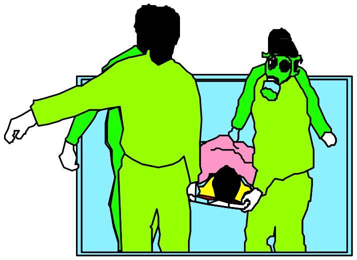

- U.S. studied its weapon potential in 1950s and 1960s.
- Symptoms appear in 3-5 days, including fever, chills, headache, and weakness
- Inflammation and hemorrhaging of the airways can lead to death.
- Without antibiotics, one-third die. Can be 90% if breathed in, in aerosol form.
- Vaccine developed and under review by FDA.

Hemorrhagic fevers, such as Ebola

- E.g., origin of Ebola is unknown. Probably transmitted to humans by animals, to begin a breakout.
- Symptoms in 3-5 days, include fever, aching muscles, diarrhea.
- Hemorrhaging of fluids out of tissues and orifices.
- From 30 to 90 percent die, depending on specific fever type.
- Some of these fevers respond to antiviral drugs.
- The drugs are in short supply.
- Presently *containment* is the primary goal.

A factor the U.S. does not know

(Secret involvement of clandestine superweapons)

- Three nations (not the U.S.) developed quantum potential weapons using Bohm's hidden variable theory of quantum mechanics.
- Can induce disease engines in matter or bodies at a distance.
- Have developed "spreading" of immune systems in a targeted populace (cleverly tested in Gulf War against U.S. troops).
    - Cocktail mix of disease engines for 2 dozen different diseases
    - Targeted area's human immune systems react to these engines when they are still in virtual state, just below quantum threshold.
    - Spread immune system's resources thus "thinned" across response to two dozen shadow diseases at once.
- Hit with a terrorist BW attack, the spread immune systems are overwhelmed much more easily and quickly.
    - Yield (casualties) of the attack is increased by factor of 3-5.
    - Spreading of U.S. immune systems has been accomplished and is still being maintained.

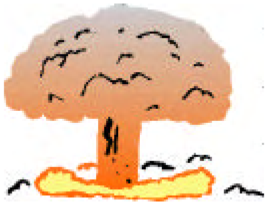

Summary and conclusion

The new war

A new Pearl Harbor: Strike on the World Trade Center in NYC

- The North Tower has already been struck and is burning.
- A second jetliner is about to strike the South Tower.

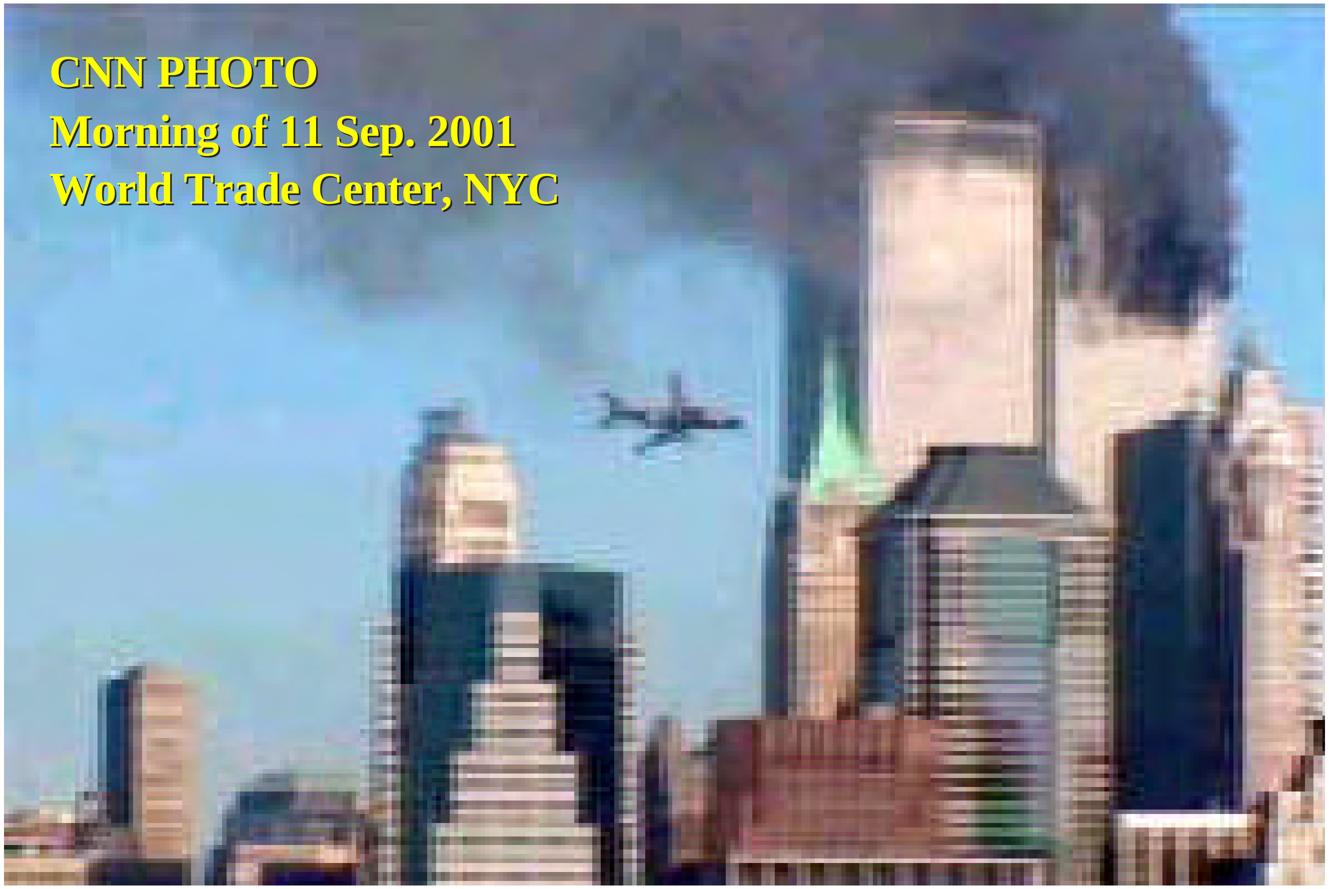
CNN PHOTO
Morning of 11 Sep. 2001
World Trade Center, NYC

Fireball From Impact on South Tower

- The two buildings held some 50,000 occupants
- Evacuation was underway after the first strike
- More than 6,000 persons were killed
- This is more than were killed in the Dec. 7, 1941 strike on Pearl Harbor

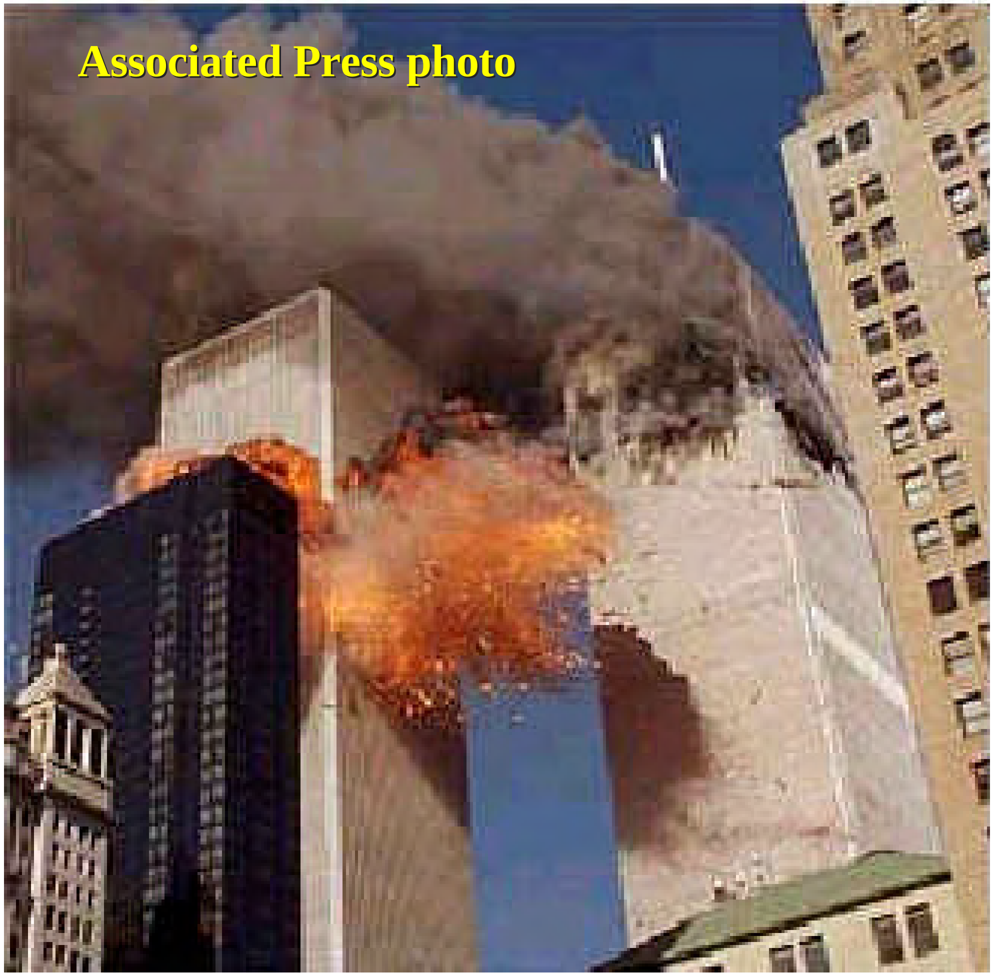
Associated Press photo

Collapse of the South Tower

- The first tower to collapse was the South Tower
- It is still uncertain just how many people were caught inside and killed
- This is a half million tons of debris, falling from the New York skyview.

Photo from CNN

Collapse of the North Tower begins

- The North Tower then collapsed
- This was another half-million tons of debris falling from the NYC skyview

Collapse of North Tower finishes

- Collapse of the North Tower killed many rescue workers, fire-men, and policemen
- At this writing, the total casualties are still unknown

Photos from CNN

Next began the recovery efforts

- Recovery operations will require months
- At this writing, the total casualties are still unknown
- The damage was done by two civilian jetliner "bombs"

The Pentagon was hit on the same day

- Hundreds were killed the same day when another jetliner struck the Pentagon.
- Yet another jetliner, possibly headed for the White House, crashed enroute when the passengers attacked the suicide terrorist hijackers.

A sobering thought

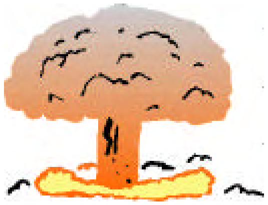

- Nuclear weapons are already smuggled into the U.S., as are BW agents such as anthrax, smallpox, etc.
- Had a 40-80kT weapon been exploded in New York and one in Washington, millions would have perished and both cities would have been devastated
- There would have been no recovery of those cities for many decades

Present Status of the WMD Threat to the United States

- Many foreign nations are hostile to the U.S. and sponsor terrorists
- Some 25 nations have WMD or are acquiring them
  - BW agents and weapons
  - Chemical agents and weapons
  - Nuclear materials and weapons
- Thousands of students and émigrés
- Infiltrated teams, BW, other WMD already
- Castro guerrillas infiltrated over the years
- Can do unacceptable damage to U.S. now
- *May reach knockout capability*

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*Per OTA Report to Congress, 1993

The U.S. is terribly unprepared

- Limited medical supplies, antibiotics, vaccines
- Insufficient facilities, emergency teams
- No civilian shelters (much less BW-filtered)
- Not enough doctors, nurses, masks, etc.
- Present treatment methods woefully inadequate
- Triage will apply
  - First treat those most likely to recover
  - Others (showing symptoms, or advanced) are just set aside to die
- Other attacks are a matter of *when*, not *if*.

Conclusion

- As several cities are struck, millions of U.S. civilian casualties will result. Devastation will be enormous.
- We shall eventually lose more American lives than in all the rest of our wars to date.
- Present medical therapeutic science is totally inadequate to do the job. It cannot save us.
- At some point, when we are sufficiently damaged, the Spetznaz or other terrorists may detonate nuclear weapons in our cities, with appalling carnage.
- A combined superweapon technology and terrorist groups will then destroy the remaining populace.
- On its present course, the inadequacy of Western medicine may doom us.

A difficult truth to consider

- In any strategic strike, the first phase is to get the strategic weapons (weapons of mass destruction) delivered to their distant targets.
- That has already been done.
- Eerily, the first phase of World War III has already been accomplished.
- It was already accomplished before the Sept. 11, 2001 strike on New York and Washington. That was the new "Pearl Harbor", and only the opening round. It already killed more Americans than died at Pearl Harbor on Dec. 7, 1941.
- Unless we improve our medical therapy quickly and dramatically, we will lose -- particularly when the hidden energetics weapons and outside terrorist sponsorship by hostile nations are factored in.

A personal perspective

- There now exists an overwhelming, immediate moral imperative to get this development program done at the utmost speed humanly possible.
- The sheer survival of the United States and Western civilization depends upon it.
- Officialdom is aware that the KGB/Russians have long planned to finish the U.S., after initial nuclear exchanges, by fierce and massive BW strikes.
- It appears that the plan has changed to let the terrorists do the main work, while augmenting U.S. casualty levels by energetics weapons.

China is also involved

- China has declared South China Sea the territorial waters of China
- China will eventually take Taiwan
  - Has massed missile artillery trained on Taiwan
  - Recently held invasion practice on an island near Taiwan
- Recently deployed fearsome EMP weapons utilizing negative energy rather than positive energy (Dirac sea theory)
  - Extinguishes all electron currents
  - Duds electrical and electron systems instantly
  - Instant death to struck bodies
  - Instant kill of missiles, aircraft, electronics in nuclear warheads
  - Ultimate "death ray"; can be made small or large
- Recent 2-carrier U.S. task force maneuvered in South China Sea to caution China
  - The new Chinese EMP weapon was trained on that task force
  - Could have destroyed it within minutes

Final thoughts

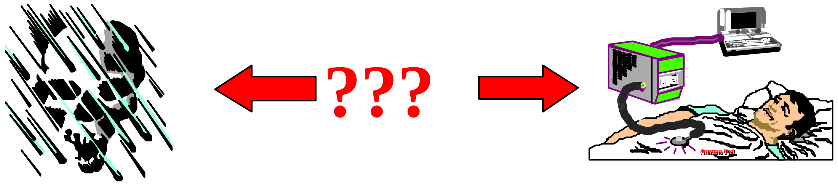

- This is one of the great turning points in history.
- The development program is eminently doable. That it works has been experimentally demonstrated. The long-vexing puzzle of the active mechanism has been solved.
- Our scientific community bitterly opposes any use of electromagnetics -- even an advanced, higher symmetry electrodynamics -- for medical treatment.
- A consortium of the scientific community, the large pharmaceuticals, FDA, and the AMA will oppose this project even while the U.S. is being destroyed wholesale.
- It can only be done in the private sector, and there will likely be no funding unless by philanthropists.

Continuation

Business plan, development program, budget breakdown, proposed schedule etc. go here.

Weapons Slides

The Tom Bearden Website

Help support the research

"Others [terrorists] are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves… So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations…It's real, and that's the reason why we have to intensify our [counterterrorism] efforts." *

Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.

Slides
(covers period up to 1999)

- The Coming Strategic Attack on the United States
- Outline
- Loss of two separate A-10 Warthogs in 1997
- Typical ABM Defenses (Widely Deployed by mid-70s)

- Launch Phase Anti-Missile System
- Launch Phase Anti-Bomber System
- HC-130s Engines Quit, Aircraft Crashes
  Nov. 22, 1996
- 1996 Actions by this analyst
- Additional Information Exists: Not Analyzed, Not Integrated in Briefing
- Kill of Arrow DC-8, Gander AFB, Dec. 12, 1985
- Satellite Photos of Plumes in Soviet Arctic Since 1974
  See "Fer de Lance" for additional information
- Aum Shinrikyo ("Supreme Truth" Cult), Shoko Asahara, Leader

  Aum Shinrikyo - Anatomy of a Dangerous Cult
- Ashkhabad Problem and Its Solution
- Strange Characteristics of Iran Quake, Sep. 1978
- Iran Earthquake, September 1978
- Situation Now (Assessment)
- Situation Now (Assessment 2)
- Aspects of Strong Local Asymmetry
- Mass Casualty Problem: Aerial Anthrax

Spray on Washington, D.C.

- Present Status of the WMD Threat to the United States
- Some Present Problems in the U.S. WMD Defense Capabilities
- Internal Terrorist Threat with Weapons of Mass Destruction: Now & Future
- Attempt to Ban Energetics Weapons Worldwide
- Brezhnev's Schedule
- Large glowing Tesla globe witnessed in Red China by hundreds
- Cold Explosion -- 9 April 1984 Near Kurils, and formation and growth of spherical shell (globe)
  Sequence of Events
- Cold Explosion -- 9 April 1984 Near Kurils, and formation and growth of spherical shell (globe)
  What They Were
- Cold Explosion -- 9 April 1984 Near Kurils (Plus additional weapons effects)
- Countering Insane MAD Systems:
  Find Loophole, Exploit It
- Next Generation Counter to Both Sane and Insane MAD systems
- Simultaneous Dudding of Nuclear Weapons Worldwide

- Simultaneous Dudding of Nuclear Weapons Worldwide
- Operation Divine Wind II
- Advanced EMBW Applications
- EM Biological Warfare (EMBW)
- Microwave Radiation of U.S. Embassy in Moscow
- Pentagon EMI Studies, 1989
- EM Missile Practice (6 slides)
- Subdivisions of Soviet Energetics Program
- Communism's Goal
- Manuilsky's Goal vs. Status Today (Dec. 1996)
- Professor Hellman, German Scientist Released from Work in Soviet Union
- Hemispheres and Globes of Light (4 slides)
- How Could Such Superweapons Ever Be Concealed?
- Soviets Easily Concealed These Superweapons for Four Decades
- Microscope-type, laser-like interferometer for inducing quick α-decay in samples of otherwise longer-lived isotopes
- Longitudinal Wave Interferometry: Endothermic

- Longitudinal Wave Interferometry: Exothermic
- U.S. Air Attack on Libya, April 1986
- Lightning Wall
  circa 1959-1960
- Lisitsyn's Report: Brain Code Broken
- Large Longitudinal Wave Interferometer (LWI) Accident
- Large Longitudinal Wave Interferometer (LWI) Accident
- Use of Hidden Information Content of the Field Can Provide Action-At-A-Distance
- Two Types of Mutual Assured Destruction (MAD) System
- Psychoenergetics Weapons Teams Mentally Disable All Personnel
- Strikes Against Special Ship and Energetics Weapons Sites
- "Mindsnapper" Attack on Special Ships and Energetics Weapons Sites
- How Much Off Guard Are We?
  (7 Slides)
- Possible Targets: 1995-9 Escalation Phase
- Propagation of Weapon Effects
- Yugoslav Earthquake, Followed by Cold Explosion
  April 15th, 1979

- Countering an Insane QP Weapon
- Gulf War Disease: KGB QP Weapon Induced ST Curvature Engines for a Cocktail of Diseases
- Self-Targeting in Inner EM Channel Can Produce a Quantum Potential
- Mechanism for Producing a Quantum Potential
- Major Principles for Use of Quantum Potential Weapons
- Major Principles for Use of Quantum Potential Weapons (2)
- Instantaneous Communication by a Quantum Potential
- Participants in a quantum potential share a common multiply-connected spacetime (MCST)
- Quake in Tangshan, China
  28 July, 1976
- Exchanging Earthquakes
- Instant Communication by a Quantum Potential
- Westerners Do Not React to Slow Threats
- Characterizing a Given Risk or Risk Factor
- Technical Risk Management
- Aum Shinrikyo's Sarin Facility

- In Scalar Beam Interference Zone
- Physicist Schappeller Auralaz Munster, Austria
- Initial Soviet Plan for Cold War, After WWII
- Josef Stalin: Absolute Dictator
- Exploding any Resistance by Operational Scientists
- Significant Soviet Statements
- Captain Svoboda Dives Headlong to Her Death
- T-polarized Beam Projector
- Possible Tests (1)
- Possible Tests (2)
- Possible Tests (3)
- Possible Tests (4)
- Mushroom Cloud Rising From Sea
- Launches from Cape Canaveral and Vandenberg AFB Provided Practice Targets of Opportunity
- The sinking U.S.S. Thresher, with her controls jammed, implodes when she reaches crush depth
- Embodiment of an instrument array sufficient to discriminate when time-density charging has occurred, and that transduction

of time-charge decay has occurred.

- Time-Polarized EM Wave Interferometer Creating Space-Time Curvature Engines in a Distant Interference Zone
- Transmutation of Radioactive Nuclei at a Distance
- Transmutation of Radioactive Nuclei
- Typical Tesla Shield, Northern Route of Japan
- A Curious Tide in Human Affairs
- Large Scalar EM Interferometer (LASI) Accident Near Urals, 1958
- The Superpower Paradox: Asymmetric Cheap WMD Strategic Strike and Destruction
- The KGB/Yakuza-Aum War Plan
- Why Western Science is Ignorant of KGB Energetics
- Transmutation of Radioactive Nuclei at a Distance
- TheYakuza
- Yugoslav Earthquake, Followed by Cold Explosion
  April 15, 1979

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* Note that the Secretary did not speak the words in square blocks; these were added by the writers later,

probably to "soften the tone" of the Secretary's information release. So the Secretary confirmed that some nations of the world -- not just some ragged terrorists, as the writers tried to imply for spin control -- do possess novel electromagnetic weapons and are using them to induce earthquakes, engineer the weather and climate, and trigger volcanic eruptions.

THE COMING STRATEGIC ATTACK ON THE UNITED STATES

By an AUM/Yakuza/KGB/Communist Coalition Using Energetics SuperWeapons

T.E. Bearden, LTC
U.S. Army (Retired)
M.S. Nuclear Eng.
Fellow Emeritus, AIAS

With Technical Background and History of Energetics Weapons

Partial support by the Association of Distinguished American Scientists is gratefully acknowledged.d

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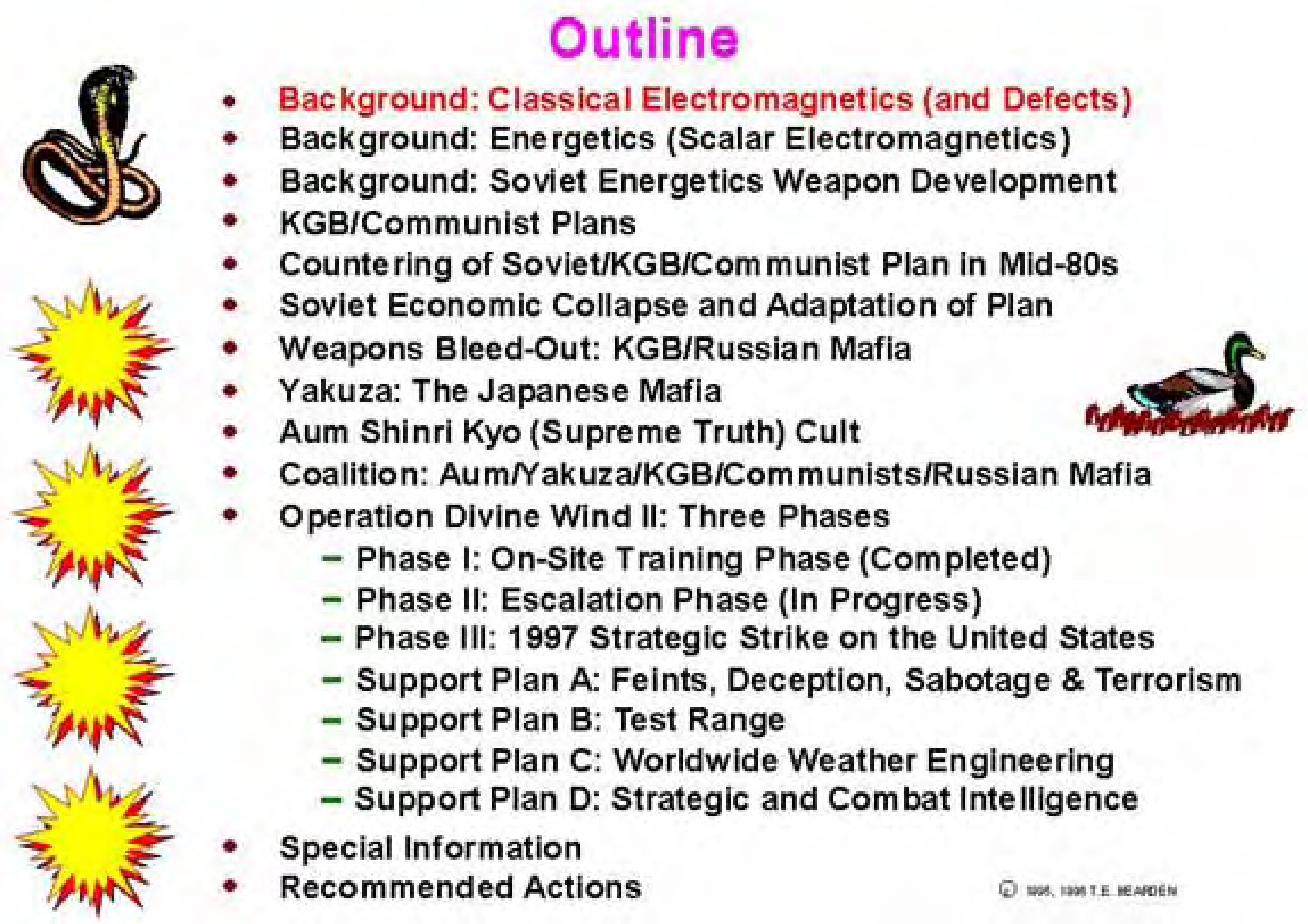

Outline

- Background: Classical Electromagnetics (and Defects)
- Background: Energetics (Scalar Electromagnetics)
- Background: Soviet Energetics Weapon Development
- KGB/Communist Plans
- Countering of Soviet/KGB/Communist Plan in Mid-80s
- Soviet Economic Collapse and Adaptation of Plan
- Weapons Bleed-Out: KGB/Russian Mafia
- Yakuza: The Japanese Mafia
- Aum Shinri Kyo (Supreme Truth) Cult
- Coalition: Aum/Yakuza/KGB/Communists/Russian Mafia
- Operation Divine Wind II: Three Phases
    - Phase I: On-Site Training Phase (Completed)
    - Phase II: Escalation Phase (In Progress)
    - Phase III: 1997 Strategic Strike on the United States
    - Support Plan A: Feints, Deception, Sabotage & Terrorism
    - Support Plan B: Test Range
    - Support Plan C: Worldwide Weather Engineering
    - Support Plan D: Strategic and Combat Intelligence
- Special Information
- Recommended Actions

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The Tom Bearden Website

Help support the research

Loss of two separate A-10 Warthogs in 1997

- A-10 Mysterious Flyaway and Crash - April 2, 1997
- Death of Second A-10 Pilot - May 27, 1997
- Captain Button's Mysterious Flyaway and Eventual Crash
- Death of Second A-10 Pilot - May 27, 1997

A-10 Mysterious Flyaway and Crash

April 2, 1997

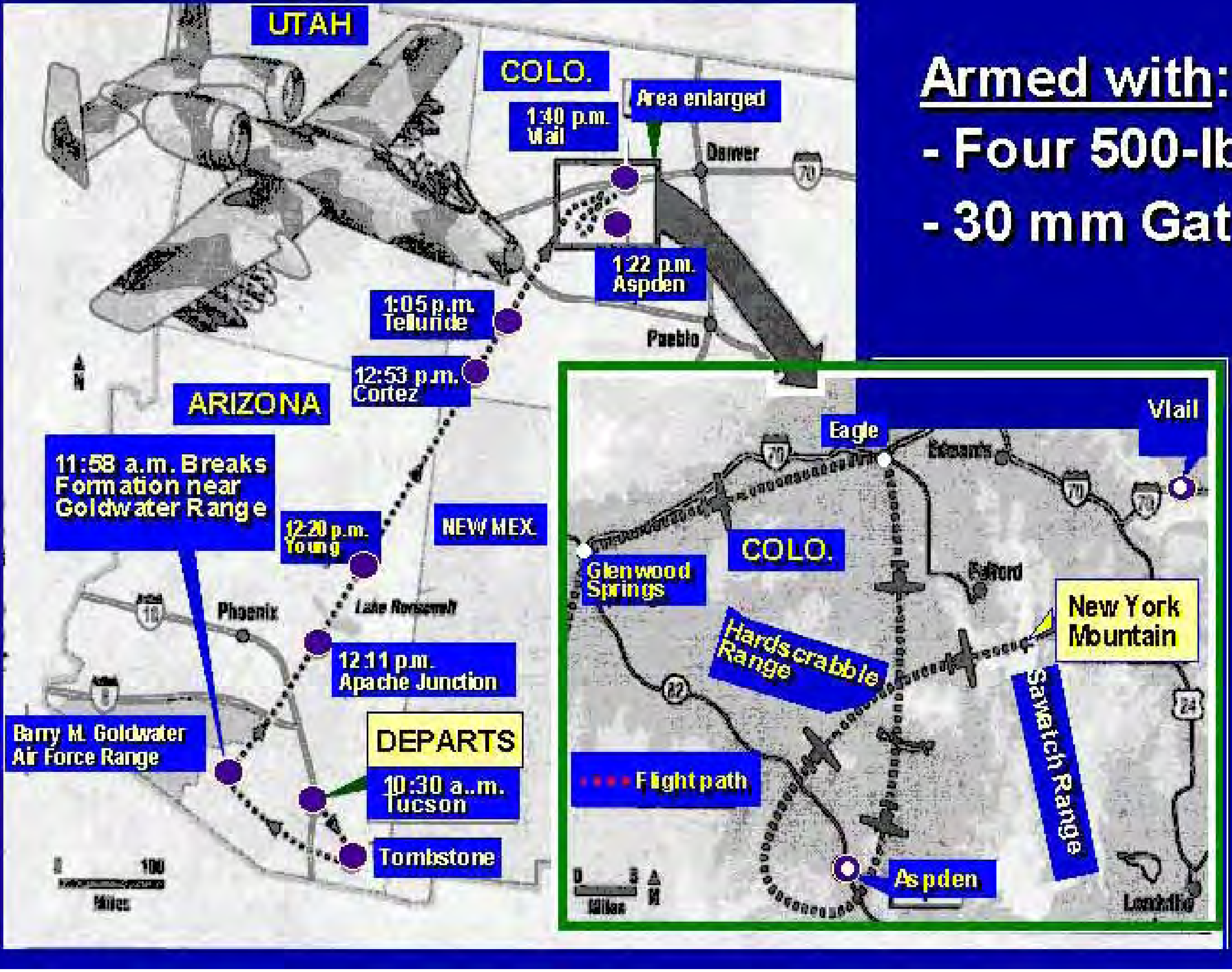
UTAH
COLO.
Area enlarged
1:40 p.m. Vail
Denver
70
1:22 p.m. Aspden
1:05 p.m. Telluride
Pueblo
12:53 p.m. Cortez
ARIZONA
11:58 a.m. Breaks Formation near Goldwater Range
12:20 p.m. Young
NEW MEX.
10
Phoenix
Lake Roosevelt
12:11 p.m. Apache Junction
8
Barry M. Goldwater Air Force Range
DEPARTS
10:30 a..m. Tucson
Tombstone
0 100
Miles
N
Eagle
Edwards
Vlail
70
70
COLO.
Glenwood Springs
Fulford
New York Mountain
Hardscrabble Range
82
Sawatch Range
24
Flight path
Aspden
0 5
Miles
N
Leadville

Armed with:

- Four 500-lb bombs
- 30 mm Gatling gun

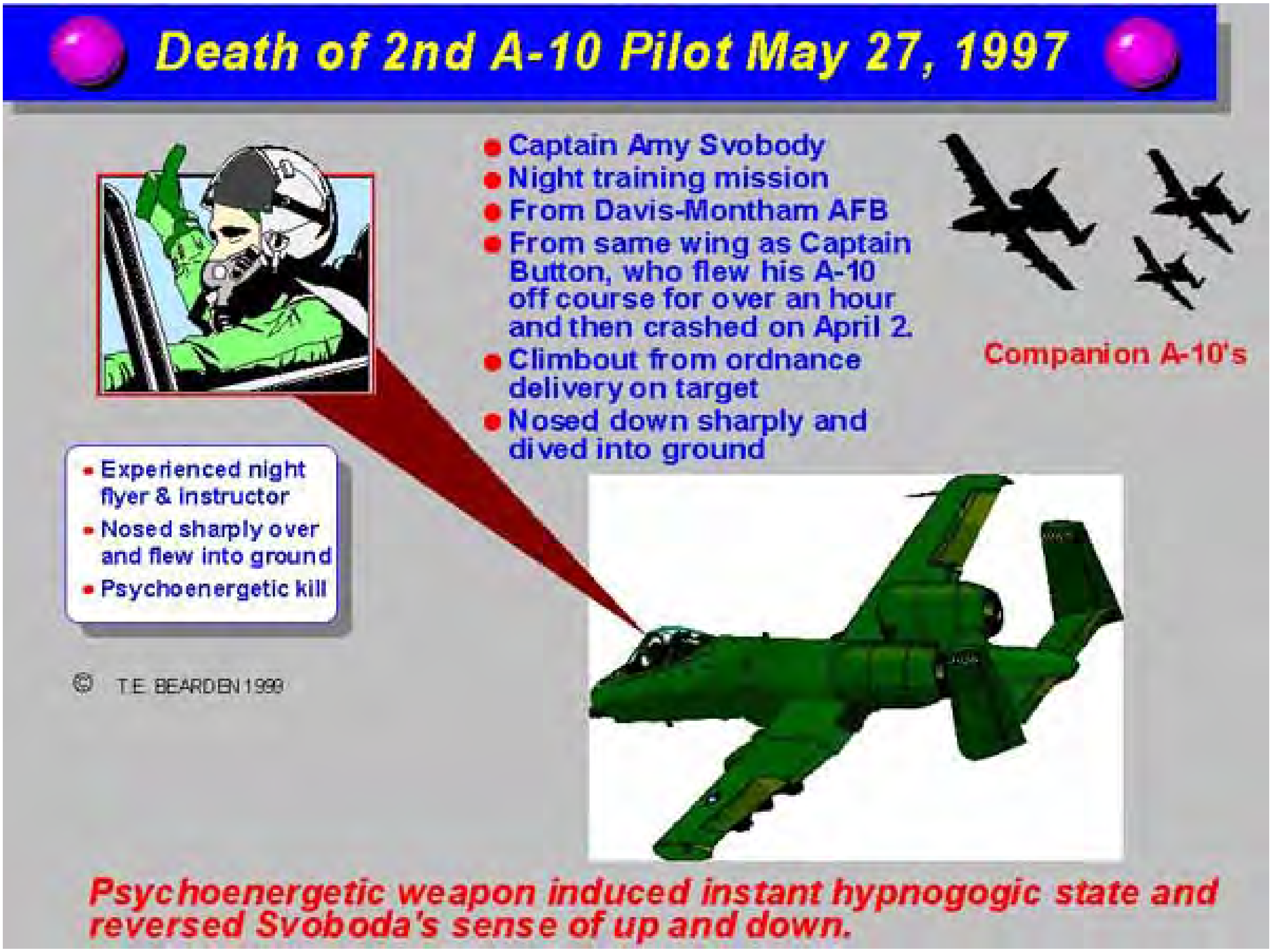

Death of 2nd A-10 Pilot May 27, 1997

- Captain Amy Svobody
- Night training mission
- From Davis-Montham AFB
- From same wing as Captain Button, who flew his A-10 off course for over an hour and then crashed on April 2.
- Climbout from ordnance delivery on target
- Nosed down sharply and dived into ground

Companion A-10's

- Experienced night flyer & instructor
- Nosed sharply over and flew into ground
- Psychoenergetic kill

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Psychoenergetic weapon induced instant hypnogogic state and reversed Svoboda's sense of up and down.

A-10 Mysterious Flyaway and Crash

April 2, 1997

Armed with:

- Four 500-lb bombs
- 30 mm Gatling gun

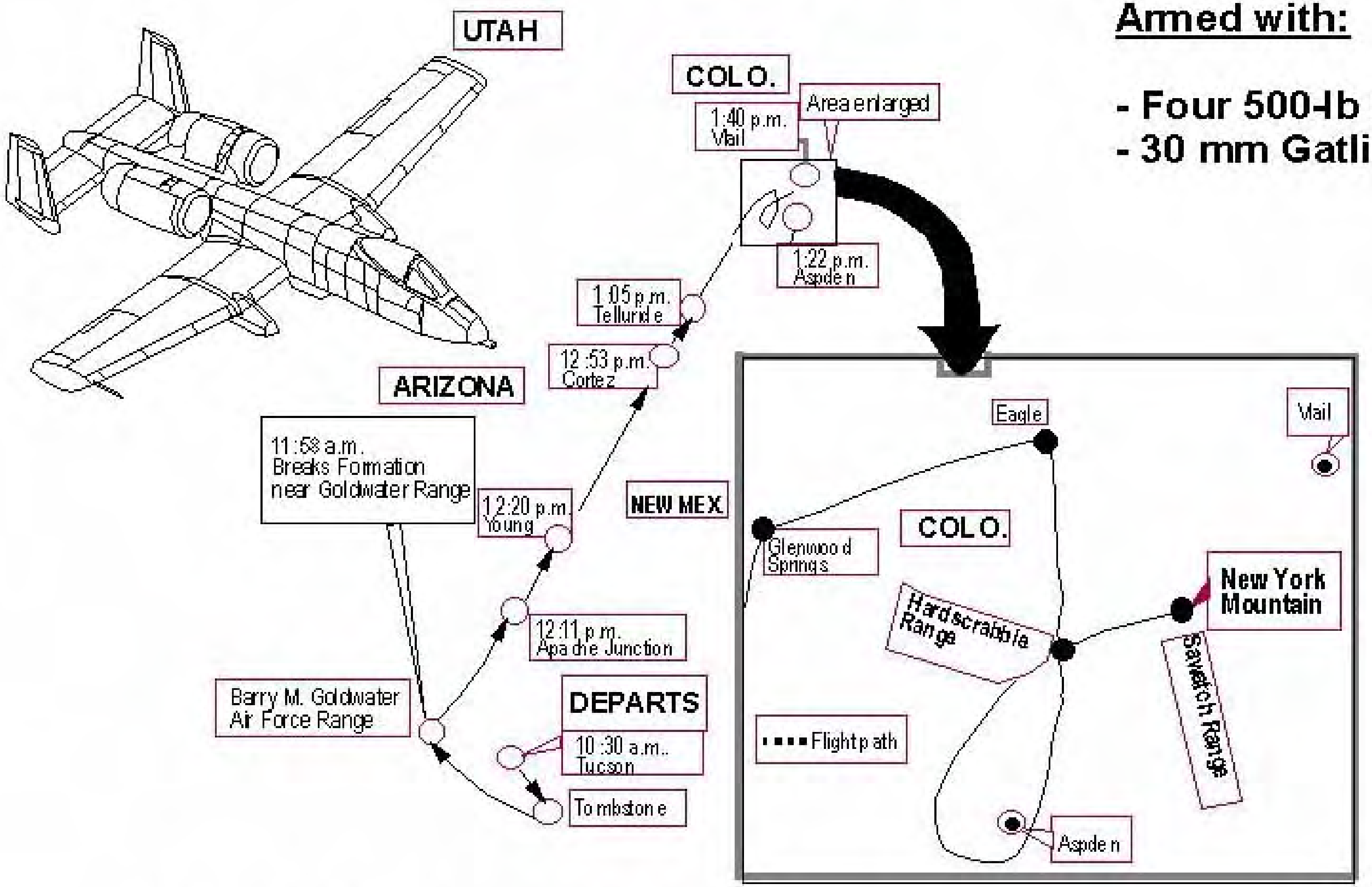
UTAH
COLO.
1:40 p.m.
Vail
Area enlarged
1:22 p.m.
Aspden
1:05 p.m.
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near Goldwater Range
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Apache Junction
Barry M. Goldwater
Air Force Range
DEPARTS
10:30 a.m..
Tucson
Tombstone
Eagle
Vail
Glenwood
Springs
COLO.
Hardscrabble
Range
New York
Mountain
Savatch Range
Flight path
Aspden

Figure 14a. Captain Button's mysterious flyaway and eventual crash.

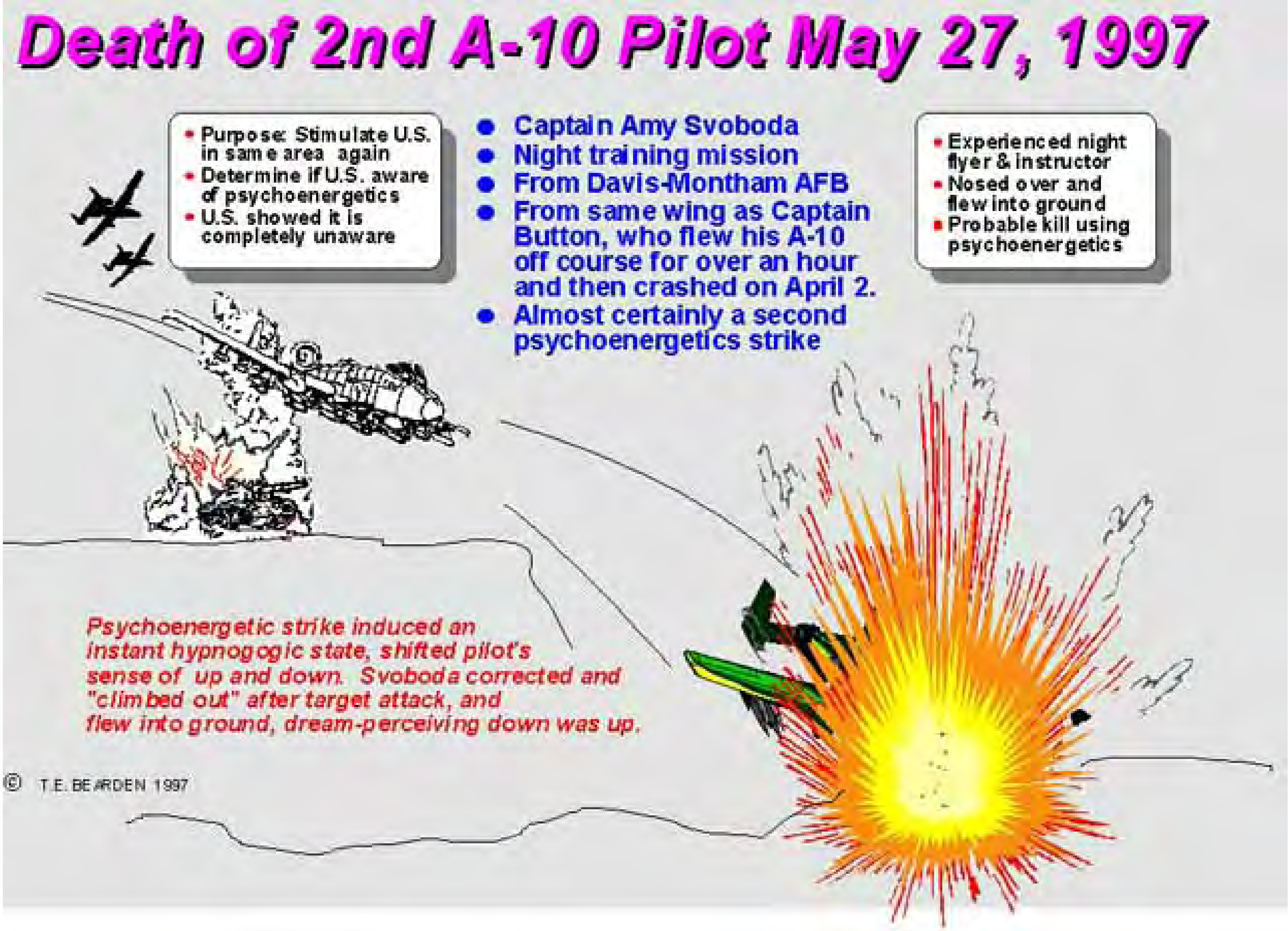

Death of 2nd A-10 Pilot May 27, 1997

- Purpose: Stimulate U.S. in same area again
- Determine if U.S. aware of psychoenergetics
- U.S. showed it is completely unaware

- Captain Amy Svoboda
- Night training mission
- From Davis-Montham AFB
- From same wing as Captain Button, who flew his A-10 off course for over an hour and then crashed on April 2.
- Almost certainly a second psychoenergetics strike

- Experienced night flyer & instructor
- Nosed over and flew into ground
- Probable kill using psychoenergetics

Psychoenergetic strike induced an instant hypnogogic state, shifted pilot's sense of up and down. Svoboda corrected and "climbed out" after target attack, and flew into ground, dream-perceiving down was up.

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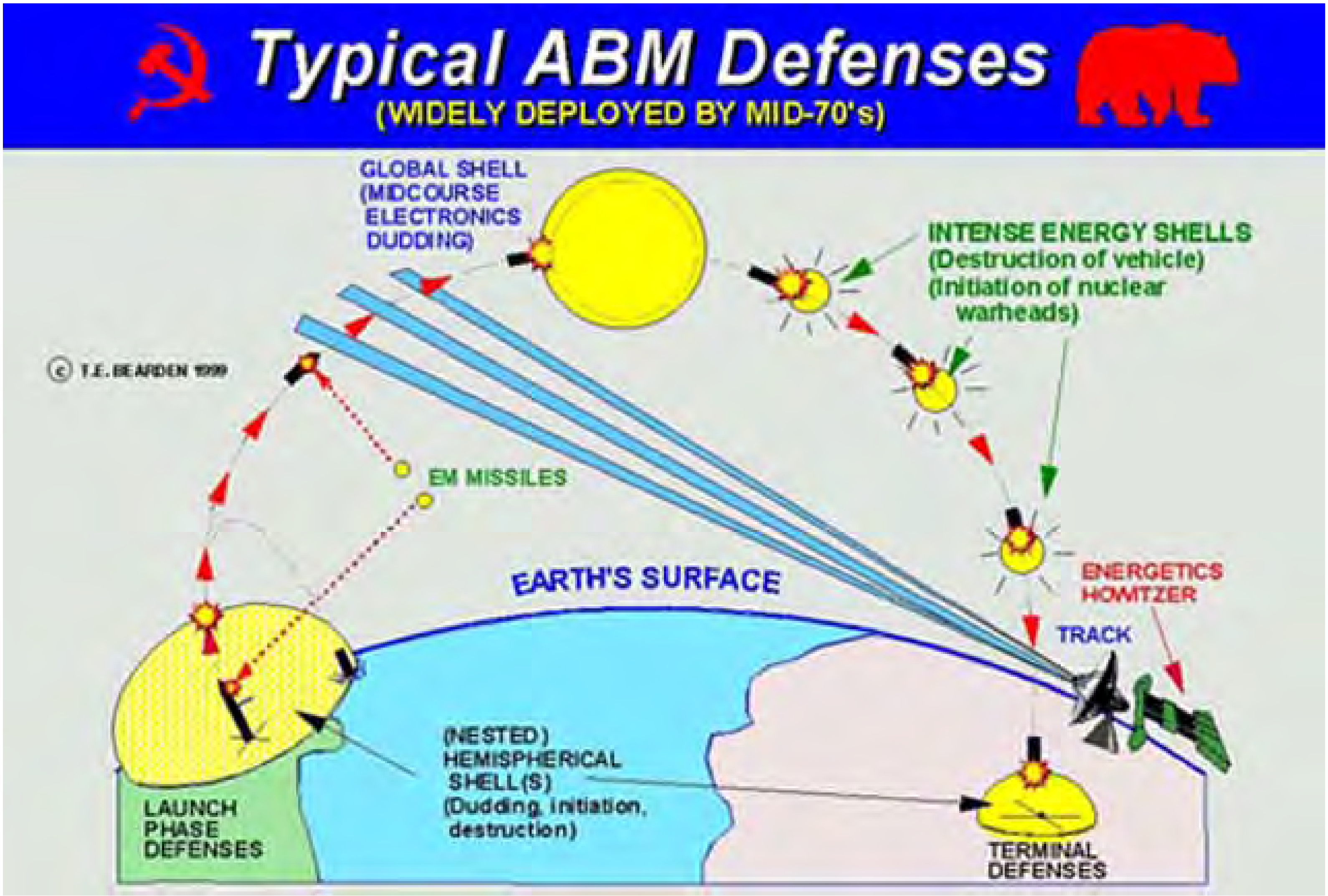
Typical ABM Defenses
(WIDELY DEPLOYED BY MID-70's)
GLOBAL SHELL
(MIDCOURSE
ELECTRONICS
DUDDING)
INTENSE ENERGY SHELLS
(Destruction of vehicle)
(Initiation of nuclear
warheads)
© T.E. BEARDEN 1999
EM MISSILES
EARTH'S SURFACE
ENERGETICS
HOWITZER
TRACK
(NESTED)
HEMISPHERICAL
SHELL(S)
(Dudding, initiation,
destruction)
LAUNCH
PHASE
DEFENSES
TERMINAL
DEFENSES

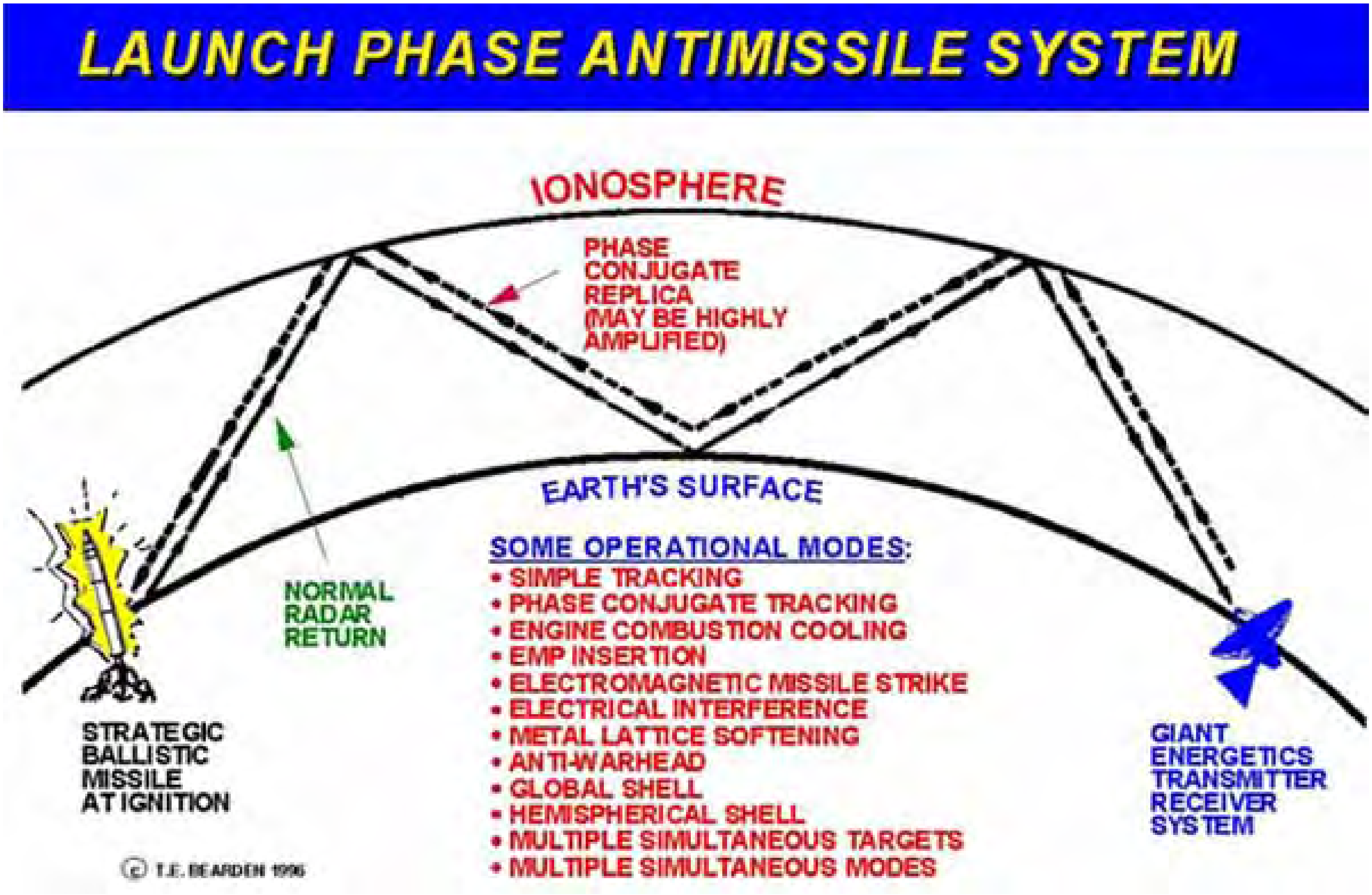

LAUNCH PHASE ANTIMISSILE SYSTEM

IONOSPHERE
PHASE CONJUGATE REPLICA (MAY BE HIGHLY AMPLIFIED)
EARTH'S SURFACE
NORMAL RADAR RETURN
STRATEGIC BALLISTIC MISSILE AT IGNITION
GIANT ENERGETICS TRANSMITTER RECEIVER SYSTEM

SOME OPERATIONAL MODES:

- SIMPLE TRACKING
- PHASE CONJUGATE TRACKING
- ENGINE COMBUSTION COOLING
- EMP INSERTION
- ELECTROMAGNETIC MISSILE STRIKE
- ELECTRICAL INTERFERENCE
- METAL LATTICE SOFTENING
- ANTI-WARHEAD
- GLOBAL SHELL
- HEMISPHERICAL SHELL
- MULTIPLE SIMULTANEOUS TARGETS
- MULTIPLE SIMULTANEOUS MODES

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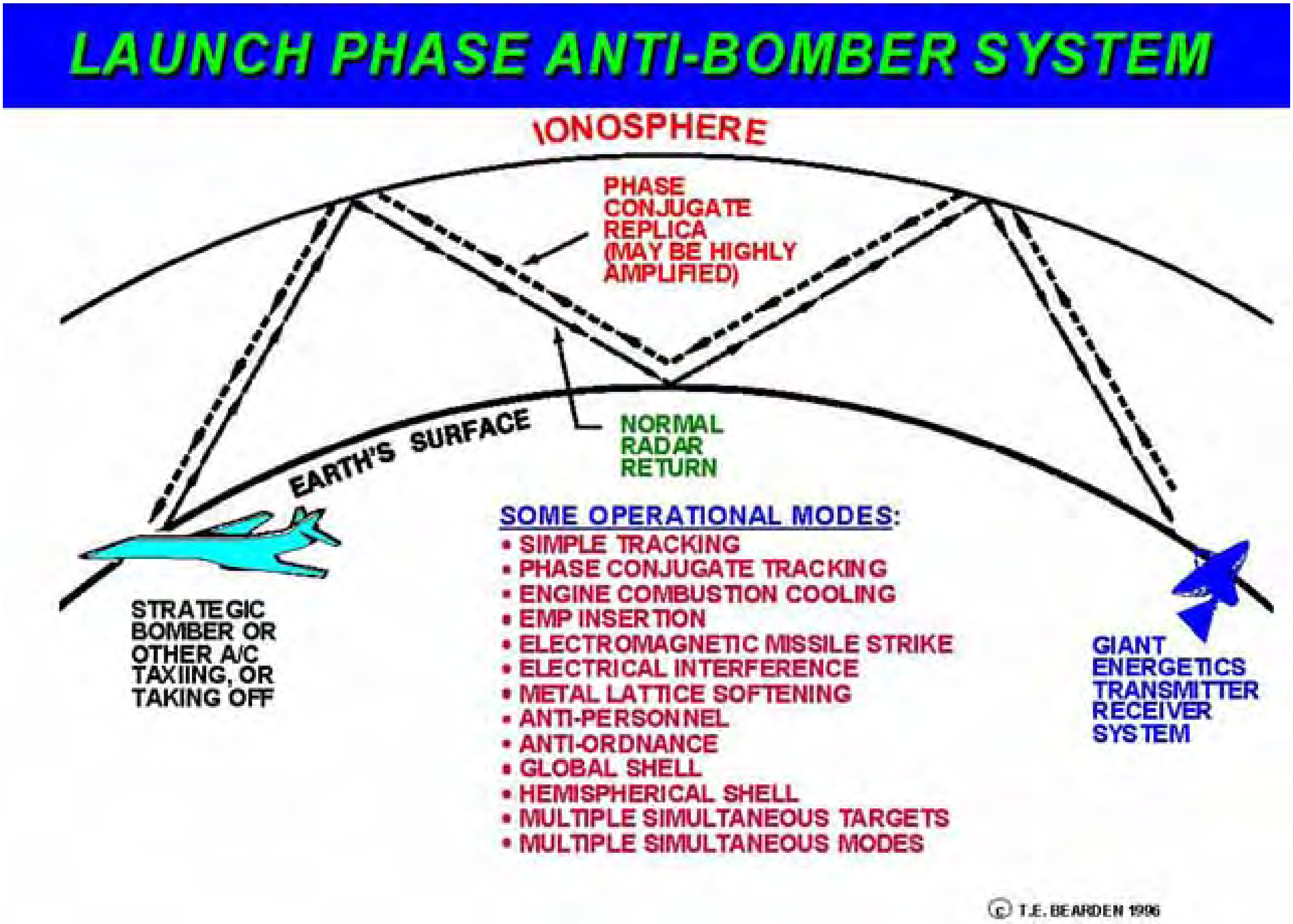

LAUNCH PHASE ANTI-BOMBER SYSTEM

IONOSPHERE

PHASE
CONJUGATE
REPLICA
(MAY BE HIGHLY
AMPLIFIED)

EARTH'S SURFACE

NORMAL
RADAR
RETURN

STRATEGIC
BOMBER OR
OTHER A/C
TAXIING, OR
TAKING OFF

GIANT
ENERGETICS
TRANSMITTER
RECEIVER
SYSTEM

SOME OPERATIONAL MODES:

- SIMPLE TRACKING
- PHASE CONJUGATE TRACKING
- ENGINE COMBUSTION COOLING
- EMP INSERTION
- ELECTROMAGNETIC MISSILE STRIKE
- ELECTRICAL INTERFERENCE
- METAL LATTICE SOFTENING
- ANTI-PERSONNEL
- ANTI-ORDNANCE
- GLOBAL SHELL
- HEMISPHERICAL SHELL
- MULTIPLE SIMULTANEOUS TARGETS
- MULTIPLE SIMULTANEOUS MODES

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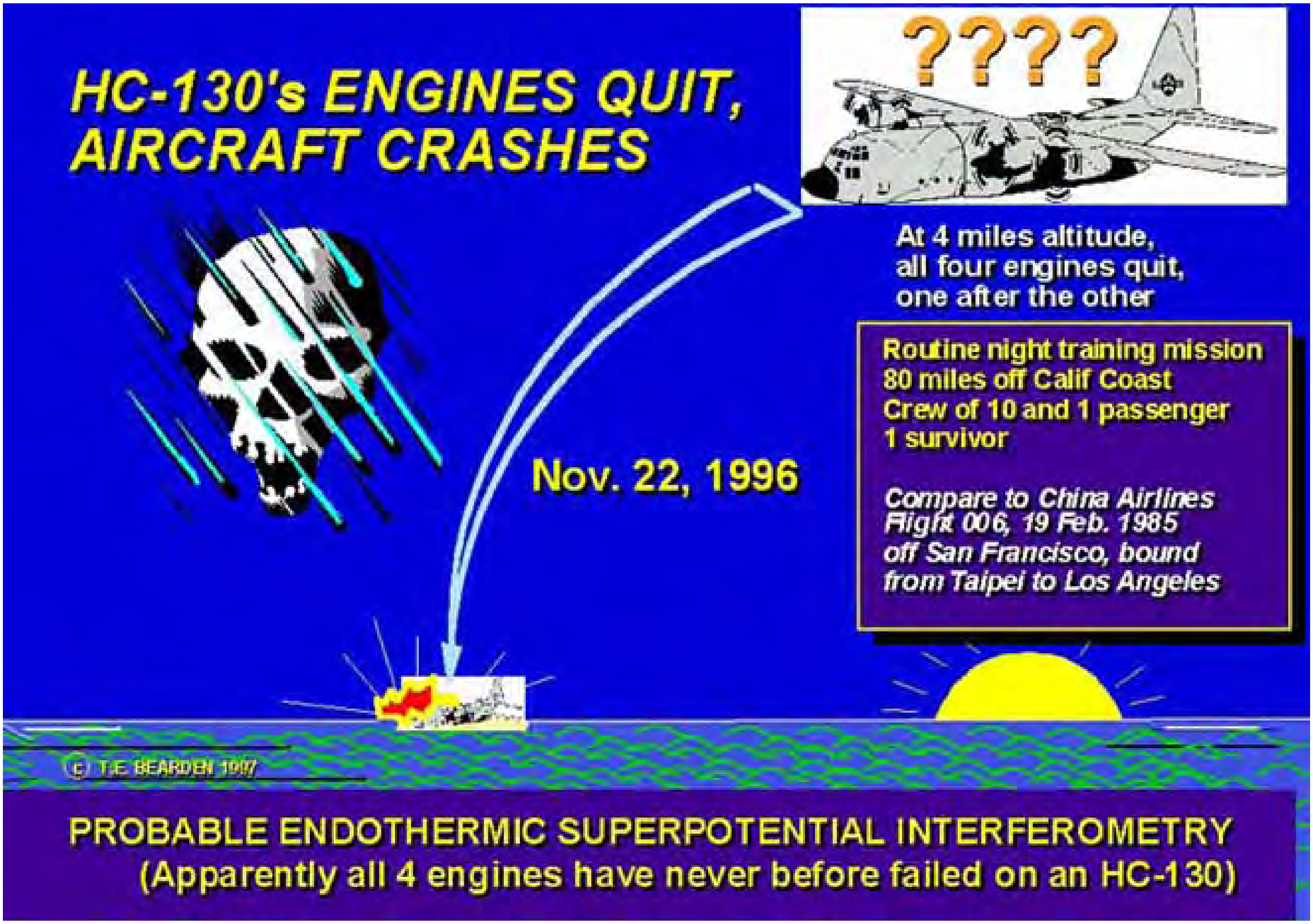

HC-130's ENGINES QUIT, AIRCRAFT CRASHES

At 4 miles altitude,
all four engines quit,
one after the other

Routine night training mission
80 miles off Calif Coast
Crew of 10 and 1 passenger
1 survivor

Compare to China Airlines
Flight 006, 19 Feb. 1985
off San Francisco, bound
from Taipei to Los Angeles

Nov. 22, 1996

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PROBABLE ENDOTHERMIC SUPERPOTENTIAL INTERFEROMETRY
(Apparently all 4 engines have never before failed on an HC-130)

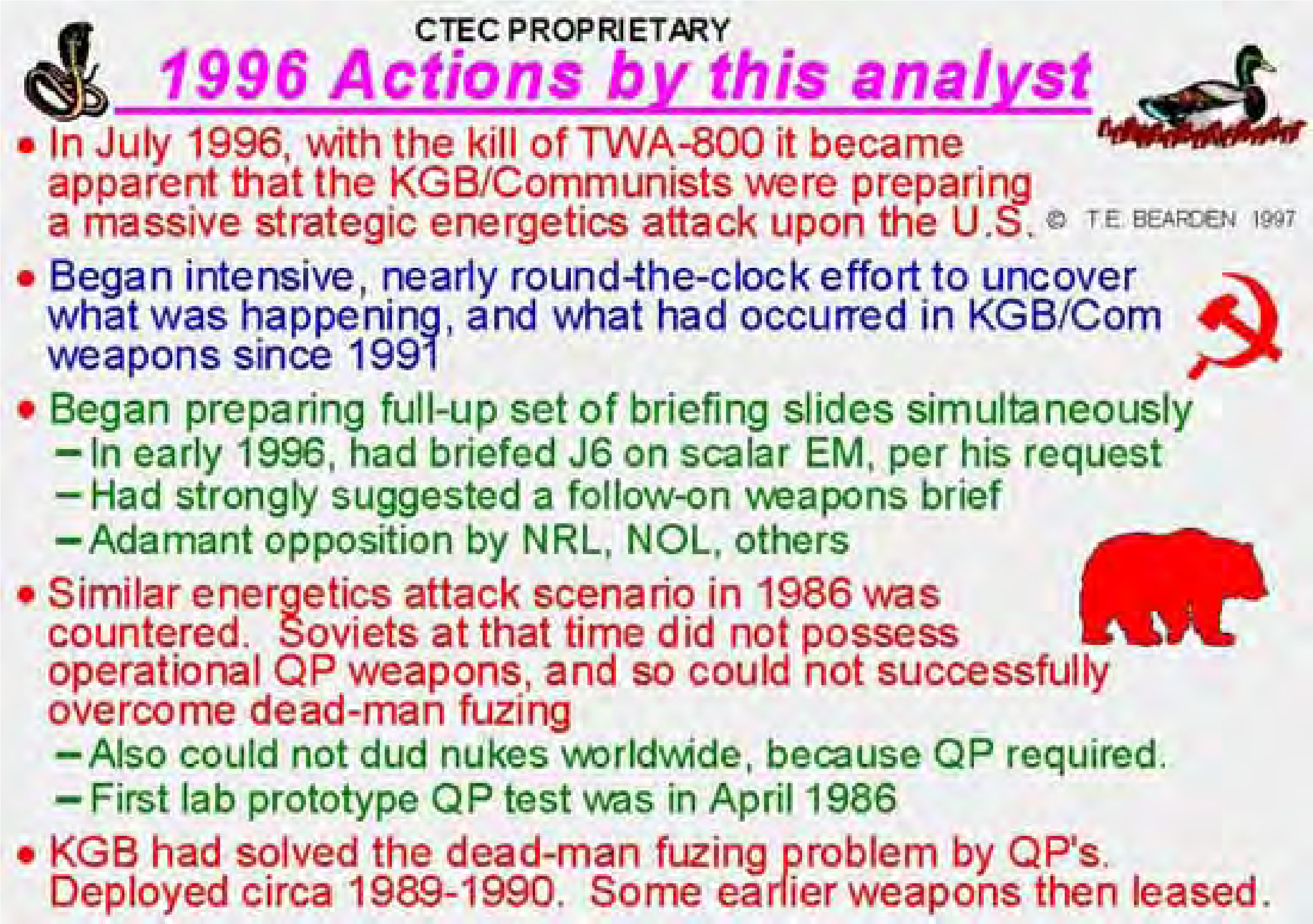

CTEC PROPRIETARY

1996 Actions by this analyst

- In July 1996, with the kill of TWA-800 it became apparent that the KGB/Communists were preparing a massive strategic energetics attack upon the U.S.

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- Began intensive, nearly round-the-clock effort to uncover what was happening, and what had occurred in KGB/Com weapons since 1991
- Began preparing full-up set of briefing slides simultaneously
  - In early 1996, had briefed J6 on scalar EM, per his request
  - Had strongly suggested a follow-on weapons brief
  - Adamant opposition by NRL, NOL, others
- Similar energetics attack scenario in 1986 was countered. Soviets at that time did not possess operational QP weapons, and so could not successfully overcome dead-man fuzing
  - Also could not dud nukes worldwide, because QP required.
  - First lab prototype QP test was in April 1986
- KGB had solved the dead-man fuzing problem by QP's. Deployed circa 1989-1990. Some earlier weapons then leased.

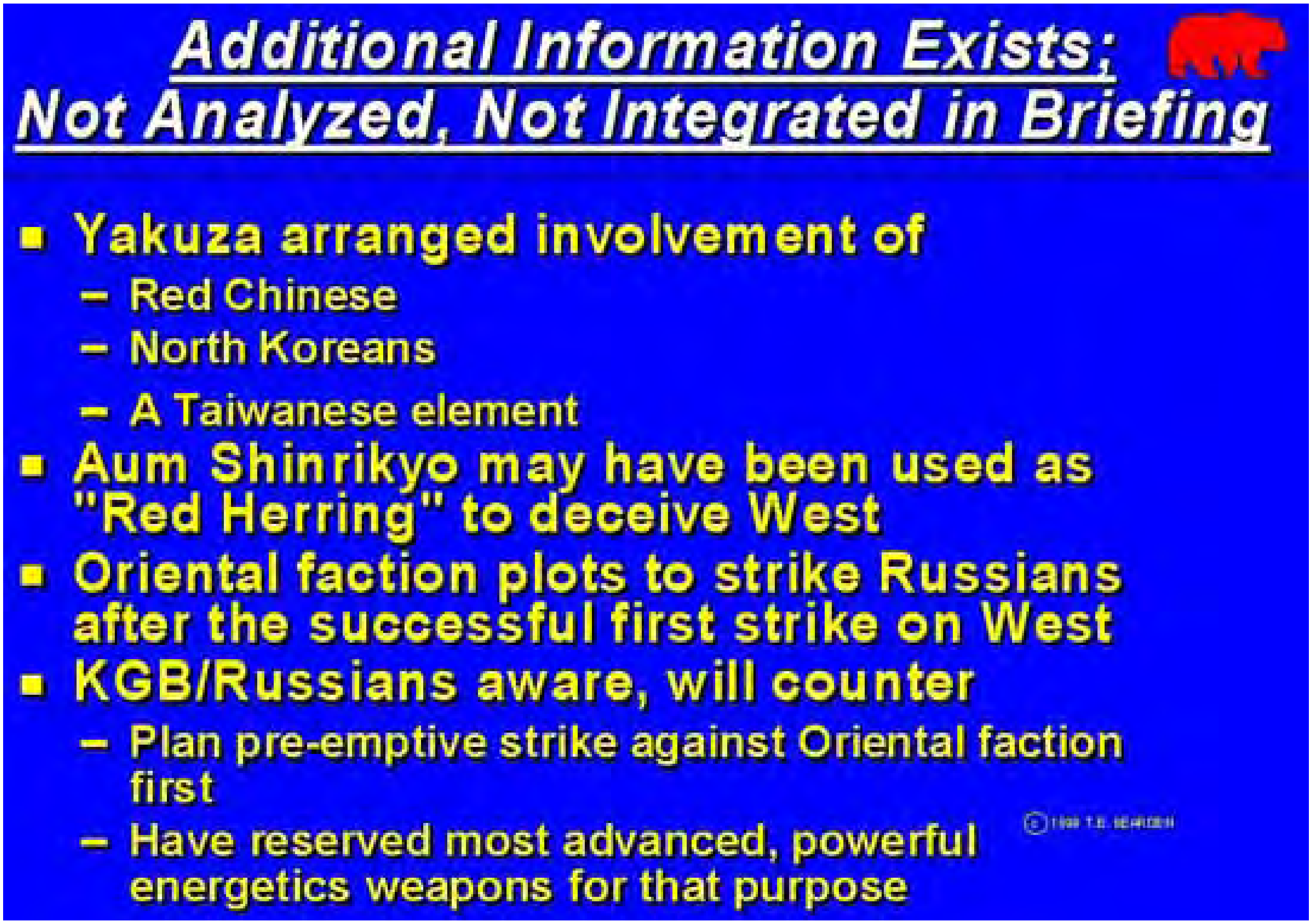

Additional Information Exists; Not Analyzed, Not Integrated in Briefing

- Yakuza arranged involvement of
  - Red Chinese
  - North Koreans
  - A Taiwanese element
- Aum Shinrikyo may have been used as "Red Herring" to deceive West
- Oriental faction plots to strike Russians after the successful first strike on West
- KGB/Russians aware, will counter
  - Plan pre-emptive strike against Oriental faction first
  - Have reserved most advanced, powerful energetics weapons for that purpose

The Tom Bearden Website

Help support the research

Kill of Arrow DC-8, Gander AFB, Dec. 12, 1985

- Slide 1
- Slide 2
- Slide 3
- Slide 4
- Slide 5
- Slide 6

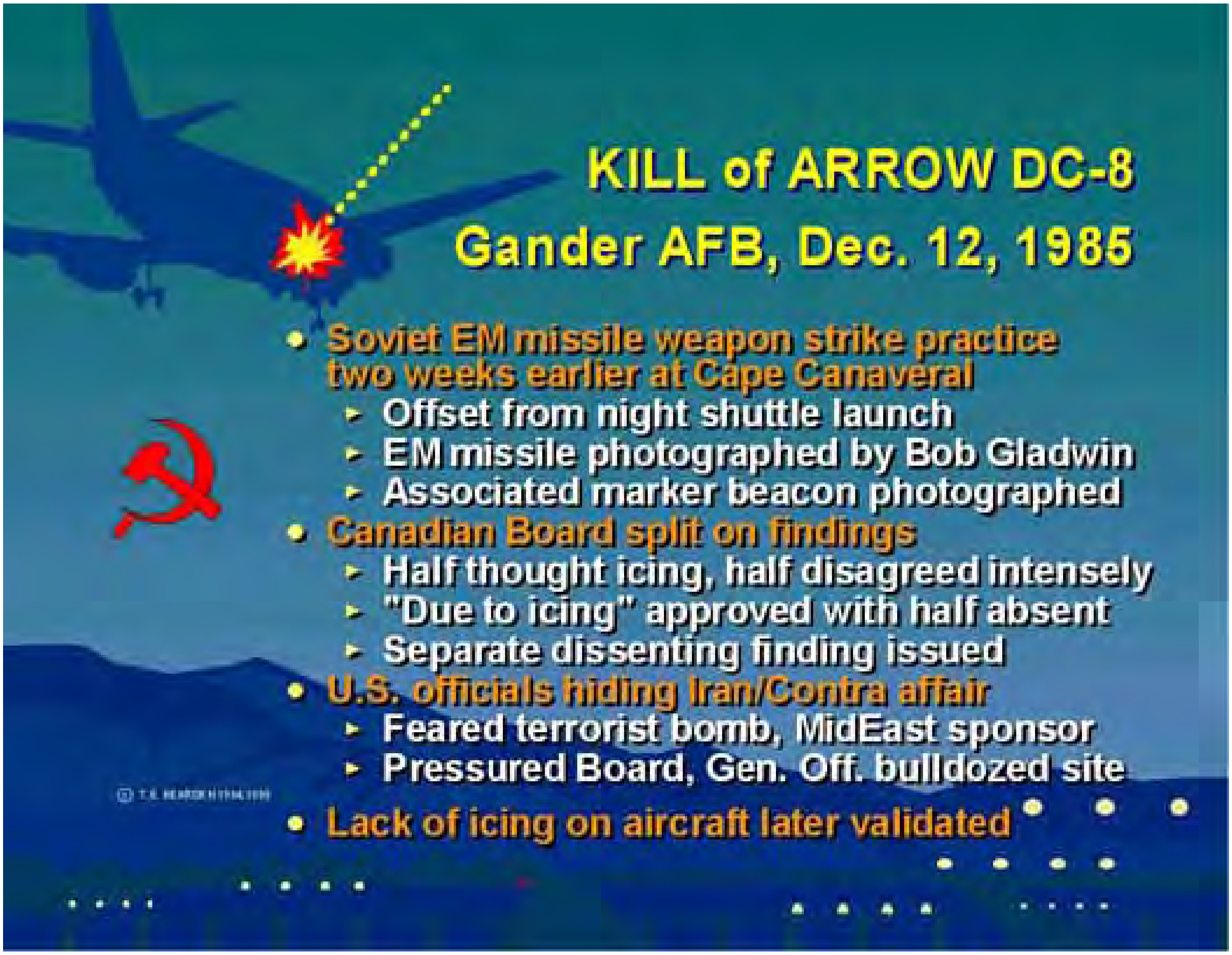

KILL of ARROW DC-8

Gander AFB, Dec. 12, 1985

- Soviet EM missile weapon strike practice two weeks earlier at Cape Canaveral
  - Offset from night shuttle launch
  - EM missile photographed by Bob Gladwin
  - Associated marker beacon photographed
- Canadian Board split on findings
  - Half thought icing, half disagreed intensely
  - "Due to icing" approved with half absent
  - Separate dissenting finding issued
- U.S. officials hiding Iran/Contra affair
  - Feared terrorist bomb, MidEast sponsor
  - Pressured Board, Gen. Off. bulldozed site
- Lack of icing on aircraft later validated

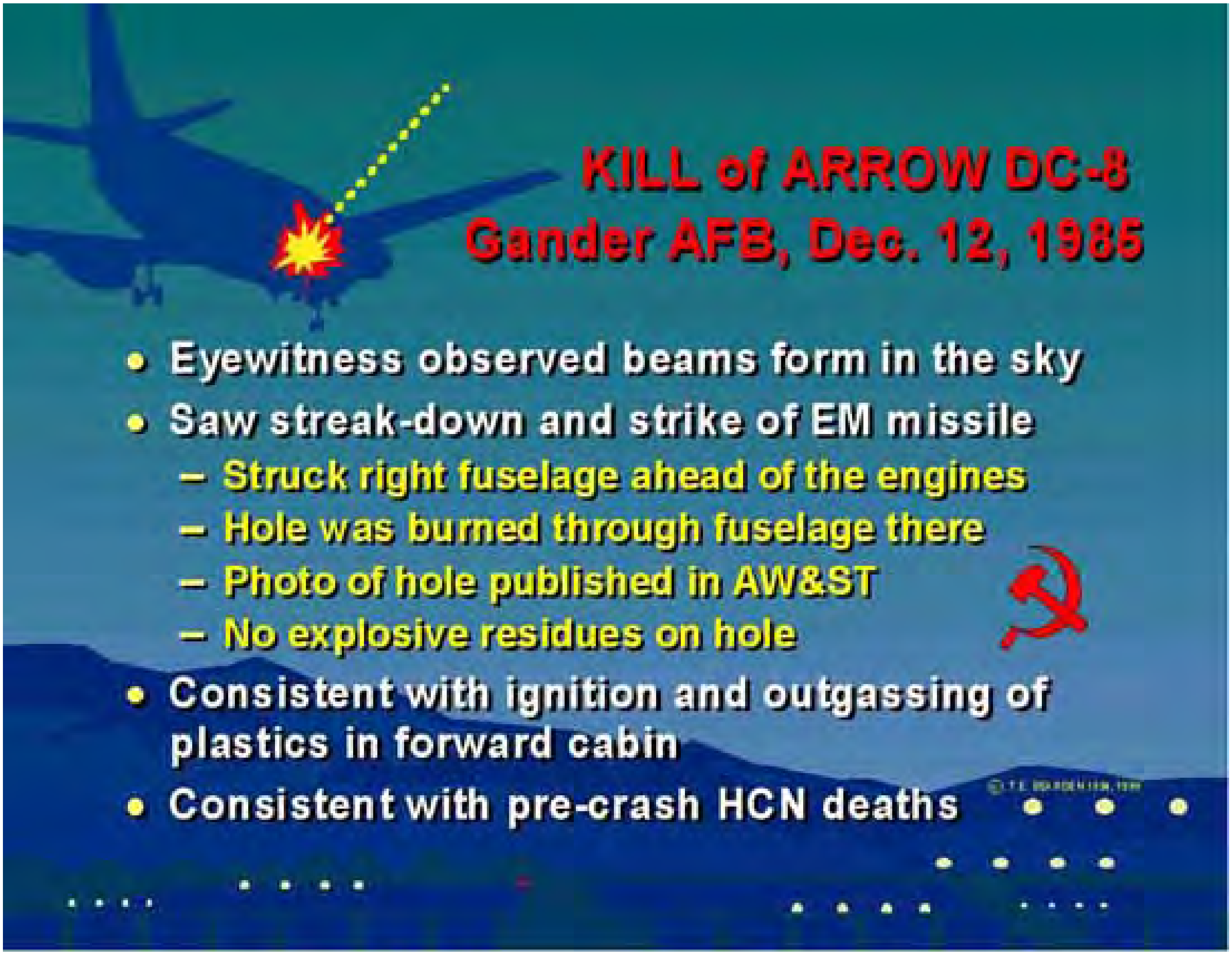

KILL of ARROW DC-8
Gander AFB, Dec. 12, 1985

- Eyewitness observed beams form in the sky
- Saw streak-down and strike of EM missile
  - Struck right fuselage ahead of the engines
  - Hole was burned through fuselage there
  - Photo of hole published in AW&ST
  - No explosive residues on hole
- Consistent with ignition and outgassing of plastics in forward cabin
- Consistent with pre-crash HCN deaths

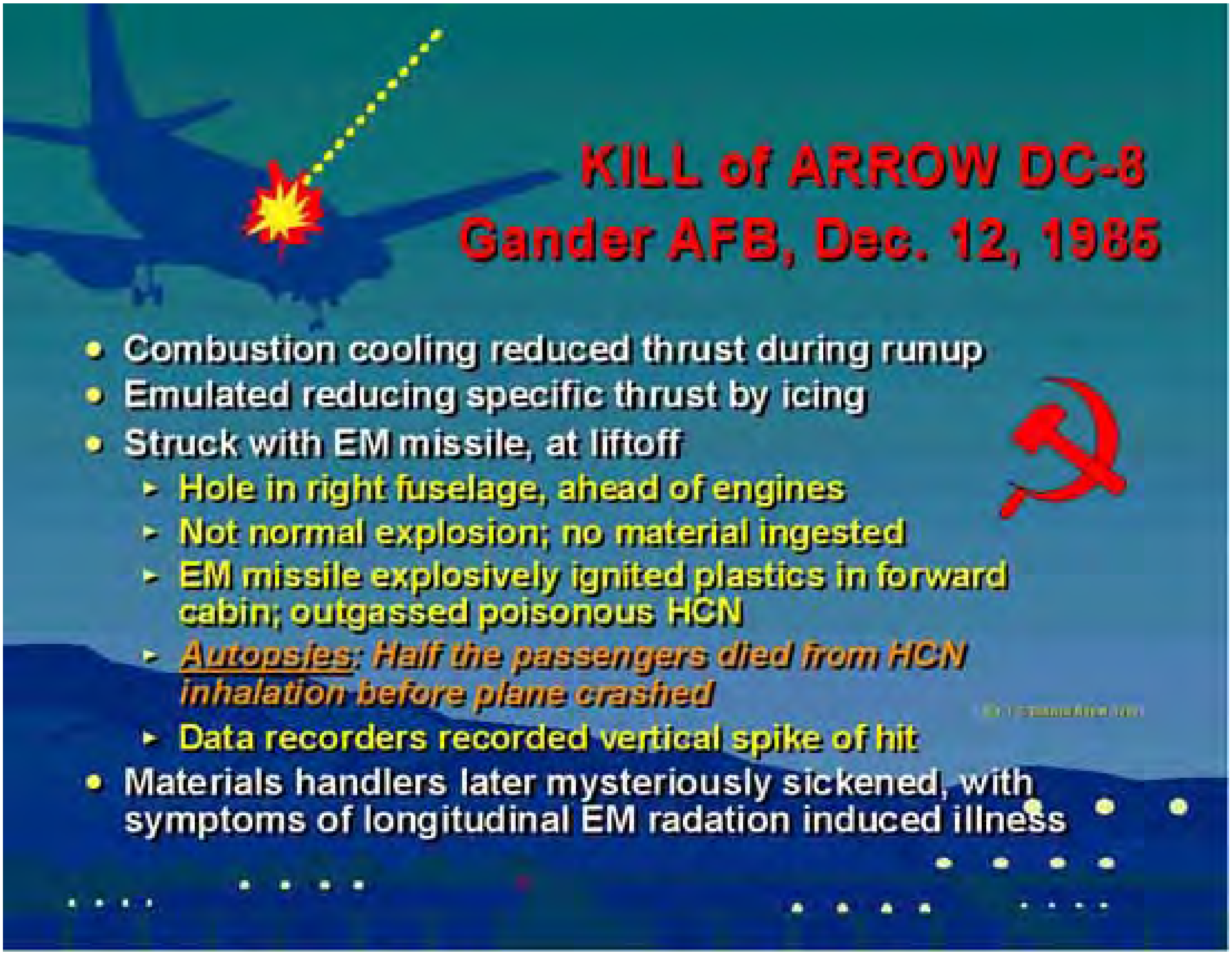

KILL of ARROW DC-8
Gander AFB, Dec. 12, 1985

- Combustion cooling reduced thrust during runup
- Emulated reducing specific thrust by icing
- Struck with EM missile, at liftoff
  - Hole in right fuselage, ahead of engines
  - Not normal explosion; no material ingested
  - EM missile explosively ignited plastics in forward cabin; outgassed poisonous HCN
  - *Autopsies: Half the passengers died from HCN inhalation before plane crashed*
  - Data recorders recorded vertical spike of hit
- Materials handlers later mysteriously sickened, with symptoms of longitudinal EM radation induced illness

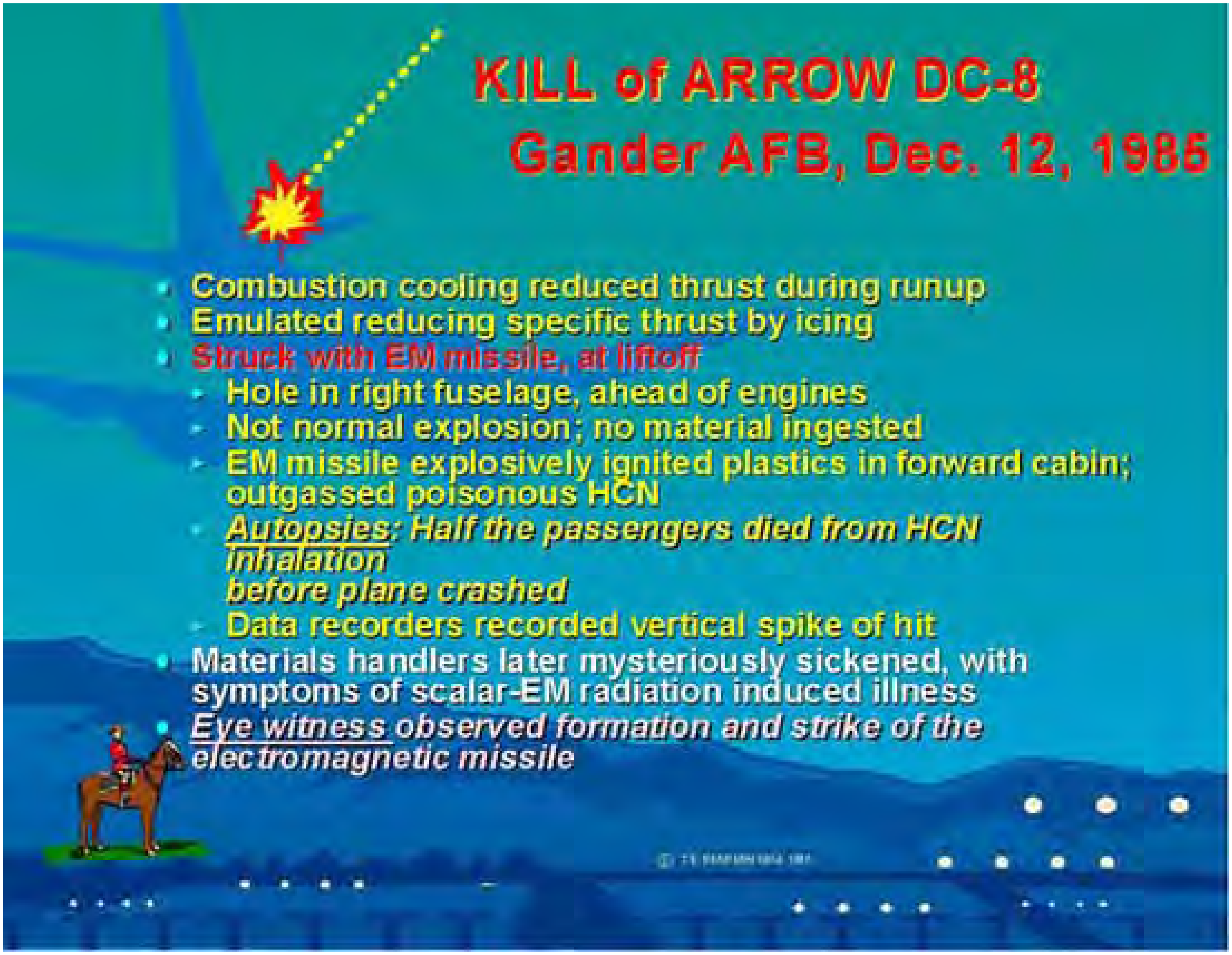

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    - Data recorders recorded vertical spike of hit
- Materials handlers later mysteriously sickened, with symptoms of scalar-EM radiation induced illness
- *Eye witness observed formation and strike of the electromagnetic missile*

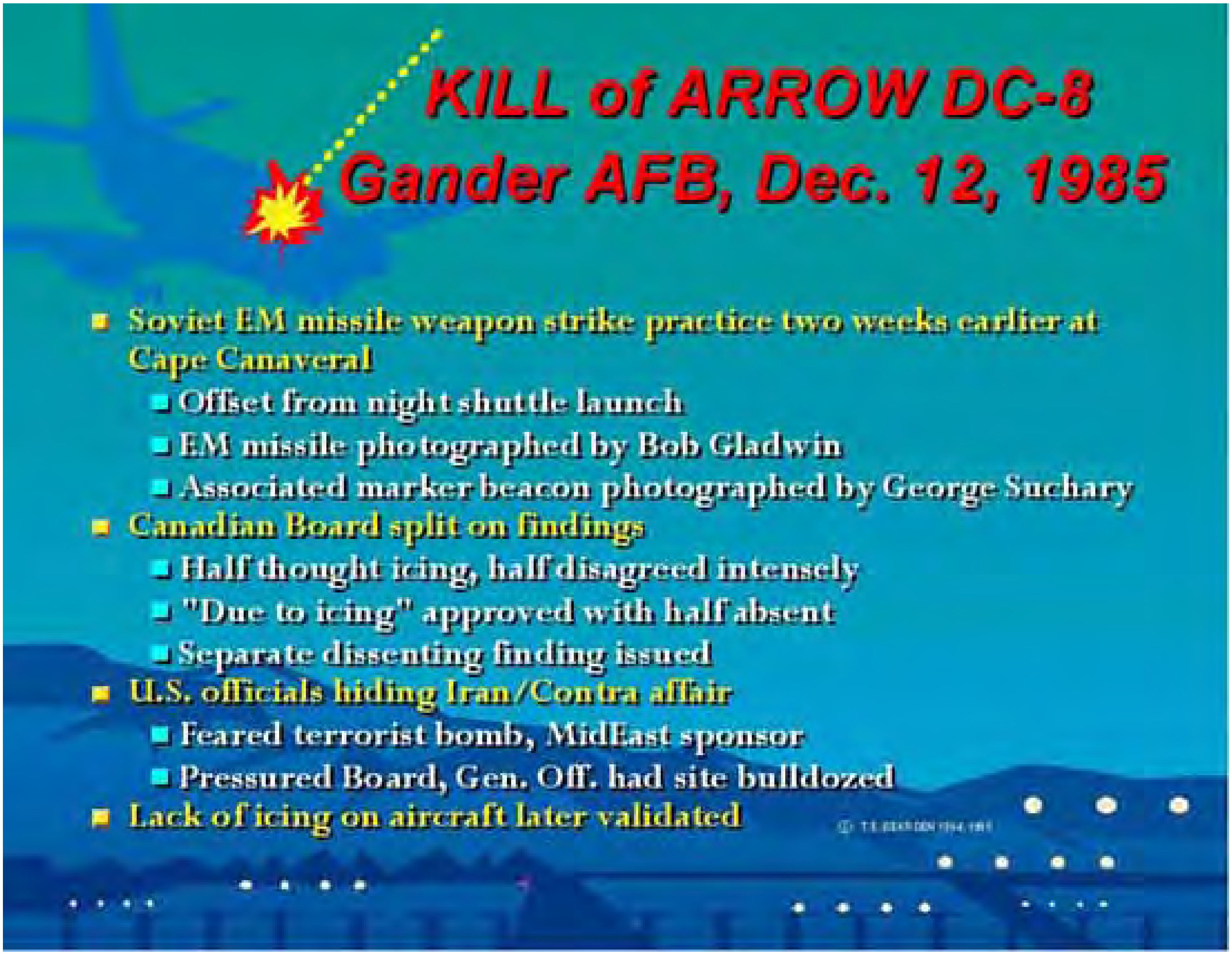

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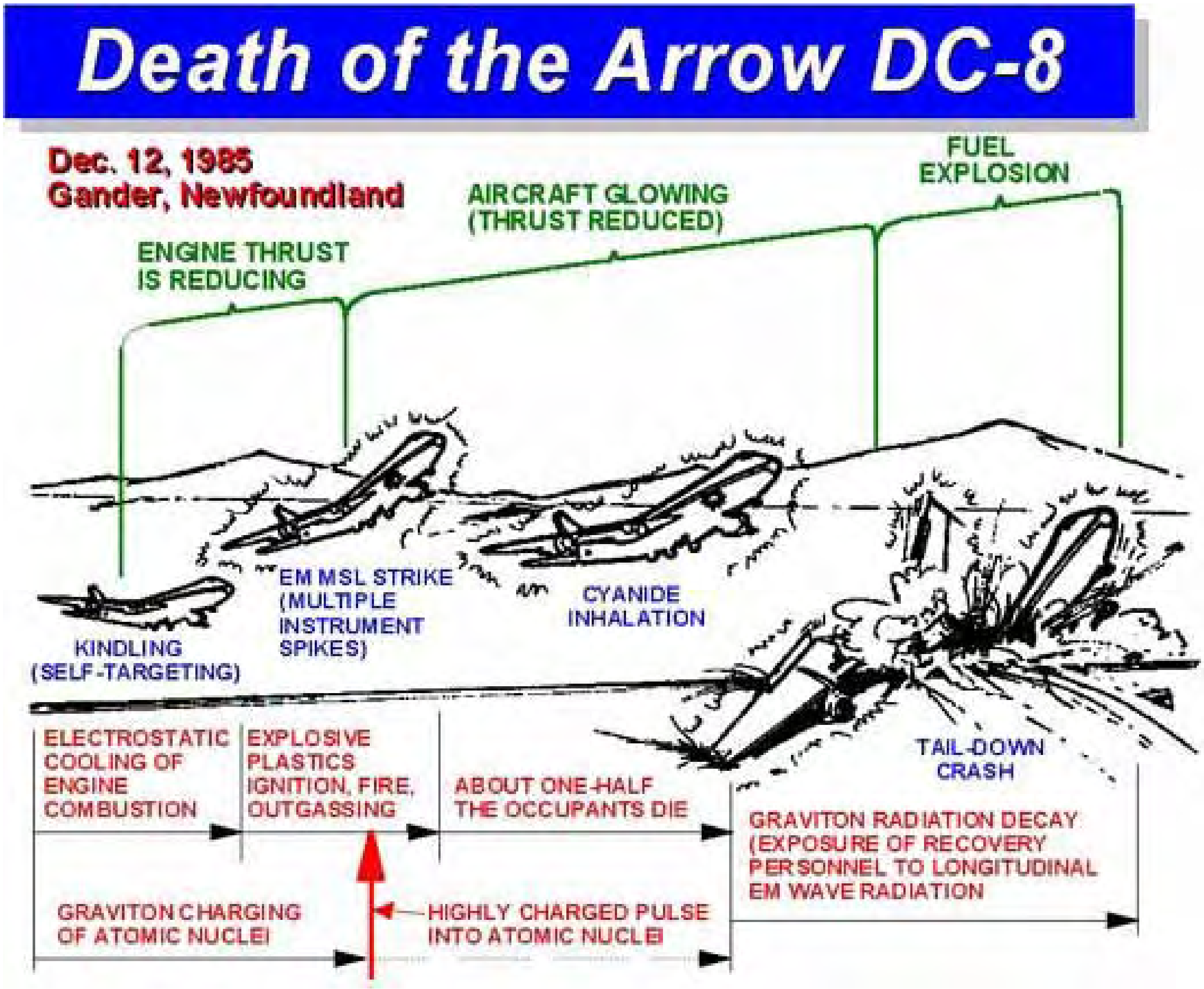
Death of the Arrow DC-8
Dec. 12, 1985
Gander, Newfoundland
ENGINE THRUST IS REDUCING
AIRCRAFT GLOWING (THRUST REDUCED)
FUEL EXPLOSION
KINDLING (SELF-TARGETING)
EM MSL STRIKE (MULTIPLE INSTRUMENT SPIKES)
CYANIDE INHALATION
TAIL-DOWN CRASH
ELECTROSTATIC COOLING OF ENGINE COMBUSTION
EXPLOSIVE PLASTICS IGNITION, FIRE, OUTGASSING
ABOUT ONE-HALF THE OCCUPANTS DIE
GRAVITON RADIATION DECAY (EXPOSURE OF RECOVERY PERSONNEL TO LONGITUDINAL EM WAVE RADIATION
GRAVITON CHARGING OF ATOMIC NUCLEI
HIGHLY CHARGED PULSE INTO ATOMIC NUCLEI

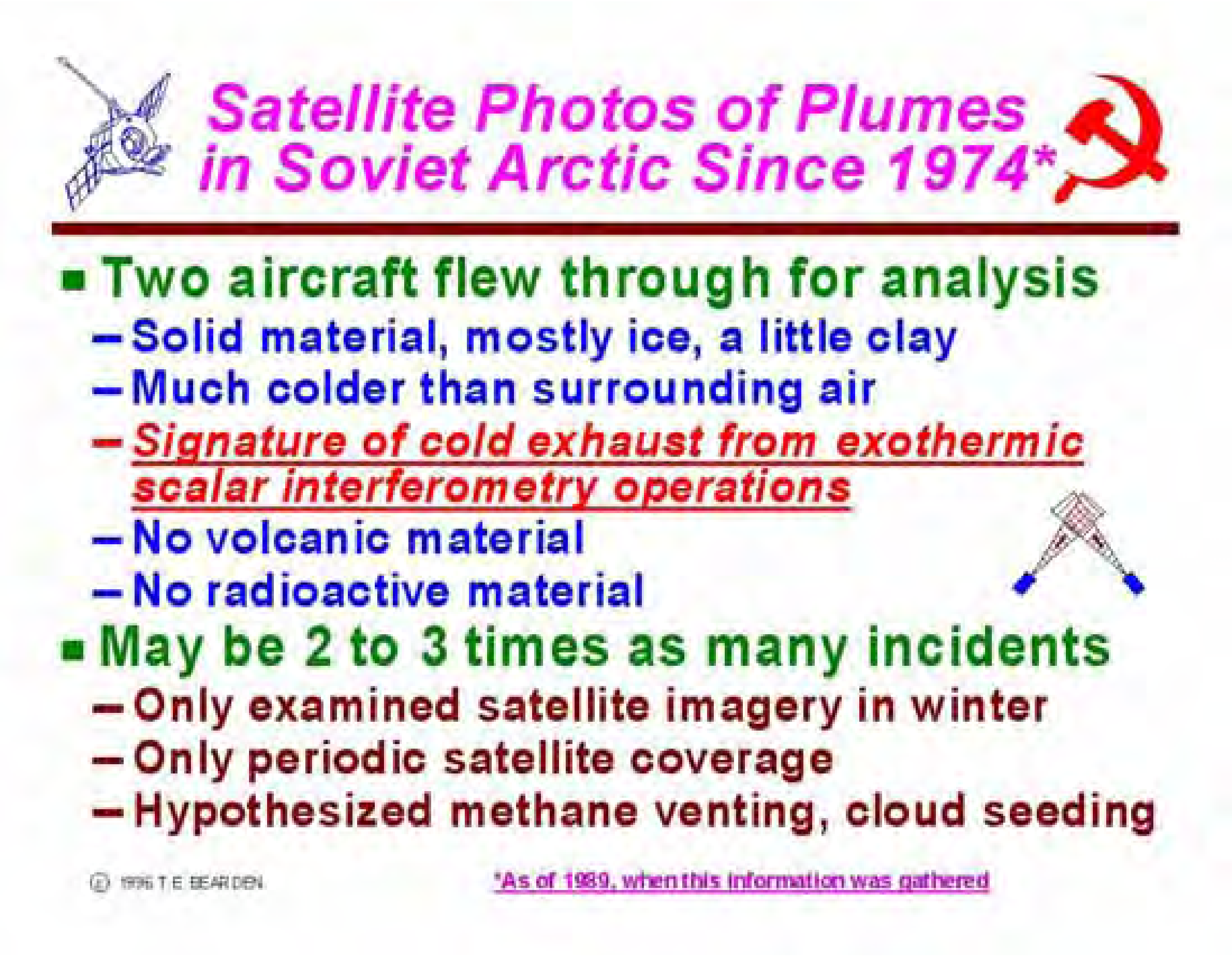

Satellite Photos of Plumes in Soviet Arctic Since 1974*

- Two aircraft flew through for analysis
  - Solid material, mostly ice, a little clay
  - Much colder than surrounding air
  - *Signature of cold exhaust from exothermic scalar interferometry operations*
  - No volcanic material
  - No radioactive material
- May be 2 to 3 times as many incidents
  - Only examined satellite imagery in winter
  - Only periodic satellite coverage
  - Hypothesized methane venting, cloud seeding

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*As of 1989, when this information was gathered

AUM SHINRIKYO

("SUPREME TRUTH" CULT)

Shoko Asahara, Leader

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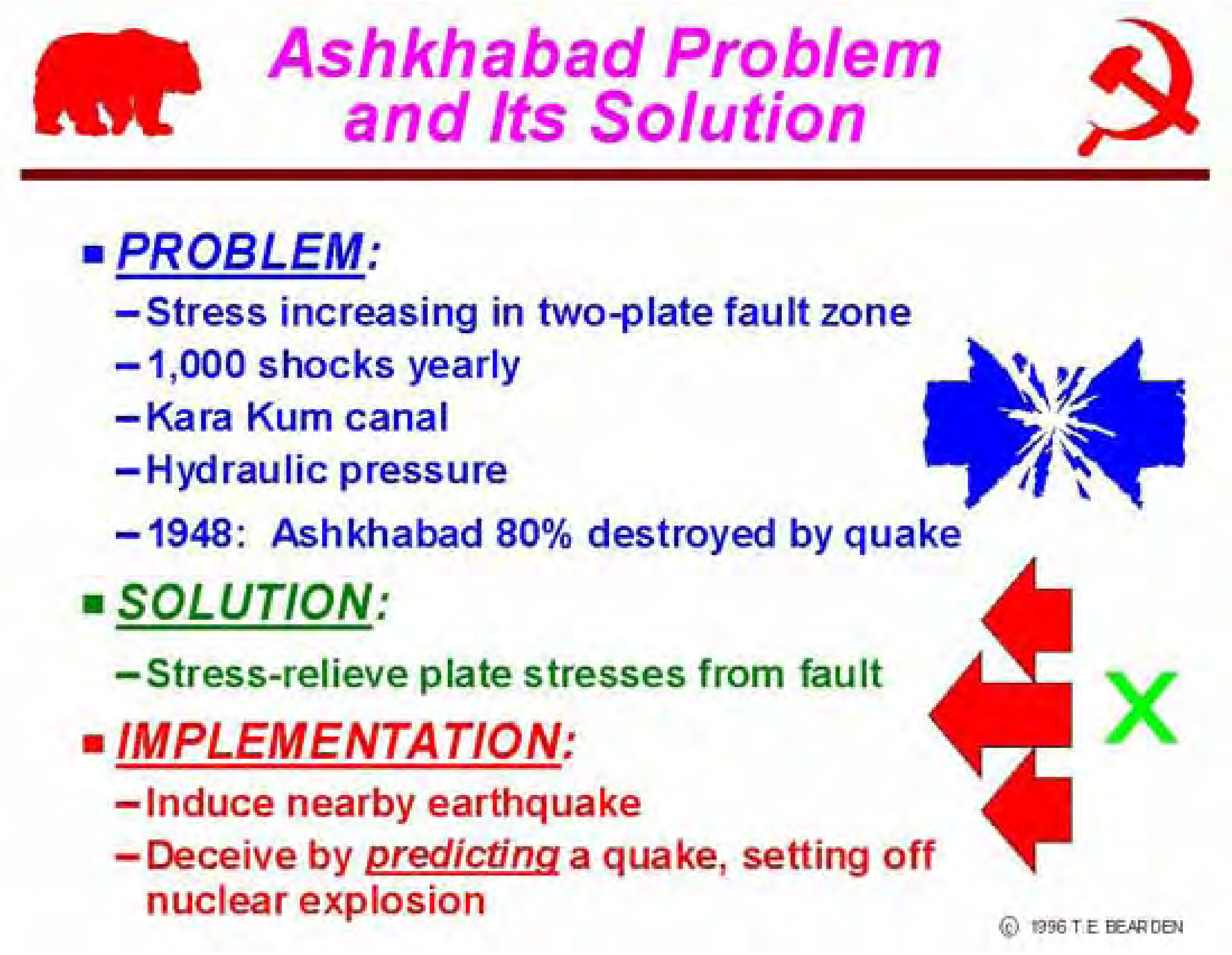

Ashkhabad Problem and Its Solution

- ***PROBLEM:***
  - Stress increasing in two-plate fault zone
  - 1,000 shocks yearly
  - Kara Kum canal
  - Hydraulic pressure
  - 1948: Ashkhabad 80% destroyed by quake
- ***SOLUTION:***
  - Stress-relieve plate stresses from fault
- ***IMPLEMENTATION:***
  - Induce nearby earthquake
  - Deceive by *predicting* a quake, setting off nuclear explosion

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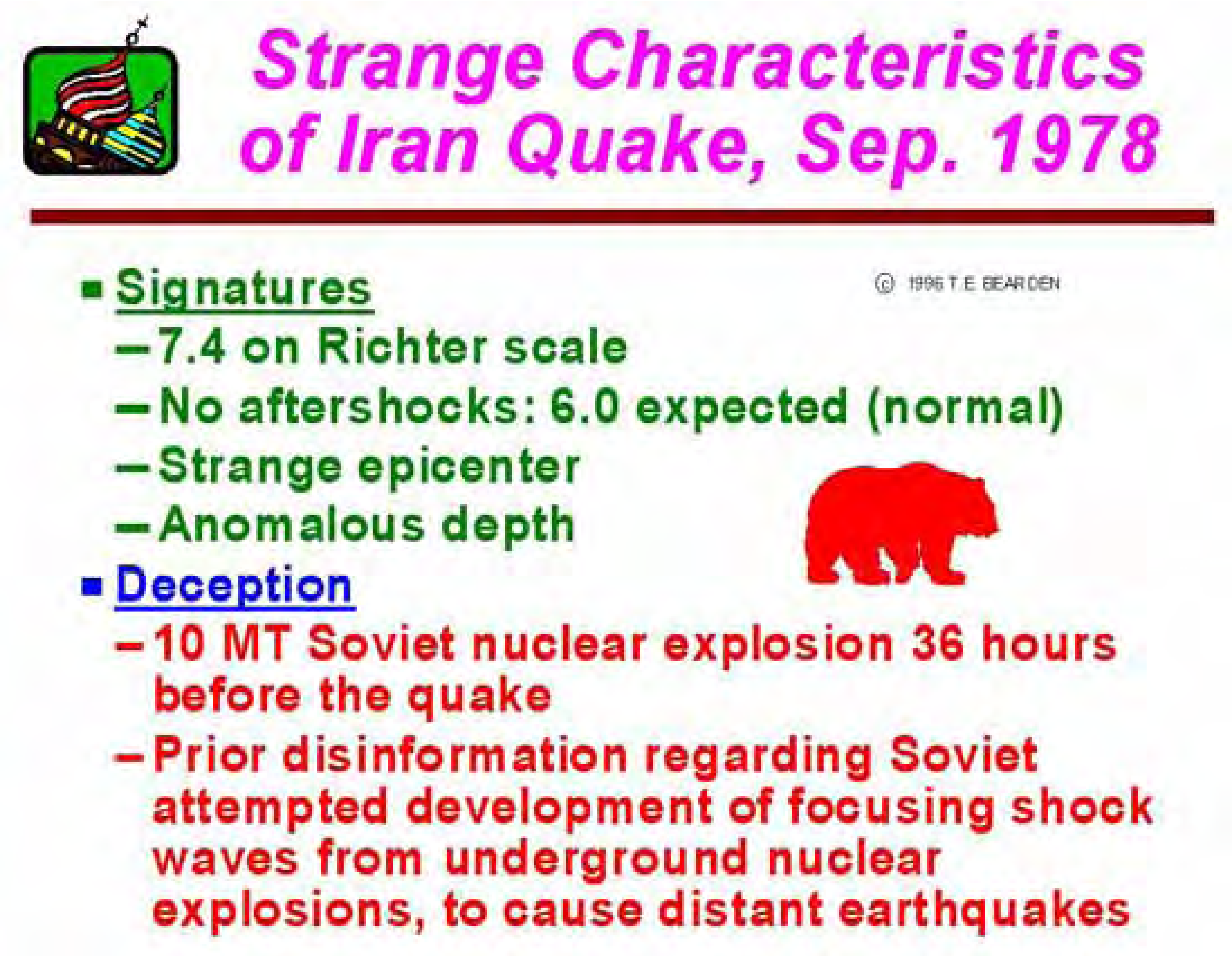

Strange Characteristics of Iran Quake, Sep. 1978

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- Signatures
  - 7.4 on Richter scale
  - No aftershocks: 6.0 expected (normal)
  - Strange epicenter
  - Anomalous depth
- Deception
  - 10 MT Soviet nuclear explosion 36 hours before the quake
  - Prior disinformation regarding Soviet attempted development of focusing shock waves from underground nuclear explosions, to cause distant earthquakes

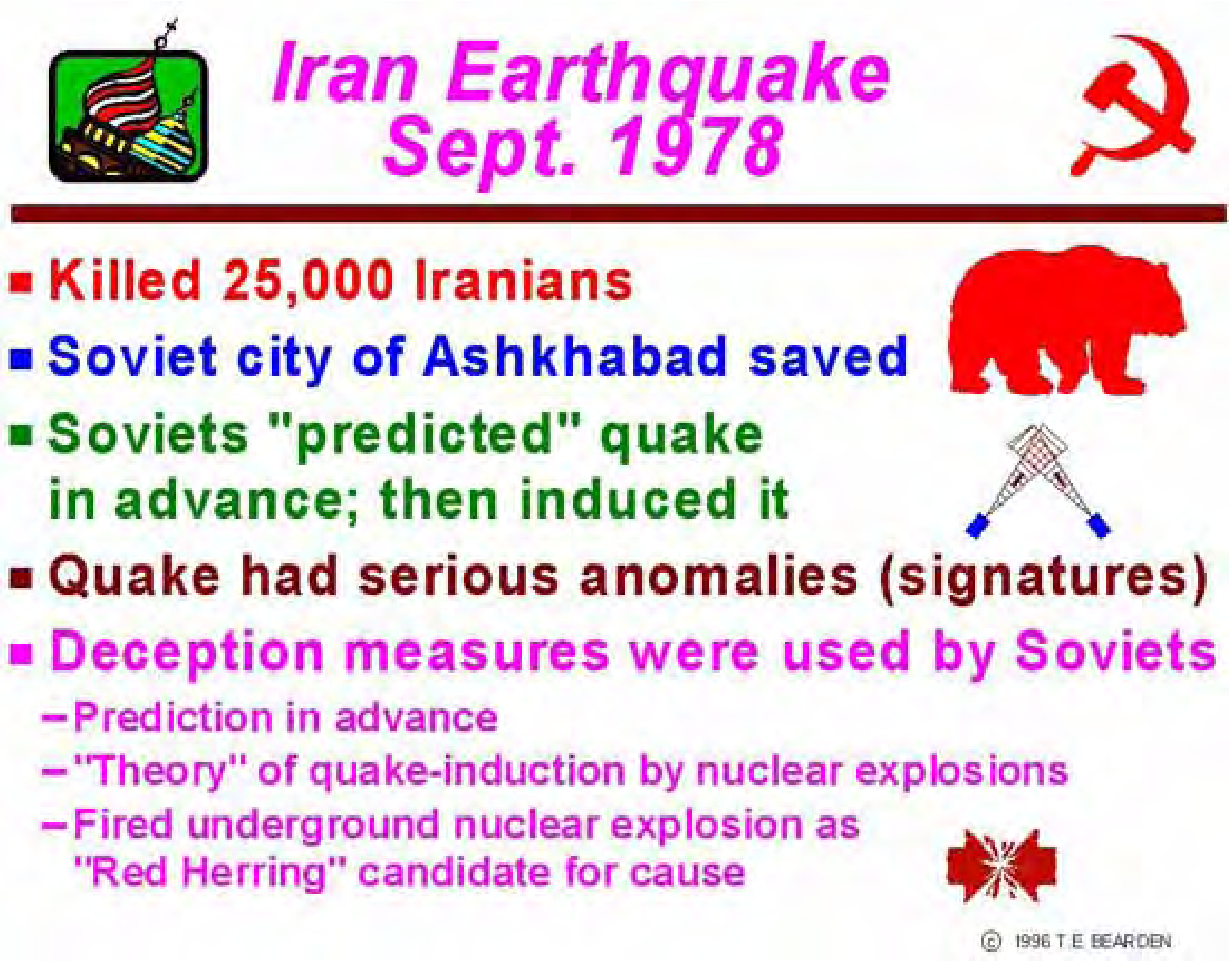

Iran Earthquake Sept. 1978

- Killed 25,000 Iranians
- Soviet city of Ashkhabad saved
- Soviets "predicted" quake in advance; then induced it
- Quake had serious anomalies (signatures)
- Deception measures were used by Soviets
  - Prediction in advance
  - "Theory" of quake-induction by nuclear explosions
  - Fired underground nuclear explosion as "Red Herring" candidate for cause

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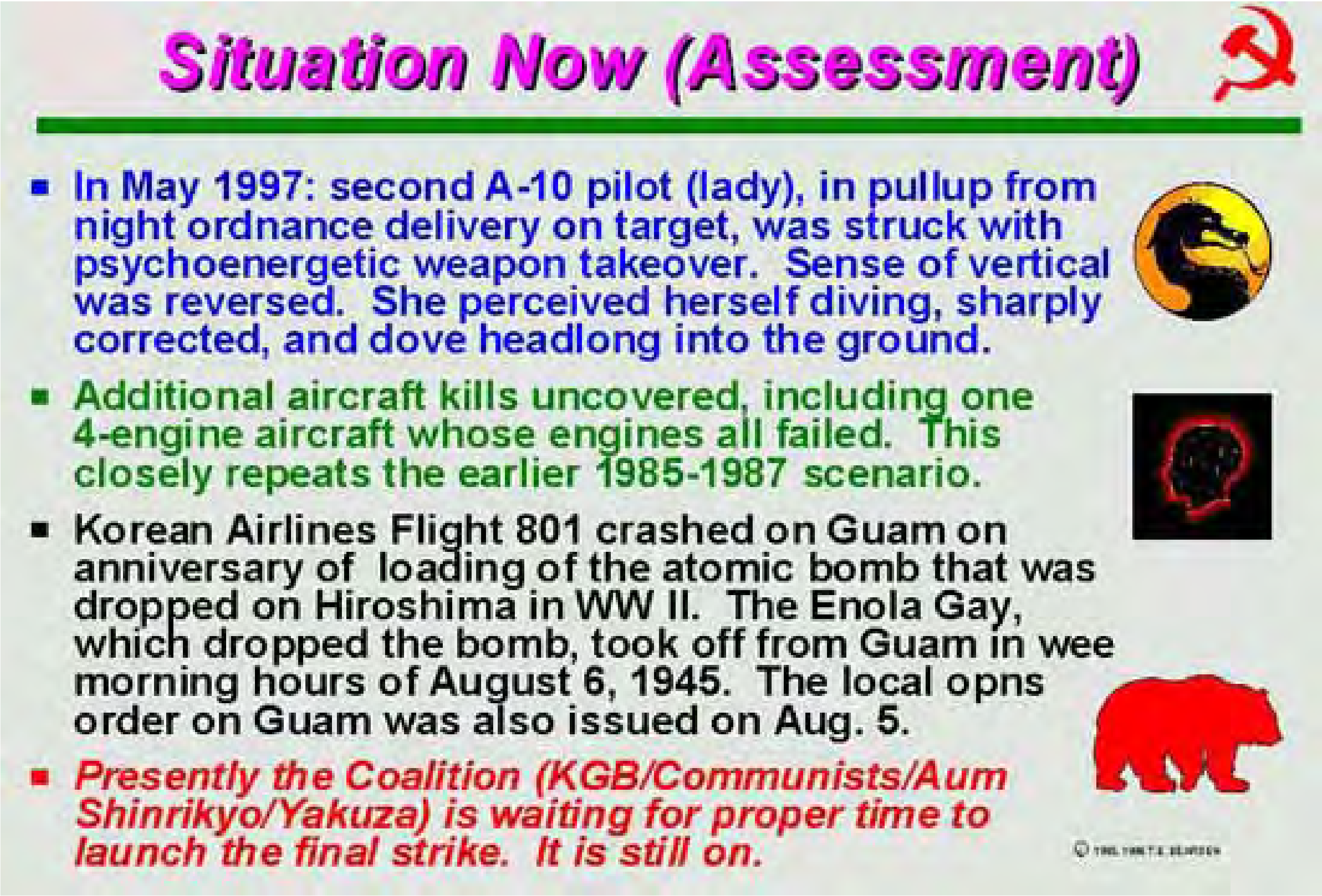

Situation Now (Assessment)

- In May 1997: second A-10 pilot (lady), in pullup from night ordnance delivery on target, was struck with psychoenergetic weapon takeover. Sense of vertical was reversed. She perceived herself diving, sharply corrected, and dove headlong into the ground.
- Additional aircraft kills uncovered, including one 4-engine aircraft whose engines all failed. This closely repeats the earlier 1985-1987 scenario.
- Korean Airlines Flight 801 crashed on Guam on anniversary of loading of the atomic bomb that was dropped on Hiroshima in WW II. The Enola Gay, which dropped the bomb, took off from Guam in wee morning hours of August 6, 1945. The local opns order on Guam was also issued on Aug. 5.
- *Presently the Coalition (KGB/Communists/Aum Shinrikyo/Yakuza) is waiting for proper time to launch the final strike. It is still on.*

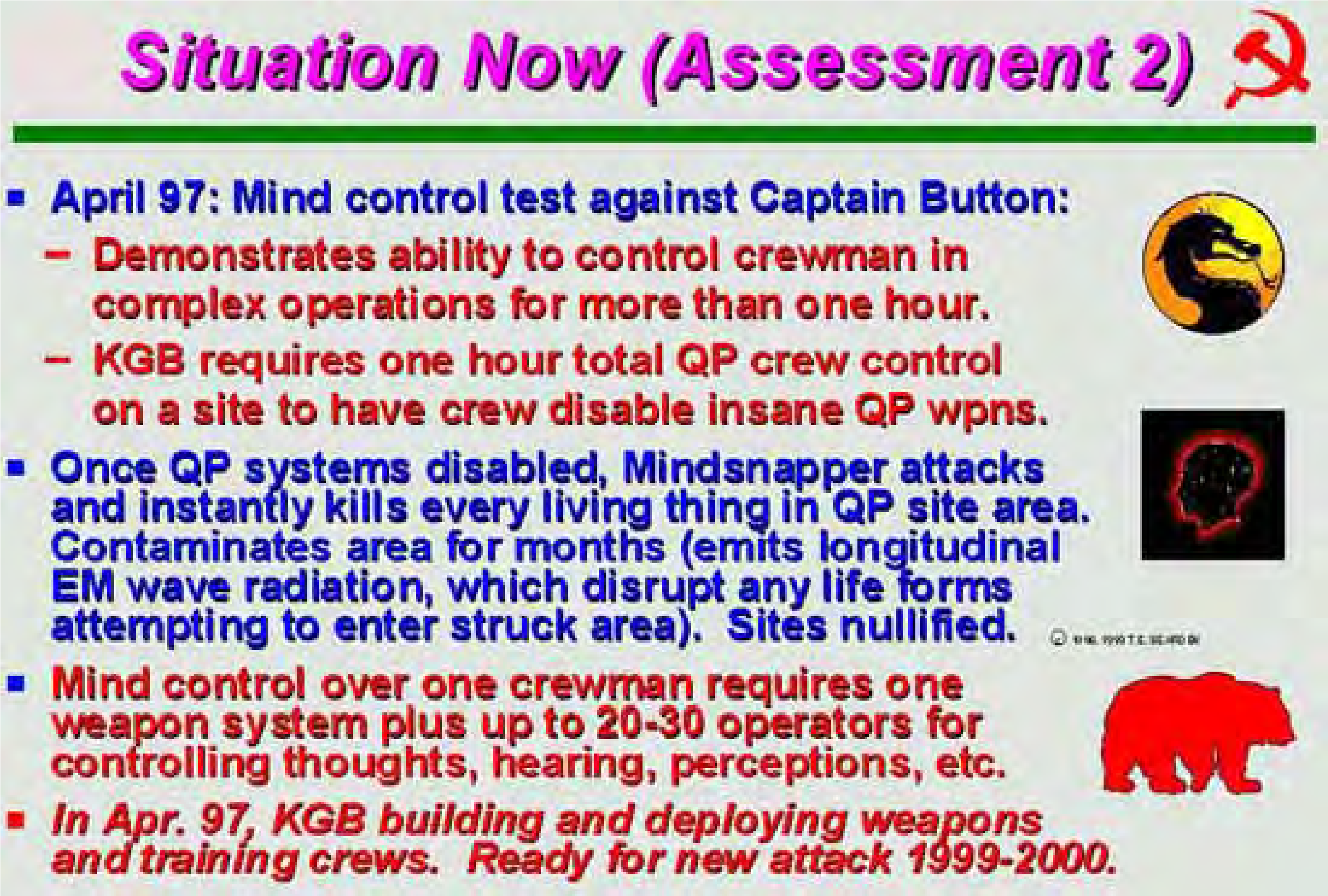

Situation Now (Assessment 2)

- April 97: Mind control test against Captain Button:
  - Demonstrates ability to control crewman in complex operations for more than one hour.
  - KGB requires one hour total QP crew control on a site to have crew disable insane QP wpns.
- Once QP systems disabled, Mindsnapper attacks and instantly kills every living thing in QP site area. Contaminates area for months (emits longitudinal EM wave radiation, which disrupt any life forms attempting to enter struck area). Sites nullified.
- Mind control over one crewman requires one weapon system plus up to 20-30 operators for controlling thoughts, hearing, perceptions, etc.
- *In Apr. 97, KGB building and deploying weapons and training crews. Ready for new attack 1999-2000.*

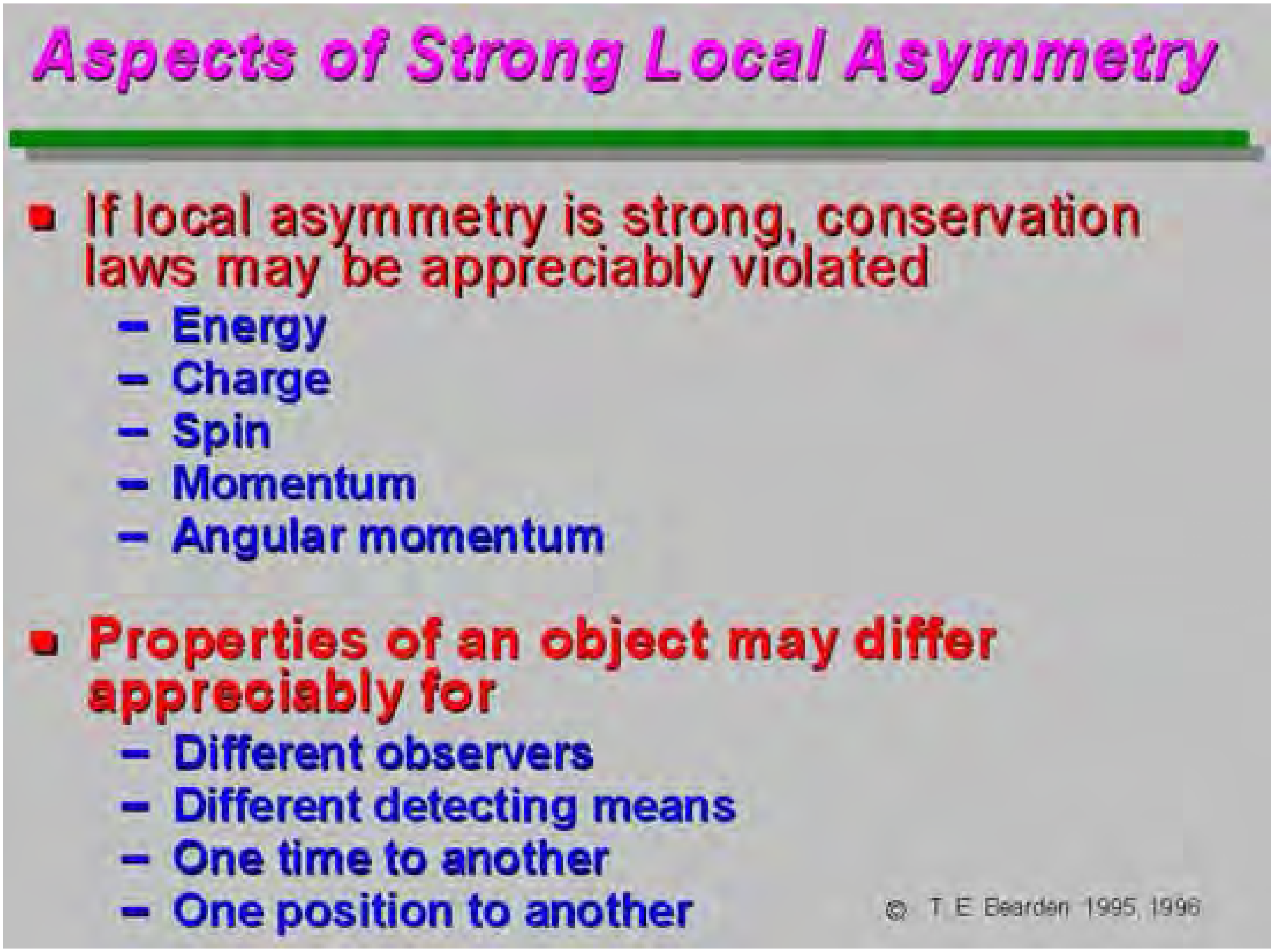

Aspects of Strong Local Asymmetry

- If local asymmetry is strong, conservation laws may be appreciably violated
  - Energy
  - Charge
  - Spin
  - Momentum
  - Angular momentum
- Properties of an object may differ appreciably for
  - Different observers
  - Different detecting means
  - One time to another
  - One position to another

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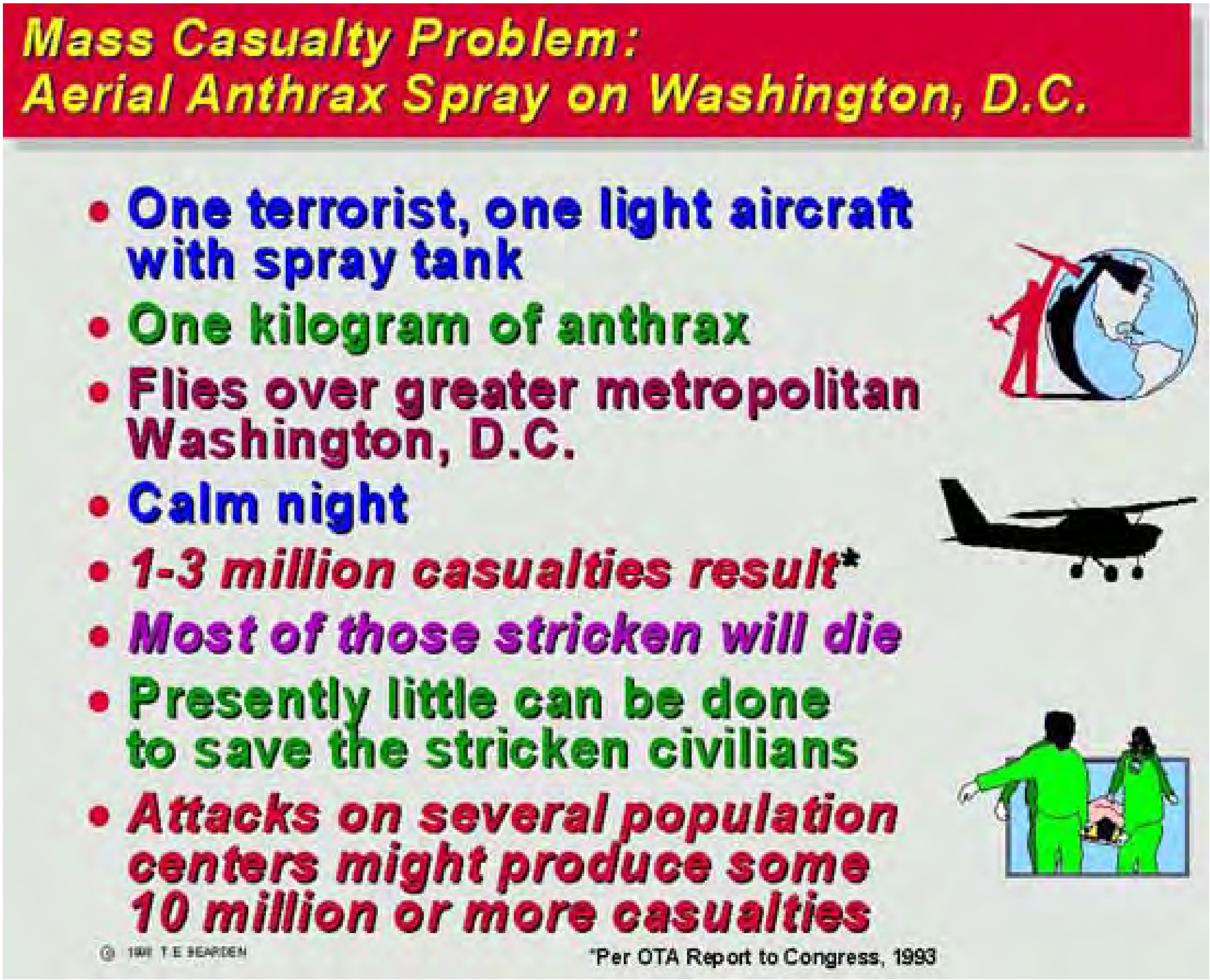

Mass Casualty Problem:
Aerial Anthrax Spray on Washington, D.C.

- One terrorist, one light aircraft with spray tank
- One kilogram of anthrax
- Flies over greater metropolitan Washington, D.C.
- Calm night
- *1-3 million casualties result**
- *Most of those stricken will die*
- Presently little can be done to save the stricken civilians
- *Attacks on several population centers might produce some 10 million or more casualties*

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*Per OTA Report to Congress, 1993

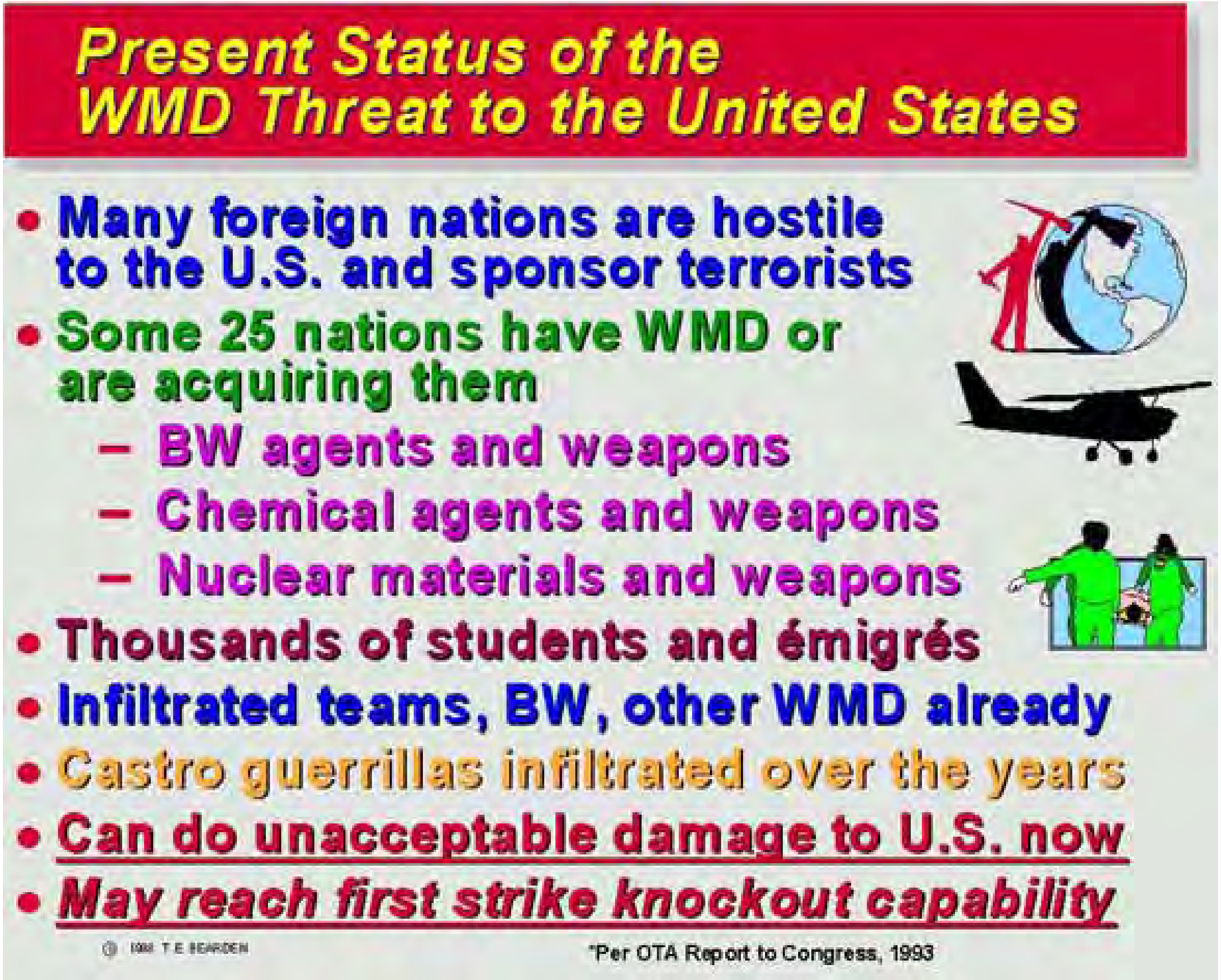

Present Status of the WMD Threat to the United States

- Many foreign nations are hostile to the U.S. and sponsor terrorists
- Some 25 nations have WMD or are acquiring them
  - BW agents and weapons
  - Chemical agents and weapons
  - Nuclear materials and weapons
- Thousands of students and émigrés
- Infiltrated teams, BW, other WMD already
- Castro guerrillas infiltrated over the years
- Can do unacceptable damage to U.S. now
- ***May reach first strike knockout capability***

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*Per OTA Report to Congress, 1993

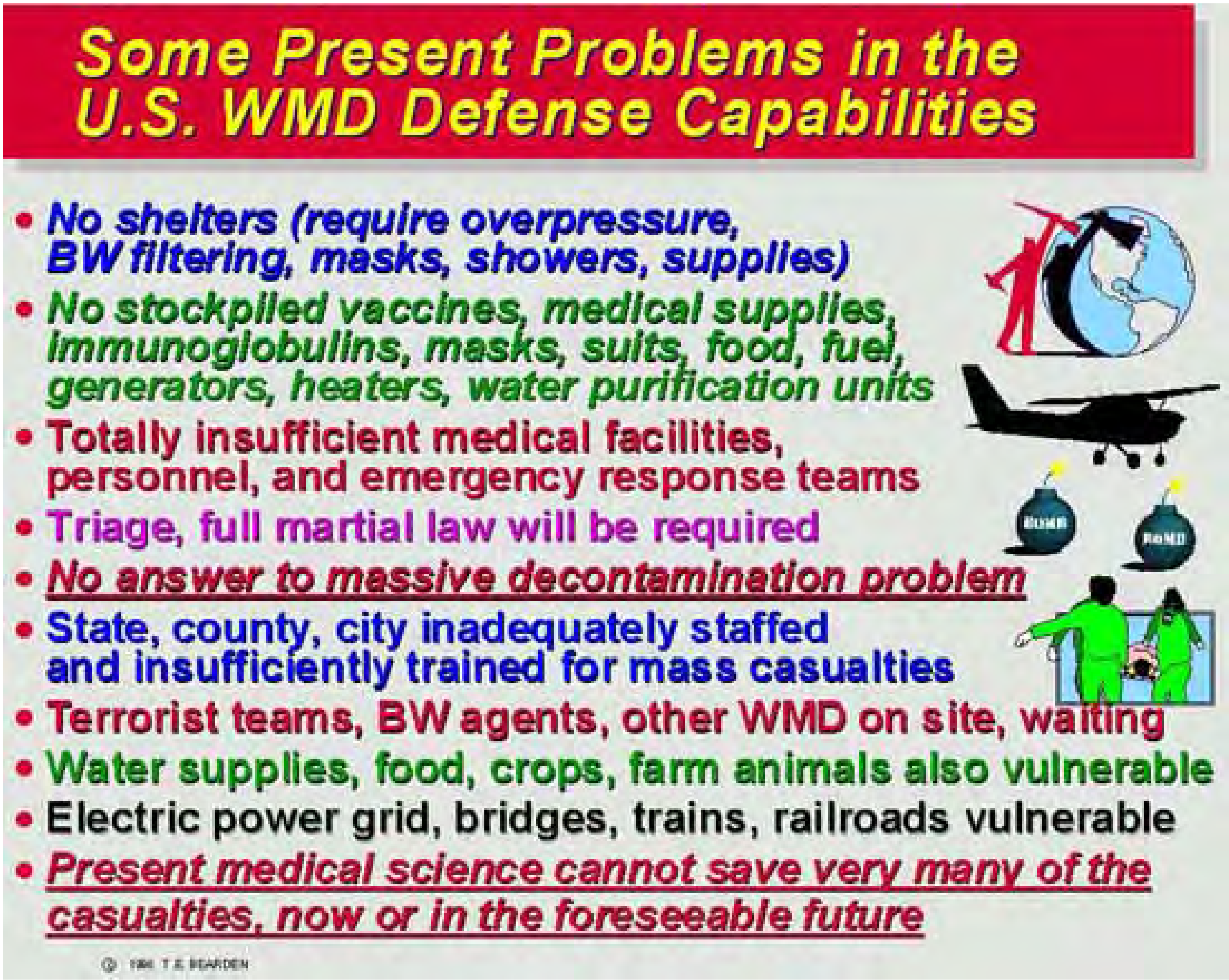

Some Present Problems in the U.S. WMD Defense Capabilities

- *No shelters (require overpressure, BW filtering, masks, showers, supplies)*
- *No stockpiled vaccines, medical supplies, immunoglobulins, masks, suits, food, fuel, generators, heaters, water purification units*
- Totally insufficient medical facilities, personnel, and emergency response teams
- Triage, full martial law will be required
- *No answer to massive decontamination problem*
- State, county, city inadequately staffed and insufficiently trained for mass casualties
- Terrorist teams, BW agents, other WMD on site, waiting
- Water supplies, food, crops, farm animals also vulnerable
- Electric power grid, bridges, trains, railroads vulnerable
- *Present medical science cannot save very many of the casualties, now or in the foreseeable future*

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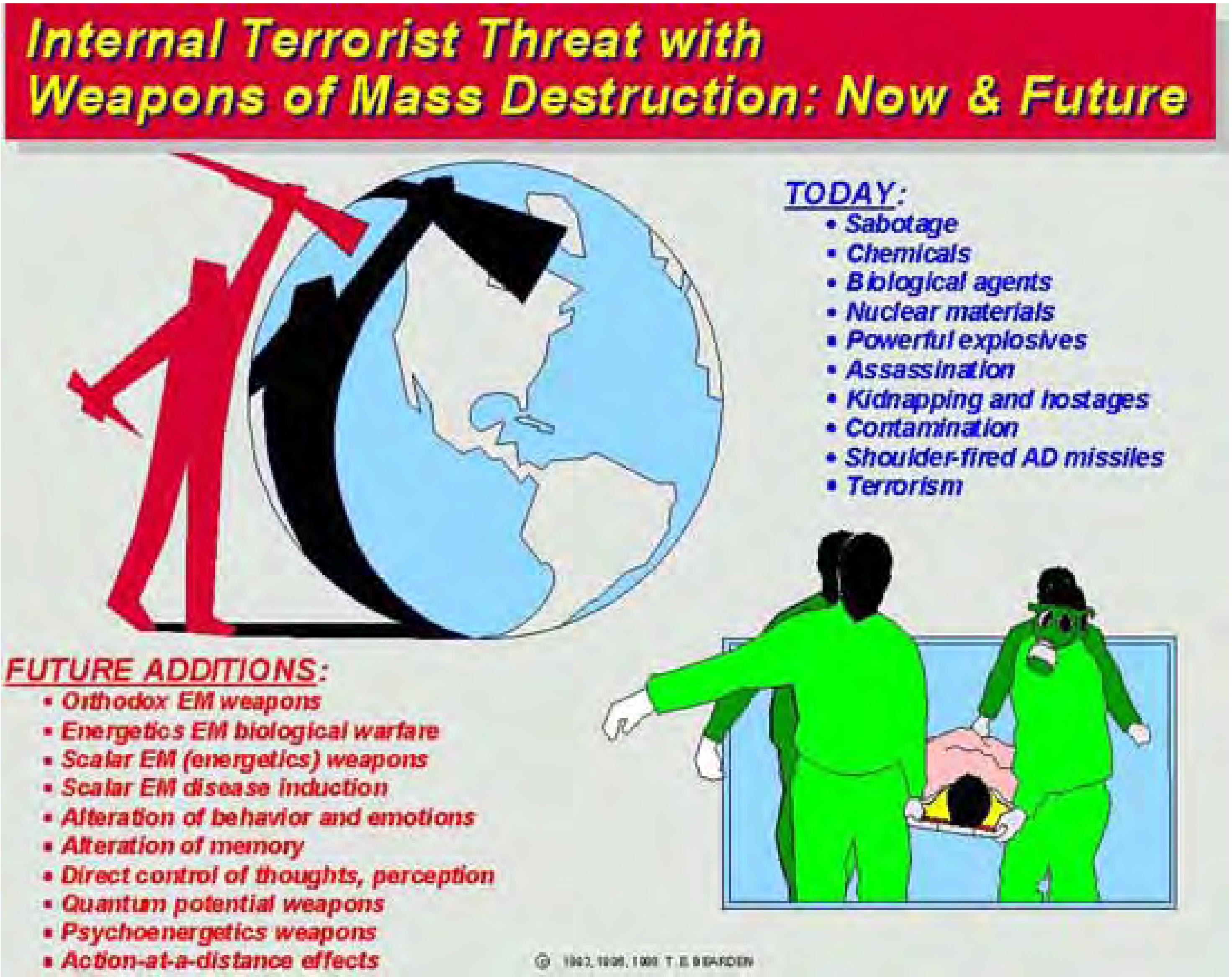

Internal Terrorist Threat with Weapons of Mass Destruction: Now & Future

TODAY:
- Sabotage
- Chemicals
- Biological agents
- Nuclear materials
- Powerful explosives
- Assassination
- Kidnapping and hostages
- Contamination
- Shoulder-fired AD missiles
- Terrorism

FUTURE ADDITIONS:
- Orthodox EM weapons
- Energetics EM biological warfare
- Scalar EM (energetics) weapons
- Scalar EM disease induction
- Alteration of behavior and emotions
- Alteration of memory
- Direct control of thoughts, perception
- Quantum potential weapons
- Psychoenergetics weapons
- Action-at-a-distance effects

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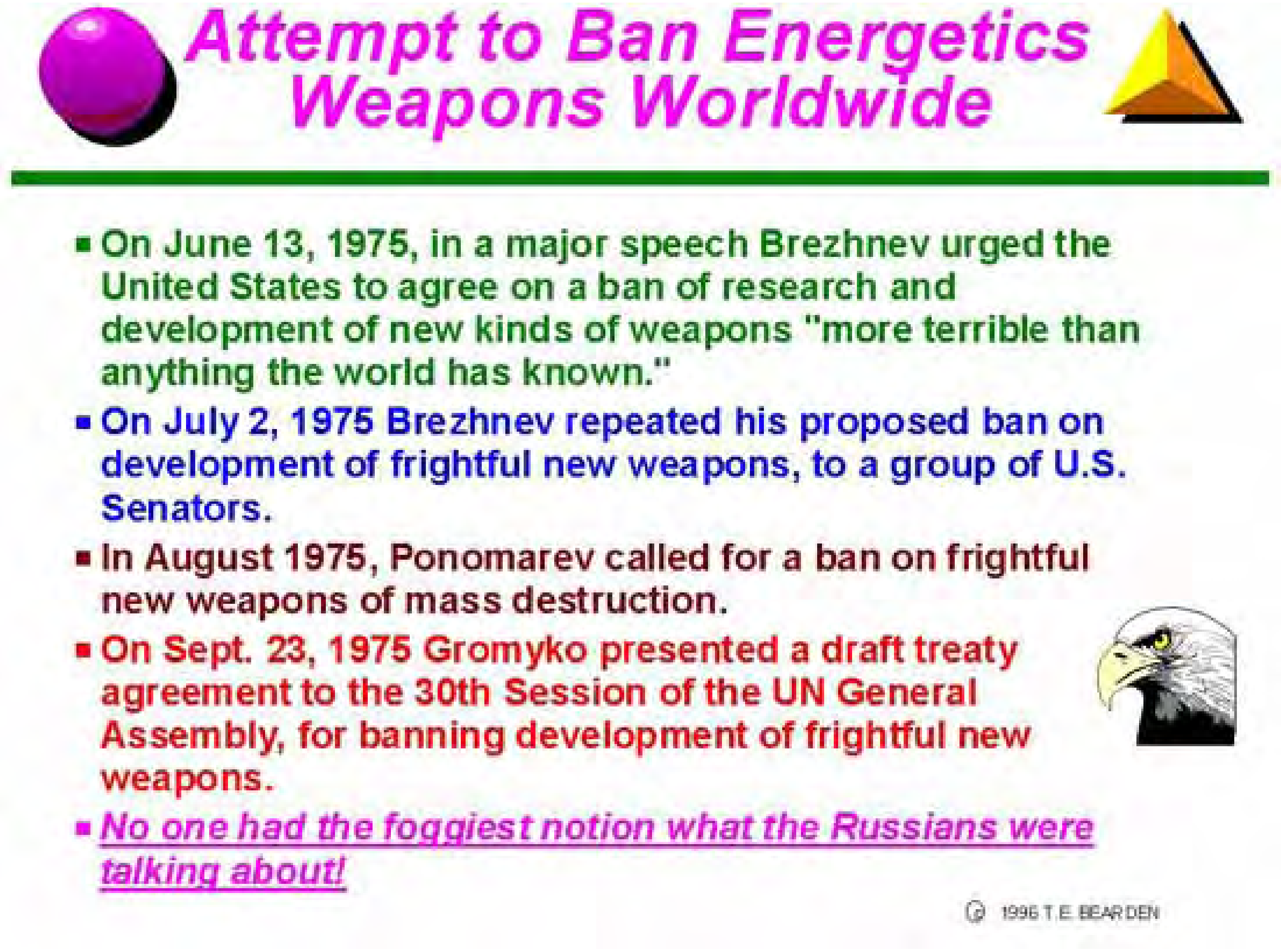

Attempt to Ban Energetics Weapons Worldwide

- On June 13, 1975, in a major speech Brezhnev urged the United States to agree on a ban of research and development of new kinds of weapons "more terrible than anything the world has known."
- On July 2, 1975 Brezhnev repeated his proposed ban on development of frightful new weapons, to a group of U.S. Senators.
- In August 1975, Ponomarev called for a ban on frightful new weapons of mass destruction.
- On Sept. 23, 1975 Gromyko presented a draft treaty agreement to the 30th Session of the UN General Assembly, for banning development of frightful new weapons.
- *No one had the foggiest notion what the Russians were talking about!*

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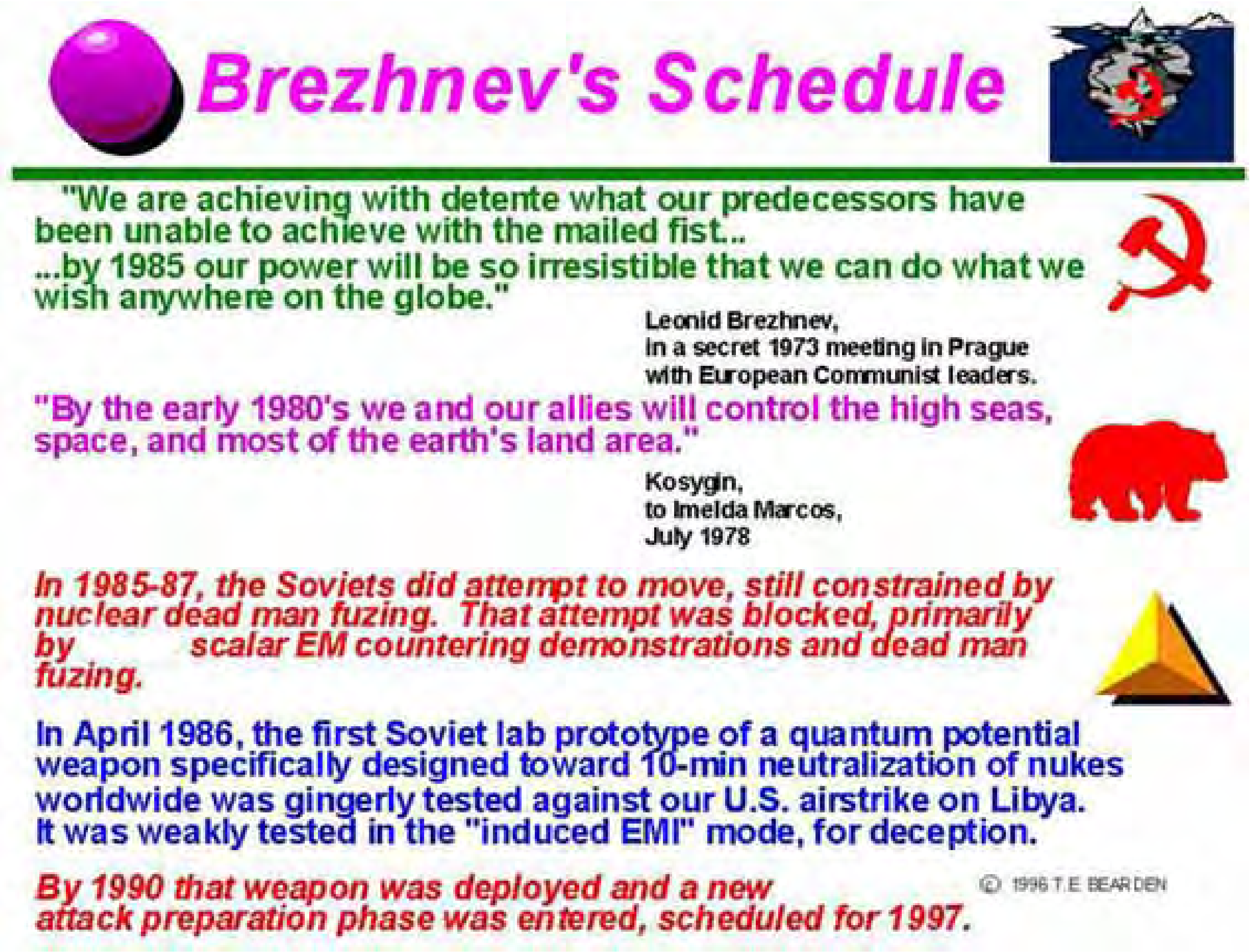

Brezhnev's Schedule

"We are achieving with detente what our predecessors have been unable to achieve with the mailed fist..
...by 1985 our power will be so irresistible that we can do what we wish anywhere on the globe."

Leonid Brezhnev,
In a secret 1973 meeting in Prague
with European Communist leaders.

"By the early 1980's we and our allies will control the high seas, space, and most of the earth's land area."

Kosygin,
to Imelda Marcos,
July 1978

In 1985-87, the Soviets did attempt to move, still constrained by nuclear dead man fuzing. That attempt was blocked, primarily by scalar EM countering demonstrations and dead man fuzing.

In April 1986, the first Soviet lab prototype of a quantum potential weapon specifically designed toward 10-min neutralization of nukes worldwide was gingerly tested against our U.S. airstrike on Libya. It was weakly tested in the "induced EMI" mode, for deception.

By 1990 that weapon was deployed and a new attack preparation phase was entered, scheduled for 1997.

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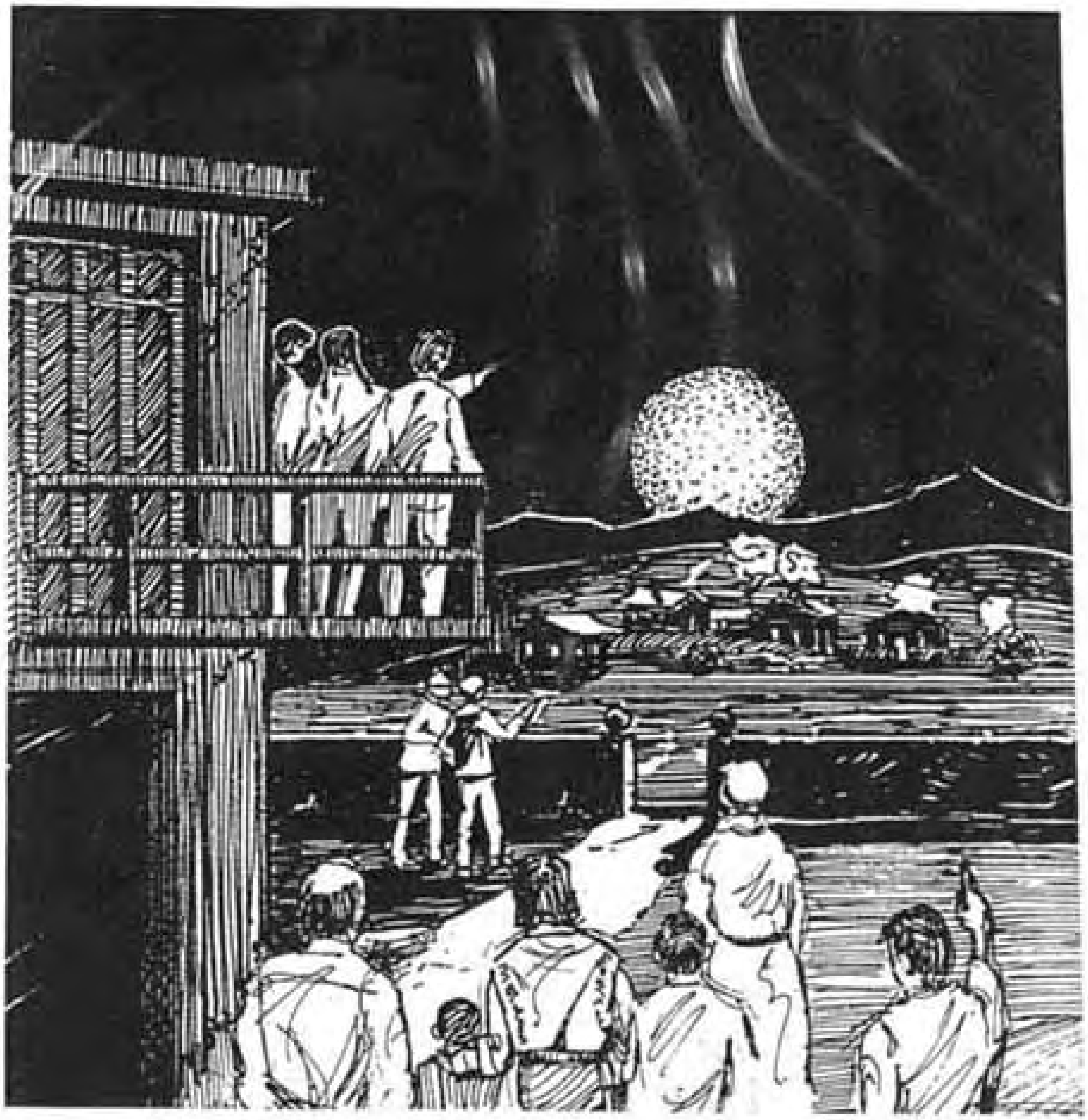

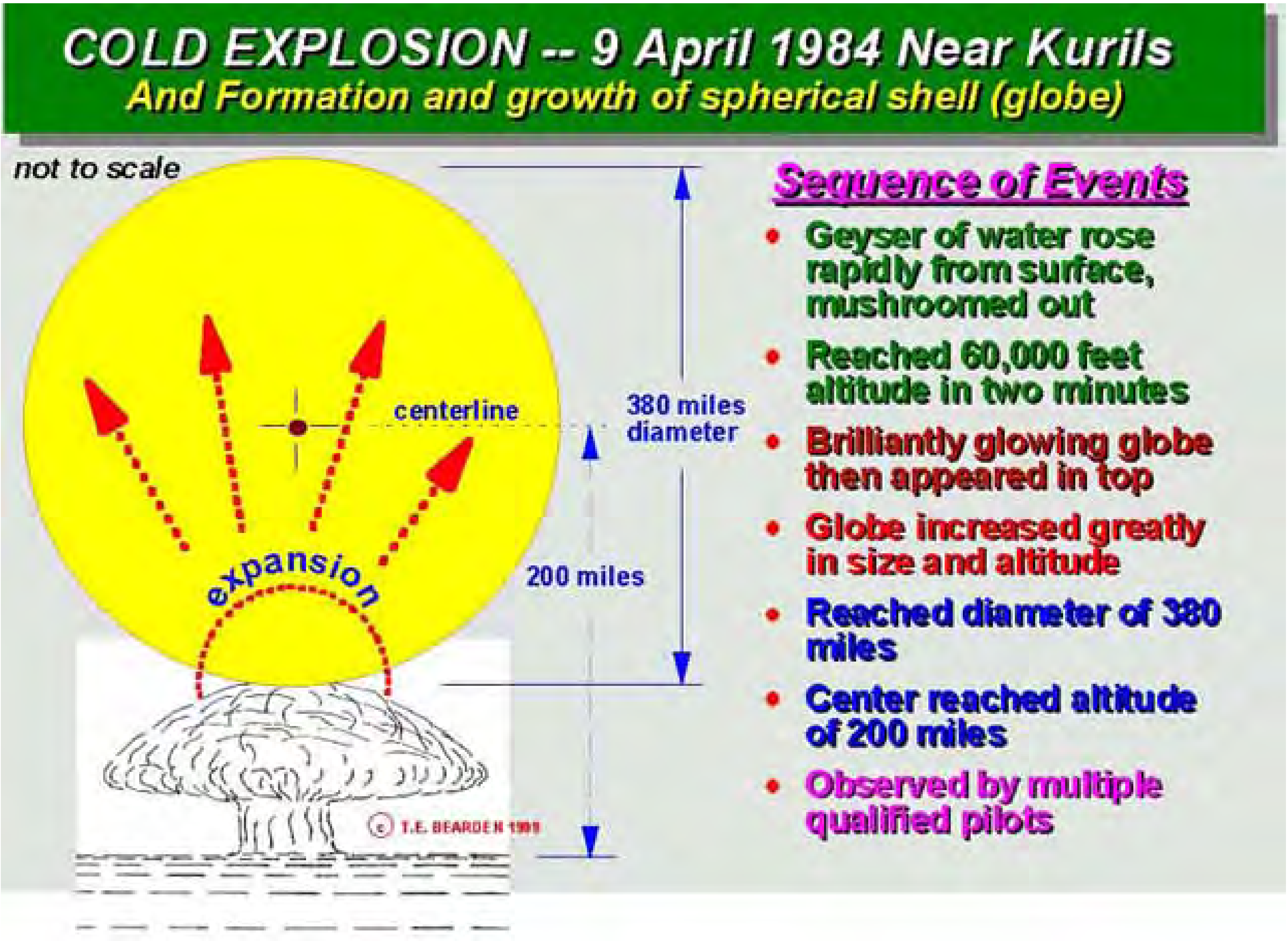

COLD EXPLOSION -- 9 April 1984 Near Kurils
And Formation and growth of spherical shell (globe)

not to scale
centerline
380 miles diameter
200 miles
expansion
© T.E. BEARDEN 199[illegible]

Sequence of Events

- Geyser of water rose rapidly from surface, mushroomed out
- Reached 60,000 feet altitude in two minutes
- Brilliantly glowing globe then appeared in top
- Globe increased greatly in size and altitude
- Reached diameter of 380 miles
- Center reached altitude of 200 miles
- Observed by multiple qualified pilots

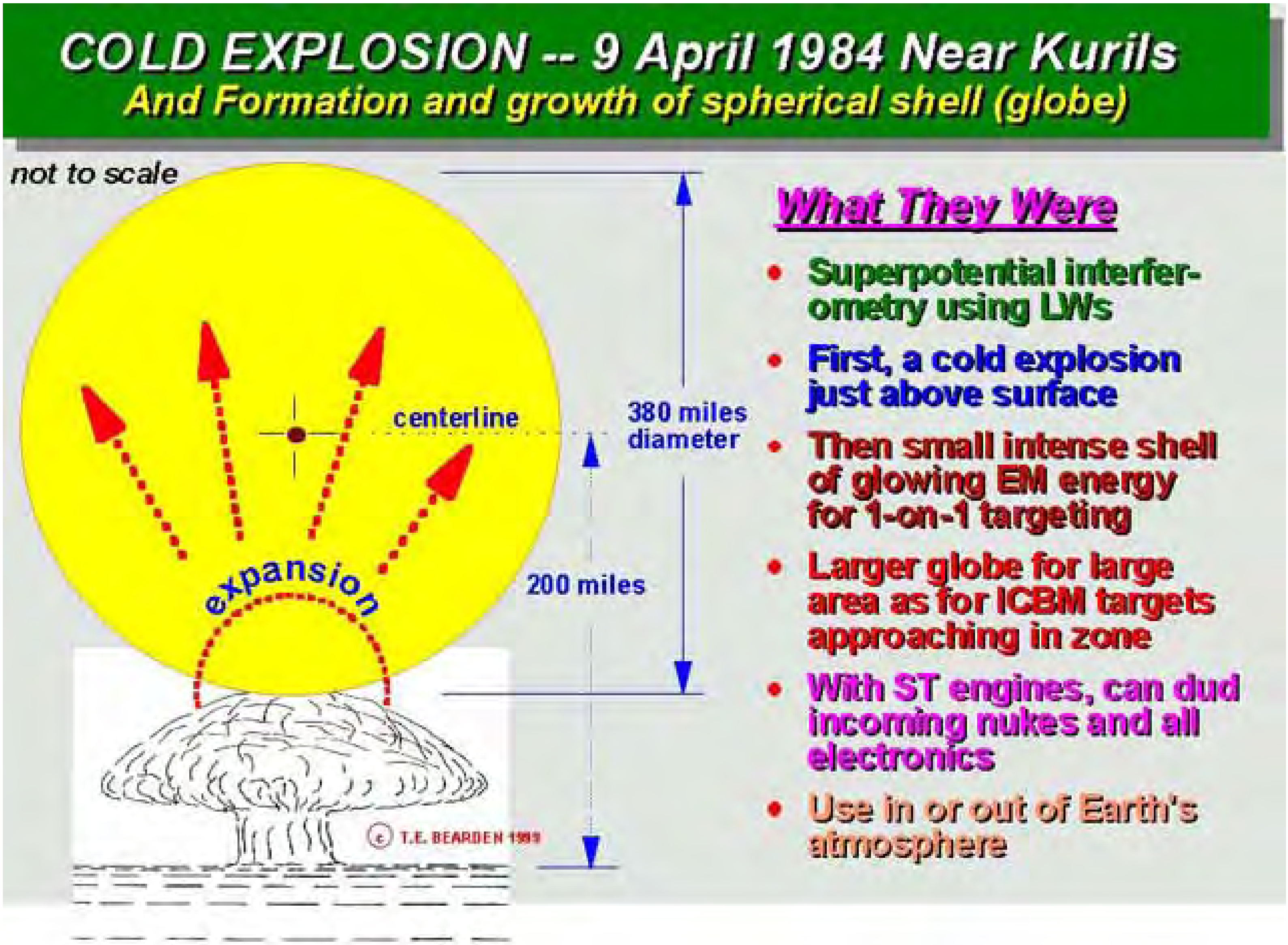

COLD EXPLOSION -- 9 April 1984 Near Kurils

And Formation and growth of spherical shell (globe)

not to scale
centerline
380 miles
diameter
200 miles
expansion
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What They Were

- Superpotential interferometry using LWs
- First, a cold explosion just above surface
- Then small intense shell of glowing EM energy for 1-on-1 targeting
- Larger globe for large area as for ICBM targets approaching in zone
- With ST engines, can dud incoming nukes and all electronics
- Use in or out of Earth's atmosphere

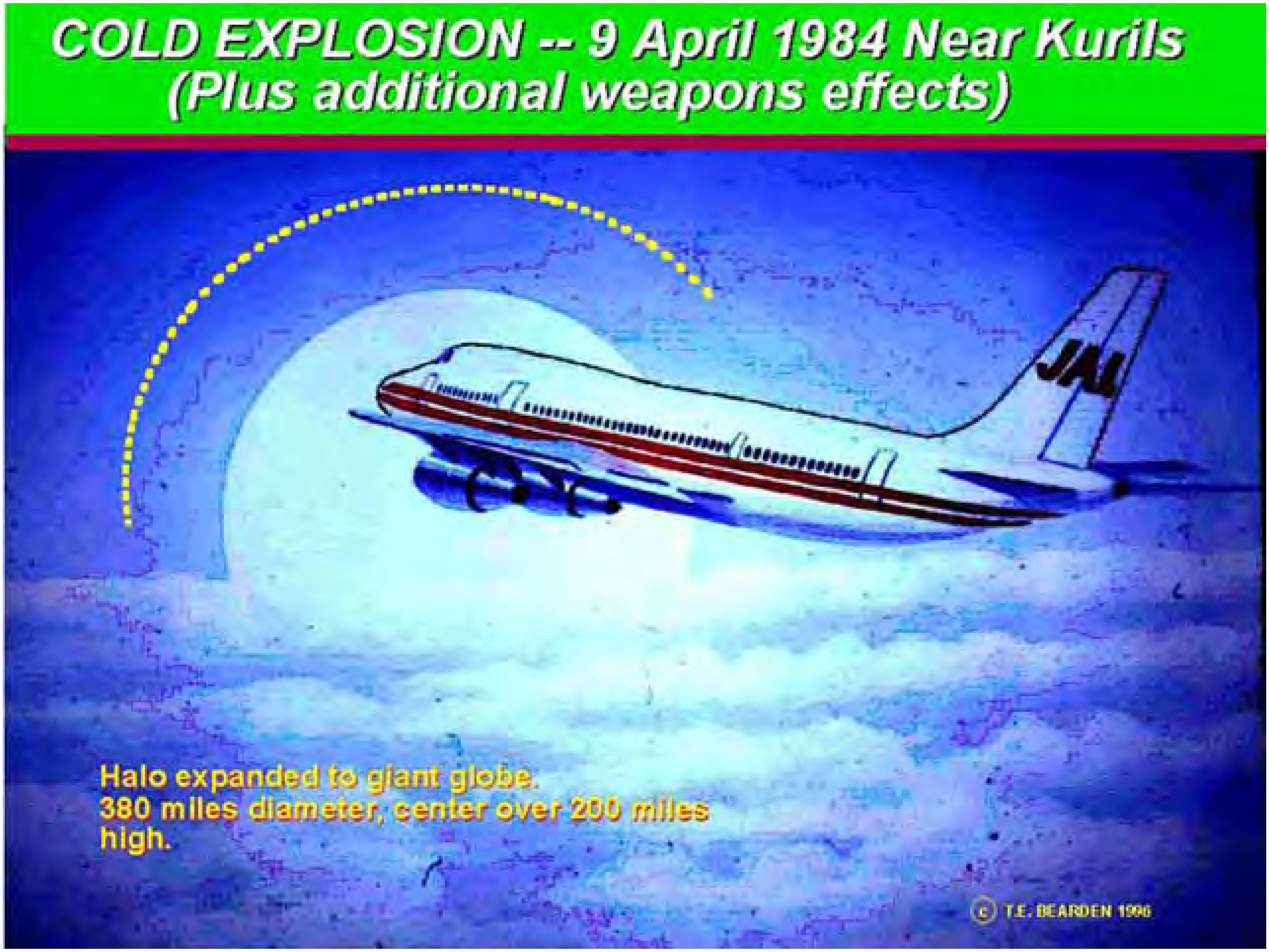

COLD EXPLOSION -- 9 April 1984 Near Kurils
(Plus additional weapons effects)

Halo expanded to giant globe.
380 miles diameter, center over 200 miles high.

© T.E. BEARDEN 1996

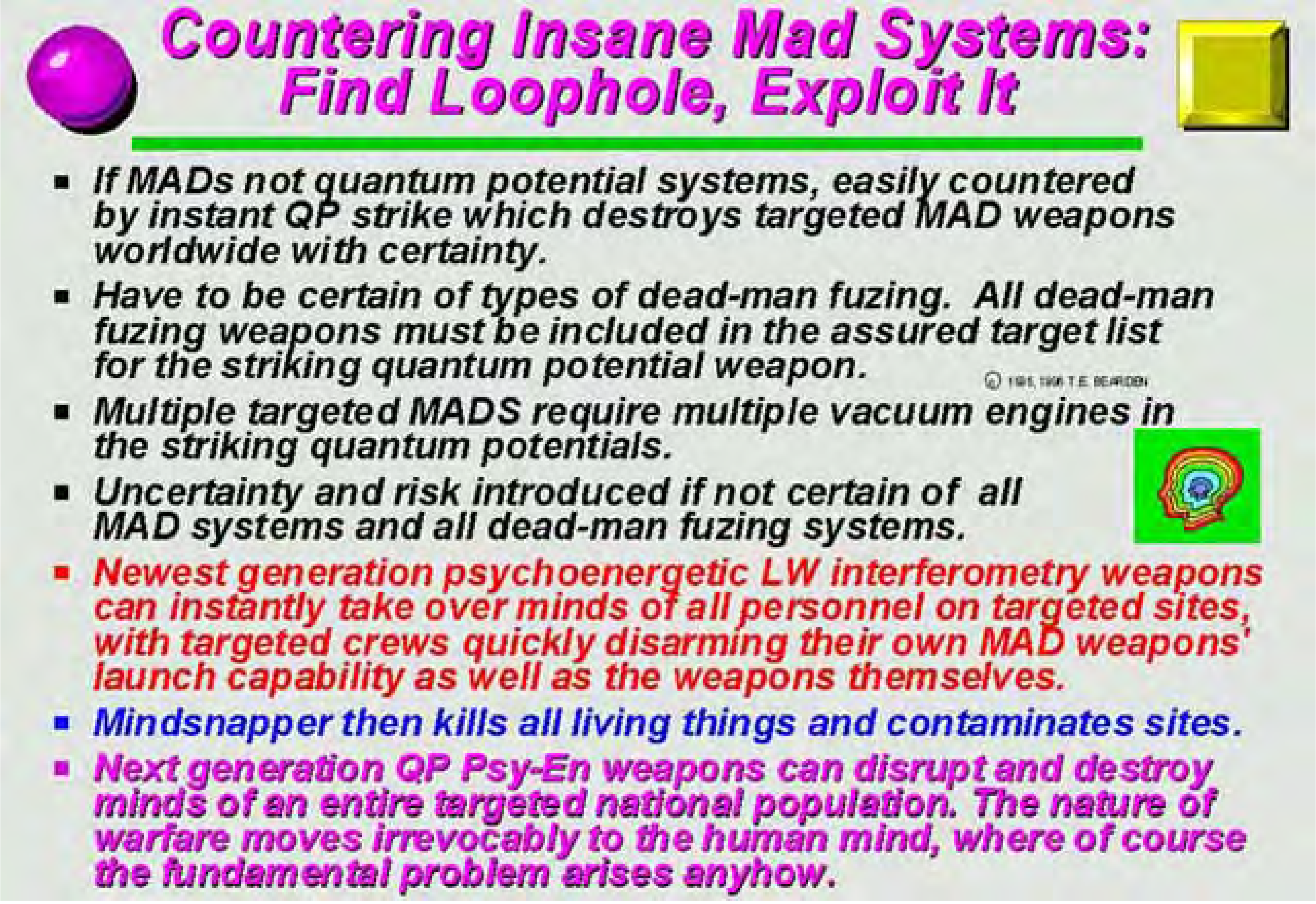

Countering Insane Mad Systems: Find Loophole, Exploit It

- *If MADs not quantum potential systems, easily countered by instant QP strike which destroys targeted MAD weapons worldwide with certainty.*
- *Have to be certain of types of dead-man fuzing. All dead-man fuzing weapons must be included in the assured target list for the striking quantum potential weapon.*

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- *Multiple targeted MADS require multiple vacuum engines in the striking quantum potentials.*
- *Uncertainty and risk introduced if not certain of all MAD systems and all dead-man fuzing systems.*
- *Newest generation psychoenergetic LW interferometry weapons can instantly take over minds of all personnel on targeted sites, with targeted crews quickly disarming their own MAD weapons' launch capability as well as the weapons themselves.*
- *Mindsnapper then kills all living things and contaminates sites.*
- *Next generation QP Psy-En weapons can disrupt and destroy minds of an entire targeted national population. The nature of warfare moves irrevocably to the human mind, where of course the fundamental problem arises anyhow.*

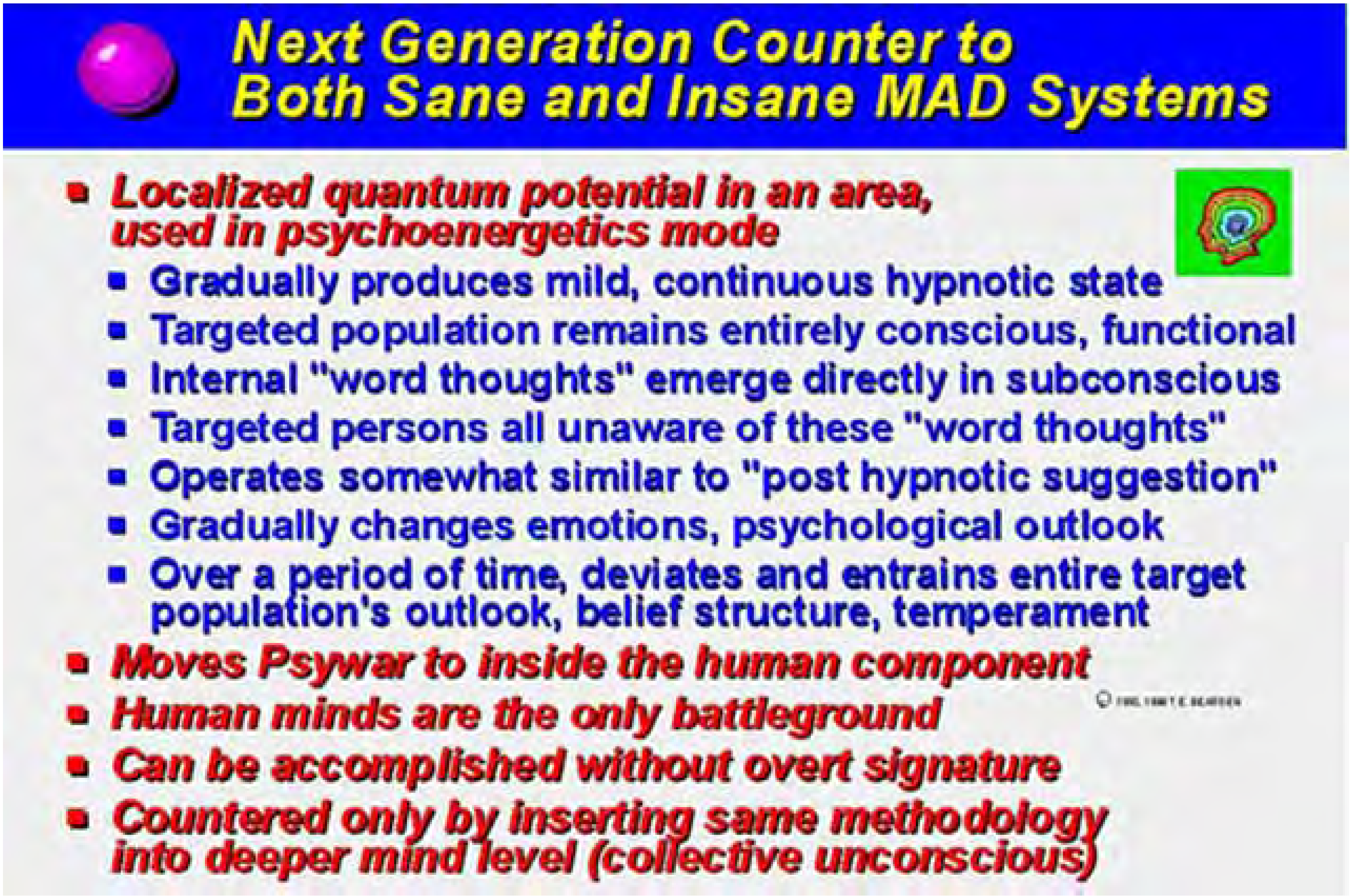

Next Generation Counter to Both Sane and Insane MAD Systems

- ***Localized quantum potential in an area, used in psychoenergetics mode***
  - **Gradually produces mild, continuous hypnotic state**
  - **Targeted population remains entirely conscious, functional**
  - **Internal "word thoughts" emerge directly in subconscious**
  - **Targeted persons all unaware of these "word thoughts"**
  - **Operates somewhat similar to "post hypnotic suggestion"**
  - **Gradually changes emotions, psychological outlook**
  - **Over a period of time, deviates and entrains entire target population's outlook, belief structure, temperament**
- ***Moves Psywar to inside the human component***
- ***Human minds are the only battleground***
- ***Can be accomplished without overt signature***
- ***Countered only by inserting same methodology into deeper mind level (collective unconscious)***

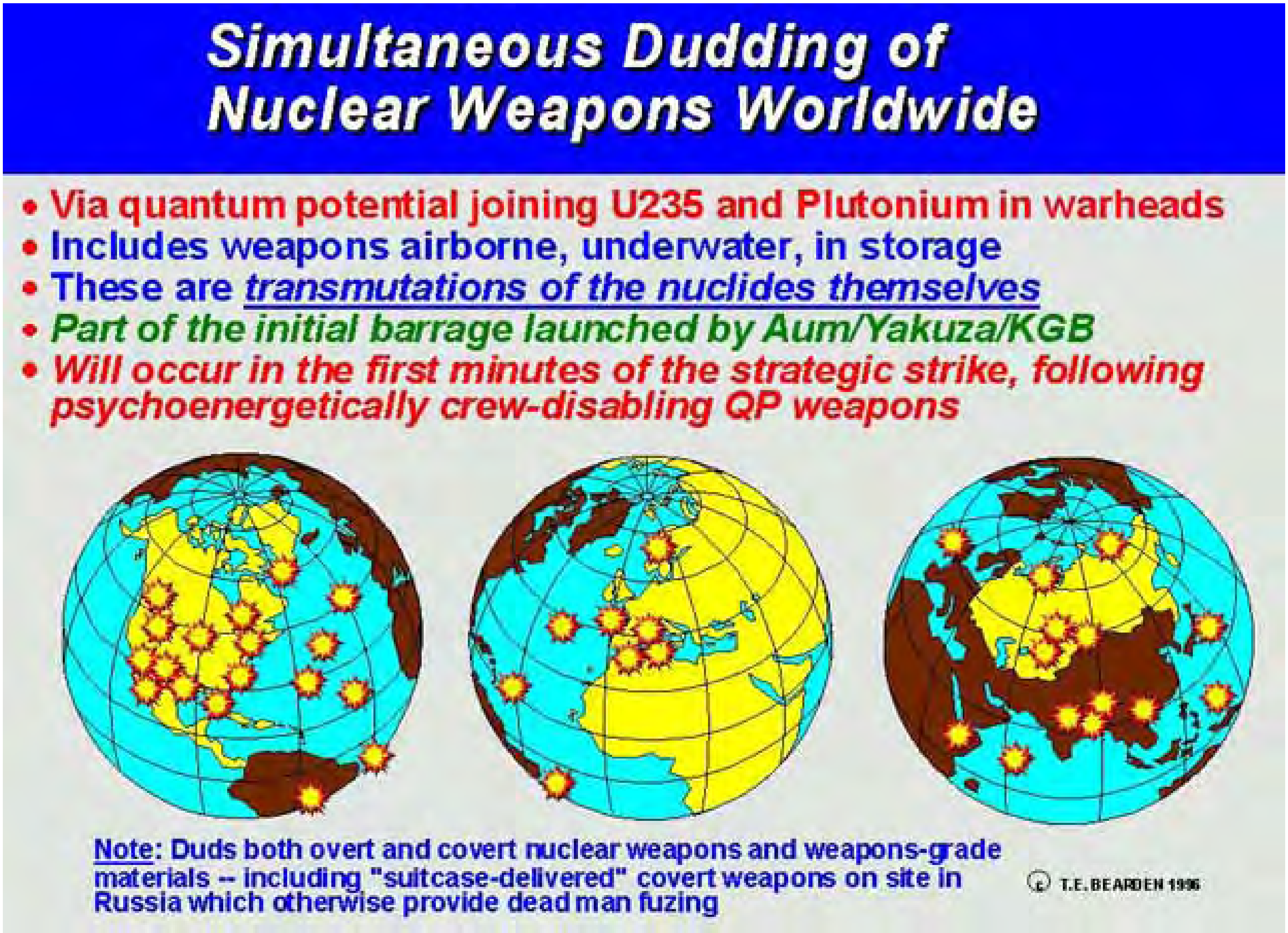

Simultaneous Dudding of Nuclear Weapons Worldwide

- Via quantum potential joining U235 and Plutonium in warheads
- Includes weapons airborne, underwater, in storage
- These are *transmutations of the nuclides themselves*
- *Part of the initial barrage launched by Aum/Yakuza/KGB*
- *Will occur in the first minutes of the strategic strike, following psychoenergetically crew-disabling QP weapons*

Note: Duds both overt and covert nuclear weapons and weapons-grade materials -- including "suitcase-delivered" covert weapons on site in Russia which otherwise provide dead man fuzing

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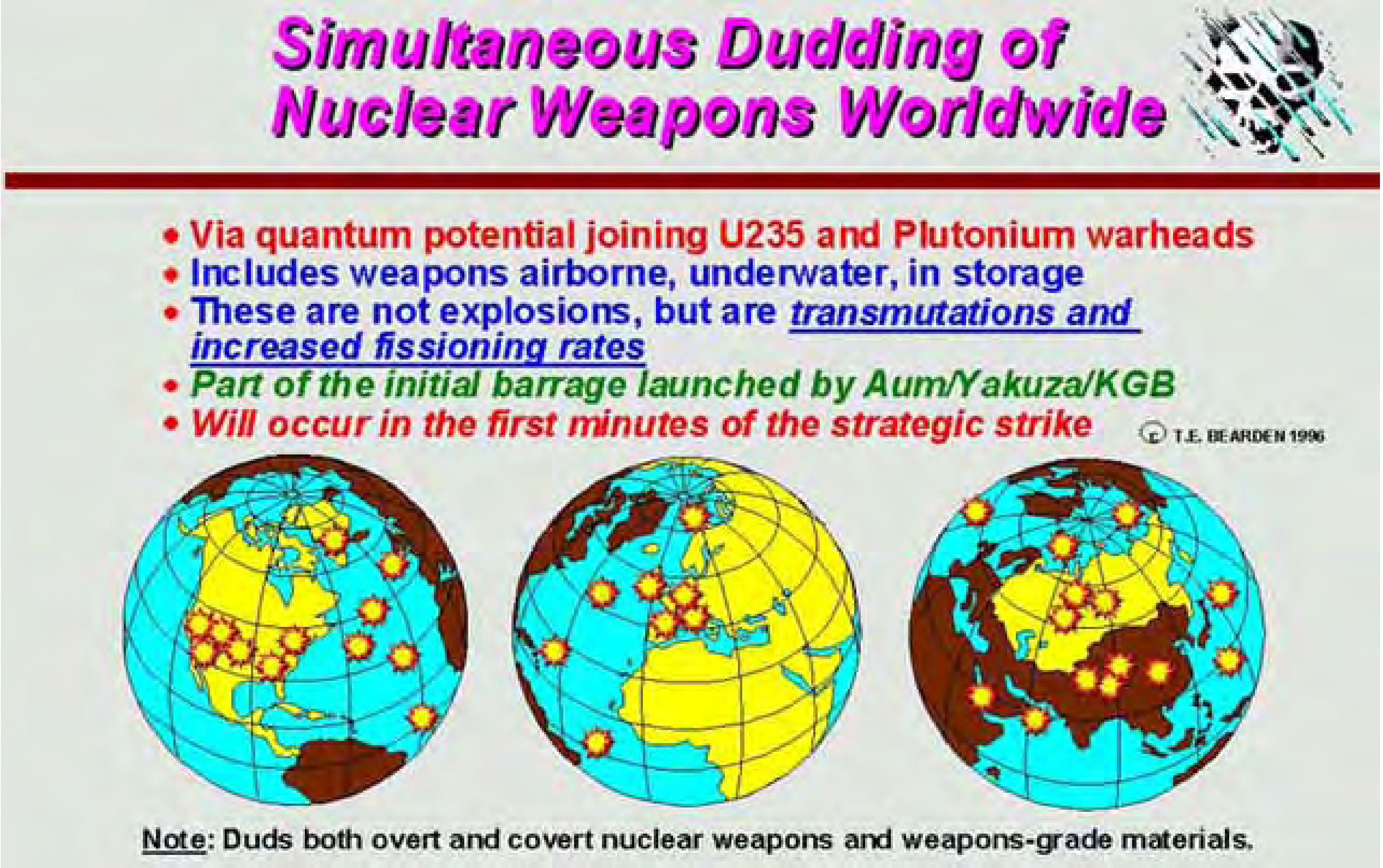

Simultaneous Dudding of Nuclear Weapons Worldwide

- Via quantum potential joining U235 and Plutonium warheads
- Includes weapons airborne, underwater, in storage
- These are not explosions, but are *transmutations and increased fissioning rates*
- *Part of the initial barrage launched by Aum/Yakuza/KGB*
- *Will occur in the first minutes of the strategic strike*

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Note: Duds both overt and covert nuclear weapons and weapons-grade materials.

Operation Divine Wind II

[Slide 1](#)

[Slide 2](#)

[Slide 3](#)

[Slide 4](#)

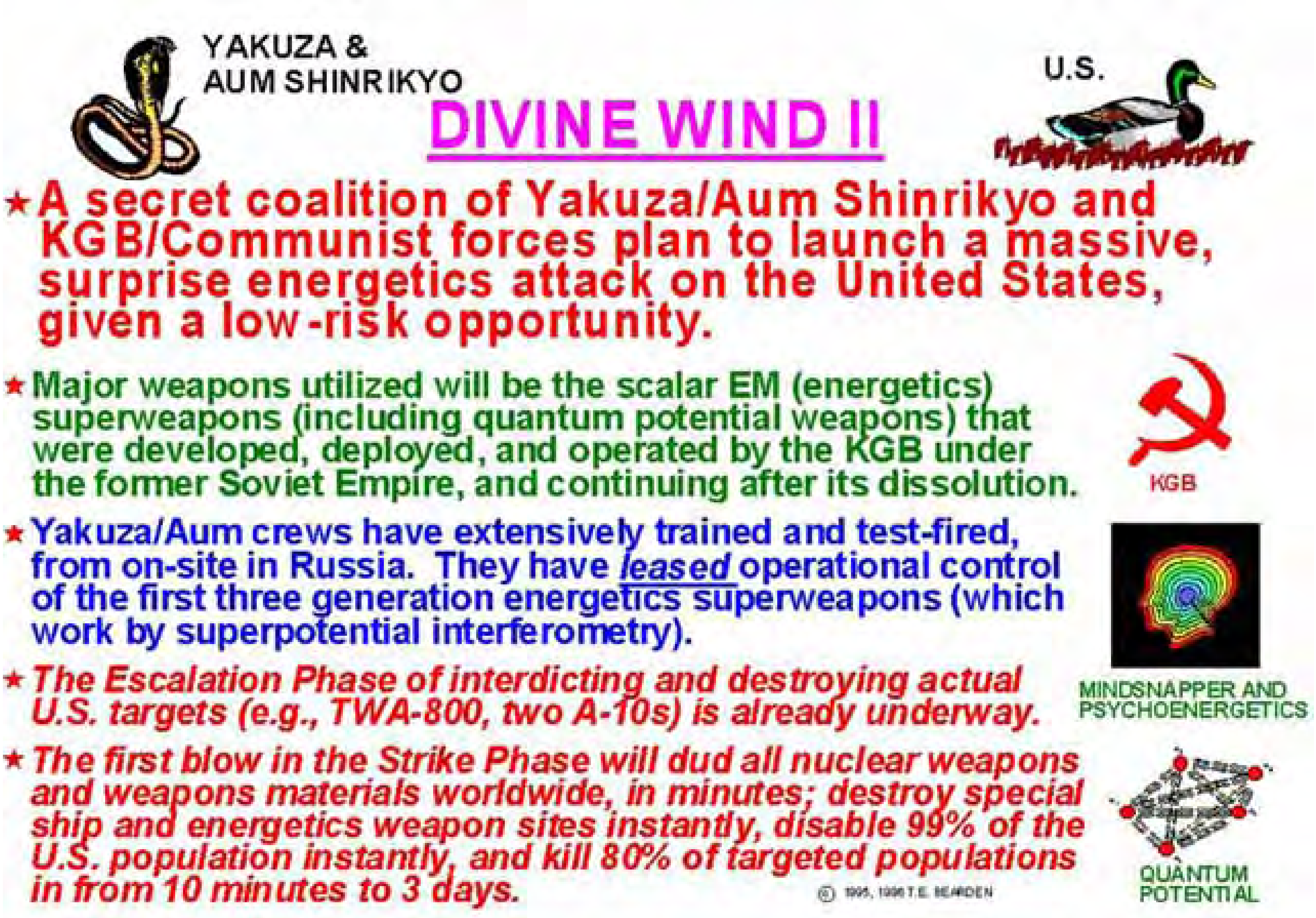
YAKUZA &
AUM SHINRIKYO
U.S.
KGB
MINDSNAPPER AND
PSYCHOENERGETICS
QUANTUM
POTENTIAL

DIVINE WIND II

- ★ **A secret coalition of Yakuza/Aum Shinrikyo and KGB/Communist forces plan to launch a massive, surprise energetics attack on the United States, given a low-risk opportunity.**
- ★ **Major weapons utilized will be the scalar EM (energetics) superweapons (including quantum potential weapons) that were developed, deployed, and operated by the KGB under the former Soviet Empire, and continuing after its dissolution.**
- ★ **Yakuza/Aum crews have extensively trained and test-fired, from on-site in Russia. They have *leased* operational control of the first three generation energetics superweapons (which work by superpotential interferometry).**
- ★ ***The Escalation Phase of interdicting and destroying actual U.S. targets (e.g., TWA-800, two A-10s) is already underway.***
- ★ ***The first blow in the Strike Phase will dud all nuclear weapons and weapons materials worldwide, in minutes; destroy special ship and energetics weapon sites instantly, disable 99% of the U.S. population instantly, and kill 80% of targeted populations in from 10 minutes to 3 days.***

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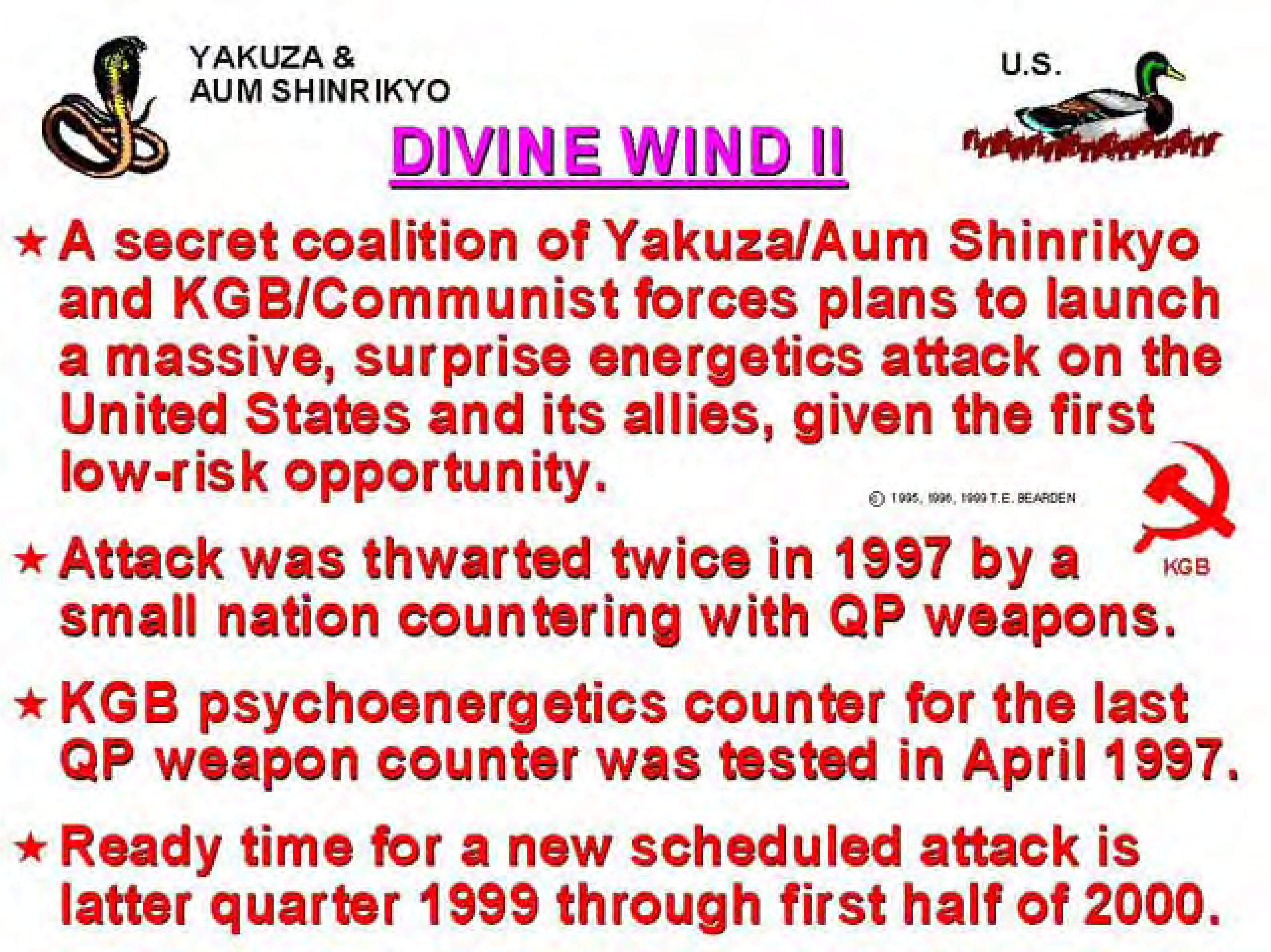
YAKUZA &
AUM SHINRIKYO
U.S.
KGB

DIVINE WIND II

- ★ A secret coalition of Yakuza/Aum Shinrikyo and KGB/Communist forces plans to launch a massive, surprise energetics attack on the United States and its allies, given the first low-risk opportunity.

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- ★ Attack was thwarted twice in 1997 by a small nation countering with QP weapons.
- ★ KGB psychoenergetics counter for the last QP weapon counter was tested in April 1997.
- ★ Ready time for a new scheduled attack is latter quarter 1999 through first half of 2000.

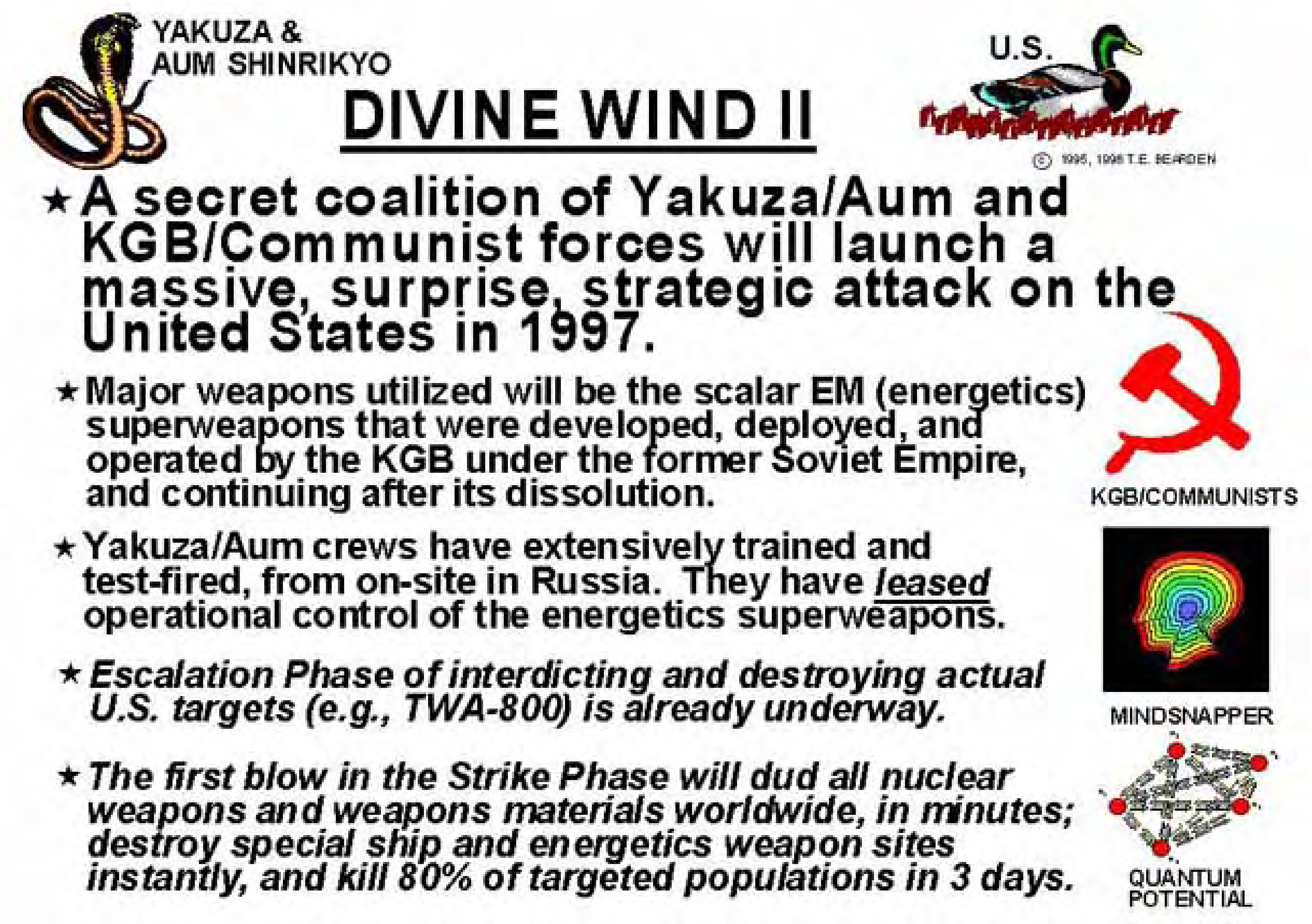

YAKUZA &
AUM SHINRIKYO

U.S.

DIVINE WIND II

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★ **A secret coalition of Yakuza/Aum and KGB/Communist forces will launch a massive, surprise, strategic attack on the United States in 1997.**

★ Major weapons utilized will be the scalar EM (energetics) superweapons that were developed, deployed, and operated by the KGB under the former Soviet Empire, and continuing after its dissolution.

★ Yakuza/Aum crews have extensively trained and test-fired, from on-site in Russia. They have *leased* operational control of the energetics superweapons.

★ *Escalation Phase of interdicting and destroying actual U.S. targets (e.g., TWA-800) is already underway.*

★ *The first blow in the Strike Phase will dud all nuclear weapons and weapons materials worldwide, in minutes; destroy special ship and energetics weapon sites instantly, and kill 80% of targeted populations in 3 days.*

KGB/COMMUNISTS

MINDSNAPPER

QUANTUM
POTENTIAL

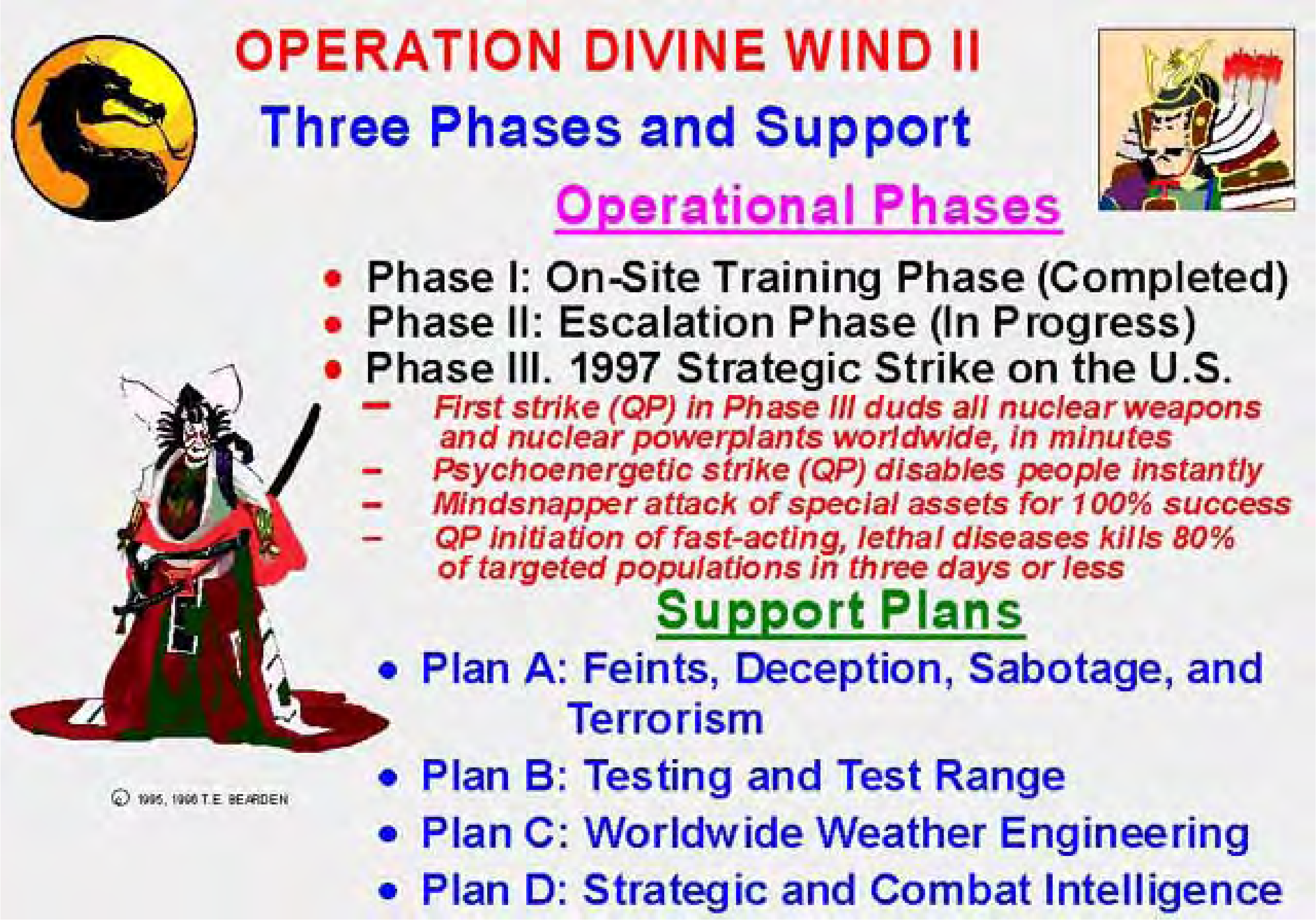

OPERATION DIVINE WIND II

Three Phases and Support

Operational Phases

- Phase I: On-Site Training Phase (Completed)
- Phase II: Escalation Phase (In Progress)
- Phase III. 1997 Strategic Strike on the U.S.
  - *First strike (QP) in Phase III duds all nuclear weapons and nuclear powerplants worldwide, in minutes*
  - *Psychoenergetic strike (QP) disables people instantly*
  - *Mindsnapper attack of special assets for 100% success*
  - *QP initiation of fast-acting, lethal diseases kills 80% of targeted populations in three days or less*

Support Plans

- Plan A: Feints, Deception, Sabotage, and Terrorism
- Plan B: Testing and Test Range
- Plan C: Worldwide Weather Engineering
- Plan D: Strategic and Combat Intelligence

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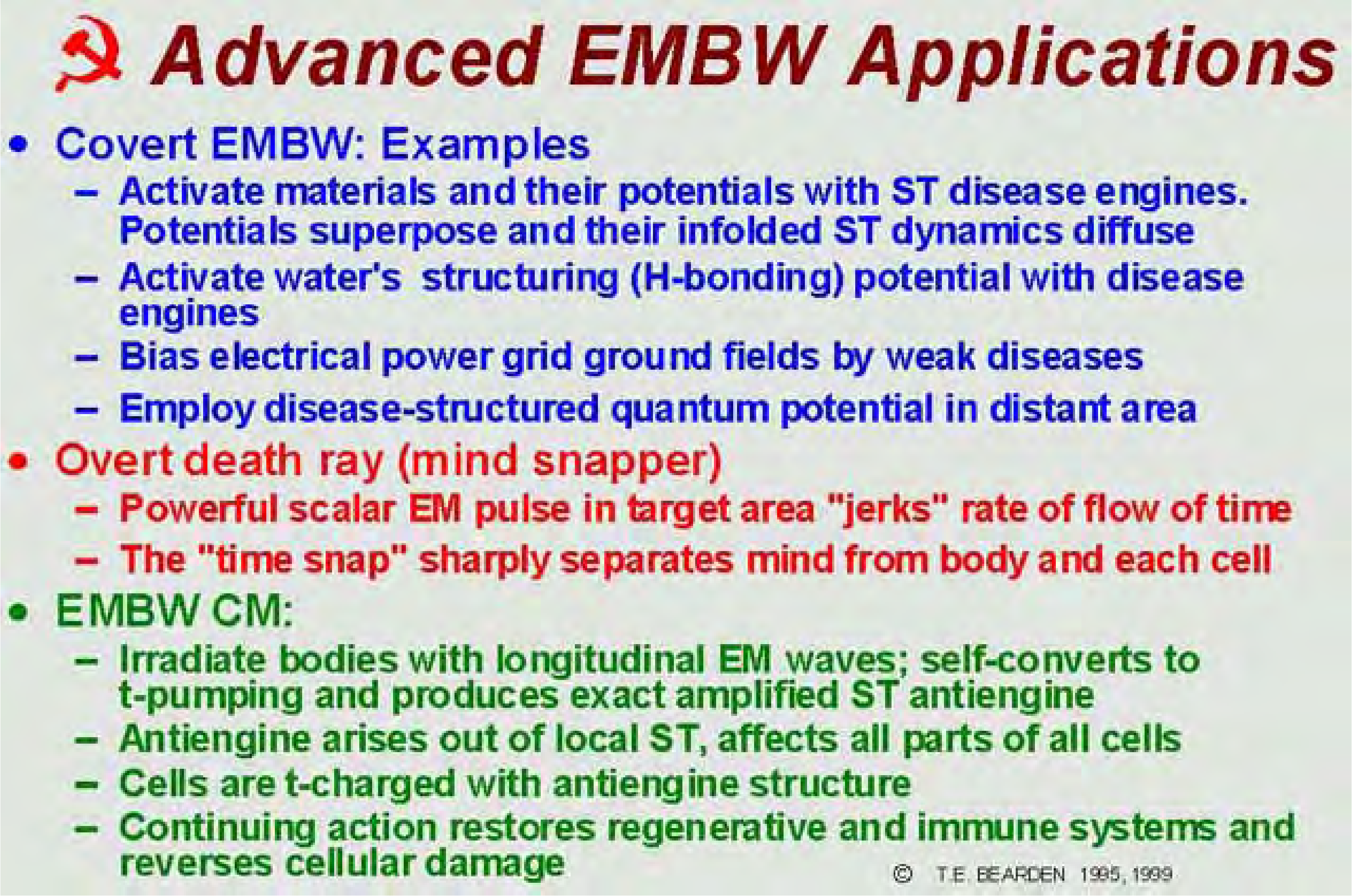

Advanced EMBW Applications

- Covert EMBW: Examples
  - Activate materials and their potentials with ST disease engines. Potentials superpose and their infolded ST dynamics diffuse
  - Activate water's structuring (H-bonding) potential with disease engines
  - Bias electrical power grid ground fields by weak diseases
  - Employ disease-structured quantum potential in distant area
- Overt death ray (mind snapper)
  - Powerful scalar EM pulse in target area "jerks" rate of flow of time
  - The "time snap" sharply separates mind from body and each cell
- EMBW CM:
  - Irradiate bodies with longitudinal EM waves; self-converts to t-pumping and produces exact amplified ST antiengine
  - Antiengine arises out of local ST, affects all parts of all cells
  - Cells are t-charged with antiengine structure
  - Continuing action restores regenerative and immune systems and reverses cellular damage

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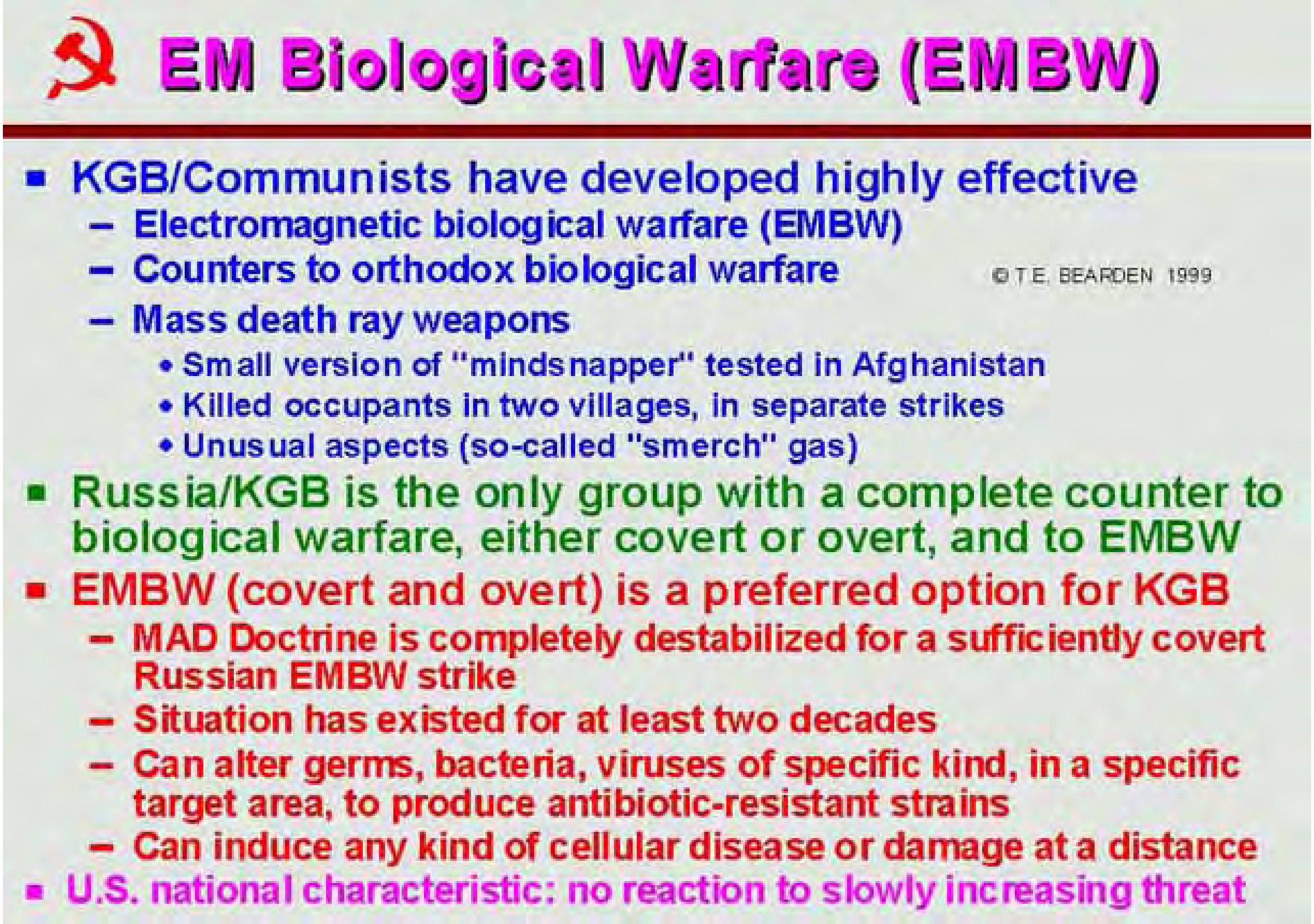

EM Biological Warfare (EMBW)

- KGB/Communists have developed highly effective
  - Electromagnetic biological warfare (EMBW)
  - Counters to orthodox biological warfare
  - Mass death ray weapons
    - Small version of "mindsnapper" tested in Afghanistan
    - Killed occupants in two villages, in separate strikes
    - Unusual aspects (so-called "smerch" gas)
- Russia/KGB is the only group with a complete counter to biological warfare, either covert or overt, and to EMBW
- EMBW (covert and overt) is a preferred option for KGB
  - MAD Doctrine is completely destabilized for a sufficiently covert Russian EMBW strike
  - Situation has existed for at least two decades
  - Can alter germs, bacteria, viruses of specific kind, in a specific target area, to produce antibiotic-resistant strains
  - Can induce any kind of cellular disease or damage at a distance
- U.S. national characteristic: no reaction to slowly increasing threat

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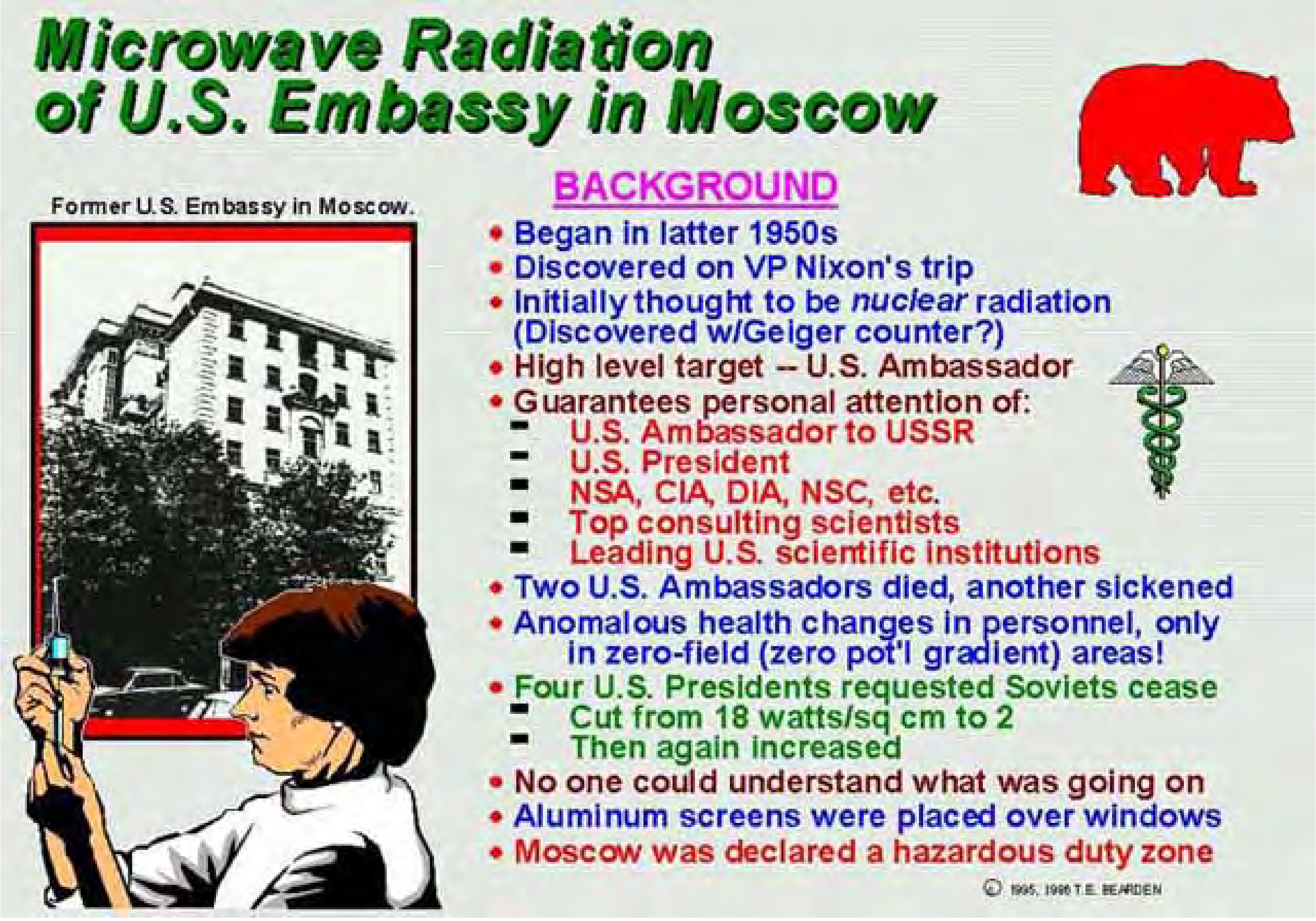

Microwave Radiation of U.S. Embassy in Moscow

Former U.S. Embassy in Moscow.

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter?)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
  - U.S. Ambassador to USSR
  - U.S. President
  - NSA, CIA, DIA, NSC, etc.
  - Top consulting scientists
  - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero pot'l gradient) areas!
- Four U.S. Presidents requested Soviets cease
  - Cut from 18 watts/sq cm to 2
  - Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

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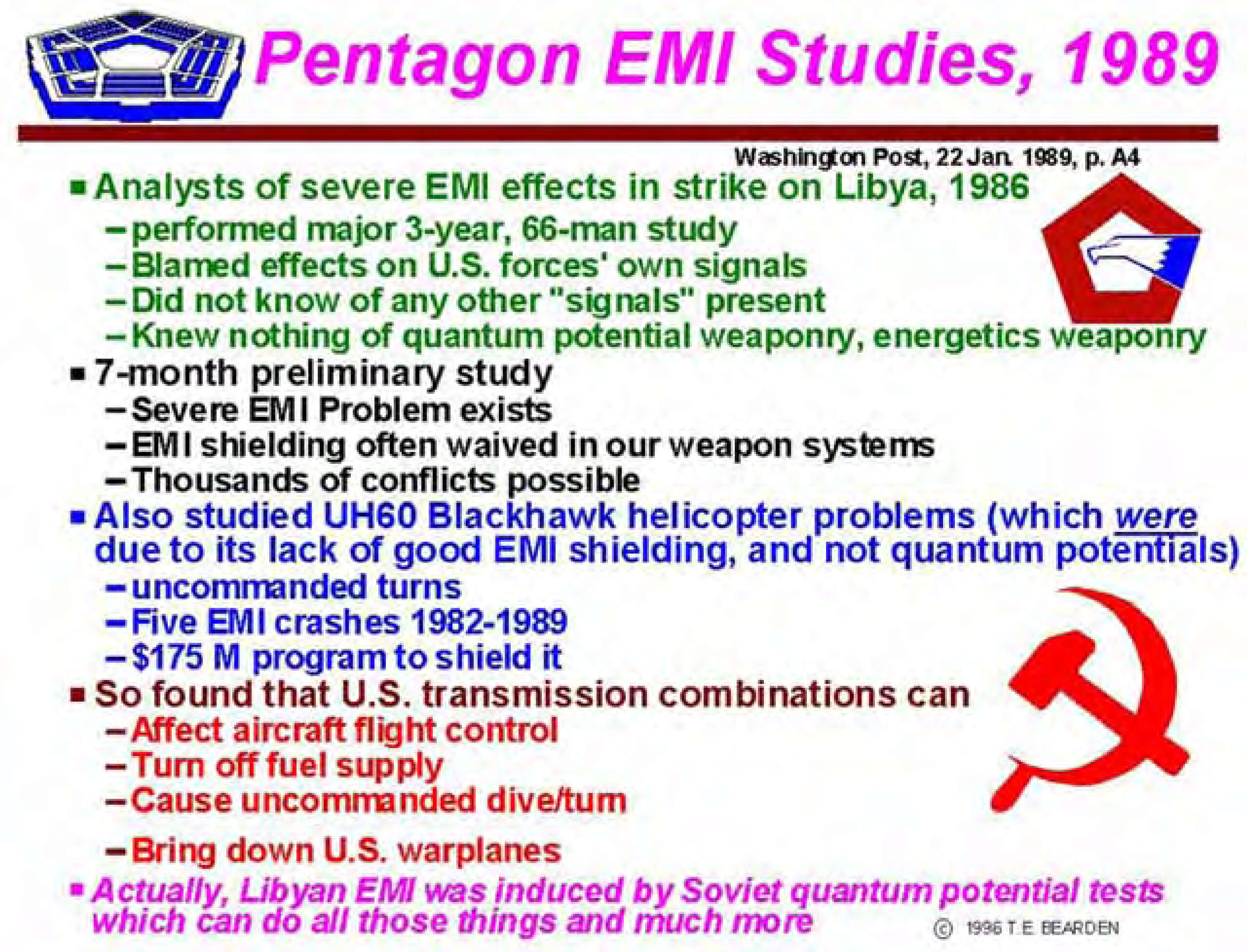

Pentagon EMI Studies, 1989

Washington Post, 22 Jan. 1989, p. A4

- Analysts of severe EMI effects in strike on Libya, 1986
  - performed major 3-year, 66-man study
  - Blamed effects on U.S. forces' own signals
  - Did not know of any other "signals" present
  - Knew nothing of quantum potential weaponry, energetics weaponry
- 7-month preliminary study
  - Severe EMI Problem exists
  - EMI shielding often waived in our weapon systems
  - Thousands of conflicts possible
- Also studied UH60 Blackhawk helicopter problems (which *were* due to its lack of good EMI shielding, and not quantum potentials)
  - uncommanded turns
  - Five EMI crashes 1982-1989
  - $175 M program to shield it
- So found that U.S. transmission combinations can
  - Affect aircraft flight control
  - Turn off fuel supply
  - Cause uncommanded dive/turn
  - Bring down U.S. warplanes
- *Actually, Libyan EMI was induced by Soviet quantum potential tests which can do all those things and much more*

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EM Missile Practice

- EM Missile Practice
  Latter Sept. - Early Nov. 1996
  Melbourne, Australia

- Deception: Using EM Missile to Reinforce Notion of SAM Attack
  Saturday evening, Nov. 16, 1996

- Intelligence Probe: Insuring U.S. Still Unaware of Energetics Weaponry
  Thursday, December 12th, 1996

- EM Missile Strike, Offset from Night Shuttle Launch, Cape Canaveral, Florida
  The Smoking Gun in November 1985

- Distant Operator Onsite in Russia Slew Away Registration Point
  Marker Beacon over Night Shuttle Launch, 26 November, 1985

- EM Missile Practice and Deception
  November 17, 1996

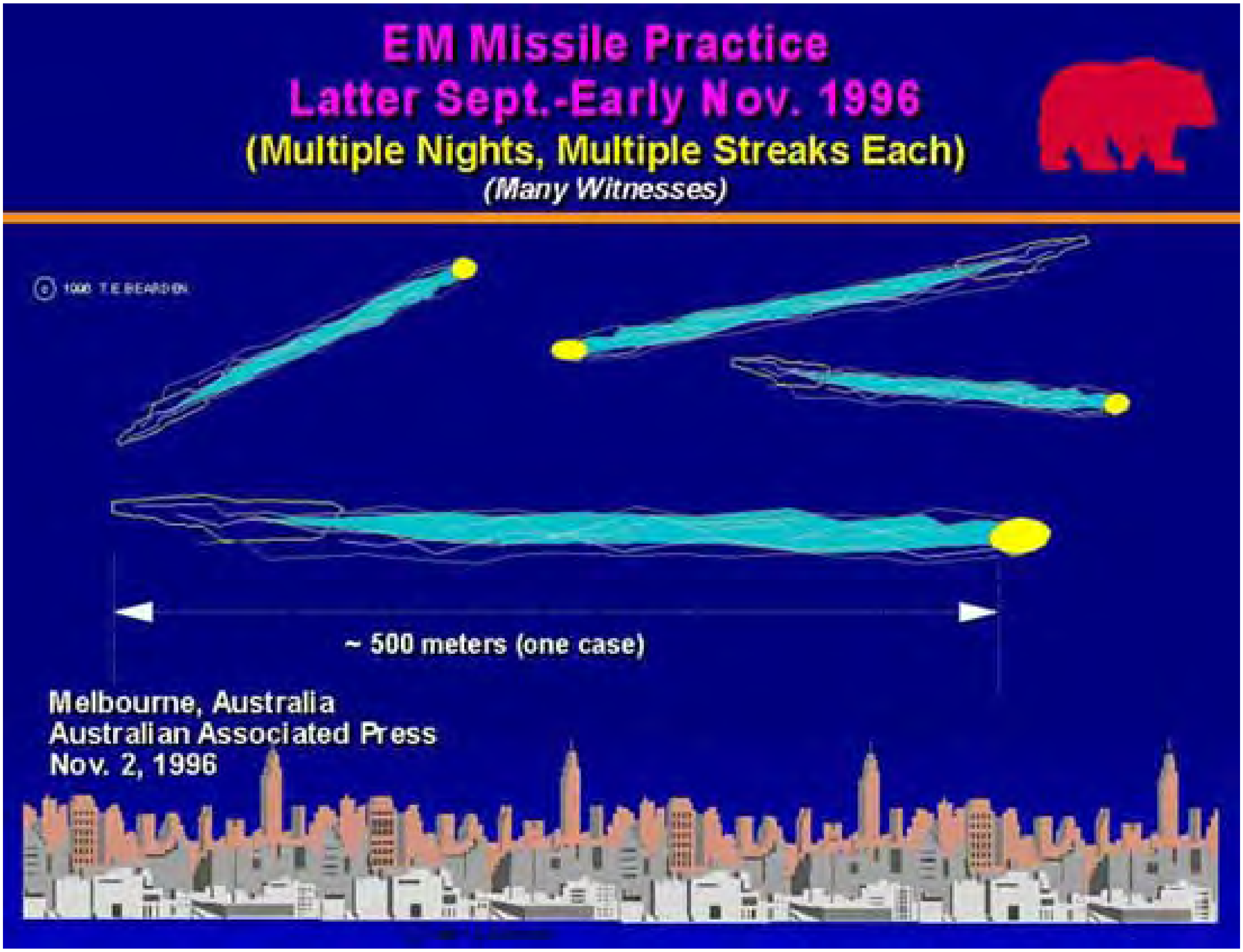

EM Missile Practice
Latter Sept.-Early Nov. 1996

(Multiple Nights, Multiple Streaks Each)

(Many Witnesses)

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~ 500 meters (one case)

Melbourne, Australia
Australian Associated Press
Nov. 2, 1996

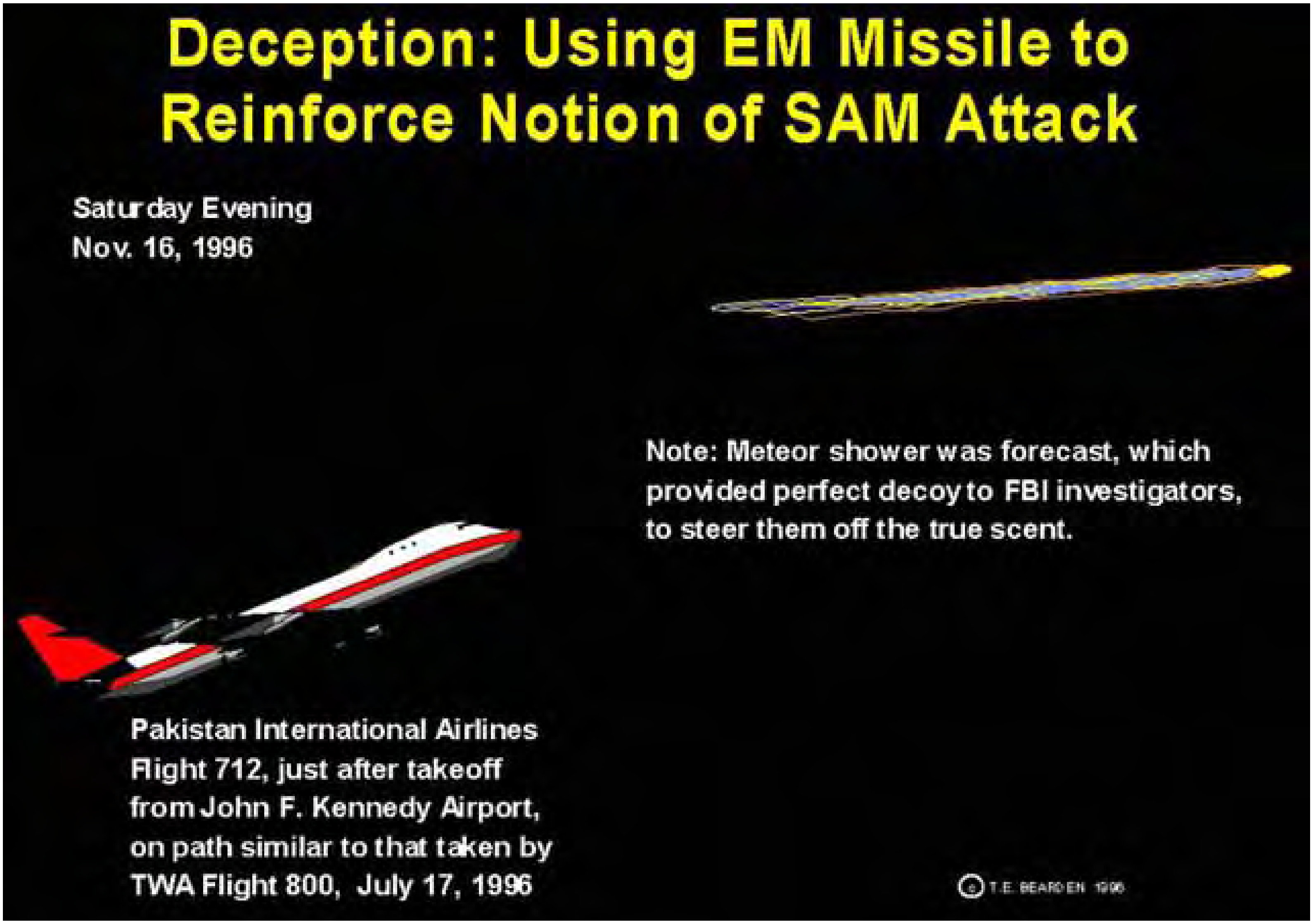

Deception: Using EM Missile to Reinforce Notion of SAM Attack

Saturday Evening
Nov. 16, 1996

Note: Meteor shower was forecast, which provided perfect decoy to FBI investigators, to steer them off the true scent.

Pakistan International Airlines Flight 712, just after takeoff from John F. Kennedy Airport, on path similar to that taken by TWA Flight 800, July 17, 1996

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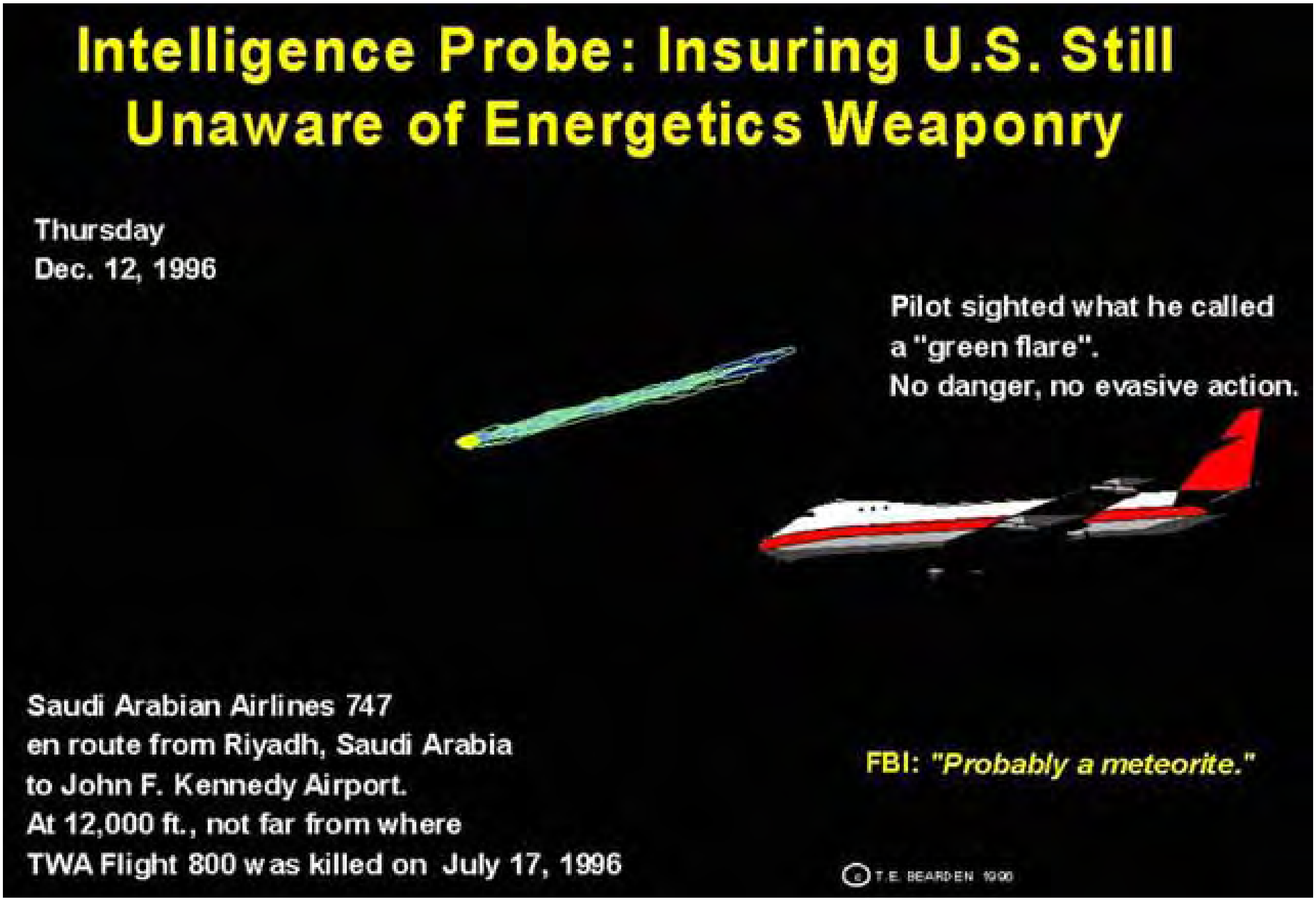

Intelligence Probe: Insuring U.S. Still Unaware of Energetics Weaponry

Thursday
Dec. 12, 1996

Pilot sighted what he called
a "green flare".
No danger, no evasive action.

Saudi Arabian Airlines 747
en route from Riyadh, Saudi Arabia
to John F. Kennedy Airport.
At 12,000 ft., not far from where
TWA Flight 800 was killed on July 17, 1996

FBI: *"Probably a meteorite."*

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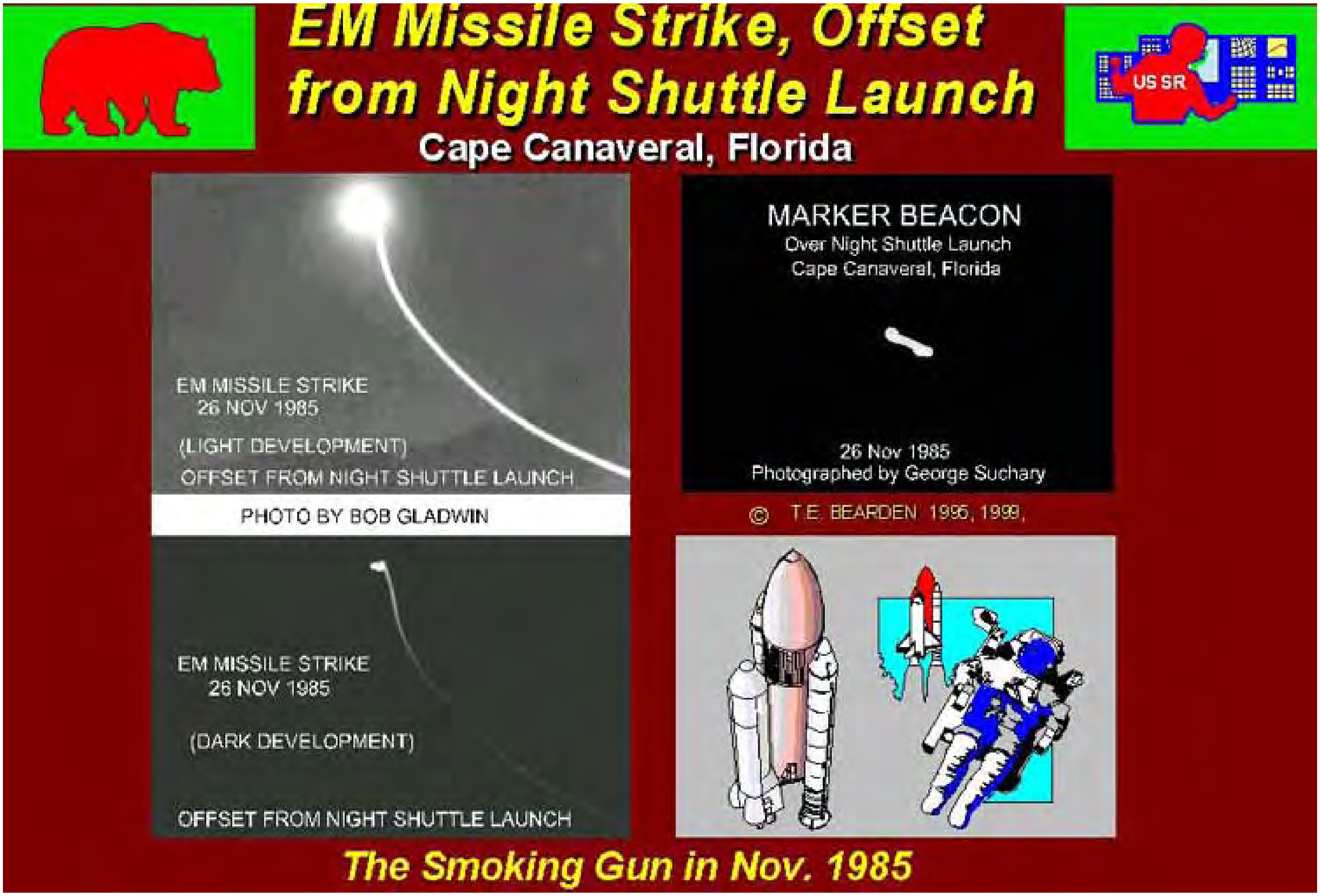

EM Missile Strike, Offset from Night Shuttle Launch

Cape Canaveral, Florida

EM MISSILE STRIKE
26 NOV 1985

(LIGHT DEVELOPMENT)
OFFSET FROM NIGHT SHUTTLE LAUNCH

PHOTO BY BOB GLADWIN

MARKER BEACON
Over Night Shuttle Launch
Cape Canaveral, Florida

26 Nov 1985
Photographed by George Suchary

© T.E. BEARDEN 1996, 1999,

EM MISSILE STRIKE
26 NOV 1985

(DARK DEVELOPMENT)

OFFSET FROM NIGHT SHUTTLE LAUNCH

The Smoking Gun in Nov. 1985

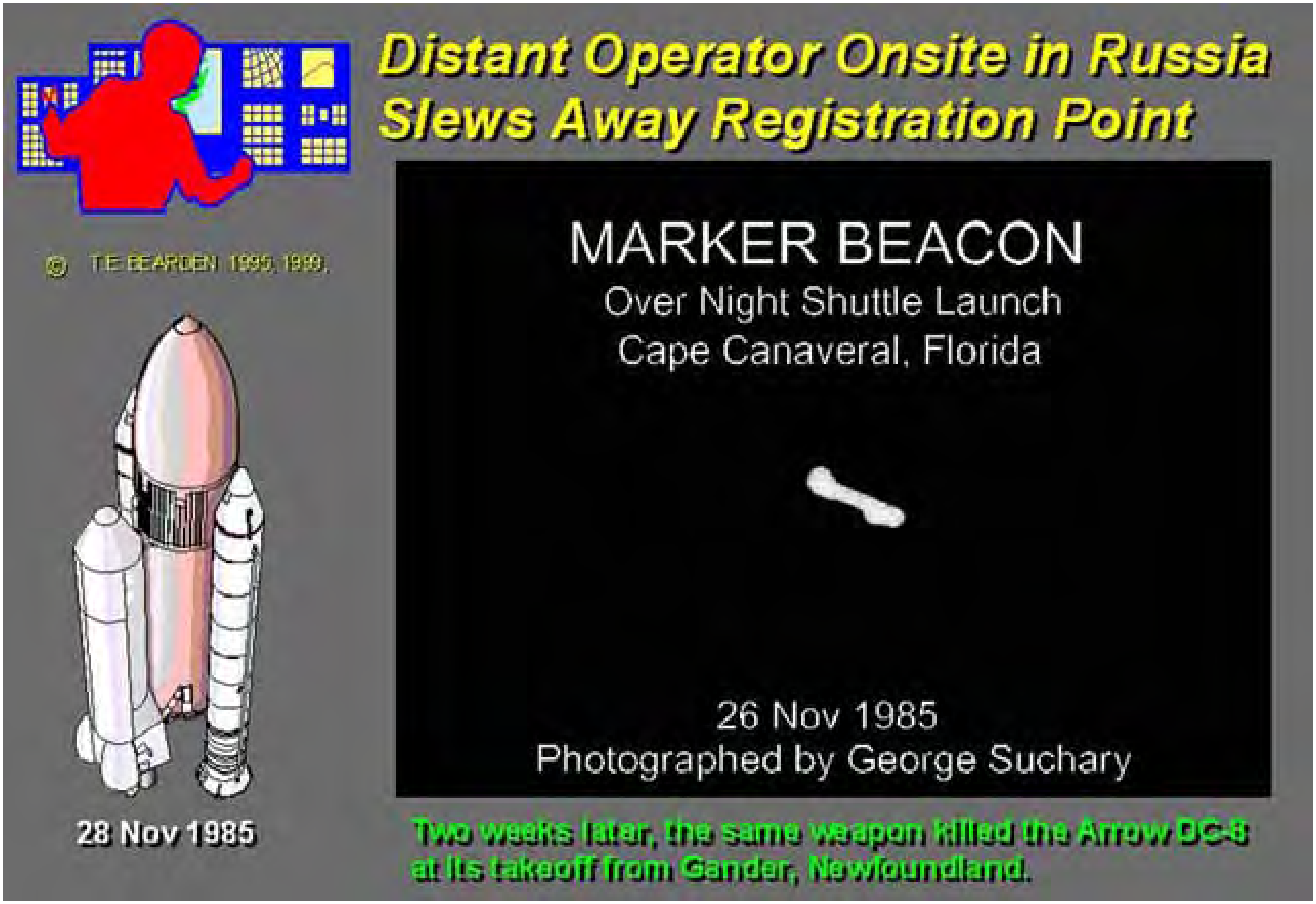

Distant Operator Onsite in Russia Slews Away Registration Point

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MARKER BEACON

Over Night Shuttle Launch

Cape Canaveral, Florida

26 Nov 1985

Photographed by George Suchary

28 Nov 1985

Two weeks later, the same weapon killed the Arrow DC-8 at its takeoff from Gander, Newfoundland.

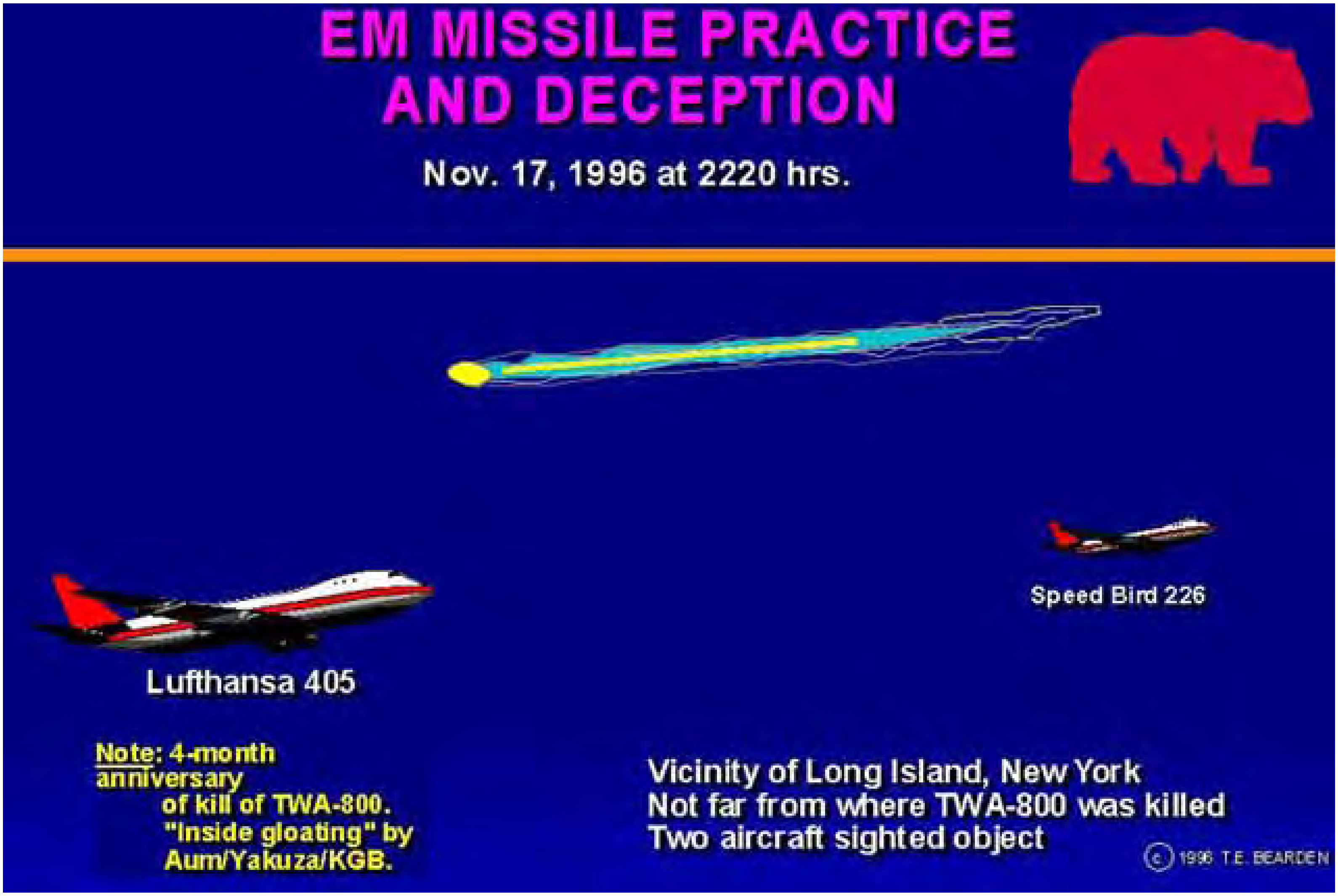

EM MISSILE PRACTICE AND DECEPTION

Nov. 17, 1996 at 2220 hrs.

Speed Bird 226

Lufthansa 405

Note: 4-month anniversary
of kill of TWA-800.
"Inside gloating" by
Aum/Yakuza/KGB.

Vicinity of Long Island, New York
Not far from where TWA-800 was killed
Two aircraft sighted object

(c) 1996 T.E. BEARDEN

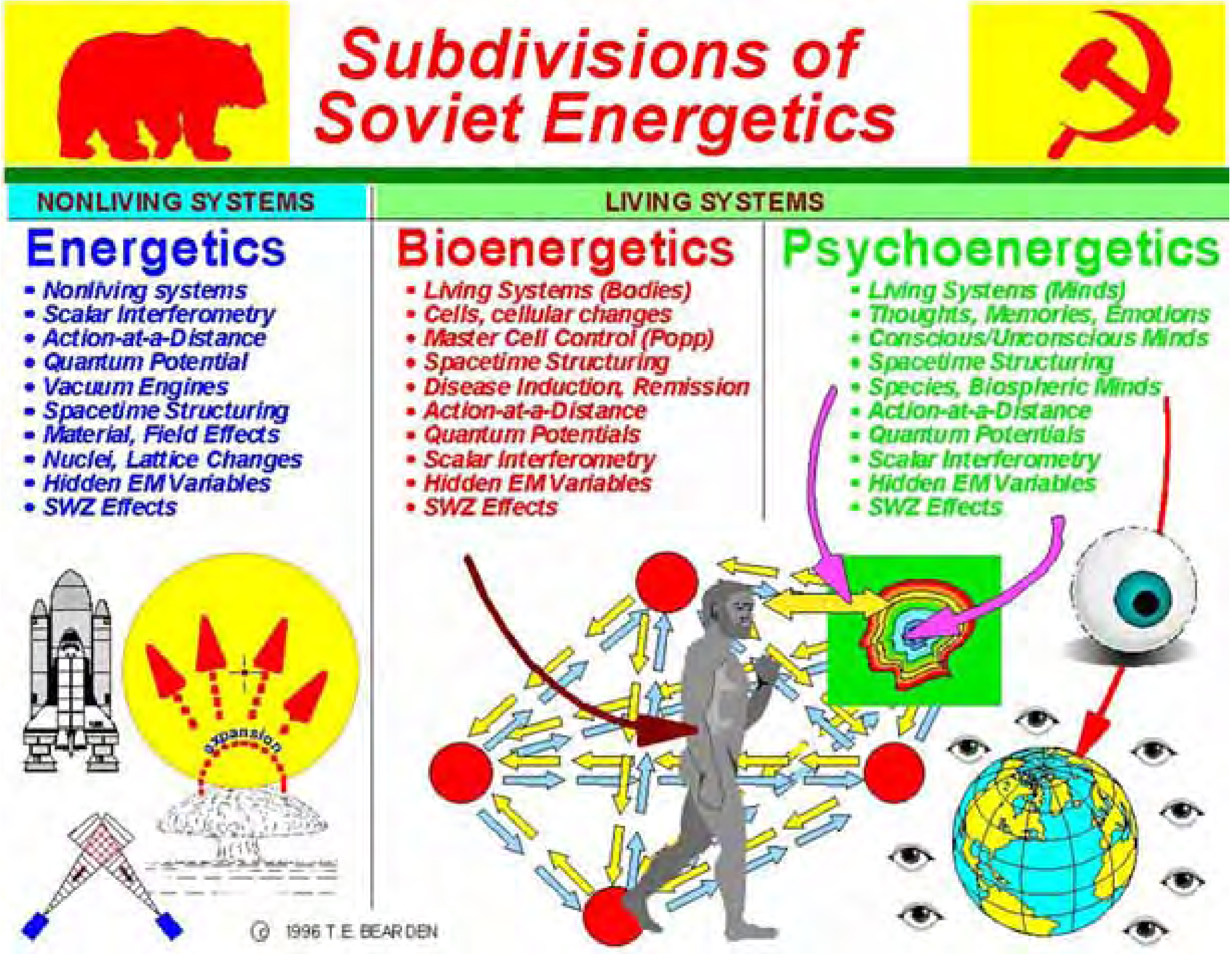

Subdivisions of Soviet Energetics

NONLIVING SYSTEMS

Energetics

- *Nonliving systems*
- *Scalar Interferometry*
- *Action-at-a-Distance*
- *Quantum Potential*
- *Vacuum Engines*
- *Spacetime Structuring*
- *Material, Field Effects*
- *Nuclei, Lattice Changes*
- *Hidden EM Variables*
- *SWZ Effects*

LIVING SYSTEMS

Bioenergetics

- *Living Systems (Bodies)*
- *Cells, cellular changes*
- *Master Cell Control (Popp)*
- *Spacetime Structuring*
- *Disease Induction, Remission*
- *Action-at-a-Distance*
- *Quantum Potentials*
- *Scalar Interferometry*
- *Hidden EM Variables*
- *SWZ Effects*

Psychoenergetics

- *Living Systems (Minds)*
- *Thoughts, Memories, Emotions*
- *Conscious/Unconscious Minds*
- *Spacetime Structuring*
- *Species, Biospheric Minds*
- *Action-at-a-Distance*
- *Quantum Potentials*
- *Scalar Interferometry*
- *Hidden EM Variables*
- *SWZ Effects*

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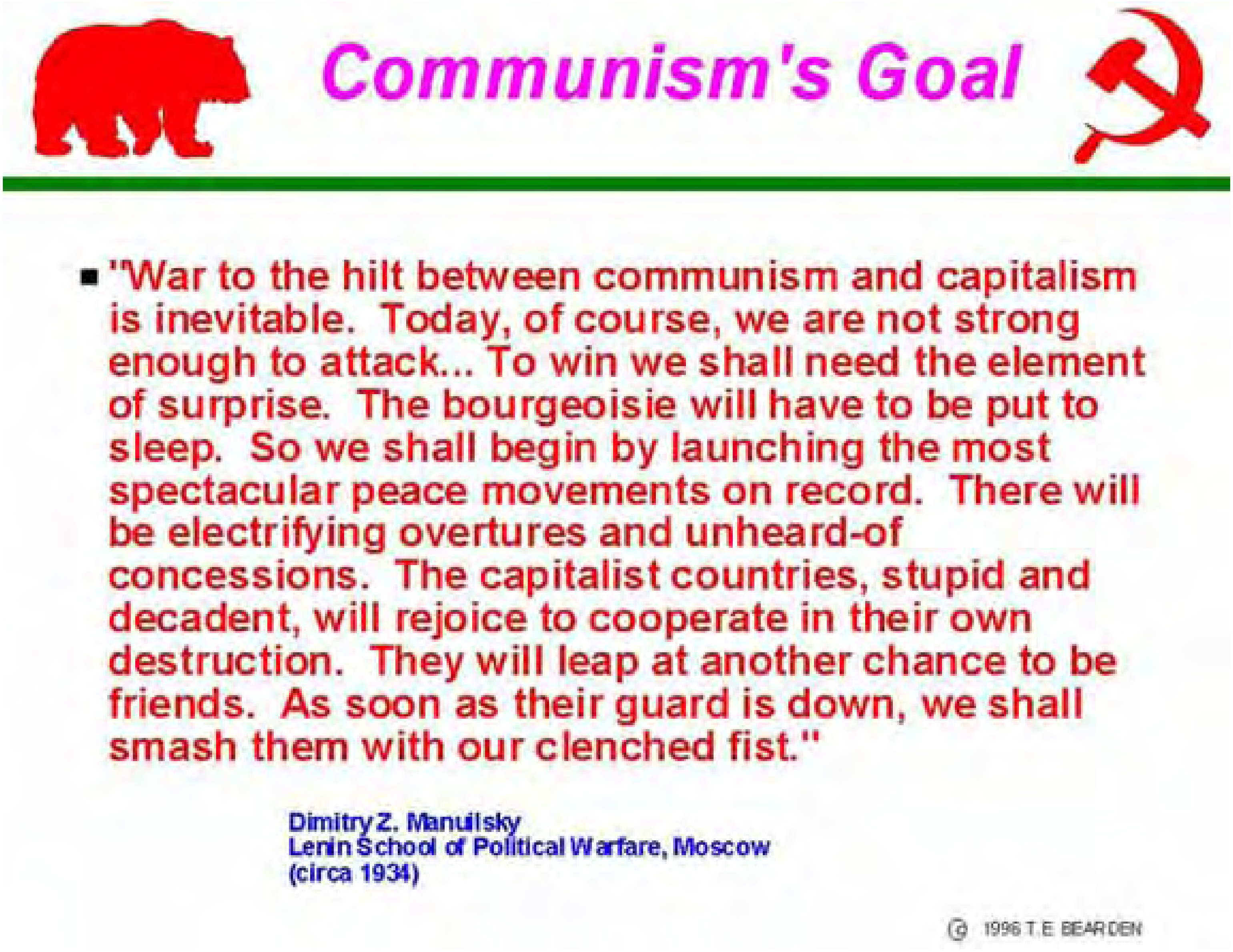

Communism's Goal

- "War to the hilt between communism and capitalism is inevitable. Today, of course, we are not strong enough to attack... To win we shall need the element of surprise. The bourgeoisie will have to be put to sleep. So we shall begin by launching the most spectacular peace movements on record. There will be electrifying overtures and unheard-of concessions. The capitalist countries, stupid and decadent, will rejoice to cooperate in their own destruction. They will leap at another chance to be friends. As soon as their guard is down, we shall smash them with our clenched fist."

Dimitry Z. Manuilsky
Lenin School of Political Warfare, Moscow
(circa 1934)

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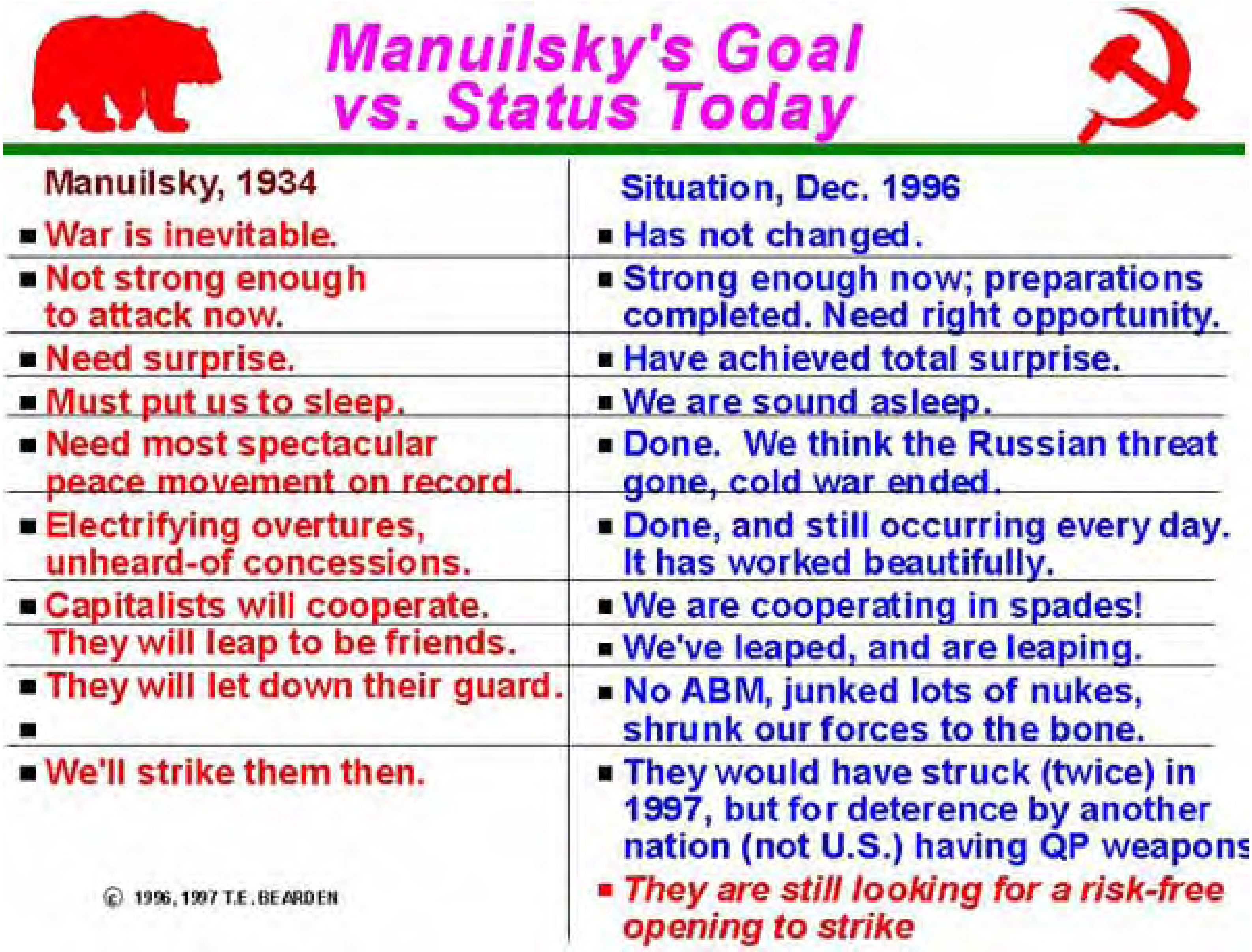

Manuilsky's Goal vs. Status Today

Manuilsky, 1934	Situation, Dec. 1996
- War is inevitable.	- Has not changed.
- Not strong enough to attack now.	- Strong enough now; preparations completed. Need right opportunity.
- Need surprise.	- Have achieved total surprise.
- Must put us to sleep.	- We are sound asleep.
- Need most spectacular peace movement on record.	- Done. We think the Russian threat gone, cold war ended.
- Electrifying overtures, unheard-of concessions.	- Done, and still occurring every day. It has worked beautifully.
- Capitalists will cooperate.	- We are cooperating in spades!
They will leap to be friends.	- We've leaped, and are leaping.
- They will let down their guard. -	- No ABM, junked lots of nukes, shrunk our forces to the bone.
- We'll strike them then.	- They would have struck (twice) in 1997, but for deterence by another nation (not U.S.) having QP weapons - *They are still looking for a risk-free opening to strike*

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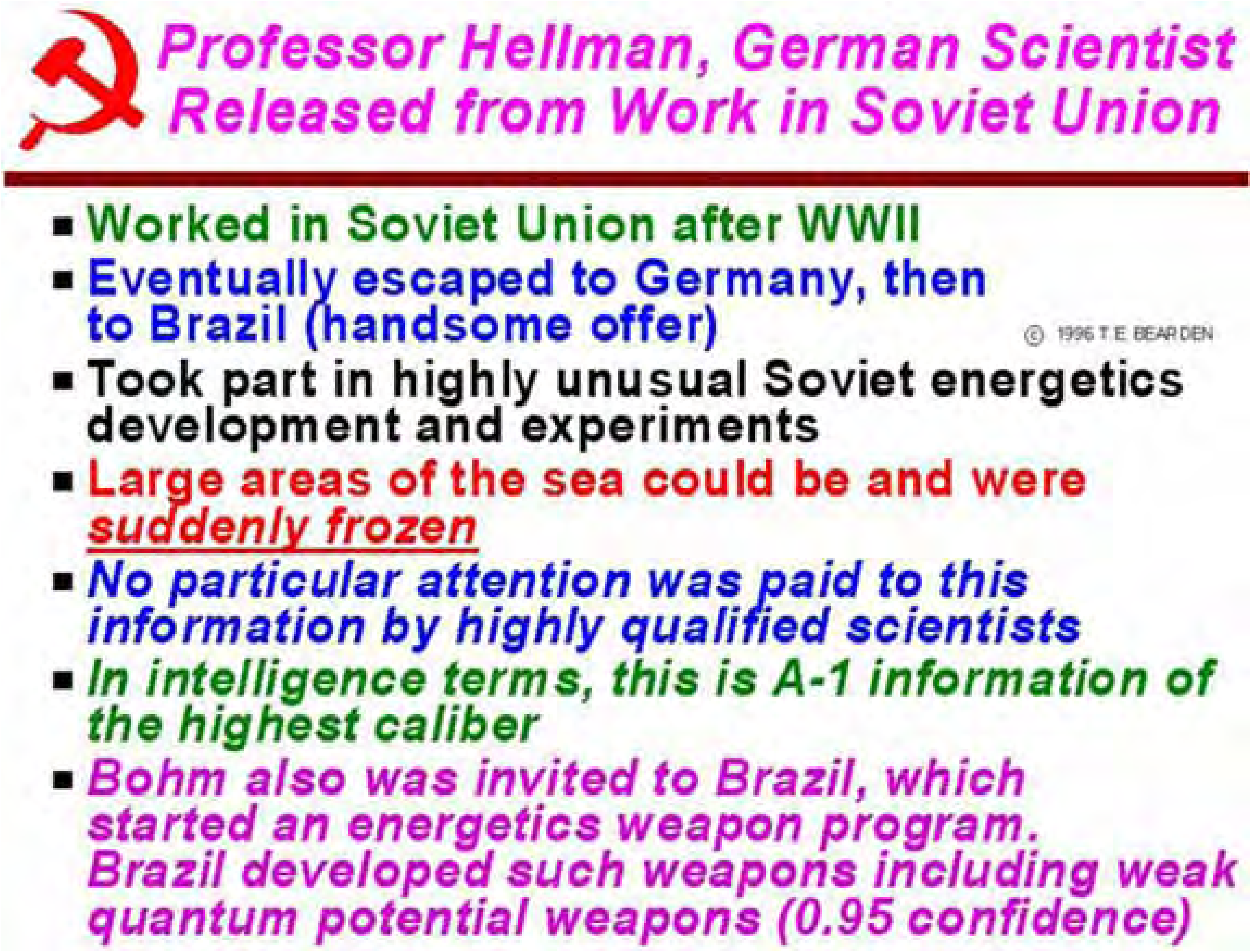

Professor Hellman, German Scientist Released from Work in Soviet Union

- Worked in Soviet Union after WWII
- Eventually escaped to Germany, then to Brazil (handsome offer)
- Took part in highly unusual Soviet energetics development and experiments
- Large areas of the sea could be and were *suddenly frozen*
- *No particular attention was paid to this information by highly qualified scientists*
- *In intelligence terms, this is A-1 information of the highest caliber*
- *Bohm also was invited to Brazil, which started an energetics weapon program. Brazil developed such weapons including weak quantum potential weapons (0.95 confidence)*

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The Tom Bearden Website

Help support the research

Hemispheres of Light

- March 20th, 1969
  Caribbean and Western North Atlantic
- Hemisphere and Globes, 1977
  24 March, 1977
- Virgin Islands Incident
  August 1969
- Typical Shield Test, Northern Route to Japan
  June, 1982

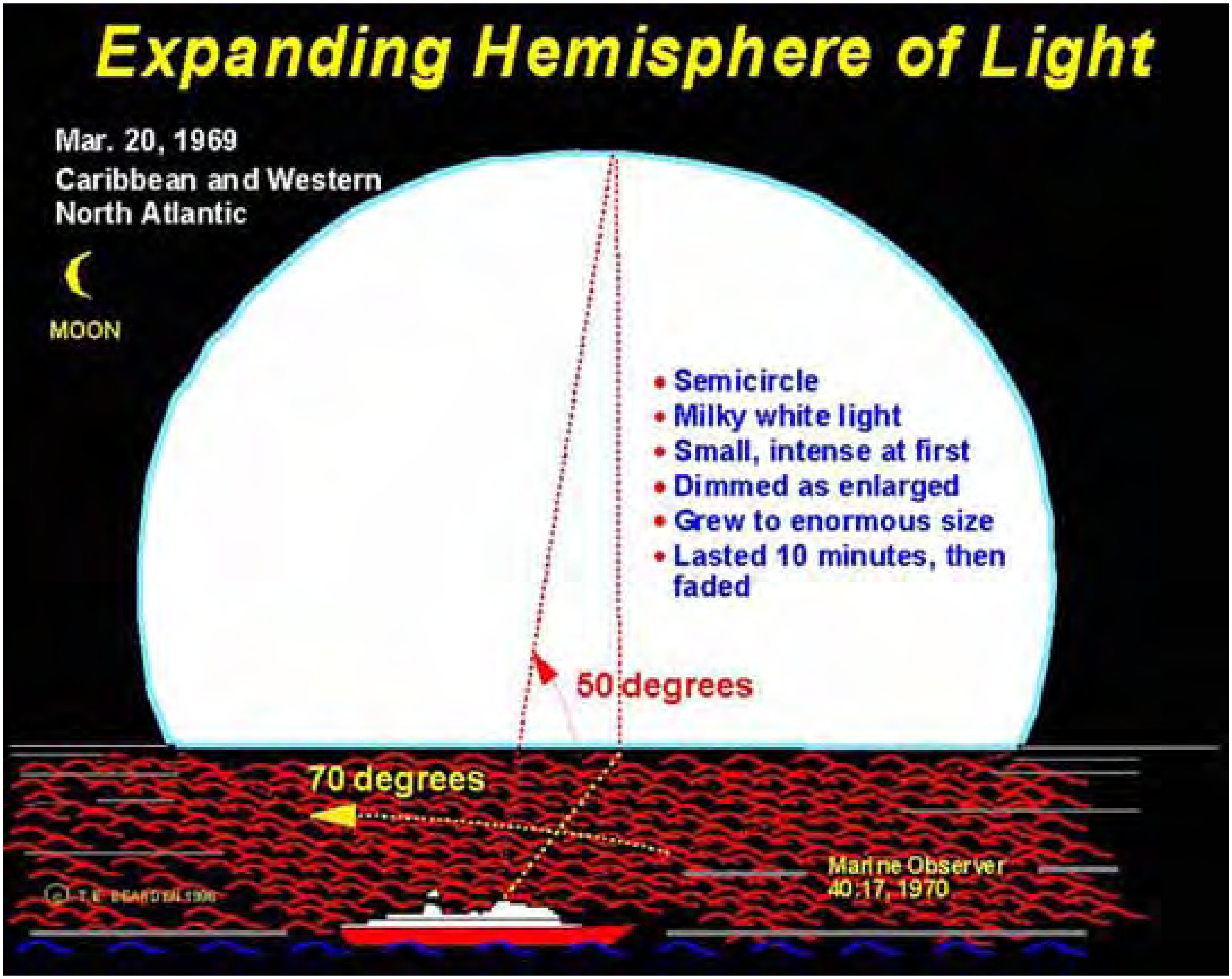

Expanding Hemisphere of Light

Mar. 20, 1969
Caribbean and Western
North Atlantic

- Semicircle
- Milky white light
- Small, intense at first
- Dimmed as enlarged
- Grew to enormous size
- Lasted 10 minutes, then faded

MOON
50 degrees
70 degrees
Marine Observer
40:17, 1970

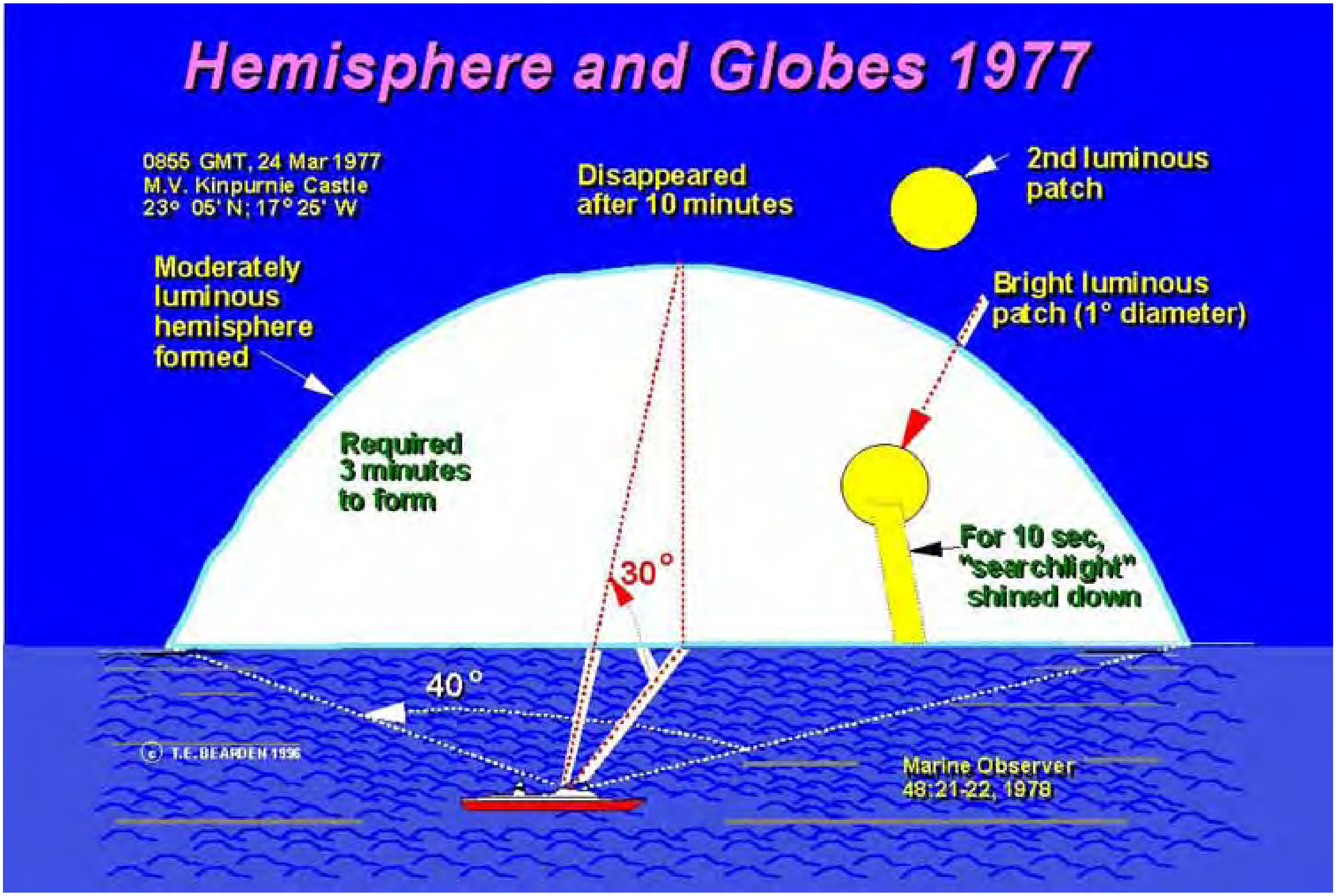
Hemisphere and Globes 1977
0855 GMT, 24 Mar 1977
M.V. Kinpurnie Castle
23° 05' N; 17° 25' W
Disappeared after 10 minutes
2nd luminous patch
Moderately luminous hemisphere formed
Bright luminous patch (1° diameter)
Required 3 minutes to form
30°
For 10 sec, "searchlight" shined down
40°
© T.E. BEARDEN 1996
Marine Observer 48:21-22, 1978

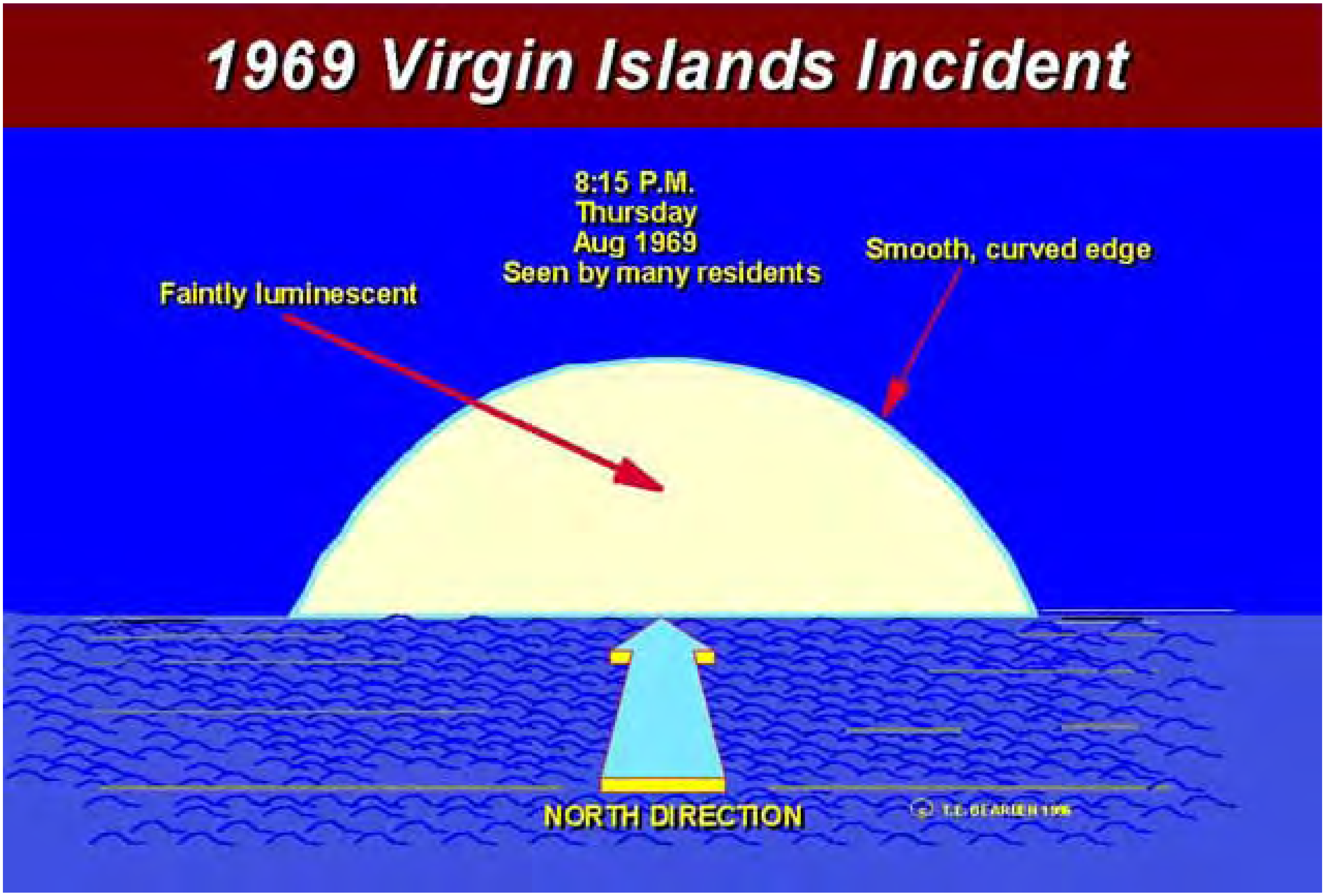

1969 Virgin Islands Incident

8:15 P.M.
Thursday
Aug 1969
Seen by many residents

Faintly luminescent

Smooth, curved edge

NORTH DIRECTION

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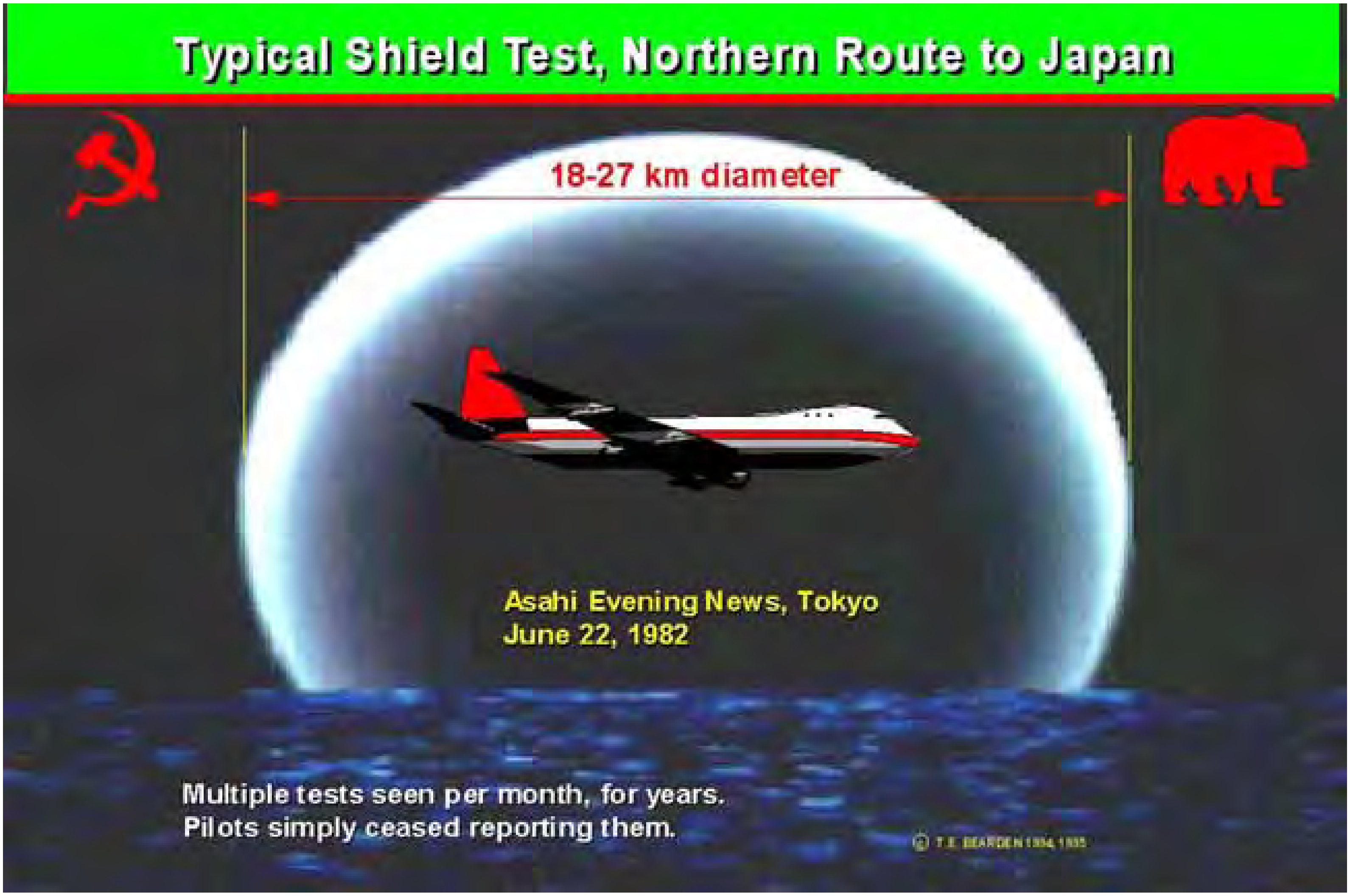

Typical Shield Test, Northern Route to Japan

18-27 km diameter

Asahi Evening News, Tokyo
June 22, 1982

Multiple tests seen per month, for years.
Pilots simply ceased reporting them.

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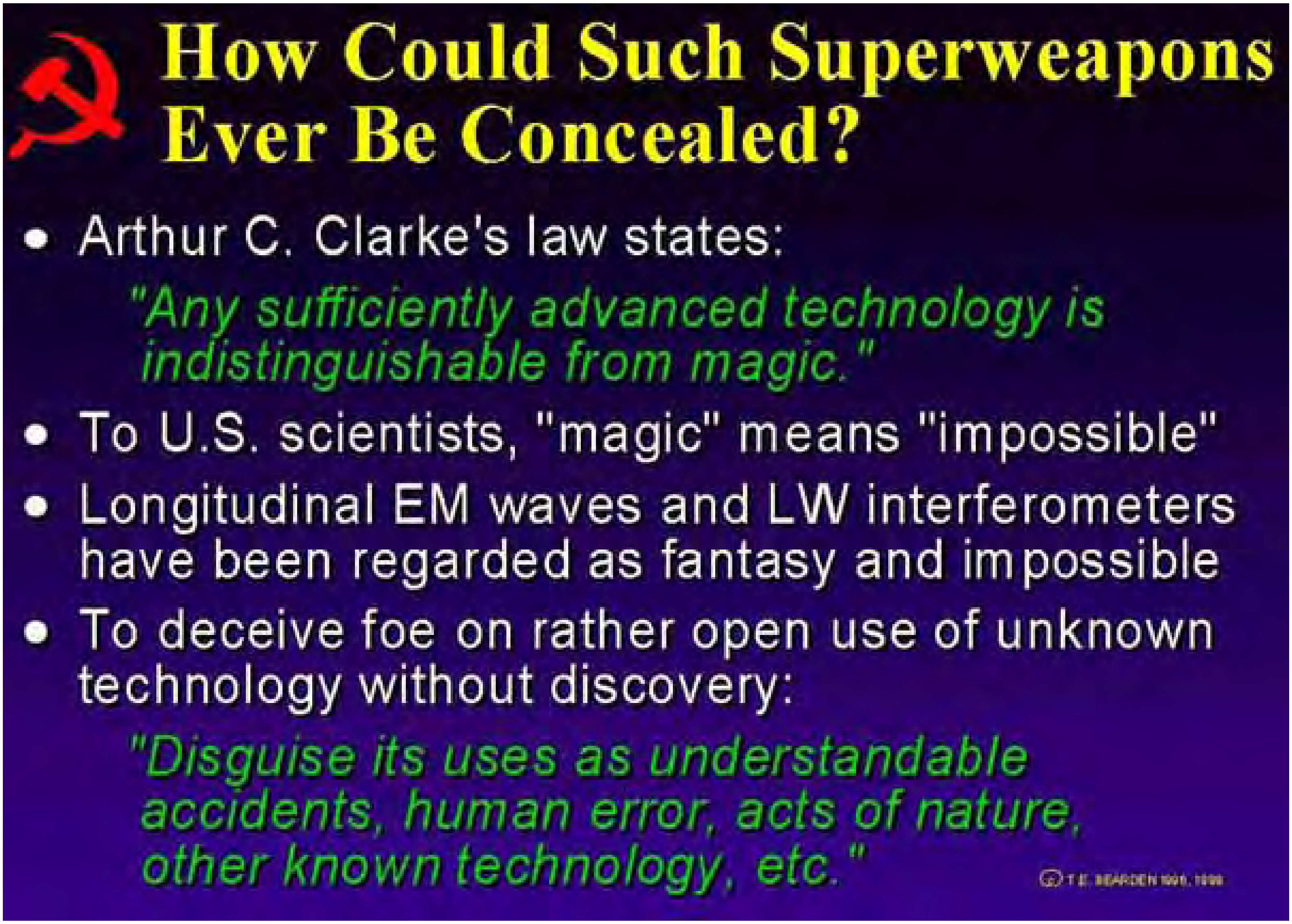

How Could Such Superweapons Ever Be Concealed?

- Arthur C. Clarke's law states:

  "Any sufficiently advanced technology is indistinguishable from magic."
- To U.S. scientists, "magic" means "impossible"
- Longitudinal EM waves and LW interferometers have been regarded as fantasy and impossible
- To deceive foe on rather open use of unknown technology without discovery:

  "Disguise its uses as understandable accidents, human error, acts of nature, other known technology, etc."

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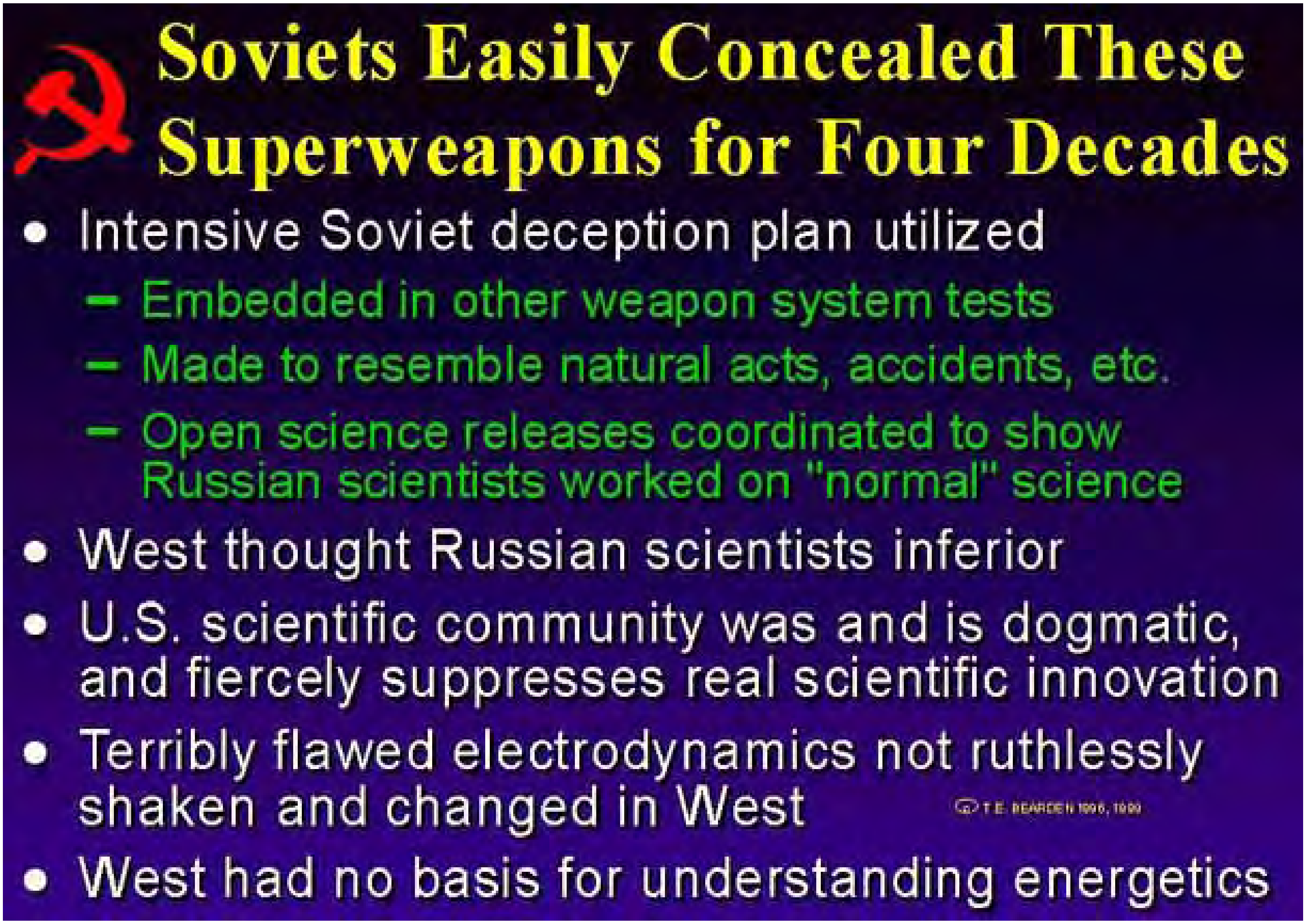

Soviets Easily Concealed These Superweapons for Four Decades

- Intensive Soviet deception plan utilized
  - Embedded in other weapon system tests
  - Made to resemble natural acts, accidents, etc.
  - Open science releases coordinated to show Russian scientists worked on "normal" science
- West thought Russian scientists inferior
- U.S. scientific community was and is dogmatic, and fiercely suppresses real scientific innovation
- Terribly flawed electrodynamics not ruthlessly shaken and changed in West
- West had no basis for understanding energetics

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Precise spacetime curvature engine adds energy to $_2He_4$ α-particles inside atomic nuclei, causing tunneling α-decay

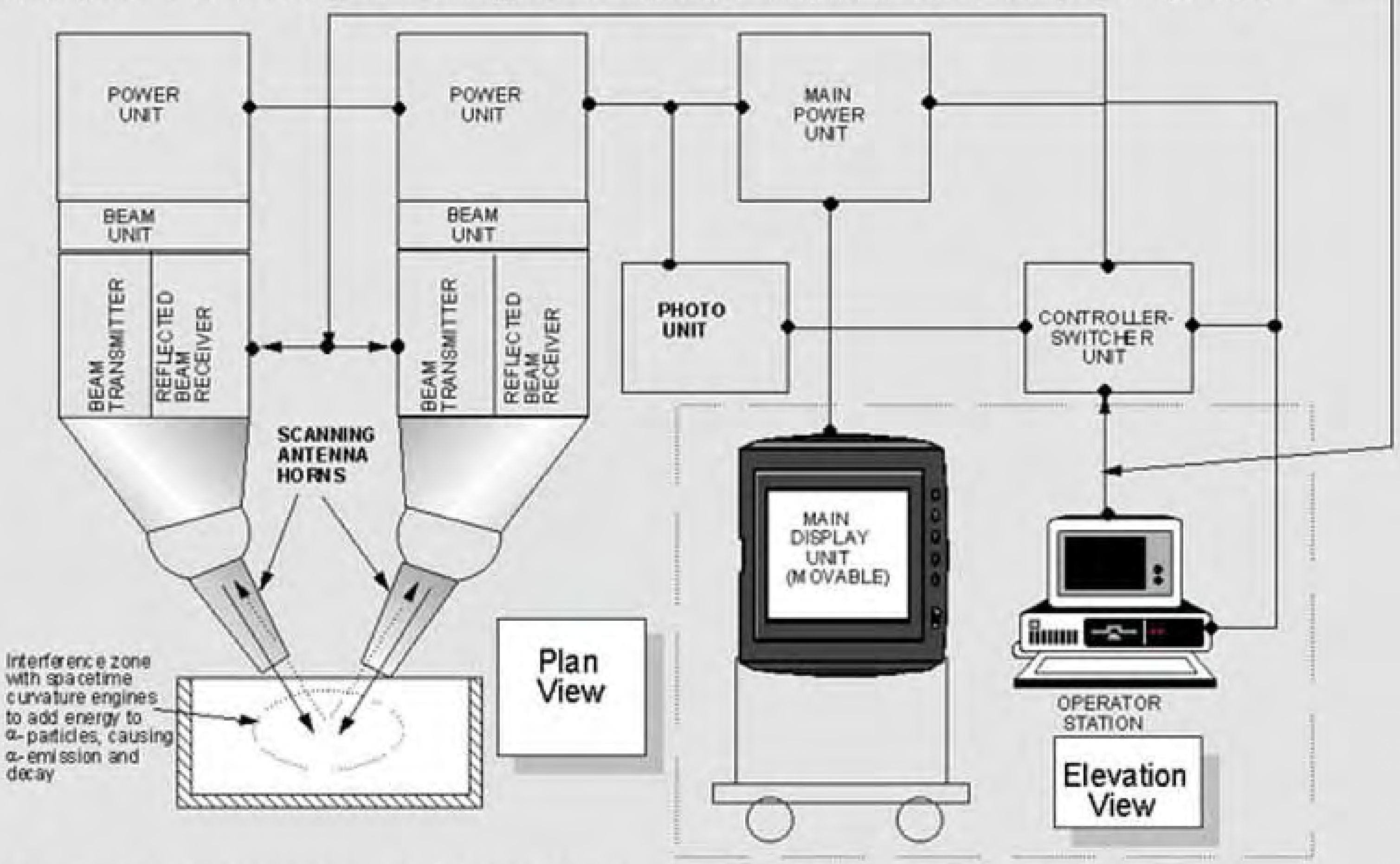
POWER UNIT
BEAM UNIT
BEAM TRANSMITTER
REFLECTED BEAM RECEIVER
POWER UNIT
BEAM UNIT
BEAM TRANSMITTER
REFLECTED BEAM RECEIVER
MAIN POWER UNIT
PHOTO UNIT
CONTROLLER-SWITCHER UNIT
SCANNING ANTENNA HORNS
Interference zone with spacetime curvature engines to add energy to α-particles, causing α-emission and decay
Plan View
MAIN DISPLAY UNIT (MOVABLE)
OPERATOR STATION
Elevation View

Figure 26. Microscope-type, laser-like interferometer for inducing quick α-decay in samples of otherwise longer-lived isotopes.

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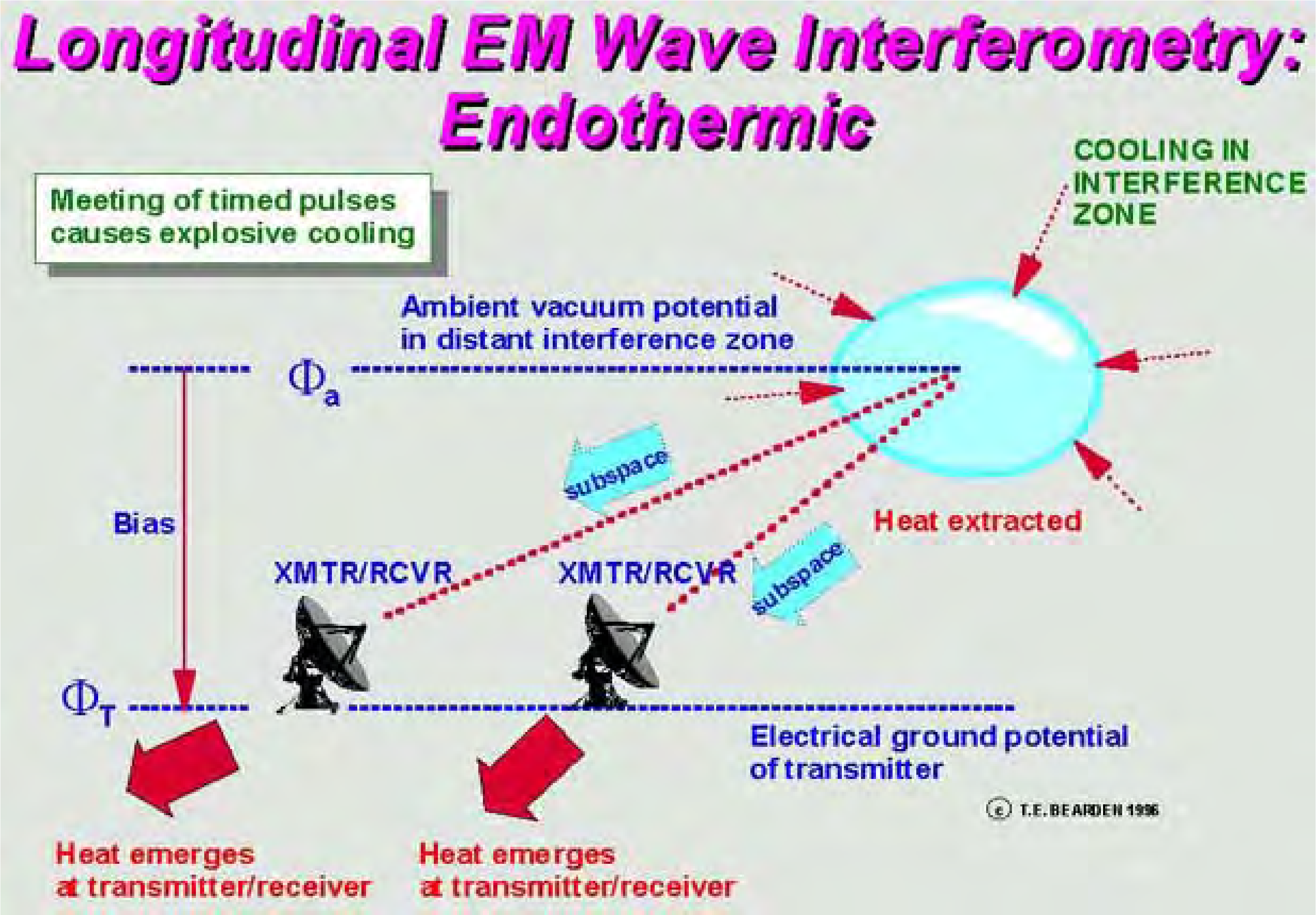

Longitudinal EM Wave Interferometry: Endothermic

Meeting of timed pulses causes explosive cooling

COOLING IN INTERFERENCE ZONE

Ambient vacuum potential in distant interference zone

Φ_a

Bias

subspace

Heat extracted

XMTR/RCVR

XMTR/RCVR

subspace

Φ_T

Electrical ground potential of transmitter

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Heat emerges at transmitter/receiver

Heat emerges at transmitter/receiver

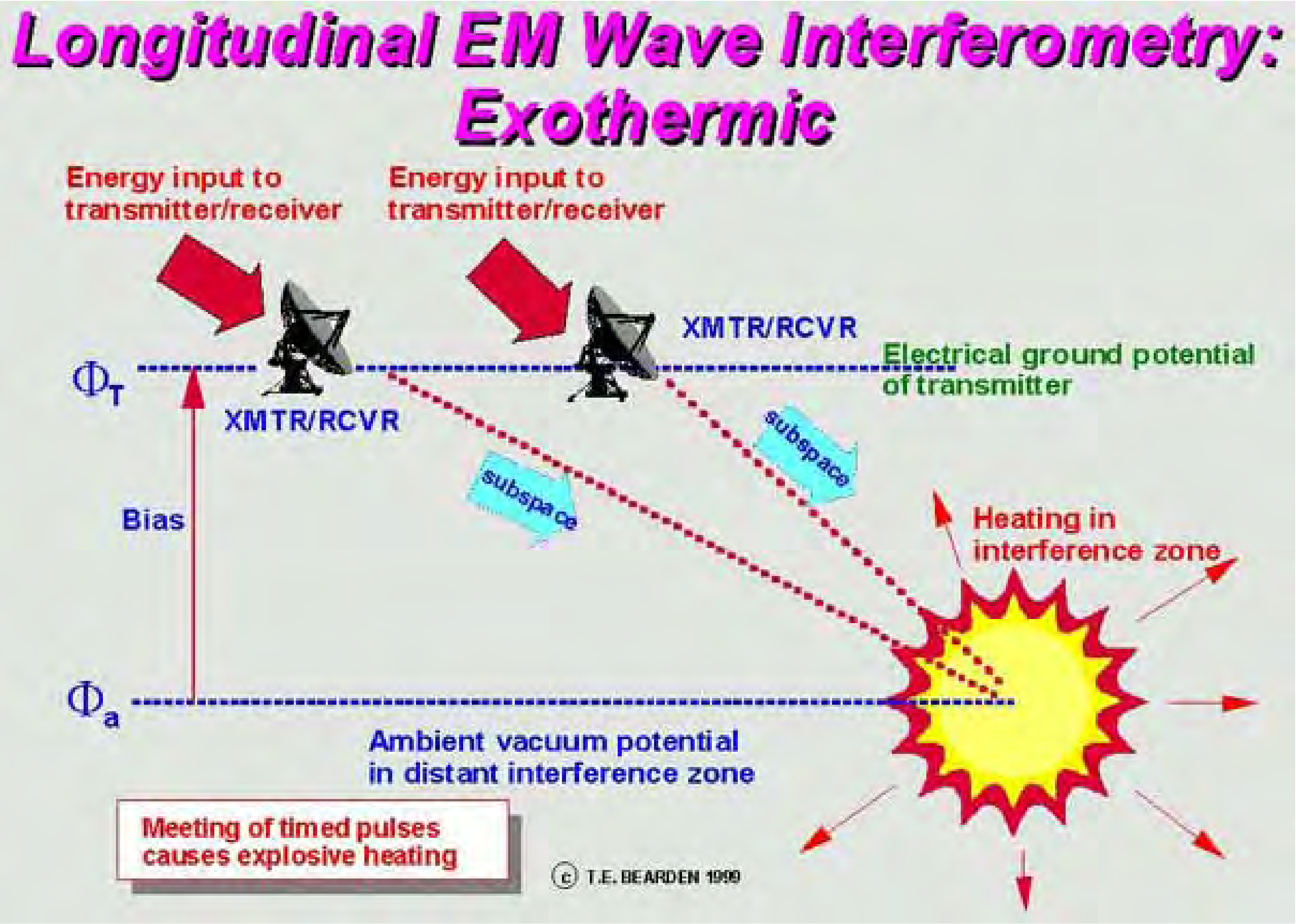

Longitudinal EM Wave Interferometry: Exothermic

Energy input to transmitter/receiver

Energy input to transmitter/receiver

XMTR/RCVR

XMTR/RCVR

Φ_T

Electrical ground potential of transmitter

subspace

subspace

Bias

Heating in interference zone

Φ_a

Ambient vacuum potential in distant interference zone

Meeting of timed pulses causes explosive heating

ⓒ T.E. BEARDEN 1999

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Help support the research

U.S. Air Attack on Libya
April 1986

- Slide 1
- Slide 2
- "Washington Post" Article
  January 22, 1989

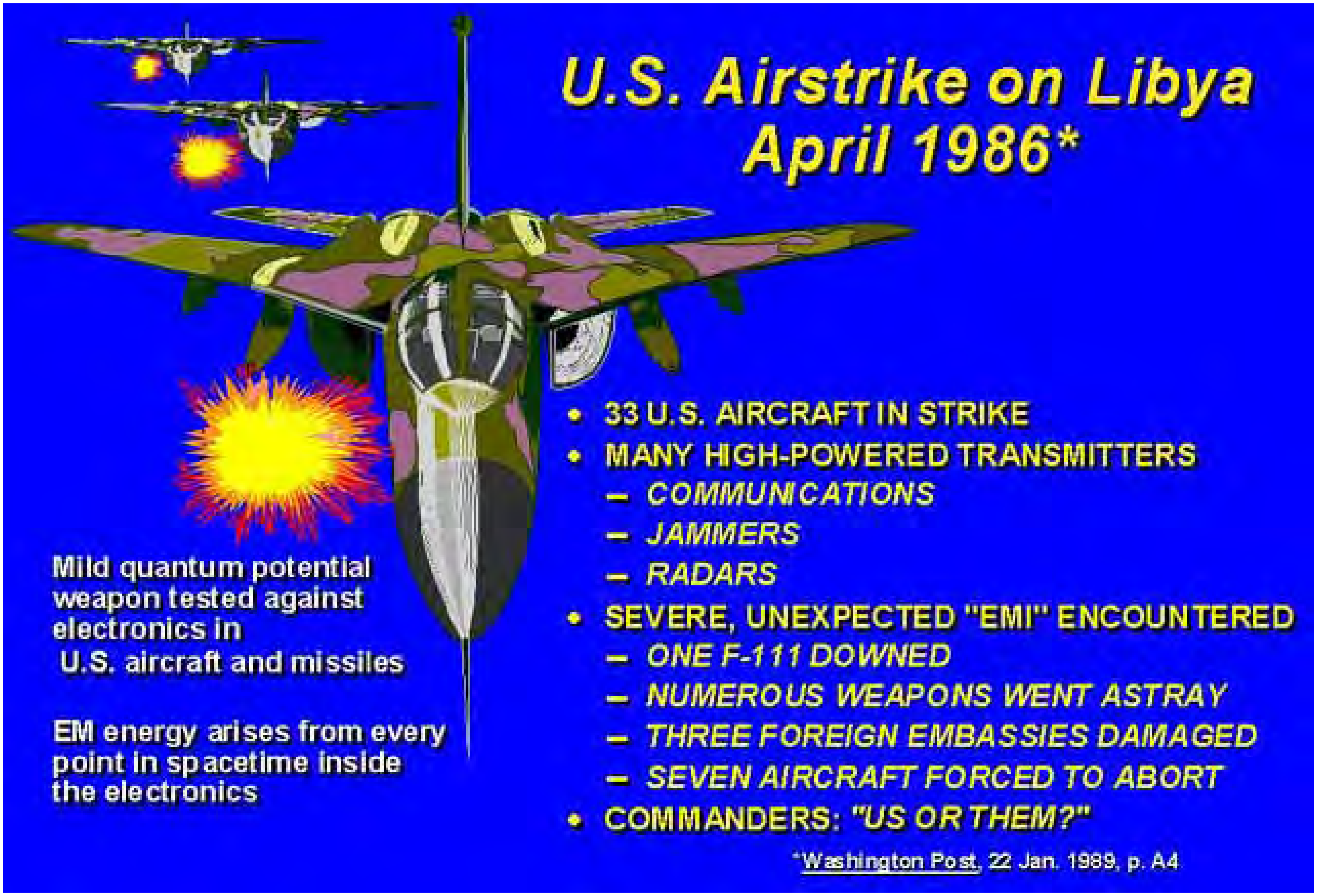

U.S. Airstrike on Libya April 1986*

- 33 U.S. AIRCRAFT IN STRIKE
- MANY HIGH-POWERED TRANSMITTERS
  - *COMMUNICATIONS*
  - *JAMMERS*
  - *RADARS*
- SEVERE, UNEXPECTED "EMI" ENCOUNTERED
  - *ONE F-111 DOWNED*
  - *NUMEROUS WEAPONS WENT ASTRAY*
  - *THREE FOREIGN EMBASSIES DAMAGED*
  - *SEVEN AIRCRAFT FORCED TO ABORT*
- COMMANDERS: *"US OR THEM?"*

Mild quantum potential weapon tested against electronics in U.S. aircraft and missiles

EM energy arises from every point in spacetime inside the electronics

*Washington Post, 22 Jan. 1989, p. A4

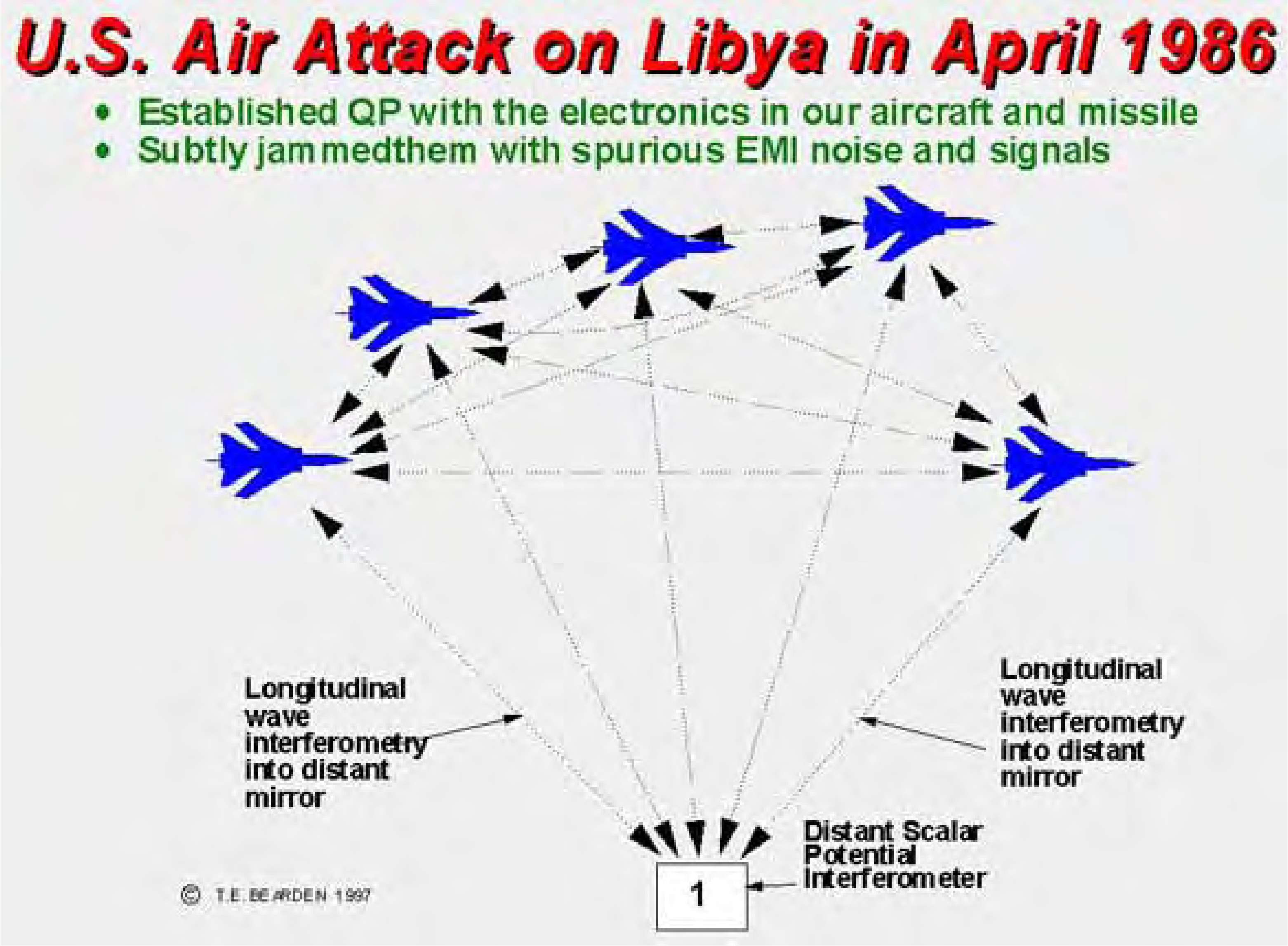

U.S. Air Attack on Libya in April 1986

- Established QP with the electronics in our aircraft and missile
- Subtly jammedthem with spurious EMI noise and signals

Longitudinal wave interferometry into distant mirror

Longitudinal wave interferometry into distant mirror

Distant Scalar Potential Interferometer

1

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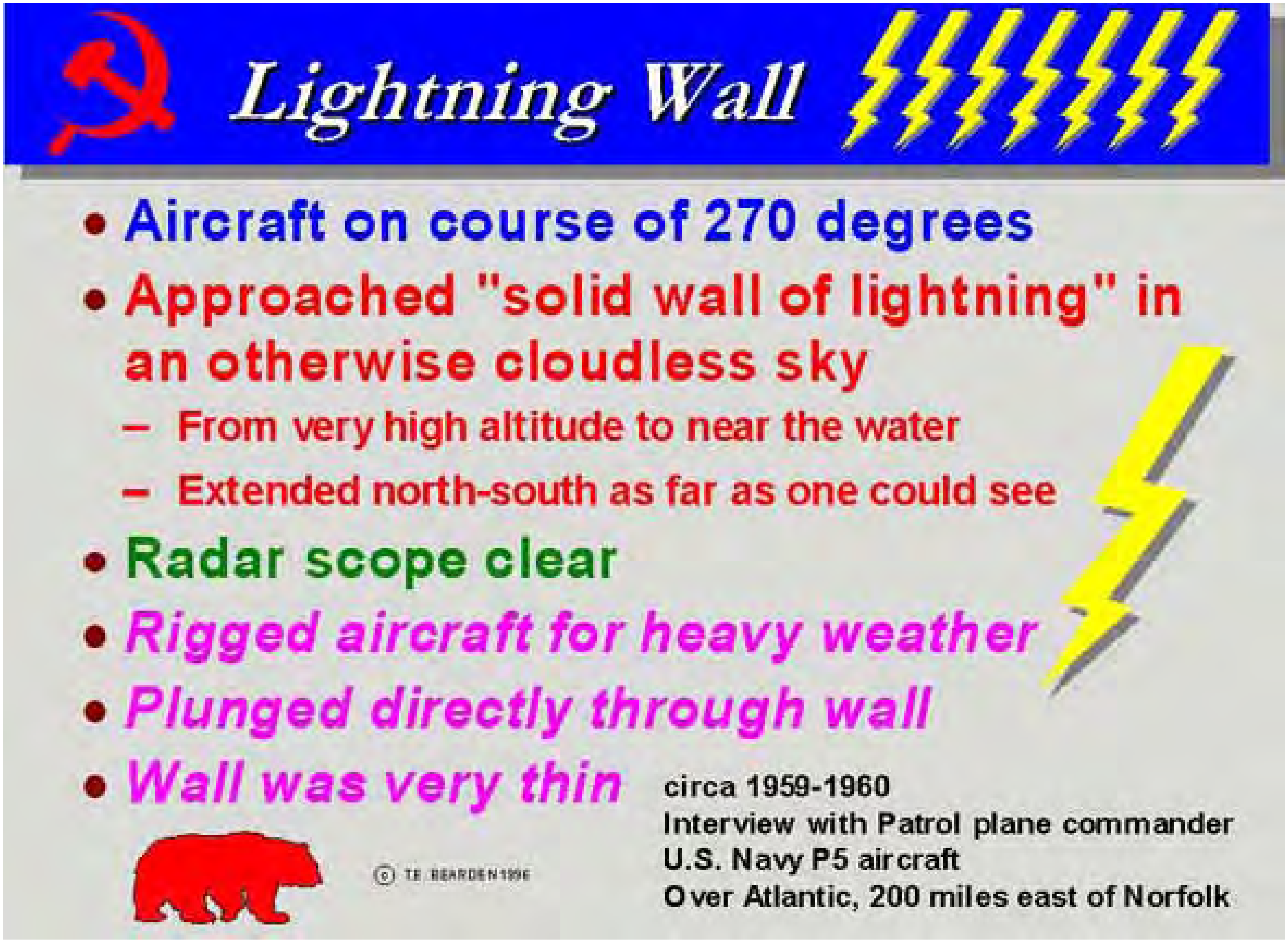

Lightning Wall

- Aircraft on course of 270 degrees
- Approached "solid wall of lightning" in an otherwise cloudless sky
  - From very high altitude to near the water
  - Extended north-south as far as one could see
- Radar scope clear
- *Rigged aircraft for heavy weather*
- *Plunged directly through wall*
- *Wall was very thin*

circa 1959-1960
Interview with Patrol plane commander
U.S. Navy P5 aircraft
Over Atlantic, 200 miles east of Norfolk

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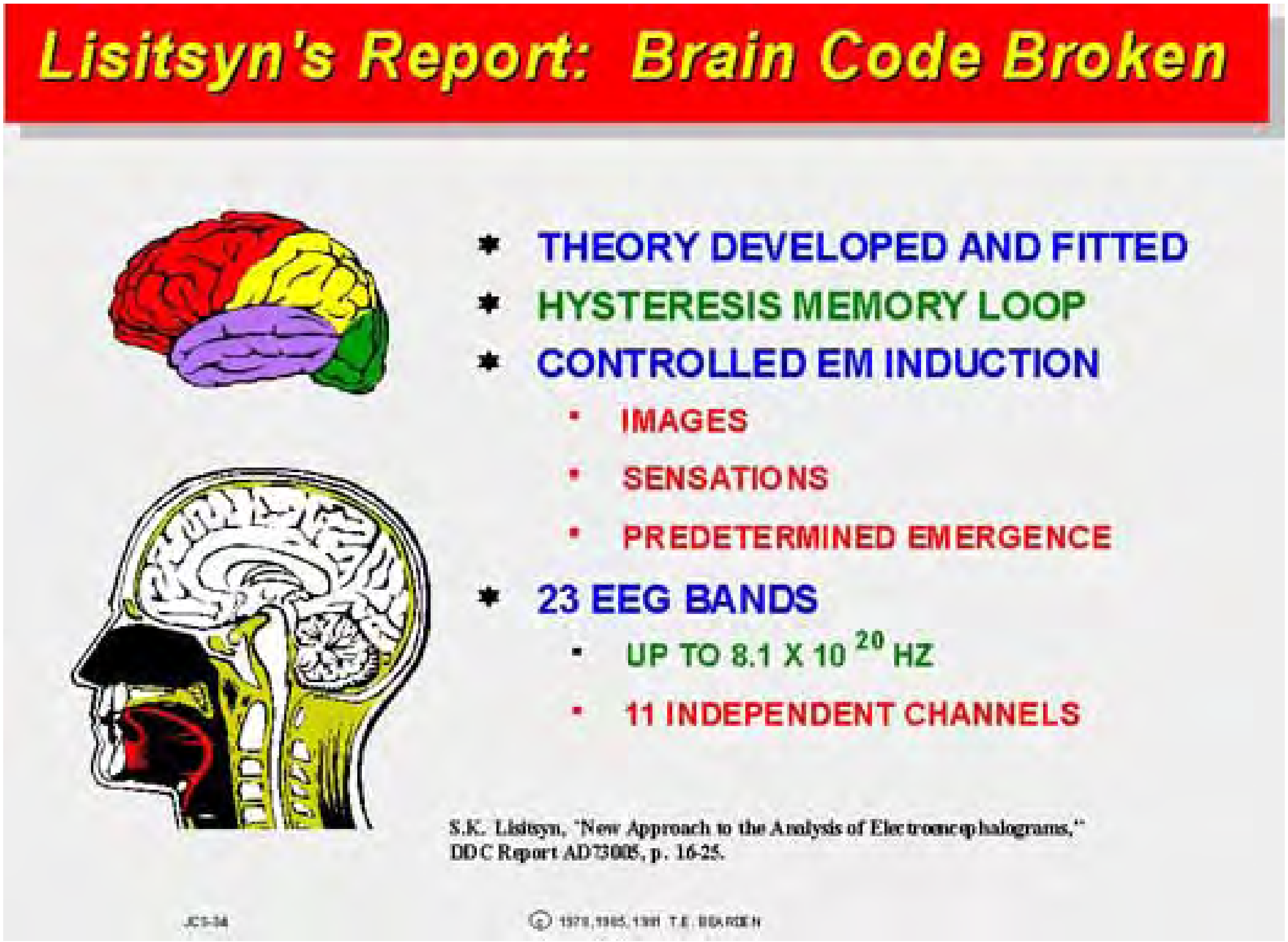

Lisitsyn's Report: Brain Code Broken

- THEORY DEVELOPED AND FITTED
- HYSTERESIS MEMORY LOOP
- CONTROLLED EM INDUCTION
  - IMAGES
  - SENSATIONS
  - PREDETERMINED EMERGENCE
- 23 EEG BANDS
  - UP TO 8.1 X 10^{20} HZ
  - 11 INDEPENDENT CHANNELS

S.K. Lisitsyn, "New Approach to the Analysis of Electroencephalograms,"
DDC Report AD73005, p. 16-25.

JCS-34

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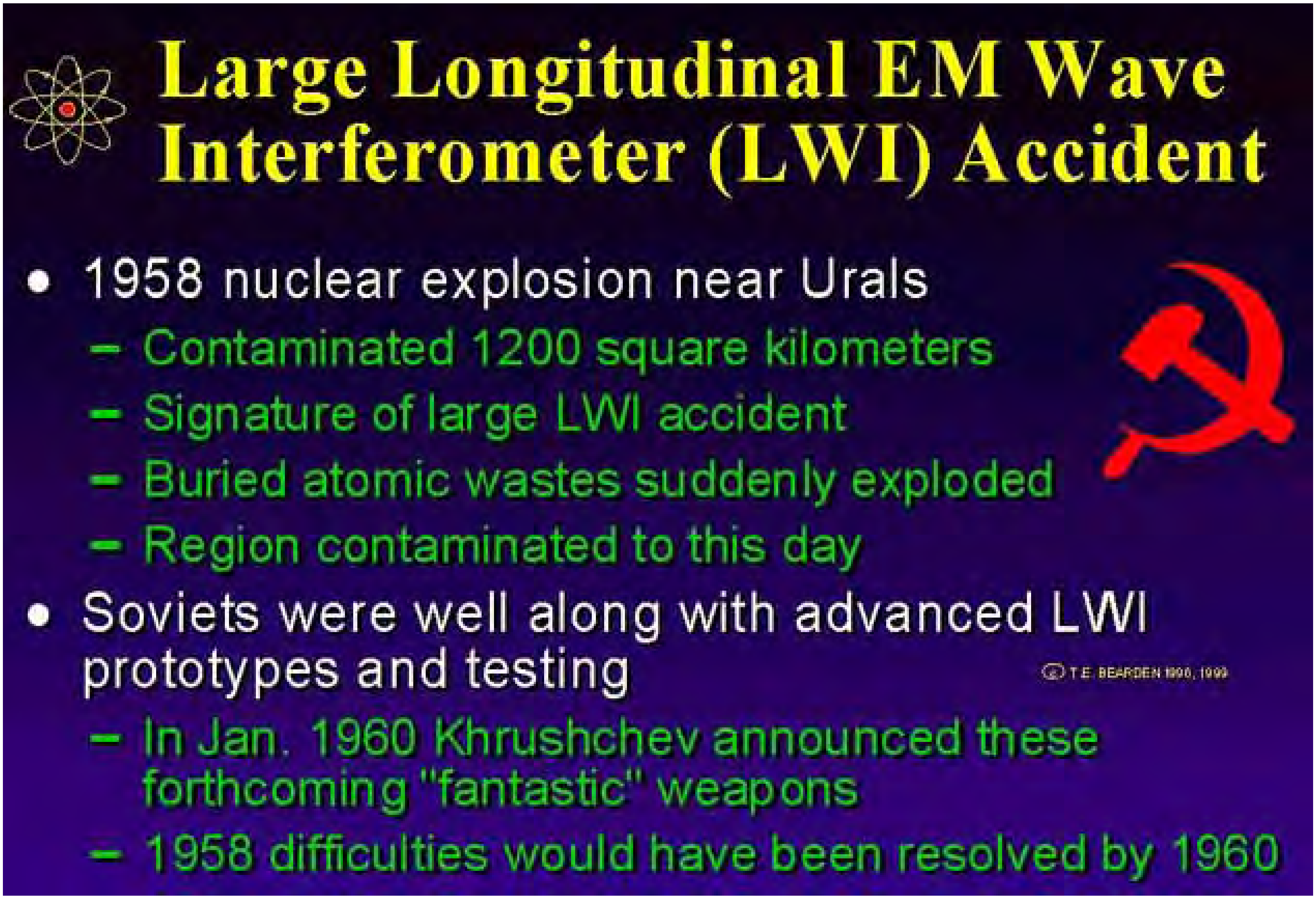

Large Longitudinal EM Wave Interferometer (LWI) Accident

- 1958 nuclear explosion near Urals
  - Contaminated 1200 square kilometers
  - Signature of large LWI accident
  - Buried atomic wastes suddenly exploded
  - Region contaminated to this day
- Soviets were well along with advanced LWI prototypes and testing
  - In Jan. 1960 Khrushchev announced these forthcoming "fantastic" weapons
  - 1958 difficulties would have been resolved by 1960

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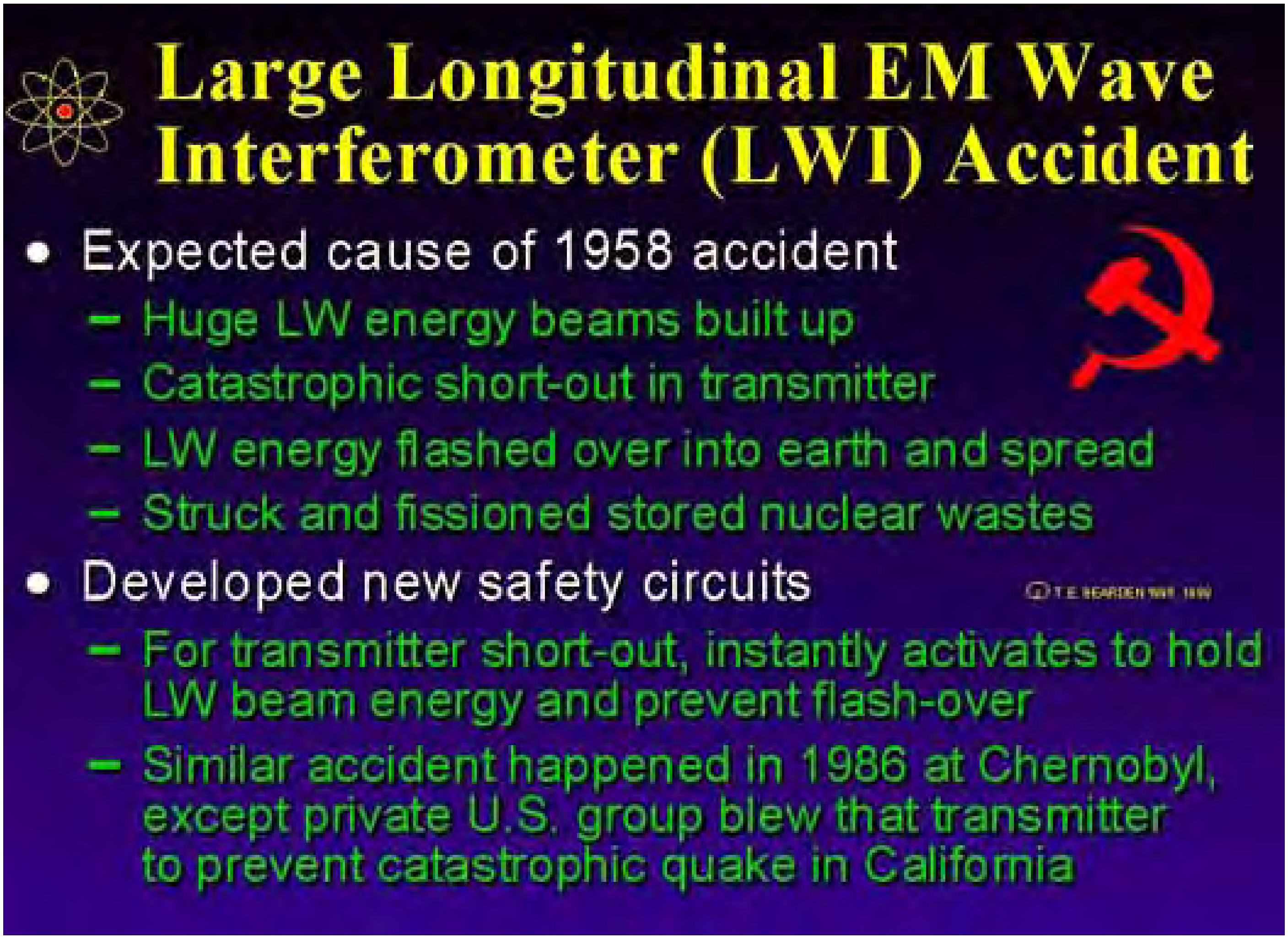

Large Longitudinal EM Wave Interferometer (LWI) Accident

- Expected cause of 1958 accident
  - Huge LW energy beams built up
  - Catastrophic short-out in transmitter
  - LW energy flashed over into earth and spread
  - Struck and fissioned stored nuclear wastes
- Developed new safety circuits
  - For transmitter short-out, instantly activates to hold LW beam energy and prevent flash-over
  - Similar accident happened in 1986 at Chernobyl, except private U.S. group blew that transmitter to prevent catastrophic quake in California

© T.E. BEARDEN [illegible]

(Use of Hidden Information Content of the Field)
(Can Provide Action-at-a-Distance)

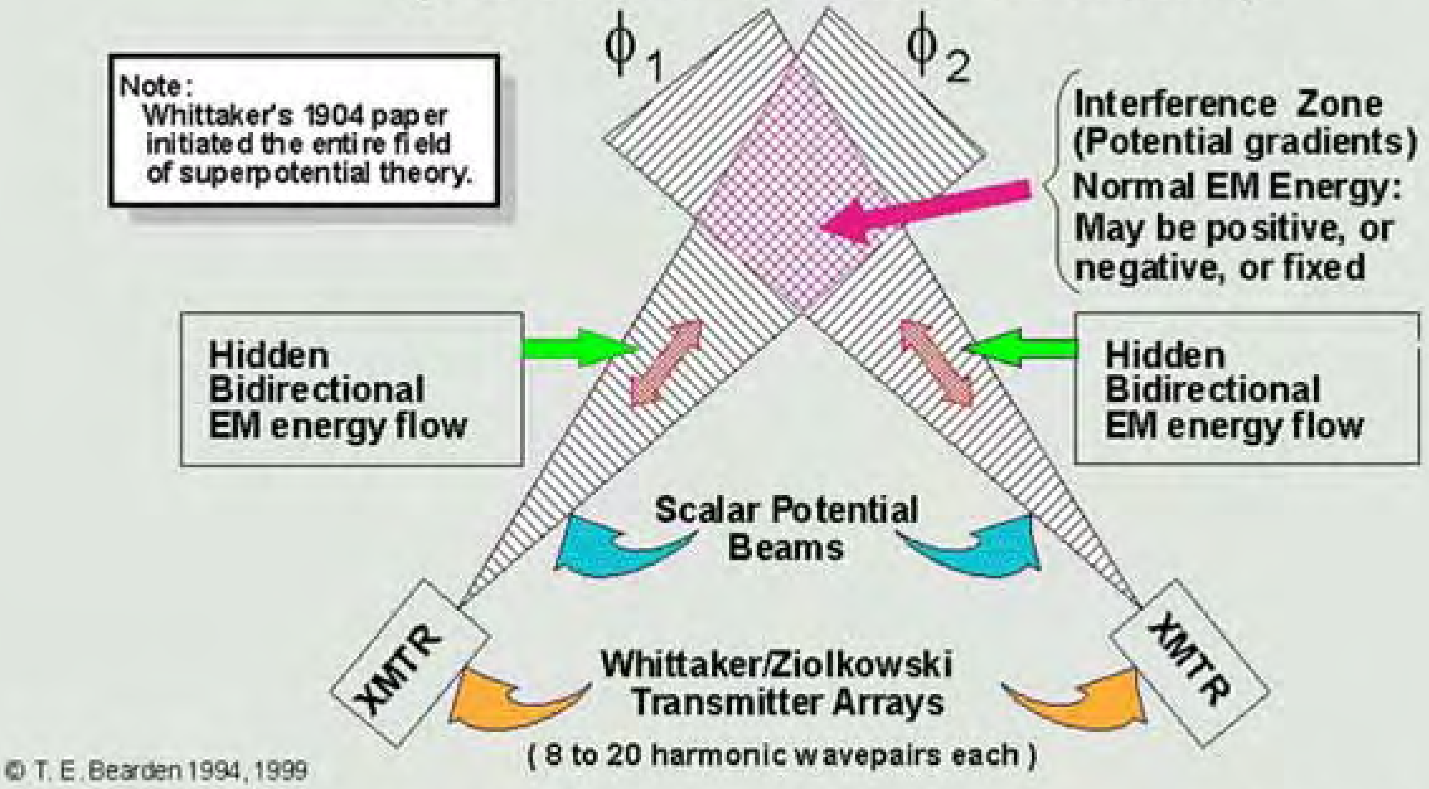
ϕ1
ϕ2
Note:
Whittaker's 1904 paper initiated the entire field of superpotential theory.
Interference Zone (Potential gradients)
Normal EM Energy: May be positive, or negative, or fixed
Hidden Bidirectional EM energy flow
Hidden Bidirectional EM energy flow
Scalar Potential Beams
XMTR
XMTR
Whittaker/Ziolkowski Transmitter Arrays
(8 to 20 harmonic wavepairs each)
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Figure 5. Scalar potential interferometry (between the two sets of bidirectional longitudinal EM wavepair functions) produces all EM force fields and waves.

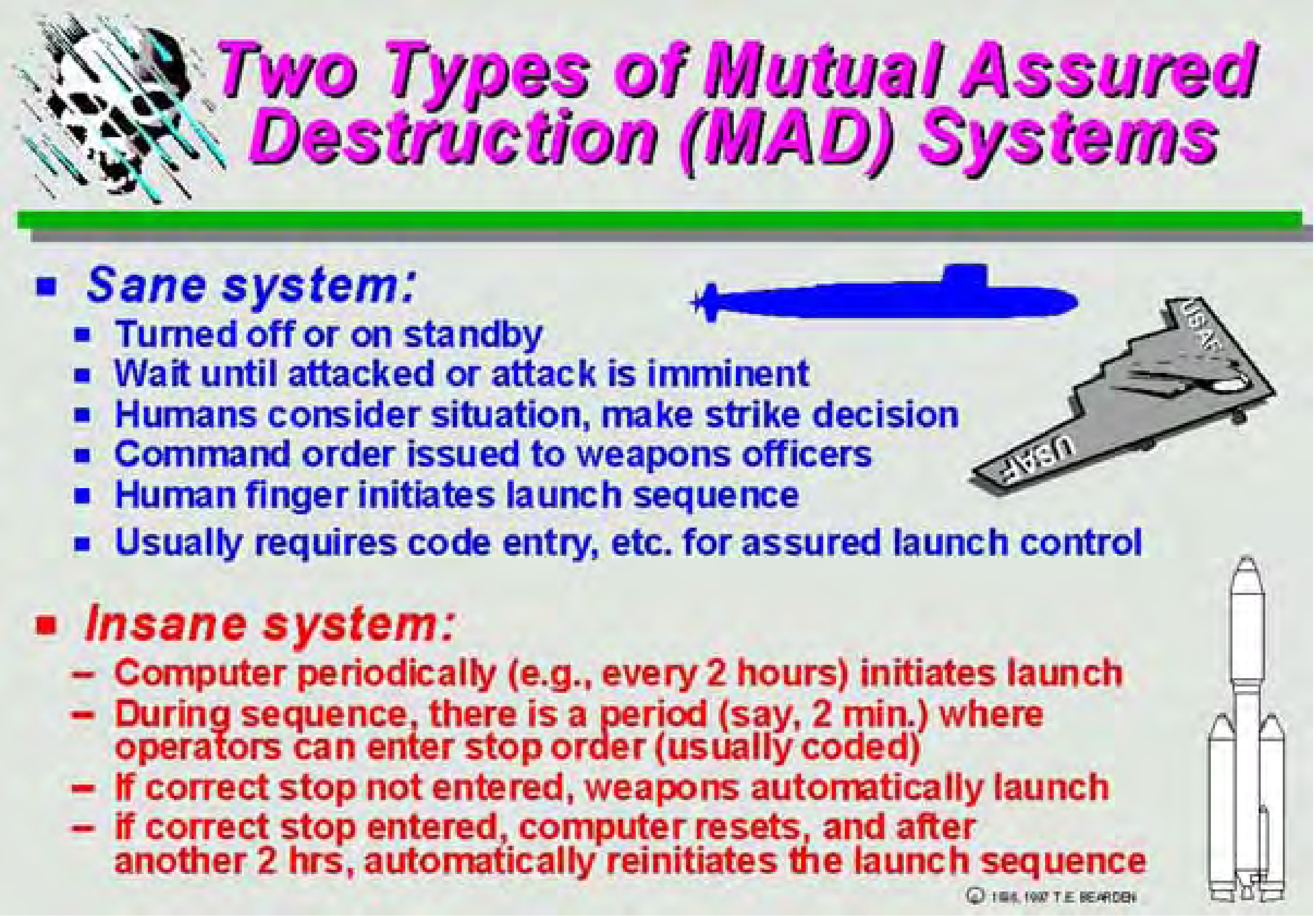

Two Types of Mutual Assured Destruction (MAD) Systems

- *Sane system:*
  - Turned off or on standby
  - Wait until attacked or attack is imminent
  - Humans consider situation, make strike decision
  - Command order issued to weapons officers
  - Human finger initiates launch sequence
  - Usually requires code entry, etc. for assured launch control
- *Insane system:*
  - Computer periodically (e.g., every 2 hours) initiates launch
  - During sequence, there is a period (say, 2 min.) where operators can enter stop order (usually coded)
  - If correct stop not entered, weapons automatically launch
  - If correct stop entered, computer resets, and after another 2 hrs, automatically reinitiates the launch sequence

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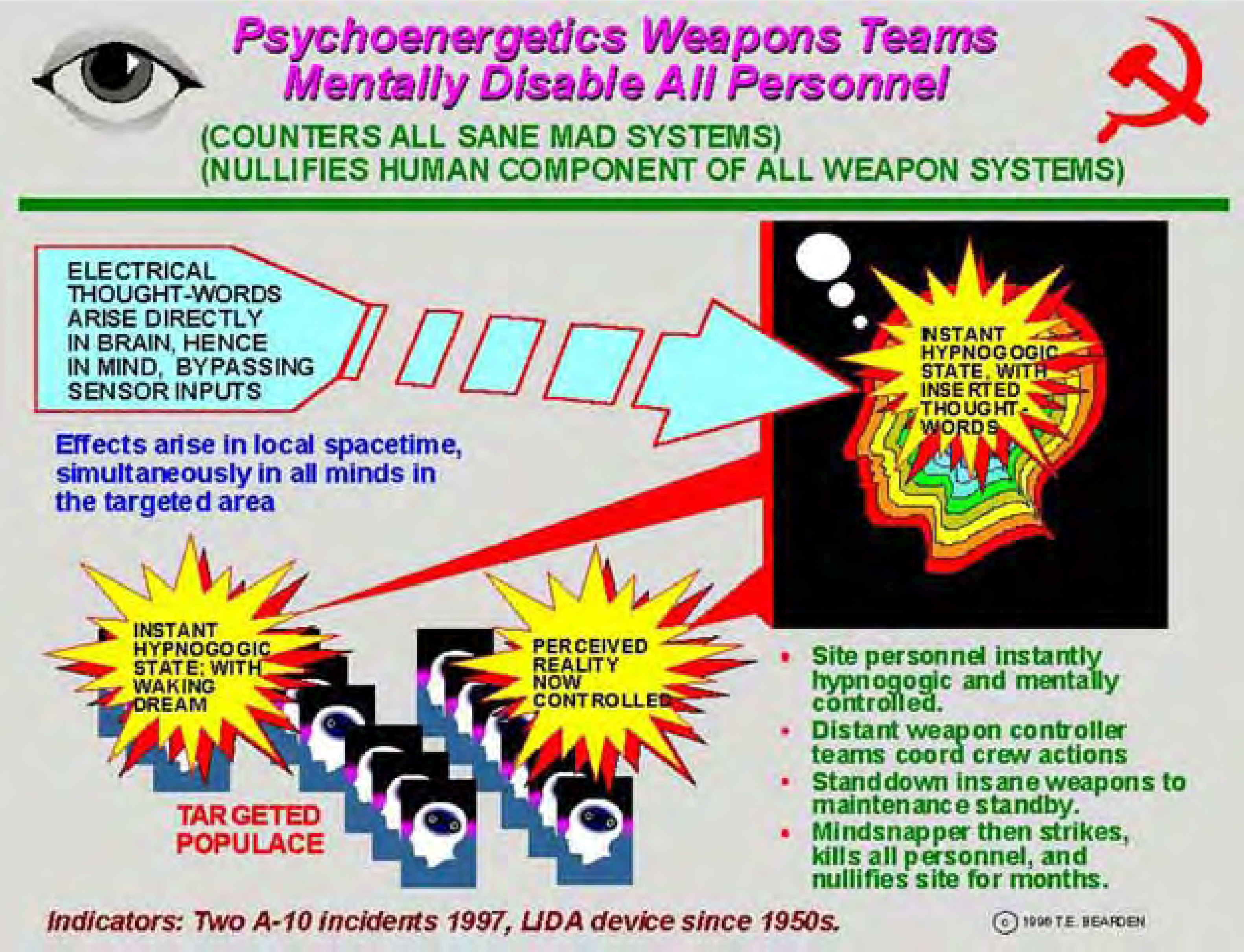

Psychoenergetics Weapons Teams Mentally Disable All Personnel

(COUNTERS ALL SANE MAD SYSTEMS)
(NULLIFIES HUMAN COMPONENT OF ALL WEAPON SYSTEMS)

ELECTRICAL THOUGHT-WORDS ARISE DIRECTLY IN BRAIN, HENCE IN MIND, BYPASSING SENSOR INPUTS

INSTANT HYPNOGOGIC STATE, WITH INSERTED THOUGHT-WORDS

Effects arise in local spacetime, simultaneously in all minds in the targeted area

INSTANT HYPNOGOGIC STATE: WITH WAKING DREAM

PERCEIVED REALITY NOW CONTROLLED

TARGETED POPULACE

- Site personnel instantly hypnogogic and mentally controlled.
- Distant weapon controller teams coord crew actions
- Standdown insane weapons to maintenance standby.
- Mindsnapper then strikes, kills all personnel, and nullifies site for months.

Indicators: Two A-10 incidents 1997, LIDA device since 1950s.

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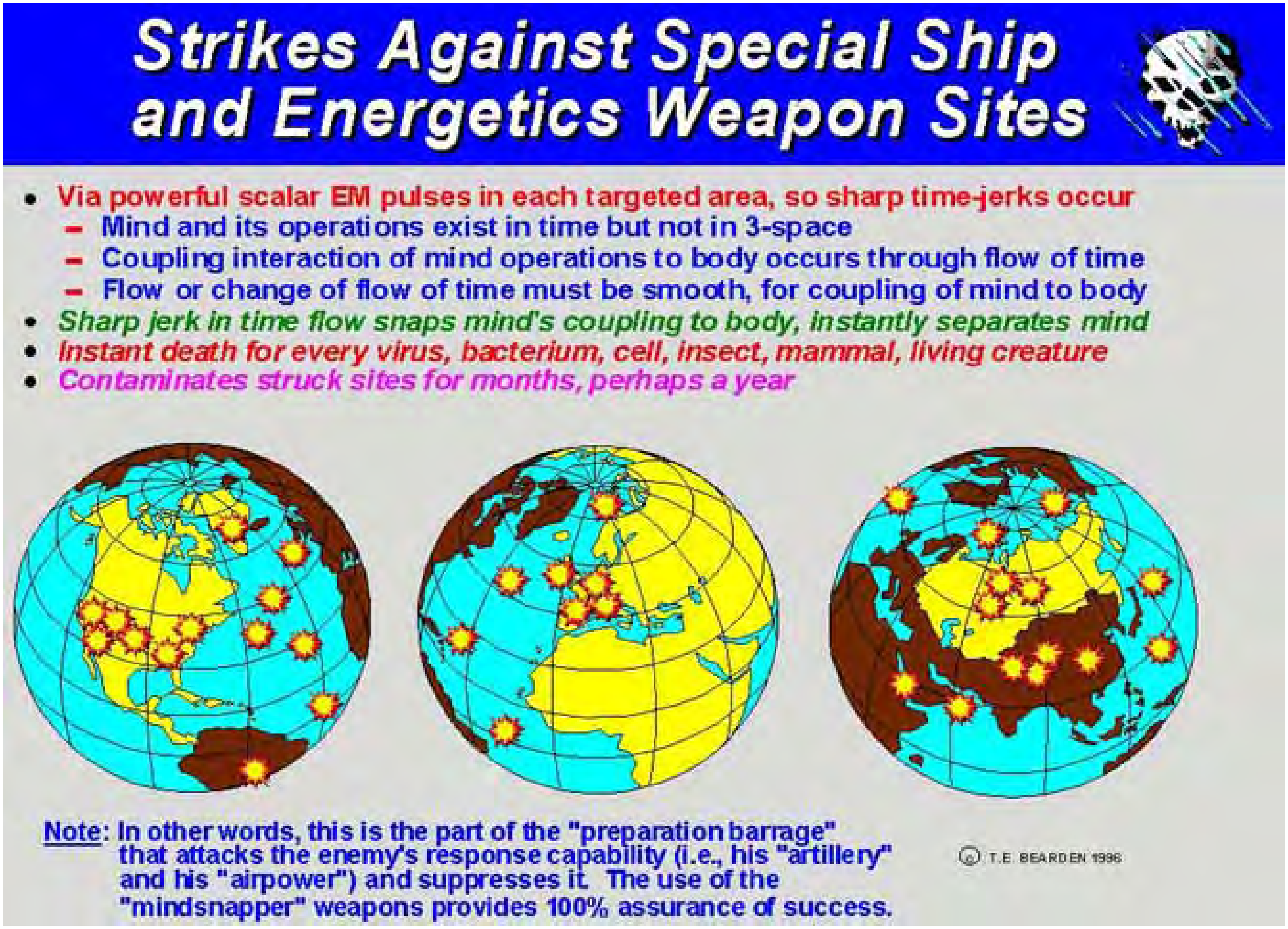

Strikes Against Special Ship and Energetics Weapon Sites

- Via powerful scalar EM pulses in each targeted area, so sharp time-jerks occur
  - Mind and its operations exist in time but not in 3-space
  - Coupling interaction of mind operations to body occurs through flow of time
  - Flow or change of flow of time must be smooth, for coupling of mind to body
- *Sharp jerk in time flow snaps mind's coupling to body, instantly separates mind*
- *Instant death for every virus, bacterium, cell, insect, mammal, living creature*
- *Contaminates struck sites for months, perhaps a year*

Note: In other words, this is the part of the "preparation barrage" that attacks the enemy's response capability (i.e., his "artillery" and his "airpower") and suppresses it. The use of the "mindsnapper" weapons provides 100% assurance of success.

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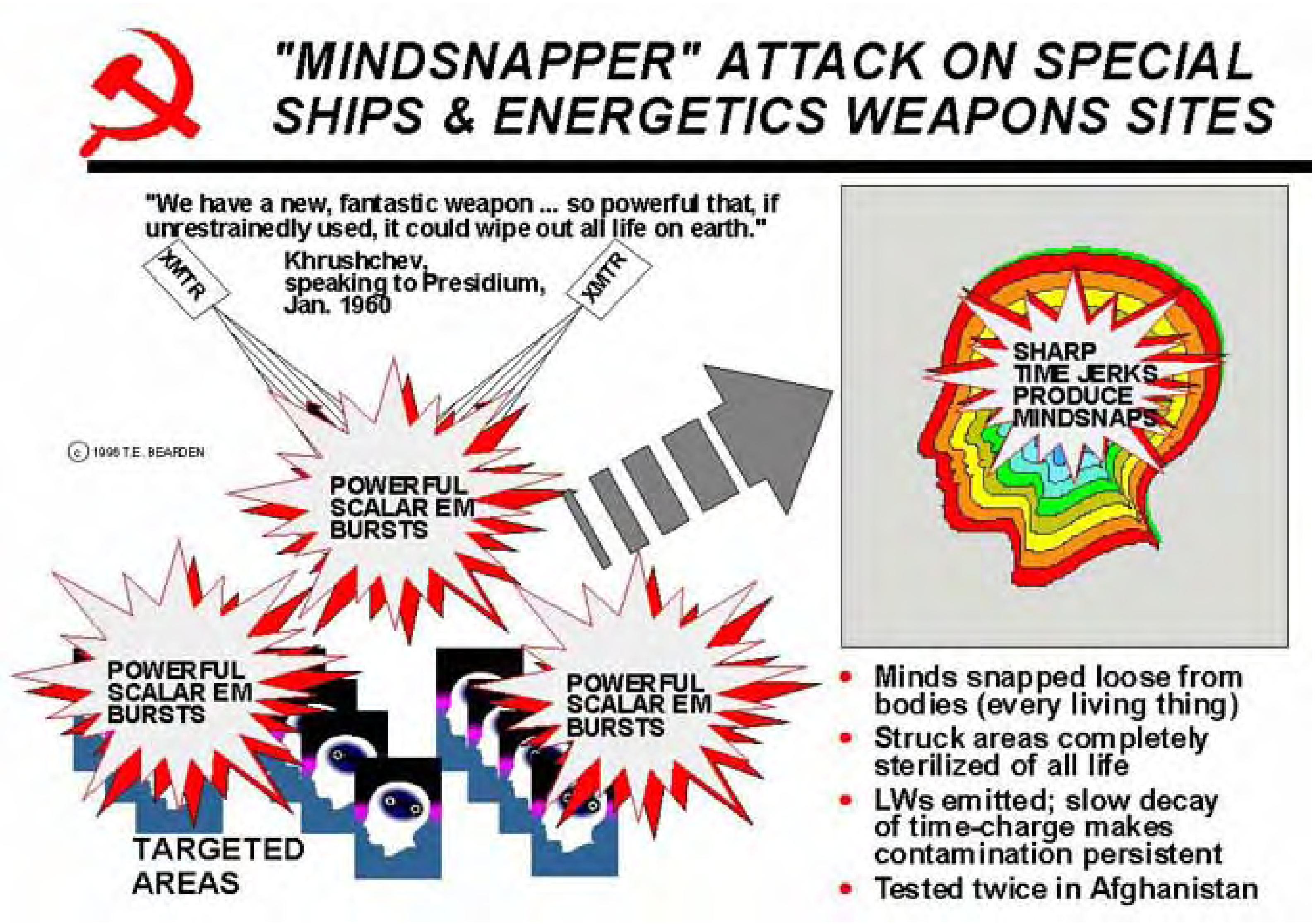

"MINDSNAPPER" ATTACK ON SPECIAL SHIPS & ENERGETICS WEAPONS SITES

"We have a new, fantastic weapon ... so powerful that, if unrestrainedly used, it could wipe out all life on earth."

Khrushchev,
speaking to Presidium,
Jan. 1960

XMTR
XMTR
POWERFUL SCALAR EM BURSTS
POWERFUL SCALAR EM BURSTS
POWERFUL SCALAR EM BURSTS
TARGETED AREAS
SHARP TIME JERKS PRODUCE MINDSNAPS

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- Minds snapped loose from bodies (every living thing)
- Struck areas completely sterilized of all life
- LWs emitted; slow decay of time-charge makes contamination persistent
- Tested twice in Afghanistan

The Tom Bearden Website

Help support the research

How Much Off Guard Are We?

- Slide 1
- Slide 2
- Slide 3
- Slide 4
- Slide 5
- Slide 6
- Slide 7

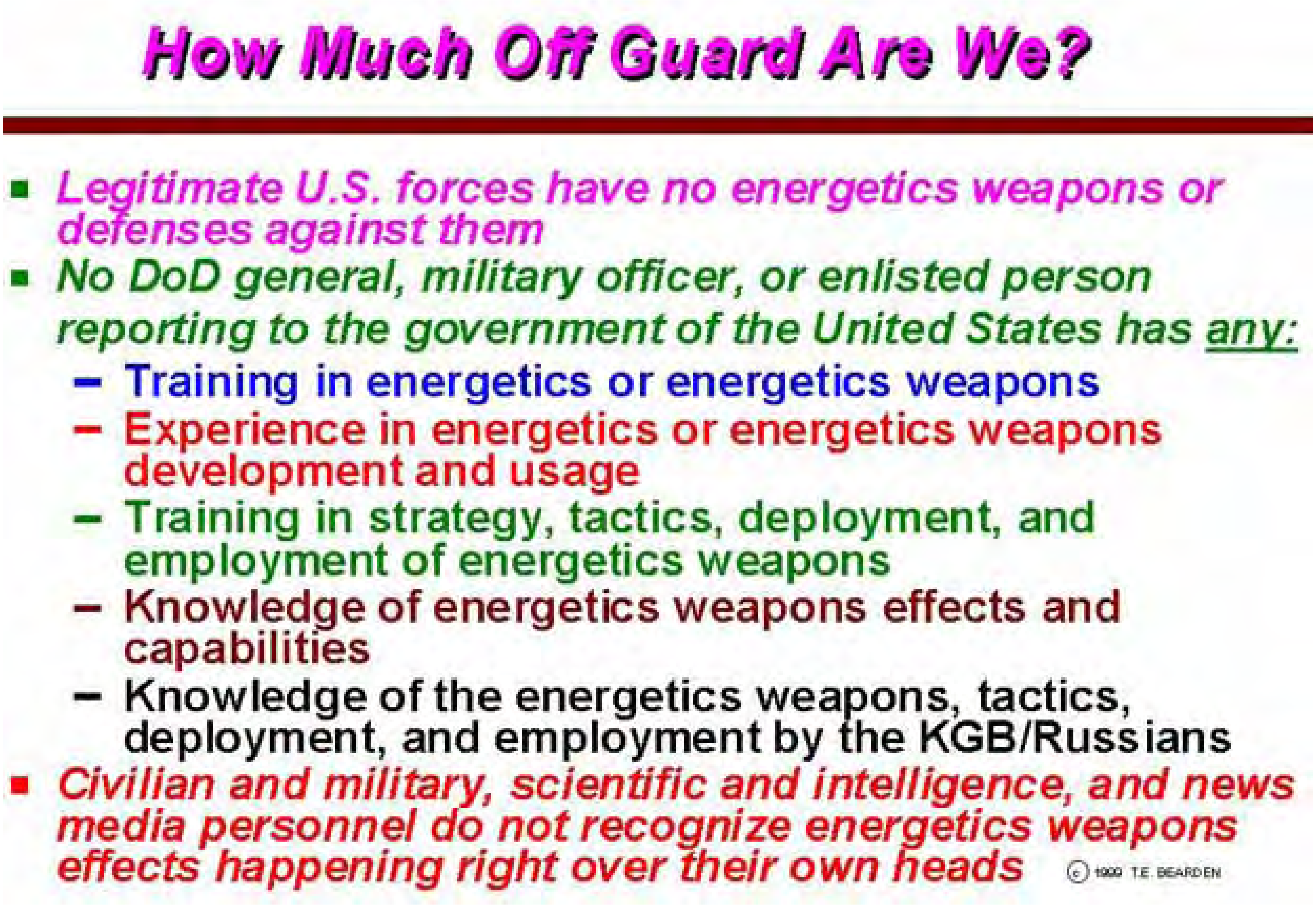

How Much Off Guard Are We?

- *Legitimate U.S. forces have no energetics weapons or defenses against them*
- *No DoD general, military officer, or enlisted person reporting to the government of the United States has any:*
  - Training in energetics or energetics weapons
  - Experience in energetics or energetics weapons development and usage
  - Training in strategy, tactics, deployment, and employment of energetics weapons
  - Knowledge of energetics weapons effects and capabilities
  - Knowledge of the energetics weapons, tactics, deployment, and employment by the KGB/Russians
- *Civilian and military, scientific and intelligence, and news media personnel do not recognize energetics weapons effects happening right over their own heads*

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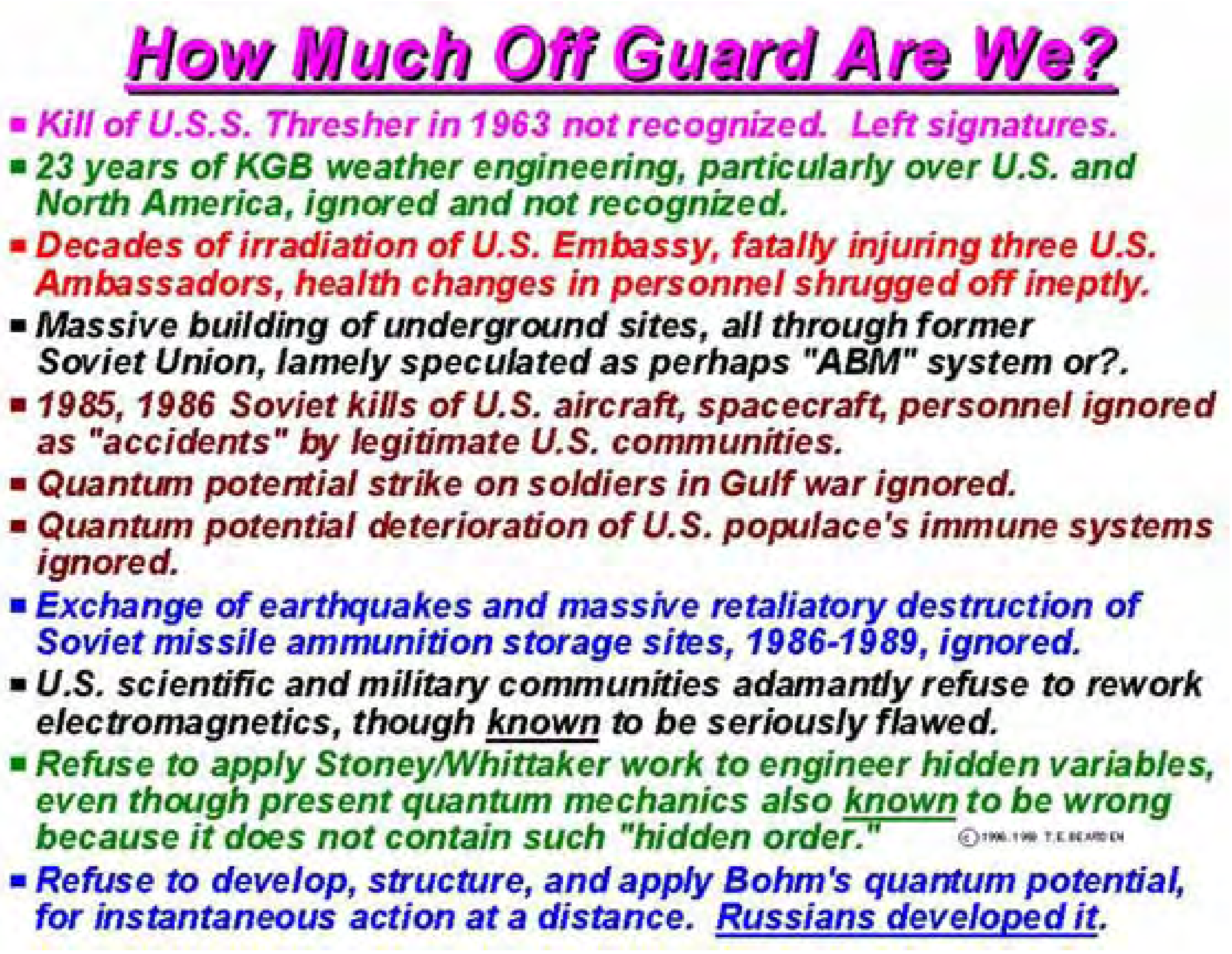

How Much Off Guard Are We?

- *Kill of U.S.S. Thresher in 1963 not recognized. Left signatures.*
- *23 years of KGB weather engineering, particularly over U.S. and North America, ignored and not recognized.*
- *Decades of irradiation of U.S. Embassy, fatally injuring three U.S. Ambassadors, health changes in personnel shrugged off ineptly.*
- *Massive building of underground sites, all through former Soviet Union, lamely speculated as perhaps "ABM" system or?.*
- *1985, 1986 Soviet kills of U.S. aircraft, spacecraft, personnel ignored as "accidents" by legitimate U.S. communities.*
- *Quantum potential strike on soldiers in Gulf war ignored.*
- *Quantum potential deterioration of U.S. populace's immune systems ignored.*
- *Exchange of earthquakes and massive retaliatory destruction of Soviet missile ammunition storage sites, 1986-1989, ignored.*
- *U.S. scientific and military communities adamantly refuse to rework electromagnetics, though known to be seriously flawed.*
- *Refuse to apply Stoney/Whittaker work to engineer hidden variables, even though present quantum mechanics also known to be wrong because it does not contain such "hidden order."*
- *Refuse to develop, structure, and apply Bohm's quantum potential, for instantaneous action at a distance. Russians developed it.*

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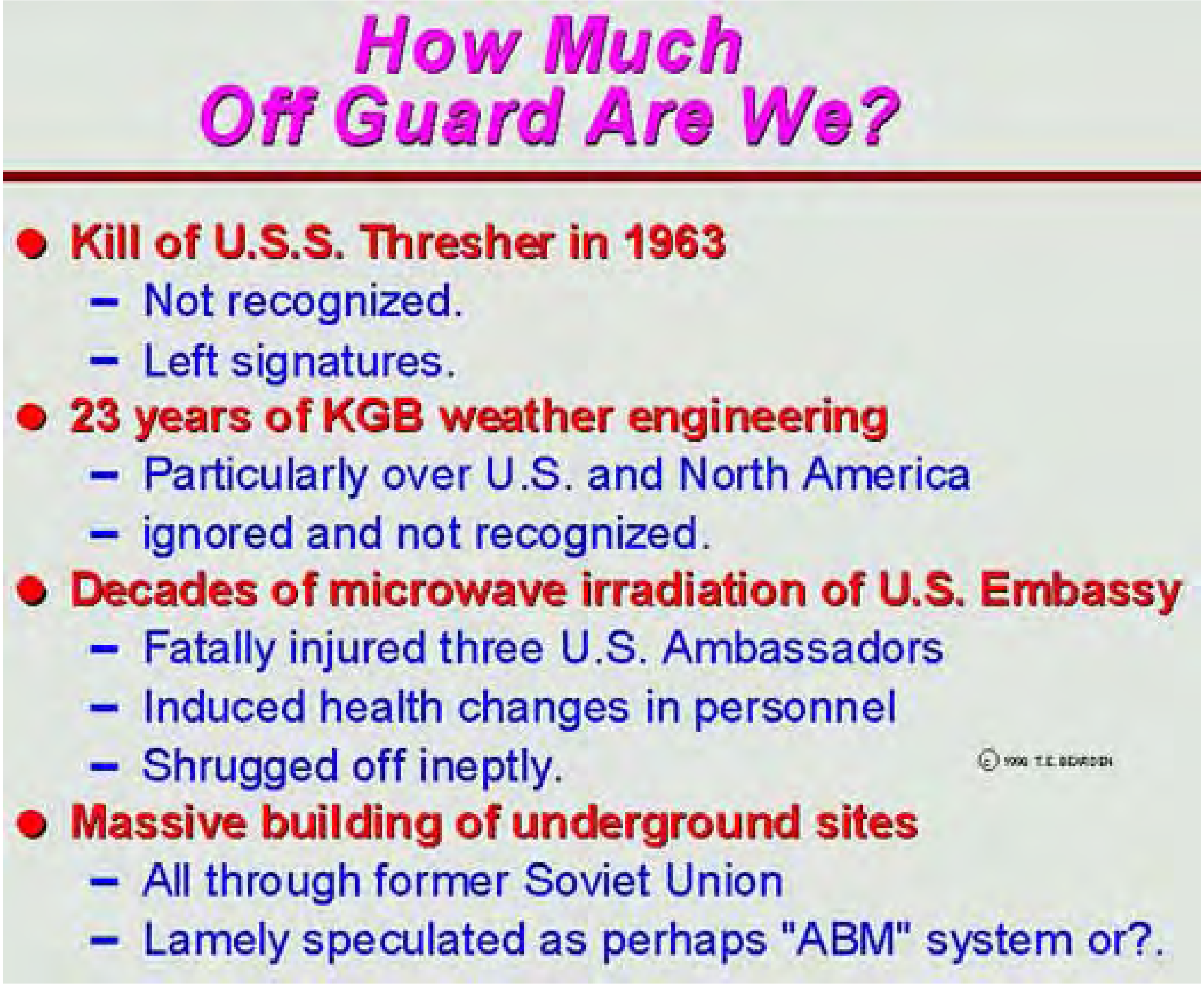

How Much Off Guard Are We?

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    - Left signatures.
- 23 years of KGB weather engineering
    - Particularly over U.S. and North America
    - ignored and not recognized.
- Decades of microwave irradiation of U.S. Embassy
    - Fatally injured three U.S. Ambassadors
    - Induced health changes in personnel
    - Shrugged off ineptly.
- Massive building of underground sites
    - All through former Soviet Union
    - Lamely speculated as perhaps "ABM" system or?.

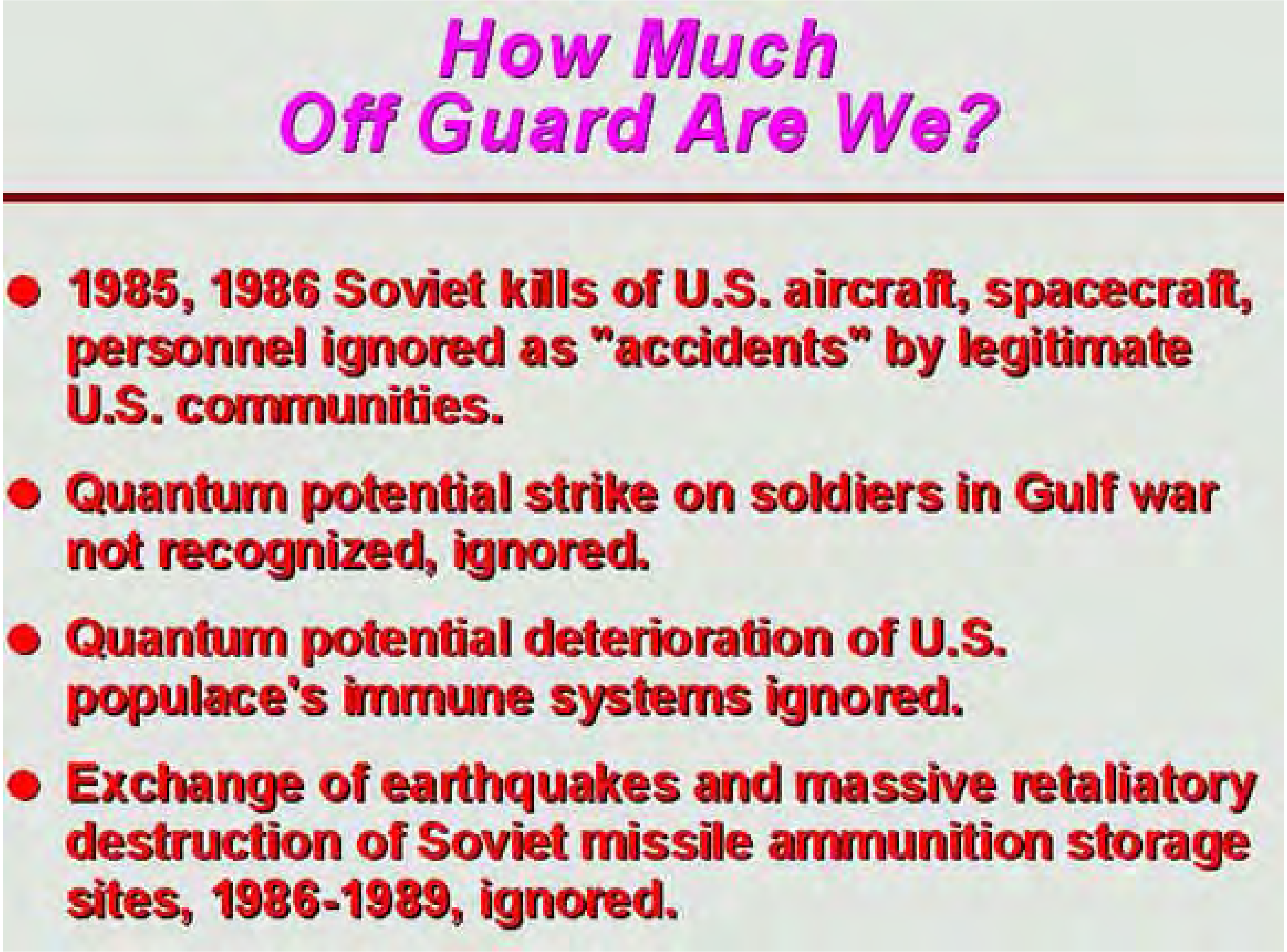

How Much Off Guard Are We?

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- Quantum potential strike on soldiers in Gulf war not recognized, ignored.
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- Exchange of earthquakes and massive retaliatory destruction of Soviet missile ammunition storage sites, 1986-1989, ignored.

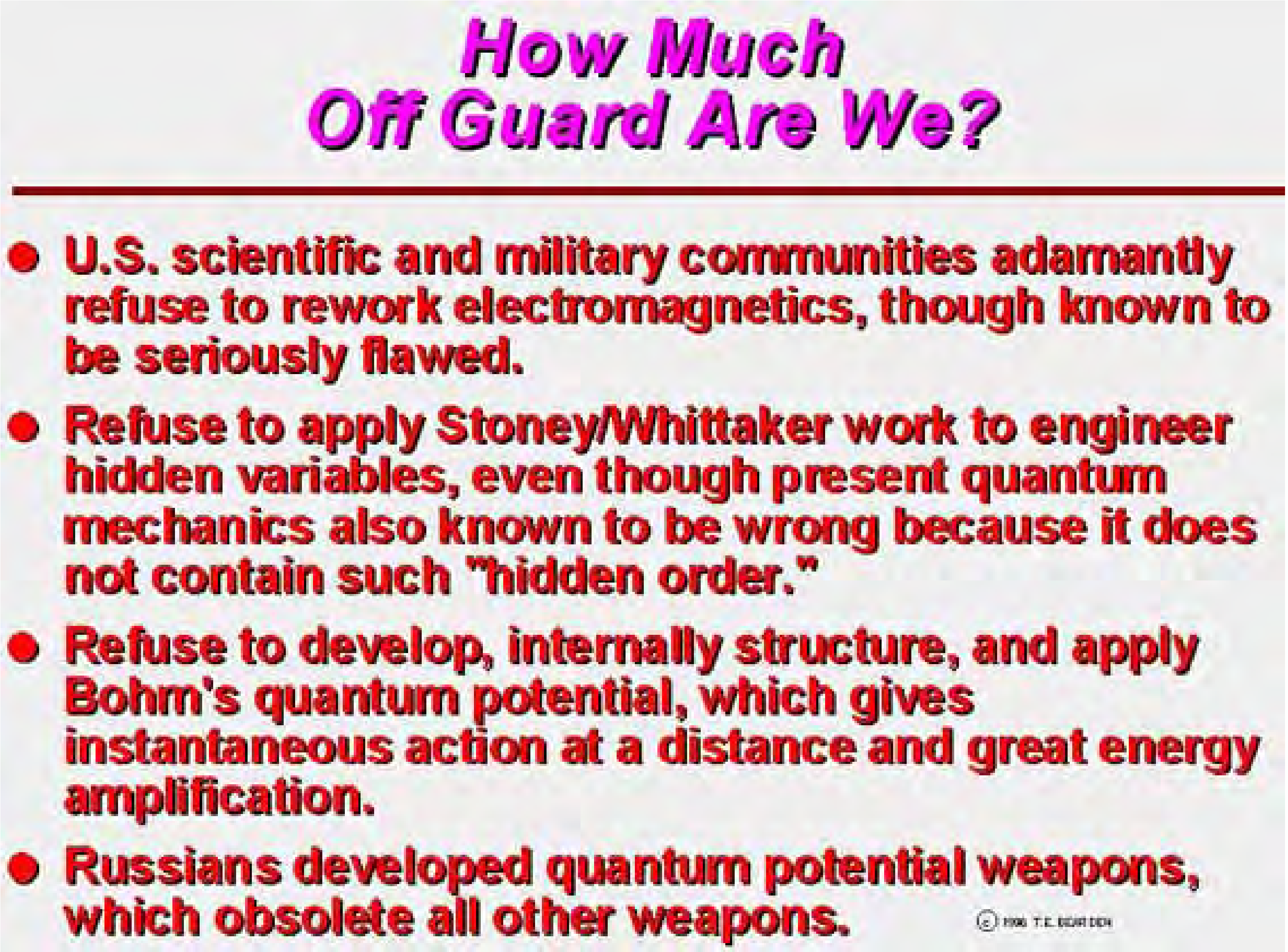

How Much Off Guard Are We?

- U.S. scientific and military communities adamantly refuse to rework electromagnetics, though known to be seriously flawed.
- Refuse to apply Stoney/Whittaker work to engineer hidden variables, even though present quantum mechanics also known to be wrong because it does not contain such "hidden order."
- Refuse to develop, internally structure, and apply Bohm's quantum potential, which gives instantaneous action at a distance and great energy amplification.
- Russians developed quantum potential weapons, which obsolete all other weapons.

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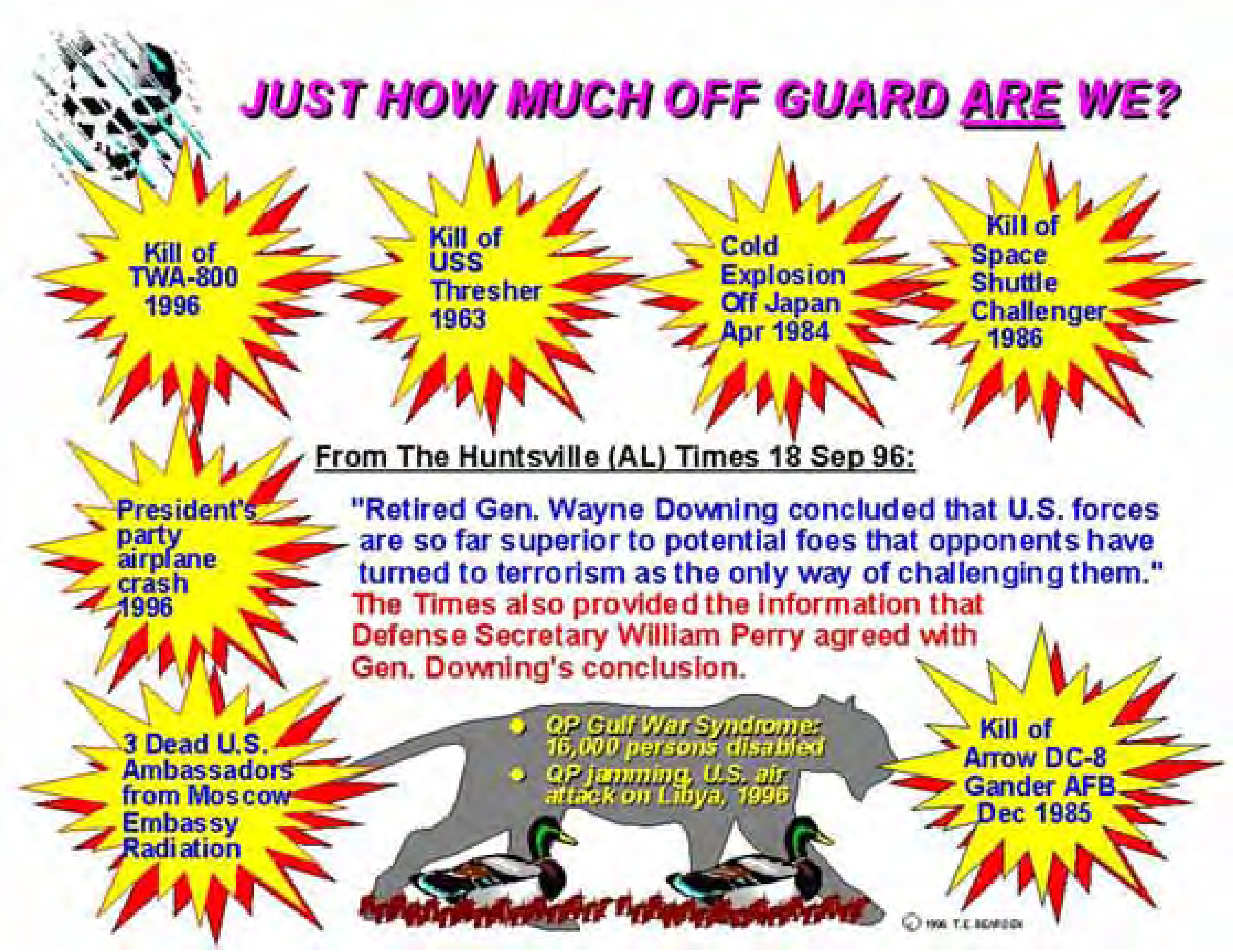

JUST HOW MUCH OFF GUARD ARE WE?

Kill of
TWA-800
1996

Kill of
USS
Thresher
1963

Cold
Explosion
Off Japan
Apr 1984

Kill of
Space
Shuttle
Challenger
1986

President's
party
airplane
crash
1996

From The Huntsville (AL) Times 18 Sep 96:

"Retired Gen. Wayne Downing concluded that U.S. forces are so far superior to potential foes that opponents have turned to terrorism as the only way of challenging them."

The Times also provided the information that Defense Secretary William Perry agreed with Gen. Downing's conclusion.

3 Dead U.S.
Ambassadors
from Moscow
Embassy
Radiation

- QP Gulf War Syndrome: 16,000 persons disabled
- QP jamming, U.S. air attack on Libya, 1996

Kill of
Arrow DC-8
Gander AFB
Dec 1985

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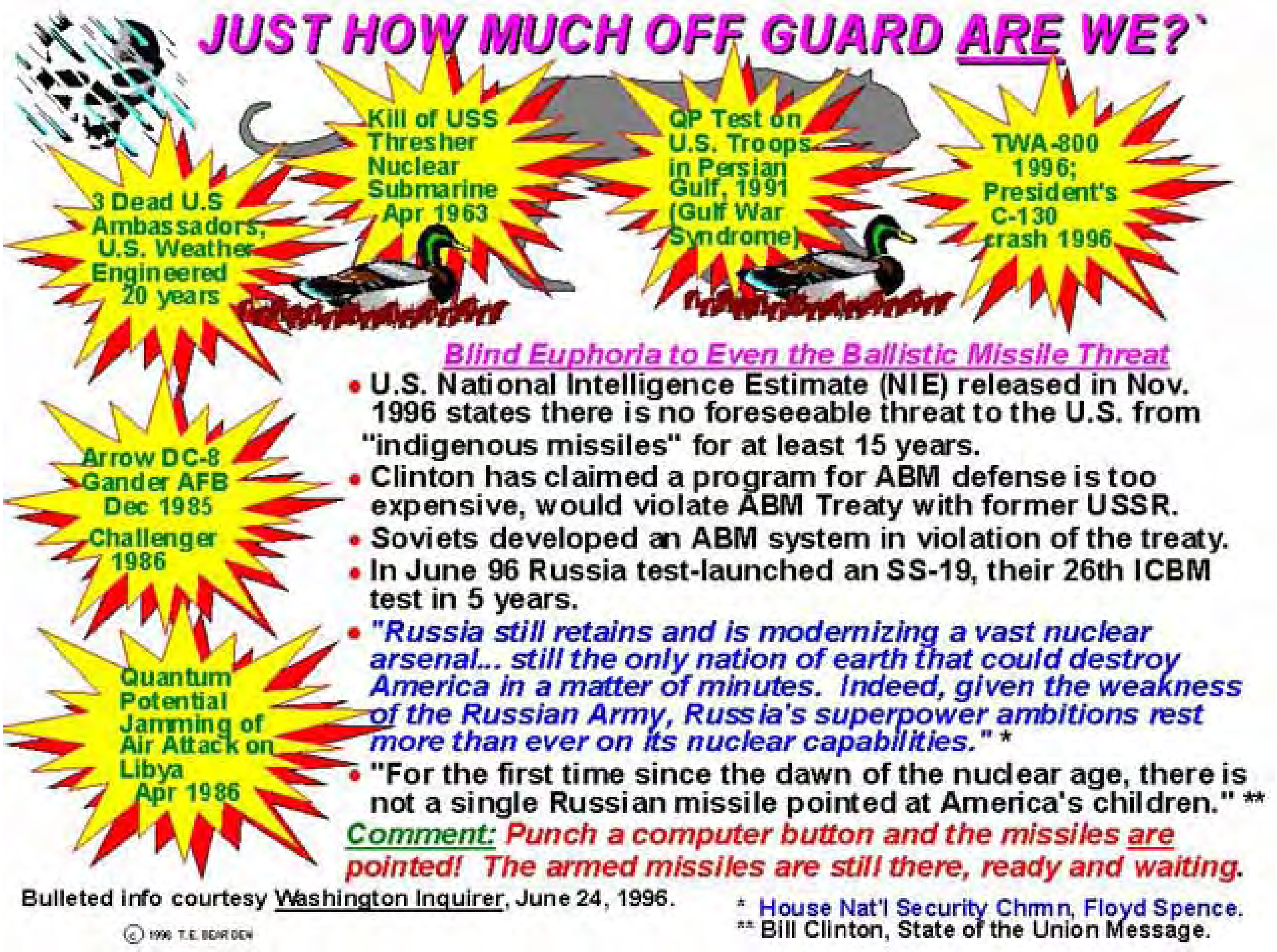

JUST HOW MUCH OFF GUARD ARE WE?

3 Dead U.S Ambassadors, U.S. Weather Engineered 20 years

Kill of USS Thresher Nuclear Submarine Apr 1963

QP Test on U.S. Troops in Persian Gulf, 1991 (Gulf War Syndrome)

TWA-800 1996; President's C-130 crash 1996

Arrow DC-8 Gander AFB Dec 1985

Challenger 1986

Quantum Potential Jamming of Air Attack on Libya Apr 1986

Blind Euphoria to Even the Ballistic Missile Threat

- U.S. National Intelligence Estimate (NIE) released in Nov. 1996 states there is no foreseeable threat to the U.S. from "indigenous missiles" for at least 15 years.
- Clinton has claimed a program for ABM defense is too expensive, would violate ABM Treaty with former USSR.
- Soviets developed an ABM system in violation of the treaty.
- In June 96 Russia test-launched an SS-19, their 26th ICBM test in 5 years.
- *"Russia still retains and is modernizing a vast nuclear arsenal... still the only nation of earth that could destroy America in a matter of minutes. Indeed, given the weakness of the Russian Army, Russia's superpower ambitions rest more than ever on its nuclear capabilities."* *
- "For the first time since the dawn of the nuclear age, there is not a single Russian missile pointed at America's children." **

Comment: Punch a computer button and the missiles are pointed! The armed missiles are still there, ready and waiting.

Bulleted info courtesy Washington Inquirer, June 24, 1996.

* House Nat'l Security Chmn, Floyd Spence.
** Bill Clinton, State of the Union Message.

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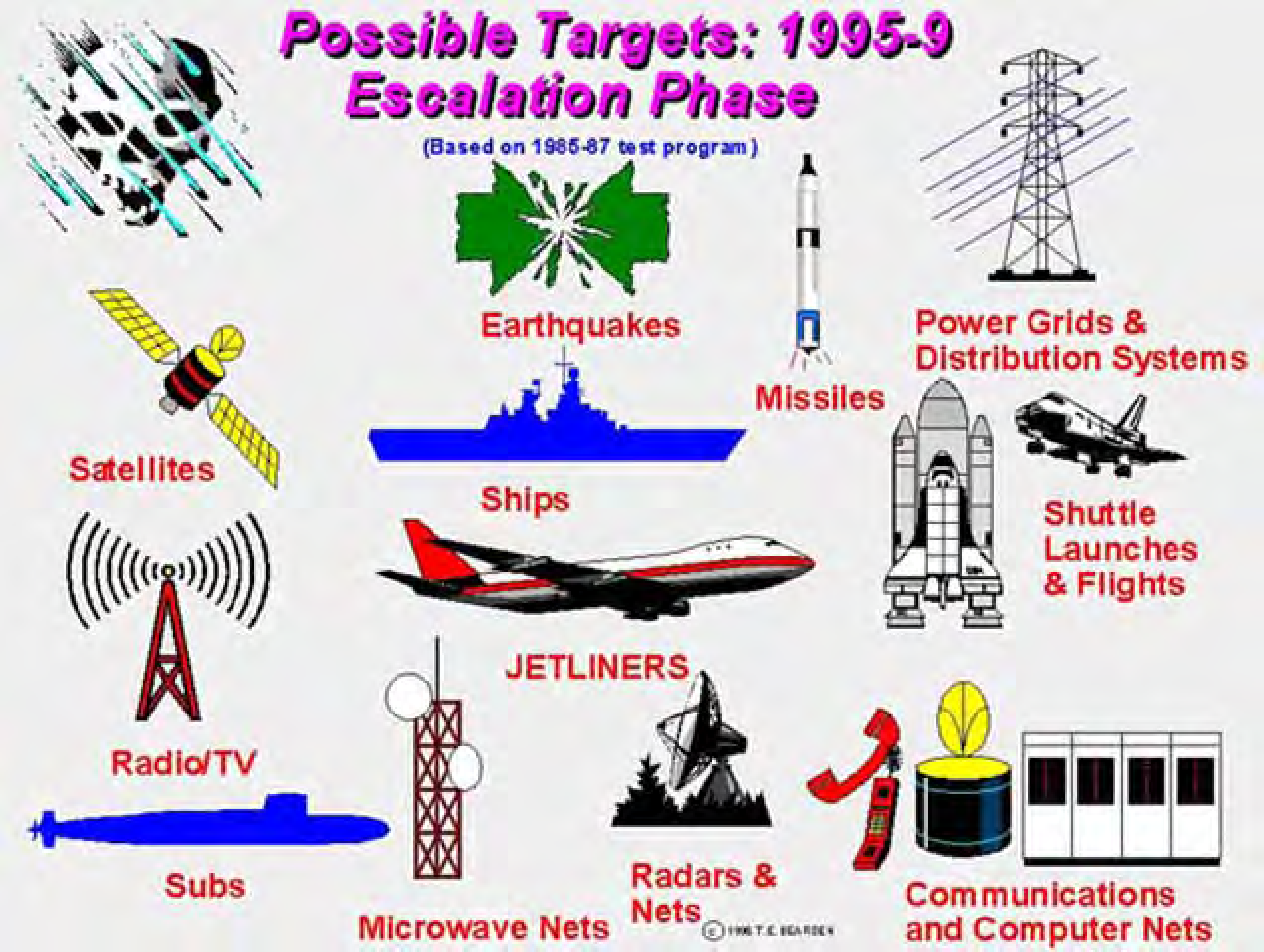
Possible Targets: 1995-9
Escalation Phase
(Based on 1985-87 test program)
Earthquakes
Missiles
Power Grids &
Distribution Systems
Satellites
Ships
Shuttle
Launches
& Flights
JETLINERS
Radio/TV
Subs
Microwave Nets
Radars &
Nets
Communications
and Computer Nets

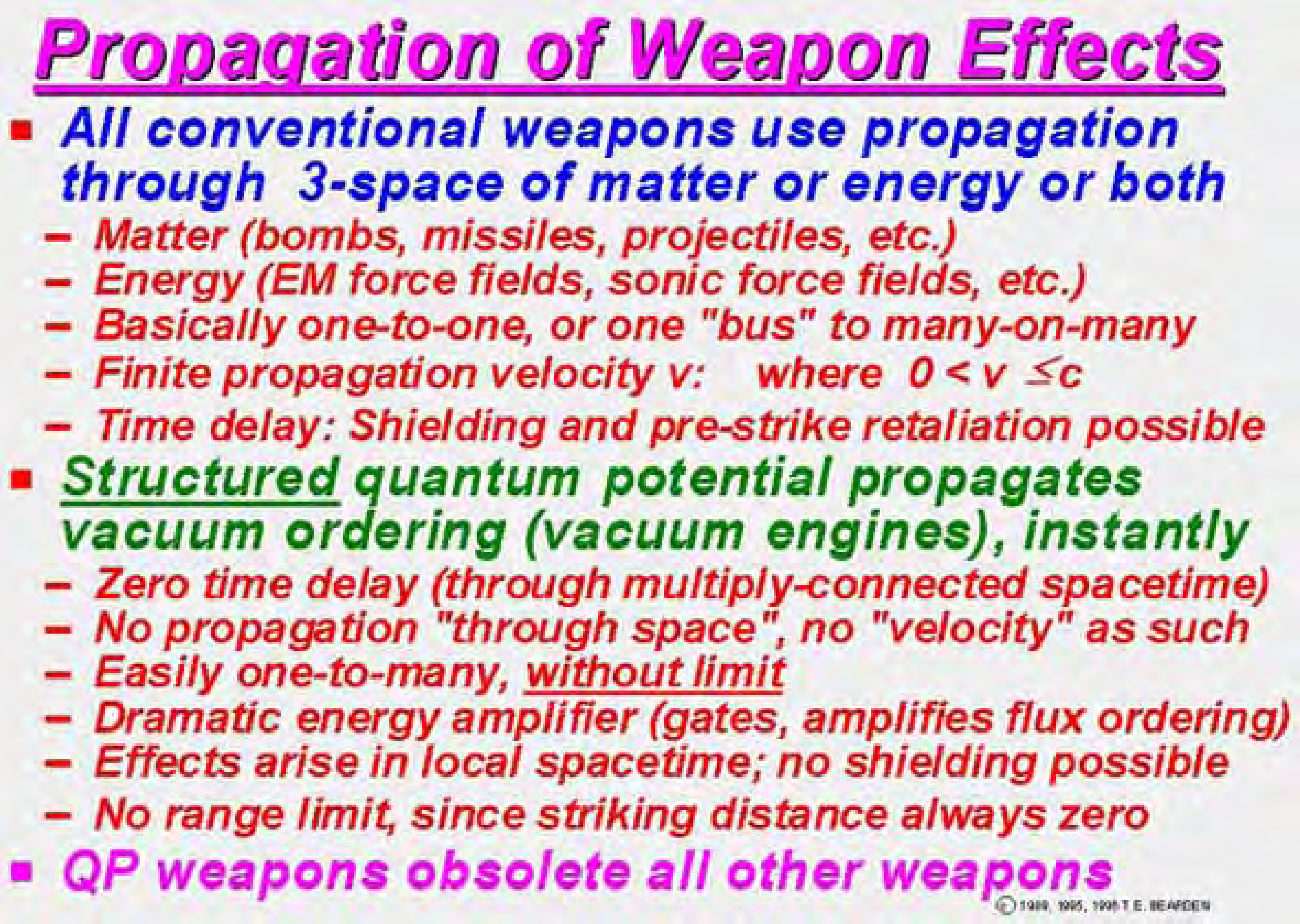

Propagation of Weapon Effects

- All conventional weapons use propagation through 3-space of matter or energy or both
  - Matter (bombs, missiles, projectiles, etc.)
  - Energy (EM force fields, sonic force fields, etc.)
  - Basically one-to-one, or one "bus" to many-on-many
  - Finite propagation velocity v: where $0 < v \leq c$
  - Time delay: Shielding and pre-strike retaliation possible
- Structured quantum potential propagates vacuum ordering (vacuum engines), instantly
  - Zero time delay (through multiply-connected spacetime)
  - No propagation "through space", no "velocity" as such
  - Easily one-to-many, without limit
  - Dramatic energy amplifier (gates, amplifies flux ordering)
  - Effects arise in local spacetime; no shielding possible
  - No range limit, since striking distance always zero
- QP weapons obsolete all other weapons

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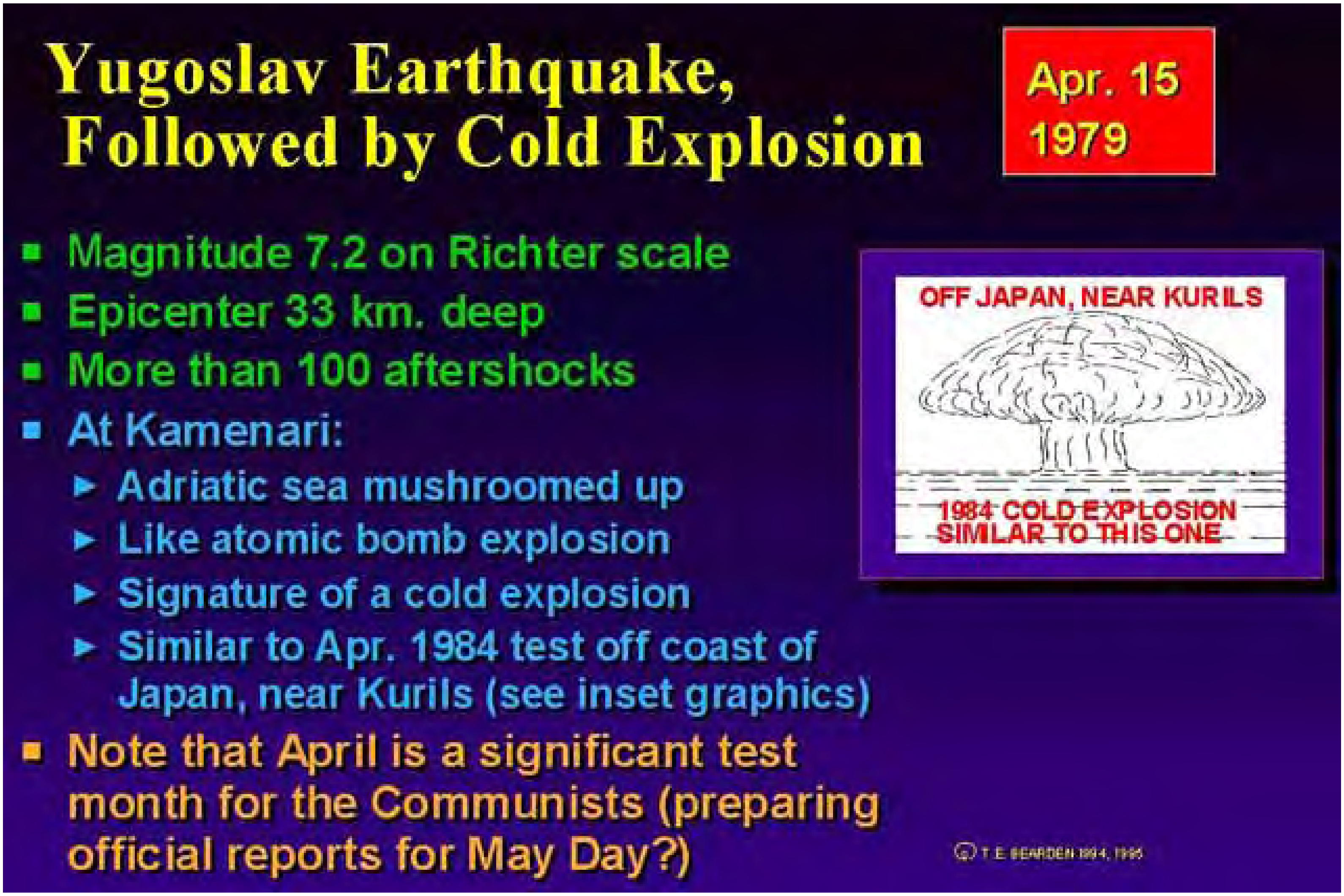

Yugoslav Earthquake, Followed by Cold Explosion

Apr. 15
1979

- Magnitude 7.2 on Richter scale
- Epicenter 33 km. deep
- More than 100 aftershocks
- At Kamenari:
  - Adriatic sea mushroomed up
  - Like atomic bomb explosion
  - Signature of a cold explosion
  - Similar to Apr. 1984 test off coast of Japan, near Kurils (see inset graphics)
- Note that April is a significant test month for the Communists (preparing official reports for May Day?)

OFF JAPAN, NEAR KURILS

1984 COLD EXPLOSION
SIMILAR TO THIS ONE

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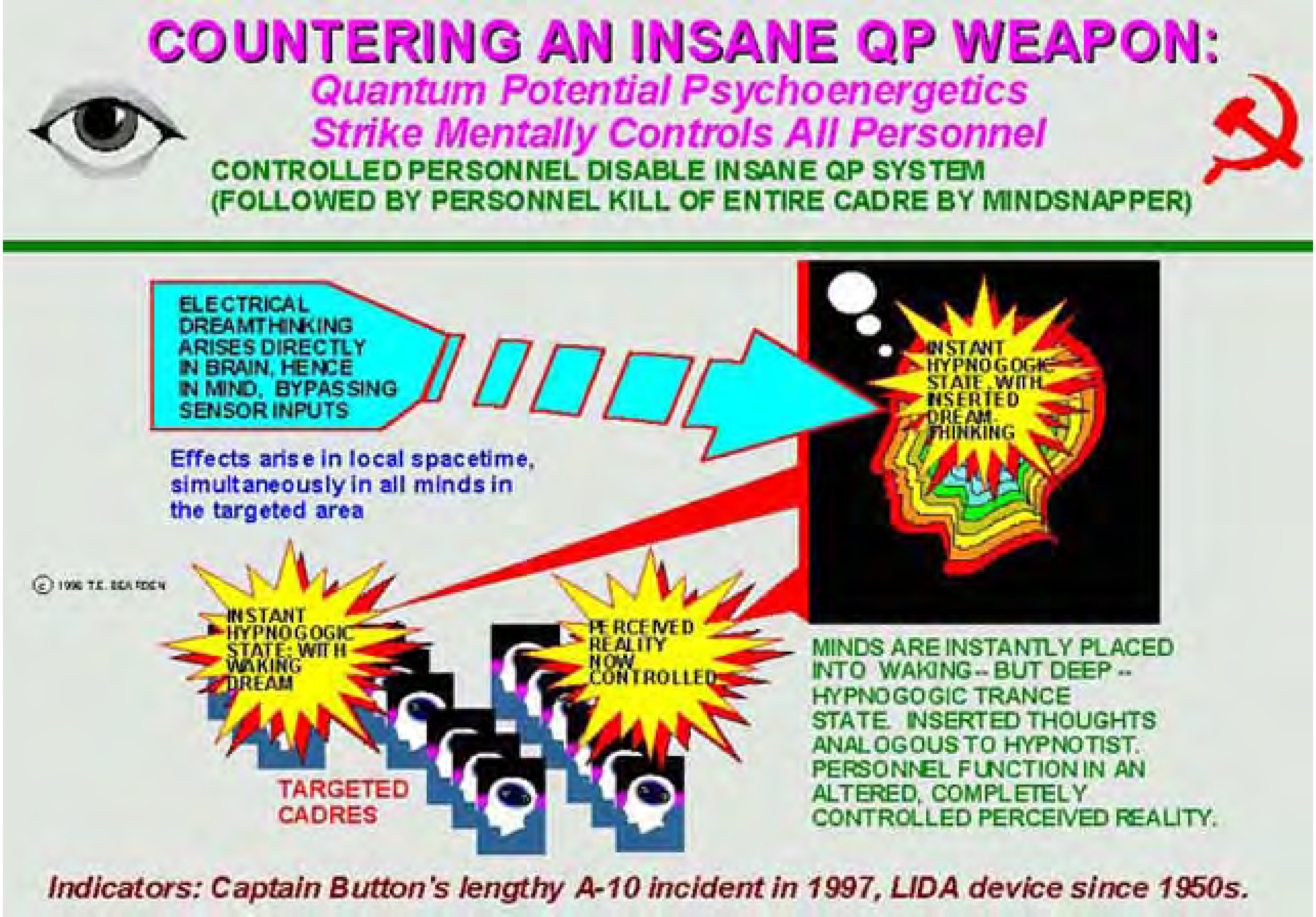

COUNTERING AN INSANE QP WEAPON:

Quantum Potential Psychoenergetics
Strike Mentally Controls All Personnel

CONTROLLED PERSONNEL DISABLE INSANE QP SYSTEM
(FOLLOWED BY PERSONNEL KILL OF ENTIRE CADRE BY MINDSNAPPER)

ELECTRICAL DREAMTHINKING ARISES DIRECTLY IN BRAIN, HENCE IN MIND, BYPASSING SENSOR INPUTS

Effects arise in local spacetime, simultaneously in all minds in the targeted area

INSTANT HYPNOGOGIC STATE, WITH INSERTED DREAM THINKING

INSTANT HYPNOGOGIC STATE: WITH WAKING DREAM

PERCEIVED REALITY NOW CONTROLLED

TARGETED CADRES

MINDS ARE INSTANTLY PLACED INTO WAKING-- BUT DEEP -- HYPNOGOGIC TRANCE STATE. INSERTED THOUGHTS ANALOGOUS TO HYPNOTIST. PERSONNEL FUNCTION IN AN ALTERED, COMPLETELY CONTROLLED PERCEIVED REALITY.

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Indicators: Captain Button's lengthy A-10 incident in 1997, LIDA device since 1950s.

Gulf War Disease: KGB QP Weapon Induced ST Curvature Engines for a Cocktail of Diseases

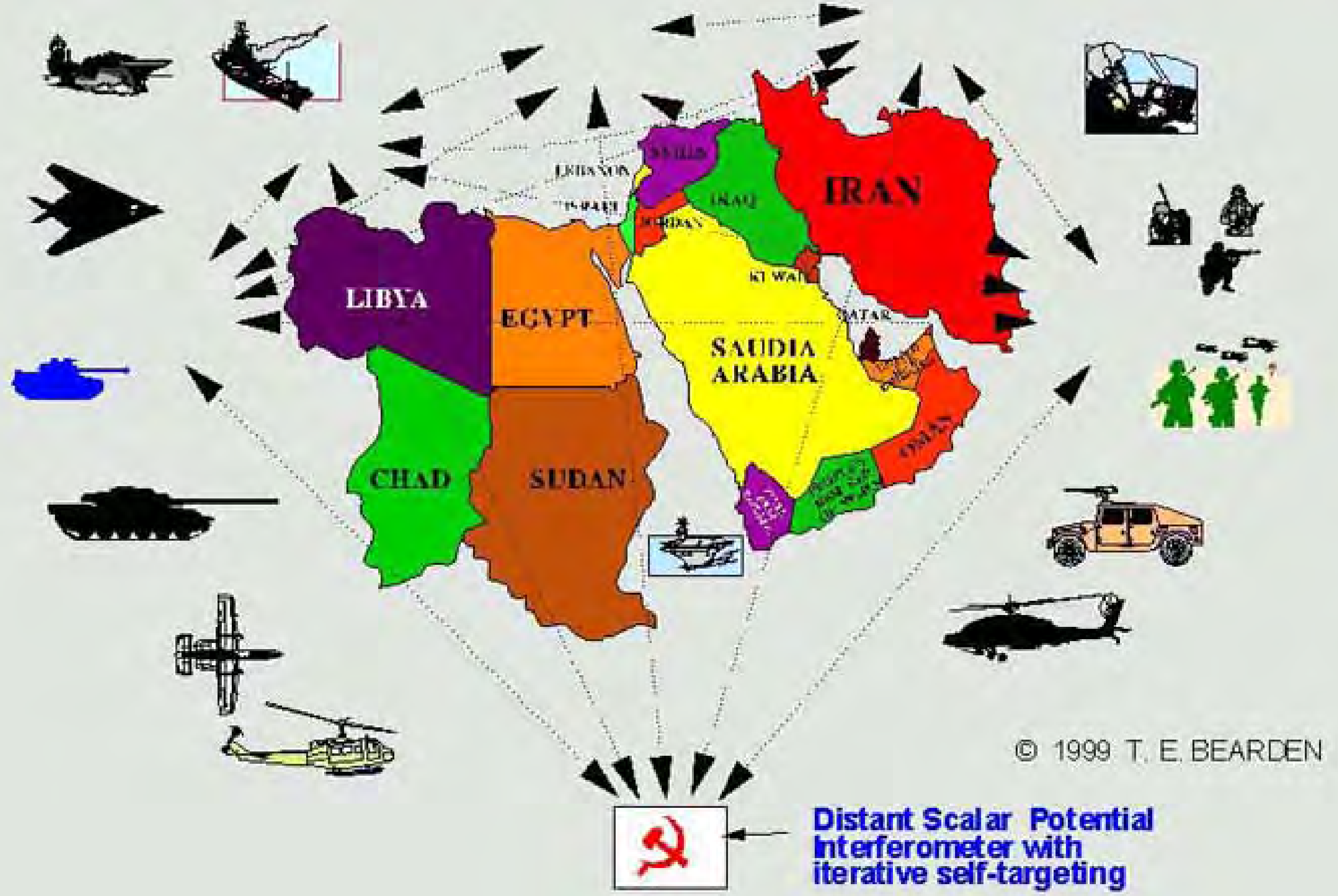
LEBANON
ISRAEL
SYRIA
JORDAN
IRAQ
IRAN
KUWAIT
QATAR
LIBYA
EGYPT
SAUDIA ARABIA
OMAN
CHAD
SUDAN

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Distant Scalar Potential Interferometer with iterative self-targeting

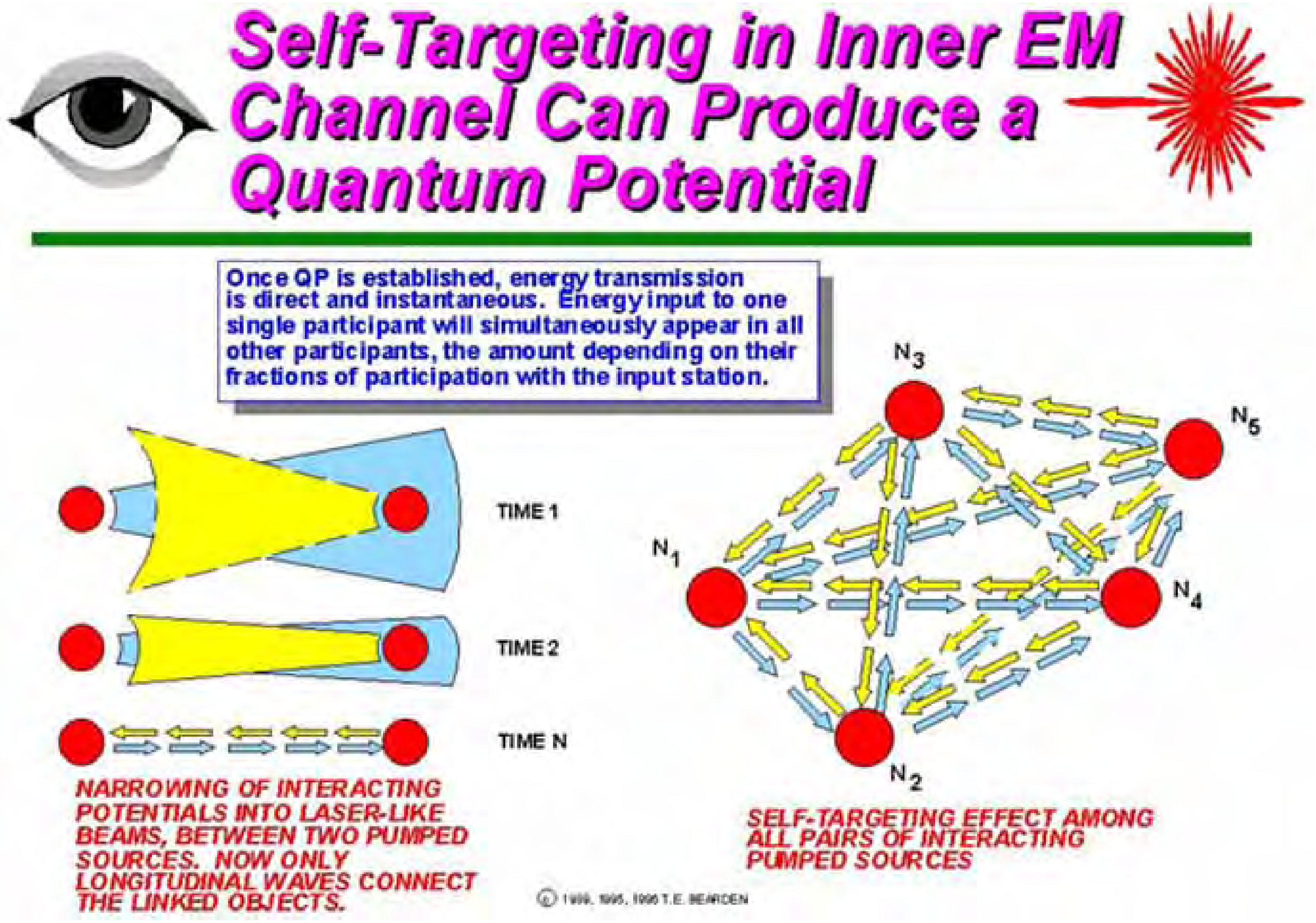

Self-Targeting in Inner EM Channel Can Produce a Quantum Potential

Once QP is established, energy transmission is direct and instantaneous. Energy input to one single participant will simultaneously appear in all other participants, the amount depending on their fractions of participation with the input station.

NARROWING OF INTERACTING POTENTIALS INTO LASER-LIKE BEAMS, BETWEEN TWO PUMPED SOURCES. NOW ONLY LONGITUDINAL WAVES CONNECT THE LINKED OBJECTS.

SELF-TARGETING EFFECT AMONG ALL PAIRS OF INTERACTING PUMPED SOURCES

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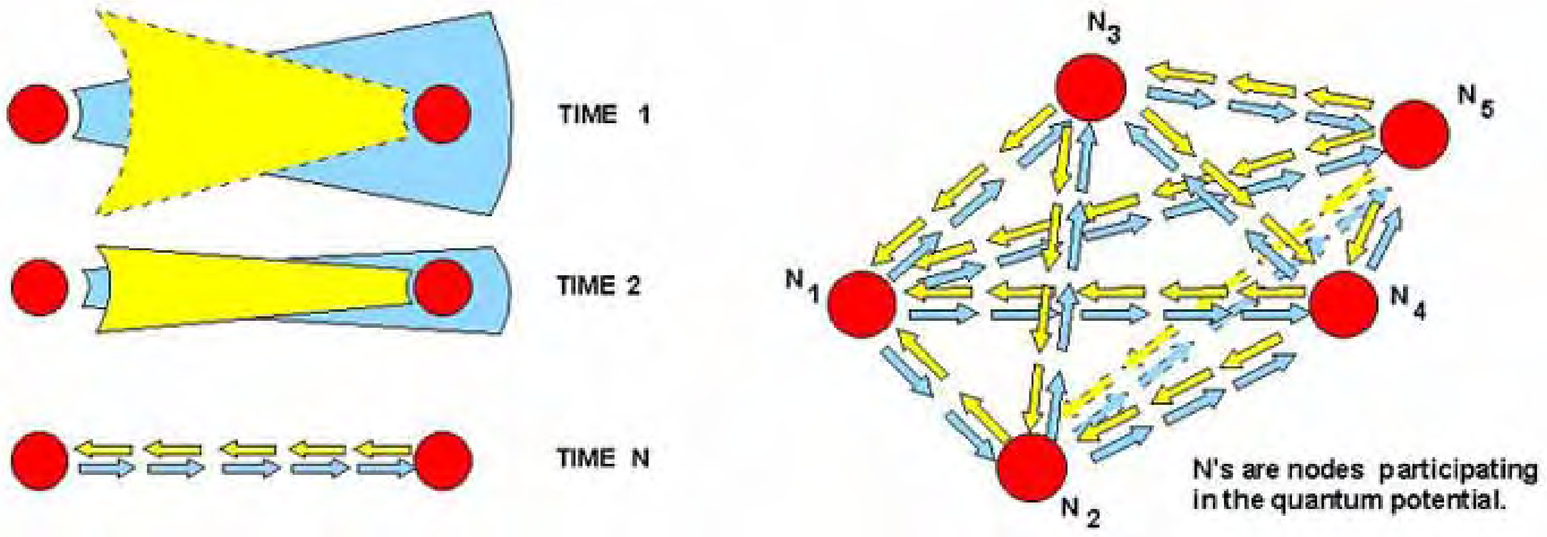

N's are nodes participating in the quantum potential.

a. Iterative retroreflection between any pair of nodes narrows the interconnecting potentials to a laser-like, bidirectional beam. Iterative phase conjugate reflection provides self-targeting.

b. The quantum potential exists as narrow, laser-like beams between participating nodes, even when the nodes are widely separated. The beam space is multiply-connected; transmission is instantaneous.

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Consider the hidden Stoney/Whittaker bidirectional EM waves that comprise the potential from each source node. If these nodes have sufficient intersymmetry of dynamic material form, then self-targeting occurs between the two nodes of any nodal pair. By iterative phase conjugate reflection, the scattering is narrowed into interconnecting wavepairs, in laser-like beams, between each two nodes. Thus the interconnecting potentials narrow into laser-like, bidirectional beams. The Coulomb gauge may apply, and a quantum potential may be formed.

Figure 30. Mechanism for generating a quantum potential, by iterative self-targeting induced into a system of multiple scattering nodes. Once a QP is established, spatial separation has little or no effect.

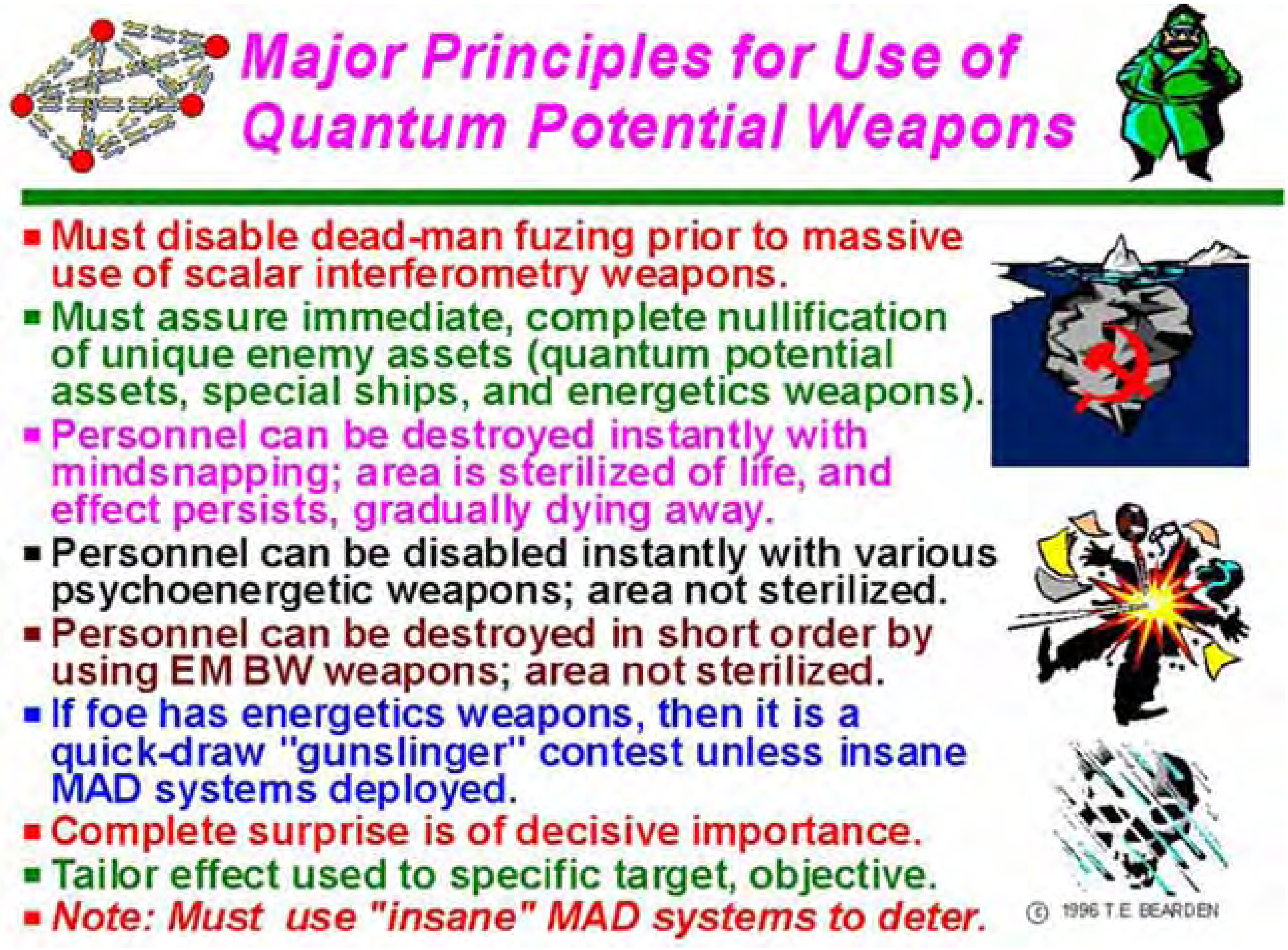

Major Principles for Use of Quantum Potential Weapons

- Must disable dead-man fuzing prior to massive use of scalar interferometry weapons.
- Must assure immediate, complete nullification of unique enemy assets (quantum potential assets, special ships, and energetics weapons).
- Personnel can be destroyed instantly with mindsnapping; area is sterilized of life, and effect persists, gradually dying away.
- Personnel can be disabled instantly with various psychoenergetic weapons; area not sterilized.
- Personnel can be destroyed in short order by using EM BW weapons; area not sterilized.
- If foe has energetics weapons, then it is a quick-draw "gunslinger" contest unless insane MAD systems deployed.
- Complete surprise is of decisive importance.
- Tailor effect used to specific target, objective.
- *Note: Must use "insane" MAD systems to deter.*

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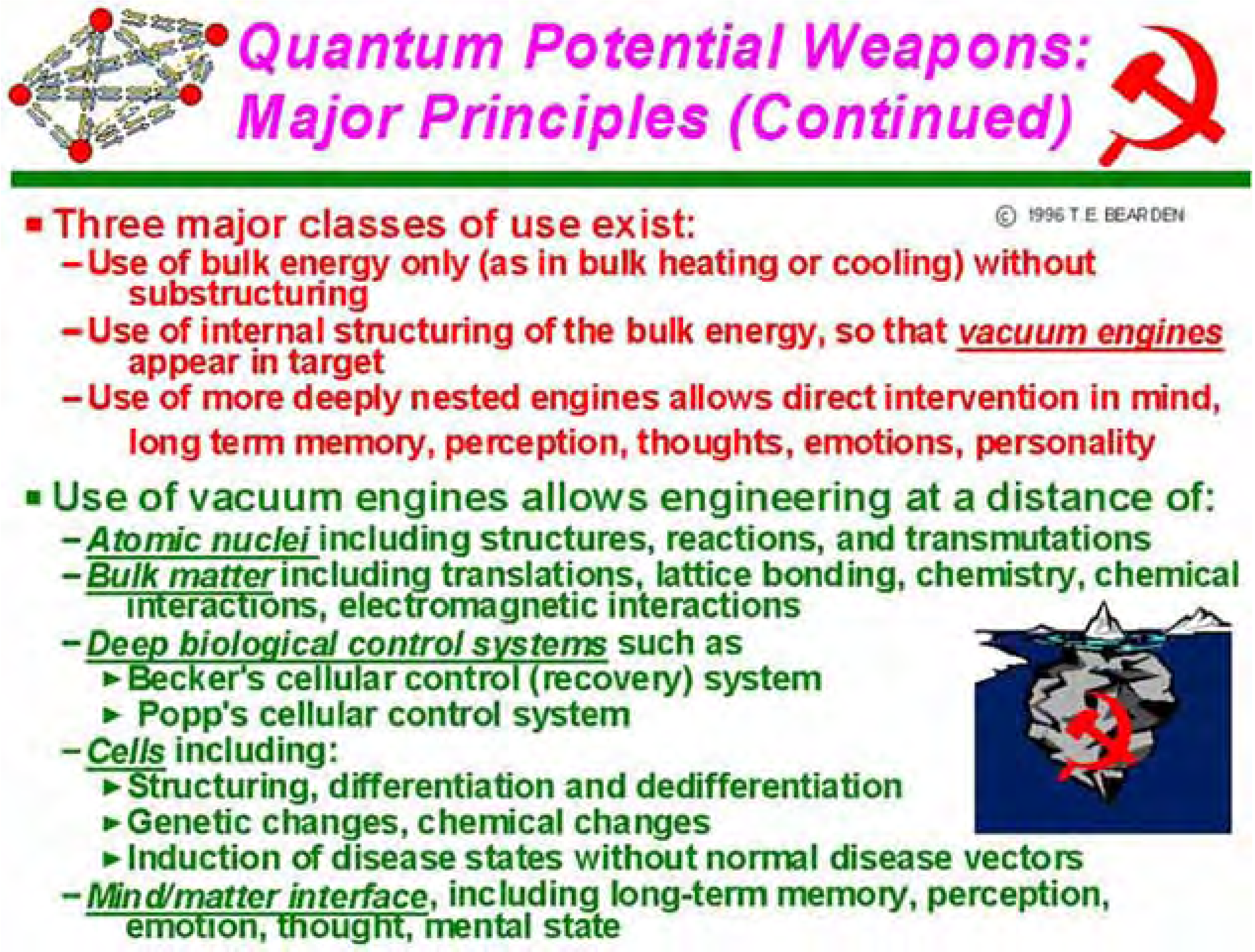

Quantum Potential Weapons: Major Principles (Continued)

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- Three major classes of use exist:
  - Use of bulk energy only (as in bulk heating or cooling) without substructuring
  - Use of internal structuring of the bulk energy, so that *vacuum engines* appear in target
  - Use of more deeply nested engines allows direct intervention in mind, long term memory, perception, thoughts, emotions, personality
- Use of vacuum engines allows engineering at a distance of:
  - *Atomic nuclei* including structures, reactions, and transmutations
  - *Bulk matter* including translations, lattice bonding, chemistry, chemical interactions, electromagnetic interactions
  - *Deep biological control systems* such as
    - ► Becker's cellular control (recovery) system
    - ► Popp's cellular control system
  - *Cells* including:
    - ► Structuring, differentiation and dedifferentiation
    - ► Genetic changes, chemical changes
    - ► Induction of disease states without normal disease vectors
  - *Mind/matter interface*, including long-term memory, perception, emotion, thought, mental state

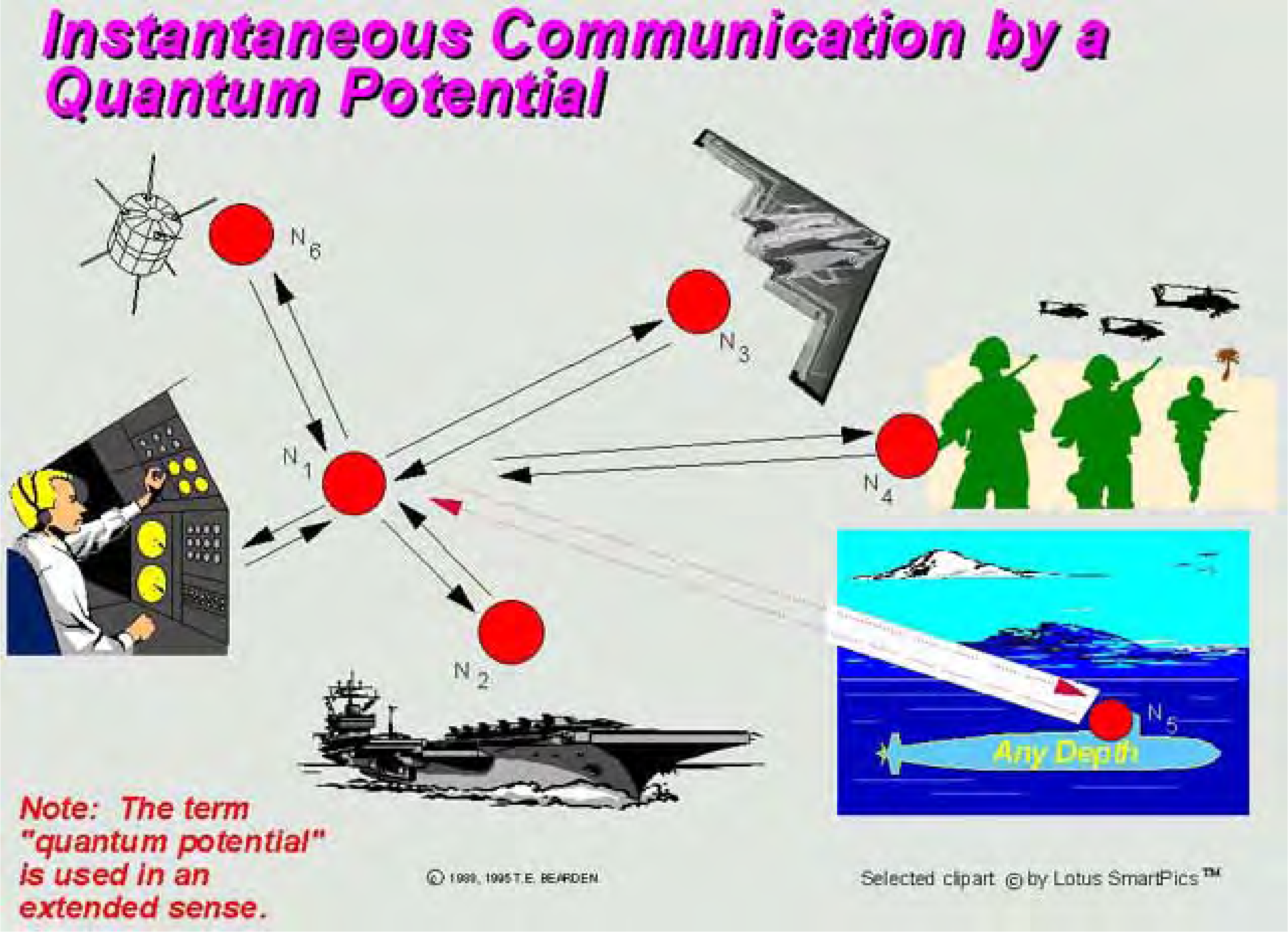

Instantaneous Communication by a Quantum Potential

Note: The term "quantum potential" is used in an extended sense.

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Selected clipart © by Lotus SmartPics ™

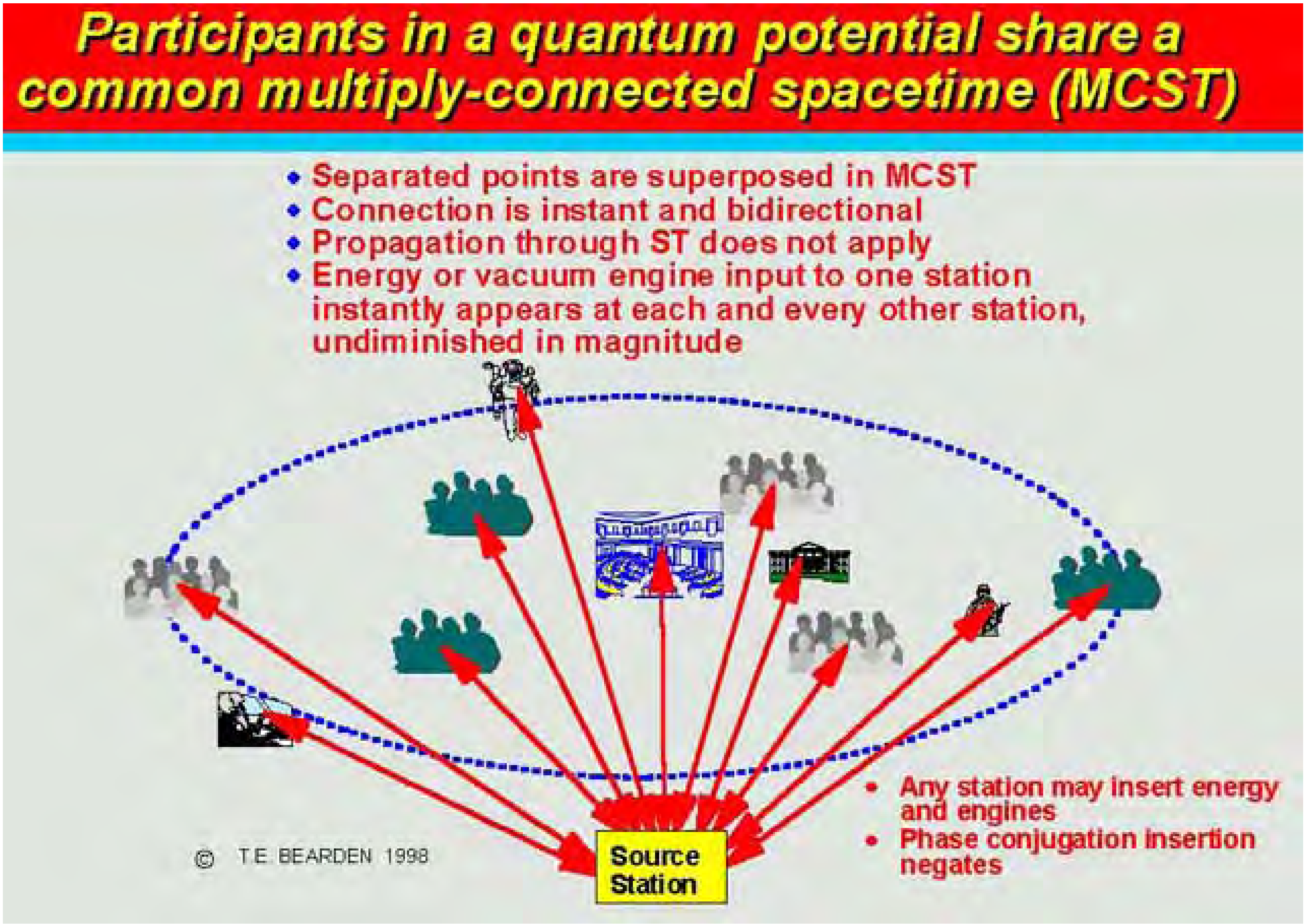

Participants in a quantum potential share a common multiply-connected spacetime (MCST)

- Separated points are superposed in MCST
- Connection is instant and bidirectional
- Propagation through ST does not apply
- Energy or vacuum engine input to one station instantly appears at each and every other station, undiminished in magnitude

Source Station

- Any station may insert energy and engines
- Phase conjugation insertion negates

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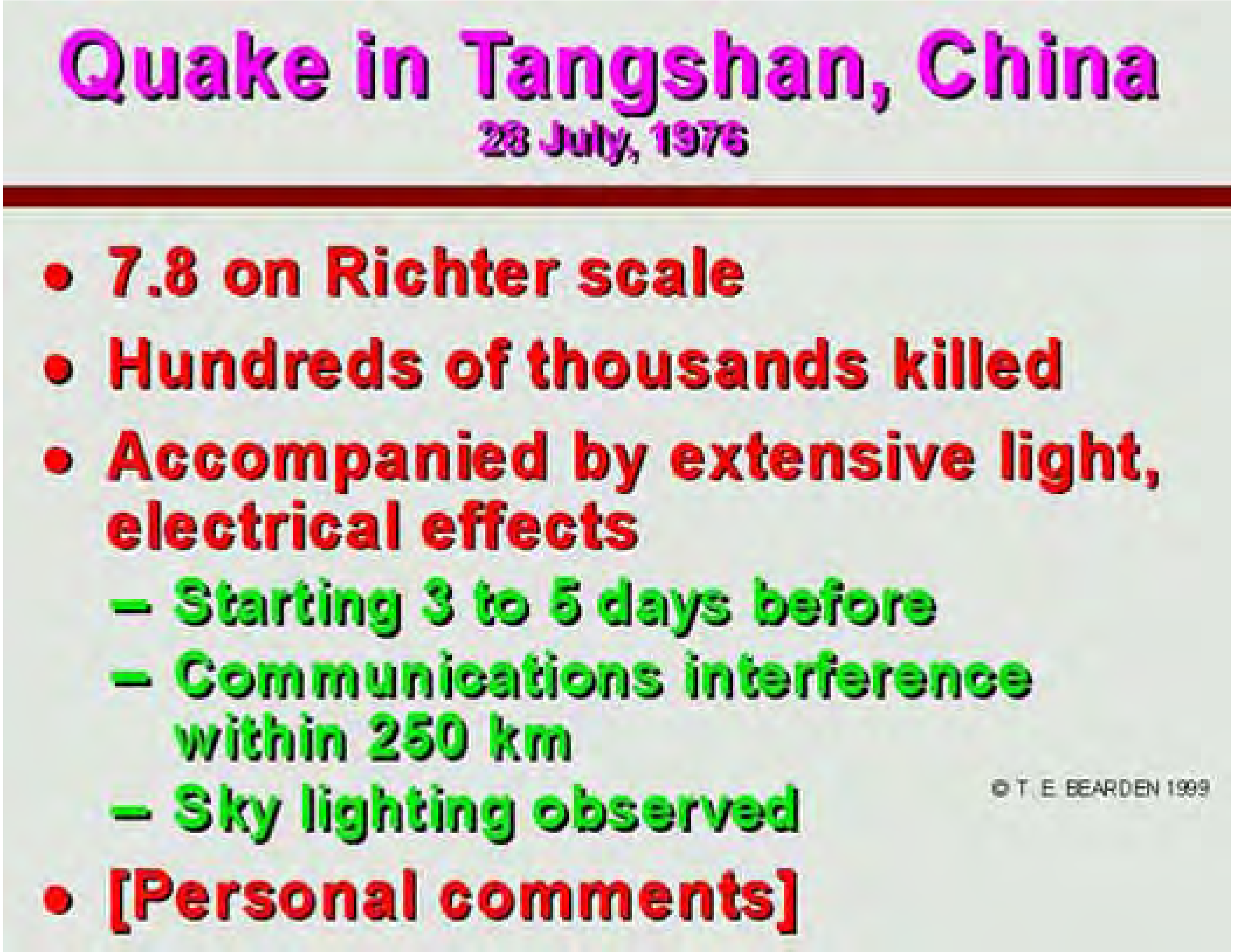

Quake in Tangshan, China

28 July, 1976

- 7.8 on Richter scale
- Hundreds of thousands killed
- Accompanied by extensive light, electrical effects
  - Starting 3 to 5 days before
  - Communications interference within 250 km
  - Sky lighting observed
- [Personal comments]

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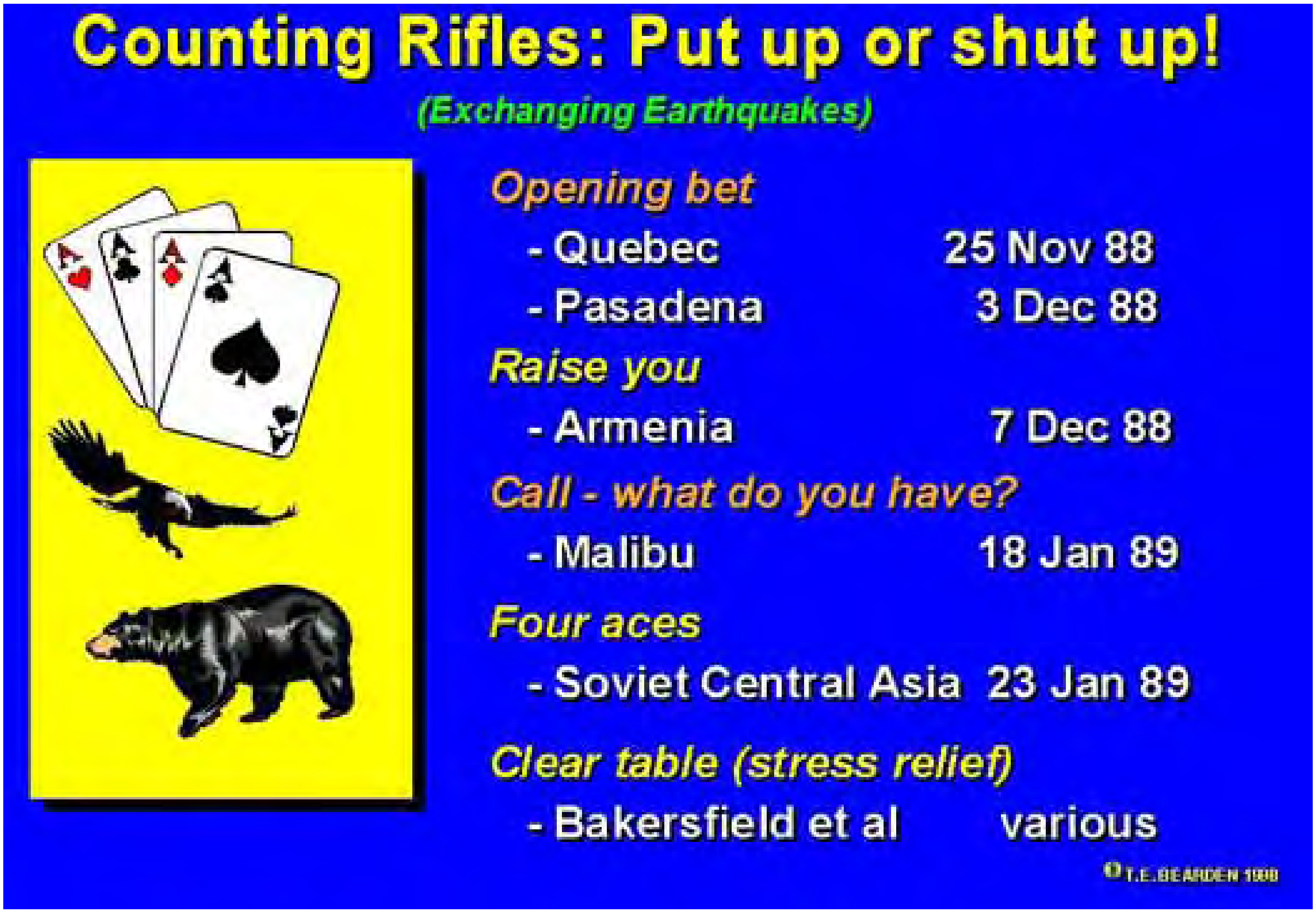

Counting Rifles: Put up or shut up!

(Exchanging Earthquakes)

Opening bet
- Quebec 25 Nov 88
- Pasadena 3 Dec 88

Raise you
- Armenia 7 Dec 88

Call - what do you have?
- Malibu 18 Jan 89

Four aces
- Soviet Central Asia 23 Jan 89

Clear table (stress relief)
- Bakersfield et al various

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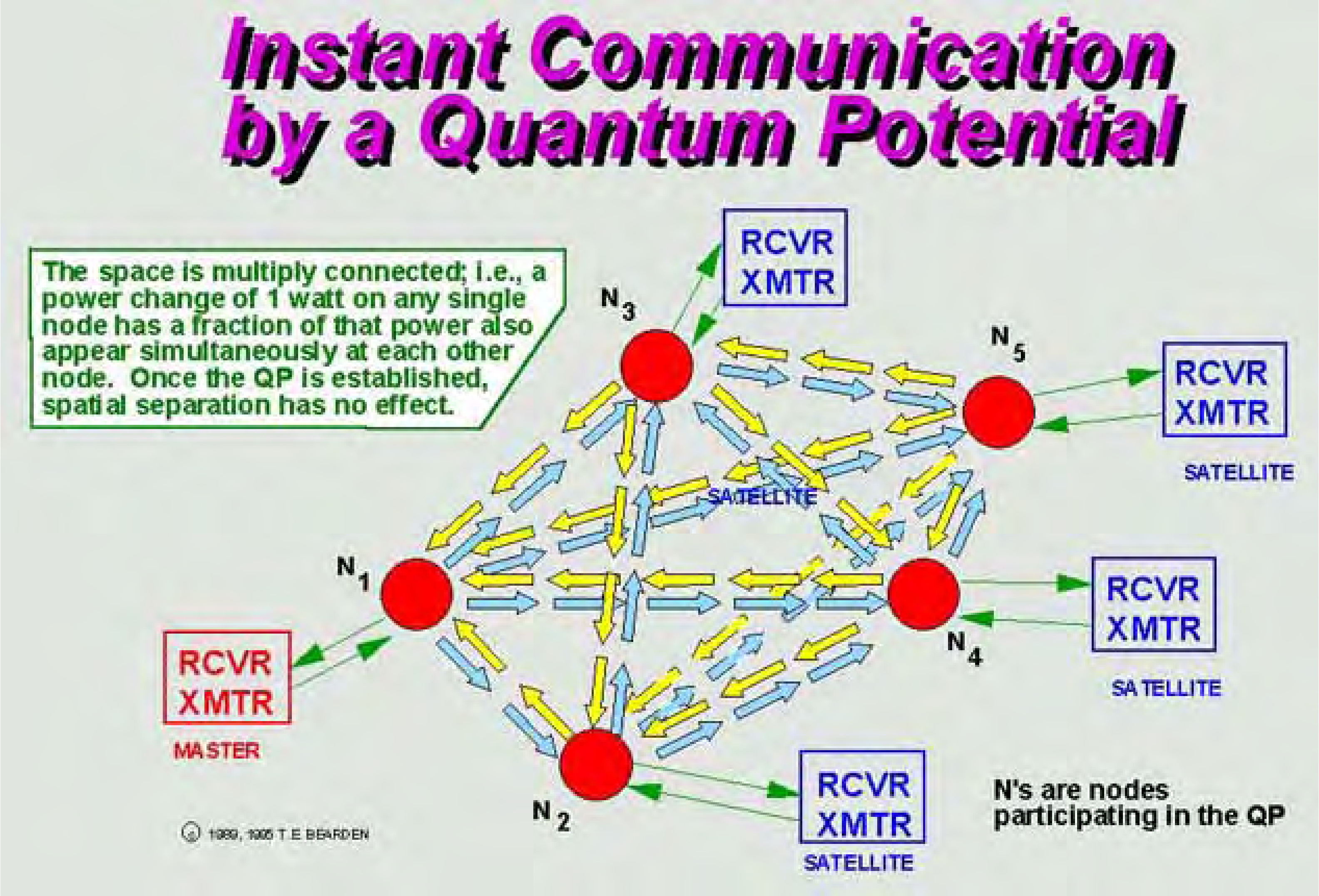

Instant Communication by a Quantum Potential

The space is multiply connected; i.e., a power change of 1 watt on any single node has a fraction of that power also appear simultaneously at each other node. Once the QP is established, spatial separation has no effect.

N's are nodes participating in the QP

N1
N2
N3
N4
N5
RCVR XMTR
MASTER
RCVR XMTR
SATELLITE
RCVR XMTR
SATELLITE
RCVR XMTR
SATELLITE
RCVR XMTR
SATELLITE

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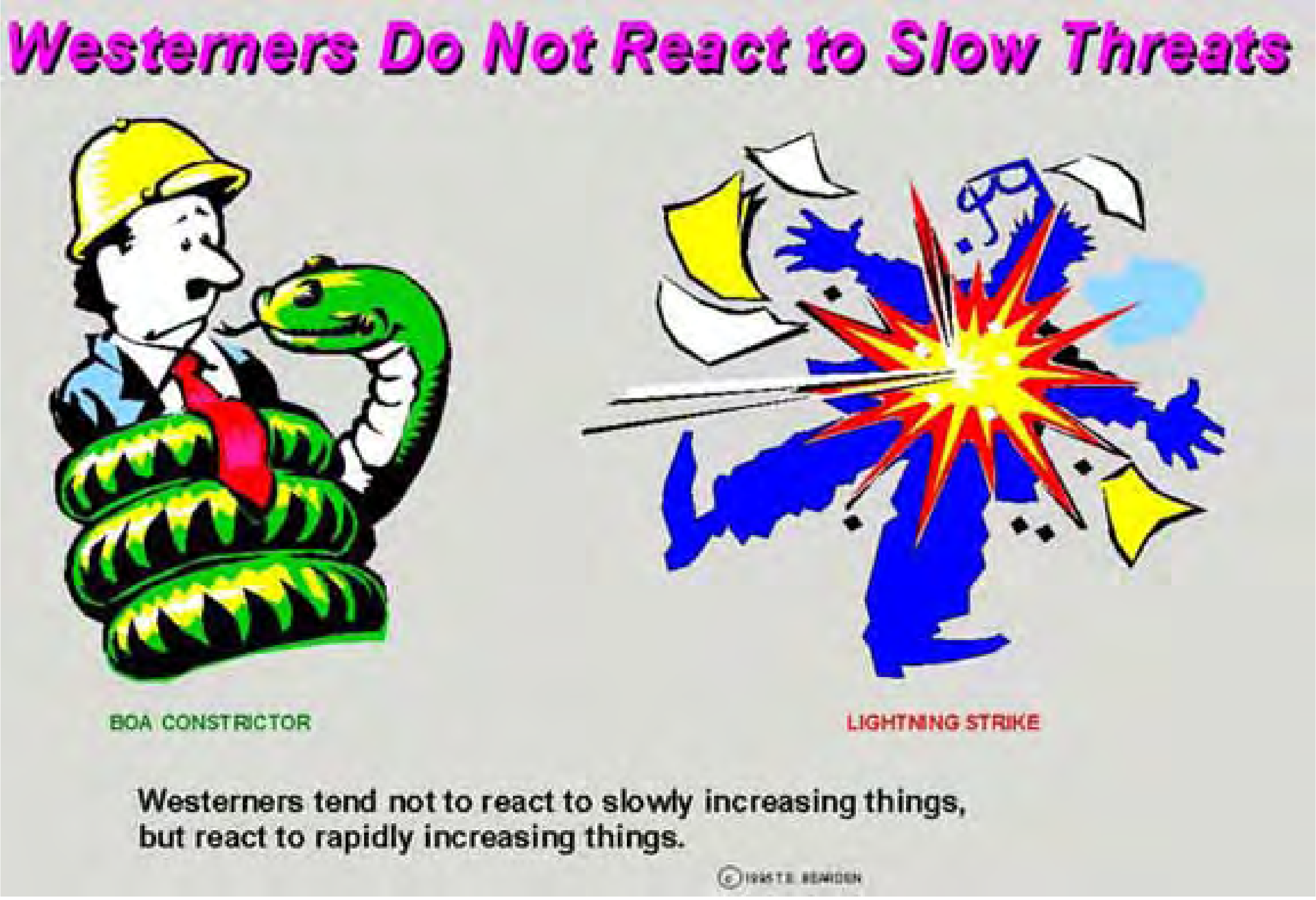
BOA CONSTRICTOR
LIGHTNING STRIKE

Westerners Do Not React to Slow Threats

Westerners tend not to react to slowly increasing things,
but react to rapidly increasing things.

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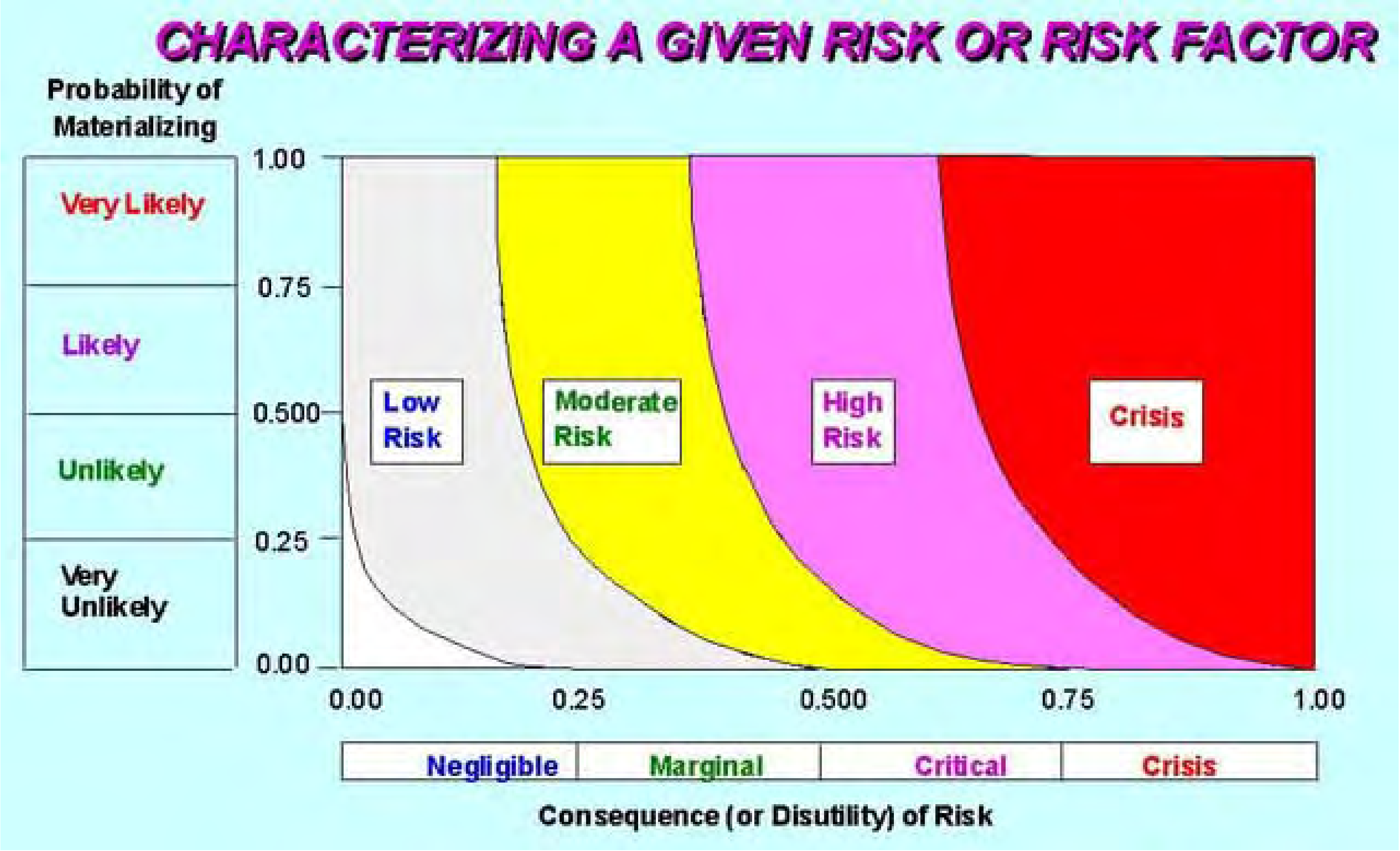
CHARACTERIZING A GIVEN RISK OR RISK FACTOR
Probability of Materializing
Very Likely
Likely
Unlikely
Very Unlikely
1.00
0.75
0.500
0.25
0.00
Low Risk
Moderate Risk
High Risk
Crisis
0.00
0.25
0.500
0.75
1.00
Negligible
Marginal
Critical
Crisis
Consequence (or Disutility) of Risk

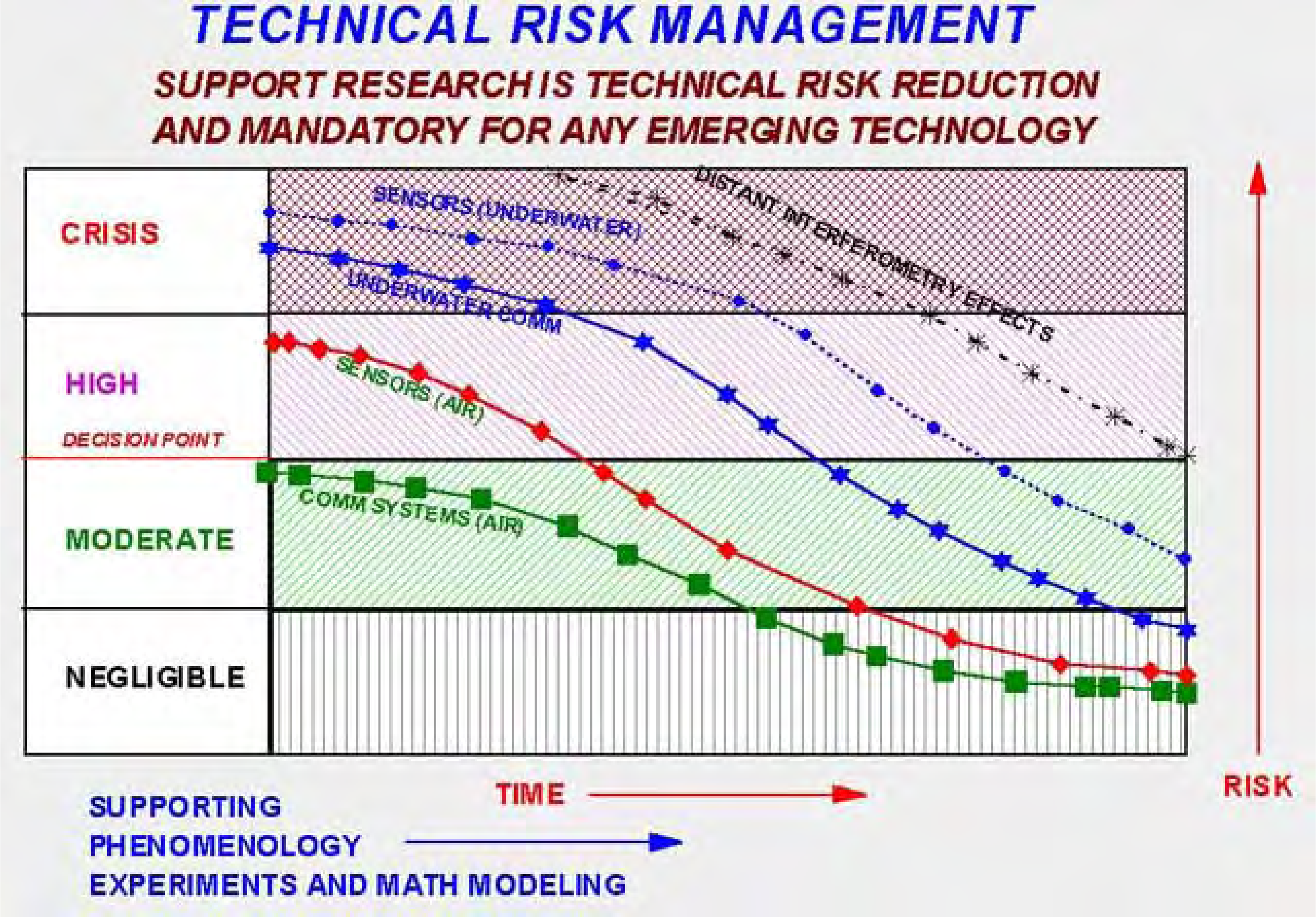

TECHNICAL RISK MANAGEMENT

SUPPORT RESEARCH IS TECHNICAL RISK REDUCTION AND MANDATORY FOR ANY EMERGING TECHNOLOGY

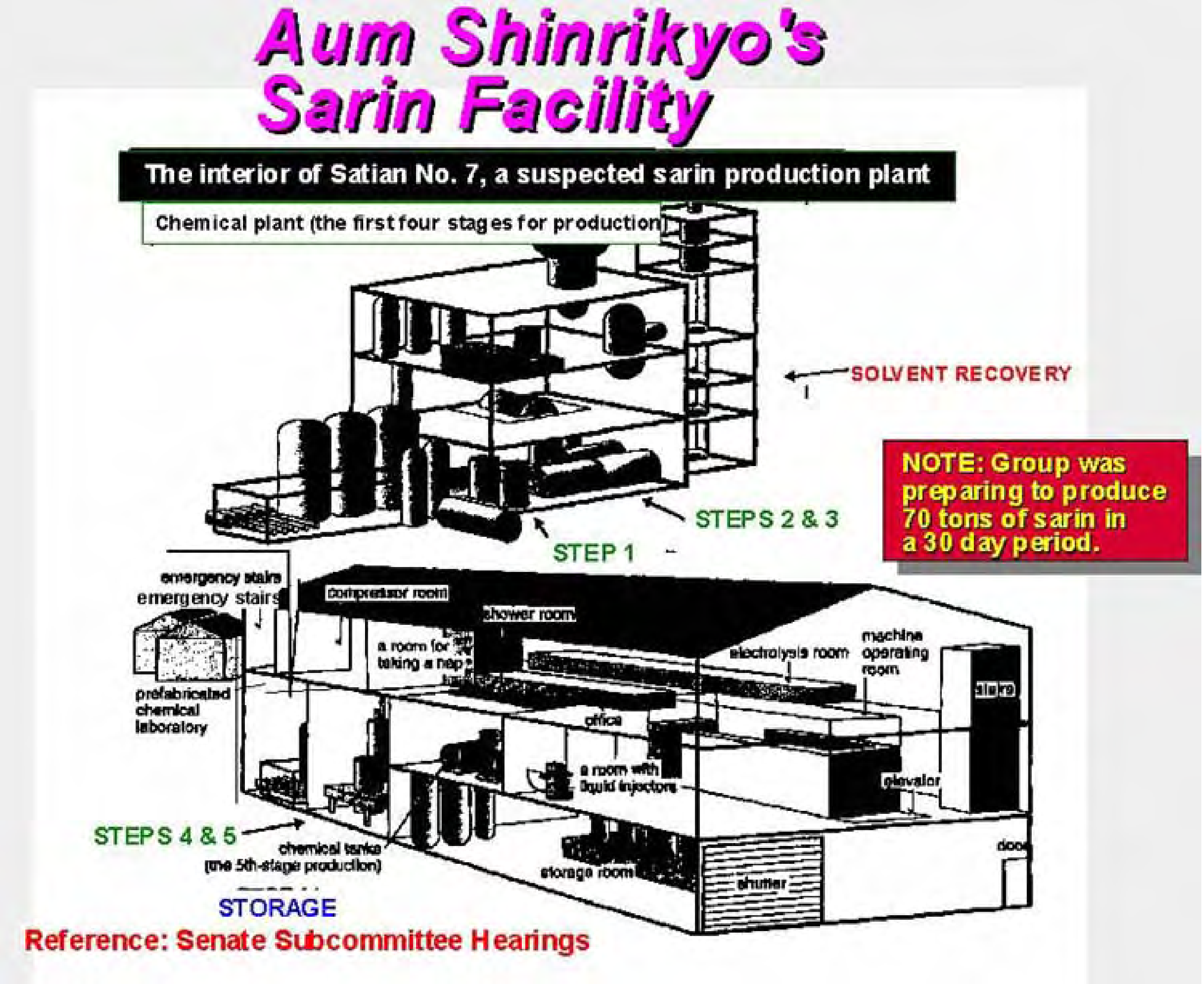

Aum Shinrikyo's Sarin Facility

The interior of Satian No. 7, a suspected sarin production plant

Chemical plant (the first four stages for production)
SOLVENT RECOVERY
STEPS 2 & 3
STEP 1
emergency stairs
emergency stairs
compressor room
shower room
a room for taking a nap
electrolysis room
machine operating room
stairs
prefabricated chemical laboratory
office
a room with liquid injectors
elevator
STEPS 4 & 5
chemical tanks (the 5th-stage production)
storage room
shutter
door
STORAGE

NOTE: Group was preparing to produce 70 tons of sarin in a 30 day period.

Reference: Senate Subcommittee Hearings

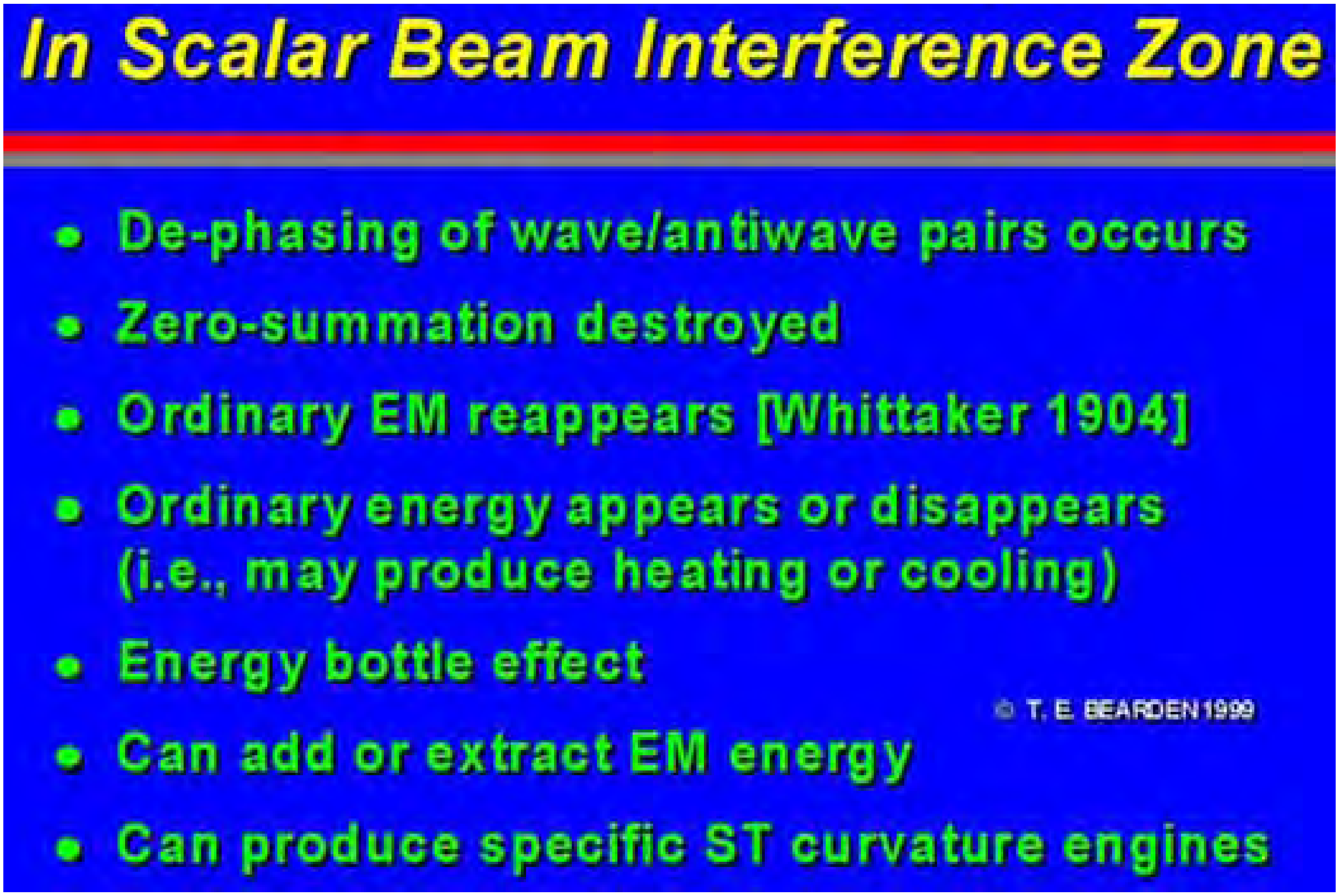

In Scalar Beam Interference Zone

- De-phasing of wave/antiwave pairs occurs
- Zero-summation destroyed
- Ordinary EM reappears [Whittaker 1904]
- Ordinary energy appears or disappears (i.e., may produce heating or cooling)
- Energy bottle effect
- Can add or extract EM energy
- Can produce specific ST curvature engines

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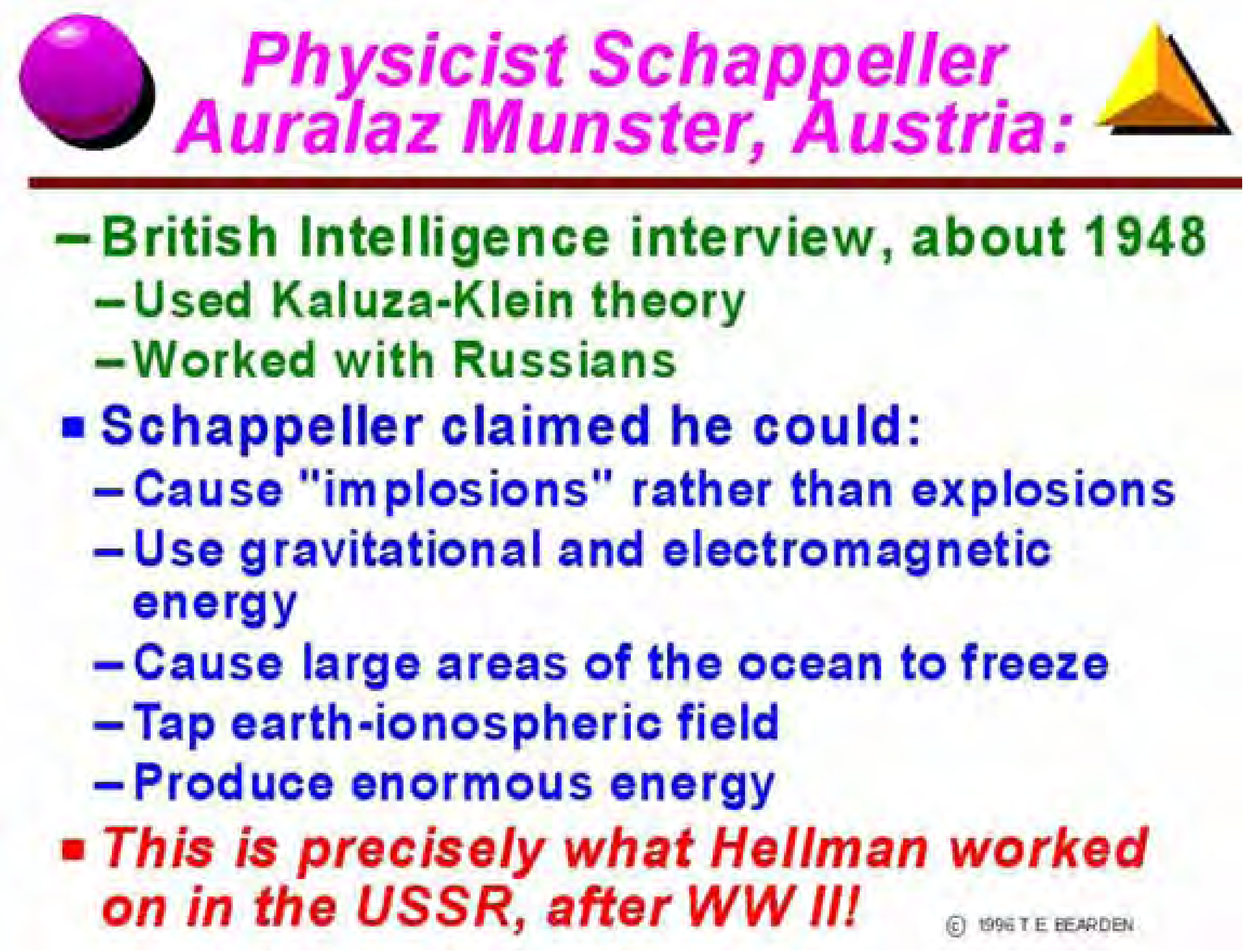

Physicist Schappeller Auralaz Munster, Austria:

- British Intelligence interview, about 1948
  - Used Kaluza-Klein theory
  - Worked with Russians
- Schappeller claimed he could:
  - Cause "implosions" rather than explosions
  - Use gravitational and electromagnetic energy
  - Cause large areas of the ocean to freeze
  - Tap earth-ionospheric field
  - Produce enormous energy
- *This is precisely what Hellman worked on in the USSR, after WW II!*

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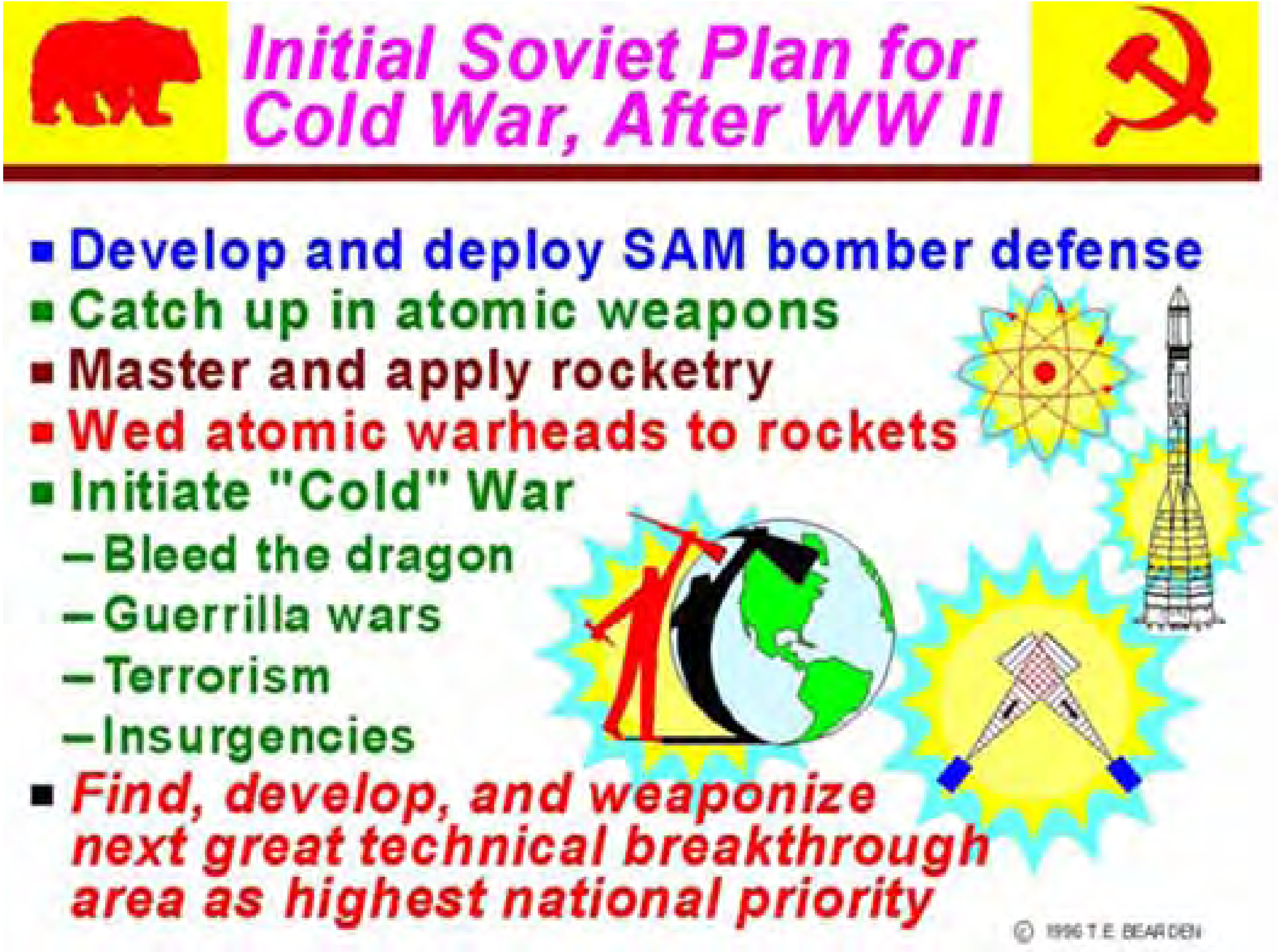

Initial Soviet Plan for Cold War, After WW II

- Develop and deploy SAM bomber defense
- Catch up in atomic weapons
- Master and apply rocketry
- Wed atomic warheads to rockets
- Initiate "Cold" War
  - Bleed the dragon
  - Guerrilla wars
  - Terrorism
  - Insurgencies
- *Find, develop, and weaponize next great technical breakthrough area as highest national priority*

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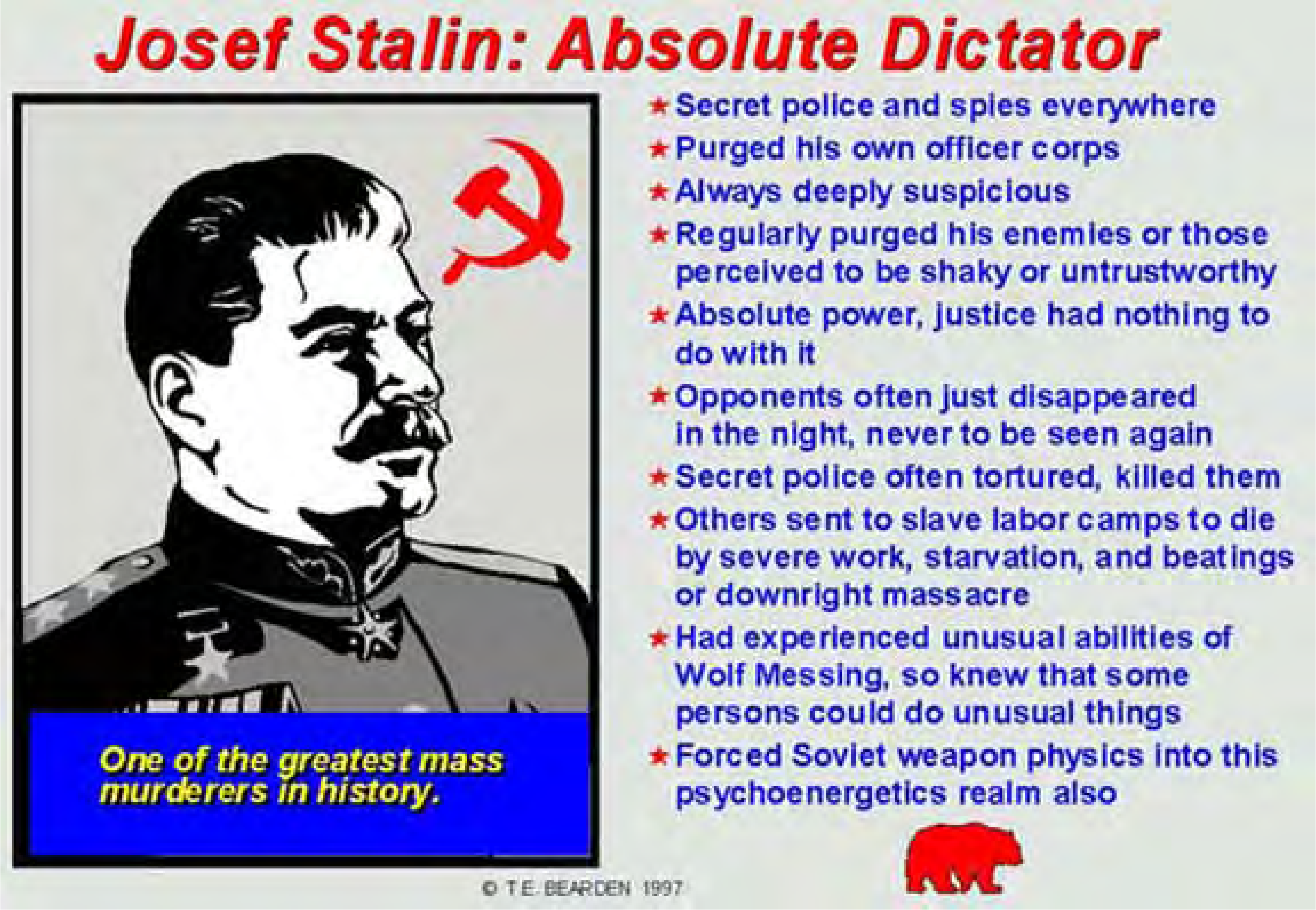

Josef Stalin: Absolute Dictator

- ★ Secret police and spies everywhere
- ★ Purged his own officer corps
- ★ Always deeply suspicious
- ★ Regularly purged his enemies or those perceived to be shaky or untrustworthy
- ★ Absolute power, justice had nothing to do with it
- ★ Opponents often just disappeared in the night, never to be seen again
- ★ Secret police often tortured, killed them
- ★ Others sent to slave labor camps to die by severe work, starvation, and beatings or downright massacre
- ★ Had experienced unusual abilities of Wolf Messing, so knew that some persons could do unusual things
- ★ Forced Soviet weapon physics into this psychoenergetics realm also

One of the greatest mass murderers in history.

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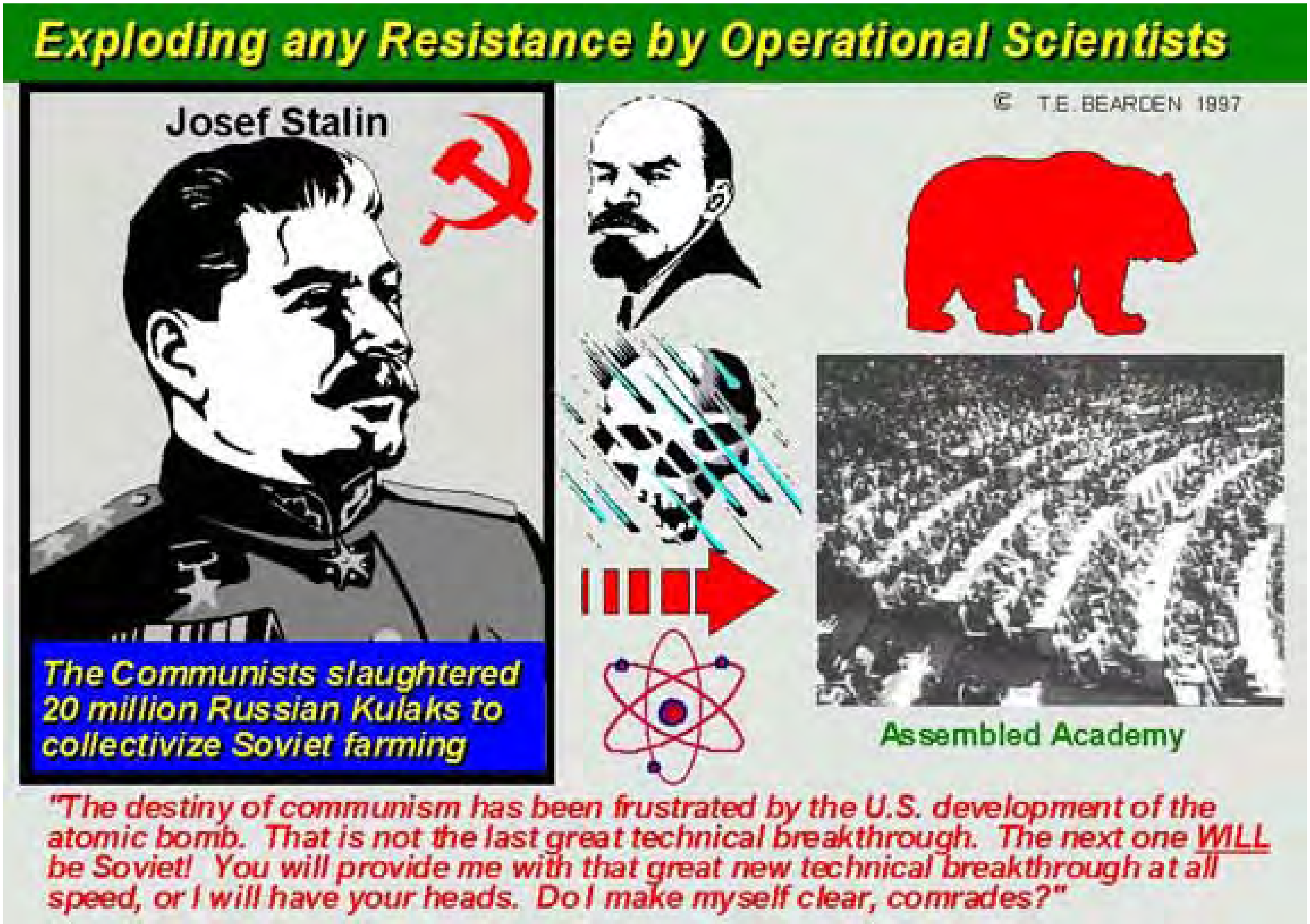

Exploding any Resistance by Operational Scientists

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Josef Stalin

The Communists slaughtered 20 million Russian Kulaks to collectivize Soviet farming

Assembled Academy

"The destiny of communism has been frustrated by the U.S. development of the atomic bomb. That is not the last great technical breakthrough. The next one WILL be Soviet! You will provide me with that great new technical breakthrough at all speed, or I will have your heads. Do I make myself clear, comrades?"

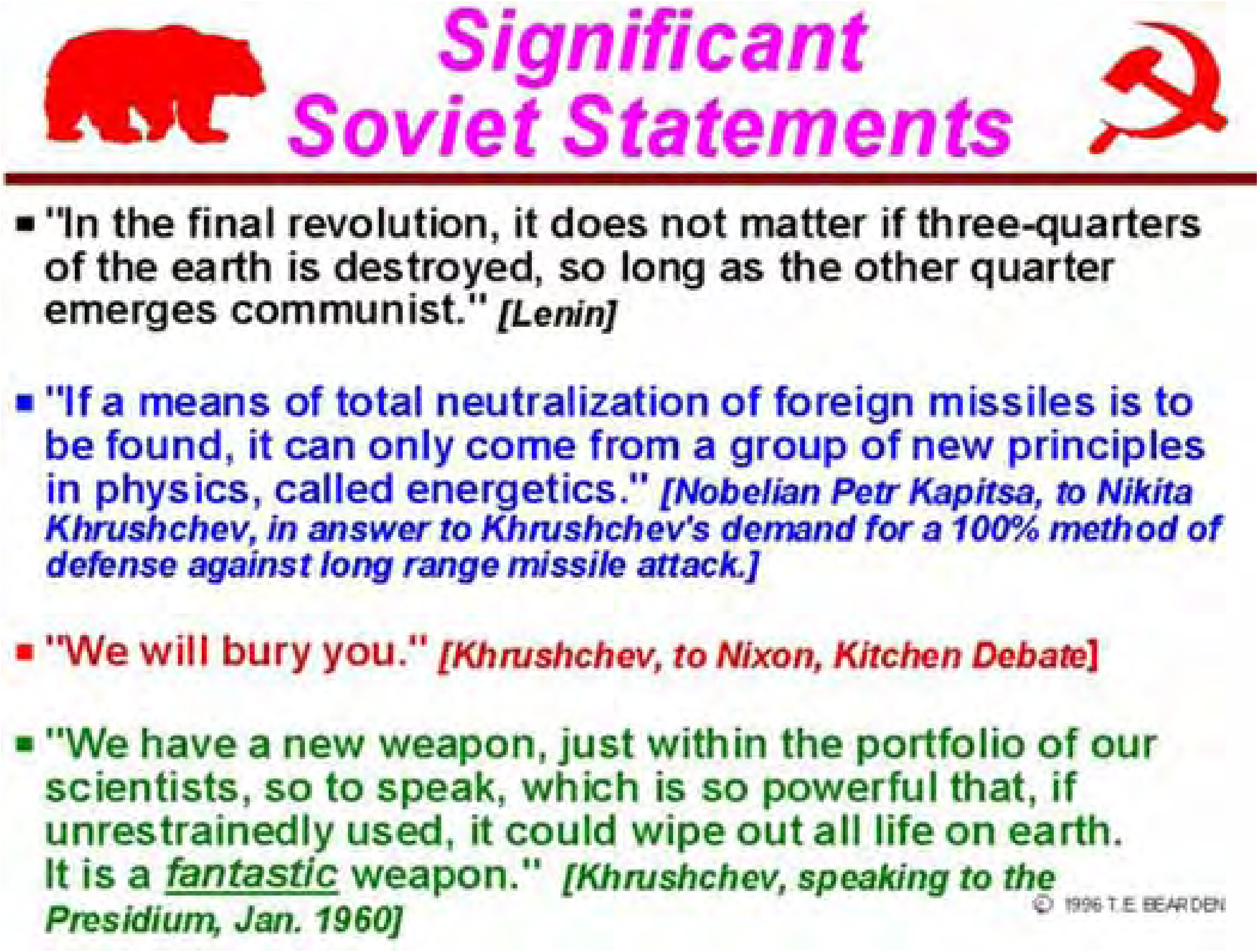

Significant Soviet Statements

- "In the final revolution, it does not matter if three-quarters of the earth is destroyed, so long as the other quarter emerges communist." *[Lenin]*

- "If a means of total neutralization of foreign missiles is to be found, it can only come from a group of new principles in physics, called energetics." *[Nobelian Petr Kapitsa, to Nikita Khrushchev, in answer to Khrushchev's demand for a 100% method of defense against long range missile attack.]*

- "We will bury you." *[Khrushchev, to Nixon, Kitchen Debate*]

- "We have a new weapon, just within the portfolio of our scientists, so to speak, which is so powerful that, if unrestrainedly used, it could wipe out all life on earth. It is a *fantastic* weapon." *[Khrushchev, speaking to the Presidium, Jan. 1960]*

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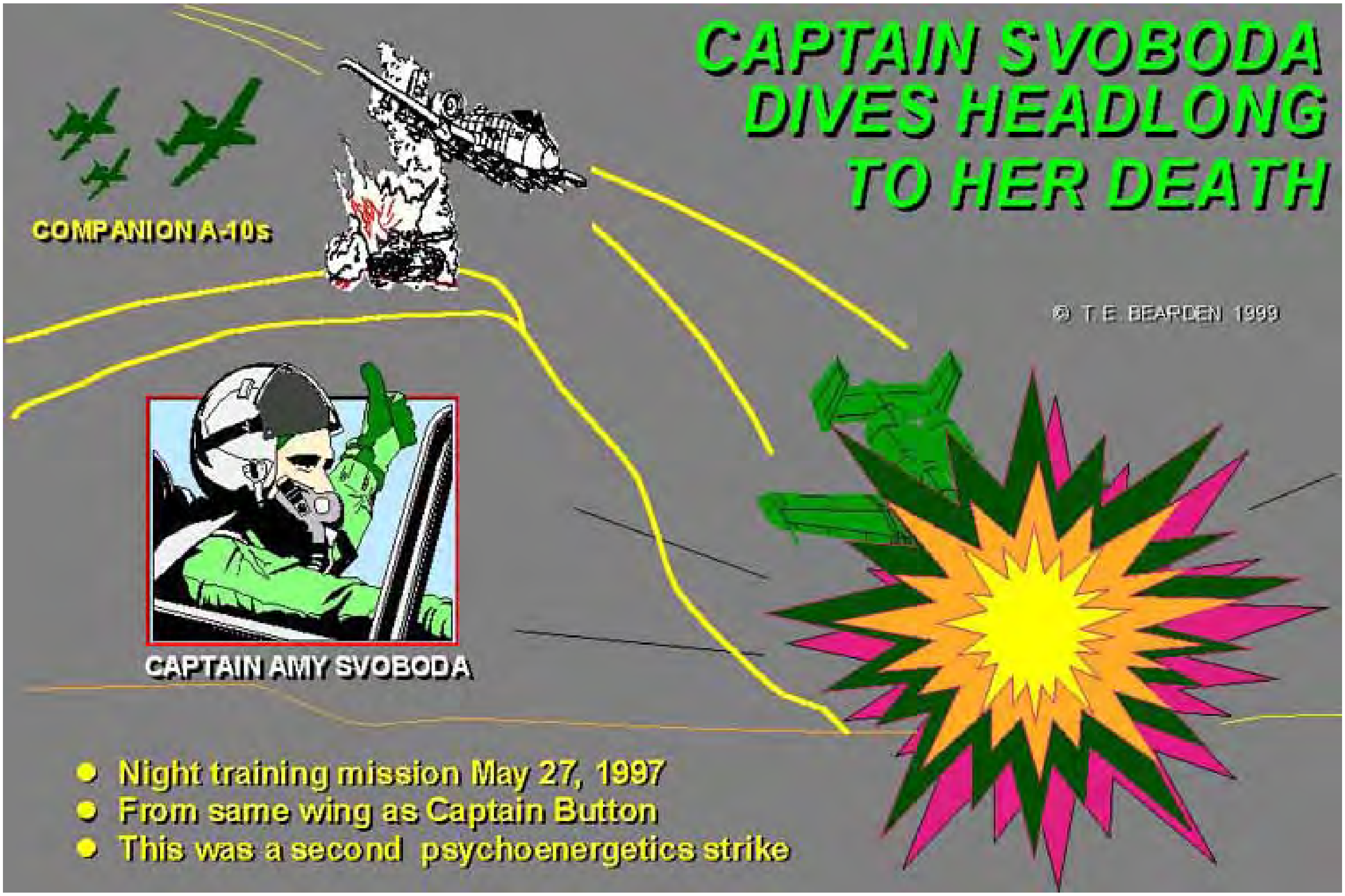

CAPTAIN SVOBODA DIVES HEADLONG TO HER DEATH

COMPANION A-10s
CAPTAIN AMY SVOBODA

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- Night training mission May 27, 1997
- From same wing as Captain Button
- This was a second psychoenergetics strike

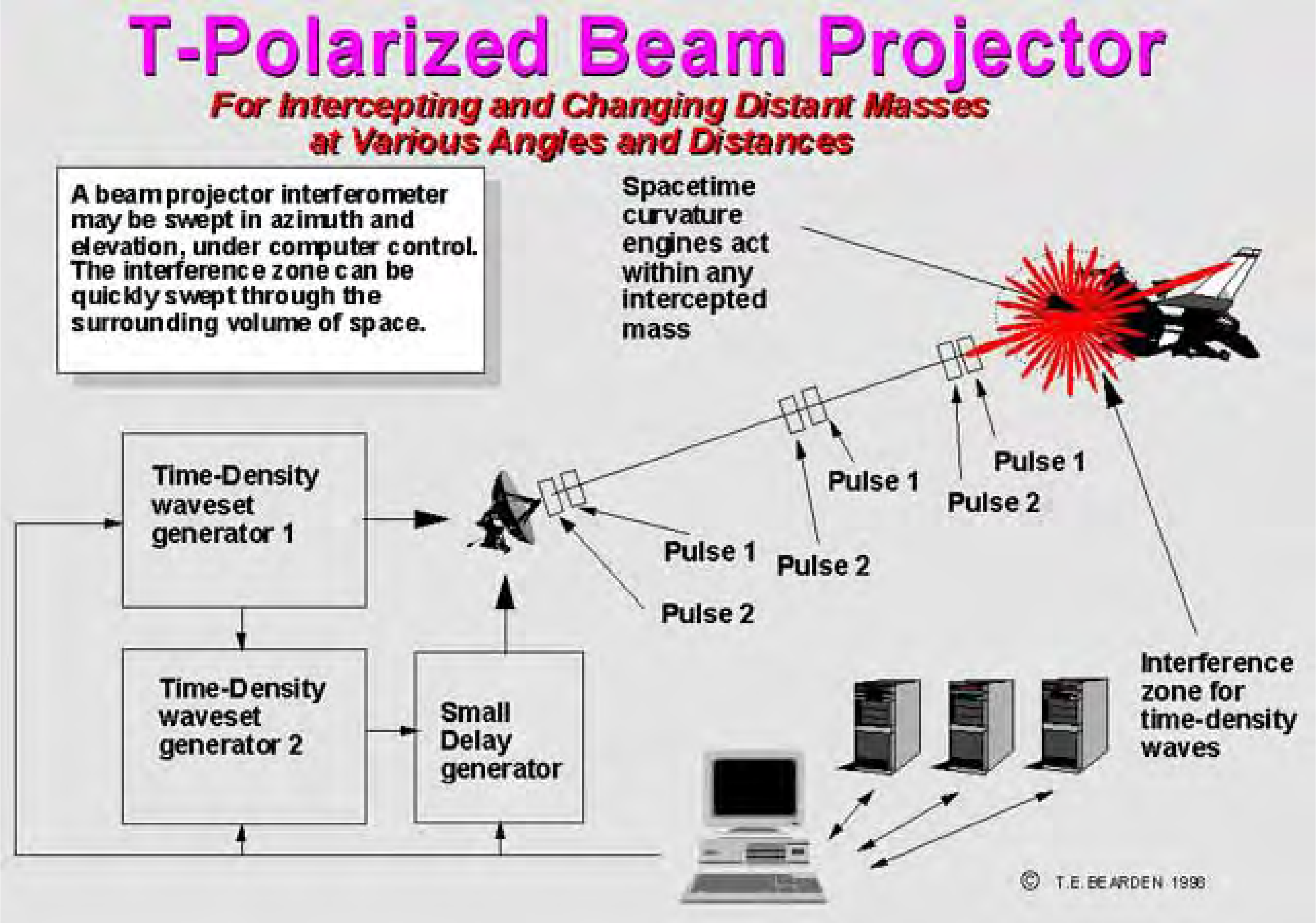

T-Polarized Beam Projector

For Intercepting and Changing Distant Masses at Various Angles and Distances

A beam projector interferometer may be swept in azimuth and elevation, under computer control. The interference zone can be quickly swept through the surrounding volume of space.

Spacetime curvature engines act within any intercepted mass
Time-Density waveset generator 1
Time-Density waveset generator 2
Small Delay generator
Pulse 1
Pulse 2
Pulse 1
Pulse 2
Pulse 1
Pulse 2
Interference zone for time-density waves
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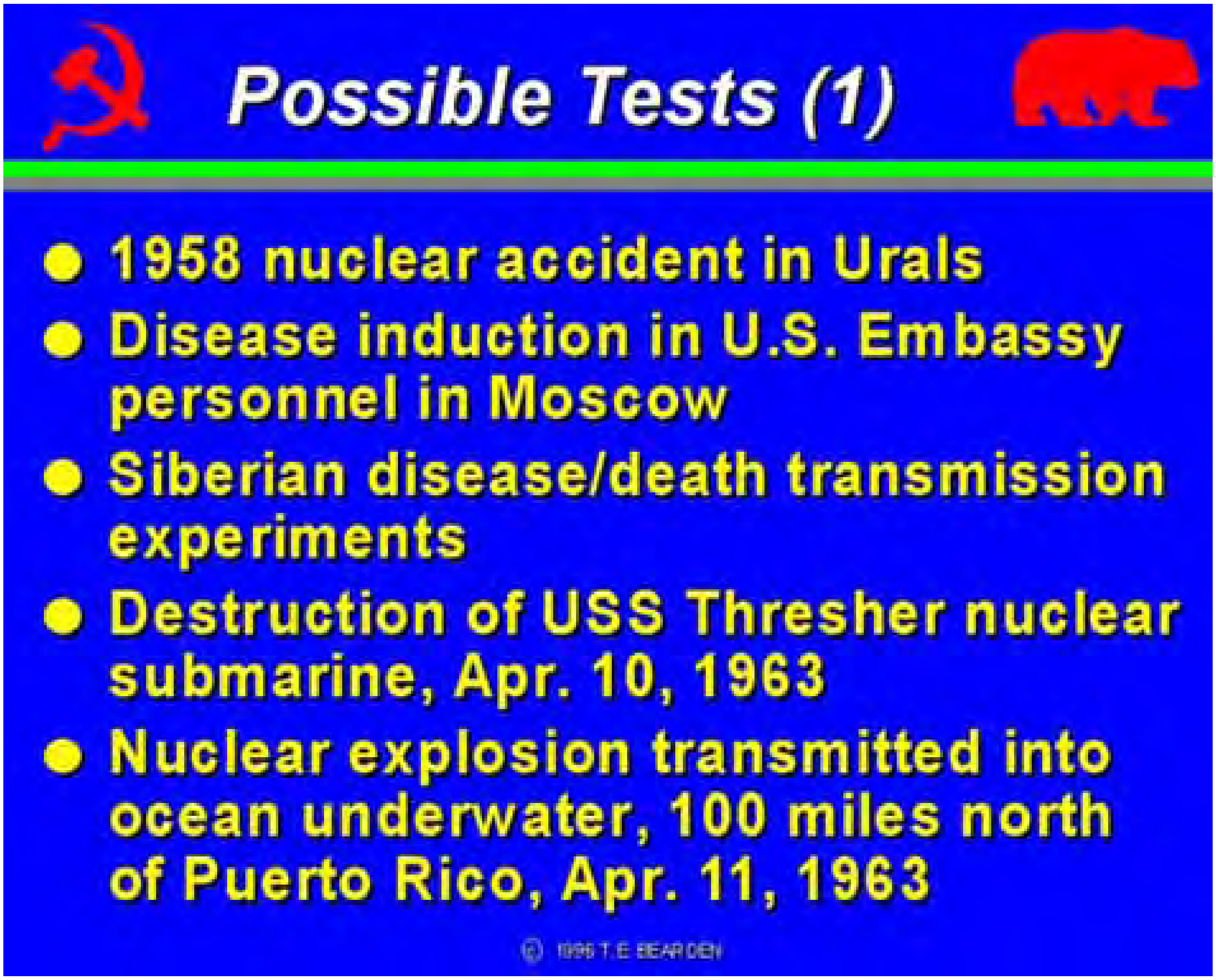

Possible Tests (1)

- 1958 nuclear accident in Urals
- Disease induction in U.S. Embassy personnel in Moscow
- Siberian disease/death transmission experiments
- Destruction of USS Thresher nuclear submarine, Apr. 10, 1963
- Nuclear explosion transmitted into ocean underwater, 100 miles north of Puerto Rico, Apr. 11, 1963

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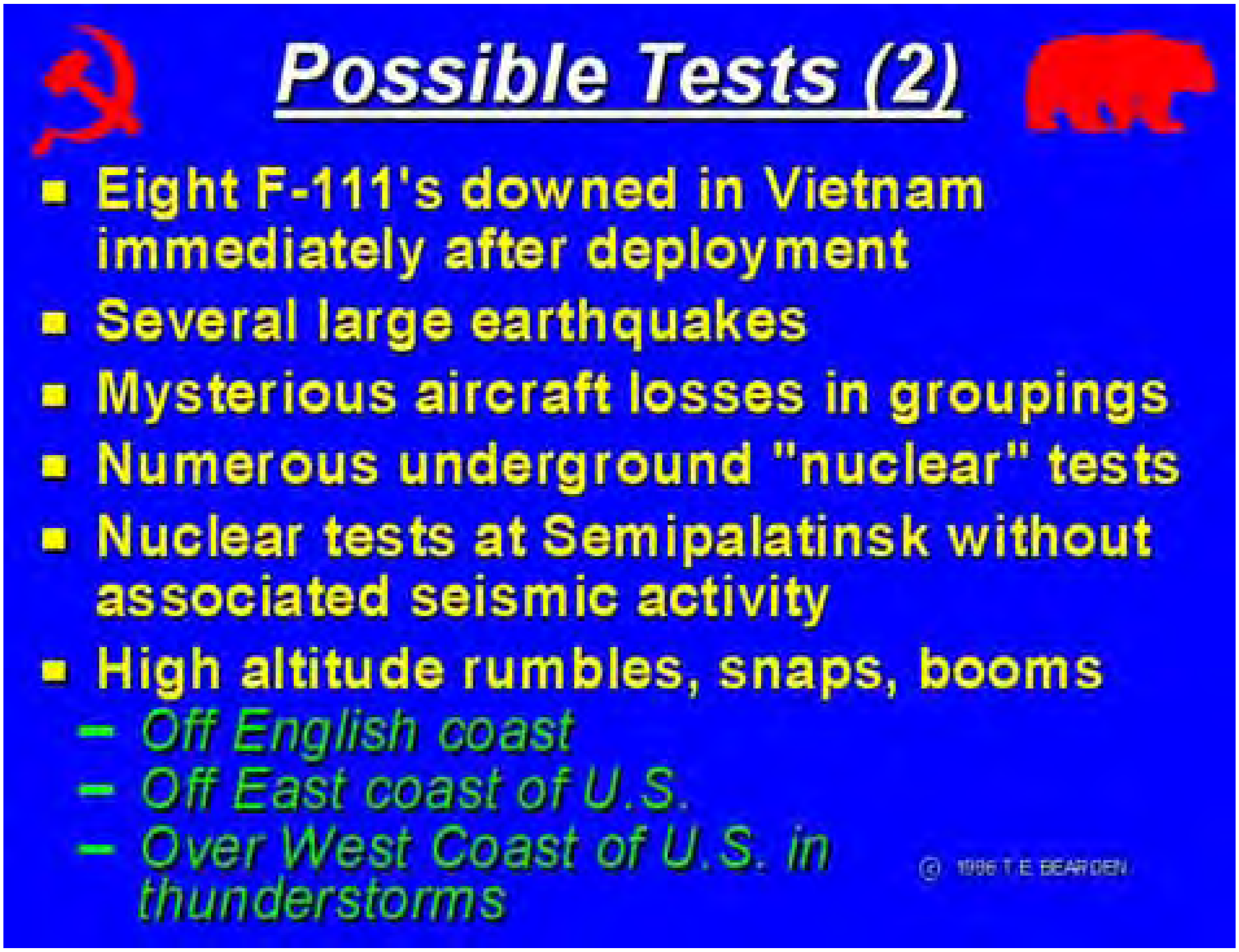

Possible Tests (2)

- Eight F-111's downed in Vietnam immediately after deployment
- Several large earthquakes
- Mysterious aircraft losses in groupings
- Numerous underground "nuclear" tests
- Nuclear tests at Semipalatinsk without associated seismic activity
- High altitude rumbles, snaps, booms
  - *Off English coast*
  - *Off East coast of U.S.*
  - *Over West Coast of U.S. in thunderstorms*

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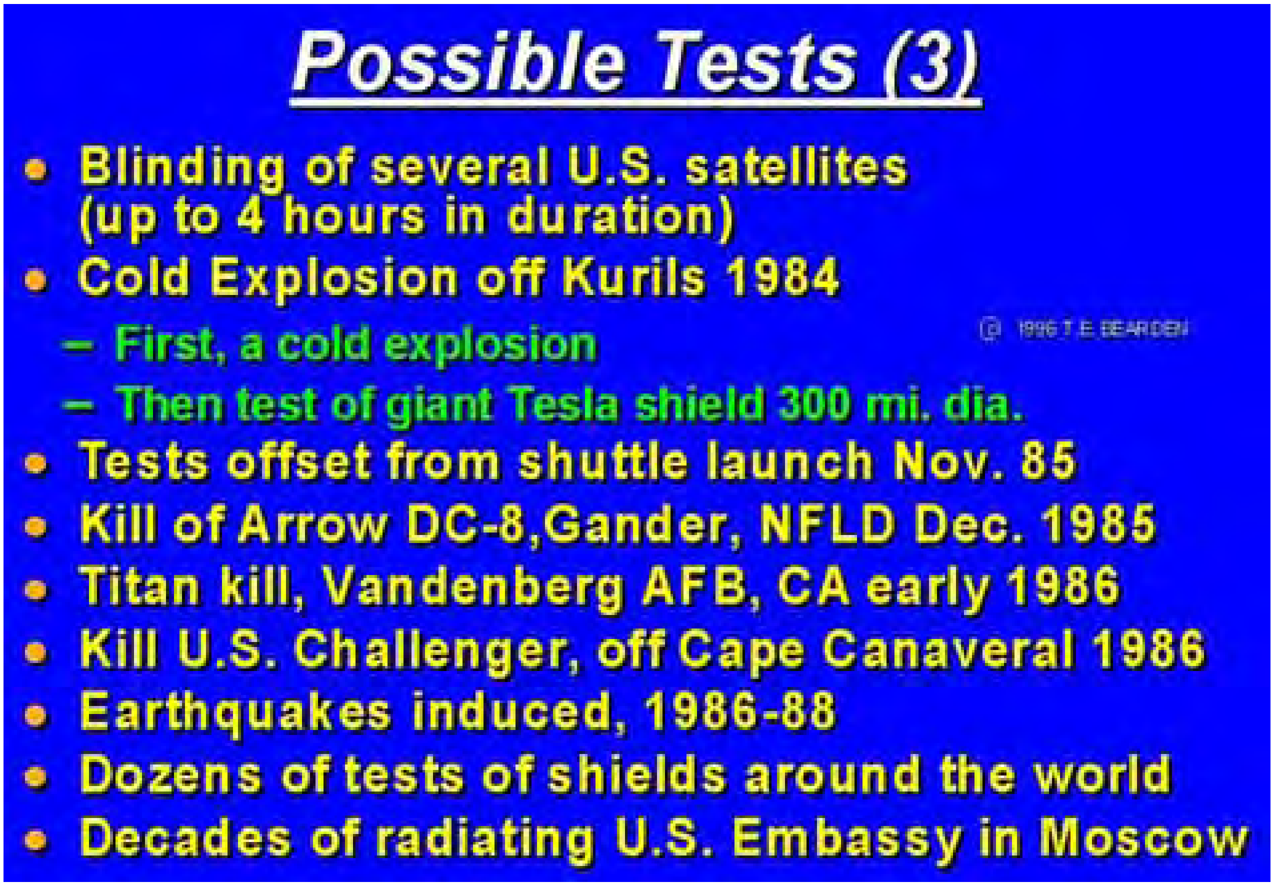

Possible Tests (3)

- Blinding of several U.S. satellites (up to 4 hours in duration)
- Cold Explosion off Kurils 1984
  - First, a cold explosion
  - Then test of giant Tesla shield 300 mi. dia.
- Tests offset from shuttle launch Nov. 85
- Kill of Arrow DC-8,Gander, NFLD Dec. 1985
- Titan kill, Vandenberg AFB, CA early 1986
- Kill U.S. Challenger, off Cape Canaveral 1986
- Earthquakes induced, 1986-88
- Dozens of tests of shields around the world
- Decades of radiating U.S. Embassy in Moscow

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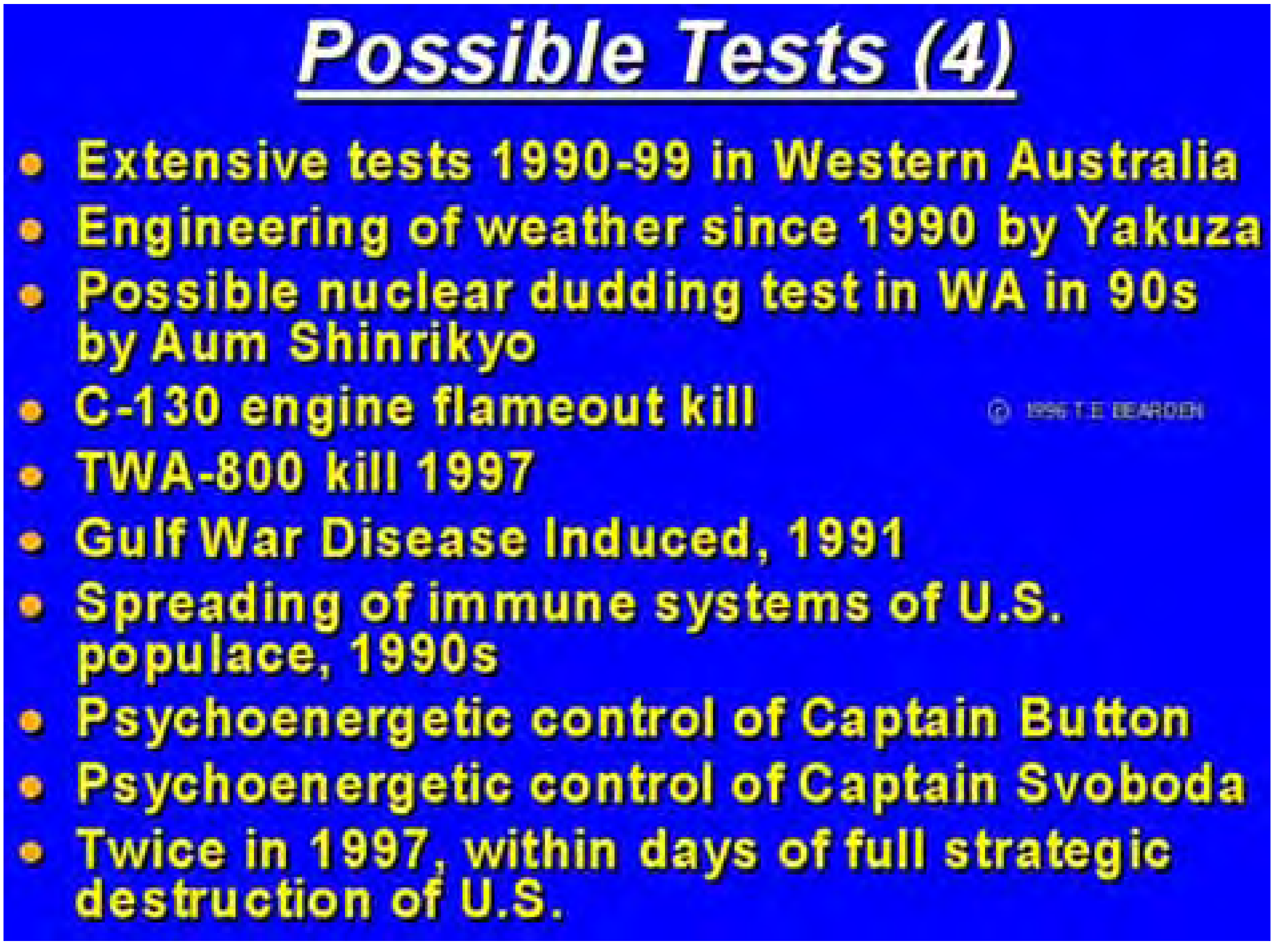

Possible Tests (4)

- Extensive tests 1990-99 in Western Australia
- Engineering of weather since 1990 by Yakuza
- Possible nuclear dudding test in WA in 90s by Aum Shinrikyo
- C-130 engine flameout kill
- TWA-800 kill 1997
- Gulf War Disease Induced, 1991
- Spreading of immune systems of U.S. populace, 1990s
- Psychoenergetic control of Captain Button
- Psychoenergetic control of Captain Svoboda
- Twice in 1997, within days of full strategic destruction of U.S.

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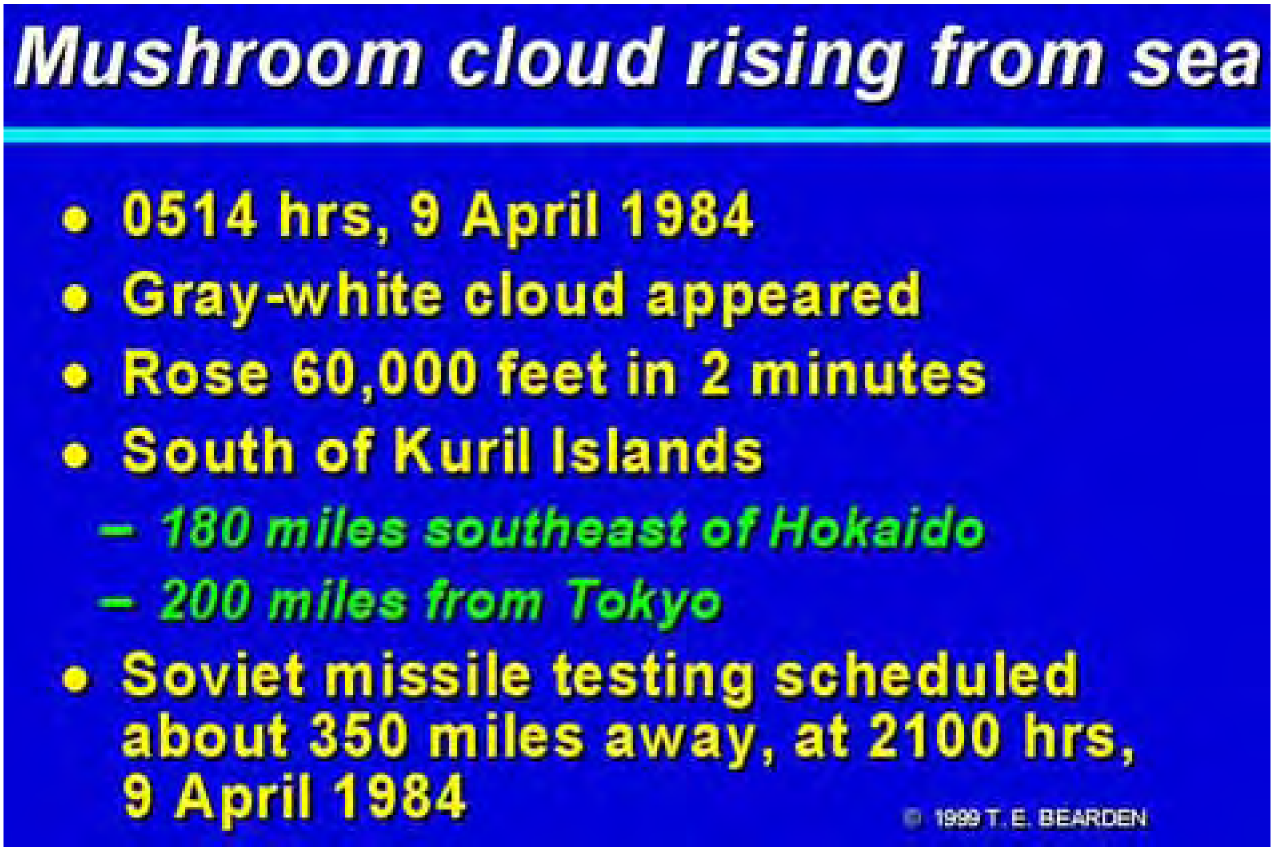

Mushroom cloud rising from sea

- 0514 hrs, 9 April 1984
- Gray-white cloud appeared
- Rose 60,000 feet in 2 minutes
- South of Kuril Islands
  - *180 miles southeast of Hokaido*
  - *200 miles from Tokyo*
- Soviet missile testing scheduled about 350 miles away, at 2100 hrs, 9 April 1984

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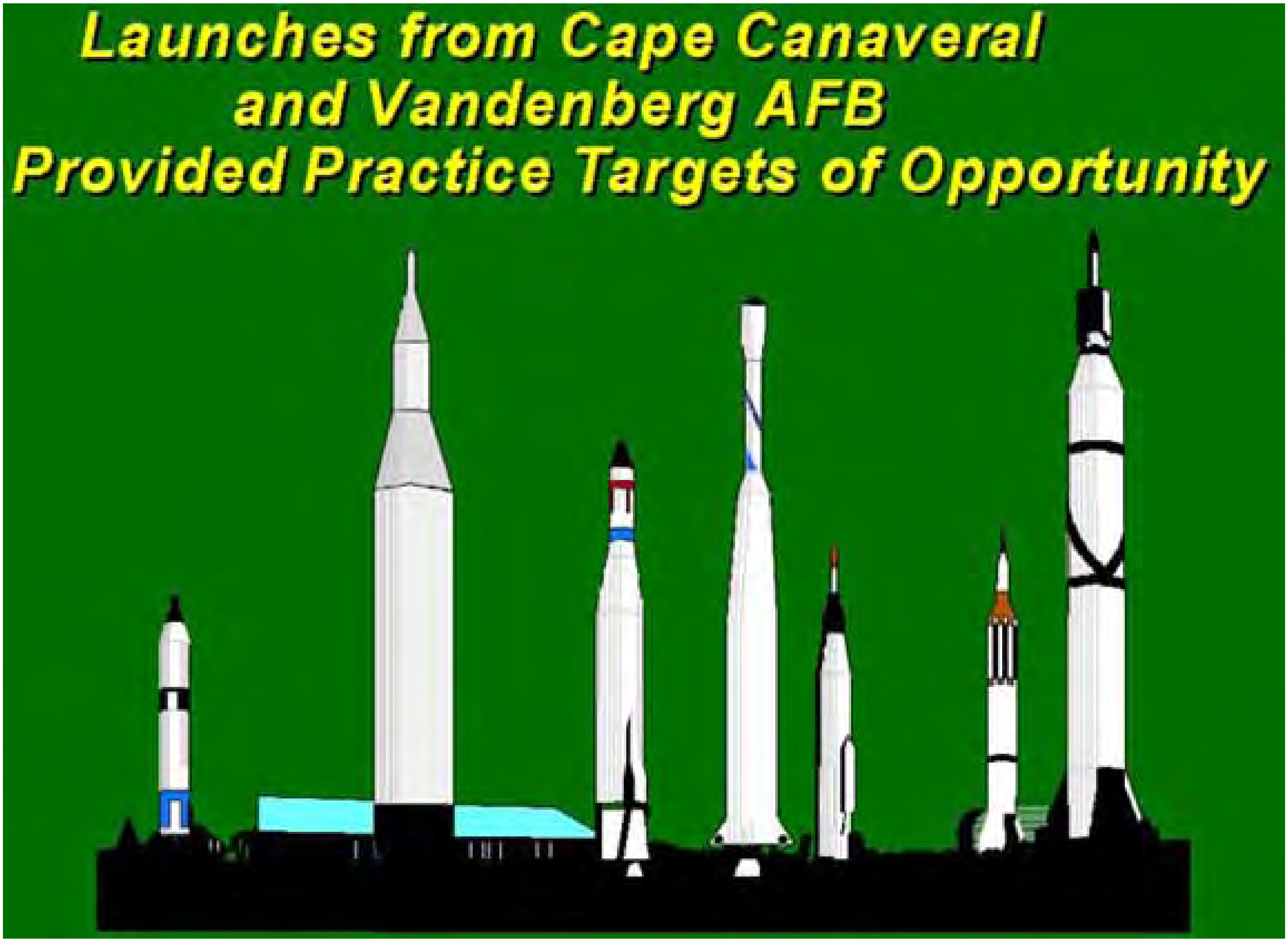
Launches from Cape Canaveral
and Vandenberg AFB
Provided Practice Targets of Opportunity

The sinking U.S.S. Thresher, with her controls jammed, implodes when she reaches crush depth

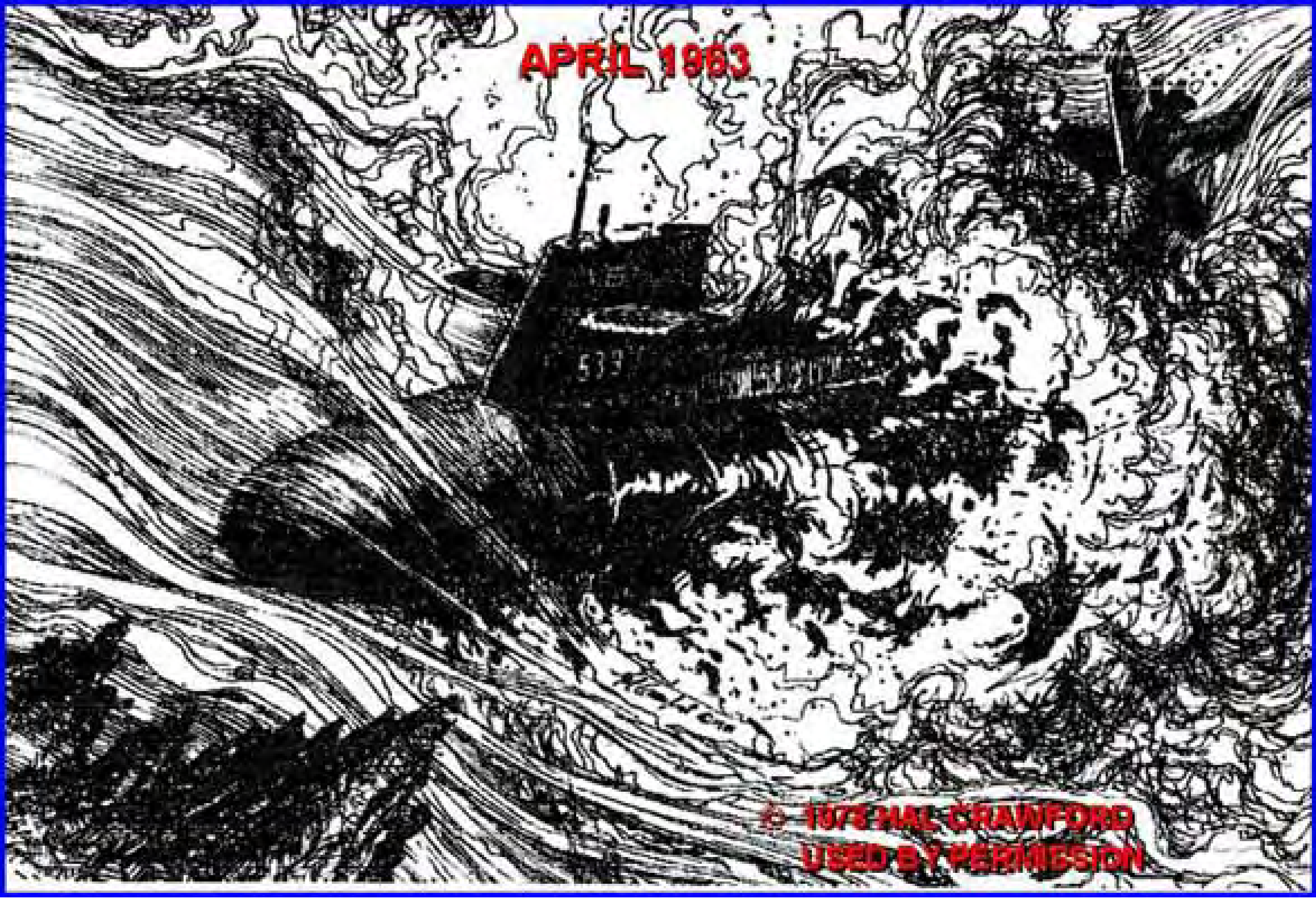
APRIL 1963
593
© 1978 HAL CRAWFORD
USED BY PERMISSION

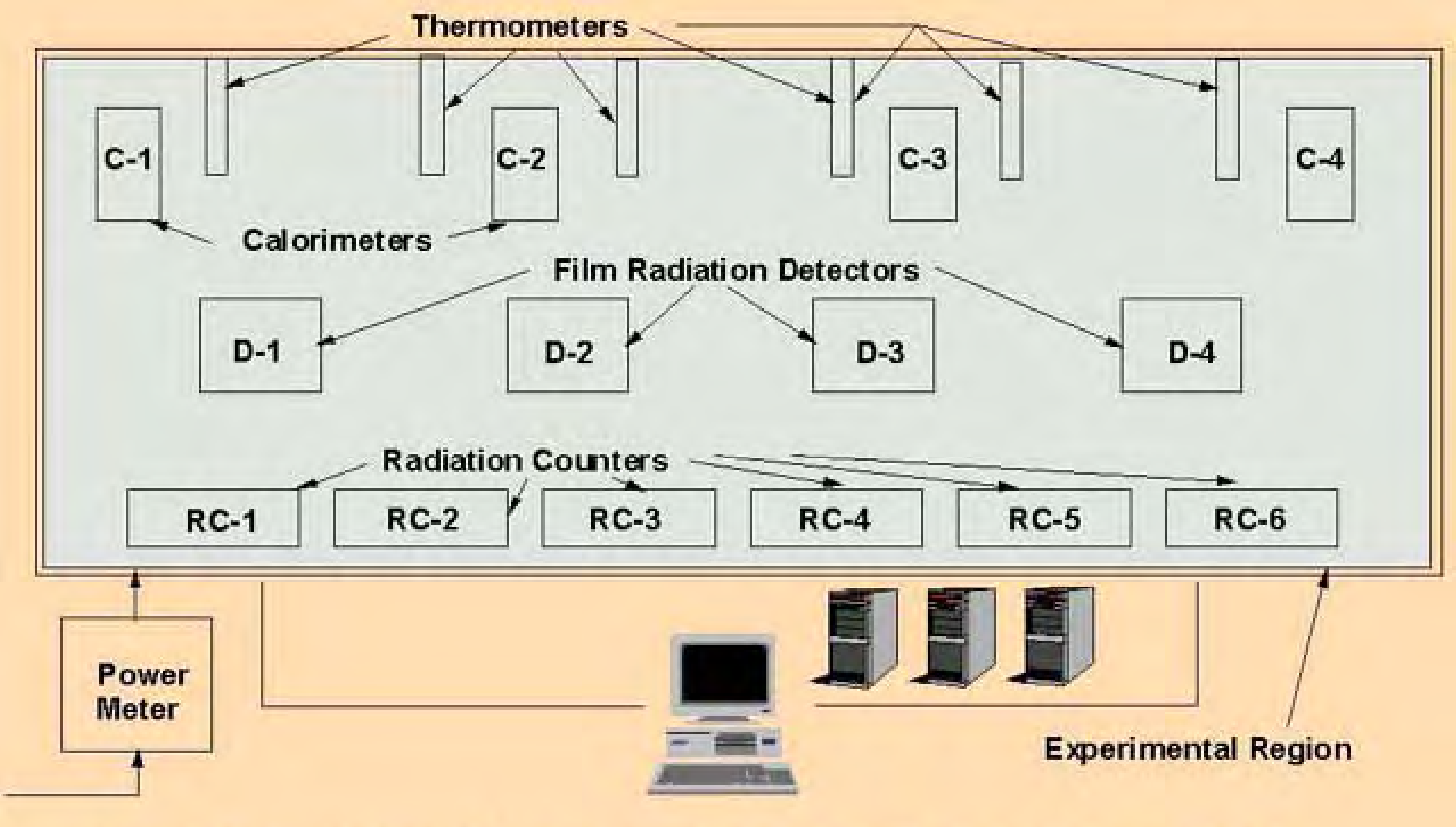
Thermometers
C-1
C-2
C-3
C-4
Calorimeters
Film Radiation Detectors
D-1
D-2
D-3
D-4
Radiation Counters
RC-1
RC-2
RC-3
RC-4
RC-5
RC-6
Power
Meter
Experimental Region

Figure 32. Embodiment of an instrumental array sufficient to discriminate when time-density charging has occurred, and that transduction of time-charge decay is occurring.

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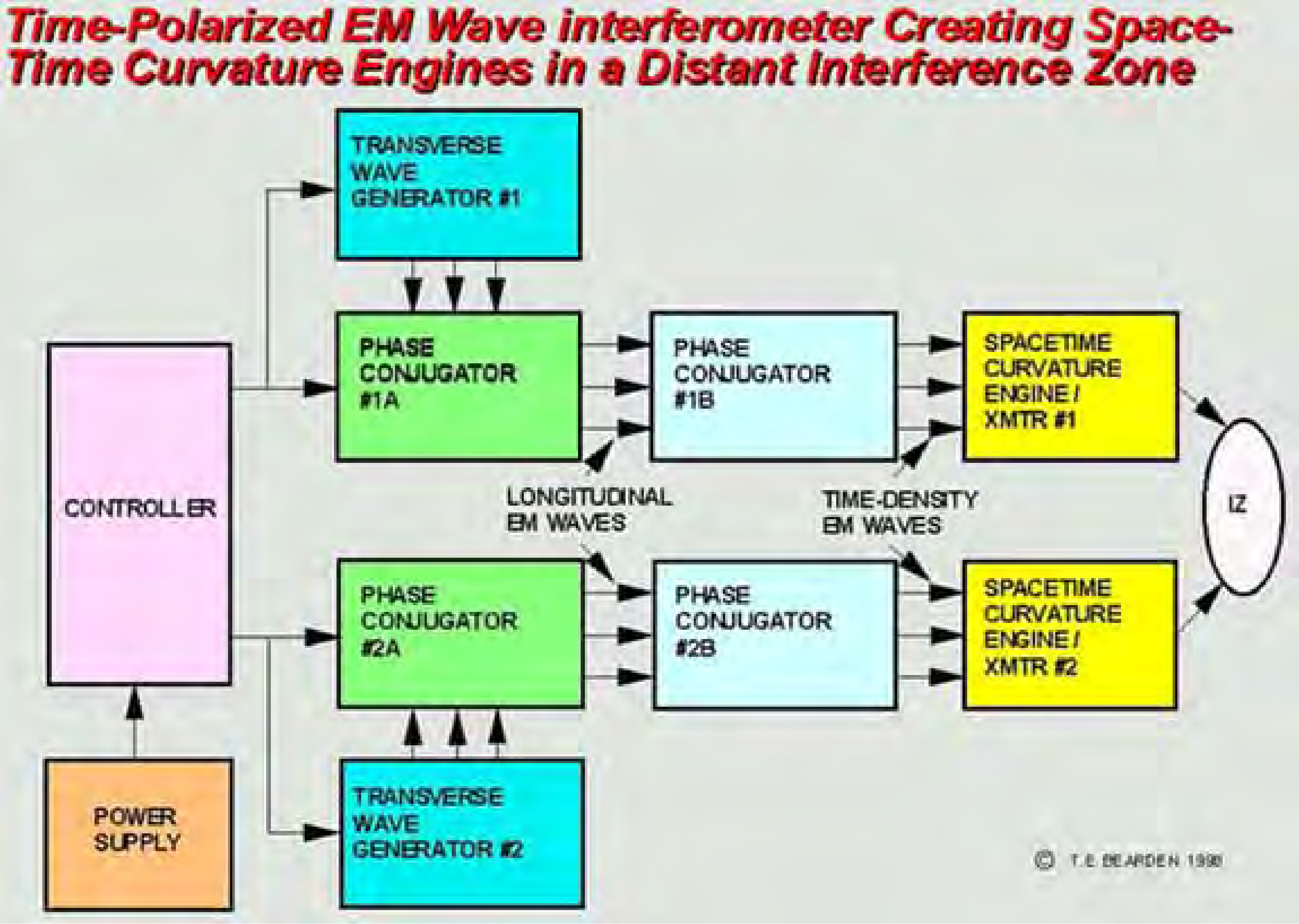

Time-Polarized EM Wave interferometer Creating Space-Time Curvature Engines in a Distant Interference Zone

TRANSVERSE WAVE GENERATOR #1
PHASE CONJUGATOR #1A
PHASE CONJUGATOR #1B
SPACETIME CURVATURE ENGINE / XMTR #1
CONTROLLER
LONGITUDINAL EM WAVES
TIME-DENSITY EM WAVES
IZ
PHASE CONJUGATOR #2A
PHASE CONJUGATOR #2B
SPACETIME CURVATURE ENGINE / XMTR #2
POWER SUPPLY
TRANSVERSE WAVE GENERATOR #2
© T.E. BEARDEN 1998

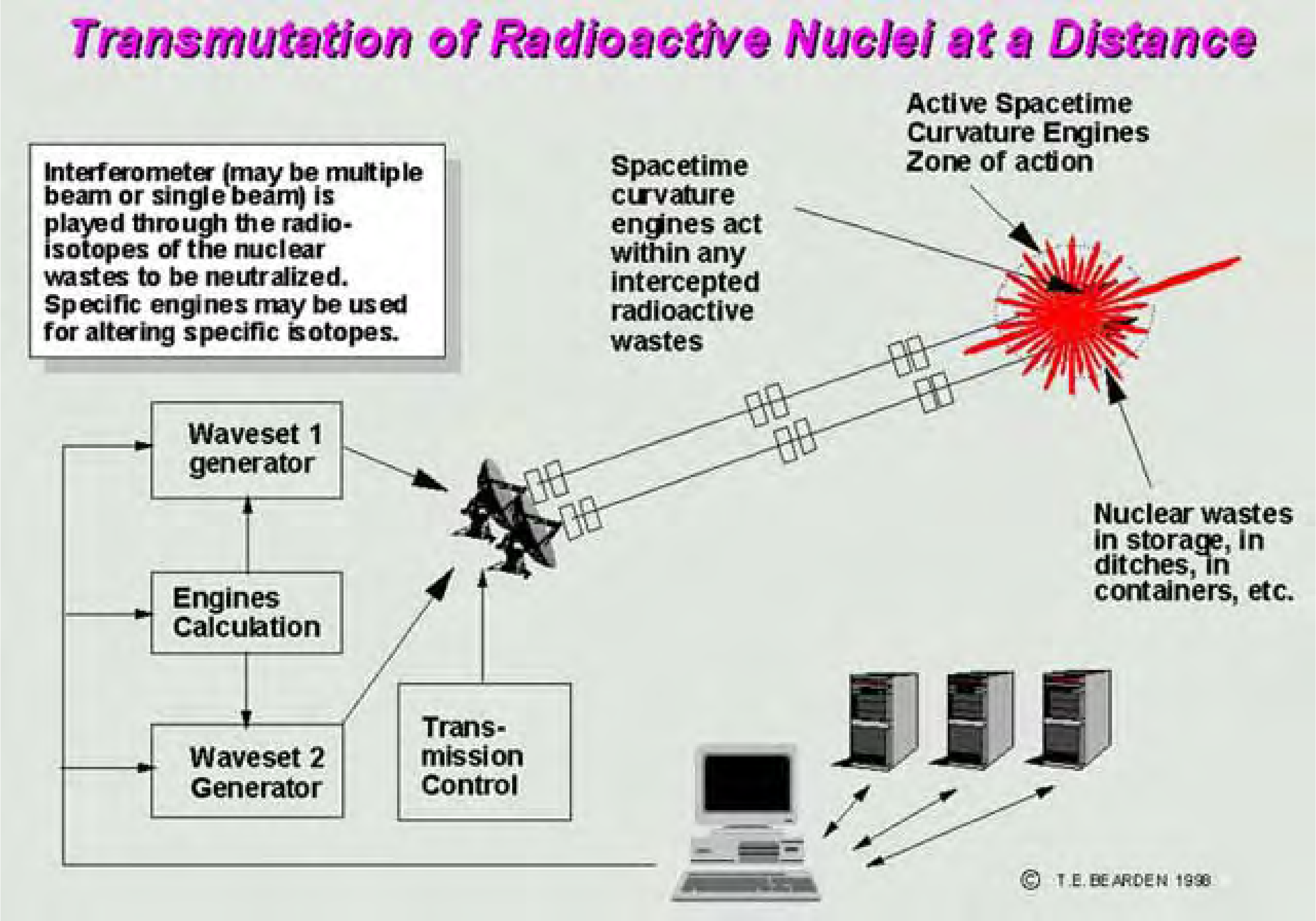

Transmutation of Radioactive Nuclei at a Distance

Interferometer (may be multiple beam or single beam) is played through the radioisotopes of the nuclear wastes to be neutralized. Specific engines may be used for altering specific isotopes.

Spacetime curvature engines act within any intercepted radioactive wastes

Active Spacetime Curvature Engines Zone of action
Waveset 1 generator
Engines Calculation
Waveset 2 Generator
Trans-mission Control
Nuclear wastes in storage, in ditches, in containers, etc.
© T.E. BEARDEN 1998

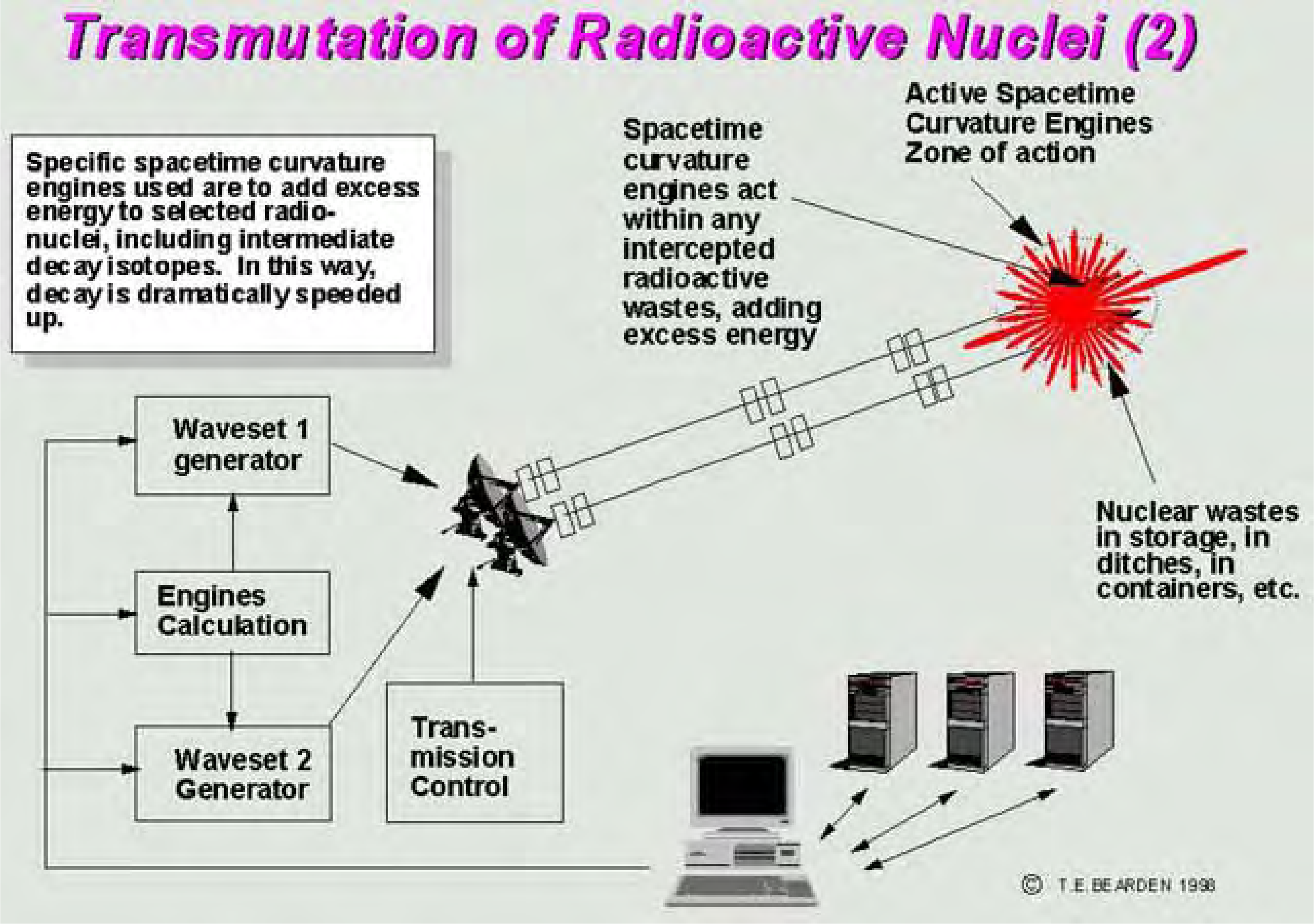

Transmutation of Radioactive Nuclei (2)

Specific spacetime curvature engines used are to add excess energy to selected radionuclei, including intermediate decay isotopes. In this way, decay is dramatically speeded up.

Spacetime curvature engines act within any intercepted radioactive wastes, adding excess energy

Active Spacetime Curvature Engines Zone of action

Nuclear wastes in storage, in ditches, in containers, etc.

Waveset 1 generator
Engines Calculation
Waveset 2 Generator
Trans-mission Control
© T.E. BEARDEN 1998

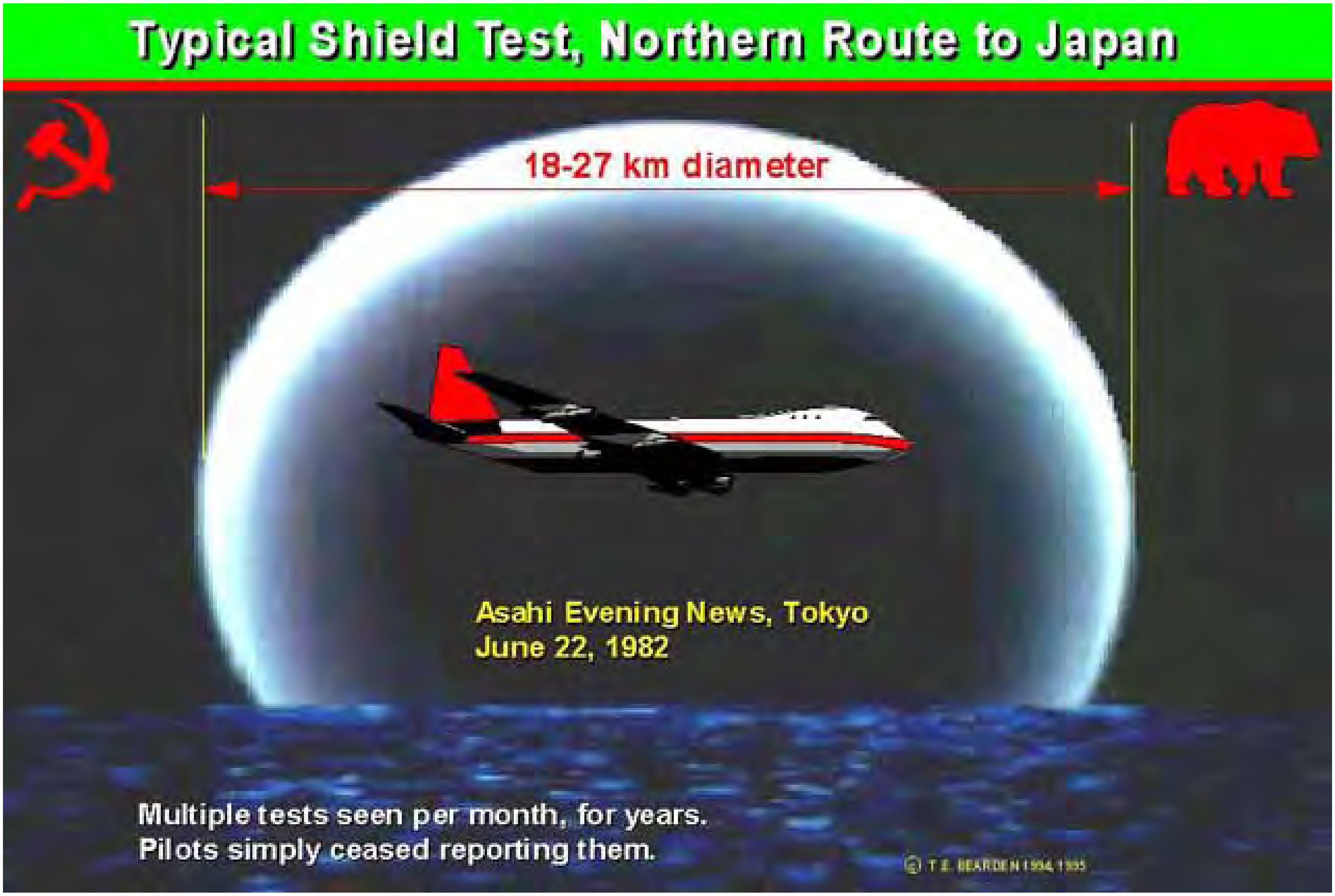

Typical Shield Test, Northern Route to Japan

Asahi Evening News, Tokyo
June 22, 1982

Multiple tests seen per month, for years.
Pilots simply ceased reporting them.

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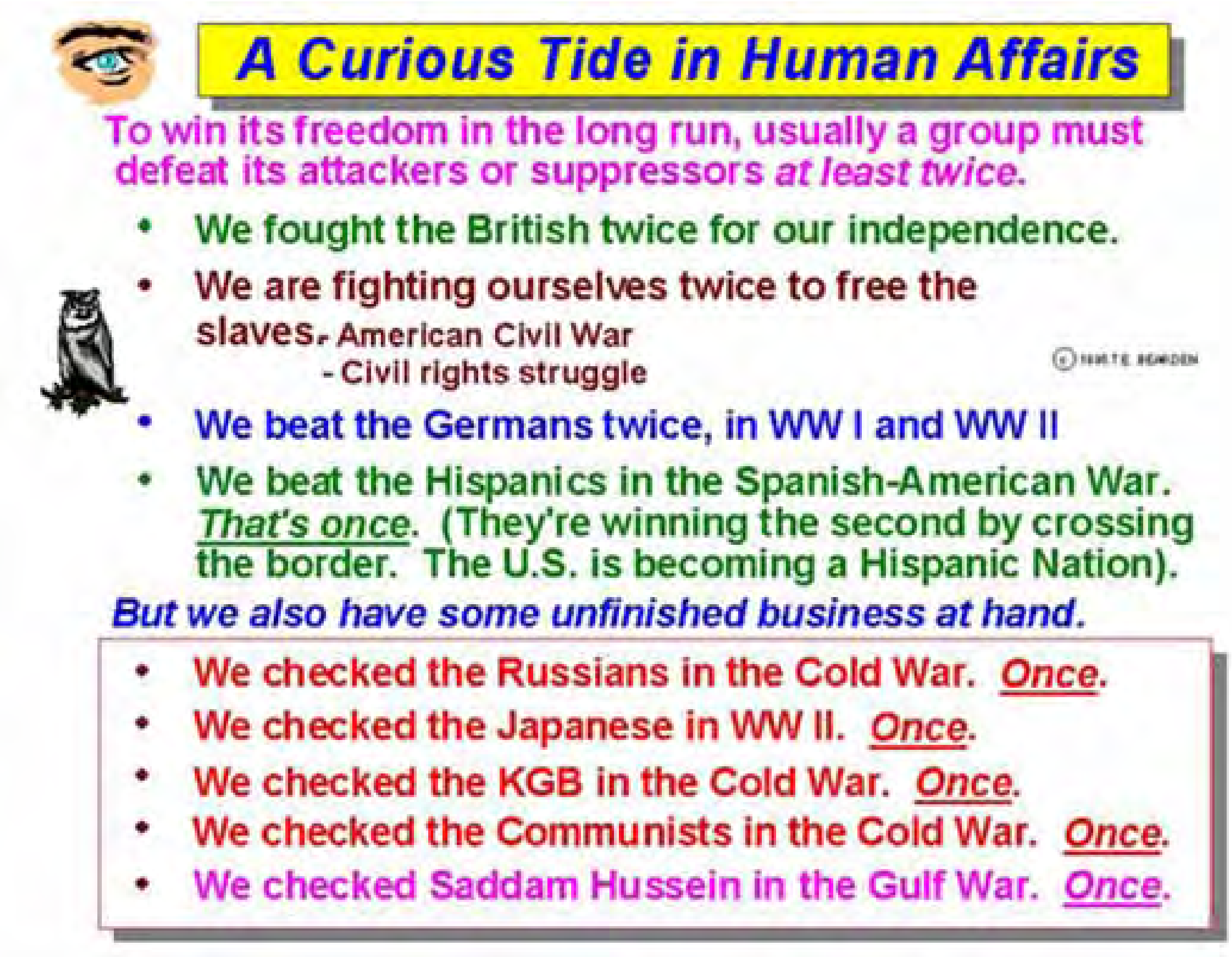

A Curious Tide in Human Affairs

To win its freedom in the long run, usually a group must defeat its attackers or suppressors *at least twice*.

- We fought the British twice for our independence.
- We are fighting ourselves twice to free the slaves. - American Civil War
  - Civil rights struggle

© [illegible]

- We beat the Germans twice, in WW I and WW II
- We beat the Hispanics in the Spanish-American War. *That's once*. (They're winning the second by crossing the border. The U.S. is becoming a Hispanic Nation).

But we also have some unfinished business at hand.

- We checked the Russians in the Cold War. *Once*.
- We checked the Japanese in WW II. *Once*.
- We checked the KGB in the Cold War. *Once*.
- We checked the Communists in the Cold War. *Once*.
- We checked Saddam Hussein in the Gulf War. *Once*.

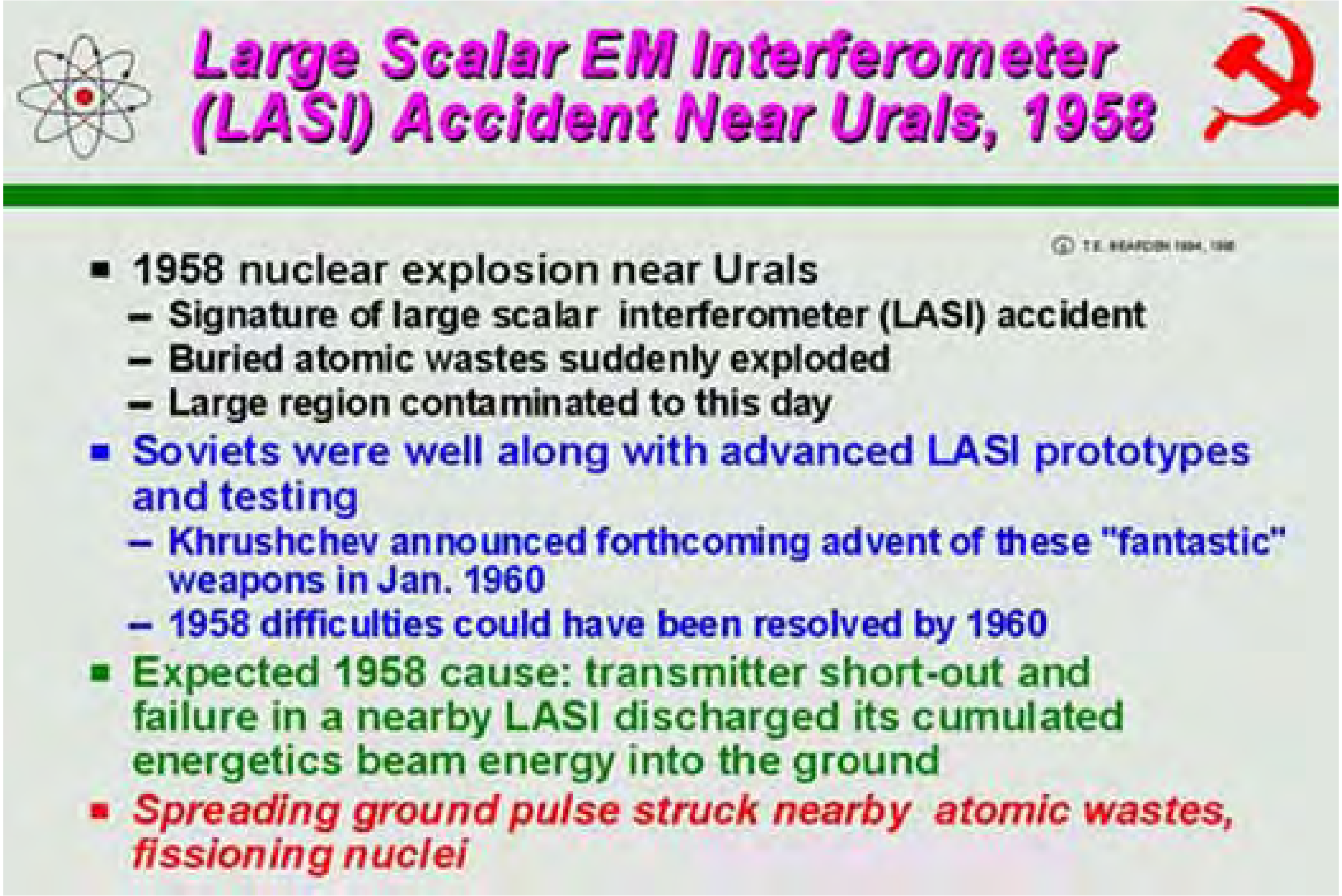

Large Scalar EM Interferometer (LASI) Accident Near Urals, 1958

- 1958 nuclear explosion near Urals
  - Signature of large scalar interferometer (LASI) accident
  - Buried atomic wastes suddenly exploded
  - Large region contaminated to this day
- Soviets were well along with advanced LASI prototypes and testing
  - Khrushchev announced forthcoming advent of these "fantastic" weapons in Jan. 1960
  - 1958 difficulties could have been resolved by 1960
- Expected 1958 cause: transmitter short-out and failure in a nearby LASI discharged its cumulated energetics beam energy into the ground
- *Spreading ground pulse struck nearby atomic wastes, fissioning nuclei*

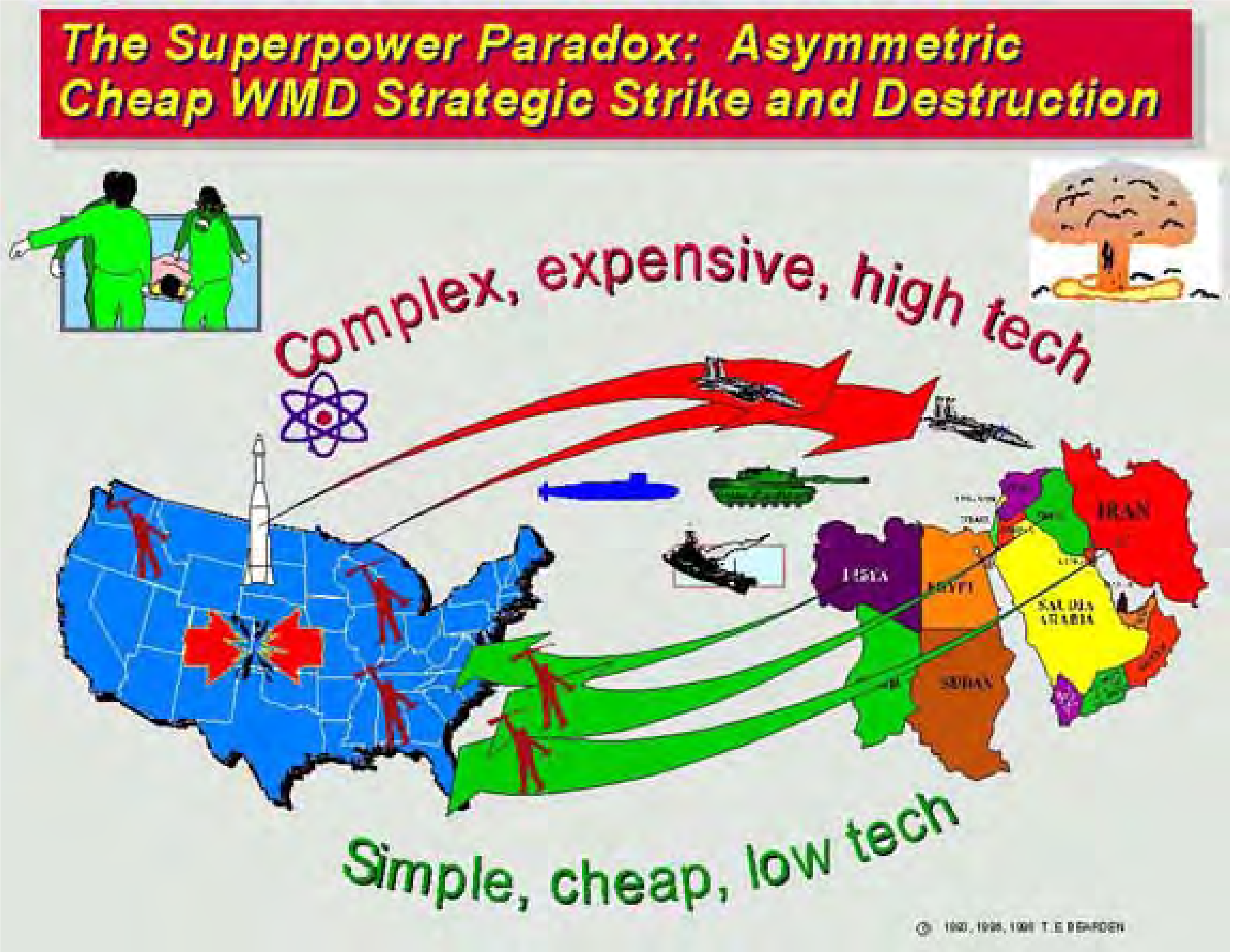

The Superpower Paradox: Asymmetric Cheap WMD Strategic Strike and Destruction

Complex, expensive, high tech

Simple, cheap, low tech

LIBYA
EGYPT
SUDAN
SAUDI ARABIA
IRAN

© 1990, 1996, 1998 T. E. BEARDEN

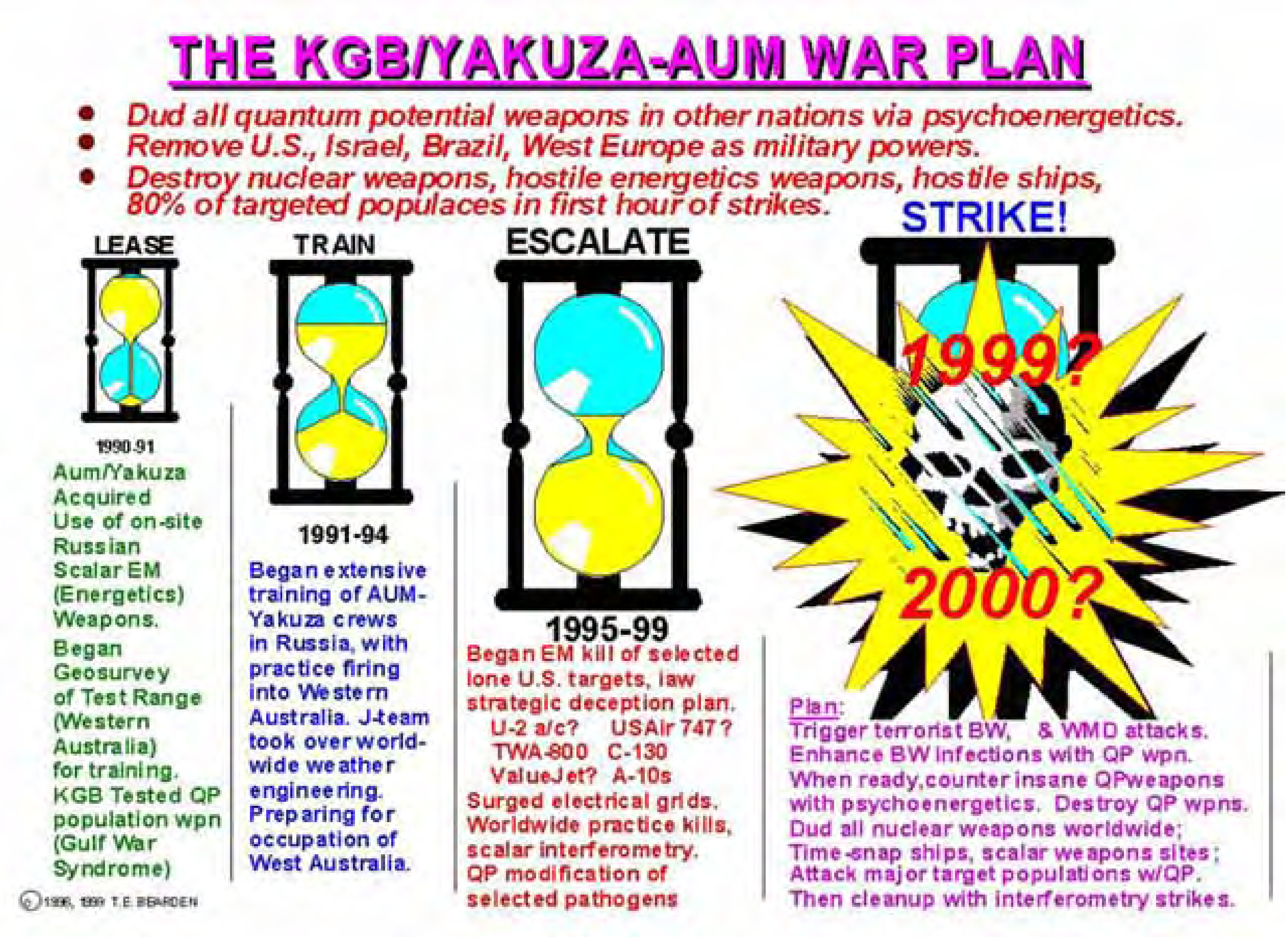

THE KGB/YAKUZA-AUM WAR PLAN

- *Dud all quantum potential weapons in other nations via psychoenergetics.*
- *Remove U.S., Israel, Brazil, West Europe as military powers.*
- *Destroy nuclear weapons, hostile energetics weapons, hostile ships, 80% of targeted populaces in first hour of strikes.*

LEASE

1990-91

Aum/Yakuza Acquired Use of on-site Russian Scalar EM (Energetics) Weapons.

Began Geosurvey of Test Range (Western Australia) for training.

KGB Tested QP population wpn (Gulf War Syndrome)

TRAIN

1991-94

Began extensive training of AUM-Yakuza crews in Russia, with practice firing into Western Australia. J-team took over world-wide weather engineering. Preparing for occupation of West Australia.

ESCALATE

1995-99

Began EM kill of selected lone U.S. targets, law strategic deception plan.

U-2 a/c?   USAir 747 ?
TWA-800   C-130
ValueJet?   A-10s

Surged electrical grids. Worldwide practice kills, scalar interferometry. QP modification of selected pathogens

STRIKE!

Plan:
Trigger terrorist BW, & WMD attacks.
Enhance BW infections with QP wpn.
When ready, counter insane QPweapons with psychoenergetics. Destroy QP wpns.
Dud all nuclear weapons worldwide;
Time-snap ships, scalar weapons sites;
Attack major target populations w/QP.
Then cleanup with interferometry strikes.

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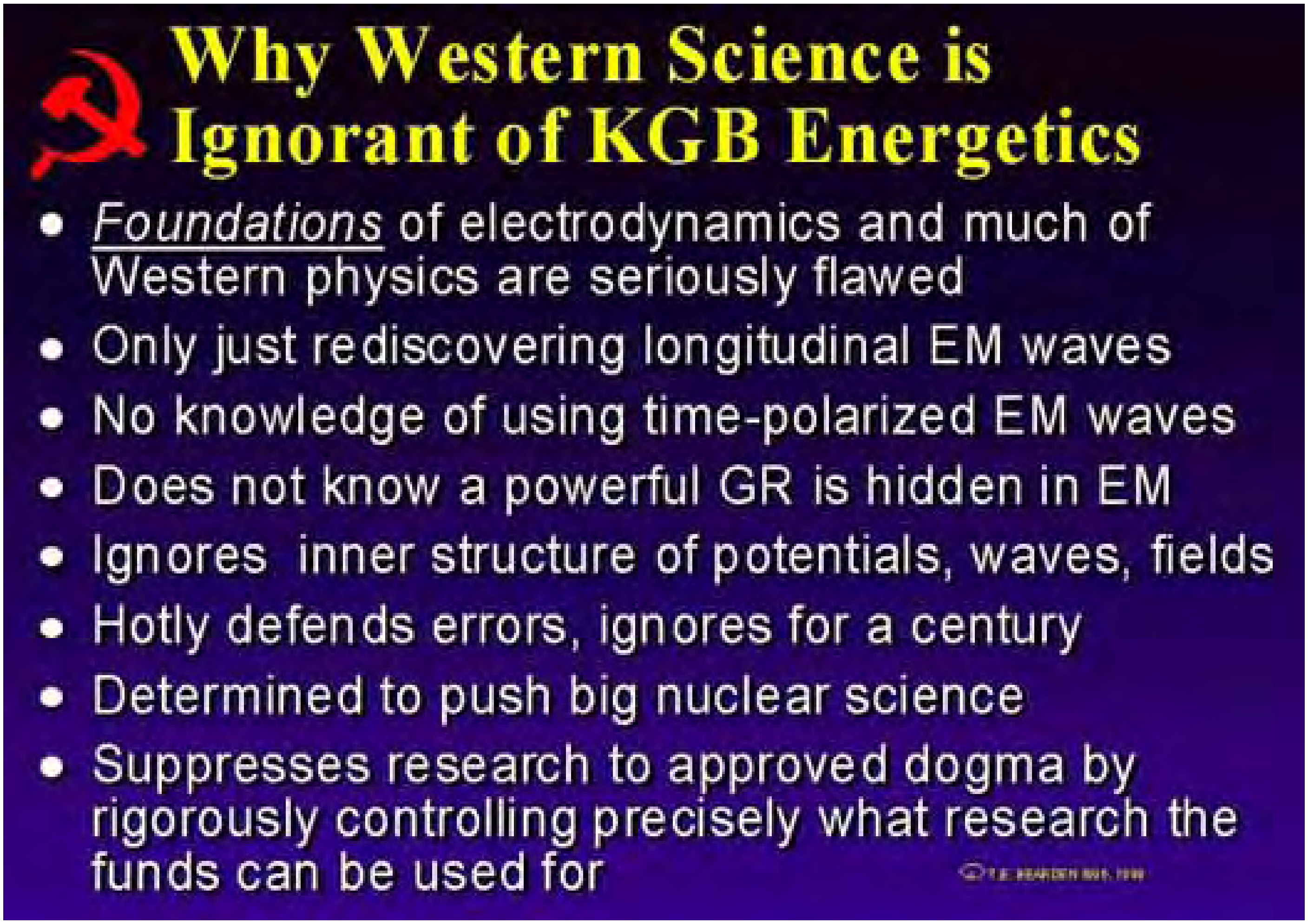

Why Western Science is Ignorant of KGB Energetics

- *Foundations* of electrodynamics and much of Western physics are seriously flawed
- Only just rediscovering longitudinal EM waves
- No knowledge of using time-polarized EM waves
- Does not know a powerful GR is hidden in EM
- Ignores inner structure of potentials, waves, fields
- Hotly defends errors, ignores for a century
- Determined to push big nuclear science
- Suppresses research to approved dogma by rigorously controlling precisely what research the funds can be used for

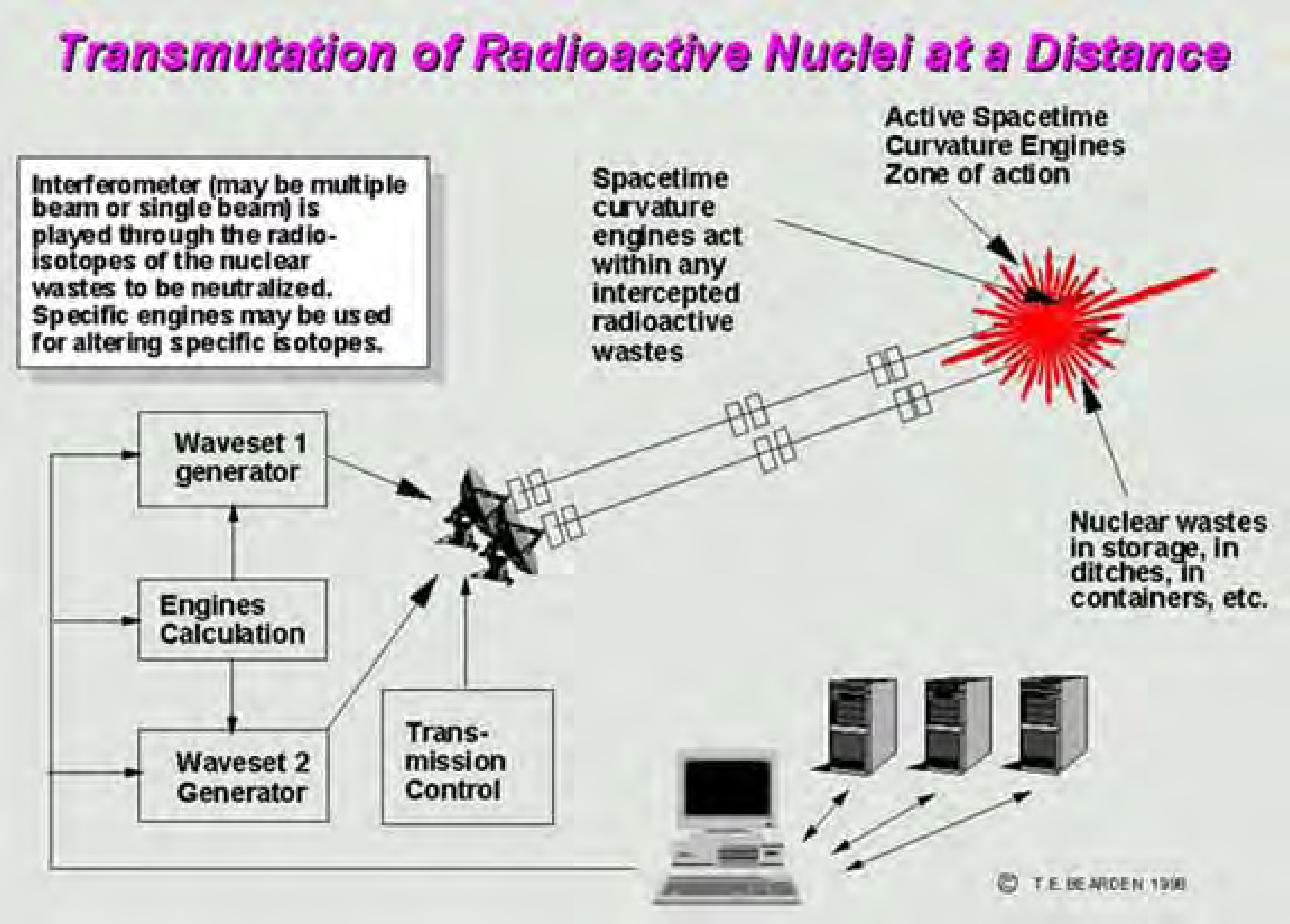

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Waveset 1 generator
Engines Calculation
Waveset 2 Generator
Trans-mission Control
Spacetime curvature engines act within any intercepted radioactive wastes
Active Spacetime Curvature Engines Zone of action
Nuclear wastes in storage, in ditches, in containers, etc.
© T.E. BEARDEN 1998

THE YAKUZA

(JAPANESE MAFIA)

To do business with Japan is to do business with the Yakuza

The Last Samurai, Defending Bushido

- 3 Major Yakuza Groups, In Coalition.
- Penetrate Japanese Government.
- Open Offices, Signs on Street.
- Public Romanticizes Yakuza as Last Japanese Samurai
- In Large High-Tech Corporations.
- In Control of Japanese Banks.
- Japanese Real-Estate Rip-off.
- $500 - 1,000 Billion per Year Income.
- Rapidly Spreading in U.S.
- Uniting Mafia Groups Worldwide.
- Coalition with Aum Shinrikyo.
- Leased Russian Energetics Weapons.
- Crews On-site in Russia, Trained.
- Practice Firings into Western Australia for Three Years. (Dozens of Shots per Month)
- Now in Escalation Phase, Killing U.S. Targets.
- All-out Strike on U.S. ready 1999-2000.
- Now held in check by KGB, dead-man fuzed by small nation friendly to U. S.

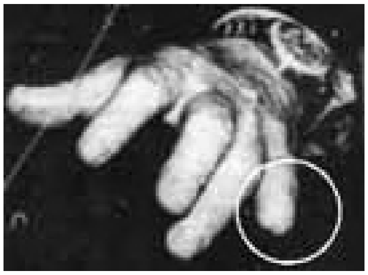

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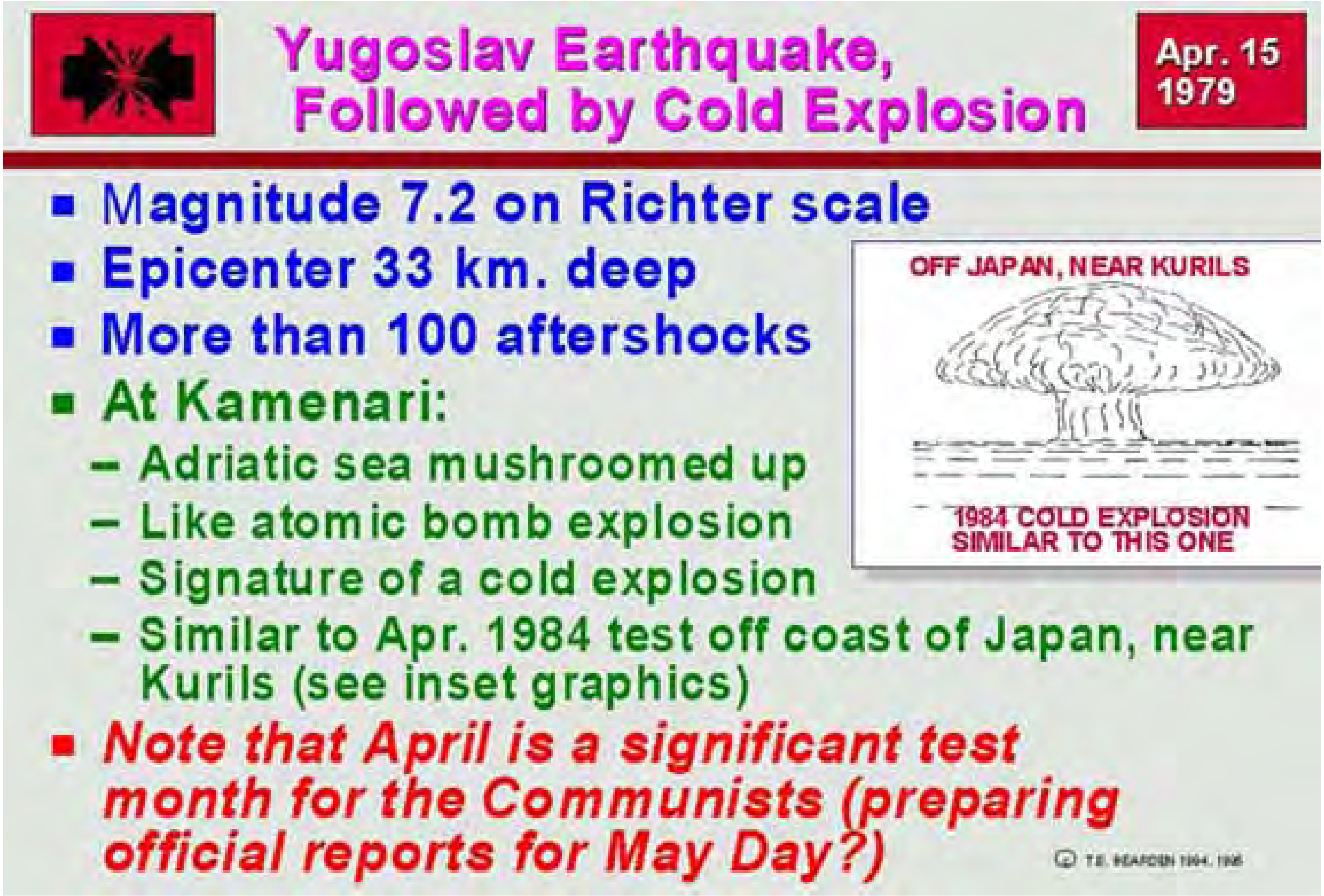

Yugoslav Earthquake, Followed by Cold Explosion

Apr. 15 1979

- Magnitude 7.2 on Richter scale
- Epicenter 33 km. deep
- More than 100 aftershocks
- At Kamenari:
  - Adriatic sea mushroomed up
  - Like atomic bomb explosion
  - Signature of a cold explosion
  - Similar to Apr. 1984 test off coast of Japan, near Kurils (see inset graphics)
- *Note that April is a significant test month for the Communists (preparing official reports for May Day?)*

OFF JAPAN, NEAR KURILS

1984 COLD EXPLOSION SIMILAR TO THIS ONE

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Technical Background on the Priore Healing Process

Contents

1. Technical Background on the Priore Healing Process
2. Transduction of EM wave types by successive phase conjugation.
3. Time-charging and Time-density excited states
4. Interference for transduction in slow decay of time-density excited states
5. Infolded longitudinal biwaves composition of a scalar potential
6. Scalar potential interferometry produces all EM force fields and waves
7. Some serious flaws and errors in classical EM theory (#1-16)
8. Some serious flaws and errors in classical EM theory (#17-32)
9. Abnormal penetration depth of weak signals due to photon interaction
10. Amplified replica of body's signal complex to reverse cellular disease & damage
11. Amplified replica of body's signal complex to correct a congenital condition

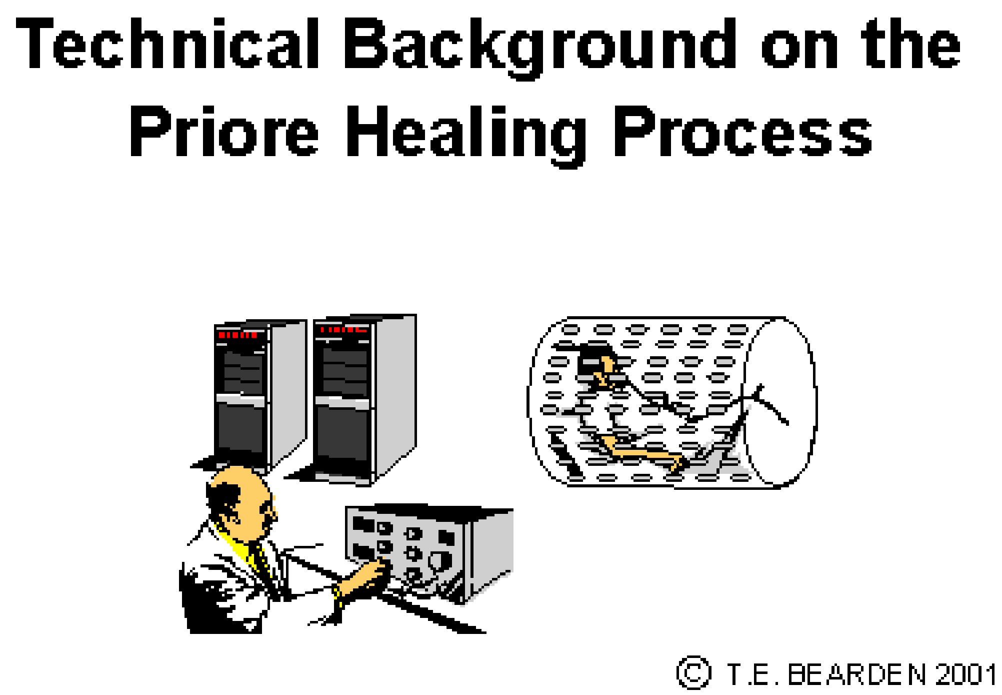

Technical Background on the Priore Healing Process

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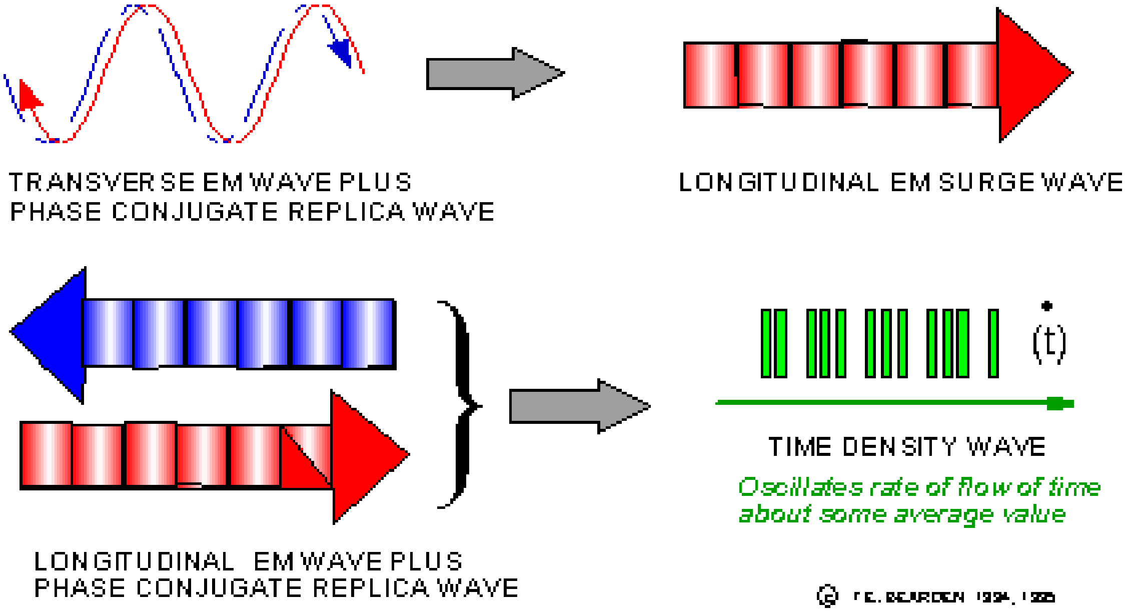
TRANSVERSE EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE
LONGITUDINAL EM SURGE WAVE
LONGITUDINAL EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE
(t)
TIME DENSITY WAVE
Oscillates rate of flow of time
about some average value
© T.E. BEARDEN 1994, 1995

Figure 1. Transduction of EM wave types by successive phase conjugation.

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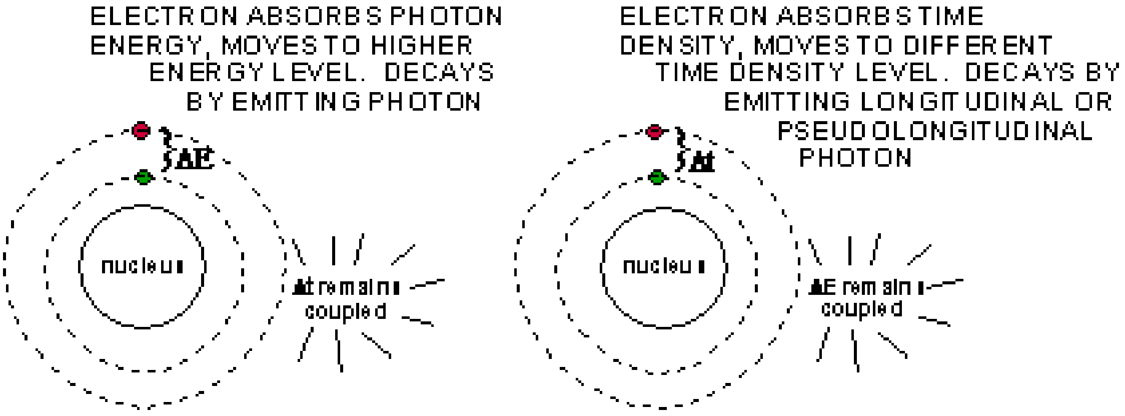
ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON
ΔE
nucleus
Δt remains coupled
ELECTRON ABSORBS TIME DENSITY, MOVES TO DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTON
Δt
nucleus
ΔE remains coupled

Figure A. Excited energy density level.

Figure B. Excited time density level.

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Figure 2. Time-charging and Time-density excited states, contrasted to ordinary spatial energy excited state.

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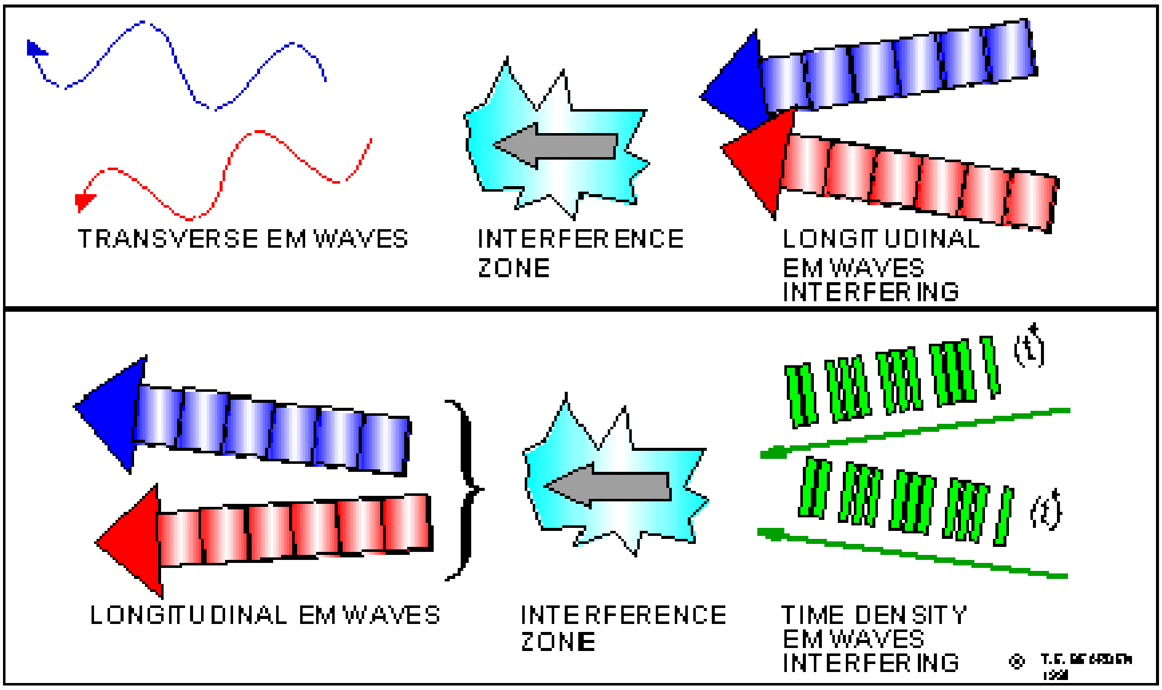
TRANSVERSE EM WAVES
INTERFERENCE ZONE
LONGITUDINAL EM WAVES INTERFERING
(t)
(t)
LONGITUDINAL EM WAVES
INTERFERENCE ZONE
TIME DENSITY EM WAVES INTERFERING

Figure 3. Interference processes for transduction in slow decay of time-density excited states.

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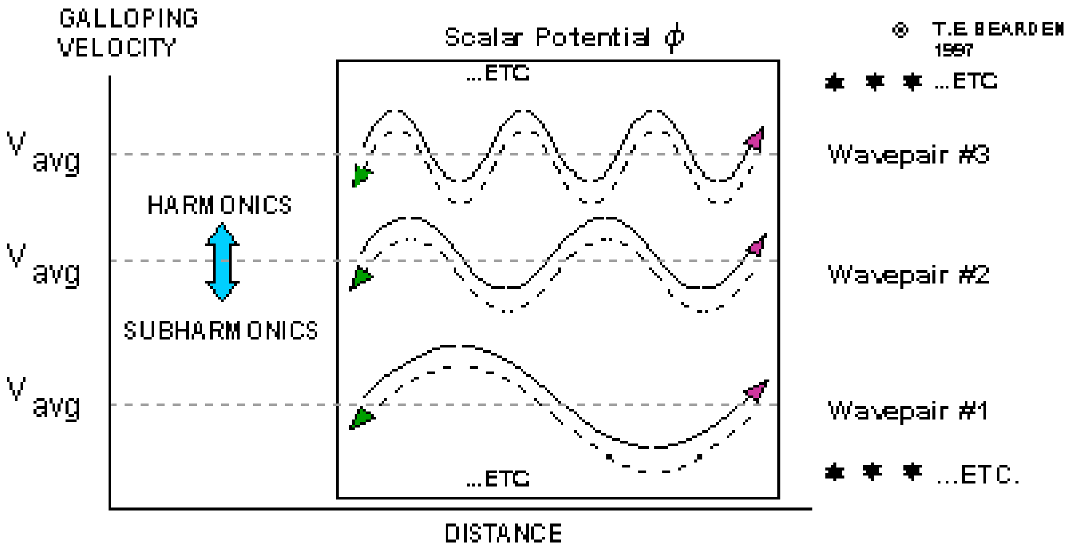
GALLOPING VELOCITY
Scalar Potential ϕ
© T.E. BEARDEN 1997
...ETC
✱ ✱ ✱ ...ETC
V avg
Wavepair #3
HARMONICS
SUBHARMONICS
V avg
Wavepair #2
V avg
Wavepair #1
...ETC
✱ ✱ ✱ ...ETC.
DISTANCE

The Structure Is:

A harmonic set of longitudinal wavepairs. In each wavepair the two waves superpose spatially, but travel in opposite directions. The two are phase conjugates and time-reversed replicas of each other. Thus they comprise a coupled longitudinal wave and antiwave. Each wavepair is a time-density wave and therefore an electrogravitational wave.

Figure 4. Infolded longitudinal biwaves (time-density EM waves) composition of a scalar potential.

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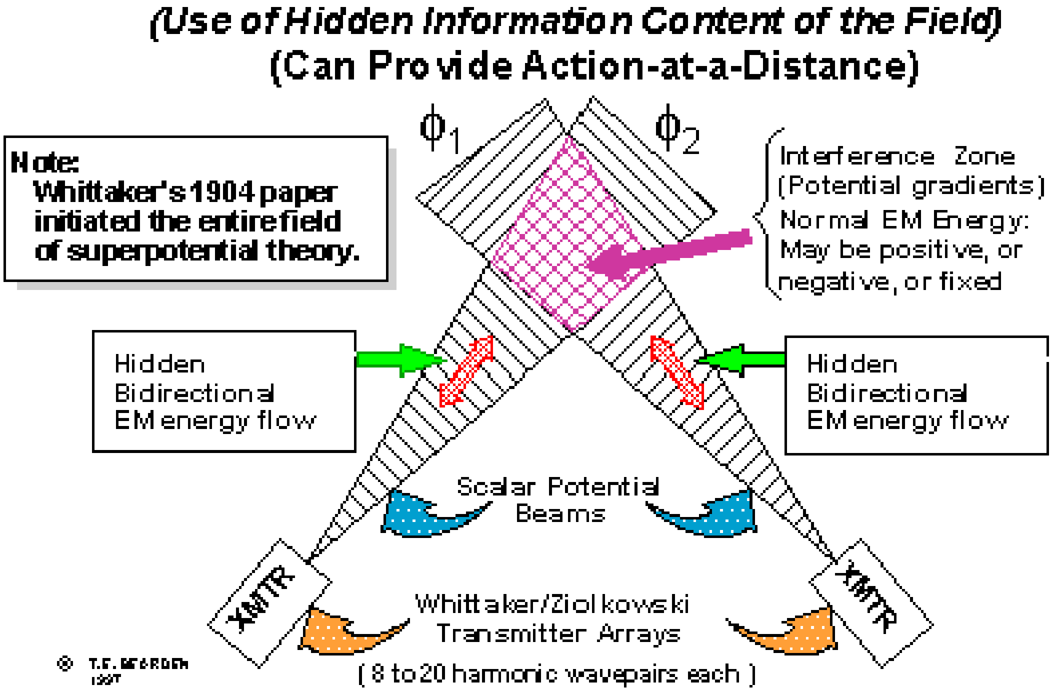
(Use of Hidden Information Content of the Field)
(Can Provide Action-at-a-Distance)
ϕ_1
ϕ_2
Note:
Whittaker's 1904 paper initiated the entire field of superpotential theory.
Interference Zone (Potential gradients)
Normal EM Energy: May be positive, or negative, or fixed
Hidden Bidirectional EM energy flow
Hidden Bidirectional EM energy flow
Scalar Potential Beams
XMTR
XMTR
Whittaker/Ziolkowski Transmitter Arrays
(8 to 20 harmonic wavepairs each)
© T.E. BEARDEN 1997

Figure 5. Scalar potential interferometry (between the two sets of bidirectional longitudinal EM wavepairfunctions) produces all EM force fields and waves.

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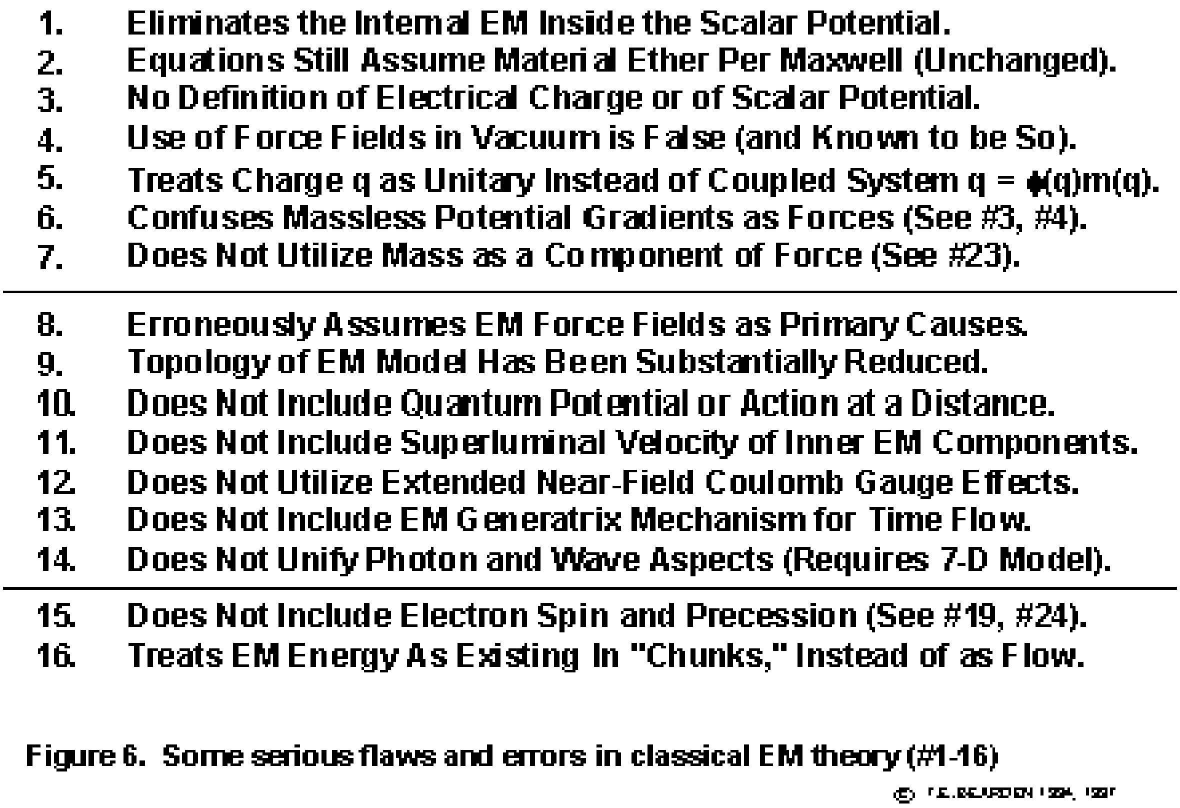

1. Eliminates the Internal EM Inside the Scalar Potential.
2. Equations Still Assume Material Ether Per Maxwell (Unchanged).
3. No Definition of Electrical Charge or of Scalar Potential.
4. Use of Force Fields in Vacuum is False (and Known to be So).
5. Treats Charge q as Unitary Instead of Coupled System $q = \phi(q)m(q)$.
6. Confuses Massless Potential Gradients as Forces (See #3, #4).
7. Does Not Utilize Mass as a Component of Force (See #23).

8. Erroneously Assumes EM Force Fields as Primary Causes.
9. Topology of EM Model Has Been Substantially Reduced.
10. Does Not Include Quantum Potential or Action at a Distance.
11. Does Not Include Superluminal Velocity of Inner EM Components.
12. Does Not Utilize Extended Near-Field Coulomb Gauge Effects.
13. Does Not Include EM Generatrix Mechanism for Time Flow.
14. Does Not Unify Photon and Wave Aspects (Requires 7-D Model).

15. Does Not Include Electron Spin and Precession (See #19, #24).
16. Treats EM Energy As Existing In "Chunks," Instead of as Flow.

Figure 6. Some serious flaws and errors in classical EM theory (#1-16)

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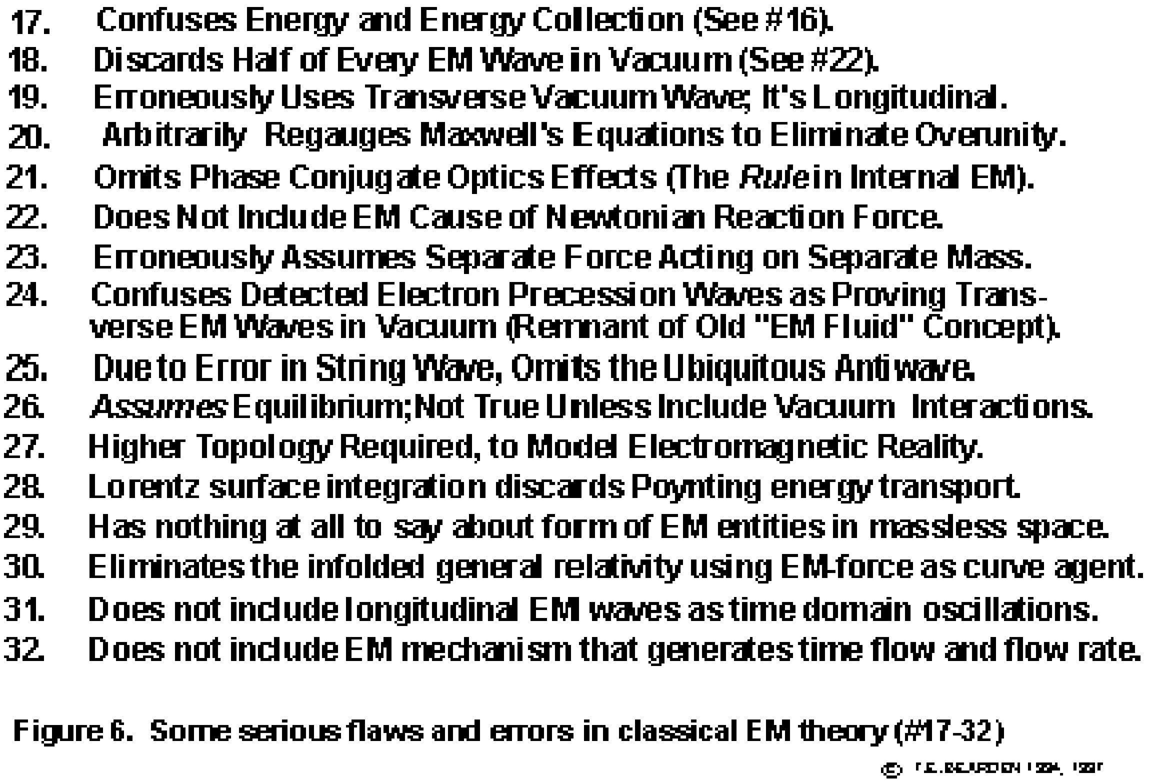

17. Confuses Energy and Energy Collection (See #16).
18. Discards Half of Every EM Wave in Vacuum (See #22).
19. Erroneously Uses Transverse Vacuum Wave; It's Longitudinal.
20. Arbitrarily Regauges Maxwell's Equations to Eliminate Overunity.
21. Omits Phase Conjugate Optics Effects (The *Rule* in Internal EM).
22. Does Not Include EM Cause of Newtonian Reaction Force.
23. Erroneously Assumes Separate Force Acting on Separate Mass.
24. Confuses Detected Electron Precession Waves as Proving Transverse EM Waves in Vacuum (Remnant of Old "EM Fluid" Concept).
25. Due to Error in String Wave, Omits the Ubiquitous Antiwave.
26. *Assumes* Equilibrium; Not True Unless Include Vacuum Interactions.
27. Higher Topology Required, to Model Electromagnetic Reality.
28. Lorentz surface integration discards Poynting energy transport.
29. Has nothing at all to say about form of EM entities in massless space.
30. Eliminates the infolded general relativity using EM-force as curve agent.
31. Does not include longitudinal EM waves as time domain oscillations.
32. Does not include EM mechanism that generates time flow and flow rate.

Figure 6. Some serious flaws and errors in classical EM theory (#17-32)

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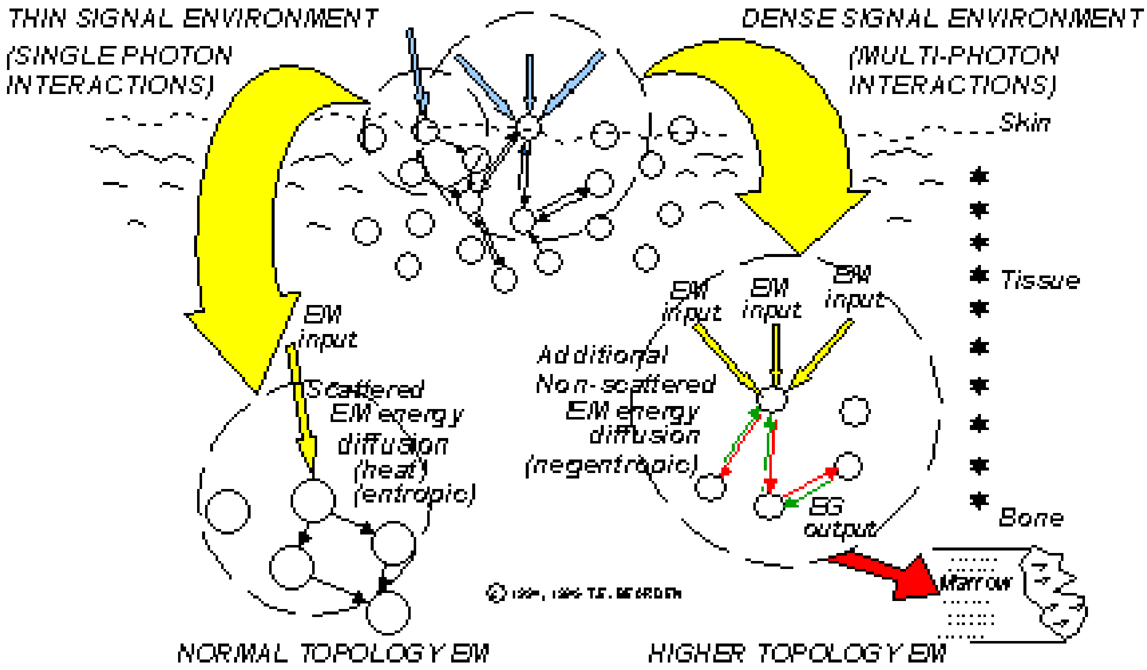
THIN SIGNAL ENVIRONMENT
(SINGLE PHOTON INTERACTIONS)
DENSE SIGNAL ENVIRONMENT
(MULTI-PHOTON INTERACTIONS)
Skin
Tissue
Bone
Marrow
EM input
Scattered EM energy diffusion (heat) (entropic)
EM input
EM input
EM input
Additional Non-scattered EM energy diffusion (negentropic)
EG output
T.E. BEARDEN
NORMAL TOPOLOGY EM
HIGHER TOPOLOGY EM

In a dense signal environment, phase conjugation effects become significant, generating PCR signals which couple to and backtrack the cells' and tissues' own signals, thus penetrating deeply throughout the body with weak partial cancellation jamming.

Figure 30. Abnormal penetration depth of incident weak signals due to multiphoton interaction in a dense weak signal environment.

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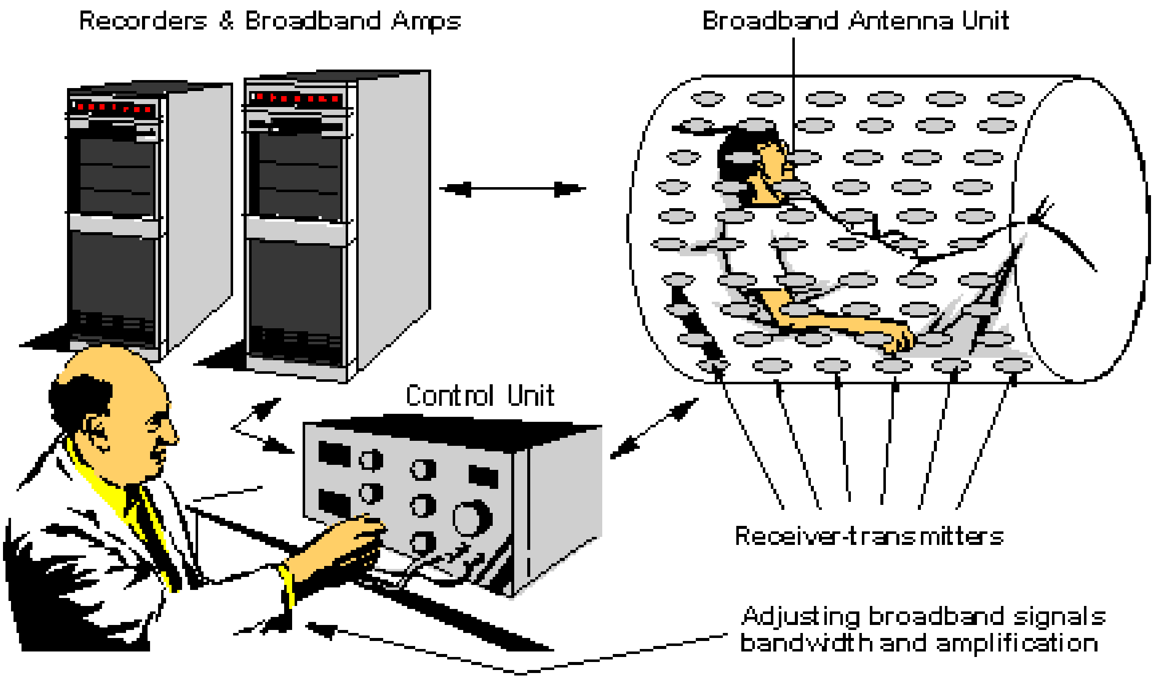
Recorders & Broadband Amps
Broadband Antenna Unit
Control Unit
Receiver-transmitters
Adjusting broadband signals bandwidth and amplification

Figure 31. Using an amplified replica of the body's own dense, broadband signal complex to irradiate it, producing deeply-penetrating and precise longitudinal EM wave sets that pump cells and reverse cellular disease and damage.

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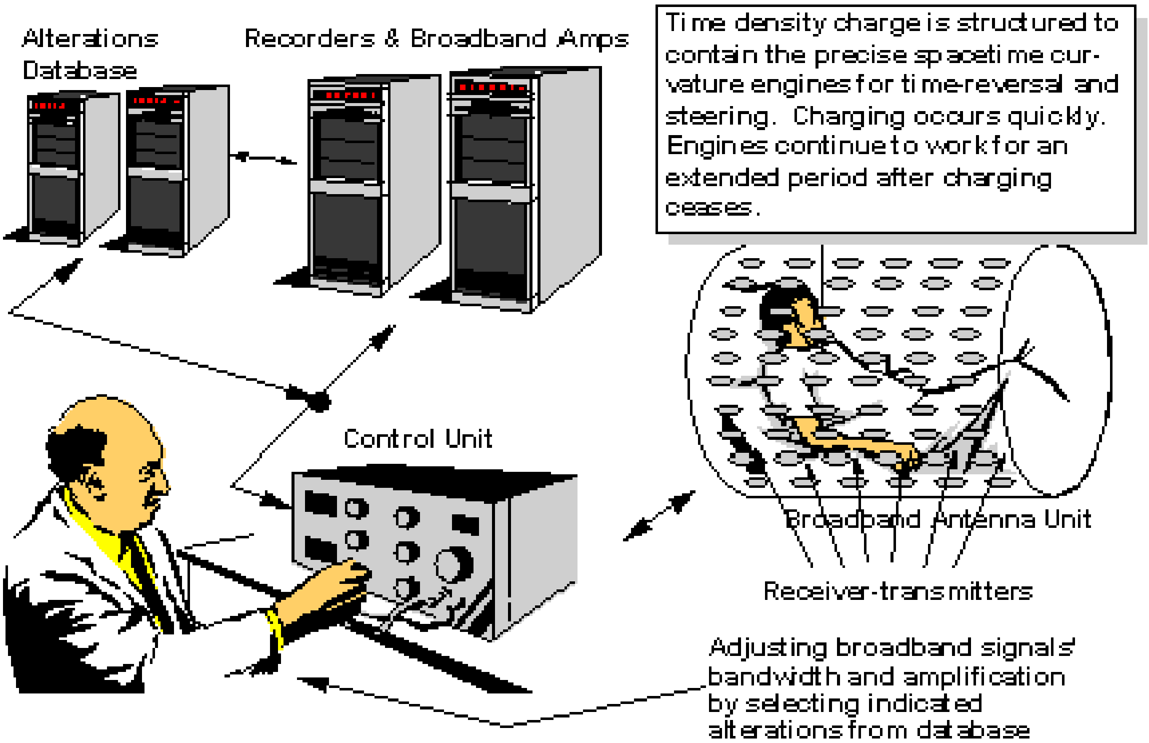
Alterations Database
Recorders & Broadband Amps
Control Unit
Broadband Antenna Unit
Receiver-transmitters

Time density charge is structured to contain the precise spacetime curvature engines for time-reversal and steering. Charging occurs quickly. Engines continue to work for an extended period after charging ceases.

Adjusting broadband signals' bandwidth and amplification by selecting indicated alterations from database

Figure 9. Using an amplified replica of the body's own dense, broadband signal complex containing added alterations, to irradiate the body and produce deeply-penetrating precise time-density charging for cellular time-reversal, while steering the time-reversal trajectory to also correct a congenital condition.

© T.E. [illegible]

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San
Francisco
R-2508
China
Lake
Point
Mugu
Sea
Range
Ft.Irwin
Edwards AFB
Los Angeles
San Diego
Santa Fe
Albuquerque
Missile
Range
White
Sands
Las
Cruces

The Anomalies in Navy Electrolyte Experiments at China Lake

These novel experimental anomalies, like those of Cold Fusion, were caused by using time as an energy source by transducing time-energy into spatial energy. Transducing one microsecond per second of time into spatial EM energy, yields nearly 10^{11} watts of power

- Melvin H. Miles and Benjamin F. Bush, "Radiation measurements at China Lake: Real or Artifacts?", *Proc. ICCF-7 (International Conference on Cold Fusion—7)*, Vancouver, BC, Canada, Apr. 1998, p. 101.

- Consistency of China Lake Anomalies
- Anomalous LW EM Emission Phenomena at China Lake (1)
- Anomalous LW EM Emission Phenomena at China Lake (2)
- Sufficient LW-to-TW Transduction Ionizes GM Tube Gas (3)
- Sufficient LW-to-TW Transduction Ionizes GM Tube Gas (4)
- Consistency of Anomalies
- Consistency of Anomalies (2)

- Experimental LW Emission Phenomena in Electrolysis

Next Slide Return to Index Previous Slide

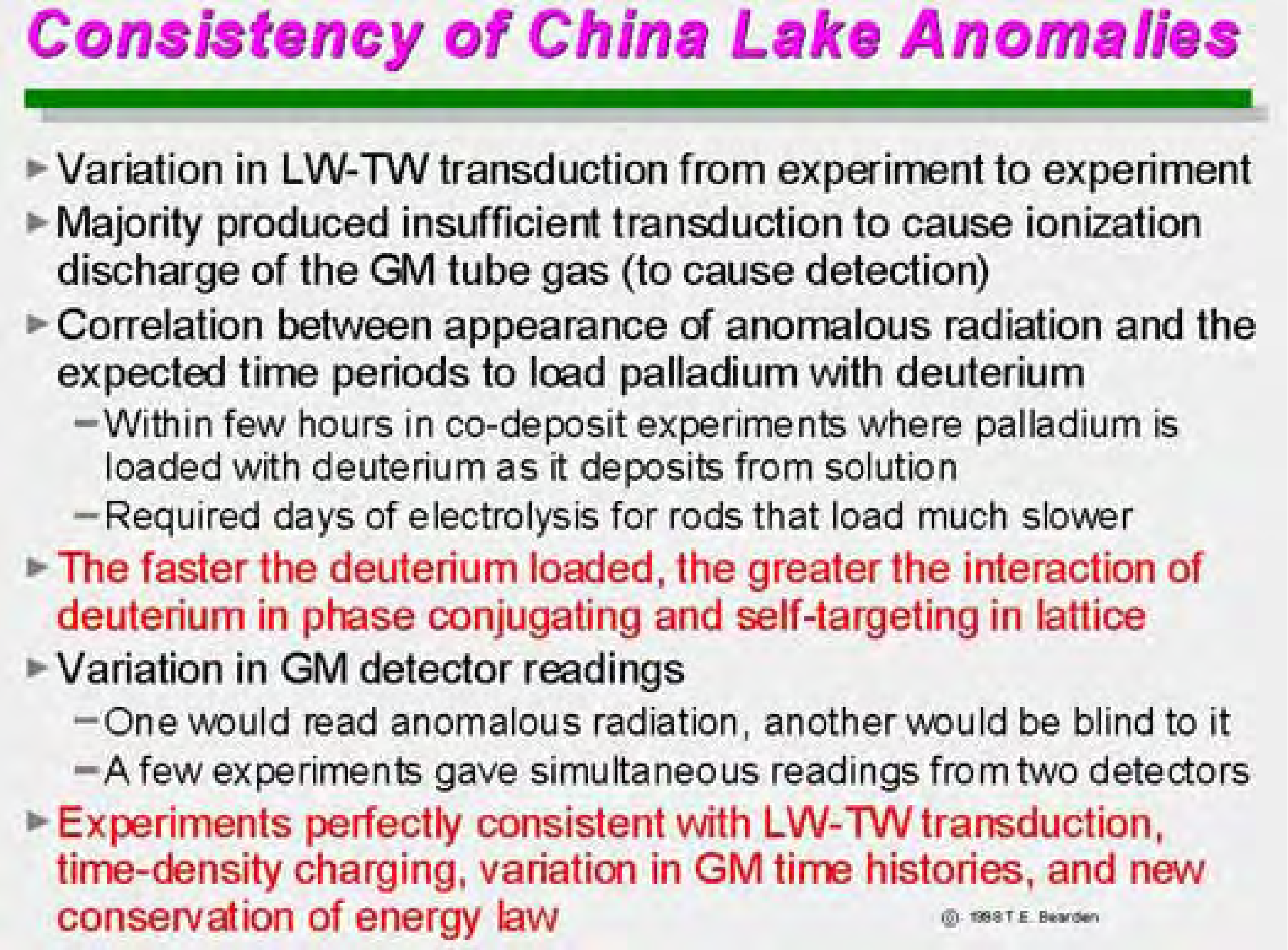

Consistency of China Lake Anomalies

- Variation in LW-TW transduction from experiment to experiment
- Majority produced insufficient transduction to cause ionization discharge of the GM tube gas (to cause detection)
- Correlation between appearance of anomalous radiation and the expected time periods to load palladium with deuterium
  - Within few hours in co-deposit experiments where palladium is loaded with deuterium as it deposits from solution
  - Required days of electrolysis for rods that load much slower
- The faster the deuterium loaded, the greater the interaction of deuterium in phase conjugating and self-targeting in lattice
- Variation in GM detector readings
  - One would read anomalous radiation, another would be blind to it
  - A few experiments gave simultaneous readings from two detectors
- Experiments perfectly consistent with LW-TW transduction, time-density charging, variation in GM time histories, and new conservation of energy law

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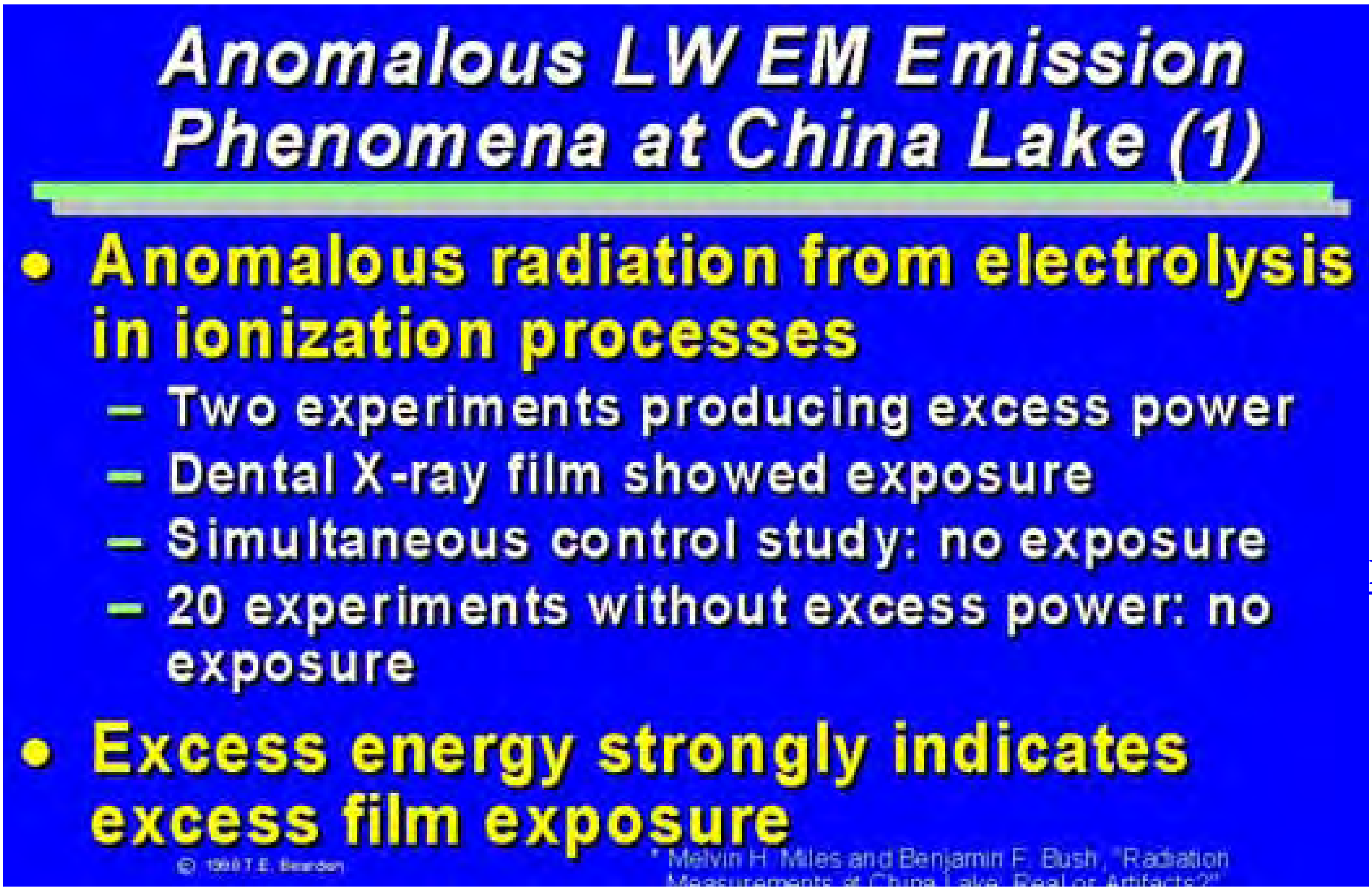

Anomalous LW EM Emission Phenomena at China Lake (1)

- Anomalous radiation from electrolysis in ionization processes
  - Two experiments producing excess power
  - Dental X-ray film showed exposure
  - Simultaneous control study: no exposure
  - 20 experiments without excess power: no exposure
- Excess energy strongly indicates excess film exposure

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* Melvin H. Miles and Benjamin F. Bush, "Radiation Measurements at China Lake: Real or Artifacts?"

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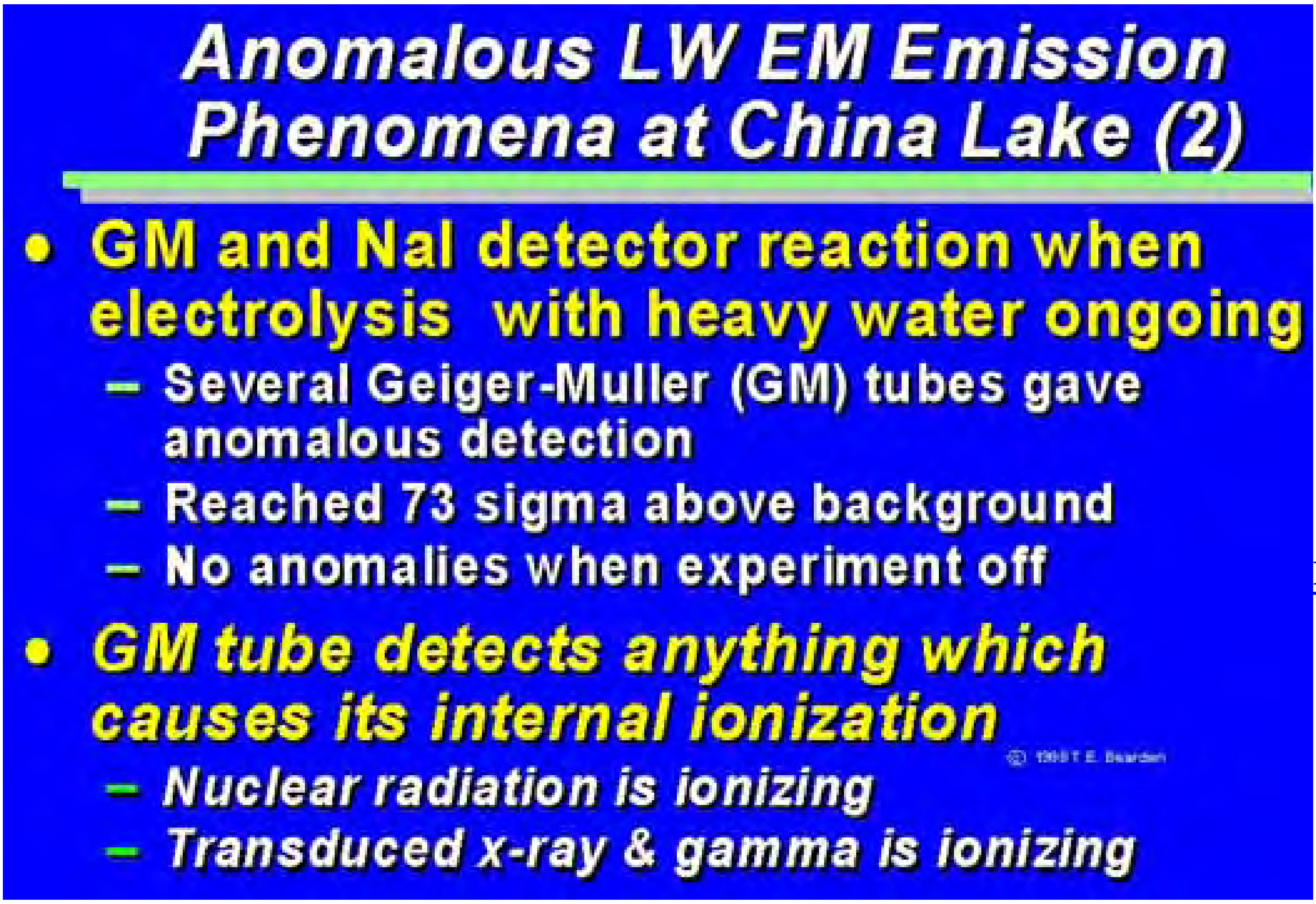

Anomalous LW EM Emission Phenomena at China Lake (2)

- GM and NaI detector reaction when electrolysis with heavy water ongoing
  - Several Geiger-Muller (GM) tubes gave anomalous detection
  - Reached 73 sigma above background
  - No anomalies when experiment off
- *GM tube detects anything which causes its internal ionization*
  - *Nuclear radiation is ionizing*
  - *Transduced x-ray & gamma is ionizing*

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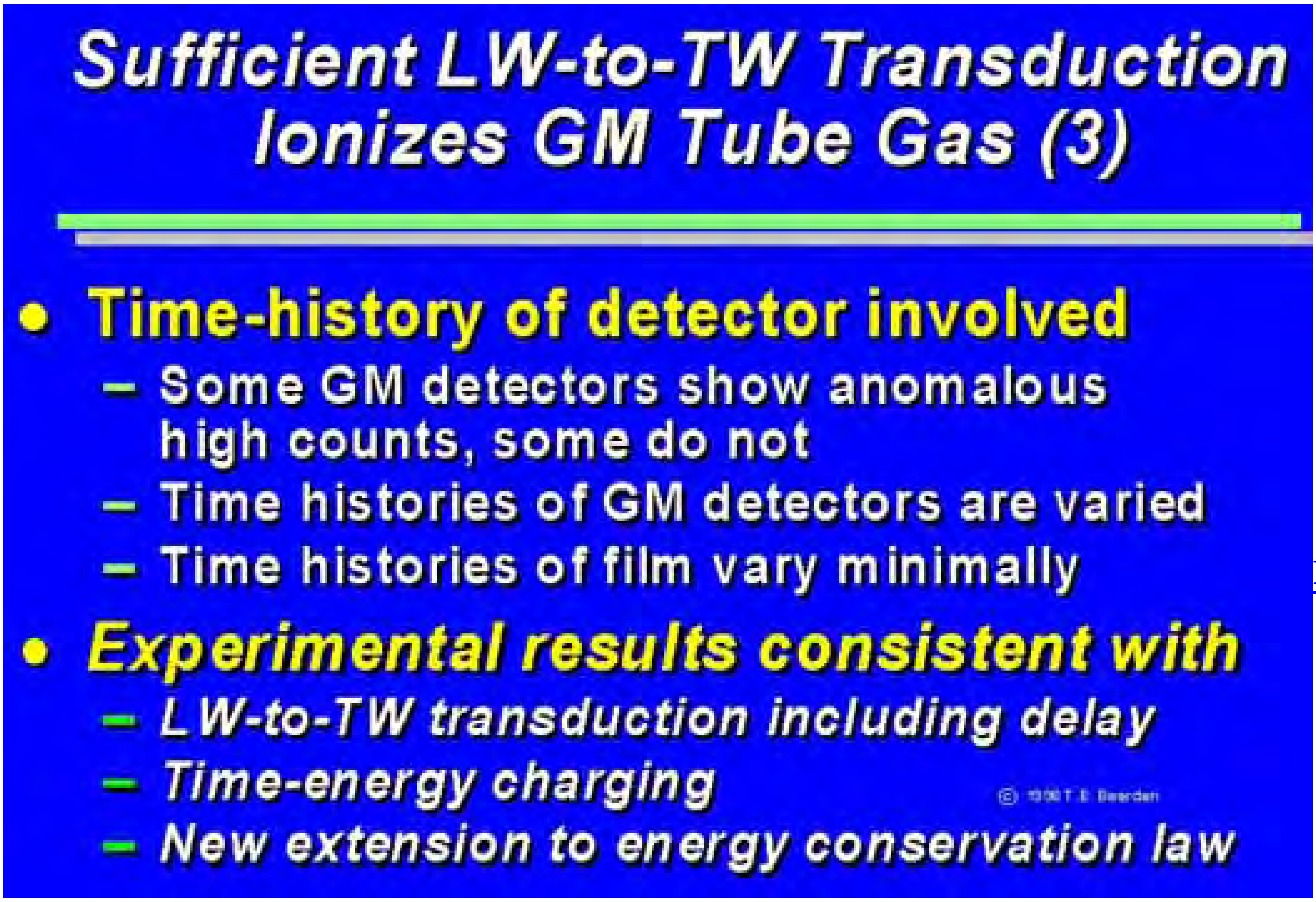

Sufficient LW-to-TW Transduction Ionizes GM Tube Gas (3)

- **Time-history of detector involved**
  - Some GM detectors show anomalous high counts, some do not
  - Time histories of GM detectors are varied
  - Time histories of film vary minimally
- ***Experimental results consistent with***
  - *LW-to-TW transduction including delay*
  - *Time-energy charging*
  - *New extension to energy conservation law*

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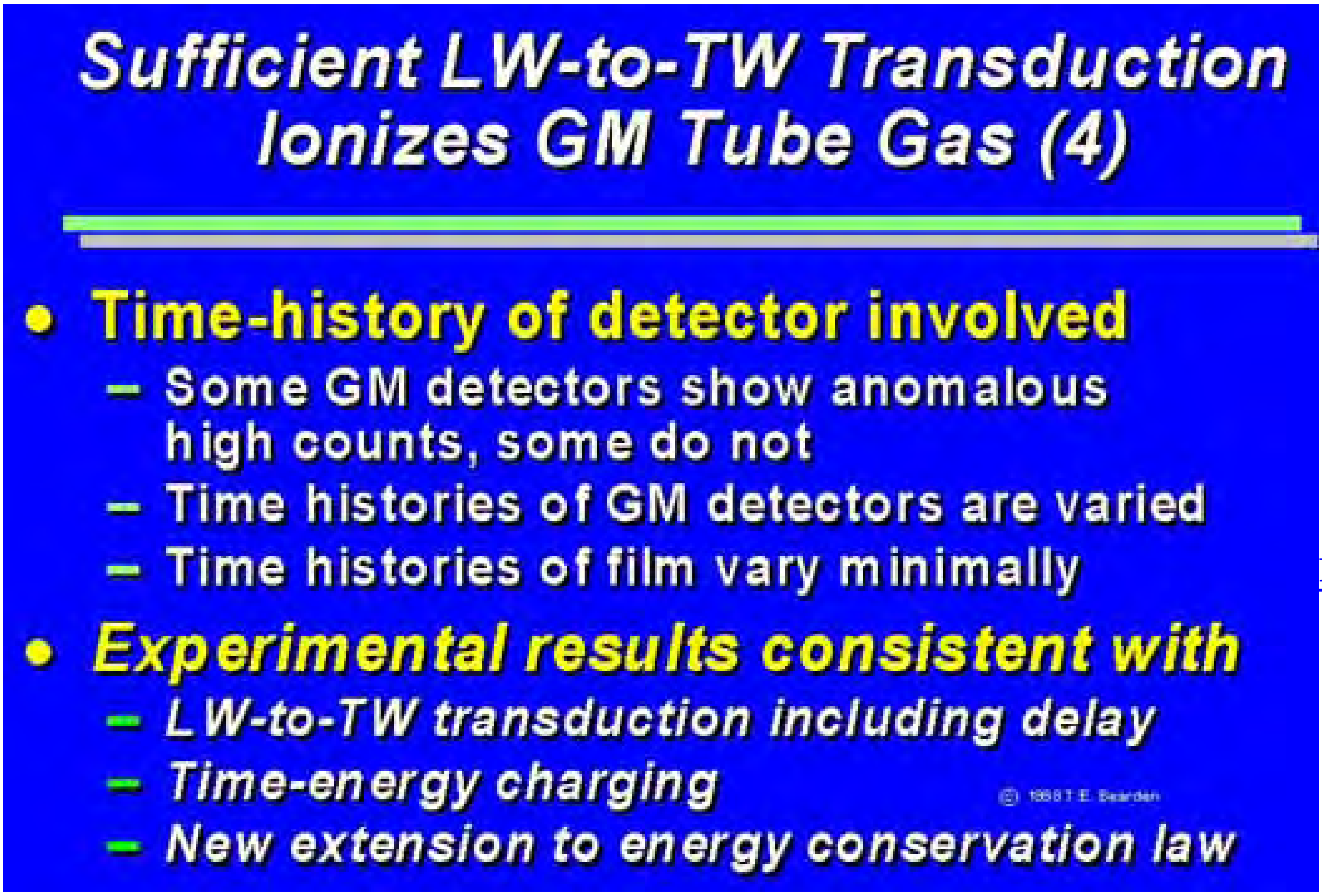

Sufficient LW-to-TW Transduction Ionizes GM Tube Gas (4)

- **Time-history of detector involved**
  - Some GM detectors show anomalous high counts, some do not
  - Time histories of GM detectors are varied
  - Time histories of film vary minimally
- ***Experimental results consistent with***
  - *LW-to-TW transduction including delay*
  - *Time-energy charging*
  - *New extension to energy conservation law*

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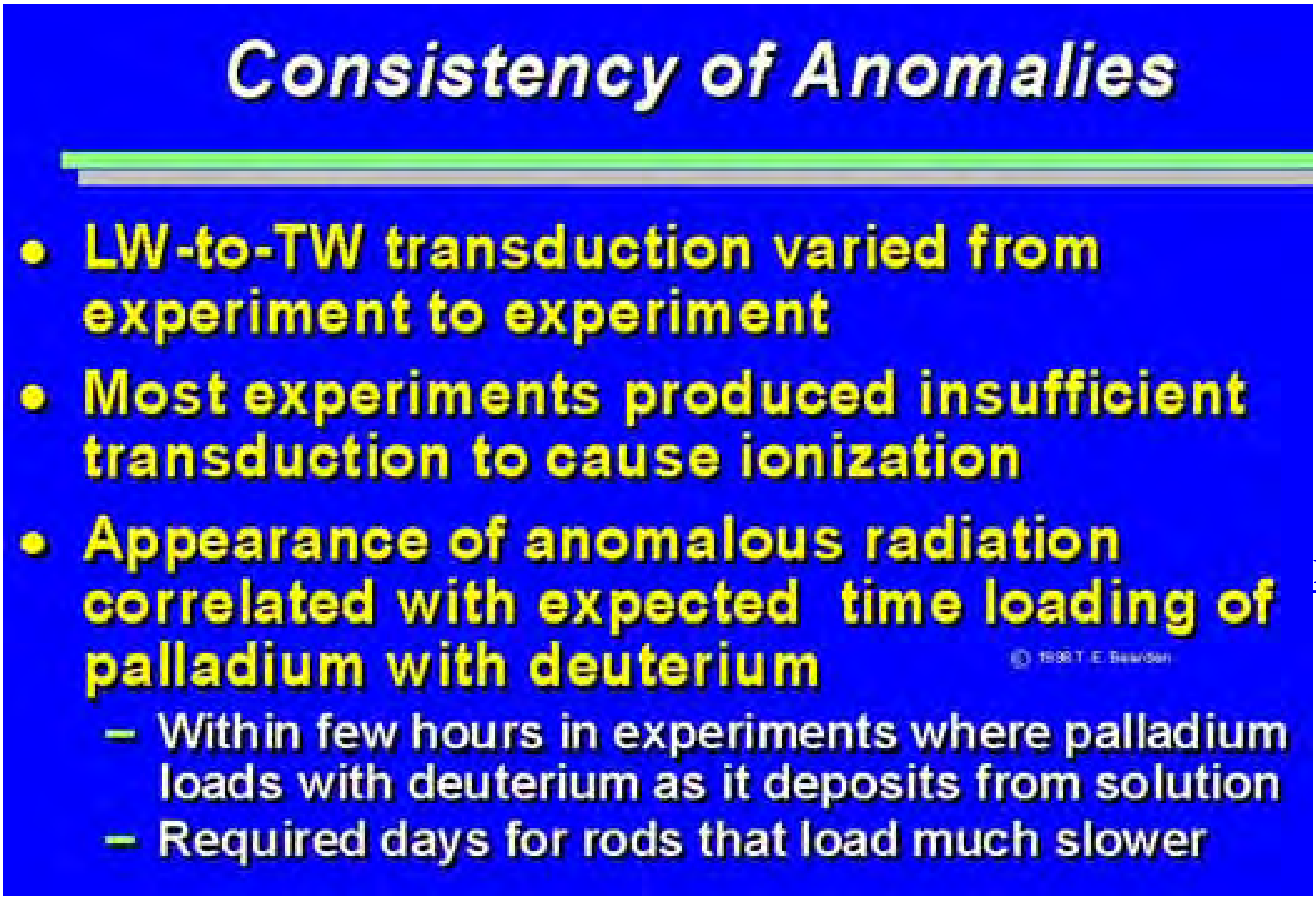

Consistency of Anomalies

- LW-to-TW transduction varied from experiment to experiment
- Most experiments produced insufficient transduction to cause ionization
- Appearance of anomalous radiation correlated with expected time loading of palladium with deuterium
  - Within few hours in experiments where palladium loads with deuterium as it deposits from solution
  - Required days for rods that load much slower

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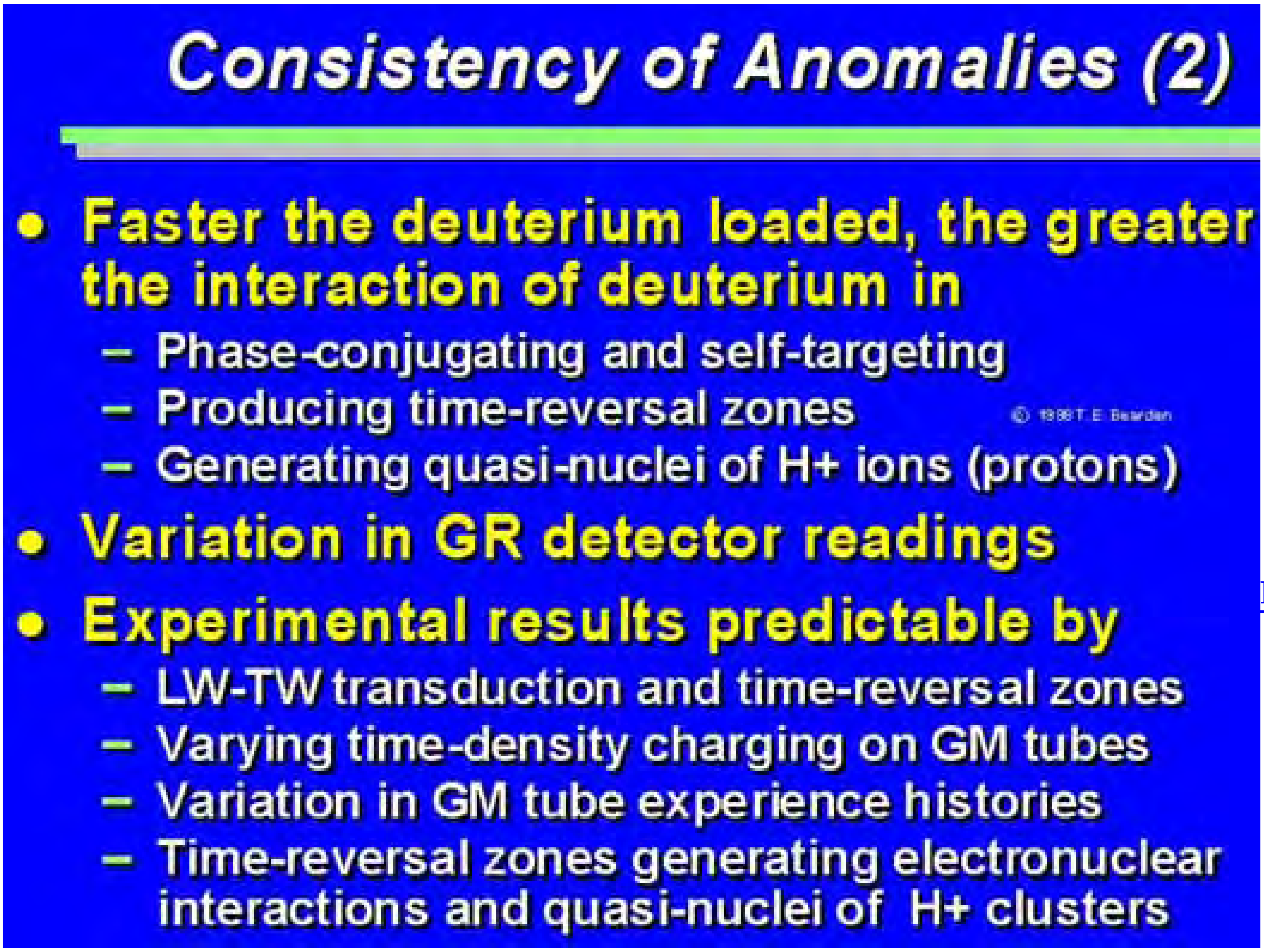

Consistency of Anomalies (2)

- Faster the deuterium loaded, the greater the interaction of deuterium in
  - Phase-conjugating and self-targeting
  - Producing time-reversal zones
  - Generating quasi-nuclei of H+ ions (protons)
- Variation in GR detector readings
- Experimental results predictable by
  - LW-TW transduction and time-reversal zones
  - Varying time-density charging on GM tubes
  - Variation in GM tube experience histories
  - Time-reversal zones generating electronuclear interactions and quasi-nuclei of H+ clusters

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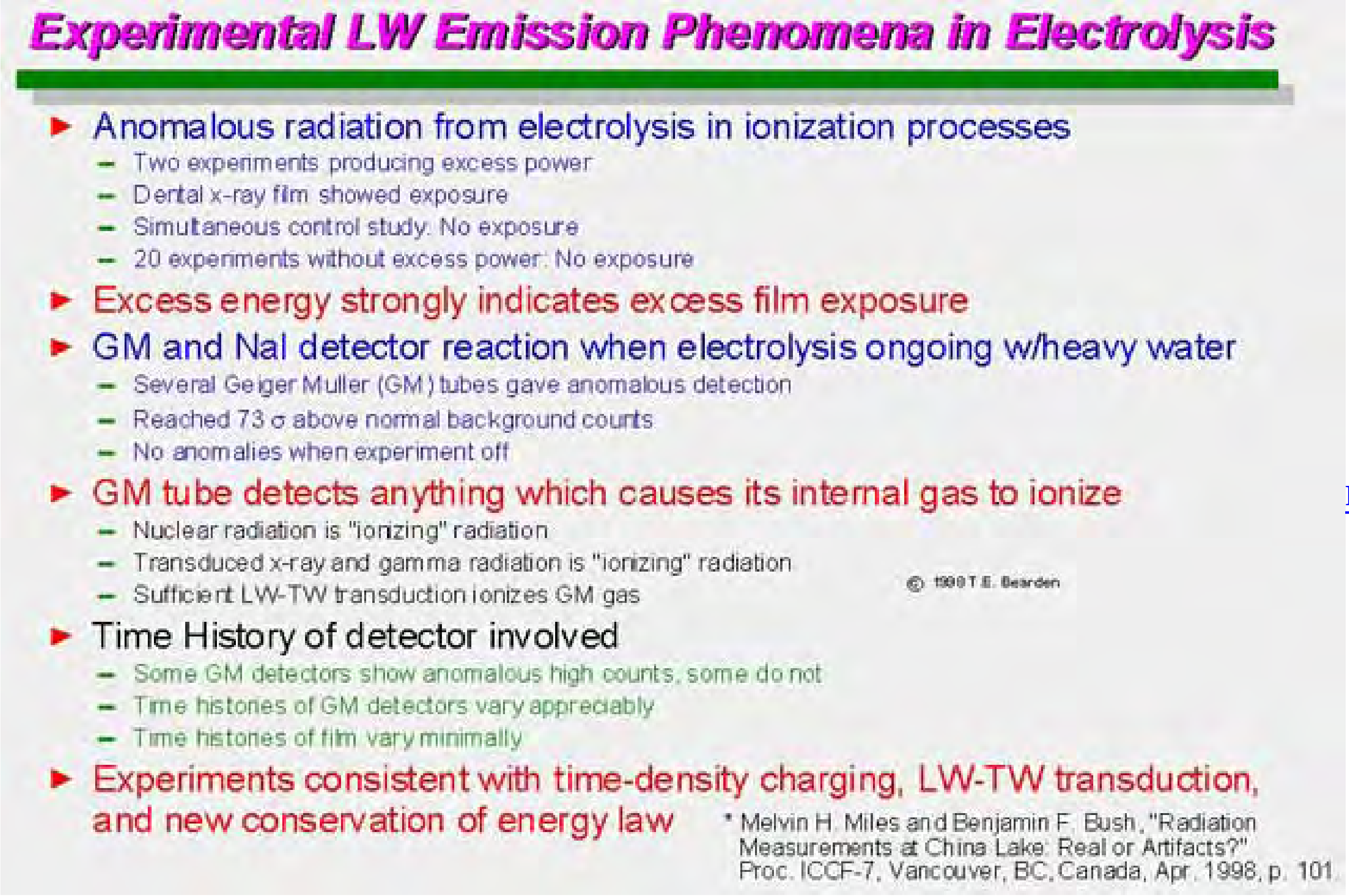

Experimental LW Emission Phenomena in Electrolysis

- Anomalous radiation from electrolysis in ionization processes
  - Two experiments producing excess power
  - Dental x-ray film showed exposure
  - Simultaneous control study: No exposure
  - 20 experiments without excess power: No exposure
- Excess energy strongly indicates excess film exposure
- GM and NaI detector reaction when electrolysis ongoing w/heavy water
  - Several Geiger Muller (GM) tubes gave anomalous detection
  - Reached 73 σ above normal background counts
  - No anomalies when experiment off
- GM tube detects anything which causes its internal gas to ionize
  - Nuclear radiation is "ionizing" radiation
  - Transduced x-ray and gamma radiation is "ionizing" radiation
  - Sufficient LW-TW transduction ionizes GM gas
- Time History of detector involved
  - Some GM detectors show anomalous high counts, some do not
  - Time histories of GM detectors vary appreciably
  - Time histories of film vary minimally
- Experiments consistent with time-density charging, LW-TW transduction, and new conservation of energy law

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* Melvin H. Miles and Benjamin F. Bush, "Radiation Measurements at China Lake: Real or Artifacts?" Proc. ICCF-7, Vancouver, BC, Canada, Apr. 1998, p. 101

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A Visual Tour of what they don't want you to know about electrical circuits

10 TRILLION PERCENT OF THE CURRENT PRODUCED IS WASTED!

---

1. The scalar potential is a harmonic set of phase conjugate longitudinal EM waves.
2. The dipole is a true negative resistor.
3. The dipole's broken 3-symmetry initiates a spreading giant negentropic reordering of a fraction of the vacuum's energy.
4. Energy flow contours surrounding a transmission line.
5. Heaviside and Poynting energy flow components. The Heaviside component is often **10 trillion times** the Poynting component, but **is simply wasted** in ordinary single-pass energy circuits.
6. Negative resistance process v. positive resistance process.
7. Lorentz's integration trick to discard the enormous Heaviside non-diverged energy flow component.

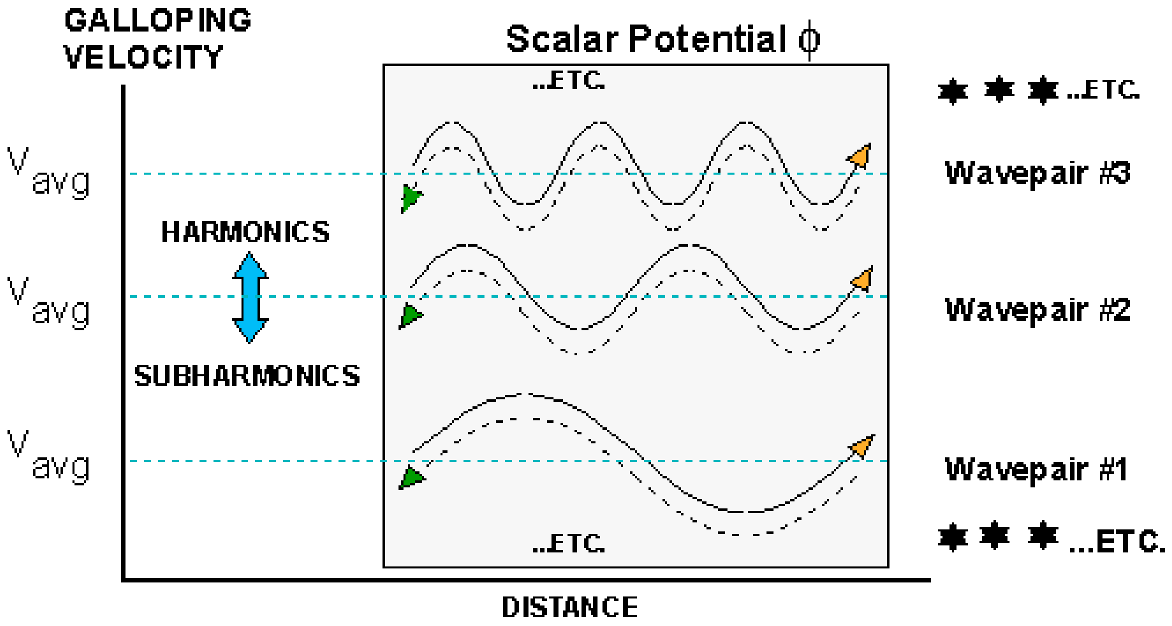

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The Structure Is:

- A harmonic set of longitudinal phase conjugate wavepairs.
- In each wavepair the two waves superpose spatially after detection, but travel in opposite directions.
- The convergent wave set is in the imaginary plane, and hence is not observable. It is EM energy incoming to the potential (dipolarity) from the time domain.
- The charge's spin is 720 degrees, 360 in the real plane and 360 in the imaginary plane.
- Hence the charge receives the complex convergent EM energy, transduces it into real EM energy, and emits enormous energy at the speed of light in all directions -- which includes bidirectional pairs in 3-space (after the reaction, being after "observation").
- This produces the fields and potentials from the "source charge or dipole."
- Mandl and Shaw argue that the scalar (time-polarized) photon and longitudinal photon are observable only in similar pairs, which then makes the instantaneous scalar potential. Thus their quantum field theory work strongly supports the "negative resistor" interpretation of the scalar potential and our solution to the source charge and source dipole problem.

Figure 1. The scalar potential is a harmonic set of phase conjugate longitudinal EM waves.

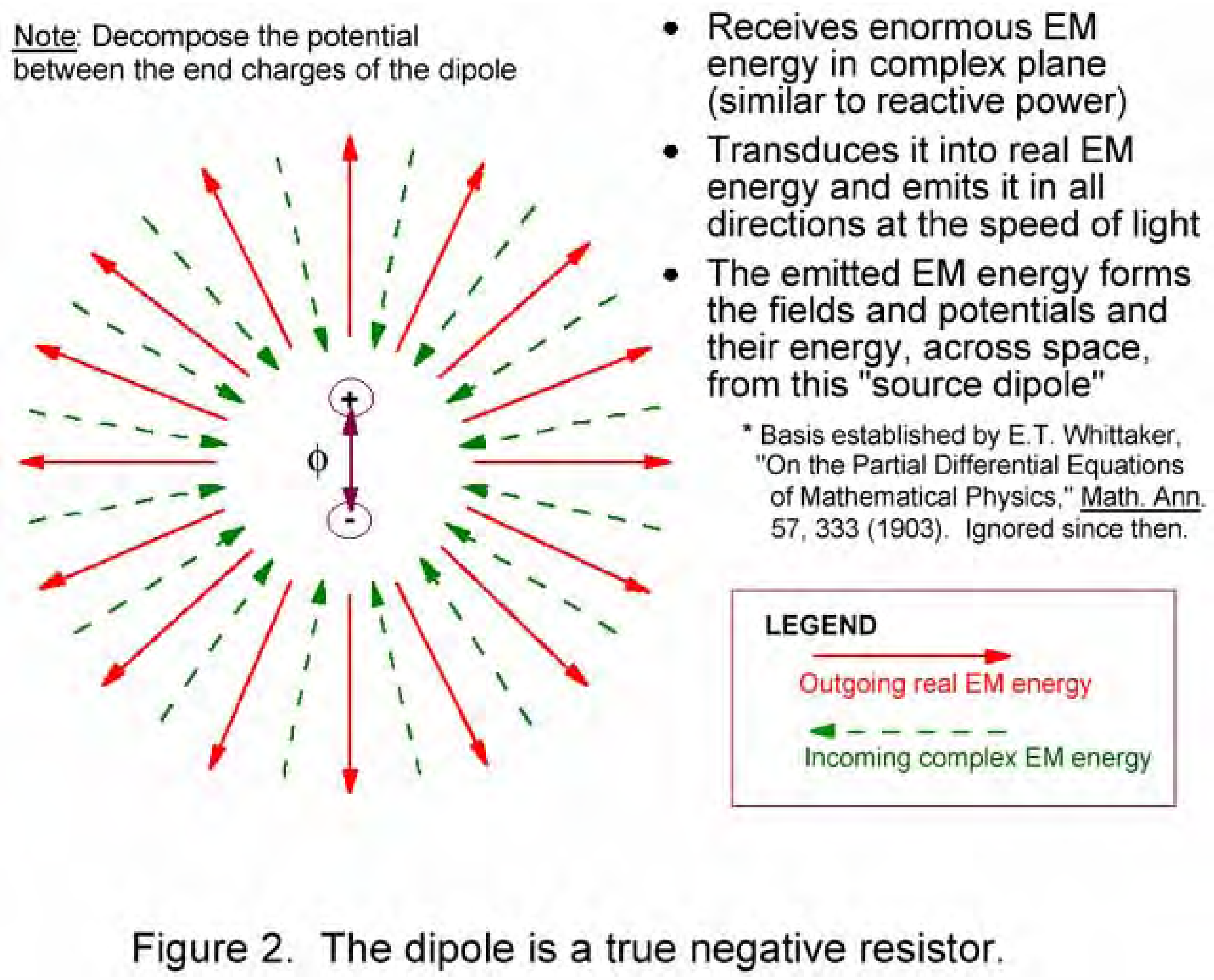

Note: Decompose the potential between the end charges of the dipole

- Receives enormous EM energy in complex plane (similar to reactive power)
- Transduces it into real EM energy and emits it in all directions at the speed of light
- The emitted EM energy forms the fields and potentials and their energy, across space, from this "source dipole"

* Basis established by E.T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," Math. Ann. 57, 333 (1903). Ignored since then.

LEGEND

→ Outgoing real EM energy

← – – – – – Incoming complex EM energy

Figure 2. The dipole is a true negative resistor.

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Broken 3-space symmetry initiates jump to 4-space symmetry between complex plane and real plane. Energy flow is now conserved in 4-space, but not in 3-space. This is the true negative resistor effect, and a negentropic reordering of the vacuum.

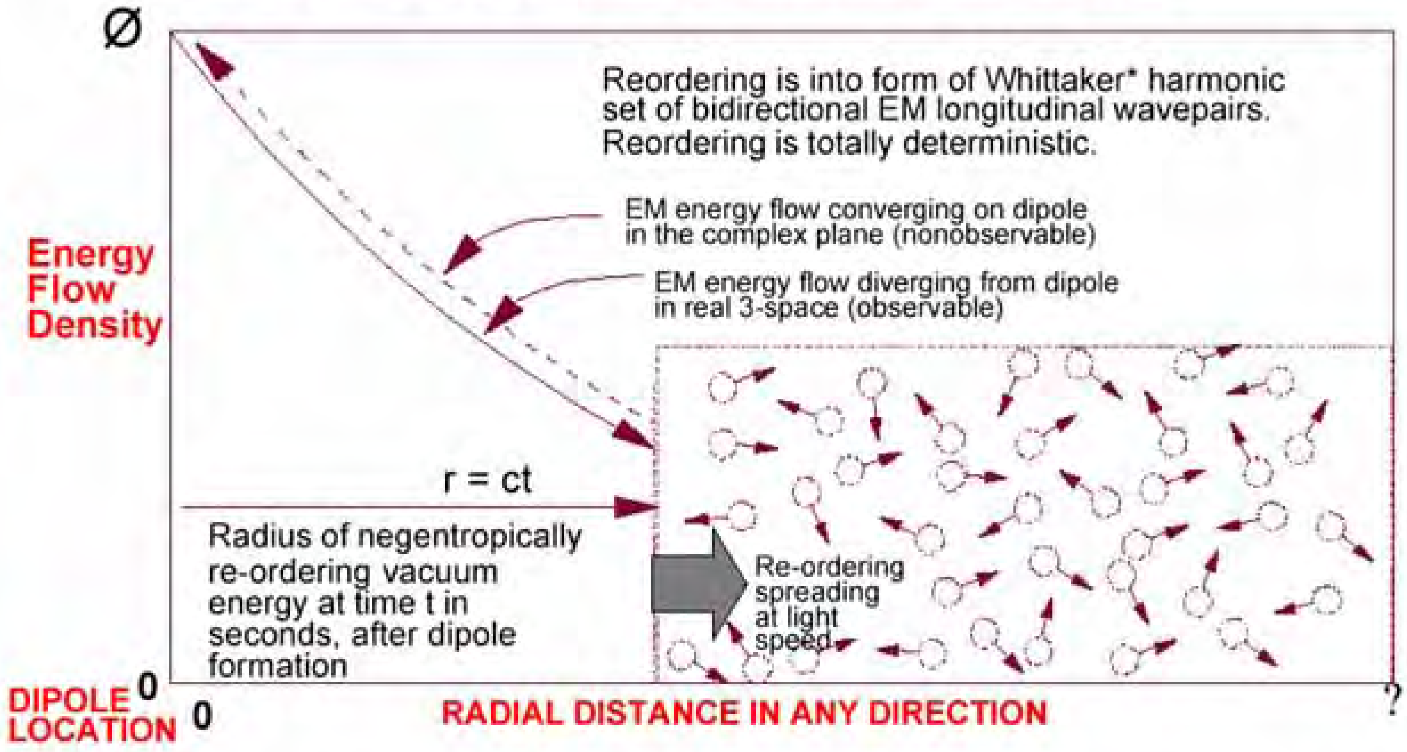

Reordering is into form of Whittaker* harmonic set of bidirectional EM longitudinal wavepairs. Reordering is totally deterministic.

EM energy flow converging on dipole in the complex plane (nonobservable)

EM energy flow diverging from dipole in real 3-space (observable)

Radius of negentropically re-ordering vacuum energy at time t in seconds, after dipole formation

Re-ordering spreading at light speed

Figure 3. The dipole's broken 3-symmetry initiates a spreading giant negentropic reordering of a fraction of the vacuum's energy.

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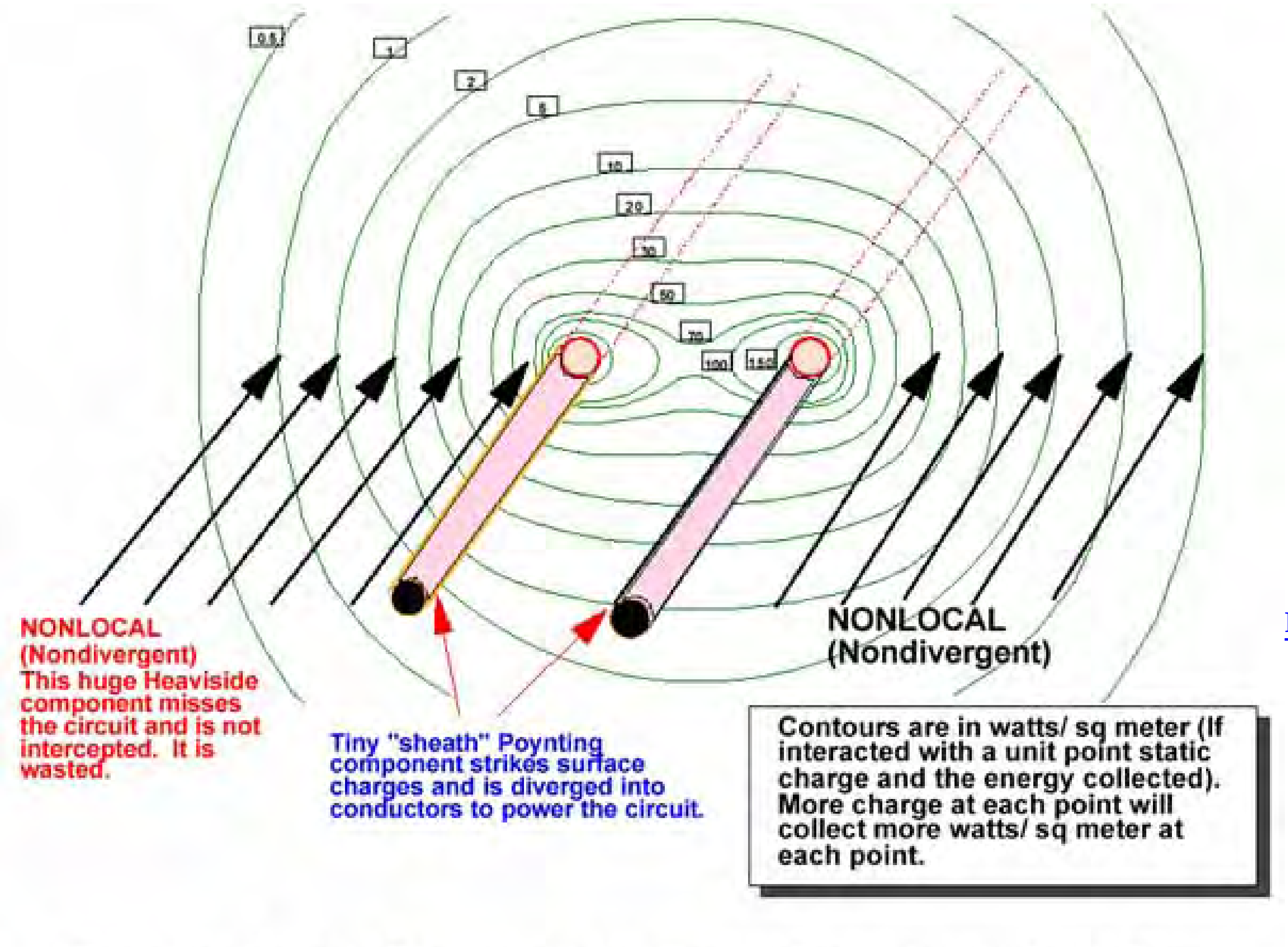

NONLOCAL
(Nondivergent)
This huge Heaviside component misses the circuit and is not intercepted. It is wasted.

Tiny "sheath" Poynting component strikes surface charges and is diverged into conductors to power the circuit.

NONLOCAL
(Nondivergent)

Contours are in watts/ sq meter (If interacted with a unit point static charge and the energy collected). More charge at each point will collect more watts/ sq meter at each point.

Figure 4. Energy flow contours surrounding a transmission line.

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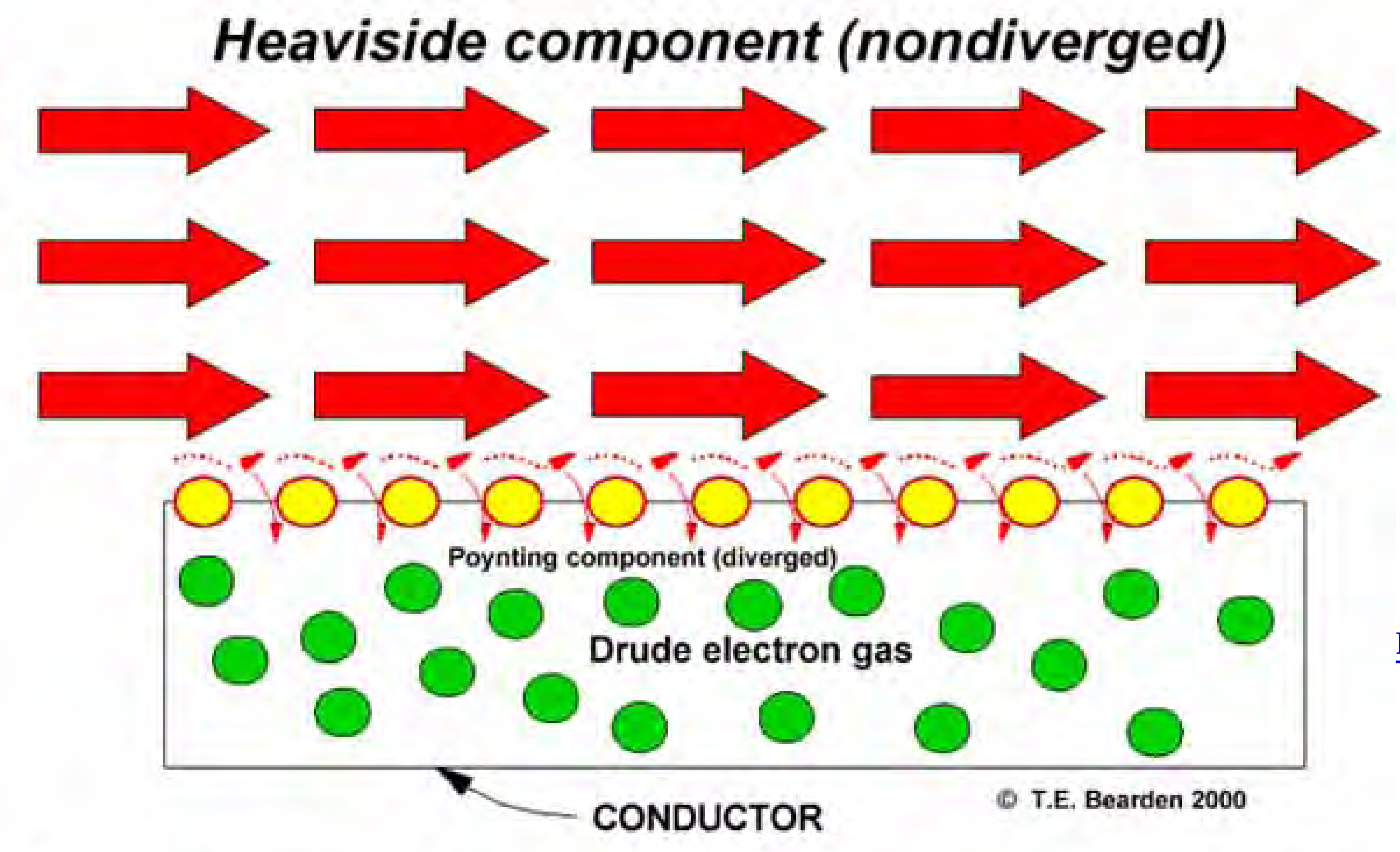
Heaviside component (nondiverged)
Poynting component (diverged)
Drude electron gas
CONDUCTOR
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Figure 5. Heaviside and Poynting energy flow components. The Heaviside component is often 10 trillion times the Poynting component, but is simply wasted in ordinary single-pass energy flow circuits.

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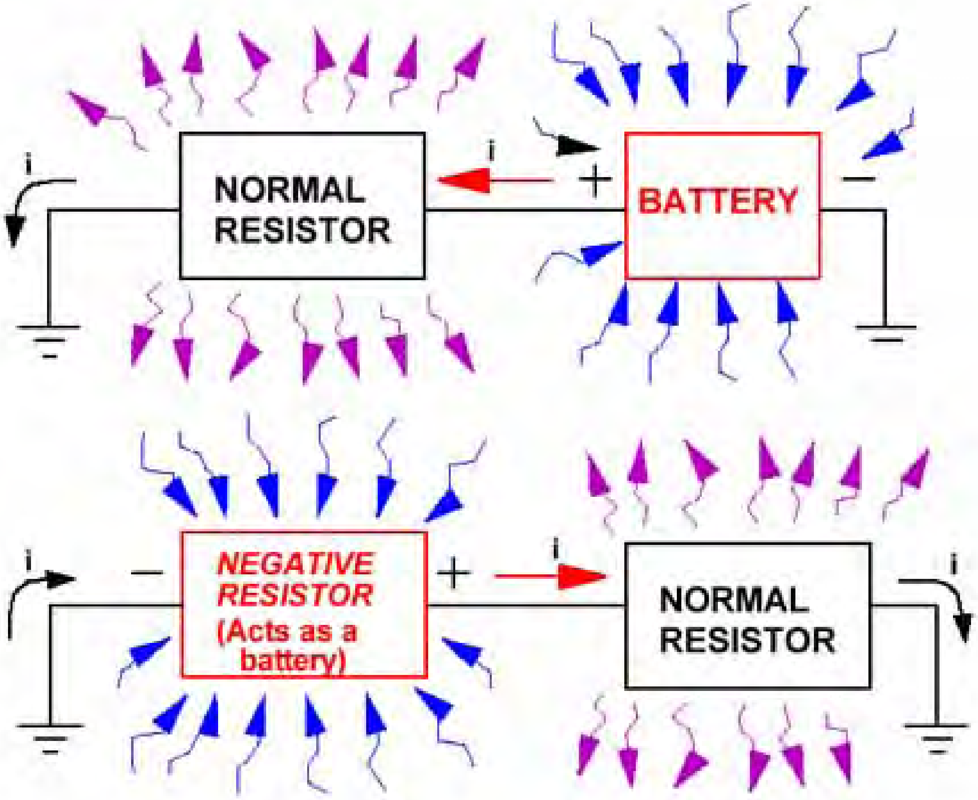
NORMAL
RESISTOR
i
+
BATTERY
−
i
NEGATIVE
RESISTOR
(Acts as a
battery)
−
+
i
NORMAL
RESISTOR
i
i

Figure 6. Negative resistance process vs. positive resistance process. A negative resistor receives energy in unusable form, transduces it, and outputs it in usable form. A positive resistor receives energy in usable form, and scatters it into unusable form.

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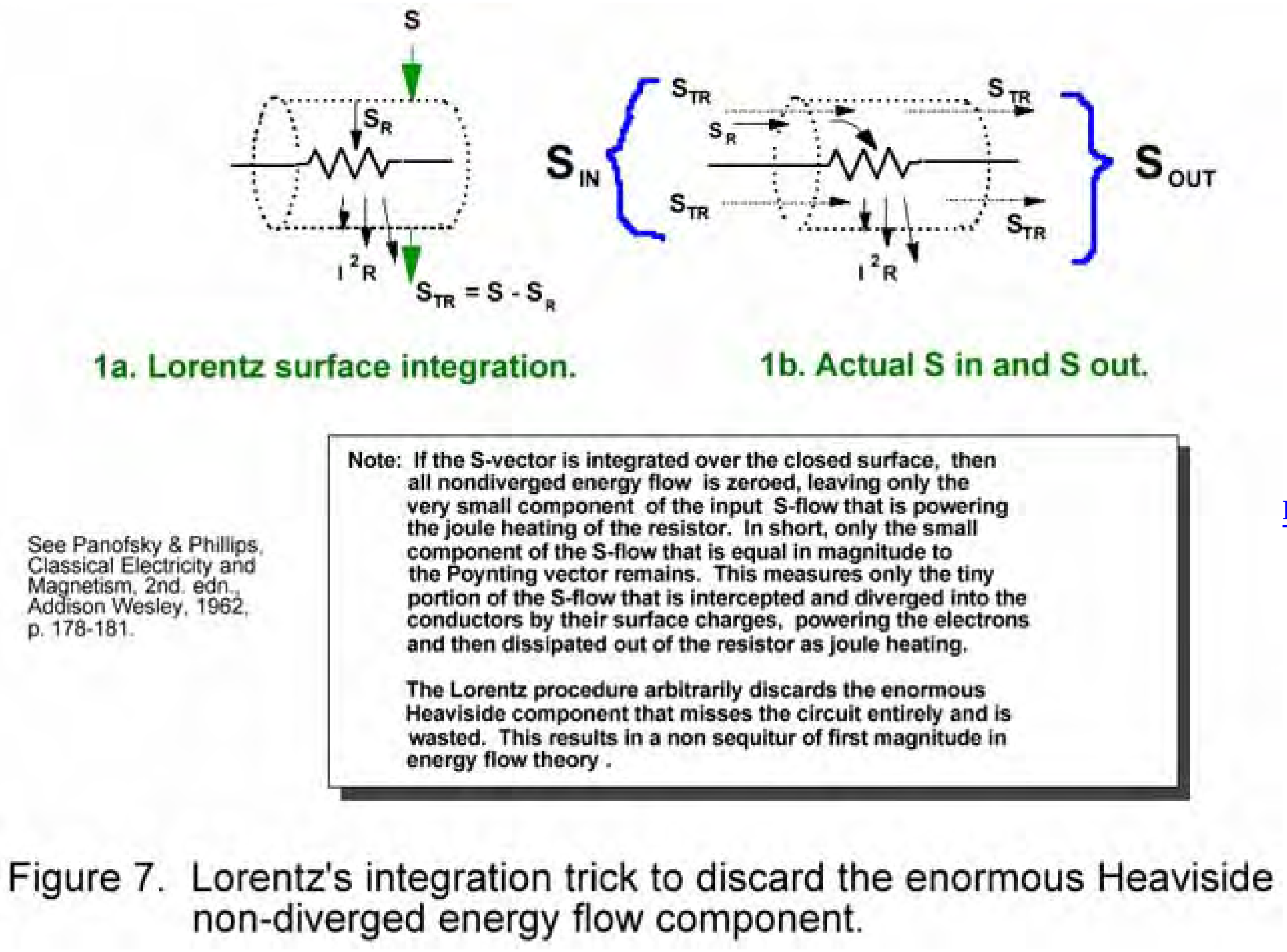

1a. Lorentz surface integration.

1b. Actual S in and S out.

See Panofsky & Phillips, Classical Electricity and Magnetism, 2nd. edn., Addison Wesley, 1962, p. 178-181.

Note: If the S-vector is integrated over the closed surface, then all nondiverged energy flow is zeroed, leaving only the very small component of the input S-flow that is powering the joule heating of the resistor. In short, only the small component of the S-flow that is equal in magnitude to the Poynting vector remains. This measures only the tiny portion of the S-flow that is intercepted and diverged into the conductors by their surface charges, powering the electrons and then dissipated out of the resistor as joule heating.

The Lorentz procedure arbitrarily discards the enormous Heaviside component that misses the circuit entirely and is wasted. This results in a non sequitur of first magnitude in energy flow theory .

Figure 7. Lorentz's integration trick to discard the enormous Heaviside non-diverged energy flow component.

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THE VIRTUAL TIMES

CHASING THE WILD DRAGON:

Foundations of a New Science

By T.E. Bearden
November 12, 1995

It is a pleasure to accept the offer of John and Larry to write a column in their new InterNet magazine. Theirs is a great venture, and with the energy and knowledge they bring to the task, one can be confident of their success in making this a very interesting and informative publication.

There is a new "rebel" science slowly being born, with most of the work being done outside the universities and orthodox scientific community. In the months ahead it will be my job to try to acquaint you with the gist of what's going on, and what all the excitement is about.

This first article is deliberately just introductory, and its purpose is to interest you in the unusual fields we are going to be covering in more scientific detail, in future columns. We will also be listing a variety of references from the technical literature, which bear upon the various points addressed.

In this first article a little of my own background experience [note 1] is given, so you can decide whether you will be interested in what we have to say!

The real purpose of the column will just be to *present information* that you may not be able to readily obtain any other way. We will not argue or debate with skeptics; nothing productive is to be gained by that. If the information we present is useful to you, then our purpose has been accomplished. If it isn't of use to you, then just file it in the old wastebasket. Also, from time to time I may answer a generic question, constructed from multiple queries. Individual responses to correspondence cannot be provided.

The work toward a new breakthrough science is going on in a broad spectrum of "fields," most of which are not yet recognized by academia as even constituting legitimate areas of scientific endeavor (Table 1).

Some of the major areas involved are:

1. theoretical and experimental research in overunity electrical machines,
2. free energy research of other kinds, such as devices utilizing thermodynamics phase changes,
3. rapidly advancing efforts in cold fusion,
4. work on permanent magnet motors,
5. antigravity research, both theoretical and experimental,
6. development and utilization of a "hidden" electrodynamics inside the scalar potential (inside voltage),
7. the "memory" of space and materials; where this "memory" can be deliberately conditioned so that space and the materials themselves become causal actants rather than simple inert entities,

8. direct engineering of quantum change via a new kind of "hidden electrodynamic variables,"
9. the direct engineering of the vacuum's virtual photon flux exchange with matter,
10. action at a distance, including the deliberate formation and usage of quantum potentials,
11. direct engineering of the local curvature of spacetime (yes, the direct engineering of general relativity, using the new hidden kind of electrodynamics),
12. use of the new "hidden" electromagnetics to engineer body cells including the reversal of diseased cells, genetics and all, back to a previous healthy state (cellular dedifferentiation, in biophysical terms, or cellular phase conjugation, in physics terminology),
13. research toward the direct engineering of the mind, including both the conscious and unconscious minds, long-term memory, and the personality itself, and
14. a ruthless re-examination (and correction where necessary and possible) of the definitions, concepts, and postulates that present physics is founded upon.

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Comments may be sent to
the **Editor** of The Virtual Times

[1] For those interested in orthodox qualifications, I have an M.S. in nuclear engineering (1971) from Georgia Institute of Technology and a BS in mathematics (1953) from what is now Northeast Louisiana University with a minor in electronic engineering.

Table 1. Fourteen Emerging New Science Areas

1. Overunity Electrical Machines and Power Systems
2. Overunity Devices Using Thermodynamical Phase Changes
3. Cold Fusion and Non-Nuclear Transmutation
4. Self-Powered Permanent Magnet Motors
5. Antigravity and Antigravity Engineering
6. Use of the "Inner" EM Inside the Scalar Potential
7. Vacuum Engineering, With Vacuum and Materials Memory
8. Direct Engineering of Quantum Change
9. Engineering and Structuring of Massless Charge Flux
10. Action-At-A-Distance, Including Use of Quantum Potentials
11. Direct Engineering of Local Spacetime Curvature
12. "Inner EM" Time Reversal of Diseased Cells Back to Health
13. Direct Engineering of the Mind, Including Software Loading
14. Unified Field Revision of Foundations Concepts of Science

Each of these "major areas" as yet has no single "experts" in the sense that individuals exist who possess a "mastery" of the given area. As an example, in spite of multiple researchers and decades of vigorous research, no one is really an "overall expert" in the overunity electrical power systems field. The "field" itself is still struggling to be born and is not recognized at all by orthodoxy; in fact, many orthodox scientists bitterly resent one even attempting to work in this area. There is as yet no cohesive single "theory" of overunity electrical or magnetic machines, although our own group is making rapid progress in that respect. But there is still no universal agreement amongst even the researchers themselves. Literally the field is still being *discovered*.

This "groping dimly toward a new field" should not be too surprising. After all, the early electromagnetics researchers went through the same tortuous, agonizing kind of development. They were playing with cat fur, glass rods, and pith balls for quite an extended period before understanding progressed to the point where Maxwell could mathematically tie together and model the results of the experimenters such as Faraday and others. It has taken a century and a half for modern electromagnetics and electronics to reach its own present development. It is going to take another decade or so before the overunity researchers can overturn several ill-founded parts of the present electromagnetics and get the emerging field onto a solid foundations footing and into a solid theoretical position.

In the effort to produce a theoretical model of electromagnetics, Maxwell and his predecessors performed a magnificent work. Yet they also made very serious errors (Table 2), which persist to this day. [note 2] Let us list just a few of the more blatant errors in classical EM theory today:

First, Franklin guessed wrong on which way electrical current flowed in a circuit. There is no definition at all of electrical charge in all of physics, and there is no acceptable definition of potential (that is, there is no rigorous definition of just good old "voltage.") There are no "fields of force" in the vacuum; there are just potential gradients __ because the vacuum is just one vast potential (virtual particle flux) in the first place. Force fields actually occur only in and of the matter in a material system. The primary causative agents of electromagnetics are not the so-called "force fields' at all, but are the potentials __ as is well-known in quantum mechanics. [note 3] Maxwell assumed a material ether in his equations. The Michelson-Morley experiment destroyed the material ether, but the Maxwell equations have never been changed accordingly. The electron was not yet discovered when the Maxwell equations were written; the theory does not address electron spin. Maxwell was already dead some two decades when Barus' 1898 paper [note 4] was published, pointing out the strange "backwards-traveling" wave (i.e., time-reversed wave) solution to the wave equation. In addition, Heaviside and Gibbs had already produced their vector truncation __ this truncated theory is the modern so-called "Maxwell's equations" that universities teach today __ of Maxwell's theory. Not a single one of them ever appeared in any book or paper by James Clerk Maxwell. [note 5]

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Table 2. Some Defects In Electrodynamics

1. Conventional Current Direction Is Reversed
2. No Definition of Charge or Potential
3. Equations Still Assume Material Ether
4. Use of Force Fields in Vacuum is Known to be False
5. Treats Charge as Unitary; lnstead, It is a Coupled System
6. Confuses Massless Potential Gradients as Forces
7. Does Not Utilize Mass as a Component of Force
8. Erroneously Assumes Force Fields as Primary Causes
9. Topology of EM Model Has Been Substantially Reduced
10. Does Not Include Quantum Potential
11. Does Not Include Proven Action At A Distance
12. Does Not Utilize Near Field Coulornb Gauge Effects
13. Does Not Include EM Generatrix for Time Flow
14. Does Not Unify Photon and Wave Aspects
15. Does Not Include Electron Spin and Precession
16. Treats Energy As Existing In "Chunks," instead of as Flow
17. Confuses Energy and Energy Collection
18. Discards Half of Every EM Wave in Vacuum
19. Erroneously Uses Transverse Vacuum Wave; It's Longitudinal
20. Omits Phase Conjugate Optics Effects
21. Does Not Include EM Cause of Newtonjan Reaction Force
22. Erroneously Assumes Separate Force Acting on Separate Mass

[2] For an independent statement that electrodynamics, both classical and quantal, are in serious disarray, see Mario Bunge, Foundations of Physics, Springer-Verlag, New York, 1967, p. 176. Quoting: "...it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state." Bunge points out many errors in electrodynamics. See also Terence W. Barrett, "Electromagnetic Phenomena Not Explained by Maxwell's Equations," in Lakhtakia, A. (ed.): Essays on the Formal Aspects of Electromaqnetic Theory, World Scientific, Singapore, 1992, p. 6-86. To find information on what's wrong with EM theory, one must read foundations literature, not the standard textbooks. One of my own contributions has been to point out that the notion of charge q is not unitary. In fact, electrical charge should be defined in terms of q ~ m(sub q)~(sub q). In other words, electric charge q has a massive part m, and a massless part consisting of its potential phi. Further, the magnitude of phi is just the change in the virtual photon flux of the ambient vacuum, due to the [quantum field theoretic] virtual photon exchange with the mass of the q. It follows that the true electrical charge of a particle is just its native potential ~, which is also a dynamic energy exchange with the surrounding vacuum. It also follows that this massless electrical charge changes whenever the particle is placed in a potential (in a different ambient virtual photon flux). After all, potentials superpose; that is their major characteristic. Note that the potential of the test particle is ignored in classical electromagnetics, whenever one speaks of the "E-field" upon the particle. Further, the actual structure of this virtual photon flux that comprises massless electrical charge, can itself be deterministically structured and utilized to generate nonlinear effects that do not appear at all in the present conventional theory. We will be covering many of these effects in future articles.

[3] E.g., see Y. Aharonov and D. Bohm, "Significance of Electromagnetic Potentials in the Quantum Theory," Physical Review, Second Series, 115(3), 1959, p. 485-491. Effects of potentials on charged particles exist even in the region where all the fields (and therefore the forces on the particles) vanish, contrary to classical electrodynamics. The quantum effects are due to the phenomenon of interference. These effects occur in spite of Faraday shielding. The Lorentz force does not appear anywhere in the fundamental quantum theory, but appears only as an approximation that holds in the classical limit. In QM, the fundamental physical entities are the potentials, while the fields are derived from them by differentiation.

[4] Carl Barus, "A Curious Inversion in the Wave Mechanism of the Electromagnetic Theory of Light," American Journal of Science, Vol. 5, Fourth Series, 1898, p. 343-348.

[5] E.g., see Paul J. Nahin, Oliver Heaviside: Saqe in Solitude, IEEE Press, New York. Quoting from p. 9: "...nowhere in Maxwell's writings do the equations for the electromagnetic field appear as we write them today. Maxwell used an amalgamation of Cartesian component and quaternion notation, and it was Heaviside who first wrote the electromagnetic field equations in modern vector form." Quoting from p. 92: "In actuality , however, the fields were not the primary reality to Maxwell at all (that is an idea that developed after Maxwell's death and is due to Hertz and Heaviside), but rather it was Faraday's 'electrotonic state' that he thought to be the real thing. Like Faraday, Maxwell believed that electromagnetic effects are observable results of an altered state of the ether. The mathematical formulation of this electrotonic state, for Maxwell, is what we today (as he did) call the vector potential." And again, from p. 96: "To Maxwell, however, the vector potential had a most definite physical meaning."

So the time-reversed EM wave that one finally sees emerging in nonlinear phase conjugate optics in the early 1970s was omitted from the Maxwellian theory and its later modification by Heaviside and Gibbs. Maxwell's actual theory is in a higher topology (quaternion algebra), and involves some 20 quaternion equations. Heaviside and Gibbs created vector algebra, and seriously curtailed Maxwell's theory when they "translated" it into the much lower topology of vectors and some four equations. The later addition of tensors as the basis mathematics did not restore the lost topology provided by the quaternion model.[note 6]

For the EM wave, Maxwell simply assumed the transverse EM wave that had come from the much earlier derivation of the familiar wave equation from the old "plucked taut string" notions. [note 7] Yet when one closely examines and corrects some of the erroneous *assumptions* [note 8] made for the actual mathematical derivation of this "taut string" transverse wave, one finds (Figure 1) that an equal-energy second antiphased transverse "antiwave" is actually produced by the instrument and added to the "plucked string's" transverse wave disturbance of the air medium, to produce a longitudinal wave of compression and rarefaction in the air itself. The "transverse string wave" in fact never leaves the string. The string wave is not the wave that is launched into the medium.

A similar electromagnetic situation exists. In a whip antenna (Figure 2), the Drude electron gas in the conductor does exhibit a transverse "string-type" EM wave of electron precession. However, at the same time, by Newton's third law (which Maxwell neglected because at the time the atom was regarded as just a blob with no internal structure) the positively charged, phase conjugated atomic nuclei have equal energy, highly damped transverse recoil waves created in them. Further, these "nuclei-recoil" waves are phase conjugate replicas of the electron gas waves. The total disturbance that is launched into the vacuum from the whip antenna is (a) the normal transverse disturbance of the virtual photon flux of vacuum caused by the electron gas wave, and (b) the coupled equal-energy transverse antiwave caused by the nuclei-recoil via Newton's third law. The amplitude of the material antiwaves of nuclei vibration are highly damped because of the massiveness of the nuclei; however, they are of equal energy to the electron wave. But when launched into the same vacuum, the two equal-energy wave disturbances experience equal damping because they are in the same medium. Hence the wave and antiwave are (a) locked together in the vacuum, and (b) of equal energy, and (3) of equal amplitude once launched into the vacuum. What results is a vacuum EM wave of rarefaction (reduction in intensity) and compression (increase in intensity) of the virtual photon flux of vacuum __ just exactly like what is launched into the surrounding gaseous air medium from the "plucked taut string" and perturbed body of a physical instrument. The EM wave in vacuum is a longitudinal wave directly analogous to a sound wave __ just as Nikola Tesla stated. [note 9]

The vacuum may be considered a scalar potential, in which case it has an internal biwave structure (Figure 3). Interference of two potentials __ i.e., the hidden interference (Figure 4) of their internal wave structures __ in fact already creates all EM fields and waves.

When the incoming longitudinal "biwave" from the vacuum strikes the atoms of the receiving antenna, each atom may be considered a dynamic assembly of multiple dipoles, where each dipole consists of one of the electrons in the electron shells and one of the positive charges in the nucleus. The receiving dipole in the interacting atom splits the two waves apart again (Figure 5). The negatively charged end of the dipole is time-forward, and the positively charged end is time-reversed.

Hence the separated normal-wave-half of the biwave interacts with the electron, to give again the familiar transverse "electron precession" wave that we detect with our "electron wiggle-detecting" instruments (Figure 6). This detected electron precession wave is what all our textbooks prescribe erroneously as the vacuum wave! The separated time-reversed-wave-half of the incoming vacuum wave is split off and interacts with the positive end of the receiving atomic dipole, in the time-reversed atomic nucleus, thus generating Newton's third law reaction force to provide the recoil of the nucleus. Present physics has ignored this second wave altogether, because of the serious error in the original derivation of the wave equation from plucked strings. Thus physics presently has absolutely no causative mechanism for Newton's reaction force. Instead, scientists just "mystically invoke the appearance of this magic force." Describing that something occurs, and naming its occurrence, does not constitute advancing a causative mechanism!

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[6] E.g., see T.W. Barrett, "Tesla's Nonlinear Oscillator- Shuttle-Circuit (OSC) Theory," Annales de la Fondation Louis de Broglie, 16(1), 1991, p. 23-41. Barrett shows that a higher topology EM model (e.g., quaternions) allows shuttling and storage of potentials in circuits, and also allows additional EM functioning of a circuit that a conventional EM analysis cannot reveal. Tesla's actual patented circuits in fact exhibit this higher topology, when a quaternion EM analysis of them is performed. No orthodox vector/tensor analysis can show this.

[7] All the early experimenters seemed to assume the transverse string-type wave automatically for the vacuum medium. E.g., Faraday speculated that light and radiant heat might be transverse vibrations propagated along his "lines of force," from which the direct "plucked string" analogy can readily be seen. In short, he considered that his lines of force could be perturbed to vibrate laterally, just like a plucked string. See M. Faraday, "Thoughts of Ray-Vibrations," Philosophical Magazine, (3), vol. xxvii, 1846, p. 345. Maxwell also assumed the transverse EM wave in vacuum without question, as did Heaviside, Hertz, and Gibbs and as has almost every electrodynamicist since then.

[8] The worst is the assumption of infinitely rigid endposts holding the taut string, so that no movement of these endposts occurs. This further assumes that no induced movement of the body of the instrument occurs. The end result is to eliminate all of that wave that is produced in the body of the instrument, and retain only the transverse wave produced in the string. In the first place, this standard procedure has now become a total violation of Newton's third law, which among other things requires that forces be formed in oppositional pairs. So the standard method for the launch of a wave from an instrument is flawed. Specifically, the "transverse string wave" is falsified insolaf as its appearance in the surrounding medium. This is not the wave that actually exits the instrument and that is launched into the medium. This universal oversight on the part of mathematicians and physicists is a colossal joke upon them. Literally, when a physicist writes the transverse wave equation on the board, he has just discarded exactly half the physics. This means that, in his interactions, at the end there will suddenly appear this mysterious, mystical "equal and opposite reaction force" that is created by the erroneously ignored antiwave. So he has to piously invoke this reaction force "from the blue." Yet quantum field theory teaches us already that all mechanical and electromagnetic forces on a mass are generated by absorption and emission of virtual photons. Hence Newton's third law reaction force must also be so generated. This means that there must exist an equal number of virtual antiphotons interacting in the antiforce, as there was virtual photons interacting in the causative force. By symmetry there must also exist an equal and opposite wave, or antiwave, made of these same antiphotons. The actual disturbance that entered from the vacuum must therefore have consisted of both wave and antiwave. QED.

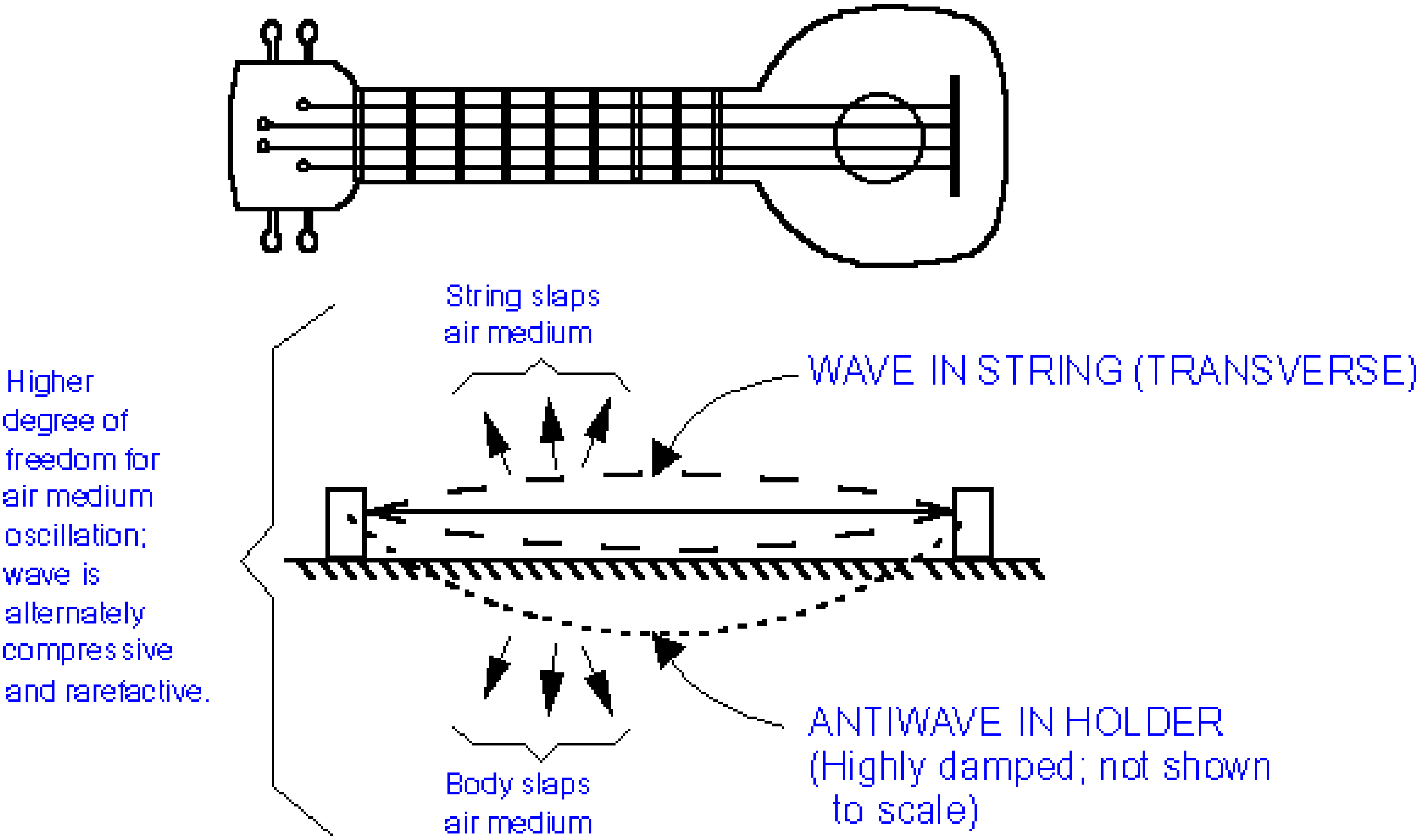
String slaps
air medium
WAVE IN STRING (TRANSVERSE)
Higher
degree of
freedom for
air medium
oscillation;
wave is
alternately
compressive
and rarefactive.
ANTIWAVE IN HOLDER
(Highly damped; not shown
to scale)
Body slaps
air medium

Figure 1. Air medium disturbances generated by plucked string.

Two waves are created, both slapping the air medium at the same time, but in opposite directions. A disturbed medium oscillates according to its own degrees of freedom. The air has more degrees of freedom than the string. A wave of compression and rarefaction is created in the air medium.

D-1-F 1

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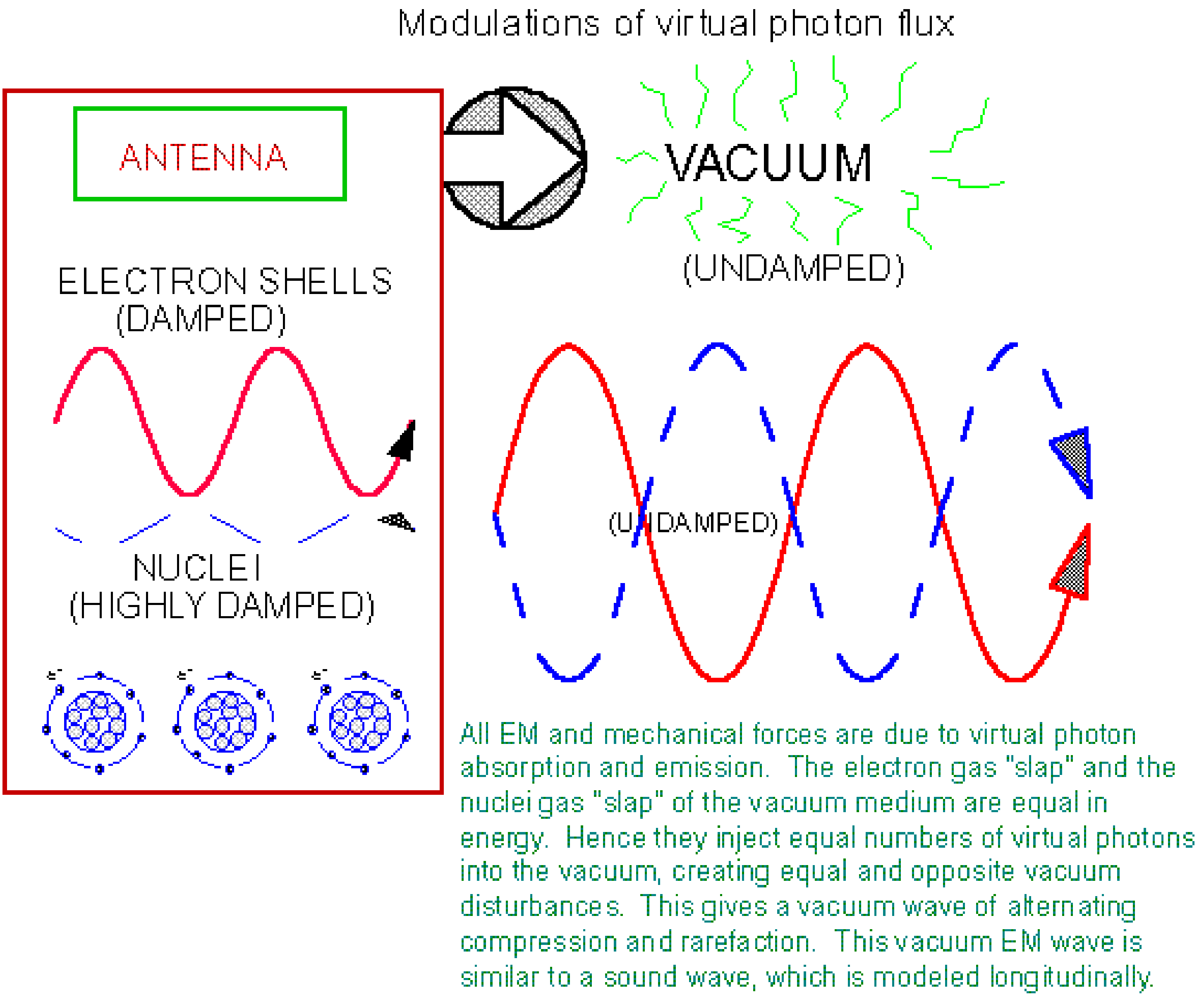
Modulations of virtual photon flux
ANTENNA
ELECTRON SHELLS
(DAMPED)
NUCLEI
(HIGHLY DAMPED)
VACUUM
(UNDAMPED)
(UNDAMPED)

All EM and mechanical forces are due to virtual photon absorption and emission. The electron gas "slap" and the nuclei gas "slap" of the vacuum medium are equal in energy. Hence they inject equal numbers of virtual photons into the vacuum, creating equal and opposite vacuum disturbances. This gives a vacuum wave of alternating compression and rarefaction. This vacuum EM wave is similar to a sound wave, which is modeled longitudinally.

Figure 2. Launching an EM wave from a wire antenna.

D-1-F2

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[9] See Nikola Tesla, "Pioneer Radio Engineer Gives Views on Power," New York Herald Tribune, Sep. 11, 1932. Quoting: "...I showed that the universal medium is a gaseous body in which only longitudinal pulses can be propagated, involving alternating compressions and expansions similar to those produced by sound waves in the air. Thus, a wireless transmitter does not emit Hertz waves which are a myth, but sound waves in the ether, behaving in every respect like those in the air, except that, owing to the great elastic force and extremely small density of the medium, their speed is that of light." Today the QM vacuum has been theoretically and experimentally shown to consist of a "gas" of virtual particles, rather like Tesla stated. Tesla was also correct about the longitudinal EM wave in the vacuum. He was also correct in his statement that a fundamental charged particle can alter its charge, if one considers the massless charge ~ of charge q separately from the mass m of charge q. When the charge q is placed in a nonzero potential V, it follows that the new charge of the electron is simply (~+V).

Tables:

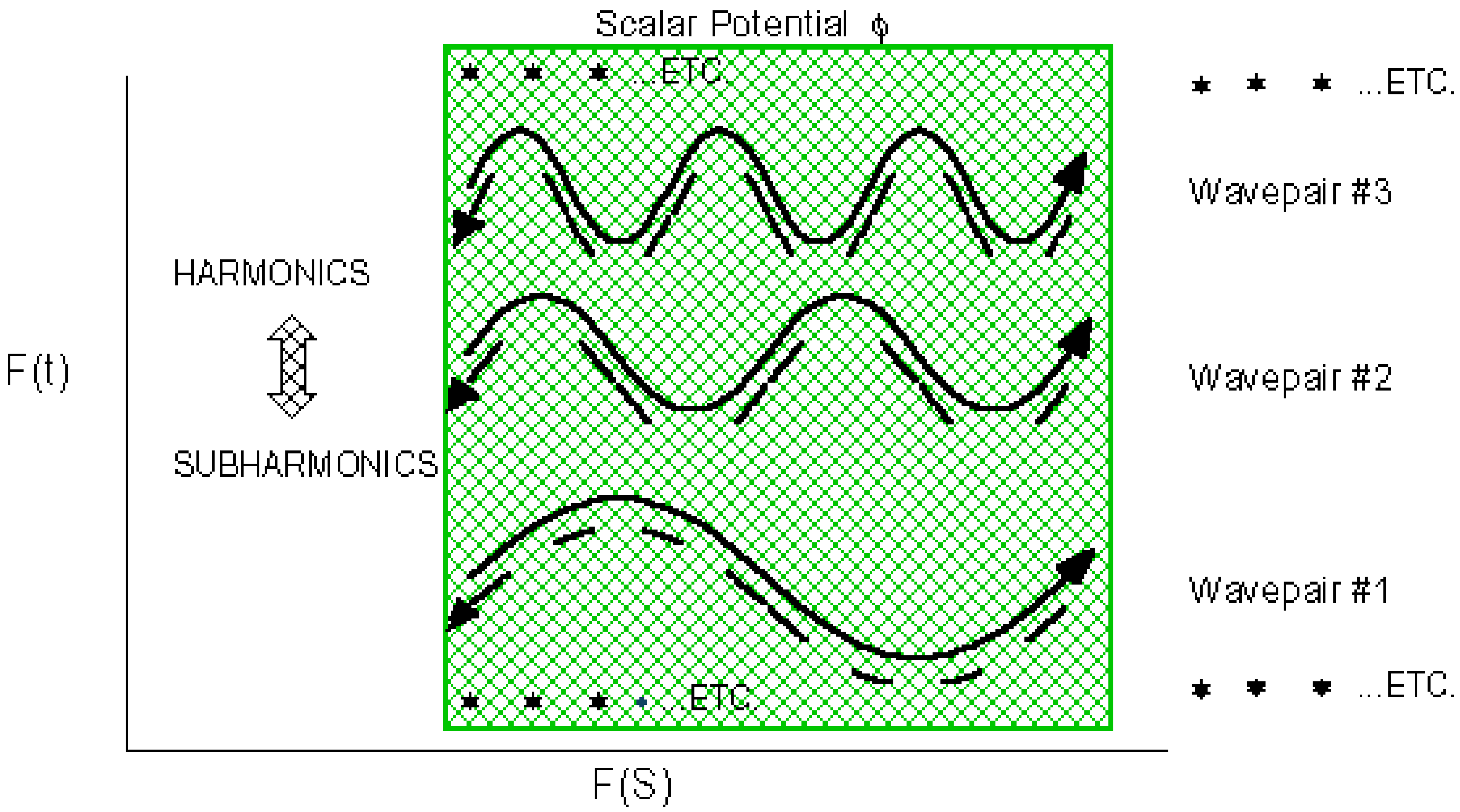
Scalar Potential ϕ
* * * ...ETC.
HARMONICS
SUBHARMONICS
F(t)
Wavepair #3
Wavepair #2
Wavepair #1
* * * ...ETC.
* * * ...ETC.
* * * ...ETC.
F(S)

Figure 3. Internal Wave Structure of the scalar potential.

A harmonic set if wavepairs, where in each wavepair the two waves superpose spatially, but travel in opposite directions. The two waves in each pair are true phase conjugates and time-reversals of each other. Thus they comprise a coupled wave and antiwave. The photons must also be coupled into photon/antiphoton pairs, by a strong application of the distortion correction theorem of nonlinear optics.

Each wavepair is a standing electrogravitational wave.

D-1-F3

© T.E. Bearden 1984, 1985

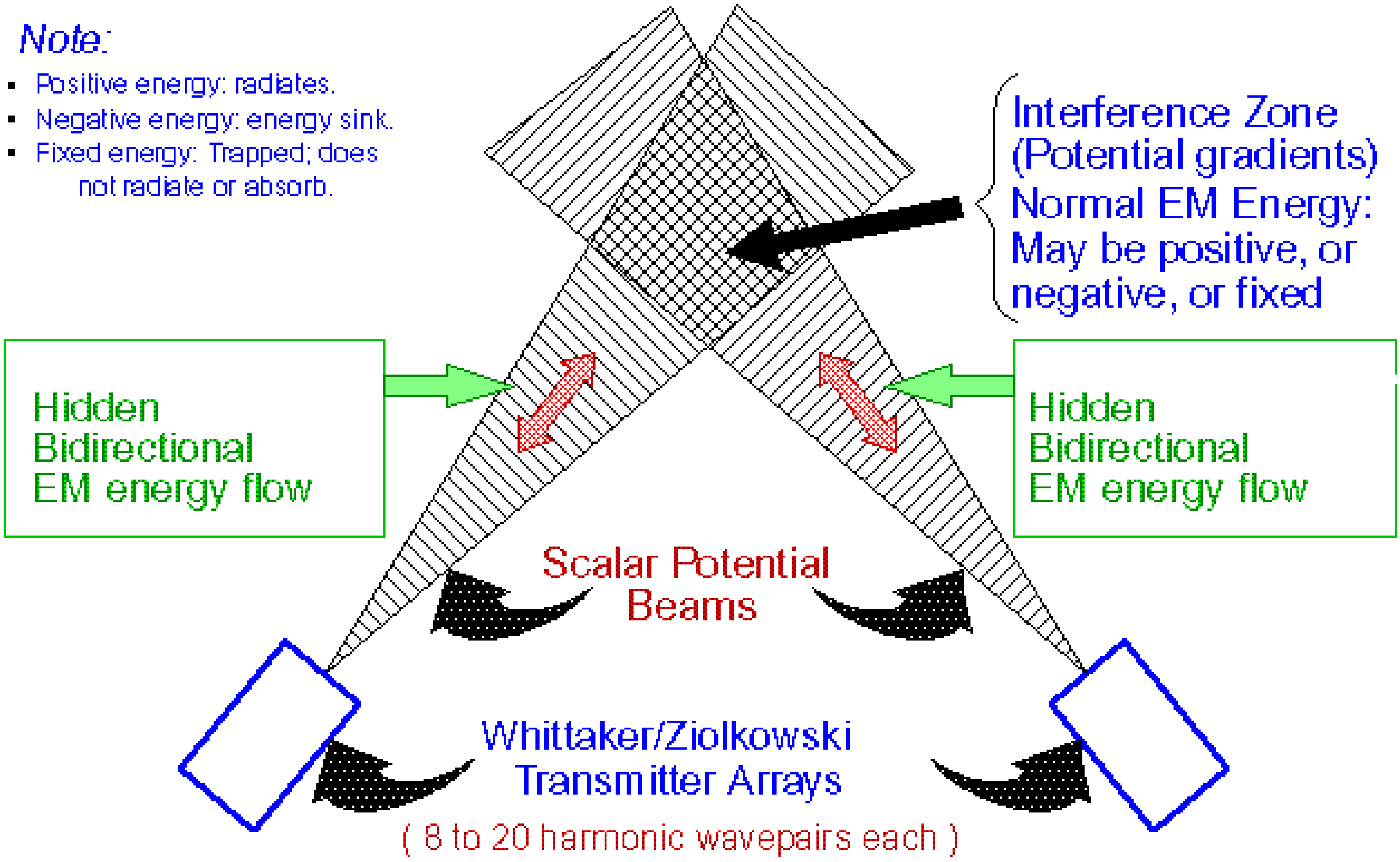
Note:
Positive energy: radiates.
Negative energy: energy sink.
Fixed energy: Trapped; does not radiate or absorb.
Interference Zone (Potential gradients)
Normal EM Energy: May be positive, or negative, or fixed
Hidden Bidirectional EM energy flow
Hidden Bidirectional EM energy flow
Scalar Potential Beams
Whittaker/Ziolkowski Transmitter Arrays
(8 to 20 harmonic wavepairs each)

Figure 4. Scalar potential interferometry provides action-at-a-distance. It already creates normal EM fields and waves.

D-1-F4

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Tables:

MECHANISM FOR NEWTON'S THIRD LAW

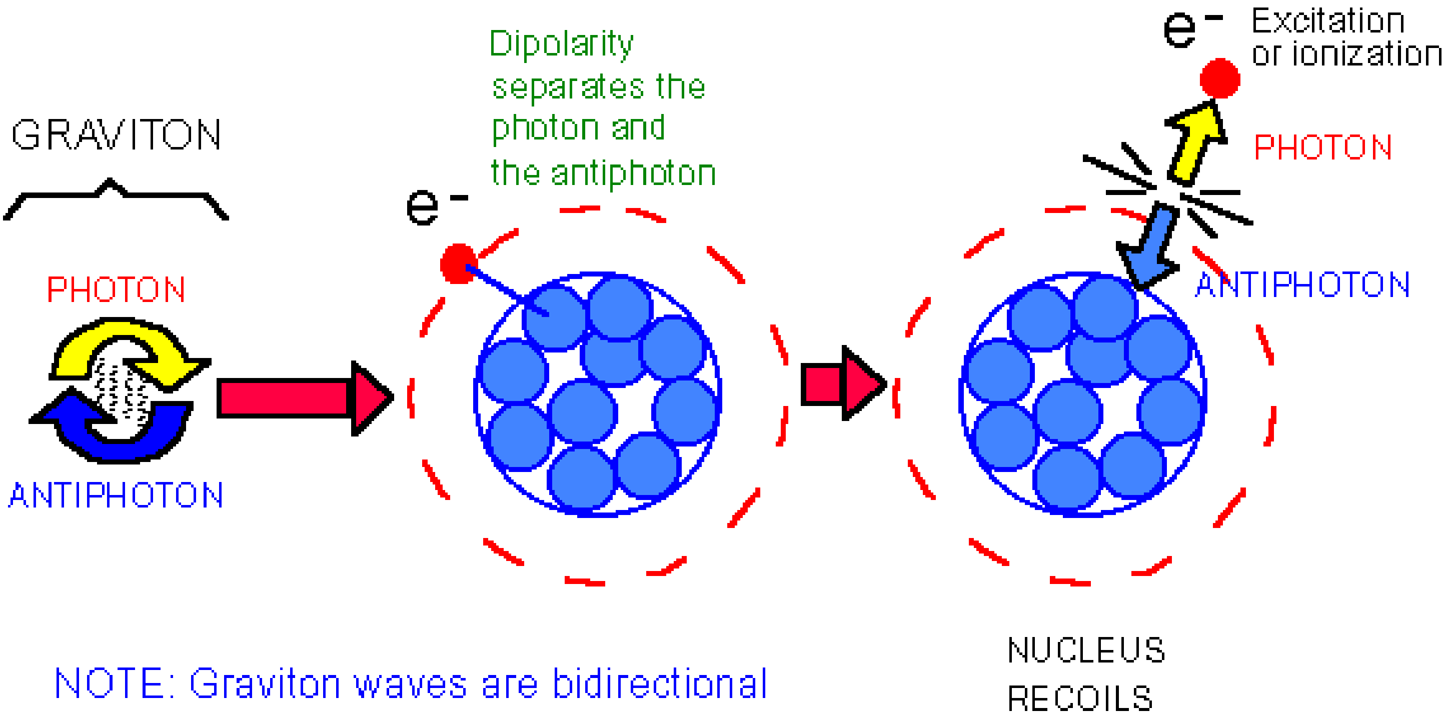
GRAVITON
PHOTON
ANTIPHOTON
e -
Dipolarity separates the photon and the antiphoton
e -
Excitation or ionization
PHOTON
ANTIPHOTON
NUCLEUS RECOILS

NOTE: Graviton waves are bidirectional phase waves of photon/antiphoton coupling and uncoupling in the vacuum.

The atom is an assembly of dynamic dipoles.

A dipole splits the graviton into a photon and an antiphoton.
The photon interacts with the electron, producing the action.
The antiphoton interacts with the nucleus, producing the reaction.

Figure 5. Graviton interaction with matter produces the photon interaction and Newton's third law reaction.

D-1-F5

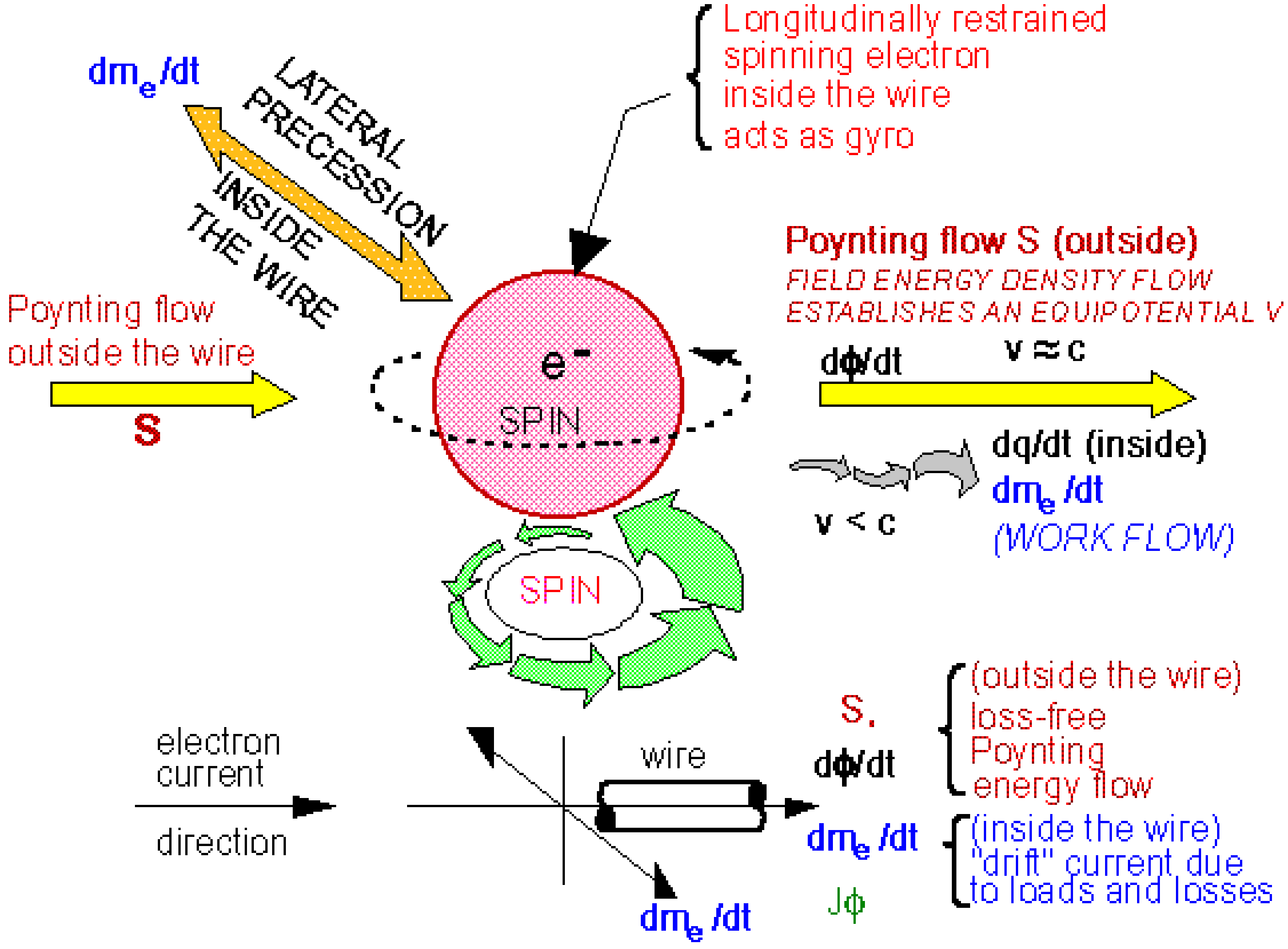
dm_e/dt
LATERAL PRECESSION INSIDE THE WIRE
Longitudinally restrained spinning electron inside the wire acts as gyro
Poynting flow S (outside)
FIELD ENERGY DENSITY FLOW ESTABLISHES AN EQUIPOTENTIAL V
Poynting flow outside the wire
S
e⁻
SPIN
dφ/dt
v ≈ c
dq/dt (inside)
dm_e /dt
(WORK FLOW)
v < c
SPIN
S,
dφ/dt
(outside the wire) loss-free Poynting energy flow
electron current direction
wire
dm_e /dt
(inside the wire) "drift" current due to loads and losses
Jφ
dm_e /dt

Figure 6. Currents in and along a conductor, with electron precession.

D-1-F6

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Further, if we should trick the time-reversed wave half into coming outside the atom instead of going inside to interact with the nucleus (Figure 7), then it follows that the nucleus would not recoil. In that case the interaction would appear to violate Newtonian third law reaction. Phase conjugate mirrors already do just exactly this when they emit a phase conjugate replica wave. They direct the antiwave outside and away from the atom instead of inwards into the nucleus. So they do not recoil, no matter how powerful a phase conjugate replica wave they emit.

Finally, we can also show that the EM wave in vacuum is longitudinal, by yet another approach. The electrons in the electron gas in a conductor are spinning, and they are severely constrained longitudinally to be able to move only very, very slowly down the wire. So when perturbed, they act as gyroscopes, and precess at right angles to the perturbing force. The fact that the gyroelectrons in a wire move radially almost entirely, and only "slip" down the wire very slowly with a "drift" velocity, already proves conclusively that the incoming vacuum disturbance was longitudinal. The precession of a gyro is at right angles to the perturbing force. Therefore rigorously the vacuum EM waves are longitudinal, because the gyroelectrons moved transversely. The present assumption of the transverse EM wave in vacuum contradicts the entire theory of gyroscopes! [note 10] There are many other errors in classical EM that we will point out in future articles; this should give the reader a flavor of what is in store for him in future articles.

So there are no truly satisfactory "experts" in any of the 14 fields. Yet there is still something to be said for having some years of experience in one or more of the areas. I have had the good fortune or misfortune, depending upon one's viewpoint, to be involved in various of those 14 activities for some 30 years or more, and am active in several of the areas now. My colleagues and I are particularly active in researching overunity electrical devices (see Figure 8), to include the effects of controlled chaotic oscillators, charge-blocking oscillators, and oscillators driven by in-shuttled (bridged) Poynting field energy density flow ExH. Parametric oscillation is known to have yielded overunity electrical machines and was fully reported by Russian researchers in the Russian and French technical journals in the mid 1930s. [note 11] We will further cite that little-known work in future articles. Also, we are working mightily upon true negative resistors (Figure 9), wherein the resistor scavenges some of the disorganized energy from the vacuum's energetic exchange with the charges in the system, organizes and collects it, and then outputs that collected energy flow into the external circuit. Such a resistor acts as a power source. Kron, perhaps the greatest of the electrical machinery scientists, is known to have produced such true negative resistors.

I have also proposed a theoretical explanation of the Priore device (Figure 10) in France which in laboratory animals demonstrated remarkable cures of terminal tumors, cured trypanosomias, reversed atheriosclerosis, and restored suppressed immune systems. The Priore work was not anecdotal, but was performed under rigorous scientific protocols, working under the auspices of renowned French scientists such as Courrier and Pautrizel. The work is properly reported in numerous papers in the French medical literature. [note 12] The results were certainly achieved, but neither Priore himself nor the scientists of the day could understand the mechanism involved. The deciphering of that causative technical mechanism utilized by the Priore group required 10 years of intense effort. The results have now been published in the journal Explore! and are there for anyone to read. [note 13]

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PHOTON INTERACTION WHEN ATOM PHASE CONJUGATES

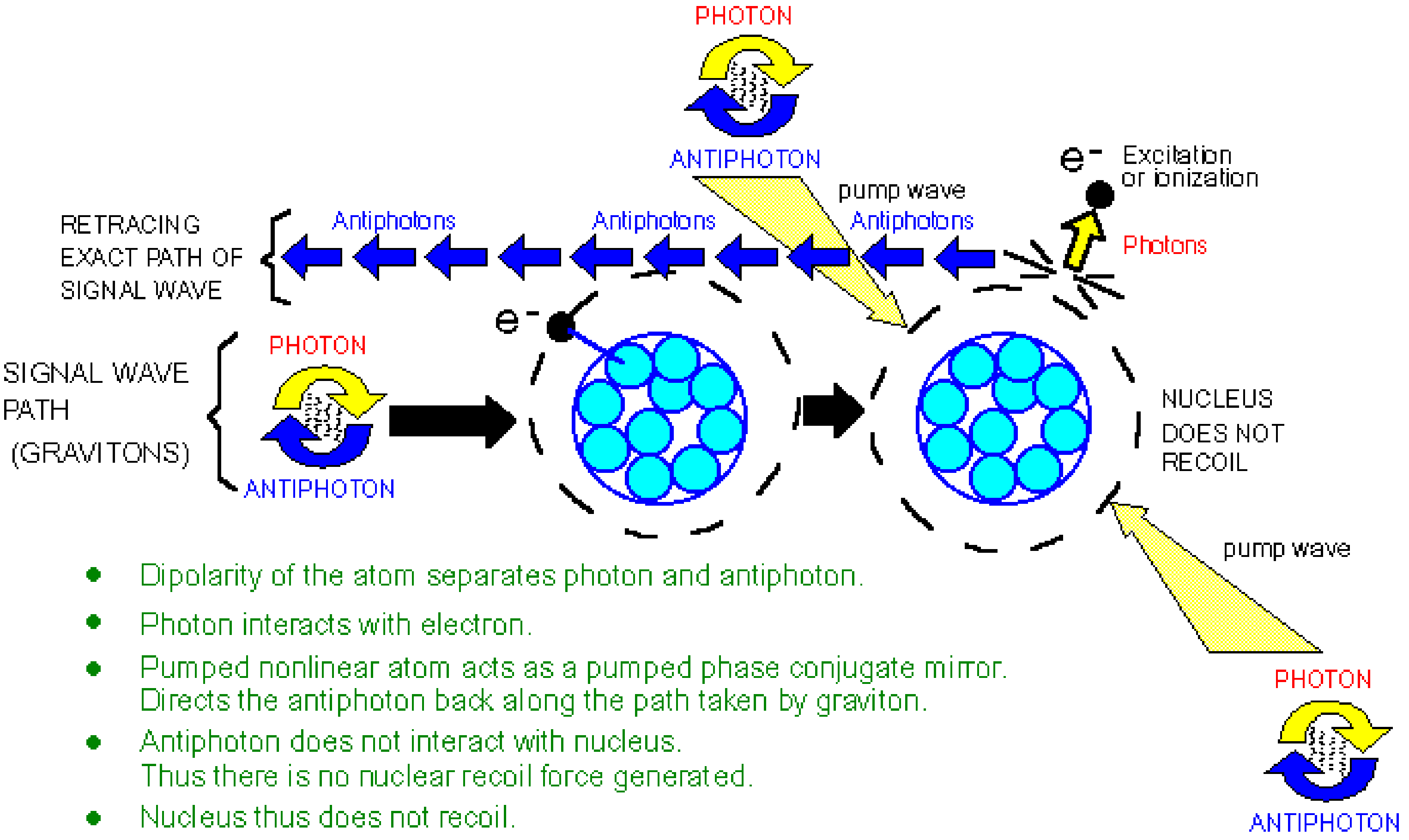
PHOTON
ANTIPHOTON
pump wave
e⁻
Excitation or ionization
Photons
RETRACING EXACT PATH OF SIGNAL WAVE
Antiphotons
Antiphotons
Antiphotons
e⁻
SIGNAL WAVE PATH (GRAVITONS)
PHOTON
ANTIPHOTON
NUCLEUS DOES NOT RECOIL
pump wave
PHOTON
ANTIPHOTON

- Dipolarity of the atom separates photon and antiphoton.
- Photon interacts with electron.
- Pumped nonlinear atom acts as a pumped phase conjugate mirror. Directs the antiphoton back along the path taken by graviton.
- Antiphoton does not interact with nucleus. Thus there is no nuclear recoil force generated.
- Nucleus thus does not recoil.
- Not a violation of Newton's third law, once one understands the mechanism that generates third law reaction. In the absence of the generating mechanism, there is no third law recoil. In EM field theory, the "missing antiwave" has necessitated third law omission.

Figure 7. Emission of antiphoton; nucleus does not recoil.
Atom acts as a pumped phase conjugate mirror.

D-1-F7

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[10] When Maxwell's theory was constructed, the electron had not yet been discovered, and so the dipolarity of the atom was unknown. An atom was regarded just as a "blob." Electricity in a conductor was regarded as a thin material fluid Maxwell's equations are in fact hydrodynamic equations. So the founders regarded the detection of induced motion in the electric fluid as induced translation, not induced precession. They had no idea of "spins" of particles of the fluid, nor of gyro precession of those particles. Instead, q was regarded just as a "piece of electric fluid," similar to a cubic centimeter of fluid.

A fundamental AC resonant principle for an overunity electrical power system

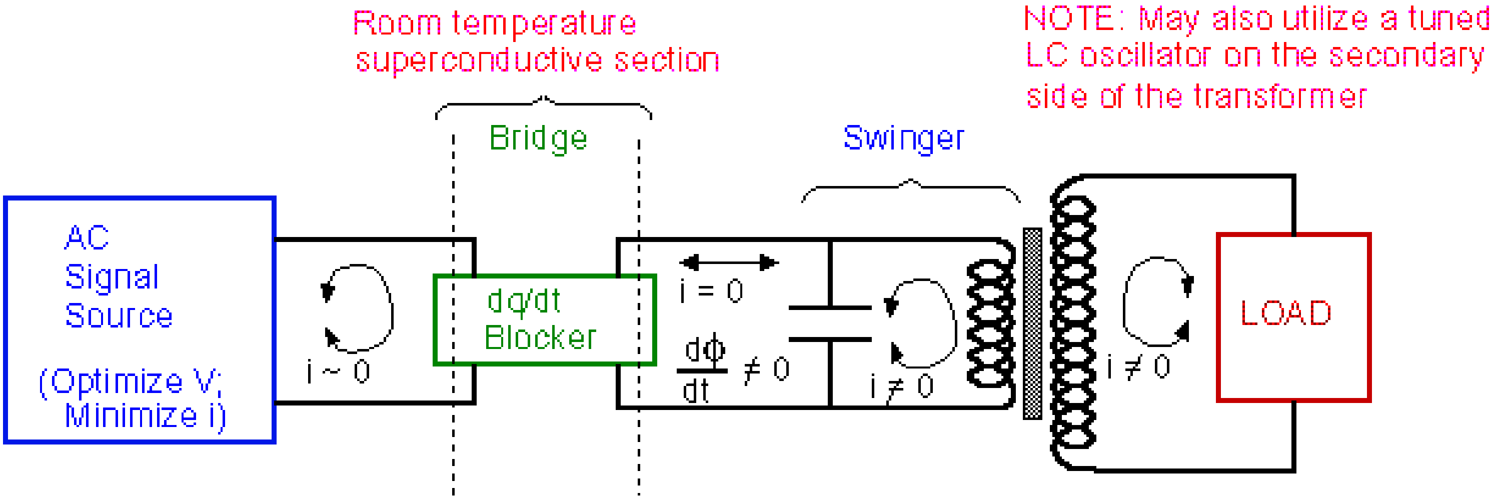
Room temperature
superconductive section
NOTE: May also utilize a tuned
LC oscillator on the secondary
side of the transformer
Bridge
Swinger
AC
Signal
Source
(Optimize V;
Minimize i)
i ~ 0
dq/dt
Blocker
i = 0
$\frac{d\phi}{dt} \neq 0$
$i \neq 0$
$i \neq 0$
LOAD

Patent Pending

Figure 8. dq/dt-free driving a swinger by S-flow.

Poynting energy flow S with its accompanying potential V is shuttled from the source to a tuned LC oscillator in resonance at the driving frequency or slightly below. The LC oscillator is driven by S-flow and dV/dt flow alone. The swinger furnishes its own free electrons, which receive S and EMF from the bridge, thereby producing dq/dt.

D-1-F8

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[11] E.g., see L. Mandelstam [Mendel'shtam, L.I.], N. Papalexi, A. Andronov, S. Chaikin and A. Witt. (1935) "Report on Recent Research on Nonlinear Oscillations," Translation of "Expose Des Recherches Recentes Sur Les Oscillations Non Lineaires," Technical Physics of the USSR, Leningrad, Vol. 2, 1935, p. 81-134. NASA Translation Doc. TT F-12,678, Nov. 1969. Summarizes lengthy work at the Institute of Physics of the University of Moscow and several of the laboratories on the problem of self-powered, self- oscillating nonlinear oscillators. The paper reports significant work and progress in oscillations created by the oscillating system itself (self-oscillation) without participation of any external forces varying with time and without the expense of a constant source of energy (e.g., a storage battery). Such a system was shown to self-increase in an underdamped manner until system self-destruction. Adding a nonlinear load allowed the systems to stabilize its dynamic operation so that it powered a load under overunity conditions and did not self-destruct. Extensive additional references on this spectacularly successful overunity energy project are listed.

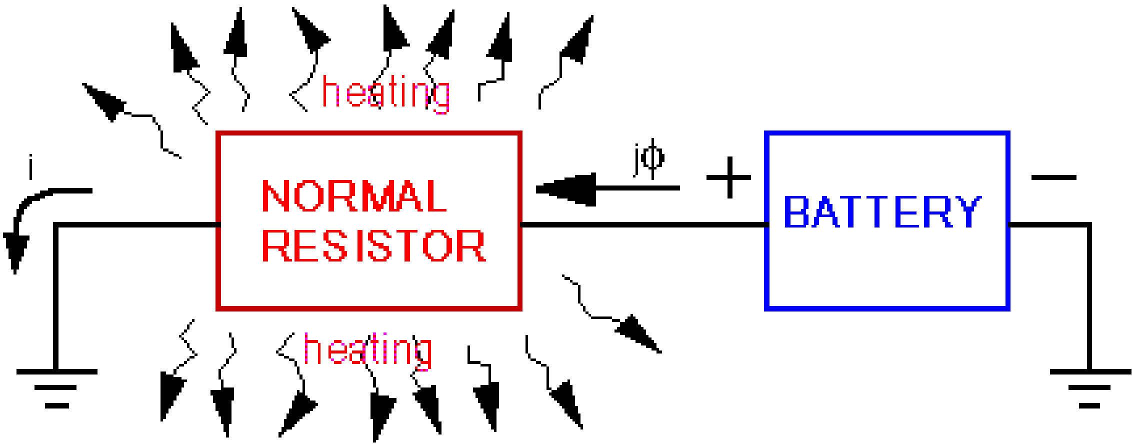
heating
NORMAL RESISTOR
jϕ
+
BATTERY
−
i
heating

Figure 9a. Normal resistor receives ordered energy and scatters it.

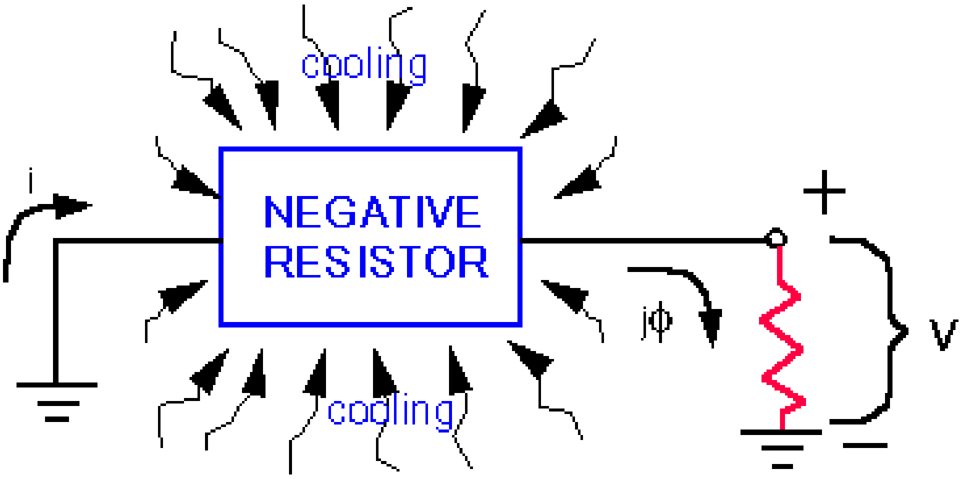
cooling
i
NEGATIVE RESISTOR
+
jϕ
V
−
cooling

Figure 9b. Negative resistor receives, concentrates, and reorders scattered energy.

Figure 9. Normal resistor versus a negative resistor.

D-1-F9

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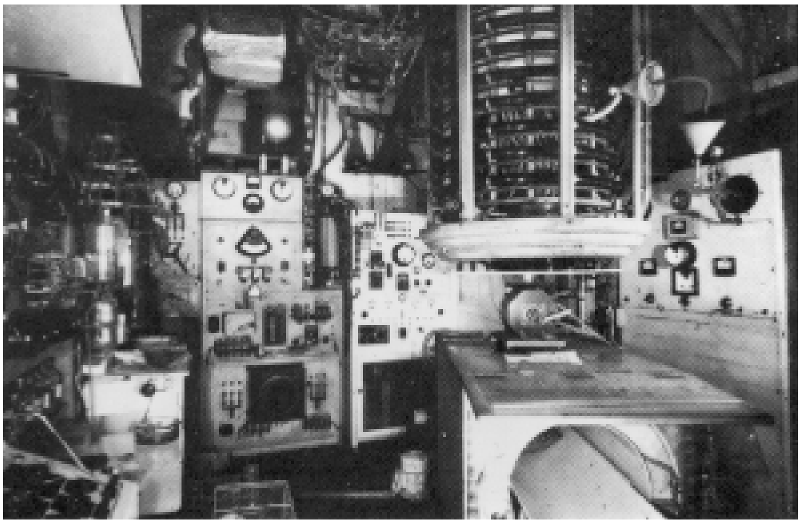

Some 17 signals were fed into a rotating plasma, which added phase conjugates to them. This infolded 17 wavepairs, each pair a coupled wave/antiwave, thereby forming a scalar potential with an artificial Whittaker pump wave internal structure. This infolded pump wave complex was modulated onto a powerful, rippling magnetic field, guaranteeing penetration even into the atomic nuclei. A specific, amplified antiengine for the exact cellular disease state was generated, reversing the diseased cells back to a previous healthy state.

Figure 10. Priore's laboratory apparatus for cellular reversal.

D-1-F10

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[12] For citations and the exposition of our proposed explanation of the Priore mechanism, see T.E. Bearden, "Vacuum engines and Priore's methodology: The true science of energy-medicine." Part I, Explore!, 6(1), 1995, p. 66- 76, Part II, Explore!, 6(2), 1995, p. 50-62.

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[13] Bearden, "Vacuum engines and...," ibid.

Presently my CTEC colleagues and I have filed three patent applications and a continuation, on various methods for overunity processes and apparatuses, room temperature superconductivity, Poynting generators, etc.

As an example, we took exactly the opposite approach to room temperature superconductivity as has been taken by all the orthodox researchers to date. What exactly is sought, after all, for superconductivity (SC) in a section of an electrical circuit? Well, one has some electrons on one side of that SC section that are transporting excess potential, as given by the Slepian vector J*. [note 14] What is desired is to get some electrons on the other side of the SC section that also are transporting the same amount of excess energy in the form of J*. You can do that in two ways: (1) you can flow the electron carriers through the SC section, carrying their J*, or (2) you can block the J and flow the * itself across as the Poynting flow S. [note 15] Nondivergent Poynting flow flows along an equipotential, which is just another way of saying that, if the S-flow does not diverge, it carries the same potential * along with it. Hence it carries the EMF right along with it as it flows without divergence.

Conventional approaches have all tried to shove the electron carriers through the SC lattice section. Doing that is like trying to fire a very slow bullet through several million rotating fans in a straight line. So cryogenics (to slow the fanblades to a crawl) and massive correlation of the electrons and of the electron-to-lattice interactions is necessary if one is to get the electrons through there without excess collisions that shake off some of the excess * from J*, as scattered photons (heat) or as a change of form of the energy (as in straining the dielectric of a capacitor to convert electrical energy to mechanical strain energy via the piezoelectric effect.)

Our approach is exactly the opposite (Figure 11 and Figure 12). Why not just *stop* the flow of excited electron carriers on one side of the SC section, and continue the nondiverging flow of the Poynting field energy density S across that section at room temperature? Then the cryogenics is not needed at all. After all, circuits already work that way anyhow __ except standard practice is to nullify the process by letting current be driven around the sourcing current loop and back through the back EMF of the primary source. A quantum well (or several other methods) can be used to trap the "sourcing" electrons in the conductor just prior to entering the SC section. The "receiving" electrons on the other side of the SC section, however, must be in their own dq/dt-isolated current loop.

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[14] Briefly, the S-flow outside the wire will be flowing along essentially at the speed of light, at or with the same since S-flow without divergence is along an equipotential. Said another way, a nondiverging Poynting flow S exhibits a constant potential ~ along its streamlines. A tiny, tiny portion of the S-flow is intercepted by the sluggish electrons (which may be moving as dq/dt at 11 feet per hour, in a typical case), to form the Slepian vector J~. The J~ portion is just the minute fraction of the S-flow that is actually intercepted by the electron current and transported to the impedances, for releasing the excess ~ in the loads and losses. [Incidentally, this wee note resolves a century of controversy over exactly how EM energy flows in circuits. The orthodox literature abounds with discussions, differing positions, and debates and with errors.]

[15] Note that this also automatically involves a host of other types of controversial displacement currents, such as d~/dt, dV/dt, dE/dt, dP/dt, dD/dt, etc. The literature is thoroughly floundering as to exactly how all these currents are related, together with the Slepian vector J~ and the Poynting vector S, as well as the "normal" current dq/dt. We will be discussing the "master key" for these relationships in future articles.

Tables:

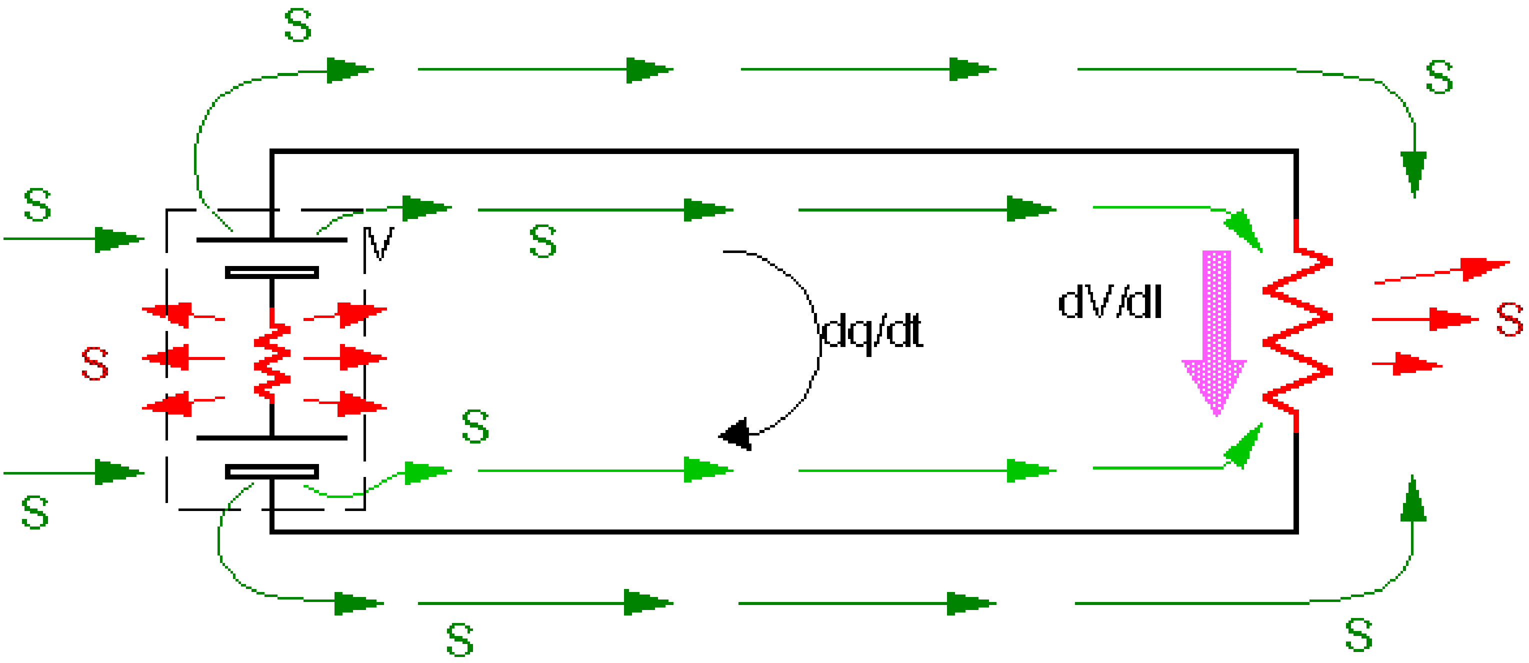

Note: EM texts err in showing the battery "gate" as the source of energy.

Figure 11. Poynting S-flow along a simple circuit.

From particle physics, any electric charge is a broken symmetry in the vacuum's virtual particle flux. Any dipole is thus two locally broken symmetries. Thus the dipole acts as a gate/source, driven by the fierce vacuum flux. So a dipole already "extracts" and gates EM energy flow, directly from the seething vacuum.

Every battery and generator is already a "free energy" source of extracted and gated EM energy from the vacuum.

D-1-F11

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Tables:

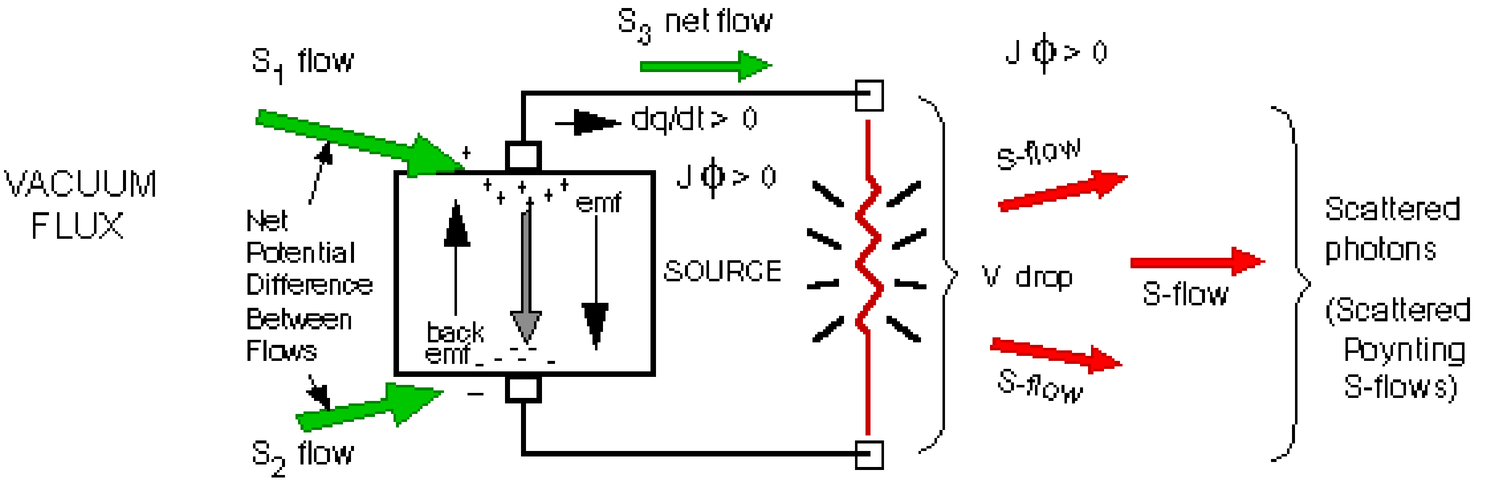
S_3 net flow
S_1 flow
VACUUM FLUX
dq/dt > 0
J φ > 0
J φ > 0
Net Potential Difference Between Flows
emf
back emf
SOURCE
S-flow
V drop
S-flow
S-flow
Scattered photons
(Scattered Poynting S-flows)
S_2 flow
+
–

Figure 12a. Normal current flow; Jφ is the electron transport of energy, while S is the speed-of-light Poynting energy flow.

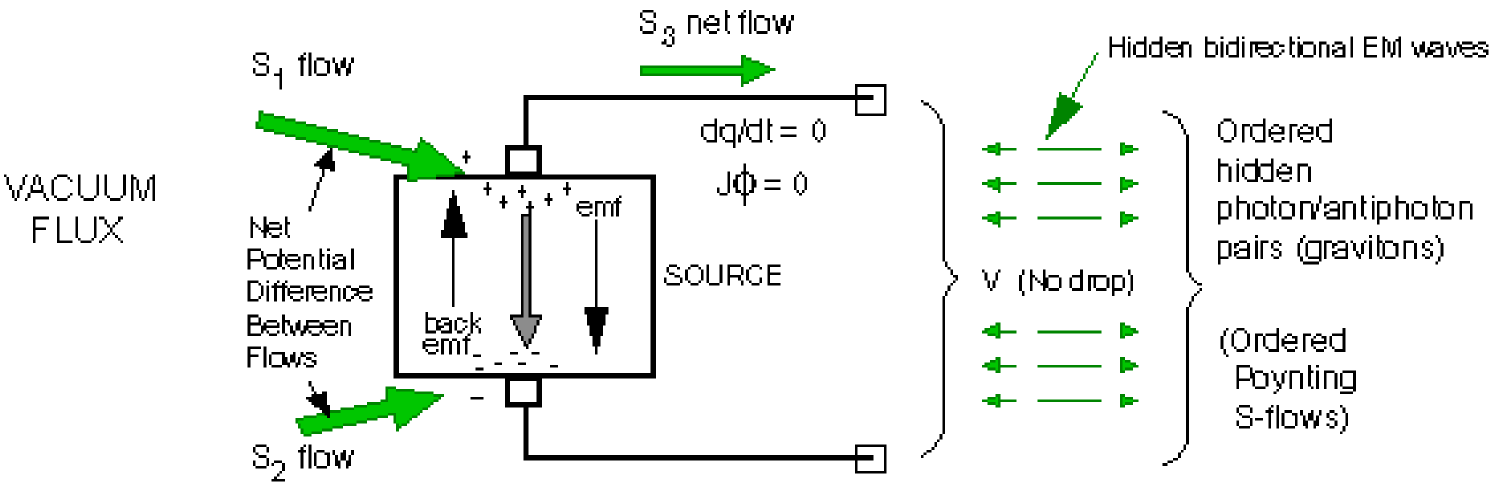
S_3 net flow
S_1 flow
Hidden bidirectional EM waves
VACUUM FLUX
dq/dt = 0
Jφ = 0
Net Potential Difference Between Flows
emf
back emf
SOURCE
V (No drop)
Ordered hidden photon/antiphoton pairs (gravitons)
(Ordered Poynting S-flows)
S_2 flow
+
–

Figure 12b. In a conductor with dq/dt blocked; S-flow and hidden Whittaker-wave flow continue.

Figure 12. Overt and covert field energy density flows.

D-1-F12

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Normal sources do not furnish electrons and current to a circuit anyway. Sources just furnish Poynting flow S and EMF. [note 16] In the receiving current loop, the EMF appears automatically once the S-flow flows in and is "locked on to" by the receiving electrons. Given q**, you will immediately have J* if the electrons are free to move in the conducting circuit (see Figure 13). Further, you have eliminated all the loss terms from the standard Poynting equation for energy losses. So all the energy flow S just flows across the SC section, without any current or Cooper pairs flowing through that SC section. The SC section has become a "bridge" which (1) strips off the Poynting field energy density flow S from the electron current dq/dt on the sourcing side of the SC/bridge section, by simply reducing the dq/dt to zero; and (2) continues to pass the S-flow across the dq/dt-blocked SC/bridge section to the other side (Figure 14). The excess S-flow (and EMF) pours into the receiving dq/dt-isolated current loop, exciting the electrons therein to produce dq/dt and J*. *Any closed current loop is self-powered, once it receives S and EMF. It furnishes its own electrons; it only requires excess energy and EMF.* [note 17]

So our approach gives room temperature superconductivity in a very straightforward manner, once you discover how to block the current dq/dt in a conductor. Blocking it in an insulator is not sufficient, because that drops the potential and stops the S-flow and the equipotential * (the EMF). However, a degenerate semiconductor such as the Fogal chip can be used, as can several other processes for blocking dq/dt in a conductor. We will discuss these in a future article.

Another advantage of this approach to room temperature superconductivity is that now one can also have permissible overunity coefficient of performance. Now the load can be placed in its own S-receiving, isolated current loop. With the sourcing current loop furnishing only S and not dq/dt, the load is still powered normally in its own closed dq/dt current loop, but none of the load current is passed back through the back EMF of the primary source in the sourcing circuit.

This principle -- that at least a substantial portion of the load current must not pass back through the primary source -- is the primary principle required for a permissible overunity electrical machine (Figure 15). A permissible overunity electrical machine is one which produces more power in the load than you have to put into the machine to run it.

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[16] E.g., see Robert L. Shrader, Electronic Communication, Sixth Edn., MacMillan/McGraw-Hill, New York, NY, 1991. (1993 Imprint). Quoting from p. 6: "A source of electric energy does not increase the number of ~ree electrons in a circuit; it merely produces a concerted pressure on any aimlessly moving electrons."

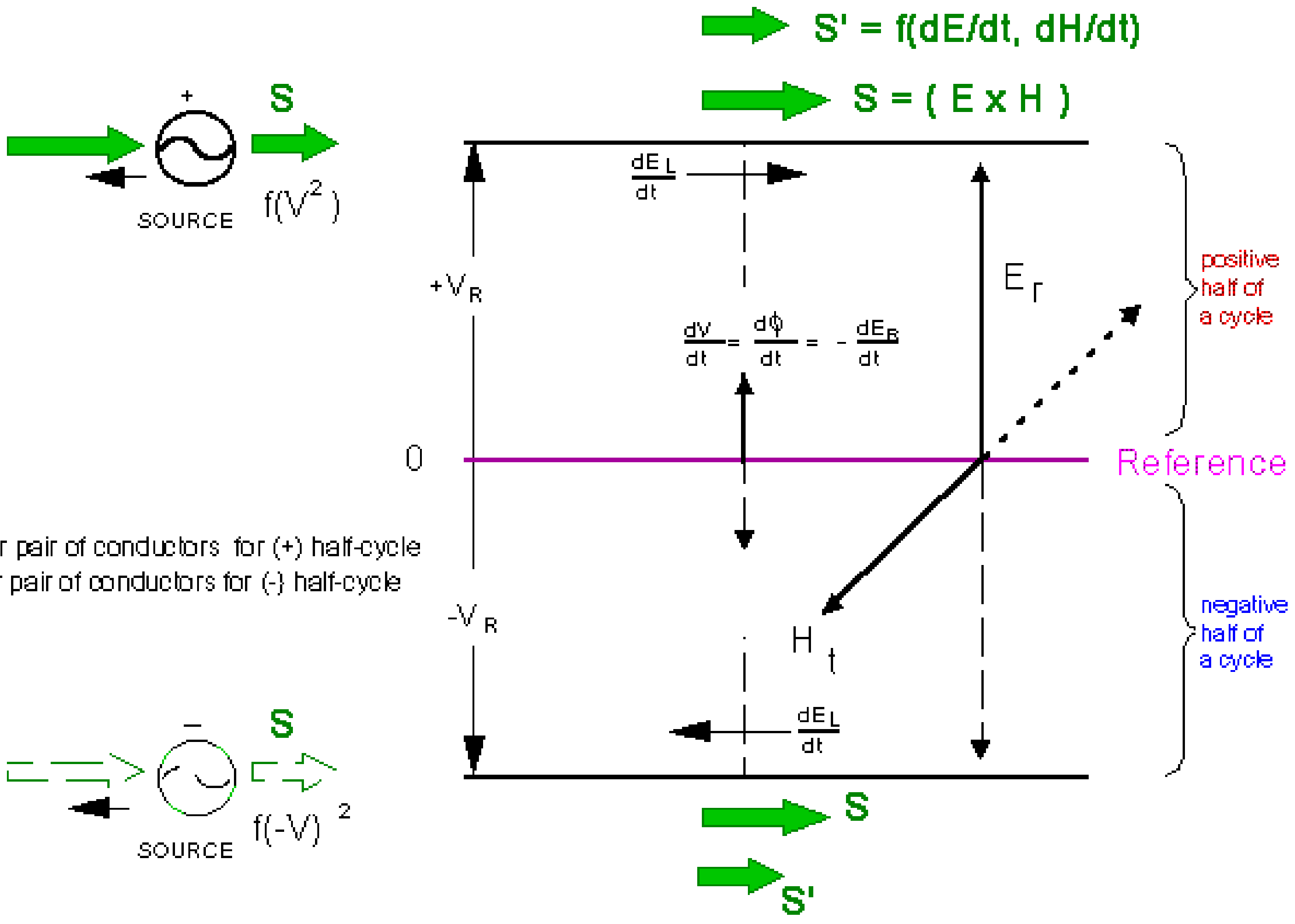
S' = f(dE/dt, dH/dt)
S = (E x H)
+
S
SOURCE
f(V²)
dE_L/dt
+V_R
E_r
positive half of a cycle
dV/dt = dφ/dt = - dE_B/dt
0
Reference
-V_R
H_t
negative half of a cycle
−
S
SOURCE
f(-V)²
dE_L/dt
S
S'

NOTE:
Use upper pair of conductors for (+) half-cycle
Use lower pair of conductors for (-) half-cycle

Figure 13. Poynting vector currents S and S' versus massless displacement currents.

D-1-F13

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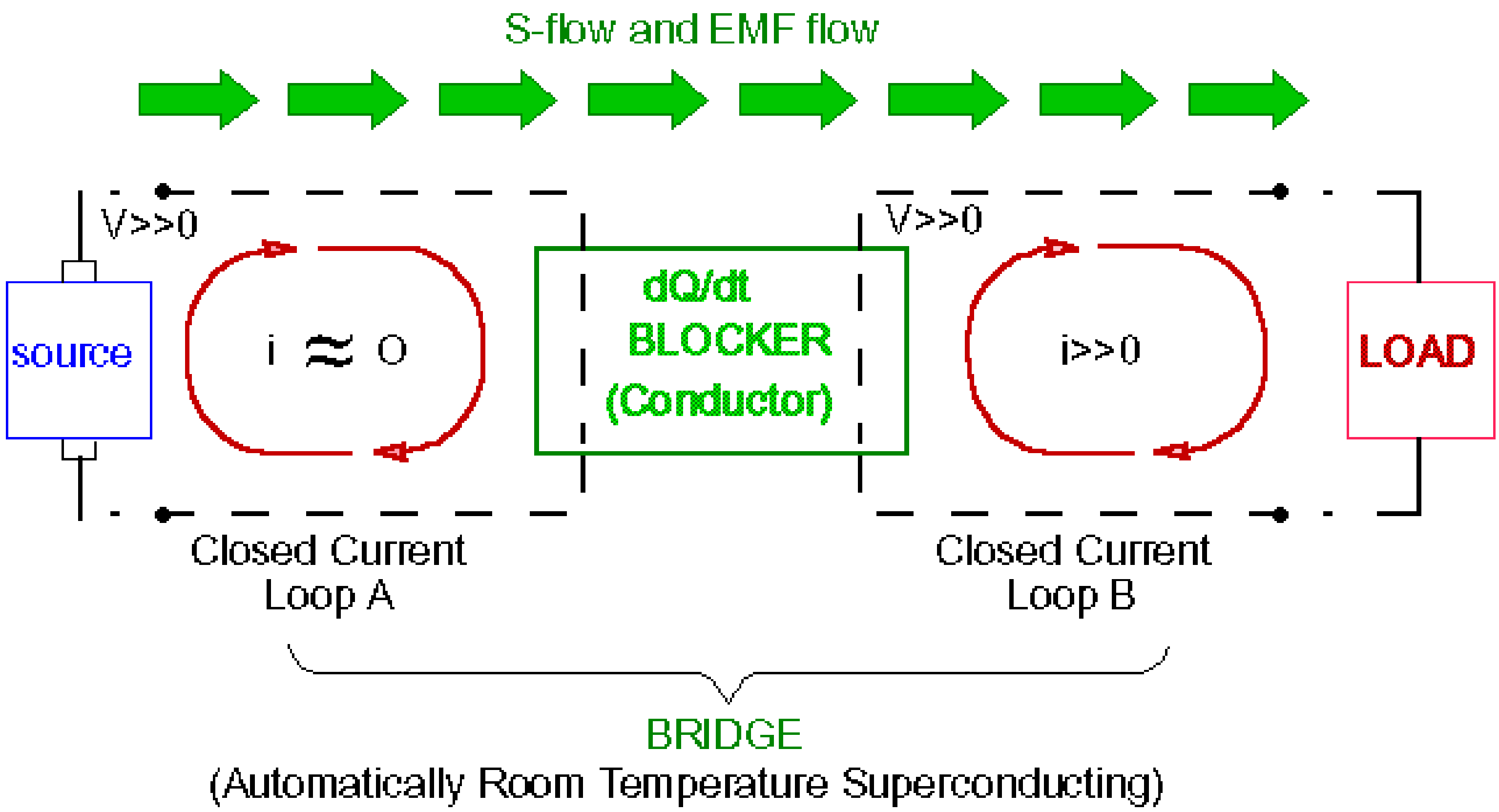
S-flow and EMF flow
V>>0
source
i ≈ 0
dQ/dt
BLOCKER
(Conductor)
V>>0
i>>0
LOAD
Closed Current
Loop A
Closed Current
Loop B
BRIDGE
(Automatically Room Temperature Superconducting)

Figure 14. Bridging to enable room temperature superconductivity.

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[17] My own approach has been, if that's all that the circuits require from our primary power source, then let's simply accept that directly from the source without performing any work in the source. Iœ you do it this way, the source is never dissipated, but will last indefinitely. Sources furnish flowing field energy density, not "energy" per se. If you only demand S-flow, you can have all you wish from a source, without exhausting your source. The trick is to find how to steadily dissipate some of this "artesian well" of flowing S to drive electrons through the load, but without driving electrons back through the back EMF of the source.

Tables:

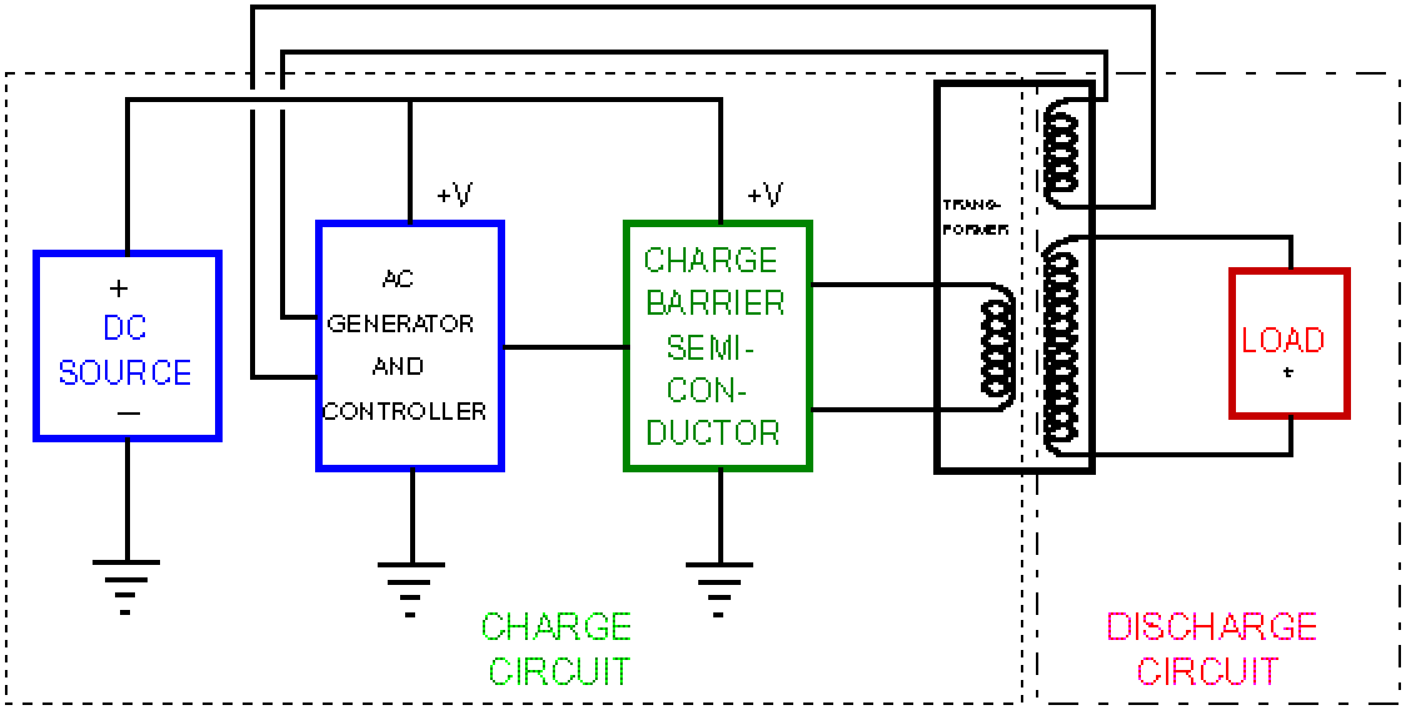
+
DC
SOURCE
—
+V
AC
GENERATOR
AND
CONTROLLER
+V
CHARGE
BARRIER
SEMI-
CON-
DUCTOR
TRANS-
FORMER
LOAD
+
CHARGE
CIRCUIT
DISCHARGE
CIRCUIT

* NOTE:
DISCHARGE CIRCUIT AND LOAD GROUND
MUST BE ISOLATED FROM THE
CHARGE CIRCUIT GROUND.
FEEDBACK LOOP MUST BE RIGIDLY CLAMPED AND LIMITED.

Patent Pending

Figure 15. Use of Fogal semiconductor for overunity (closed system).

D-1-F15

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Obviously, the laws of physics and thermodynamics require such an overunity machine to be an open system that extracts and utilizes excess energy from an external source. In the case outlined, we extract the excess energy directly from the vacuum in the form of S-flow; essentially we convert our primary source to a Poynting generator rather than a "power" (energy flow loss rate) generator. The resulting overunity machine accomplishes both room temperature superconductivity and also overunity coefficient of performance (Figure 16). It does not violate the conservation laws of physics. It does not violate the second law of thermodynamics because it is an open system receiving and utilizing excess energy from the vacuum, and the second law need not apply to such systems. [note 18]

You see, all power systems are already free energy density flow sourcing systems, if we but use them correctly. Every dipole is a "gating device" for extracting excess field energy density flow from the violent bidirectional flux exchange between the vacuum and each end of the dipole. [note 19] [note 20] When we attach "conducting leads" to a dipolar source, as in the simple two-wire circuit, all we are doing with the conductors is providing waveguides for the extracted S-flows from the vacuum to flow along (it flows outside the conductors) without loss. In effect, each lead is simply extending the pole (i.e., the terminal) to which it is connected.

My associates and I are also working on several other inventions at present, including two more patent applications to be filed in the near future. One of those is in the field of overunity power systems, while the other is in an entirely different, highly proprietary nuclear effort. I will address all these areas in future columns, and those columns will have real "meat" in them.

Present "big science" proclaims that overunity electrical machines are impossible. The reader should understand that the U.S. Patent and Trademarks Office is never going to grant a patent for an overunity electrical machine unless the machine is independently tested and replicated, and unless it is certified by scientists of impeccable credentials. This is as it should be. Legitimate free energy researchers accept that dictum. Eventually the stuff has to work on the bench in order to be validated. On the other hand, free energy researchers also point out that one must not demand of us the next 100 years of national research by a hundred major laboratories immediately! This is still a shoestring operation, because all conventional sources of research funds are denied to the serious overunity researcher (with the single exception of occasional personal funding of a researcher by a private individual). In other words, we demand at least the same kind of consideration that the orthodox nuclear fusion community has enjoyed. Billions of dollars have been poured into that sinkhole, and not a single controlled fusion power unit is working anywhere in the world after decades of work at enormous expense to the taxpayers.

So we overunity researchers deserve at least a decade or two of our own, to try to accomplish overunity electrical system development. We also painfully point out that "Big Science" will not fund a single overunity researcher, for specific overunity purpose, no matter what his credentials or capability. In fact, "Big Science" is part of the problem, because it fervently seeks to prevent any legitimate research in overunity. To carry out its suppression campaign. it resorts to vilification, character assassination, libel, and slander of the overunity researchers themselves __ again, regardless of their qualifications or legitimate scientific procedures. [note 13]

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Tables:

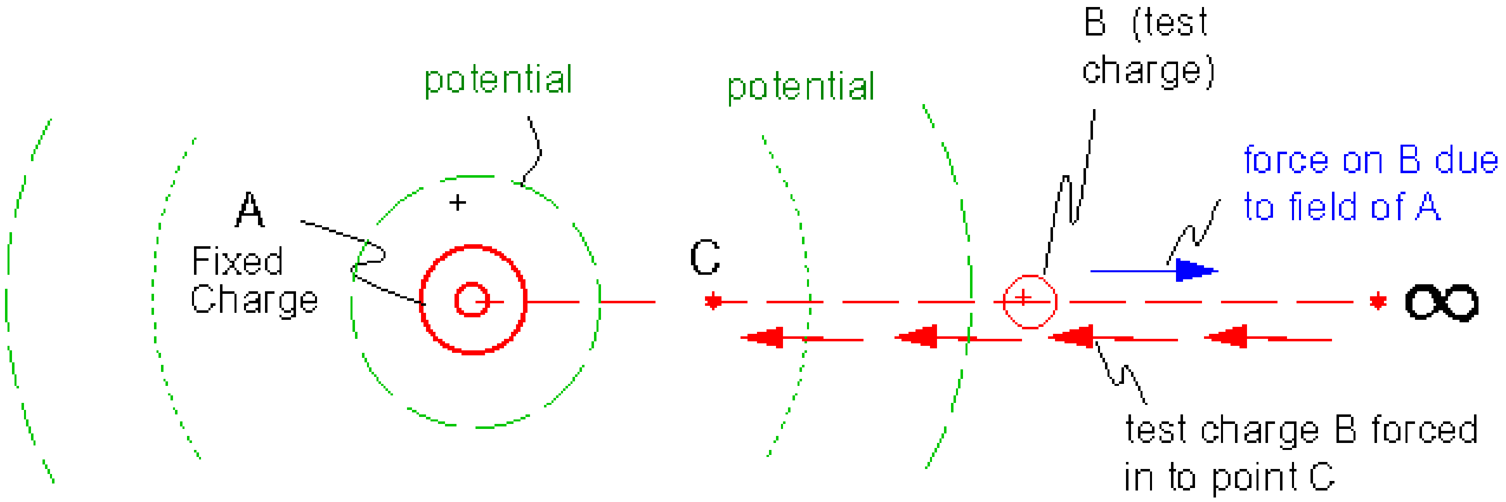
B (test
charge)
potential
potential
force on B due
to field of A
A
Fixed
Charge
+
C
∞
test charge B forced
in to point C

Figure 16a. Magnitude of the scalar potential is determined by work required to push in a unit charge from infinity; e.g., against a repelling like charge. If test charge is released, work will be performed upon it to translate it back toward infinity

Figure 16a. Process for overunity coefficient of performance.

D-1-F16A

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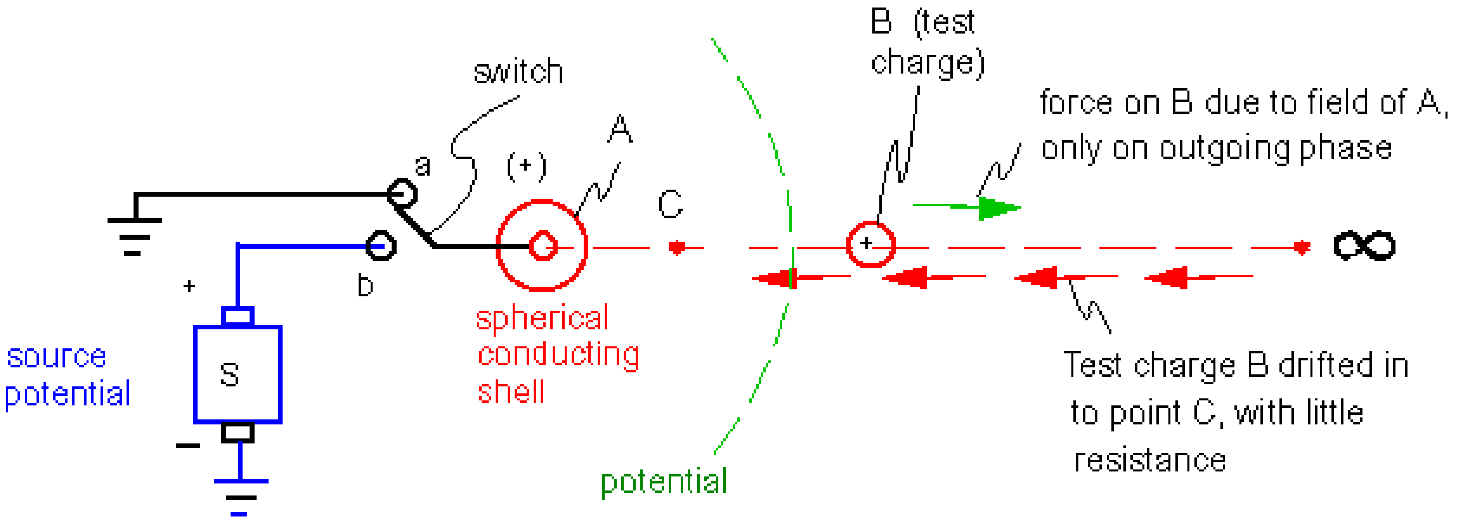
switch
B (test charge)
force on B due to field of A, only on outgoing phase
a
(+)
A
C
∞
+
b
source potential
S
−
spherical conducting shell
Test charge B drifted in to point C, with little resistance
potential

Assumptions: Capacitance of A very small; charge B large, power-free switching

Switch potential off, drift in test charge B, switch potential back on. Can now get free work from repelled test charge B. Get much more free work if A is at a high potential, and charge B is large.

Figure 16 b. Demonstration of overunity efficiency.

D-1-F16B © T.E. Bearden, 1993, 1994, 1995

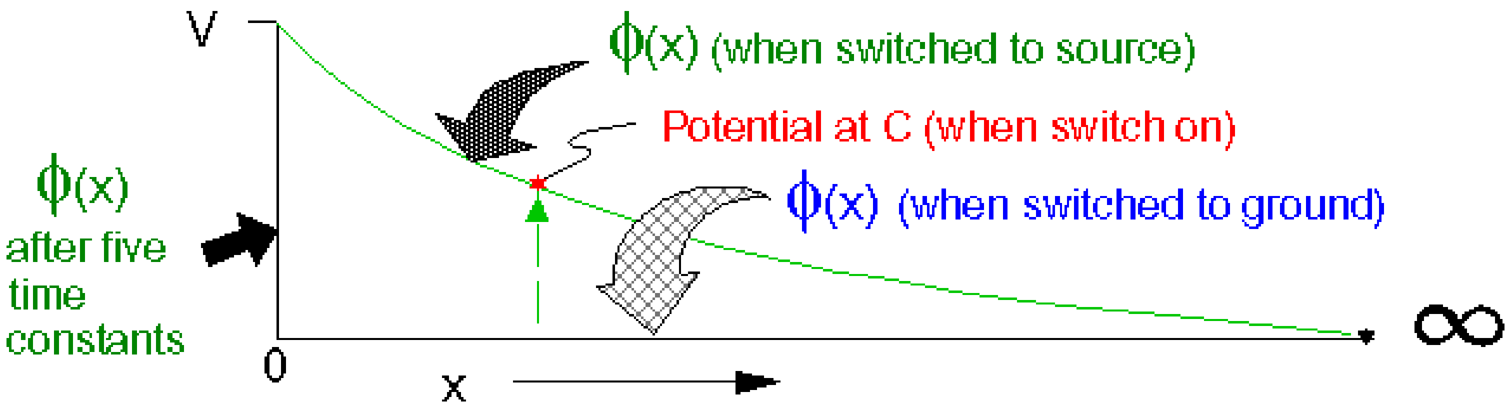

Ideally, switching the potential, rather than flowing charges, requires only minuscule overhead energy dissipation

Figure 16c. Potential to which test charge is exposed.

D-1-F16C © T.E. Bearden, 1993, 1994, 1995

[18] The system does comply with the nonlinear thermodynamics of a system œar from equilibrium. E.g., Prigogine received the Nobel Prize œor significantly developing this new field. For a detailed technical presentation of nonlinear thermodynamics of a system far from thermodynamic equilibrium, see G. Nicolis and I. Prigogine, Explorinq Complexity, Piper, Munich, 1987. Such systems can exhibit negentropy, self-organization, and other effects outside the confines of classical thermodynamics. Since local symmetry is broken, they can also permissibly exhibit overunity coefficient of perœormance.

[19] Each end 0œ a dipole has its own potential (with respect to the local vacuum), which differs from the potential of the surrounding ambient vacuum. For each of these "end-potentials," one can mathematically decompose that end-potential into a hidden bidirectional set of harmonic wavepairs in harmonic sequence. Each wavepair consists of the wave and its phase conjugate. For the proof, see E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," Mathematische Annglen, Vol. 57, 1903, p. 333-355. Since one of the dipole potentials exceeds the local vacuum potential and the other dipole potential is lower than the local vacuum potential, the two bidirectional EM wave flows are at or "carry" different equipotentials. This is the generatrix for the automatic dual œ1ow of energy from the vacuum through the dipolar power source and out along the two leads of the "transmission line" conducting the S-flow to the components of the circuit for powering the loads. So as can be seen, rigorously every dipole is already a "free energy source" if we learn how to properly use it. The energy will flow forever, if we do not allow the destruction of the sourcing dipole.

[20] See also E.T. Whittaker, "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions," Proceedinqs of the London Mathematical Society, Series 2, Vol. 1, 1904, p. 367-372. Here Whittaker shows that the fields of classical electromagnetics can be replaced by scalar potential interferometry of two potentials. Our own comment is to note that by Whittaker 1903, we can with a little difficulty make artificial potentials with deliberate substructures. We can then interfere those potentials (actually, interfere their hidden multiwave structures) even at a distance, to create new EM fields. Or we can dissolve EM fields that exist at a distance, simply by constructing the correct negative EM fields by distant scalar interferometry. My point is that, when we utilize the "inner" electromagnetics inside the potential, we are employing a vastly more powerful electromagnetics of a new kind, which includes and extends the present inadequate EM theory.

Indeed, orthodoxy has a black record with respect to energy. When Mayer advanced the conservation of energy law, orthodoxy hounded him unmercifully. He was universally ridiculed as the very epitome of a fool. He lost his job and suffered a nervous breakdown. Then years later toward the end of his life, scientists came to accept the conservation of energy as a most useful tool that dramatically simplified much of their analyses. So then science began to laud Mayer. There are a thousand other such examples; suffice it to say that "big science" is a bureaucracy and a "bell-shaped distribution curve" just like any other large group of people. Some scientists are near-angels. Others are near-devils. The vast majority are neither, but are just ordinary persons doing a special kind of job. In the scientific bureaucracy, however, the manipulative scientists scurry, slash, and manipulate their way toward the top. So the leadership of any big bureaucracy __ including the scientific bureaucracy __ is always rife with such near-scalawags and power-hungry individuals. Scientists are not exceptions to the same human weaknesses that we all evidence. If you really want to see jealousy, backbiting, and fierce "back-room dealing" and power-struggling, just get into a university research environment! But because the "power merchants" of any bureaucracy always fiercely resist any challenge to their position or superiority, big science has always fiercely resisted anything truly revolutionary. And today they also enlist the power of the state to enforce their dictums. We will devote one of our future columns to pointing out some glaring examples of persecution of independent researchers by big science. It is an area that all unorthodox researchers should be well-aware of. The world of science does not run by sweet reason and lofty ideals; that is just the dogma. It runs strictly by "who's going to be the big monkey," just like everything else. Primate dominance is still a dictum of the functioning of all bureaucratic human systems.

The free energy researchers are not working on the so-called "perpetual motion machine," where a closed system is erroneously stated to produce more output than must be put into it to operate it. That old saw is actually a red herring that dogmatic scientists use to vilify free energy researchers. It is a lie that they have also successfully sold to the U.S. Patent and Trademarks Office. Anyone with a modicum of knowledge of modern physics already knows that there does not exist a single closed system in the universe, anywhere. In particular, every physical system is continuously "open" to the violent exchange of energy with the surrounding vacuum. It's just that most systems are in local equilibrium in these flow exchanges, except for minuscule gating accomplished for such things as the Lamb shift, etc.

By analogy it's something like this. The free energy researcher is standing by the banks of a mighty, rushing river with breathtaking falls, turbulent areas, etc. Big Science is begrudgingly admitting that, yes, there is a river there, but it is an insane delusion to think that you can tap that energy. The free energy researcher is saying that, well, if I can build a gating sluice a little distance upstream, perhaps I can divert a small portion of the river's flow downstream to my waterwheel, and power my mill. The orthodox scientist then vilifies the free energy researcher for even having such a heretical thought. In fact, says the orthodox researcher, any fool can see that the laws of nature force the river's flow to stay firmly in its banks, because it is a closed system, and Moses brought that law down off the mountain with him on a special stone tablet. Then he adds all the other smug remarks such as, "If it could be done, then we at MIT and Harvard and Caltech would already have done it!" So until the orthodox scientist develops a little less dogma and a little more common sense, and learns the difference between a scientific discussion and a dogfight, the free energy researcher can hardly communicate with him.

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The goal of the legitimate free energy researcher is to find a way to break the local equilibrium of this universal energy exchange, and gate a tiny bit of it up into the external circuit as excess electrical energy (Figure 17). Then he must collect the excess energy, and shuttle it from the "gating and collecting circuit" over to a dq/dt-closed current loop containing the load. He must also prevent the load current, or most of it, from passing back through the primary source against its back EMF, because if it does that, he will destroy the separation of charges in the dipolar source, killing the dipole and extinguishing the "excess energy gating." In other words he must find a way to process and transport the energy flow across dq/dt-blocked bridges between the source's closed dq/dt-current loop and the load's closed dq/dt-current loop. Ruthlessly it is an energy transport S-flow problem, not a J* energy transport problem. If he uses J* in his sourcing current loop, he automatically drives the current dq/dt back through the back EMF of his source and kills it. If he does not drive dq/dt back through the source, the source will furnish S-flow for an indefinite period! Every battery and generator we have ever built is already a "free energy" machine in that it already involves broken local symmetry in the vacuum energy exchange. We have just not realized how to use our power sources purely as Poynting S-flow sources.

So we must treat an electrical system as an open system with broken local symmetry (Table 3) in the vacuum flux exchange, so that the system extracts (gates) excess energy from an external source. In this case the source is the system's flux exchange with the vacuum. This approach is no more mysterious or bizarre than putting a waterwheel in a river, or a windmill in a wind, or a bank of solar cells out in the sunshine. The universal "free source of energy" that the overunity researcher seeks to tap is the violent exchange of virtual photons between the electrical charges of the system and the surrounding quantum mechanical vacuum (Figure 18). In quantum physics this powerful, energetic exchange of the vacuum with electrical matter is now proven both experimentally and theoretically. It is already accepted in quantum physics that the vacuum is filled with electromagnetic energy. The researcher doesn't have to prove it anymore; he just has to find out how to properly use it. The artesian well is already there; we just have to learn how to collect and use the flowing water without dynamiting the well!

The remaining objection orthodox scientists usually raise against the notion of extracting vacuum energy has been that "thermodynamics doesn't permit it." However, Cole and Puthoff have rigorously shown that, on the contrary, the theory of thermodynamics does not prohibit the vacuum's energy being extracted and used to produce heat, light, and power. [note 22] So the validity of that final objection has now vanished.

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Open system receiving excess energy from an external source

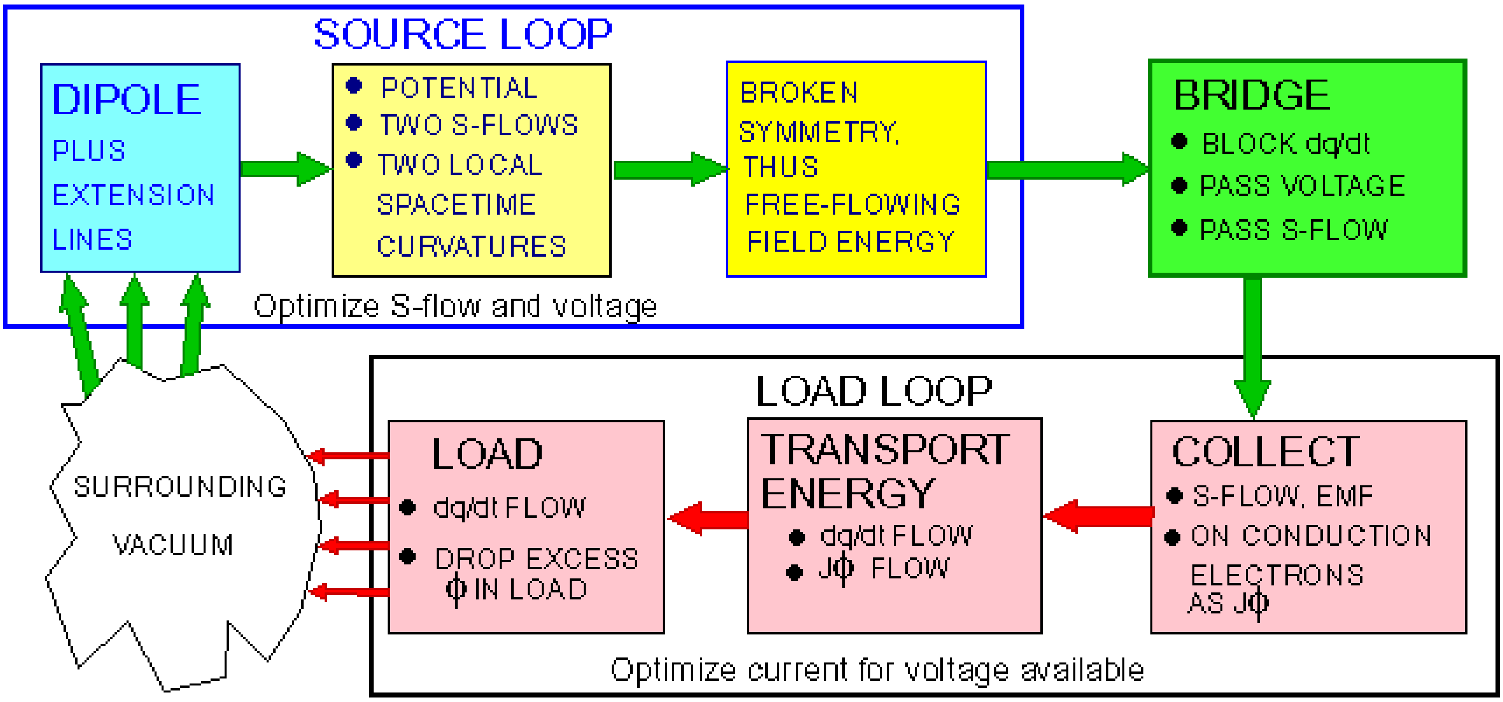
SOURCE LOOP
DIPOLE
PLUS
EXTENSION
LINES
● POTENTIAL
● TWO S-FLOWS
● TWO LOCAL SPACETIME CURVATURES
BROKEN SYMMETRY, THUS FREE-FLOWING FIELD ENERGY
Optimize S-flow and voltage
BRIDGE
● BLOCK dq/dt
● PASS VOLTAGE
● PASS S-FLOW
SURROUNDING VACUUM
LOAD LOOP
LOAD
● dq/dt FLOW
● DROP EXCESS ϕ IN LOAD
TRANSPORT ENERGY
● dq/dt FLOW
● Jϕ FLOW
COLLECT
● S-FLOW, EMF
● ON CONDUCTION ELECTRONS AS Jϕ
Optimize current for voltage available

Figure 17. Operation of an overunity electrical power system.

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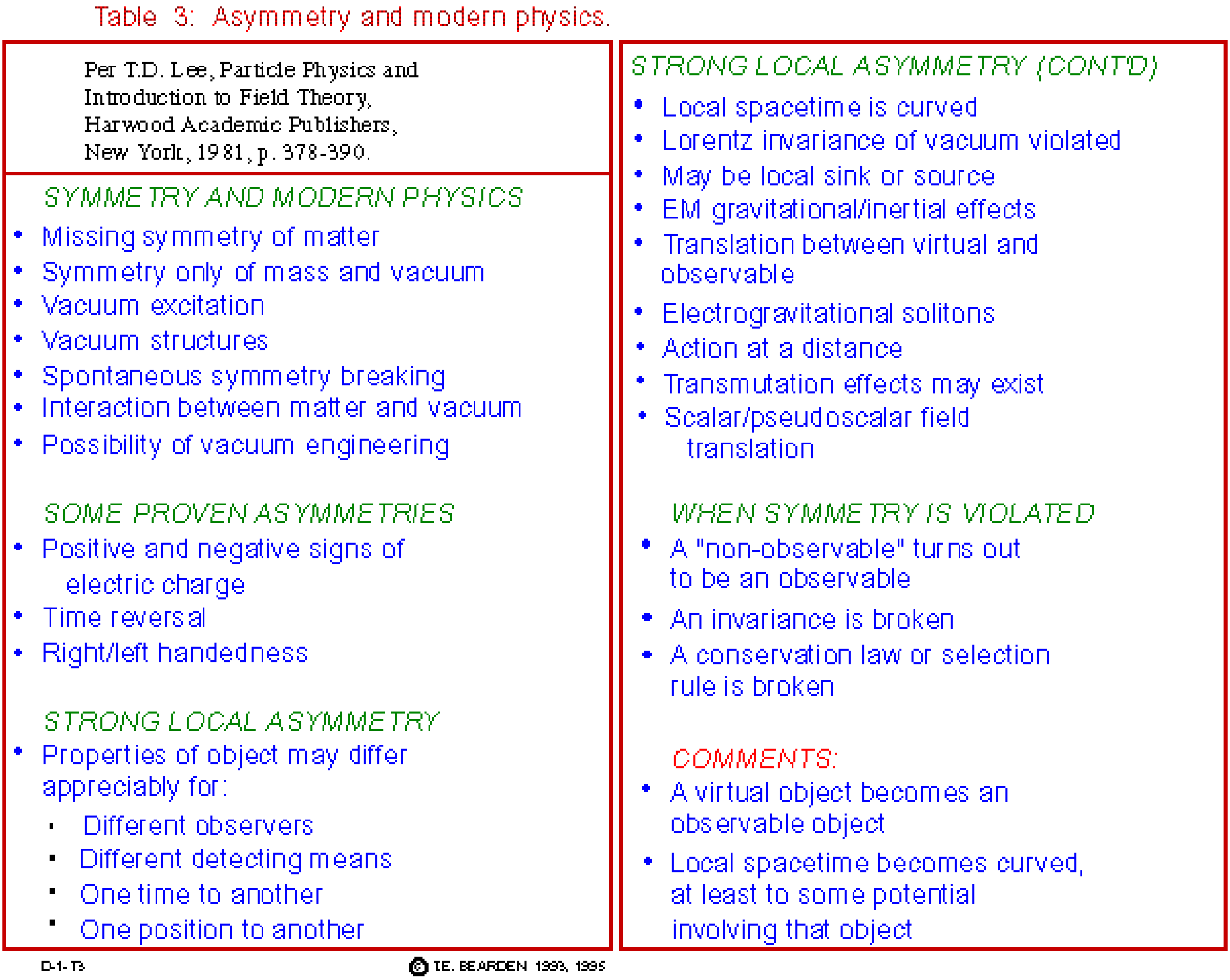

Table 3: Asymmetry and modern physics.

Per T.D. Lee, Particle Physics and
Introduction to Field Theory,
Harwood Academic Publishers,
New York, 1981, p. 378-390.

SYMMETRY AND MODERN PHYSICS

- Missing symmetry of matter
- Symmetry only of mass and vacuum
- Vacuum excitation
- Vacuum structures
- Spontaneous symmetry breaking
- Interaction between matter and vacuum
- Possibility of vacuum engineering

SOME PROVEN ASYMMETRIES

- Positive and negative signs of electric charge
- Time reversal
- Right/left handedness

STRONG LOCAL ASYMMETRY

- Properties of object may differ appreciably for:
  - Different observers
  - Different detecting means
  - One time to another
  - One position to another

STRONG LOCAL ASYMMETRY (CONT'D)

- Local spacetime is curved
- Lorentz invariance of vacuum violated
- May be local sink or source
- EM gravitational/inertial effects
- Translation between virtual and observable
- Electrogravitational solitons
- Action at a distance
- Transmutation effects may exist
- Scalar/pseudoscalar field translation

WHEN SYMMETRY IS VIOLATED

- A "non-observable" turns out to be an observable
- An invariance is broken
- A conservation law or selection rule is broken

COMMENTS:

- A virtual object becomes an observable object
- Local spacetime becomes curved, at least to some potential involving that object

D-1-T3

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A Charged Particle Is a Coupled System

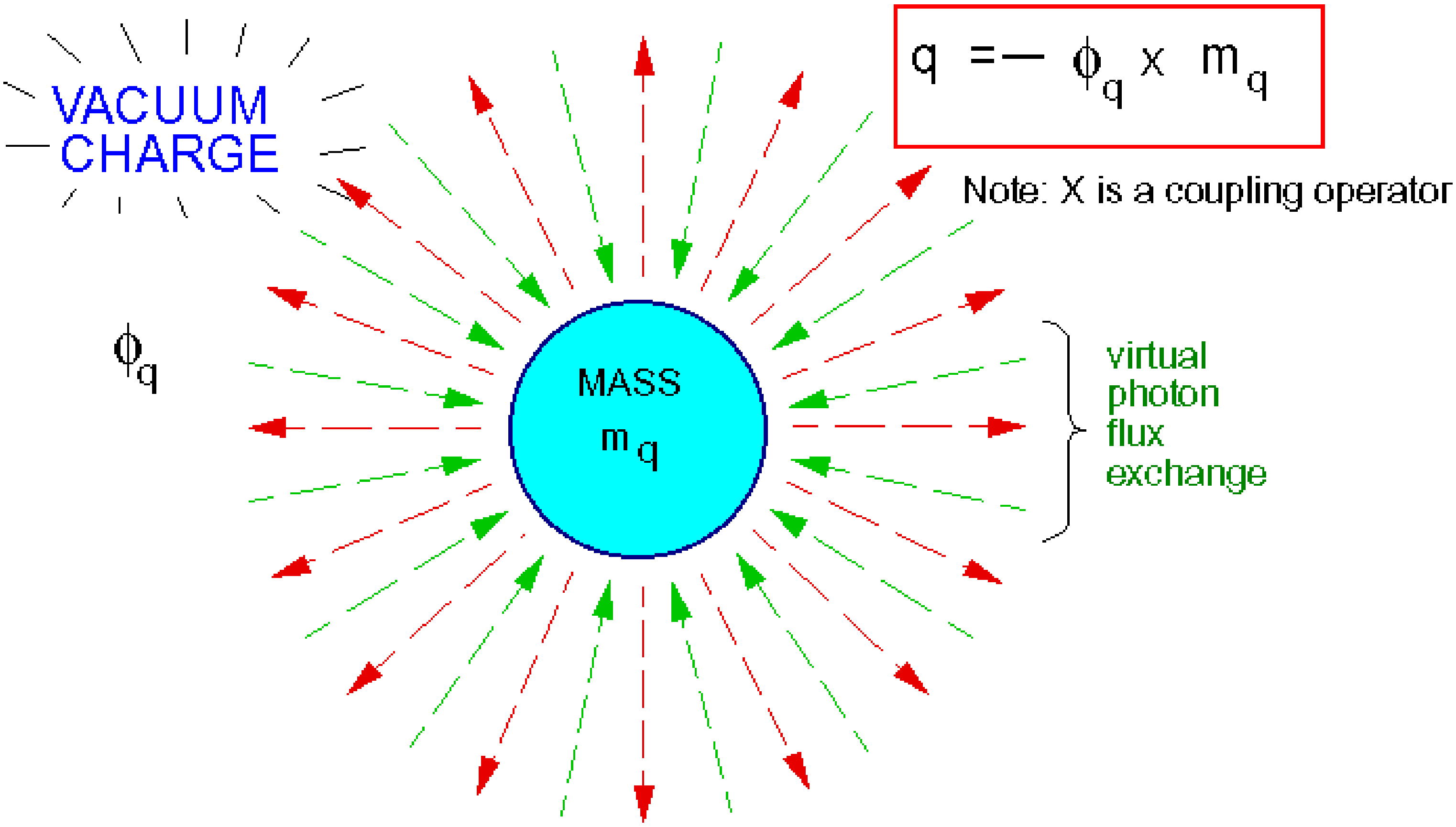
VACUUM CHARGE
ϕ_q
$q = — \phi_q \times m_q$
Note: X is a coupling operator
MASS
m_q
virtual photon flux exchange

Figure 18. An electric charge q is a broken symmetry. It continuously and violently exchanges energy with the vacuum.

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[22] Cole, Daniel C. and Harold E. Putboll. (1993) "Extracting Energy and Heat from the Vacuum," Physical Review E, 48(2), Aug. 1993, p. 1562-1565.

And there is mind-numbing energy density there in the vacuum, waiting to be extracted. The well-known Lamb shift, e.g., in a single hydrogen atom is due to that vacuum exchange. [note 23] Interestingly, the calculated energy density of the exchange causing the Lamb shift is greater than the surface energy density of the sun. Different physicists have made various theoretical estimates of the energy density of this seething vacuum. A conservative ballpark figure is something on the order of 1090 grams per cubic centimeter, expressed in mass units.

It has also been my good fortune to know and work closely with several other free energy researchers. I was a colleague of Floyd ("Sparky") Sweet (recently deceased) for about seven years; Sparky held a Master's degree in EE from MIT and had years of experience with General Electric and other firms. He was a highly skilled researcher who invented the solid state vacuum triode amplifier (Figure 19), a unit which produced 500 watts of output and a coefficient of performance of 1,500,000. I personally tested the machine, activated the magnets on one occasion, and understand how it all worked. [note 24] The paper [note 25] I co-authored in 1991 with Floyd is still the only paper in the orthodox engineering literature that reports (a) successful overunity functioning of a solid state magnetic device, and (b) a successful antigravity experiment on the laboratory bench, reducing the weight of an object by 90%. [note 26]

We stress again that a legitimate overunity electrical machine must be an open system, receiving excess electrical energy from the surrounding vacuum. As such, it must operate in a higher topology than normal electrical machines (Figure 20).

My good friend Frank Golden has long been a close colleague. Years ago Frank developed a motor that produced overunity efficiency, but then to our astonishment we found (courtesy of Bill Tiller, [note 27] with whom we were working at the time) that its operation depended upon a 5-year-long conditioning (structuring) of the local ambient potential in order to work. Previously we had been entirely unaware that one can sometimes condition the local vacuum and the local matter in the area with a particular dynamic form. Given the local conditioning, a motor with that form will then work in that vicinity, but not necessarily elsewhere at an appreciable distance away. We now understand the mechanism for such "conditioning of the vacuum." We also now know what to do if an overunity machine is actually a machine of that type (many of them are not). In other words, we know how to convert it to a machine that will work anywhere, anytime. We will be addressing such little-known things in future articles.

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[23] Lamb, W.E. Jr. and R.C. Retherford. "Fine structure of the hydrogen atom by a microwave method." Physical Review, Vol. 72, 1947, p. 241-243. Lamb received the Nobel prize for this work.

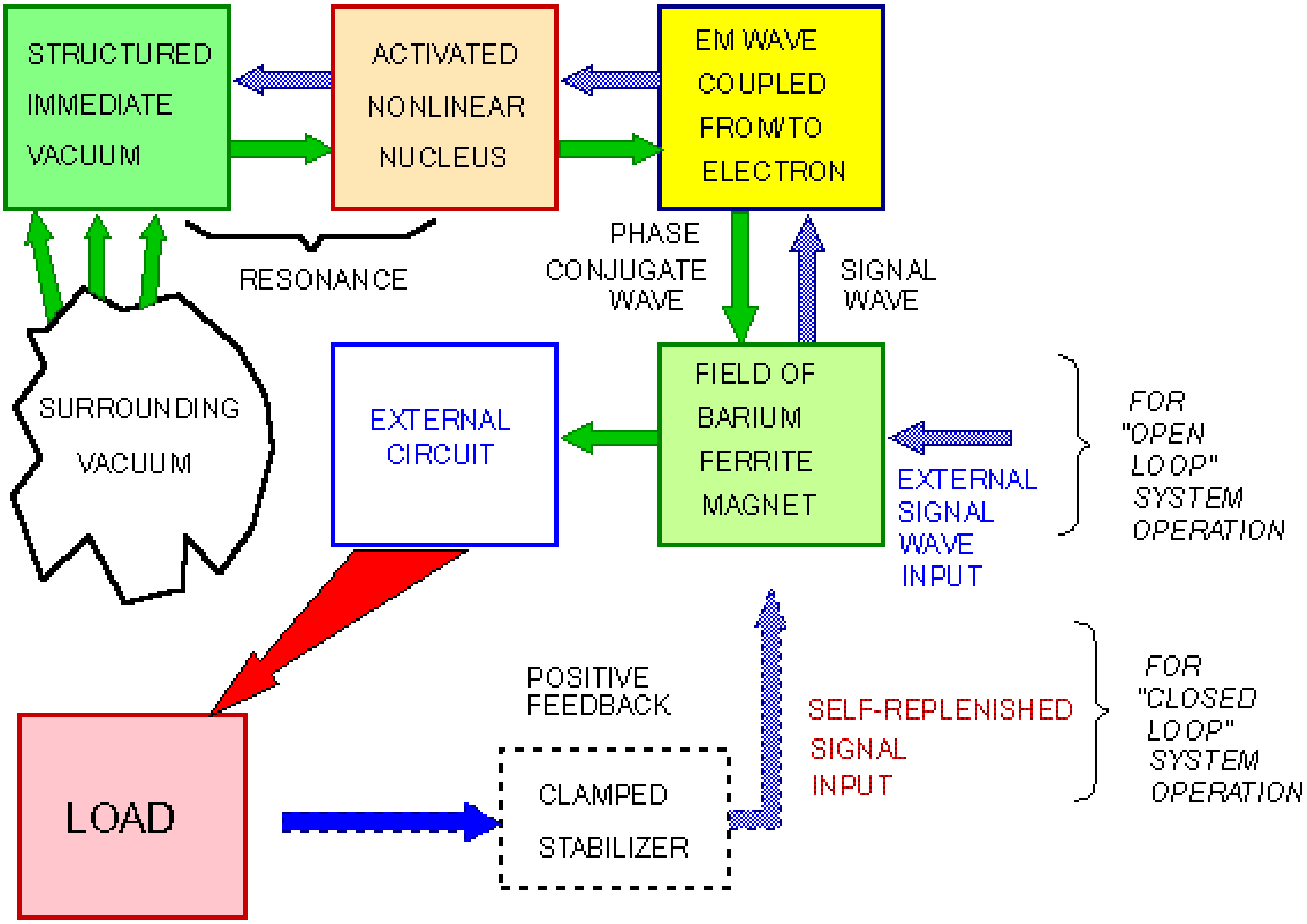
STRUCTURED IMMEDIATE VACUUM
ACTIVATED NONLINEAR NUCLEUS
EM WAVE COUPLED FROM/TO ELECTRON
RESONANCE
PHASE CONJUGATE WAVE
SIGNAL WAVE
SURROUNDING VACUUM
EXTERNAL CIRCUIT
FIELD OF BARIUM FERRITE MAGNET
EXTERNAL SIGNAL WAVE INPUT
FOR "OPEN LOOP" SYSTEM OPERATION
POSITIVE FEEDBACK
SELF-REPLENISHED SIGNAL INPUT
FOR "CLOSED LOOP" SYSTEM OPERATION
LOAD
CLAMPED STABILIZER

Figure 19. Block diagram of the Sweet Vacuum Triode Amplifier.

Adding positive feedback circuit enables self-oscillation.

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[24] Unfortunately Sweet made conflicting agreements with multiple backers, resulting in a most thorough legal foul- up. It appears that nothing can ever be done with this machine, because its status is a legal nightmare.

[25] Floyd Sweet and T. E. Bearden, "Utilizing Scalar Electromagnetics to Tap Vacuum Energy," Proceedings of the 26th Intersociety Energy Conversion Engineerinq Conference (IECEC '91), Boston, Massachusetts, 1991, p. 370-375. Paper also distributed over Internet.

[26] The unit was specially rigged and "pushed" to 1,000 watts output to perform the antigravity experiment.

Example: Conservation in 2D versus 3D topologies.

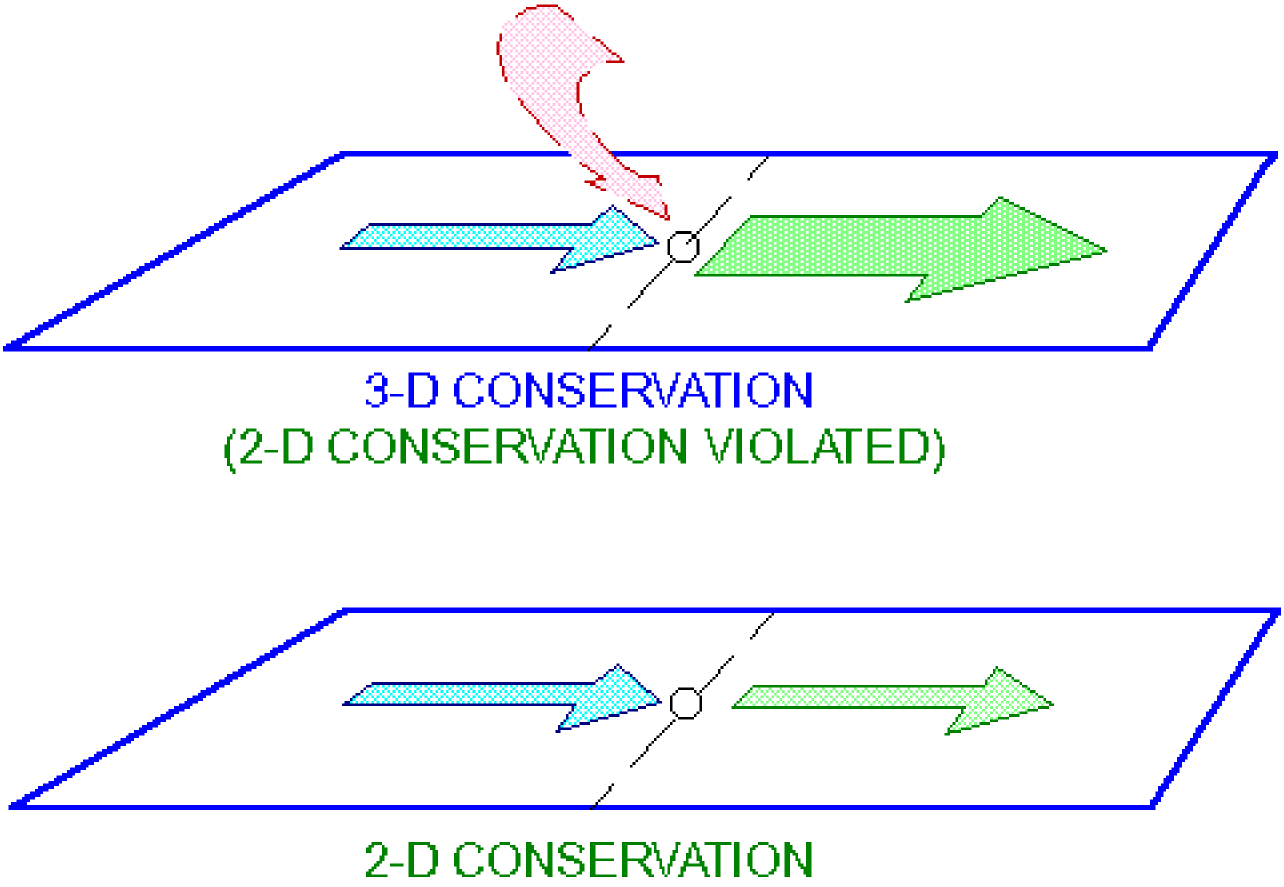
3-D CONSERVATION
(2-D CONSERVATION VIOLATED)
2-D CONSERVATION

Figure 20. Increasing the dynamic topology allows lower topology conservation laws to be violated. Conservation now applies in the higher topology, but not necessarily in the lower. The lower topology system is now an open system and may seemingly act as a source or sink.

D-1-20

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[27] Tiller was already familiar with the fact that devices that function by more subtle energy often require special conditioning of the vacuum spacetime. He expressed it as "an archetype must first be created for the machine to function efficiently." Tiller had previously experimented with such an effect for several years.

John Bedini is also a close friend and colleague; John built several experimental motors (both electrical and magnetic) in the overunity area, and performed successful trans-mutation experiments. John is a recognized genius in high-end sound amplifier development. Many audiophiles worldwide still swear that the Bedini amplifier is the best and sweetest-sounding audio amplifier ever built. One of John's battery-powered electrical motors (Figure 21), for example, ran continuously off its battery for about five years, and kept the battery charged. When you realize that such a small electric motor is only about 35% efficient, then you realize that about 65% of the energy flowing out of the battery was being dissipated in the motor as heat, core losses, etc. So the unit was continuously performing work for that five years. [note 28] The 1/8 hp motor represented a load in which the continuous rate of work being done (the rate of energy dissipation) was about 0.08 hp. We will have more to say on this motor and its technical process in a future article.

Bill Fogal is a close colleague; Bill has patented the world's first dq/dt-blocking semiconductor, [note 29] which partially blocks the normal current while continuing to pass the flow of voltage (Table 4). I have written a proprietary technical explanation of the Fogal semiconductor, which utilizes an extremely little-known feature called the "overpotential." The overpotential part of the theory is experimentally proven and theoretically explained in an obscure part of electrochemistry, by a few chemists who specialize in electrode effects. J. O'M. Bockris is probably the leading world expert in overpotential theory; he authored the textbook on it. [note 30]

One of the latest overunity developments is the magnetic resonance amplifier (MRA) developed by Joel McLain and Norm Wooten (Figure 22). Earlier testing disputed the overunity functioning. More recent testing at several well-known laboratories has resulted in the instrumental measurements clearly showing overunity. While the test institute scientists themselves may be willing to attest to overunity results of their testing, none of the corporate heads will allow it. I have personally stated that the MRA is capable of overunity. Our own measurements had to be discarded because we did not have the proper instruments available. E.g., all our oscilloscopes were "hard grounded" to building ground, and we needed to make "floating differential ground" measurements in order to settle things once and for all. McLain and Wooten have filed for a patent, and multiple tests with excellent equipment have indeed indicated overunity. What happens next remains to be seen. I suspect that the two inventors may simply accept foreign capital investment and go offshore.

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WARNING: Highly dangerous operation. Pulsed battery outgasses hydrogen gas and explosion is possible.

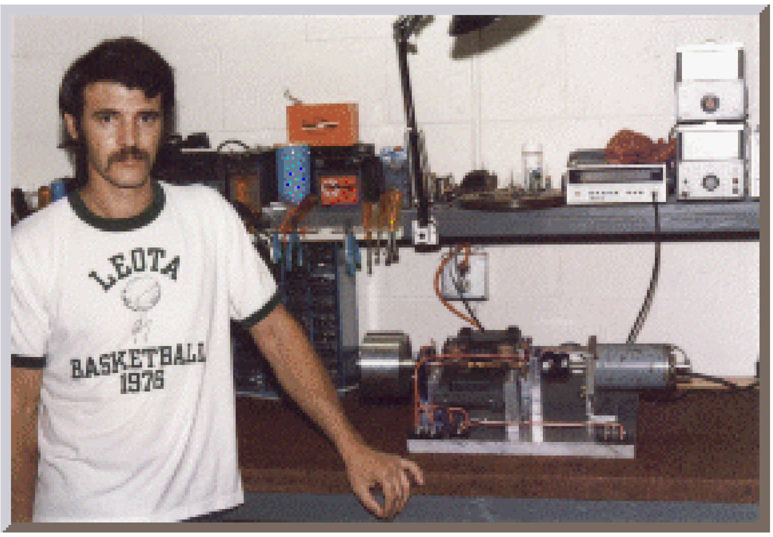

Open system using higher topology extraction of excess vacuum energy. Uses sluggish reversal and recoil time of lead ion onrushing current versus rapid backlash of amplified voltage discharge from a magneto ignition coil, to force the battery to act as an excess S-flow collector during the ion-current charging half-cycle. Thus the inefficient motor is continuously powered and the battery is continually recharged.

Figure 21. Bedini's battery-powered, back-popping electric motor.

D-1-21

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[28] We strongly emphasize that there is no conservation of work law in physics! It is the overall energy of the universe that must be conserved, not work. More rigorously, the flow of energy must be conserved. But from a free flow of energy, you can continuously extract a little and dissipate it as work, without cutting off the main flow and without violating any of the laws of physics. If this were not so, then waterwheels, windmills, and solar cells would not work. In fact, you can even do better than that. The basic energy conservation law is this: Energy can neither be created nor destroyed. So even when you "use" (i.e., dissipate or scatter) the energy, it is still there. It is only the hierarchical ordering of the photons that constitutes entropy. Each individual photon is perfectly ordered and still contains all its energy. By retroreflection, you can even cause those disordered photons to gather back in your system into perfect order once again and then you can scatter them again to do some more work. You can use the same energy over and over again! The perfect retroreflection is more easily accomplished by phase conjugate reflection. For a vivid example of just such retroreflection of previously scattered EM energy to restore the former order, see David M. Pepper, "Applications of Optical Phase Conjugation," Scientific American, Vol. 254, No. 1, Jan. 1986, p. 74-83. See particularly the striking photographic demonstration of time reversal of disorder on p. 75.

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[29] William Jay Fogal, "High gain, low distortion, faster switching transistor." U.S. Patent No. 5,196,809, Mar. 23, 1993. Also William J. Fogal, "High Gain, Low Distortion, Faster Switching Transistor." U.S. Patent No. 5,430,413, July 4, 1995.

Table 4. Fogal's Semiconductor.

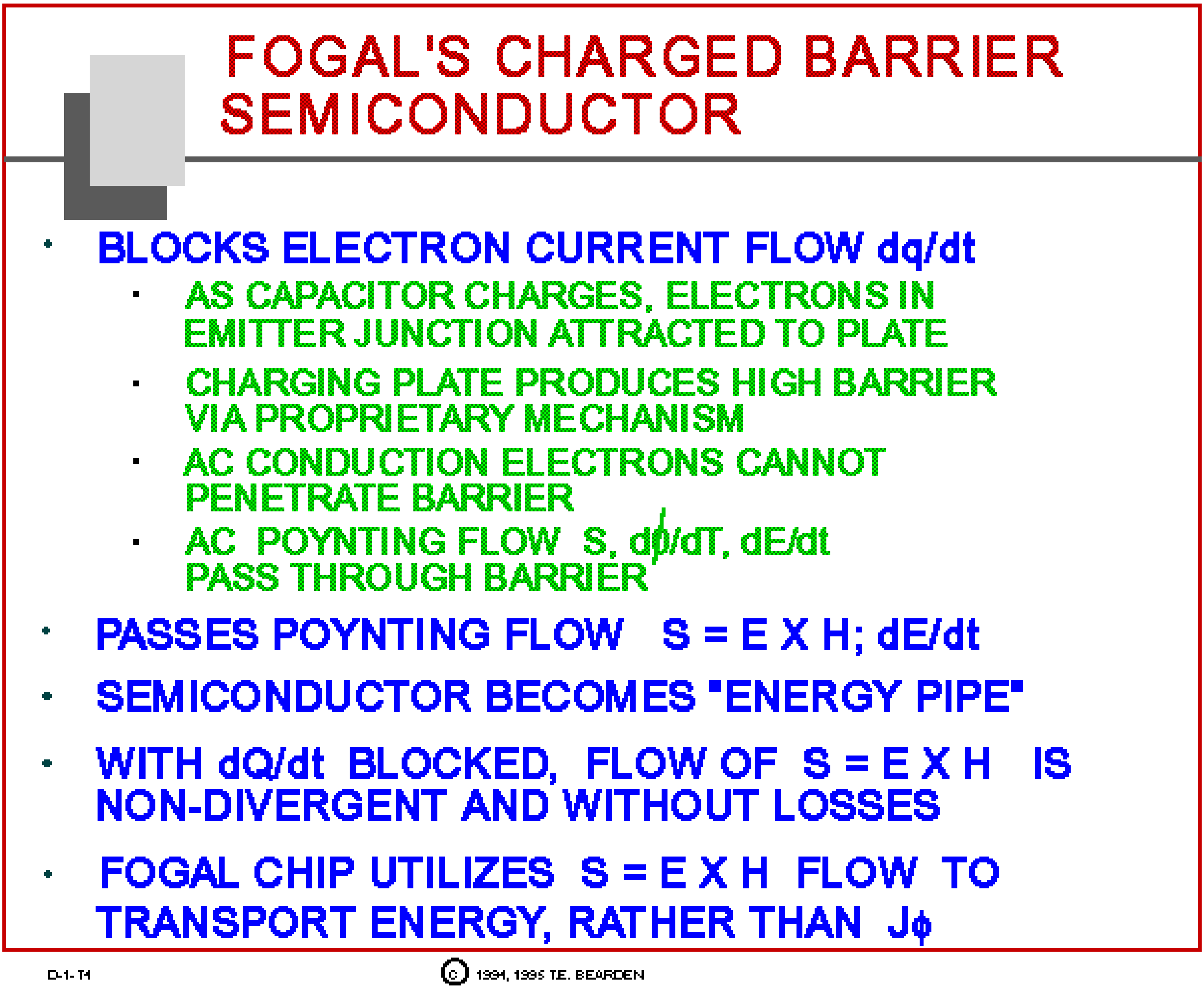

FOGAL'S CHARGED BARRIER SEMICONDUCTOR

- BLOCKS ELECTRON CURRENT FLOW dq/dt
  - AS CAPACITOR CHARGES, ELECTRONS IN EMITTER JUNCTION ATTRACTED TO PLATE
  - CHARGING PLATE PRODUCES HIGH BARRIER VIA PROPRIETARY MECHANISM
  - AC CONDUCTION ELECTRONS CANNOT PENETRATE BARRIER
  - AC POYNTING FLOW S, $d\phi/dT$, dE/dt PASS THROUGH BARRIER
- PASSES POYNTING FLOW S = E X H; dE/dt
- SEMICONDUCTOR BECOMES "ENERGY PIPE"
- WITH dQ/dt BLOCKED, FLOW OF S = E X H IS NON-DIVERGENT AND WITHOUT LOSSES
- FOGAL CHIP UTILIZES S = E X H FLOW TO TRANSPORT ENERGY, RATHER THAN $J\phi$

D-1-T4

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[30] In a correspondence with Bockris lasting several years, he had graciously furnished me with material on the overpotential, which is how I found out about this esoteric area. Bockris is well-known as a leading scientist on the chemistry of hydrogen, and also as one of the leading scientists in the rapidly developing field of cold fusion. He is a marvelous scientist, and one day his largely unsung work with the overpotential will revolutionize the entire electronics industry.

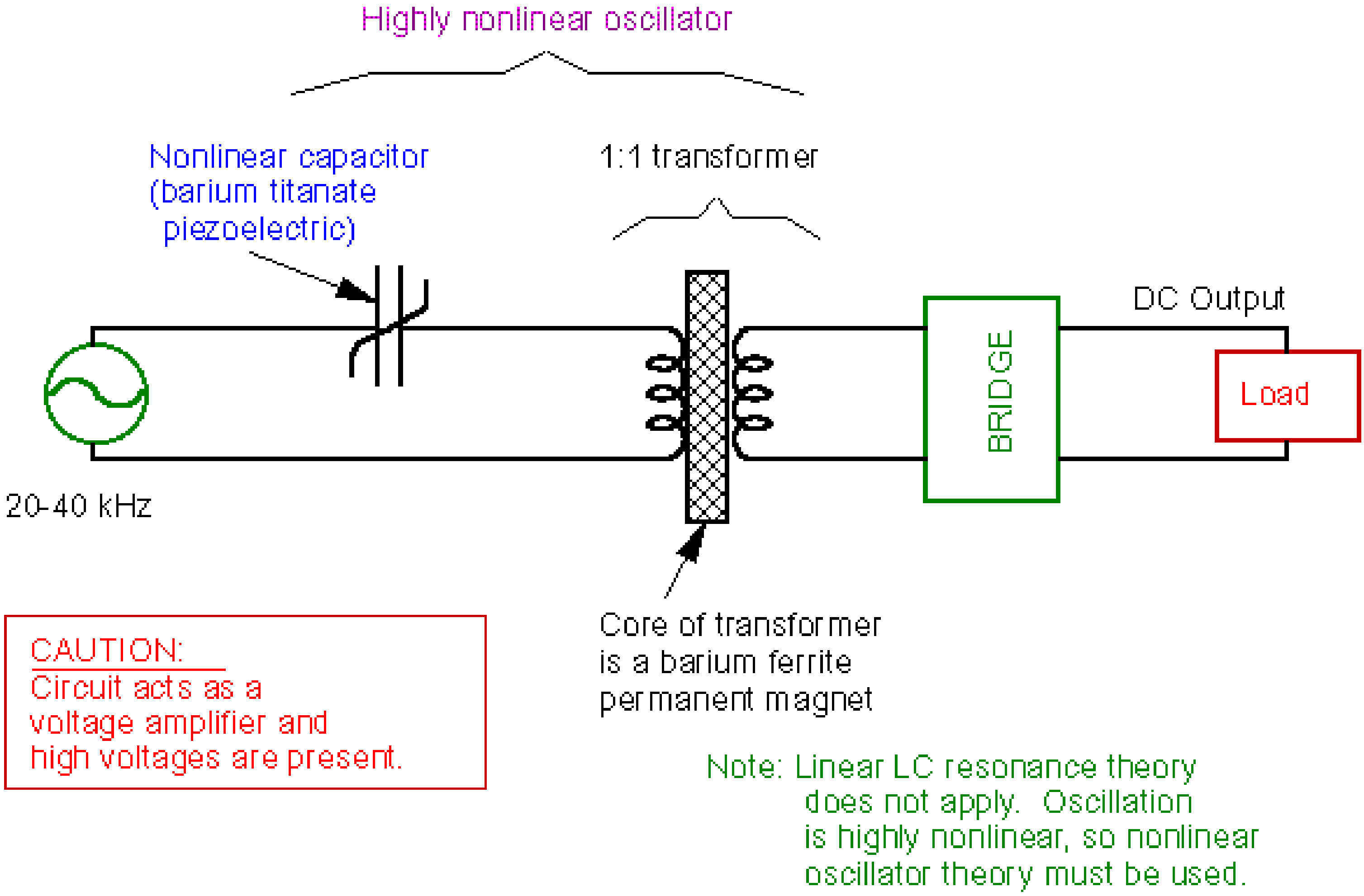
Highly nonlinear oscillator
Nonlinear capacitor
(barium titanate
piezoelectric)
1:1 transformer
DC Output
BRIDGE
Load
20-40 kHz
CAUTION:
Circuit acts as a
voltage amplifier and
high voltages are present.
Core of transformer
is a barium ferrite
permanent magnet
Note: Linear LC resonance theory
does not apply. Oscillation
is highly nonlinear, so nonlinear
oscillator theory must be used.

Figure 22. Schema for the magnetic resonance amplifier (MRA).

D-1-F22

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Howard Johnson is also a respected colleague, whom I very much admire. (See Figure 23). Howard has continued to work quietly and patiently upon his patented permanent magnet motor, [note 31] including patenting various magnetic gates, etc. that are necessary to make such a motor work in a rotary configuration. [note 32] Howard employs a two-particle theory of magnetism; i.e., each magnetic flux line is envisioned as having a particle traveling from the north pole to the south pole, and also a particle traveling from the south pole to the north pole. The particles are spinning; the forward-time particle spins in one direction, and the antiparticle spins in the other direction. Howard then slightly separates the two particle flows. [note 33] In other words, Johnson splits the flux lines themselves, into two different pieces. When so separated, the component lines are now curls, so their paths curve. The paths of the two "curl particles" are different; one curls in one direction and the other curls in the opposite direction. Further, a predominance of one form of curl particle gives a "time-forward" aspect, while a predominance of the other form of curl particle gives a "time-reversed" aspect. Johnson is thus able to employ a deeper kind of magnetism than the textbooks presently contain. He demonstrates that a "spin-altered" magnetic assembly exhibiting (to a compass or other such detector) a north polarity can attract another unaltered magnetic assembly exhibiting a north polarity. In short, he can make a north pole attract a north pole. We will give you further insight into Johnson's two-particle theory in a future article. [note 34] We will also explain how and why the physicists missed that antiparticle in the magnetic field's flux lines, and thereby failed to advance the theory of magnetism to a deeper level. Make no mistake, one day when the new theory is done, Johnson may well be awarded a Nobel Prize for his epochal discovery of a deeper structure of magnetism.

Bits and pieces of the new science approach are just now beginning to spill into a few conventional journals and symposia. For some time a few of the rebels spearheading this new science have been doing something that the University scientists should have been doing all along. The rebels have been meticulously examining the concepts, postulates, and definitions that the present scientific models are founded upon, to reveal serious foundations errors. Corrections for some of these errors have been discovered and made. [note 35] Others are still problems yet to be resolved. Yet slow progress is being made, and a "flip-over" of the old science is likely to occur within the next decade if not sooner. By then the new concepts will have become "solid" enough to allow producing an engineering mathematical model. Also the supporting experiments will have become solid enough to justify the new concepts and the model.

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Tables:

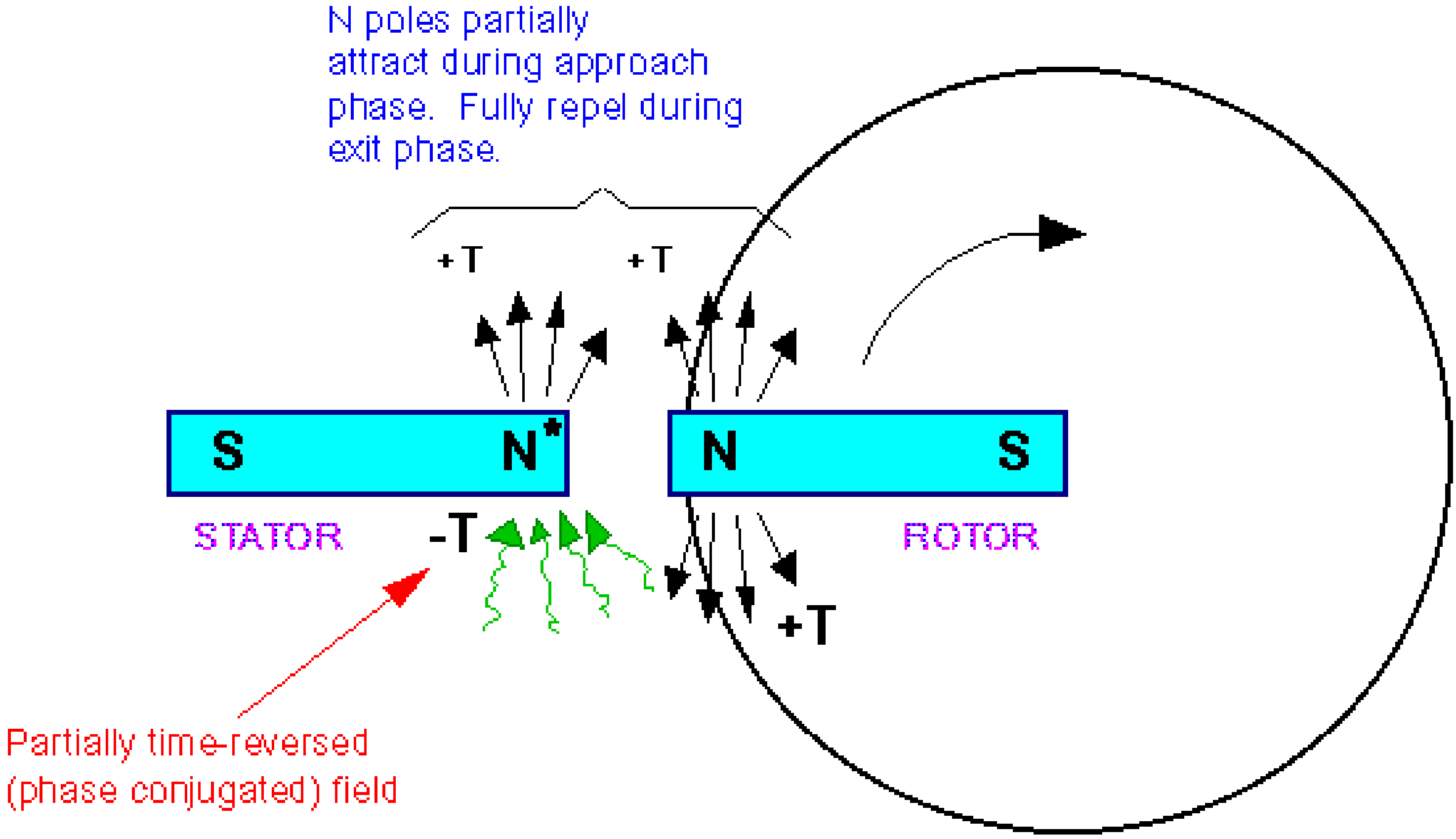
N poles partially attract during approach phase. Fully repel during exit phase.
+T
+T
S
N*
N
S
STATOR
-T
ROTOR
+T
Partially time-reversed (phase conjugated) field

Implications of a time-reversed field area on only one side of a magnetic pole in a permanent magnet motor

Figure 23. Schema for Johnson's permanent magnet motor.

T31H-L03

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[31] Howard Johnson, "Permanent Magnet Motor." U.S. Patent No. 4,151,431. Apr. 24, 1979.

[[32] I personally saw and closely examined one demonstration rotary Johnson permanent magnet motor some years ago, and toyed with it for about one hour. It would definitely self- rotate as long as you wished to permit it to turn. It was not a powerful device at all, but just a small laboratory "proof of principle" prototype. It had cost Johnson an enormous amount of time, labor, and optimization to get the critical adjustment required of his two magnet assemblies. But the device had no power source other than the permanent magnet assemblies themselves. Johnson's nonlinear rotor and stator magnets interacted with each other in a manner to break local symmetry. So his machine was an open system and therefore a permissible overunity device; it was not a perpetuum mobile.

[33] As I have pointed out repeatedly in the past, photons also carry time, not just energy. We have previously shown the process and the photon interaction mechanism that creates the flow of time itself; we will discuss this mechanism in the future. So when Johnson separates the particles and antiparticles, not only does he partially separate them according to spin, but he also alters the local character of time flow during which the resulting magnetic field forces must appear. In other words, he accomplishes a partial separation of time-forward and time- reversed polar interactions. A south pole is just a time- reversed magnetic north pole, in the first place! So a north pole of a bar magnet that is slightly time reversed on one side will partially act on that side just like a south pole. On the other side it will continue to act like a normal north pole. By partially time-reversing (phase conjugating) one side of the north magnetic pole piece, Johnson makes that side look and act like a south pole. that way Howard is able to create two north poles, one on a stator and the other on a rotor, and time-reverse part of one face of the stator's north magnetic pole-piece. Therefore when the proper sides of the stator and rotor north poles are facing, they attract each other, contrary to the conventional textbook. The two poles then repel each other normally as soon as the north rotor poles passes the north stator pole. Hence Johnson can make a surrounding north pole stator assembly "draw in" an approaching north pole rotor assembly, and then kick it on out the other side, because he has broken the local magnetic symmetry. In short, Johnson's magnetic gate can provide a legitimate component of unidirectional magnetic thrust, which means that he can indeed make a rotary permanent motor. Simply put, this "partially separating the spin particles," and thereby partially phase conjugating one face of a magnet, is what Johnson calls a "gate," and this is the patented secret by which his magnet assemblies can be made self-powering. The entire process is still very meticulous, and assembly and adjustments are extremely critical. With Johnson's blessings we hope to shed more light on this subject in coming articles.

[34] For a basic article on rotary permanent magnet motors, see T.E. Bearden, "On Rotary Permanent Magnet Motors and 'Free' Energy," Raum&Zeit, 1(3), Aug.-Sep. 1989, p. 43-53.

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[35] The most blatant error in all of physics is the erroneous notion that an acting force is separate from its receiving mass. Force is defined as F ~ d/dt(mv). From that definition alone, it can be seen that the affected mass is a component of the force itself. If you remove the mass m, you do not have force but merely acceleration. The notion of force separated from the mass came from ancient and familiar experiences of pushing on stones with one's hand, etc. In this primitive case the force-creating agent (i.e., the hand) is certainly separate from the affected mass (i.e., the stone). But the "force on the stone" is actually the force created of and with the stone. It is "stone-force," not "force upon the stone." Quantum field theory already tells us that it is the absorption and emission of virtual photons by the stone's mass that "creates the force." In fact it should go one step further: It is the coupled ensemble of the virtual photon flux and the mass of the stone that constitutes a "stone-force." In your mind, you should try mentally replacing the word "force" with the phrase "mass-force" until you root out the deeply ingrained erroneous notion that force and mass are separate. Because of this archaic error, today's physics can only define a mass in terms of its resistance to a disturbing force, and it can only define a force in terms of its overcoming a resisting mass. This error has prevented any proper definition of either force or mass! But the problem is solvable. For a proper definition of mass without the notion of force, see T.E. Bearden, Quiton/Perceptron Physics: A Theory of Existence, Perception, and Physical Phenomena, National Technical Information System, Report AD-763210, 1973.

In this first article I wanted to introduce the 14 major areas. We will be discussing these areas in some technical detail in the future. We'll also include current major news items of development in these areas, for the interested lay reader. I'll particularly try to give you the benefit of extensive reference citations painfully gathered over the last 30 years. The articles will be targeted toward both the serious researcher and the interested, educated layman.

So that's the agenda for the months ahead. We hope you find this information and the approach of direct interest and use.

Again, it's a privilege to be aboard. And we invite you to hang on in the future; it's going to be a wild but exciting ride. We really are going to chase this wild dragon with great vigor.

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Novel Principles In The Rife Microscope

And Rife's Great Secret [1]

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Substantially updated Aug. 20, 2001

Foreword

In the 1930s and 1940s, Royal Raymond Rife {1} made revolutionary discoveries in microscopy, including development of novel microscopes that could see far beyond the accustomed one-tenth wavelength limitation according to Rayleigh theory. With his microscope, he was able to "see" ultramicroscopic living forms much smaller than anything considered in the observable state. It would appear that his microscope was somehow capable of peering directly into the virtual state itself, and finding living forms at that level that were far beyond anything ever suspected by conventional science, even to this day.

Obviously this work was dramatically controversial. Rife went on to develop treatment methods and devices based on the new level of living organisms that his microscope revealed. In short, he arrived at essentially a new theory of disease, and did achieve success with his—to conventional scientists—completely unprecedented devices and methods of treating and healing. While we do not discuss his treatment methods in this paper, we do discuss the methods of Prioré, whom we believe to have used similar principles. So these discussions may shed some light on Rife's therapeutic mechanisms also.

Rife and others reported his results in the proper scientific literature. For his efforts, he was ostracized, essentially imprisoned in a medical treatment facility, broken, and rejected by his peers. His findings were harshly ridiculed and discredited. Finally escaping from his enforced confinement, Rife lived out his remaining years and died quietly and unknown.

In the present paper it is not our purpose to address Rife's theory of disease or his treatment devices and methods. It is solely our purpose to propose a higher symmetry electrodynamics functioning of his microscope, as one possible explanation of the startling microscopy results he achieved. We will reveal what we are convinced is Rife's great secret: recursive virtual state magnification (amplification) by iterative difference frequency serial summation of vacuum engines. This is a substantial change from an earlier mechanism proposed by the present author, which proved to be in error {1}.

We accent that this is not a "standard electrodynamics" examination of the Rife microscope; normal U(1) electrodynamics and transverse EM waves contain no mechanisms that can explain the functioning of the instrument. Accordingly, since no such explanation is contained in the usual electrodynamics, one must of necessity turn to those available electrodynamics models that are of much higher symmetry than afforded by vector and tensor algebra. To show the fit to experiments, we must also address an enormous amount of the work performed by Prioré and his colleagues. Only in such EM models and their known fit to actual experiments are the additional phenomena and principles available that can possibly explain Rife's epochal results.

Also, because of the importance of this unified field theory area, we include substantial references and additional extended discussions in the endnotes for further technical clarification. Thirty figures are added to illustrate the material.

The Rife Microscope

The Rife microscope { [1] } (Figure 1) cannot be made to work by normal optical principles at the level utilized by Rife. With normal optics, about one-tenth wavelength is as fine an optical resolution as one can get. Since Rife went far beyond that, it should be obvious that he was using optics and electrodynamics of a *novel kind*, and of a type not yet in the conventional textbook.

We believe we are aware of the major principles used in Rife's microscope, or at least some of them, but prior to 1998 we shied away from anything to do with the scope. My major interests have been in extracting EM energy from the vacuum and in developing a new kind of medical therapy utilizing higher symmetry electrodynamics—and thus unified field theory—to directly and slowly change cellular disease or disorder back to a normal previous state. Obviously, if one is to produce a microscope that "sees" optically further into the realm of smallness than any other microscope can conventionally do (even in theory), that microscope must be functioning in a higher electrodynamics mode rather than in the conventional one.

In this paper, we will try to summarize some deep physics principles underlying the Rife microscope, at least as we see them terms of a higher symmetry EM model, and we cite some references for the bits and pieces. A more detailed explanation must wait for a future time and assistance from very high-level theorists.

Introduction

A good hint is this: Rife (Figure 2) often painfully adjusted his microscope stages for up to *24 hours* before he finally got the instrument "focused." Immediately that shows it is not standard optical equipment. Well-made standard optics—and Rife's microscope was beautifully made—can be adjusted far more easily than that (in minutes!).

So far as we are aware, no one ever looked at the Rife work except through essentially rather orthodox electrodynamics and rather orthodox optics eyes. Normal optical theory permits resolution of about one tenth of the wavelength of the light used, and a few microscopes in the last few years have gone just a wee bit further. But none have gone anywhere to the degree of smallness that Rife reported.

In our view, the orthodox approach to explaining the operation of Rife's microscope is doomed to fail from the beginning. Even a very good scientist will fail with replication, if that approach is exclusively taken. An entire scientific team and substantial funding will not do any better, unless something technically deeper is understood and tackled from the outset. We give an overview of our approach to tackling that problem. To begin with, we must present some errors in electrodynamics and an omission in general relativity, so that we can develop the necessary background. The discussion is not simple and will require considerable development. Once the considerable background is developed, the application to the Rife microscope will be straightforward.

Errors in Electrodynamics and Adjustments to General Relativity

First, present electrodynamics itself has serious flaws and shortcomings, and needs substantial revision {[2] }. As foundations scientist Bunge points out {[3]}:

> *"...it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state."*

Bunge {[4] } also said:

"... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling not only to better cover their own domains but also to join smoothly so as to produce a coherent picture of the various levels of physical reality."

The flaws in electrodynamics pass over into what has been constructed for optical theory—both linear and nonlinear—which just assumes the electrodynamics as a subset.

For our purpose, we need to clarify what modern electrodynamics does and does not say about the massless vacuum, and about the state and form of EM entities—such as potentials, fields, and waves—created in it (in *empty space*) by matter dynamics, or acting from it (from *empty space*) onto matter and causing matter dynamics.

Maxwell and all his peers believed firmly in the material ether, a thin material fluid filling all space and every crevice. To scientists at the time, not one single point in the universe was devoid of this material etheric fluid—this *thin matter*. The atom had not been discovered, the electron had not been discovered, and electricity was also considered a thin material fluid. Charge had no more meaning than “a piece of the electric fluid,” much like a cubic centimeter of water.

Faraday {[5] } believed that the EM influence in space consisted of *material lines of force which acted as taut strings under tension from some mysterious source*. He believed that EM disturbances were just the transverse wave “perturbations” of these taut strings. In his concept, Faraday omitted the string holder or other agent producing the tensile forces upon the string (Figure 3). He thus omitted Newton’s third law from his electrodynamics concept. He also omitted precisely half the energy, by omitting the equal-energy time-reversed EM wave that accompanies the formation of every ordinary EM wave we take account of. In a receiving copper wire antenna, for example, not only do the electrons interact with the incoming fields, but so do the protons in the nuclei—though highly damped in amplitude by the proton's large mass with respect to the mass of a disturbed Drude electron. However, the two energetic interactions (of perturbed protons and perturbed electrons) are of equal *energy* magnitude. So in the conductor, equal energy is expended to move the "lattice holes" (positrons) as is used to move the Drude electrons, else field theory itself is falsified. Except in semiconductors, electrical engineers mostly just ignore the "disturbed lattice hole current" energy.

Maxwell deliberately captured Faraday's thinking, mathematically {[6] }, and so just *assumed* Faraday's lines of force and the "plucked tight string" transverse EM wave in the material ether {[7] } as well as the unexplained tension . The notion of the transverse EM wave in vacuum has essentially no other theoretical justification than that Faraday-Maxwell assumption and the observed "transverse waves" generated in the receiving "electric fluid in the conductor" in and on the Drude electrons. The transverse EM wave notion in vacuum was maintained only by discarding its missing antiwave that is always formed simultaneously in our transmitters and receivers (e.g., when we perturb the Drude electrons in a transmitting wire antenna, we also perturb the protons in the nuclei with the same energy. The two disturbances—proton disturbance in the nucleus and Drude electron disturbance in the Drude electron gas—perturb the local surrounding vacuum/ spacetime with equal energy, so in the vacuum "virtual particle flux gas" the two perturbations are energetically equal. The receiving wire receives both perturbation waves from the vacuum; one perturbs the electrons and the other perturbs the nuclei. Since the second wave is unaccounted, the perturbation of the nuclei is just considered a "mysterious force" that always appears. In a pumped phase conjugate mirror material, e.g., we interact the waves prior to their reaching the nuclei, by multi-wave mixing. Since the "causative" but neglected second wave coming in from space does not reach the nuclei, but are redirected to form the phase conjugate replica wave produced by the pumping, *the mirror does not recoil and it does not exhibit Newtonian third law reaction*. However, since electrodynamics *omits* the EM causative wave that generates Newton's third law forces in the receiver, which in normal detection always appear, then presently electrodynamic fields are erroneously said to be devoid of Newton's third law reaction. To the contrary, the effects of that hidden, neglected EM cause of the Newtonian third law reaction do appear, either as recoil of the physical receiving antenna or as the production of the time-reverse phase conjugate replica wave in optical pumping. But in standard electrodynamics, equal-and-opposite forces in the receiving antenna are assumed to arise "mystically" or from some hidden *electrodynamic demon*. The electrodynamic cause of Newton's third law has been lost since Maxwell wrote his theory.

Maxwell, however, was careful to point out the ad hoc nature of assuming the stress in the vacuum, and that no mechanism for it had been discovered, nor was such a mechanism contained in his theory. Specifically, Maxwell said {[8] }:

> *"It must be carefully borne in mind that we have made only one step in the theory of the action of the medium. We have supposed it to be in a state of stress, but we have not in any way accounted for this stress, or explained how it is maintained. This step, however, seems to me to be an important one, as it explains, by the action of the consecutive parts of the medium, phenomena which were formerly supposed to be explicable only by direct action at a distance. … I have not been able to make the next step, namely, to account by mechanical considerations for these stresses in the dielectric. I therefore leave the theory at this point, merely stating what are the other parts of the phenomenon of induction in dielectrics."*

Indeed, we now know of electrons and their spin. The longitudinally-constrained, spinning Drude electrons in receiving wires will gyroprecess laterally in the wire when an EM disturbance from the vacuum interacts with them. (Figure 4) It is well-known that these Drude electrons are highly restrained longitudinally down the wire; the longitudinal movement is the "drift" velocity and may be nominally only a few inches per hour. The lateral precession of the longitudinally constrained, spinning Drude electrons establishes that the incoming vacuum disturbance, before its interaction with the gyroelectrons, is *longitudinal*. Else one must discard electron spin, electron gyroprecession, and indeed the theory of gyroscopic precession itself. In our view, the EM wave *in vacuum* is longitudinal, always has been, and always will be {[9] }. It also *does not* consist of EM force fields, contrary to present classical theory. Instead, only the potentiality {[10]} for the transverse force fields—*should* the longitudinally perturbed vacuum EM entity be intercepted by a spinning charged particle and interact with it—exists in mass-free space, as pointed out by Feynman. Quoting Feynman again {[11] }:

> . *"We may think of* ***E****(x, y, z, t) and* ***B****(x, y, z, t) as giving the forces that would be experienced at the time t by a charge located at (x, y, z), with the condition that placing the charge there did not disturb the positions or motion of all the other charges responsible for the fields."*

Rigorously the force fields exist only in and of matter. In matter-free space, there is no force at all in what we call the "field as it exists in massfree space" {[12] }. E. g., Jackson states it this way {[13]}:

"Most classical electrodynamicists continue to adhere to the notion that the EM force field exists as such in the vacuum, but do admit that physically measurable quantities such as force somehow involve the product of charge and field."

But again, Jackson also states {[14] }:

> *"...the thing that eventually gets measured is a force..." "At the moment, the electric field can be defined as the force per unit charge acting at a given point. It is a vector function of position, denoted by E. One must be careful in its definition, however. It is not necessarily the force that one would observe by placing one unit of charge on a pith ball and placing it in position. The reason is that one unit of charge may be so large that its presence alters appreciably the field configuration of the array. Consequently one must use a limiting process whereby the ratio of the force on the small test*

> *body to the charge on it is measured for smaller and smaller amounts of charge. Experimentally, this ratio and the direction of the force will become constant as the amount of test charge is made smaller and smaller. These limiting values of magnitude and direction define the magnitude and direction of the electric field E at the point in question. In symbols we may write F = qE where F is the force, E the electric field, and q the charge. In this equation it is assumed that the charge q is located at a point, and the force and the electric field are evaluated at that point."*

As can be seen, much of the difficulty occurs because physicists continue to erroneously utilize an *equation* as if it were a *definition*. An equation defines nothing at all; it merely states that all the "things on the left" of the equality sign and all the "things on the right" have the same overall magnitudes. It does not *define* any of the things on the left or right, and so it tells us nothing at all about what anything in it *really is*. A definition requires an identity, not an equality. E.g., if we take as an identity the very equation advanced by Jackson's explanation above, we then have a definition:

$$F \equiv qE \Rightarrow E \equiv F/q$$

And now that identity clearly states that charged mass is a *component* of the **E**-field. Similar argument prevails for the **B**-field, etc.

The identity also shows that E is not the *magnitude* of the force field at all, but is its *local intensity* at any given point in the E field, in terms of force per unit point static coulomb—a force formed in, on, and of the charged mass of the coulomb. The misstatement that E represents the *magnitude of the field* is another great non sequitur. No textbook gives the calculation of the *magnitude* of the E-field, though all purport to. Instead, they all give the calculation of the *intensity* of the E-field at each point in it. There is a great difference between the magnitude of an automobile's mounted tire and its pressure per sq. inch on the pavement. In all fairness, some of the better texts do use the term "field intensity", at least occasionally.

As *defined*, the EM force fields are effects produced in, on, and of charged matter and *only* in, on, and of charged matter. They are not at all the same effects produced in matter-free space (in the vacuum/ spacetime). The EM force field (in matter) is not the same as the "massfree" E-field in massfree spacetime. Ultimately, all that exists in spacetime are *spacetime* and *changes to spacetime*.

We may accurately take the mass-free, force-free EM field to be a pattern of spacetime curvatures. The coupling of this spacetime curvature set, or any part of it, with charged mass, then constitutes an EM force field. Again, the problem is the hoary old mechanics notion of having a separate massless force acting upon a separate mass. No such thing exists in all nature, and mechanics should have been rather thoroughly overhauled long ago as a result of this horrendous *foundations of mechanics* error that is centuries old.

In present classical electrodynamics—certainly the kind taught to electrical engineers and used in the electrical engineering discipline—the EM potential {[15] }, field, and wave, as they truly exist in space and in the vacuum, are rigorously not prescribed at all. Instead, the effect of the "causal entity" as it exists in vacuum prior to interaction with charged mass, is used a if it were what exists in and on the charged mass as the effect of the interaction. (See Figure 5, Figure 6, and Figure 7). This substitution of the effect for the cause is arguably the greatest uncorrected error in classical electrodynamics today. It is a hangover from the old days of the material ether, and the refusal to change the Maxwell-Heaviside equations to eliminate that material ether assumption, once the Michelson-Morley experiments falsified it. This has long been known to foundations physicists, and to most of the better electrodynamicists as well. But it still seems to be known to very few electrical engineers!

Many attempts have been made to “modify” the standard classical electrodynamics theory, but most have failed. For some reason, most of these attempted modifications seem to have accepted the present “matter-to-matter transform” approach (Figure 8) of present electrodynamics, failing to see that the two missing transforms of matter-to-spacetime and spacetime-to-matter (Figure 9) are in fact just general relativity itself {[16] , [17] } The solution for adding the missing two transforms into electrodynamics therefore may lie in “infolding” general relativity directly within electrodynamics, rather than placing the two on an equal footing. That requires the analysis of the supersystem rather than the system, a concept which will be discussed shortly. Figure 10 shows the utilization of the "vacuum engine" that results from this "infolded GR" solution.

To our knowledge, the Sachs unified field theory {[18] a,b,c,d,e} is presently the only practical unified field theory that can be directly engineered by higher symmetry electrodynamics, such as the O(3) group symmetry EM model advanced by Evans and Vigier and perfected by Evans {[19] }. The engineering power of Sachs' theory is remarkable {[20] }, and the O(3) electrodynamics has been shown by Evans to be an important subset of the unified electrodynamics in Sachs' theory.

Let us examine that statement a little deeper.

In classical electrodynamics the sources of all EM potentials, fields, waves, and their energies are assumed to be the charges—which are assumed to somehow act as perpetual motion machines that continuously *create and pour out* all that EM energy in the fields and potentials associated with the charge as their "source". This outpouring of 3-space energy comprising and establishing the associated potentials and fields eventually fills all space with energy. All the charges and dipoles present in the universe since shortly after its formation have done this for some 14 billion years.

Yet in classical EM—with all the existing charges in the universe implicitly assumed to continuously pour out energy into all of space, and most having done so for billions of years—inexplicably space is *then* considered to be an emptiness having no interactive energetic exchange with the charge at all {[21] }. That of course is a non sequitur because it involves a total contradiction of the conservation of energy law. If there is no active energy in spacetime for the charged particle to receive and then output in 3-space, then the energy conservation is falsified by every charge and every dipole.

In particle physics the inactive vacuum concept is known to be quite wrong, else the charge creates energy from nothing. That would violate the most sacrosanct law in physics: that *energy can neither be created nor destroyed*. So electrodynamics—both classical and quantum, neither of which contains the solution to this *source charge problem*—is in gross violation of conservation of energy laws, because it assumes that the charge is solely the source of its associated fields and potentials and their energy { [22] } and that it accordingly creates all that energy it has poured out since the beginning of the universe.

Presently the electrical engineer implicitly assumes total violation of the conservation of energy law with every equation he writes, and is blissfully unaware of it.

Particle physicists, however, have done much better and published and incorporated their results, although inexplicably the mainstream electrodynamicists have not changed their own model accordingly. Particle physicists have known and shown for more than 40 years that (i) space is a seething inferno of EM energy { [23]}, (ii) a charge continually undergoes a violent energy exchange (see Figure 11) with the vacuum EM flux. That exchange is what a charged mass is doing, to *make* it a "charged mass"), and (iii) the charge is a *broken symmetry* in that violent energetic flux of the vacuum. "Broken symmetry" means that the charge disrupts and alters part of that virtual particle flux to observable EM energy flux (see again Figures 5, 6. and 7). The charge continually absorbs virtual energy from the vacuum, radiates *some* of that absorbed energy back to the vacuum in virtual form, but *integrates and radiates the remainder* in a flow of potentially observable energy—the energy flow discovered by

Poynting {[24] } and Heaviside {[25] } after Maxwell was already deceased.

So what does the source charge really do? It coheres, transduces, and *gates* some of its virtual energy {[26] } received from the vacuum, into an EM energy flow going out in all directions in 3-space from that source charge. Contrary to present electrodynamics, this energy flow is actually longitudinal and bidirectional {[27] , [28] , [29] , [30]}, with energy *going out in 3-space from the charge* to every point in the universe, and with energy coming from every point in the universe *back to the charge through the time domain*. But as reinterpreted {22 b}, Whittaker {[31] } showed in 1903 that any such bidirectional EM flow of energy—reinterpreted with the input energy to the charge coming from the time-domain, and the output energy from the charge being emitted into 3-space, comprises a scalar potential. This also agrees with quantum field theory {[32] }

See Figure 12. As it really exists in space, a scalar potential is a harmonic set of bidirectional EM energy flows, with the "bidirectional" EM waves being outgoing EM waves in 3-space caused by interaction with the source charge or dipole of incoming time-polarized EM waves. There is a set of outgoing EM longitudinal waves in 3-space, perfectly correlated with a set of incoming time-polarized EM waves in the time domain. Hence one time-polarized EM "causal" wave couples with one outgoing longitudinal EM wave in 3-space. It is this scalar EM wave coupling (combining) with longitudinal EM wave coupling, in a harmonic set of phase conjugate pairs, that constitutes the scalar EM potential.

In short, all EM energy in 3-space comes from the time domain.

After all, no observable persists continuously in time. Any observable is a frozen 3-space momentary snapshot of an ongoing 4-space interaction. It is the result of a d/dt operation imposed upon LLLT spacetime, to yield a momentary LLL by d/dt(LLLT) => LLL

What we see as the "motion of an object in 3-space" is actually the ensemble of a continual serial iteration of such "frozen 3-space snapshots" of each observable part of the object, much as the iterative frames of a movie film are seen as a continuously moving picture.

In Whittaker's bidirectional energy flow associated with the source charge, electrodynamicists—including Whittaker himself—assumed that a point positive coulomb of charge is located at each and every point in space. (Figure 5, Figure 6, and Figure 7). A tiny bit of the impinging EM energy flow "from" the distant source charge {[33] } is geometrically intercepted and diverted by the observing/detecting point charge to streamline around it, creating a "swirl around" of diverted energy flow. As can be seen, only a tiny portion of the impinging and passing EM energy stream in 3-space is diverged into the swirl. This is rather like a small diverted whirlpool of water forming around a stable rock in a flowing river. In electrodynamics the amount of energy in that "diverged whirlpool" is said to be the "collected" energy appearing upon that point charge (upon that fixed rock). That amount of energy swirled by the intercepting point coulomb at a given point in space, is then erroneously said to be the *magnitude of the potential (the magnitude of the entire river)*. It is no such thing. The small fraction of the potential that is *diverted from* the potential's flowing rivers of energy, is not that the magnitude of that potential (the magnitude of the entire set of flowing rivers themselves!) And it is certainly not "identically" the river itself! At best it is a measure of the *intensity* of the potential (the local intensity of all those internal rivers of energy flow) at that point occupied by the intercepting/diverting rock.

The point is, *as defined and used in conventional electrodynamics*, the potential occurs only after the vacuum EM entity's reaction with the intercepting mass, and is defined only as the *effect* produced upon that coulomb by the causative potential's interaction. Literally, the potential (the cause) is erroneously defined as the "excitation" or "excess energy" it locally produces as an *effect* upon a unit point intercepting/ collecting charge.

Ironically, it appears that no electrodynamicist calculates the magnitude of the actual potential as it exists in vacuum-spacetime, before its interaction with charge {[34], [35] }. Its magnitude is enormous, since the potential may extend over all space, and energy can be intercepted and collected by a charge placed at any point therein, or from charges placed at every point therein.

Certainly no rigorous definition of the potential presently exists in physics; the reader is challenged to check for himself or herself. No legitimate definition *can* exist for the potential, until the little matter is resolved of its present erroneous definition only "in and on and deviated by" charged matter, contradicted by the simultaneous assumption that it does exist in mass-free space in undeviated form. What is *deviated from* the potential, is not the *potential itself*. A part of something torn out of that something at one point in itself, is not the whole. The *local effect* cannot be substituted for the *entire nonlocal cause*—only a small part of which interacts *locally*.

The EM force field is similarly defined—only for charge mass interception, and only as an *effect* produced upon the intercepting charge. (See again Figures 5, 6, and 7.) A flow of water across a rock (or the wind on a rock in the desert) produces a “pileup” of fluid on the windward side, and a lesser “pileup” on the downwind side. The difference (called the “gradient”) in the energy density collected across the standard charge (rock) produces a “difference in pressure” on the rock—in other words, a force per interacting rock. That *effect* is erroneously taken to be the EM field itself, when rigorously it is only the reaction cross section of the EM field. Again, rigorously this EM field *as defined in electrodynamics* only exists as the effect that occurs upon an intercepting standard charge or "rock" {[36]}.

Since the EM wave “in space” is erroneously said to be made of varying EM fields, it too is defined only as the effect upon the intercepting charged mass, after the vacuum EM wave entity—whatever it is—has interacted with the charge and changed the charge translationally and energetically. Specifically, the present "EM wave in vacuum" in the literature is not at all what is presented and taught in undergraduate texts, and even the standard illustration of "oscillating E-field and B-field vectors" lateral to the line of motion of the wave is horribly wrong. E.g., Dr. Robert Romer, former editor of American Journal of Physics, has taken that error to task as follows { [37] }:

> *"…that dreadful diagram purporting to show the electric and magnetic fields of a plane wave, as a function of position (and/or time?) that besmirch the pages of almost every introductory book. …it is a horrible diagram. 'Misleading' would be too kind a word; 'wrong' is more accurate." "…perhaps then, for historical interest, [we should] find out how that diagram came to contaminate our literature in the first place."*

The EM field and wave *as commonly regarded* are transfer functions from the source charged masses that "perturbed the vacuum medium and created an unknown kind of disturbance therein", onto the receiving charged masses that intercept the incoming "unknown vacuum wave entity that was created" and interact with it, being translated and perturbed as a result.

This "detected" translation of the receiving charged masses (usually the interacting Drude electrons in a wire) is what our instruments detect. Indeed, the Drude electrons are highly constrained from moving longitudinally down the wire, usually moving at only a few inches per hour. They are much freer to move laterally, however, and can easily do so.

Reacting with the incoming longitudinal EM wave perturbation of local spacetime, the spin of the electron produces gyroscopic precession laterally in the wire since the electron is terribly restrained in moving longitudinally down the wire. Since our instruments detect these *transverse electron precession waves*, that has been totally confused (since Faraday's "plucked taut string" notion of the EM wave and Maxwell's arbitrary adoption of it) as representing the incoming wave in vacuum. It does not represent the vacuum EM wave at all; the incoming wave is in fact a longitudinal EM wave in 3-space, associated with a precisely correlated longitudinal EM wave in the time-domain.

So we have answered Professor Romer's implied question. That horrible diagram came from the assumption by early electrodynamicists, before discovery of the electron or atom or nucleus, that the "transverse electric fluid waves" in the receiving wires represented actual "intercepted" fluid perturbations arriving in the material ether medium.

In summary: Using a transmitter-receiver analysis, the so-called “EM wave in vacuum” *as presently defined*, actually represents that “detected and measured electron precession wave” in and of the reacting Drude electron gas in the distant receiving wire antenna. The so-called EM force field wave in vacuum has been erroneously defined as observable matter wiggles, not vacuum virtual energy wiggles and not as spacetime-curvature changes and wiggles. So even the present notion of the EM transverse wave in space is wrong, and it has been corrupted as a pure matter-to-matter transform from the beginning { [38] }.

Somewhat less technical explanations are given by Lindsay and Margenau { [39] }, and a rigorous statement and discussion that EM force fields exist only in charged matter is given by Aharonov and Bohm { [40] }. Feynman of course said it bluntly: Only the potential for the field exists in the vacuum, should one place a unit point charge there to allow the force field to be developed (on, of, and containing the source charge itself).

Let us summarize this terrible EM foundations flaw: As classical electrodynamics presently is modeled, Maxwell and his modern followers only include equations which are *mass-to-mass transformations*

(Figure 8). Specifically missing { [41] } are two other transforms: (i) the mass-to-vacuum (mass-to-spacetime) transformation (which obviously is general relativistic in nature), and (ii) the vacuum-to-mass (spacetime-to-mass) transformation (again, obviously general relativistic in nature). (See again Figure 9). When these two missing transforms are added back into electrodynamics, one has suddenly extended EM theory into a new domain. One has also *infolded* general relativity (GR) inside the present EM matter-to-matter transforms, and also included the vacuum interaction including broken symmetry in that exchange, but in an *electromagnetically engineerable manner*. In short, one has a practical, engineerable unified field theory.

Highly creative inventors such as Rife and Prioré intuitively developed apparatuses that unwittingly utilized this presently undeveloped and extended union of EM, particle physics vacuum theory, and GR. The intuition of the theorists in interpreting those revolutionary experiments and their results has very seriously lagged.

The Supersystem Concept

To understand how extraordinary systems such as Rife's microscope works, one must understand the concept of the *supersystem*. (See Figure 13). The supersystem consists of three components, which are (1) the physical system and its dynamics, (2) the local active vacuum and its dynamics, and (3) the local curvatures of spacetime and their dynamics. All three components of the supersystem interact with one another, in nature. The second and third components of the system constitute the active environment in which the system is embedded, and with which it interacts.

Unfortunately, in standard classical electrodynamics either the system's environment is assumed to be inert, or the system is assumed to be in equilibrium in its interaction with that environment. This represents a totally arbitrary assumption that the system cannot receive and utilize any excess energy from its known active environment. Hence the active vacuum's interaction with the system can be and is ignored by classical electromagnetics, as are the local curvatures of spacetime and their interactions with the system.

Extraordinary EM systems invariably involve the supersystem dynamics, and not just the system dynamics. *In nature*, no system analysis is complete until the supersystem interactions and their effects have been determined and analyzed.

The Rife microscope is indeed an extraordinary system using non-negligible interactions between the system and the other two components of its supersystem. Hence in our discussions, we will be examining interactions in that regime, and not just the standard electrodynamics analysis. In these discussions, we will be holding in mind not just the mass-to-mass transforms of standard electrodynamics, but two other transforms: (1) the mass-to-vacuum/spacetime transform, and (2) the vacuum/spacetime to matter transform (previously shown in Figure 9).

The reason that Rife's work has not been understood is that researchers have been unaware of the necessity for supersystem analysis. Almost all analyses of Rife's work have been merely standard classical EM analysis and thus quite insufficient. There are other examples of the standard electrodynamics model completely failing to show higher symmetry phenomenology in an inventor's work, so that his work is not understood even today. An example is provided by Tesla's patented circuits, as rigorously demonstrated by Barrett { [42] }. Barrett went on to improve the new functions discovered in Tesla's patents, and obtained two additional patents related to signals and signal processing { [43] }.

Vacuum-Structurings as “Engines”: Key Part of the Missing Transforms

The missing mass-to-vacuum/spacetime transformation produces a massless structuring of the vacuum medium. That is a *vacuum engine* or “multiplex of specific spacetime curvatures.” (See Figure 14, Figure

15, Figure 16, Figure 17), and Figure 18. Preparing the vacuum engine is accomplished by charged matter dynamics of the source charges producing the necessary potentials, fields and waves. The charges are embedded in continual energetic exchange with the vacuum/spacetime, and moving the charges affects that exchange; it perturbs the local vacuum flux and curves the local spacetime accordingly.

The transform represents producing this vacuum engine by the vacuum-perturbing action of source charge dynamics upon the vacuum, and by *not* assuming a mystical intercepting point-charge at each point in space { [44] }. In the vacuum/spacetime, *only* vacuum/ spacetime entities and changes to them exist. *In pure water, only water and changes to that water exist!*

So a precise dynamic structuring of the energetic vacuum (and spacetime geometry) is what charges produce when they "perturb" the vacuum medium { [45] }, by the presence or dynamics of their fields, longitudinal and time-polarized EM waves, or both. This "perturbed vacuum dynamics" separate from the source charges themselves comprises an engine that consists of altered longitudinal EM wave dynamics inside the internal Whittaker structure { [46] } of the scalar potential of the ambient vacuum. That is the same as also producing internested levels of spacetime curvatures in a *template* or specific pattern { [47] }.

In turn, this vacuum engine region of local curvatures and structurings in spacetime will interact upon any mass placed therein. That action is the missing *electrodynamic vacuum-to-mass transform.*

The missing electrodynamic vacuum-to-mass transformation produces direct changes and alterations in the "receiving" mass, at all levels, by the action of such a vacuum engine. As each action occurs locally in the localized receiving mass, it produces the "local effect" as the result of that "local action." The primary causative chain (i.e., the set of "dominoes" affecting each other serially), started back at the distant source charges. One can say that we therefore have mass-to-mass *action at a distance*, via the matter-to-vacuum and vacuum-to-mass intermediary transforms and the spatial and temporal propagation of the vacuum engines in the middle of the two { [48] }. We will shortly discuss the Whittaker structuring of the potential as a fundamental process for producing vacuum engines.

General relativists mostly concentrate upon the warping and curving of spacetime (i.e., producing a vacuum engine) by the very weak gravitational force—which is only some 10^{-42} times as strong for electrons as the electric force between them. Consequently, relativists must look to huge assemblages of mass, such as in stars and other astronomical objects, for sufficient gravitationally-induced spacetime curvature to produce easily observable results. For that reason, general relativity has resisted laboratory development as an engineerable applied science. By using the far stronger EM force as the agent of spacetime curvature, and including the infolded electrodynamics inside the potential, field, and wave, general relativity then becomes engineerable and usable. But one is engineering the supersystem, not just the system.

The Infolded Electrodynamics Inside Potentials, Fields, and Waves

As previously stated, in 1903 E. T. Whittaker, a well-known mathematical physicist, showed that a scalar potential can be mathematically decomposed into a set of peculiar EM wavepairs in a harmonic set. (Again see Figure 12) These "hidden waves" are longitudinal EM waves, arranged in conjugate pairs { [49] } with the pairs also arranged in a harmonic set. In each wavepair, there is an ordinary (forward-time) longitudinal EM wave (outgoing in 3-space from the interacting/observing charge), coupled to its phase conjugate replica (time-reversed twin).

And here lies a magic secret. Prior to interacting with a charge, the phase conjugate wave in each wavepair is in the complex domain, which means that in Minkowski space it is incoming along the fourth axis, *ict*, where the only variable is *t*. Hence this wave prior to interaction with charge does not even exist in 3-

space. Instead, it exists as a longitudinal EM wave incoming in time, so that it is a time-like flow of EM energy. (See Figure 19). After interaction with a charge, the charge absorbs the incoming time-polarized EM wave, transduces that time-energy to 3-spatial energy, and re-emits the energy as longitudinal EM waves in 3-space in all directions. "In all directions" means that for every outgoing longitudinal EM wave emitted in one direction in 3-space, another wave just like it also emitted in the other direction in 3-space. So the paired "bidirectional" EM longitudinal EM waves in 3-space, as interpreted by Whittaker, do exist as the *effect* waves caused by the incoming causal time-like longitudinal EM waves (scalar EM waves). The pairing of the causal time-polarized EM incoming wave with an outgoing effect longitudinal EM wave was not interpreted by Whittaker, but does agree with more modern quantum field theory interpretations of photon polarizations and their observability or non observability, by Mandl and Shaw {22b}.

We have corrected this "effect substituted for the cause" wave to reinterpret Whittaker's 1903 decomposition of the scalar potential, into combined biwaves where one of the biwaves is incoming in the time domain, and the other is outgoing in 3-space. That re-interpretation then allowed a solution {22a} to the problem of the source charge and its associated fields and potentials, together with their energy. Every source charge and source dipole continuously emits EM energy in 3-space, without any 3-spatial EM energy input. The input is there, but in the time-domain. This problem—resolved by the present author in 2000—has been called the most difficult problem in quantum and classical electromagnetics {30 }.

Because of observed parity reversal accompanying the time-reversal operation, in his forward-time, the observer “sees”—after interacting the incoming wave with charge—the *effect* of the incoming time-reversed or phase conjugate wave (entering from the time domain) as a 3-space longitudinal EM wave leaving in the opposite spatial direction. So the basic 4-space phase conjugate longitudinal wavepair would appear to us in forward time as a “regular” time-forward longitudinal EM wavepair in 3-space, with the two waves going outward in opposite directions. But each is accompanied by a time-polarized EM wave, else it would not be observable.

Further, there is a harmonic series of such bidirectional longitudinal wavepairs comprising the scalar potential. So the staid old electrostatic potential (i) *is not* a "scalar entity" at all { [50] }, (ii) *is* a bundle of longitudinal wavepairs, (iii) *is* an entity with a remarkable internal hidden multiwave structures and dynamics, (iv) *is* a composite of very special waves whose transverse amplitude (i.e., whose spatial energy density, which is a function of transverse amplitude squared) does not change, but whose transported time structure changes, and (v) therefore is a special kind of wave that is velocity modulated about some central velocity, and is not limited to the speed of light c. Indeed, in classical electrodynamics in the Coulomb gauge, the scalar potential is already recognized as having infinite velocity, merely appearing in space instantly at every point it occupies { [51] }.

We also state without elaboration that the active vacuum is *identically* a very huge scalar potential, as indeed is “spacetime geometry”. So a unifying principle is:

vacuum ≡ spacetime ≡ potential ≡ energy
{ [52] }

Further, as a potential, the “ambient” vacuum decomposes into an incredibly rich, internal Whittaker wave structure. So then also must *spacetime* and *energy* similarly decompose. That decomposition structure is even richer when higher symmetry O(3) EM is used instead of the lower symmetry U(1) EM employed by Whittaker.

A revolution in electrodynamics has recently begun, and central to that revolution is the strong appearance of longitudinal EM waves as essentially the basis for the emerging new electrodynamics. Work by Evans { [53] }, Barrett { [54] }, Ziolkowski { [55] }, Evans { [56] }, Rodrigues {57}, and others is fundamental in this respect. One part of this emerging new electrodynamics is advanced under the label of *undistorted progressive waves* (UPWs). A good summary of UPW theory is given by Rodrigues and Lu { [57] }. Even so, to date this body of work still largely ignores the internal Whittaker dynamics { [58] } inside an EM wave. The body of work—particularly the higher symmetry O(3) electrodynamics pioneered by Evans {56} inherently possesses the capability to model such structuring, since much of it utilizes a higher topology algebra such as quaternions { [59] } or even Clifford algebra { [60] } In those higher algebras, many electrodynamic things can be done outside the operations permitted by present vector and tensor electrodynamics.

Superpotentials and Superpotential Theory

Whittaker's 1904 paper { [61] } showed that all the "normal" electrodynamics was based on, *and created by*, the interference of scalar potential functions (i.e., by the interference of those multiwave longitudinal wavepairs and their dynamics { [62] } constituting the interfering scalar potentials.) He showed that any EM field or wave whatsoever can be replaced by two scalar potential functions—in fact, is *comprised of* those two scalar potential functions and is *created by them*. Scalar potential interferometry already creates all the "normal" EM in the textbooks anyway, and a proof has been given by Evans et al. { [63] }.

The 1904 paper by Whittaker initiated a somewhat obscure branch of electrodynamics referred to as *superpotential* theory { [64] }. Whittaker's work was further extended and augmented by later scientists such as Righi { [65] }, Debye { [66] }, Bromwich { [67] }, Nisbet { [68] }, McCrea { [69] }, etc. But even with the extended superpotential theory, without the addition of Whittaker 1903 and the substructuring "internal LW electrodynamics" one cannot understand the mechanism for what Rife was actually doing.

Rife was not using normal potentials and normal **E** and

H fields—which as we discussed, only apply to observable material entities anyhow and thus could not be used to “see” far below the quantum threshold of least detectable material disturbance. His entire protocol was to get beyond those “*material interception of EM energy*” limitations. Unwittingly, Rife was using *vacuum engines*—involving structuring of the active vacuum as well as pure general relativity (GR) and pure structurings of spacetime geometry itself. He was electromagnetically using that part of GR that the GR physicists have mostly only tried to produce by use of the weak gravitational force. In GR, *the ST geometry itself is active, dynamic, energetic, and structuring!* In higher symmetry electrodynamics, *the ST geometry itself is powerfully active, dynamic, energetic, and structuring!* It is not at all just a "passive spacetime" as classical electrodynamics assumes { [70] }.

Biological Systems Use the Infolded Whittaker-Type Electrodynamics

The problem in the Rife microscope is to be able to observe very subtle ST curvatures and patterns, in an optical manner. These subtle or virtual "disturbances" of local spacetime are far finer and smaller than the one-tenth wavelength optical resolution generally the limit for optical microscopes using conventional optical EM notions and “material” potentials, fields, and waves.

In short, Rife’s twofold problem was to (i) function with vacuum engines (internal structuring of the potentials) so he could penetrate to any degree of smallness, and (ii) output, in the observable state, exact visible summations and analogues of the individual structures detected in the virtual (nonobservable) state { [71] }.

To make the subtle vacuum engines observable on the bench, the ST curvatures and their internested patterning must be accomplished by making and assembling local curvatures of ST, via making longitudinal EM wavepairs in structural pattern assemblies. *Spacetime* is in fact just a powerful scalar potential, or can be modeled as such, and as such Whittaker 1903 and 1904 rigorously applies, along with extensions from higher symmetry electrodynamics. By realizing that ST is identically potential, one has altered one's thinking from the standard GR theory into a correlated EM-GR theory. One has also extended GR: Not only is there a “topology” of things that can be externally *done to* a base spacetime, but there is also a hidden, vast EM topology *within* any overall base spacetime. So we now have “topologies within topologies.” This is in fact what the Russians have long called the *information content of the field*.

However, all living systems already use this "infolded" bidirectional, longitudinal wavepair EM in their ongoing living functions { [72] }. Just as they used frequency modulation, EM signals, EM oscillations, etc. before we even had an electrodynamics or a physics, living systems do use the infolded EM (and vacuum engines) in all their living functions, and particularly in their cellular *regeneration and restoration* (R&R) system { [73] }, as contrasted to their *immune* system. The immune system cells are the fighters and the debris scavengers/cleaners. They go after the hostile invaders, fight them, and usually win—littering the battlefield with the debris. Then the immune system scavenger cells clean up the residue.

But many of the body’s cells will have been damaged in the fight. The immune system itself cannot heal or restore a single damaged cell, even its own! It is not a *healer*! It is a searcher, a marker, a killer, and a residue-cleaner. It contains " the troops and the combat engineer," so to speak, but not the hospitals and the doctors. All healing/restoration of living cells is done by the R&R system, not by the immune system.

A high-level overview of the immune system is given in Figure 20.

No vaccine, drug, herb, vitamin, or mineral *heals* the body, although certainly they can enhance or aid the body's healing process. Each does carry its individual resident vacuum engine, and when absorbed by the cell, this added vacuum engine contributes to the resident vacuum engine in the cell by summing with it. To restore the damaged cells back to normal (i.e., to heal), the R&R system uses a novel kind of extended electrodynamics with infolded vacuum engines, and it uses a novel kind of optical phase conjugate pumping, in the time domain rather than just 3-space. The magic “unified field theory” so long sought by scientists, has long been utilized by the regeneration and restoration system of the body in its minute-to-minute and day-to-day healing and restoring actions.

The magic "universal healing mechanism" so long evading the discovery of medical scientists is none other than the exact cellular regenerative mechanism universally used by every living organism. For the first time, we are explaining the higher symmetry electromagnetic nature of this mechanism.

Robert Becker's epochal work { [74] } (Figure 21, Figure 22) strongly probed the electromagnetic control system directing the body’s cellular regeneration and repair (R&R) system. However, he did not have available the infolded Whittaker electrodynamics. He could only utilize the grossly inadequate standard electrodynamics. Modern nonlinear phase conjugate optics had not yet been born when Becker did most of his seminal work.

Since standard EM does not incorporate infolded GR, vacuum engines, or optical pumping in the time domain, Becker could not formulate the full technical mechanism of the R&R system —which uses the *supersystem*, not just the system. But Becker did strongly point out the importance of the R&R system, both theoretically and experimentally. He found that it operated electrically, with the scalar potentials being key. He modeled the R&R system as closely as can be done with classical U(1) electromagnetics (Figure 22). He proved that cells can be *dedifferentiated* (reversed back to an earlier, more primitive state) and *redifferentiated* (time-forwarded into a more complex state) by weak DC potentials and laughably weak (picoamperes) of current. He was twice nominated for a Nobel prize for his epochal work. His method of electromagnetic healing of otherwise intractable bone fractures (Figure 21) is utilized today in many hospitals.

In his microscope, Rife was in pursuit of optically "seeing" the infolded electrodynamics functioning of the living cells in the most minute detail—i.e., he wished to see the actual vacuum engines and their functions. Using the infolded EM, one can still "see" the cells and all their parts, but one can also go far beyond the one-tenth wavelength optical discrimination limitation and see into the virtual state dynamics. In theory, because the infolded EM is *recursive* as a function of wavelength, one can go to any limit in smallness desired—or at least to whatever limit is determined by the available technology's development at the time { [75] }.

Vlail Kaznacheyev's novel electromagnetic induction of cellular death, disease, and damage, *at a distance*, is instructive in this respect { [76] }. (Figure 23) Indeed, the Russians mastered, extended, and weaponized the Kaznacheyev mechanisms as disease-inducing weaponry, and slyly used it at low level on personnel in the U.S. Embassy in Moscow (Figure 24). This was done to stimulate high level officials in the U.S. government and U.S. scientific community to see if the U.S. knew of this "infolded electrodynamics and vacuum engine" technology { [77] }. The Russians were using GR, but by infolded EM means—so they were using a unified field theory involving higher group symmetry electrodynamics. The puzzled U.S. employed only standard U(1) symmetry electrodynamic analysis { [78] }, so it totally missed the entire physics of what was occurring to cause the health changes and diseases.

In GR, one is very interested in Wheeler's principle which states (slightly paraphrased):

> *Mass (trapped energy) acts upon ST geometry to curve it, and curved ST acts upon mass to produce forces upon it and move it.*

This statement after Wheeler is the very essence of general relativity. It simply states that there is a *mass-to-spacetime* dynamic transform, and also a *spacetime-to-mass* dynamic transform, as we diagrammatically showed in Figure 9.

Understanding Vacuum Engines and Their Action

Wheeler's general relativity principle includes the missing two transforms of electro-dynamics. We are extending Wheeler's principle to the corollary form:

All levels of the structures of mass (trapped energy structures) and all levels of the structures of time (the time aspects of photon structures) act upon ST geometry to structure it in both 3-spatial energy density structuring and in time domain structuring. Producing this multilevel spatial and temporal structuring of spacetime is called "forming a vacuum engine." Both 3-spatial energy density structuring of spacetime at all levels and time structuring of spacetime at all levels, act upon mass at all levels, to produce internested templates of forces and translations and stresses.

In short, energy patterns and time patterns in 3-space act upon spacetime to produce patterned curvatures of ST geometry (vacuum engines). And conversely, patterned curvatures of spacetime geometry (vacuum engines) act upon mass to produce corresponding patterns of forces at all levels in the mass —down to and including upon the quarks and gluons in the nucleons in the atomic nuclei. We note with pleasure that the Sachs unified field theory does apply from the gluons to the entire universe, as has been shown by Sachs himself {18b}.

Muscle and Skeleton Analogy of Interaction of Vacuum Engine and Mass

We call attention again to our analogy (Figures 15, 16, 17, and 18) of the interaction of a vacuum engine and mass, provided by the interaction of arm muscles and the skeletal arm bones to which they are attached. The arm muscles attach to the arm's skeletal bones, and those bones are articulated and free to dynamically move. To the bones, the muscles are mysterious agents (analogous to vacuum engines) exerting forces upon them, and causing them to move or hold. To the muscles, the bones are positioned resisting masses for them to work upon and change their positions, and the bones exert Newtonian reaction forces back upon the muscles as the muscles apply forces to the bones. So the vacuum engines (muscles) create forces upon the resisting masses (bones) to move them, and the masses act back upon the causative vacuum engines to create antiforces in resistance.

Using this analogy, when we create a set of vacuum engines, we create a set of "mysterious muscles" that act directly upon any and all "masses" (bones) that are exposed to them. The bones then change and move until the bidirectional interaction forces are balanced (equal and opposite). This symmetry between the two missing transforms is shown in Figure 9.

The Multilevel Structuring of Time is Important

We also add the extension that dynamic structuring in the time stream also occurs from trapped time domain "time component" structuring and distribution effects, as well as dynamic structuring of the spatial energy density of the ST geometry (the vacuum).

We are speaking *relativistically* of the interaction of mass and spacetime at any and all levels of a mass, down to and including the molecules, the atoms, the atomic nuclei, the nucleons, and even the quarks comprising the nucleons (comprising the protons and neutrons). One must first clearly have this vision in mind: The dynamics of everything ongoing in that mass, down to the most minute particle dynamics and in the most minute detail (and far into the virtual state beyond the one-tenth wavelength limitation of light resolution) consists of the structurings of this "mass-ST curvature" mutual interaction.

So we know from general relativity that collections of energy (such as mass) act directly upon spacetime, its structuring, and its dynamics at any and all levels, down to the tiniest. We know that the variations in local spacetime geometry (including in both energy and time), down to any and all levels and sizes, down to the tiniest conceivable lengths, act directly upon any and all exposed mass at that level, *no matter how tiny*.

There is no “quantum” limitation nor is there any “wavelength of light” limitation to this GR process. Total continuity applies.

Some Characteristics of Vacuum Engines

The great advantage of a vacuum engine is that the "action" it produces upon an exposed mass, arises directly from within each point in the local spacetime in which the mass is embedded. One does not have to "start outside" and move through space and the intervening mass toward the "inside". Every point within an object occupies every point in time, a priori. From a single time-point, the vacuum engine's 3-space action enters everywhere within the object, all-at-once, and the 3-space effects proceed outward from each interior point. (See again Figure 19). Therefore even a weak vacuum engine induced by EM forces can do with ridiculous ease what the most powerful particle accelerators on Earth cannot do. The engine is already everywhere "inside" an object or particle, and working from every point in it, toward an outward direction. On the other hand, a particle accelerator is trying to build tremendous velocity of its particles so that they can "smash" their way in there, by brute force. To get ever deeper, the particle accelerator must be made ever larger, so that a "bigger hammer" is available. Also, the vacuum engine does not smash or damage any of the matter in the object, in any fashion not desired. The particle accelerator, on the other hand, is a great disruptor and may well destroy or serious change the very object it "probes".

Further, contrary to the accelerator's "one shot for one giant amount of energy input", a vacuum engine—once formed—continually exists in that locally altered spacetime and is contained in it and is sustained by it.

Hence that locally altered spacetime—after we pay to alter it once—will continuously expend energy in the form of the action of that vacuum energy, forever, upon any mass emplaced in that local spacetime. The universe itself is furnishing the energy to do the work, via the instantaneous connection in the time domain.

That "multiply connected space" entry everywhere within an object simultaneously, is quite different from "spatial propagation of energy" through singly-connected space from outside an object to the object, striking the outside of a mass and being absorbed, producing a gross translation force upon the mass. In the “energy propagation through space” case, severe energy interaction may occur with only the absorbing part of a macroscopic mass, while the remainder of the mass is little affected or not at all. To wit, one does not get the resulting *electronuclear* alterations of the nucleus (materialization, dematerialization, transmutation, etc.) by absorbed propagated “normal” EM radiation. However, with weak EM-induced vacuum engines one can do things inside the nucleus such as easily flip quarks inside the nucleons, so that transmutations at very weak spatial energy levels are readily obtained. This in fact turned out to be the major secret of the low-energy nuclear transmutations occurring in some 600 cold fusion experiments worldwide { [79] }.

Electrodynamic force fields implicitly define primarily only translation effects upon charges or masses, in their very definitions. With normal EM, usually one will get reradiation of the absorbed energy, or partial reradiation of the absorbed energy accompanied with recoil of the absorbing mass, or no reradiation but recoil of the mass.

We took the term *vacuum engine* from Misner, Thorne, and Wheeler { [80] } and also from Nobelist T. D. Lee { [81] } who spoke of this sort of thing as *vacuum engineering*. The term is not original with us; only the novel higher symmetry electrodynamics application of the concept is original. We call the exact geometrical form of a vacuum engine a *template*. We refer to the process of internally structuring a field, wave, or potential as *dimensioning* or *activating* or *conditioning* or *charging up* the field, wave, or potential. Russian superpotential weapon scientists call the infolded structuring itself the *information content of the field*. For further discussion of some of these terms and related concepts, the reader is referred to our website, www.cheniere.org.

Wheeler's GR principle says that, for every mass with its exact mass structural dynamics condition, there exists a corresponding exact vacuum engine template containing precise spacetime curvature structural dynamics, and interacting back upon the dynamic mass at all levels. That vacuum engine is said to be resident in the mass and continuously interacting with it (see again Figure 13 on the *supersystem*).

Again, the structuring of the vacuum engine has no limitation in fineness, because spacetime is continuous. Hence it freely extends from the observable realm on down into the virtual realm. This is no more audacious than stating that virtual and observable entities occupy the same time domain simultaneously. Obviously, if one is using the structuring of time, one gathers in both those virtual structures and those observable structures, and also the exact correlation between them. This is a direct engineering application of an EM hidden variable theory, somewhat similar to that proposed by David Bohm { [82] }.

Applying Vacuum Engines to Living Cells

Any normal cell already has a normal *template* of overall ST curvature due to its mass and trapped energy structures. No matter how small, every internal part of that cell has its own *subcomponent template* of subcomponent ST curvatures embedded in that overall cellular ST curvature. As the cell functions, the dynamic normal changes of that template into other related templates, is within the range of what we call "normal, healthy cellular functioning."

Any abnormal cell has an *abnormal template* and also an abnormal set of "templating" changes. In other words, there exists a precise *vacuum engine delta* in the abnormal cell, summed to the cell's *normal vacuum engine*. The *sum engine* represents the exact vacuum engine to act on the normal cell and change it to that precise abnormal condition.

But a template depends upon the energy density structuring of the local vacuum and also the local *time* structuring—which latter is still missing from physics books, but is implicit in the nature of the photon. If one produces the necessary energy structuring and density—and the necessary time structuring and density of local ST geometry—one produces a certain vacuum engine and one also produce a certain *template of time structuring*. Time { [83] } has dynamic template structuring and functioning, just as does the 3-spatial energy density of ST geometry.

Indeed, the total (virtual and observable) photon interaction with a mass or particle generates the "flow of that mass or particle through time" (Figure 25).

But one *can* make vacuum engines using EM energy and structuring, rather than with normal gravitational (G) energy and structuring { [84] }. The advantage is that, for electrons, the EM structuring is on the order of 10^{42} times as strong as the G structuring. For protons, the EM force is something like 10^{38} times as strong as the G force. So by using the much stronger EM force as the "agent of ST curvature," one can make vacuum engines that are quite strong at their local level. These engines will affect and profoundly change any exposed mass, including cellular mass—in any fashion desired, given only that one makes the appropriate vacuum engine. Again, *we are simply engineering practical but ultra-strong general relativity on the laboratory bench*, by electromagnetically engineering Wheeler's principle in an extended form.

For any physical cellular deviation from normal—any deviation whatsoever—a corresponding exact deviation (i.e., an exact delta) exists in the cell's otherwise normal vacuum engine template. This includes deviations in the genetics of the cell and everything else, not just the chemistry and gross physical structure.

Now if one could produce the negative (time-reversal) of the sum template of the resident vacuum engine and *amplify* it, one would have a powerful new type of vacuum engine. (Figure 26) It would be an exact *vacuum anti-engine* to act upon that specific diseased or abnormal condition of the cell and gradually erase the delta and bring the cell physically back to normal. The new anti-engine would operate upon all the mass of the cell, at every level no matter how small. It would change the cell's abnormal genetics back to normal genetics.

One could of course reverse cellular damage due to aging, and rejuvenate the body. It is quite doable; all that is needed are the funds, scientific team, and laboratory facilities to develop it. It is doable whenever the U.S. medical science community and the giant pharmaceutical community will allow it to be done.

One could reverse a cancer cell back to a normal cell, by applying the specific summation vacuum antiengine for the exact delta between the cancer cell and a normal cell.

One could reverse an AIDS cell back to a normal cell with normal genetics, where it no longer was an "HIV factory". An AIDS patient could be completely, quickly, and cheaply cured, the moment he or she tested HIV positive. There would be no need to wait for the debilitations of the progressing disease to appear. Not a single HIV-infected cell would be left in the body, even those resistant strains that have developed after the original infection.

One could do precisely the same thing with Ebola infections, and with the "tough" staph infections that now resist everything and are killing more than 120 thousand Americans in our hospitals every year, with the figures rising. *These are patients who did not have the disease that killed them, when they entered the hospital.*

With development of portable treatment units and mass production, one could treat and heal those millions of mass casualties that could well erupt in one or more large U.S. city areas—e.g., from an Iraqi-sponsored terrorist biological warfare (BW) strike, using anthrax { [85]). In 1998, we proposed a crash development of just such portable units { [86] }. With the present world situation, it is not a matter of *if* such terrorist BW strikes will be made in the U.S., it is a matter of *when* { [87] }. Since our 1998 proposal, there has now been time to have had those portable units developed and mass-produced, at a total program cost of perhaps $100 million. Sadly, no one apparently had the foggiest notion of what was actually being proposed, and its vital importance to the survival of the nation. With a looming war in the MidEast—and with hordes of terrorist teams with biological warfare agents already infiltrated into U.S. cities and population centers—this negligence is particularly of concern at this very moment. These officially-forecast attacks on our cities by weapons of mass destruction could now be imminent, if and when the MidEast does explode into war, which appears imminent.

The Process Has Been Experimentally Proven

A very similar thing is also what Becker { [88] } demonstrated, without considering the vacuum engine (general relativistic curvature of spacetime) effects. It is also precisely what Prioré { [89] } unwittingly did in France, with a team of renowned French scientists, to cure terminal cancers, atherosclerosis, lethal infectious diseases, etc. in laboratory animals under rigorous scientific protocols. The team also demonstrated the restoration of suppressed immune systems.

In Germany, Popp { [90] } *et al*. were also involved in studies dealing with the R&R system, but from a quantum electrodynamics viewpoint.

We can also consider the vacuum engine from a nonlinear optics view, and obtain startling extensions of both general relativity and nonlinear phase conjugate optics. That in fact is exactly what Prioré did, though he did not think in those terms. Prioré roughly created a complex set of bidirectional longitudinal EM wavepairs—i.e., a set of “time domain pump waves.” So he produced a kind of vacuum engine that itself is a crude *anti-engine generator* when used to pump a mass such as a living cell.

Prioré unwittingly used an extension to nonlinear optical (NLO) phase conjugation *before nonlinear phase conjugate optics was even born*. Pumping diseased cells in the Prioré manner causes the formation of exact "antiengines" for the specific cellular disease or disorder to be created in the cells themselves.

First, Prioré mixed up to 17 or so EM transverse waves in a rotating plasma { [91] }. Today we know that such a plasma will transform transverse radiations into longitudinal radiations, and it will also phase conjugate the input waves and add their phase conjugate replicas. In short, it is a procedure for somewhat crudely making a set of longitudinal bidirectional EM wavepairs, which is required to produce a scalar potential with a deterministic internal structuring. In short, it produces a scalar potential with an internal vacuum engine template.

These infolded longitudinal biwaves are NLO pump waves of a new kind: They pump the PCM material in the time domain only. This kind of pumping is a *vacuum antiengine-making process*.

The plasma tube was surrounded by a giant coil, and a pulsed magnetic field was produced by the coil. Per Whittaker’s 1904 paper, that pulsed DC magnetic field can be decomposed into two scalar potentials. Hence we have three potentials superposing: (1) the potential function set made by Prioré in his plasma tube, and containing a selected “vacuum antiengine maker” consisting of bidirectional pump waves in the time domain, and (2 and 3) the two Whittaker potential functions comprising the DC pulsed magnetic field of the coil.

The end result of this superposition/mixing of potentials is that their “internal structures”—including their vacuum engines—also diffuse one into the other.

Fundamentally, Prioré produced what to the observer seemed just a pulsed DC magnetic field, but one in which there was a specific "vacuum engine maker" of his deliberate creation and "tailoring." Originally by trial and error, he adjusted the 17 frequencies introduced to the plasma, thus varying the frequencies of the "infolded bidirectional pump waves" produced and infolded into the pulsed DC magnetic field carrier. In this manner he was "tuning the "vacuum antiengine-maker" content.

Again, Russian energetics weapons scientists call those vacuum engine templates the *information content of the field*. They do not refer to ordinary spectral analysis.

Explaining the Time-Pumping Vacuum Anti-Engine Maker

Irradiating the cell (with non-ionizing radiation) containing infolded specific bidirectional longitudinal waves, precisely corresponds to pumping the cells in the time domain, rather than pumping them in the "spatial energy distribution" domain. Because of the shift of the pumping from the 3-space domain to the time domain, this constitutes a dramatic extension of phase conjugate optics. Because of the amplified phase conjugating action of the "vacuum antiengine maker" upon the vacuum engine in a mass, this also constitutes a dramatic extension of general relativity and of four-wave mixing theory. Let us explain briefly:

When one pumps a nonlinear mass [phase conjugate mirror (PCM) material] with ordinary "transverse" EM waves { [92] } (Figure 27a), one is pumping (stressing, or "squeezing and relaxing") the mass with dynamic oscillating energy distributions in 3-space. One inputs a similar weak wave (called the "signal" wave) to the mass simultaneously. In that case, multiwave mixing theory tells us that the pumping of the PCM will cause the formation of a fourth EM wave, that is a time-reversed replica of the input "signal" EM wave. The time-reversed wave may contain up to all the energy in the pump waves, so it can be highly amplified in magnitude compared to the input signal wave. The distortion correction theorem tells us that this time-reversed replica wave will then appear precisely superposing in space back along the exact spatial track taken by the input signal wave { [93] }.

When the pumping is shifted to the time domain by pumping with bidirectional *longitudinal* EM waves, we now are pumping the time aspects of the mass—during it iterative existence as masstime; see again Figure 25—rather than just pumping the spatial energy aspects. In other words, we are not pumping *spatially*, but *spatiotemporally*. We are pumping *temporally*—rhythmically squeezing (compressing) and relaxing (extending) the "density of the time interactions" producing the rate of flow of time itself. This is a totally new extension to nonlinear phase conjugate optics.

In this case, the "signal wave input" to the "time-domain-pumped" nonlinear mass PCM is just the resident vacuum engine in the local spacetime in which that PCM mass is embedded (see Figure 27b). The sickened cell's abnormal vacuum engine—consisting of the sum of the normal cellular vacuum engine and the disease delta vacuum engine—is present in the cell and is the input to the time-pumped phase conjugate mirror (cellular masstime). The output is the formation of an amplified time-reversed replica of that vacuum engine. In other words, an exact, amplified *vacuum antiengine* for reversing the precise abnormal condition of the mass, down to and including even the quarks in the atomic nuclei, is formed by time-domain (longitudinal EM biwave) pumping. The result or "output" is that *the entire cellular PCM mass and all its constituent parts are "time-reversed" back along their previous "track through time", back to a previous normal physical state* { [94] }. Figure 27b illustrates this process.

So when Prioré pumped the abnormal cells, he simply time-reversed them—genetics and all—right back to their normal physical state before the abnormality arose.

The beauty of the method is that, by adjusting the input waves to the rotating plasma, Prioré could "tailor" and "tune" the pumping waves to what was needed for a particular class of disease. He used trial and error methods to arrive at the proper settings for the disease to be treated. In theory, by the Prioré method one can time reverse any mass back to an earlier physical state. This mechanism is used by the cellular control portion of the body's regenerative and restorative (R&R) system to restore damaged cells back to normal. It is the basis for the body's ability to heal itself!

Applied to diseased cells, the method causes the formation of specific amplified antiengines for the exact specific cellular abnormality, no matter how complex, and no matter what it is. *In applied medicine this is a revolutionary new healing and therapeutic modality*, accomplished by novel EM means, and justified by general relativity, higher symmetry electrodynamics, and longitudinal EM wave pumping in the time domain rather than classical electrodynamics and transverse EM wave pumping. Prioré's discovery, once understood, may just be the greatest medical discovery of all time, and the discoveries of Rife and of Becker may rank a close second. The Prioré process is shown in Figure 28.

The body's cellular regeneration system uses this same methodology and process. A block diagram of the operation of the body's cellular regeneration system is shown in Figure 29.

Further Principles Needed for Rife's Microscope

In his microscope (Figures 1 and 2), Rife just wanted to observe the templates [2] corresponding to the cells, germs, viruses, etc. and all their parts, without any smallness limit. To do that, we need to (1) amplify the tiny, tiny amplitudes (actually, in the virtual state and subquantal) of the tiny vacuum engines accompanying tiny spatial locations containing living, functioning entities (no matter how small), and (2) "transduce" that amplified result into the optical spectrum, so that we see a perfect optical analog and thus are "looking" visually at localized ST regions far smaller than the one-tenth wavelength optical resolution limit.

We need another principle to do that. Suppose that, to first order, we have an isotropic nonlinear medium. Then if we transmit a sine wave into it, pandemonium sets loose with our wave. The speed of each part of the wave in this medium is a function of the location of that part upon the wave amplitude, so the peaks move faster than the intermediate parts of the wave of lesser magnitude. The wave has "peak overtake", breakup, collapse, and all sorts of things happening to it. So a simple sine wave is not going to pass smoothly into that medium and "pass back out" coherently and nicely, and ordinary light is not going to give stable reflections from that medium!

However, if we transmit *two* sine waves simultaneously, some frequency interval apart, and then if we *pretend* that we actually transmitted their *difference* frequency, a very strange thing happens. The two individual sine waves themselves still break up and go bananas. However, that difference frequency acts as if it were a simple sine wave transmitted into a *linear* medium! So we get back out a very nice, smooth, well-behaved sine wave of the *difference* frequency, even though terrible things happened to the individual waves themselves. We can detect and use that "difference frequency" nicely.

Several very neat sonar systems presently use that sort of transmission schema in underwater work { [95] }. The principle applies for waves of all frequencies, for all media which can be approximated as nonlinear isotropic in nature. As we shall see, it applies to the Rife microscope also.

Rife's Secret: Recursive Coherent Increase of the Signal-to-Noise Ratio (SNR)

To first order, without too much error we can pretend that the molecules and atoms etc. in the cells and body tissues, together with their finer components, comprise such an isotropic nonlinear medium. That's not entirely true, of course, but it does work to an extent sufficient for our purposes. Fortunately for the Rife process, the parts that *do not* obey this isotropic rule add randomly, while the parts that *do* obey the rule add coherently. So the "signal-to-noise ratio" (SNR) increases with the increasing amplification, and one "grows" the desired signal right up out of the noise (SNR) of the parts that do not obey the isotropic medium assumption. With sufficient number of amplifier stages, in theory the SNR of even the tiniest parts can be made as large as desired { [96] }.

With optical functioning as in Rife's microscope, one may substitute "light gathering power" or "magnification" for the electrical term "amplifier gain".

As we stated, Whittaker in 1904 (and superpotential theory thereafter) shows us that—if we wish—any EM field, wave, and pattern can be represented by two scalar potentials. Each of these two scalar potentials is further comprised of bidirectional EM longitudinal waves, in a harmonic series, in the Whittaker 1903 manner as reinterpreted. So we can reduce any pattern, field, or wave from any assemblage of charge sources, into two potentials, and then further into two sets of bidirectional EM waves interfering with each other. That process already *makes* all conventional EM waves, fields, etc.

An EM structuring of the local vacuum-spacetime occurs by all the electrical charges in the mass of the living cell, down to and including the virtual charges exchanged in the nuclear interactions in the nucleus of the atoms. By Whittaker 1903 and superpotential theory, all of that structuring itself is a potential with an internal set of bidirectional harmonic longitudinal EM waves interfering with each other.

Further this potential is recursively organized, because the inner bidirectional EM wavepair structuring of the potential is already recursive, as can be shown by applying Whittaker-1903 and Whittaker-1904 successively and iteratively { [97] }. This means we get deeper and deeper internested levels of patterns that still precisely correspond to the operational mechanisms of the lower levels. It's similar to an infinitely fractal { [98] } type of process.

Because this conglomerate is recursive as a function of harmonic intervals, it means that we can pick any harmonic interval we choose in the "big world" where we observe things, and we can have an exact observational representation of the dynamics of that ongoing hidden longitudinal EM wavepair interferometry in the two waves bounding that harmonic interval. Of course, the more additional harmonics we add, the better dynamics we have. The greater the number of harmonic intervals applied, the greater the gain. However, these harmonic intervals can be recursively applied using just one "macroscopic" harmonic interval, iteratively and serially applied over and over. The more iterative serial recursive application of one harmonic interval, the mote the "gain" or "amplification"—in the case of a microscope, the more the *amplification*. That was Rife's real secret, finally revealed. See Figure 30.

The Difference Frequency Provides Visible Output

Rife wanted to look at very, very small things *visually*, even though those “small things” were far below the one-tenth wavelength visible light barrier. In other words, to understand the Rife microscope’s visual representation of the virtual state, we need to choose the harmonic interval of the throughput so as to span the visible spectrum. Well, for optical purposes, luckily the IR and UV do exactly that. Examine the frequencies, and you will see that a harmonic interval exists from a spot in the IR to a spot in the UV, and of course the interval in between includes the entire visible spectrum. The visible spectrum in between, however, represents the observable noise that would block what we seek to have emerge in that region in our "Rife microscope", so the presence of the visible spectrum is highly undesirable. Various filters can be used to block the visible spectrum while transmitting the UV and IR regions, or one can just work in the dark or in suitably dim visible light.

Rife then applied his iterative multiple "difference frequency" lenses in serial order, one after the other. While it is doubtful that he understood the theoretical method being utilized, he certainly persisted and found how to use it. This method of iteratively summing a recursive virtual state vacuum engine "template" results in the formation of an observable state vacuum engine template. In short, it magnifies the virtual state entities and dynamics directly to observable state analogues that capture all the virtual state entities and their dynamics.

That is why, if we use special filters on your camera and flash lenses, where the filters are open in the IR and UV but opaque in the visible spectrum in between, we can often photograph the ongoing "longitudinal EM hidden biwave interferometry"—*the subtle energy or vacuum engine functioning*—of nature and of living systems, *even displaced in time*, as Trevor Constable { [99] } and Joe Gambill { [100] } (a researcher friend now deceased) demonstrated, as George Meek { [101] } demonstrated, and as Fogal { [102] } has successfully experimented with.

Occasionally when one gets things just right, one can get pictures of the subtle invisible reality in the virtual state, going on around oneself and in one's surroundings. With Rife-like iterative serial amplification, one can get them all the time, dependably, as with a Fogal semiconductor specially adapted for such operation. One can in fact build instruments that indirectly observe the so-called "unobservable" virtual energy state and its entities and dynamics with one-to-one correspondence.

That's a whole new "subtle physics" reality. Present physics with its assumed quantum observation limitations just has not even gone into it—primarily because physics has been focusing upon the quantized aspects of the photon (which is quantized in one aspect only—its magnetic vector potential—and not in its unquantized aspect—its scalar electrical potential!). Physics has rather ignored the unquantized (and therefore continuous from the smallest to the largest scale) time aspect of the photon { [103] }. Using the continuous aspect of the photon, one can assemble photon “time interval” structures—and in fact one does so whenever one assembles a 3-spatial energy density structuring such as in ordinary EM theory. Simultaneously, one has assembled a “structuring of the time domain” also, because each photon in the spatial energy density structuring consists of both time and energy as its canonical components.

All EM fields and waves, being comprised of photons, thus also carry (1) energy and energy internal structuring, and (2) time and internal time structuring. Again, this is the Russian *information content of the field*. The Russians simply understand 4-vector theory and Whittaker 1903 and 1904, and how to combine them with quantum mechanics and general relativity in a unified field theory.

The above explanation is why Kaznacheyev's { [104] } mitogenetic radiation { [105] } from his control (deliberately damaged or infected) cells would pass through a quartz window and induce the same damage (or disease) in targeted cells on the other side and otherwise environmentally shielded, but would not induce the changes through a normal window glass window. (See again Figure 23) Quartz passes the full optical spectrum from IR to UV, while window glass does not. So quartz passes the *vacuum engines* for the disease or damage, while window glass breaks them up and does not pass them as such. We stress that the vacuum engines are part of the “continuous” aspect of the photons, and so are not bound to any limitation on magnitude (either fineness or largeness) as are the quantized aspects of the photon.

For such a "far beyond the one-tenth wavelength" microscope as Rife’s, one must use vacuum engines (time domain structuring, and longitudinal EM waves) and extraordinary iterative unified field theory optics, rather than the ordinary transverse EM waves and ordinary optics. The lenses must all pass at least one harmonic interval (and the same one!), to provide and utilize the “difference frequency band” needed for recursive *visual* connection to the subquantal state (the hidden virtual structures in terms of the continuity aspects of photons). Successive stages thus "serial iteration" use the recursive principle to coherently amplify and show the vacuum engines, their dynamics, and the dynamics of deeper organizations and dynamics in the virtual state itself. Since Rife wished to “see” the results in the optical spectrum, then the two frequencies chosen for “differencing” had to bound the visible spectrum.

Rife used quartz lenses or at least very good optical glass that is open from IR to UV. That bounds the visible spectrum with a harmonic interval. Rife used multiple stages for successive coherent recursive amplification and increasing the SNR magnitude by coherent integration. One must also have some scheme for filtering out (or avoiding) too much visible spectrum light. One such scheme is to just use enough stages so that, in the new theory where the wavelength limitation is bypassed, one has amplified ("resolved") to the depth or fineness desired. The process long ago removed itself from the "normal visible light" domain, well before it reached the deeper resolution limit utilized by the definition state of the new method.

By using sufficient multiple stages in this fashion, the "tiny" virtual state vacuum engine templates passing through the IR-UV harmonic interval in a lens can be recursively summed and magnified many, many times—essentially without limit, because the phenomenon being magnified is recursive and bidirectional longitudinal in nature. It is definitely *not* normal visible light optics, and it *is not* conventional classical electrodynamics.

Rife’s Recursive “Vacuum Engine” Microscope

The Rife microscope coherently sums (and thus coherently amplifies) the virtual state vacuum engine patterns with the increasing number of stages. For the *subtle* vacuum engine templates, such an arrangement becomes a direct amplifier (magnifier), for amplifying (magnifying) the internested virtual state vacuum engine templates and their dynamic functioning, into the observable state. With a properly designed “vacuum engine” recursive microscope, one can see inside a molecule, inside the atomic nucleus, and even inside a nucleon, given development and perfection of the process. However, at this initial stage of understanding, one can forecast that finely adjusting the various stages of an early laboratory prototype would indeed prove to be a tedious and formidable task, just as Rife reported. With further development, however, that obstacle can be removed.

What comes out the output end of such a “vacuum engine” recursive microscope, is a direct visible light *analogue* of the much more subtle ST functioning in the microscope’s highly localized viewing area. This output imaging is put together "electrically" in ways analogous to the construction of a video picture on the screen of a TV tube. Since the result emerges through an output end that still passes an entire harmonic interval bounding the visible spectrum, the amplified virtual state recursive template is not destroyed but is highly amplified and produced as an observable image and dynamics in the visible spectrum. This final "interferometry" of two *internally structured* potential functions now produces "visible light" EM fields and waves and patterns, in accord with Whittaker 1904. These visible patterns are direct analogues representing exactly the very, very minute regions far below the one-tenth wavelength limitation of ordinary optical resolution. Those regions were the regions “being focused onto” when Rife so arduously “adjusted” his microscope's multiple stages.

With Rife’s recursive magnifying microscope process, one can see direct visible analogs of what is actually far, far smaller than anything ever before seen in normal optical microscopes, or even in electron microscopes etc. Indeed, one can see directly into the virtual state itself, and observe virtual state structures. While this is unthinkable in quantum mechanics if one considers only quantized aspects of light, it is perfectly feasible if one considers the concomitant unquantized (continuous) aspects of light, and shifts to general relativity and vacuum engines to utilize the unquantized structuring of the time domain.

Conclusion

Rife unquestionably found a way to produce visible recursive amplification and magnification of invisible virtual state dynamics and functions. We hope we have shed at least some light on the extraordinary technical mechanisms involved. This is good conceptual science, consistent with theory and some known experiments, and it certainly can be made a rigorous science and technology and mathematically modeled, using higher symmetry electrodynamics that is part of a unified field theory such as that of Sachs. The basis for all of it is in the literature already, but it is scattered widely in uncorrelated bits and pieces. It is not in the normal electrodynamics courses, nor is it in the normal optical science curriculum. And it is not taught in the normal physics curriculum. Needless to add, it is absent from the medical curriculum as well.

As an additional proposal, we tentatively suggest that this principle also may be the long-sought "hidden chaos" or "hidden order" in quantum mechanics that is known to be present, but has not yet been explained { [106] }. If so, then it becomes a new law of physics, with the experimental proof first demonstrated by Royal Raymond Rife.

With the conceptual technical matrix of Rife's mechanism in hand, it should be possible for a proper scientific multi-disciplinary team to redevelop and extend the Rife microscope. Marvelous new instruments will emerge, once the quantum physics conceptual blockage of continuous physics is constrained to its place as only "one view of the physics reality elephant." With the ability to directly "measure", "observe," and engineer the virtual state, a breathtaking expansion of physics will occur, dramatically extending the vacuum engineering suggested by Nobelist Lee.

If so, then Rife's tragic life will have served its noble purpose, and his intuitive insight will have been resoundingly verified. The follow-on results will have untold benefit to science and to all the human generations to come.

NOTES AND REFERENCES

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[1] For work on the theoretical aspects of this paper, partial financial support by A. Dreyer, R. Francis, H. Ledger, M. Peters, T. Craddock, and the Association of Distinguished American Scientists (ADAS) is gratefully acknowledged, as are helpful discussions with Dr. Bob Flowers and Dr. Myron Evans.

[2] We emphasize that Rife himself did not think in these terms.

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[1] . (a) Some Rife-related references are: Royal R. Rife, "The filterable virus of carcinoma," Apr. 26, 1939; — "The Rife Microscopes," Apr. 28, 1939; — "Bacteria," Apr. 28, 1939; — "History of the development of a successful treatment for cancer and other viruses, bacteria, and fungi," Allied Industries, Dec. 1, 1953.

(b) Arthur Isaac Kendall and Royal Raymond Rife, "Observations on Bacillus Typhosus in its filterable state," California and Western Medicine, Ca. Med. Assoc., Dec. 1931.

(c) Arthur Isaac Kendall, "The filtration of bacteria," Science, Mar. 18, 1932.

(d) See particularly E. C. Rosenow, "Observations on filter-passing forms…," Proc. Staff Meeting of the Mayo Clinic, July 13, 1932; — "Observations with the Rife microscope of Filter-passing forms of micro-organisms," Science, Vol. 76, Aug. 26, 1932, p. 192-193; — "Microdiplococci in filtrates of natural and experimental poliomyelitic virus compared under the electron and light microscopes," Proc. Staff Meeting of the Mayo Clinic, 17(7), Feb. 18, 1942, p. 99-106; — "Observations of filter-passing forms of Eberthella Typhi (Bacillus Typhosus) and of the Streptococcus from Poliomyelitis," Proc. Staff Mtg.

Mayo Clinic 7, July 13, 1932, p. 408-413; — "Transmutations within the Streptococcus-Pneumonococcus Group," J. Infective Diseases, Vol. 14, 1941.

(e) R. E. Seidel and M. Elizabeth Winter, “The new microscopes,” Journal of the Franklin Institute, Feb. 1944, p. 103-129; — "Filterable bodies seen with the Rife microscope," Science Supplement, Science, Dec. 11, 1932, p. 10-11.

(f) "Is a new field about to be opened in the science of bacteriology?", Editorial, California and Western Medicine, Ca. Med. Assoc., Dec. 1931; "Powerful microscope makes very tiny objects visible," Science Newsletter, Vol. 33, Jan. 22, 1938, p. 55; "The Rife microscope or 'facts and their fate'," Reprint No. 4l7, The Lee Foundation for Nutritional Research, Milwaukee, Wisconsin, undated.

(g) A good lay overview is given by Christopher Bird, “What has become of the Rife microscope?”, New Age Journal, Mar. 1976.

(h) See also T. E. Bearden, AIDS: Biological Warfare, Tesla Book Co., 1988, p. 267-279. The author gives a short introduction to the Rife microscope and includes some pictures. The proposed evanescent wave explanation proved to be wrong. Much additional work by the author eventually culminated in the proposed mechanism presented in the present paper.

[2]. We have one viewgraph listing some 32 flaws, errors, and shortcomings of classical electrodynamics, and there are even more than that. Additional errors are listed, for example, by important scientists such as Feynman, Wheeler, Evans, Bunge, Cornille, Barrett, and others. So a substantial number of errors in classical U(1) EM theory are well known to foundations scientists. We discuss only a minimal few in this paper.

[3]. Mario Bunge, Foundations of Physics, Springer-Verlag, New York, 1967, p. 176.

[4] . *Ibid*., p. 182.

[5] . M. Faraday, Experimental Researches in Electricity and Magnetism. Vol. 1, Taylor and Francis, London, 1839.; Vol. 2, Richard & John E. Taylor, London, 1844; Vol. 3, Taylor and Francis, London, 1855. Reprinted by Dover in 1965. Also see M. Faraday, "On Static Electrical Inductive Action," Phil. Mag., 1843; — "Remarks on Static Induction," Proc. Roy. Inst., Feb. 12, 1858.

[6] . James Clerk Maxwell, Preface to the First Edition, A Treatise on Electricity and Magnetism, third edition, Vol. 1, Dover Publications, New York, 1954, p. viii-ix.

[7] . J. C. Maxwell, Preface to the First Edition, A Treatise on Electricity and Magnetism, third edition, Vol. 1, Dover Publications, New York, 1954, p. viii-ix. Quoting: *"…before I began the study of electricity I resolved to read no mathematics on the subject till I had first read through* Faraday's Experimental Researches in Electricity. *…I perceived that his method was also a mathematical one, though not exhibited in the conventional form of mathematical symbols. I also found that these methods were capable of being expressed in the ordinary mathematical forms…."*

[8] . James Clerk Maxwell, A Treatise on Electricity and Magnetism, Third Edition, Vol. 1, Dover Publications, NY, 1954, p. 165-166.

[9] . Else the precessing electrons in a signal-receiving wire antenna would not precess laterally. Since their precession is at right angles to the disturbing force, the disturbance arriving from the vacuum was a longitudinal disturbance. This also agrees with Whittaker's 1903 decomposition of the scalar potential, and Mandl and Shaw's note that the combined scalar photon and longitudinal photon are observable as the instantaneous scalar potential,

while neither of them is observable individually. See citations for Whittaker and for Mandl and Shaw elsewhere in these references.

[10] . This word "potentiality" (by Feynman) is given flesh and blood in the present paper. What actually exists in the vacuum is potential and structures of potential. Vacuum, spacetime, and potential are identities. Hence we may say that the structured vacuum potentials are indeed structurings of spacetime curvature. We refer to these as *vacuum engines*, which are explained in this paper.

[11] . Richard P. Feynman, Robert B. Leighton and Matthew Sands, The Feynman Lectures on Physics, Addison-Wesley, New York, Vol. II, p. 1-3.

[12] . This is easily shown. F ≡ d/dt(mv), which expands to F = (m)dv/dt + v(dm/dt). Let the mass m be zero continuously, and both terms on the right go to zero, hence F = 0. That is, the force disappears because mass is a component of force. It is the use in mechanics of the separate massless force acting on a mass that is the non sequitur and to blame for this giant error in electrodynamics as a hold-over from the hoary old mechanics theory.

[13] . J. D. Jackson, Classical Electrodynamics, Second Edition, Wiley, 1975, p. 249.

[14] . Jackson, ibid. p. 28.

[15] . Melba Phillips, "Classical Electrodynamics," Vol. IV: Principles of Electrodynamics and Relativity, in Encyclopedia of Physics, Edited by S. Flugge, Springer-Verlag, Berlin, 1962, p. 4. Quoting: "The utility for electrical problems of a scalar potential, first introduced in the theory of gravitation, was pointed out by Simeon Denis Poisson, Bull. Soc.

Philomatheique **3**, 388(1813). See also Mem. Institut, Pt. **1**, 1, Pt. **2**, 163 (1811). The word *potential* was introduced by George Green in 1828."

[16]. E.g., see W. Misner, K. S. Thorne, and J. A. Wheeler, Gravitation, W. H. Freeman and Co., San Francisco, 1973, p. 5.

[17]. Two methods of dealing with this problem, and rectifying it, are the use of a topological definition of the fields in mass-free spacetime, and the use of a unified field theory where the "field in space" is not a forcefield per se, but merely a curvature or set of curvatures of spacetime. As an example, the O(3) electrodynamics largely pioneered by Evans takes the latter approach, and it is usable in directly engineering unified field theory effects.

[18]. (a). Mendel Sachs, The Field Concept in Contemporary Science, Charles C. Thomas Publishers, 1973;
(b) — General Relativity and Matter: A Spinor Field Theory from Fermis to Light-Years (Fundamental Theories of Physics), Reidel (now Kluwer), 1982 provides a great generalization of general relativity and electrodynamics reaching from the quarks and gluons to the entire universe. See also
(c) Mendel Sachs, Quantum Mechanics from General Relativity: An Approximation for a Theory of Inertia, Reidel (now Kluwer), 1986;
(d) — "Relativistic Implications in Electromagnetic Field Theory," in T. W. Barrett and D. M. Grimes, eds., Advanced Electromagnetism, World Scientific, 1995, p. 541-559. In the latter, Sachs shows that the most general expression for the field theory is in terms of spinor and quaternion variables, rather than the vector and tensor variables of the conventional expression of Maxwell's theory. This generalized expression leads to extra conservation laws and

invariants, thus increasing the predictive capacity of the theory.

(e) For a marvelous treatise for the educated layman, see M. Sachs, Relativity in Our Time: From Physics to Human Relations, Taylor & Francis, 1993.

[19] . E.g., see the several Evans' reviews in Modern Nonlinear Optics, Second Edition, Edited by M.W. Evans, Wiley, 2002 (in press). Many other O(3) electrodynamics papers are also carried in this set of three volumes, as well as in the standard literature.

[20] . Mendel Sachs, "Relativistic Implications in Electromagnetic Field Theory," ibid.

[21] . Without interaction with the vacuum, mass does not exhibit perfect symmetry. For a discussion, see T. D. Lee, Particle Physics and Introduction to Field Theory, Harwood Academic Publishers, New York, p. 378-389.

[22] . In both classical and quantal electrodynamics, the problem of the source charge and its associated fields and potentials—and their energy—has been considered to be the most difficult problem.

(a) For a solution to that problem, see T. E. Bearden, "Giant Negentropy from the Common Dipole," Journal of New Energy, 5(1), Summer 2000, p. 11-23. On DoE open website http://www.ott.doe.gov/electromagnetic/papersbooks.html and this author's website www.cheniere.org.

(b) For very powerful support of that proposed solution, see F. Mandl and G. Shaw, Quantum Field Theory, Wiley, 1984, Chapter 5. Neither the time-polarized photon nor the longitudinal photon is individually observable, yet the combination of the two is observable as the instantaneous scalar potential. The Mandl and Shaw combination of a scalar (time-polarized) photon and a longitudinal photon is explained by Bearden as the interaction of the causal incoming scalar photon with a charge, the charge subsequently transducing the absorbed energy from the time-domain into 3-space, and re-emission of the energy as an emitted longitudinal photon in 3-space. The actual interaction provides the coupling, and clarifies which is the *cause* and which is the *effect*.

[23]. As the electrodynamicists implicitly assume, by assuming fields and potentials from all charges in the universe penetrating and existing and superposing and interfering in each cubic centimeter of space, and in fact at every point in space. But then the electrodynamicists continue to utilize a material ether assumption in their equations, embedded implicitly upon the notion of an "empty space" filled with this material ether. Tesla called it "*… one of the most remarkable and inexplicable aberrations of the scientific mind which has ever been recorded in history*." (Nikola Tesla, "The True Wireless," Electrical Experimenter, May 1919). While that biting remark certainly did not endear him to struggling electrical scientists, it did strike uncomfortably close to the mark, and it still does.

[24]. J. H. Poynting, "On the transfer of energy in the electromagnetic field," Phil. Trans. Roy. Soc. Lond., Vol. 175, Part II, 1885, p. 343-361.

[25]. Oliver Heaviside, "Electromagnetic Induction and Its Propagation," The Electrician, 1885, 1886, 1887, and later. This is a series of 47 sections, published section by section in numerous issues of The Electrician during 1885, 1886, and 1887. See also Oliver Heaviside, "On the Forces, Stresses, and Fluxes of Energy in the Electromagnetic Field," Phil. Trans. Roy. Soc. London, 183A, 1893, p. 423-480.

[26] . By a crude analogy, one may think of the "virtual" energy of the vacuum as energy that has been disintegrated into incredibly tiny bits—each so small that the bits fade in and out of existence at an incredible rate. The spinning action of the charge may be thought of as similar to that of an old spinning wheel. The charge spins, so that it coheres some of the "virtual fibers" continually fed to it by the vacuum, into "thread-sized" portions that are emitted radially outward. So the charge "splatters back" some of the fibers as fibers, but "spins" the remainder into useful quantum-sized "threads" which are emitted in observable form.

[27] . Presently electrodynamicists are likely to specify the Poynting energy flow **S** as $\mathbf{S} = \mathbf{E}\times\mathbf{H}$. However, in the vacuum (spacetime) neither **E** nor **H** exists as such *observed force fields*, which requires presence of charged mass. Only potentials and potential structuring of the virtual particle flux exist in the vacuum (which is after all just potential comprised of virtual particle flux). Those structurings or their analogues also exist as sets of curved spacetime regions (i.e., spacetime structurings comprising the elements of the "vacuum engine"). See E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," Mathematische Annalen, Vol. 57, 1903, p. 333-355. Whittaker that any scalar potential decomposes into a multiplicity of longitudinal bidirectional flows of energy. This decomposition must also comprise the vacuum scalar potential, as well as the "spacetime curvature" potential.

[28] . However, Whittaker misinterpreted the *causal* phase conjugate wave (that half of his phase conjugate wavepair) as the *effect* after the wave interacts with charged mass, in which case parity is broken and the *effect* wave produced by the interaction is a longitudinal EM wave going in the opposite direction in 3-space from its "biwave" 3-space partner. The correct interpretation is that,

prior to interaction, the phase conjugate wave exists in the fourth axis of Minkowski 4-space, hence is in the time domain. It is literally a longitudinal EM wave moving on the fourth axis (in the time domain) to the interacting charge, and the other Whittaker biwave partner is the effect longitudinal EM wave emitted in 3-space by the interacting charge after it absorbs the incoming time-polarized EM wave. We point out that a longitudinal EM wave along the time axis is a time-polarized EM wave, corresponding to the known time-polarized photon in quantum field theory.

[29] . After publication of my "Giant Negentropy" paper, I discovered very strong support for my reinterpretation of Whittaker's 1903 decomposition of the scalar potential. This support was by F. Mandl and G. Shaw, ibid. Mandl and Shaw give a deeper coverage of the photon polarizations. They argue that the longitudinal and scalar polarizations individually are not directly observable, but only in combination, wherein they manifest as the "instantaneous" Coulomb (i.e., electrostatic) potential. Our comment is that this argument, translated from particle terminology to wave terminology, directly fits my re-interpretation of Whittaker's 1903 decomposition of the scalar potential. However, Mandl and Shaw fail to account for their assumed interaction of the detecting/observing unit point charge to perform the perfectly correlated "combining", and thus fail to account for the absorption of the incoming *causal* time-polarized wave or photon, the transduction of that excitation energy of the charge into longitudinal EM wave/photon energy in 3-space, and the subsequent emission of that excitation energy as a perfectly correlated longitudinal EM wave in 3-space.

Thus Mandl and Shaw missed the time-excitation charging of the source charge via absorption of the "coupled" time-polarized EM wave/photon, and the subsequent decay of the time-charge excited state by emission of a 3-space longitudinal EM wave/photon. This omitted interaction represents the discovery of nature's giant negentropy mechanism in EM energy flow, whenever 3-space energy flow symmetry is broken, as with a common dipole. So Mandl and Shaw do not account for photon (or wave) polarization transduction, where the "causal" time-polarized EM wave or photon comes in and is absorbed by the detecting charge or dipole to energetically excite it in the time-domain, then the excitation energy is re-emitted as the longitudinally polarized EM wave or photon in 3-space.

Recognition of these missing functions allowed at last a solution to the long-vexing problem of the source charge. We actually solved the problem for a source dipole, then pointed out that any "isolated" charge is a set of dipoles when its clustering virtual charges of opposite sign are considered.

[30]. The source charge problem was recognized as the most difficult problem in electrodynamics. E.g., see D. K. Sen, Fields and/or Particles, Academic Press, London and New York, 1968, p. viii. Quoting: *"The connection between the field and its source has always been and still is the most difficult problem in classical and quantum electrodynamics."* Since our proposed solution is consistent with particle physics (broken 3-symmetry of the dipole) and with quantum field theory (combination of the time-polarized and longitudinal photon comprises the scalar EM potential), it is robust and we believe it will stand up to meticulous scrutiny.

[31]. E. T. Whittaker, 1903, *ibid*.

[32]. Mandl and Shaw, *ibid*.

[33]. Poynting only assumed that diverged part of the energy flow. Heaviside, on the other hand, showed that there is a much larger energy

flow component that misses the intercepting charges (or circuit) altogether, and is wasted. Since this means that far more EM energy flows from the terminals of a generator than the external circuit intercepts and catches, it means that all generators produce more energy flow output than the textbook states, or that Poynting assumed. In fact, as *transducers of vacuum energy*, all dipolar generators already exhibit COP>1.0. Since no one in the 1880s could explain where such an astounding extra energy flow was coming from, Lorentz originated an integration trick to discard the nondiverged Heaviside EM energy flow component.

(a) See J. H. Poynting, "On the transfer of energy in the electromagnetic field," Philosophical Transactions of the Royal Society of London, Vol. 175, Part II, 1885, p. 343-361.

(b) See Oliver Heaviside, "Electromagnetic Induction and Its Propagation," The Electrician, 1885, 1886, 1887, and later—a series of 47 sections, published section by section in numerous issues of The Electrician during 1885, 1886, and 1887.

(c) See also Oliver Heaviside, "On the Forces, Stresses, and Fluxes of Energy in the Electromagnetic Field," Phil. Trans. Roy. Soc. London, 183A, 1893, p. 423-480.

(d) For Lorentz' trick to discard the nondiverged component, see H. A. Lorentz, Vorlesungen über Theoretische Physik an der Universität Leiden, Vol. V, Die Maxwellsche Theorie (1900-1902), Akademische Verlagsgesellschaft M.B.H., Leipzig, 1931, "Die Energie im elektromagnetischen Feld," p. 179-186. Figure 25 on p. 185 shows the Lorentz concept of integrating the Poynting vector around a closed cylindrical surface surrounding a volumetric element. This is the procedure which arbitrarily selects only a small component of the energy flow associated with a circuit—specifically, the small Poynting component striking the surface charges and being diverged into the circuit to power it—and then treats that tiny component as the "entire" Poynting energy flow. Thereby Lorentz arbitrarily discarded all that extra Heaviside energy transport component which does not strike the circuit at all, and is just wasted.

[34] . In fact, the simple equation W = ϕq, where W is the diverged/collected energy, q is the intercepting coulomb, and ϕ is the reaction cross section of the potential, shows that electrodynamicists implicitly assume the “true” causal potential to contain unlimited energy. E.g., using that equation, any desired amount W of energy can be collected from any nonzero potential ϕ, no matter how small its intensity, simply by adding sufficient intercepting/collecting charges.

[35] . A back-of-the-envelope calculation for a nominal simple circuit has been made and previously presented by the present author. In the nominal circuit used, the source dipole extracts from the vacuum and sends down the outside of the attached circuit about 10^{13} times as much energy as the circuit itself intercepts, diverges, and utilizes. The huge remainder is not intercepted, remains nondivergent and just passes on out into space at the speed of light.

[36] . Solving the standard equation **E** = **F**/q for **F**, one has **F** = **E**q. Again, from any nonzero **E**-field, no matter how small, as much force can be “gathered” and produced as one desires, merely by increasing the intercepting/collecting charge q.

[37] . Robert H. Romer, "Heat is not a noun," American Journal of Physics, 69(2), Feb. 2001, p. 107-109. This is an editorial discussion by the Editor of AJP of the concept of heat in thermodynamics. Heat is not a substance, not a thermodynamic function of state, and should not be used as a noun. The quotation castigating the standard "field diagram" of an EM wave in space is

from endnote 24, p. 109.

[38] . This is readily understood when one realizes that the founders of electromagnetics assumed a material ether. So to them, there was not a single point in all the universe where mass was absent! Hence the field, potential, and wave "in space" were actually the field, potential, and wave "in the material ether medium", and therefore perfectly material. Even though the Michelson-Morley experiments falsified the material ether in the 1880s, the electrodynamicists (i) never changed their classical EM equations which still to this day assume the material ether filling all space, and (ii) still implicitly mistake the transverse electron precession wave in the Drude gas in a receiving antenna as representing the assumed interception of the incoming "transverse EM wave" in that external material ether medium.

[39] . Robert Bruce Lindsay and Henry Margenau, Foundations of Physics, Dover Publications, New York, 1963, p. 283-287, and passim.

[40] . Y. Aharonov and D. Bohm, "Significance of Electromagnetic Potentials in the Quantum Theory," Physical Review, Second Series, 115(3), 1959, p. 485-491. However, Aharonov and Bohm seem to have missed the similar mass interpretation of the potential, so that they utilized the potential as massless and therefore the vacuum EM entity that is the primary cause of all EM phenomena. If one truly eliminates only the potential’s effect upon the intercepting charged mass, and utilizes the non-intercepted EM entity in vacuum, one has arrived at the direct alteration of the massless spacetime geometry of general relativity. In short, suddenly one has latched onto a unified field theory, and one that is engineerable by surprising electromagnetic means.

[41] . But erroneously assumed to be present, because of Maxwell's ubiquitous use of the material ether and the continued implied material ether in the electrodynamics equations to this day.

[42] . T. W. Barrett, "Tesla's Nonlinear Oscillator-Shuttle-Circuit (OSC) Theory," Annales de la Fondation Louis de Broglie, 16(1), 1991, p. 23-41. Barrett analyzed Tesla's patented circuits in terms of quaternion electrodynamics, which is of higher symmetry than either vector or tensor algebra electrodynamics. Lo and behold, Tesla could shuttle potential energy around in his circuits at will, and that functioning would not even show up in a tensor or vector electrodynamic analysis.

[43] . T. W. Barrett, "Active Signalling Systems," U.S. Patent No. 5,486,833, Jan. 23, 1996; — Oscillator-Shuttle-Circuit (OSC) Networks for Conditioning Energy in Higher-Order Symmetry Algebraic Topological Forms and RF Phase Conjugation," U.S. Patent No. 5,493,691, Feb. 20, 1996.

[44] . As the reader can appreciate, this represents a dramatic change to the foundations of electrodynamics. It is closely allied to Sachs's unified field theory; see appropriate Sachs references in this paper.

[45] . As Dirac pointed out, the Michelson-Morley experiments of the 1880s destroyed the *material* ether assumed by Faraday and Maxwell and subsequent electrodynamicists; it *did not* destroy the ether per se. Dirac emphasized that any nonmaterial Lorentz-invariant ether is perfectly consistent with the Michelson-Morley experiments. General relativity describes the shaping and structuring of the vacuum as curvatures of spacetime geometry and clustered patterns thereof (although the latter part is essentially neglected). GR consists of the changes

of this spacetime due to the interaction of mass/trapped energy, and also the forces upon mass/trapped energy created by the interaction of such curvature-patterns of spacetime. Essentially, electrodynamics is missing just this "mass to spacetime" transform and this "spacetime to mass" transform. It is in fact missing its "infolded general relativity" dynamic internal structuring of the potential, field, and wave. KGB energetics weapon scientists call these missing transforms *the information content of the field*—which our fellows mistakenly interpret in their own flawed electrodynamics as "spectral content." Nothing could be further from the truth.

[46] . In 1903 E. T. Whittaker showed that any scalar potential is comprised of an infinite harmonic series of bidirectional longitudinal EM waves, arranged in bidirectional wavepairs. See E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," Mathematische Annalen, Vol. 57, 1903, p. 333-355.

[47] . General relativity usually stops short of including an "infolded" topology within its basic spacetime, and only applies an "exterior" topology to it. However, it does not exclude that capability. Spacetime is just potential identically, and also just vacuum identically. Since GR omits the infolding structure of spacetime/potential, and so does electrodynamics, it has not been possible to unify the two completely. The "bridge" across the chasm between them has been eliminated by both disciplines.

[48] . With finite propagation, this action-at-a-distance is retarded so that some time passes between the effect and the cause. Each Mandl-Shaw photon interaction—the receipt of the scalar (time-polarized) photon, and emission of 3-space longitudinal photon—is retarded by (requires) the amount of time that is transformed into 3-space energy. [Time may be regarded as 3-space

electromagnetic energy compressed by the factor c^2, with the compressed energy placed on the fourth Minkowski axis to appear as time (seconds), rather than being left in 3-space to appear as mass).

Transformation from time-domain EM energy to 3-space energy is a function of the spin of the charge, which "spins" 720 degrees, being 360 degrees in the time domain while absorbing the time-polarized EM photon energy, the being followed by 360 degrees in 3-space while it is emitting the 3-space longitudinal photon. This retardation due to transformation of the energy from the time domain to the 3-space domain is what limits the speed of light in the ambient vacuum to the finite velocity c.

However, when infinite velocity propagation occurs (as is permissible with longitudinal EM waves alone, which a priori implies no retardation), then the notion vanishes of a “cause” and an “effect” separated by a time interval. In that case, one is operating in a multiply-connected spacetime, where in theory there is no observable “length” or “time” between the “cause” event and the “effect” event. Further, one “causative” initiation point can be superposed simultaneously with multiple distant points widely separated in ordinary spacetime. In that case, putting a joule of energy into the “initiating cause” point (to the normal 3-space observer) results in the simultaneous appearance at each and every distant participating point, of one joule. To the normal "singly-connected spacetime" observer, this is a direct amplification of energy, directly from the vacuum energy itself. We have proposed this mechanism as an extension of Bohm’s quantum potential utilized in his hidden variable theory of quantum mechanics. See David Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of 'Hidden' Variables, I and II," Physical Review, 85(2), Jan. 15, 1952, p. 166-179 (Part I); 180-193 (Part II). Unfortunately three nations of the world have already seen fit to highly weaponize this effect, and a fourth nation is very close to deploying such a weapon. Presently quantum potential weapons are the dominant weapons on earth, and nothing can stand against them.

[49] . By conjugate pair, we mean that the wavepair consists of an EM longitudinal wave and its time-reversed twin, precisely superposed spatially but antiphased in time. In such a wave, the transverse energy density amplitude cannot vary; instead, the wave consists of (and carries) an oscillation of the rate of flow of time, about some median speed. The median speed of a longitudinal EM wave is not confined to the speed of light in vacuum.

[50] . The value of the energy continuously collected from a steady potential, in a "swirl" around a fixed intercepting charge, is of course a fixed scalar. That, however, has nothing to do with the nature of the potential as an EM entity in massless vacuum, prior to interaction with charged mass.

[51] . J. D. Jackson, Classical Electrodynamics, Second Edition, Wiley, 1975, p. 223.

[52] . Interestingly, one also cannot produce a clear definition of *energy* in physics. A good discussion of the energy concept is given by R. B. Lindsay, "The concept of energy and its early historical development." Foundations of Physics, 1 (4), 1971, p. 383-393. Lindsay investigates the concept of energy from its early historical origin, and covers from ancient times through the 18th century. The root of the concept is the notion of invariance in the midst of change. In short, the concept consists of considering "the changing" as being "nonchanging." In pursuing a rigorous definition of anything, one eventually arrives at a contradiction of Aristotelian logic. Ultimately one can only define something as identical to its own opposite. Geometry, e.g., models the presence of

mass as the absence of mass. Ultimately a “hard definition” is an “accursed necessity for the identity of opposites”—the centuries-old bane of the philosophers. In physics the problem is avoided by the “duality principle”—just treat an entity as either a particle or wave as necessary, and quit arguing about it! The problem is the incompleteness of Aristotelian logic itself. A solution to the “identity of opposites” problem is obtained by explicitly adding a fourth law of logic that has always been implicitly assumed in Aristotle’s three laws. For a discussion, see “A Conditional Criterion For Identity, Leading to a Fourth Law of Logic,” Appendix III to T. E. Bearden, Aids: Biological Warfare, Tesla Book Co., 1988, p. 428-443. A simple proof of the fourth law of logic is given in *ibid*., p. 439-440.

[53]. In addition to reference 19, see Myron W. Evans, Enigmatic Photon, Vol. II, Kluwer, ISBN 0792332881. See also Apeiron, 4(2-3), Apr.-Jul. 1997, a Special $B^{(3)}$ Field Issue, Guest editor: Myron W. Evans. In this same issue, see the Introduction by Evans, and also his “Helicity and the Electromagnetic Field.” In the same issue, see also Jean-Pierre Vigier, “Relativistic Interpretation (with Non-Zero Photon Mass) of the Small Ether Drift Velocity Detected by Michelson, Morley, and Miller." Barrett has also rigorously shown the reality of the $B^{(3)}$ field, and so the conventional closure against it is doomed to failure. The emergence of $B^{(3)}$ field theory will dramatically alter electrodynamics, and elevate the importance of the longitudinal EM wave. We are also much indebted to Bob Flowers for his penetrating elucidation of the background of the $B^{(3)}$ field in private communications, and to Myron Evans for his patient and encouraging private communications.

[54]. See particularly T. W. Barrett, "Sagnac Effect: A Consequence of Conservation of Action Due to Gauge Field Global Conformal Invariance in a Multiply-Joined Topology of Coherent Fields," in T. W. Barrett and D. M Grimes, [Eds.], Advanced Electromagnetism: Foundations, Theory,

& Applications. World Scientific, River Edge, New Jersey, 07661, 1995, p. 278-313; T. W. Barrett, "Electromagnetic Phenomena Not Explained by Maxwell's Equations," in A. Lakhtakia, (ed.): Essays on the Formal Aspects of Electromagnetic Theory, World Scientific Publishing, River Edge, NJ, 1993, p. 6-86.

[55] . Richard W. Ziolkowski, "Exact Solutions of the Wave Equation With Complex Source Locations," Journal of Mathematical Physics, 26 (4), April 1985, p. 861-863; I.M. Besieris, A.M. Shaarawi, and R. W. Ziolkowski, "A bidirectional travelling plane wave representation of exact solutions of the scalar wave equation," Journal of Mathematical Physics, 30(6), 1989, p. 1254-1269; Rod Donnelly and Richard Ziolkowski, "A method for constructing solutions of homogeneous partial differential equations: localized waves," Proceedings of the Royal Society of London A., Vol. 437, 1992, p. 673-692; — "Electromagnetic field generated by a moving point charge: A fields-only approach," American Journal of Physics, 62 (10), Oct. 1994, p. 916-922.

[56] . M. W. Evans, editor, Modern Nonlinear Optics, Wiley, 2002, 3 volumes (in press).

[57] . W. A. Rodrigues Jr. and J.-Y. Lu, “On the existence of undistorted progressive waves (UPWs) of arbitrary speeds $0 \leq v < \infty$ in nature,” Foundations of Physics, 27(3), 1997, p. 435-508; W. A. Rodrigues Jr. and J. E. Maiorino, “A unified theory for construction of arbitrary speeds ($0 \leq v \leq \infty$) solutions of the relativistic wave equations,” Random Operators and Stochastic Equations, Vol. 4, 1996, p. 355-400.

[58] . E. T. Whittaker, 1903, *ibid.*

[59] . Ironically, Maxwell’s actual theory was some 20 quaternion-like equations in 20

unknowns, as given in "A Dynamical Theory of the Electromagnetic Field," Royal Society Transactions, Vol. CLV, 1865, p 459. Read Dec. 8, 1864. Also contained in The Scientific Papers of James Clerk Maxwell, 2 vols. bound as one, edited by W. D. Niven, Dover, New York, 1952, Vol. 1, p. 526-597. Heaviside dramatically curtailed Maxwell's theory to a vector subset of some 4 equations in 4 unknowns. Lorentz further curtailed it by effectively throwing out all Maxwell-Heaviside systems that were in disequilibrium with their active vacuum and curved spacetime environments. So after over a century, the long slumbering *environmental* dynamics for electrodynamical systems is awakening and chasing its own roots again. Long live the rise of the supersystem!

[60] . E.g., see J. Vaz Jr. and W. A. Rodrigues Jr., "Maxwell and Dirac Theories as an Already Unified Theory," Advances in Applied Clifford Algebras, Vol. 7 (S), 1997, p. 369-386. See W. A. Rodrigues, Jr. and J. Vaz Jr., "Subluminal and Superluminal Solutions in Vacuum of the Maxwell Equations and the Massless Dirac Equation," Advances in Applied Clifford Algebras, Vol. 7(S), 1997, p. 457-466.

[61] . E. T. Whittaker, 1904, *ibid*.

[62] . We strongly stress that longitudinal EM waves and their dynamics, so ignored in all except the most advanced higher symmetry electrodynamics texts, are actually the key to everything. Longitudinal EM waves already comprise, create, and structure the feeble "envelope EM waves" we presently deal with. A longitudinal EM wave is also an electrogravitational wave, and oscillates the rate of flow of time itself because of its combination with a time-polarized wave. The two combined photons have a total spin two, which is a graviton. Thus internally a graviton is revealed as a particular

dynamic between time-domain EM energy and 3-space EM energy. The longitudinal EM wave in the time domain (that is combining with the longitudinal EM wave in 3-space) is thus an oscillation of time contraction and expansion, or "pulsation" in the rate of flow of time. Very powerful gravitational effects as well as very powerful and unique electrodynamics effects can be obtained by use of longitudinal EM waves, because of the additional dynamics between the time and 3-space domains. Unwitting use of such extraordinary EM waves is how Rife and Prioré achieved such remarkable results.

[63]. M. W. Evans, P. K. Anastasovski, T. E. Bearden et al., "On Whittaker's Representation of the Electromagnetic Entity in Vacuo, Part V: The Production of Transverse Fields and Energy by Scalar Interferometry," Journal of New Energy, 4 (3), Special Issue, Winter 1999, p. 76-78.

[64]. Melba Phillips, “Classical Electrodynamics,” Vol. IV: Principles of Electrodynamics and Relativity, in Encyclopedia of Physics, Edited by S. Flugge, Springer-Verlag, Berlin, 1962, p. 1-108 gives a good overall summary of the superpotential theory.

[65]. A. Righi, Nuovo Cimento, Vol. 2, No. 5, 1901, p. 104.

[66]. P. Debye, Ann. Phys., Leipzig, Vol. 30, 1909, p. 57.

[67]. Thomas John I'Anson Bromwich, An Introduction to the Theory of Infinite Series, MacMillan, London, 1908.

[68]. A. Nisbet, Physica, Vol. 21, 1955, p. 799; Proc. Roy. Soc. Lond. A, Vol. 231, 1955, p. 250.

[69]. W. H. McCrea, “Hertzian electromagnetic

potentials," Proc. Roy. Soc. Lond. A, Vol. 240, 1957, p. 447-457.

[70]. Sachs has achieved the necessary unified field theory, broadly unifying physics from the quarks and gluons to the entire universe, and including both the active vacuum and active, locally curved spacetime. See Mendel Sachs, General Relativity and Matter: A Spinor Field Theory from Fermis to Light-Years (Fundamental Theories of Physics), Reidel (now Kluwer), 1982; — Quantum Mechanics from General Relativity: An Approximation for a Theory of Inertia, Reidel (now Kluwer), 1986. It should be obvious that, unless electrodynamics theory and general relativity theory utilize the same background spacetime, it is impossible to completely merge them, from first principles. Since classical electrodynamics artificially discards its active environment, it is electrodynamics which must be changed in order to be successfully united with general relativity. Sachs has accomplished this long-sought *engineerable* unification.

[71]. Proof that the virtual state can be coherently integrated is already furnished by every source charge in the universe, which does precisely that.

[72]. We note without elaboration that all the mind functions, even of the deepest and most unconscious nature, and even of collective species unconsciousness domains—exist electromagnetically in the infolded EM domain. The "conscious mind" is a serial processor, though extremely rapid. The unconscious is a massively parallel processor. The reason the conscious mind cannot "directly see" the unconscious is that "seeing" innumerable things in the "single snapshot" at once, just obliterates all singular discrimination because of the intense summation. Mind functions are timelike, so consist of specialized structures, functioning, and dynamics

inside the time domain. Since the infolded structuring captures this entire domain, it also involves a physics of mind and matter interaction, but as a science instead of as a mysticism. In theory vacuum engines are also possible that engineer the mind at any and all levels. We have addressed this extended physics of mind and matter reactions elsewhere and do not address it here. The Russian weapon scientists refer to this mind area (which can also be engineered by novel electrodynamic means) as psychoenergetics.

[73] . R. O. Becker and David G. Murray, "The electrical control system regulating fracture healing in amphibians," Clinical Orthopaedics and Related Research, Vol. unk, No. 73, Nov.-Dec. 1970, p. 169-198. This is the definitive technical exposition by Becker of his electrical findings about the cellular control system.

[74] . See particularly Robert O. Becker, “The direct current control system. A link between environment and organism,” New York State Journal of Medicine, Vol. 62, 1962, p. 1169-1176; — and Joseph A. Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bulletin of the New York Academy of Medicine, Second Series, 48(4), May 1972, p. 627-641; — and Carlton F. Hazlewood, Abraham R. Liboff, and Jan Walleczek, Electromagnetic Applications In Medicine," NIH-OAM Electromagnetics Panel Report, Jan. 15, 1993; — "A technique for producing regenerative healing in humans," Frontier Perspectives, 1(2), Fall/Winter 1990, p. 1-2; — and Andrew A. Marino. Electromagnetism and Life, State University of New York Press, Albany, NY, 1982; — and Gary Selden, The Body Electric, William Morrow and Company, New York, 1985; — Cross Currents, Jeremy P. Tarcher, Inc., Los Angeles, 1990; — "The bioelectric field pattern in the salamander and its stimulation by an electronic analog," IRE Transactions on Medical Electronics, Vol. ME-7, July 1960, p. 202-207; —

"Some observations indicating the possibility of longitudinal charge-carrier flow in peripheral nerves," Biological Prototypes and Synthetic Systems, Plenum Press, New York, 1962, p. 31-37; — and W. Slaughter, "The longitudinal direct current gradients of spinal nerves," Nature, Vol. 196, Nov. 17, 1962, p. 675-676; — and Charles H. Bachman and Howard Friedman, The direct current (control) system: A link between the environment and the organism," New York State Journal of Medicine, Vol. 62, April 15, 1962, p. 1169-1176; — "The direct current field: A primitive control and communication system related to growth processes," Proceedings of the. XVI International. Congress of Zoology, Washington, D.C., Vol. 3, 1963, p. 179-183; — "The neutral semiconduction control system and its interaction with applied electrical current and magnetic fields," Proc. 11th International. Cong. Radiol., Amsterdam, Excerpta Medica Foundation, 1966, Series 105, p, 1753-1759; — "The bioelectric factors in amphibian limb regeneration," The Journal of Bone and Joint Surgery, Vol. 43-A, No. 5, July 1961, p. 643-656; — and David G. Murray, "A method for producing cellular dedifferentiation by means of very small electrical currents," Transactions, New York Academy of Sciences, 29(5), Mar. 1967, p. 606-615.

[75] . The ultimate tool for use in seeing and working with this "infolded" or "internal electrodynamics inside normal EM fields, waves, and potentials will probably be the Fogal semiconductor when it goes into production in the near future. Fogal's transistors are capable of (1) infolding the desired longitudinal EM waves inside normal EM signals (he demonstrates infolding TV signals inside pure DC potentials, and transmitting them over conductors as pure DC potentials for appreciable distance, then using his semiconductors to again extract the "infolded" hidden TV signals.

[76] . See Vlail Kaznacheyev, "Electromagnetic

Bioinformation in Intercellular Interactions," Psi Research, 1(1), Mar. 1982, p. 47-76; — *et al*., "Distant intercellular interactions in a system of two tissue cultures," Psychoenergetic Systems, 1 (3), Mar. 1976, p. 141-142; "A Comment" by William A. McGarey, p. 143; "A Comment" by Arthur C. Hastings, p. 143-144, — *et al*., "Apparent information transfer between two groups of cells," Psychoenergetic Systems, 1(1), Dec. 1974. See particularly Vlail P. Kaznacheyev and L. P. Mikhailova, Ultraweak Radiations in Intercellular Interactions [in Russian], Novosibirsk, 1981; "Electromagnetic Bioinformation in Intercellular Interactions," Novosibirsk, 1981 [in Russian]; V. P. Kaznacheyev, "Information Function of Ultraweak Light flows in Biological Systems," Problems in Biophysics, Novosibirsk, 1967, p. 7-18 [in Russian].

[77] . Some years ago we documented this disease-inducing "microwave radiation of the U.S. Embassy, explained its purpose and operational mechanism, and published it. E.g., see T. E. Bearden, AIDS: Biological Warfare, Tesla Book Co., Chula Vista, CA, 1988.

[78] . See Robert C. Mallieu, A Model of the Microwave Intensity Distribution Within the U.S. Embassy, Moscow 1966-1967, Report FS-80-166, Applied Physics Laboratory, Johns Hopkins University, Baltimore, Maryland, Aug. 1980. Also see Microwave Radiation at the U.S. Embassy in Moscow and Its Biological Implications: An Assessment, U.S. Department of Commerce, Doc. # NTIA-SP081-12, Mar. 1981. Also see Captain John D. LaMothe, Controlled Offensive Behavior—USSR, Report ST-CS-01-169-72, Defense Intelligence Agency, Washington, D.C. (released under FOIA). See also Captain John D. LaMothe and Mr. Louis Maire, Soviet and Czechoslovakian Parapsychology Research, Report DST-1810S-387-75, Defense Intelligence Agency, Washington, D.C. (Released under FOIA).

[79] . T. E. Bearden, "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves," Journal of New Energy, 3(2/3), 1998, p. 12-28. A slightly updated and extended version is published in Explore, 8(6), 1998, p. 7-16.

[80] . C. W. Misner, K. S. Thorne and J. A. Wheeler, Gravitation, W.H. Freeman and Co., San Francisco, 1973, p. 5, 19-21, 71-72, 163-165, 390-391, 399; 367-369.

[81] . T. D. Lee, Particle Physics and Introduction to Field Theory, Harwood, New York, 1981. See particularly Chapter 25: Outlook, "Possibility of Vacuum Engineering," p. 824-828.

[82] . David J. Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of 'Hidden' Variables, I and II," Physical Review, 85 (2), Jan. 15, 1952, p. 166-179 (Part I); 180-193 (Part II).

[83] . I.e., the rate of flow of time, or more specifically, the rate of the EM interactions with a mass or particle that generate the flow of the mass or particle through time. See Figure 25. Nobelist Lee has also shown that time is a discrete dynamical variable across all of physics, from quantum mechanics to nonrelativistic field theory, to relativistic quantum field theory. See T. D. Lee, "Can Time Be a Discrete Dynamical Variable?", Physics Letters, 122B(3, 4), Mar. 10, 1983, p. 217-220. Also in T. D. Lee, Selected Papers, Gerald Feinberg, Ed., Birkhauser, Boston, 1986, Vol. 3, p. 77-80. So we have not hesitated to consider time as any other variable, and the fourth Minkowski axis as any of the other three axes with respect to EM energy, fields, potentials, and waves.

[84] . Indeed, there is no such unique thing as “the gravitational field” anyway! The gravitational field is a conglomerate of other field energies and

functions, not a separate field of nature. See A. A. Logunov and Yu. M. Loskutov, "Nonuniqueness of the predictions of the general theory of relativity," Sov. J. Part. Nucl., 18(3), May-June 1987, p. 179. See C. W. Misner, K. S. Thorne and J. A. Wheeler, Gravitation, W.H. Freeman and Co., San Francisco, 1973, p. 399. Quoting*: "The terms 'gravitational field' and 'gravity' refer in a vague, collective sort of way to all of these entities. Another, equivalent term for them is the 'geometry of spacetime'.“* See also A. D. Sakharov, "Vacuum Quantum Fluctuations in Curved Space and the Theory of Gravitation," Soviet Physics Doklady, Vol. 12, No. 11, 1968, p. 1040-1041 [English translation.]. Finally, see our remarks under reference 62 above, particularly with respect to the proposed internal electromagnetic dynamics of the graviton.

[85] . A 1993 study by the Office of Technology Assessment, delivered to Congress, showed that a single terrorist in a small plane, with a tank of anthrax spray, and dispersing the spray as he flew around the greater Washington D.C. area on a calm night, would produce between 1 and 3 million casualties. Most of those casualties would die. So a single biological warfare (BW) strike in one U.S. metropolitan area could easily kill two million Americans. As an example, Saddam Hussein is known to have the terrorist teams and the anthrax, and he has had a decade since the Gulf war to insert additional teams and biological warfare agents into the U.S. Presently this is rated by our government as the strongest strategic threat to the U.S., after which comes nuclear strikes, followed by chemical agent strikes. Redevelopment of the Prioré approach, e.g., could easily save the lives of 90% of that nominal two million dead Americans. As matters stand now, triage would apply and almost all of those two million stricken Americans would die.

[86] . In 1998 we proposed a crash development of this kind of device in 1998, with copies to DoD,

NIH, CDC, the USAF, etc.; in T. E. Bearden, Energetics: Extensions to Physics and Advanced Technology for Medical and Military Applications, CTEC Proprietary, May 1, 1998, 200+ page inclosure to CTEC Letter, “Saving the Lives of Mass BW Casualties from Terrorist BW Strikes on U.S. Population Centers,” to Major General Thomas H. Neary, Director of Nuclear and Counterproliferation, Office of the Deputy Chief of Staff, Air and Space Operations, HQ USAF, May. 4, 1998. Also to Gen. (Ret.) Walter Busby, Deputy Secretary of Defense for Counterproliferation and Chemical and Biological Defense, March 21, 1998. Also to NIH, CDC, and several other U.S. government agencies.

DoD replied that it was not documented in the literature (a specific list of exact scientific papers reporting the results of the Prioré team's experiments and the experiments of Becker was included; no one seemed to read it). CDC and the USAF did not reply. NIH first responded (from its Policy section—read, *spin control* section) that, since I mentioned the cause of the Gulf War Disease and how it was induced, it was not a matter of their interest but of DoD's interest, and so they just shipped it to DoD and got rid of it. A second response evoked from NIH on query from my congressman (again, a response from their *policy* section) directed me to their proposals section. I don't believe a single qualified scientist even read it. DoD weakly replied that it was not documented in the literature (a specific list of citations from the hard French scientific literature, reporting the astounding results of the Prioré treatments, was included, which apparently no one read).

Not a single scientist from any agency called me to discuss the revolutionary and proven results obtained by Prioré, and documented in the attachments and in the cited literature. Sadly, it seems that no one had the foggiest notion what I was talking about, and no one much cared. My conclusion was and is that my own government bureaucrats do not give a tinker's dam about saving millions of American casualties in the coming debacle, *if it has to be done by "out-of-the-box" methods not approved by the big drug industry*. Yet these are the same officials that readily admit the exact threat I referred to, admit that it is a matter of *when* the biological warfare attacks will occur and not *if*, and admit that right now they have no effective way to cope with it or save most of those coming millions of Americans that are going to just be dragged aside to die.

My response is that the American taxpayers are certainly not getting their money's worth from the billions they shower on our medical research community. It is unconscionable to ignore for over 30 years the demonstrated and astounding results achieved by eminent French scientists—such as Pautrizel, a world-renowned parasitologist and Courier, head of the French Academy's Biological Section, and also *Secretaire Perpetuel* of the Academy) working with the Prioré team, in curing terminal tumors etc. in thousands of lab animals, all properly documented in the hard French scientific literature.

In my view, considering the certainty of those future American mass deaths, it is akin to high treason. Whether our scientific community realizes it or not, today's strategic war of massive strategic strikes has shifted to our civilian populace, and to our cities and mass population centers. It is our civilian populace that will sustain the greatest and most prompt casualties, and probably will receive the first massive strikes, totally by surprise.

The first phase of WW III—delivery of the strategic weapons to their strategic targets—has already been accomplished. Large Russian nuclear weapons are already hidden in our major cities and population centers (read Lunev's book, he tells us how they brought in these weapons), the Spetznaz teams are here to detonate them on call, multiple nations such as Iraq, Libya, and Iran already have terrorists agents in country in the U.S. with anthrax and smallpox in hand to be released, and Castro guerrillas and trained saboteurs have been trained in Southern Mexico and infiltrated across the border into the U.S. for decades.

Whether they like it or not, U.S. scientists have thus become the major front line "soldiers" and "defenders" of our nation. And frankly, they have failed abominably in their responsibility, and most do not seem to care. For a startling and even shocking characterization of our present scientific community, the reader is referred to Daniel S. Greenberg, Science, Money, and Politics: Political Triumph and Ethical Erosion, University of Chicago Press, 2001.

[87]. As we stated, just such an attack is now officially the greatest strategic threat to the United States. Second is a nuclear attack, followed by chemical attack as a distant third. E.g., see Richard K. Betts, “The New Threat of Mass Destruction,” Foreign Affairs, 77(1), Jan./Feb. 1998, p. 26-41. For the ineffectiveness of our defenses against the coming mass biological warfare strikes, see Laurie Garrett, The Coming Plague: Newly Emerging Diseases in a World Out of Balance, Farrar, Straus and Giroux, New York, 1994; — "The Nightmare of Bioterrorism," Foreign Affairs, 80(1), Jan./Feb. 2001, p. 76-89; — Betrayal of Trust: The Collapse of Global Health, Hyperion, New York, 2000.

[88]. Becker, *ibid*.

[89]. A full account of the entire Prioré affair is given in Jean-Michel Graille, Dossier Prioré: Une Nouvelle Affaire Pasteur [The Prioré Dossier: A New Pasteur Affair?], De Noel, Paris, 1984. [in French]. A summary account is given by Christopher Bird, "The Case of Antoine Prioré and His Therapeutic Machine: A Scandal in the Politics of Science," Appendix I in T.E. Bearden, AIDS: Biological Warfare, Tesla Book Co., P.O. Box 121873, Chula Vista, California 91912, 1988. Prioré's doctoral thesis (in my personal possession courtesy of Professor Courrier and the late Chris Bird), was rejected by the University of Bordeaux

when the French government suppressed the Prioré program in the mid-70s; it is A. Prioré, Guérison de la Trypanosomiase Expérimentale Aiguë et Chronique par L'action Combinée de Champs Magnétiques et D'Ondes Electromagnétiques Modulés. [Healing of intense and chronic experimental trypanosomiasis by the combined action of magnetic fields and modulated electromagnetic waves], 1973. Prioré's patents are: A. Priore, "Apparatus for producing radiations penetrating living cells," U.S. Patent No. 3,368,155, Feb. 6, 1968; — "Method of producing radiations for penetrating living cells," U.S. Patent No. 3,280,816, Oct. 25, 1966; — "Procede et dispositif de production de rayonnements utilisables notamment pour le traitement de cellules vivantes," [Procedure and Assemblage for Production of Radiation Especially Serviceable for the Treatment of Living Cells], Republique Francais Brevet d'Invention P.V. No. 899.414, No. 1,342,772, Oct. 7, 1963. Eleven years after Priore's thesis was rejected, the same university awarded a doctoral thesis to a young graduate. It is Eric Perisse, Effets des Ondes Electromagnètiques et des Champs Magnètiques sur le Cancer et la Trypanosomiase Experimentale [Effects of Electromagnetic Waves and Magnetic Fields on Cancer and Experimental Trypanosomias], Doctoral thesis, University of Bordeaux No. 83, March 16, 1984.

[90] . F. A. Popp *et al.*, "Biophoton Emission (Multi-Author Review)," Experientia, Vol. 44, 1988, p. 543-600; — "Biophoton emission: New evidence for coherence and DNA as a source," Cell. Biophys., Vol. 6, 1984, p. 33-52; — "Physical aspects of biophotons." Experientia, Vol. 44, 1988, p. 576-585; — Recent Advances in Biophoton Research and its Applications, World Scientific Publishing Co., New York, NY, 1992; F. A. Popp, "Photon Storage in Biological Systems," in Fritz Albert Popp *et al.*, eds., Electromagnetic Bio-Information: Proceedings of the Symposium,

Marburg, Federal Republic of Germany, Sep. 5, 1977; Urban & Schwarzenberg, Baltimore, 1979, p. 123-149.

[91] . David M. Rorvik, "Do the French have a Cure for Cancer?", Esquire Magazine, July 1975, p. 110-111, 142-149.

[92] . Arguably the best introduction to nonlinear optical phase conjugation is David M. Pepper, "Nonlinear Optical Phase Conjugation," Optical Engineering, 21(2), March/April 1982, p. 156-183. Another very good presentation is Amnon Yariv, Optical Electronics, 3rd Edition, Holt, Rinehart, and Winston, New York. 1985, Chapter 16: “Phase Conjugate Optics – Theory and Applications.”

[93] . A beautiful example of this “precise backtracking” of the time-reversed wave is given in David M. Pepper, "Applications of Optical Phase Conjugation," Scientific American, 254(1), Jan. 1986, p. 74-83. See particularly the striking photographic demonstration of time reversal of disorder on p. 75.

[94] . We presented some general elements of this dramatic new extension to nonlinear optical phase conjugate pumping and to general relativity, at a graduate seminar, “On the Theory and Principles of EM Systems with COP>1.0”, given to interested graduates and faculty of the University of Louisville, on Nov. 20, 1997.

[95] . E.g., see Owen Flynn, "Parametric arrays: A new concept for sonar," Electronic Warfare Magazine, June 1977, p. 107-112.

[96] . This method of increasing signal-to-noise ratio and pulling hidden signals right up out of the noise, is widely used in signal processing in modern radars. Often signals buried more than 100

dB below the noise level are routinely “pulled out of the noise” and detected, using various forms of coherent summation.

[97] . Any potential decomposes into multiple wavepair sets. In each hidden wavepair, each of the two waves further decomposes into two potentials. Each of *those* potentials then further decomposes into multiple wavepair sets. And so on *ad infinitum*. Or one can start with any wave, decompose it into two potentials, each of those potentials into multiple biwave sets, and so on.

[98] . “Fractal” means self-similarity at all levels, so that patterning or “decomposition” at one level is similar to that at the higher and lower levels. For good overview discussions and applications, see particularly Gregoire Nicolis, “Physics of far-from-equilibrium systems and self-organization,” and Joseph Ford, “What is chaos, that we should be mindful of it?”, both in The New Physics, Paul Davies, editor, Cambridge University Press, Cambridge and New York, 1989, p. 316-347 and 348-371 respectively. More detailed technical references are cited in each article.

[99] . See Trevor James Constable, “You, Too, Can Photograph UFOs from Airliners,” Psychic Observer and Chimes, 37(3), May-June 1977; — The Cosmic Pulse of Life, Merlin Press, Santa Ana, CA, 1976.

[100] . The present author has two beautiful ultraphotographs taken by Joe Gambill using the special filtering approach. One is a photograph of a room, but with its contents of *two weeks earlier*, showing the room prior to the time the photograph was taken. The other is of a “ghost” form—very similar to a photograph obtained by George Meek under rigorous laboratory conditions—and clearly showing the energy form of a "haunted" lady's dead husband. The *interpretation* of these photographs

is of course open to scientific dispute, but the *photographs themselves* are impeccable and real.

[101] . Meek used filters open to UV and IR but opaque to the visible spectrum, on the fluorescent lights in his laboratory. He also used similar filtering on the camera lenses and camera flashes. Under rigorous laboratory conditions, in several thousand photos of the living body Meek was able to take a few highly anomalous photos completely inexplicable by normal science. E.g., he photographed a purported "ghost" and obtained a clear shot of energy streaming associated with a living person. He also photographed the legs of a chair, right through the suddenly "missing" legs of the person sitting in the chair. Again, interpretation is open to dispute, but the photographs are rigorous and real.

[102] . Bill Fogal's patented charge-blocking semiconductor—U.S. Patent Numbers 5,196,809 and 5,430,413—is capable under certain circumstances—and by clever adaptation—of amplifying virtual state information, in a manner somewhat similar to Rife's methodology, but far more easily engineered. When the process works, Bill reports that a clear photograph or video camera shot can be taken right through a solid brick wall, of the hidden scenery beyond. In electrodynamics, in a dielectric absorbing or emitting EM radiation (energy), the entire dielectric participates in each absorption and emission. Emitted light from an object thus carries an astoundingly complete set of little virtual state vacuum engines rigorously representing every part of the object, no matter how small, and all the internal dynamics. This means that the light from the scene beyond the wall strikes the wall on the other side, affecting all the material in the wall, including upon the observer's side, and inserting "dimensioning" from the scene beyond the wall. When light is emitted from the observer's side, the information content of the field representing the scene on the far side, is also part of

the information content of the field in the light emitted from the observer side of the wall and striking the camera and the observers eyes. This “dimensioning” continues in the signals in the camera and on through attached electronic circuitry. Since Fogal’s semiconductor can process such information content of the field in the proper circuitry and under favorable circumstances, the phenomenon is therefore permissible and can be technically explained. Using his transistor to transduce the dimensioned information into the visual band, Fogal *can* view a distant scene right through an intervening wall, when he gets everything “just right.” At this stage of development, however, the process and adjustment are difficult, just as Rife experience with his microscope. We are convinced that the forthcoming advent of Fogal semiconductors will revolutionize the study and treatment of disease and bodily disorders.

[103] .   However, highly advanced electrodynamics does consider the photon with far greater complexity than nuclear engineers such as the present author were introduced to! E.g., a deep discussion of photon polarization is given in F. Mandl and G. Shaw, Quantum Field Theory, Wiley, 1984 under the heading "covariant quantization of the photon propagator" in Chapter 5. As pointed out by Bob Flowers in a private communication, Mandl and Shaw argue that the longitudinal and scalar polarizations are not directly observable, but only in combination, where the combination manifests as the "instantaneous" Coulomb (i.e., electrostatic) potential. Most such books do argue that the extra components of the photon remain hidden, as does the virtual state. In this paper we have revealed how Rife discovered a process by means of which the virtual state can be observed in great detail.

[104] .   V. P. Kaznacheyev, "Electromagnetic Bioinformation in Intercellular Interactions," Psi

Research, 1(1), Mar. 1982, p. 47-76; — "Information Function of Ultraweak Light Flows in Biological Systems," in Problems in Biophysics, Novosibirsk, 1967, p. 7-18 [in Russian]; — and L. P. Mikhailova, Ultraweak Radiation in Intercellular Interactions, [in Russian], Novosibirsk, 1981; — *et al.*, "Apparent information transfer between two groups of cells," Psychoenergetic Systems, 1(3), Mar. 1976; — *et al.*, "Distant intercellular interactions in a system of two tissue cultures," Psychoenergetic Systems, 1(3), Mar. 1976, p. 141-142; "A Comment" by William A. McGarey, p. 143; "A Comment" by Arthur C. Hastings, p. 143-144.

[105]. Mitogenetic radiation was studied prior to WW II by Gurwich (spelling varies). See A. Gurwitsch and L. Gurwitsch, "L'Analyse mitogenetique spectrale [The Analysis of the mitogenetic spectrum]," in Andre Mayer, Exposés de Physiologie, [Studies in Physiology], Hermann & Cie, Paris, 1934. Part IV. [In French]. Studies have continued by Popp and others. E.g., see F. A. Popp *et al.*, "Biophoton Emission (Multi-Author Review)," Experientia, Vol. 44, 1988, p. 54 3-600; — "Physical aspects of biophotons." Experientia, Vol. 44, 1988, p. 576-585; — "Biophoton emission: New evidence for coherence and DNA as a source," Cell. Biophys., Vol. 6, 1984, p. 33-52. See Fritz Albert Popp; Ke-hsueh Li, and Qiao Gu, [eds.], Recent Advances in Biophoton Research and its Applications, World Scientific Publishing Co., New York, NY, 1992.

[106]. The conventional quantum mechanics assumes that, at the microscopic level, variation (e. g., in the probabilities assigned to interpret what is propagating in the Schrödinger equation) is assumed to be random. However, there is a problem. Big things must be made of little things. If we sum a set of "random" things based on Gibbs thermodynamics statistics, we cannot and will not get an organized "big thing" because we have

assumed total disorder (randomness) *a priori*. Adding heat does not produce cooling! So one falsifies the prevailing interpretation of quantum mechanics, whenever one observes a tree, a flower, the sun, or a human being. In short, there must exist a great unifying principle in nature of a coherent summation, from the "unobservable" virtual state to the observable state. Only in that fashion can there be an macroscopic order at all—and such macroscopic order is universally observed. We believe that the principle we have elucidated, as experimentally produced by Rife, may well be that long-sought universal ordering principle that is so sorely needed by quantum mechanics. Readers interested in the "missing quantum chaos" problem are referred to P. V. Elyutin, "The Quantum Chaos Problem," Sov. Phys. Usp., Vol. 31, No. 7, 1988, p. 597-622. Elyutin discusses the crisis in quantum mechanics because of the missing hidden order. Quantum mechanics is known to be wrong unless this order can be found, because otherwise it does not predict the ordered macroscopic universe. Other useful references are Ilya Prigogine, with T. Petrosky, "Quantum Chaos, Complex Spectral Representation and Time-Symmetry Breaking," Chaos, Solitons, and Fractals, Vol. 4, 1994, p. 311-359; and Robert Pool, "Quantum Chaos: Enigma Wrapped in a Mystery," Science, 243(4893), 1989, p. 893-895.

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The Tom Bearden Website

Rife's Microscope

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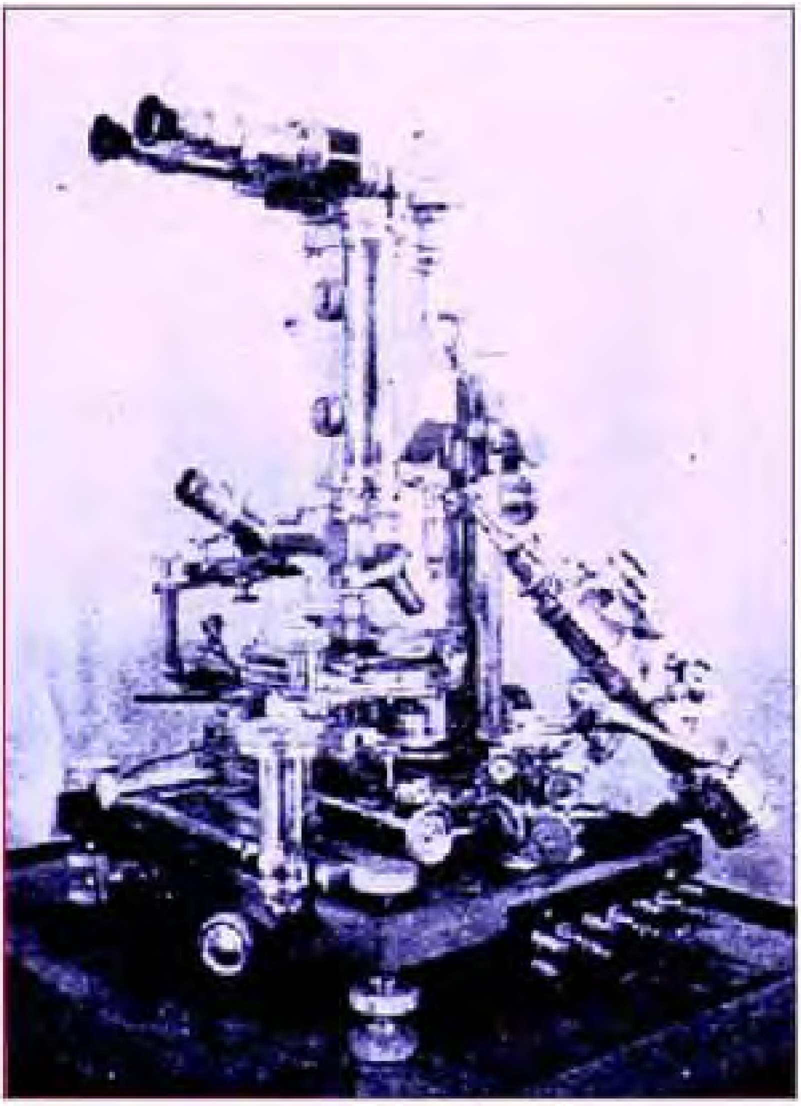

Figure 1. Rife's microscope.

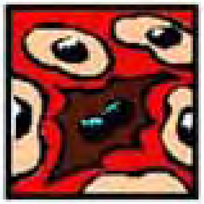

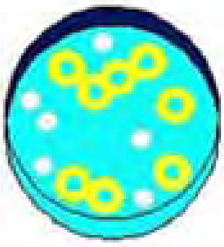

Figure 2. Royal Raymond Rife adjusts his microscope.

Air medium disturbances generated when air is perturbed by a plucked taut string

The string wave and the holder wave never leave the string and holder respectively.

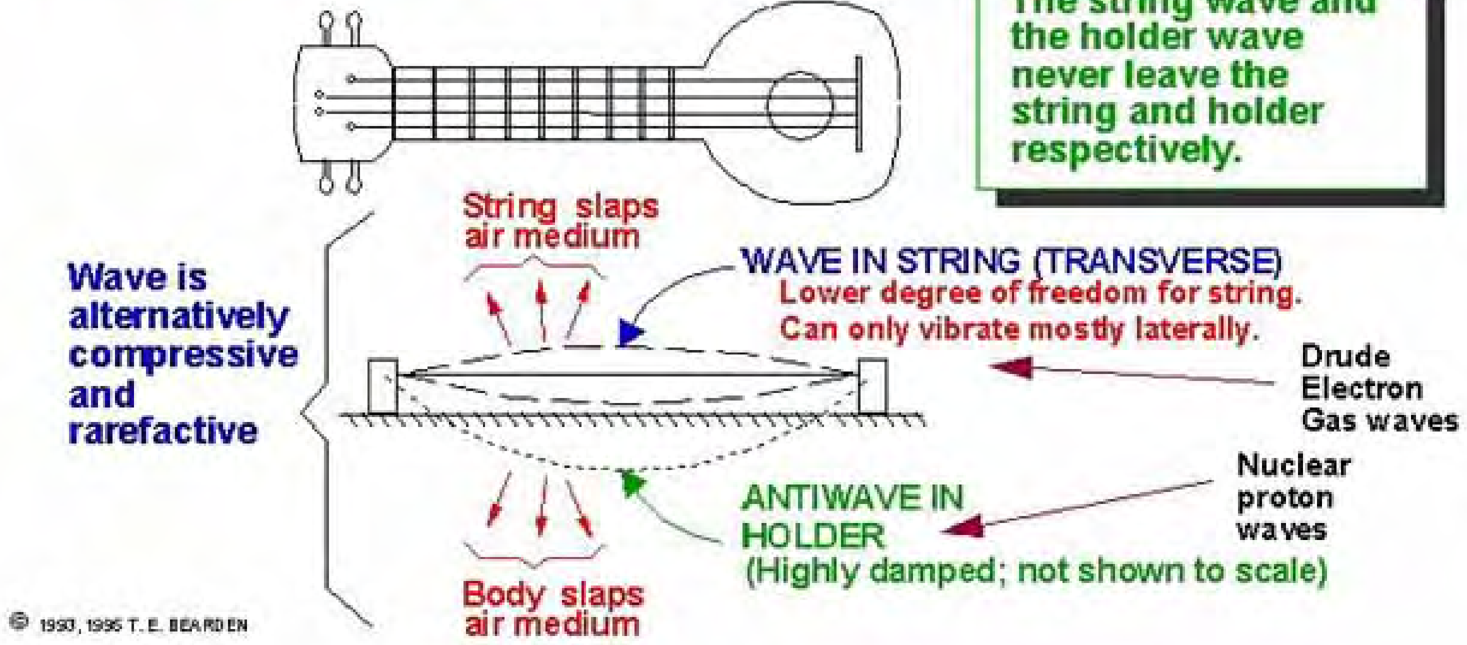
String slaps air medium
WAVE IN STRING (TRANSVERSE)
Lower degree of freedom for string.
Can only vibrate mostly laterally.
Drude Electron Gas waves
Wave is alternatively compressive and rarefactive
Nuclear proton waves
ANTIWAVE IN HOLDER
(Highly damped; not shown to scale)
Body slaps air medium

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Figure 3. Analogy of the "taut string holder" omitted by Faraday. This omitted half the electrodynamics (including in Maxwell's capture of Faraday's notion) and half the EM energy. An equal and opposite Newtonian 3rd law reaction does appear in our transmitters and receivers.

Flow of current and energy into, through, and along a conductor

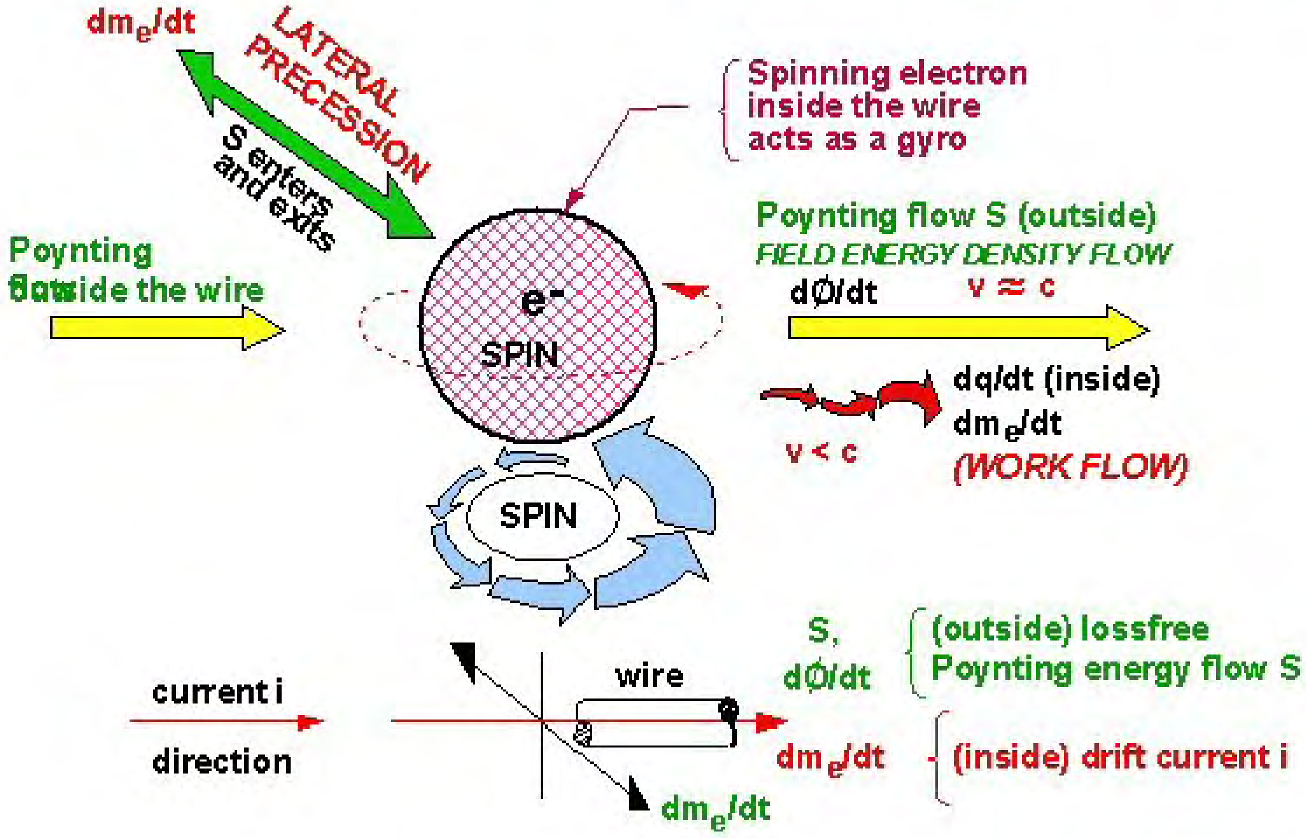
dm_e/dt
LATERAL PRECESSION
S enters and exits
Spinning electron inside the wire acts as a gyro
Poynting flow outside the wire
e^-
SPIN
SPIN
Poynting flow S (outside)
FIELD ENERGY DENSITY FLOW
$d\phi/dt$
$v \approx c$
dq/dt (inside)
dm_e/dt
(WORK FLOW)
$v < c$
S,
$d\phi/dt$
(outside) lossfree Poynting energy flow S
current i direction
wire
dm_e/dt
(inside) drift current i
dm_e/dt

Figure 4. Receiving gyroelectrons precess laterally, providing the detected transverse wave and proving the incoming vacuum disturbance to be longitudinal.

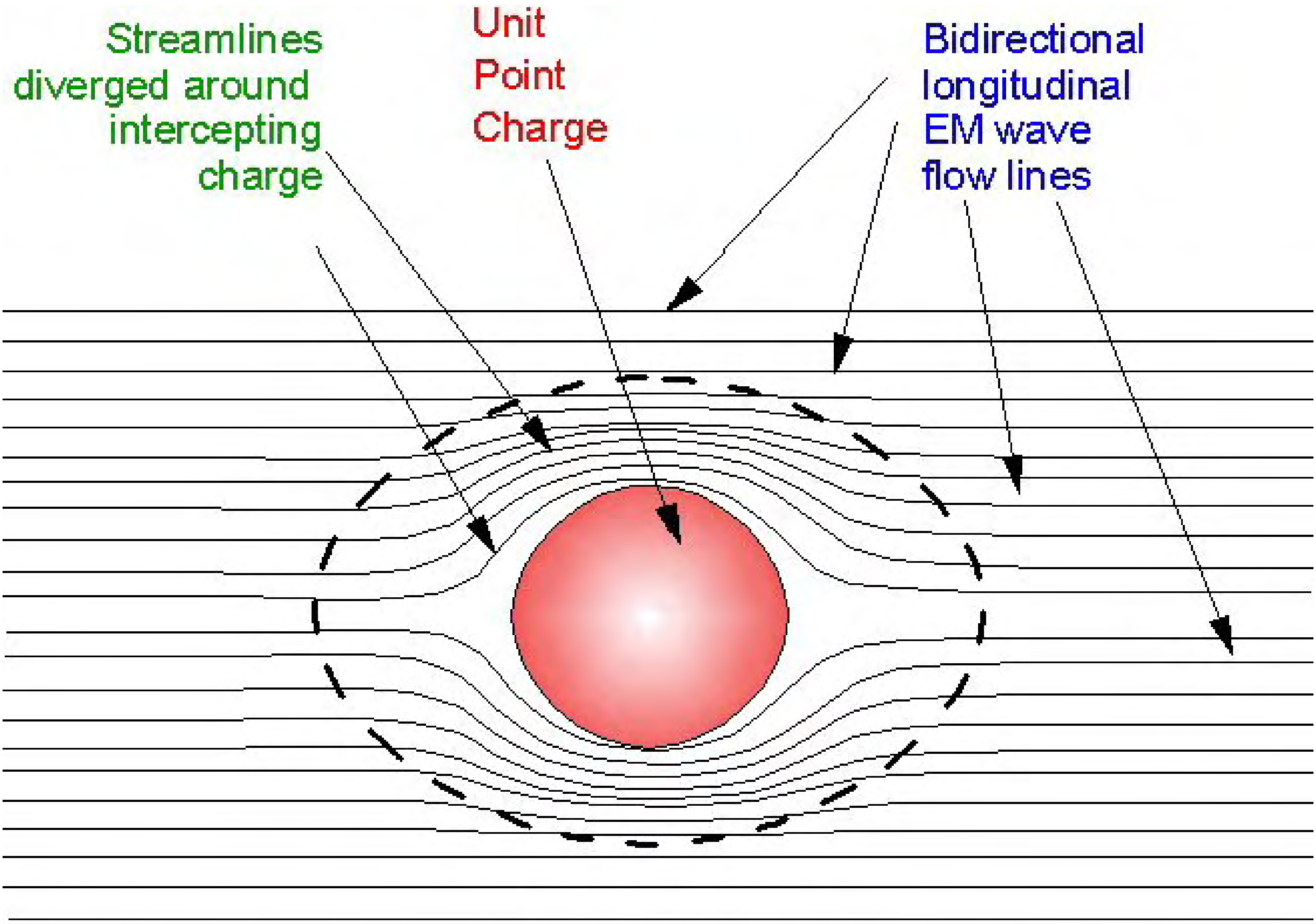
Streamlines diverged around intercepting charge
Unit Point Charge
Bidirectional longitudinal EM wave flow lines

Figure 5. The defined "magnitude of the potential" is not such at all, but is the magnitude of the energy in the diverged flow streamlining around a unit point charge at each point in space where the potential is present.

Electrodynamics has nothing to say about what exists in the vacuum in the absence of mass.

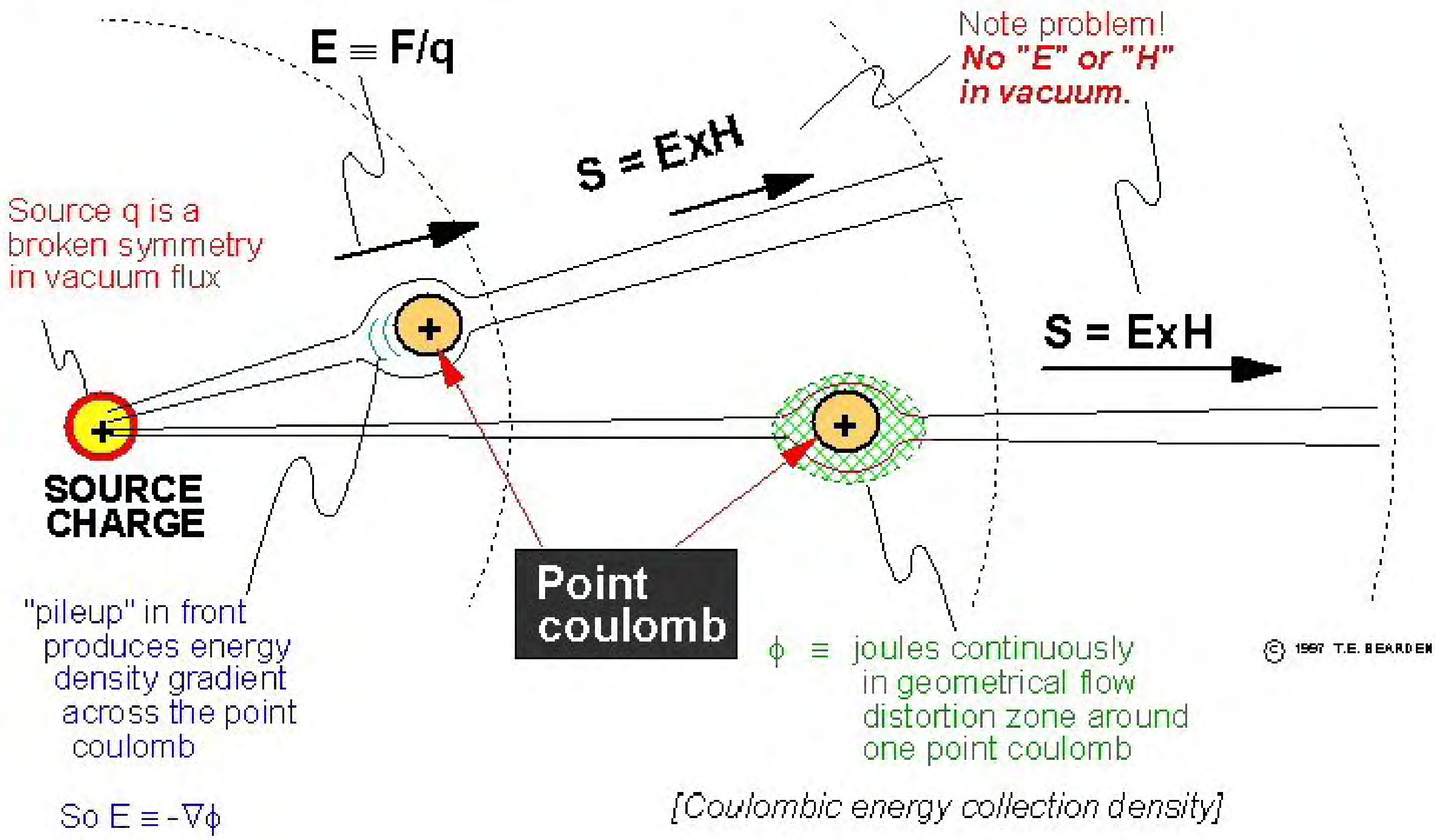
E ≡ F/q
Note problem!
No "E" or "H" in vacuum.
S = ExH
Source q is a broken symmetry in vacuum flux
S = ExH
SOURCE CHARGE
Point coulomb
"pileup" in front produces energy density gradient across the point coulomb
So E ≡ -∇ϕ
ϕ ≡ joules continuously in geometrical flow distortion zone around one point coulomb
[Coulombic energy collection density]
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Figure 6. Fields and potentials are defined in terms of the Poynting disruption of the overall energy flow from the source charge, about an intercepting and "collecting" charge. Rigorously, *as defined* E and H exist only in and on charged matter. The magnitude of the diverted water swinging around a fixed rock in a river, is not the magnitude of the river.

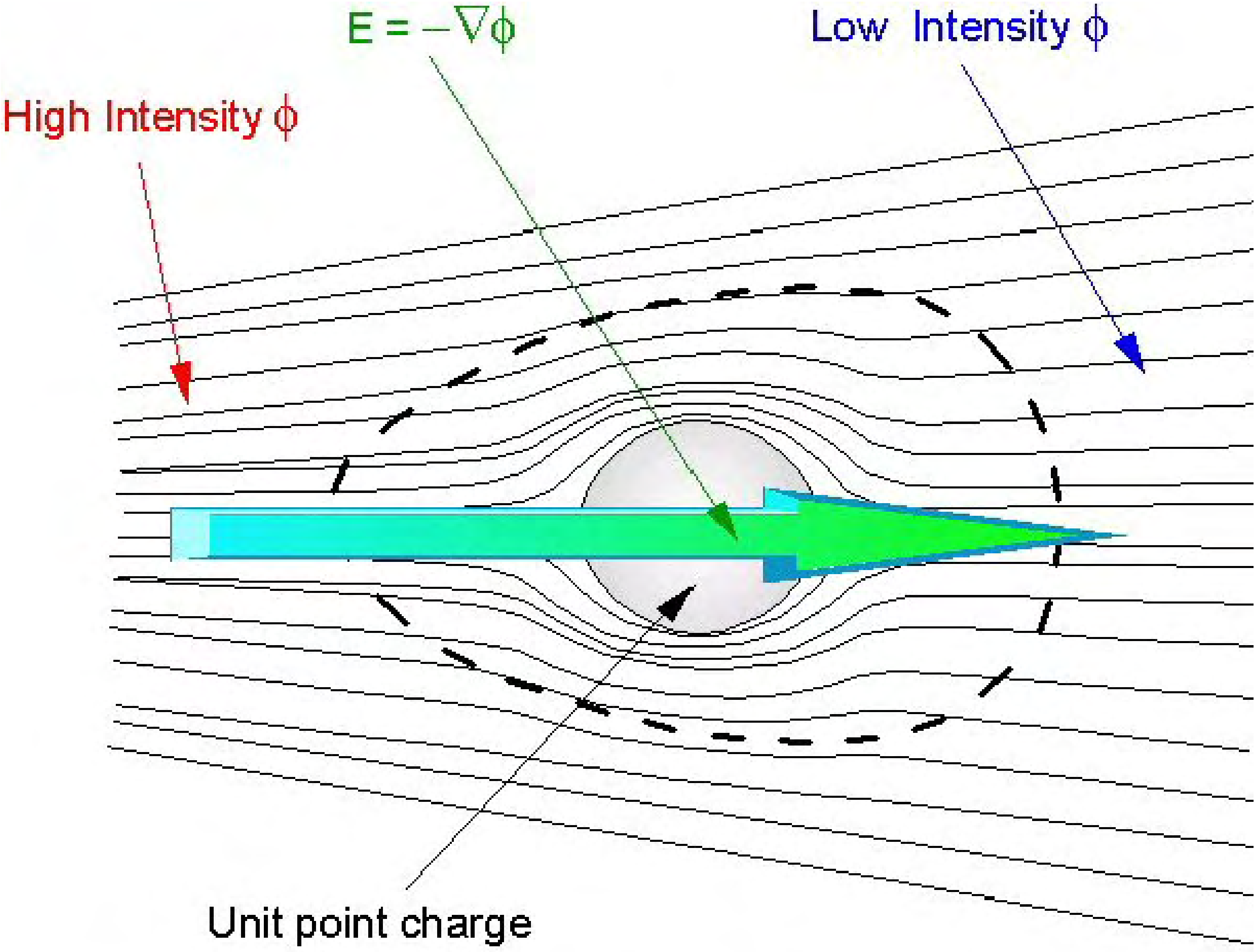
E = −∇ϕ
Low Intensity ϕ
High Intensity ϕ
Unit point charge

Figure 7. The defined "magnitude of the field" depends on the change in intensity of the flows comprising the potential. The E-field is oriented from high (pressure) in the flow to low (pressure) in energy density over a unit length.

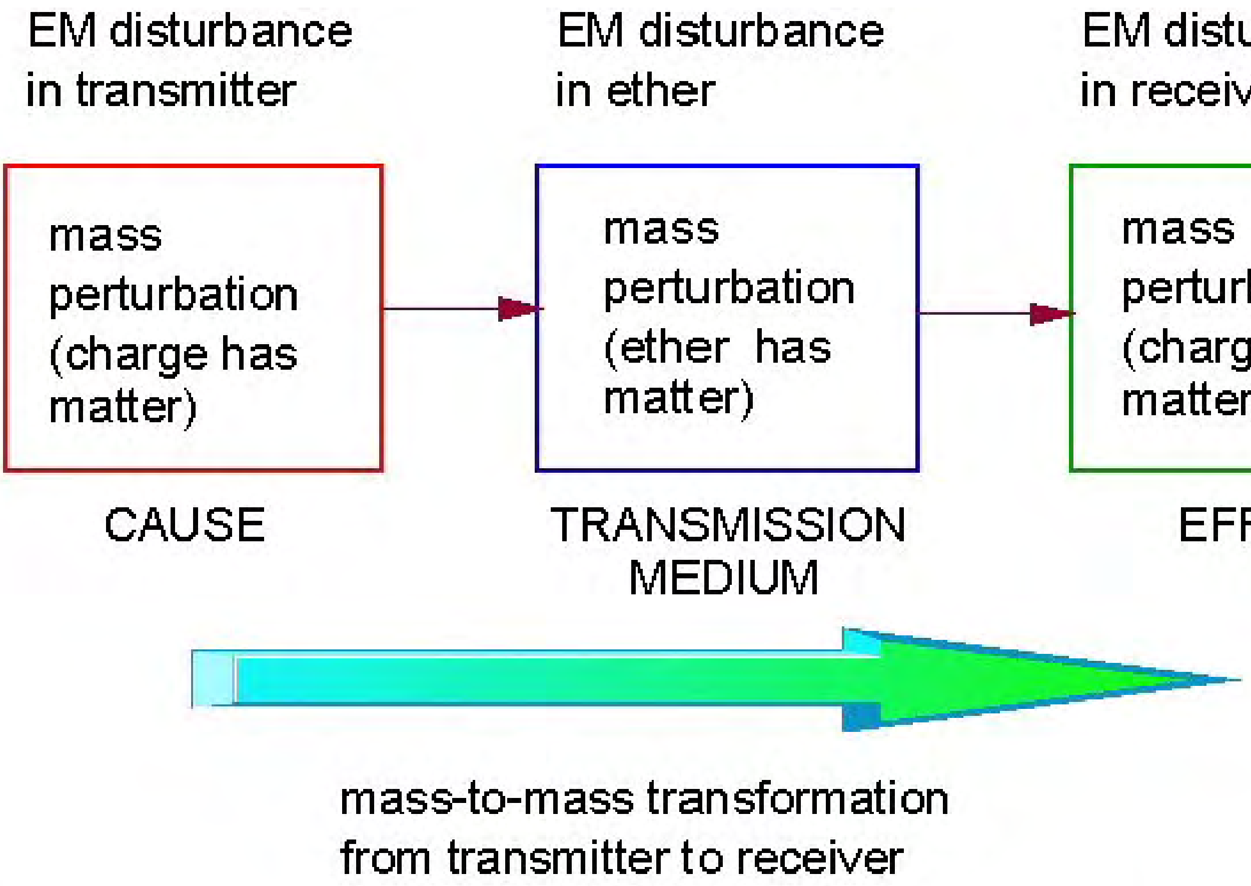
EM disturbance in transmitter
EM disturbance in ether
EM disturbance in receiver
mass perturbation (charge has matter)
mass perturbation (ether has matter)
mass perturbation (charge has matter)
CAUSE
TRANSMISSION MEDIUM
EFFECT
mass-to-mass transformation from transmitter to receiver

Figure 8. Maxwell's theory assumed a matter-to-matter transform from cause to effect.

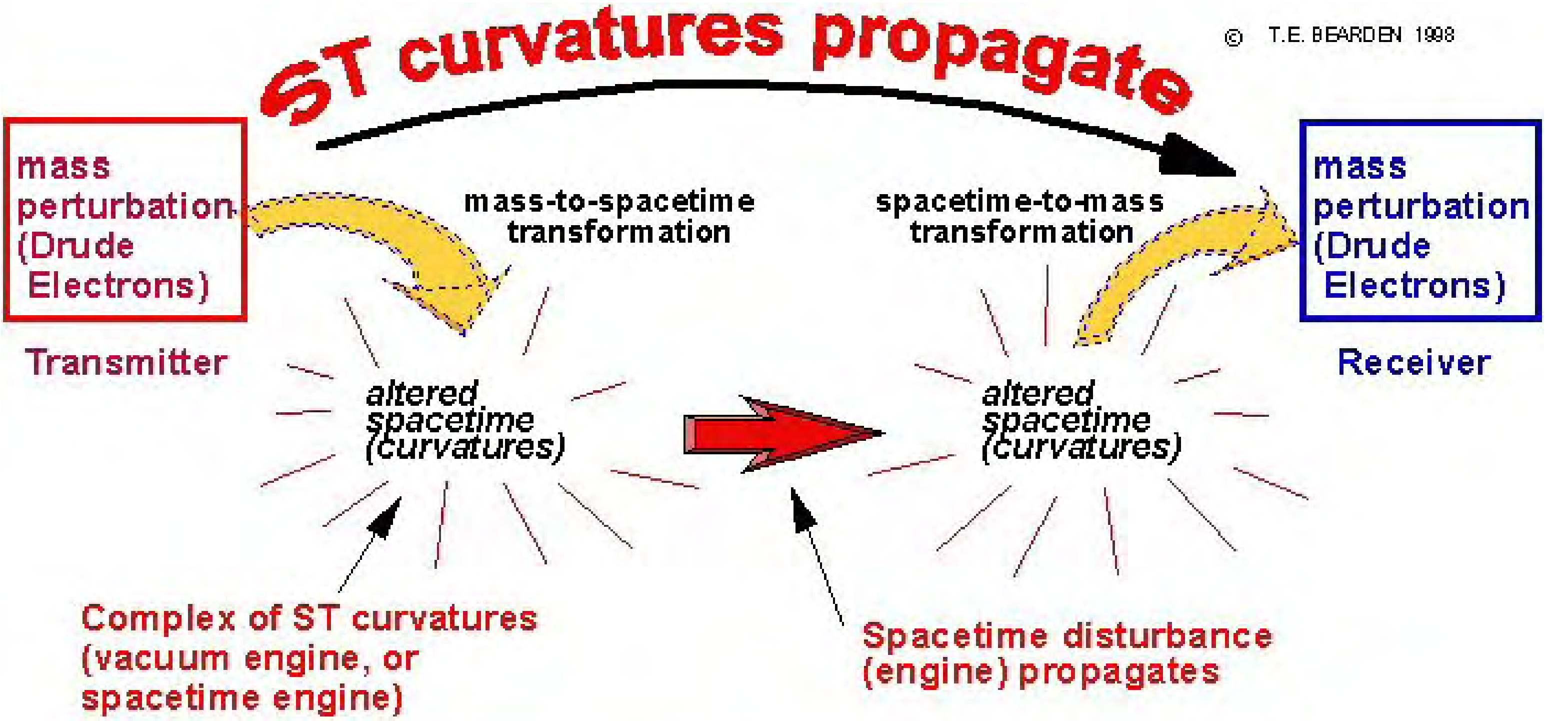
ST curvatures propagate
© T.E. BEARDEN 1998
mass perturbation (Drude Electrons)
Transmitter
mass-to-spacetime transformation
spacetime-to-mass transformation
mass perturbation (Drude Electrons)
Receiver
altered spacetime (curvatures)
altered spacetime (curvatures)
Complex of ST curvatures (vacuum engine, or spacetime engine)
Spacetime disturbance (engine) propagates

The mass-to-mass transform contains two hidden infolded transforms: (i) the mass-to-spacetime transform and (ii) the spacetime-to-mass transform. What is transmitted and propagates in space is a *spacetime perturbation*.

Figure 9. Maxwell's matter-to-matter transform contains two hidden transforms: (1) matter-to-spacetime, and (2) spacetime-to-matter.

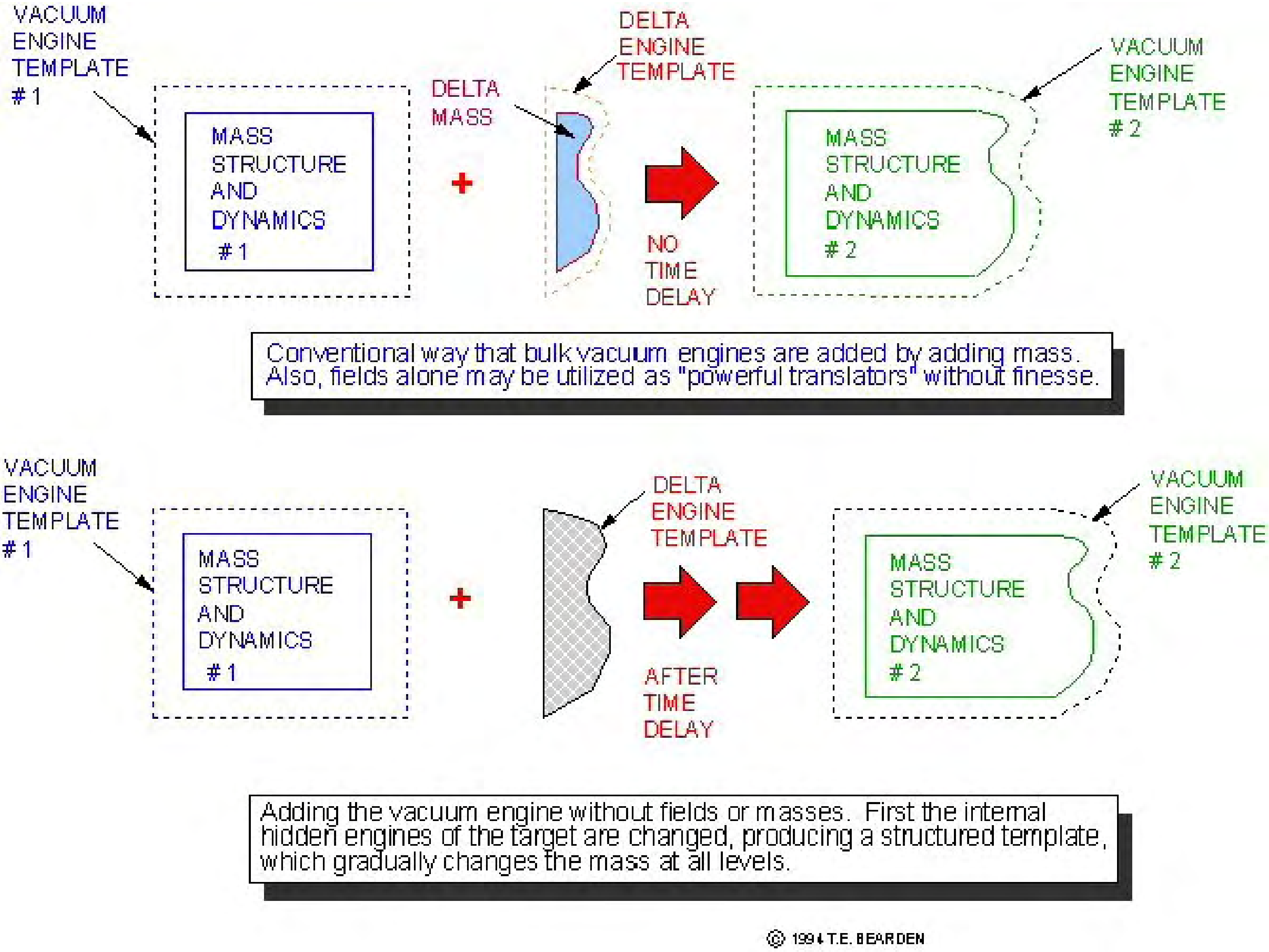
VACUUM ENGINE TEMPLATE # 1
MASS STRUCTURE AND DYNAMICS # 1
+
DELTA MASS
DELTA ENGINE TEMPLATE
NO TIME DELAY
MASS STRUCTURE AND DYNAMICS # 2
VACUUM ENGINE TEMPLATE # 2
VACUUM ENGINE TEMPLATE # 1
MASS STRUCTURE AND DYNAMICS # 1
+
DELTA ENGINE TEMPLATE
AFTER TIME DELAY
MASS STRUCTURE AND DYNAMICS # 2
VACUUM ENGINE TEMPLATE # 2
© 1994 T.E. BEARDEN

Conventional way that bulk vacuum engines are added by adding mass. Also, fields alone may be utilized as "powerful translators" without finesse.

Adding the vacuum engine without fields or masses. First the internal hidden engines of the target are changed, producing a structured template, which gradually changes the mass at all levels.

Figure 10. Vacuum engines and their utilization.

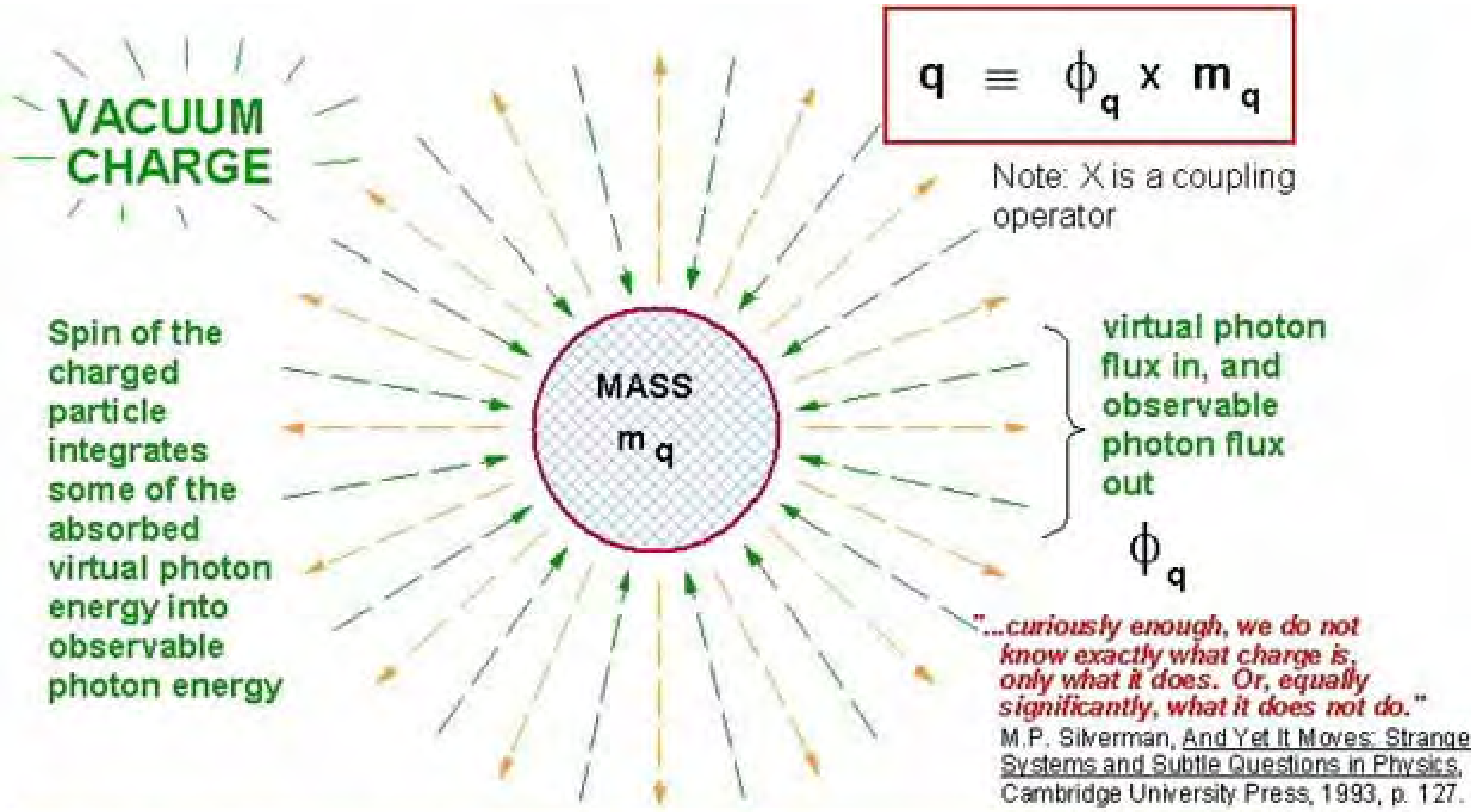
VACUUM CHARGE
MASS
m_q
Spin of the charged particle integrates some of the absorbed virtual photon energy into observable photon energy
virtual photon flux in, and observable photon flux out
ϕ_q

$$q \equiv \phi_q \times m_q$$

Note: X is a coupling operator

"...curiously enough, we do not know exactly what charge is, only what it does. Or, equally significantly, what it does not do."
M.P. Silverman, And Yet It Moves: Strange Systems and Subtle Questions in Physics, Cambridge University Press, 1993, p. 127.

An electric charge Q is a broken 3-symmetry. The mass of the charge continuously and violently absorbs virtual photons from the surrounding vacuum, and integrates some of them to observable EM longidutinal photons which it emits in 3-space.

Figure 11. A charged particle continuously absorbs virtual energy from the vacuum, integrates some of it into observable energy, and pours out this observable EM energy in 3-space in all directions.

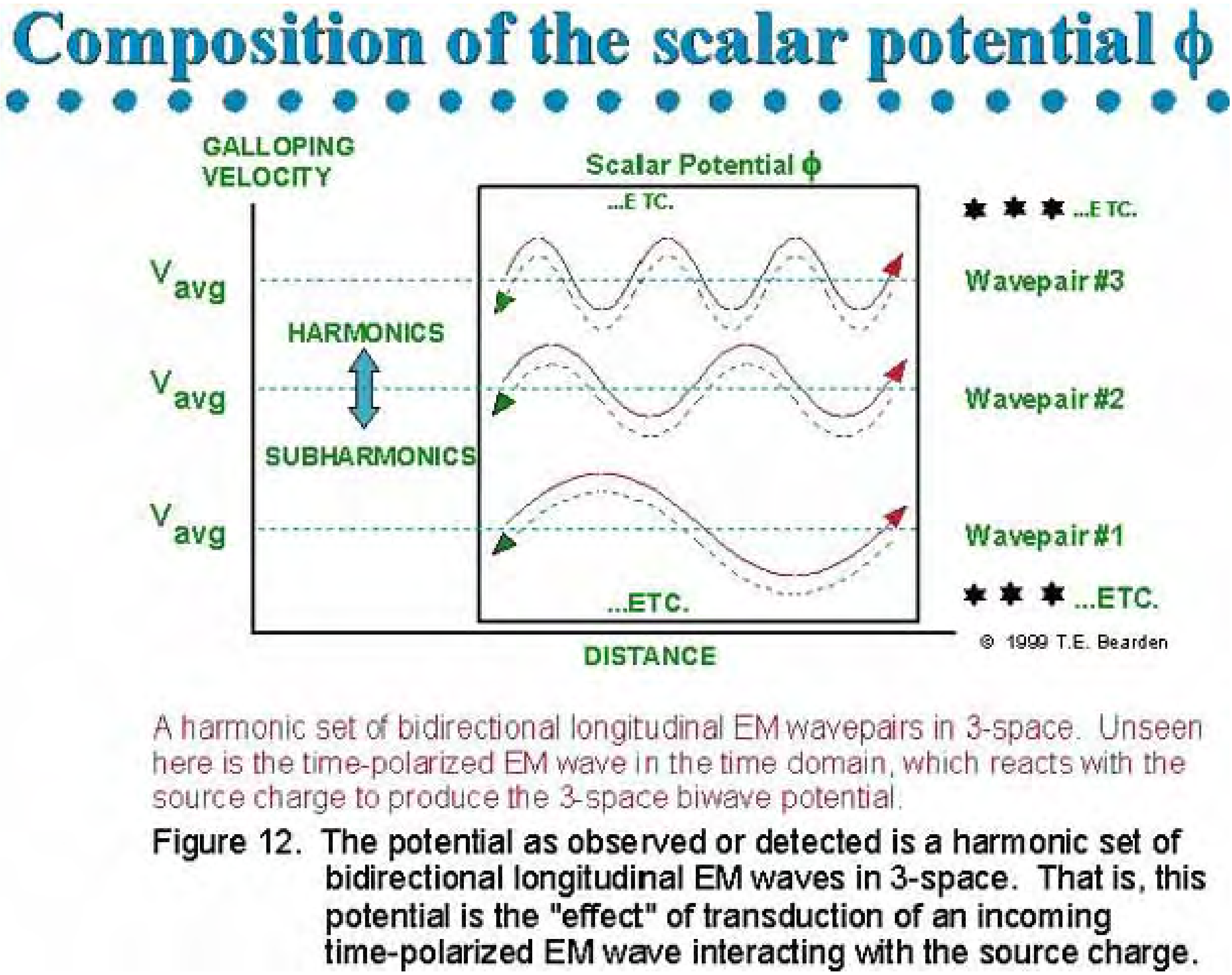

Composition of the scalar potential ϕ

GALLOPING VELOCITY
Scalar Potential ϕ
...ETC.
V_{avg}
V_{avg}
V_{avg}
HARMONICS
SUBHARMONICS
...ETC.
DISTANCE
✱ ✱ ✱ ...ETC.
Wavepair #3
Wavepair #2
Wavepair #1
✱ ✱ ✱ ...ETC.
© 1999 T.E. Bearden

A harmonic set of bidirectional longitudinal EM wavepairs in 3-space. Unseen here is the time-polarized EM wave in the time domain, which reacts with the source charge to produce the 3-space biwave potential.

Figure 12. The potential as observed or detected is a harmonic set of bidirectional longitudinal EM waves in 3-space. That is, this potential is the "effect" of transduction of an incoming time-polarized EM wave interacting with the source charge.

The supersystem concept

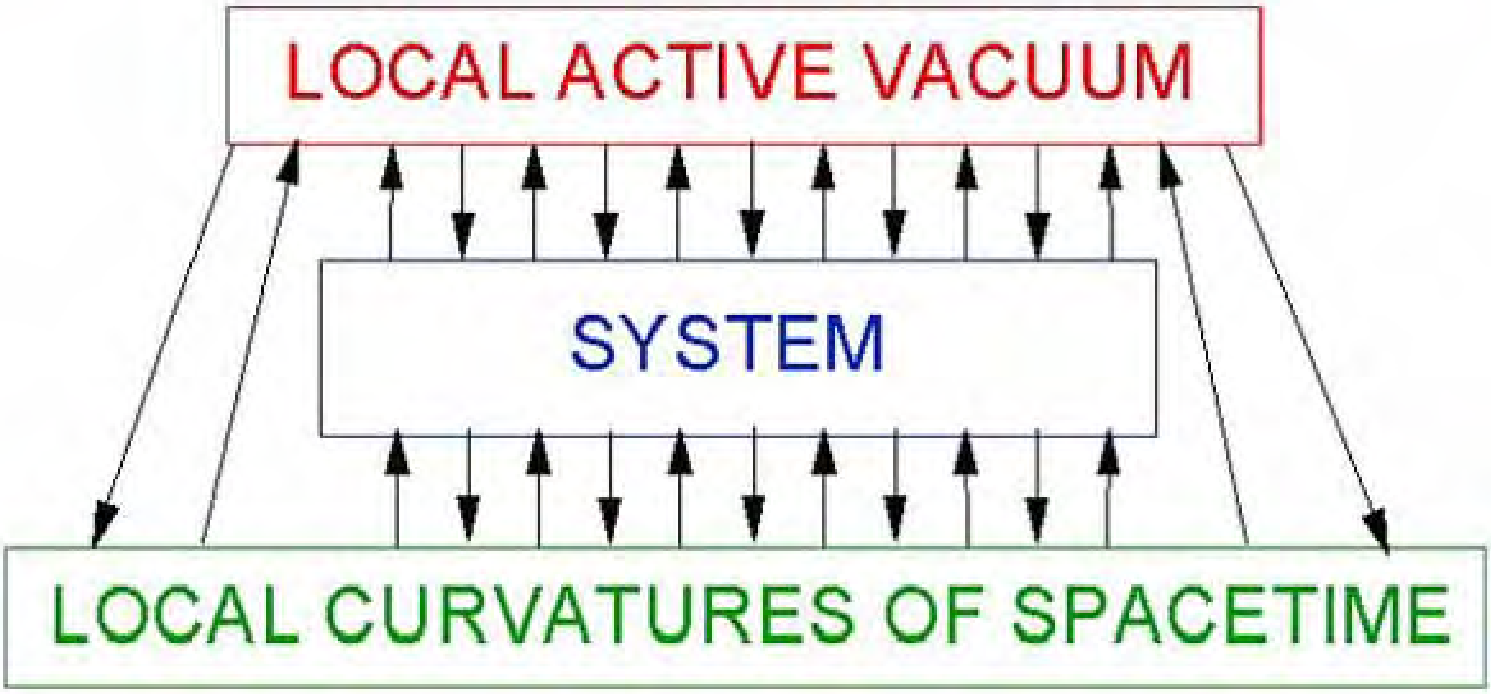

LOCAL ACTIVE VACUUM

SYSTEM

LOCAL CURVATURES OF SPACETIME

Figure 13. Concept of the supersystem and its interacting components.

Vacuum engine: Working spacetime demons

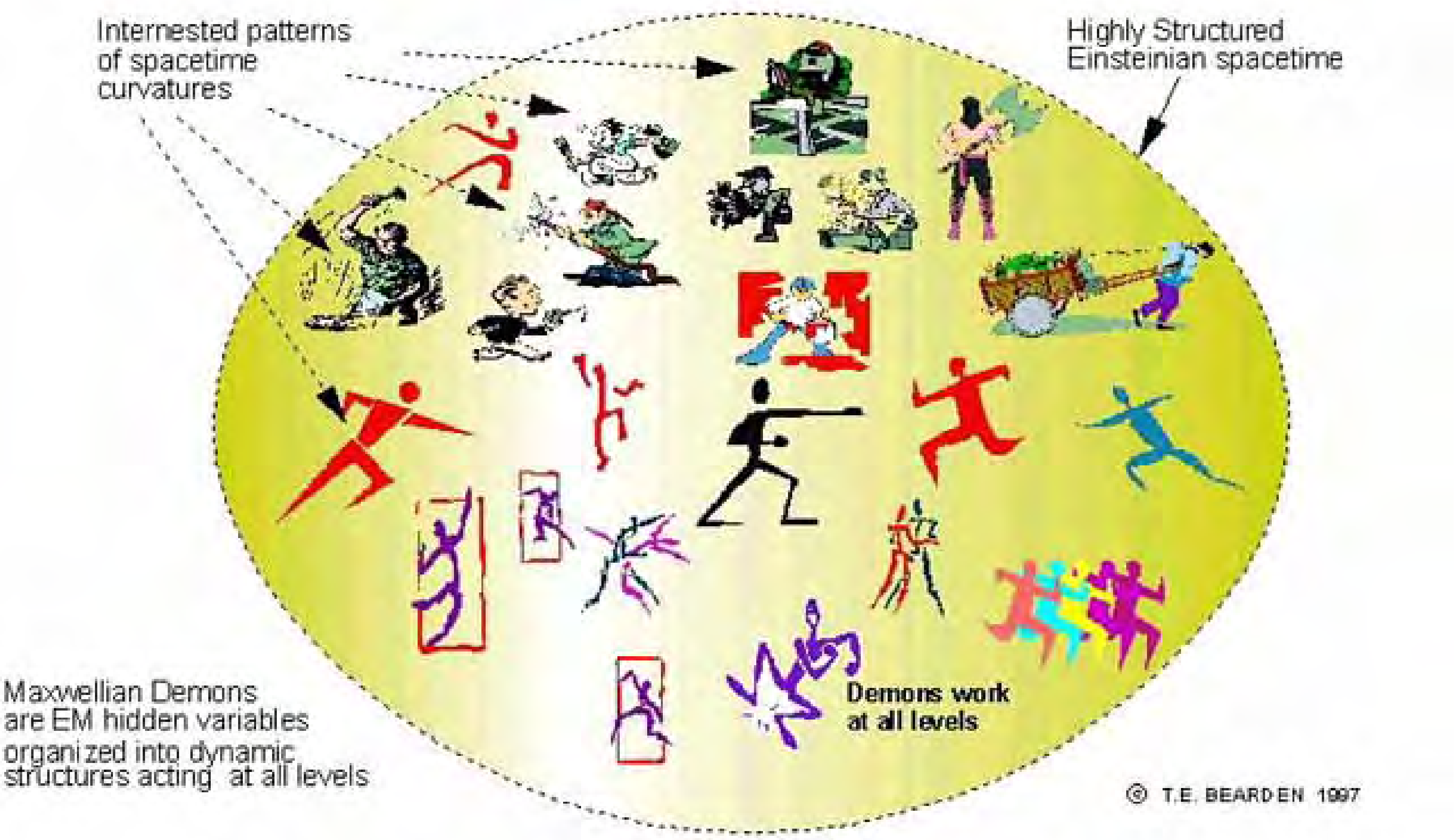
Internested patterns
of spacetime
curvatures
Highly Structured
Einsteinian spacetime
Maxwellian Demons
are EM hidden variables
organized into dynamic
structures acting at all levels
Demons work
at all levels
© T.E. BEARDEN 1997

Figure 14. A vacuum engine is a set of spacetime demons working upon a mass system and its motion through time, at every level.

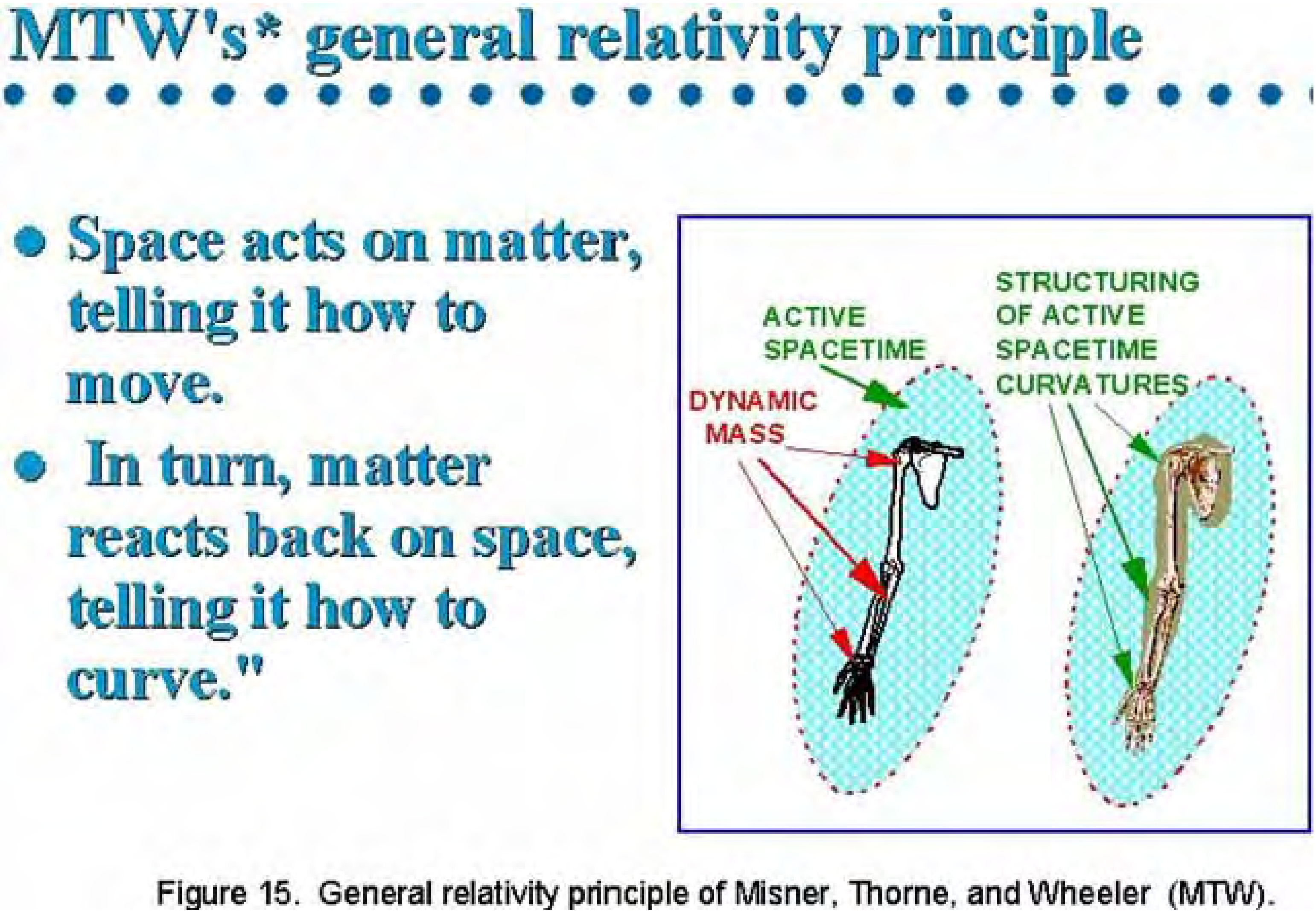

MTW's* general relativity principle

- Space acts on matter, telling it how to move.
- In turn, matter reacts back on space, telling it how to curve."

ACTIVE
SPACETIME
DYNAMIC
MASS
STRUCTURING
OF ACTIVE
SPACETIME
CURVATURES

Figure 15. General relativity principle of Misner, Thorne, and Wheeler (MTW).

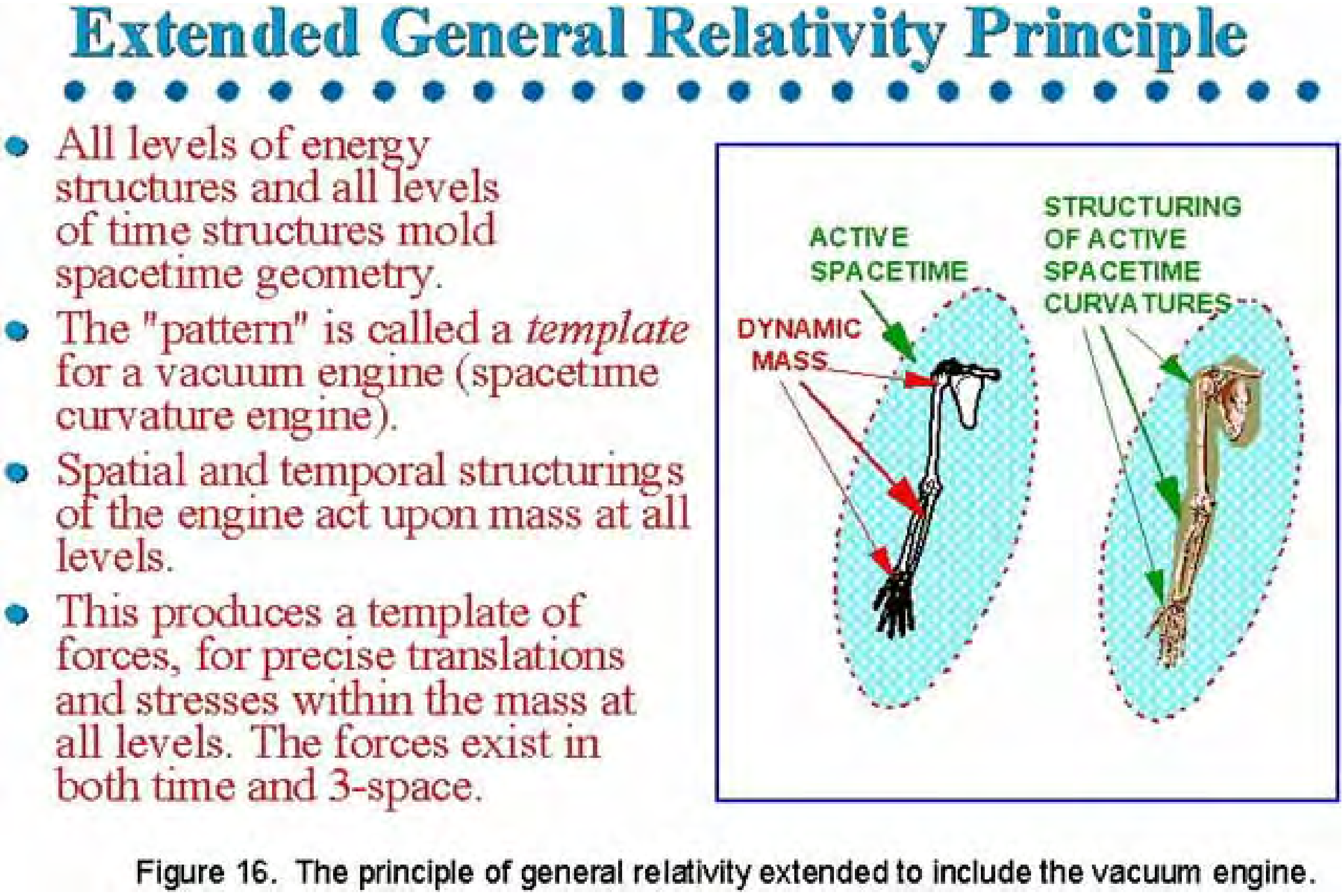

Extended General Relativity Principle

- All levels of energy structures and all levels of time structures mold spacetime geometry.
- The "pattern" is called a *template* for a vacuum engine (spacetime curvature engine).
- Spatial and temporal structurings of the engine act upon mass at all levels.
- This produces a template of forces, for precise translations and stresses within the mass at all levels. The forces exist in both time and 3-space.

ACTIVE SPACETIME
DYNAMIC MASS
STRUCTURING OF ACTIVE SPACETIME CURVATURES

Figure 16. The principle of general relativity extended to include the vacuum engine.

Active spacetime and a specific vacuum engine

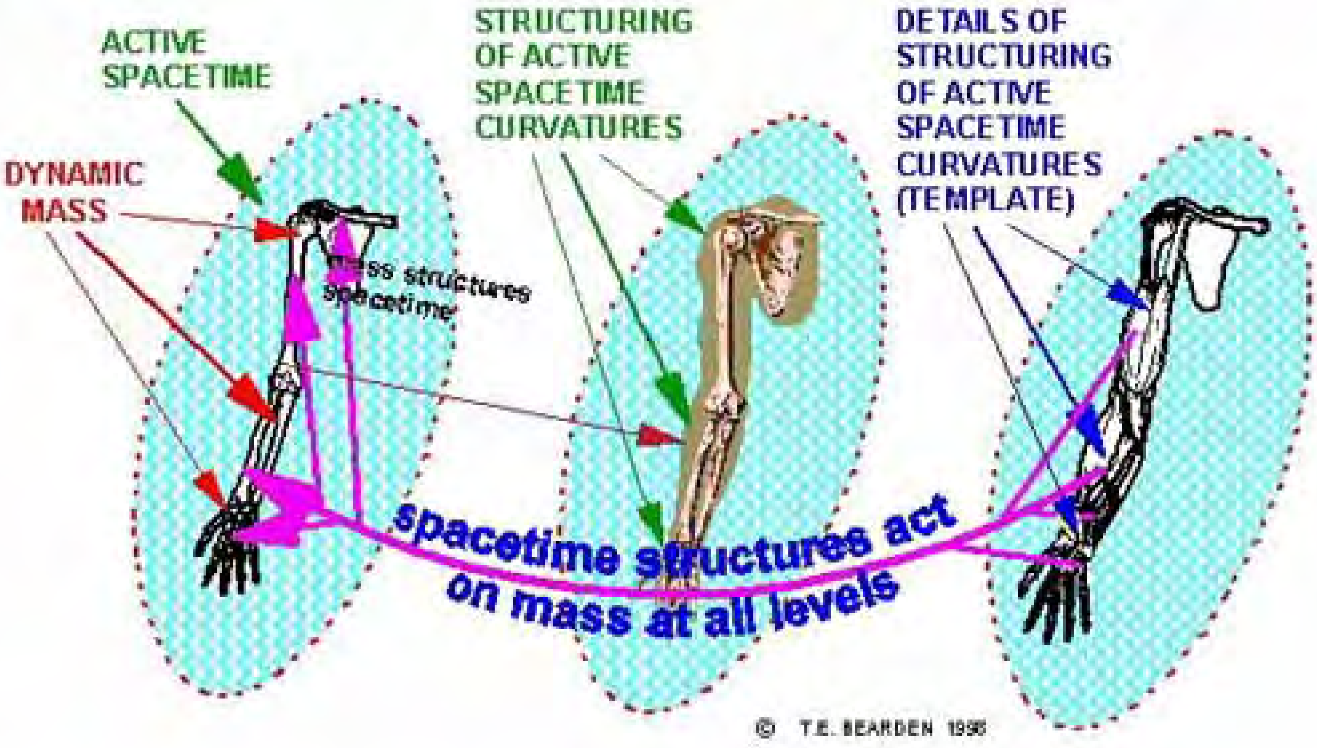
ACTIVE SPACETIME
DYNAMIC MASS
mass structures spacetime
STRUCTURING OF ACTIVE SPACETIME CURVATURES
DETAILS OF STRUCTURING OF ACTIVE SPACETIME CURVATURES (TEMPLATE)
spacetime structures act on mass at all levels
© T.E. BEARDEN 1996

Figure 17. Active spacetime and a specific vacuum engine (spacetime curvature engine).

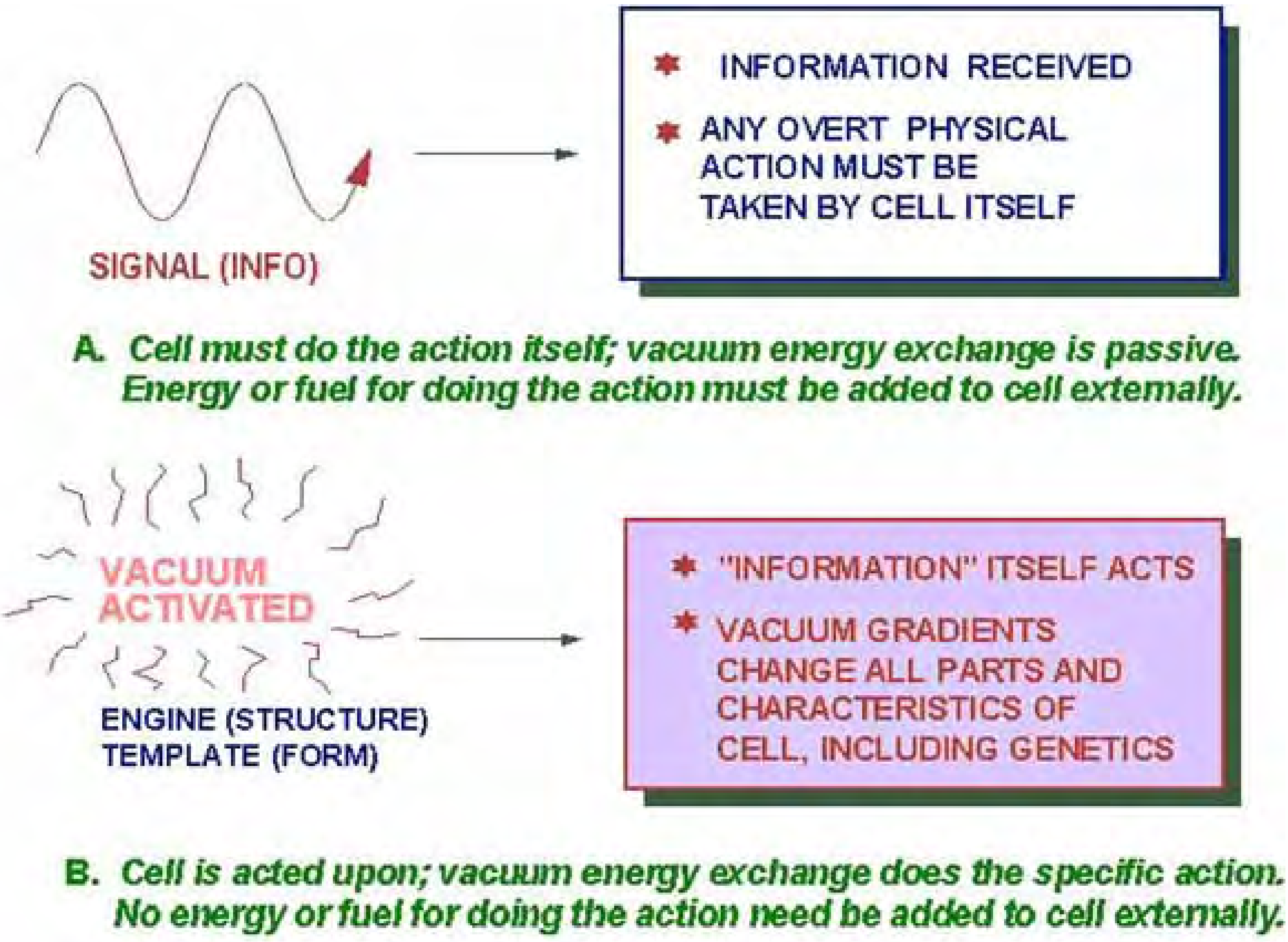

- INFORMATION RECEIVED
- ANY OVERT PHYSICAL ACTION MUST BE TAKEN BY CELL ITSELF

A. *Cell must do the action itself; vacuum energy exchange is passive. Energy or fuel for doing the action must be added to cell externally.*

- "INFORMATION" ITSELF ACTS
- VACUUM GRADIENTS CHANGE ALL PARTS AND CHARACTERISTICS OF CELL, INCLUDING GENETICS

B. *Cell is acted upon; vacuum energy exchange does the specific action. No energy or fuel for doing the action need be added to cell externally.*

Figure 18. Signal versus vacuum engine, as in Priore's cellular reversal.

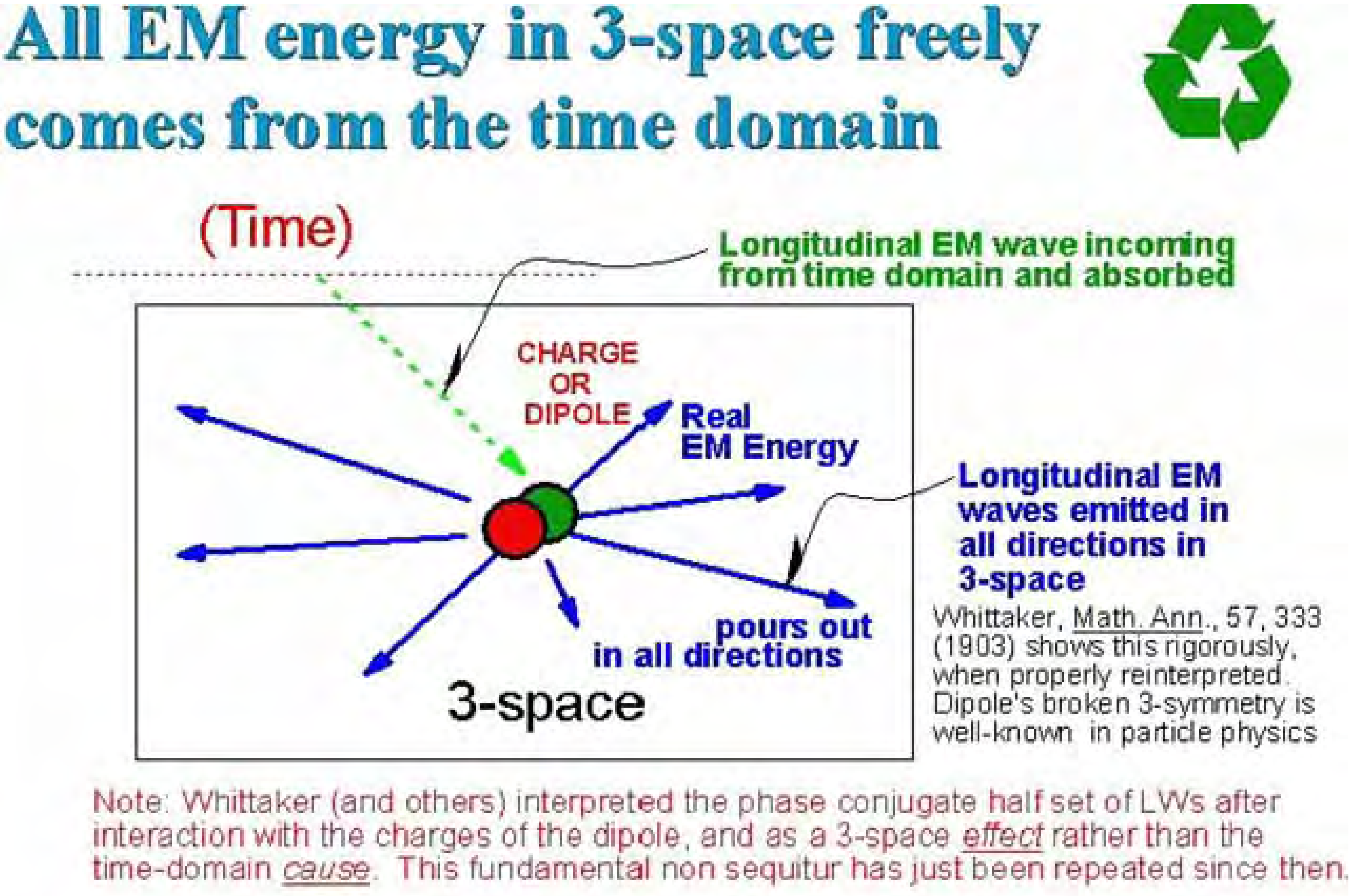

All EM energy in 3-space freely comes from the time domain

(Time)

Longitudinal EM wave incoming from time domain and absorbed

CHARGE OR DIPOLE

Real EM Energy

pours out in all directions

3-space

Longitudinal EM waves emitted in all directions in 3-space

Whittaker, Math. Ann., 57, 333 (1903) shows this rigorously, when properly reinterpreted. Dipole's broken 3-symmetry is well-known in particle physics

Note: Whittaker (and others) interpreted the phase conjugate half set of LWs after interaction with the charges of the dipole, and as a 3-space *effect* rather than the time-domain *cause*. This fundamental non sequitur has just been repeated since then.

Figure 19. All EM energy in the 3-space potential comes from the time-domain.

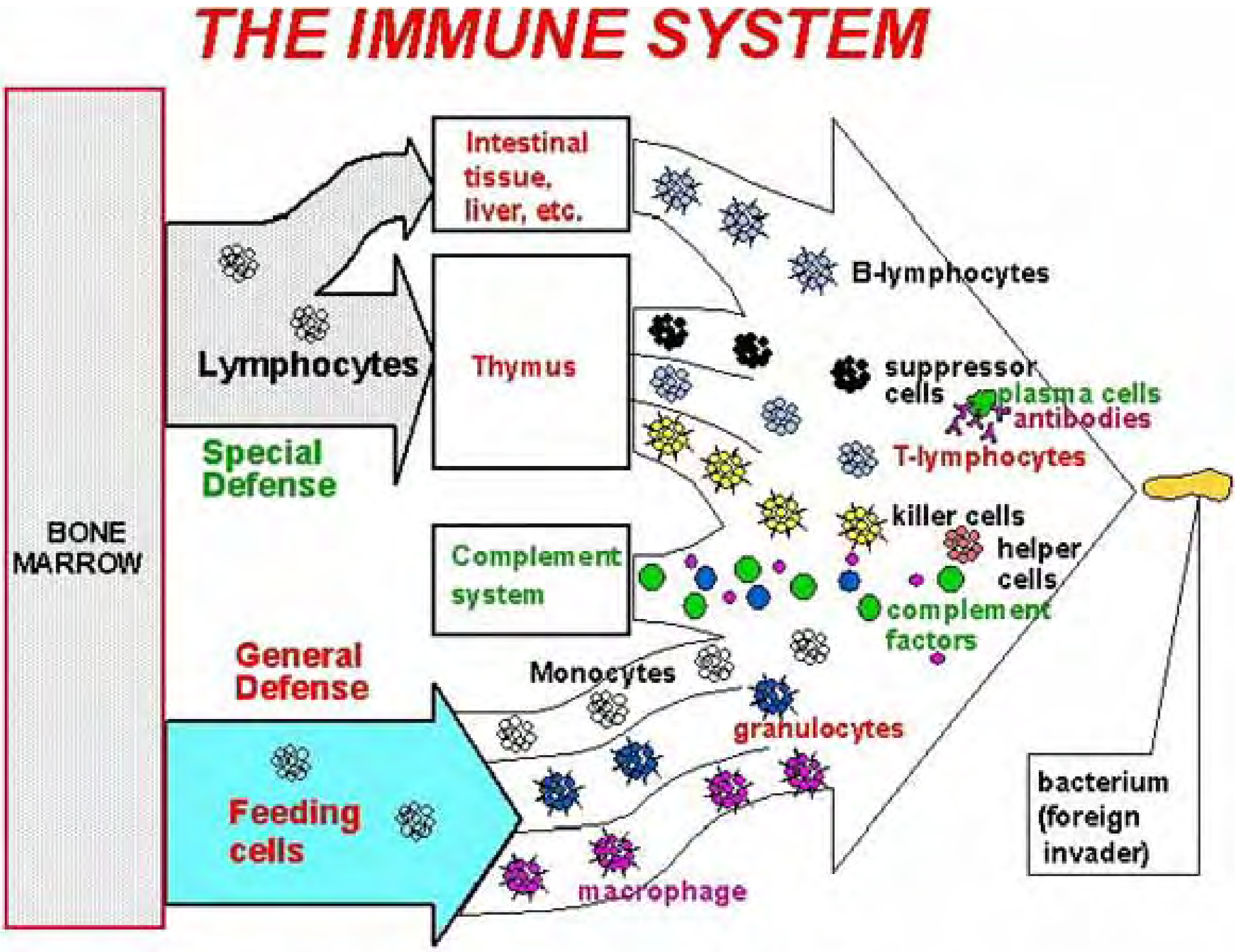
THE IMMUNE SYSTEM
BONE MARROW
Lymphocytes
Special Defense
General Defense
Feeding cells
Intestinal tissue, liver, etc.
Thymus
Complement system
Monocytes
B-lymphocytes
suppressor cells
plasma cells
antibodies
T-lymphocytes
killer cells
helper cells
complement factors
granulocytes
macrophage
bacterium (foreign invader)

Figure 20. Immune system block diagram.

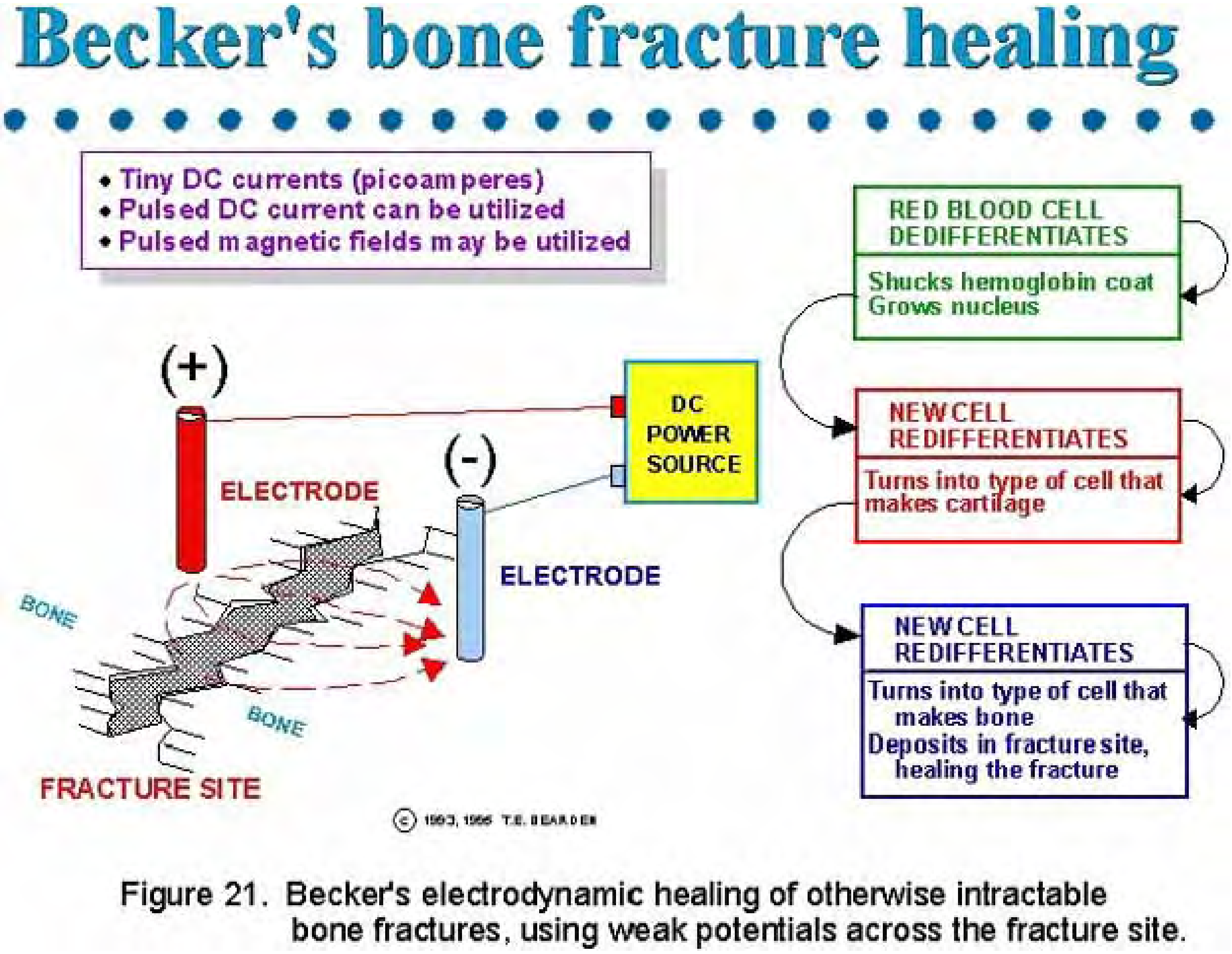

Becker's bone fracture healing

- Tiny DC currents (picoamperes)
- Pulsed DC current can be utilized
- Pulsed magnetic fields may be utilized

RED BLOOD CELL DEDIFFERENTIATES
Shucks hemoglobin coat
Grows nucleus

NEW CELL REDIFFERENTIATES
Turns into type of cell that makes cartilage

NEW CELL REDIFFERENTIATES
Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

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Figure 21. Becker's electrodynamic healing of otherwise intractable bone fractures, using weak potentials across the fracture site.

Becker's theoretical DC control system involved with response to injury

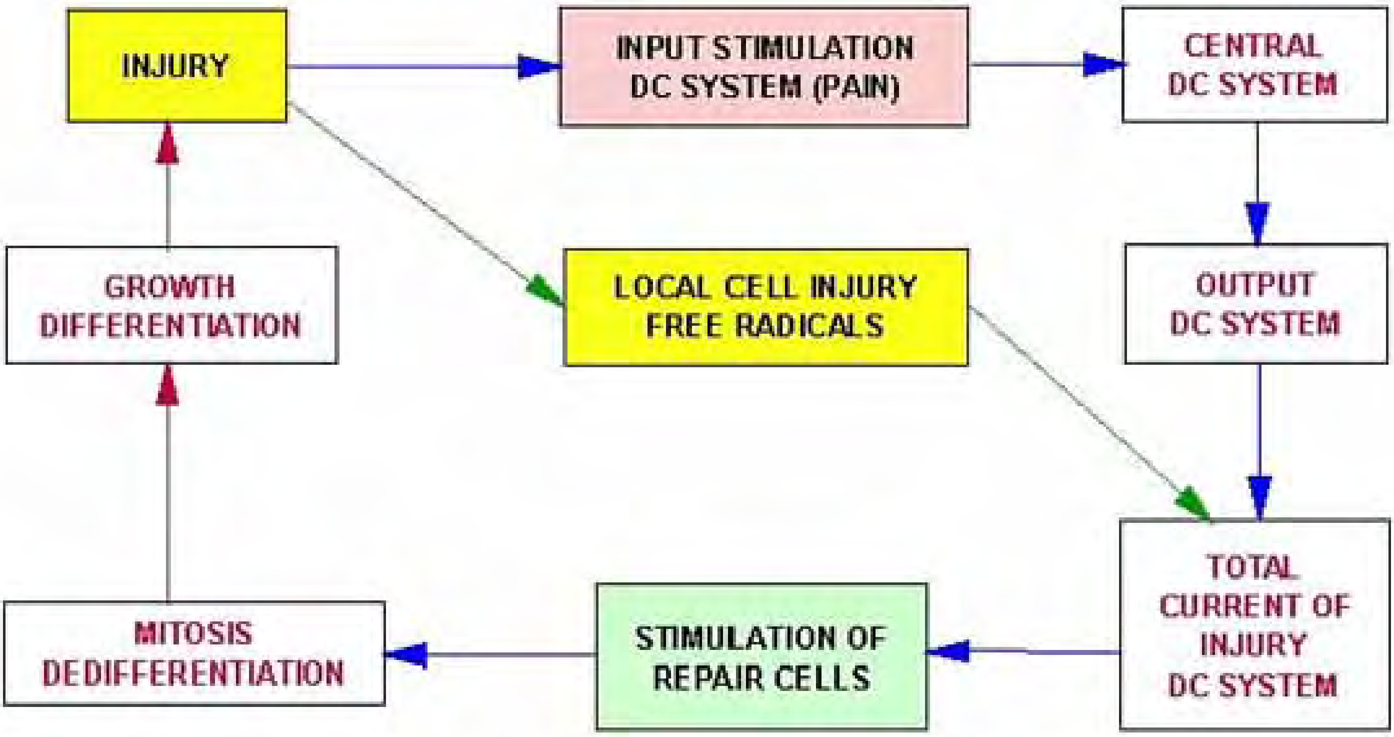
INJURY
INPUT STIMULATION DC SYSTEM (PAIN)
CENTRAL DC SYSTEM
GROWTH DIFFERENTIATION
LOCAL CELL INJURY FREE RADICALS
OUTPUT DC SYSTEM
TOTAL CURRENT OF INJURY DC SYSTEM
MITOSIS DEDIFFERENTIATION
STIMULATION OF REPAIR CELLS

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.

Figure 22. Becker's block diagram of DC control system involved with response to injury.

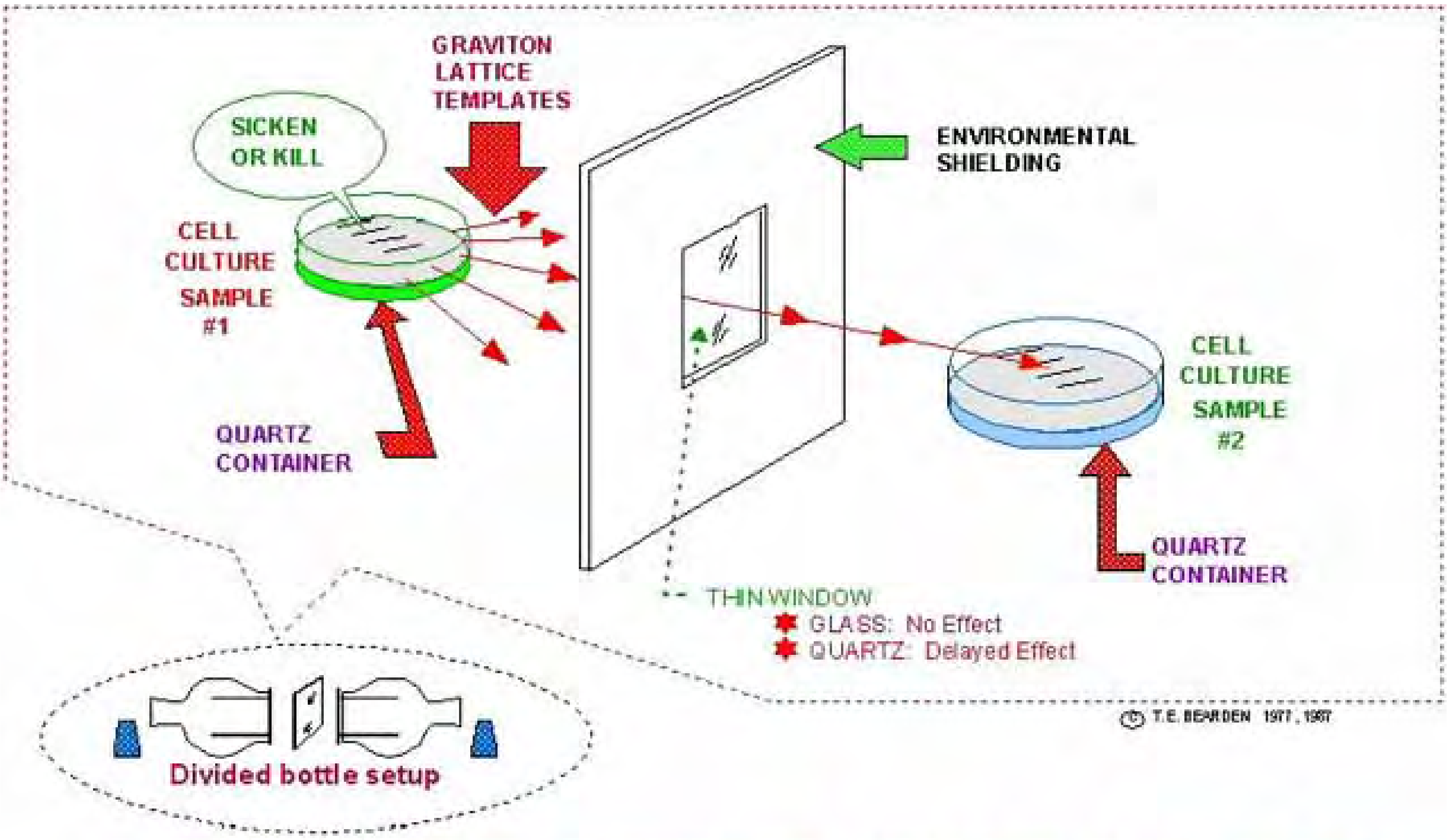
GRAVITON LATTICE TEMPLATES
SICKEN OR KILL
CELL CULTURE SAMPLE #1
QUARTZ CONTAINER
ENVIRONMENTAL SHIELDING
CELL CULTURE SAMPLE #2
QUARTZ CONTAINER
THIN WINDOW
GLASS: No Effect
QUARTZ: Delayed Effect
© T.E. BEARDEN 1977, 1987
Divided bottle setup

Note: Minimum lattice is one harmonic interval: IR to UV is such a minimum G-lattice.

Figure 23. Kaznacheyev's induction of cellular disease and disorder at a distance, using novel electromagnetic means.

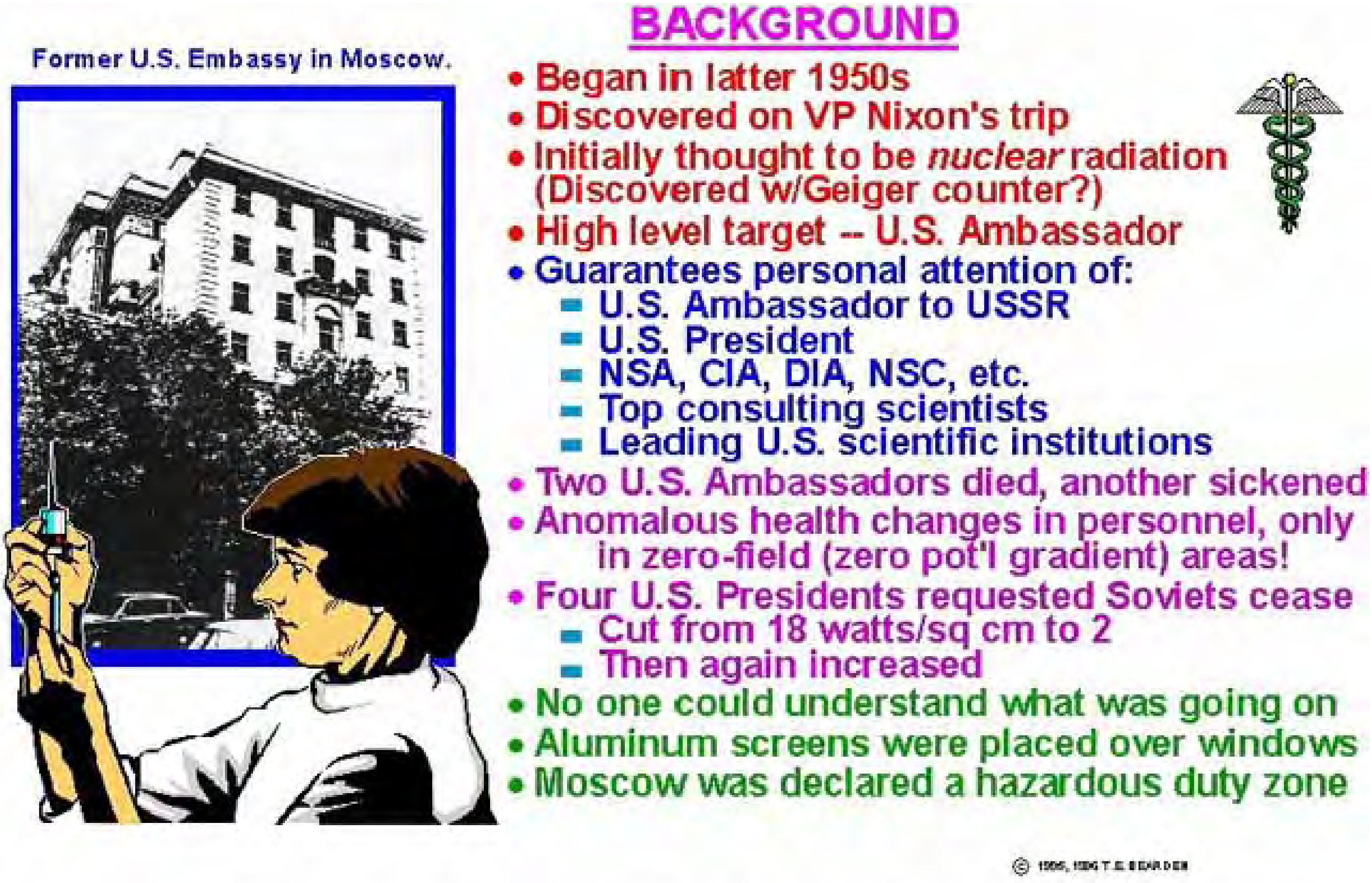

Former U.S. Embassy in Moscow.

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter?)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
    - U.S. Ambassador to USSR
    - U.S. President
    - NSA, CIA, DIA, NSC, etc.
    - Top consulting scientists
    - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero pot'l gradient) areas!
- Four U.S. Presidents requested Soviets cease
    - Cut from 18 watts/sq cm to 2
    - Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

Figure 24. Russian "microwave" radiation of the U.S. Embassy in Moscow.

Mechanism generating the flow of a mass through time

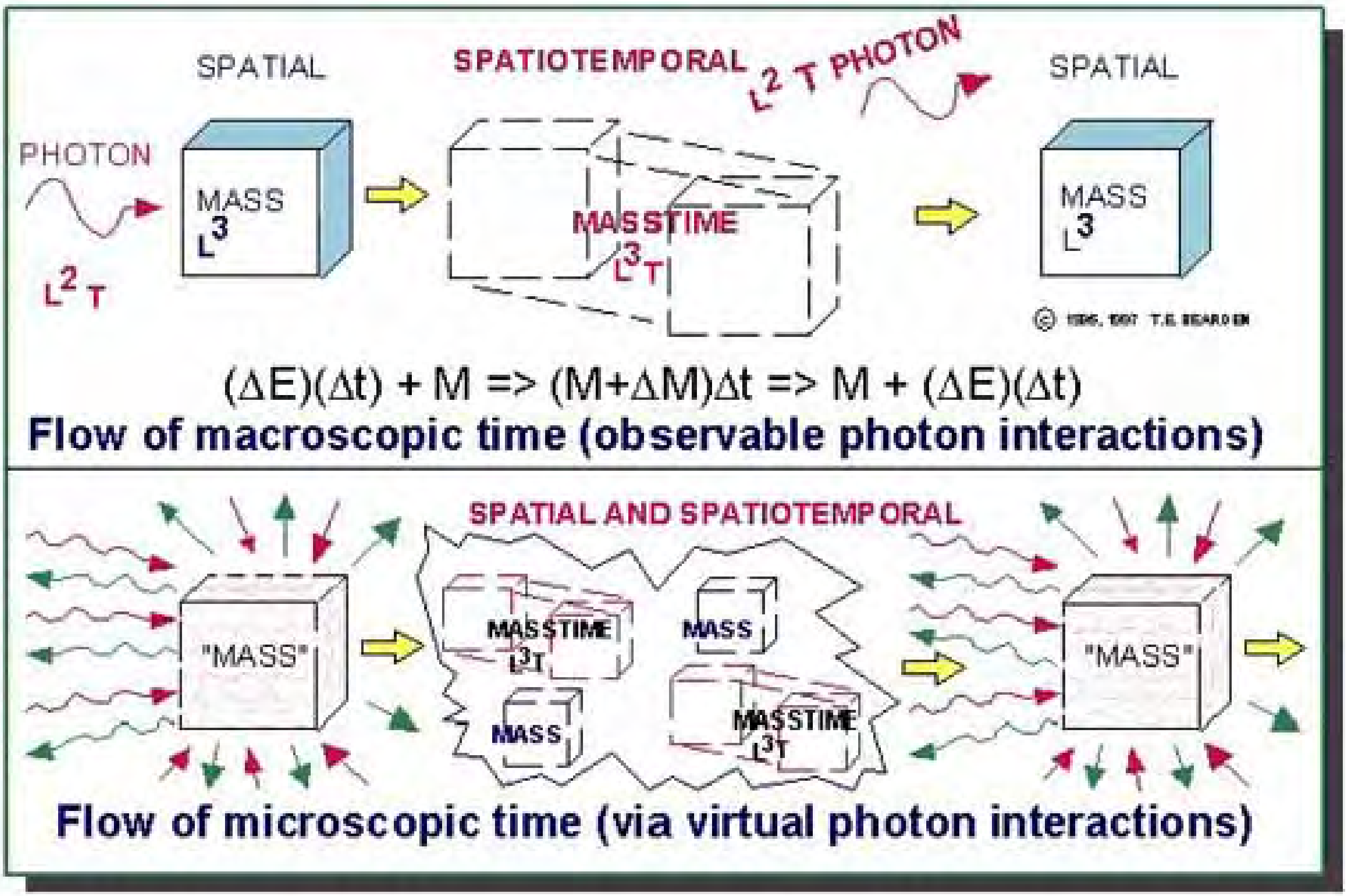
SPATIAL
SPATIOTEMPORAL
L2 T PHOTON
SPATIAL
PHOTON
MASS L3
L2 T
MASSTIME L3T
MASS L3
© 1996, 1997 T.E. BEARDEN
(ΔE)(Δt) + M => (M+ΔM)Δt => M + (ΔE)(Δt)
Flow of macroscopic time (observable photon interactions)
SPATIAL AND SPATIOTEMPORAL
"MASS"
MASSTIME L3T
MASS
MASS
MASSTIME L3T
"MASS"
Flow of microscopic time (via virtual photon interactions)

Figure 25. Mechanism generating the flow of a mass through time.

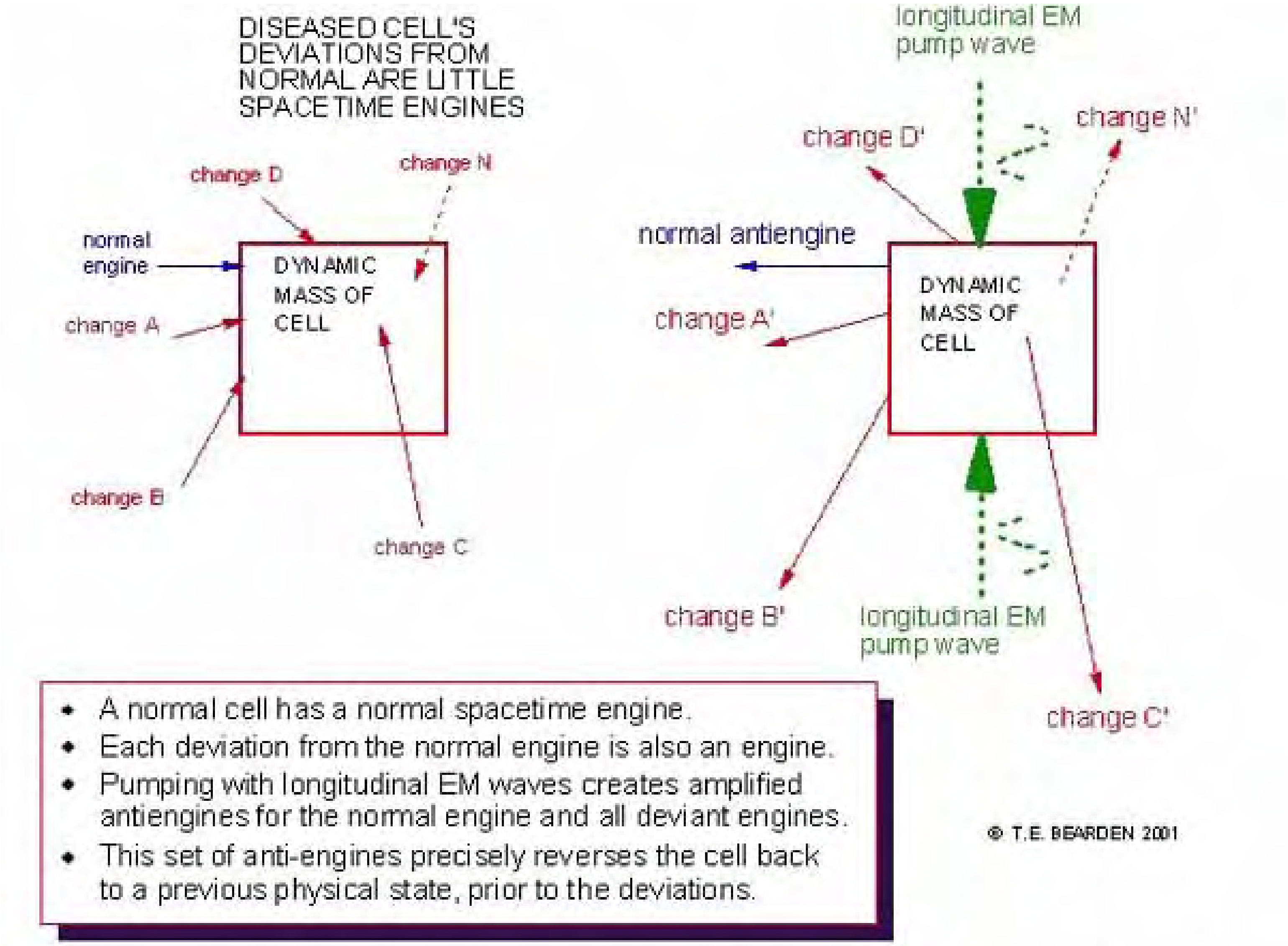
DISEASED CELL'S DEVIATIONS FROM NORMAL ARE LITTLE SPACETIME ENGINES
change D
change N
normal engine
DYNAMIC MASS OF CELL
change A
change B
change C
longitudinal EM pump wave
change D'
change N'
normal antiengine
change A'
DYNAMIC MASS OF CELL
change B'
longitudinal EM pump wave
change C'
© T.E. BEARDEN 2001

- A normal cell has a normal spacetime engine.
- Each deviation from the normal engine is also an engine.
- Pumping with longitudinal EM waves creates amplified antiengines for the normal engine and all deviant engines.
- This set of anti-engines precisely reverses the cell back to a previous physical state, prior to the deviations.

Figure 26. Producing a specific anti-engine for a specific cellular disease condition.

A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

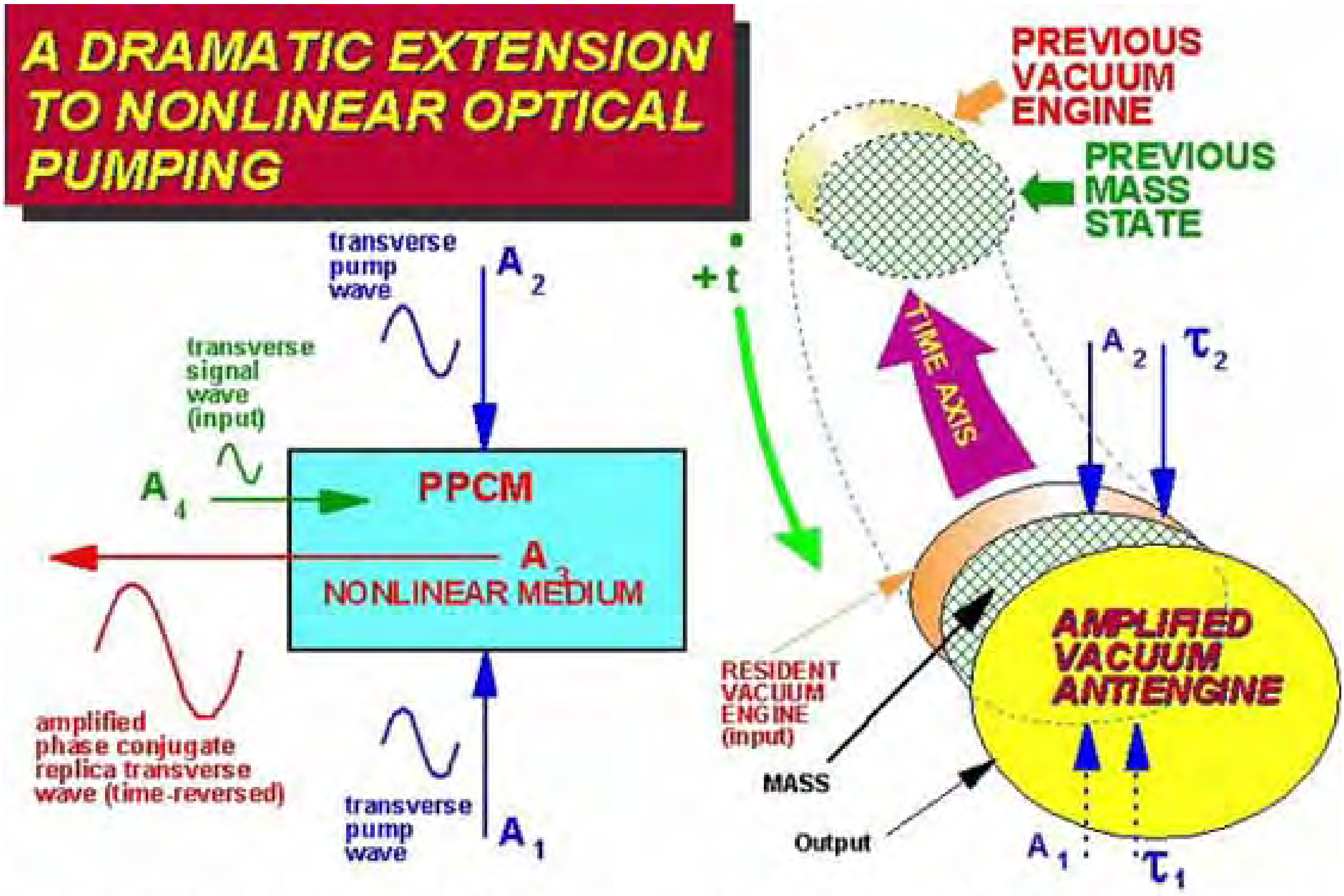
transverse pump wave
A_2
transverse signal wave (input)
A_4
PPCM
A_3
NONLINEAR MEDIUM
amplified phase conjugate replica transverse wave (time-reversed)
transverse pump wave
A_1
PREVIOUS VACUUM ENGINE
PREVIOUS MASS STATE
$+\dot{t}$
TIME AXIS
A_2
τ_2
AMPLIFIED VACUUM ANTIENGINE
RESIDENT VACUUM ENGINE (input)
MASS
Output
A_1
τ_1

a. Pumping with transverse EM waves produces a time-reversed *wave*.

b. Pumping with longitudinal EM waves A_1 and A_2 time-reverses *the mass itself*.

Figure 27. Pumping with longitudinal EM waves A also pumps in the time domain with time-polarized EM waves τ. This time-reverses a macroscopic mass and its dynamics.

Prioré's therapeutic methodology

Time-reverses the cells back to normal state

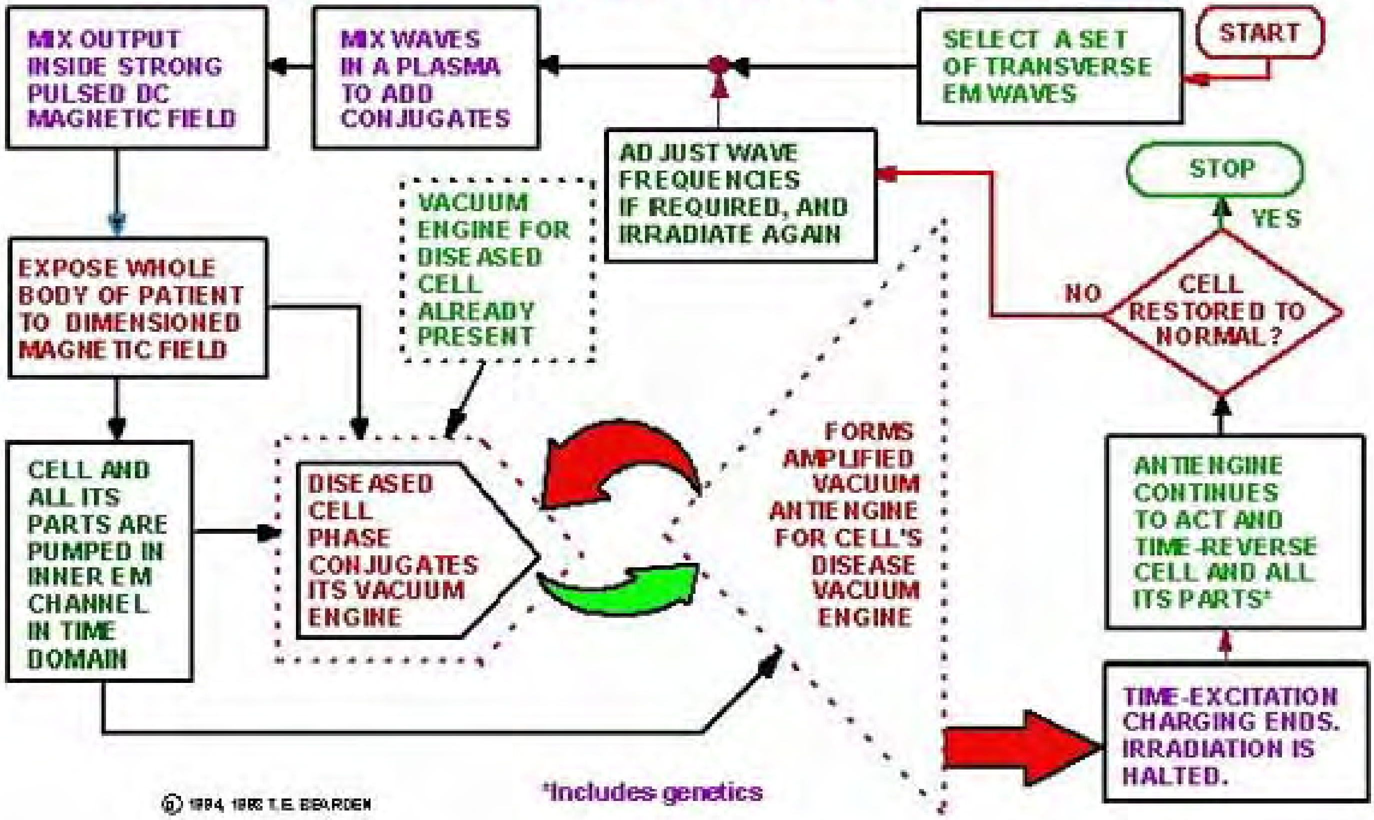
START
SELECT A SET OF TRANSVERSE EM WAVES
MIX WAVES IN A PLASMA TO ADD CONJUGATES
MIX OUTPUT INSIDE STRONG PULSED DC MAGNETIC FIELD
ADJUST WAVE FREQUENCIES IF REQUIRED, AND IRRADIATE AGAIN
EXPOSE WHOLE BODY OF PATIENT TO DIMENSIONED MAGNETIC FIELD
VACUUM ENGINE FOR DISEASED CELL ALREADY PRESENT
CELL AND ALL ITS PARTS ARE PUMPED IN INNER EM CHANNEL IN TIME DOMAIN
DISEASED CELL PHASE CONJUGATES ITS VACUUM ENGINE
FORMS AMPLIFIED VACUUM ANTIENGINE FOR CELL'S DISEASE VACUUM ENGINE
STOP
YES
NO
CELL RESTORED TO NORMAL?
ANTIENGINE CONTINUES TO ACT AND TIME-REVERSE CELL AND ALL ITS PARTS*
TIME-EXCITATION CHARGING ENDS. IRRADIATION IS HALTED.

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*Includes genetics

Figure 28. Block diagram of operation of Prioré's methodology.

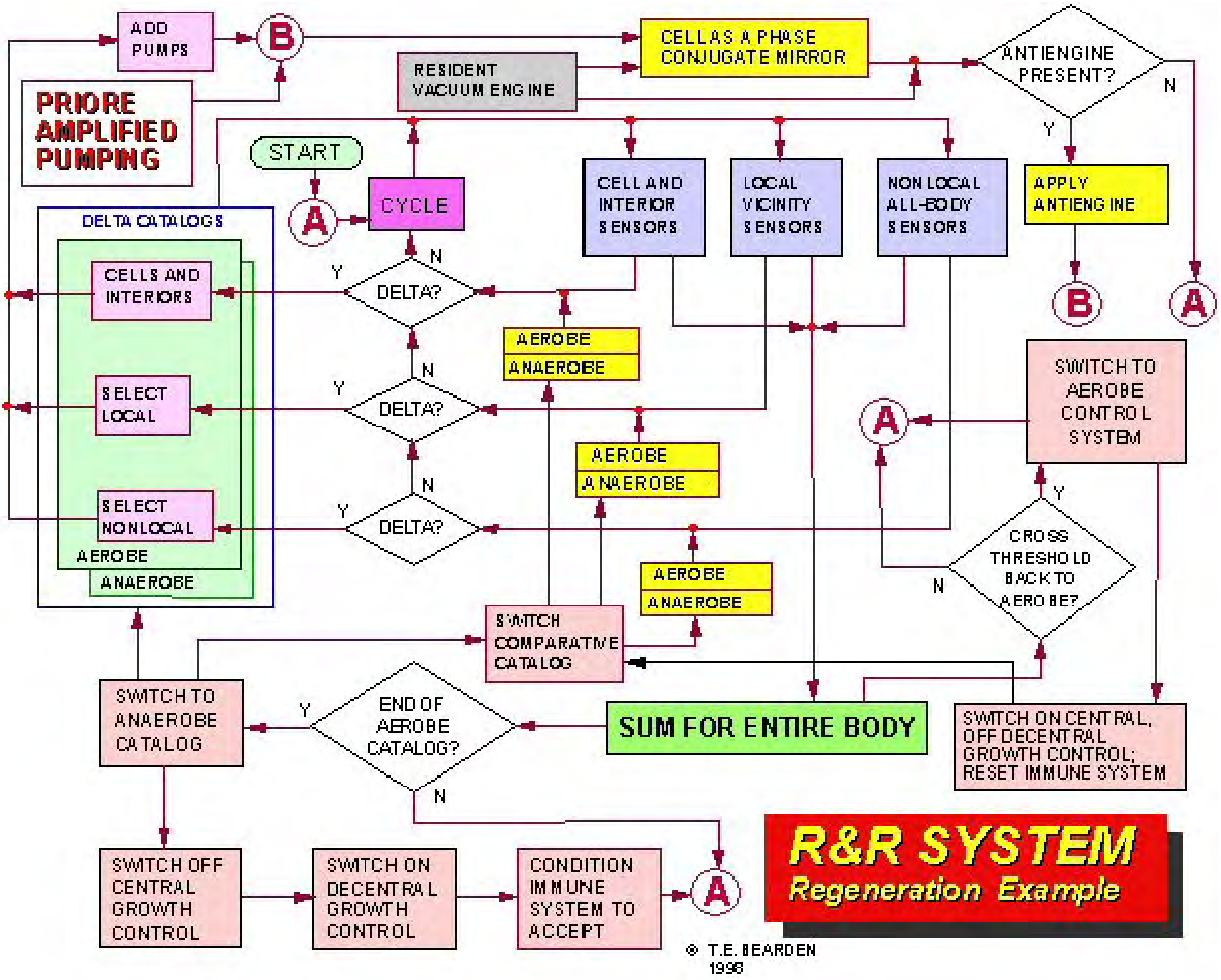
ADD PUMPS
B
PRIORE AMPLIFIED PUMPING
CELL AS A PHASE CONJUGATE MIRROR
RESIDENT VACUUM ENGINE
ANTIENGINE PRESENT?
N
Y
APPLY ANTIENGINE
B
A
START
A
CYCLE
CELL AND INTERIOR SENSORS
LOCAL VICINITY SENSORS
NON LOCAL ALL-BODY SENSORS
DELTA CATALOGS
CELLS AND INTERIORS
SELECT LOCAL
SELECT NONLOCAL
AEROBE
ANAEROBE
Y
N
DELTA?
Y
N
DELTA?
Y
N
DELTA?
AEROBE
ANAEROBE
AEROBE
ANAEROBE
AEROBE
ANAEROBE
A
SWITCH TO AEROBE CONTROL SYSTEM
Y
CROSS THRESHOLD BACK TO AEROBE?
N
SWITCH COMPARATIVE CATALOG
SWITCH TO ANAEROBE CATALOG
Y
END OF AEROBE CATALOG?
N
SUM FOR ENTIRE BODY
SWITCH ON CENTRAL, OFF DECENTRAL GROWTH CONTROL; RESET IMMUNE SYSTEM
SWITCH OFF CENTRAL GROWTH CONTROL
SWITCH ON DECENTRAL GROWTH CONTROL
CONDITION IMMUNE SYSTEM TO ACCEPT
A
R&R SYSTEM
Regeneration Example
© T.E. BEARDEN 1998

Figure 29. Block diagram of the cellular regeneration system and its overall operation (by the present author).

Rife's great secret: Recursive magnification by iterative serial summation of vacuum engines

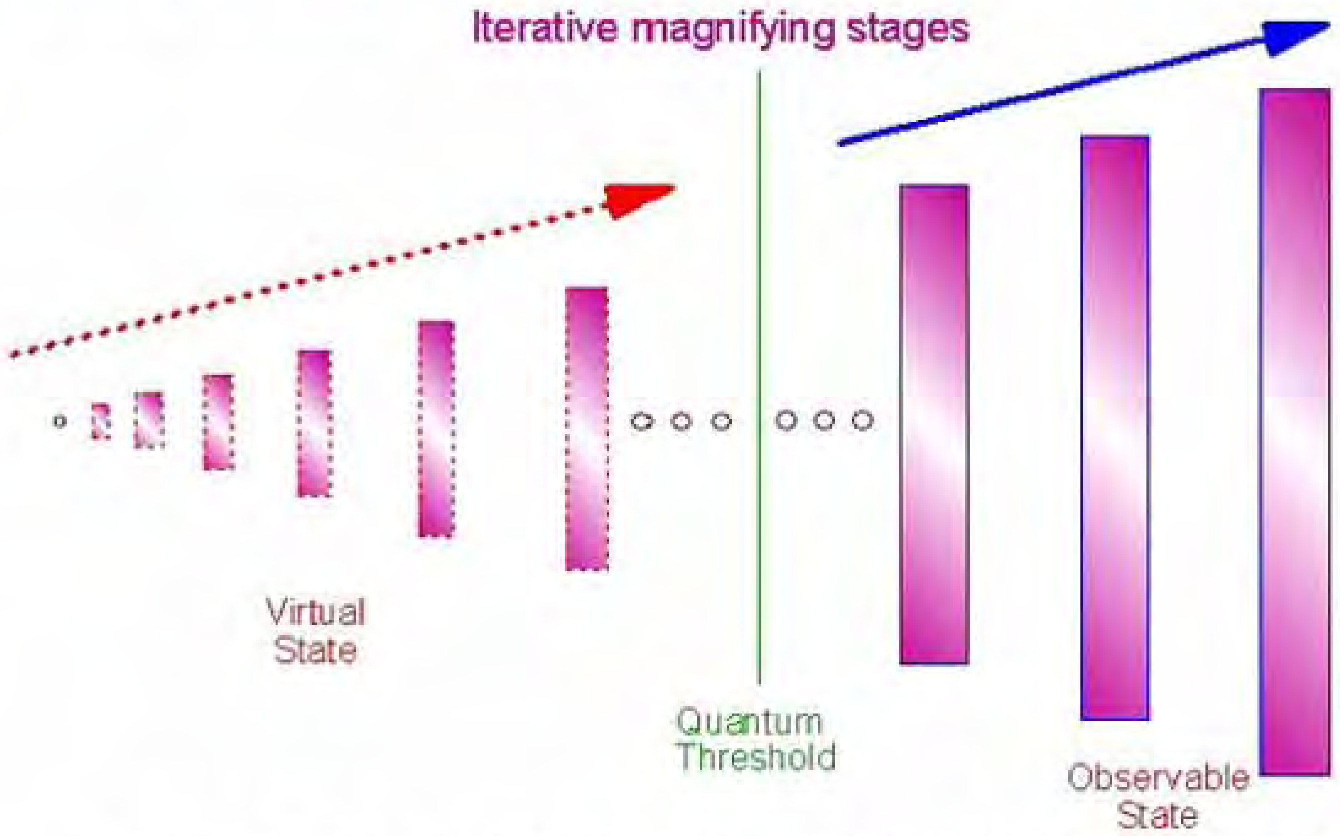
Iterative magnifying stages
Virtual State
Quantum Threshold
Observable State

Figure 30. Rife's great secret: Recursive magnification of the virtual state vacuum engines and their dynamics to the observable state.

Utilizing Scalar Electromagnetics To Tap Vacuum Energy

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(Also published in: Proceedings of the 26th Intersociety Energy Conversion Engineering Conference (IECEC Conf),
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ABSTRACT

Based on E.T. Whittaker's previously unnoticed 1903-1904 papers which established a hidden bidirectional EM wave structure in a standing forcefield free scalar potential, a method of directly engineering the ambient potential of the vacuum has been developed and realized experimentally.

Adding Whittaker's engineerable hidden variable theory to classical electro-magnetics, quantum mechanics, and general relativity produces supersets of each discipline. These supersets are joined by the common Whittaker subset, producing a unified field theory that is engineerable and tested.

By treating the nucleus of the atom as a pumped phase conjugate mirror, several working model energy units have been produced which excite and organize the local vacuum, increase the local virtual photon flux between local vacuum and nucleus, establish coherent self-oscillations between the local excited vacuum and the affected nuclei, utilize the self-oscillating standing wave for self-pumping of the nuclei/mirrors, introduce a very tiny signal wave to the mirrors, and output into an external load circuit a powerful, amplified, time-reversed phase conjugate replica wave at 60 Hertz frequency and nominal 120 volt sine wave power.

Several models have been built, ranging from 6 watts early on to one of 5 kilowatts. Both closed batteryless systems with damped positive feedback and open loop systems with battery-powered input have been successfully built. Open loop power gains of from 5×10^4 to 1.5×10^6 have been achieved.

Antigravity experiments have also been successfully conducted where the weight of the unit was reduced by 90% in controlled experiments, with a signal wave input of 175 microwatts and an output of 1 kilowatt.

The basic theory of the device is briefly explained and experimental results presented. In the demonstration session, a videotape of one operating open-loop unit with a 1.5×10^6 power gain is planned, as is the demonstration of an actual working model closed-loop system with a nominal rating of 500 watts, and without external power input of any kind.

The units are solid state, with no moving parts. Each of them comprises a unique form of self-powered vacuum triode of extraordinary gain, where the cathode power and plate power are freely furnished by the vacuum, and only a small grid signal need be furnished either from an external power source or by clamped positive feedback from the device's output. The output is negative energy, and some of its unique characteristics are pointed out.

Implications of the experimental application of the Sweet vacuum triode, the Bearden approach to the nucleus as a pumped phase conjugate mirror, and the unified field theory based on Whittaker's engineerable hidden variable scalar EM potential theory are also briefly addressed.

SCALAR ELECTROMAGNETICS

In 1837 Sir W.R. Hamilton said,

"The notion of time may be unfolded into an independent pure science... a science of pure time is possible."

As is well-known, the fundamental units utilized in physics are arbitrary. It is even possible to construct all of physics on a single unit, time. This oddity shows the truth in Hamilton's statement; it is even more odd, because quantum mechanically time is not an observable. This means that the observable world can be modeled completely in terms of the nonobservable, which is essentially what modern quantum mechanics is now doing.

Hamilton viewed his magnificent quaternions as essentially having accomplished the mathematical structuring of time. Maxwell's original EM theory, as is well-known, was modeled in Hamilton's *quaternions*, not in the highly curtailed Heaviside/Hertz vectors erroneously taught today as "Maxwell's theory."

Not a single one of the present so-called "Maxwell's" vector equations ever appeared in a book or paper by James Clerk Maxwell.

For some years the author has worked on an extended electromagnetics theory, involving the scalar component of the quaternion. [Ref. 1]

In Maxwell's original *quaternion* theory, this scalar component often remains when the directional components zero. Further, it then enfolds vectors and functions of vectors inside, in a hidden variable manner. Specifically, the author has patterned a unified field theory concept upon the previously unnoticed but remarkable early work of E.T. Whittaker. [Ref. 2]

In two fundamental papers in 1903 and 1904, Whittaker showed that all present vector EM can be replaced by scalar potential interferometry, and that bidirectional harmonic EM plane wave sets could be used to produce a standing wave of force-field-free potential (Figures 1 and 2).

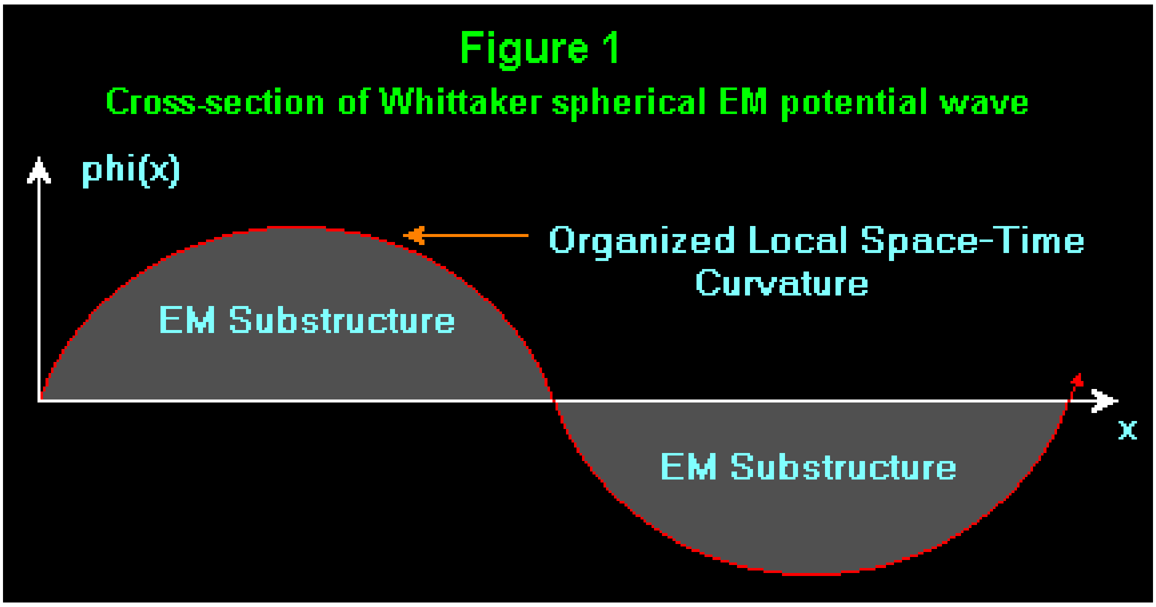
Figure 1
Cross-section of Whittaker spherical EM potential wave
phi(x)
Organized Local Space-Time Curvature
EM Substructure
EM Substructure
x

NOTE: SHAPE MAY BE ALL ABOVE OR ALL BELOW AMBIENT VACUUM POTENTIAL

Thus Whittaker anticipated the quantum mechanical Aharonov/Bohm effect by 55 years, including extending it to the macroscopic world instead of the mesoscopic realm where it has been established to date. [Ref. 3]

In modern terms, Whittaker showed how to turn EM wave energy into electrogravitational potential energy, then how to interfere two such scalar potential waves to recover electromagnetic energy, even at a distance. [Ref. 4]

This unrecognized work is of great importance: when applied to modern physics, it produces supersets of quantum mechanics (QM), classical electromagnetics (EM), and general relativity (GR).

Further, all three extended disciplines unify on their common Whittaker subset, in a testable and engineerable fashion. [Ref. 5]

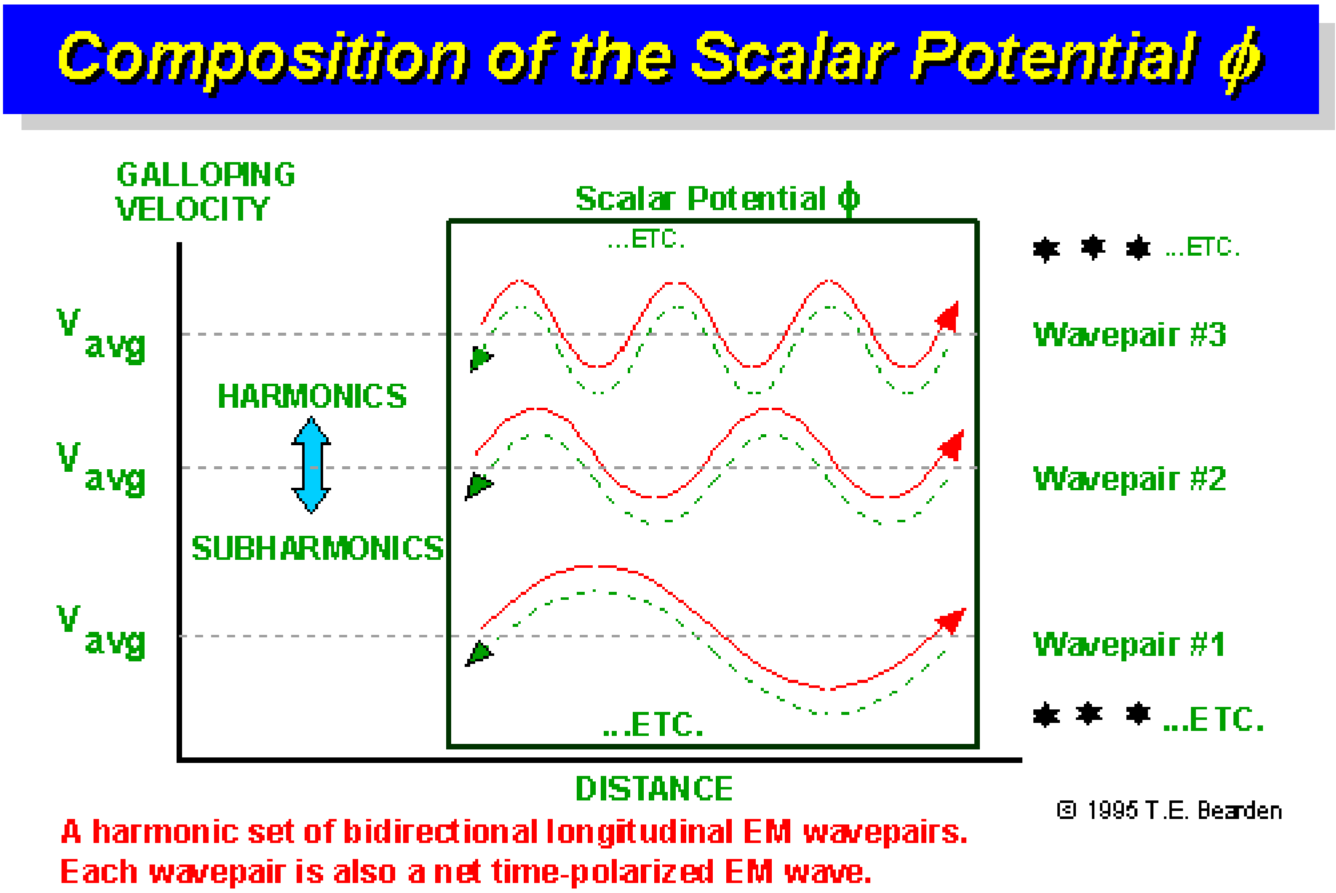
Composition of the Scalar Potential ϕ
GALLOPING VELOCITY
Scalar Potential ϕ
...ETC.
✱ ✱ ✱ ...ETC.
V_{avg}
Wavepair #3
HARMONICS
V_{avg}
Wavepair #2
SUBHARMONICS
V_{avg}
Wavepair #1
...ETC.
✱ ✱ ✱ ...ETC.
DISTANCE
© 1995 T.E. Bearden
A harmonic set of bidirectional longitudinal EM wavepairs.
Each wavepair is also a net time-polarized EM wave.

Figure 2. Infolded EM plane wave structure of a Whittaker wave.

The Nucleus As a PPCM and Triode

The author has also considered the highly nonlinear nucleus of the atom as a pumped phase conjugate mirror (PPCM), having found no other consideration of same in the literature.

The author also dubbed a PPCM a "triode," since the amplified phase conjugate replica of the signal wave is much like the amplified output of a triode, and the signal wave input to a PPCM is much like a triode's grid signal input. The PPCM pump wave then corresponds roughly to the power input to the cathode and plate of a triode. [Ref. 6]

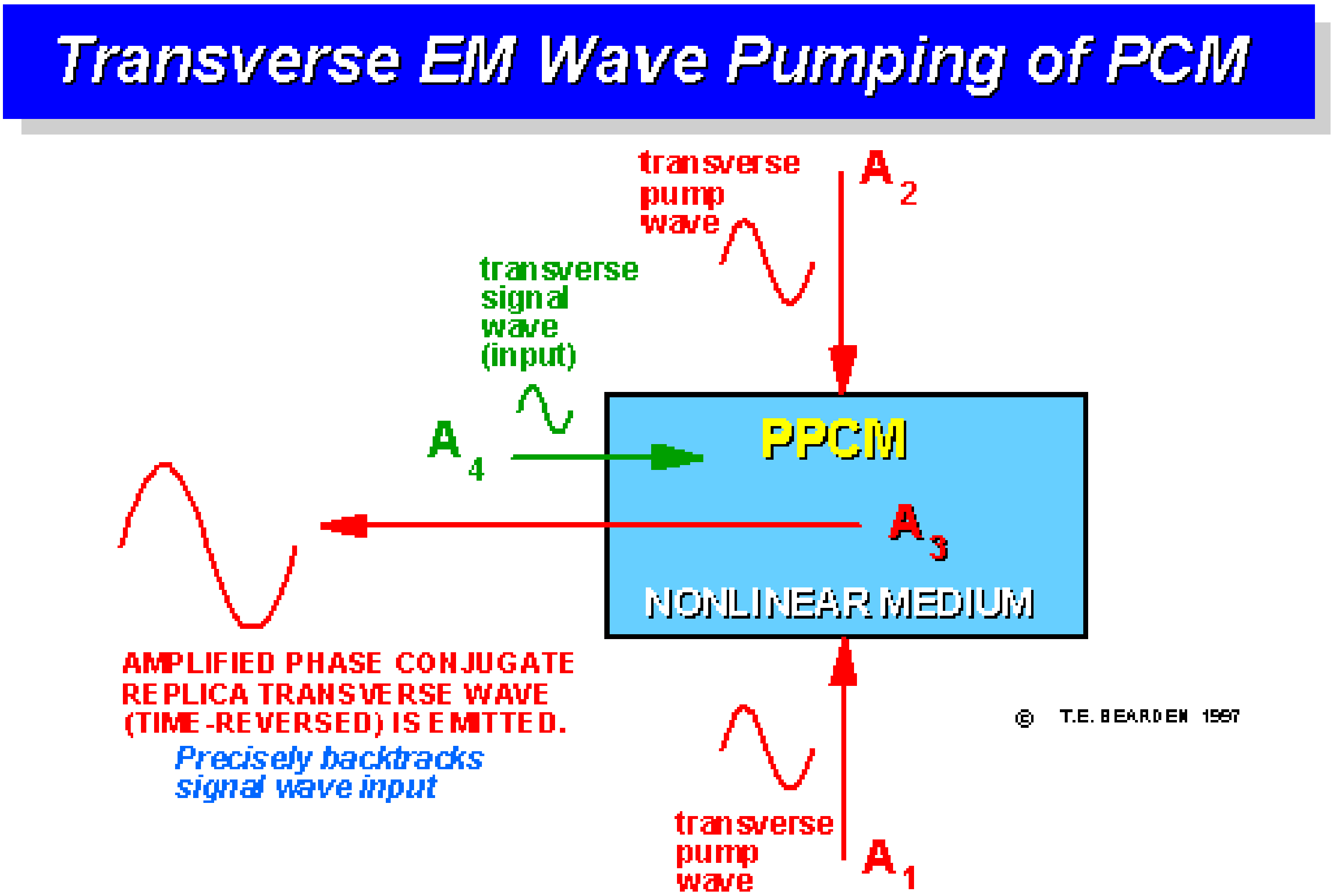
Transverse EM Wave Pumping of PCM
transverse
pump
wave
A_2
transverse
signal
wave
(input)
A_4
PPCM
A_3
NONLINEAR MEDIUM
AMPLIFIED PHASE CONJUGATE
REPLICA TRANSVERSE WAVE
(TIME-REVERSED) IS EMITTED.
Precisely backtracks
signal wave input
© T.E. BEARDEN 1997
transverse
pump
wave
A_1

Figure 3. A pumped phase conjugate mirror.

VACUUM TRIODE BACKGROUND

About seven years ago, the author was privileged to see and examine an invention of Mr. Floyd Sweet, that produced about 6 watts of electrical power from the vacuum itself.

This remarkable device, which the author dubbed a *vacuum triode*, in a single unit utilized most of the scalar EM concepts the author had so painfully and slowly formulated over the years.

Sweet, a brilliant inventor with a remarkable knowledge of magnetics, had utilized barium ferrite magnets and special coils to produce a solid-state device that successfully tapped the vacuum energy.

The author quickly put together a theoretical concept for the energy-tapping mechanism, based on treatment of the nucleus as a PPCM and Whittaker's scalar EM potential unified field theory. [Ref. 7]

The author furnished the technical concept, treating the nucleus as a pumped phase conjugate mirror, to the inventor along with copies of Whittaker's papers.

Sweet's Synthesis and Extension

Sweet is also a brilliant EM theoretician, working in four, five, or even six dimensions with ease. He immediately synthesized the entire PPCM and Whittaker theory, and developed a complete theoretical treatment of the device. [Ref. 8]

He also increased the nuclear potential utilized in the activated nuclei of the device, which increased the pumping energy and hence the energy output. He next produced an open-loop vacuum triode (VT) with an output of 500 watts, for an input of 33 microwatts.

Thereafter he produced several other models, including closed-loop systems and one with 5-KW output.

Purpose of This Paper

Our purpose is to explain the detailed scalar EM concept of the operation of the vacuum triode, since it is a universal method for cohering and tapping useful EM energy from the vacuum.

The author believes that this mechanism is the fundamental mechanism that must be invoked in any over-unity device that electromagnetically extracts vacuum energy as electromagnetic effects.

We also intend to demonstrate a full working model of the device at this conference. Sweet's detailed theoretical treatment will be completed and submitted to a major journal shortly, to complete the scientific exposition of the new methodology.

I must also express my deep admiration for my brilliant inventor colleague. It has been a privilege to work with him, though under great difficulties and at a distance. He has developed several other related devices that are of great importance to the emerging new physics of *vacuum engineering*, in the sense referred to by Lee. [Ref. 9]

To mention just one, he has produced a magnetic lens which apparently can directly display the vacuum's virtual particle flux, or a good analog of it. So far as I am aware, this is the only extant instrument today that can perform this feat.

When the vacuum triode has been proven to the scientific community, it is my intention to nominate Sweet for the Nobel Prize he so richly deserves, and seek high scientific endorsements for the recommendation.

INTRODUCTION

Entropy

As is well known, in any closed dynamic system the order existing in it will gradually be dissipated, as more and more interactions occur. This leads to the notion of *entropy* as the increasing disorder in such systems. The assumptions are

1. a closed system, and
2. a positive flow of time for the components of the system.

Actually no such thing as a completely closed system exists in nature. Every mass system is open to virtual particle flux exchange with the vacuum, for example, particularly in the nucleus of its atoms, where the bulk of its mass is located.

However, the closed system assumption is reasonably approximated by a great many systems which are in stable thermodynamic equilibrium, or nearly so.

On the other hand, in an open system far from thermodynamic equilibrium, the second law of thermodynamics does not necessarily apply, because the system violates both the closed system assumption and its equilibrium approximation. [Ref. 10]

Time Reversal

Since being discovered in 1972 in the open Soviet literature, the time-reversed (phase conjugate) EM wave has also been known. The phase conjugate EM wave is truly time-reversed, as has been shown experimentally. Since the time-reversed EM wave violates the second major assumption, the second law of thermodynamics need not necessarily hold for time-reversed entities.

Putting all this together, if one wishes negentropy and hence increased energy in a system, the candidate suggested would appear to be a system that was strongly

1. open loop,
2. time-reversed, and
3. far from thermodynamic equilibrium.

A good overview of time-reversal in physics has been provided by Sachs. [Ref. 11]

Engineering the Nucleus

Since the nucleus already provides a myriad of time-reversed processes, engineering the nucleus of an atom is a very good candidate for practical negentropy.

To engineer the nucleus directly, a Whittaker potential is first artificially constructed, by composing a harmonic set of phase-locked EM wave/antiwave pairs. It is accented that the antiwaves must be true phase conjugates; otherwise they will not constitute a gradient-free Whittaker standing potential wave.

In addition, at least one harmonic interval must be used, and additional harmonic sets are most desirable. The reason is that a space-time lattice must be formed in the vacuum, where the energy is additive spatially but oppositive in t-dot, the rate of flow of time, in the fourth dimension.

So a time-structure is required as well as a spatial structure, which is what is provided by ***n*** bidirectional harmonic Whittaker EM wave sets, where ***n*** is an integer greater than 1.

Once a specific Whittaker structure has been chosen, the local lattice of space-time is established. This establishes phase-locked lattice groupings of coupled photon/antiphoton pairs, or of *gravitons*. In turn, this Whittaker-structured vacuum now contains specific graviton *vacuum engines*, which directly engineer and structure the vacuum's virtual particle flux (VPF) exchange with the nucleus. [Ref. 12]

The nucleus is highly nonlinear, hence strongly phase conjugative, or time-reversed. The ambient potential of the local vacuum surrounding the nucleus is in a violent virtual photon exchange with it, accounting for its electrical charge.

Since the preponderant charge is positive, from the viewpoint of the ordinary light observer whose light interacts with electron shells, the nucleus may be taken to exhibit time reversal (phase conjugation).

Energy, Time, and Gravitons

We take the definition of "energy" to be fundamentally an ordering imposed upon the VPF of vacuum. We take photon scattering from the electron shells of atoms to be the fundamental exterior mechanism producing forward flow of external observer time.

It then follows that "time's arrow" for the EM observer is due to the universal scattering of photons from electron shells.

In this view, forward (positive) time flow and entropy are due to the same primary action: photon scattering from electron shells. It is unfortunate that the concept of "positive" energy has been tied to, and defined in terms of, the scattering and dissipation of VPF order as *work*, or energy expended.

Via the standard labeling, then, negative energy is the reconstitution of order in the vacuum VPF. It should be noted that, in a PPCM, dissipative or external pump wave stress energy can be scavenged and re-emitted in perfect order as the phase conjugate replica. This is a *negentropic* process, for it is capable of turning disorder into order. [Ref. 13]

In the time-reversed PPCM nucleus, we should expect to see appreciable *negative energy*—that is, energy removed from the EM scattering domain. This includes the binding energy of the nucleus, and the gravitational (G) potential energy of the EM energy removed from the "scattering interaction realm" and locked into the mass.

Following Sakharov, we hold that the G-field is not a fundamental field of nature, but a composite caused by, or made from, other fields. [Ref. 14]

To the first order, we assume the G-potential is comprised of coupled photon/antiphoton pairs, on the average, where the statistical coupled spin-2 photon/antiphoton pair is a *graviton*. [Ref. 15]

We follow the modern view of the field: because of vacuum fluctuations, rigorously one no longer speaks of "the" field, but of the *probability of a particular field configuration*. [Ref. 16]

We also hold the vacuum to be composed of potentials, and regard the three terms *space-time, vacuum*, and *scalar potential* as essentially synonymous.

Newton's Third Law and the Detection Process

The VPF EM stress of the local vacuum immediately surrounding the nucleus may be decomposed a la Whittaker into opposing bidirectional EM plane waves/forces. Thus the nonlinear nucleus may be regarded as a pumped phase conjugate mirror, normally with a gain of one.

In this view, Newton's third law reaction force is generated because the so-called "photon" interaction with an atom is in fact a graviton reaction involving a photon/antiphoton pair that is decoupled.

The decoupled photon normally is absorbed and reradiated by an orbital electron, while the decoupled antiphoton interacts with the nucleus, producing a time-reversed twin of the external force—or, in other words, Newton's third law reaction force, which gives a slight recoil of the nucleus.

Half of every measurement physicists normally make is discarded, with the missing half accounting only for Newtonian reaction in the meter or instrument, which is usually ignored.

The fact that half of our measurement interactions are ignored is occasionally discovered and noted by physicists, who may even write a paper pointing it out, but no change is instituted in the foundations. [Ref. 17 and Ref 18]

Semiconducting Vacuum and Self-Oscillation

The vacuum immediately surrounding the nucleus is structured by the nucleus, and is itself nonlinear and capable of acting as a *semiconductor*. [Ref. 19]

Since both this immediately local semiconductor vacuum and the nucleus it surrounds are highly nonlinear, then *nonlinear resonance* can conceivably be established between them.

Further, since the resonating system in such case is an open system away from thermodynamic equilibrium, the oscillation can be self-sustaining. Such self-oscillation of the pumping of a PCM is already well-known in the nonlinear optical literature, particularly with compounds containing barium. [Ref. 20]

THE VACUUM TRIODE

The Basic Concept

As is well-known, a stress can be decomposed into opposing sets of forces. But quantum mechanically, the forces we are interested in with our work here are all caused *electromagnetically*, by the exchange of virtual photons. Even mechanical force, according to QM, is caused in this manner. Thus opposing electromagnetic or mechanical "stress" sets of bidirectional EM forces are microscopically equivalent to the notion of *pump waves* in nonlinear optics.

Hence under the proper conditions, it follows that trapped EM stress energy of the vacuum can be utilized to "pump" the nucleus.

Treating the stress-pumped nonlinear nucleus as a PPCM, it follows that the stress energy of the vacuum can be tapped by a 4-wave mixing mechanism in the atomic nucleus, to provide amplified phase conjugate EM wave outputs from the atom in response to small signal wave inputs. [Ref. 21]

In the proper nonlinear material, the material may act as a PPCM, in which case there exists a suitable connection between the material's atomic nuclei and its external electromagnetic lattice bonds, and the amplified phase conjugate replica wave generated in the nucleus will be emitted from the material as an EM wave field. This field can then be tapped by suitable means and output to an external load circuit.

Block Diagram of the Vacuum Triode

Figure 4 shows a basic block diagram of the vacuum triode process, utilized by Sweet in several laboratory vacuum energy devices. These devices have ranged from a nominal 500 watt output in a 6-lb. device to 5 kilowatts for a heavier unit. Gains have ranged from 50,000 to 1,500,000 for open-loop systems. Both open-loop and closed-loop systems have been built and tested.

Figure 4 shows a combined block diagram for either a closed-loop or open-loop system. In the open-loop system, a barium ferrite magnetic material is used as a pumped phase conjugate mirror.

In the "standard" design, two opposing PPCMs are used. The advantage of this dual combination is the use of *self-targeting* (repetitive phase conjugation, signal by signal). This has the effect of

1. stabilizing the Whittaker field, and
2. producing a quantum potential between the two mirrors, so the mirrors and the Whittaker potential between them are essentially one single space-time entity.

Discussion of a quantum potential is beyond the scope of this paper, but the technical mechanism for creating one has been previously presented by the author on several occasions. [Ref. 22]

First we will explain the open-loop operation of the vacuum triode. In Figure 4, on the right an external 60 Hz, nominal 10 volt AC sine wave of several tens of microwatts in power is input into the stabilized field of the barium ferrite magnet structure, where it modulates the field, producing a signal wave input into the atoms of the material.

In the top right block, the EM signal wave interacts with the electron shell of an atom, which in turn is EM-coupled to the nucleus.

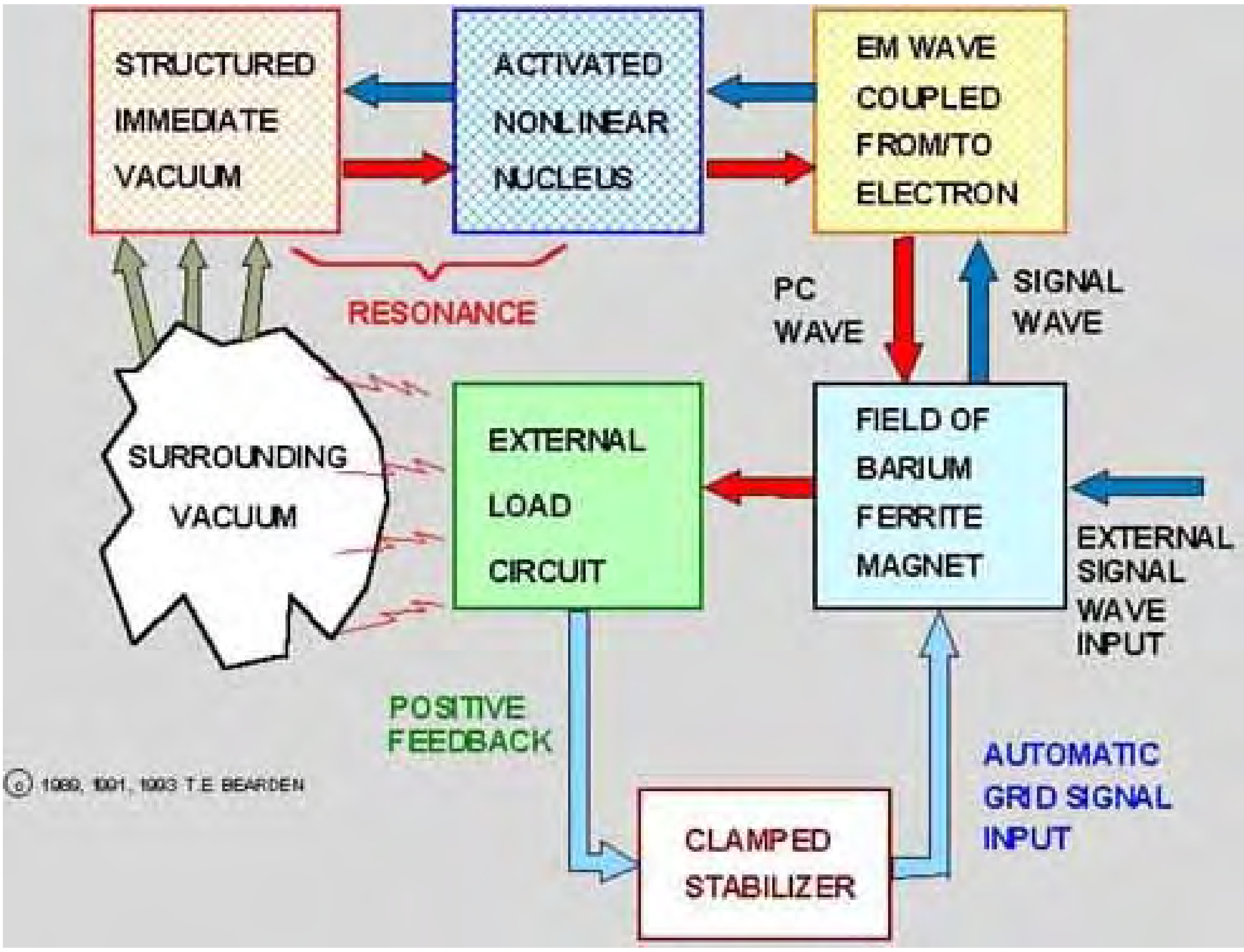
STRUCTURED IMMEDIATE VACUUM
ACTIVATED NONLINEAR NUCLEUS
EM WAVE COUPLED FROM/TO ELECTRON
RESONANCE
PC WAVE
SIGNAL WAVE
SURROUNDING VACUUM
EXTERNAL LOAD CIRCUIT
FIELD OF BARIUM FERRITE MAGNET
EXTERNAL SIGNAL WAVE INPUT
POSITIVE FEEDBACK
© 1989, 1991, 1993 T.E. BEARDEN
CLAMPED STABILIZER
AUTOMATIC GRID SIGNAL INPUT

Figure 4. The Vacuum Triode Concept.

Thus an EM signal wave is input to the nucleus of the atom, which is highly nonlinear (middle top block). Earlier, Sweet had specifically conditioned the atomic nuclei with a proprietary process, wherein in the barium nucleus a trapped 60 Hz scalar EM spherical wave resonance (self-oscillation) exists between the structured semiconductor vacuum immediately surrounding the Ba nucleus.

In the same *activation* process, the ambient potential of the surrounding vacuum was raised and stabilized, in the two leftmost blocks.

At this point the nonlinear nucleus is effectively self-pumped by the trapped, excited, spherical scalar wave oscillation between the structured semiconductor vacuum and the nucleus. The nucleus is now a strongly pumped phase conjugate mirror.

Consequently, when the signal wave input arrives, the PPCM nucleus emits an amplified phase conjugate replica (PCR) wave, which precisely backtracks the input signal wave. This precise backtracking (perfect retroreflection) is referred to as the "distortion correction theorem."

In short, the powerful PCR wave returns precisely toward the external source, passing through the electron shells and arriving in the perturbed barium ferrite magnet assembly field, where it perturbs the field.

A transformer-like system then extracts this magnetic field perturbation and conducts it to the external load circuit.

However, the PCR contains *negative* energy. Short of the load, the internal circuits run cool, rather than heating. This is a signature of a true vacuum energy tapping device.

Indeed, if the output leads of the Sweet vacuum triode are physically shorted together, a brilliant flash occurs, and the leads instantly ice as if dipped in liquid oxygen. This is another signature of the true negentropic over-unity vacuum tap.

Note that the energy extracted from the semiconducting vacuum adjacent to the nucleus is just instantly replaced by the surrounding vacuum's inexhaustible energy pool. This is an open-loop system, with a hidden energy source: the intense virtual particle flux of the vacuum's ambient charge.

It is not possible to exhaust that flux, which is often calculated to have an energy density of some 10^{100} or more grams per cm^3, if the energy were cohered and condensed into mass.

As can be seen, even a VT gain of 1.5×10^6 represents a "vacuum tap" of an incredibly small efficiency, on the order of 10^{-100} or so. However, the vacuum "river" is so energetic that such efficiencies are quite sufficient.

We accent that the barium ferrite magnetic material must be *activated* so that stable self-oscillation between the barium nucleus and the surrounding semiconductor vacuum exists. Although self-oscillating/self-pumped PCMs are known at optical frequencies, Sweet has discovered and perfected a brilliant methodology for activating PPCM nuclei at ELF frequencies.

In a resistive load such as light bulbs, the resistive material accomplishes repetitive phase conjugation. Thus in the resistor, half the total energy is expressed as photon or dissipative energy in the external (electron shell) level.

As the excited electrons decay, they emit scattered EM energy as light and heat. This is an *exothermic* interaction. The other half of the total energy reacts in the atomic nuclei, as a phase conjugative or *endothermic* interaction.

We strongly accent that, Whittaker-wise, there are two electromagnetic channels and two kinds of EM:

1. *external* EM, the common electron-shell interacting, entropic, scattering, time-forward kind, and

2. the *internal*, unsuspected, hidden variable, nuclei interacting, negentropic, reordering/ convergent kind.

Internal EM travels strictly between atomic nuclei, normally not reacting with electron shells unless a pumped phase conjugate mirror reaction is invoked in the nucleus to produce a gain somewhat greater than unity.

Thus if we wish to communicate with atomic nuclei directly, and engineer them directly, we must utilize the internal EM channel via applied Whittaker methods.

Antigravity Tests

Inherent in the preceding discussions is the possibility to turn EM energy into gravitational energy of either sign. In other words, one should be able to utilize Sweet's vacuum triode to produce and demonstrate antigravity.

Indeed this is the case. Sweet has also discovered the special alterations necessary to perform straightforward transformation of the internal energy in the nucleus to antigravitational energy, producing a unilateral thrust upward.

Note that the bulk of G-potential gradient (G-force-field) occurs Whittaker-wise at ELF frequencies. This explains why nonlinear phase conjugate opticians do not notice direct antigravity effects.

At the optical frequencies at which they work, the effects are so miniscule that they are negligible. This is readily explained as follows: In QM, the quantum (photon) is comprised of action (angular momentum), not just energy. It is rather like a "piece of energy welded to a piece of time, with no seam in the middle."

Since quantum change occurs in quanta, the decoupling of the energy and time components, in the continual interaction of photons with matter, exchanges energy between G-potential of vacuum and trapped mass of the atom or particle. In this exchange, small increments of time are continually being formed (and unformed, as photon emission occurs).

Consequently, each mass is moving forward in time in small incremental jumps, usually of exceedingly small magnitude. However, the energy and time trapped in a photon are canonical. The greater the piece of energy, the smaller the piece of time, and vice versa.

So if one wishes to stress the "rate of flow of time" significantly, one needs to produce large amounts of photons that have very large pieces of time, and consequently little pieces of energy.

Since the energy of the photon is directly proportional to its frequency, this means that the lower frequency photons have larger time increments, and hence endure over many "regular-sized photon absorption/emission changes" to appreciably stress the rate of time flow/production.

The bottom line is that the standard pumped phase conjugate mirror can be adapted to produce antigravity at ELF frequencies, but precisely the same adaptation at optical frequencies will have negligible effect.

With this in mind, the author requested Sweet to perform an antigravity experiment to prove the thesis. With Sweet's proprietary adaptation of his vacuum triode/PPCM, the experiment produced rather straightforward but spectacular results, as shown in Figure 5.

The experiment was performed as follows: Rigged for antigravity, the 6-lb. device was placed on a scale so that its weight could be continuously monitored. A special external load box was utilized in which multiple electric light sockets were connected in parallel.

Then the external load draw was adjusted by merely screwing in 100-watt lamps, one at a time, with measurement and observation pauses in between. The output of the device was 120 volt, negative AC sine-wave power at 60 Hz.

For each 100-watt increment, the load power was recorded and the weight was carefully recorded. The results are shown in the rather smooth, classic curve shown in Figure 5.

At 1,000 watts load draw, the previously 6-lb. device had reduced its weight due to gravity by 90 percent. At that point the signal-wave (grid) input to the open-loop vacuum triode was only 175.4 microamps at 10 volts, or just under two milliwatts.

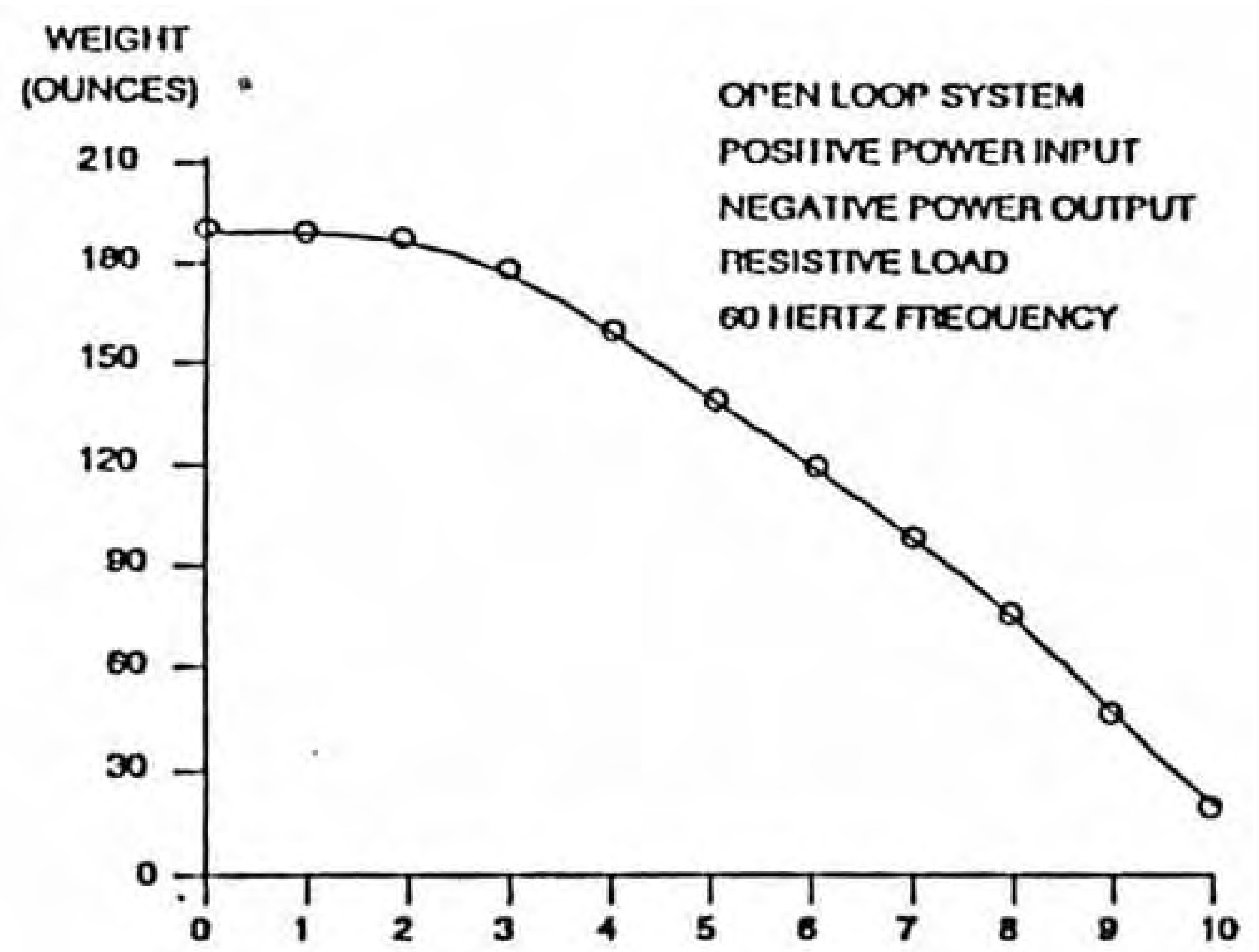

EXTERNAL ELECTRICAL LOAD

(HUNDREDS OF WATTS)

Figure 5. Antigravity Test of Sweet's Adapted Vacuum Triode.

We accent that the nominal two milliwatt input is only a gating signal. It is the organized, gated vacuum energy that is performing the action.

The experiment was stopped short of actual hovering and flying due to safety considerations. With the specific adaptation, magnetic monopoles are deposited in the magnet materials, producing internal tensile stress.

Since no explosive controlled facilities were available, and there was no wish to destroy the VT, the experiment was terminated at 90% antigravity performance.

It was completely successful, and adequately demonstrated the validity of the unified field theory concepts utilized in our approach.

CONCLUSIONS

A new unified field theory has been developed, tested, and at least partially verified experimentally.

The concepts of the theory have been applied by Sweet in a series of inventions that produce readily usable, safe electromagnetic power directly from the vacuum.

The methodology lends itself to formulation of power devices without moving parts. Antigravity, predicted by the concepts of the theory, has been demonstrated in actual practical demonstrations on the laboratory bench.

Though not discussed in this paper, application of the concepts and methodology to a large variety of other fields, such as medical reversal of aging and curing of almost the entire range of present debilitating diseases, has been previously pointed out. [Ref. 23]

We have also pointed out the mechanism for Kaznacheyev's cytopathogenic effect, or the induction of cellular pathology at a distance by electromagnetic means. [Ref. 24]

We have also pointed out the specific mechanism involved in Priore's device, which in rigorous laboratory animal testing under the auspices of eminent French scientists, demonstrated nearly 100 percent cures for terminal cancers and leukemias, sleeping sickness, artherosclerosis, and other debilitating diseases.[Ref. 25]

We believe we have also produced the concepts enabling the direct engineering and therapeutic manipulation of Popp's master cellular control system. [Ref. 26]

We conclude that the concepts we have utilized and experimentally demonstrated are universal, as implied by any notional unified field theory.

Our conclusion is that the concepts, theory, and experiments, taken together, are sufficient for investigation and replication by the scientific community.

If replicated and fully substantiated, we believe the work will directly point the way to, and usher in, a new unified field theory physics of universal application.

SPECULATED IMPLICATIONS

As can be seen, the implications of the new approach are profound. The authors believe they have ushered in the forerunner of a vast new physics, one which will change our lives, and our view of physical reality, in ways previously undreamed of.

By mastering, controlling, and gating the vast, incredible energy of the seething vacuum, we can power our automobiles, flying machines, and technology inexhaustibly. Further, it can be done absolutely cleanly; there are no noxious chemical pollutants to poison the biosphere. With practical antigravity, ships can be developed to cross the solar system as readily as one crosses the ocean today.

And the ships, automobiles, and technology will never run out of fuel; the inexhaustible vacuum fills every system, everywhere, to overflowing.

Not discussed in this paper, it turns out that living systems, faced with the problem of achieving negentropy so as to maintain their form in a dissipative external physical reality, have always used the hidden internal channel for such things as mind, thought, cell control, and living functions.

With the new methodology, one now faces the advent of access and engineering of the mind and life of the observer as readily as the observer's physical body.

Transmutation of the elements, control of the weather, lighting and powering our cities and homes cheaply and cleanly, and provision of plenty for everyone is the vista for the future. We can in fact clean up the radioactive wastes, rid ourselves of coarse nuclear and petroleum powerplants.

We strongly stress that, with the ability to engineer the Schroedinger equation itself, the new methodology allows the direct engineering and control of quantum change, and hence of physical reality itself.

The methodology is extendable to hyperdimensions; nested virtual levels of the vacuum are already precisely that. The author has already pointed out the application of this emerging technology to the absolute cure of diseases such as AIDS, cancer, leukemia, etc., and shown that the Priore device in France already proved the efficacy of the application in the 60s and 70s.

We shall be able to rid ourselves and our descendents of diseases. With direct access to the actual software of life and mind, in the future we should be able to achieve levels of education previously unattainable, by directly inputting the relevant software.

Previously we have also pointed out that four nations of the world are already embarked on weaponization of scalar EM unified field technology. It is sobering to think that, in addition to having the ability to make our planet a paradise for humankind, we also will have the ability to make it a hades.

For that reason, we are doing our best to clarify the technical concept and the theory in this 1991, hopefully with the view that humankind will seize upon the positive aspects, and develop and apply this technology for the betterment of all people everywhere.

Long ago, Albert Einstein said these words:

"It would of course be a great step forward if we succeeded in combining the gravitational field and the electromagnetic field into a single structure. Only so could the era in theoretical physics inaugurated by Faraday and Clerk Maxwell be brought to a satisfactory close."

And Teilhard de Chardin wrote:

"Someday, after we have mastered the winds, the waves, the tides and gravity, we shall harness for God the energies of love. Then for the second time in the history of the world man will have

discovered fire."

The authors fervently believe they have come upon fire for the second time, as allegorized by de Chardin. If so, let us all use the knowledge wisely.

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2. E.T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," *Math. Ann.*, Vol. 57, 1903, p. 333-355; "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions," *Proc. Lond. Math. Soc.*, Series 2, Vol. 1, 1904, pp. 367-372. The first paper was in fact a detailed theory of the scalar standing potential wave that Nikola Tesla discovered four years earlier, on the night of July 3-4 1899, being radiated from thunderstorms, which he entered in his *Colorado Springs Notebook* on the morning of the 4th. More recently the Whittaker structure (WS) inside potentials, including the Schroedinger potential, has been shown by V.K. Ignatovich, "The Remarkable Capabilities of Recursive Relations," *Am. J. Phys.*, 57(10), Oct. 1989, p. 873-878, without credit to Whittaker or to the presence of such structured scalar potentials in Maxwell's original quaternion EM theory. These WSs are universal to scalar potentials; e.g., for the same in acoustics, see Richard W. Ziolkowski, "Localized Transmission of Wave Energy," *Proc. SPIE, Vol. 1061, Microwave and Particle Beam Sources and Directed Energy Concepts*, Jan. 1989, p. 396-397.

3. See Y. Aharonov and D. Bohm, "Significance of Electromagnetic Potentials in the Quantum Theory," *Phys. Rev.*, Second Series, 115(3), Aug. 1, 1959, p. 458-491. This paper pointed out the primacy of the potentials. Instead of being causative agents, the force fields are actually effects generated from the potentials. This is in complete violation of both classical electromagnetics and classical dynamics, but it is absolutely required by quantum mechanics. For an extensive discussion of the Aharonov-Bohm effect and an extensive list of references, see S. Olariu and I. Iovitzu Popescu, "The Quantum Effects of Electromagnetic Fluxes," *Rev. Mod. Phys*. 57(2), Apr. 1985. See Bertram Schwarzschild, "Currents in Normal-Metal Rings Exhibit Aharonov-Bohm Effect," Physics Today, 39(1), Jan. 1986, p. 17-20 for confirmation that the Aharonov/Bohm effect has indeed been firmly proven experimentally.

4. It is pointed out that today all potentials are well-known to be gravitational entities. However, this was not known in Whittaker's time, and so he himself did not realize that he had actually produced an engineerable, testable unified theory of electromagnetics and gravitation.

5. T.E. Bearden, "Possible Whittaker Unification of Electromagnetics, General Relativity, and Quantum Mechanics: Part I: Background," Presented to *Ala. Acad. Sci. Annual Symp.*, Univ. Jacksonville, Mar. 1991.

6. For the theory of a pumped phase conjugate mirror, see David M. Pepper, "Nonlinear Optical Phase Conjugation," *Opt. Eng.*, 21(2), Mar./Apr. 1982, p. 156-183; Amnon Yariv, *Optical Electronics*, 3rd Edn., Holt, Rinehart, and Winston, New York, 1985. In a normal triode tube, the amplified plate signal is 180 degrees out of phase *spatially* with the grid input, but in-phase with it in respect to *rate of flow through time*. In a PPCM, the amplified phase conjugate replica wave is in phase spatially with the signal wave, but 180 degrees out of phase with it in respect to its rate of flow through time. It is pointed out that a PCM with a gain of unity produces a coupled EM wave/antiwave pair whose energy is additive in 3-space but subtractive in the first derivative of the fourth dimension, time. Hence it is no longer an electromagnetic wave as such, but an oscillatory wave of stress upon the local rate of flow of time. Hence it is a powerful *electrogravitational wave*, whose EM nature is hidden in the guise of a scalar EM potential. It is also a wave of variation in the local gauge, and of variation in the local ST curvature.

7. See T.E. Bearden, *The Phase Conjugate Vacuum Triode*, Apr. 23, 1987, privately published. An earlier pencil draft was initially produced.

8. Sweet has continued to extend his theoretical treatment. A formal paper providing the complete mathematical theory of the vacuum triode has been drafted, is in final review, and will be submitted to a leading journal by mid-1991.

9. See Chapter 25: Outlook, "Possibility of Vacuum Engineering," T.D. Lee, *Particle Physics and Introduction to Field Theory*, Harwood, New York, 1981, pp. 824-828.

10. In 1977 Ilya Prigogine received the Nobel Prize for extending thermodynamics; in particular, for the theory of dissipative structures in nonequilibrium thermodynamics. In Prigogine systems, negentropy is known to be possible.

11. Robert G. Sachs, *The Physics of Time Reversal*, Univ. Chi. Press., Chicago, 1987.

12. Note that this moves the entire notion of the charge of a fundamental particle to a deeper and more extended level. Now the charge may be *discretized*, but it is not quantized in the hard conventional sense. Further, the internal Whittaker structure of the massless VPF photon exchange of vacuum and mass, which, quantum mechanically, is what the electrical charge of the particle is in the first place, is deterministically structured. Note that this violates the present assumption that all like charged particles are identical; now two electrons may have either the same or different magnitudes of charge, and even when the magnitudes are the same, their internal charge structures (Whittaker structures) and VPF exchange with the vacuum may differ. Also note that this resolves the severe QM problem of missing chaos (hidden order) in quantum change. The reason for the problem was the use of Gibbs statistics with its assumption of random variable change, which a priori excluded hidden order (and hence chaos) from QM. That was only a special case, albeit an important one. There are now three QM cases: (1) the conventional case, where there is no hidden order; (2) the case where there is some hidden order, and the statistics is chaotic, not random; and (3) the case where the QM change is deterministic, with essentially total hidden order. Note that the Whittaker

methodology allows one to directly engineer cases (2) and (3), including the Schroedinger equation itself.

13. The present second law of thermodynamics is written only for time-forward entities, and need not apply for the time-reversed case. Merely viewing the energy-dissipating forward time case in reverse allows an appreciation of the time-reversed case. In other words, the second law of thermodynamics is incomplete as presently stated. The complete law has a corollary to cover the increase in order as the time-reversal of the system increases. Thus the complete law consists of two parts: (1) the entropic, time-forward case, and (2) the negentropic time-reversed case. Since the re-ordering can be amplified at will by a PPCM process, the correct distinction between the two subsets of the complete law is important, and applies to real systems.

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15. T. E. Bearden, *Gravitobiology: A New Biophysics*, Tesla Book Co., 604 Date Ave., Chula Vista, CA 91912, 1991.

16. C.f. Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler, *Gravitation*, W.H. Freeman and Co., San Francisco, 1973, p. 1191.

17. E.g., see Richard Kidd et al, "Evolution of the Modern Photon," *Am. J. Phys*., 57(1), Jan. 1989, pp. 27-35. See also R. Chen, "Cancellation of Internal Forces," *Am. J. Phys*. 49(4), Apr. 1981, p. 372.

18. A nonlinear material may simply emit a photon, or it may act as a phase conjugate mirror (PCM) and emit a phase conjugate replica of the absorbed photon. When the material emits a normal photon, it measurably recoils. When it emits a time-reversed photon, it does not recoil, as already experimentally established in nonlinear phase conjugate optics. The solution to the mystery is this: When emitting a normal photon, the material does not act as a PCM. In that case the matching antiphoton which split from the interacting graviton (the graviton that yielded the external photon) interacts with the nucleus, producing a recoil action with a gain of one. Thus Newtonian third-law recoil of the nucleus occurs. On the other hand, when the material acts as a PCM, it also emits the antiphoton *outside* the atom to "backtrack" the absorbed "signal wave" photon. In that case there is no Newtonian recoil of the nucleus, because the *agent* for causing recoil did not interact with the nucleus to produce it.

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20. C.f. Pepper, ibid. and Yariv, ibid. For a specific example, see Mary J. Miller et al, *Appl. Phys. Lett*. 41(8), Oct. 15, 1982, p. 689-691.

21. Again, for the theory of the PPCM, see Pepper, ibid. and Yariv, ibid.

22. E.g., see T.E. Bearden, *Gravitobiology: A New Biophysics*, Tesla Book Co., Chula Vista, CA, 1991, p. 33-36.

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Defense Department Briefing on Priore Treatment to counter Biological Warfare

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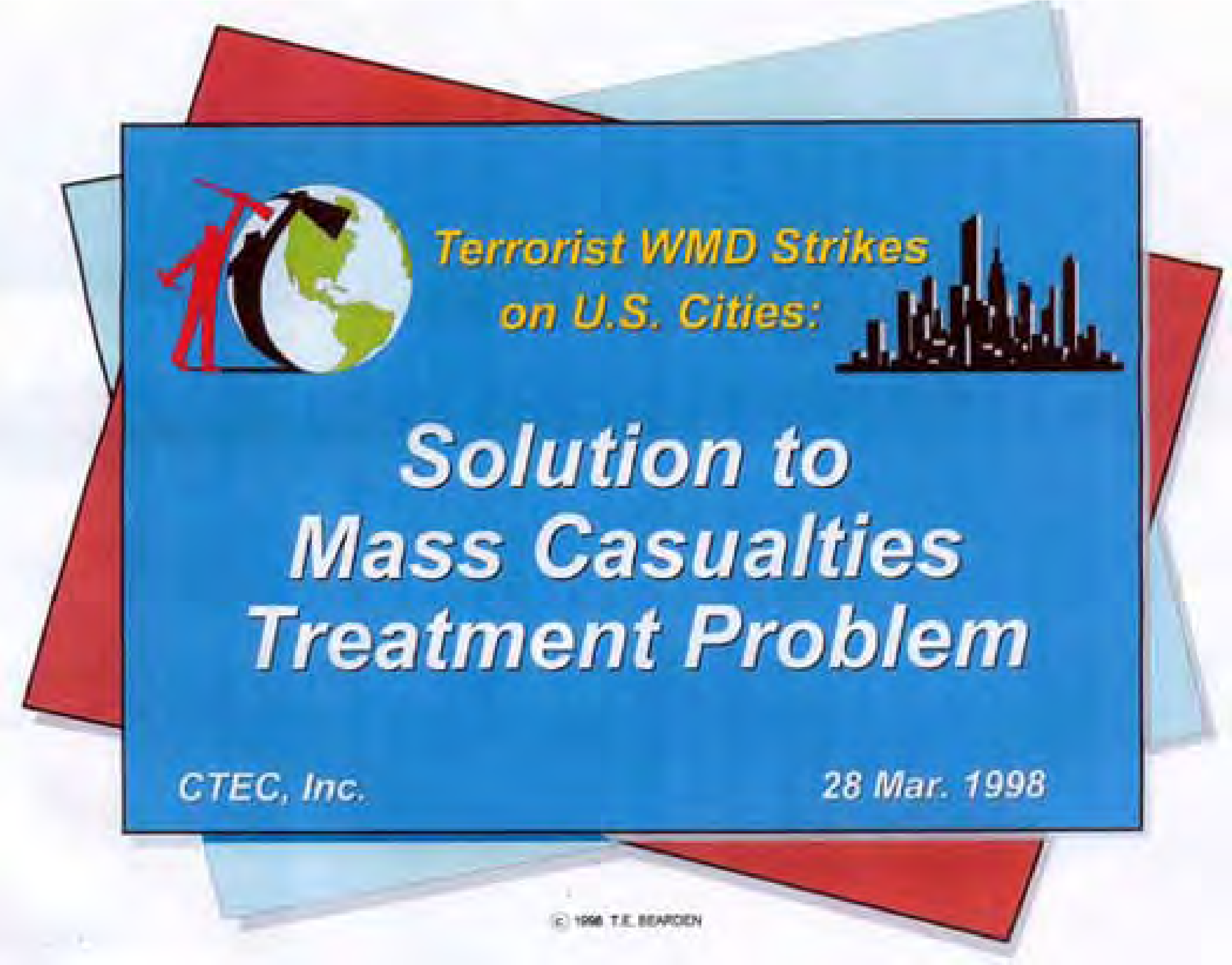

Terrorist WMD Strikes
on U.S. Cities:

Solution to
Mass Casualties
Treatment Problem

CTEC, Inc.

28 Mar. 1998

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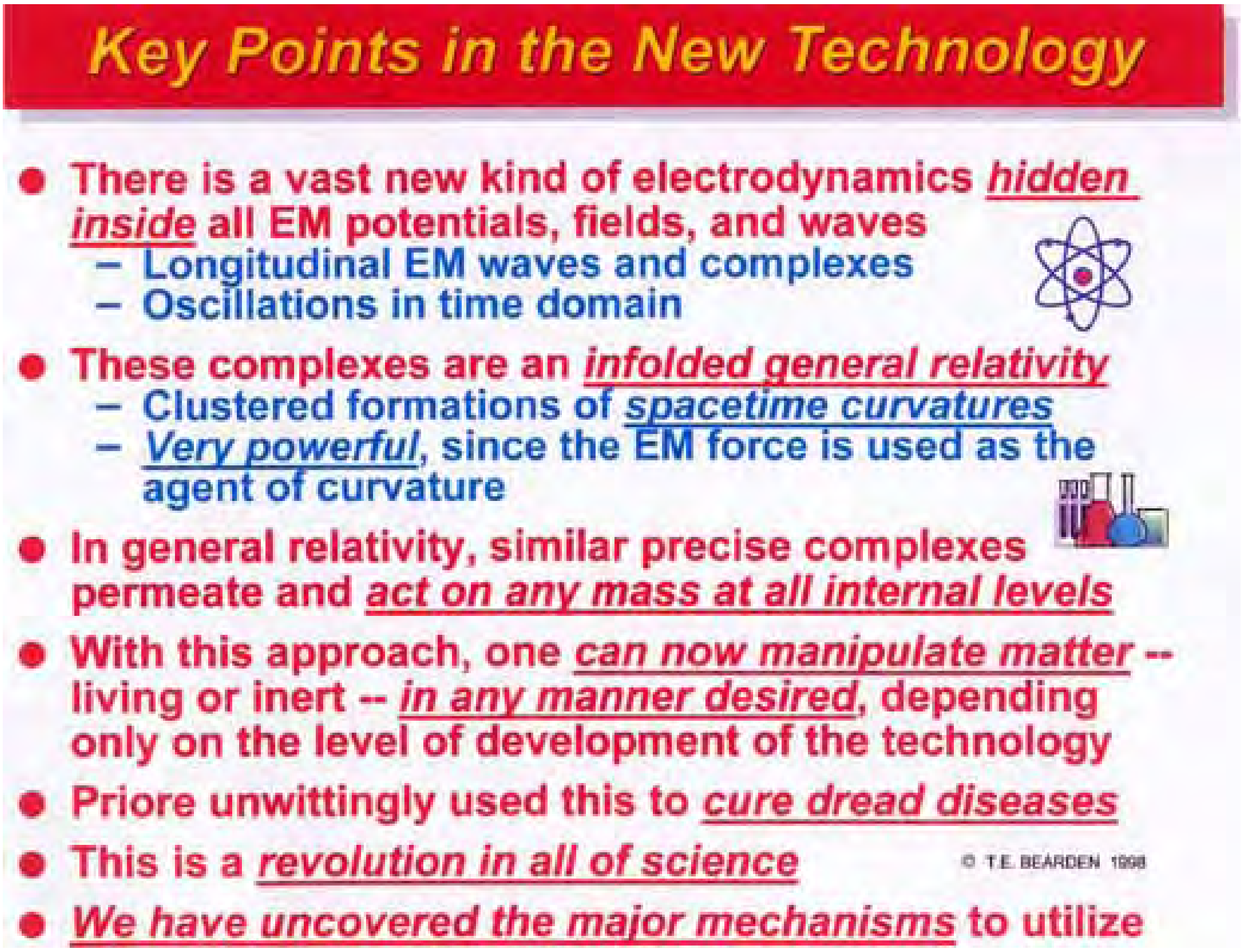

Key Points in the New Technology

- There is a vast new kind of electrodynamics *hidden inside* all EM potentials, fields, and waves
  - Longitudinal EM waves and complexes
  - Oscillations in time domain
- These complexes are an *infolded general relativity*
  - Clustered formations of *spacetime curvatures*
  - *Very powerful*, since the EM force is used as the agent of curvature
- In general relativity, similar precise complexes permeate and *act on any mass at all internal levels*
- With this approach, one *can now manipulate matter* -- living or inert -- *in any manner desired*, depending only on the level of development of the technology
- Priore unwittingly used this to *cure dread diseases*
- This is a *revolution in all of science*
- *We have uncovered the major mechanisms* to utilize

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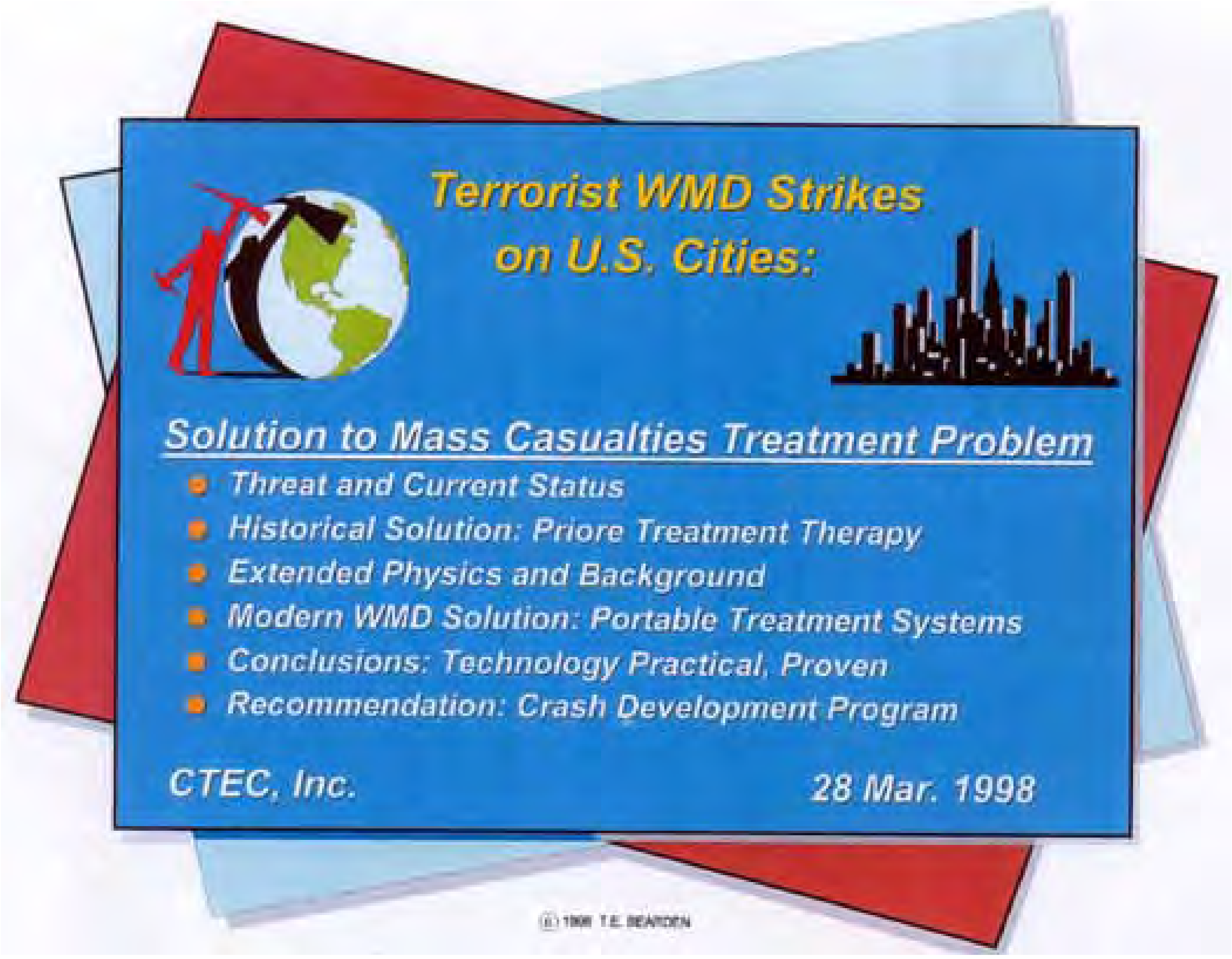

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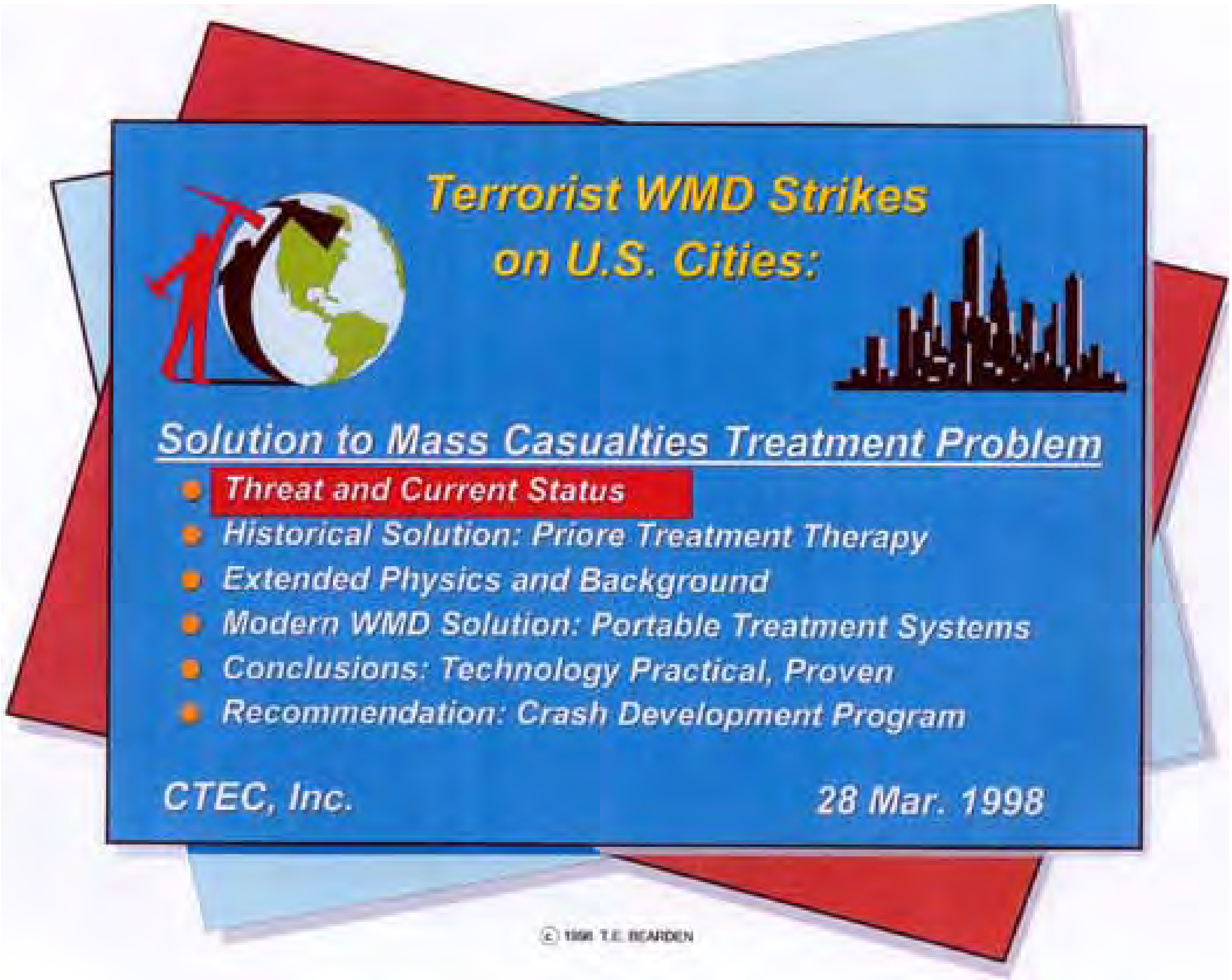

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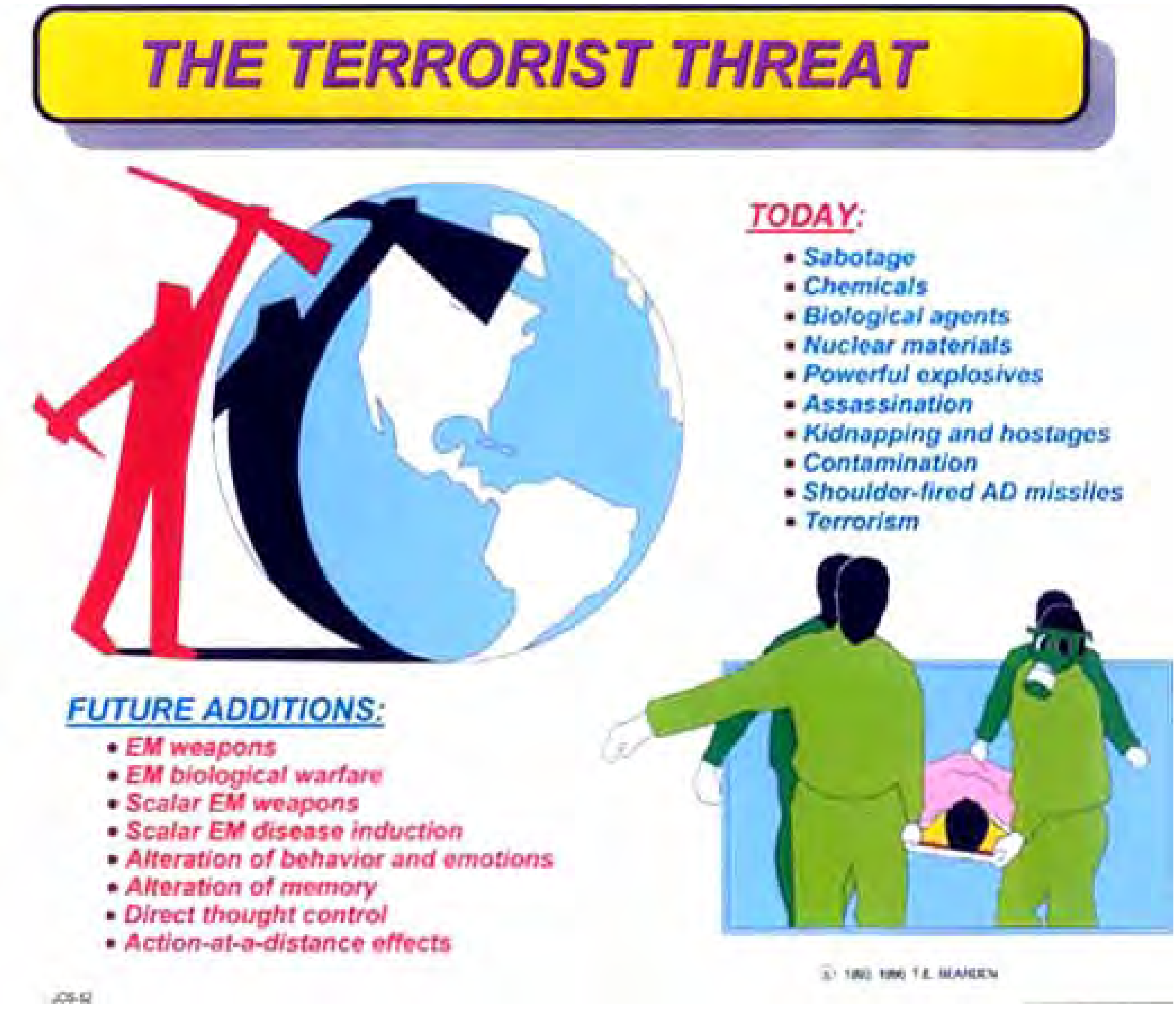

THE TERRORIST THREAT

TODAY:

- Sabotage
- Chemicals
- Biological agents
- Nuclear materials
- Powerful explosives
- Assassination
- Kidnapping and hostages
- Contamination
- Shoulder-fired AD missiles
- Terrorism

FUTURE ADDITIONS:

- EM weapons
- EM biological warfare
- Scalar EM weapons
- Scalar EM disease induction
- Alteration of behavior and emotions
- Alteration of memory
- Direct thought control
- Action-at-a-distance effects

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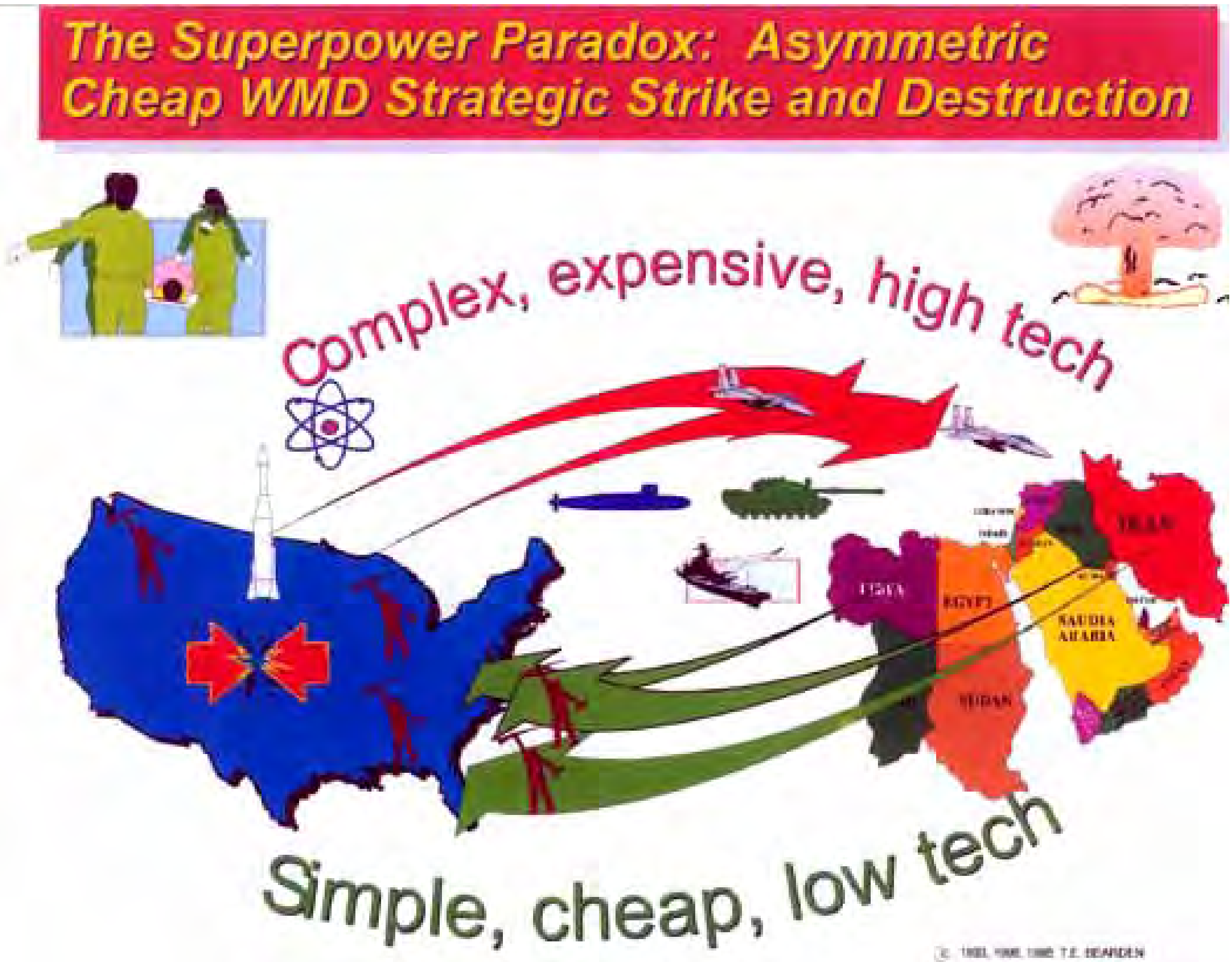

The Superpower Paradox: Asymmetric Cheap WMD Strategic Strike and Destruction

Complex, expensive, high tech

Simple, cheap, low tech

LIBYA
EGYPT
SUDAN
SAUDI ARABIA
IRAN

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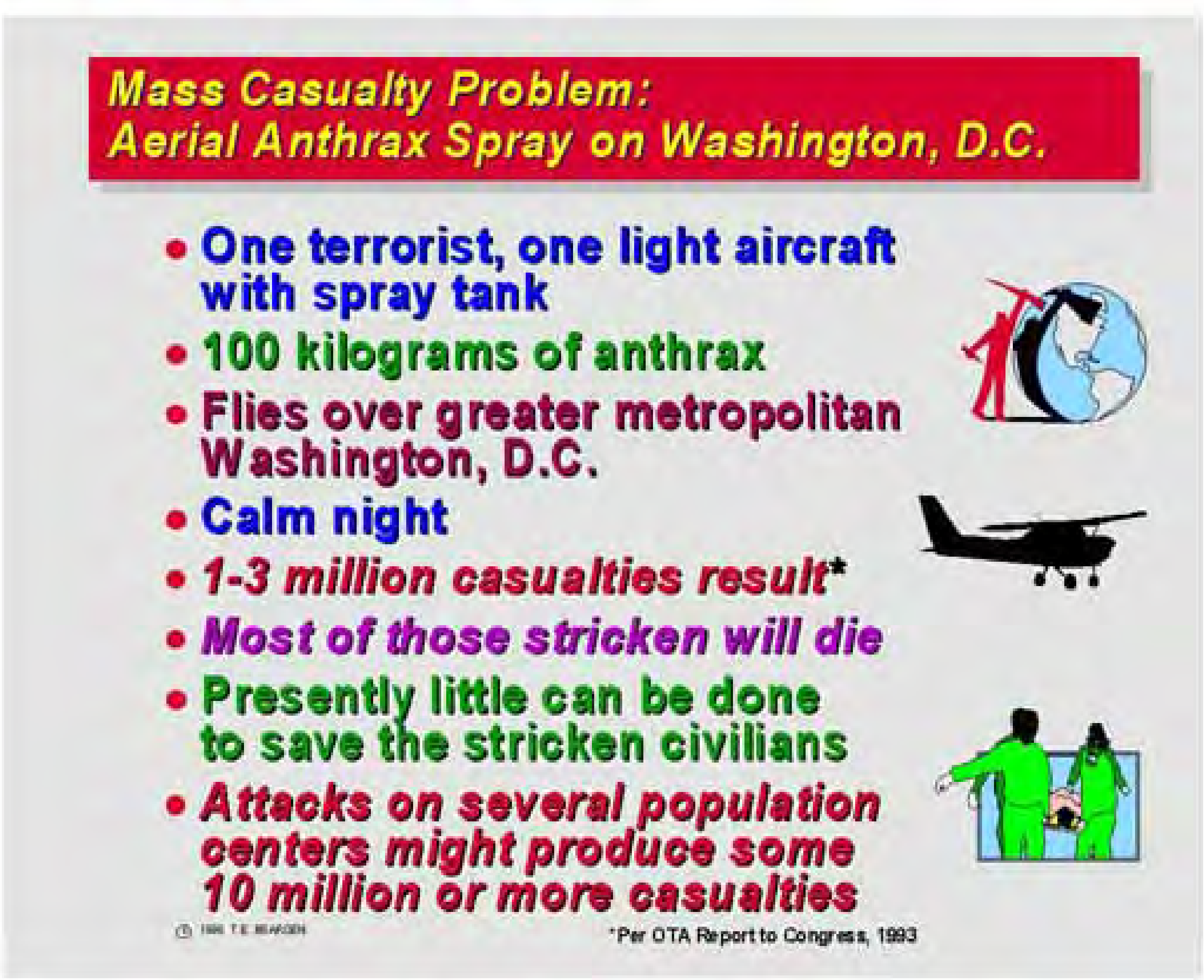

Mass Casualty Problem: Aerial Anthrax Spray on Washington, D.C.

- One terrorist, one light aircraft with spray tank
- 100 kilograms of anthrax
- Flies over greater metropolitan Washington, D.C.
- Calm night
- *1-3 million casualties result**
- *Most of those stricken will die*
- Presently little can be done to save the stricken civilians
- *Attacks on several population centers might produce some 10 million or more casualties*

*Per OTA Report to Congress, 1993

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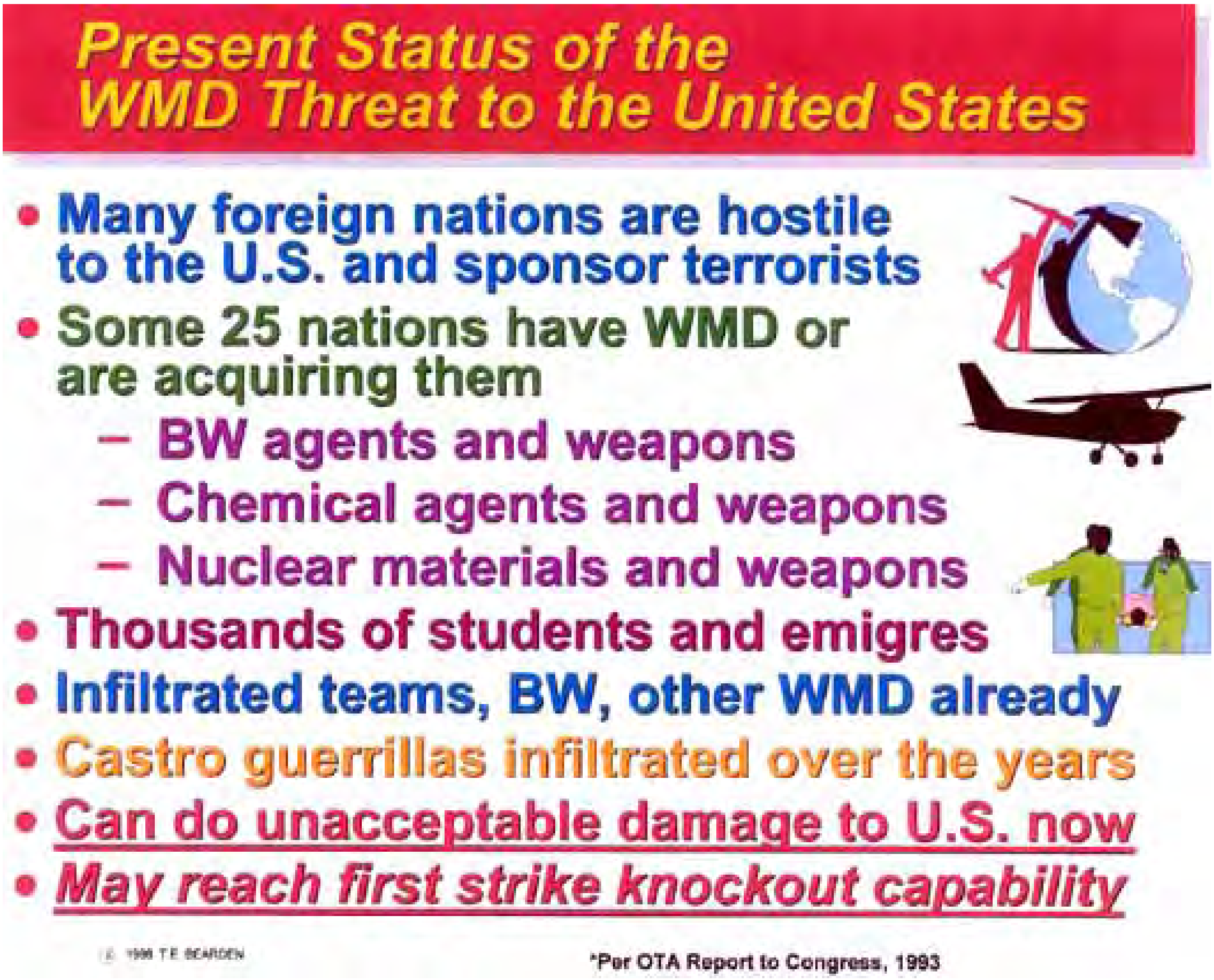

Present Status of the WMD Threat to the United States

- Many foreign nations are hostile to the U.S. and sponsor terrorists
- Some 25 nations have WMD or are acquiring them
  - BW agents and weapons
  - Chemical agents and weapons
  - Nuclear materials and weapons
- Thousands of students and emigres
- Infiltrated teams, BW, other WMD already
- Castro guerrillas infiltrated over the years
- Can do unacceptable damage to U.S. now
- *May reach first strike knockout capability*

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*Per OTA Report to Congress, 1993

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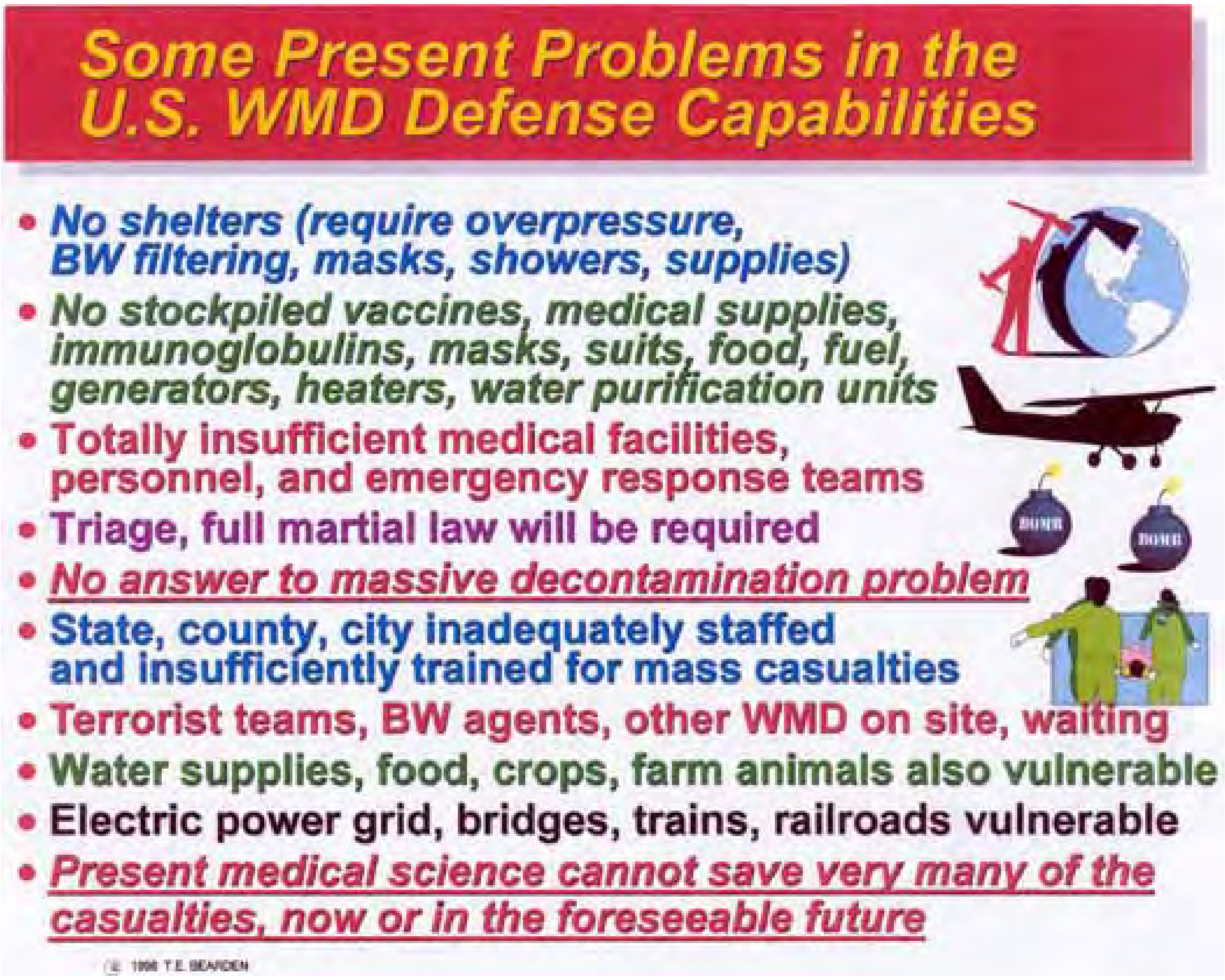

Some Present Problems in the U.S. WMD Defense Capabilities

- *No shelters (require overpressure, BW filtering, masks, showers, supplies)*
- *No stockpiled vaccines, medical supplies, immunoglobulins, masks, suits, food, fuel, generators, heaters, water purification units*
- Totally insufficient medical facilities, personnel, and emergency response teams
- Triage, full martial law will be required
- *No answer to massive decontamination problem*
- State, county, city inadequately staffed and insufficiently trained for mass casualties
- Terrorist teams, BW agents, other WMD on site, waiting
- Water supplies, food, crops, farm animals also vulnerable
- Electric power grid, bridges, trains, railroads vulnerable
- *Present medical science cannot save very many of the casualties, now or in the foreseeable future*

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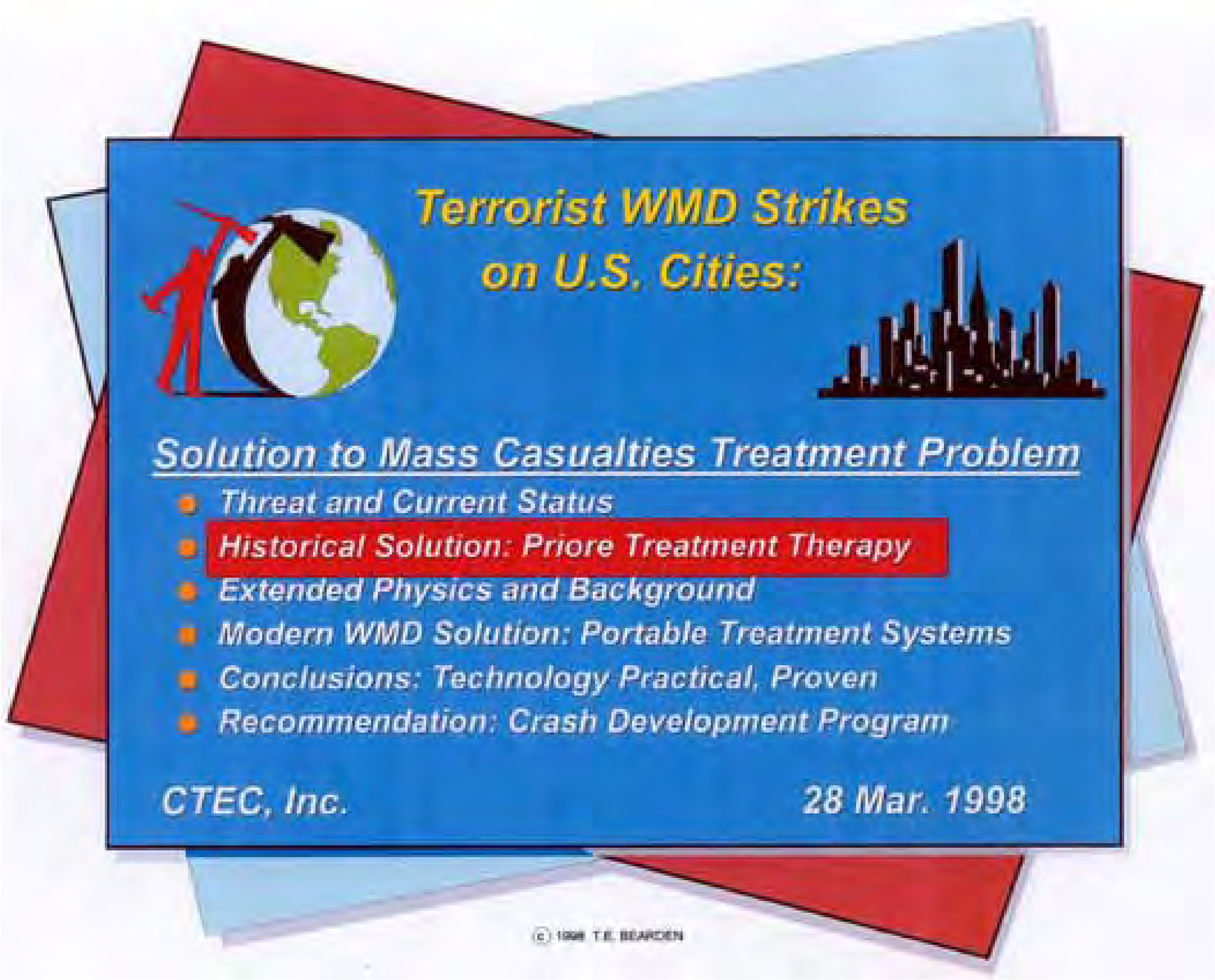

Terrorist WMD Strikes
on U.S. Cities:

Solution to Mass Casualties Treatment Problem

- Threat and Current Status
- Historical Solution: Priore Treatment Therapy
- Extended Physics and Background
- Modern WMD Solution: Portable Treatment Systems
- Conclusions: Technology Practical, Proven
- Recommendation: Crash Development Program

CTEC, Inc. 28 Mar. 1998

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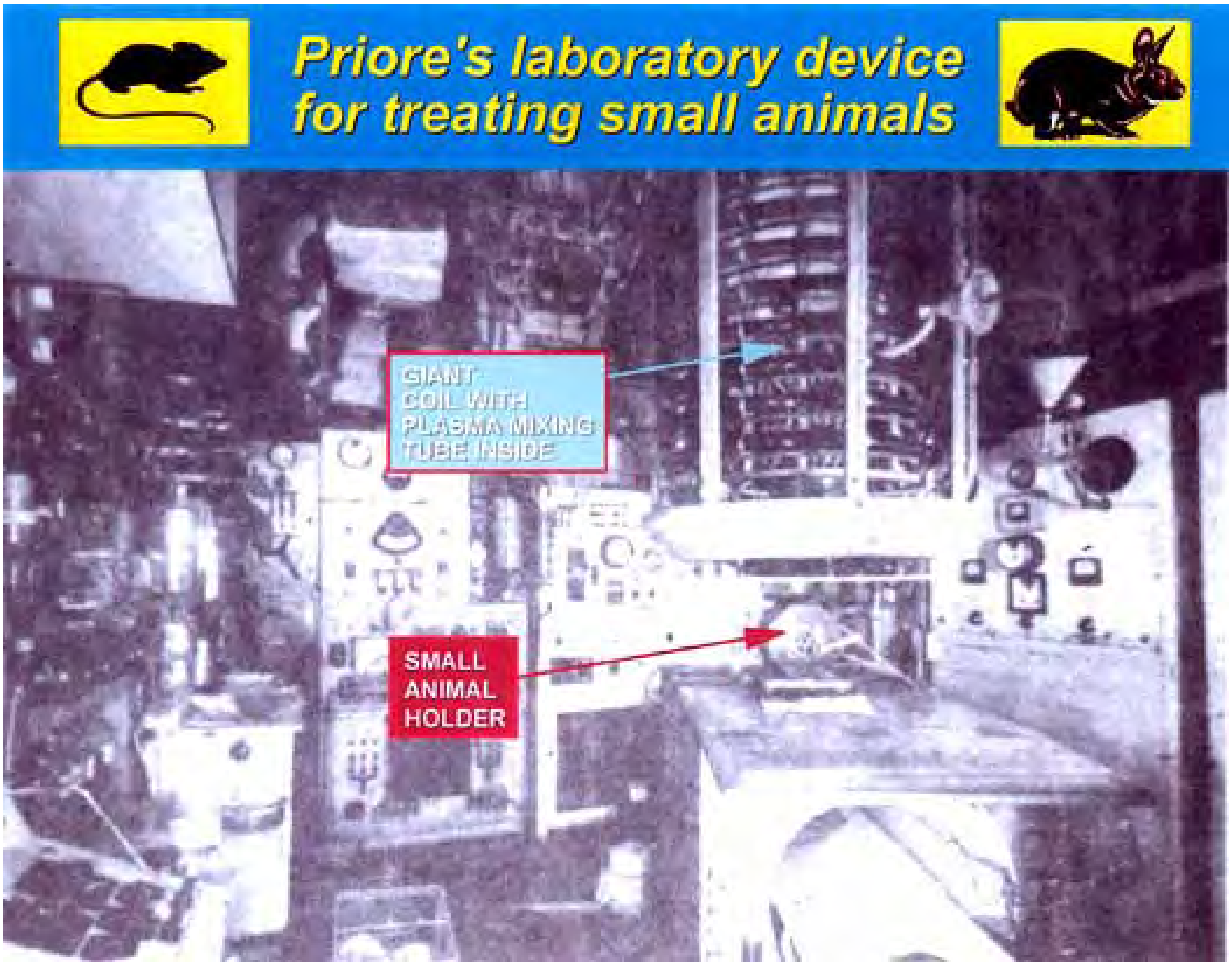

Priore's laboratory device for treating small animals

GIANT COIL WITH PLASMA MIXING TUBE INSIDE
SMALL ANIMAL HOLDER

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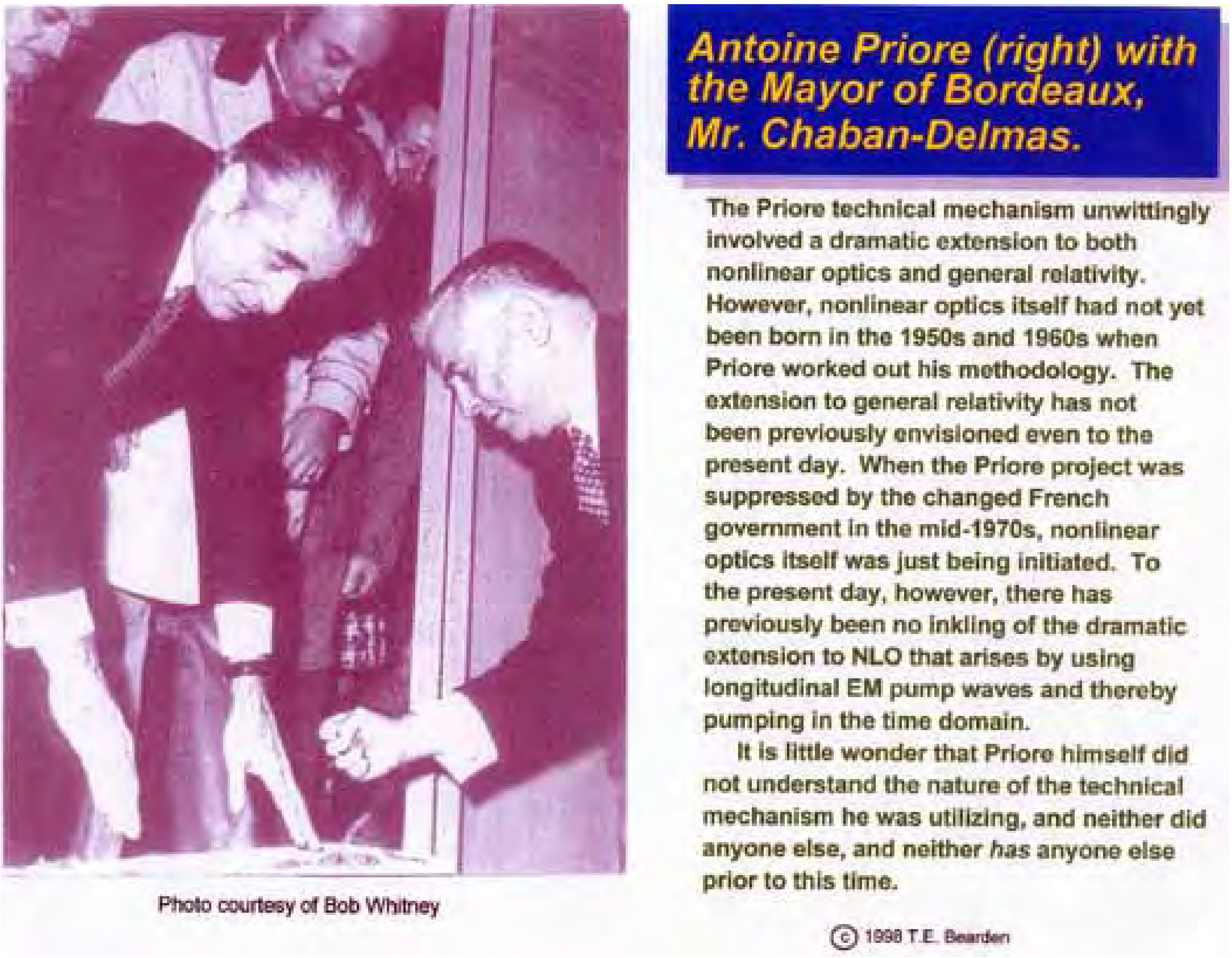

Antoine Priore (right) with the Mayor of Bordeaux, Mr. Chaban-Delmas.

The Priore technical mechanism unwittingly involved a dramatic extension to both nonlinear optics and general relativity. However, nonlinear optics itself had not yet been born in the 1950s and 1960s when Priore worked out his methodology. The extension to general relativity has not been previously envisioned even to the present day. When the Priore project was suppressed by the changed French government in the mid-1970s, nonlinear optics itself was just being initiated. To the present day, however, there has previously been no inkling of the dramatic extension to NLO that arises by using longitudinal EM pump waves and thereby pumping in the time domain.

It is little wonder that Priore himself did not understand the nature of the technical mechanism he was utilizing, and neither did anyone else, and neither *has* anyone else prior to this time.

Photo courtesy of Bob Whitney

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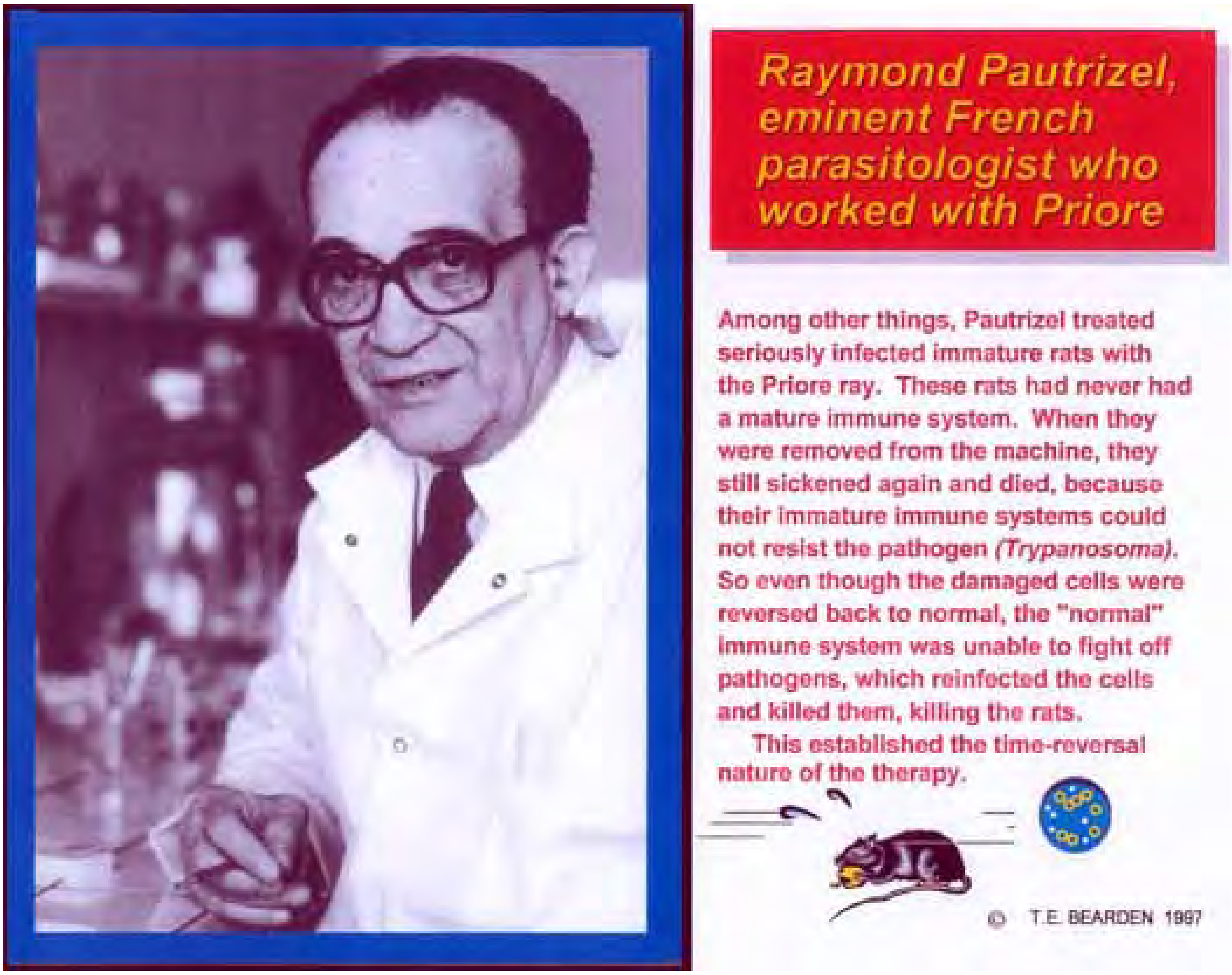

Raymond Pautrizel, eminent French parasitologist who worked with Priore

Among other things, Pautrizel treated seriously infected immature rats with the Priore ray. These rats had never had a mature immune system. When they were removed from the machine, they still sickened again and died, because their immature immune systems could not resist the pathogen *(Trypanosoma)*. So even though the damaged cells were reversed back to normal, the "normal" immune system was unable to fight off pathogens, which reinfected the cells and killed them, killing the rats.

This established the time-reversal nature of the therapy.

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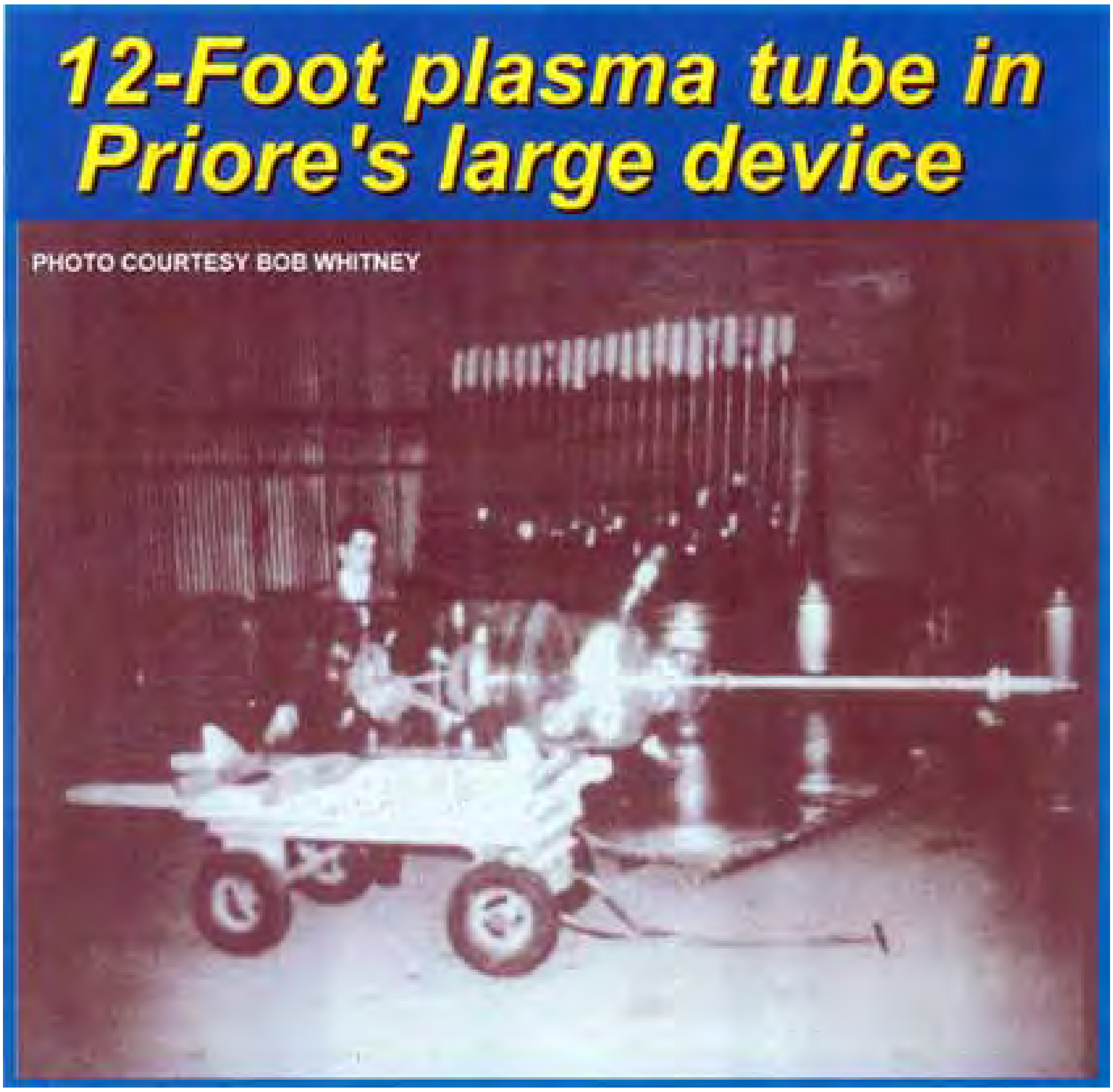

12-Foot plasma tube in Priore's large device

PHOTO COURTESY BOB WHITNEY

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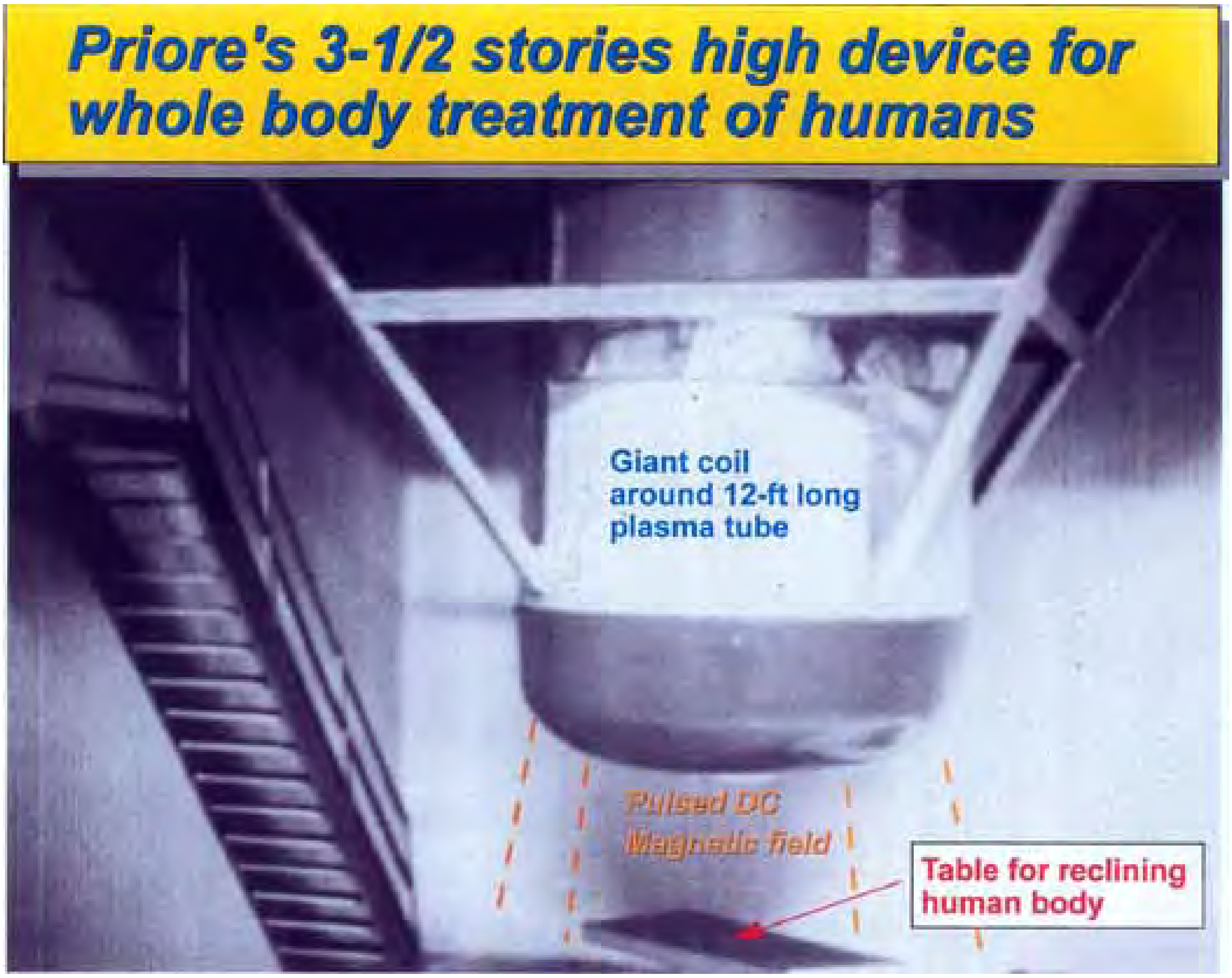

Priore's 3-1/2 stories high device for whole body treatment of humans

Giant coil around 12-ft long plasma tube
Pulsed DC Magnetic field
Table for reclining human body

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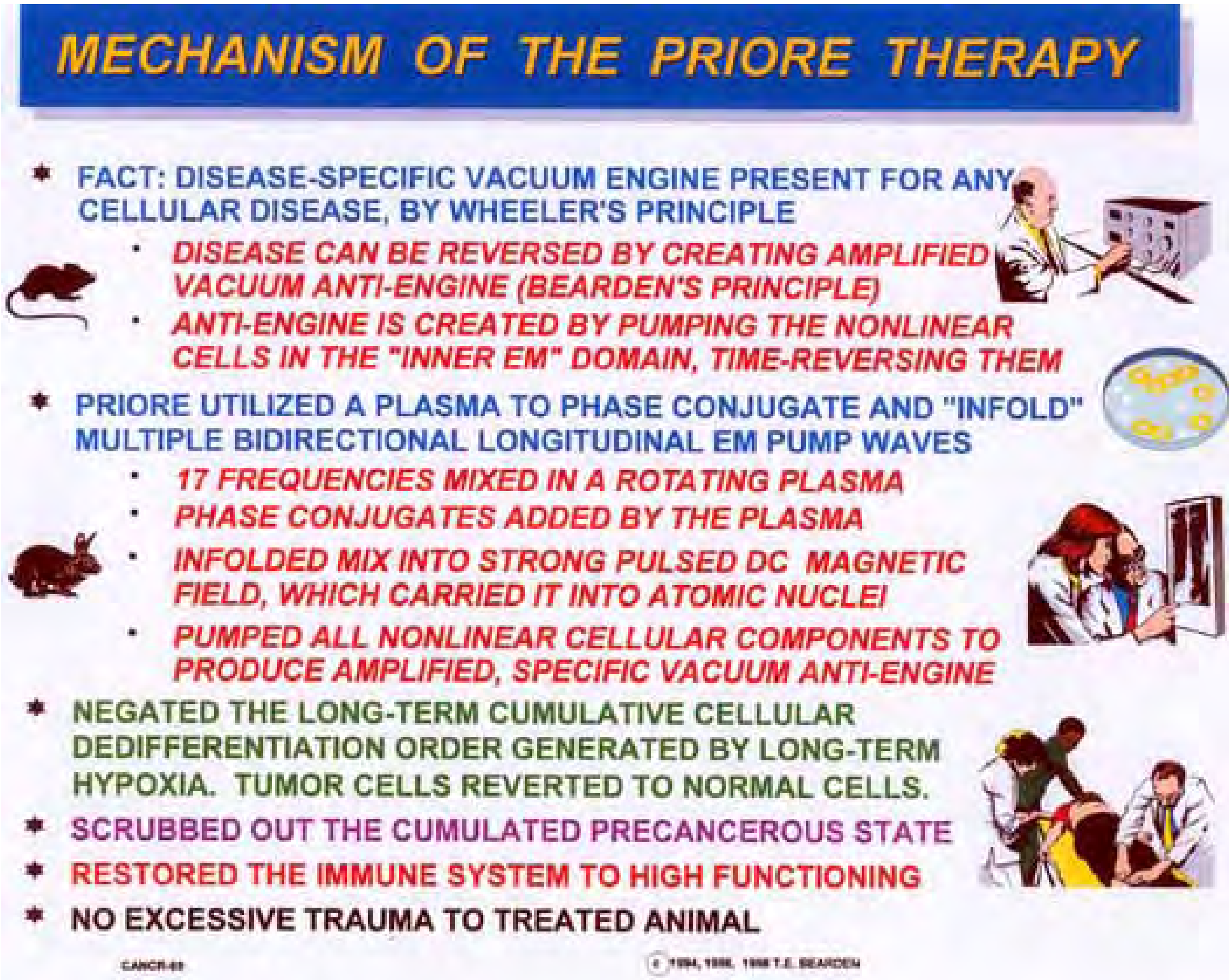

MECHANISM OF THE PRIORE THERAPY

- FACT: DISEASE-SPECIFIC VACUUM ENGINE PRESENT FOR ANY CELLULAR DISEASE, BY WHEELER'S PRINCIPLE
  - *DISEASE CAN BE REVERSED BY CREATING AMPLIFIED VACUUM ANTI-ENGINE (BEARDEN'S PRINCIPLE)*
  - *ANTI-ENGINE IS CREATED BY PUMPING THE NONLINEAR CELLS IN THE "INNER EM" DOMAIN, TIME-REVERSING THEM*
- PRIORE UTILIZED A PLASMA TO PHASE CONJUGATE AND "INFOLD" MULTIPLE BIDIRECTIONAL LONGITUDINAL EM PUMP WAVES
  - *17 FREQUENCIES MIXED IN A ROTATING PLASMA*
  - *PHASE CONJUGATES ADDED BY THE PLASMA*
  - *INFOLDED MIX INTO STRONG PULSED DC MAGNETIC FIELD, WHICH CARRIED IT INTO ATOMIC NUCLEI*
  - *PUMPED ALL NONLINEAR CELLULAR COMPONENTS TO PRODUCE AMPLIFIED, SPECIFIC VACUUM ANTI-ENGINE*
- NEGATED THE LONG-TERM CUMULATIVE CELLULAR DEDIFFERENTIATION ORDER GENERATED BY LONG-TERM HYPOXIA. TUMOR CELLS REVERTED TO NORMAL CELLS.
- SCRUBBED OUT THE CUMULATED PRECANCEROUS STATE
- RESTORED THE IMMUNE SYSTEM TO HIGH FUNCTIONING
- NO EXCESSIVE TRAUMA TO TREATED ANIMAL

CANCR-69

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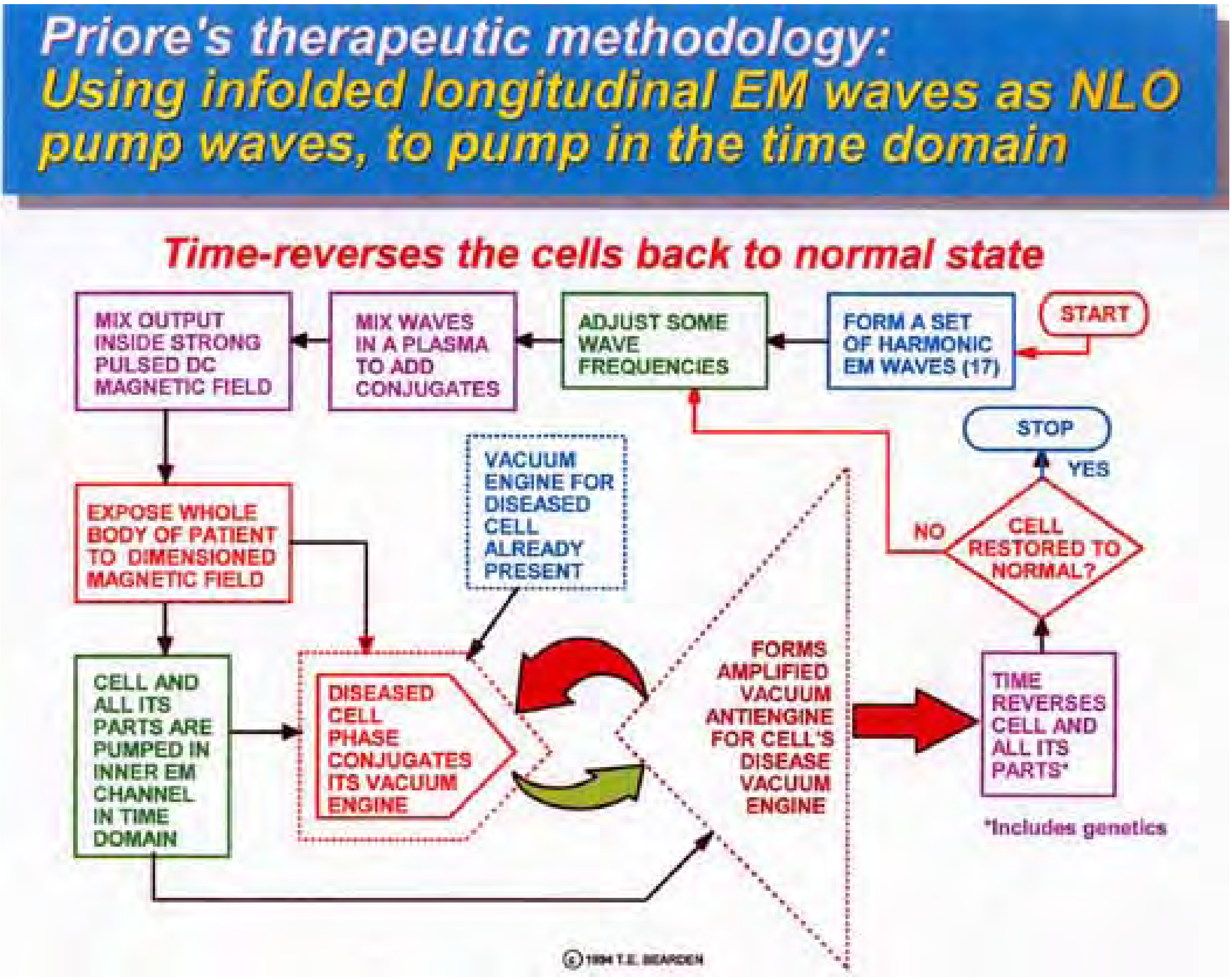

Priore's therapeutic methodology: Using infolded longitudinal EM waves as NLO pump waves, to pump in the time domain

Time-reverses the cells back to normal state

START

FORM A SET OF HARMONIC EM WAVES (17)

ADJUST SOME WAVE FREQUENCIES

MIX WAVES IN A PLASMA TO ADD CONJUGATES

MIX OUTPUT INSIDE STRONG PULSED DC MAGNETIC FIELD

EXPOSE WHOLE BODY OF PATIENT TO DIMENSIONED MAGNETIC FIELD

CELL AND ALL ITS PARTS ARE PUMPED IN INNER EM CHANNEL IN TIME DOMAIN

VACUUM ENGINE FOR DISEASED CELL ALREADY PRESENT

DISEASED CELL PHASE CONJUGATES ITS VACUUM ENGINE

FORMS AMPLIFIED VACUUM ANTIENGINE FOR CELL'S DISEASE VACUUM ENGINE

TIME REVERSES CELL AND ALL ITS PARTS*

CELL RESTORED TO NORMAL?

NO

YES

STOP

*Includes genetics

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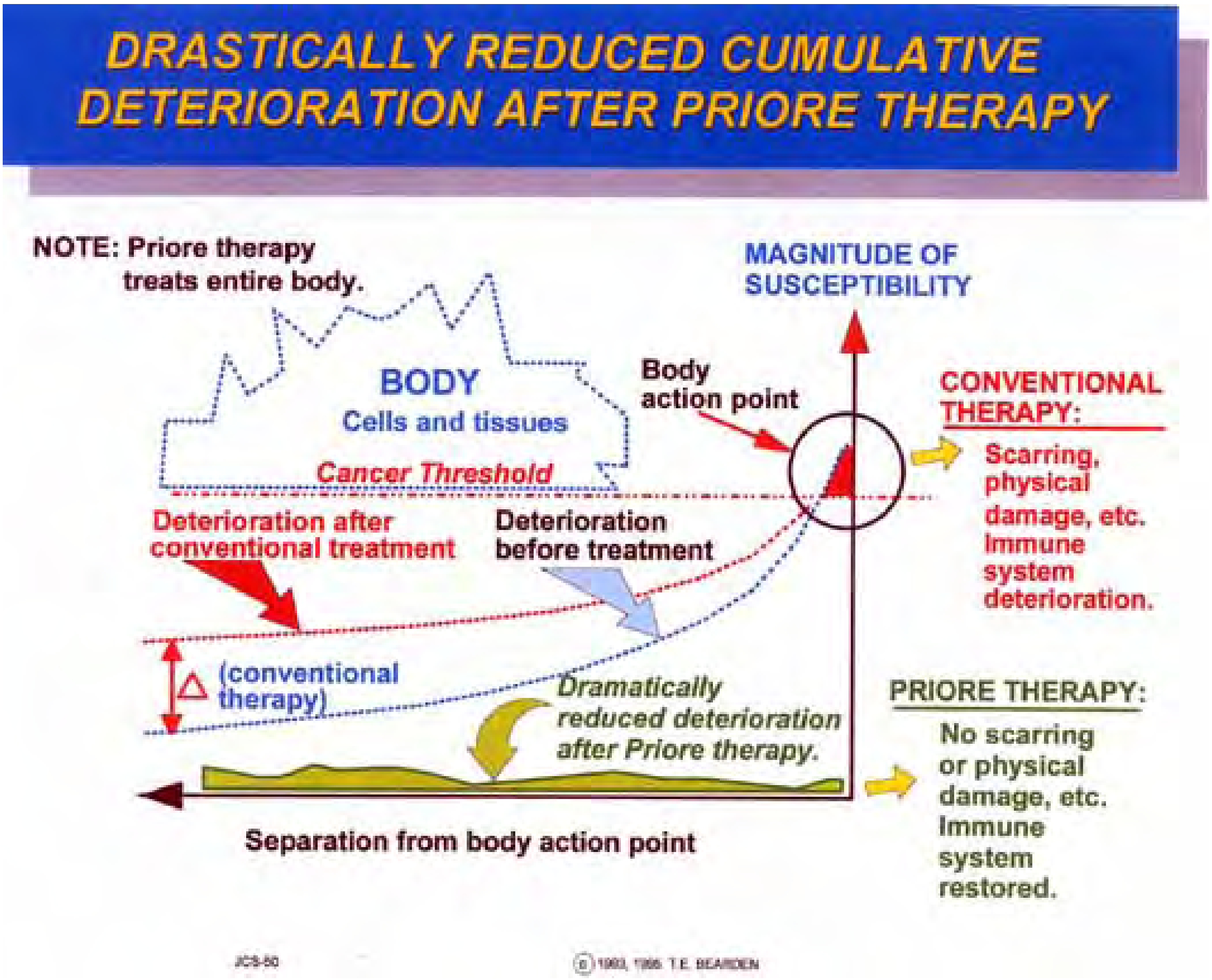

DRASTICALLY REDUCED CUMULATIVE DETERIORATION AFTER PRIORE THERAPY

NOTE: Priore therapy treats entire body.

MAGNITUDE OF SUSCEPTIBILITY

BODY

Cells and tissues

Body action point

Cancer Threshold

CONVENTIONAL THERAPY:

Scarring, physical damage, etc. Immune system deterioration.

Deterioration after conventional treatment

Deterioration before treatment

Δ (conventional therapy)

Dramatically reduced deterioration after Priore therapy.

PRIORE THERAPY:

No scarring or physical damage, etc. Immune system restored.

Separation from body action point

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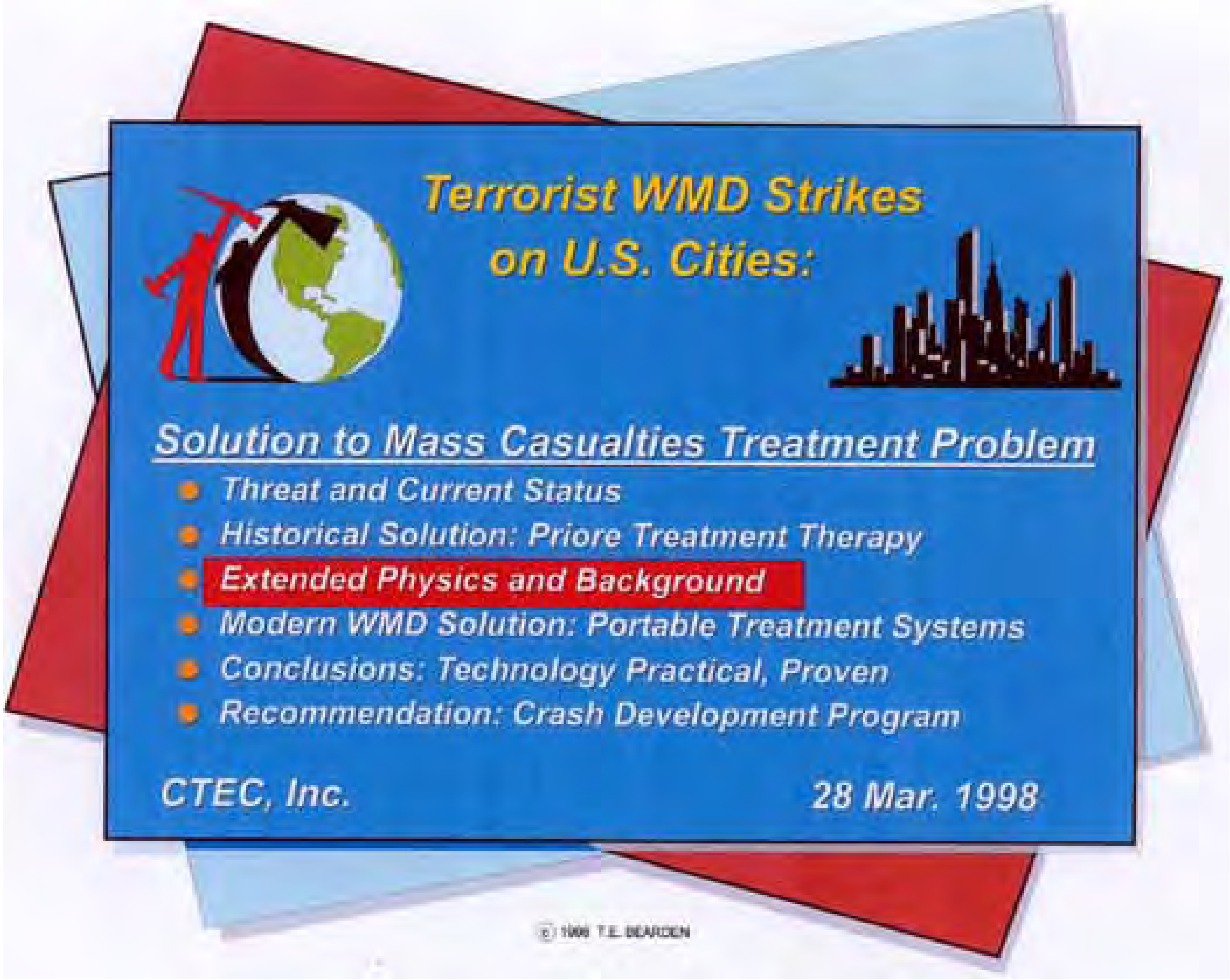

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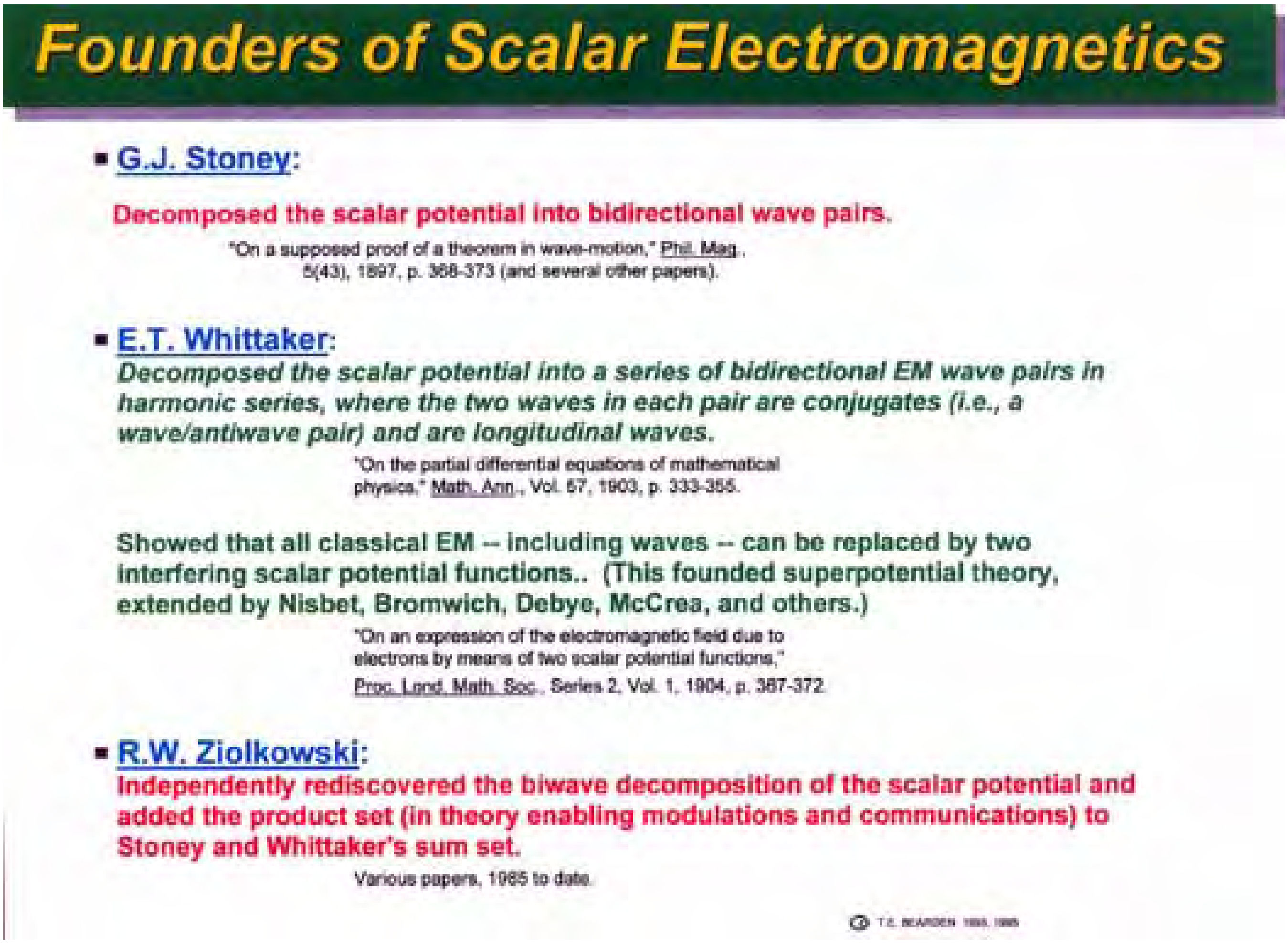

Founders of Scalar Electromagnetics

- **G.J. Stoney:**

Decomposed the scalar potential into bidirectional wave pairs.

"On a supposed proof of a theorem in wave-motion," Phil. Mag., 5(43), 1897, p. 368-373 (and several other papers).

- **E.T. Whittaker:**

Decomposed the scalar potential into a series of bidirectional EM wave pairs in harmonic series, where the two waves in each pair are conjugates (i.e., a wave/antiwave pair) and are longitudinal waves.

"On the partial differential equations of mathematical physics," Math. Ann., Vol. 57, 1903, p. 333-355.

Showed that all classical EM -- including waves -- can be replaced by two interfering scalar potential functions.. (This founded superpotential theory, extended by Nisbet, Bromwich, Debye, McCrea, and others.)

"On an expression of the electromagnetic field due to electrons by means of two scalar potential functions," Proc. Lond. Math. Soc., Series 2, Vol. 1, 1904, p. 367-372.

- **R.W. Ziolkowski:**

Independently rediscovered the biwave decomposition of the scalar potential and added the product set (in theory enabling modulations and communications) to Stoney and Whittaker's sum set.

Various papers, 1985 to date.

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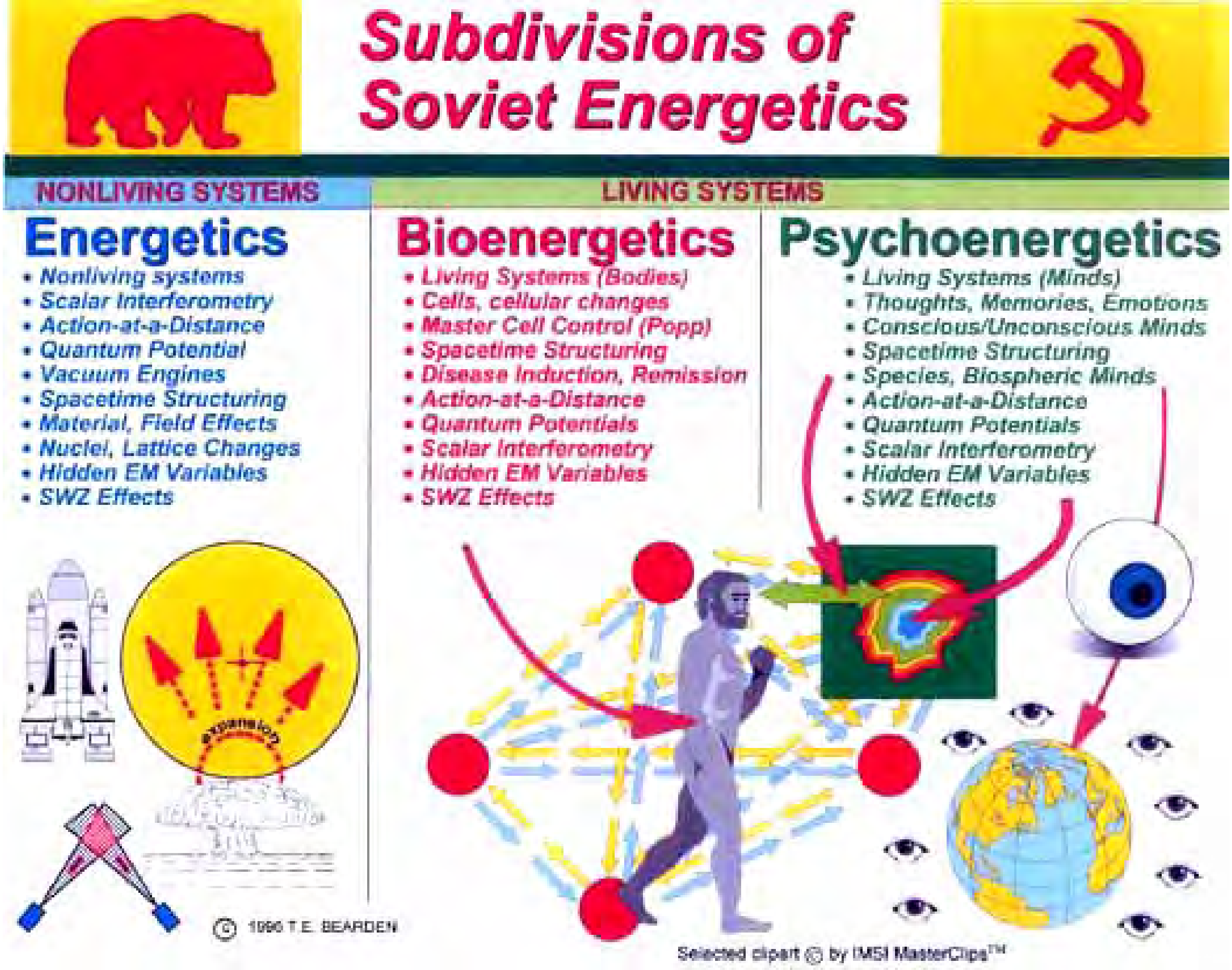

Subdivisions of Soviet Energetics

NONLIVING SYSTEMS

Energetics

- Nonliving systems
- Scalar Interferometry
- Action-at-a-Distance
- Quantum Potential
- Vacuum Engines
- Spacetime Structuring
- Material, Field Effects
- Nuclei, Lattice Changes
- Hidden EM Variables
- SWZ Effects

LIVING SYSTEMS

Bioenergetics

- Living Systems (Bodies)
- Cells, cellular changes
- Master Cell Control (Popp)
- Spacetime Structuring
- Disease Induction, Remission
- Action-at-a-Distance
- Quantum Potentials
- Scalar Interferometry
- Hidden EM Variables
- SWZ Effects

Psychoenergetics

- Living Systems (Minds)
- Thoughts, Memories, Emotions
- Conscious/Unconscious Minds
- Spacetime Structuring
- Species, Biospheric Minds
- Action-at-a-Distance
- Quantum Potentials
- Scalar Interferometry
- Hidden EM Variables
- SWZ Effects

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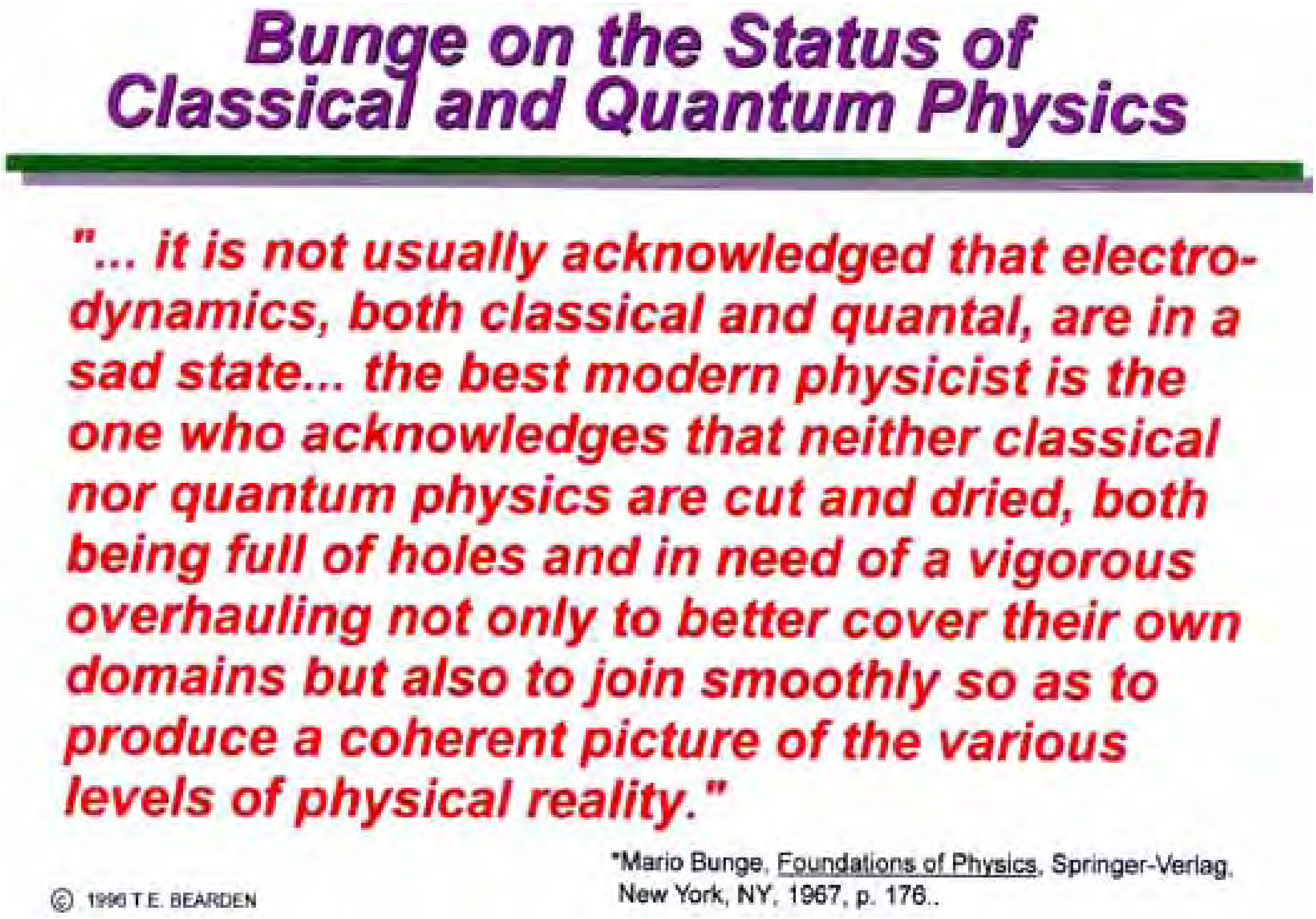

Bunge on the Status of Classical and Quantum Physics

> "... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling not only to better cover their own domains but also to join smoothly so as to produce a coherent picture of the various levels of physical reality."

*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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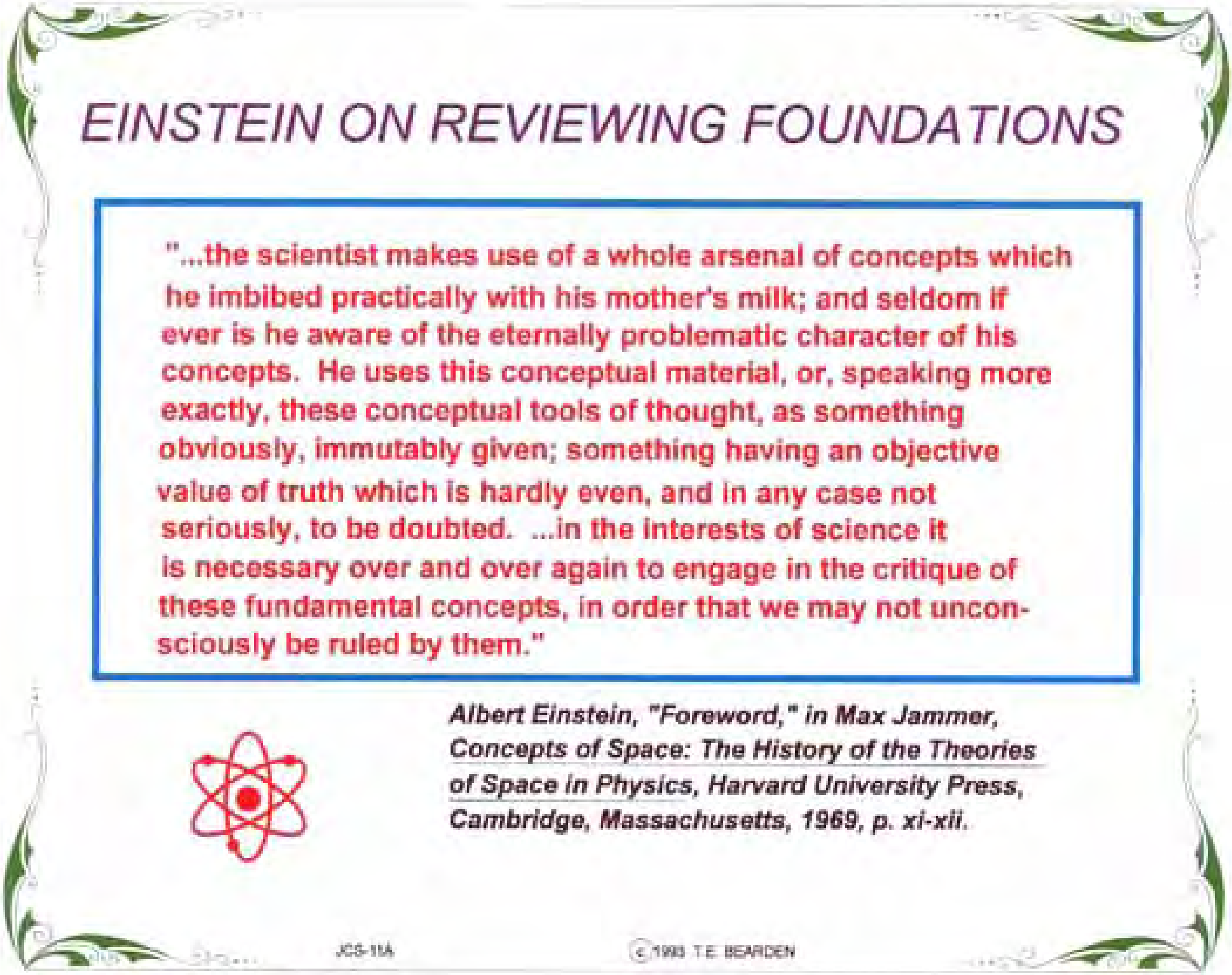

EINSTEIN ON REVIEWING FOUNDATIONS

"...the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the eternally problematic character of his concepts. He uses this conceptual material, or, speaking more exactly, these conceptual tools of thought, as something obviously, immutably given; something having an objective value of truth which is hardly even, and in any case not seriously, to be doubted. ...in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them."

Albert Einstein, "Foreword," in Max Jammer, Concepts of Space: The History of the Theories of Space in Physics, Harvard University Press, Cambridge, Massachusetts, 1969, p. xi-xii.

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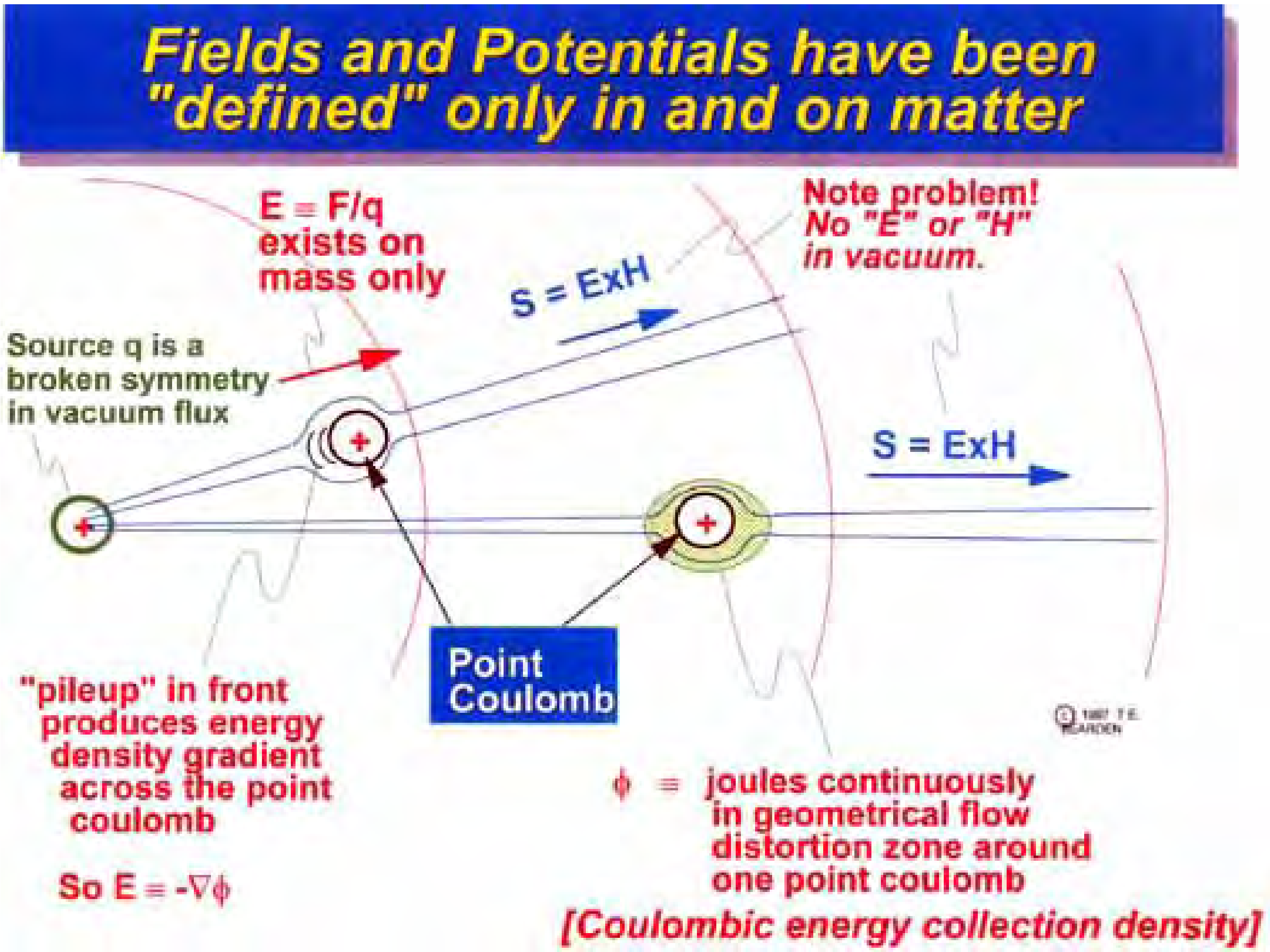

Fields and Potentials have been "defined" only in and on matter

E ≡ F/q
exists on
mass only

Note problem!
No "E" or "H"
in vacuum.

S = ExH

Source q is a
broken symmetry
in vacuum flux

S = ExH

Point
Coulomb

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"pileup" in front
produces energy
density gradient
across the point
coulomb

So $E \equiv -\nabla\phi$

ϕ ≡ joules continuously
in geometrical flow
distortion zone around
one point coulomb

[Coulombic energy collection density]

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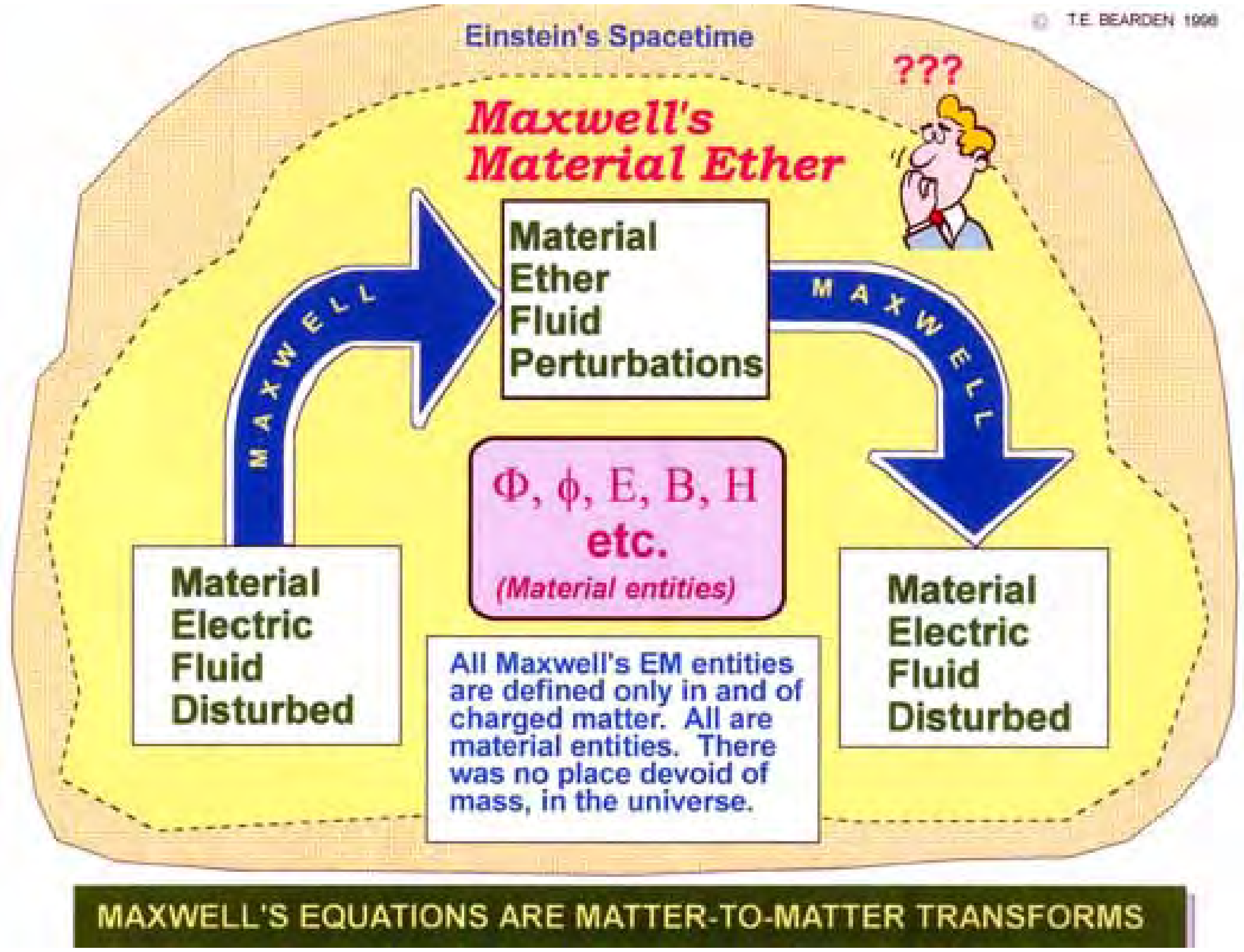

Maxwell's Material Ether

Material Ether Fluid Perturbations

Material Electric Fluid Disturbed

Φ, ϕ, E, B, H etc.

(Material entities)

Material Electric Fluid Disturbed

All Maxwell's EM entities are defined only in and of charged matter. All are material entities. There was no place devoid of mass, in the universe.

MAXWELL'S EQUATIONS ARE MATTER-TO-MATTER TRANSFORMS

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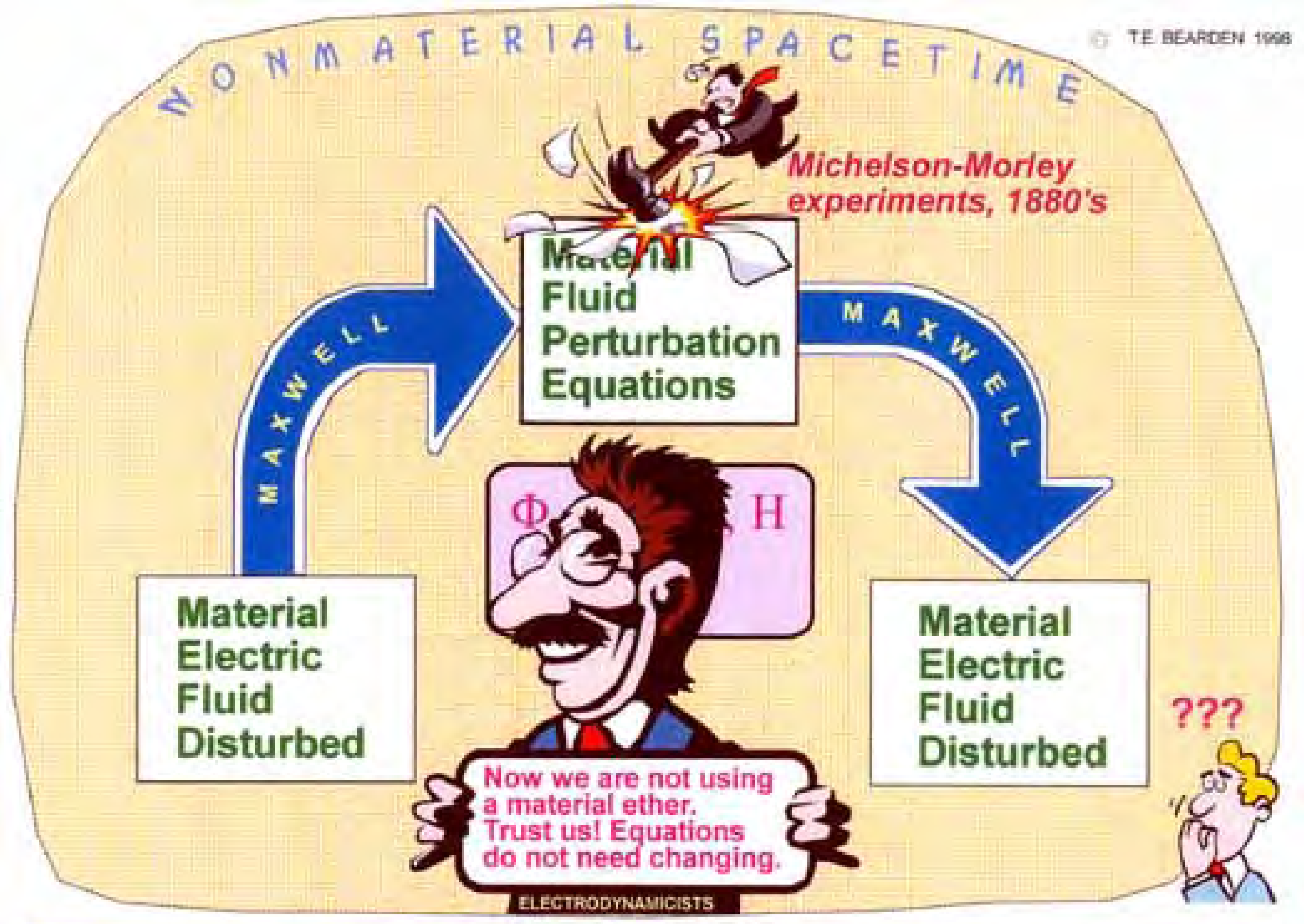
NONMATERIAL SPACETIME
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Michelson-Morley experiments, 1880's
MAXWELL
Material Fluid Perturbation Equations
MAXWELL
Φ
H
Material Electric Fluid Disturbed
Material Electric Fluid Disturbed
???
Now we are not using a material ether. Trust us! Equations do not need changing.
ELECTRODYNAMICISTS

Electrodynamicists' Reaction to Removal of the Material Ether

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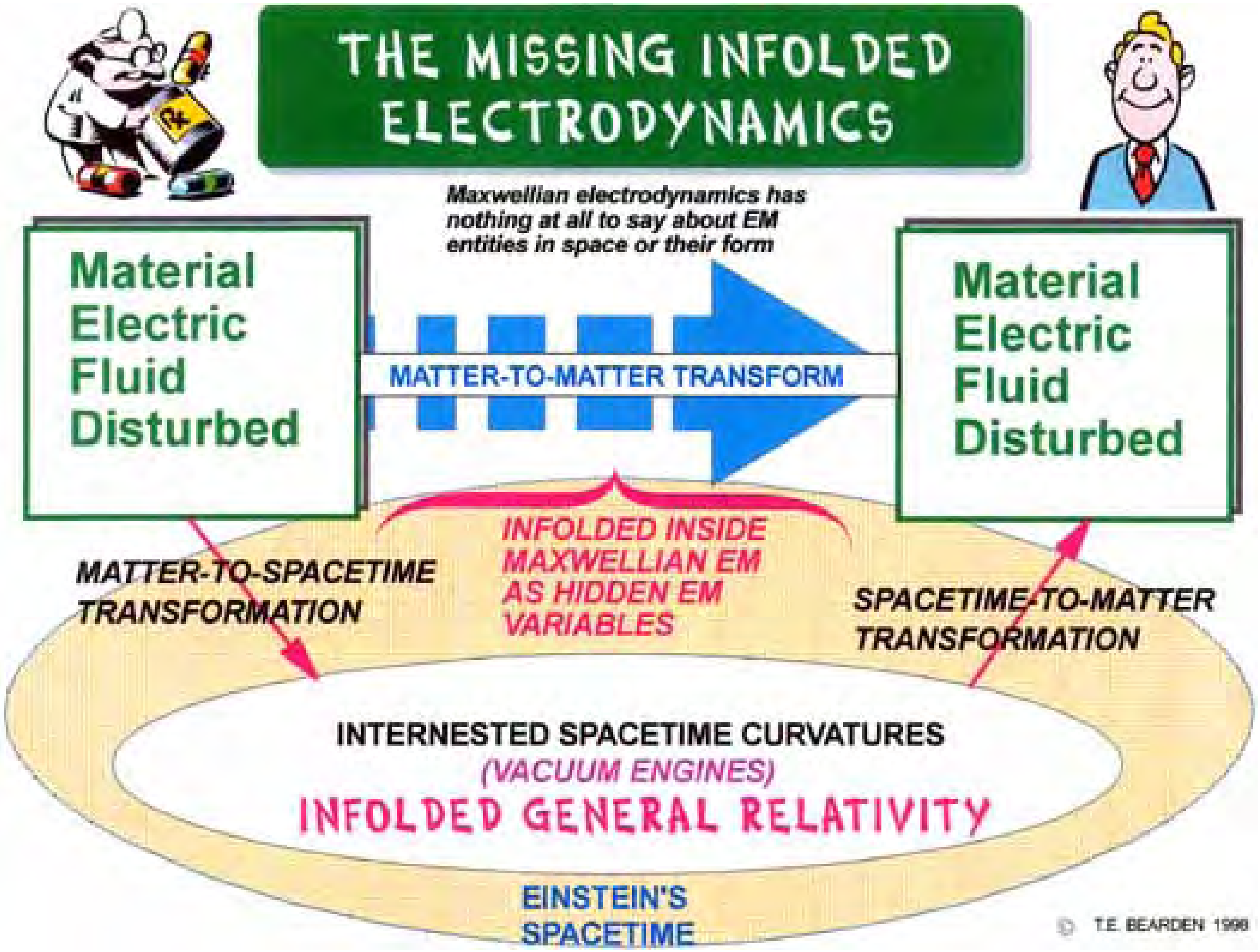

THE MISSING INFOLDED ELECTRODYNAMICS

Maxwellian electrodynamics has nothing at all to say about EM entities in space or their form

Material Electric Fluid Disturbed

MATTER-TO-MATTER TRANSFORM

Material Electric Fluid Disturbed

MATTER-TO-SPACETIME TRANSFORMATION

INFOLDED INSIDE MAXWELLIAN EM AS HIDDEN EM VARIABLES

SPACETIME-TO-MATTER TRANSFORMATION

INTERNESTED SPACETIME CURVATURES

(VACUUM ENGINES)

INFOLDED GENERAL RELATIVITY

EINSTEIN'S SPACETIME

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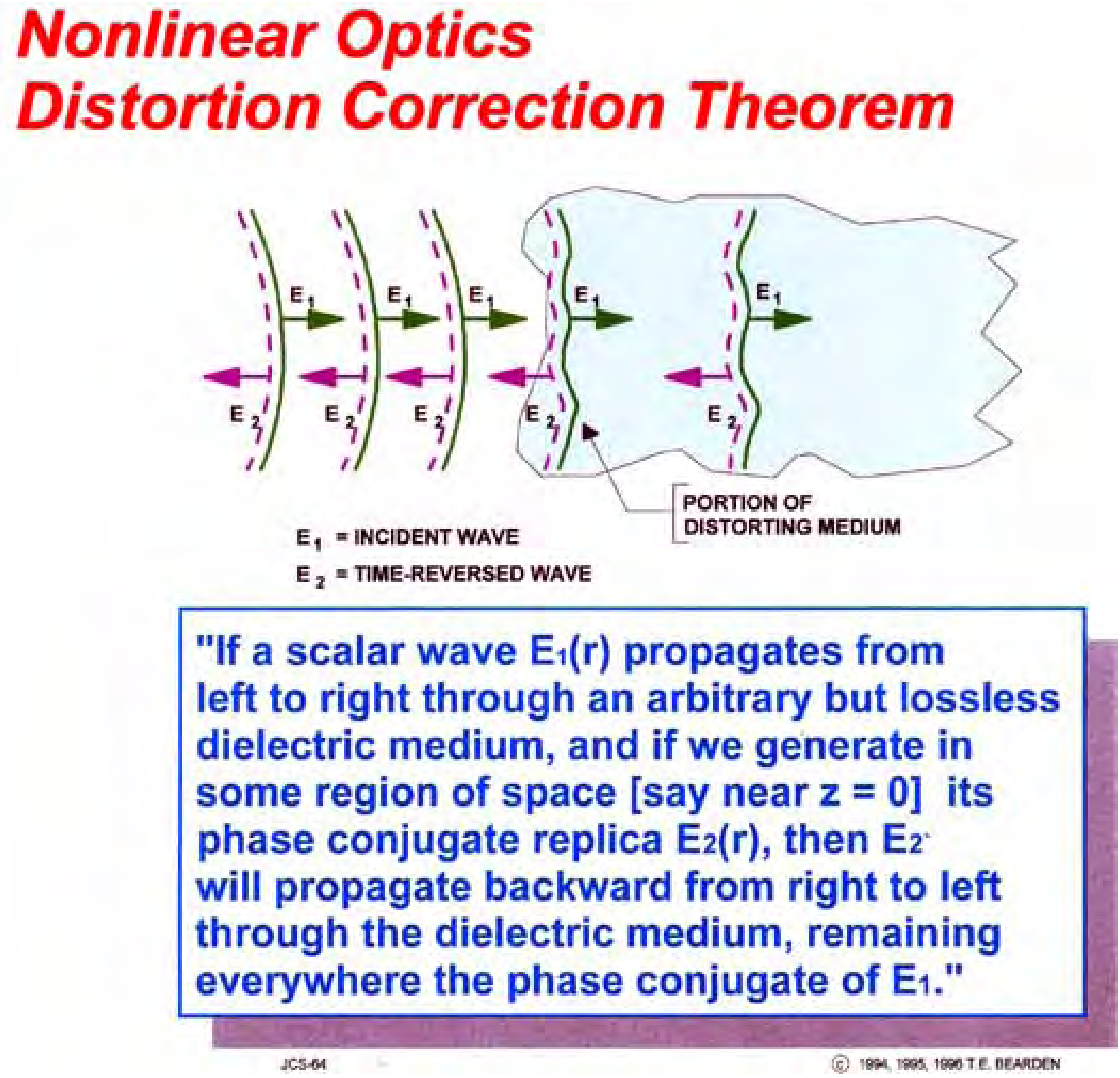

Nonlinear Optics Distortion Correction Theorem

E_1 = INCIDENT WAVE

E_2 = TIME-REVERSED WAVE

"If a scalar wave $E_1(r)$ propagates from left to right through an arbitrary but lossless dielectric medium, and if we generate in some region of space [say near z = 0] its phase conjugate replica $E_2(r)$, then E_2 will propagate backward from right to left through the dielectric medium, remaining everywhere the phase conjugate of E_1."

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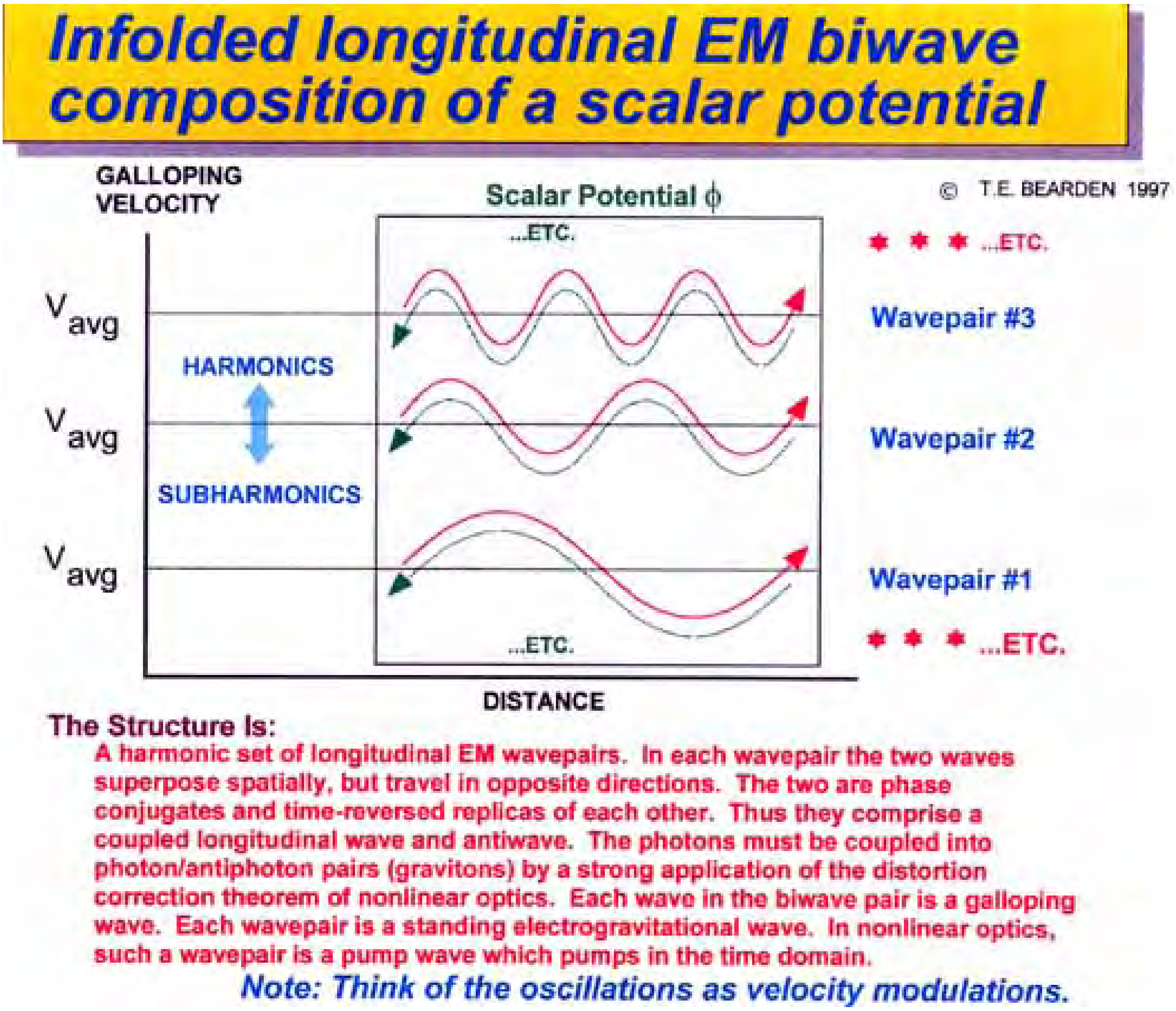

Infolded longitudinal EM biwave composition of a scalar potential

GALLOPING VELOCITY
Scalar Potential ϕ
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...ETC.
✱ ✱ ✱ ...ETC.
V_{avg}
Wavepair #3
HARMONICS
V_{avg}
Wavepair #2
SUBHARMONICS
V_{avg}
Wavepair #1
...ETC.
✱ ✱ ✱ ...ETC.
DISTANCE

The Structure Is:

A harmonic set of longitudinal EM wavepairs. In each wavepair the two waves superpose spatially, but travel in opposite directions. The two are phase conjugates and time-reversed replicas of each other. Thus they comprise a coupled longitudinal wave and antiwave. The photons must be coupled into photon/antiphoton pairs (gravitons) by a strong application of the distortion correction theorem of nonlinear optics. Each wave in the biwave pair is a galloping wave. Each wavepair is a standing electrogravitational wave. In nonlinear optics, such a wavepair is a pump wave which pumps in the time domain.

Note: Think of the oscillations as velocity modulations.

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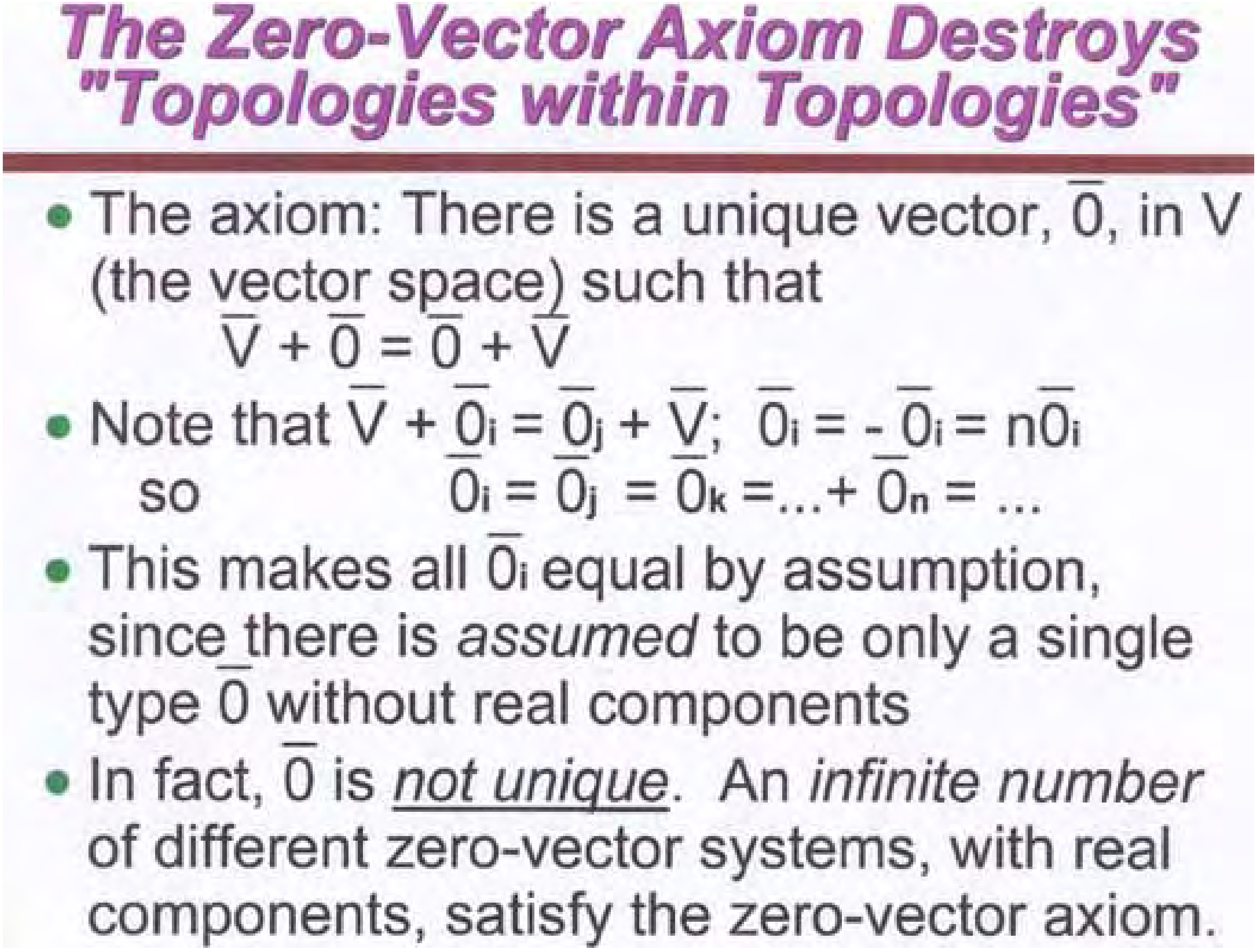

The Zero-Vector Axiom Destroys "Topologies within Topologies"

- The axiom: There is a unique vector, $\overline{0}$, in V (the vector space) such that
  $$\overline{V} + \overline{0} = \overline{0} + \overline{V}$$
- Note that $\overline{V} + \overline{0}_i = \overline{0}_j + \overline{V}$; $\overline{0}_i = -\overline{0}_i = n\overline{0}_i$
  so $\overline{0}_i = \overline{0}_j = \overline{0}_k = \ldots + \overline{0}_n = \ldots$
- This makes all $\overline{0}_i$ equal by assumption, since there is *assumed* to be only a single type $\overline{0}$ without real components
- In fact, $\overline{0}$ is *not unique*. An *infinite number* of different zero-vector systems, with real components, satisfy the zero-vector axiom.

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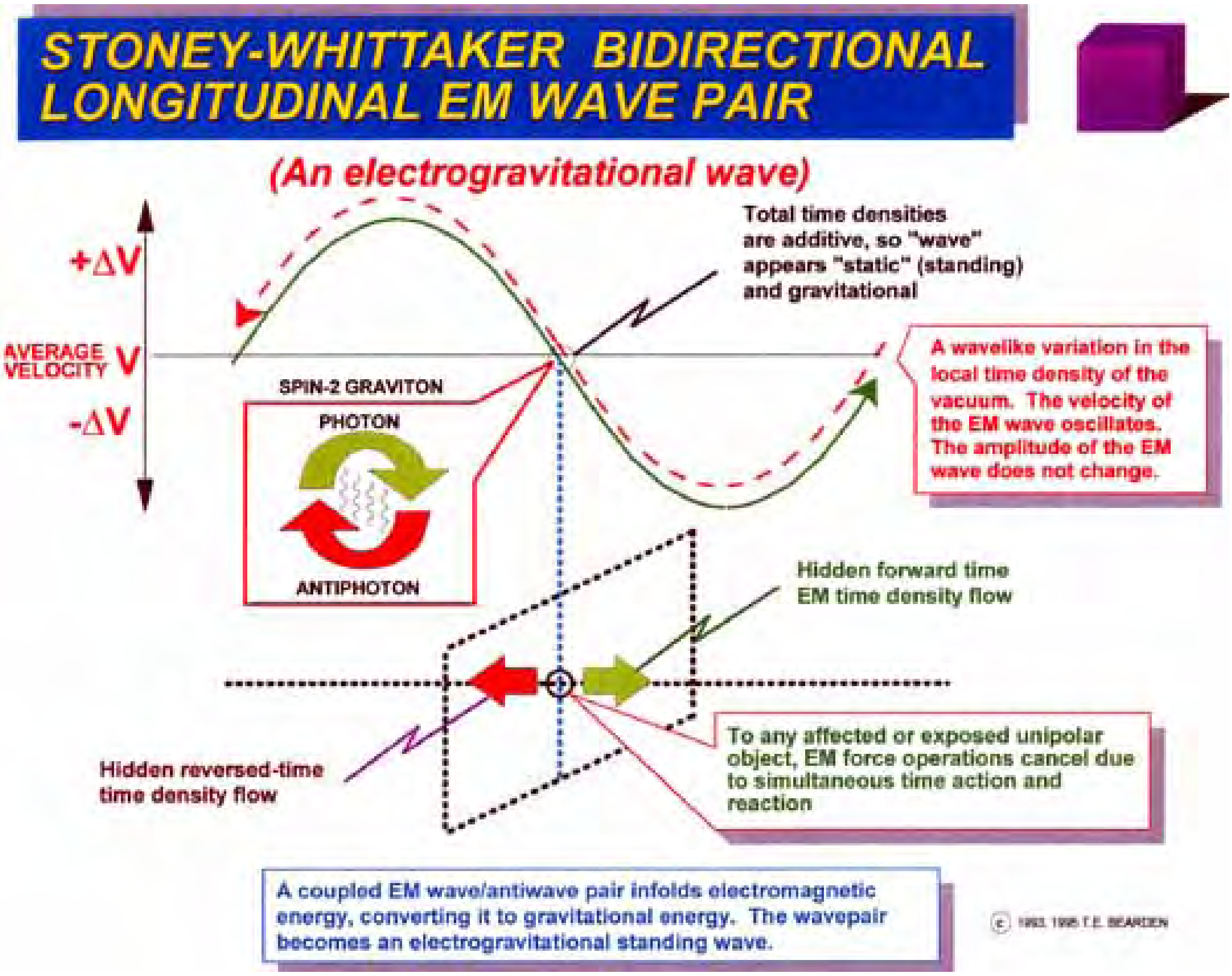

STONEY-WHITTAKER BIDIRECTIONAL LONGITUDINAL EM WAVE PAIR

(An electrogravitational wave)

Total time densities are additive, so "wave" appears "static" (standing) and gravitational

A wavelike variation in the local time density of the vacuum. The velocity of the EM wave oscillates. The amplitude of the EM wave does not change.

Hidden forward time EM time density flow

Hidden reversed-time time density flow

To any affected or exposed unipolar object, EM force operations cancel due to simultaneous time action and reaction

A coupled EM wave/antiwave pair infolds electromagnetic energy, converting it to gravitational energy. The wavepair becomes an electrogravitational standing wave.

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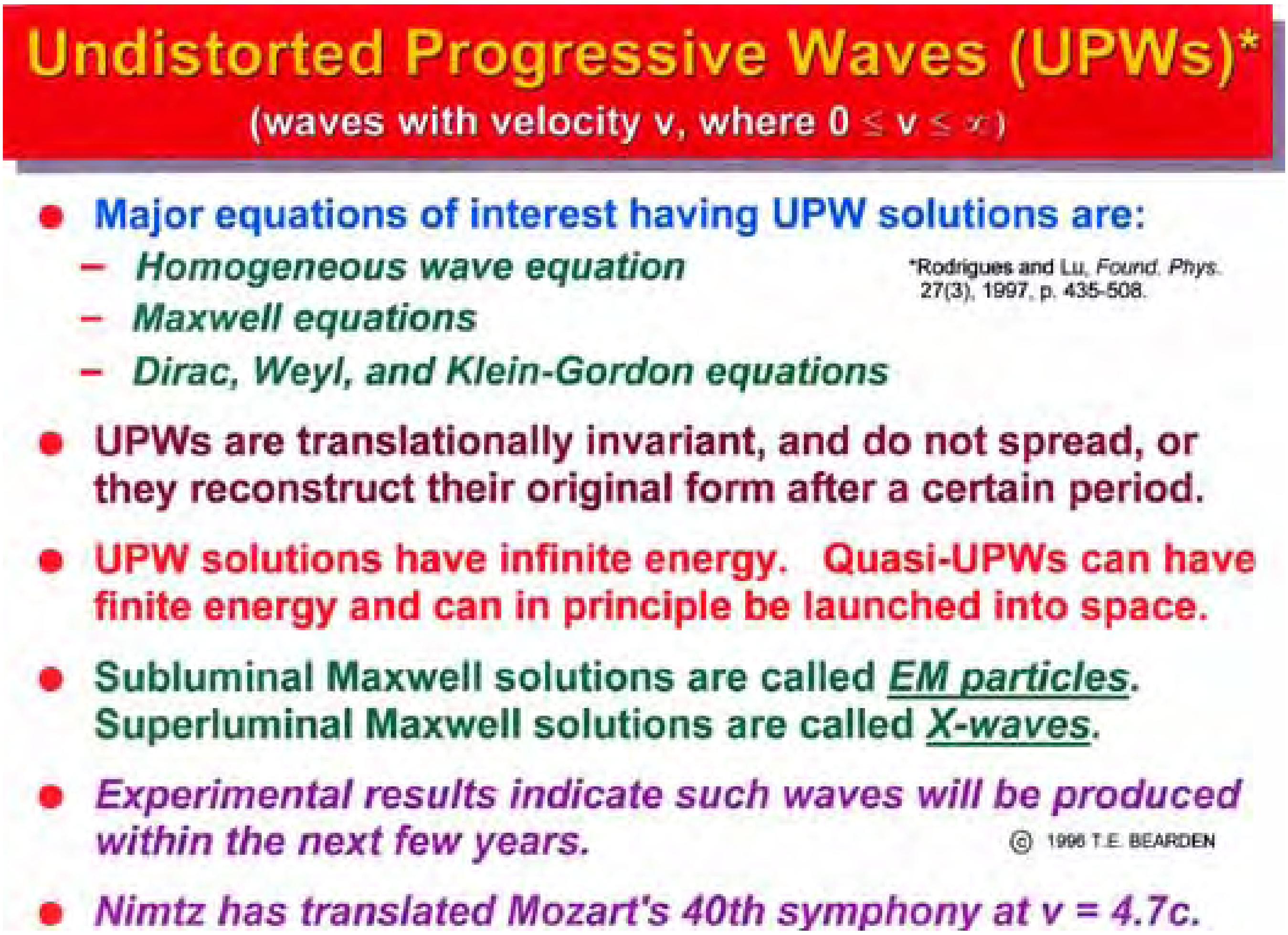

Undistorted Progressive Waves (UPWs)*

(waves with velocity v, where $0 \leq v \leq \infty$)

- Major equations of interest having UPW solutions are:
  - *Homogeneous wave equation*
  - *Maxwell equations*
  - *Dirac, Weyl, and Klein-Gordon equations*
- UPWs are translationally invariant, and do not spread, or they reconstruct their original form after a certain period.
- UPW solutions have infinite energy. Quasi-UPWs can have finite energy and can in principle be launched into space.
- Subluminal Maxwell solutions are called *EM particles*. Superluminal Maxwell solutions are called *X-waves*.
- *Experimental results indicate such waves will be produced within the next few years.*
- *Nimtz has translated Mozart's 40th symphony at v = 4.7c.*

*Rodrigues and Lu, *Found. Phys.* 27(3), 1997, p. 435-508.

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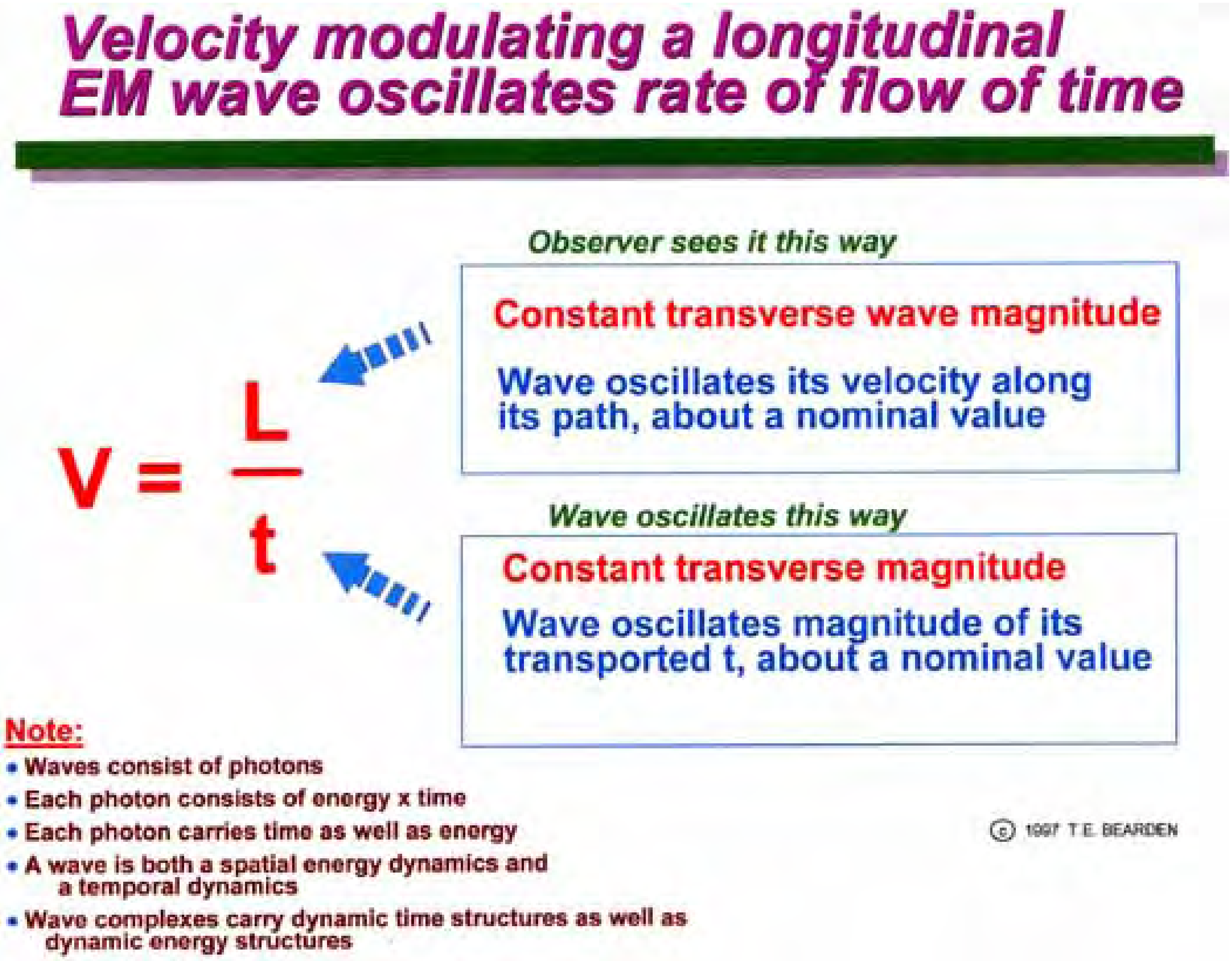

Velocity modulating a longitudinal EM wave oscillates rate of flow of time

$$V = \frac{L}{t}$$

Observer sees it this way

Constant transverse wave magnitude

Wave oscillates its velocity along its path, about a nominal value

Wave oscillates this way

Constant transverse magnitude

Wave oscillates magnitude of its transported t, about a nominal value

Note:

- Waves consist of photons
- Each photon consists of energy x time
- Each photon carries time as well as energy
- A wave is both a spatial energy dynamics and a temporal dynamics
- Wave complexes carry dynamic time structures as well as dynamic energy structures

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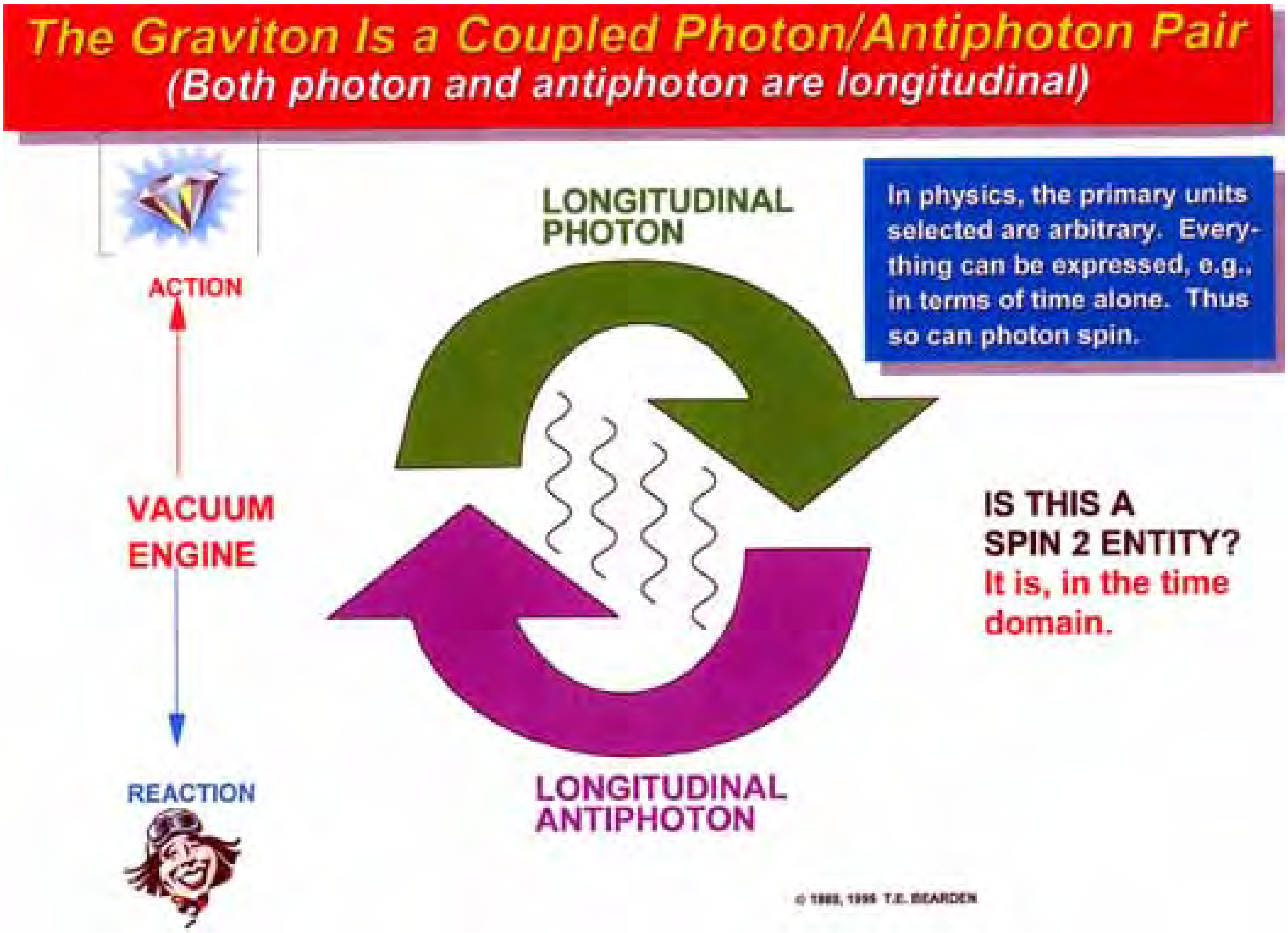

The Graviton Is a Coupled Photon/Antiphoton Pair

(Both photon and antiphoton are longitudinal)

In physics, the primary units selected are arbitrary. Everything can be expressed, e.g., in terms of time alone. Thus so can photon spin.

IS THIS A SPIN 2 ENTITY?

It is, in the time domain.

ACTION
VACUUM ENGINE
REACTION
LONGITUDINAL PHOTON
LONGITUDINAL ANTIPHOTON

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Mechanisms for Physical Change and the Flow of Time

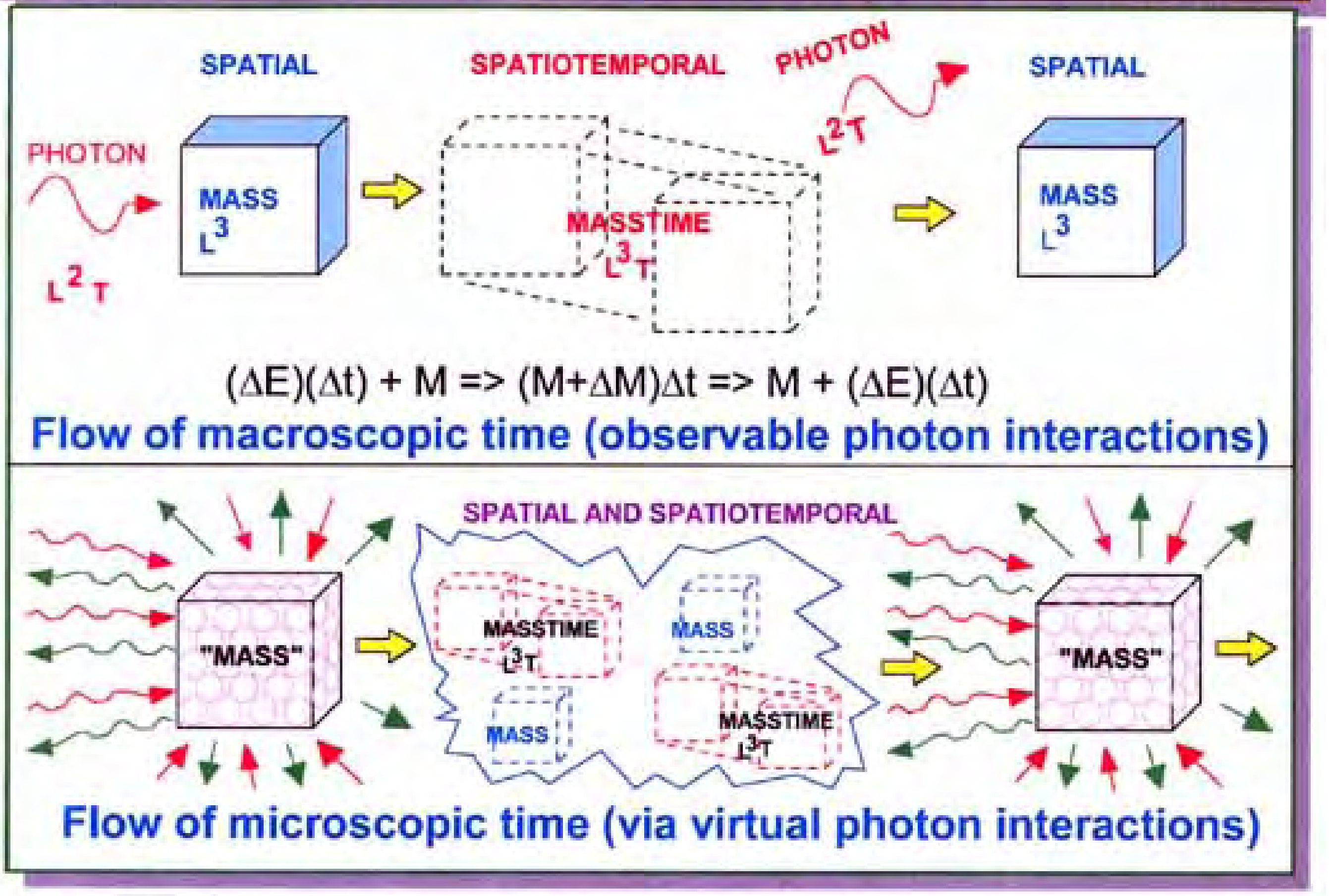
SPATIAL
SPATIOTEMPORAL
PHOTON
SPATIAL
PHOTON
MASS
L^3
L^2T
MASSTIME
L^3T
L^2T
MASS
L^3
SPATIAL AND SPATIOTEMPORAL
"MASS"
MASSTIME
L^3T
MASS
MASS
MASSTIME
L^3T
"MASS"

$$(\Delta E)(\Delta t) + M \Rightarrow (M+\Delta M)\Delta t \Rightarrow M + (\Delta E)(\Delta t)$$

Flow of macroscopic time (observable photon interactions)

Flow of microscopic time (via virtual photon interactions)

The photon interaction generates an observed quantum change and a discretized jump in the rate of time flow. A particle observably changes by only a single Δt at a time. The background flow of time in which the jump in rate occurs, is created by the continual absorption and emission of virtual photons.

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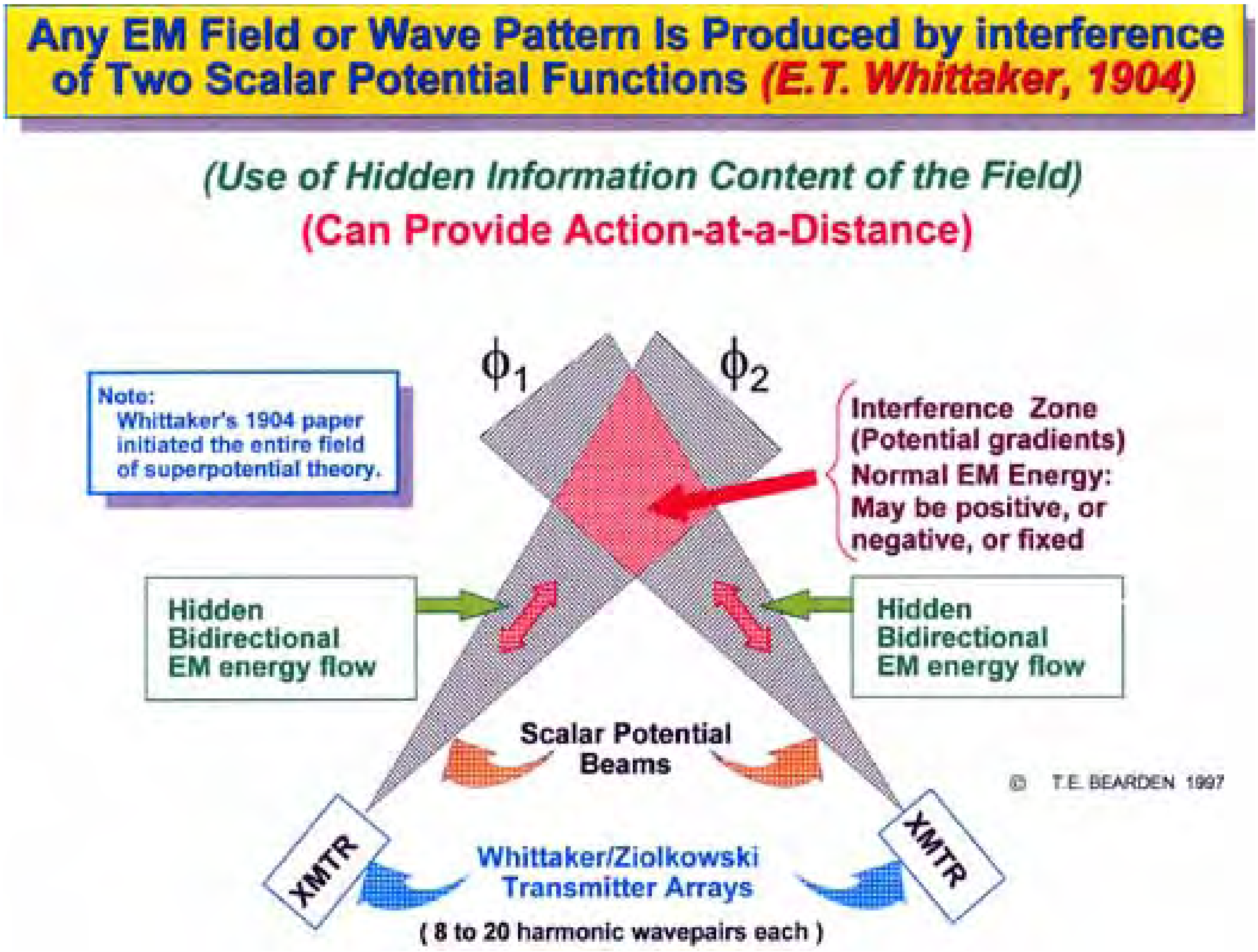

Any EM Field or Wave Pattern Is Produced by interference of Two Scalar Potential Functions *(E.T. Whittaker, 1904)*

(Use of Hidden Information Content of the Field)

(Can Provide Action-at-a-Distance)

Note:
Whittaker's 1904 paper initiated the entire field of superpotential theory.

Interference Zone
(Potential gradients)
Normal EM Energy:
May be positive, or negative, or fixed

Hidden
Bidirectional
EM energy flow

Hidden
Bidirectional
EM energy flow

Scalar Potential
Beams

Whittaker/Ziolkowski
Transmitter Arrays
(8 to 20 harmonic wavepairs each)

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Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass

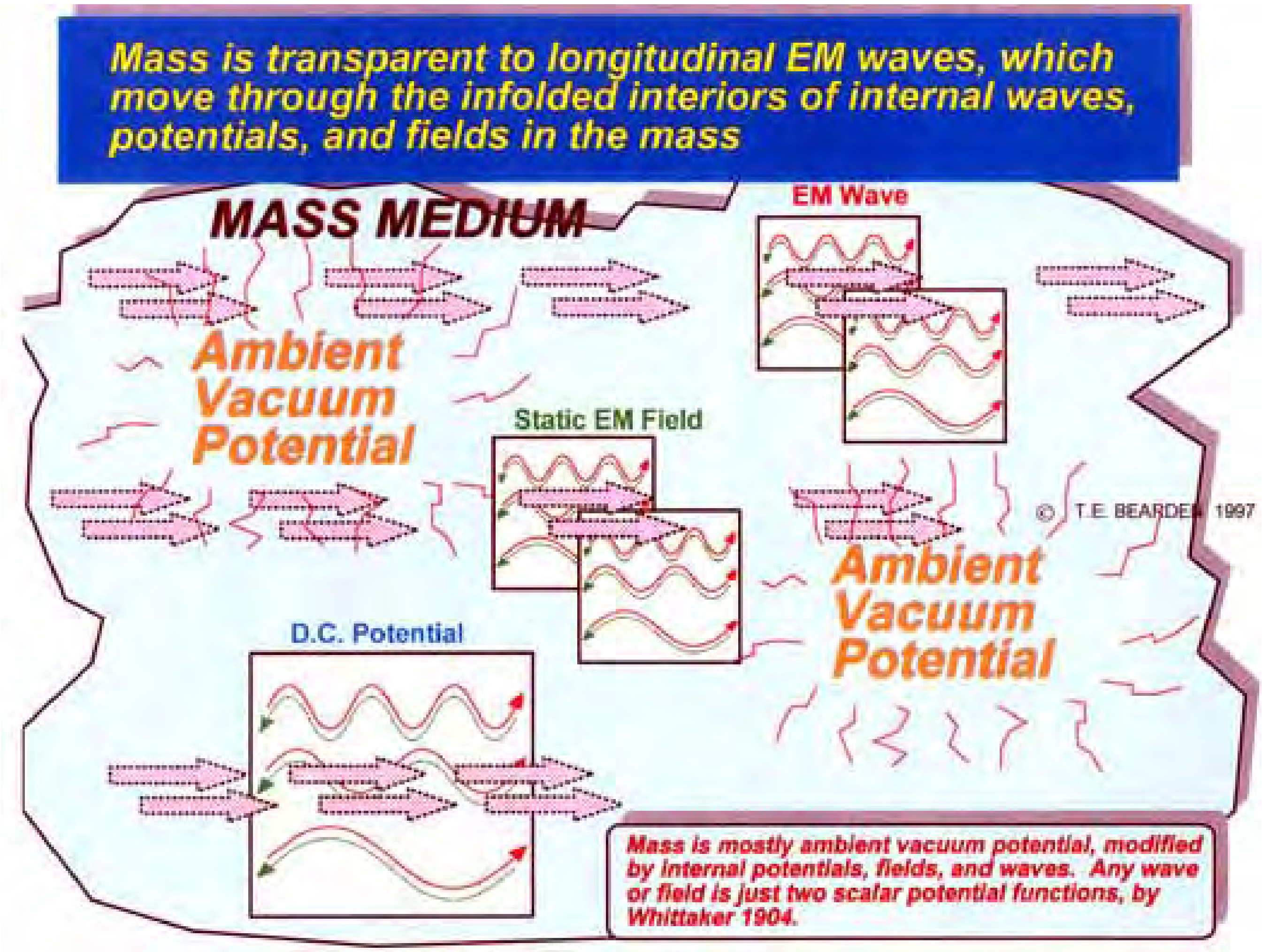
MASS MEDIUM
Ambient Vacuum Potential
EM Wave
Static EM Field
D.C. Potential
Ambient Vacuum Potential
© T.E. BEARDEN 1997

Mass is mostly ambient vacuum potential, modified by internal potentials, fields, and waves. Any wave or field is just two scalar potential functions, by Whittaker 1904.

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Deep penetration of weak signals in a dense signal environment, by nonlinear retroreflection

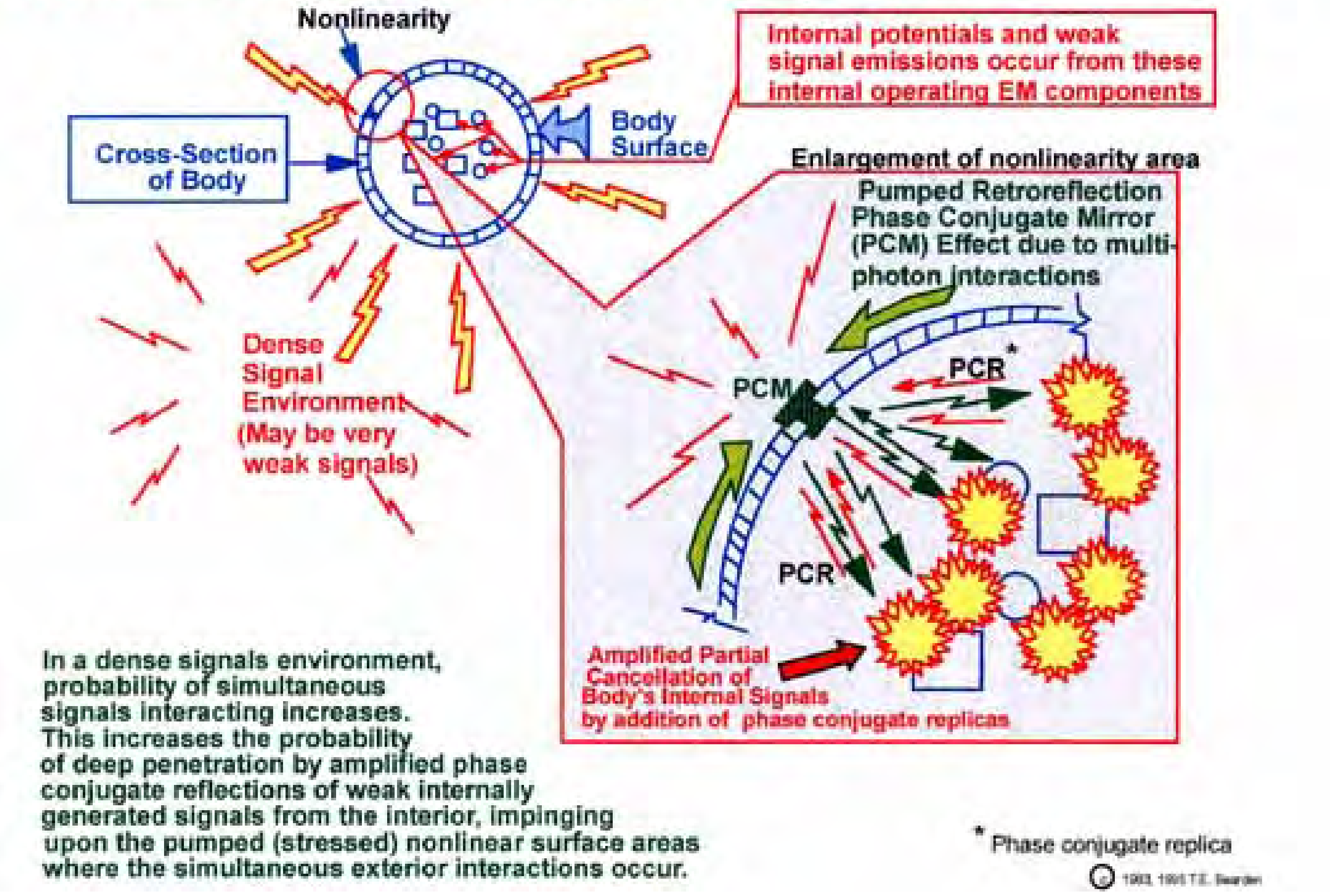
Nonlinearity
Internal potentials and weak signal emissions occur from these internal operating EM components
Cross-Section of Body
Body Surface
Enlargement of nonlinearity area
Pumped Retroreflection Phase Conjugate Mirror (PCM) Effect due to multi-photon interactions
Dense Signal Environment (May be very weak signals)
PCM
PCR*
PCR
Amplified Partial Cancellation of Body's Internal Signals by addition of phase conjugate replicas

In a dense signals environment, probability of simultaneous signals interacting increases. This increases the probability of deep penetration by amplified phase conjugate reflections of weak internally generated signals from the interior, impinging upon the pumped (stressed) nonlinear surface areas where the simultaneous exterior interactions occur.

* Phase conjugate replica

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THE IMMUNE SYSTEM

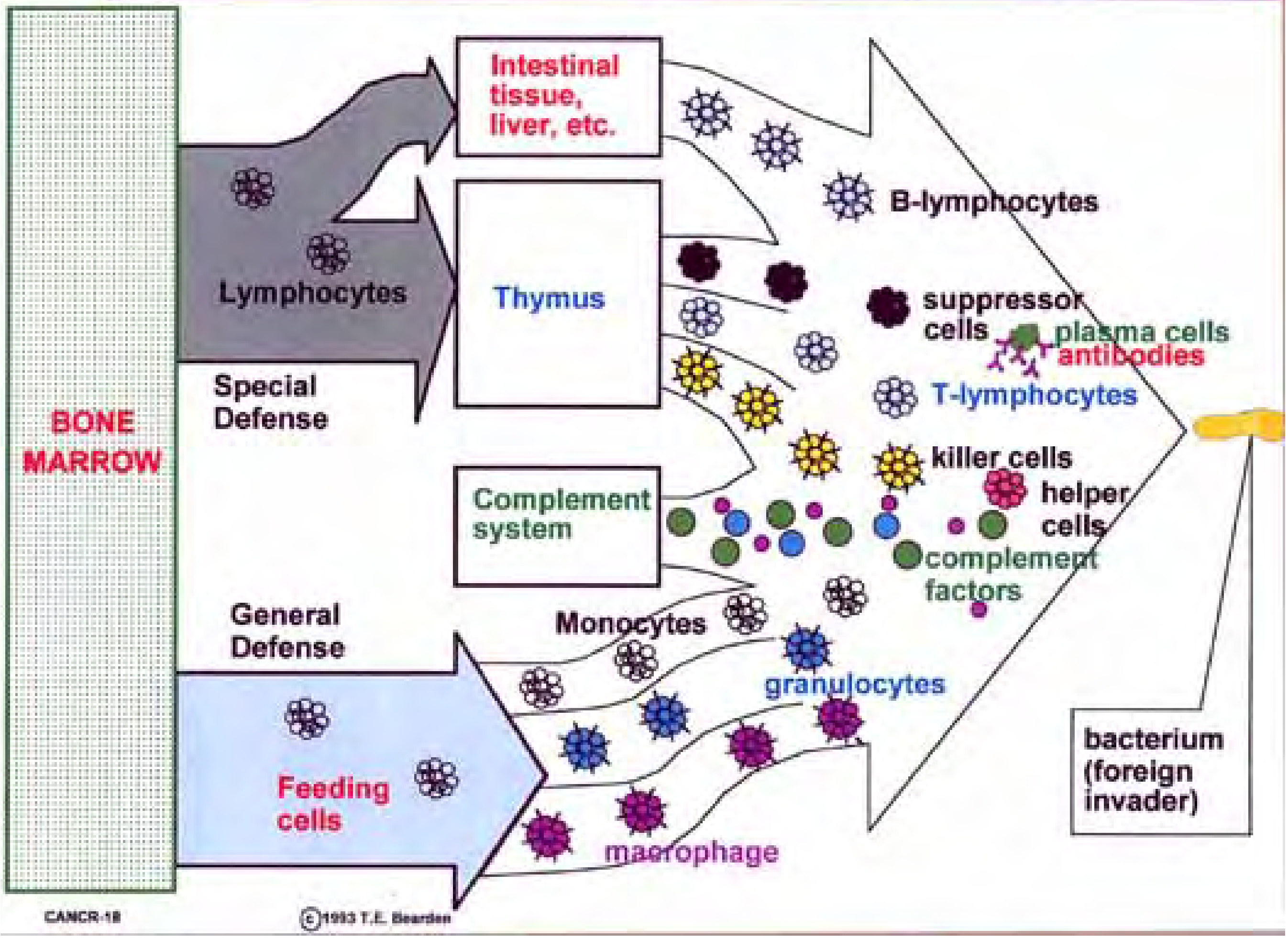
BONE MARROW
Lymphocytes
Special Defense
General Defense
Feeding cells
Intestinal tissue, liver, etc.
Thymus
Complement system
B-lymphocytes
suppressor cells
plasma cells
antibodies
T-lymphocytes
killer cells
helper cells
complement factors
Monocytes
granulocytes
macrophage
bacterium (foreign invader)

CANCR-18

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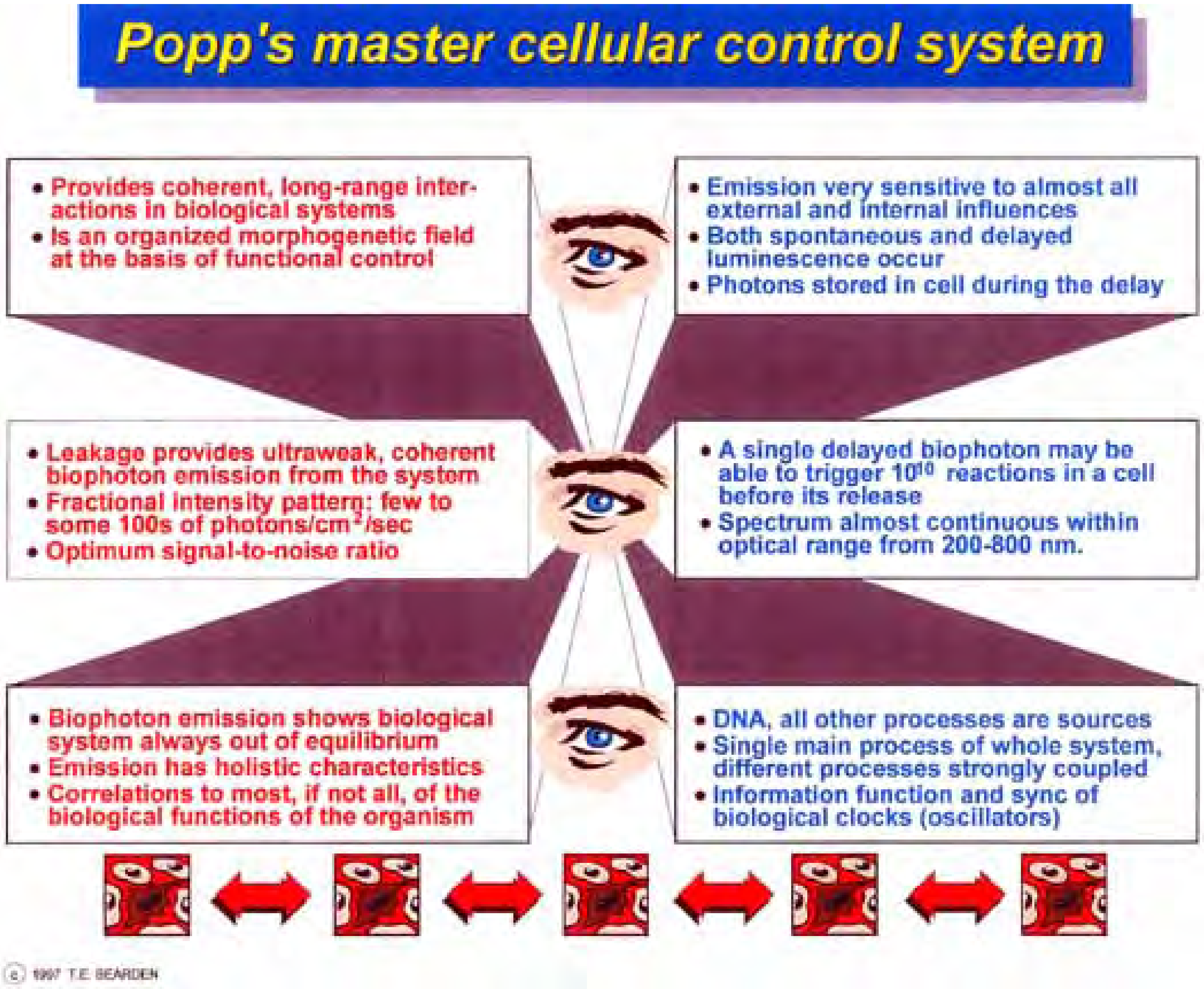

Popp's master cellular control system

- Provides coherent, long-range interactions in biological systems
- Is an organized morphogenetic field at the basis of functional control

- Emission very sensitive to almost all external and internal influences
- Both spontaneous and delayed luminescence occur
- Photons stored in cell during the delay

- Leakage provides ultraweak, coherent biophoton emission from the system
- Fractional intensity pattern: few to some 100s of photons/cm^2/sec
- Optimum signal-to-noise ratio

- A single delayed biophoton may be able to trigger 10^{10} reactions in a cell before its release
- Spectrum almost continuous within optical range from 200-800 nm.

- Biophoton emission shows biological system always out of equilibrium
- Emission has holistic characteristics
- Correlations to most, if not all, of the biological functions of the organism

- DNA, all other processes are sources
- Single main process of whole system, different processes strongly coupled
- Information function and sync of biological clocks (oscillators)

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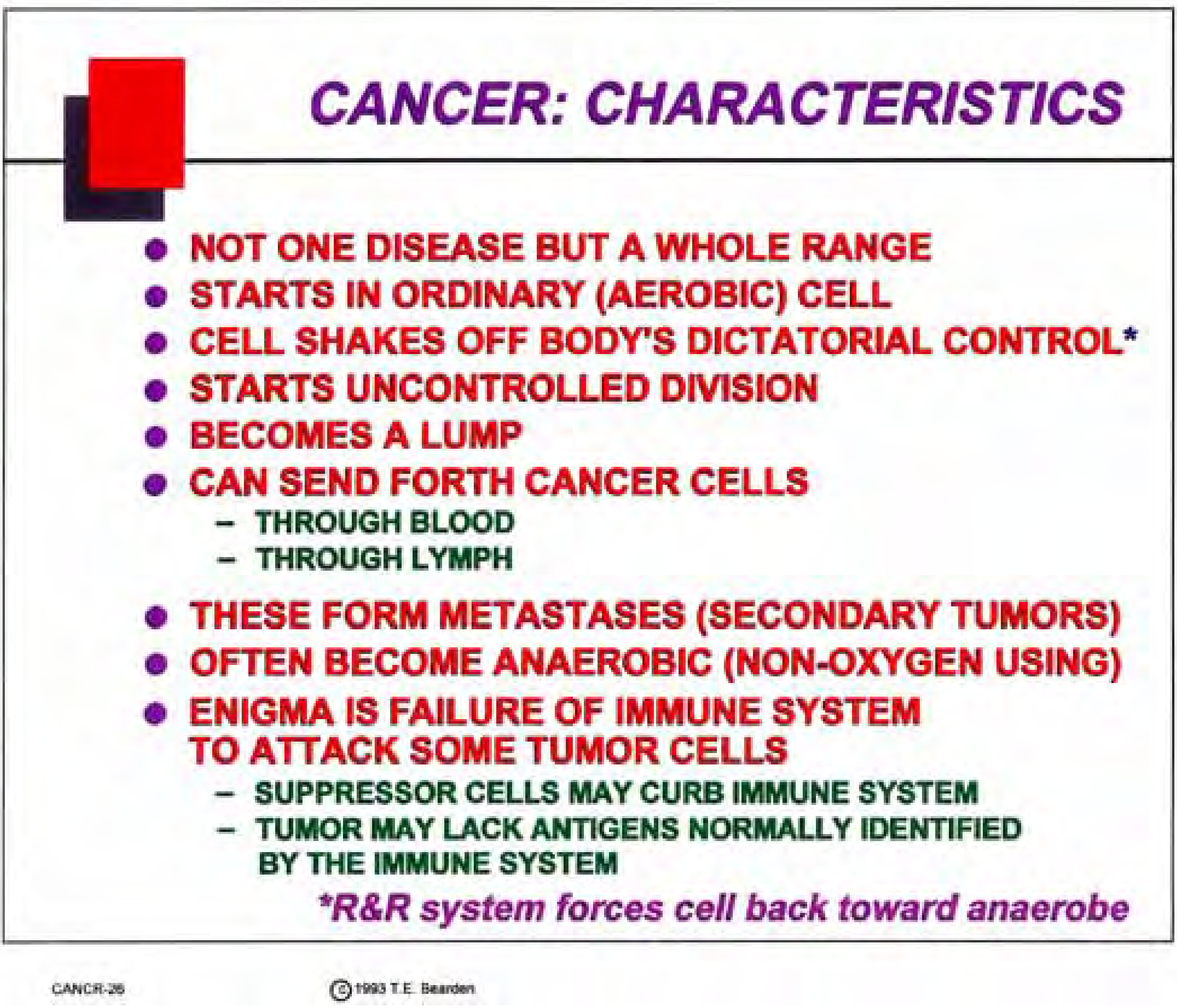

CANCER: CHARACTERISTICS

- NOT ONE DISEASE BUT A WHOLE RANGE
- STARTS IN ORDINARY (AEROBIC) CELL
- CELL SHAKES OFF BODY'S DICTATORIAL CONTROL*
- STARTS UNCONTROLLED DIVISION
- BECOMES A LUMP
- CAN SEND FORTH CANCER CELLS
  - THROUGH BLOOD
  - THROUGH LYMPH
- THESE FORM METASTASES (SECONDARY TUMORS)
- OFTEN BECOME ANAEROBIC (NON-OXYGEN USING)
- ENIGMA IS FAILURE OF IMMUNE SYSTEM TO ATTACK SOME TUMOR CELLS
  - SUPPRESSOR CELLS MAY CURB IMMUNE SYSTEM
  - TUMOR MAY LACK ANTIGENS NORMALLY IDENTIFIED BY THE IMMUNE SYSTEM

*R&R system forces cell back toward anaerobe

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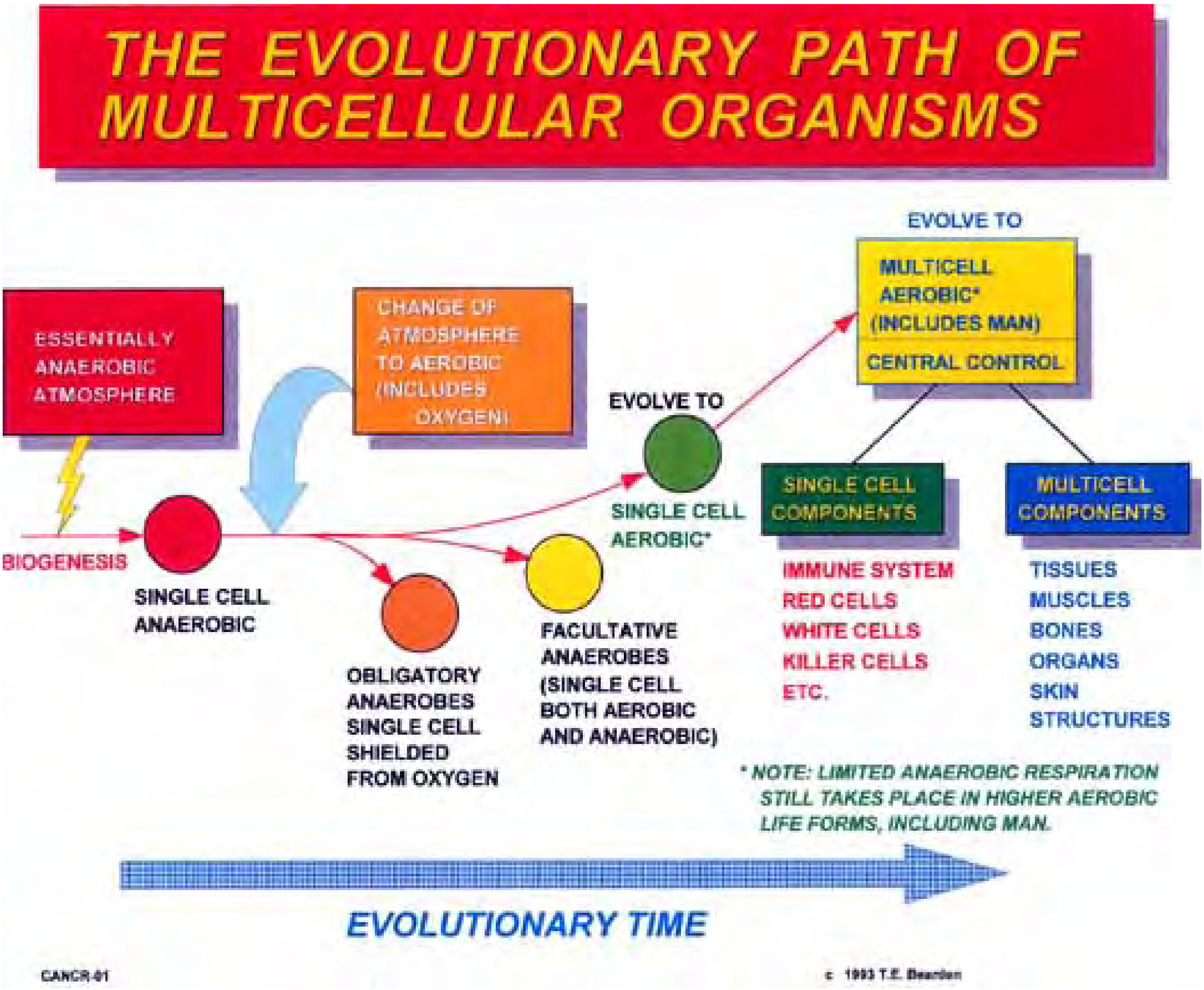

THE EVOLUTIONARY PATH OF MULTICELLULAR ORGANISMS

ESSENTIALLY ANAEROBIC ATMOSPHERE

CHANGE OF ATMOSPHERE TO AEROBIC (INCLUDES OXYGEN)

BIOGENESIS

SINGLE CELL ANAEROBIC

OBLIGATORY ANAEROBES SINGLE CELL SHIELDED FROM OXYGEN

FACULTATIVE ANAEROBES (SINGLE CELL BOTH AEROBIC AND ANAEROBIC)

EVOLVE TO

SINGLE CELL AEROBIC*

EVOLVE TO

MULTICELL AEROBIC* (INCLUDES MAN)

CENTRAL CONTROL

SINGLE CELL COMPONENTS

- IMMUNE SYSTEM
- RED CELLS
- WHITE CELLS
- KILLER CELLS
- ETC.

MULTICELL COMPONENTS

- TISSUES
- MUSCLES
- BONES
- ORGANS
- SKIN
- STRUCTURES

* NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.

EVOLUTIONARY TIME

CANCR-01

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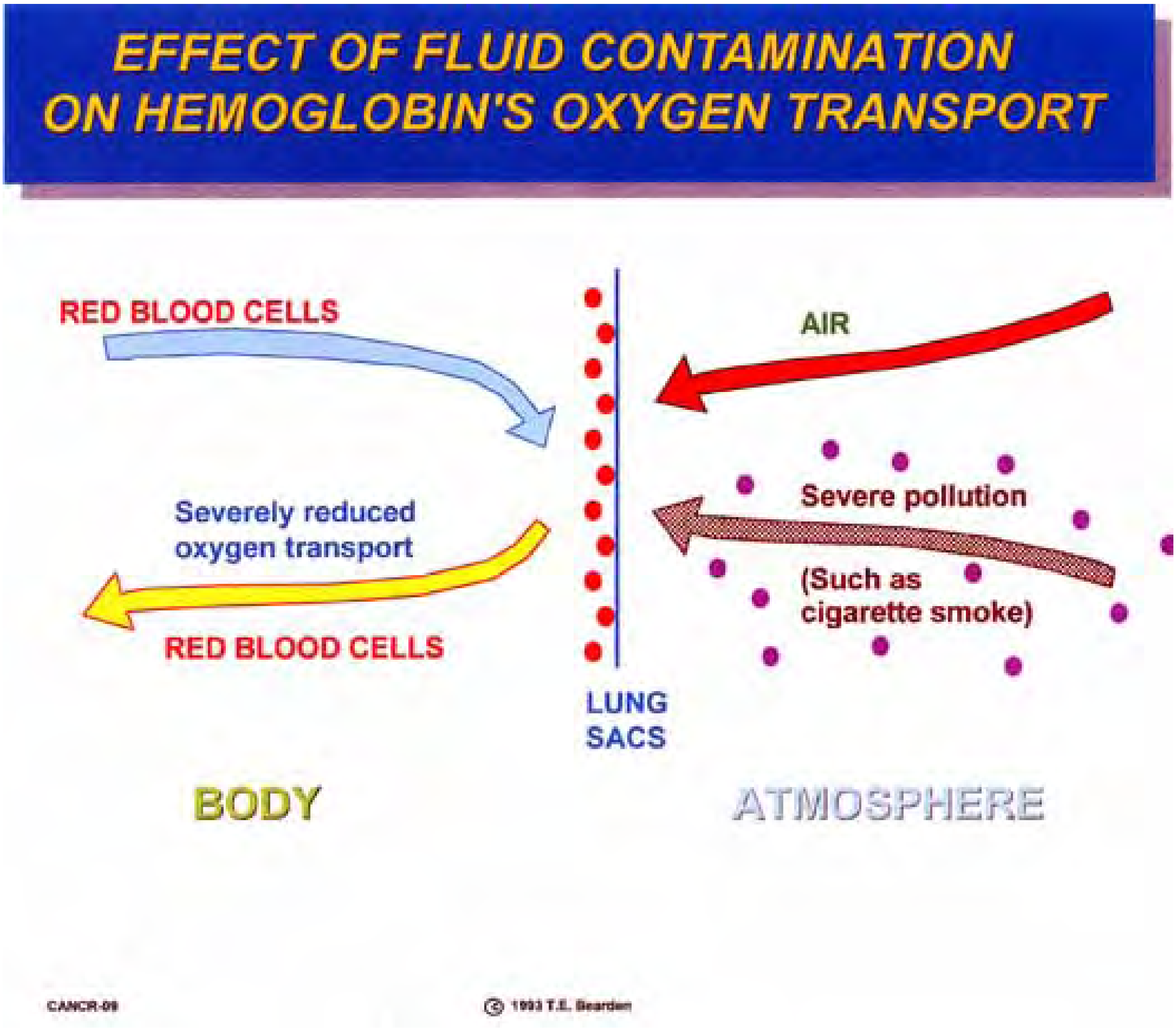

EFFECT OF FLUID CONTAMINATION ON HEMOGLOBIN'S OXYGEN TRANSPORT

RED BLOOD CELLS

AIR

Severe pollution

(Such as cigarette smoke)

Severely reduced oxygen transport

RED BLOOD CELLS

LUNG SACS

BODY

ATMOSPHERE

CANCR-09

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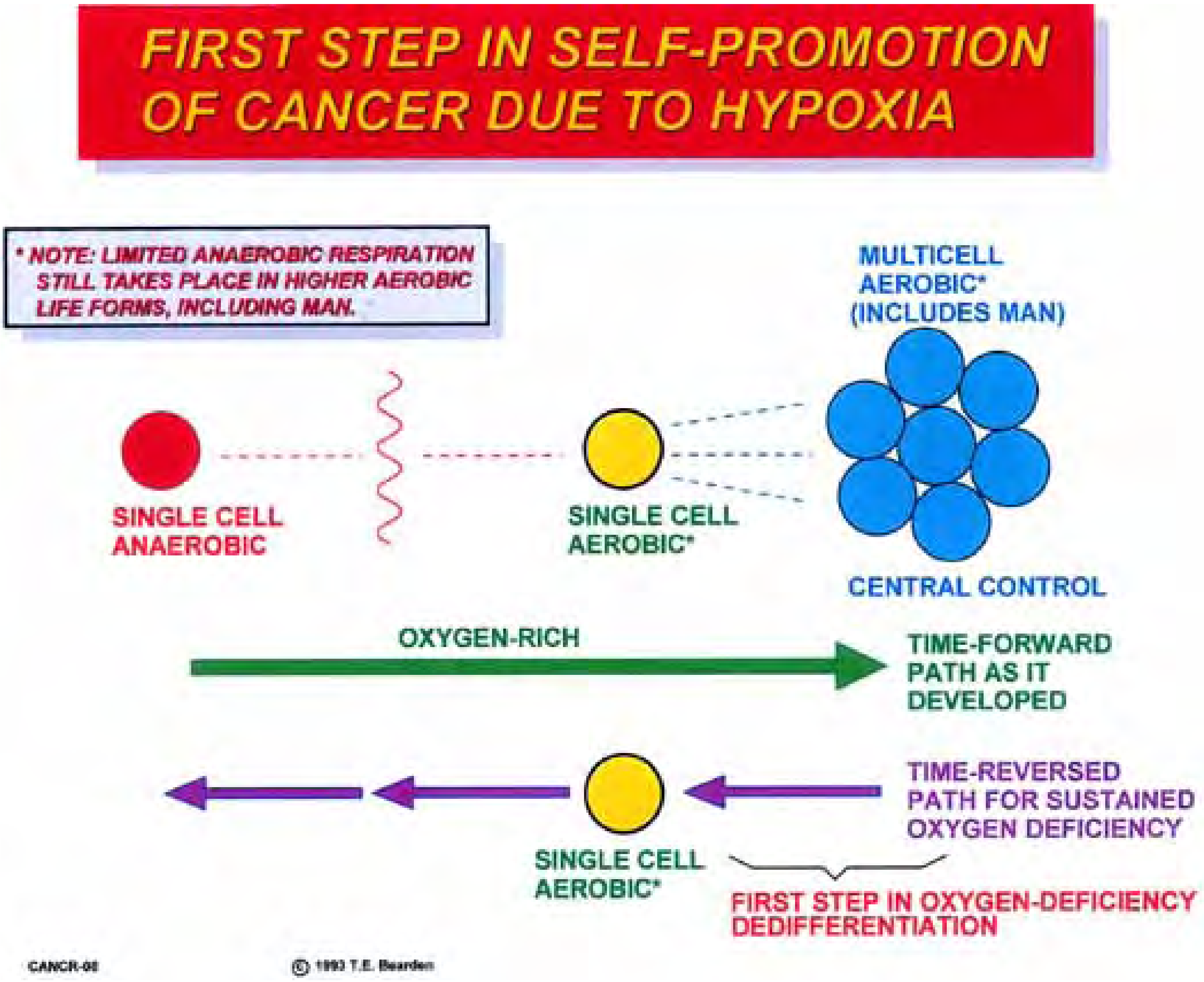

FIRST STEP IN SELF-PROMOTION OF CANCER DUE TO HYPOXIA

* NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.

SINGLE CELL
ANAEROBIC
SINGLE CELL
AEROBIC*
MULTICELL
AEROBIC*
(INCLUDES MAN)
CENTRAL CONTROL
OXYGEN-RICH
TIME-FORWARD
PATH AS IT
DEVELOPED
TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY
SINGLE CELL
AEROBIC*
FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION

CANCR-08

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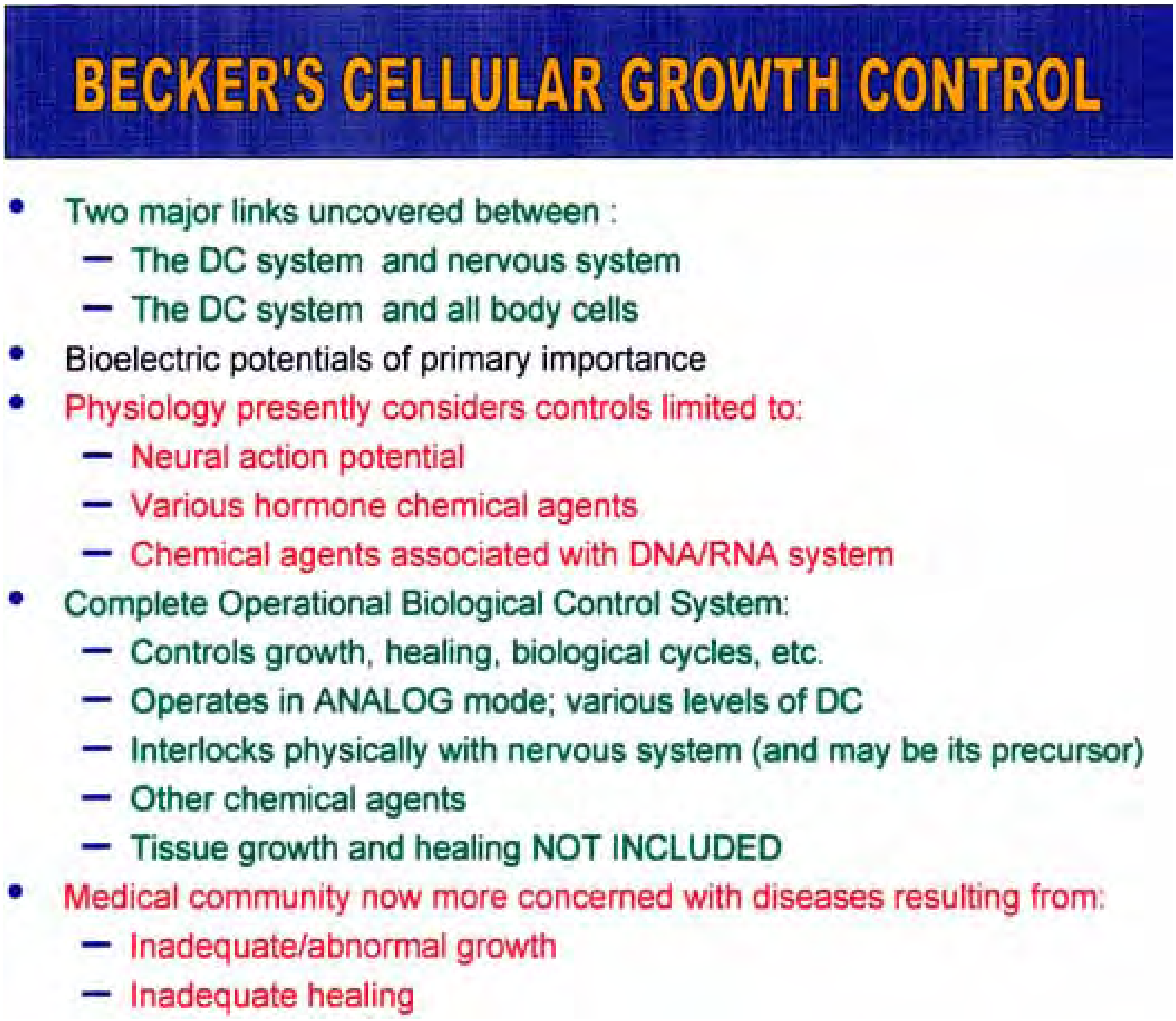

BECKER'S CELLULAR GROWTH CONTROL

- Two major links uncovered between :
  - The DC system and nervous system
  - The DC system and all body cells
- Bioelectric potentials of primary importance
- Physiology presently considers controls limited to:
  - Neural action potential
  - Various hormone chemical agents
  - Chemical agents associated with DNA/RNA system
- Complete Operational Biological Control System:
  - Controls growth, healing, biological cycles, etc.
  - Operates in ANALOG mode; various levels of DC
  - Interlocks physically with nervous system (and may be its precursor)
  - Other chemical agents
  - Tissue growth and healing NOT INCLUDED
- Medical community now more concerned with diseases resulting from:
  - Inadequate/abnormal growth
  - Inadequate healing

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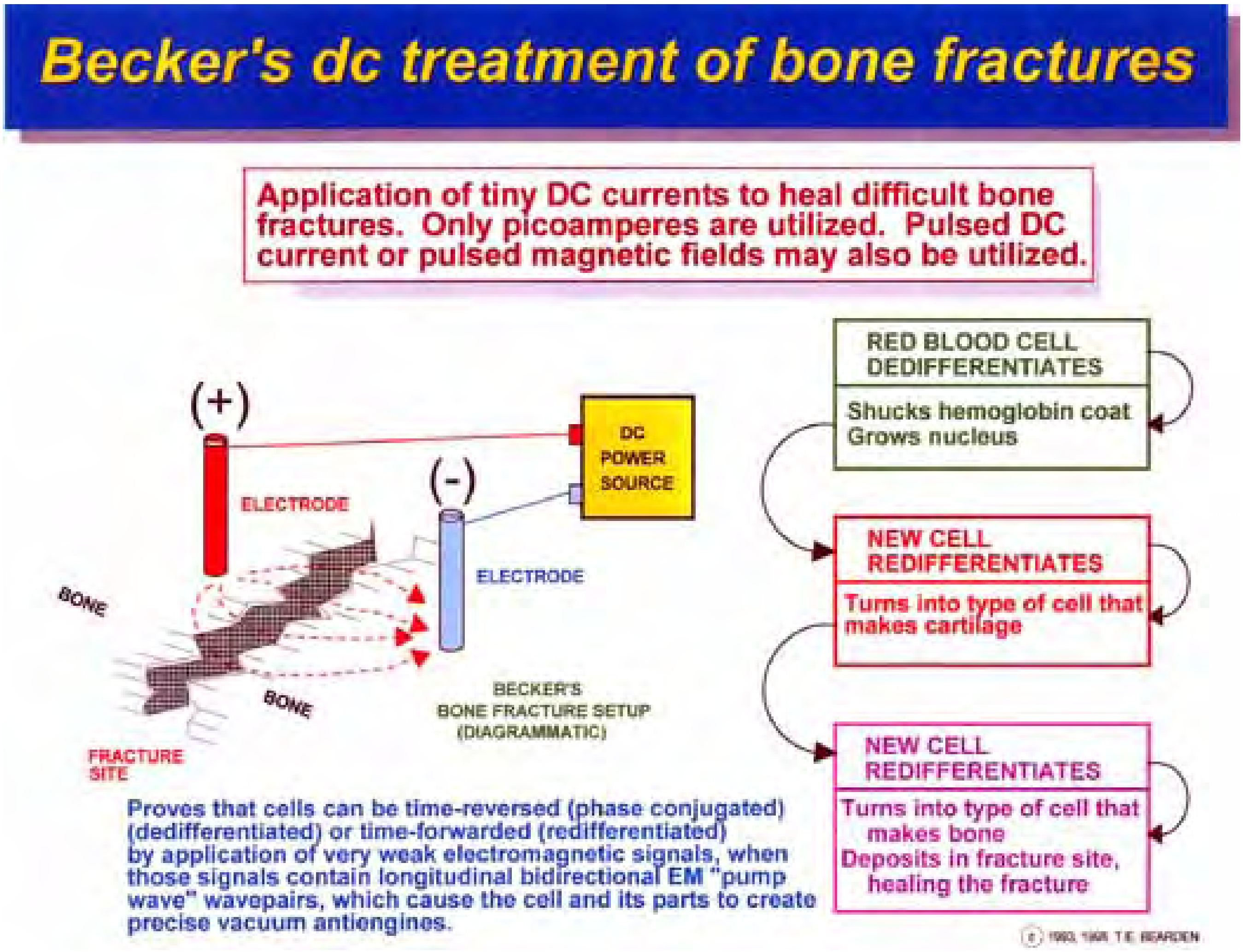

Becker's dc treatment of bone fractures

Application of tiny DC currents to heal difficult bone fractures. Only picoamperes are utilized. Pulsed DC current or pulsed magnetic fields may also be utilized.

(+)
ELECTRODE
(-)
DC POWER SOURCE
ELECTRODE
BONE
BONE
FRACTURE SITE
BECKER'S BONE FRACTURE SETUP (DIAGRAMMATIC)

RED BLOOD CELL DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

Proves that cells can be time-reversed (phase conjugated) (dedifferentiated) or time-forwarded (redifferentiated) by application of very weak electromagnetic signals, when those signals contain longitudinal bidirectional EM "pump wave" wavepairs, which cause the cell and its parts to create precise vacuum antiengines.

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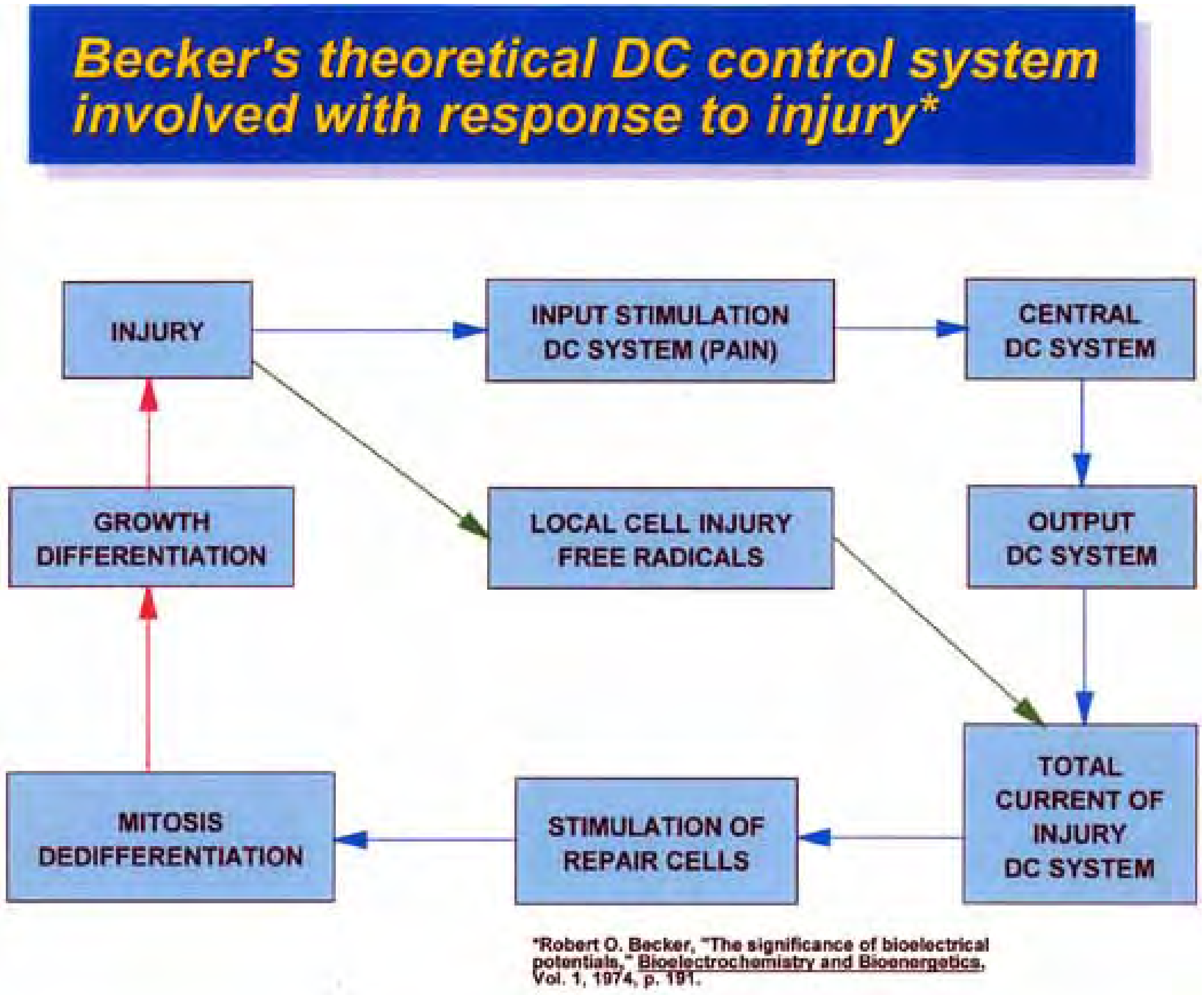

*Becker's theoretical DC control system involved with response to injury**

INJURY

INPUT STIMULATION
DC SYSTEM (PAIN)

CENTRAL
DC SYSTEM

GROWTH
DIFFERENTIATION

LOCAL CELL INJURY
FREE RADICALS

OUTPUT
DC SYSTEM

MITOSIS
DEDIFFERENTIATION

STIMULATION OF
REPAIR CELLS

TOTAL
CURRENT OF
INJURY
DC SYSTEM

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.

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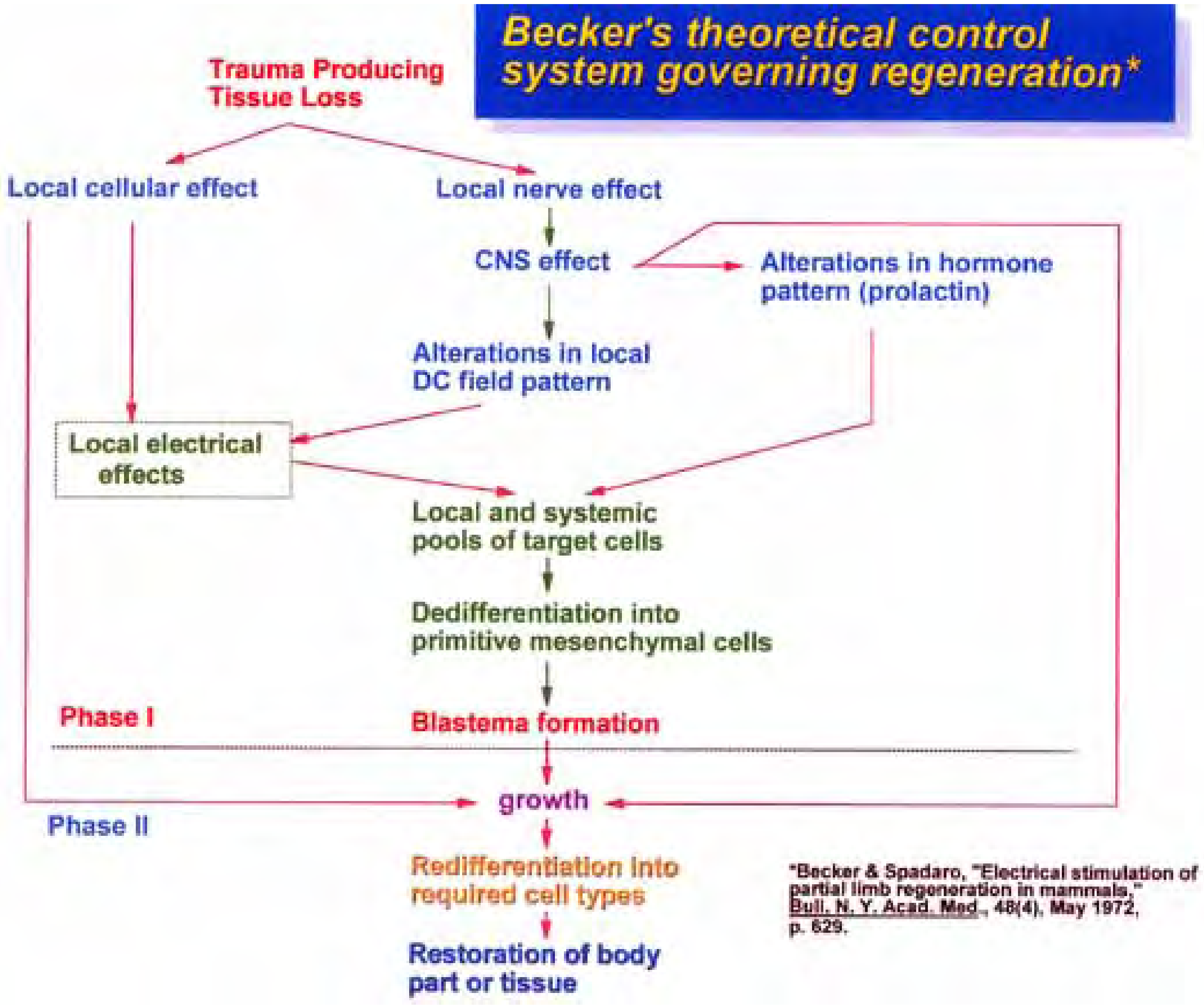

Becker's theoretical control system governing regeneration*

Trauma Producing Tissue Loss

Local cellular effect

Local nerve effect

CNS effect

Alterations in hormone pattern (prolactin)

Alterations in local DC field pattern

Local electrical effects

Local and systemic pools of target cells

Dedifferentiation into primitive mesenchymal cells

Phase I

Blastema formation

growth

Phase II

Redifferentiation into required cell types

Restoration of body part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bull. N. Y. Acad. Med., 48(4), May 1972, p. 629.

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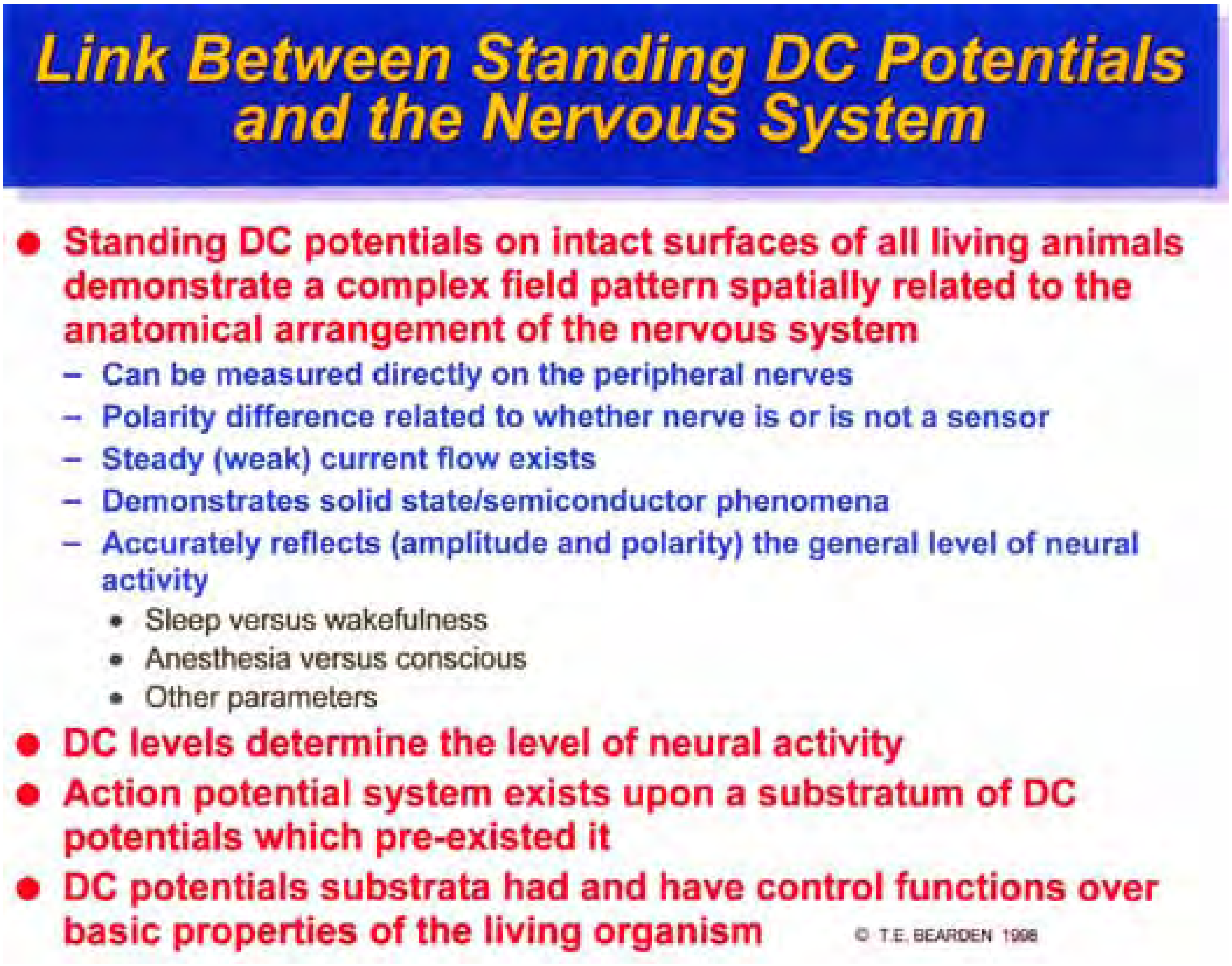

Link Between Standing DC Potentials and the Nervous System

- Standing DC potentials on intact surfaces of all living animals demonstrate a complex field pattern spatially related to the anatomical arrangement of the nervous system
  - Can be measured directly on the peripheral nerves
  - Polarity difference related to whether nerve is or is not a sensor
  - Steady (weak) current flow exists
  - Demonstrates solid state/semiconductor phenomena
  - Accurately reflects (amplitude and polarity) the general level of neural activity
    - Sleep versus wakefulness
    - Anesthesia versus conscious
    - Other parameters
- DC levels determine the level of neural activity
- Action potential system exists upon a substratum of DC potentials which pre-existed it
- DC potentials substrata had and have control functions over basic properties of the living organism

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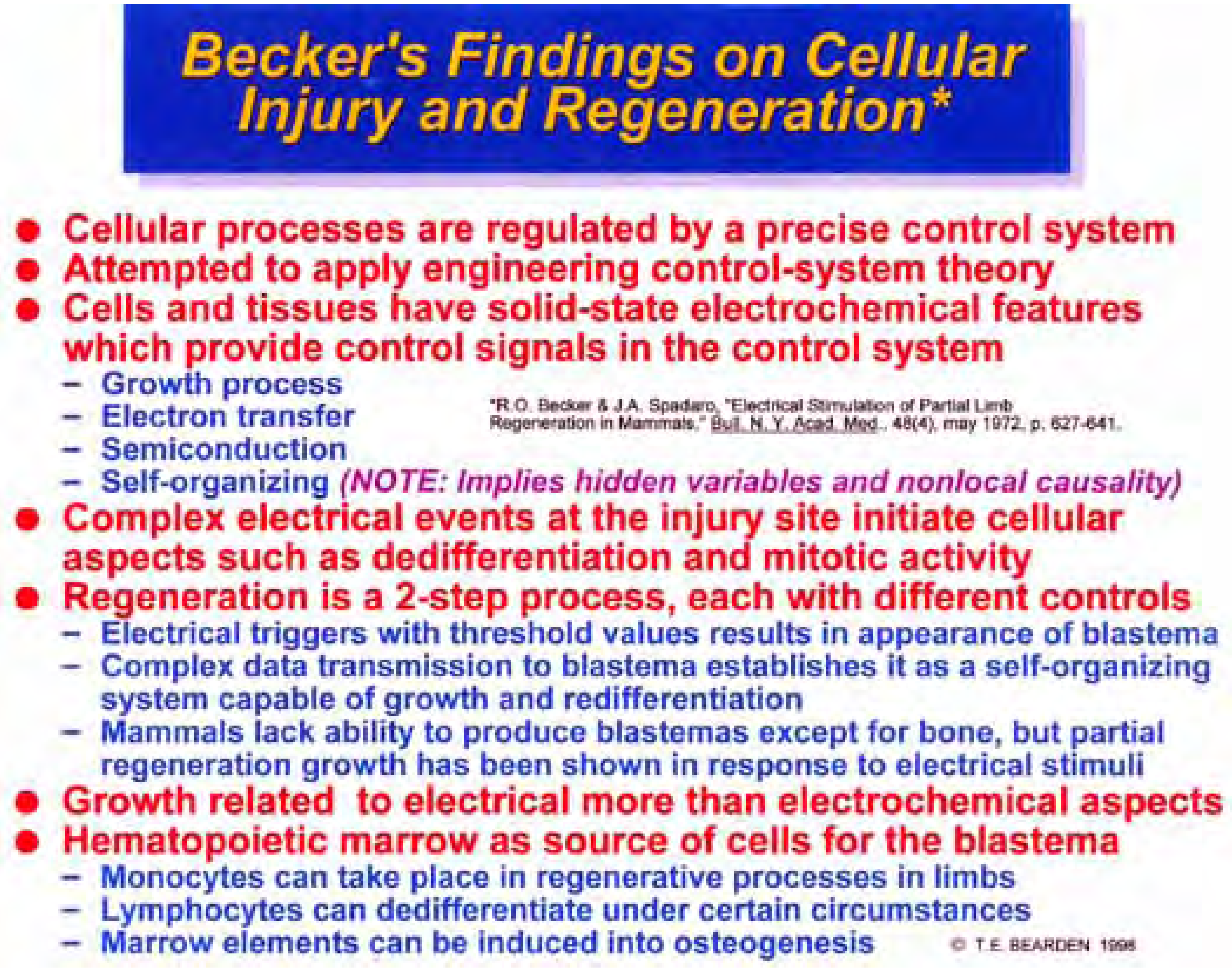

Becker's Findings on Cellular Injury and Regeneration*

- Cellular processes are regulated by a precise control system
- Attempted to apply engineering control-system theory
- Cells and tissues have solid-state electrochemical features which provide control signals in the control system
  - Growth process
  - Electron transfer
  - Semiconduction
  - Self-organizing *(NOTE: Implies hidden variables and nonlocal causality)*
- Complex electrical events at the injury site initiate cellular aspects such as dedifferentiation and mitotic activity
- Regeneration is a 2-step process, each with different controls
  - Electrical triggers with threshold values results in appearance of blastema
  - Complex data transmission to blastema establishes it as a self-organizing system capable of growth and redifferentiation
  - Mammals lack ability to produce blastemas except for bone, but partial regeneration growth has been shown in response to electrical stimuli
- Growth related to electrical more than electrochemical aspects
- Hematopoietic marrow as source of cells for the blastema
  - Monocytes can take place in regenerative processes in limbs
  - Lymphocytes can dedifferentiate under certain circumstances
  - Marrow elements can be induced into osteogenesis

*R.O. Becker & J.A. Spadaro, "Electrical Stimulation of Partial Limb Regeneration in Mammals," Bull. N. Y. Acad. Med., 48(4), may 1972, p. 627-641.

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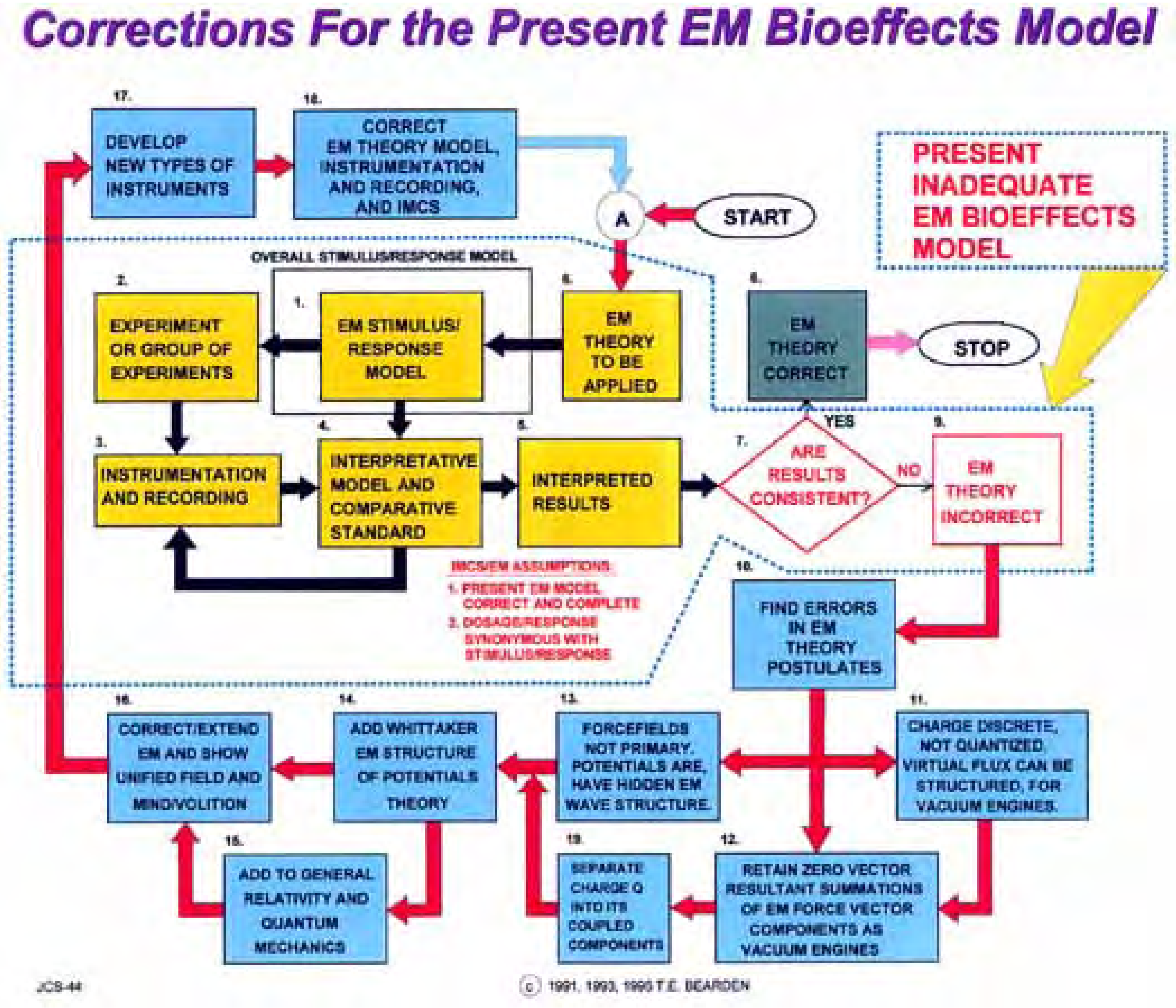

Corrections For the Present EM Bioeffects Model

17. DEVELOP NEW TYPES OF INSTRUMENTS

18. CORRECT EM THEORY MODEL, INSTRUMENTATION AND RECORDING, AND IMCS

A

START

PRESENT INADEQUATE EM BIOEFFECTS MODEL

OVERALL STIMULUS/RESPONSE MODEL

2. EXPERIMENT OR GROUP OF EXPERIMENTS

1. EM STIMULUS/ RESPONSE MODEL

6. EM THEORY TO BE APPLIED

8. EM THEORY CORRECT

STOP

3. INSTRUMENTATION AND RECORDING

4. INTERPRETATIVE MODEL AND COMPARATIVE STANDARD

5. INTERPRETED RESULTS

7. ARE RESULTS CONSISTENT?

YES

NO

9. EM THEORY INCORRECT

IMCS/EM ASSUMPTIONS

1. PRESENT EM MODEL CORRECT AND COMPLETE
2. DOSAGE/RESPONSE SYNONYMOUS WITH STIMULUS/RESPONSE

10. FIND ERRORS IN EM THEORY POSTULATES

16. CORRECT/EXTEND EM AND SHOW UNIFIED FIELD AND MIND/VOLITION

14. ADD WHITTAKER EM STRUCTURE OF POTENTIALS THEORY

13. FORCEFIELDS NOT PRIMARY. POTENTIALS ARE, HAVE HIDDEN EM WAVE STRUCTURE.

11. CHARGE DISCRETE, NOT QUANTIZED. VIRTUAL FLUX CAN BE STRUCTURED, FOR VACUUM ENGINES.

15. ADD TO GENERAL RELATIVITY AND QUANTUM MECHANICS

19. SEPARATE CHARGE Q INTO ITS COUPLED COMPONENTS

12. RETAIN ZERO VECTOR RESULTANT SUMMATIONS OF EM FORCE VECTOR COMPONENTS AS VACUUM ENGINES

JCS-44

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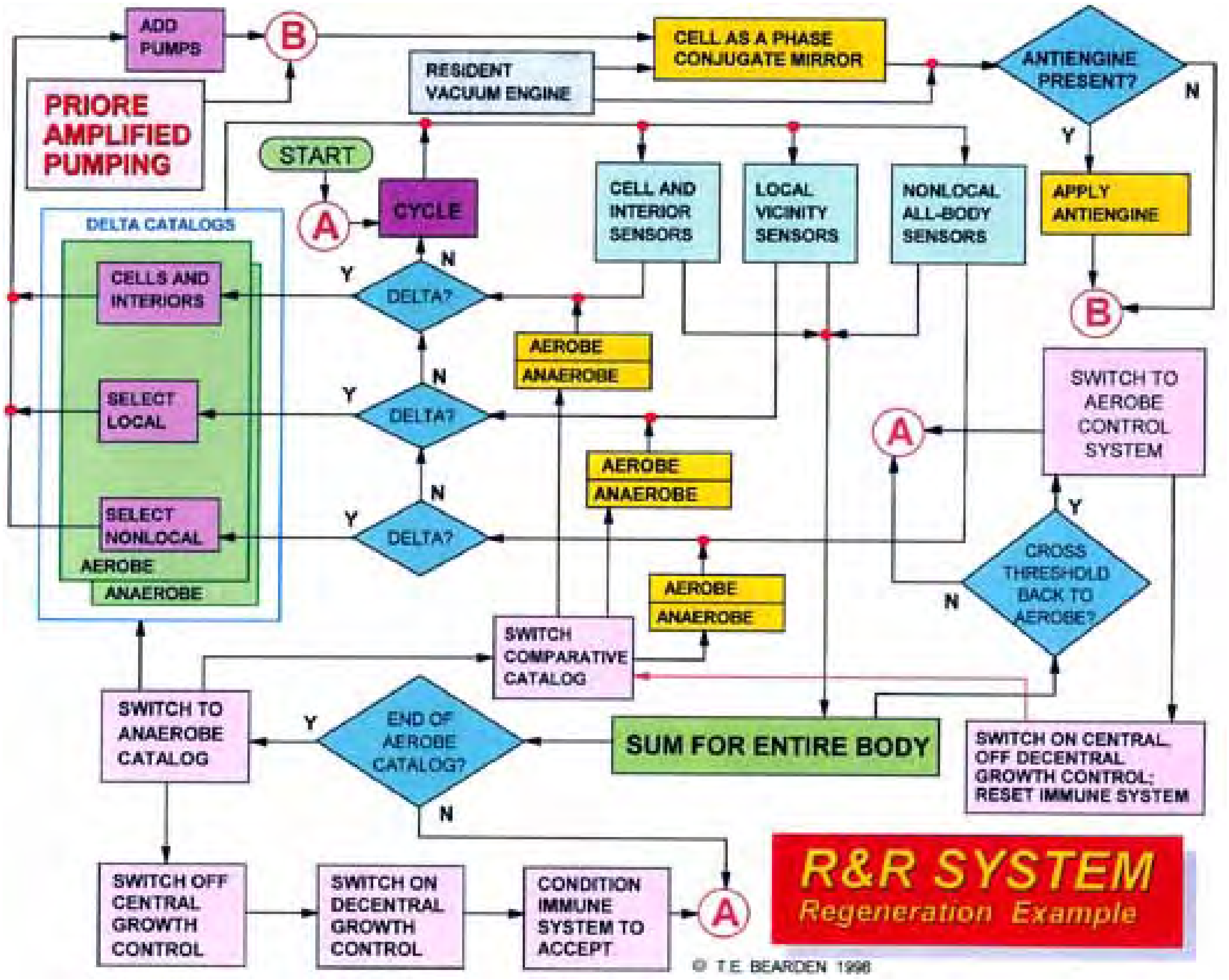
PRIORE AMPLIFIED PUMPING
ADD PUMPS
B
CELL AS A PHASE CONJUGATE MIRROR
RESIDENT VACUUM ENGINE
ANTIENGINE PRESENT?
N
Y
APPLY ANTIENGINE
B
START
A
CYCLE
CELL AND INTERIOR SENSORS
LOCAL VICINITY SENSORS
NONLOCAL ALL-BODY SENSORS
DELTA CATALOGS
CELLS AND INTERIORS
SELECT LOCAL
SELECT NONLOCAL
AEROBE
ANAEROBE
Y
N
DELTA?
Y
N
DELTA?
Y
N
DELTA?
AEROBE
ANAEROBE
AEROBE
ANAEROBE
AEROBE
ANAEROBE
SWITCH TO AEROBE CONTROL SYSTEM
A
Y
CROSS THRESHOLD BACK TO AEROBE?
N
SWITCH COMPARATIVE CATALOG
SWITCH TO ANAEROBE CATALOG
Y
END OF AEROBE CATALOG?
N
SUM FOR ENTIRE BODY
SWITCH ON CENTRAL, OFF DECENTRAL GROWTH CONTROL; RESET IMMUNE SYSTEM
SWITCH OFF CENTRAL GROWTH CONTROL
SWITCH ON DECENTRAL GROWTH CONTROL
CONDITION IMMUNE SYSTEM TO ACCEPT
A
R&R SYSTEM
Regeneration Example

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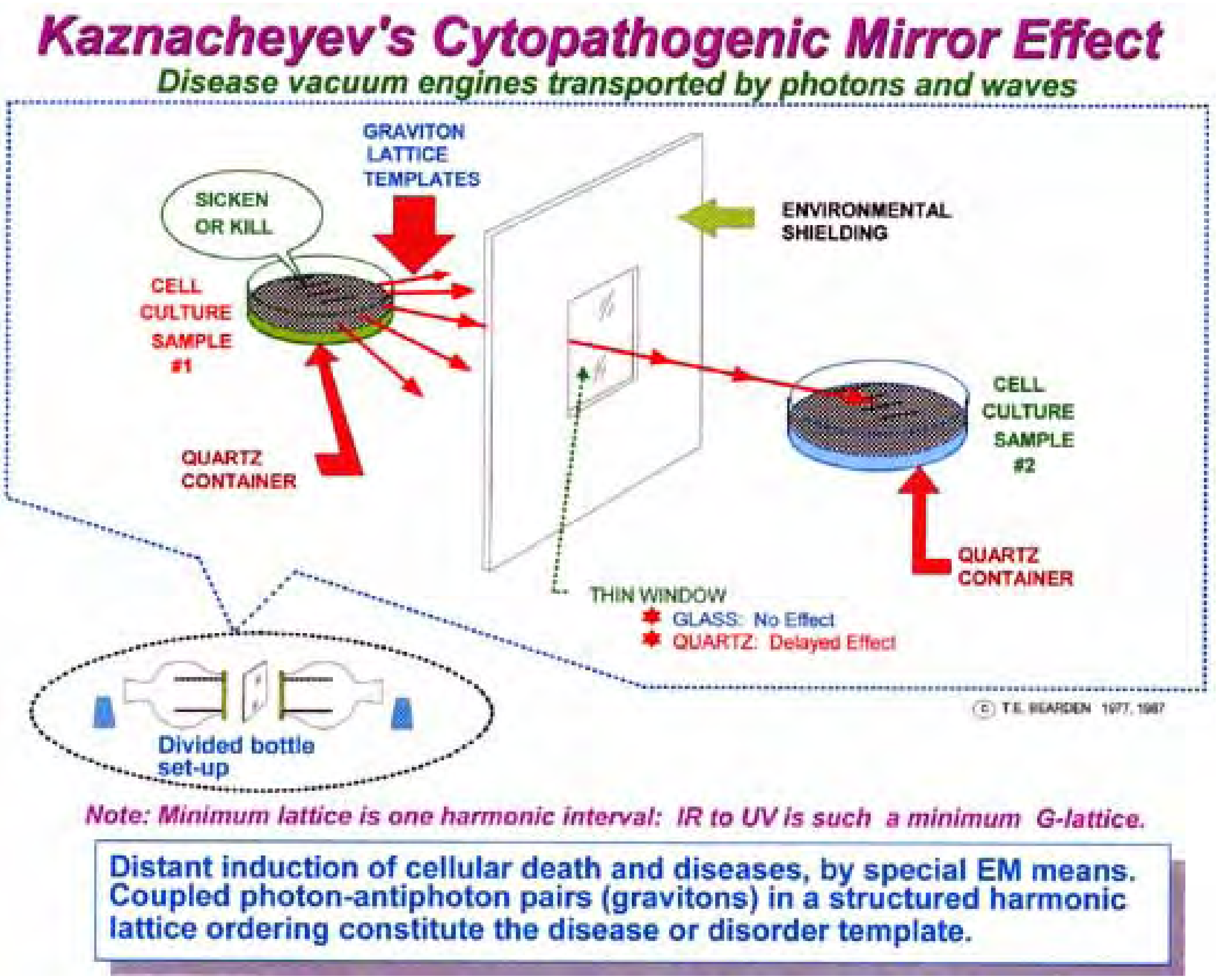

Kaznacheyev's Cytopathogenic Mirror Effect

Disease vacuum engines transported by photons and waves

GRAVITON
LATTICE
TEMPLATES
SICKEN
OR KILL
CELL
CULTURE
SAMPLE
#1
QUARTZ
CONTAINER
ENVIRONMENTAL
SHIELDING
CELL
CULTURE
SAMPLE
#2
QUARTZ
CONTAINER
THIN WINDOW
GLASS: No Effect
QUARTZ: Delayed Effect
Divided bottle
set-up

© T.E. BEARDEN 1977, 1987

Note: Minimum lattice is one harmonic interval: IR to UV is such a minimum G-lattice.

Distant induction of cellular death and diseases, by special EM means. Coupled photon-antiphoton pairs (gravitons) in a structured harmonic lattice ordering constitute the disease or disorder template.

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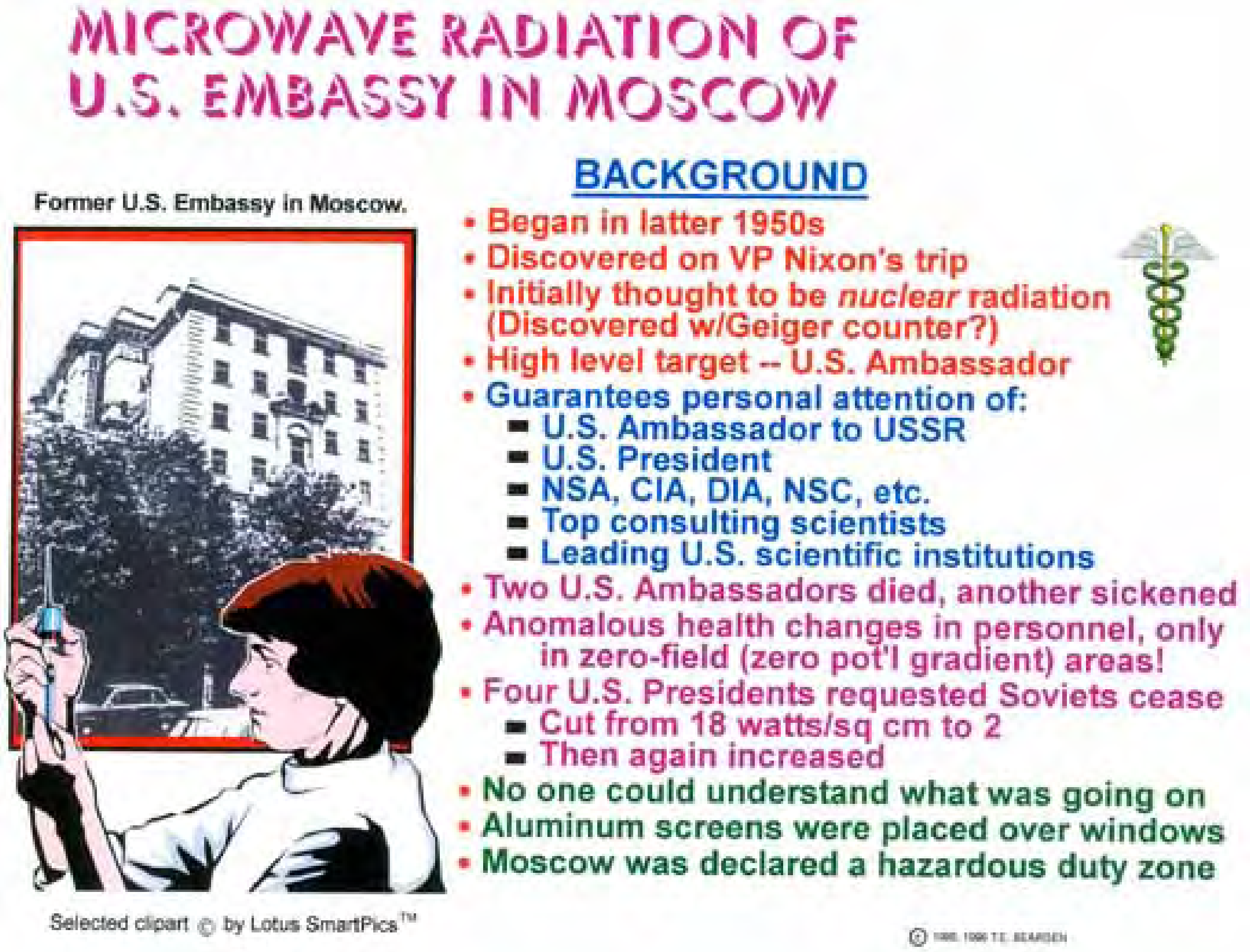

MICROWAVE RADIATION OF U.S. EMBASSY IN MOSCOW

Former U.S. Embassy in Moscow.

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter?)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
    - U.S. Ambassador to USSR
    - U.S. President
    - NSA, CIA, DIA, NSC, etc.
    - Top consulting scientists
    - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero pot'l gradient) areas!
- Four U.S. Presidents requested Soviets cease
    - Cut from 18 watts/sq cm to 2
    - Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

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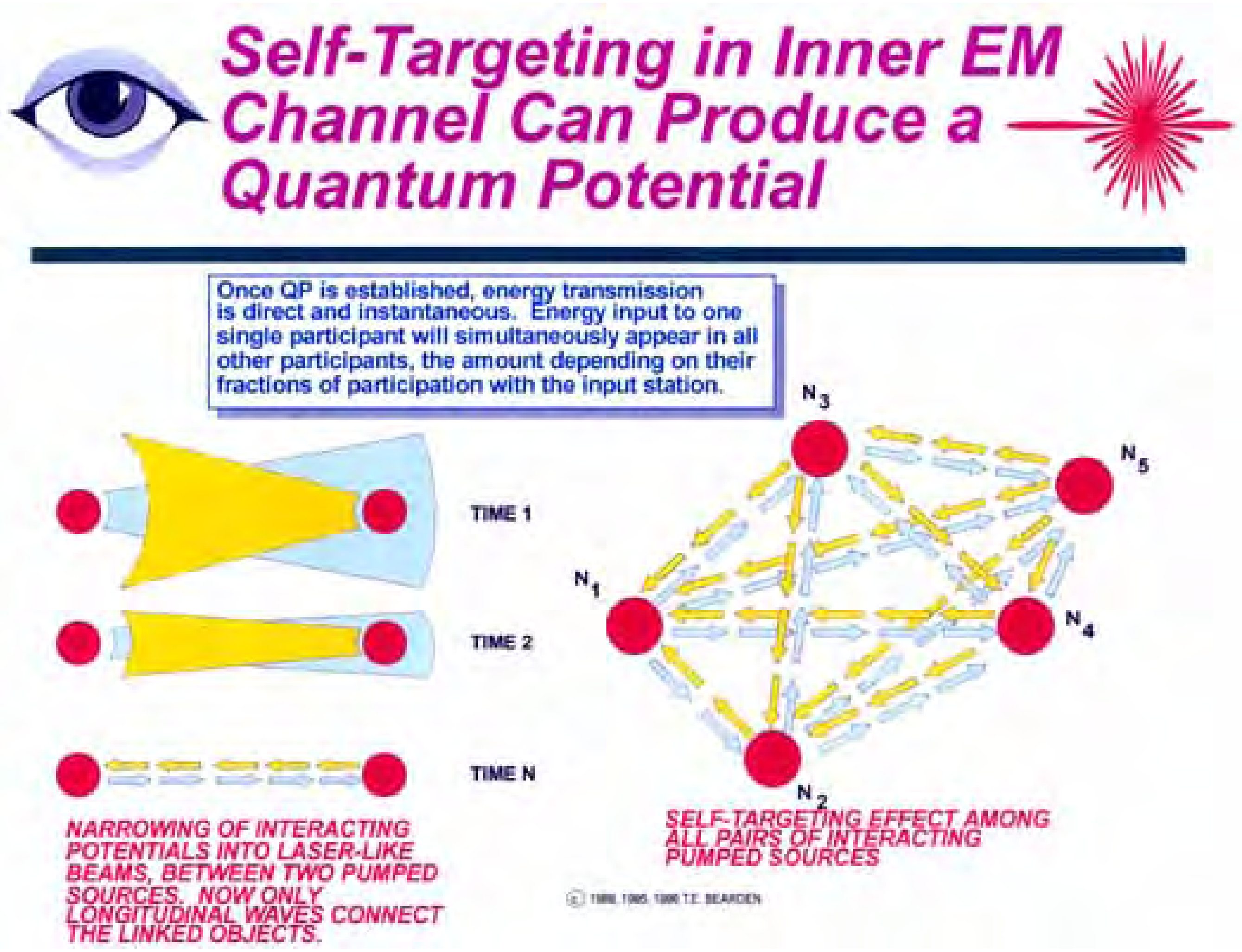

Self-Targeting in Inner EM Channel Can Produce a Quantum Potential

Once QP is established, energy transmission is direct and instantaneous. Energy input to one single participant will simultaneously appear in all other participants, the amount depending on their fractions of participation with the input station.

NARROWING OF INTERACTING POTENTIALS INTO LASER-LIKE BEAMS, BETWEEN TWO PUMPED SOURCES. NOW ONLY LONGITUDINAL WAVES CONNECT THE LINKED OBJECTS.

SELF-TARGETING EFFECT AMONG ALL PAIRS OF INTERACTING PUMPED SOURCES

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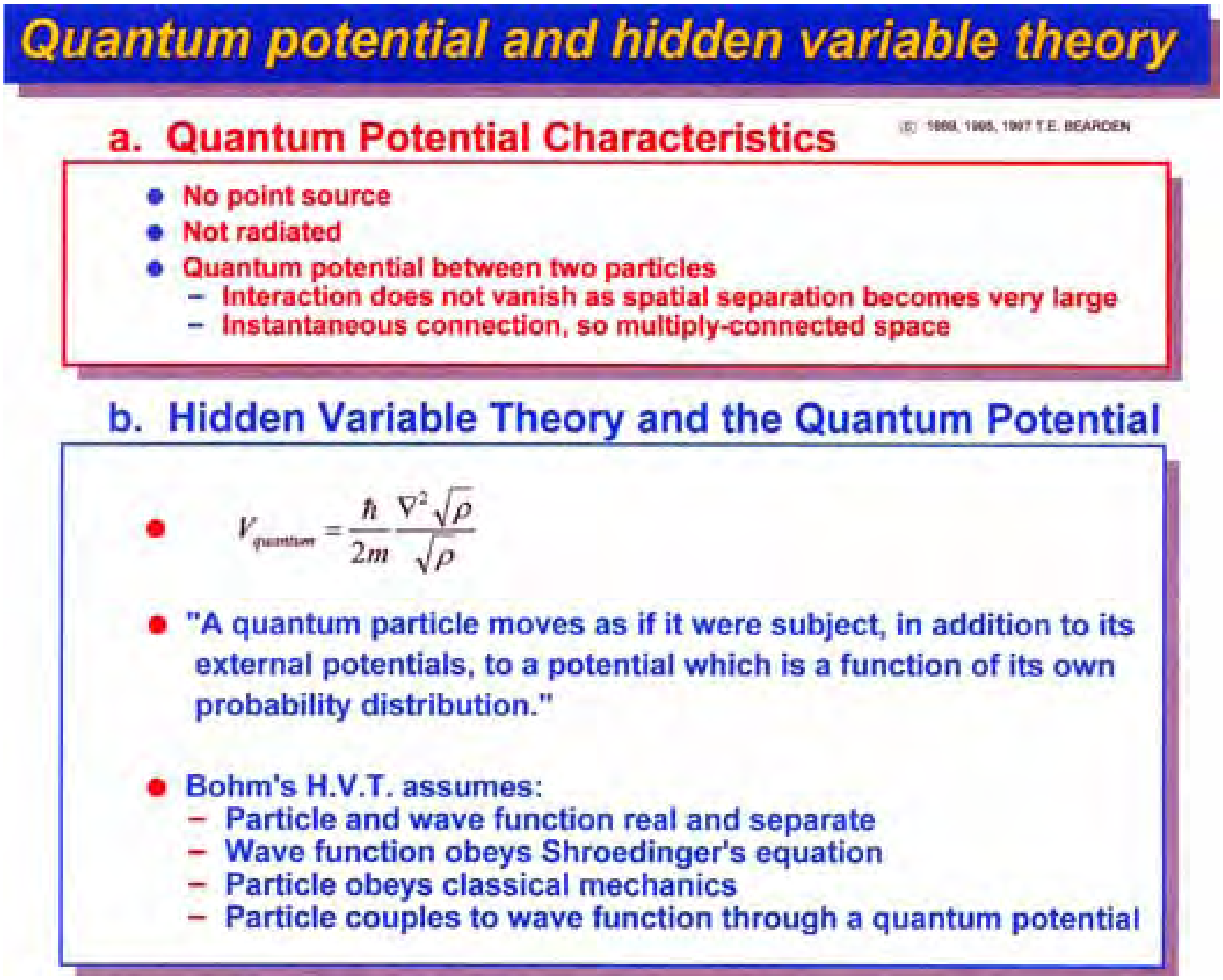

Quantum potential and hidden variable theory

a. Quantum Potential Characteristics

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- No point source
- Not radiated
- Quantum potential between two particles
  - Interaction does not vanish as spatial separation becomes very large
  - Instantaneous connection, so multiply-connected space

b. Hidden Variable Theory and the Quantum Potential

- $$V_{quantum} = \frac{\hbar}{2m} \frac{\nabla^2 \sqrt{\rho}}{\sqrt{\rho}}$$
- "A quantum particle moves as if it were subject, in addition to its external potentials, to a potential which is a function of its own probability distribution."
- Bohm's H.V.T. assumes:
  - Particle and wave function real and separate
  - Wave function obeys Shroedinger's equation
  - Particle obeys classical mechanics
  - Particle couples to wave function through a quantum potential

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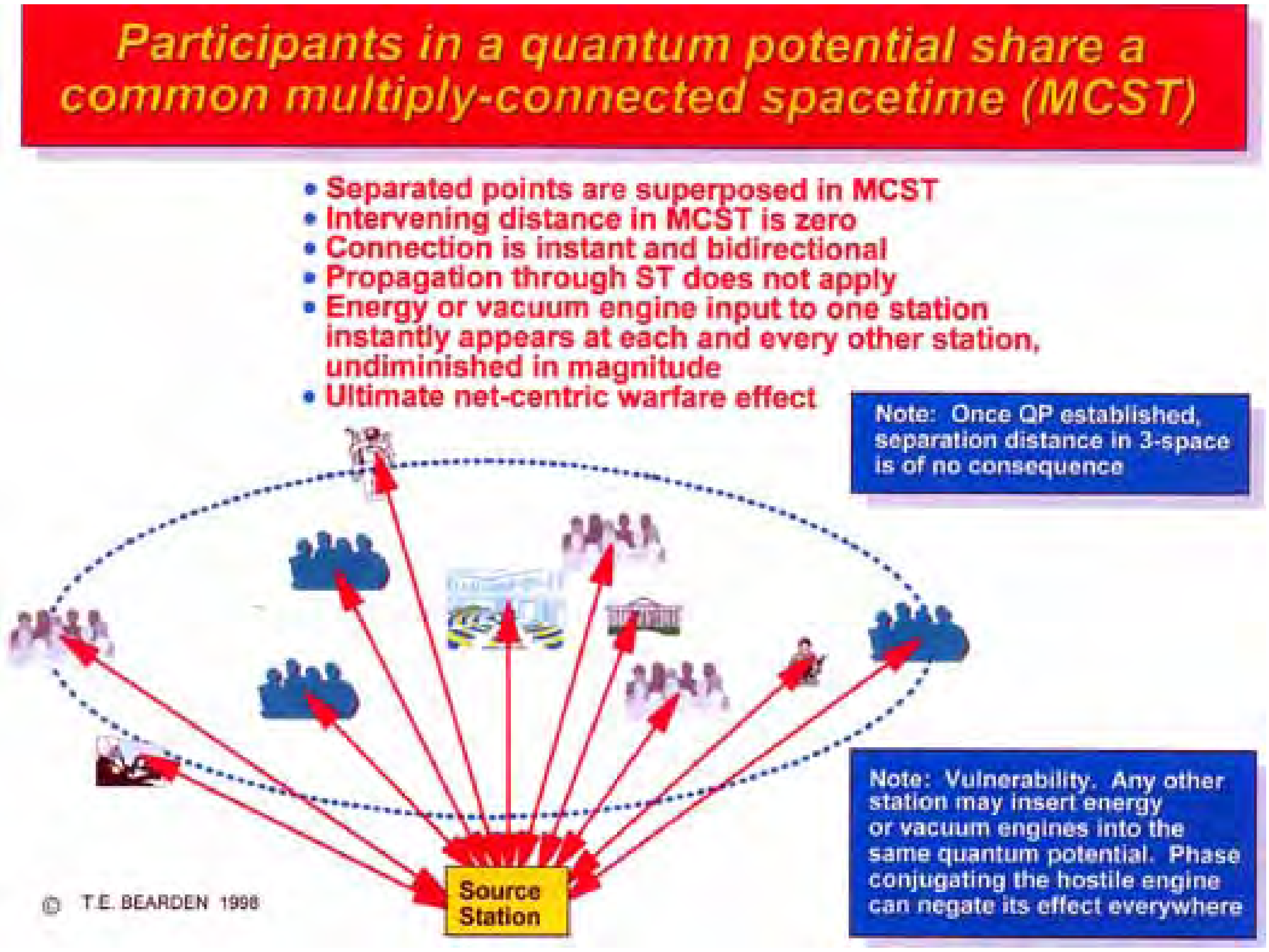

Participants in a quantum potential share a common multiply-connected spacetime (MCST)

- Separated points are superposed in MCST
- Intervening distance in MCST is zero
- Connection is instant and bidirectional
- Propagation through ST does not apply
- Energy or vacuum engine input to one station instantly appears at each and every other station, undiminished in magnitude
- Ultimate net-centric warfare effect

Note: Once QP established, separation distance in 3-space is of no consequence

Note: Vulnerability. Any other station may insert energy or vacuum engines into the same quantum potential. Phase conjugating the hostile engine can negate its effect everywhere

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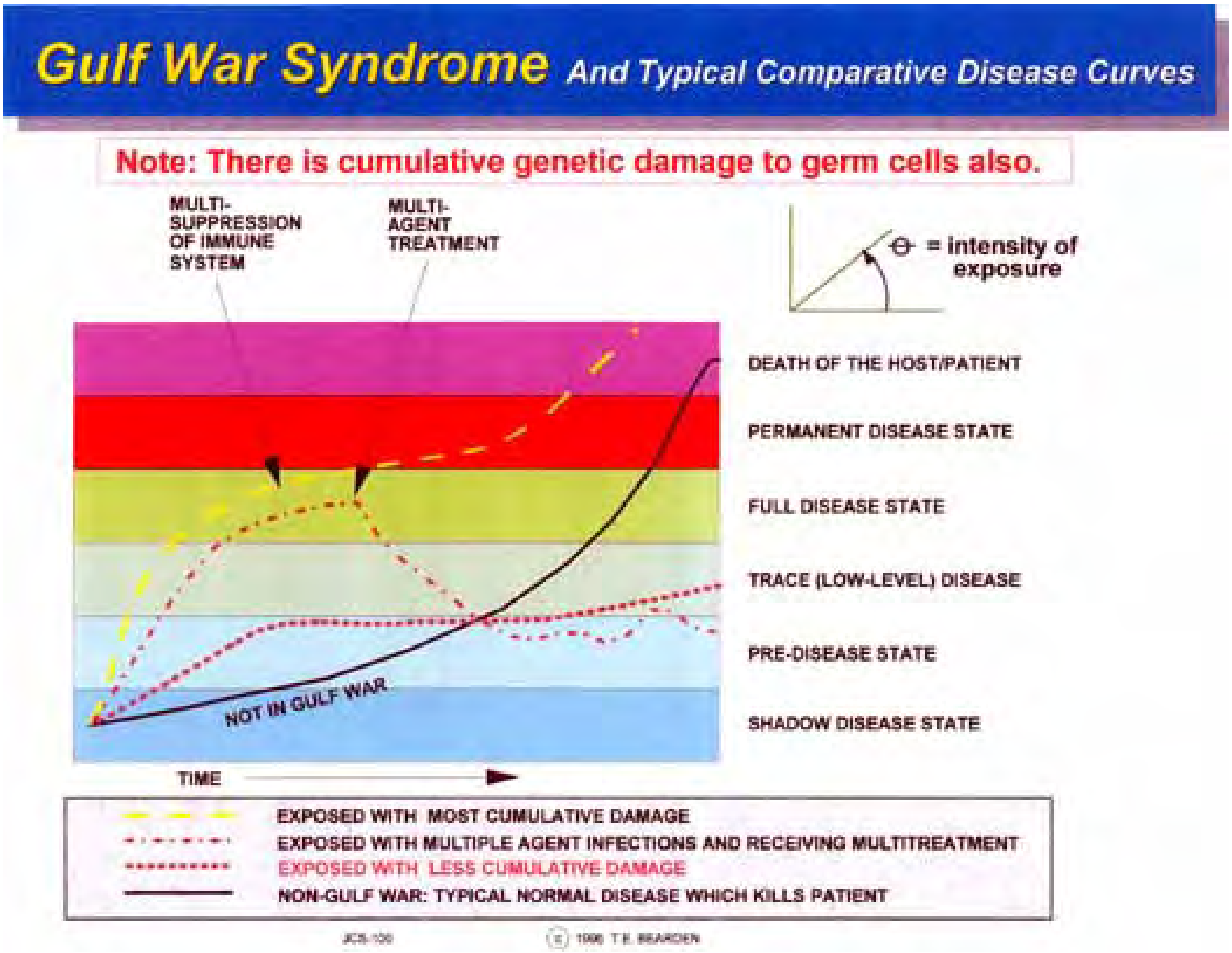

Gulf War Syndrome And Typical Comparative Disease Curves

Note: There is cumulative genetic damage to germ cells also.

- - - EXPOSED WITH MOST CUMULATIVE DAMAGE
-·-·-· EXPOSED WITH MULTIPLE AGENT INFECTIONS AND RECEIVING MULTITREATMENT
******** EXPOSED WITH LESS CUMULATIVE DAMAGE
—— NON-GULF WAR: TYPICAL NORMAL DISEASE WHICH KILLS PATIENT

JCS-100

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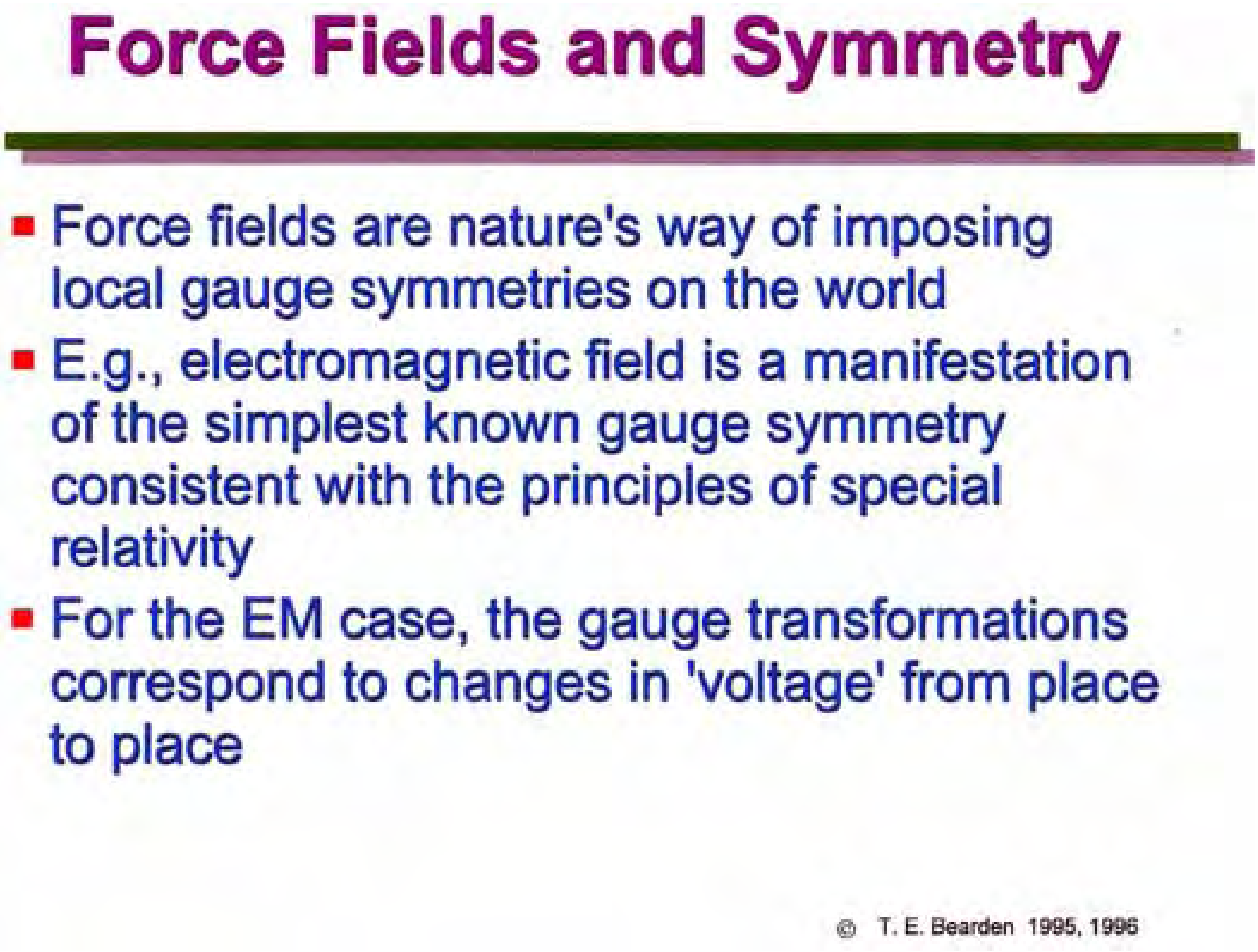

Force Fields and Symmetry

- Force fields are nature's way of imposing local gauge symmetries on the world
- E.g., electromagnetic field is a manifestation of the simplest known gauge symmetry consistent with the principles of special relativity
- For the EM case, the gauge transformations correspond to changes in 'voltage' from place to place

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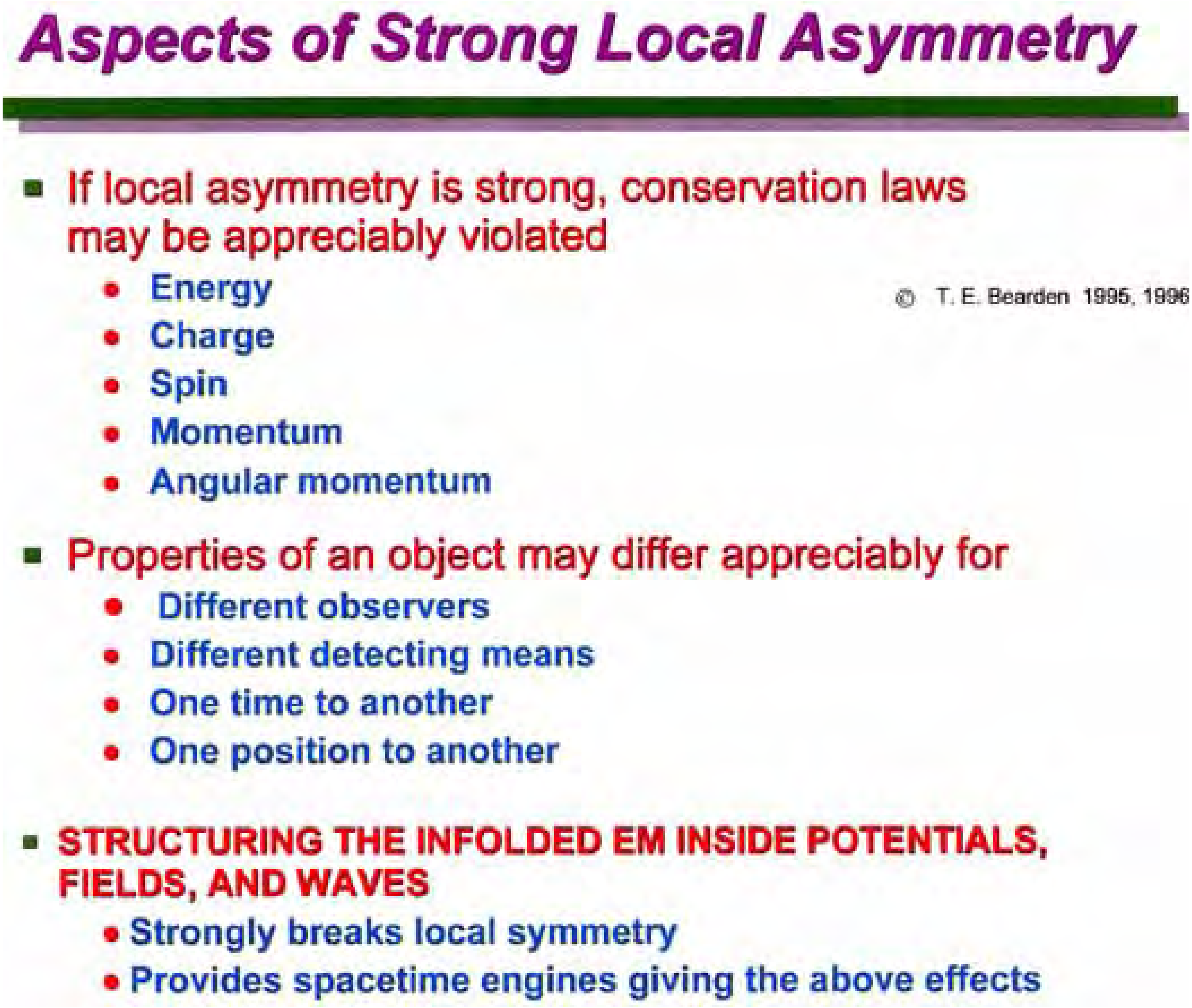

Aspects of Strong Local Asymmetry

- If local asymmetry is strong, conservation laws may be appreciably violated
  - Energy
  - Charge
  - Spin
  - Momentum
  - Angular momentum

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- Properties of an object may differ appreciably for
  - Different observers
  - Different detecting means
  - One time to another
  - One position to another
- STRUCTURING THE INFOLDED EM INSIDE POTENTIALS, FIELDS, AND WAVES
  - Strongly breaks local symmetry
  - Provides spacetime engines giving the above effects

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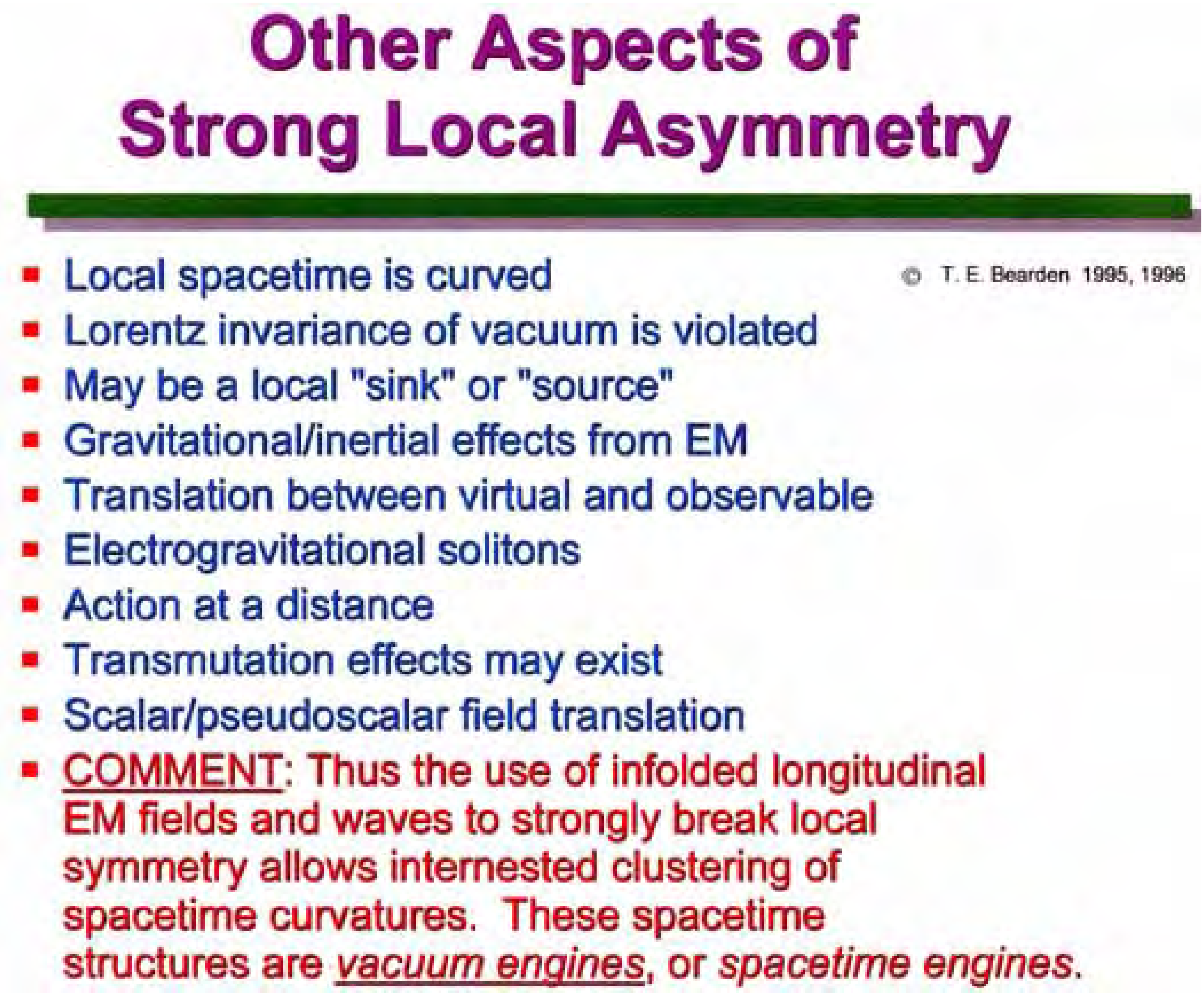

Other Aspects of Strong Local Asymmetry

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- Local spacetime is curved
- Lorentz invariance of vacuum is violated
- May be a local "sink" or "source"
- Gravitational/inertial effects from EM
- Translation between virtual and observable
- Electrogravitational solitons
- Action at a distance
- Transmutation effects may exist
- Scalar/pseudoscalar field translation
- COMMENT: Thus the use of infolded longitudinal EM fields and waves to strongly break local symmetry allows internested clustering of spacetime curvatures. These spacetime structures are *vacuum engines*, or *spacetime engines*.

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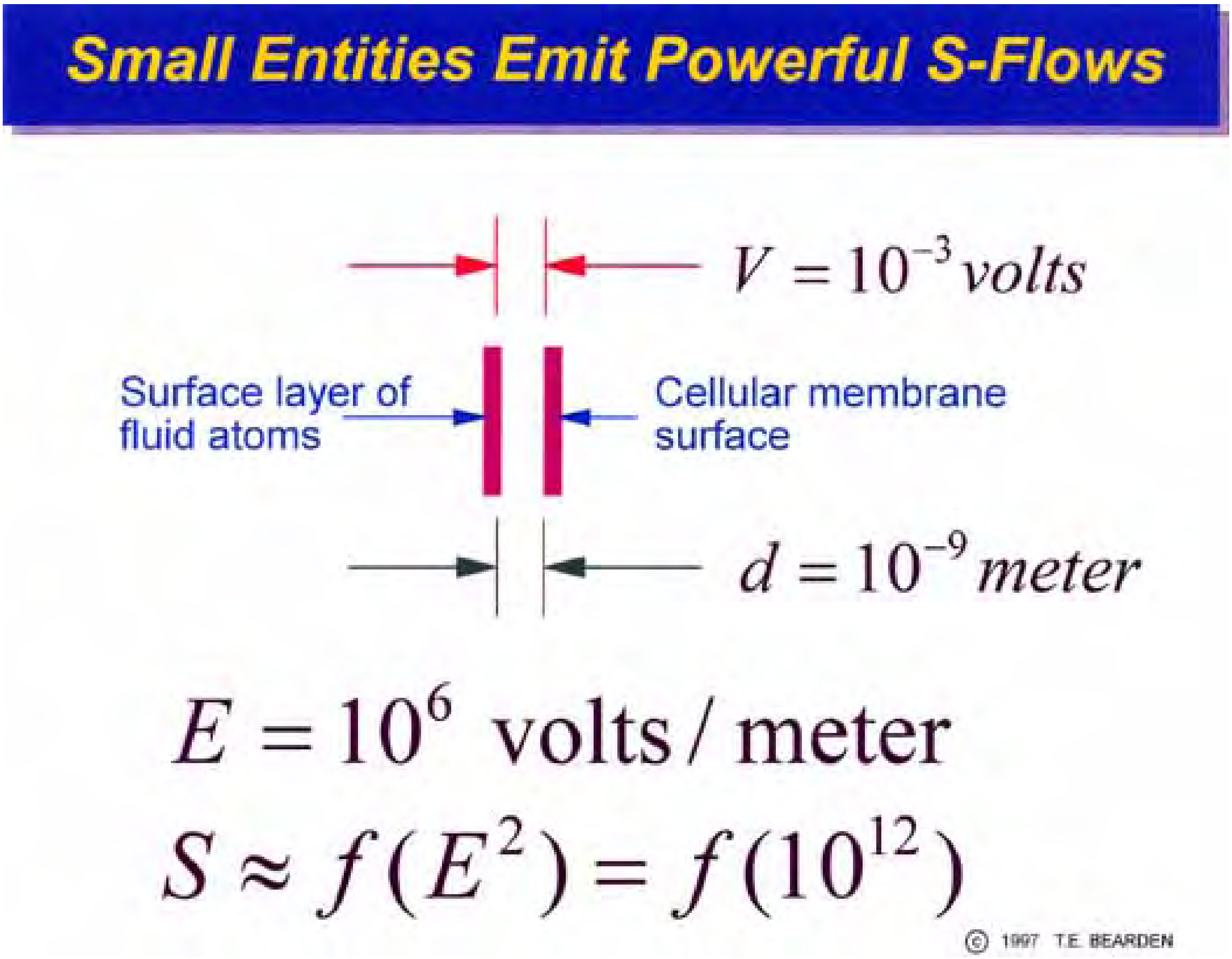

Small Entities Emit Powerful S-Flows

$V = 10^{-3}\, volts$

Surface layer of fluid atoms

Cellular membrane surface

$d = 10^{-9}\, meter$

$$E = 10^{6} \text{ volts / meter}$$

$$S \approx f(E^{2}) = f(10^{12})$$

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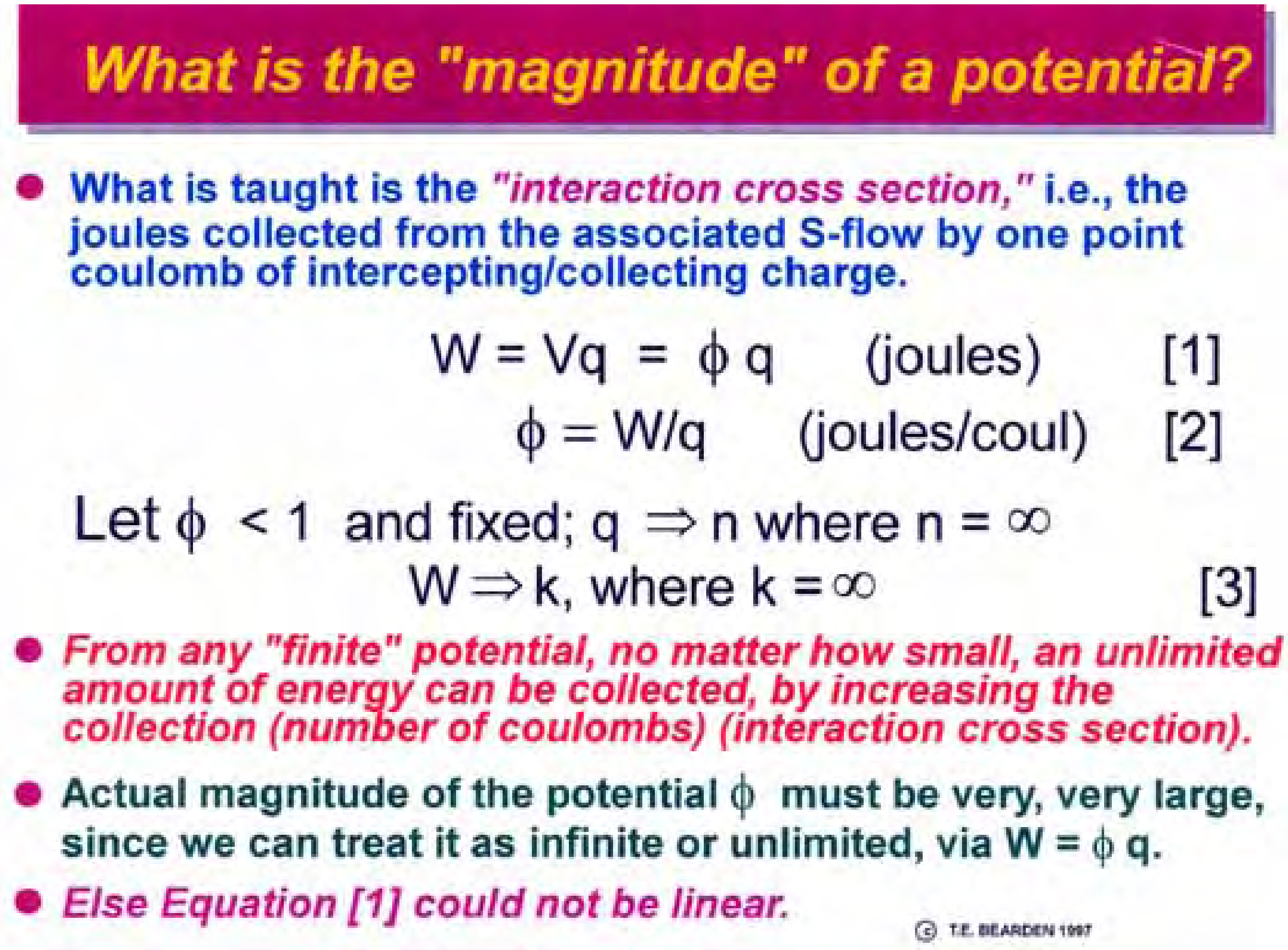

What is the "magnitude" of a potential?

- What is taught is the *"interaction cross section,"* i.e., the joules collected from the associated S-flow by one point coulomb of intercepting/collecting charge.

$$W = Vq = \phi q \qquad \text{(joules)} \qquad [1]$$

$$\phi = W/q \qquad \text{(joules/coul)} \qquad [2]$$

$$\text{Let } \phi < 1 \text{ and fixed; } q \Rightarrow n \text{ where } n = \infty$$

$$W \Rightarrow k, \text{ where } k = \infty \qquad [3]$$

- *From any "finite" potential, no matter how small, an unlimited amount of energy can be collected, by increasing the collection (number of coulombs) (interaction cross section).*
- Actual magnitude of the potential ϕ must be very, very large, since we can treat it as infinite or unlimited, via $W = \phi q$.
- *Else Equation [1] could not be linear.*

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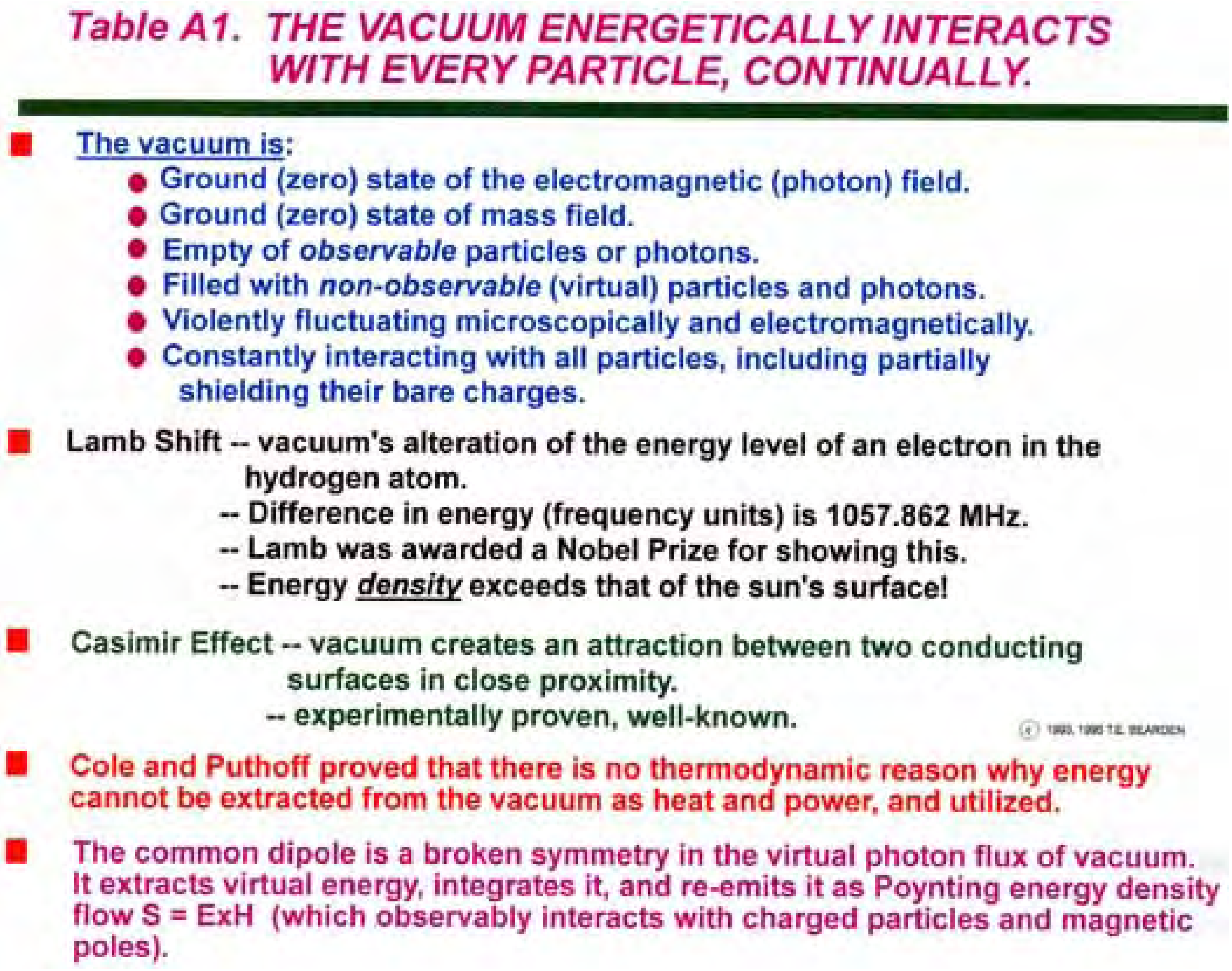

Table A1. THE VACUUM ENERGETICALLY INTERACTS WITH EVERY PARTICLE, CONTINUALLY.

- The vacuum is:
  - Ground (zero) state of the electromagnetic (photon) field.
  - Ground (zero) state of mass field.
  - Empty of *observable* particles or photons.
  - Filled with *non-observable* (virtual) particles and photons.
  - Violently fluctuating microscopically and electromagnetically.
  - Constantly interacting with all particles, including partially shielding their bare charges.
- Lamb Shift -- vacuum's alteration of the energy level of an electron in the hydrogen atom.
  - -- Difference in energy (frequency units) is 1057.862 MHz.
  - -- Lamb was awarded a Nobel Prize for showing this.
  - -- Energy ***density*** exceeds that of the sun's surface!
- Casimir Effect -- vacuum creates an attraction between two conducting surfaces in close proximity.
  - -- experimentally proven, well-known.

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- Cole and Puthoff proved that there is no thermodynamic reason why energy cannot be extracted from the vacuum as heat and power, and utilized.
- The common dipole is a broken symmetry in the virtual photon flux of vacuum. It extracts virtual energy, integrates it, and re-emits it as Poynting energy density flow S = ExH (which observably interacts with charged particles and magnetic poles).

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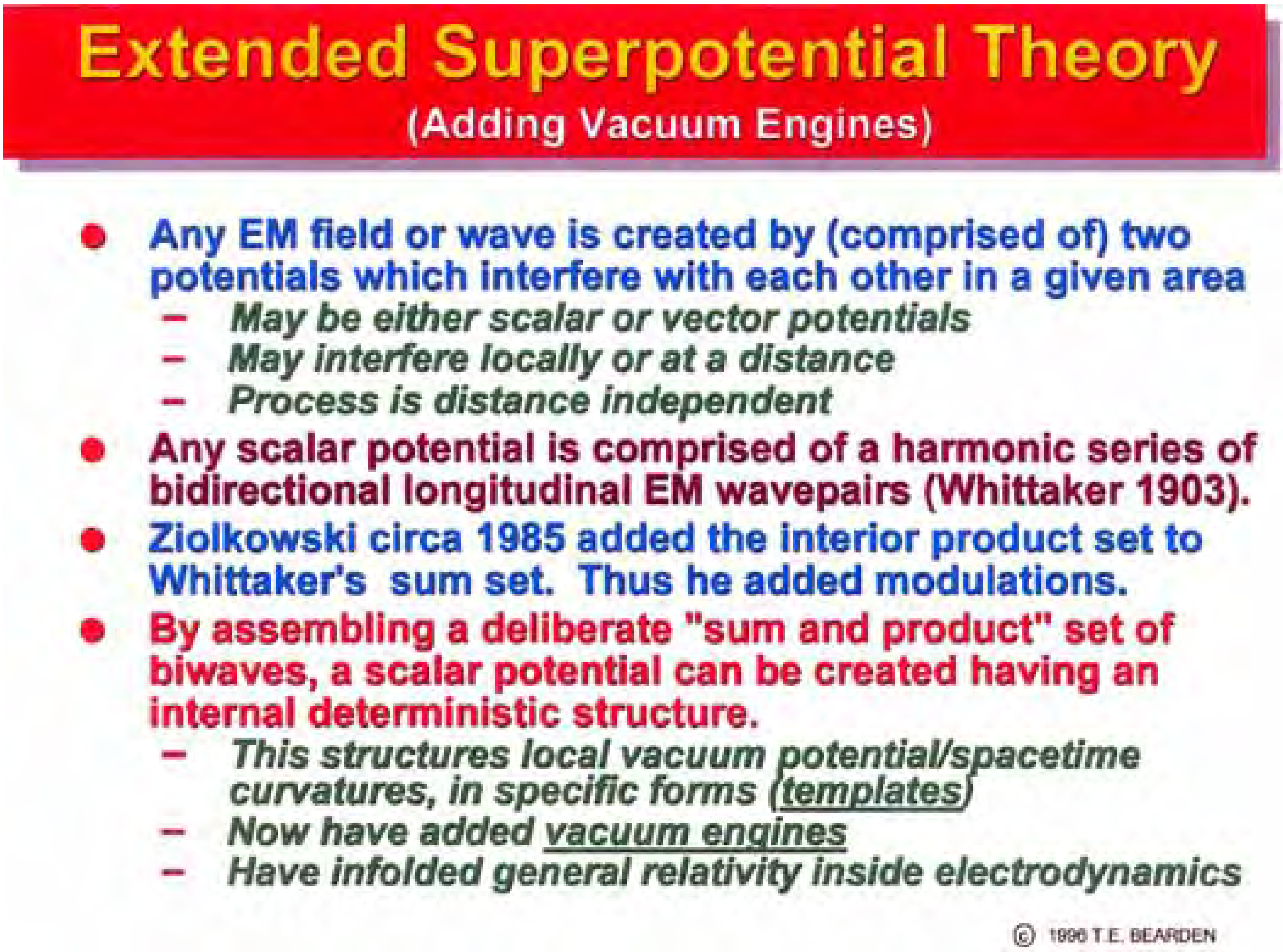

Extended Superpotential Theory

(Adding Vacuum Engines)

- Any EM field or wave is created by (comprised of) two potentials which interfere with each other in a given area
  - *May be either scalar or vector potentials*
  - *May interfere locally or at a distance*
  - *Process is distance independent*
- Any scalar potential is comprised of a harmonic series of bidirectional longitudinal EM wavepairs (Whittaker 1903).
- Ziolkowski circa 1985 added the interior product set to Whittaker's sum set. Thus he added modulations.
- By assembling a deliberate "sum and product" set of biwaves, a scalar potential can be created having an internal deterministic structure.
  - *This structures local vacuum potential/spacetime curvatures, in specific forms (templates)*
  - *Now have added vacuum engines*
  - *Have infolded general relativity inside electrodynamics*

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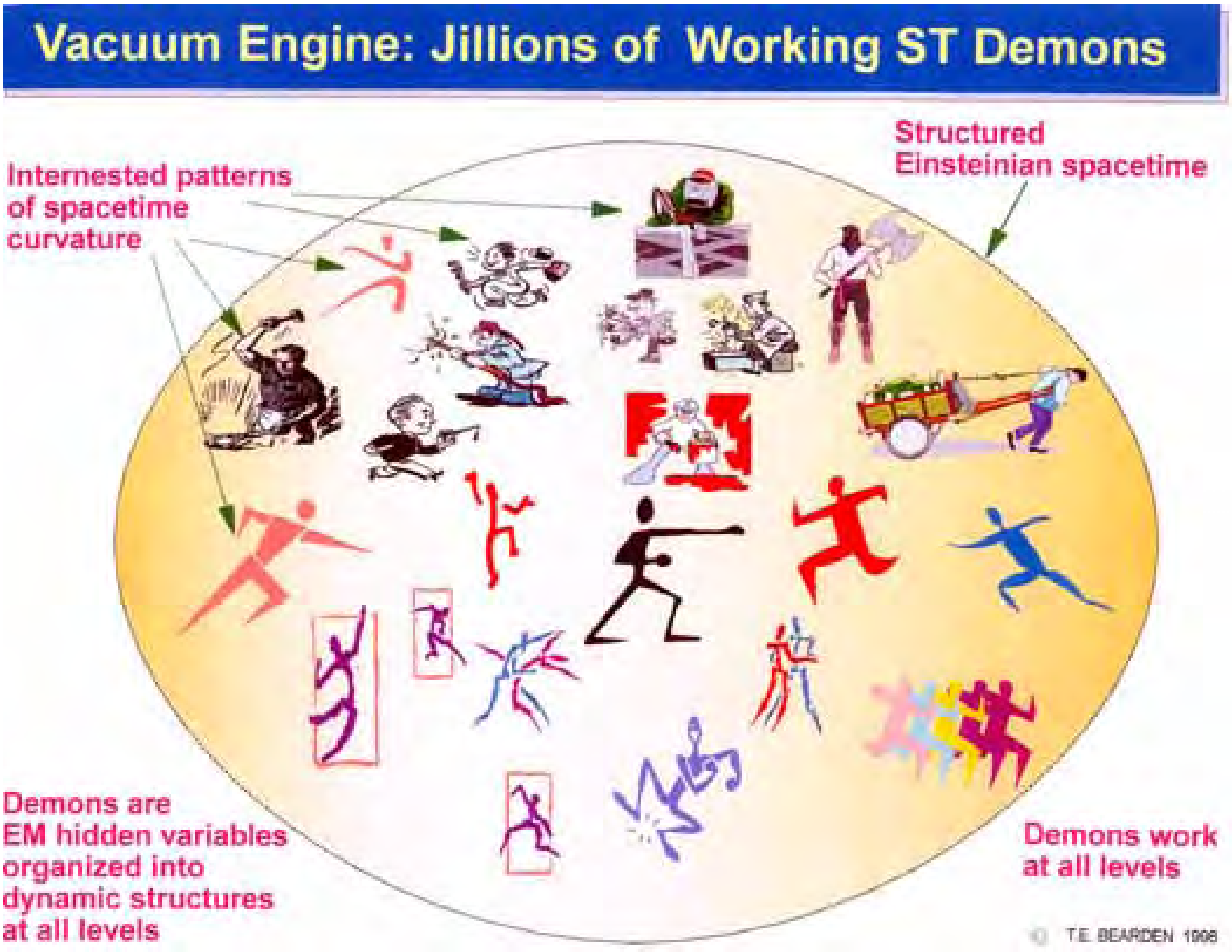

Vacuum Engine: Jillions of Working ST Demons

Internested patterns of spacetime curvature

Structured Einsteinian spacetime

Demons are EM hidden variables organized into dynamic structures at all levels

Demons work at all levels

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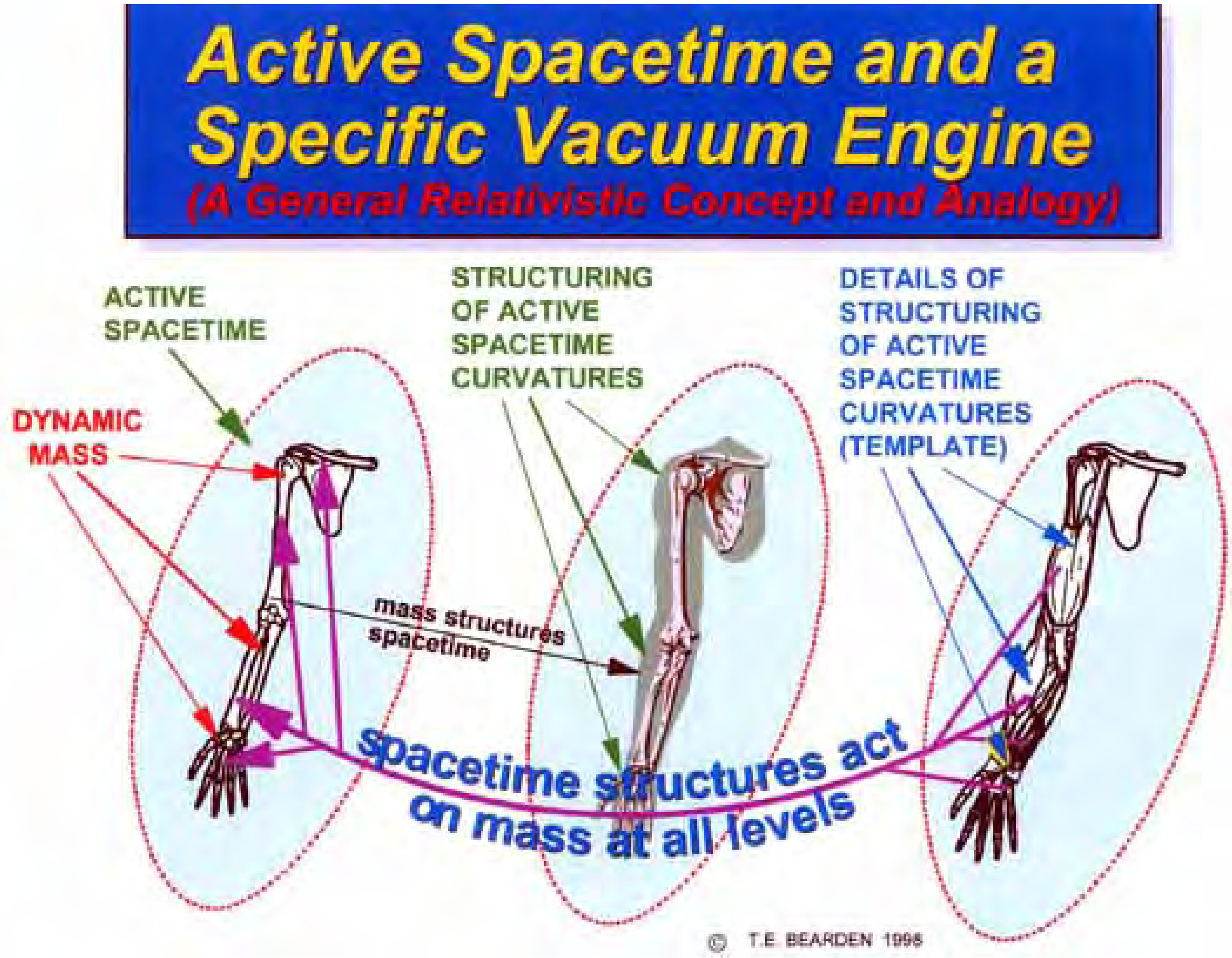

Active Spacetime and a Specific Vacuum Engine

(A General Relativistic Concept and Analogy)

ACTIVE SPACETIME

DYNAMIC MASS

STRUCTURING OF ACTIVE SPACETIME CURVATURES

DETAILS OF STRUCTURING OF ACTIVE SPACETIME CURVATURES (TEMPLATE)

mass structures spacetime

spacetime structures act on mass at all levels

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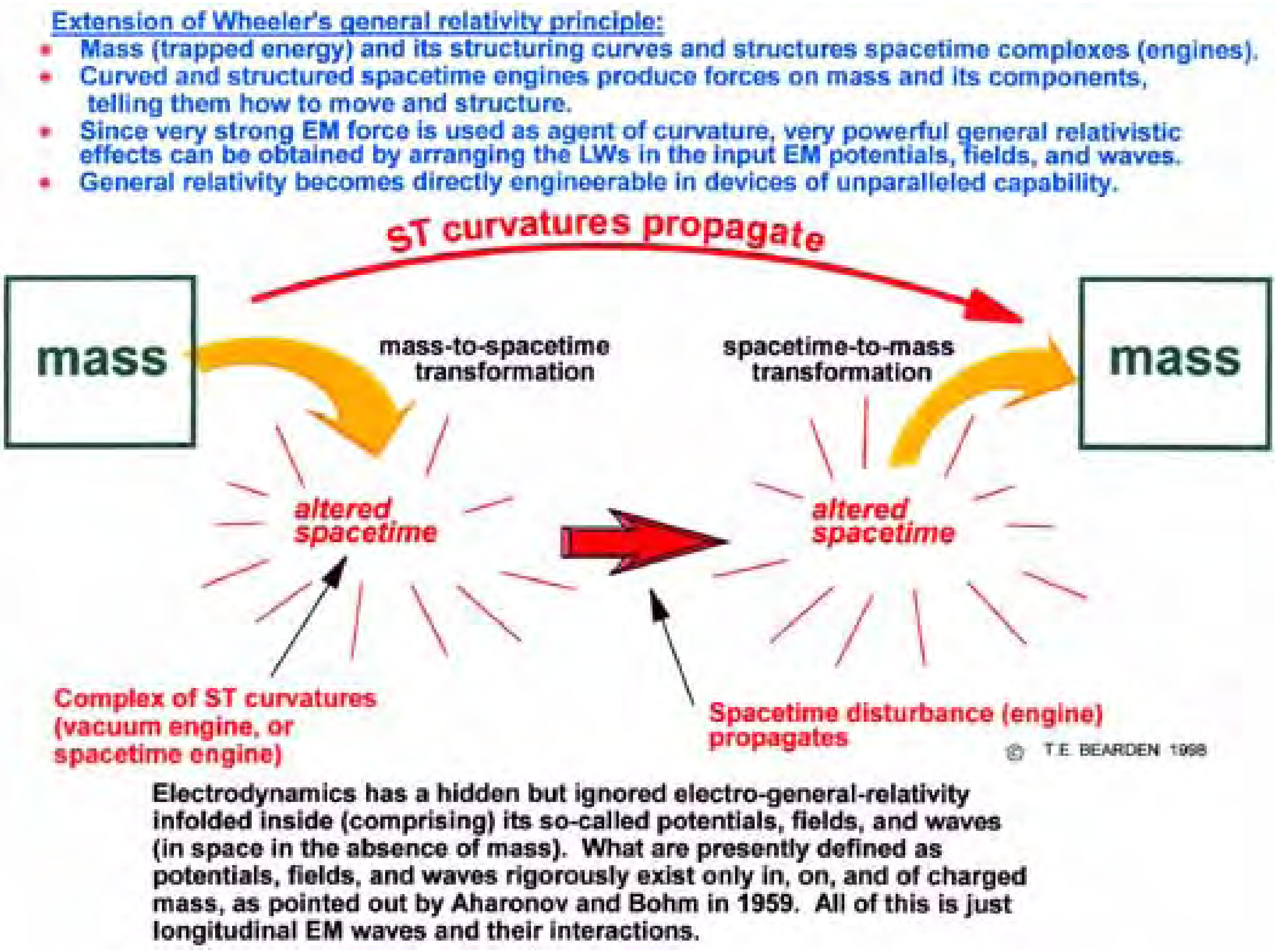

Extension of Wheeler's general relativity principle:

- Mass (trapped energy) and its structuring curves and structures spacetime complexes (engines).
- Curved and structured spacetime engines produce forces on mass and its components, telling them how to move and structure.
- Since very strong EM force is used as agent of curvature, very powerful general relativistic effects can be obtained by arranging the LWs in the input EM potentials, fields, and waves.
- General relativity becomes directly engineerable in devices of unparalleled capability.

ST curvatures propagate

mass

mass-to-spacetime transformation

spacetime-to-mass transformation

mass

altered spacetime

altered spacetime

Complex of ST curvatures (vacuum engine, or spacetime engine)

Spacetime disturbance (engine) propagates

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Electrodynamics has a hidden but ignored electro-general-relativity infolded inside (comprising) its so-called potentials, fields, and waves (in space in the absence of mass). What are presently defined as potentials, fields, and waves rigorously exist only in, on, and of charged mass, as pointed out by Aharonov and Bohm in 1959. All of this is just longitudinal EM waves and their interactions.

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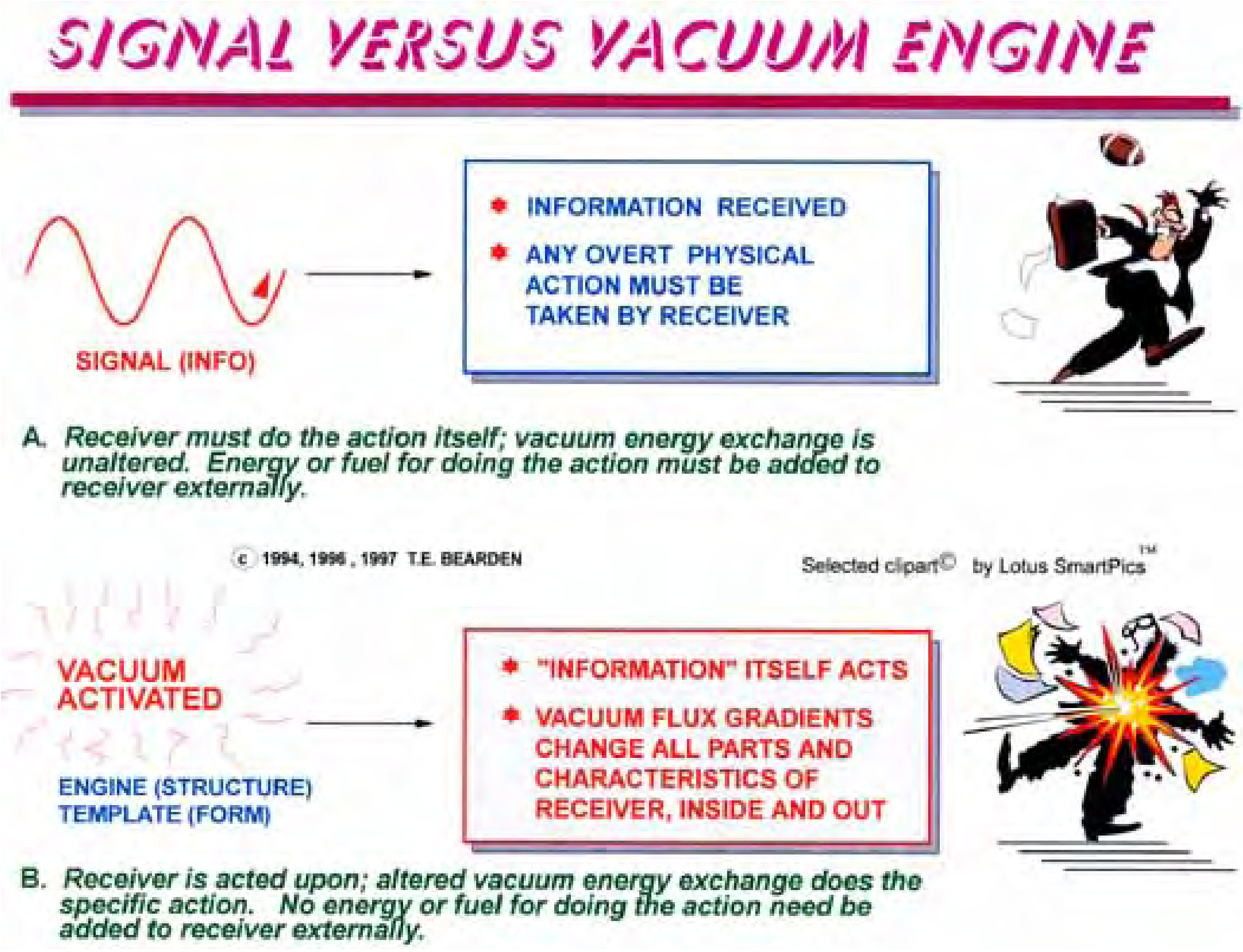

SIGNAL VERSUS VACUUM ENGINE

SIGNAL (INFO)

- INFORMATION RECEIVED
- ANY OVERT PHYSICAL ACTION MUST BE TAKEN BY RECEIVER

A. *Receiver must do the action itself; vacuum energy exchange is unaltered. Energy or fuel for doing the action must be added to receiver externally.*

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Selected clipart© by Lotus SmartPics™

VACUUM ACTIVATED

ENGINE (STRUCTURE) TEMPLATE (FORM)

- "INFORMATION" ITSELF ACTS
- VACUUM FLUX GRADIENTS CHANGE ALL PARTS AND CHARACTERISTICS OF RECEIVER, INSIDE AND OUT

B. *Receiver is acted upon; altered vacuum energy exchange does the specific action. No energy or fuel for doing the action need be added to receiver externally.*

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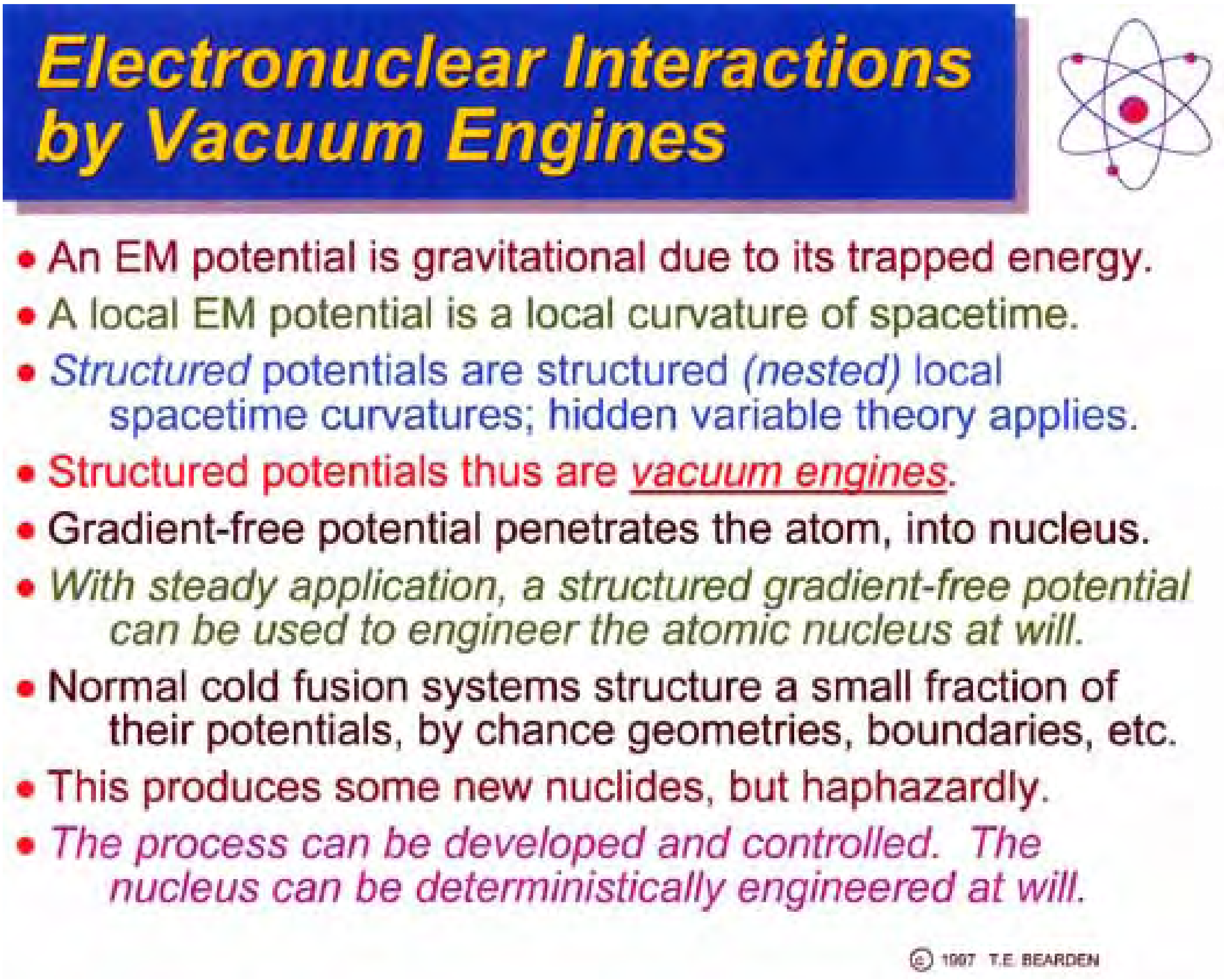

Electronuclear Interactions by Vacuum Engines

- An EM potential is gravitational due to its trapped energy.
- A local EM potential is a local curvature of spacetime.
- *Structured* potentials are structured *(nested)* local spacetime curvatures; hidden variable theory applies.
- Structured potentials thus are *vacuum engines*.
- Gradient-free potential penetrates the atom, into nucleus.
- *With steady application, a structured gradient-free potential can be used to engineer the atomic nucleus at will.*
- Normal cold fusion systems structure a small fraction of their potentials, by chance geometries, boundaries, etc.
- This produces some new nuclides, but haphazardly.
- *The process can be developed and controlled. The nucleus can be deterministically engineered at will.*

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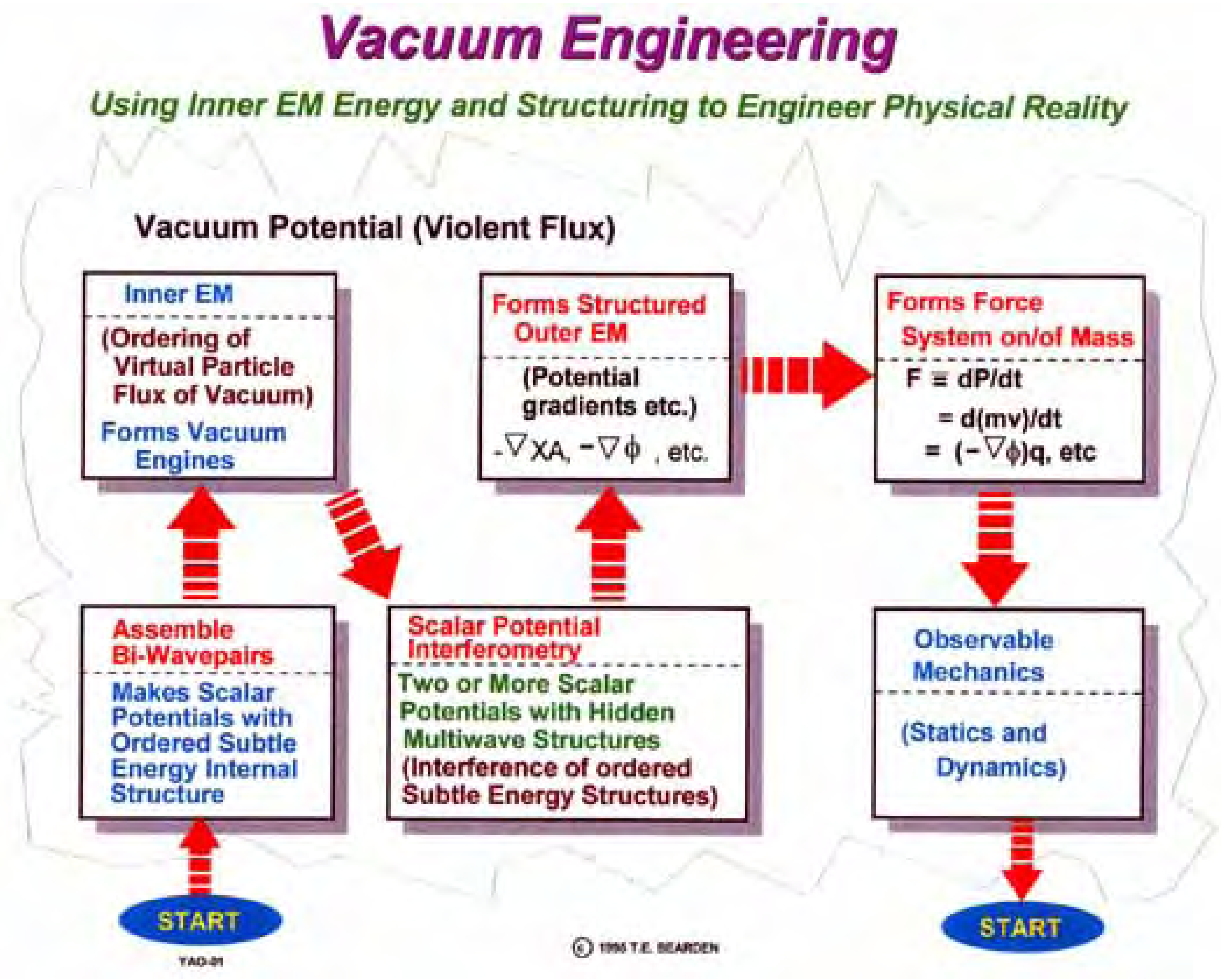

Vacuum Engineering

Using Inner EM Energy and Structuring to Engineer Physical Reality

Vacuum Potential (Violent Flux)

Inner EM

(Ordering of Virtual Particle Flux of Vacuum)

Forms Vacuum Engines

Forms Structured Outer EM

(Potential gradients etc.)

$-\nabla \times A$, $-\nabla \phi$, etc.

Forms Force System on/of Mass

$F \equiv dP/dt$

$= d(mv)/dt$

$\equiv (-\nabla \phi)q$, etc

Assemble Bi-Wavepairs

Makes Scalar Potentials with Ordered Subtle Energy Internal Structure

Scalar Potential Interferometry

Two or More Scalar Potentials with Hidden Multiwave Structures (Interference of ordered Subtle Energy Structures)

Observable Mechanics

(Statics and Dynamics)

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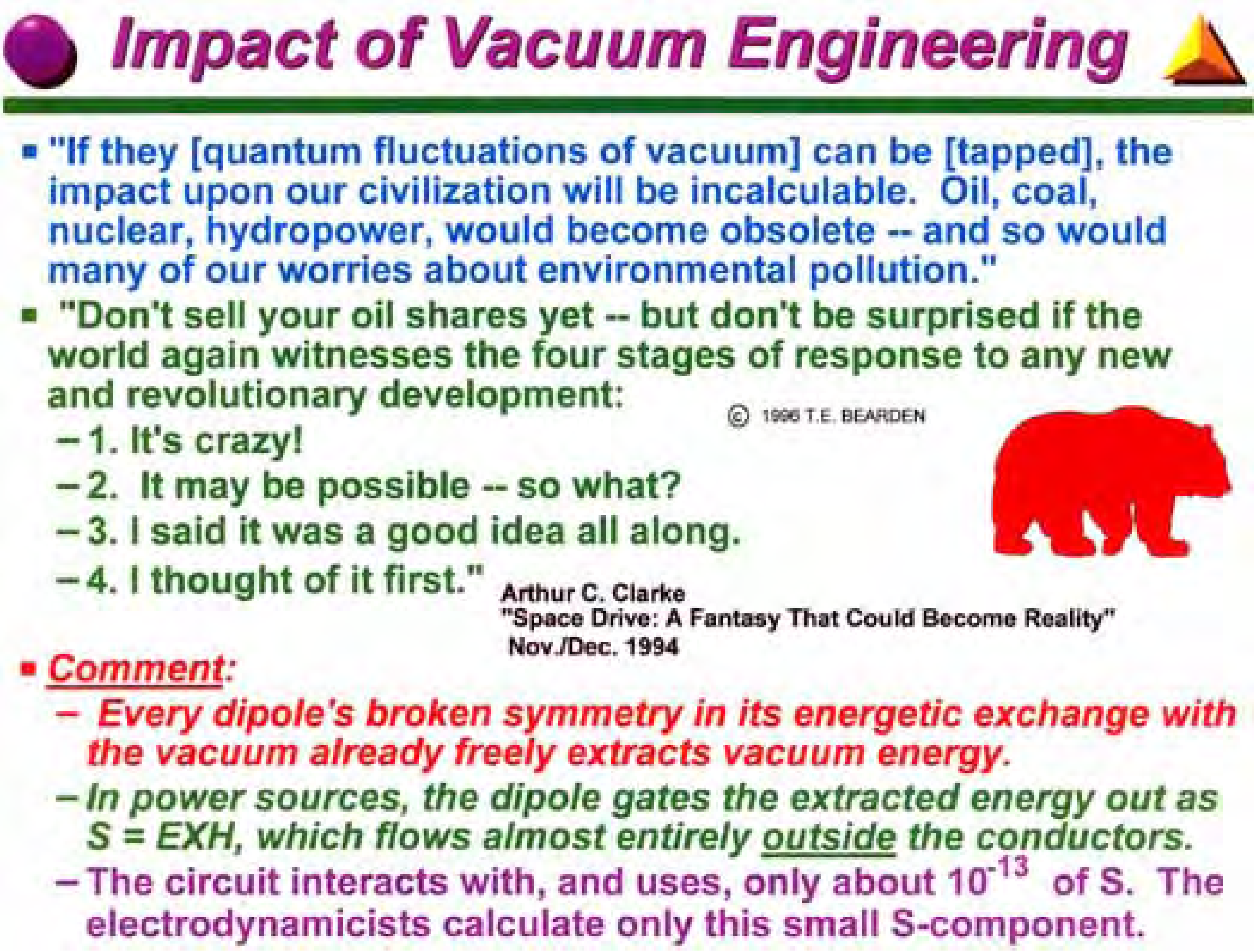

Impact of Vacuum Engineering

- "If they [quantum fluctuations of vacuum] can be [tapped], the impact upon our civilization will be incalculable. Oil, coal, nuclear, hydropower, would become obsolete -- and so would many of our worries about environmental pollution."
- "Don't sell your oil shares yet -- but don't be surprised if the world again witnesses the four stages of response to any new and revolutionary development:
  - 1. It's crazy!
  - 2. It may be possible -- so what?
  - 3. I said it was a good idea all along.
  - 4. I thought of it first."

Arthur C. Clarke
"Space Drive: A Fantasy That Could Become Reality"
Nov./Dec. 1994

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- *Comment:*
  - *Every dipole's broken symmetry in its energetic exchange with the vacuum already freely extracts vacuum energy.*
  - *In power sources, the dipole gates the extracted energy out as S = EXH, which flows almost entirely outside the conductors.*
  - The circuit interacts with, and uses, only about 10^{-13} of S. The electrodynamicists calculate only this small S-component.

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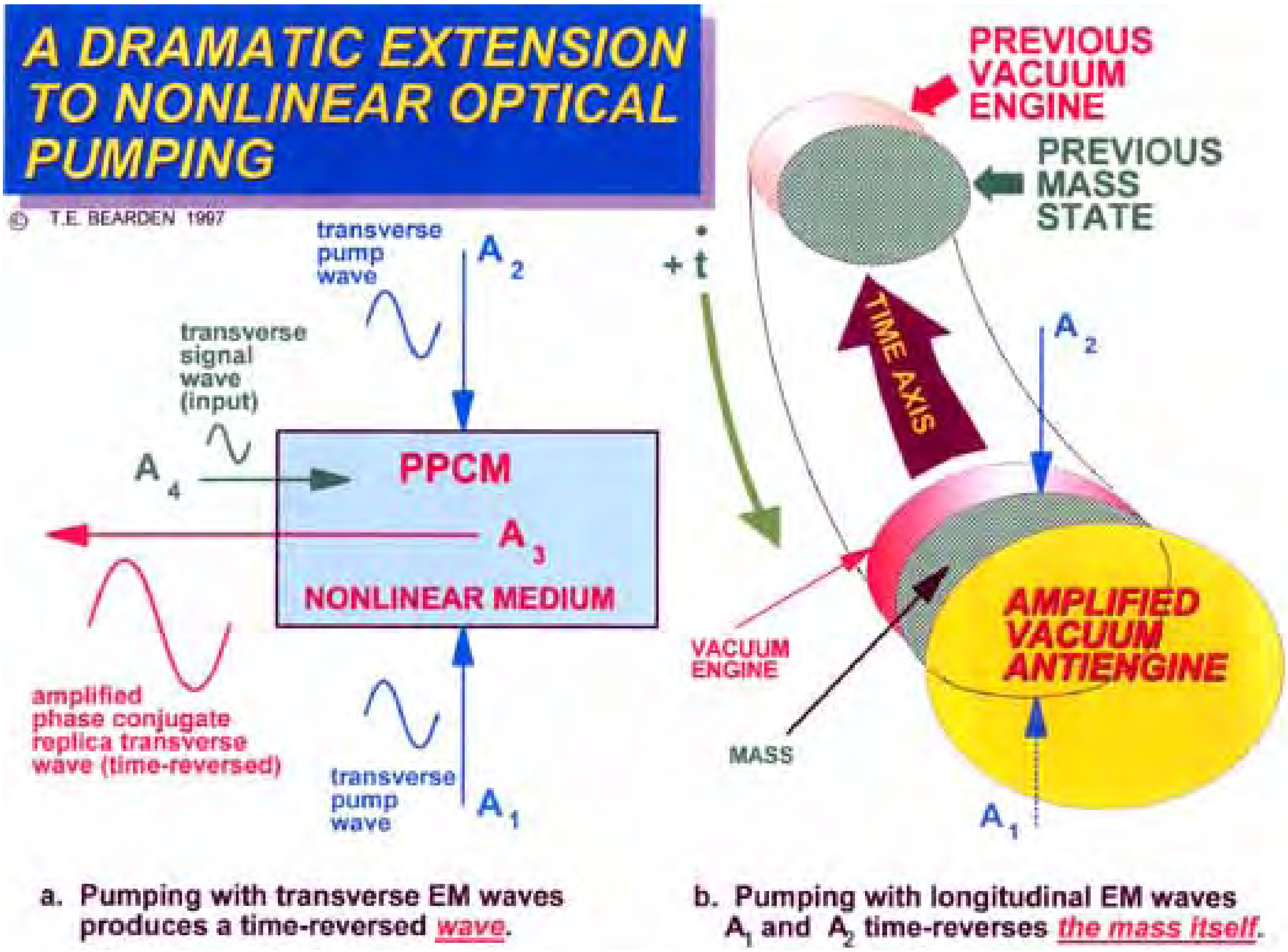

A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

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transverse pump wave
A_2
transverse signal wave (input)
A_4
PPCM
A_3
NONLINEAR MEDIUM
amplified phase conjugate replica transverse wave (time-reversed)
transverse pump wave
A_1
+ t
TIME AXIS
PREVIOUS VACUUM ENGINE
PREVIOUS MASS STATE
A_2
VACUUM ENGINE
AMPLIFIED VACUUM ANTIENGINE
MASS
A_1

a. Pumping with transverse EM waves produces a time-reversed *wave*.

b. Pumping with longitudinal EM waves A_1 and A_2 time-reverses *the mass itself*.

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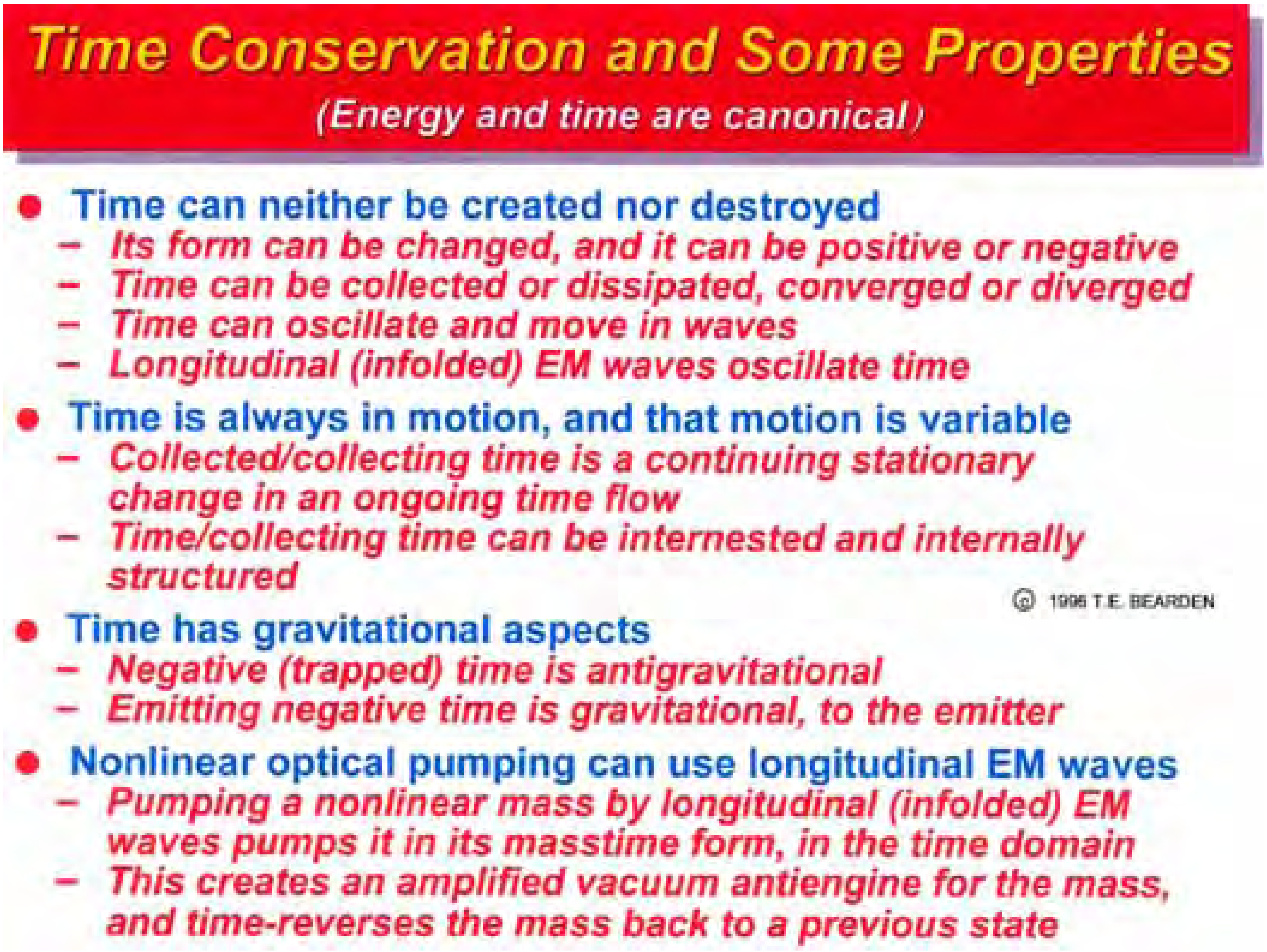

Time Conservation and Some Properties

(Energy and time are canonical)

- Time can neither be created nor destroyed
  - *Its form can be changed, and it can be positive or negative*
  - *Time can be collected or dissipated, converged or diverged*
  - *Time can oscillate and move in waves*
  - *Longitudinal (infolded) EM waves oscillate time*
- Time is always in motion, and that motion is variable
  - *Collected/collecting time is a continuing stationary change in an ongoing time flow*
  - *Time/collecting time can be internested and internally structured*

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- Time has gravitational aspects
  - *Negative (trapped) time is antigravitational*
  - *Emitting negative time is gravitational, to the emitter*
- Nonlinear optical pumping can use longitudinal EM waves
  - *Pumping a nonlinear mass by longitudinal (infolded) EM waves pumps it in its masstime form, in the time domain*
  - *This creates an amplified vacuum antiengine for the mass, and time-reverses the mass back to a previous state*

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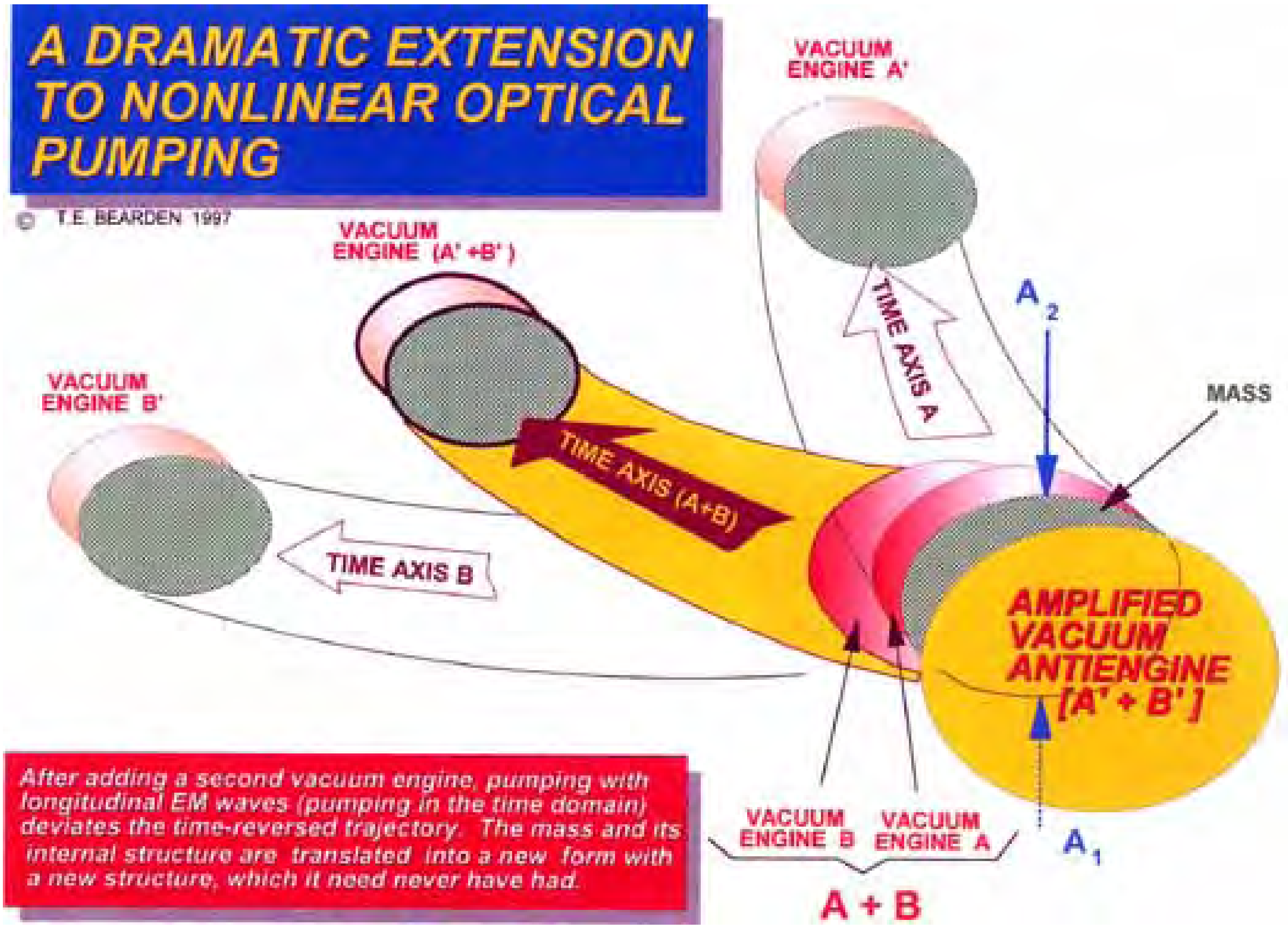

A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

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VACUUM ENGINE A'
VACUUM ENGINE (A' +B')
VACUUM ENGINE B'
TIME AXIS A
TIME AXIS (A+B)
TIME AXIS B
A_2
MASS
AMPLIFIED VACUUM ANTIENGINE [A' + B']
VACUUM ENGINE B
VACUUM ENGINE A
A_1
A + B

After adding a second vacuum engine, pumping with longitudinal EM waves (pumping in the time domain) deviates the time-reversed trajectory. The mass and its internal structure are translated into a new form with a new structure, which it need never have had.

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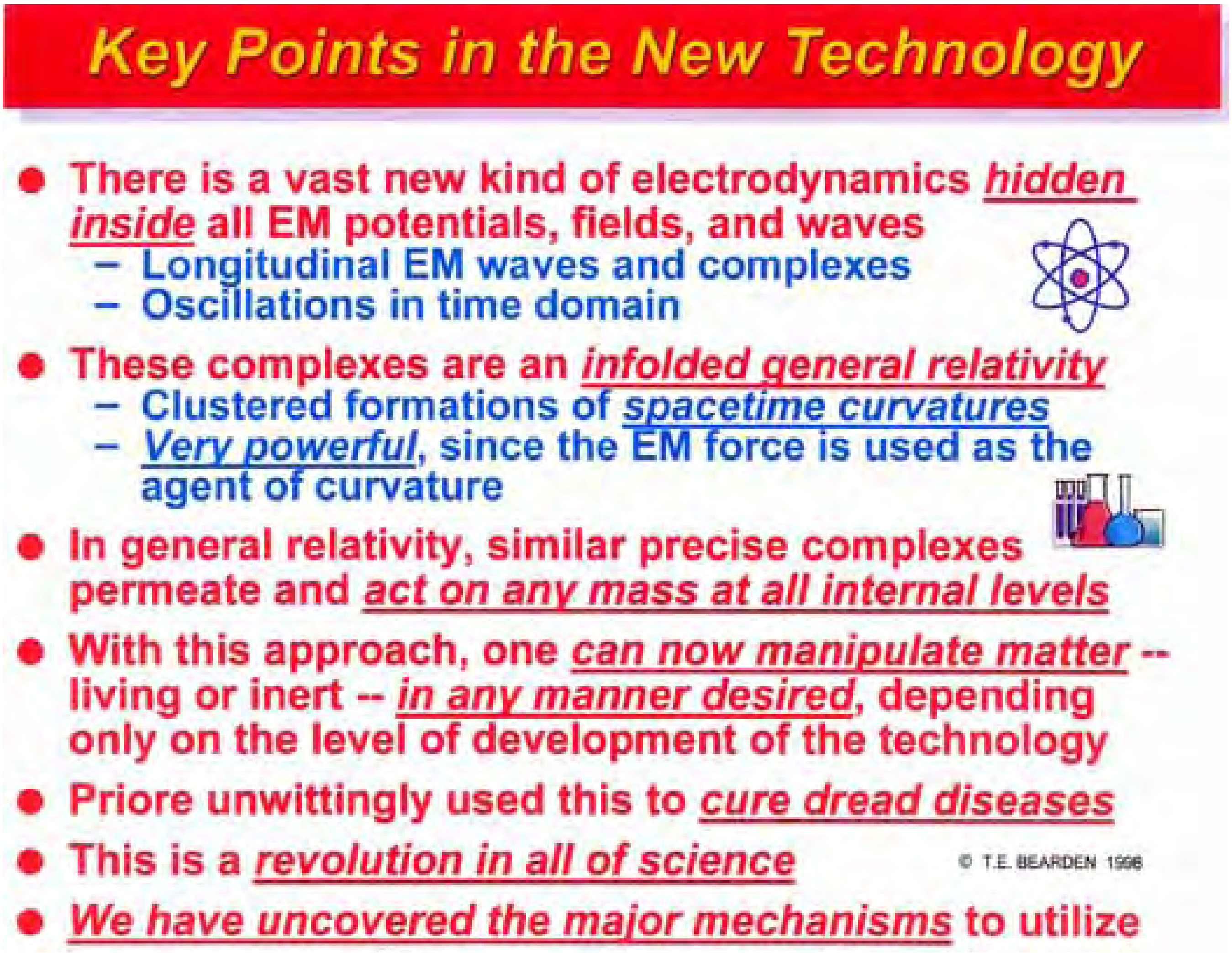

Key Points in the New Technology

- There is a vast new kind of electrodynamics *hidden inside* all EM potentials, fields, and waves
  - Longitudinal EM waves and complexes
  - Oscillations in time domain
- These complexes are an *infolded general relativity*
  - Clustered formations of *spacetime curvatures*
  - *Very powerful*, since the EM force is used as the agent of curvature
- In general relativity, similar precise complexes permeate and *act on any mass at all internal levels*
- With this approach, one *can now manipulate matter* -- living or inert -- *in any manner desired*, depending only on the level of development of the technology
- Priore unwittingly used this to *cure dread diseases*
- This is a *revolution in all of science*
- *We have uncovered the major mechanisms* to utilize

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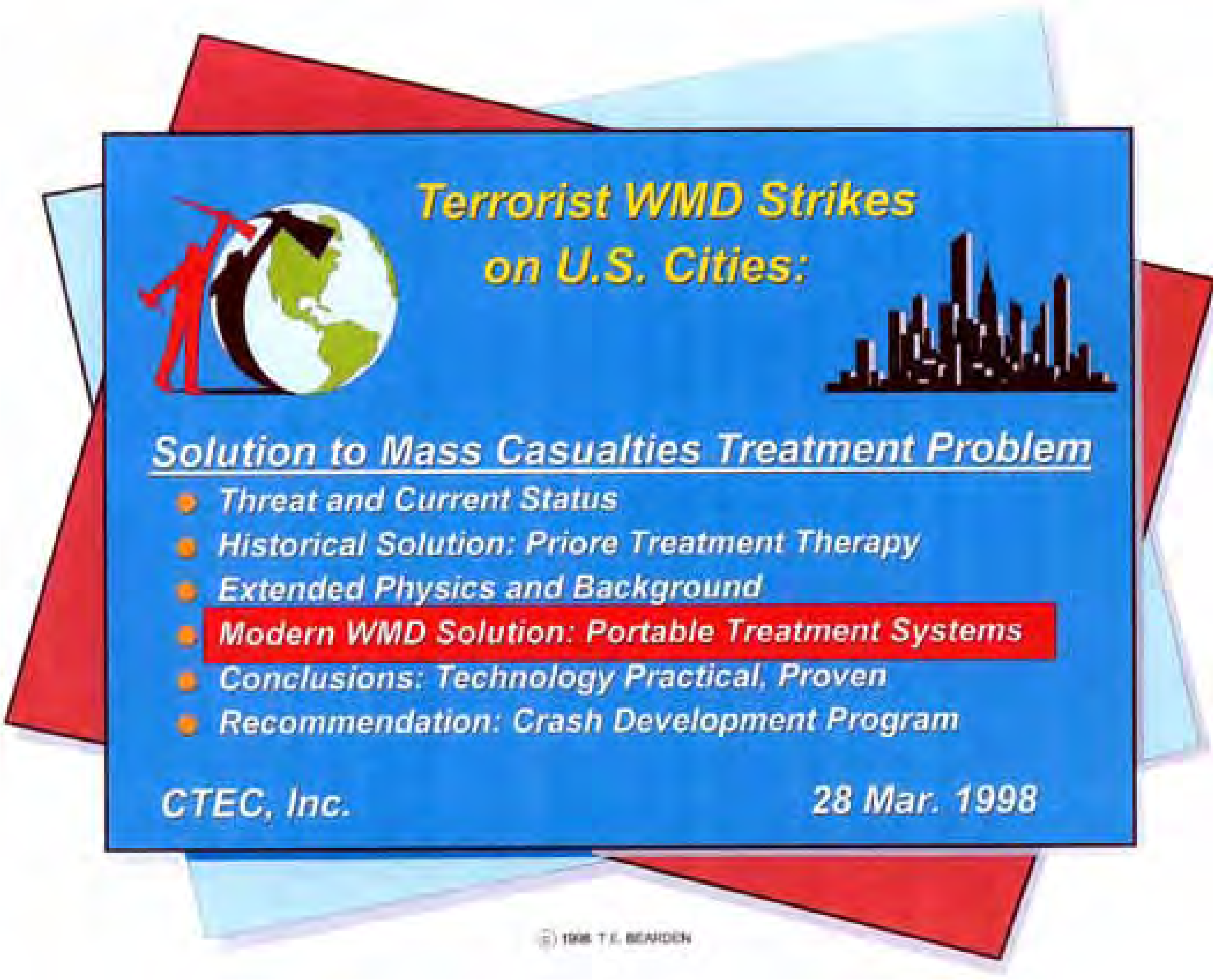

Terrorist WMD Strikes
on U.S. Cities:

Solution to Mass Casualties Treatment Problem

- Threat and Current Status
- Historical Solution: Priore Treatment Therapy
- Extended Physics and Background
- Modern WMD Solution: Portable Treatment Systems
- Conclusions: Technology Practical, Proven
- Recommendation: Crash Development Program

CTEC, Inc.

28 Mar. 1998

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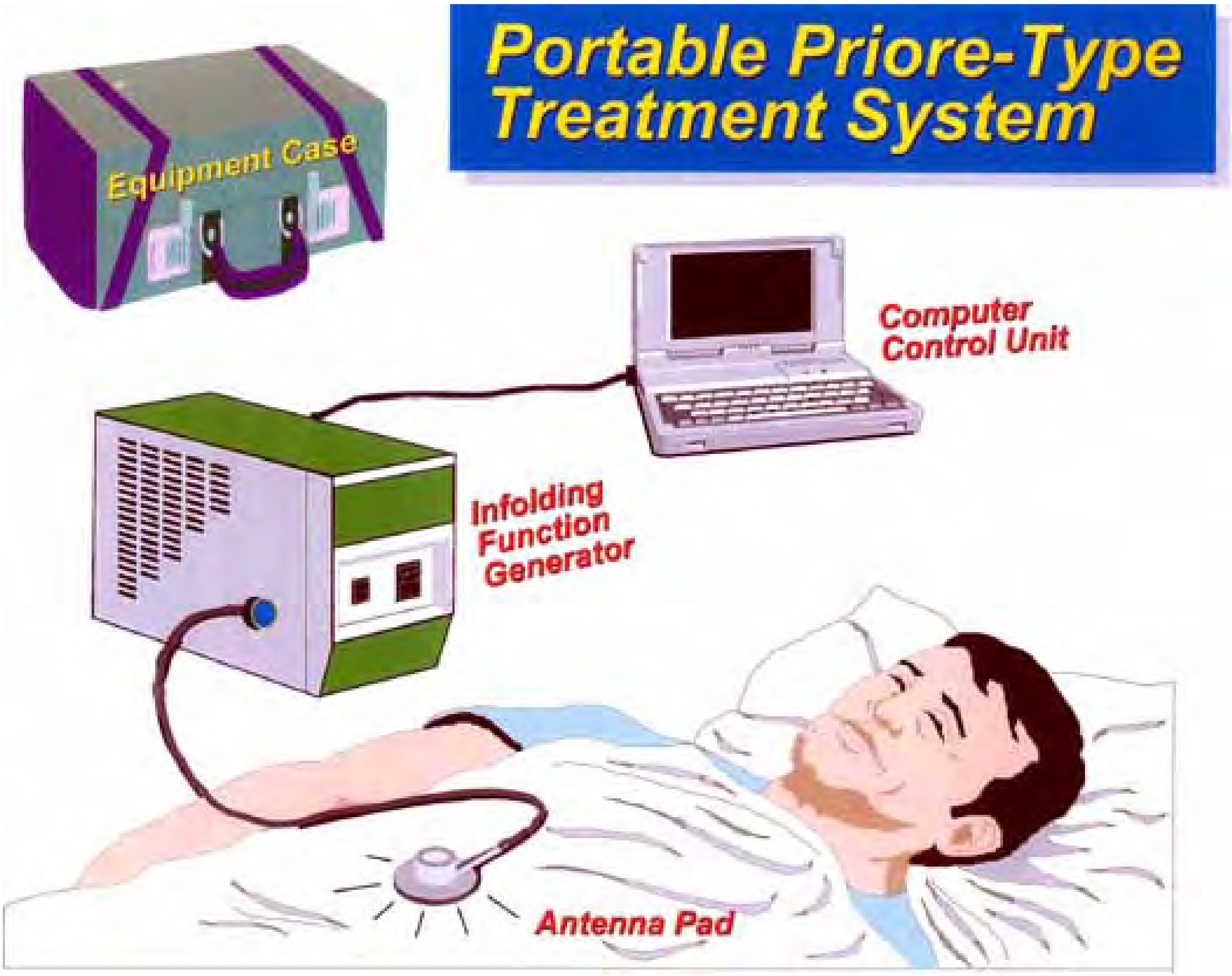

Portable Priore-Type Treatment System

Equipment Case
Computer Control Unit
Infolding Function Generator
Antenna Pad

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Portable System Block Diagram

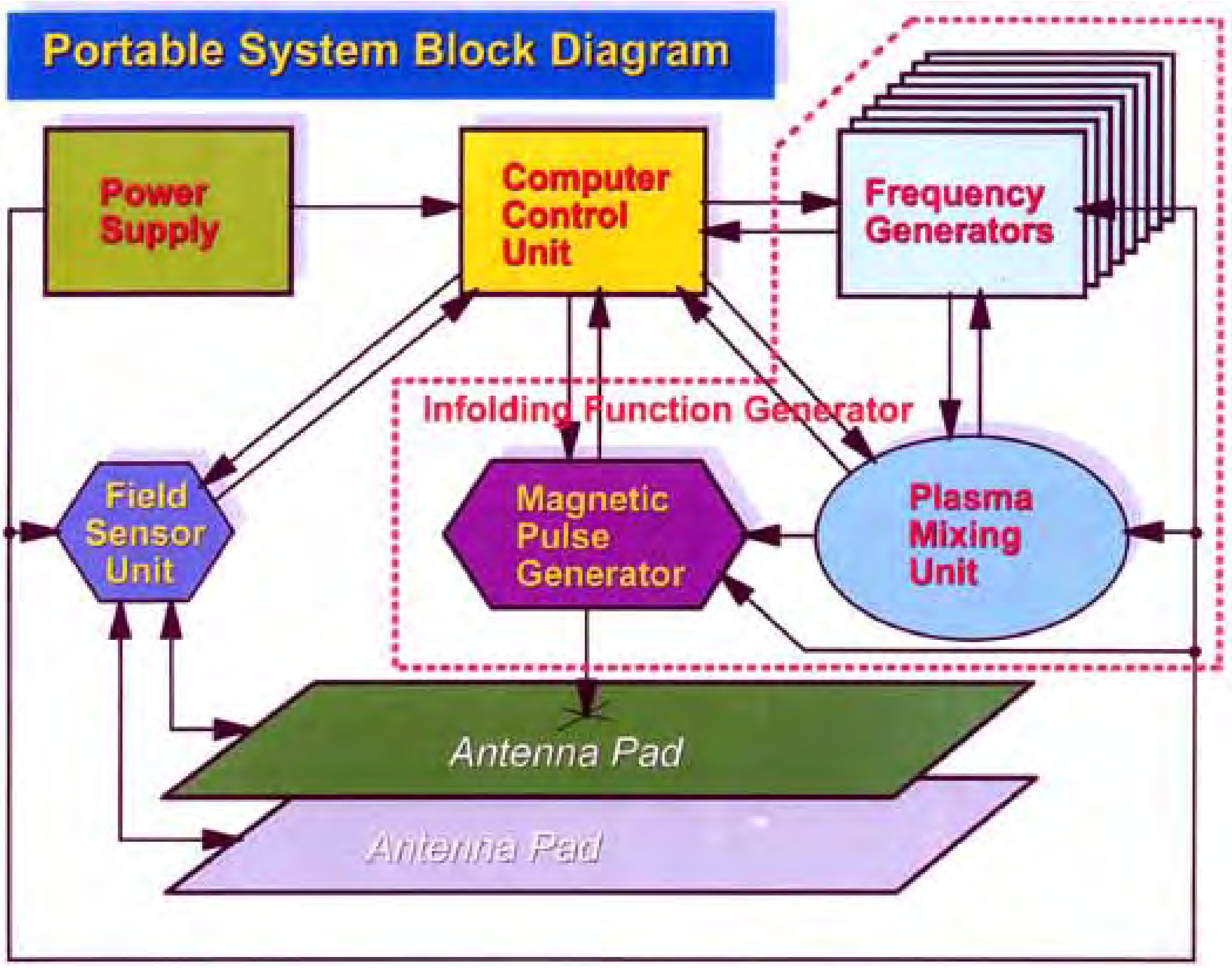
Power Supply
Computer Control Unit
Frequency Generators
Infolding Function Generator
Field Sensor Unit
Magnetic Pulse Generator
Plasma Mixing Unit
Antenna Pad
Antenna Pad

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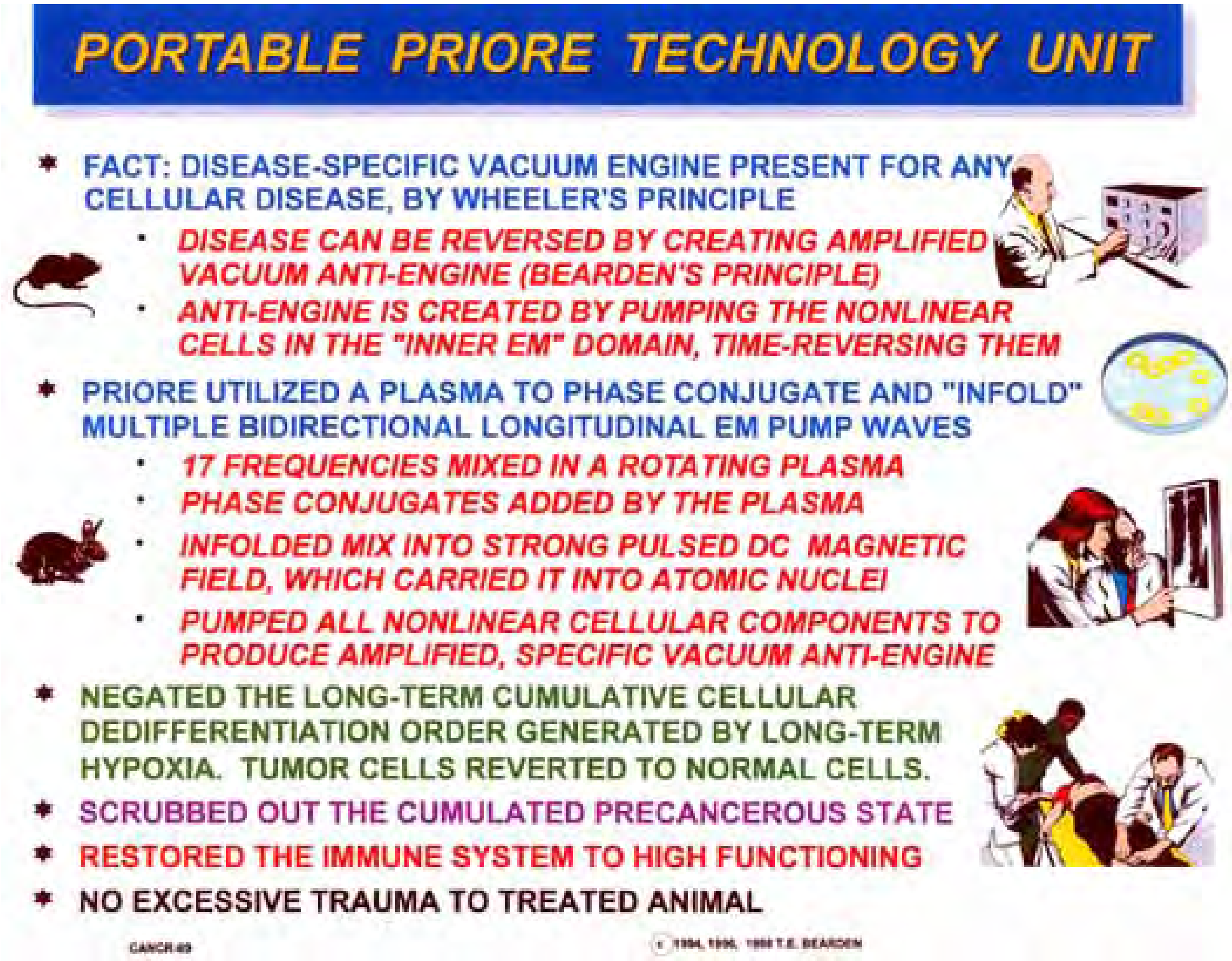

PORTABLE PRIORE TECHNOLOGY UNIT

- FACT: DISEASE-SPECIFIC VACUUM ENGINE PRESENT FOR ANY CELLULAR DISEASE, BY WHEELER'S PRINCIPLE
    - *DISEASE CAN BE REVERSED BY CREATING AMPLIFIED VACUUM ANTI-ENGINE (BEARDEN'S PRINCIPLE)*
    - *ANTI-ENGINE IS CREATED BY PUMPING THE NONLINEAR CELLS IN THE "INNER EM" DOMAIN, TIME-REVERSING THEM*
- PRIORE UTILIZED A PLASMA TO PHASE CONJUGATE AND "INFOLD" MULTIPLE BIDIRECTIONAL LONGITUDINAL EM PUMP WAVES
    - *17 FREQUENCIES MIXED IN A ROTATING PLASMA*
    - *PHASE CONJUGATES ADDED BY THE PLASMA*
    - *INFOLDED MIX INTO STRONG PULSED DC MAGNETIC FIELD, WHICH CARRIED IT INTO ATOMIC NUCLEI*
    - *PUMPED ALL NONLINEAR CELLULAR COMPONENTS TO PRODUCE AMPLIFIED, SPECIFIC VACUUM ANTI-ENGINE*
- NEGATED THE LONG-TERM CUMULATIVE CELLULAR DEDIFFERENTIATION ORDER GENERATED BY LONG-TERM HYPOXIA. TUMOR CELLS REVERTED TO NORMAL CELLS.
- SCRUBBED OUT THE CUMULATED PRECANCEROUS STATE
- RESTORED THE IMMUNE SYSTEM TO HIGH FUNCTIONING
- NO EXCESSIVE TRAUMA TO TREATED ANIMAL

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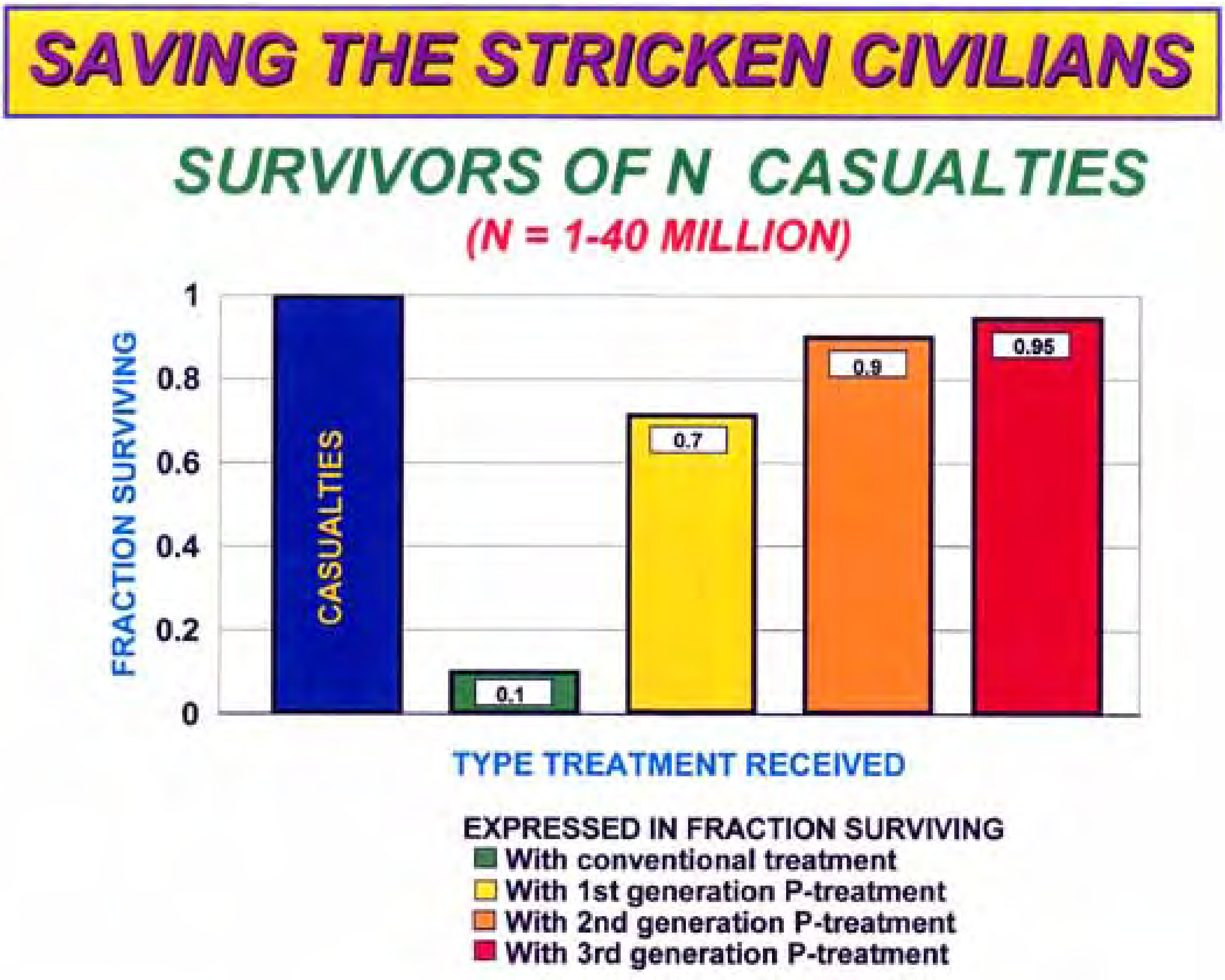

SAVING THE STRICKEN CIVILIANS

SURVIVORS OF N CASUALTIES

(N = 1-40 MILLION)

EXPRESSED IN FRACTION SURVIVING

🟩 With conventional treatment

🟨 With 1st generation P-treatment

🟧 With 2nd generation P-treatment

🟥 With 3rd generation P-treatment

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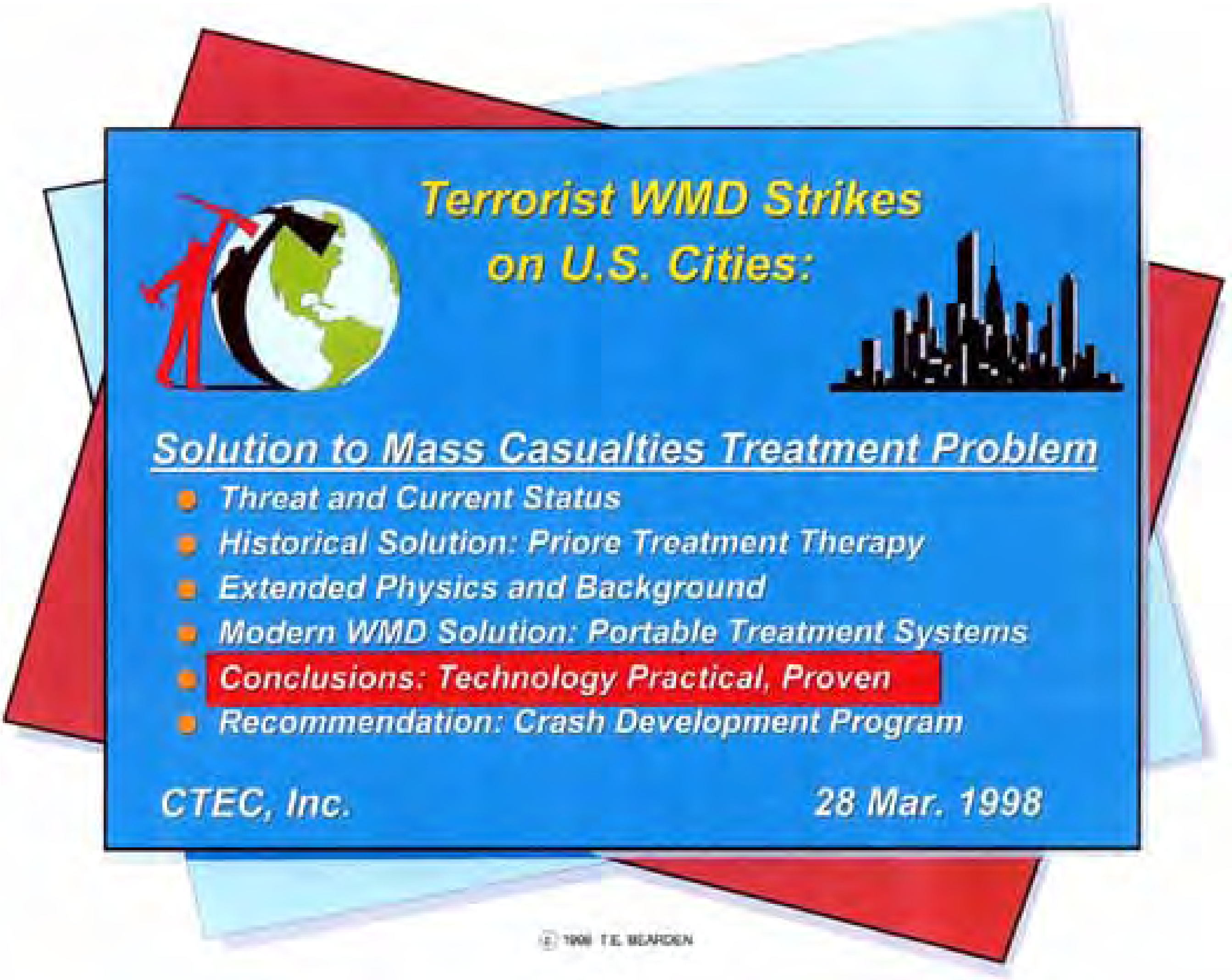

Terrorist WMD Strikes on U.S. Cities:

Solution to Mass Casualties Treatment Problem

- Threat and Current Status
- Historical Solution: Priore Treatment Therapy
- Extended Physics and Background
- Modern WMD Solution: Portable Treatment Systems
- Conclusions: Technology Practical, Proven
- Recommendation: Crash Development Program

CTEC, Inc. 28 Mar. 1998

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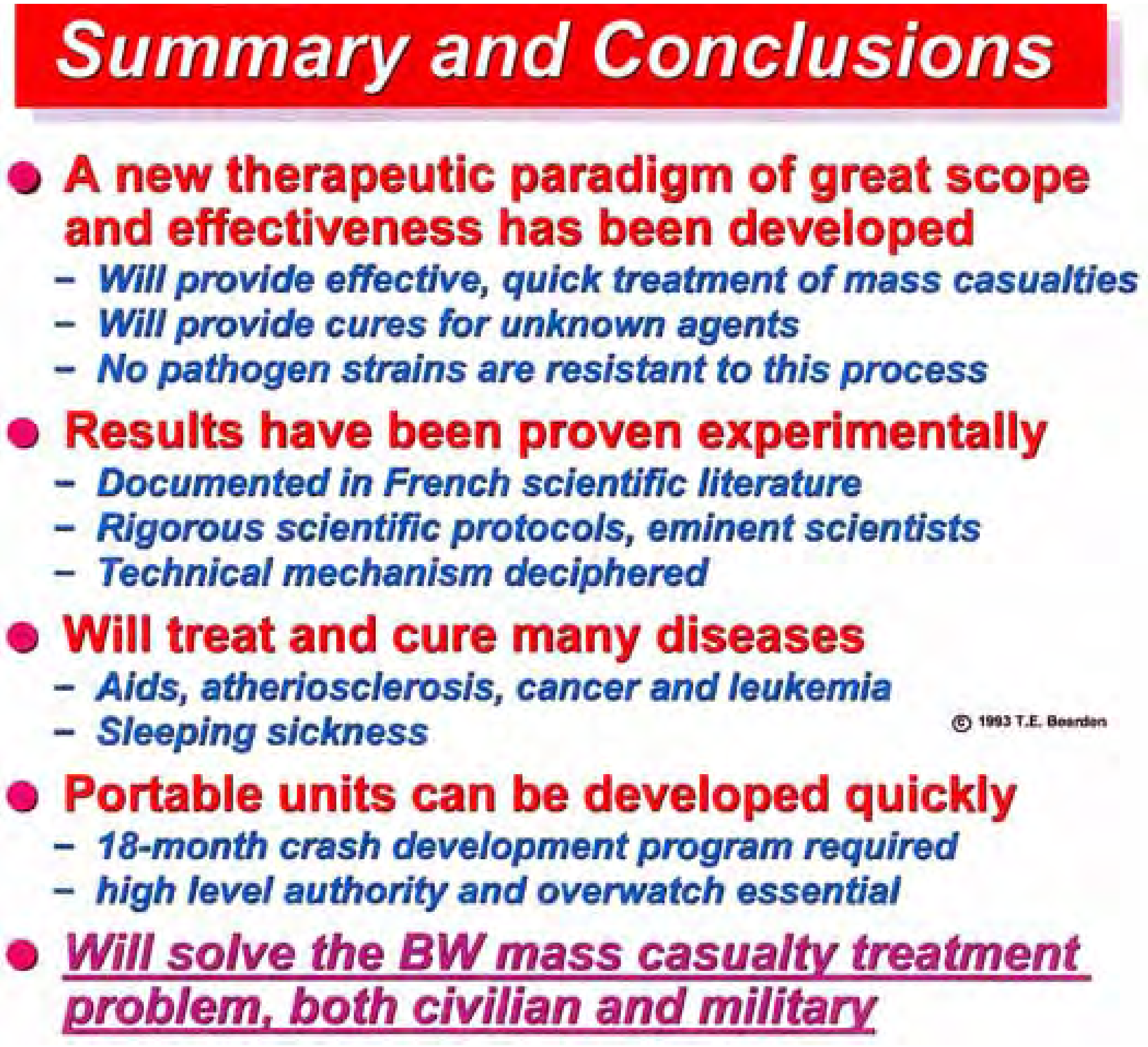

Summary and Conclusions

- A new therapeutic paradigm of great scope and effectiveness has been developed
  - *Will provide effective, quick treatment of mass casualties*
  - *Will provide cures for unknown agents*
  - *No pathogen strains are resistant to this process*
- Results have been proven experimentally
  - *Documented in French scientific literature*
  - *Rigorous scientific protocols, eminent scientists*
  - *Technical mechanism deciphered*
- Will treat and cure many diseases
  - *Aids, atheriosclerosis, cancer and leukemia*
  - *Sleeping sickness*
- Portable units can be developed quickly
  - *18-month crash development program required*
  - *high level authority and overwatch essential*
- *Will solve the BW mass casualty treatment problem, both civilian and military*

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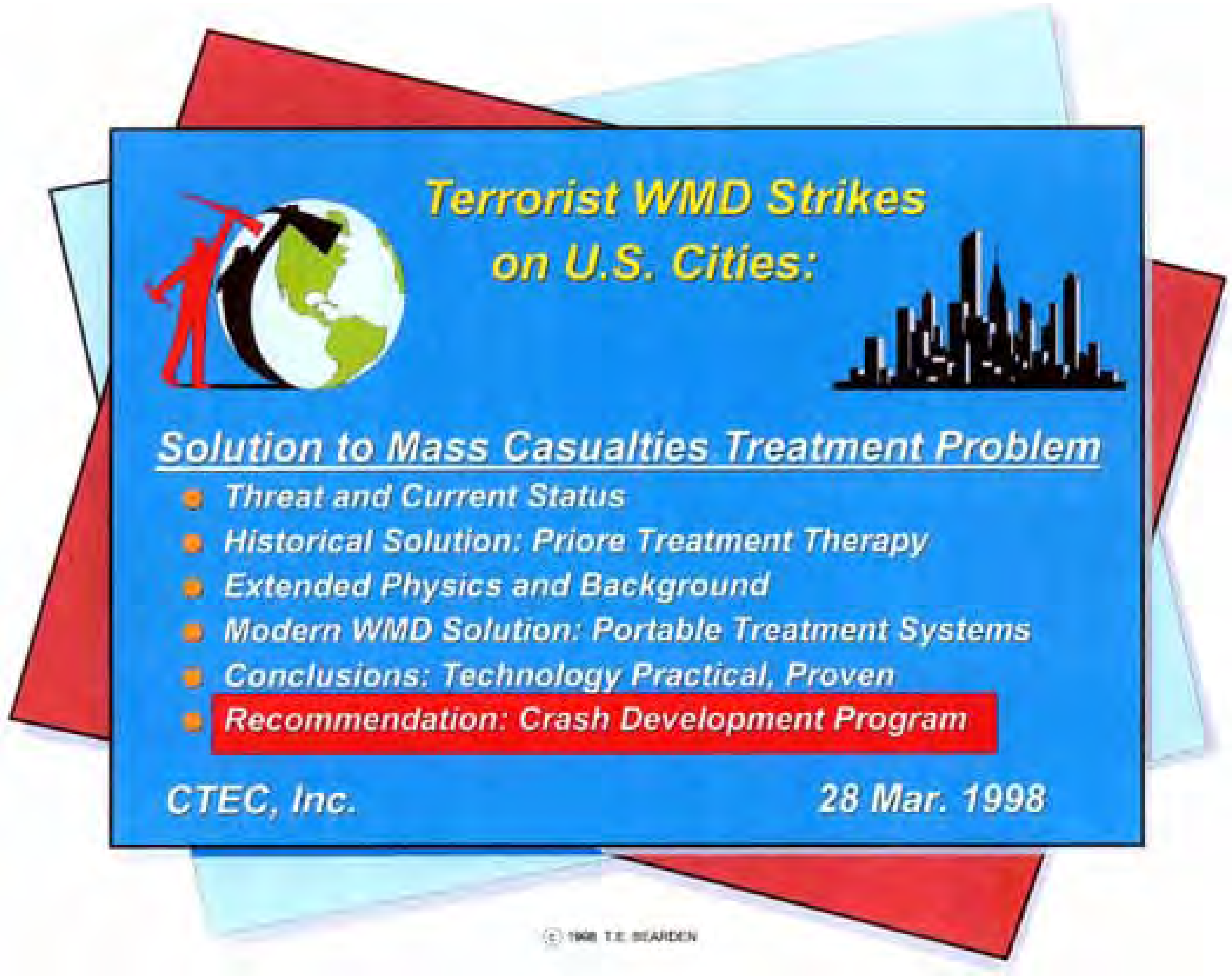

Terrorist WMD Strikes on U.S. Cities:

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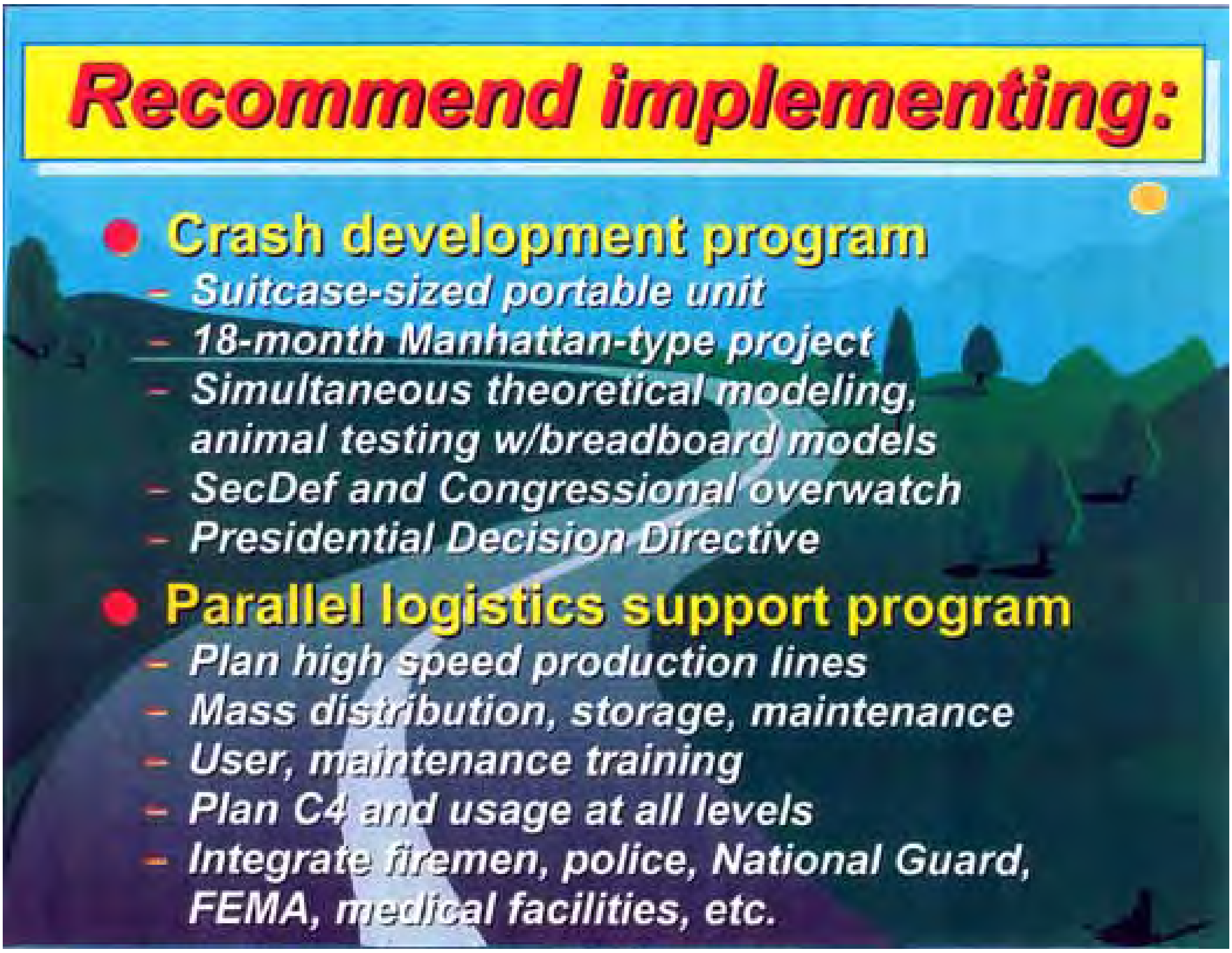

Recommend implementing:

- Crash development program
  - Suitcase-sized portable unit
  - 18-month Manhattan-type project
  - Simultaneous theoretical modeling, animal testing w/breadboard models
  - SecDef and Congressional overwatch
  - Presidential Decision Directive
- Parallel logistics support program
  - Plan high speed production lines
  - Mass distribution, storage, maintenance
  - User, maintenance training
  - Plan C4 and usage at all levels
  - Integrate firemen, police, National Guard, FEMA, medical facilities, etc.

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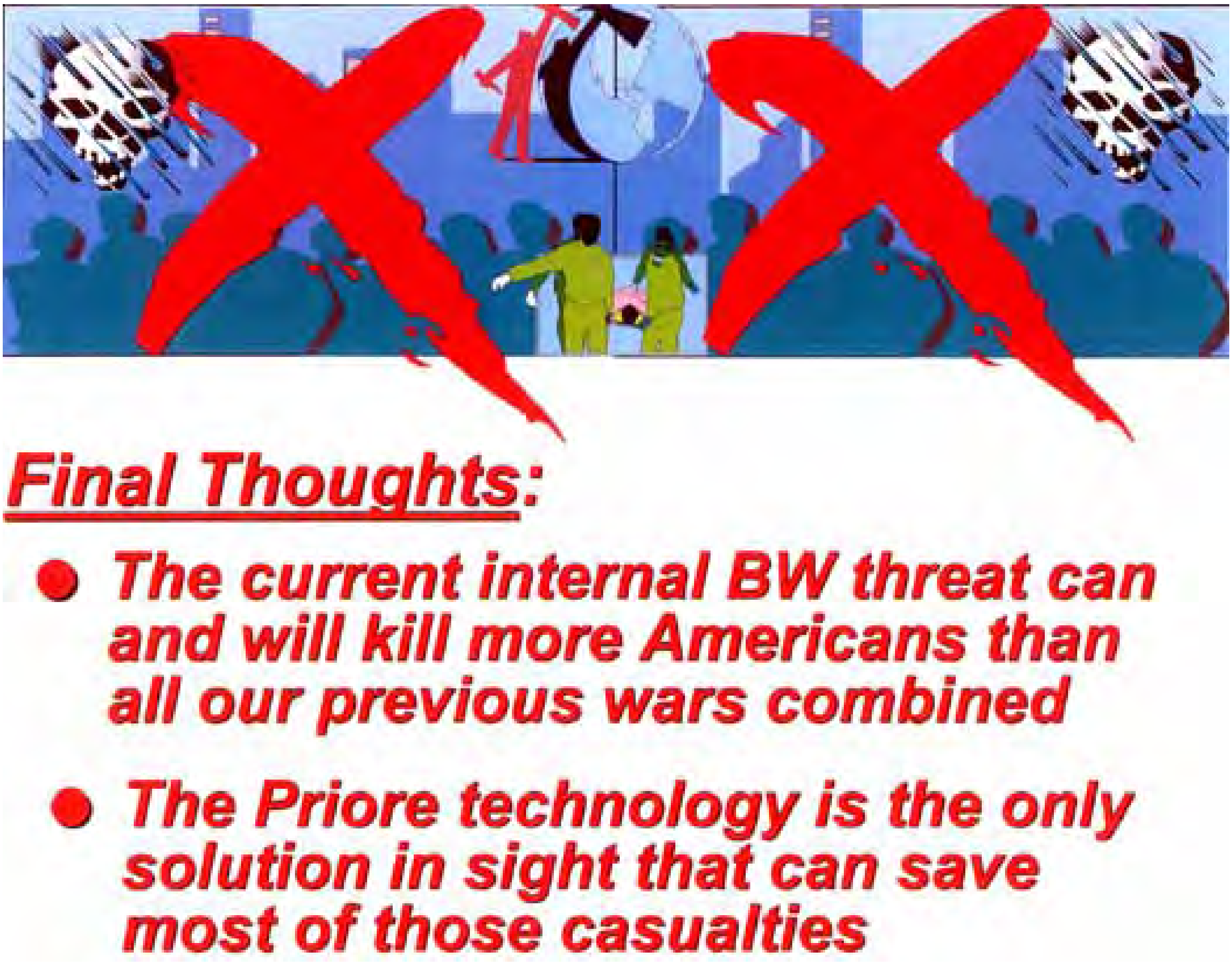

Final Thoughts:

- The current internal BW threat can and will kill more Americans than all our previous wars combined
- The Priore technology is the only solution in sight that can save most of those casualties

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CTEC, Inc.

June 24, 1998

Dr. Jane F. Kinsel, Director
Office of Policy Analysis
Department of Health & Human Services
Bathesda, MD 20892

Dear Dr. Kinsel:

Your letter of June 8 is appreciated. However, the entire action package had already gone to the Assistant SecDef and also to Major General Neary in the USAF.

The proof of a revolution in medical treatment was in the package. The basis for it is already demonstrated experimentally in the scientific literature, both in the U.S. and in France. We are speaking of something already proven, but missed by the entire U.S. medical community. Strong words, but true. Let me be specific.

Any cell in the body can be time-reversed (physics term) or dedifferentiated (biology term) back to an earlier state, by pumping (i.e., "squeezing" in simple terms) that cell with longitudinal EM waves as pump waves. There are considerable papers in the French scientific literature showing the experimental results.

Apply that to cancer. We are stating bluntly that all cancerous cells in the body can be "depromoted" back to normal cells easily. Further, the damage previously done to them (such as by sustained hypoxia due to contaminants reducing the oxygen-carrying ability normally given to it by some 60-to-80 surrounding water molecules per red cell and the consequent H-bonding interactions) will also be reversed. The cells can all be returned to healthy, normal cells again, without "killing" or "burning" or "cutting" anything.

With some development of the technology, you can quickly and easily cure every cancer patient in every hospital in the United States.

Now apply it to AIDS. Since you can time-reverse every cell in the body, you can time-reverse the HIV-infected cells – genetics and all – right back to normal cells with normal genetics. Those cells not infected and healthy, will just get a "little younger" again.

So with that small development, you can quickly and easily cure every AIDS patient in every hospital in the United States.

I would have thought that NIH would certainly be interested in such a revolutionary therapy which has already been demonstrated in laboratory experiments. World-renowned French scientists – such as the eminent parasitologist Pautrizel and research PhDs assigned directly by Robert Courrier, head of the Biology Section of the French Academy of Sciences, worked with Prioré in performing those startling experiments that proved what we are saying.

The method was rigorously shown to cure infectious diseases (such as trypanosomiasis), atherosclerosis (which now afflicts millions of Americans), and terminal tumors. It was shown to reverse suppressed immune systems back to normal vigorous functioning.

Please permit me to disagree with you that the examination of such is not the mission of the NIH. To the contrary, it is precisely the NIH which should have some of its very best scientists looking into this.

The action package to DoD was to propose a crash program to develop this methodology in the form of a small, portable unit for treatment of mass casualties resulting from a terrorist BW attack on our cities (now expected in the next few weeks, as you must be aware). The leading Arab terrorist of the world has already promised just this.

We are speaking of several million Americans who are going to die. They are going to die in spite of everything that NIH and its labs can do, even though I know you will make a heroic effort. With NIH present methods, you cannot do very much for those stricken Americans at all. Everything we have in the "normal" kit bag is almost useless against a knowledgeable spray attack of modified smallpox (as you know, the Russian secret BW labs have made and sold tons of that already, to guess who!). Or a spray of tularemia (you are well aware of the extreme lethality of that), or anthrax (easily obtained). It is also common knowledge that these terrorist teams with their BW agents are already on site in this country, waiting for the word to attack. This has now been officially raised to our primary Strategic Threat.

In the face of such looming strikes on the U.S., I simply cannot believe that the NIH does not feel it within their mission to rigorously check out a proposed method for saving perhaps 70% of those coming deaths (first generation equipment), and up to 90% with second generation equipment.

Perhaps you just did not read the package carefully. I urge you to do so.

Else NIH is going to look very, very bad when (1) the strikes do occur, (2) they can't handle them (and they cannot, as you well know), (3) they had within their hands in advance, a proposed methodology that could have been investigated intensely, to save millions of those stricken Americans.

As a staunch supporter of NIH and especially CDC, I have to believe that there is a different attitude there. If NIH is not interested in a previously experimentally demonstrated method of saving millions of Americans, then the only recourse left is the political channel.

I assure you that my critique of electrodynamics is well-founded, as supported by various leading physicists such as Nobelist Feynman (who stated bluntly that the field concept is wrong), Wheeler, Bunge, and so on. It is inexplicable why all our universities are still teaching a 130 year old abridged (Heaviside's) subset of Maxwell's theory, and one that still contains a material ether even though that was falsified 110 years ago!

You already have seen the misuse of this technology by the Russians, in the decades-long radiation of the U.S. Embassy in Moscow. Is it not NIH's mission to understand how they generated all those diseases and health changes? Have you ever looked into Kaznacheyev's experiments showing that ANY cellular disease or disorder can be induced in cells at a distance by purely EM means? Have you looked into what got eliminated from electrodynamics by ignoring the hidden longitudinal EM inside every potential, field, and wave? Do you realize what ignoring that has done to American chemistry, biochemistry, and medical science?"

I would hope that the NIH would at least be interested in its own mission area!

I challenge you bluntly to admit that no one presently understands the primary operation of the human cellular ***regenerative*** system. That's because its technical principle is not presently in our recognized physics, biochemistry, and medical science – even though it has been in the hard physics literature since 1903-4. Becker's epochal work came closest; since he only had access to the conventional EM model, it failed him. But he at least showed you rigorously that cells can be changed (both differentiated and redifferentiated) all over the map by laughably weak EM – picoamperes of current, which means persistent DC potentials. In the microwave radiation of the U.S. Embassy, all the health changes occurred in regions absent of fields – i.e., absent of bleed-off of the potentials. Hence in regions of stable DC potentials! With 100% correlation of the health changes to persistent, gradient free potentials, and 100% anticorrelation to changing potentials (i.e., fields), our own scientists concluded totally erroneously that it could not have been the EM radiation causing the changes, when their own results had just proven that it was.

Now I ask you: Can NIH explain how it was that the DC potentials caused those health changes? I think not. If it could, it would understand the action package I wrote, and its importance.

This is not a "political" letter. I'm just an ordinary American citizen who has done about 30 years very hard work on this particular area. The work is good enough now to stand on its own merits. The scientific community will eventually accept it, about 50 years from now. But we cannot wait 50 years! Those millions of Americans are going to die, because of the bureaucracy and inaction of our own scientific organizations. Whether they like it or not, the U.S. scientific community is now the forefront of the struggle for this nation to survive. And they are failing us dramatically.

So as a parent who wants his children to live, and his neighbors' children to live, and those millions of soon-to-be stricken Americans to live also, I urge you to at least have someone competent in physics (and knowledgeable that the foundations of physics itself are in woeful shape!) check the work. Has anybody there *read* any of the references to the Prioré work I cited? Does anyone there realize that *there are no EM forcefields in space?* Probably not.

Dr. Kinsel, there is a time for "business as usual" and there is a time to do some serious new work. Those stricken Americans are going to be lying there. Nothing NIH can do is going to stop that. That's a given, and it is not my own estimate. It's the official estimate. And you *know* you presently do not have the tools to do anything really effective about it.

Frankly, I interpret your letter to me as just the normal "spin control" for easy disposition. I would hope that NIH would seriously rethink the situation, get off the "spin control" and "business as usual" posturing, and do something dramatically different for a change.

What have you got to lose? A little time from perhaps two or three of your best scientists.

What have you got to gain? Saving untold millions of American lives. A new, *already partially demonstrated* cure for most dread diseases such as AIDS and cancer – diseases which you presently cannot do very much about in spite of decades of heroic struggle.

Sincerely,

cc: Senator Shelby, Congr. Cramer

T.E. Bearden
President and CEO

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CTEC, Inc.

May 12, 1998

Dr. Harold Varmus, Director
National Institute of Health
Bathesda, MD 20892
(301) 496-1766

Dear Dr Varmus:

We have recently sent action documents to the Director of Nuclear and Counterproliferation, Office of the DCS, Air and Space Operations, HQ USAF and to the DoD (General Busbee) Assistant Secretary of Defense, as well as several Senate and House committees, which may be of interest to you. For one thing, we give the technical mechanism used to generate the Gulf War Syndrome. The same weaponry is now being used to rapidly induce new strains of certain pathogens worldwide. I urge you to closely read that section of the letter to MG Neary which explains the GWS, why the French did not get it, and why Southern Iraqis got an increase in cancer and leukemia but not GWS. Also explained is how the "microwave radiation" of the U.S. Embassy in Moscow induced diseases for decades, and how we failed to comprehend it because the standard EM model deceived us.

There is a way to treat and quickly cure most diseases, including the mass casualties resulting from a terrorist BW strike on our civilian population centers, our military bases, or our forces in the field. The method is little known, but was scientifically demonstrated in France in the 1960s and early 1970s before cancellation of the Prioré Project when the French Government changed. Eminent French scientists worked on the project, and the results are fully documented in leading French scientific journals. References are listed in a separate attachment.

Previously the Western scientific community has been unable to understand the technical mechanism responsible for such remarkable cures, because of serious foundations flaws in Western physics and electrodynamics. *Foundations* physicists have long been aware our science is flawed, and have pointed out many of these fundamental errors. However, the operational science establishment has not paid attention, even though physicists such as Feynman and Wheeler pointed out that the notion of "force fields in space" was totally wrong.

As a primary example, there is an "infolded" electrodynamics inside all potentials, fields, and waves that is far more primary than the coarse EM that is in our textbooks. It is actually an infolded general relativity, and this is what the Russians have weaponized. This infolded EM-GR has been ignored in the West (but not in Russia) since 1903.

As another example the potentials, fields, and waves of present electrodynamics are rigorously defined – and exist – only in the presence of mass. They do not exist in such form (force fields and oscillating force fields) at all in space, in the absence of mass. Rigorously, Maxwell's equations are mass-to-mass transforms, since Maxwell and everyone at the time assumed the ubiquitous presence of the material ether. In other words, to the founding electrodynamicists, there was no place in all the universe that was devoid of mass. Hence they defined all EM entities as entities containing mass. Even though Michelson-Morley experiments of more than a century ago destroyed that material ether, not a single Maxwellian equation has ever been changed! They still assume the material ether.

Specifically missing from our electrodynamics are two essential transforms: (1) the mass-to-spacetime transform, and (2) the spacetime-to-mass transform. In other words, these two transforms are "infolded" or hidden inside (comprise) the end point extremum case – the mass-to-mass transform actually written by Maxwell.

But these two missing transforms are just general relativity (they correspond precisely to Wheeler's principle of general relativity). So general relativity has always been infolded inside electrodynamics as we know it, but ignored. Further, this is a very powerful general relativity, since it uses the very strong EM force as the agent of spacetime curvature. Hence now one can engineer a powerful general relativity in the laboratory and in practical devices, and even action-at-a-distance, which one cannot do using merely the staid and weak G-force.

It turns out that longitudinal EM waves as shown by E.T. Whittaker in 1903 and 1904 are far more primary than our present EM theory and even our present GR theory. Both EM and GR are directly engineerable using longitudinal EM waves, including subluminal and superluminal EM waves in vacuum, and including action at a distance. One can engineer complexes of spacetime curvatures as desired, which in turn are *spacetime engines* (Wheeler's term). These engines can act upon mass – either living or inert – in any fashion desired, and at any distance desired.

The little-known and poorly understood Regeneration & Recovery (R&R) system – as contrasted to the immune system – utilizes this exact "spacetime engine" methodology to restore damaged or diseased cells, within its limitations – "dedifferentiating" or "time-reversing" them back to normal. The mechanism is fully explained in the attached package. The proposed program applies this fundamental method to greatly amplify the effect. Thus cancer cells can be reversed back to normal cells, HIV-infected cells (HIV-factories) can be reversed back to normal cells (genetics and all), etc. This represents a dramatic and unparalleled new medical therapeutic methodology of extreme power. The same techniques can simply be conjugated one additional time, and used to produce diseases and cellular changes at a distance, including in entire mass populations, as the KGB is doing right now. Specifically, by impressing an extremely weak "cocktail mix" of disease spacetime engines on the U.S. populace, the immune systems are reacting and being "spread thin" across several "shadow state" infectious pathogenic conditions. Thus when an actual terrorist BW attack occurs, the lethality of the strike will be remarkably enhanced because the immune systems will be "thinned" in their ability to fend off this new pathogen. By doing it this way, BW warfare can actually be conducted upon the U.S. without anyone being the wiser.

Our very survival as a nation is threatened by remarkable KGB weapons using this fully documented, extended electrodynamics. Bluntly, unless we take off our scientific blinders and understand Russian energetics weapon science, GWS and the Embassy health changes in Moscow were just a picnic before what is upon us. After two decades of work on the KGB energetics weapon problem, we have fully deciphered the technical mechanisms and what energetics is, as well as citing many of the Russian weapon tests and how they were done. Again, you can see that for yourself in the package.

Now that we understand the technical mechanisms, we are proposing rapid redevelopment of the Prioré process, in portable suitcase-sized units to be mass produced and filtered down into the entire emergency community for mass treatment of lethal infectious diseases resulting from BW strikes. And we are strongly urging the U.S. scientific community to quickly investigate and come to grips with this vast new *biological engineering* mechanism. Our very survival depends on it.

The inclosed documents provide an overview of the process. There is nothing else on the scientific horizon that can save the majority of all those stricken Americans, once the first foreign-sponsored terrorist teams strike our population centers with BW agents.

Sincerely,

Incls: Full package with table of contents

T.E. Bearden
President & CEO

Scalar Wars

The Brave New World of Scalar Electromagnetics

by Bill Morgan

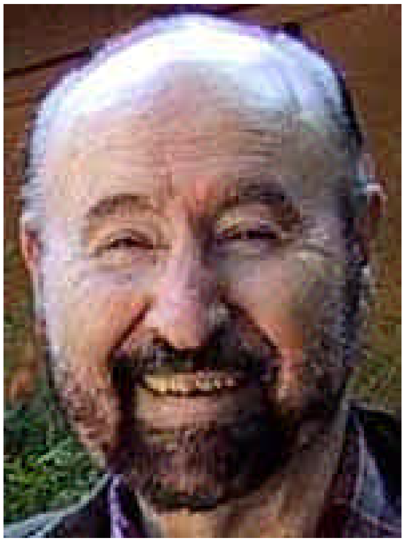

For the past six months I have been undergoing the greatest **paradigm shift** I have ever had to go through. It has rattled my nerves and shaken my bones. This intense adjustment of my "world" has come about by studying the information given by Col. Tom Bearden at his website Cheniere. The new knowledge there has necessitated a total revision of my ideas about physical reality, the world we live in, and the future of humanity. This paradigm shifting even actually made me dizzy on certain days as I tried to absorb and digest Bearden's vast amount of information. I am not a scientist at all, just a layman, and I have little comprehension of the math and high physics of this new science called "**Scalar Electromagnetics**." But there is a great deal of information at Cheniere which needs to become common knowledge as fast as possible, for the sake of the survival of life on earth. To that end I have put together this small primer of Bearden's ideas, as a kind of "beginner's guide" to his website. (I have tried to underline certain words and phrases which are part of the new "jargon" of talking about these "new" phenomena. Also I have taken the liberty of bolding certain words and phrases to help them stick in the mind).

(Note: Throughout "**EM**" means "**electromagnetic**," and "**LW**" means "**longitudinal wave**")

This article has six sections:

New Waves 2. Tapping the Waves 3. Weaponization 4. Healing 5. Psychoenergetics 6. As It Stands

1. New waves discovered

Longitudinal EM energy fills vacuum of space, the time domain of spacetime, time as compressed energy, E=tc2, waves of time, phase conjugate wave pairs.

"Electric power is everywhere present in unlimited quantities and can drive the world's machinery without the need of coal, oil, gas, or any other of the common fuels." Nikola Tesla

"At any point and at any time, one can freely and inexpensively extract enormous EM energy flows directly from the active vacuum itself." Tom Bearden

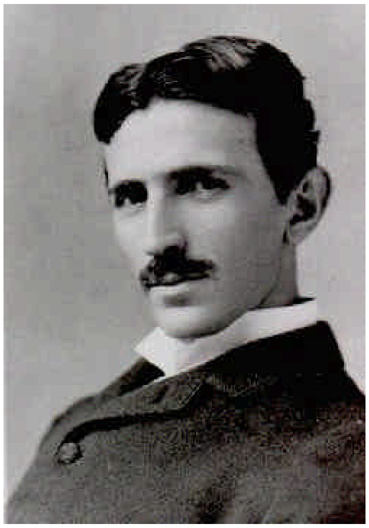

I guess the first thing to try to comprehend is that a "new" kind of electromagnetic (EM) wave has been discovered in the empty vacuum of space called “longitudinal” waves, which, when engineered, can be an inexhaustible supply of energy in great magnitude at any place in the universe. The word "new" is in quotes because the discovery really goes back to **Nikola Tesla** and his discovery of what he called "radiant energy." It is also not "new" because the Russians (KGB) have been working on this technology for over 30 years and have **weaponized** these "new" longitudinal scalar waves to a great degree.

These are the very weapons **Nikita Khrushchev** spoke of in January, 1960.

> "By 1957-8 the Soviets had progressed to the point of a giant scalar EM accident in the Urals which exploded nearby atomic wastes, devastating the area. They had also progressed to development of great new superweapons using their new energetics - weapons to which Khrushchev referred in 1960 when he informed the Soviet Presidium of a new, fantastic weapon in development, a weapon so powerful that it could wipe out all life on earth if unrestrainedly employed.'" Tom Bearden

After over 30 years of development, and extensive testing around the globe, these new scalar electromagnetic weapons are up and running and ready to go. Tom Bearden, at his website Cheniere, discusses the history of these new scalar electromagnetic weapons in his paper "Historical Background of Scalar EM Weapons."

Some Immediate Implications

> The implications of successful engineering of the longitudinal waves are enormous, and will change the world as we know it, one way or another. Among other things, these discoveries mean that:
>
> 1. The **solutions to the energy crisis and the "oil problem" are in hand**. These oil wars are unnecessary. There is endless energy available freely from the domain of time.

2. **Unbelievably powerful weapons** are not only possible, but are already operating in several nations. The many powers of these weapons are unprecedented and mind-boggling.

3. The **cure of diseases such as cancer and AIDS**, in fact nearly any disease, has become possible within a few years of sufficient funding. Everyone can be made healthy and stay healthy.

4. **Mind control on a mass scale** has now become possible, and the machines to do it are already in place in certain nations. It has become possible to mentally enslave whole populations with the twist of a few dials.

So the layman will need to understand that there is a new kind of electromagnetic energy that is altogether different from what he knows, e.g. radio, TV, cell phones, etc. The ordinary EM waves that we have known about are called transverse EM waves, to distinguish them from the new longitudinal EM waves. These scalar waves do not actually exist in our "material" world, but exist only in the vacuum of empty space, or the time domain. And we must keep in mind that this vacuum of space we speak of exists all through everything. Even our bodies are mostly empty space between atoms and molecules. So the gateway to this seething ocean of energy can be there at every point in the universe. This seething ocean of energy is all around us and all through us.

Emptiness is Full

This amazing discovery announces that the "emptiness" of empty space is in fact not empty, but a great ocean of seething energy!

Col. Bearden refers to this ocean of energy as being of the "time domain." It seems like something from Star Trek but this is where scalar electromagnetics has come to. And where it is going may be beyond anything Star Trek could have dreamed of.

We live in a 3-dimensional world, which physics calls "3-space." But there is also spacetime, or 4-space, or the "4th dimension." Then suddenly comes this amazing new knowledge that time itself is actually compressed energy. And it is energy which is compressed by exactly the same factor by which matter is considered compressed energy: the speed-of-light-squared!

So we have a new companion to the famous E=mc2. It is now paired with E=tc2 (where t is actually "delta-t," or change in time). Or (amaze your family and friends and) say:

"E equals em-cee-squared"

and

"E equals delta-tee-cee-squared"

It has a nice ring to it, like some freedom bell announcing a new era.

And as the atomic bomb released the compressed energy in matter, so can we now unleash the tremendous energy that is compressed into time itself. It gives a completely new meaning to the term "time bomb."

Some New Terminology of Scalar Electromagnetics

A new science, several new names

> "Those [Russian] weapon scientists resurrected an old term from the history of electrodynamics, called "energetics". That is their approach to a unified field theory, where everything is based on "energetics". This model as its foundations uses a very similar approach to that "single fundamental unit" model, where energy is the unit. If one makes the energy EM in nature, then one has the Russian energetics approach. This unified approach gathers everything in, including all energy actions and relations in inert matter (the first branch of energetics, called by the same name), all field and matter interactions in living matter (the second branch of energetics, called "bioenergetics"), and all mind operations and mind-matter interactions (the third branch of energetics, called "psychoenergetics"). [ed: sometimes also called "psychotronics" by the Russians]

Rick Andersen in an article called "What is Scalar Electromagnetics?" describes the new science this way:

> "Scalar EM is the brainchild of Lt. Col. (retired) Thomas E. Bearden, a systems analyst and wargames specialist who has been advocating a view of electromagnetics which is based on the notion of a vast, unseen background of scalar energies (as opposed to vector energies) which underlie all physical reality.
>
> "If Bearden is correct in his Scalar EM theory, then we can build devices which would enable us to alter gravity, time, inertia, and the apparent mass of an object. This of course has ENORMOUS implications for military applications, space-vehicle drives, time-travel, teleportation, paranormal phenomena, and just about every other area one can think of." http://twm.co.nz/Beard_scalem.html

> "Time-energy, time-currents, and time-structuring play the dominant role in electromagnetics. Time-as-energy eventually becomes engineerable, as easily as is spatial energy now. We are always dealing with spacetime and with spacetime curvature."
>
> Bearden: http://www.cheniere.org/techpapers/Vision%202000%20paper.doc

The scalar energy discovered in the vacuum of space is sometimes called "zero-point" energy. Thomas Valone explains how this term came about.

What does "Zero Point" mean?

"Boyer traces the historical “creation of the vacuum” as proceeding in stages in parallel with the historical development of ideas about the vacuum. To paraphrase, he says that in the 17th century, it was thought that a totally empty volume of space could be created by simply removing all matter and, in particular, all gases. That was our first concept of the vacuum. Just get rid of all the gas. Late in the 19th century, it became apparent that the region still contained thermal radiation. But it seemed that the radiation might be eliminated by cooling. So the second concept of getting a real vacuum is to cool it down to zero temperature. Just go all the way to absolute zero. Then we’ve got a real vacuum. Right? Well, since then, both theory and experiment have shown that there is a non-thermal radiation in the vacuum and that it persists even if the temperature could be lowered to absolute zero. Therefore, it was simply called the “zero point” radiation. "Thomas Valone http://www.seaspower.com/InsideZeroPoint.htm

> "**For our very survival, it is absolutely imperative that informed citizens be aware of this dramatic change, which is just now starting. The powerful new science and engineering must be controlled and used for humanity's benefit, not its detriment. Else it will eventually be let loose unrestrainedly, to destroy all life on earth - a possibility indicated by Nikita Khrushchev in 1960**." - Bearden
>
> http://www.cheniere.org/explore%20articles/priore1/p4.jpg

2. Tapping the waves

Endless free energy, Tesla's radiant energy, the dipole as the gateway to the energy of the void, MEG in one year, Bedini, Yakuza, etc. End of Oil, geopolitical chaos, rogue groups

Move Over G.E. & Big Oil, Energy is Everywhere!

Third-world nations set to rise

> "Certain powerful interests did not wish the extended electromagnetics to be discovered or taught. That, after all, would lead to free energy and loss of economic control of the citizens. That was precisely why Nikola Tesla had already been suppressed ... Today it is still being suppressed by the orthodox establishment."
> http://www.cheniere.org/books/ferdelance/s25.htm

The vast seething ocean of energy of the vacuum, the longitudinal scalar EM waves of the time domain, can now be tapped and "transduced" into ordinary (transverse) EM energy in our 3-Space world. The process can be compared to putting a paddlewheel into a river. The energy acquired is free, since the river is there flowing whether we tap it or not. And it is a mighty river, and is not diminished by our paddlewheel.

This means that a permanent solution to the "energy crisis" is at hand, if only those who hold it so secret would give it up to humankind.

It means our species' insane use of oil is no longer necessary. We can make automobiles that need no fuel at all. We can build motors that power themselves. It means that unlimited electrical power can be available for free anywhere in the world. Every house and even shack can have its own power supply.

Of course there is the cost of the equipment at first, but the energy flow is free for the presumably very long life (no moving parts) of the generator. It will probably take decades to shift over to scalar power.

But the ability to tap the scalar (longitudinal) EM waves of the vacuum (which exists everywhere) also means that unbelievably powerful weapons can be, and already have been developed. In fact these weapons are so dangerous that the fear engendered becomes a psychological obstacle to the grasping of the facts.

I struggled with this myself for months, and even though Tom Bearden had completely convinced me already, it is hard to accept the fact that for everyone on earth the "worst that might happen" has suddenly gotten much worse. It takes time to deal with that, to realize it and get over it.

Indeed, the possibilities of these new weapons, which are tapping the huge energies of time, are so terrifying it is natural for the mind to simply say: "I don't want to hear about that."

And the government, likewise, pretends these weapons do not exist and tries to keep it secret from the people. Because most people would indeed be truly alarmed to know the actual situation. Col. Tom Bearden has decided that the people need to know the truth anyway. As a People on a Planet we must face this now, and ban the use of scalar weapons in war or in mass mind control. The current deployment of these weapons is a world emergency which we must all face.

The physics and mathematics of the longitudinal waves and the time domain are clearly beyond the layman, but I recommend scanning through them anyway just to get a sense of the wonder and the elegance of it all and some of the exotic terms which are used. Two of the most important papers by Col. Bearden are:

Giant Negentropy from the Common Dipole

The Final Secret of Free Energy.

Despite the complexity of the science involved, Bearden sums up the essential secret of it all in a few words.

> "There is no problem at all in extracting all the energy one wishes from the active vacuum, anywhere in the universe, at any time. Just make a dipole.

> The problem is in (1) catching some of that freely gushing EM energy in a circuit containing a load, and (2) dissipating the caught and collected EM energy in that load to power it, without using half the caught energy to destroy the source dipole's).
>
> That is the ONLY real energy problem on the planet, and always has been."
>
> http://www.cheniere.org/correspondence/022502.htm

A dipole could be a battery, which is polarized into negative and positive. Or the terminals of a generator. Or any magnet with its two poles. Or an atom with its positive and negative charges. Or the earth's magnetic field, the sun, and all heavenly bodies. Even a galaxy must be some kind of mega-dipole. Wherever there is a dipole there is already immense scalar EM energy ushering out of and back into the vacuum. And there have already been demonstrated a number of diverse methods for tapping that energy as it flows. (John Bedini, Edwin Gray, Bruce de Palma, and others). Bearden provides what he calls a "partial list" on his website.

> "In other words, nature then gladly gives us as much EM energy flow as we need, indefinitely — just for paying a tiny little bit initially to "make the little dipole." After that, we never have to pay anything again, and nature will happily keep on pouring out that 3-flow of EM energy for us. This is the giant negentropy mechanism I uncovered, performed in the simplest way imaginable: just make an ordinary little dipole."
>
> Bearden http://www.cheniere.org/techpapers/Unnecessary%20Energy%20Crisis.doc

How to Buy a Free Energy Machine

Answer: Just wait one more year! 2003. Then get off the Grid!

Perhaps the most eagerly awaited event now is the marketing of Bearden's Motionless Electromagnetic Generator (MEG) scheduled to begin in about a year's time. This is when the proof will hit the fan. Many people have said to me, when talking about free energy, "I'll believe it when I can go to the store and buy one." Hopefully in a year's time they will be able to order their own MEG. And then they will believe, because it works and is working.

Says Bearden: "I will admit that the chief scientist of an important experimental group in a large company was rather stunned at the type of output we were able to obtain. The MEG may look like just a transformer, but it is not. It is a completely different breed of cat."

(Bearden : http://www.cheniere.org/correspondence/011202.htm)

Soon the cat will be fully out of the bag. The first MEG units will supply 2.5 kilowatts of free electricity. Forever. Units can be connected together to double or triple the wattage. After that gets going, 10 kilowatt generators are planned. Energy will flow freely from the time domain indefinitely, and there are no moving parts to wear out. This manufacturing project is a heroic effort and will change the world as we know it. For once people are in possession of such devices there can be no further denial from anyone, including the government and/or "secret-government."

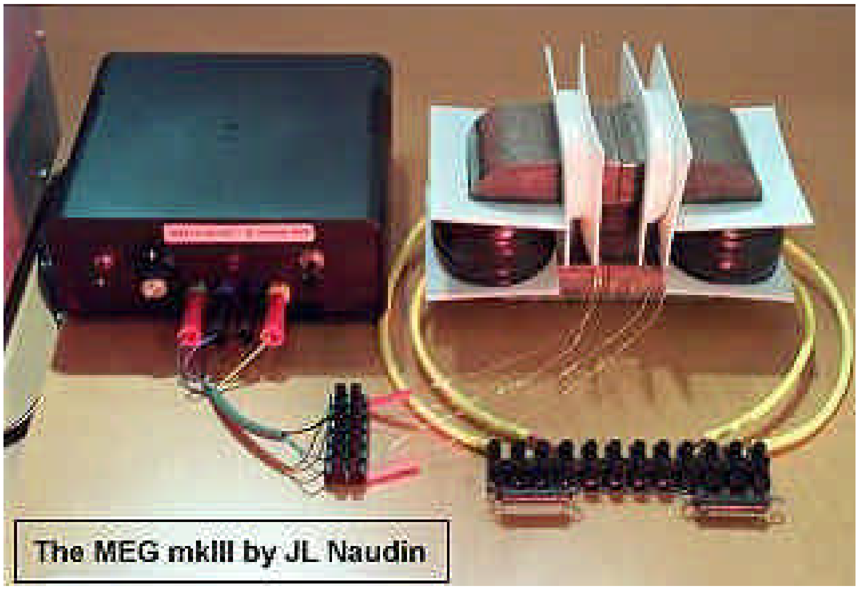

The Motionless Electromagnetic Generator

(Successfully replicated here by J. L. Naudin)

The physics of how the MEG works is explained in the paper "The Motionless Electromagnetic Generator: Extracting Energy from a Permanent Magnet with Energy Replenishment from the Active Vacuum."

The device was successfully replicated by J.L. Naudin in France, and others, like Steve Utne, are also working on their own models. But Magnetic Energy Limited's MEG is actually scheduled for production soon and looks to be the first commercially available free-energy generator in history!

I imagine it will not take long for tinkerers to put them into their electric cars and make the first fuelless automobiles since Tesla's unheralded (and unheeded) experiments. Or for builders to begin building houses powered by MEG's. Houses which will never see electric bills. How can they ever make enough of these to meet the demand that will suddenly be there? Bearden is right, it needs to be an all-out crash program of the government on the order of the Manhattan Project.

I must include here that Bearden is quick to point out that he is not himself the inventor of the MEG, but is a partner and advisor in bringing it to the public market through Magnetic Energy Limited, Inc. I must also admit that I am praying for the success of this venture, and the ending of the absurd and criminal withholding of this technology from the people by the black-ops military-industrial people. This secrecy has cost the planet over 30 years of unnecessary pollution.

The first units off the assembly line, which is being set up in a "friendly" unnamed nation, will usher the public at last into the new era of scalar electromagnetics.

As of December, 2001, the situation with the MEG was described by Bearden in a letter.

> "What we presently have with the MEG is a successful laboratory experiment. At least a year's very hard research will have to be done before we will be ready to put a commercial power supply into production.
>
> "Consequently, we have made an agreement with a foreign partner (the National Materials Science Lab of the National Academy of Sciences of a friendly foreign nation) to do that year's research. At the same time, we are trying to make an agreement with one or more large financial partners here in the U.S."
>
> Bearden http://www.cheniere.org/correspondence/121901.htm
>
> "So we are hopeful that we will be able to start introducing units on the market about a year from now. Quite simply, we will either succeed or we will fail. But we will give it our very best effort."
>
> Bearden http://www.cheniere.org/correspondence/012202a.htm

Bearden has given another technical explanation of how the MEG works here in a letter.

Motionless Electromagnetic Generator patented, 3-26-2002

Click here to read the patent

"In Magnetic Energy Limited, all business discussions and arrangements are taken care of by Dr. Lee Kenny, Managing Partner. There are five of us who are co-inventors of the MEG, and two of the others are really the principal inventors." Bearden http://www.cheniere.org/megstatus.htm

Free Energy has been Suppressed

Secret Government Aware of Free Energy

> "In this world of contemporary times, all the agencies, CIA, FBI, KGB, NSA, Electric Power Research Institute, DARPA, Brookings Institution, Henry Kissinger, Edward Teller, et al., all are aware of [free-energy researcher Bruce] De Palma and his ideas.
>
> "Because these individuals and institutions are employed by the ruling elite to forecast the future and satisfy present needs and demands, it is clear that free energy is a threat to the world order constructed by business and the mindset of those who want to own the world.
>
> "Free energy represents Man's aspirations and dreams of freedom and equality, uniform division of resources and the ability to choose one's own future.
>
> "The fact that free energy is suppressed speaks to the greed and self-interest of a ruling elite which, even in the face of an emergency of global starvation, resource depletion and environmental pollution, will not give one inch if it means loss of control. This is an

> attitude of paranoid delusion and fantasy which can only arise from the alienation of a class of elitists who, through their money, are completely insulated from the reality of the day to day fight for existence of the common man."
>
> http://depalma.pair.com/Absurdity/Absurdity07/ProblemOfFreeEnergy.html

Bearden describes one case of suppression when the Yakuza killed the Kawai engine in his very presence in Huntsville, Alabama.

> "That night a jet arrived from Los Angeles, with a Yakuza on board. The next morning Kawai no longer controlled his company, his invention, or his own fate. The Kawai party was in fear and trembling. The Yakuza coldly dissolved the agreement, they packed up the two Kawai engines we had, and left. And that was that."

So it is not only governments who are keeping this revolutionary technology from seeing the light of day. The Yakuza? KGB? The Aum Shinrikyo cult? Our "leaders" need to be honest about what is going on, otherwise they look foolish, acting out a kind of "Alice In Wonderland" script before the public, a script that has become completely unbelievable.

Concerning the criminal withholding of this scalar technology by the military black-budget people, and the cover-up of the actual situation regarding scalar weapons throughout the world, Tom has this to say:

> "The high government officials of the United States of America grossly violated our constitution and their sworn oaths of office. Our constitution specifically charges the government of the United States to defend the people of the United States. That means our officials are specifically charged with defending our people. Yet they deliberately agreed not to do so, and they deliberately sacrificed us in advance.
>
> "They committed treason of the highest kind, by deliberately surrendering us to total destruction anytime the big balloon goes up."
>
> Bearden http://www.cheniere.org/books/ferdelance/s75.htm

Energy Crisis Solved

One of the "must read" documents at Cheniere is “The Unnecessary Energy Crisis: How to Solve It Quickly,” especially since the "oil wars," which Bearden has foreseen for decades, have now already begun.

Here are some clips from that Document:

> "To avoid the impending collapse of the world economy and/or the destruction of civilization and the biosphere, we must quickly replace much of the "electrical energy from oil" heart of the crisis at great speed, and simultaneously replace a significant part of the "transportation using oil products" factor also.

> "The technical basis for that solution and part of the prototype technology required, are now at hand. We discuss that solution in this paper."

And although the solution to the energy problem and the oil wars may be at hand, Bearden suggests there is still an urgent rush that needs to be made to save human civilization from collapse.

> "Once the technology hardware solutions are ready for mass production, even with a massive worldwide deployment effort some five years are required to deploy the new systems sufficiently to contain the problem of world economic collapse. This means that, by the end of 2003, those hardware technology solutions must have been completed, and the production replacement power systems must be ready to roll off the assembly lines en masse.
>
> "The 2003 date appears to be the critical "point of no return" for the survival of civilization as we have known it.
>
> "Reaching that point, say, in 2005 will not solve the crisis in time, and the collapse of the world economy as well as the destruction of civilization and the biosphere will still almost certainly occur, even with the solutions in hand."
>
> "The good news is that we now know how to easily initiate continuous and powerful "electromagnetic winds" from the vacuum at will. Once initiated, each free EM energy wind flows continuously so long as the simple initiator is not deliberately destroyed."

On page 9 he explains the concept of the dipole, and how there is already huge scalar energy flowing in the time domain around any dipole. Hold a magnet or a battery in your hand and you hold a stress in time and a beautiful flowing loop of longitudinal waves!

Bearden decries the scientific community in the West for being unable to let go of their dogma long enough to see that the greatest discovery in human history lies at their feet, but for their stubborn ignorance.

> "The present energy crisis then is due totally to that "conspiracy of ignorance" we referred to, that is maintained by the scientific community, and that has been maintained by it for more than 100 years.
>
> "This is the real situation that the environmentalists must become aware of, if they are to see the correct path into which their energies and efforts should be directed — to solve both the energy crisis and the problem of gigantic pollution of the biosphere. "As far as anyone in the legislative branch of government ever understanding the profundity of the discovery and engineering of scalar waves, Tom Bearden says they are at a great disadvantage in doing so.
>
> "The nontechnical person — e.g., a Senator or a Congressperson — is operating under a distinct disadvantage. If he or she takes the stance that much better electrical power systems can readily be achieved, he or she is in fact opposing almost the entire set of University, Government Technical, Power Company, Battery Company, and Organized

> Science communities. Further, in most cases his technical advisors are themselves from one or the other of those communities, and likely to go back into that community or those communities when the Senator or Congressperson leaves office, or even before. So the Congress and the non-technical government community at large operate at a great disadvantage...Bearden National Emergency Declaration is Needed
>
> "The Government Non-Technical community (the Senate and the Congress, in particular) are in far better shape than the Government Technical community, to appreciate the world implications of the pending economic disaster. I am hopeful that both the environmentalists and the Government Non-Technical community will rapidly unite in a common goal to get this vacuum energy program launched, under a National Emergency declaration. If so, then they can solve the energy crisis and the pending economic crisis, in fairly short order, and permanently."
>
> unnecessary_energy_crisis.htm#congress_disadvantage

In the conclusion of his paper The Unnecessary Energy Crisis: How to Solve It Quickly Bearden again states the urgency of replacing our centralized power grids with highly dispersed and local taps on the freely flowing energy of the active vacuum. Given the abilities of the Tesla howitzers, the power grids of all nations are sitting ducks.

> "Personally, the present author regards the increasing energy crisis as the greatest strategic threat to the United States in its entire history. I will do anything within my power to help prevent what I perceive to be the looming economic collapse of the Western world, preceded or accompanied by a sudden, explosive, all-out and continuing exchange of the WMD arsenals of most of the world.
>
> ...In the name of all humanity, let us begin! Else by the time this first decade of the new millennium ends, much of humanity may not remain to see the second decade."

3. Weaponization

Scalar interferometry, Tesla howitzer, Tesla dome, heat/cold, dudding, 10 nations have them, dead-man fusing & Insane Systems, scalar strategy, earthquakes and weather wars, solar storms, mind attacks, leased to Yakuza, many examples of testing, quantum potential weapons.

> "Indeed, Soviet energetics weapons are now capable of destroying both our triad shield, our homeland, our armed forces in the field, and our population, quickly and efficiently. We have a new "gap" of monumental proportions: not a missile gap, not a submarine or bomber gap, and not even a particle beam or laser gap. We have a scalar electromagnetics or electrogravitation gap." Bearden http://www.cheniere.org/books/ferdelance/intro.htm

"**We have a new weapon, just within the portfolio of our scientists, so to speak, which is so powerful that,**

if unrestrainedly used, it could wipe out all life on earth. It is a fantastic weapon." Khrushchev, to the Presidium, Jan. 1960

> "We've totally missed the most incredible "secret superweapons" development program of all times, and the worldwide testing of the weapons themselves.
>
> "Hiroshima and Nagasaki should serve as object lessons in the price of ignorance of such technological breakthroughs.
>
> "History does repeat itself. But this time it's not we Americans who got the great new superweapon first."
>
> Bearden http://www.cheniere.org/books/ferdelance/s75.htm

Warfare has been changed forever by the development of these scalar energy longitudinal wave howitzers. To get a basic understanding of scalar waves is to have the imagination suddenly run wild as all the implications and possibilities regarding warfare fall into place. One realizes with a certain horror that the world has totally changed, and that there are some very fearsome possibilities. Remember, the power for these weapons comes from the time domain, longitudinal EM waves in the vacuum of empty space, and the power is tremendous and mind-boggling. Being able to blast away at any target from a distant control booth is something that has never happened before. This is incredible power to be in control of and it divides the history of weaponry into "before" and "after." And the destructive power of these weapons is delivered instantaneously to the target from the local vacuum at the place of the target.

From an interview:

> Questioner: "Are you saying that real energy can be transmitted faster than the speed of light?"
>
> Bearden: "Yes. But hyperspatially. Not through 3-space, but "around" it. Again, this means that it's possible to produce energetic changes in a distant system at a distant place, without transmitting energy "through space" in the normal sense. You transmit "around" space, so to speak, and directly in time or through a higher dimension, depending on the model you're using to understand this. Further, the speed of the internal EM energy transmission is not limited to the speed of light."
>
> http://twm.co.nz/beard_interview.htm

Here are some initial considerations about scalar weapons and scalar wars

1. Tesla Howitzer 2. Tesla Domes 3. Rogue groups 4. WW III 5. Russian "UFOs?"

3a. The Tesla Howitzer and its modes of action

Source: Tom Bearden's weapons slides and Fer-de-Lance Briefing

For one thing there is no delivery of any thing to any place. Bombs are obsolete. So are the planes to get them there. No helicopters necessary. All current nuclear devices are rendered nearly useless by electronic "dudding." All distant-destruction can be done from a control room, and to any point on earth. The destructive power of "men" has just increased by orders of magnitude. The new weapons could even cause storms on the sun! Thus there is great urgency to make these new facts public and known, with the hope that all nations would come together to ban the use of scalar weapons.

Two scalar antennae together along with the computers to control them, make up a scalar interferometer, and according to Col. Bearden the Russians have hundreds of such installations already. These interferometers are called "Tesla Howitzers." They can deliver a giant blast of energy to the distant target site, true "action-at-a-distance".

The first howitzer mode is called the "exothermic" mode of operation because immense EM energy blasts outward at the target site. The blast of a scalar howitzer can be of near nuclear level in destructiveness, and can be repeated easily, at that place, or nearby, or anywhere.

The howitzer can use a lesser exothermic power setting and simply destroy all electronics in the target area. Thus they can render our nuclear missiles inoperable as they sit in their silos by "frying" the electronic circuits that guide them. They can bring down any airplane, anywhere in the world, at any time. Any person anywhere, if their exact position is known, can be assassinated without a shot being fired.

The howitzers can also bring down power grids anywhere in the world, at any time. Thus they could bring Wall Street to an instant halt by disabling all its electronics. Even this one little easy tweak of the howitzer could cripple the U.S. economy in a single day. No wonder the "leaders" don't want you to know! This is a new era we are in. The discovery and development of scalar interferometry has put us in a new world, whether we like it or not. Anyone could be expected to go into denial, the befuddled senators and congressmen included. But we have to wake up.

In a second howitzer mode called the "endothermic" mode, the howitzer sucks energy out of the target area, essentially creating a blast of cold at the distant target. It is even capable of freezing parts of the ocean. Bearden gives a number of cases where these "cold explosions" have been witnessed, mostly by airline pilots. April 9, 1984: 1 2 3) A huge mushroom cloud of mostly water is seen rising miles into the sky from out of the ocean, an awesome sight.

In the endothermic mode the sucked-out energy must go somewhere, so it is vented out at some other chosen spot on the earth. These endothermic plumes have been photographed by satellite.

> "The exhaust in the left picture is about 150 miles long, and is nearly horizontal (about 1.5 degrees above the horizontal). It is entirely consistent with the continuous exhaust from a "dumping transfer" scalar EM howitzer in the continuous exothermic mode. (The primary howitzer, of course, was activated in the endothermic mode.)" Bearden More Plumes

By using both of these heat (exothermic) and cold (endothermic) modes together the weather can be altered anywhere. Warm the air over here, cool it down over there, put a curl in the jet stream, dissipate clouds, create clouds, whip up a tornado. Bearden speaks about using the endothermic howitzer mode as a weapon of war:

"Cold explosions can be used to freeze tanks, personnel, and equipment. The equipment and tanks thaw out. The personnel thaw out too, but they are dead when they do." Bearden, Fer-de-Lance

(This endothermic mode of the howitzers makes me think that there might one day be a cure for the problem of global warming after all. Could not a big device, situated in space or on the moon, be able to vent a great deal of excess heat outside the atmosphere into space, thus functioning as a kind of planetary thermostat?)

While the United States has experimented with electomagnetic weapons using ordinary transverse EM waves, the longitudinal [LW] weaponized waves are truly of another order altogether.

For one thing they do not have to travel through space, for they come from the time domain, which is everywhere. The energy of the blast, the heat or light or whatever, comes from the vacuum of space at the location of the target itself. This is astonishing. The weapons actually just trigger the release of immense energy from the vacuum at the target location.

> "... it is possible to focus the potential for the effects of a weapon through spacetime itself, in a manner so that mass and energy do not "travel through space" from the transmitter to the target at all. Instead, ripples and patterns in the fabric of spacetime itself are manipulated to meet and interfere in and at the local spacetime of some distant target. There interference of these ripple patterns creates the desired energetic effect (hence the term energetics) directly in and through the target itself, emerging from the very spacetime (vacuum) in which the target is imbedded at its distant location." Bearden Fer-de-Lance

The big Tesla howitzers are aimed at their targets by using a worldwide electromagnetic pattern called the "Woodpecker Grid," begun by the Russians in 1976.

You can hear the Woodpecker signal here: http://www.cheniere.org/misc/woodpeckersound.htm

The woodpecker grid is just that, a grid of EM waves which provide a channel for the LW waves to any point on earth. Computers use the woodpecker grid information to hone down the aiming of the howitzers to a pinpoint location on earth. (For that matter, it could be under the earth, in space, or under the sea).

A third howitzer mode is what Col. Bearden calls "Mindsnapper" mode. This is a truly frightening mode which affects the electromagnetic mind-body connection. Being mind-snapped at a low level would cause you to lose consciousness. Being mind-snapped at a slightly higher power would "entrain" all minds in the target area into a kind of hypnogogic trance, a state in which they would all be highly susceptible to suggestions and orders.

Being mind-snapped at high level would so disrupt the mind-body connection that everyone in the target area would fall down, instantly dead. Not only that, everything around you and inside you would be killed, so that your sterilized body would not rot for quite a long time.

The Mindsnapper can be used for a small area, or to kill an entire population. In fact, using the scalar waves to affect the human mind has become a new field in its own right, and has been dubbed "psychoenergetics." (This is discussed below in section 5).

Bearden describes the use of the howitzer in mind-snapping mode against people, to cause unconsciousness or death:

> "From a military viewpoint, these scalar EM weapons are really quite all-around weapons.
>
> "For example, they are very lethal against personnel.
>
> "Set in the "high intensity pulse mode," one blast and a person's nervous system is destroyed instantly. Total, instantaneous death results. One can blast away at entire groups of infantrymen, for example. It's the peak power that's important, not the average power. So the weapon doesn't require too much battery power.
>
> "Set on a lower intensity pulse mode, one zap can simply knock out a person, rendering him instantly unconscious. Quite useful if one needs prisoners to interrogate. Also very silent, which is useful in operations employing stealth and surprise." Bearden http://www.cheniere.org/books/ferdelance/s80.htm
>
> "Those hit by the scalar EM weapon, however, have a most peculiar death mode.
>
> "Death comes-instantly and totally. There is no convulsion, no response. The entire nervous system is destroyed instantly. Every living cell in the body is killed instantly, including all bacteria, germs, etc.
>
> "A body hit with this thing falls like a limp rag and lies where it falls. It doesn't decay in even 30-45 days. In a macabre fashion, it's been reduced to something like food irradiated with nuclear radiation; everything is killed, so the material is preserved for an extended period before any decay can set in."
>
> Bearden http://www.cheniere.org/books/ferdelance/s81.htm

He goes on to say that the same "bazooka-sized scalar EM pulse weapon" can also be used to knock out a tank with one shot (or pulse). So tank warfare is obsolete. Helicopters? Bearden points out: "... if he's attacked by a helicopter or a fixed-wing aircraft, he can bring the same weapon to bear on it. He can knock down a chopper or a jet. With one shot."

Obituary for Tank Warfare

Tanks useless against portable LW weapons

> "For example, suppose one attacks a tank. [with an LW weapon] With scalar EM pulse, the personnel die instantly. Total personnel kill is achieved.
>
> All electronic systems of the tank are dudded. Total systems kill is achieved. The ammunition in the tank explodes. Total kill is achieved.
>
> The fuel explodes. This is another total kill mechanism.
>
> That tank has been killed totally, by a variety of mechanisms, all simultaneously.
>
> That's a k-kill in any analyst's book.
>
> And don't worry about retrieval and repair. That tank is finished permanently.
>
> Even the most modern tank is just as vulnerable as the most obsolete."
>
> Bearden http://www.cheniere.org/books/ferdelance/s88.htm

One begins to get the idea how profoundly the conventional means of warfare have been obsoleted. All the usual weapons of war have been rendered nearly useless! And Star Trek's "Phaser," with its "stun" and "kill" modes is here at last.

Although it is the weapons aspect of scalar electromagnetic which has received the most developmental effort, Bearden points out that a great many other amazing things that may be accomplished in this new field of science. Beam me up Scotty!

> "Superluminal communications systems, hyperspace drive, and materialization and dematerialization are all hypothetically possible, using scalar electromagnetics. As the technology develops, we should see the development of many of the systems long thought impossible except in science- fiction."
>
> Bearden http://www.cheniere.org/books/ferdelance/s15.htm

Bearden describes a huge test of the Russian scalar weapons systems which occurred in 1985, a test that went completely unnoticed by western scientists:

> "Just before May 1, 1985 the Soviet Union performed a "full-up" operational test of their entire strategic scalar EM weapons complex. This test was detected and monitored periodically by Frank Golden. Some 27 of these giant Soviet "power taps" were locked into the molten core of the earth, producing forced (entrained) scalar resonance of the entire planet on 54 controlled frequencies under our very feet. The remainder of the scalar frequency spectrum was ablaze with literally hundreds of Soviet scalar transmitters: probably the entire strategic scalar command and control system to

> underwater submarines, higher command centers, distant commands, etc. was activated in the giant exercise.
>
> "For several days, the system was exercised on a mind-boggling scale, apparently as part of the Soviet Union's highly accentuated 40th anniversary celebration of the end of World War II.
>
> "Ironically, not a single U.S. intelligence agency, laboratory, or scientist detected this monstrous exercise for the new Soviet leader, Gorbachev. Not a one of them had a detector for scalar EM radiation, and not a one of them officially believes the exercise ever happened."
>
> Bearden http://www.cheniere.org/books/ferdelance/s38.htm
>
> "The Woodpecker grid/howitzer weapon system can be placed over the ocean and used against cruise missiles, naval surface-to-air and surface-to-surface missiles, submarine-launched ballistic and cruise missiles, etc. Placed over a carrier task force, it can also take care of the aircraft launched by the carrier as fast as they are launched. It can also handily take care of the missiles launched by guided-missile cruisers of the accompanying task force."
>
> (Bearden http://www.cheniere.org/books/ferdelance/s65.htm)

The whole series of the Fer-de-Lance briefing slides and comments is a "must read" for anyone wanting to be aware of the actual state of things in this world right now. It is a new world and it takes some getting used to. Fer-de-Lance speaks clearly, for the layman, of the way things stand.

What is it like to operate these Tesla Howitzers? Col. Bearden gives us an idea in his "Fer-de-Lance" briefing, Slides 66-71.

Who needs armies anymore? A entire war can be fought and won by a handful of men sitting in a comfortable control booth! The scalar electromagnetics revolution has made all previous forms of warfare nearly obsolete.

Why haven't the Russians used the scalar weapons yet?

Bearden gives his thoughts on this in "Fer-de-Lance." The power of these weapons is so great that an accident or war could wipe out all life on earth, and even affect the sun.

> "As can be appreciated, this entire concept [MAD] is now totally obsoleted by the Soviet possession of scalar EM weapons.
>
> 'The "mutual assured destruction" capability -- or MAD concept as it was so aptly named! -- is no longer mutual. And for two reasons: (1) the Soviet surprise attack could destroy essentially all our Triad forces wherever they are, in the first attack. (2) Even if a very small number of our strategic forces survive, the puny strike we could attempt to launch could be repeatedly decimated from launch to terminal phase.

> 'The restraint on the Soviets is not because of our Triad forces. The restraint is twofold: (1) a second nation has scalar EM weapons, and would undoubtedly unleash them upon the Soviet Union with great violence if such a massive world-wide destruction of U.S. forces occurred or was threatened (is it really "accidental" that six major Soviet missile ammunition storage sites mysteriously exploded within seven months?); (2) the closed-loop scalar radiation exchange system of Earth-Sun could be inadvertently "tweaked" in the feedback loop from Earth to Sun, so that a large solar scalar resonance was stimulated. In that case the Sun could emit a mighty resonant "burp" that would simply wipe out all life on Earth in a fiery shower.
>
> 'The "terror" in the "balance of terror" between nations has just increased by many, many orders of magnitude.
>
> 'The biblical prophecy that the Earth will be wiped out by "fire and brimstone from heaven" is very near fulfillment now.
>
> 'Put another way, the pucker factor -- even on the Russians who may contemplate unleashing Armageddon -- is higher than any Western strategic analyst has ever imagined, even in his wildest nightmares.
>
> 'Truly these weapons are "more frightening than the mind of man has imagined," as Brezhnev put it in 1975.
>
> 'The frightening scalar EM weapons can be used, but only very, very gingerly indeed. If a slight mistake is made, everybody loses everything."
>
> Bearden http://www.cheniere.org/books/ferdelance/s74.htm

But the Russians (KGB) are not the worst of it. Bearden claims that some of the scalar weapons have been leased to the Yakuza for about a billion a year, and that only the KGB is holding the Yakuza in check from making a full-scale all out scalar attack on the west.

U.S. Defense Secretary William Cohen

Warns about eco-terrorism using scalar electromagnetic weapons

> "Others [terrorists] are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves... So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations...It's real, and that's the reason why we have to intensify our [counter terrorism] efforts." - Defense Secretary William Cohen, 1997
>
> In a letter to a writer named "Russell" Bearden says,
>
> "In short, Russell, the Secretary of Defense of the United States confirmed that there are indeed novel kinds of EM weapons, right now and have been for some time, which have been and are being used to (1) initiate earthquakes, (2) engineer the weather and climate,

> and (3) initiate the eruption of volcanoes. We wrote about those exact uses of the weaponry decades ago. Several nations now have such weapons. Three of them (two on one side and the other on a hostile side) are even firing practice shots into Western Australia, as a convenient test range."
>
> http://www.earthchangestv.com/ufo/0209gandor.htm

Tesla Howitzers in Weather mode

How to Make Weather

> "Engineering the weather is duck soup; they tested that over the U.S. in 1967, and entered upon continuing operations over North America on July 4, 1976 as a grim kind of KGB "Bicentennial Gift" to the United States. Here's how it is done with several interferometers.
>
> "First, the interferometers can deliberately make "high pressure areas" (cool the air so it shrinks and its "footprint" pressure on the ground increases because its density increases) and "low pressure areas" (heat the air so that expands and its "footprint" pressure on the ground decreases because its density decreases). Well, if one makes the highs and lows where one wishes them, and judiciously and somewhat slowly moves them along a given path, these highs and lows will entrain the jet streams and thus "steer" the weather.
>
> "So if you wish a very cold snap or attack, go up into Canada and start these actions to steer down some streams that bring some very frigid air. Establish other highs and lows judiciously to "block" or "slow" other jet streams and flows as desired. In this way, one can pull the "large cold air masses coming down from Canada" deep into the southern U.S. at will. They do it regularly. If you wish an ice storm, add an additional current of warm moist air you bring up (steer up by using artificial highs and lows) from the ocean. Where they meet, you will get freezing rain, then sleet, then severe icing accumulating. This type of attack does rather large damage to the struck area."
>
> http://www.earthchangestv.com/ufo/0209gandor.htm

Whole websites have now sprung up showing weather radar anomalies which may well be indications of scalar weather engineering. One list of over 500 images is here. Cheniere has its own collection here.

In another section at Cheniere are many photos of cloud anomalies which reveal the underlying grid along which the clouds are forming or un-forming. Bearden relates a startling incident in these clandestine ongoing "weather wars."

> "During the spring of 1986, abnormally strong Soviet weather engineering occurred over the U. S., causing a drastic drought in the southeastern U.S. This drought was broken by a colleague who used an extremely powerful scalar EM device to redirect jetstreams. A most unusual and unique signature of the "blocking" against the Soviet scalar EM actions

resulted: Two huge circulations developed in the atmosphere, clearly showed as two adjacent giant "holes" in the swirling cloud cover over the middle and eastern U.S.

"Between these two giant holes, the cloud circulations formed a stream of clouds, moving to the south, looking very: much like a giant vertical "bar" of a huge "Y-shaped" cloud flow.* Several national weathermen commented on this unusual pattern, which had not been observed before. The pattern continued, day after day, as the blocking continued."

* On the weather maps.

http://www.cheniere.org/books/analysis/history.htm

Tesla Howitzers in Earthquake mode
How to Make an Earthquake

"Here's how you initiate a very large earthquake with such weapons. Take a convenient fault zone of set of them. Focus the interferometry on the fault zone, in the "diverging" mode, and deposit EM energy there in the rocks on both sides, increasing (slowly) the stress in the rocks by the reverse piezoelectric effect (deposit excess energy, get crystal mechanical movements).

"Do it slowly, and the stress will build up to large pressures well-above a plate slip minimum energy required. At some point, the rocks yield and one or both sides "slip" and move rather sharply, giving a very large earthquake in that zone.

"Do the same thing down in the earth (remember, LWs easily penetrate right through the earth and ocean at will, and so the "interference zone" focus can be inside the earth or beneath the ocean, at will.

"Anyway, focus this thing down to where the active part of the volcano is still slumbering, down where the hole in the plate has been made. Keep increasing the deposition of energy in the magma itself, and eventually the increasing pressure from deep within that volcano, underground, will cause an eruption. Build the energy slow, and the eruption will likely be much larger."

http://www.earthchangestv.com/ufo/0209gandor.htm

Yugoslav Earthquake, Followed by Cold Explosion

Strange Characteristics of Iran Quake, Sep. 1978

Tesla Howitzers in Tesla's "Big Eye" mode

How to make a Big Eye in the Sky

By using longitudinal wave interferometry in a weakly endothermic mode a new kind of "radar" is now possible, one which can look right through the earth and oceans. Because the endothermic mode extracts energy from the distant target, a pattern of the target area can be scanned for in the returned energy.

> "Thus the receiver produces a representation of the energy extracted from various locations within the distant endothermic zone. By displaying the received signals on an appropriately scanned screen, a representation of the distant scene in the intersection zone can be created. Indeed this is a special kind of "microwave interferometry," and -- with modern techniques -- the imagery obtained might be surprisingly good. With development, it might even become as good as the image presently obtained by side-looking acquisition radars.
>
> "Interestingly enough, since scalar EM beams will easily penetrate the earth or the ocean, one can also look beneath the earth or beneath the ocean with this type of scanning scalar interferometer.
>
> "The importance of this capability to strategic and tactical reconnaissance is obvious. Camouflage, cover, and concealment have no effect on such a system. One can easily look inside buildings and into underground facilities. With a small system such as this, the U.S. Marines at Khe Sahn would have had little difficulty locating the tunnels continually dug under the perimeter by the Viet Cong. And targets under jungle canopies are directly visible."
>
> Bearden http://www.cheniere.org/books/ferdelance/s42.htm

Tesla Howitzers can destroy all life on earth

How to Make a Storm on the Sun!!

(Just make a big mistake with your Tesla howitzers)

The deepest dangers of the use of scalar weapons are frighteningly pointed out by Bearden here where he considers that the sun, earth and moon (actually the whole solar system) is a delicately balanced arrangement of scalar (longitudinal) EM radiation. There is a scalar connection between the earth and the sun, which are both giant dipoles gushing energy in the time domain. Big scalar events on the earth could alter this balance causing true catastrophe.

"Indeed, a solar response could be stimulated so that the Sun would violently belch and destroy our biosphere, among other effects."

Unrestrained scalar warfare could cause huge solar storms? To realize that human activity could actually affect the sun itself is truly mind boggling.

Bearden goes on to say:

> "Accordingly, use of huge scalar EM weapons is a double-edged sword. Unless carefully employed, use of the weapons could cause a terrible backlash to the user as well as the victim, and even accidentally cause the destruction of the earth itself. It is not accidental

that in 1960 Khrushchev stated that his new fantastic weapon could -- if unrestrainedly used -- destroy all life on earth.

"This appalling backlash potential is apparently what prompted Brezhnev in 1975 to make so strong an effort to get agreement to outlaw the development of "new weapons of mass destruction" more frightful than the mind of man had even dreamed of. Gromyko even introduced such a draft agreement into the proceedings of the United Nations. The first article of the draft agreement indicated that the nature of the weapons referred to would be negotiated. Sadly, the entire Western world did not even know what the Russians were talking about."

http://www.cheniere.org/books/ferdelance/s24.htm

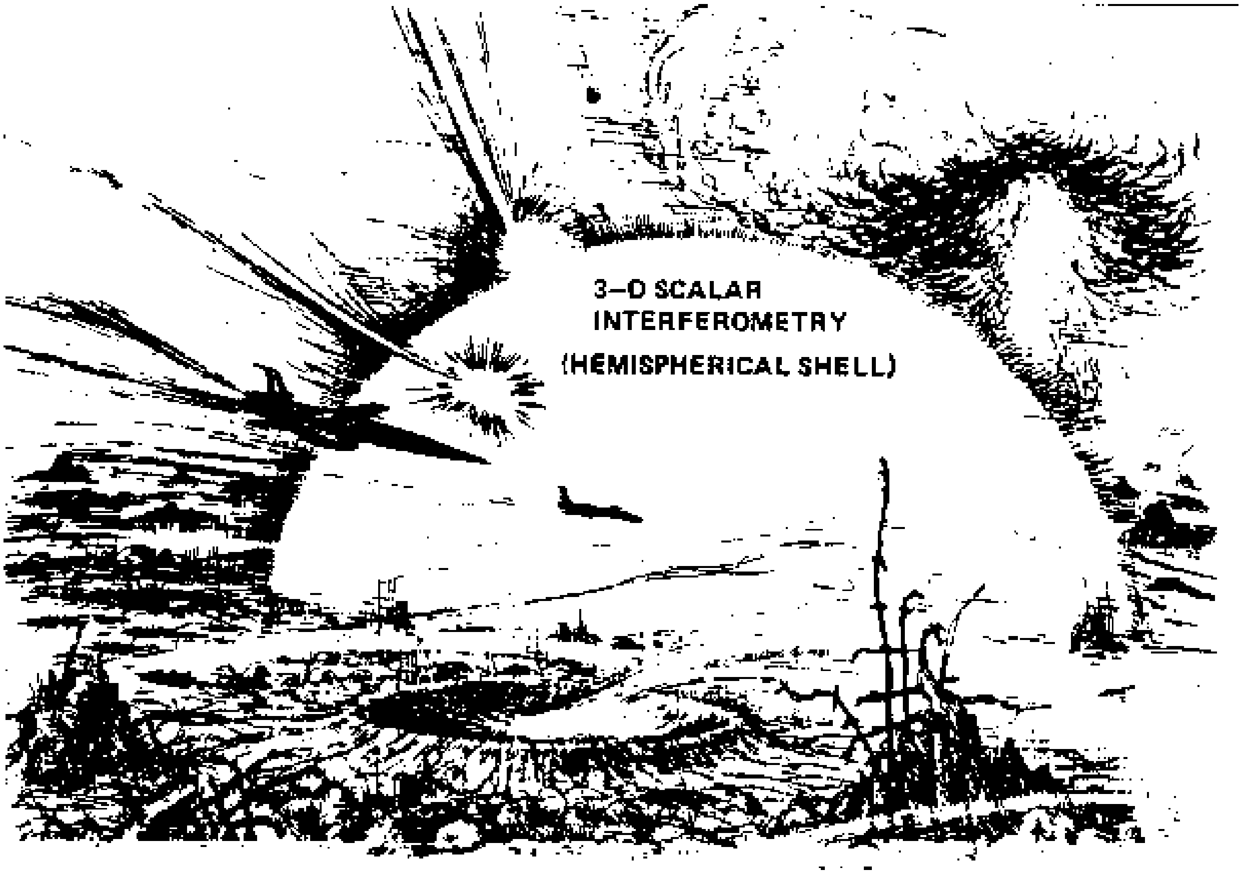

3b. Tesla domes provide near-perfect defense shield.

(Slide from Cheniere.org)

The Tesla howitzers can be used in a nearly impregnable defensive mode whereby they throw up a dome (**Tesla Dome**) or a sphere (**Tesla Globe**) of highly powerful electromagnetic energy, enough to "dud" or destroy missiles which try to penetrate them. Once again, this energy is not going through space from the howitzer, but being made to emerge from the local vacuum at the location of the shell. KGB tests of these domes have been witnessed by airline pilots around the world. Bearden gives many examples of the Tesla domes being sighted around the world in his briefing paper "Fer-de-Lance." (Russian dome test, another globe incident, yet another globe test). These giant electromagnetic domes can be hundreds of miles across, or narrowed down more to total impermeability.

> "Such a shell may be several hundred miles in diameter at the base. The enormous energy required to form such a defense shell is obtained by a "scalar power tap" into the molten core of the earth itself, as previously explained. In late April/early May of 1985, 27 such "power taps" were placed in the earth by the Soviets. If each tap is capable of powering four to six large scalar EM weapons, then the Soviet strategic scalar EM arsenal contains over 100 monstrous superweapons capable of generating exothermic explosions, endothermic explosions, engineering the weather, locating and destroying underwater submarines, detecting and destroying ballistic missiles shortly after launch, detecting and destroying long range strategic bombers as soon as they are airborne, etc."
>
> http://www.cheniere.org/books/ferdelance/s52.htm

By using nested domes one can protect the domed area even against nuclear radiation itself. Tesla globes can be used to hit airborne targets by simply placing a globe of any chosen size in the flight path of the incoming missile. It does double duty because the missile hits it going in, and then the rubble hits it again going out the other side.

While the U.S. persists in its useless boondoggle "missile defense system" by shooting a missile with a missile (missiles which would already have been "dudded" by the Tesla howitzers), between the domes and the globes the Russians (KGB) have in hand (operational) a nearly perfect missile defense system. Someone should ask the Secretary of Defense if the U.S. Tesla domes are in place. And over which cities? How powerful are our American Tesla domes?

Bearden cites a number of examples of these domes being tested around the world:

March 20, 1969 | March 24, 1977 | August 17, 1980 | June 17, 1966 | June 18, 1982 | June 22, 1976

In a slide from the Fer-de-Lance briefing it is shown how the "woodpecker grid" itself also acts as a sensor, detecting any missile launch anywhere, and how the howitzers can respond instantly by delivering a blast to exactly the right coordinates, right along the channels of that same grid which is feeding the location information about the missile launch. This certainly beats "trying to hit a bullet with a bullet." Especially since YOUR bullet would probably be instantly inoperable in a real scalar war situation.

3c. Rogue Groups in the government

Bearden fears that these scalar electromagnetic secrets may have fallen into the hands of what he called secret "rogue groups" within the labyrinthine depths of the black-ops special-access domain of the secret government. "In the extreme, such a deep black program can even become a "captured" program," he says, "which is totally in the hands of rogues and no longer reports to or is bound by the dictates of the parent government."

> "They have their own agendas. And being rogue groups, they may well bring in unethical, immoral tricks: assassination, bribery, entrapment, disinformation, plausible deniability, etc. A certain percentage of a highly secret rogue group will wind up using all these things and more. It's a human characteristic, the old primate dominance game. Only now disguised and hidden under deep classification. ...
>
> "In highly classified groups, these groups are greatly enabled to joust more widely, unethically, and immorally because it is so deeply hidden. So very deep classification evokes the growth and intensity of rogue groups. It's the old 'Power corrupts, and absolute power corrupts absolutely' routine. ... Due to loose formation of rogue groups inside such programs, they may have dual or triple purposes, may not operate under very much legitimate government control at all, and may operate specifically for the purposes of the rogue group or groups that have gained control."
>
> "The involvement of at least some rogue groups, some being "cowboys" who operate well outside all laws and ethics, could also result in such things as assassinations, clandestine testing on individuals without their consent, etc. In short, it could account for what seems to be actually occurring. "
>
> http://www.cheniere.org/explore%20articles/mind%20control3/p05.htm

3d. World War III has already begun

Because it is now possible to cripple the power grids and electronics of any nation, that nation could be reduced to economic ruin without ever firing an actual "shot." Without electricity Wall Street cannot operate. Without electricity you quickly need martial law. One no longer needs to wage a conventional war anymore at all. There are now lots of new ways to bring any nation to its knees.

> "We are at war, whether we like it or not. And we are going to have strategic strikes on an unparalleled scale for us. Pearl Harbor was nothing compared to what is coming down, once we consider the "augmentation" and such.
>
> "When that factor is considered, then it's a totally new ball game on replacing the power system. There isn't going to be much choice; the old one is going to be destroyed or so badly crippled that it will collapse the U.S. economy in a way we have not seen since 1929. Of course, in such a case hitting us, we will be under martial law, the works, everywhere. For one thing, it's the only way you can keep the cities from imploding from within, by the criminal element, looting, robbing, killing, etc. Simply wait and see; it's on the way."

> Although Bearden has for years decried the "scalar-gap," and chided the military for falling so far behind the Russian KGB in the field of scalar electromagnetics, recent statements indicate that things may at last have changed somewhat.
>
> "In the new war, the first phase of WW III has already been completed. Hence President Bush's recognition that this is a total war, and has to be taken to the enemy no matter where he may be hiding or in what sanctuary or in what foreign nation. This is an entirely different war than anything the U.S. has ever fought in its history. And before it is over, it is going to kill more Americans than have died in all the previous wars in our history. The news media and the public have not yet recognized that awful situation and predicament. Most are already thinking that, well, we won in Afghanistan so it's just about over. Instead, it has only just begun.
>
> "Anyway, that's a brief uptake on some of the weapon situation today. Some 10 nations or more now have LWIs, and five have the QPs. I'm still working on how many have the appalling negative EMP weapons, but would estimate 6 or 7 nations have them in one stage or the other, either deployed or in at least advanced development. And in my estimation, the Yakuza will have them within three to five years if they have to build them themselves, and quicker if they can buy them from the Russians, Chinese, or???"
>
> Bearden http://www.cheniere.org/correspondence/030202a.htm

When he was asked the question '**Does the government listen to Tom Bearden?**" Bearden said:

> "Let me speak carefully. I am very satisfied with how I've been listened to in the quarters where the rubber meets the road. The West is no longer defenseless, not by any means. Cannot amplify it further than that."
>
> http://www.cheniere.org/correspondence/030202a.htm

Bearden has briefed the government a number of times and the Cheniere website contains a great number of his graphic military briefing slides.

3e. Are the Russians making "UFOs?"

Scalar electromagnetics engineering opens the possibility of antigravity vehicles and "hyperspace travel." In other words we can now make our own UFO's! Of such scalar-powered antigravity vehicles, which have now become possible, Bearden has this to say:

> "We might expect to see such vehicles glowing. Their various surface features and mechanisms might appear to be glowing or revolving lights, etc.
>
> "They could exhibit incredible "aerodynamic performance," seemingly in the atmosphere. Actually they would not be moving "through" the atmosphere at all, but through a higher space outside each particle of atmosphere.

> "They could seem to materialize and dematerialize.
>
> "They could seem to plunge into the ocean or rise out of it.
>
> "They could even seem to operate under the ocean or inside the earth itself.
>
> "Such anomalous vehicle performances have been seen all over the world, particularly since a few years after WWII.
>
> "It appears that one or more nations of Earth are operating such vehicles now in great secrecy. Our own "government" may even be one of these.
>
> "If so, it isn't our true "government/government." Instead, it's the "control group/government." It's government at the operational level, but at higher level it belongs to certain control groups who have penetrated our government's vitals and taken over all such projects."
>
> Bearden http://www.cheniere.org/books/ferdelance/slide32.htm

In an excellent article on her Earthfiles website, Linda Moulton Howe reports on the utter bafflement of Norwegian scientists over mysterious lights appearing in the valley of Hessdalen, Norway.

She writes of the research there: "The results can be broken down into two groups: 95% are thermal plasmas and 5% are unidentified solid objects. The plasmas emit long wave radio frequencies and strangely, their temperatures do not vary with change in size or brightness." She quotes the scientists' research summary:

> "1) most of the luminous phenomenon is a thermal plasma;
>
> 2) the light-balls are not single objects but are constituted of many small components which are vibrating around a common barycenter;
>
> 3) the light-balls are able to eject smaller light-balls;
>
> 4) the light-balls change shape all the time;
>
> 5) the luminosity increase of the light balls is due to the increase of the radiating area. But the cause, and the physical mechanism with which radiation is emitted, is currently unknown."

This would almost certainly seem to be another example of the testing of the scalar howitzers. It is baffling because, as Bearden points out repeatedly, Western scientists have limited knowledge of the scalar electromagnetic principles by which the howitzers operate. The Hessdalen scientists were completely baffled as to where the energy of these plasma balls was coming from.

Ms. Howe interviews Massimo Teodorani, Ph.D., Astrophysicist, who released the report on the 2001 Hessdalen sightings. The scientist speaks of the baffling phenomenon observed.

> "I don't know how it is possible that Nature is spontaneously able to do that. Anyway, we deduce that the plasma is trapped inside a sort of magnetic cage and the magnetic cage closes around the plasma and keeps it fixed in some way, prevents it from expanding. But where does it come from? We don't know."

By what we have been considering here, we can recognize the signatures of scalar electromagnetic engineering. If it is a Tesla howitzer, then the energy for the plasma balls is coming from the vacuum of spacetime at the very location of the balls themselves, triggered by scalar interferometers aimed through the woodpecker grid.

These kind of balls can be used as marker beacons giving feedback for precision aiming of the howitzers. The energy of the marker beacon can be read back into the computers giving precise location information for pinpoint aiming. The target area can be very small, or widened out.

There is a little movie of one of the Hessdalen plasma balls here. It would seem to be a clear documentation of a scalar howitzer marker-beacon. How many other current "UFO" sightings are actually the witnessing of Tesla howitzer tests?

In fact there are a great many anomalous events of the past few decades which might very well be explained by the Russian testing of their longitudinal electromagnetic weapons. It would seem that the mysterious appearance of crop circles around the world could be accomplished by feeding a precise mathematical graphic pattern into the computerized aiming software and change the very molecular structure of the crops themselves along the lines of that pattern. The

stalks fall over from the localized effect of the longitudinal waves. A plasma ball tracing patterns? Are they slyly sending a message to see if we are "getting it" yet?

The "Cambridge Angel" - Made by Russian scalar plasma balls?

Also see: Interview with Tom Bearden

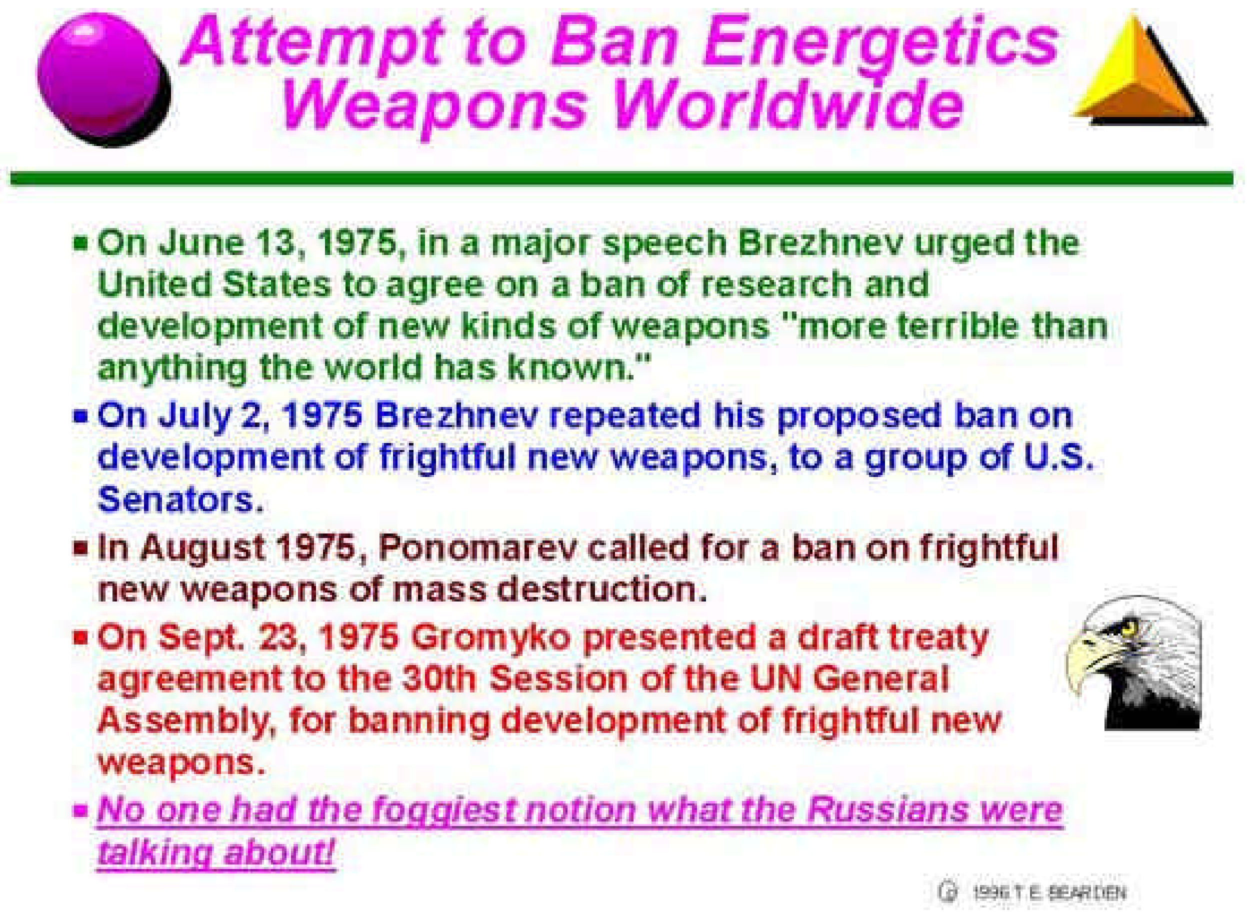

Attempt to Ban Energetics Weapons Worldwide

- On June 13, 1975, in a major speech Brezhnev urged the United States to agree on a ban of research and development of new kinds of weapons "more terrible than anything the world has known."
- On July 2, 1975 Brezhnev repeated his proposed ban on development of frightful new weapons, to a group of U.S. Senators.
- In August 1975, Ponomarev called for a ban on frightful new weapons of mass destruction.
- On Sept. 23, 1975 Gromyko presented a draft treaty agreement to the 30th Session of the UN General Assembly, for banning development of frightful new weapons.
- *No one had the foggiest notion what the Russians were talking about!*

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(Slide from Cheniere.org)

4. Healing powers of longitudinal waves

Healing via longitudinal waves, time reversal of cells (de-differentiation), Priore's machine, Bearden's proposed "blanket" version, using the electric power grid for healing waves or for broadcasting disease patterns. Scalar Biowar.

The good news!

> "Any sort of disease whatsoever - physical or mental - will be rapidly curable, simply and cheaply. It will be possible to reverse aging and rejuvenate the person. It will be possible to regrow limbs and straighten misshapen spines - and directly remove the causes of mental diseases and cure them as well. Lifespan will be staggeringly increased, without 'old age's debilitation.' AIDS, cancer, leukemia, and genetic diseases will be completely conquered. The potential for a true golden era is upon us, for all humanity."
>
> Bearden- http://twm.co.nz/beard_interview.htm

Proof of the healing powers of longitudinal waves from the vacuum is seen in the work of Antoine Priore who produced longitudinal scalar waves using a gigantic glass tube filled with plasma. He himself did not understand why it worked or how it cured cancer in animals.

> "The Priore team cured terminal tumors, trypanosomias, and other dread diseases in laboratory animals in France, in the 1960s and 1970s, under rigorous scientific protocols by eminent scientists. The Priore project was funded by the French Government to the tune of several millions of dollars (equivalent).
> http://www.explorepub.com/articles/energetics.html
>
> ". . . Prioré's machines concretely demonstrated a nearly 100% cure of all kinds of terminal cancers and leukemias, in thousands of rigorous laboratory tests with animals. These results were shown to medical scientists as early as 1960." http://www.cheniere.org/priore/index.html

Bearden has stated that the longitudinal EM waves can have a healing effect because they always come in pairs called "phase conjugate pairs" and one of the pair is time-reversed. This enables engineering of the waves to "pump" the cells of the body (with waves from the time domain) and actually time-reverse the cells back to a previous healthy condition. The scalar cure of cancer does not involve killing the cancer cells but rather pumping them with time energy into a previous condition. I know, this seems miraculous, and is it not?

Priore and his giant plasma tube

This healing power in the longitudinal waves of the time domain is a mind-boggling thing to face. It took me months to get through it, and to suffer the fact that the cure for cancer and AIDS was right there, in this new scalar electromagnetics technology, and that it has been kept back from the people for so many decades now.

Bearden has a great deal to say about the work of Priore, who himself did not understand why his machine worked. Priore did not know about the longitudinal scalar waves of the time domain. In fact, Tom Bearden has supplied, at last, the missing explanation as to how that big giant two-story glass tube consistently cured cancer in animals.

"**The medical implications are enormous**. By just reversing the damaged cells back to a previous physical state, this gives a physics mechanism for controlled cellular dedifferentiation, in biology terms. Physicians will time-reverse diseased, damaged or aged cells back to an earlier healthy condition, including all the cellular genetics. Normal cells are just reversed to a slightly younger condition."

> "We believe this mechanism explains the revolutionary but baffling electromagnetic cures achieved by a team of outstanding French scientists in the 1960s and early 70s, working with inventor Antoine Prioré. In lab animals, cures were achieved for terminal tumors, infectious diseases such as trypanosomiasis, and atheriosclerosis. In addition, deliberately suppressed immune systems were dramatically restored.
>
> "We hypothesize that this is the long-sought mechanism of how the living body heals itself. In short, the body's cellular control system induces cellular reversal by weak time-domain pumping of the damaged cells and the affected area. The cellular regeneration system performs all healing of cellular damage in the body; the immune system heals nothing, not even its own damaged cells) .
>
> "For the first time medical science can develop as a science of healing rather than a science of intervention. And it will develop as a science of unlimited healing, since no pathogen can resist action by curved spacetime engines." Bearden
>
> http://www.cheniere.org/techpapers/Vision%202000%20paper.doc

See Priore's machine See Slides of how it works.

Bearden has extended the Priore work, with the previously missing knowledge now in place, and designed a revised system (for irradiating the body with longitudinal waves) which gets rid of Priore's giant glass plasma tube and uses instead an antenna unit which surrounds the body. He has also provided the missing explanation of how it works. There is an article from "Explore" magazine, Part I and Part II.

In fact, Bearden has presented to the U.S. government a plan to use a portable version of a Scalar Healing Blanket where wire channels in the blanket act as a scalar antenna, which can both send and receive scalar electromagnetic waves. A two minute treatment of the waves is sufficient to restore the body to its earlier healthy condition. Thus even thousands could be treated easily and quickly in a biowar mass attack situation.

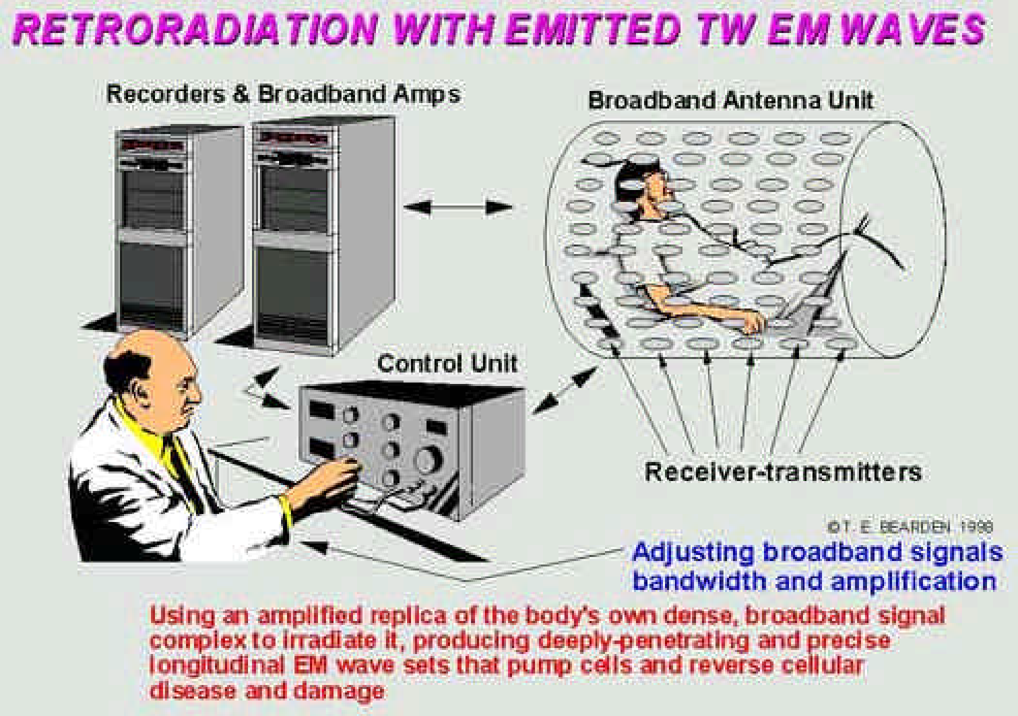
RETRORADIATION WITH EMITTED TW EM WAVES
Recorders & Broadband Amps
Broadband Antenna Unit
Control Unit
Receiver-transmitters
© T. E. BEARDEN 1998
Adjusting broadband signals bandwidth and amplification
Using an amplified replica of the body's own dense, broadband signal complex to irradiate it, producing deeply-penetrating and precise longitudinal EM wave sets that pump cells and reverse cellular disease and damage

"To defend against things like anthrax attacks on our civilian population centers, we also have recommended to the U.S. Government the crash development of small, portable treatment machines—using similar "antiengine-forming" and cellular reversing "porthole technology". [See Figure 13 on previous page]. Such portable machines could be developed cheaply and quickly, and present government facilities could be used to massively attack the correlate database production problem. "The portable treatment units could be cranked out by the hundreds of thousands and flooded down through emergency response agencies such as the police forces, the National Guard, emergency hospitals,

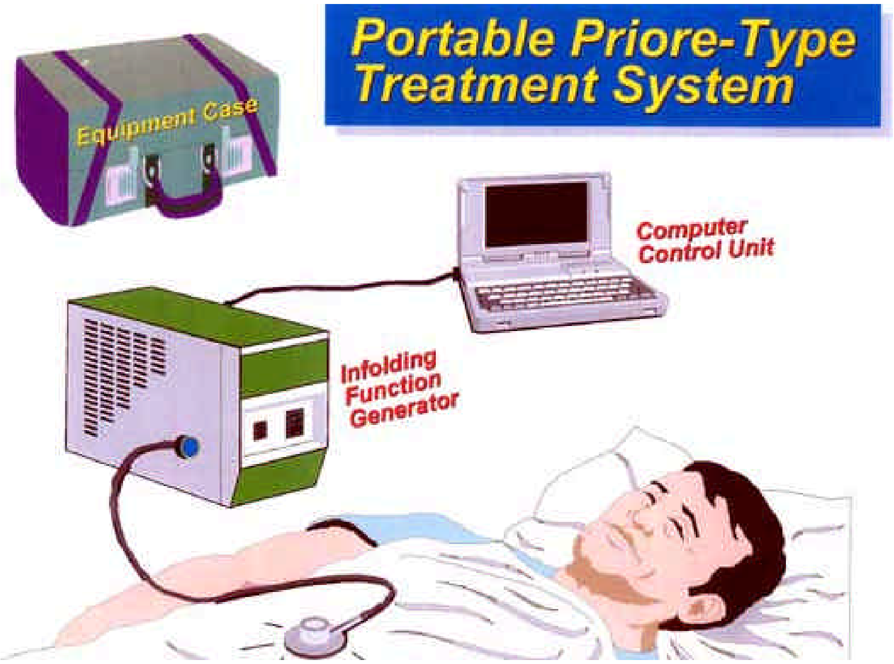
Portable Priore-Type Treatment System
Equipment Case
Computer Control Unit
Infolding Function Generator

> emergency response teams, etc."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p04.htm

The Scalar Healing Blanket would fit into large suitcase. It has three basic parts, the longitudinal wave generator, a laptop computer, and the antenna-blanket. The plan was a stroke of Bearden's genius, but unfortunately it fell on befuddled government ears. "Unfortunately, so far the DOD [Dept. of Defense] doesn't even understand what the heck we're talking about!"

Article "**Healing with Energy**": http://www.explorepub.com/articles/energetics.html

> "We tried very hard in 1998 to call attention to the extreme national need for the most urgent possible development of a portable computer-controlled treatment device based on the experimentally proven Prioré methodology, but extended to a much simpler and far more rapid method of treatment.
>
> "Quick development of this technology could lead to a suitcase size device, capable of treating a patient in less than one minute, and stopping the symptoms and disease progress cold, then reversing it. Three "less than a minute" treatments one week apart would be required for complete cure. As an added advantage, partial reversal of aging in older patients would also be accomplished as a bonus, in addition to time-reversing the damaged and diseased cells...
>
> "The method proposed to the DoD in 1998 used normal EM in a peculiar way to force the body itself to make its own time-polarized EM waves, and pump every part of its cells -- including the genetics -- in the time domain.
>
> "Quite simply, we are going to be struck this way (QP spreading the immune systems of the populace plus professional smallpox, anthrax, etc. BW attacks on our population centers) and by other means we've spoken of in other papers and briefings."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

The Dark Side of the Force:
Creating and broadcasting disease

Speaking of the scalar wave induction of disease by longitudinal wave patterns Bearden refers to work by French scientist Kervran Russian scientist Kaznacheyev, who proved that any disease could be transmitted electromagnetically.

> "It works this way: the Kaznacheyev experiments (and others) demonstrated that any cellular disease or disorder can be initiated into cells at a distance, by electromagnetic means (albeit unusual EM in nature). The decades of microwave radiation of the U.S. Embassy in Moscow, was an ongoing set of "stimuli" to ping the U.S. system and, by its response, ascertain how far along (or if it was "along") in its knowledge of such weapons. The radiation was responsible for many health changes in personnel and for the eventual deaths of three U.S. Ambassadors."

> Bearden http://www.cheniere.org/correspondence/021702a.htm

In a letter he writes,

> "Yes, the Kaznacheyev experiments were quite real; 15,000 or so in military research institutes in Siberia. As with so many other novel areas investigated and developed by the Soviets, most U.S. investigators just assumed normal EM, which is not what the Kaznacheyev experiments involved, and not what was carrying disease induction patterns from one cell culture to another in rigorous lab tests."

How to "Broadcast" Diseases

Longitudinal EM Biowars

Bearden explains how the new quantum potential weapons can be used to induce disease-at-a-distance in a population, or to "spread" the immune system so thin that a conventional bio-attack would be greatly potentiated. By "broadcasting" virtual disease patterns over a population, the immune system is so overloaded by the presence of the "shadow" diseases that its effectiveness is thinned out.

> "In short, alter the internal wavestructure, and one creates a curved spacetime 'engine' that acts on mass in any fashion one chooses to design -- including initiate diseases . . . Now visualize one of these 'vacuum engines' or 'spacetime curvature engines' that acts on mass to generate the exact effects produced by anthrax. (Or any other disease one wishes) . . . Call the virtual state of a disease engine the disease pattern in the "shadow" state, just prior to becoming observable. . . .
>
> "And the master cellular control system responds to "coming events that cast their shadows before". In short, it responds to the upper level of the "shadow state" of a disease, still in the virtual state! (Hey, virtual particles are real, virtual photons are real, virtual ST curvatures are real --- just very fleeting, only for another to immediately arise). The exchange of virtual particles is known to generate all forces in physics anyway! . . .
>
> "So the cellular control system responds to "shadow state" disease patterns. Enter a QP weapon application. Place a quantum potential weapon "area" on the United States, so that the entire populace is in it. The slowly introduce and bring up in the shadow state, the necrotizing fasciitis disease engine. At some point, the cellular control systems will react, and order the immune system into action. In other words, immune system resources will be committed against this "immediately coming" enemy. Bring it on up a little, but still just in the shadow state. Voila! Humans form a bell-shaped distribution curve. And even if the structure of the QP fluctuates a little, fluctuating a bit stronger and a bit weaker, etc. A few of those targeted bodies will now actually develop necrotizing fasciitis. So far, just like the U.S. Embassy targeting, except a different "carrier".
>
> "But now there is an exact signature that this is what is doing it, and not normal vector carriers of disease and contact or exposure infection. The few cases of necrotizing fasciitis that break out will be most puzzling. They will be randomly scattered across the

> entire nation, and so few that the vector carrier and contact or exposure explanation completely fails."
>
> "And that one happened, right here in the U.S., not so long ago. Check it out.
>
> "So carefully adjust the patterns for, say, 12 major terrible diseases, to that "adjusted and desired shadow state level". Now add all 12 patterns into the internal structure of the quantum potential. Now it has 12 shadow state disease engines in it.
>
> "Place that one on a populace. The cellular control systems order the immune systems into action, and they now have to commit their finite resources to 12 different areas. This greatly thins the response an immune system can make to any one of those 12 disease patterns! In short, it "spreads" the capabilities of the immune system, which can be galvanized to great effort, but only can perform a small bit against each area.
>
> "Suppose one of those "galvanized" areas in the targeted populace's immune systems is anthrax. And suppose the bad guys now hit one or more of those cities with a professional anthrax attack. A former OTA study showed that a professional anthrax aerial spray attack against Washington D.C., dispensing 100 kilograms of anthrax spores in the spray, will account for 1 to 3 million casualties. And that's in an "unthinned" set of immune systems. In the "thinned" set, one can at least double or triple, and even up to five times, that estimate. So conservatively, now there would be from 2 to 6 million casualties. And even mild anthrax spray attacks in other "thinned" cities would also be amplified.
>
> "That one is being set up, or already set up, right now. There are other such "augmentation" setups also under way.
>
> "So the weapons alluded to by the SecDef in 1997 are already being employed. WW III has already begun, and our populace (and our scientific community) is blissfully unaware of it."
>
> http://www.cheniere.org/correspondence/021702a.htm

Most of us can remember the strange outbreaks of the so-called "flesh eating disease." It seemed to break out here and there randomly with no known cause. Bearden believes this was a test of the newer quantum potential weapons which go even beyond the capabilities of the Tesla howitzers.

> "The Kaznacheyev "disease induction by novel electrodynamics" work is also the basis for the spacetime curvature engines (not EM signals!) carried by quantum potential EM biological weapons for distant induction of diseases etc. into the population of an entire nation or area, such as the U.S.
>
> "This quantum potential disease induction weapon -- capable of attacking an entire population of a nation or area -- has been tested several times in the U.S. at very low levels, in the shadow state only (we explain shortly) and it has a most peculiar signature. E.g., one test used necrotizing fasciitis (flesh-rotting disease) engines.

> "The disease 'engine' was deliberately kept down in the 'shadow state' (virtual state, just below the observable state) so that only a tiny bit of the populace with depressed thresholds would "breach the observable threshold' due to the population forming a bell-shaped curve as to the threshold level. The major signature of the test was that the cases of the disease broke out totally statistically and randomly, spread all over, without any 'disease vector' in between.
>
> "In short, it was not spread in any manner required by normal deterministic disease vectoring, but was a totally random set of occurrences. Several other diseases were also tested this way in the American populace, with precisely the same signature."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

"Apparently one planned use of such an augmented clandestine BW weapon will be smallpox, e.g. As you know, the Russians did develop smallpox for biological warfare, and even developed a new strain against which previous vaccination is ineffective.

> "The vast numbers of expected casualties, coupled with immune system spreading, are absolutely irresistible to the Russian mind. You can count on it that they have seen that the smallpox is already on site here, in the U.S. and in the hands of professional terrorist teams. Of course, the Russians/KGB will protest they have nothing to do with that! Yet likely the KGB will have flatly arranged it or at least assisted it. The capability for mass destruction of the nation is so lucrative and easy to achieve in advance, that they would never be able to resist doing it."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

Bearden believes the Gulf War Syndrome involved the use of scalar technology to induce a disease state, as he stated in a 1997 interview:

> "I'll say this flatly, and I won't answer any further questions about it; the Gulf War Syndrome was induced... It was induced with this stuff. All the rest... was contributing factors that everybody's talking about... There are some deeper signatures, if you look into it very deeply, that show you exactly how it was done and the fact that it was induced. It was a test. It was a test of a very special kind of weapon I have not talked about yet. Anyway you can use it to create diseases."
>
> Bearden http://twm.co.nz/beard_weapon.htm

Besides using the woodpecker grid to target a population, the entire electrical grids of nations can be used as "channels" for disease patterns to be broadcast to all people near that grid. Your own house wiring can become an antenna, broadcasting these "shadow" patterns of disease, weakening your immune system.

And here one faces the frustrating fact that the same power grids could be set to channel patterns which would keep the entire population healthy, rejuvenated, continuously bathing in the time-reversing old-age-defying energy of the spacetime vacuum. We have no idea yet of how long the human life span could be increased with this new technology. People might be able to live two centuries given full humane development of this technology.

5. Psychoenergetics

Mental entrainment, inducing hypnogogic trance, mind control, broadcasting thoughts and feelings, the Ant World, education via EM [LW] mental download, the "Feelies," revolution in spirituality, "enlightenment machine?" Scalar churches?

Psychoenergetics is simply using the scalar interferometers to manipulate and engineer the human psyche. To me it is the most mind-boggling and frightening aspect of longitudinal wave engineering.

The mind is electromagnetic in nature, and itself of the time-domain. It is not observable in 3-space. There is no thing you can point to that is the mind. As Bearden says**, "The mind is time-like**."

The longitudinal scalar EM waves are also of the time-domain. By overlaying certain infolded patterns (oscillations in time) on the longitudinal waves, a thought or feeling may be made to arise in a person or persons who are in the **interference zone** (where the wave beams cross).

The person will not notice anything, feeling that this thought or idea is his or her own idea. The longitudinal wave pattern might be a wave of panic or fear that spontaneously sweeps over you, perhaps inexplicably. It could even be in the form of a sudden intense patriotism. It could be explicit words and phrases, which everyone would think they had thought of by themselves. Or it could be rage and hatred, angry and violent. On the other hand It could also be a continuous sense of docility and placidity. This is the brave new world of psychoenergetics and the coming "Mind Wars."

Scalar Psychoenergetics in its most primitive form simply "entrains" all minds in the target area into a deep hypnogogic trance. In this state of mind people would be suddenly extremely suggestible, and would likely believe anything they are told, and would obey any orders given. Talk about winning the hearts and minds of the American People!

Tom Bearden makes me think of **Paul Revere**, who heroically conveyed important warnings for the sake of the new nation. But the words of the famous phrase have now strangely and curiously mutated into the once-inconceivable: '**One if by land, Two if by mind**."

Indeed one strategy in a Mind War would be to simply take over the minds of the "leaders" of the enemy nation. The targeted leader would not be aware that anything was amiss, although he might begin to make unexpected changes in policy.

And are, in fact, any of our "leaders" already having secret thoughts that are not their own? Who knows? Frighteningly, we can no longer be sure. The new sciences of scalar electromagnetics and psychoenergetics are even now plunging humanity into a sudden science-fiction-like world beyond anything in humanity's previous imaginings.

> "The Russians reached the point in the mid 1990s that they could take over control of a person's mind, with modified longitudinal EM waves including some time-polarized EM waves, and with a team of specialists (estimate 25-30 per transmitter, and one transmitter and team per controlled person)." Bearden http://www.cheniere.org/misc/time.htm

In a slide Bearden illustrates how a Scalar War would involve a psychoenergetics attack on the operators of the enemy scalar installation, entraining their minds into hypnogogic trance and getting them to shut down their systems.

And ultimately psychoenergetic warfare goes to the very heart of human identity itself. For if my thoughts might no longer be "mine," then who and what am I? Can my very sense of being "me" be hijacked by some nefarious psychoenergetic scheme? Will the "secret government" eventually dictate directly into your mind how you feel about yourself? Or what you think you are? Or what you should do?

How Does Longitudinal EM Mind Control Work?

The physics of scalar psychoenergetics as expounded by Col. Bearden seems even more arcane and over-my-head than that of extracting energy from the vacuum. I can't understand it, but I look through it anyway. Each time another tiny understanding might occur, or a term might fall into place. I know the mathematics is forever beyond me.

One paper to begin with is “Mind Control and EM Wave Polarization Transductions” This is such serious stuff that Bearden includes a strong warning about misuse of this knowledge. Psychoenergetics weapons can mentally maim and physically kill.

Warning!

(From "Mind Control and EM Wave Polarization Transductions")

> "This article refers to experimental research techniques which can be detrimental or lethal in the hands of any but highly skilled, qualified experimental scientists proceeding under proper laboratory safety procedures. The purpose of this article is strictly for information to properly qualified and authorized scientists in certified laboratories. We do not propose or condone any use of these procedures for nonapproved practice of medicine without a license. Neither the publisher nor the author are responsible for accidents or outcomes in the use of these experimental procedures and techniques. Any researcher who performs these procedures and experiments is acting on his or her own volition, and is solely responsible for insuring safety, qualifications, and legality of the acts and their results. We neither suggest nor condone unauthorized experimentation on human subjects. Such is a criminal violation of the constitutional rights of the subject under Federal and State laws, and is both illegal and immoral."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control1/p01.htm

After the serious warning comes the description of the paper. This is heady stuff for the layman.

> "Calling full attention to the special note above, in this paper we present a high-level overview of the novel electromagnetic nature of mind operations, mind and body coupling, and intent - the induction of physical 3-space EM energy changes into the brain and nervous system, and into every cell of the body, from the mind's time-like coherent operations. We summarize the time-polarized electrodynamics used to engineer and affect mind operations and the mind-body coupling loop. Transaction mechanisms whereby differing EM wave polarization's can be transformed one-into-the-other are presented."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control1/p01.htm

I will leave it to the technically astute to try to understand the mechanisms of operation which are described in scientific language. But there are tidbits for the layman. Here he speaks of the difficulty Western scientists have in opening up to the "immaterial" (longitudinal wave) nature of the human mind.

Western Science Remains Largely Materialistic

> "Ironically, most Western scientists are materialists and consider "mind" as a mystical and nonscientific concept. They tend to consider mind operations and functions either to be simply "meat computer" operations and functions, or at best to be very weak ordinary transverse-wave EM operations and functions in the brain and nervous system. This serious self-limitation exists because in the body we measure only weak TW [transverse wave] EM operations and functions correlated to biological behavior and brain operations. We simply do not know how to measure "mind operations" directly.
>
> "With no mind measurements possible and no instruments, it is understandable that Western science considers only the physical side of the mind-matter interface.
>
> "Presently our scientists do not measure the longitudinally-polarized EM wave operations and functions in the body and around it in nature. Few of them are aware that a maelstrom of such LW [longitudinal wave] functions exist in the body and in all of nature in general."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control1/p05.htm

Western methods of influencing the mind with EM waves have only used transverse waves, not the longitudinal waves of the vacuum. If only transverse waves are used one pretty well has to hit the target mind with a sledgehammer of waves.

Western Science knows only transverse EM waves

Brute Forcing Time Functions versus Fine Control Methods

> "Ironically, Western mind control researchers using transverse EM waves for mind control research, are using a brute force method of evoking and using vacuum engines

> (spacetime curvature engines) and a special form of general relativity, although they do not appear to realize it.
>
> "While KGB scientists also use TW EM "brute force" TW waves when necessary, they do "imprint" or "activate" those waves with the desired internal LW and time-polarized EM wave and photon structures required to directly perform the mind engineering desired... Bearden
>
> "These "fitted brute-force models" certainly can be very powerful, and certainly can produce the exact results shown in the experimental verifications of the fittings. However, they do not of themselves allow sophisticated design for example of the necessary time-polarized wave assemblies for engineering the entire human collective unconscious simultaneously, or for engineering the entire collective unconscious of all species on Earth (i.e., Gail's collective unconscious), or even for precisely engineering the memory and knowledge base of an individual.
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control1/p09.htm

The seemingly magical operations of psychoenergetics, sometimes called "psychotronics," cannot be achieved with ordinary transverse EM wave energy. But they are possible with longitudinal scalar waves because the mind itself is scalar in nature.

> "We note that all mind operations are time-like, i.e., they are comprised as scalar EM photon functions and scalar EM wave functions. Thus the mind is a very special kind of electromagnetic system, existing in the time domain..."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control1/p08.htm

The engineering of the mind can only be accomplished with the waves of time.

The course of psychoenergetics development necessitates the building of a vast database of settings and patterns which bring about given mental and/or emotional states. A kind of "gnome" of the psyche. Bearden describes the process of the decoding of this "gnome."

> "Now the scientists would perform many phenomenology experiments, making one little change at a time and profusely recording the data. Each time, they would establish the physical change(s) that occur in the body and/or the mental and emotional changes that occur in the mind for each spectral reinsertion back through the "ship's portholes". They would simply but painstakingly (over some years) build up an extensive database of those individual correlates.
>
> "In these experiments, the experimenters will eventually be able to provoke any body or mind change they wish. Strong emotion. Intense pain. Intense pleasure. Painful thoughts. Images. Memories. Perceptions. Dreams. Visions. Memory losses. Memory changes. Personality changes. Etc. The "delta" in the emission spectrum (the changes from zero reference spectrum) represent the precise totality of all mental, physical, organic, chemical, etc. changes and interactions."

> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p01.htm

> "A second stage in the research would be to test the correlates and porthole insertions upon a statistically significant cross section of ordinary people, and/or specialized populations (such as toughened soldiers). The program would evolve a highly complex, very effective, ever-improving science and technology of mind and behavior control and engineering mechanisms, complete with finished database and developed applications equipment."

> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p02.htm

Summing up his paper Bearden speculates on what the actual situation the science of psychoenergetics probably is. The intense secrecy with which this knowledge has been kept from the public has led to the current farce of the "government" pretending it all does not exist, and this secrecy may have now put us at great risk.

> "The implication is that in the West one or more highly classified, sustained, heavily funded developments in advanced mind control programs, probably exists and probably has existed for some time. Due to loose formation of rogue groups inside such programs, they may have dual or triple purposes, may not operate under very much legitimate government control at all, and may operate specifically for the purposes of the rogue group or groups that have gained control.

> "In a nutshell, that's what may be going on in the clandestine mind control projects in several Western governments. The involvement of at least some rogue groups, some being "cowboys" who operate well outside all laws and ethics, could also result in such things as assassinations, clandestine testing on individuals without their consent, etc. In short, it could account for what seems to be actually occurring. As also is "usual" in such a mess, one or more of the rogue groups eventually may become very powerful because their secret weapons are very powerful. They may become confident, thinking they have the "best in the world." They may actually believe they are ahead of the Russians..."

> "Remember that, in every large and powerful human organization, the basis for rogue groups is power and secrecy. They are always seeking to increase their power, control, influence, prestige, etc. Nothing else. Patriotism and mission are—to rogue groups—often just idle words. They have their own agendas. And being rogue groups, they may well bring in unethical, immoral tricks: assassination, bribery, entrapment, disinformation, plausible deniability, etc. A certain percentage of a highly secret rogue group will wind up using all these things and more. It's a human characteristic, the old primate dominance game. Only now disguised and hidden under deep classification."

> "The Russians, with their additional knowledge of the actual mechanisms in the transforms, will be much more advanced than the West, because their fundamental psychoenergetics science is far more advanced, so long as we continue to use the old U(l) electrodynamics. Further, the Russians have decades of use of longitudinal interferometry beams to reach right through the earth and ocean and produce stringent EM effects at a distance. So they will also be able to do the same things here in "mind control" with LW [longitudinal wave] interferometers, through intervening mass."

> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p05.htm

Bearden cites two examples where he believes the Russian KGB tested the psychoenergetics capabilities of their scalar interferometers. One was the case of Captain Button in his A-10 "Warthog" aircraft on April 2, 1997.

> "Over Arizona, Captain Button was thrown into a hypnogogic state, and his perceptions instantly altered and controlled. In his instant "dream-waking" state, everything seemed perfectly normal. His sense of direction was altered a bit more than 90 degrees, so he simply corrected and turned and "flew toward the range", actually flying off course by more than 90 degrees and ignoring radio contacts. He flew right on out of Arizona."
>
> "At one point he circled, probably thinking he was over the range, and he probably dropped his ordnance there. Then he "flew on back toward home," as he thought in his waking dream state, until his fuel ran out and he crashed and died in the explosion—dream-thinking until he died that everything was normal. All the while, his sense of the passage of time was altered. To him, in his dream-thinking, dream-acting state, everything was normal and nothing untoward had happened. So the distant KGB transmitters and associated psychoenergetics team controlled him for over an hour. "Indeed, that was the exact purpose of the test: demonstrate control (at a great distance) of a skilled person performing highly skilled tasks."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p06.htm

The paper "Mind Control and EM Wave Polarization Transductions" ends with the most chilling and frightening possibility of all: the psychoenergetic engineering of the human species as a whole.

The Ant World

The Final Race for Direct Mind Control of the Entire Human Species

> "The KGB psychoenergetics weapons scientists—because of their direct measurements and detections (and use) of t-polarized waves and LWs [longitudinal waves] for decades—also understand that Jung's collective unconscious mind (of the entire human species) also has its own time-like operations and correlates, which one measures also when using t-polarization measurements and sorting it all out. The collective unconscious mind operations are buried several levels deeper inside the recursive Whittaker structuring inside the EM fields, waves, and potentials. "The KGB scientists also know that something very like Gaia — a collective unconscious mind for all species on earth — also exists, and they are striving to be able to sort out and measure that one as well. The Gaia operations are buried even deeper in the recursive structuring inside the EM fields, waves, and potentials.""Actually, from day one, the Russian mind control scientists have had their eventual goal set upon this "deeper area of mind and possible mind control" of the entire human species.
>
> "I am convinced that the KGB psychoenergetics scientists understand this deeper area. If they can learn to directly engineer the collective human species unconscious, they can

> then convert the human species easily into a sort of "ant" society, modeled along ideal Communism lines, except of course with an excluded "hierarchy at the top" running everything. The "ant society" — communist style — is still a variation of feudalism (all systems tend to feudalism or some form thereof). "The KGB psychoenergetics weapon scientists are seriously pressing on toward that very goal. In my opinion they are not very far from it right now...
>
> "Some versions of Russian mind control devices were used on Russian soldiers in the Afghan War to condition them for performance of merciless acts." 13
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p07.htm

More about "The Ant World"

Whether it is the Russians planning an "ant world" society or rogue U.S. black-ops groups withholding a great boon from human race, the secrecy on all sides around has allowed largely criminal elements to take over this technology while leaving the civilized elements in the dark. Openness and the spreading of this knowledge among good and decent people is essential, and for that we will have to overcome our frightened denial.

> "Meanwhile, rogue groups amongst Western clandestine mind control researchers will probably arise if they have not already done so. They will likely seek to increase their personal control and further isolate the programs from orthodox government review and from government and legislative control. They may even divert the research into highly illegal and unethical means, because it furthers their own rogue agendas. That is how clandestine U.S. government research can sometimes go sour, unless great care is exercised by the oversight committees in the House and the Senate.
>
> "Sometimes when rogue groups do gain control and total secrecy of a given new technological area, then what appears to be "U.S. government operations" do start to encompass a criminal and unethical operations, hidden usually beneath the deep veil of high classification. Also, if it's "scientific," no one is ever brought to justice, even if the "evil science actions" are uncovered and publicly revealed."
>
> Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p08.htm

Like the huge energy of the Tesla howitzers, the ability to engineer the mind with longitudinal waveforms is a seeming "magical" thing which can be used for good or ill. Bearden envisions that further developments will allow something like the "downloading" of knowledge via scalar interferometry. Everyone could be highly educated, and quickly and easily.

In the conclusion of the paper "Mind Control and EM Wave Polarization Transductions" Bearden makes a plea to the nations of the world regarding the use of psychoenergetic engineering.

> "Let us hope this great new area, already off to a bad start, can be bridled and steered in the direction helping and healing people, rather than killing or abusing them. The excesses in its bad use are a potent threat to all nations on earth.

"Yet it can revolutionize medical science, education, communication, and psychology. We foresee the day -- perhaps 30 years hence -- when education will be accomplished by directly loading the software into the mind. Then in three weeks one will "load" a doctorate, say, in physics. In three more weeks on will also load a doctorate in chemistry. Another three weeks, in electrical engineering. Another three weeks, an MD And so on. When that happens then truly everyone on earth can be educated. Freedom from ignorance may well be another great freedom that is legally recognized. There will be no impoverished large groups lacking the education to find decent, productive jobs.

"We urge all nations to use the principles involved: not for human abuse, but for healing, educating, uplifting, and life-expanding of every person on earth. If we do, we shall all have a far brighter future. Then we shall check what has started out to be the Sword of Damocles and turn it into the golden Millennium."

Bearden http://www.cheniere.org/explore%20articles/mind%20control3/p08.htm

(Perhaps after so many frightening topics a slight break is in order here to consider the lighter side of psychoenergetics. For example, what will be the ultimate impact on the entertainment industry?)

The Feelies at Last!

Psychoenergetics will be able to bring about at last, for better or for worse, Aldous Huxley's fanciful idea in his novel "Brave New World," an entertainment format which he called "The Feelies." Those were something you went to, like going to the movies, but you would experience all the actual feelings themselves, as if the depicted events were actually happening to you. Although our "leaders" seem too dim to grasp what is going on in the world of scalar electromagnetics, it should not take some young Hollywood genius too long to understand that The Feelies are now possible, and that the immense megabucks of potential profit more than justify heavy investment in bringing it to market.

One can imagine that first "Feelie" theater, "The Huxley" perhaps, a large comfortable area surrounded by nine giant screens (not just one screen!), which become 3D if you put on your headset. And The Huxley is fitted with the finest sound, and oh, by the way, a modest sized scalar interferometer with computer. And there are one or more new tracks now recorded on the film next to the sound track. These are the digital patterns of thoughts, feelings, and ideas to be fed into the theater's interferometer. And these thoughts and feelings and ideas will be felt by the audience as if they were their own thoughts and ideas. It is an entirely new art form. Psychevision.

As important (and no doubt famous) as the actors would be the "feelers," those from whose minds the feelings were lifted in the original programming of the Feelie tracks. Because, for example, Brad Pitt might be a good and handsome actor, but can he really feel it? Like the dubbing of foreign language films, it might be necessary to dub the "emotional track" using a deeper and more profound person's feelings, thoughts and ideas.

It might even be engineered so that if you sat on one side of the theater you would feel like the hero, and on the other side you would feel exactly like the bad guy! What would that lead to?

We have all cried at a movie some time, most people have, though they might not want to admit it. But this would be deep sobbing and a flood of tears, if the director so desired it. You would feel it at your core. Or, take a big chase scene, you would be terrified. They are breathing down your neck! You would be gripped by panic.

For that matter, the whole genre of Horror-Feelie would be too much for many people to take. Do I really want to feel that an actual vampire is tearing at my throat with his fangs?

A Religious Feelie would make you feel the exaltation of a saint at his prayers, or give you the definite feeling that you are Christ suffering on the cross. All the pain could be there too. The stickiness of the blood. The very feeling itself: "Why hast thou forsaken me?" Who among us could come up that despair for scanning? Had this been developed a bit earlier we might watch a documentary of, say, Mother Theresa, containing her own actual deep sense of compassion, which we would feel arising in us as our own.

Then again, a Psychedelic Feelie could induce an LSD-like state and simply blow the audience's minds.

Even in its simplest most primitive mode, the hypnogogic trance induction with its increased suggestibility, would completely alter the experience of even ordinary current movie going.

6. As it Stands - 2002

"Anyway, it's presently a "Mexican stand-off" with the various parties maneuvering with check and countercheck. That is the real "balance of terror" that is held by such a fragile balance."

"You can see the implications if such weapons fall into the hands of the radical terrorists. Ordinary positive energy EMP shooters can be made fairly readily and cheaply from nearly just Radio Shack parts or surplus parts. It just takes some know-how... When and if the Yakuza [Japanese mafia] gets those (and they will, it's just a question of time), you can begin to appreciate some of the turns this present terrorism and our war on it will take."

Bearden http://www.cheniere.org/correspondence/021702a.htm

The very thought of the building of one of these howitzers by "some lone-nut gunman" from Radio Shack parts makes one realize how serious it is for humanity to face the crisis it has come to.

Once again, as at the dawn of the nuclear era, humanity finds itself at the crossroads of Heaven and Hell. As a species, we must stop and consider. And there is at least one real difference between this visit to the crossroads and the last: this time there is a very real possibility of a true "earthly heaven" on the Heaven side.

The poor nations could come to a good life. Disease could be largely eliminated. Fossil fuel pollution could end. Global warming could be solved, and the weather could be managed in a humane way, bringing water where there is drought, and sunny skies where there is flood. Scalar interferometry would be there to avert any possible hits by asteroids or comets. Mars could be colonized and terraformed. Everyone would be highly educated through psychoenergetic downloading of knowledge. And the wisdom of the wise could be realized directly through scalar connection to their minds and hearts.

These stunning sudden possibilities give me pause to think: if our species has reached this crossroads in such a short span of centuries, then surely other species in this vast universe have passed this way before and long ago. And of those who chose the path to "planetary heaven," what is their life like now? It might be good if some of them were with us now, to guide us through this last struggle over this pesky old good-and-evil problem. It is our last chance to choose the path which benefits the whole species, and not just some elite group or faction.

The Disclosure Project

One person working tirelessly to bring to bring these technologies into the open is Dr. Stephen Greer of the Disclosure Project, which is calling for congressional hearings into the issues of UFOs and the free energy technology that was, perhaps in part, reverse-engineered from them.

> "Once abundant and nearly free energy is available in impoverished areas for agriculture, transportation, construction, manufacturing and electrification, there is no limit to what humanity can achieve. It is ridiculous — obscene even — that mind-boggling poverty and famine exists in the world while we sit on classified technologies that could completely reverse this situation. "So why not release these technologies? Because the social, economic and geo-political order of the world would be greatly altered. Every deep insider with whom I have met has emphasized that this would be the greatest change in known human history. The matter is so highly classified not because it is so silly, but because its implications are so profound and far reaching. By nature, those who control such projects do not like change. And here we are talking about the biggest economic, technological, social and geo-political change in known human history. Hence, the status quo is maintained, even as our civilization hurtles towards oblivion...
>
> "With the types of weapons currently in the covert arsenal — weapons more fearsome even than thermonuclear devices — there is no possibility of a survivable conflict. Yet in the darkness of secrecy, actions have been taken on behalf of every human that may

> endanger our future. Only a full, honest disclosure will correct this situation. It is not possible for me to convey in words the urgency of this."
>
> Dr. Stephen Greer http://www.disclosureproject.org/ES-DisclosureImplications-2.htm

Greer and his team have assembled hundreds of witnesses, many of whom are military or ex-military, who are ready to testify to congressional hearings what they know about the covert black projects which have kept free-energy and antigravity propulsion technology secret from the people.

Greer points out the need to regulate these technologies so they are limited to peaceful uses, but this is of course difficult when the government simply chooses to pretend they do not exist. In the meantime, as the President and the Defense Department continue the charade of war-as-usual, those scalar (longitudinal wave) installations which DO exist continue to fall into ever more sinister hands. And there is no reporter in the press brave enough to ask, "Mr. Secretary of Defense, what steps are you taking to defend our MINDS from attack by the big Russian longitudinal interferometers?"

Longitudinal Interferometers are Proliferating

In a later statement Bearden reveals that in fact the Yakuza [Japanese mafia] has already leased some of the interferometers with a nearly $1 billion "down payment:"

> "After the collapse of the Soviet Union's economy, lots of things got available for lease or purchase that would never have been under the old system. That happened in the resulting economic chaos. The Russian Mafia rose to prominence, as did some wheeling and dealing entrepreneurs who played both ends against the middle.
>
> "In that atmosphere, and in the need for money, the KGB allowed leasing of the earlier longitudinal EM wave interferometers to a consortium of the Yakuza and Aum Shinrikyo. They did this only after they had tested and deployed their great new quantum potential weapons. That class of weapon is the dominant weapon on earth. Five nations now have it: Brazil, Russia (KGB), China, and two nations friendly to the U.S. The deal to lease many of the earlier LWIs [longitudinal wave interferometers] to the Japanese Yakuza and Aum Shinrikyo was consummated at the end of 1989, with a down payment of $900 million in gold bullion as "up front" money. I don't know what the lease per year was and is, but probably something like a billion dollars a year. So the rogue Japanese acquired longitudinal EM weapons and that technical know-how. In fact, the Yakuza is producing certain kinds of those in its own facilities in Japan now."
>
> Bearden http://www.cheniere.org/correspondence/030202a.htm

Personally, I am a little uncomfortable with the knowledge that the Japanese mafia may now be able to insert things into my mind. I'd like to sleep at night knowing that my dreams are my own, such as they may be, and not some weird fantastic visions cooked up by a criminal organization. This is a world emergency.

And in Bearden's analysis, it all comes back to the issue of energy. It is the energy crisis which is now provoking the current "oil wars," since oil production has hit the "Hubbert Peak" and will decline. And the electrical power grids must be replaced with scalar power as fast as possible, for these grids are now totally vulnerable to any possessor of longitudinal interferometers. They can all be wiped out in minutes. By anyone who possesses or controls a Tesla howitzer.

> "Anyway, in my personal view, we should have a national Manhattan Project right now, to develop decentralized electrical power systems taking their energy from the vacuum . . . The MEG is real and so are several other systems invented by private inventors and colleagues. All these efforts should be massively funded and massively and quickly developed. The survival of this nation is going to depend upon it. . . . There are many other facets, but the major point is that our scientific apparatus and the public are still unaware of what a desperate struggle we have entered, since it was thrust upon us. 9-11 was a wake-up call. It was certainly bad enough, and one grieves for those lost American lives. But I fear the worst is yet to come, and it is coming at us like a runaway train hurtling right down the track at us."
>
> Bearden http://www.cheniere.org/correspondence/021702a.htm
>
> "The electromagnetic weapons mentioned by the Secretary of Defense in April 1997 are in terrorist hands also, including the Yakuza and Aum Shinrikyo. That rogue group leased those earlier weapons on site in Russia, from the KGB, at the end of 1989. The SecDef stated that such weapons were being used to initiate earthquakes, initiate volcanoes into eruption, and control and engineer the weather. Quite true. And presently there is a truly massive set of weather engineering operations going on over North America, from that rogue Japanese group manning the weapons in Russia. Some 10 nations of the world now have the type of longitudinal EM wave interferometer weapons (which are what the SecDef was most probably referring to). There are other even more fearsome weapons, possessed by five nations. So a great deal of the state of the world is not covered in the news at all, and will not be . . .
>
> "We have been in an undeclared war of an eerie kind for some decades. That war seems now to have started to heat up also. The destructive capability of some of these weapons is awesome, and far greater than nuclear."
>
> Bearden http://www.cheniere.org/correspondence/021702a.htm
>
> "In that sense, the first phase of WW III is already completed. Now we are only waiting for Phase II.
>
> "It is against that backdrop that I think one must "analyze" such things as how fast we will be replacing the power grid (it's going to go anyway, and catastrophically, the terrorists will see to that). And everything we have is critically dependent upon energy, from the economy to jobs to mobility, to the millions of trucks that transport our goods every day, etc.
>
> "As far as I am concerned, we are already late in declaring a great national emergency in energy, because of the coming destruction of the present energy infrastructure. The

> scientific community should lead, follow, or get out of the way. The emergency is not in seeking "alternative but conventional" systems. It is in developing "energy from the vacuum" on an emergency, crash basis.
>
> "Unfortunately, everywhere I look I just see business as usual. Most Americans (and news media) seem to think, hey, Afghanistan is finished except for a bit of cleanup, and it's just about over).
>
> "It isn't. It has only just begun."
>
> Bearden http://www.cheniere.org/correspondence/021702a.htm

Beyond the Howitzers: Quantum Potential Weapons

Do not use EM propagation through space

As more and more nations acquire the scalar interferometers, Bearden speculates on the next generation of longitudinal weapons called "quantum potential" [QP] weapons.

> "The quantum potential weapons are presently only held by three nations: Russia (in the hands of the KGB, which is now know by its new name), Brazil, and the "friendly little nation." Red China may be working on them, but is just at the beginning...
>
> "The QP weapons have been highly reserved by the Russians. However, the complete extent of their capabilities is still being figured out...
>
> "The quantum potential weaponry (possessed by only three nations) is supreme, because it uses multiply connected spacetime, and DOES NOT involve propagation of EM energy through space as does the longitudinal EM wave interferometers.
>
> Bearden http://www.cheniere.org/misc/qp.htm
>
> "The operational deployment of full-scale strategic QP weapons on site in Russia occurred at the end of 1989, which is when the formal weapons first went operational. These weapons are not in the inventory of the regular Russian armed forces, but all research and development, manufacturing, deployment, an manning and employment is under the ruthless control of the KGB. Shortly thereafter (within weeks), the KGB leased many of their earlier longitudinal EM wave interferometer (LWI) weapons to a rogue Japanese group comprised of the Aum Shinrikyo and Yakuza."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

In another paper, "Time Polarization - Significance and Weaponization," Bearden tells the story of how a KGB longitudinal wave attack was averted by the longitudinal weapons of a "friendly small nation."

So as it stands, it is precarious. Not until the people demand an end of what author Jim Marrs has dubbed the "Rule by Secrecy," can the people's representatives tackle the big problems of a worldwide ban on Scalar Wars and the shifting over to an essentially oil-free economy.

Latest Update from Tom Bearden - March 2002

The whole situation is changing so fast that when I asked Tom to look over this article he mentioned the seeming contradiction when some of the above statements are taken together. At different times the information he has is updated so one has to keep a kind of running track. He was kind enough to clear up the confusion here with the situation as it stands as of March, 2002.

> "We knew of three nations having the QP weapons for some time. Then we found out last year that five nations had it. So that explains my using the figure "three" first (which represented what I knew at the time). Later I found out about the other two nations. China, e.g., only deployed its QP weapon this past year. So that explains the apparent contradiction between me using "five" in later papers and "three" in earlier ones. It was the best information I had at that time. Might mention that so the reader will understand the apparent discrepancy." Tom Bearden

Emptiness is Full of Energy

"The Tao is an empty vessel;
it is used, but never filled.
Oh, unfathomable source
of ten thousand things!

"Oh, hidden deep but ever present!
I do not know from whence it comes.
It is the forefather of the gods."

Lao Tzu -Tao te Ching

Afterward

Because of the extreme seriousness of the topics brought forward in this article, I asked Tom Bearden to look it over to make sure I had not gotten anything too terribly wrong or mixed up. I did not want to pass on any misunderstanding of my own. I felt a little nervous writing to an eminent scientist, and hoped I had not presumed upon his time.

But Tom was so kind as to answer immediately, and to my relief I had not gotten anything too terribly wrong. Here is his letter, in which he clears up a misunderstanding, and reports on his current health treatment, and gives a call to the young grad students to turn themselves loose in the whole new field of scalar electromagnetics and free energy.

Subject: RE: Article on Tom Bearden and "Scalar Wars"
Date: Fri, 22 Mar 2002 22:54:01 -0600

Bill,

Well, I must say I'm astounded at your persistence and hard work in congealing all that together. My compliments on a hard job quite well done.

Couple tiny things: In the area mentioning Kervran and Kaznacheyev: Kervran was French; Kaznacheyev was and is Russian. Little typo of "spredding" the immune system. Should be "spreading".

We knew of three nations having the QP weapons for some time. Then we found out last year that five nations had it. So that explains my using the figure "three" first (which represented what I knew at the time). Later I found out about the other two nations. China, e.g., only deployed its QP weapon this past year. So that explains the apparent contradiction between me using "five" in later papers and "three" in earlier ones. It was the best information I had at that time. Might mention that so the reader will understand the apparent discrepancy.

Otherwise, it's pretty accurate.

Just now I'm letting the weapons take care of themselves; have to, as I will be recovering now for nearly a year from now after the heart attack last year and discovering that I had contracted mycoplasia (the BW modified kind) in Canada in 1968. Finally got a test which confirmed the chronic mycoplasia (which I had for 33 years!). The stuff burrows inside one's red corpuscles, then draws nutrients from the hemoglobin, hardening it and reducing its ability to take on oxygen (by as much as 50% or more). The resulting symptom is loss of endurance (which I had for that 33 years) -- the so-called "chronic fatigue syndrome".

Many of the Gulf War Veterans who are sick also have it, though they apparently have other complicating factors as well. A very high percentage of persons with chronic fatigue syndrome also have mycoplasia. The treatment for the long-standing mycoplasma infection of that nature is to stay on antibiotics for a year. The only time the mycoplasma is vulnerable is when one wears out a red cell in normal usage, and the body makes a new red cell to replace it. The mycoplasma comes out of the dying cell to infect the new replacement cell, so it is exposed and vulnerable at that specific time and that time only. The antibiotics kills it at that time. Hence the necessity to stay on antibiotics for such a long time so it is continuously in your bloodstream (I've already been on antibiotics for over two months, and have at least 10 more months to go). We also take a little medical oxygen every day.

Another symptom of the mycoplasma infection is the association of runaway fibrillation of the heart. To stop that, there are pills one takes, and they stop it. But they also further reduce the volume of blood pumped by the heart, so that this projects one right back into the hypoxia, dizzy, loss of balance, etc. Catch 22 situation; the fibrillation will build and cause heart attack, stroke, etc. if not stopped, and if stopped it puts you back in the hypoxia which can cause many things! With the conventional treatment, you're damned if you do and damned if you don't. Hence the need for a little extra medical oxygen, so you can take the "heart clamp" pill and stop the fibrillation, but also augment the oxygen enough to continue to survive without a stroke or some such. Interestingly, it's very difficult to even obtain a mycoplasma test, and Medicare fights you tooth and nail over paying for the oxygen. Either they will pay for it or I'll pay for it myself; it is absolutely necessary.

After a heart attack, one is treated in the heart clinic by specialists who are very caring and excellent practitioners, but know nothing of mycoplasma infection, so not consider it even a part of "heart disease", and who are rather puzzled when one has no clogging of the arteries, has the right count of red corpuscles (largely nonfunctional, of course, but there), pumps the right amount of blood, etc. So they identify and treat only the runaway fibrillation, do not prescribe the oxygen -- and essentially place you on a regime as best they know, but one that is guaranteed to kill or maim you or turn you into a totally disabled person or human vegetable via stroke, paralysis, etc. Fortunately my family doctor will prescribe the oxygen anyway, though I may have to pay for it myself. Whatever works!

However, I'm slowly improving little by little, working as much as I'm able to and trying to finish my book: Energy from the Vacuum: Concepts and Principles, and get it to the publisher for publication later this year. Hopefully the book will turn all the interested young grad students and post-docs loose in the free-energy area. They will not have to spend 30 agonizing years to get to where I am, and where a few others are, but can simply start here and go forward. Since speed to develop energy from the vacuum is of the essence because of the world situation, I'm moving on it as fast as I am physically able to.

Meanwhile, working with the AIAS (Alpha Foundation's Institute for Advanced Study), the AIAS (15 authors) has now gotten about 20 scientific papers published in leading journals (Foundations of Physics, Foundations of Physics Letters, Physical Scripta, Optik, etc.) dealing with electromagnetic energy from the vacuum. Several more are either approved for publication or in the review process also. So slowly we are getting it into the mainstream scientific literature. Hopefully it will be in time, but it's cutting it close.

Very best wishes,

Tom Bearden

Late update

Massive display of longitudinal interferometers?

UFO Fleet Taped Over Bedhampton, England

Is this sighting a case of the testing of all the Russian (KGB) longitudinal interferometers at once? And coordinating their targeting through the woodpecker grid to a common place, as an exercise in making a massive scalar attack upon a given region? Was this a confluence of Russian Tesla howitzer marker-beacons?

Bedhampton, England - March 22, 2002 - Video Frames by: Anthony Woods

Certainly for a massive all-out scalar attack you would want coordinated movements of the target areas of many howitzers at once, for you could then just cut a bloody swath across a wide area, all the howitzer blasts marching across the land in a kind of scalar version of the "scorched-earth policy." All in a line, blasting, and heat, and mind waves. Or you might want to put the blasts all in the same place for a truly horrendous destruction. And on top of that biowar on citizens whose immune systems have been weakened with the quantum potential weapons. This is the latest version of Armageddon.

And should any madmen gain control of these weapons, any rogue group at all, and should they have some agenda to radically depopulate the world, to simply kill by the billion, the means will be in their hands to do so.

Update: MEG patent granted

Motionless Electromagnetic Generator Patent Granted

This message is from Jean-Louis Naudin, the French scientist who successfully replicated the Motionless Electromagnetic Generator (MEG) in France. He announces the granting of the patent to the MEG Builder's group at Yahoo.

----- Original Message -----

From: jnaudin509@aol.com
To: jlnlabs@yahoogroups.com
Sent: Tuesday, March 26, 2002 2:20 PM
Subject: [jlnlabs] (Info) GOOD NEWS : The Tom Bearden's MEG IS PATENTED

Dear ALL,

GOOD NEWS !!!!

The Motionless Electromagnetic Generator from Tom Bearden is now PATENTED US 6362718 granted on March 26, 2002

US Patent 6,362,718 :
Motionless Electromagnetic Generator (MEG)

Abstract: An electromagnetic generator without moving parts includes a permanent magnet and a magnetic core including first and second magnetic paths. A first input coil and a first output coil extend around portions of the first magnetic path, while a second input coil and a second output coil extend around portions of the second magnetic path. The input coils are alternatively pulsed to provide induced current pulses in the output coils. Driving electrical current through each of the input coils reduces a level of flux from the permanent magnet within the magnet path around which the input coil extends. In an alternative embodiment of an electromagnetic generator, the magnetic core includes annular spaced-apart plates, with posts and permanent magnets extending in an alternating fashion between the plates. An output coil extends around each of these posts. Input coils extending around portions of the plates are pulsed to cause the induction of current within the output coils.

Inventors: Patrick; Stephen L. (2511 Woodview Dr. SE., Huntsville, AL 35801); Bearden; Thomas E. (2211 Cove Rd., Huntsville, AL 35801); Hayes; James C. (16026 Deaton Dr. SE., Huntsville, AL 35803); Moore; Kenneth D. (1704 Montdale Rd., Huntsville, FL 35801); Kenny; James L. (925 Tascosa Dr., Huntsville, AL 35802)

Appl. No.: 656313
Filed: September 6, 2000

For some technical info see my web site at : http://jnaudin.free.fr/html/meg.htm

Best Regards
Jean-Louis Naudin
Email: JNaudin509@aol.com
Main Web site : http://jlnlabs.org
Site France : http://jlnlabs.multimania.com

Click here to view patent # 6,362,718

Patent Story on Rense.com:

Rense.com

MEG Scalar Energy Device
Patented - Production Starts Next Year

From Bill Morgan
wmorgan@nycap.rr.com
3-28-2

Patent was granted on March 26, 2002 for "The Motionless Magnetic Generator," (MEG) US Patent 6,362,718, which is likely to become the first commercially available free energy device in history in about one year from now. The machine will provide free electricity from the vacuum, for the life of the device, which should be a very long life since it has no moving parts. You can see a picture of scientist Jean-Louis Naudin's MEG replication model at: http://jnaudin.free.fr/html/meg.htm.

It has strong magnets, coils, and a controller unit with the electronics. Naudin made the announcement to the MEG-builder's Yahoo group. The announcement has significance since the patent office has always been skeptical of devices which seem to "get-something-for-nothing." But according to the new science of scalar electromagnetics, the MEG does not break the law of conservation of energy. It's just that the energy is conserved in the fourth dimension, time, and not our 3-space world.

The MEG provides electrical energy by tapping the longitudinal electromagnetic (EM) waves which exist in almost infinite abundance in the vacuum of space. This ocean of energy which permeates everything is sometimes called the "zero point" energy, since it remains there even at absolute zero temperature.

Four inventors are listed: Stephen L. Patrick, Thomas E. Bearden, James C. Hayes, Kenneth D. Moore.

Tom Bearden has explained the operation of the MEG on his website Cheniere.org, and also speaks about the new fearful weapons that can and have been made using the same "longitudinal waves" of the vacuum.

The complicated physics of how the MEG works is explained in the paper "The Motionless Electromagnetic Generator: Extracting Energy from a Permanent Magnet with Energy Replenishment from the Active Vacuum," which can be found at Tom Bearden's website:

cheniere.org.(http://www.help4all.de/energy/MEGpaper.pdf)

The first MEG units to be produced for sale will output 2.5 kilowatts of free electricity. Forever. They should be in production about a year from now. Facilities for manufacturing the device are being set up in an unnamed "friendly nation."

This free electricity will flow indefinitely, without much, or any maintenance. The units may be hooked together to provide more wattage, so four of them would provide 10 kilowatts. After some production experience units will be made which output 10 kilowatts each. With a couple of those units a house could get off the electrical grid.

Tom Bearden, one of the inventors has said "I will admit that the chief scientist of an important experimental group in a large company was rather stunned at the type of output we were able to obtain. The MEG may look like just a transformer, but it is not. It is a completely different breed of cat." This cat, it would seem, is out of the bag now.

The ordinary EM waves we are familiar with are called "transverse" waves, to distinguish them from the new "longitudinal" EM waves of the vacuum. Bearden has explained in depth on his website cheniere.org that wherever there is a dipole (battery, generator, magnet) there is an unseen flow of longitudinal EM waves in that local vacuum, the only problem is in tapping that energy and "transducing" it to electricity. Bearden says that the problem with all the electrical circuits we have is that they are two-wire circuits, a loop by which half the energy goes back to destroy the dipole. In the MEG that closed loop is never made. So the dipole is not being destroyed.

Patents are not granted on devices which do not work, so in a sense this announcement proclaims a new era. The MEG device itself proclaims and proves that energy is abundantly available everywhere, for free. We only have to build the devices to tap it. MEG type devices could be put into a car with an electric engine to make a truly fuel-less automobile. Electricity can be available in very remote places. People will be able to get off our very terrorist-vulnerable power grids. In an era of terrorism a highly dispersed power system would be most desirable rather than our centralized systems.

What is somewhat astonishing to me is the discovery by Bearden et. al. that time itself is actually compressed energy, and that this free energy is actually coming from the time domain, the ocean of longitudinal EM waves which fill the empty vacuum of spacetime. In fact, time is energy compressed by the same factor that matter is compressed energy: the speed-of-light squared. Thus there is a new companion to Einstein's E=mc2. Can you say "E equals delta-tee-cee-squared?" The "tee" is time and delta-tee is change in time.

A company has been set up to manufacture the MEG called Magnetic Energy Limited.

The ramifications of free energy are enormous. The oil wars are not necessary. If we threw as much money at this technology as we are spending on the oil wars we would be free of the need for oil in less than a decade. With fuel-less cars air pollution will be greatly lessened. Third world nations can raise their standard of living eventually. And the energy is free. And it never runs out.

I have put together a kind of "Bearden for Beginners" article which explains some of the basic concepts of the current state of scalar technology.

http://www.prahlad.org/pub/bearden/scalar_wars.htm

The granting of the MEG patent is the herald of the new era of scalar electromagnetics, and the free energy which flows forever and never runs out.

Bill Morgan
wmorgan@nycap.rr.com

Do the magnets run down after a while?

Further developments: Tom Bearden clears up a question

When the MEG patent was released many questioned the patent language which seemed to imply that permanent magnets of the MEG would "wear out" after awhile. I myself wondered about the same thing so I put the question to Tom, and here is his reply.

> Dear Bill,
>
> Thanks for the kind words; much appreciated.
>
> I'm not up to going on radio or TV, and won't be for quite some time. Still suffering from hypoxia, though very slowly improving, and will still be on antibiotics for 10 more months at least (maybe longer).
>
> Obviously an extensive dialog developed between the Patent office and our patent attorneys. As best I can understand it, the Patent office accepts the fact that a permanent magnet produces and emits energy, or has a history of accepting it. They do not appear to be at all cognizant of the broken symmetry of opposite charges, and hence of a dipole. So in their opinion (which seems to be vague), the magnet has to use itself up very gradually, or some such. So some rewrites were essentially required by the Patent office.
>
> All I can say is that a magnet is a very durable thing, so long as you don't heat it up too much or shock it to much. Certainly one will make a good 20 years, and of course there are plenty of magnets that have been around awhile longer.
>
> That said, in our earliest experiments we did "measure" some such effect, or so we thought, until we found that a particular instrument was bad and giving erroneous readings. So with a new instrument, we have not observed since then any such readings.
>
> Out of all that fuzziness came the inclusion of "using up the magnets gradually". So far as we are aware (after correcting those early readings on a defective instrument), we have seen no such measurements or effects since then at all. Nonetheless, just in case there is some very small effect in that respect, at least it's in there.
>
> Actually, as you are aware, capacitors and solid state components are the major concerns for failure, and any system does require maintenance, both periodic and whenever malfunction or failure occurs. The MEG is no different from any other device in that respect, so of course it will have a component failure rate and maintenance required from time to time, just as any other electromagnetic device. But without moving parts, it can be ruggedized and made very durable indeed.
>
> Please give Jeff Rense my regrets, and I do admire his work and his show. He's laying it in there.
>
> The depth of the scientific mindset against COP>1.0 is inexplicable, particularly when physics itself already has COP>1.0 validated experiments (such as Bohren's experiment,

which outputs 18 times as much as one inputs by Poynting calculations), and it works every time. Any competent university optics lab can perform the experiment. Also, even the conventional texts admit that a charged capacitor or electret laid on a permanent magnet, so that the E of the cap or electret and the H of the magnet are at right angles, is a "free energy machine". That silly thing will just sit there and pour out Poynting energy S = EXH indefinitely. Years and years and years. If you wait just a single year, that silly thing has changed the energy density of a volume of space a light year in radius, reaching out well beyond the solar system. Now that's a WHALE of a lot of EM energy that beast poured out in that year, and it will still be going strong and pouring it out at a steady rate. The charges and dipoles in original matter in the universe have been pouring out EM energy in that fashion for some 14 billion years, give or take a billion or so. It's also easy to see that, prior to Lorentz's ARBITRARY symmetrical regauging of the Maxwell-Heaviside equations, those equations prescribe both EM systems in equilibrium with their active environment, and EM systems not in equilibrium with it. The latter systems are permitted by the thermodynamics of open disequilibrium systems to perform five magic functions: (1) self-order, (2) self-oscillate or self-rotate, (3) output more energy than the operator inputs (the active environment inputs the rest of it), (4) power itself and its load (the active environment inputs all the energy, like a windmill), and (5) exhibit negentropy. That is a well-established thermodynamics. Lorentz arbitrarily discarded all such open disequilibrium EM systems in order to get simpler equations having analytical solutions and not requiring numerical methods. So he simply scrapped all the really interesting and challenging EM systems in Maxwell's theory. ARBITRARILY!

That our scientific establishment continues to teach only that "half" of the theory, and not point out the rest to the young students, and not fund research into developing such systems that take energy from the vacuum, is simply inexplicable. It's a matter of total dogma, not science at all.

But hopefully it is changing a little bit. At least now we cite chapter and verse when these things were done, and what they are, and the young grad students and post docs can go check the papers and make up their own minds.

That is the real hope of the future: that we get a generation of young fellows, with excellent skills, who now know where all the skeletons got hidden in the closet, and understand that the electrical engineering model arbitrarily assumes an inert vacuum environment (falsified for more than a half century in particle physics) and a local flat spacetime (falsified for nearly a century by general relativity).

Once they know that past history, and go read into what broken symmetry of opposite charges means for a dipole and for all dipolar EM circuits, they will set to and change that more than a century of error. In that case, we shall have numerous solutions to the energy crisis rather quickly, popping up all over.

Good thing. It will certainly displace some great energy barons, but it will also free the populace. One can extract all the EM energy from the vacuum one wishes, anywhere, anytime, with ridiculous ease. One can produce that "electrical wind of energy" at will, by making a simple dipole and then letting it alone. The only energy problem is in how to then intercept some of that energy flow and "catch" it in a circuit, discharge it in a load to power it, and not use half the "caught" energy to kill that dipole that is gushing out the extracted EM energy from the vacuum.

Very best wishes,

Tom Bearden

END

The Tom Bearden Website

Help support the research

Foundations of Electro-Magnetism
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- Chung's Carbon Filament Negative Resistor
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- Asymmetric regauging produces excess force, which can be used to do work on the regauging system
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- Aspects of Strong Local Symmetry
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- Bunge on the Status of Electrodynamics
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- Fractions of BW Casualties Surviving
- First Step in Self-Promotion of Cancer Due to Hypoxia
- Differentiation and Dedifferentiation Timelines
- Evolution of Cells on Earth
- A Charged Particle q is a Coupled System of m and Ø
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (1)
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (2)
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (3)
- A Charged Particle is a Coupled System
- The Anomalies in Navy Electrolyte Experiments at China Lake
- Chung's Carbon Filament Negative Resistor

- Typical circuit has about 10^{-13} energy collection efficiency
- Classical View of EM
- Curved Spacetime acts as source or sink
- Chronic Disease Puzzling
- Cancer Characteristics
- Solving a Cancer Enigma
- Cancer: Characteristics
- Nonlinear Optics Distortion Correction Theorem
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (1)
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (2)
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (3)
- In Time-Reversed Zone: Nuclear reactions are biased
- In Time-Reversed Zone: Dynamics may be reversed
- Time-Reversed Zone: Significant only after time-density charging
- A New Conservation of Energy Law
- Questions on Carcinogens and EM

Radiation

- AS DEFINED, fields and potentials only exist in and on charged matter
- Serious flaws and errors in classical EM theory
- Electrodynamicists' Reaction to Removal of the Material Ether
- Reaction to Loss of Material Ether (1)
- Reaction to Loss of Material Ether (2)
- Some EM waves in Spacetime
- Air Medium Disturbances Generated When Air is Perturbed by a Plucked Taut String
- Launching a Spacetime Perturbation ("EM Wave") from a Wire Antenna
- Phase Conjugate Wavepairs Produce New Waves
- Scalar Electromagnetics (Energetics) View of EM (1)
- Scalar Electromagnetics (Energetics) View of EM (2)

- Scalar Electromagnetics (Energetics) View of EM (3)
- Extended General Relativity Principle
- Extension of Work-Energy Theorem
- 34 Flaws in Classical EM Theory
- MTW's General Relativity Principle
- Use of General Relativity (GR) in Particle Physics
- The Missing Infolded Electrodynamics
- Infolded Engines: Excluded by Present Physics
- Mass curves and structures spacetime; ST curvatures change and structure mass (1)
- Mass curves and structures spacetime; ST curvatures change and structure mass (2)
- At Infinite Velocity: Each Is Every Other
- Lisitsyn's Report: Brain Code Broken
- Lorentz Closed Surface Integration
- Lorentz's physically insignificant energy flow can be collected and utilized
- Lorentz surface integration of the Poynting vector around a closed surface
- Longitudinal EM Photon Interaction with Charge
- Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass.

- Pumping with Longitudinal EM waves Time-reverses the Mass
- Maxwell's Quaternion Theory
- Maxwellian Systems before and after Regauging
- Maxwell's four equations reduce to: Page 1
- Maxwell's four equations reduce to: Page 2
- More to come

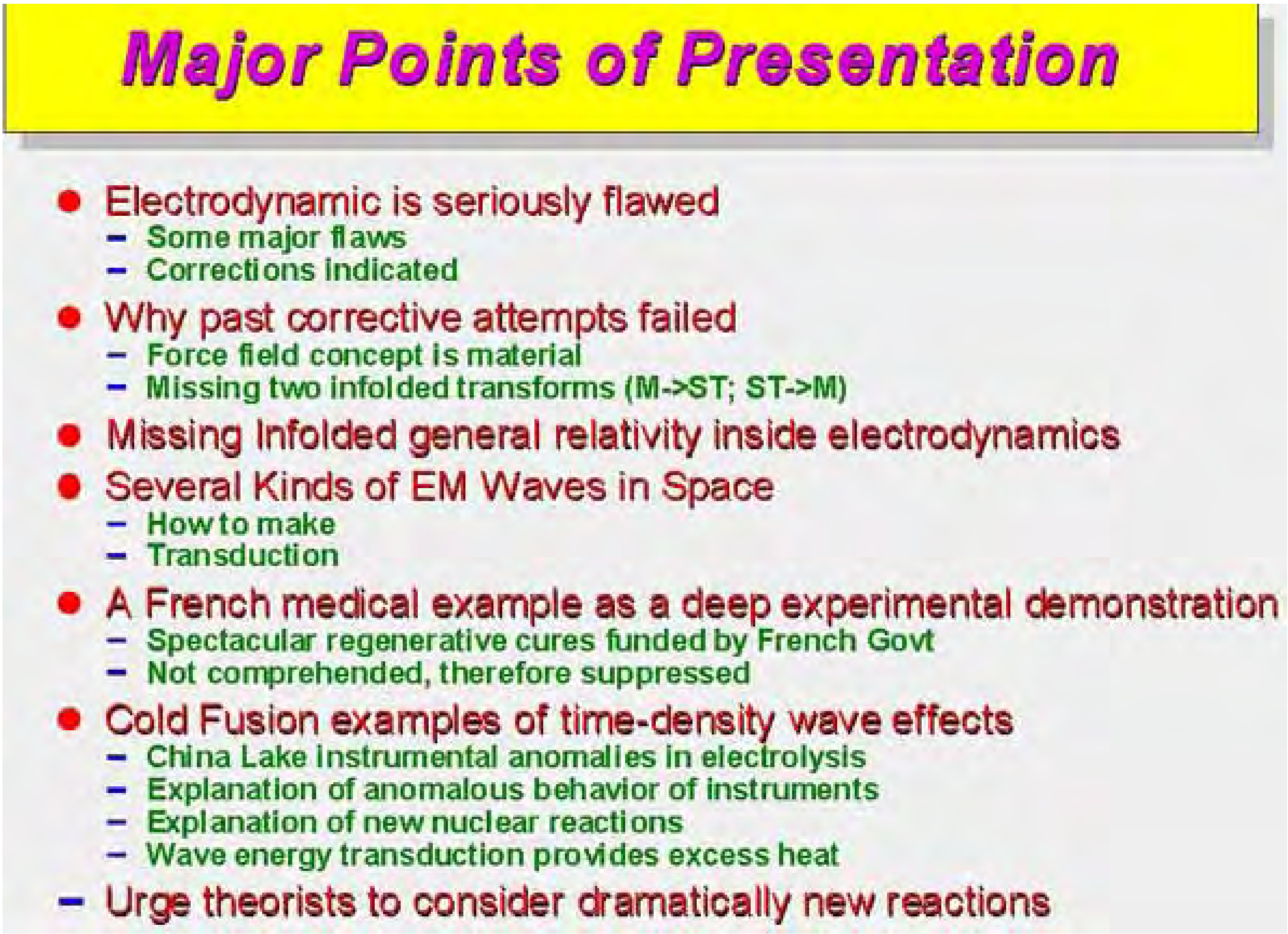

Major Points of Presentation

- Electrodynamic is seriously flawed
  - Some major flaws
  - Corrections indicated
- Why past corrective attempts failed
  - Force field concept is material
  - Missing two infolded transforms (M->ST; ST->M)
- Missing infolded general relativity inside electrodynamics
- Several Kinds of EM Waves in Space
  - How to make
  - Transduction
- A French medical example as a deep experimental demonstration
  - Spectacular regenerative cures funded by French Govt
  - Not comprehended, therefore suppressed
- Cold Fusion examples of time-density wave effects
  - China Lake instrumental anomalies in electrolysis
  - Explanation of anomalous behavior of instruments
  - Explanation of new nuclear reactions
  - Wave energy transduction provides excess heat
- Urge theorists to consider dramatically new reactions

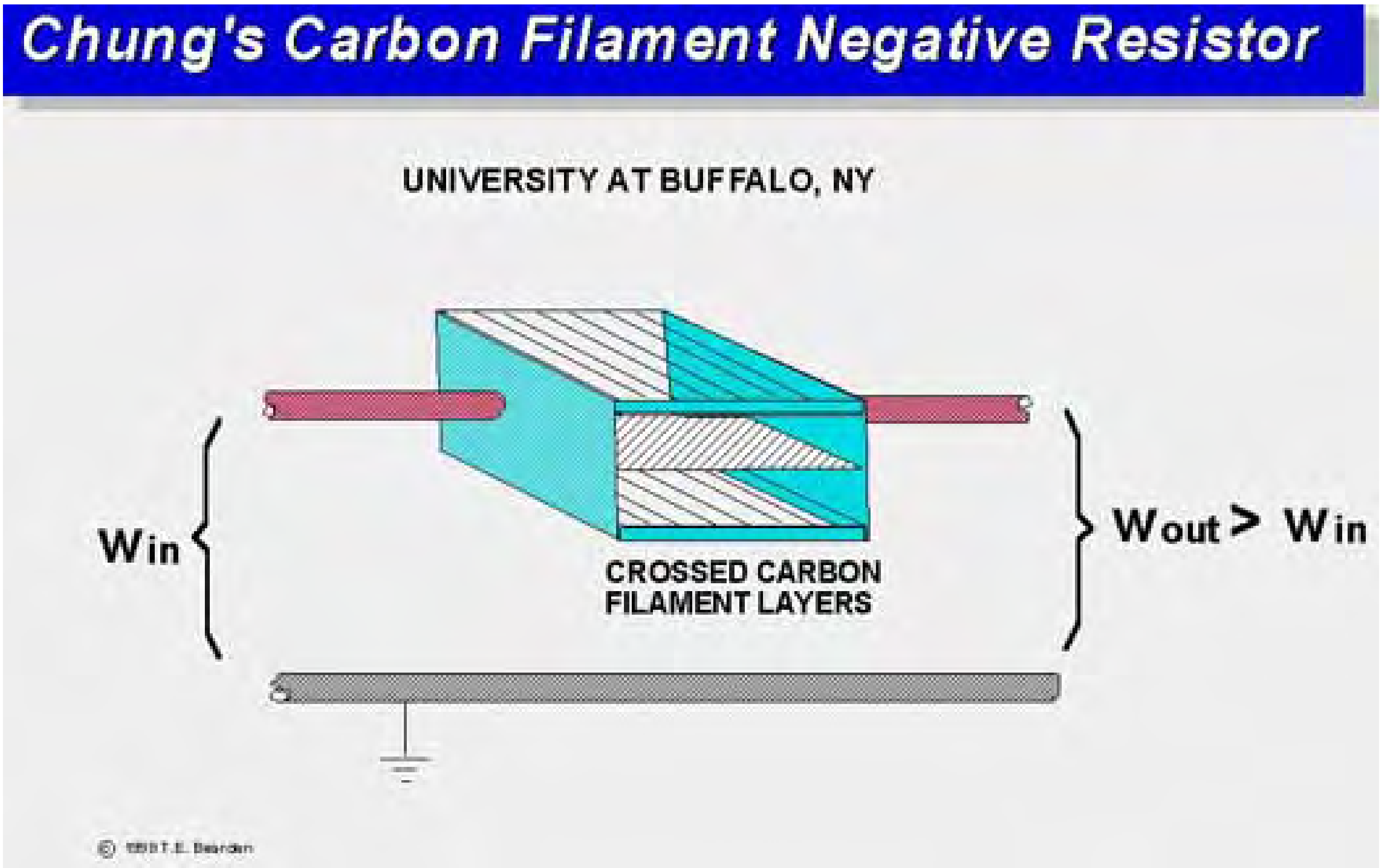

Chung's Carbon Filament Negative Resistor

UNIVERSITY AT BUFFALO, NY

W_{in}
CROSSED CARBON FILAMENT LAYERS
$W_{out} > W_{in}$

© [illegible] T.E. Bearden

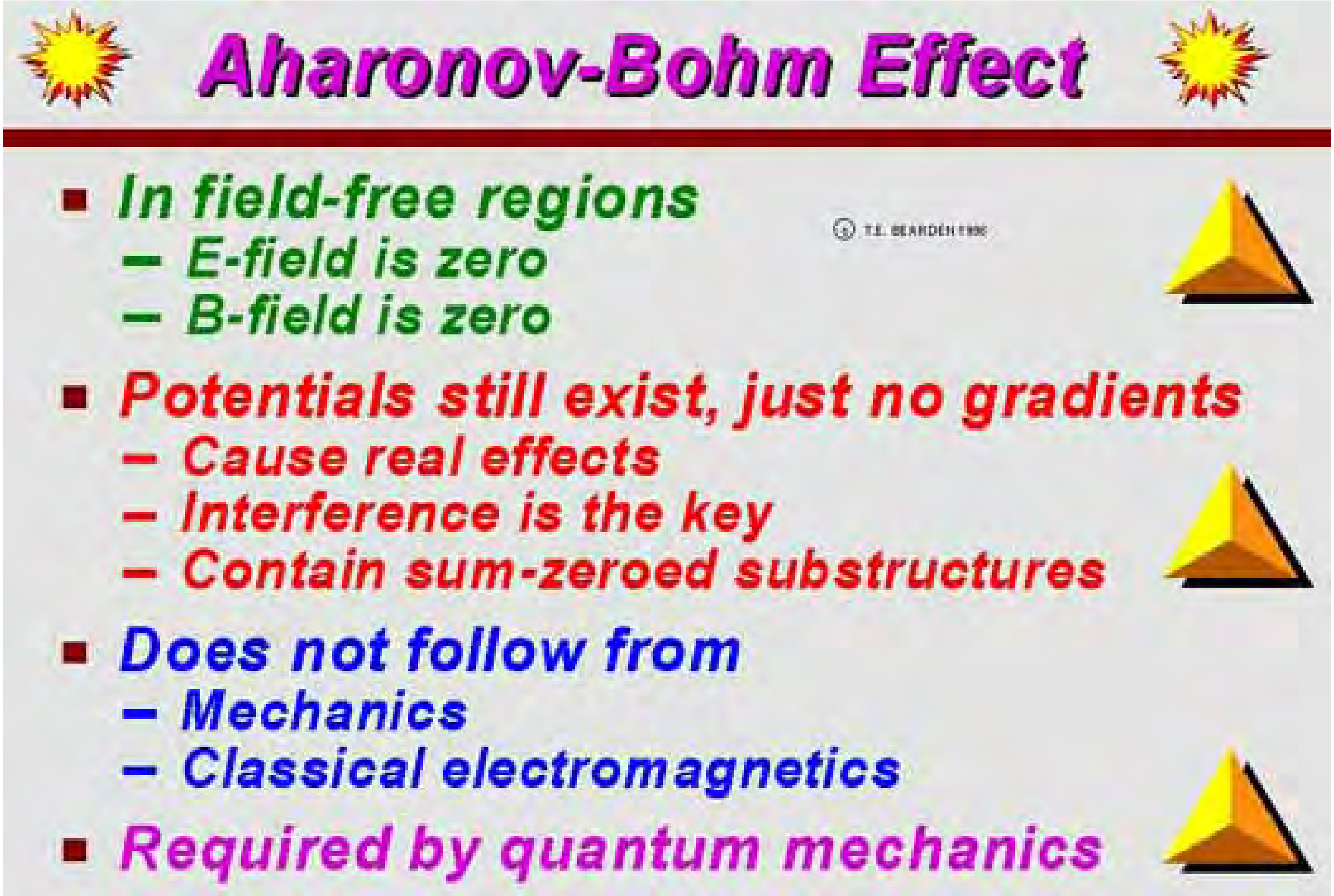

Aharonov-Bohm Effect

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- In field-free regions
  - E-field is zero
  - B-field is zero
- Potentials still exist, just no gradients
  - Cause real effects
  - Interference is the key
  - Contain sum-zeroed substructures
- Does not follow from
  - Mechanics
  - Classical electromagnetics
- Required by quantum mechanics

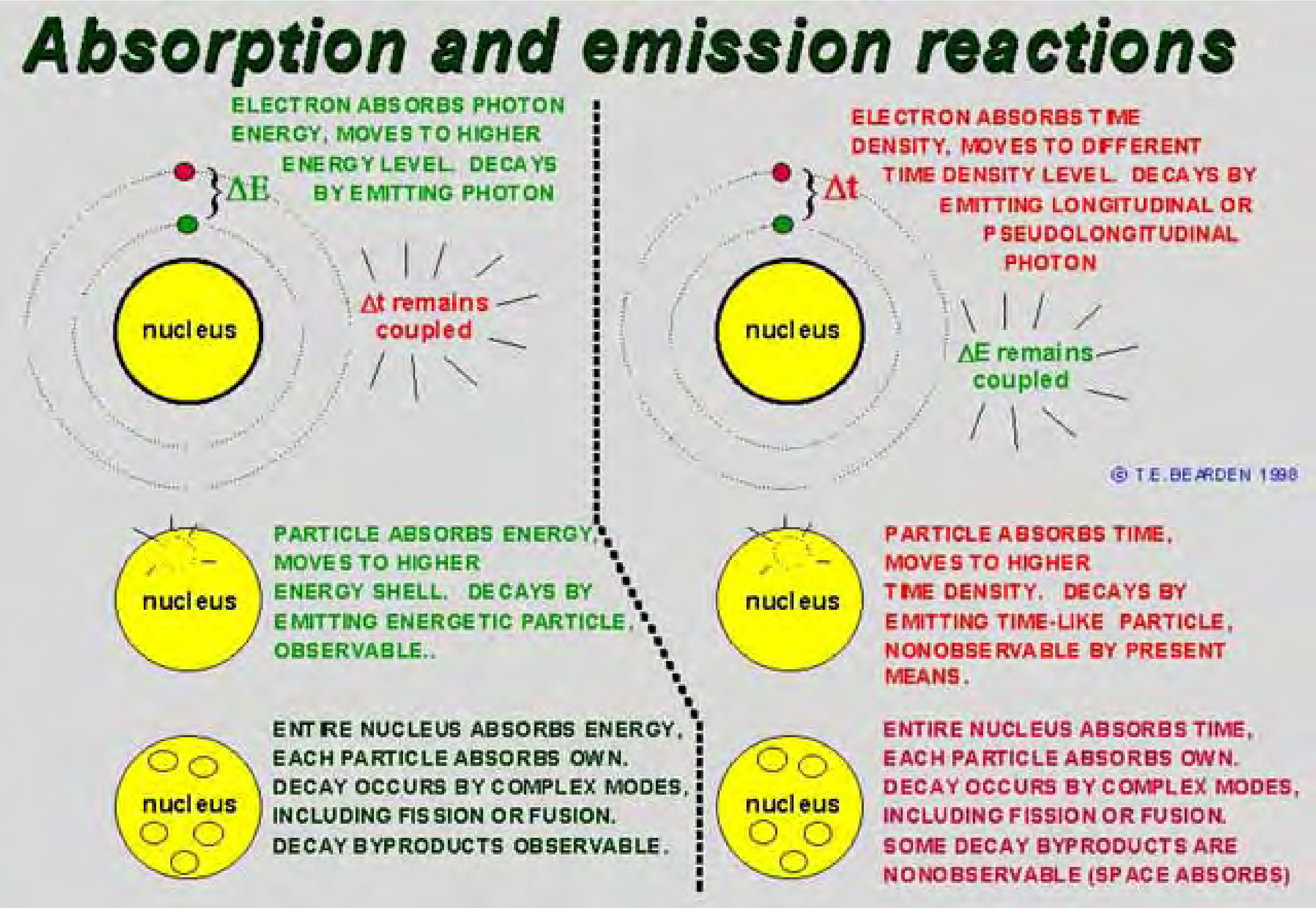

Absorption and emission reactions

ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON

Δt remains coupled

ELECTRON ABSORBS TIME DENSITY, MOVES TO DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTON

ΔE remains coupled

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PARTICLE ABSORBS ENERGY, MOVES TO HIGHER ENERGY SHELL. DECAYS BY EMITTING ENERGETIC PARTICLE, OBSERVABLE..

PARTICLE ABSORBS TIME, MOVES TO HIGHER TIME DENSITY. DECAYS BY EMITTING TIME-LIKE PARTICLE, NONOBSERVABLE BY PRESENT MEANS.

ENTIRE NUCLEUS ABSORBS ENERGY, EACH PARTICLE ABSORBS OWN. DECAY OCCURS BY COMPLEX MODES, INCLUDING FISSION OR FUSION. DECAY BYPRODUCTS OBSERVABLE.

ENTIRE NUCLEUS ABSORBS TIME, EACH PARTICLE ABSORBS OWN. DECAY OCCURS BY COMPLEX MODES, INCLUDING FISSION OR FUSION. SOME DECAY BYPRODUCTS ARE NONOBSERVABLE (SPACE ABSORBS)

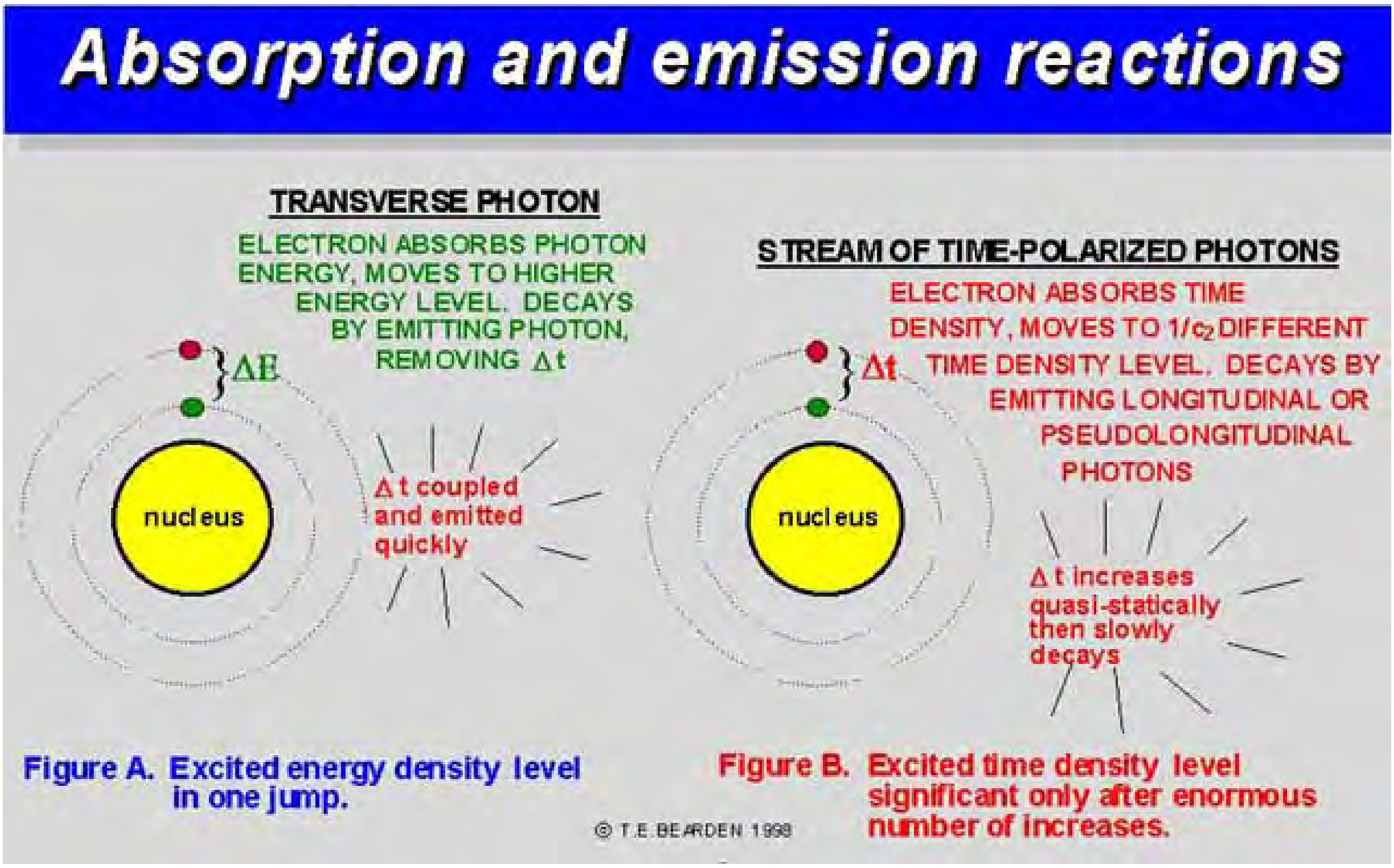

Absorption and emission reactions

TRANSVERSE PHOTON

ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON, REMOVING Δt

STREAM OF TIME-POLARIZED PHOTONS

ELECTRON ABSORBS TIME DENSITY, MOVES TO 1/c^2 DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTONS

ΔE
nucleus
Δt coupled and emitted quickly
Δt
nucleus
Δt increases quasi-statically then slowly decays

Figure A. Excited energy density level in one jump.

Figure B. Excited time density level significant only after enormous number of increases.

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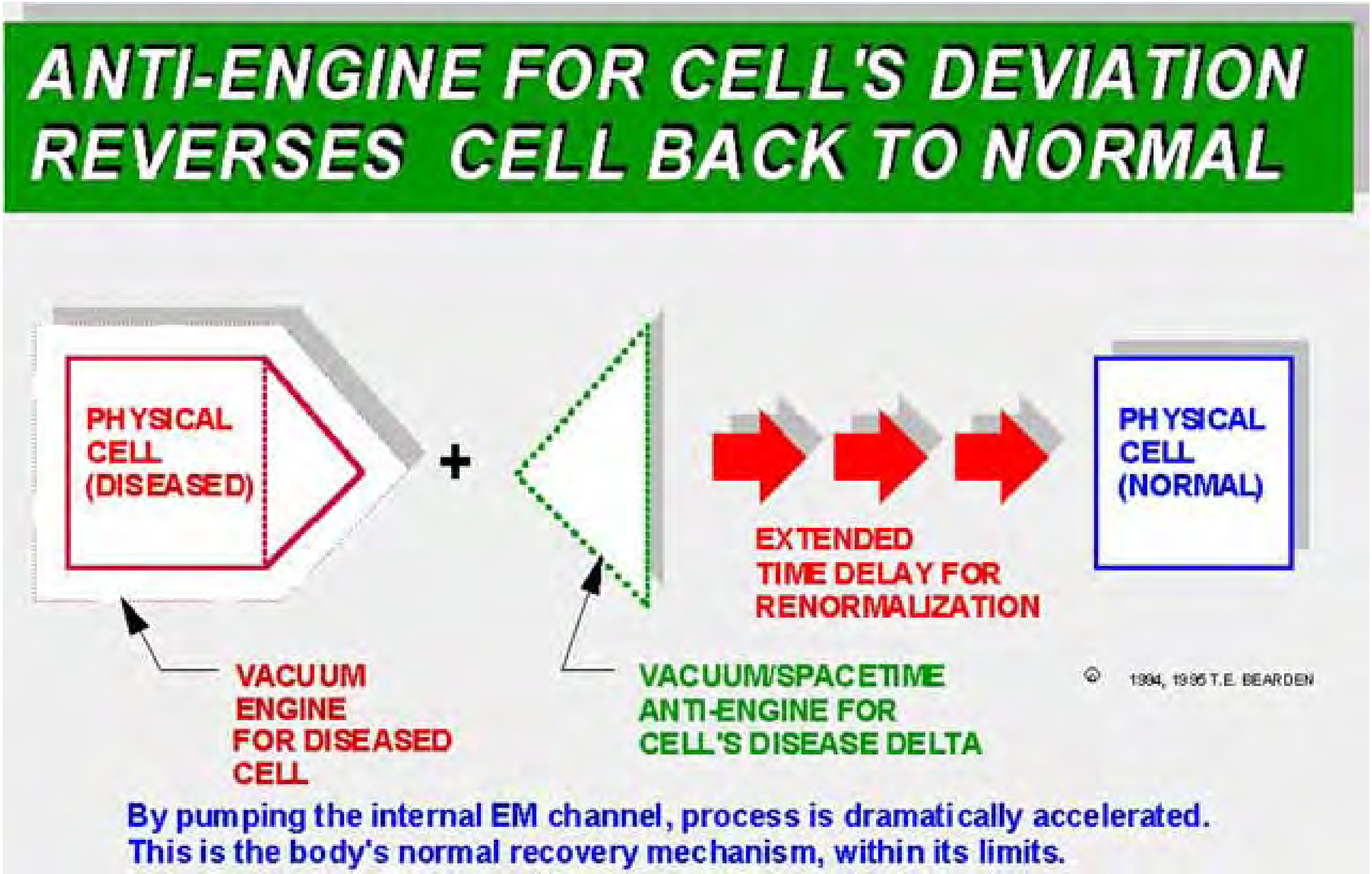

ANTI-ENGINE FOR CELL'S DEVIATION REVERSES CELL BACK TO NORMAL

PHYSICAL CELL (DISEASED)

+

EXTENDED TIME DELAY FOR RENORMALIZATION

PHYSICAL CELL (NORMAL)

VACUUM ENGINE FOR DISEASED CELL

VACUUM/SPACETIME ANTI-ENGINE FOR CELL'S DISEASE DELTA

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By pumping the internal EM channel, process is dramatically accelerated. This is the body's normal recovery mechanism, within its limits.

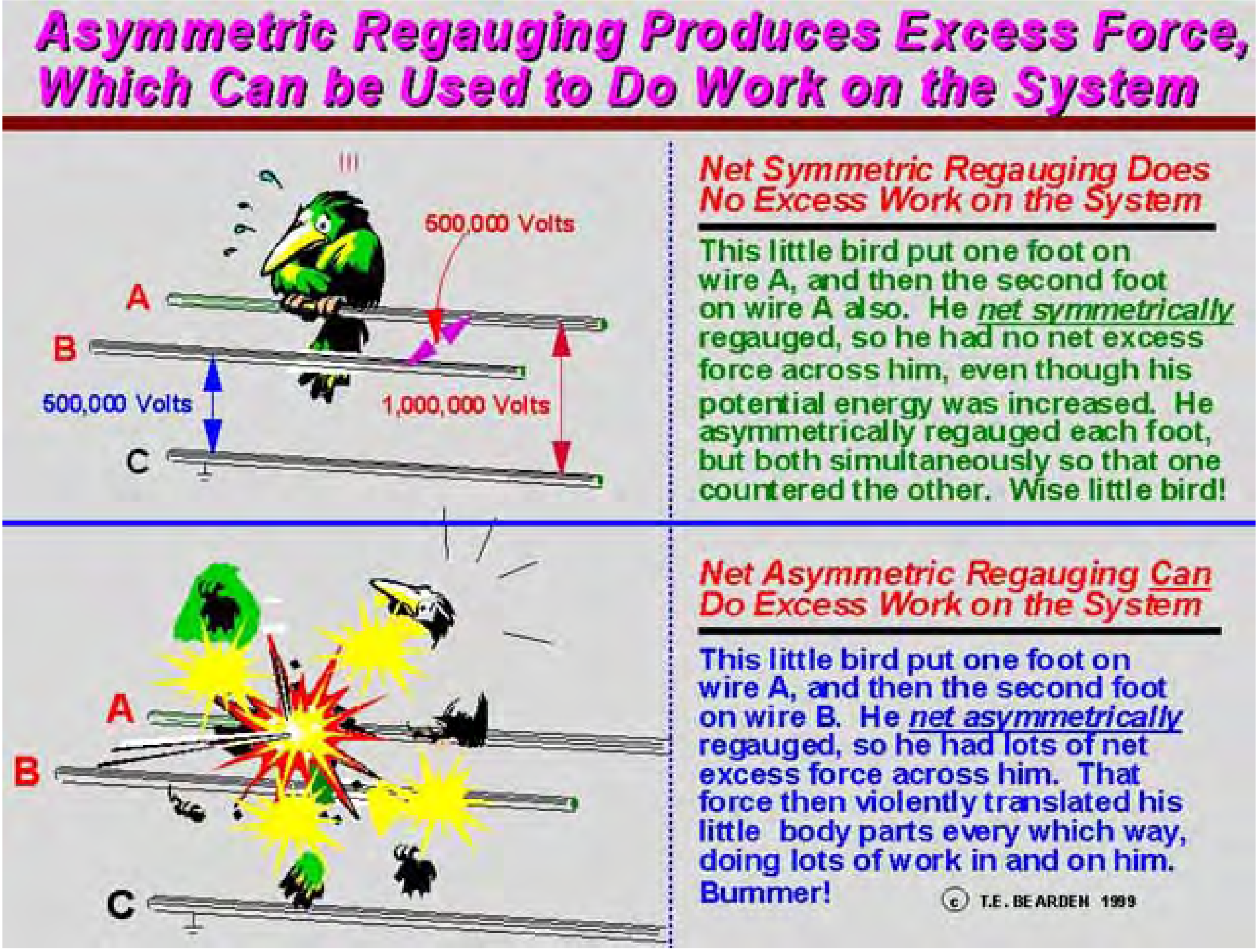

Asymmetric Regauging Produces Excess Force, Which Can be Used to Do Work on the System

Net Symmetric Regauging Does No Excess Work on the System

This little bird put one foot on wire A, and then the second foot on wire A also. He *net symmetrically* regauged, so he had no net excess force across him, even though his potential energy was increased. He asymmetrically regauged each foot, but both simultaneously so that one countered the other. Wise little bird!

Net Asymmetric Regauging *Can* Do Excess Work on the System

This little bird put one foot on wire A, and then the second foot on wire B. He *net asymmetrically* regauged, so he had lots of net excess force across him. That force then violently translated his little body parts every which way, doing lots of work in and on him. Bummer!

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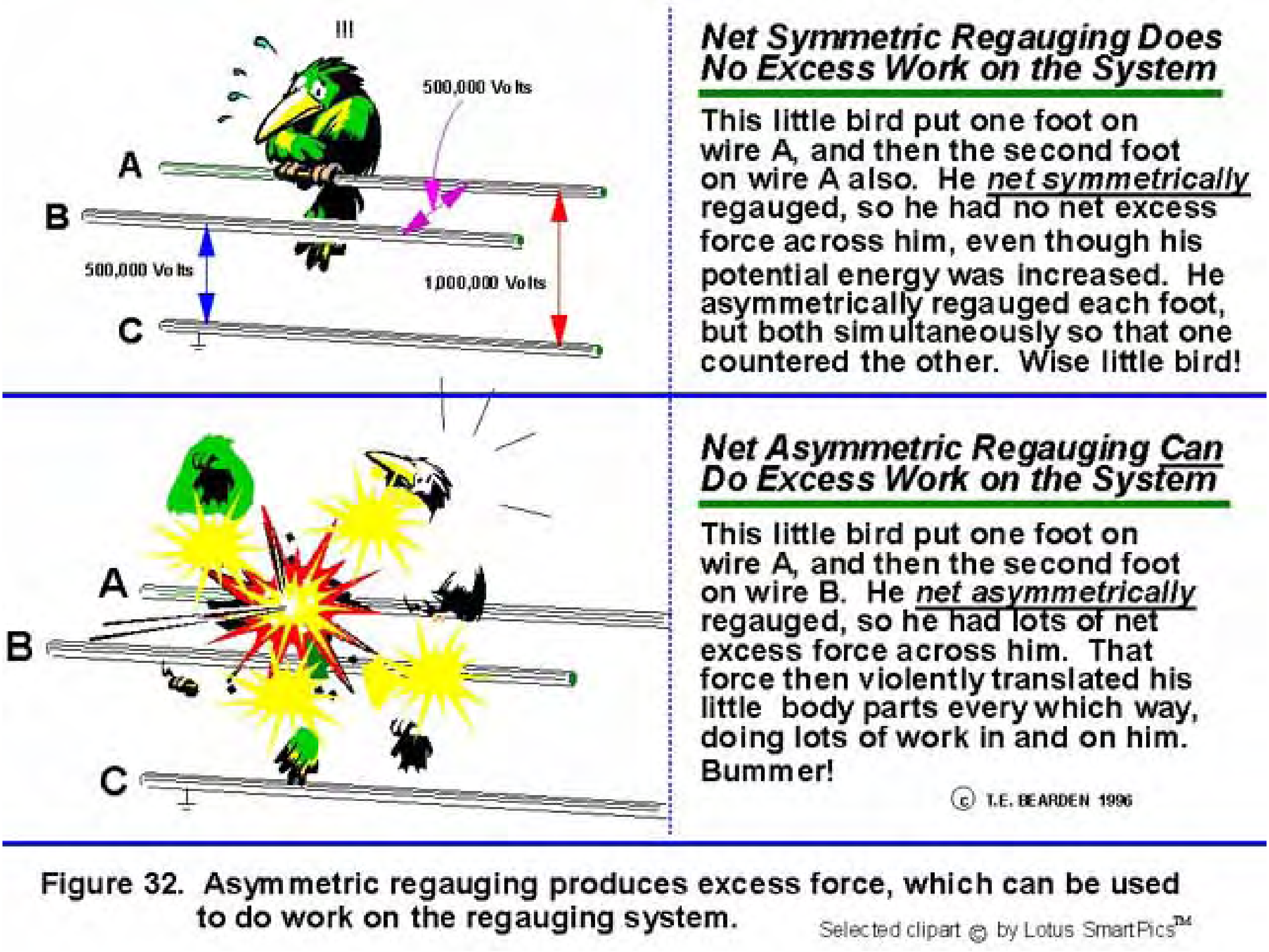

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Net Asymmetric Regauging Can Do Excess Work on the System

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ⓒ T.E. BEARDEN 1996

Figure 32. Asymmetric regauging produces excess force, which can be used to do work on the regauging system.

Selected clipart © by Lotus SmartPics™

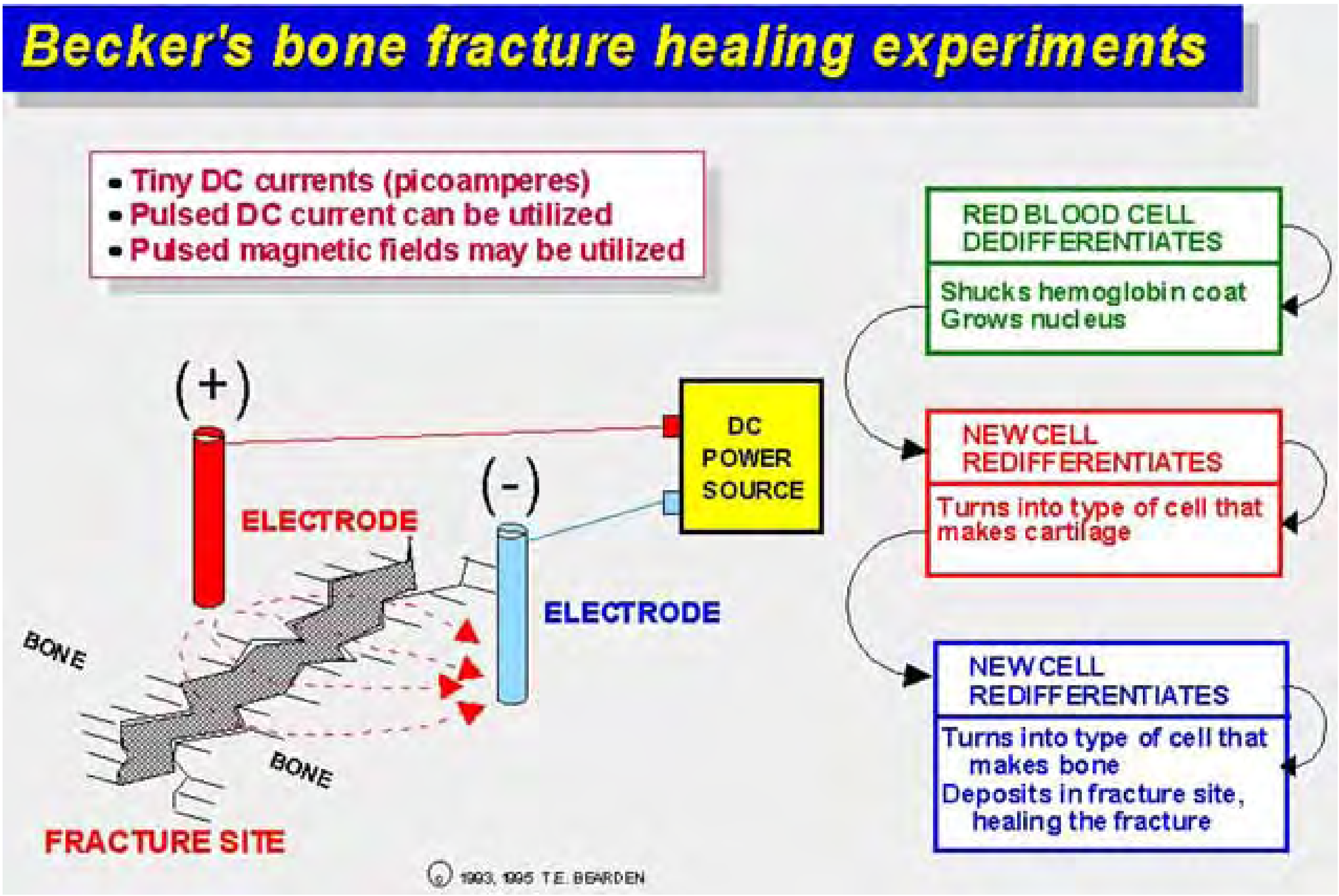

Becker's bone fracture healing experiments

- Tiny DC currents (picoamperes)
- Pulsed DC current can be utilized
- Pulsed magnetic fields may be utilized

(+)
ELECTRODE
(-)
ELECTRODE
DC
POWER
SOURCE
BONE
BONE
FRACTURE SITE

RED BLOOD CELL DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

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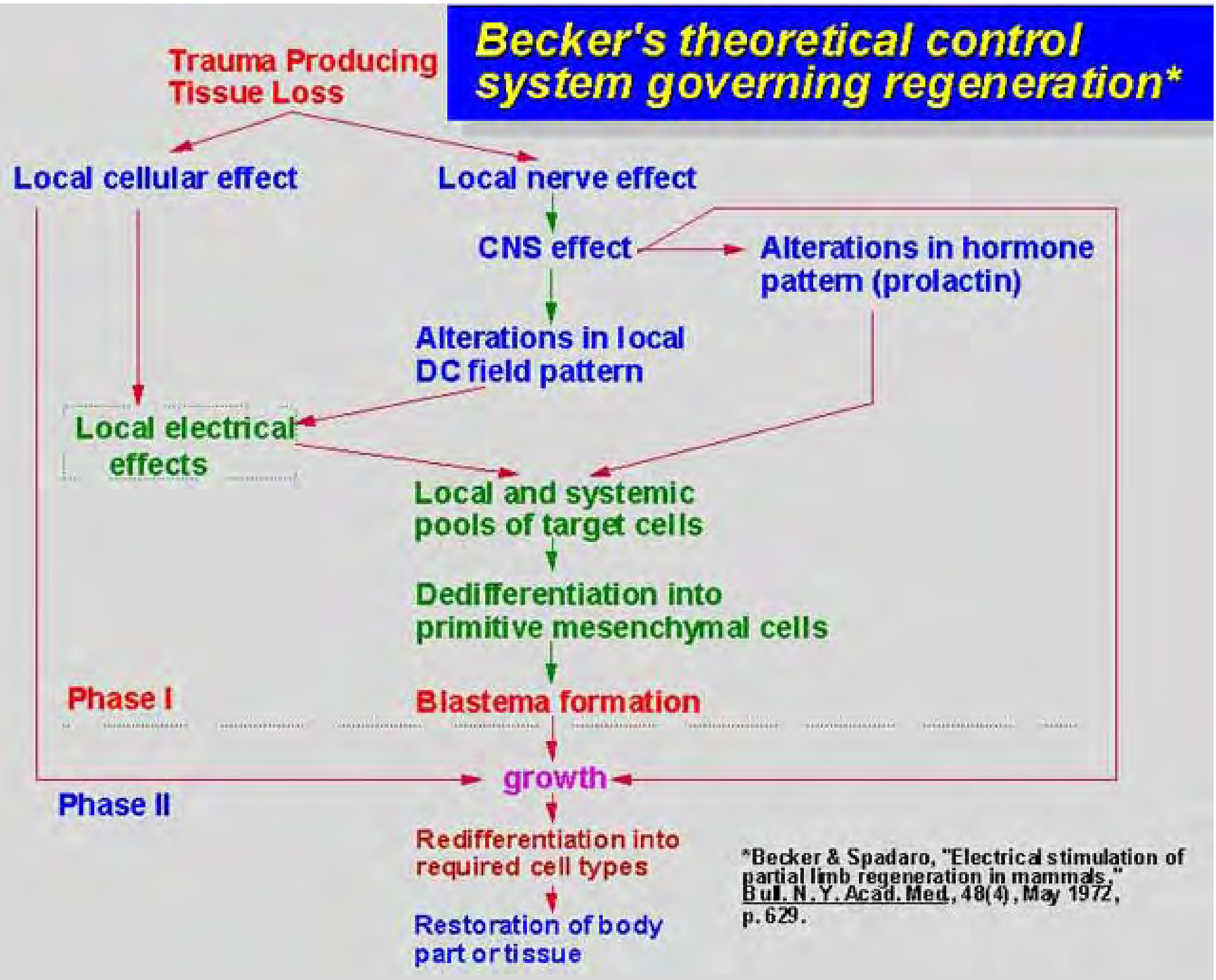

Becker's theoretical control system governing regeneration*

Trauma Producing Tissue Loss

Local cellular effect

Local nerve effect

CNS effect

Alterations in hormone pattern (prolactin)

Alterations in local DC field pattern

Local electrical effects

Local and systemic pools of target cells

Dedifferentiation into primitive mesenchymal cells

Phase I

Blastema formation

growth

Phase II

Redifferentiation into required cell types

Restoration of body part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bul. N.Y. Acad. Med., 48(4), May 1972, p. 629.

Becker's theoretical DC control system involved with response to injury*

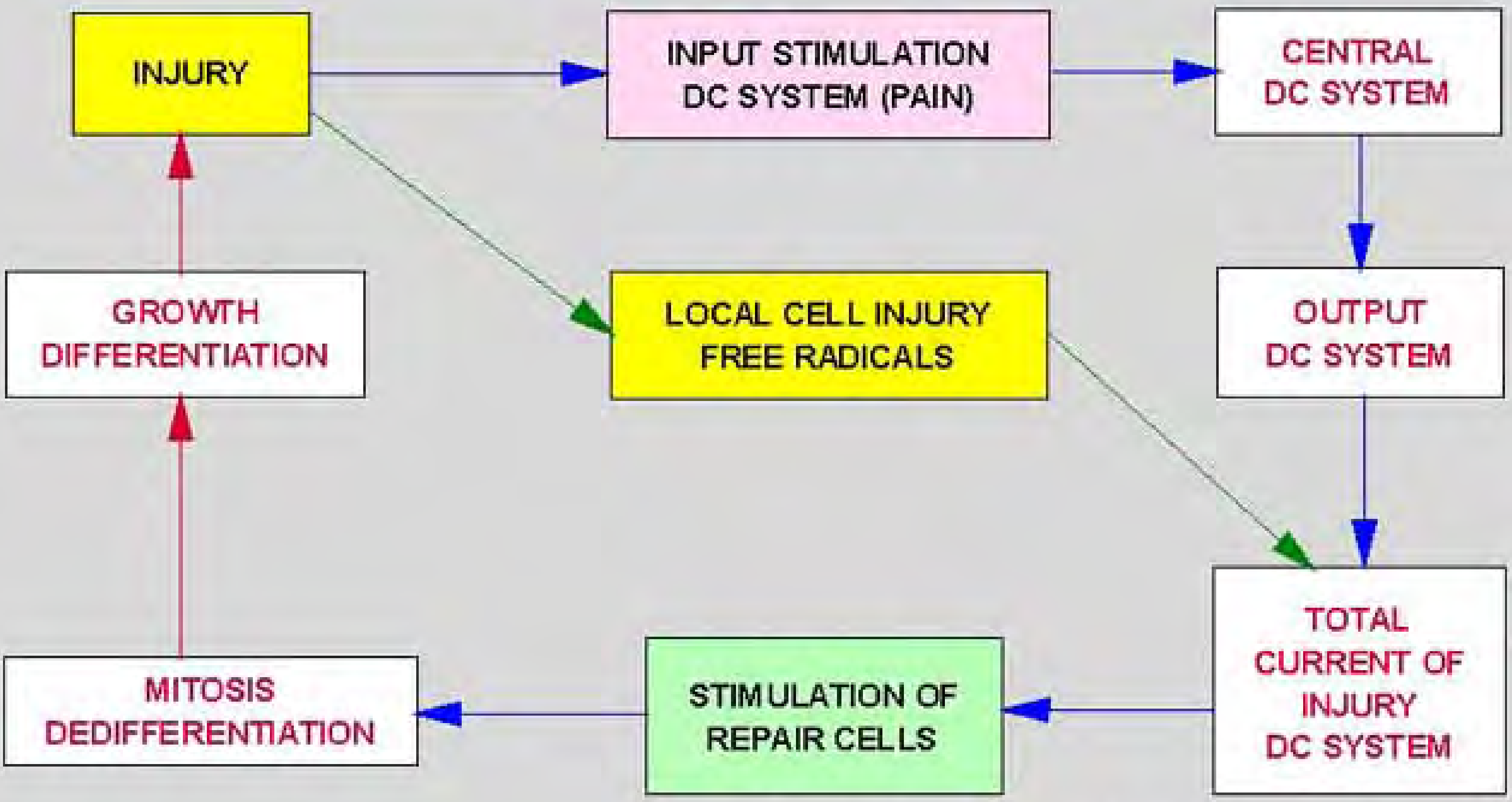

INJURY

INPUT STIMULATION
DC SYSTEM (PAIN)

CENTRAL
DC SYSTEM

LOCAL CELL INJURY
FREE RADICALS

OUTPUT
DC SYSTEM

TOTAL
CURRENT OF
INJURY
DC SYSTEM

STIMULATION OF
REPAIR CELLS

MITOSIS
DEDIFFERENTIATION

GROWTH
DIFFERENTIATION

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.

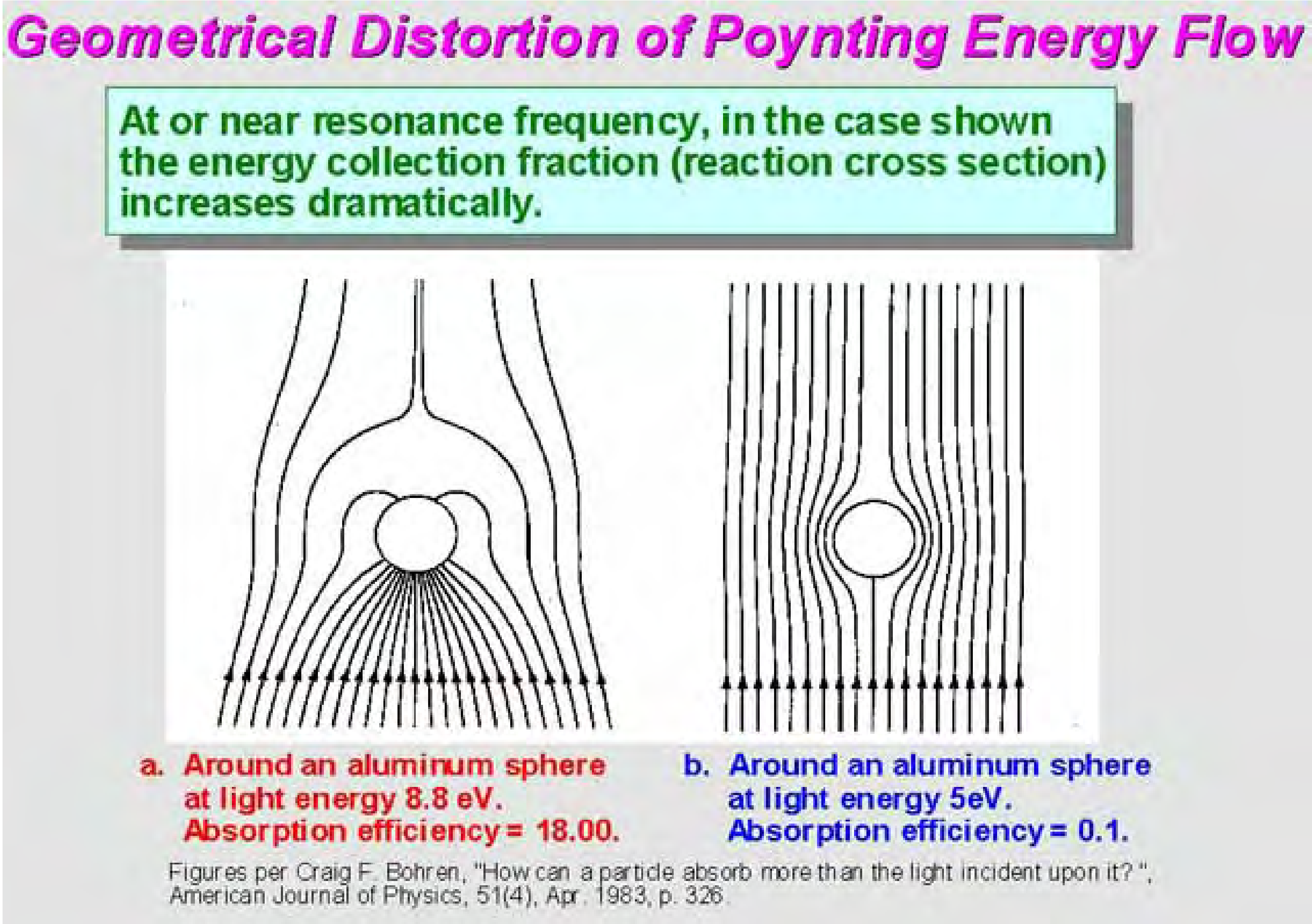

Geometrical Distortion of Poynting Energy Flow

At or near resonance frequency, in the case shown the energy collection fraction (reaction cross section) increases dramatically.

a. Around an aluminum sphere at light energy 8.8 eV. Absorption efficiency = 18.00.

b. Around an aluminum sphere at light energy 5eV. Absorption efficiency = 0.1.

Figures per Craig F. Bohren, "How can a particle absorb more than the light incident upon it? ", American Journal of Physics, 51(4), Apr. 1983, p. 326.

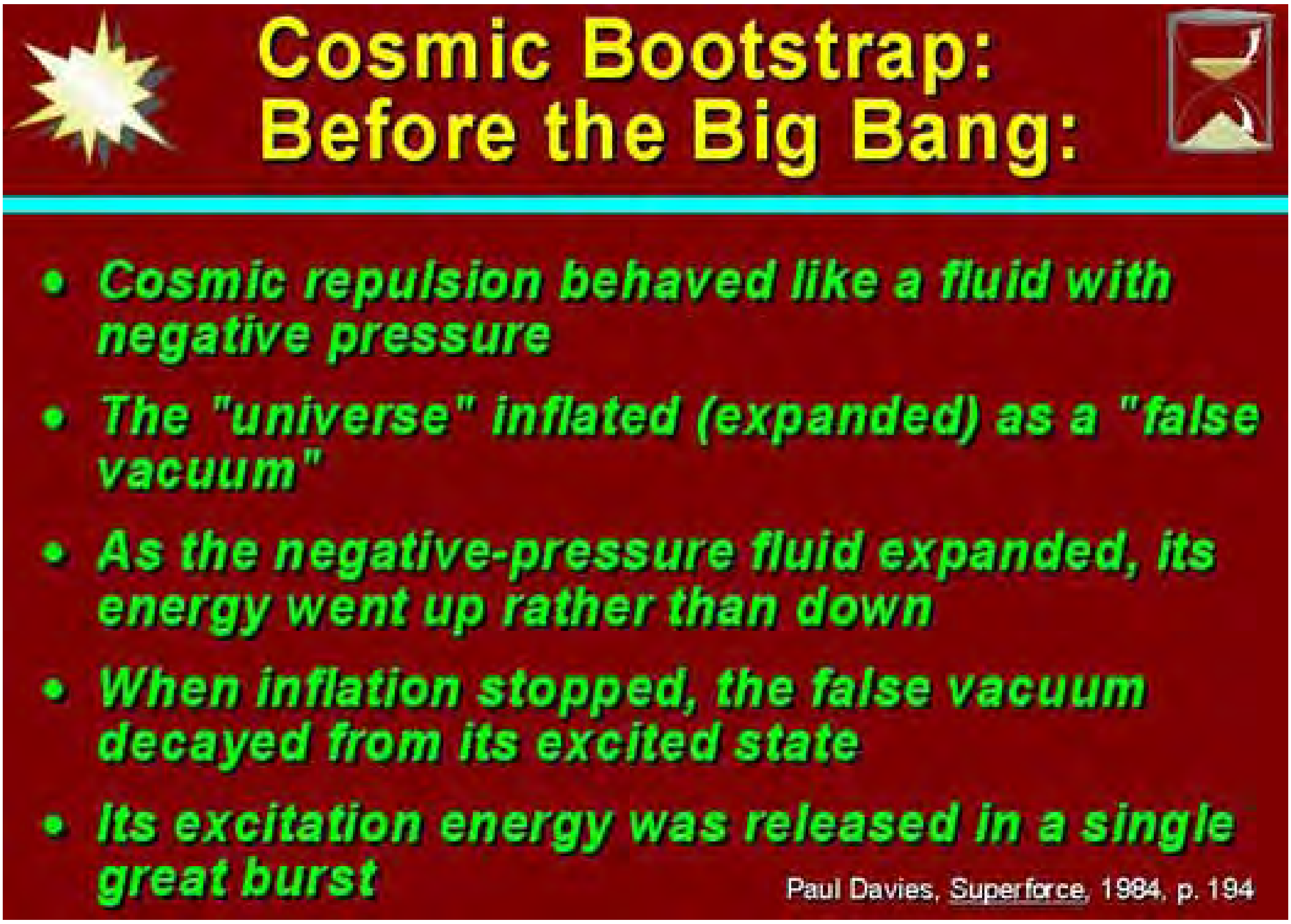

Cosmic Bootstrap: Before the Big Bang:

- *Cosmic repulsion behaved like a fluid with negative pressure*
- *The "universe" inflated (expanded) as a "false vacuum"*
- *As the negative-pressure fluid expanded, its energy went up rather than down*
- *When inflation stopped, the false vacuum decayed from its excited state*
- *Its excitation energy was released in a single great burst*

Paul Davies, Superforce, 1984, p. 194

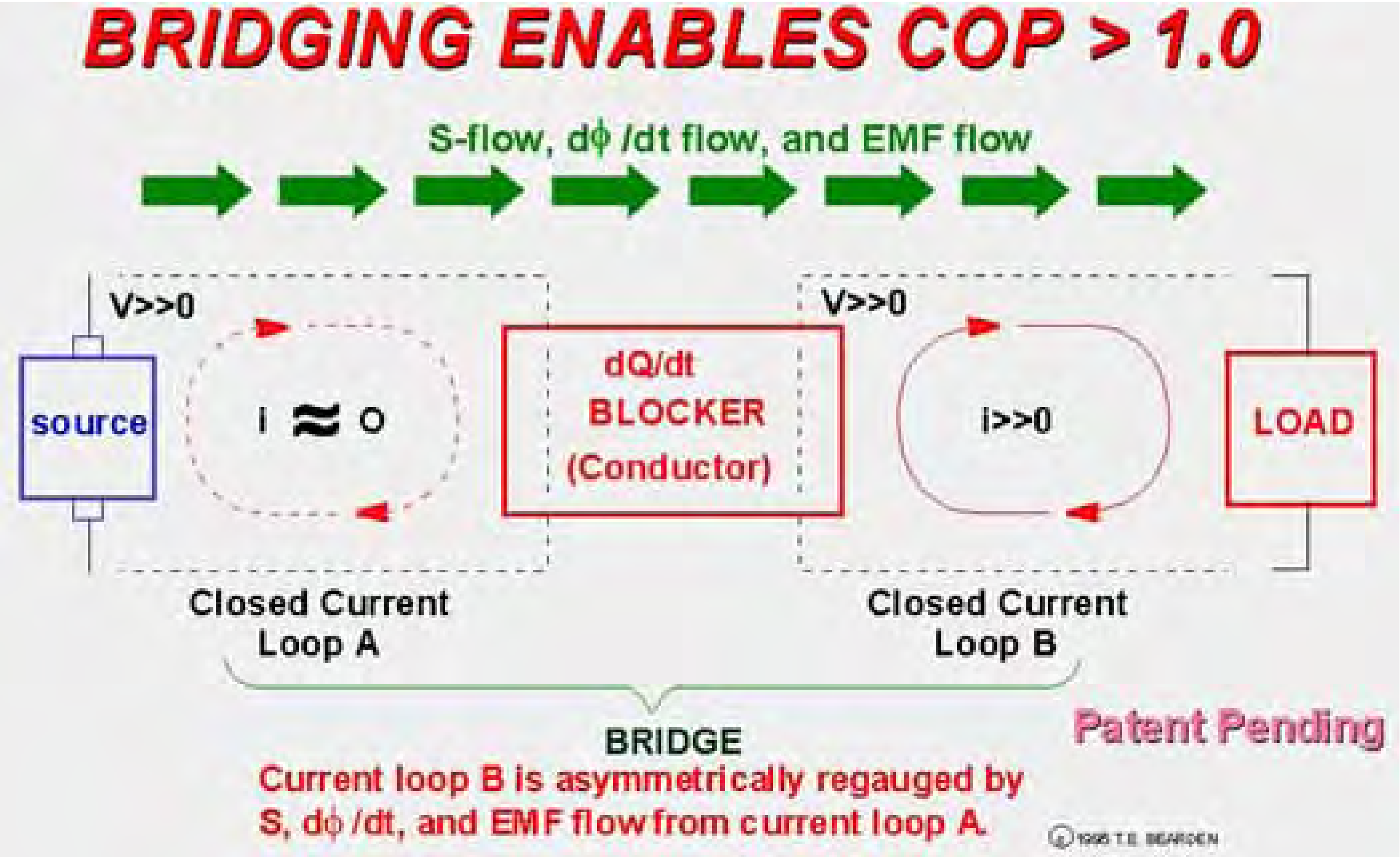

BRIDGING ENABLES COP > 1.0

S-flow, dφ /dt flow, and EMF flow

V>>0
source
i ≈ 0
dQ/dt
BLOCKER
(Conductor)
V>>0
i>>0
LOAD
Closed Current Loop A
Closed Current Loop B

BRIDGE

Current loop B is asymmetrically regauged by S, dφ /dt, and EMF flow from current loop A.

Patent Pending

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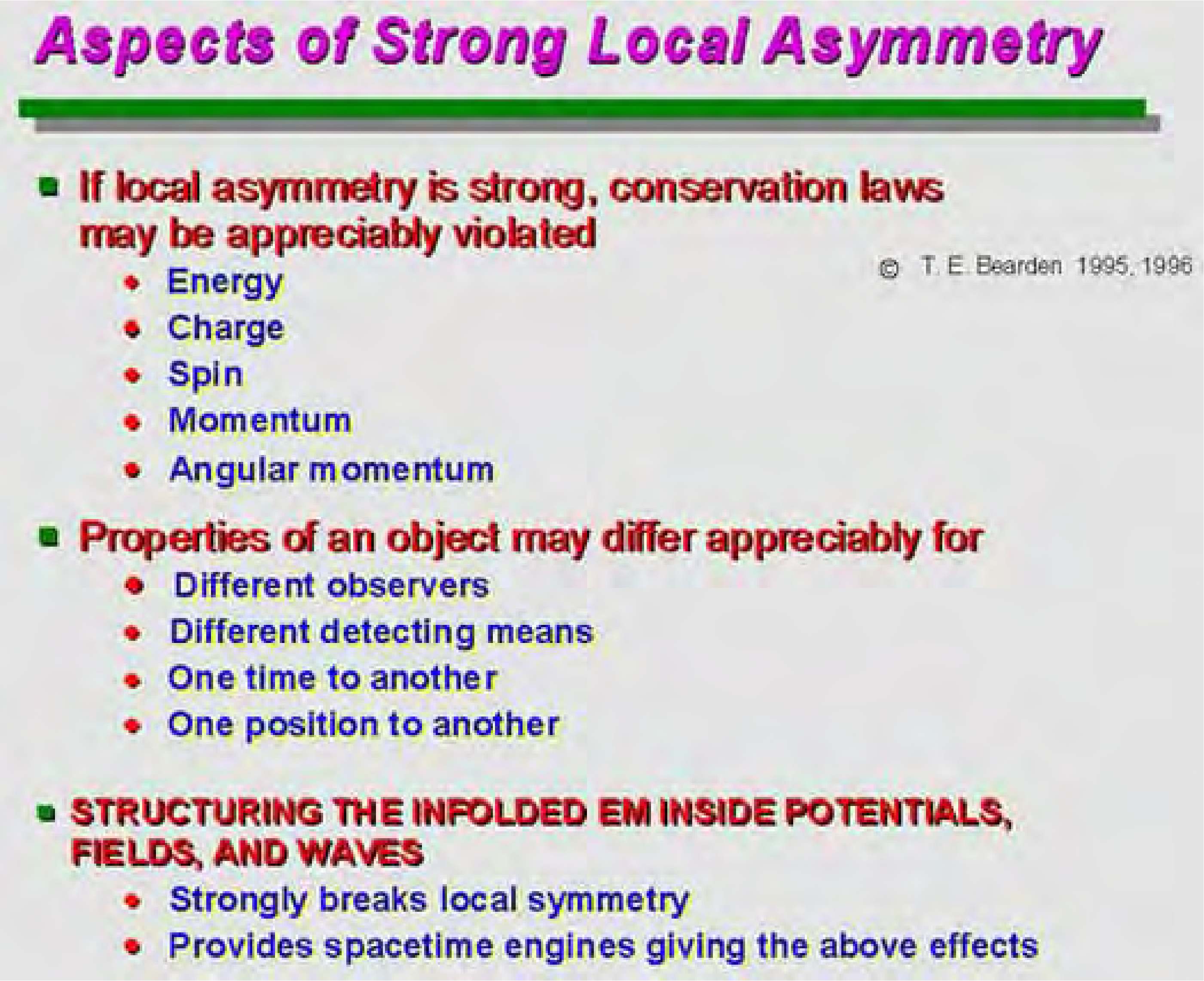

Aspects of Strong Local Asymmetry

- If local asymmetry is strong, conservation laws may be appreciably violated
  - Energy
  - Charge
  - Spin
  - Momentum
  - Angular momentum

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- Properties of an object may differ appreciably for
  - Different observers
  - Different detecting means
  - One time to another
  - One position to another
- STRUCTURING THE INFOLDED EM INSIDE POTENTIALS, FIELDS, AND WAVES
  - Strongly breaks local symmetry
  - Provides spacetime engines giving the above effects

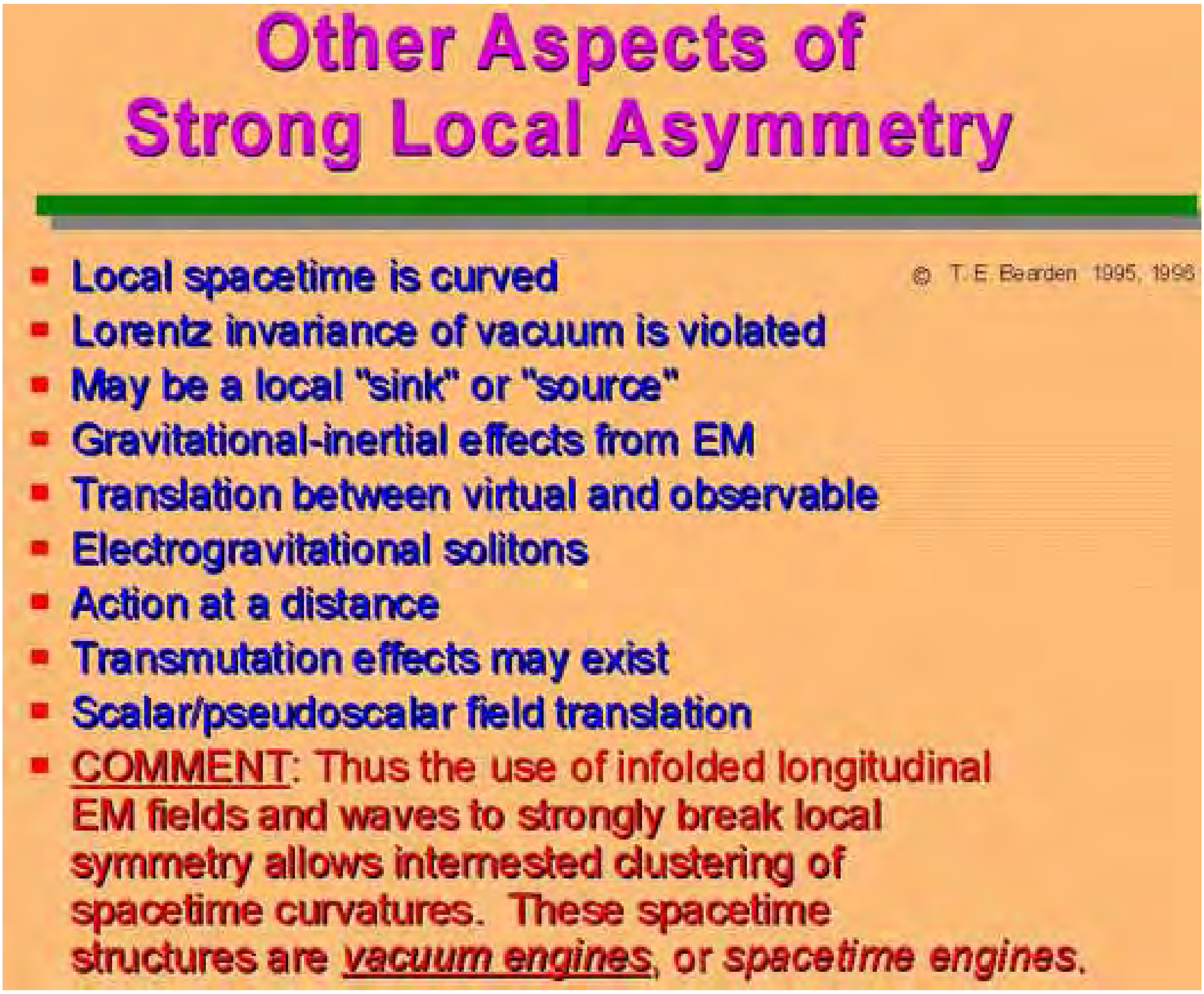

Other Aspects of Strong Local Asymmetry

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- Local spacetime is curved
- Lorentz invariance of vacuum is violated
- May be a local "sink" or "source"
- Gravitational-inertial effects from EM
- Translation between virtual and observable
- Electrogravitational solitons
- Action at a distance
- Transmutation effects may exist
- Scalar/pseudoscalar field translation
- COMMENT: Thus the use of infolded longitudinal EM fields and waves to strongly break local symmetry allows internested clustering of spacetime curvatures. These spacetime structures are *vacuum engines*, or *spacetime engines*.

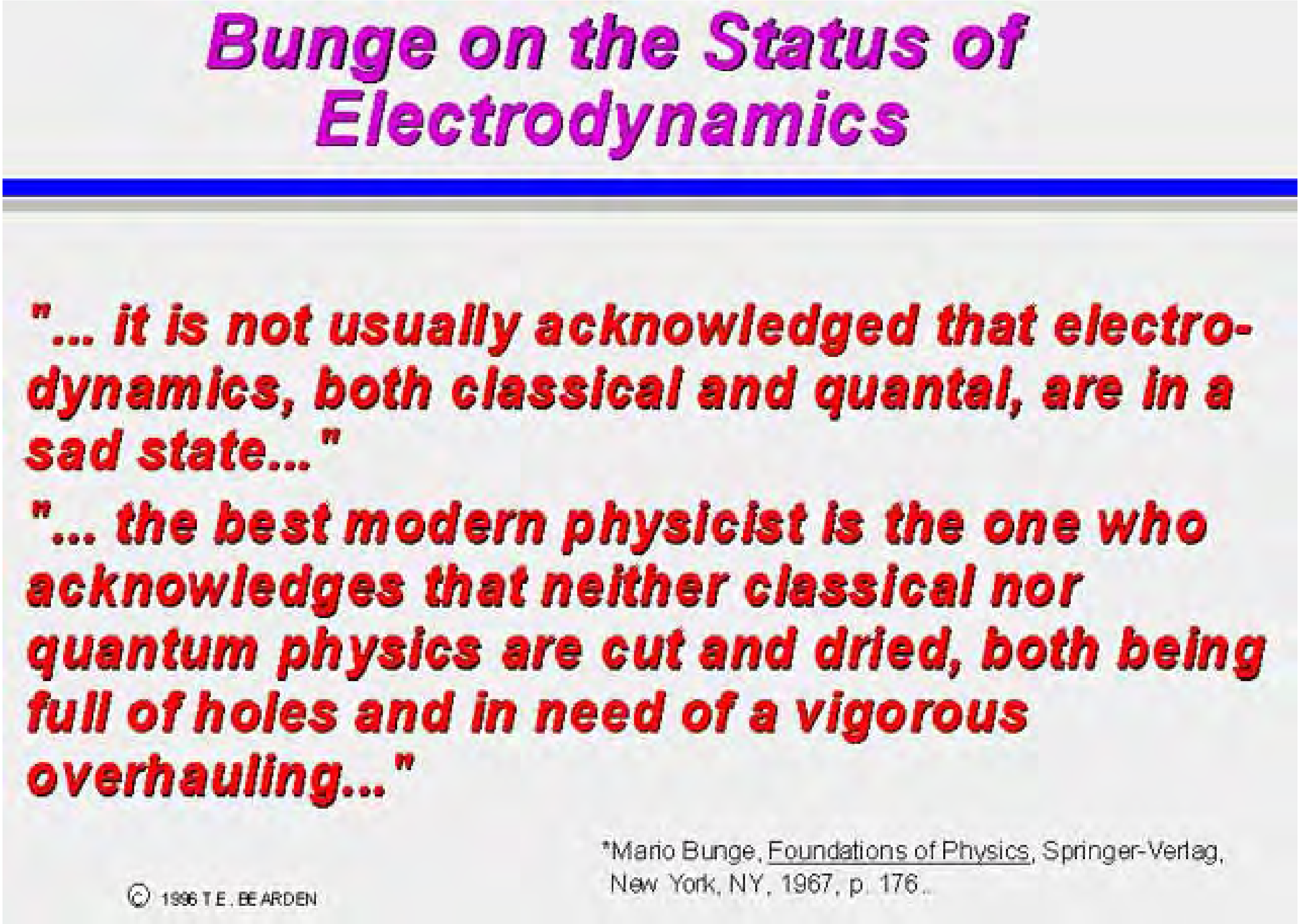

Bunge on the Status of Electrodynamics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state..."

"... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling..."

*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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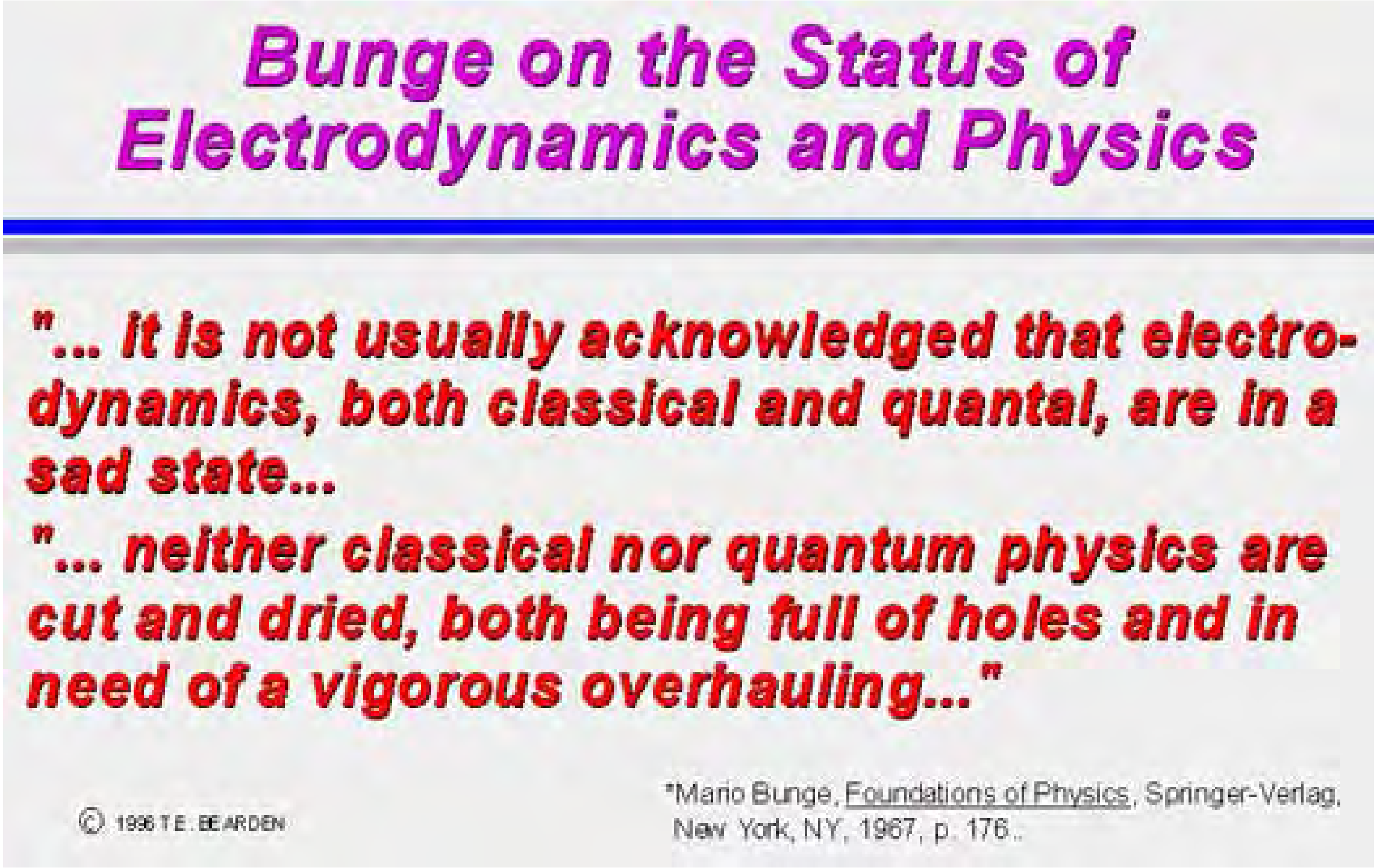

Bunge on the Status of Electrodynamics and Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state...

"... neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling..."

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*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

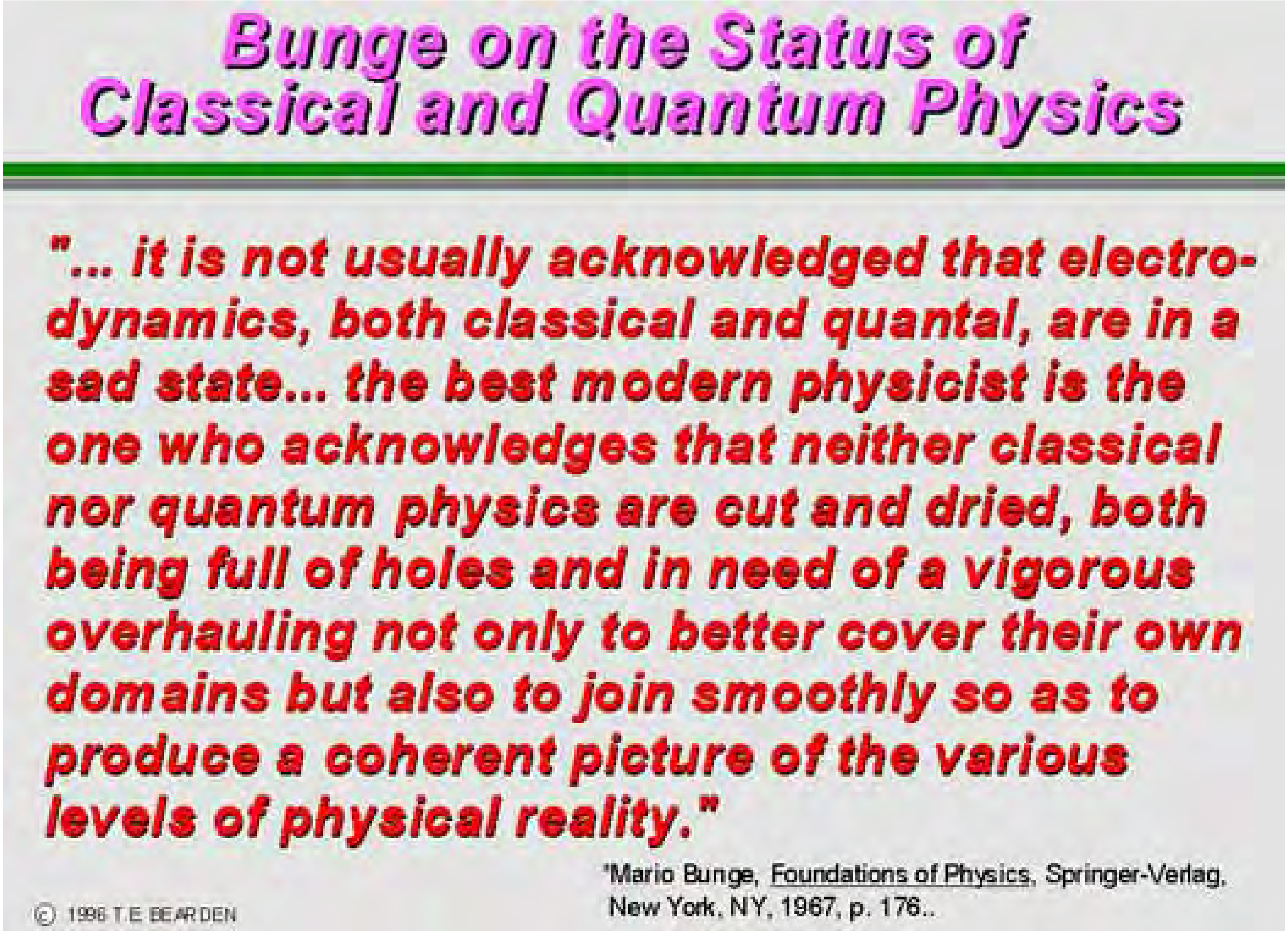

Bunge on the Status of Classical and Quantum Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling not only to better cover their own domains but also to join smoothly so as to produce a coherent picture of the various levels of physical reality."

"Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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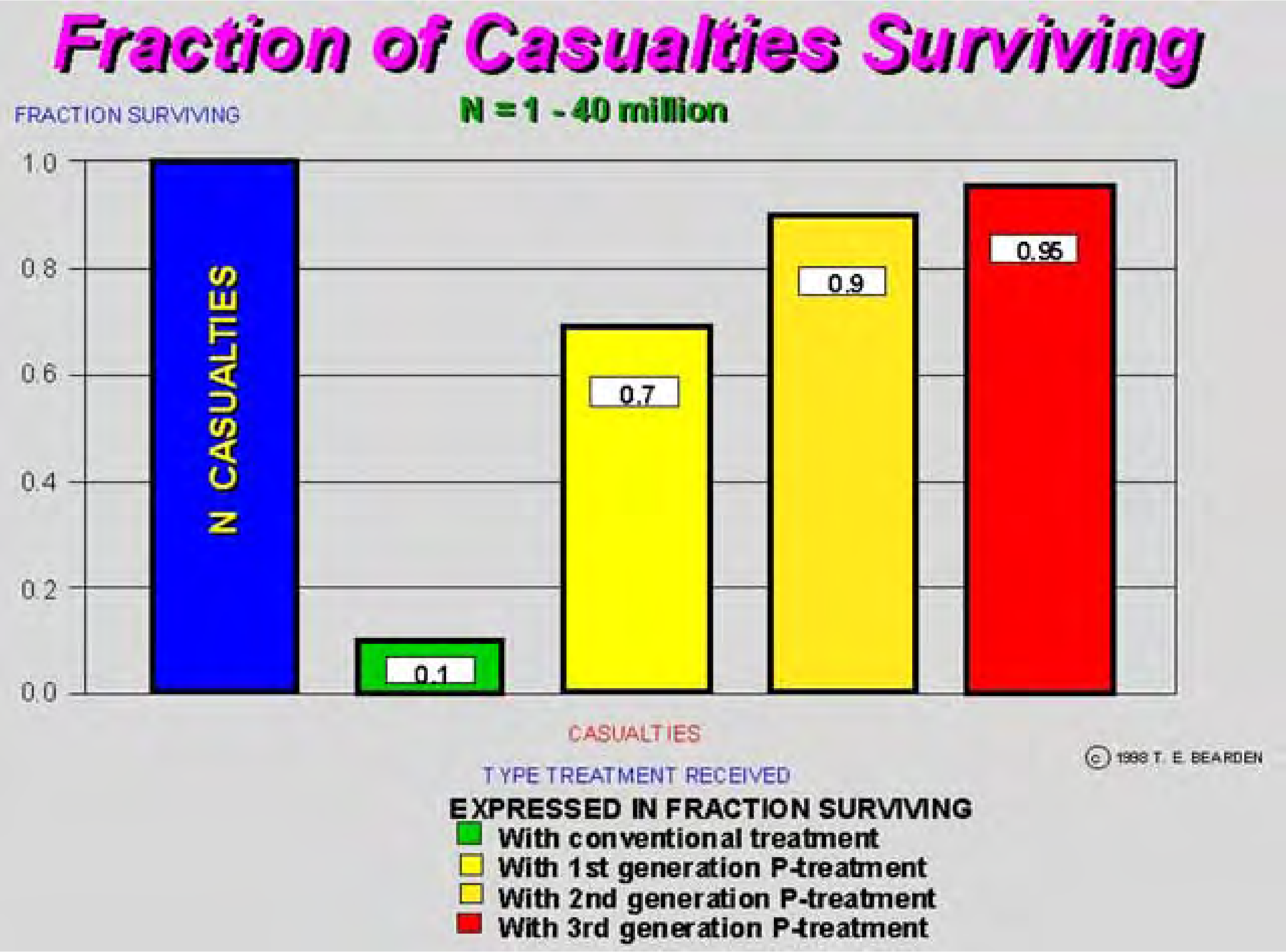
Fraction of Casualties Surviving
FRACTION SURVIVING
N = 1 - 40 million
1.0
0.8
0.6
0.4
0.2
0.0
N CASUALTIES
0.1
0.7
0.9
0.95
CASUALTIES
TYPE TREATMENT RECEIVED
© 1998 T. E. BEARDEN
EXPRESSED IN FRACTION SURVIVING
🟩 With conventional treatment
🟨 With 1st generation P-treatment
🟨 With 2nd generation P-treatment
🟥 With 3rd generation P-treatment

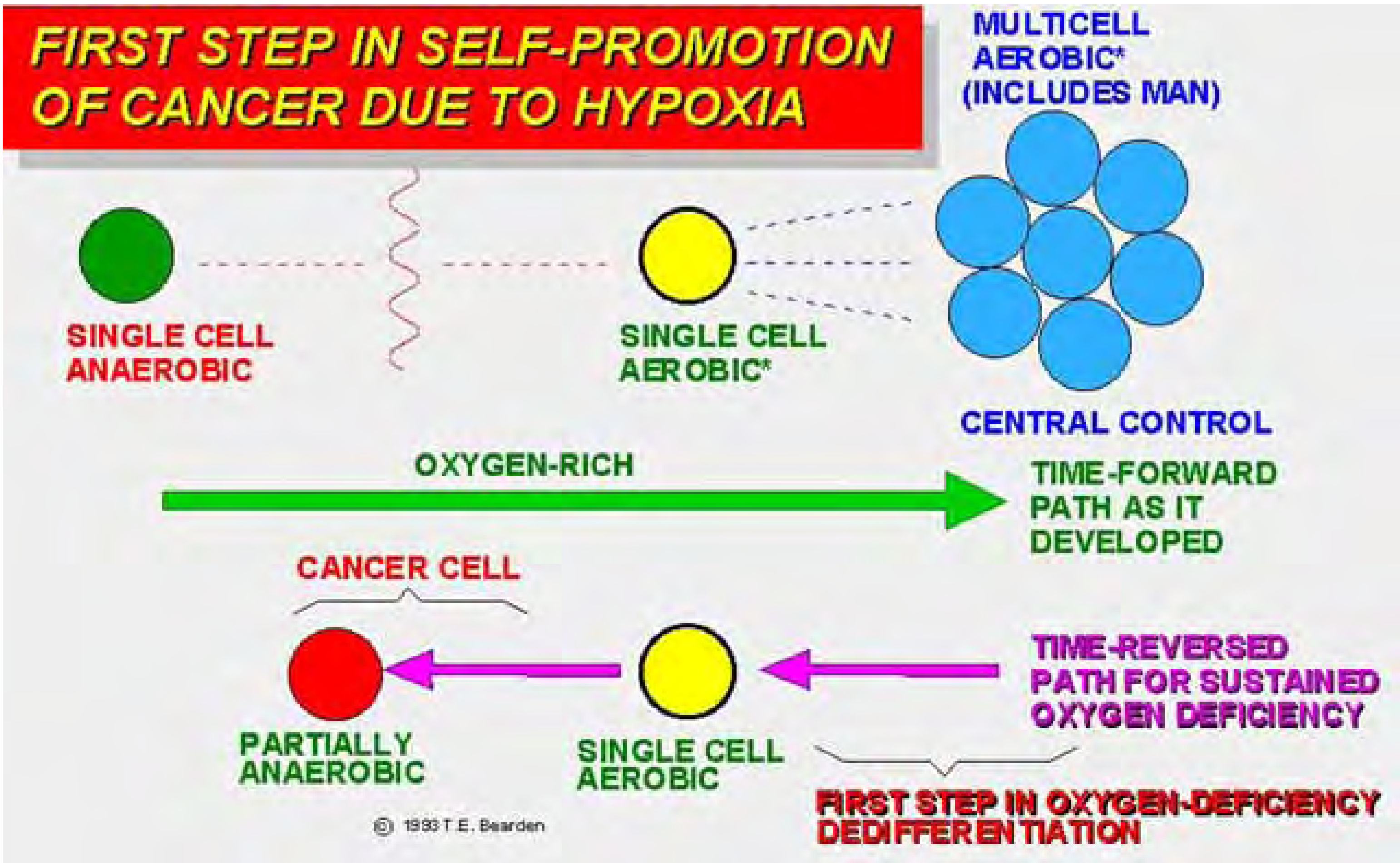

FIRST STEP IN SELF-PROMOTION OF CANCER DUE TO HYPOXIA

MULTICELL
AEROBIC*
(INCLUDES MAN)

SINGLE CELL
ANAEROBIC

SINGLE CELL
AEROBIC*

CENTRAL CONTROL

OXYGEN-RICH

TIME-FORWARD
PATH AS IT
DEVELOPED

CANCER CELL

TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY

PARTIALLY
ANAEROBIC

SINGLE CELL
AEROBIC

FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION

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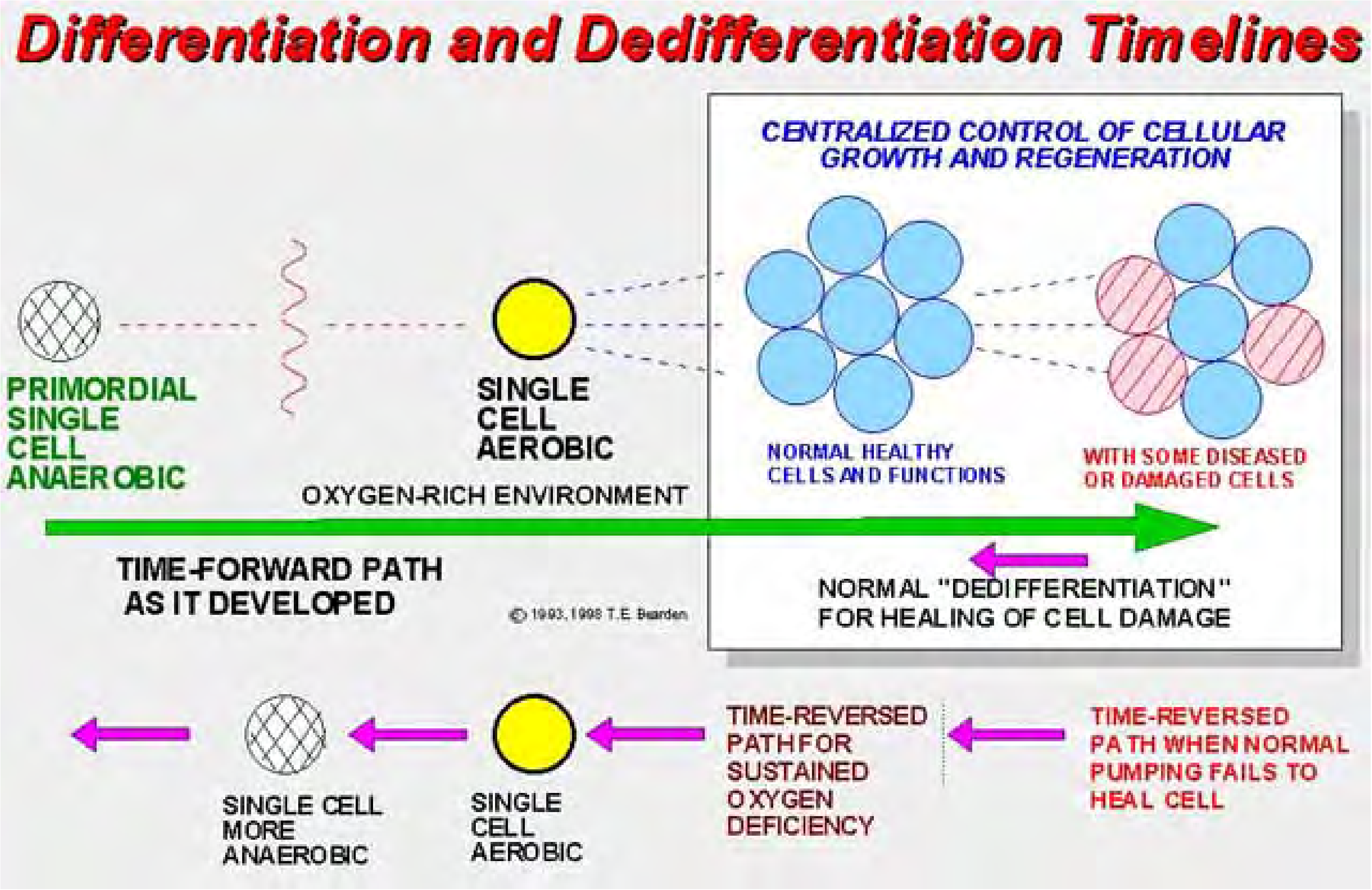

Differentiation and Dedifferentiation Timelines

CENTRALIZED CONTROL OF CELLULAR GROWTH AND REGENERATION

PRIMORDIAL SINGLE CELL ANAEROBIC

SINGLE CELL AEROBIC

OXYGEN-RICH ENVIRONMENT

NORMAL HEALTHY CELLS AND FUNCTIONS

WITH SOME DISEASED OR DAMAGED CELLS

TIME-FORWARD PATH AS IT DEVELOPED

NORMAL "DEDIFFERENTIATION" FOR HEALING OF CELL DAMAGE

SINGLE CELL MORE ANAEROBIC

SINGLE CELL AEROBIC

TIME-REVERSED PATH FOR SUSTAINED OXYGEN DEFICIENCY

TIME-REVERSED PATH WHEN NORMAL PUMPING FAILS TO HEAL CELL

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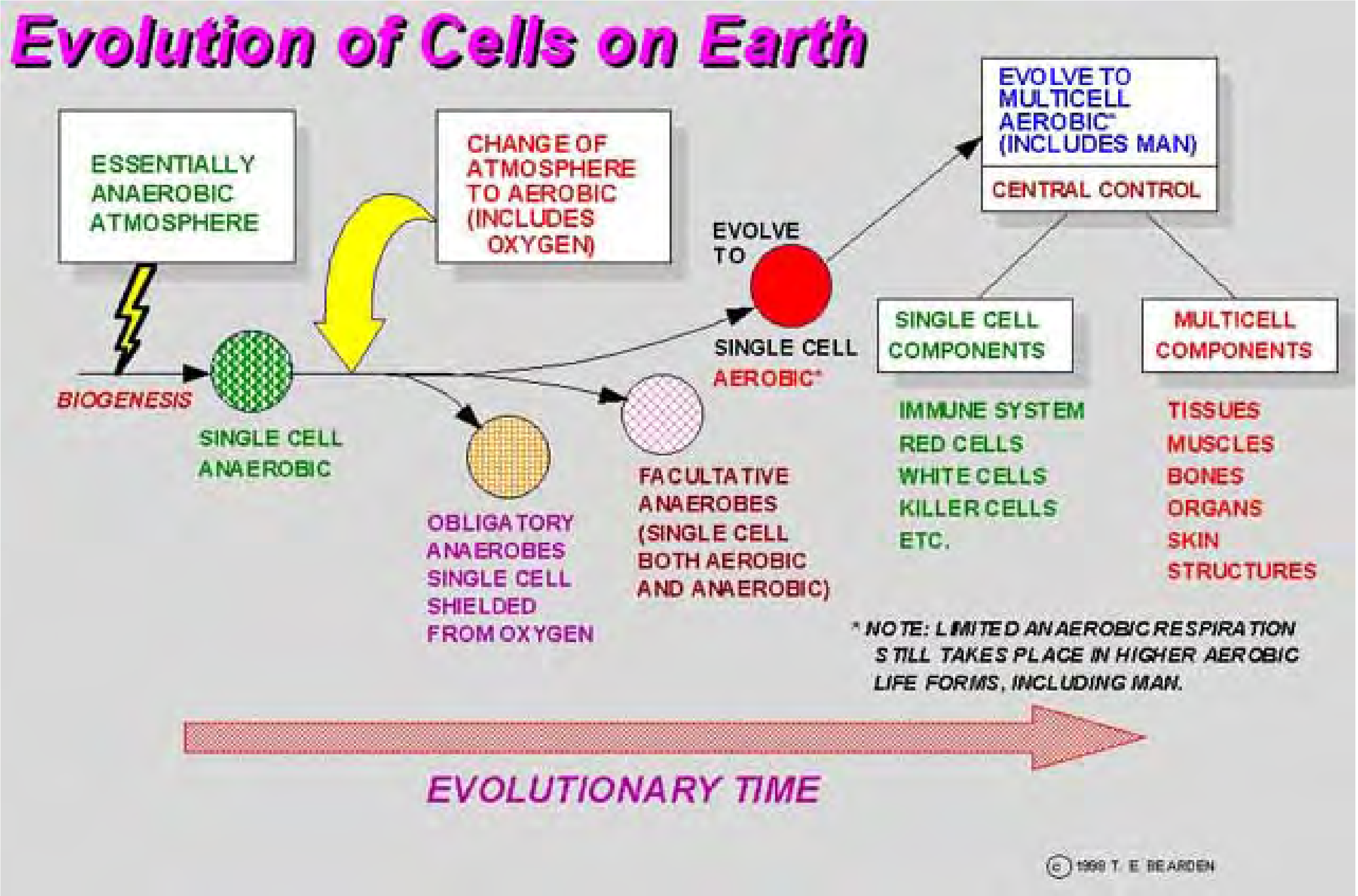

Evolution of Cells on Earth

ESSENTIALLY ANAEROBIC ATMOSPHERE

CHANGE OF ATMOSPHERE TO AEROBIC (INCLUDES OXYGEN)

BIOGENESIS

SINGLE CELL ANAEROBIC

OBLIGATORY ANAEROBES SINGLE CELL SHIELDED FROM OXYGEN

FACULTATIVE ANAEROBES (SINGLE CELL BOTH AEROBIC AND ANAEROBIC)

EVOLVE TO

SINGLE CELL AEROBIC*

EVOLVE TO MULTICELL AEROBIC* (INCLUDES MAN)

CENTRAL CONTROL

SINGLE CELL COMPONENTS

- IMMUNE SYSTEM
- RED CELLS
- WHITE CELLS
- KILLER CELLS
- ETC.

MULTICELL COMPONENTS

- TISSUES
- MUSCLES
- BONES
- ORGANS
- SKIN
- STRUCTURES

** NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.*

EVOLUTIONARY TIME

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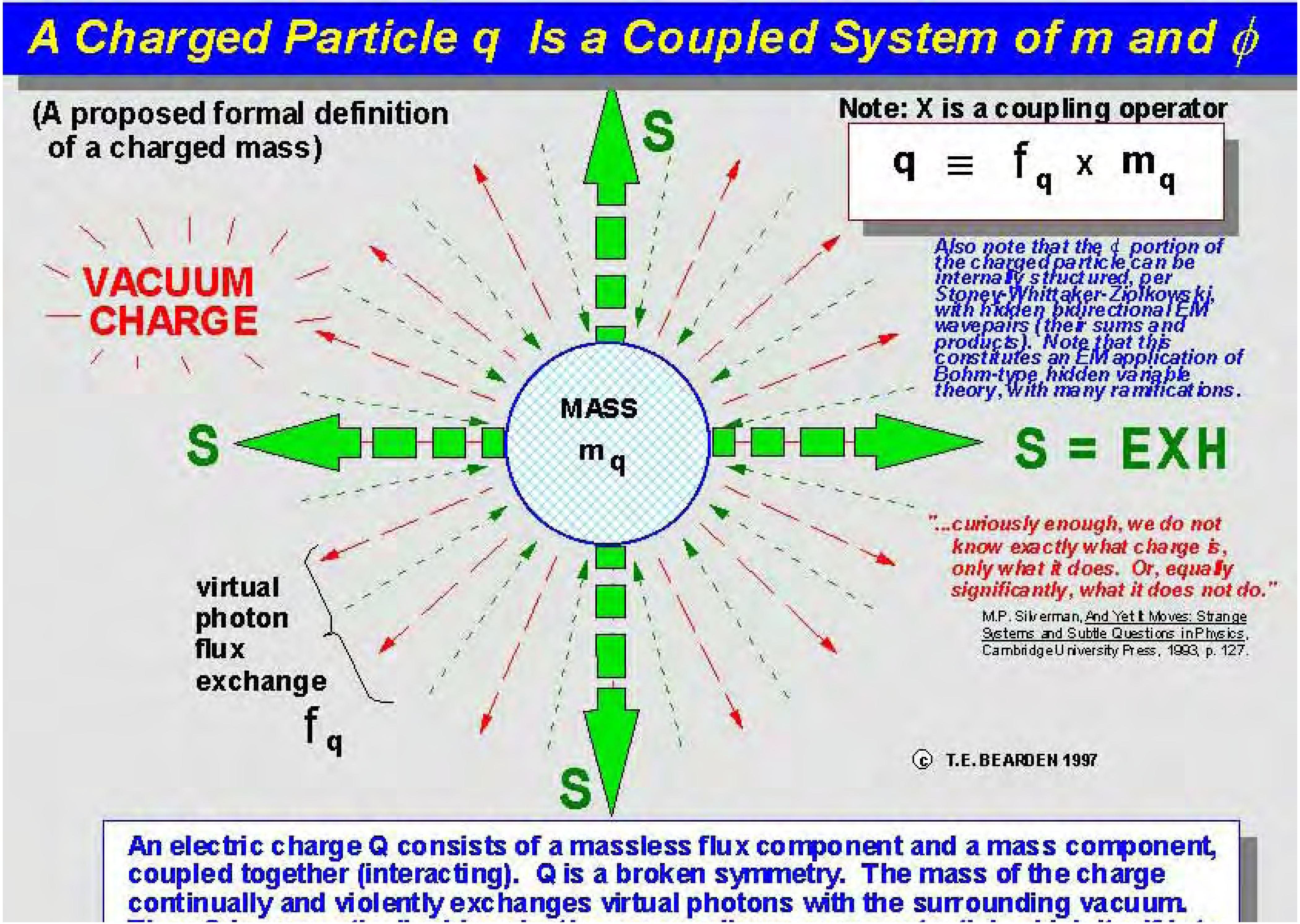

A Charged Particle q Is a Coupled System of m and ϕ

(A proposed formal definition of a charged mass)

Note: X is a coupling operator

$$q \equiv f_q \times m_q$$

Also note that the ϕ portion of the charged particle can be internally structured, per Stoney-Whittaker-Ziolkowski, with hidden bidirectional EM wavepairs (their sums and products). Note that this constitutes an EM application of Bohm-type hidden variable theory, with many ramifications.

$$S = E \times H$$

"...curiously enough, we do not know exactly what charge is, only what it does. Or, equally significantly, what it does not do."

M.P. Silverman, And Yet It Moves: Strange Systems and Subtle Questions in Physics, Cambridge University Press, 1993, p. 127.

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An electric charge Q consists of a massless flux component and a mass component, coupled together (interacting). Q is a broken symmetry. The mass of the charge continually and violently exchanges virtual photons with the surrounding vacuum.

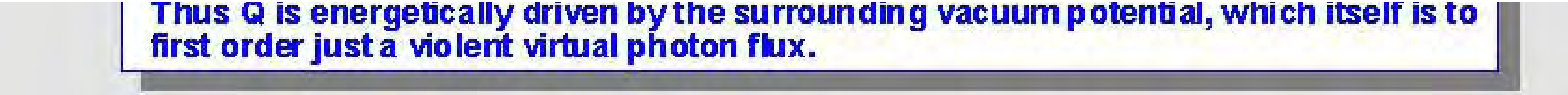

Thus Q is energetically driven by the surrounding vacuum potential, which itself is to first order just a violent virtual photon flux.

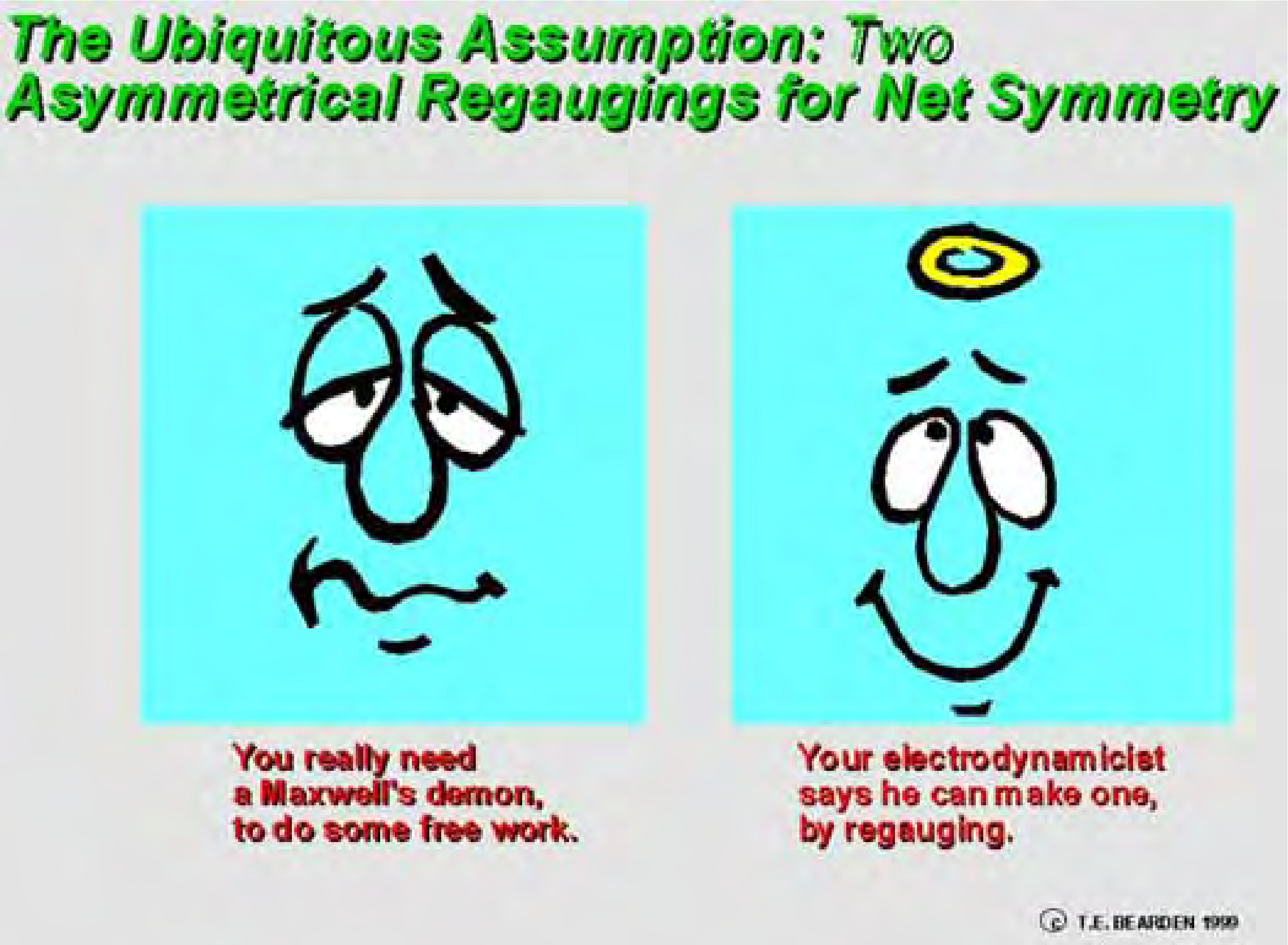

The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry

You really need
a Maxwell's demon,
to do some free work.

Your electrodynamicist
says he can make one,
by regauging.

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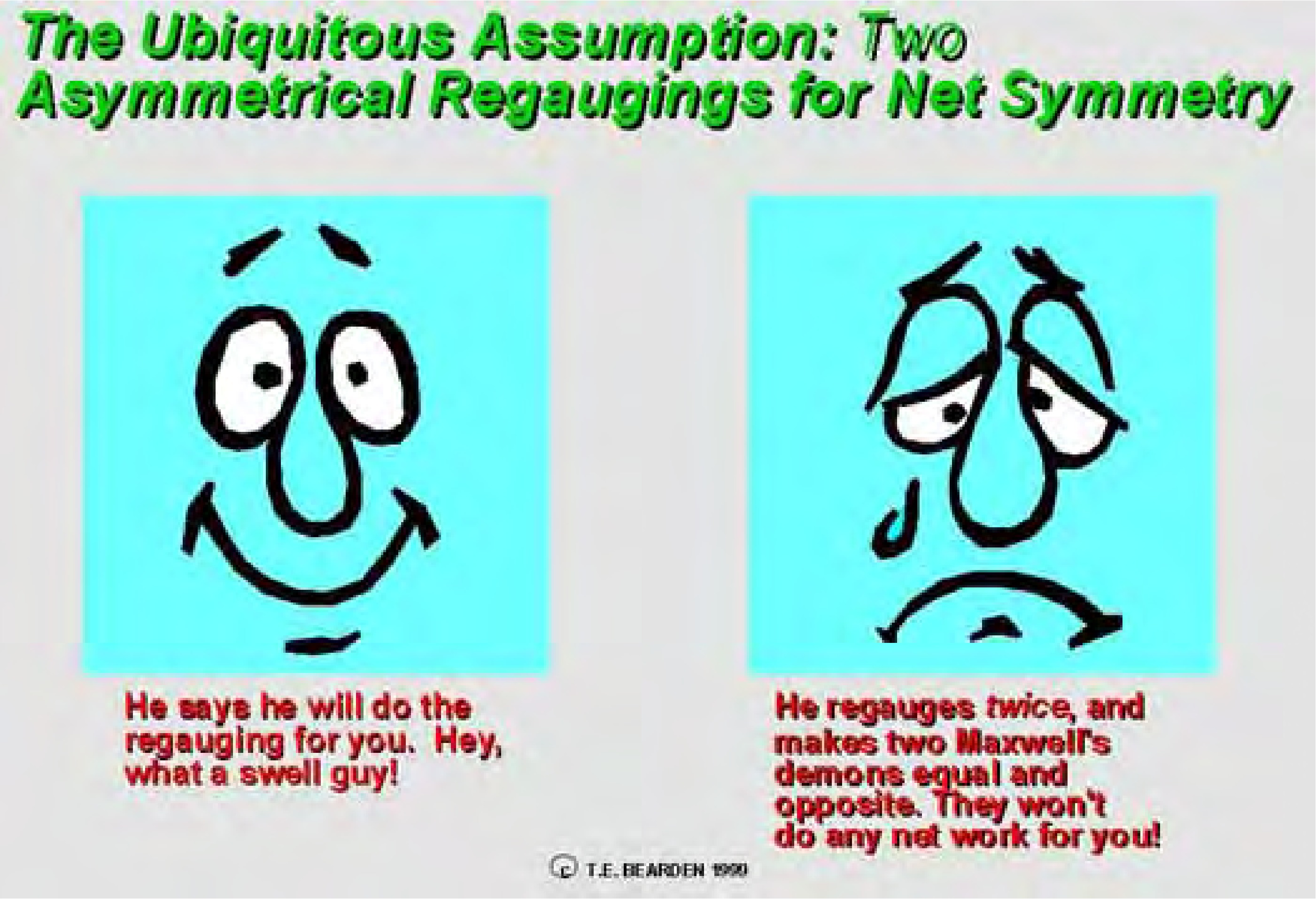

The Ubiquitous Assumption: *Two* Asymmetrical Regaugings for Net Symmetry

He says he will do the regauging for you. Hey, what a swell guy!

He regauges *twice*, and makes two Maxwell's demons equal and opposite. They won't do any net work for you!

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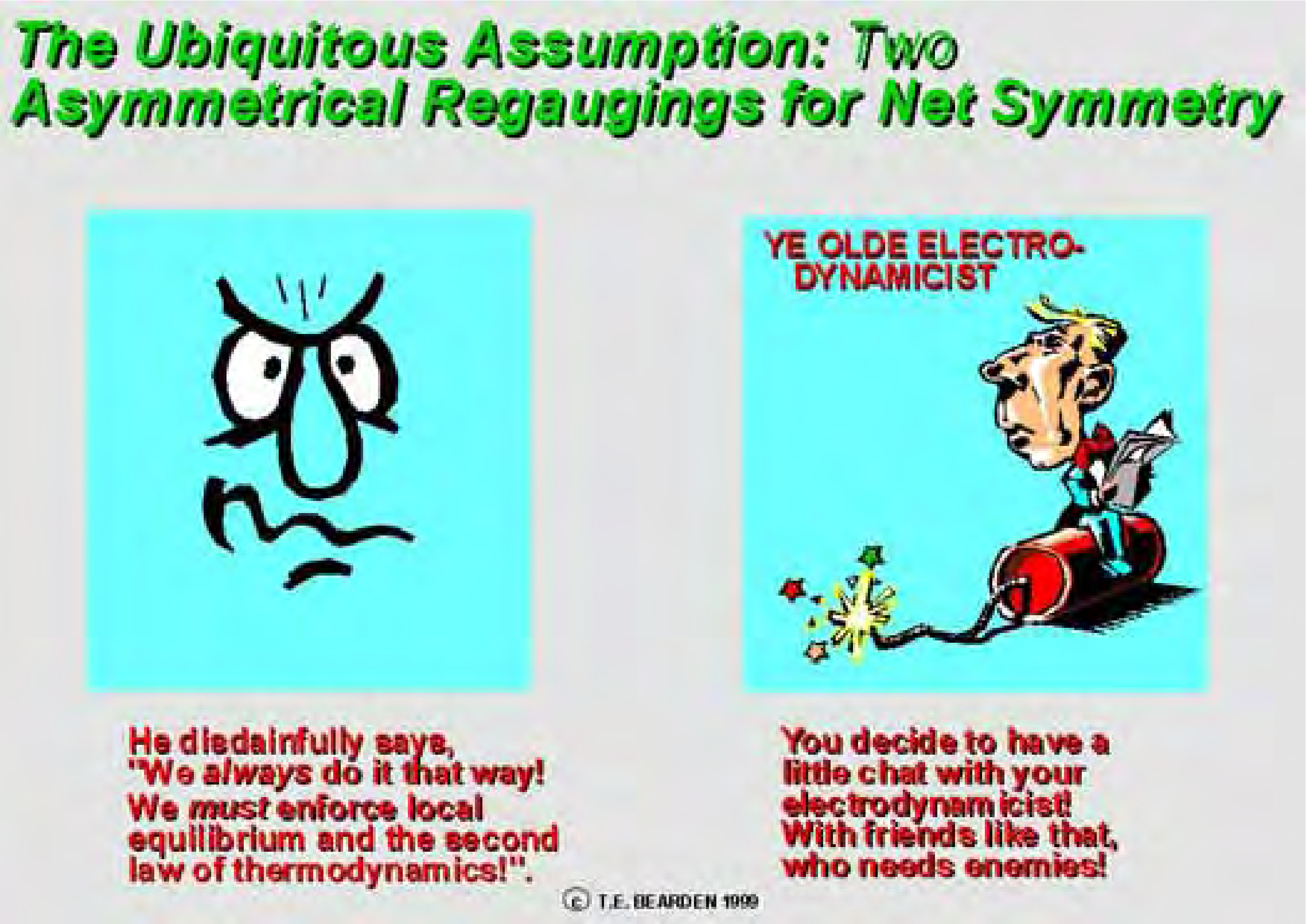

The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry

YE OLDE ELECTRO-
DYNAMICIST

He disdainfully says,
"We *always* do it that way!
We *must* enforce local
equilibrium and the second
law of thermodynamics!".

You decide to have a
little chat with your
electrodynamicist!
With friends like that,
who needs enemies!

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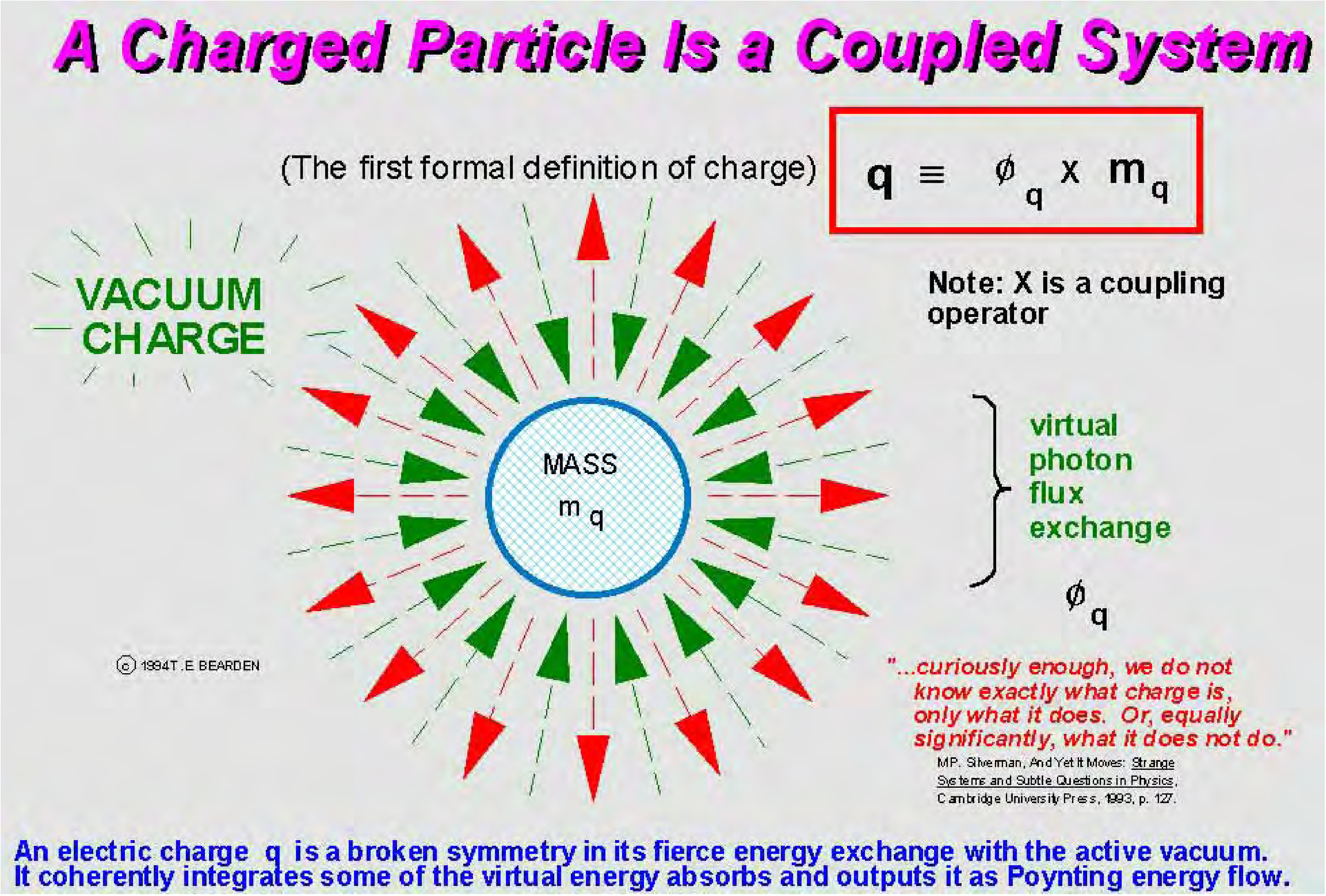

A Charged Particle Is a Coupled System

(The first formal definition of charge)

$$q \equiv \phi_q \times m_q$$

Note: X is a coupling operator

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"...curiously enough, we do not know exactly what charge is, only what it does. Or, equally significantly, what it does not do."

M.P. Silverman, And Yet It Moves: Strange Systems and Subtle Questions in Physics, Cambridge University Press, 1993, p. 127.

An electric charge q is a broken symmetry in its fierce energy exchange with the active vacuum. It coherently integrates some of the virtual energy absorbs and outputs it as Poynting energy flow.

Chung's Carbon Filament Negative Resistor

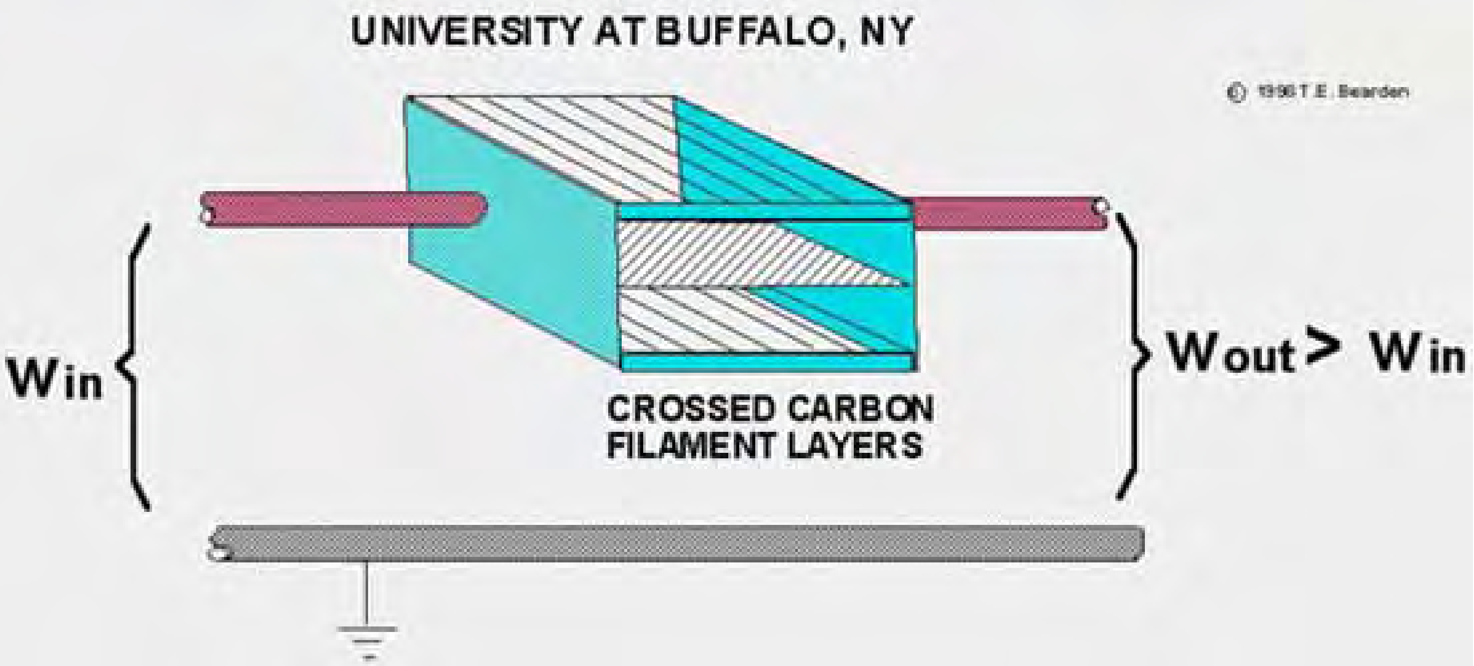
UNIVERSITY AT BUFFALO, NY
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Win
Wout > Win
CROSSED CARBON
FILAMENT LAYERS

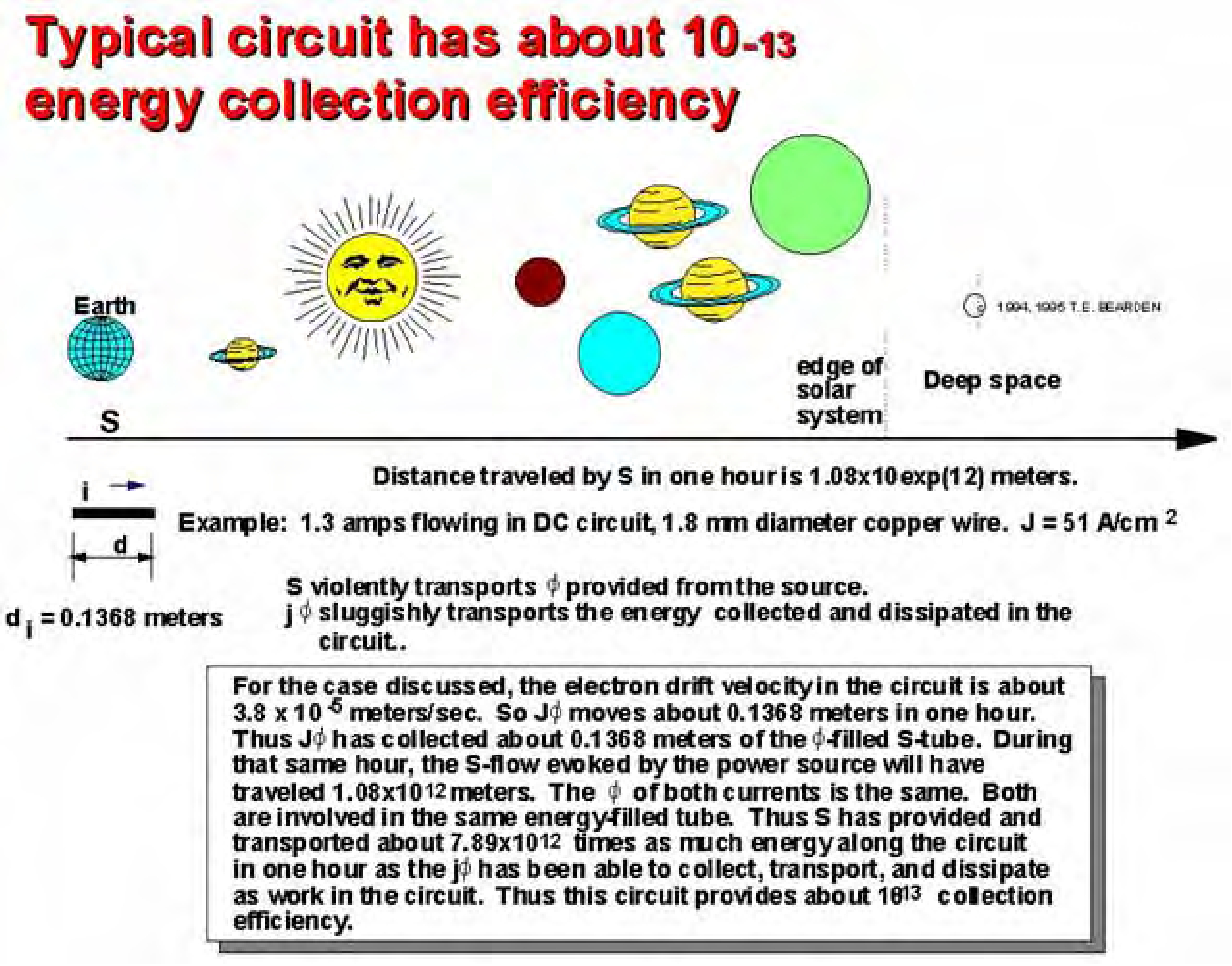

Typical circuit has about 10^{-13} energy collection efficiency

Earth
edge of solar system
Deep space
S
© 1994, 1995 T.E. BEARDEN
i
d

Distance traveled by S in one hour is 1.08x10exp(12) meters.

Example: 1.3 amps flowing in DC circuit, 1.8 mm diameter copper wire. $J = 51$ A/cm ^{2}

$d_i = 0.1368$ meters

S violently transports ϕ provided from the source.
j ϕ sluggishly transports the energy collected and dissipated in the circuit..

For the case discussed, the electron drift velocity in the circuit is about 3.8×10^{-5} meters/sec. So Jϕ moves about 0.1368 meters in one hour. Thus Jϕ has collected about 0.1368 meters of the ϕ-filled S-tube. During that same hour, the S-flow evoked by the power source will have traveled 1.08×10^{12} meters. The ϕ of both currents is the same. Both are involved in the same energy-filled tube. Thus S has provided and transported about 7.89×10^{12} times as much energy along the circuit in one hour as the jϕ has been able to collect, transport, and dissipate as work in the circuit. Thus this circuit provides about 10^{13} collection efficiency.

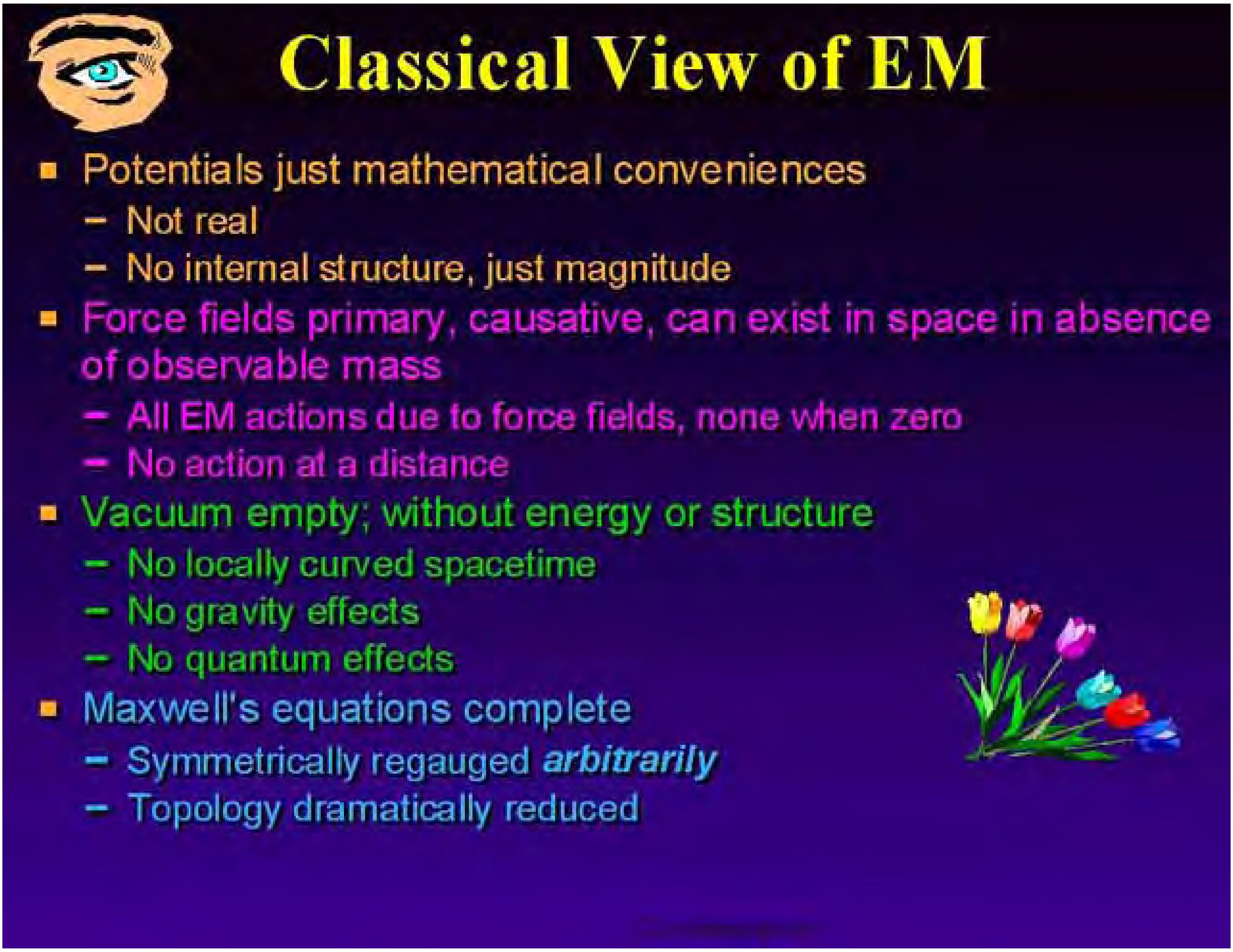

Classical View of EM

- Potentials just mathematical conveniences
  - Not real
  - No internal structure, just magnitude
- Force fields primary, causative, can exist in space in absence of observable mass
  - All EM actions due to force fields, none when zero
  - No action at a distance
- Vacuum empty; without energy or structure
  - No locally curved spacetime
  - No gravity effects
  - No quantum effects
- Maxwell's equations complete
  - Symmetrically regauged ***arbitrarily***
  - Topology dramatically reduced

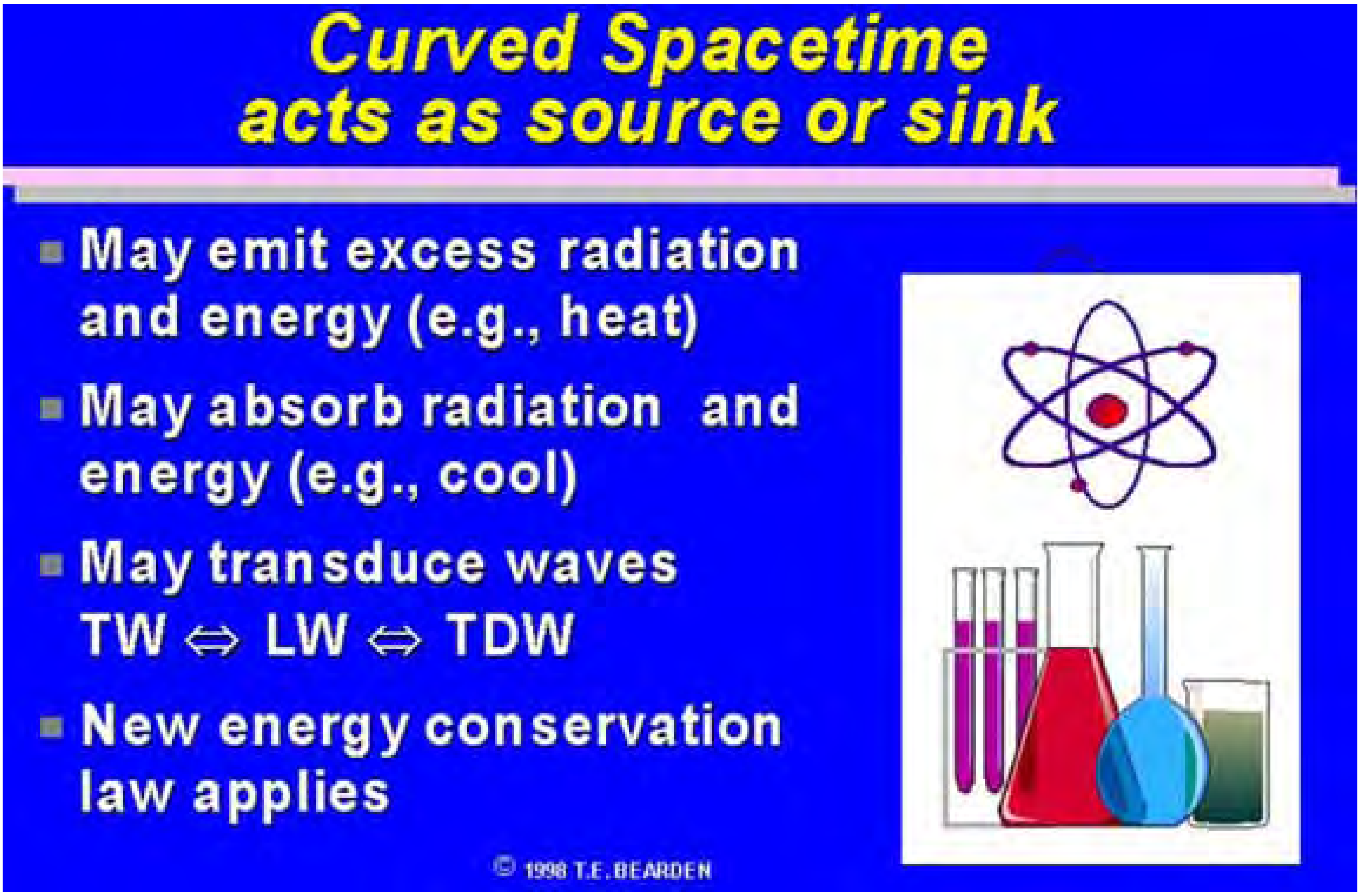

Curved Spacetime acts as source or sink

- May emit excess radiation and energy (e.g., heat)
- May absorb radiation and energy (e.g., cool)
- May transduce waves TW ⇔ LW ⇔ TDW
- New energy conservation law applies

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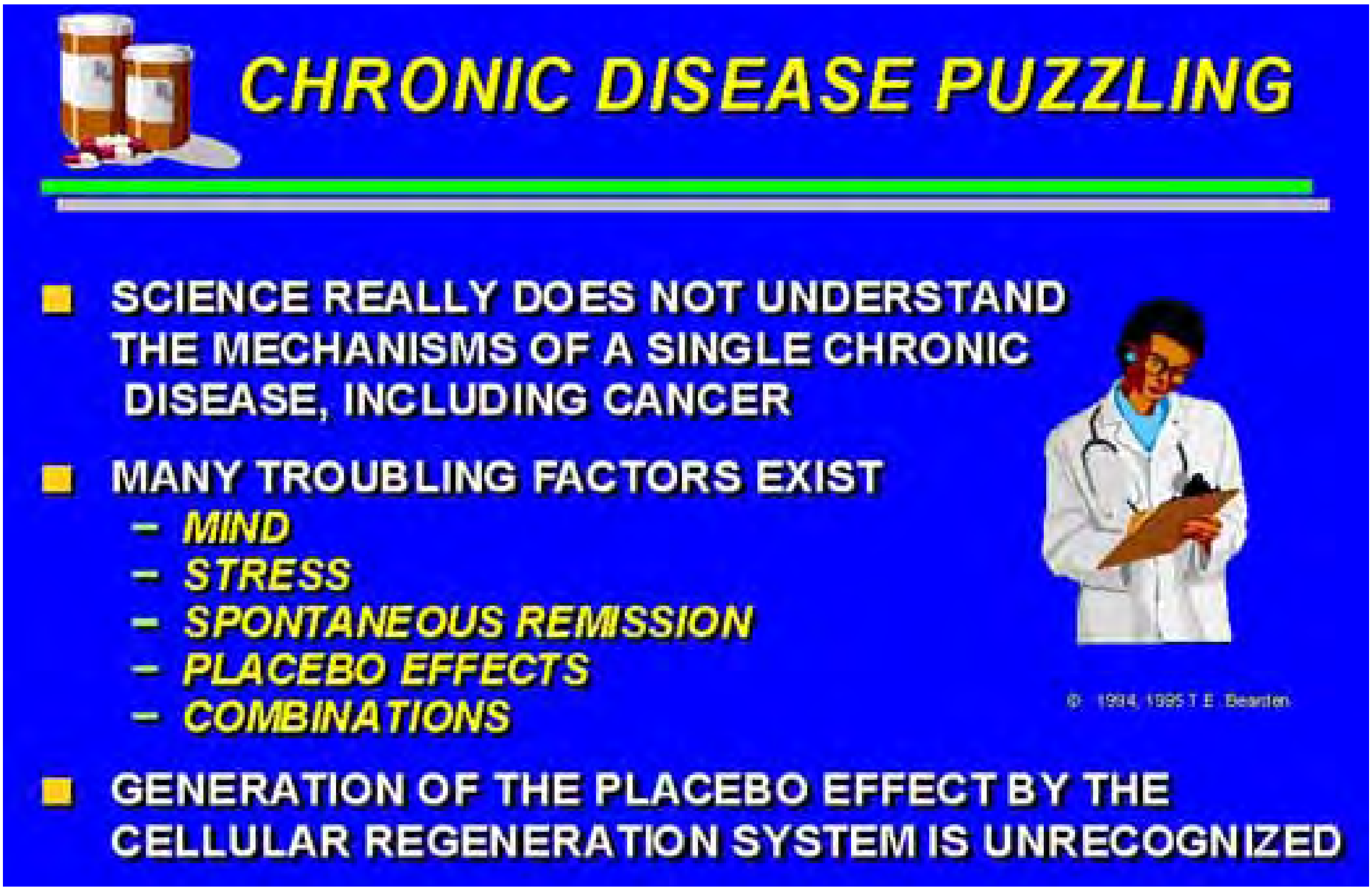

CHRONIC DISEASE PUZZLING

- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
- MANY TROUBLING FACTORS EXIST
  - *MIND*
  - *STRESS*
  - *SPONTANEOUS REMISSION*
  - *PLACEBO EFFECTS*
  - *COMBINATIONS*
- GENERATION OF THE PLACEBO EFFECT BY THE CELLULAR REGENERATION SYSTEM IS UNRECOGNIZED

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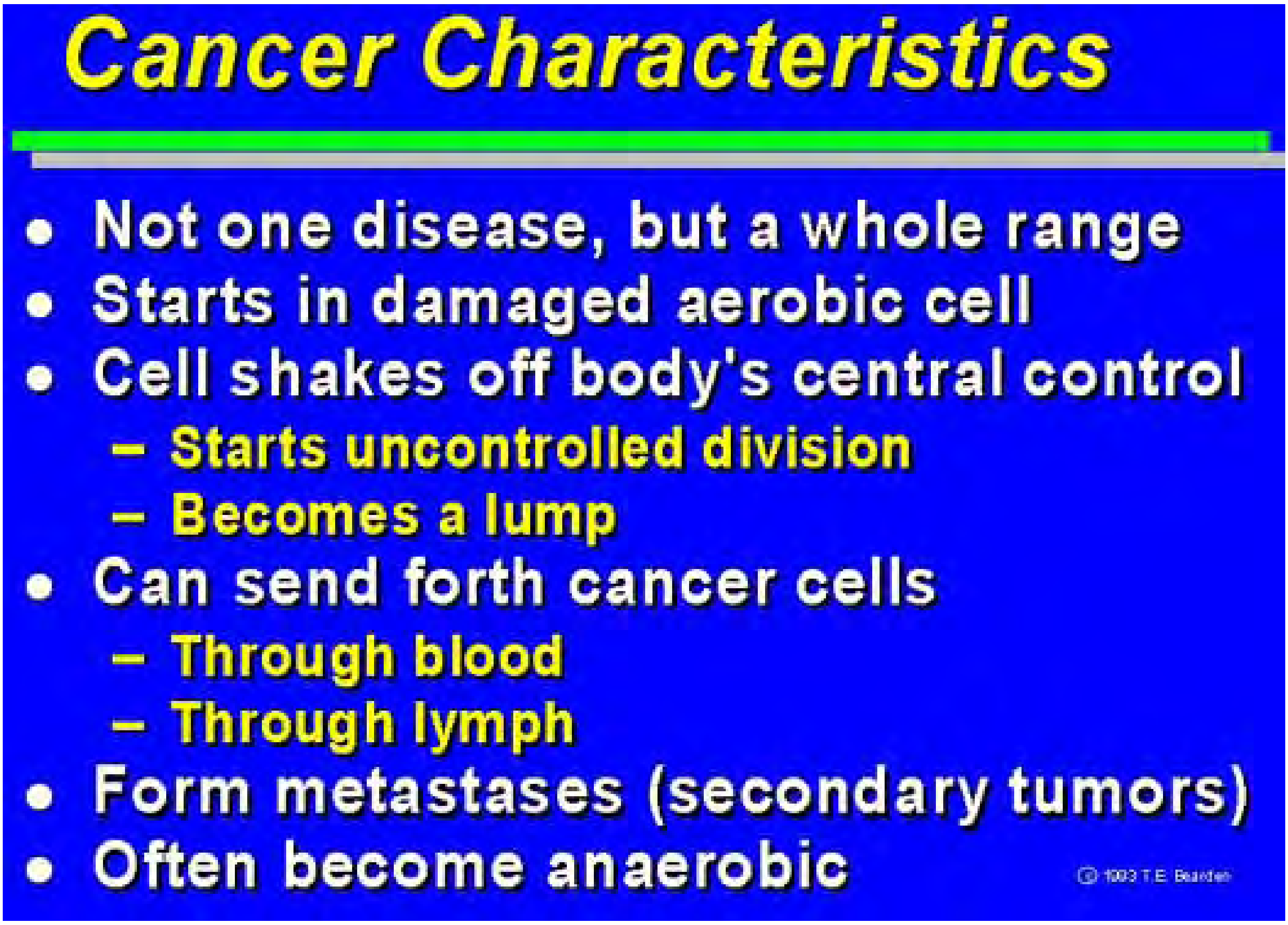

Cancer Characteristics

- Not one disease, but a whole range
- Starts in damaged aerobic cell
- Cell shakes off body's central control
  - Starts uncontrolled division
  - Becomes a lump
- Can send forth cancer cells
  - Through blood
  - Through lymph
- Form metastases (secondary tumors)
- Often become anaerobic

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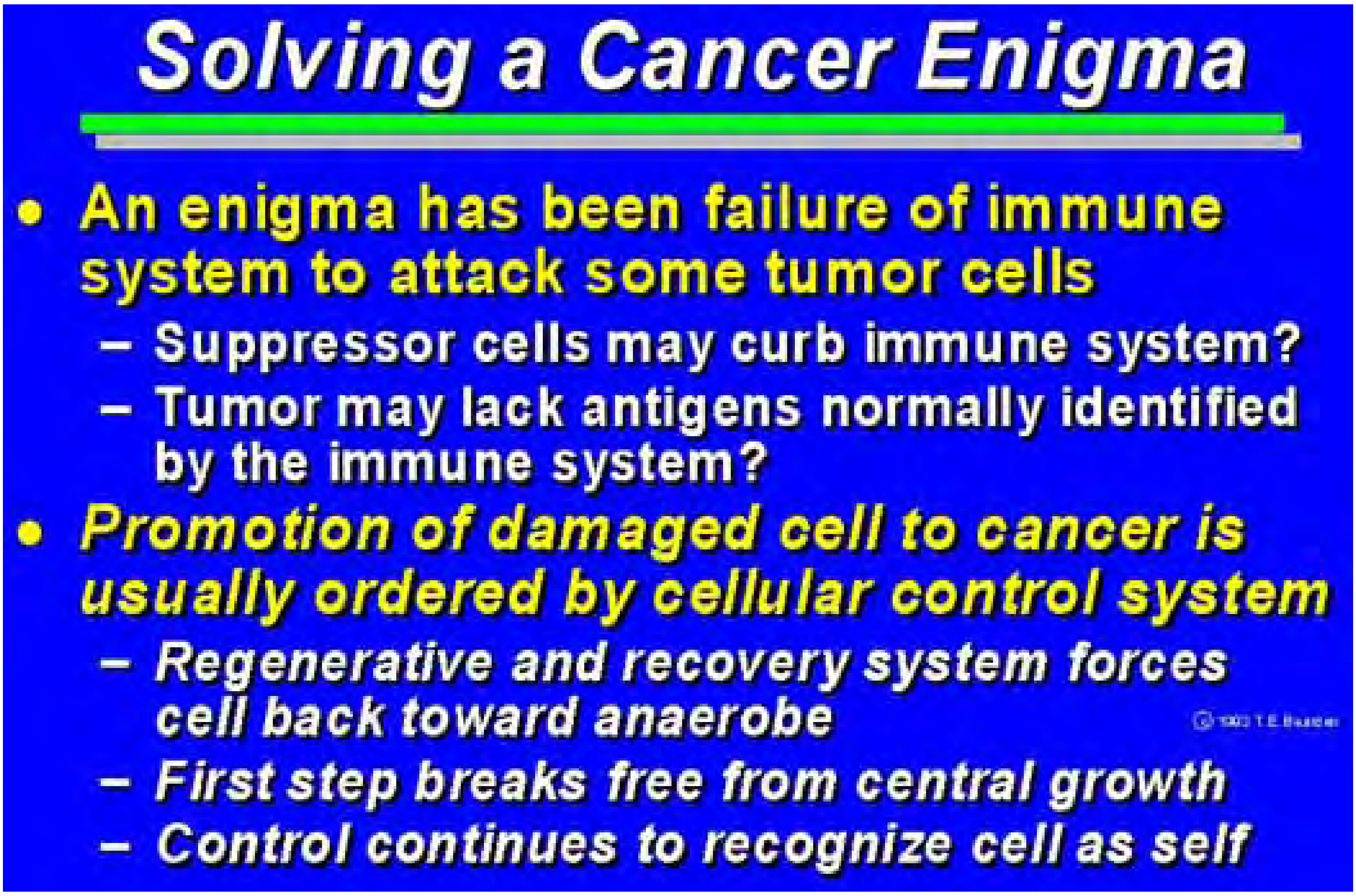

Solving a Cancer Enigma

- An enigma has been failure of immune system to attack some tumor cells
  - Suppressor cells may curb immune system?
  - Tumor may lack antigens normally identified by the immune system?
- *Promotion of damaged cell to cancer is usually ordered by cellular control system*
  - *Regenerative and recovery system forces cell back toward anaerobe*
  - *First step breaks free from central growth*
  - *Control continues to recognize cell as self*

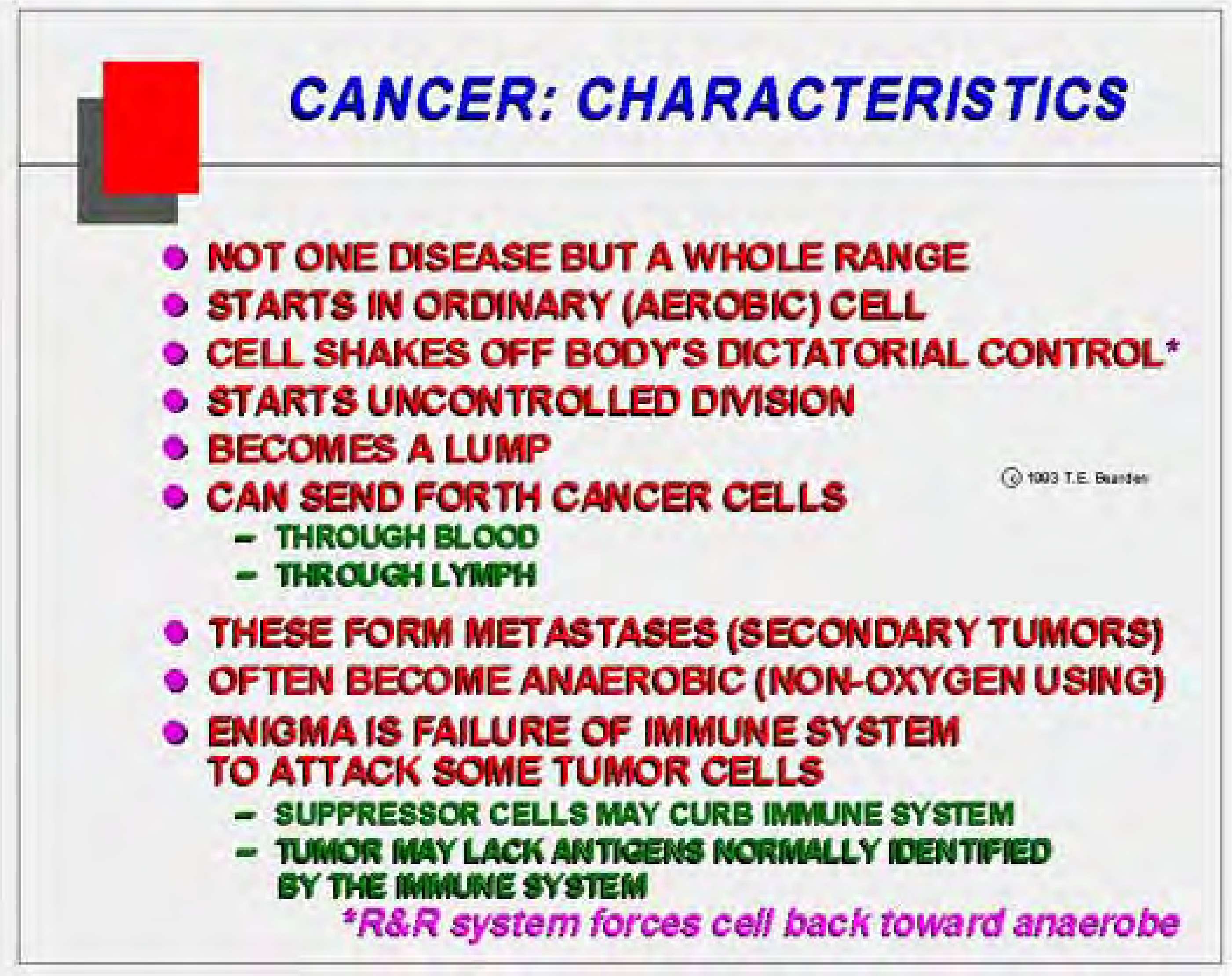

CANCER: CHARACTERISTICS

- NOT ONE DISEASE BUT A WHOLE RANGE
- STARTS IN ORDINARY (AEROBIC) CELL
- CELL SHAKES OFF BODY'S DICTATORIAL CONTROL*
- STARTS UNCONTROLLED DIVISION
- BECOMES A LUMP
- CAN SEND FORTH CANCER CELLS
  - THROUGH BLOOD
  - THROUGH LYMPH
- THESE FORM METASTASES (SECONDARY TUMORS)
- OFTEN BECOME ANAEROBIC (NON-OXYGEN USING)
- ENIGMA IS FAILURE OF IMMUNE SYSTEM TO ATTACK SOME TUMOR CELLS
  - SUPPRESSOR CELLS MAY CURB IMMUNE SYSTEM
  - TUMOR MAY LACK ANTIGENS NORMALLY IDENTIFIED BY THE IMMUNE SYSTEM

*R&R system forces cell back toward anaerobe

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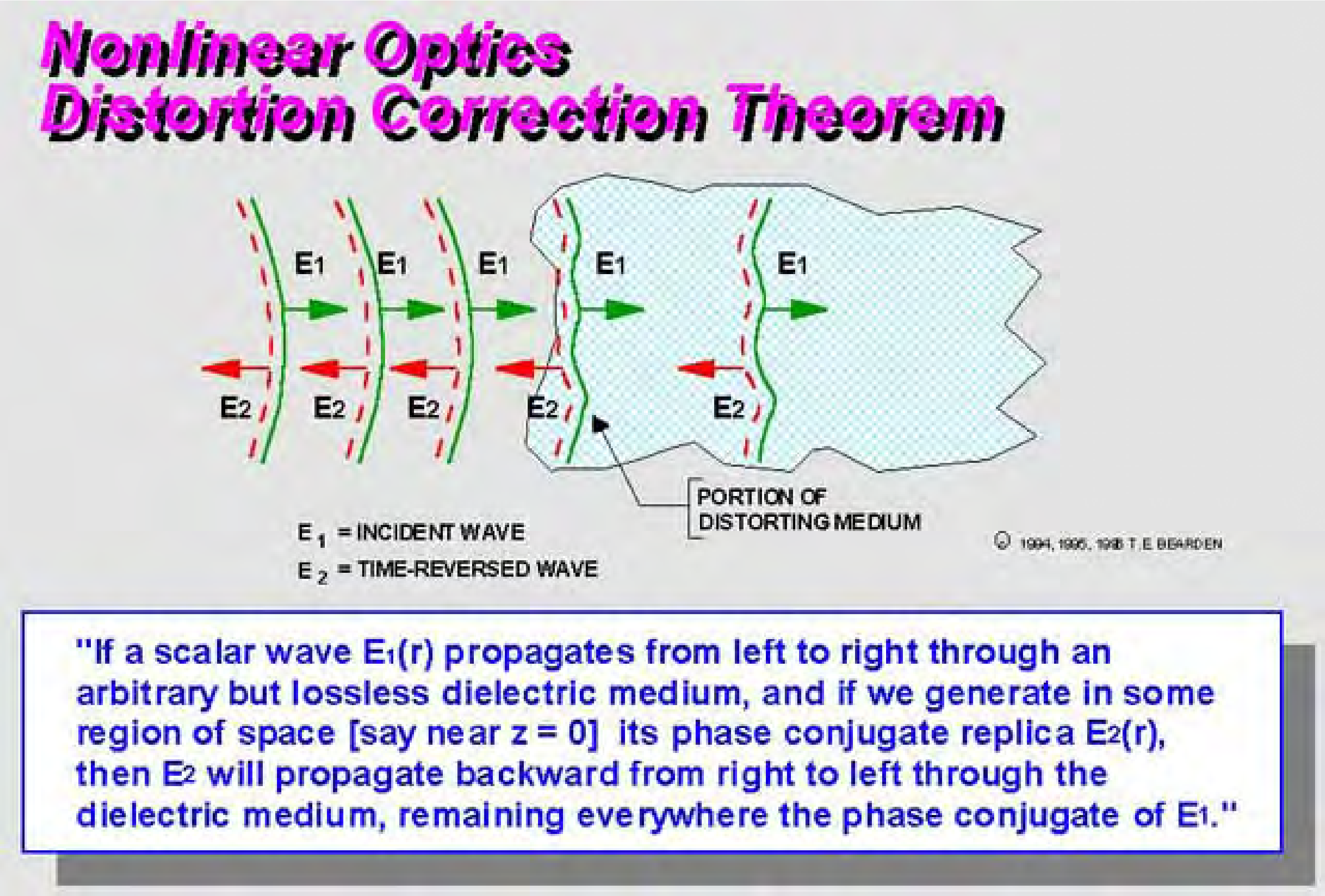

Nonlinear Optics
Distortion Correction Theorem

E1
E1
E1
E1
E1
E2
E2
E2
E2
E2
PORTION OF DISTORTING MEDIUM

E_1 = INCIDENT WAVE

E_2 = TIME-REVERSED WAVE

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"If a scalar wave $E_1(r)$ propagates from left to right through an arbitrary but lossless dielectric medium, and if we generate in some region of space [say near $z = 0$] its phase conjugate replica $E_2(r)$, then E_2 will propagate backward from right to left through the dielectric medium, remaining everywhere the phase conjugate of E_1."

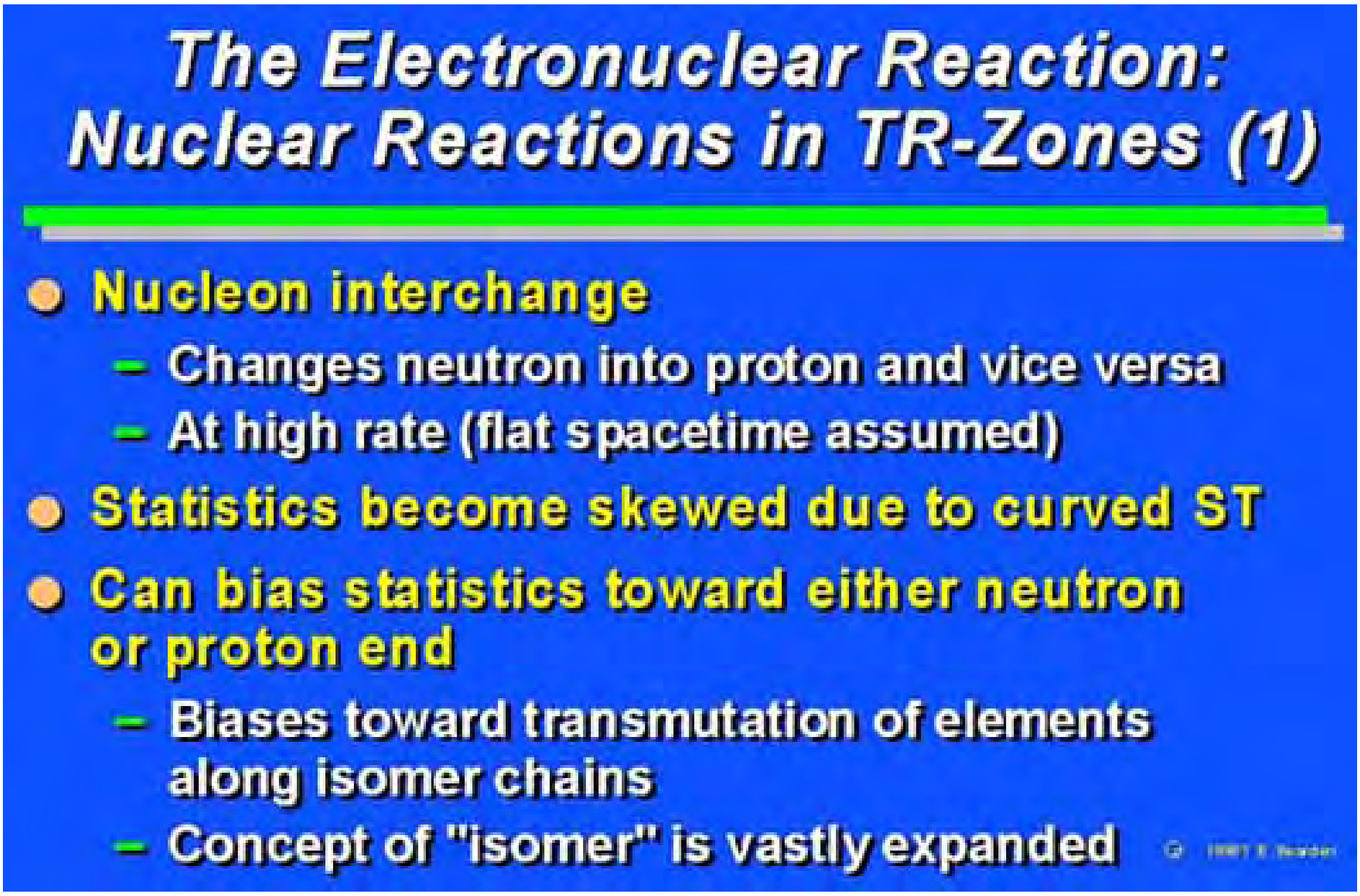

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (1)

- **Nucleon interchange**
  - Changes neutron into proton and vice versa
  - At high rate (flat spacetime assumed)
- **Statistics become skewed due to curved ST**
- **Can bias statistics toward either neutron or proton end**
  - Biases toward transmutation of elements along isomer chains
  - Concept of "isomer" is vastly expanded

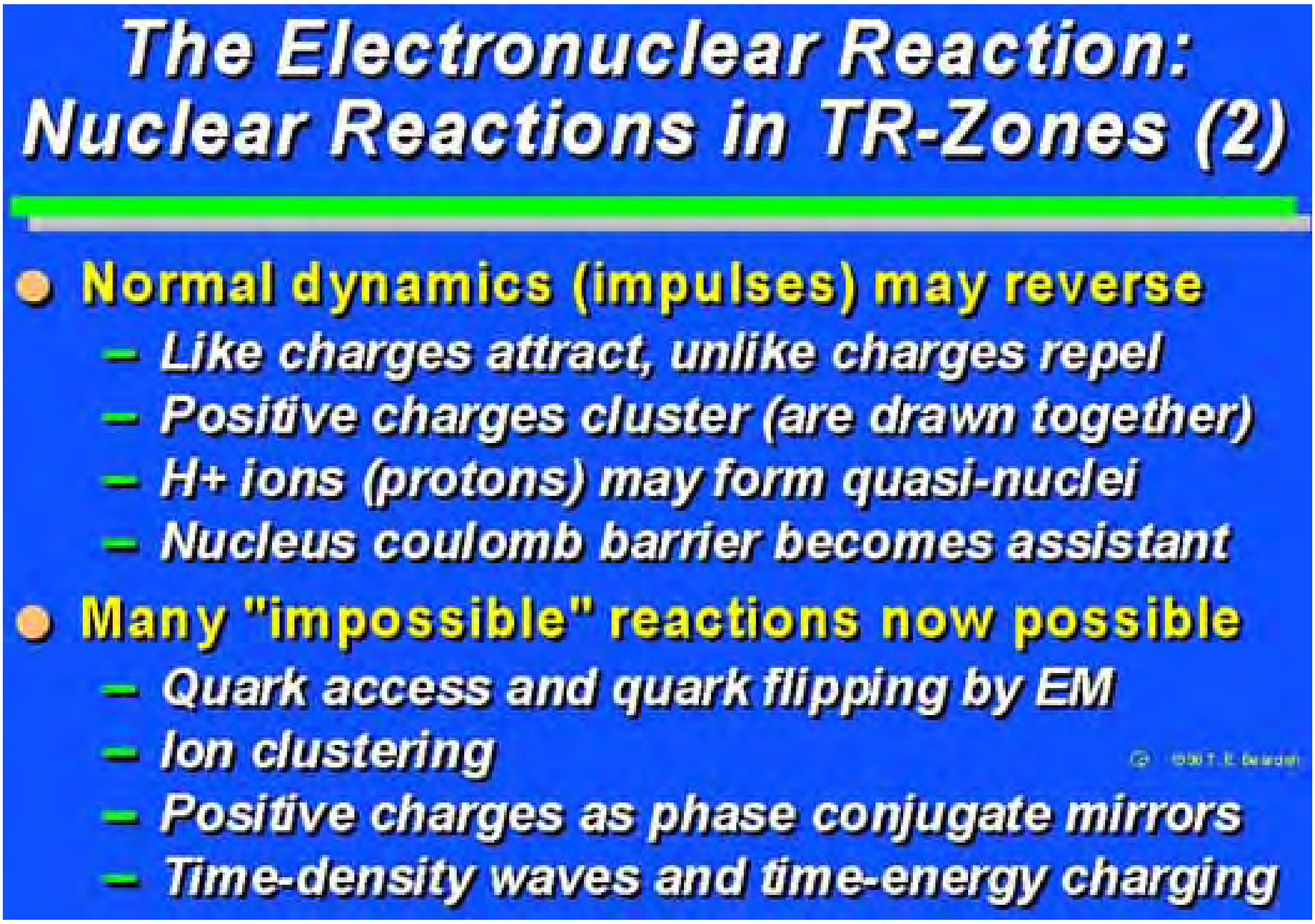

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (2)

- **Normal dynamics (impulses) may reverse**
  - *Like charges attract, unlike charges repel*
  - *Positive charges cluster (are drawn together)*
  - *H+ ions (protons) may form quasi-nuclei*
  - *Nucleus coulomb barrier becomes assistant*
- **Many "impossible" reactions now possible**
  - *Quark access and quark flipping by EM*
  - *Ion clustering*
  - *Positive charges as phase conjugate mirrors*
  - *Time-density waves and time-energy charging*

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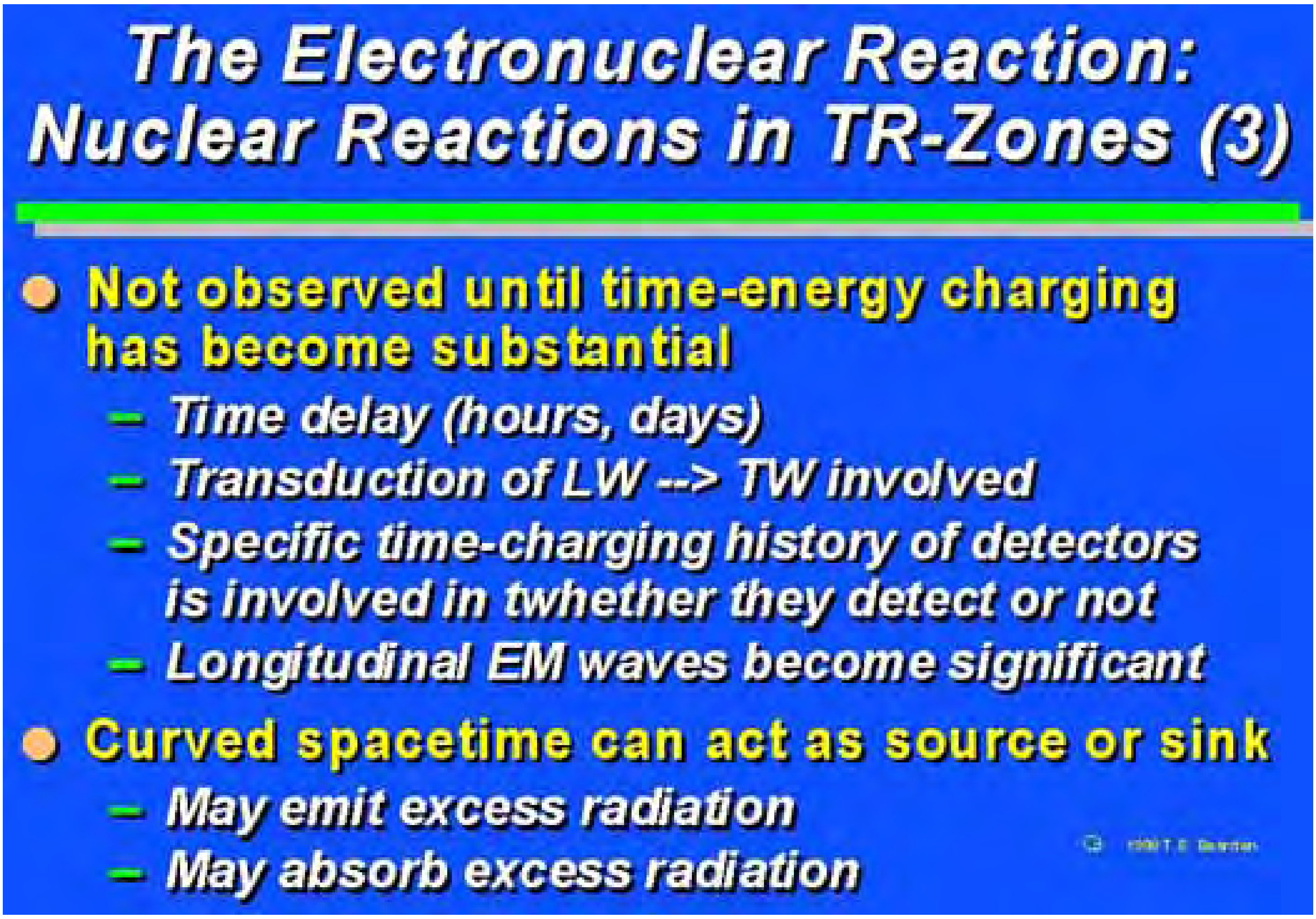

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (3)

- **Not observed until time-energy charging has become substantial**
  - *Time delay (hours, days)*
  - *Transduction of LW --> TW involved*
  - *Specific time-charging history of detectors is involved in twhether they detect or not*
  - *Longitudinal EM waves become significant*
- **Curved spacetime can act as source or sink**
  - *May emit excess radiation*
  - *May absorb excess radiation*

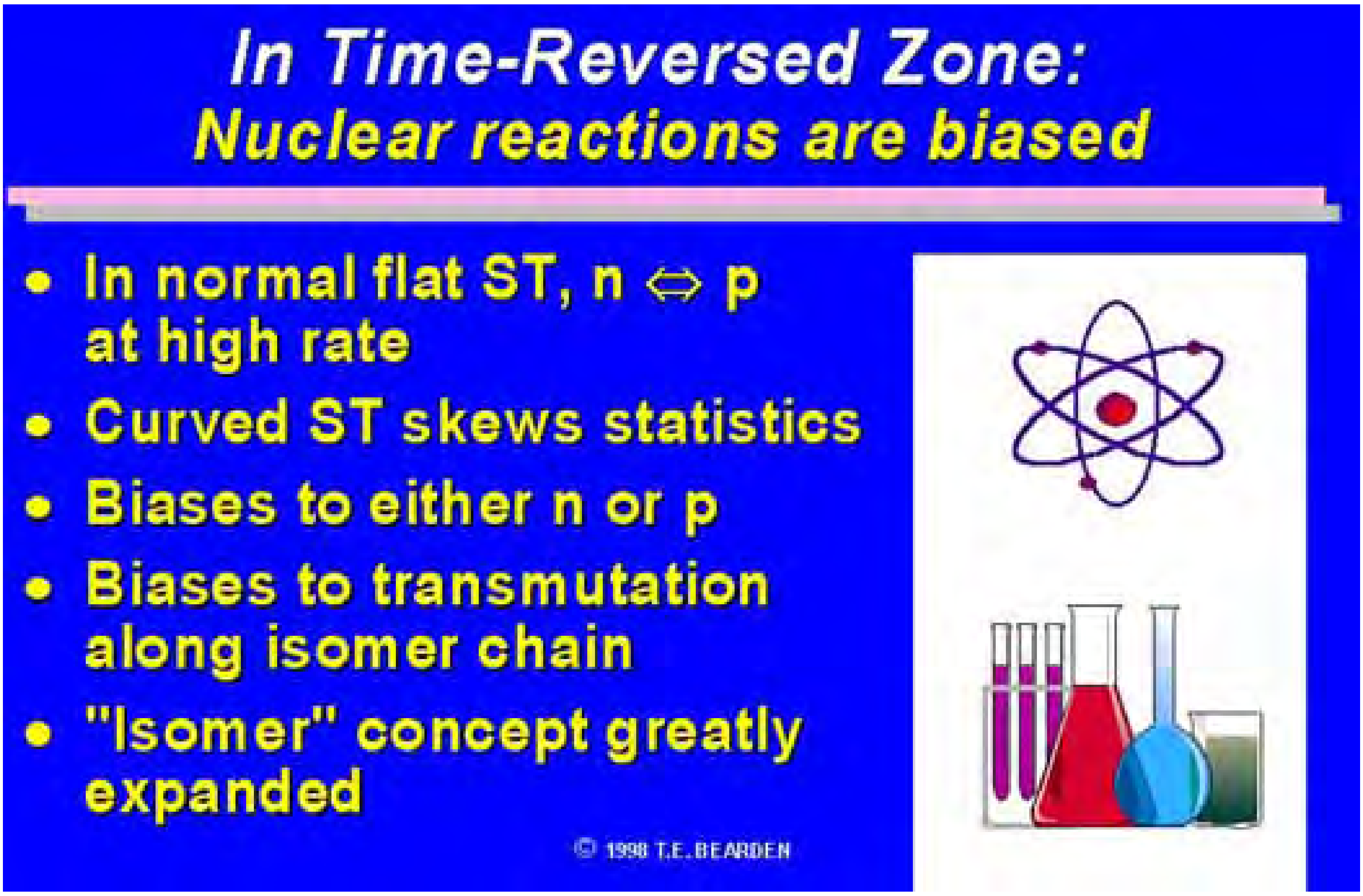

In Time-Reversed Zone:
Nuclear reactions are biased

- In normal flat ST, n ⇔ p at high rate
- Curved ST skews statistics
- Biases to either n or p
- Biases to transmutation along isomer chain
- "Isomer" concept greatly expanded

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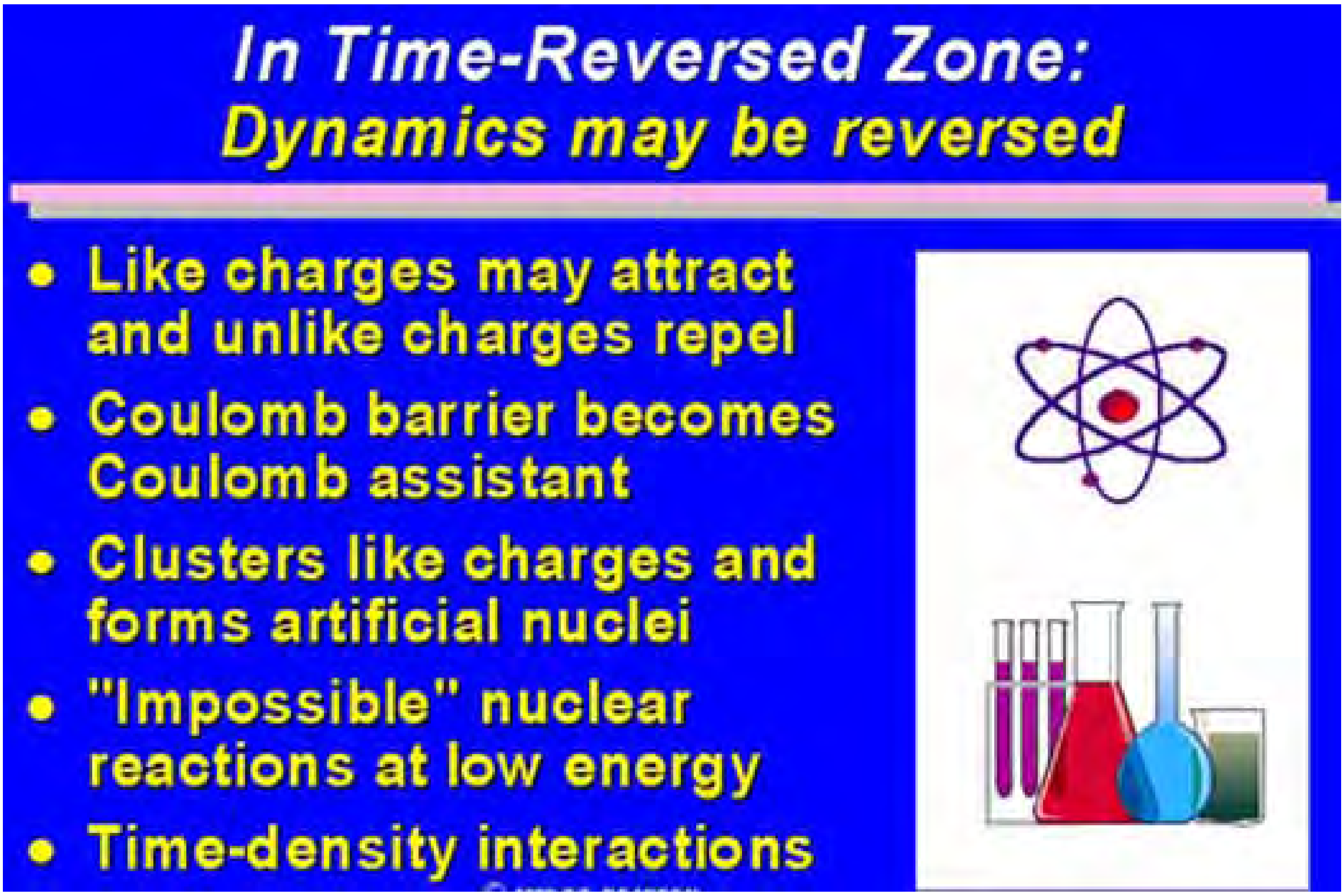

In Time-Reversed Zone:
Dynamics may be reversed

- Like charges may attract and unlike charges repel
- Coulomb barrier becomes Coulomb assistant
- Clusters like charges and forms artificial nuclei
- "Impossible" nuclear reactions at low energy
- Time-density interactions

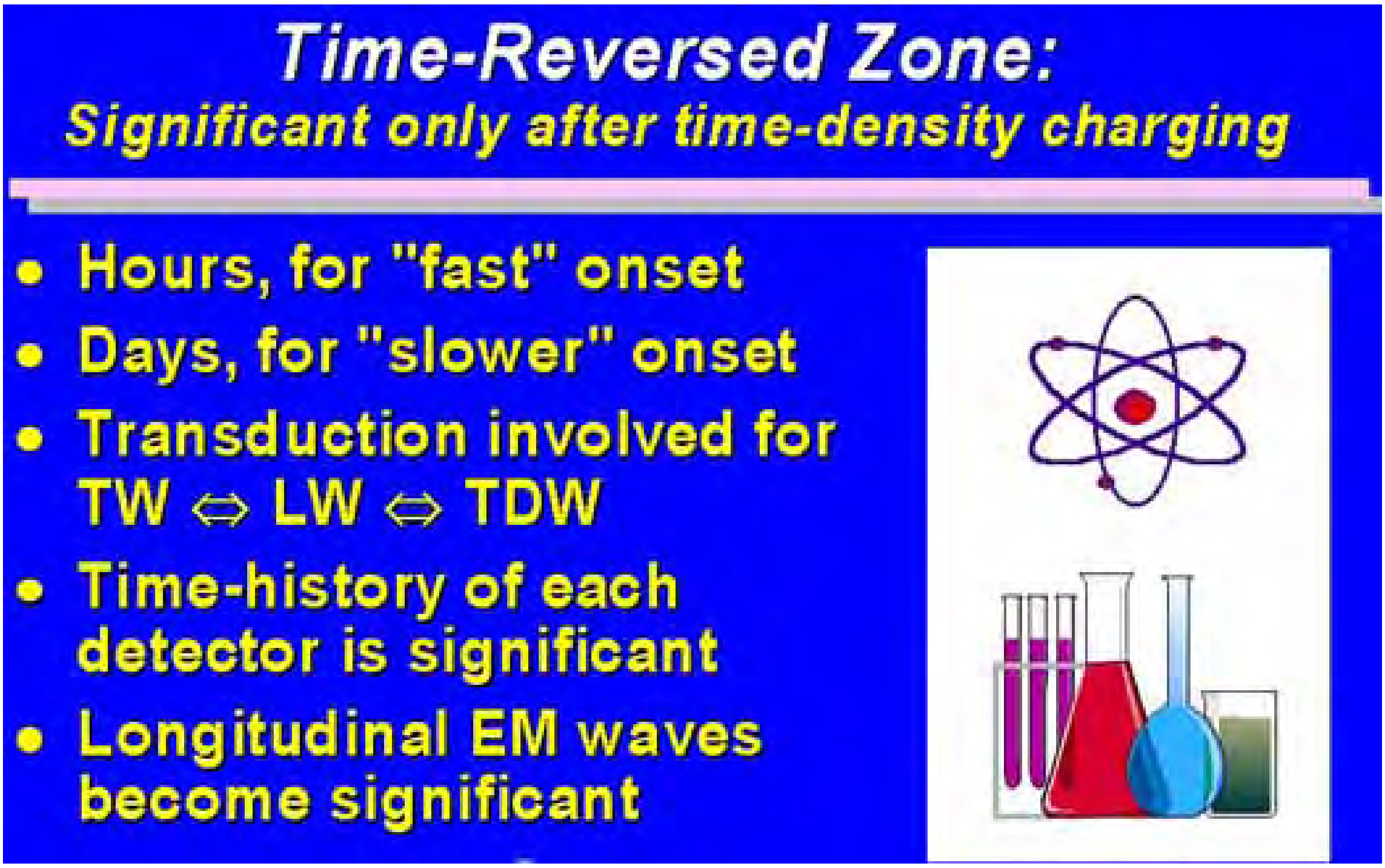

Time-Reversed Zone:

Significant only after time-density charging

- Hours, for "fast" onset
- Days, for "slower" onset
- Transduction involved for TW ⇔ LW ⇔ TDW
- Time-history of each detector is significant
- Longitudinal EM waves become significant

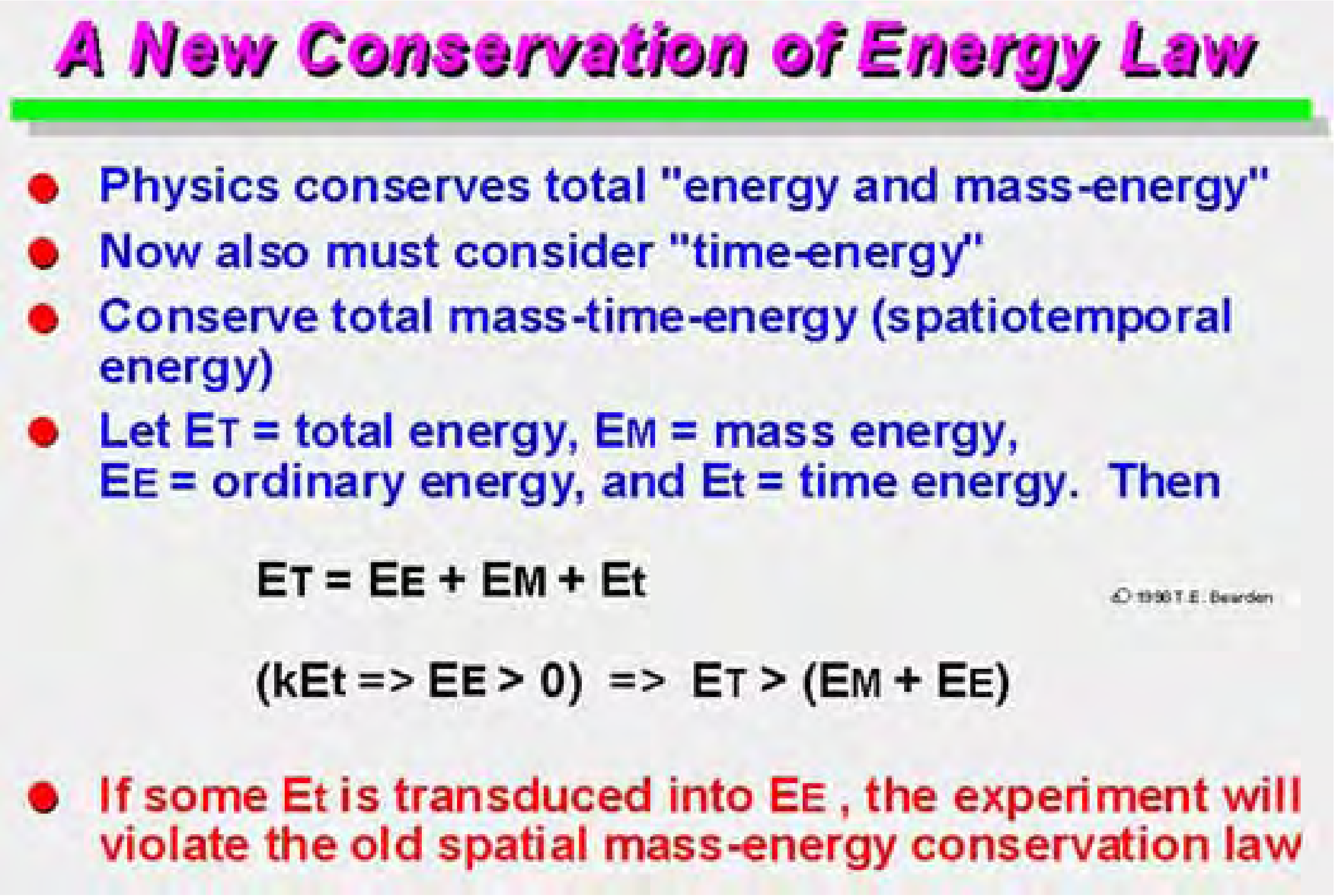

A New Conservation of Energy Law

- Physics conserves total "energy and mass-energy"
- Now also must consider "time-energy"
- Conserve total mass-time-energy (spatiotemporal energy)
- Let E_T = total energy, E_M = mass energy, E_E = ordinary energy, and E_t = time energy. Then

$$E_T = E_E + E_M + E_t$$

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$$(kE_t \Rightarrow E_E > 0) \Rightarrow E_T > (E_M + E_E)$$

- If some E_t is transduced into E_E, the experiment will violate the old spatial mass-energy conservation law

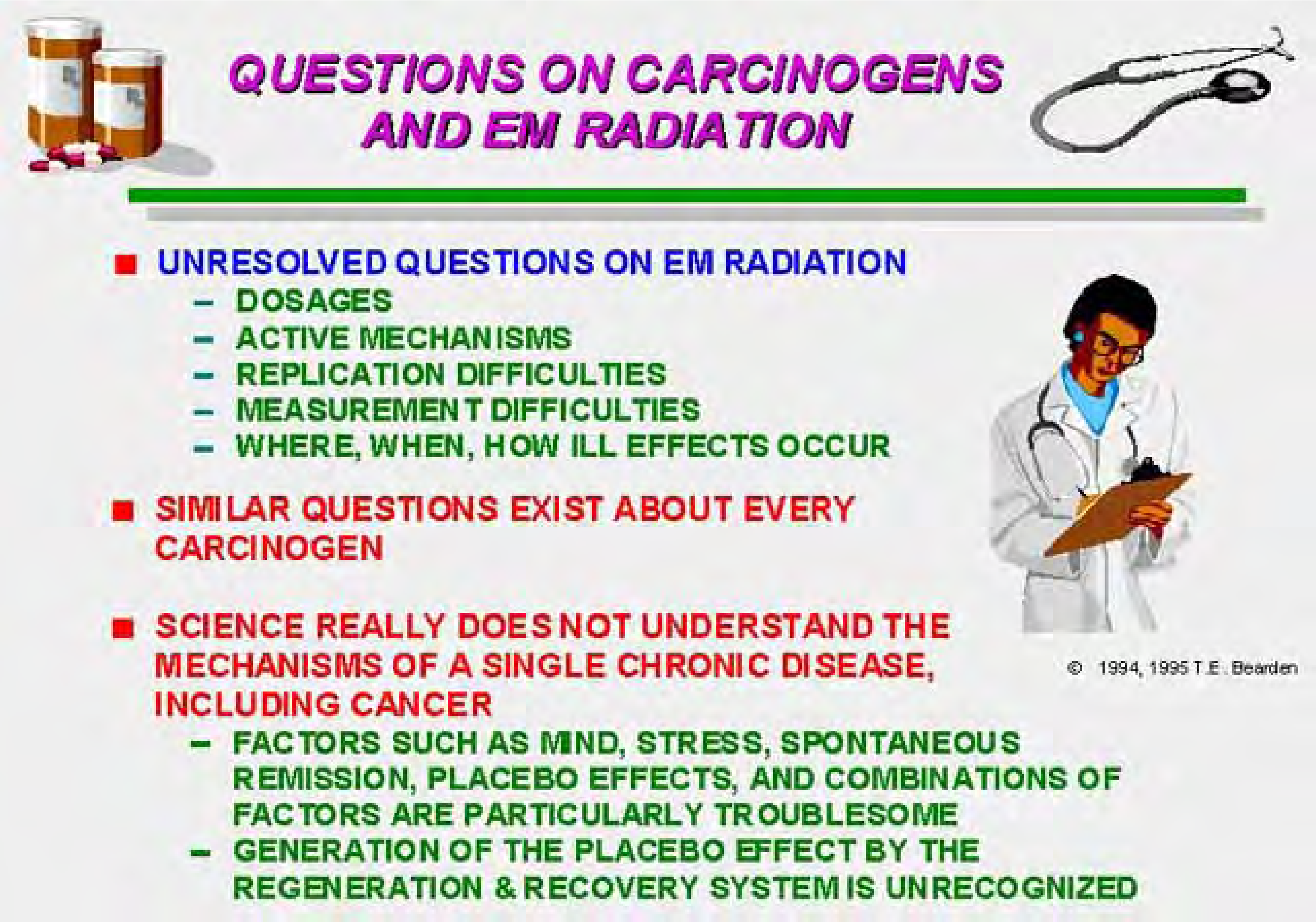

QUESTIONS ON CARCINOGENS AND EM RADIATION

- UNRESOLVED QUESTIONS ON EM RADIATION
  - DOSAGES
  - ACTIVE MECHANISMS
  - REPLICATION DIFFICULTIES
  - MEASUREMENT DIFFICULTIES
  - WHERE, WHEN, HOW ILL EFFECTS OCCUR
- SIMILAR QUESTIONS EXIST ABOUT EVERY CARCINOGEN
- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
  - FACTORS SUCH AS MIND, STRESS, SPONTANEOUS REMISSION, PLACEBO EFFECTS, AND COMBINATIONS OF FACTORS ARE PARTICULARLY TROUBLESOME
  - GENERATION OF THE PLACEBO EFFECT BY THE REGENERATION & RECOVERY SYSTEM IS UNRECOGNIZED

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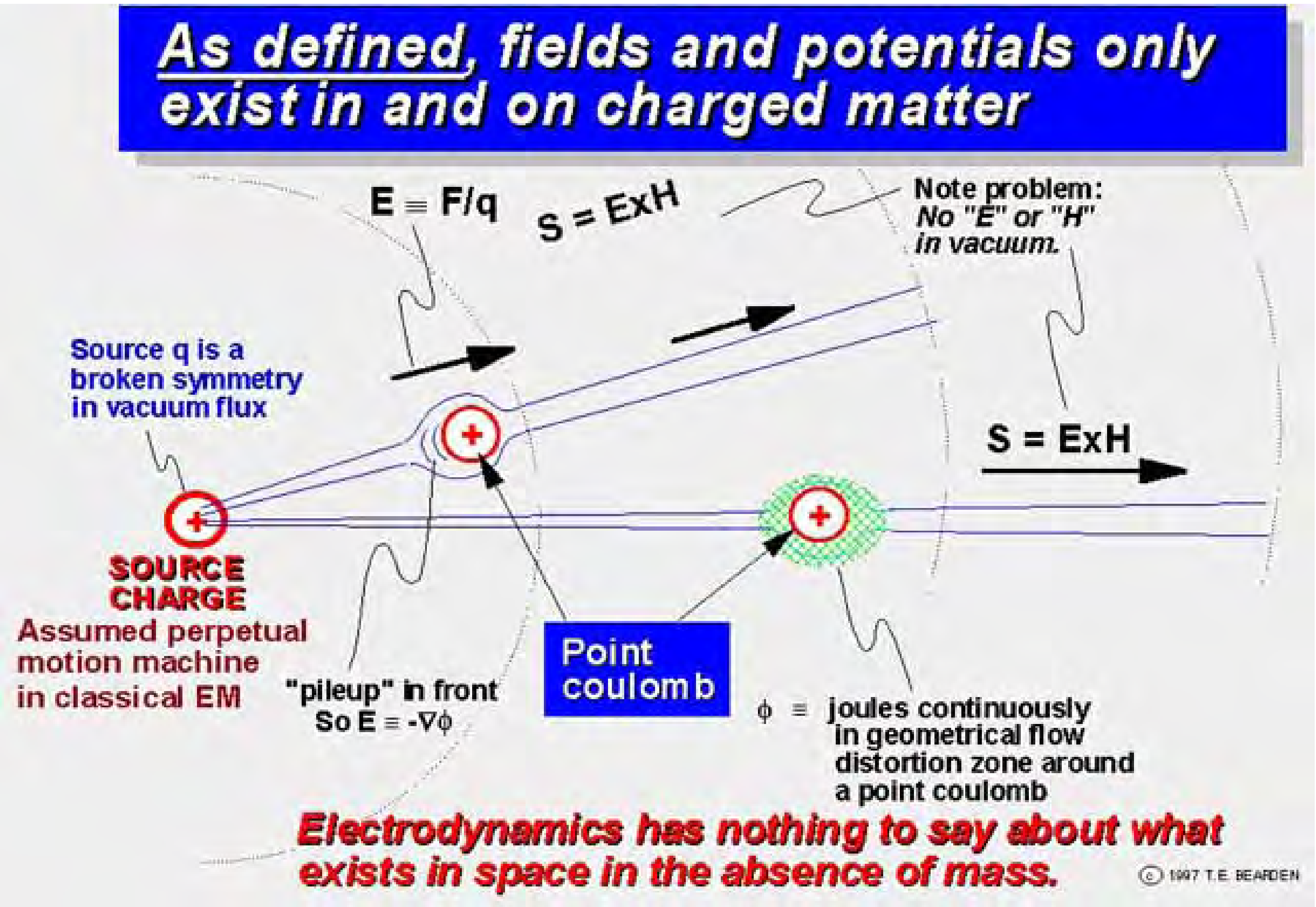

As defined, fields and potentials only exist in and on charged matter

$E \equiv F/q$

$S = E \times H$

Note problem:
No "E" or "H" in vacuum.

Source q is a broken symmetry in vacuum flux

SOURCE CHARGE

Assumed perpetual motion machine in classical EM

$S = E \times H$

"pileup" in front
So $E \equiv -\nabla\phi$

Point coulomb

$\phi \equiv$ joules continuously in geometrical flow distortion zone around a point coulomb

Electrodynamics has nothing to say about what exists in space in the absence of mass.

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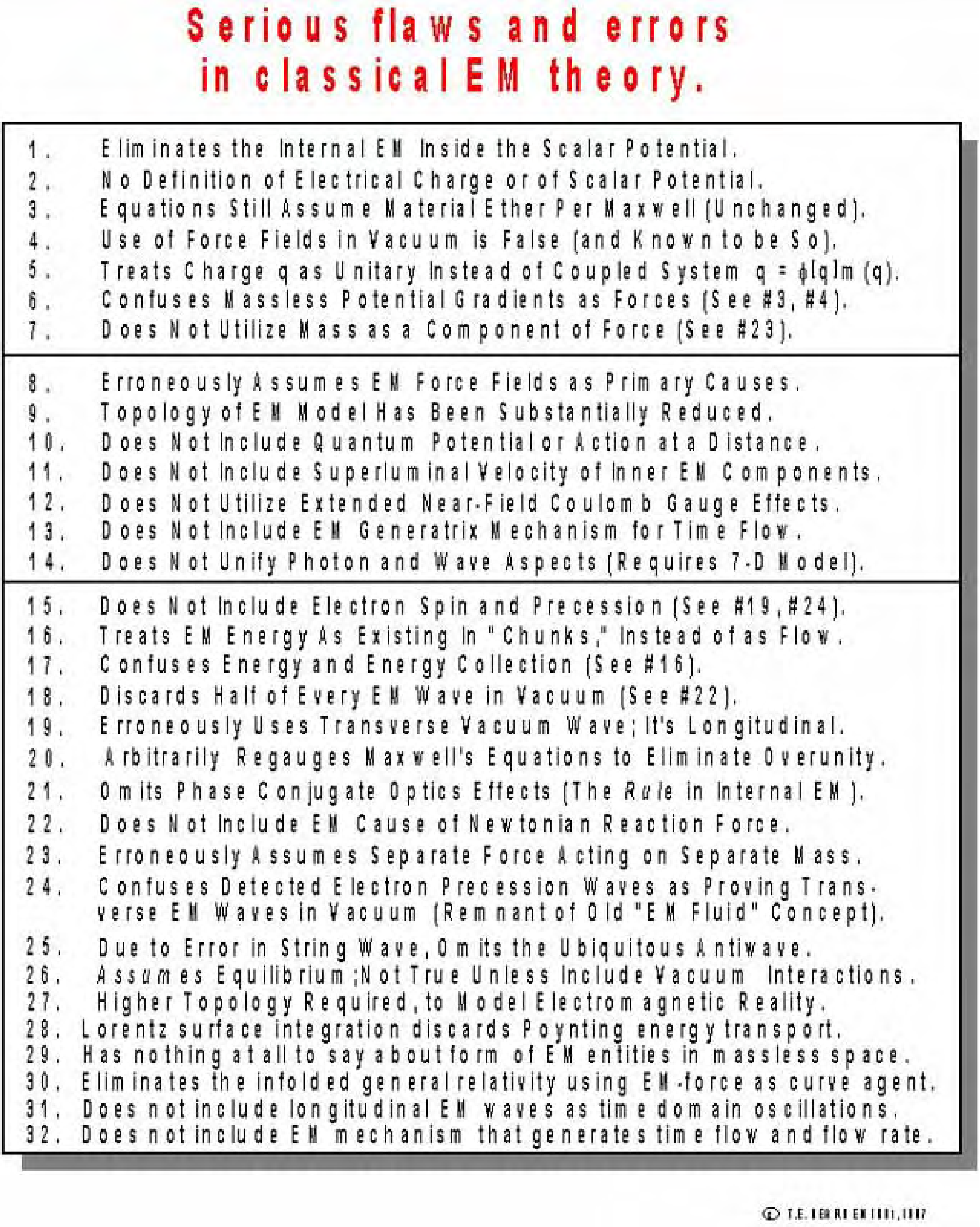

Serious flaws and errors in classical EM theory.

1. Eliminates the Internal EM Inside the Scalar Potential.
2. No Definition of Electrical Charge or of Scalar Potential.
3. Equations Still Assume Material Ether Per Maxwell (Unchanged).
4. Use of Force Fields in Vacuum is False (and Known to be So).
5. Treats Charge q as Unitary Instead of Coupled System $q = \phi(q)m(q)$.
6. Confuses Massless Potential Gradients as Forces (See #3, #4).
7. Does Not Utilize Mass as a Component of Force (See #23).

8. Erroneously Assumes EM Force Fields as Primary Causes.
9. Topology of EM Model Has Been Substantially Reduced.
10. Does Not Include Quantum Potential or Action at a Distance.
11. Does Not Include Superluminal Velocity of Inner EM Components.
12. Does Not Utilize Extended Near-Field Coulomb Gauge Effects.
13. Does Not Include EM Generatrix Mechanism for Time Flow.
14. Does Not Unify Photon and Wave Aspects (Requires 7-D Model).

15. Does Not Include Electron Spin and Precession (See #19, #24).
16. Treats EM Energy As Existing In "Chunks," Instead of as Flow.
17. Confuses Energy and Energy Collection (See #16).
18. Discards Half of Every EM Wave in Vacuum (See #22).
19. Erroneously Uses Transverse Vacuum Wave; It's Longitudinal.
20. Arbitrarily Regauges Maxwell's Equations to Eliminate Overunity.
21. Omits Phase Conjugate Optics Effects (The *Rule* in Internal EM).
22. Does Not Include EM Cause of Newtonian Reaction Force.
23. Erroneously Assumes Separate Force Acting on Separate Mass.
24. Confuses Detected Electron Precession Waves as Proving Transverse EM Waves in Vacuum (Remnant of Old "EM Fluid" Concept).
25. Due to Error in String Wave, Omits the Ubiquitous Antiwave.
26. Assumes Equilibrium; Not True Unless Include Vacuum Interactions.
27. Higher Topology Required, to Model Electromagnetic Reality.
28. Lorentz surface integration discards Poynting energy transport.
29. Has nothing at all to say about form of EM entities in massless space.
30. Eliminates the infolded general relativity using EM-force as curve agent.
31. Does not include longitudinal EM waves as time domain oscillations.
32. Does not include EM mechanism that generates time flow and flow rate.

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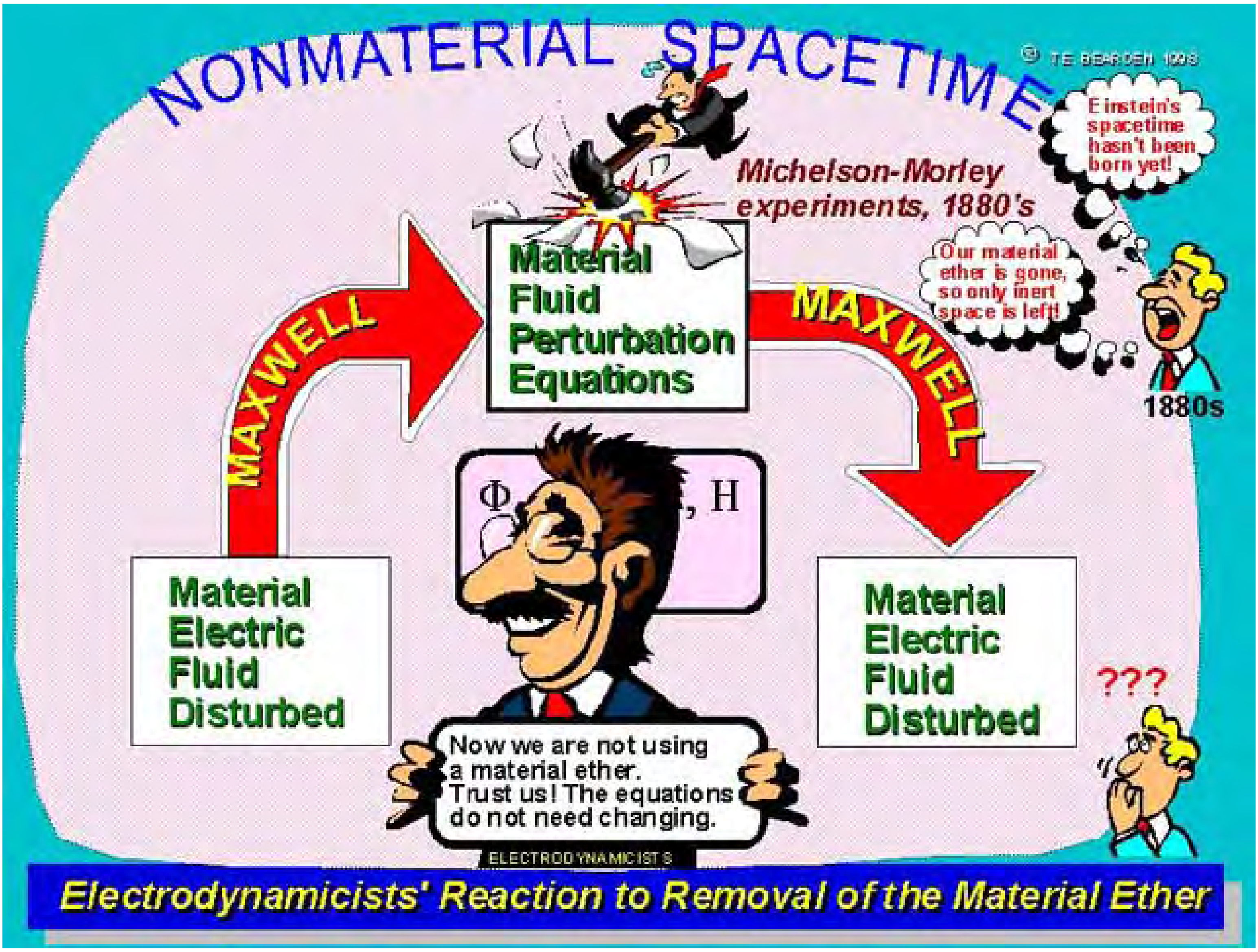

NONMATERIAL SPACETIME

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Michelson-Morley experiments, 1880's

Material Fluid Perturbation Equations

Material Electric Fluid Disturbed

Material Electric Fluid Disturbed

Einstein's spacetime hasn't been born yet!
Our material ether is gone, so only inert space is left!
1880s
MAXWELL
MAXWELL
Φ
, H
Now we are not using a material ether. Trust us! The equations do not need changing.
ELECTRODYNAMICISTS
???

Electrodynamicists' Reaction to Removal of the Material Ether

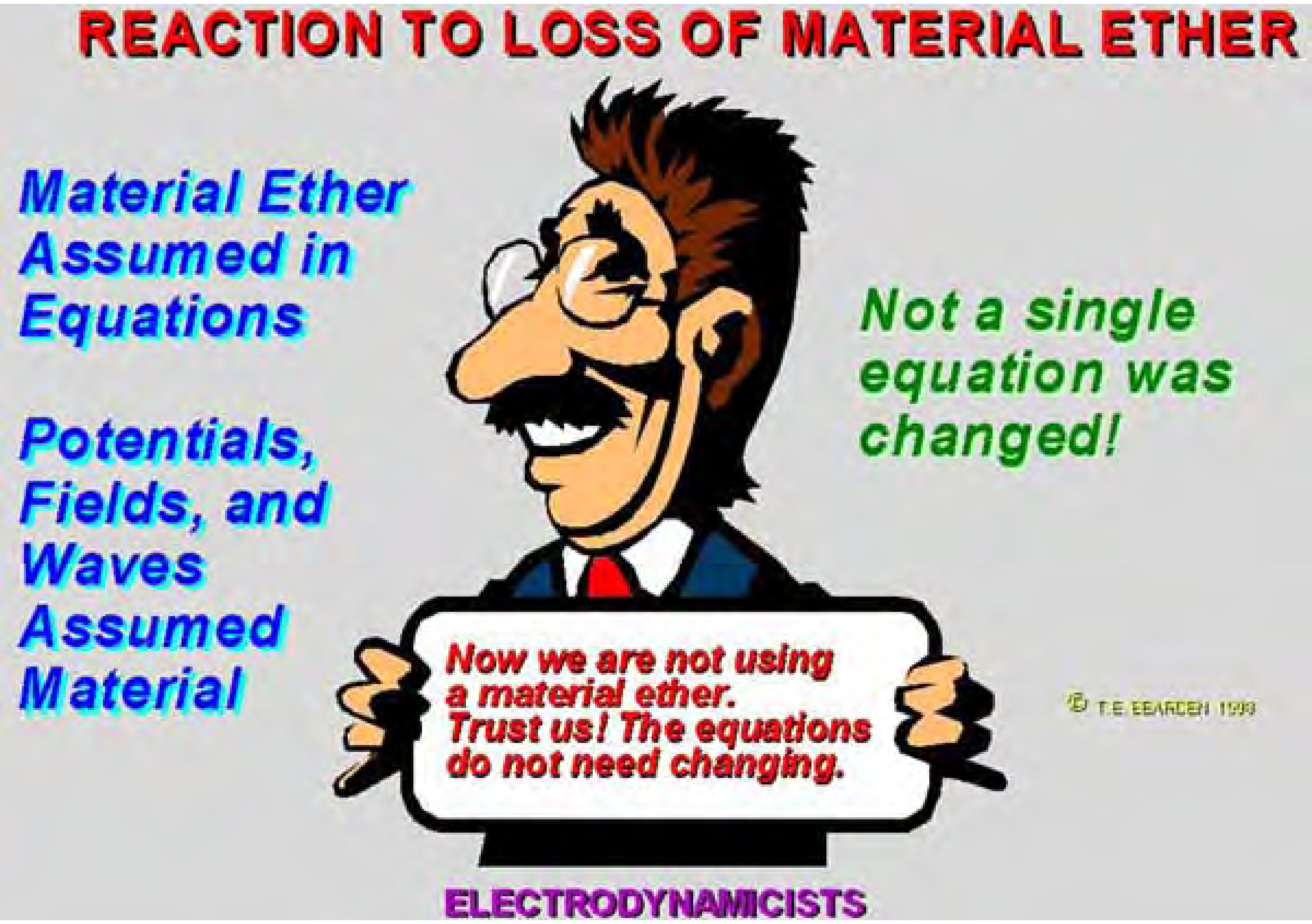

REACTION TO LOSS OF MATERIAL ETHER

Material Ether
Assumed in
Equations

Potentials,
Fields, and
Waves
Assumed
Material

Not a single
equation was
changed!

Now we are not using
a material ether.
Trust us! The equations
do not need changing.

ELECTRODYNAMICISTS

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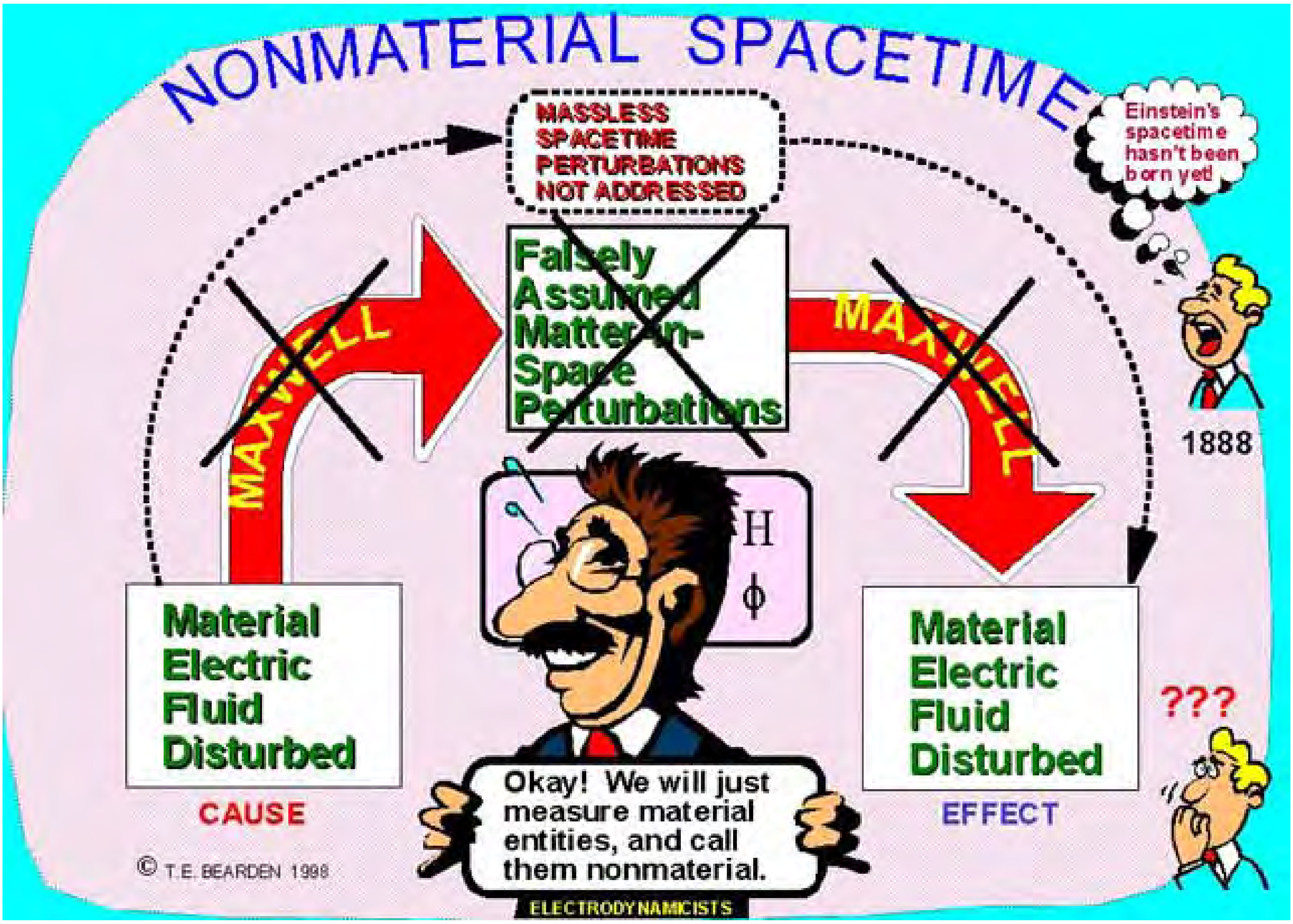
NONMATERIAL SPACETIME
MASSLESS SPACETIME PERTURBATIONS NOT ADDRESSED
Einstein's spacetime hasn't been born yet!
MAXWELL
Falsely Assumed Matter-in-Space Perturbations
MAXWELL
1888
H
ϕ
Material Electric Fluid Disturbed
CAUSE
Material Electric Fluid Disturbed
EFFECT
???
Okay! We will just measure material entities, and call them nonmaterial.
ELECTRODYNAMICISTS
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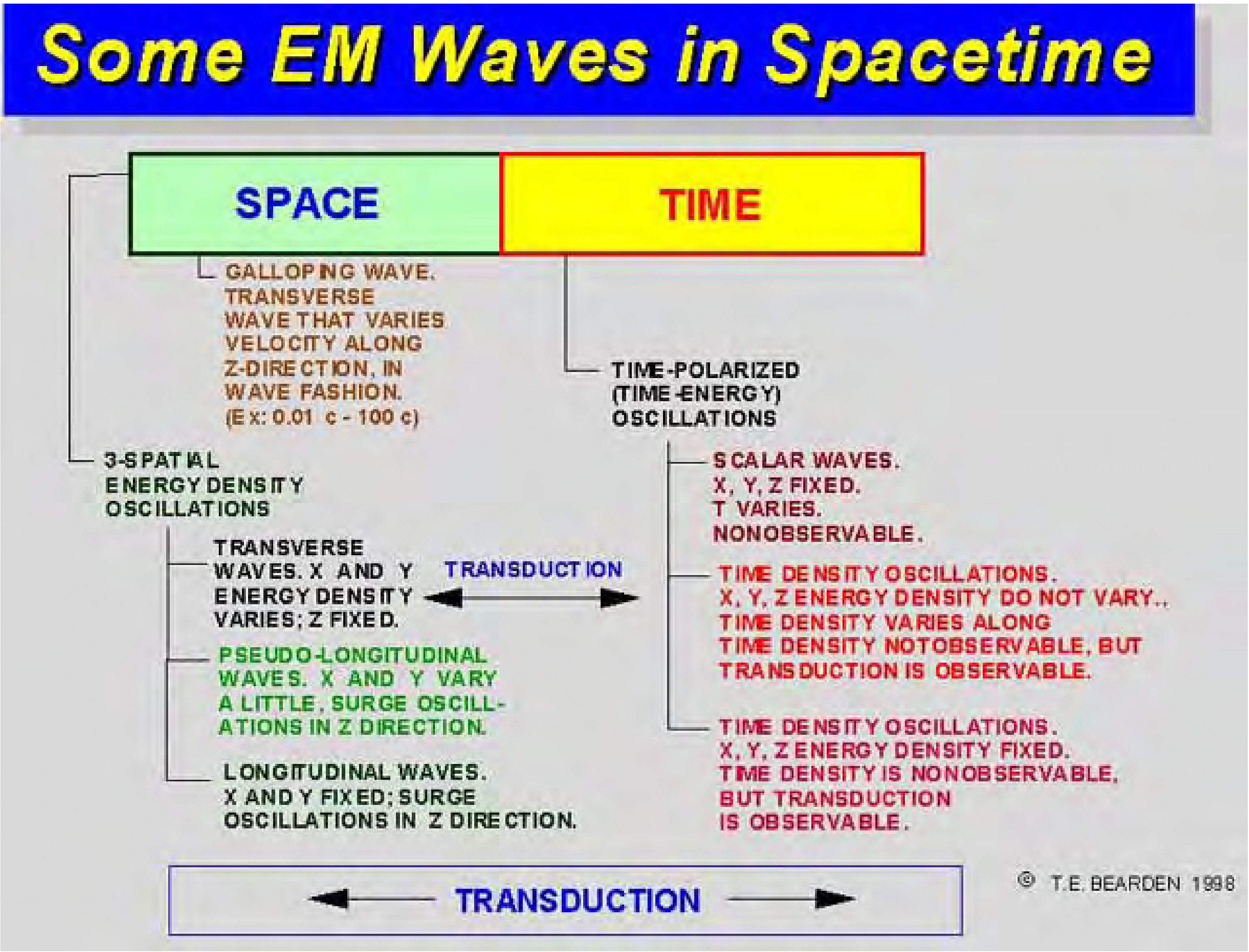

Some EM Waves in Spacetime

SPACE

TIME

GALLOPING WAVE. TRANSVERSE WAVE THAT VARIES VELOCITY ALONG Z-DIRECTION, IN WAVE FASHION. (Ex: 0.01 c - 100 c)

TIME-POLARIZED (TIME-ENERGY) OSCILLATIONS

3-SPATIAL ENERGY DENSITY OSCILLATIONS

TRANSVERSE WAVES. X AND Y ENERGY DENSITY VARIES; Z FIXED.

TRANSDUCTION

PSEUDO-LONGITUDINAL WAVES. X AND Y VARY A LITTLE, SURGE OSCILLATIONS IN Z DIRECTION.

LONGITUDINAL WAVES. X AND Y FIXED; SURGE OSCILLATIONS IN Z DIRECTION.

SCALAR WAVES. X, Y, Z FIXED. T VARIES. NONOBSERVABLE.

TIME DENSITY OSCILLATIONS. X, Y, Z ENERGY DENSITY DO NOT VARY.. TIME DENSITY VARIES ALONG TIME DENSITY NOTOBSERVABLE, BUT TRANSDUCTION IS OBSERVABLE.

TIME DENSITY OSCILLATIONS. X, Y, Z ENERGY DENSITY FIXED. TIME DENSITY IS NONOBSERVABLE, BUT TRANSDUCTION IS OBSERVABLE.

TRANSDUCTION

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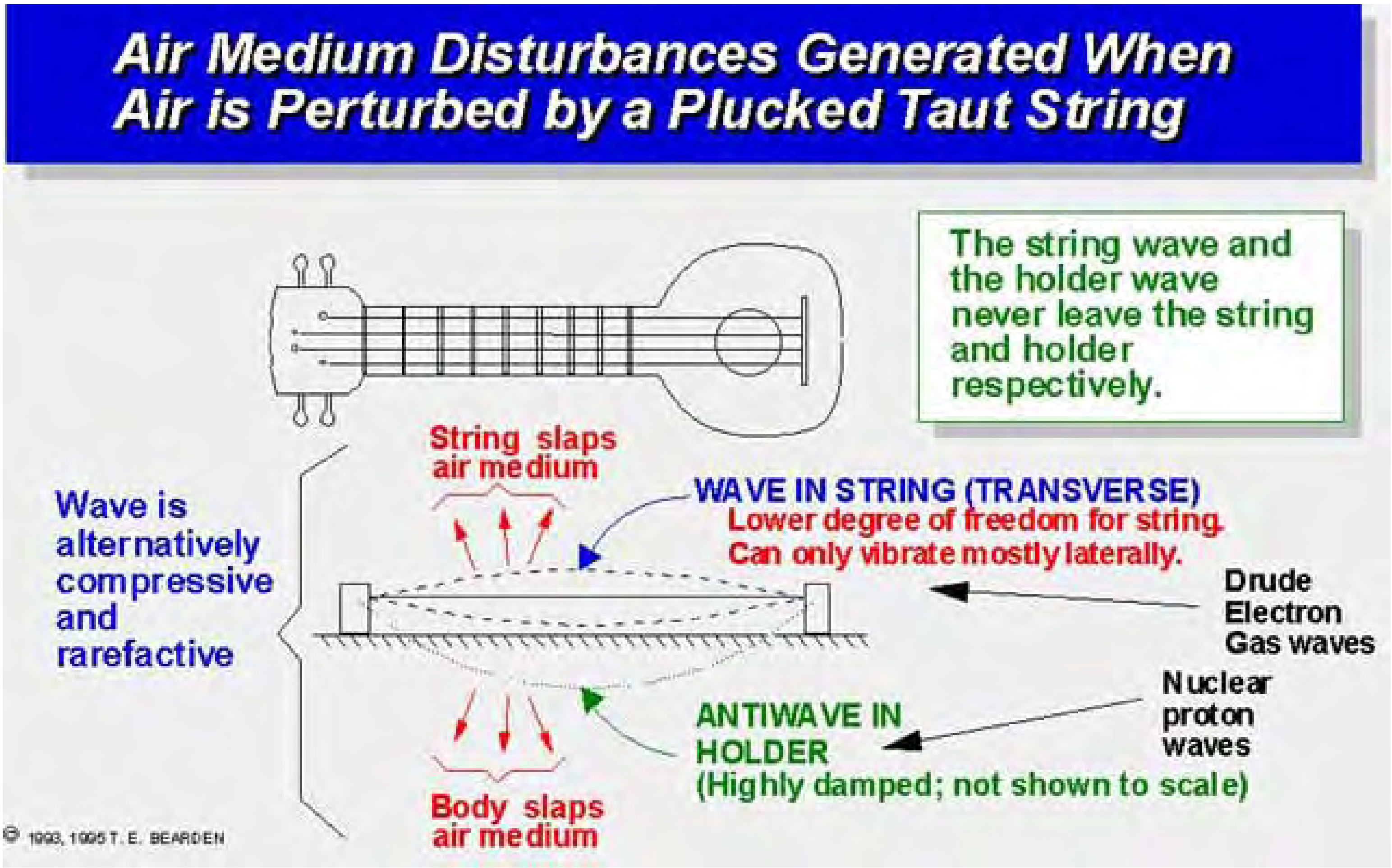

Air Medium Disturbances Generated When Air is Perturbed by a Plucked Taut String

The string wave and the holder wave never leave the string and holder respectively.

String slaps air medium

WAVE IN STRING (TRANSVERSE)
Lower degree of freedom for string.
Can only vibrate mostly laterally.

Wave is alternatively compressive and rarefactive

Drude Electron Gas waves

Nuclear proton waves

ANTIWAVE IN HOLDER
(Highly damped; not shown to scale)

Body slaps air medium

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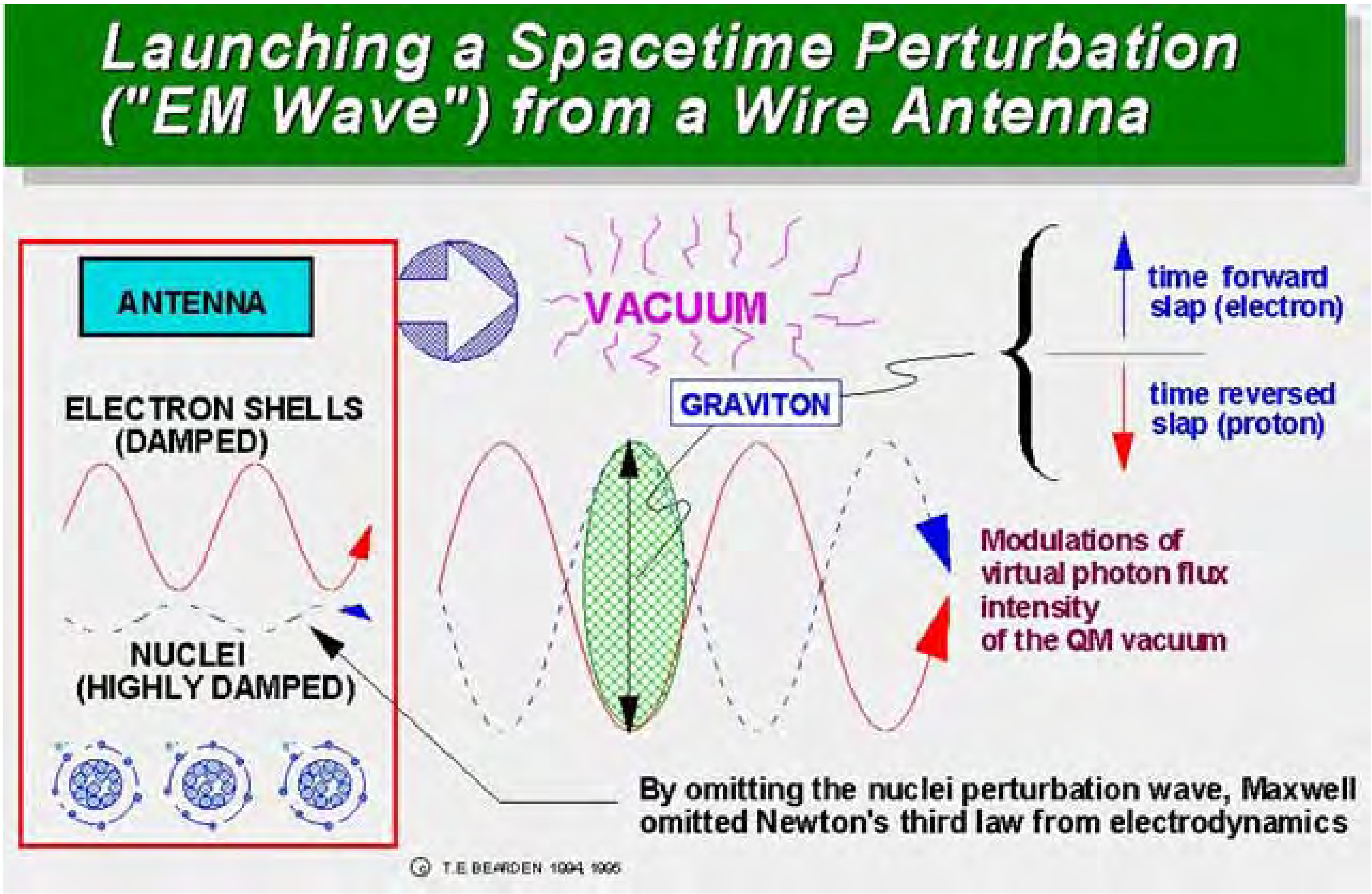

Launching a Spacetime Perturbation ("EM Wave") from a Wire Antenna

ANTENNA

ELECTRON SHELLS
(DAMPED)

NUCLEI
(HIGHLY DAMPED)

VACUUM

GRAVITON

time forward
slap (electron)

time reversed
slap (proton)

Modulations of
virtual photon flux
intensity
of the QM vacuum

By omitting the nuclei perturbation wave, Maxwell
omitted Newton's third law from electrodynamics

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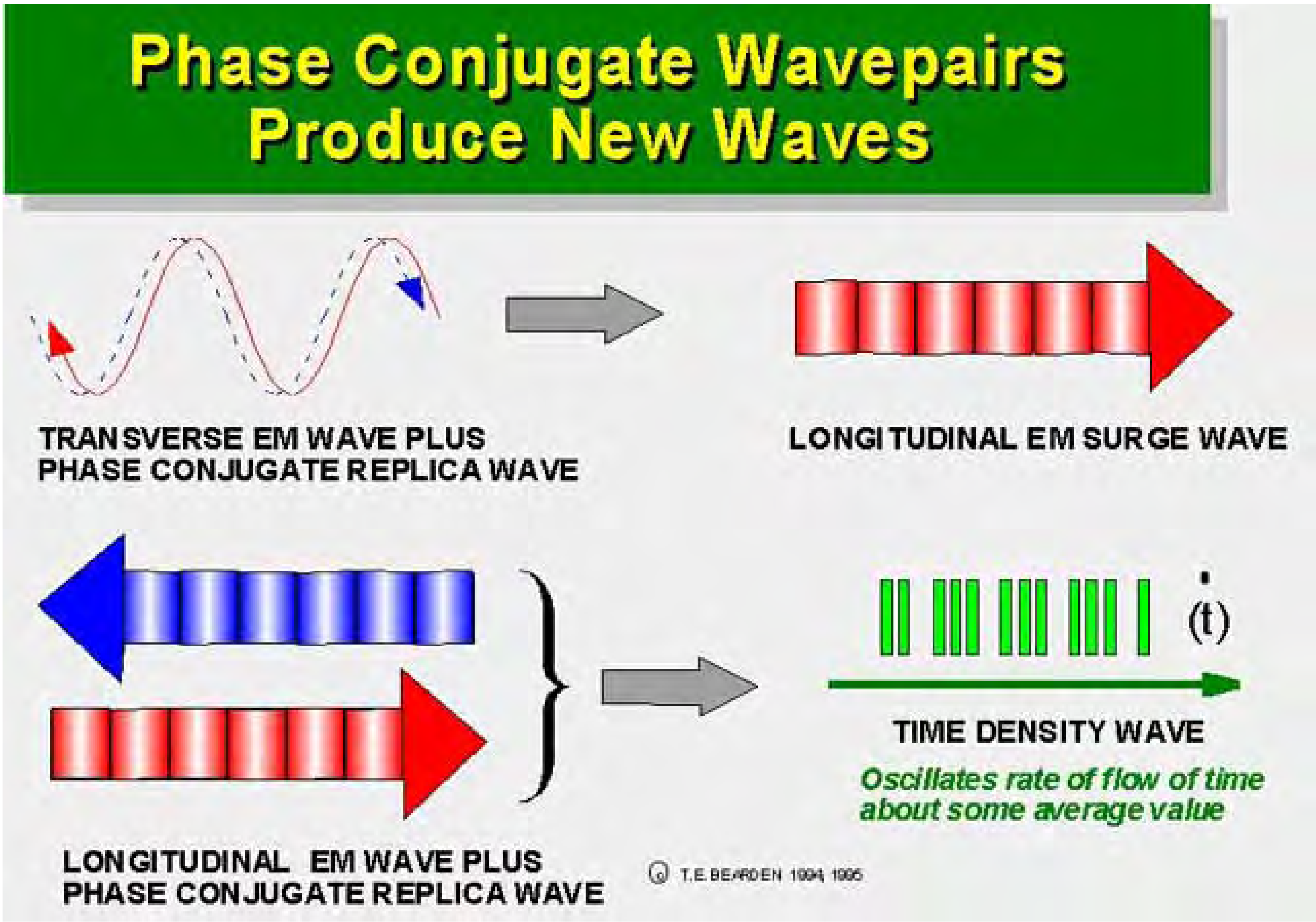

Phase Conjugate Wavepairs Produce New Waves

TRANSVERSE EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE

LONGITUDINAL EM SURGE WAVE

LONGITUDINAL EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE

$\dot{(t)}$

TIME DENSITY WAVE

*Oscillates rate of flow of time
about some average value*

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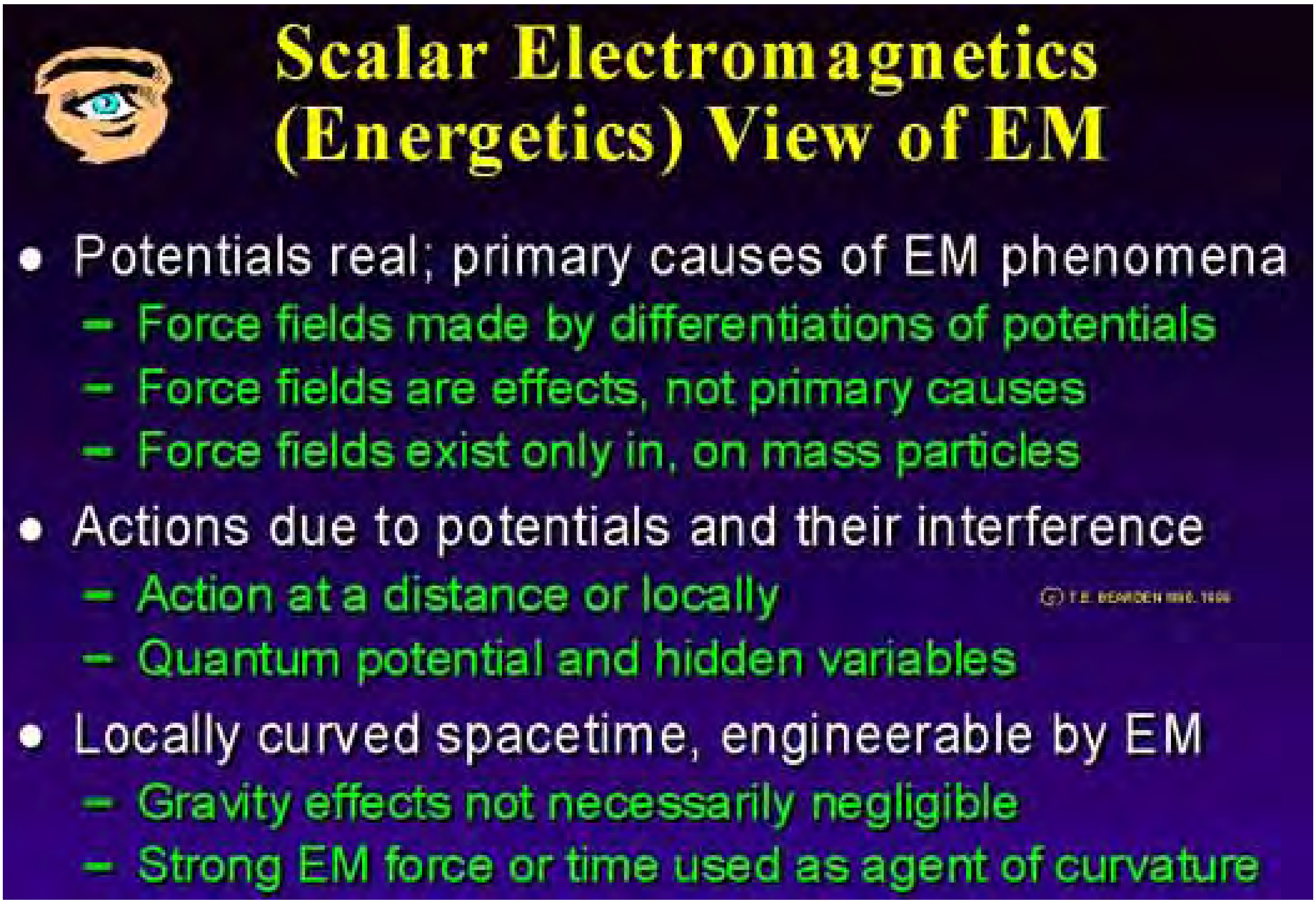

Scalar Electromagnetics (Energetics) View of EM

- Potentials real; primary causes of EM phenomena
  - Force fields made by differentiations of potentials
  - Force fields are effects, not primary causes
  - Force fields exist only in, on mass particles
- Actions due to potentials and their interference
  - Action at a distance or locally
  - Quantum potential and hidden variables
- Locally curved spacetime, engineerable by EM
  - Gravity effects not necessarily negligible
  - Strong EM force or time used as agent of curvature

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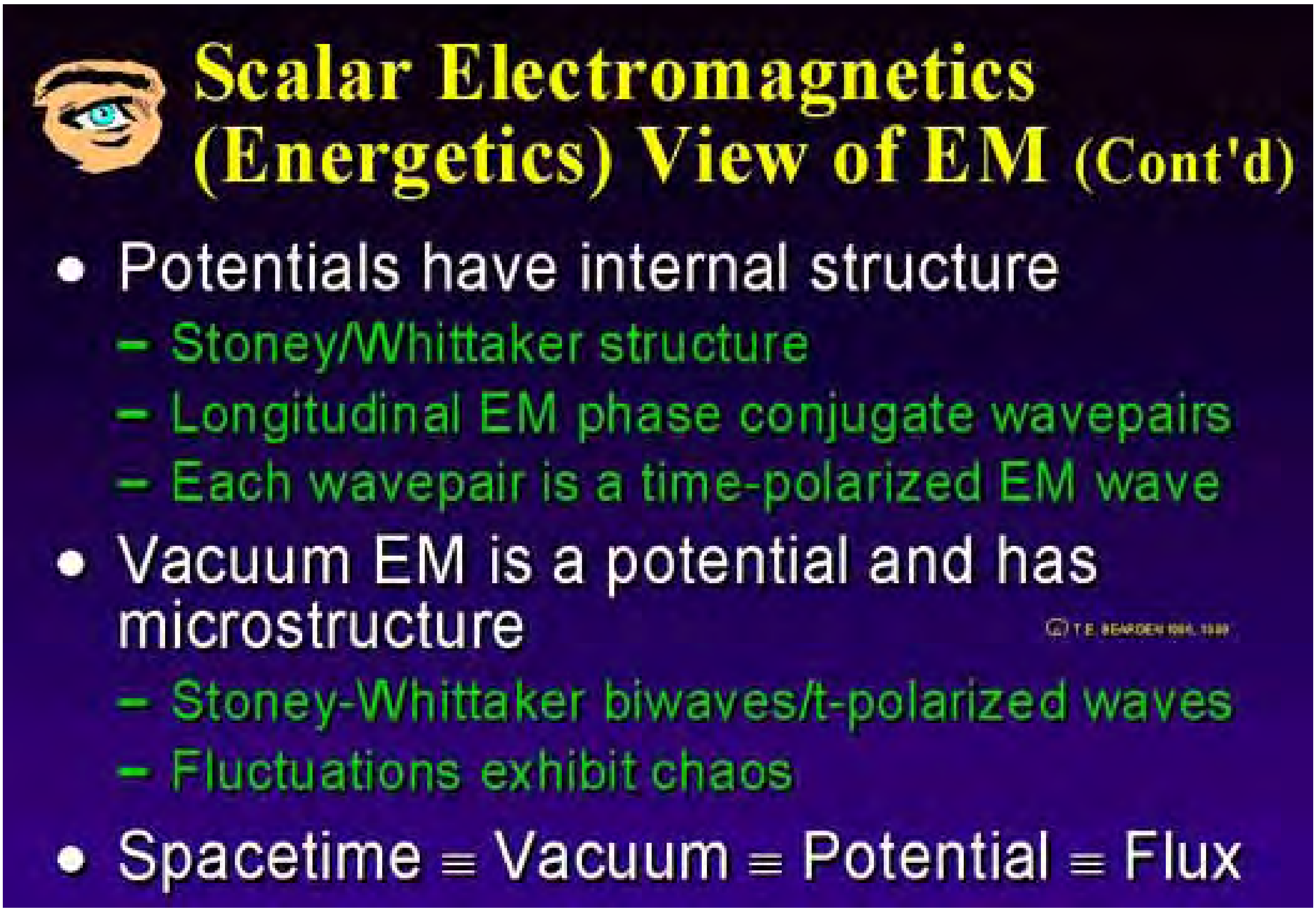

Scalar Electromagnetics (Energetics) View of EM (Cont'd)

- Potentials have internal structure
  - Stoney/Whittaker structure
  - Longitudinal EM phase conjugate wavepairs
  - Each wavepair is a time-polarized EM wave
- Vacuum EM is a potential and has microstructure
  - Stoney-Whittaker biwaves/t-polarized waves
  - Fluctuations exhibit chaos
- Spacetime ≡ Vacuum ≡ Potential ≡ Flux

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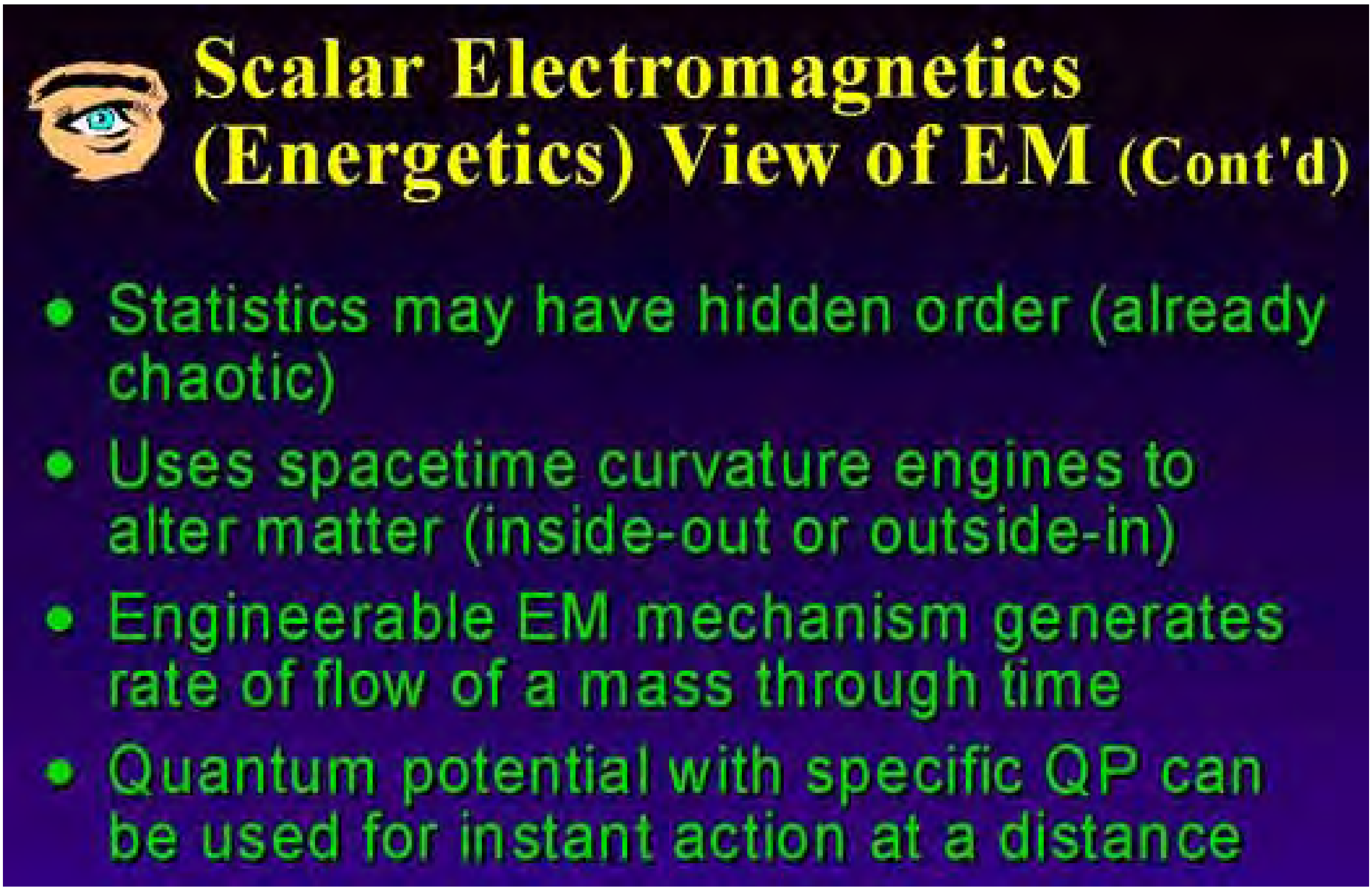

Scalar Electromagnetics (Energetics) View of EM (Cont'd)

- Statistics may have hidden order (already chaotic)
- Uses spacetime curvature engines to alter matter (inside-out or outside-in)
- Engineerable EM mechanism generates rate of flow of a mass through time
- Quantum potential with specific QP can be used for instant action at a distance

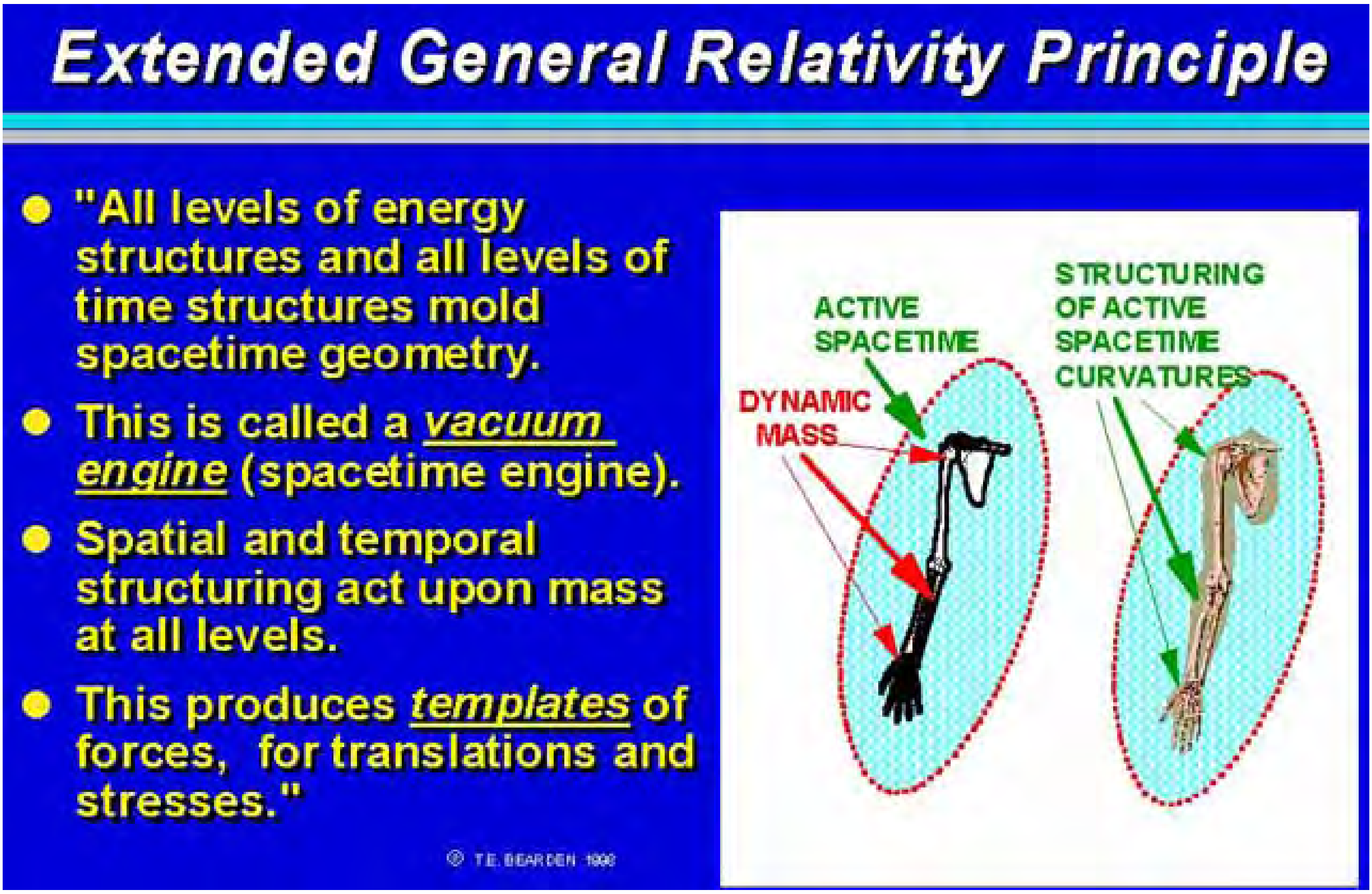

Extended General Relativity Principle

- "All levels of energy structures and all levels of time structures mold spacetime geometry.
- This is called a ***vacuum engine*** (spacetime engine).
- Spatial and temporal structuring act upon mass at all levels.
- This produces ***templates*** of forces, for translations and stresses."

ACTIVE SPACETIME
DYNAMIC MASS
STRUCTURING OF ACTIVE SPACETIME CURVATURES

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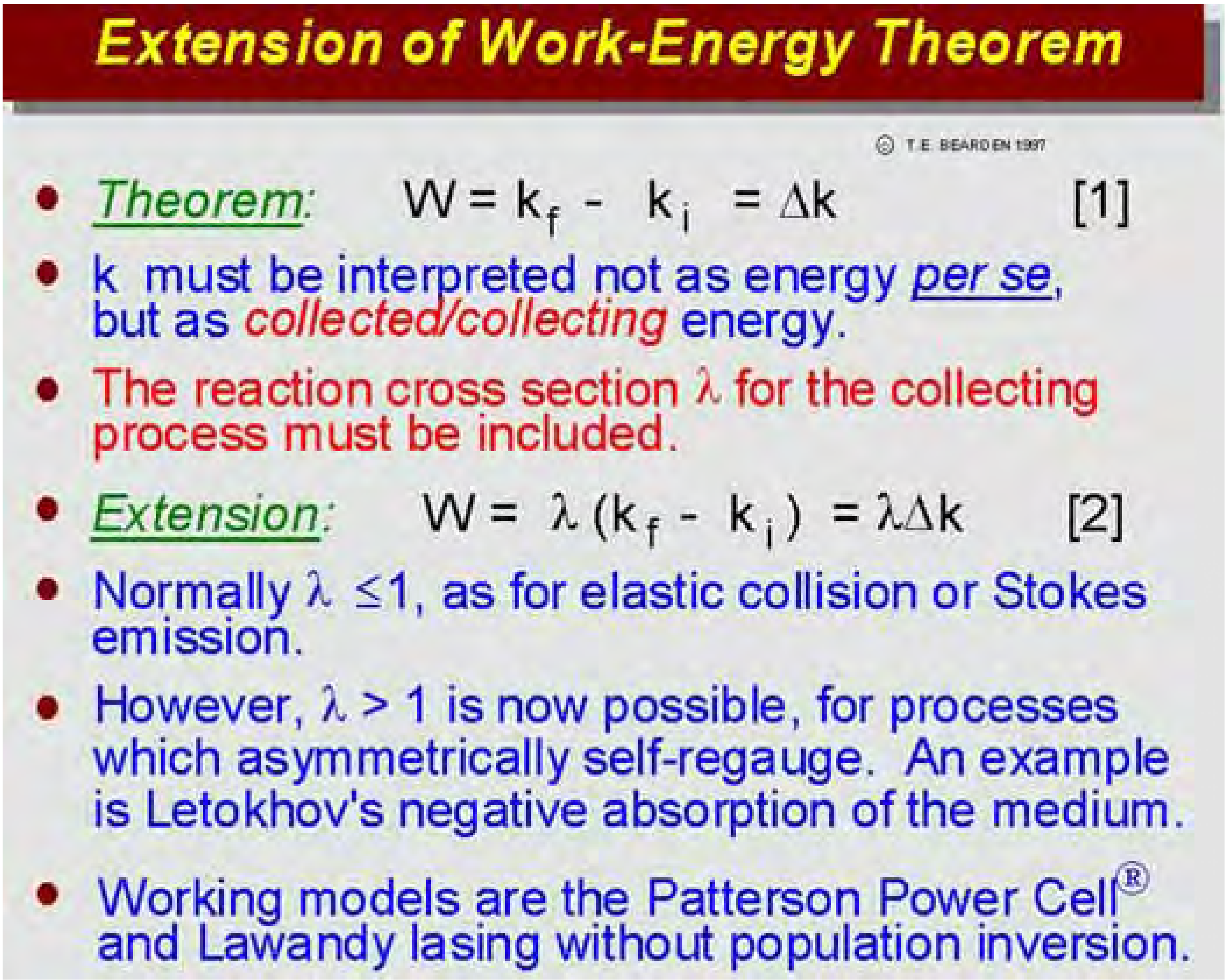

Extension of Work-Energy Theorem

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- *Theorem*: $W = k_f - k_i = \Delta k$ [1]
- k must be interpreted not as energy *per se*, but as *collected/collecting* energy.
- The reaction cross section λ for the collecting process must be included.
- *Extension*: $W = \lambda (k_f - k_i) = \lambda \Delta k$ [2]
- Normally $\lambda \leq 1$, as for elastic collision or Stokes emission.
- However, $\lambda > 1$ is now possible, for processes which asymmetrically self-regauge. An example is Letokhov's negative absorption of the medium.
- Working models are the Patterson Power Cell® and Lawandy lasing without population inversion.

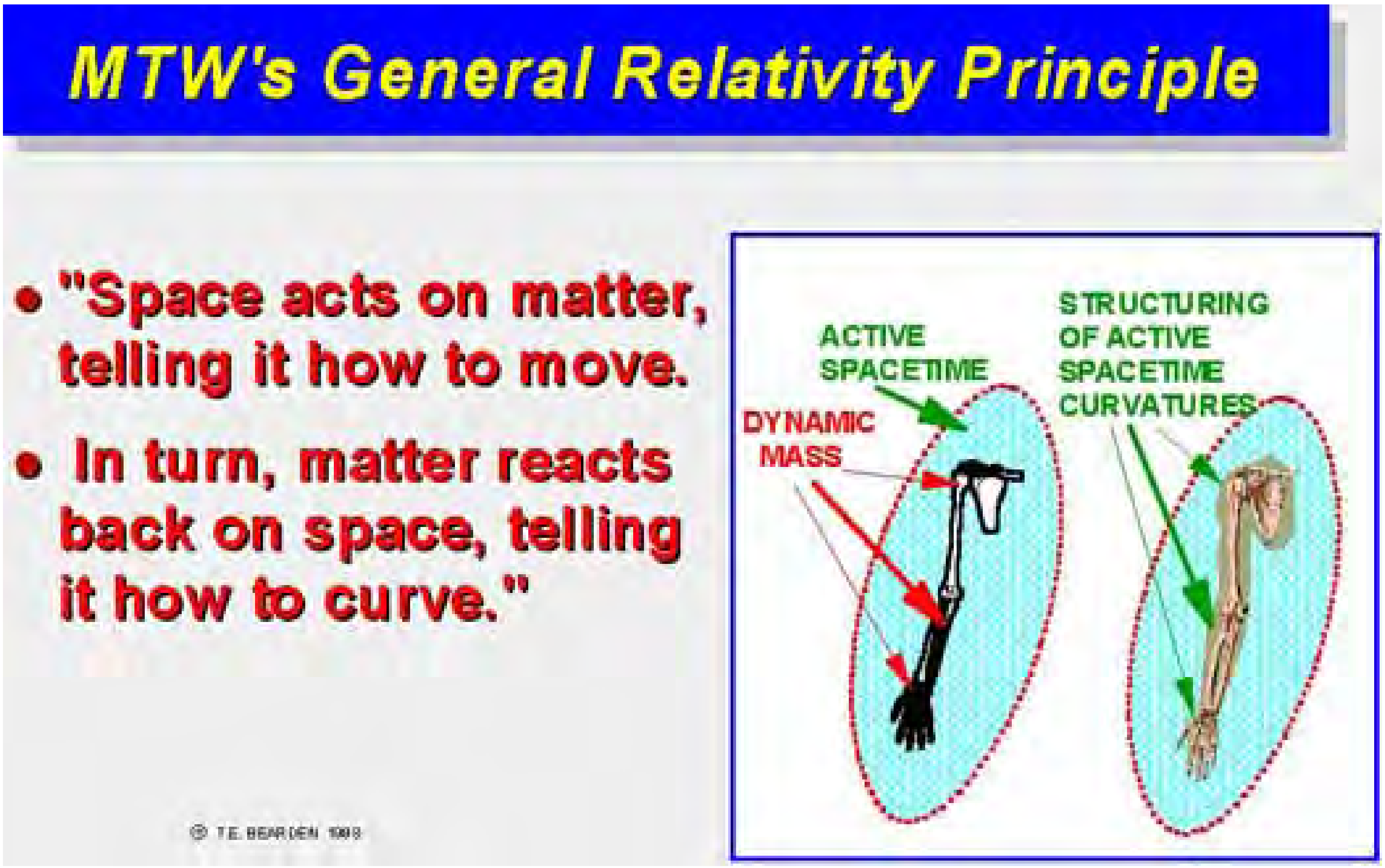

MTW's General Relativity Principle

- "Space acts on matter, telling it how to move.
- In turn, matter reacts back on space, telling it how to curve."

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ACTIVE SPACETIME
STRUCTURING OF ACTIVE SPACETIME CURVATURES
DYNAMIC MASS

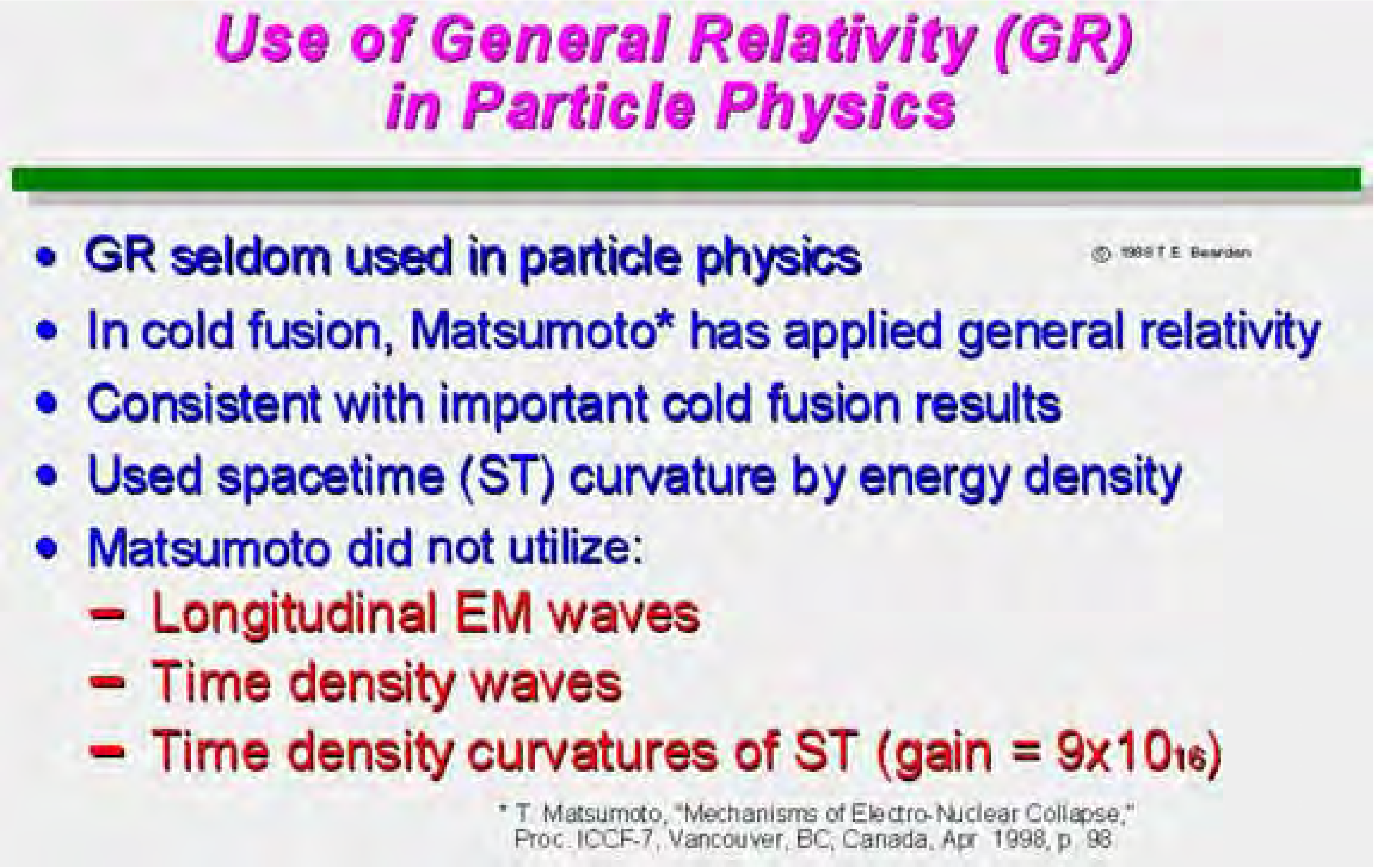

Use of General Relativity (GR) in Particle Physics

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- GR seldom used in particle physics
- In cold fusion, Matsumoto* has applied general relativity
- Consistent with important cold fusion results
- Used spacetime (ST) curvature by energy density
- Matsumoto did not utilize:
  - Longitudinal EM waves
  - Time density waves
  - Time density curvatures of ST (gain = 9x10^{16})

* T. Matsumoto, "Mechanisms of Electro-Nuclear Collapse," Proc. ICCF-7, Vancouver, BC, Canada, Apr 1998, p. 98

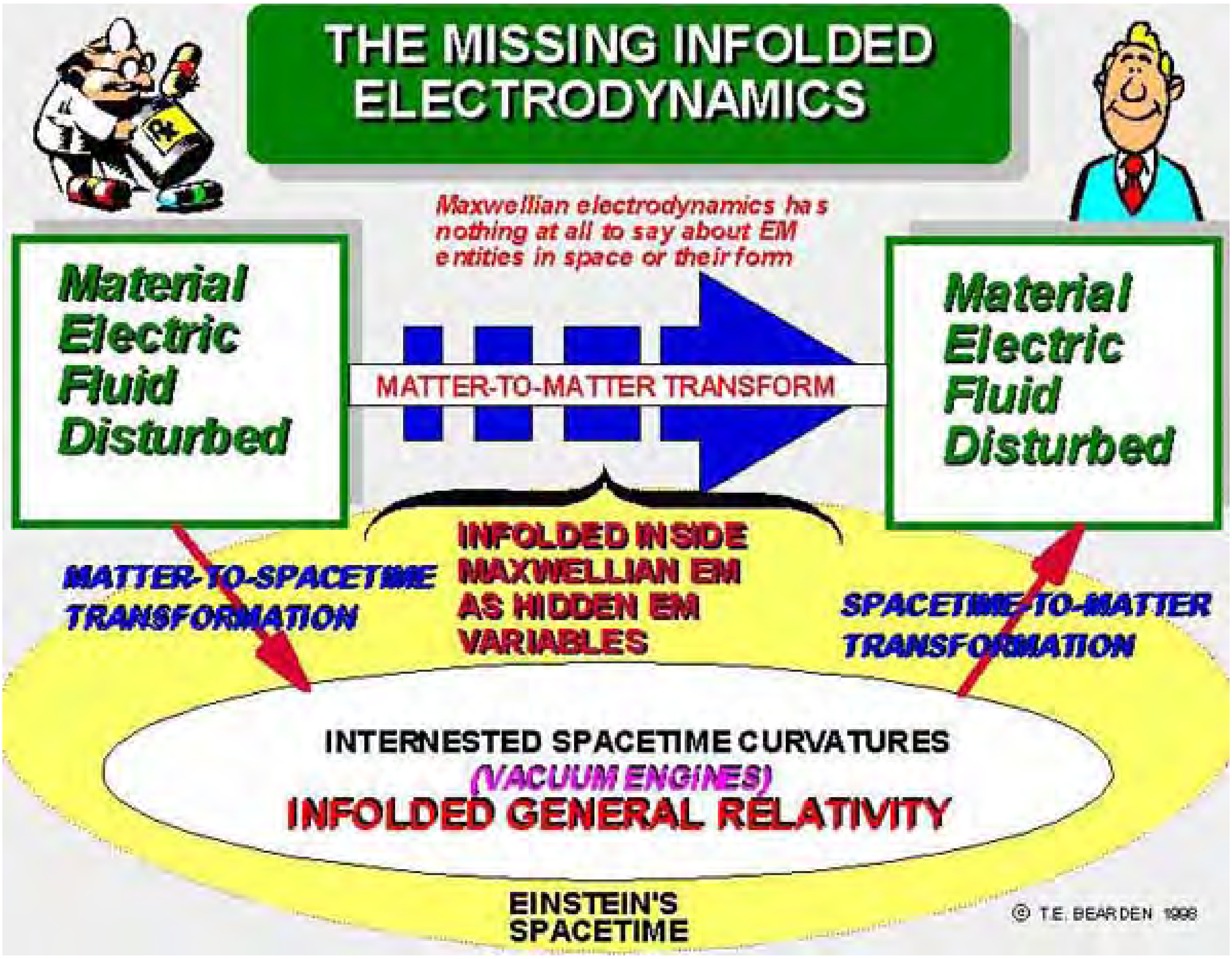

THE MISSING INFOLDED ELECTRODYNAMICS

Maxwellian electrodynamics has nothing at all to say about EM entities in space or their form

Material Electric Fluid Disturbed

MATTER-TO-MATTER TRANSFORM

Material Electric Fluid Disturbed

MATTER-TO-SPACETIME TRANSFORMATION

INFOLDED INSIDE MAXWELLIAN EM AS HIDDEN EM VARIABLES

SPACETIME-TO-MATTER TRANSFORMATION

INTERNESTED SPACETIME CURVATURES

(VACUUM ENGINES)

INFOLDED GENERAL RELATIVITY

EINSTEIN'S SPACETIME

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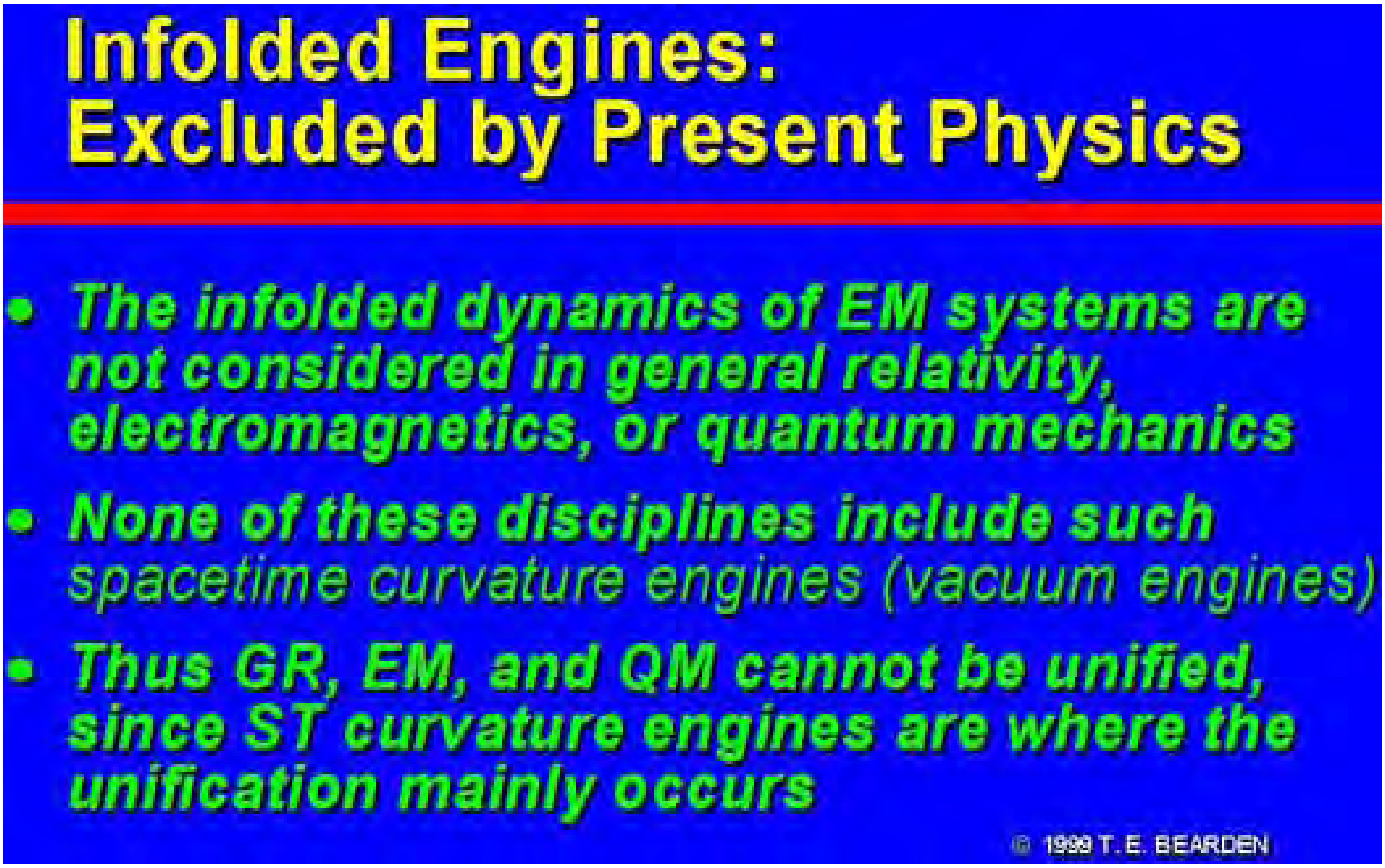

Infolded Engines: Excluded by Present Physics

- *The infolded dynamics of EM systems are not considered in general relativity, electromagnetics, or quantum mechanics*
- *None of these disciplines include such spacetime curvature engines (vacuum engines)*
- *Thus GR, EM, and QM cannot be unified, since ST curvature engines are where the unification mainly occurs*

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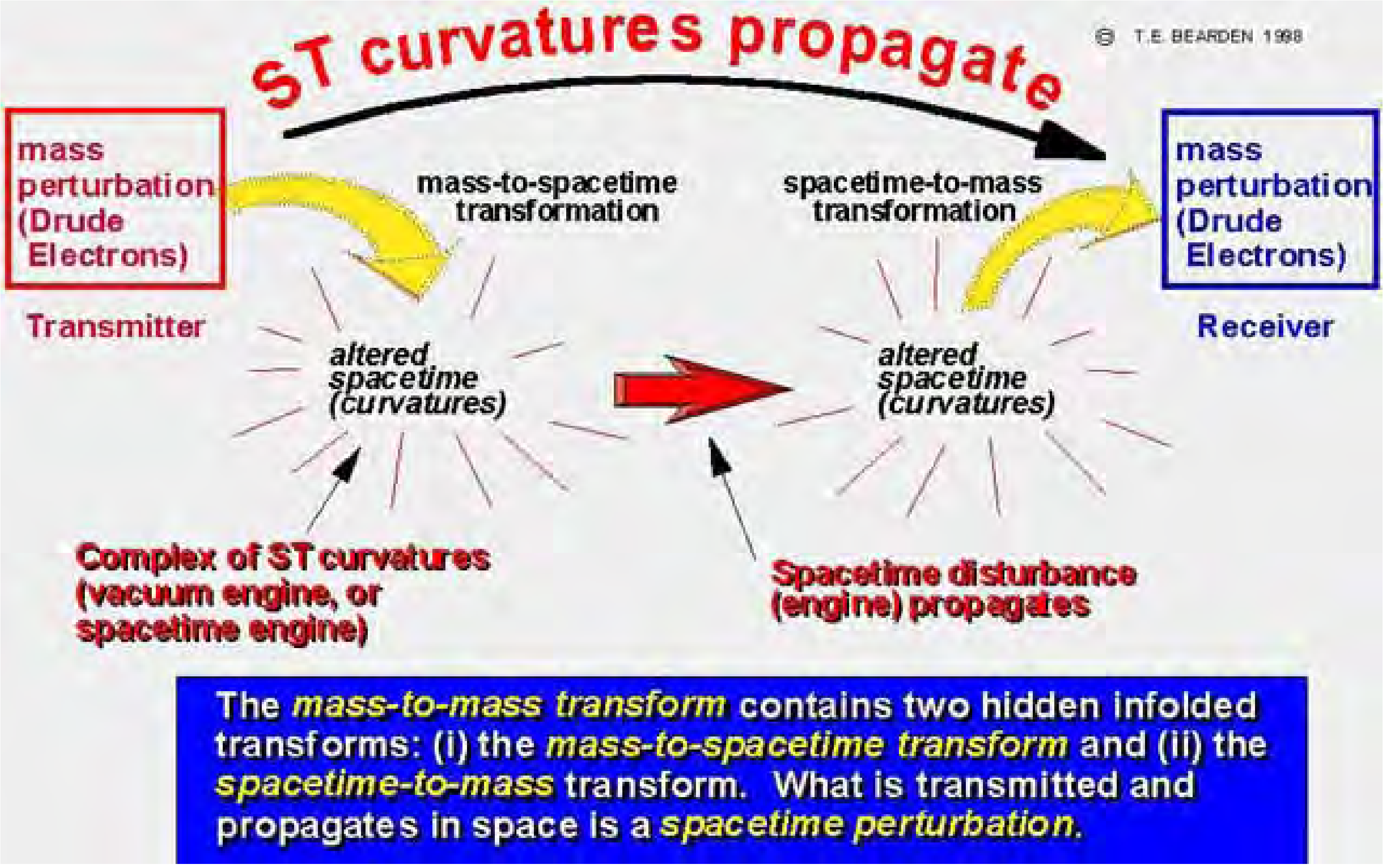

ST curvatures propagate

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mass perturbation (Drude Electrons)

Transmitter

mass-to-spacetime transformation

altered spacetime (curvatures)

Complex of ST curvatures (vacuum engine, or spacetime engine)

spacetime-to-mass transformation

altered spacetime (curvatures)

Spacetime disturbance (engine) propagates

mass perturbation (Drude Electrons)

Receiver

The *mass-to-mass transform* contains two hidden infolded transforms: (i) the *mass-to-spacetime transform* and (ii) the *spacetime-to-mass* transform. What is transmitted and propagates in space is a *spacetime perturbation*.

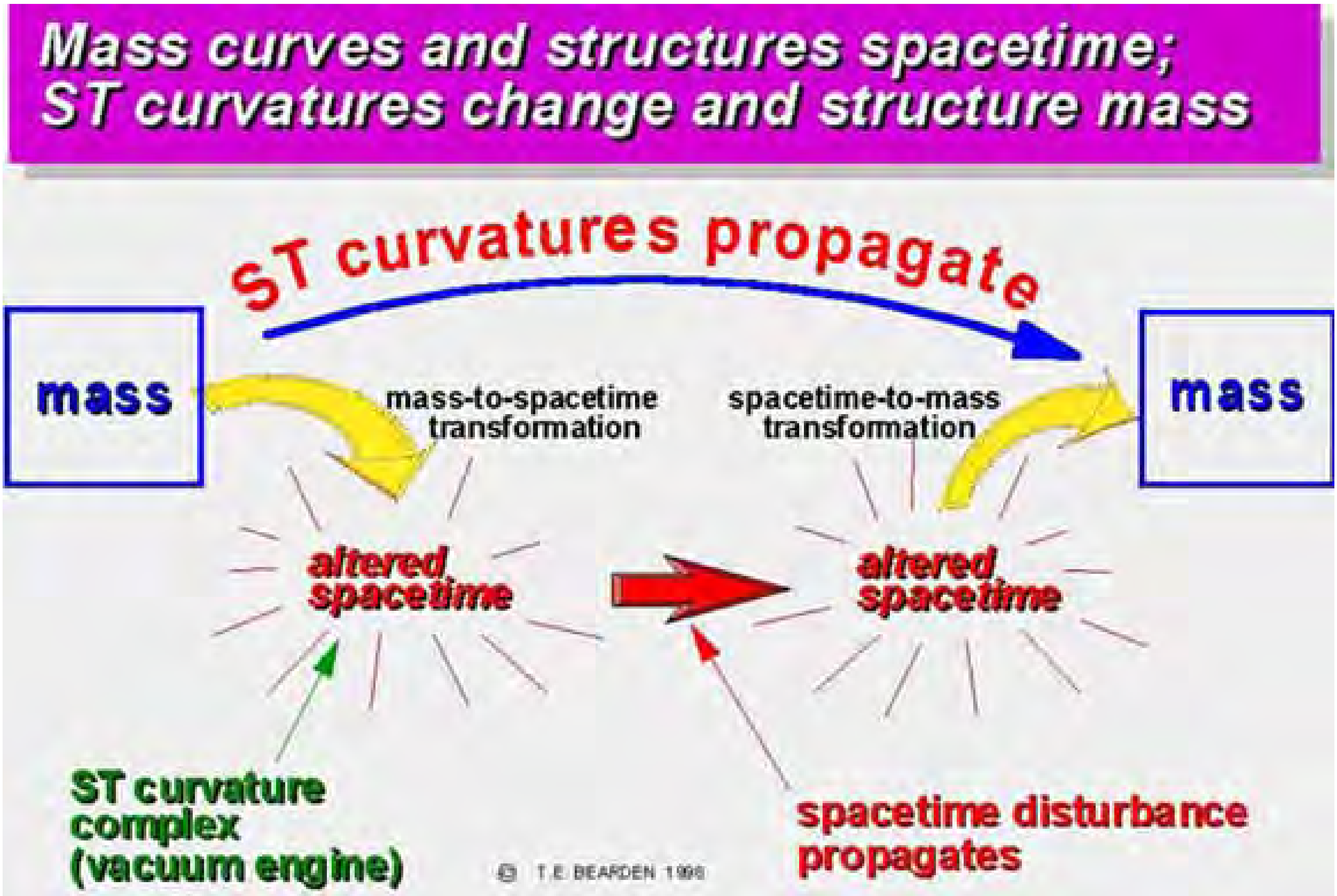

Mass curves and structures spacetime; ST curvatures change and structure mass

ST curvatures propagate

mass

mass-to-spacetime transformation

spacetime-to-mass transformation

mass

altered spacetime

altered spacetime

ST curvature complex (vacuum engine)

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spacetime disturbance propagates

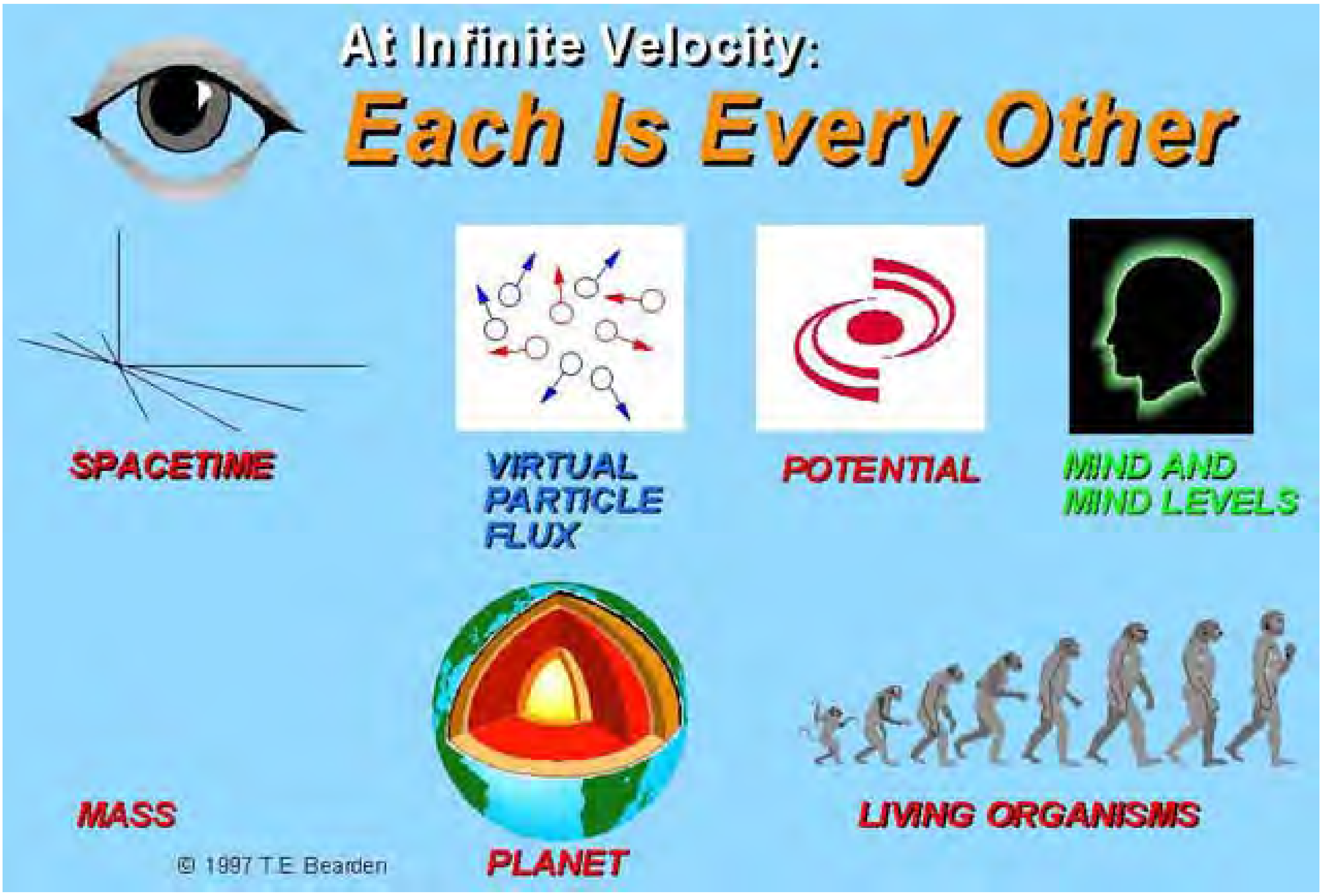

At Infinite Velocity:

Each Is Every Other

SPACETIME

VIRTUAL PARTICLE FLUX

POTENTIAL

MIND AND MIND LEVELS

MASS

PLANET

LIVING ORGANISMS

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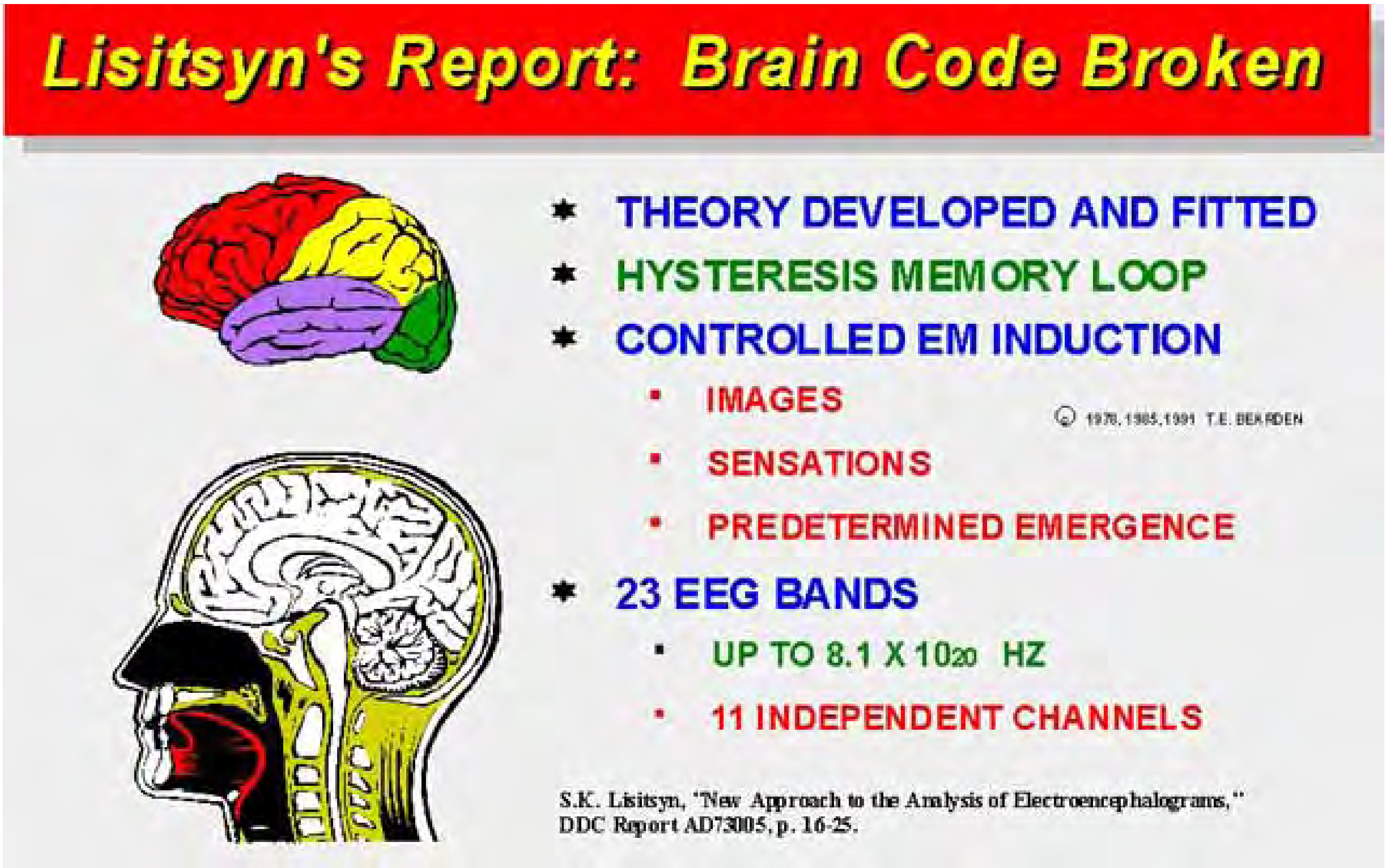

Lisitsyn's Report: Brain Code Broken

- THEORY DEVELOPED AND FITTED
- HYSTERESIS MEMORY LOOP
- CONTROLLED EM INDUCTION
  - IMAGES
  - SENSATIONS
  - PREDETERMINED EMERGENCE
- 23 EEG BANDS
  - UP TO 8.1 X 10^{20} HZ
  - 11 INDEPENDENT CHANNELS

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S.K. Lisitsyn, "New Approach to the Analysis of Electroencephalograms," DDC Report AD73005, p. 16-25.

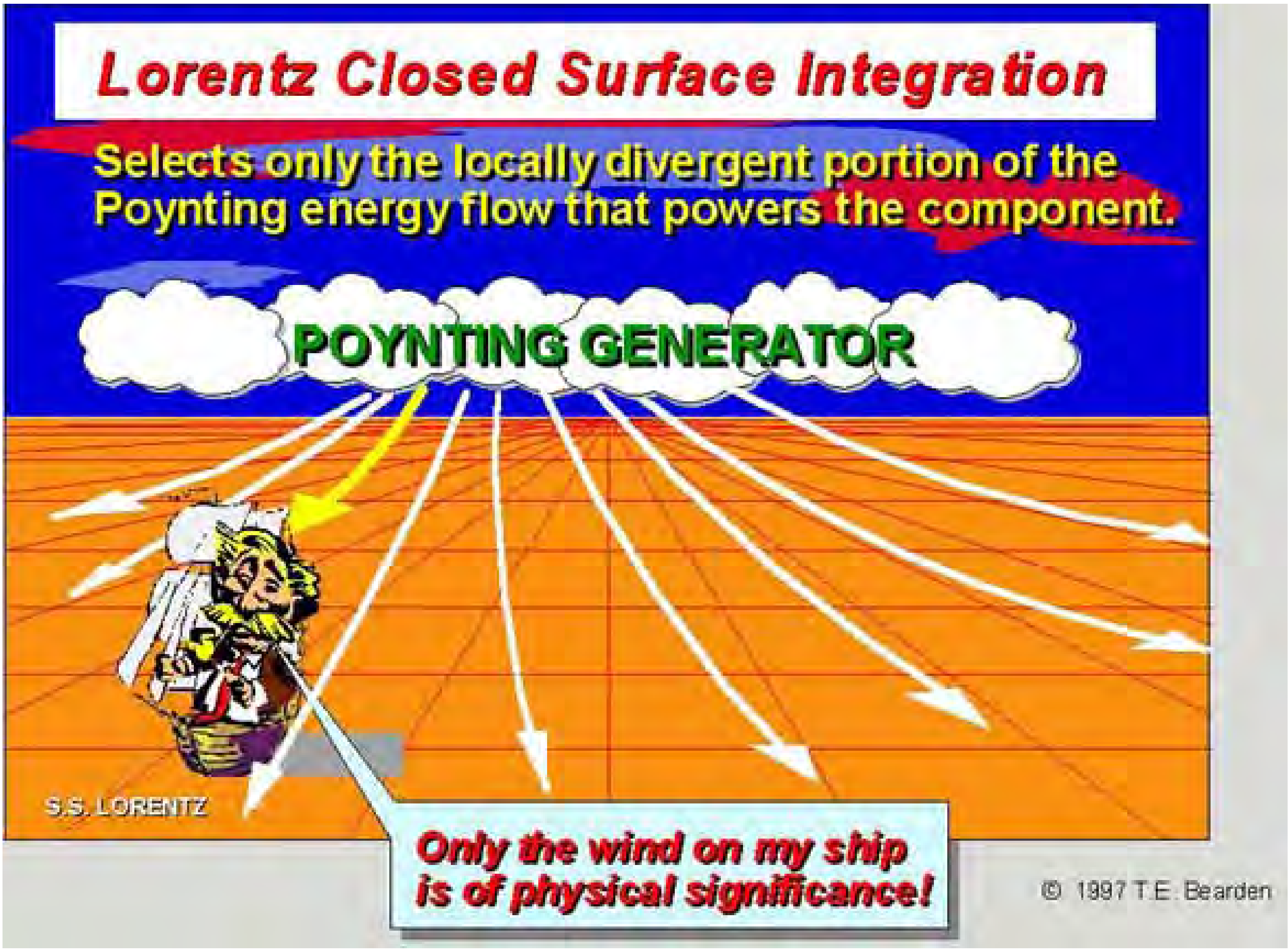

Lorentz Closed Surface Integration

Selects only the locally divergent portion of the Poynting energy flow that powers the component.

Only the wind on my ship is of physical significance!

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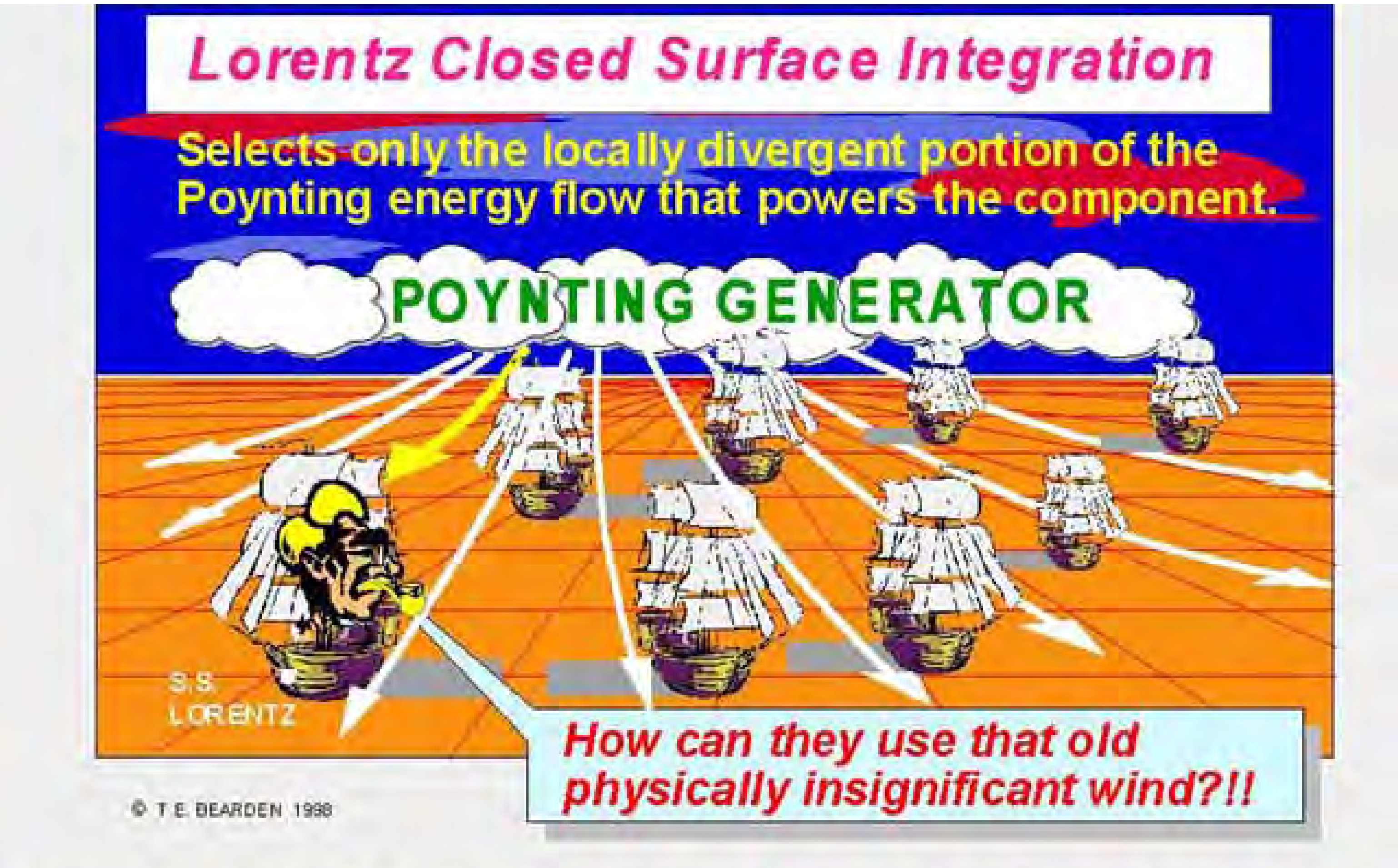

Lorentz Closed Surface Integration

Selects only the locally divergent portion of the Poynting energy flow that powers the component.

How can they use that old physically insignificant wind?!!

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Lorentz's physically insignificant energy flow can be collected and utilized.

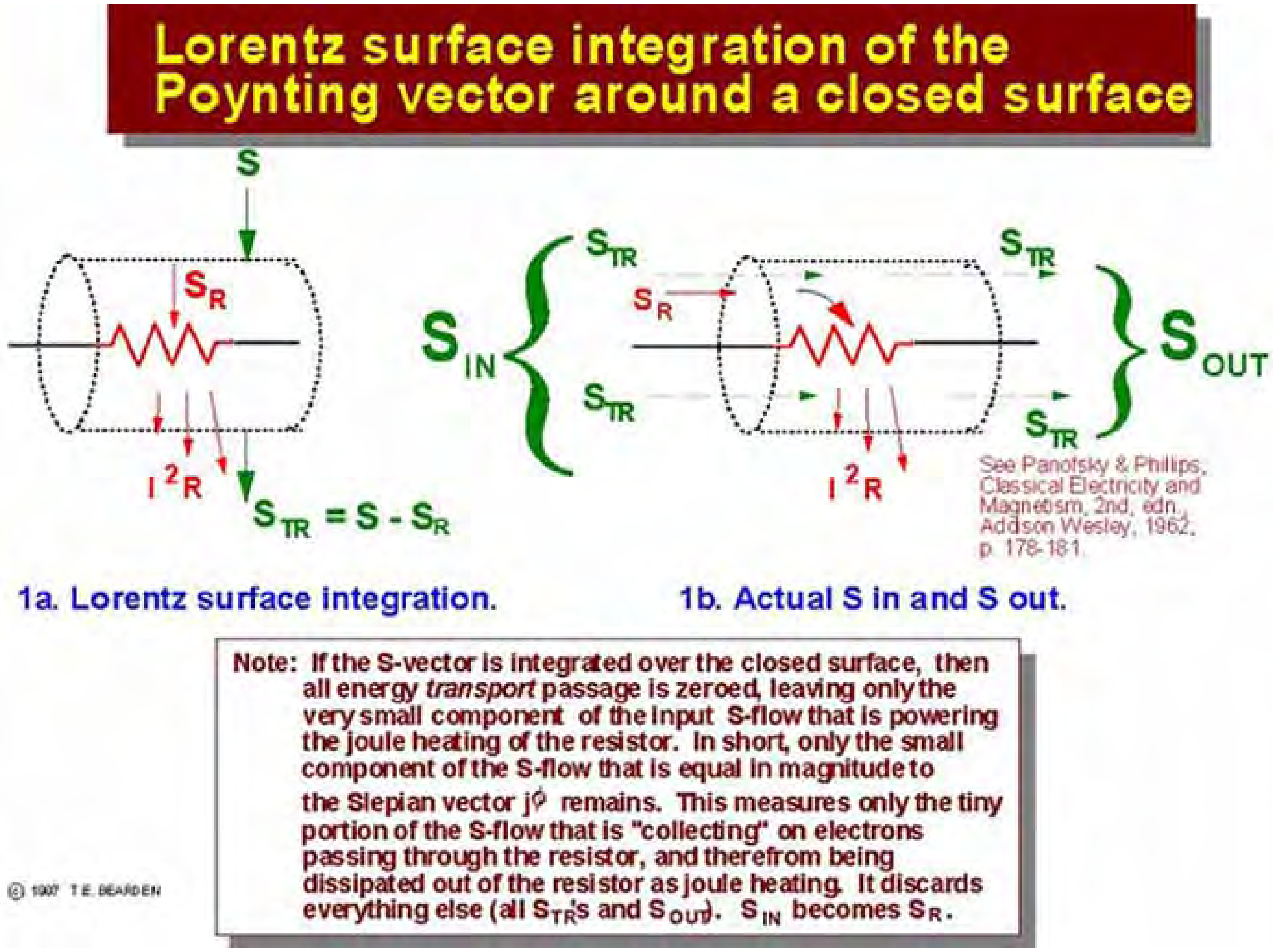

Lorentz surface integration of the Poynting vector around a closed surface

See Panofsky & Phillips, Classical Electricity and Magnetism, 2nd, edn., Addison Wesley, 1962, p. 178-181.

1a. Lorentz surface integration.

1b. Actual S in and S out.

Note: If the S-vector is integrated over the closed surface, then all energy *transport* passage is zeroed, leaving only the very small component of the input S-flow that is powering the joule heating of the resistor. In short, only the small component of the S-flow that is equal in magnitude to the Slepian vector $j\phi$ remains. This measures only the tiny portion of the S-flow that is "collecting" on electrons passing through the resistor, and therefrom being dissipated out of the resistor as joule heating. It discards everything else (all S_{TR}'s and S_{OUT}). S_{IN} becomes S_R.

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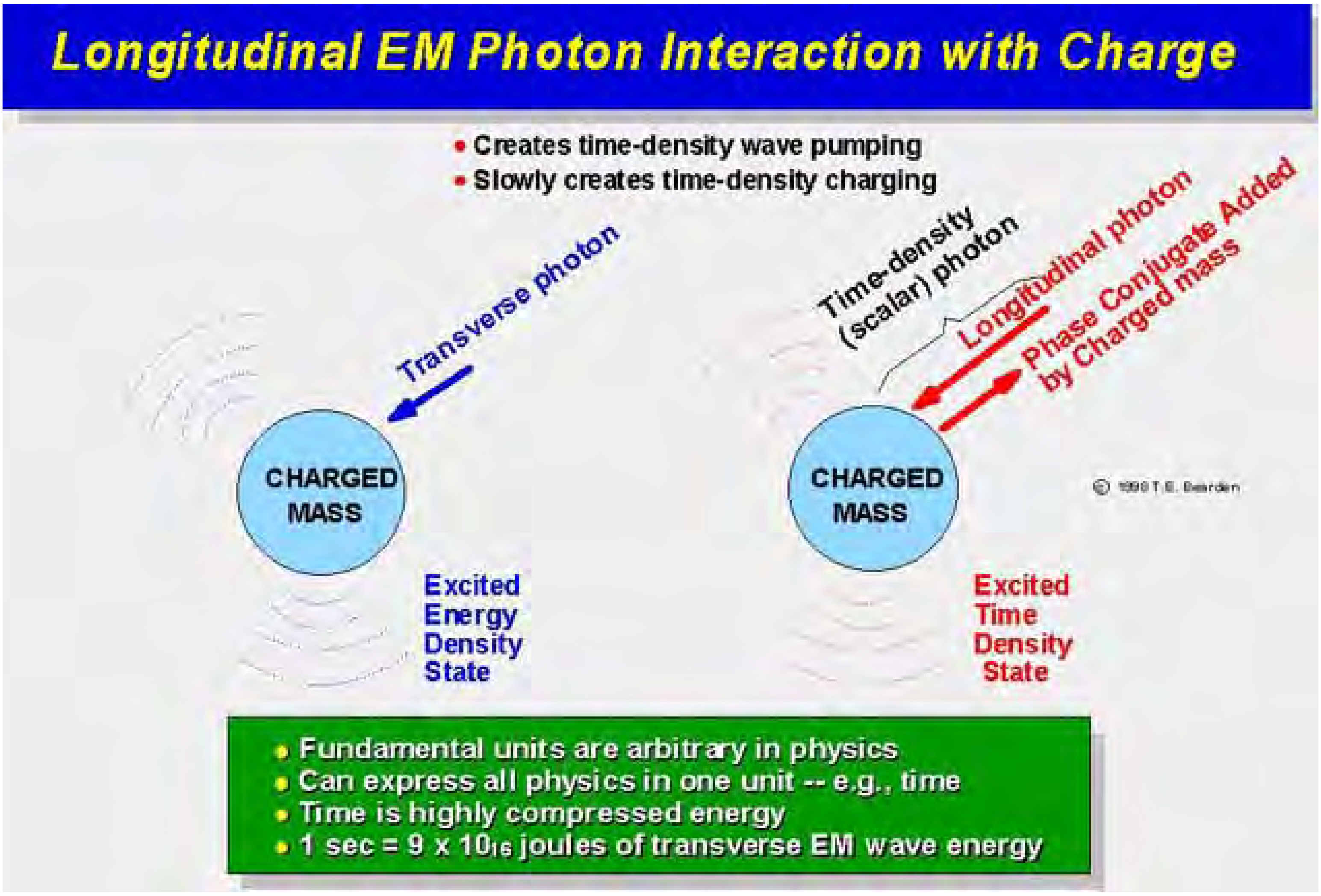

Longitudinal EM Photon Interaction with Charge

- Creates time-density wave pumping
- Slowly creates time-density charging

Transverse photon
CHARGED MASS
Excited Energy Density State
Time-density (scalar) photon
Longitudinal photon
Phase Conjugate Added by Charged mass
CHARGED MASS
Excited Time Density State

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- Fundamental units are arbitrary in physics
- Can express all physics in one unit -- e.g., time
- Time is highly compressed energy
- 1 sec = 9 x 10^{16} joules of transverse EM wave energy

Figure 1-8. Infolded biwave composition of a scalar potential.

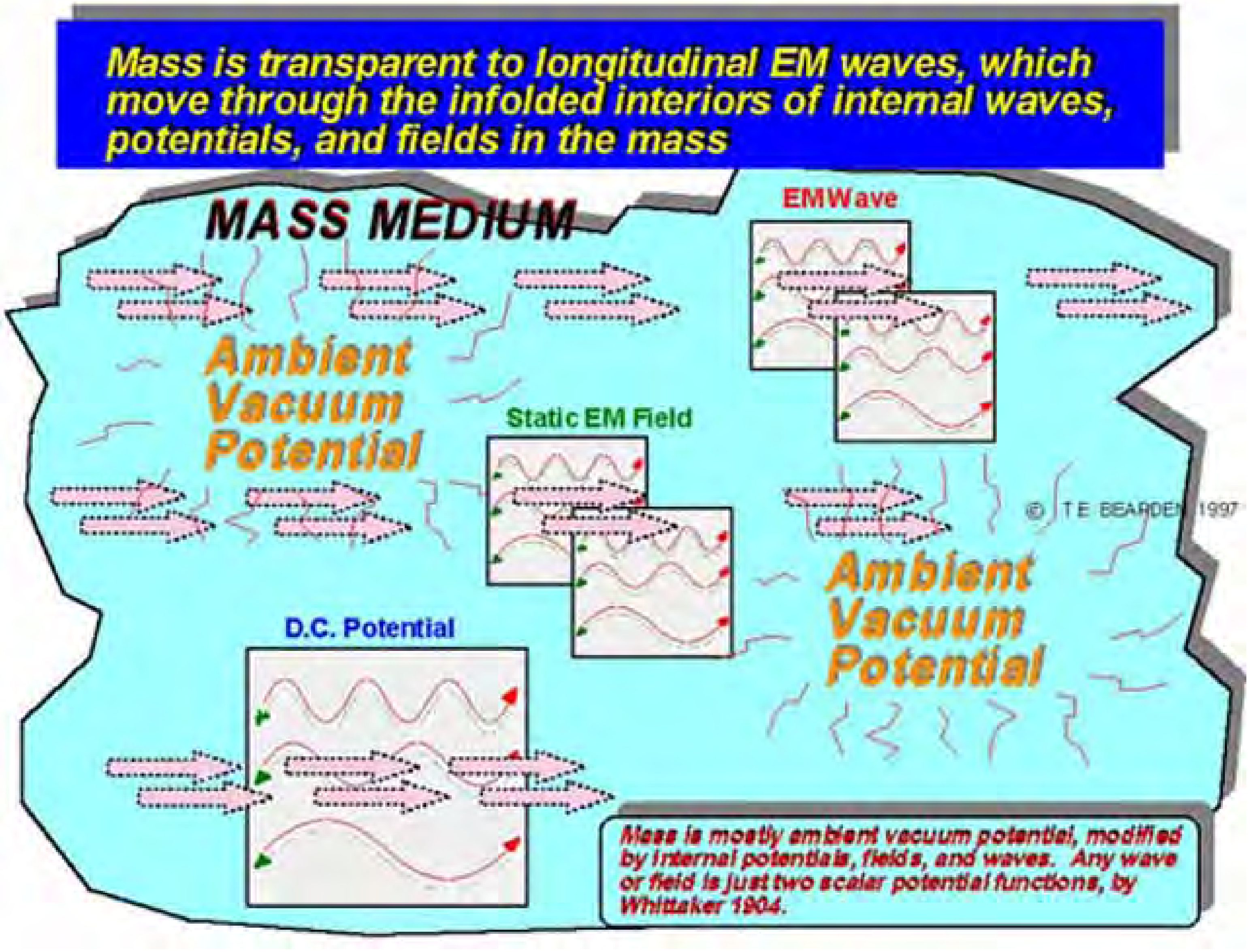

Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass

MASS MEDIUM
Ambient Vacuum Potential
EMWave
Static EM Field
© T.E. BEARDEN 1997
Ambient Vacuum Potential
D.C. Potential

Mass is mostly ambient vacuum potential, modified by internal potentials, fields, and waves. Any wave or field is just two scalar potential functions, by Whittaker 1904.

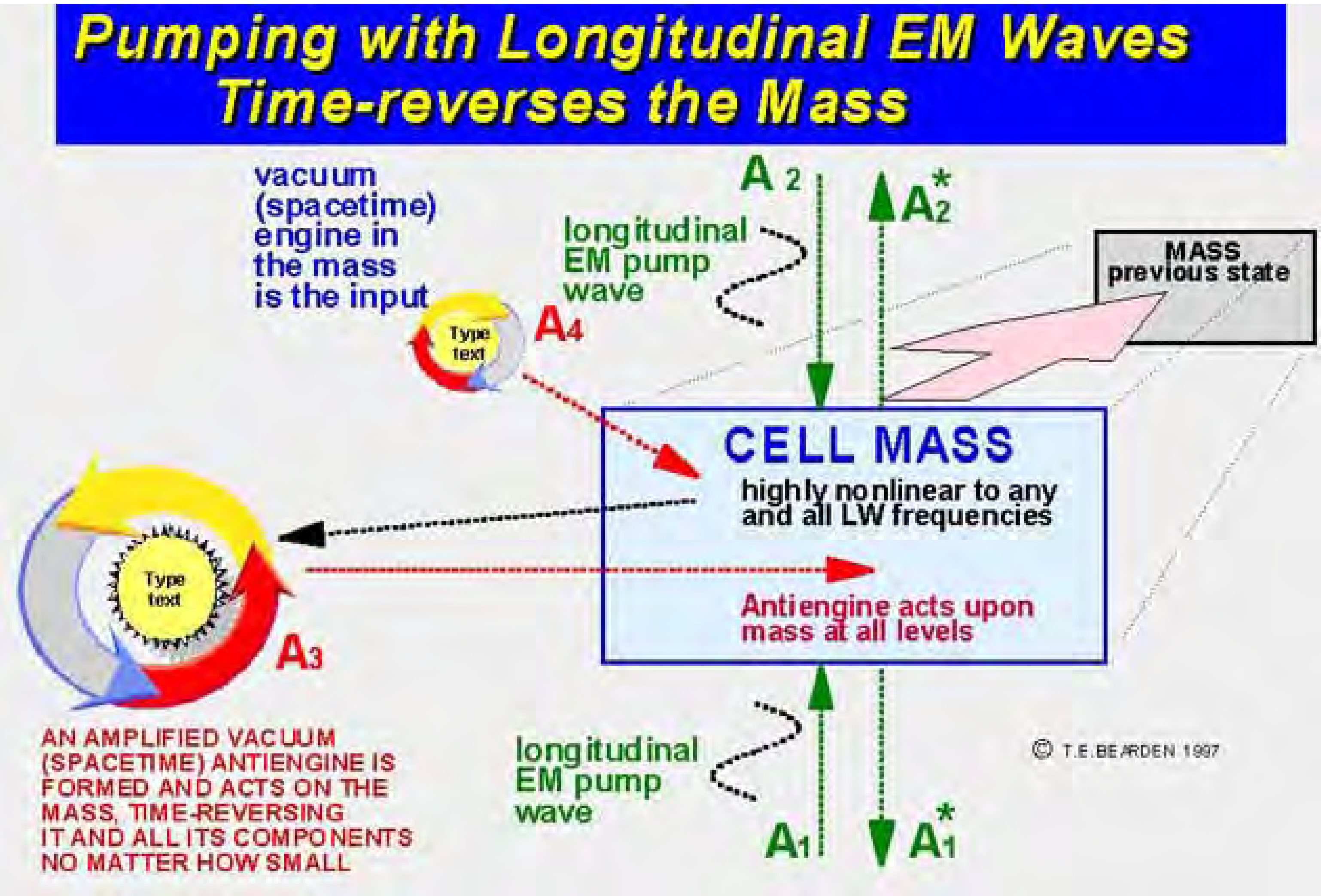

Pumping with Longitudinal EM Waves Time-reverses the Mass

vacuum (spacetime) engine in the mass is the input

longitudinal EM pump wave

MASS previous state

CELL MASS

highly nonlinear to any and all LW frequencies

Antiengine acts upon mass at all levels

AN AMPLIFIED VACUUM (SPACETIME) ANTIENGINE IS FORMED AND ACTS ON THE MASS, TIME-REVERSING IT AND ALL ITS COMPONENTS NO MATTER HOW SMALL

longitudinal EM pump wave

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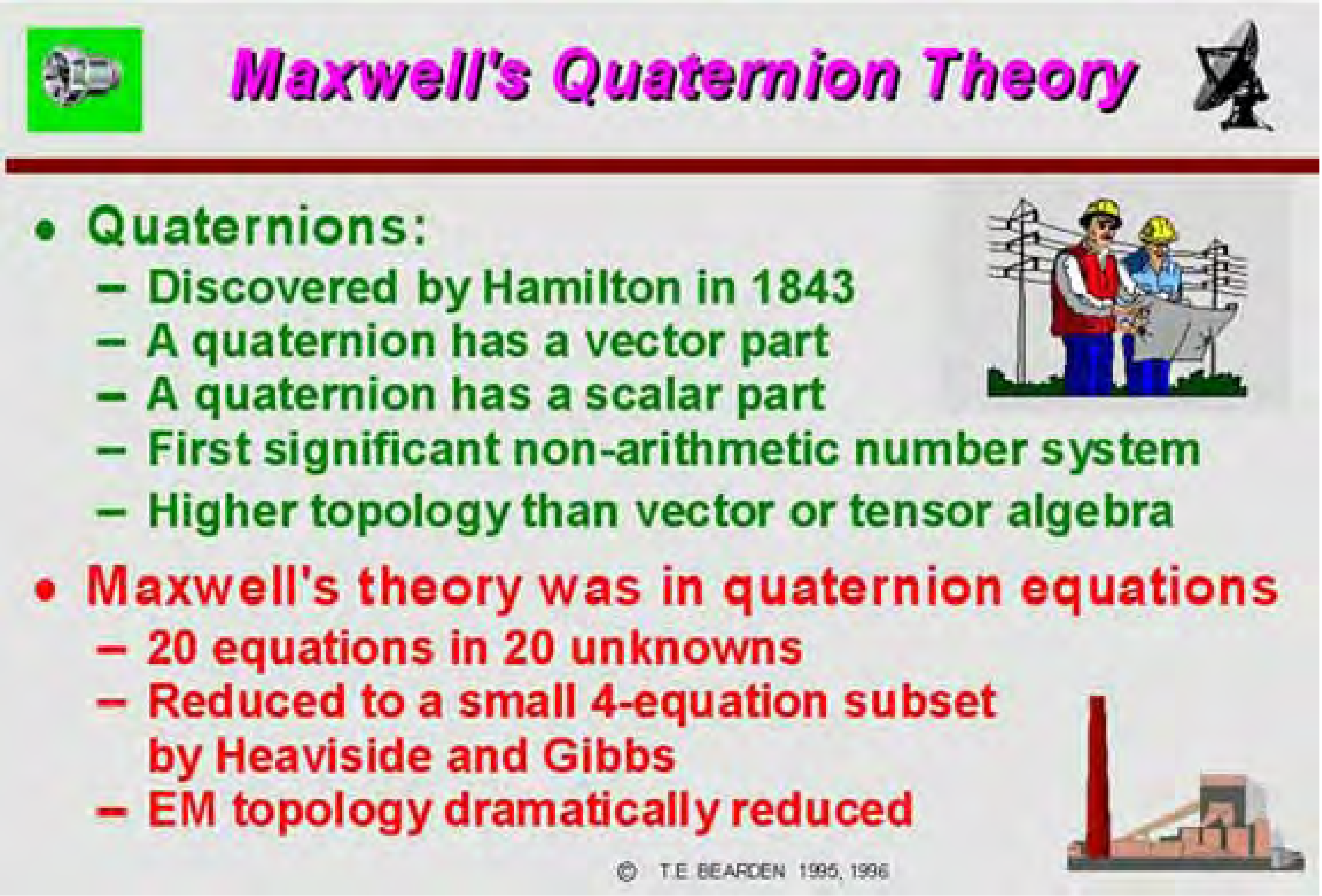

Maxwell's Quaternion Theory

- Quaternions:
  - Discovered by Hamilton in 1843
  - A quaternion has a vector part
  - A quaternion has a scalar part
  - First significant non-arithmetic number system
  - Higher topology than vector or tensor algebra
- Maxwell's theory was in quaternion equations
  - 20 equations in 20 unknowns
  - Reduced to a small 4-equation subset by Heaviside and Gibbs
  - EM topology dramatically reduced

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Maxwellian Systems
Before regauging, after symmetrical regauging, and after asymmetrical regauging

Note: Any system must first break equilibrium in its vacuum exchange, before it can energize Drude electrons and "power" the load. Asymmetric regauging is always utilized. Powering loads and losses is a symmetry-restoring operation.

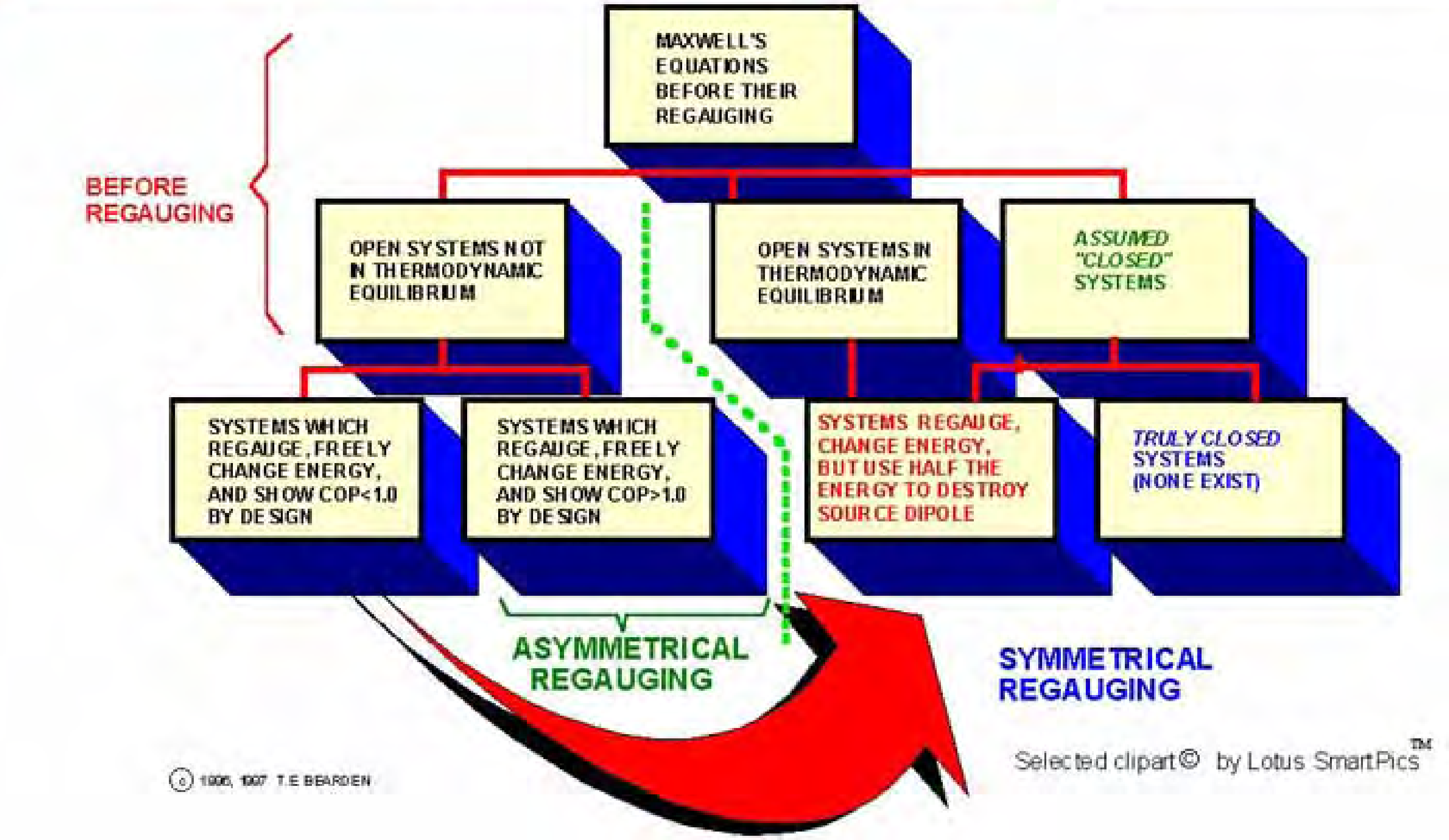

BEFORE REGAUGING

MAXWELL'S EQUATIONS BEFORE THEIR REGAUGING

OPEN SYSTEMS NOT IN THERMODYNAMIC EQUILIBRIUM

OPEN SYSTEMS IN THERMODYNAMIC EQUILIBRIUM

ASSUMED "CLOSED" SYSTEMS

SYSTEMS WHICH REGAUGE, FREELY CHANGE ENERGY, AND SHOW COP<1.0 BY DESIGN

SYSTEMS WHICH REGAUGE, FREELY CHANGE ENERGY, AND SHOW COP>1.0 BY DESIGN

SYSTEMS REGAUGE, CHANGE ENERGY, BUT USE HALF THE ENERGY TO DESTROY SOURCE DIPOLE

TRULY CLOSED SYSTEMS (NONE EXIST)

ASYMMETRICAL REGAUGING

SYMMETRICAL REGAUGING

Selected clipart© by Lotus SmartPics™

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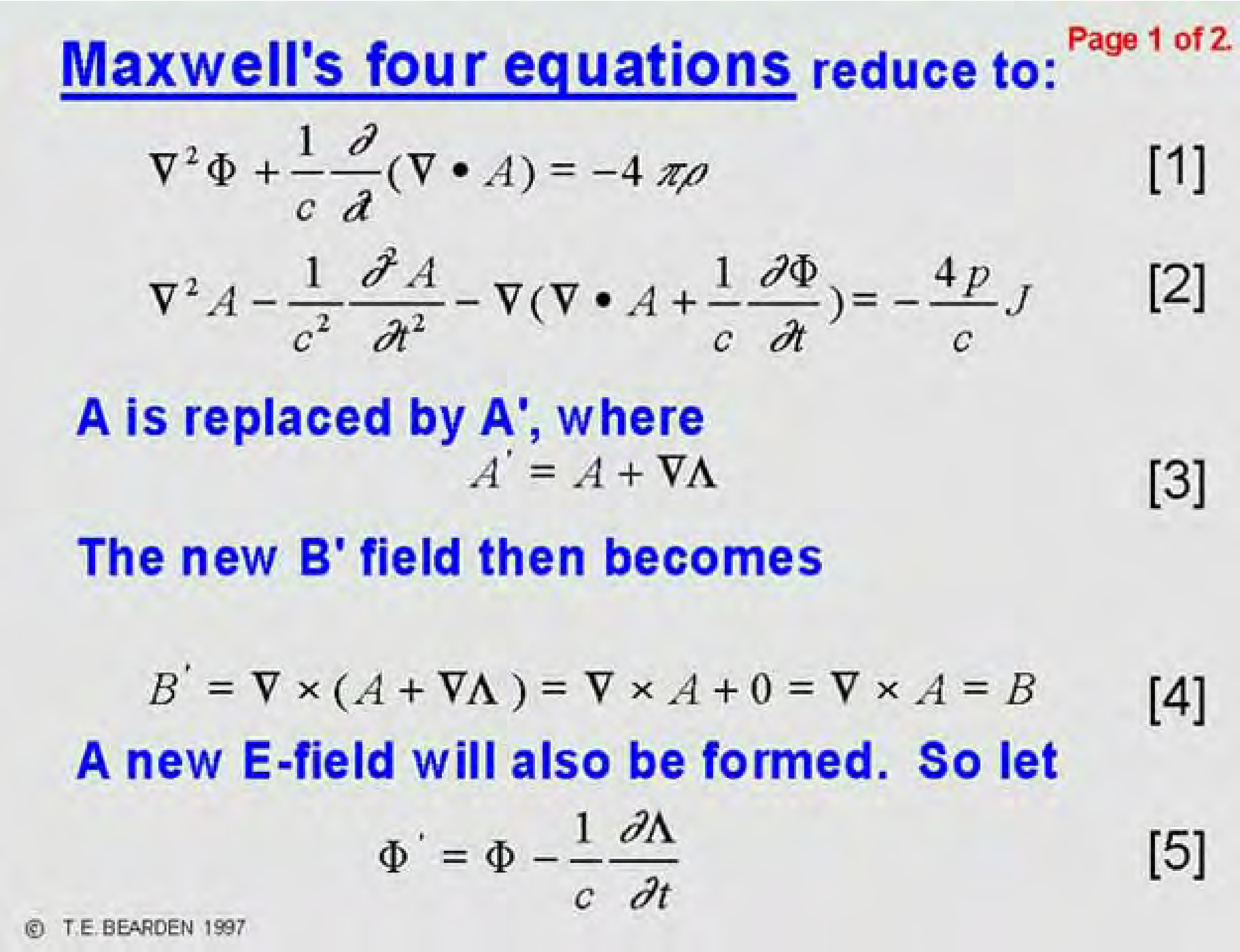

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Maxwell's four equations reduce to:

$$\nabla^2 \Phi + \frac{1}{c}\frac{\partial}{\partial t}(\nabla \bullet A) = -4\pi\rho \qquad [1]$$

$$\nabla^2 A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} - \nabla(\nabla \bullet A + \frac{1}{c}\frac{\partial \Phi}{\partial t}) = -\frac{4p}{c}J \qquad [2]$$

A is replaced by A', where

$$A' = A + \nabla\Lambda \qquad [3]$$

The new B' field then becomes

$$B' = \nabla \times (A + \nabla\Lambda) = \nabla \times A + 0 = \nabla \times A = B \qquad [4]$$

A new E-field will also be formed. So let

$$\Phi' = \Phi - \frac{1}{c}\frac{\partial\Lambda}{\partial t} \qquad [5]$$

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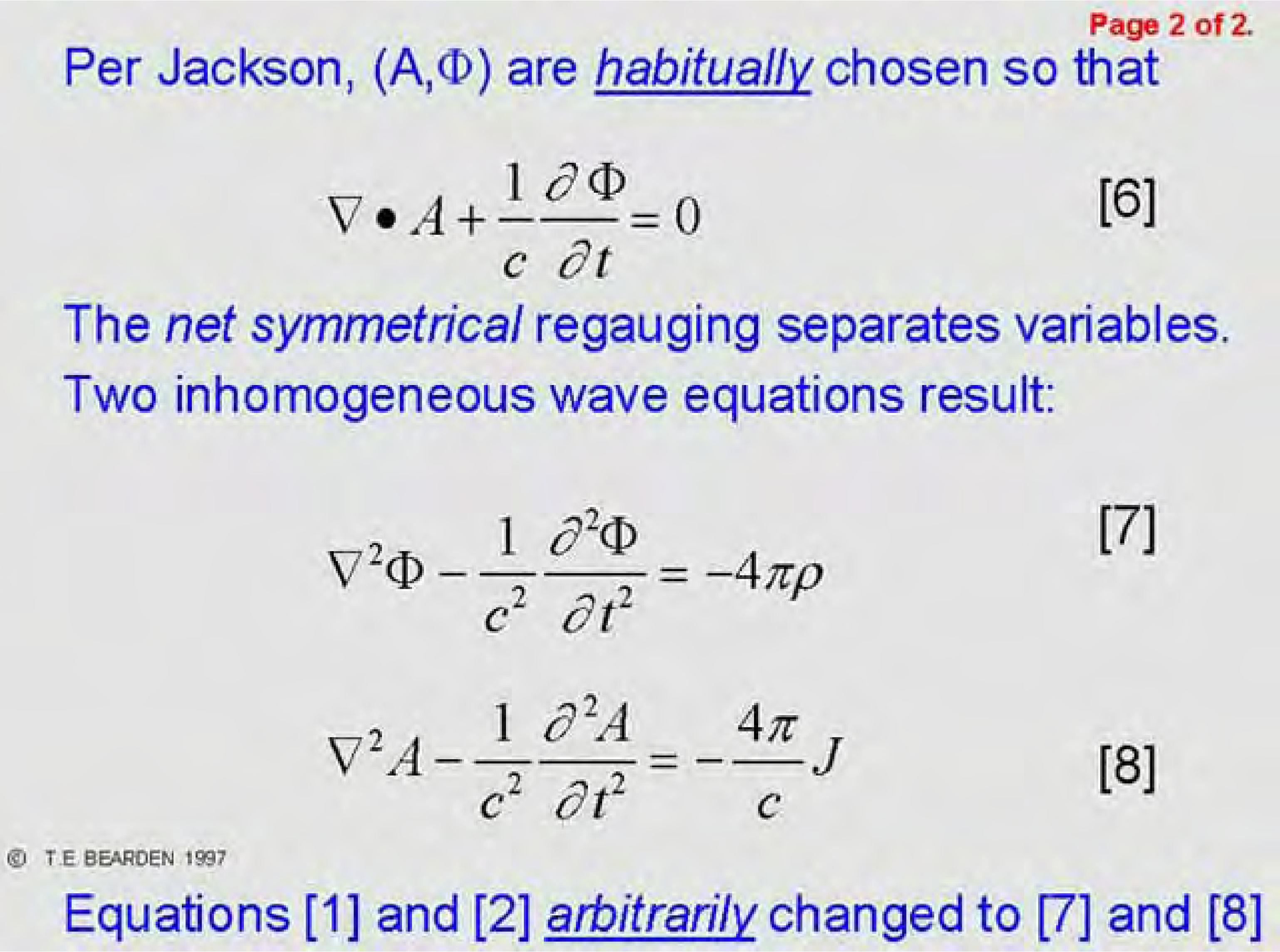

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Per Jackson, (A,Φ) are *habitually* chosen so that

$$\nabla \bullet A + \frac{1}{c}\frac{\partial \Phi}{\partial t} = 0 \qquad [6]$$

The *net symmetrical* regauging separates variables.

Two inhomogeneous wave equations result:

$$\nabla^2 \Phi - \frac{1}{c^2}\frac{\partial^2 \Phi}{\partial t^2} = -4\pi\rho \qquad [7]$$

$$\nabla^2 A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} = -\frac{4\pi}{c} J \qquad [8]$$

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Equations [1] and [2] *arbitrarily* changed to [7] and [8]

The Tom Bearden Website

Energy, Observations and Comments

---

1. A Conservative Field Requires a Single-Valued Potential
2. Earth-Electrosphere and Earth-Ionosphere Capacitors
3. Earth's Poynting Energy Flow
4. The Hidden Energy Flow around us
5. Electrostatic Fields of the Earth's Electrosphere Capacitor in Fair Weather and Thunderstorms
6. Flow of Current and Energy Into, Through, and Along a Conductor
7. Energy "collected" on a charge
8. Fiber Fuse Effect
9. Impact of Vacuum Engineering
10. Lawandy's Experiment
11. Field may be nonconservative for a multivalued potential
12. The Ostrich Problem - Part 1
13. The Ostrich Problem - Part 2
14. Russia had Overunity Devices in 1930s
15. Energy output of human body
16. A "static" Poynting S-flow free-energy generator
17. Topology and Energy Conservation
18. Block Diagram: Sweet's Vacuum Triode

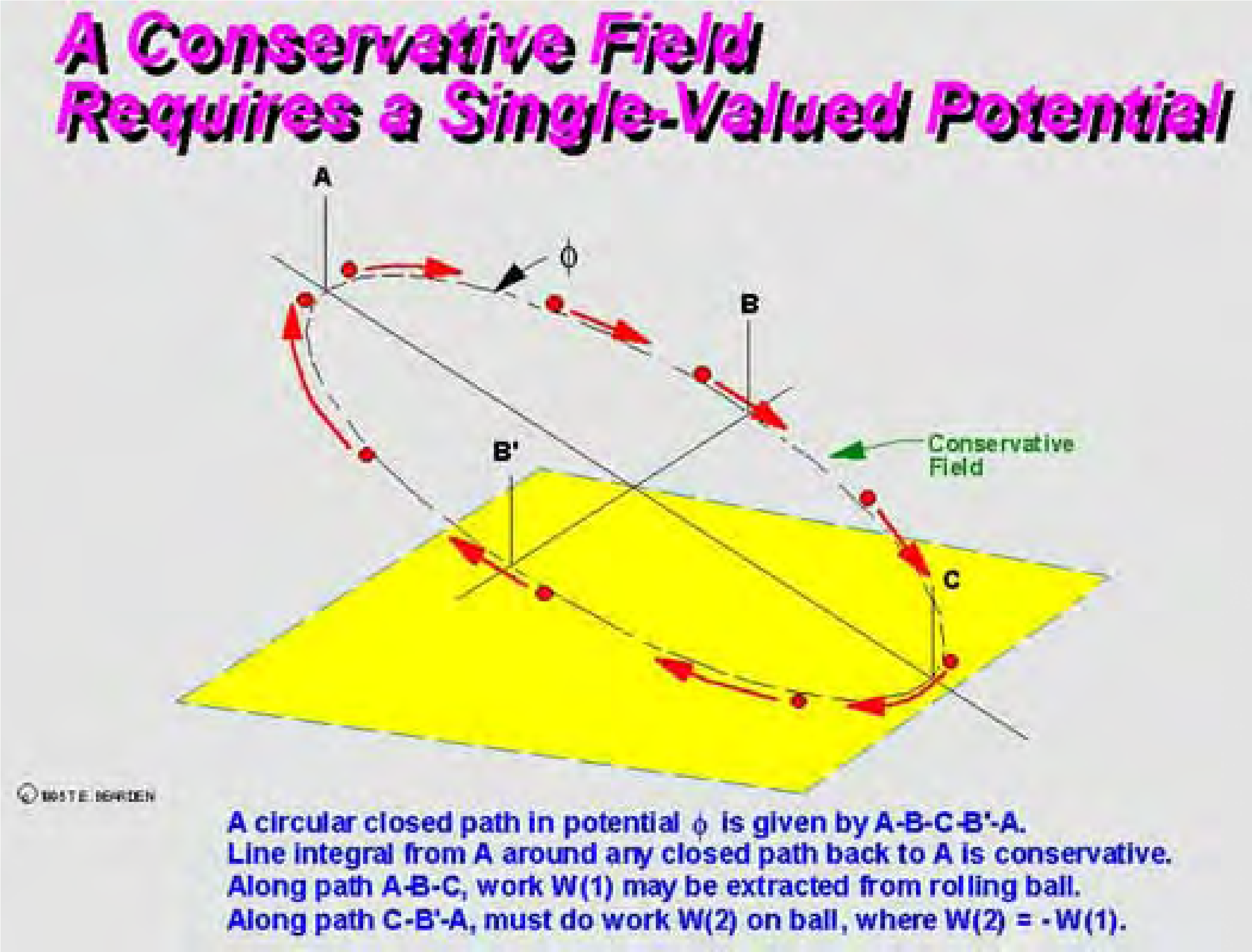

A Conservative Field Requires a Single-Valued Potential

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A circular closed path in potential ϕ is given by A-B-C-B'-A.
Line integral from A around any closed path back to A is conservative.
Along path A-B-C, work W(1) may be extracted from rolling ball.
Along path C-B'-A, must do work W(2) on ball, where W(2) = - W(1).

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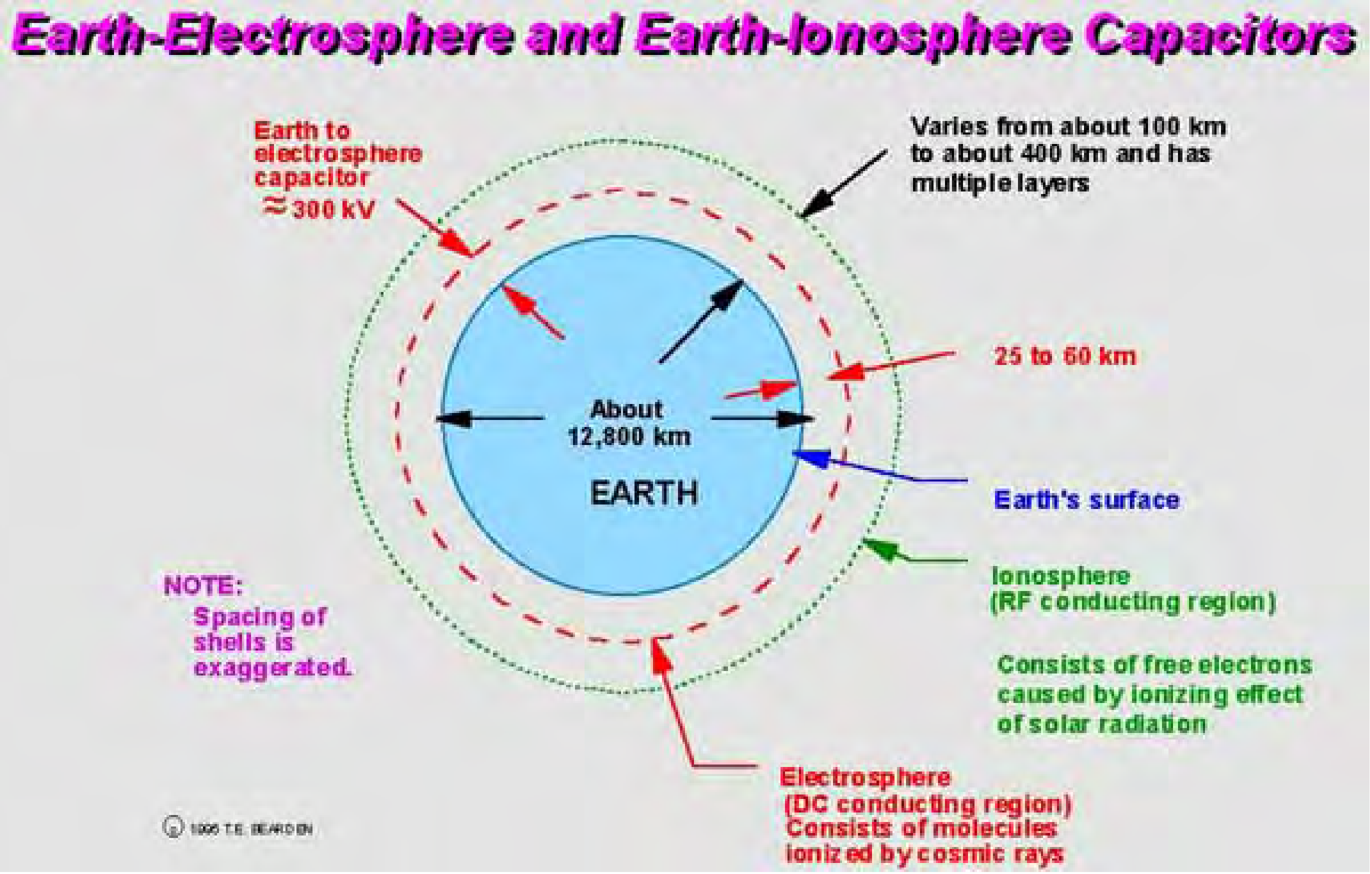

Earth-Electrosphere and Earth-Ionosphere Capacitors

Earth to electrosphere capacitor ≈300 kV

Varies from about 100 km to about 400 km and has multiple layers

25 to 60 km

About 12,800 km

EARTH

Earth's surface

Ionosphere (RF conducting region)

Consists of free electrons caused by ionizing effect of solar radiation

NOTE: Spacing of shells is exaggerated.

Electrosphere (DC conducting region) Consists of molecules ionized by cosmic rays

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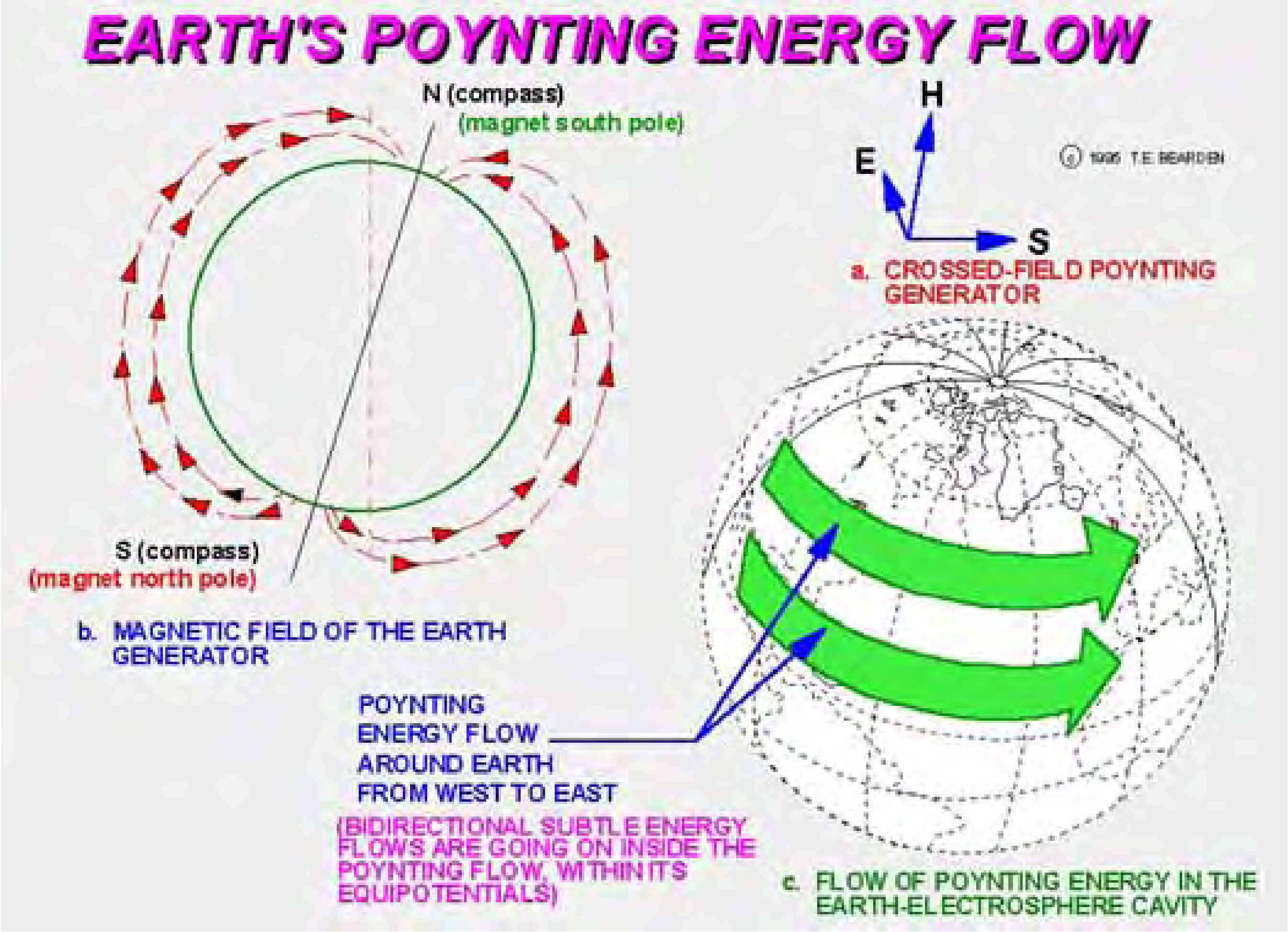

EARTH'S POYNTING ENERGY FLOW

N (compass)
(magnet south pole)
H
E
S
S (compass)
(magnet north pole)

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a. CROSSED-FIELD POYNTING GENERATOR

b. MAGNETIC FIELD OF THE EARTH GENERATOR

POYNTING ENERGY FLOW AROUND EARTH FROM WEST TO EAST

(BIDIRECTIONAL SUBTLE ENERGY FLOWS ARE GOING ON INSIDE THE POYNTING FLOW, WITHIN ITS EQUIPOTENTIALS)

c. FLOW OF POYNTING ENERGY IN THE EARTH-ELECTROSPHERE CAVITY

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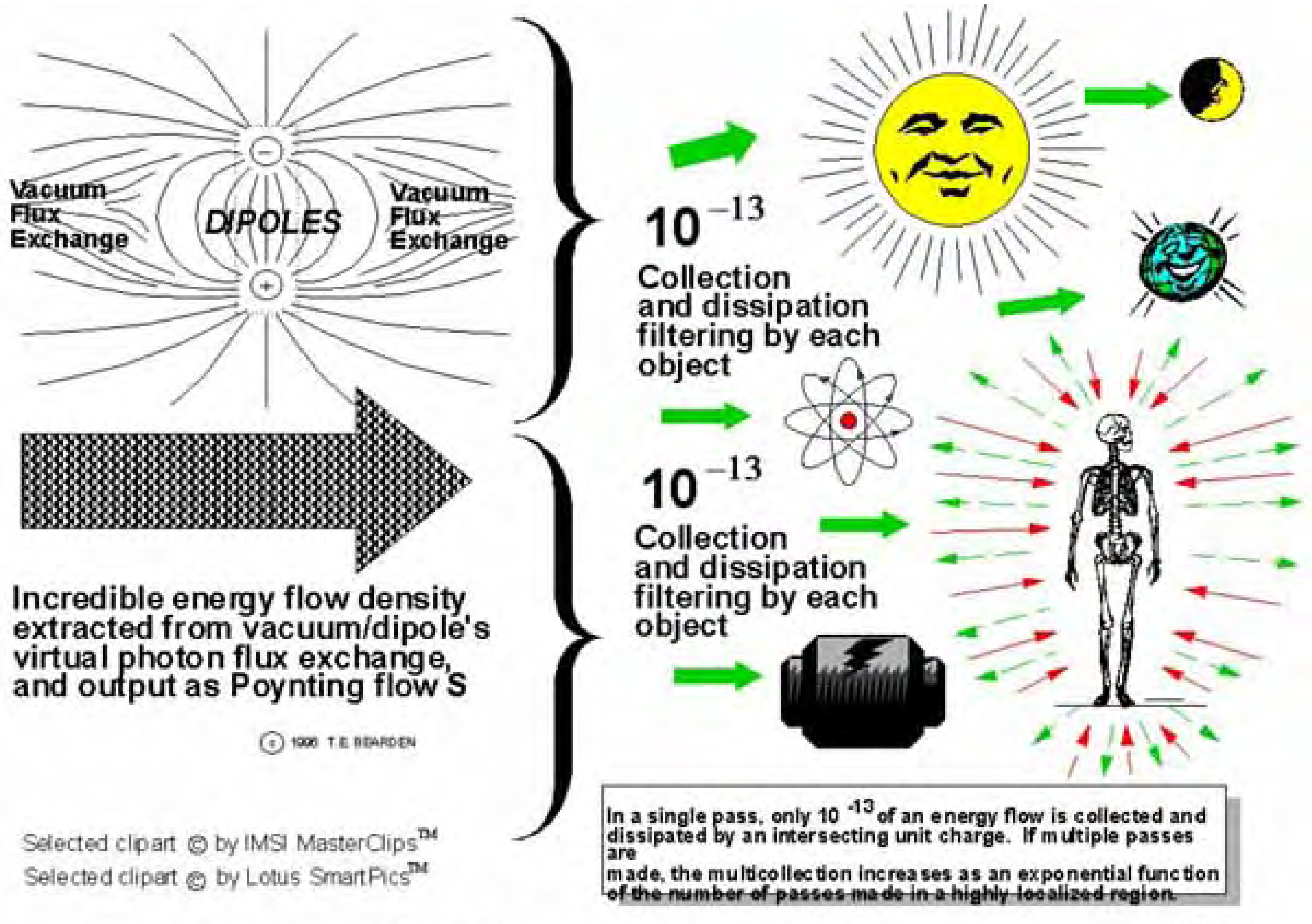
Vacuum Flux Exchange
DIPOLES
Vacuum Flux Exchange
10^{-13}
Collection and dissipation filtering by each object
10^{-13}
Collection and dissipation filtering by each object

Incredible energy flow density extracted from vacuum/dipole's virtual photon flux exchange, and output as Poynting flow S

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Selected clipart © by Lotus SmartPics™

In a single pass, only 10^{-13} of an energy flow is collected and dissipated by an intersecting unit charge. If multiple passes are made, the multicollection increases as an exponential function of the number of passes made in a highly localized region.

Figure 19. The world of physical matter exists behind a dramatic 10^{-13} filter in a fiery cauldron of fierce and primeval EM energy flow.

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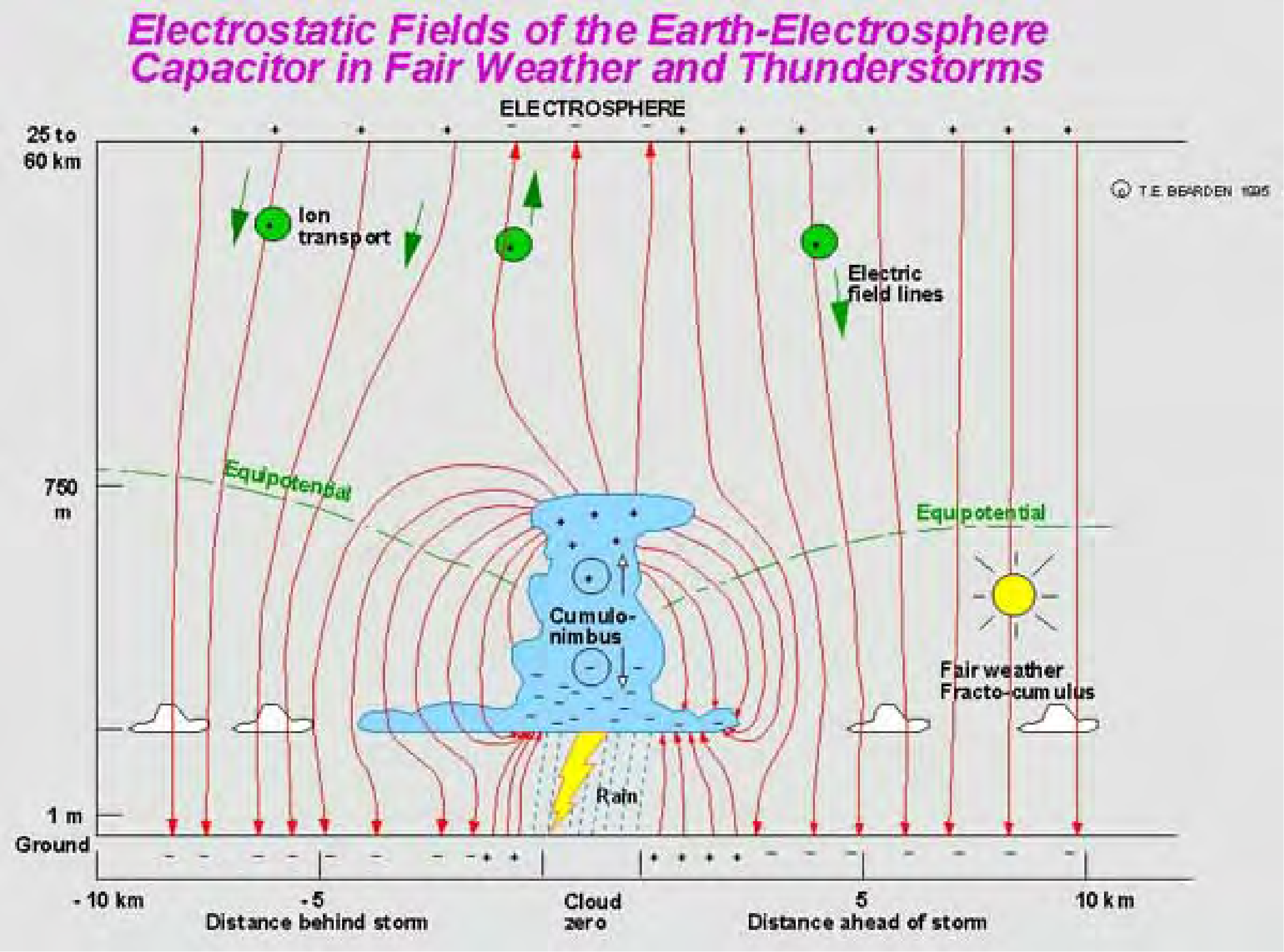

Electrostatic Fields of the Earth-Electrosphere Capacitor in Fair Weather and Thunderstorms

ELECTROSPHERE
25 to
60 km
750
m
1 m
Ground
Ion
transport
Electric
field lines
© T.E. BEARDEN 1995
Equipotential
Equipotential
Cumulo-
nimbus
Fair weather
Fracto-cumulus
Rain
- 10 km
- 5
Distance behind storm
Cloud
zero
5
Distance ahead of storm
10 km

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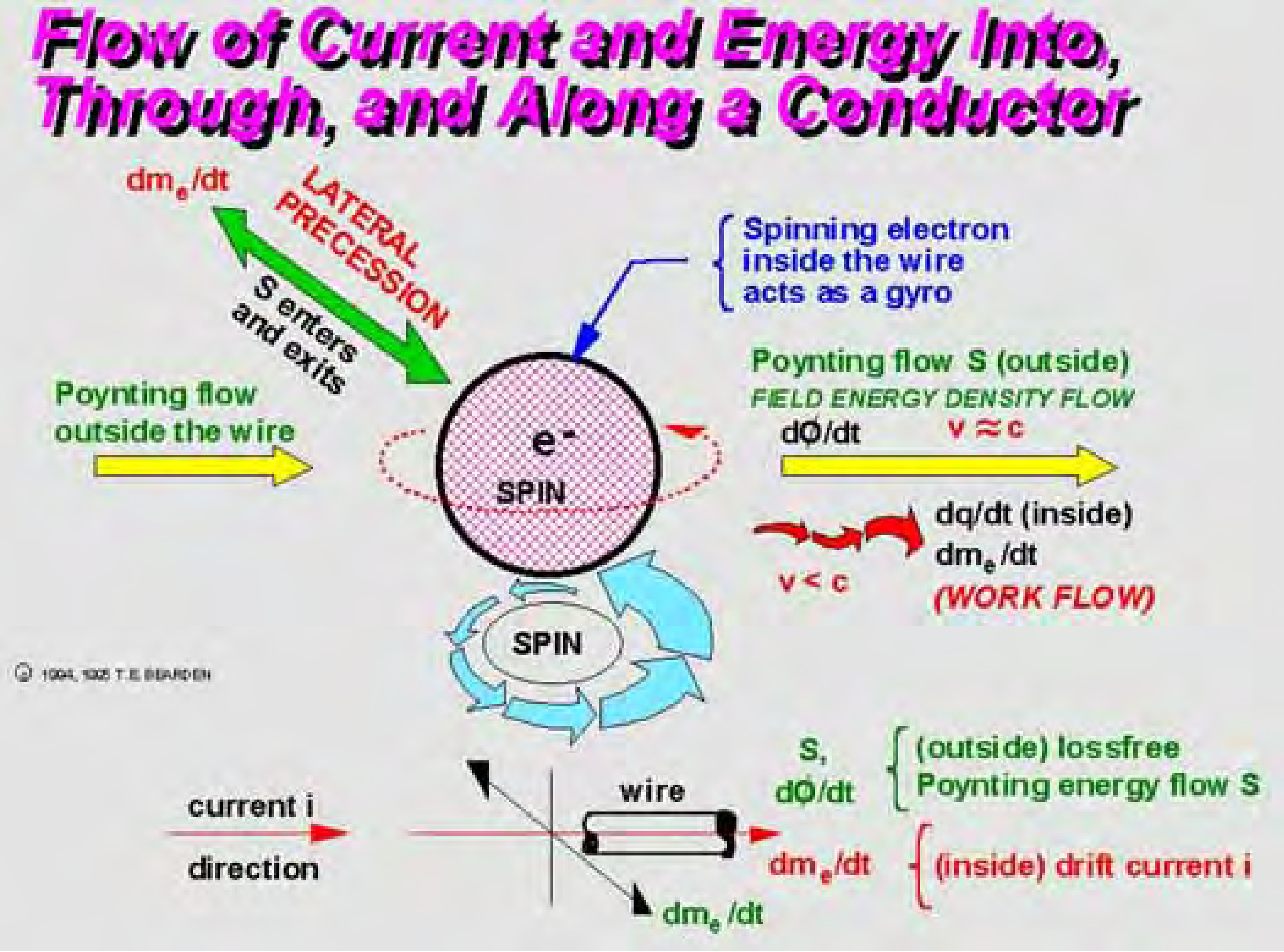

Flow of Current and Energy Into, Through, and Along a Conductor

dm_e/dt

LATERAL PRECESSION

S enters and exits

Spinning electron inside the wire acts as a gyro

Poynting flow outside the wire

Poynting flow S (outside)

FIELD ENERGY DENSITY FLOW

$d\phi/dt$ $v \approx c$

e^-

SPIN

dq/dt (inside)

dm_e/dt

(WORK FLOW)

$v < c$

SPIN

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S, $d\phi/dt$ (outside) lossfree Poynting energy flow S

current i direction

wire

dm_e/dt (inside) drift current i

dm_e/dt

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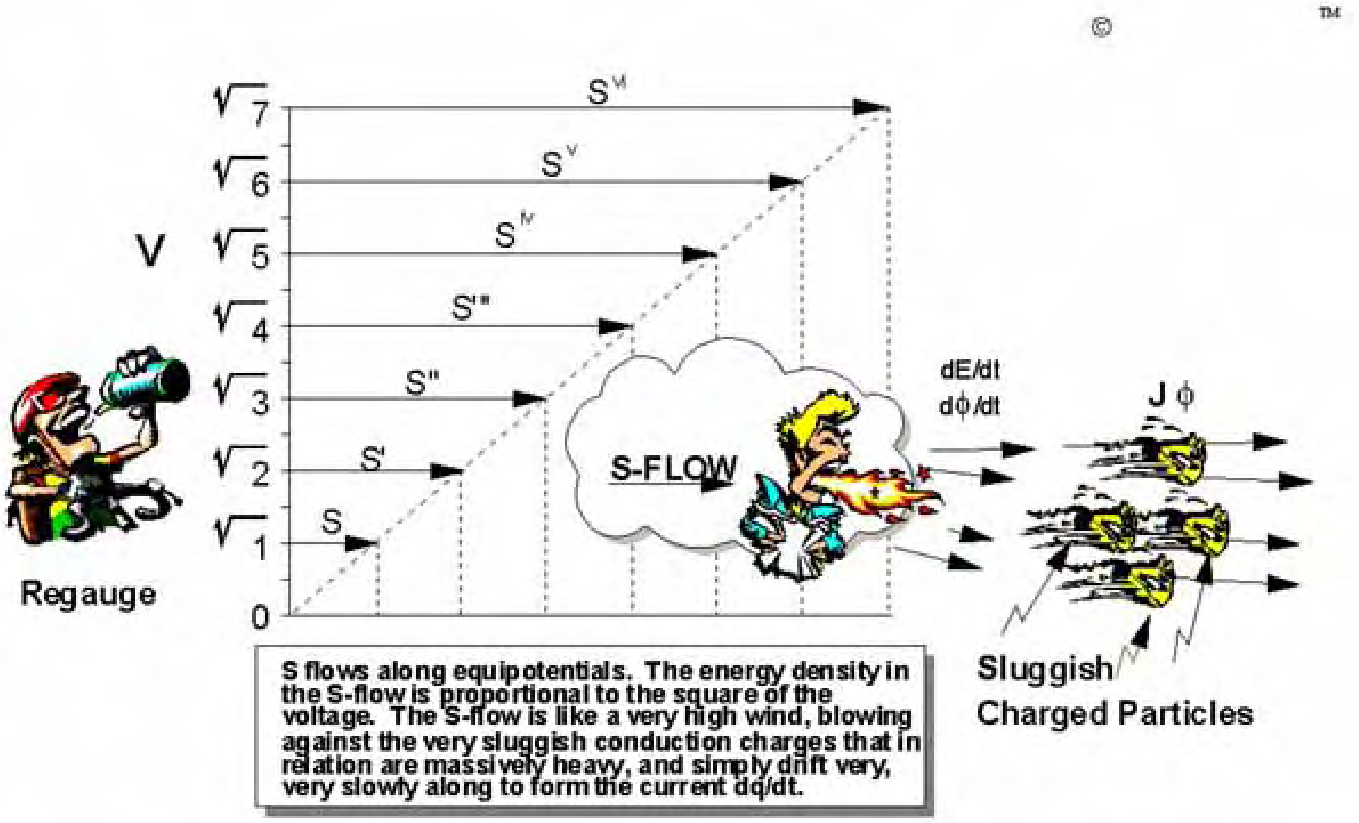
©
™
V
√7
√6
√5
√4
√3
√2
√1
0
S
S'
S''
S'''
S^IV
S^V
S^VI
S-FLOW
Regauge
dE/dt
dφ/dt
J φ
Sluggish
Charged Particles

S flows along equipotentials. The energy density in the S-flow is proportional to the square of the voltage. The S-flow is like a very high wind, blowing against the very sluggish conduction charges that in relation are massively heavy, and simply drift very, very slowly along to form the current dq/dt.

Figure 17. Energy "collected" on a charge depends upon the charge being in a continuous Poynting S-flow. When S ceases, there is no excess energy "collected" on the charge. Energy collection never occurs in chunks, but is always a dynamic, ongoing process.

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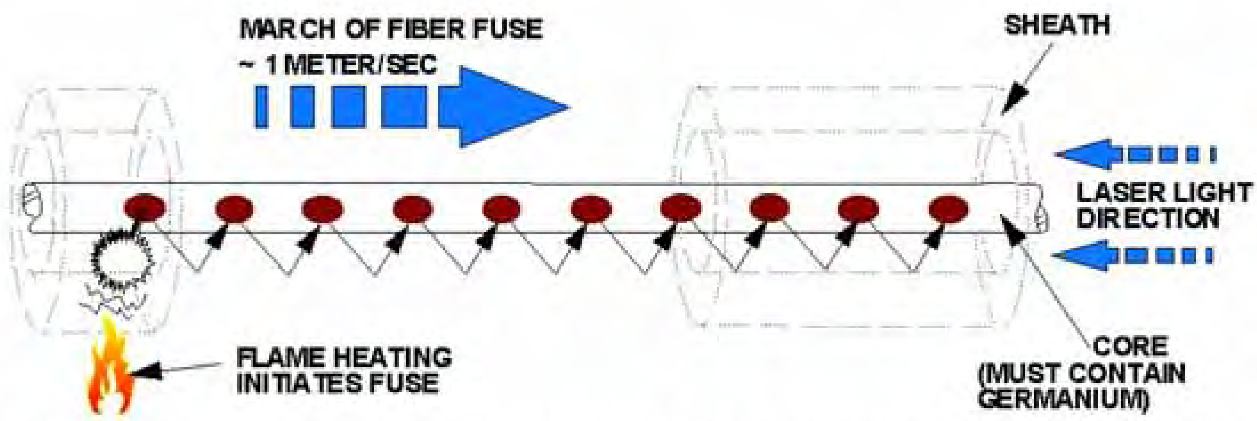
MARCH OF FIBER FUSE
~ 1 METER/SEC
SHEATH
LASER LIGHT DIRECTION
FLAME HEATING INITIATES FUSE
CORE (MUST CONTAIN GERMANIUM)

31A. Fiber fuse destroys core of fiber optics cable of indefinite length, pitting core with holes.

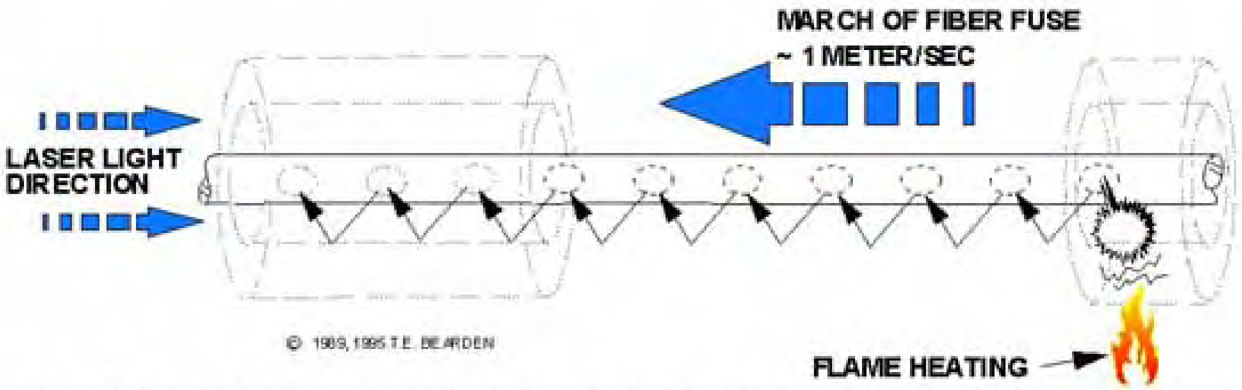
MARCH OF FIBER FUSE
~ 1 METER/SEC
LASER LIGHT DIRECTION
© 1989, 1995 T.E. BEARDEN
FLAME HEATING

31B. Reversed second fiber fuse often *restores* pitted core in cable, filling holes back up.

Figure 31. Fiber fuse effect and its strange anomalies.

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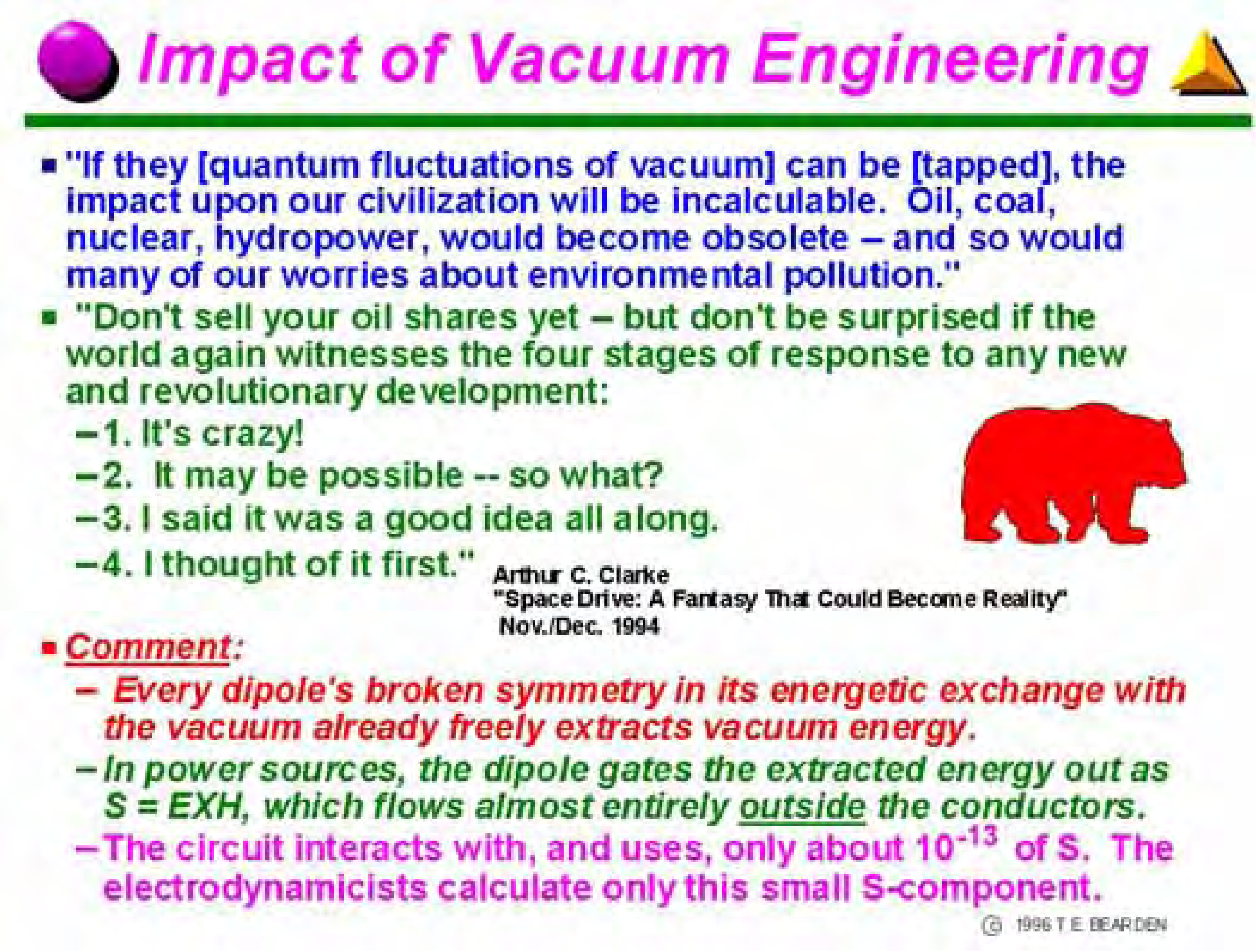

Impact of Vacuum Engineering

- "If they [quantum fluctuations of vacuum] can be [tapped], the impact upon our civilization will be incalculable. Oil, coal, nuclear, hydropower, would become obsolete – and so would many of our worries about environmental pollution."
- "Don't sell your oil shares yet – but don't be surprised if the world again witnesses the four stages of response to any new and revolutionary development:
  - 1. It's crazy!
  - 2. It may be possible -- so what?
  - 3. I said it was a good idea all along.
  - 4. I thought of it first."

Arthur C. Clarke
"Space Drive: A Fantasy That Could Become Reality"
Nov./Dec. 1994

- *Comment:*
  - *Every dipole's broken symmetry in its energetic exchange with the vacuum already freely extracts vacuum energy.*
  - *In power sources, the dipole gates the extracted energy out as S = EXH, which flows almost entirely outside the conductors.*
  - The circuit interacts with, and uses, only about 10^{-13} of S. The electrodynamicists calculate only this small S-component.

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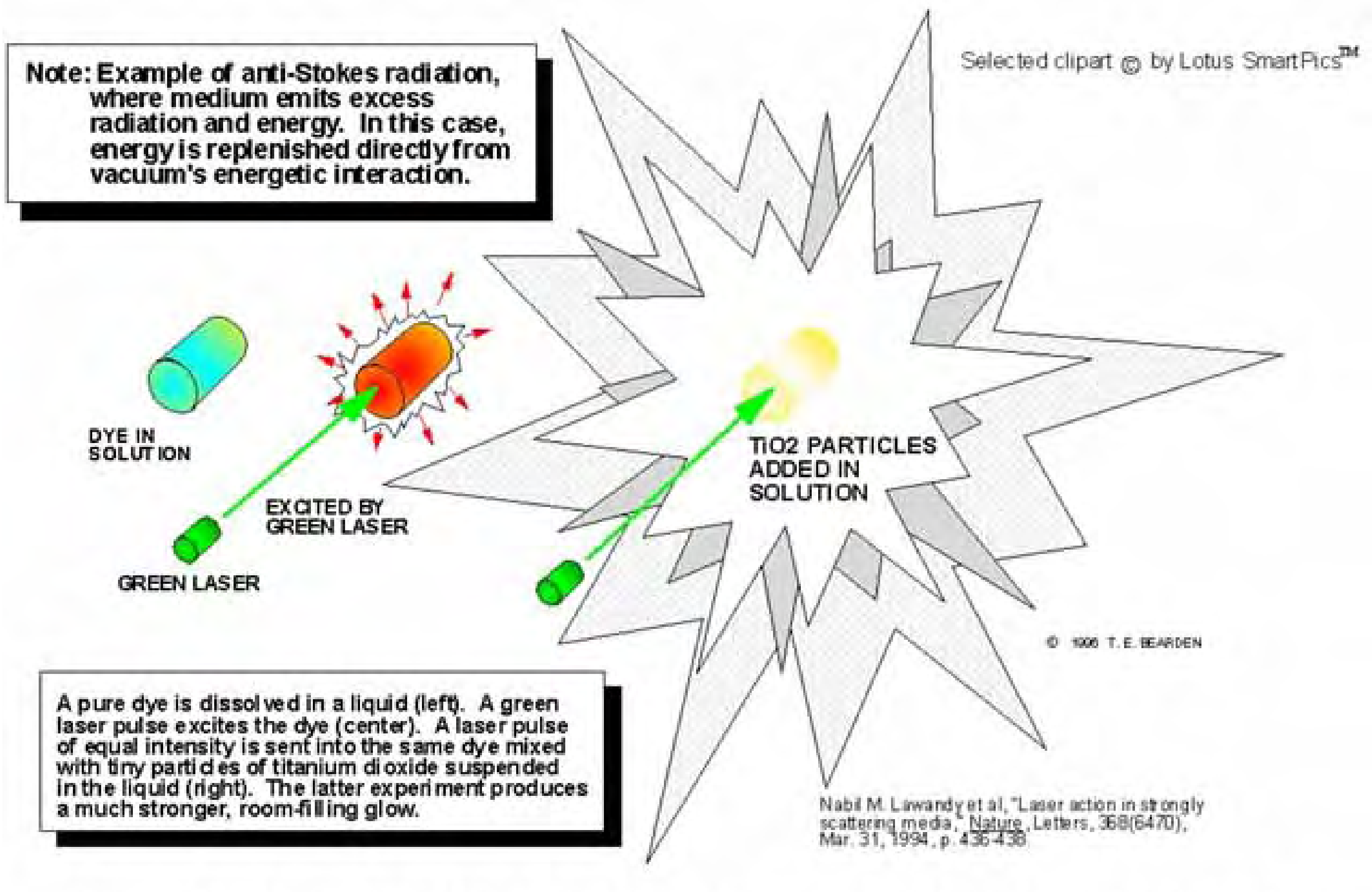

Note: Example of anti-Stokes radiation, where medium emits excess radiation and energy. In this case, energy is replenished directly from vacuum's energetic interaction.

Selected clipart © by Lotus SmartPics™

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A pure dye is dissolved in a liquid (left). A green laser pulse excites the dye (center). A laser pulse of equal intensity is sent into the same dye mixed with tiny particles of titanium dioxide suspended in the liquid (right). The latter experiment produces a much stronger, room-filling glow.

Nabil M. Lawandy et al, "Laser action in strongly scattering media," Nature, Letters, 368(6470), Mar. 31, 1994, p. 436-438

Figure 28. Lawandy's experiment (Letokhov-Lawandy effect) with multipass, multicollection of energy. Formation of a quantum potential can also become involved. Retroreflection and self-targeting are key.

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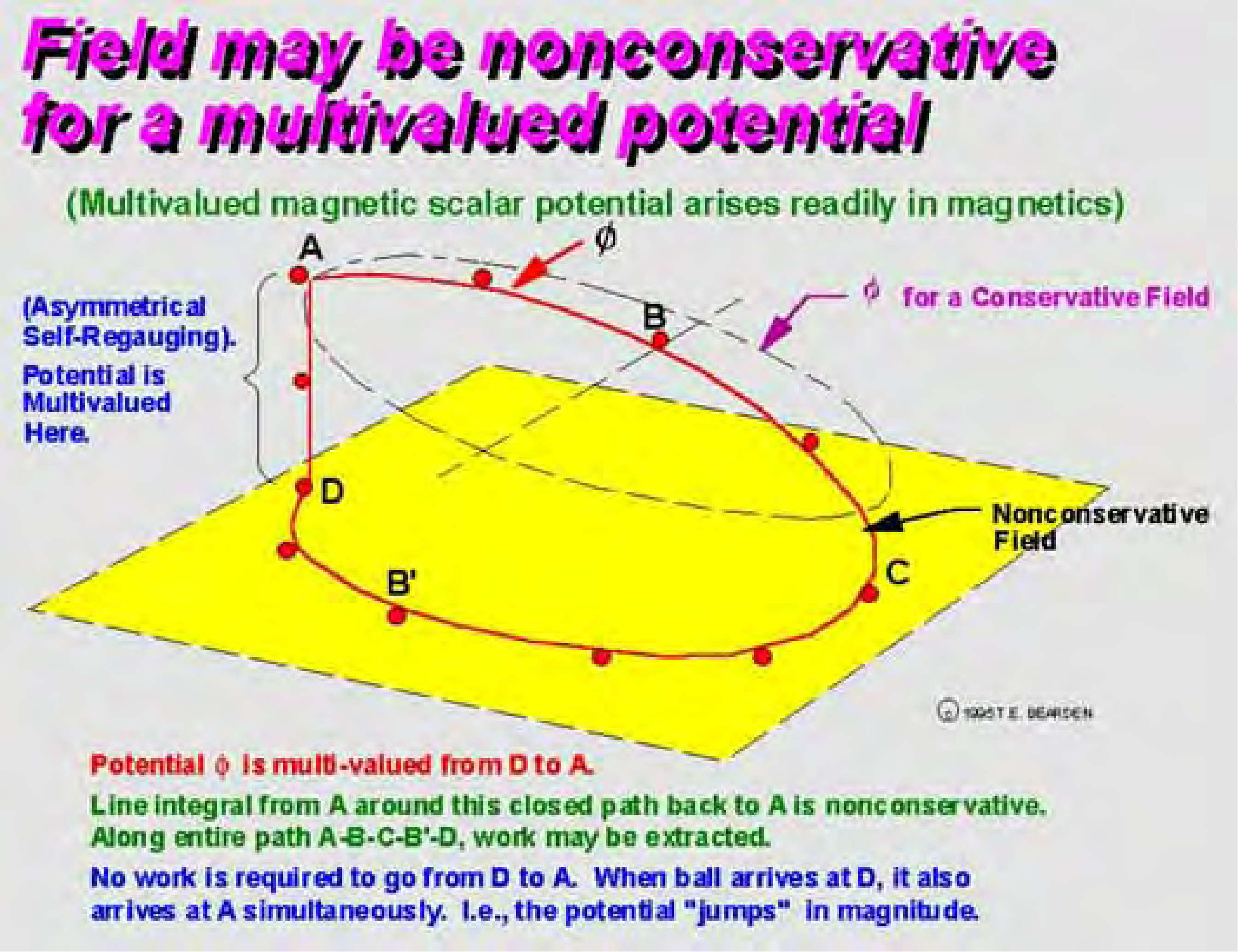

Field may be nonconservative for a multivalued potential

(Multivalued magnetic scalar potential arises readily in magnetics)

A
ϕ
ϕ for a Conservative Field
B
(Asymmetrical Self-Regauging).
Potential is Multivalued Here.
D
Nonconservative Field
C
B'
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Potential ϕ is multi-valued from D to A.

Line integral from A around this closed path back to A is nonconservative. Along entire path A-B-C-B'-D, work may be extracted.

No work is required to go from D to A. When ball arrives at D, it also arrives at A simultaneously. I.e., the potential "jumps" in magnitude.

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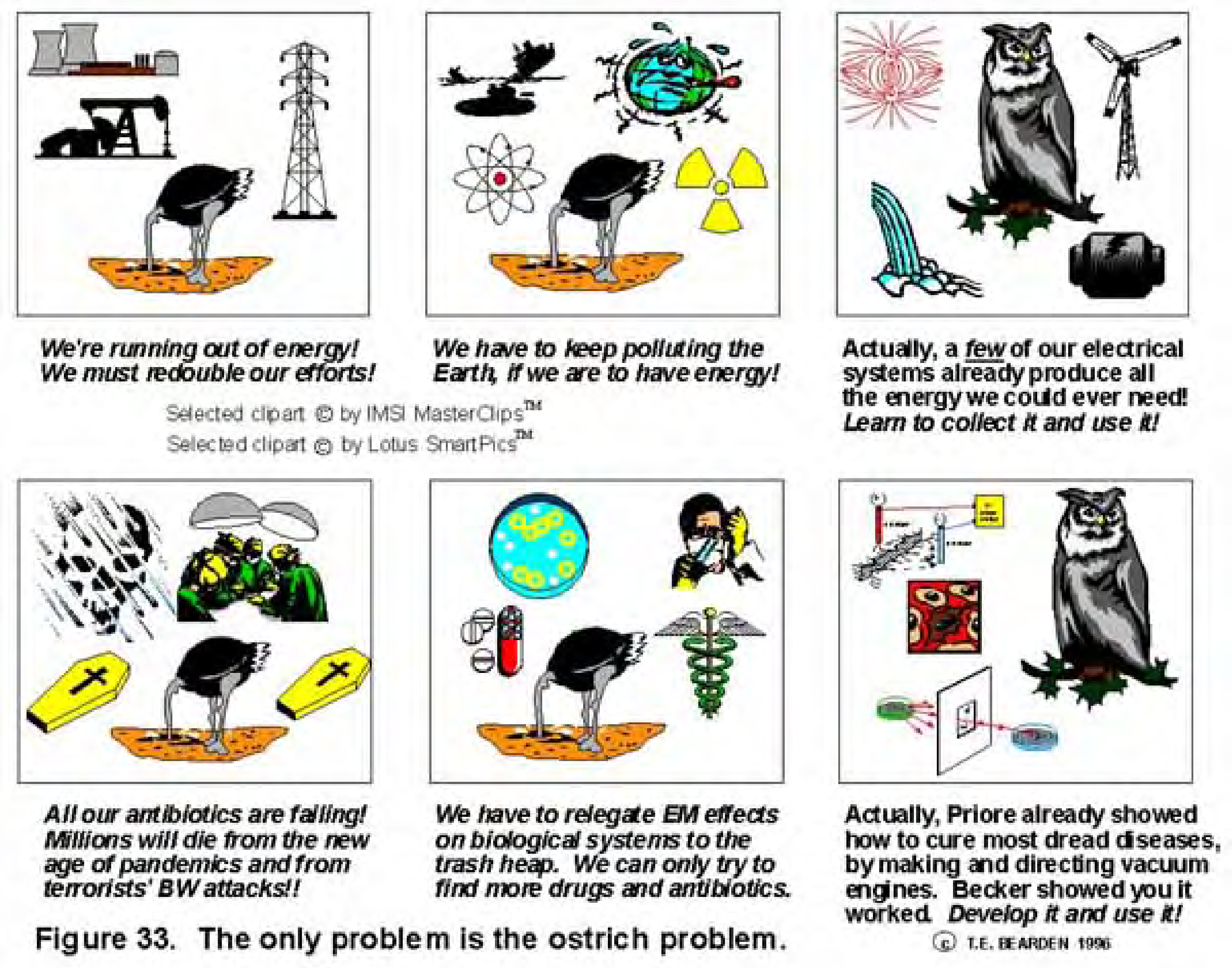

We're running out of energy! We must redouble our efforts!

We have to keep polluting the Earth, if we are to have energy!

Actually, a few of our electrical systems already produce all the energy we could ever need! *Learn to collect it and use it!*

Selected clipart © by IMSI MasterClips™
Selected clipart © by Lotus SmartPics™

All our antibiotics are failing! Millions will die from the new age of pandemics and from terrorists' BW attacks!!

We have to relegate EM effects on biological systems to the trash heap. We can only try to find more drugs and antibiotics.

Actually, Priore already showed how to cure most dread diseases, by making and directing vacuum engines. Becker showed you it worked. *Develop it and use it!*

Figure 33. The only problem is the ostrich problem.

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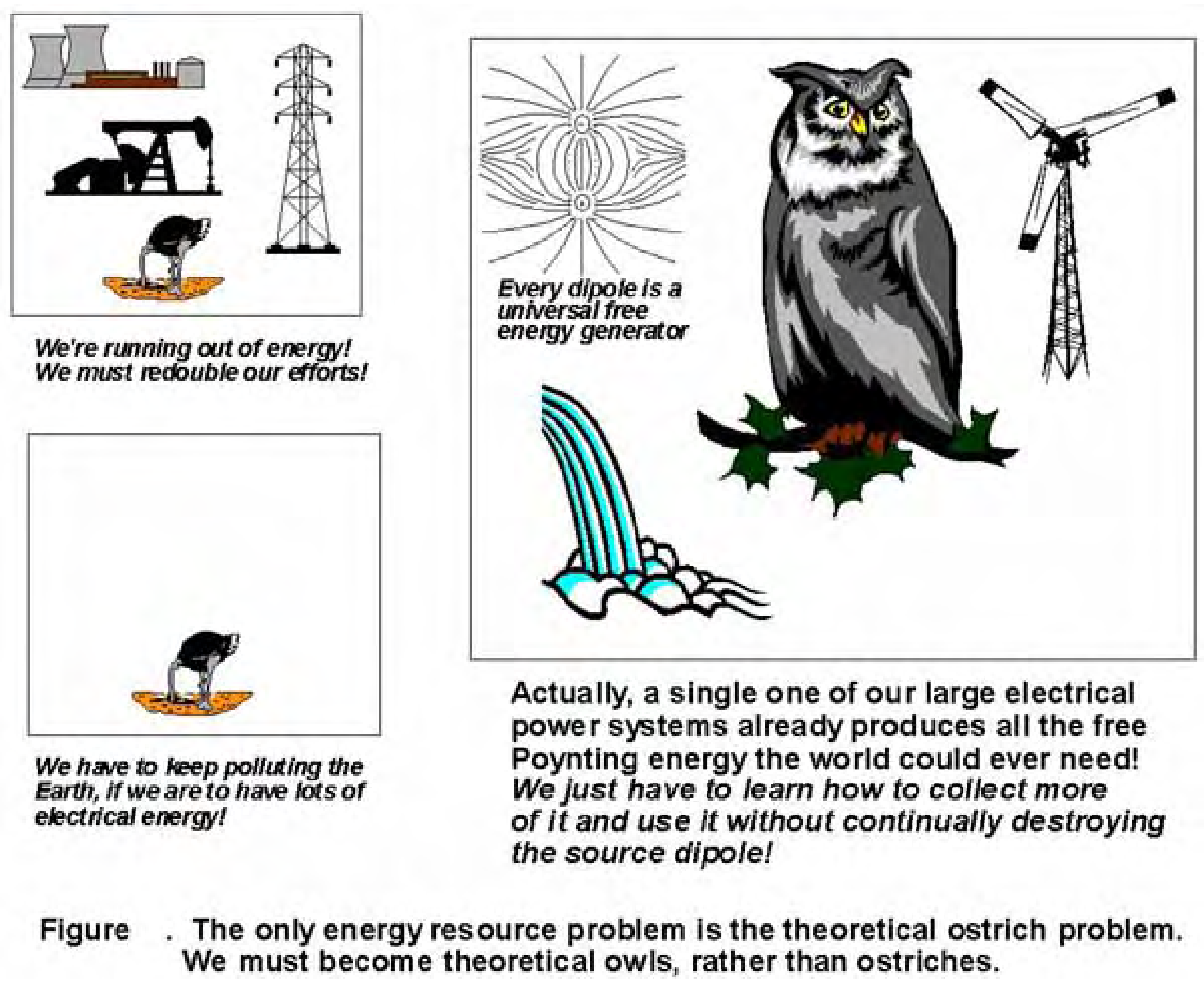

We're running out of energy!
We must redouble our efforts!

We have to keep polluting the Earth, if we are to have lots of electrical energy!

Every dipole is a universal free energy generator

Actually, a single one of our large electrical power systems already produces all the free Poynting energy the world could ever need! *We just have to learn how to collect more of it and use it without continually destroying the source dipole!*

Figure . The only energy resource problem is the theoretical ostrich problem. We must become theoretical owls, rather than ostriches.

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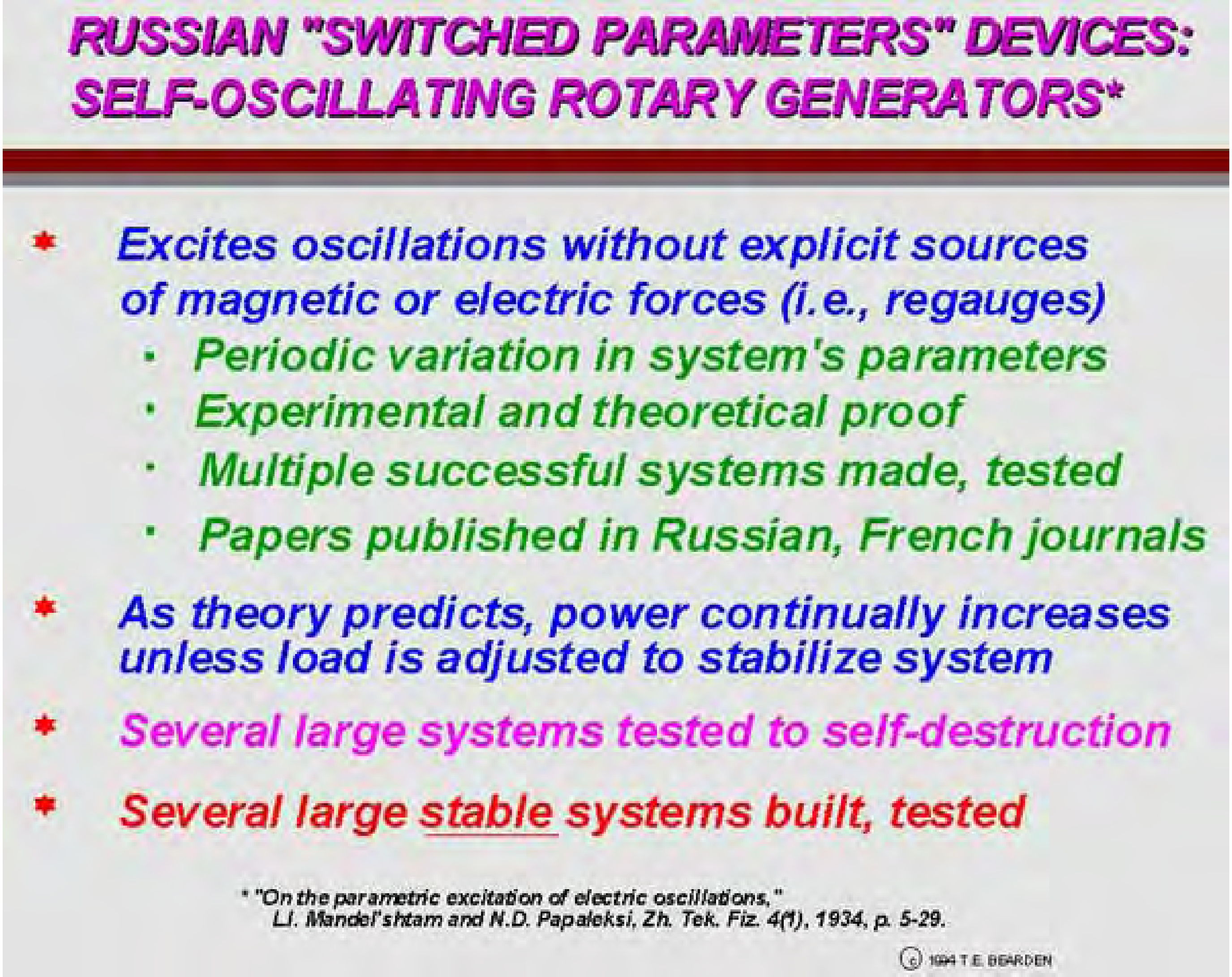

RUSSIAN "SWITCHED PARAMETERS" DEVICES: SELF-OSCILLATING ROTARY GENERATORS*

- Excites oscillations without explicit sources of magnetic or electric forces (i.e., regauges)
  - Periodic variation in system's parameters
  - Experimental and theoretical proof
  - Multiple successful systems made, tested
  - Papers published in Russian, French journals
- As theory predicts, power continually increases unless load is adjusted to stabilize system
- Several large systems tested to self-destruction
- Several large stable systems built, tested

* "On the parametric excitation of electric oscillations," L.I. Mandel'shtam and N.D. Papaleksi, Zh. Tek. Fiz. 4(1), 1934, p. 5-29.

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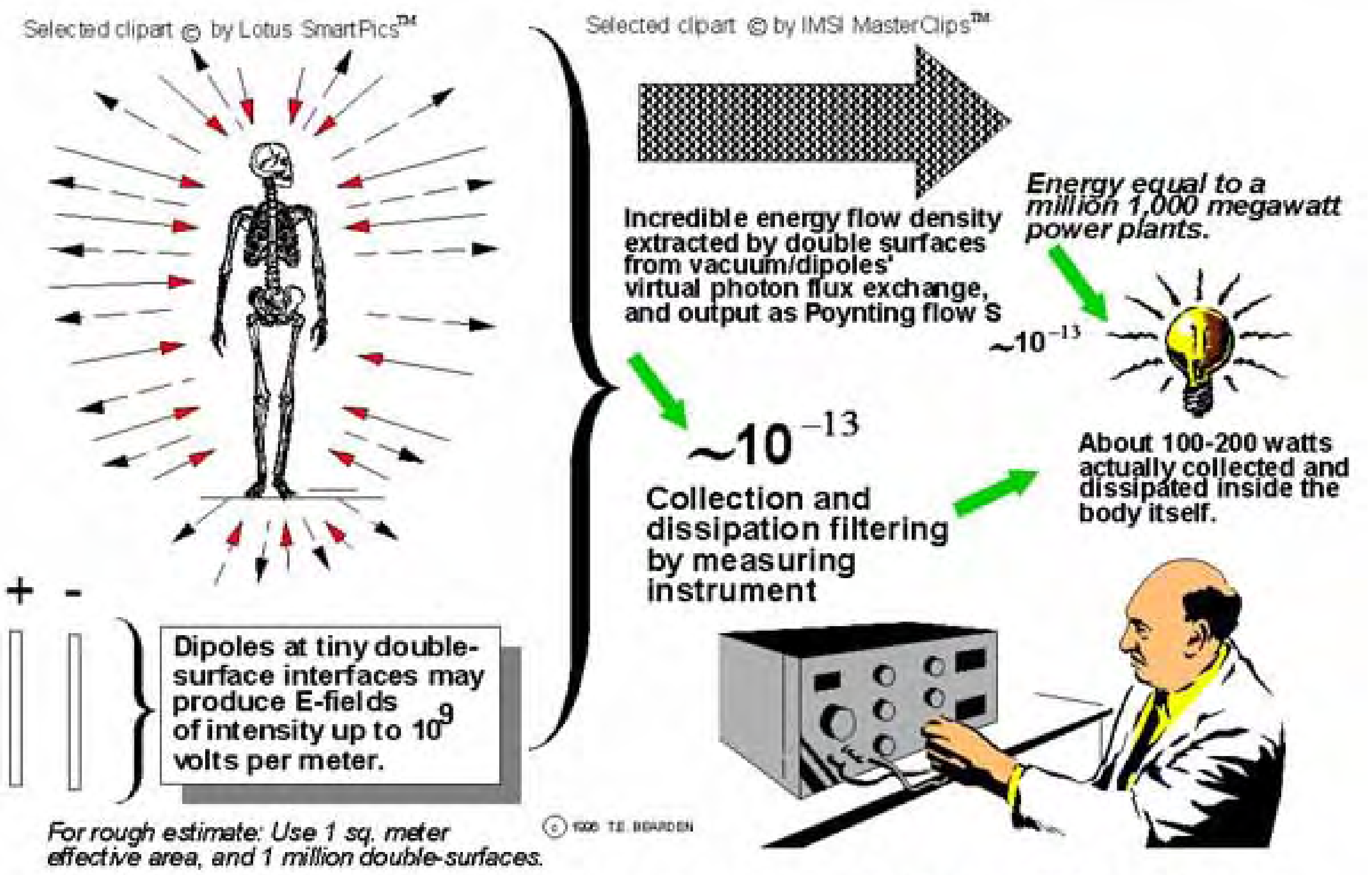
Selected clipart © by Lotus SmartPics™
Selected clipart © by IMSI MasterClips™
Energy equal to a million 1,000 megawatt power plants.
Incredible energy flow density extracted by double surfaces from vacuum/dipoles' virtual photon flux exchange, and output as Poynting flow S
~10⁻¹³
~10⁻¹³
Collection and dissipation filtering by measuring instrument
About 100-200 watts actually collected and dissipated inside the body itself.
+ -
Dipoles at tiny double-surface interfaces may produce E-fields of intensity up to 10⁹ volts per meter.
For rough estimate: Use 1 sq. meter effective area, and 1 million double-surfaces.
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Figure 20. One human body produces more energy flow than all the electrical power loads on earth dissipate. However, only 100-200 watts of its own energy output is collected and dissipated by the body.

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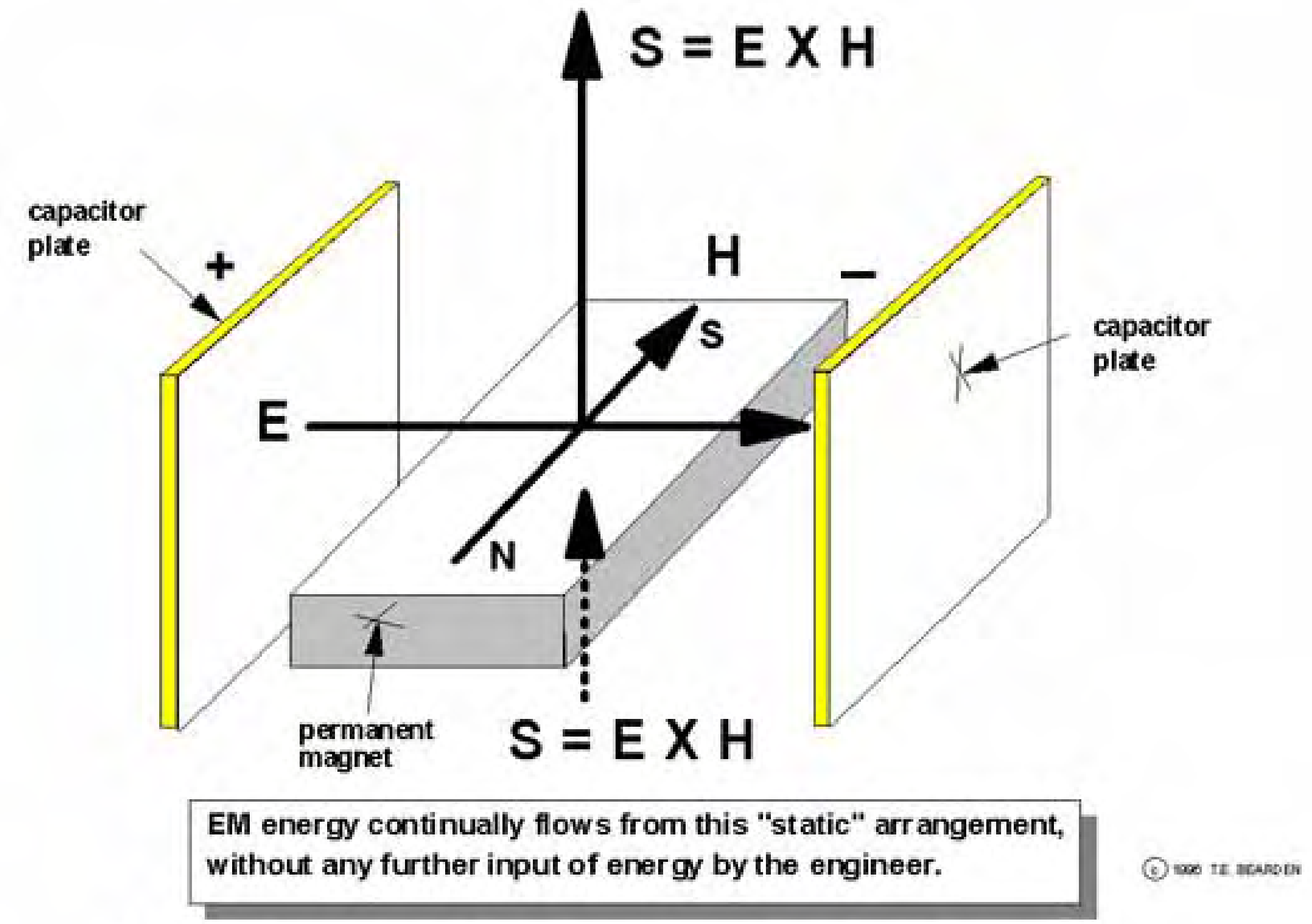
S = E X H
capacitor plate
+
H
–
S
capacitor plate
E
N
permanent magnet
S = E X H

EM energy continually flows from this "static" arrangement, without any further input of energy by the engineer.

Figure 18. A "static" Poynting S-flow free-energy generator.

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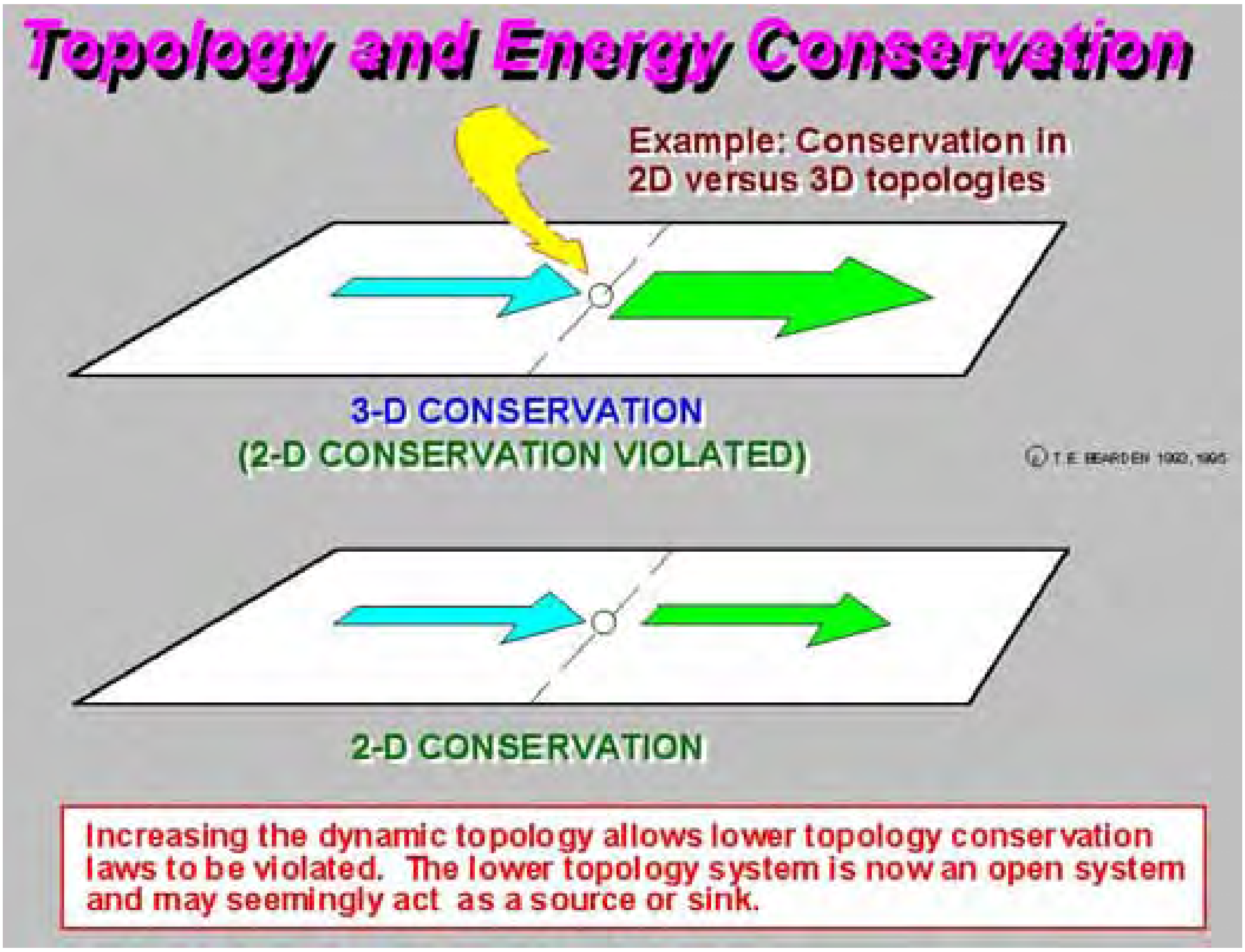

Topology and Energy Conservation

Example: Conservation in
2D versus 3D topologies

3-D CONSERVATION
(2-D CONSERVATION VIOLATED)

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2-D CONSERVATION

Increasing the dynamic topology allows lower topology conservation laws to be violated. The lower topology system is now an open system and may seemingly act as a source or sink.

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Block Diagram: Sweet's Vacuum Triode

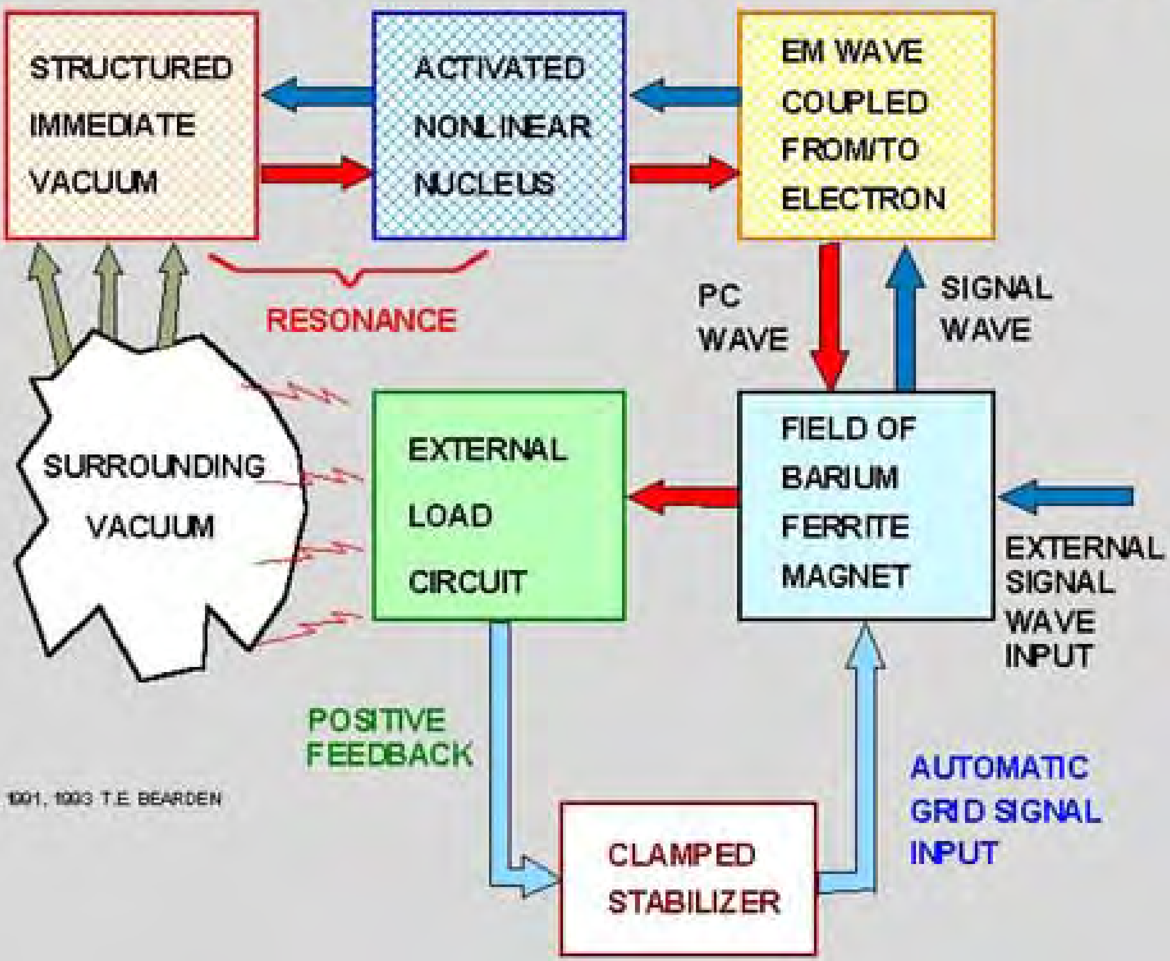
STRUCTURED IMMEDIATE VACUUM
ACTIVATED NONLINEAR NUCLEUS
EM WAVE COUPLED FROM/TO ELECTRON
RESONANCE
PC WAVE
SIGNAL WAVE
SURROUNDING VACUUM
EXTERNAL LOAD CIRCUIT
FIELD OF BARIUM FERRITE MAGNET
EXTERNAL SIGNAL WAVE INPUT
POSITIVE FEEDBACK
AUTOMATIC GRID SIGNAL INPUT
CLAMPED STABILIZER

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Defense Department Briefing on Priore Treatment to counter Biological Warfare

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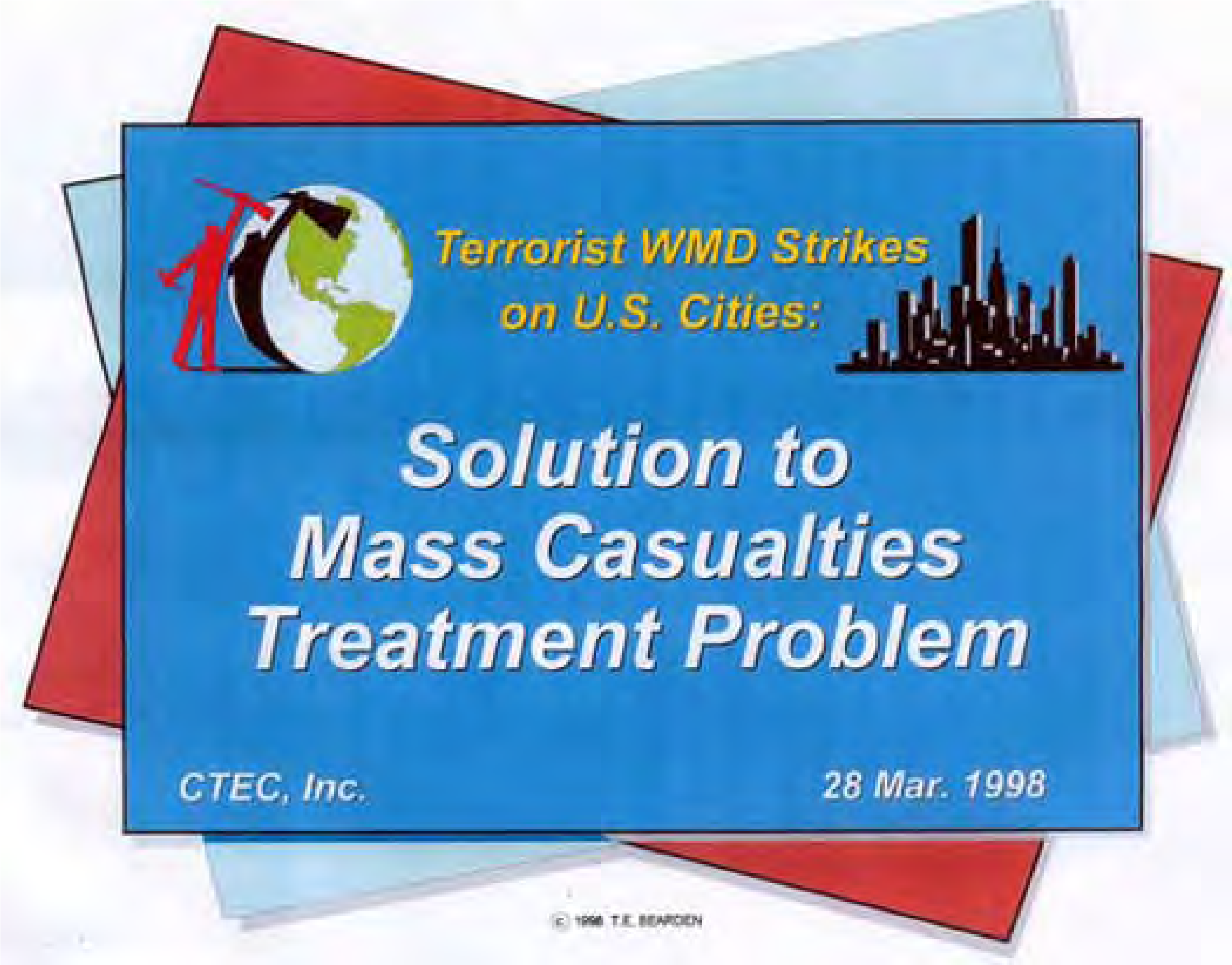

Terrorist WMD Strikes
on U.S. Cities:

Solution to
Mass Casualties
Treatment Problem

CTEC, Inc.

28 Mar. 1998

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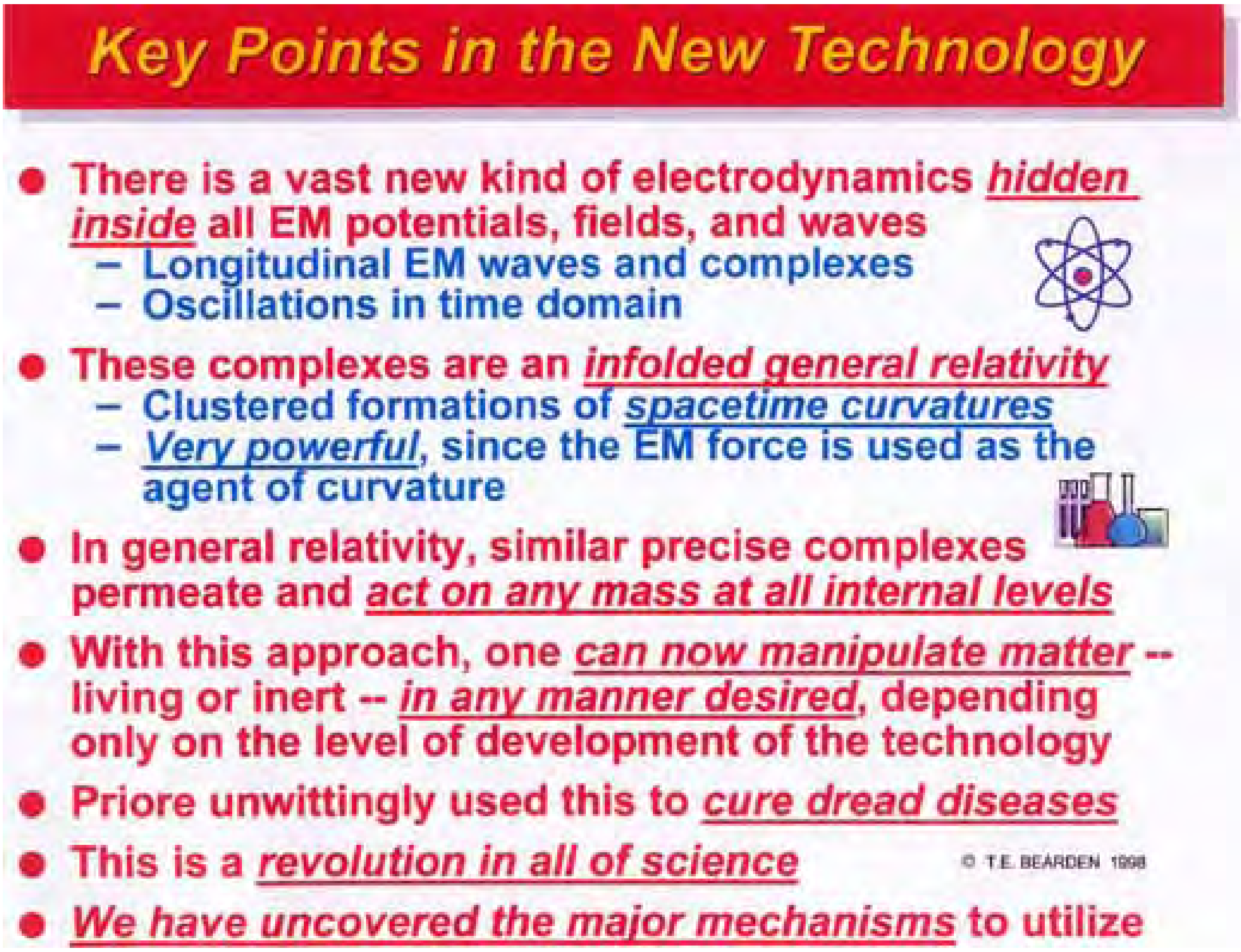

Key Points in the New Technology

- There is a vast new kind of electrodynamics *hidden inside* all EM potentials, fields, and waves
  - Longitudinal EM waves and complexes
  - Oscillations in time domain
- These complexes are an *infolded general relativity*
  - Clustered formations of *spacetime curvatures*
  - *Very powerful*, since the EM force is used as the agent of curvature
- In general relativity, similar precise complexes permeate and *act on any mass at all internal levels*
- With this approach, one *can now manipulate matter* -- living or inert -- *in any manner desired*, depending only on the level of development of the technology
- Priore unwittingly used this to *cure dread diseases*
- This is a *revolution in all of science*
- *We have uncovered the major mechanisms* to utilize

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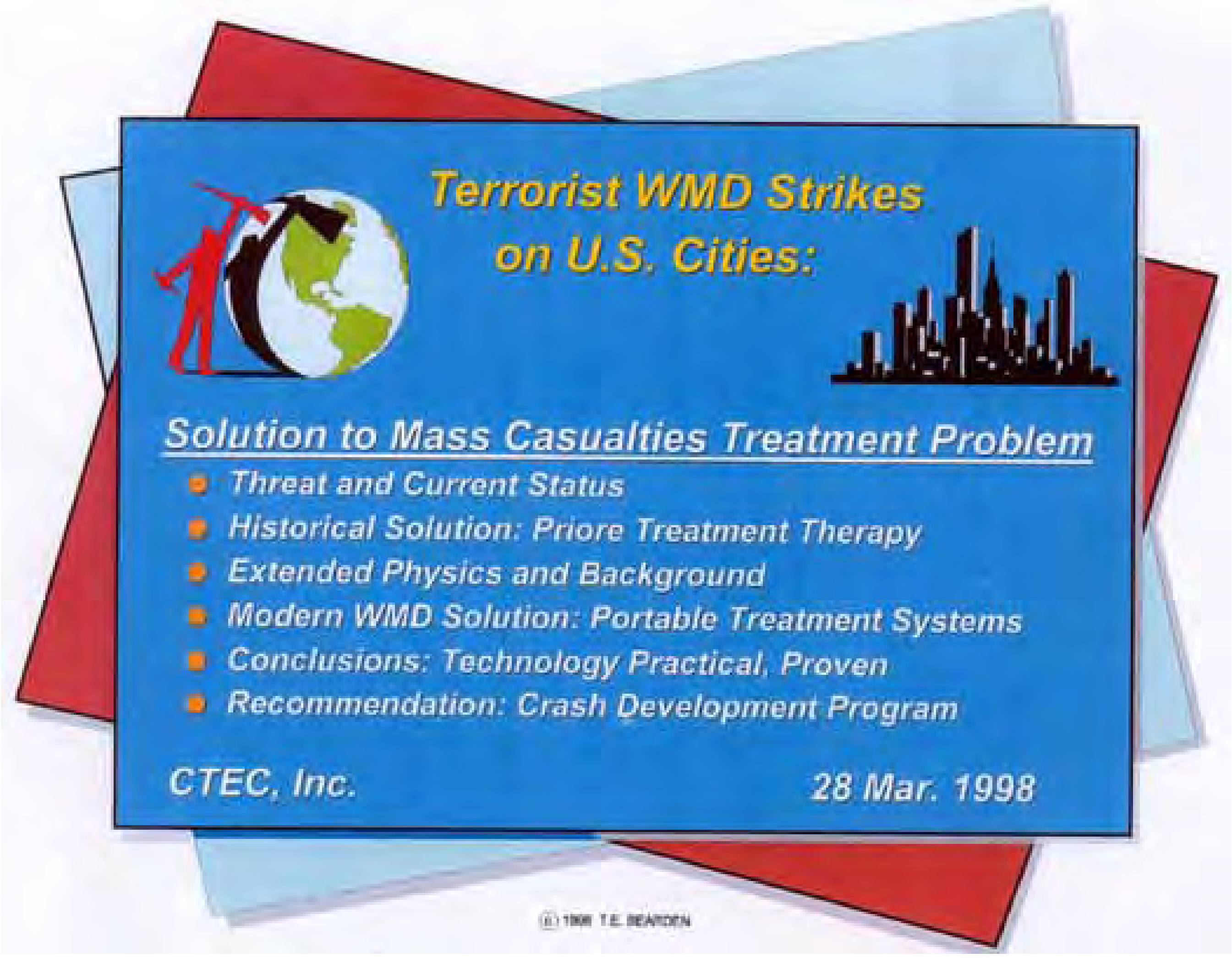

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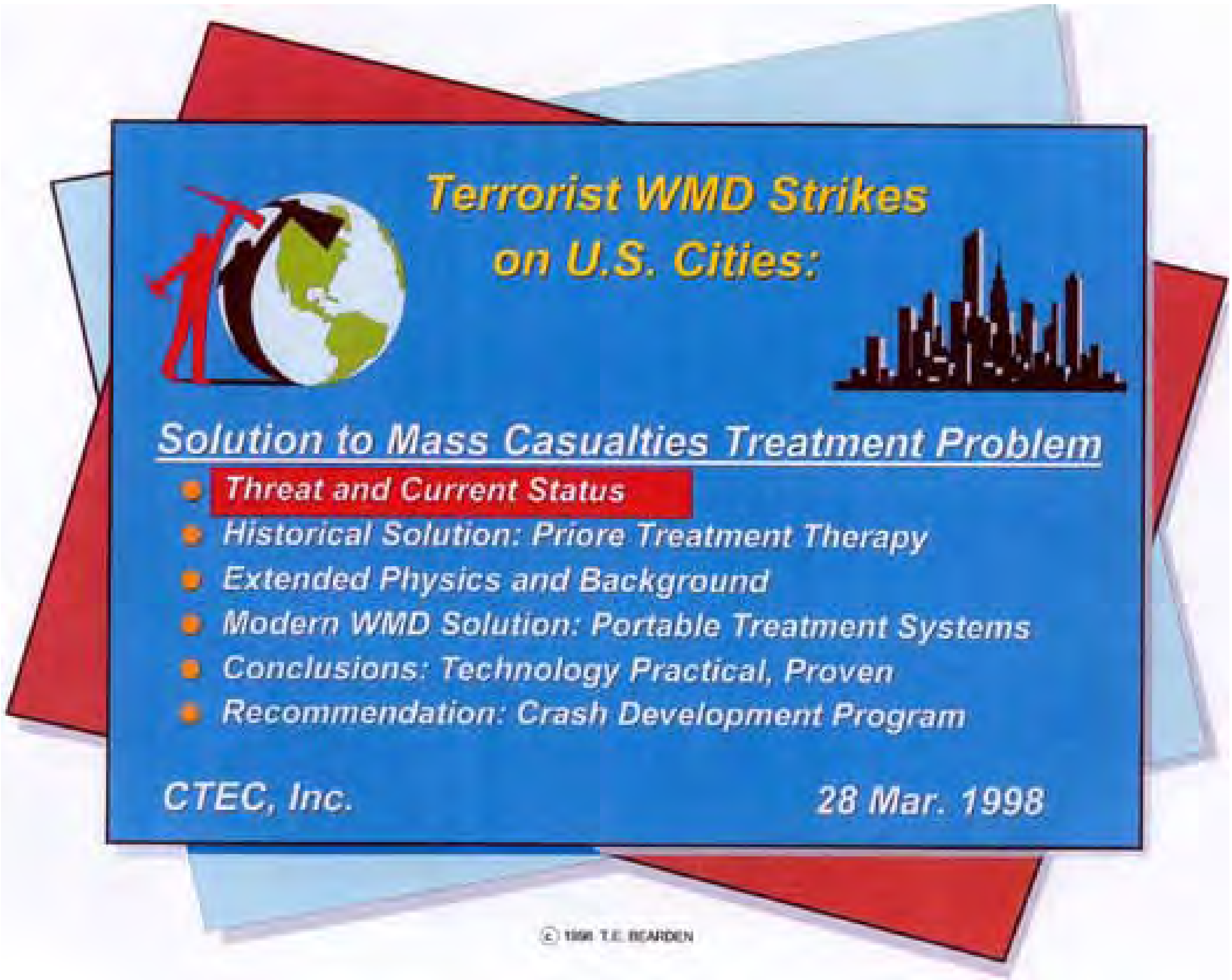

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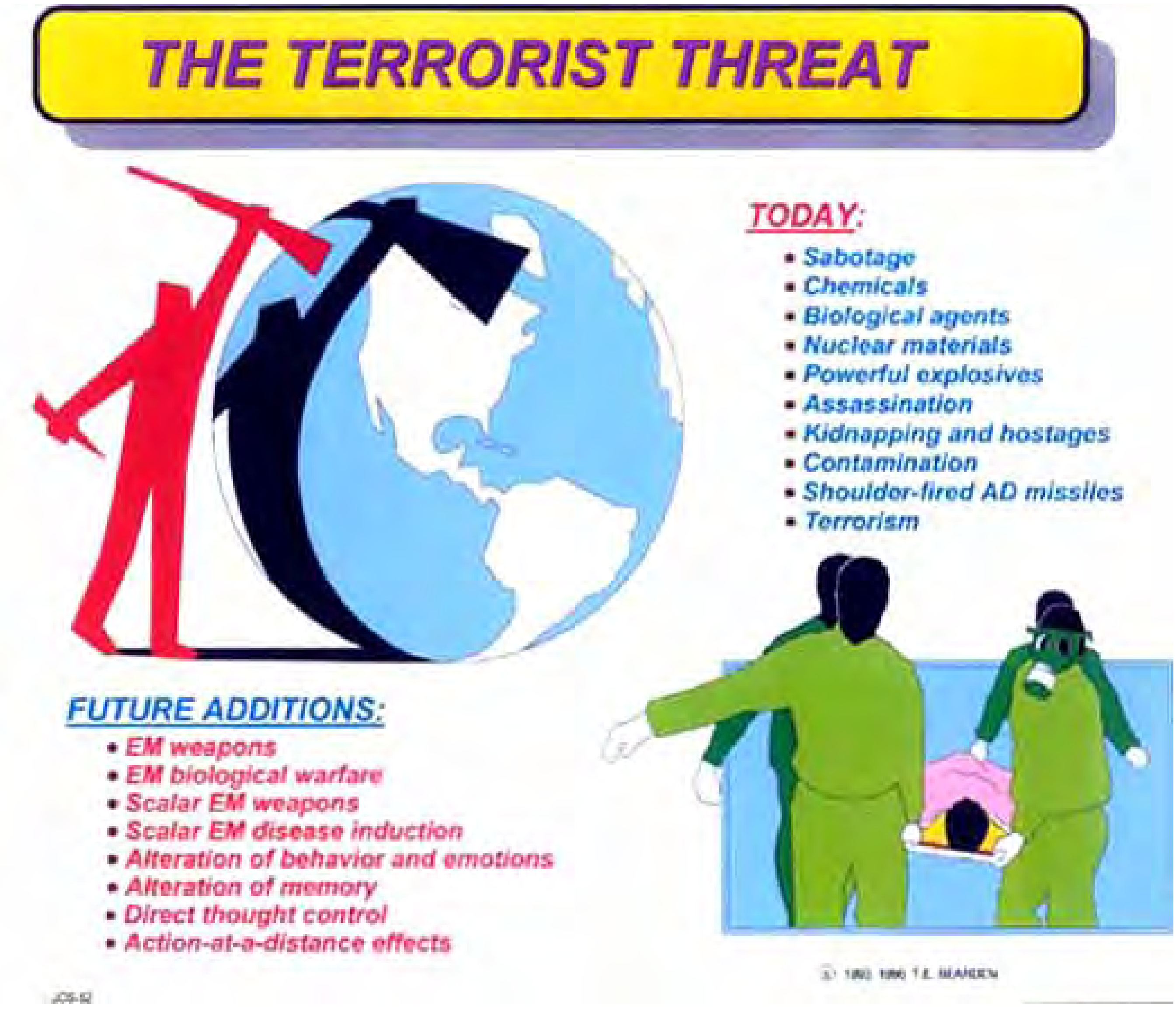

THE TERRORIST THREAT

TODAY:

- Sabotage
- Chemicals
- Biological agents
- Nuclear materials
- Powerful explosives
- Assassination
- Kidnapping and hostages
- Contamination
- Shoulder-fired AD missiles
- Terrorism

FUTURE ADDITIONS:

- EM weapons
- EM biological warfare
- Scalar EM weapons
- Scalar EM disease induction
- Alteration of behavior and emotions
- Alteration of memory
- Direct thought control
- Action-at-a-distance effects

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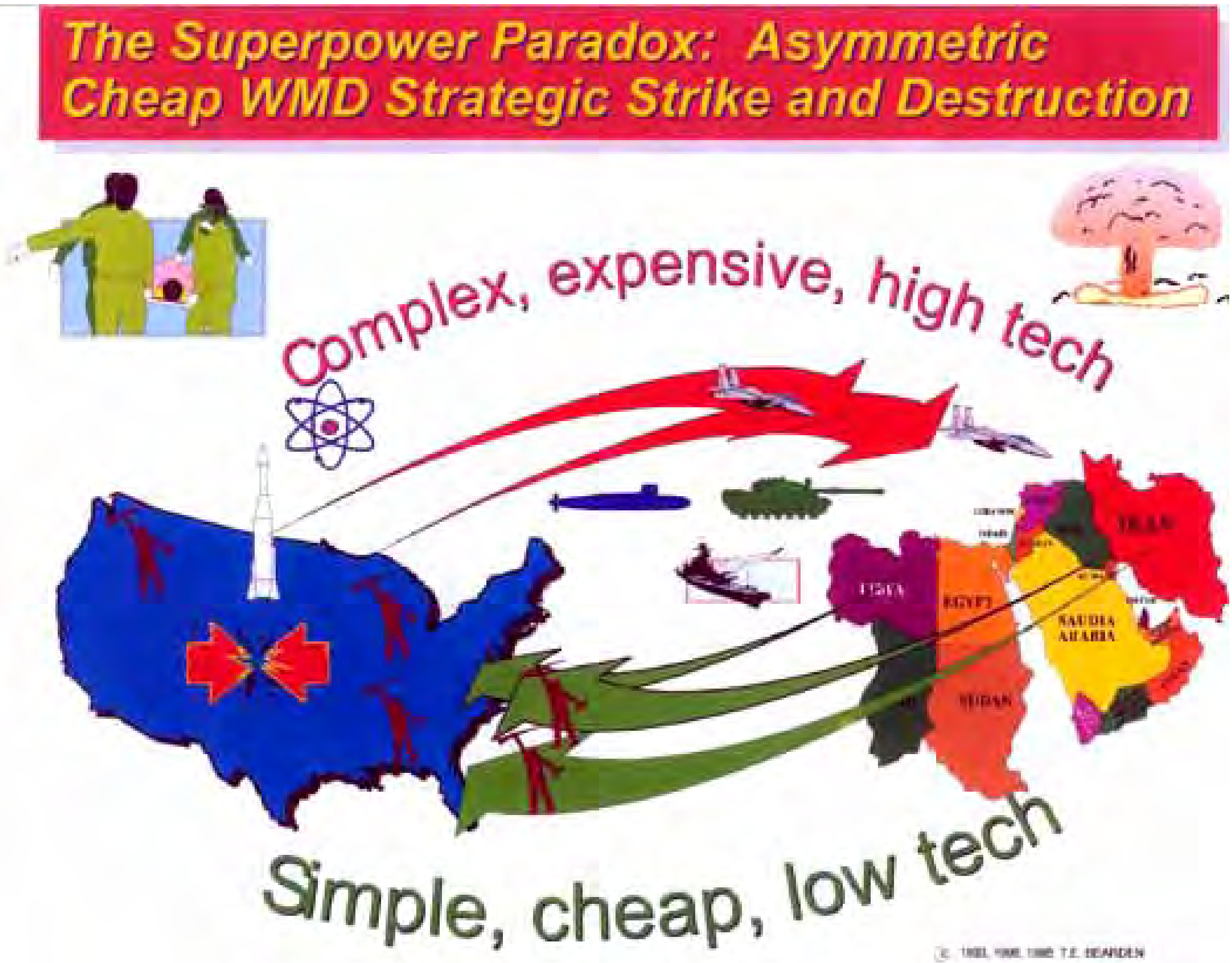

The Superpower Paradox: Asymmetric Cheap WMD Strategic Strike and Destruction

Complex, expensive, high tech

Simple, cheap, low tech

LIBYA
EGYPT
SUDAN
SAUDI ARABIA
IRAN

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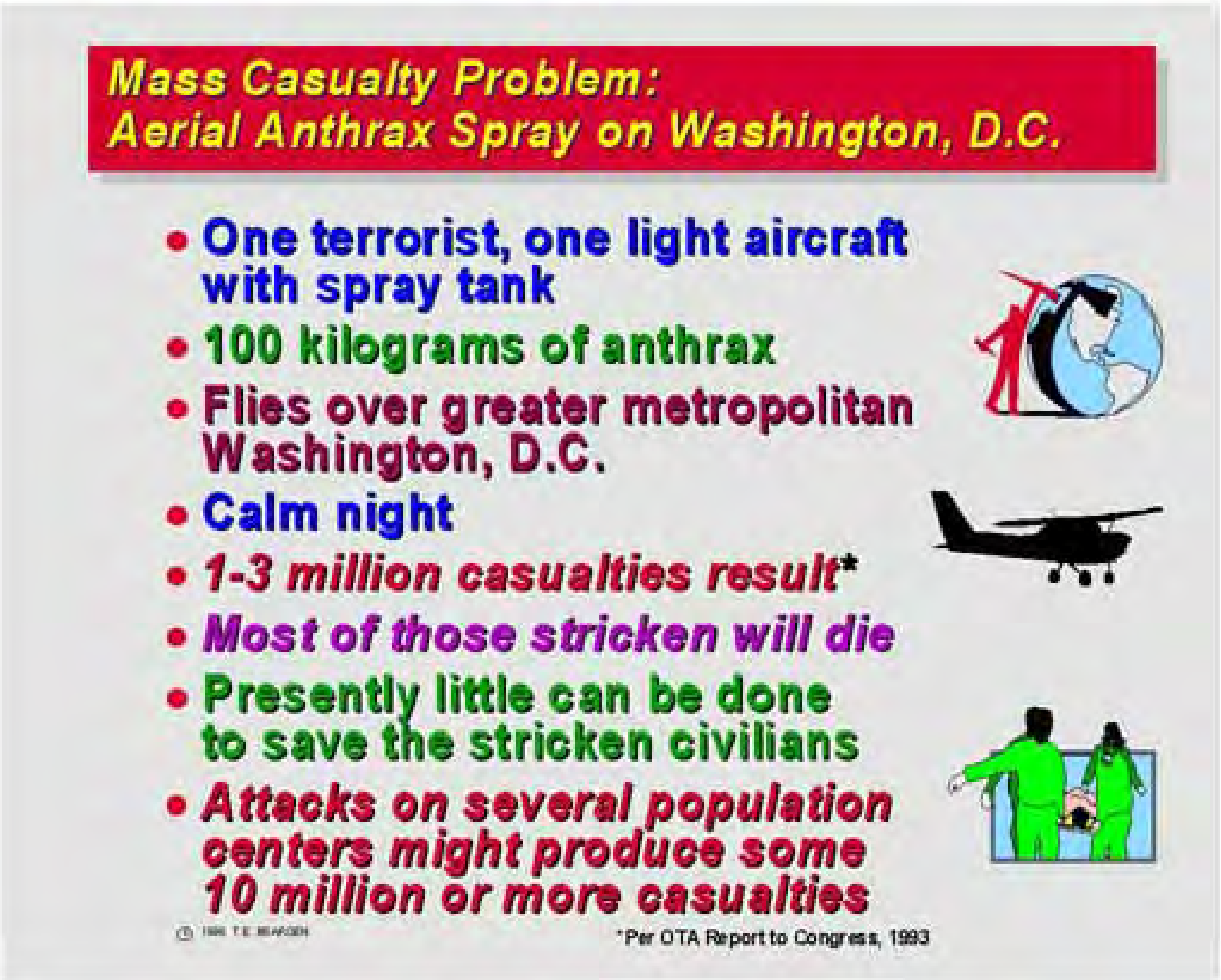

Mass Casualty Problem: Aerial Anthrax Spray on Washington, D.C.

- One terrorist, one light aircraft with spray tank
- 100 kilograms of anthrax
- Flies over greater metropolitan Washington, D.C.
- Calm night
- *1-3 million casualties result**
- *Most of those stricken will die*
- Presently little can be done to save the stricken civilians
- *Attacks on several population centers might produce some 10 million or more casualties*

*Per OTA Report to Congress, 1993

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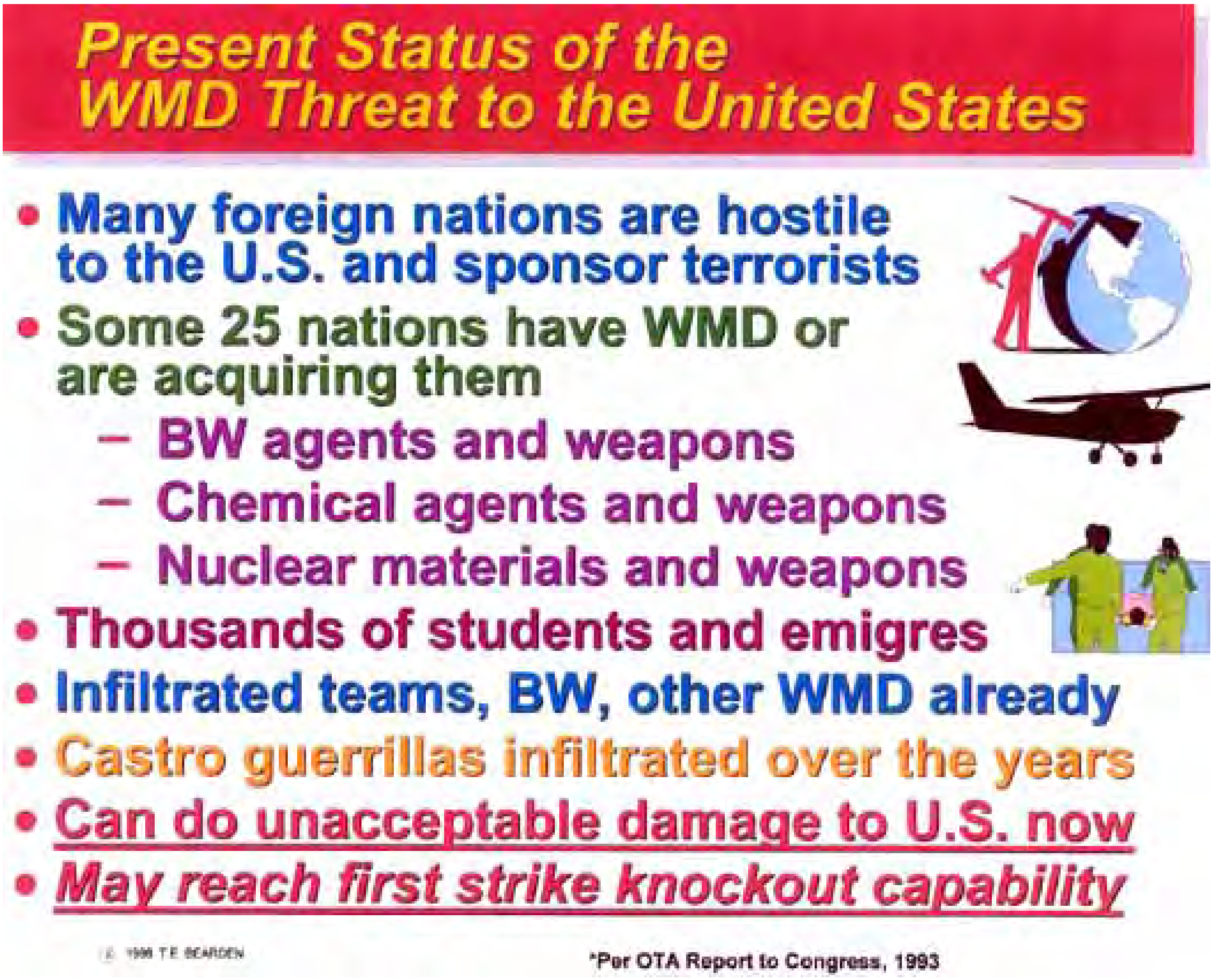

Present Status of the WMD Threat to the United States

- Many foreign nations are hostile to the U.S. and sponsor terrorists
- Some 25 nations have WMD or are acquiring them
  - BW agents and weapons
  - Chemical agents and weapons
  - Nuclear materials and weapons
- Thousands of students and emigres
- Infiltrated teams, BW, other WMD already
- Castro guerrillas infiltrated over the years
- Can do unacceptable damage to U.S. now
- *May reach first strike knockout capability*

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*Per OTA Report to Congress, 1993

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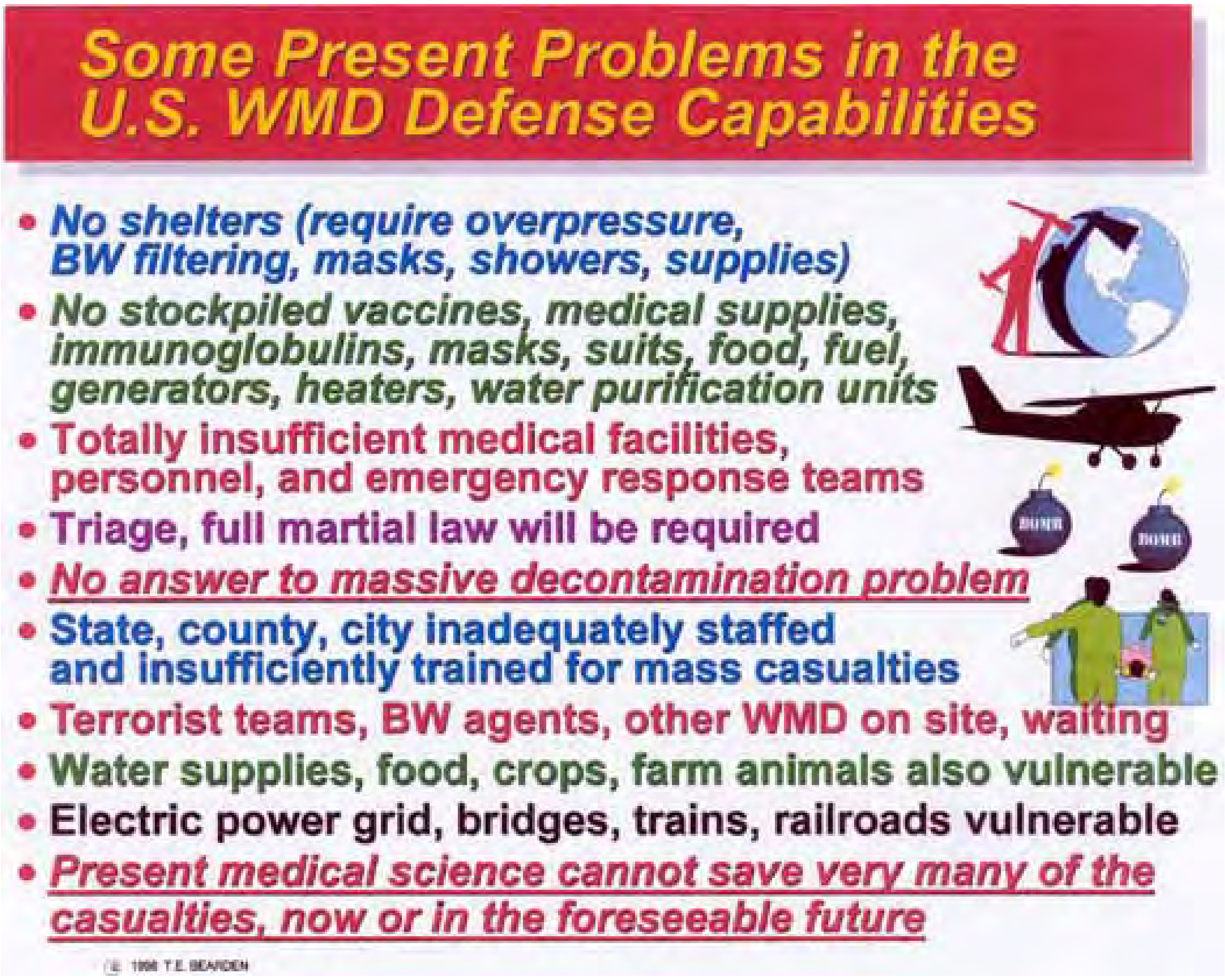

Some Present Problems in the U.S. WMD Defense Capabilities

- *No shelters (require overpressure, BW filtering, masks, showers, supplies)*
- *No stockpiled vaccines, medical supplies, immunoglobulins, masks, suits, food, fuel, generators, heaters, water purification units*
- Totally insufficient medical facilities, personnel, and emergency response teams
- Triage, full martial law will be required
- *No answer to massive decontamination problem*
- State, county, city inadequately staffed and insufficiently trained for mass casualties
- Terrorist teams, BW agents, other WMD on site, waiting
- Water supplies, food, crops, farm animals also vulnerable
- Electric power grid, bridges, trains, railroads vulnerable
- *Present medical science cannot save very many of the casualties, now or in the foreseeable future*

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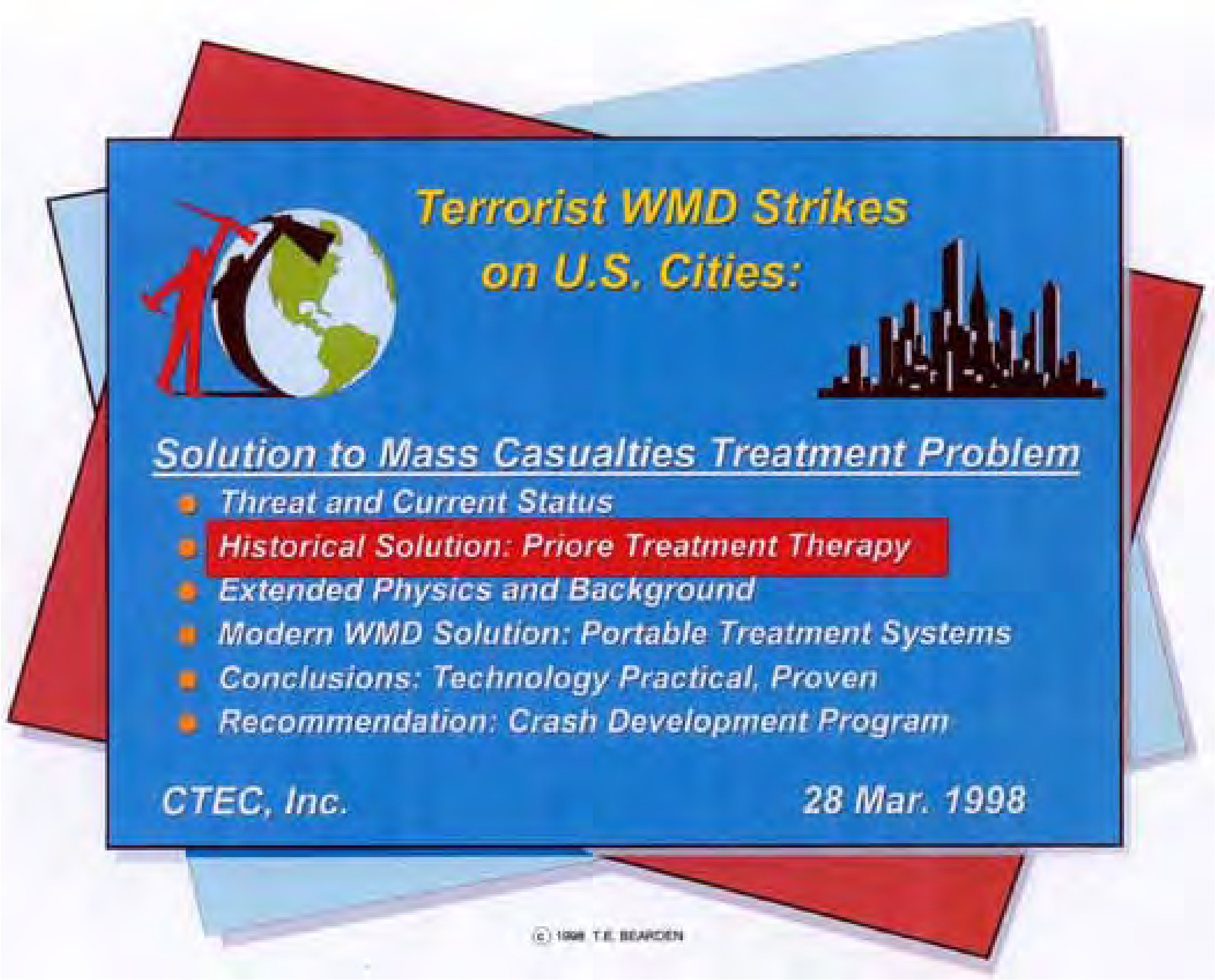

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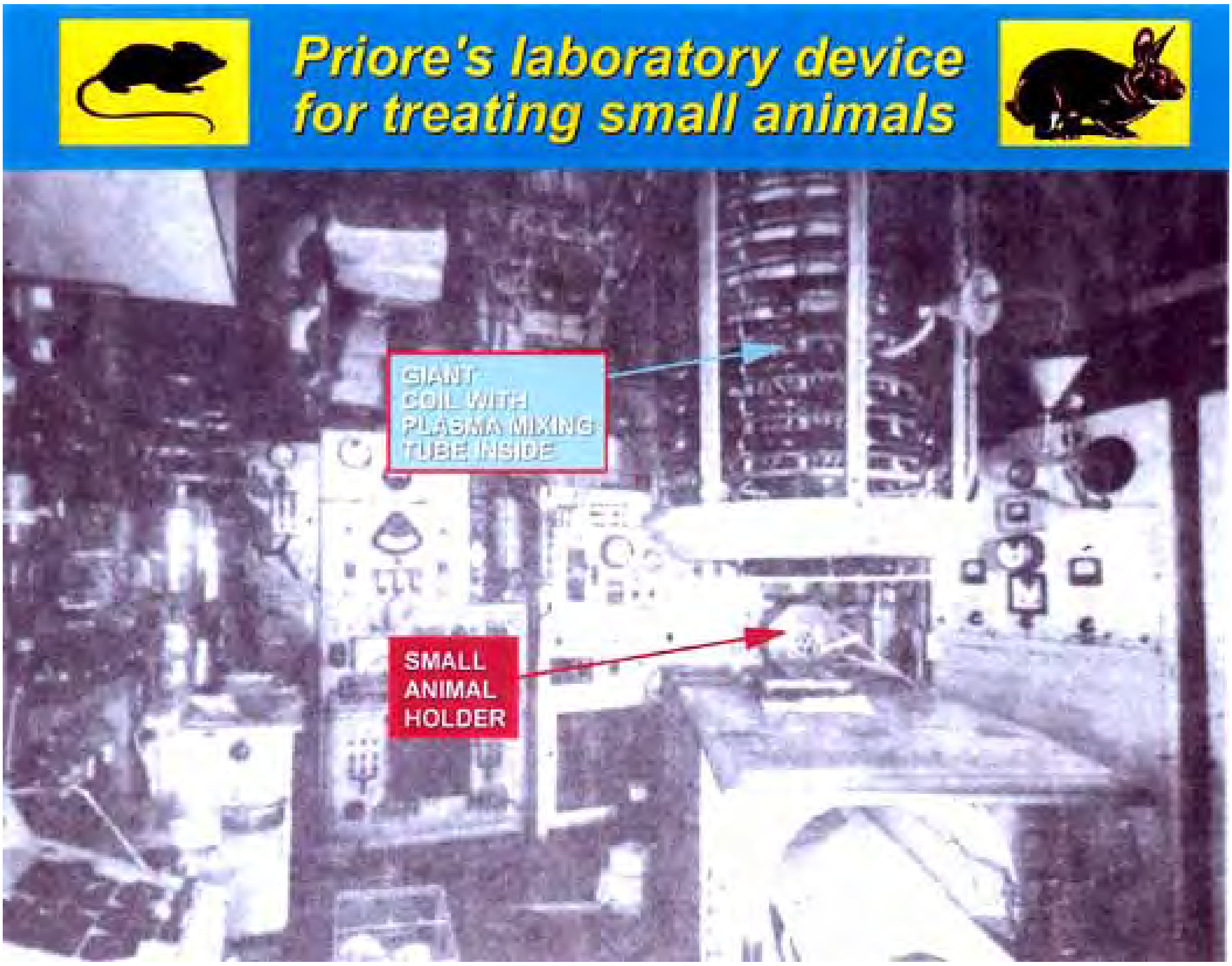

Priore's laboratory device for treating small animals

GIANT COIL WITH PLASMA MIXING TUBE INSIDE

SMALL ANIMAL HOLDER

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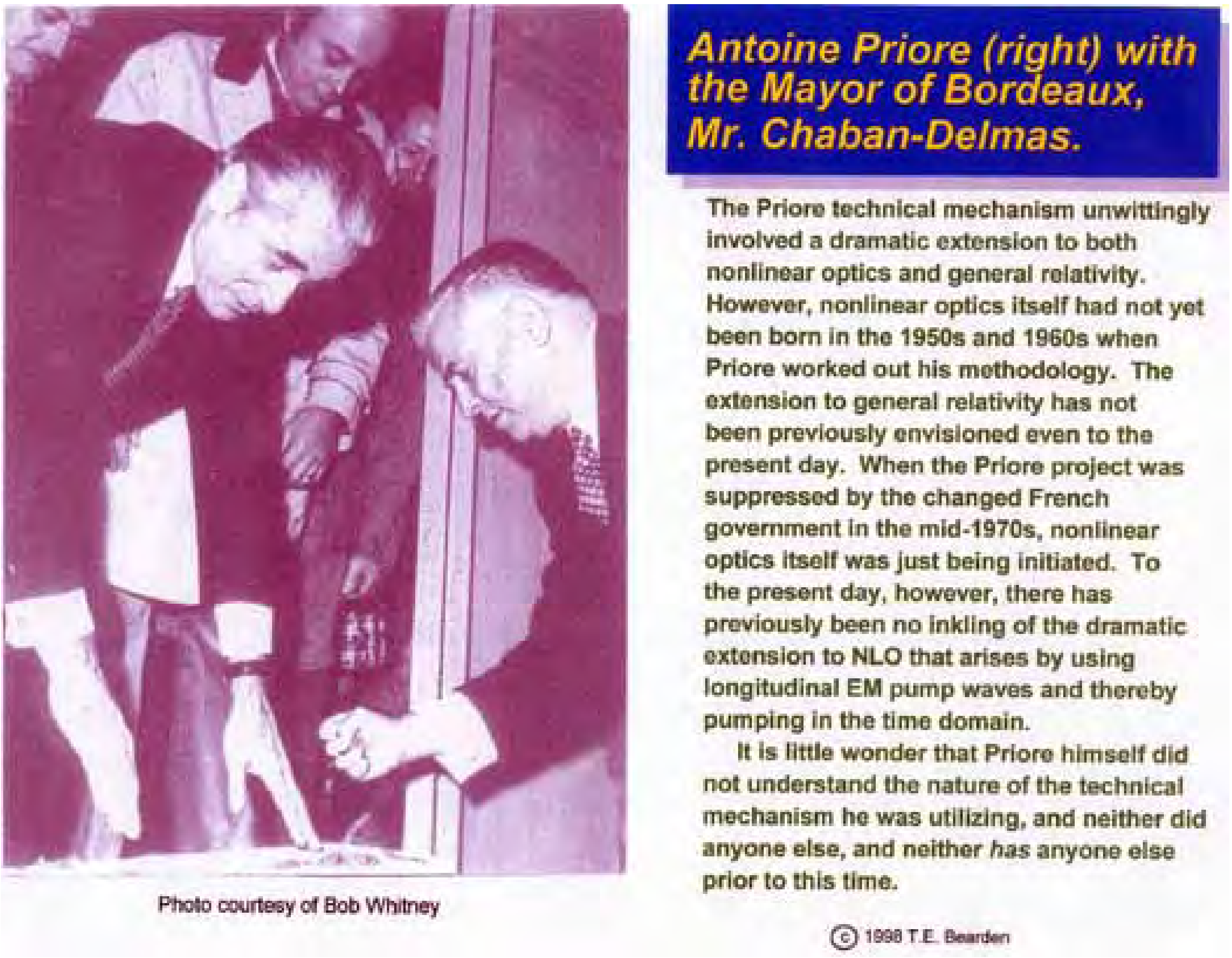

Antoine Priore (right) with the Mayor of Bordeaux, Mr. Chaban-Delmas.

Photo courtesy of Bob Whitney

The Priore technical mechanism unwittingly involved a dramatic extension to both nonlinear optics and general relativity. However, nonlinear optics itself had not yet been born in the 1950s and 1960s when Priore worked out his methodology. The extension to general relativity has not been previously envisioned even to the present day. When the Priore project was suppressed by the changed French government in the mid-1970s, nonlinear optics itself was just being initiated. To the present day, however, there has previously been no inkling of the dramatic extension to NLO that arises by using longitudinal EM pump waves and thereby pumping in the time domain.

It is little wonder that Priore himself did not understand the nature of the technical mechanism he was utilizing, and neither did anyone else, and neither *has* anyone else prior to this time.

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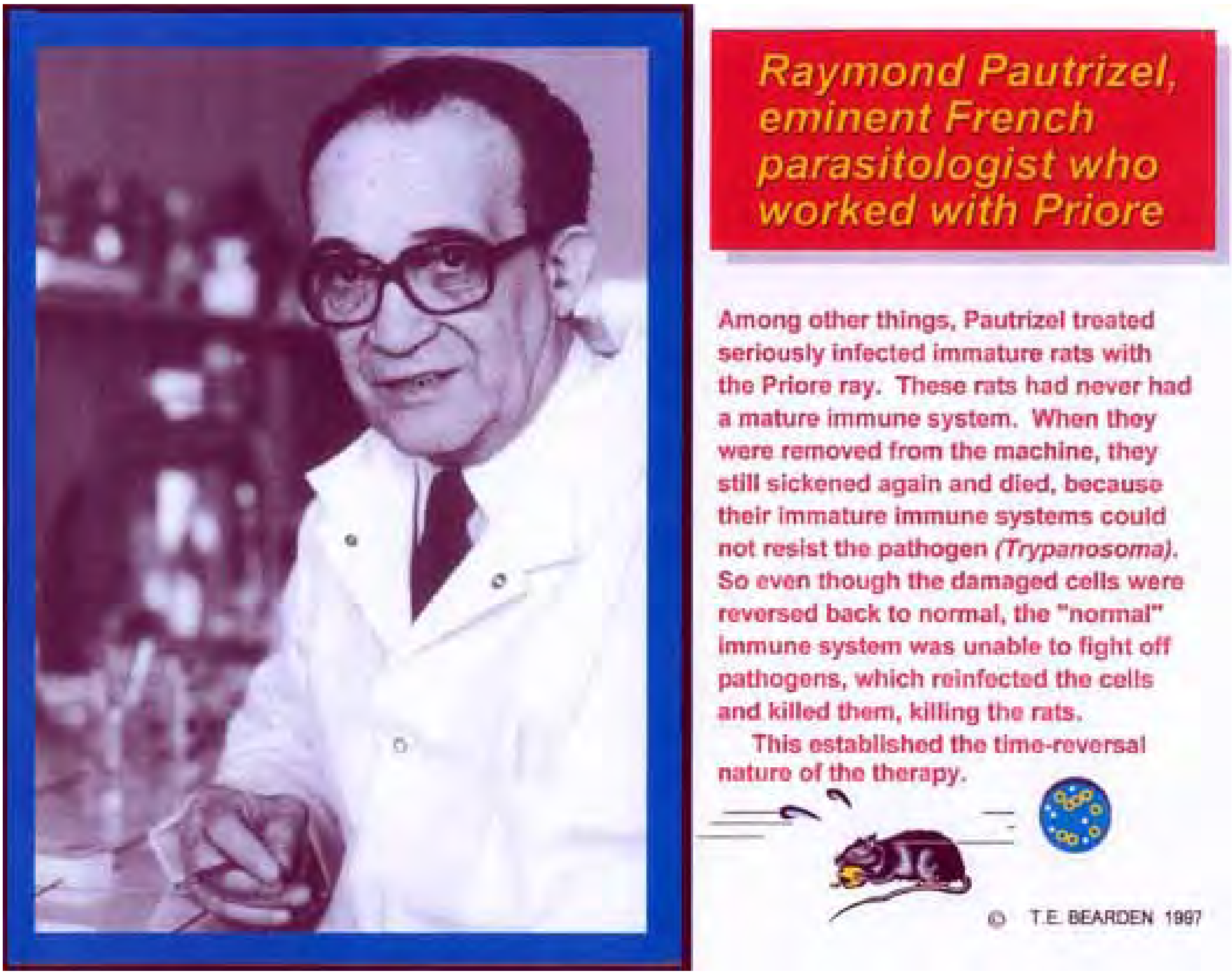

Raymond Pautrizel, eminent French parasitologist who worked with Priore

Among other things, Pautrizel treated seriously infected immature rats with the Priore ray. These rats had never had a mature immune system. When they were removed from the machine, they still sickened again and died, because their immature immune systems could not resist the pathogen *(Trypanosoma)*. So even though the damaged cells were reversed back to normal, the "normal" immune system was unable to fight off pathogens, which reinfected the cells and killed them, killing the rats.

This established the time-reversal nature of the therapy.

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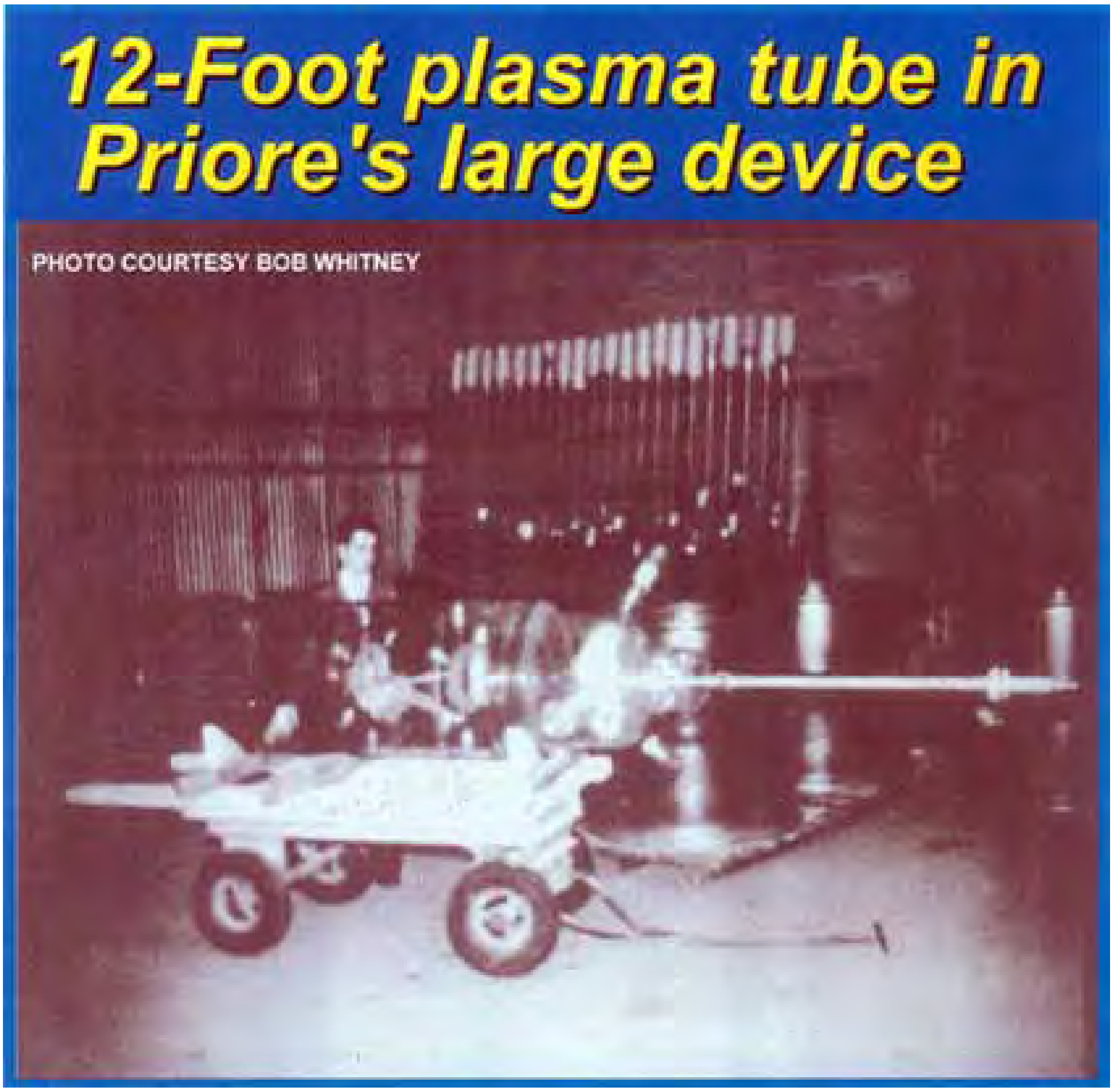

12-Foot plasma tube in Priore's large device

PHOTO COURTESY BOB WHITNEY

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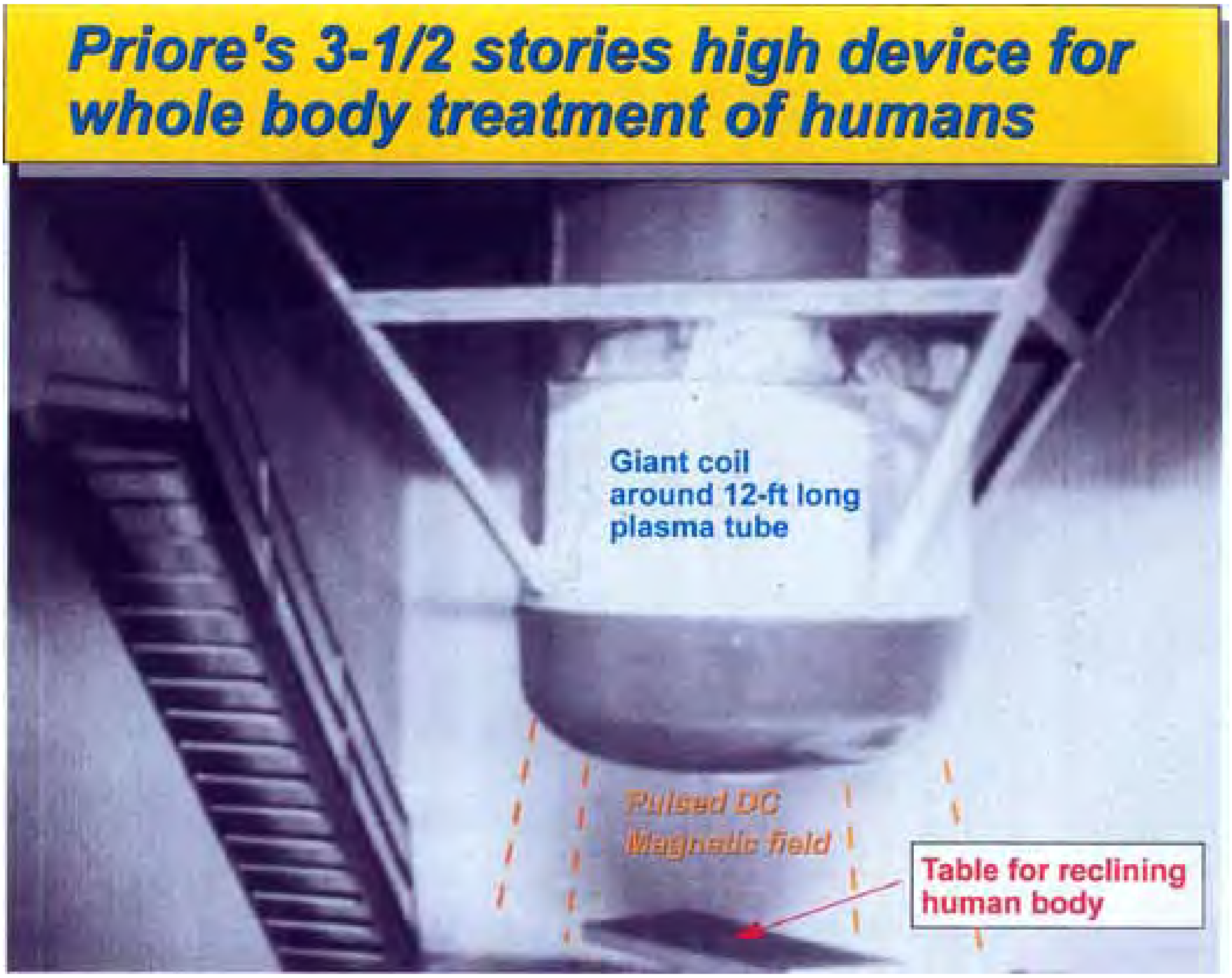

Priore's 3-1/2 stories high device for whole body treatment of humans

Giant coil
around 12-ft long
plasma tube
Pulsed DC
Magnetic field
Table for reclining
human body

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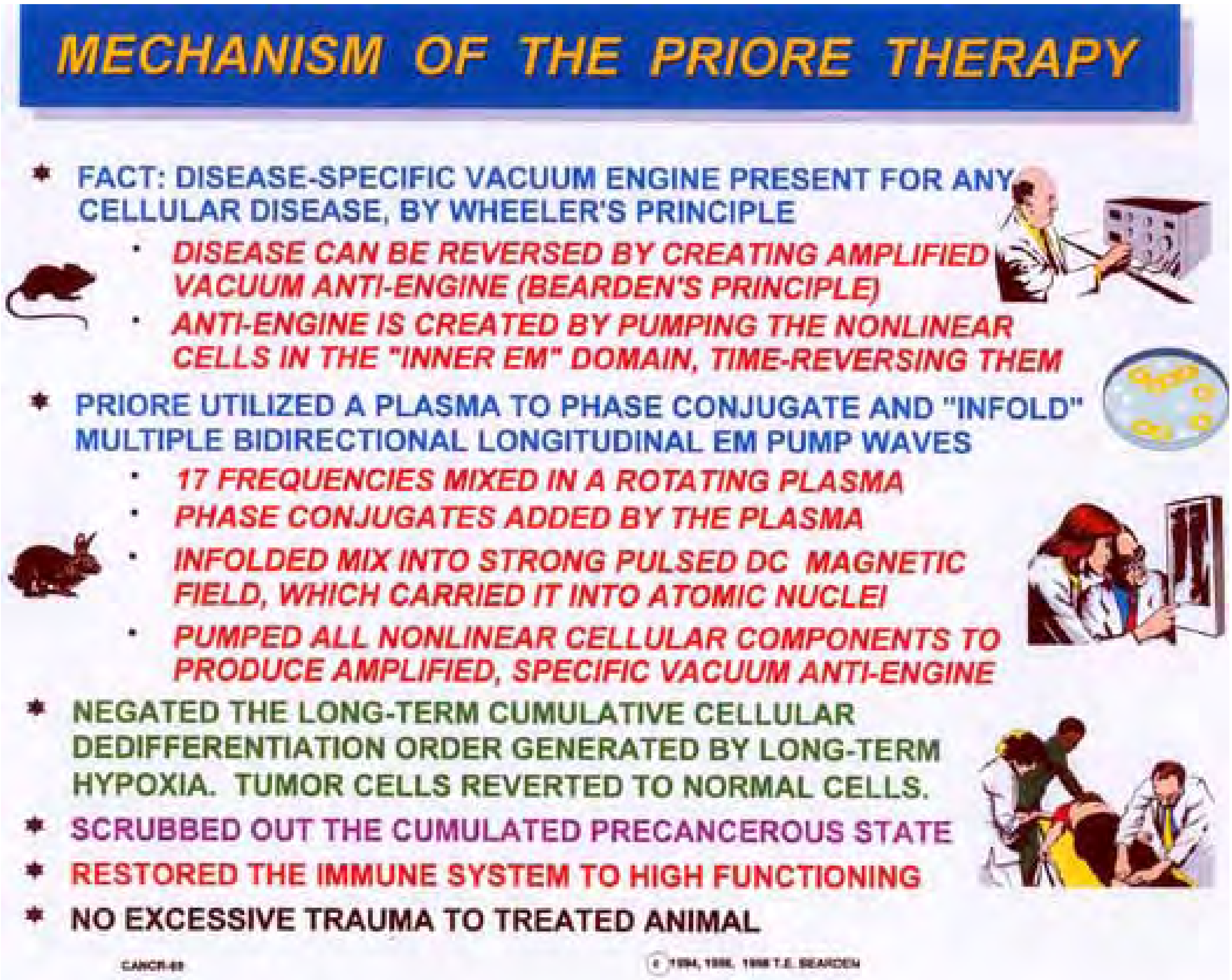

MECHANISM OF THE PRIORE THERAPY

- FACT: DISEASE-SPECIFIC VACUUM ENGINE PRESENT FOR ANY CELLULAR DISEASE, BY WHEELER'S PRINCIPLE
  - *DISEASE CAN BE REVERSED BY CREATING AMPLIFIED VACUUM ANTI-ENGINE (BEARDEN'S PRINCIPLE)*
  - *ANTI-ENGINE IS CREATED BY PUMPING THE NONLINEAR CELLS IN THE "INNER EM" DOMAIN, TIME-REVERSING THEM*
- PRIORE UTILIZED A PLASMA TO PHASE CONJUGATE AND "INFOLD" MULTIPLE BIDIRECTIONAL LONGITUDINAL EM PUMP WAVES
  - *17 FREQUENCIES MIXED IN A ROTATING PLASMA*
  - *PHASE CONJUGATES ADDED BY THE PLASMA*
  - *INFOLDED MIX INTO STRONG PULSED DC MAGNETIC FIELD, WHICH CARRIED IT INTO ATOMIC NUCLEI*
  - *PUMPED ALL NONLINEAR CELLULAR COMPONENTS TO PRODUCE AMPLIFIED, SPECIFIC VACUUM ANTI-ENGINE*
- NEGATED THE LONG-TERM CUMULATIVE CELLULAR DEDIFFERENTIATION ORDER GENERATED BY LONG-TERM HYPOXIA. TUMOR CELLS REVERTED TO NORMAL CELLS.
- SCRUBBED OUT THE CUMULATED PRECANCEROUS STATE
- RESTORED THE IMMUNE SYSTEM TO HIGH FUNCTIONING
- NO EXCESSIVE TRAUMA TO TREATED ANIMAL

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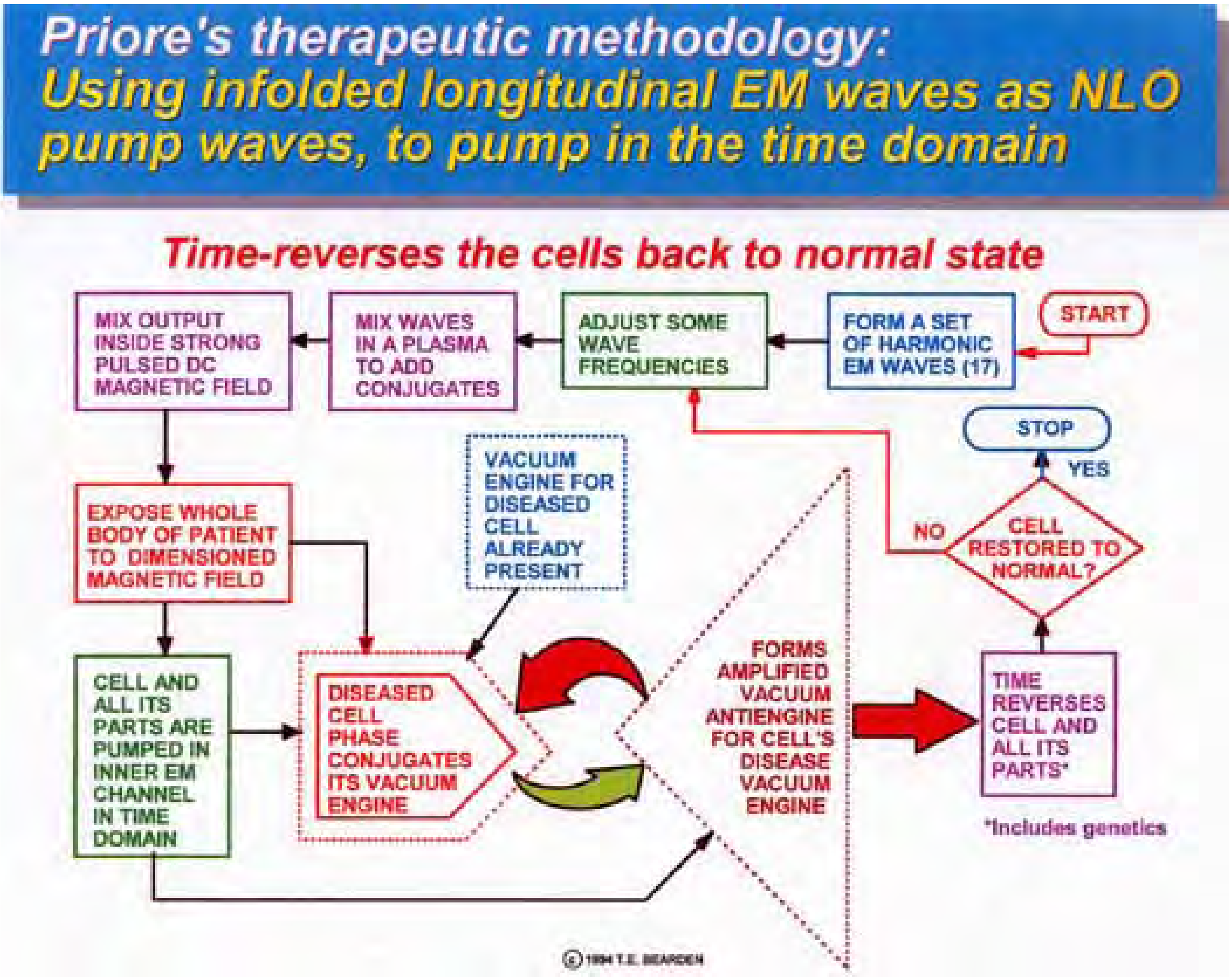

Priore's therapeutic methodology: Using infolded longitudinal EM waves as NLO pump waves, to pump in the time domain

Time-reverses the cells back to normal state

START

FORM A SET OF HARMONIC EM WAVES (17)

ADJUST SOME WAVE FREQUENCIES

MIX WAVES IN A PLASMA TO ADD CONJUGATES

MIX OUTPUT INSIDE STRONG PULSED DC MAGNETIC FIELD

EXPOSE WHOLE BODY OF PATIENT TO DIMENSIONED MAGNETIC FIELD

CELL AND ALL ITS PARTS ARE PUMPED IN INNER EM CHANNEL IN TIME DOMAIN

VACUUM ENGINE FOR DISEASED CELL ALREADY PRESENT

DISEASED CELL PHASE CONJUGATES ITS VACUUM ENGINE

FORMS AMPLIFIED VACUUM ANTIENGINE FOR CELL'S DISEASE VACUUM ENGINE

TIME REVERSES CELL AND ALL ITS PARTS*

CELL RESTORED TO NORMAL?

NO

YES

STOP

*Includes genetics

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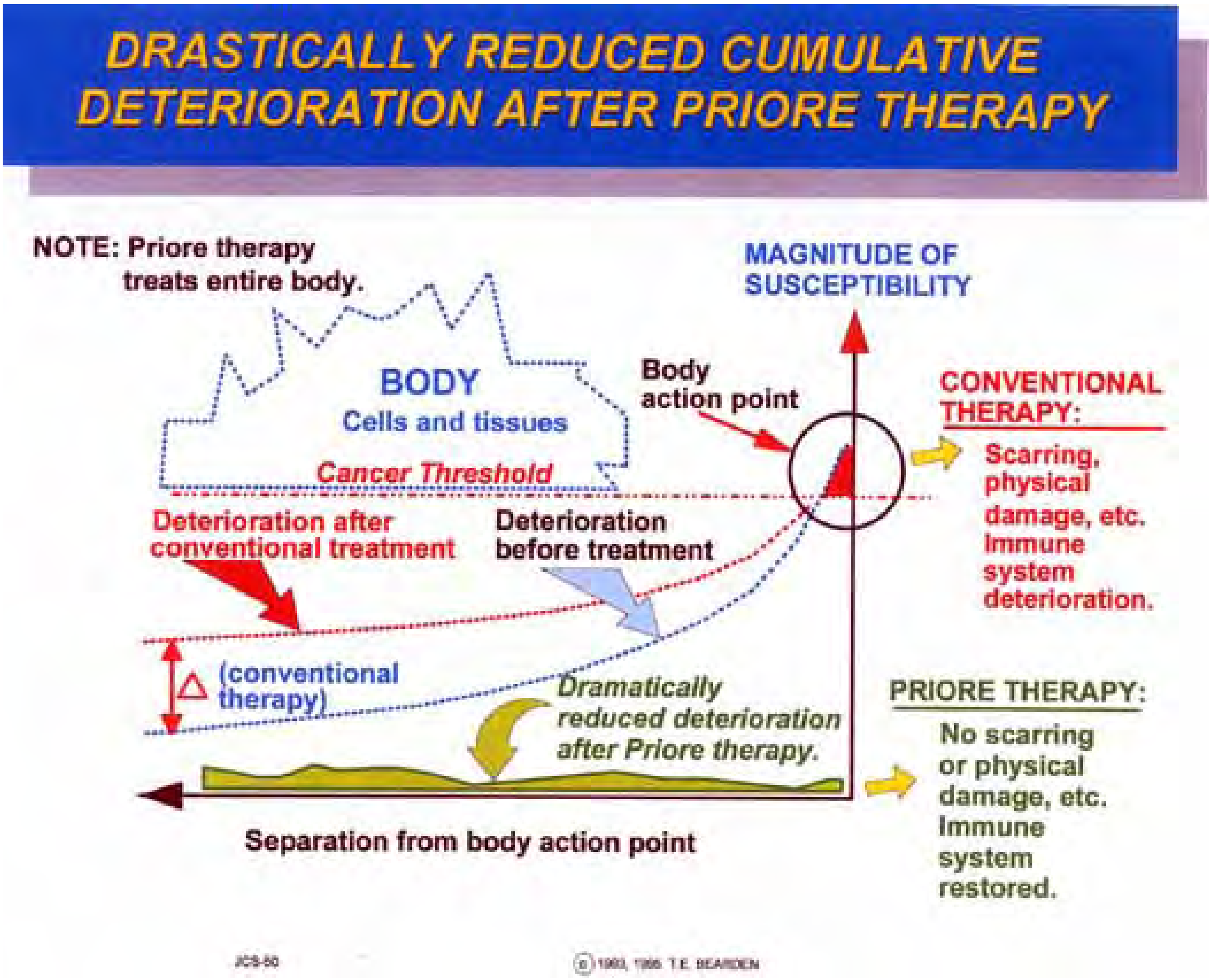

DRASTICALLY REDUCED CUMULATIVE DETERIORATION AFTER PRIORE THERAPY

NOTE: Priore therapy treats entire body.

BODY
Cells and tissues
Cancer Threshold
Body action point
MAGNITUDE OF SUSCEPTIBILITY
Deterioration after conventional treatment
Deterioration before treatment
Δ (conventional therapy)
Dramatically reduced deterioration after Priore therapy.
Separation from body action point

CONVENTIONAL THERAPY:

Scarring, physical damage, etc. Immune system deterioration.

PRIORE THERAPY:

No scarring or physical damage, etc. Immune system restored.

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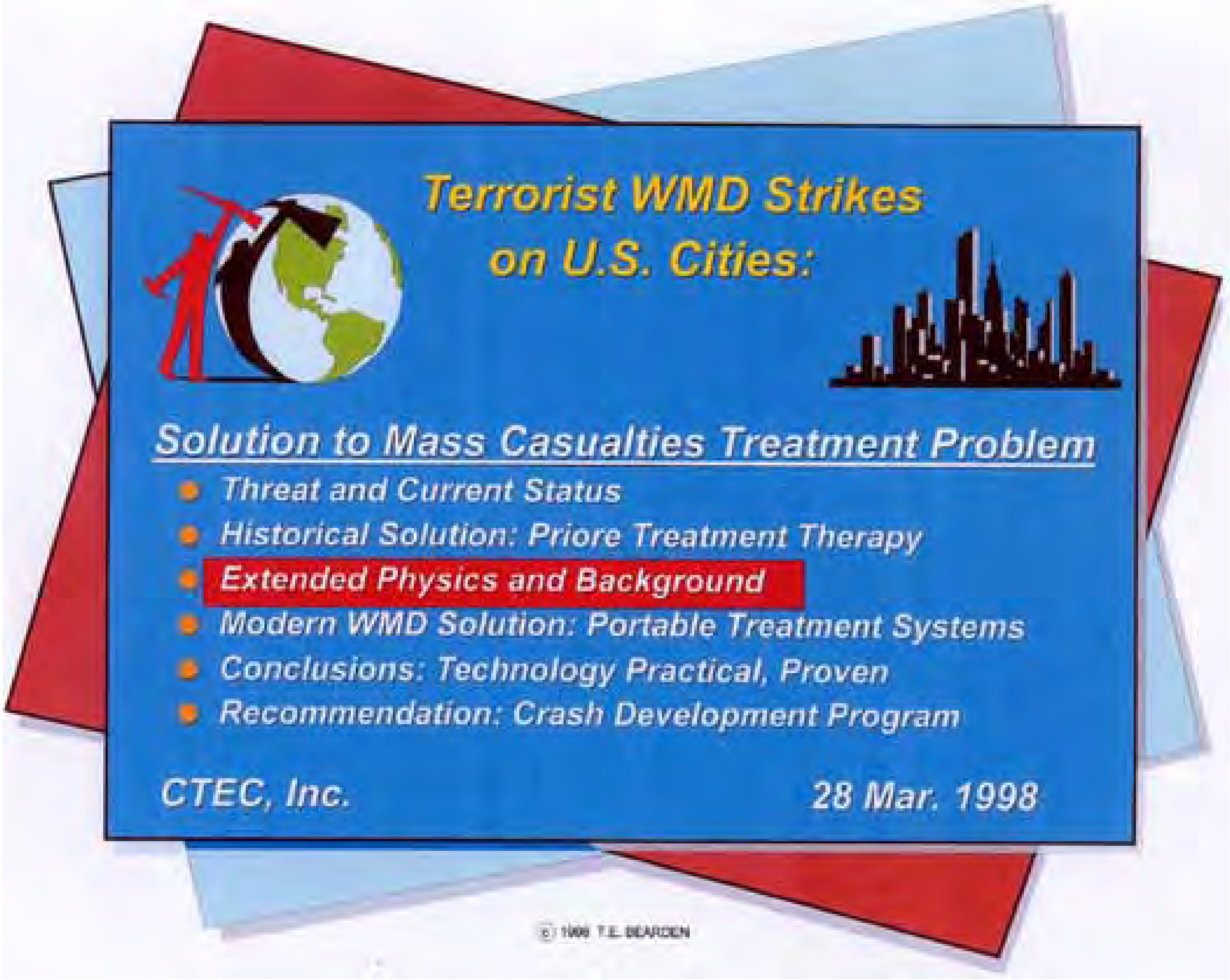

Terrorist WMD Strikes
on U.S. Cities:

Solution to Mass Casualties Treatment Problem

- Threat and Current Status
- Historical Solution: Priore Treatment Therapy
- Extended Physics and Background
- Modern WMD Solution: Portable Treatment Systems
- Conclusions: Technology Practical, Proven
- Recommendation: Crash Development Program

CTEC, Inc.

28 Mar. 1998

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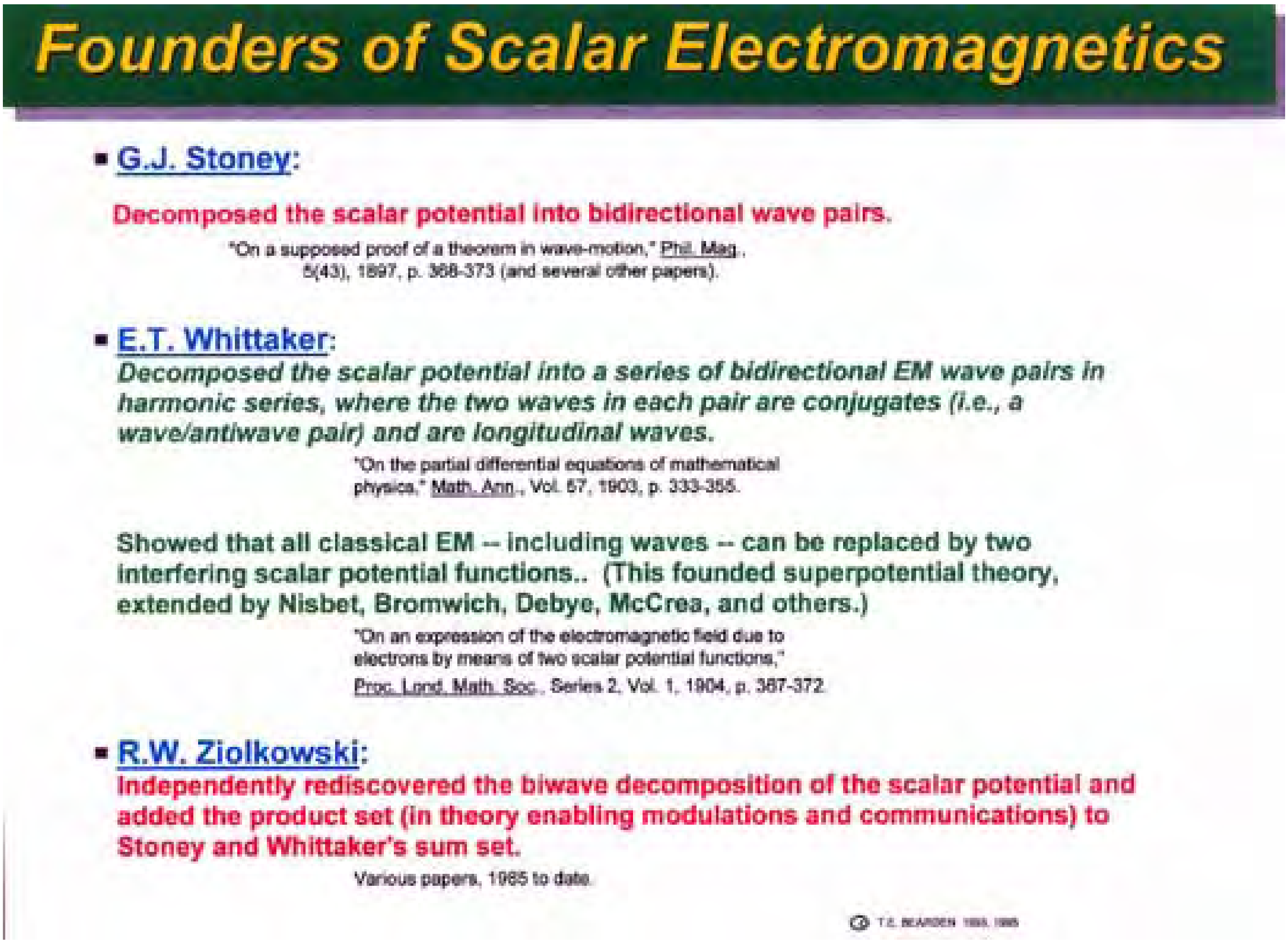

Founders of Scalar Electromagnetics

- **G.J. Stoney:**

Decomposed the scalar potential into bidirectional wave pairs.

"On a supposed proof of a theorem in wave-motion," Phil. Mag., 5(43), 1897, p. 368-373 (and several other papers).

- **E.T. Whittaker:**

Decomposed the scalar potential into a series of bidirectional EM wave pairs in harmonic series, where the two waves in each pair are conjugates (i.e., a wave/antiwave pair) and are longitudinal waves.

"On the partial differential equations of mathematical physics," Math. Ann., Vol. 57, 1903, p. 333-355.

Showed that all classical EM -- including waves -- can be replaced by two interfering scalar potential functions.. (This founded superpotential theory, extended by Nisbet, Bromwich, Debye, McCrea, and others.)

"On an expression of the electromagnetic field due to electrons by means of two scalar potential functions," Proc. Lond. Math. Soc., Series 2, Vol. 1, 1904, p. 367-372.

- **R.W. Ziolkowski:**

Independently rediscovered the biwave decomposition of the scalar potential and added the product set (in theory enabling modulations and communications) to Stoney and Whittaker's sum set.

Various papers, 1985 to date.

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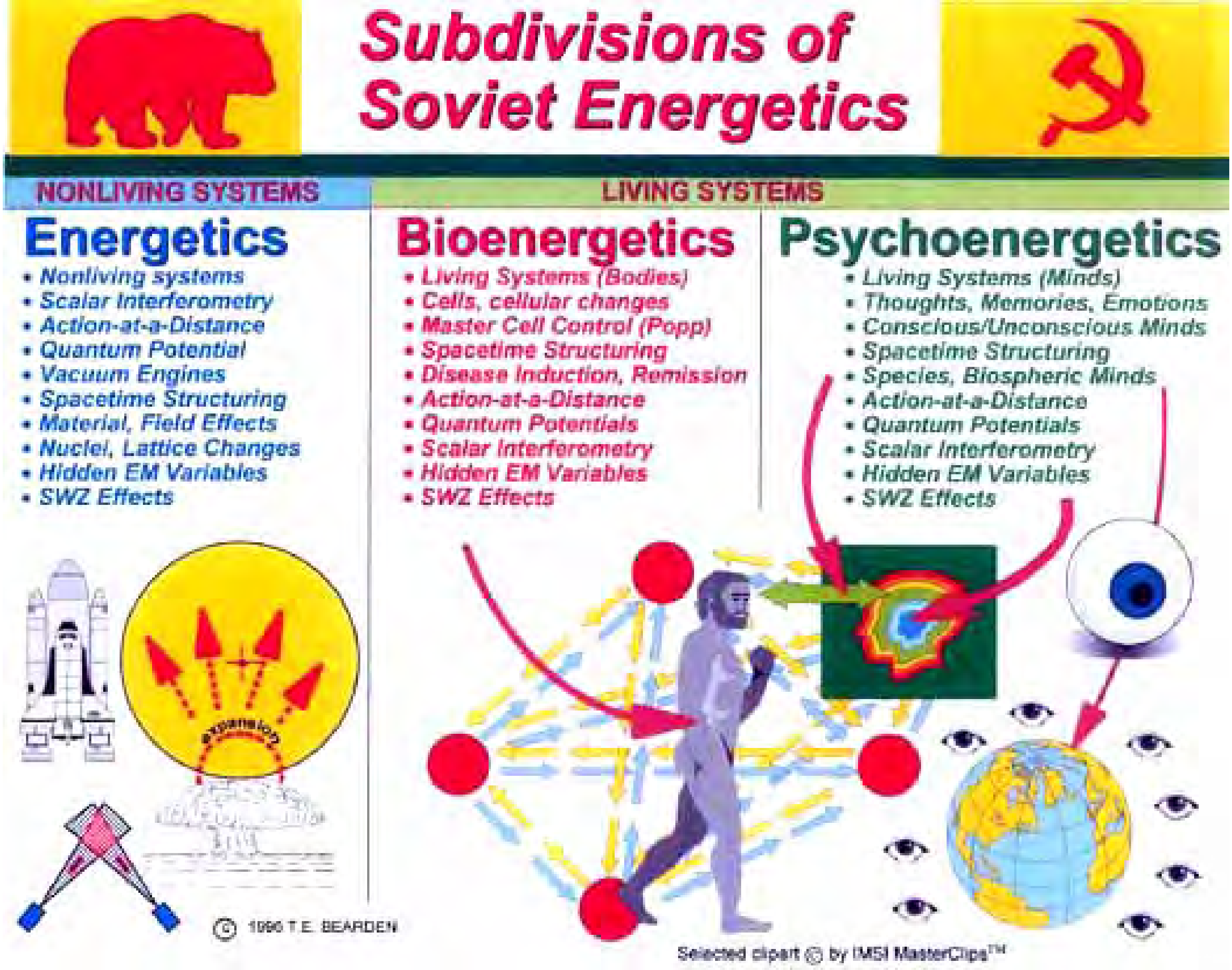

Subdivisions of Soviet Energetics

NONLIVING SYSTEMS

Energetics

- Nonliving systems
- Scalar Interferometry
- Action-at-a-Distance
- Quantum Potential
- Vacuum Engines
- Spacetime Structuring
- Material, Field Effects
- Nuclei, Lattice Changes
- Hidden EM Variables
- SWZ Effects

LIVING SYSTEMS

Bioenergetics

- Living Systems (Bodies)
- Cells, cellular changes
- Master Cell Control (Popp)
- Spacetime Structuring
- Disease Induction, Remission
- Action-at-a-Distance
- Quantum Potentials
- Scalar Interferometry
- Hidden EM Variables
- SWZ Effects

Psychoenergetics

- Living Systems (Minds)
- Thoughts, Memories, Emotions
- Conscious/Unconscious Minds
- Spacetime Structuring
- Species, Biospheric Minds
- Action-at-a-Distance
- Quantum Potentials
- Scalar Interferometry
- Hidden EM Variables
- SWZ Effects

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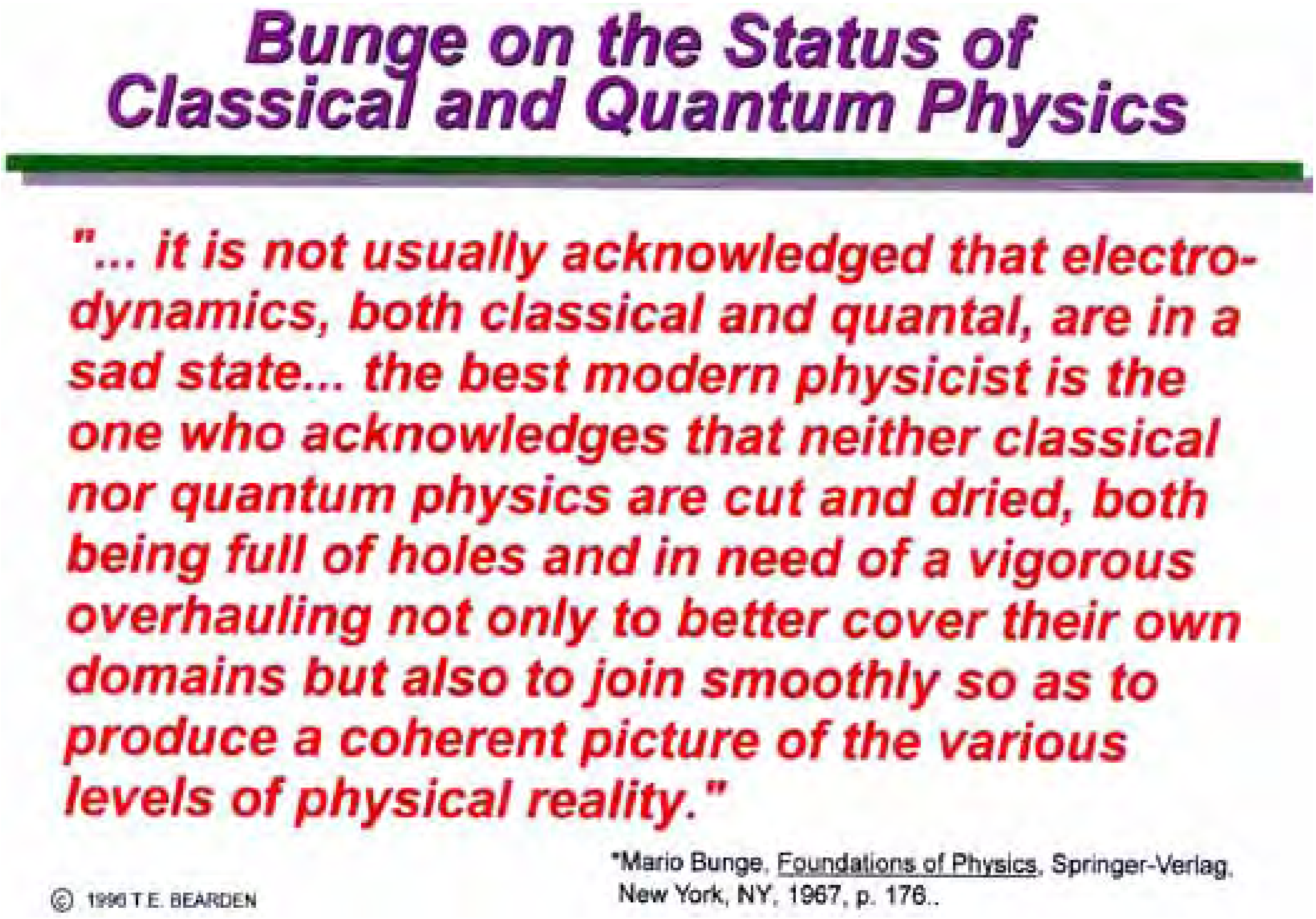

Bunge on the Status of Classical and Quantum Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling not only to better cover their own domains but also to join smoothly so as to produce a coherent picture of the various levels of physical reality."

*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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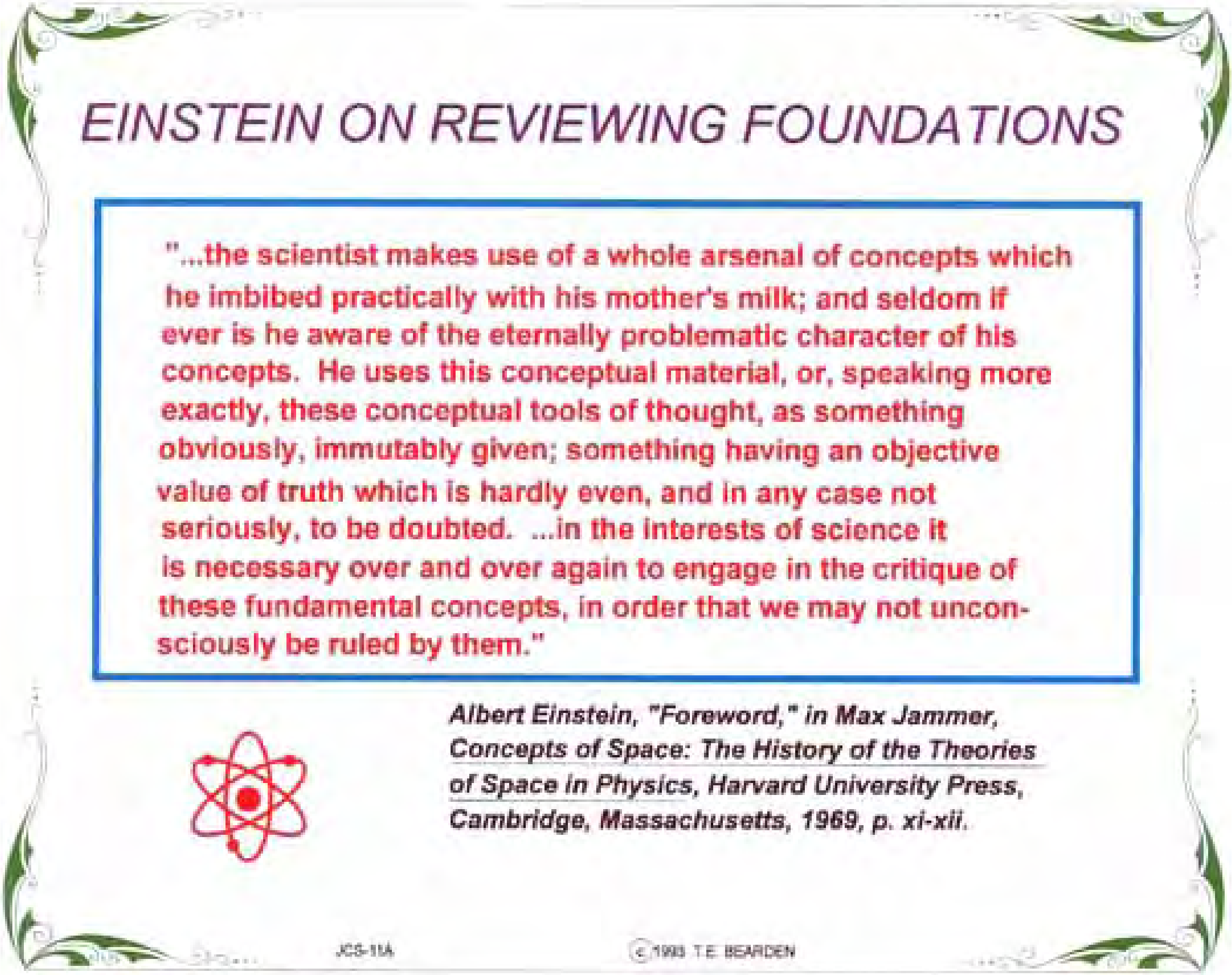

EINSTEIN ON REVIEWING FOUNDATIONS

"...the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the eternally problematic character of his concepts. He uses this conceptual material, or, speaking more exactly, these conceptual tools of thought, as something obviously, immutably given; something having an objective value of truth which is hardly even, and in any case not seriously, to be doubted. ...in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them."

Albert Einstein, "Foreword," in Max Jammer, Concepts of Space: The History of the Theories of Space in Physics, Harvard University Press, Cambridge, Massachusetts, 1969, p. xi-xii.

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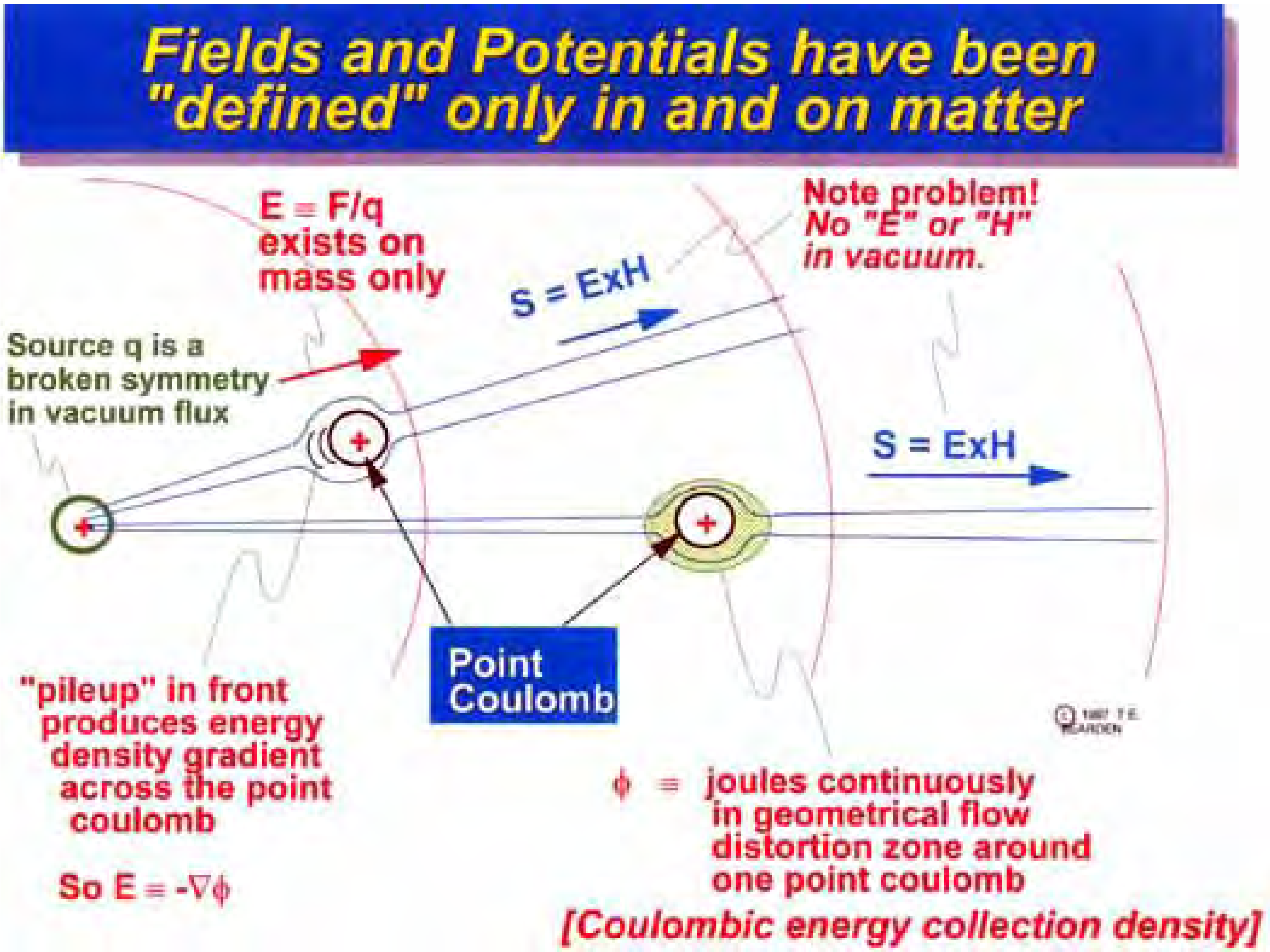

Fields and Potentials have been "defined" only in and on matter

E ≡ F/q
exists on
mass only

Note problem!
No "E" or "H"
in vacuum.

S = ExH

Source q is a
broken symmetry
in vacuum flux

S = ExH

Point
Coulomb

"pileup" in front
produces energy
density gradient
across the point
coulomb

So $E \equiv -\nabla\phi$

ϕ ≡ joules continuously
in geometrical flow
distortion zone around
one point coulomb

[Coulombic energy collection density]

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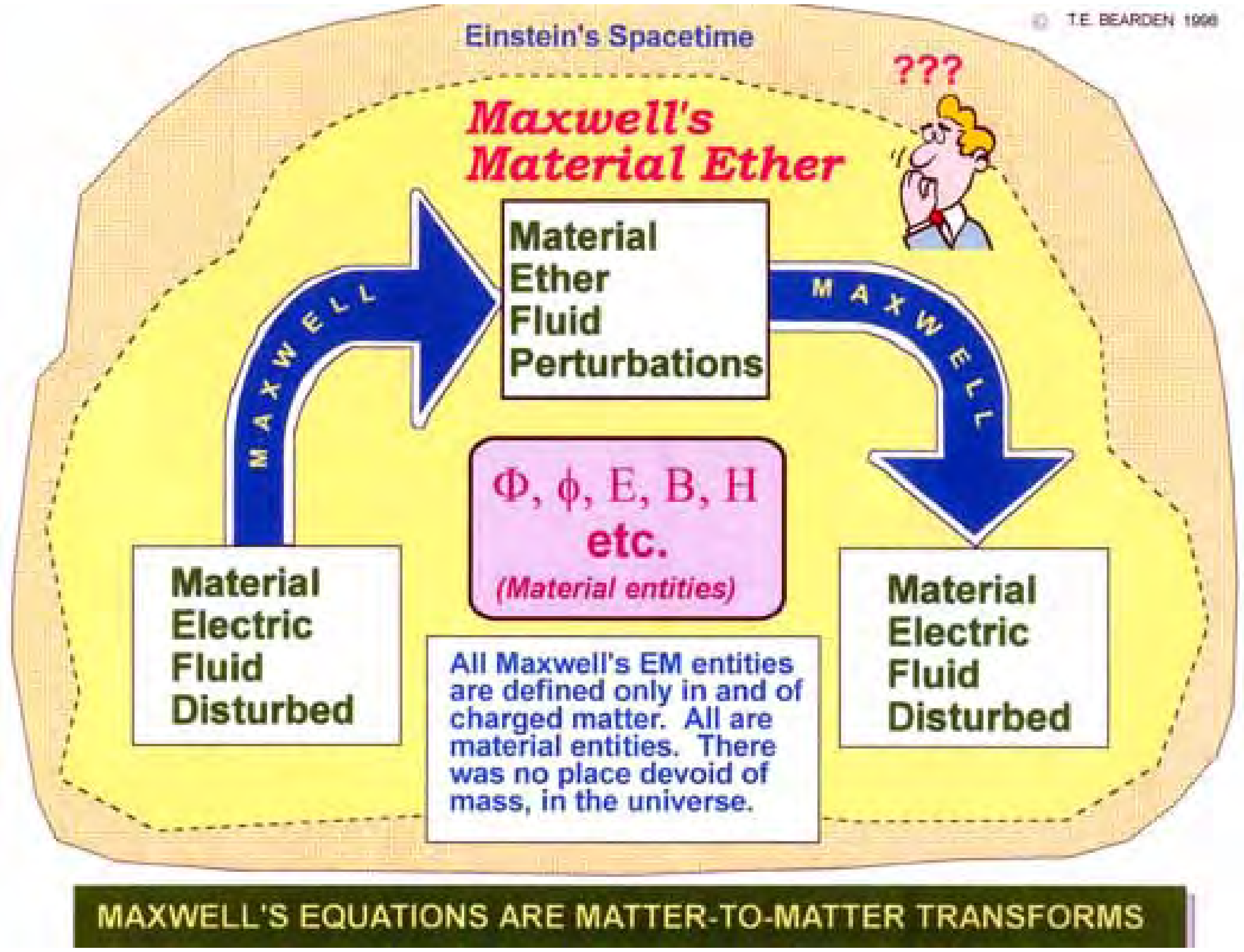

Einstein's Spacetime

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Maxwell's Material Ether

Material Ether Fluid Perturbations

Material Electric Fluid Disturbed

Φ, ϕ, E, B, H **etc.**

(Material entities)

Material Electric Fluid Disturbed

All Maxwell's EM entities are defined only in and of charged matter. All are material entities. There was no place devoid of mass, in the universe.

MAXWELL'S EQUATIONS ARE MATTER-TO-MATTER TRANSFORMS

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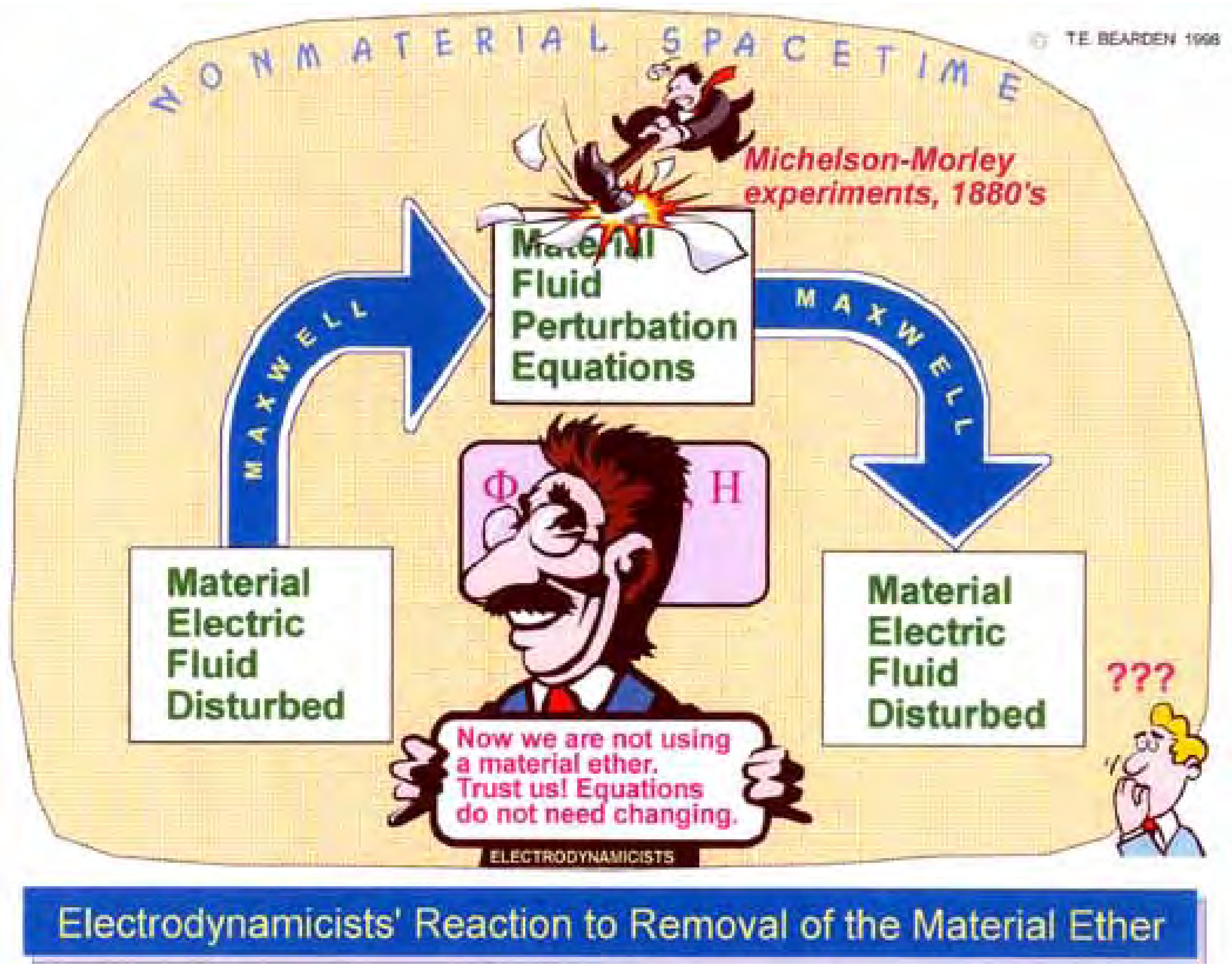

NONMATERIAL SPACETIME

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Michelson-Morley experiments, 1880's

Material Fluid Perturbation Equations

MAXWELL

MAXWELL

Material Electric Fluid Disturbed

Material Electric Fluid Disturbed

Φ

H

Now we are not using a material ether. Trust us! Equations do not need changing.

ELECTRODYNAMICISTS

???

Electrodynamicists' Reaction to Removal of the Material Ether

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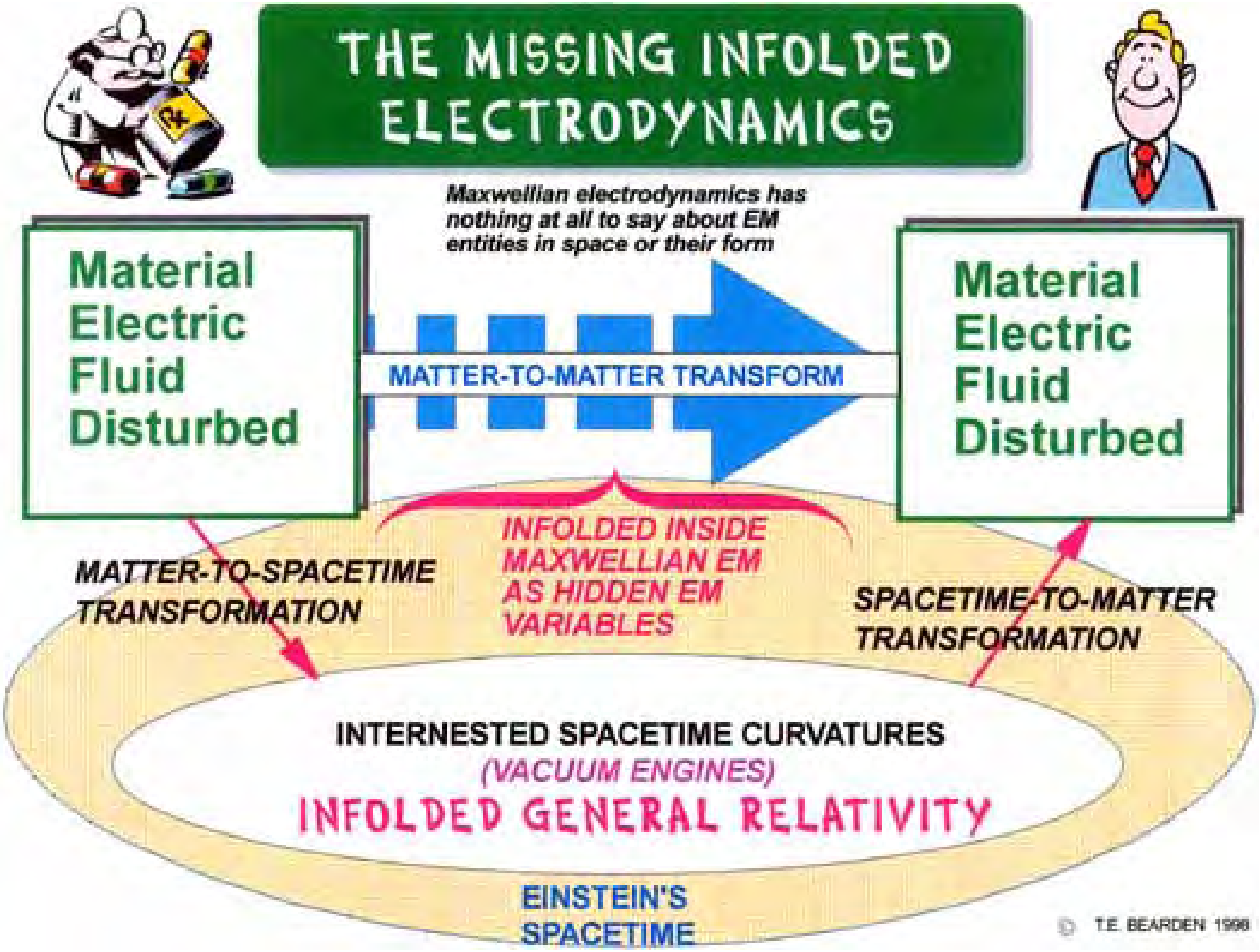

THE MISSING INFOLDED ELECTRODYNAMICS

Maxwellian electrodynamics has nothing at all to say about EM entities in space or their form

Material Electric Fluid Disturbed

MATTER-TO-MATTER TRANSFORM

Material Electric Fluid Disturbed

MATTER-TO-SPACETIME TRANSFORMATION

INFOLDED INSIDE MAXWELLIAN EM AS HIDDEN EM VARIABLES

SPACETIME-TO-MATTER TRANSFORMATION

INTERNESTED SPACETIME CURVATURES

(VACUUM ENGINES)

INFOLDED GENERAL RELATIVITY

EINSTEIN'S SPACETIME

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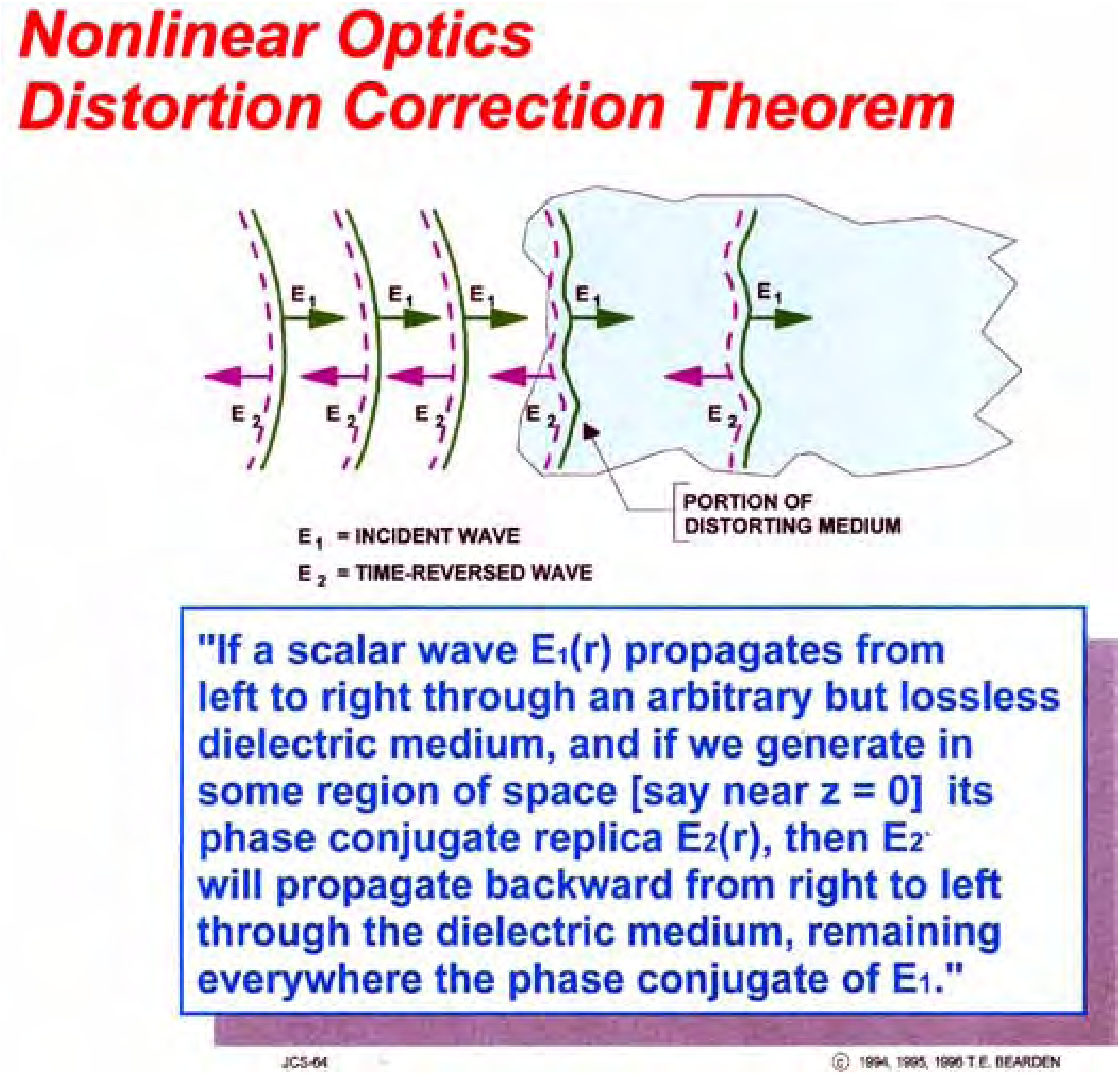

Nonlinear Optics Distortion Correction Theorem

E1
E1
E1
E1
E1
E2
E2
E2
E2
E2
PORTION OF DISTORTING MEDIUM

E_1 = INCIDENT WAVE

E_2 = TIME-REVERSED WAVE

"If a scalar wave $E_1(r)$ propagates from left to right through an arbitrary but lossless dielectric medium, and if we generate in some region of space [say near z = 0] its phase conjugate replica $E_2(r)$, then E_2 will propagate backward from right to left through the dielectric medium, remaining everywhere the phase conjugate of E_1."

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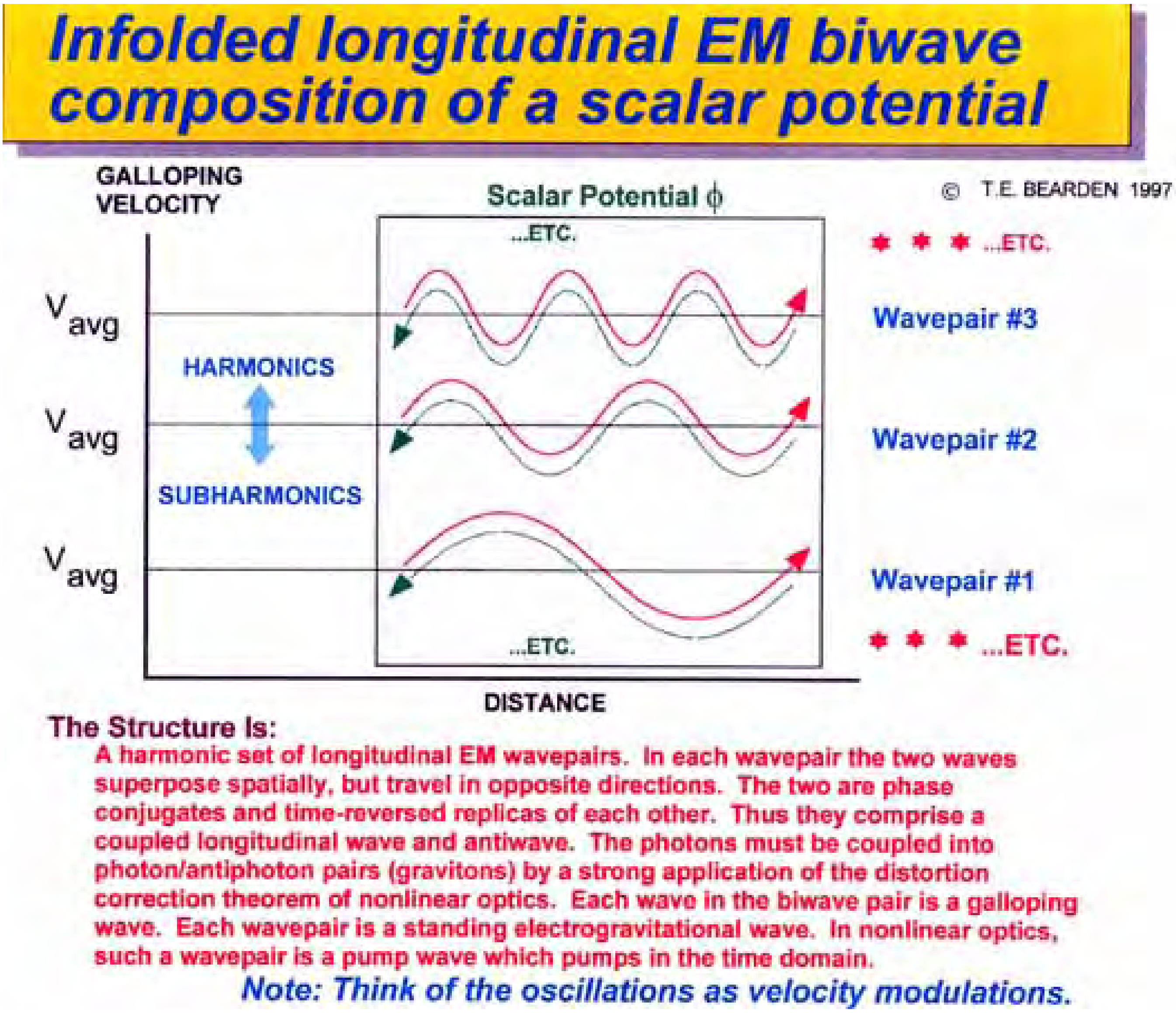

Infolded longitudinal EM biwave composition of a scalar potential

GALLOPING VELOCITY
Scalar Potential ϕ
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...ETC.
✱ ✱ ✱ ...ETC.
V_{avg}
Wavepair #3
HARMONICS
V_{avg}
Wavepair #2
SUBHARMONICS
V_{avg}
Wavepair #1
...ETC.
✱ ✱ ✱ ...ETC.
DISTANCE

The Structure Is:

A harmonic set of longitudinal EM wavepairs. In each wavepair the two waves superpose spatially, but travel in opposite directions. The two are phase conjugates and time-reversed replicas of each other. Thus they comprise a coupled longitudinal wave and antiwave. The photons must be coupled into photon/antiphoton pairs (gravitons) by a strong application of the distortion correction theorem of nonlinear optics. Each wave in the biwave pair is a galloping wave. Each wavepair is a standing electrogravitational wave. In nonlinear optics, such a wavepair is a pump wave which pumps in the time domain.

Note: Think of the oscillations as velocity modulations.

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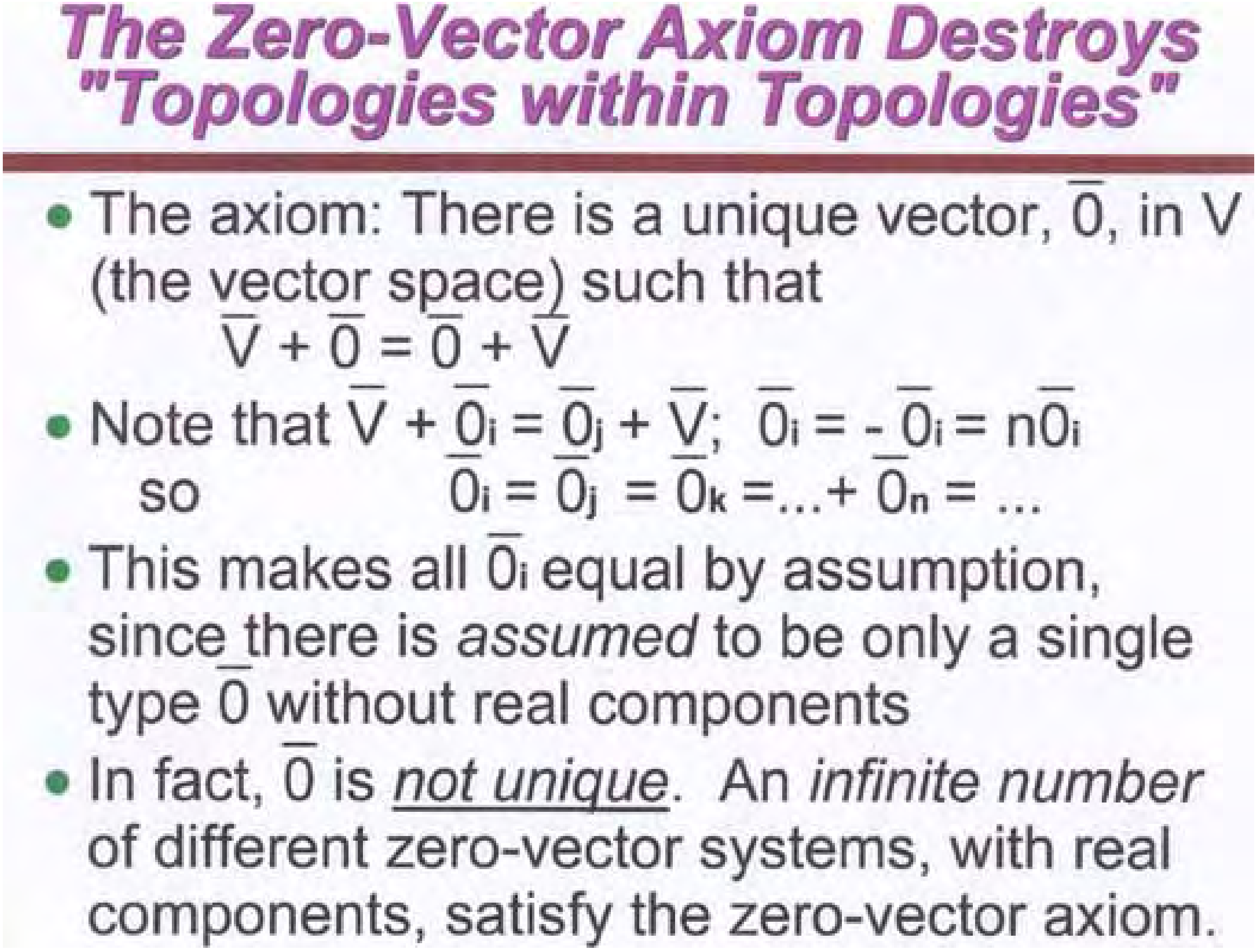

The Zero-Vector Axiom Destroys "Topologies within Topologies"

- The axiom: There is a unique vector, $\bar{0}$, in V (the vector space) such that
  $$\bar{V} + \bar{0} = \bar{0} + \bar{V}$$
- Note that $\bar{V} + \bar{0}_i = \bar{0}_j + \bar{V}$; $\bar{0}_i = -\bar{0}_i = n\bar{0}_i$
  so $\bar{0}_i = \bar{0}_j = \bar{0}_k = \ldots + \bar{0}_n = \ldots$
- This makes all $\bar{0}_i$ equal by assumption, since there is *assumed* to be only a single type $\bar{0}$ without real components
- In fact, $\bar{0}$ is *not unique*. An *infinite number* of different zero-vector systems, with real components, satisfy the zero-vector axiom.

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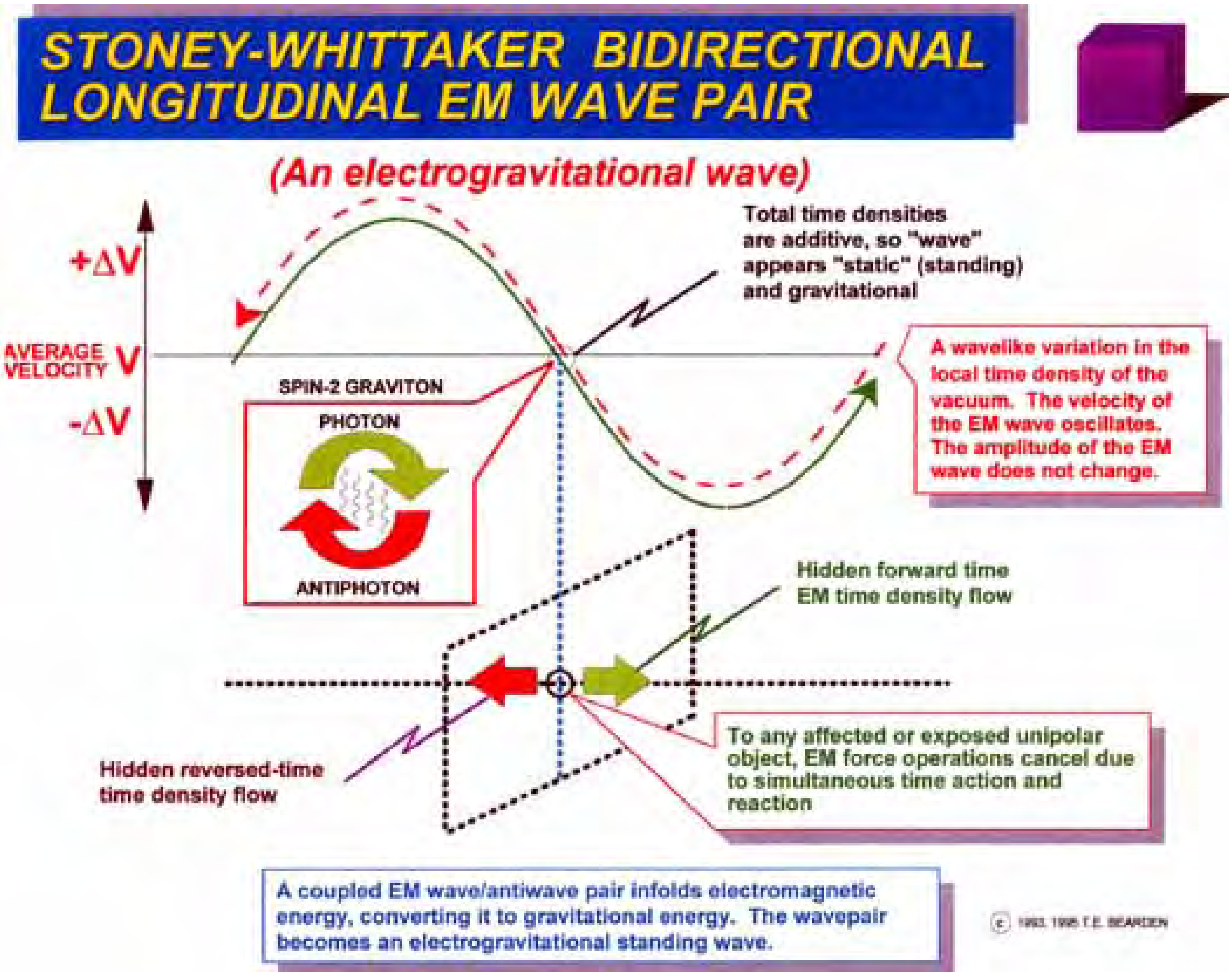

STONEY-WHITTAKER BIDIRECTIONAL LONGITUDINAL EM WAVE PAIR

(An electrogravitational wave)

Total time densities are additive, so "wave" appears "static" (standing) and gravitational

A wavelike variation in the local time density of the vacuum. The velocity of the EM wave oscillates. The amplitude of the EM wave does not change.

Hidden forward time EM time density flow

Hidden reversed-time time density flow

To any affected or exposed unipolar object, EM force operations cancel due to simultaneous time action and reaction

A coupled EM wave/antiwave pair infolds electromagnetic energy, converting it to gravitational energy. The wavepair becomes an electrogravitational standing wave.

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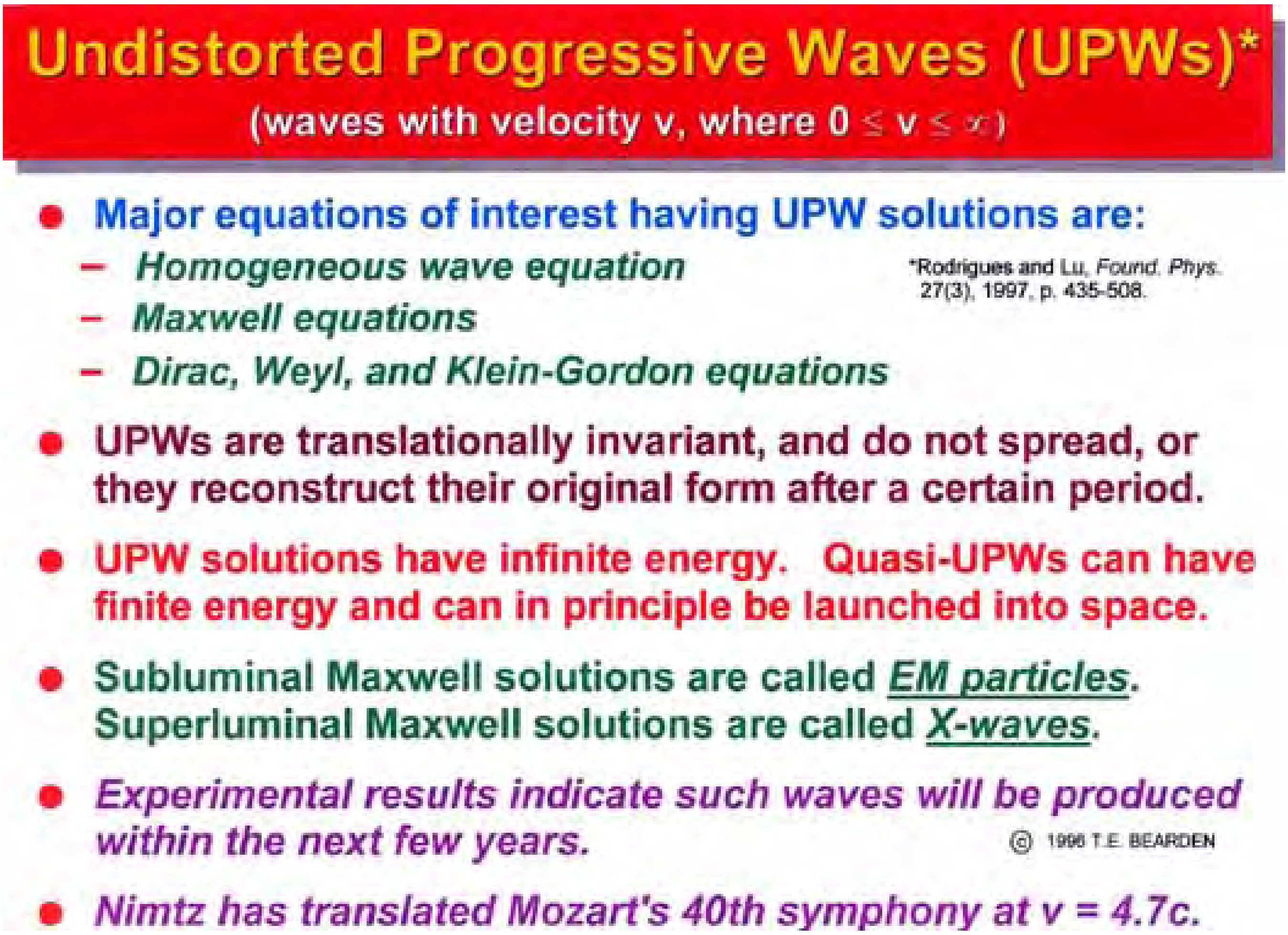

Undistorted Progressive Waves (UPWs)*

(waves with velocity v, where $0 \leq v \leq \infty$)

- Major equations of interest having UPW solutions are:
  - *Homogeneous wave equation*
  - *Maxwell equations*
  - *Dirac, Weyl, and Klein-Gordon equations*
- UPWs are translationally invariant, and do not spread, or they reconstruct their original form after a certain period.
- UPW solutions have infinite energy. Quasi-UPWs can have finite energy and can in principle be launched into space.
- Subluminal Maxwell solutions are called *EM particles*. Superluminal Maxwell solutions are called *X-waves*.
- *Experimental results indicate such waves will be produced within the next few years.*
- *Nimtz has translated Mozart's 40th symphony at v = 4.7c.*

*Rodrigues and Lu, *Found. Phys.* 27(3), 1997, p. 435-508.

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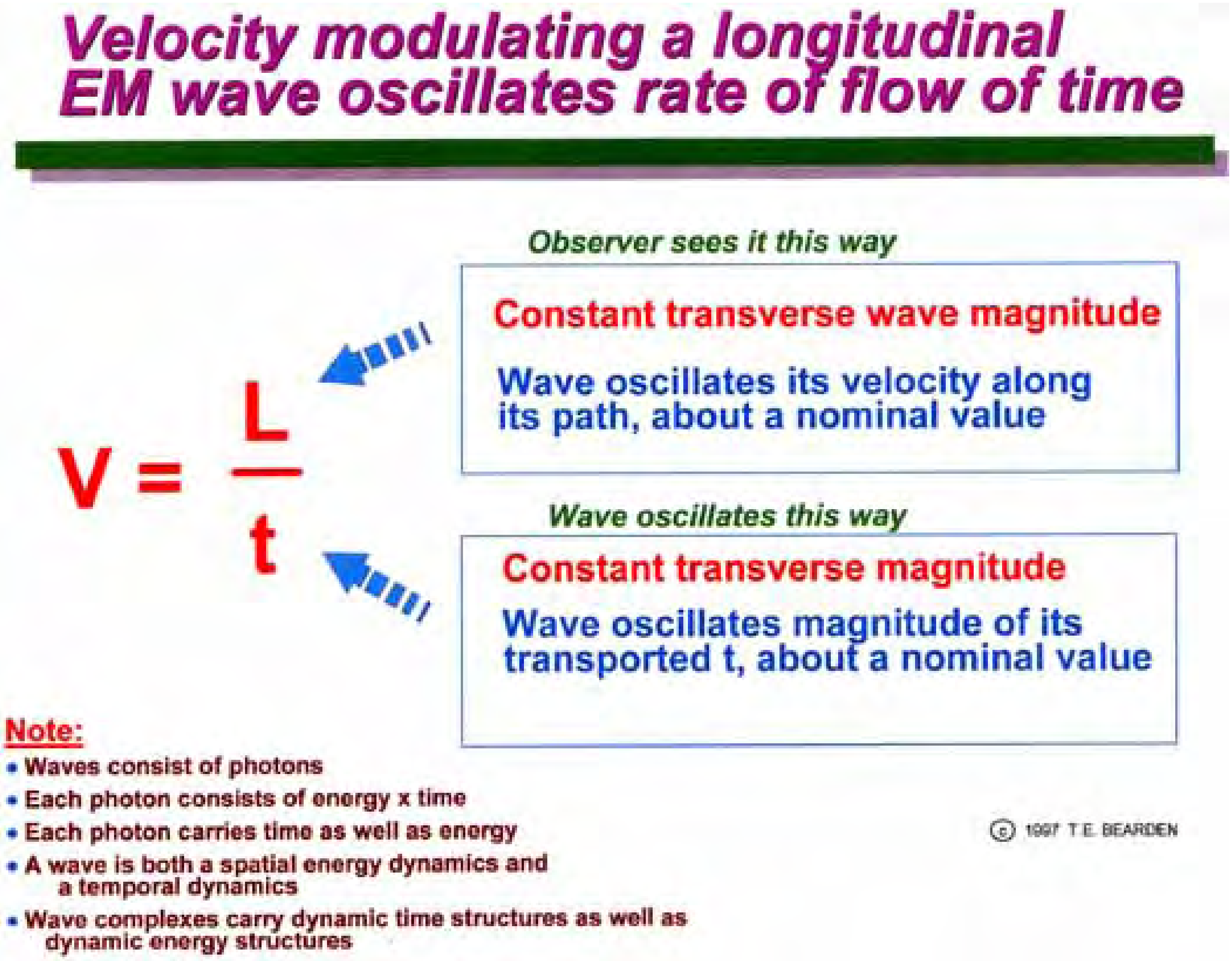

Velocity modulating a longitudinal EM wave oscillates rate of flow of time

$$V = \frac{L}{t}$$

Observer sees it this way

Constant transverse wave magnitude

Wave oscillates its velocity along its path, about a nominal value

Wave oscillates this way

Constant transverse magnitude

Wave oscillates magnitude of its transported t, about a nominal value

Note:

- Waves consist of photons
- Each photon consists of energy x time
- Each photon carries time as well as energy
- A wave is both a spatial energy dynamics and a temporal dynamics
- Wave complexes carry dynamic time structures as well as dynamic energy structures

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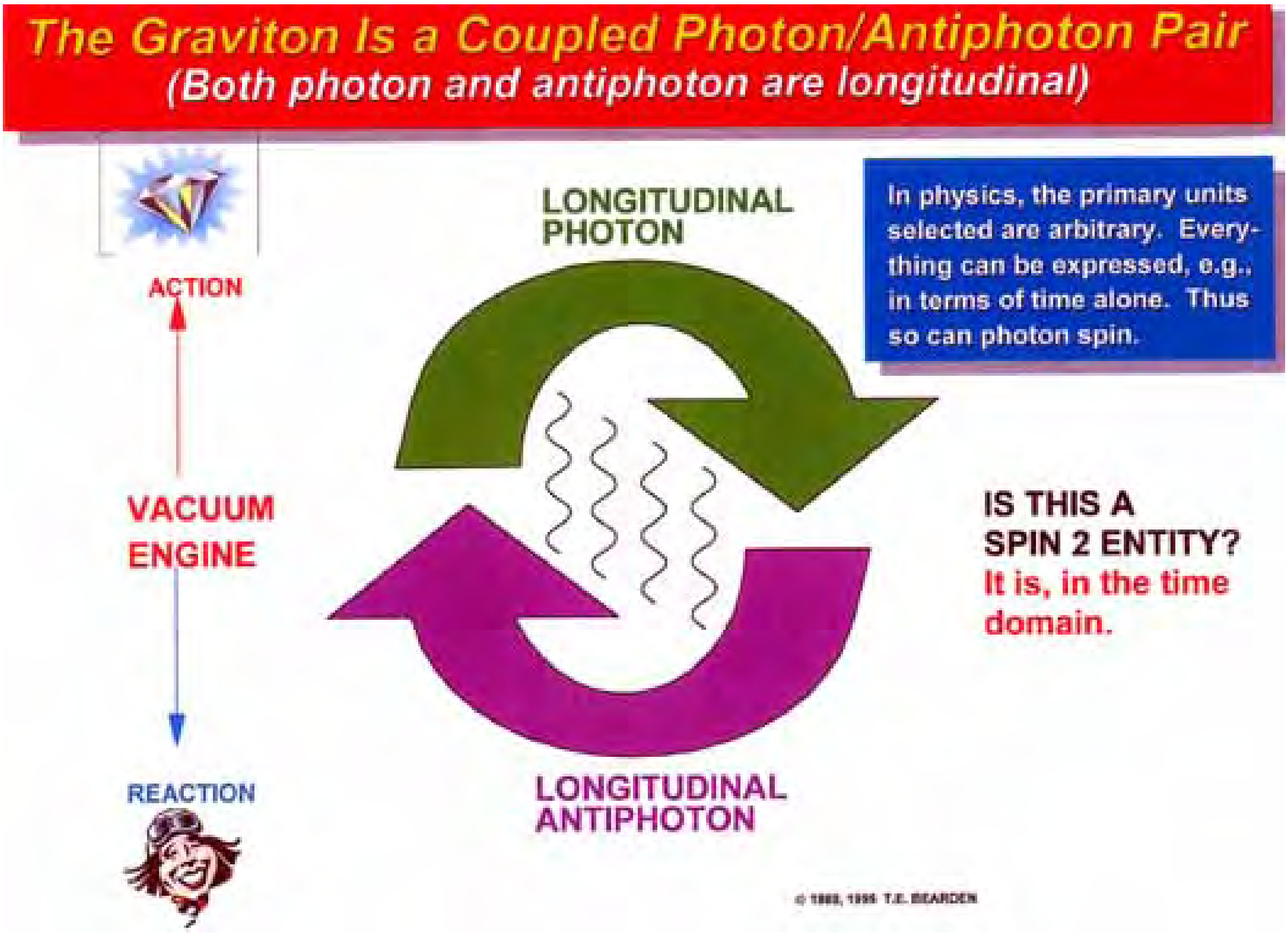

The Graviton Is a Coupled Photon/Antiphoton Pair

(Both photon and antiphoton are longitudinal)

In physics, the primary units selected are arbitrary. Everything can be expressed, e.g., in terms of time alone. Thus so can photon spin.

ACTION
VACUUM ENGINE
REACTION
LONGITUDINAL PHOTON
LONGITUDINAL ANTIPHOTON

IS THIS A SPIN 2 ENTITY?

It is, in the time domain.

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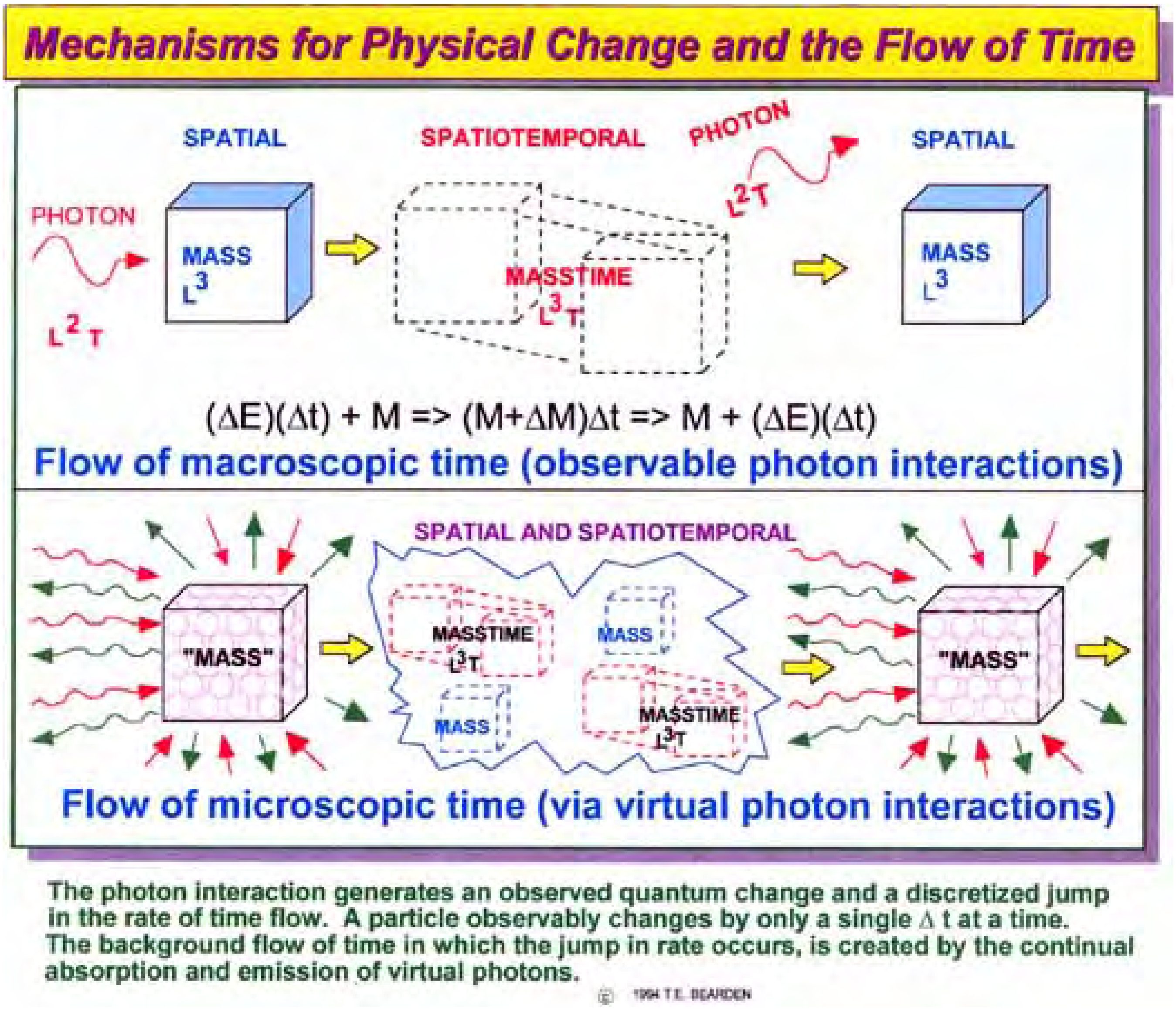

Mechanisms for Physical Change and the Flow of Time

SPATIAL
SPATIOTEMPORAL
PHOTON
SPATIAL
PHOTON
MASS
L^3
L^2T
MASSTIME
L^3T
L^2T
MASS
L^3

$(\Delta E)(\Delta t) + M \Rightarrow (M+\Delta M)\Delta t \Rightarrow M + (\Delta E)(\Delta t)$

Flow of macroscopic time (observable photon interactions)

SPATIAL AND SPATIOTEMPORAL
"MASS"
MASSTIME
L^3T
MASS
MASS
MASSTIME
L^3T
"MASS"

Flow of microscopic time (via virtual photon interactions)

The photon interaction generates an observed quantum change and a discretized jump in the rate of time flow. A particle observably changes by only a single Δt at a time. The background flow of time in which the jump in rate occurs, is created by the continual absorption and emission of virtual photons.

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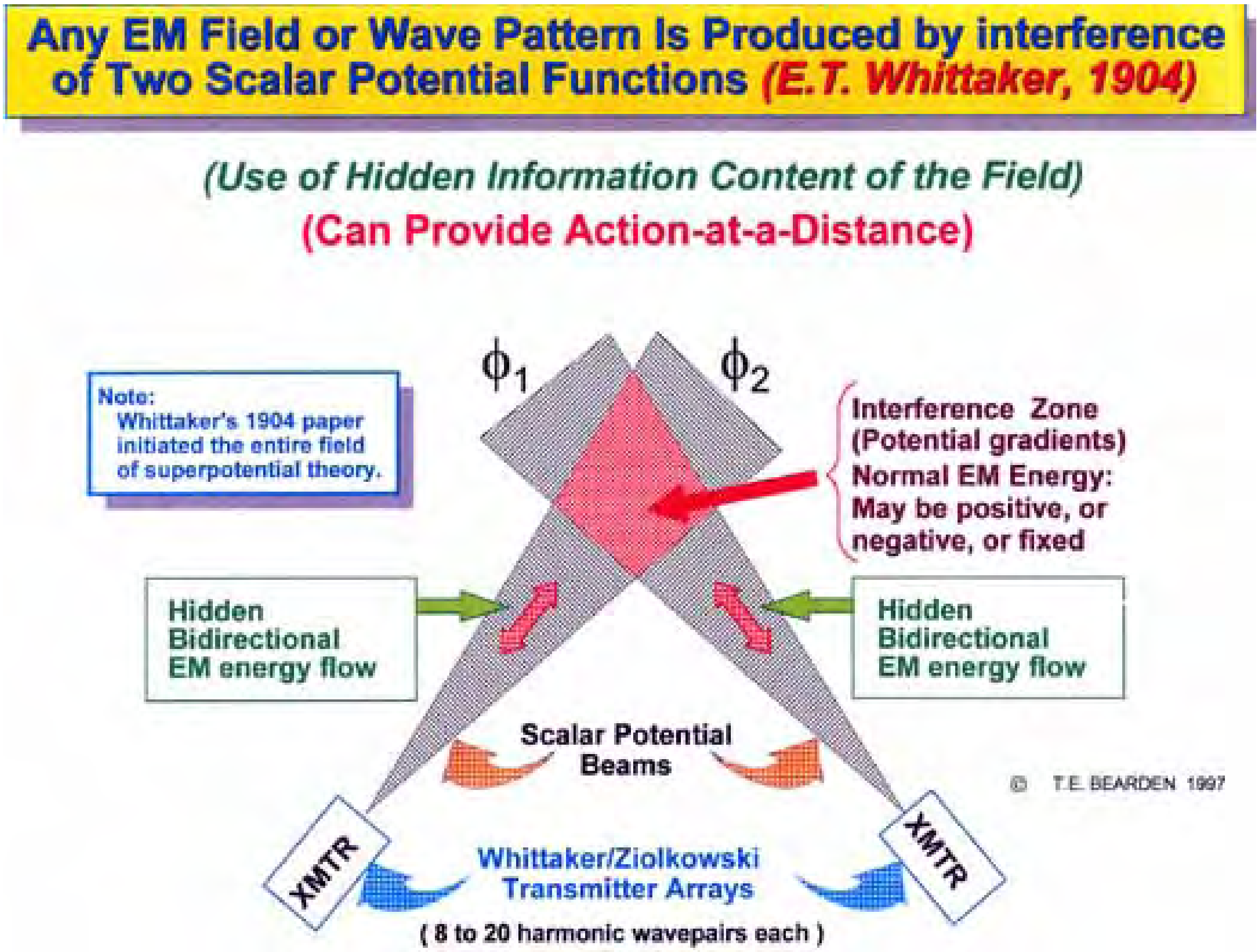

Any EM Field or Wave Pattern Is Produced by interference of Two Scalar Potential Functions *(E.T. Whittaker, 1904)*

(Use of Hidden Information Content of the Field)

(Can Provide Action-at-a-Distance)

Note:
Whittaker's 1904 paper initiated the entire field of superpotential theory.

Interference Zone
(Potential gradients)
Normal EM Energy:
May be positive, or
negative, or fixed

Hidden
Bidirectional
EM energy flow

Hidden
Bidirectional
EM energy flow

Scalar Potential
Beams

Whittaker/Ziolkowski
Transmitter Arrays
(8 to 20 harmonic wavepairs each)

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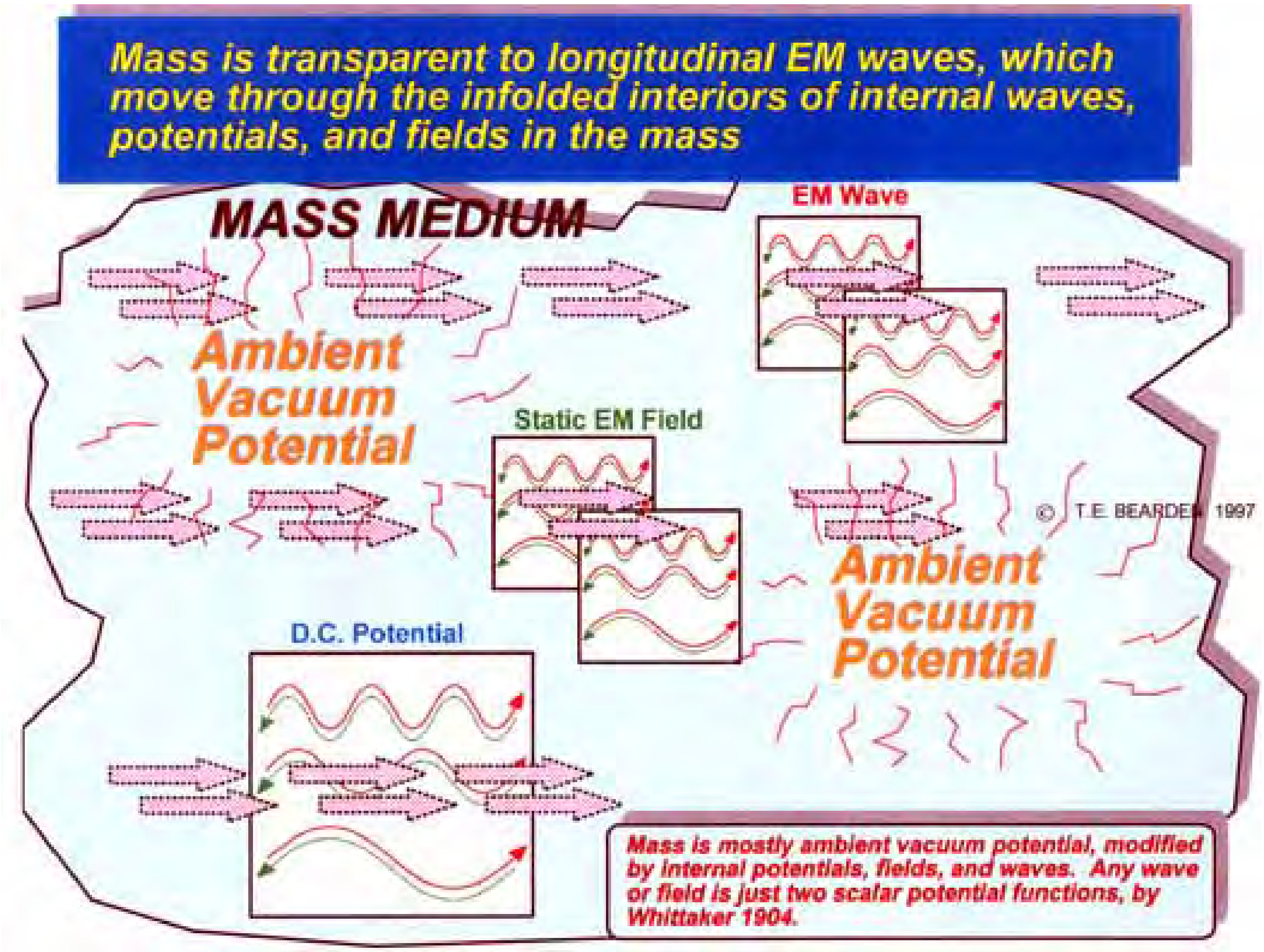

Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass

MASS MEDIUM
EM Wave
Ambient Vacuum Potential
Static EM Field
© T.E. BEARDEN 1997
Ambient Vacuum Potential
D.C. Potential

Mass is mostly ambient vacuum potential, modified by internal potentials, fields, and waves. Any wave or field is just two scalar potential functions, by Whittaker 1904.

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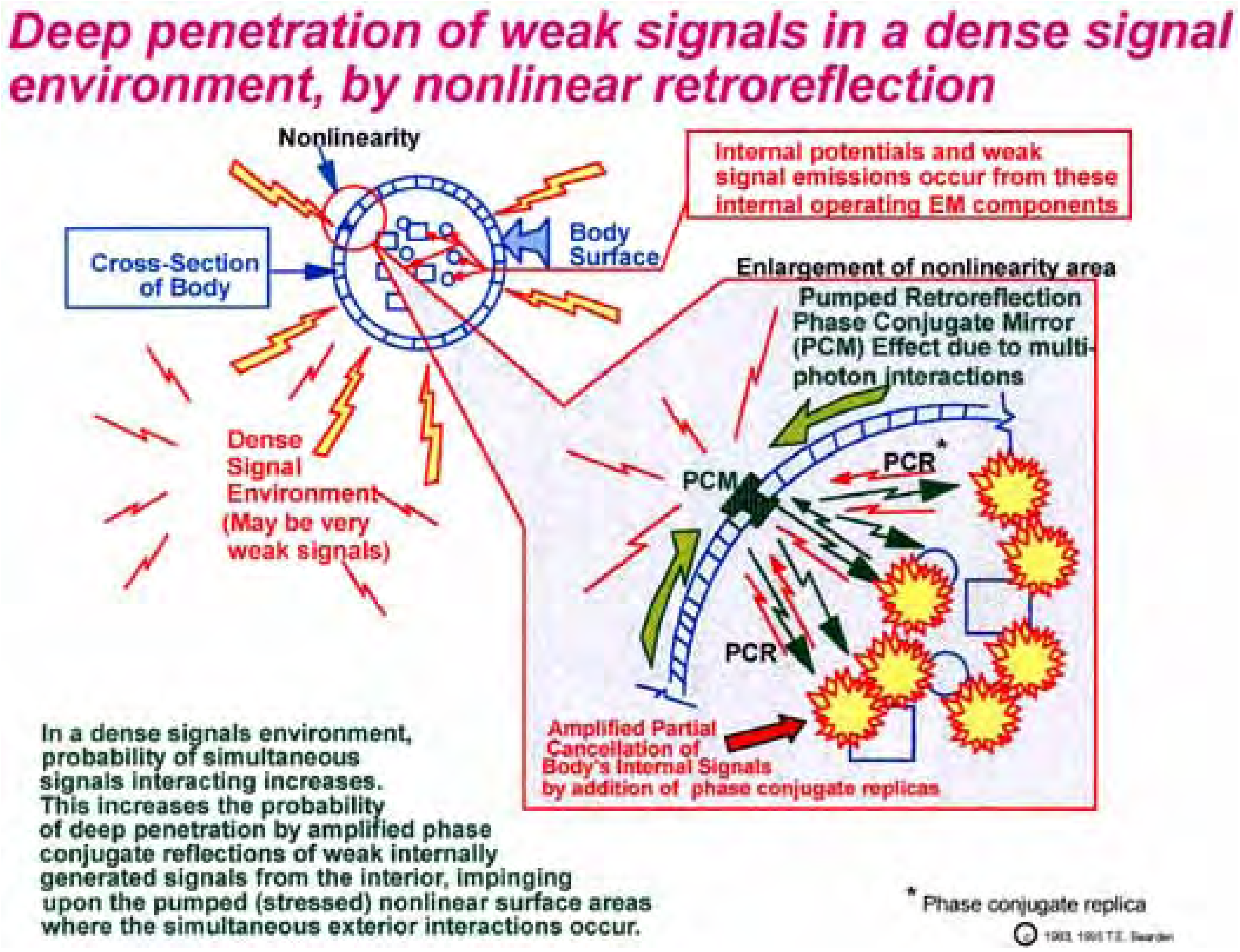

Deep penetration of weak signals in a dense signal environment, by nonlinear retroreflection

Nonlinearity
Cross-Section of Body
Body Surface
Internal potentials and weak signal emissions occur from these internal operating EM components
Dense Signal Environment (May be very weak signals)
Enlargement of nonlinearity area
Pumped Retroreflection Phase Conjugate Mirror (PCM) Effect due to multi-photon interactions
PCM
PCR*
PCR
Amplified Partial Cancellation of Body's Internal Signals by addition of phase conjugate replicas

In a dense signals environment, probability of simultaneous signals interacting increases. This increases the probability of deep penetration by amplified phase conjugate reflections of weak internally generated signals from the interior, impinging upon the pumped (stressed) nonlinear surface areas where the simultaneous exterior interactions occur.

* Phase conjugate replica

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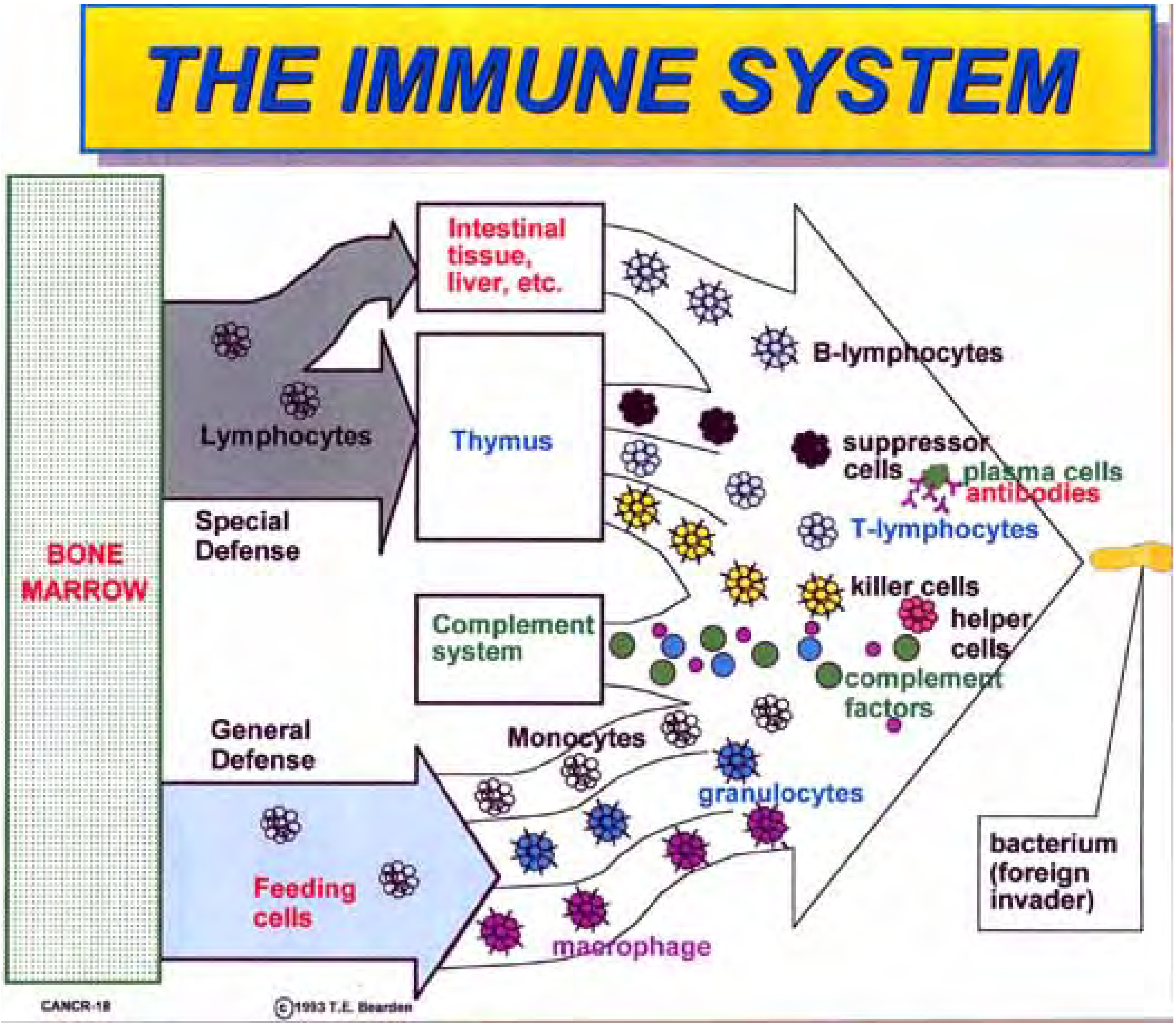

THE IMMUNE SYSTEM

BONE MARROW

Lymphocytes

Special Defense

Intestinal tissue, liver, etc.

Thymus

Complement system

General Defense

Feeding cells

Monocytes

B-lymphocytes

suppressor cells

plasma cells

antibodies

T-lymphocytes

killer cells

helper cells

complement factors

granulocytes

macrophage

bacterium (foreign invader)

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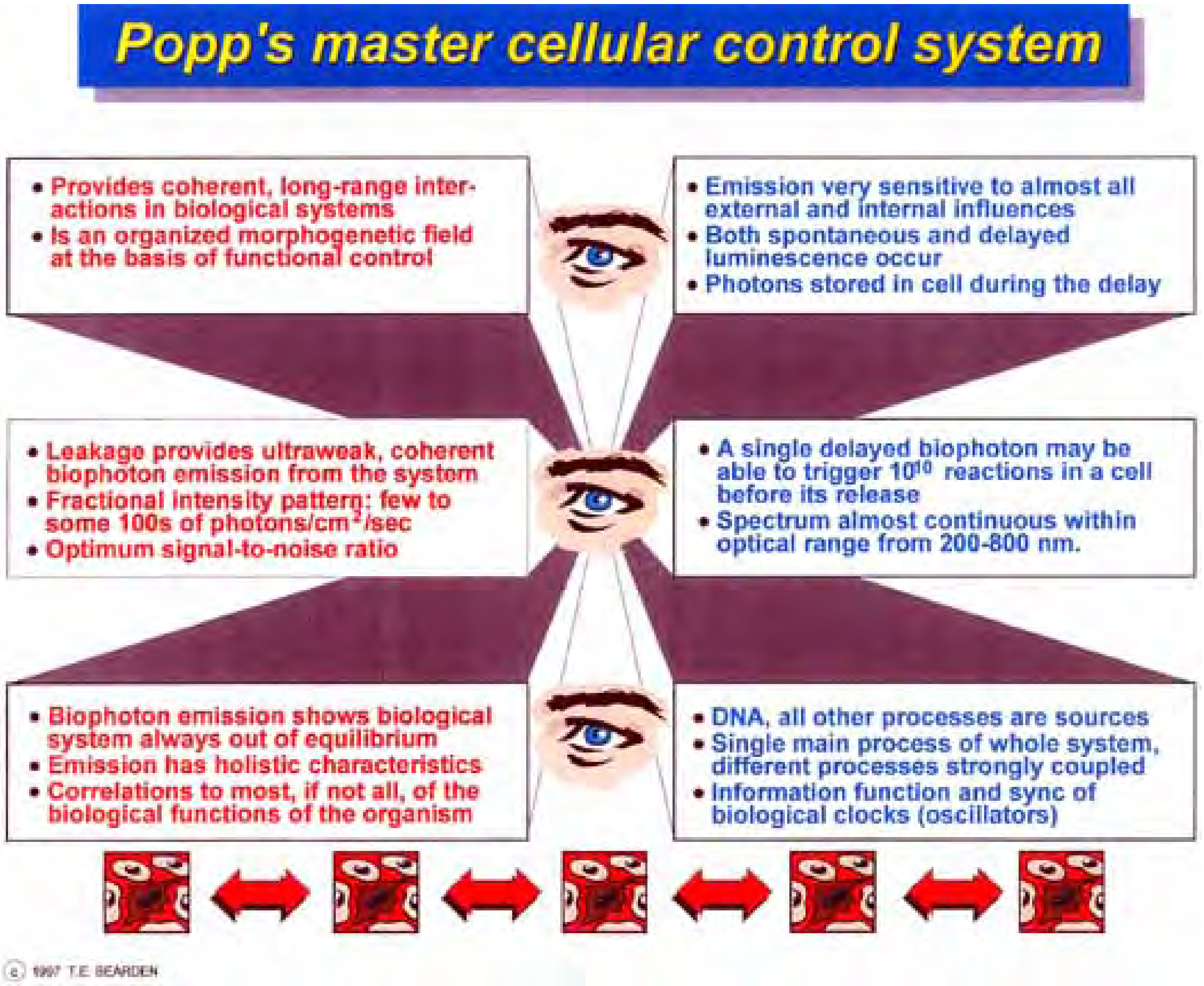

Popp's master cellular control system

- Provides coherent, long-range interactions in biological systems
- Is an organized morphogenetic field at the basis of functional control

- Emission very sensitive to almost all external and internal influences
- Both spontaneous and delayed luminescence occur
- Photons stored in cell during the delay

- Leakage provides ultraweak, coherent biophoton emission from the system
- Fractional intensity pattern: few to some 100s of photons/cm^2/sec
- Optimum signal-to-noise ratio

- A single delayed biophoton may be able to trigger 10^{10} reactions in a cell before its release
- Spectrum almost continuous within optical range from 200-800 nm.

- Biophoton emission shows biological system always out of equilibrium
- Emission has holistic characteristics
- Correlations to most, if not all, of the biological functions of the organism

- DNA, all other processes are sources
- Single main process of whole system, different processes strongly coupled
- Information function and sync of biological clocks (oscillators)

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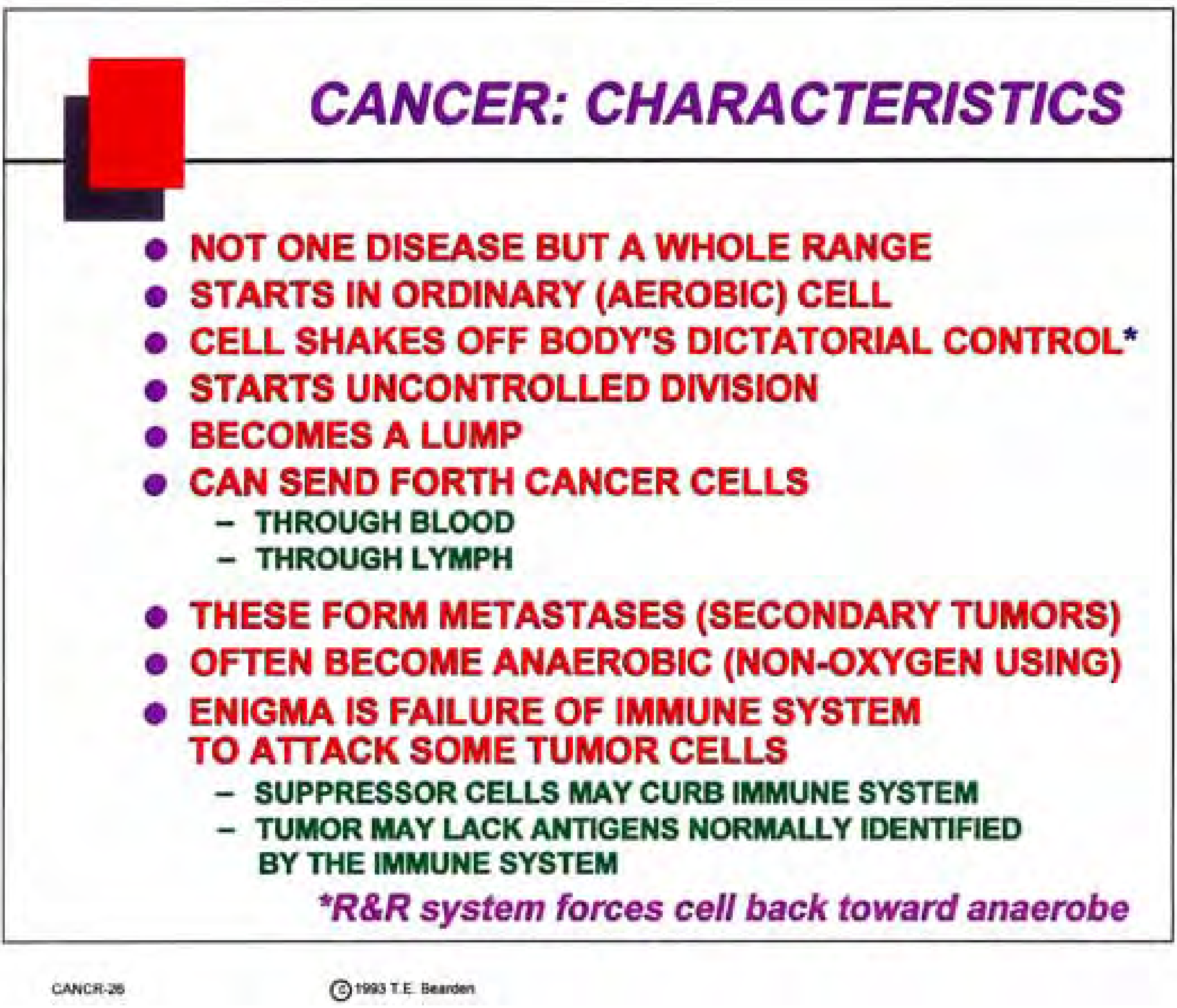

CANCER: CHARACTERISTICS

- NOT ONE DISEASE BUT A WHOLE RANGE
- STARTS IN ORDINARY (AEROBIC) CELL
- CELL SHAKES OFF BODY'S DICTATORIAL CONTROL*
- STARTS UNCONTROLLED DIVISION
- BECOMES A LUMP
- CAN SEND FORTH CANCER CELLS
  - THROUGH BLOOD
  - THROUGH LYMPH
- THESE FORM METASTASES (SECONDARY TUMORS)
- OFTEN BECOME ANAEROBIC (NON-OXYGEN USING)
- ENIGMA IS FAILURE OF IMMUNE SYSTEM TO ATTACK SOME TUMOR CELLS
  - SUPPRESSOR CELLS MAY CURB IMMUNE SYSTEM
  - TUMOR MAY LACK ANTIGENS NORMALLY IDENTIFIED BY THE IMMUNE SYSTEM

**R&R system forces cell back toward anaerobe*

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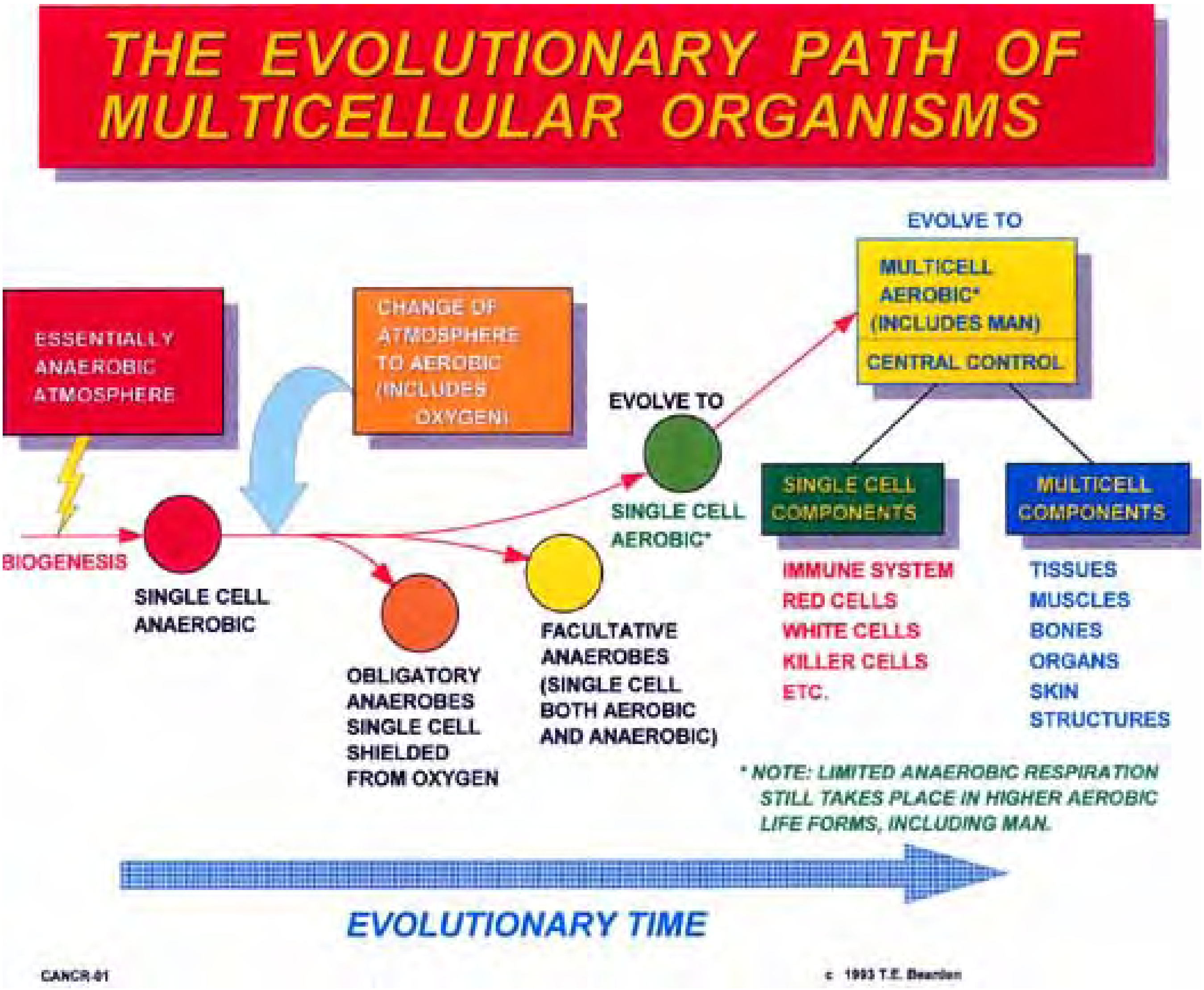

THE EVOLUTIONARY PATH OF MULTICELLULAR ORGANISMS

ESSENTIALLY ANAEROBIC ATMOSPHERE

CHANGE OF ATMOSPHERE TO AEROBIC (INCLUDES OXYGEN)

BIOGENESIS

SINGLE CELL ANAEROBIC

OBLIGATORY ANAEROBES SINGLE CELL SHIELDED FROM OXYGEN

FACULTATIVE ANAEROBES (SINGLE CELL BOTH AEROBIC AND ANAEROBIC)

EVOLVE TO

SINGLE CELL AEROBIC*

EVOLVE TO

MULTICELL AEROBIC* (INCLUDES MAN)

CENTRAL CONTROL

SINGLE CELL COMPONENTS

- IMMUNE SYSTEM
- RED CELLS
- WHITE CELLS
- KILLER CELLS
- ETC.

MULTICELL COMPONENTS

- TISSUES
- MUSCLES
- BONES
- ORGANS
- SKIN
- STRUCTURES

* NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.

EVOLUTIONARY TIME

CANCR-01

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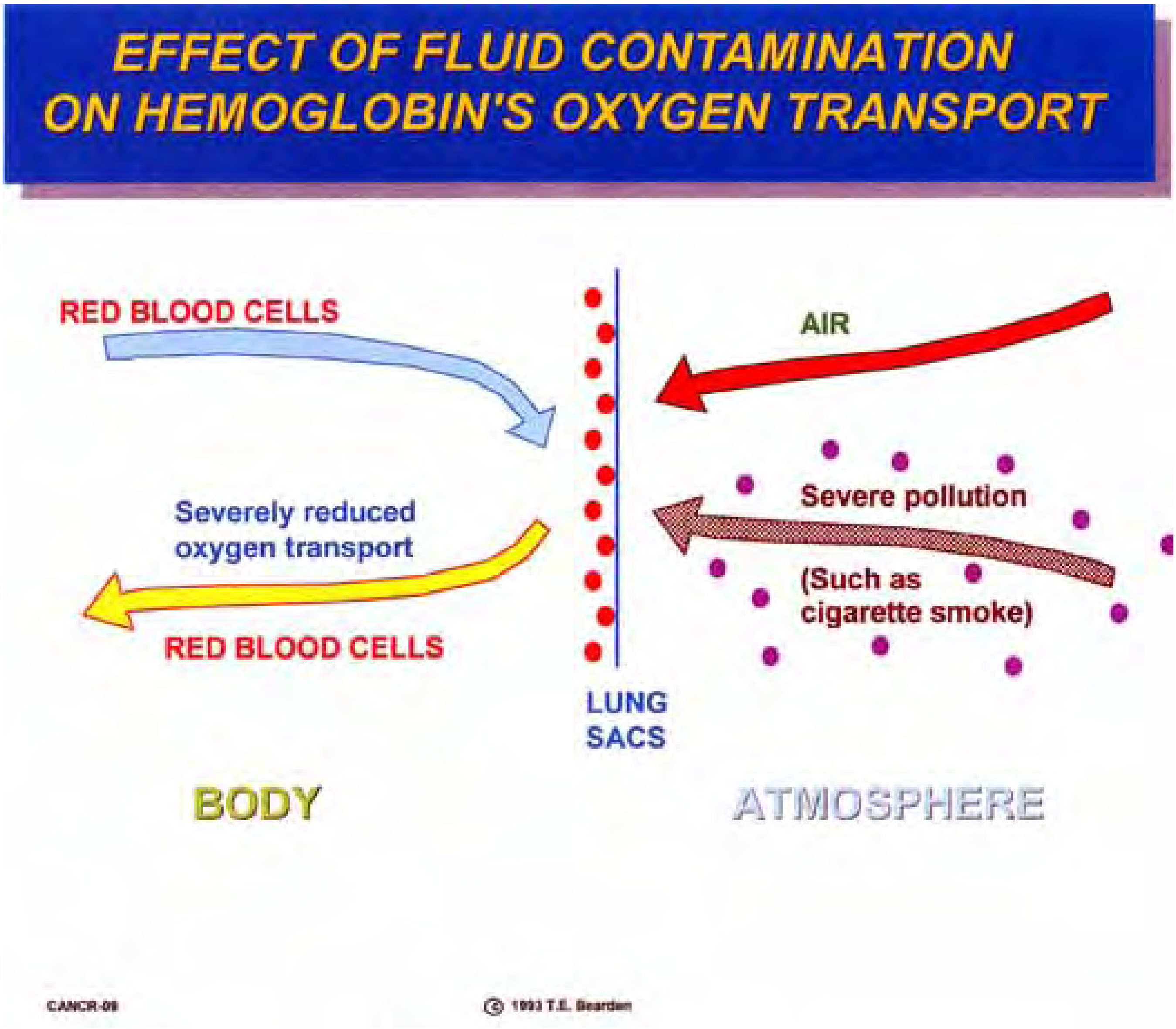

EFFECT OF FLUID CONTAMINATION ON HEMOGLOBIN'S OXYGEN TRANSPORT

RED BLOOD CELLS

AIR

Severely reduced
oxygen transport

Severe pollution

(Such as
cigarette smoke)

RED BLOOD CELLS

LUNG
SACS

BODY

ATMOSPHERE

CANCR-09

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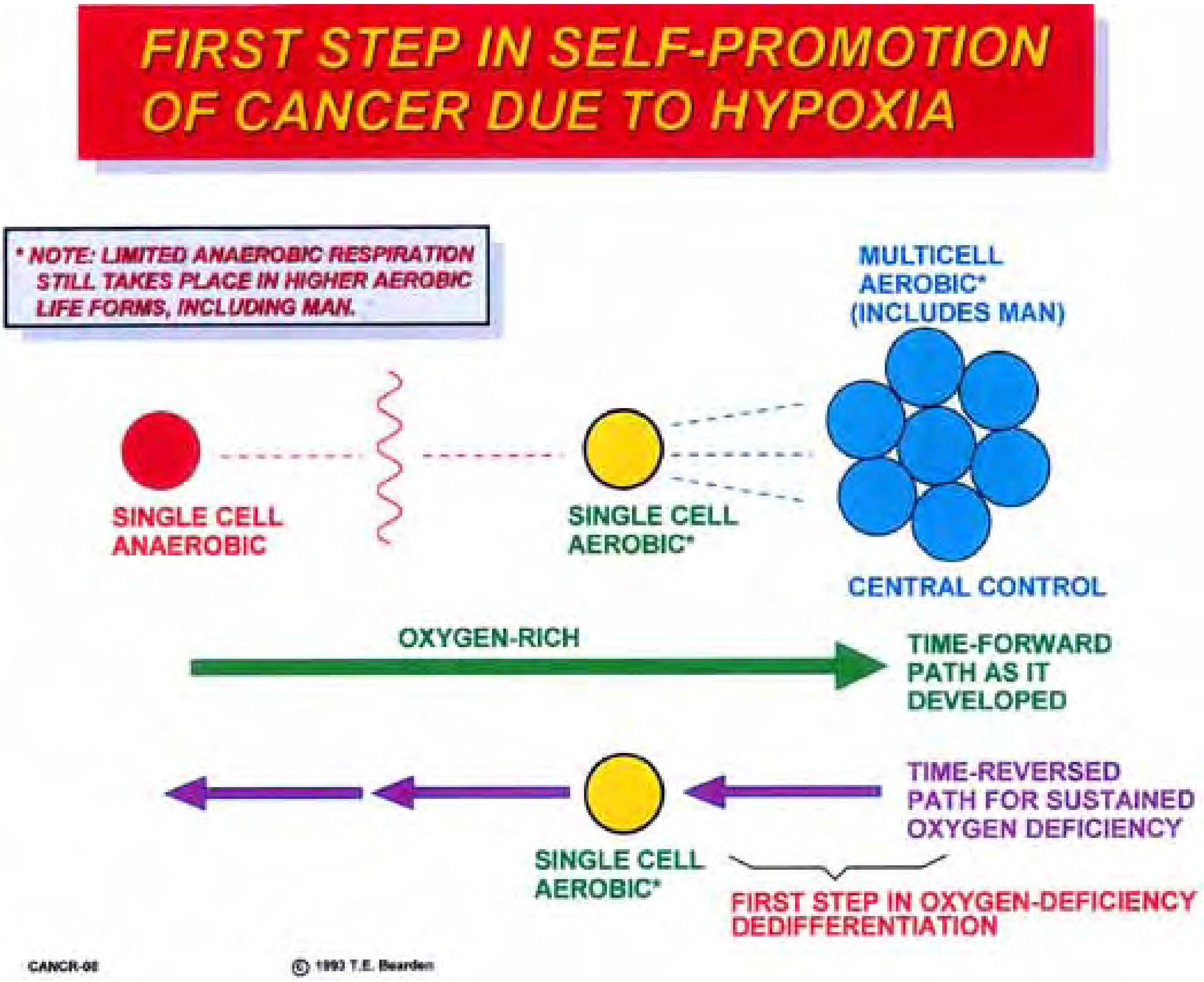

FIRST STEP IN SELF-PROMOTION OF CANCER DUE TO HYPOXIA

* NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.

SINGLE CELL
ANAEROBIC
SINGLE CELL
AEROBIC*
MULTICELL
AEROBIC*
(INCLUDES MAN)
CENTRAL CONTROL
OXYGEN-RICH
TIME-FORWARD
PATH AS IT
DEVELOPED
TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY
SINGLE CELL
AEROBIC*
FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION

CANCR-08

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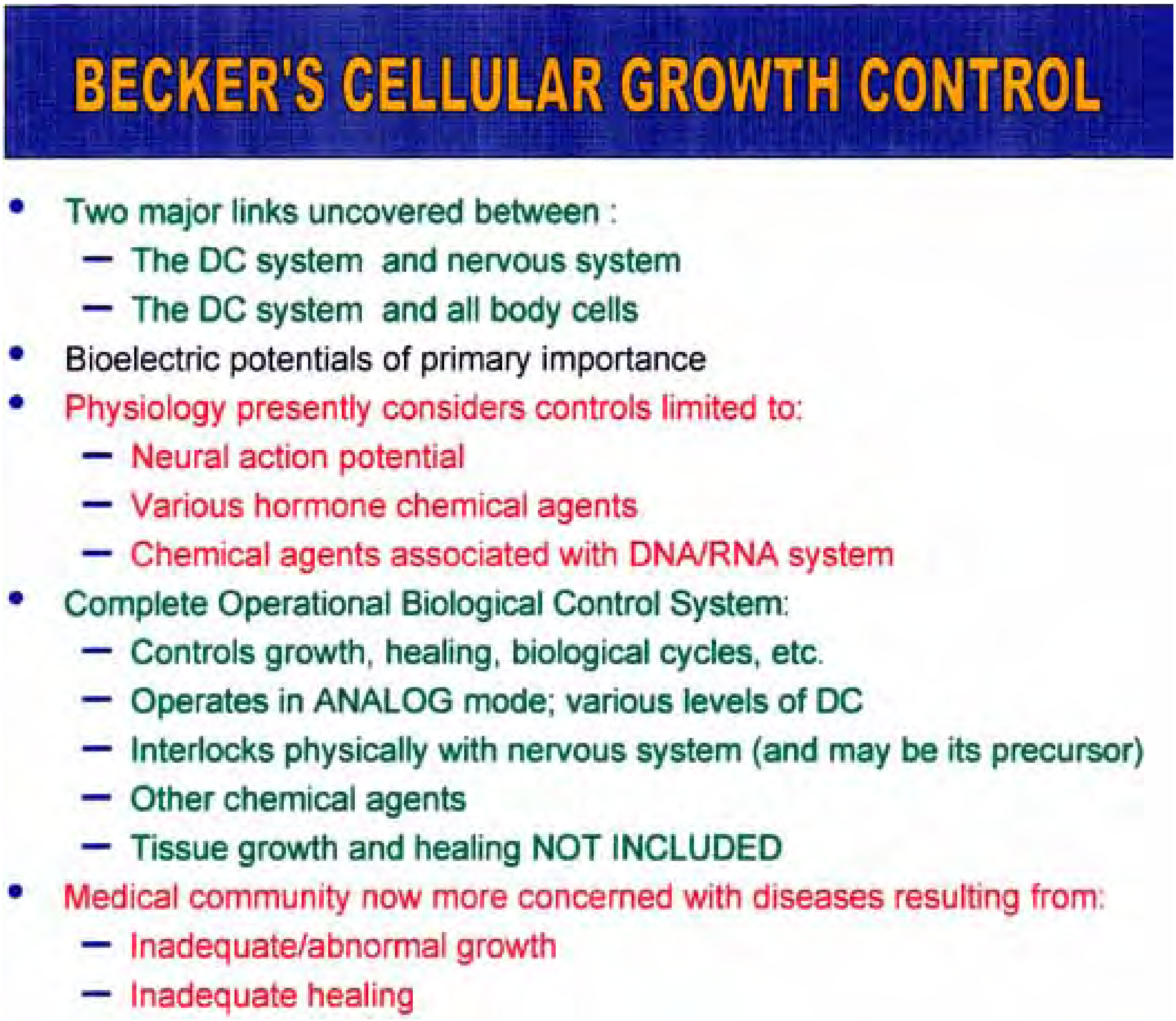

BECKER'S CELLULAR GROWTH CONTROL

- Two major links uncovered between :
  - The DC system and nervous system
  - The DC system and all body cells
- Bioelectric potentials of primary importance
- Physiology presently considers controls limited to:
  - Neural action potential
  - Various hormone chemical agents
  - Chemical agents associated with DNA/RNA system
- Complete Operational Biological Control System:
  - Controls growth, healing, biological cycles, etc.
  - Operates in ANALOG mode; various levels of DC
  - Interlocks physically with nervous system (and may be its precursor)
  - Other chemical agents
  - Tissue growth and healing NOT INCLUDED
- Medical community now more concerned with diseases resulting from:
  - Inadequate/abnormal growth
  - Inadequate healing

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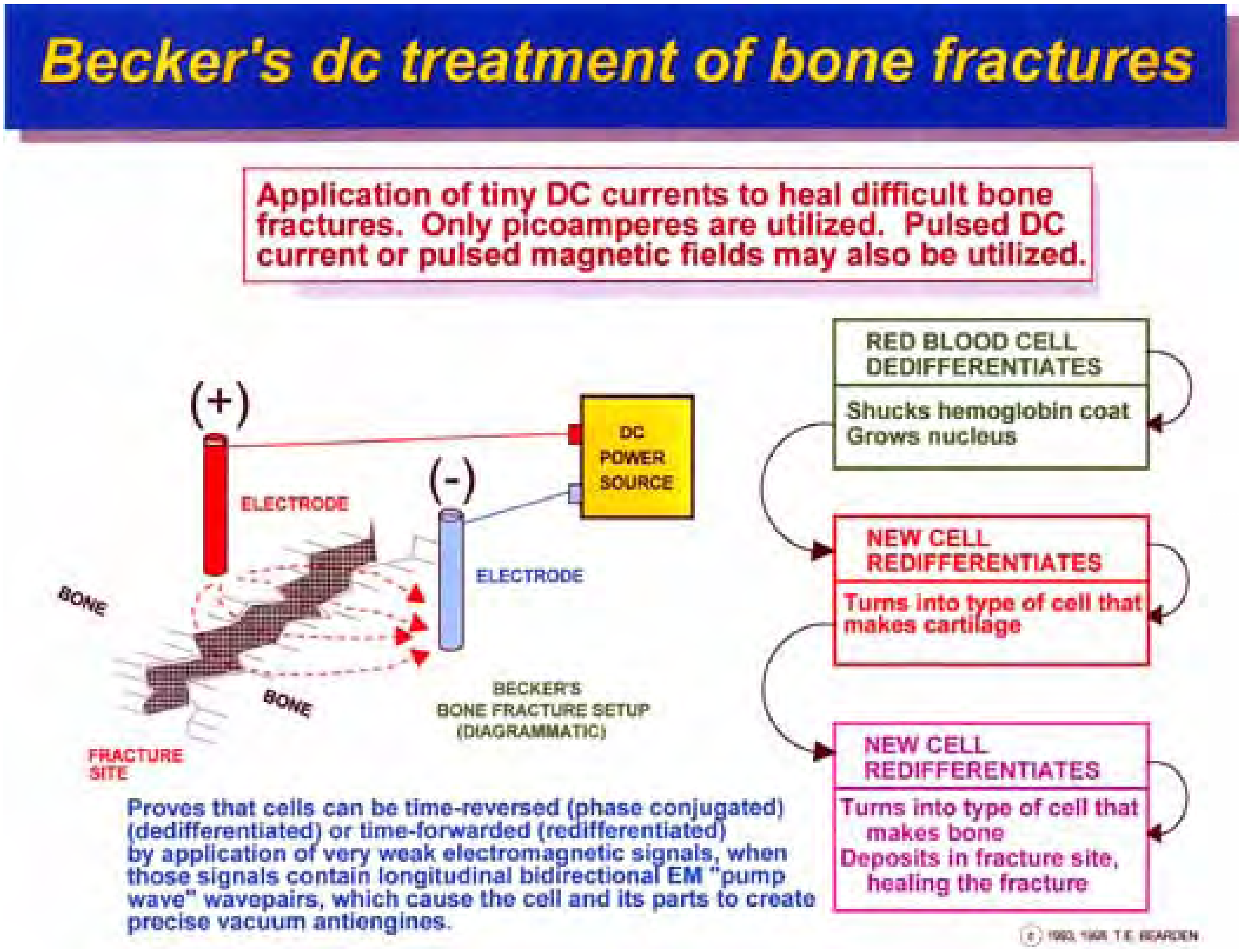

Becker's dc treatment of bone fractures

Application of tiny DC currents to heal difficult bone fractures. Only picoamperes are utilized. Pulsed DC current or pulsed magnetic fields may also be utilized.

BECKER'S
BONE FRACTURE SETUP
(DIAGRAMMATIC)

RED BLOOD CELL
DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL
REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL
REDIFFERENTIATES

Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

Proves that cells can be time-reversed (phase conjugated) (dedifferentiated) or time-forwarded (redifferentiated) by application of very weak electromagnetic signals, when those signals contain longitudinal bidirectional EM "pump wave" wavepairs, which cause the cell and its parts to create precise vacuum antiengines.

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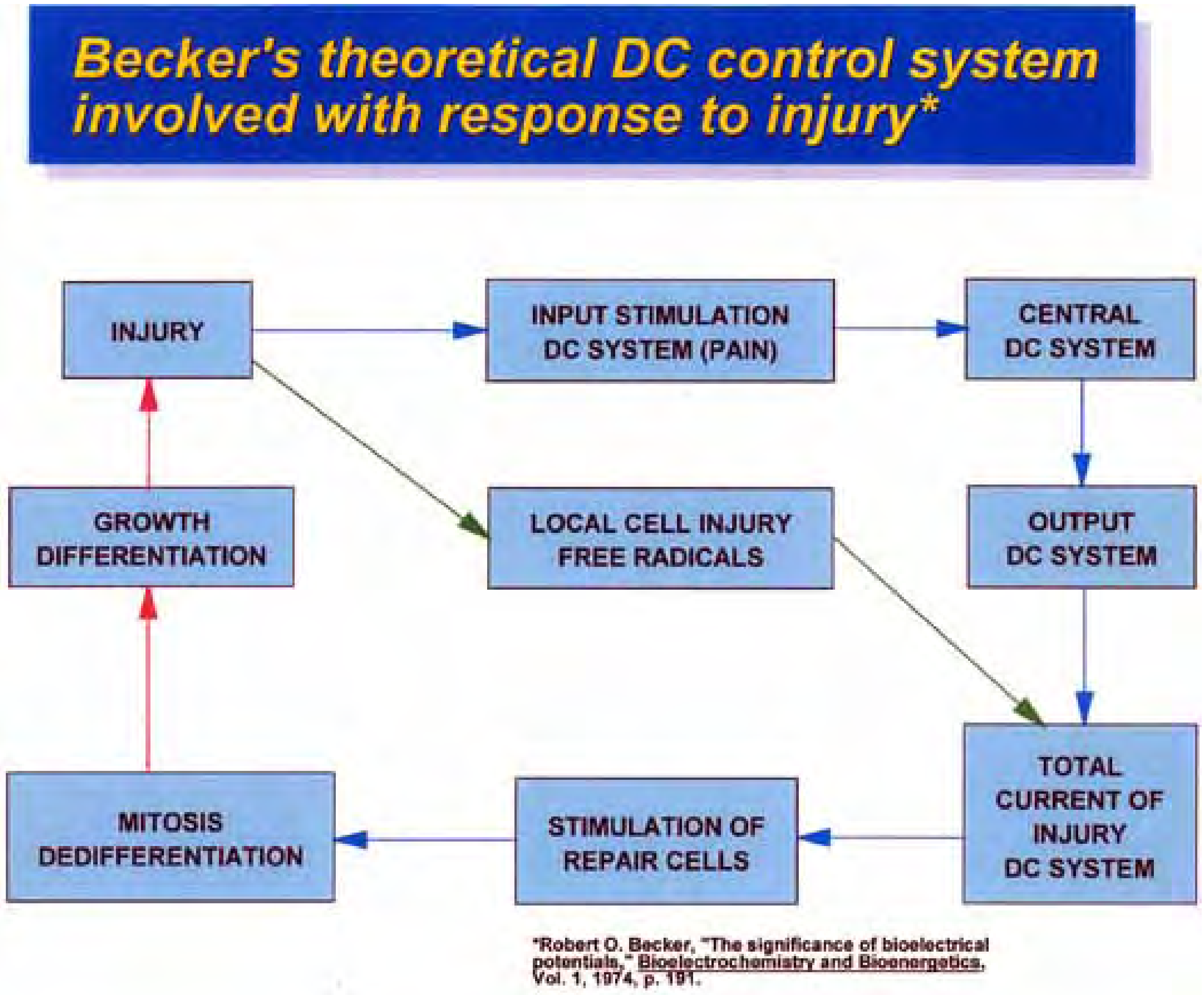

Becker's theoretical DC control system involved with response to injury*

INJURY

INPUT STIMULATION DC SYSTEM (PAIN)

CENTRAL DC SYSTEM

GROWTH DIFFERENTIATION

LOCAL CELL INJURY FREE RADICALS

OUTPUT DC SYSTEM

MITOSIS DEDIFFERENTIATION

STIMULATION OF REPAIR CELLS

TOTAL CURRENT OF INJURY DC SYSTEM

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.

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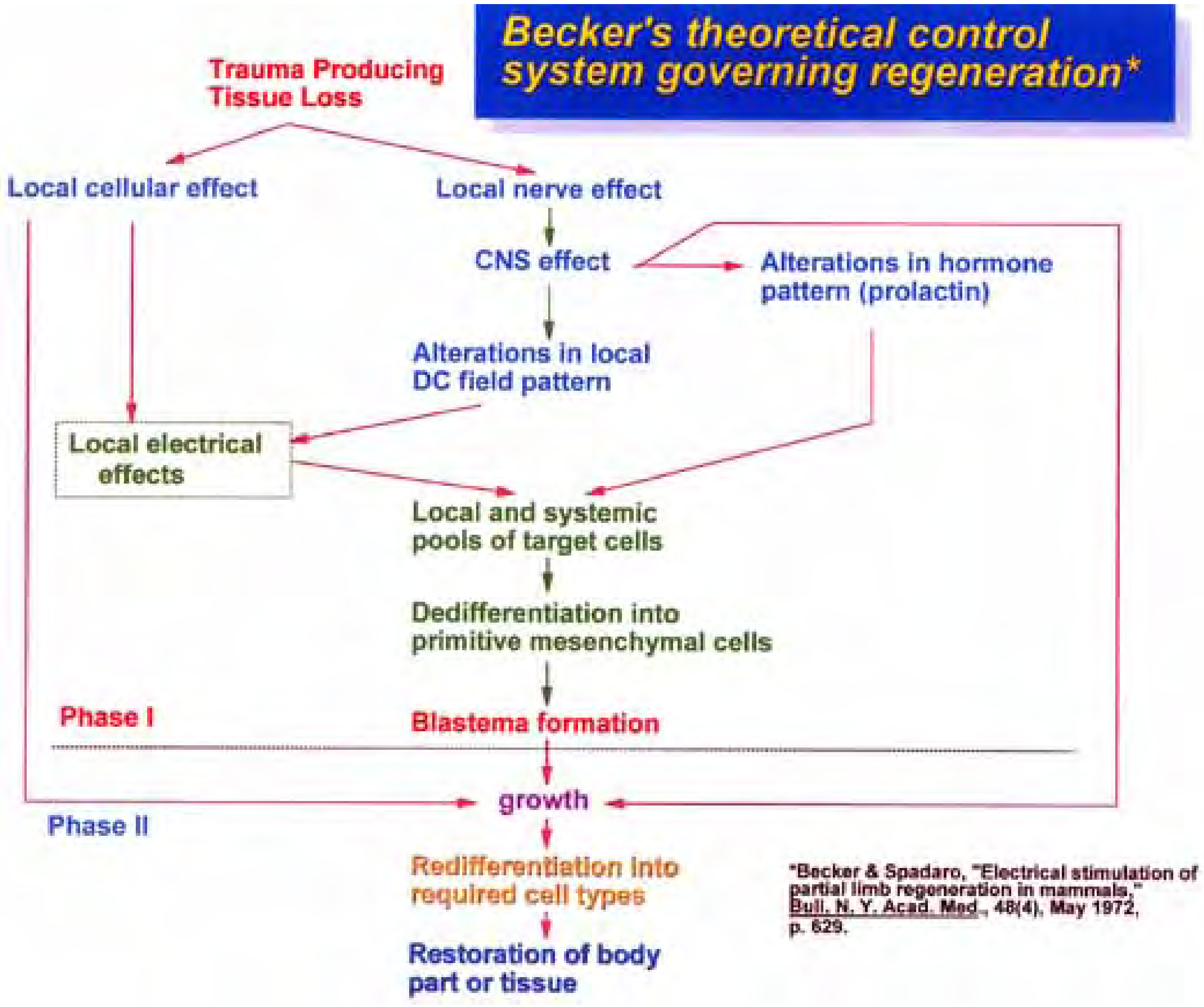

Becker's theoretical control system governing regeneration*

Trauma Producing Tissue Loss

Local cellular effect

Local nerve effect

CNS effect

Alterations in hormone pattern (prolactin)

Alterations in local DC field pattern

Local electrical effects

Local and systemic pools of target cells

Dedifferentiation into primitive mesenchymal cells

Phase I

Blastema formation

growth

Phase II

Redifferentiation into required cell types

Restoration of body part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bull. N. Y. Acad. Med., 48(4), May 1972, p. 629.

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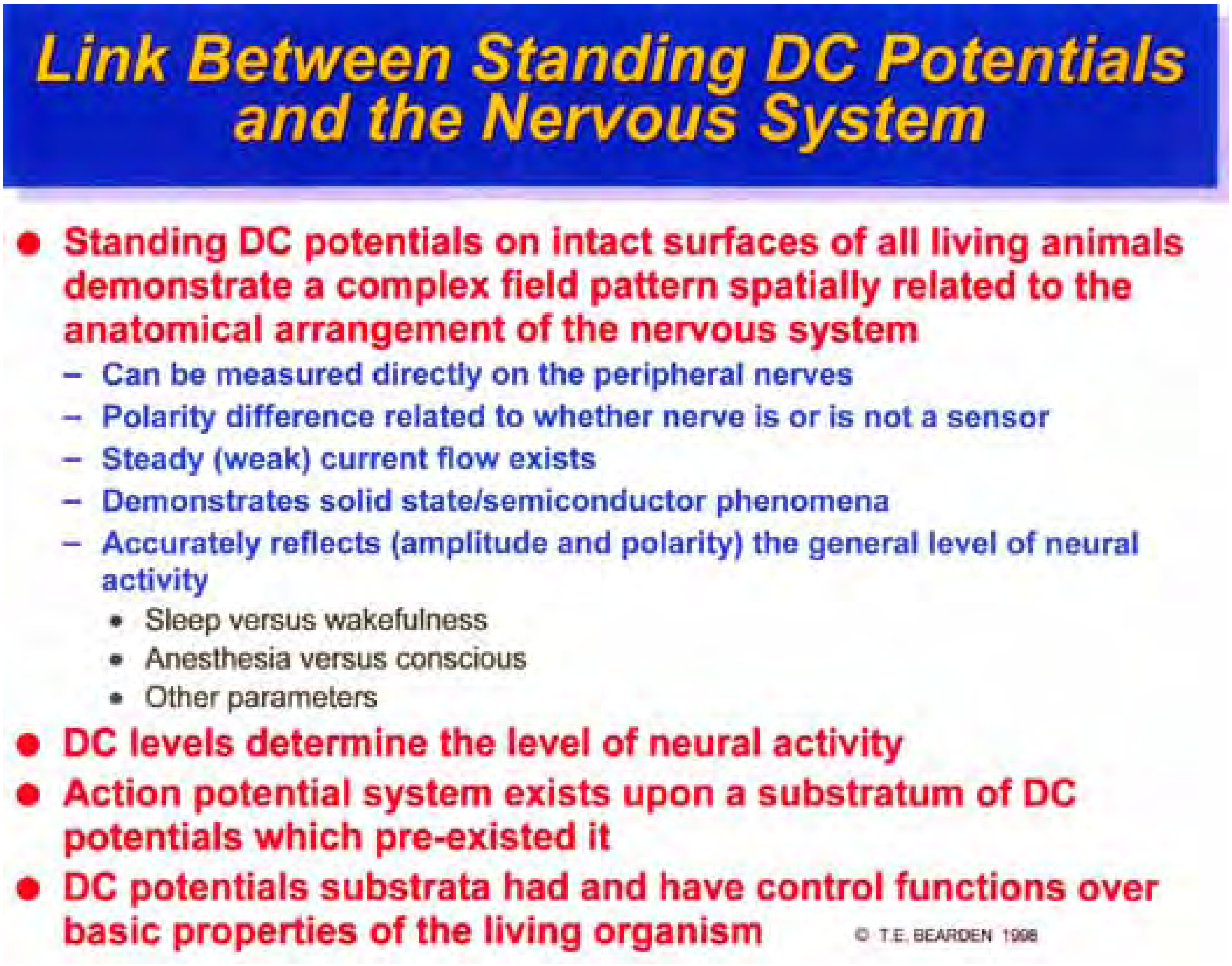

Link Between Standing DC Potentials and the Nervous System

- Standing DC potentials on intact surfaces of all living animals demonstrate a complex field pattern spatially related to the anatomical arrangement of the nervous system
  - Can be measured directly on the peripheral nerves
  - Polarity difference related to whether nerve is or is not a sensor
  - Steady (weak) current flow exists
  - Demonstrates solid state/semiconductor phenomena
  - Accurately reflects (amplitude and polarity) the general level of neural activity
    - Sleep versus wakefulness
    - Anesthesia versus conscious
    - Other parameters
- DC levels determine the level of neural activity
- Action potential system exists upon a substratum of DC potentials which pre-existed it
- DC potentials substrata had and have control functions over basic properties of the living organism

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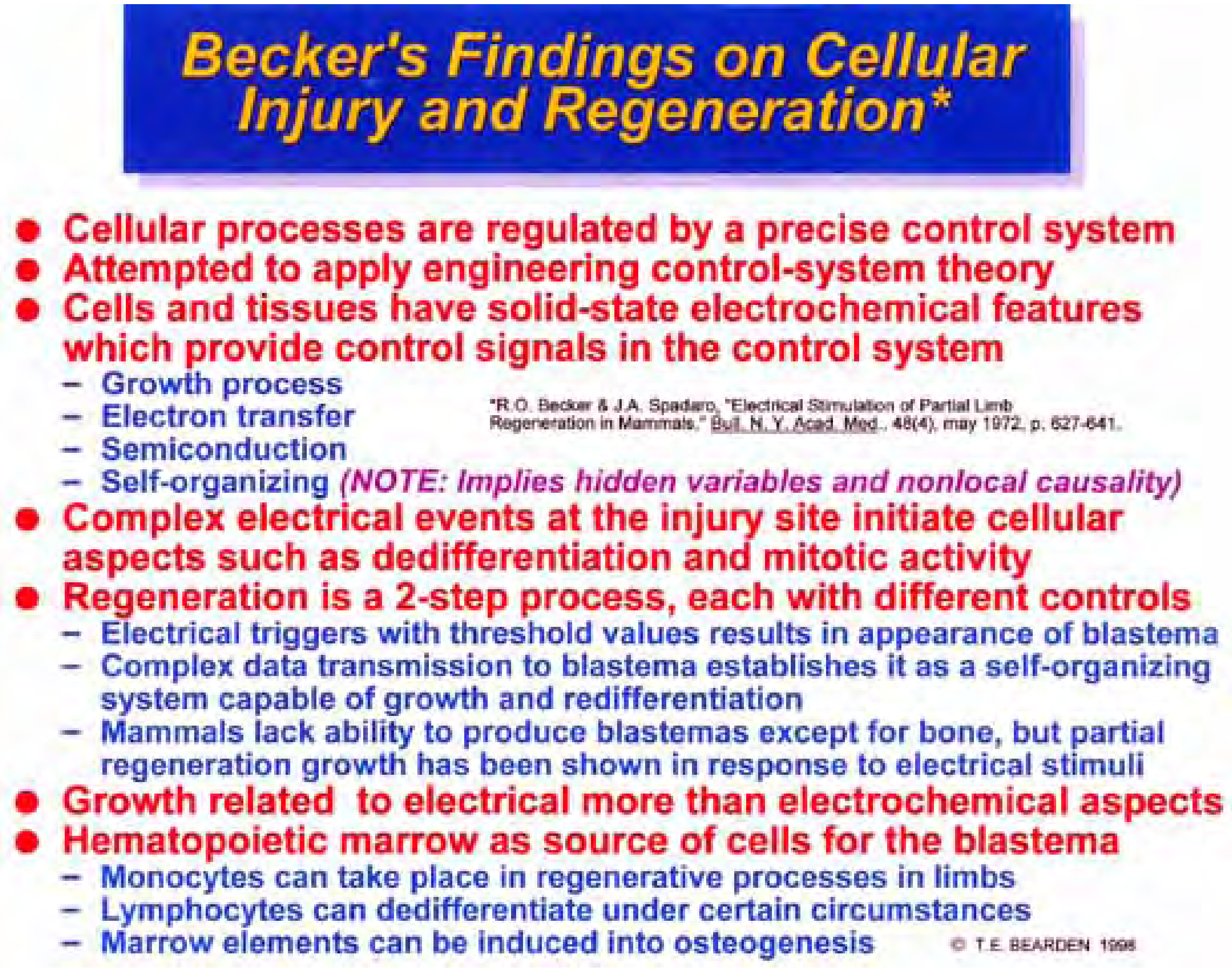

Becker's Findings on Cellular Injury and Regeneration*

- Cellular processes are regulated by a precise control system
- Attempted to apply engineering control-system theory
- Cells and tissues have solid-state electrochemical features which provide control signals in the control system
  - Growth process
  - Electron transfer
  - Semiconduction
  - Self-organizing *(NOTE: Implies hidden variables and nonlocal causality)*
- Complex electrical events at the injury site initiate cellular aspects such as dedifferentiation and mitotic activity
- Regeneration is a 2-step process, each with different controls
  - Electrical triggers with threshold values results in appearance of blastema
  - Complex data transmission to blastema establishes it as a self-organizing system capable of growth and redifferentiation
  - Mammals lack ability to produce blastemas except for bone, but partial regeneration growth has been shown in response to electrical stimuli
- Growth related to electrical more than electrochemical aspects
- Hematopoietic marrow as source of cells for the blastema
  - Monocytes can take place in regenerative processes in limbs
  - Lymphocytes can dedifferentiate under certain circumstances
  - Marrow elements can be induced into osteogenesis

*R.O. Becker & J.A. Spadaro, "Electrical Stimulation of Partial Limb Regeneration in Mammals," Bull. N. Y. Acad. Med., 48(4), may 1972, p. 627-641.

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Corrections For the Present EM Bioeffects Model

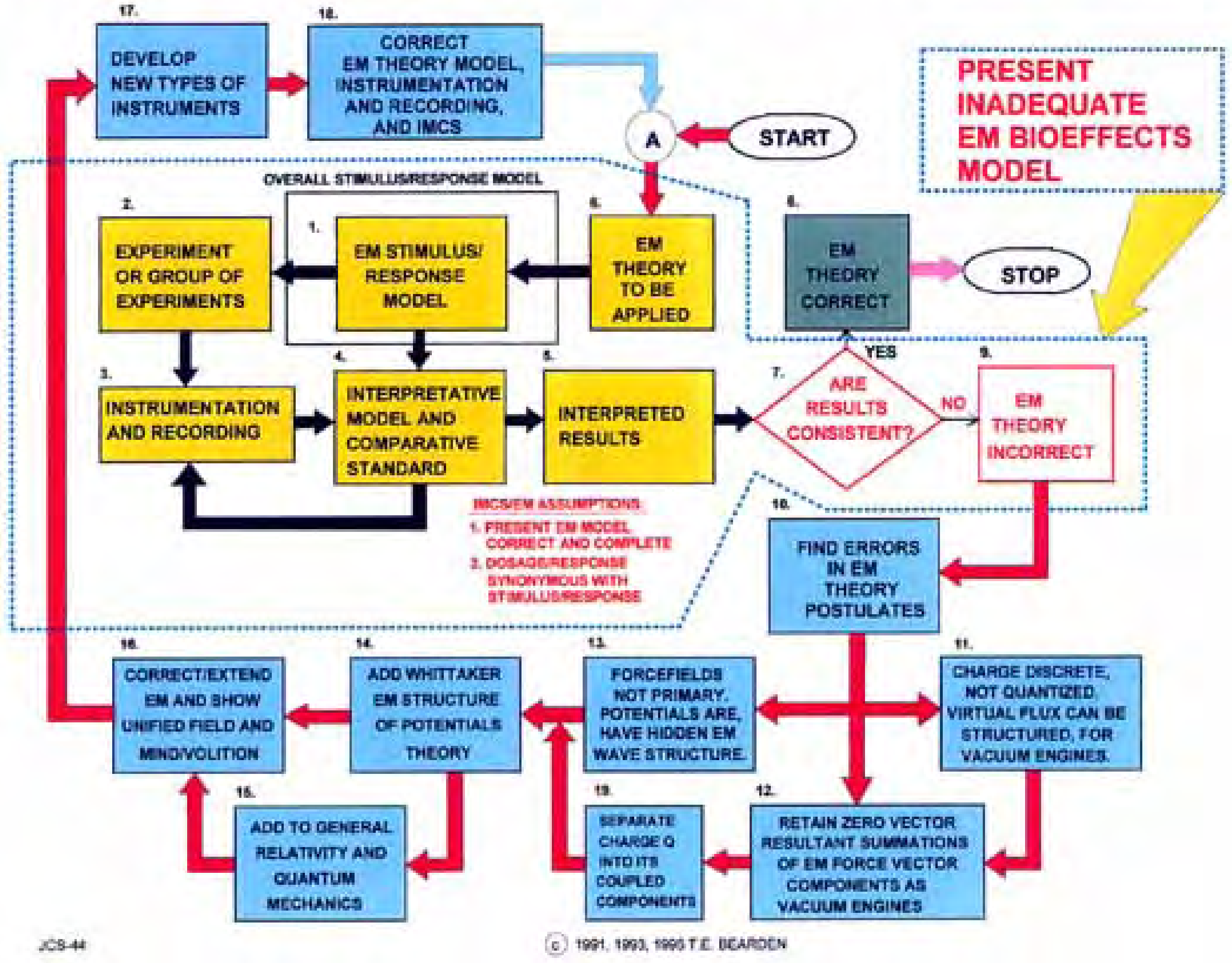

17. DEVELOP NEW TYPES OF INSTRUMENTS

18. CORRECT EM THEORY MODEL, INSTRUMENTATION AND RECORDING, AND IMCS

A

START

PRESENT INADEQUATE EM BIOEFFECTS MODEL

OVERALL STIMULUS/RESPONSE MODEL

2. EXPERIMENT OR GROUP OF EXPERIMENTS

1. EM STIMULUS/ RESPONSE MODEL

6. EM THEORY TO BE APPLIED

8. EM THEORY CORRECT

STOP

3. INSTRUMENTATION AND RECORDING

4. INTERPRETATIVE MODEL AND COMPARATIVE STANDARD

5. INTERPRETED RESULTS

7. ARE RESULTS CONSISTENT?

YES

NO

9. EM THEORY INCORRECT

IMCS/EM ASSUMPTIONS
1. PRESENT EM MODEL CORRECT AND COMPLETE
2. DOSAGE/RESPONSE SYNONYMOUS WITH STIMULUS/RESPONSE

10. FIND ERRORS IN EM THEORY POSTULATES

16. CORRECT/EXTEND EM AND SHOW UNIFIED FIELD AND MIND/VOLITION

14. ADD WHITTAKER EM STRUCTURE OF POTENTIALS THEORY

13. FORCEFIELDS NOT PRIMARY. POTENTIALS ARE, HAVE HIDDEN EM WAVE STRUCTURE.

11. CHARGE DISCRETE, NOT QUANTIZED. VIRTUAL FLUX CAN BE STRUCTURED, FOR VACUUM ENGINES.

15. ADD TO GENERAL RELATIVITY AND QUANTUM MECHANICS

19. SEPARATE CHARGE Q INTO ITS COUPLED COMPONENTS

12. RETAIN ZERO VECTOR RESULTANT SUMMATIONS OF EM FORCE VECTOR COMPONENTS AS VACUUM ENGINES

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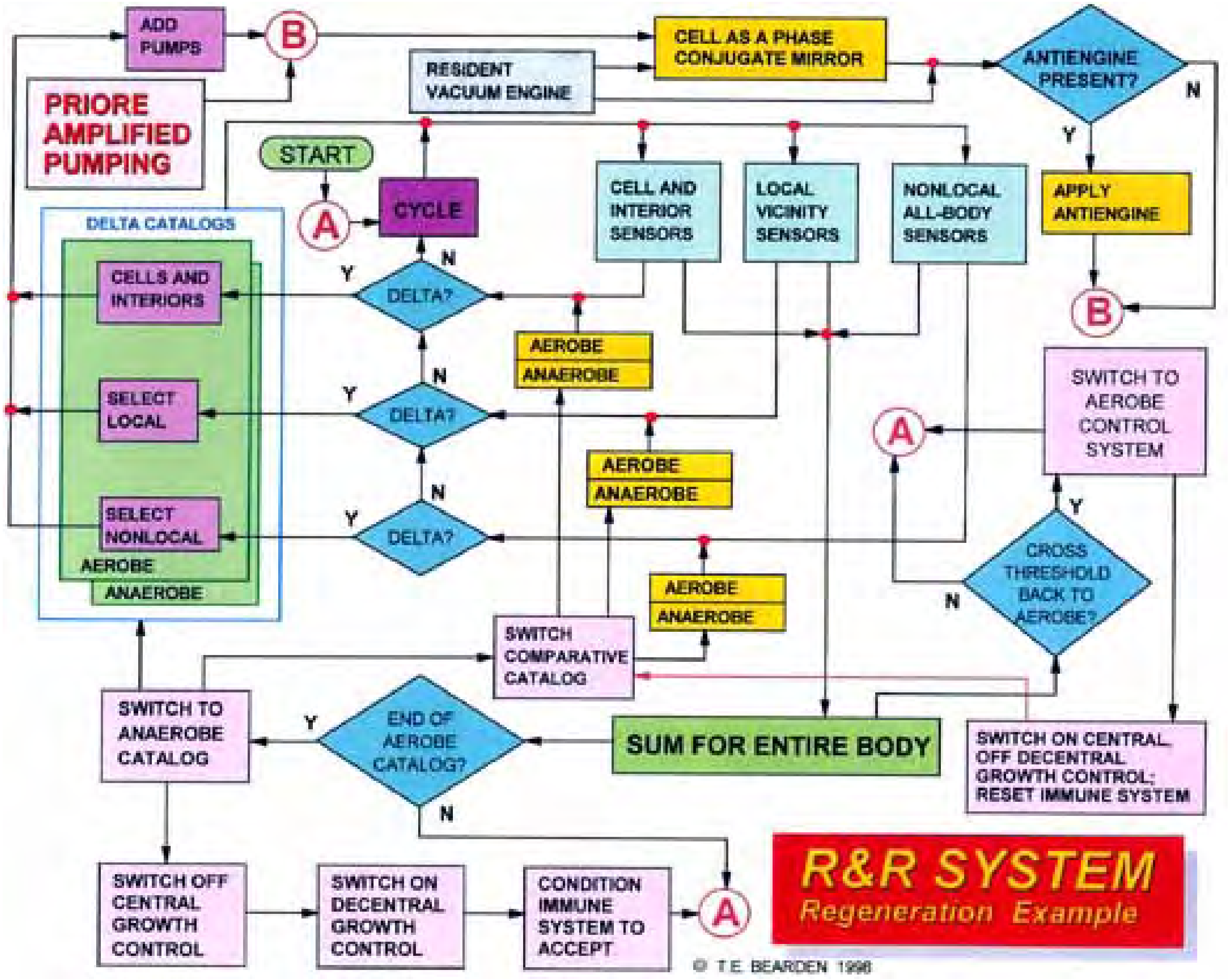

PRIORE AMPLIFIED PUMPING

ADD PUMPS

B

CELL AS A PHASE CONJUGATE MIRROR

RESIDENT VACUUM ENGINE

ANTIENGINE PRESENT?

N

Y

APPLY ANTIENGINE

B

START

A

CYCLE

CELL AND INTERIOR SENSORS

LOCAL VICINITY SENSORS

NONLOCAL ALL-BODY SENSORS

DELTA CATALOGS

CELLS AND INTERIORS

SELECT LOCAL

SELECT NONLOCAL

AEROBE

ANAEROBE

Y

DELTA?

N

Y

DELTA?

N

Y

DELTA?

N

AEROBE

ANAEROBE

AEROBE

ANAEROBE

AEROBE

ANAEROBE

SWITCH TO AEROBE CONTROL SYSTEM

A

Y

CROSS THRESHOLD BACK TO AEROBE?

N

SWITCH COMPARATIVE CATALOG

SWITCH TO ANAEROBE CATALOG

Y

END OF AEROBE CATALOG?

N

SUM FOR ENTIRE BODY

SWITCH ON CENTRAL, OFF DECENTRAL GROWTH CONTROL; RESET IMMUNE SYSTEM

SWITCH OFF CENTRAL GROWTH CONTROL

SWITCH ON DECENTRAL GROWTH CONTROL

CONDITION IMMUNE SYSTEM TO ACCEPT

A

R&R SYSTEM

Regeneration Example

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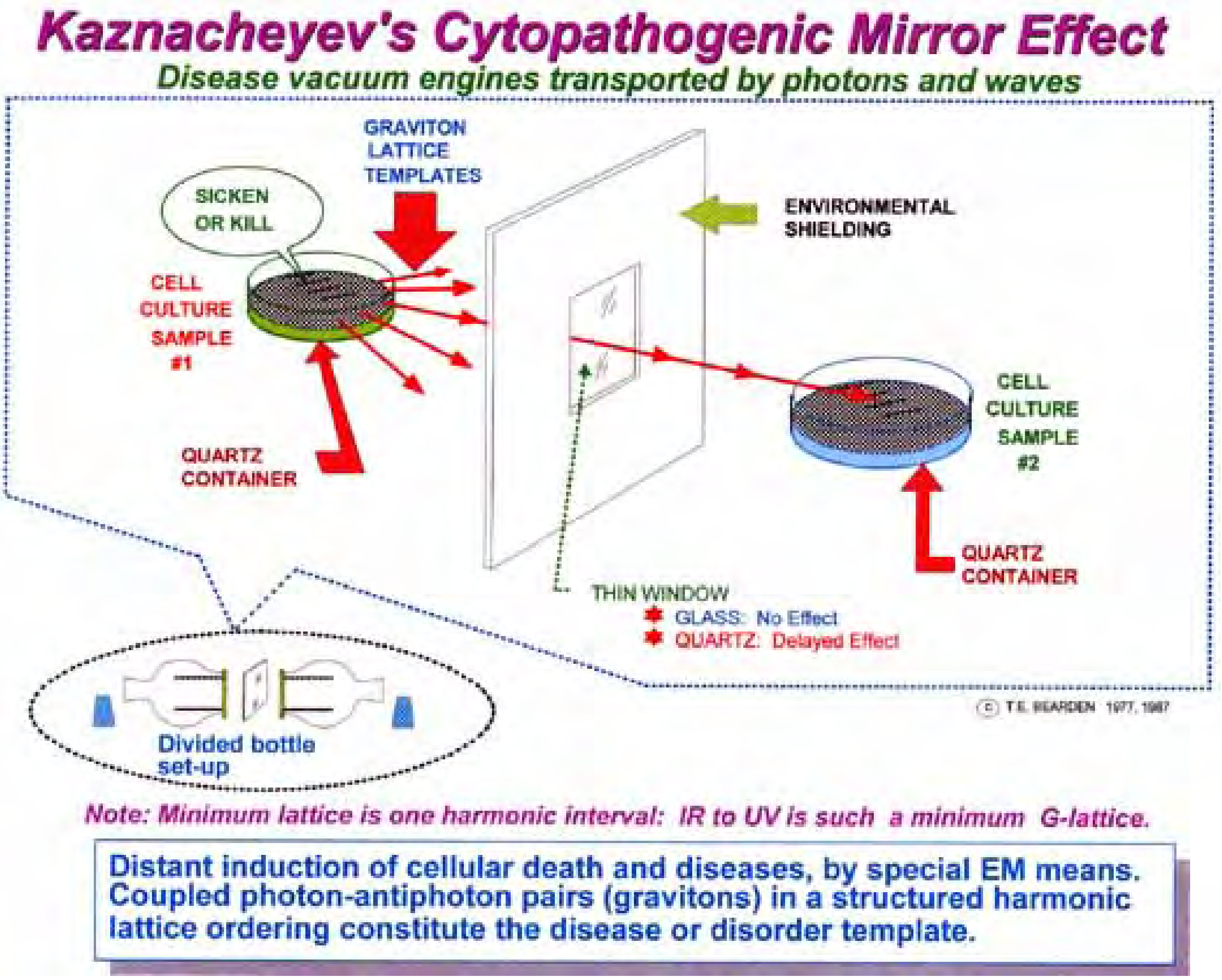

Kaznacheyev's Cytopathogenic Mirror Effect

Disease vacuum engines transported by photons and waves

GRAVITON
LATTICE
TEMPLATES
SICKEN
OR KILL
ENVIRONMENTAL
SHIELDING
CELL
CULTURE
SAMPLE
#1
QUARTZ
CONTAINER
CELL
CULTURE
SAMPLE
#2
QUARTZ
CONTAINER
THIN WINDOW
GLASS: No Effect
QUARTZ: Delayed Effect
Divided bottle
set-up
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Note: Minimum lattice is one harmonic interval: IR to UV is such a minimum G-lattice.

Distant induction of cellular death and diseases, by special EM means. Coupled photon-antiphoton pairs (gravitons) in a structured harmonic lattice ordering constitute the disease or disorder template.

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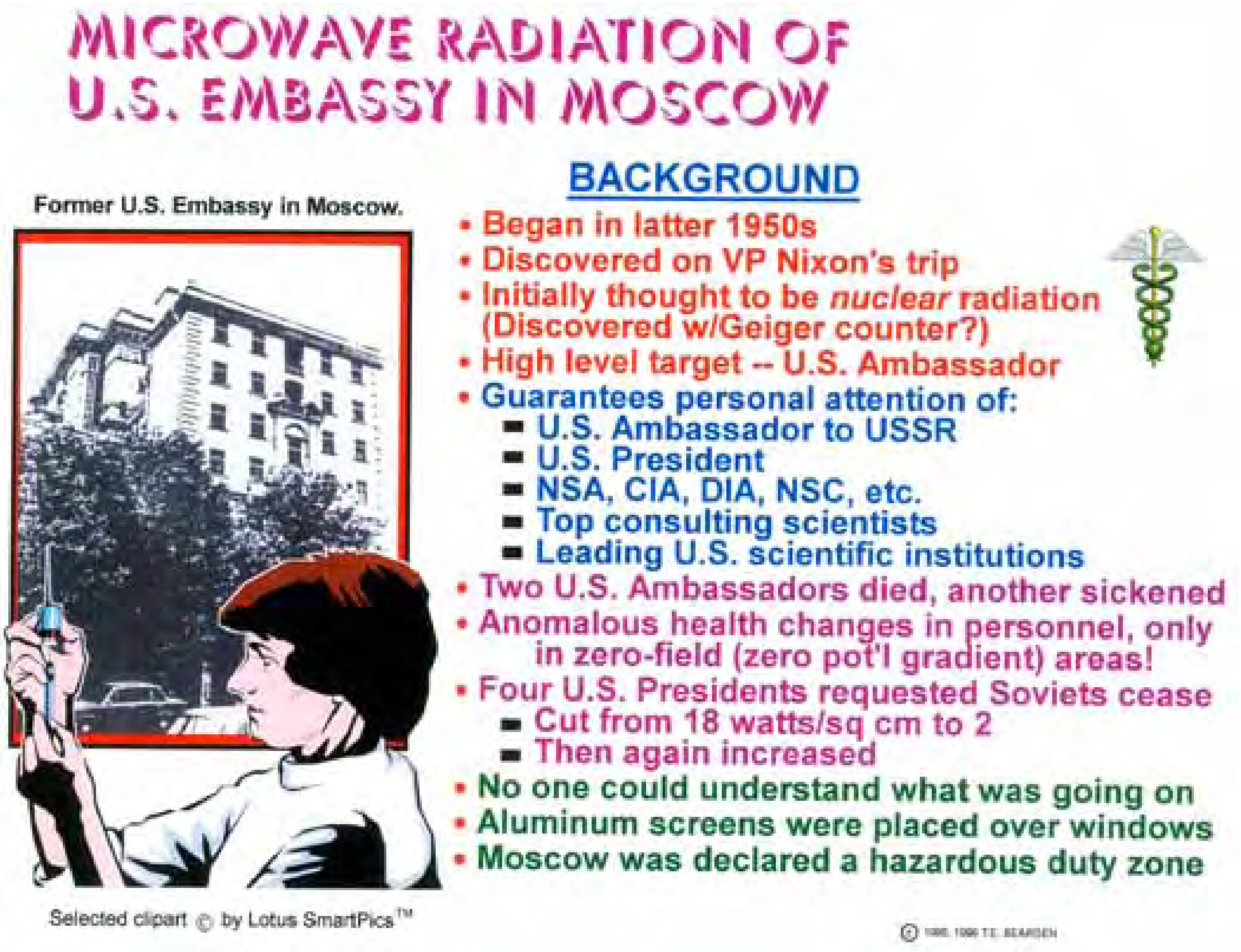

MICROWAVE RADIATION OF U.S. EMBASSY IN MOSCOW

Former U.S. Embassy in Moscow.

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter?)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
  - U.S. Ambassador to USSR
  - U.S. President
  - NSA, CIA, DIA, NSC, etc.
  - Top consulting scientists
  - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero pot'l gradient) areas!
- Four U.S. Presidents requested Soviets cease
  - Cut from 18 watts/sq cm to 2
  - Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

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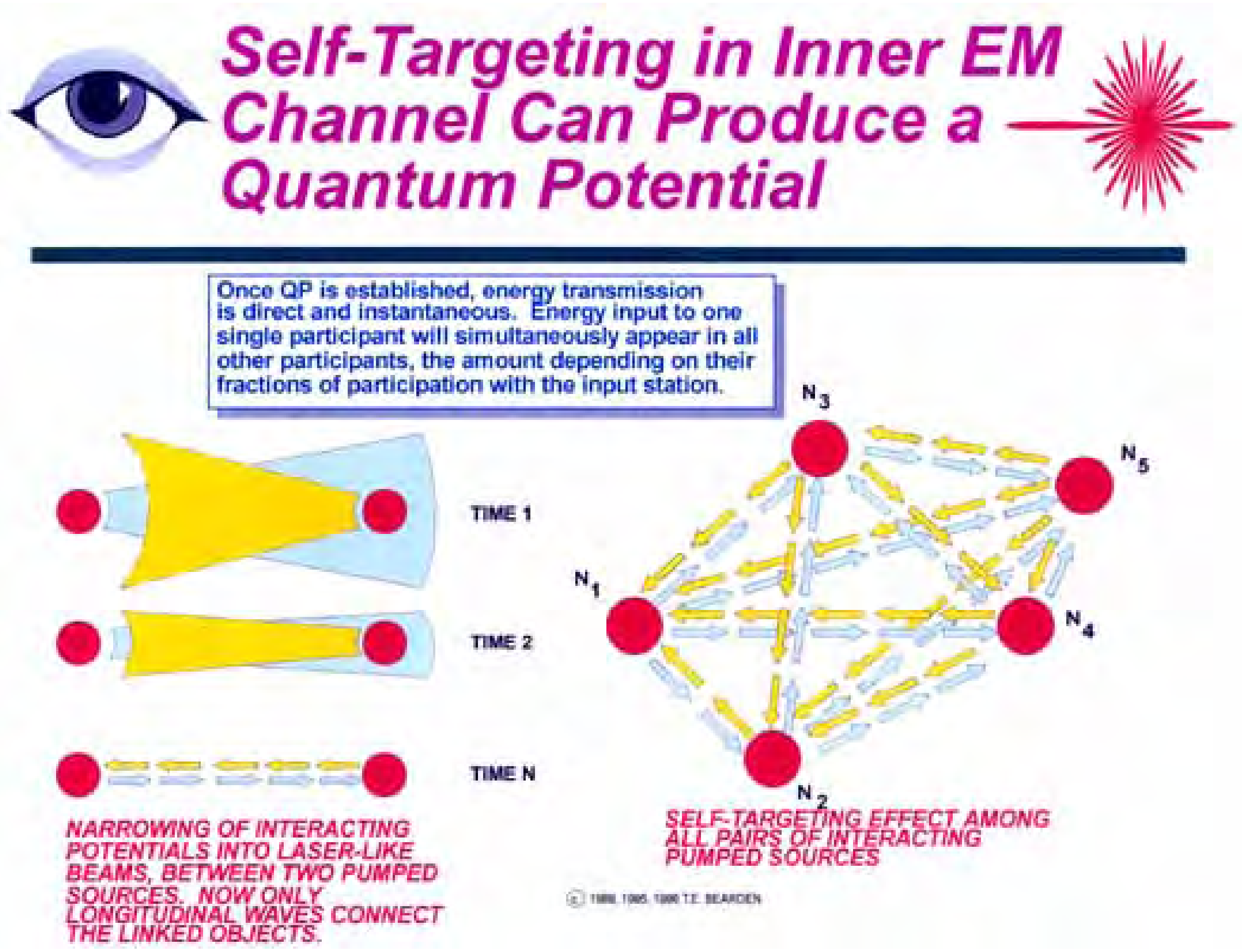

Self-Targeting in Inner EM Channel Can Produce a Quantum Potential

Once QP is established, energy transmission is direct and instantaneous. Energy input to one single participant will simultaneously appear in all other participants, the amount depending on their fractions of participation with the input station.

NARROWING OF INTERACTING POTENTIALS INTO LASER-LIKE BEAMS, BETWEEN TWO PUMPED SOURCES. NOW ONLY LONGITUDINAL WAVES CONNECT THE LINKED OBJECTS.

SELF-TARGETING EFFECT AMONG ALL PAIRS OF INTERACTING PUMPED SOURCES

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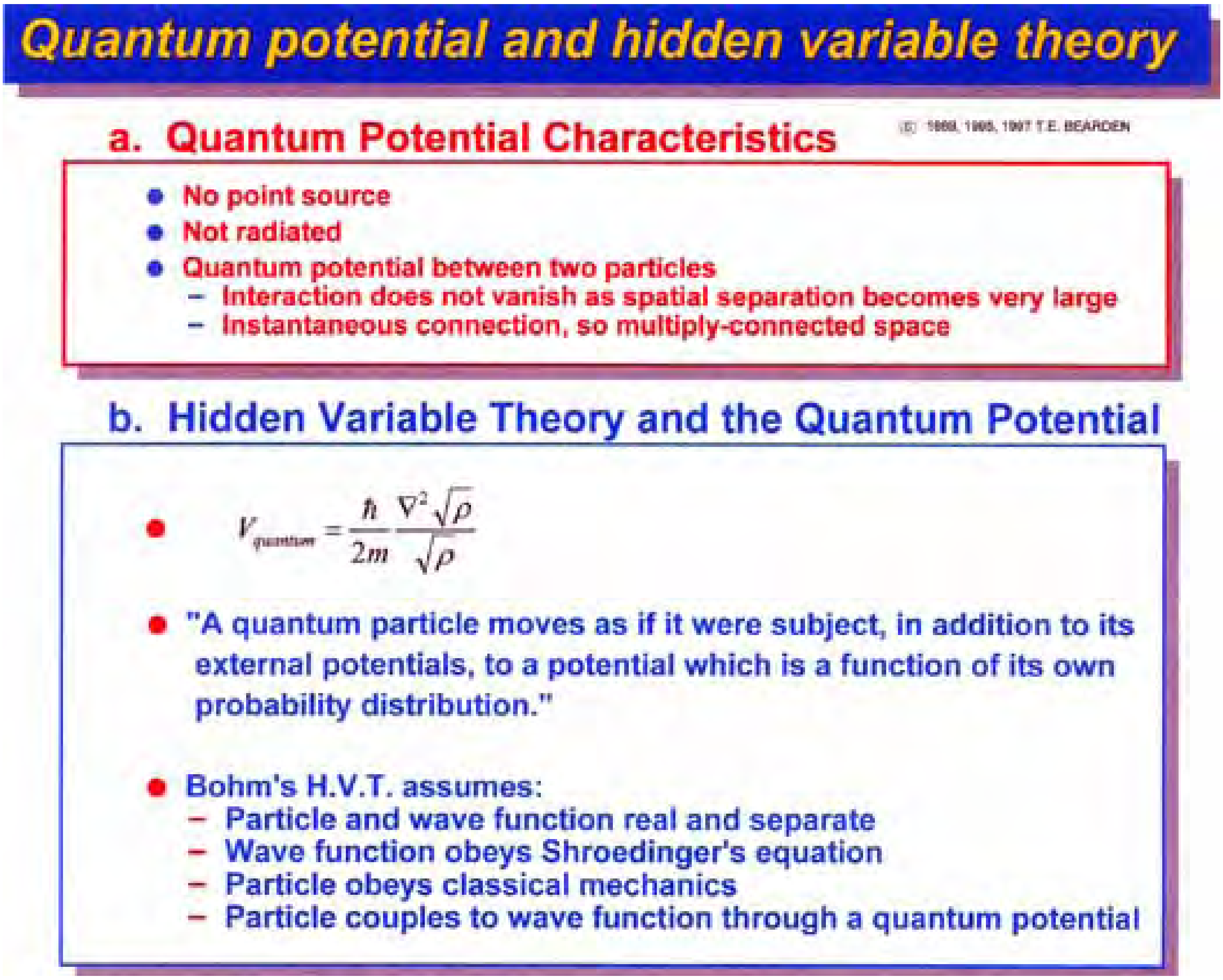

Quantum potential and hidden variable theory

a. Quantum Potential Characteristics

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- No point source
- Not radiated
- Quantum potential between two particles
  - Interaction does not vanish as spatial separation becomes very large
  - Instantaneous connection, so multiply-connected space

b. Hidden Variable Theory and the Quantum Potential

- $V_{quantum} = \frac{\hbar}{2m} \frac{\nabla^2 \sqrt{\rho}}{\sqrt{\rho}}$
- "A quantum particle moves as if it were subject, in addition to its external potentials, to a potential which is a function of its own probability distribution."
- Bohm's H.V.T. assumes:
  - Particle and wave function real and separate
  - Wave function obeys Shroedinger's equation
  - Particle obeys classical mechanics
  - Particle couples to wave function through a quantum potential

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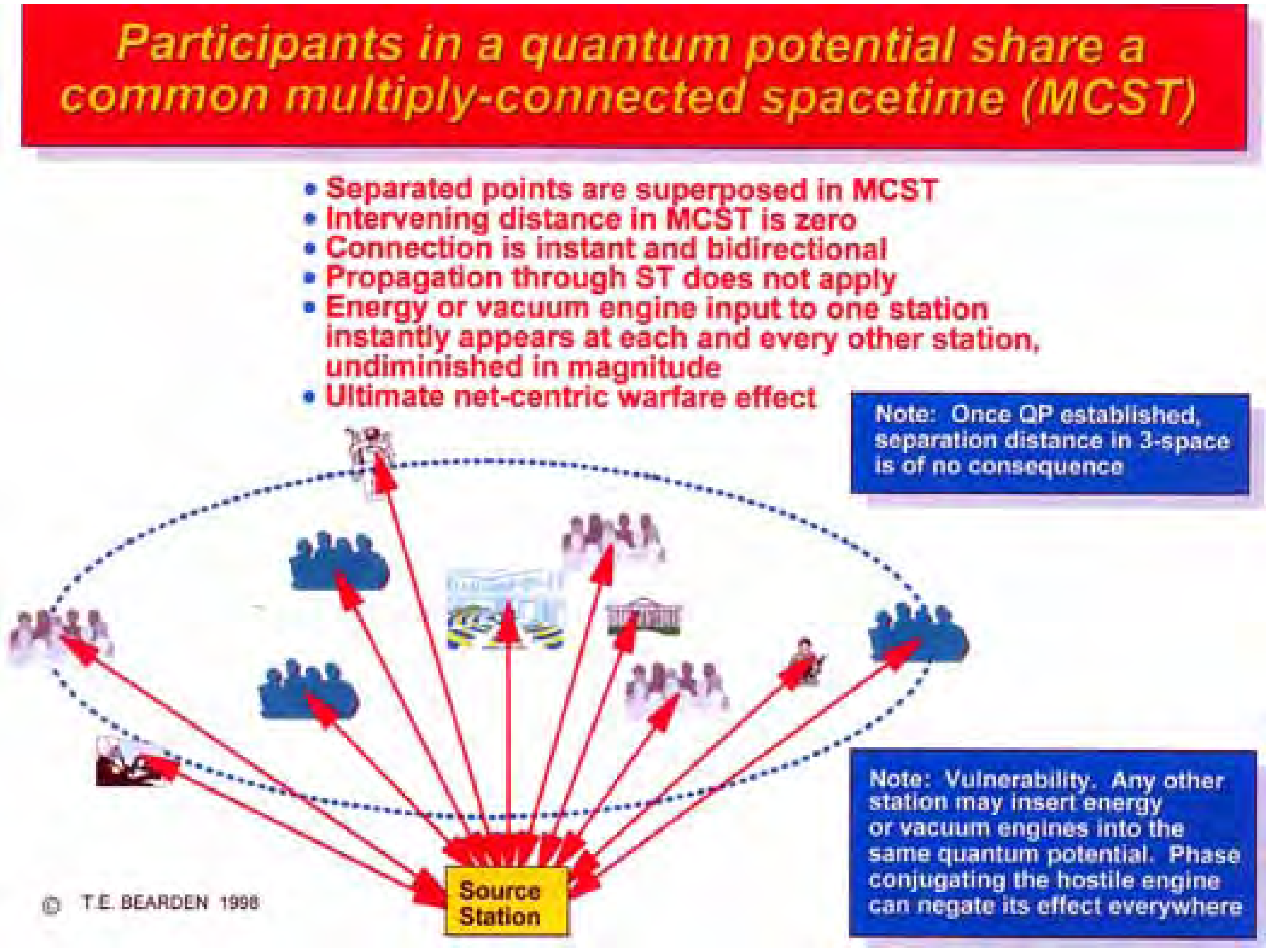

Participants in a quantum potential share a common multiply-connected spacetime (MCST)

- Separated points are superposed in MCST
- Intervening distance in MCST is zero
- Connection is instant and bidirectional
- Propagation through ST does not apply
- Energy or vacuum engine input to one station instantly appears at each and every other station, undiminished in magnitude
- Ultimate net-centric warfare effect

Note: Once QP established, separation distance in 3-space is of no consequence

Note: Vulnerability. Any other station may insert energy or vacuum engines into the same quantum potential. Phase conjugating the hostile engine can negate its effect everywhere

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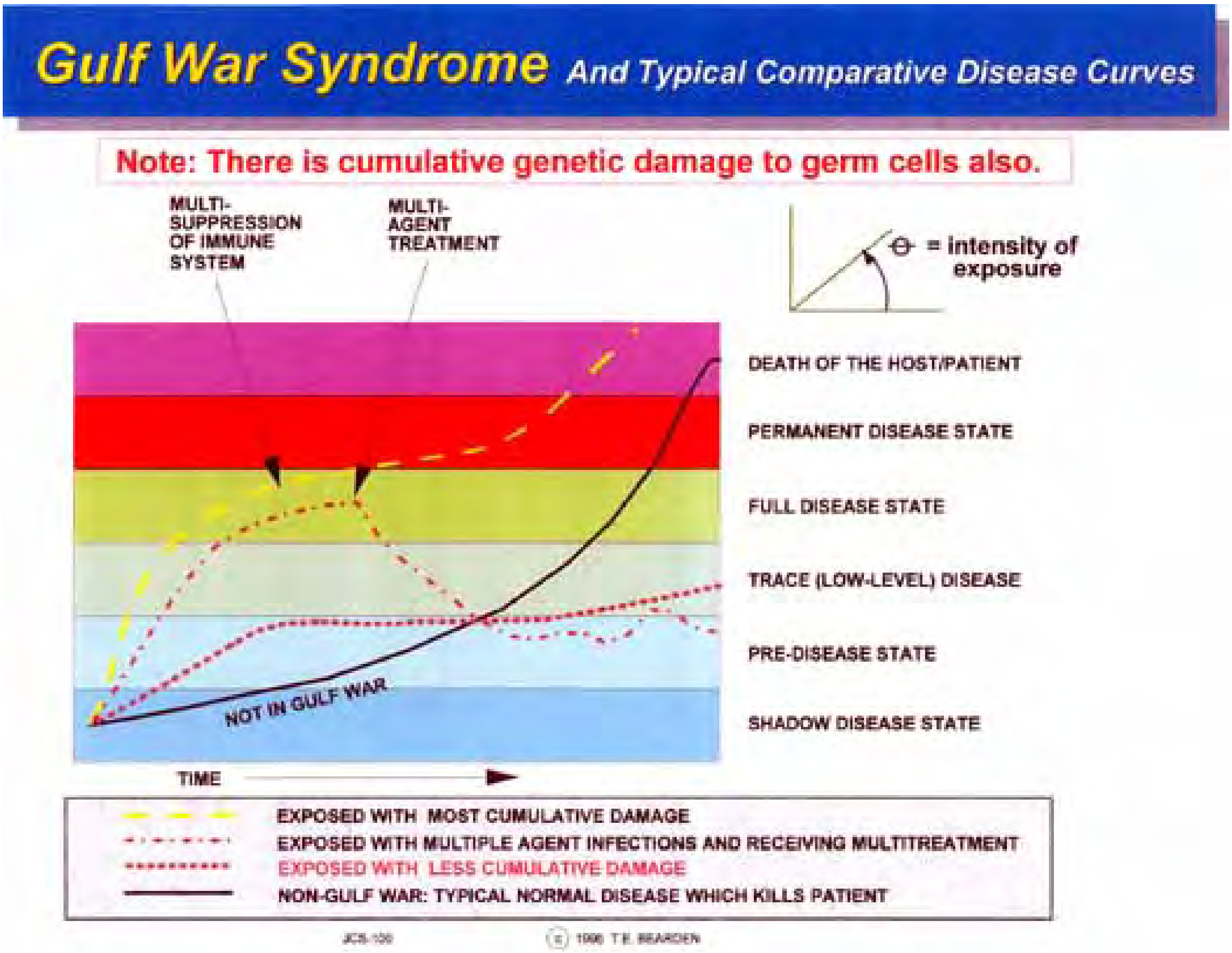

Gulf War Syndrome And Typical Comparative Disease Curves

Note: There is cumulative genetic damage to germ cells also.

— — —	EXPOSED WITH MOST CUMULATIVE DAMAGE
-·-·-·-·	EXPOSED WITH MULTIPLE AGENT INFECTIONS AND RECEIVING MULLTITREATMENT
**********	EXPOSED WITH LESS CUMULATIVE DAMAGE
——	NON-GULF WAR: TYPICAL NORMAL DISEASE WHICH KILLS PATIENT

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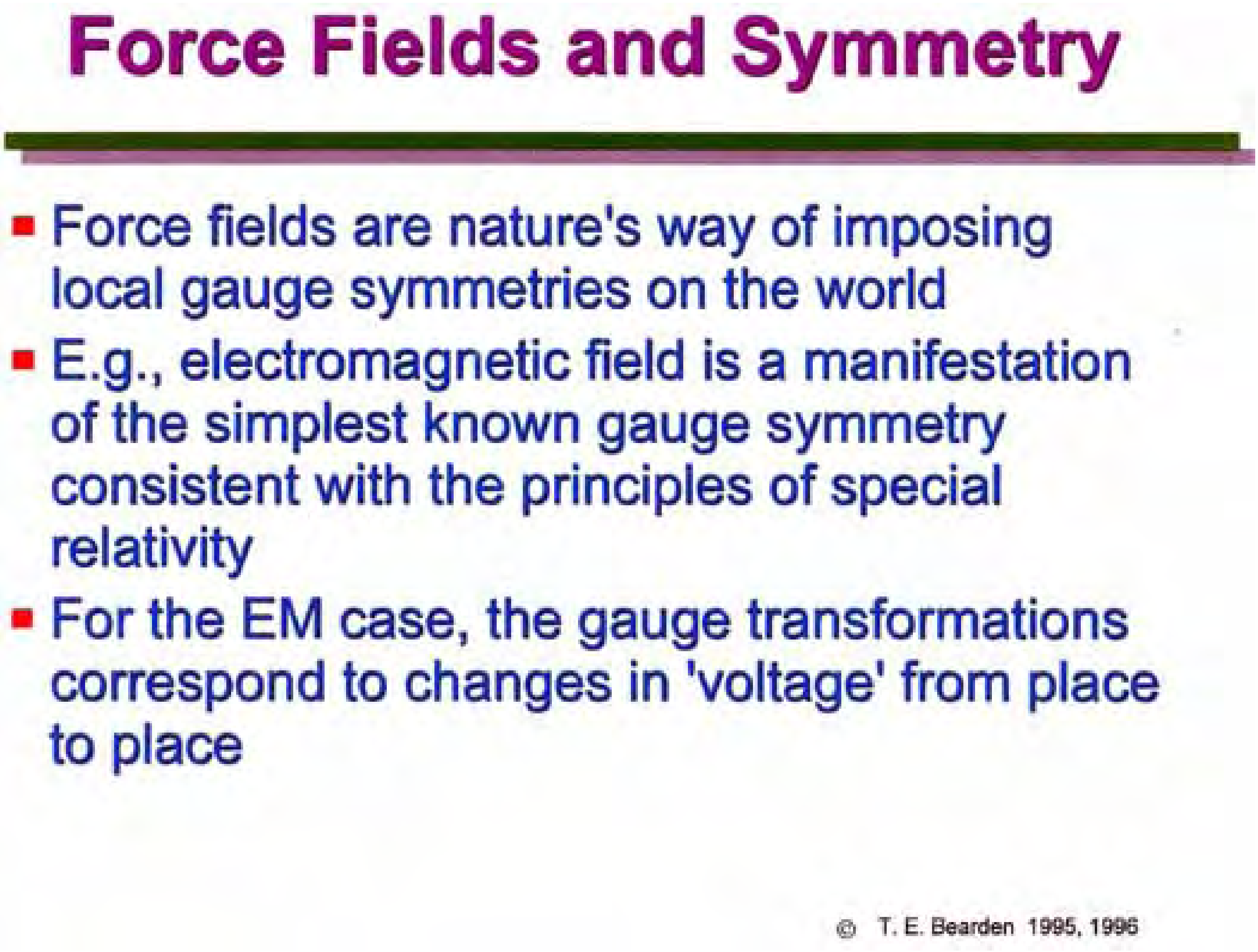

Force Fields and Symmetry

- Force fields are nature's way of imposing local gauge symmetries on the world
- E.g., electromagnetic field is a manifestation of the simplest known gauge symmetry consistent with the principles of special relativity
- For the EM case, the gauge transformations correspond to changes in 'voltage' from place to place

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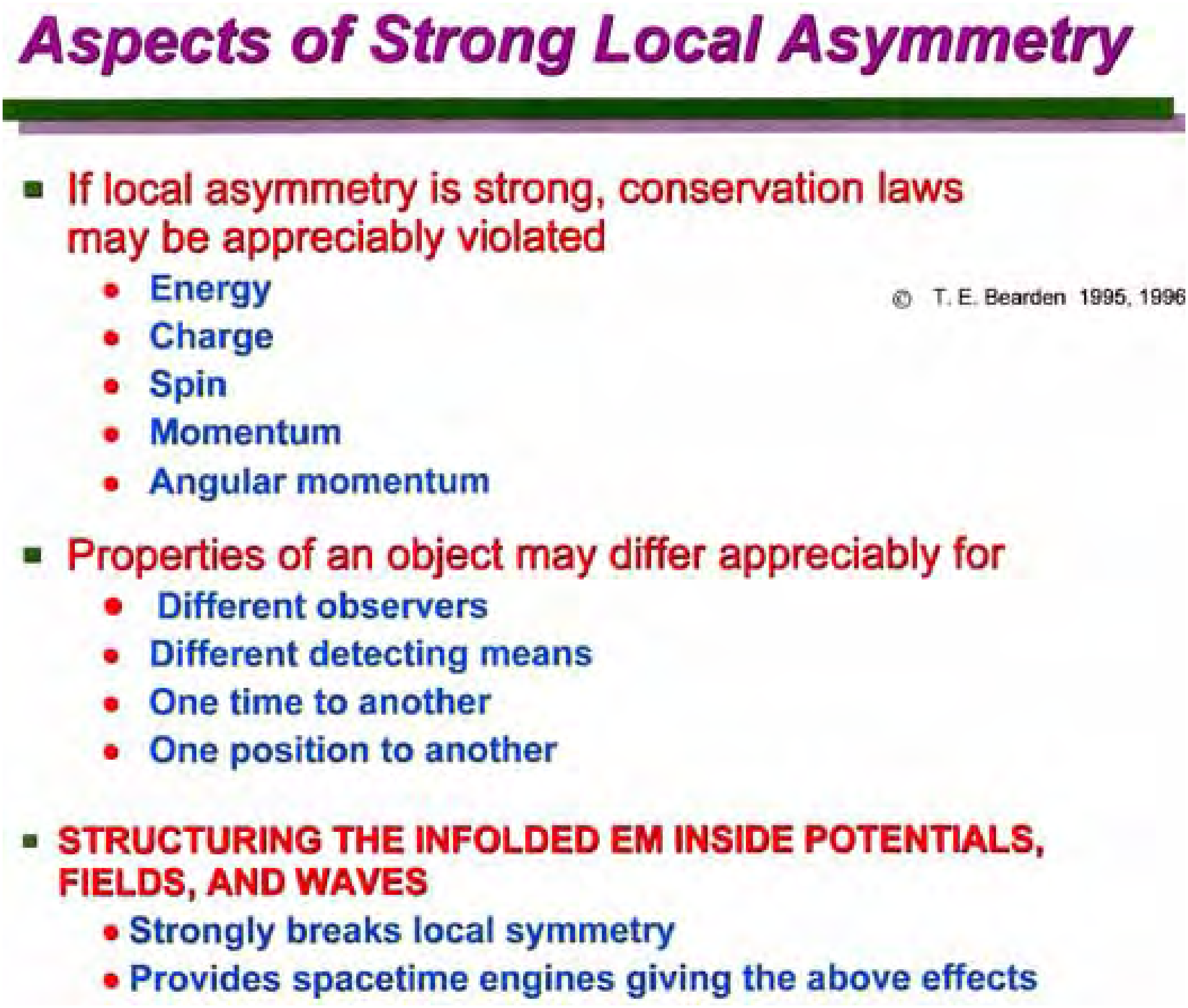

Aspects of Strong Local Asymmetry

- If local asymmetry is strong, conservation laws may be appreciably violated
  - Energy
  - Charge
  - Spin
  - Momentum
  - Angular momentum

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- Properties of an object may differ appreciably for
  - Different observers
  - Different detecting means
  - One time to another
  - One position to another
- STRUCTURING THE INFOLDED EM INSIDE POTENTIALS, FIELDS, AND WAVES
  - Strongly breaks local symmetry
  - Provides spacetime engines giving the above effects

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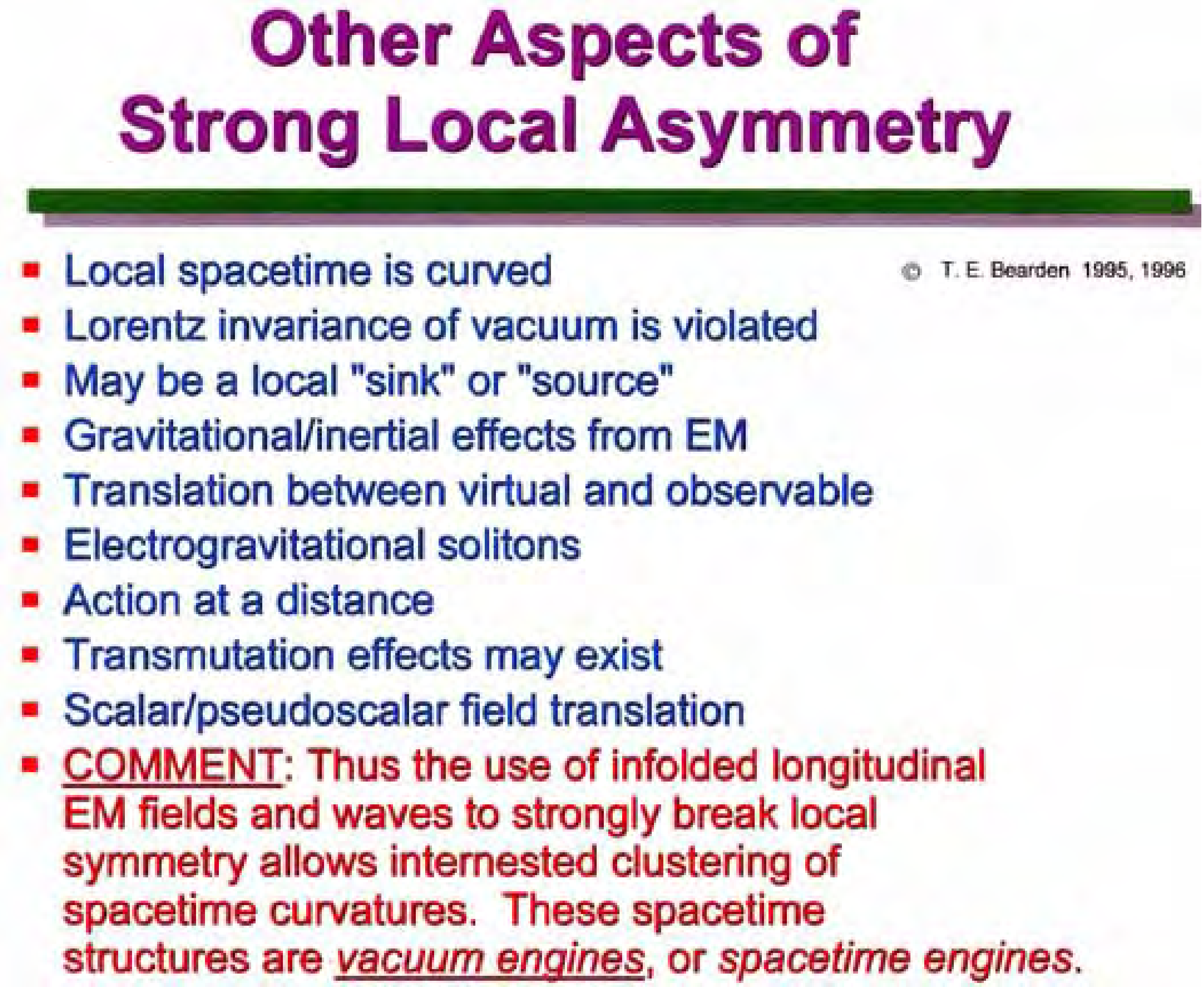

Other Aspects of Strong Local Asymmetry

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- Local spacetime is curved
- Lorentz invariance of vacuum is violated
- May be a local "sink" or "source"
- Gravitational/inertial effects from EM
- Translation between virtual and observable
- Electrogravitational solitons
- Action at a distance
- Transmutation effects may exist
- Scalar/pseudoscalar field translation
- COMMENT: Thus the use of infolded longitudinal EM fields and waves to strongly break local symmetry allows internested clustering of spacetime curvatures. These spacetime structures are *vacuum engines*, or *spacetime engines*.

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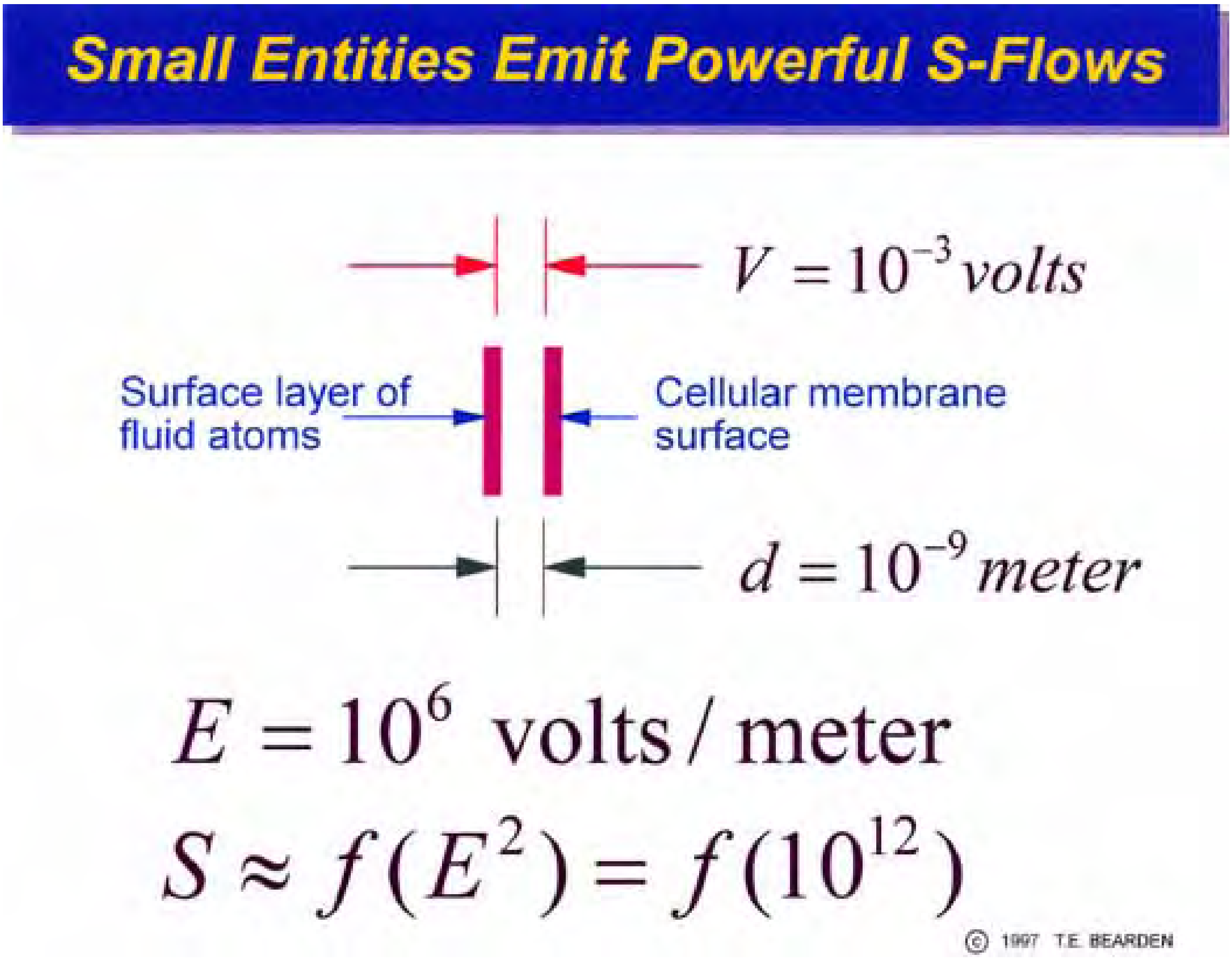

Small Entities Emit Powerful S-Flows

$V = 10^{-3}\, volts$

Surface layer of fluid atoms

Cellular membrane surface

$d = 10^{-9}\, meter$

$$E = 10^{6} \text{ volts / meter}$$

$$S \approx f(E^{2}) = f(10^{12})$$

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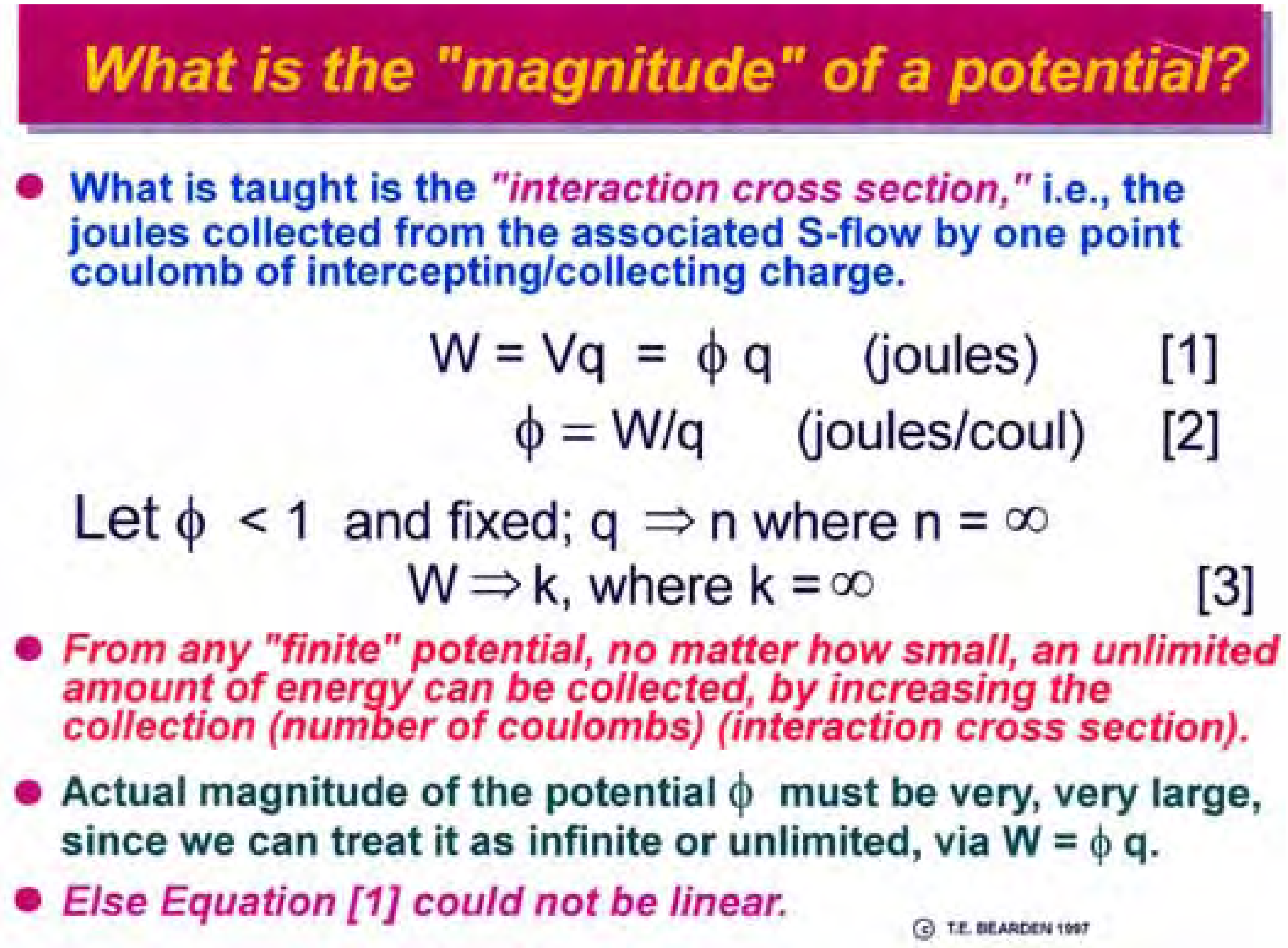

What is the "magnitude" of a potential?

- What is taught is the *"interaction cross section,"* i.e., the joules collected from the associated S-flow by one point coulomb of intercepting/collecting charge.

$$W = Vq = \phi q \qquad \text{(joules)} \qquad [1]$$

$$\phi = W/q \qquad \text{(joules/coul)} \qquad [2]$$

Let $\phi < 1$ and fixed; $q \Rightarrow n$ where $n = \infty$

$$W \Rightarrow k, \text{ where } k = \infty \qquad [3]$$

- *From any "finite" potential, no matter how small, an unlimited amount of energy can be collected, by increasing the collection (number of coulombs) (interaction cross section).*
- Actual magnitude of the potential ϕ must be very, very large, since we can treat it as infinite or unlimited, via $W = \phi q$.
- *Else Equation [1] could not be linear.*

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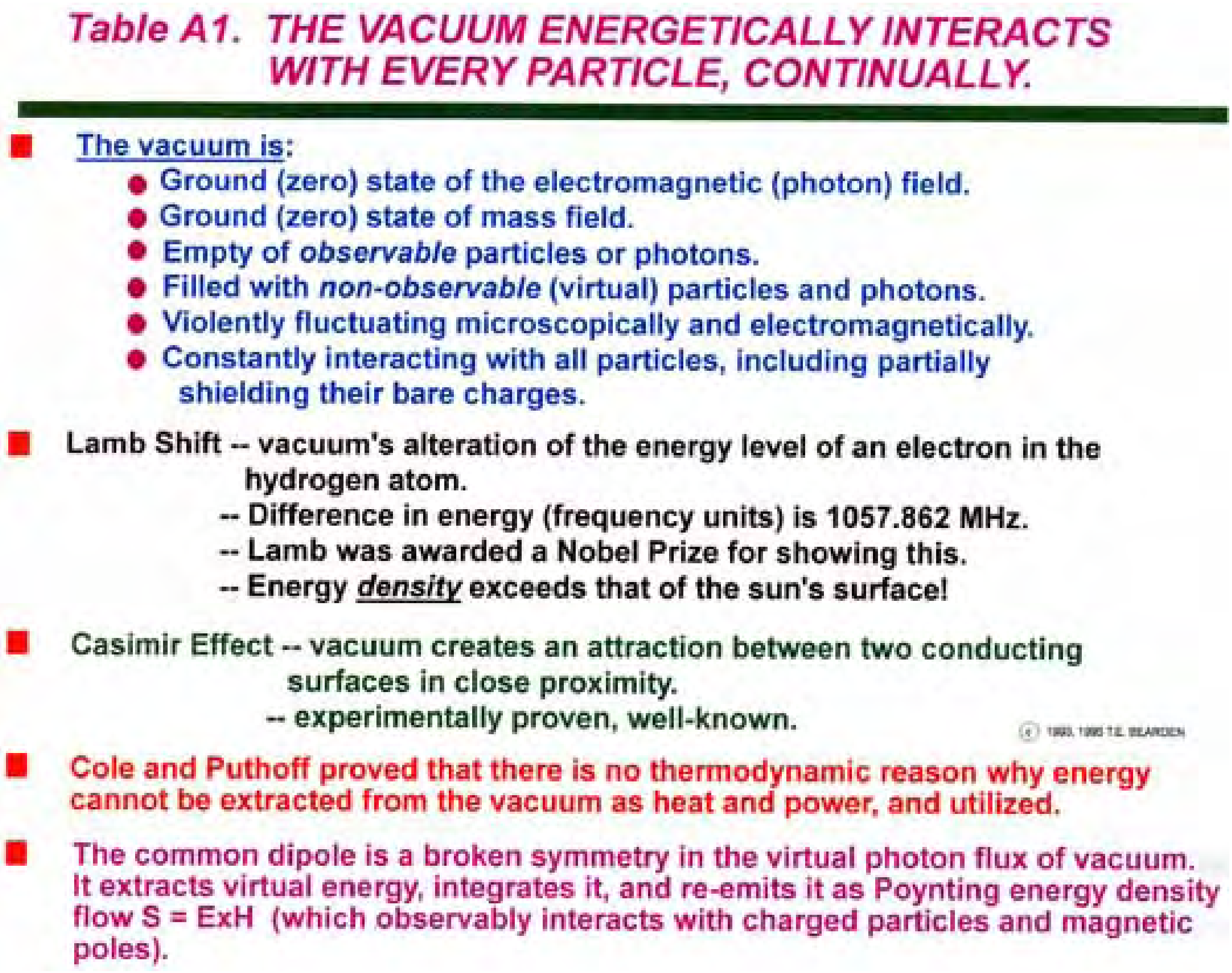

Table A1. THE VACUUM ENERGETICALLY INTERACTS WITH EVERY PARTICLE, CONTINUALLY.

- The vacuum is:
    - Ground (zero) state of the electromagnetic (photon) field.
    - Ground (zero) state of mass field.
    - Empty of *observable* particles or photons.
    - Filled with *non-observable* (virtual) particles and photons.
    - Violently fluctuating microscopically and electromagnetically.
    - Constantly interacting with all particles, including partially shielding their bare charges.
- Lamb Shift -- vacuum's alteration of the energy level of an electron in the hydrogen atom.
    - -- Difference in energy (frequency units) is 1057.862 MHz.
    - -- Lamb was awarded a Nobel Prize for showing this.
    - -- Energy ***density*** exceeds that of the sun's surface!
- Casimir Effect -- vacuum creates an attraction between two conducting surfaces in close proximity.
    - -- experimentally proven, well-known.
- Cole and Puthoff proved that there is no thermodynamic reason why energy cannot be extracted from the vacuum as heat and power, and utilized.
- The common dipole is a broken symmetry in the virtual photon flux of vacuum. It extracts virtual energy, integrates it, and re-emits it as Poynting energy density flow S = ExH (which observably interacts with charged particles and magnetic poles).

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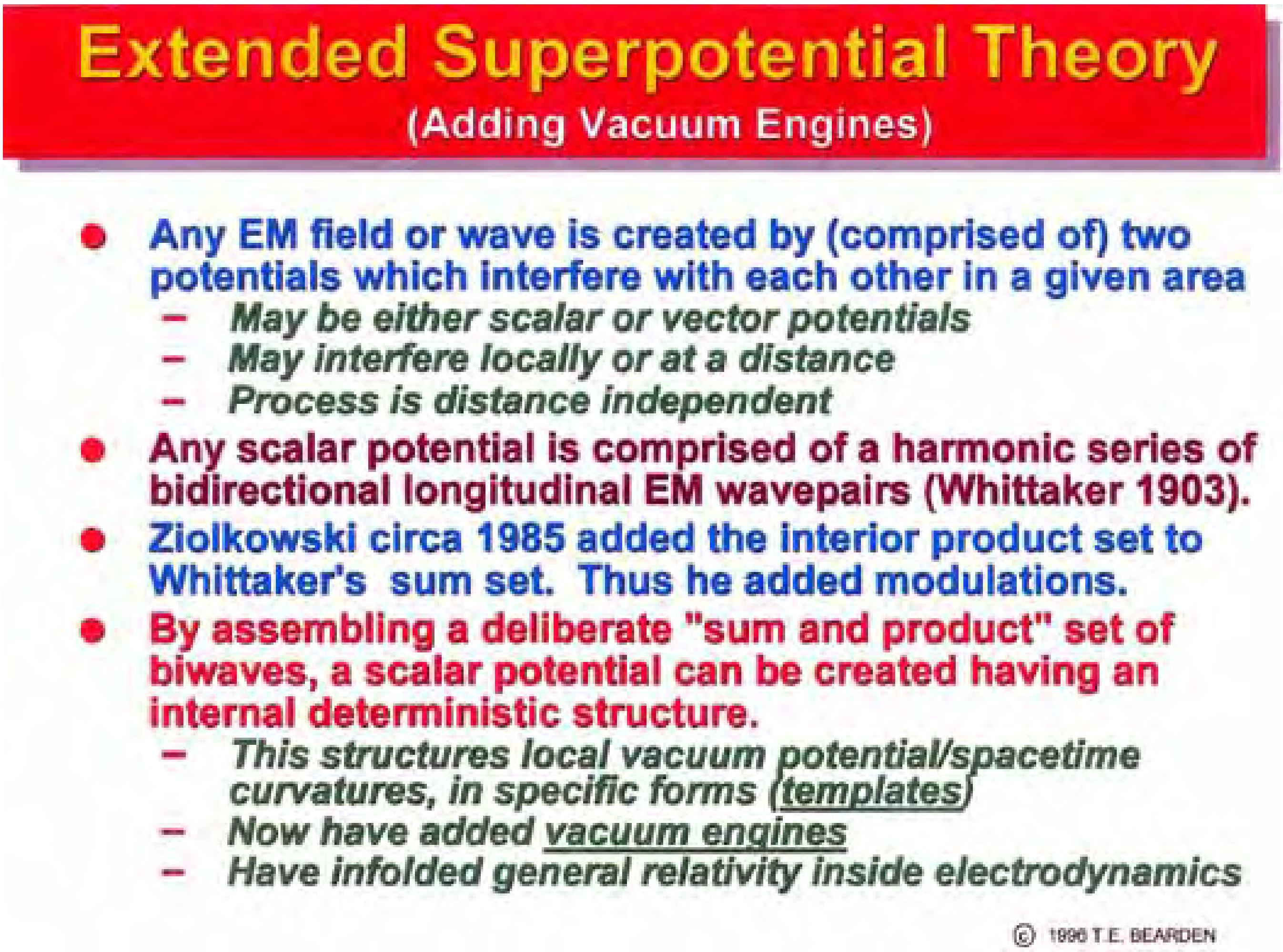

Extended Superpotential Theory

(Adding Vacuum Engines)

- Any EM field or wave is created by (comprised of) two potentials which interfere with each other in a given area
  - *May be either scalar or vector potentials*
  - *May interfere locally or at a distance*
  - *Process is distance independent*
- Any scalar potential is comprised of a harmonic series of bidirectional longitudinal EM wavepairs (Whittaker 1903).
- Ziolkowski circa 1985 added the interior product set to Whittaker's sum set. Thus he added modulations.
- By assembling a deliberate "sum and product" set of biwaves, a scalar potential can be created having an internal deterministic structure.
  - *This structures local vacuum potential/spacetime curvatures, in specific forms (templates)*
  - *Now have added vacuum engines*
  - *Have infolded general relativity inside electrodynamics*

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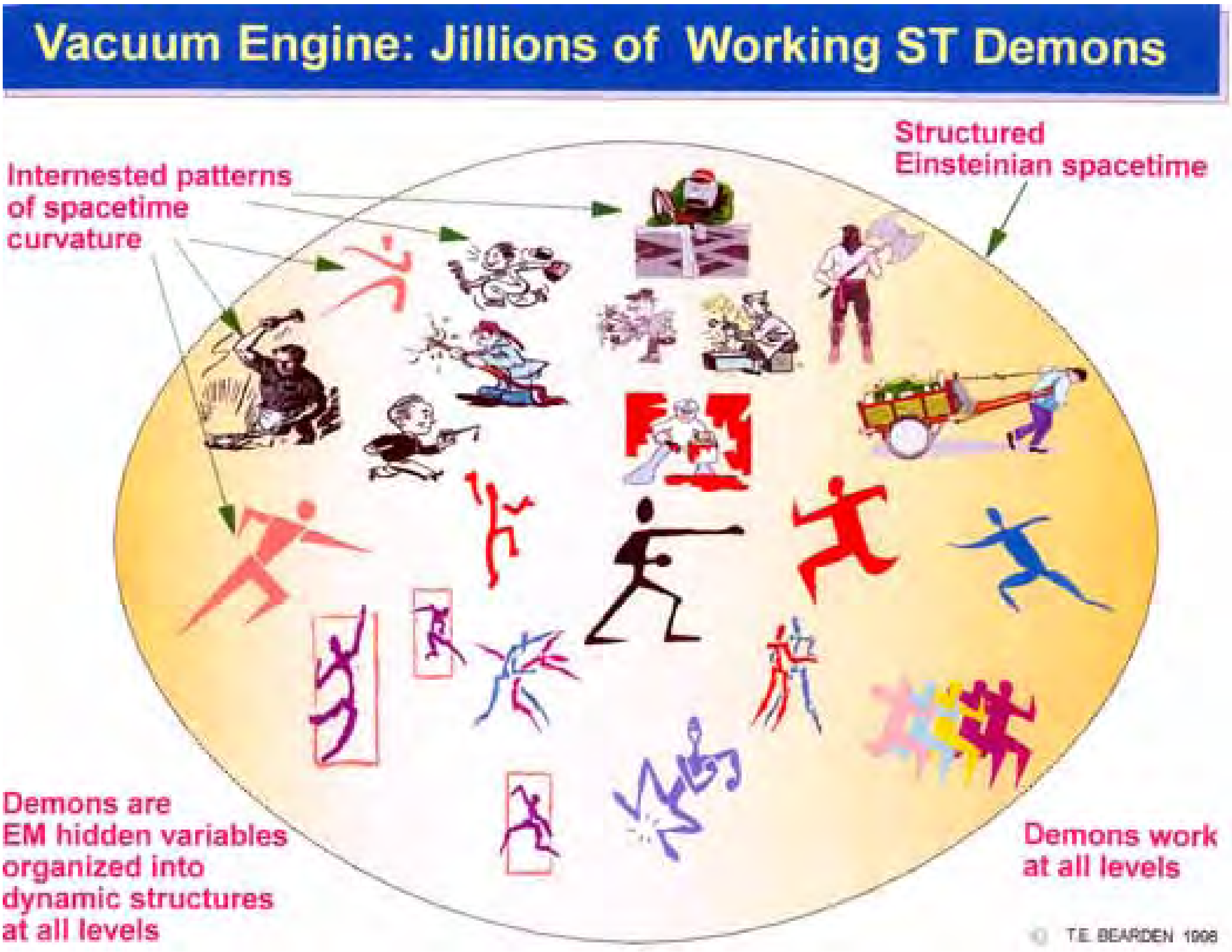

Vacuum Engine: Jillions of Working ST Demons

Internested patterns of spacetime curvature

Structured Einsteinian spacetime

Demons are EM hidden variables organized into dynamic structures at all levels

Demons work at all levels

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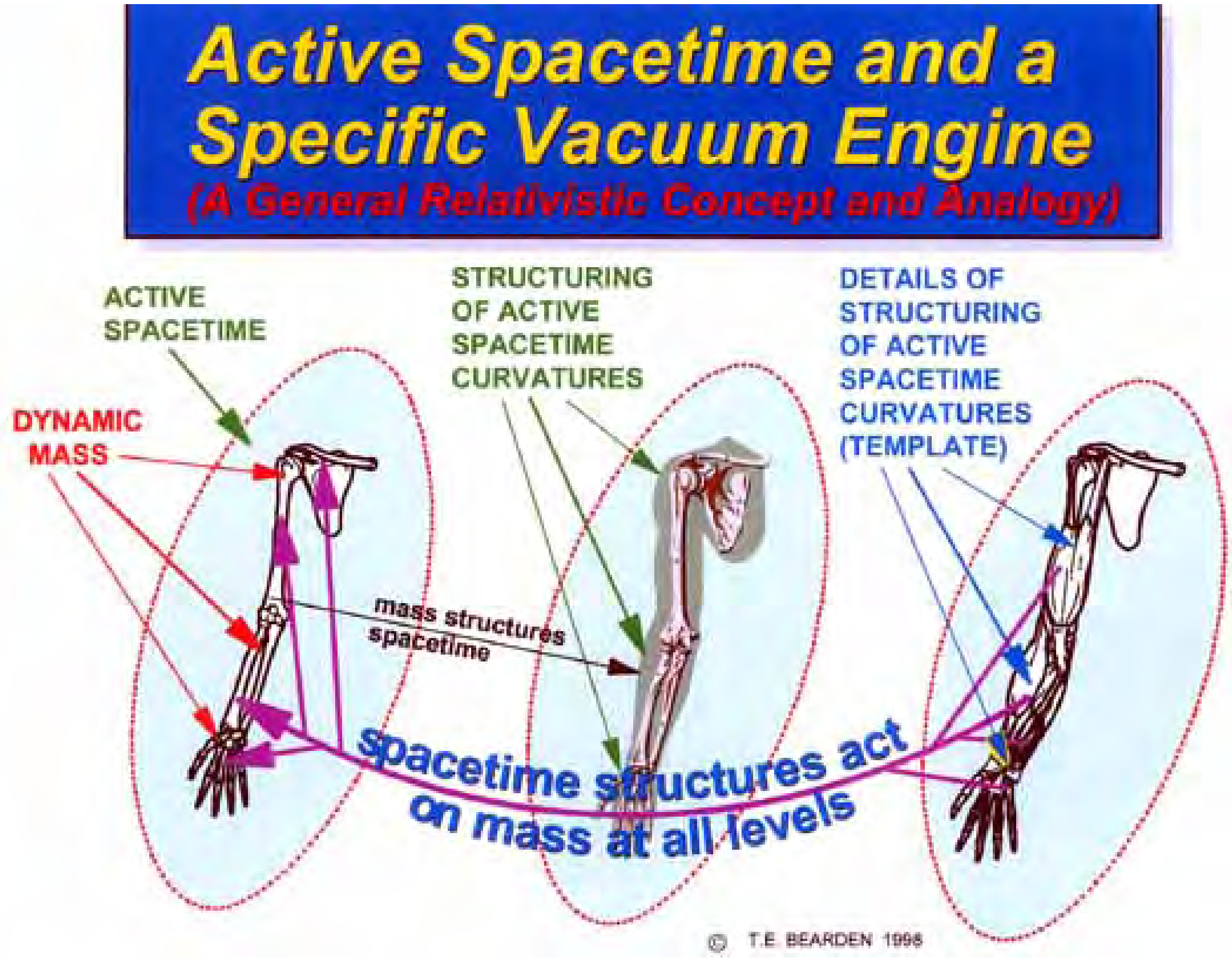

Active Spacetime and a Specific Vacuum Engine

(A General Relativistic Concept and Analogy)

ACTIVE SPACETIME

DYNAMIC MASS

STRUCTURING OF ACTIVE SPACETIME CURVATURES

DETAILS OF STRUCTURING OF ACTIVE SPACETIME CURVATURES (TEMPLATE)

mass structures spacetime

spacetime structures act on mass at all levels

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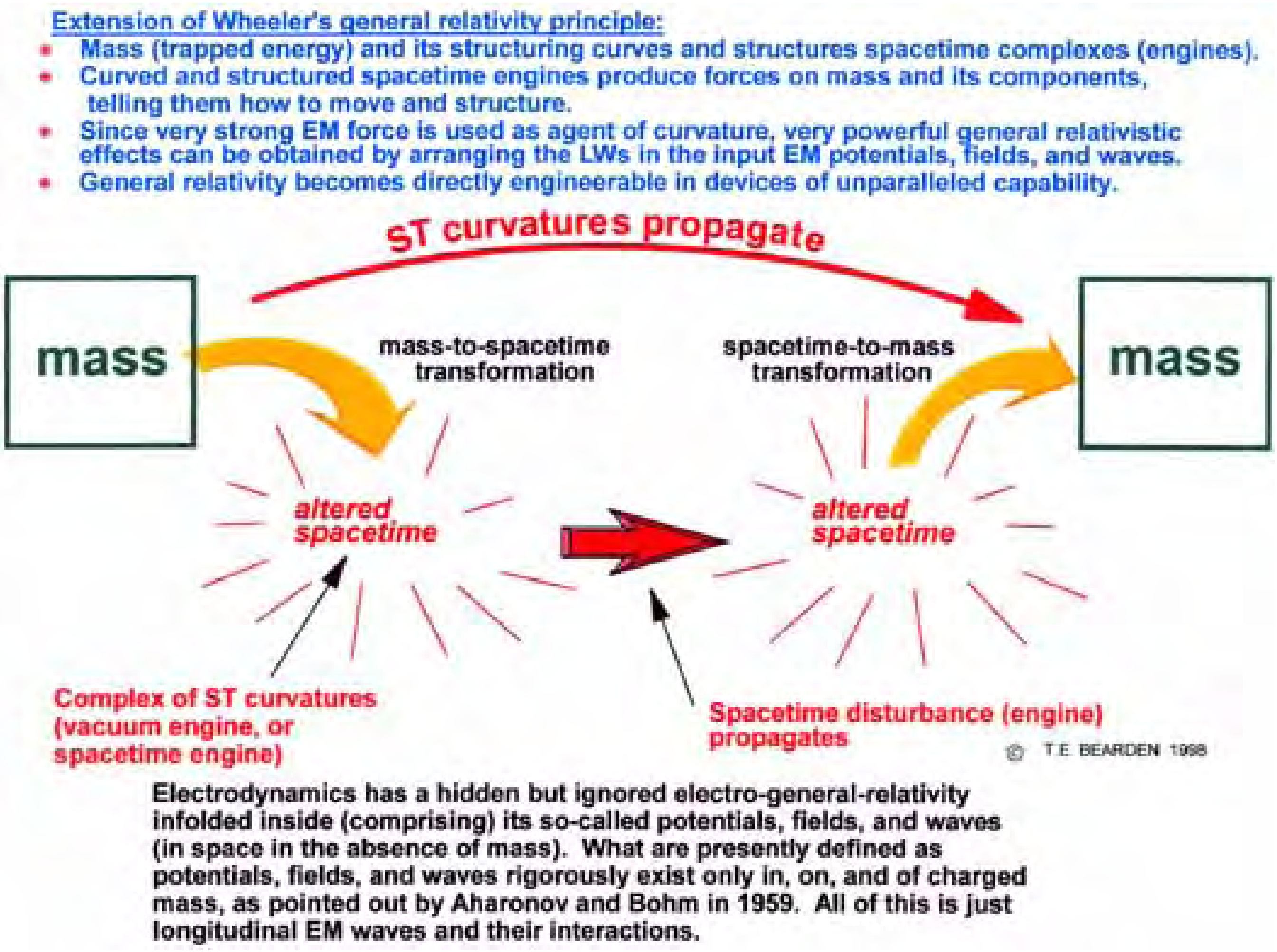

Extension of Wheeler's general relativity principle:

- Mass (trapped energy) and its structuring curves and structures spacetime complexes (engines).
- Curved and structured spacetime engines produce forces on mass and its components, telling them how to move and structure.
- Since very strong EM force is used as agent of curvature, very powerful general relativistic effects can be obtained by arranging the LWs in the input EM potentials, fields, and waves.
- General relativity becomes directly engineerable in devices of unparalleled capability.

ST curvatures propagate

mass

mass-to-spacetime transformation

spacetime-to-mass transformation

mass

altered spacetime

altered spacetime

Complex of ST curvatures (vacuum engine, or spacetime engine)

Spacetime disturbance (engine) propagates

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Electrodynamics has a hidden but ignored electro-general-relativity infolded inside (comprising) its so-called potentials, fields, and waves (in space in the absence of mass). What are presently defined as potentials, fields, and waves rigorously exist only in, on, and of charged mass, as pointed out by Aharonov and Bohm in 1959. All of this is just longitudinal EM waves and their interactions.

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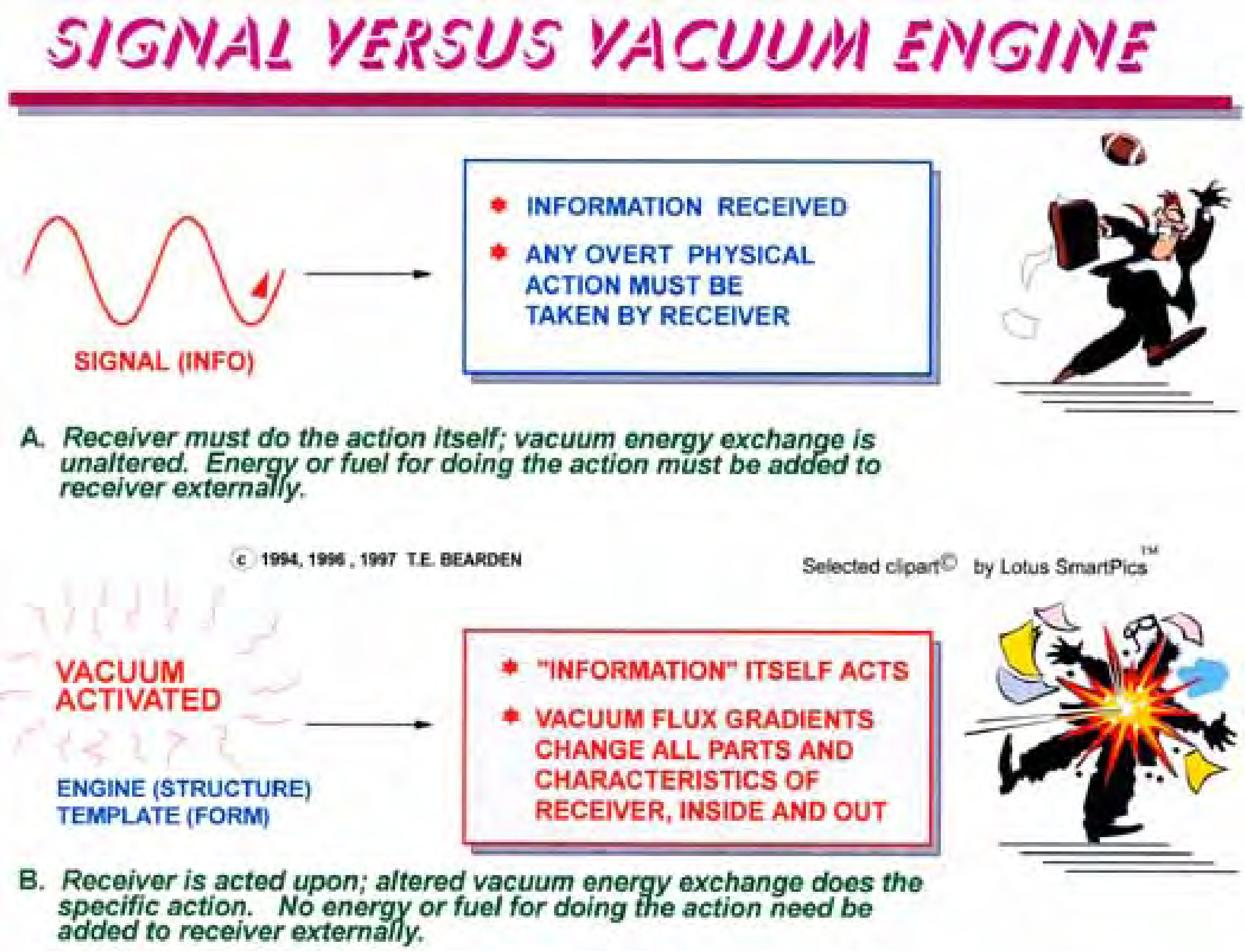

SIGNAL VERSUS VACUUM ENGINE

SIGNAL (INFO)

- INFORMATION RECEIVED
- ANY OVERT PHYSICAL ACTION MUST BE TAKEN BY RECEIVER

A. *Receiver must do the action itself; vacuum energy exchange is unaltered. Energy or fuel for doing the action must be added to receiver externally.*

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VACUUM ACTIVATED

ENGINE (STRUCTURE)
TEMPLATE (FORM)

- "INFORMATION" ITSELF ACTS
- VACUUM FLUX GRADIENTS CHANGE ALL PARTS AND CHARACTERISTICS OF RECEIVER, INSIDE AND OUT

B. *Receiver is acted upon; altered vacuum energy exchange does the specific action. No energy or fuel for doing the action need be added to receiver externally.*

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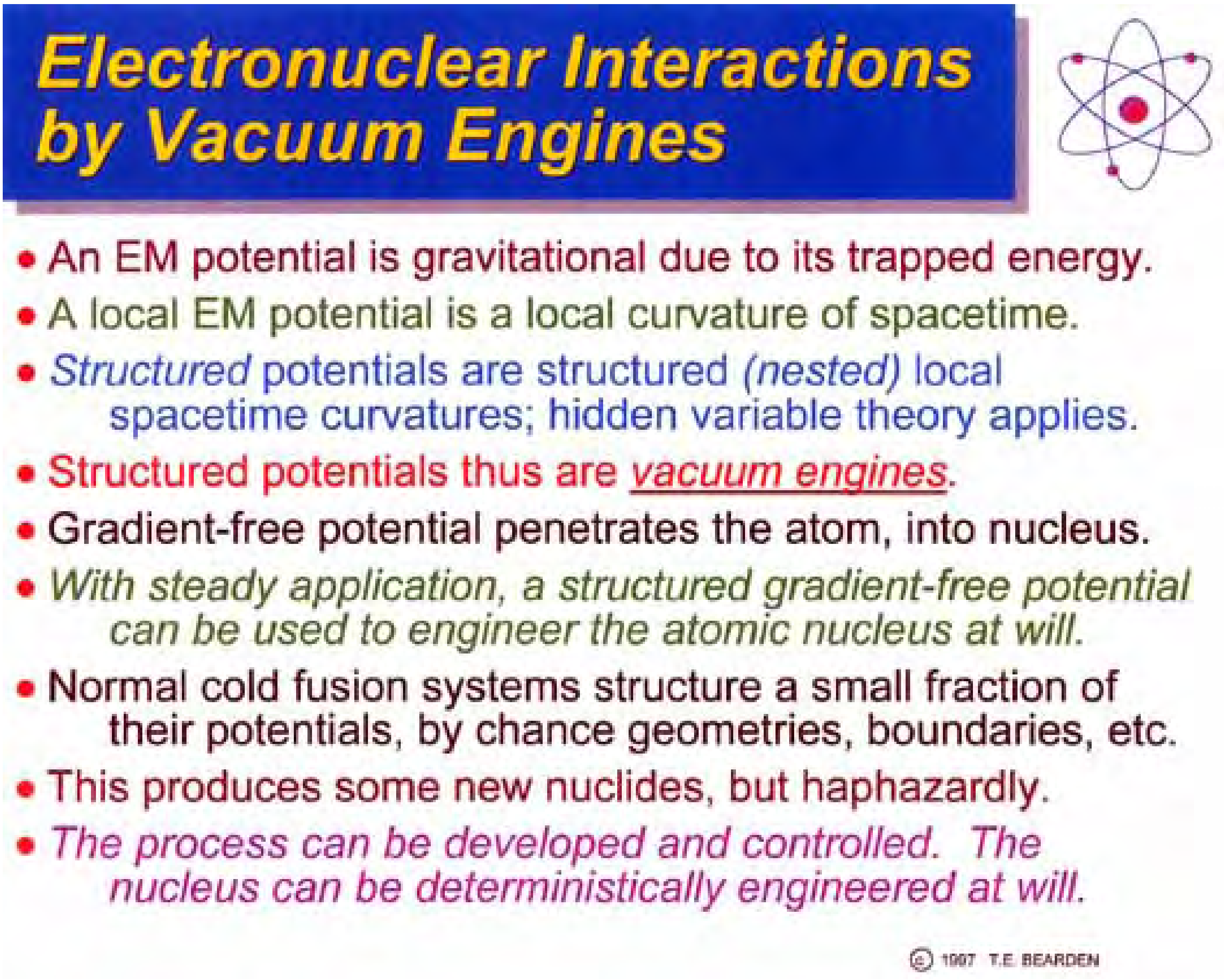

Electronuclear Interactions by Vacuum Engines

- An EM potential is gravitational due to its trapped energy.
- A local EM potential is a local curvature of spacetime.
- *Structured* potentials are structured *(nested)* local spacetime curvatures; hidden variable theory applies.
- Structured potentials thus are *vacuum engines*.
- Gradient-free potential penetrates the atom, into nucleus.
- *With steady application, a structured gradient-free potential can be used to engineer the atomic nucleus at will.*
- Normal cold fusion systems structure a small fraction of their potentials, by chance geometries, boundaries, etc.
- This produces some new nuclides, but haphazardly.
- *The process can be developed and controlled. The nucleus can be deterministically engineered at will.*

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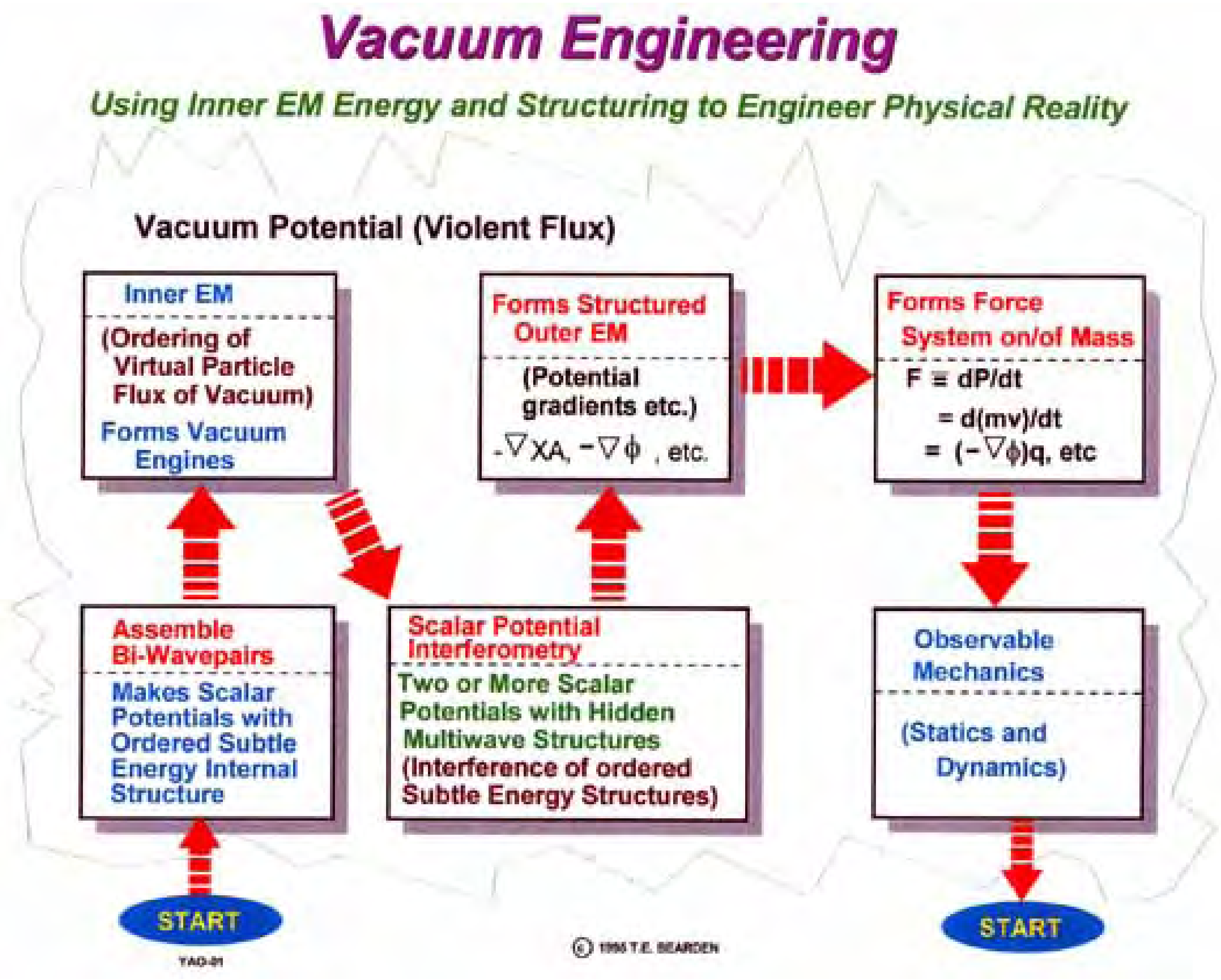

Vacuum Engineering

Using Inner EM Energy and Structuring to Engineer Physical Reality

Vacuum Potential (Violent Flux)

Inner EM
(Ordering of
Virtual Particle
Flux of Vacuum)
Forms Vacuum
Engines

**Forms Structured
Outer EM**
(Potential
gradients etc.)
$-\nabla \times A, -\nabla \phi$, etc.

**Forms Force
System on/of Mass**
$F \equiv dP/dt$
$= d(mv)/dt$
$= (-\nabla \phi)q$, etc

**Assemble
Bi-Wavepairs**
Makes Scalar
Potentials with
Ordered Subtle
Energy Internal
Structure

**Scalar Potential
Interferometry**
Two or More Scalar
Potentials with Hidden
Multiwave Structures
(Interference of ordered
Subtle Energy Structures)

**Observable
Mechanics**
(Statics and
Dynamics)

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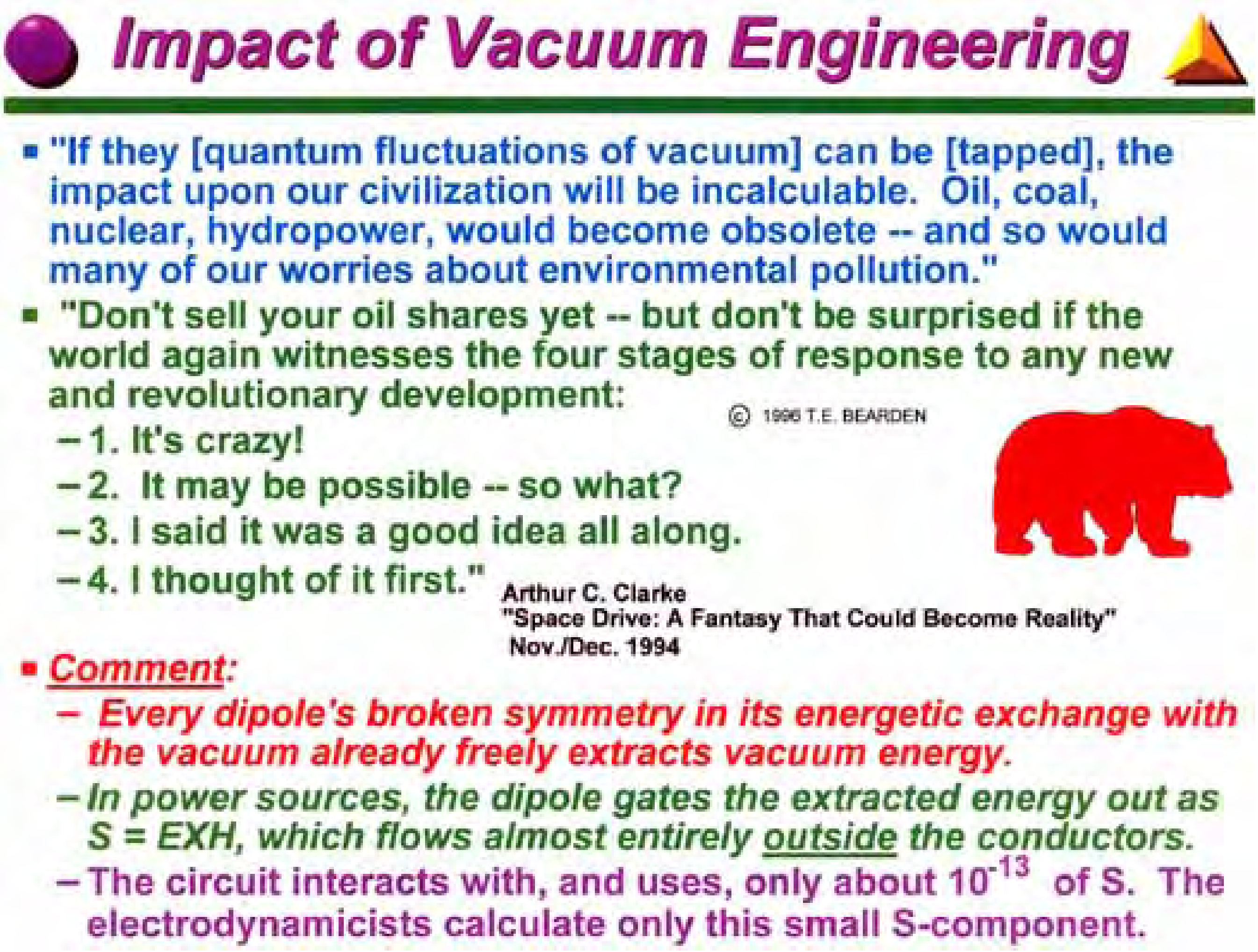

Impact of Vacuum Engineering

- "If they [quantum fluctuations of vacuum] can be [tapped], the impact upon our civilization will be incalculable. Oil, coal, nuclear, hydropower, would become obsolete -- and so would many of our worries about environmental pollution."
- "Don't sell your oil shares yet -- but don't be surprised if the world again witnesses the four stages of response to any new and revolutionary development:
  - 1. It's crazy!
  - 2. It may be possible -- so what?
  - 3. I said it was a good idea all along.
  - 4. I thought of it first."

Arthur C. Clarke
"Space Drive: A Fantasy That Could Become Reality"
Nov./Dec. 1994

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- *Comment:*
  - *Every dipole's broken symmetry in its energetic exchange with the vacuum already freely extracts vacuum energy.*
  - *In power sources, the dipole gates the extracted energy out as S = EXH, which flows almost entirely outside the conductors.*
  - The circuit interacts with, and uses, only about 10^{-13} of S. The electrodynamicists calculate only this small S-component.

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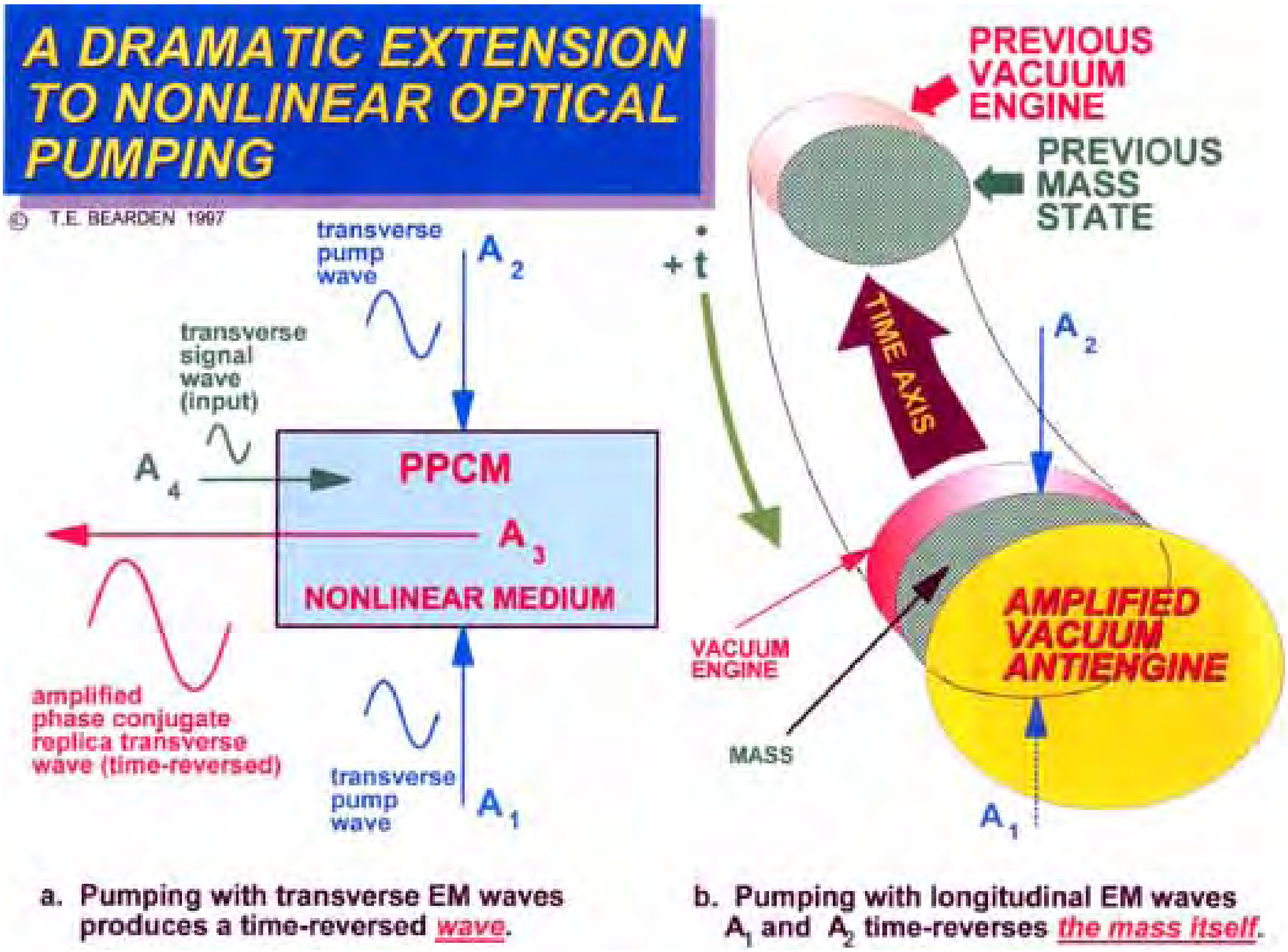

A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

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transverse pump wave
A_2
transverse signal wave (input)
A_4
PPCM
A_3
NONLINEAR MEDIUM
amplified phase conjugate replica transverse wave (time-reversed)
transverse pump wave
A_1
+ t
TIME AXIS
PREVIOUS VACUUM ENGINE
PREVIOUS MASS STATE
A_2
VACUUM ENGINE
MASS
AMPLIFIED VACUUM ANTIENGINE
A_1

a. Pumping with transverse EM waves produces a time-reversed wave.

b. Pumping with longitudinal EM waves A_1 and A_2 time-reverses *the mass itself*.

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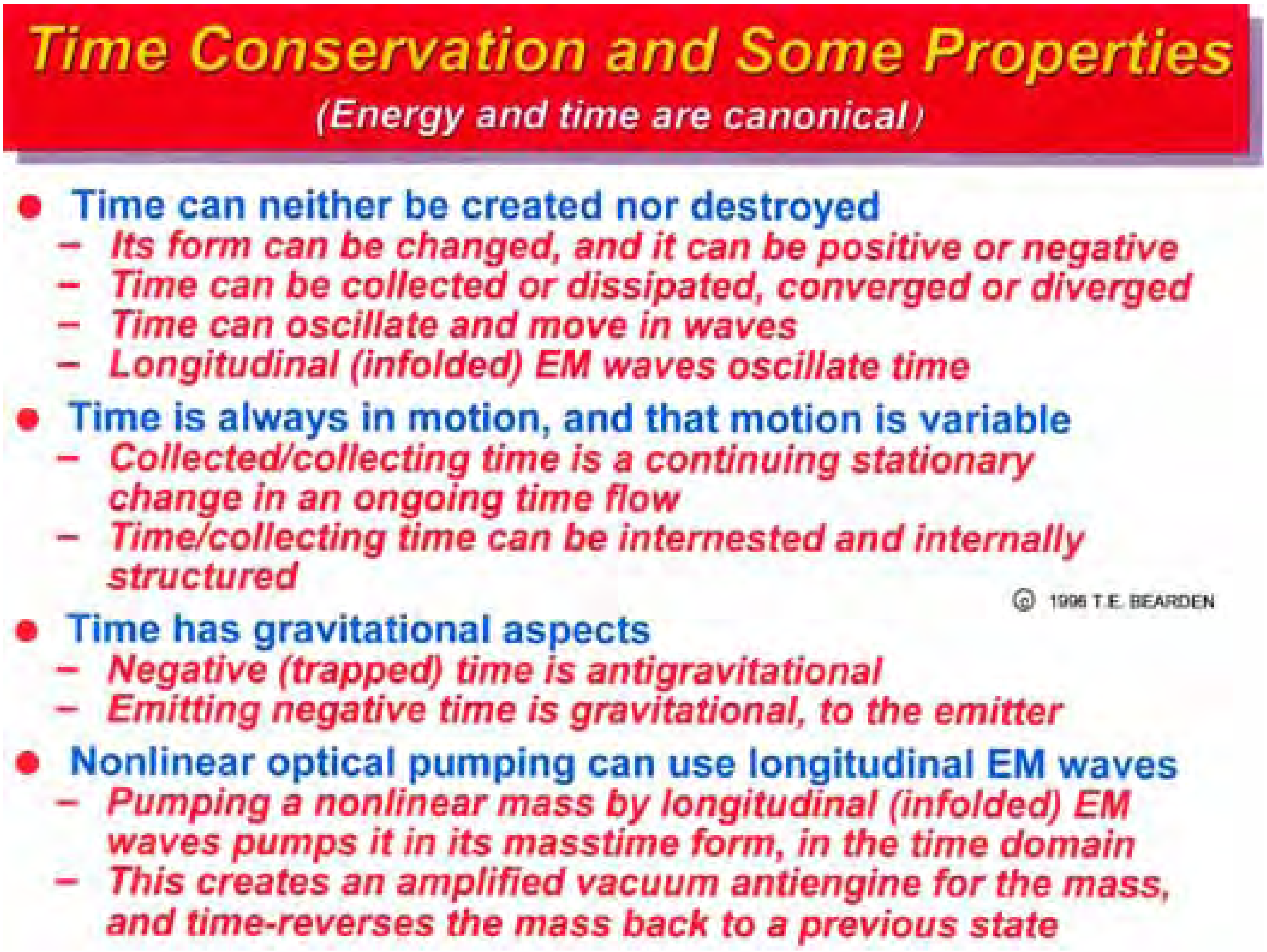

Time Conservation and Some Properties

(Energy and time are canonical)

- Time can neither be created nor destroyed
  - *Its form can be changed, and it can be positive or negative*
  - *Time can be collected or dissipated, converged or diverged*
  - *Time can oscillate and move in waves*
  - *Longitudinal (infolded) EM waves oscillate time*
- Time is always in motion, and that motion is variable
  - *Collected/collecting time is a continuing stationary change in an ongoing time flow*
  - *Time/collecting time can be internested and internally structured*
- Time has gravitational aspects
  - *Negative (trapped) time is antigravitational*
  - *Emitting negative time is gravitational, to the emitter*
- Nonlinear optical pumping can use longitudinal EM waves
  - *Pumping a nonlinear mass by longitudinal (infolded) EM waves pumps it in its masstime form, in the time domain*
  - *This creates an amplified vacuum antiengine for the mass, and time-reverses the mass back to a previous state*

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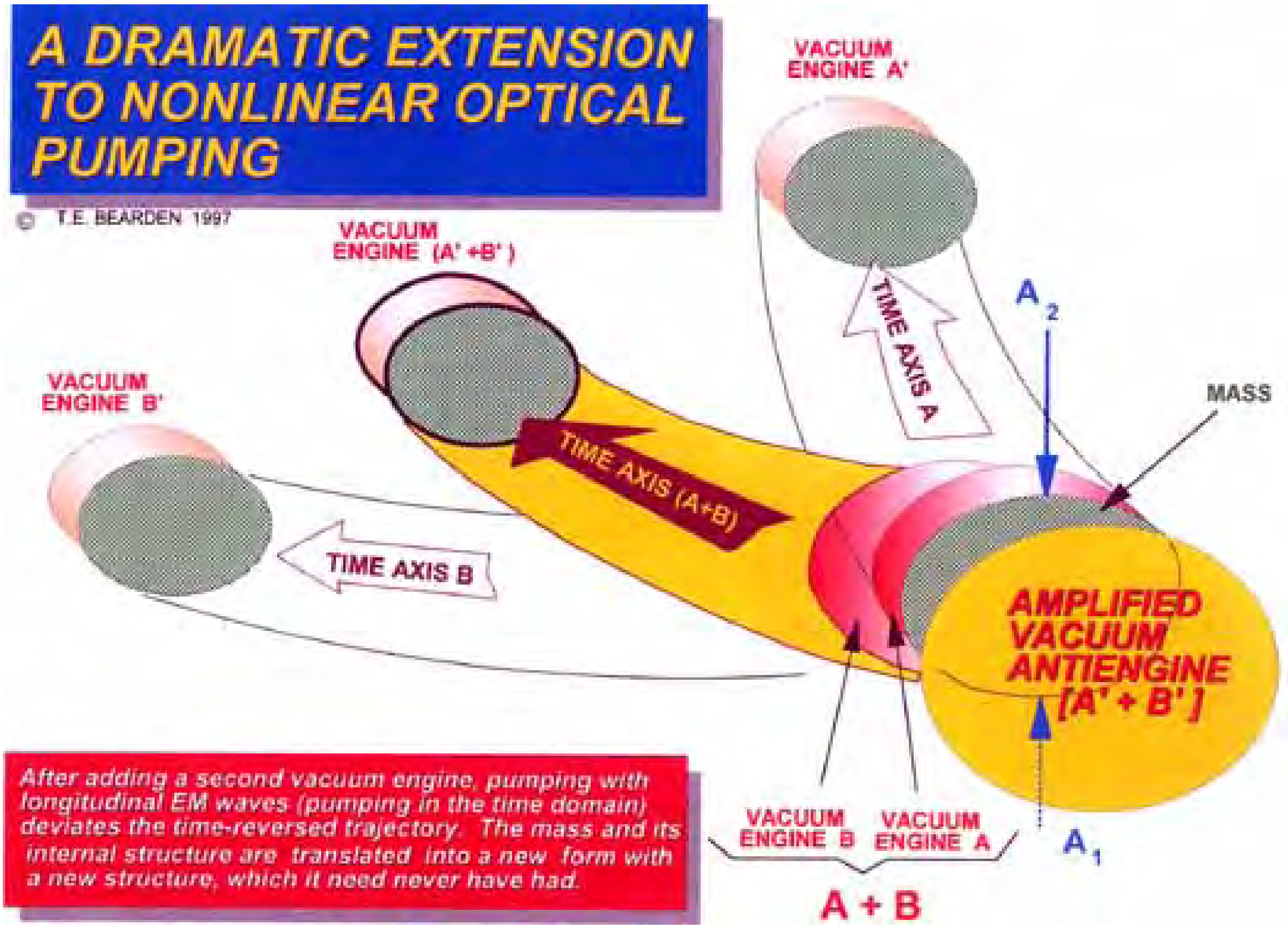

A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

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VACUUM ENGINE A'
VACUUM ENGINE (A' +B')
VACUUM ENGINE B'
TIME AXIS A
TIME AXIS (A+B)
TIME AXIS B
A 2
MASS
AMPLIFIED VACUUM ANTIENGINE [A' + B']
VACUUM ENGINE B
VACUUM ENGINE A
A 1
A + B

After adding a second vacuum engine, pumping with longitudinal EM waves (pumping in the time domain) deviates the time-reversed trajectory. The mass and its internal structure are translated into a new form with a new structure, which it need never have had.

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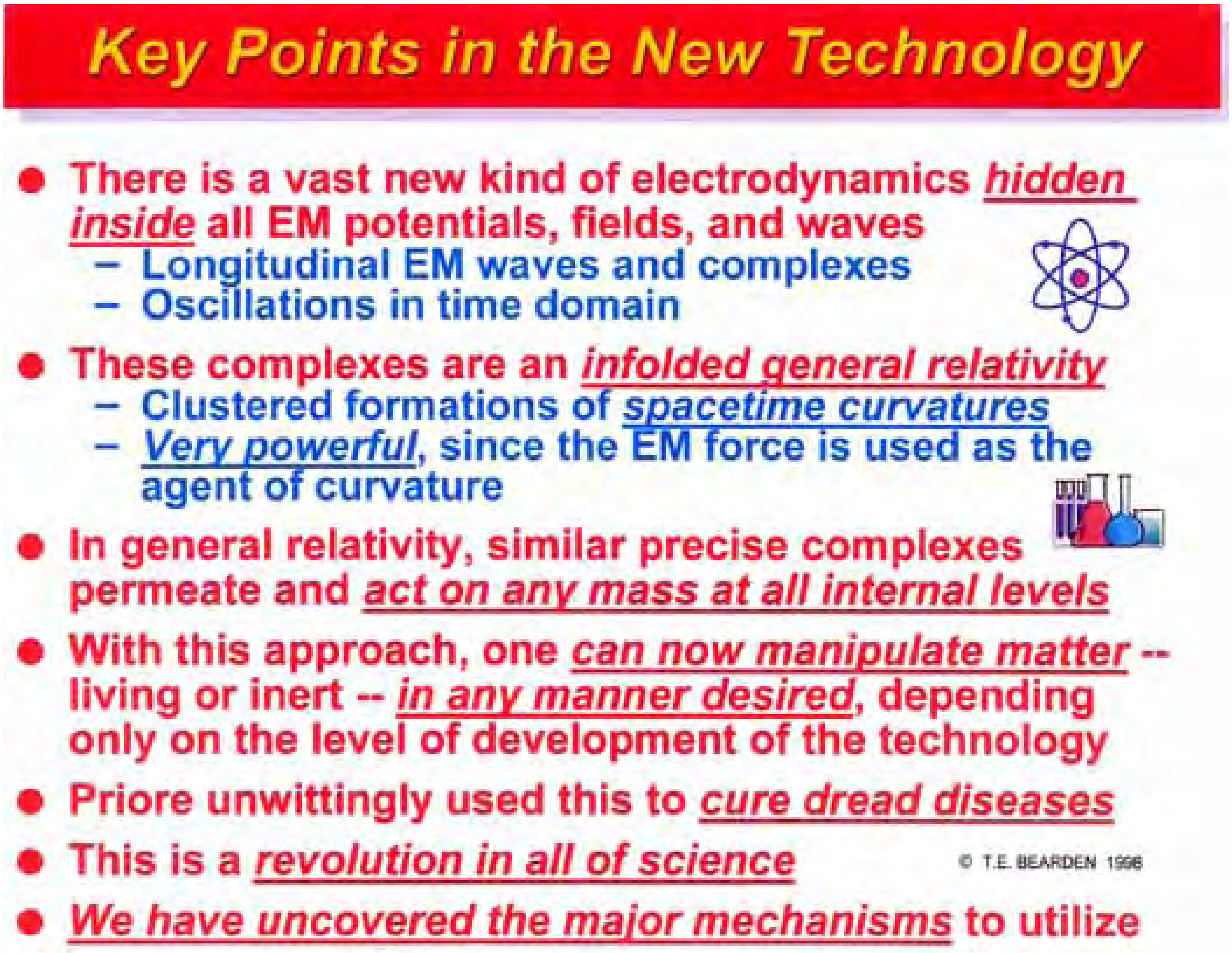

Key Points in the New Technology

- There is a vast new kind of electrodynamics *hidden inside* all EM potentials, fields, and waves
  - Longitudinal EM waves and complexes
  - Oscillations in time domain
- These complexes are an *infolded general relativity*
  - Clustered formations of *spacetime curvatures*
  - *Very powerful*, since the EM force is used as the agent of curvature
- In general relativity, similar precise complexes permeate and *act on any mass at all internal levels*
- With this approach, one *can now manipulate matter* -- living or inert -- *in any manner desired*, depending only on the level of development of the technology
- Priore unwittingly used this to *cure dread diseases*
- This is a *revolution in all of science*
- *We have uncovered the major mechanisms* to utilize

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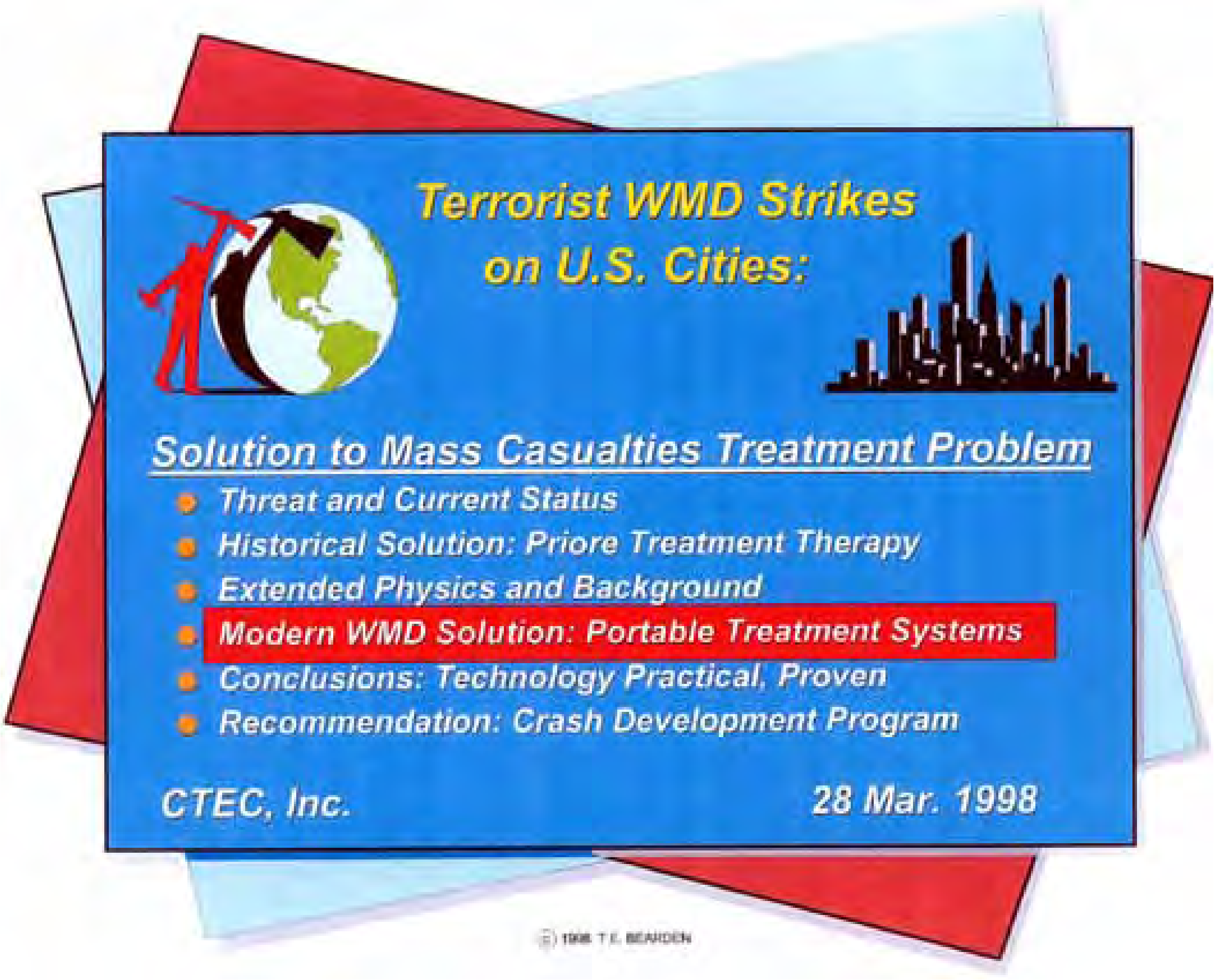

Terrorist WMD Strikes
on U.S. Cities:

Solution to Mass Casualties Treatment Problem

- Threat and Current Status
- Historical Solution: Priore Treatment Therapy
- Extended Physics and Background
- Modern WMD Solution: Portable Treatment Systems
- Conclusions: Technology Practical, Proven
- Recommendation: Crash Development Program

CTEC, Inc.

28 Mar. 1998

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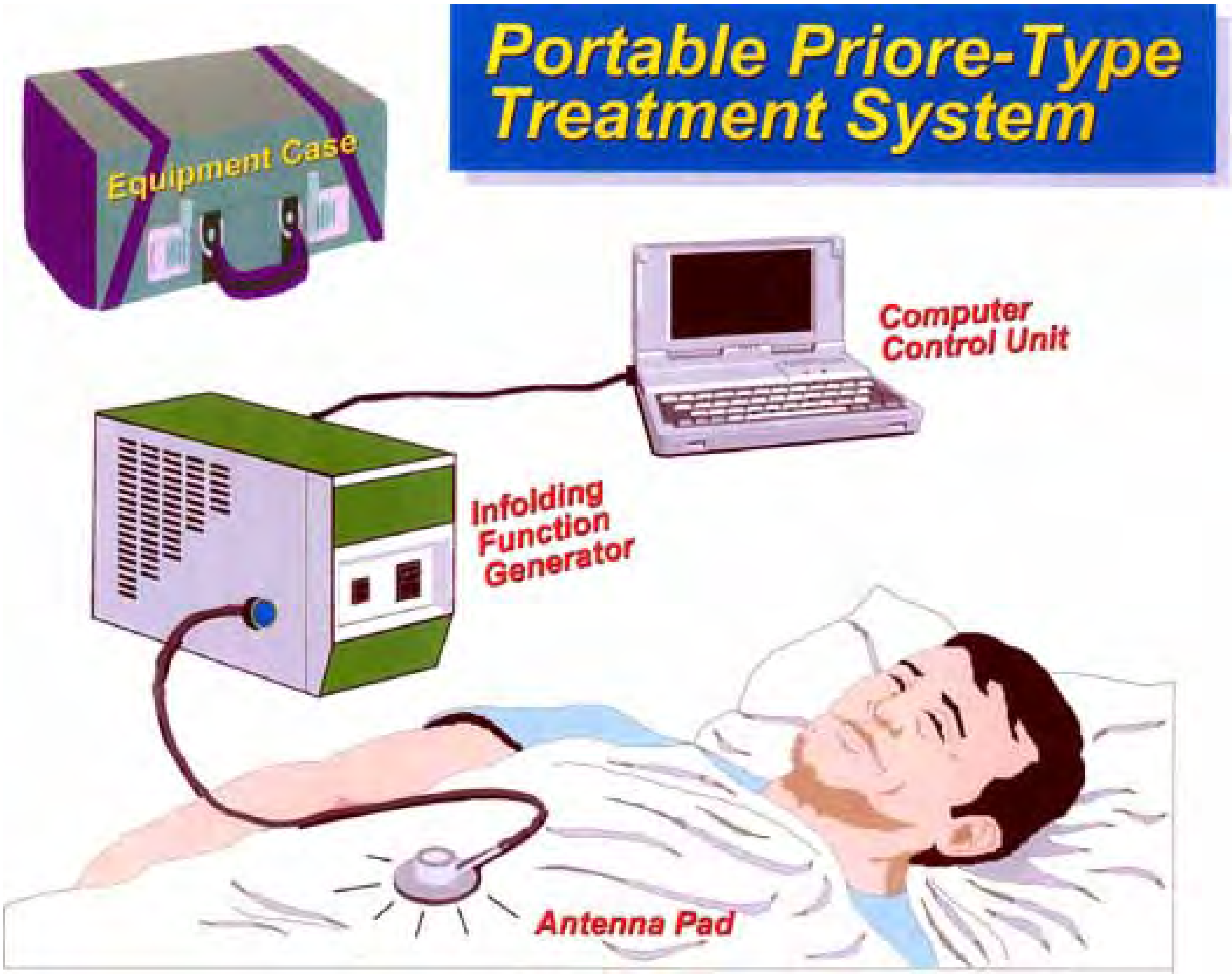

Portable Priore-Type Treatment System

Equipment Case
Computer Control Unit
Infolding Function Generator
Antenna Pad

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Portable System Block Diagram

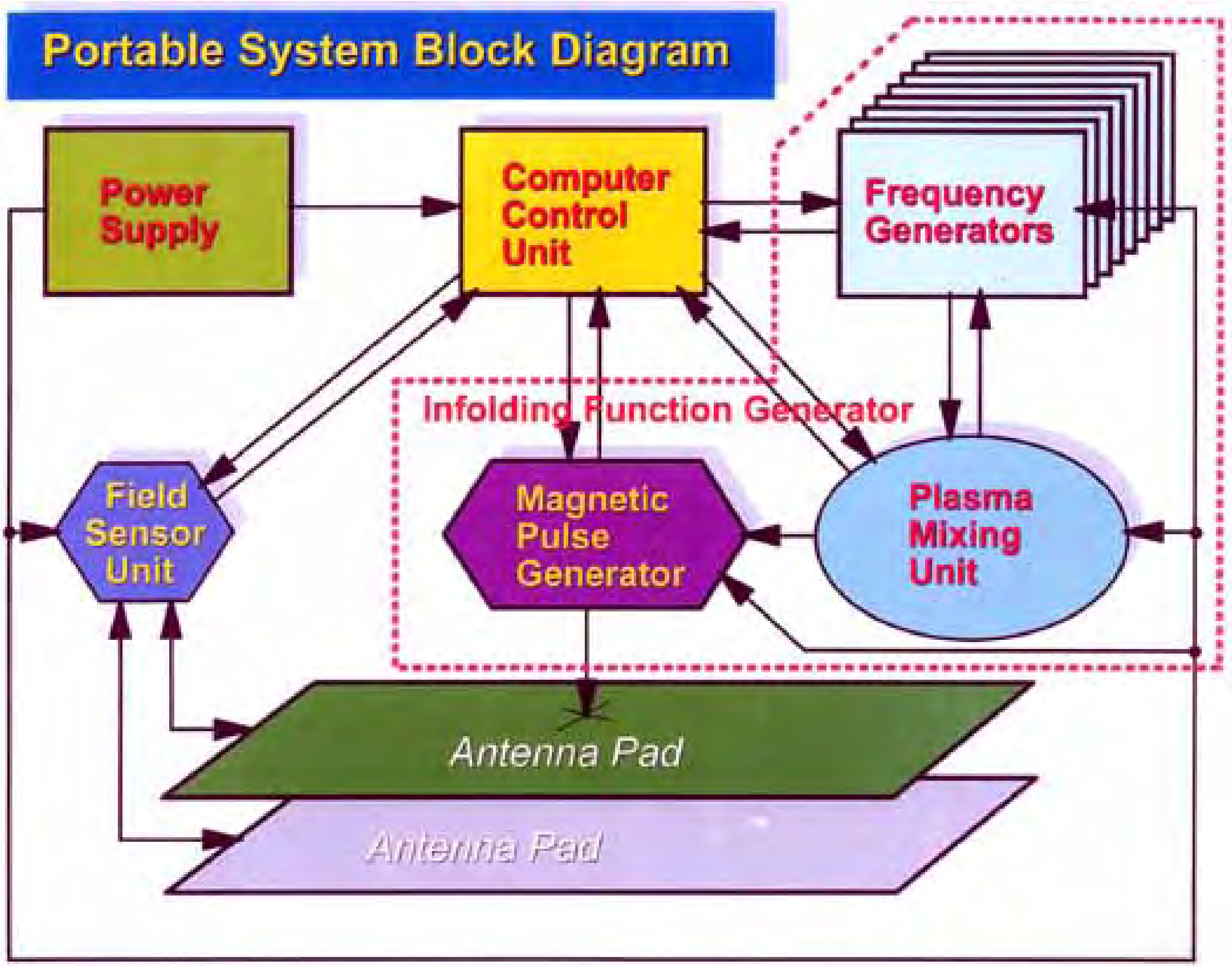
Power Supply
Computer Control Unit
Frequency Generators
Infolding Function Generator
Field Sensor Unit
Magnetic Pulse Generator
Plasma Mixing Unit
Antenna Pad
Antenna Pad

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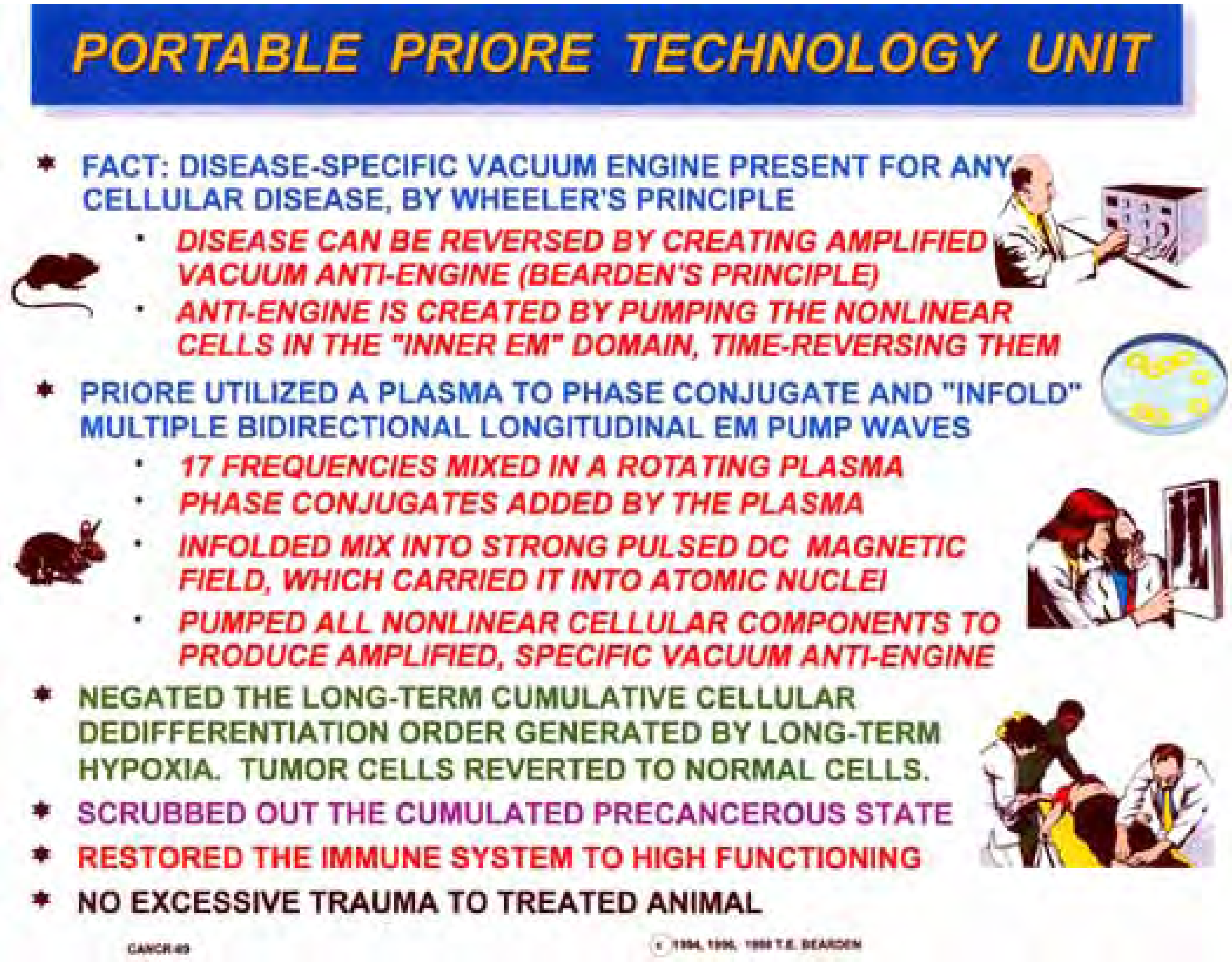

PORTABLE PRIORE TECHNOLOGY UNIT

- FACT: DISEASE-SPECIFIC VACUUM ENGINE PRESENT FOR ANY CELLULAR DISEASE, BY WHEELER'S PRINCIPLE
  - *DISEASE CAN BE REVERSED BY CREATING AMPLIFIED VACUUM ANTI-ENGINE (BEARDEN'S PRINCIPLE)*
  - *ANTI-ENGINE IS CREATED BY PUMPING THE NONLINEAR CELLS IN THE "INNER EM" DOMAIN, TIME-REVERSING THEM*
- PRIORE UTILIZED A PLASMA TO PHASE CONJUGATE AND "INFOLD" MULTIPLE BIDIRECTIONAL LONGITUDINAL EM PUMP WAVES
  - *17 FREQUENCIES MIXED IN A ROTATING PLASMA*
  - *PHASE CONJUGATES ADDED BY THE PLASMA*
  - *INFOLDED MIX INTO STRONG PULSED DC MAGNETIC FIELD, WHICH CARRIED IT INTO ATOMIC NUCLEI*
  - *PUMPED ALL NONLINEAR CELLULAR COMPONENTS TO PRODUCE AMPLIFIED, SPECIFIC VACUUM ANTI-ENGINE*
- NEGATED THE LONG-TERM CUMULATIVE CELLULAR DEDIFFERENTIATION ORDER GENERATED BY LONG-TERM HYPOXIA. TUMOR CELLS REVERTED TO NORMAL CELLS.
- SCRUBBED OUT THE CUMULATED PRECANCEROUS STATE
- RESTORED THE IMMUNE SYSTEM TO HIGH FUNCTIONING
- NO EXCESSIVE TRAUMA TO TREATED ANIMAL

CANCR-69

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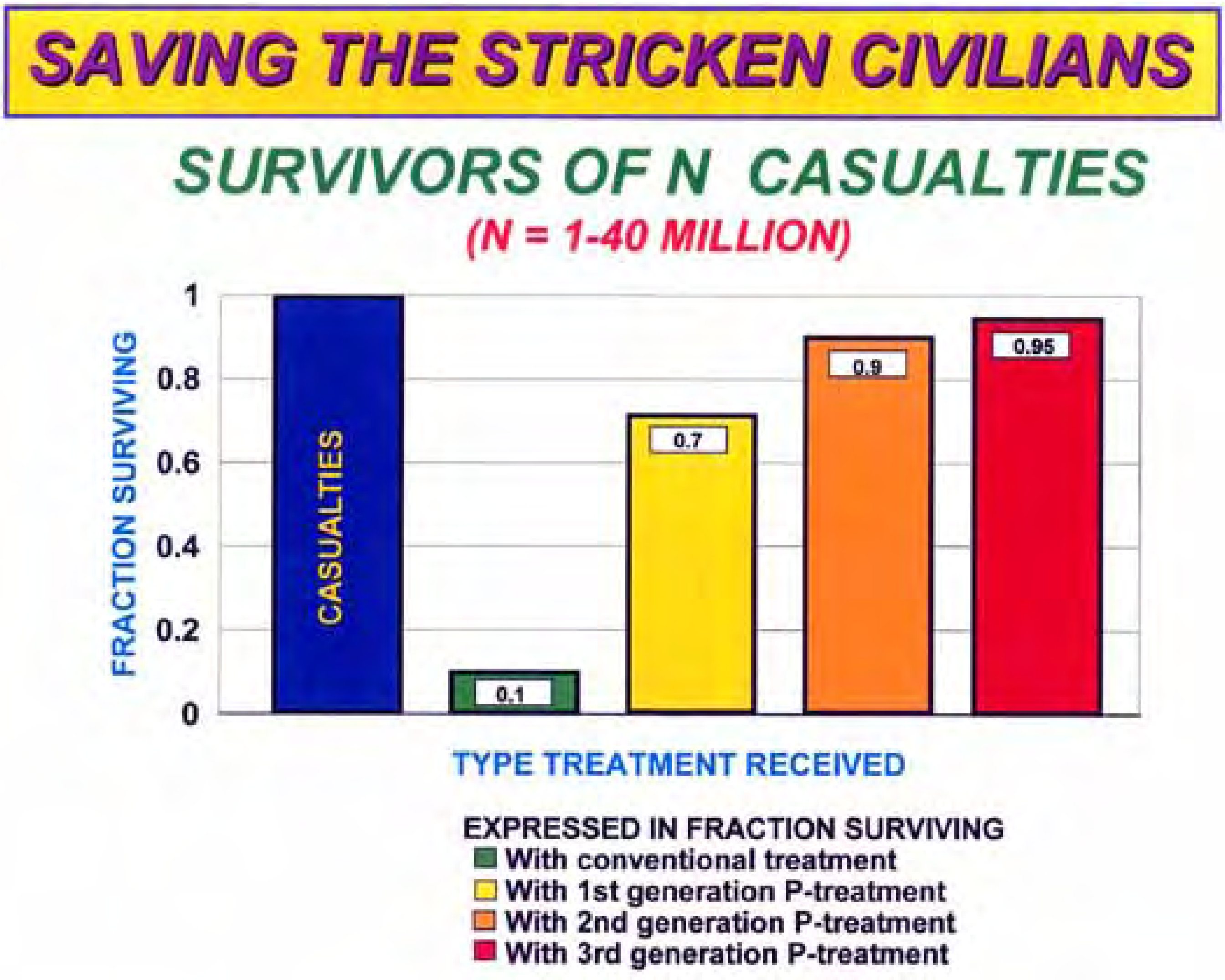

SAVING THE STRICKEN CIVILIANS

SURVIVORS OF N CASUALTIES

(N = 1-40 MILLION)

EXPRESSED IN FRACTION SURVIVING

- 🟩 With conventional treatment
- 🟨 With 1st generation P-treatment
- 🟧 With 2nd generation P-treatment
- 🟥 With 3rd generation P-treatment

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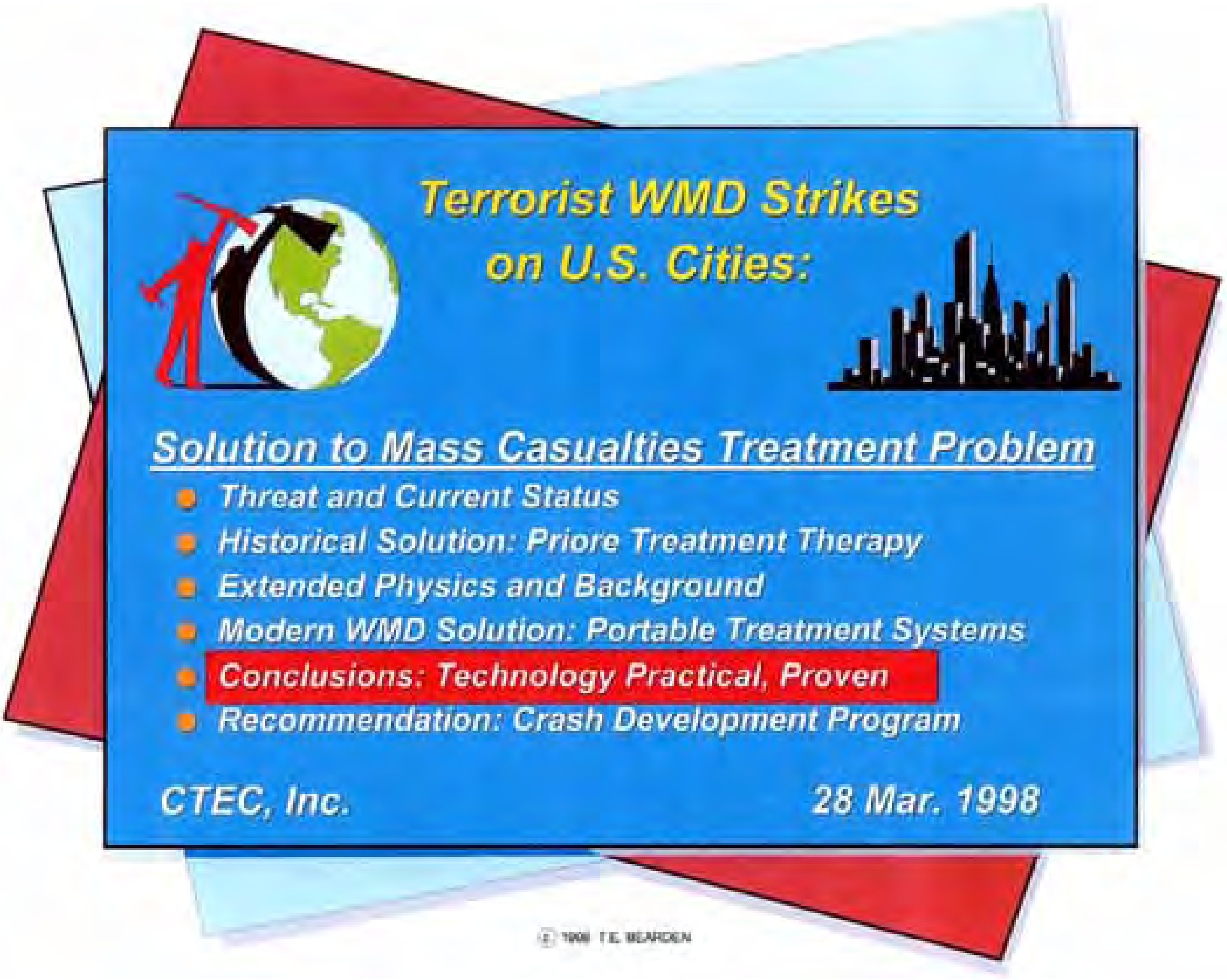

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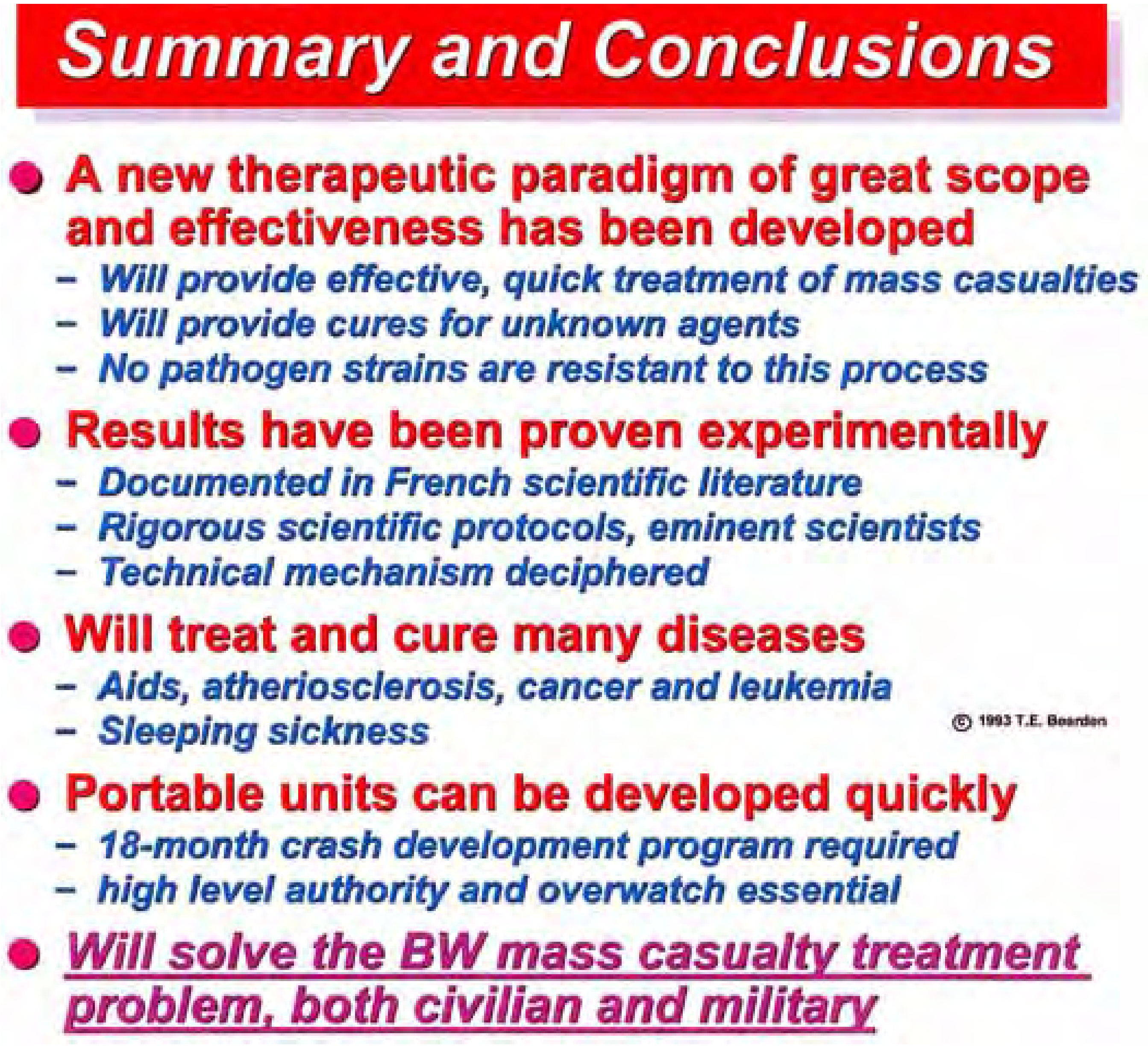

Summary and Conclusions

- A new therapeutic paradigm of great scope and effectiveness has been developed
  - *Will provide effective, quick treatment of mass casualties*
  - *Will provide cures for unknown agents*
  - *No pathogen strains are resistant to this process*
- Results have been proven experimentally
  - *Documented in French scientific literature*
  - *Rigorous scientific protocols, eminent scientists*
  - *Technical mechanism deciphered*
- Will treat and cure many diseases
  - *Aids, atheriosclerosis, cancer and leukemia*
  - *Sleeping sickness*

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- Portable units can be developed quickly
  - *18-month crash development program required*
  - *high level authority and overwatch essential*
- *Will solve the BW mass casualty treatment problem, both civilian and military*

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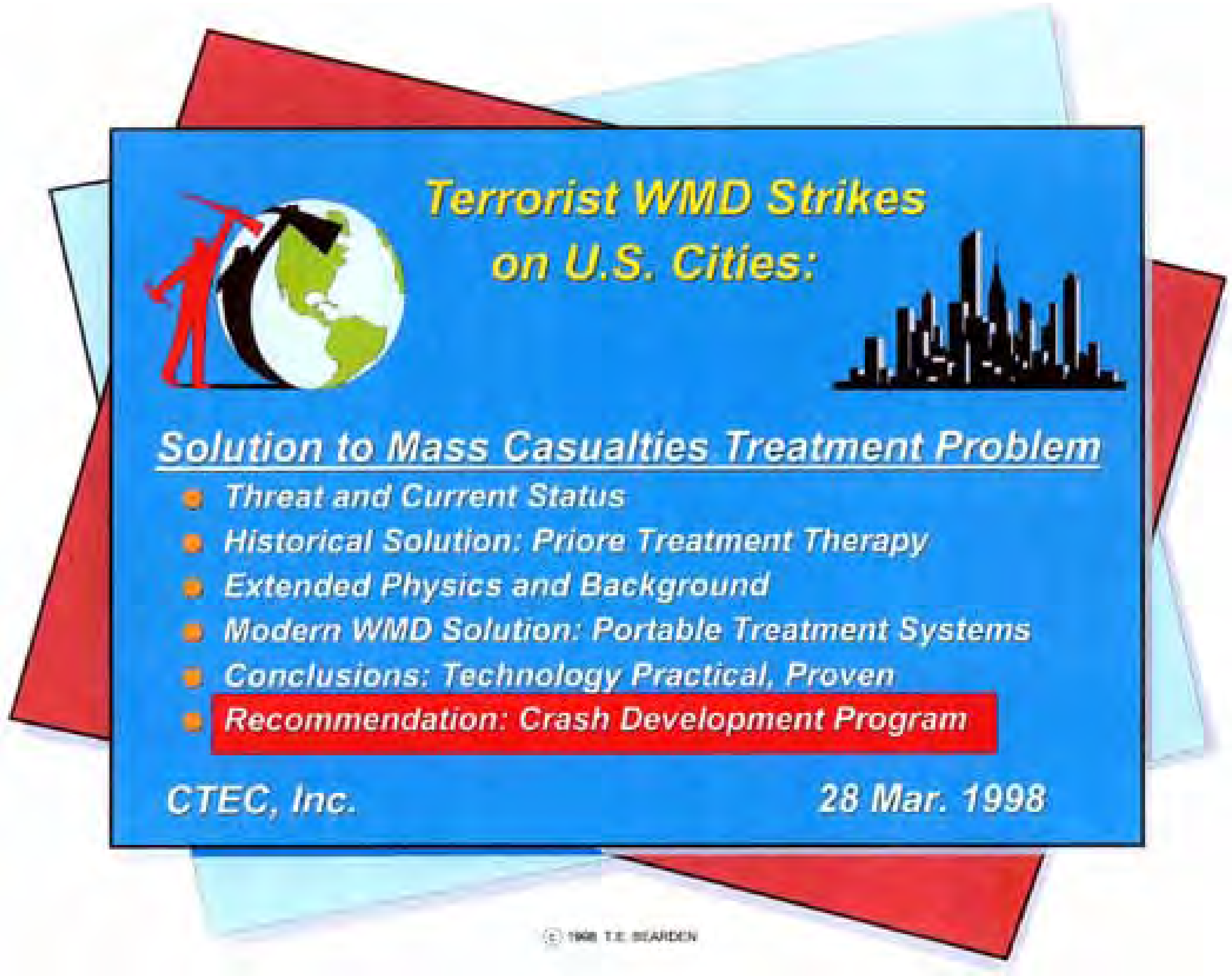

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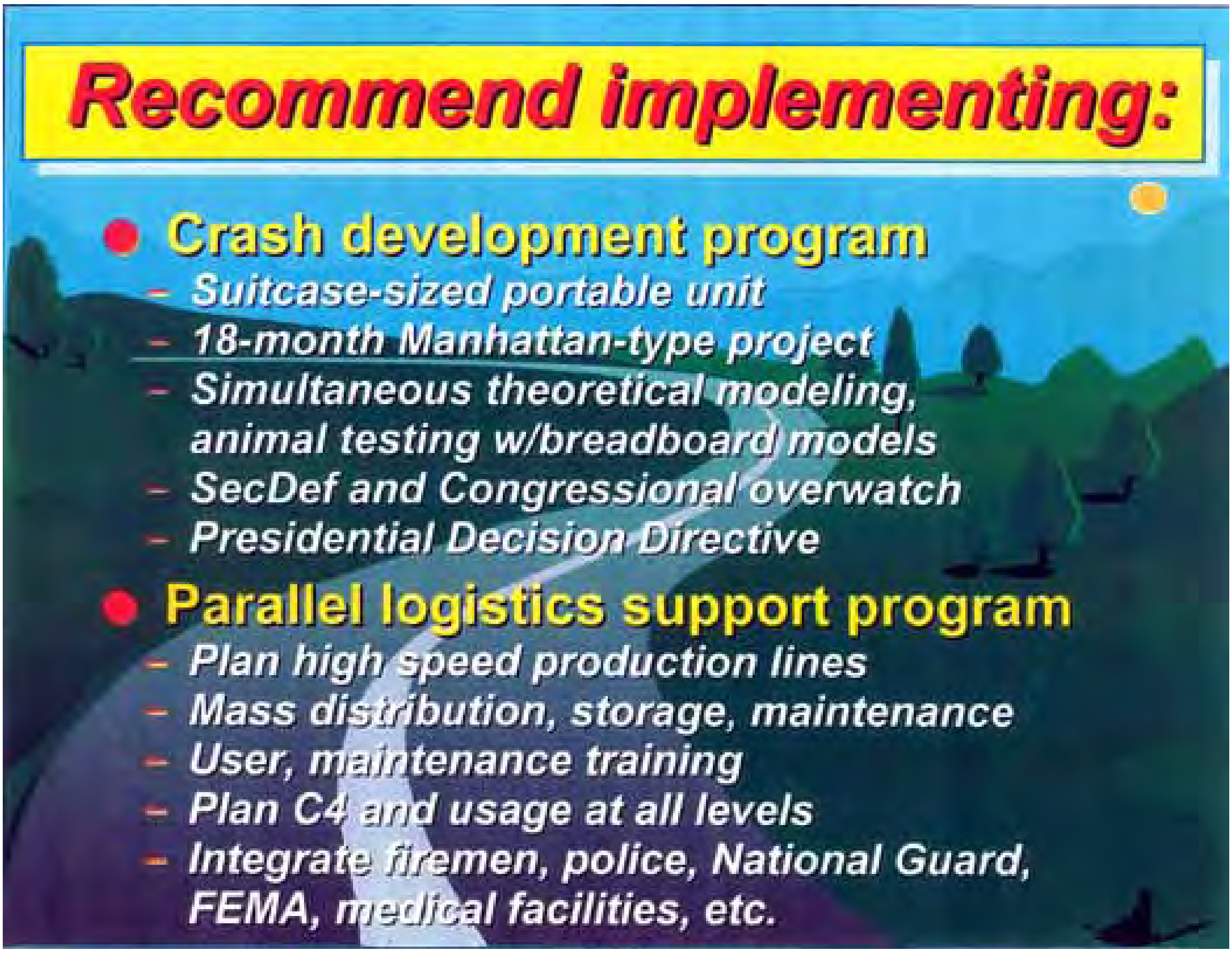

Recommend implementing:

- Crash development program
  - Suitcase-sized portable unit
  - 18-month Manhattan-type project
  - Simultaneous theoretical modeling, animal testing w/breadboard models
  - SecDef and Congressional overwatch
  - Presidential Decision Directive
- Parallel logistics support program
  - Plan high speed production lines
  - Mass distribution, storage, maintenance
  - User, maintenance training
  - Plan C4 and usage at all levels
  - Integrate firemen, police, National Guard, FEMA, medical facilities, etc.

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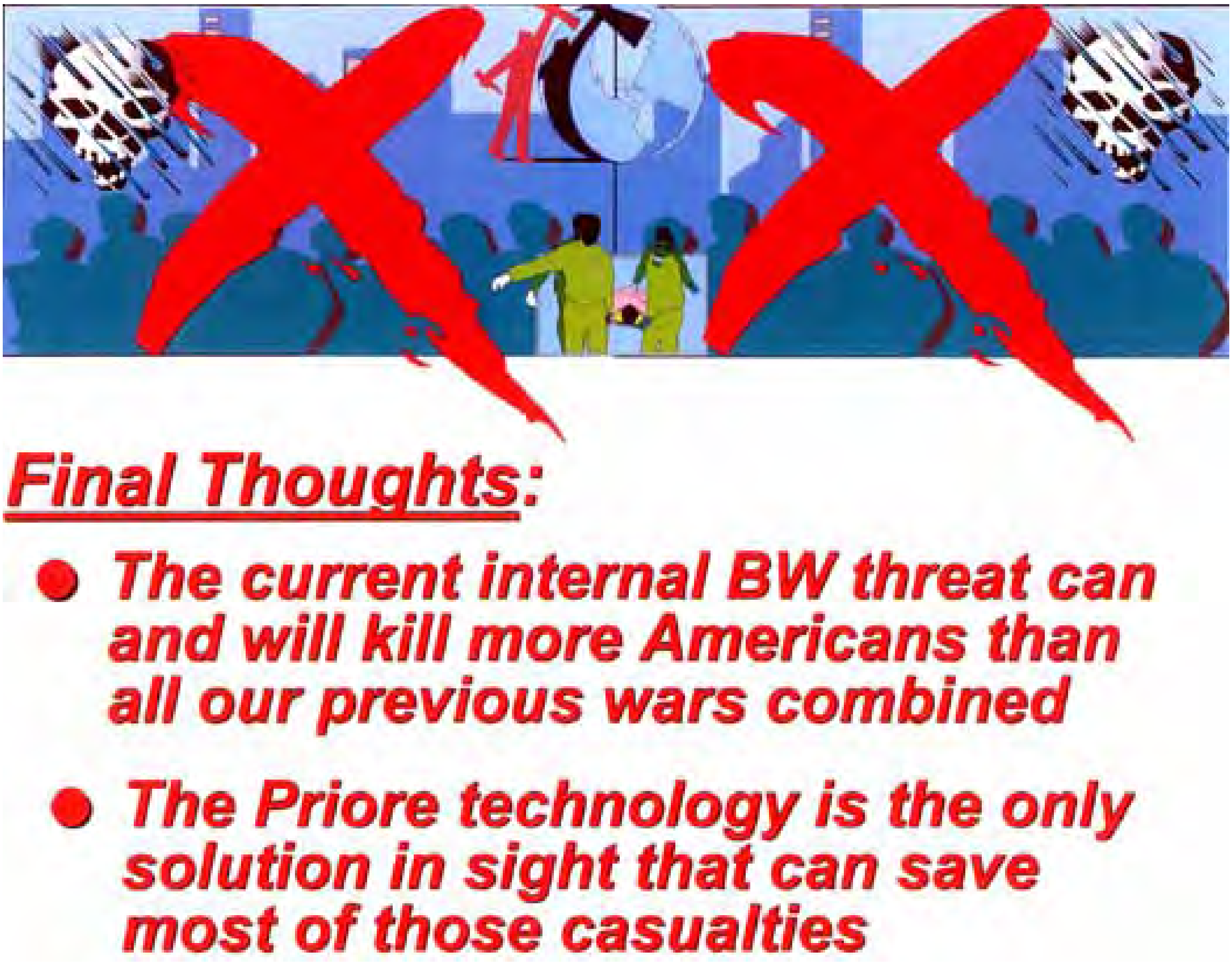

Final Thoughts:

- The current internal BW threat can and will kill more Americans than all our previous wars combined
- The Priore technology is the only solution in sight that can save most of those casualties

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2311 Big Cove Road
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CTEC, Inc.

June 24, 1998

Dr. Jane F. Kinsel, Director
Office of Policy Analysis
Department of Health & Human Services
Bathesda, MD 20892

Dear Dr. Kinsel:

Your letter of June 8 is appreciated. However, the entire action package had already gone to the Assistant SecDef and also to Major General Neary in the USAF.

The proof of a revolution in medical treatment was in the package. The basis for it is already demonstrated experimentally in the scientific literature, both in the U.S. and in France. We are speaking of something already proven, but missed by the entire U.S. medical community. Strong words, but true. Let me be specific.

Any cell in the body can be time-reversed (physics term) or dedifferentiated (biology term) back to an earlier state, by pumping (i.e., "squeezing" in simple terms) that cell with longitudinal EM waves as pump waves. There are considerable papers in the French scientific literature showing the experimental results.

Apply that to cancer. We are stating bluntly that all cancerous cells in the body can be "depromoted" back to normal cells easily. Further, the damage previously done to them (such as by sustained hypoxia due to contaminants reducing the oxygen-carrying ability normally given to it by some 60-to-80 surrounding water molecules per red cell and the consequent H-bonding interactions) will also be reversed. The cells can all be returned to healthy, normal cells again, without "killing" or "burning" or "cutting" anything.

With some development of the technology, you can quickly and easily cure every cancer patient in every hospital in the United States.

Now apply it to AIDS. Since you can time-reverse every cell in the body, you can time-reverse the HIV-infected cells – genetics and all – right back to normal cells with normal genetics. Those cells not infected and healthy, will just get a "little younger" again.

So with that small development, you can quickly and easily cure every AIDS patient in every hospital in the United States.

I would have thought that NIH would certainly be interested in such a revolutionary therapy which has already been demonstrated in laboratory experiments. World-renowned French scientists – such as the eminent parasitologist Pautrizel and research PhDs assigned directly by Robert Courrier, head of the Biology Section of the French Academy of Sciences, worked with Prioré in performing those startling experiments that proved what we are saying.

The method was rigorously shown to cure infectious diseases (such as trypanosomiasis), atherosclerosis (which now afflicts millions of Americans), and terminal tumors. It was shown to reverse suppressed immune systems back to normal vigorous functioning.

Please permit me to disagree with you that the examination of such is not the mission of the NIH. To the contrary, it is precisely the NIH which should have some of its very best scientists looking into this.

The action package to DoD was to propose a crash program to develop this methodology in the form of a small, portable unit for treatment of mass casualties resulting from a terrorist BW attack on our cities (now expected in the next few weeks, as you must be aware). The leading Arab terrorist of the world has already promised just this.

We are speaking of several million Americans who are going to die. They are going to die in spite of everything that NIH and its labs can do, even though I know you will make a heroic effort. With NIH present methods, you cannot do very much for those stricken Americans at all. Everything we have in the "normal" kit bag is almost useless against a knowledgeable spray attack of modified smallpox (as you know, the Russian secret BW labs have made and sold tons of that already, to guess who!). Or a spray of tularemia (you are well aware of the extreme lethality of that), or anthrax (easily obtained). It is also common knowledge that these terrorist teams with their BW agents are already on site in this country, waiting for the word to attack. This has now been officially raised to our primary Strategic Threat.

In the face of such looming strikes on the U.S., I simply cannot believe that the NIH does not feel it within their mission to rigorously check out a proposed method for saving perhaps 70% of those coming deaths (first generation equipment), and up to 90% with second generation equipment.

Perhaps you just did not read the package carefully. I urge you to do so.

Else NIH is going to look very, very bad when (1) the strikes do occur, (2) they can't handle them (and they cannot, as you well know), (3) they had within their hands in advance, a proposed methodology that could have been investigated intensely, to save millions of those stricken Americans.

As a staunch supporter of NIH and especially CDC, I have to believe that there is a different attitude there. If NIH is not interested in a previously experimentally demonstrated method of saving millions of Americans, then the only recourse left is the political channel.

I assure you that my critique of electrodynamics is well-founded, as supported by various leading physicists such as Nobelist Feynman (who stated bluntly that the field concept is wrong), Wheeler, Bunge, and so on. It is inexplicable why all our universities are still teaching a 130 year old abridged (Heaviside's) subset of Maxwell's theory, and one that still contains a material ether even though that was falsified 110 years ago!

You already have seen the misuse of this technology by the Russians, in the decades-long radiation of the U.S. Embassy in Moscow. Is it not NIH's mission to understand how they generated all those diseases and health changes? Have you ever looked into Kaznacheyev's experiments showing that ANY cellular disease or disorder can be induced in cells at a distance by purely EM means? Have you looked into what got eliminated from electrodynamics by ignoring the hidden longitudinal EM inside every potential, field, and wave? Do you realize what ignoring that has done to American chemistry, biochemistry, and medical science?"

I would hope that the NIH would at least be interested in its own mission area!

I challenge you bluntly to admit that no one presently understands the primary operation of the human cellular *regenerative* system. That's because its technical principle is not presently in our recognized physics, biochemistry, and medical science – even though it has been in the hard physics literature since 1903-4. Becker's epochal work came closest; since he only had access to the conventional EM model, it failed him. But he at least showed you rigorously that cells can be changed (both differentiated and redifferentiated) all over the map by laughably weak EM – picoamperes of current, which means persistent DC potentials. In the microwave radiation of the U.S. Embassy, all the health changes occurred in regions absent of fields – i.e., absent of bleed-off of the potentials. Hence in regions of stable DC potentials! With 100% correlation of the health changes to persistent, gradient free potentials, and 100% anticorrelation to changing potentials (i.e., fields), our own scientists concluded totally erroneously that it could not have been the EM radiation causing the changes, when their own results had just proven that it was.

Now I ask you: Can NIH explain how it was that the DC potentials caused those health changes? I think not. If it could, it would understand the action package I wrote, and its importance.

This is not a "political" letter. I'm just an ordinary American citizen who has done about 30 years very hard work on this particular area. The work is good enough now to stand on its own merits. The scientific community will eventually accept it, about 50 years from now. But we cannot wait 50 years! Those millions of Americans are going to die, because of the bureaucracy and inaction of our own scientific organizations. Whether they like it or not, the U.S. scientific community is now the forefront of the struggle for this nation to survive. And they are failing us dramatically.

So as a parent who wants his children to live, and his neighbors' children to live, and those millions of soon-to-be stricken Americans to live also, I urge you to at least have someone competent in physics (and knowledgeable that the foundations of physics itself are in woeful shape!) check the work. Has anybody there *read* any of the references to the Prioré work I cited? Does anyone there realize that *there are no EM forcefields in space?* Probably not.

Dr. Kinsel, there is a time for "business as usual" and there is a time to do some serious new work. Those stricken Americans are going to be lying there. Nothing NIH can do is going to stop that. That's a given, and it is not my own estimate. It's the official estimate. And you *know* you presently do not have the tools to do anything really effective about it.

Frankly, I interpret your letter to me as just the normal "spin control" for easy disposition. I would hope that NIH would seriously rethink the situation, get off the "spin control" and "business as usual" posturing, and do something dramatically different for a change.

What have you got to lose? A little time from perhaps two or three of your best scientists.

What have you got to gain? Saving untold millions of American lives. A new, *already partially demonstrated* cure for most dread diseases such as AIDS and cancer – diseases which you presently cannot do very much about in spite of decades of heroic struggle.

Sincerely,

cc: Senator Shelby, Congr. Cramer

T.E. Bearden
President and CEO

CTEC, Inc.
T.E. Bearden, President & CEO
2311 Big Cove Road
Huntsville, AL 35801-1351
(256)533-3682 ph/(256)536-0411 Fax

CTEC, Inc.

May 12, 1998

Dr. Harold Varmus, Director
National Institute of Health
Bathesda, MD 20892
(301) 496-1766

Dear Dr Varmus:

We have recently sent action documents to the Director of Nuclear and Counterproliferation, Office of the DCS, Air and Space Operations, HQ USAF and to the DoD (General Busbee) Assistant Secretary of Defense, as well as several Senate and House committees, which may be of interest to you. For one thing, we give the technical mechanism used to generate the Gulf War Syndrome. The same weaponry is now being used to rapidly induce new strains of certain pathogens worldwide. I urge you to closely read that section of the letter to MG Neary which explains the GWS, why the French did not get it, and why Southern Iraqis got an increase in cancer and leukemia but not GWS. Also explained is how the "microwave radiation" of the U.S. Embassy in Moscow induced diseases for decades, and how we failed to comprehend it because the standard EM model deceived us.

There is a way to treat and quickly cure most diseases, including the mass casualties resulting from a terrorist BW strike on our civilian population centers, our military bases, or our forces in the field. The method is little known, but was scientifically demonstrated in France in the 1960s and early 1970s before cancellation of the Prioré Project when the French Government changed. Eminent French scientists worked on the project, and the results are fully documented in leading French scientific journals. References are listed in a separate attachment.

Previously the Western scientific community has been unable to understand the technical mechanism responsible for such remarkable cures, because of serious foundations flaws in Western physics and electrodynamics. *Foundations* physicists have long been aware our science is flawed, and have pointed out many of these fundamental errors. However, the operational science establishment has not paid attention, even though physicists such as Feynman and Wheeler pointed out that the notion of "force fields in space" was totally wrong.

As a primary example, there is an "infolded" electrodynamics inside all potentials, fields, and waves that is far more primary than the coarse EM that is in our textbooks. It is actually an infolded general relativity, and this is what the Russians have weaponized. This infolded EM-GR has been ignored in the West (but not in Russia) since 1903.

As another example the potentials, fields, and waves of present electrodynamics are rigorously defined – and exist – only in the presence of mass. They do not exist in such form (force fields and oscillating force fields) at all in space, in the absence of mass. Rigorously, Maxwell's equations are mass-to-mass transforms, since Maxwell and everyone at the time assumed the ubiquitous presence of the material ether. In other words, to the founding electrodynamicists, there was no place in all the universe that was devoid of mass. Hence they defined all EM entities as entities containing mass. Even though Michelson-Morley experiments of more than a century ago destroyed that material ether, not a single Maxwellian equation has ever been changed! They still assume the material ether.

Specifically missing from our electrodynamics are two essential transforms: (1) the mass-to-spacetime transform, and (2) the spacetime-to-mass transform. In other words, these two transforms are "infolded" or hidden inside (comprise) the end point extremum case – the mass-to-mass transform actually written by Maxwell.

But these two missing transforms are just general relativity (they correspond precisely to Wheeler's principle of general relativity). So general relativity has always been infolded inside electrodynamics as we know it, but ignored. Further, this is a very powerful general relativity, since it uses the very strong EM force as the agent of spacetime curvature. Hence now one can engineer a powerful general relativity in the laboratory and in practical devices, and even action-at-a-distance, which one cannot do using merely the staid and weak G-force.

It turns out that longitudinal EM waves as shown by E.T. Whittaker in 1903 and 1904 are far more primary than our present EM theory and even our present GR theory. Both EM and GR are directly engineerable using longitudinal EM waves, including subluminal and superluminal EM waves in vacuum, and including action at a distance. One can engineer complexes of spacetime curvatures as desired, which in turn are *spacetime engines* (Wheeler's term). These engines can act upon mass – either living or inert – in any fashion desired, and at any distance desired.

The little-known and poorly understood Regeneration & Recovery (R&R) system – as contrasted to the immune system – utilizes this exact "spacetime engine" methodology to restore damaged or diseased cells, within its limitations – "dedifferentiating" or "time-reversing" them back to normal. The mechanism is fully explained in the attached package. The proposed program applies this fundamental method to greatly amplify the effect. Thus cancer cells can be reversed back to normal cells, HIV-infected cells (HIV-factories) can be reversed back to normal cells (genetics and all), etc. This represents a dramatic and unparalleled new medical therapeutic methodology of extreme power. The same techniques can simply be conjugated one additional time, and used to produce diseases and cellular changes at a distance, including in entire mass populations, as the KGB is doing right now. Specifically, by impressing an extremely weak "cocktail mix" of disease spacetime engines on the U.S. populace, the immune systems are reacting and being "spread thin" across several "shadow state" infectious pathogenic conditions. Thus when an actual terrorist BW attack occurs, the lethality of the strike will be remarkably enhanced because the immune systems will be "thinned" in their ability to fend off this new pathogen. By doing it this way, BW warfare can actually be conducted upon the U.S. without anyone being the wiser.

Our very survival as a nation is threatened by remarkable KGB weapons using this fully documented, extended electrodynamics. Bluntly, unless we take off our scientific blinders and understand Russian energetics weapon science, GWS and the Embassy health changes in Moscow were just a picnic before what is upon us. After two decades of work on the KGB energetics weapon problem, we have fully deciphered the technical mechanisms and what energetics is, as well as citing many of the Russian weapon tests and how they were done. Again, you can see that for yourself in the package.

Now that we understand the technical mechanisms, we are proposing rapid redevelopment of the Prioré process, in portable suitcase-sized units to be mass produced and filtered down into the entire emergency community for mass treatment of lethal infectious diseases resulting from BW strikes. And we are strongly urging the U.S. scientific community to quickly investigate and come to grips with this vast new *biological engineering* mechanism. Our very survival depends on it.

The inclosed documents provide an overview of the process. There is nothing else on the scientific horizon that can save the majority of all those stricken Americans, once the first foreign-sponsored terrorist teams strike our population centers with BW agents.

Sincerely,

Incls: Full package with table of contents

T.E. Bearden
President & CEO

Weapons Slides

The Tom Bearden Website

Help support the research

"Others [terrorists] are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves… So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations…It's real, and that's the reason why we have to intensify our [counterterrorism] efforts." *

Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.

Slides
(covers period up to 1999)

- The Coming Strategic Attack on the United States
- Outline
- Loss of two separate A-10 Warthogs in 1997
- Typical ABM Defenses (Widely Deployed by mid-70s)

- Launch Phase Anti-Missile System
- Launch Phase Anti-Bomber System
- HC-130s Engines Quit, Aircraft Crashes
  Nov. 22, 1996
- 1996 Actions by this analyst
- Additional Information Exists: Not Analyzed, Not Integrated in Briefing
- Kill of Arrow DC-8, Gander AFB, Dec. 12, 1985
- Satellite Photos of Plumes in Soviet Arctic Since 1974
  See "Fer de Lance" for additional information
- Aum Shinrikyo ("Supreme Truth" Cult), Shoko Asahara, Leader

  Aum Shinrikyo - Anatomy of a Dangerous Cult
- Ashkhabad Problem and Its Solution
- Strange Characteristics of Iran Quake, Sep. 1978
- Iran Earthquake, September 1978
- Situation Now (Assessment)
- Situation Now (Assessment 2)
- Aspects of Strong Local Asymmetry
- Mass Casualty Problem: Aerial Anthrax

Spray on Washington, D.C.

- Present Status of the WMD Threat to the United States
- Some Present Problems in the U.S. WMD Defense Capabilities
- Internal Terrorist Threat with Weapons of Mass Destruction: Now & Future
- Attempt to Ban Energetics Weapons Worldwide
- Brezhnev's Schedule
- Large glowing Tesla globe witnessed in Red China by hundreds
- Cold Explosion -- 9 April 1984 Near Kurils, and formation and growth of spherical shell (globe)
  Sequence of Events
- Cold Explosion -- 9 April 1984 Near Kurils, and formation and growth of spherical shell (globe)
  What They Were
- Cold Explosion -- 9 April 1984 Near Kurils (Plus additional weapons effects)
- Countering Insane MAD Systems:
  Find Loophole, Exploit It
- Next Generation Counter to Both Sane and Insane MAD systems
- Simultaneous Dudding of Nuclear Weapons Worldwide

- Simultaneous Dudding of Nuclear Weapons Worldwide
- Operation Divine Wind II
- Advanced EMBW Applications
- EM Biological Warfare (EMBW)
- Microwave Radiation of U.S. Embassy in Moscow
- Pentagon EMI Studies, 1989
- EM Missile Practice (6 slides)
- Subdivisions of Soviet Energetics Program
- Communism's Goal
- Manuilsky's Goal vs. Status Today (Dec. 1996)
- Professor Hellman, German Scientist Released from Work in Soviet Union
- Hemispheres and Globes of Light (4 slides)
- How Could Such Superweapons Ever Be Concealed?
- Soviets Easily Concealed These Superweapons for Four Decades
- Microscope-type, laser-like interferometer for inducing quick α-decay in samples of otherwise longer-lived isotopes
- Longitudinal Wave Interferometry: Endothermic

- Longitudinal Wave Interferometry: Exothermic
- U.S. Air Attack on Libya, April 1986
- Lightning Wall
  circa 1959-1960
- Lisitsyn's Report: Brain Code Broken
- Large Longitudinal Wave Interferometer (LWI) Accident
- Large Longitudinal Wave Interferometer (LWI) Accident
- Use of Hidden Information Content of the Field Can Provide Action-At-A-Distance
- Two Types of Mutual Assured Destruction (MAD) System
- Psychoenergetics Weapons Teams Mentally Disable All Personnel
- Strikes Against Special Ship and Energetics Weapons Sites
- "Mindsnapper" Attack on Special Ships and Energetics Weapons Sites
- How Much Off Guard Are We?
  (7 Slides)
- Possible Targets: 1995-9 Escalation Phase
- Propagation of Weapon Effects
- Yugoslav Earthquake, Followed by Cold Explosion
  April 15th, 1979

- Countering an Insane QP Weapon
- Gulf War Disease: KGB QP Weapon Induced ST Curvature Engines for a Cocktail of Diseases
- Self-Targeting in Inner EM Channel Can Produce a Quantum Potential
- Mechanism for Producing a Quantum Potential
- Major Principles for Use of Quantum Potential Weapons
- Major Principles for Use of Quantum Potential Weapons (2)
- Instantaneous Communication by a Quantum Potential
- Participants in a quantum potential share a common multiply-connected spacetime (MCST)
- Quake in Tangshan, China
  28 July, 1976
- Exchanging Earthquakes
- Instant Communication by a Quantum Potential
- Westerners Do Not React to Slow Threats
- Characterizing a Given Risk or Risk Factor
- Technical Risk Management
- Aum Shinrikyo's Sarin Facility

- In Scalar Beam Interference Zone
- Physicist Schappeller Auralaz Munster, Austria
- Initial Soviet Plan for Cold War, After WWII
- Josef Stalin: Absolute Dictator
- Exploding any Resistance by Operational Scientists
- Significant Soviet Statements
- Captain Svoboda Dives Headlong to Her Death
- T-polarized Beam Projector
- Possible Tests (1)
- Possible Tests (2)
- Possible Tests (3)
- Possible Tests (4)
- Mushroom Cloud Rising From Sea
- Launches from Cape Canaveral and Vandenberg AFB Provided Practice Targets of Opportunity
- The sinking U.S.S. Thresher, with her controls jammed, implodes when she reaches crush depth
- Embodiment of an instrument array sufficient to discriminate when time-density charging has occurred, and that transduction

of time-charge decay has occurred.

- Time-Polarized EM Wave Interferometer Creating Space-Time Curvature Engines in a Distant Interference Zone
- Transmutation of Radioactive Nuclei at a Distance
- Transmutation of Radioactive Nuclei
- Typical Tesla Shield, Northern Route of Japan
- A Curious Tide in Human Affairs
- Large Scalar EM Interferometer (LASI) Accident Near Urals, 1958
- The Superpower Paradox: Asymmetric Cheap WMD Strategic Strike and Destruction
- The KGB/Yakuza-Aum War Plan
- Why Western Science is Ignorant of KGB Energetics
- Transmutation of Radioactive Nuclei at a Distance
- TheYakuza
- Yugoslav Earthquake, Followed by Cold Explosion
  April 15, 1979

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* Note that the Secretary did not speak the words in square blocks; these were added by the writers later,

probably to "soften the tone" of the Secretary's information release. So the Secretary confirmed that some nations of the world -- not just some ragged terrorists, as the writers tried to imply for spin control -- do possess novel electromagnetic weapons and are using them to induce earthquakes, engineer the weather and climate, and trigger volcanic eruptions.

THE COMING STRATEGIC ATTACK ON THE UNITED STATES

By an AUM/Yakuza/KGB/Communist Coalition Using Energetics SuperWeapons

T.E. Bearden, LTC
U.S. Army (Retired)
M.S. Nuclear Eng.
Fellow Emeritus, AIAS

With Technical Background and History of Energetics Weapons

Partial support by the Association of Distinguished American Scientists is gratefully acknowledged.d

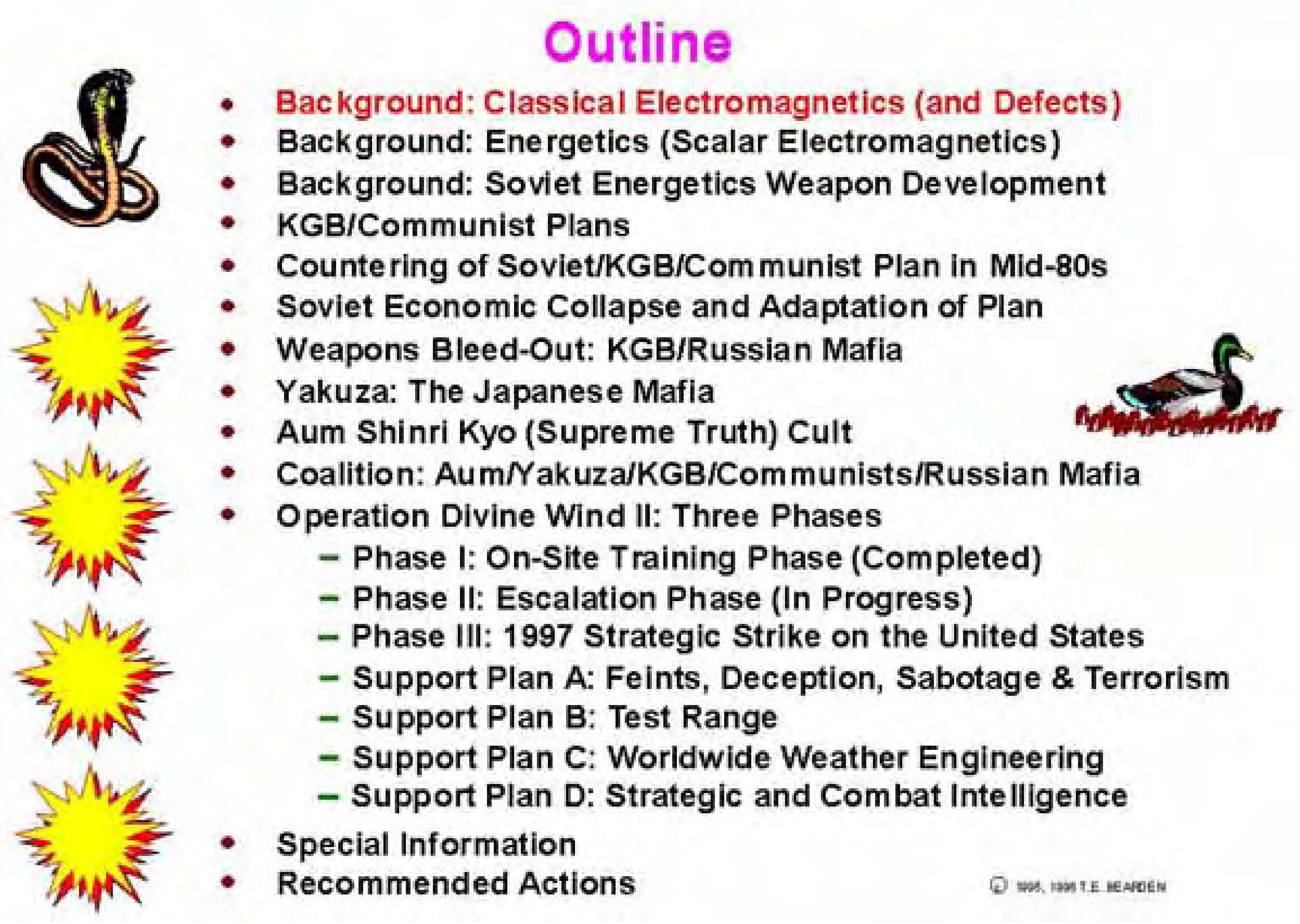

Outline

- Background: Classical Electromagnetics (and Defects)
- Background: Energetics (Scalar Electromagnetics)
- Background: Soviet Energetics Weapon Development
- KGB/Communist Plans
- Countering of Soviet/KGB/Communist Plan in Mid-80s
- Soviet Economic Collapse and Adaptation of Plan
- Weapons Bleed-Out: KGB/Russian Mafia
- Yakuza: The Japanese Mafia
- Aum Shinri Kyo (Supreme Truth) Cult
- Coalition: Aum/Yakuza/KGB/Communists/Russian Mafia
- Operation Divine Wind II: Three Phases
  - Phase I: On-Site Training Phase (Completed)
  - Phase II: Escalation Phase (In Progress)
  - Phase III: 1997 Strategic Strike on the United States
  - Support Plan A: Feints, Deception, Sabotage & Terrorism
  - Support Plan B: Test Range
  - Support Plan C: Worldwide Weather Engineering
  - Support Plan D: Strategic and Combat Intelligence
- Special Information
- Recommended Actions

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The Tom Bearden Website

Help support the research

Loss of two separate A-10 Warthogs in 1997

- A-10 Mysterious Flyaway and Crash - April 2, 1997
- Death of Second A-10 Pilot - May 27, 1997
- Captain Button's Mysterious Flyaway and Eventual Crash
- Death of Second A-10 Pilot - May 27, 1997

A-10 Mysterious Flyaway and Crash

April 2, 1997

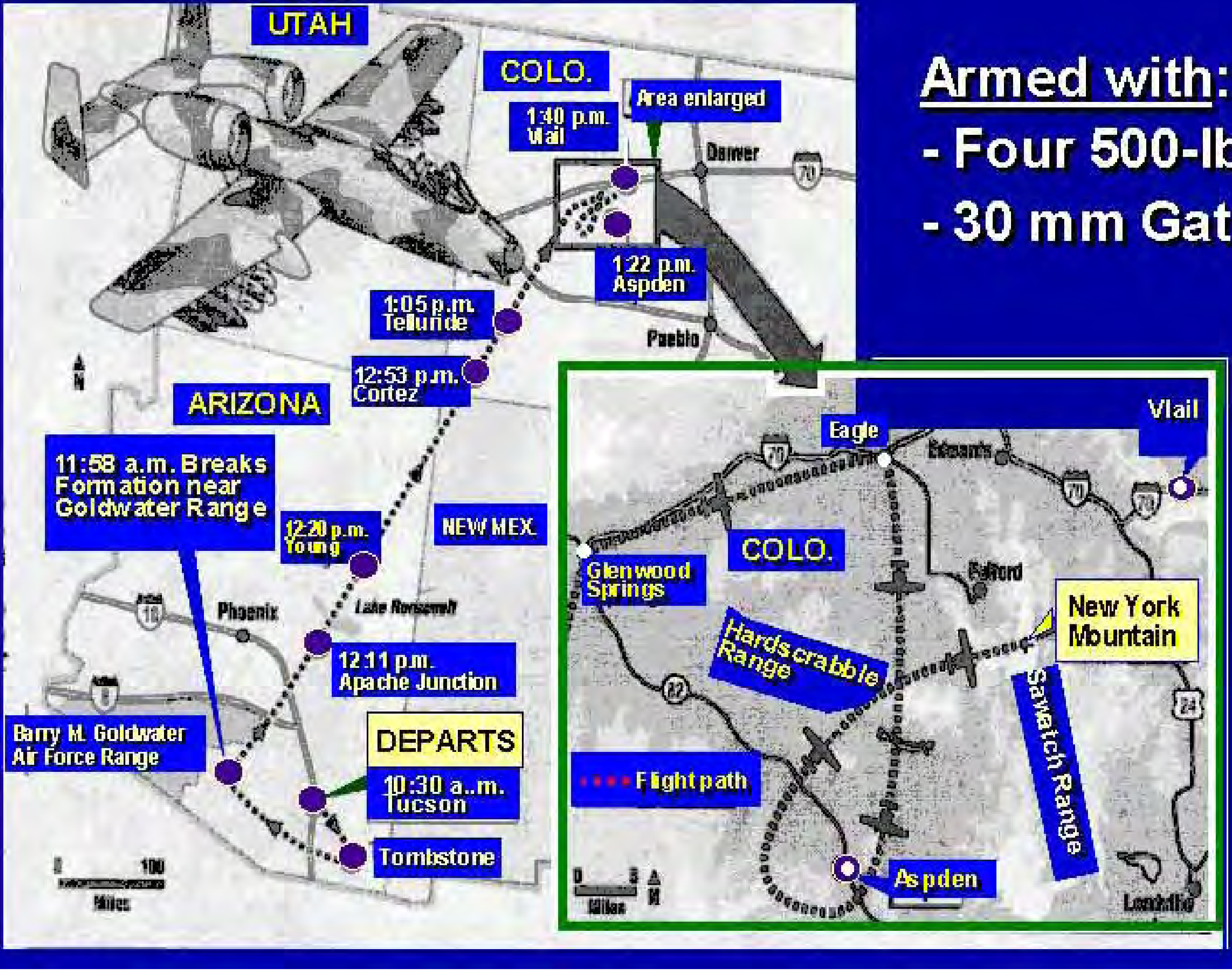
UTAH
COLO.
Area enlarged
1:40 p.m.
Vail
Denver
70
1:22 p.m.
Aspden
1:05 p.m.
Telluride
Pueblo
12:53 p.m.
Cortez
ARIZONA
11:58 a.m. Breaks
Formation near
Goldwater Range
12:20 p.m.
Young
NEW MEX.
Phoenix
Lake Roosevelt
10
12:11 p.m.
Apache Junction
8
Barry M. Goldwater
Air Force Range
DEPARTS
10:30 a..m.
Tucson
Tombstone
0 100
Miles
N
Eagle
Edwards
Vlail
70
COLO.
Glenwood
Springs
Fulford
New York
Mountain
Hardscrabble
Range
82
Sawatch Range
24
Flight path
Aspden
0 5
Miles
N
Leadville

Armed with:

- Four 500-lb bombs
- 30 mm Gatling gun

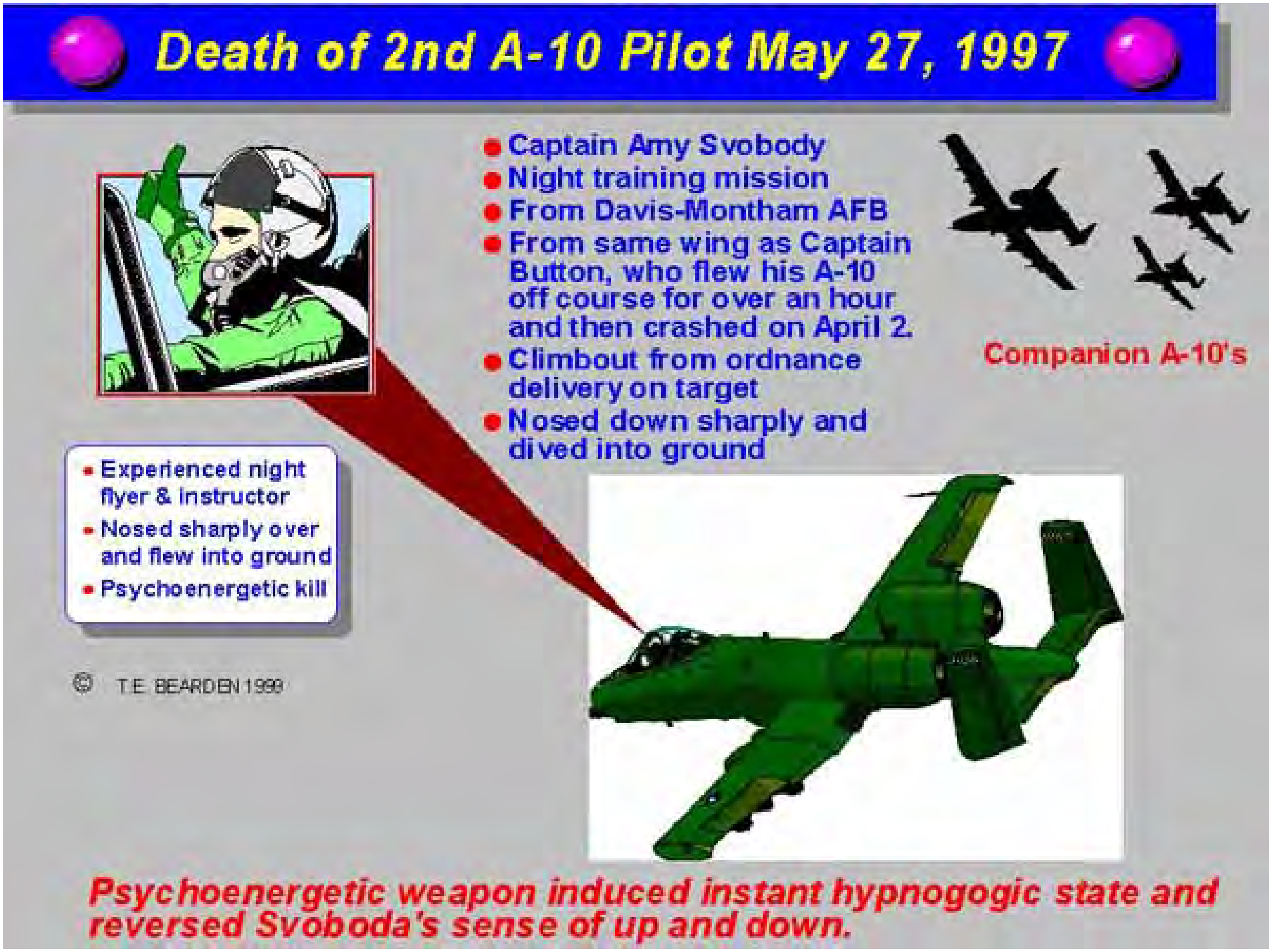

Death of 2nd A-10 Pilot May 27, 1997

- Captain Amy Svobody
- Night training mission
- From Davis-Montham AFB
- From same wing as Captain Button, who flew his A-10 off course for over an hour and then crashed on April 2.
- Climbout from ordnance delivery on target
- Nosed down sharply and dived into ground

Companion A-10's

- Experienced night flyer & instructor
- Nosed sharply over and flew into ground
- Psychoenergetic kill

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Psychoenergetic weapon induced instant hypnogogic state and reversed Svoboda's sense of up and down.

A-10 Mysterious Flyaway and Crash

April 2, 1997

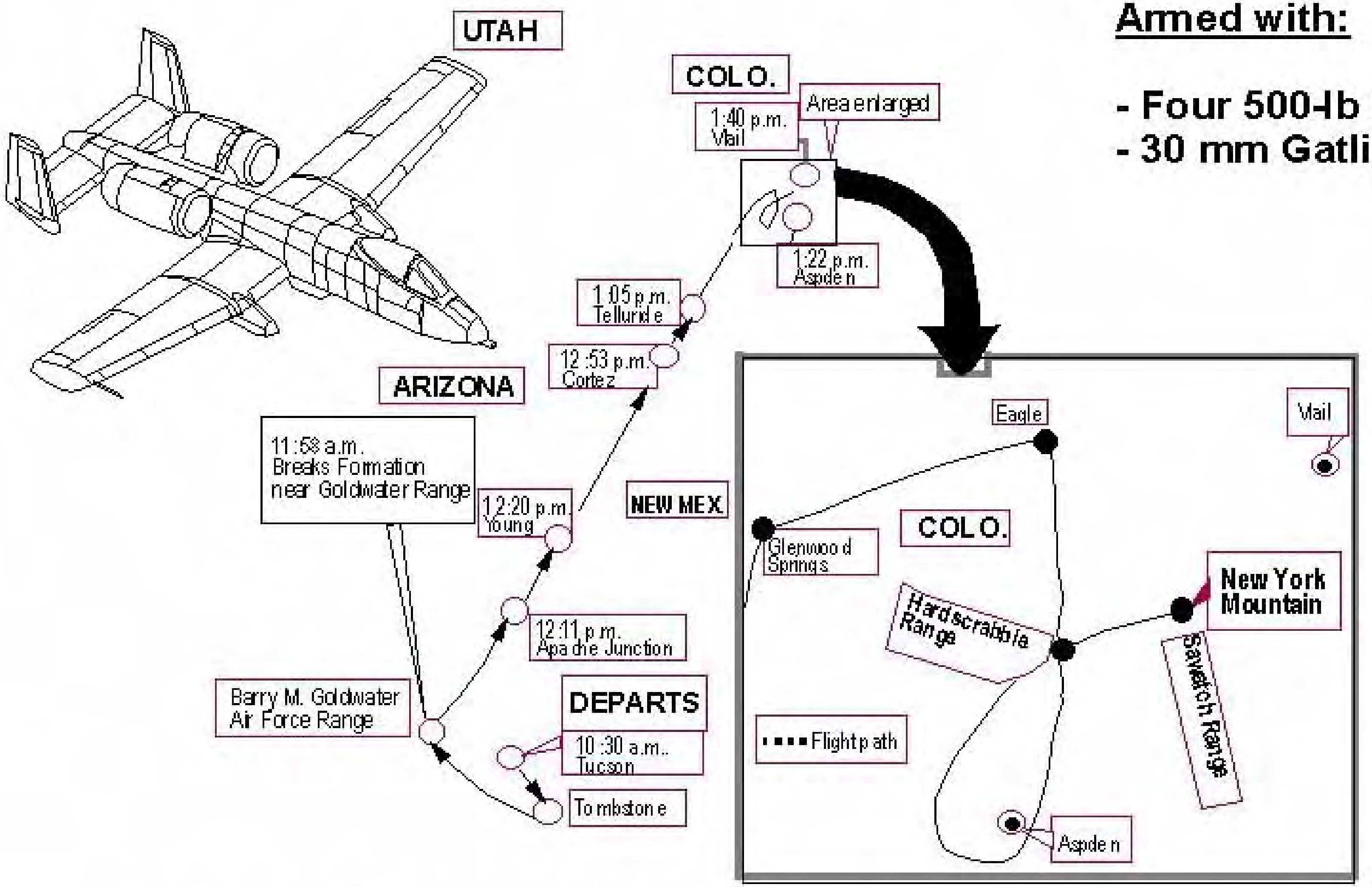
UTAH
COLO.
1:40 p.m.
Vail
Area enlarged
1:22 p.m.
Aspden
1:05 p.m.
Telluride
12:53 p.m.
Cortez
ARIZONA
11:58 a.m.
Breaks Formation
near Goldwater Range
12:20 p.m.
Young
NEW MEX.
12:11 p.m.
Apache Junction
Barry M. Goldwater
Air Force Range
DEPARTS
10:30 a.m..
Tucson
Tombstone
Eagle
Vail
Glenwood
Springs
COLO.
Hardscrabble
Range
New York
Mountain
Sawatch Range
Flight path
Aspden

Armed with:

- Four 500-lb bombs
- 30 mm Gatling gun

Figure 14a. Captain Button's mysterious flyaway and eventual crash.

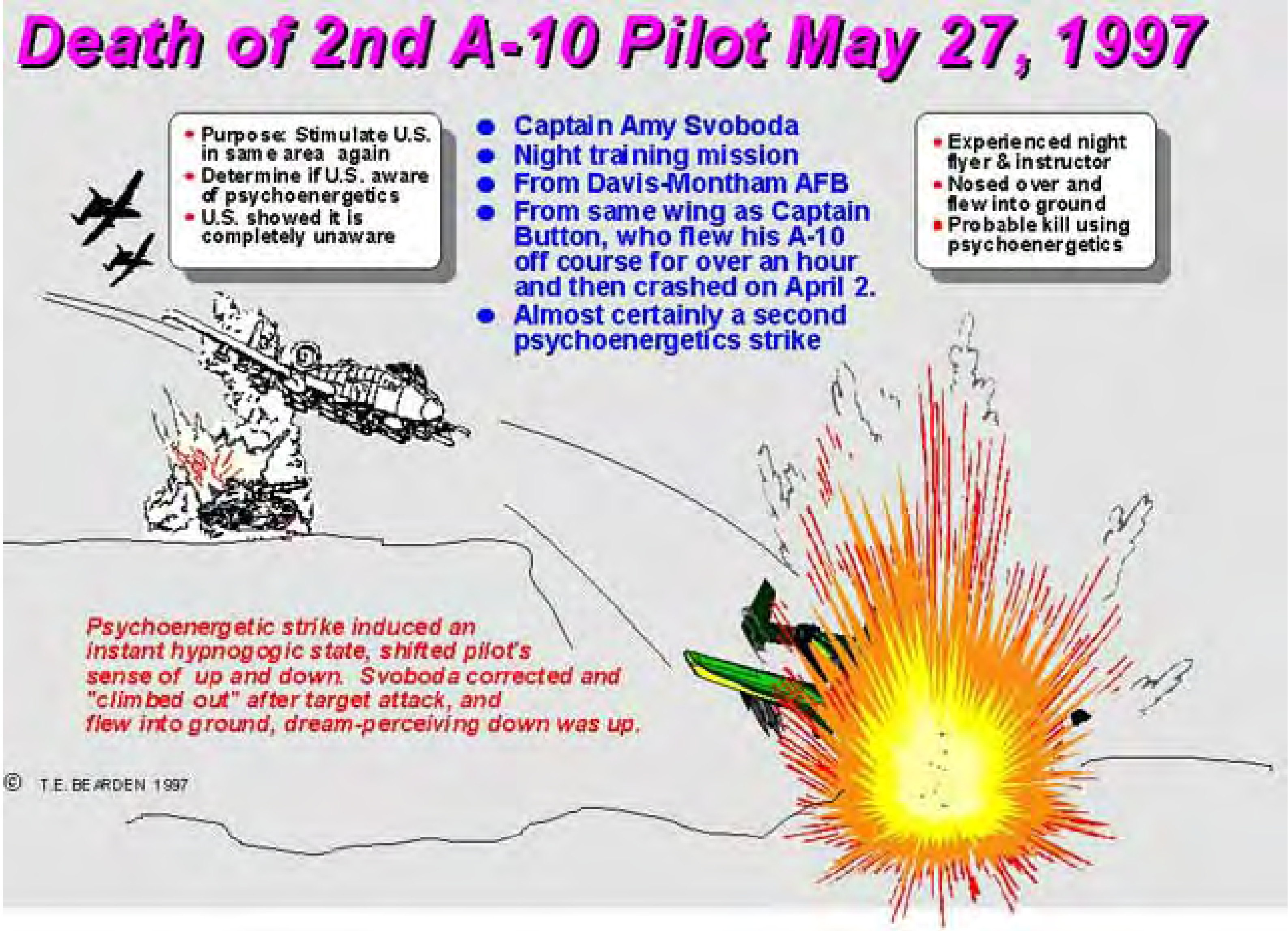

Death of 2nd A-10 Pilot May 27, 1997

- Purpose: Stimulate U.S. in same area again
- Determine if U.S. aware of psychoenergetics
- U.S. showed it is completely unaware

- Captain Amy Svoboda
- Night training mission
- From Davis-Montham AFB
- From same wing as Captain Button, who flew his A-10 off course for over an hour and then crashed on April 2.
- Almost certainly a second psychoenergetics strike

- Experienced night flyer & instructor
- Nosed over and flew into ground
- Probable kill using psychoenergetics

Psychoenergetic strike induced an instant hypnogogic state, shifted pilot's sense of up and down. Svoboda corrected and "climbed out" after target attack, and flew into ground, dream-perceiving down was up.

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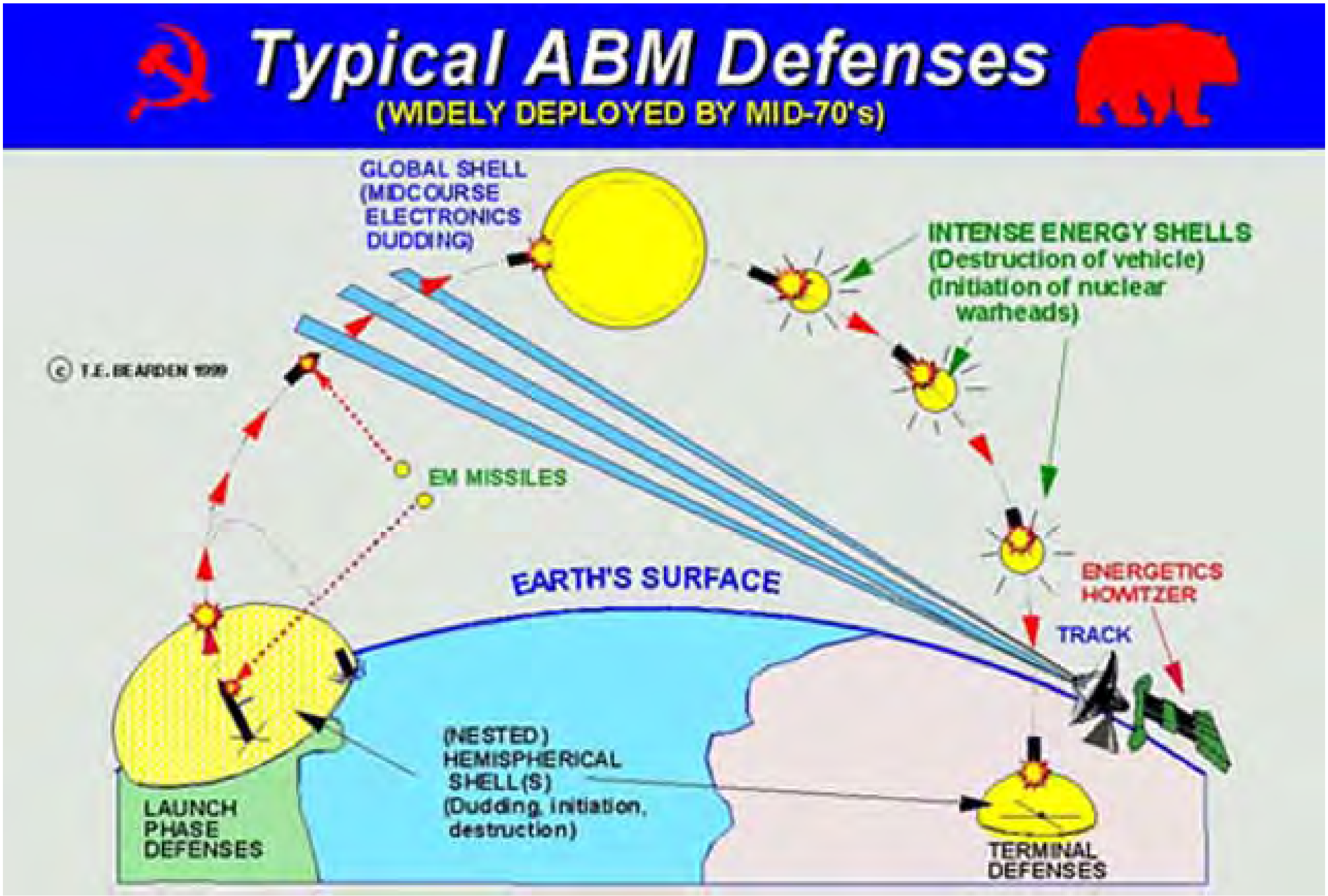
Typical ABM Defenses
(WIDELY DEPLOYED BY MID-70's)
GLOBAL SHELL (MIDCOURSE ELECTRONICS DUDDING)
INTENSE ENERGY SHELLS (Destruction of vehicle) (Initiation of nuclear warheads)
© T.E. BEARDEN 1999
EM MISSILES
EARTH'S SURFACE
ENERGETICS HOWITZER
TRACK
(NESTED) HEMISPHERICAL SHELL(S) (Dudding, initiation, destruction)
LAUNCH PHASE DEFENSES
TERMINAL DEFENSES

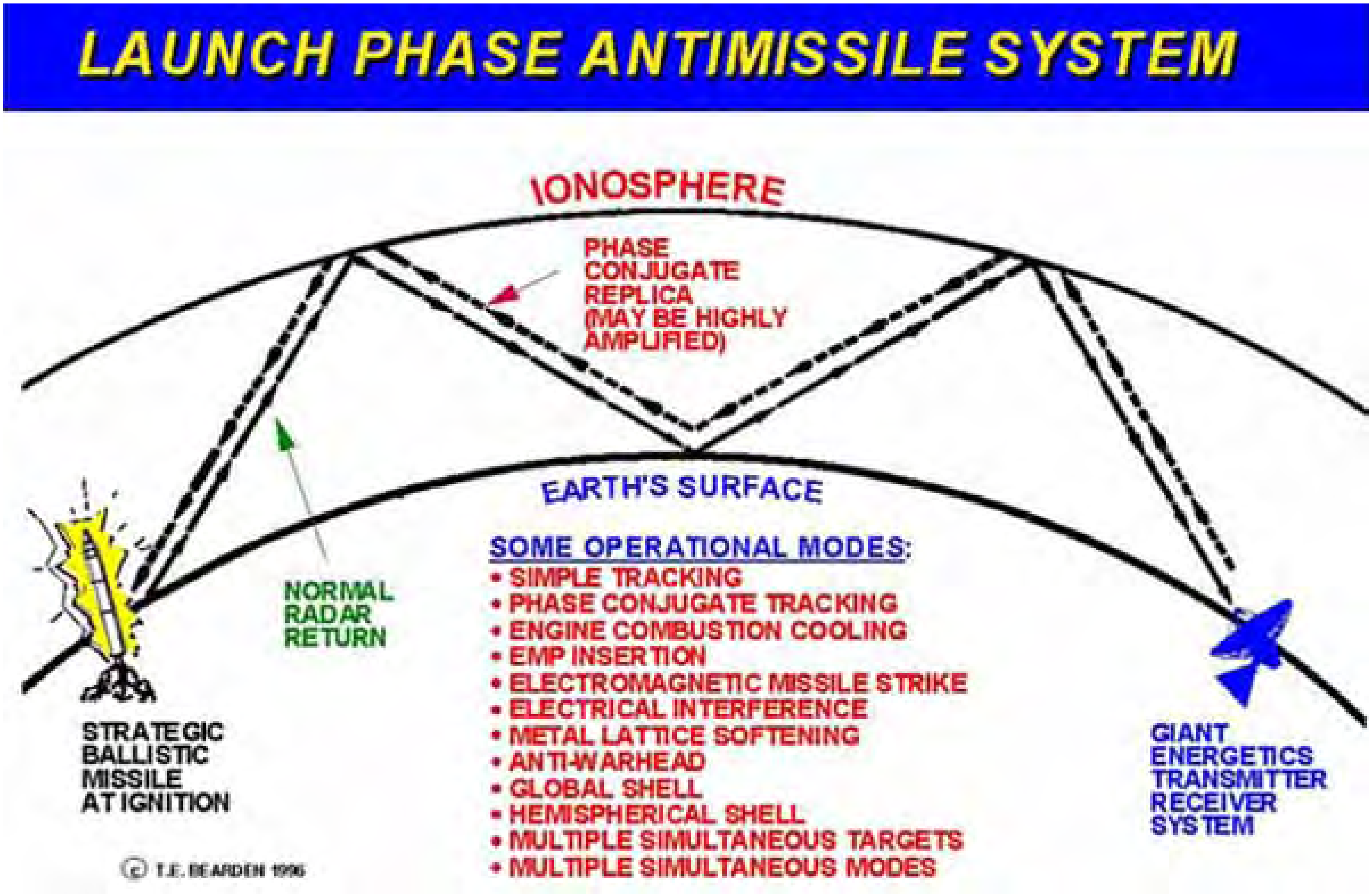

LAUNCH PHASE ANTIMISSILE SYSTEM

IONOSPHERE

PHASE
CONJUGATE
REPLICA
(MAY BE HIGHLY
AMPLIFIED)

NORMAL
RADAR
RETURN

EARTH'S SURFACE

STRATEGIC
BALLISTIC
MISSILE
AT IGNITION

GIANT
ENERGETICS
TRANSMITTER
RECEIVER
SYSTEM

SOME OPERATIONAL MODES:

- SIMPLE TRACKING
- PHASE CONJUGATE TRACKING
- ENGINE COMBUSTION COOLING
- EMP INSERTION
- ELECTROMAGNETIC MISSILE STRIKE
- ELECTRICAL INTERFERENCE
- METAL LATTICE SOFTENING
- ANTI-WARHEAD
- GLOBAL SHELL
- HEMISPHERICAL SHELL
- MULTIPLE SIMULTANEOUS TARGETS
- MULTIPLE SIMULTANEOUS MODES

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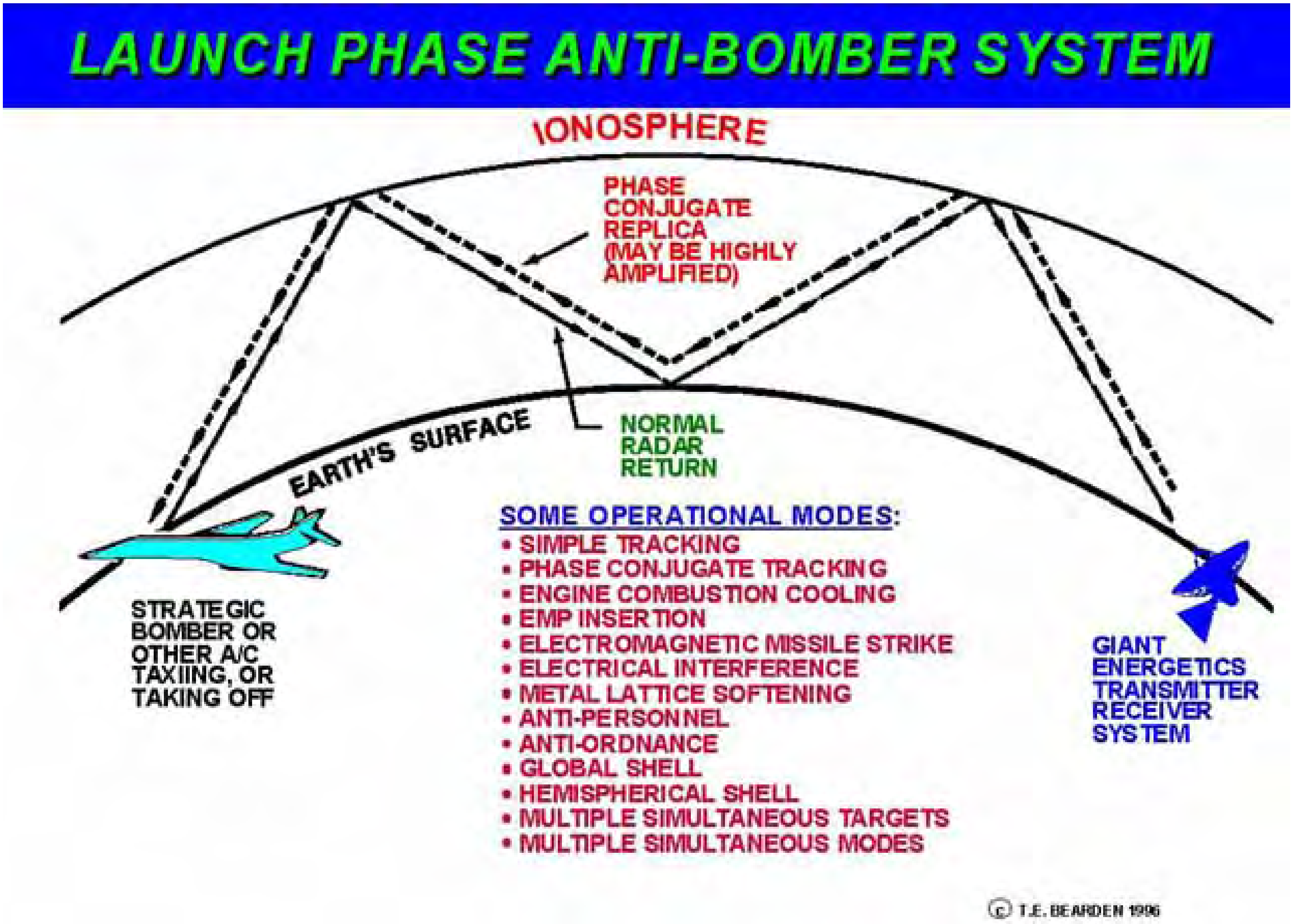

LAUNCH PHASE ANTI-BOMBER SYSTEM

IONOSPHERE
PHASE CONJUGATE REPLICA (MAY BE HIGHLY AMPLIFIED)
NORMAL RADAR RETURN
EARTH'S SURFACE
STRATEGIC BOMBER OR OTHER A/C TAXIING, OR TAKING OFF
GIANT ENERGETICS TRANSMITTER RECEIVER SYSTEM

SOME OPERATIONAL MODES:

- SIMPLE TRACKING
- PHASE CONJUGATE TRACKING
- ENGINE COMBUSTION COOLING
- EMP INSERTION
- ELECTROMAGNETIC MISSILE STRIKE
- ELECTRICAL INTERFERENCE
- METAL LATTICE SOFTENING
- ANTI-PERSONNEL
- ANTI-ORDNANCE
- GLOBAL SHELL
- HEMISPHERICAL SHELL
- MULTIPLE SIMULTANEOUS TARGETS
- MULTIPLE SIMULTANEOUS MODES

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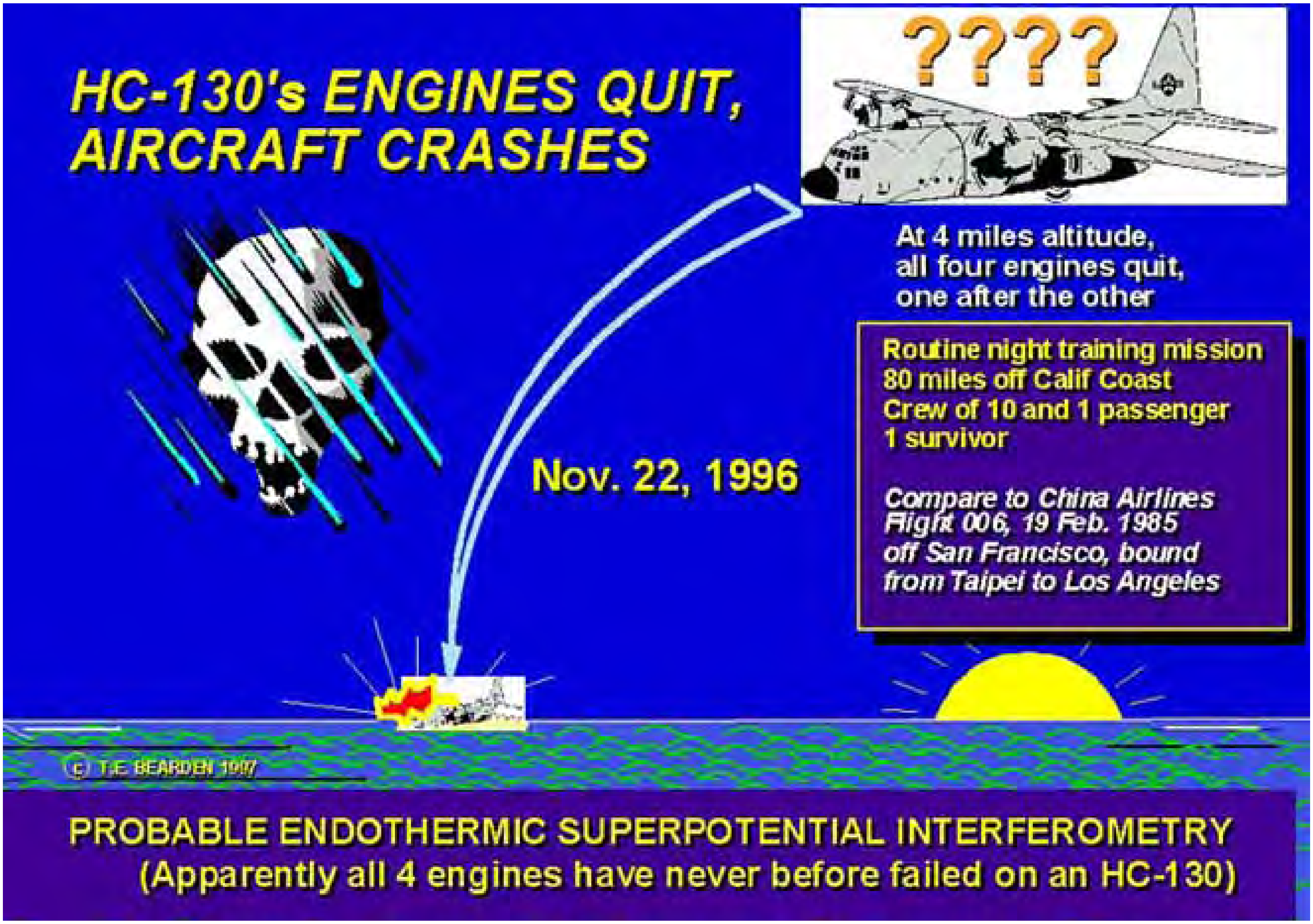

HC-130's ENGINES QUIT, AIRCRAFT CRASHES

At 4 miles altitude,
all four engines quit,
one after the other

Nov. 22, 1996

Routine night training mission
80 miles off Calif Coast
Crew of 10 and 1 passenger
1 survivor

Compare to China Airlines Flight 006, 19 Feb. 1985 off San Francisco, bound from Taipei to Los Angeles

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PROBABLE ENDOTHERMIC SUPERPOTENTIAL INTERFEROMETRY
(Apparently all 4 engines have never before failed on an HC-130)

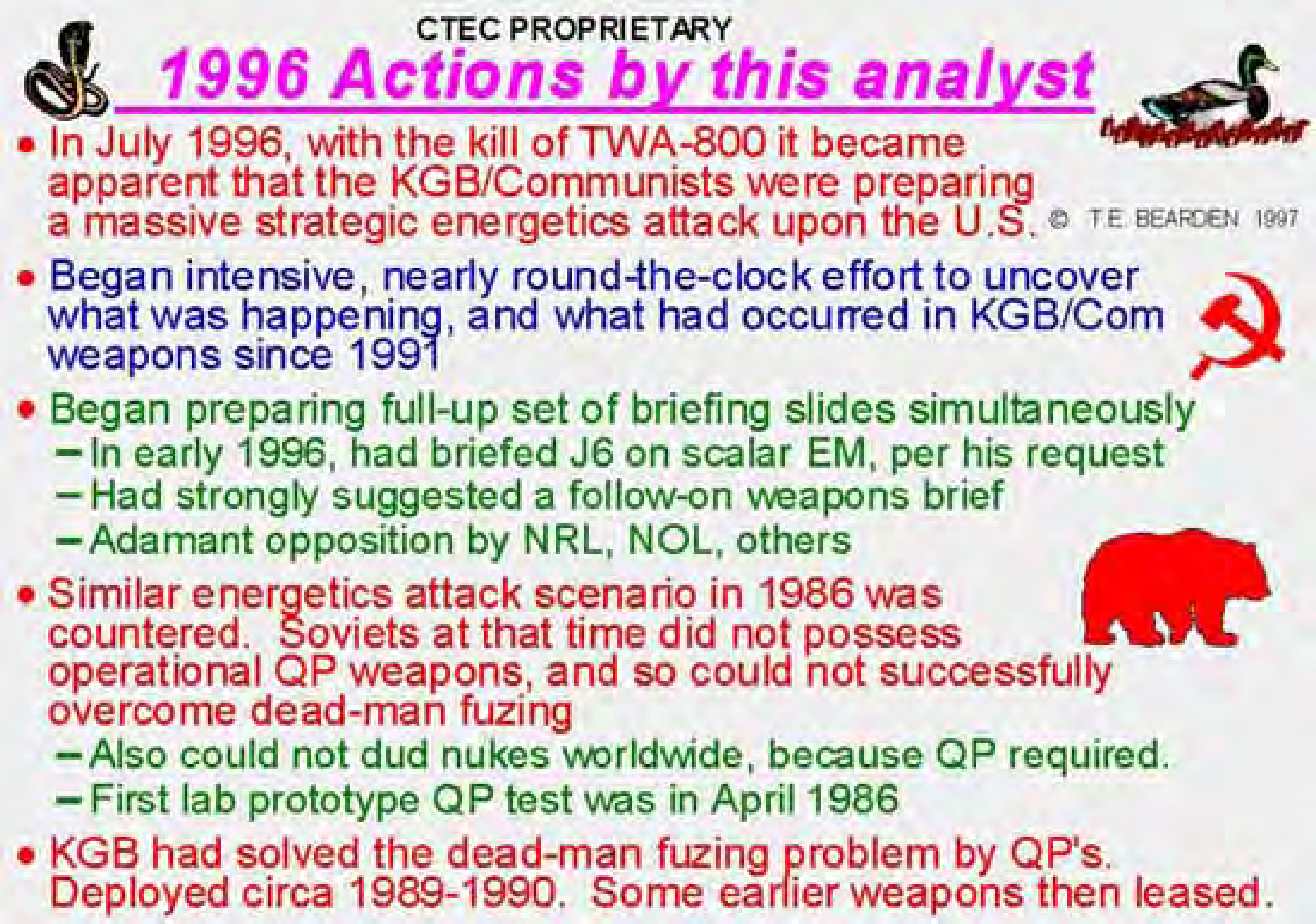

CTEC PROPRIETARY

1996 Actions by this analyst

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- In July 1996, with the kill of TWA-800 it became apparent that the KGB/Communists were preparing a massive strategic energetics attack upon the U.S.
- Began intensive, nearly round-the-clock effort to uncover what was happening, and what had occurred in KGB/Com weapons since 1991
- Began preparing full-up set of briefing slides simultaneously
  - In early 1996, had briefed J6 on scalar EM, per his request
  - Had strongly suggested a follow-on weapons brief
  - Adamant opposition by NRL, NOL, others
- Similar energetics attack scenario in 1986 was countered. Soviets at that time did not possess operational QP weapons, and so could not successfully overcome dead-man fuzing
  - Also could not dud nukes worldwide, because QP required.
  - First lab prototype QP test was in April 1986
- KGB had solved the dead-man fuzing problem by QP's. Deployed circa 1989-1990. Some earlier weapons then leased.

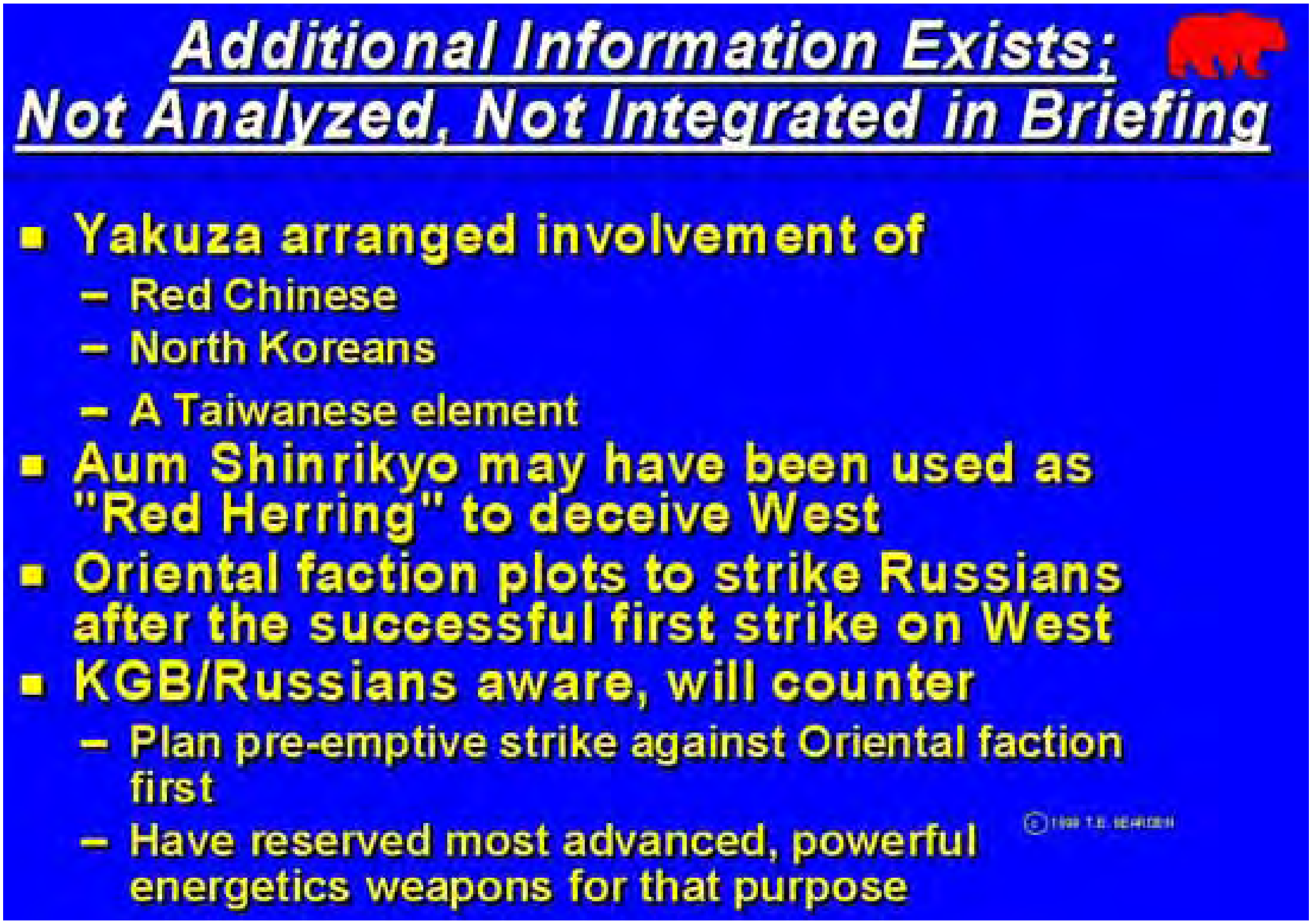

Additional Information Exists; Not Analyzed, Not Integrated in Briefing

- Yakuza arranged involvement of
  - Red Chinese
  - North Koreans
  - A Taiwanese element
- Aum Shinrikyo may have been used as "Red Herring" to deceive West
- Oriental faction plots to strike Russians after the successful first strike on West
- KGB/Russians aware, will counter
  - Plan pre-emptive strike against Oriental faction first
  - Have reserved most advanced, powerful energetics weapons for that purpose

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The Tom Bearden Website

Help support the research

Kill of Arrow DC-8, Gander AFB, Dec. 12, 1985

- Slide 1
- Slide 2
- Slide 3
- Slide 4
- Slide 5
- Slide 6

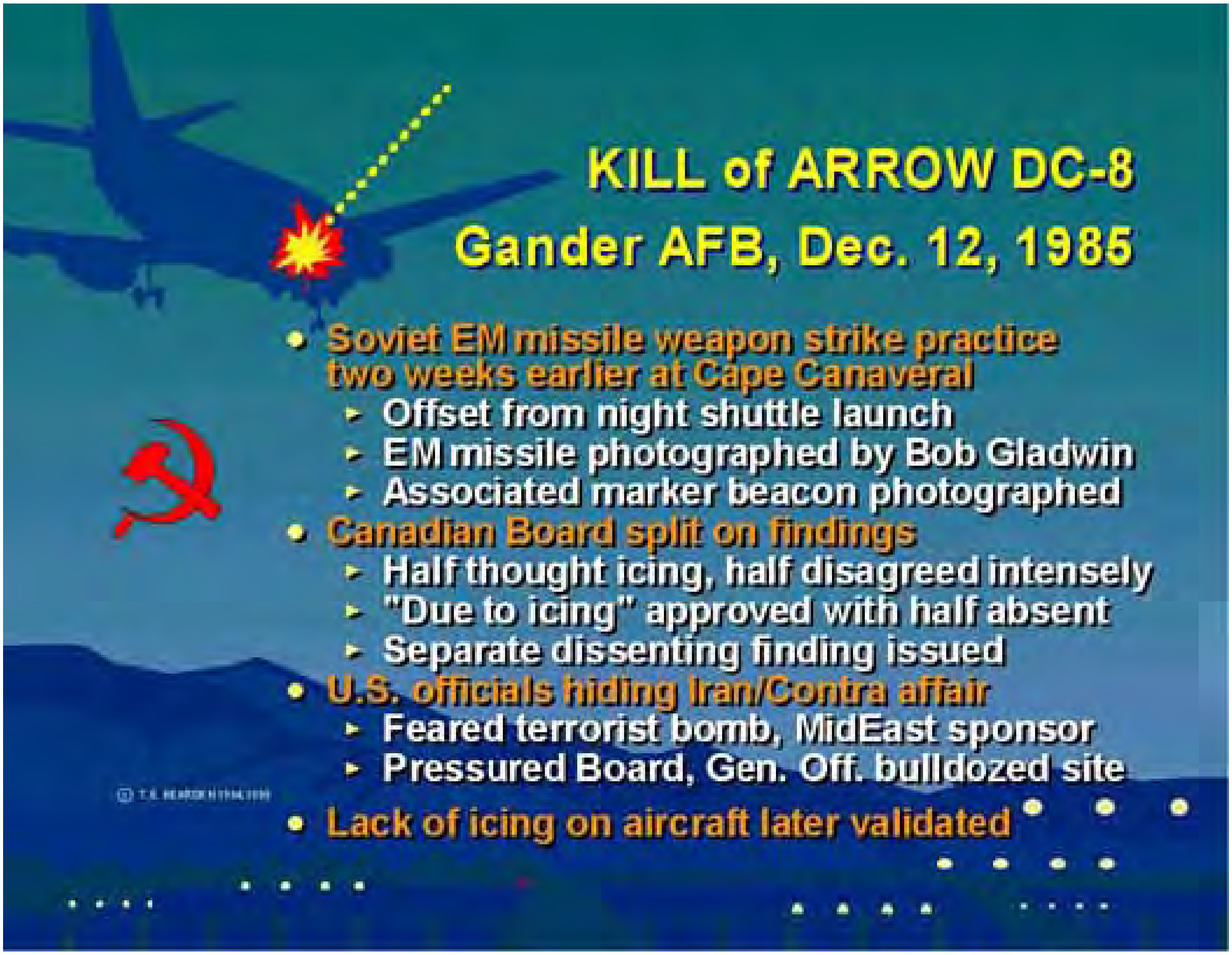

KILL of ARROW DC-8
Gander AFB, Dec. 12, 1985

- Soviet EM missile weapon strike practice two weeks earlier at Cape Canaveral
    - Offset from night shuttle launch
    - EM missile photographed by Bob Gladwin
    - Associated marker beacon photographed
- Canadian Board split on findings
    - Half thought icing, half disagreed intensely
    - "Due to icing" approved with half absent
    - Separate dissenting finding issued
- U.S. officials hiding Iran/Contra affair
    - Feared terrorist bomb, MidEast sponsor
    - Pressured Board, Gen. Off. bulldozed site
- Lack of icing on aircraft later validated

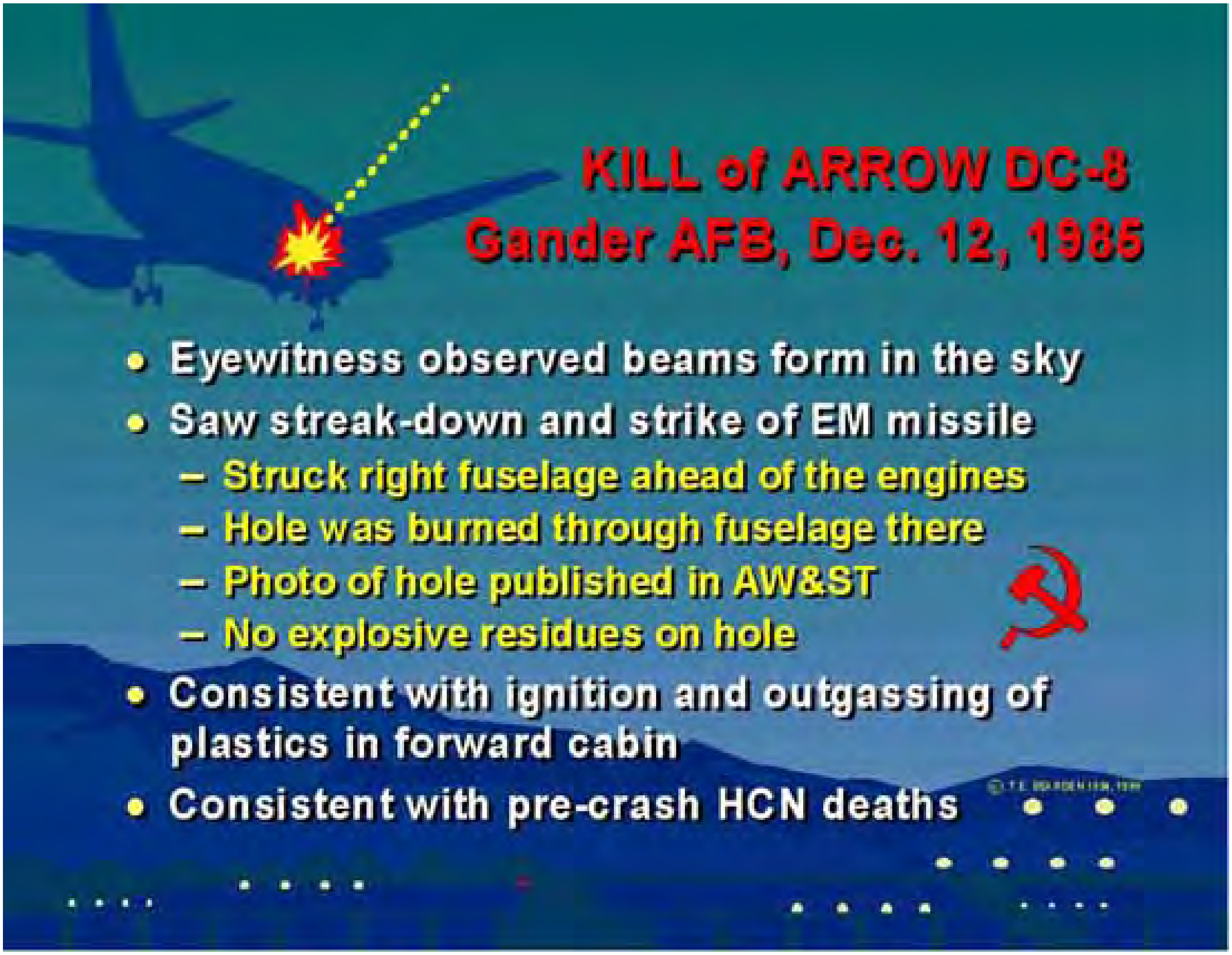

KILL of ARROW DC-8
Gander AFB, Dec. 12, 1985

- Eyewitness observed beams form in the sky
- Saw streak-down and strike of EM missile
  - Struck right fuselage ahead of the engines
  - Hole was burned through fuselage there
  - Photo of hole published in AW&ST
  - No explosive residues on hole
- Consistent with ignition and outgassing of plastics in forward cabin
- Consistent with pre-crash HCN deaths

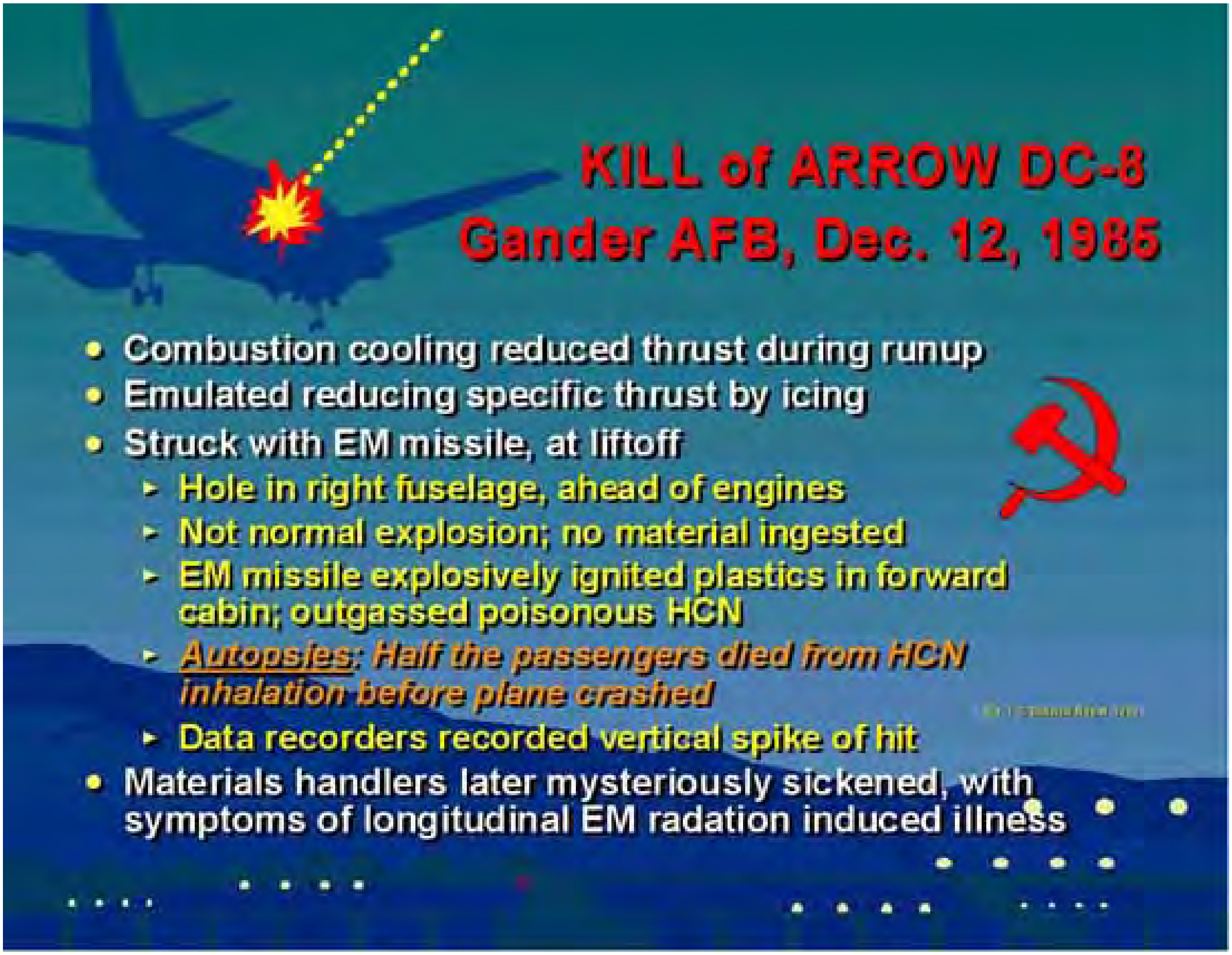

KILL of ARROW DC-8
Gander AFB, Dec. 12, 1985

- Combustion cooling reduced thrust during runup
- Emulated reducing specific thrust by icing
- Struck with EM missile, at liftoff
  - Hole in right fuselage, ahead of engines
  - Not normal explosion; no material ingested
  - EM missile explosively ignited plastics in forward cabin; outgassed poisonous HCN
  - *__Autopsies__: Half the passengers died from HCN inhalation before plane crashed*
  - Data recorders recorded vertical spike of hit
- Materials handlers later mysteriously sickened, with symptoms of longitudinal EM radation induced illness

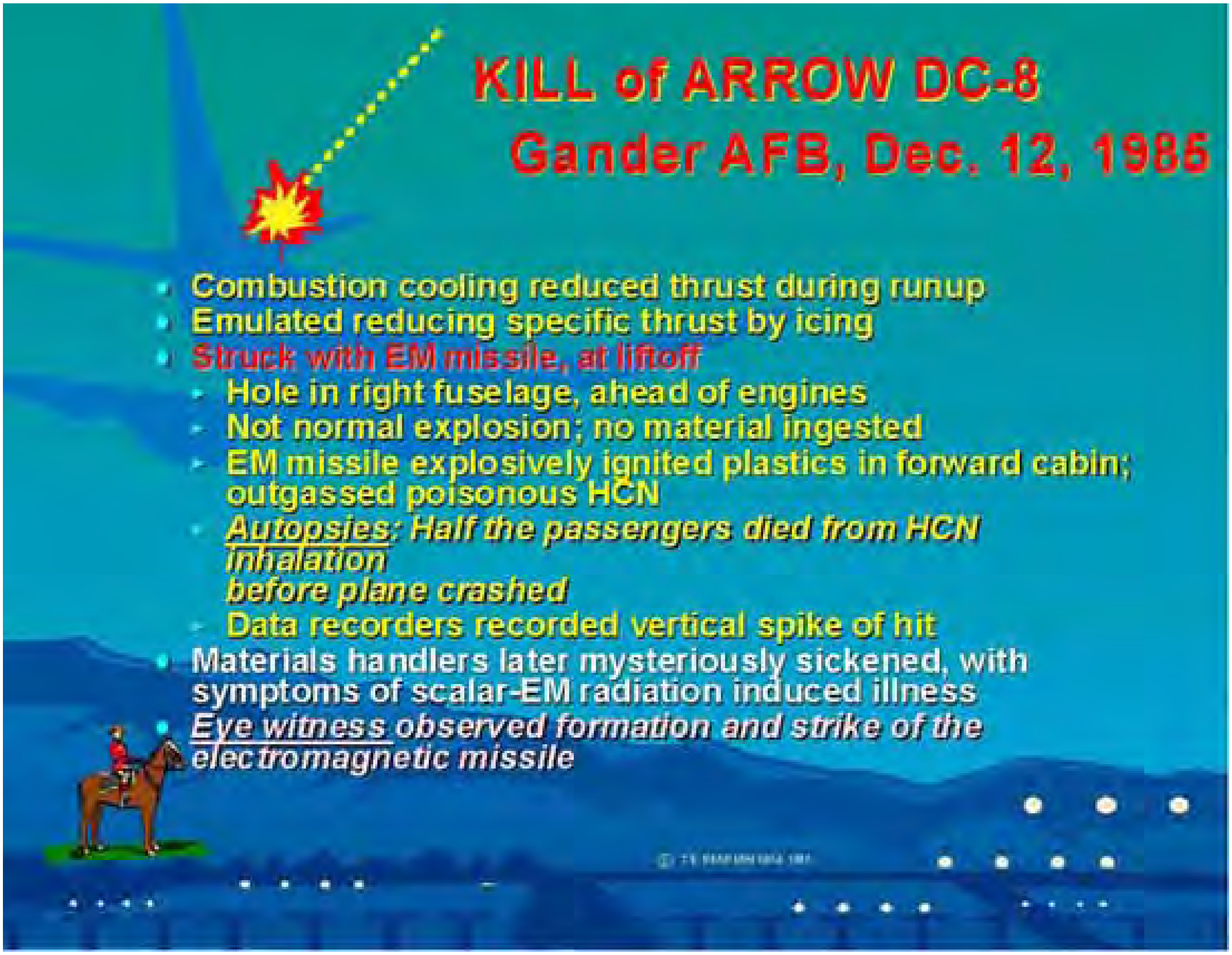

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  - Data recorders recorded vertical spike of hit
- Materials handlers later mysteriously sickened, with symptoms of scalar-EM radiation induced illness
- *Eye witness observed formation and strike of the electromagnetic missile*

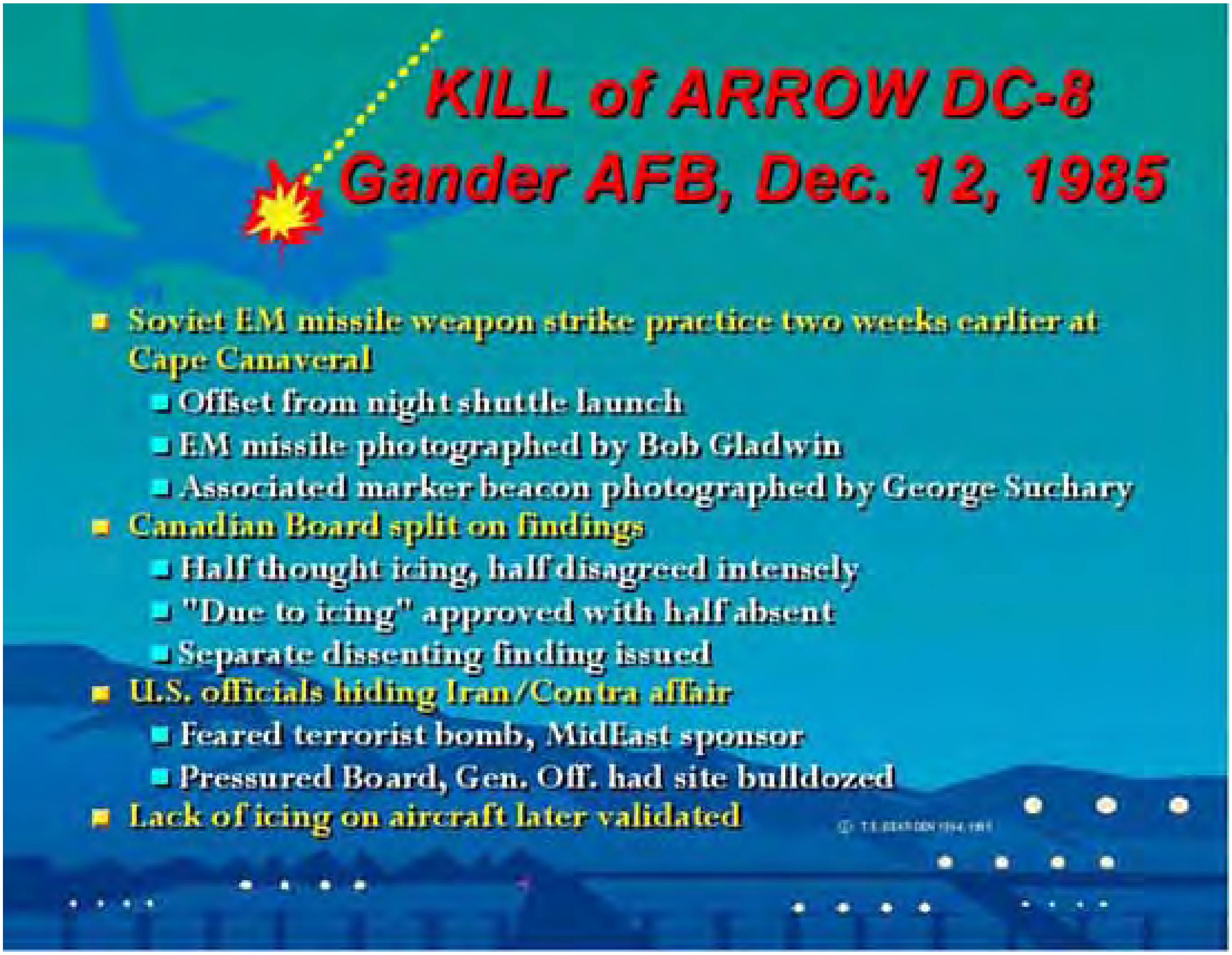

KILL of ARROW DC-8 Gander AFB, Dec. 12, 1985

- Soviet EM missile weapon strike practice two weeks earlier at Cape Canaveral
  - Offset from night shuttle launch
  - EM missile photographed by Bob Gladwin
  - Associated marker beacon photographed by George Suchary
- Canadian Board split on findings
  - Half thought icing, half disagreed intensely
  - "Due to icing" approved with half absent
  - Separate dissenting finding issued
- U.S. officials hiding Iran/Contra affair
  - Feared terrorist bomb, MidEast sponsor
  - Pressured Board, Gen. Off. had site bulldozed
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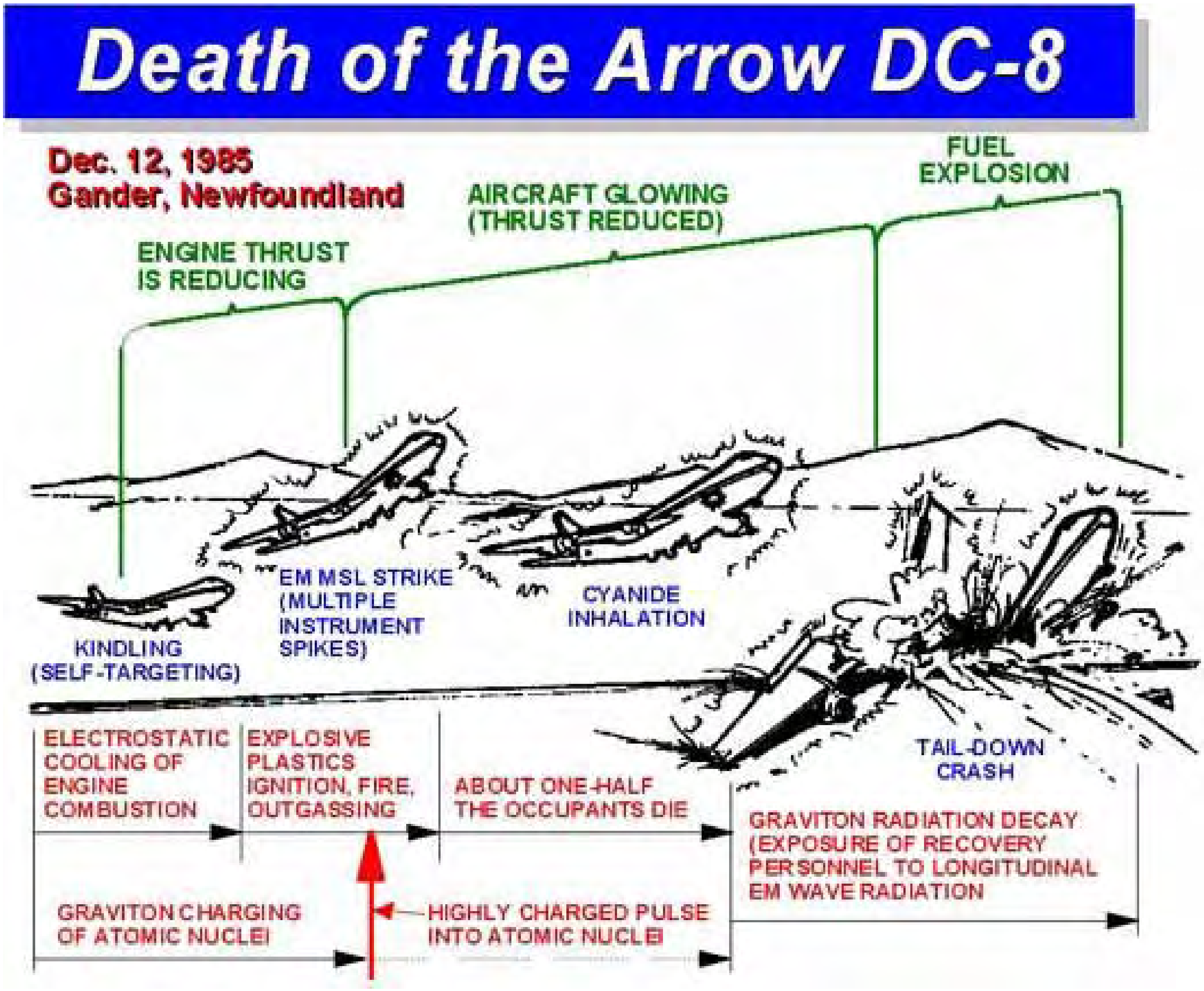

Death of the Arrow DC-8

Dec. 12, 1985
Gander, Newfoundland
ENGINE THRUST IS REDUCING
AIRCRAFT GLOWING (THRUST REDUCED)
FUEL EXPLOSION
KINDLING (SELF-TARGETING)
EM MSL STRIKE (MULTIPLE INSTRUMENT SPIKES)
CYANIDE INHALATION
TAIL-DOWN CRASH
ELECTROSTATIC COOLING OF ENGINE COMBUSTION
EXPLOSIVE PLASTICS IGNITION, FIRE, OUTGASSING
ABOUT ONE-HALF THE OCCUPANTS DIE
GRAVITON RADIATION DECAY (EXPOSURE OF RECOVERY PERSONNEL TO LONGITUDINAL EM WAVE RADIATION
GRAVITON CHARGING OF ATOMIC NUCLEI
HIGHLY CHARGED PULSE INTO ATOMIC NUCLEI

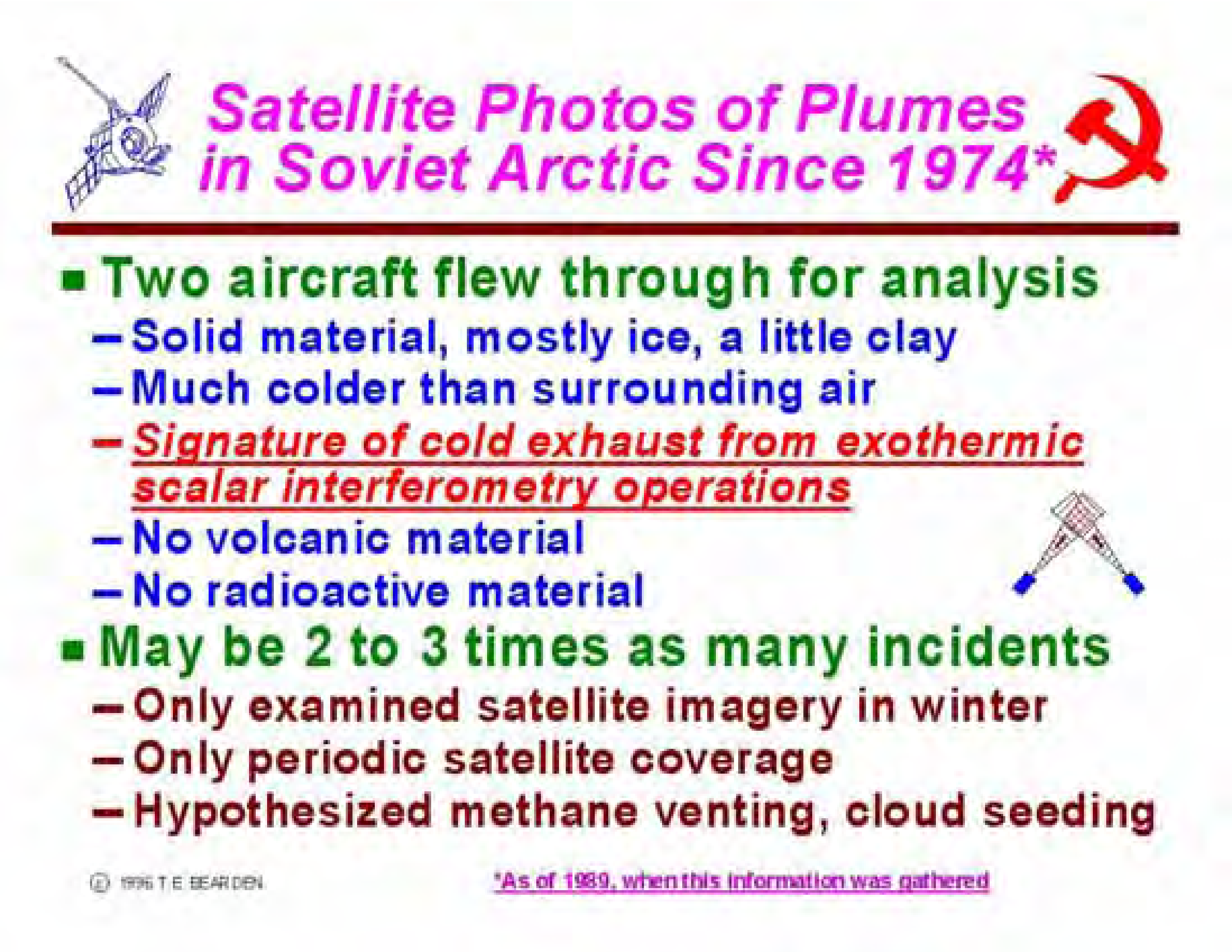

Satellite Photos of Plumes in Soviet Arctic Since 1974*

- Two aircraft flew through for analysis
  - Solid material, mostly ice, a little clay
  - Much colder than surrounding air
  - *Signature of cold exhaust from exothermic scalar interferometry operations*
  - No volcanic material
  - No radioactive material
- May be 2 to 3 times as many incidents
  - Only examined satellite imagery in winter
  - Only periodic satellite coverage
  - Hypothesized methane venting, cloud seeding

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*As of 1989, when this information was gathered

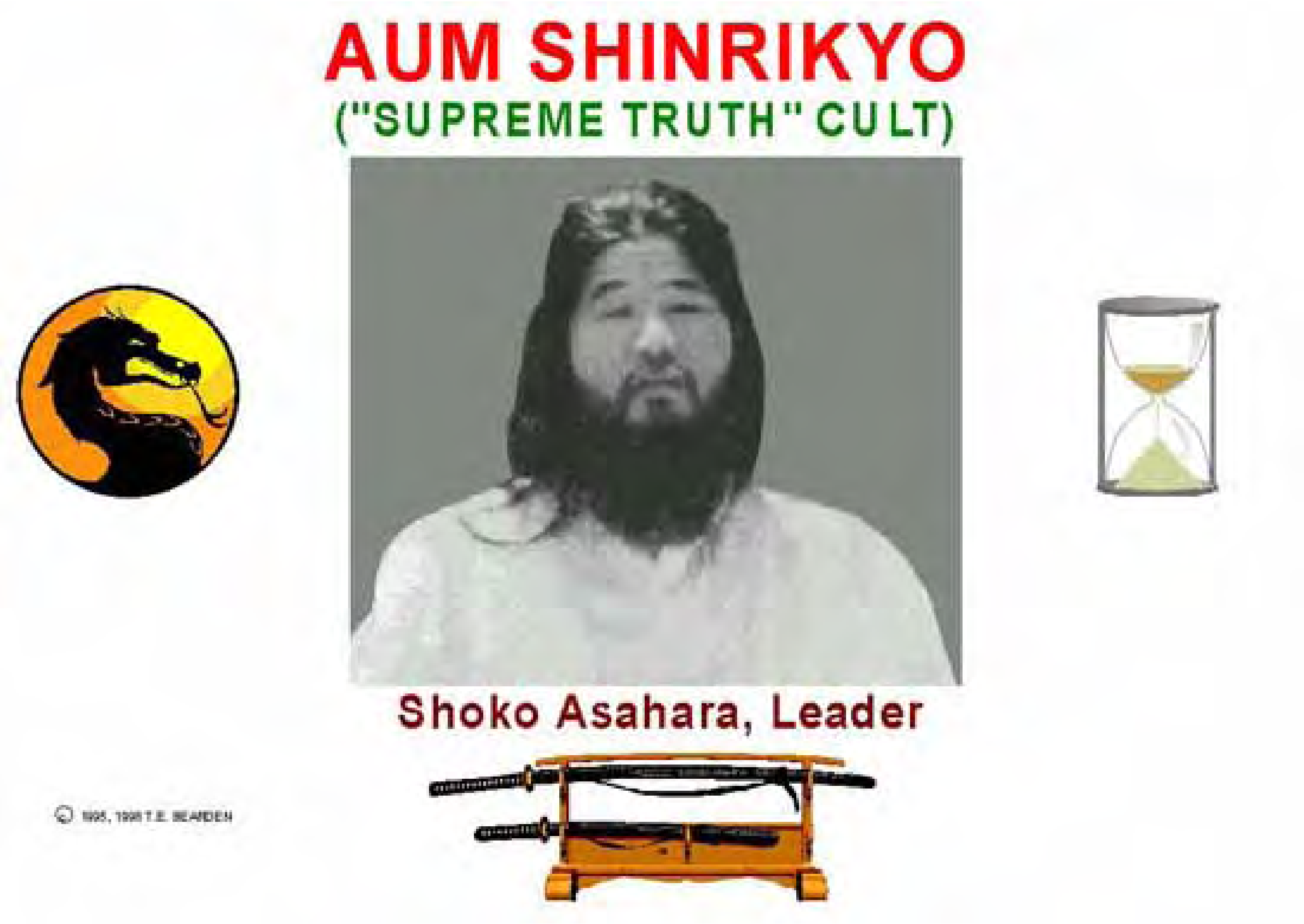
AUM SHINRIKYO
("SUPREME TRUTH" CULT)
Shoko Asahara, Leader
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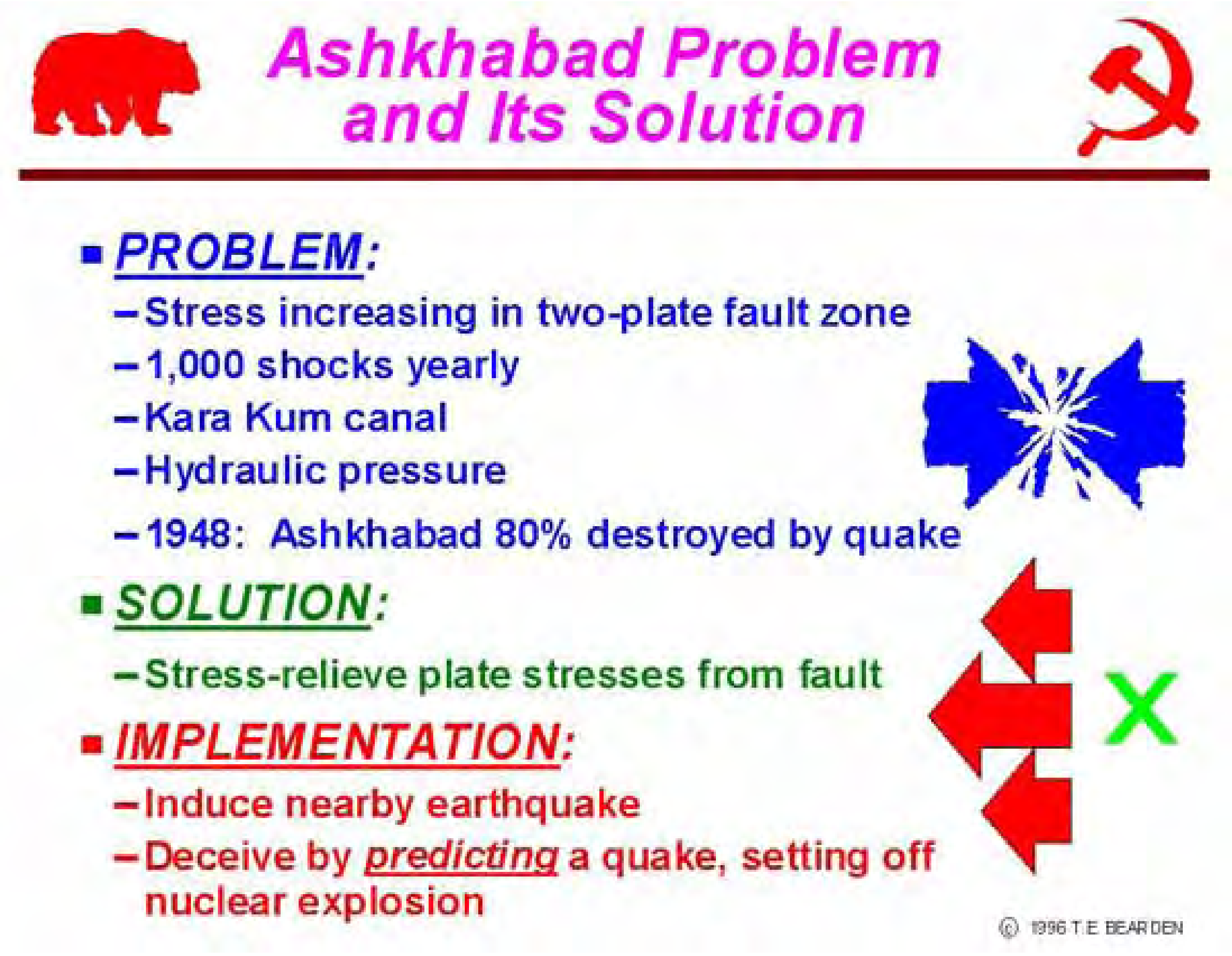

Ashkhabad Problem and Its Solution

- ***PROBLEM:***
  - Stress increasing in two-plate fault zone
  - 1,000 shocks yearly
  - Kara Kum canal
  - Hydraulic pressure
  - 1948: Ashkhabad 80% destroyed by quake
- ***SOLUTION:***
  - Stress-relieve plate stresses from fault
- ***IMPLEMENTATION:***
  - Induce nearby earthquake
  - Deceive by *predicting* a quake, setting off nuclear explosion

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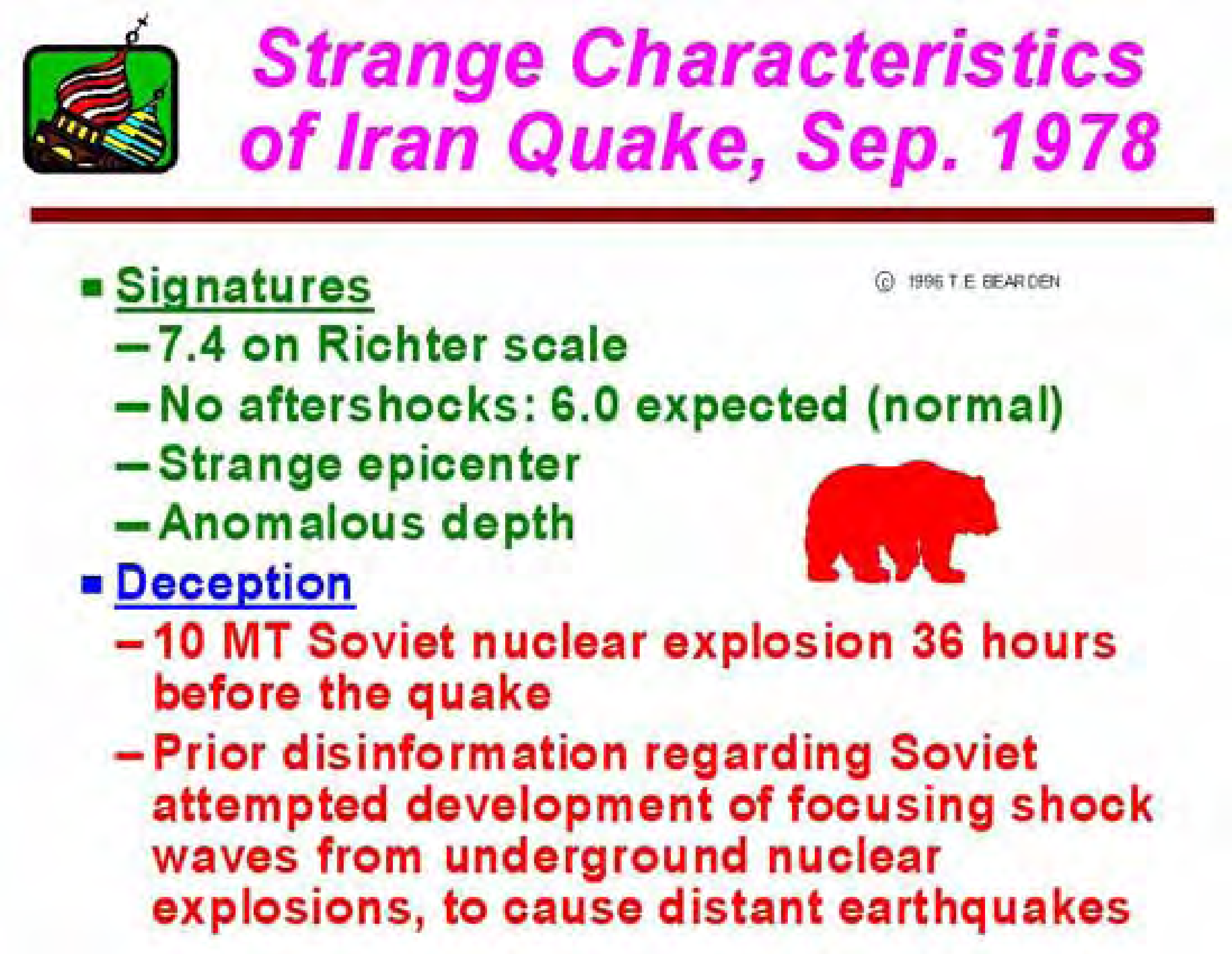

Strange Characteristics of Iran Quake, Sep. 1978

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- Signatures
  - 7.4 on Richter scale
  - No aftershocks: 6.0 expected (normal)
  - Strange epicenter
  - Anomalous depth
- Deception
  - 10 MT Soviet nuclear explosion 36 hours before the quake
  - Prior disinformation regarding Soviet attempted development of focusing shock waves from underground nuclear explosions, to cause distant earthquakes

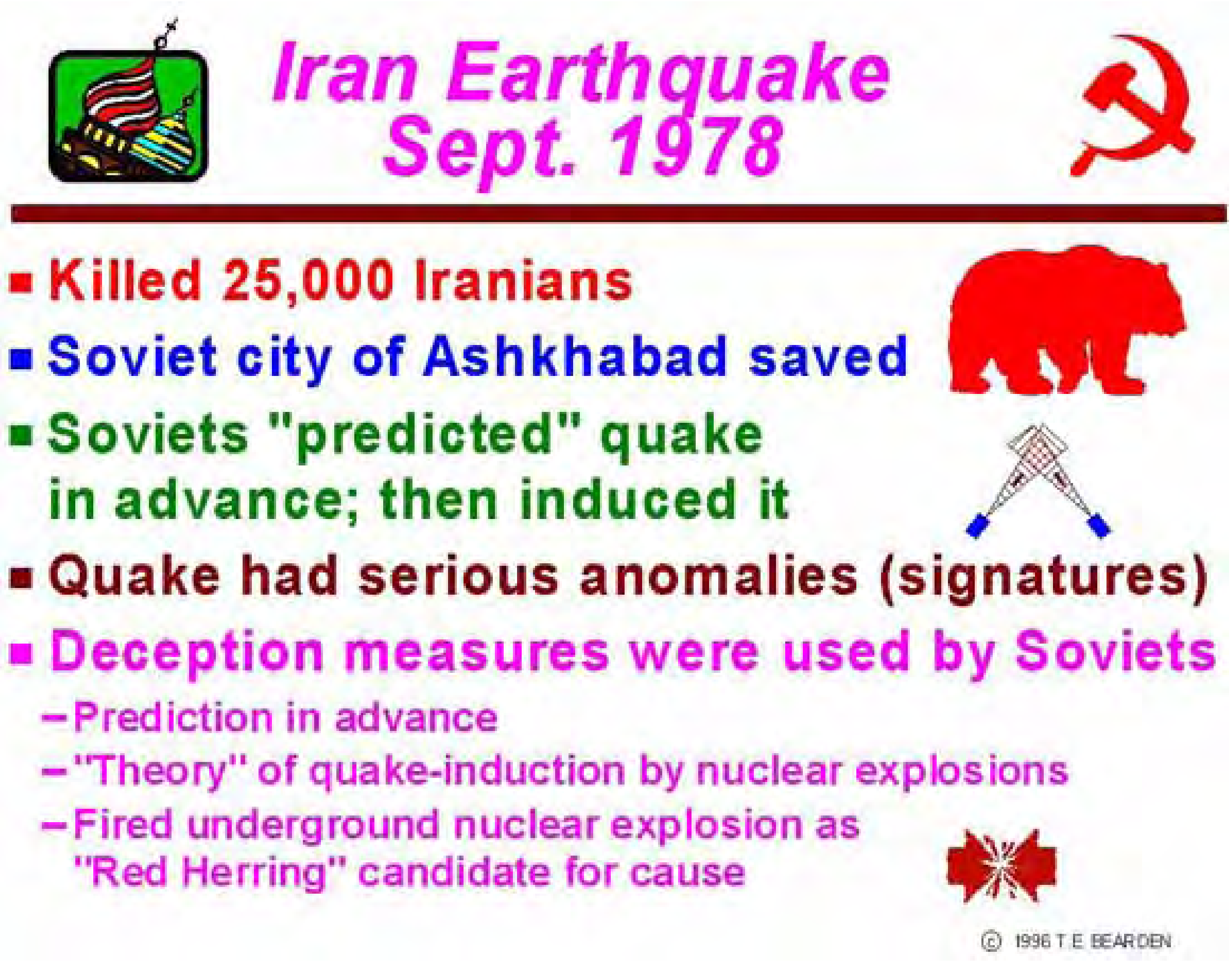

Iran Earthquake Sept. 1978

- Killed 25,000 Iranians
- Soviet city of Ashkhabad saved
- Soviets "predicted" quake in advance; then induced it
- Quake had serious anomalies (signatures)
- Deception measures were used by Soviets
  - Prediction in advance
  - "Theory" of quake-induction by nuclear explosions
  - Fired underground nuclear explosion as "Red Herring" candidate for cause

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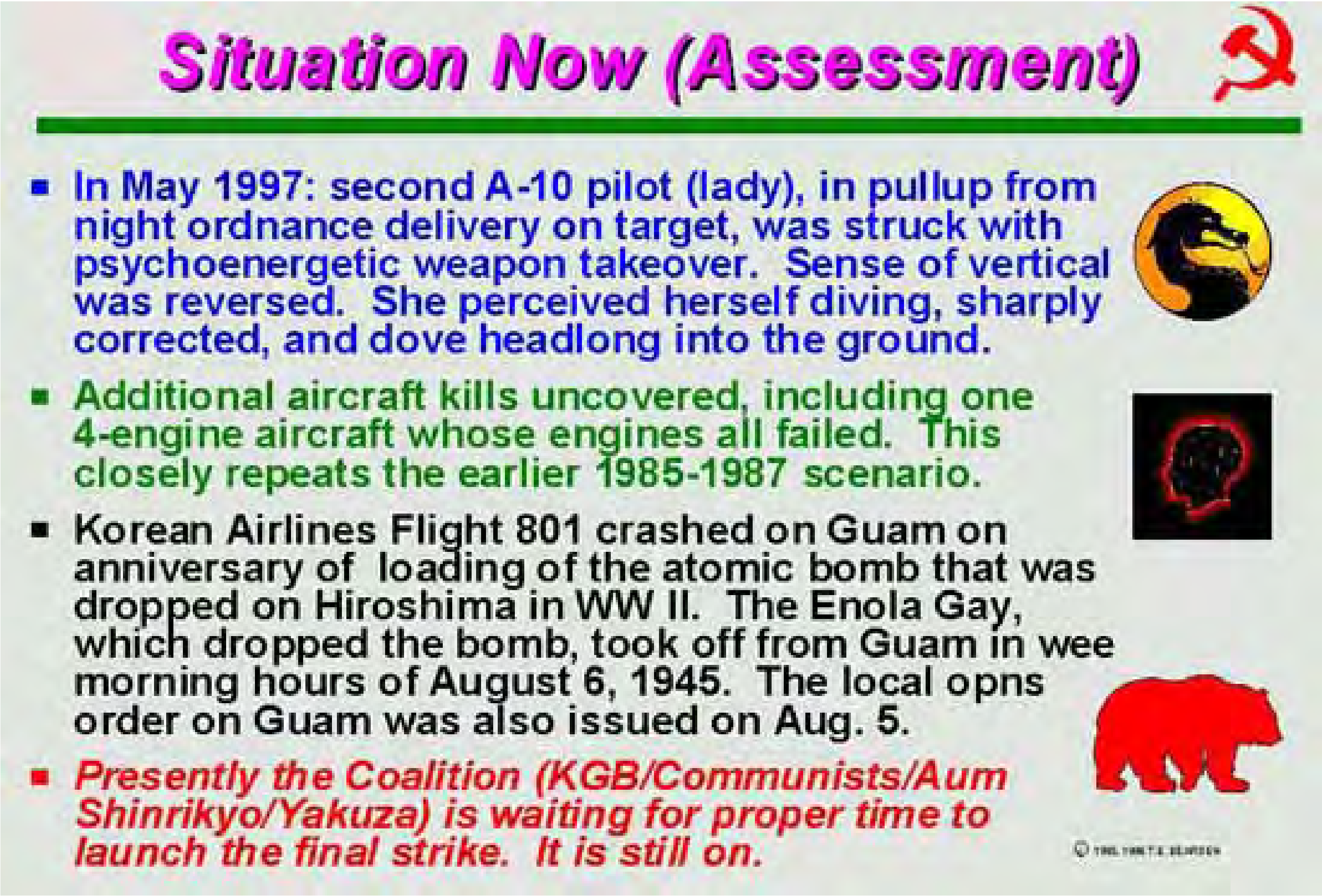

Situation Now (Assessment)

- In May 1997: second A-10 pilot (lady), in pullup from night ordnance delivery on target, was struck with psychoenergetic weapon takeover. Sense of vertical was reversed. She perceived herself diving, sharply corrected, and dove headlong into the ground.
- Additional aircraft kills uncovered, including one 4-engine aircraft whose engines all failed. This closely repeats the earlier 1985-1987 scenario.
- Korean Airlines Flight 801 crashed on Guam on anniversary of loading of the atomic bomb that was dropped on Hiroshima in WW II. The Enola Gay, which dropped the bomb, took off from Guam in wee morning hours of August 6, 1945. The local opns order on Guam was also issued on Aug. 5.
- *Presently the Coalition (KGB/Communists/Aum Shinrikyo/Yakuza) is waiting for proper time to launch the final strike. It is still on.*

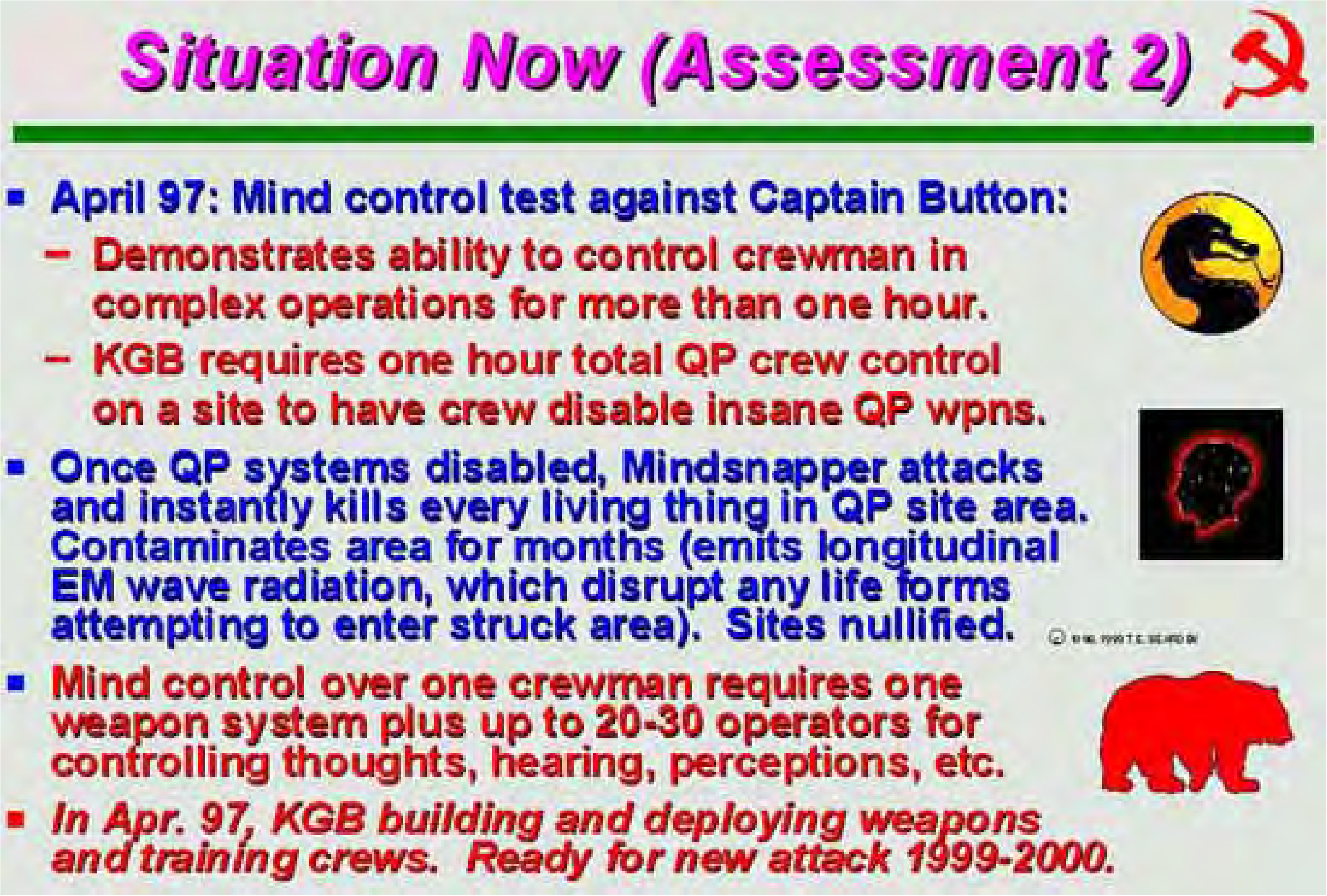

Situation Now (Assessment 2)

- April 97: Mind control test against Captain Button:
  - Demonstrates ability to control crewman in complex operations for more than one hour.
  - KGB requires one hour total QP crew control on a site to have crew disable insane QP wpns.
- Once QP systems disabled, Mindsnapper attacks and instantly kills every living thing in QP site area. Contaminates area for months (emits longitudinal EM wave radiation, which disrupt any life forms attempting to enter struck area). Sites nullified.
- Mind control over one crewman requires one weapon system plus up to 20-30 operators for controlling thoughts, hearing, perceptions, etc.
- *In Apr. 97, KGB building and deploying weapons and training crews. Ready for new attack 1999-2000.*

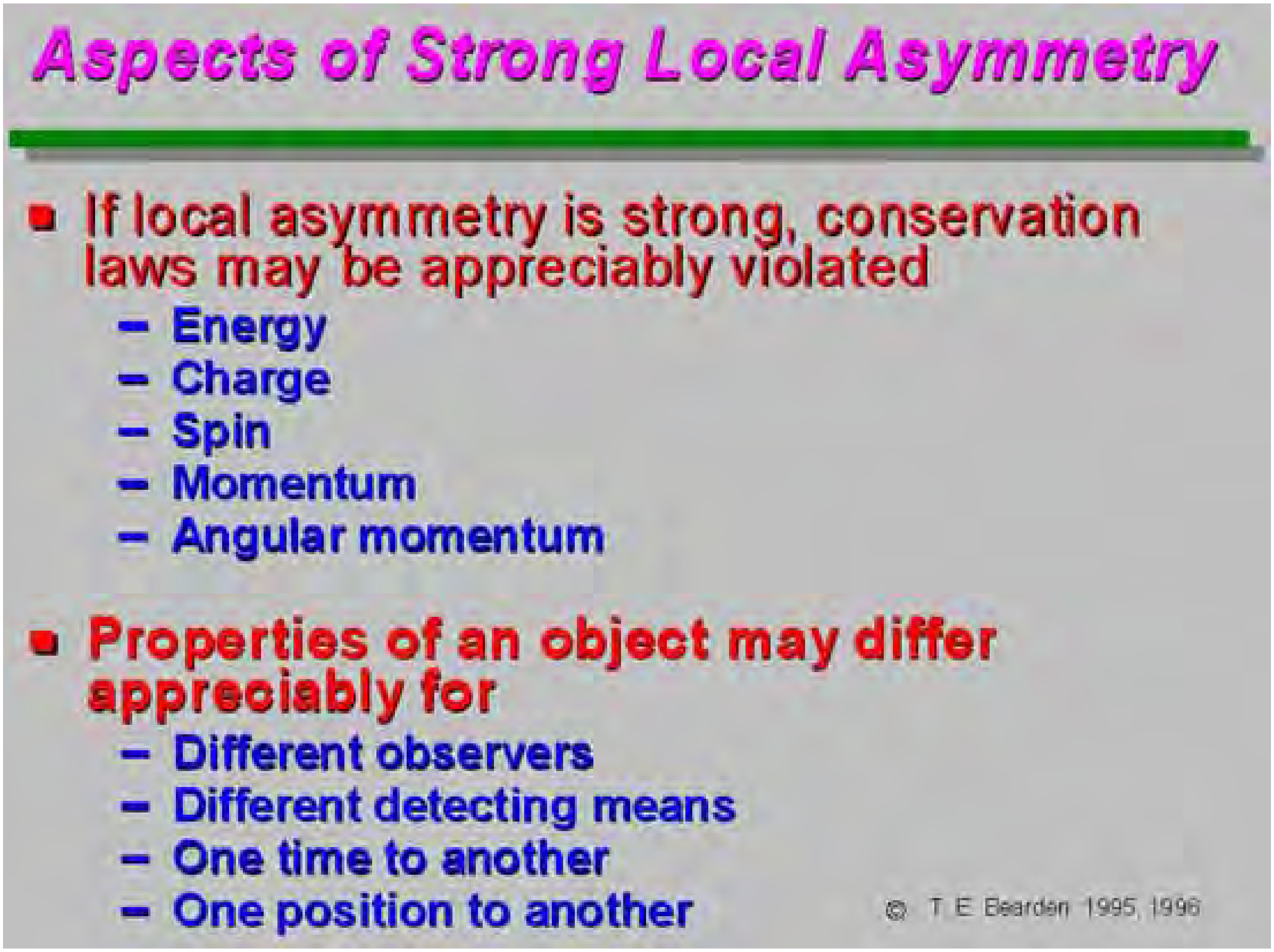

Aspects of Strong Local Asymmetry

- If local asymmetry is strong, conservation laws may be appreciably violated
  - Energy
  - Charge
  - Spin
  - Momentum
  - Angular momentum
- Properties of an object may differ appreciably for
  - Different observers
  - Different detecting means
  - One time to another
  - One position to another

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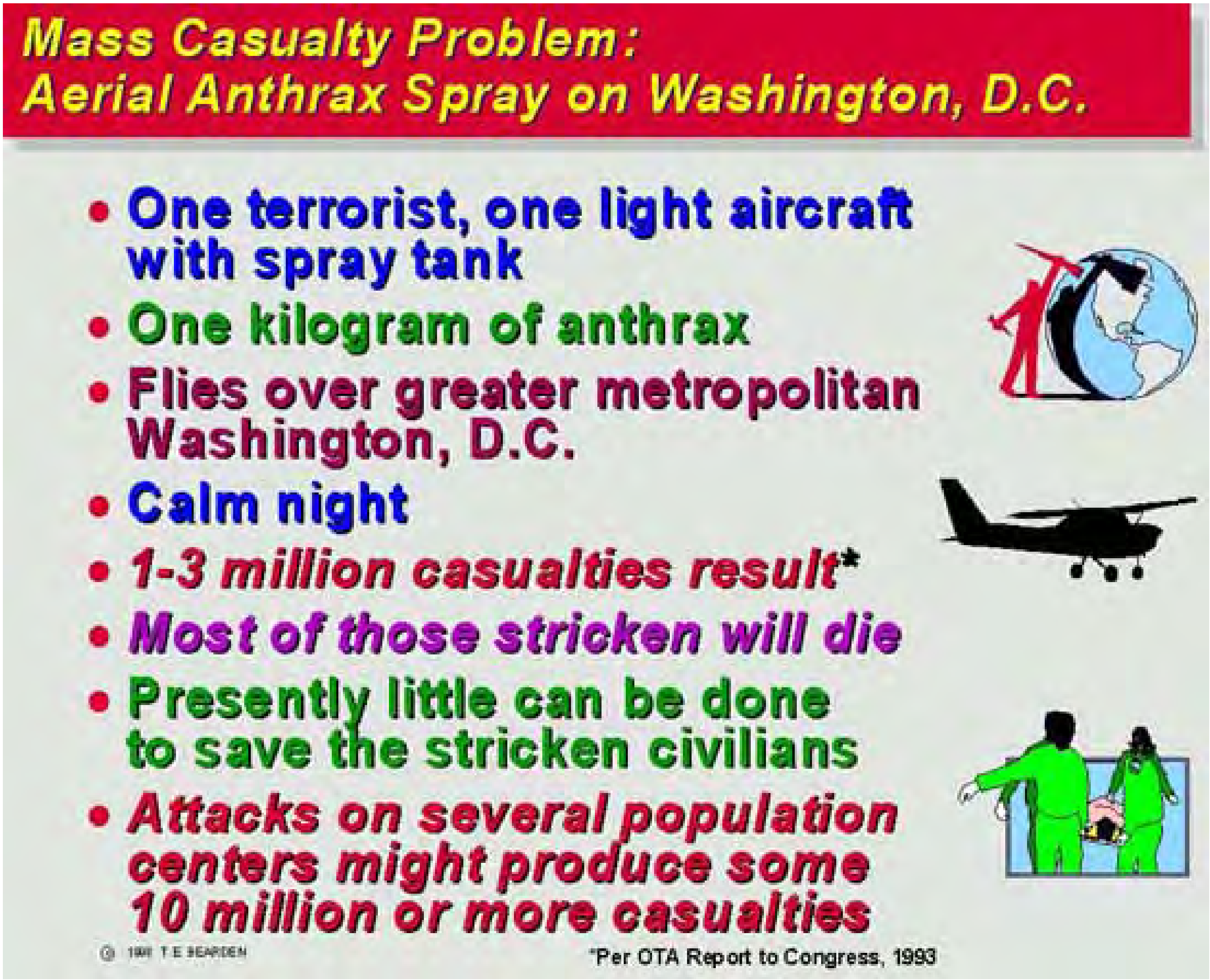

Mass Casualty Problem: Aerial Anthrax Spray on Washington, D.C.

- **One terrorist, one light aircraft with spray tank**
- **One kilogram of anthrax**
- **Flies over greater metropolitan Washington, D.C.**
- **Calm night**
- ***1-3 million casualties result****
- ***Most of those stricken will die***
- **Presently little can be done to save the stricken civilians**
- ***Attacks on several population centers might produce some 10 million or more casualties***

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*Per OTA Report to Congress, 1993

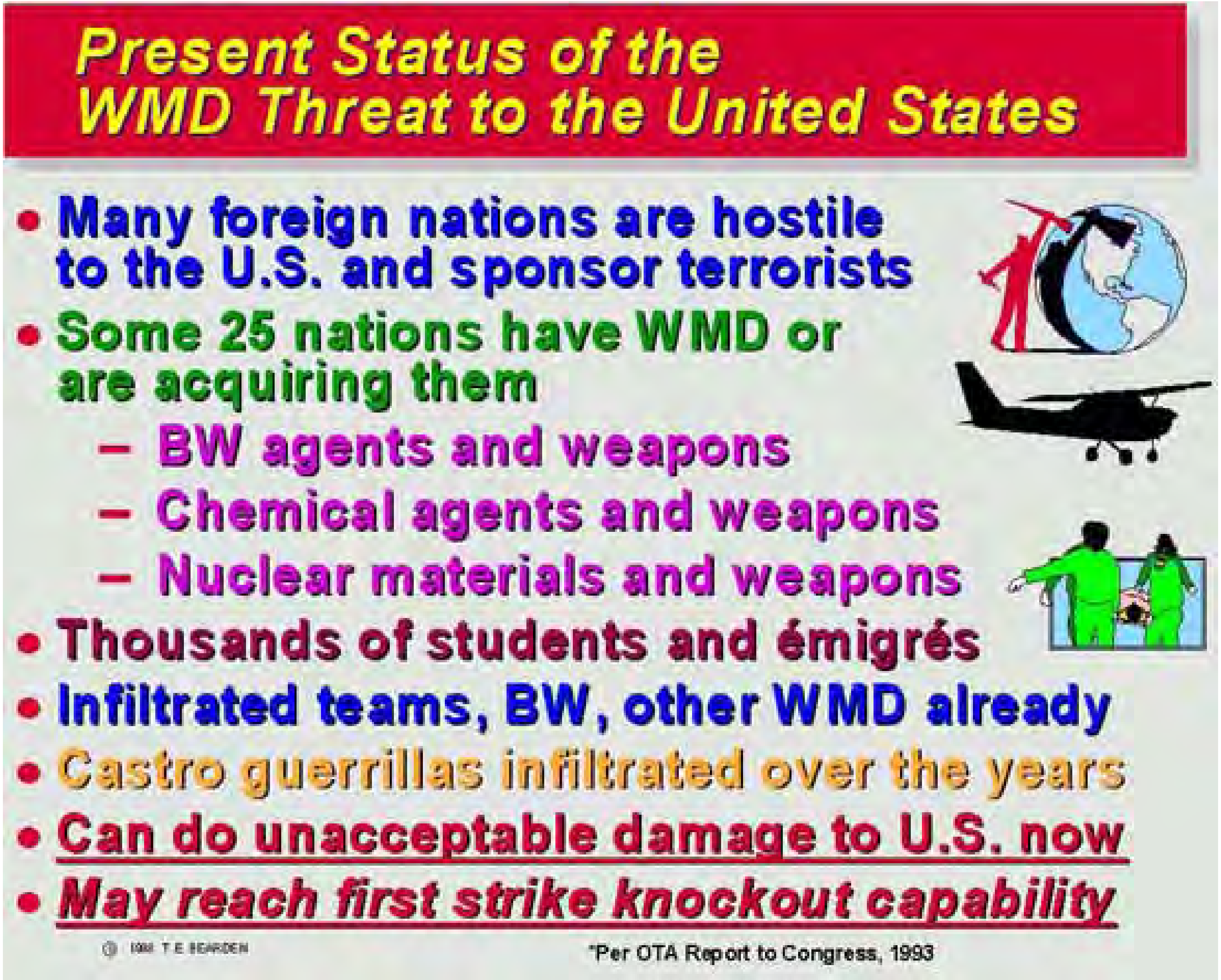

Present Status of the WMD Threat to the United States

- Many foreign nations are hostile to the U.S. and sponsor terrorists
- Some 25 nations have WMD or are acquiring them*
  - BW agents and weapons
  - Chemical agents and weapons
  - Nuclear materials and weapons
- Thousands of students and émigrés
- Infiltrated teams, BW, other WMD already
- Castro guerrillas infiltrated over the years
- Can do unacceptable damage to U.S. now
- *May reach first strike knockout capability*

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*Per OTA Report to Congress, 1993

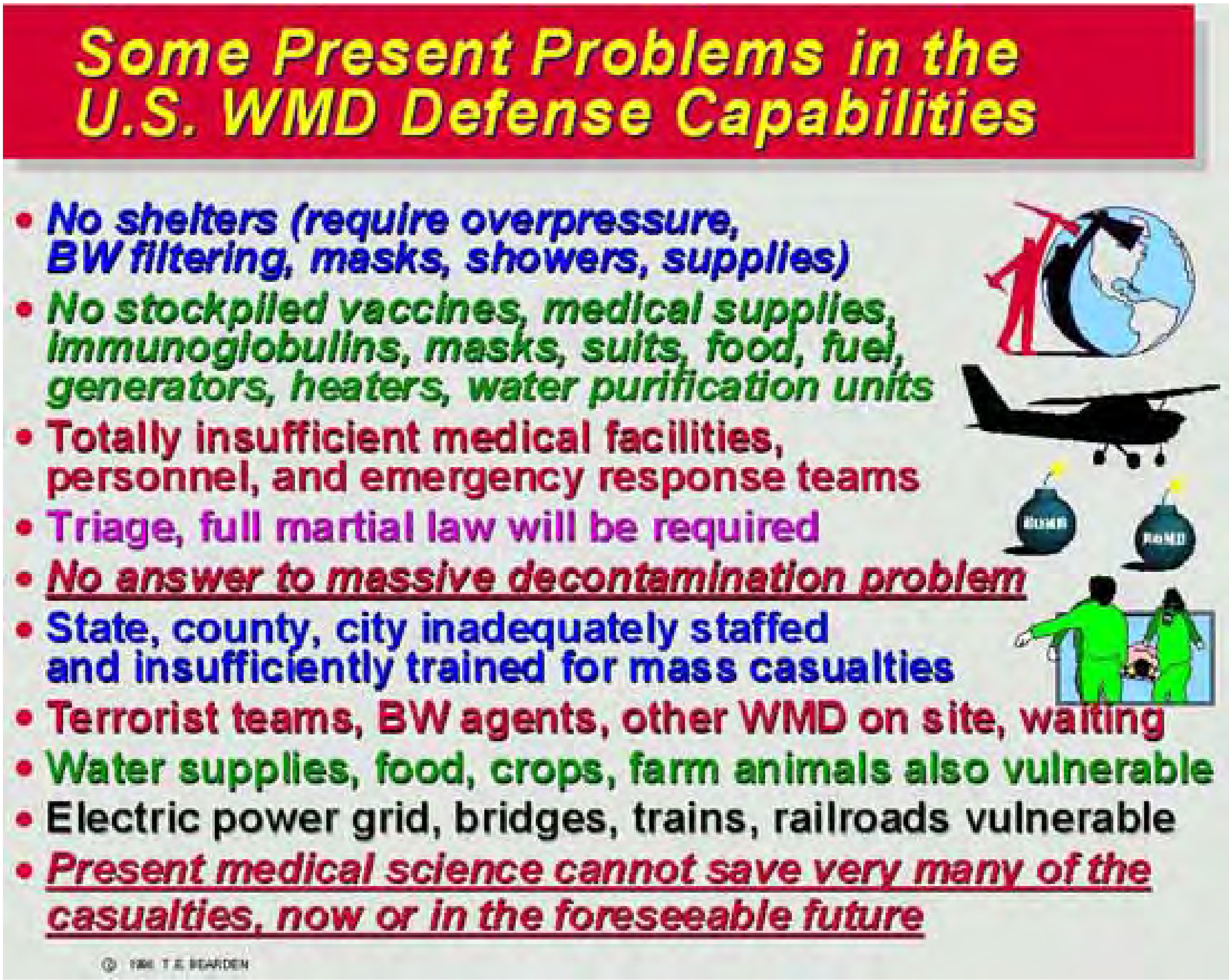

Some Present Problems in the U.S. WMD Defense Capabilities

- *No shelters (require overpressure, BW filtering, masks, showers, supplies)*
- *No stockpiled vaccines, medical supplies, immunoglobulins, masks, suits, food, fuel, generators, heaters, water purification units*
- Totally insufficient medical facilities, personnel, and emergency response teams
- Triage, full martial law will be required
- *No answer to massive decontamination problem*
- State, county, city inadequately staffed and insufficiently trained for mass casualties
- Terrorist teams, BW agents, other WMD on site, waiting
- Water supplies, food, crops, farm animals also vulnerable
- Electric power grid, bridges, trains, railroads vulnerable
- *Present medical science cannot save very many of the casualties, now or in the foreseeable future*

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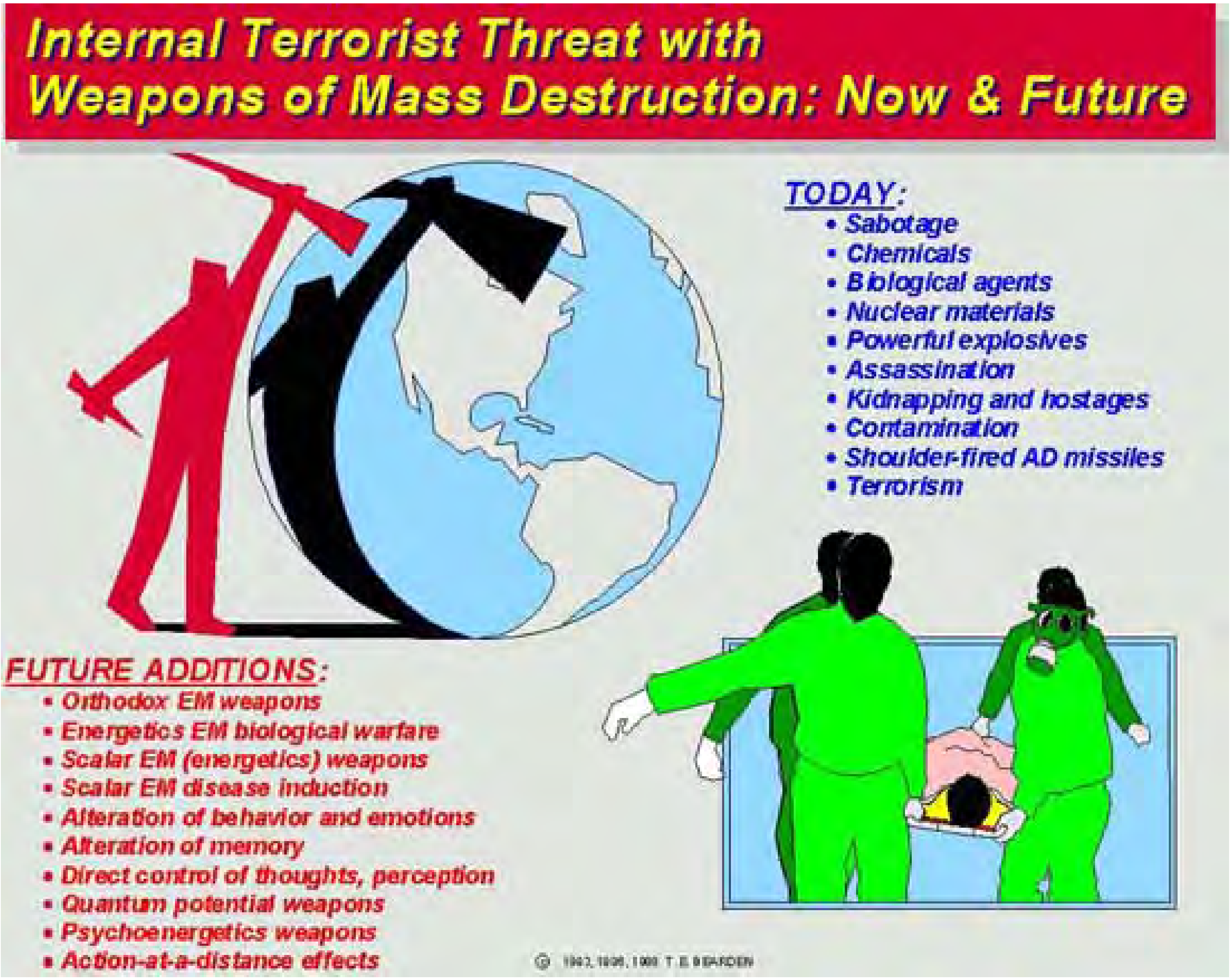

Internal Terrorist Threat with Weapons of Mass Destruction: Now & Future

TODAY:

- Sabotage
- Chemicals
- Biological agents
- Nuclear materials
- Powerful explosives
- Assassination
- Kidnapping and hostages
- Contamination
- Shoulder-fired AD missiles
- Terrorism

FUTURE ADDITIONS:

- Orthodox EM weapons
- Energetics EM biological warfare
- Scalar EM (energetics) weapons
- Scalar EM disease induction
- Alteration of behavior and emotions
- Alteration of memory
- Direct control of thoughts, perception
- Quantum potential weapons
- Psychoenergetics weapons
- Action-at-a-distance effects

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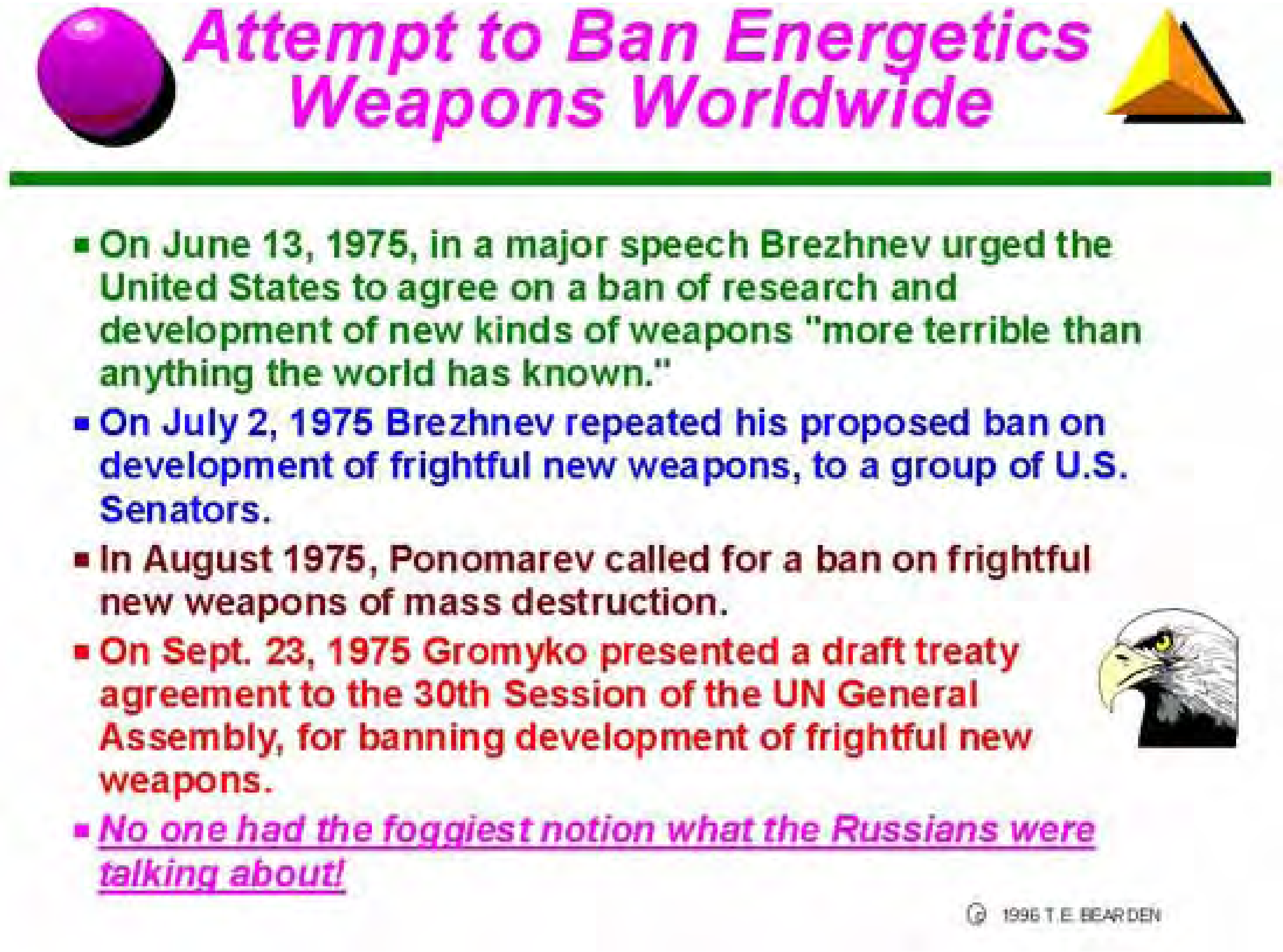

Attempt to Ban Energetics Weapons Worldwide

- On June 13, 1975, in a major speech Brezhnev urged the United States to agree on a ban of research and development of new kinds of weapons "more terrible than anything the world has known."
- On July 2, 1975 Brezhnev repeated his proposed ban on development of frightful new weapons, to a group of U.S. Senators.
- In August 1975, Ponomarev called for a ban on frightful new weapons of mass destruction.
- On Sept. 23, 1975 Gromyko presented a draft treaty agreement to the 30th Session of the UN General Assembly, for banning development of frightful new weapons.
- *No one had the foggiest notion what the Russians were talking about!*

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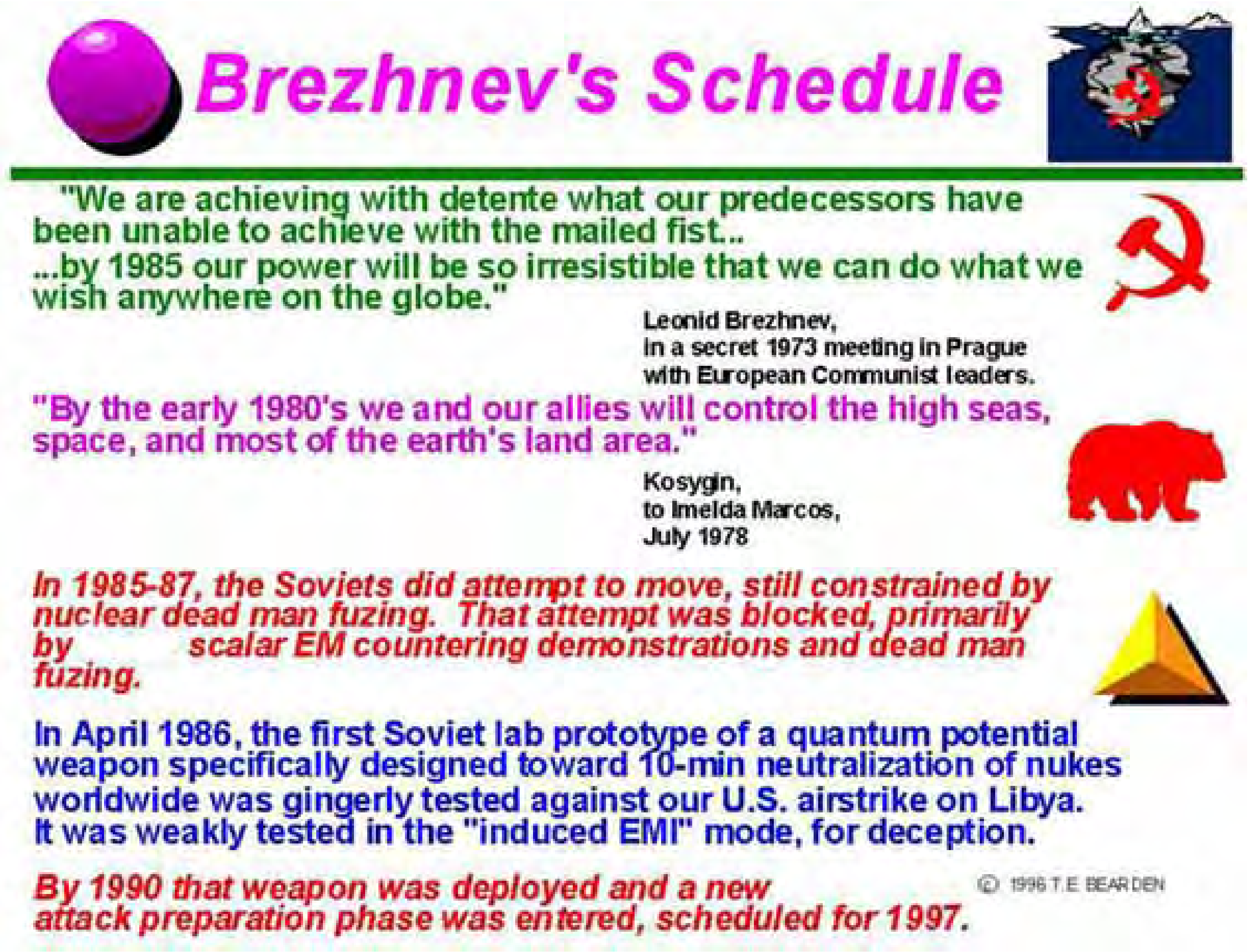

Brezhnev's Schedule

"We are achieving with detente what our predecessors have been unable to achieve with the mailed fist..
...by 1985 our power will be so irresistible that we can do what we wish anywhere on the globe."

Leonid Brezhnev,
in a secret 1973 meeting in Prague
with European Communist leaders.

"By the early 1980's we and our allies will control the high seas, space, and most of the earth's land area."

Kosygin,
to Imelda Marcos,
July 1978

In 1985-87, the Soviets did attempt to move, still constrained by nuclear dead man fuzing. That attempt was blocked, primarily by scalar EM countering demonstrations and dead man fuzing.

In April 1986, the first Soviet lab prototype of a quantum potential weapon specifically designed toward 10-min neutralization of nukes worldwide was gingerly tested against our U.S. airstrike on Libya. It was weakly tested in the "induced EMI" mode, for deception.

By 1990 that weapon was deployed and a new attack preparation phase was entered, scheduled for 1997.

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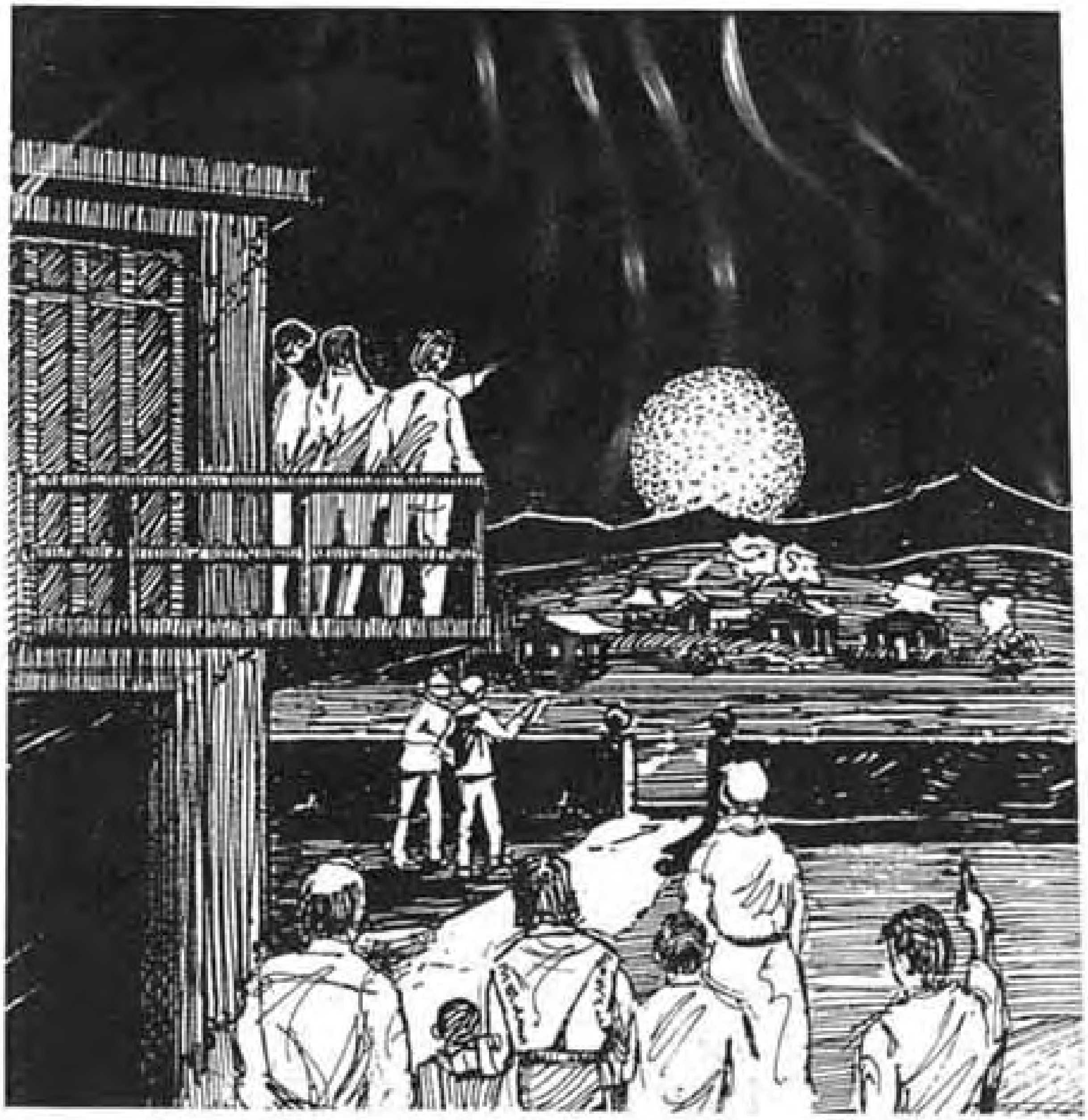

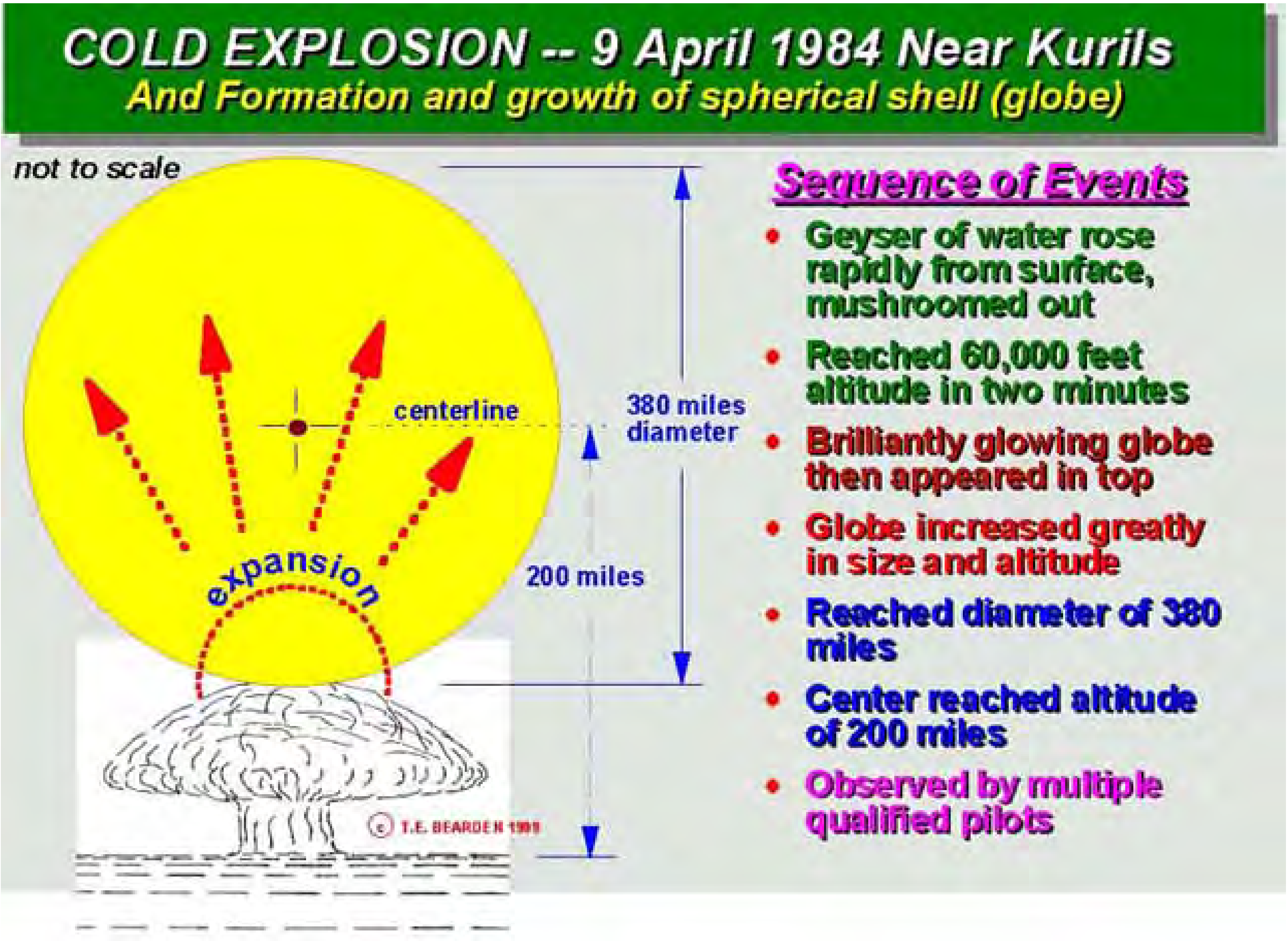

COLD EXPLOSION -- 9 April 1984 Near Kurils
And Formation and growth of spherical shell (globe)

not to scale
centerline
380 miles diameter
200 miles
expansion
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Sequence of Events

- Geyser of water rose rapidly from surface, mushroomed out
- Reached 60,000 feet altitude in two minutes
- Brilliantly glowing globe then appeared in top
- Globe increased greatly in size and altitude
- Reached diameter of 380 miles
- Center reached altitude of 200 miles
- Observed by multiple qualified pilots

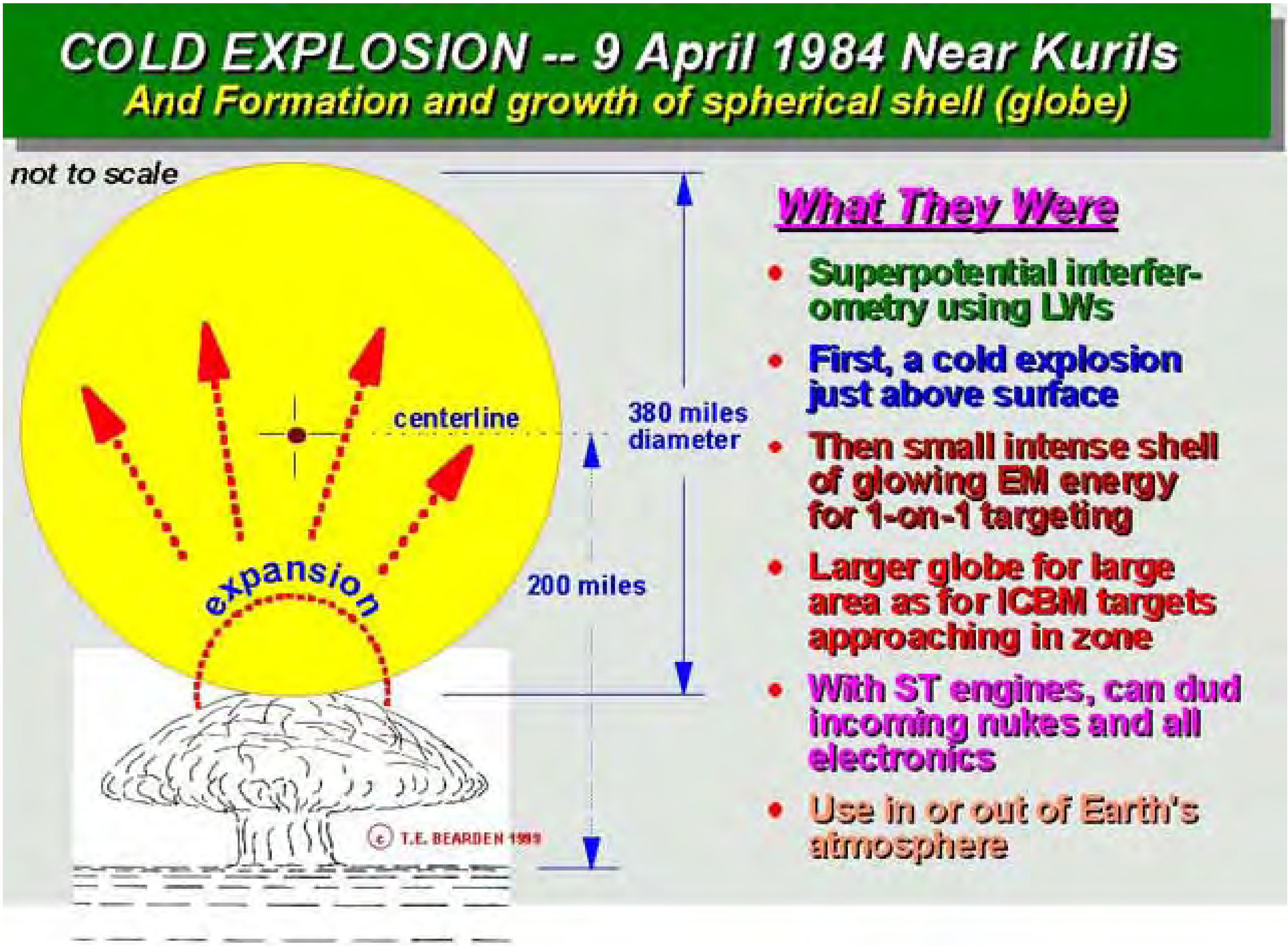

COLD EXPLOSION -- 9 April 1984 Near Kurils

And Formation and growth of spherical shell (globe)

not to scale
centerline
expansion
380 miles diameter
200 miles
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What They Were

- Superpotential interferometry using LWs
- First, a cold explosion just above surface
- Then small intense shell of glowing EM energy for 1-on-1 targeting
- Larger globe for large area as for ICBM targets approaching in zone
- With ST engines, can dud incoming nukes and all electronics
- Use in or out of Earth's atmosphere

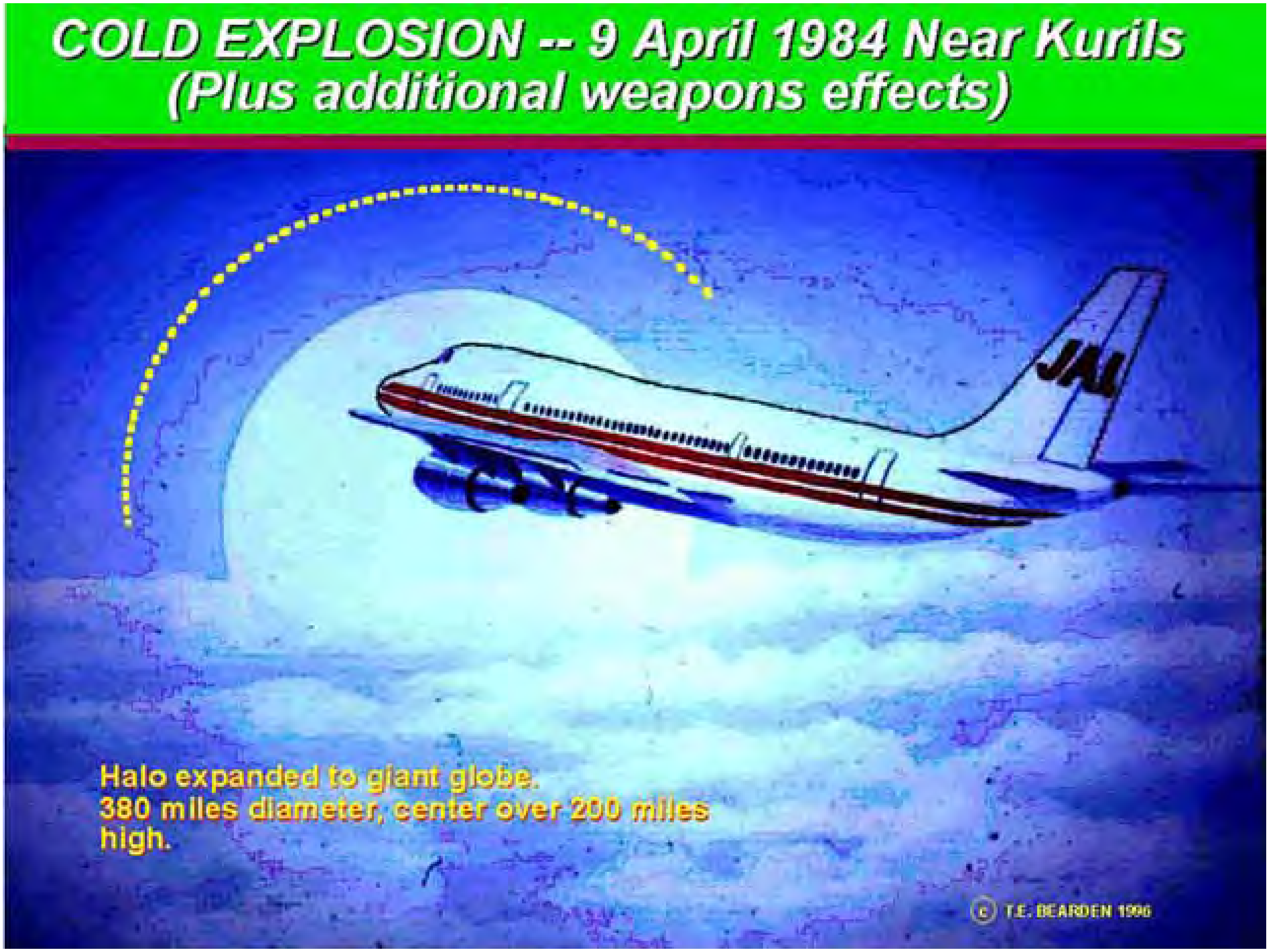

COLD EXPLOSION -- 9 April 1984 Near Kurils (Plus additional weapons effects)

Halo expanded to giant globe.
380 miles diameter, center over 200 miles high.

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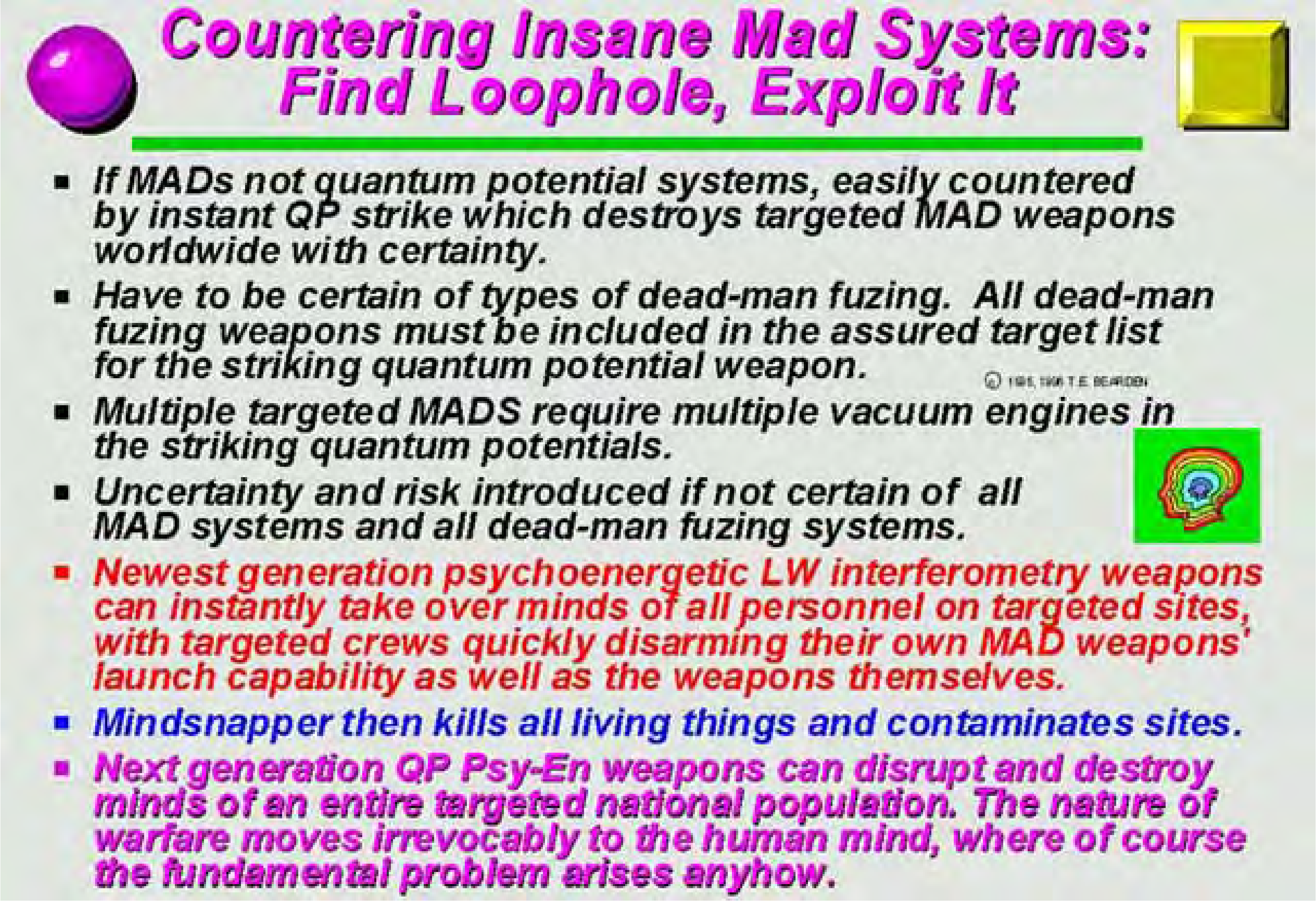

Countering Insane Mad Systems: Find Loophole, Exploit It

- *If MADs not quantum potential systems, easily countered by instant QP strike which destroys targeted MAD weapons worldwide with certainty.*
- *Have to be certain of types of dead-man fuzing. All dead-man fuzing weapons must be included in the assured target list for the striking quantum potential weapon.*

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- *Multiple targeted MADS require multiple vacuum engines in the striking quantum potentials.*
- *Uncertainty and risk introduced if not certain of all MAD systems and all dead-man fuzing systems.*
- *Newest generation psychoenergetic LW interferometry weapons can instantly take over minds of all personnel on targeted sites, with targeted crews quickly disarming their own MAD weapons' launch capability as well as the weapons themselves.*
- *Mindsnapper then kills all living things and contaminates sites.*
- ***Next generation QP Psy-En weapons can disrupt and destroy minds of an entire targeted national population. The nature of warfare moves irrevocably to the human mind, where of course the fundamental problem arises anyhow.***

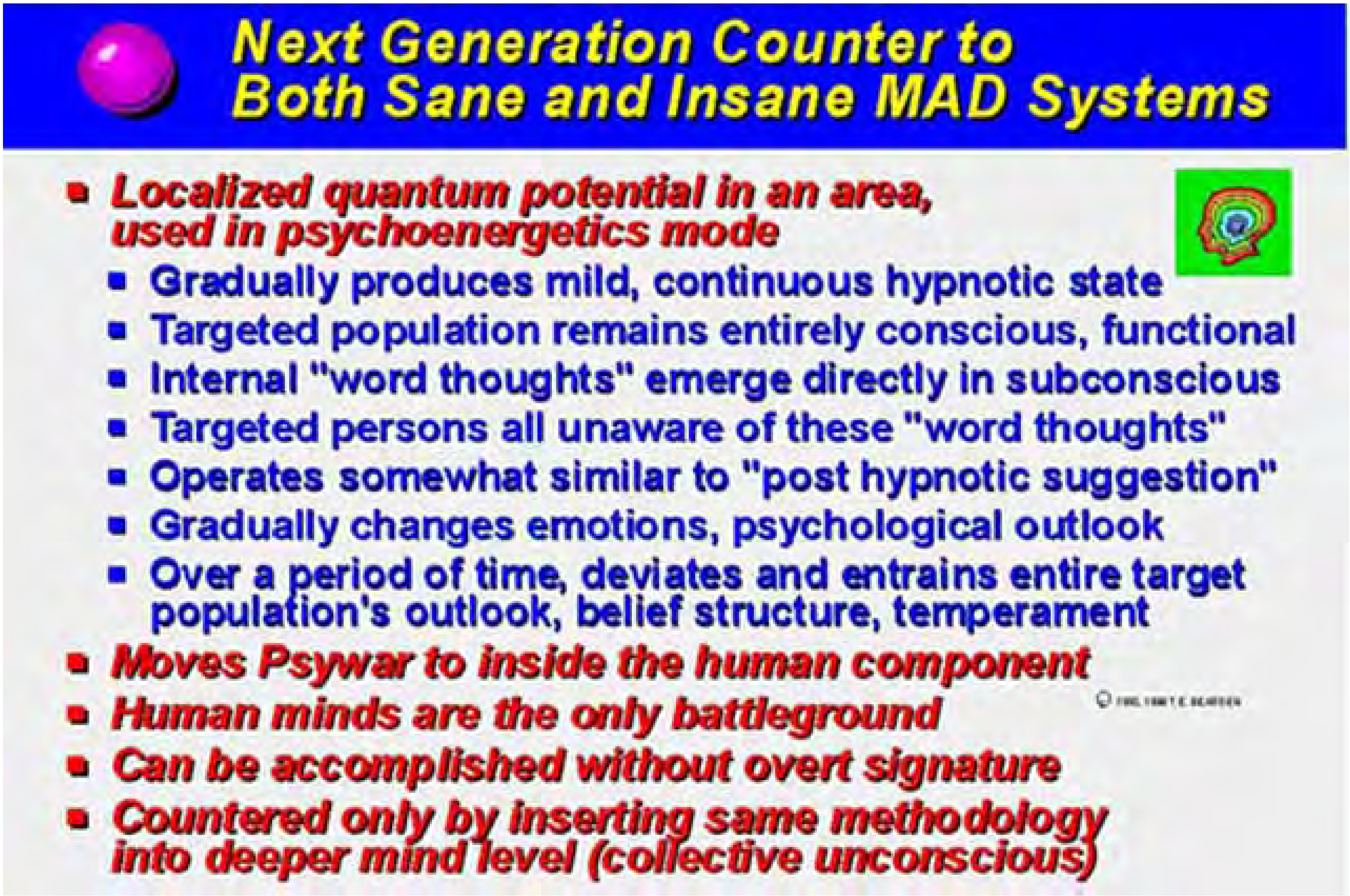

Next Generation Counter to Both Sane and Insane MAD Systems

- *Localized quantum potential in an area, used in psychoenergetics mode*
  - Gradually produces mild, continuous hypnotic state
  - Targeted population remains entirely conscious, functional
  - Internal "word thoughts" emerge directly in subconscious
  - Targeted persons all unaware of these "word thoughts"
  - Operates somewhat similar to "post hypnotic suggestion"
  - Gradually changes emotions, psychological outlook
  - Over a period of time, deviates and entrains entire target population's outlook, belief structure, temperament
- *Moves Psywar to inside the human component*
- *Human minds are the only battleground*
- *Can be accomplished without overt signature*
- *Countered only by inserting same methodology into deeper mind level (collective unconscious)*

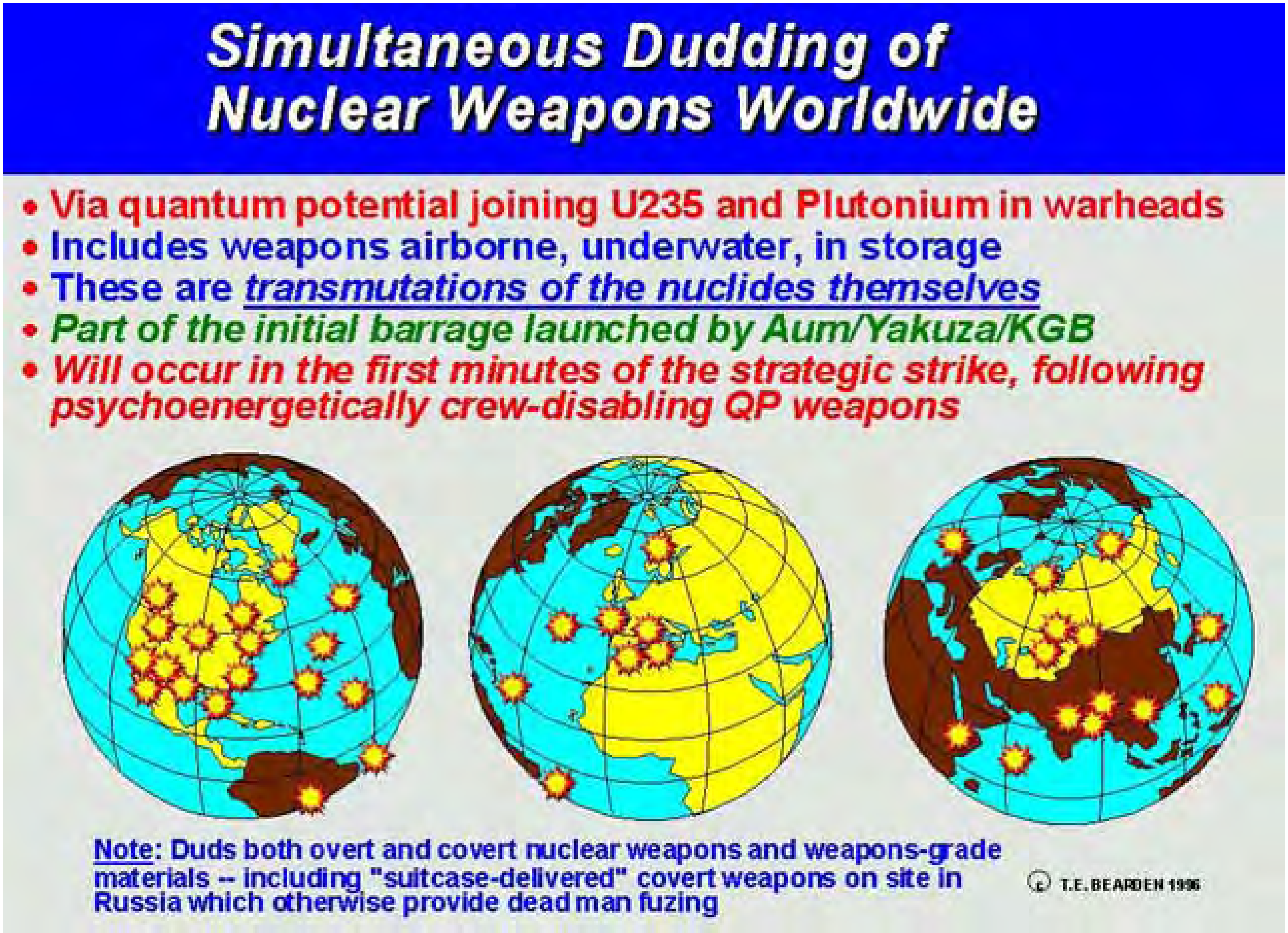

Simultaneous Dudding of Nuclear Weapons Worldwide

- Via quantum potential joining U235 and Plutonium in warheads
- Includes weapons airborne, underwater, in storage
- These are *transmutations of the nuclides themselves*
- *Part of the initial barrage launched by Aum/Yakuza/KGB*
- *Will occur in the first minutes of the strategic strike, following psychoenergetically crew-disabling QP weapons*

Note: Duds both overt and covert nuclear weapons and weapons-grade materials -- including "suitcase-delivered" covert weapons on site in Russia which otherwise provide dead man fuzing

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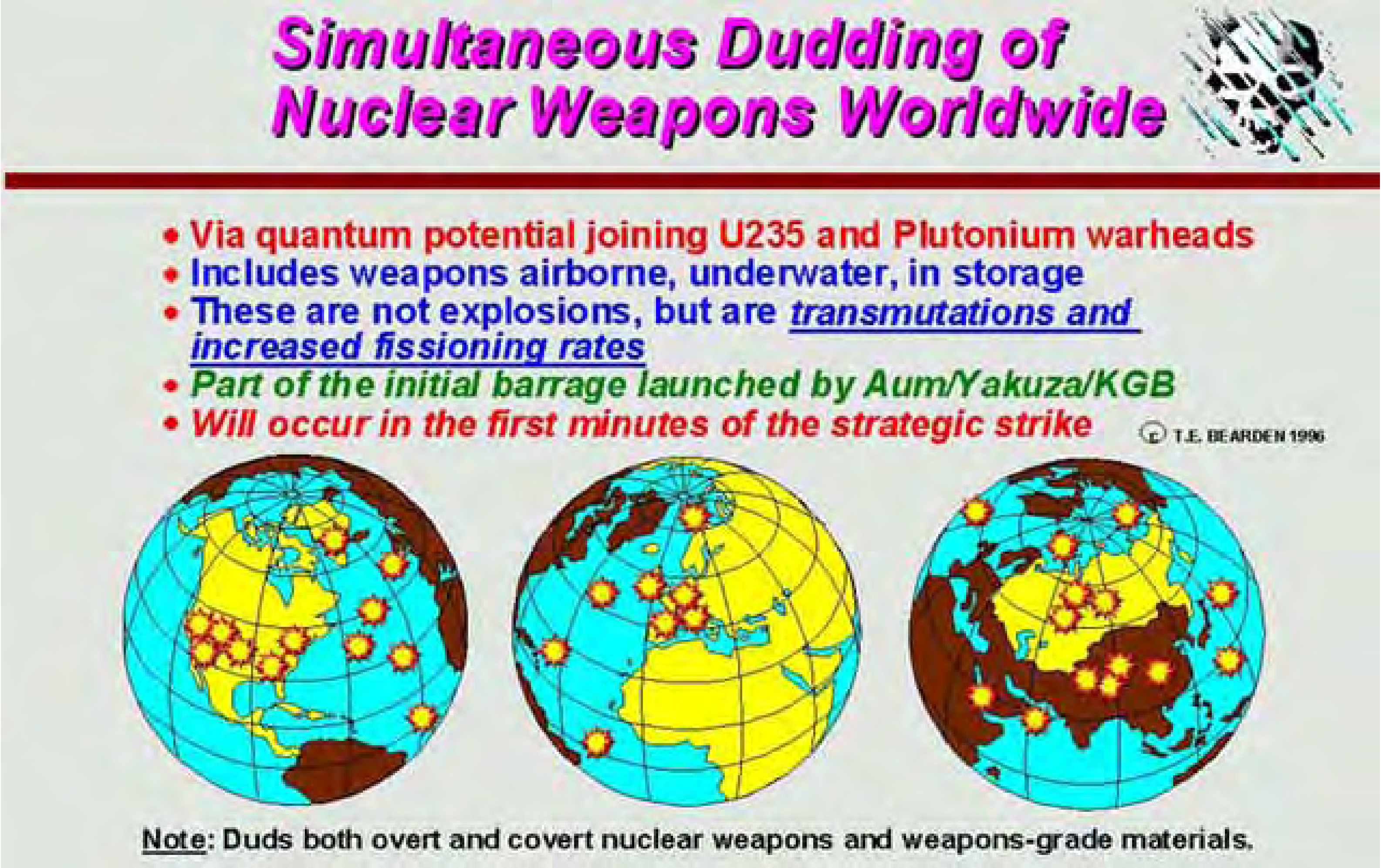

Simultaneous Dudding of Nuclear Weapons Worldwide

- Via quantum potential joining U235 and Plutonium warheads
- Includes weapons airborne, underwater, in storage
- These are not explosions, but are ***transmutations and increased fissioning rates***
- *Part of the initial barrage launched by Aum/Yakuza/KGB*
- *Will occur in the first minutes of the strategic strike*

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Note: Duds both overt and covert nuclear weapons and weapons-grade materials.

The Tom Bearden Website

Help support the research

Operation Divine Wind II

Slide 1

Slide 2

Slide 3

Slide 4

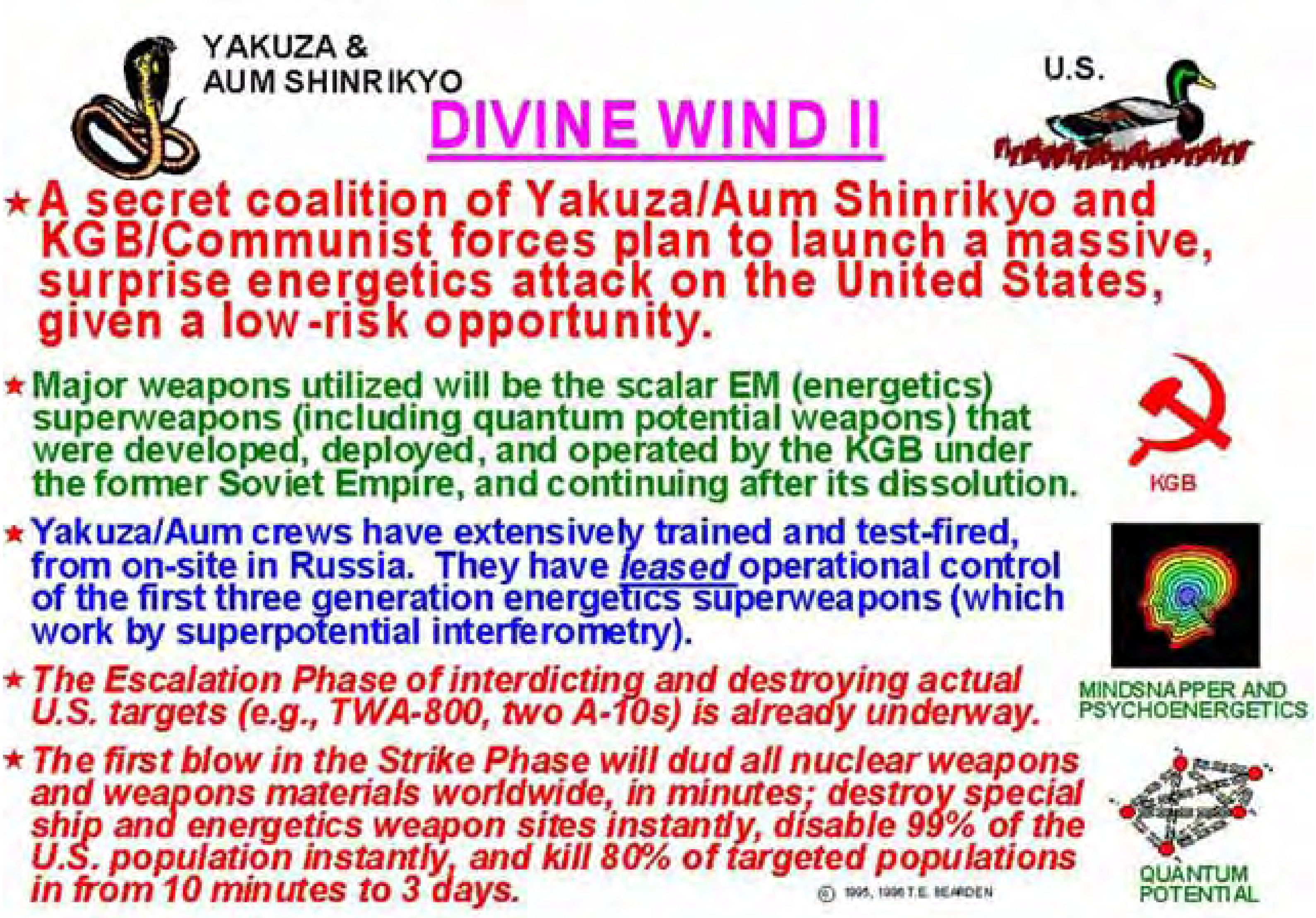

YAKUZA &
AUM SHINRIKYO

U.S.

DIVINE WIND II

- ★ **A secret coalition of Yakuza/Aum Shinrikyo and KGB/Communist forces plan to launch a massive, surprise energetics attack on the United States, given a low-risk opportunity.**
- ★ **Major weapons utilized will be the scalar EM (energetics) superweapons (including quantum potential weapons) that were developed, deployed, and operated by the KGB under the former Soviet Empire, and continuing after its dissolution.**
- ★ **Yakuza/Aum crews have extensively trained and test-fired, from on-site in Russia. They have *leased* operational control of the first three generation energetics superweapons (which work by superpotential interferometry).**
- ★ ***The Escalation Phase of interdicting and destroying actual U.S. targets (e.g., TWA-800, two A-10s) is already underway.***
- ★ ***The first blow in the Strike Phase will dud all nuclear weapons and weapons materials worldwide, in minutes; destroy special ship and energetics weapon sites instantly, disable 99% of the U.S. population instantly, and kill 80% of targeted populations in from 10 minutes to 3 days.***

KGB

MINDSNAPPER AND
PSYCHOENERGETICS

QUANTUM
POTENTIAL

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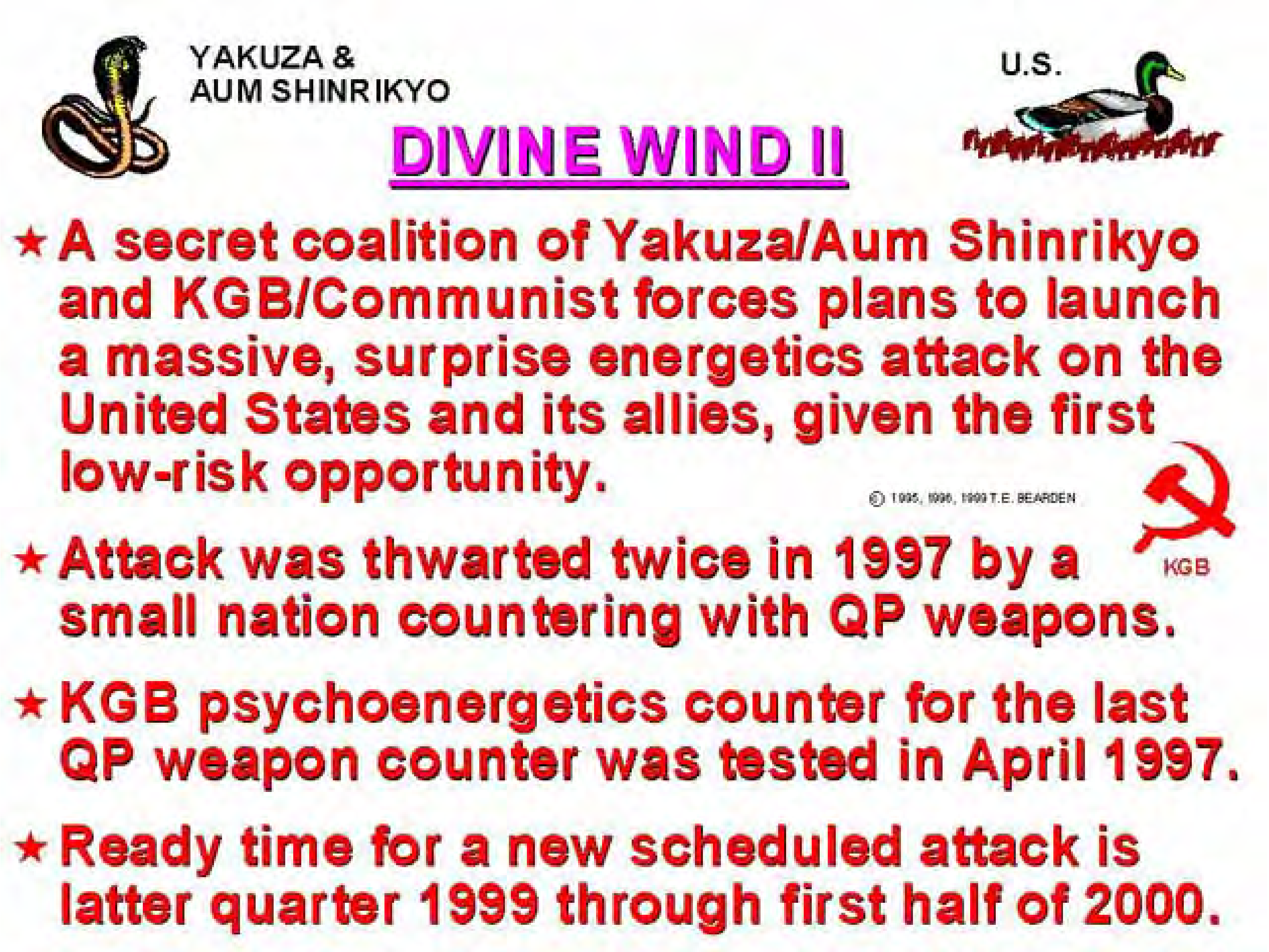

YAKUZA &
AUM SHINRIKYO

U.S.

DIVINE WIND II

- ★ A secret coalition of Yakuza/Aum Shinrikyo and KGB/Communist forces plans to launch a massive, surprise energetics attack on the United States and its allies, given the first low-risk opportunity.

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KGB

- ★ Attack was thwarted twice in 1997 by a small nation countering with QP weapons.
- ★ KGB psychoenergetics counter for the last QP weapon counter was tested in April 1997.
- ★ Ready time for a new scheduled attack is latter quarter 1999 through first half of 2000.

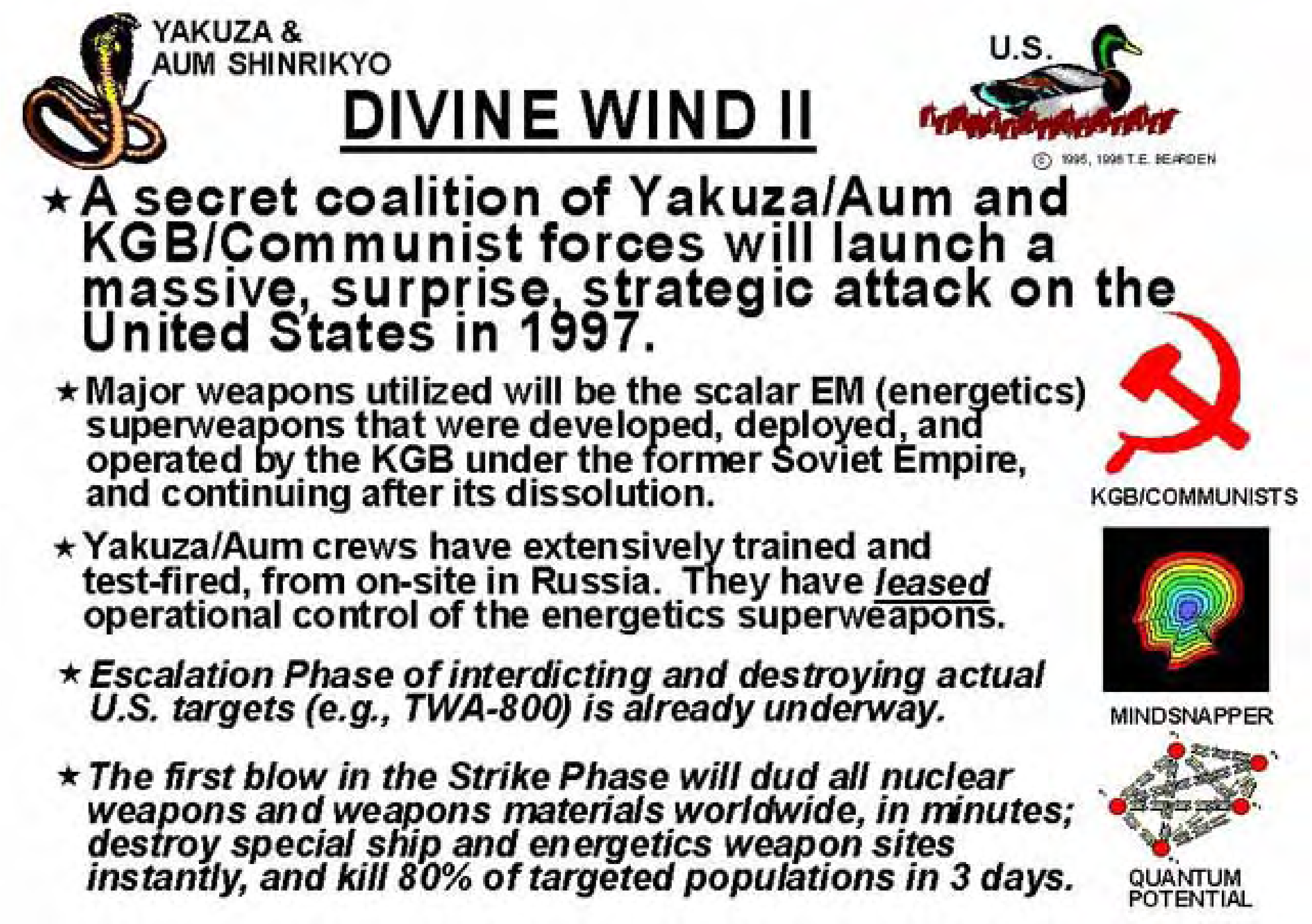
YAKUZA &
AUM SHINRIKYO
U.S.
KGB/COMMUNISTS
MINDSNAPPER
QUANTUM POTENTIAL

DIVINE WIND II

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★ **A secret coalition of Yakuza/Aum and KGB/Communist forces will launch a massive, surprise, strategic attack on the United States in 1997.**

★ Major weapons utilized will be the scalar EM (energetics) superweapons that were developed, deployed, and operated by the KGB under the former Soviet Empire, and continuing after its dissolution.

★ Yakuza/Aum crews have extensively trained and test-fired, from on-site in Russia. They have *leased* operational control of the energetics superweapons.

★ *Escalation Phase of interdicting and destroying actual U.S. targets (e.g., TWA-800) is already underway.*

★ *The first blow in the Strike Phase will dud all nuclear weapons and weapons materials worldwide, in minutes; destroy special ship and energetics weapon sites instantly, and kill 80% of targeted populations in 3 days.*

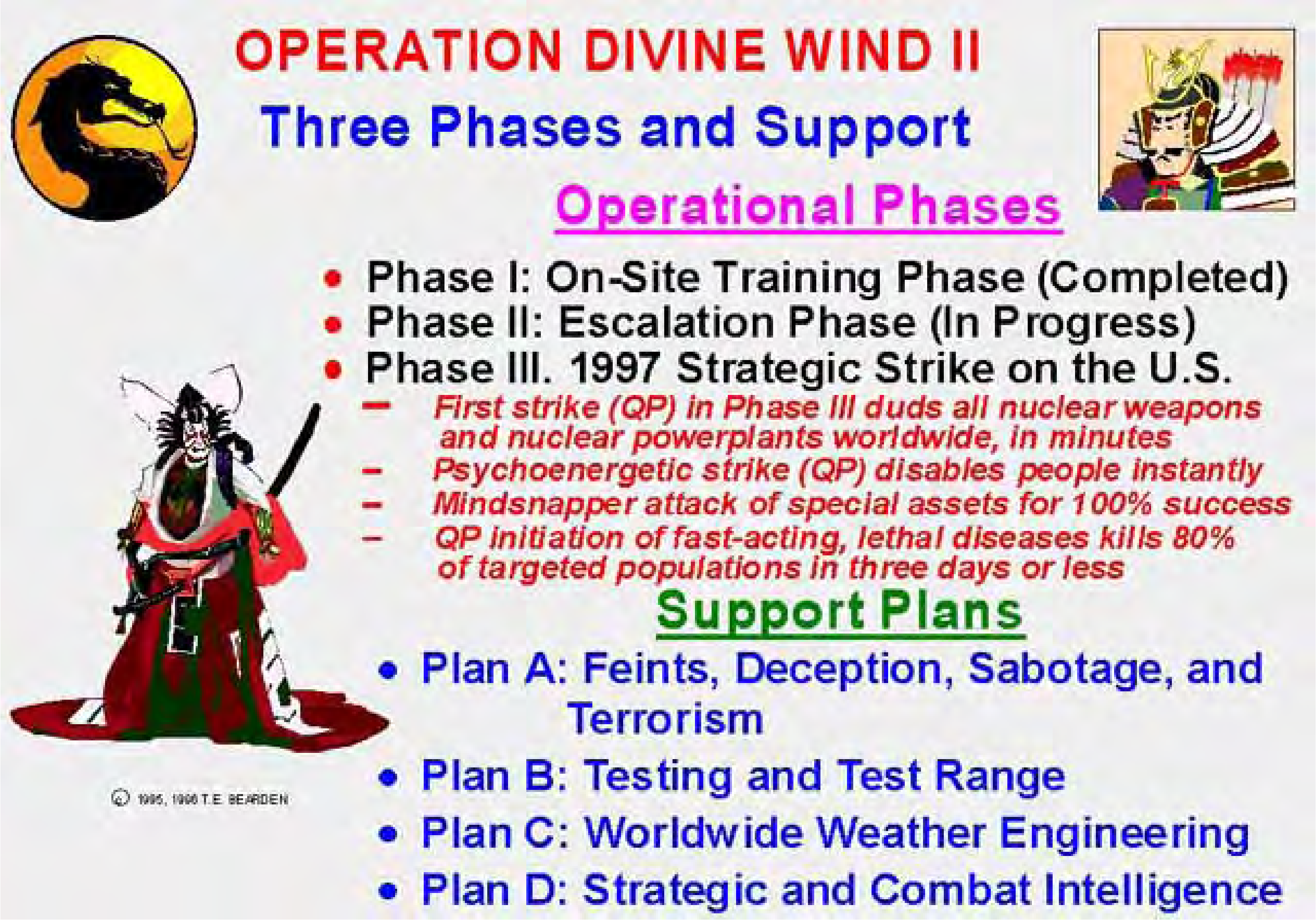

OPERATION DIVINE WIND II

Three Phases and Support

Operational Phases

- Phase I: On-Site Training Phase (Completed)
- Phase II: Escalation Phase (In Progress)
- Phase III. 1997 Strategic Strike on the U.S.
  - *First strike (QP) in Phase III duds all nuclear weapons and nuclear powerplants worldwide, in minutes*
  - *Psychoenergetic strike (QP) disables people instantly*
  - *Mindsnapper attack of special assets for 100% success*
  - *QP initiation of fast-acting, lethal diseases kills 80% of targeted populations in three days or less*

Support Plans

- Plan A: Feints, Deception, Sabotage, and Terrorism
- Plan B: Testing and Test Range
- Plan C: Worldwide Weather Engineering
- Plan D: Strategic and Combat Intelligence

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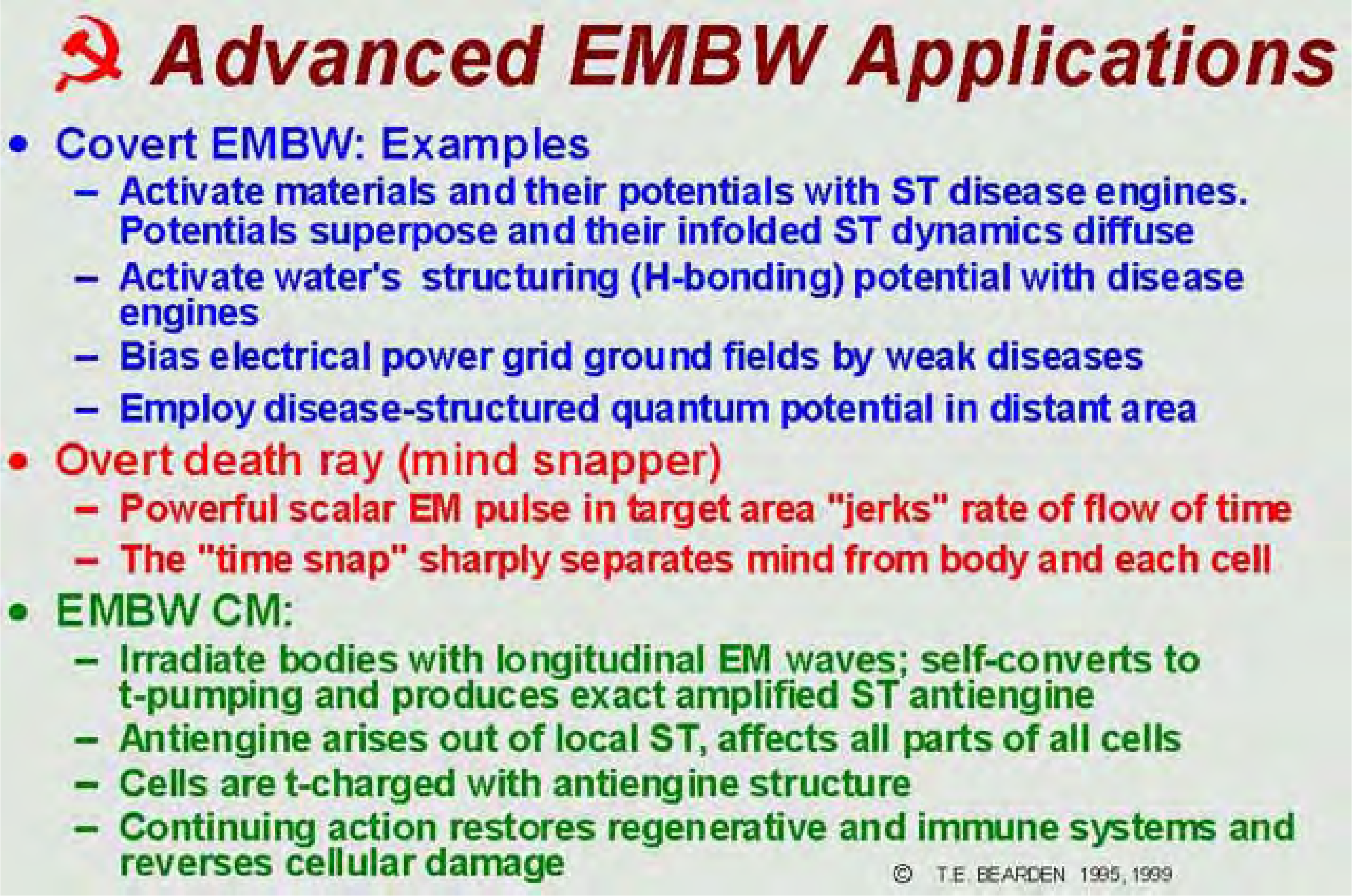

Advanced EMBW Applications

- Covert EMBW: Examples
  - Activate materials and their potentials with ST disease engines. Potentials superpose and their infolded ST dynamics diffuse
  - Activate water's structuring (H-bonding) potential with disease engines
  - Bias electrical power grid ground fields by weak diseases
  - Employ disease-structured quantum potential in distant area
- Overt death ray (mind snapper)
  - Powerful scalar EM pulse in target area "jerks" rate of flow of time
  - The "time snap" sharply separates mind from body and each cell
- EMBW CM:
  - Irradiate bodies with longitudinal EM waves; self-converts to t-pumping and produces exact amplified ST antiengine
  - Antiengine arises out of local ST, affects all parts of all cells
  - Cells are t-charged with antiengine structure
  - Continuing action restores regenerative and immune systems and reverses cellular damage

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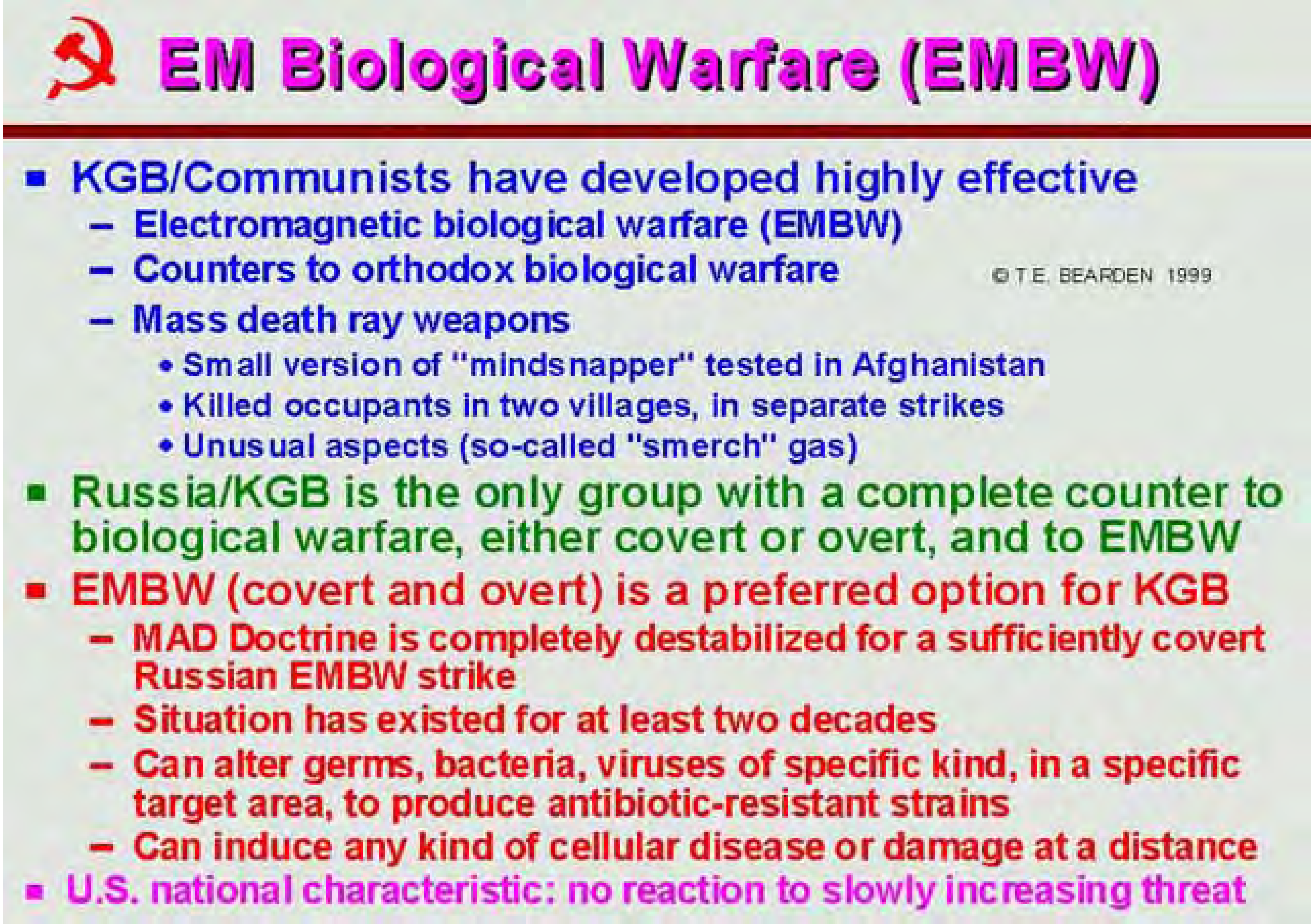

EM Biological Warfare (EMBW)

- KGB/Communists have developed highly effective
  - Electromagnetic biological warfare (EMBW)
  - Counters to orthodox biological warfare
  - Mass death ray weapons
    - Small version of "mindsnapper" tested in Afghanistan
    - Killed occupants in two villages, in separate strikes
    - Unusual aspects (so-called "smerch" gas)
- Russia/KGB is the only group with a complete counter to biological warfare, either covert or overt, and to EMBW
- EMBW (covert and overt) is a preferred option for KGB
  - MAD Doctrine is completely destabilized for a sufficiently covert Russian EMBW strike
  - Situation has existed for at least two decades
  - Can alter germs, bacteria, viruses of specific kind, in a specific target area, to produce antibiotic-resistant strains
  - Can induce any kind of cellular disease or damage at a distance
- U.S. national characteristic: no reaction to slowly increasing threat

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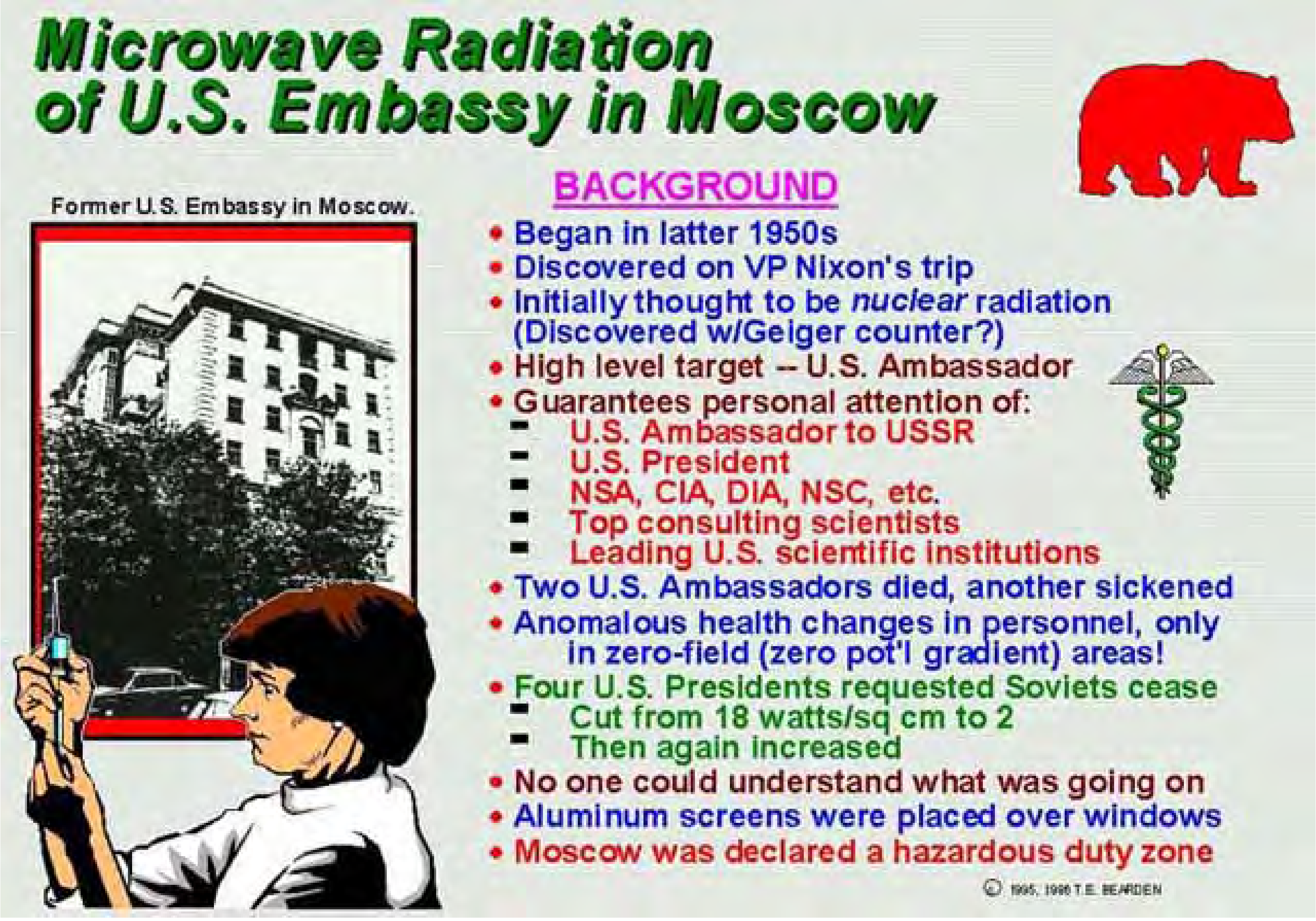

Microwave Radiation of U.S. Embassy in Moscow

Former U.S. Embassy in Moscow.

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter?)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
  - U.S. Ambassador to USSR
  - U.S. President
  - NSA, CIA, DIA, NSC, etc.
  - Top consulting scientists
  - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero pot'l gradient) areas!
- Four U.S. Presidents requested Soviets cease
  - Cut from 18 watts/sq cm to 2
  - Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

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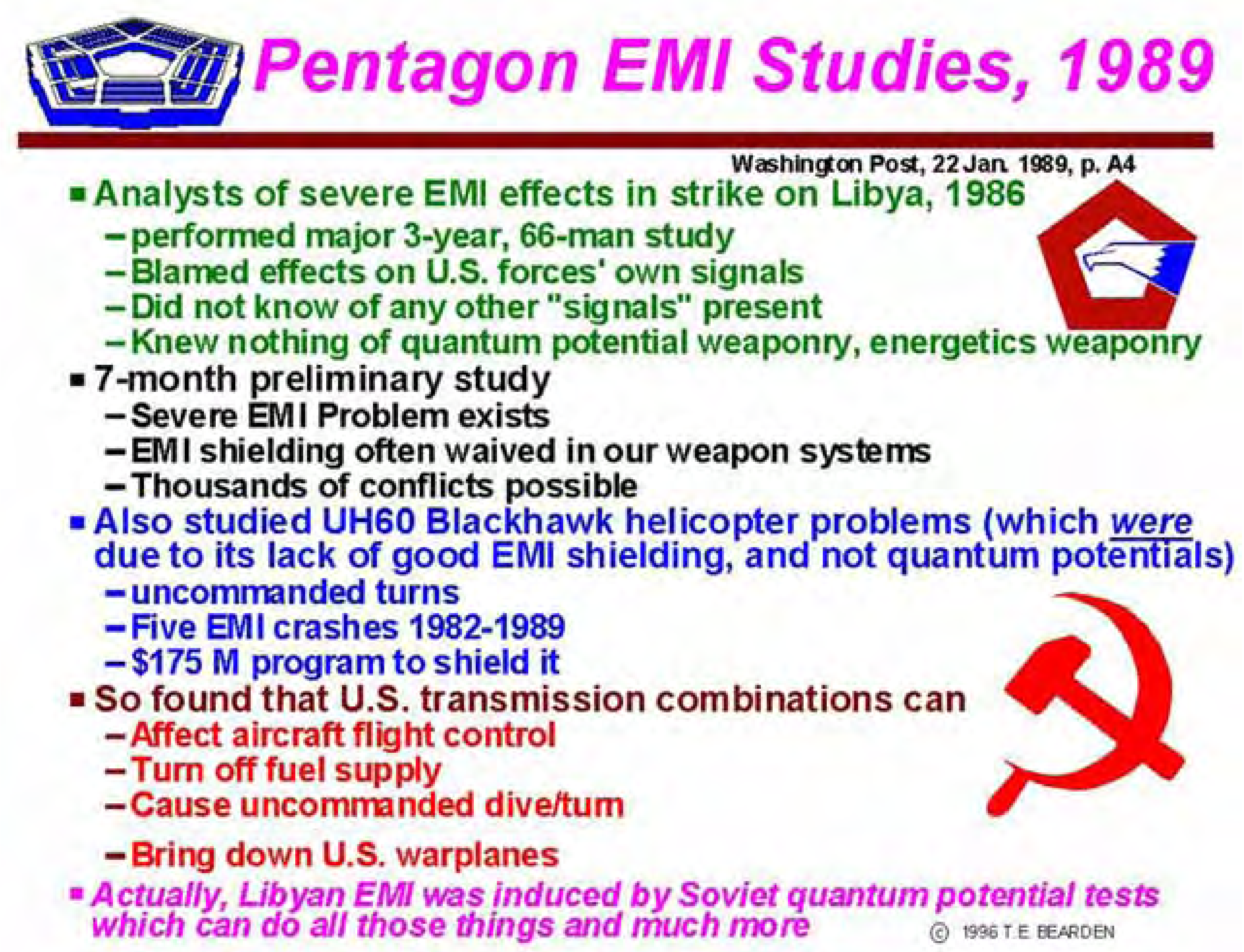

Pentagon EMI Studies, 1989

Washington Post, 22 Jan. 1989, p. A4

- Analysts of severe EMI effects in strike on Libya, 1986
  - –performed major 3-year, 66-man study
  - –Blamed effects on U.S. forces' own signals
  - –Did not know of any other "signals" present
  - –Knew nothing of quantum potential weaponry, energetics weaponry
- 7-month preliminary study
  - –Severe EMI Problem exists
  - –EMI shielding often waived in our weapon systems
  - –Thousands of conflicts possible
- Also studied UH60 Blackhawk helicopter problems (which *were* due to its lack of good EMI shielding, and not quantum potentials)
  - –uncommanded turns
  - –Five EMI crashes 1982-1989
  - –$175 M program to shield it
- So found that U.S. transmission combinations can
  - –Affect aircraft flight control
  - –Turn off fuel supply
  - –Cause uncommanded dive/turn
  - –Bring down U.S. warplanes
- *Actually, Libyan EMI was induced by Soviet quantum potential tests which can do all those things and much more*

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EM Missile Practice

- EM Missile Practice
  Latter Sept. - Early Nov. 1996
  Melbourne, Australia

- Deception: Using EM Missile to Reinforce Notion of SAM Attack
  Saturday evening, Nov. 16, 1996

- Intelligence Probe: Insuring U.S. Still Unaware of Energetics Weaponry
  Thursday, December 12th, 1996

- EM Missile Strike, Offset from Night Shuttle Launch, Cape Canaveral, Florida
  The Smoking Gun in November 1985

- Distant Operator Onsite in Russia Slew Away Registration Point
  Marker Beacon over Night Shuttle Launch, 26 November, 1985

- EM Missile Practice and Deception
  November 17, 1996

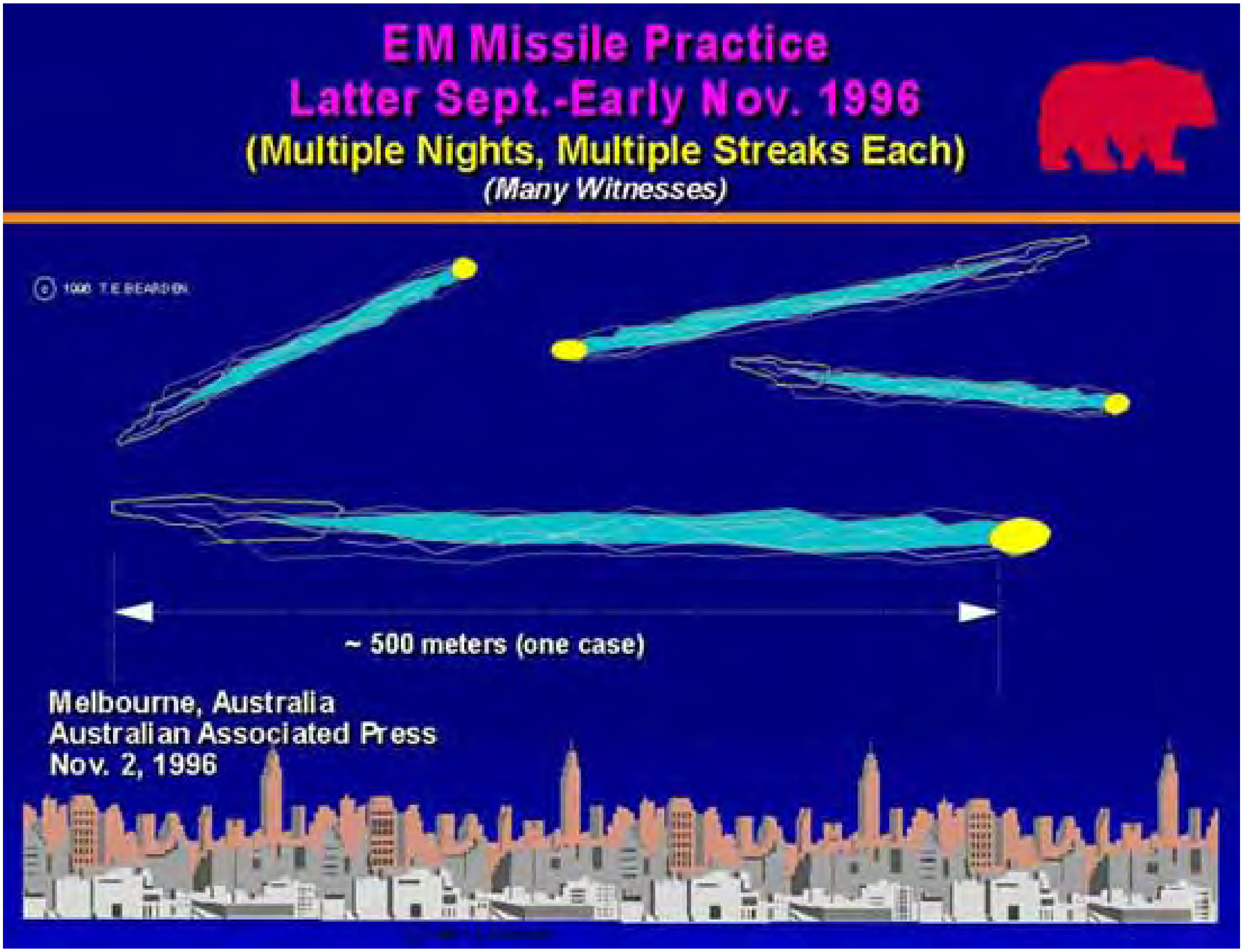

EM Missile Practice
Latter Sept.-Early Nov. 1996

(Multiple Nights, Multiple Streaks Each)

(Many Witnesses)

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~ 500 meters (one case)

Melbourne, Australia
Australian Associated Press
Nov. 2, 1996

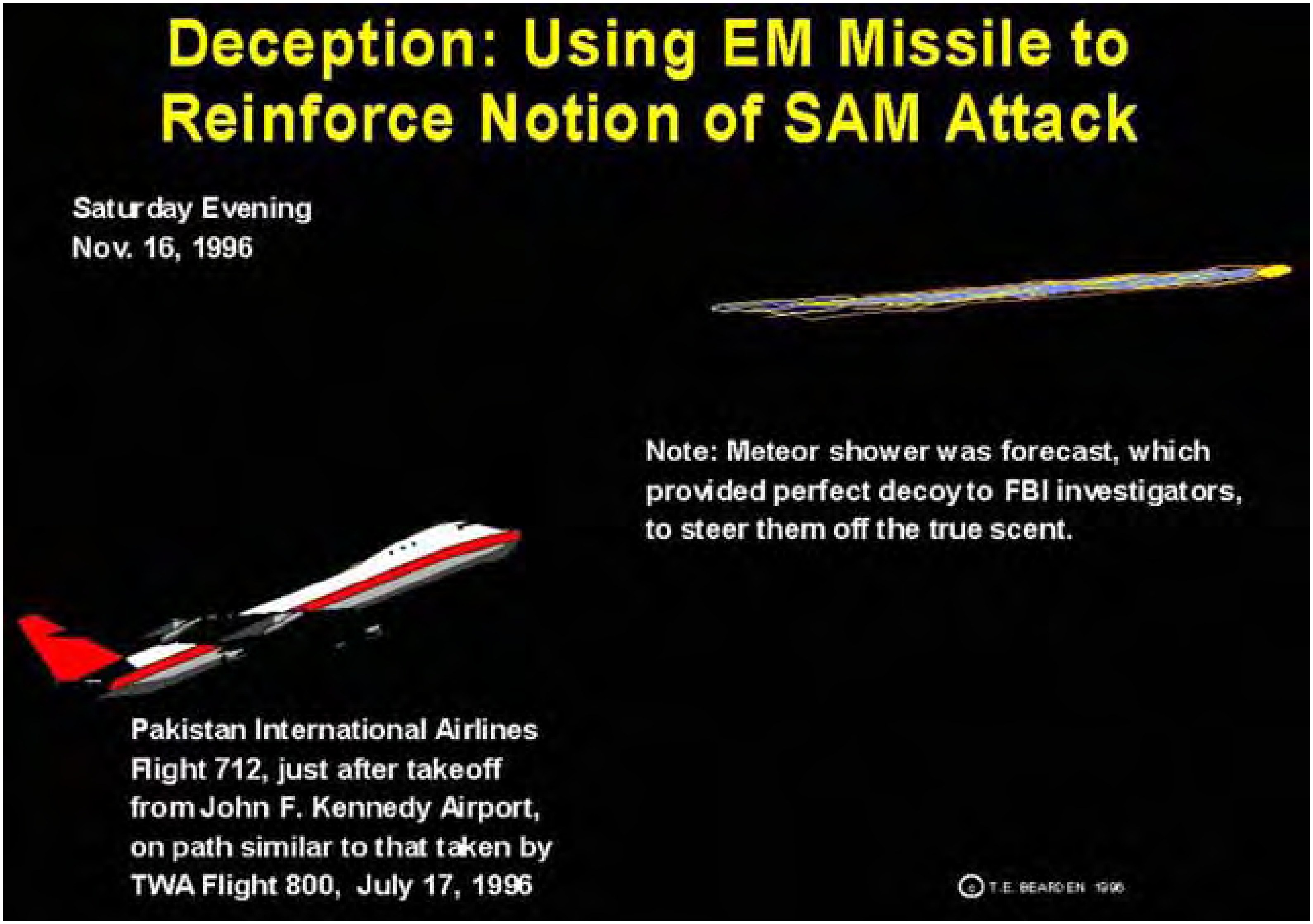

Deception: Using EM Missile to Reinforce Notion of SAM Attack

Saturday Evening
Nov. 16, 1996

Note: Meteor shower was forecast, which provided perfect decoy to FBI investigators, to steer them off the true scent.

Pakistan International Airlines Flight 712, just after takeoff from John F. Kennedy Airport, on path similar to that taken by TWA Flight 800, July 17, 1996

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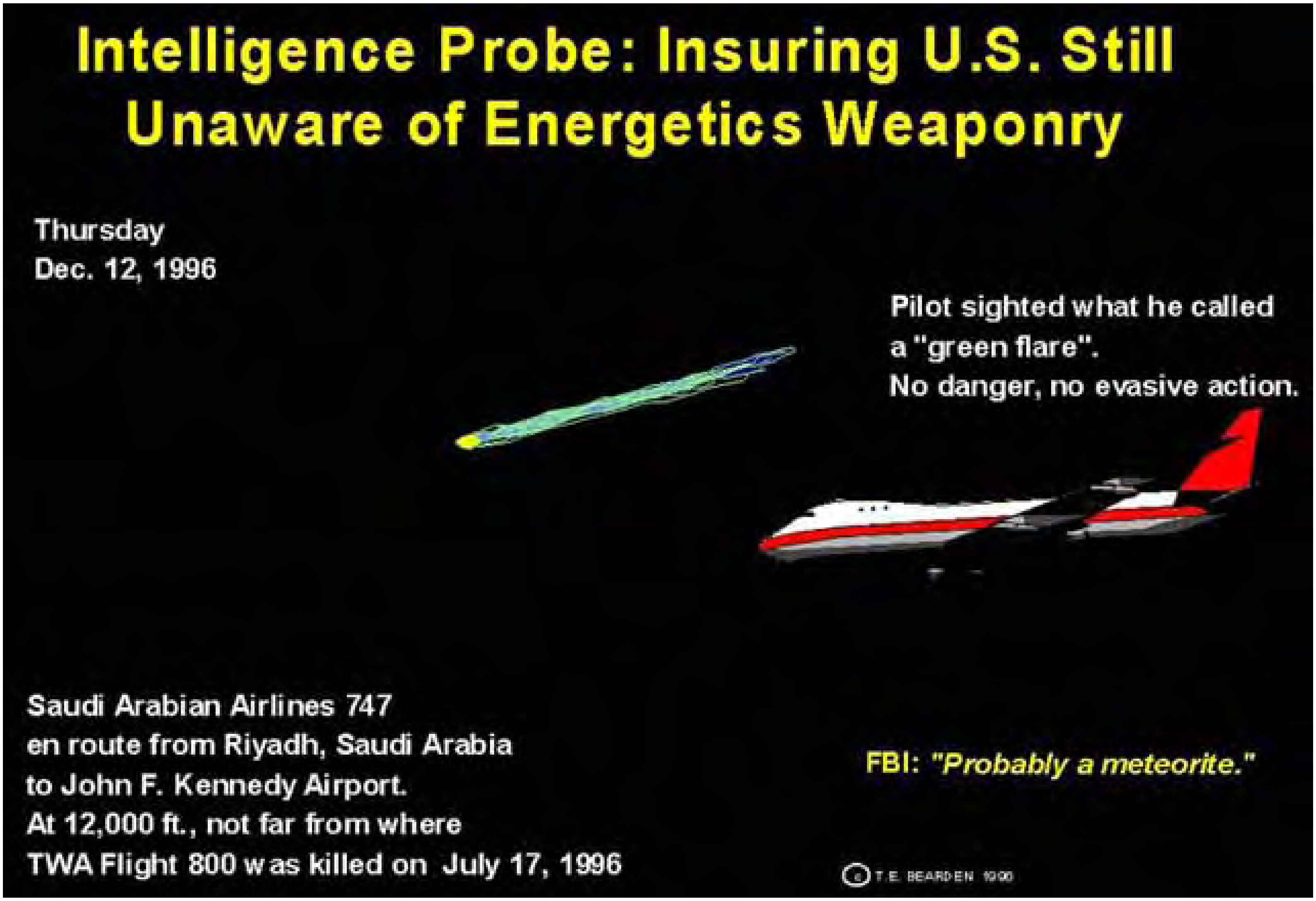

Intelligence Probe: Insuring U.S. Still Unaware of Energetics Weaponry

Thursday
Dec. 12, 1996

Pilot sighted what he called
a "green flare".
No danger, no evasive action.

Saudi Arabian Airlines 747
en route from Riyadh, Saudi Arabia
to John F. Kennedy Airport.
At 12,000 ft., not far from where
TWA Flight 800 was killed on July 17, 1996

FBI: *"Probably a meteorite."*

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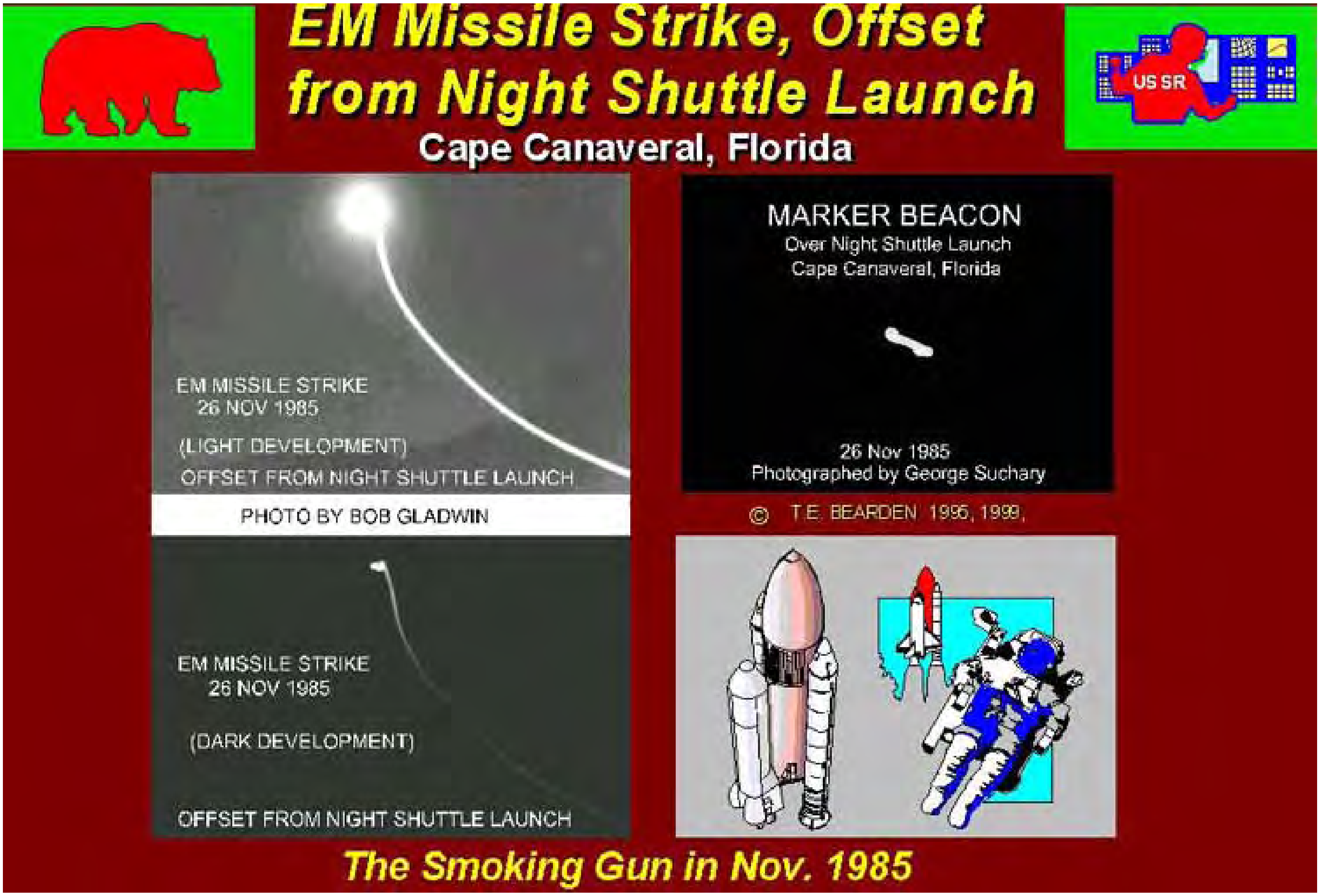

EM Missile Strike, Offset from Night Shuttle Launch

Cape Canaveral, Florida

EM MISSILE STRIKE
26 NOV 1985

(LIGHT DEVELOPMENT)
OFFSET FROM NIGHT SHUTTLE LAUNCH

PHOTO BY BOB GLADWIN

MARKER BEACON
Over Night Shuttle Launch
Cape Canaveral, Florida

26 Nov 1985
Photographed by George Suchary

© T.E. BEARDEN 1996, 1999,

EM MISSILE STRIKE
26 NOV 1985

(DARK DEVELOPMENT)

OFFSET FROM NIGHT SHUTTLE LAUNCH

The Smoking Gun in Nov. 1985

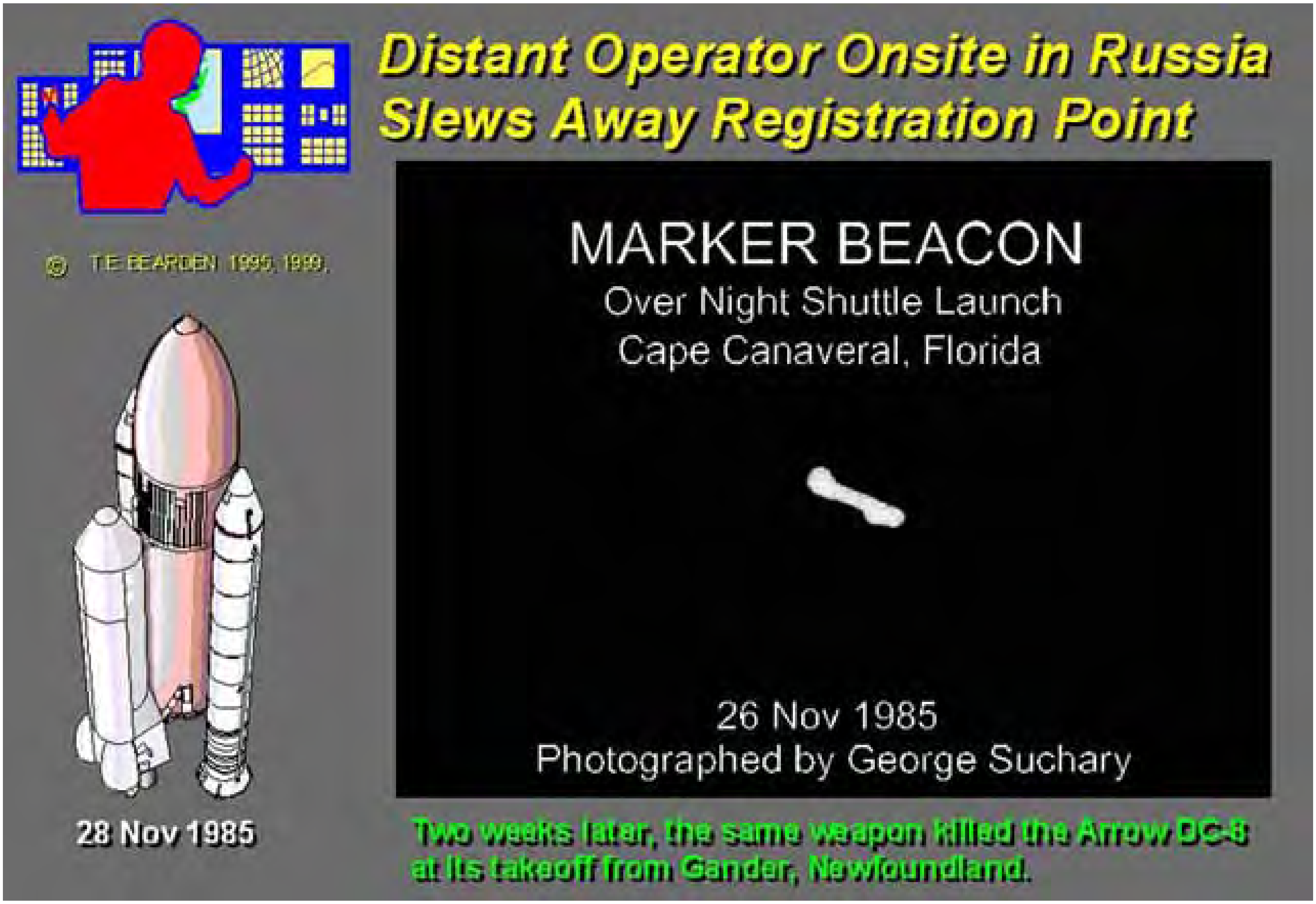

Distant Operator Onsite in Russia Slews Away Registration Point

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MARKER BEACON
Over Night Shuttle Launch
Cape Canaveral, Florida

26 Nov 1985
Photographed by George Suchary

28 Nov 1985

Two weeks later, the same weapon killed the Arrow DC-8 at its takeoff from Gander, Newfoundland.

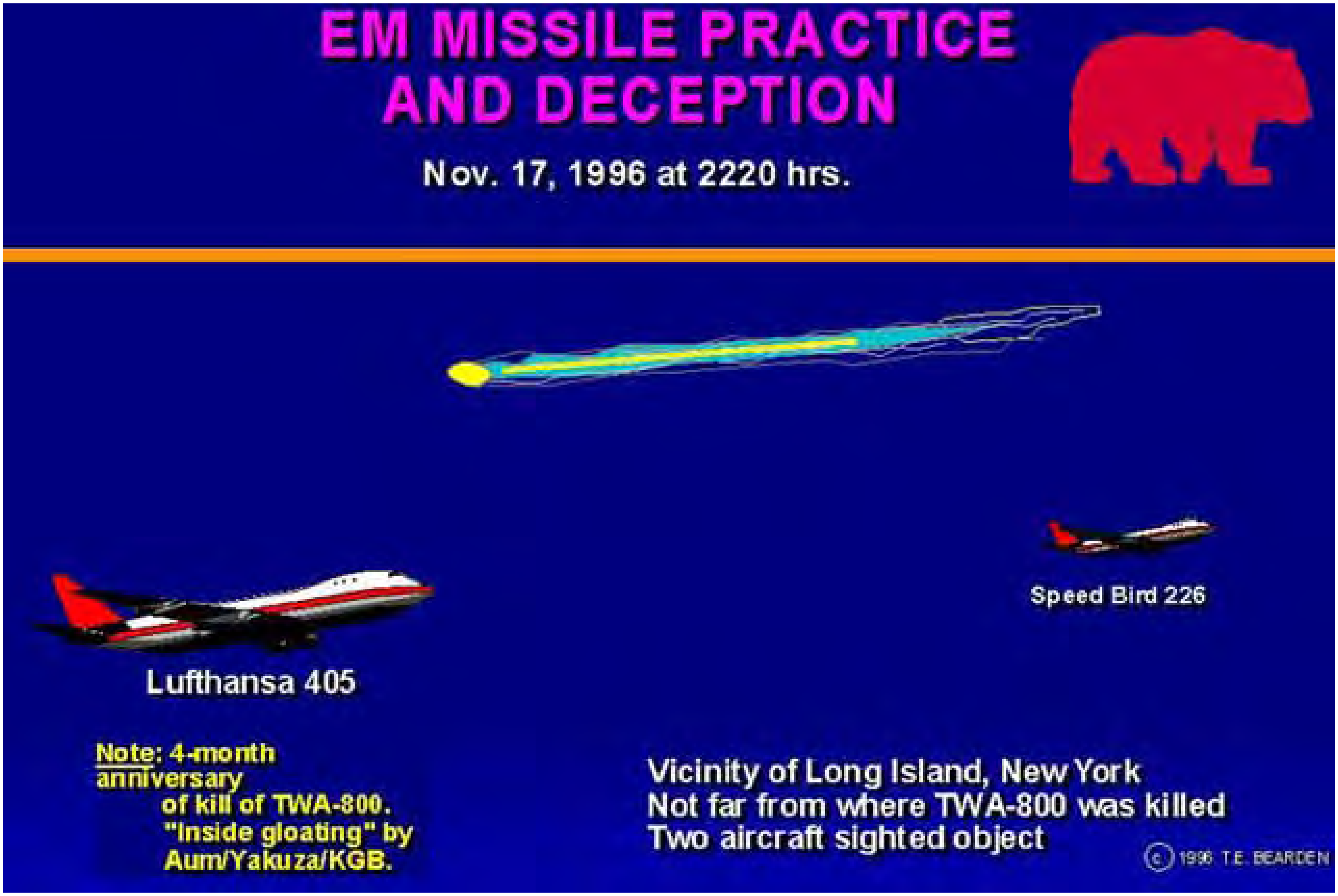

EM MISSILE PRACTICE AND DECEPTION

Nov. 17, 1996 at 2220 hrs.

Note: 4-month anniversary of kill of TWA-800. "Inside gloating" by Aum/Yakuza/KGB.

Vicinity of Long Island, New York
Not far from where TWA-800 was killed
Two aircraft sighted object

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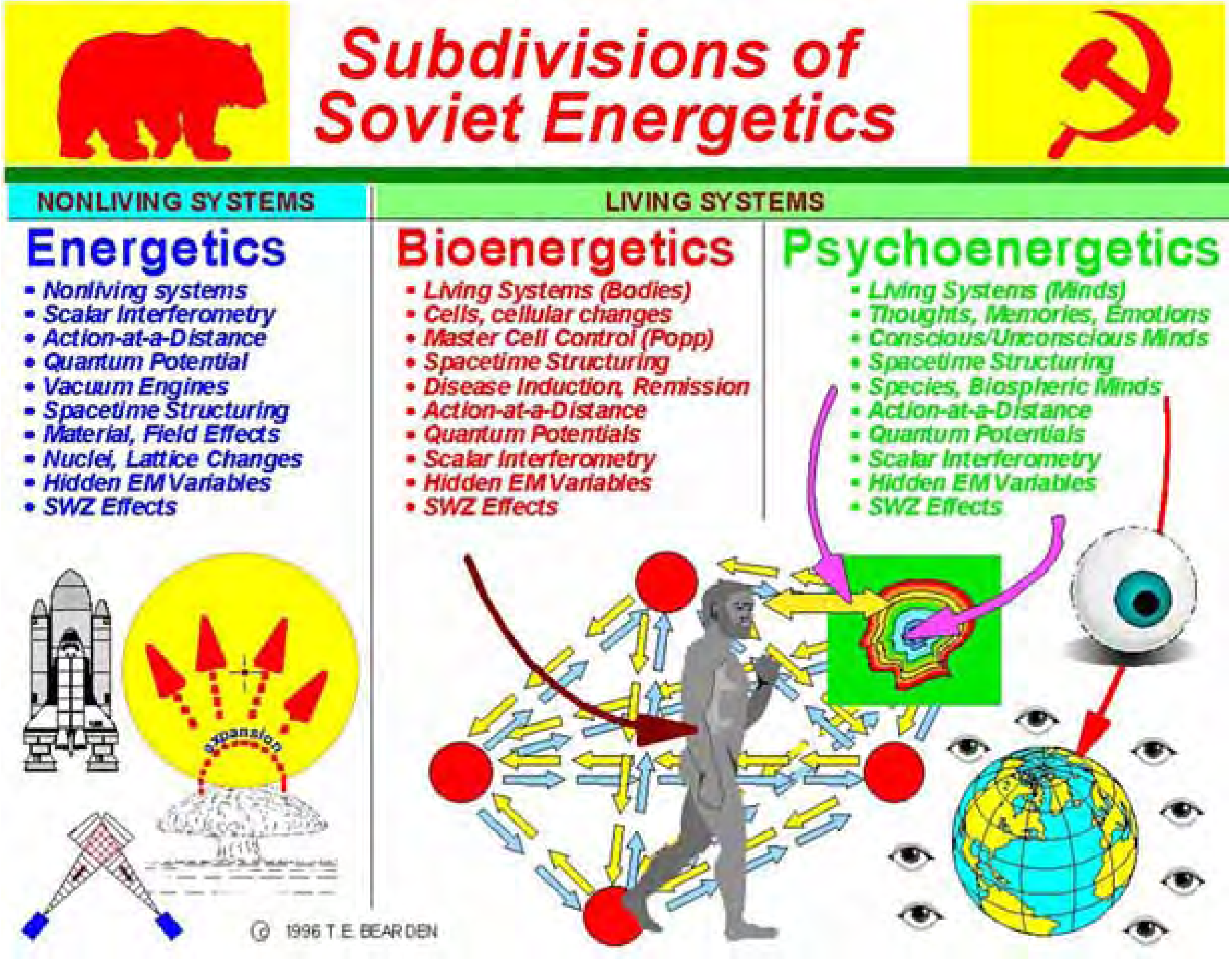

Subdivisions of Soviet Energetics

NONLIVING SYSTEMS

LIVING SYSTEMS

Energetics

- *Nonliving systems*
- *Scalar Interferometry*
- *Action-at-a-Distance*
- *Quantum Potential*
- *Vacuum Engines*
- *Spacetime Structuring*
- *Material, Field Effects*
- *Nuclei, Lattice Changes*
- *Hidden EM Variables*
- *SWZ Effects*

Bioenergetics

- *Living Systems (Bodies)*
- *Cells, cellular changes*
- *Master Cell Control (Popp)*
- *Spacetime Structuring*
- *Disease Induction, Remission*
- *Action-at-a-Distance*
- *Quantum Potentials*
- *Scalar Interferometry*
- *Hidden EM Variables*
- *SWZ Effects*

Psychoenergetics

- *Living Systems (Minds)*
- *Thoughts, Memories, Emotions*
- *Conscious/Unconscious Minds*
- *Spacetime Structuring*
- *Species, Biospheric Minds*
- *Action-at-a-Distance*
- *Quantum Potentials*
- *Scalar Interferometry*
- *Hidden EM Variables*
- *SWZ Effects*

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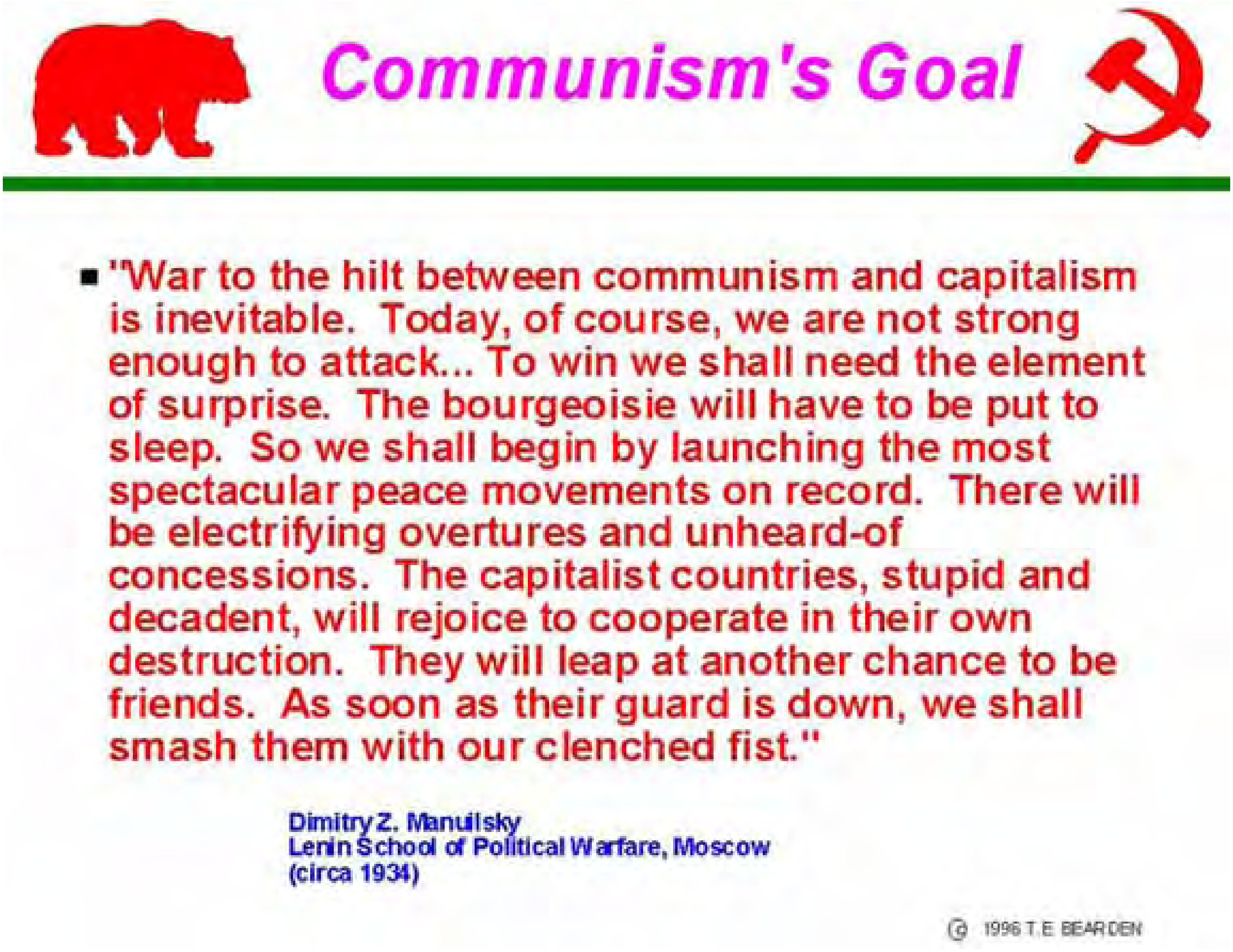

Communism's Goal

- "War to the hilt between communism and capitalism is inevitable. Today, of course, we are not strong enough to attack... To win we shall need the element of surprise. The bourgeoisie will have to be put to sleep. So we shall begin by launching the most spectacular peace movements on record. There will be electrifying overtures and unheard-of concessions. The capitalist countries, stupid and decadent, will rejoice to cooperate in their own destruction. They will leap at another chance to be friends. As soon as their guard is down, we shall smash them with our clenched fist."

Dimitry Z. Manuilsky
Lenin School of Political Warfare, Moscow
(circa 1934)

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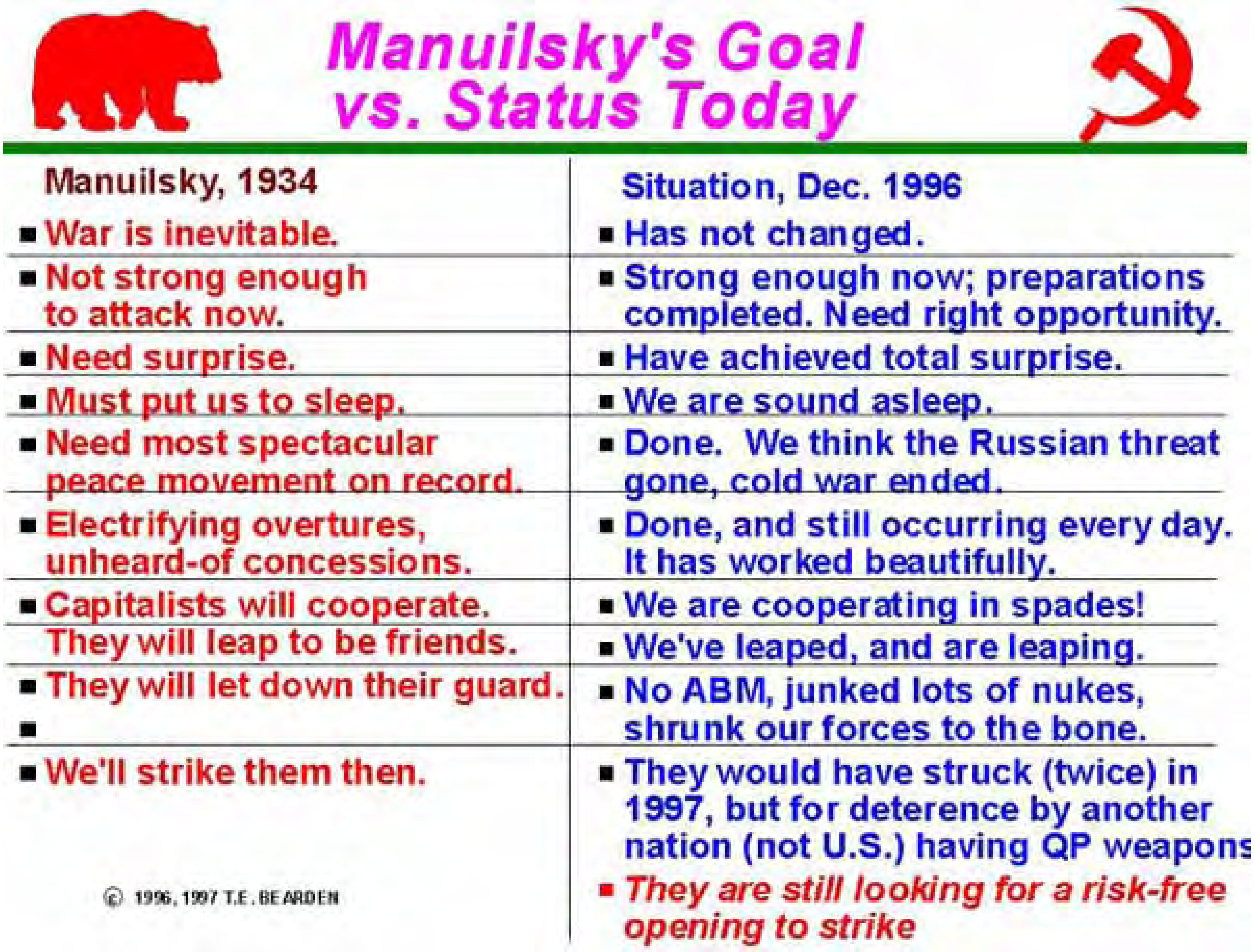

Manuilsky's Goal vs. Status Today

Manuilsky, 1934	Situation, Dec. 1996
■ War is inevitable.	■ Has not changed.
■ Not strong enough to attack now.	■ Strong enough now; preparations completed. Need right opportunity.
■ Need surprise.	■ Have achieved total surprise.
■ Must put us to sleep.	■ We are sound asleep.
■ Need most spectacular peace movement on record.	■ Done. We think the Russian threat gone, cold war ended.
■ Electrifying overtures, unheard-of concessions.	■ Done, and still occurring every day. It has worked beautifully.
■ Capitalists will cooperate.	■ We are cooperating in spades!
They will leap to be friends.	■ We've leaped, and are leaping.
■ They will let down their guard. ■	■ No ABM, junked lots of nukes, shrunk our forces to the bone.
■ We'll strike them then.	■ They would have struck (twice) in 1997, but for deterence by another nation (not U.S.) having QP weapons ■ *They are still looking for a risk-free opening to strike*

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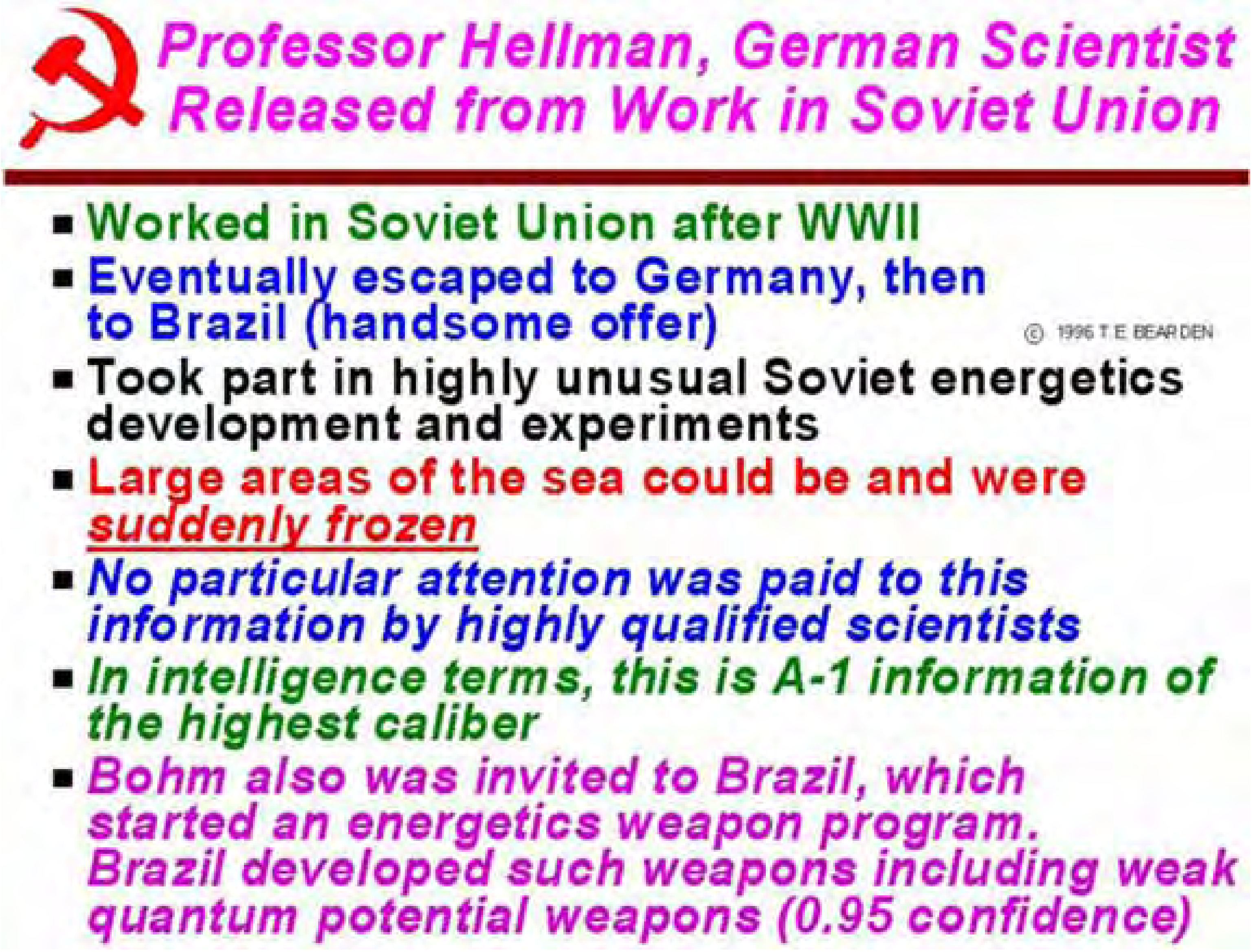

Professor Hellman, German Scientist Released from Work in Soviet Union

- Worked in Soviet Union after WWII
- Eventually escaped to Germany, then to Brazil (handsome offer)
- Took part in highly unusual Soviet energetics development and experiments
- Large areas of the sea could be and were *suddenly frozen*
- *No particular attention was paid to this information by highly qualified scientists*
- *In intelligence terms, this is A-1 information of the highest caliber*
- *Bohm also was invited to Brazil, which started an energetics weapon program. Brazil developed such weapons including weak quantum potential weapons (0.95 confidence)*

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The Tom Bearden Website

Help support the research

Hemispheres of Light

- March 20th, 1969
  Caribbean and Western North Atlantic
- Hemisphere and Globes, 1977
  24 March, 1977
- Virgin Islands Incident
  August 1969
- Typical Shield Test, Northern Route to Japan
  June, 1982

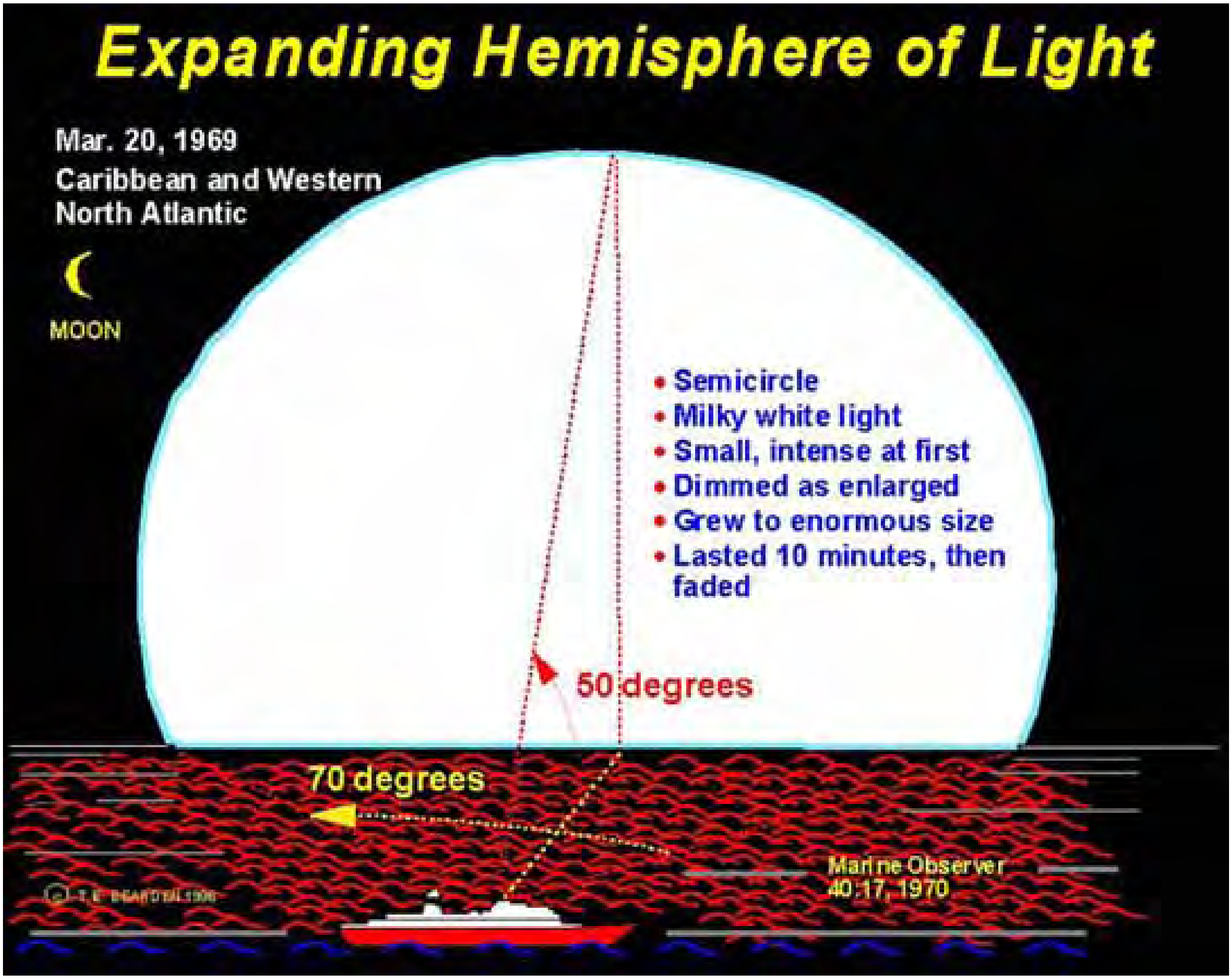

Expanding Hemisphere of Light

Mar. 20, 1969
Caribbean and Western
North Atlantic

- Semicircle
- Milky white light
- Small, intense at first
- Dimmed as enlarged
- Grew to enormous size
- Lasted 10 minutes, then faded

Marine Observer
40:17, 1970

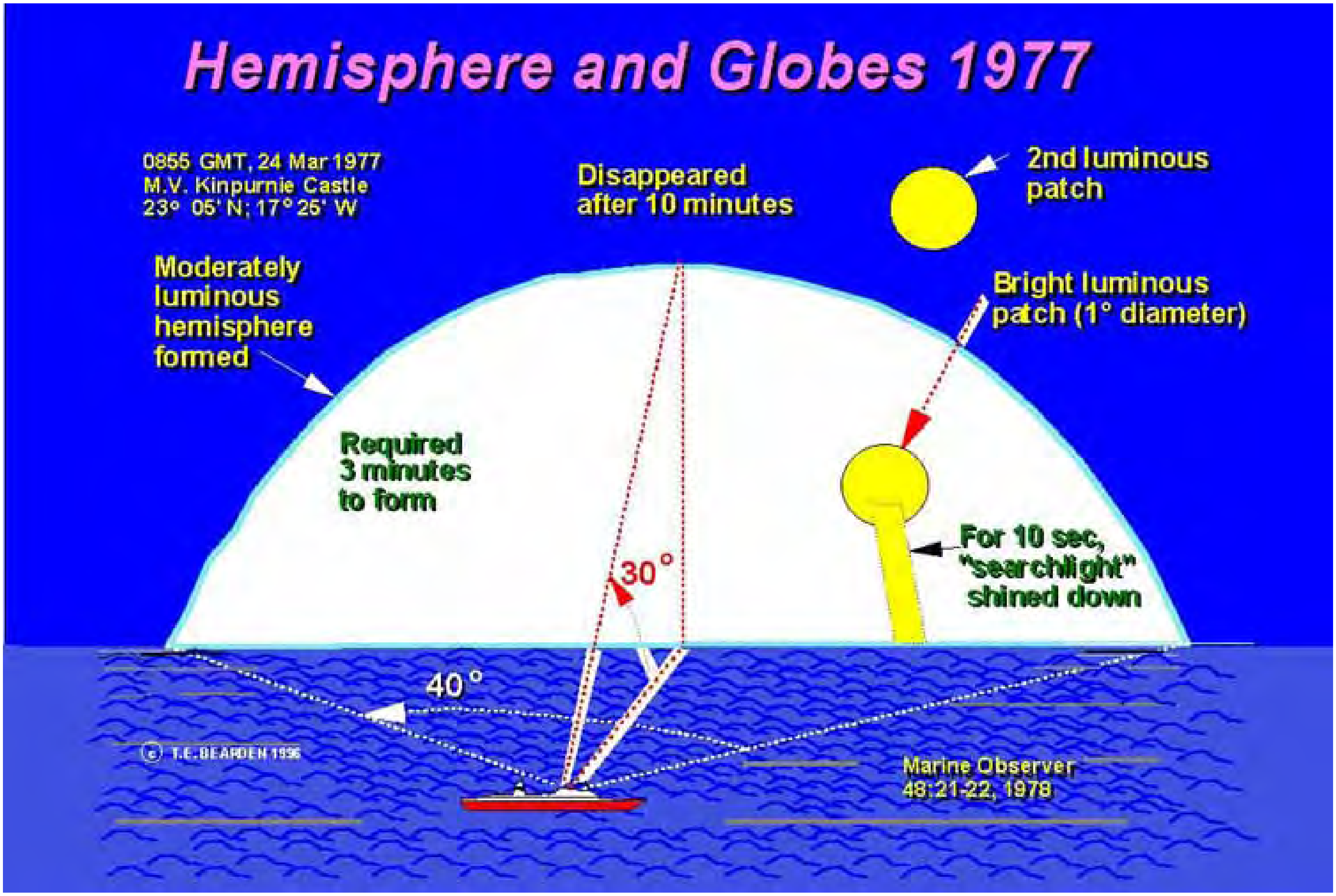
Hemisphere and Globes 1977
0855 GMT, 24 Mar 1977
M.V. Kinpurnie Castle
23° 05' N; 17° 25' W
Disappeared after 10 minutes
2nd luminous patch
Moderately luminous hemisphere formed
Bright luminous patch (1° diameter)
Required 3 minutes to form
30°
For 10 sec, "searchlight" shined down
40°
© T.E. BEARDEN 1996
Marine Observer 48:21-22, 1978

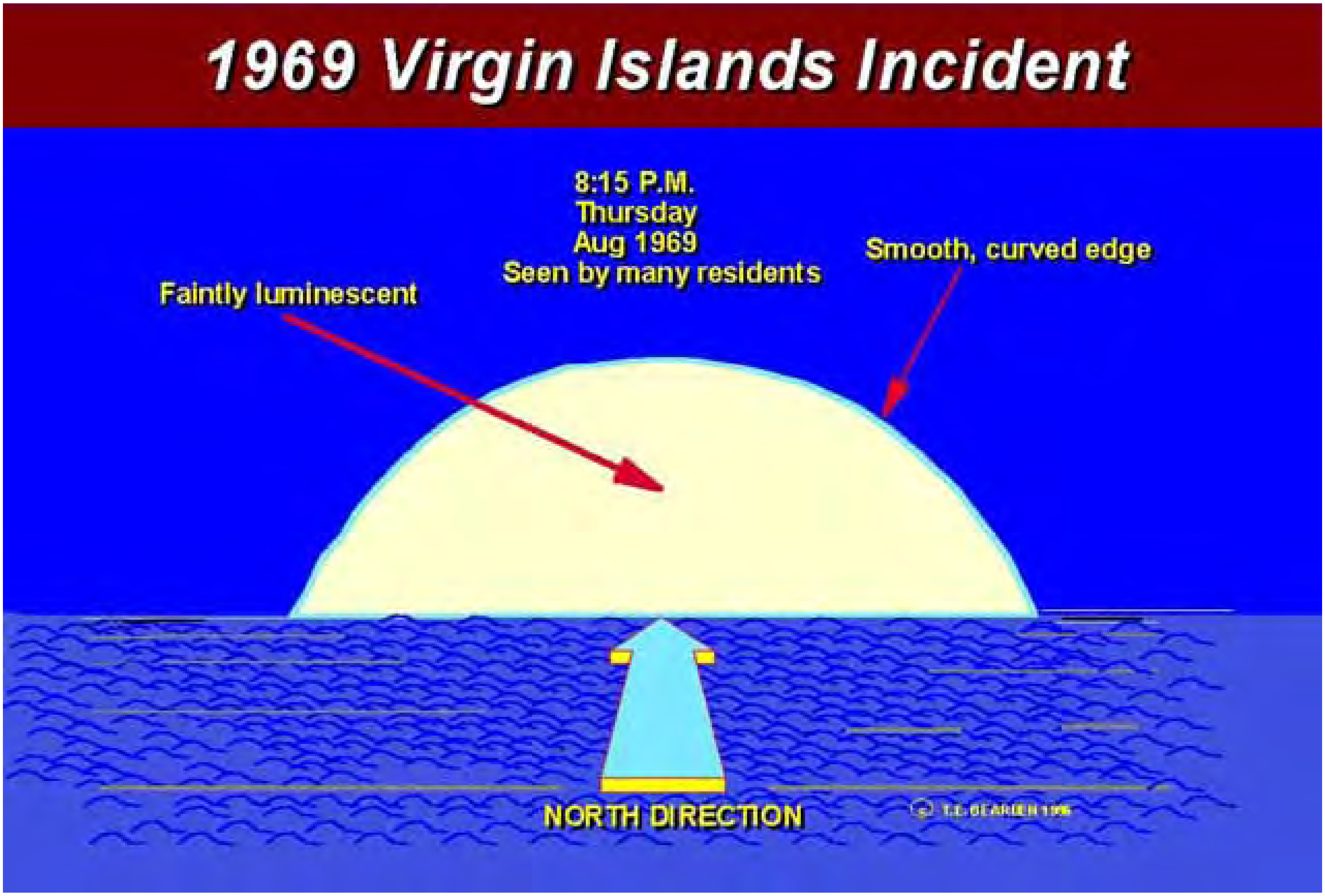

1969 Virgin Islands Incident

8:15 P.M.
Thursday
Aug 1969
Seen by many residents

Faintly luminescent

Smooth, curved edge

NORTH DIRECTION

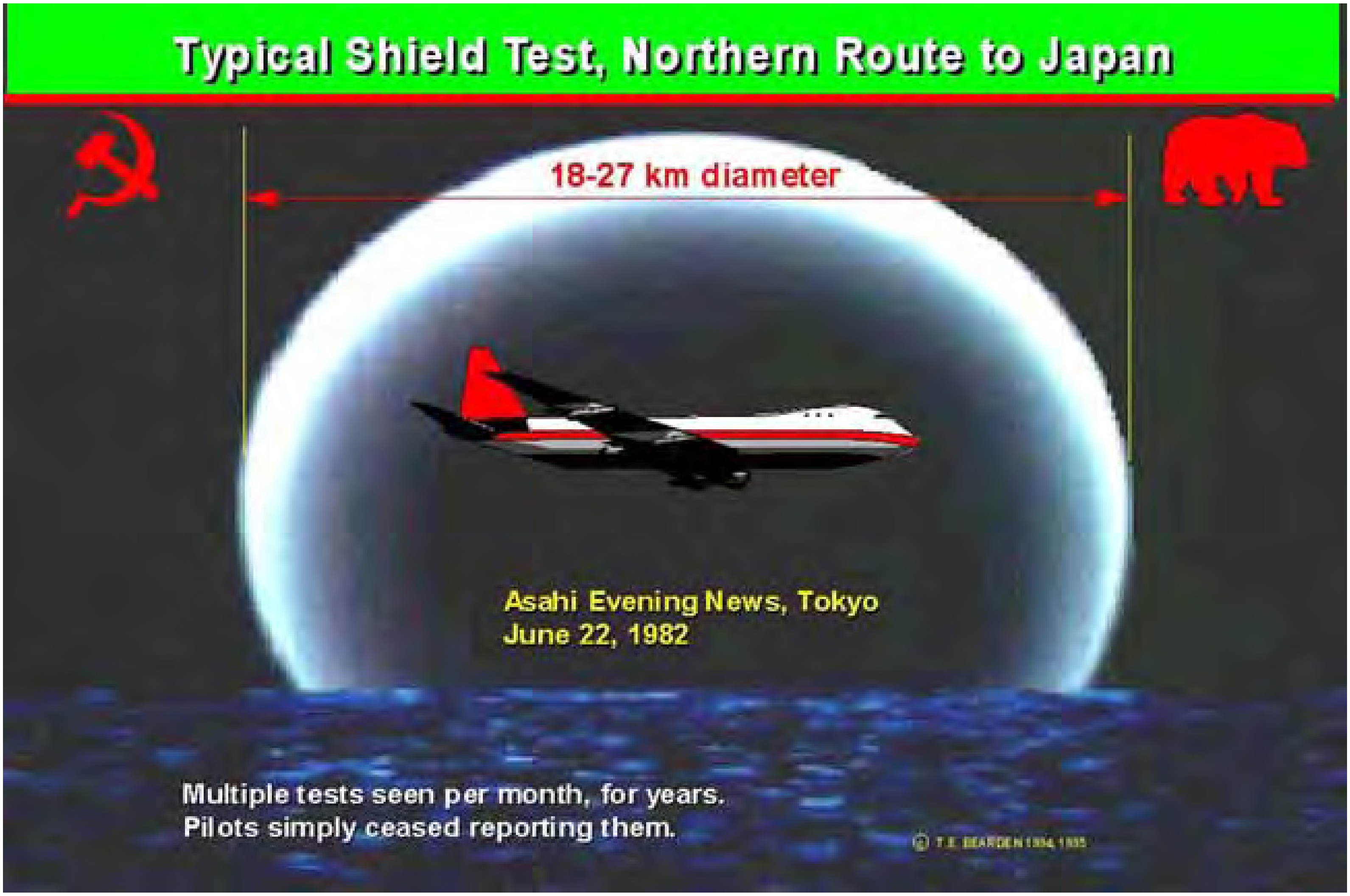

Typical Shield Test, Northern Route to Japan

18-27 km diameter

Asahi Evening News, Tokyo
June 22, 1982

Multiple tests seen per month, for years.
Pilots simply ceased reporting them.

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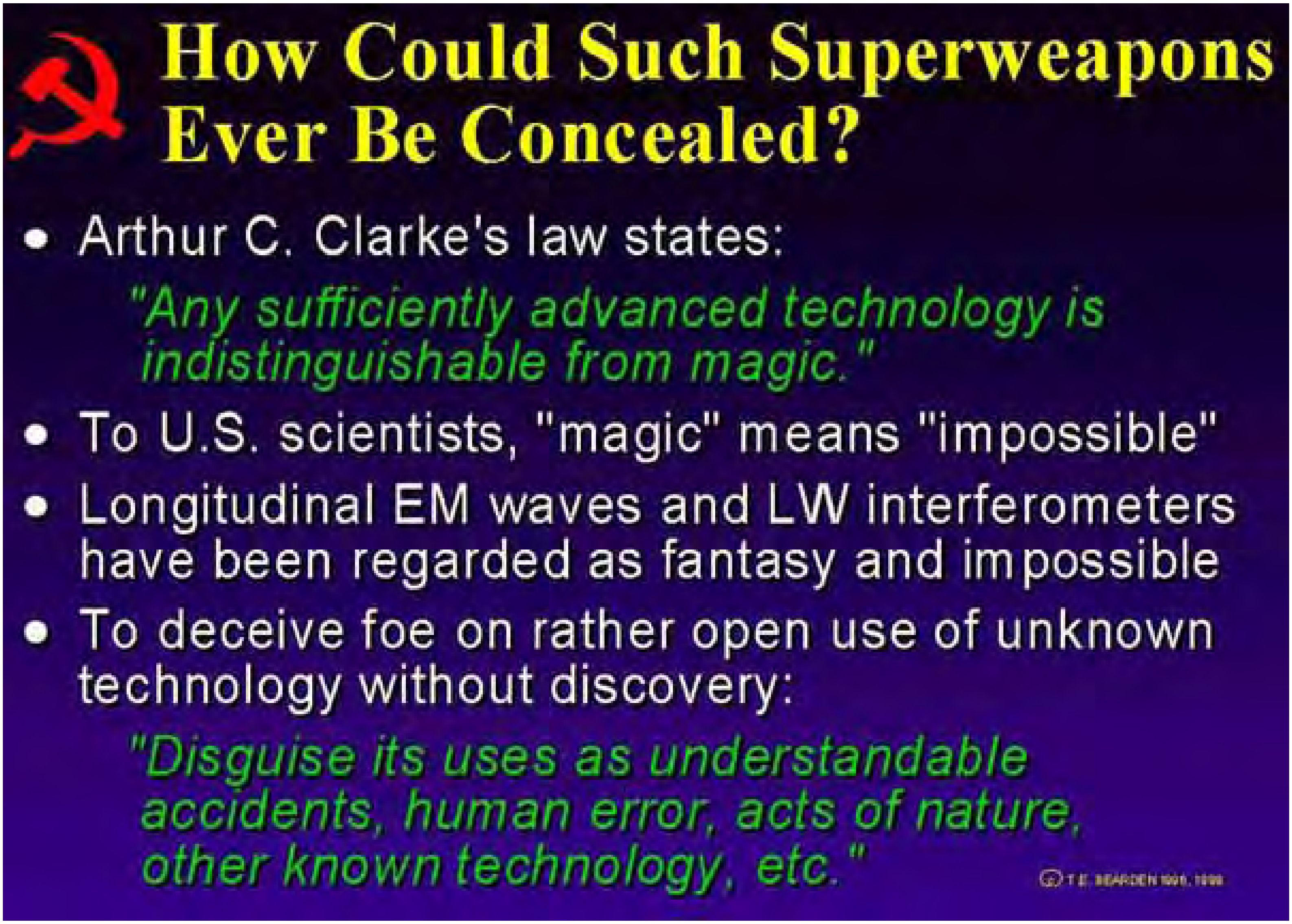

How Could Such Superweapons Ever Be Concealed?

- Arthur C. Clarke's law states:

  "Any sufficiently advanced technology is indistinguishable from magic."
- To U.S. scientists, "magic" means "impossible"
- Longitudinal EM waves and LW interferometers have been regarded as fantasy and impossible
- To deceive foe on rather open use of unknown technology without discovery:

  "Disguise its uses as understandable accidents, human error, acts of nature, other known technology, etc."

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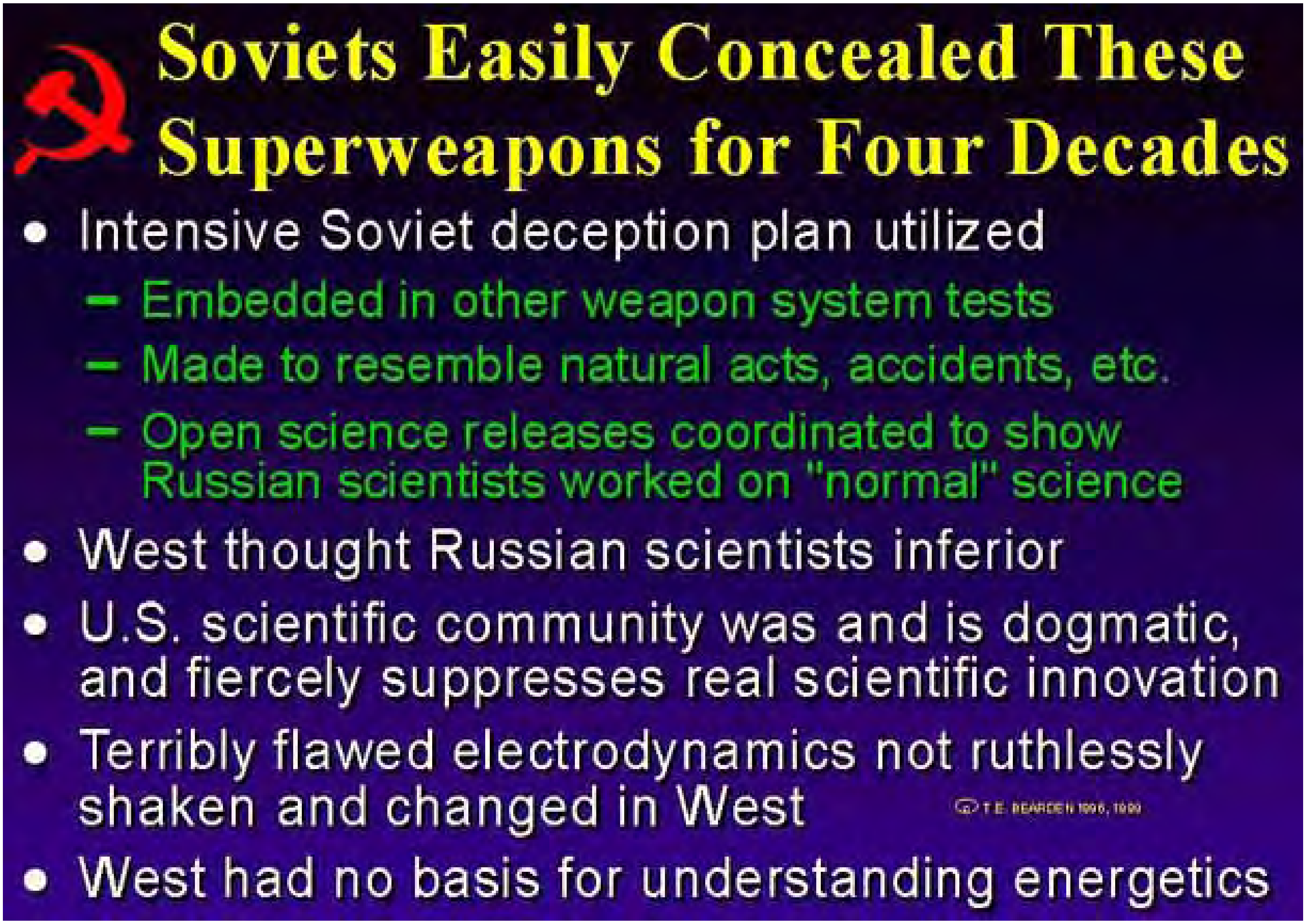

Soviets Easily Concealed These Superweapons for Four Decades

- Intensive Soviet deception plan utilized
  - Embedded in other weapon system tests
  - Made to resemble natural acts, accidents, etc.
  - Open science releases coordinated to show Russian scientists worked on "normal" science
- West thought Russian scientists inferior
- U.S. scientific community was and is dogmatic, and fiercely suppresses real scientific innovation
- Terribly flawed electrodynamics not ruthlessly shaken and changed in West
- West had no basis for understanding energetics

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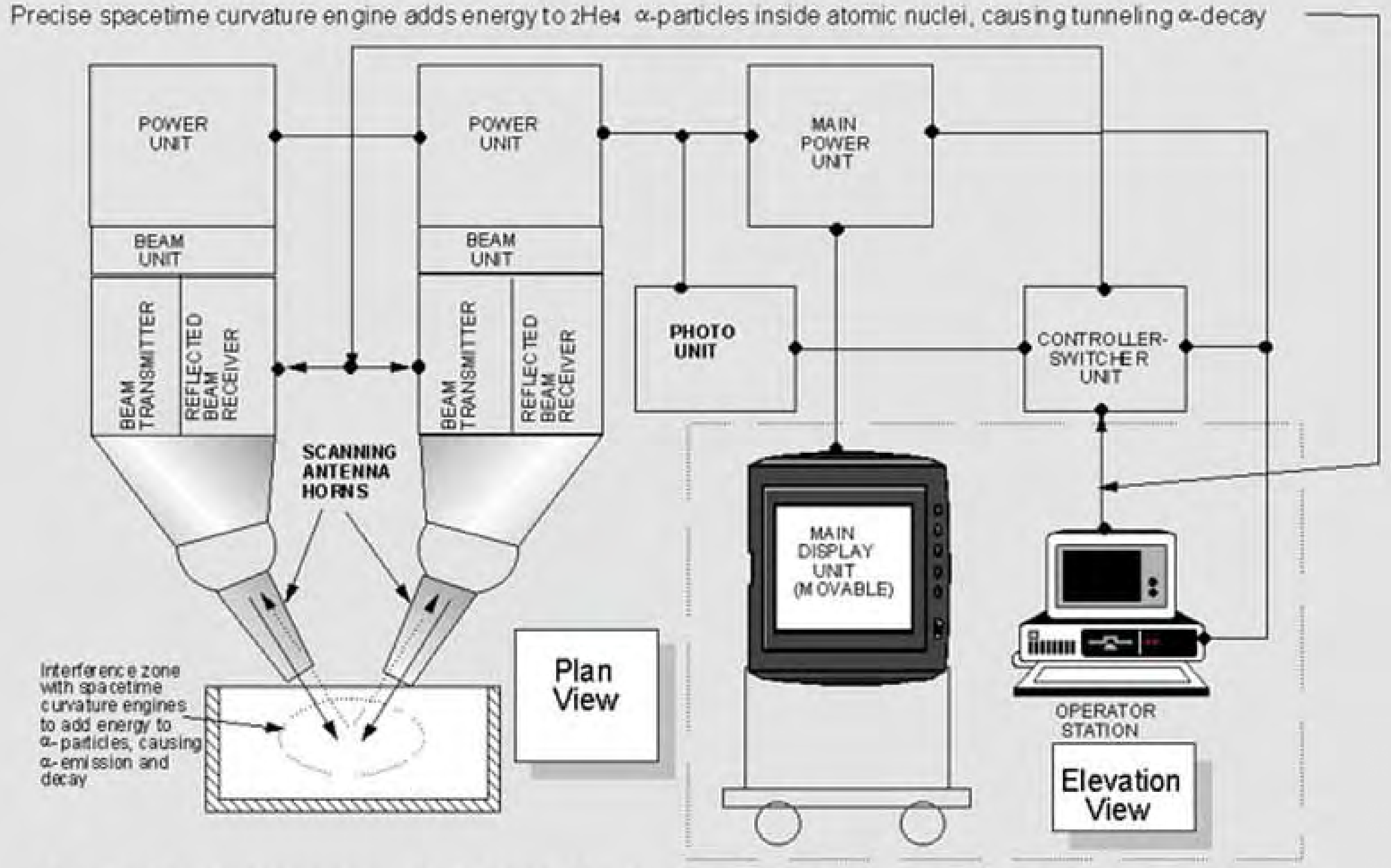
Precise spacetime curvature engine adds energy to $_2He_4$ α-particles inside atomic nuclei, causing tunneling α-decay
POWER UNIT
BEAM UNIT
BEAM TRANSMITTER
REFLECTED BEAM RECEIVER
POWER UNIT
BEAM UNIT
BEAM TRANSMITTER
REFLECTED BEAM RECEIVER
MAIN POWER UNIT
PHOTO UNIT
CONTROLLER-SWITCHER UNIT
SCANNING ANTENNA HORNS
Interference zone with spacetime curvature engines to add energy to α-particles, causing α-emission and decay
Plan View
MAIN DISPLAY UNIT (MOVABLE)
OPERATOR STATION
Elevation View

Figure 26. Microscope-type, laser-like interferometer for inducing quick α-decay in samples of otherwise longer-lived isotopes.

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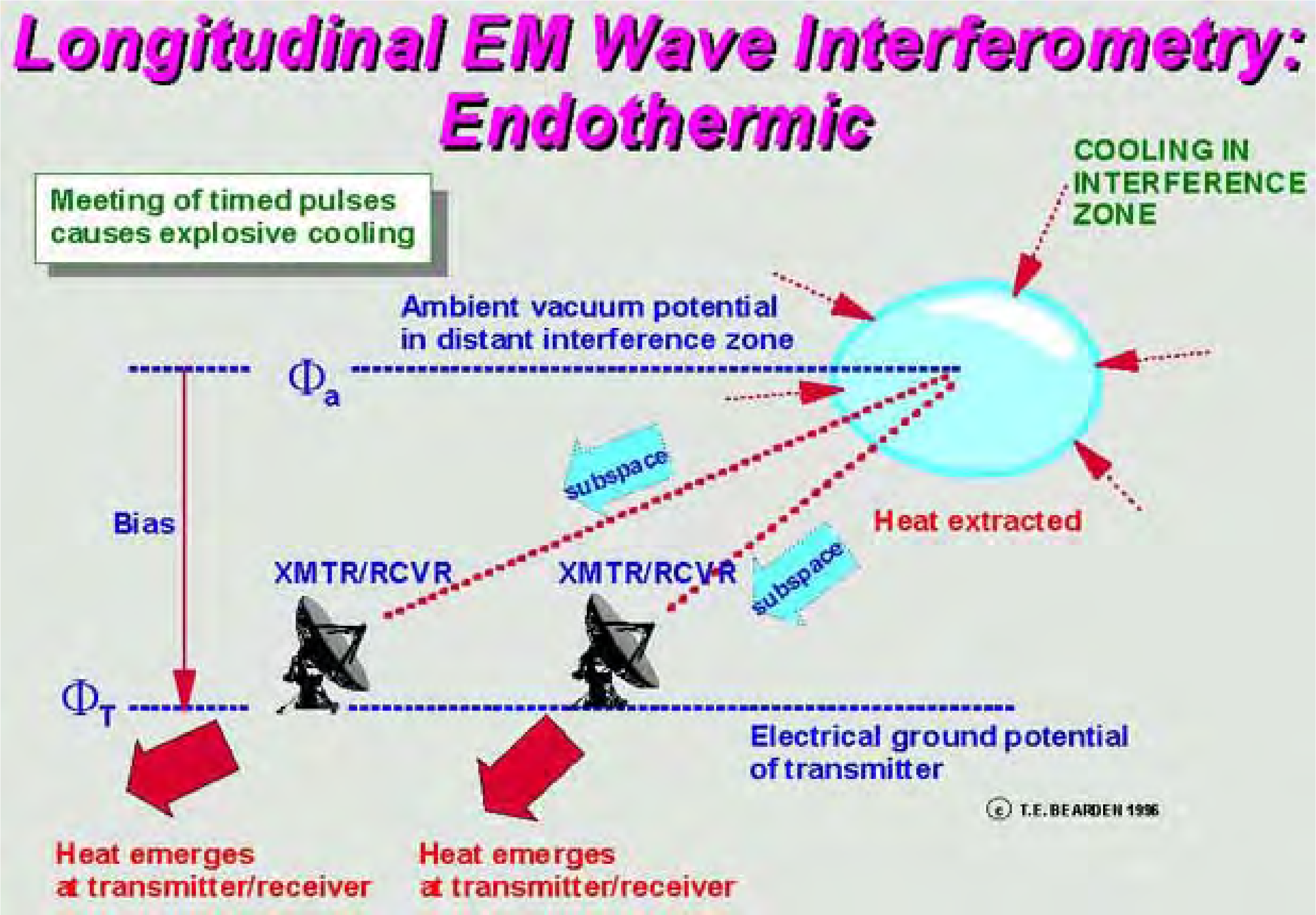

Longitudinal EM Wave Interferometry: Endothermic

Meeting of timed pulses
causes explosive cooling

COOLING IN
INTERFERENCE
ZONE

Ambient vacuum potential
in distant interference zone

Φ_a

subspace

Bias

Heat extracted

XMTR/RCVR

XMTR/RCVR

subspace

Φ_T

Electrical ground potential
of transmitter

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Heat emerges
at transmitter/receiver

Heat emerges
at transmitter/receiver

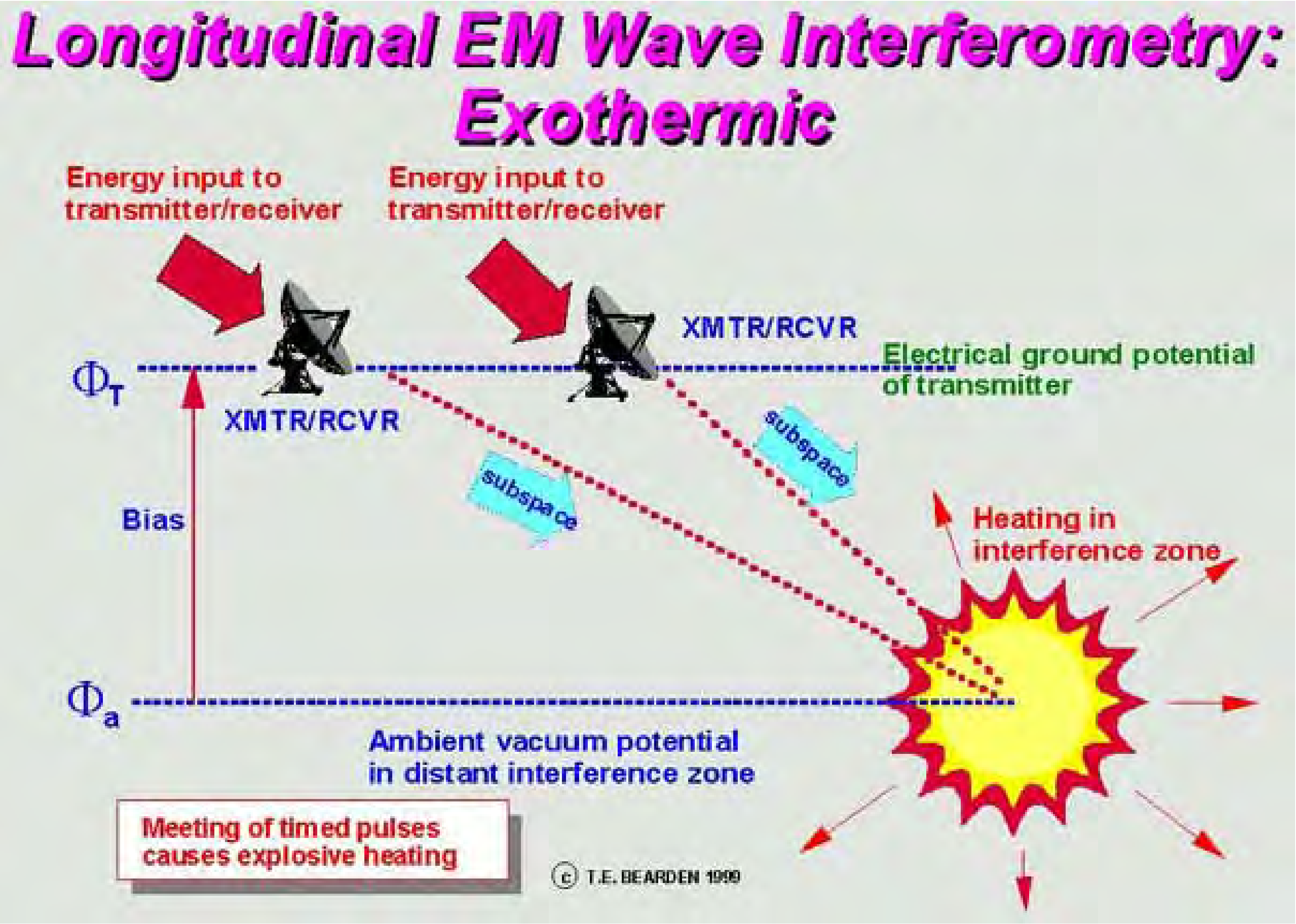

Longitudinal EM Wave Interferometry: Exothermic

Energy input to transmitter/receiver

Energy input to transmitter/receiver

XMTR/RCVR

XMTR/RCVR

Electrical ground potential of transmitter

Heating in interference zone

Ambient vacuum potential in distant interference zone

Meeting of timed pulses causes explosive heating

ⓒ T.E. BEARDEN 1999

The Tom Bearden Website

Help support the research

U.S. Air Attack on Libya

April 1986

- Slide 1
- Slide 2
- "Washington Post" Article
  January 22, 1989

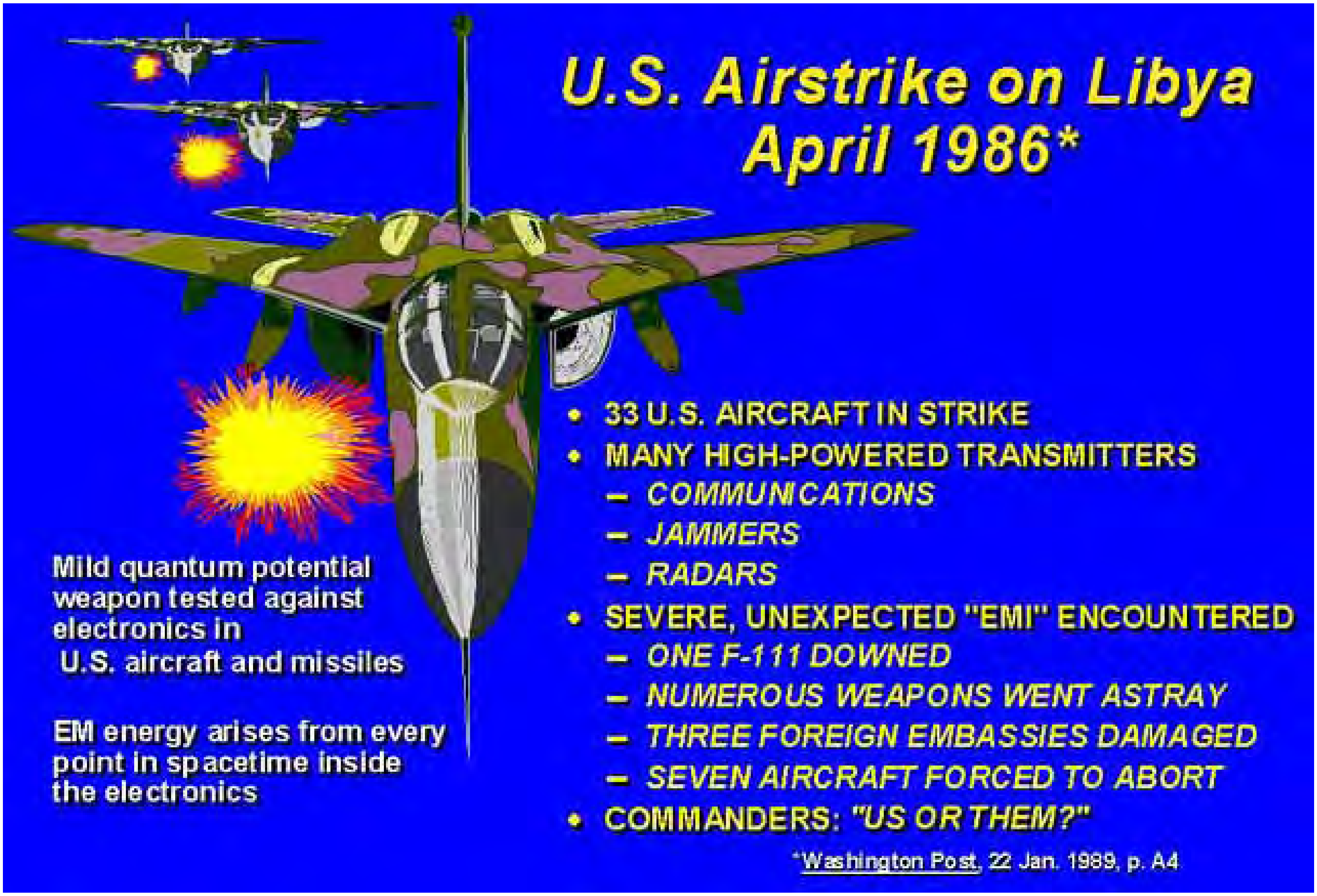

U.S. Airstrike on Libya April 1986*

- 33 U.S. AIRCRAFT IN STRIKE
- MANY HIGH-POWERED TRANSMITTERS
  - *COMMUNICATIONS*
  - *JAMMERS*
  - *RADARS*
- SEVERE, UNEXPECTED "EMI" ENCOUNTERED
  - *ONE F-111 DOWNED*
  - *NUMEROUS WEAPONS WENT ASTRAY*
  - *THREE FOREIGN EMBASSIES DAMAGED*
  - *SEVEN AIRCRAFT FORCED TO ABORT*
- COMMANDERS: *"US OR THEM?"*

Mild quantum potential weapon tested against electronics in U.S. aircraft and missiles

EM energy arises from every point in spacetime inside the electronics

*Washington Post, 22 Jan. 1989, p. A4

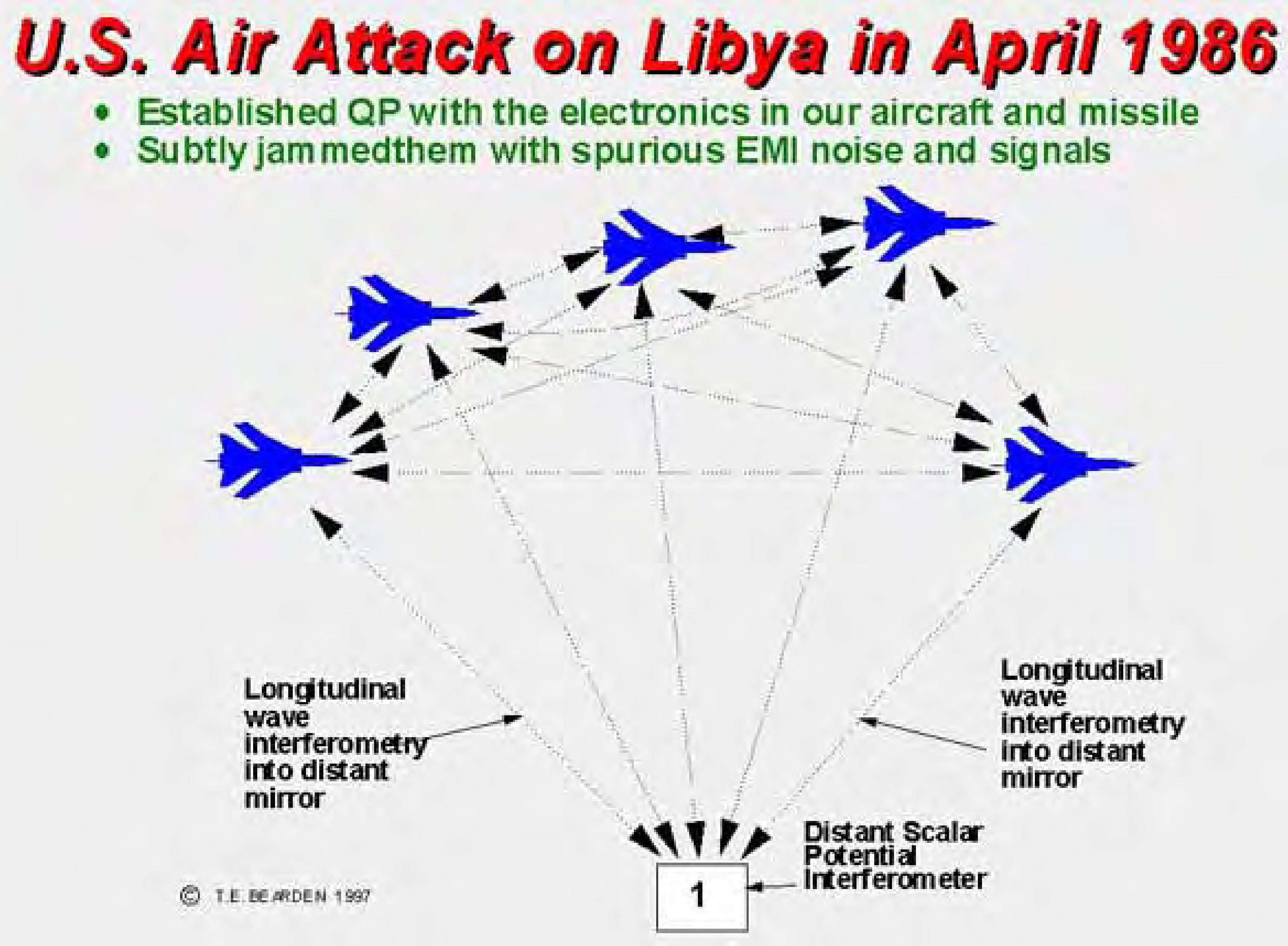

U.S. Air Attack on Libya in April 1986

- Established QP with the electronics in our aircraft and missile
- Subtly jammedthem with spurious EMI noise and signals

Longitudinal wave interferometry into distant mirror

Longitudinal wave interferometry into distant mirror

Distant Scalar Potential Interferometer

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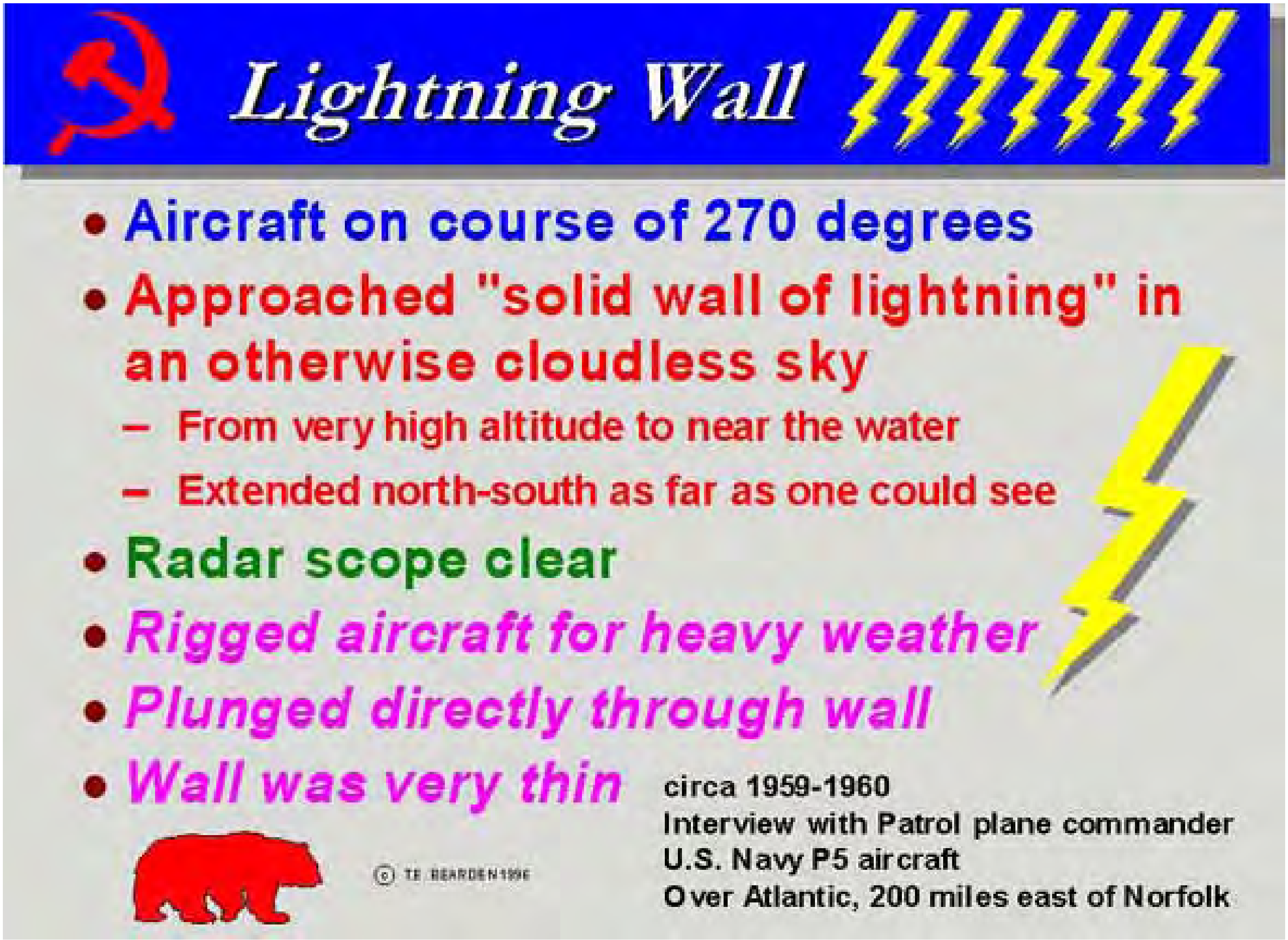

Lightning Wall

- Aircraft on course of 270 degrees
- Approached "solid wall of lightning" in an otherwise cloudless sky
  - From very high altitude to near the water
  - Extended north-south as far as one could see
- Radar scope clear
- *Rigged aircraft for heavy weather*
- *Plunged directly through wall*
- *Wall was very thin*

circa 1959-1960
Interview with Patrol plane commander
U.S. Navy P5 aircraft
Over Atlantic, 200 miles east of Norfolk

© T.E. BEARDEN 1996

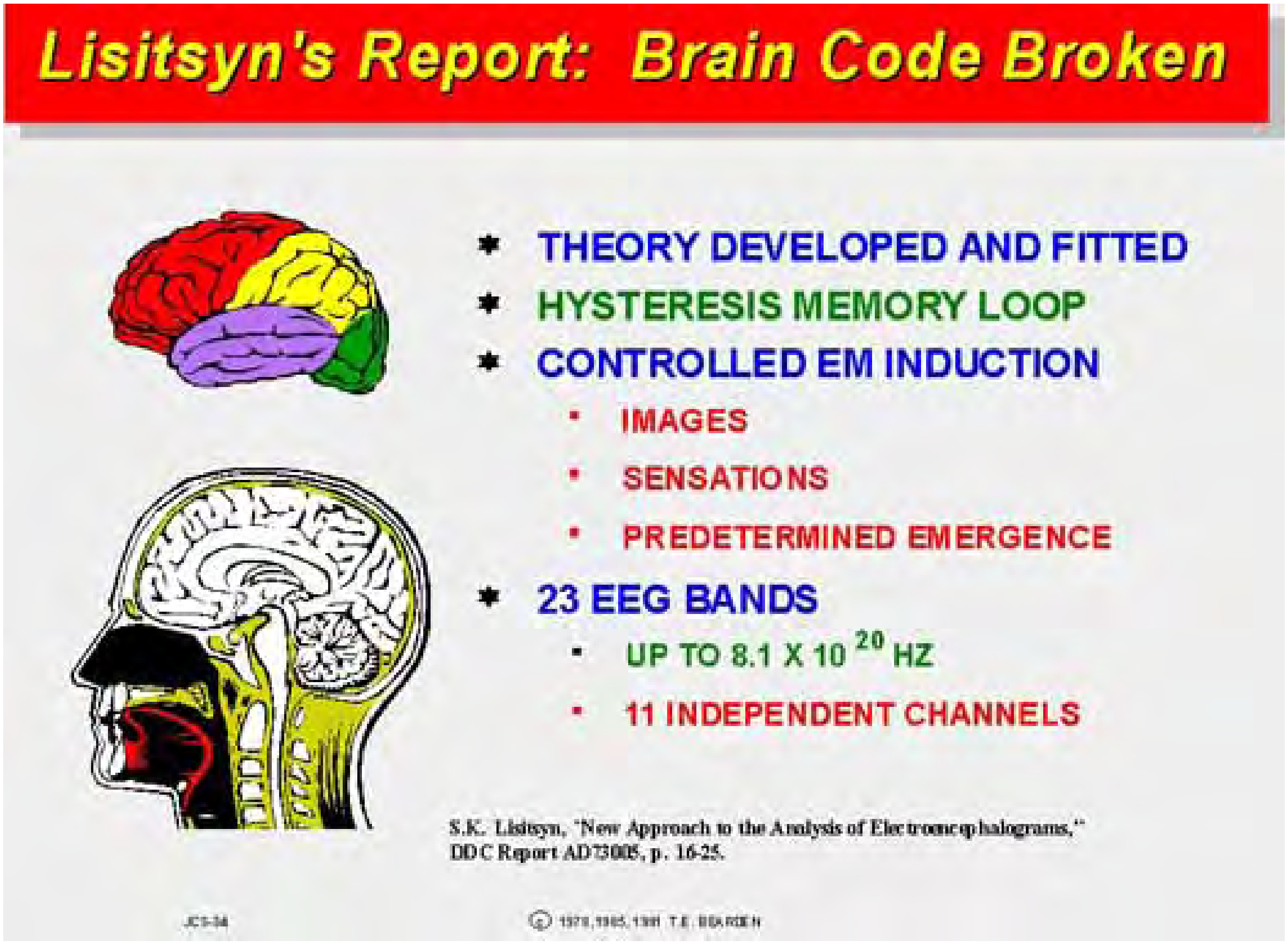

Lisitsyn's Report: Brain Code Broken

- THEORY DEVELOPED AND FITTED
- HYSTERESIS MEMORY LOOP
- CONTROLLED EM INDUCTION
  - IMAGES
  - SENSATIONS
  - PREDETERMINED EMERGENCE
- 23 EEG BANDS
  - UP TO 8.1×10^{20} HZ
  - 11 INDEPENDENT CHANNELS

S.K. Lisitsyn, "New Approach to the Analysis of Electroencephalograms," DDC Report AD73005, p. 16-25.

JCS-34

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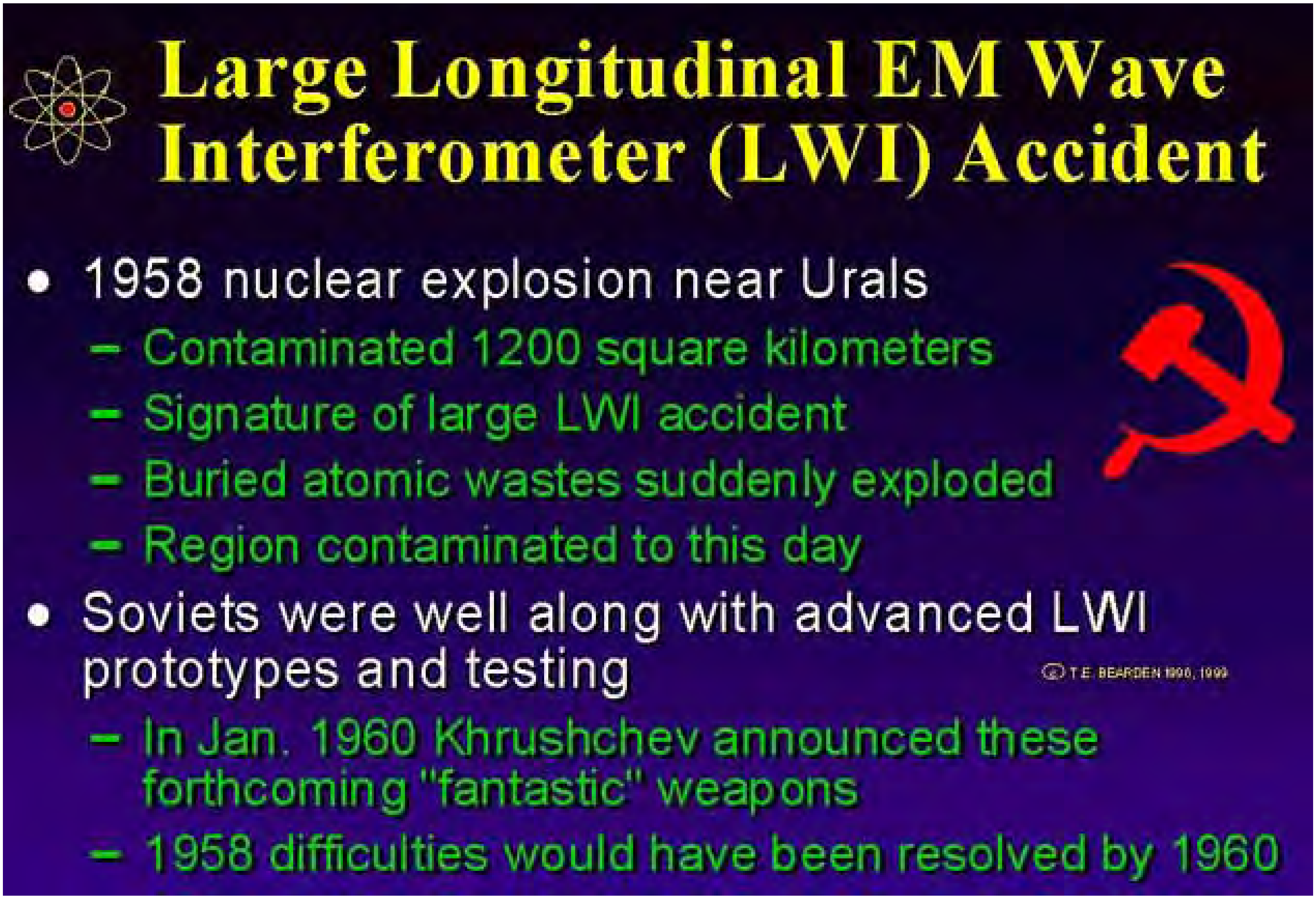

Large Longitudinal EM Wave Interferometer (LWI) Accident

- 1958 nuclear explosion near Urals
  - Contaminated 1200 square kilometers
  - Signature of large LWI accident
  - Buried atomic wastes suddenly exploded
  - Region contaminated to this day
- Soviets were well along with advanced LWI prototypes and testing
  - In Jan. 1960 Khrushchev announced these forthcoming "fantastic" weapons
  - 1958 difficulties would have been resolved by 1960

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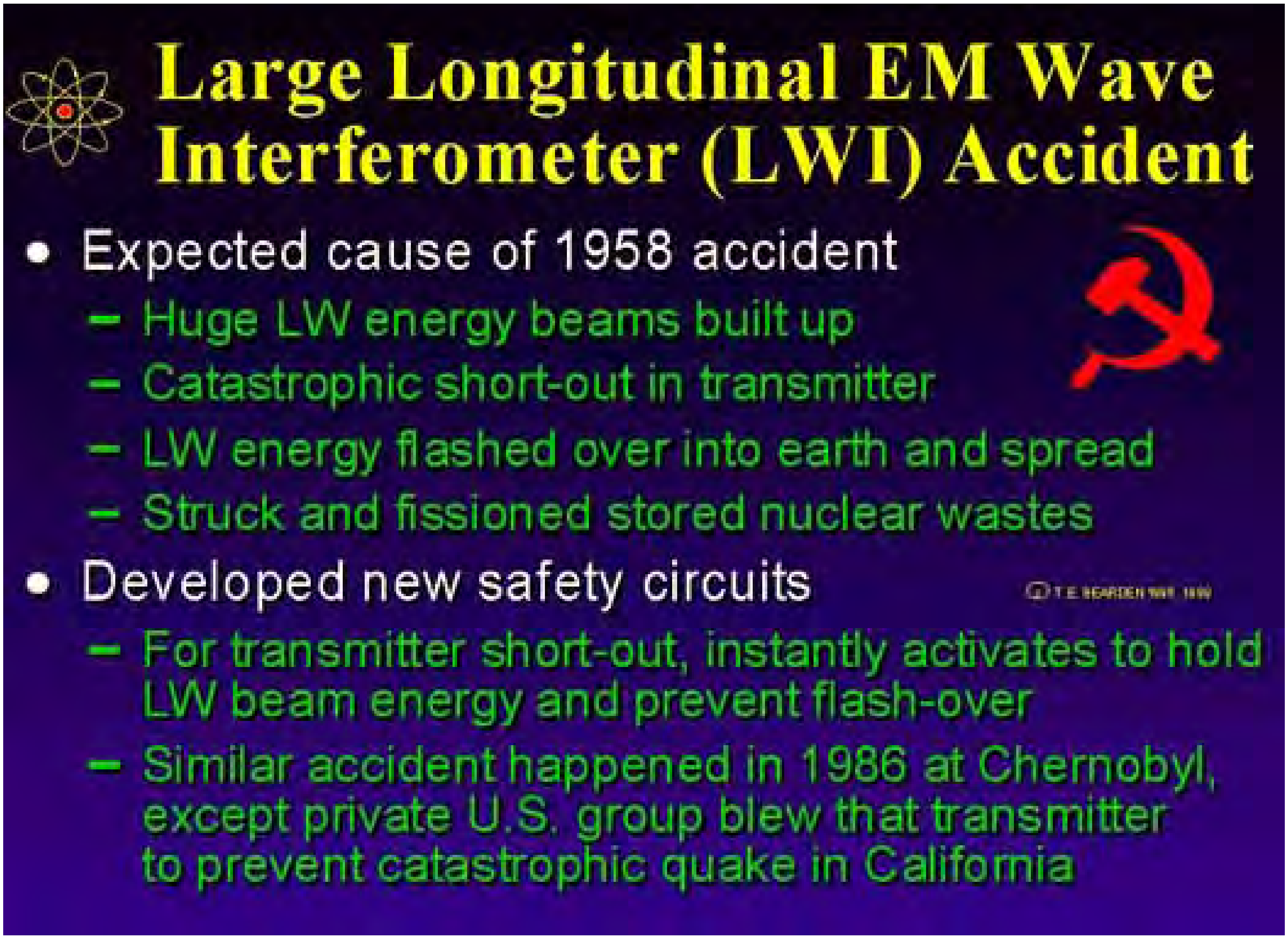

Large Longitudinal EM Wave Interferometer (LWI) Accident

- Expected cause of 1958 accident
  - Huge LW energy beams built up
  - Catastrophic short-out in transmitter
  - LW energy flashed over into earth and spread
  - Struck and fissioned stored nuclear wastes
- Developed new safety circuits
  - For transmitter short-out, instantly activates to hold LW beam energy and prevent flash-over
  - Similar accident happened in 1986 at Chernobyl, except private U.S. group blew that transmitter to prevent catastrophic quake in California

© T.E. BEARDEN [illegible]

(Use of Hidden Information Content of the Field)
(Can Provide Action-at-a-Distance)

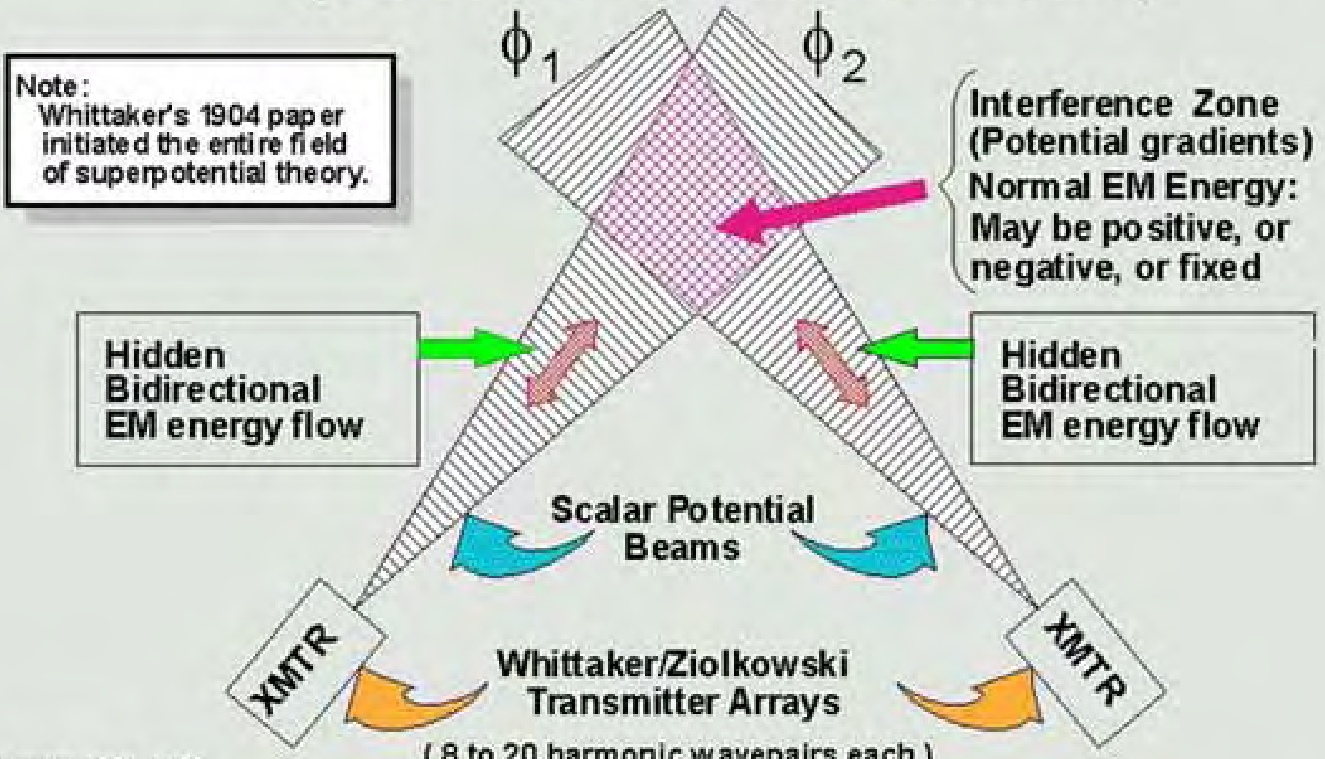
ϕ_1
ϕ_2
Note:
Whittaker's 1904 paper initiated the entire field of superpotential theory.
Interference Zone
(Potential gradients)
Normal EM Energy:
May be positive, or negative, or fixed
Hidden Bidirectional EM energy flow
Hidden Bidirectional EM energy flow
Scalar Potential Beams
XMTR
XMTR
Whittaker/Ziolkowski Transmitter Arrays
(8 to 20 harmonic wavepairs each)

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Figure 5. Scalar potential interferometry (between the two sets of bidirectional longitudinal EM wavepair functions) produces all EM force fields and waves.

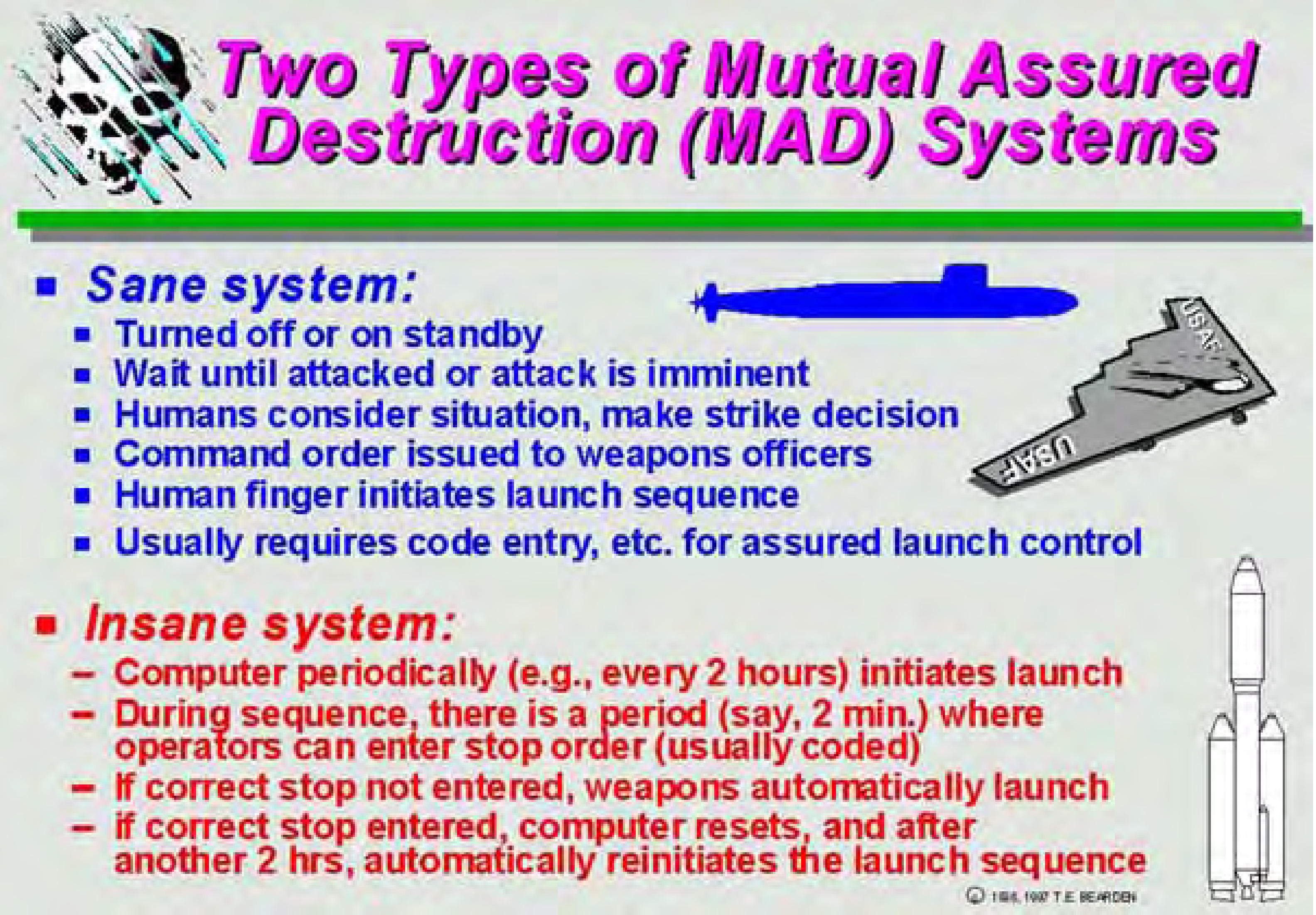

Two Types of Mutual Assured Destruction (MAD) Systems

- **Sane system:**
  - Turned off or on standby
  - Wait until attacked or attack is imminent
  - Humans consider situation, make strike decision
  - Command order issued to weapons officers
  - Human finger initiates launch sequence
  - Usually requires code entry, etc. for assured launch control
- **Insane system:**
  - Computer periodically (e.g., every 2 hours) initiates launch
  - During sequence, there is a period (say, 2 min.) where operators can enter stop order (usually coded)
  - If correct stop not entered, weapons automatically launch
  - If correct stop entered, computer resets, and after another 2 hrs, automatically reinitiates the launch sequence

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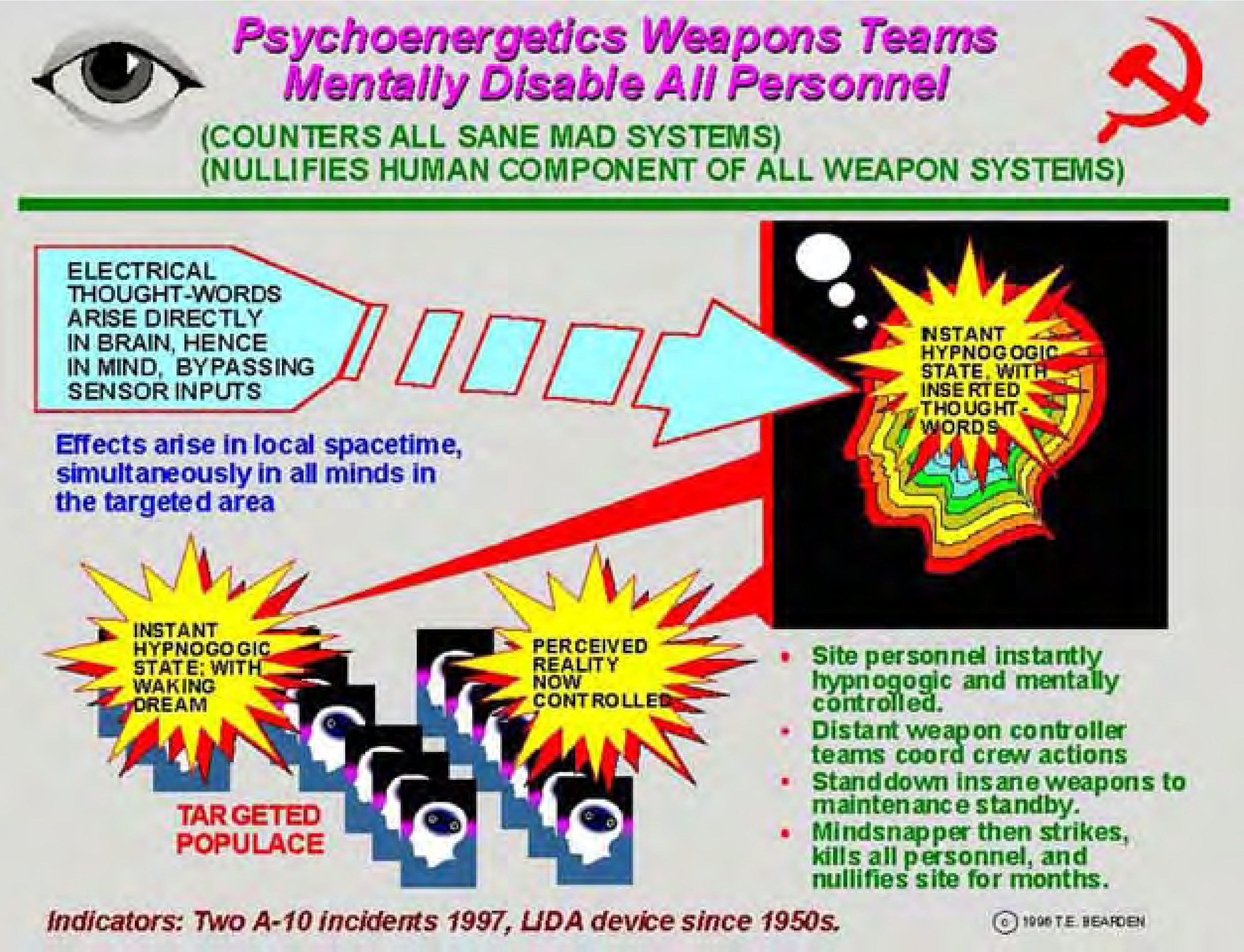

Psychoenergetics Weapons Teams Mentally Disable All Personnel

(COUNTERS ALL SANE MAD SYSTEMS)
(NULLIFIES HUMAN COMPONENT OF ALL WEAPON SYSTEMS)

ELECTRICAL THOUGHT-WORDS ARISE DIRECTLY IN BRAIN, HENCE IN MIND, BYPASSING SENSOR INPUTS

INSTANT HYPNOGOGIC STATE, WITH INSERTED THOUGHT-WORDS

Effects arise in local spacetime, simultaneously in all minds in the targeted area

INSTANT HYPNOGOGIC STATE: WITH WAKING DREAM

PERCEIVED REALITY NOW CONTROLLED

TARGETED POPULACE

- Site personnel instantly hypnogogic and mentally controlled.
- Distant weapon controller teams coord crew actions
- Standdown insane weapons to maintenance standby.
- Mindsnapper then strikes, kills all personnel, and nullifies site for months.

Indicators: Two A-10 incidents 1997, LIDA device since 1950s.

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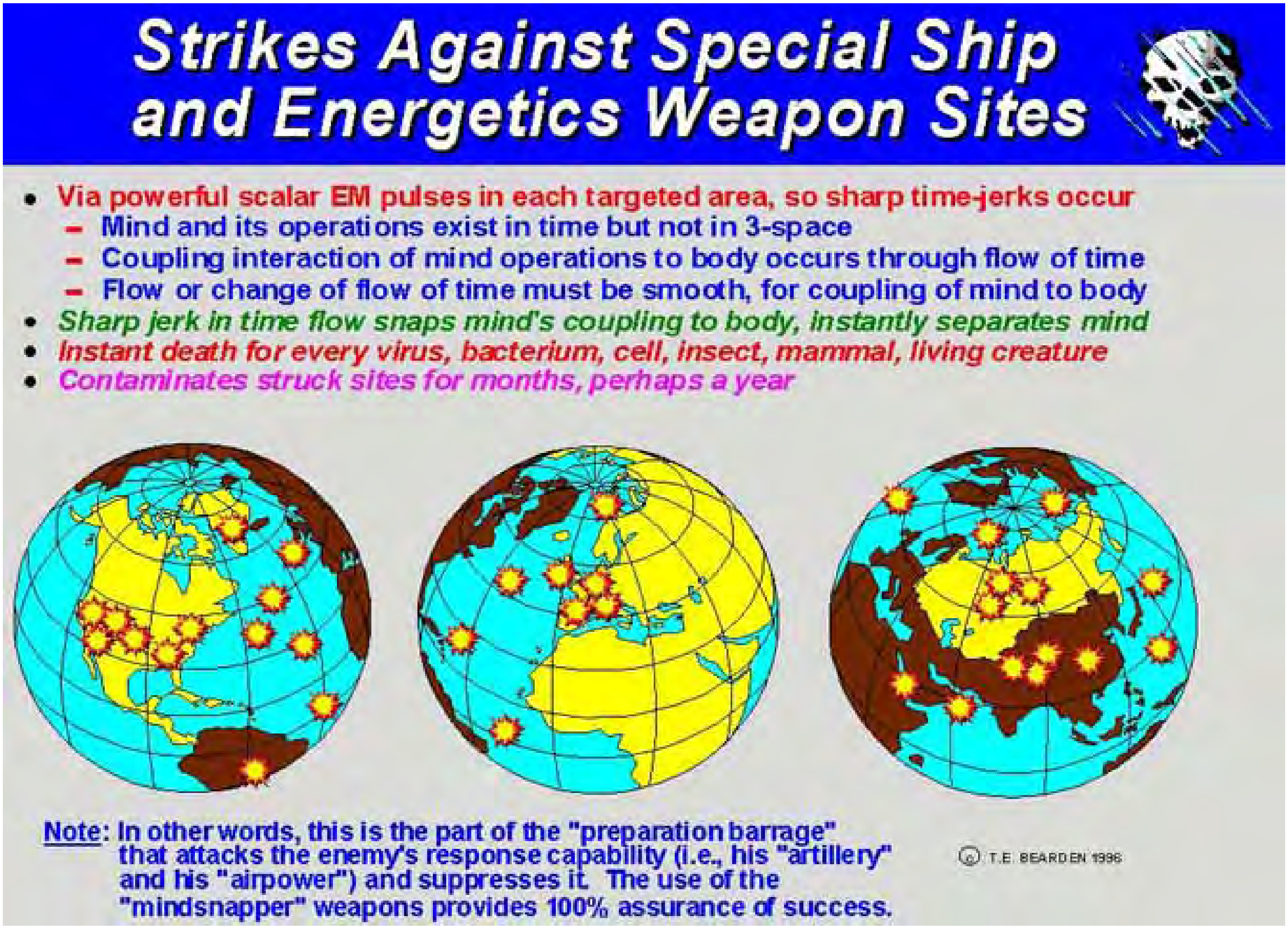

Strikes Against Special Ship and Energetics Weapon Sites

- Via powerful scalar EM pulses in each targeted area, so sharp time-jerks occur
  - Mind and its operations exist in time but not in 3-space
  - Coupling interaction of mind operations to body occurs through flow of time
  - Flow or change of flow of time must be smooth, for coupling of mind to body
- *Sharp jerk in time flow snaps mind's coupling to body, instantly separates mind*
- *Instant death for every virus, bacterium, cell, insect, mammal, living creature*
- *Contaminates struck sites for months, perhaps a year*

Note: In other words, this is the part of the "preparation barrage" that attacks the enemy's response capability (i.e., his "artillery" and his "airpower") and suppresses it. The use of the "mindsnapper" weapons provides 100% assurance of success.

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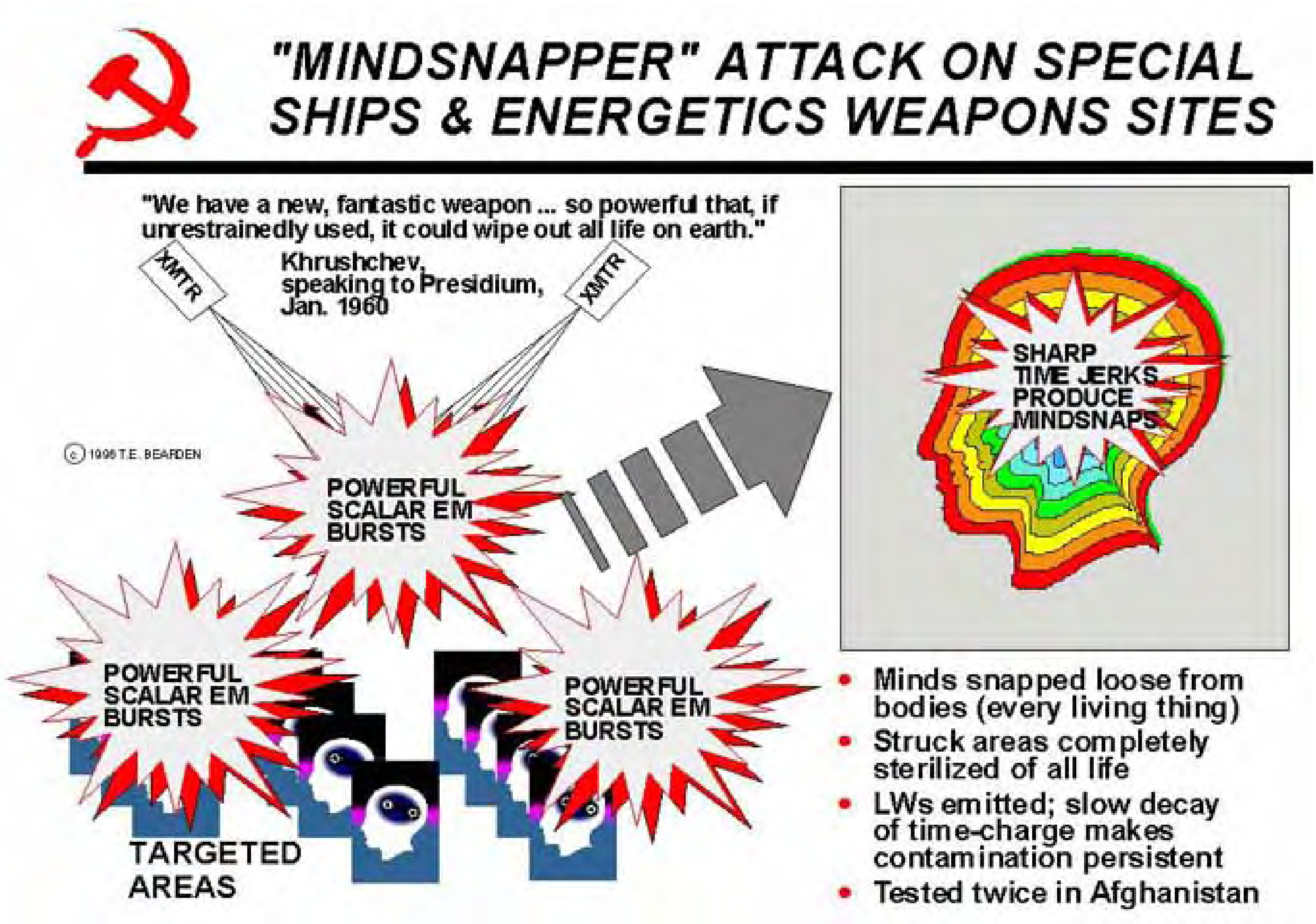

"MINDSNAPPER" ATTACK ON SPECIAL SHIPS & ENERGETICS WEAPONS SITES

"We have a new, fantastic weapon ... so powerful that, if unrestrainedly used, it could wipe out all life on earth."

Khrushchev,
speaking to Presidium,
Jan. 1960

XMTR
XMTR
POWERFUL SCALAR EM BURSTS
POWERFUL SCALAR EM BURSTS
POWERFUL SCALAR EM BURSTS
TARGETED AREAS
SHARP TIME JERKS PRODUCE MINDSNAPS

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- Minds snapped loose from bodies (every living thing)
- Struck areas completely sterilized of all life
- LWs emitted; slow decay of time-charge makes contamination persistent
- Tested twice in Afghanistan

The Tom Bearden Website

Help support the research

How Much Off Guard Are We?

- Slide 1
- Slide 2
- Slide 3
- Slide 4
- Slide 5
- Slide 6
- Slide 7

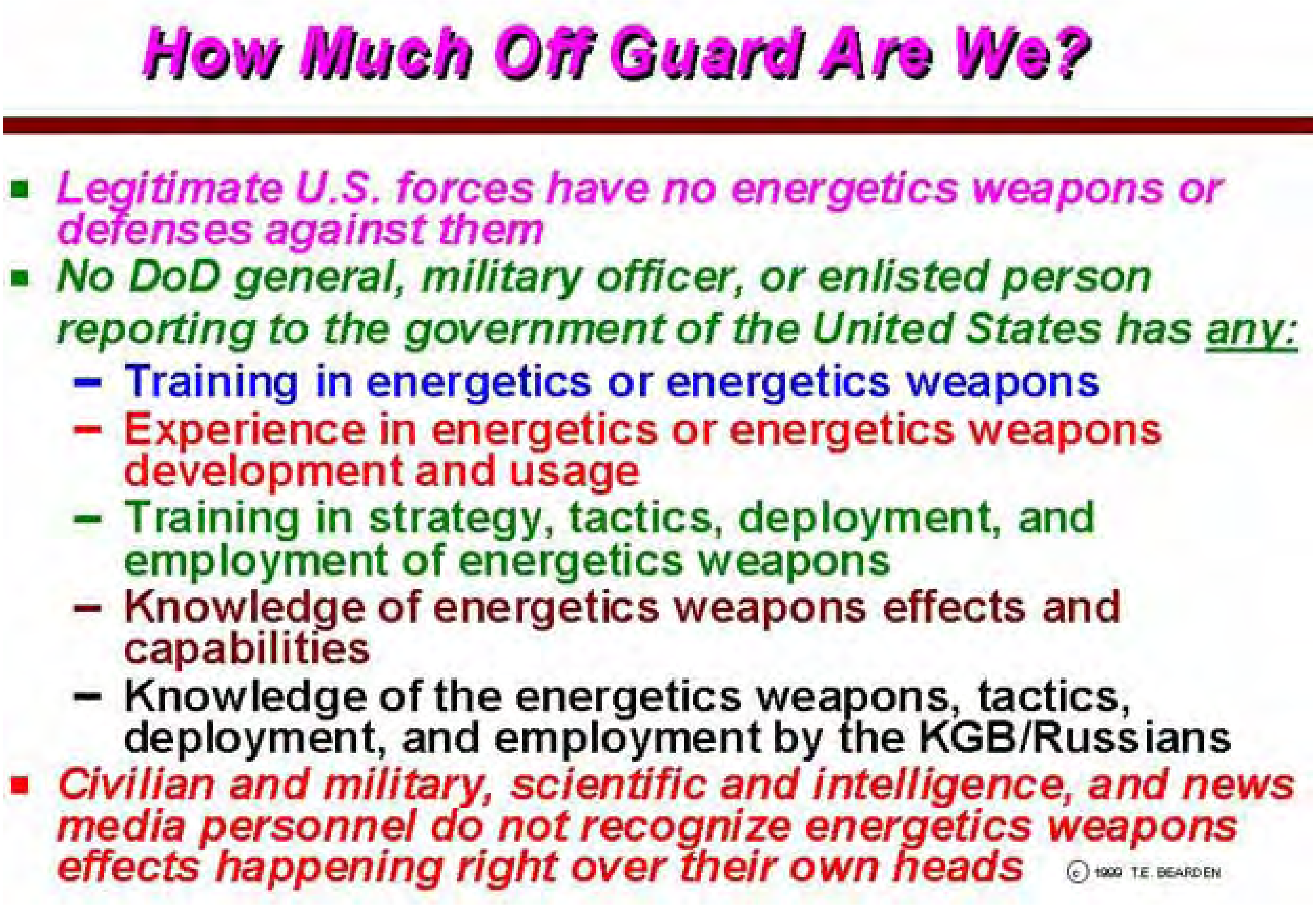

How Much Off Guard Are We?

- *Legitimate U.S. forces have no energetics weapons or defenses against them*
- *No DoD general, military officer, or enlisted person reporting to the government of the United States has any:*
  - Training in energetics or energetics weapons
  - Experience in energetics or energetics weapons development and usage
  - Training in strategy, tactics, deployment, and employment of energetics weapons
  - Knowledge of energetics weapons effects and capabilities
  - Knowledge of the energetics weapons, tactics, deployment, and employment by the KGB/Russians
- *Civilian and military, scientific and intelligence, and news media personnel do not recognize energetics weapons effects happening right over their own heads*

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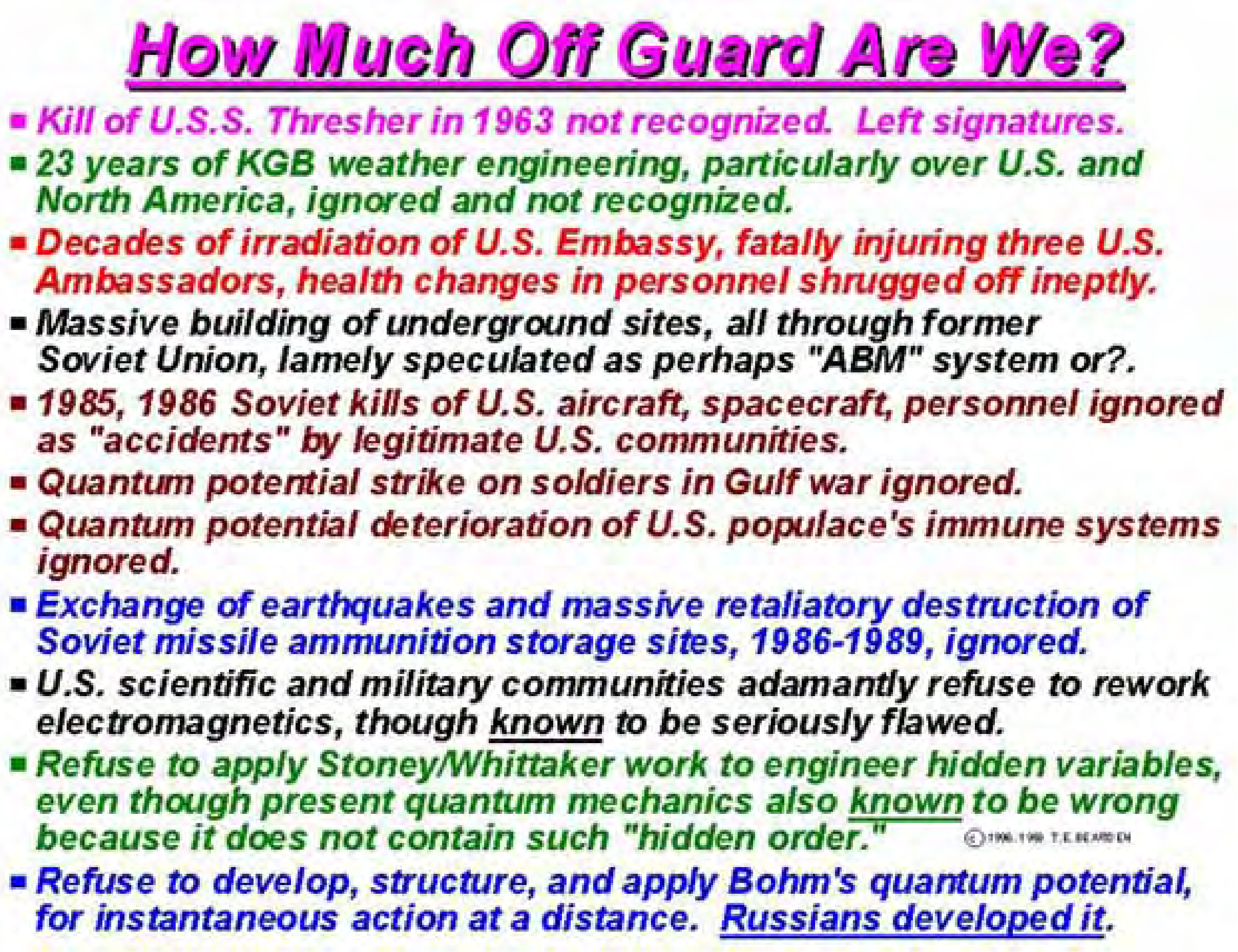

How Much Off Guard Are We?

- *Kill of U.S.S. Thresher in 1963 not recognized. Left signatures.*
- *23 years of KGB weather engineering, particularly over U.S. and North America, ignored and not recognized.*
- *Decades of irradiation of U.S. Embassy, fatally injuring three U.S. Ambassadors, health changes in personnel shrugged off ineptly.*
- *Massive building of underground sites, all through former Soviet Union, lamely speculated as perhaps "ABM" system or?.*
- *1985, 1986 Soviet kills of U.S. aircraft, spacecraft, personnel ignored as "accidents" by legitimate U.S. communities.*
- *Quantum potential strike on soldiers in Gulf war ignored.*
- *Quantum potential deterioration of U.S. populace's immune systems ignored.*
- *Exchange of earthquakes and massive retaliatory destruction of Soviet missile ammunition storage sites, 1986-1989, ignored.*
- *U.S. scientific and military communities adamantly refuse to rework electromagnetics, though known to be seriously flawed.*
- *Refuse to apply Stoney/Whittaker work to engineer hidden variables, even though present quantum mechanics also known to be wrong because it does not contain such "hidden order."*
- *Refuse to develop, structure, and apply Bohm's quantum potential, for instantaneous action at a distance. Russians developed it.*

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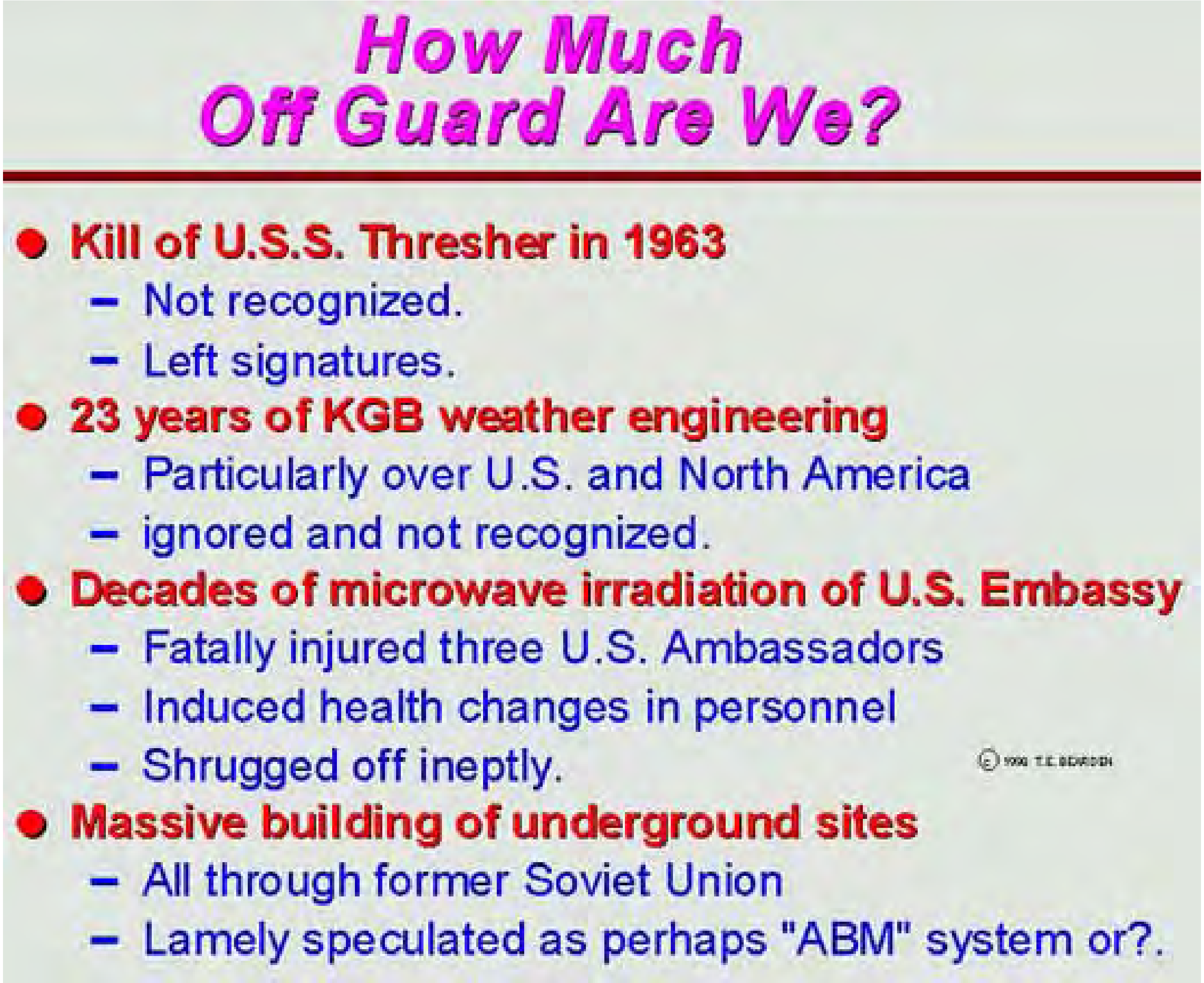

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  - Left signatures.
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  - Fatally injured three U.S. Ambassadors
  - Induced health changes in personnel
  - Shrugged off ineptly.
- **Massive building of underground sites**
  - All through former Soviet Union
  - Lamely speculated as perhaps "ABM" system or?.

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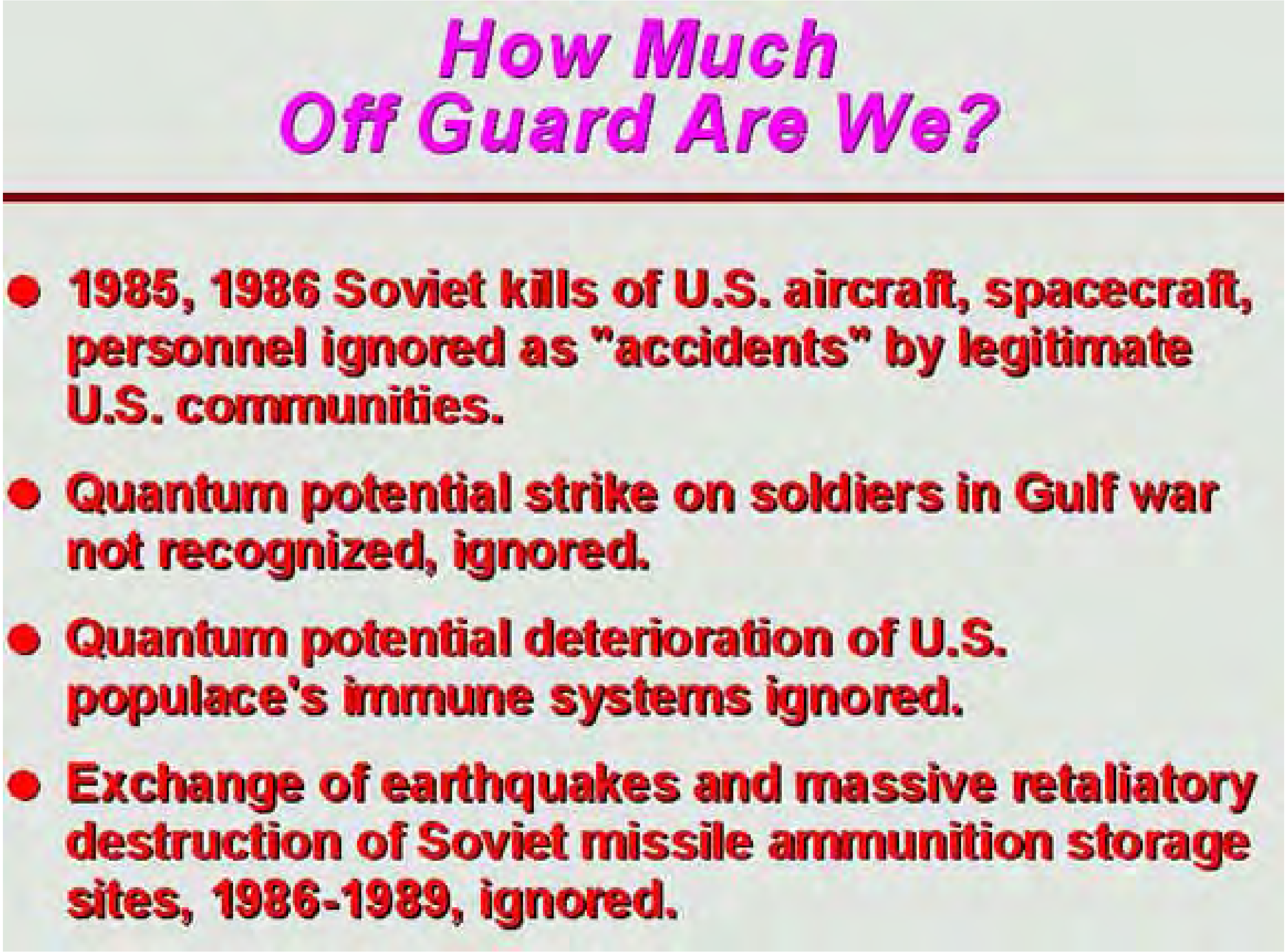

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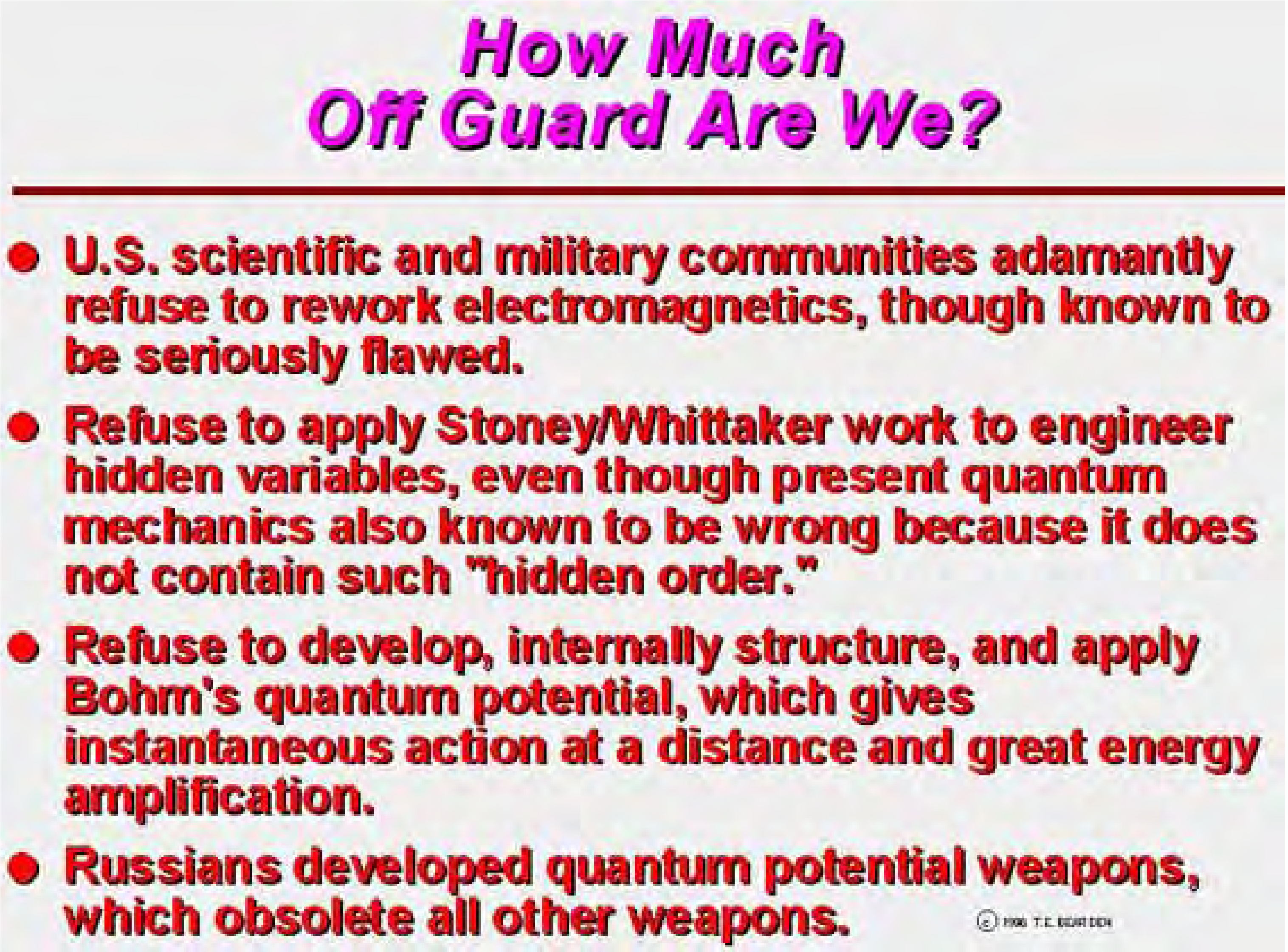

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- Refuse to apply Stoney/Whittaker work to engineer hidden variables, even though present quantum mechanics also known to be wrong because it does not contain such "hidden order."
- Refuse to develop, internally structure, and apply Bohm's quantum potential, which gives instantaneous action at a distance and great energy amplification.
- Russians developed quantum potential weapons, which obsolete all other weapons.

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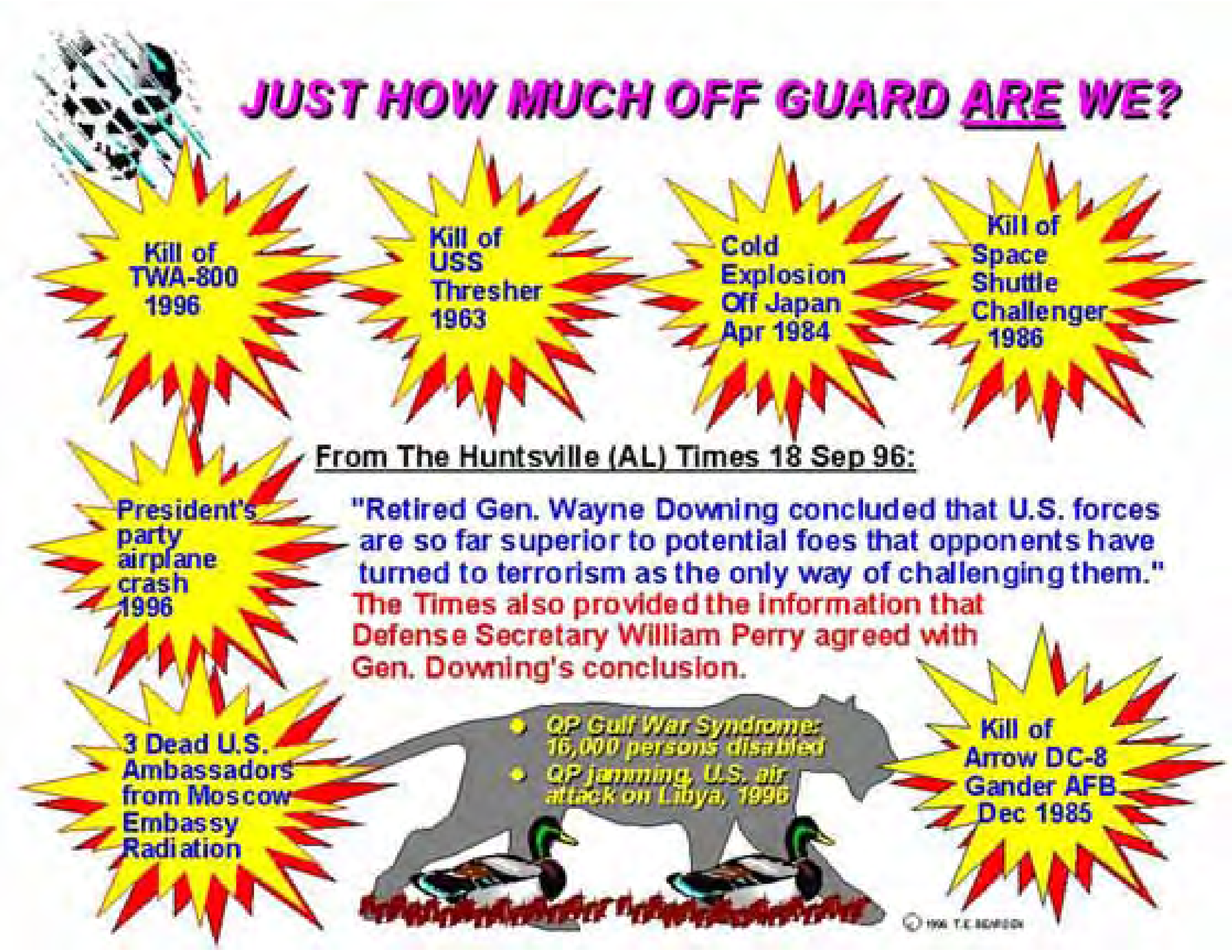

JUST HOW MUCH OFF GUARD ARE WE?

Kill of
TWA-800
1996

Kill of
USS
Thresher
1963

Cold
Explosion
Off Japan
Apr 1984

Kill of
Space
Shuttle
Challenger
1986

President's
party
airplane
crash
1996

From The Huntsville (AL) Times 18 Sep 96:

"Retired Gen. Wayne Downing concluded that U.S. forces are so far superior to potential foes that opponents have turned to terrorism as the only way of challenging them."

The Times also provided the information that Defense Secretary William Perry agreed with Gen. Downing's conclusion.

3 Dead U.S.
Ambassadors
from Moscow
Embassy
Radiation

- *QP Gulf War Syndrome: 16,000 persons disabled*
- *QP jamming, U.S. air attack on Libya, 1996*

Kill of
Arrow DC-8
Gander AFB
Dec 1985

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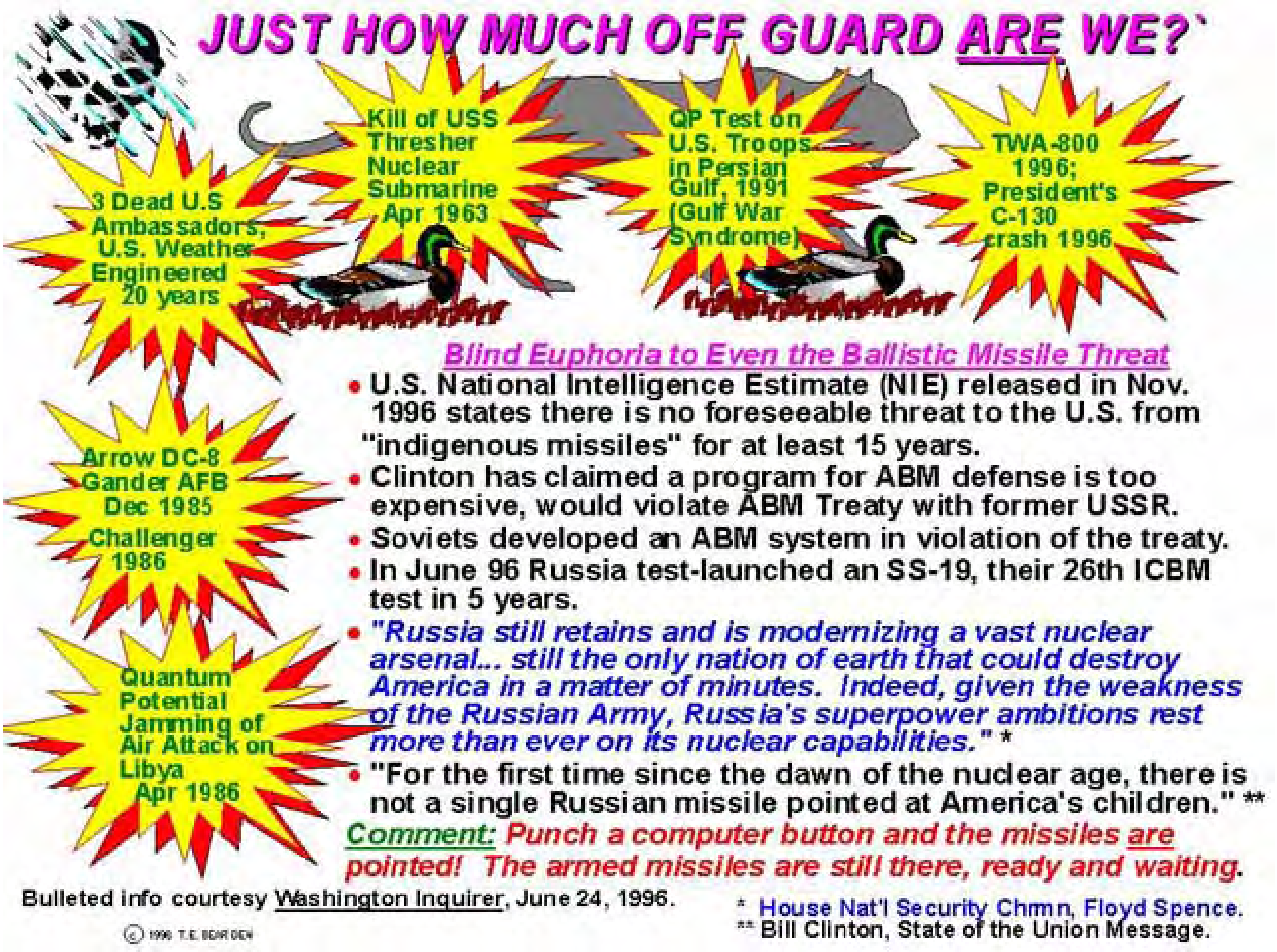

JUST HOW MUCH OFF GUARD <u>ARE</u> WE?`

3 Dead U.S Ambassadors, U.S. Weather Engineered 20 years

Kill of USS Thresher Nuclear Submarine Apr 1963

QP Test on U.S. Troops in Persian Gulf, 1991 (Gulf War Syndrome)

TWA-800 1996; President's C-130 crash 1996

Arrow DC-8 Gander AFB Dec 1985

Challenger 1986

Quantum Potential Jamming of Air Attack on Libya Apr 1986

Blind Euphoria to Even the Ballistic Missile Threat

- U.S. National Intelligence Estimate (NIE) released in Nov. 1996 states there is no foreseeable threat to the U.S. from "indigenous missiles" for at least 15 years.
- Clinton has claimed a program for ABM defense is too expensive, would violate ABM Treaty with former USSR.
- Soviets developed an ABM system in violation of the treaty.
- In June 96 Russia test-launched an SS-19, their 26th ICBM test in 5 years.
- *"Russia still retains and is modernizing a vast nuclear arsenal... still the only nation of earth that could destroy America in a matter of minutes. Indeed, given the weakness of the Russian Army, Russia's superpower ambitions rest more than ever on its nuclear capabilities."* *
- "For the first time since the dawn of the nuclear age, there is not a single Russian missile pointed at America's children." **

Comment: Punch a computer button and the missiles are pointed! The armed missiles are still there, ready and waiting.

Bulleted info courtesy Washington Inquirer, June 24, 1996.

* House Nat'l Security Chmn, Floyd Spence.
** Bill Clinton, State of the Union Message.

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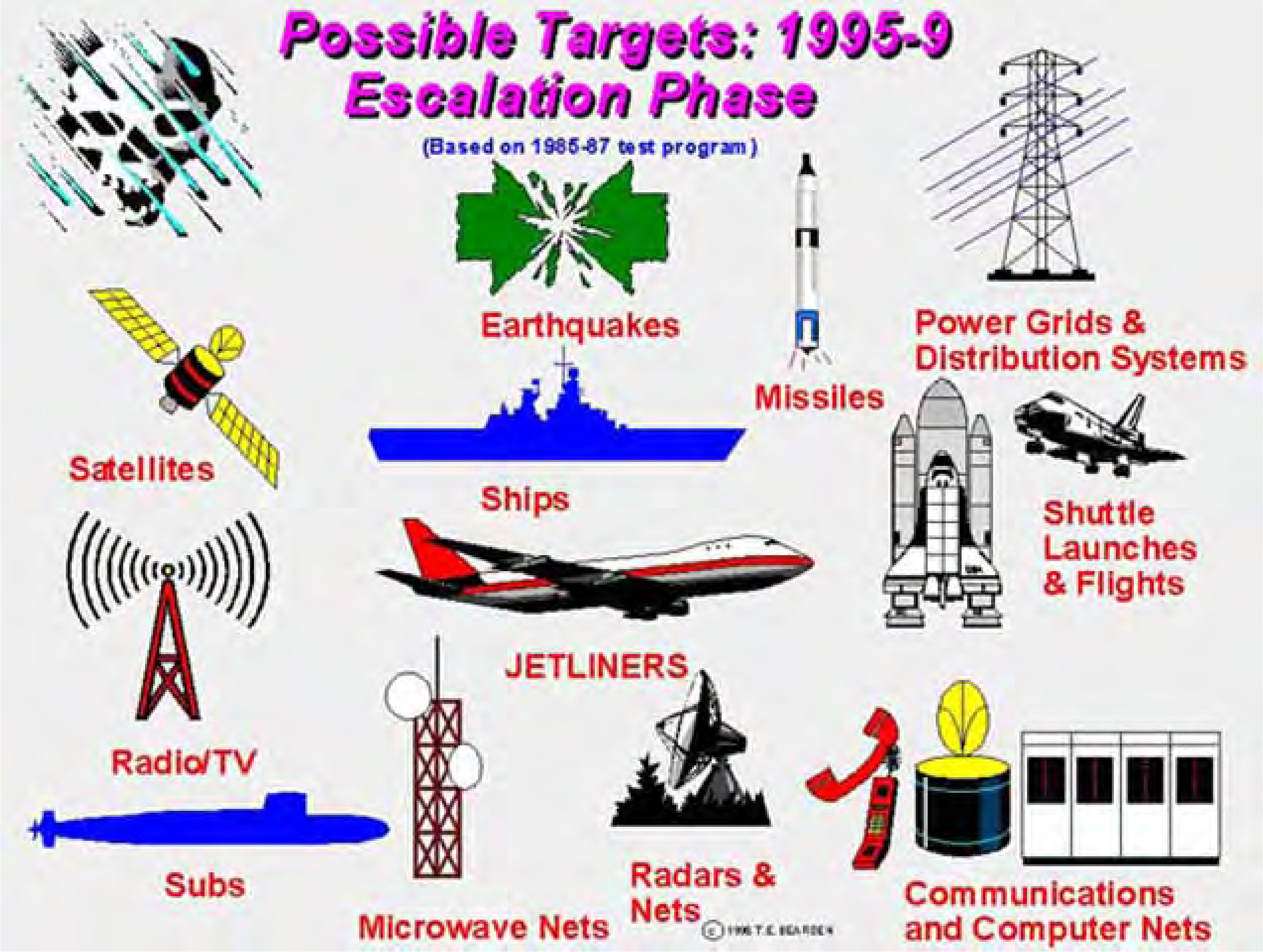
Possible Targets: 1995-9
Escalation Phase
(Based on 1985-87 test program)
Earthquakes
Missiles
Power Grids & Distribution Systems
Satellites
Ships
Shuttle Launches & Flights
JETLINERS
Radio/TV
Subs
Microwave Nets
Radars & Nets
Communications and Computer Nets

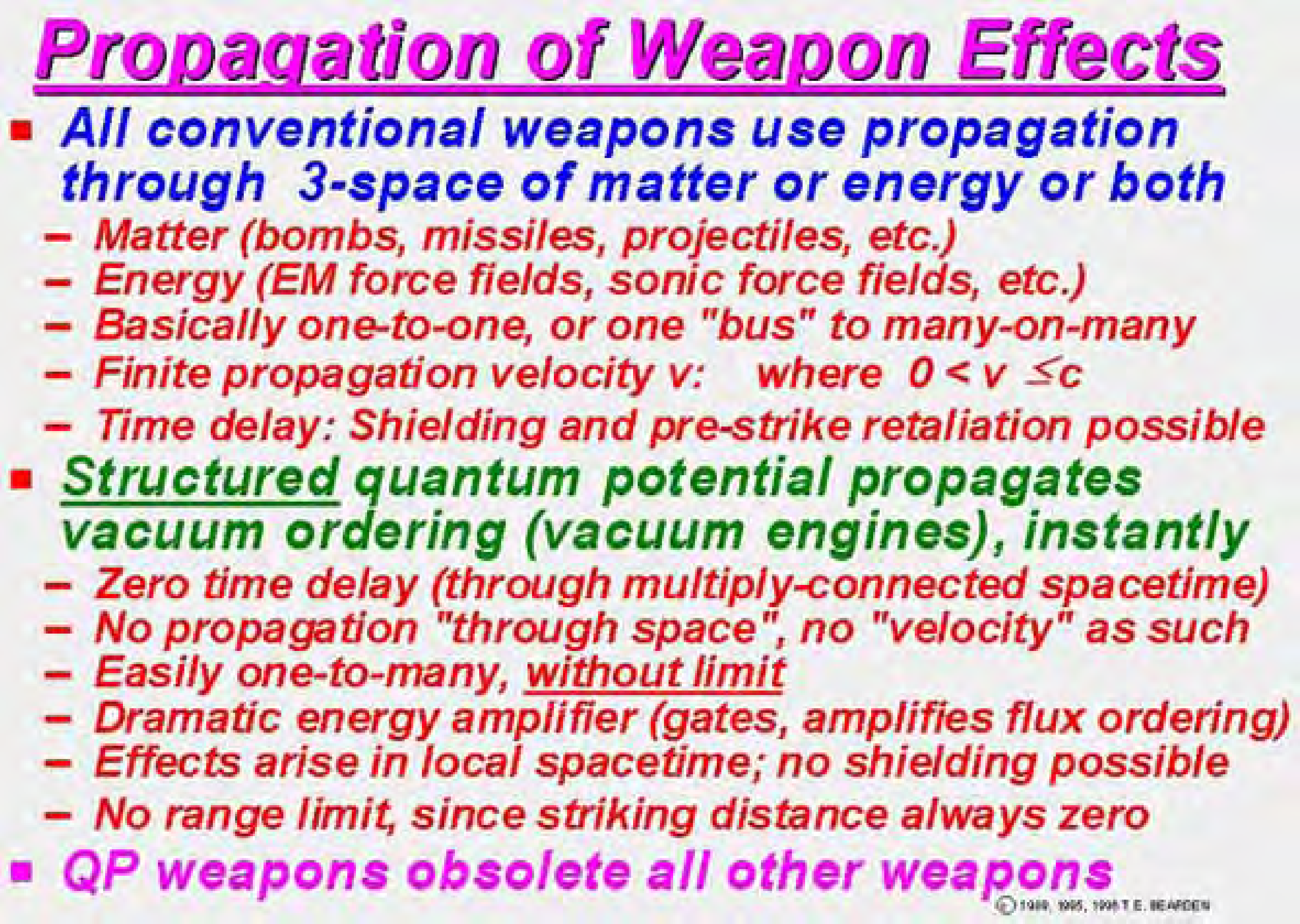

Propagation of Weapon Effects

- **All conventional weapons use propagation through 3-space of matter or energy or both**
  - *Matter (bombs, missiles, projectiles, etc.)*
  - *Energy (EM force fields, sonic force fields, etc.)*
  - *Basically one-to-one, or one "bus" to many-on-many*
  - *Finite propagation velocity v: where $0 < v \leq c$*
  - *Time delay: Shielding and pre-strike retaliation possible*
- **Structured quantum potential propagates vacuum ordering (vacuum engines), instantly**
  - *Zero time delay (through multiply-connected spacetime)*
  - *No propagation "through space", no "velocity" as such*
  - *Easily one-to-many, without limit*
  - *Dramatic energy amplifier (gates, amplifies flux ordering)*
  - *Effects arise in local spacetime; no shielding possible*
  - *No range limit, since striking distance always zero*
- **QP weapons obsolete all other weapons**

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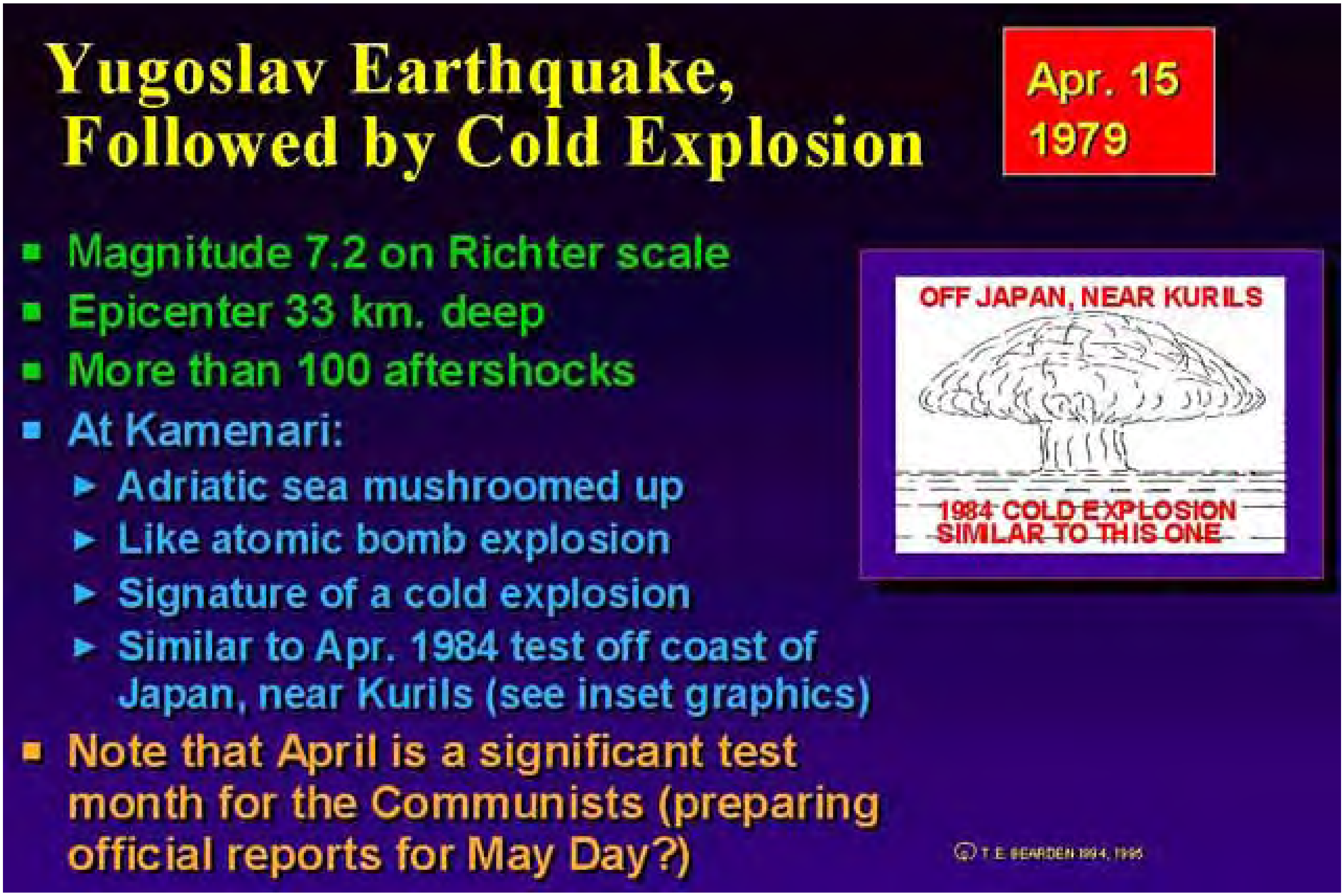

Yugoslav Earthquake, Followed by Cold Explosion

Apr. 15 1979

- Magnitude 7.2 on Richter scale
- Epicenter 33 km. deep
- More than 100 aftershocks
- At Kamenari:
  - Adriatic sea mushroomed up
  - Like atomic bomb explosion
  - Signature of a cold explosion
  - Similar to Apr. 1984 test off coast of Japan, near Kurils (see inset graphics)
- Note that April is a significant test month for the Communists (preparing official reports for May Day?)

OFF JAPAN, NEAR KURILS

1984 COLD EXPLOSION SIMILAR TO THIS ONE

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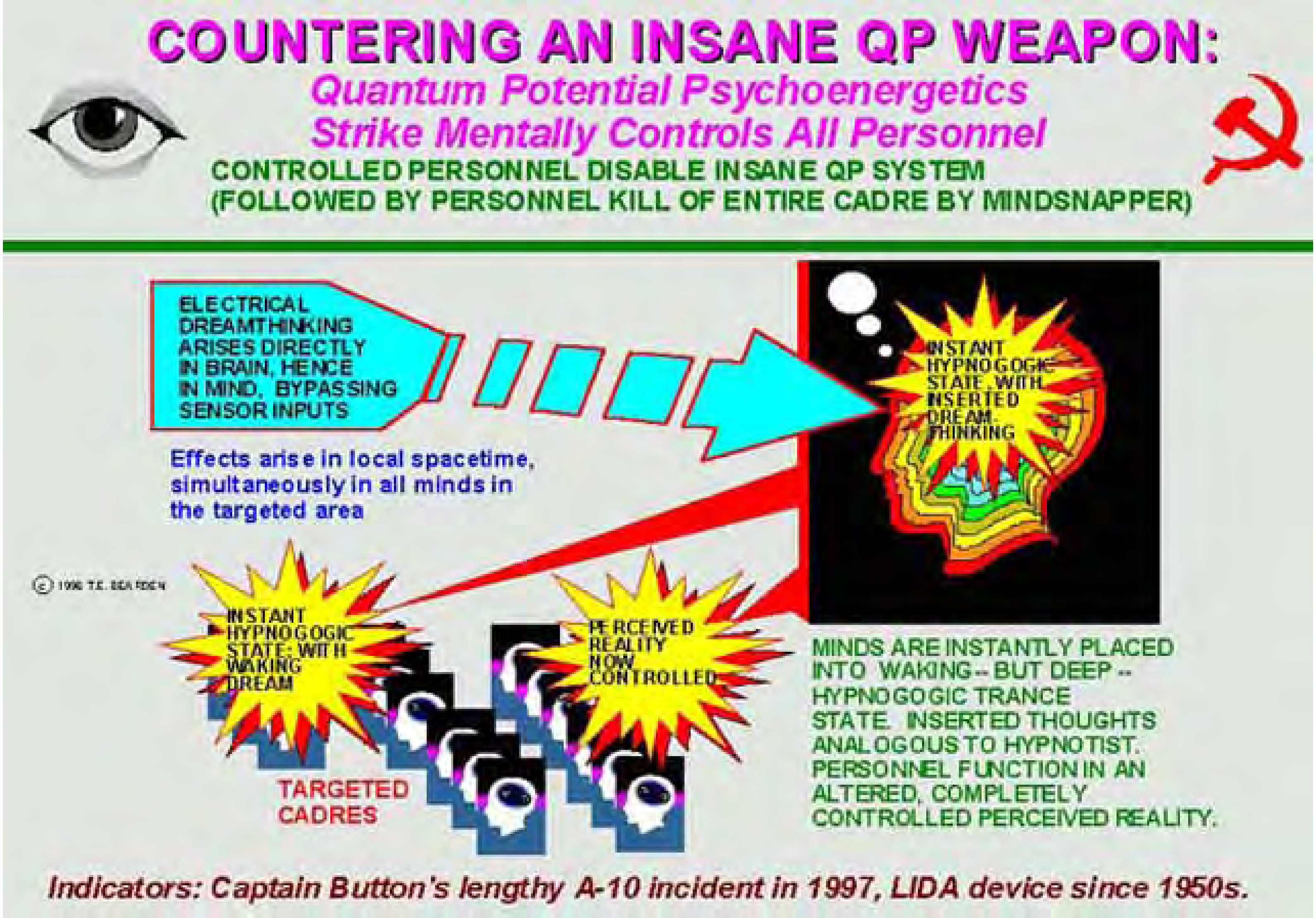

COUNTERING AN INSANE QP WEAPON:

Quantum Potential Psychoenergetics Strike Mentally Controls All Personnel

CONTROLLED PERSONNEL DISABLE INSANE QP SYSTEM (FOLLOWED BY PERSONNEL KILL OF ENTIRE CADRE BY MINDSNAPPER)

ELECTRICAL DREAMTHINKING ARISES DIRECTLY IN BRAIN, HENCE IN MIND, BYPASSING SENSOR INPUTS

Effects arise in local spacetime, simultaneously in all minds in the targeted area

INSTANT HYPNOGOGIC STATE, WITH INSERTED DREAM THINKING
INSTANT HYPNOGOGIC STATE: WITH WAKING DREAM
PERCEIVED REALITY NOW CONTROLLED
TARGETED CADRES

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MINDS ARE INSTANTLY PLACED INTO WAKING-- BUT DEEP -- HYPNOGOGIC TRANCE STATE. INSERTED THOUGHTS ANALOGOUS TO HYPNOTIST. PERSONNEL FUNCTION IN AN ALTERED, COMPLETELY CONTROLLED PERCEIVED REALITY.

Indicators: Captain Button's lengthy A-10 incident in 1997, LIDA device since 1950s.

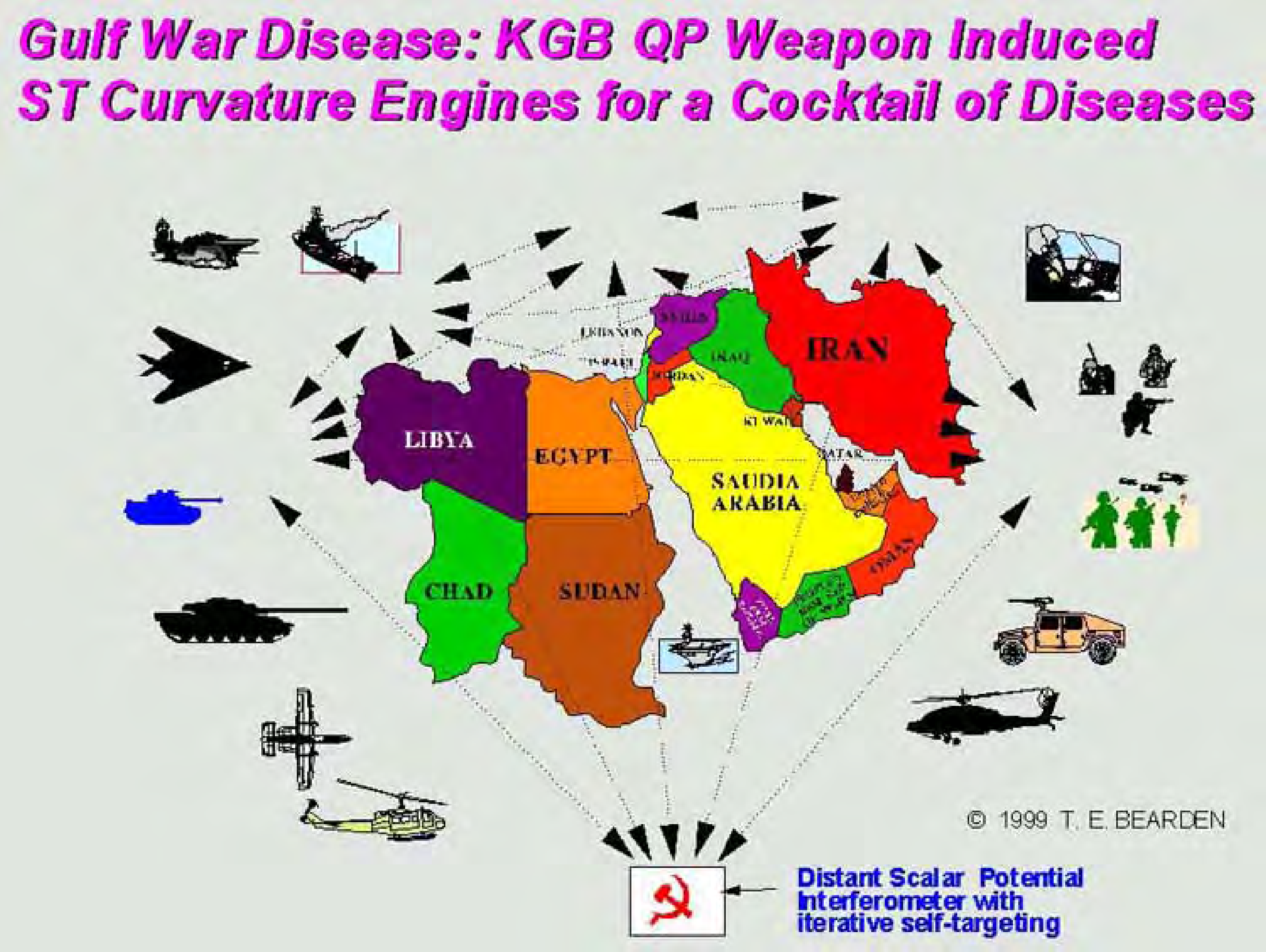

Gulf War Disease: KGB QP Weapon Induced ST Curvature Engines for a Cocktail of Diseases

LEBANON
SYRIA
ISRAEL
JORDAN
IRAQ
IRAN
KUWAIT
LIBYA
EGYPT
QATAR
SAUDIA ARABIA
CHAD
SUDAN
OMAN

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Distant Scalar Potential Interferometer with iterative self-targeting

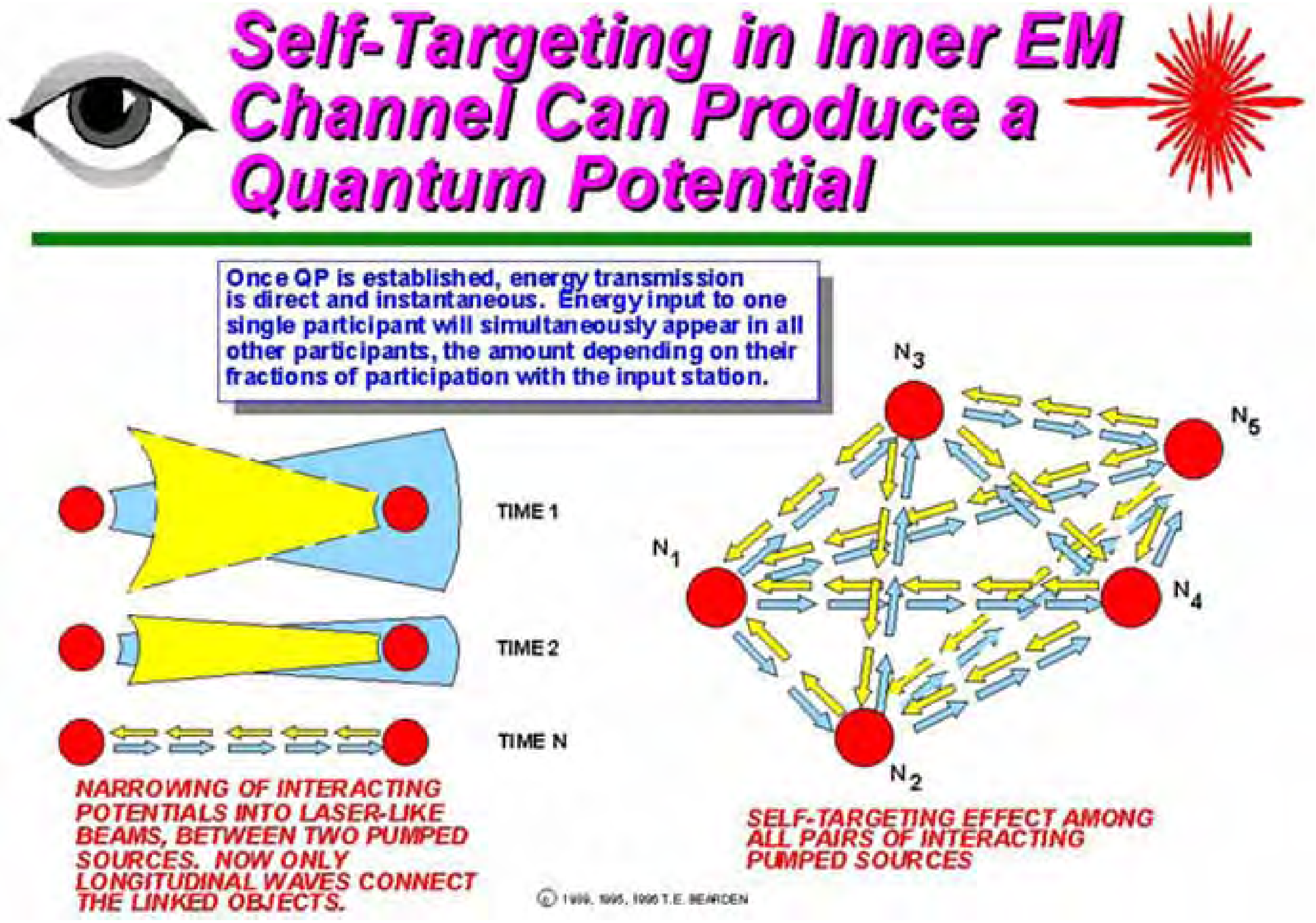

Self-Targeting in Inner EM Channel Can Produce a Quantum Potential

Once QP is established, energy transmission is direct and instantaneous. Energy input to one single participant will simultaneously appear in all other participants, the amount depending on their fractions of participation with the input station.

NARROWING OF INTERACTING POTENTIALS INTO LASER-LIKE BEAMS, BETWEEN TWO PUMPED SOURCES. NOW ONLY LONGITUDINAL WAVES CONNECT THE LINKED OBJECTS.

SELF-TARGETING EFFECT AMONG ALL PAIRS OF INTERACTING PUMPED SOURCES

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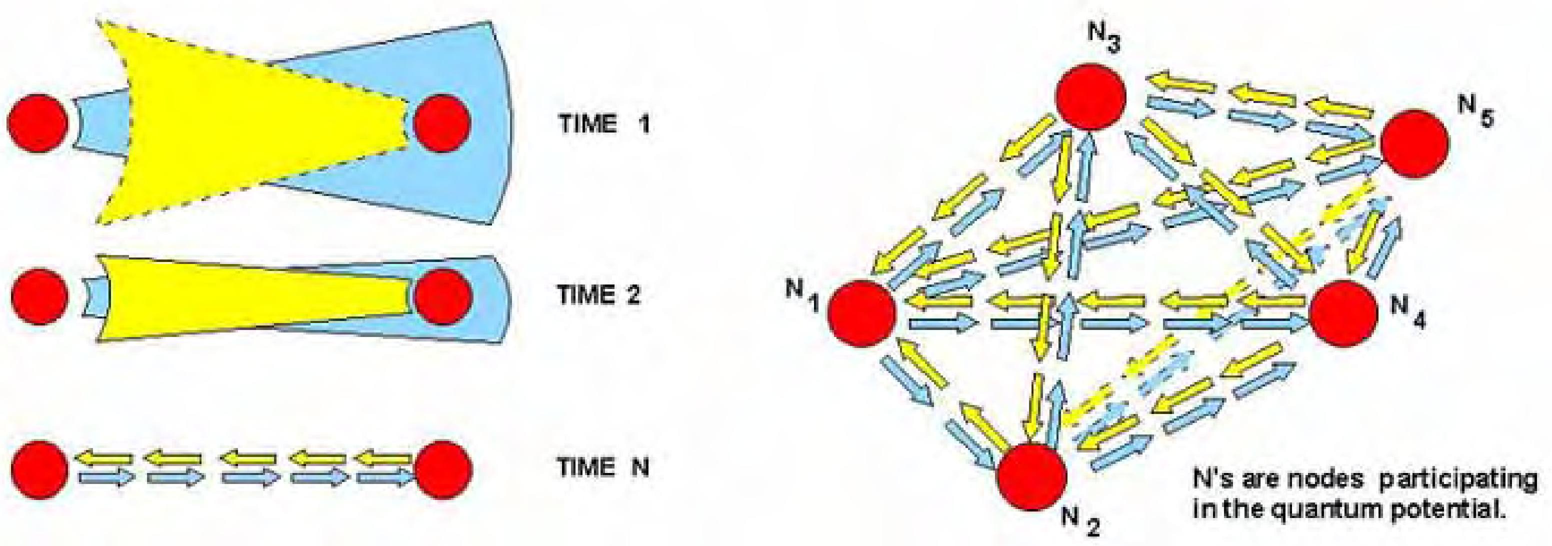

N's are nodes participating in the quantum potential.

a. Iterative retroreflection between any pair of nodes narrows the interconnecting potentials to a laser-like, bidirectional beam. Iterative phase conjugate reflection provides self-targeting.

b. The quantum potential exists as narrow, laser-like beams between participating nodes, even when the nodes are widely separated. The beam space is multiply-connected; transmission is instantaneous.

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Consider the hidden Stoney/Whittaker bidirectional EM waves that comprise the potential from each source node. If these nodes have sufficient intersymmetry of dynamic material form, then self-targeting occurs between the two nodes of any nodal pair. By iterative phase conjugate reflection, the scattering is narrowed into interconnecting wavepairs, in laser-like beams, between each two nodes. Thus the interconnecting potentials narrow into laser-like, bidirectional beams. The Coulomb gauge may apply, and a quantum potential may be formed.

Figure 30. Mechanism for generating a quantum potential, by iterative self-targeting induced into a system of multiple scattering nodes. Once a QP is established, spatial separation has little or no effect.

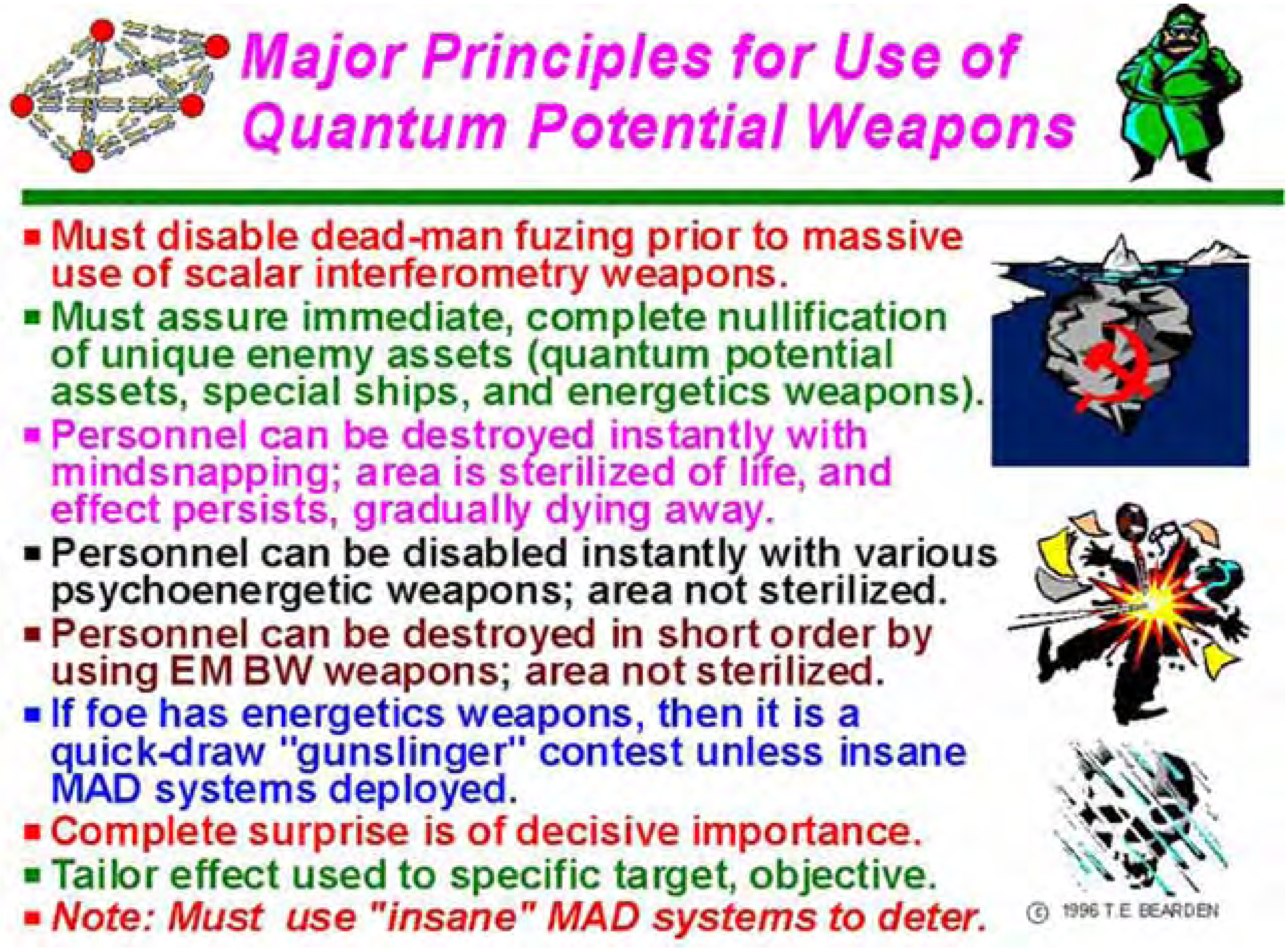

Major Principles for Use of Quantum Potential Weapons

- Must disable dead-man fuzing prior to massive use of scalar interferometry weapons.
- Must assure immediate, complete nullification of unique enemy assets (quantum potential assets, special ships, and energetics weapons).
- Personnel can be destroyed instantly with mindsnapping; area is sterilized of life, and effect persists, gradually dying away.
- Personnel can be disabled instantly with various psychoenergetic weapons; area not sterilized.
- Personnel can be destroyed in short order by using EM BW weapons; area not sterilized.
- If foe has energetics weapons, then it is a quick-draw "gunslinger" contest unless insane MAD systems deployed.
- Complete surprise is of decisive importance.
- Tailor effect used to specific target, objective.
- *Note: Must use "insane" MAD systems to deter.*

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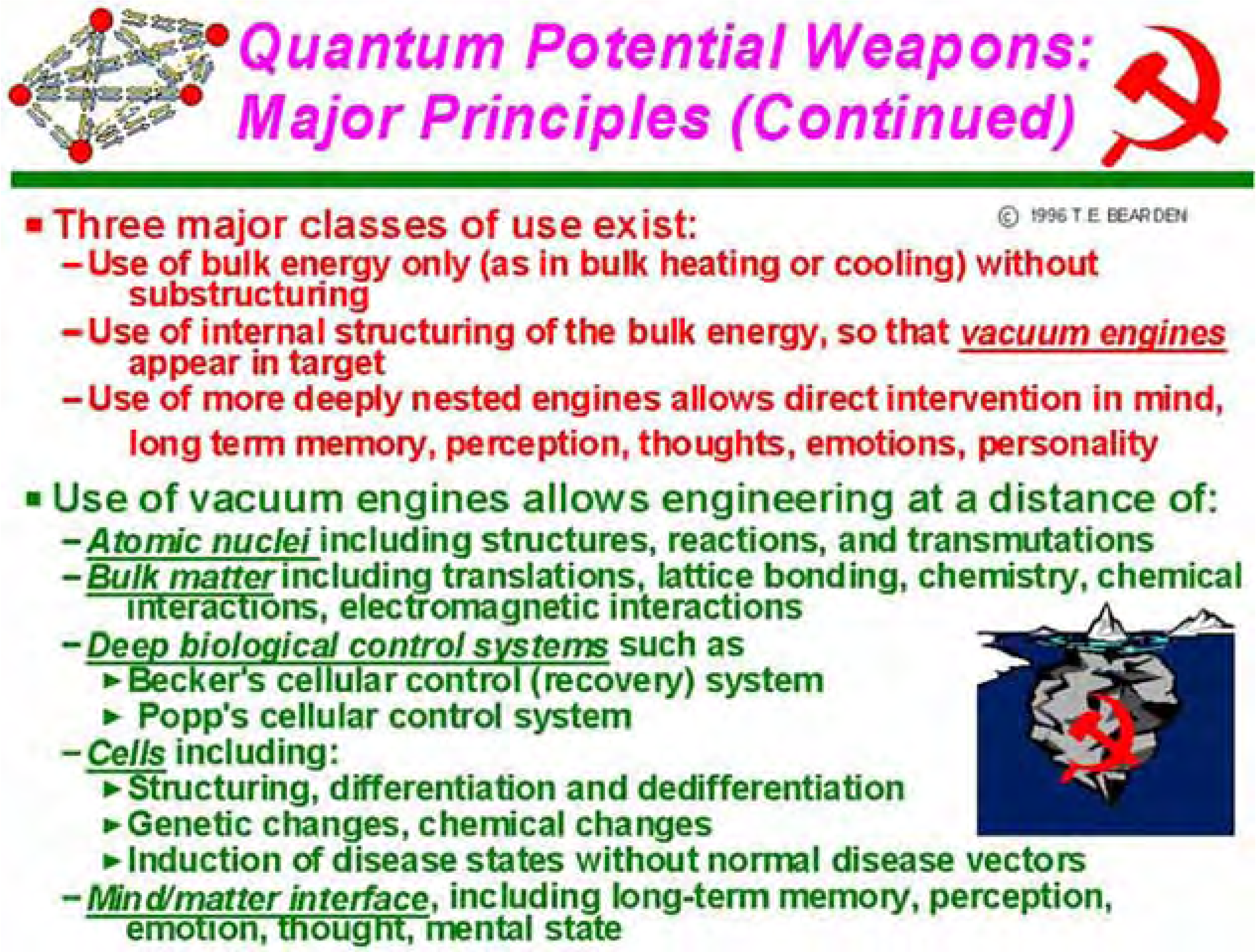

Quantum Potential Weapons: Major Principles (Continued)

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- Three major classes of use exist:
  - Use of bulk energy only (as in bulk heating or cooling) without substructuring
  - Use of internal structuring of the bulk energy, so that *vacuum engines* appear in target
  - Use of more deeply nested engines allows direct intervention in mind, long term memory, perception, thoughts, emotions, personality
- Use of vacuum engines allows engineering at a distance of:
  - *Atomic nuclei* including structures, reactions, and transmutations
  - *Bulk matter* including translations, lattice bonding, chemistry, chemical interactions, electromagnetic interactions
  - *Deep biological control systems* such as
    - Becker's cellular control (recovery) system
    - Popp's cellular control system
  - *Cells* including:
    - Structuring, differentiation and dedifferentiation
    - Genetic changes, chemical changes
    - Induction of disease states without normal disease vectors
  - *Mind/matter interface*, including long-term memory, perception, emotion, thought, mental state

Instantaneous Communication by a Quantum Potential

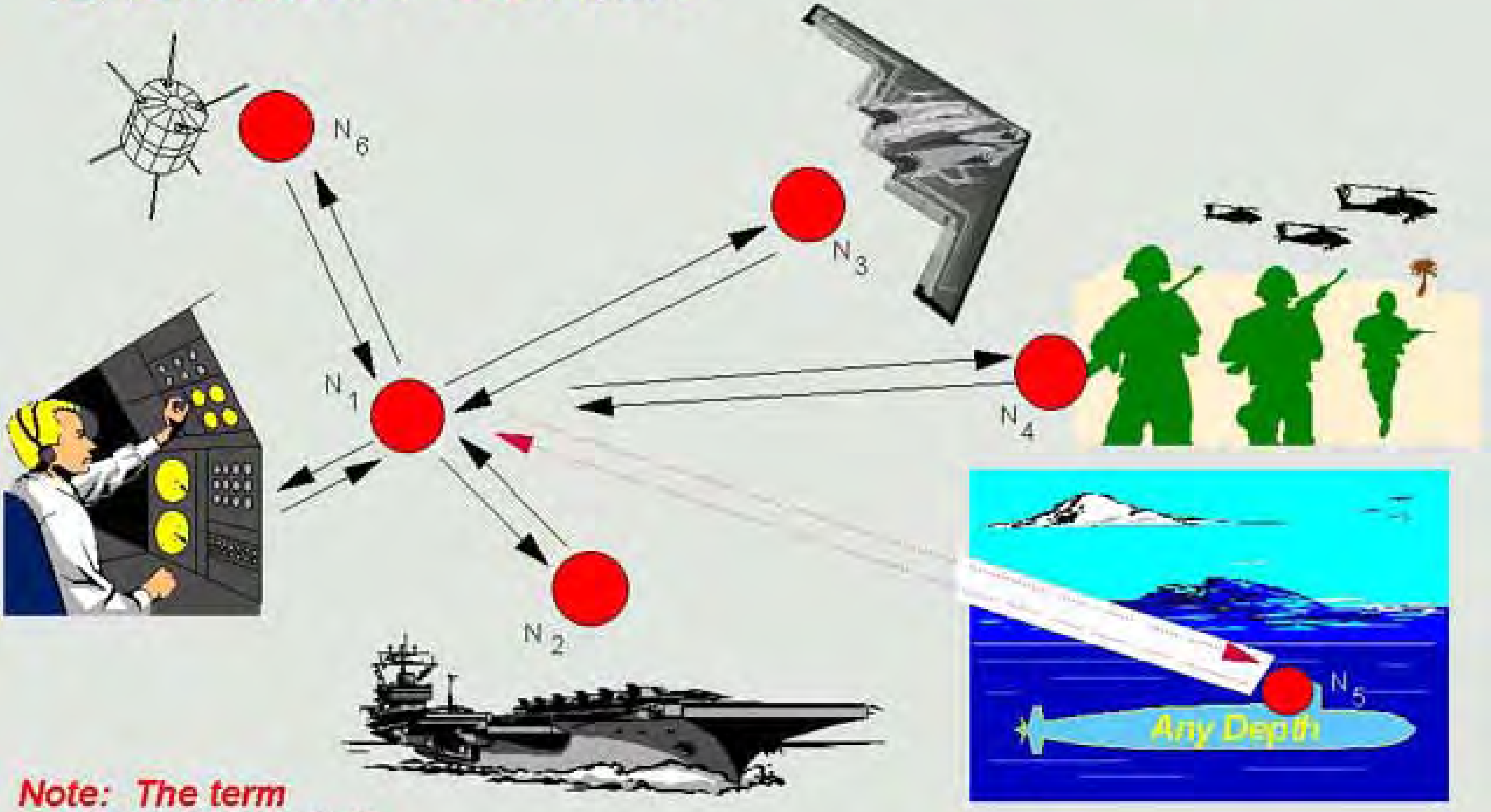

Note: The term "quantum potential" is used in an extended sense.

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Selected clipart © by Lotus SmartPics™

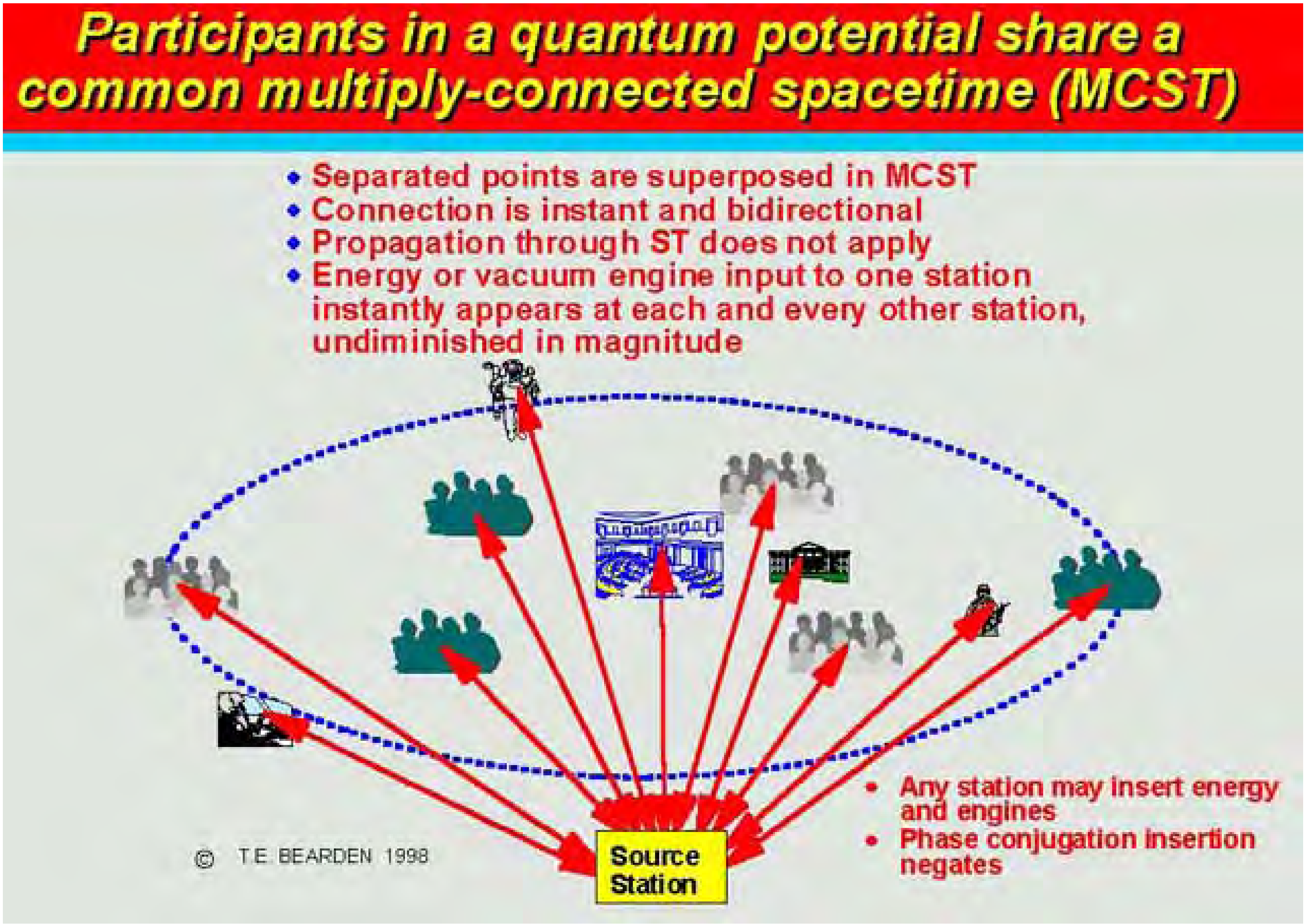

Participants in a quantum potential share a common multiply-connected spacetime (MCST)

- Separated points are superposed in MCST
- Connection is instant and bidirectional
- Propagation through ST does not apply
- Energy or vacuum engine input to one station instantly appears at each and every other station, undiminished in magnitude

- Any station may insert energy and engines
- Phase conjugation insertion negates

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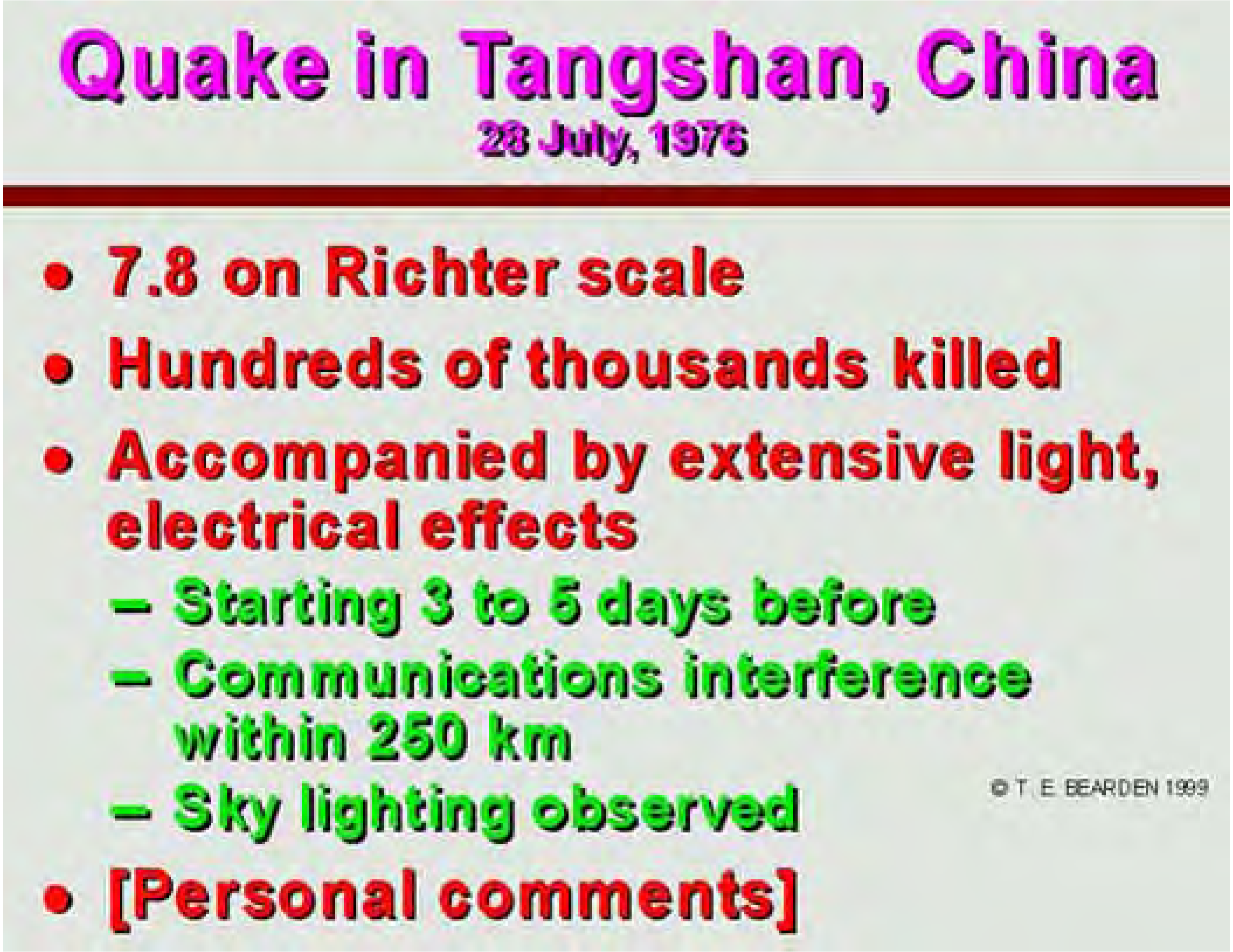

Quake in Tangshan, China

28 July, 1976

- 7.8 on Richter scale
- Hundreds of thousands killed
- Accompanied by extensive light, electrical effects
  - Starting 3 to 5 days before
  - Communications interference within 250 km
  - Sky lighting observed
- [Personal comments]

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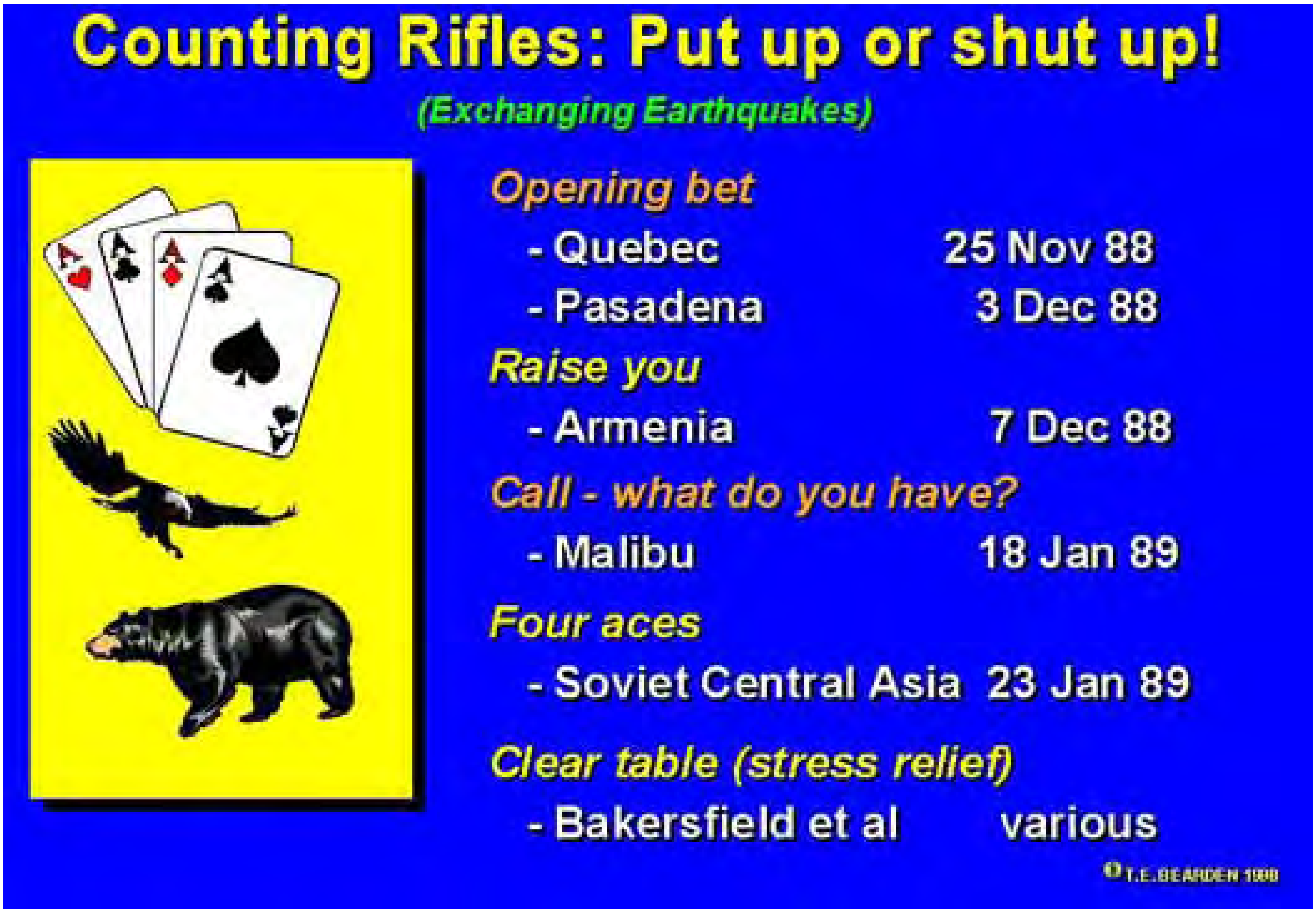

Counting Rifles: Put up or shut up!

(Exchanging Earthquakes)

Opening bet
- Quebec 25 Nov 88
- Pasadena 3 Dec 88

Raise you
- Armenia 7 Dec 88

Call - what do you have?
- Malibu 18 Jan 89

Four aces
- Soviet Central Asia 23 Jan 89

Clear table (stress relief)
- Bakersfield et al various

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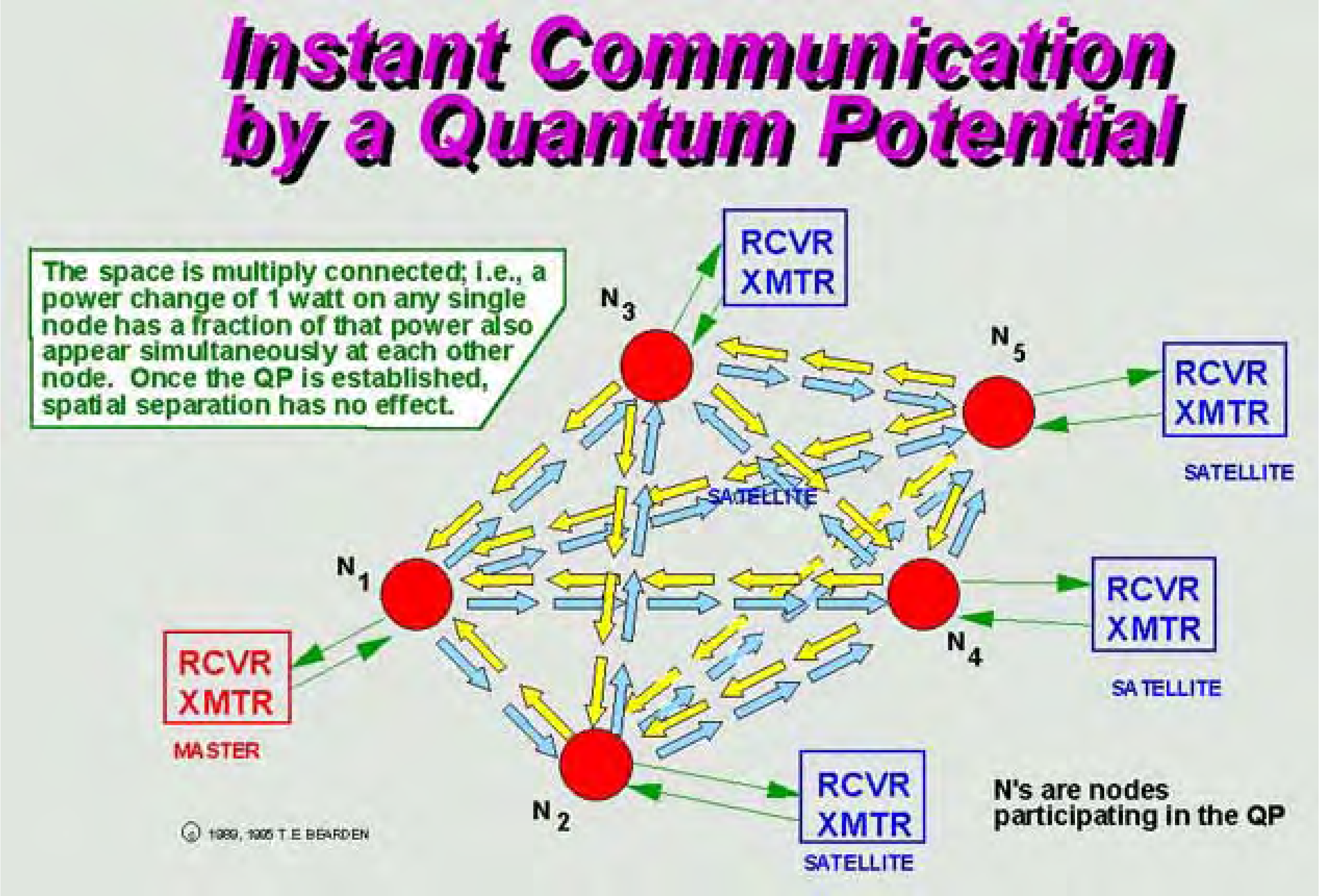

Instant Communication by a Quantum Potential

The space is multiply connected; i.e., a power change of 1 watt on any single node has a fraction of that power also appear simultaneously at each other node. Once the QP is established, spatial separation has no effect.

N's are nodes participating in the QP

N1
N2
N3
N4
N5
RCVR XMTR
MASTER
RCVR XMTR
SATELLITE
RCVR XMTR
SATELLITE
RCVR XMTR
SATELLITE
RCVR XMTR
SATELLITE

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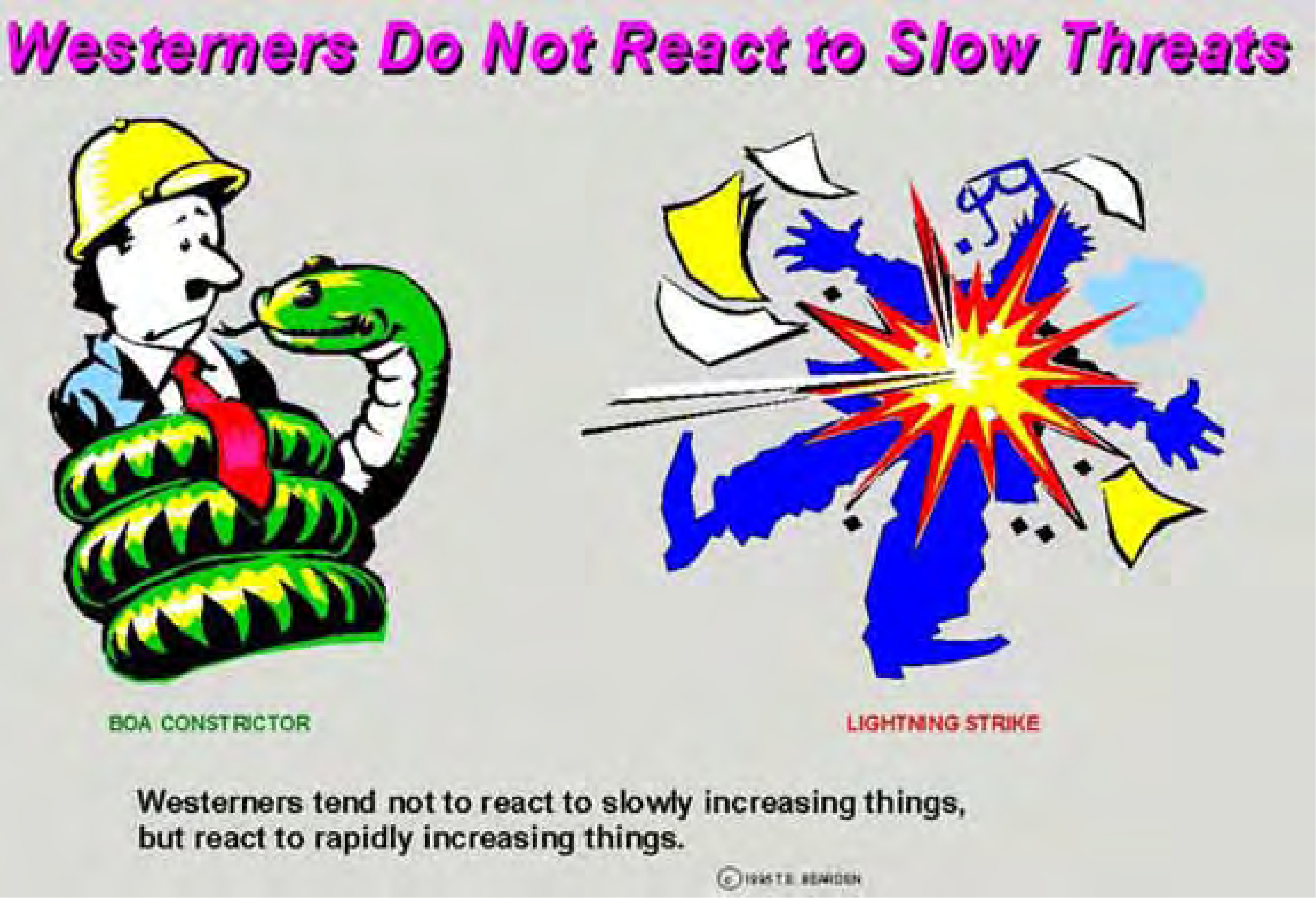

Westerners Do Not React to Slow Threats

BOA CONSTRICTOR
LIGHTNING STRIKE

Westerners tend not to react to slowly increasing things, but react to rapidly increasing things.

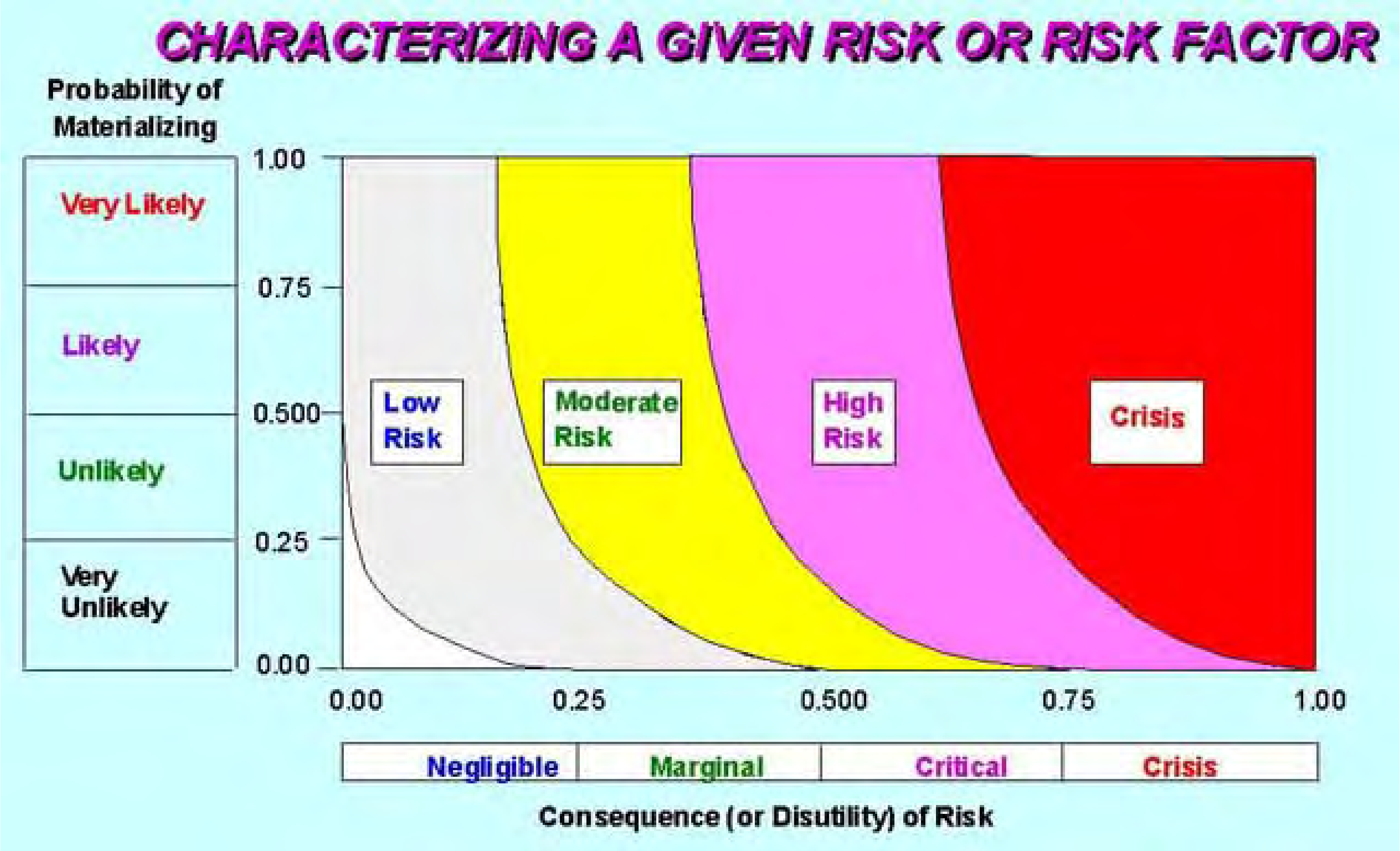
CHARACTERIZING A GIVEN RISK OR RISK FACTOR
Probability of Materializing
Very Likely
Likely
Unlikely
Very Unlikely
1.00
0.75
0.500
0.25
0.00
Low Risk
Moderate Risk
High Risk
Crisis
0.00
0.25
0.500
0.75
1.00
Negligible
Marginal
Critical
Crisis
Consequence (or Disutility) of Risk

TECHNICAL RISK MANAGEMENT

SUPPORT RESEARCH IS TECHNICAL RISK REDUCTION AND MANDATORY FOR ANY EMERGING TECHNOLOGY

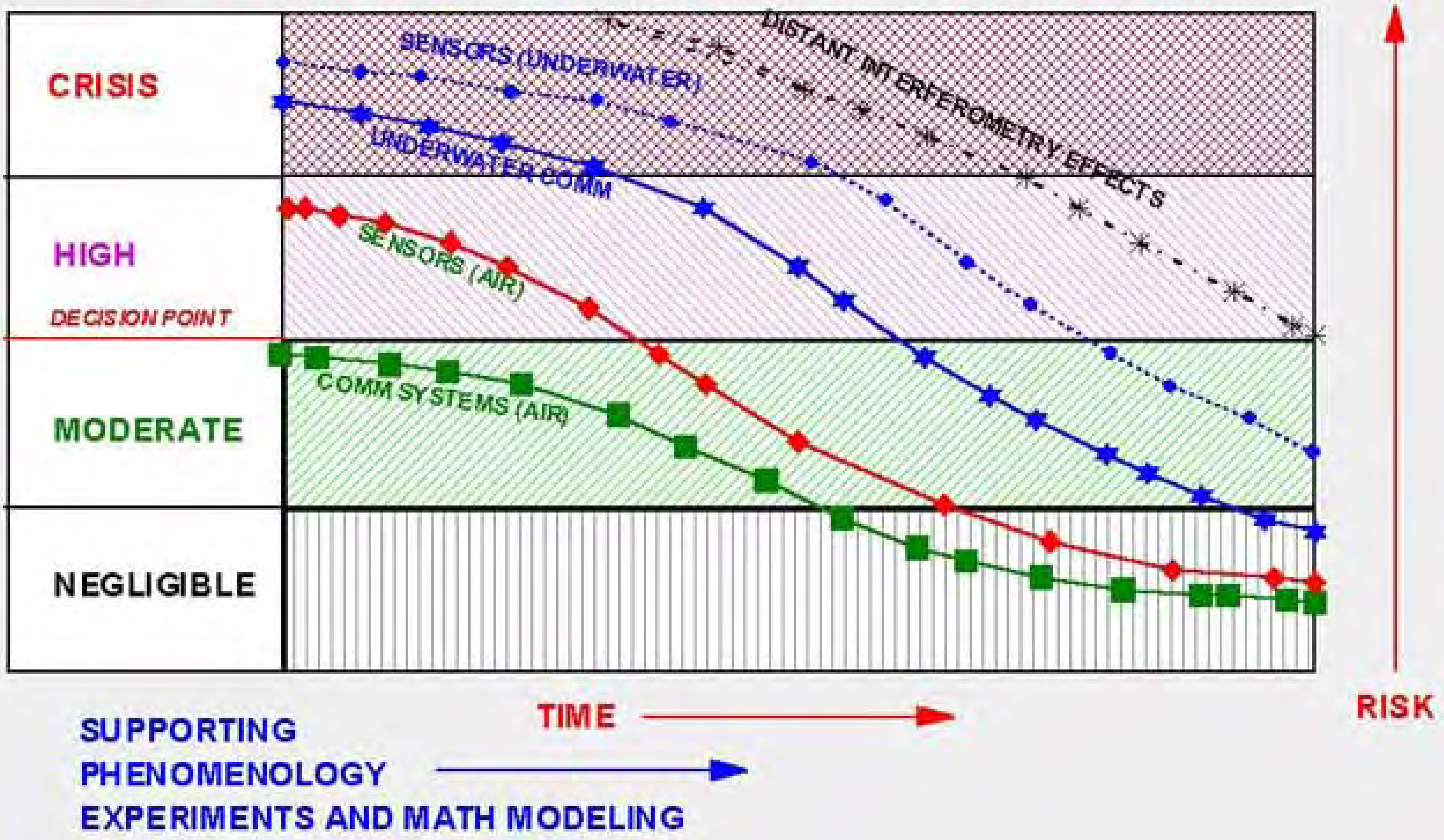

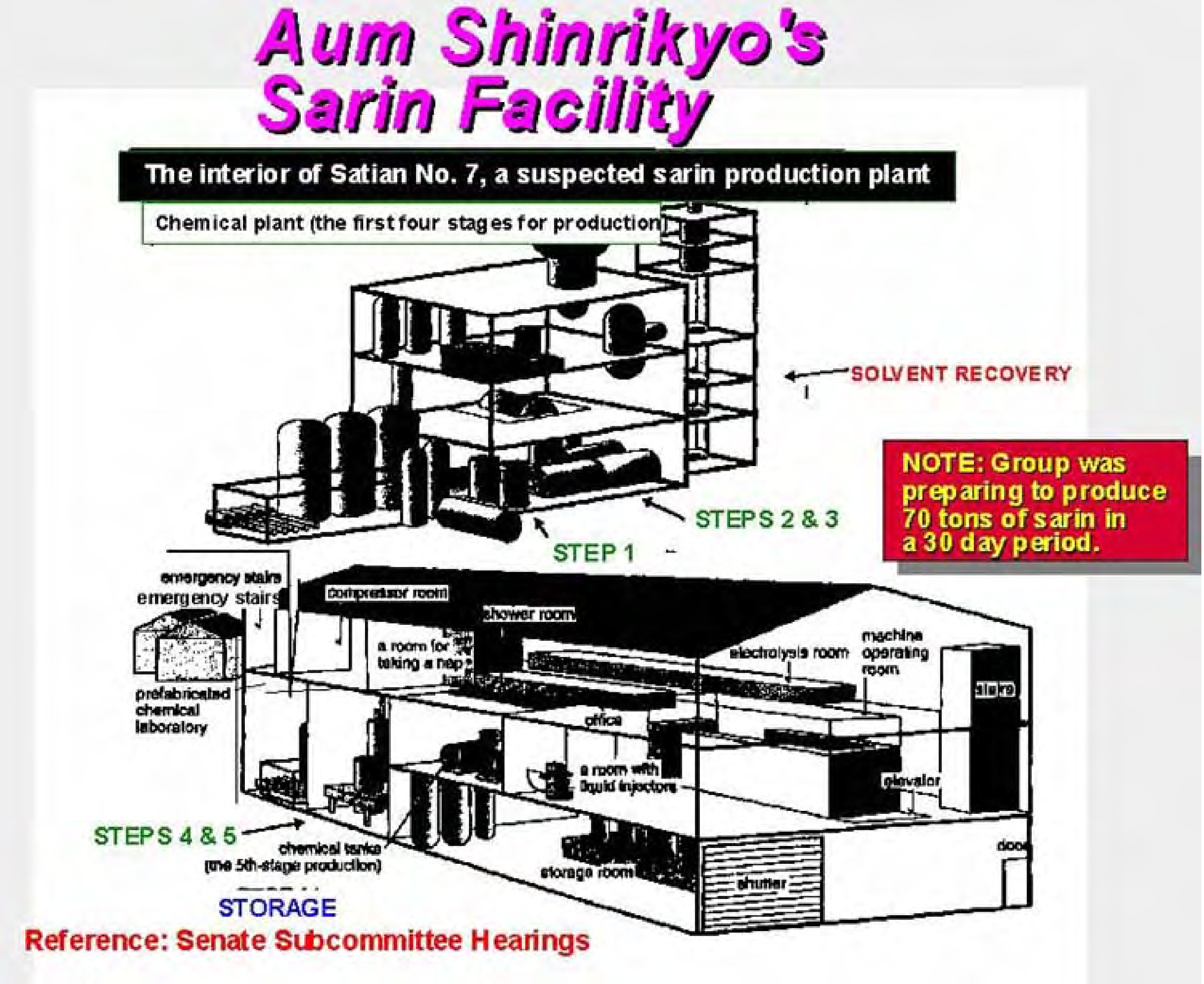

Aum Shinrikyo's Sarin Facility

The interior of Satian No. 7, a suspected sarin production plant

Chemical plant (the first four stages for production)

SOLVENT RECOVERY
STEPS 2 & 3
STEP 1
emergency stairs
emergency stairs
compressor room
shower room
a room for taking a nap
electrolysis room
machine operating room
stairs
prefabricated chemical laboratory
office
a room with liquid injectors
elevator
STEPS 4 & 5
chemical tanks (the 5th-stage production)
storage room
shutter
door
STORAGE

NOTE: Group was preparing to produce 70 tons of sarin in a 30 day period.

Reference: Senate Subcommittee Hearings

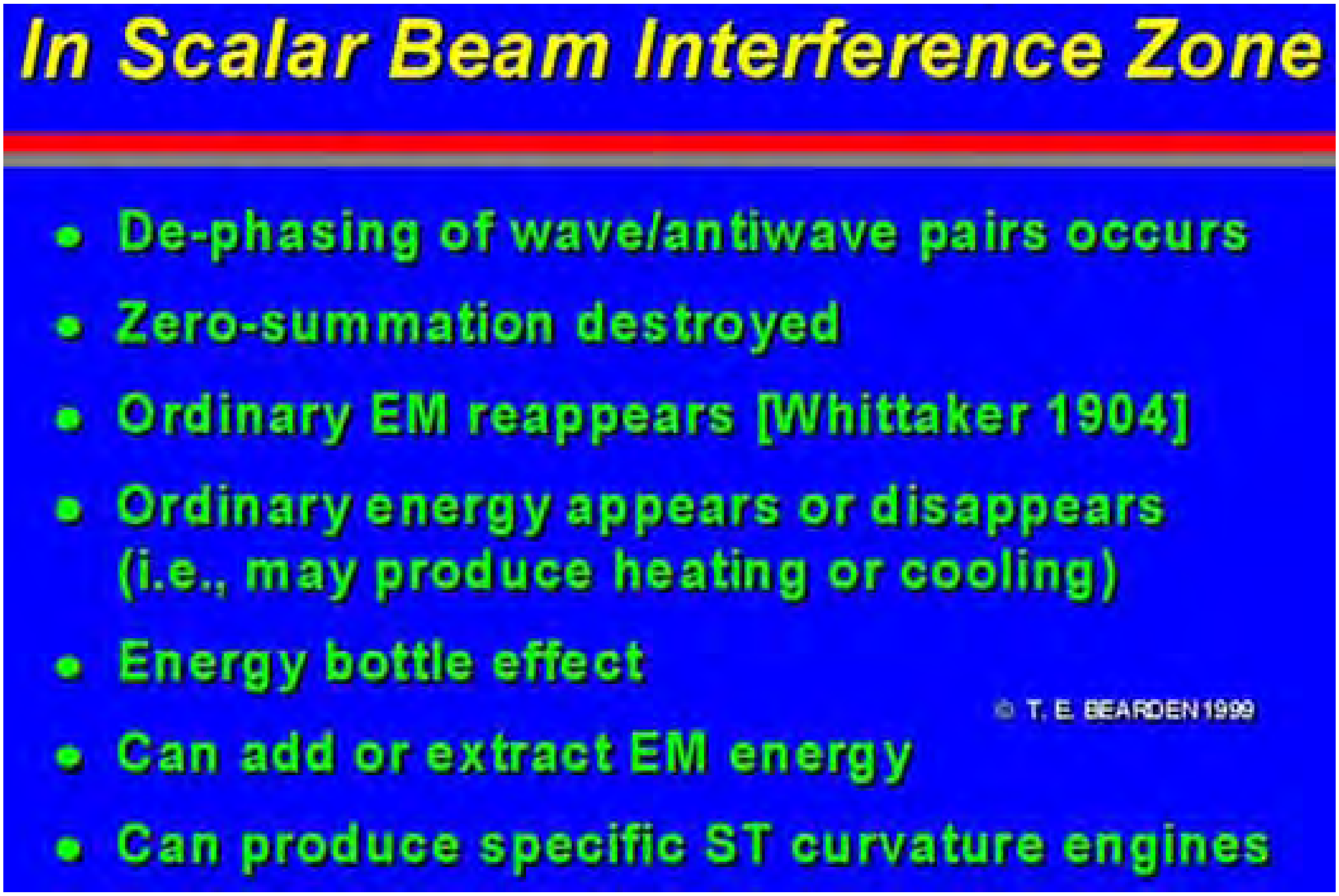

In Scalar Beam Interference Zone

- De-phasing of wave/antiwave pairs occurs
- Zero-summation destroyed
- Ordinary EM reappears [Whittaker 1904]
- Ordinary energy appears or disappears (i.e., may produce heating or cooling)
- Energy bottle effect
- Can add or extract EM energy
- Can produce specific ST curvature engines

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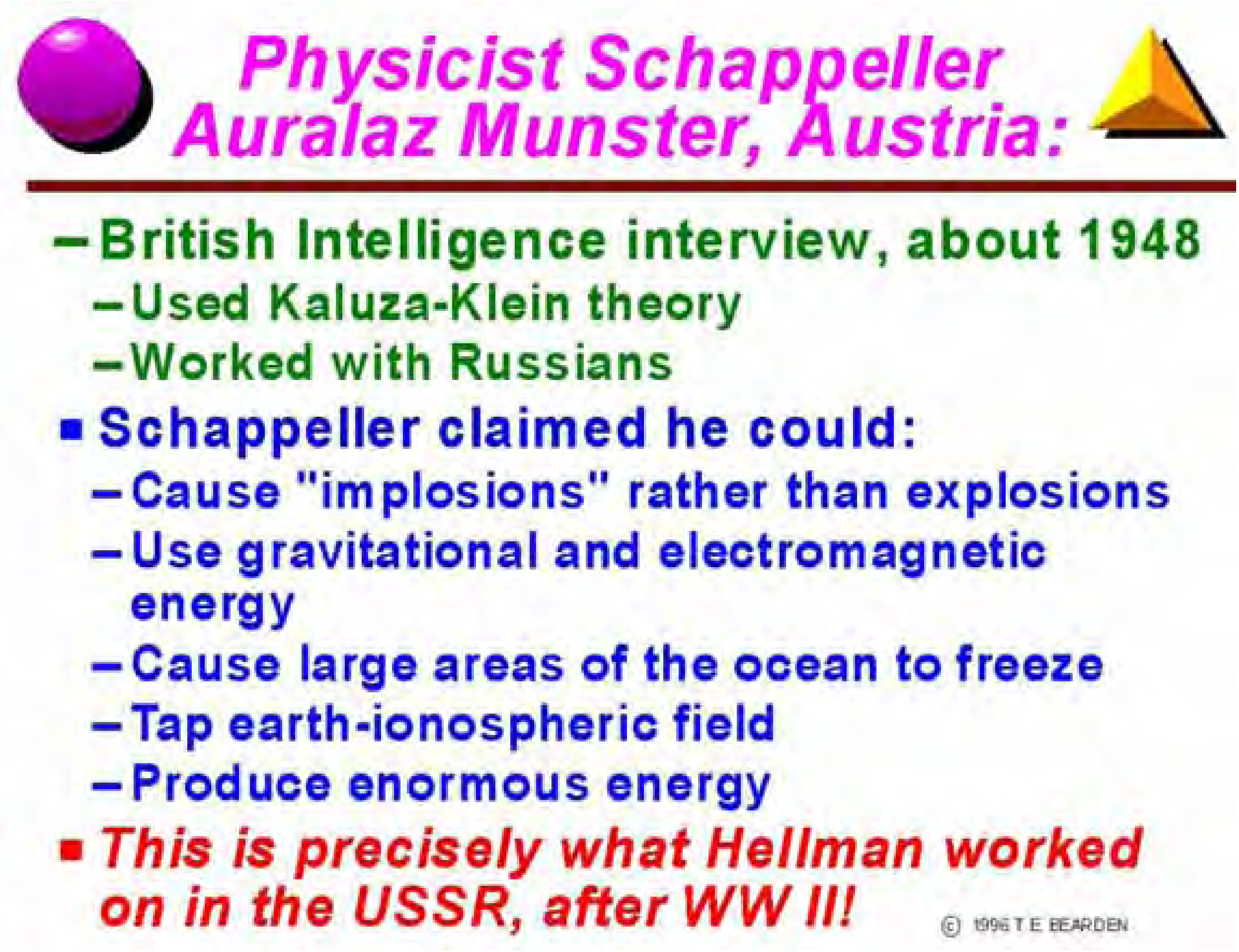

Physicist Schappeller Auralaz Munster, Austria:

- British Intelligence interview, about 1948
  - Used Kaluza-Klein theory
  - Worked with Russians
- Schappeller claimed he could:
  - Cause "implosions" rather than explosions
  - Use gravitational and electromagnetic energy
  - Cause large areas of the ocean to freeze
  - Tap earth-ionospheric field
  - Produce enormous energy
- *This is precisely what Hellman worked on in the USSR, after WW II!*

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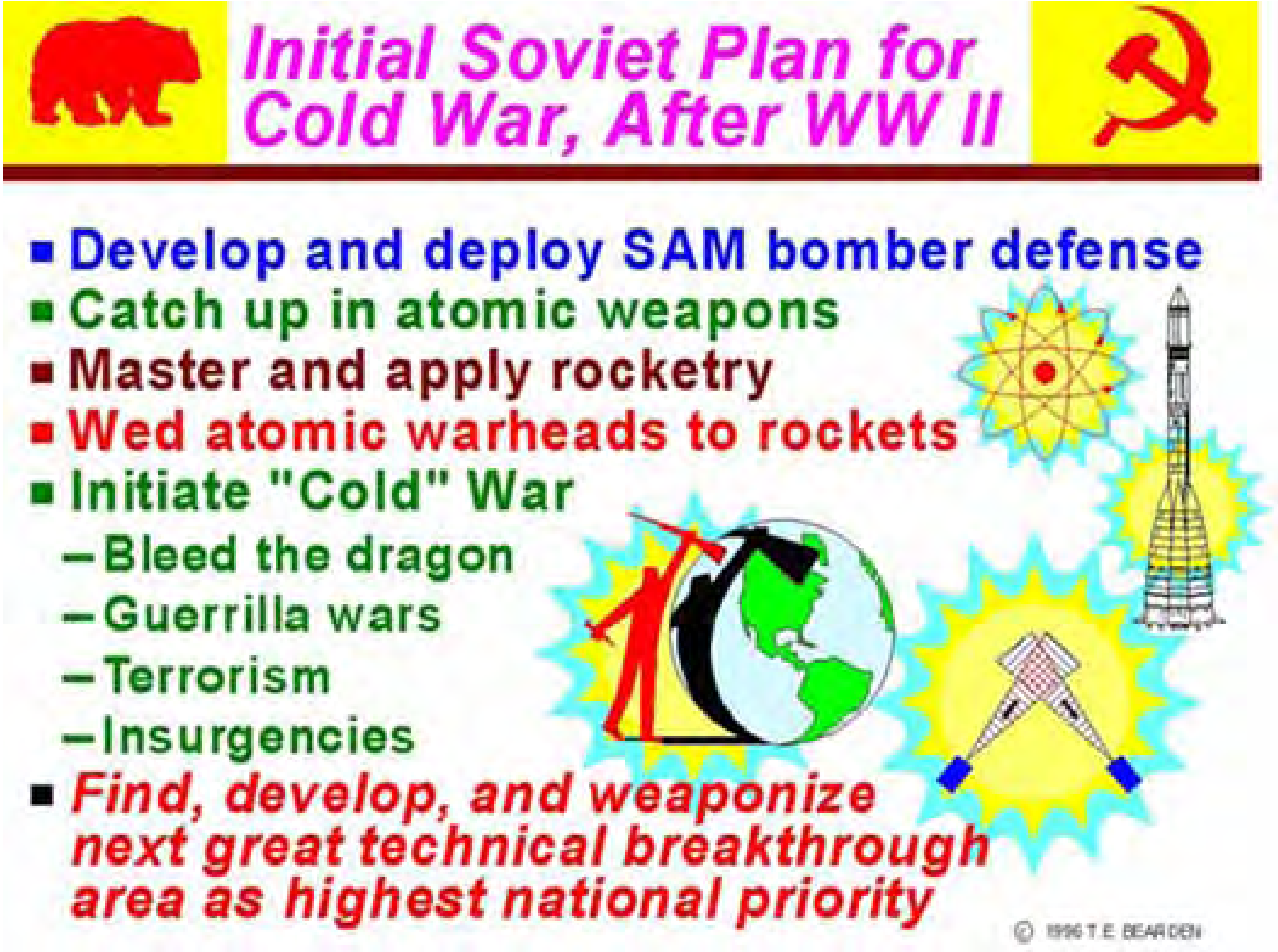

Initial Soviet Plan for Cold War, After WW II

- Develop and deploy SAM bomber defense
- Catch up in atomic weapons
- Master and apply rocketry
- Wed atomic warheads to rockets
- Initiate "Cold" War
  - Bleed the dragon
  - Guerrilla wars
  - Terrorism
  - Insurgencies
- *Find, develop, and weaponize next great technical breakthrough area as highest national priority*

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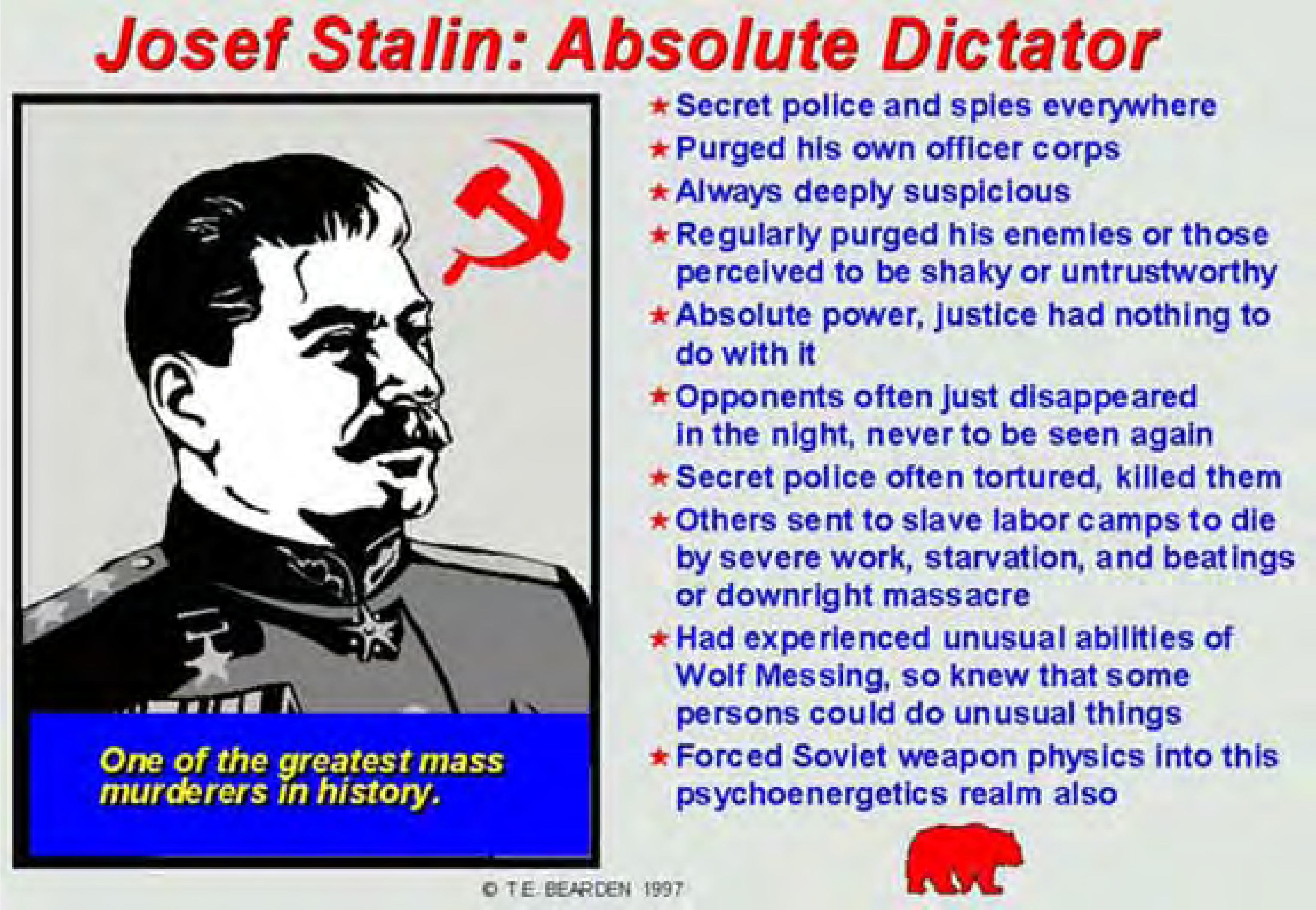

Josef Stalin: Absolute Dictator

- Secret police and spies everywhere
- Purged his own officer corps
- Always deeply suspicious
- Regularly purged his enemies or those perceived to be shaky or untrustworthy
- Absolute power, justice had nothing to do with it
- Opponents often just disappeared in the night, never to be seen again
- Secret police often tortured, killed them
- Others sent to slave labor camps to die by severe work, starvation, and beatings or downright massacre
- Had experienced unusual abilities of Wolf Messing, so knew that some persons could do unusual things
- Forced Soviet weapon physics into this psychoenergetics realm also

One of the greatest mass murderers in history.

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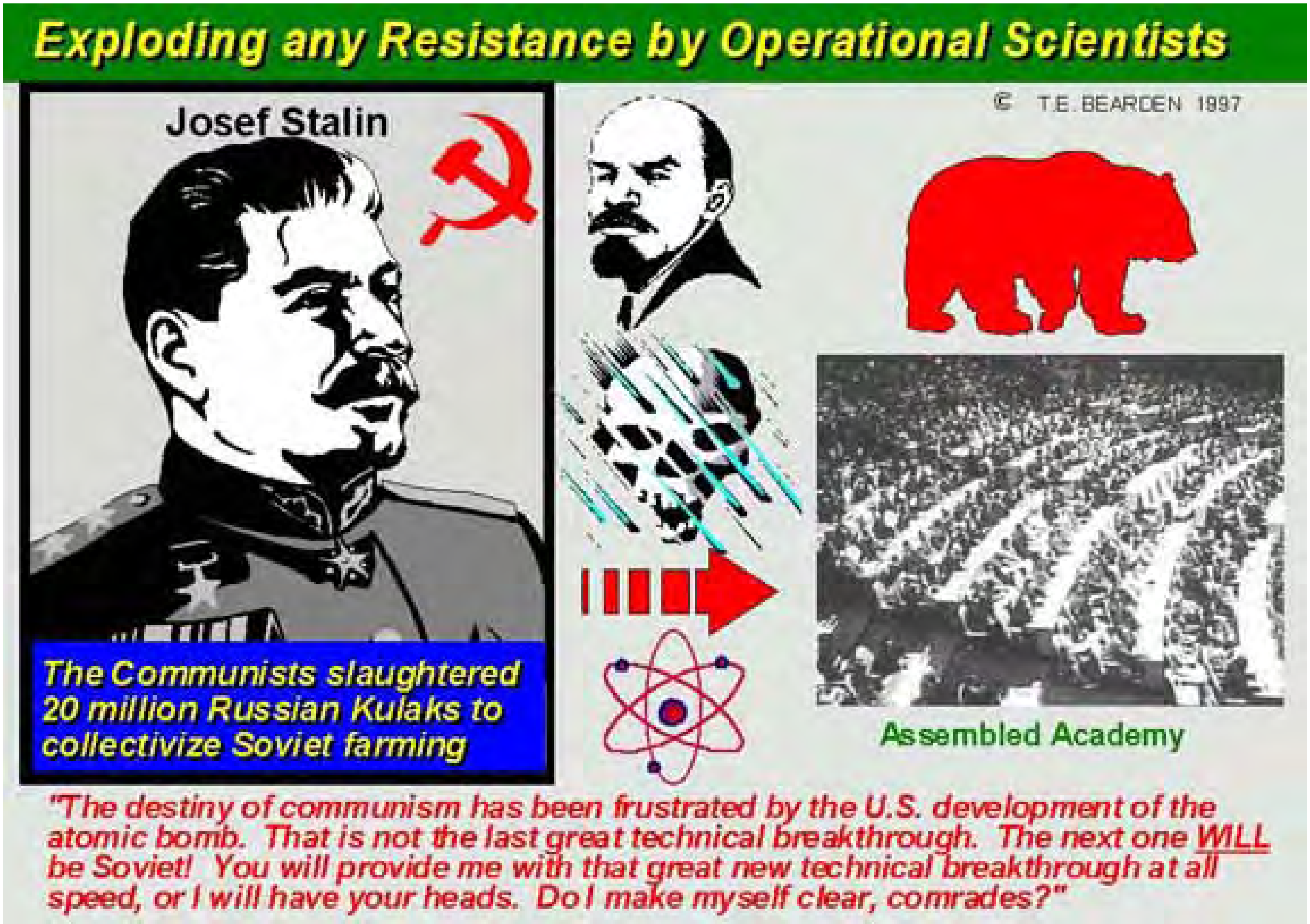

Exploding any Resistance by Operational Scientists

© T.E. BEARDEN 1997

Josef Stalin

The Communists slaughtered 20 million Russian Kulaks to collectivize Soviet farming

Assembled Academy

"The destiny of communism has been frustrated by the U.S. development of the atomic bomb. That is not the last great technical breakthrough. The next one WILL be Soviet! You will provide me with that great new technical breakthrough at all speed, or I will have your heads. Do I make myself clear, comrades?"

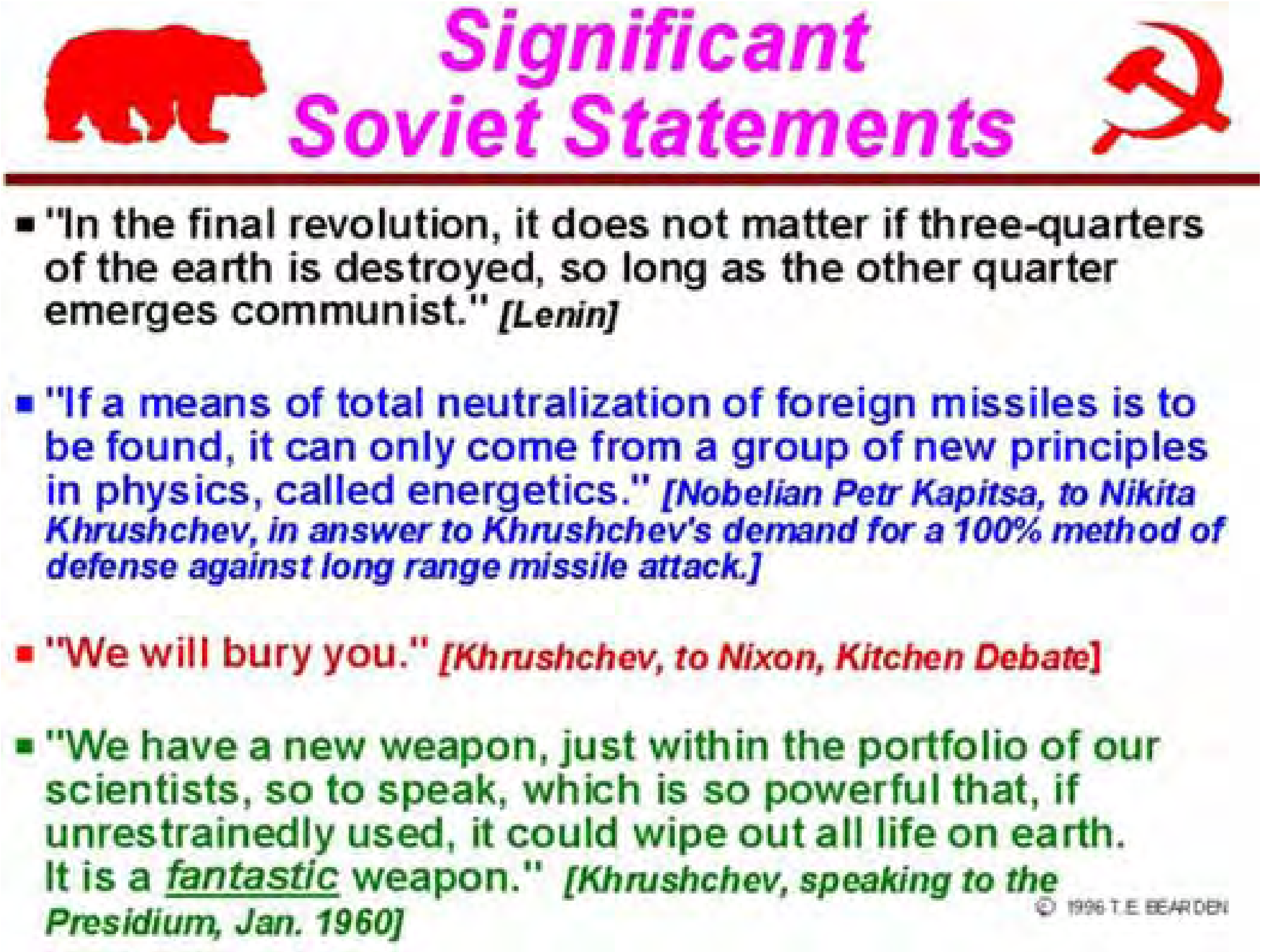

Significant Soviet Statements

- "In the final revolution, it does not matter if three-quarters of the earth is destroyed, so long as the other quarter emerges communist." *[Lenin]*
- "If a means of total neutralization of foreign missiles is to be found, it can only come from a group of new principles in physics, called energetics." *[Nobelian Petr Kapitsa, to Nikita Khrushchev, in answer to Khrushchev's demand for a 100% method of defense against long range missile attack.]*
- "We will bury you." *[Khrushchev, to Nixon, Kitchen Debate*]
- "We have a new weapon, just within the portfolio of our scientists, so to speak, which is so powerful that, if unrestrainedly used, it could wipe out all life on earth. It is a *fantastic* weapon." *[Khrushchev, speaking to the Presidium, Jan. 1960]*

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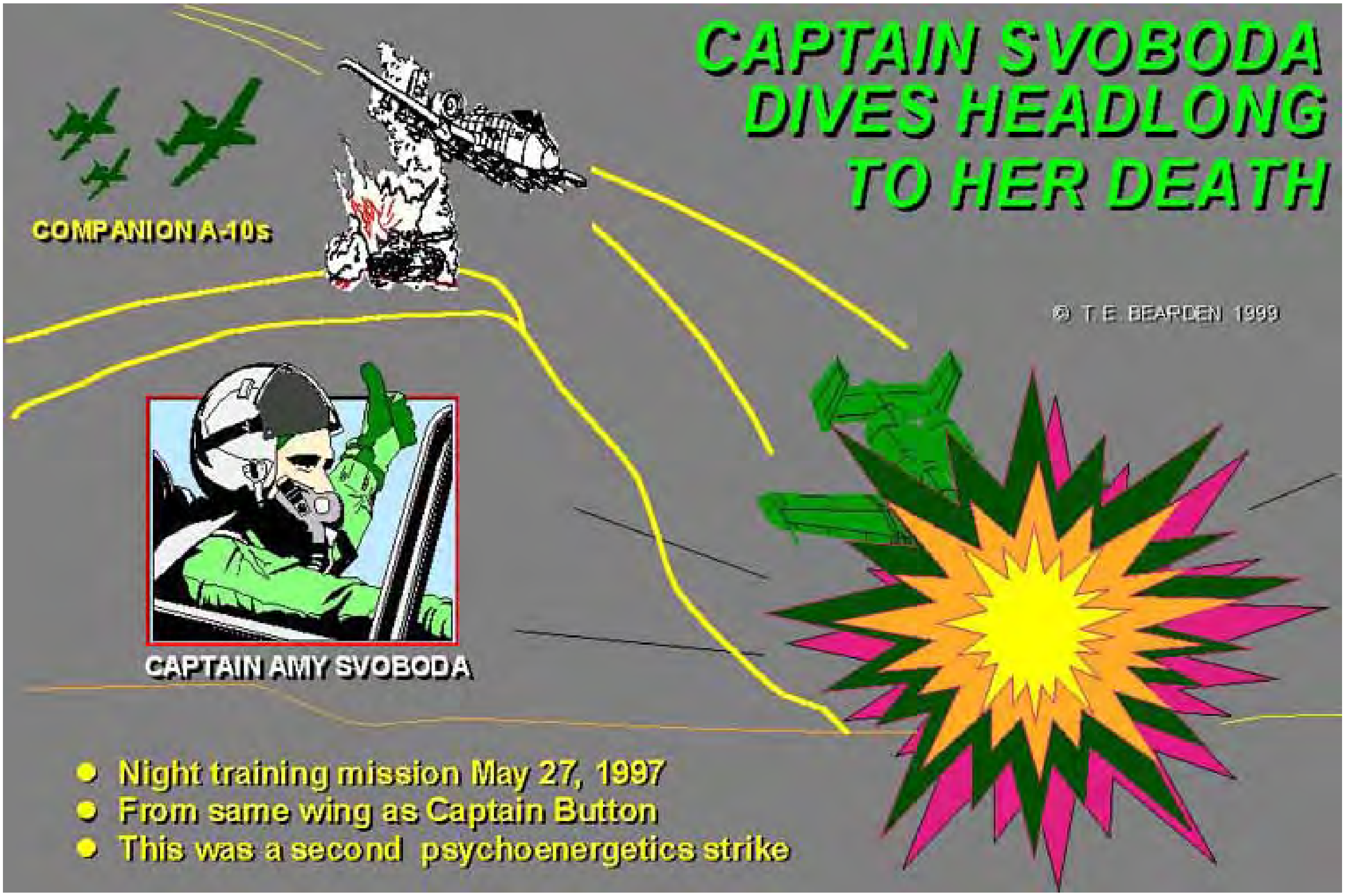

CAPTAIN SVOBODA DIVES HEADLONG TO HER DEATH

COMPANION A-10s

© T.E. BEARDEN 1999

CAPTAIN AMY SVOBODA

- Night training mission May 27, 1997
- From same wing as Captain Button
- This was a second psychoenergetics strike

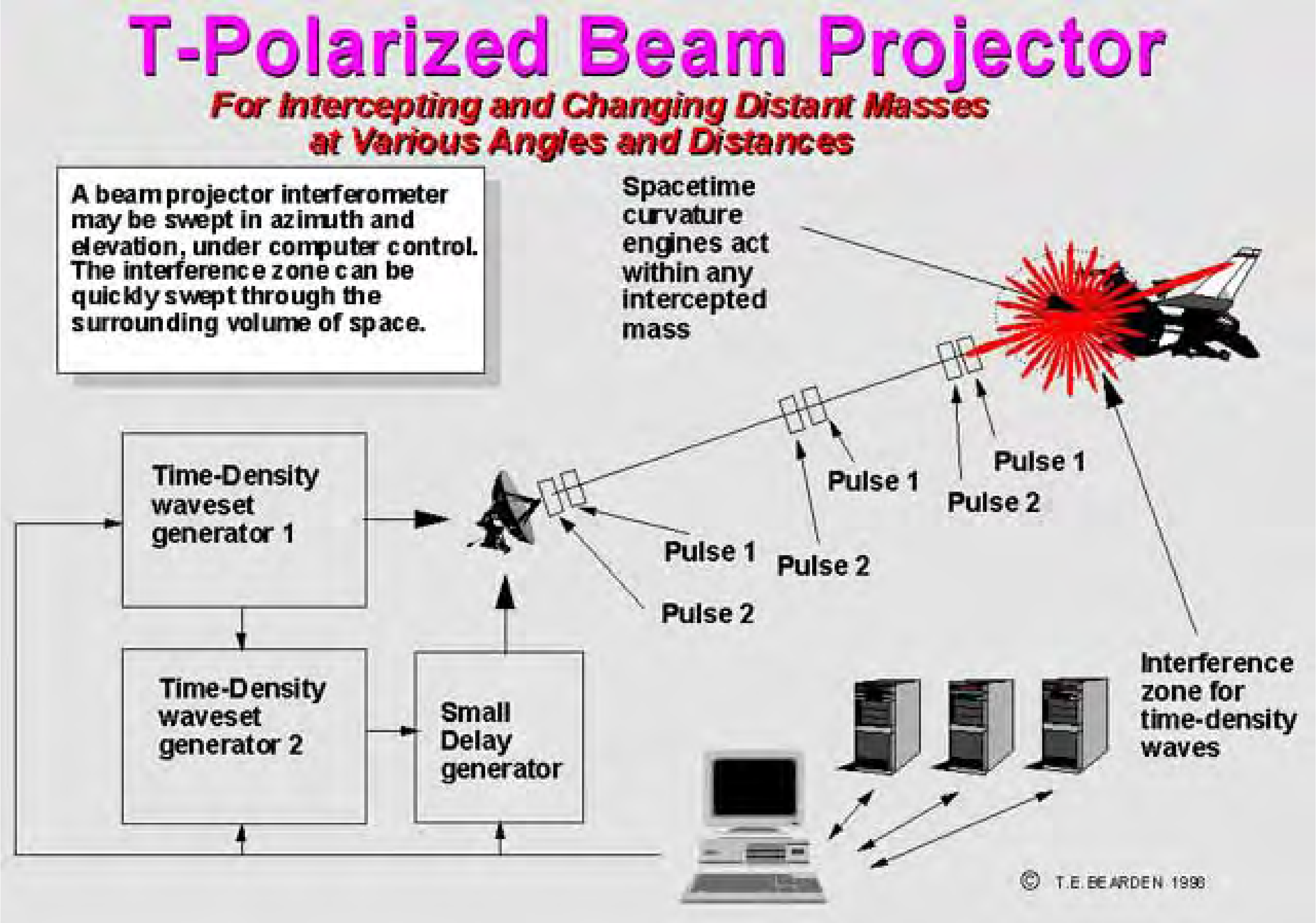

T-Polarized Beam Projector

For Intercepting and Changing Distant Masses at Various Angles and Distances

A beam projector interferometer may be swept in azimuth and elevation, under computer control. The interference zone can be quickly swept through the surrounding volume of space.

Spacetime curvature engines act within any intercepted mass
Time-Density waveset generator 1
Time-Density waveset generator 2
Small Delay generator
Pulse 1
Pulse 2
Pulse 1
Pulse 2
Pulse 1
Pulse 2
Interference zone for time-density waves

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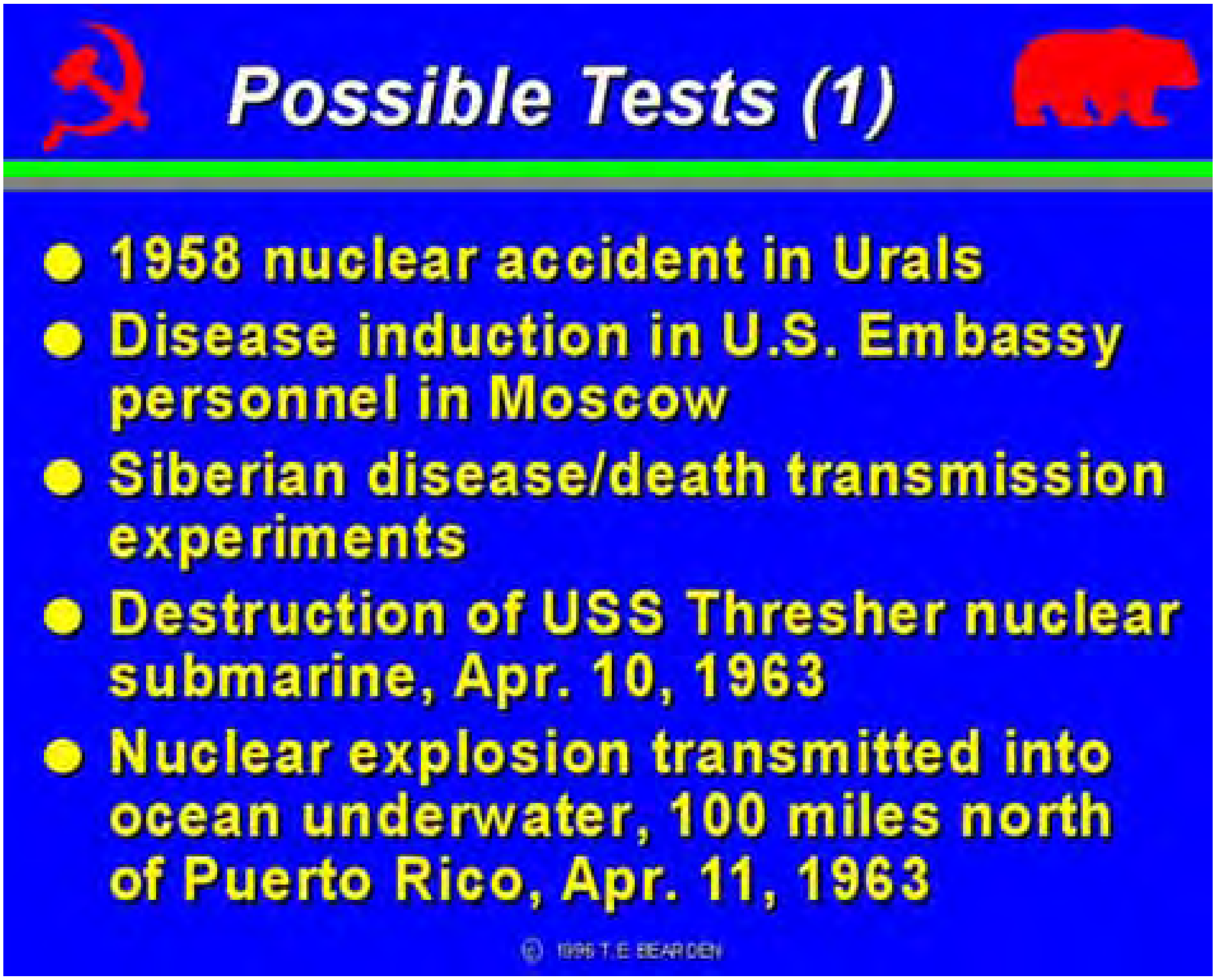

Possible Tests (1)

- 1958 nuclear accident in Urals
- Disease induction in U.S. Embassy personnel in Moscow
- Siberian disease/death transmission experiments
- Destruction of USS Thresher nuclear submarine, Apr. 10, 1963
- Nuclear explosion transmitted into ocean underwater, 100 miles north of Puerto Rico, Apr. 11, 1963

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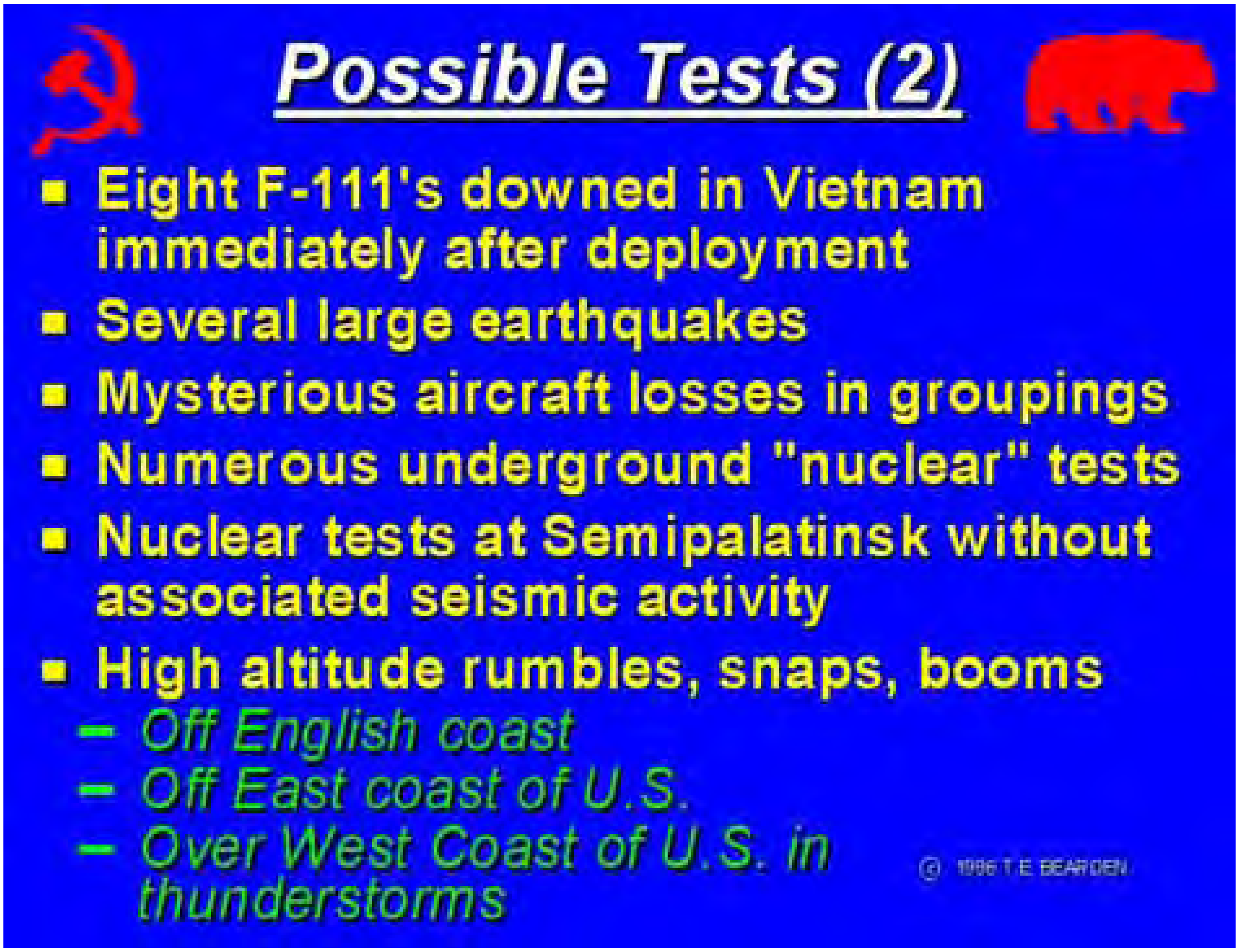

Possible Tests (2)

- Eight F-111's downed in Vietnam immediately after deployment
- Several large earthquakes
- Mysterious aircraft losses in groupings
- Numerous underground "nuclear" tests
- Nuclear tests at Semipalatinsk without associated seismic activity
- High altitude rumbles, snaps, booms
  - *Off English coast*
  - *Off East coast of U.S.*
  - *Over West Coast of U.S. in thunderstorms*

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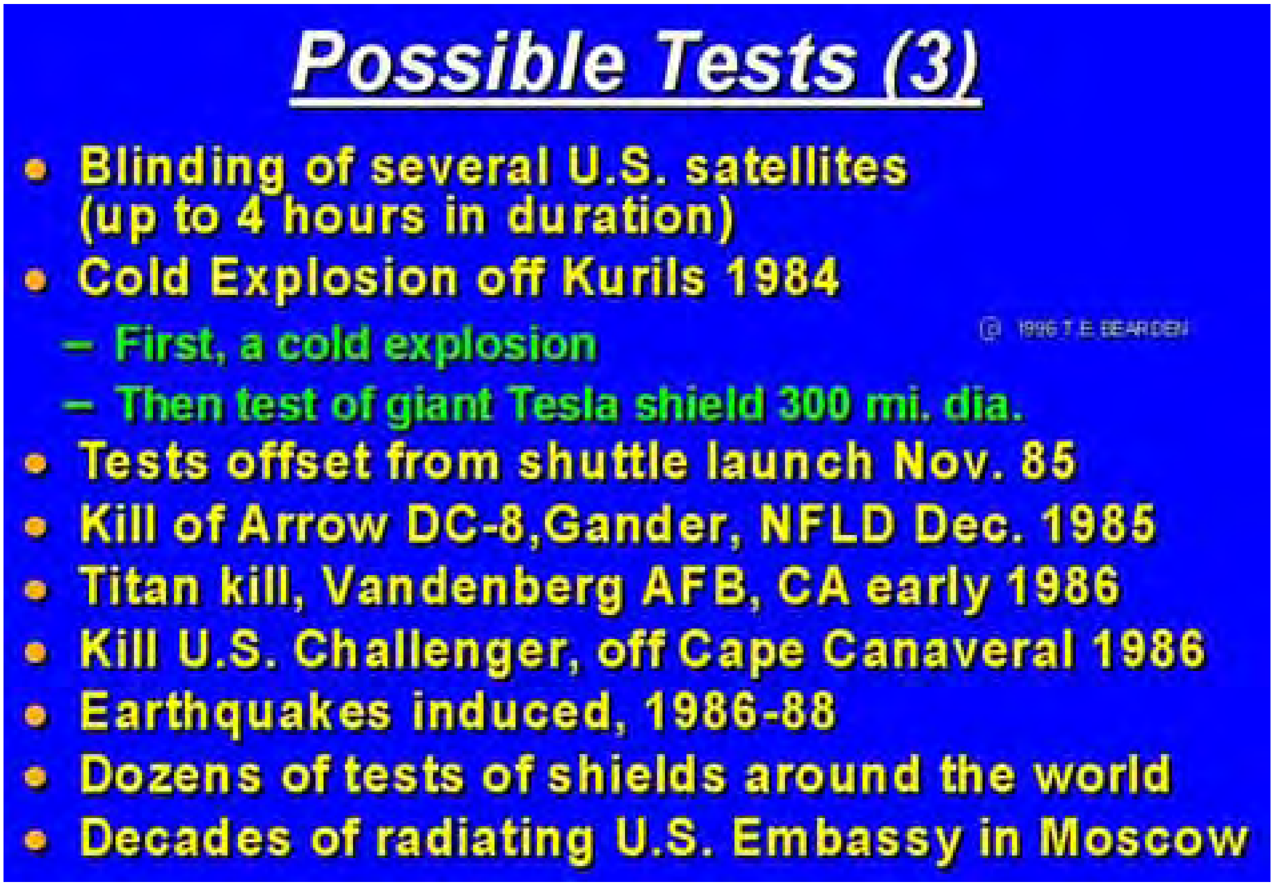

Possible Tests (3)

- Blinding of several U.S. satellites (up to 4 hours in duration)
- Cold Explosion off Kurils 1984
  - First, a cold explosion
  - Then test of giant Tesla shield 300 mi. dia.
- Tests offset from shuttle launch Nov. 85
- Kill of Arrow DC-8,Gander, NFLD Dec. 1985
- Titan kill, Vandenberg AFB, CA early 1986
- Kill U.S. Challenger, off Cape Canaveral 1986
- Earthquakes induced, 1986-88
- Dozens of tests of shields around the world
- Decades of radiating U.S. Embassy in Moscow

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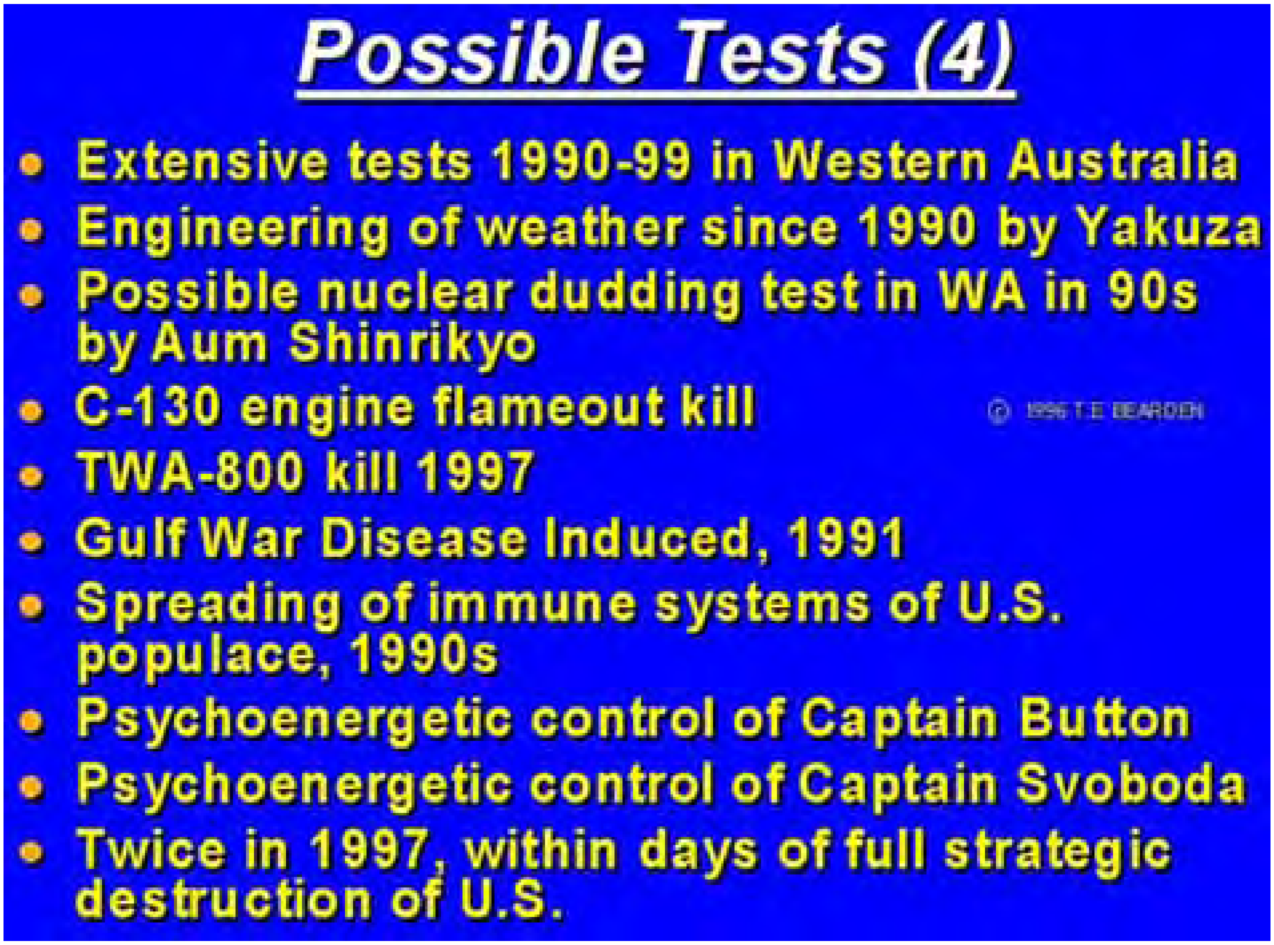

Possible Tests (4)

- Extensive tests 1990-99 in Western Australia
- Engineering of weather since 1990 by Yakuza
- Possible nuclear dudding test in WA in 90s by Aum Shinrikyo
- C-130 engine flameout kill
- TWA-800 kill 1997
- Gulf War Disease Induced, 1991
- Spreading of immune systems of U.S. populace, 1990s
- Psychoenergetic control of Captain Button
- Psychoenergetic control of Captain Svoboda
- Twice in 1997, within days of full strategic destruction of U.S.

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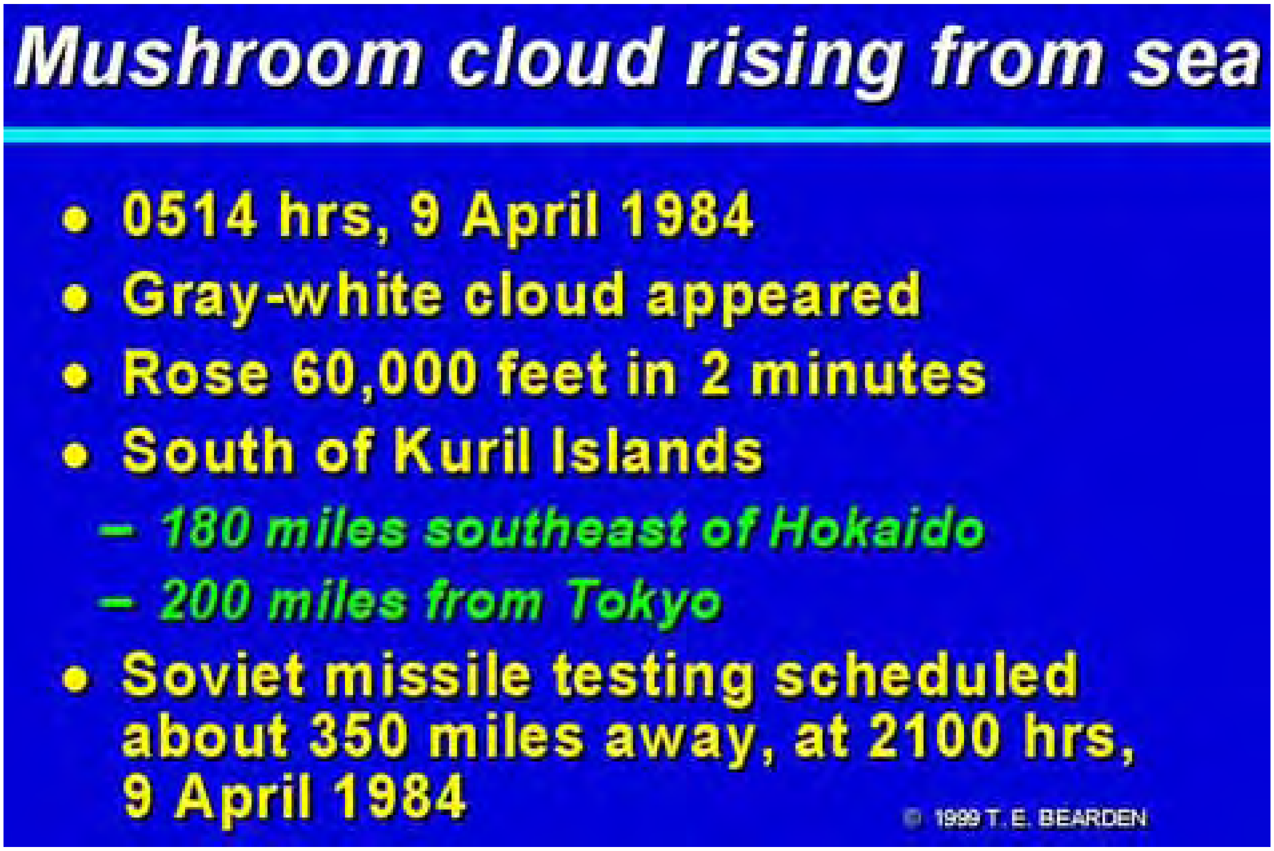

Mushroom cloud rising from sea

- 0514 hrs, 9 April 1984
- Gray-white cloud appeared
- Rose 60,000 feet in 2 minutes
- South of Kuril Islands
  - 180 miles southeast of Hokaido
  - 200 miles from Tokyo
- Soviet missile testing scheduled about 350 miles away, at 2100 hrs, 9 April 1984

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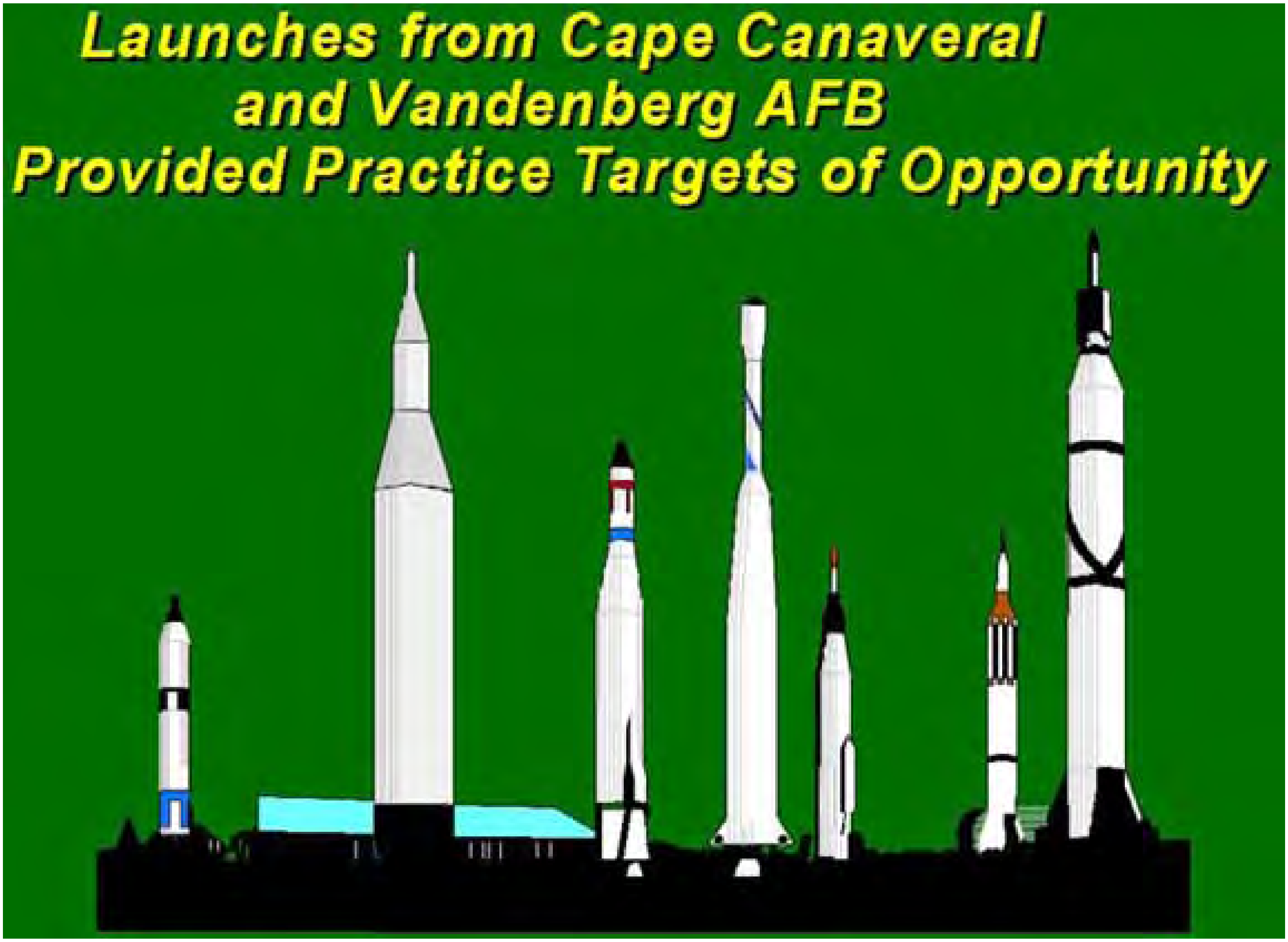

Launches from Cape Canaveral
and Vandenberg AFB
Provided Practice Targets of Opportunity

The sinking U.S.S. Thresher, with her controls jammed, implodes when she reaches crush depth

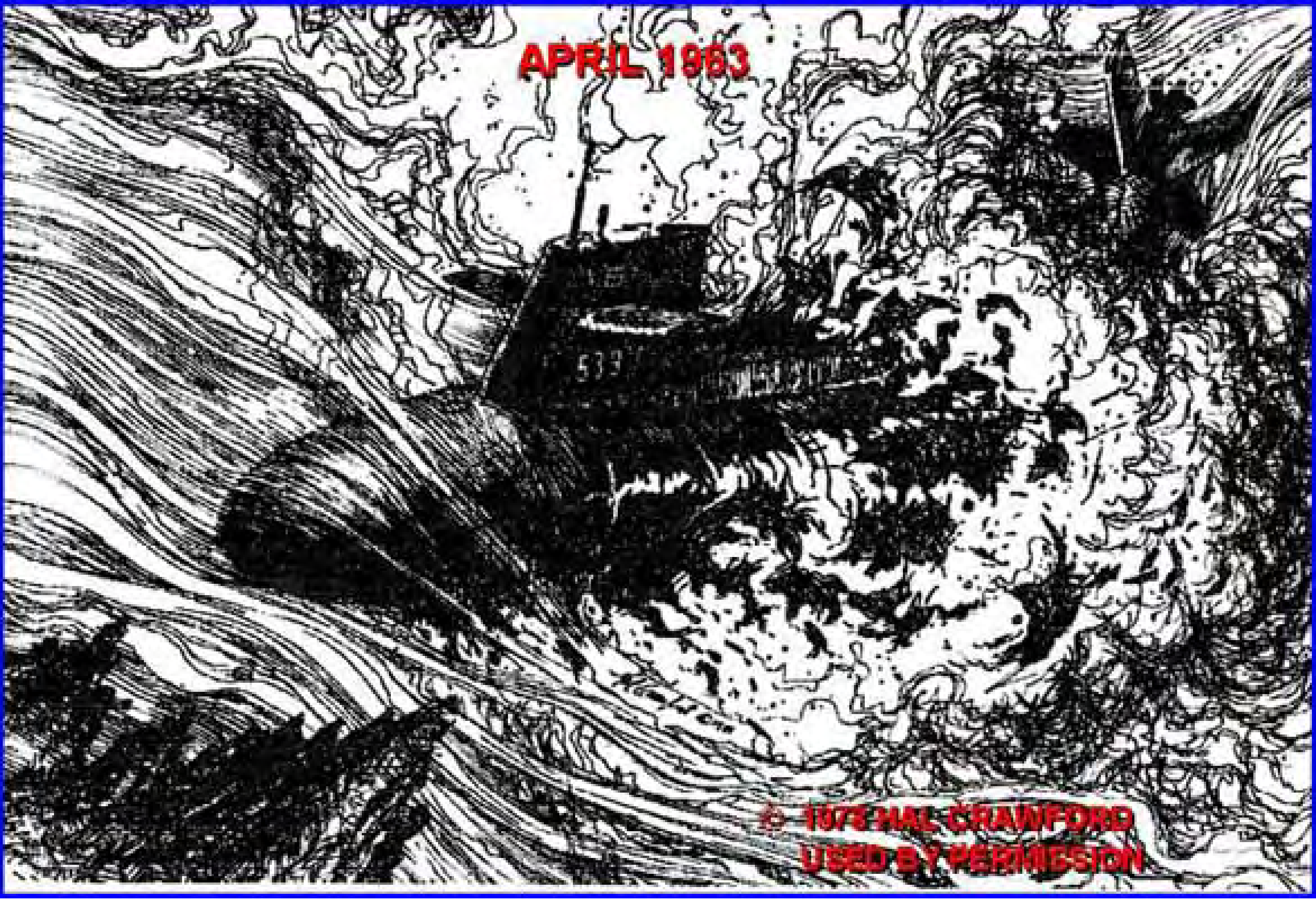
APRIL 1963
593
© 1978 HAL CRAWFORD
USED BY PERMISSION

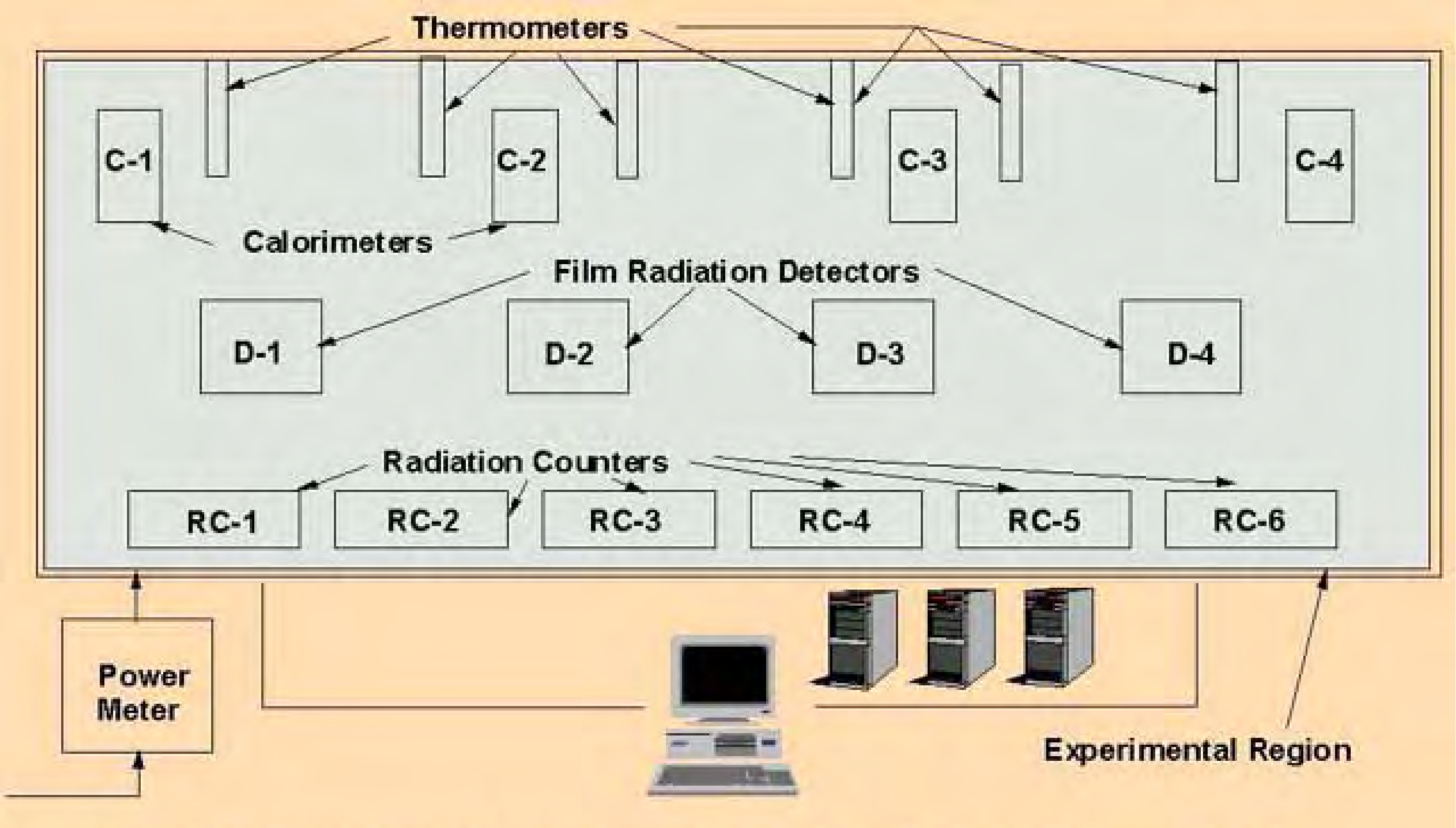
Thermometers
C-1
C-2
C-3
C-4
Calorimeters
Film Radiation Detectors
D-1
D-2
D-3
D-4
Radiation Counters
RC-1
RC-2
RC-3
RC-4
RC-5
RC-6
Power Meter
Experimental Region

Figure 32. Embodiment of an instrumental array sufficient to discriminate when time-density charging has occurred, and that transduction of time-charge decay is occurring.

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Time-Polarized EM Wave interferometer Creating Space-Time Curvature Engines in a Distant Interference Zone

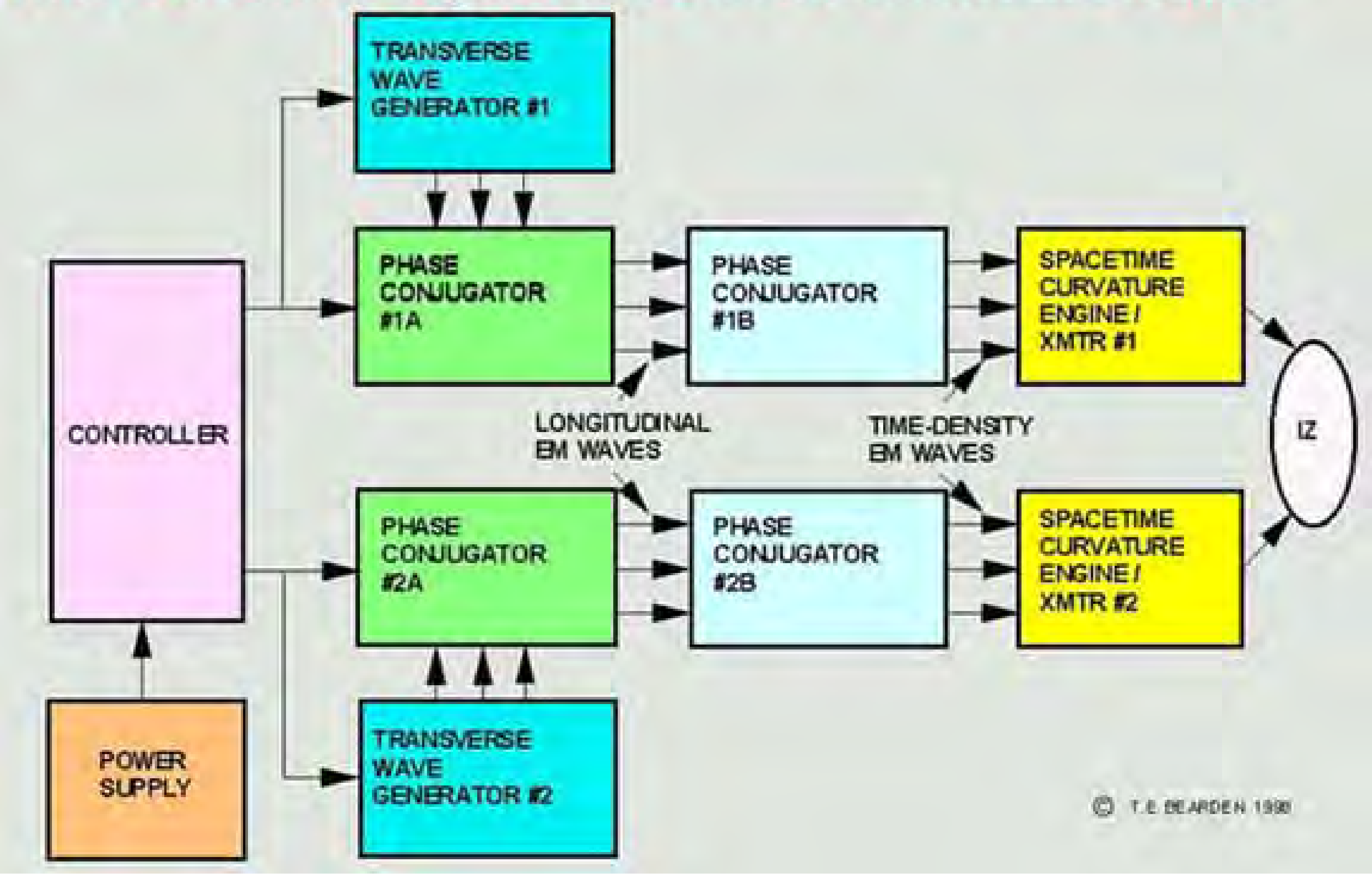
TRANSVERSE WAVE GENERATOR #1
PHASE CONJUGATOR #1A
PHASE CONJUGATOR #1B
SPACETIME CURVATURE ENGINE / XMTR #1
CONTROLLER
LONGITUDINAL EM WAVES
TIME-DENSITY EM WAVES
IZ
PHASE CONJUGATOR #2A
PHASE CONJUGATOR #2B
SPACETIME CURVATURE ENGINE / XMTR #2
POWER SUPPLY
TRANSVERSE WAVE GENERATOR #2
© T.E. BEARDEN 1990

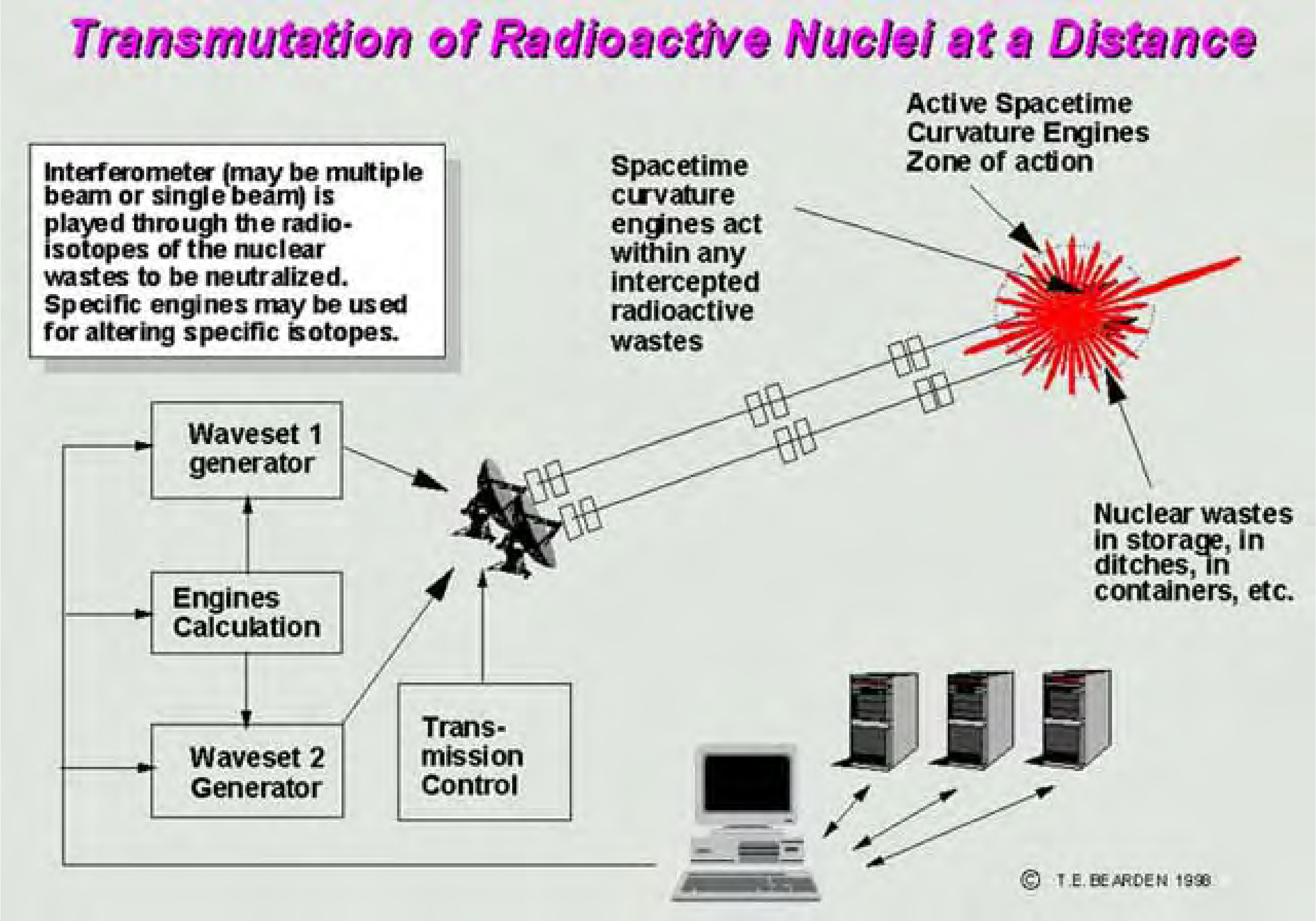

Transmutation of Radioactive Nuclei at a Distance

Interferometer (may be multiple beam or single beam) is played through the radioisotopes of the nuclear wastes to be neutralized. Specific engines may be used for altering specific isotopes.

Spacetime curvature engines act within any intercepted radioactive wastes

Active Spacetime Curvature Engines Zone of action
Waveset 1 generator
Engines Calculation
Waveset 2 Generator
Trans-mission Control
Nuclear wastes in storage, in ditches, in containers, etc.
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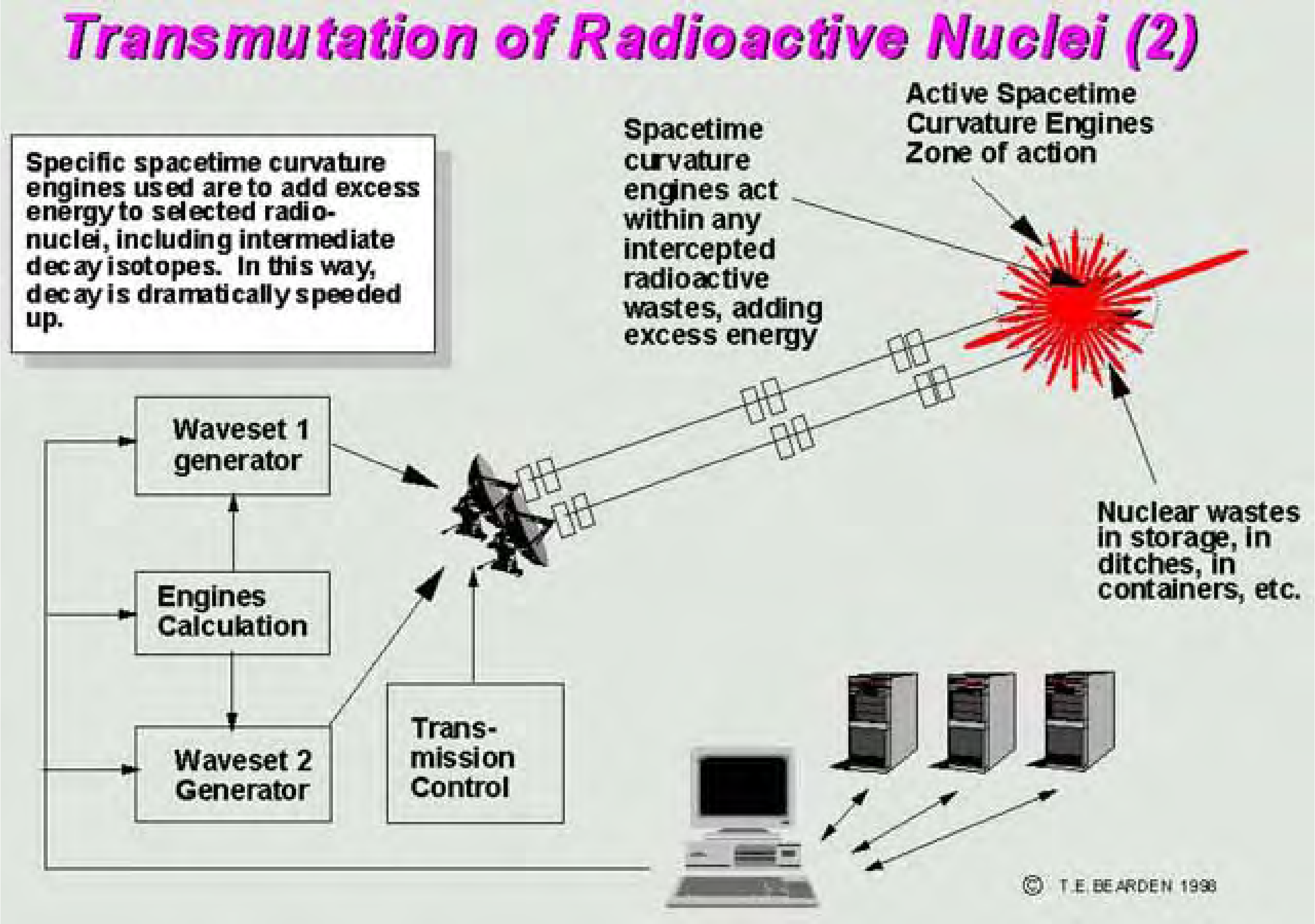

Transmutation of Radioactive Nuclei (2)

Specific spacetime curvature engines used are to add excess energy to selected radio-nuclei, including intermediate decay isotopes. In this way, decay is dramatically speeded up.

Spacetime curvature engines act within any intercepted radioactive wastes, adding excess energy

Active Spacetime Curvature Engines Zone of action
Nuclear wastes in storage, in ditches, in containers, etc.
Waveset 1 generator
Engines Calculation
Waveset 2 Generator
Trans-mission Control
© T.E. BEARDEN 1998

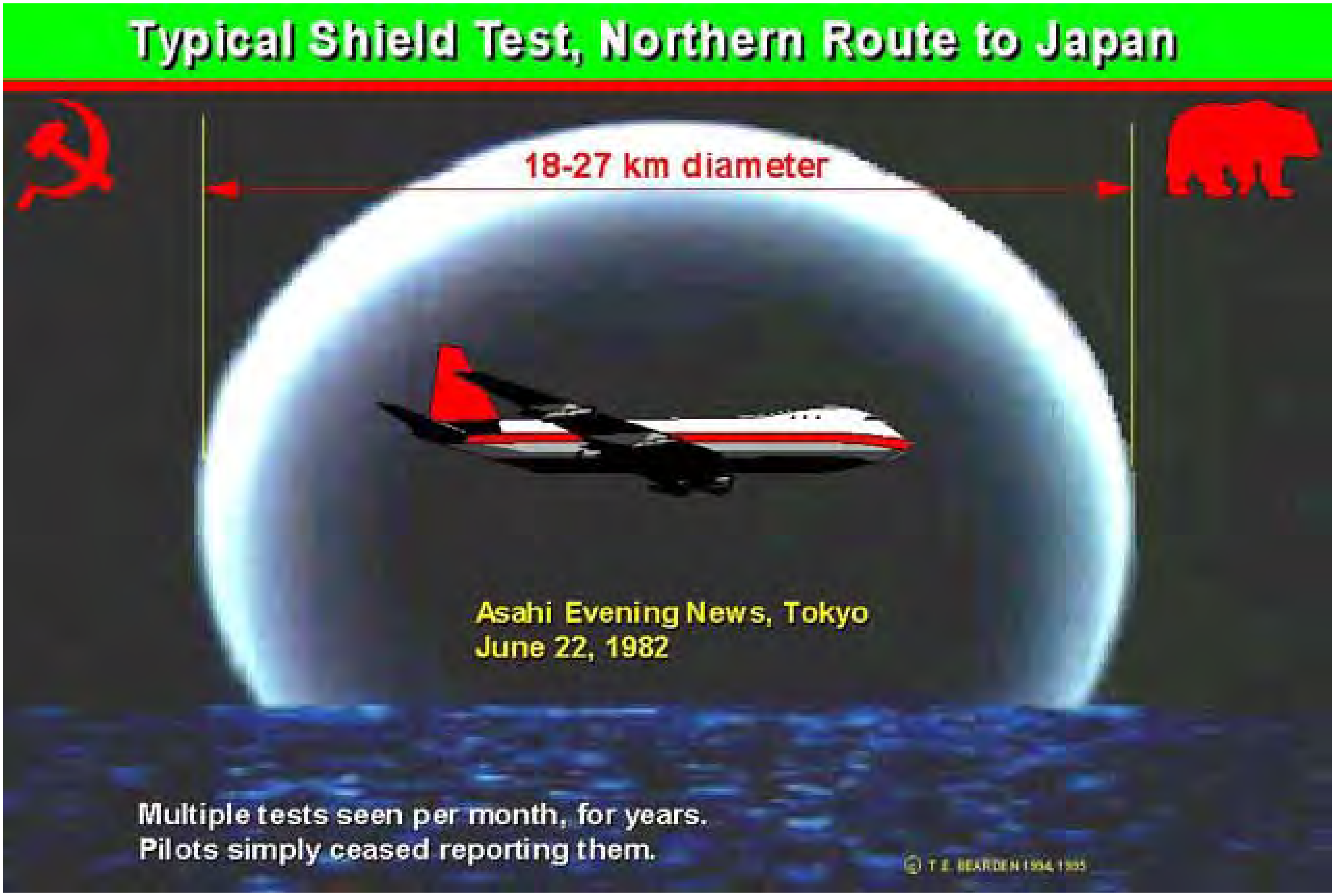

Typical Shield Test, Northern Route to Japan

Asahi Evening News, Tokyo
June 22, 1982

Multiple tests seen per month, for years.
Pilots simply ceased reporting them.

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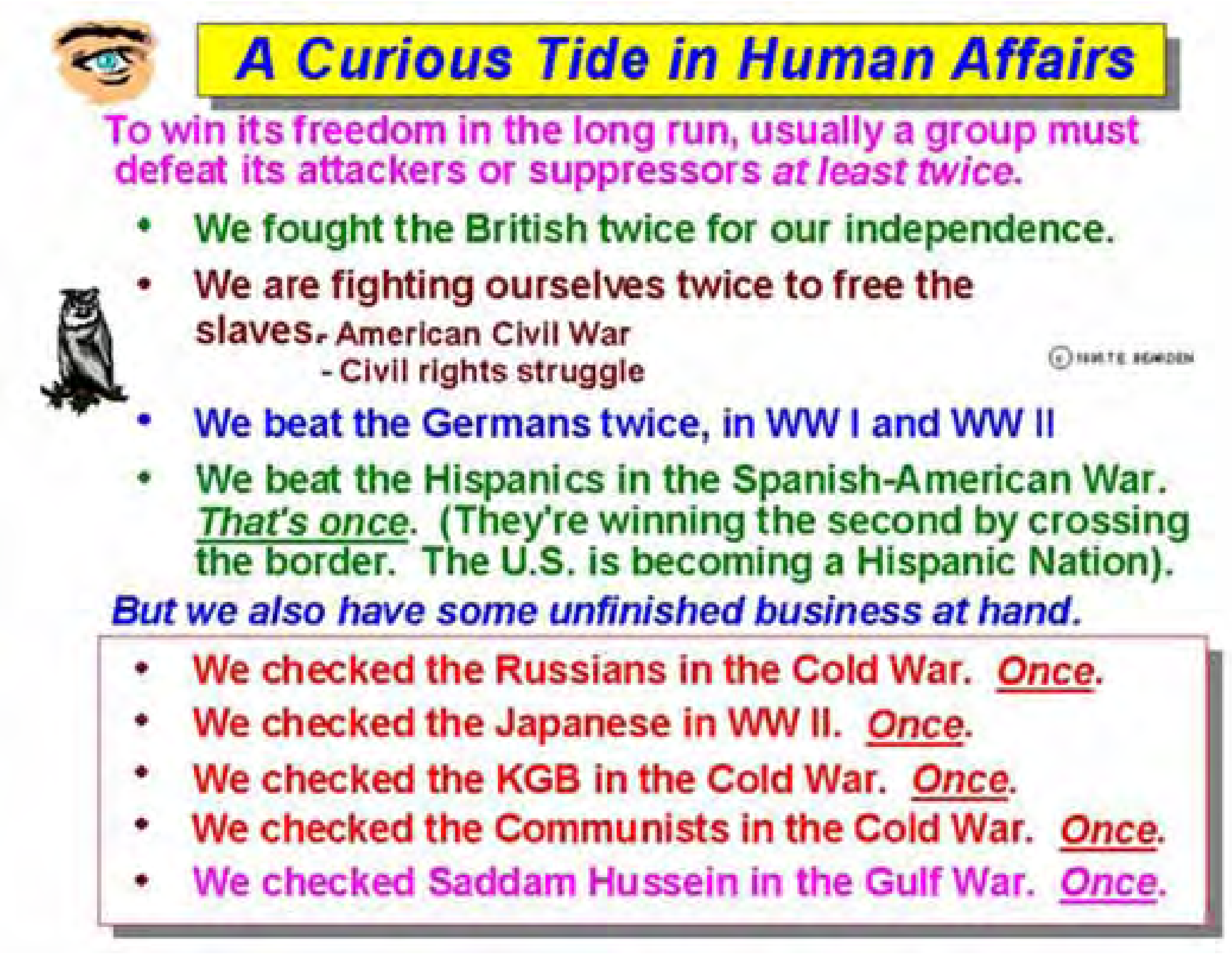

A Curious Tide in Human Affairs

To win its freedom in the long run, usually a group must defeat its attackers or suppressors *at least twice*.

- We fought the British twice for our independence.
- We are fighting ourselves twice to free the slaves. - American Civil War
  - Civil rights struggle
- We beat the Germans twice, in WW I and WW II
- We beat the Hispanics in the Spanish-American War. *That's once*. (They're winning the second by crossing the border. The U.S. is becoming a Hispanic Nation).

But we also have some unfinished business at hand.

- We checked the Russians in the Cold War. *Once*.
- We checked the Japanese in WW II. *Once*.
- We checked the KGB in the Cold War. *Once*.
- We checked the Communists in the Cold War. *Once*.
- We checked Saddam Hussein in the Gulf War. *Once*.

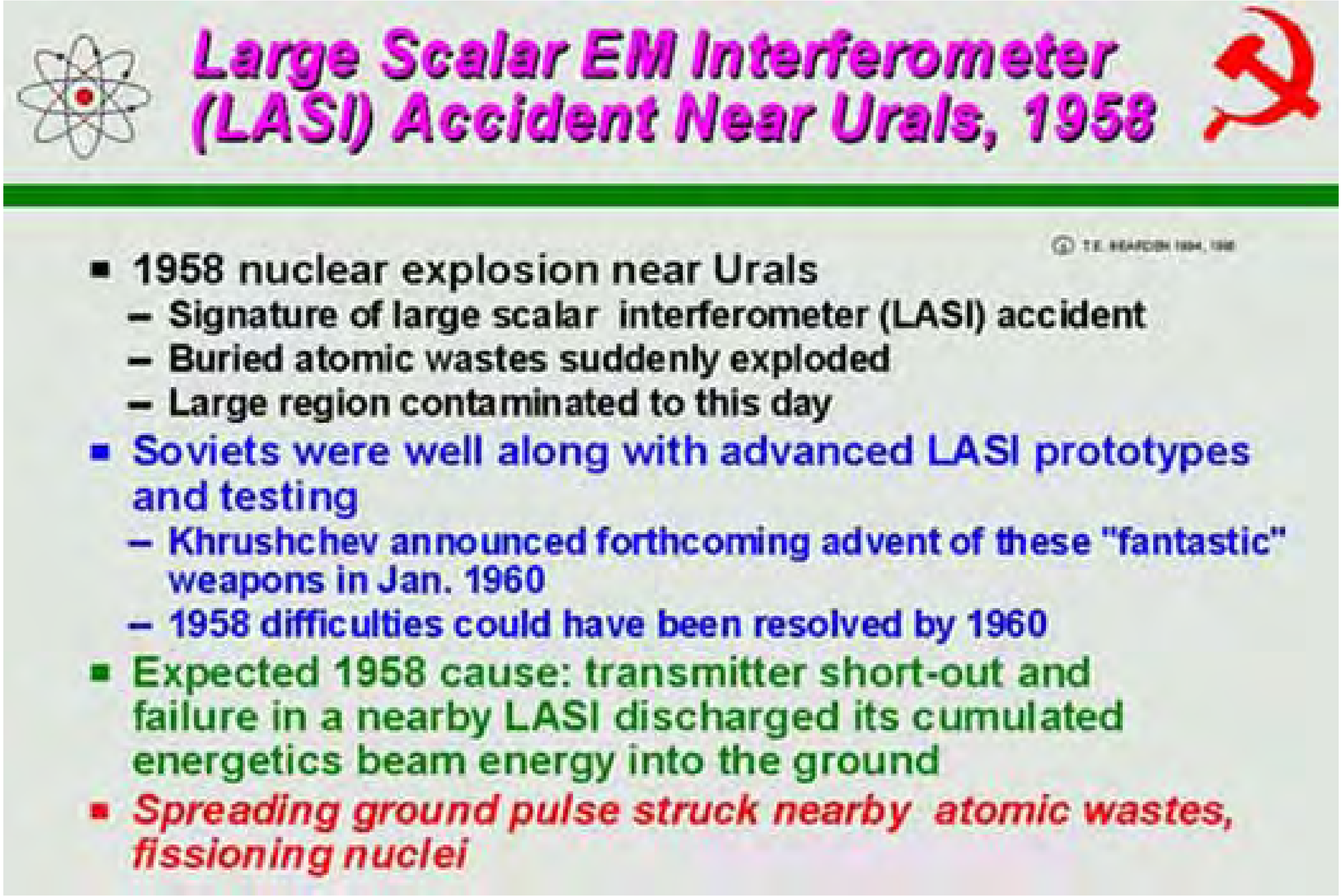

Large Scalar EM Interferometer (LASI) Accident Near Urals, 1958

- 1958 nuclear explosion near Urals
  - Signature of large scalar interferometer (LASI) accident
  - Buried atomic wastes suddenly exploded
  - Large region contaminated to this day
- Soviets were well along with advanced LASI prototypes and testing
  - Khrushchev announced forthcoming advent of these "fantastic" weapons in Jan. 1960
  - 1958 difficulties could have been resolved by 1960
- Expected 1958 cause: transmitter short-out and failure in a nearby LASI discharged its cumulated energetics beam energy into the ground
- *Spreading ground pulse struck nearby atomic wastes, fissioning nuclei*

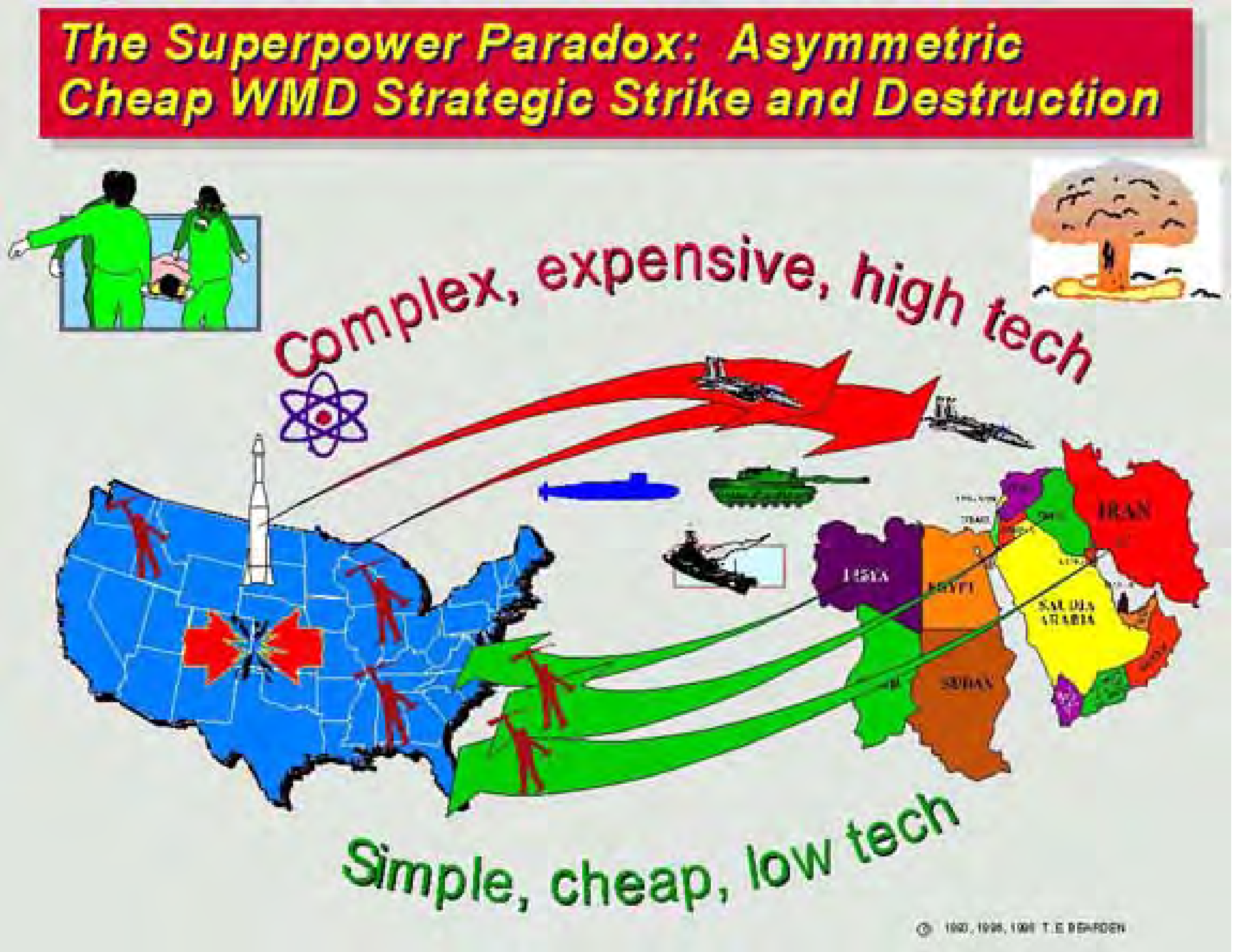

The Superpower Paradox: Asymmetric Cheap WMD Strategic Strike and Destruction

Complex, expensive, high tech

LIBYA
EGYPT
SUDAN
SAUDI ARABIA
IRAN

Simple, cheap, low tech

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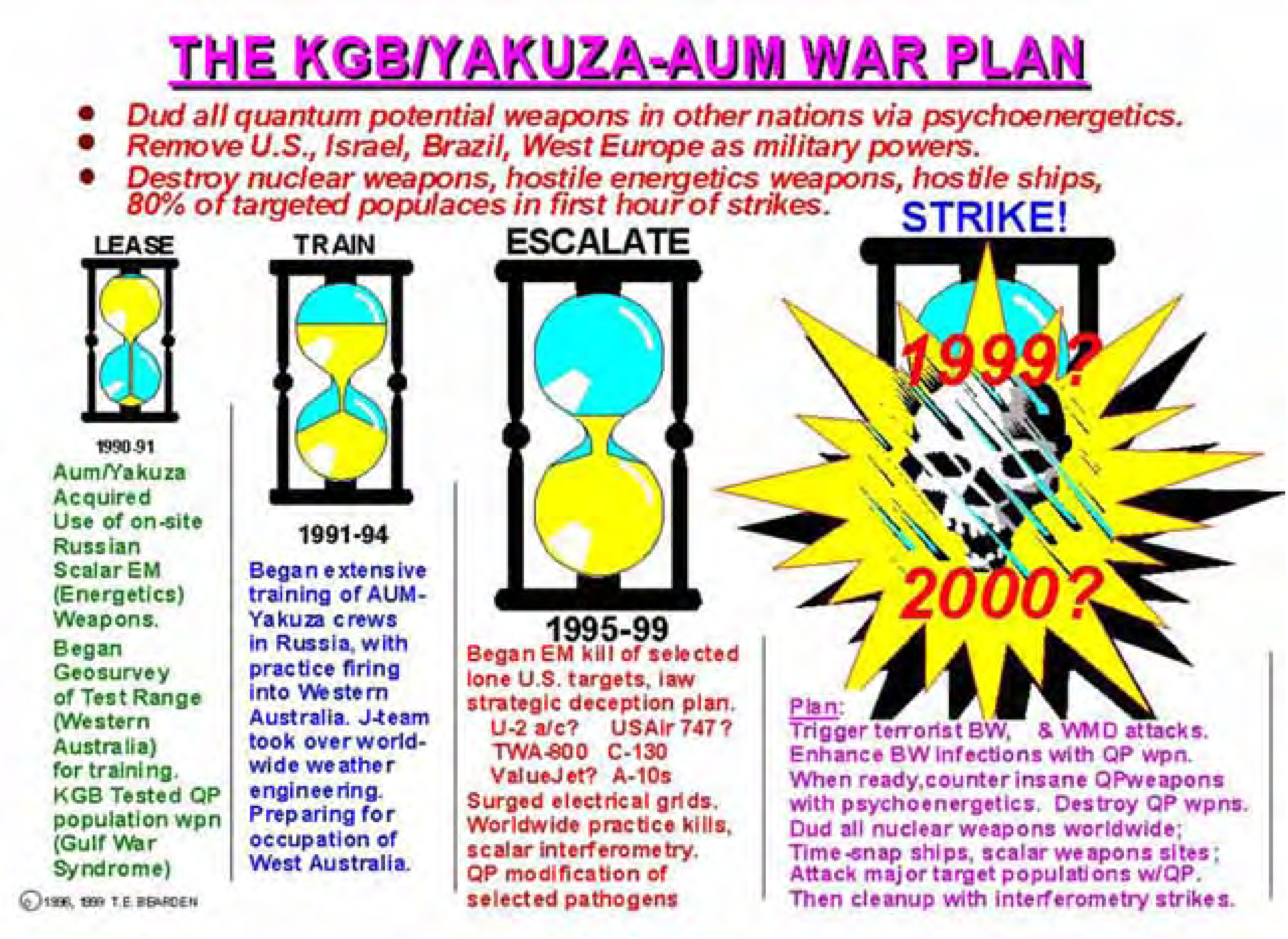

THE KGB/YAKUZA-AUM WAR PLAN

- *Dud all quantum potential weapons in other nations via psychoenergetics.*
- *Remove U.S., Israel, Brazil, West Europe as military powers.*
- *Destroy nuclear weapons, hostile energetics weapons, hostile ships, 80% of targeted populaces in first hour of strikes.*

LEASE

1990-91

Aum/Yakuza Acquired Use of on-site Russian Scalar EM (Energetics) Weapons.

Began Geosurvey of Test Range (Western Australia) for training.

KGB Tested QP population wpn (Gulf War Syndrome)

TRAIN

1991-94

Began extensive training of AUM-Yakuza crews in Russia, with practice firing into Western Australia. J-team took over world-wide weather engineering. Preparing for occupation of West Australia.

ESCALATE

1995-99

Began EM kill of selected lone U.S. targets, law strategic deception plan.

U-2 a/c?	USAir 747 ?
TWA-800	C-130
ValueJet?	A-10s

Surged electrical grids.

Worldwide practice kills, scalar interferometry.

QP modification of selected pathogens

STRIKE!

1999?

2000?

Plan:

Trigger terrorist BW, & WMD attacks.

Enhance BW infections with QP wpn.

When ready, counter insane QPweapons with psychoenergetics. Destroy QP wpns.

Dud all nuclear weapons worldwide;

Time-snap ships, scalar weapons sites;

Attack major target populations w/QP.

Then cleanup with interferometry strikes.

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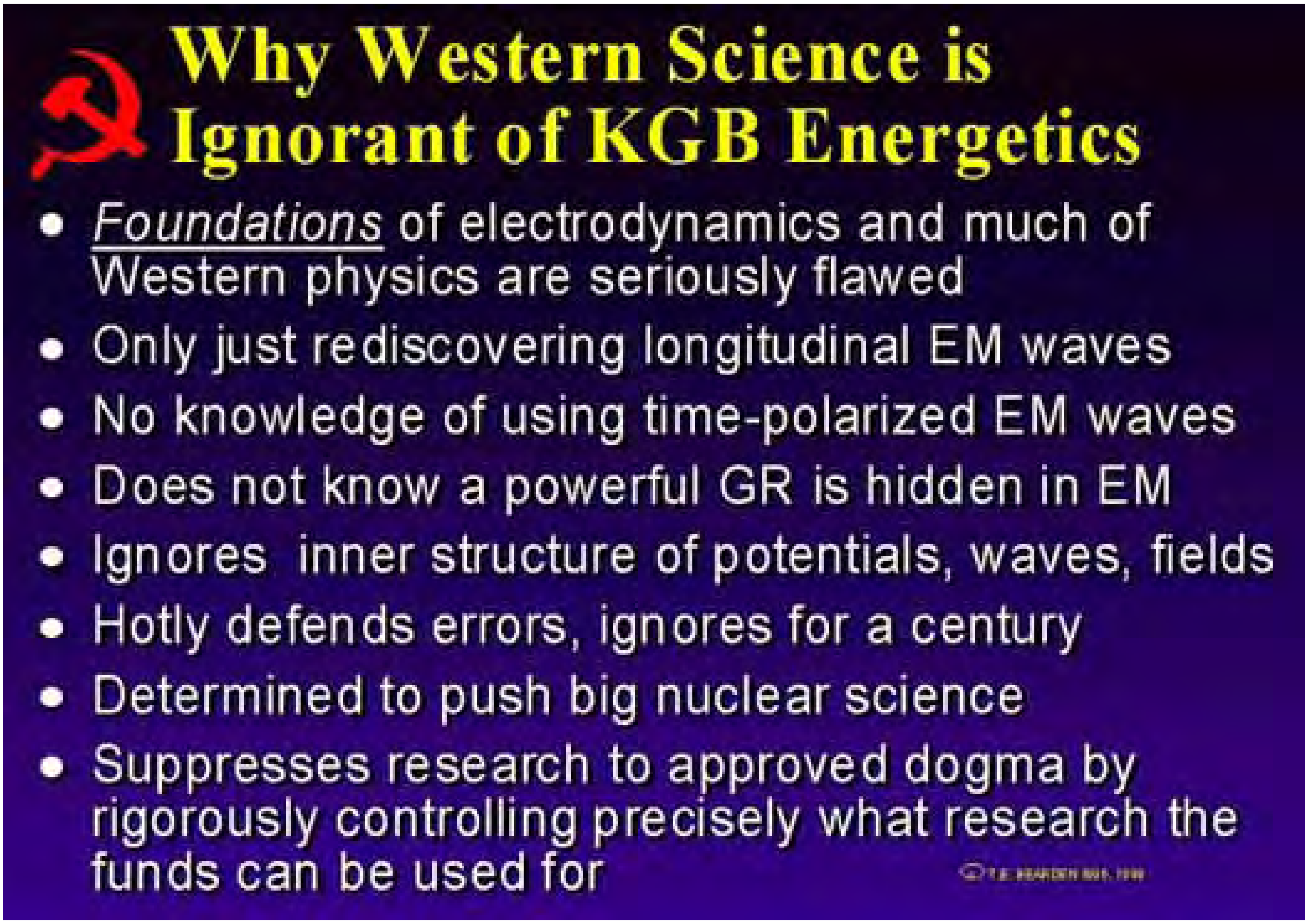

Why Western Science is Ignorant of KGB Energetics

- *Foundations* of electrodynamics and much of Western physics are seriously flawed
- Only just rediscovering longitudinal EM waves
- No knowledge of using time-polarized EM waves
- Does not know a powerful GR is hidden in EM
- Ignores inner structure of potentials, waves, fields
- Hotly defends errors, ignores for a century
- Determined to push big nuclear science
- Suppresses research to approved dogma by rigorously controlling precisely what research the funds can be used for

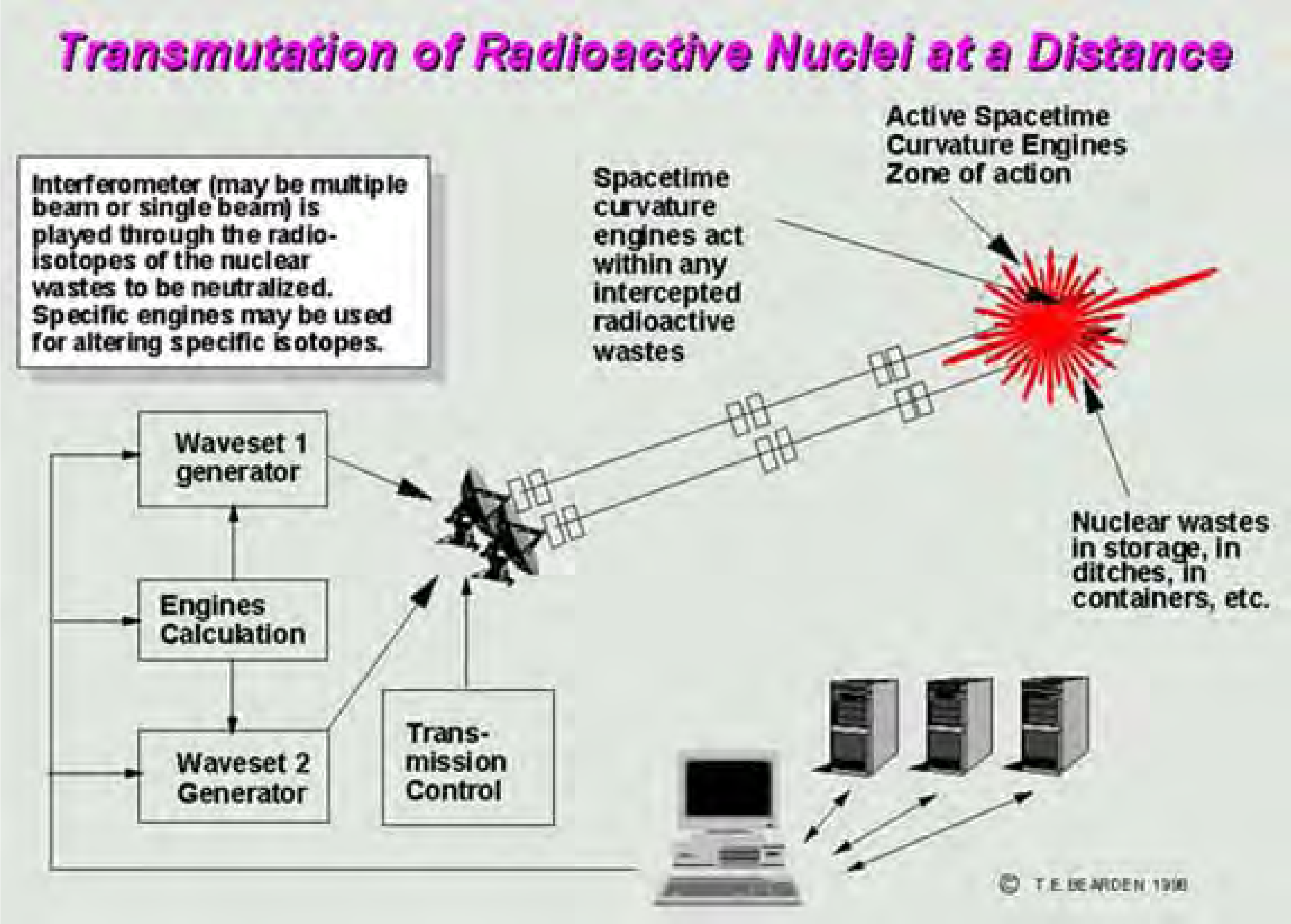

Transmutation of Radioactive Nuclei at a Distance

Interferometer (may be multiple beam or single beam) is played through the radioisotopes of the nuclear wastes to be neutralized. Specific engines may be used for altering specific isotopes.

Spacetime curvature engines act within any intercepted radioactive wastes

Active Spacetime Curvature Engines Zone of action

Nuclear wastes in storage, in ditches, in containers, etc.

Waveset 1 generator
Engines Calculation
Waveset 2 Generator
Trans-mission Control

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THE YAKUZA

(JAPANESE MAFIA)

To do business with Japan is to do business with the Yakuza

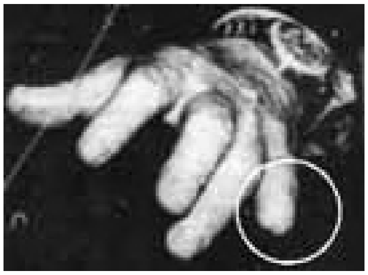

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The Last Samurai, Defending Bushido

- 3 Major Yakuza Groups, In Coalition.
- Penetrate Japanese Government.
- Open Offices, Signs on Street.
- Public Romanticizes Yakuza as Last Japanese Samurai
- In Large High-Tech Corporations.
- In Control of Japanese Banks.
- Japanese Real-Estate Rip-off.
- $500 - 1,000 Billion per Year Income.
- Rapidly Spreading in U.S.
- Uniting Mafia Groups Worldwide.
- Coalition with Aum Shinrikyo.
- Leased Russian Energetics Weapons.
- Crews On-site in Russia, Trained.
- Practice Firings into Western Australia for Three Years. (Dozens of Shots per Month)
- Now in Escalation Phase, Killing U.S. Targets.
- All-out Strike on U.S. ready 1999-2000.
- Now held in check by KGB, dead-man fuzed by small nation friendly to U.S.

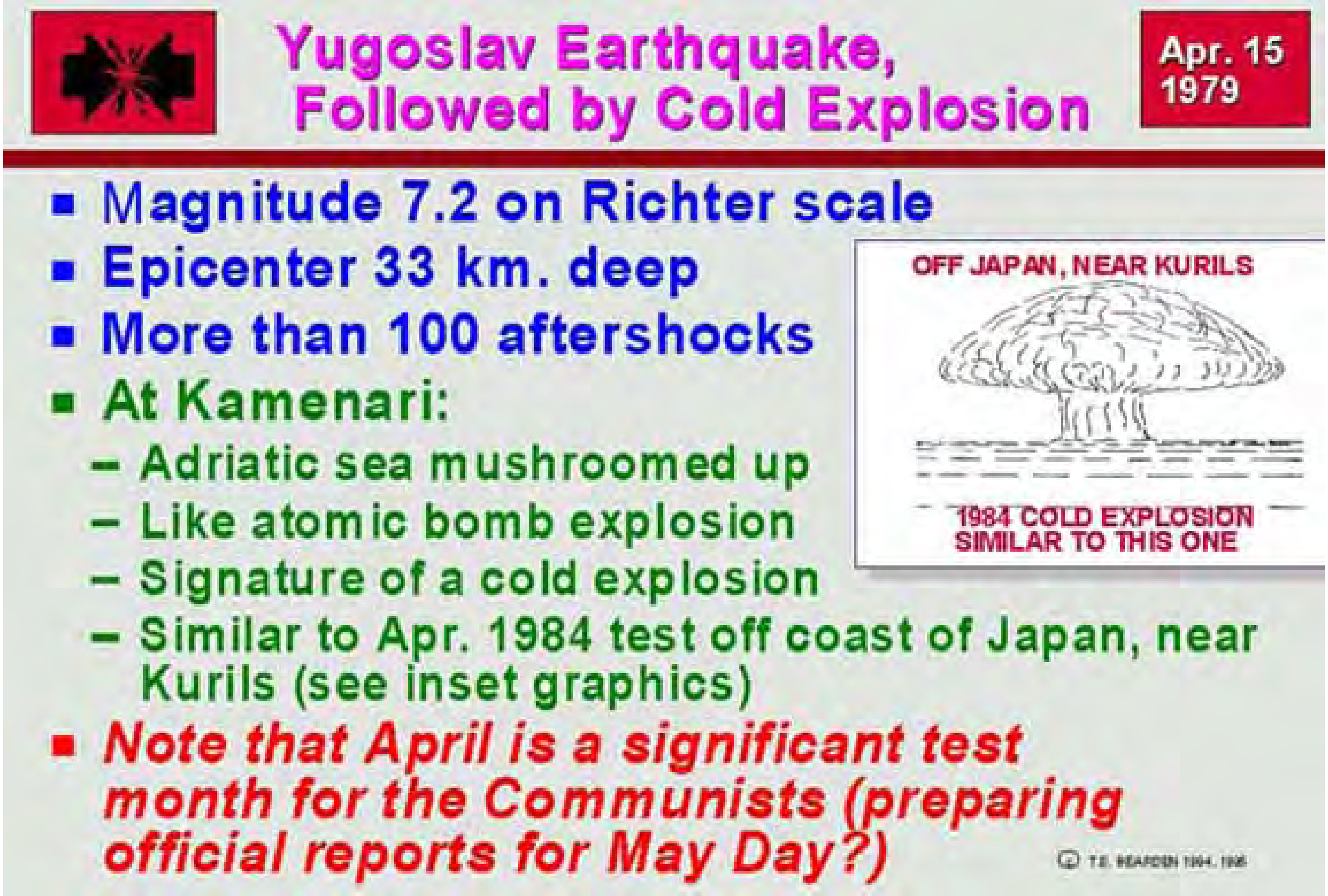

Yugoslav Earthquake, Followed by Cold Explosion

Apr. 15
1979

- Magnitude 7.2 on Richter scale
- Epicenter 33 km. deep
- More than 100 aftershocks
- At Kamenari:
  - Adriatic sea mushroomed up
  - Like atomic bomb explosion
  - Signature of a cold explosion
  - Similar to Apr. 1984 test off coast of Japan, near Kurils (see inset graphics)
- *Note that April is a significant test month for the Communists (preparing official reports for May Day?)*

OFF JAPAN, NEAR KURILS

1984 COLD EXPLOSION
SIMILAR TO THIS ONE

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Briefing to
Request for Information Symposium

14 February 2000

Air Force Research Laboratory

Directed Energy Directorate
AFRL/DE

Kirtland AFB, New Mexico

Colonel Doug Beason
Deputy Director

“VICTORY SMILES UPON THOSE WHO ANTICIPATE THE CHANGES IN THE CHARACTER OF WAR”

Guilio Douhet

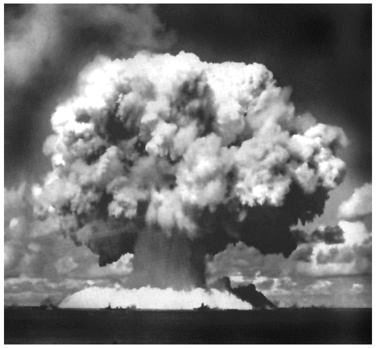

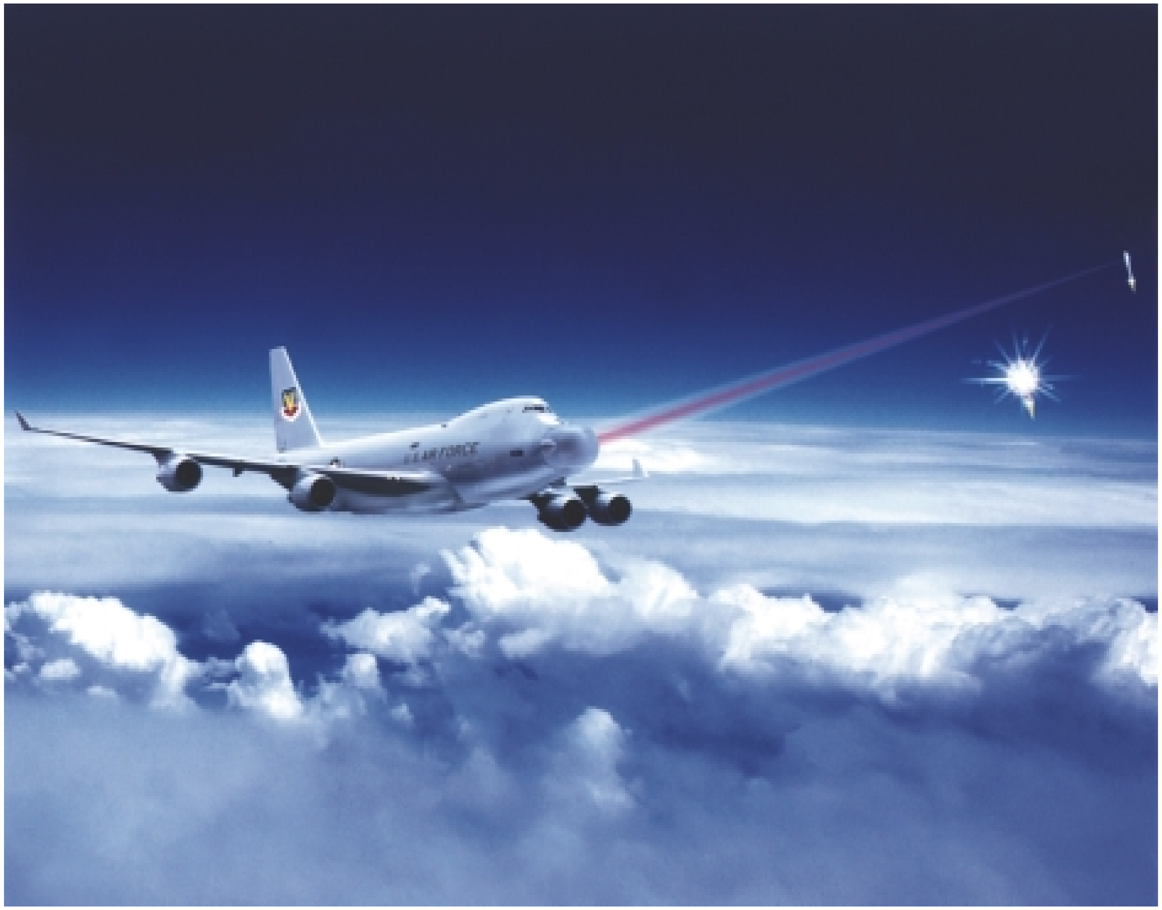
U.S. AIR FORCE

Directed Energy Directorate

A paradigm shift in weapon system technology for the 21st Century.

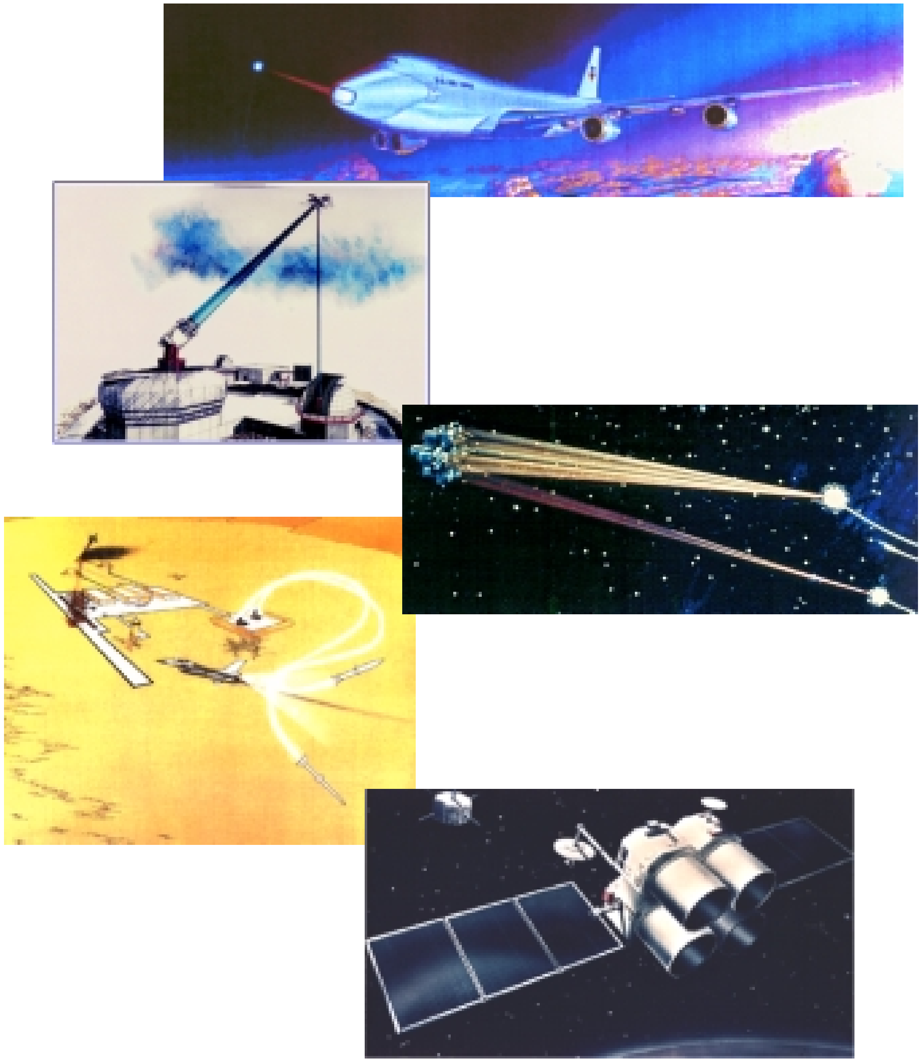

Our Mission

- ***To support*** user needs for DEW applications and to address mission area deficiencies
- ***To exploit*** the relevance of Directed Energy technology to Air Force and DoD needs
- ***To foster*** user awareness of the potential of Directed Energy for Air Force and DoD applications
- ***To avoid*** technological surprise
- ***To explore*** DE technology avenues that offer high payoff to directed energy capabilities and applications

To do what has never been done before!

Directed Energy Directorate

Our Vision of the Future:
Directed Energy will Dominate the Battlespace of the 21st Century

Strike

We will strike deep in the enemy's territory at the speed of light, with little or no collateral damage or loss of life, crippling his ability to wage aggression.

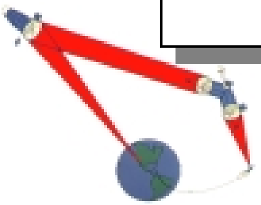

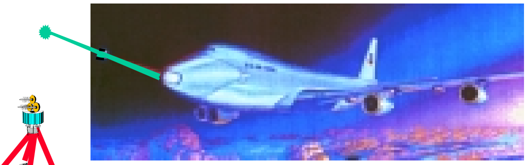

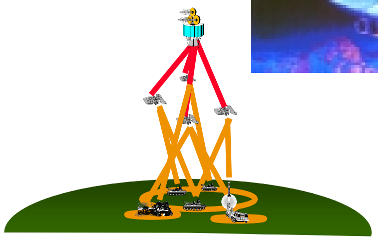

Protect

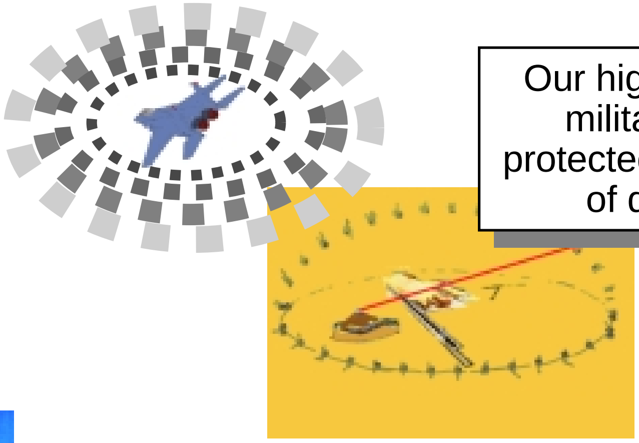

Our high value and limited military assets will be protected by invisible shields of directed energy.

Graduated Deterrence

We will provide our warfighters with weapons that provide a wide range of graduated force for every military contingency.

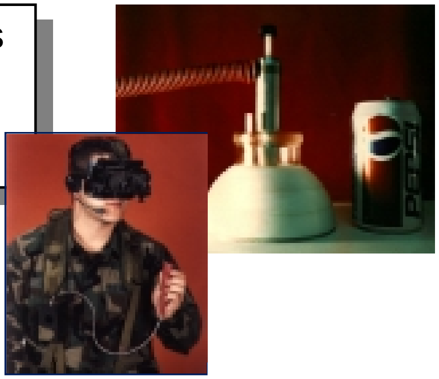

Awareness

Our battleflield awareness will be greatly enhanced with directed energy tools capable of detection and identification

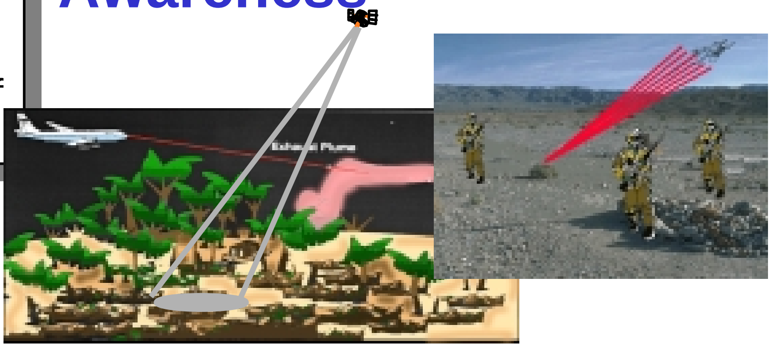

Security & safety in
isolated canyons

Access to 50,000
acres for testing

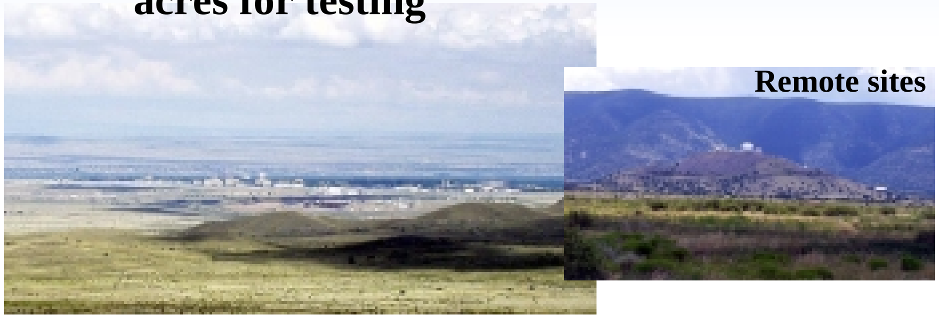
Remote sites

Ideal weather
“thin” atmosphere

Kirtland AFB

Unique & ideally suited for the nation’s

directed energy technology development

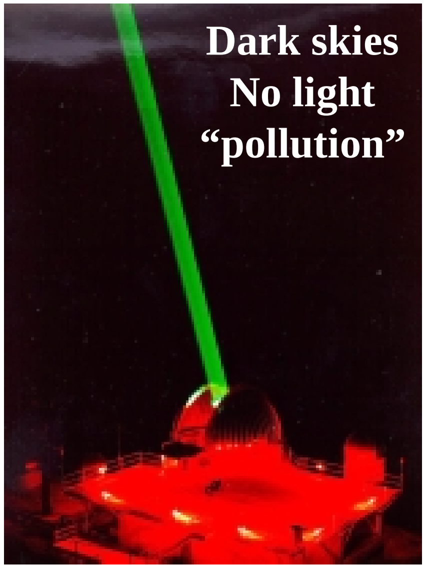
Dark skies
No light
“pollution”

Sandia National Laboratories

Many diverse, high tech tenants

International airport & metro area

Directed Energy Directorate
Remote Sites

- Maui, HI (leased land)
    - Relay Mirror Experiment Facility
    - Maui High Performance Computer Center
    - Maui Space Surveillance Complex

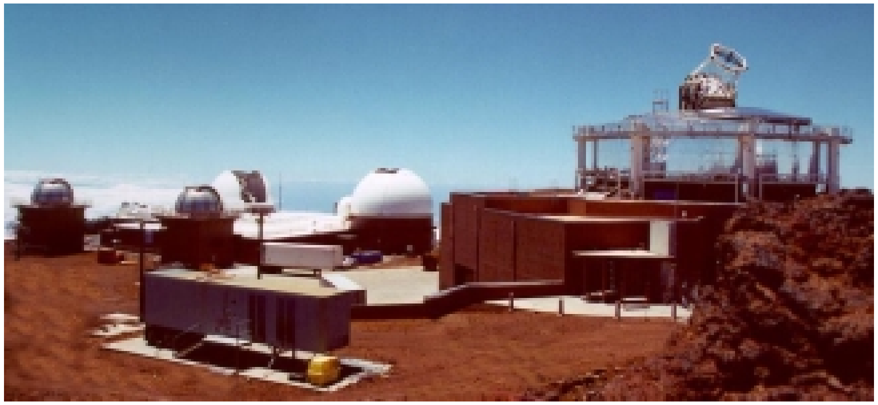

- North Oscura Peak, NM
    - Telescope site at White Sands Missile Range
    - Supports Space Imaging R&D (ABL Technology)

Lasers and Microwaves

Synergistic, Complementary and Capable

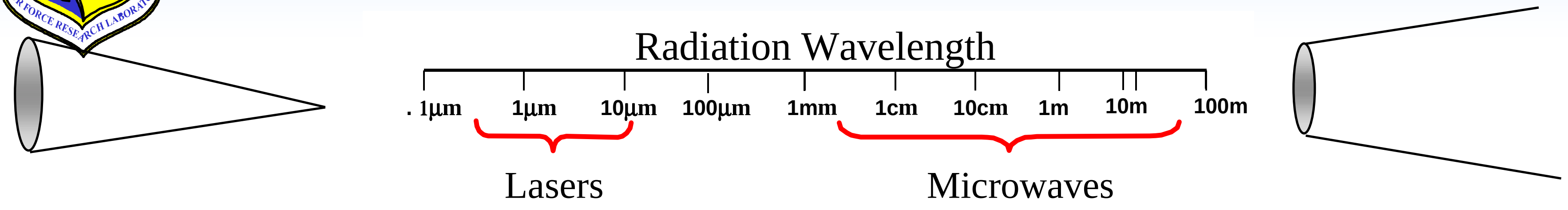
Radiation Wavelength
. 1µm
1µm
10µm
100µm
1mm
1cm
10cm
1m
10m
100m
Lasers
Microwaves

High Energy Lasers	High Power Microwave s
Small spot: surgical attack	**Flood target area: multiple simultaneous targets**
Affects targets from outside: structural destruction	**Affects components inside: electronic disruption**
Weather sensitive: clouds, dust, molecular absorption	**Weather insensitive: sees through clouds and dust.**
Modest apertures: glass mirrors, coatings	**Big apertures: metal antennas, ground planes**

But on the other hand,... they both

- **Travel at the speed of light to the target**
- **Capable of graduated effects from deny, disrupt, degrade, and destroy.**
- **Minimum collateral damage**

Directed Energy Directorate
Broad Technology Investments

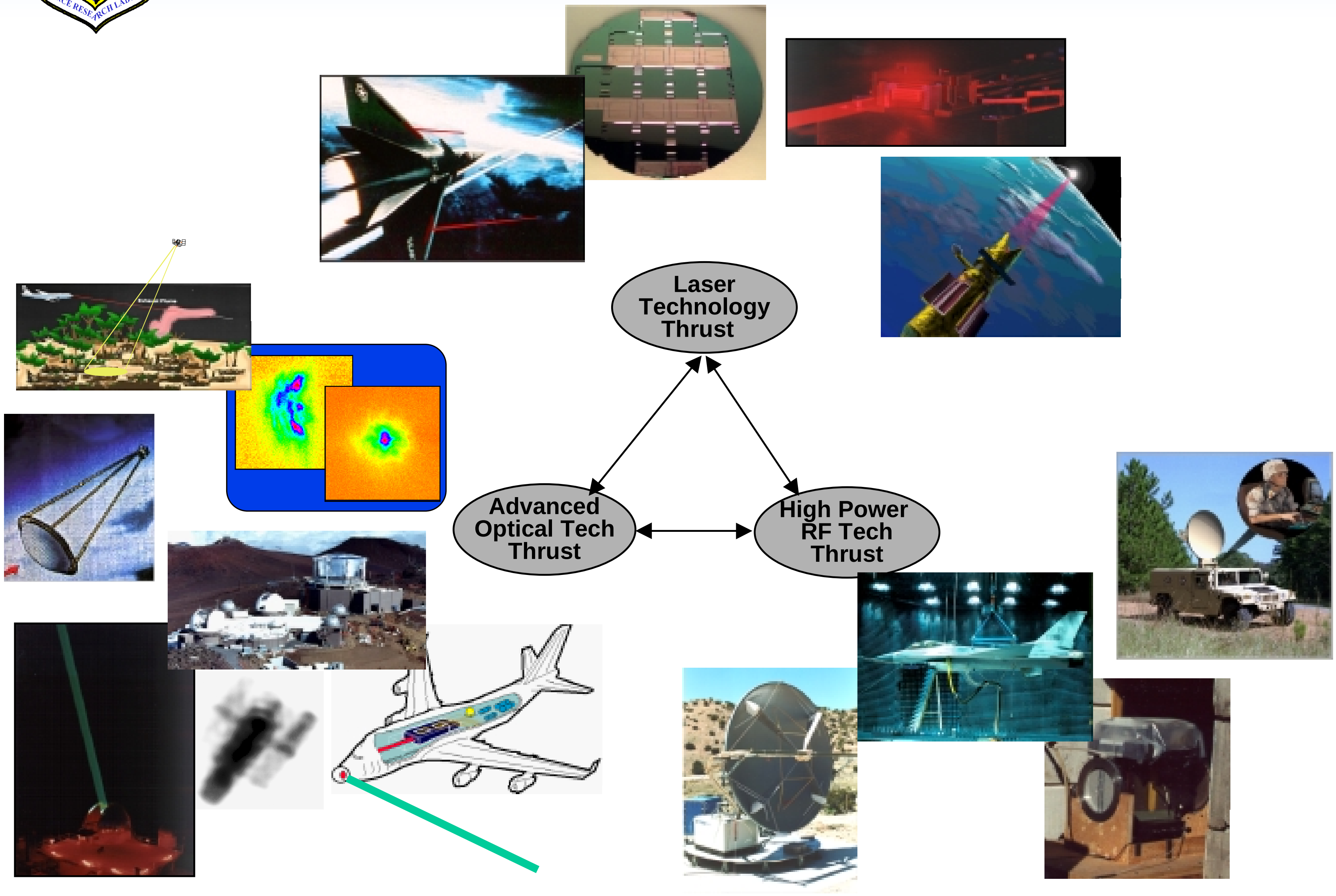
Laser Technology Thrust

Advanced Optical Tech Thrust

High Power RF Tech Thrust

Directed Energy Directorate

12 Major DE Technology Programs

Ground Based Laser Technology Program

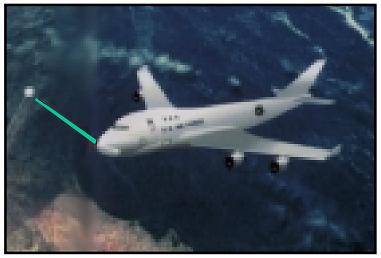
Airborne Laser Technology Program

High Power Laser Program

Scalable Multi-Wavelength Laser Program

High Efficiency Electric Laser Program

Remote Sensing
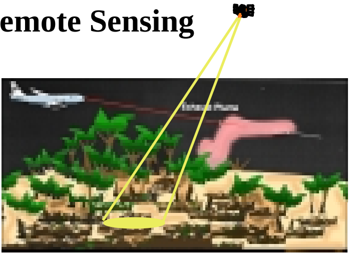

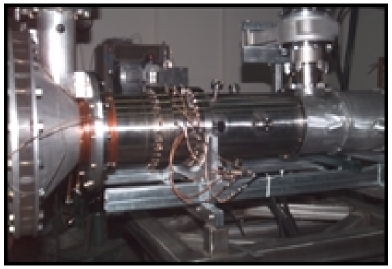
HPM Sources Program

HPM Pulsed Power Program

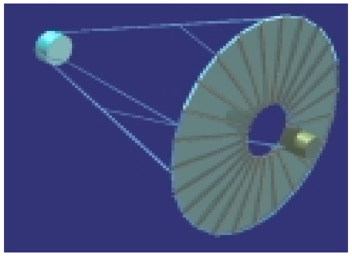
Large Optics

Space Awareness Program

HPM Applications Program

HPM Effects Program

AFRL
Directed Energy Directorate

Mission

Develop, integrate and transition science & technology for Directed Energy to include high power microwaves, lasers, adaptive optics, imaging and its effects to assure the preeminence of US in air & space

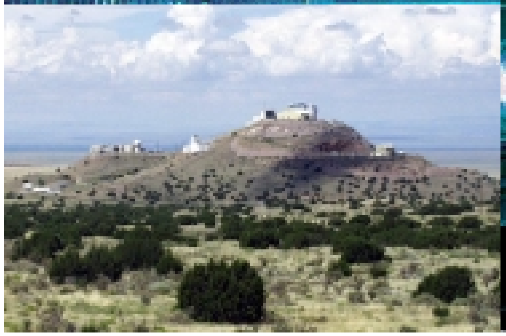

DANGER
HIGH VOLTAGE

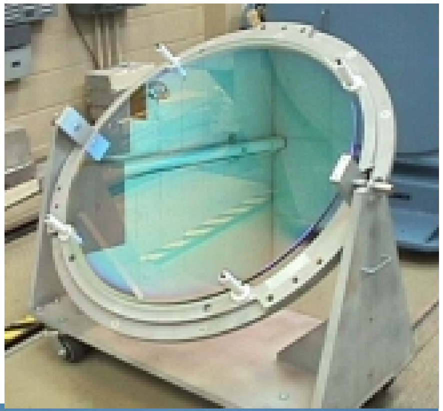
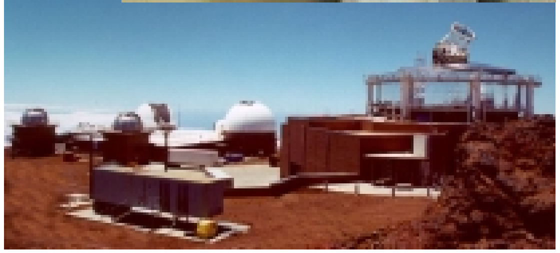

Major Technology Programs

Ground Based Laser
Airborne Laser
High Power Lasers
Multi-Wavelength Laser
Electric Lasers
Large Optics
Space Awareness
HPM Applications
HPM Effects
HPM Pulsed Power
HPM Sources
Remote Sensing

AFRL/DE - factoids

- **952 people (Civ, Mil, Contr)**
- **$109M FY00 budget**
- **4,325 acres**
- **757,000 sf of space**
- **Located throughout Kirtland**
- **Sites at Maui & WSMR**

Air Force Research Laboratory
Directed Energy Directorate

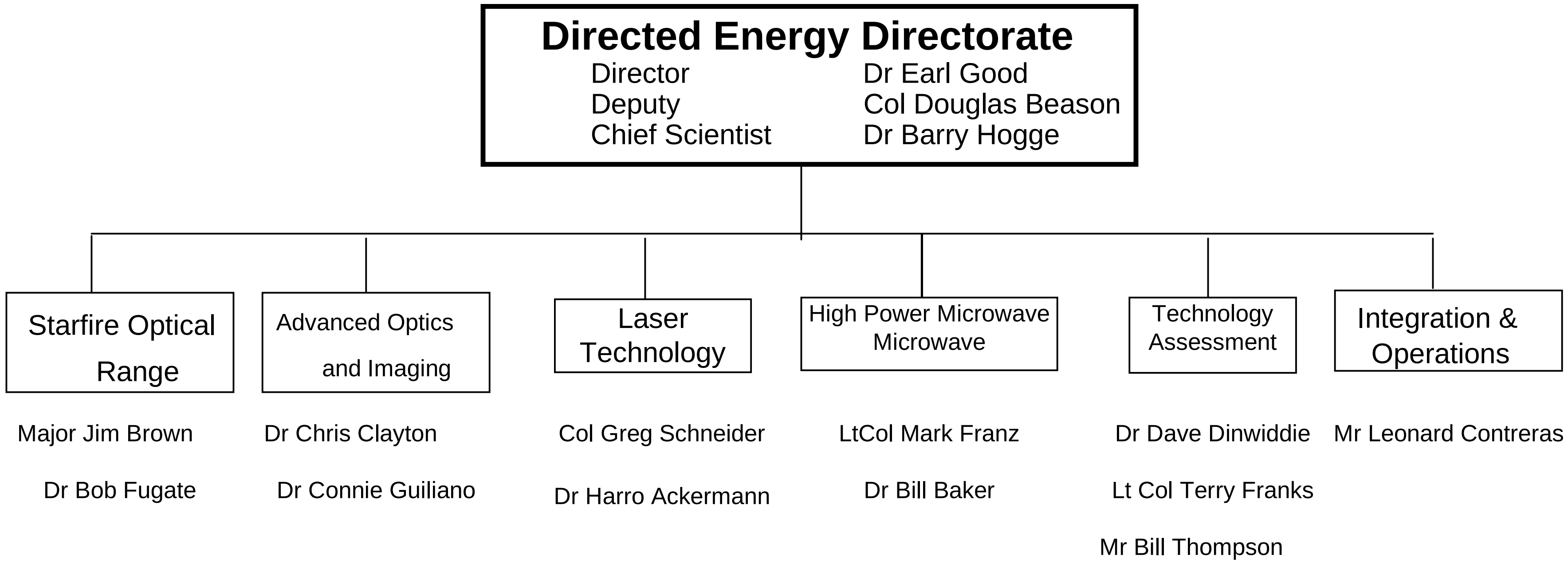

Directed Energy Directorate

Director: Dr Earl Good
Deputy: Col Douglas Beason
Chief Scientist: Dr Barry Hogge

Starfire Optical Range
- Major Jim Brown
- Dr Bob Fugate

Advanced Optics and Imaging
- Dr Chris Clayton
- Dr Connie Guiliano

Laser Technology
- Col Greg Schneider
- Dr Harro Ackermann

High Power Microwave Microwave
- LtCol Mark Franz
- Dr Bill Baker

Technology Assessment
- Dr Dave Dinwiddie
- Lt Col Terry Franks
- Mr Bill Thompson

Integration & Operations
- Mr Leonard Contreras

Directed Energy Directorate

Major Kirtland Facilities

Lasers, Optics, Imaging

Starfire Optical Range

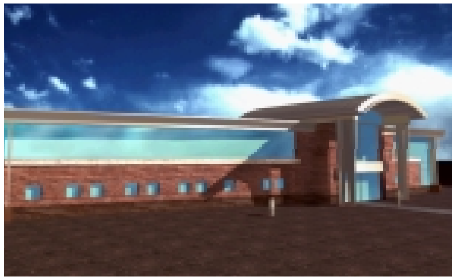
Advanced Laser Facility

Argus Facility

Optics Development
& Beam Control Laboratory

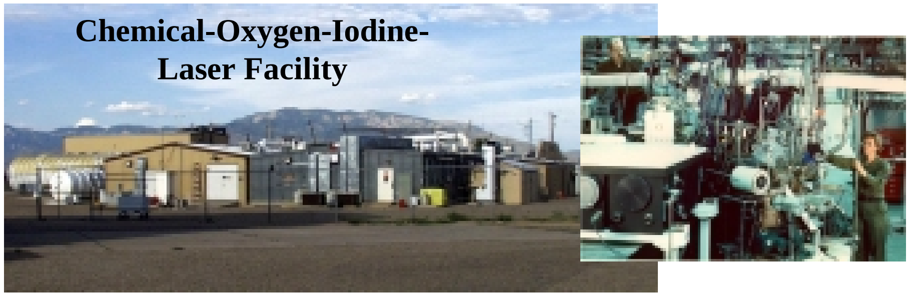
Chemical-Oxygen-Iodine-
Laser Facility

Optics Coating & Components Evaluation Laboratory

Laser Effects Test Facility

Directed Energy Directorate

Major Facilities - High Power Microwave

High Energy Microwave Laboratory

High Energy Research & Technology Facility

Plasma Research Laboratory

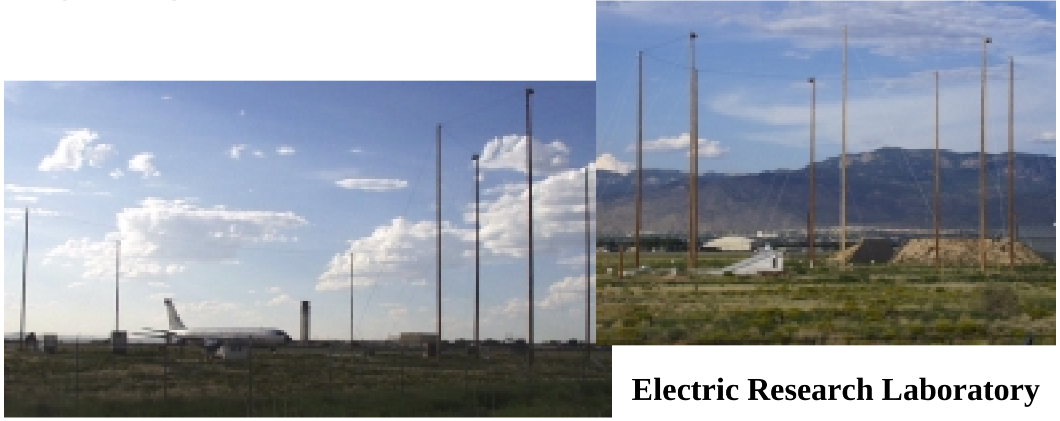
Electric Research Laboratory

Electromagnetic Energy/RF Effects Laboratory

Directed Energy Directorate

Manning

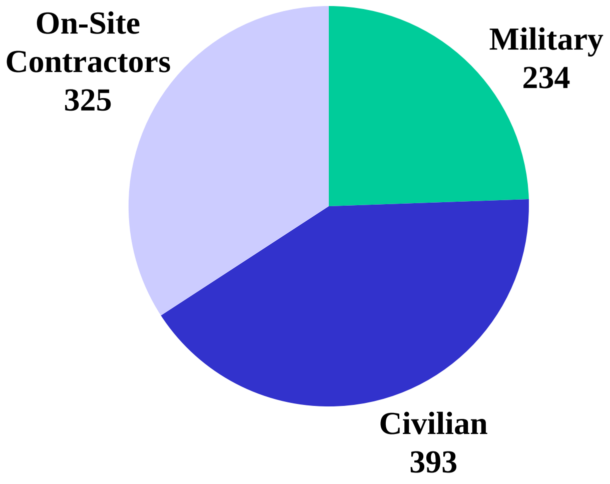

Assigned Personnel
952

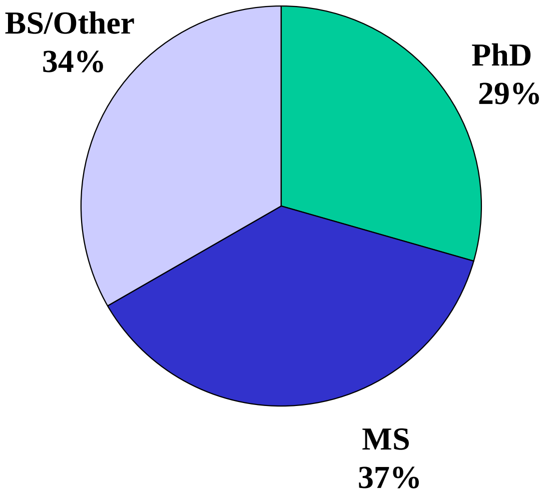

Government S&E Education Levels

Directed Energy Directorate
FY00 AFRL PB Resources

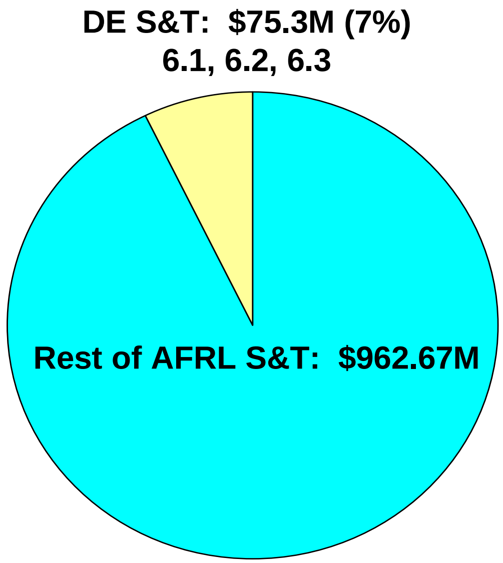

AFRL TOTAL S&T: $1,037.98M

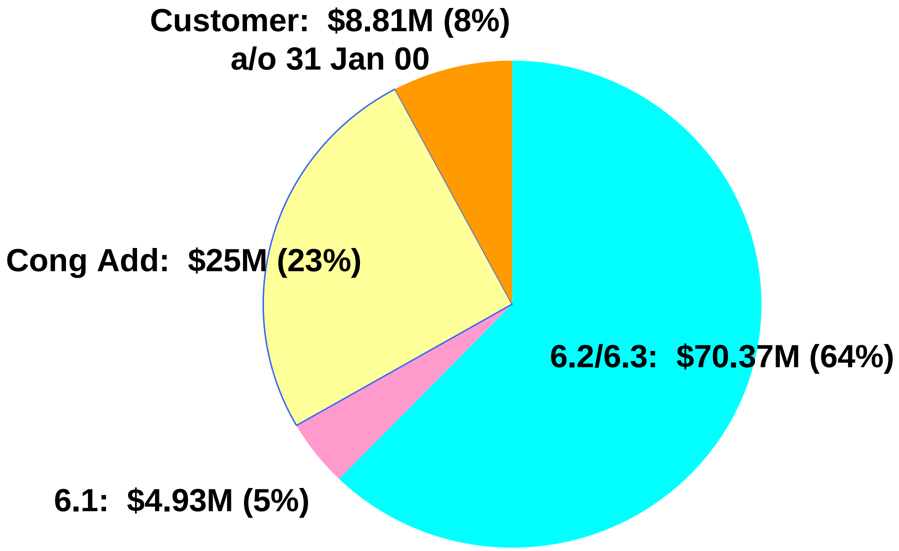

Directed Energy Total: $109.11M

Directed Energy Directorate

Potential Areas for Collaboration

- Electric Lasers
- Beam Control
- Large, Lightweight Optics
- Optical Coatings

- High Power RF Sources
- High Power RF Antennae
- Atmospheric Compensation
- Remote Sensing

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Directed Energy Weapons in Modern Battlefield

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Abstract:

The paper deals with electromagnetic threats caused due to Directed Energy Weapons (DEW). The area of interest is focused on HPM (High Power Microwaves) and UWB (Ultra Wide Bandwidth) as an important part of DEW area. Possible impact on electronic structures which can be part of military systems is considered in this paper. Some practical results achieved during experiments related to assessment of electronic equipment vulnerability is provided with overview of immunity of some equipment to HPM and UWB signals at the end of this study.

Keywords:

DEW, HPM, UWB, electromagnetic threats, NEC, vulnerability

1. Introduction

Directed Energy Weapons (DEW) with various principles seem to be more important in the future battlefield. There are several principles which are considered for use in the DEW area. Special optical technologies (lasers), sound technologies as well as microwave technologies are developed and can be used in special weapon systems to disturb military system behaviour or can be used for counter personnel weapons (for example Active Denial System working on frequency 94 GHz, see Fig. 1). DEW has been mainly considered as technologies suitable for less-lethal or even non-lethal technologies which have been subjects of interest within the past years.

Recent developed military systems consist of equipment which is more and more sophisticated and relying on electronics. Very high importance of electronics within the military systems is obvious from development of Network Enabled Capabilities (NEC) which is a key task of the Czech Armed Forces as well as within the NATO (NNEC – NATO Network Enabled Capability). The stage related to "Communication and information sharing" has been topical in recent years and characterised by development of communication networks. Common network infrastructure can be

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considered as a fundament of integrated NEC environment. Communication network and especially its reliability will have significant influence on mission success. Disturbance of these networks could be obviously critical.

Power electromagnetic fields can be generated by relevant power technologies and focused (directed) towards the target with electronics. Shortcuts like HPM (High Power Microwave) and UWB (Ultra Wide Bandwidth) are widely used in this area as well as HPEM (High Power Electromagnetics) and IEMI (Intentional Electromagnetic Interference). Examples of developed technologies which could be easily used like DEW against electronics are shown in Figs 2-6 (these technologies were offered or presented mainly during relevant conferences in past few years, radiated pulse power was hundreds of MW or higher in frequency range of microwaves).

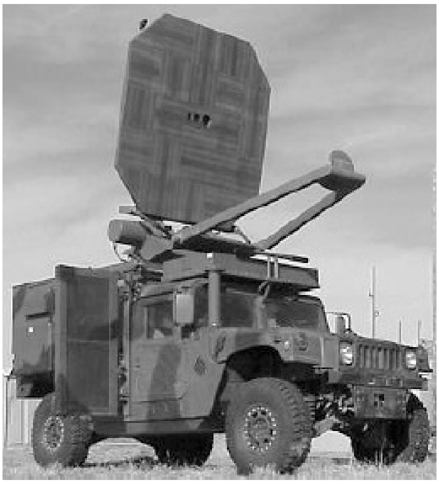

Fig. 1 Humvee with ADS (Active Denial System) mounted [1]

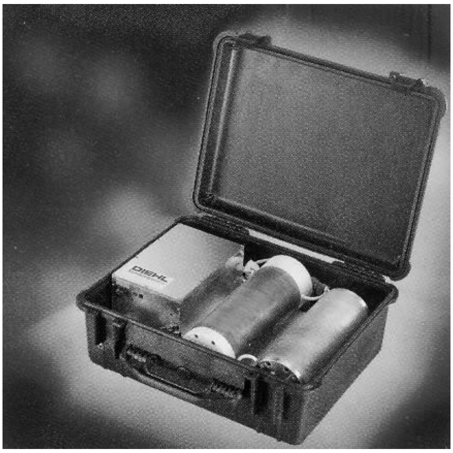

Fig. 2 HPM system DS-110 (built in suitcase, pulse power 250 MW [2]

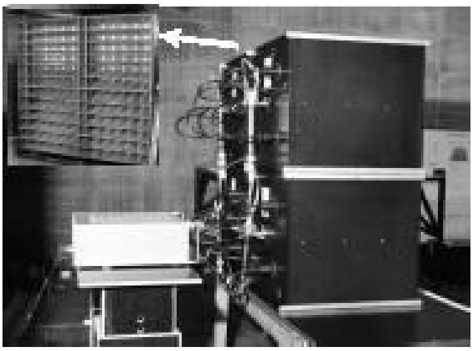

Fig. 3 HPM system with antenna array [2]

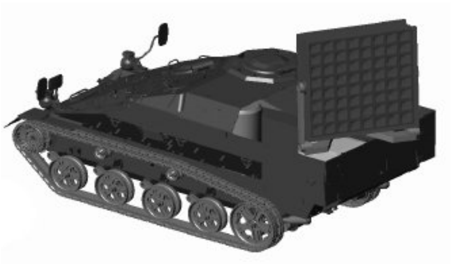

Fig. 4 HPM system with antenna array installed on a tank [2]

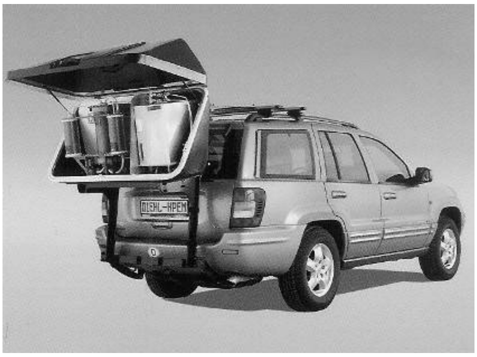

Fig. 5 Electromagnetic System for Selective Car Stopping [2]

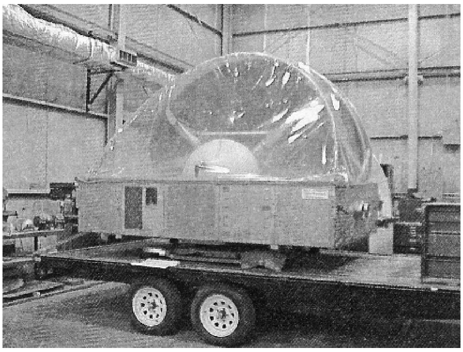

Fig. 6 JOLT hyperband system, UWB system [3]

2. Electromagnetic Threats

As it was mentioned in the introduction an important group of DEW technologies, non-lethal technologies, was represented by weapons with use of power electromagnetic field destructive effects.

Next electromagnetic environments are typically considered related to DEW (see Fig. 7):

- HPM: High Power Microwaves, narrowband signals in frequency range from hundreds of MHz up to several GHz, electromagnetic strength at the place of target typically up to tens of kV/m (strong dependence on range).
- UWB: Ultra Wide Bandwidth, pulses with rise time typically in hundreds of picoseconds and with duration of several nanoseconds, electromagnetic strength at the place of target typically up to tens of kV/m (strong dependence on range).

Because HPM and UWB environment is strongly dependent on range and moreover these environments may have a wide variety of wave shapes, their standardization is very difficult. Now there are only few standards which describe HPM and UWB environment generally (e.g. IEC 61000-2-13 [4]). A possible approach is to consider various types of HPM and UWB environments that have been produced and to consider their possible use in the future against sensitive targets. It is always necessary to make relevant analysis of electromagnetic threat where the shortest possible distance from HPM or UWB source is a very important parameter.

2.1. Electromagnetic Strength Assessment

As a typical possible scenario can be considered HPM (UWB) source with real pulse power P = 1 GW and as a worst case special antenna with extremely narrow radiation pattern (G = 40 dB, respectively D = 8 750). Now the expected electromagnetic strength at the place of threatened equipment (system) can be calculated according to next Eq. (1)

$$E = \frac{\sqrt{30PD}}{r} \qquad (1)$$

where *P* is radiated power, *D* is directivity of antenna, *r* is a distance of threatened equipment (system) from radiating antenna.
Note: Eq. (1) is valid only for direct propagation where reflections are neglected. This simplified equation is usually used for the microwave area and short distances.

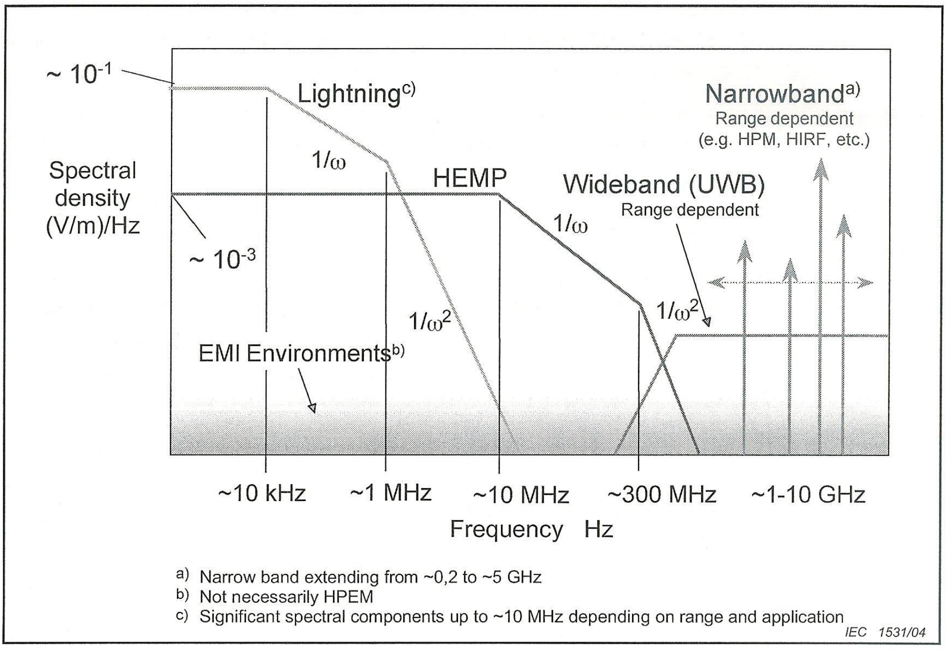

a) Narrow band extending from ~0,2 to ~5 GHz
b) Not necessarily HPEM
c) Significant spectral components up to ~10 MHz depending on range and application

Fig. 7 HPM and UWB comparison with other electromagnetic threats [4]

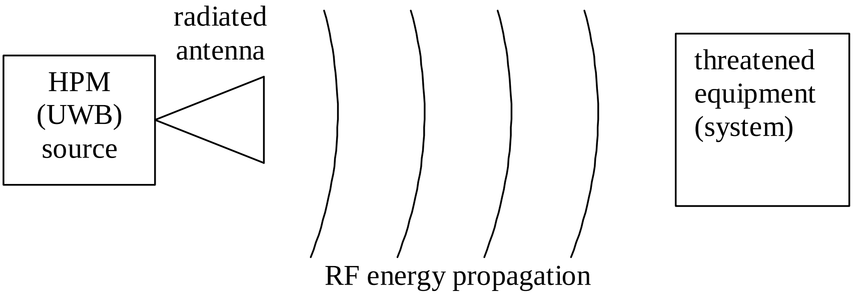

Fig. 8 RF energy propagation from source (HPM or UWB) to equipment (system)

It is obvious from Eq. (1) that for most cases (distance of directed energy weapon from equipment (system) is generally tens of meters), it is possible to consider electromagnetic strength up to tens of kV/m.

2.2. *Critical Frequencies Assessment*

It is very useful to consider transfer function (*T*) of investigated equipment (system) for critical frequencies assessment. Transfer function T_O (outer) is combined with T_I (internal) to form a composite transfer function from incident fields to response box inputs in Fig. 9 [5]. Note: T_O typically corresponds to relationship between incident electromagnetic field and surface current and charge densities on the outer surface. T_I corresponds to transfer function from the surface current and charge densities on the outer surface to some interior port of interest, producing voltage and current waveforms there.

From Fig. 9 it is obvious the most important part related to critical frequencies of considered system (equipment) is band 2 – resonance region. It is possible to use first of all analysis where sizes of equipment (system) as well as used cable lengths are considered and next it is important to make relevant measurement of transfer functions (shielding effectiveness of used boxes, induced currents and voltages etc.) for transfer function (*T*) assessment.

Considered frequency spectrum is divided as follows [5] (see Fig. 9):

Band 1: $f \le f_l \approx \dfrac{c}{4l}$ (aperture and small antenna coupling region),

Band 2: $f_1 \le f \le f_h \approx \dfrac{5c}{l}$ (resonance region, external and internal),

Band 3: $f_h \le f$ (integration region),

where *l* is characteristic dimension of the object, *c* is speed of the light, *f* is considered frequency.

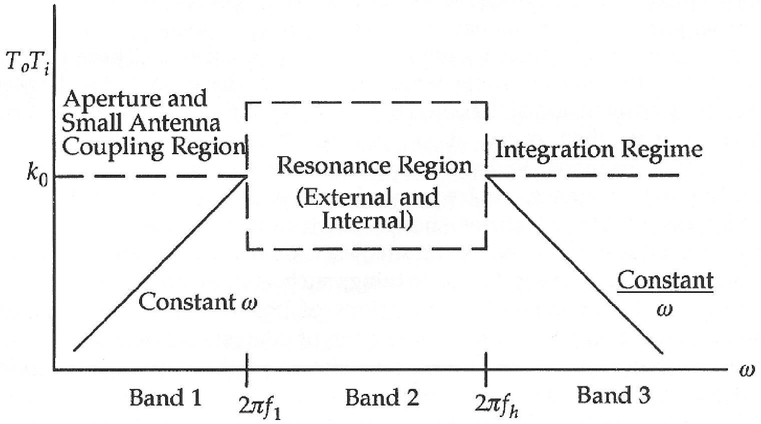

Fig. 9 System response as a function of frequency (logarithmic scales) [5]

3. HPM and UWB Impact on Electronics

Electronic systems can be affected by high intense electromagnetic fields causing the disturbance or even the permanent damage of the system. According to relevant EMC (Electromagnetic Compatibility) standards next performance criteria are usually used:

A - normal performance within the specification limits

B - temporary loss or degradation of function (self-recoverable)

C - temporary loss of degradation of function, which requires operator intervention or resetting

D - degradation or loss of function which is not recoverable due to damage of equipment (components) or software damage

On the one hand performance criteria are a very important parameter on the other hand consequence of IEMI (Intentional Electromagnetic Interference) attack has to be considered too. For consequence scaling it is possible to use for example such terms like "very limited", "limited", "severe", "very severe" and "catastrophic" [6].

4. Vulnerability Assessment

First of all it is necessary to make analysis where electromagnetic threat assessment is done (see chapter 2). Moreover it is necessary to consider criticality of relevant system (consequences – see chapter 3). Finally testing plan and testing can be prepared. The best way is to start with transfer function measurements (shielding effectiveness measurement, induced currents and voltages measurement) which is possible to carry out in wide frequency range up to few GHz or higher. After that it is necessary to choose possible critical frequencies according to transfer function measurements and according to analysis. Chosen frequencies can be used for final high power electromagnetic field measurement with HPM and UWB simulator use. Possibilities of these simulators are restricted to parameters which cannot be changed or changing these parameters takes too much time. Due to this fact it is necessary to choose suitable parameters according to analysis and transfer function measurement results for this testing. The data gained from analyses and testing has to be considered together with possible consequences which can occur. Such data can be used for vulnerability assessment.

5. Practical Results

A lot of experiments related to electronic equipment vulnerability have been carried out in previous projects within the last few years.

Transfer function measurements were carried out for better understanding of electromagnetic field coupling into relevant cables. Tested cables were irradiated with electromagnetic field with vertical polarisation and induced voltages were measured in frequency range 30 MHz to 1 GHz. It was low power measurement, electromagnetic strength of incident electromagnetic field was 1 V/m and measured results were recalculated for expected high power electromagnetic field 10 kV/m. Mainly cables which are widely installed in computer technologies were used for the purpose of these experimental measurements. Few examples are shown in Figs. 10-12. It is possible to expect induced voltage levels on regular widely used cables approximately up to 1 kV during electromagnetic field incidence with electromagnetic strength 10 kV/m on the basis of presented results. The highest induced voltages occur when the length of cables is comparable with wavelength of used signal (resonant region, see Figs. 10-12). For lower frequencies as well as for higher frequencies induced voltages are becoming lower.

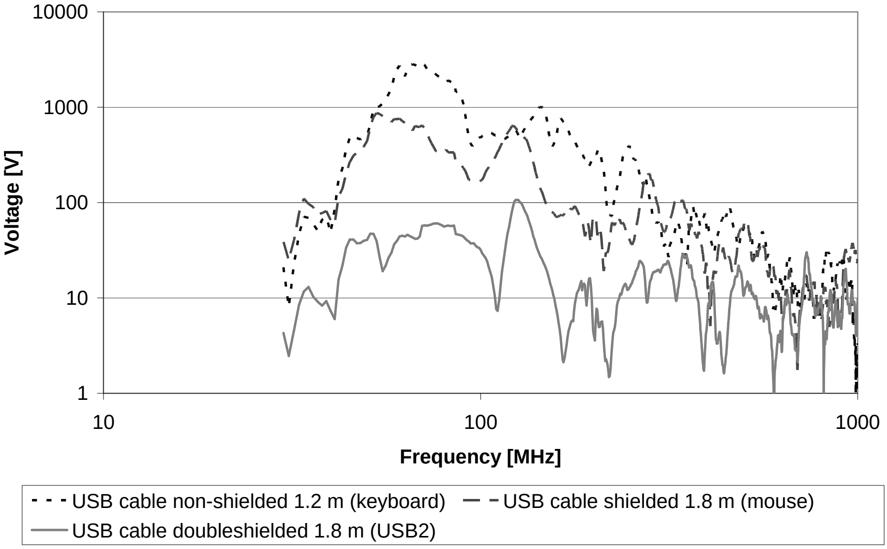

Fig. 10 Induced voltages on USB cables for electromagnetic strength E = 10 kV/m

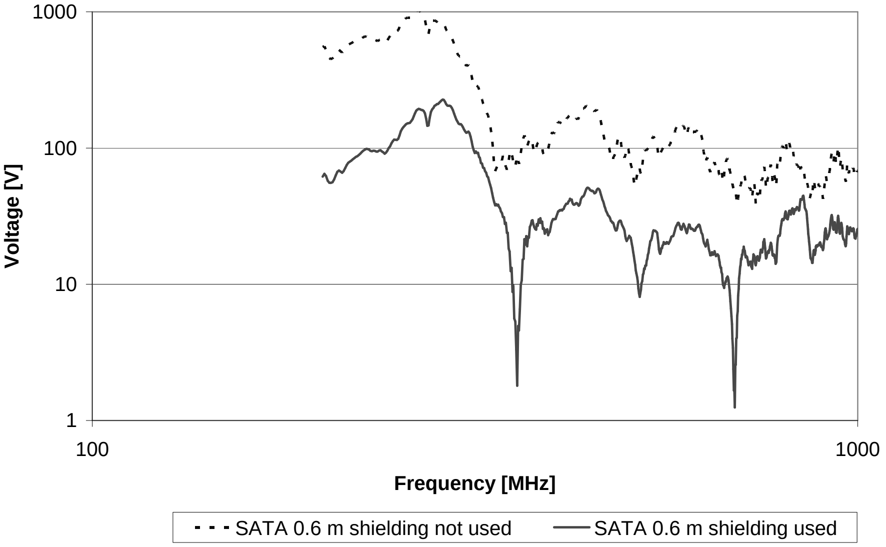

Fig. 11 Induced voltages on SATA cables for electromagnetic strength E = 10 kV/m

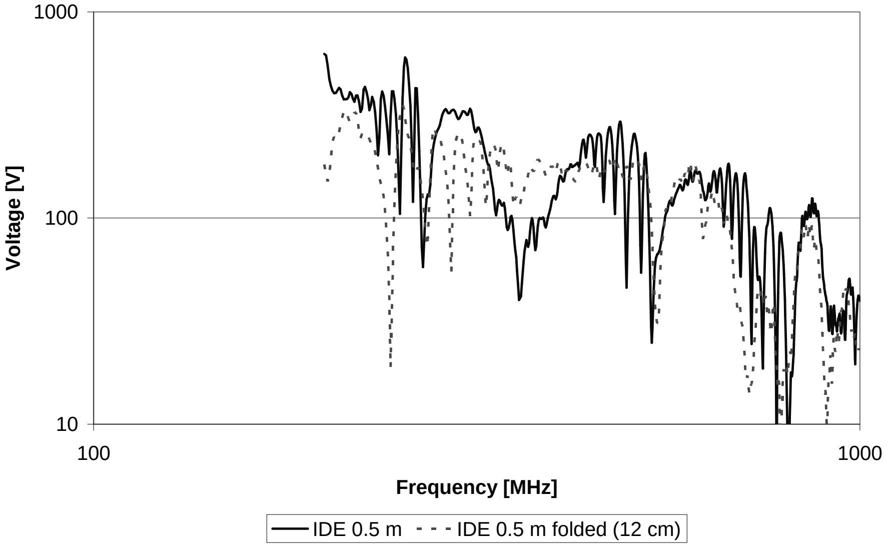

Fig. 12 Induced voltages on IDE cables for electromagnetic strength E = 10 kV/m

Other kinds of experiments in this area are testing with high power electromagnetic field irradiation of possible "targets" and evaluation of effects which can occur.

Some examples of tested setups are shown in Figs 13-15. It was verified that HPM signals can be used for stopping the car engine (see Fig. 13, HPM generator working on frequency 3 GHz with pulse power 500 kW was used for this experiment in shielded semi-anechoic chamber) as well as for effective disrupting of computer technologies and data transfers (see Figs. 14-16). Standard performance criteria (see chapter 3) are usually used for the evaluation of effects. From experiments which were carried out it was obvious that electromagnetic strength of few kV/m can be enough to achieve effective disturbance on electronics.

Repetition rate as a parameter of HPM and UWB signals can have an influence on some kind of temporary failures (see Fig. 16). Overview of immunity of some equipment to HPM and UWB signals is shown in Fig. 17. Typical electronic equipment was tested against effects of HPM 3 GHz, 6 GHz, and 9 GHz signals with pulse widths in hundreds of ns, repetition rates in hundreds of Hz and against effects of UWB signal with rise time of 0.5 ns, pulse duration of 3 ns in single shot regime. The most effective signal to disturb electronics from used ones was HPM 3 GHz. Very often the sensitivity level was very close to damage level (see Fig. 17). For UWB signal it was more typical to achieve temporary failures (sensitivity level) rather than some kind of damage. The results from testing showed the most vulnerable parts of recent systems are computer technologies including data transfers.

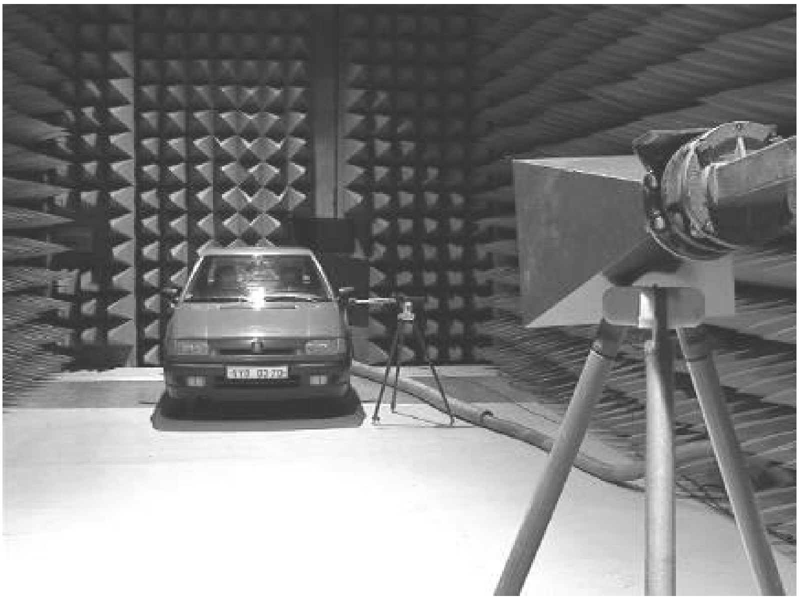

Fig. 13 Stopping the car engine with HPM irradiation use (HPM 3 GHz)

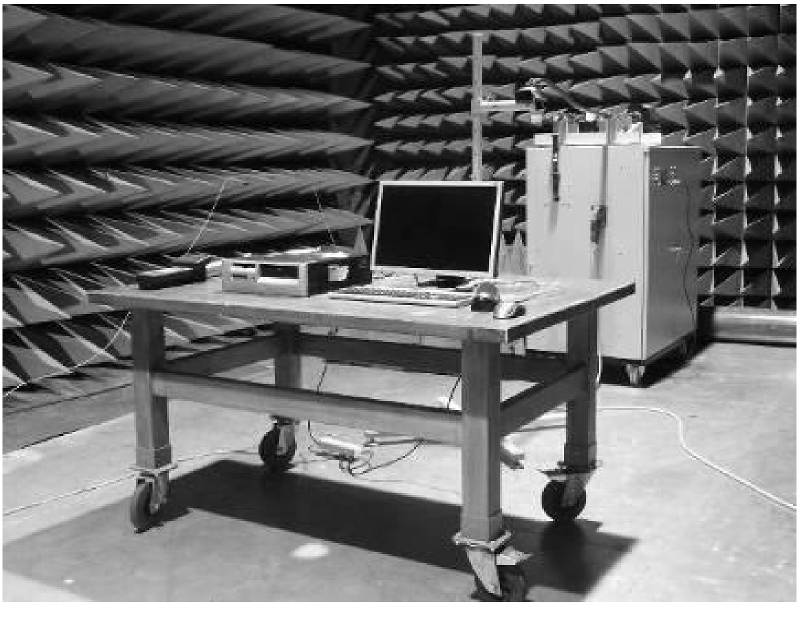

Fig. 14 PC setup irradiated with HPM 9 GHz

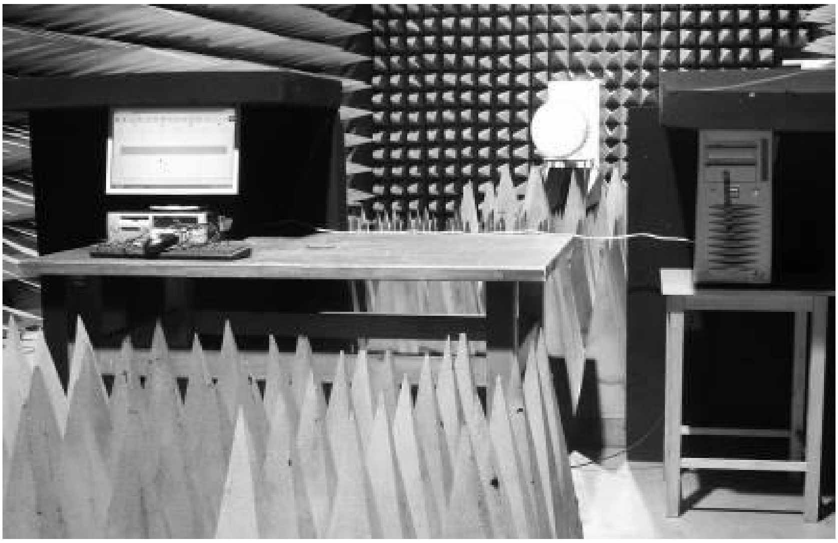

Fig. 15 Data transfer through UTP cable irradiated with UWB signal

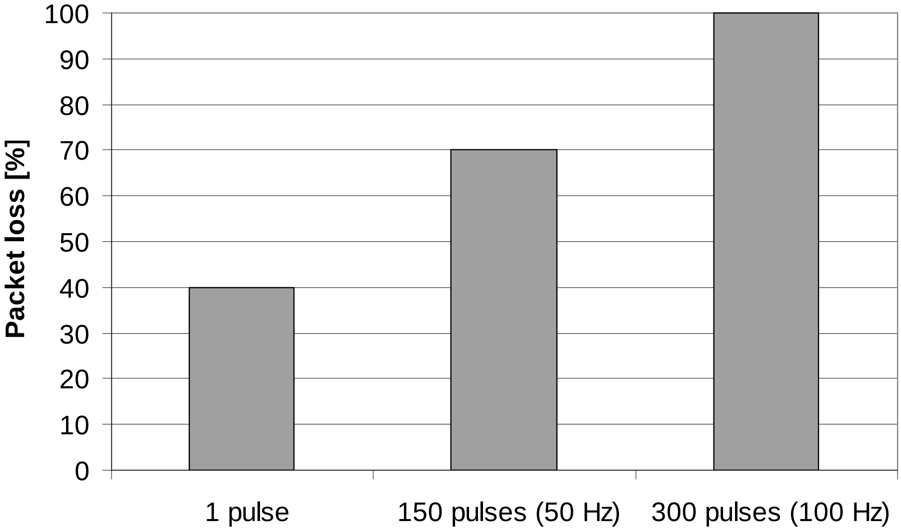

Fig. 16 UTP 2 m irradiated with UWB

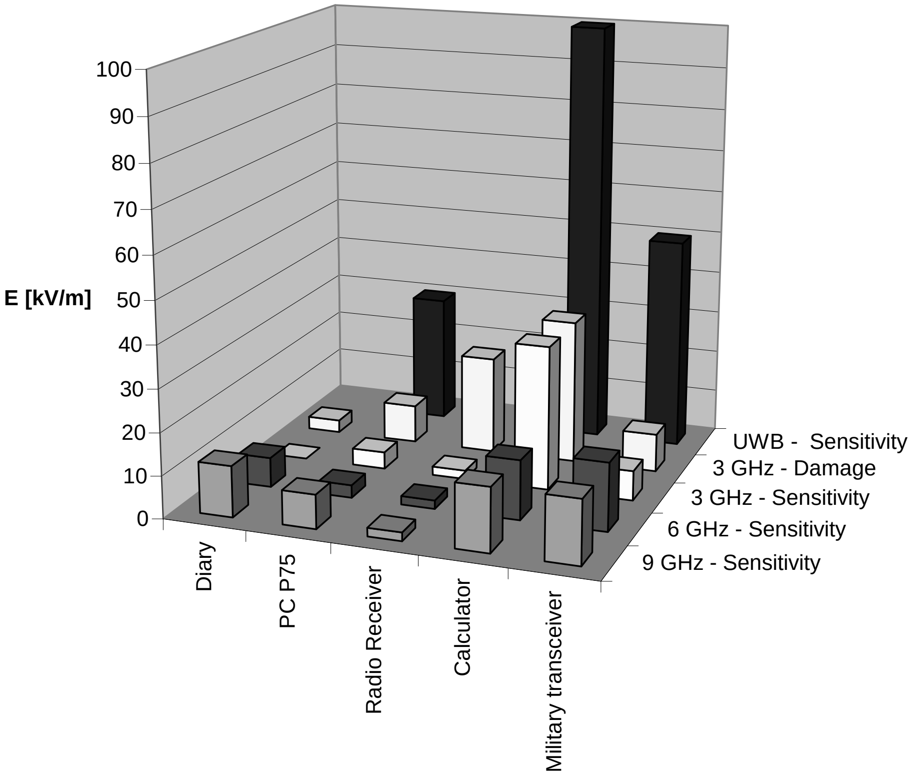

Fig. 17 Sensitivity and damage levels comparison for tested equipment against HPM and UWB effects

6. Conclusion

Electromagnetic threats HPM and UWB as a part of DEW technologies were briefly defined in this paper. Electromagnetic threats assessment as well as vulnerability assessment was introduced. Vulnerability of chosen tested equipment was presented on relevant examples. It was demonstrated that electronic equipment was vulnerable due to electromagnetic field irradiation. In case sensitive electronic equipment is used in crucial applications it is necessary to evaluate vulnerability of the system to such threats.

Gained results in the past have lead to starting a new project for the Ministry of Defence of the Czech Republic (OSPROZ-DEW1) focused on the assessment of vulnerability of weapon systems and parts of communication and information systems integrated in NEC which are installed to ordnance of the Army of the Czech Republic now. Assessment will be carried out on the basis of relevant analyses as well as relevant experimental measurements. The project started in 2009.

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Acknowledgement

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will be available to treat and possibly cure diabetes, hemophilia and other life-threatening and chronic illnesses.

Space manufacturing will develop the new metal alloys needed for high-temperature processing using advanced nuclear and fusion energy sources. Larger and more perfect crystals for the electronics and other industries will be produced.

By themselves, these new industries created by exploiting the unique environment of space, "pay" for the NASA programs. But the indirect impact to the economy has been even greater, and more important. These are the so-called "spin-offs" from space exploration which have been developed by industry using technological breakthroughs funded by NASA.

New materials, such as refractory ceramics and new alloys which withstand the temperature extremes of space flight, are used in everything from nuclear power plants to everyday kitchen implements. Developments in electronics, including miniaturization and sophisticated automation techniques, have streamlined the functioning of industry and shortened the time (thereby increasing the productivity) of almost everything we do.

The machines that monitor all of the vital bodily functions of the astronauts who walked on the Moon, now monitor premature infants in incubators, and have provided heart monitors and miniaturized pacemakers for thousands of people.

The same qualitative impact, magnified many times, will result from the development of beam weapons combined with the recommitment of the civilian space program to establish a permanently manned station in space toward the goal of colonizing the Moon and other planets.

However, studies done by Chase Econometrics and confirmed by independent studies using the Fusion Energy Foundation's econometric model show that there is a much greater impact that the development of a qualitatively new technology has on an economy. This impact is, strictly speaking, not measurable by adding up all the new products and new techniques that a new technology introduces; it is the *increase in productivity* throughout the economy as the result of the combination of higher manpower skill levels and new scientific knowledge entering industrial production. One study of this induced productivity effect estimated that U.S. productivity increased 0.1 percent for every billion dollars spent on the space program. This change in productivity alone represented an additional $3 billion to the GNP every year it was present. An interesting comparison is possible between the expenditure of a $1 billion aliquot of the federal budget on a high-technology R&D oriented program (like the Apollo program or the development of a beam weapon) and its expenditure on transfer payments, bureaucratic services, or the like. The Chase Econometrics study showed that the expenditure of this money on high-technology R&D actually *lowered* inflation, while the other expenditure had the opposite effect, raising inflation by 0.2 percent.

Four types of directed-energy weapons

by Mary McCourt

In his *EIR* multi-client report, *Beam Weapons: The Science to Prevent Nuclear War,* Dr. Steven Bardwell describes the types of beam weapons on line for development. Each type, laser beams, particle beams, microwave beams, and plasma beams, is, Bardwell states, "in principle capable of generating the required power and energy [to reach and disarm its target] in a form efficiently absorbed by the missile." A beam weapon effectively disarms a nuclear warhead. A hydrogen bomb can be detonated only by an initial powerful atomic-bomb explosion capable of setting off a chain reaction in the lithium-deuterium fuel. A beam weapon, by pumping energy into the very delicately balanced triggering mechanism, prevents the initial explosion and essentially turns the warhead into a "dud." The missile, like a satellite, might fall to the earth, but it can no longer be detonated.

Scientists agree that laser-defense battle stations, even with the lowest level of laser-beam technology, can be defended from other beam weapons themselves. But a missile cannot be effectively defended from the beam without such massive protection that it would lose both the necessary speed and distance.

Laser-beam weapons

Laser beams, particularly the chemical laser, will likely be the first deployable beam weapons developed. A laser is a beam of very intense, single wavelength electromagnetic waves, either of light or high energy X-rays. Such a weapon can be focused very precisely because either the light or X-ray wavelengths all have the same frequency and phase. The five different types of lasers, which can be applied to fusion energy as well as beam weapons, are all being researched at U.S. laboratories.

The **chemical laser,** which could be developed for military deployment within five years, uses a gaseous medium in which a chemical reaction is induced. The product of the reaction emits laser light. The Soviet Union used such a laser last year in tests that downed a ballistic missile.

In a **gas laser,** a burning gas such as a hydrogen and fluorine mixture is suddenly compressed, and the energy distribution that results from the compression is then stimulated to emit single-frequency light waves at very high energy. Both the United States and Japan are currently using huge gas lasers for nuclear fusion development.

An **electron discharge laser** uses replaceable energy

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from an electron beam to create the source of laser light. Such a laser would be very efficient for use in space because its energy source is electricity, not an exhaustible chemical fuel.

Two other types of lasers, **X-ray lasers** and **free-electron lasers,** yet to be perfected technologically, have greater advantages of energy density and flexibility than those listed above. The **X-ray laser** is widely recognized as the most promising long-range laser for ballistic missile defense, based in space. The X-ray laser, which is just a single pulse, is by far the most energy-dense, delivering thousands of times more energy per pulse than conventional lasers. In addition, the target absorbs the X-rays very efficiently, making this weapon capable of very efficient destruction of missiles.

Particle-beam weapons

Particle beams also deliver energy in a highly controlled pulse traveling at near the speed of light. But instead of a pulse of intense electro-magnetic radiation, the particle beam consists of **subatomic particles, (electrons** or **protons), neutral atoms** (usually hydrogen), or (usually magnetized) **macroscopic particles** accelerated to high speeds. A particle beam destroys its target, the triggering mechanism, by creating a very intense shock wave within the mechanism, like a very small, but extremely heavy and powerful hammer striking down on the target.

Electron beams can be generated in the range of millions of volts. Scientists researching the electron beam for military or civilian energy use have discovered that the electron beam becomes a complex structure of electrons and a magnetic field. Such structured beams are capable of carrying higher currents and more energy for much longer distances at much great levels of power output.

Proton beams, which have been researched intensively for the past 30 years, use an electron beam as a seed and then are accelerated in their own right. As protons are 2,000 times heavier than electrons, a proton beam of the same velocity has 2,000 times the energy of an electron beam.

Neutral particles eliminate many of the problems of charged-particle beams, which can degrade both the efficiency and controllability of the beam. By spring of 1983, U.S. researchers will have produced a beam of protons at an energy of 2.5 million electron volts, capable of traveling at 99 percent of the speed of light.

Control and targeting of a **macroscopic particle beam** would be more difficult, but the unparalleled power density of the beam—due to the large mass of the particles—gives it great potential as a beam weapon.

Microwave and **plasma beams** have only been discussed in the United States in the past two years, although it is estimated that the Soviet Union is two or three years ahead in the production of microwaves. Intense, directional microwaves are generated when electron beams are propagated at or near the speed of light through a plasma. Such beams, if focused, could destroy delicate electronic equipment in a target.

A plasma beam consists of the highest energy-dense form of matter, a gas so hot that the electrons and neutrons have separated. The plasma forms itself into a complex structure of particles and magnetic fields. The unique feature of a plasma beam is that it actually requires the atmosphere, which hinders the guidance and propagation of other beams, to hold in the plasma and sustain the structure.

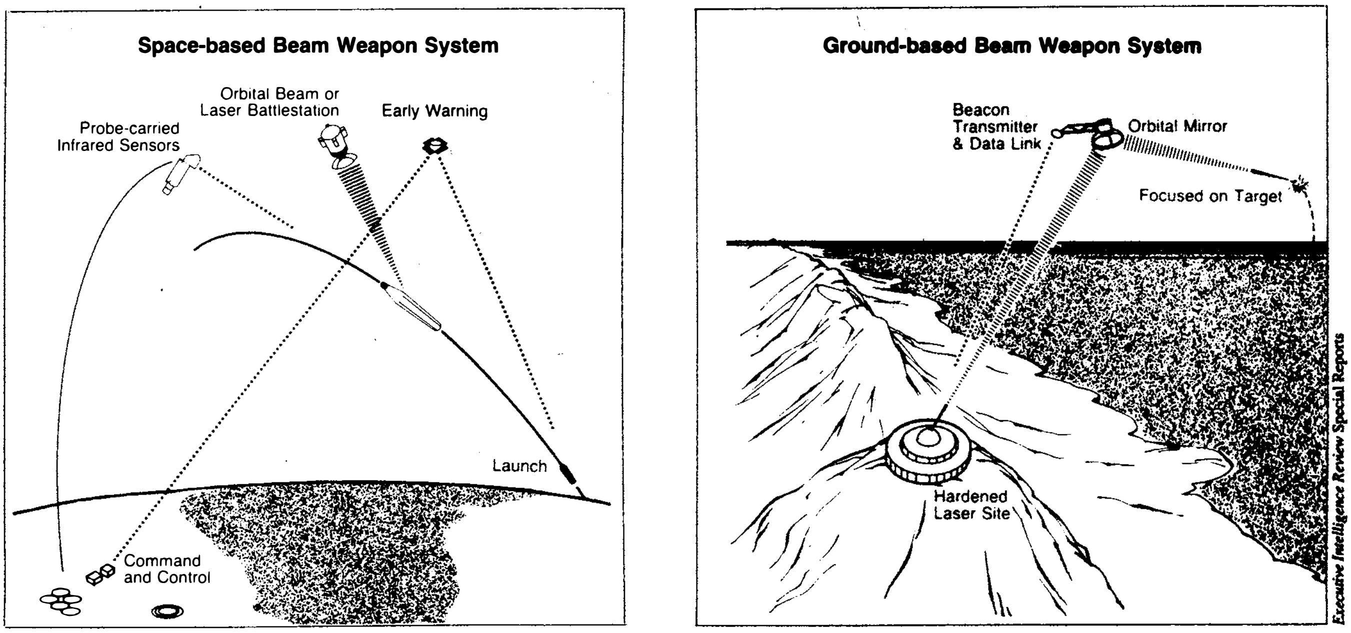
Space-based Beam Weapon System
Orbital Beam or Laser Battlestation
Early Warning
Probe-carried Infrared Sensors
Launch
Command and Control
Ground-based Beam Weapon System
Beacon Transmitter & Data Link
Orbital Mirror
Focused on Target
Hardened Laser Site
Executive Intelligence Review Special Reports

Space-based beam weapons, (left) provide the only feasible means for area defense against nuclear-armed ballistic missiles. The deployment of a weapon capable of generating an intense beam of laser light, atomic particles, or plasma, in an orbit around the earth, would protect the entire United States from incoming ballistic missiles. **Ground-based beam weapons** (right) can provide both area and point defense. Shown here is a conceptual design of a laser beam-weapon system built on a mountaintop, which uses a relay mirror to provide aiming and tracking for the weapon.

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ELECTROMAGNETIC DIRECTED ENERGY WEAPONS FOR ELIMINATING ELECTRONIC SYSTEMS

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ELECTROMAGNETIC DIRECTED ENERGY WEAPONS FOR ELIMINATING ELECTRONIC SYSTEMS

Capt. Dipl. Eng. Jan VALOUCH

Annotation:

The article presents information on the current situation in the development and application of electromagnetic weapons and indicates possible trends of their future employment. Under the term electromagnetic weapons we understand means and systems that use technology generating directed power electromagnetic pulses degrading the activities or destructing the electronic circuits of the enemy equipment. This will also enable to neutralize or completely destroy the operation of information, communication, control, firing and other electronic devices. Electromagnetic weapons are currently in use and greater number of countries realizes the perspectives of their future development.

* * *

1. CURRENT SITUATION OF DEVELOPMENT AND USE OF ELECTROMAGNETIC WEAPONS IN FOREIGN COUNTRIES

Principle of electromagnetic weapon activities

Typical representative of electromagnetic (EMC) weapons are so called **Directed Energy Weapons** (DEW) employing the technology of **High Power Microwave** (HPM). These weapons represent highly sophisticated technology of 21st century. Their destructive effect results from the electromagnetic field and they threaten the operation of all devices equipped with electronic circuits, especially by the effect of arcing, overload or by discharge of single electronic component parts. These weapons have strong physical and psychological impact.

In general, DEW consists of impulse source of energy, source of microwave radiation and antenna. The impulse source transforms accumulated energy to high power electric pulse with the length of duration in units of nanoseconds. Accumulated energy can be in kilo-Joule with the power of gigawatt. In the source of microwave radiation this impulse then acts upon diode and generates a beam of electrons with energy – approx, 400 kV, 10—60 kA. This energy is dissipated by the directional antenna.

Electromagnetic weapons can fundamentally differ in terms of its design and application e.g. according to the used frequency band. EMC wide band weapons emit in wide frequency range but with low density of energy. These equipments are suitable where it is not possible to exactly identify the characteristics of the target – especially its working frequencies. Contrary to the narrow-band EMC weapons emit pulses on individual frequencies with enormously high power. Their action upon the target is very effective since impulse resonate with the known frequency of the attacked device.

Development and application of electromagnetic weapons

Concerning a development and application of electromagnetic weapons we can say that after the EMC weapons emerged from “the unknown” world of classified projects, now they are tuned and EMC weapon capability is enhanced. And they are gradually mounted on suitable carriers – vehicles, aircraft, ships, bombs, missiles and even space ships. The interest is focused not only on single pieces of equipment but also on complete systems incl. sensors and equipment to control the combat functions.

Within the armed forces the employment of EMC weapons have the following advantages:

- very rapid effect against the enemy targets,
- usage irrespective of the weather conditions,
- coverage of a great amount of various targets with minimum need to be informed about their characteristics,
- threat to less available target – under ground,
- operational attack (neutralization, destruction or denial of activities of electronic assets) at selected levels of warfare,
- minimum of collateral destruction in politically sensitive environment and use of this environment after the end of conflict,
- reduction of minimum time for tracking and guidance to target.

USA, Russia, France, China and UK are the countries that achieved the greatest progress in the development and application of electromagnetic weapons. The interest of other countries (Germany, Belgium, the Netherlands, Denmark, Norway …) is for a long time focused on High Power Microwave (HPM) especially on protection against the effects of HPM. As to my opinion this is the beginning of the path for research in the Czech Republic.

Currently, discussions are held on their employment in Iraqi by the U.S. armed forces. They could facilitate quickly eliminate the command and control systems of Iraq and eliminate communication of their forces without any loss of lives and any collateral damage. There were some intentions to employ these weapons of electromagnetic warfare by the U.S. force in Kosovo and Afghanistan at least in trial operation. It is also interesting the assumption that Russian forces used DEW prior the action against terrorists in Moscow theatre in 2002. This weapon was designed to disable the electronic detonating primers. The fact is that no Chechen managed to initiate her primer.

Misuse of electromagnetic weapons

More frequent are the attacks of terrorists and criminal underworld using the electromagnetic means. Among the targets of terrorists can be financial institutions, medical facilities, aircraft, automobiles, computer network and other daily used civilian and military equipment. The EMC radiation generators can be for example in the briefcase and that is why it is quite easy to prepare such an attack. First known terrorist application of electromagnetic weapons is from 1995 when Chechen rebels used this technology against the security system of Russian facility.

Nobody knows about the use of DEW for criminal activities and terrorist attacks with exception of the offenders themselves and their victims. The German experts even officially recommended application of these means to the German police units since there were recorded several cases of use of DEW by the German underground. With DEW it is possible to commit perfect crime, as they leave no evidence. No doubt, in future a wide use of these weapons can be expected which can means an increased risk of their misuse.

Future of electromagnetic weapons

Future of DEW is often discussed in many articles and literature. A part of study called Air Force 2025 also deals with the future of DEW employment that was developed by the Air University Maxwell Air Force Base, Alabama. This study discusses a possibility to employ these means in the spaceships or satellites in order to destroy the hostile satellite information and communication channels.

Development of DEW in terms of their employment is mainly connected with mutual co-operation of the army, air force and navy forces. These will be the components that are the potential users of DEW. Protection of the aircraft and ships against the effects of enemy DEW is being solved. Further, e.g. active use of DEW against the air defense and employment of DEW in the aerospace. Within 3—5 years it is expected that DEW will be installed into the drones (USA). In respect of technologies for DEW, the research will be especially focused on increase of input power of DEW, reduction of size and weight and improvement of antenna systems. A very interesting is also a research of biological impact of DEW on human being and hazard for the personnel.

2. CURRENT SITUATION IN THE AREA OF ELECTROMAGNETIC WEAPONS IN THE CZECH REPUBLIC

The following part of this article briefly discusses NATO RTO – Research and Technology Organization (http://www.rta.nato.int), or the activities of selected panels with representation of the Czech Republic and which deal with the mentioned issue.

The panels dealing with this topic are:

- SCI–119 Tactical Implications of High Power Microwaves,
- SCI–132 High Power Microwave Threat to Infrastructure and Military Equipment.

Since most of activities of these technical panels is classified as NATO SECRET, only general character information not subject to classification are provided.

Panel SCI–119 Tactical Implications of High Power Microwaves started its activities in 1998 and terminated it in this year. The objective of the work of its members have been mainly solution of issues of use of HPM in the military sector both in terms of defense as well as of potential active employment in attack. The most important areas solved:

- design of resources generating HPM,
- vulnerability of information technology of military infrastructure,
- risk of back effect of electromagnetic weapons on friendly troops,
- testing of HPM effects on the off-the-shelf equipment equipped with electronic components (personal computers, cellular phones, vehicles, aircraft …),
- content of HPM national programs from the viewpoint of:
    - earmarking of specialized workplaces,
    - refinement of the content of solution in the given country,
    - allocation of funds,
    - planning of the number of students studying HPM at the universities,
    - gathering of results.

The issue of HPM is solved by NATO systematically since the beginning of 80-ies of the last century. In the short time, it is assumed that new advanced HPM weapons will be developed and within NATO this process must be systematically controlled. In this area – development of electromagnetic weapons – USA, Russian, France and the UK have the greatest success.

Panel SCI–132 High Power Microwave Threat to Infrastructure and Military Equipment commenced its activity by the introductory session in October 2002, held in Munster in Germany. Its orientation is linked to the preceding activity of the Panel SCI–119. The main activities of the Panel are planned for the period of 2003—2005 and single members will deal with the following issues:

- identification of potential threat of HPM on the military and civilian infrastructure and equipment,

- research of the penetration and dissemination of HPM in specific devices,
- research of DEW (Directed Energy Weapons),
- possibilities how to protect the military equipment against the effect of weapon assets on the basis of HPM.

Other areas considered important by the member of the Panel SCI–132 and that are to be in the area of interest are:

- resistance of military equipment against HPM,
- implication of HPM in the military field test and system of their evaluation,
- EMC terrorism.

The Panel consists of representatives of the following countries: Canada, Czech Republic, Denmark, Germany, France, UK, USA, the Netherlands, Norway and Italy.

CONCLUSION

Currently, the use of electromagnetic weapons plays the more important role. Though, the wider employment of these weapons is expected within 5—10 years, there already exist and are used the devices/equipment capable to reliably effect on the enemy electronic assets (control, information, communication…) and deny the enemy any further operations. The issue of electromagnetic weapons in the Czech Republic is in the stage of research and that is why the representation and involvement of the Czech representatives in the special Panels of NATO RTO or any other international organizations and boards is desirable.

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August, 2011

High Power Electromagnetic Weapons: A Brief Tutorial

George H Baker, III, *James Madison University*

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High Power Electromagnetic Weapons: A Brief Tutorial

George H. Baker

Background. High power electromagnetic weapons, also referred to as high power radiofrequency (HPRF) weapons, are a type of directed energy weapons. The system effects of high power electromagnetic environments are well recognized by world scientific and military communities. Former CIA Director John Deutch has said that, "the electron is the ultimate precision-guided weapon." In the course of the investigation ofnuclear EMP effects on electronics during the Cold War period, it became evident that garden variety, unprotected electronics would malfunction, in some cases burn out, in the presence of electromagnetic fields in the hundreds to thousands of volts per meter. The EMP experience has led to the development of non-nuclear high power electromagnetic sources to create fields that equal or exceed EMP levels, albeit over relatively small ranges. Achievable electronic effects could have serious consequences in terms of interruption or termination of critical system operation. The effects are of particular interest to the military in the context of information warfare and missile defense. Because most critical infrastructures are controlled by electronics, HPRF weapons are a concern for civilian systems as well. The weapons could be used to disrupt computer electronics controlling electric power grids, telecommunications networks, financial institution databases, security systems, and aircraft.

Military forces in many countries are pursuing the development of HPRF weapons. These programs are normally classified. HPRF weapons represent a revolutionary concept because they operate at the speed of light, can be used covertly, and harm equipment rather than humans (non-lethal). HPRF weapons may be enclosed in briefcases, packing containers, truck beds, or aircraft and maneuvered to expose critical military or infrastructure systems.

Electromagnetic Weapon Characteristics. There are three elements to be considered in discussing HPRF weapons systems: the weapon itself, the propagation of the weapon output to the target, and the target response (see Figure 1).

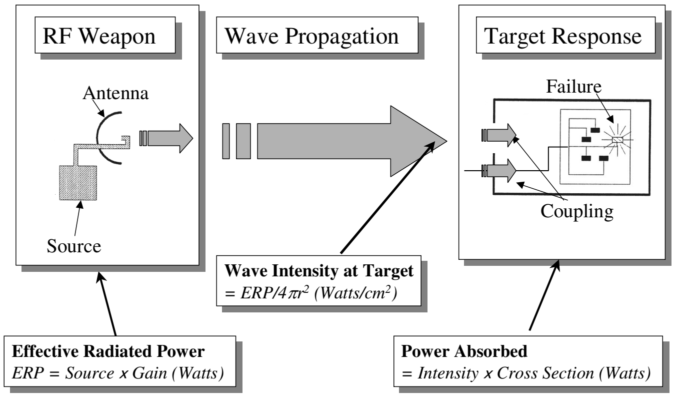

Figure 1. High Power RF Weapon Operation Elements

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Weapon Design. An HPRF weapon consists of a power source, or driver and a radiating antenna. The source is normally pulsed. Outputs may be sine waves (providing a narrow frequency band signal) or pulses (providing a wide frequency band signal). High power electromagnetic source technology includes electron beam devices (magnetrons, vircators, gyrotrons, backward wave oscillators), solid-state devices (bulk avalanche, optical switches, silicon carbide circuits) and explosive generators (magnetic flux compression using high explosives). Output power levels in the gigawatts are feasible over a wide range of frequencies. Design details will determine output characteristics. Power, frequency, bandwidth, repetition rate, and duty cycle are the important HPRF weapon output parameters.

The HPRF weapon source must be connected to an antenna with sufficient gain to "beam" the RF energy to a useful range. Portability requirements impose major limits on antenna area which in turn largely governs the maximum intensity (power per area) that can be delivered to a target system at a given range. Compact sources that may be moved covertly in briefcases, packing containers, truck beds, or aircraft and maneuvered for close-up exposures of critical military or infrastructure systems are of most interest. Antenna size limits largely determine the maximum intensity (power/area) that can be delivered to a target system at a given range. A table of approximate relative portable platform sizes is provided below.

Table 1. Portable Platform Size Comparisons (Approximate)

Capacity: Platform:	Volume	RF system Weight	Basis
Briefcase	0.02 m^3	5 kg	Typical hard side
Footlocker	0.15	40 kg	1 person portable
Pickup truck	4 m^3	1000 kg	1 ton capacity
Econoline van	8 m^3	2000 kg	Bed volume
Tractor trailer	80 m^3	20,000 kg	20 ton capacity

High Power Electromagnetic Wave Propagation. Electromagnetic waves propagate at the speed of light through the atmosphere. Under most conditions, the atmosphere will not attenuate HPRF waves as they travel from source to target. However, if the electromagnetic wave's peak field level exceeds the air ionization threshold a cascade process will occur in which an atmospheric plasma is created that will absorb most or all of the energy in the wave. This phenomenon is referred to as air breakdown.

A typical threshold for breakdown at sea level is approximately 1 megawatt/cm^2 . As an example, a 1 Gigawatt source radiating through a 1-foot radius circular antenna will produce an average intensity over the antenna of 0.35 megawatts/cm^2, a factor of 3 below air breakdown. Once away from the antenna, EM intensity falls off as the beam spreads (typically as $1/4\pi r^2$ where r is the distance to the target).

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The HPRF signal intensity on target depends on source transmission power (P_t), antenna gain, and range according to the following equation:

$$S_t = \frac{ERP}{4\pi r^2} = \frac{P_t \cdot G}{4\pi r^2} \frac{watts}{m^2}$$

The antenna gain may be approximated by $G \approx \frac{4\pi A_e}{\lambda^2}$ where A_e is the effective antenna area and λ is the wavelength of the radiated HPRF signal. This yields a simple formula for the intensity on target:

$$S_t = \frac{P_t A_e}{r^2 \lambda^2}$$

So, for example, a 1 Gigawatt source radiating at 1 GigaHz ($\lambda = 0.3$m) with a 1-m^2 antenna will produce a beam intensity of 11 kW/m^2 (or 1.1 watts/cm^2) on a target 1000 meters away. If the pulse duration were 1 microsecond, the energy fluence on target would be power x time or, 1.1 microjoules/cm^2.

Target Response. Once the electromagnetic wave signal reaches the target, its energy couples to the system in a very complex manner through various paths associated with the topology of the target system. The HPRF signal will induce currents on any external conductors (antennas, wires, etc) that penetrate to the system interior. The signal will also couple to any external metal shielding and then may reradiate to internal conductors. Signal waves will penetrate through any holes in external shielding to interior portions of the system. The main concern is the amount of energy that finds its way to critical electronic circuits, causing the system to malfunction.

To simplify coupling calculations, it is possible to determine an effective "coupling cross section" for critical internal circuits. In effect, this treats each internal circuit as a receiver. The power received by the circuit may be expressed as a simple function in incident wave power and an effective coupling cross section:

$$P_i = S_t \mathrm{A}_\sigma$$

P_i is the power induced in the internal circuit, S_t is the incident power at the system's exterior, and A_σ is the coupling cross section of the internal circuit. A_σ is a function of frequency and incorporates all the complexity of coupling including multiple paths, layers and mechanisms. There are two major coupling modes, front door and back door, as shown in figure 2.

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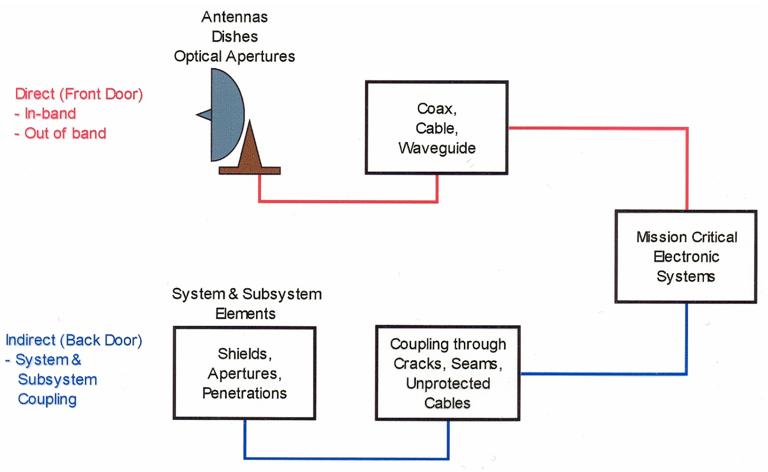
Antennas
Dishes
Optical Apertures
Direct (Front Door)
- In-band
- Out of band
Coax,
Cable,
Waveguide
Mission Critical
Electronic
Systems
System & Subsystem
Elements
Indirect (Back Door)
- System &
Subsystem
Coupling
Shields,
Apertures,
Penetrations
Coupling through
Cracks, Seams,
Unprotected
Cables

Figure 2. Front Door and Back Door Coupling Modes

The physics of front and back door coupling are the same. In each case, energy resident in the incident wave induces currents in the system that flow to a sensitive system circuit. Each can be characterized parametrically by equation $P_i = S_t A_\sigma$. The coupling cross-section, A_σ, is typically large for front door coupling and small for back door coupling. The coupling cross sections for front door coupling are of the order of the physical area of the antenna or aperture. Effective coupling cross section values for back door coupling of unhardened systems range from $10^{-4} - 10^{2}$ cm^2. Coupling cross-sections are hard to predict analytically and can be determined confidently only by direct measurement. This creates a problem for an attacker's confidence since HPRF effects are subject to much higher uncertainties than conventional weapon effects.

HPRF Weapon Effects on Systems. EMP and HPRF affect systems by disrupting the operation of electronic components either temporarily (upset or latchup) or permanently (component damage). Damage may be "direct" where energy inherent in the EMP/HPRF field is sufficient to cause malfunctions or "indirect" where EMP/HPRF energy triggers effects involving a system internal power supply. Even though the power delivered to a circuit by the HPRF field is small, the much larger energy available in the system's power supply (or fuel and ordnance) can be improperly diverted by an HPRF induced overvoltage arc or malfunction of system digital control circuit, causing major system damage.

Upset refers to an induced change of state in a digital circuit in which the system continues to operate, although possibly with erroneous data bit streams. Latchup refers to changes of state in digital circuits where the affected portion of the system ceases to operate until the system resets itself or (worse) a manual reset is required. In either case, system components are not directly damaged and recovery is often possible (depending on time criticality of affected function).

Exploitation of upset effects should not be discounted. In some cases they are tantamount to permanent damage. Upset may result in major system damage, e.g., a missile plunges into ocean due to a guidance system upset, or computer equipment is destroyed by an upset sprinkler system. Small, upset-level transient pulses can also act to

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trigger the release of energy from a system's own power supply causing components to burn out at fluences much lower than would normally cause permanent damage.

To give an indication of HPRF wave energies required to cause system effects, ITT industries (formerly Kaman Sciences) openly exposed circuit cards to 2.9 GHz microwave pulses with duration 1 microsecond. Onset of upset occurred at 1 watt/ cm^2 (equivalent to 1 microjoule/cm^2 for this pulse duration). All components were upset at wave intensities of 1000W/cm^2. Onset of damage occurred at 100W/cm^2 (for a 1 microsecond pulse, this is equivalent to 100 microjoules/cm^2). All components were damaged at wave intensities of 1000 W/ cm^2 (equivalent to 1000 microjoules/cm^2).

System Protection. System hardening involves a combination of operational and hardware techniques. Operational techniques may include the provision of spares for soft critical subsystems or boxes, disconnecting susceptible circuits upon warning, and/ or establishment of a physical keep-out perimeter (with barriers and/or security force) or zones around critical equipment to prevent positioning of HPRF weapons at close ranges. Operational controls may also be built into software to provide circumvention and reset, error-correcting codes, voting logic, and status detection. For some non time-sensitive systems, provisions for rapid system repair may be an option.

Conceptually, hardware approaches involve placing a conducting material between the incident HPRF wave and susceptible internal circuits. Hardening techniques have been successfully demonstrated and codified for EMP (ref. article on nuclear EMP). The EMP community has placed a heavy reliance on exterior shielding while limiting the number of penetrations that have to be individually protected. Such protection applied at the system exterior allows interior boxes to go untreated. This approach works well when designed in from the start. For retrofit protection, however, it is often prohibitively expensive.

Hardware approaches for HPRF protection, while conceptually similar, have some differences in emphasis from EMP. Because EMP is extremely broadband, typically only a small fraction of the energy comes through the front door in band. HPRF weapons can be tuned to the front door center frequency such that all the beam energy flows into the system. Also since HPRF weapons operate at higher frequencies, attention to smaller apertures (including cracks and seams) is required and dimensions of waveguide-beyond-cutoff penetration treatments will require changes (longer and more narrow waveguides are needed).

Front door in-band protection is one of the more challenging (but not insurmountable) HPRF protection problems. The high gains associated with most front door paths make these potentially the most susceptible portion of the system. However these well-characterized front door receive paths have received much attention in terms of protection engineering. Radar systems are often protected from their own or neighboring transmitters by a receiver protector or RP. Similar protection can be applied to communication receivers against in band HPRF environments. Table 2 summarizes HPRF hardening techniques.

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Table 2. HPRF Hardening Methods

Operational Techniques	Hardware Techniques	
	Front Door	**Back Door**
Disconnect on warning	Tuned metallic radomes	Shielding, topology control
Spares	Bandstop reflectors	Internal cable shields
Physical keep-out perimeters or zones	Antenna gain pattern control	Non corrosive mating surfaces
Software Techniques: Circumvention/reset Error correcting codes Voting logic Status detection/ alarm	Filters	Closely spaced fasteners
	TR devices/ limiters	RF gaskets and seals
	Terminal protection devices	Aperture screens and conductive films
		Selection of hard circuits and components
		Pin protection
		Fiber Optics
		Filtering, limiting at penetration points

Future Directions. HPRF generation techniques have matured to the point where practical devices have become technically feasible. Miniaturization of pulse-power source components, more efficient power supplies, and advances in electronic pulse forming, energy conversion, and antennas enable reduced size and increased efficiency of HPRF generation hardware. Simple weapons can also be built using inexpensive magnetrons from common microwave ovens.

Military trends to computerized battle management, weapons tracking, and landline/wireless network communications are a double-edged sword, introducing serious HPRF vulnerabilities. Military use of commercial off-the-shelf equipment and dependence on civilian infrastructure exacerbate the problem. Senior military officials have dropped hints about pursuing offense technology but there are no officially published details concerning weapon availability or capabilities.

Several other countries also have extensive background in the development of RF weaponry. The former Soviet Union pioneered the development of HPRF weapon technology and this technology is now being offered to other countries. According to a recent report from the Office of the US Secretary of Defense on the military power of China, “Captain Shen Zhongchang from the Chinese Navy Research Institute…envisions a weaker military defeating a superior one by attacking its space-based communications and surveillance systems…in future wars, Shen highlights radar, radio stations, communications facilities, and command ships as priority targets vulnerable to smart weapons, electronic attack, and electromagnetic pulse weapons.” It is expected that in future conflicts the United States will encounter adversaries using HPRF weapons as part of asymmetric tactics to disrupt information systems.

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See also: Nuclear Electromagnetic Pulse (EMP)

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About the author: George Baker is Professor of Integrated Science and Technology at James Madison University. He also serves as Technical Director of the University's Institute for Infrastructure and Information Assurance (IIIA). He is a consultant in the areas of critical infrastructure assurance, high power electromagnetics, nuclear and directed energy weapon effects, and risk assessment. He served as senior staff on the Congressional EMP Commission. Baker is former director of the Defense Threat Reduction Agency's Springfield Research Facility, a national center for critical system vulnerability assessment. Much of his career was spent at the Defense Nuclear Agency (DNA) as the Integrated Electromagnetics Team Leader directing the development of

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electromagnetic protection, underground testing, and standards including MIL-STD-188-125, MIL-STD-2169B, and MIL-HDBK-423. He also headed the Agency's Innovative Concepts Division overseeing the joint US-Russian space nuclear power technology, electro-thermal chemical (ETC) gun development, radiofrequency directed energy source concept development and testing, and DNA's university grants programs. Baker received the Agency Legacy Award for his leadership and innovation. He is a member of the NDIA Homeland Security Executive Board, the Institute of Electrical and Electronic Engineers, the Directed Energy Professional Society (Charter Member), and the Association of Old Crows. He is a Summa Foundation EMP Fellow and holds a Ph.D. from the U.S. Air Force Institute of Technology.

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archived as **http://www.stealthskater.com/Documents/Hamilton_04.pdf**

more of Dan Burisch is at ***http://www.stealthskater.com/Burisch.htm***

note: because important websites are frequently "here today but gone tomorrow", the following was archived from http://www.skywatch-research.org/QuantumHolographic.htm on April 8, 2004 . This is NOT an attempt to divert readers from the aforementioned web-site. Indeed, the reader should only read this back-up copy if it cannot be found at the original author's site.

The Biophotonic Quantum Holographic Matrix

by **William F. Hamilton III**

ABSTRACT: *This paper is an attempt to integrate studies of the quantum potential, quantum holography, biophotonics and the enveloping matrix of biointegration, biocommunication, and bioinformation that composes the web of light and life in living organisms and their possible genesis in an electromagnetic infoton.*

Introduction:

Theoretical physicist David Bohm proposed a new hidden variables theory of Quantum Mechanics. He assumes the wave function does not represent just a set of probabilities but an actual field. This field exists and acts upon particles the same way a classical potential does. Thus it is a quantum potential which is associated to this field and is a function of the wave function. It is postulated here that the quantum potential is active -- as a field -- in living cells and organisms and acts upon them.

The equation Bohm used to represent this quantum potential is:

$$U = -\sum_{k} \left(\hbar^2 / 2m_k\right)\left(\partial_k^2 R / R\right) \qquad (1)$$

Research reveals that Bohmian quantum potential is still used, but that it may only represent a means to extend Quantum Theory into a realistic theory of particles and fields.

It resolves the dilemma of the appearance -- in one and the same phenomenon -- of both particle and wave properties in a rather straightforward manner. Bohmian mechanics is a theory of motion describing a particle (or particles) guided by a wave. This guiding wave is usually attributed to atomic particles. But it might be more insightfully seen as a traveling **soliton** or vortex.

Bohmian mechanics is manifestly nonlocal, and the velocity may depend upon the positions of other -- even distant -- particles whenever the wave function of the system is entangled.

The behavior of the particle is determined by the particle’s position and momentum, the wave field, and the sub-quantum fluctuations.

Bohm's quantum potential binds the entire Universe together into what he liked to call a seamless "unbroken wholeness". Every particle in the Universe is connected by the quantum potential to every other particle. He likened the cosmos to a **hologram** in which each point on the film carries information about the entire picture. Bohm's GWT -- far more sophisticated than de Broglie's crude version -- is a "holistic" vision in which all parts of the Universe are joined to every other part. "Interconnectedness" was one of Bohm's favorite words. He saw the Universe as resembling the unity of a living organism. A kind of pantheism not unlike Spinoza's -- a pantheism Einstein himself favored." **[2]**

Bohm referred the holomovement as the basic reality. The pattern formed on a photographic plate by light waves that interfere and create a hologram. This pattern is the interaction or interference pattern of two parts of a laser light (coherent light). One beam reflects off an object, the other off a mirror. In addition, any portion of the holographic plate contains information on the whole object.

Biohologram:

Every cell in the human body contains nuclear DNA. Information on the whole body -- much like a hologram -- only the cells can go through a process of division and reproduction (mitosis).

In quantum holography, things are spookier still. While holograms are typically constructed with interfering beams of light, in quantum holography the researchers measure the simultaneous arrivals of an illuminating photon that is sent into a chamber and a companion photon in the other entangled beam.**[2]**

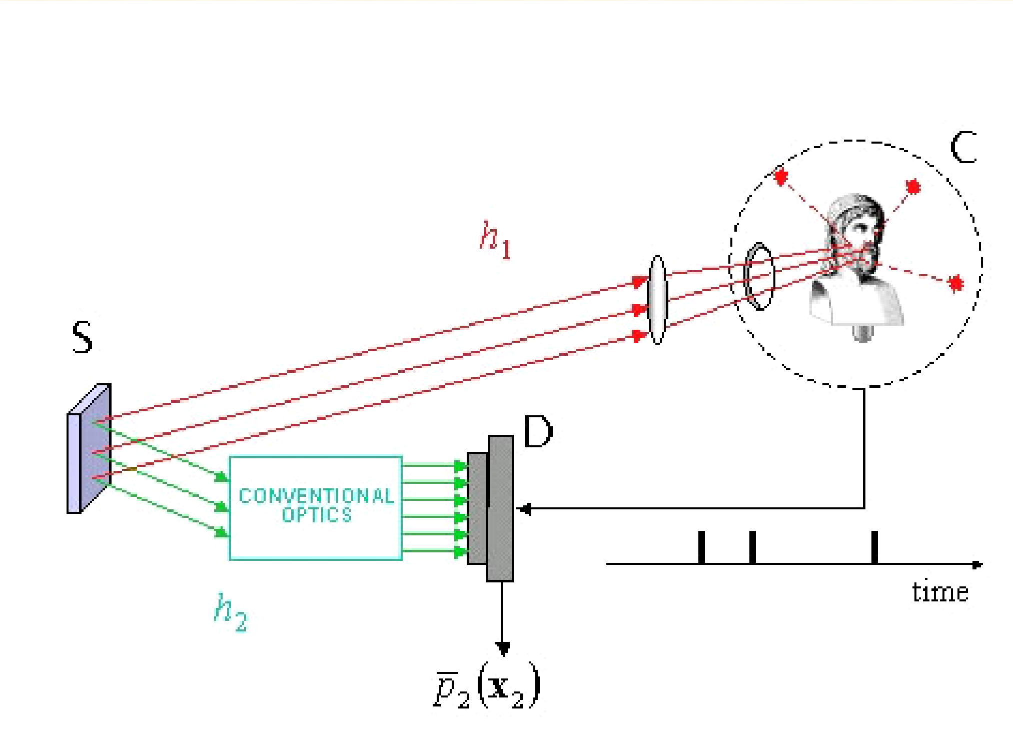

Quantum holography -- as depicted in this cartoon -- is a way that physicists could produce 3-dimensional images of objects that would be invisible to systems relying on classical physics. A source **S** produces 2 photon beams (**h_1** and **h_2**). The photons in **h_1** are quantum mechanically **entangled** with the photons in **h_2**. When a photon in **h_1** enters chamber **C**, it encodes 3-dimension information about the enclosed object (in this case a Grecian bust) in the interference of the 2 paths it could take -- a path that intercepts the object and subsequently is reflected to the chamber wall, and a path that misses the object and strikes the chamber wall directly. The second beam **h_2** passes through conventional optics and strikes a detector array **D**. A coincidence counter extracts the holographic information by monitoring the relative time between a photon in **h_1** striking the chamber wall and its entangled mate in **h_2** arriving at detector **D**.

Wave Genetics Inc. and the Moscow Institute of Control Sciences are exploring a new concept of the genetic code that asserts:

(1) that the evolution of biosystems has created genetic "texts" -- similar to natural context dependent texts in human languages -- shaping the text of these speech-like patterns.

2) that the chromosome apparatus acts simultaneously both as a source and receiver of these genetic texts, respectively decoding-and-encoding them.

3) that the chromosome continuum of multicellular organisms is analogous to a static-dynamical multiplex time-space holographic grating, which comprises the space-time of an organism in a convoluted form.

That is to say, the DNA action -- theory predicts and which experiment confirms -- is …

(i) that of a "gene-sign" laser and its solitonic electro-acoustic fields, such that the gene-biocomputer "reads and understands" these texts in a manner similar to human thinking but at its own genomic level of "reasoning". It asserts that natural human texts (irrespectively of the language used) and genetic "texts" have similar mathematical-linguistic and entropic-statistic characteristics, where these concern the fractality of the distribution of the character frequency density in the natural and genetic texts and where -- in case of genetic "texts" -- the characters are identified with the nucleotides, and

(ii) that DNA molecules -- conceived as a gene-sign continuum of any biosystem -- are able to form holographic pre-images of biostructures and of the organism as a whole as a registry of dynamical "wave copies" (or "**matrixes**") succeeding each other. This continuum is the measuring, calibrating field for constructing its biosystem.

“Complex information can be encoded in EM fields, as we all know from coding-and-decoding of television and radio signals. Even more complex information can be encoded in holographic images. DNA acts as a holographic projector of acoustic and EM information which contains the informational quintessence of the biohologram. Only 3% of human DNA encodes the physical body. The remaining 97% of the 3 billion base pair genome contains over a million genetic structures -- called transposons -- that have the capacity to jump from one chromosomal location to another (Kelleher, 1999). We are 99.9% alike in our genetic legacy. Our individuality is expressed in 3 million small variations in our cells called single nucleotide polymorphisms.

"**Gene-expression** is the mechanism by which new patterns are called into being (Rossi, 2000). There is also a strong correlation between modulation of the brain’s EM field and consciousness (Persinger, 1987; McFadden, 2002). The Gariaev group has discovered a wave-based genome and DNA phantom effect which strongly supports the holographic concept of reality (Miller, Webb, Dickson, 1975). This main information channel of DNA is the same for both photons and radio waves. Superposed coherent waves of different types in the cells interact to form diffraction patterns, first in the acoustic domain and second in the electromagnetic domain -- a **quantum hologram** -- a translation process between acoustical and optical holograms.” **[4]**

The distribution of the character frequency in genetic texts is fractal, so the nucleotides of DNA molecules are able to form holographic pre-images of biostructures. This process of "reading and writing" the very matter of our being manifests from the genome's associative holographic memory in conjunction with its quantum nonlocality. Rapid transmission of genetic information and gene-expression unite the organism as holistic entity embedded in the larger Whole. The system works as a biocomputer -- a **wave biocomputer**.

The quantum nonlocality of the genetic information is fundamental. Experimental work of the Gariaev group shows how quantum nonlocality is directly related to laser radiation from chromosomes (coherent light), which jitterbugs its polarization plane to radiate or occlude photons. DNA and the genome have now been identified as active "laser-like" environments. Roughly speaking, DNA can be considered as a liquid crystal gel-like state that acts on the incoming light in the manner of a solitonic lattice. **[5]**

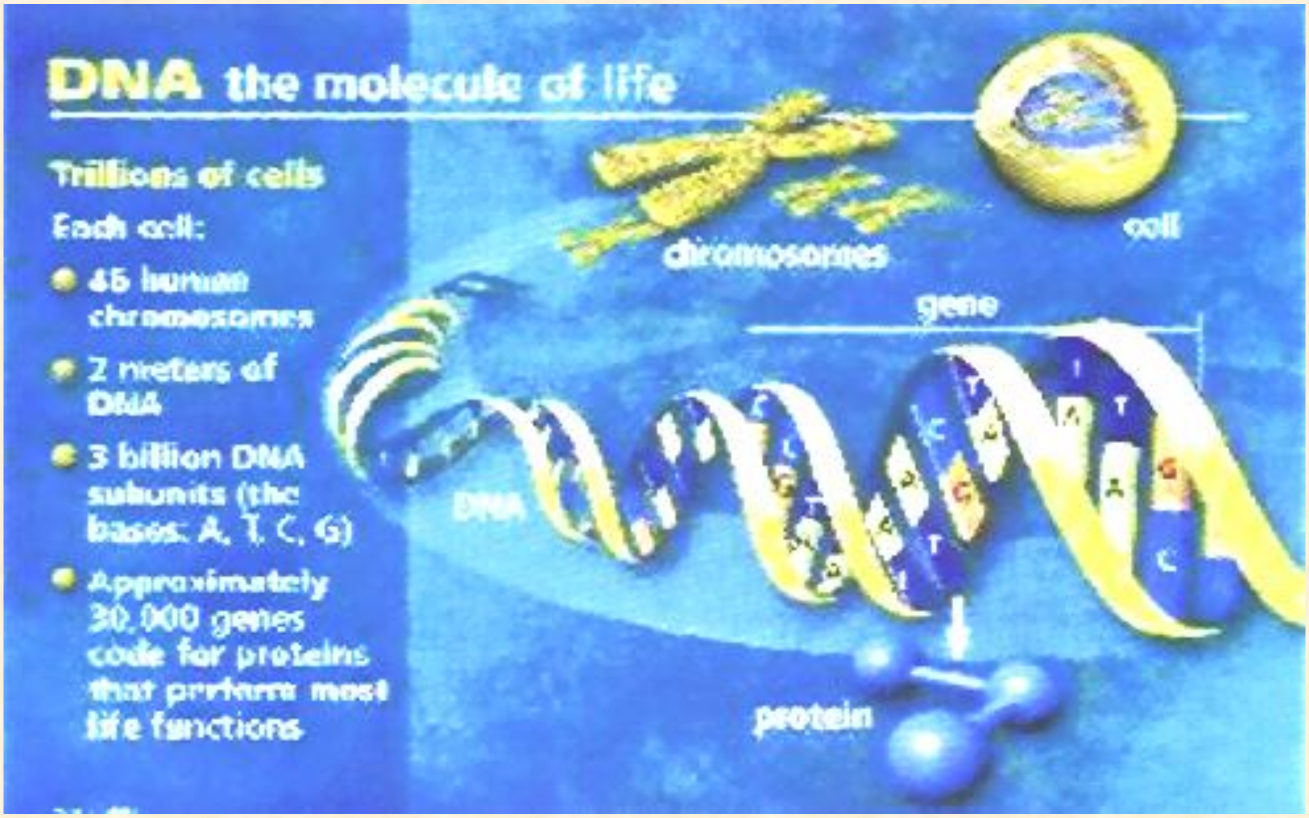
DNA the molecule of life
Trillions of cells
Each cell:
46 human chromosomes
2 meters of DNA
3 billion DNA subunits (the bases: A, T, C, G)
Approximately 30,000 genes code for proteins that perform most life functions
chromosomes
cell
gene
DNA
protein

Biophotonics

This entire section is extracted from the History of Biophotonics website:

Around 1923, Alexander Gurwitsch discovers an "ultra-weak" photon emission from living systems (onions, yeast, ...), since he suggested connections between photon emission and cell division rate. He calls this **photonemission "mitogenetic radiation**". His experiments indicate that the wavelength is in the range around 260 nm (Bibliography under Gurwisch and also Ruth (1977, 1979)).

Around 1950, Russian scientists rediscover "ultra-weak photon emission" from living organisms. Most results are published in "Biophysics" (Engl.) and originally in "Biofizika"). (Bibliography under Ruth, 1979).

Italian nuclear physicists discover by chance "bioluminescence" of seedlings. They do not think that this finding is significant, but they publish the results (Colli et al. 1954, 1955, Ruth 1979).

The Russian biophysicist and the American chemist enunciate the first theory of ultra-weak photonemission (UWPE) from biological systems -- the so called "**imperfection theory**". UWPE shall be an expression of the deviation from equilibrium -- some kind of distortion of metabolic processes (Zhuravlev 1972, Seliger 1975, Ruth 1979).

Independently from each other and by different motivations, scientific groups in Australia (Quickenden), Germany (Fritz-Albert Popp), Japan (Inaba), and Poland (Slawinski) show evidence of ultra-weak photon emission from biological systems by use of modern single-photon counting systems. Bibliography (Quickenden, Inaba, Popp &Ruth, Slawinski).

While Quickenden, Slawinski, and Inaba prefer the imperfection theory, Popp and his group enunciate just the opposite theory:

1. The radiation originates from an almost perfect coherent photon field.
2. Essential sources are the DNA and corresponding resonators in the cells.
3. The mechanism describes photon storage in cavities and information channels, tuned by Casimir forces.
4. There is a close connection to delayed luminescence which corresponds to excited states of the coherent photon field.
5. The radiation is not the product but essentially the initiator of chemical reactions in the cells. The radiation submits the information within and between cells.
6. The radiation is not limited to the optical range but follows an **f = const** rule (the occupation probability of the phase space is equal for all wavelengths) and extends to longer wavelengths including the so-called heat radiation of the body.
7. This radiation is the proper regulator and information carrier of life.

The Marburg group of Fritz-Albert Popp calls this phenomenon "**biophotons**" in order to stress the difference to "bioluminescence". Biophotons are single quanta which are permanently-and-continuously emitted by all living systems. They are subjects of quantum physics, and they display a universal phenomenon attributed to all living systems. Worldwide, all scientists who agree with these statements call the radiation "biophotons" and the scientific field "**biophotonics**".

From 1972 to 1980, the Marburg group of the leader -- the physicist and Dr. Habil Fritz-Albert Popp -- evaluated experimentally all the essential physical properties of biophotons.

1. The intensity ranges from a few up to some hundreds photons/(sec-cm^2).
2. The spectral distribution follows in the time average an **f = const** rule.
3. The modes are strongly coupled.
4. The delayed luminescence that approaches continuously the biophoton emission follows a hyperbolic rather than an exponential relaxation function.
5. The biophotons origin from an almost fully coherent field.
6. Cells are able to establish cavity resonators which contribute to biophoton regulation.

7. The essential source of non-equilibrium biophoton emission is the DNA.

This group introduces the first time photocount statistics (PCS) into biophotonics. They show evidence that biophotons are emitted according to a Poissonian PCS. Furthermore, they show evidence that (1) the delayed luminescence follows a hyperbolic relaxation function rather than an exponential one; (2) the modes are strongly coupled; and (3) there are hyperbolic oscillations around the continuous hyperbolic relaxation function. The group finds the first time intercellular communication by means of biophotons. Later this was confirmed by Albrecht-Bühler (Bacteria), Popp and Chang (dinoflagellates), Galle (daphnia), Shen (blood), and Vogel (bacteria).

(Bibliography under Popp and coworkers, i.e., Bahr, Böhm, Grass, Grolig, Herrmann, Kramer, Rattemeyer, Ruth, Schmidt, Wulle, Albrecht-Bühler, Chang, Galle, Shen, Vogel).

The papers of Popp and his group are examined mainly by the group of B. Chwirot (Kopernikus University, Torun). They confirm the essential results (Bibliography Chwirot et al.).

Herbert Klima (Atom Institute Vienna) performs his dissertation in Popp`s group at the University in Marburg. He transfers "Biophotonics" to the University in Vienna -- in particular investigations on laser excitation of living systems.

(Bibliography Klima or Atominstitut Wien).

J.Slawinski cooperates with the groups in Japan, USA and the Popp-group in Germany. He follows mainly the links between biophotons and biochemical reactions. There arises a branch biochemical biophotonics that becomes an essential part mainly in Japan and USA.” **[6]**

Bioinfotons

This term “**bioinfoton**” is one that I am adopting to specify any particle (such as the **Ganesh Particle***), wave, or biomolecule that transfers information from an emitter to a receptor. It is possible that if a biophoton is emitted from a coherent source that it will carry holographic information as a form of modulation (possibly frequency-modulated) and produce action or results in biological systems.

It is possible that biophotons may even be carriers of ***psi*** information and that a coherent coupling can be established between 2 conscious lifeforms resulting in a transference of information from a higher potential field to a field at lower potential. Even though this is conjecture at this point, it suggests other means by which disparate lifeforms can communicate. We know there is a process by which trees communicate and even signal each other in the face of danger. We may be exchanging information with pets and other animals through biophotonic communication. This may be how some people who have a "green thumb" affect plants they care for.

Even communication with other intelligent life forms in the Cosmos may be effected by the amplification and vectoring of biophotons or -- via the quantum potential -- produce information at a distance.

A virtual photon flux in the quantum potential may be integrating the coordinated wholeness of the organism while the action of bioinfotons may keep every part of the organism in communication with every other part.

Conclusions

Life and living organisms are more than the sum of their parts and are composed of material and non-material parts. The spiral form of DNA evidently produces an electromagnetic wave field that informs the organism's growth and structure.

Scientist Richard Alan Miller is a pioneer in this field and has written:

"In a hologram, wave fields interfere with one another to lay the foundations for the reconstruction of the image of an object. But how are the wave fields produced?

The term "holography" comes from the Greek roots meaning "entire" and "to write". In holography, the image is projected by a coherent light source split into both the object wave and the reference wave background. This dichotomous nature is reflected in the particle/wave nature of the DNA molecule, which can be "read out" with biophotons from chromosomes to set up a holographically-produced wave field. This superposition of wave fields (object wave and reference wave) creates a wave guide for the formation of biological structure. The image is constructed according to the reference information contained in the genes. The reconstructed object wave is identical with the object wave field. The reconstructed wave fields reproduce exactly the recorded ones (the DNA with genetic code)." **[7]**

Mr. Miller also proposes this hypothesis:

"QUANTUM BIOHOLOGRAPHY

Hypothesis: The organization of any biological system is established by a complex electrodynamical field that is, in part, determined by its atomic physiochemical components. These, in part, determine the behavior and orientation of these components. This dynamic is mediated through wave-based genomes wherein DNA functions as the holographic projector of the psychophysical system -- a quantum biohologram."

I propose that the biohologram is embedded as an integral part of the biocosmic hologram we call the"Universe".

Dr. Dan Burisch has seen evidence that a **Ganesh Particle*** can transmute itself into a fully functional atypical eukaryotic cell in a matter of seconds -- not eons. Such evidence -- when it becomes available -- will change our entire perspective on the existence of a universal holonomic mind that informs its creation.

**Ganesh Particles are charged clusters that extracted from ancient bedrock and have a seemingly unknown origin, but carry information which is transferred to cells via a crossbridge. (discovered by Dr. Dan B.C. Burisch)*

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- Bunge on the Status of Classical and Quantum Physics
- Fractions of BW Casualties Surviving
- First Step in Self-Promotion of Cancer Due to Hypoxia
- Differentiation and Dedifferentiation Timelines
- Evolution of Cells on Earth
- A Charged Particle q is a Coupled System of m and Ø
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (1)
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (2)
- The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry (3)
- A Charged Particle is a Coupled System
- The Anomalies in Navy Electrolyte Experiments at China Lake
- Chung's Carbon Filament Negative Resistor

- Typical circuit has about 10^{-13} energy collection efficiency
- Classical View of EM
- Curved Spacetime acts as source or sink
- Chronic Disease Puzzling
- Cancer Characteristics
- Solving a Cancer Enigma
- Cancer: Characteristics
- Nonlinear Optics Distortion Correction Theorem
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (1)
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (2)
- The Electronuclear Reaction: Nuclear Reactions in TR-Zones (3)
- In Time-Reversed Zone: Nuclear reactions are biased
- In Time-Reversed Zone: Dynamics may be reversed
- Time-Reversed Zone: Significant only after time-density charging
- A New Conservation of Energy Law
- Questions on Carcinogens and EM

Radiation

- AS DEFINED, fields and potentials only exist in and on charged matter
- Serious flaws and errors in classical EM theory
- Electrodynamicists' Reaction to Removal of the Material Ether
- Reaction to Loss of Material Ether (1)
- Reaction to Loss of Material Ether (2)
- Some EM waves in Spacetime
- Air Medium Disturbances Generated When Air is Perturbed by a Plucked Taut String
- Launching a Spacetime Perturbation ("EM Wave") from a Wire Antenna
- Phase Conjugate Wavepairs Produce New Waves
- Scalar Electromagnetics (Energetics) View of EM (1)
- Scalar Electromagnetics (Energetics) View of EM (2)

- Scalar Electromagnetics (Energetics) View of EM (3)
- Extended General Relativity Principle
- Extension of Work-Energy Theorem
- 34 Flaws in Classical EM Theory
- MTW's General Relativity Principle
- Use of General Relativity (GR) in Particle Physics
- The Missing Infolded Electrodynamics
- Infolded Engines: Excluded by Present Physics
- Mass curves and structures spacetime; ST curvatures change and structure mass (1)
- Mass curves and structures spacetime; ST curvatures change and structure mass (2)
- At Infinite Velocity: Each Is Every Other
- Lisitsyn's Report: Brain Code Broken
- Lorentz Closed Surface Integration
- Lorentz's physically insignificant energy flow can be collected and utilized
- Lorentz surface integration of the Poynting vector around a closed surface
- Longitudinal EM Photon Interaction with Charge
- Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass.

- Pumping with Longitudinal EM waves Time-reverses the Mass
- Maxwell's Quaternion Theory
- Maxwellian Systems before and after Regauging
- Maxwell's four equations reduce to: Page 1
- Maxwell's four equations reduce to: Page 2
- More to come

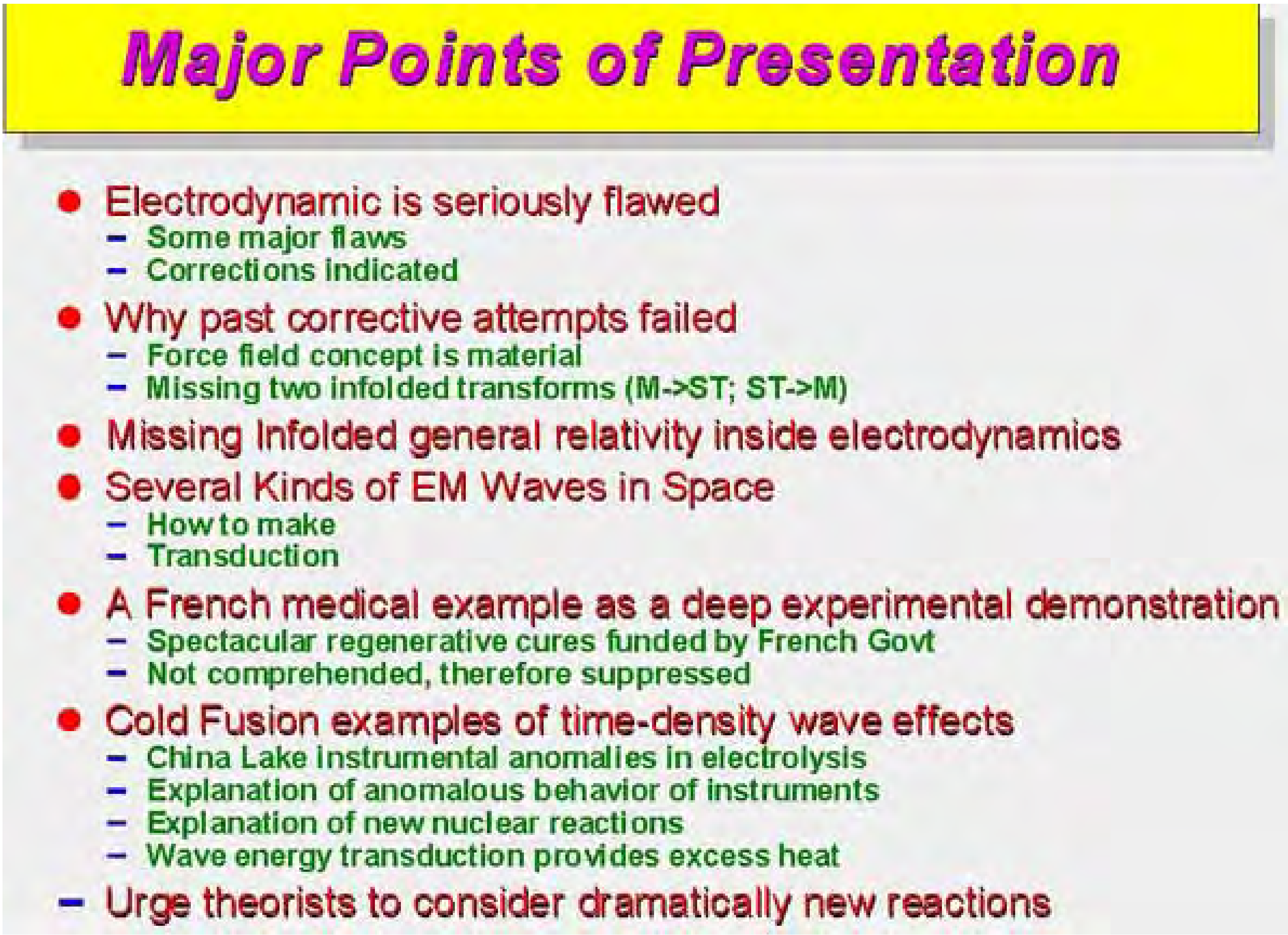

Major Points of Presentation

- Electrodynamic is seriously flawed
  - Some major flaws
  - Corrections indicated
- Why past corrective attempts failed
  - Force field concept is material
  - Missing two infolded transforms (M->ST; ST->M)
- Missing infolded general relativity inside electrodynamics
- Several Kinds of EM Waves in Space
  - How to make
  - Transduction
- A French medical example as a deep experimental demonstration
  - Spectacular regenerative cures funded by French Govt
  - Not comprehended, therefore suppressed
- Cold Fusion examples of time-density wave effects
  - China Lake instrumental anomalies in electrolysis
  - Explanation of anomalous behavior of instruments
  - Explanation of new nuclear reactions
  - Wave energy transduction provides excess heat
- Urge theorists to consider dramatically new reactions

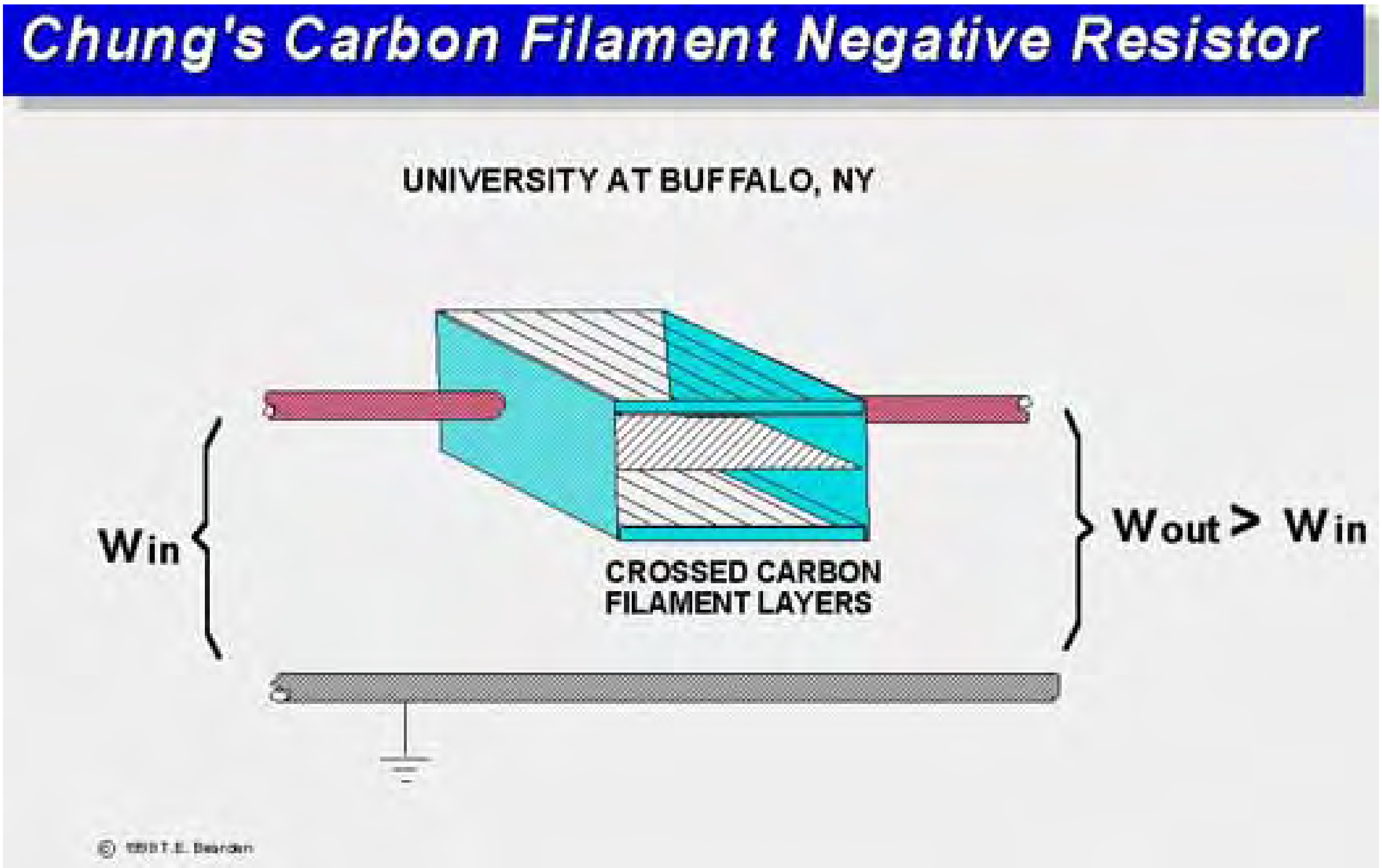

Chung's Carbon Filament Negative Resistor

UNIVERSITY AT BUFFALO, NY

W_{in}
CROSSED CARBON FILAMENT LAYERS
$W_{out} > W_{in}$

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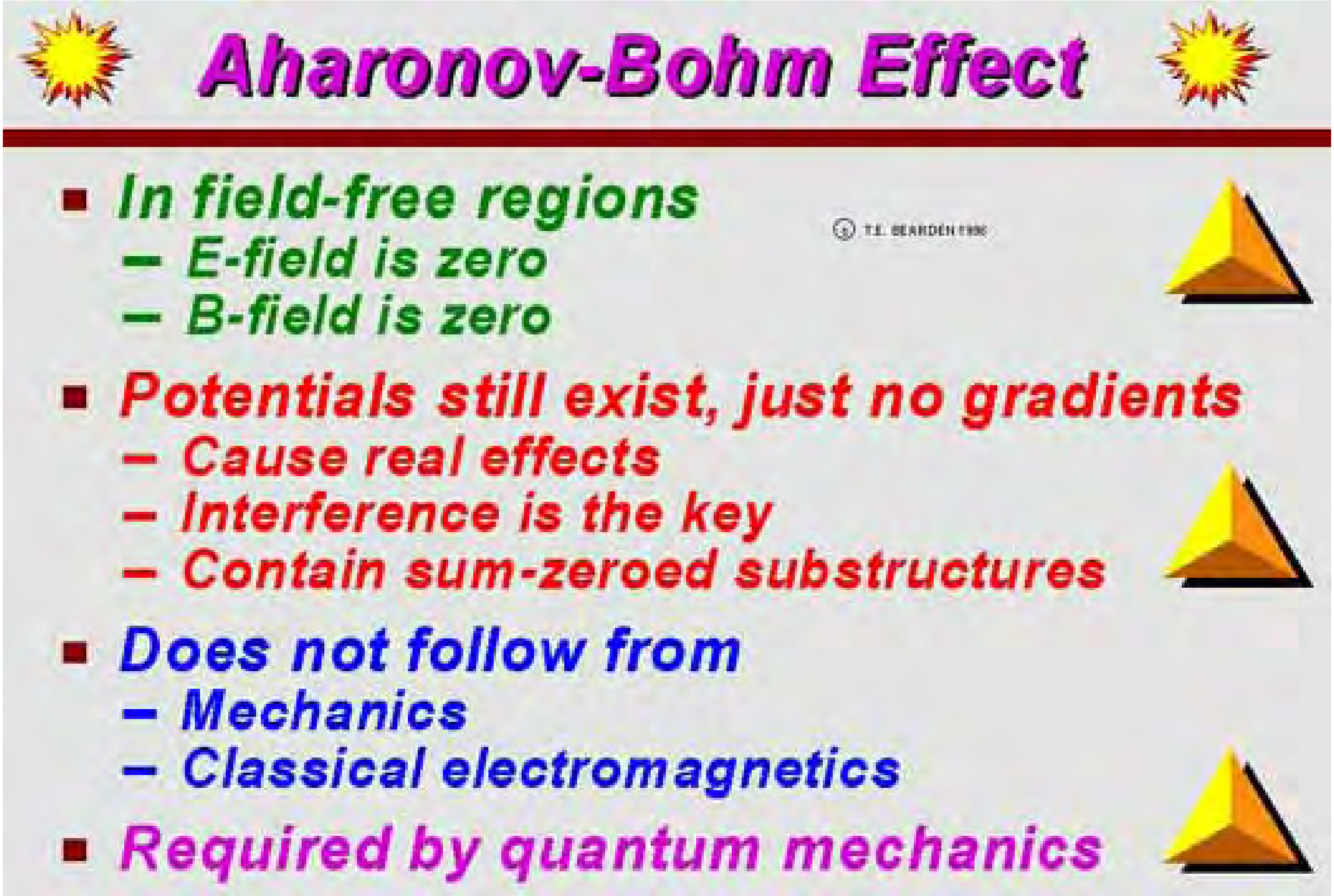

Aharonov-Bohm Effect

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- In field-free regions
  - E-field is zero
  - B-field is zero
- Potentials still exist, just no gradients
  - Cause real effects
  - Interference is the key
  - Contain sum-zeroed substructures
- Does not follow from
  - Mechanics
  - Classical electromagnetics
- Required by quantum mechanics

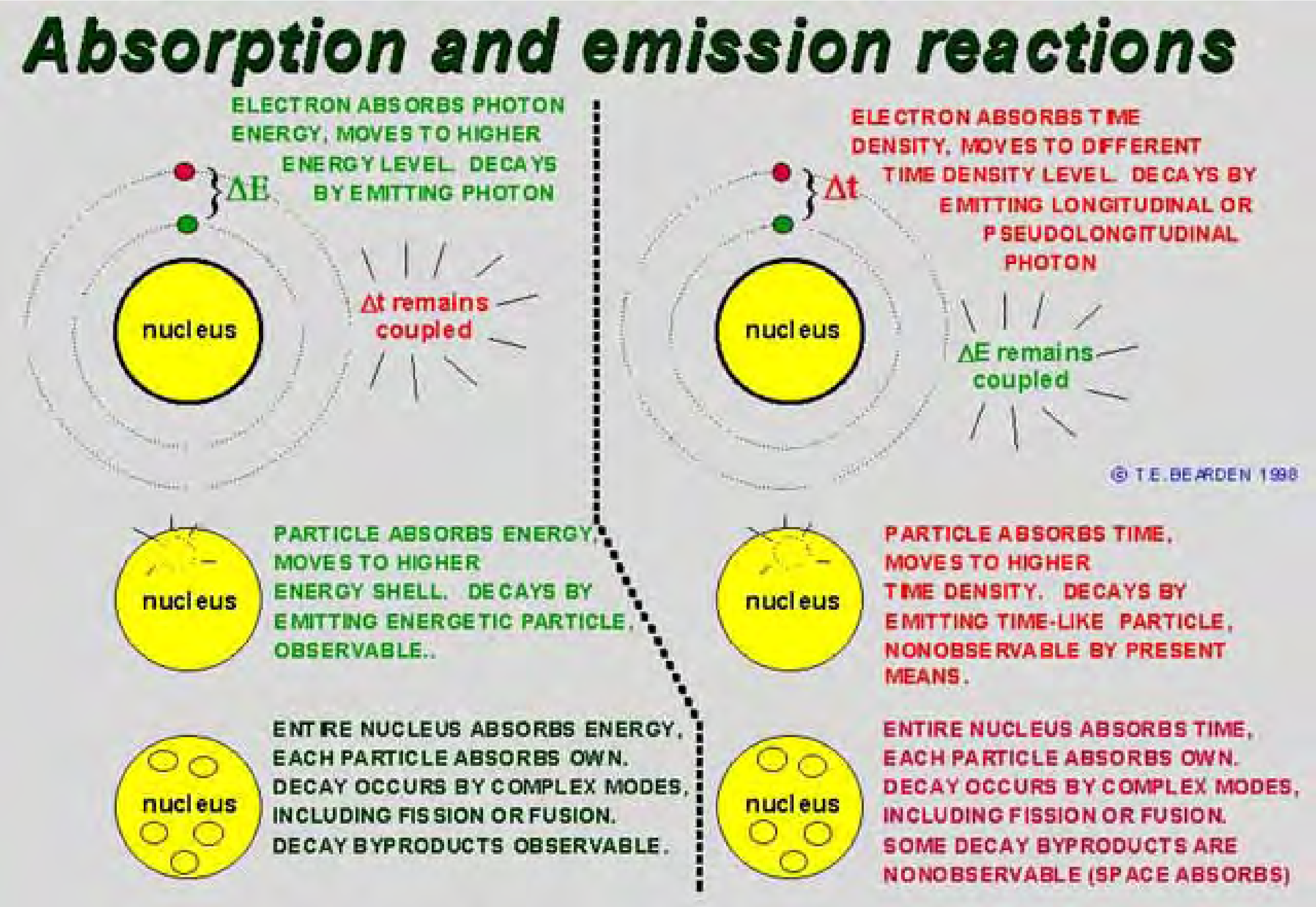

Absorption and emission reactions

ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON

ELECTRON ABSORBS TIME DENSITY, MOVES TO DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTON

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PARTICLE ABSORBS ENERGY, MOVES TO HIGHER ENERGY SHELL. DECAYS BY EMITTING ENERGETIC PARTICLE. OBSERVABLE..

PARTICLE ABSORBS TIME, MOVES TO HIGHER TIME DENSITY. DECAYS BY EMITTING TIME-LIKE PARTICLE, NONOBSERVABLE BY PRESENT MEANS.

ENTIRE NUCLEUS ABSORBS ENERGY, EACH PARTICLE ABSORBS OWN. DECAY OCCURS BY COMPLEX MODES, INCLUDING FISSION OR FUSION. DECAY BYPRODUCTS OBSERVABLE.

ENTIRE NUCLEUS ABSORBS TIME, EACH PARTICLE ABSORBS OWN. DECAY OCCURS BY COMPLEX MODES, INCLUDING FISSION OR FUSION. SOME DECAY BYPRODUCTS ARE NONOBSERVABLE (SPACE ABSORBS)

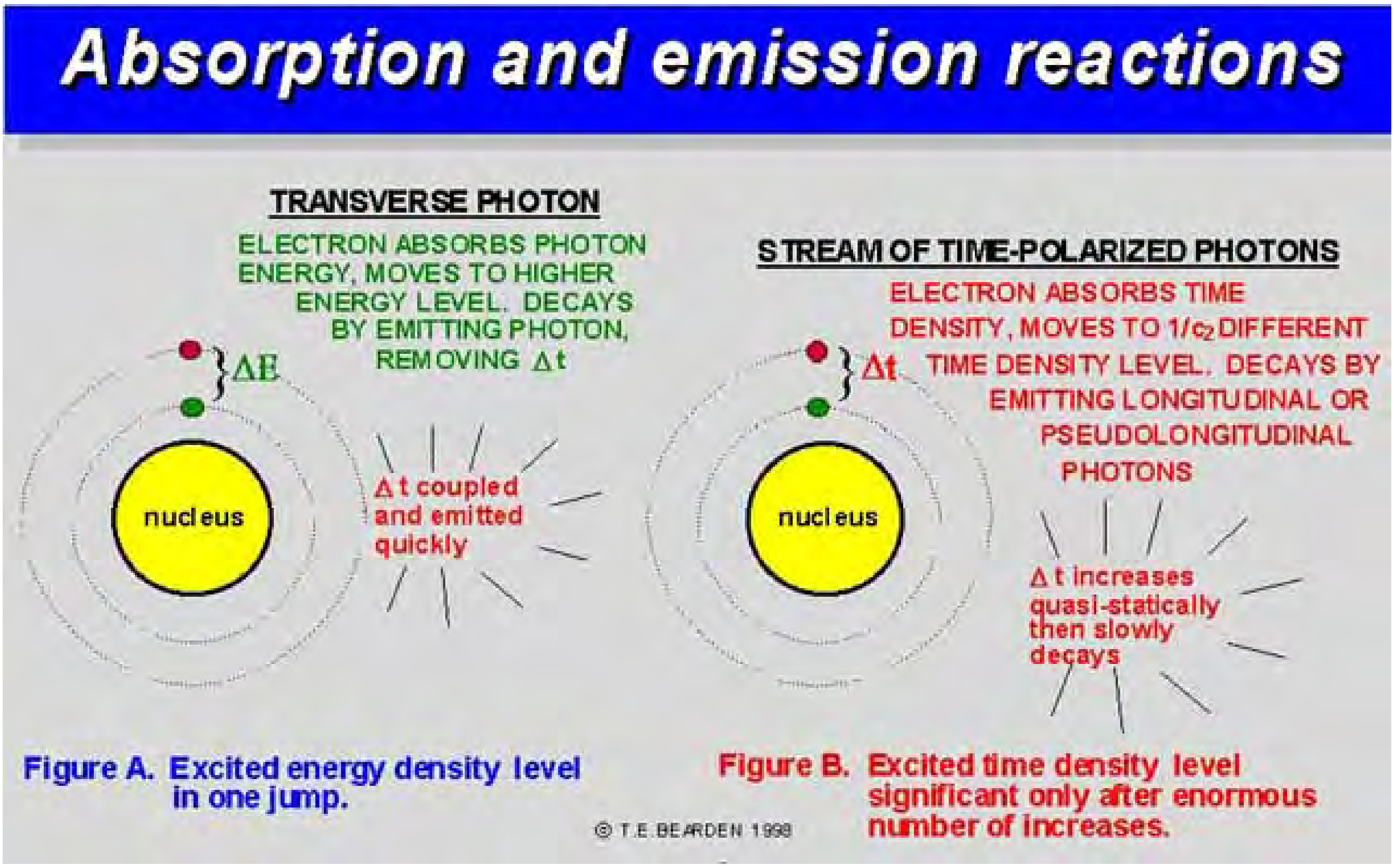

Absorption and emission reactions

TRANSVERSE PHOTON

ELECTRON ABSORBS PHOTON ENERGY, MOVES TO HIGHER ENERGY LEVEL. DECAYS BY EMITTING PHOTON, REMOVING Δt

Δt coupled and emitted quickly

Figure A. Excited energy density level in one jump.

STREAM OF TIME-POLARIZED PHOTONS

ELECTRON ABSORBS TIME DENSITY, MOVES TO $1/c_2$ DIFFERENT TIME DENSITY LEVEL. DECAYS BY EMITTING LONGITUDINAL OR PSEUDOLONGITUDINAL PHOTONS

Δt increases quasi-statically then slowly decays

Figure B. Excited time density level significant only after enormous number of increases.

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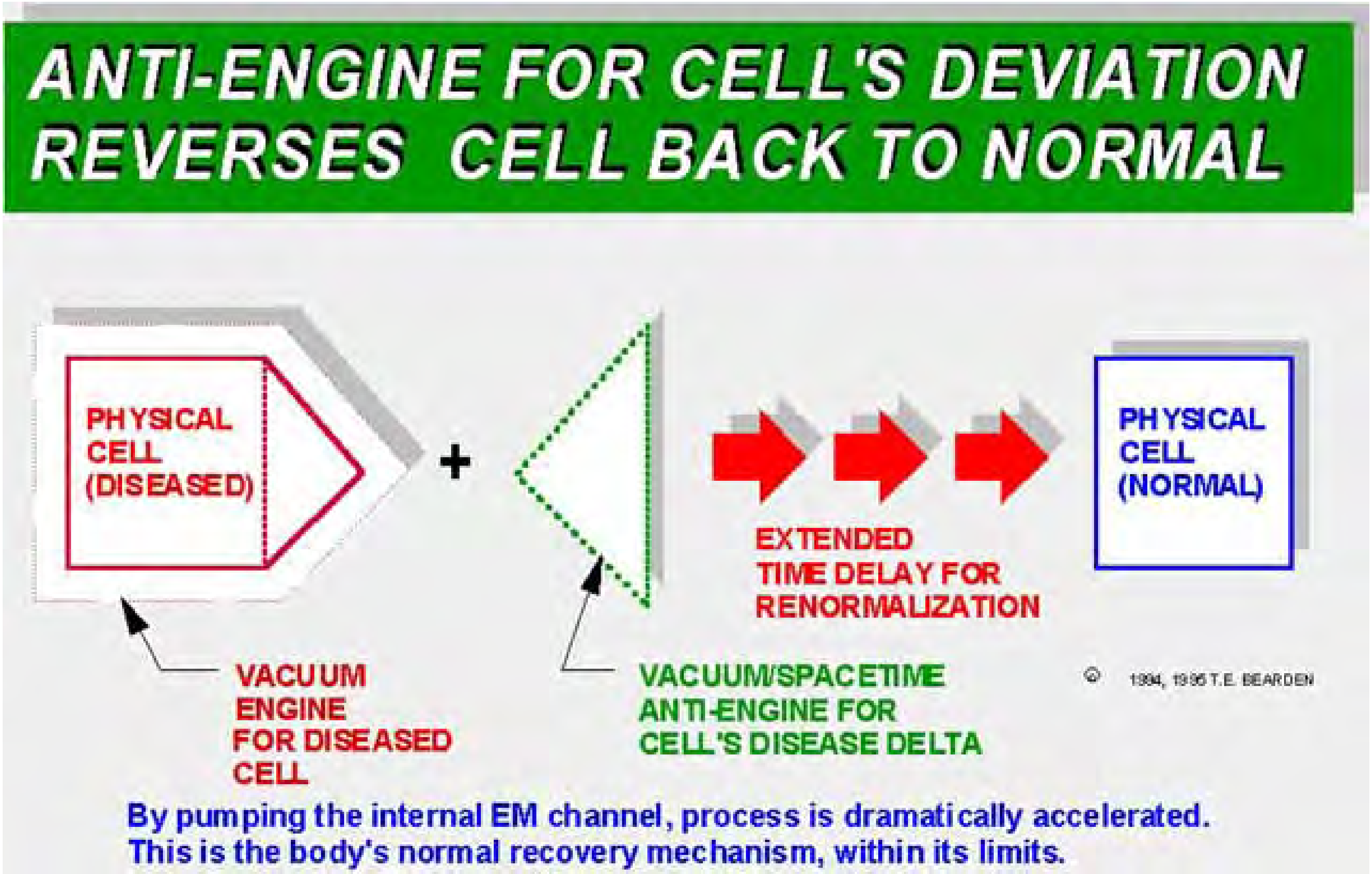

ANTI-ENGINE FOR CELL'S DEVIATION REVERSES CELL BACK TO NORMAL

PHYSICAL CELL (DISEASED)

+

EXTENDED TIME DELAY FOR RENORMALIZATION

PHYSICAL CELL (NORMAL)

VACUUM ENGINE FOR DISEASED CELL

VACUUM/SPACETIME ANTI-ENGINE FOR CELL'S DISEASE DELTA

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By pumping the internal EM channel, process is dramatically accelerated.
This is the body's normal recovery mechanism, within its limits.

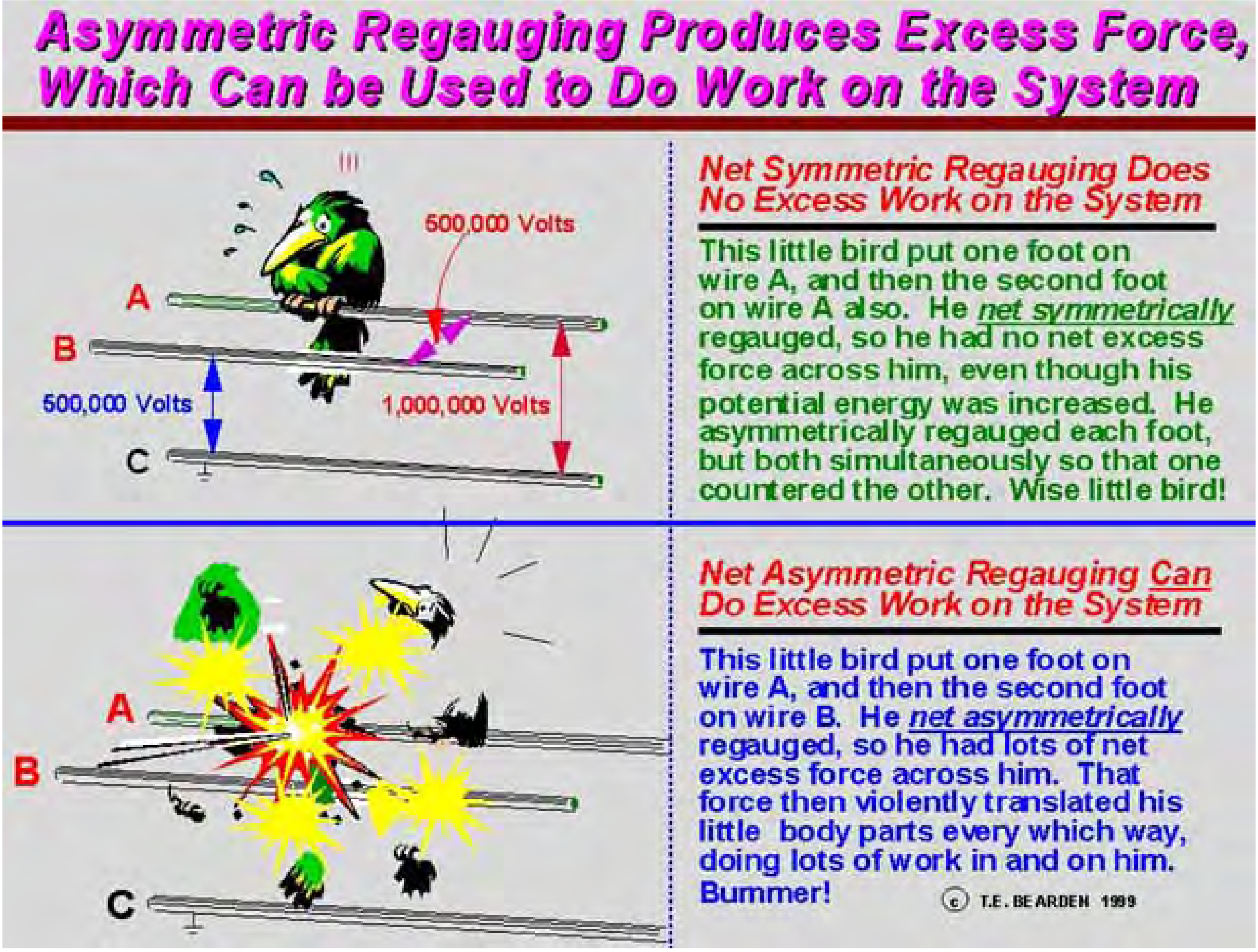

Asymmetric Regauging Produces Excess Force, Which Can be Used to Do Work on the System

Net Symmetric Regauging Does No Excess Work on the System

This little bird put one foot on wire A, and then the second foot on wire A also. He *net symmetrically* regauged, so he had no net excess force across him, even though his potential energy was increased. He asymmetrically regauged each foot, but both simultaneously so that one countered the other. Wise little bird!

Net Asymmetric Regauging *Can* Do Excess Work on the System

This little bird put one foot on wire A, and then the second foot on wire B. He *net asymmetrically* regauged, so he had lots of net excess force across him. That force then violently translated his little body parts every which way, doing lots of work in and on him. Bummer!

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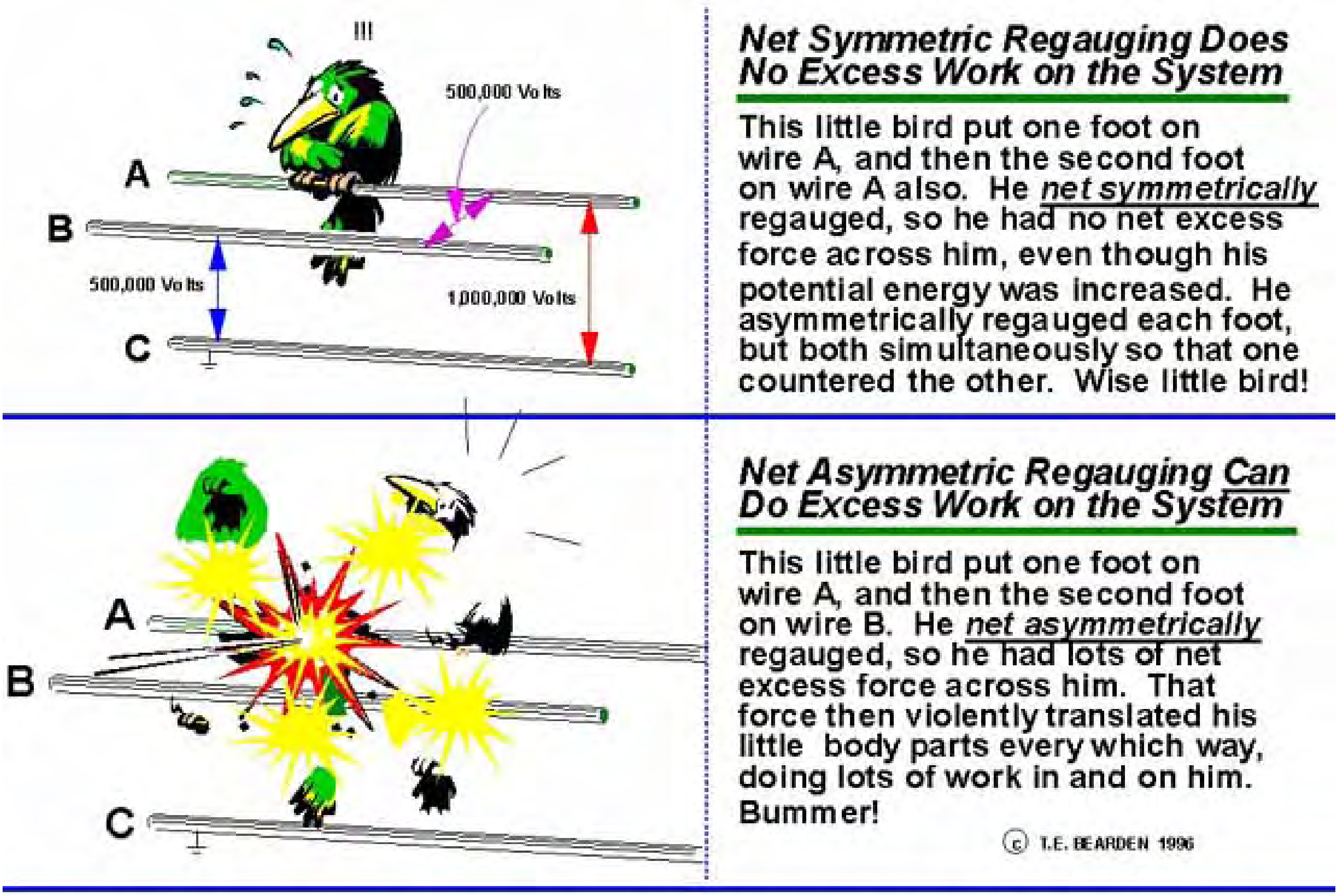

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Net Asymmetric Regauging Can Do Excess Work on the System

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Figure 32. Asymmetric regauging produces excess force, which can be used to do work on the regauging system.

Selected clipart © by Lotus SmartPics™

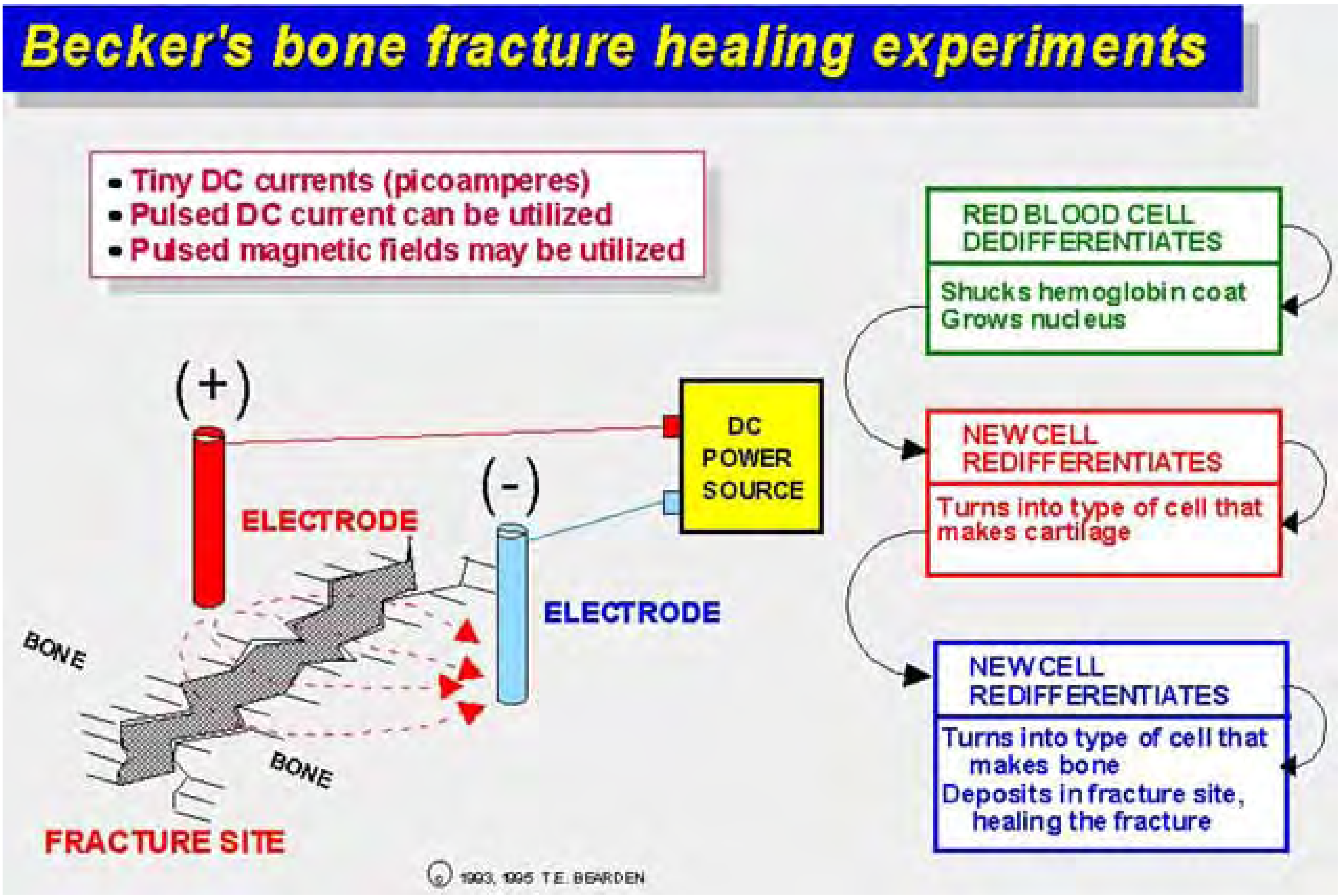

Becker's bone fracture healing experiments

- Tiny DC currents (picoamperes)
- Pulsed DC current can be utilized
- Pulsed magnetic fields may be utilized

(+)
ELECTRODE
(-)
ELECTRODE
DC POWER SOURCE
BONE
BONE
FRACTURE SITE

RED BLOOD CELL DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

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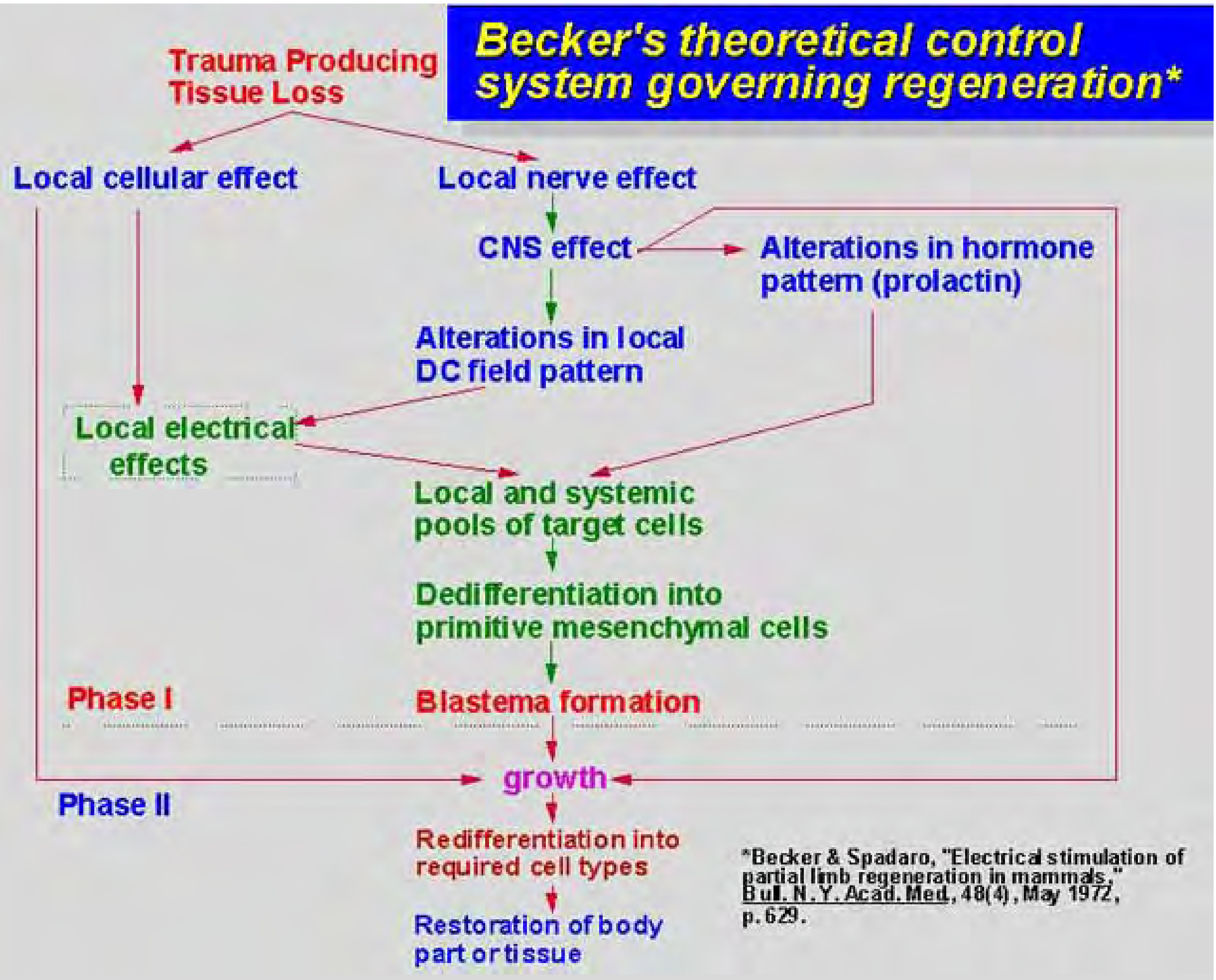

Becker's theoretical control system governing regeneration*

Trauma Producing Tissue Loss

Local cellular effect

Local nerve effect

CNS effect

Alterations in hormone pattern (prolactin)

Alterations in local DC field pattern

Local electrical effects

Local and systemic pools of target cells

Dedifferentiation into primitive mesenchymal cells

Phase I

Blastema formation

growth

Phase II

Redifferentiation into required cell types

Restoration of body part or tissue

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bul. N.Y. Acad. Med., 48(4), May 1972, p.629.

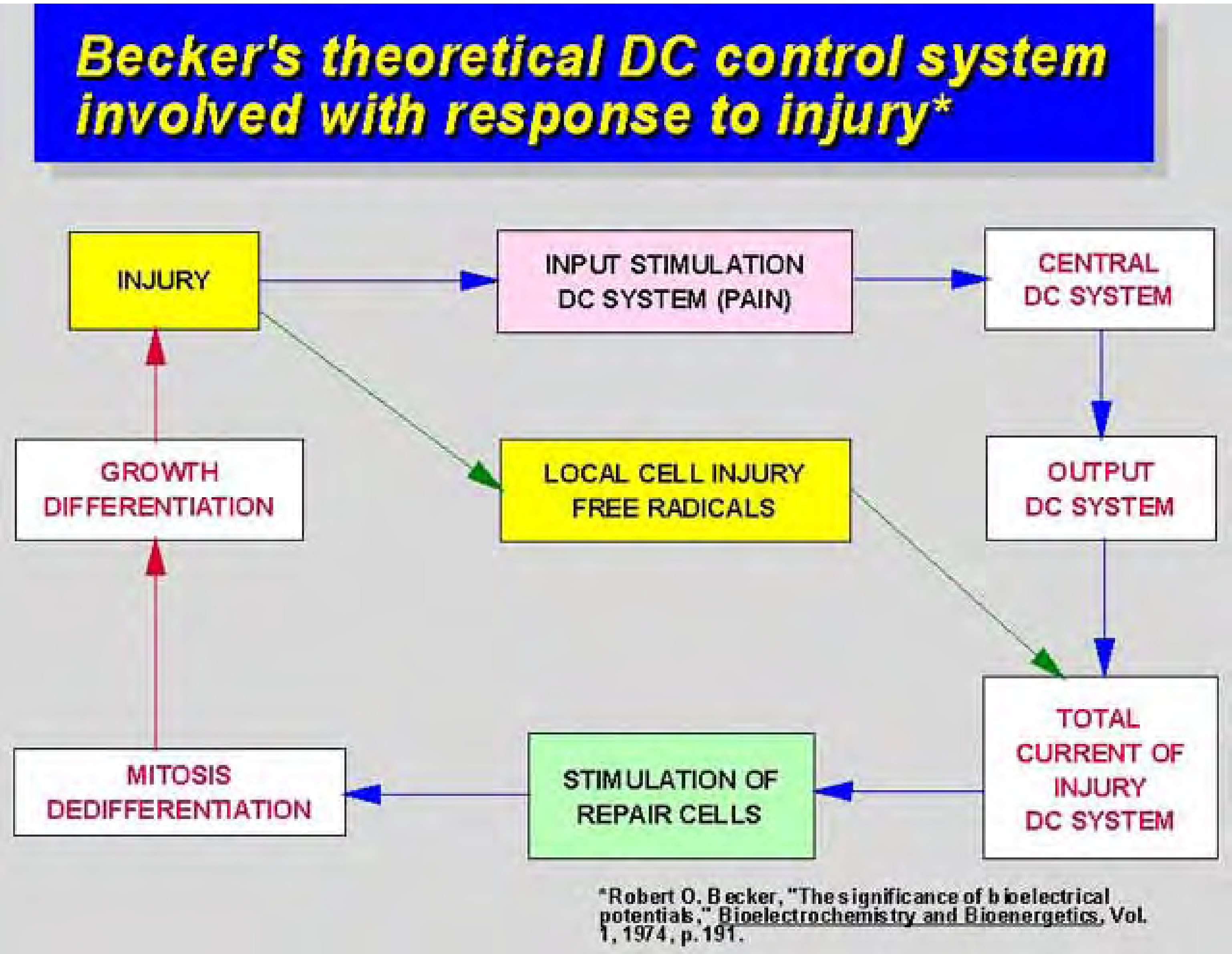

Becker's theoretical DC control system involved with response to injury*

INJURY

INPUT STIMULATION DC SYSTEM (PAIN)

CENTRAL DC SYSTEM

GROWTH DIFFERENTIATION

LOCAL CELL INJURY FREE RADICALS

OUTPUT DC SYSTEM

TOTAL CURRENT OF INJURY DC SYSTEM

MITOSIS DEDIFFERENTIATION

STIMULATION OF REPAIR CELLS

*Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p.191.

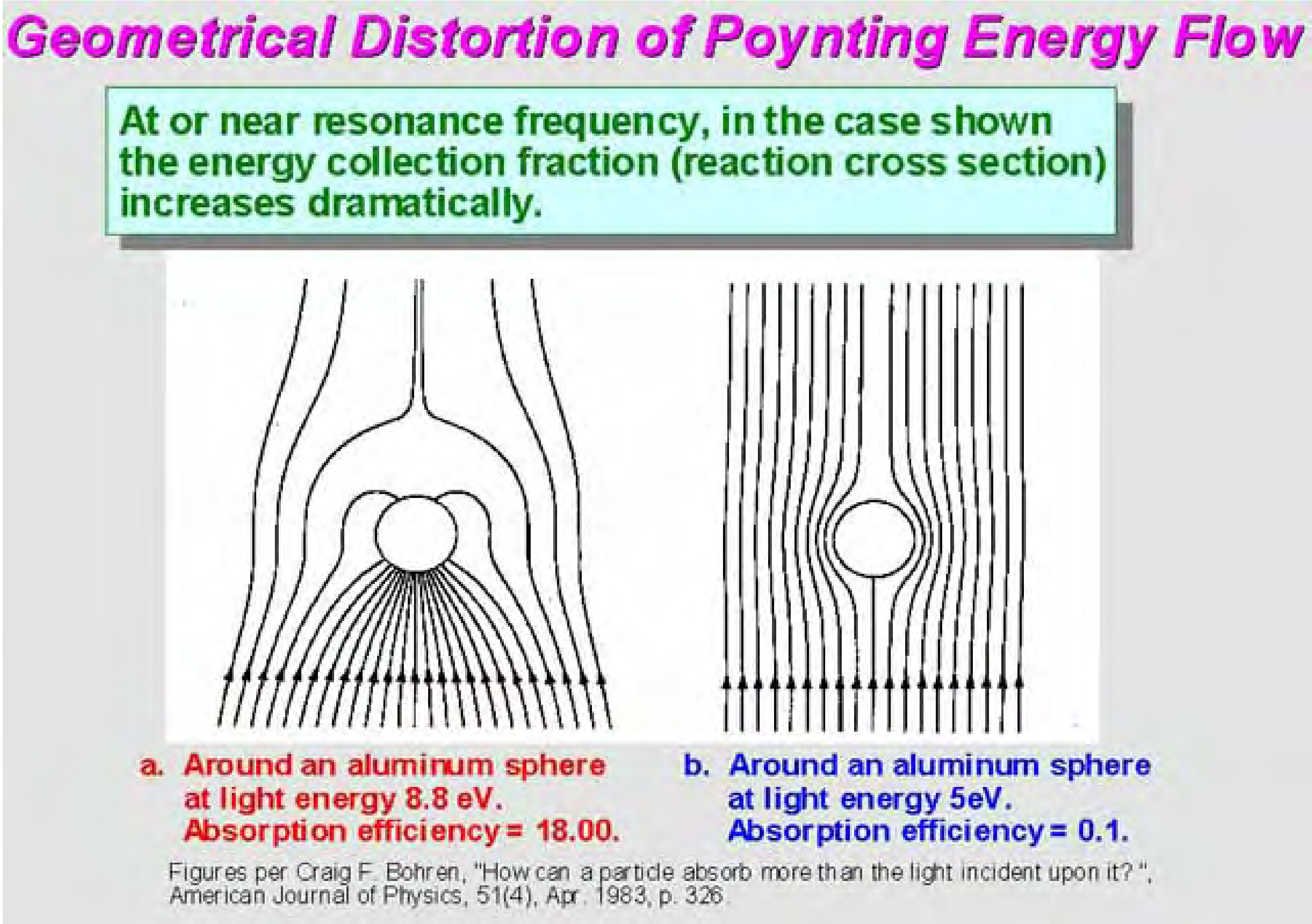

Geometrical Distortion of Poynting Energy Flow

At or near resonance frequency, in the case shown the energy collection fraction (reaction cross section) increases dramatically.

a. Around an aluminum sphere at light energy 8.8 eV. Absorption efficiency = 18.00.

b. Around an aluminum sphere at light energy 5eV. Absorption efficiency = 0.1.

Figures per Craig F. Bohren, "How can a particle absorb more than the light incident upon it?", American Journal of Physics, 51(4), Apr. 1983, p. 326.

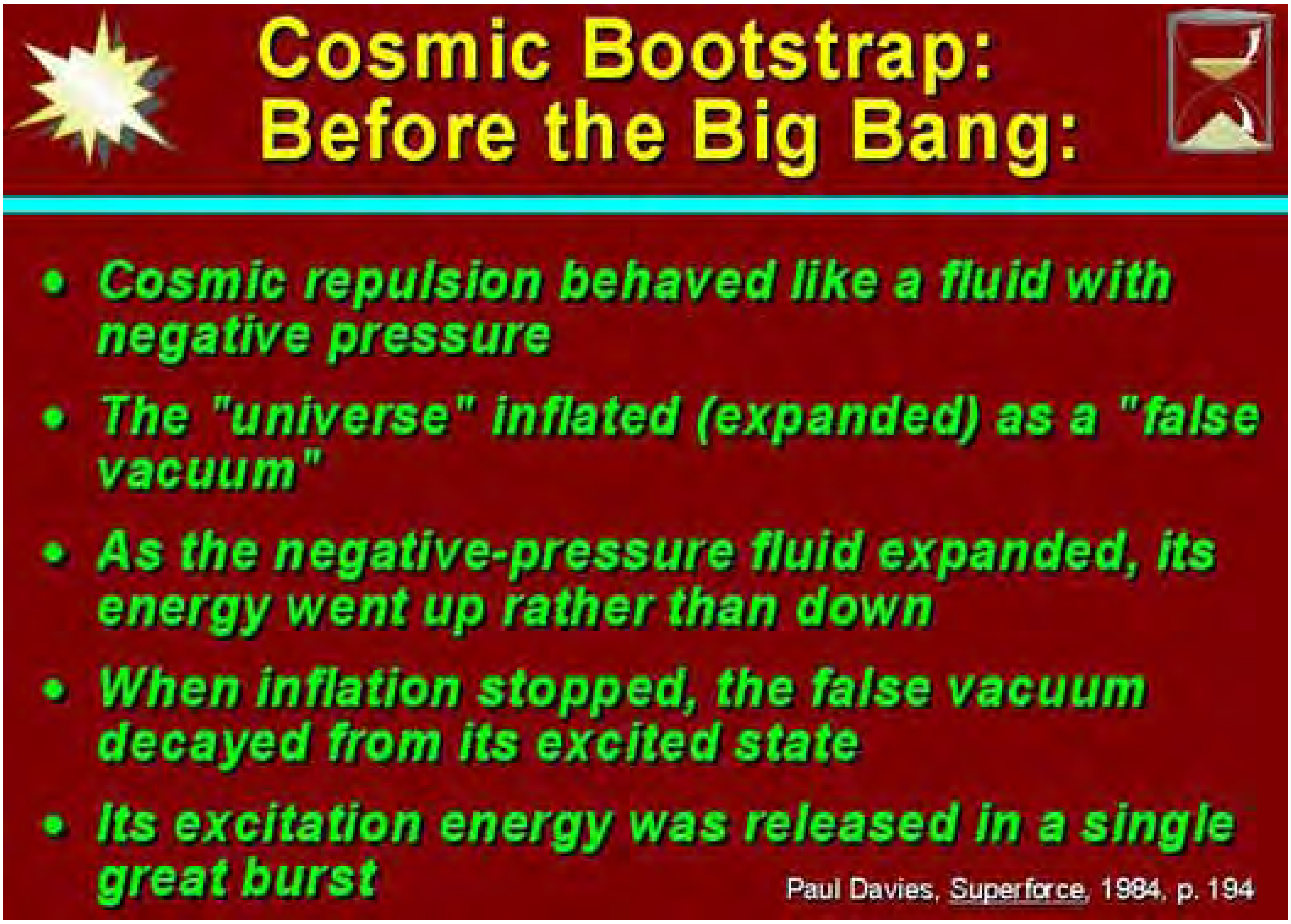

Cosmic Bootstrap: Before the Big Bang:

- *Cosmic repulsion behaved like a fluid with negative pressure*
- *The "universe" inflated (expanded) as a "false vacuum"*
- *As the negative-pressure fluid expanded, its energy went up rather than down*
- *When inflation stopped, the false vacuum decayed from its excited state*
- *Its excitation energy was released in a single great burst*

Paul Davies, Superforce, 1984, p. 194

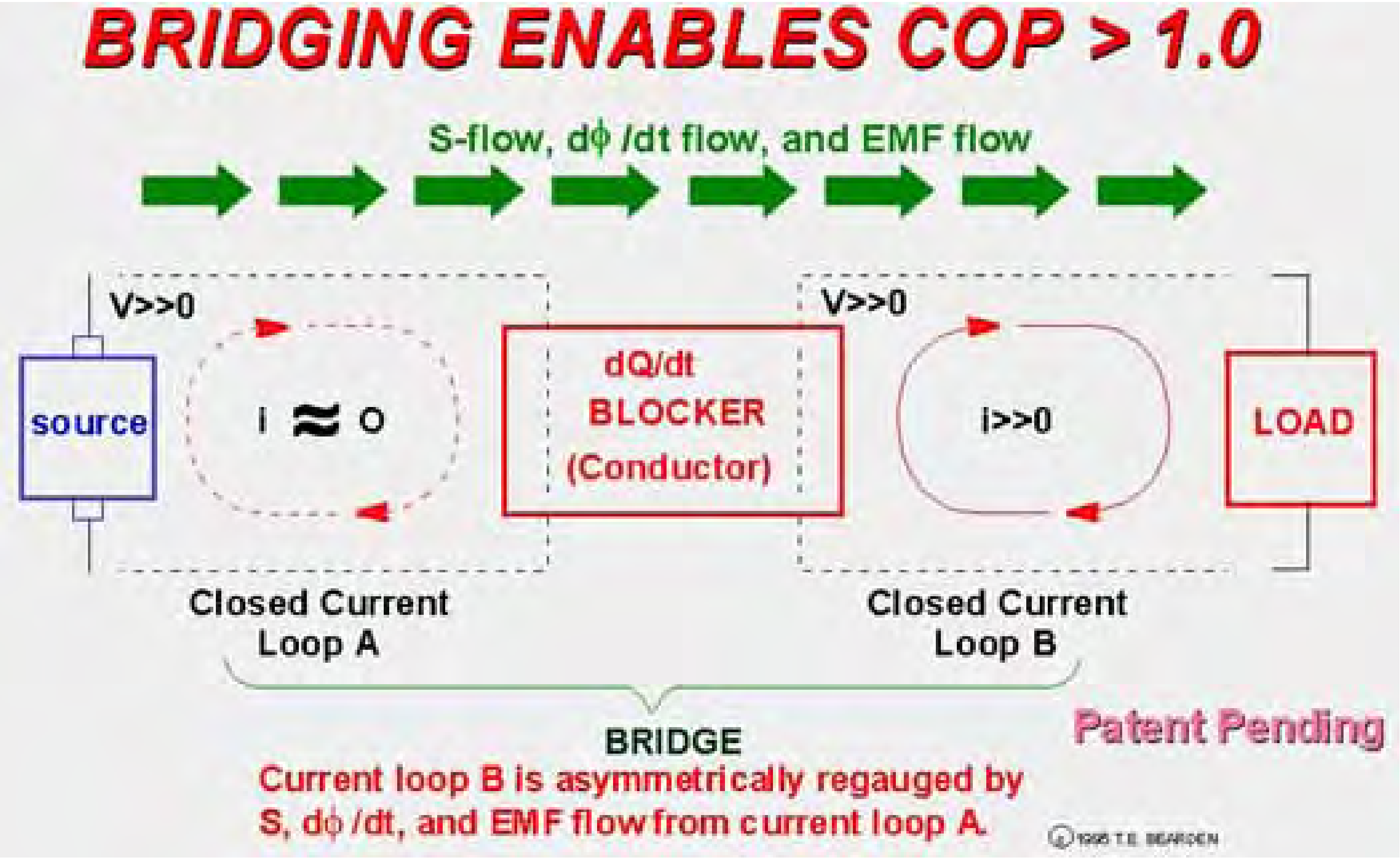

BRIDGING ENABLES COP > 1.0

S-flow, dφ /dt flow, and EMF flow
V>>0
source
i ≈ 0
dQ/dt
BLOCKER
(Conductor)
V>>0
i>>0
LOAD
Closed Current
Loop A
Closed Current
Loop B
Patent Pending

BRIDGE

Current loop B is asymmetrically regauged by
S, dφ /dt, and EMF flow from current loop A.

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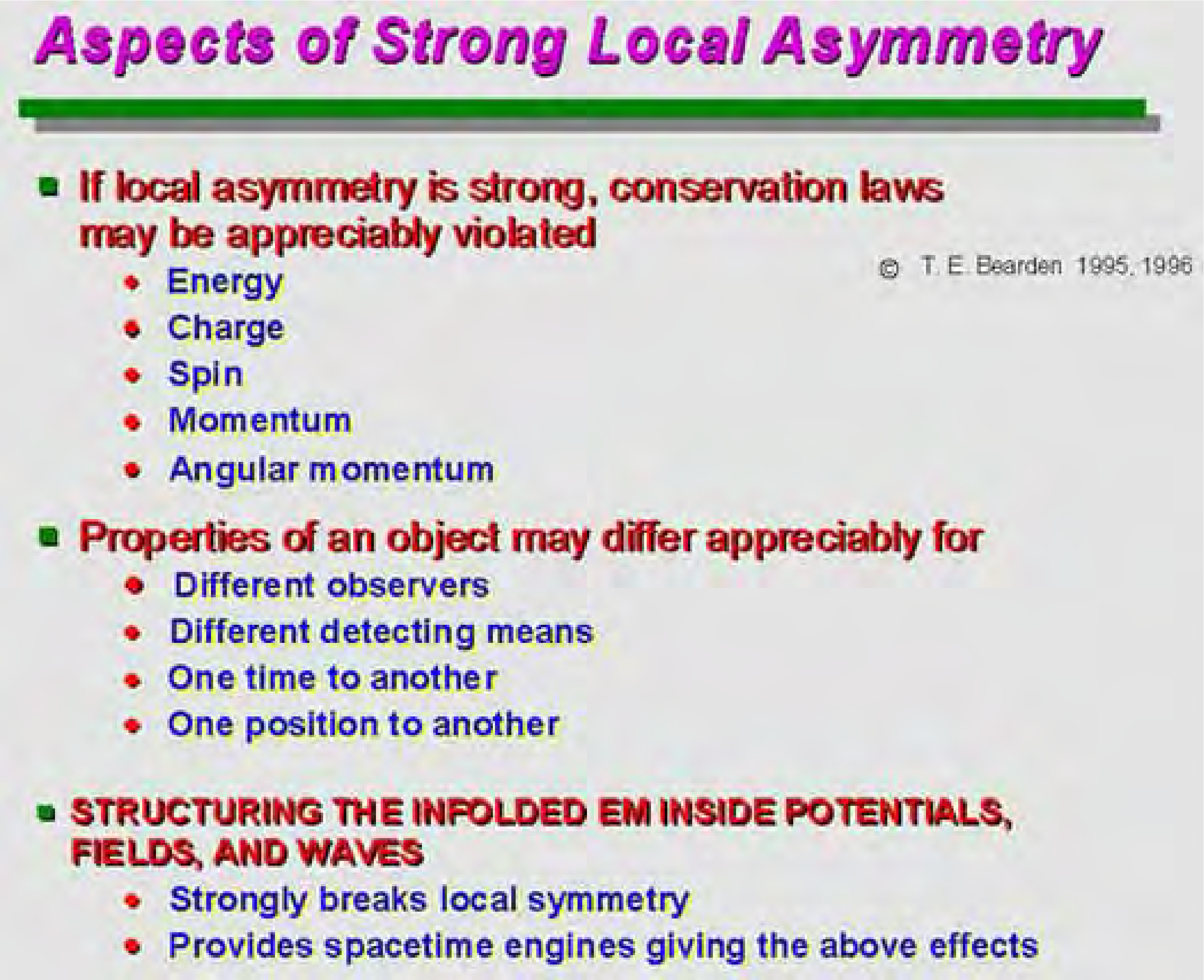

Aspects of Strong Local Asymmetry

- If local asymmetry is strong, conservation laws may be appreciably violated
  - Energy
  - Charge
  - Spin
  - Momentum
  - Angular momentum

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- Properties of an object may differ appreciably for
  - Different observers
  - Different detecting means
  - One time to another
  - One position to another
- STRUCTURING THE INFOLDED EM INSIDE POTENTIALS, FIELDS, AND WAVES
  - Strongly breaks local symmetry
  - Provides spacetime engines giving the above effects

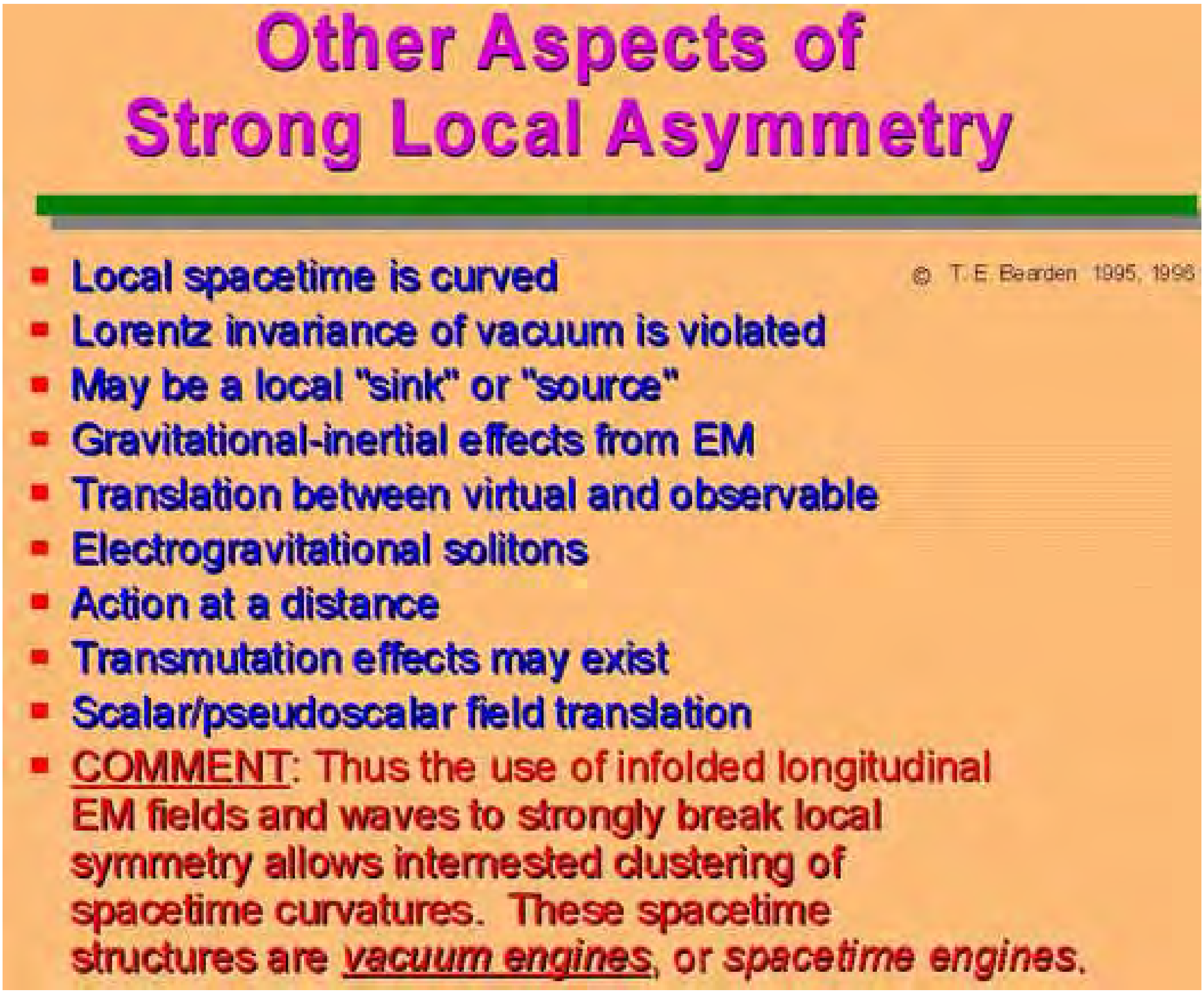

Other Aspects of Strong Local Asymmetry

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- Local spacetime is curved
- Lorentz invariance of vacuum is violated
- May be a local "sink" or "source"
- Gravitational-inertial effects from EM
- Translation between virtual and observable
- Electrogravitational solitons
- Action at a distance
- Transmutation effects may exist
- Scalar/pseudoscalar field translation
- COMMENT: Thus the use of infolded longitudinal EM fields and waves to strongly break local symmetry allows internested clustering of spacetime curvatures. These spacetime structures are *vacuum engines*, or *spacetime engines*.

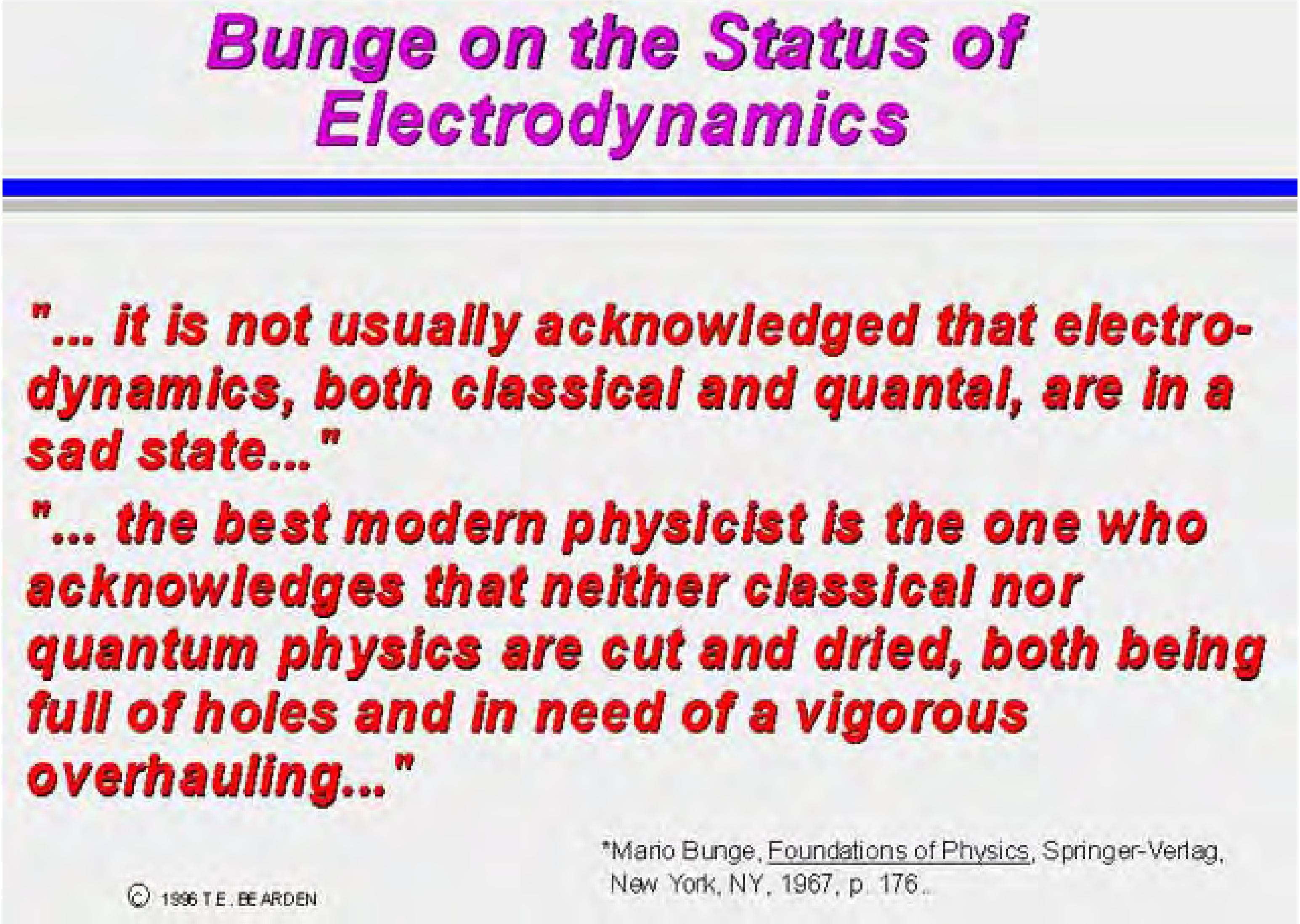

Bunge on the Status of Electrodynamics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state..."

"... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling..."

*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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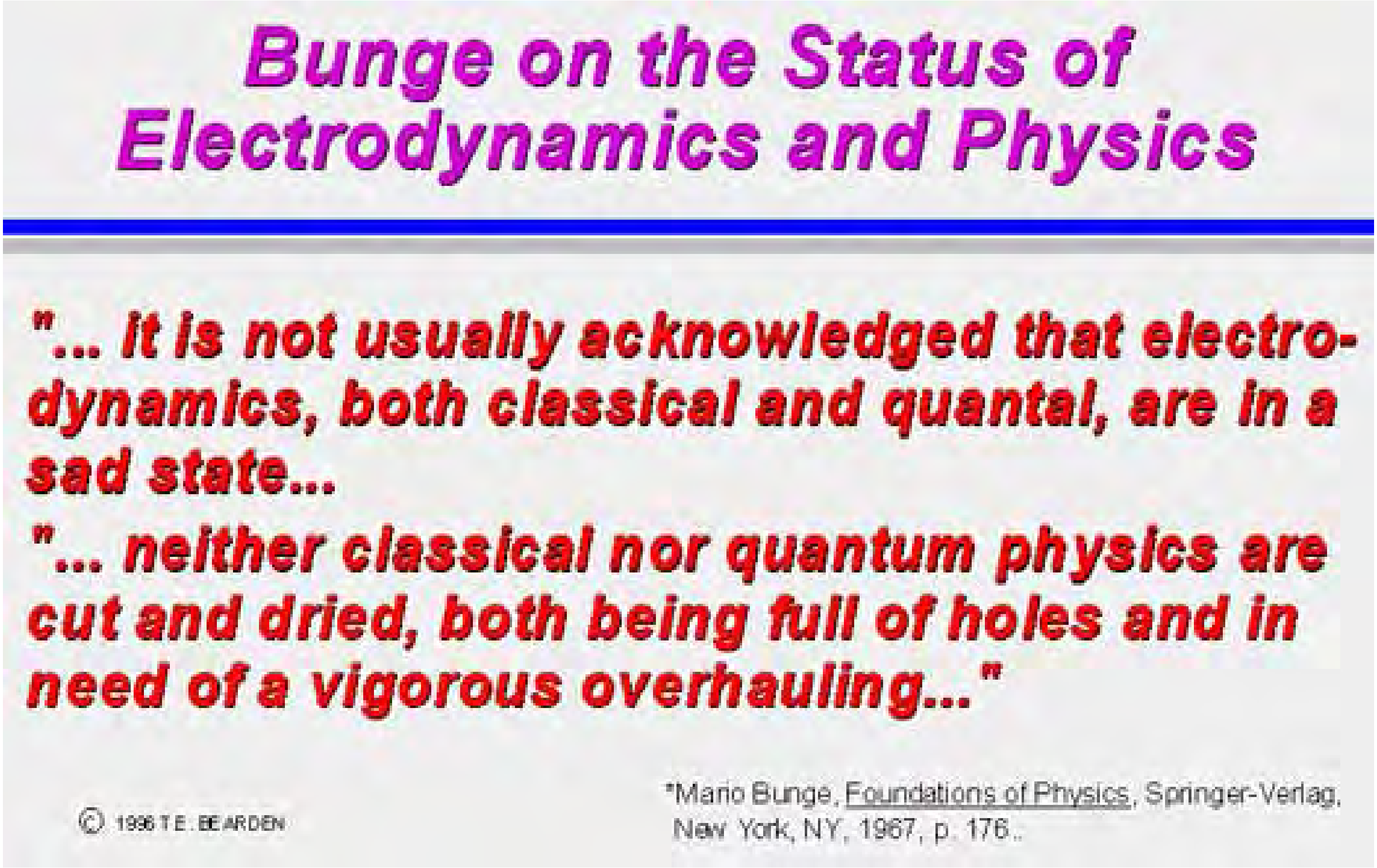

Bunge on the Status of Electrodynamics and Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state...

"... neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling..."

*Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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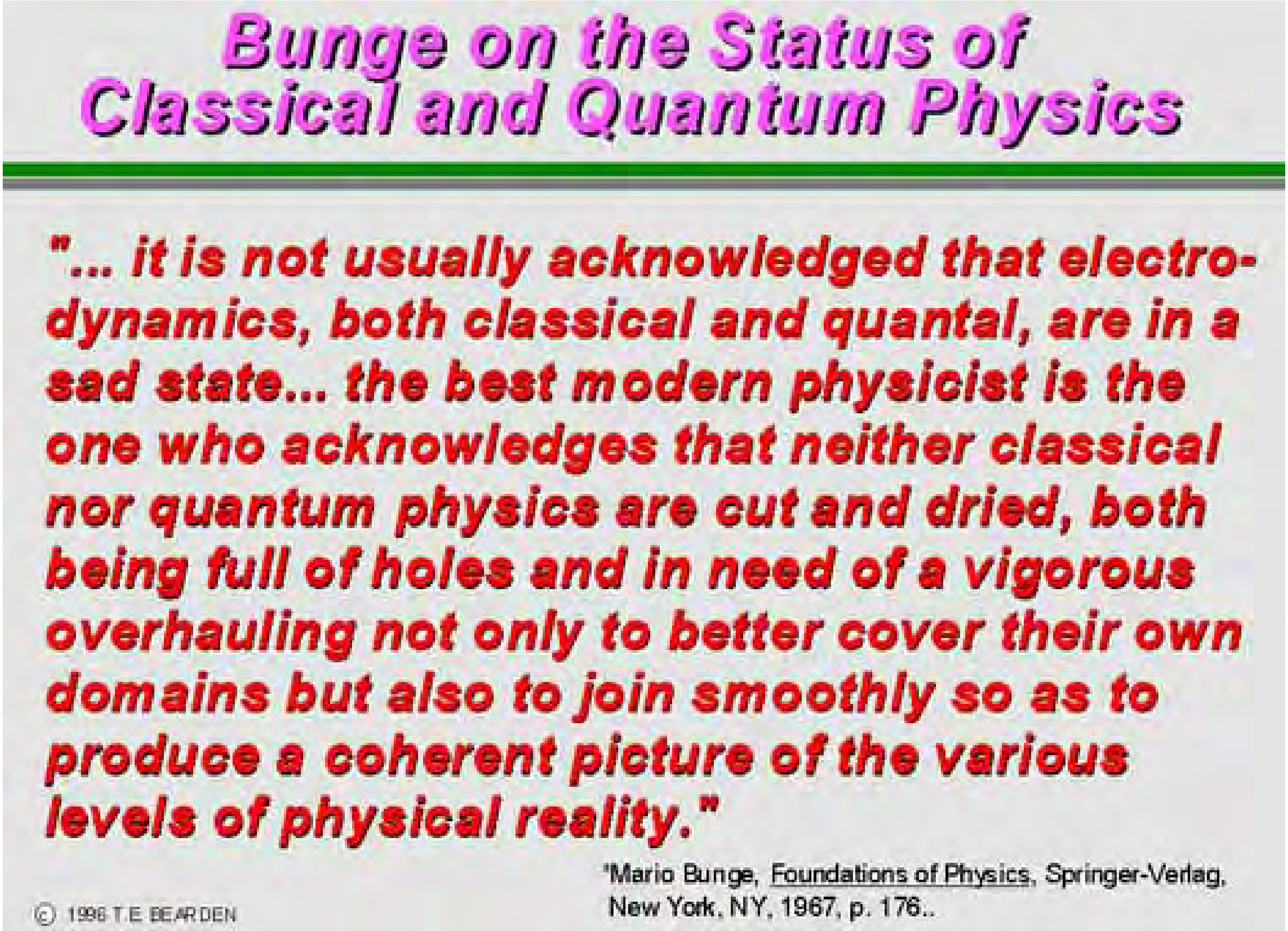

Bunge on the Status of Classical and Quantum Physics

"... it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling not only to better cover their own domains but also to join smoothly so as to produce a coherent picture of the various levels of physical reality."

'Mario Bunge, Foundations of Physics, Springer-Verlag, New York, NY, 1967, p. 176..

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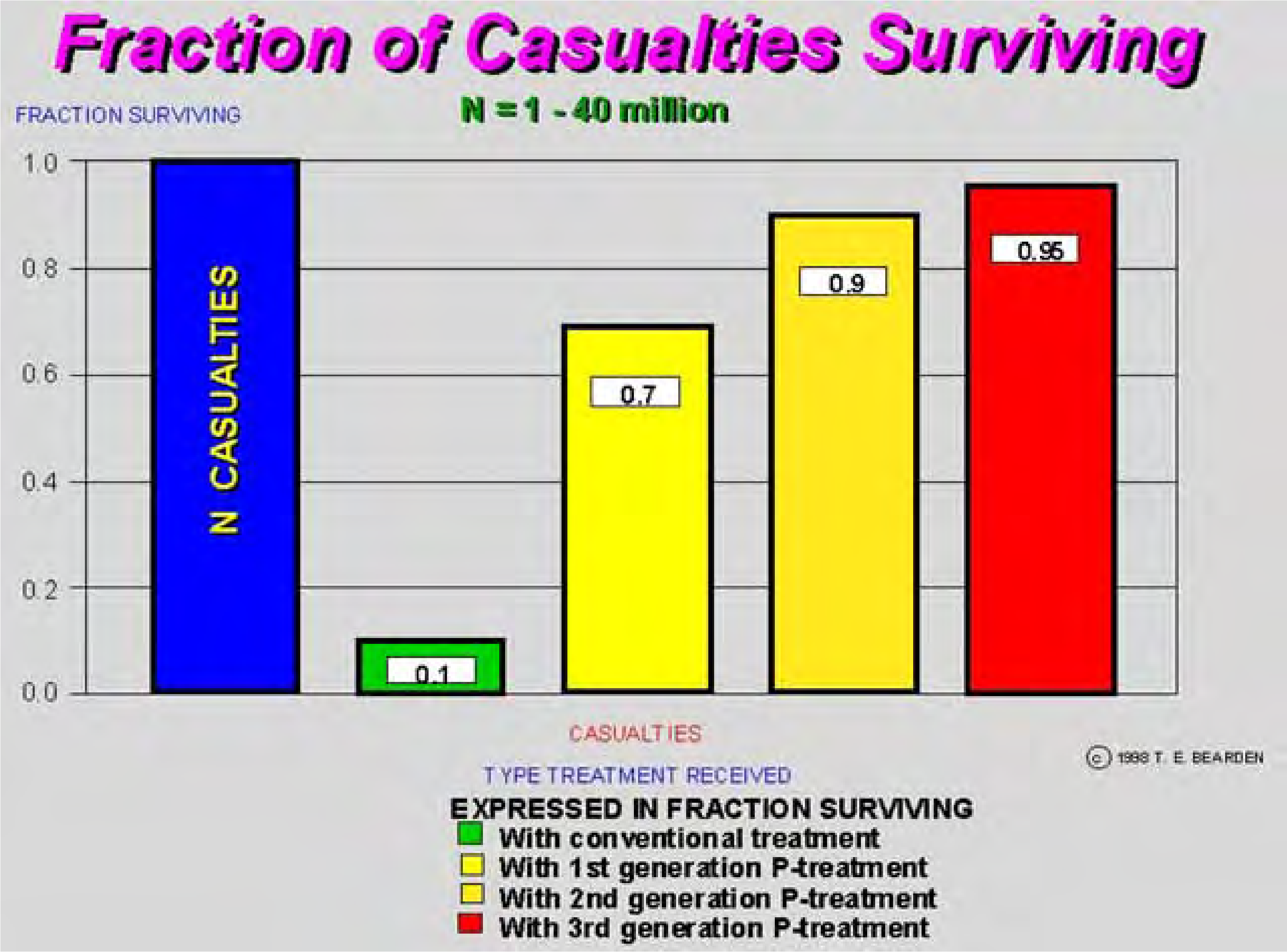
Fraction of Casualties Surviving
FRACTION SURVIVING
N = 1 - 40 million
1.0
0.8
0.6
0.4
0.2
0.0
N CASUALTIES
0.1
0.7
0.9
0.95
CASUALTIES
TYPE TREATMENT RECEIVED
© 1998 T. E. BEARDEN
EXPRESSED IN FRACTION SURVIVING
🟩 With conventional treatment
🟨 With 1st generation P-treatment
🟨 With 2nd generation P-treatment
🟥 With 3rd generation P-treatment

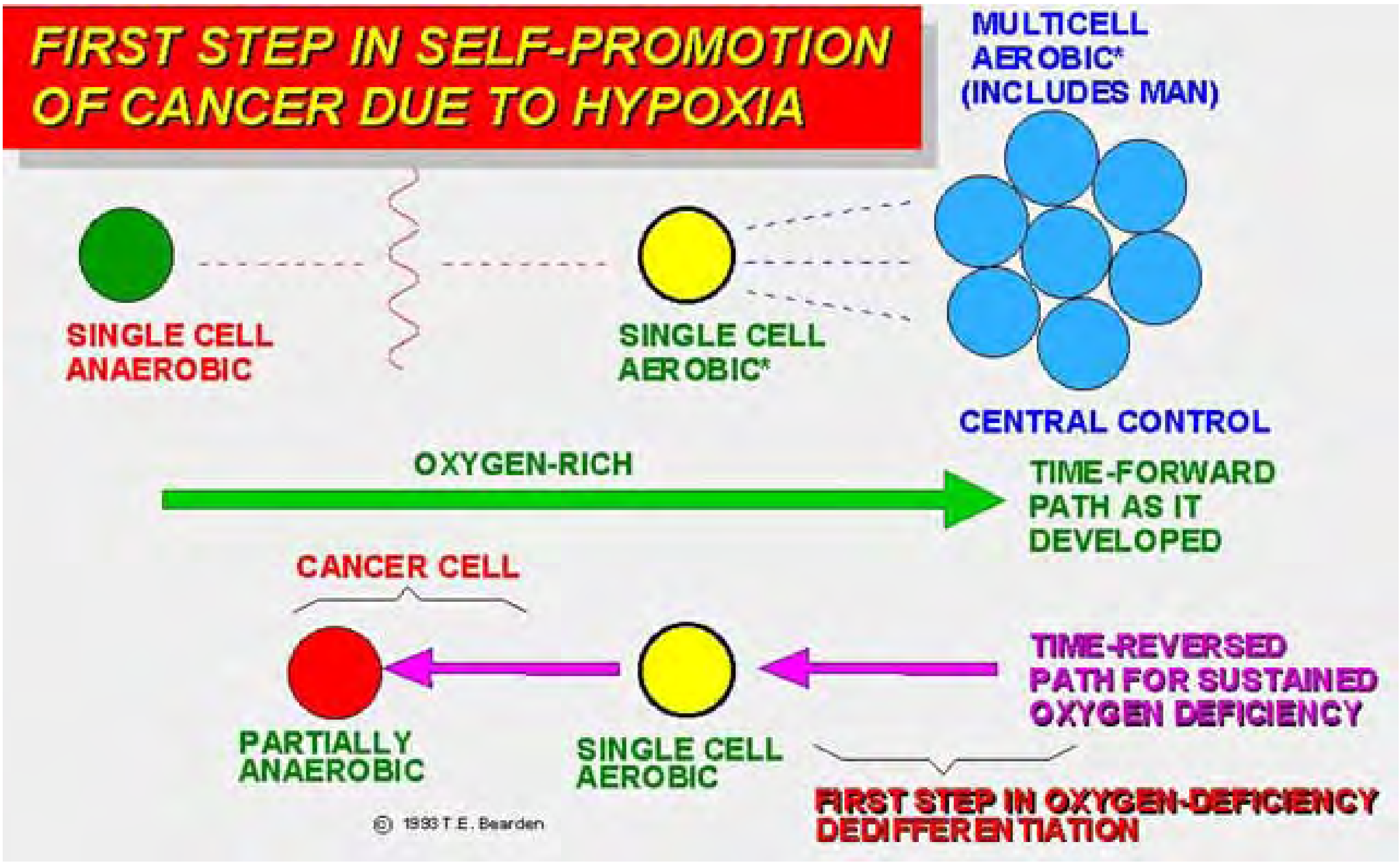

FIRST STEP IN SELF-PROMOTION OF CANCER DUE TO HYPOXIA

MULTICELL
AEROBIC*
(INCLUDES MAN)

SINGLE CELL
ANAEROBIC

SINGLE CELL
AEROBIC*

CENTRAL CONTROL

OXYGEN-RICH

TIME-FORWARD
PATH AS IT
DEVELOPED

CANCER CELL

PARTIALLY
ANAEROBIC

SINGLE CELL
AEROBIC

TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY

FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION

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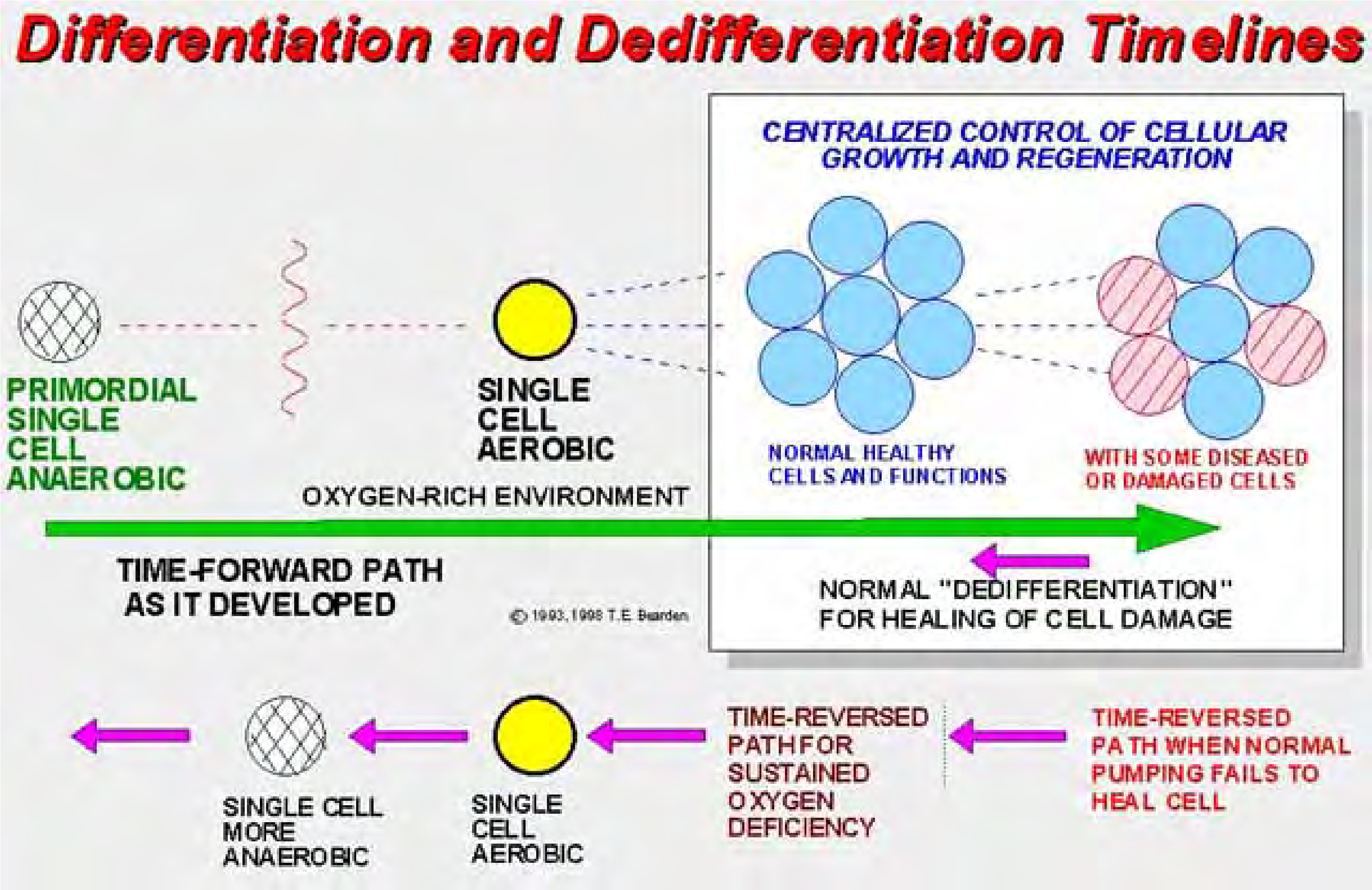

Differentiation and Dedifferentiation Timelines

CENTRALIZED CONTROL OF CELLULAR GROWTH AND REGENERATION

PRIMORDIAL SINGLE CELL ANAEROBIC

SINGLE CELL AEROBIC

OXYGEN-RICH ENVIRONMENT

NORMAL HEALTHY CELLS AND FUNCTIONS

WITH SOME DISEASED OR DAMAGED CELLS

TIME-FORWARD PATH AS IT DEVELOPED

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NORMAL "DEDIFFERENTIATION" FOR HEALING OF CELL DAMAGE

SINGLE CELL MORE ANAEROBIC

SINGLE CELL AEROBIC

TIME-REVERSED PATH FOR SUSTAINED OXYGEN DEFICIENCY

TIME-REVERSED PATH WHEN NORMAL PUMPING FAILS TO HEAL CELL

Evolution of Cells on Earth

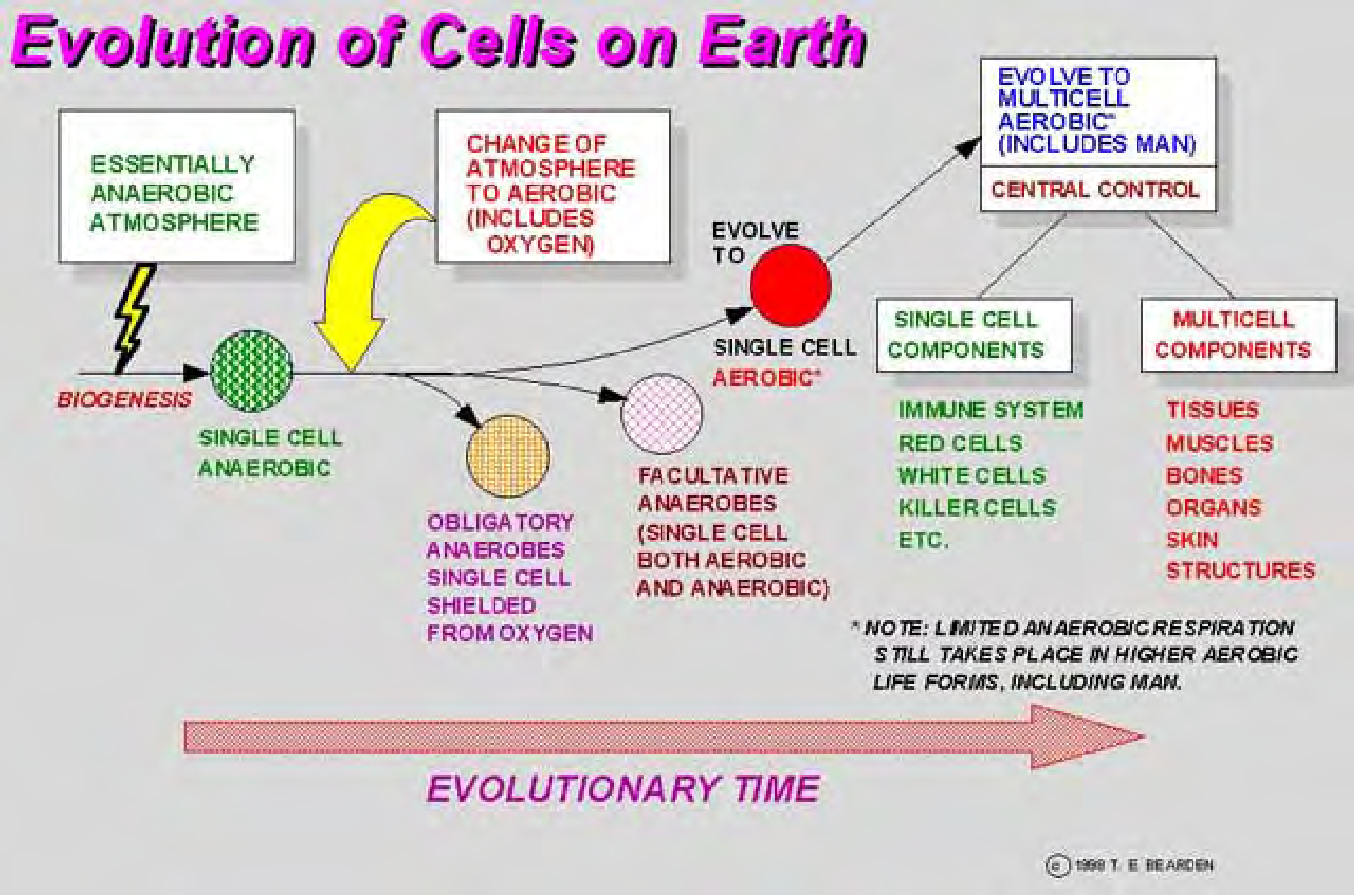

ESSENTIALLY
ANAEROBIC
ATMOSPHERE

CHANGE OF
ATMOSPHERE
TO AEROBIC
(INCLUDES
OXYGEN)

BIOGENESIS

SINGLE CELL
ANAEROBIC

OBLIGATORY
ANAEROBES
SINGLE CELL
SHIELDED
FROM OXYGEN

FACULTATIVE
ANAEROBES
(SINGLE CELL
BOTH AEROBIC
AND ANAEROBIC)

EVOLVE
TO

SINGLE CELL
AEROBIC*

EVOLVE TO
MULTICELL
AEROBIC*
(INCLUDES MAN)

CENTRAL CONTROL

SINGLE CELL
COMPONENTS

- IMMUNE SYSTEM
- RED CELLS
- WHITE CELLS
- KILLER CELLS
- ETC.

MULTICELL
COMPONENTS

- TISSUES
- MUSCLES
- BONES
- ORGANS
- SKIN
- STRUCTURES

** NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.*

EVOLUTIONARY TIME

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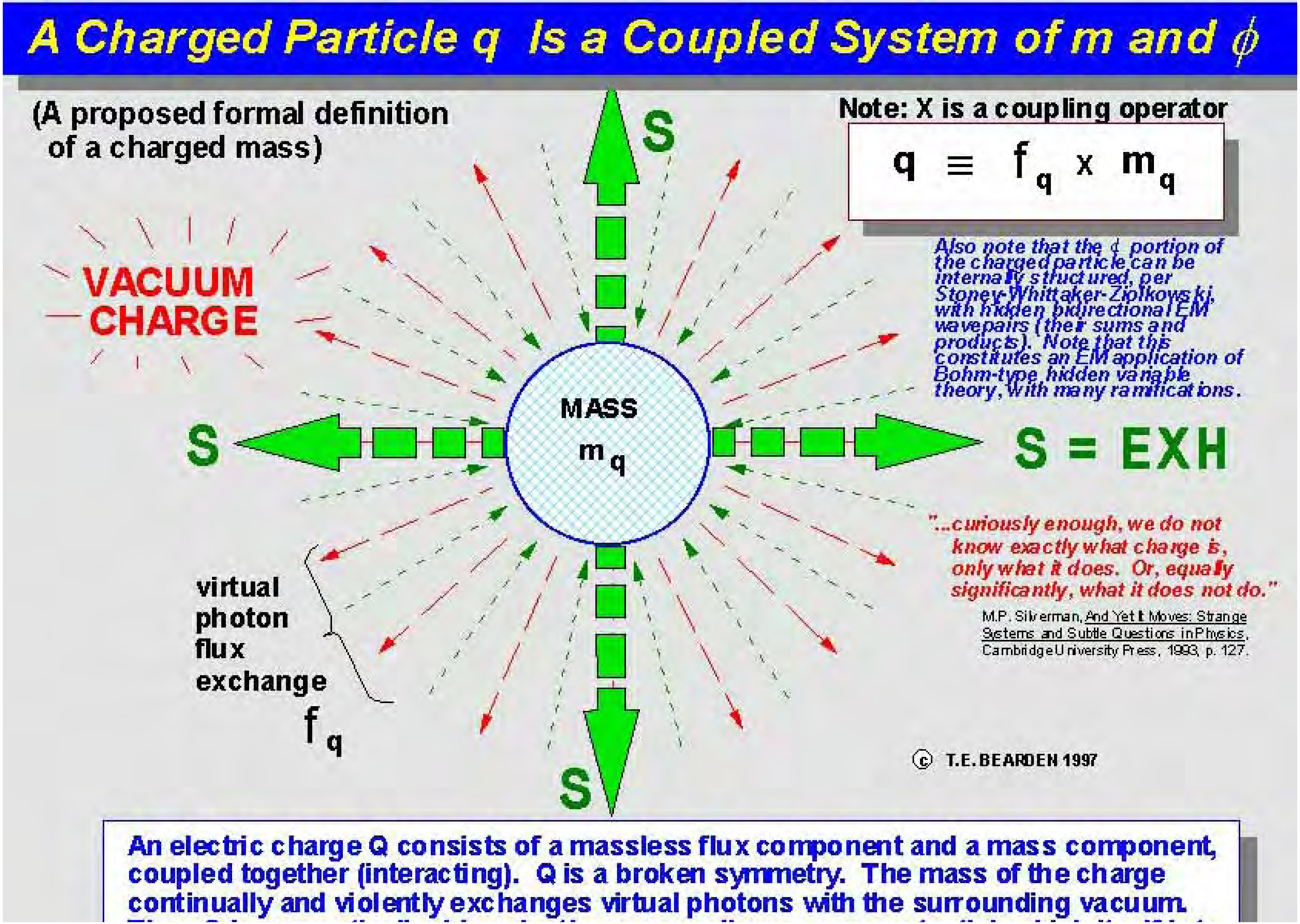

A Charged Particle q Is a Coupled System of m and ϕ

(A proposed formal definition of a charged mass)

Note: X is a coupling operator

$$q \equiv f_q \times m_q$$

Also note that the ϕ portion of the charged particle can be internally structured, per Stoney-Whittaker-Ziolkowski, with hidden bidirectional EM wavepairs (their sums and products). Note that this constitutes an EM application of Bohm-type hidden variable theory, with many ramifications.

"...curiously enough, we do not know exactly what charge is, only what it does. Or, equally significantly, what it does not do."

M.P. Silverman, And Yet It Moves: Strange Systems and Subtle Questions in Physics, Cambridge University Press, 1993, p. 127.

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An electric charge Q consists of a massless flux component and a mass component, coupled together (interacting). Q is a broken symmetry. The mass of the charge continually and violently exchanges virtual photons with the surrounding vacuum.

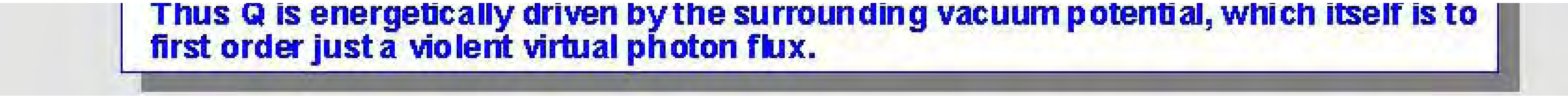

Thus Q is energetically driven by the surrounding vacuum potential, which itself is to first order just a violent virtual photon flux.

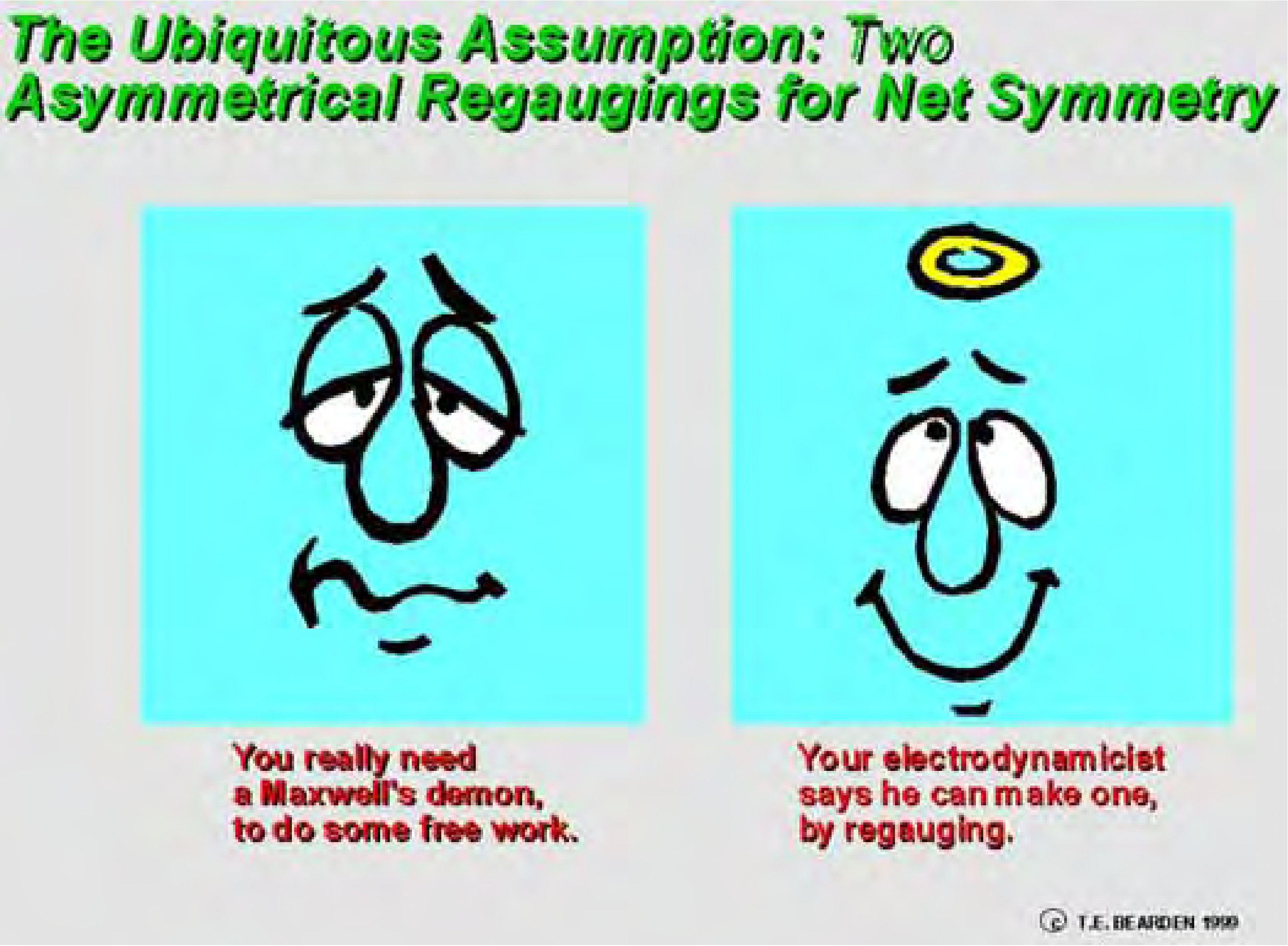

The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry

You really need
a Maxwell's demon,
to do some free work.

Your electrodynamicist
says he can make one,
by regauging.

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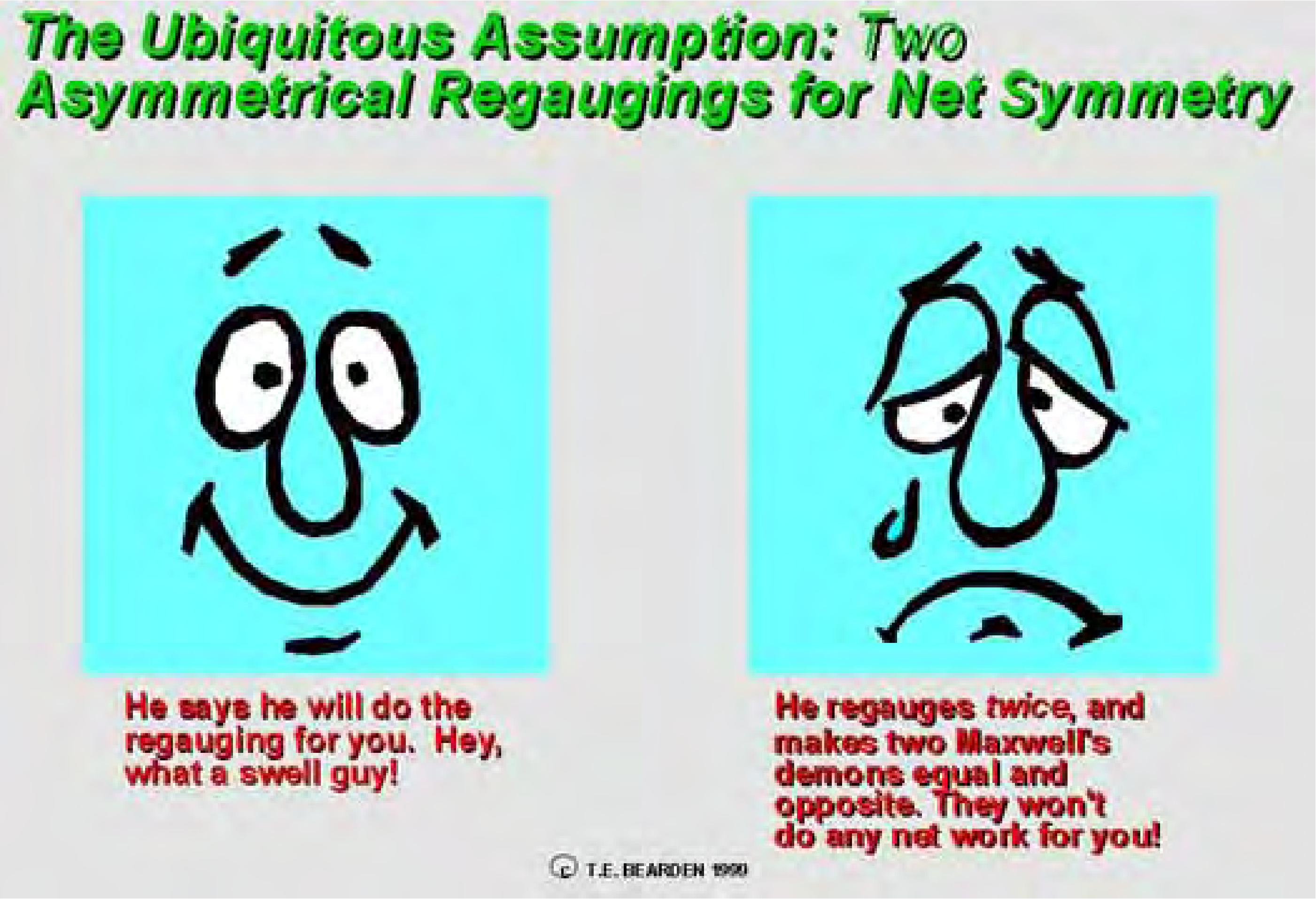

The Ubiquitous Assumption: *Two* Asymmetrical Regaugings for Net Symmetry

He says he will do the regauging for you. Hey, what a swell guy!

He regauges *twice*, and makes two Maxwell's demons equal and opposite. They won't do any net work for you!

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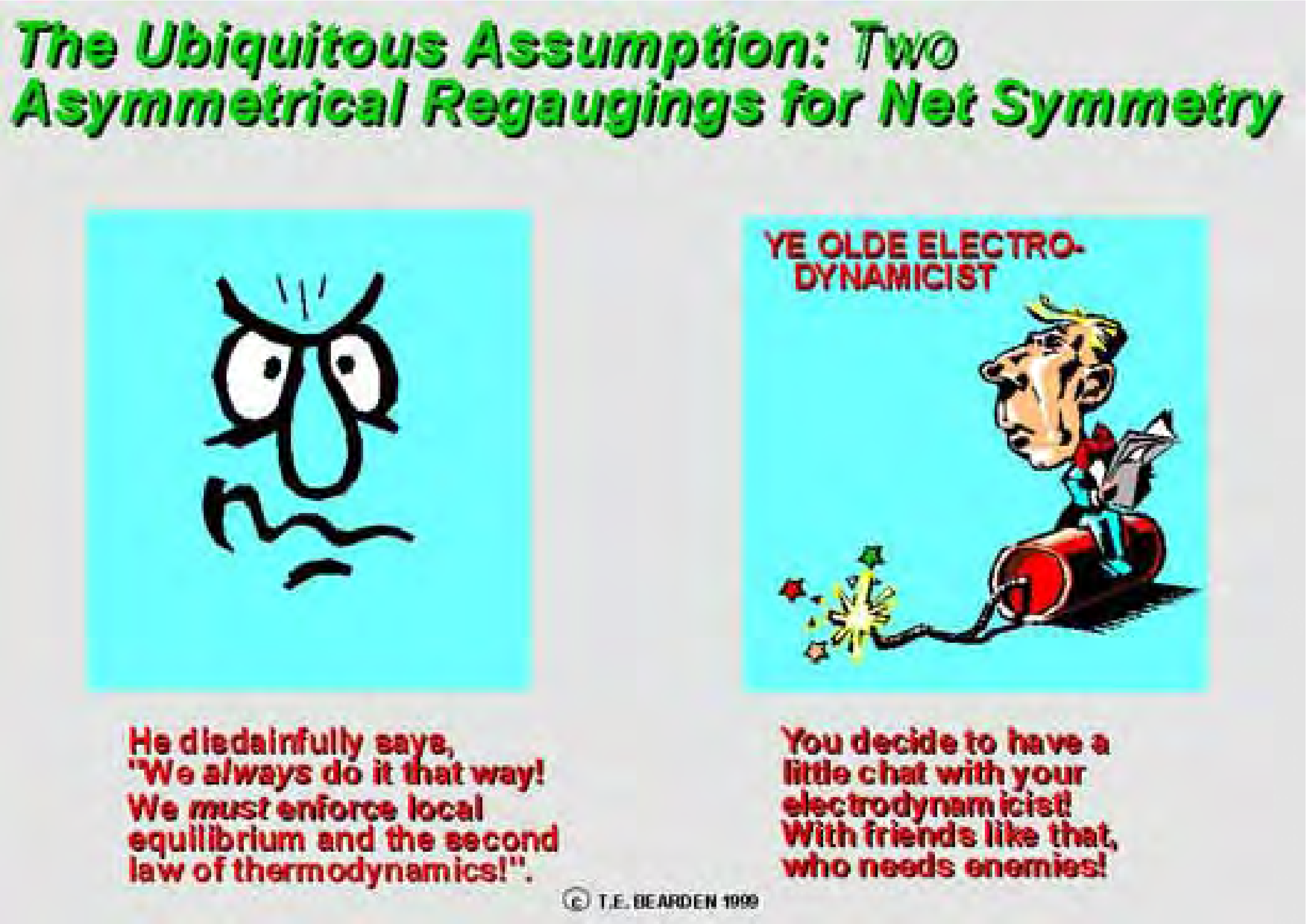

The Ubiquitous Assumption: Two Asymmetrical Regaugings for Net Symmetry

He disdainfully says,
"We *always* do it that way!
We *must* enforce local
equilibrium and the second
law of thermodynamics!".

You decide to have a
little chat with your
electrodynamicist!
With friends like that,
who needs enemies!

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A Charged Particle Is a Coupled System

(The first formal definition of charge)

$$\boxed{q \equiv \phi_q \times m_q}$$

Note: X is a coupling operator

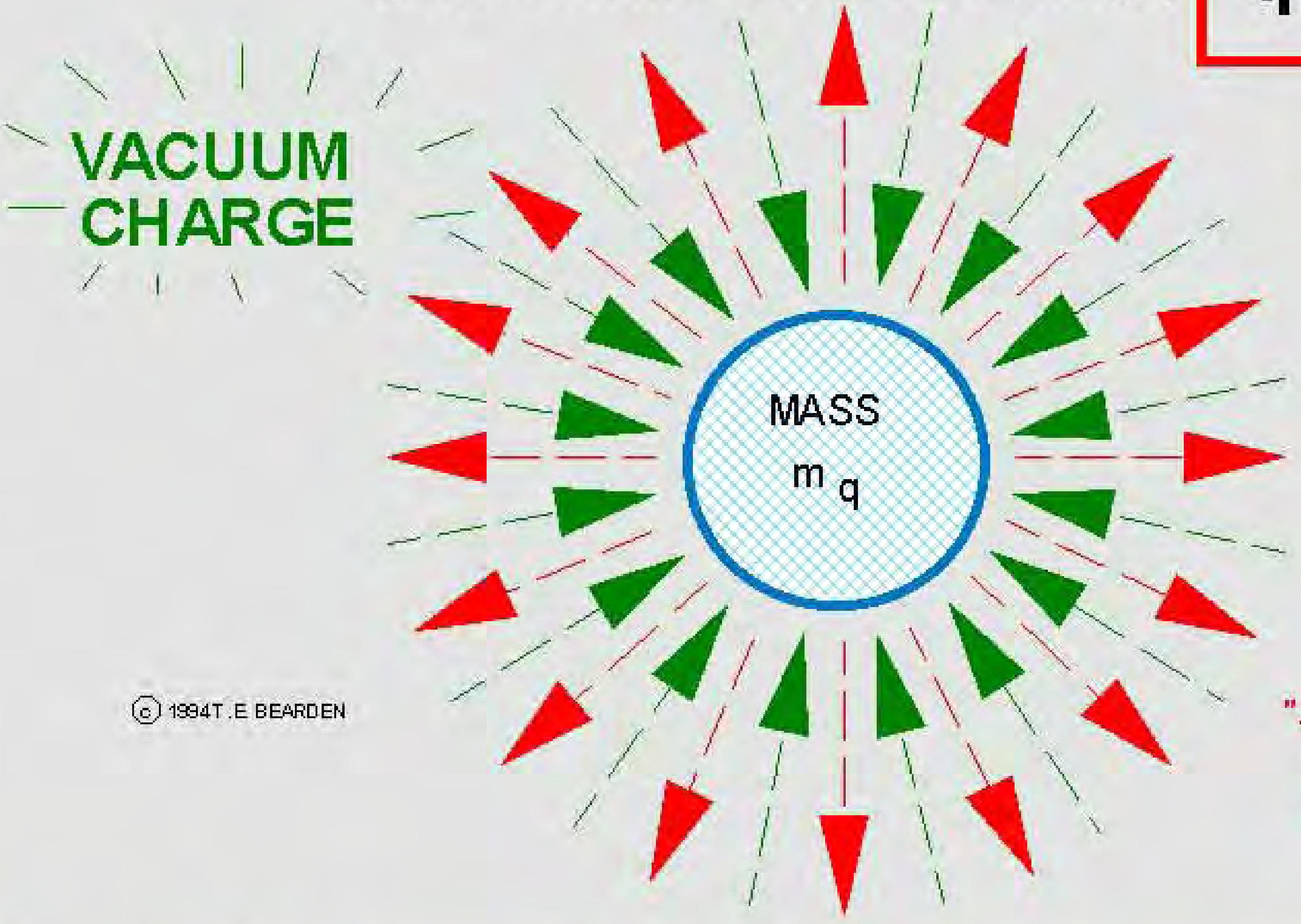

virtual photon flux exchange

ϕ_q

"...curiously enough, we do not know exactly what charge is, only what it does. Or, equally significantly, what it does not do."

M.P. Silverman, And Yet It Moves: Strange Systems and Subtle Questions in Physics, Cambridge University Press, 1993, p. 127.

An electric charge q is a broken symmetry in its fierce energy exchange with the active vacuum. It coherently integrates some of the virtual energy absorbs and outputs it as Poynting energy flow.

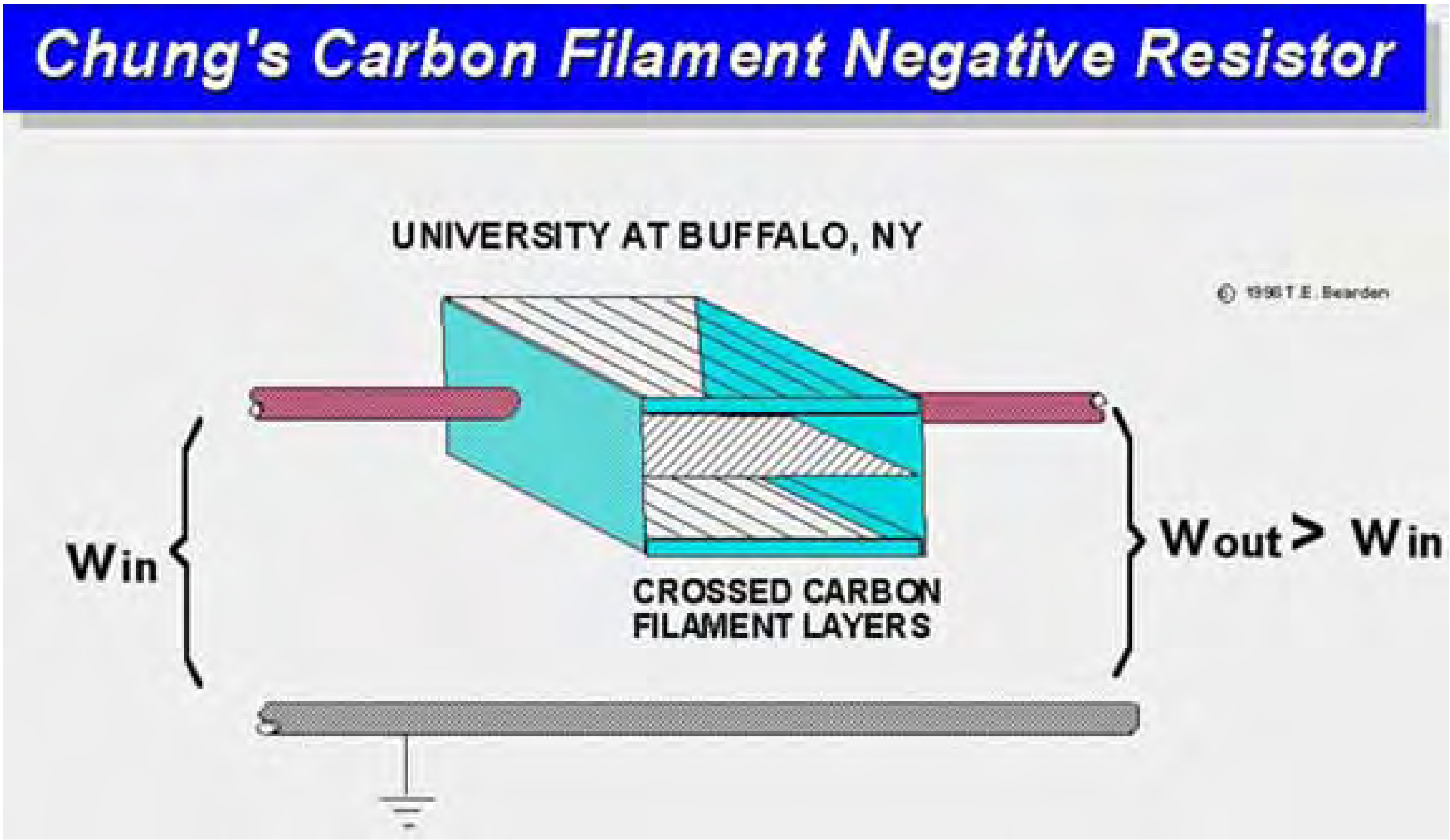

Chung's Carbon Filament Negative Resistor

UNIVERSITY AT BUFFALO, NY
Win
Wout > Win
CROSSED CARBON FILAMENT LAYERS

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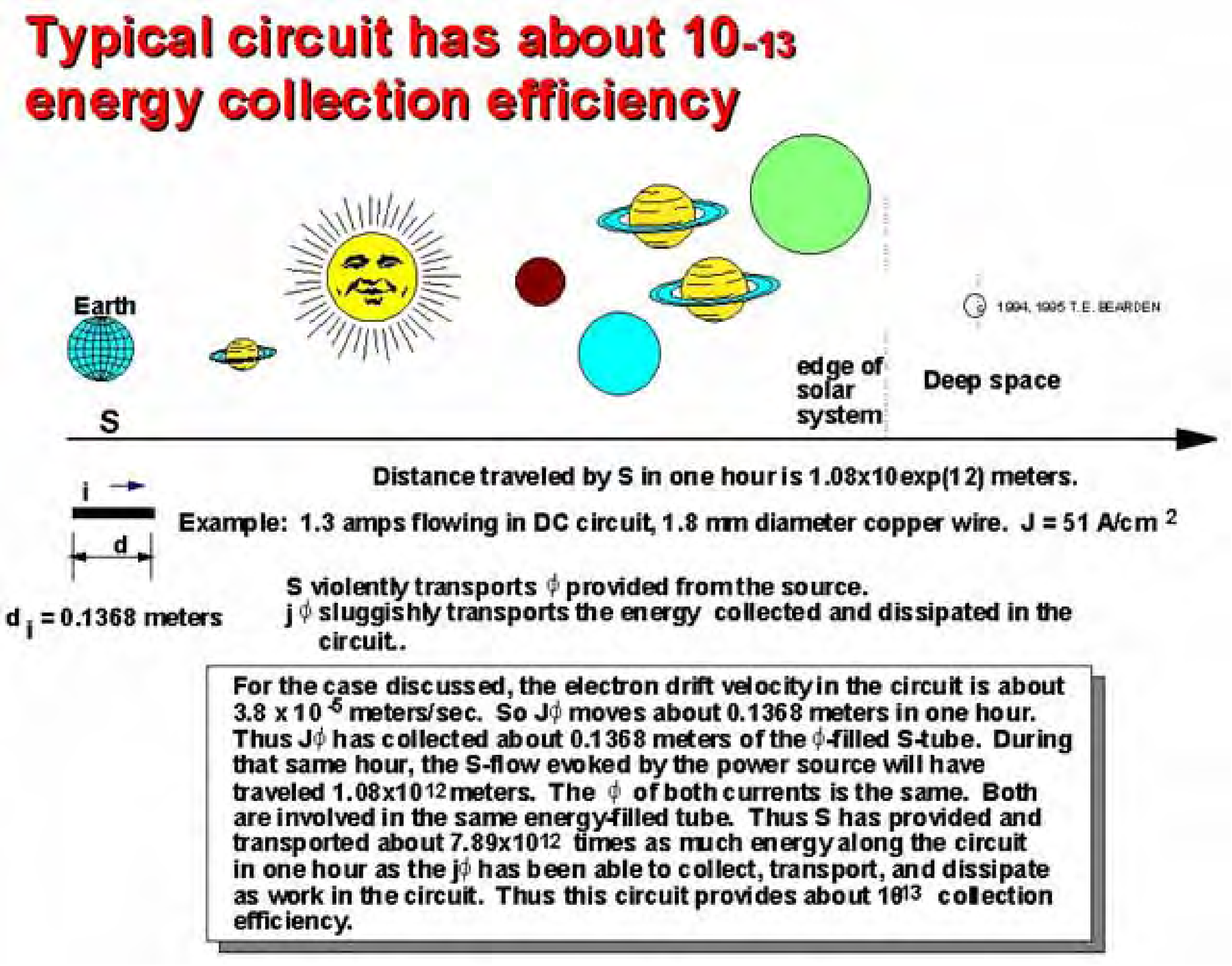

Typical circuit has about 10$_{-13}$ energy collection efficiency

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Distance traveled by S in one hour is 1.08x10exp(12) meters.

Example: 1.3 amps flowing in DC circuit, 1.8 mm diameter copper wire. J = 51 A/cm ^{2}

d_i = 0.1368 meters

S violently transports ϕ provided from the source.
j ϕ sluggishly transports the energy collected and dissipated in the circuit..

For the case discussed, the electron drift velocity in the circuit is about 3.8 x 10 $^{-5}$ meters/sec. So Jϕ moves about 0.1368 meters in one hour. Thus Jϕ has collected about 0.1368 meters of the ϕ-filled S-tube. During that same hour, the S-flow evoked by the power source will have traveled 1.08x10^{12} meters. The ϕ of both currents is the same. Both are involved in the same energy-filled tube. Thus S has provided and transported about 7.89x10^{12} times as much energy along the circuit in one hour as the jϕ has been able to collect, transport, and dissipate as work in the circuit. Thus this circuit provides about 10^{13} collection efficiency.

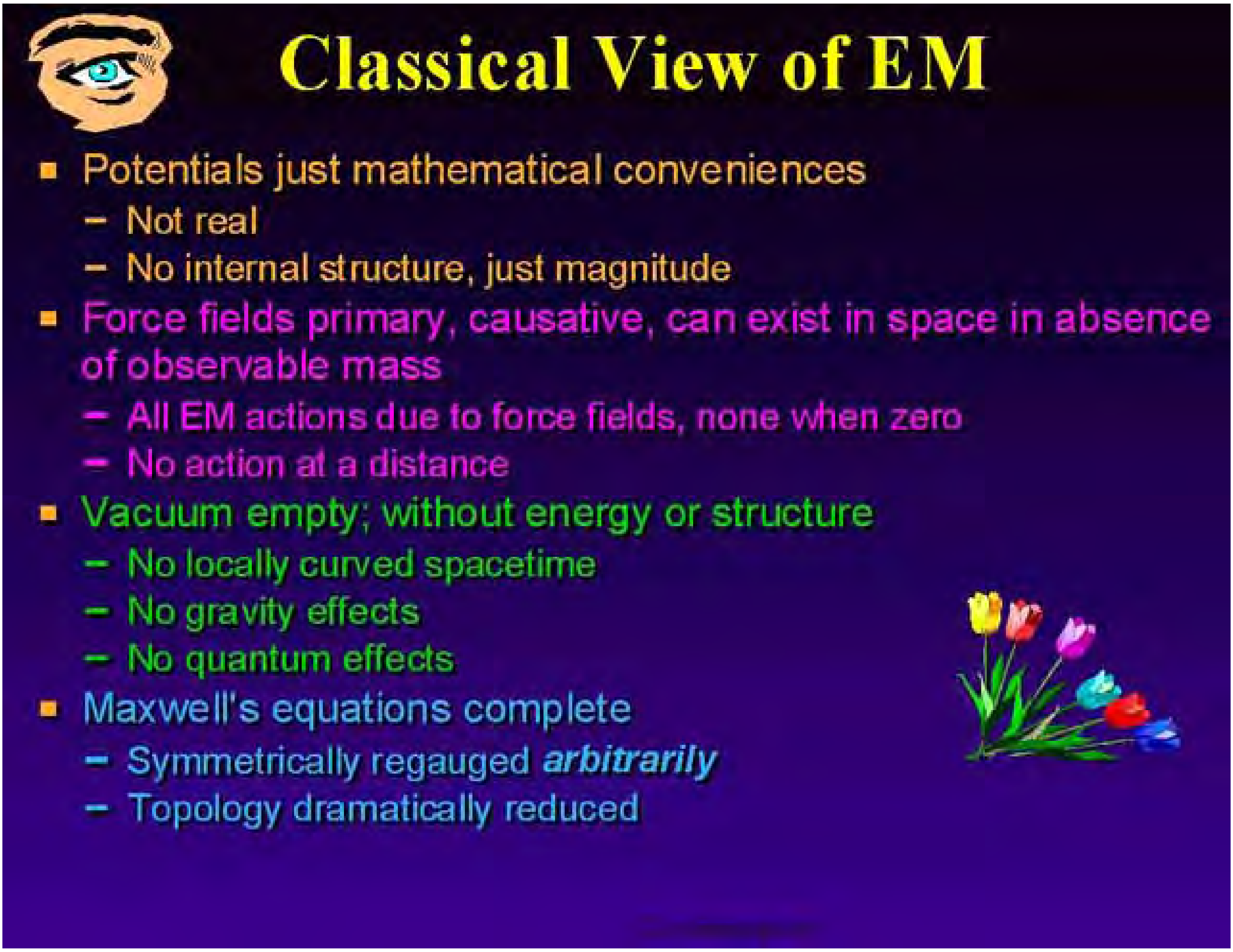

Classical View of EM

- Potentials just mathematical conveniences
  - Not real
  - No internal structure, just magnitude
- Force fields primary, causative, can exist in space in absence of observable mass
  - All EM actions due to force fields, none when zero
  - No action at a distance
- Vacuum empty; without energy or structure
  - No locally curved spacetime
  - No gravity effects
  - No quantum effects
- Maxwell's equations complete
  - Symmetrically regauged ***arbitrarily***
  - Topology dramatically reduced

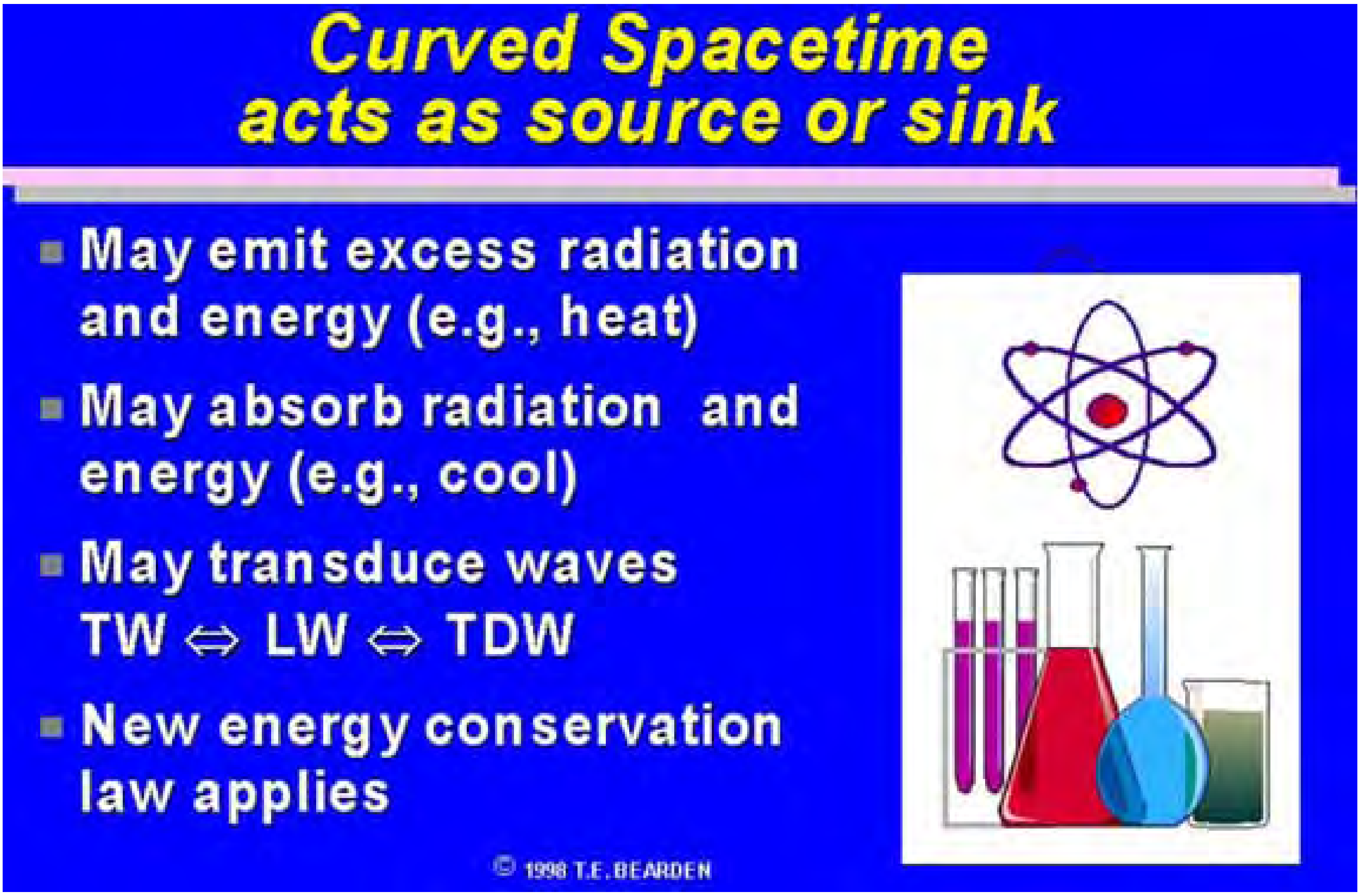

Curved Spacetime acts as source or sink

- May emit excess radiation and energy (e.g., heat)
- May absorb radiation and energy (e.g., cool)
- May transduce waves TW ⇔ LW ⇔ TDW
- New energy conservation law applies

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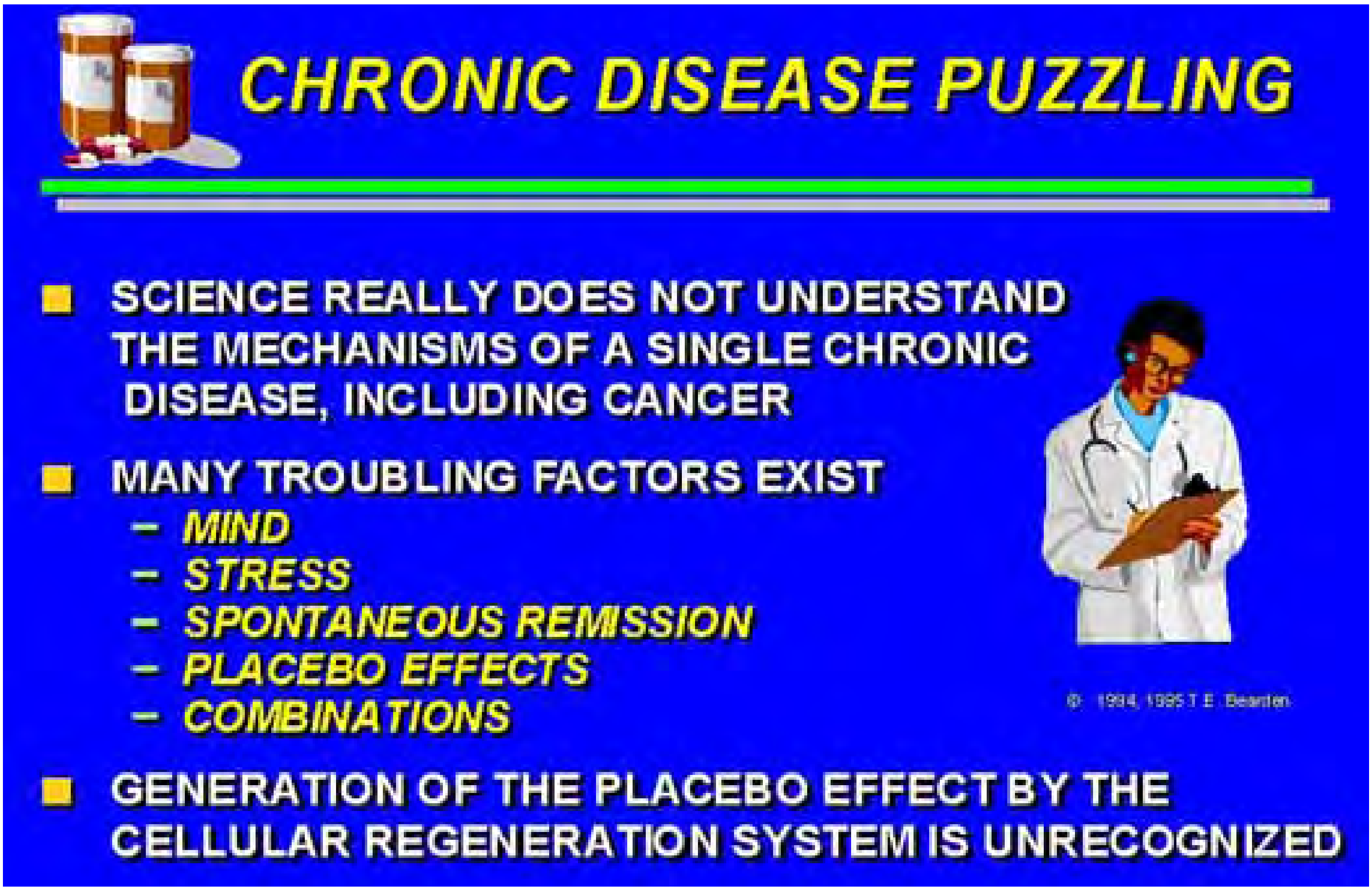

CHRONIC DISEASE PUZZLING

- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
- MANY TROUBLING FACTORS EXIST
  - *MIND*
  - *STRESS*
  - *SPONTANEOUS REMISSION*
  - *PLACEBO EFFECTS*
  - *COMBINATIONS*
- GENERATION OF THE PLACEBO EFFECT BY THE CELLULAR REGENERATION SYSTEM IS UNRECOGNIZED

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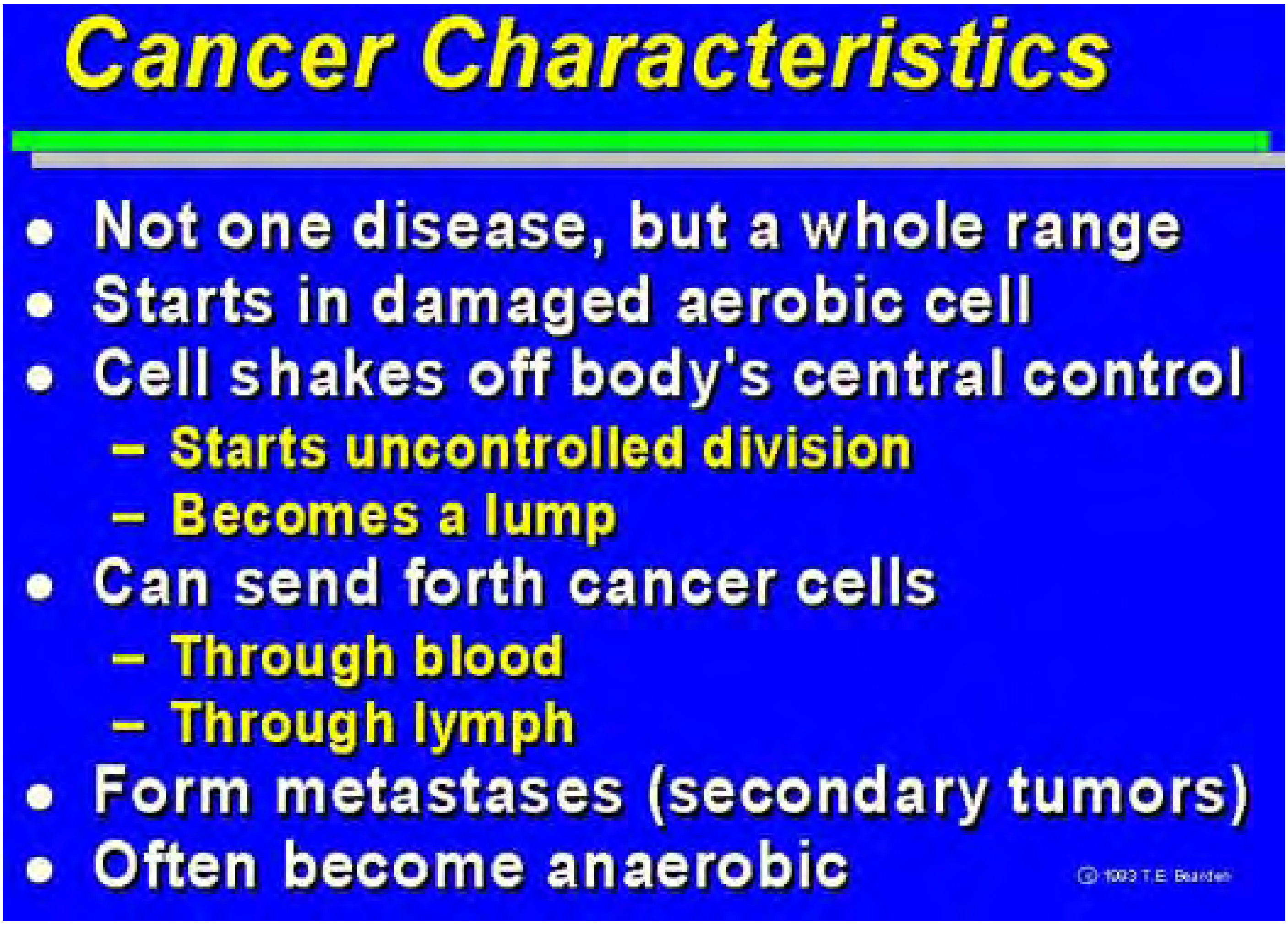

Cancer Characteristics

- Not one disease, but a whole range
- Starts in damaged aerobic cell
- Cell shakes off body's central control
  - Starts uncontrolled division
  - Becomes a lump
- Can send forth cancer cells
  - Through blood
  - Through lymph
- Form metastases (secondary tumors)
- Often become anaerobic

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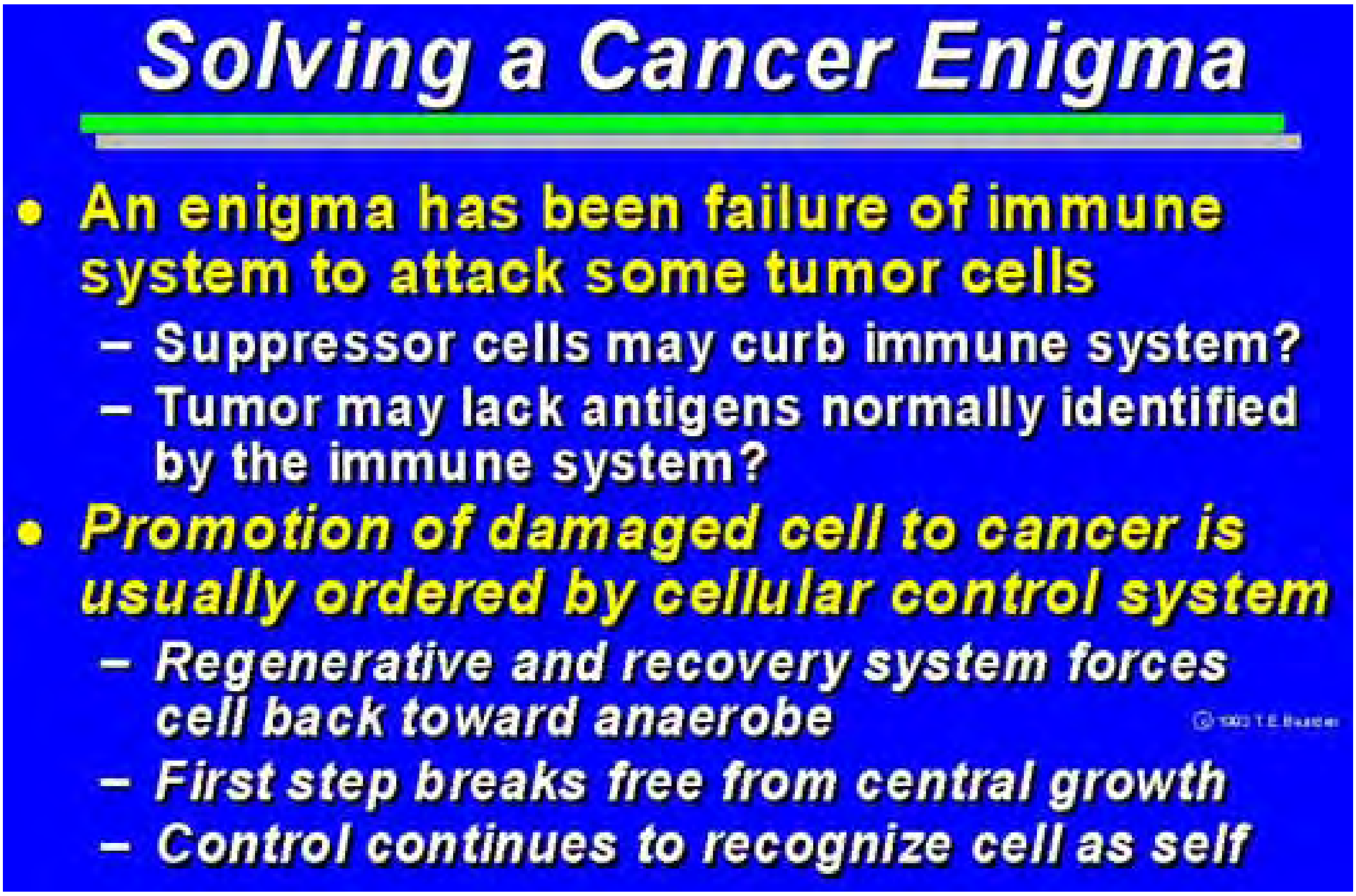

Solving a Cancer Enigma

- An enigma has been failure of immune system to attack some tumor cells
  - Suppressor cells may curb immune system?
  - Tumor may lack antigens normally identified by the immune system?
- *Promotion of damaged cell to cancer is usually ordered by cellular control system*
  - *Regenerative and recovery system forces cell back toward anaerobe*
  - *First step breaks free from central growth*
  - *Control continues to recognize cell as self*

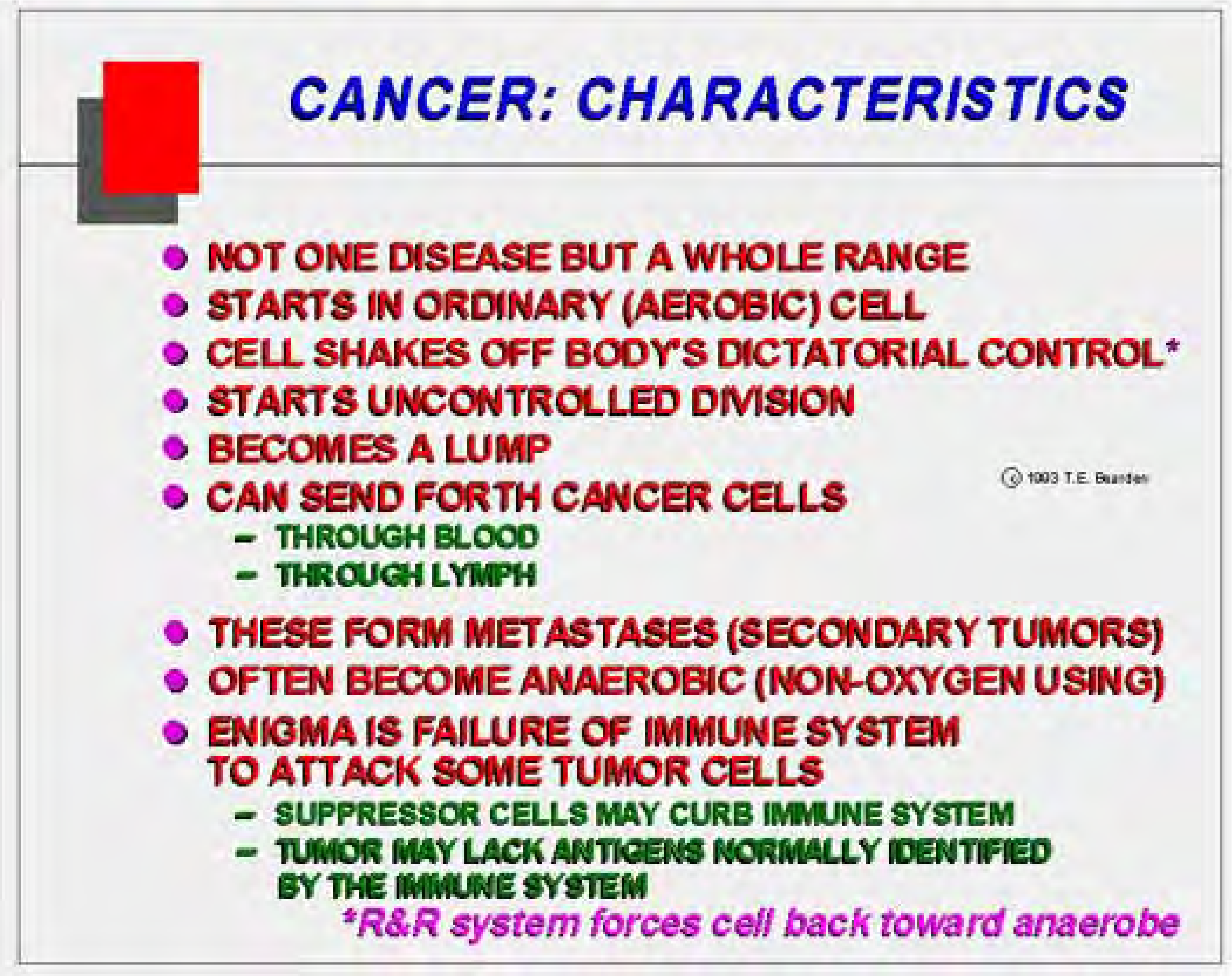

CANCER: CHARACTERISTICS

- NOT ONE DISEASE BUT A WHOLE RANGE
- STARTS IN ORDINARY (AEROBIC) CELL
- CELL SHAKES OFF BODY'S DICTATORIAL CONTROL*
- STARTS UNCONTROLLED DIVISION
- BECOMES A LUMP
- CAN SEND FORTH CANCER CELLS
  - THROUGH BLOOD
  - THROUGH LYMPH
- THESE FORM METASTASES (SECONDARY TUMORS)
- OFTEN BECOME ANAEROBIC (NON-OXYGEN USING)
- ENIGMA IS FAILURE OF IMMUNE SYSTEM TO ATTACK SOME TUMOR CELLS
  - SUPPRESSOR CELLS MAY CURB IMMUNE SYSTEM
  - TUMOR MAY LACK ANTIGENS NORMALLY IDENTIFIED BY THE IMMUNE SYSTEM

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*R&R system forces cell back toward anaerobe

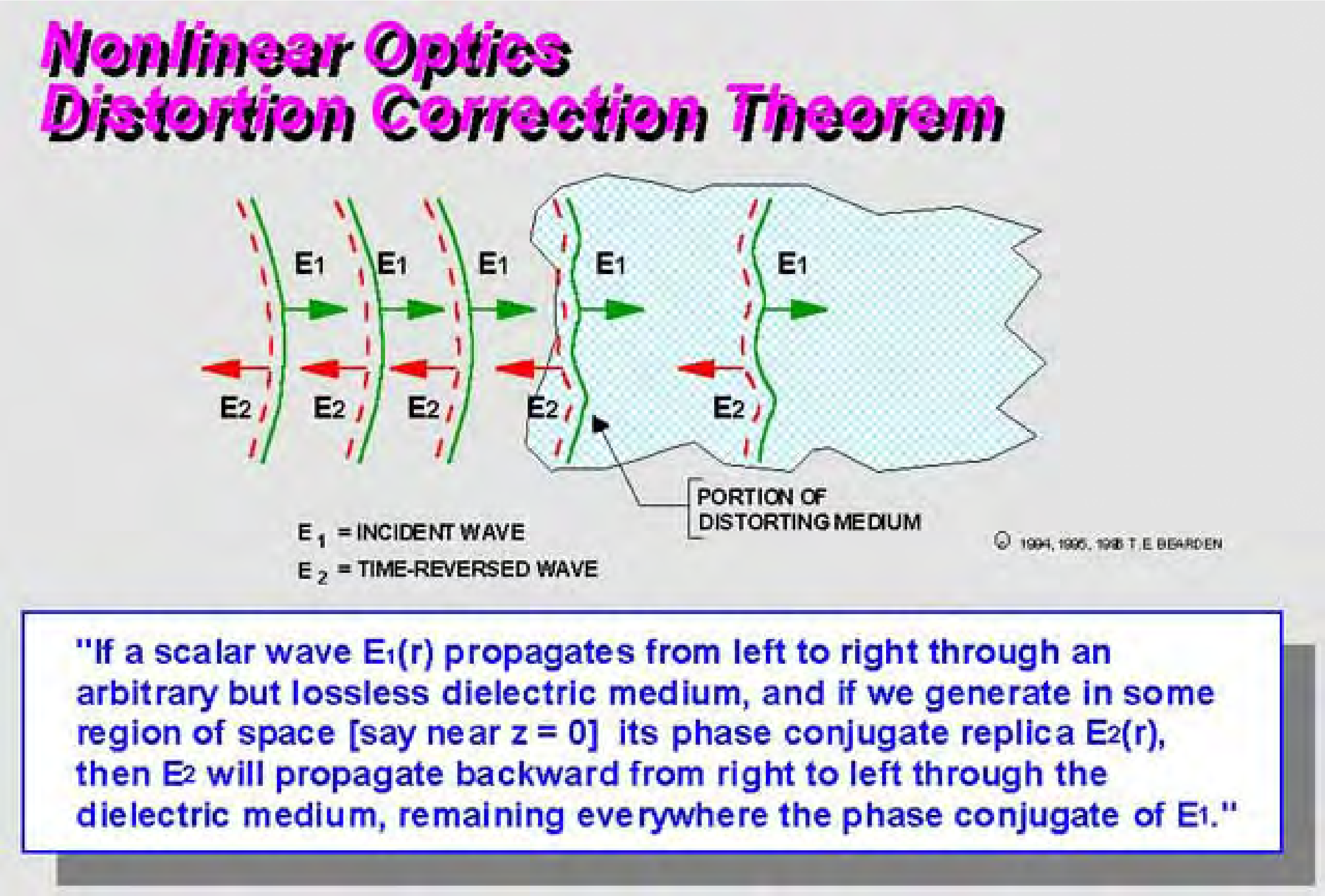

Nonlinear Optics
Distortion Correction Theorem

E_1 = INCIDENT WAVE
E_2 = TIME-REVERSED WAVE

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> "If a scalar wave $E_1(r)$ propagates from left to right through an arbitrary but lossless dielectric medium, and if we generate in some region of space [say near z = 0] its phase conjugate replica $E_2(r)$, then E_2 will propagate backward from right to left through the dielectric medium, remaining everywhere the phase conjugate of E_1."

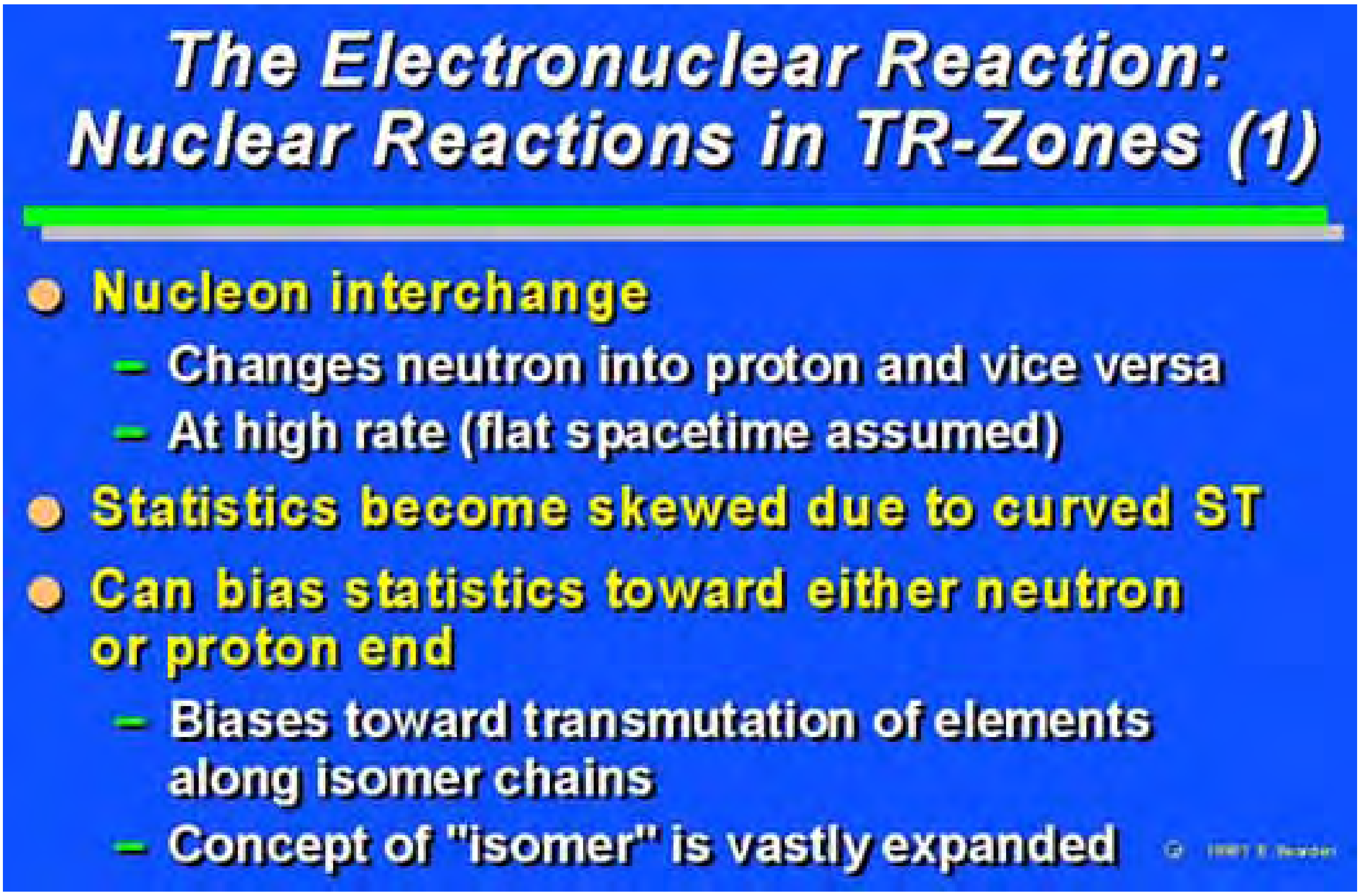

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (1)

- **Nucleon interchange**
  - Changes neutron into proton and vice versa
  - At high rate (flat spacetime assumed)
- **Statistics become skewed due to curved ST**
- **Can bias statistics toward either neutron or proton end**
  - Biases toward transmutation of elements along isomer chains
  - Concept of "isomer" is vastly expanded

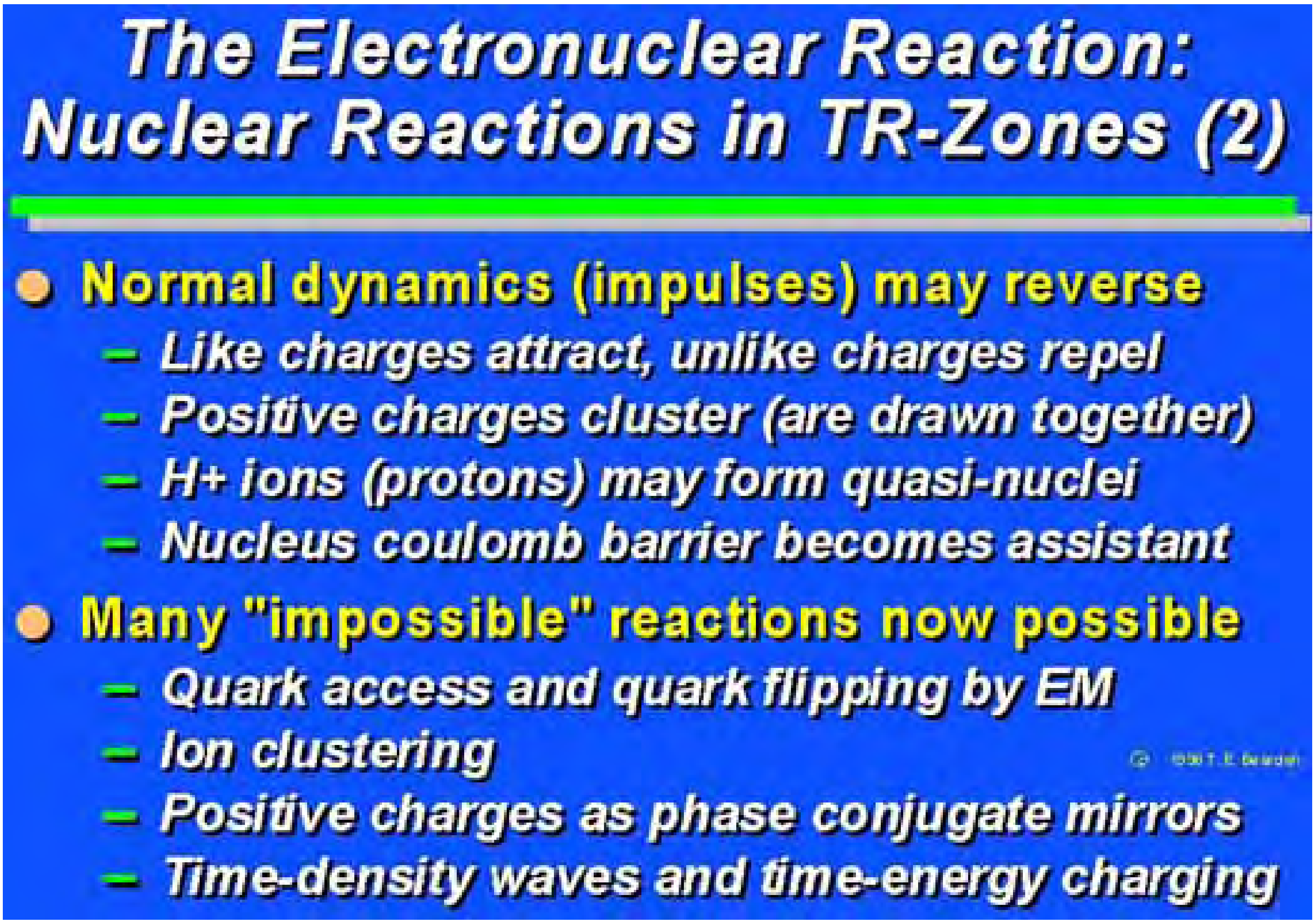

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (2)

- **Normal dynamics (impulses) may reverse**
  - *Like charges attract, unlike charges repel*
  - *Positive charges cluster (are drawn together)*
  - *H+ ions (protons) may form quasi-nuclei*
  - *Nucleus coulomb barrier becomes assistant*
- **Many "impossible" reactions now possible**
  - *Quark access and quark flipping by EM*
  - *Ion clustering*
  - *Positive charges as phase conjugate mirrors*
  - *Time-density waves and time-energy charging*

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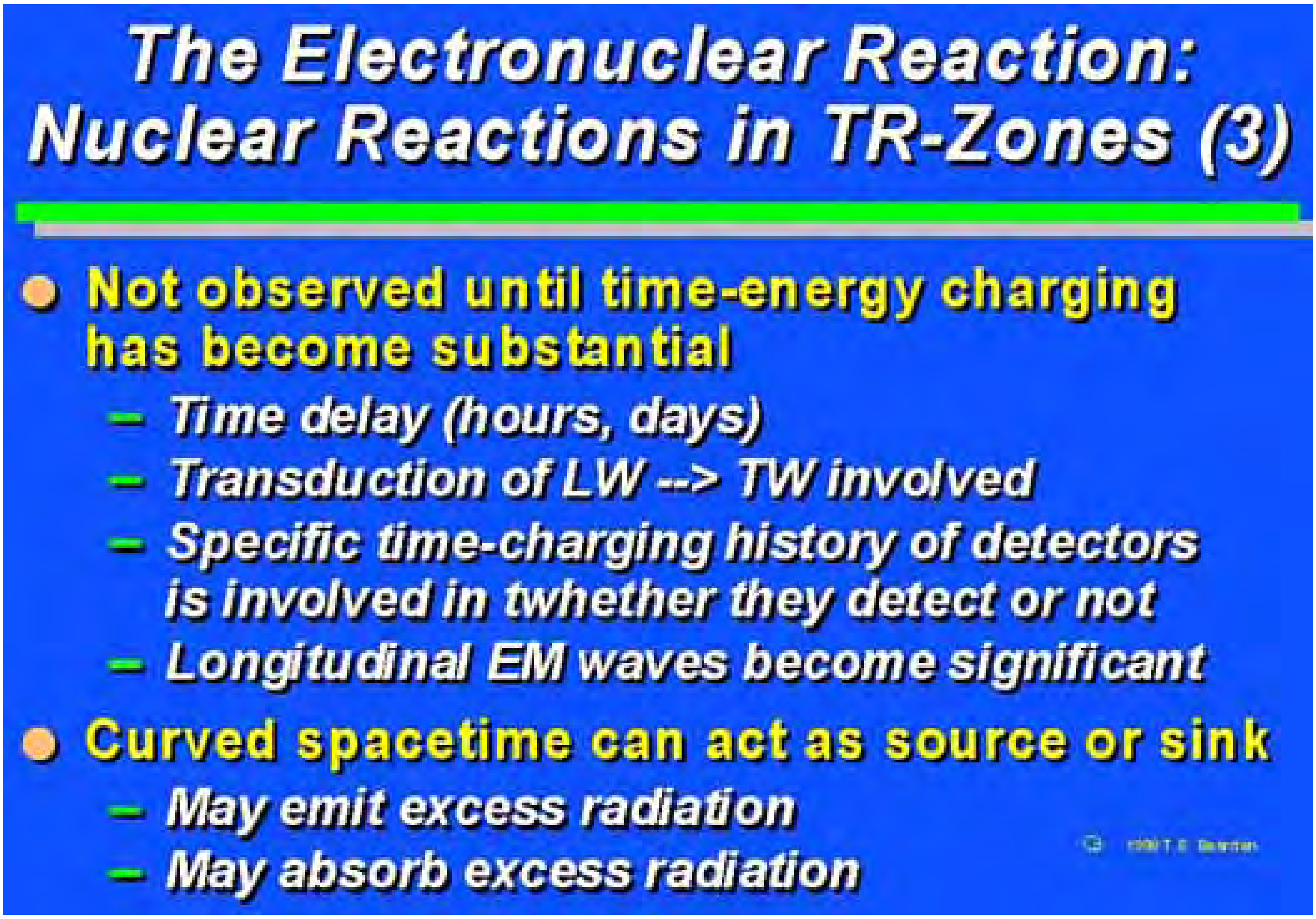

The Electronuclear Reaction: Nuclear Reactions in TR-Zones (3)

- **Not observed until time-energy charging has become substantial**
  - *Time delay (hours, days)*
  - *Transduction of LW --> TW involved*
  - *Specific time-charging history of detectors is involved in twhether they detect or not*
  - *Longitudinal EM waves become significant*
- **Curved spacetime can act as source or sink**
  - *May emit excess radiation*
  - *May absorb excess radiation*

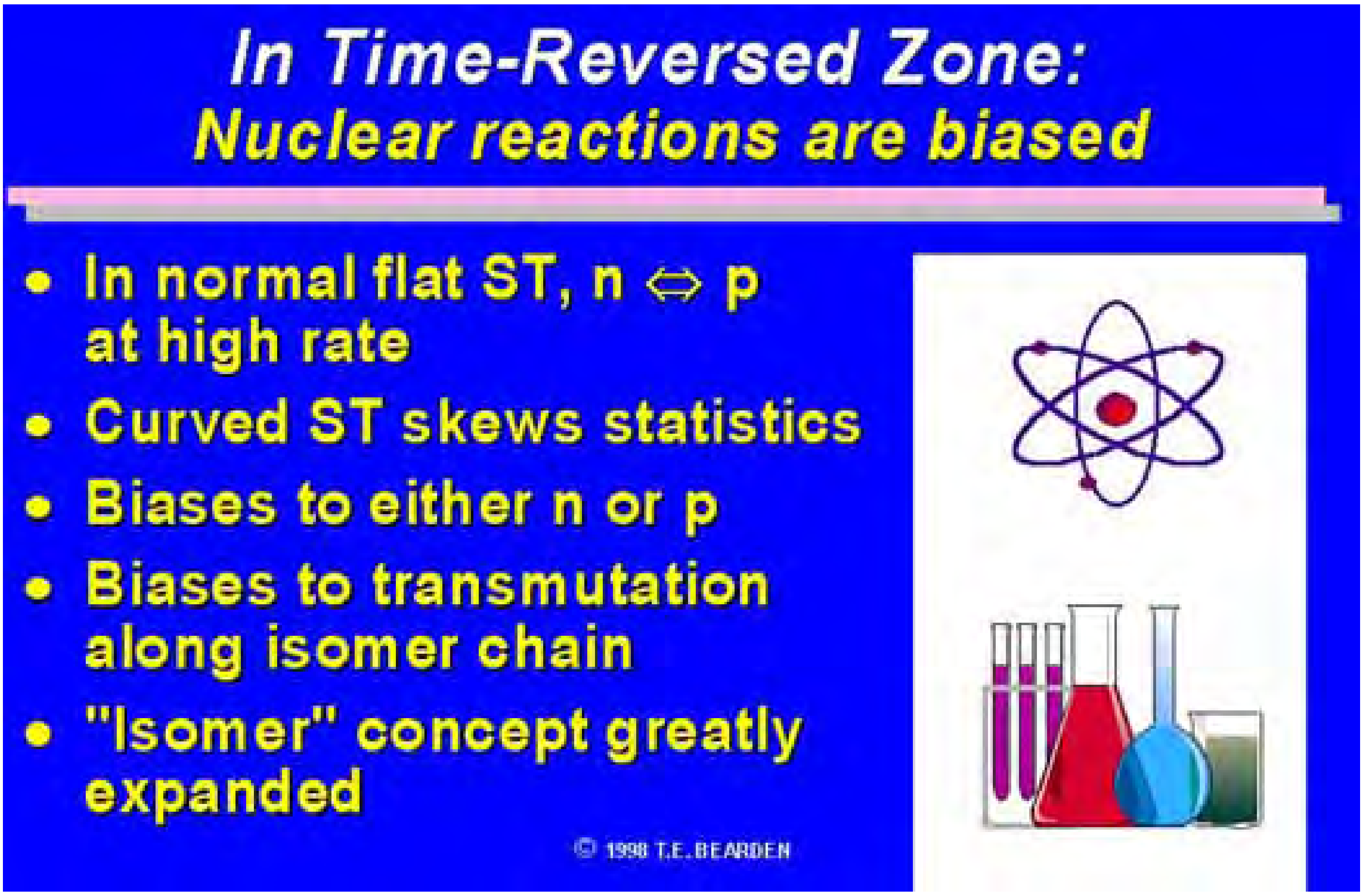

In Time-Reversed Zone:
Nuclear reactions are biased

- In normal flat ST, n ⇔ p at high rate
- Curved ST skews statistics
- Biases to either n or p
- Biases to transmutation along isomer chain
- "Isomer" concept greatly expanded

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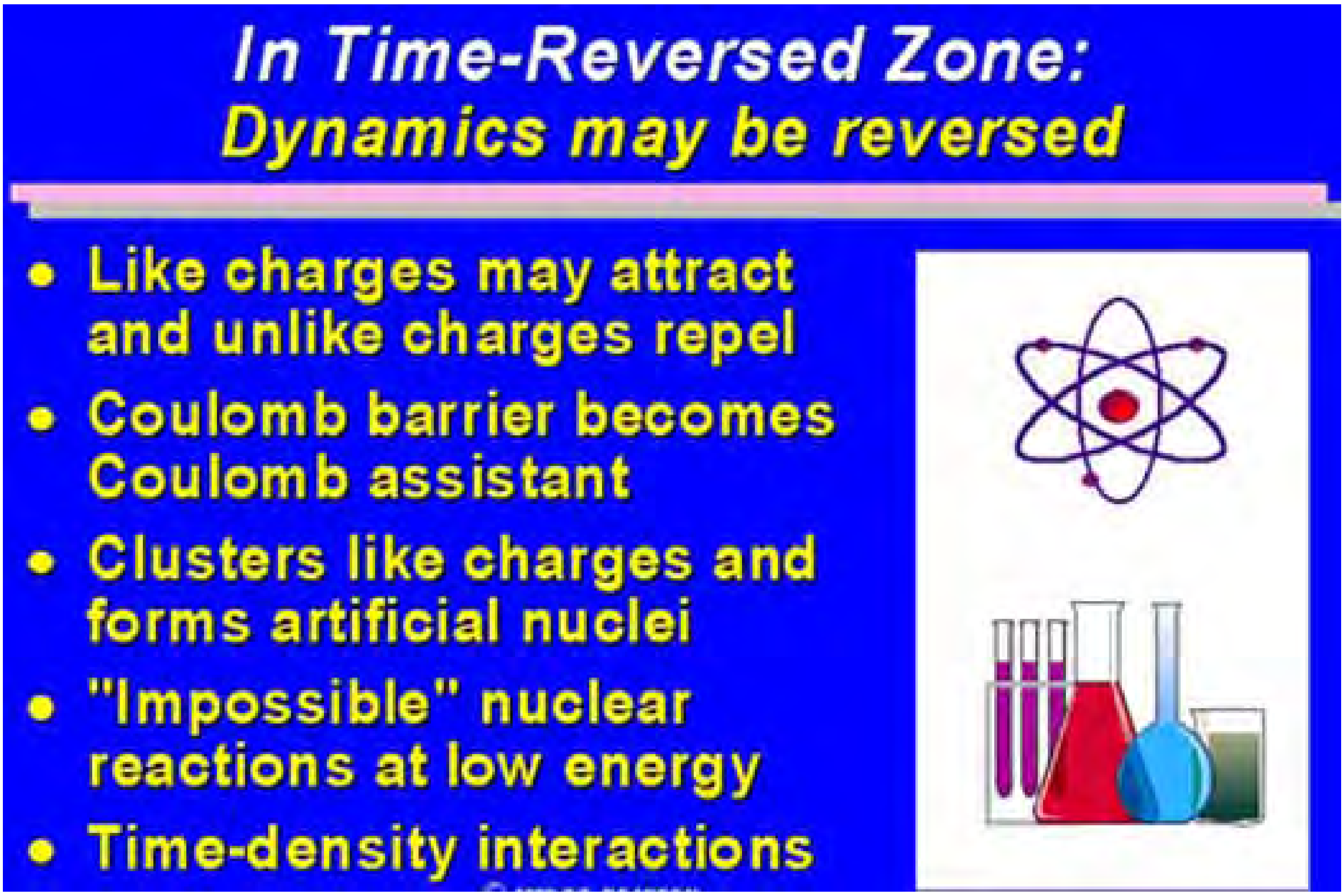

In Time-Reversed Zone:
Dynamics may be reversed

- Like charges may attract and unlike charges repel
- Coulomb barrier becomes Coulomb assistant
- Clusters like charges and forms artificial nuclei
- "Impossible" nuclear reactions at low energy
- Time-density interactions

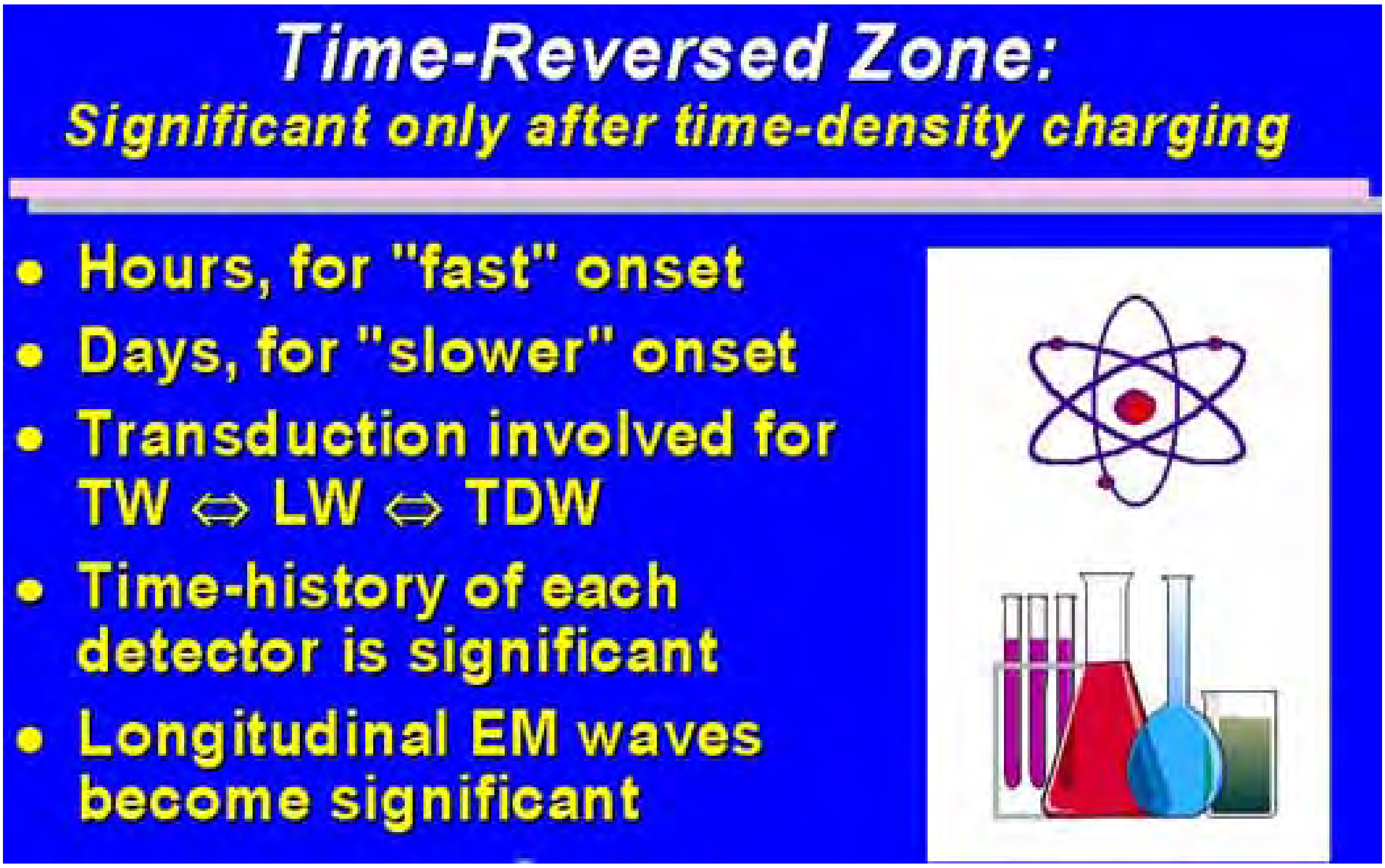

Time-Reversed Zone:

Significant only after time-density charging

- Hours, for "fast" onset
- Days, for "slower" onset
- Transduction involved for TW ⇔ LW ⇔ TDW
- Time-history of each detector is significant
- Longitudinal EM waves become significant

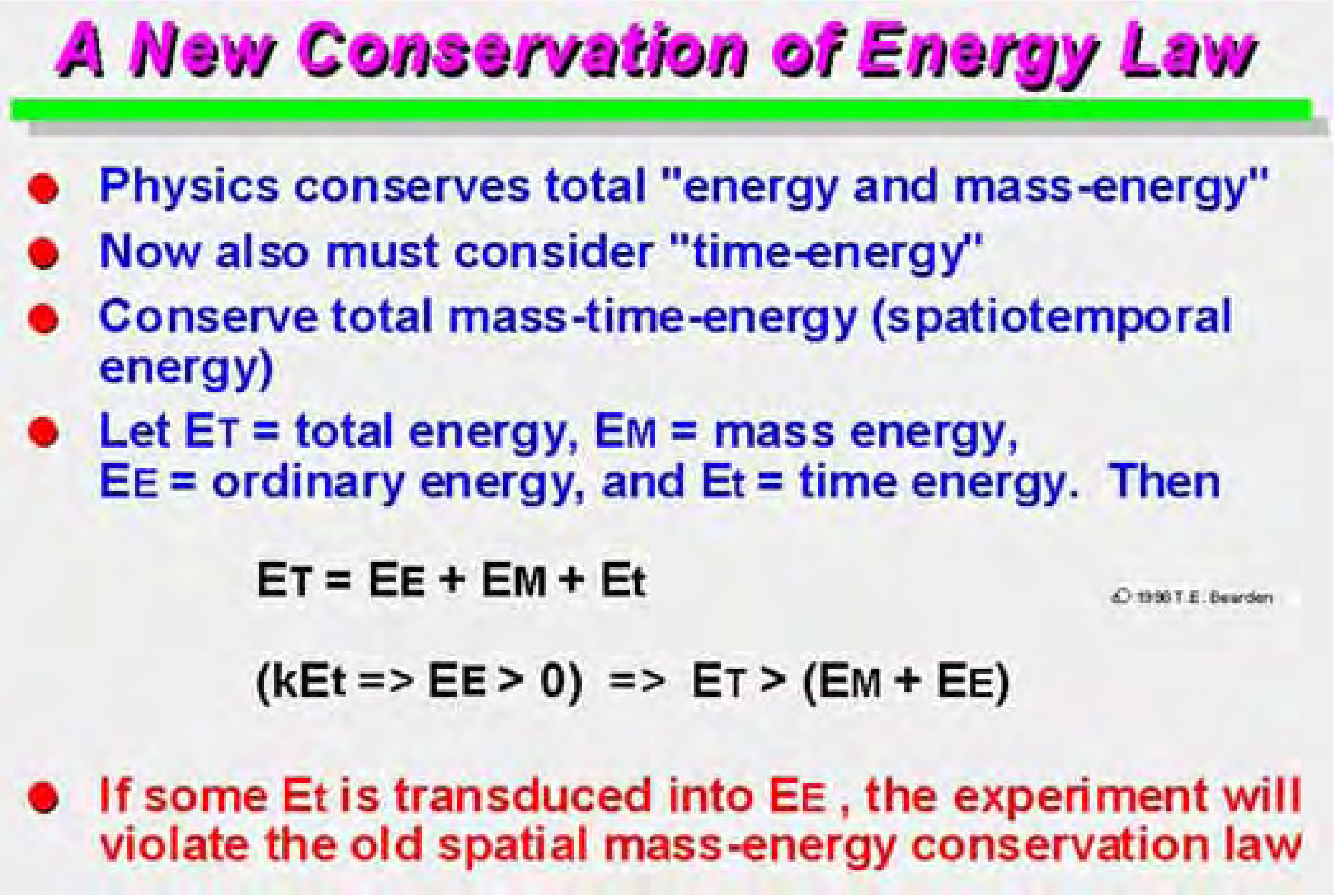

A New Conservation of Energy Law

- Physics conserves total "energy and mass-energy"
- Now also must consider "time-energy"
- Conserve total mass-time-energy (spatiotemporal energy)
- Let E_T = total energy, E_M = mass energy, E_E = ordinary energy, and E_t = time energy. Then

$$E_T = E_E + E_M + E_t$$

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$$(kE_t \Rightarrow E_E > 0) \;\Rightarrow\; E_T > (E_M + E_E)$$

- If some E_t is transduced into E_E, the experiment will violate the old spatial mass-energy conservation law

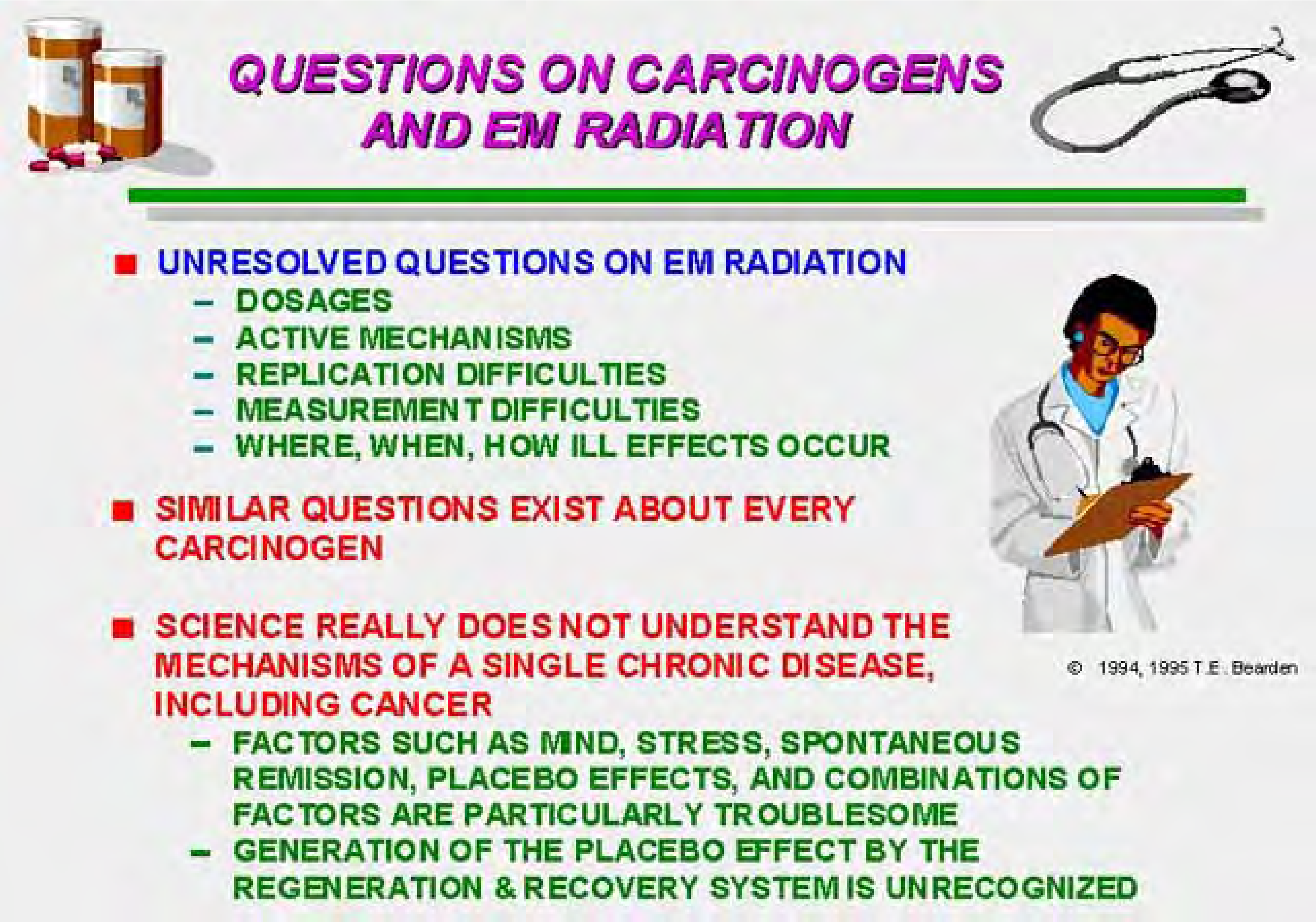

QUESTIONS ON CARCINOGENS AND EM RADIATION

- UNRESOLVED QUESTIONS ON EM RADIATION
  - DOSAGES
  - ACTIVE MECHANISMS
  - REPLICATION DIFFICULTIES
  - MEASUREMENT DIFFICULTIES
  - WHERE, WHEN, HOW ILL EFFECTS OCCUR
- SIMILAR QUESTIONS EXIST ABOUT EVERY CARCINOGEN
- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
  - FACTORS SUCH AS MIND, STRESS, SPONTANEOUS REMISSION, PLACEBO EFFECTS, AND COMBINATIONS OF FACTORS ARE PARTICULARLY TROUBLESOME
  - GENERATION OF THE PLACEBO EFFECT BY THE REGENERATION & RECOVERY SYSTEM IS UNRECOGNIZED

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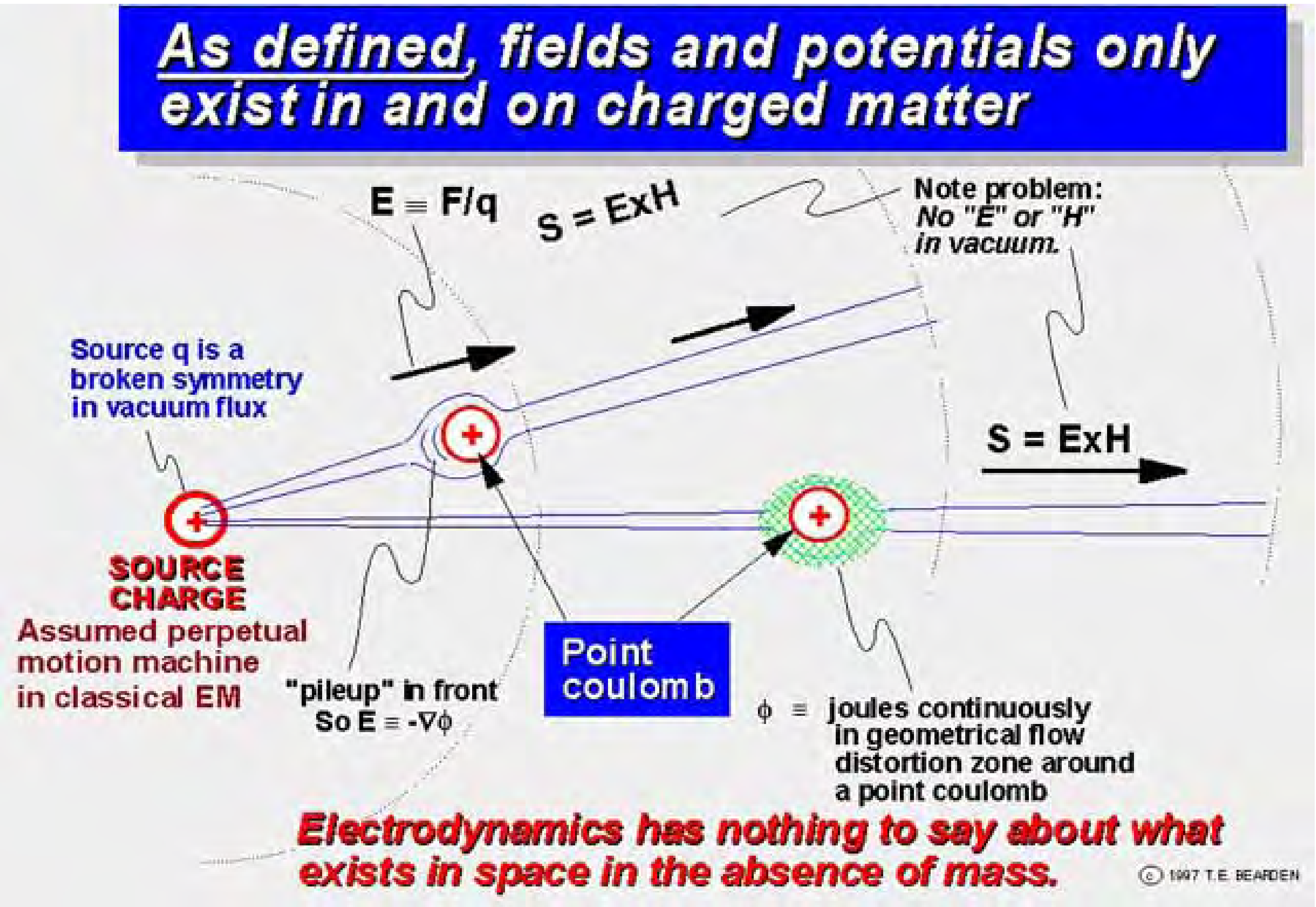

As defined, fields and potentials only exist in and on charged matter

$E \equiv F/q$

$S = E \times H$

Note problem:
No "E" or "H" in vacuum.

Source q is a broken symmetry in vacuum flux

$S = E \times H$

SOURCE CHARGE

Assumed perpetual motion machine in classical EM

"pileup" in front
So $E \equiv -\nabla\phi$

Point coulomb

$\phi \equiv$ joules continuously in geometrical flow distortion zone around a point coulomb

Electrodynamics has nothing to say about what exists in space in the absence of mass.

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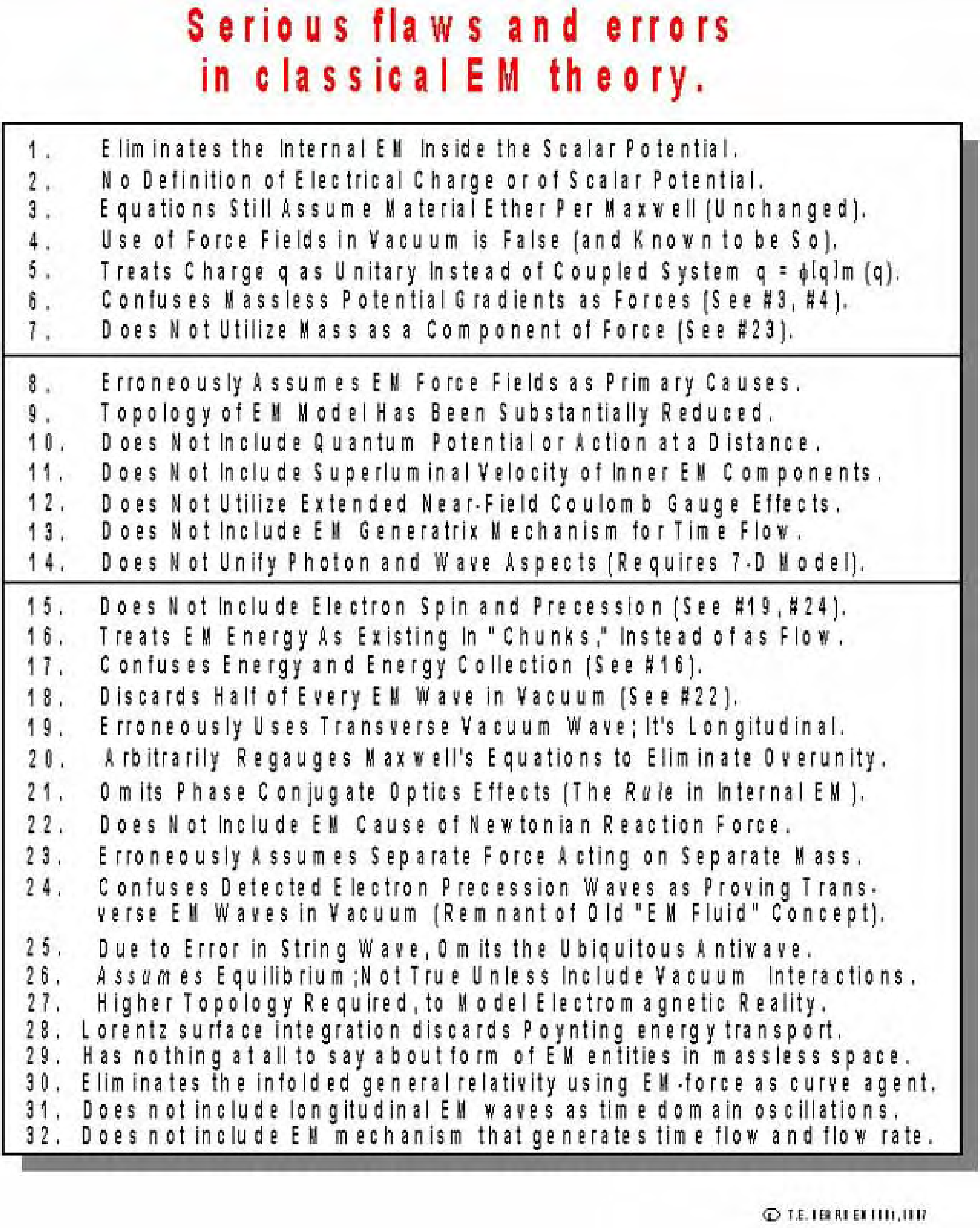

Serious flaws and errors in classical EM theory.

1. Eliminates the Internal EM Inside the Scalar Potential.
2. No Definition of Electrical Charge or of Scalar Potential.
3. Equations Still Assume Material Ether Per Maxwell (Unchanged).
4. Use of Force Fields in Vacuum is False (and Known to be So).
5. Treats Charge q as Unitary Instead of Coupled System $q = \phi[q]m(q)$.
6. Confuses Massless Potential Gradients as Forces (See #3, #4).
7. Does Not Utilize Mass as a Component of Force (See #23).
8. Erroneously Assumes EM Force Fields as Primary Causes.
9. Topology of EM Model Has Been Substantially Reduced.
10. Does Not Include Quantum Potential or Action at a Distance.
11. Does Not Include Superluminal Velocity of Inner EM Components.
12. Does Not Utilize Extended Near-Field Coulomb Gauge Effects.
13. Does Not Include EM Generatrix Mechanism for Time Flow.
14. Does Not Unify Photon and Wave Aspects (Requires 7-D Model).
15. Does Not Include Electron Spin and Precession (See #19, #24).
16. Treats EM Energy As Existing In "Chunks," Instead of as Flow.
17. Confuses Energy and Energy Collection (See #16).
18. Discards Half of Every EM Wave in Vacuum (See #22).
19. Erroneously Uses Transverse Vacuum Wave; It's Longitudinal.
20. Arbitrarily Regauges Maxwell's Equations to Eliminate Overunity.
21. Omits Phase Conjugate Optics Effects (The *Rule* in Internal EM).
22. Does Not Include EM Cause of Newtonian Reaction Force.
23. Erroneously Assumes Separate Force Acting on Separate Mass.
24. Confuses Detected Electron Precession Waves as Proving Transverse EM Waves in Vacuum (Remnant of Old "EM Fluid" Concept).
25. Due to Error in String Wave, Omits the Ubiquitous Antiwave.
26. *Assumes* Equilibrium; Not True Unless Include Vacuum Interactions.
27. Higher Topology Required, to Model Electromagnetic Reality.
28. Lorentz surface integration discards Poynting energy transport.
29. Has nothing at all to say about form of EM entities in massless space.
30. Eliminates the infolded general relativity using EM-force as curve agent.
31. Does not include longitudinal EM waves as time domain oscillations.
32. Does not include EM mechanism that generates time flow and flow rate.

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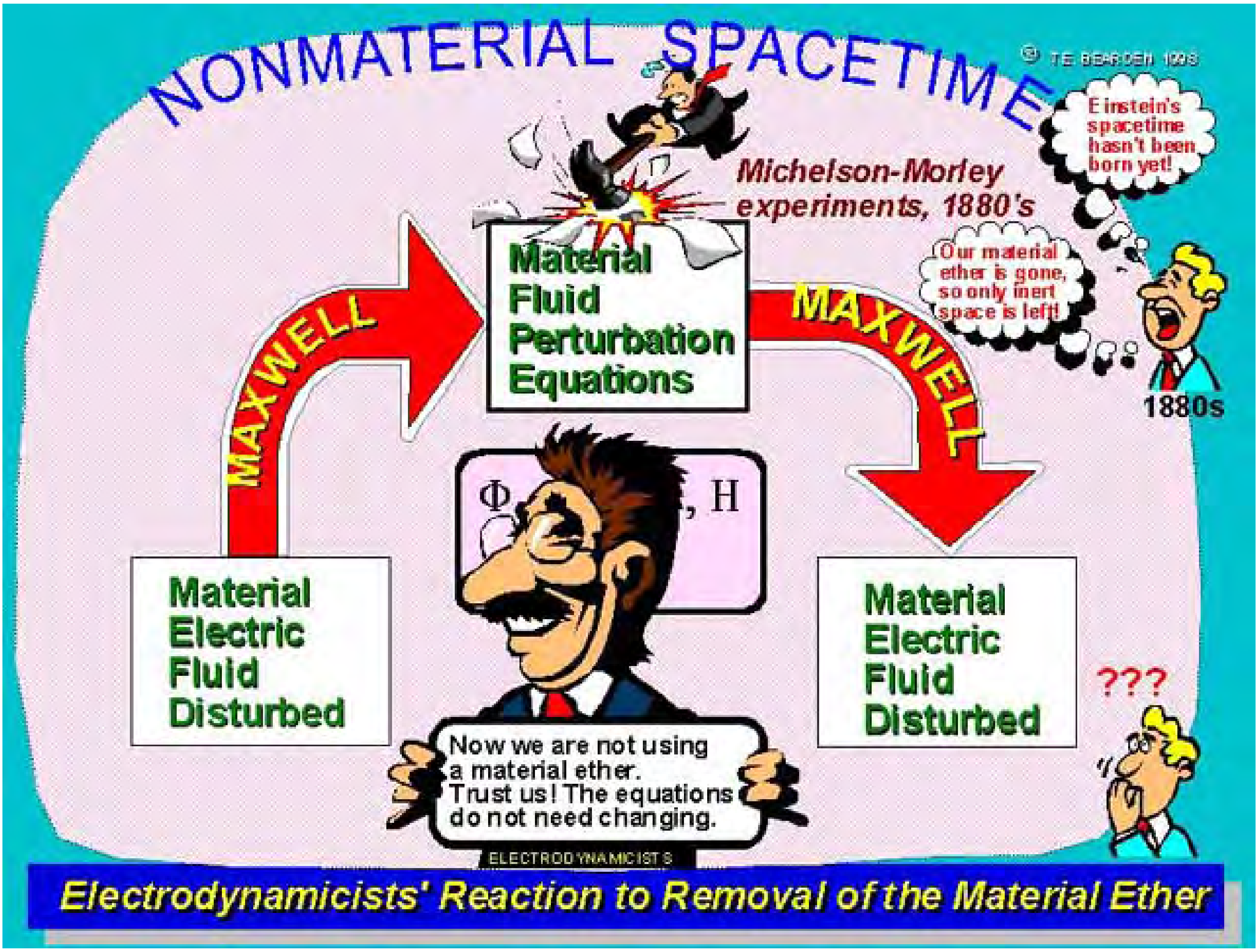
NONMATERIAL SPACETIME
© T.E. BEARDEN 1998
Einstein's spacetime hasn't been born yet!
Michelson-Morley experiments, 1880's
Our material ether is gone, so only inert space is left!
1880s
MAXWELL
Material Fluid Perturbation Equations
MAXWELL
Φ, H
Material Electric Fluid Disturbed
Material Electric Fluid Disturbed
???
Now we are not using a material ether. Trust us! The equations do not need changing.
ELECTRODYNAMICISTS

Electrodynamicists' Reaction to Removal of the Material Ether

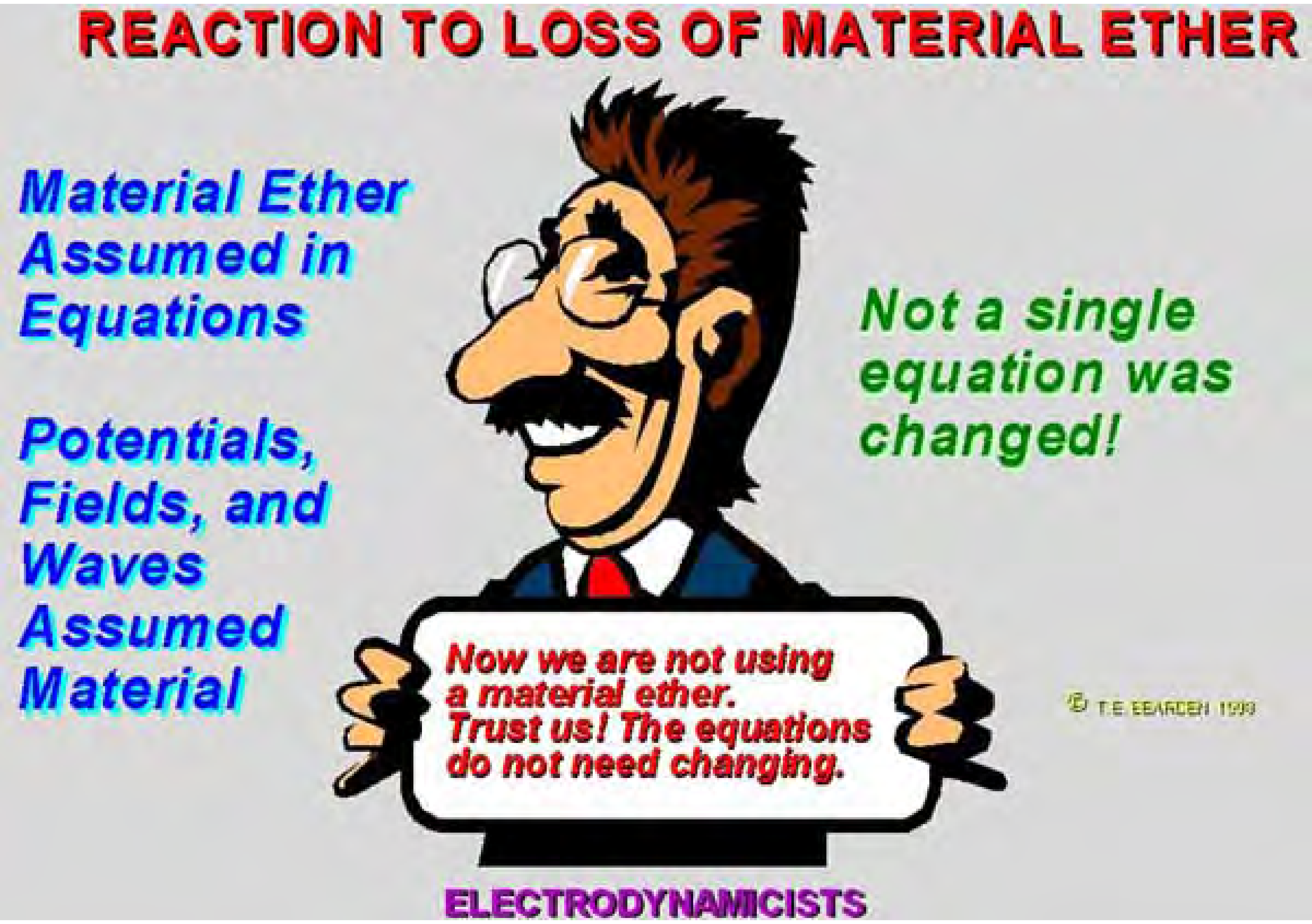

REACTION TO LOSS OF MATERIAL ETHER

Material Ether
Assumed in
Equations

Potentials,
Fields, and
Waves
Assumed
Material

Not a single
equation was
changed!

Now we are not using
a material ether.
Trust us! The equations
do not need changing.

ELECTRODYNAMICISTS

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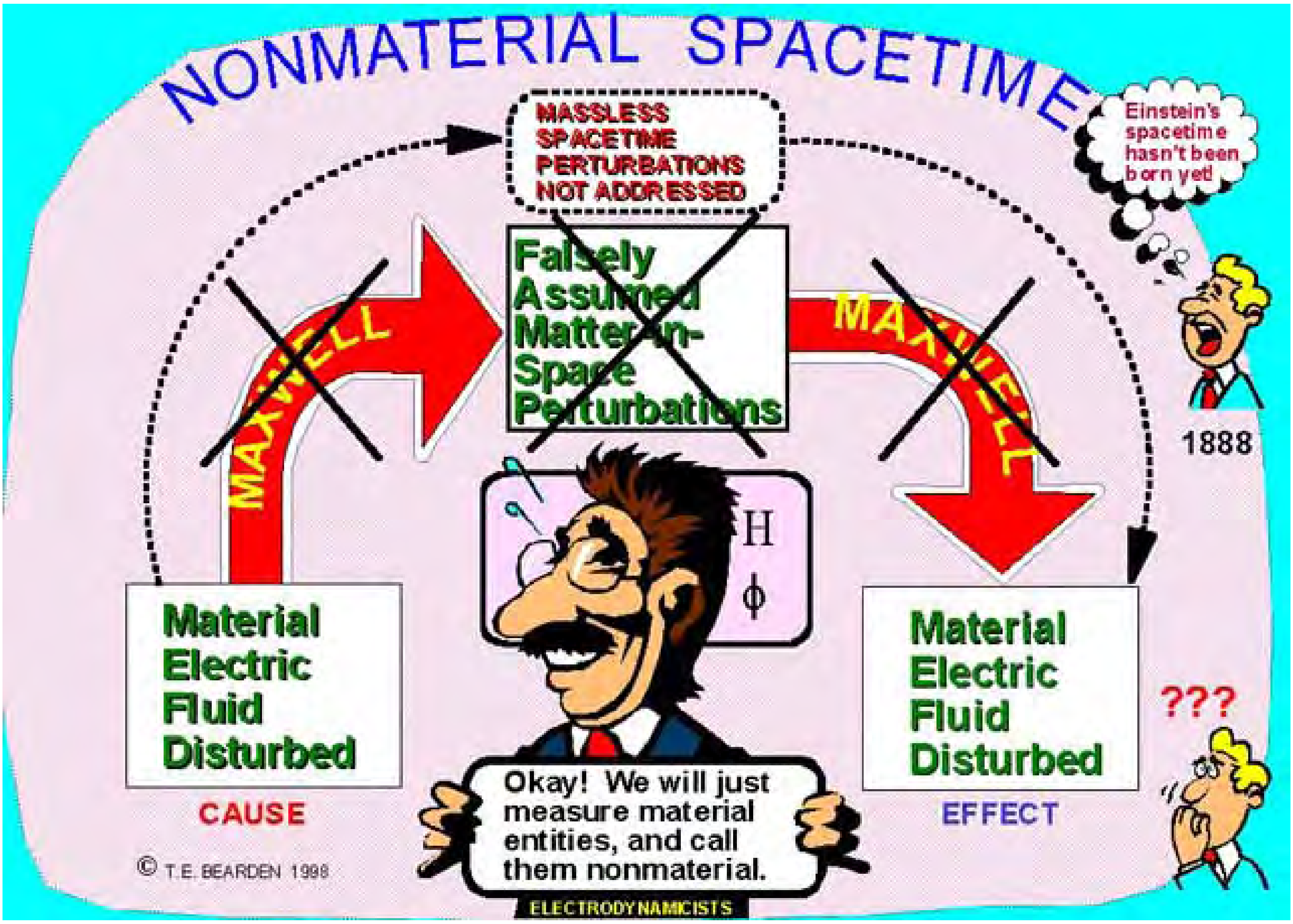
NONMATERIAL SPACETIME
MASSLESS SPACETIME PERTURBATIONS NOT ADDRESSED
Einstein's spacetime hasn't been born yet!
Falsely Assumed Matter-in-Space Perturbations
MAXWELL
MAXWELL
1888
H
ϕ
Material Electric Fluid Disturbed
CAUSE
Material Electric Fluid Disturbed
EFFECT
???
Okay! We will just measure material entities, and call them nonmaterial.
ELECTRODYNAMICISTS
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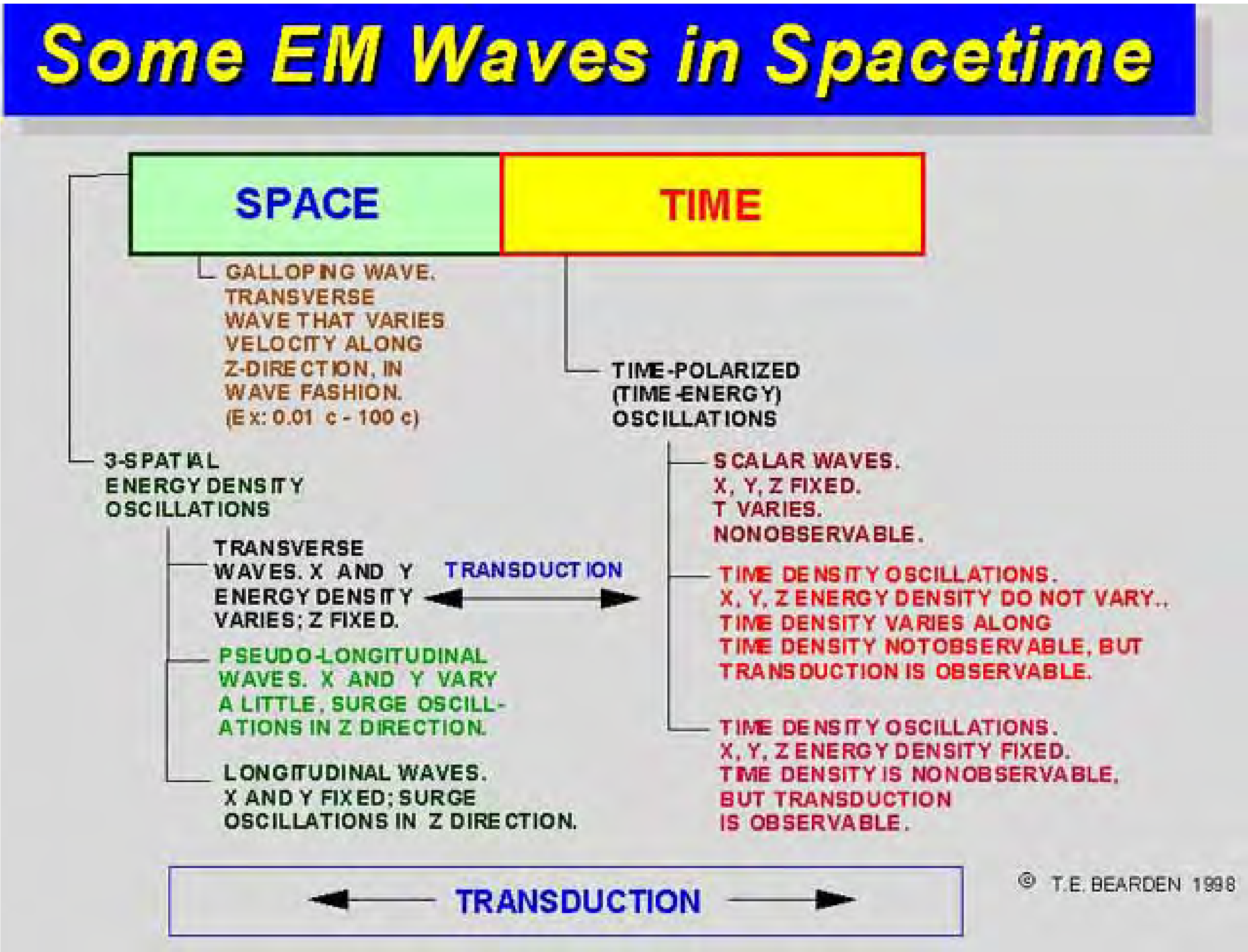

Some EM Waves in Spacetime

SPACE

TIME

GALLOPING WAVE. TRANSVERSE WAVE THAT VARIES VELOCITY ALONG Z-DIRECTION, IN WAVE FASHION. (Ex: 0.01 c - 100 c)

TIME-POLARIZED (TIME-ENERGY) OSCILLATIONS

3-SPATIAL ENERGY DENSITY OSCILLATIONS

SCALAR WAVES. X, Y, Z FIXED. T VARIES. NONOBSERVABLE.

TRANSVERSE WAVES. X AND Y ENERGY DENSITY VARIES; Z FIXED.

TRANSDUCTION

TIME DENSITY OSCILLATIONS. X, Y, Z ENERGY DENSITY DO NOT VARY.. TIME DENSITY VARIES ALONG TIME DENSITY NOTOBSERVABLE, BUT TRANSDUCTION IS OBSERVABLE.

PSEUDO-LONGITUDINAL WAVES. X AND Y VARY A LITTLE, SURGE OSCILLATIONS IN Z DIRECTION.

TIME DENSITY OSCILLATIONS. X, Y, Z ENERGY DENSITY FIXED. TIME DENSITY IS NONOBSERVABLE, BUT TRANSDUCTION IS OBSERVABLE.

LONGITUDINAL WAVES. X AND Y FIXED; SURGE OSCILLATIONS IN Z DIRECTION.

TRANSDUCTION

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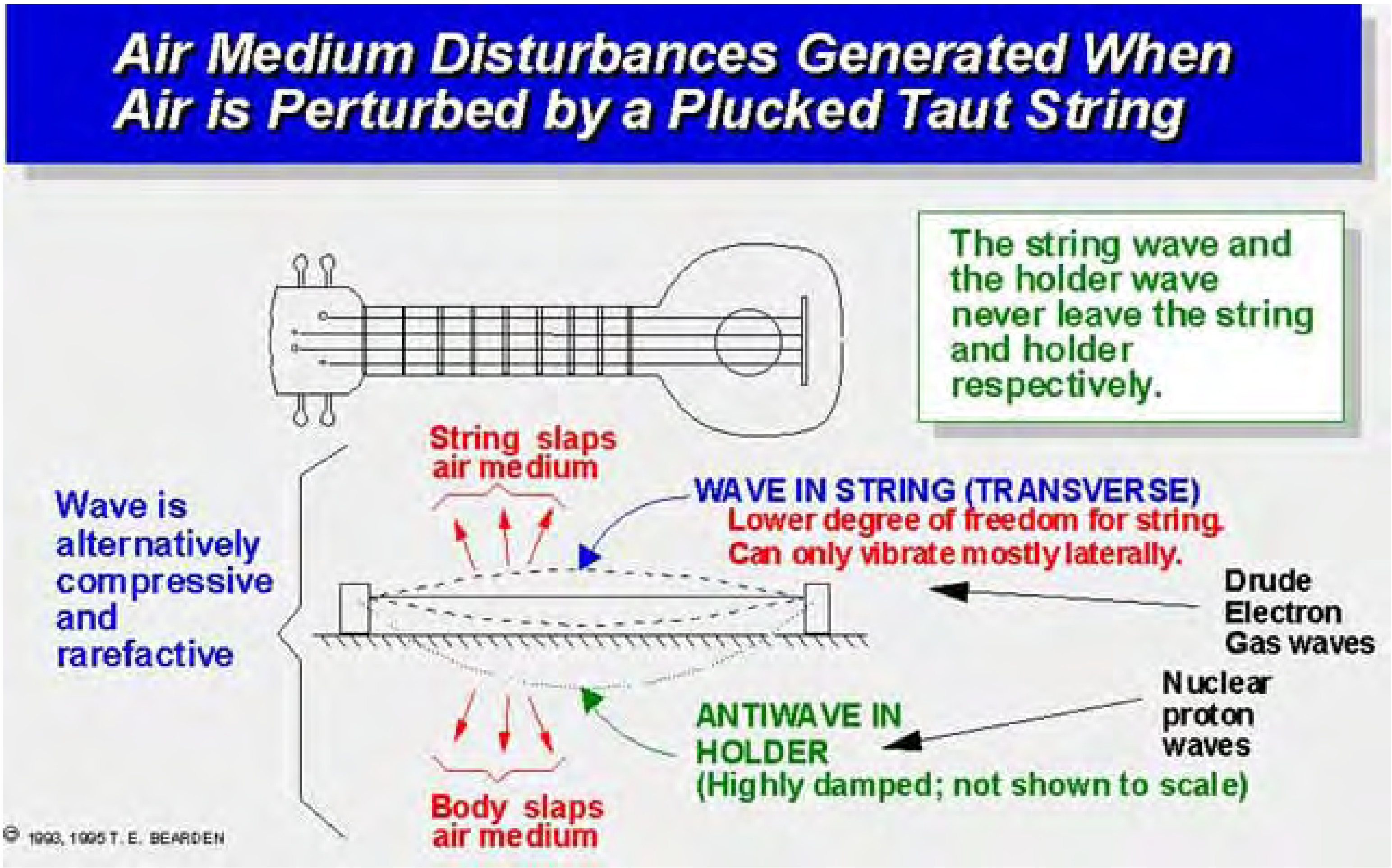

Air Medium Disturbances Generated When Air is Perturbed by a Plucked Taut String

The string wave and the holder wave never leave the string and holder respectively.

String slaps air medium

WAVE IN STRING (TRANSVERSE)

Lower degree of freedom for string. Can only vibrate mostly laterally.

Drude Electron Gas waves

Wave is alternatively compressive and rarefactive

Nuclear proton waves

ANTIWAVE IN HOLDER (Highly damped; not shown to scale)

Body slaps air medium

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Launching a Spacetime Perturbation ("EM Wave") from a Wire Antenna

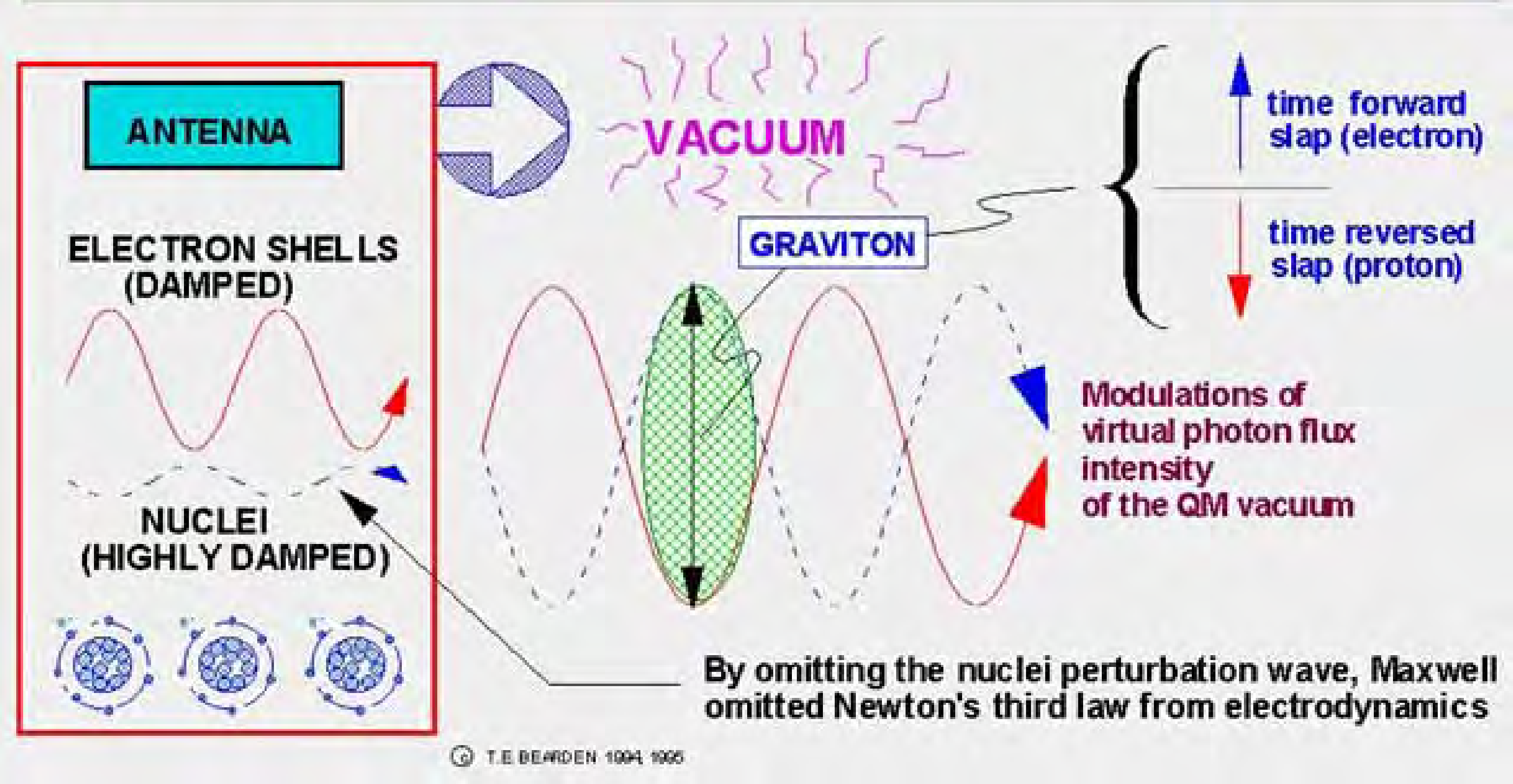
ANTENNA
ELECTRON SHELLS (DAMPED)
NUCLEI (HIGHLY DAMPED)
VACUUM
GRAVITON
time forward slap (electron)
time reversed slap (proton)
Modulations of virtual photon flux intensity of the QM vacuum

By omitting the nuclei perturbation wave, Maxwell omitted Newton's third law from electrodynamics

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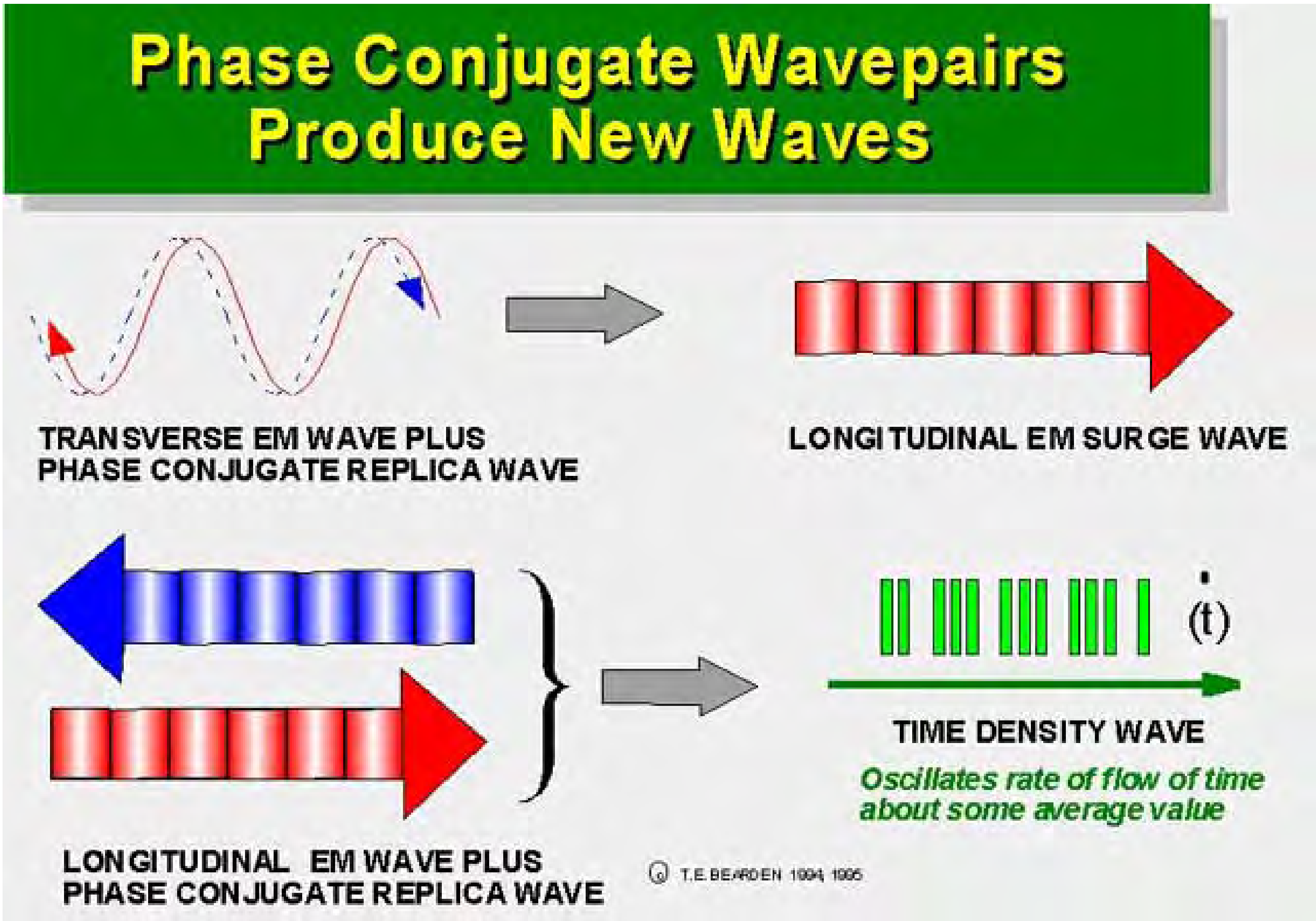

Phase Conjugate Wavepairs Produce New Waves

TRANSVERSE EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE

LONGITUDINAL EM SURGE WAVE

LONGITUDINAL EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE

TIME DENSITY WAVE

Oscillates rate of flow of time about some average value

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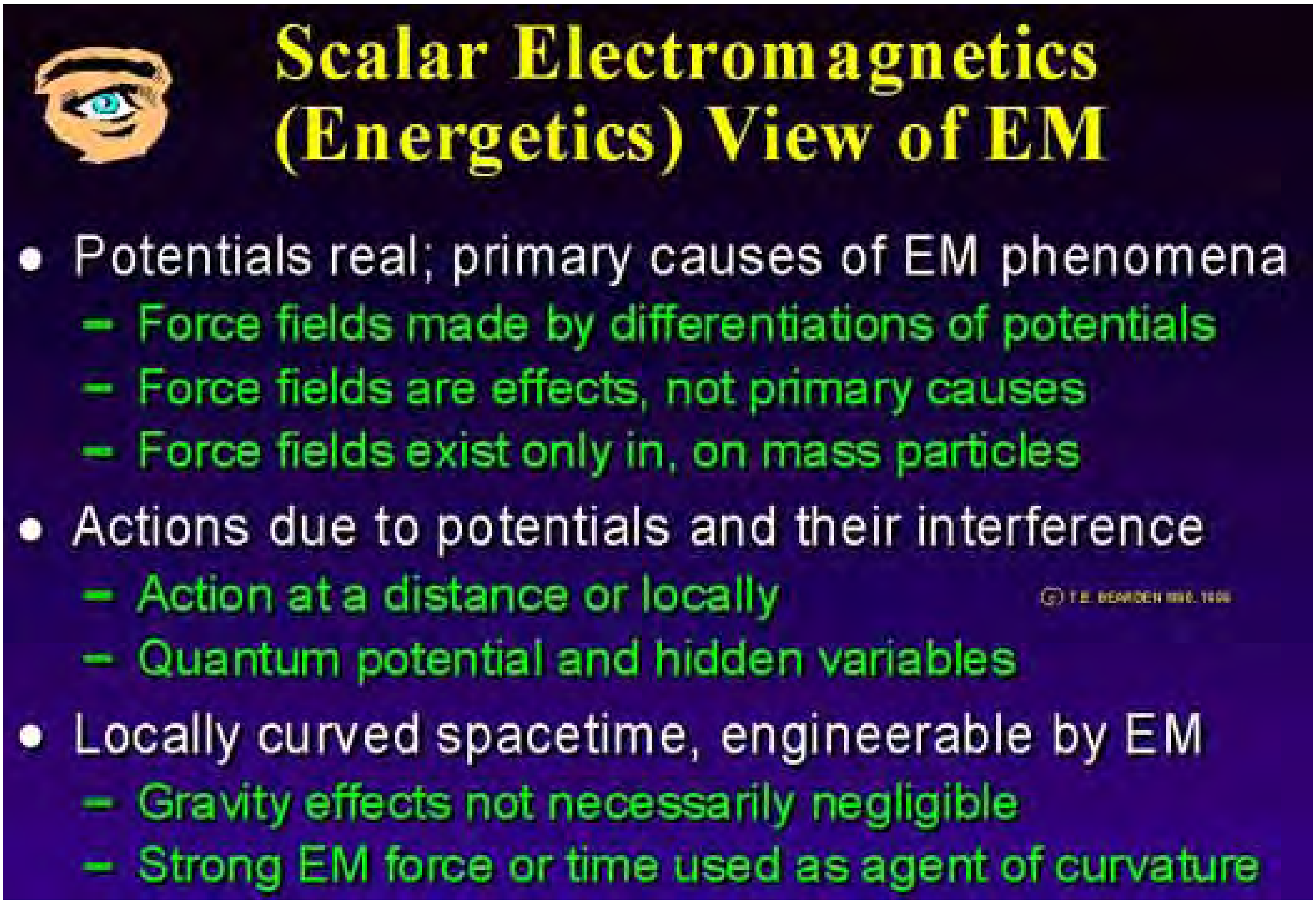

Scalar Electromagnetics (Energetics) View of EM

- Potentials real; primary causes of EM phenomena
  - Force fields made by differentiations of potentials
  - Force fields are effects, not primary causes
  - Force fields exist only in, on mass particles
- Actions due to potentials and their interference
  - Action at a distance or locally
  - Quantum potential and hidden variables
- Locally curved spacetime, engineerable by EM
  - Gravity effects not necessarily negligible
  - Strong EM force or time used as agent of curvature

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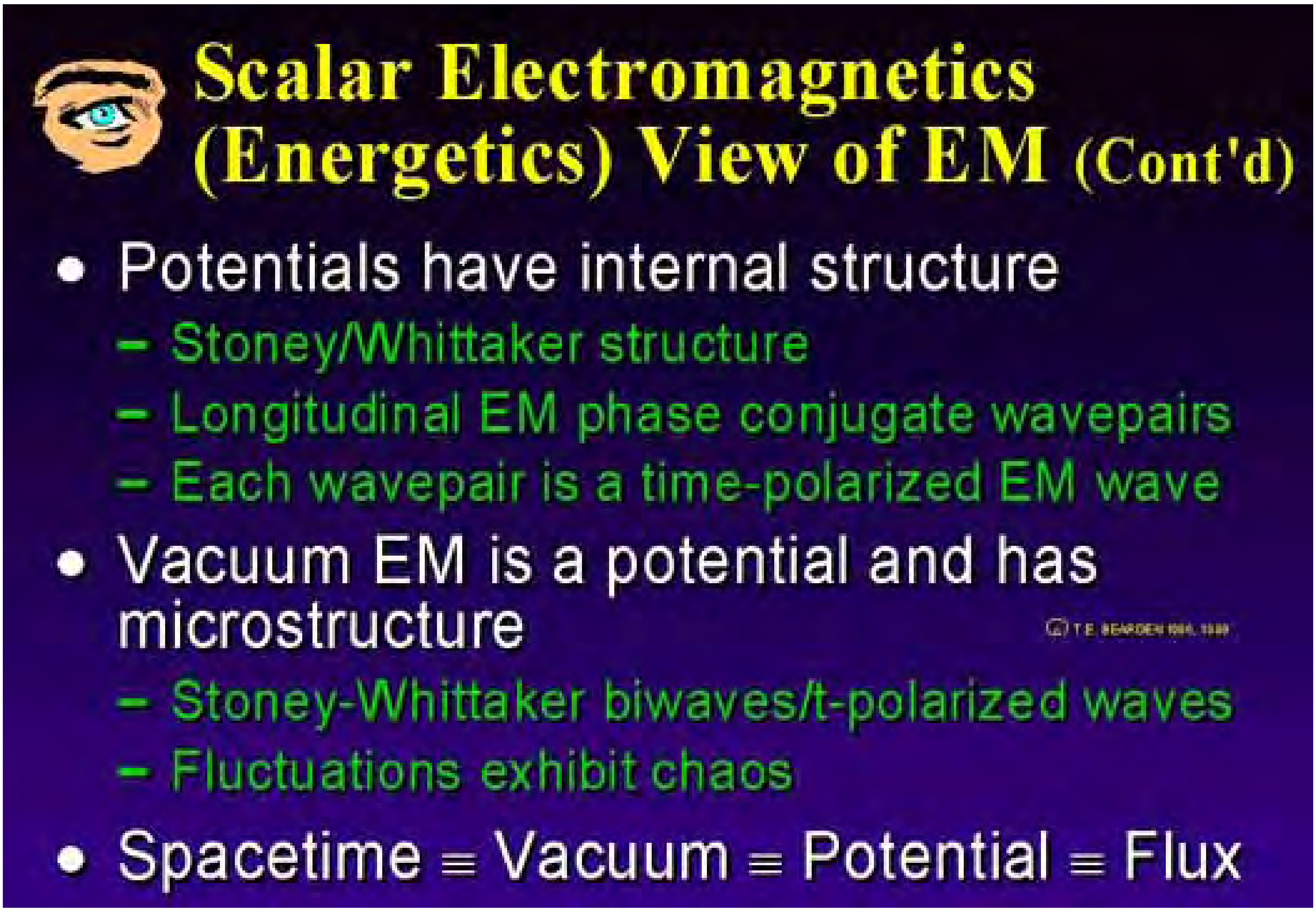

Scalar Electromagnetics (Energetics) View of EM (Cont'd)

- Potentials have internal structure
  - Stoney/Whittaker structure
  - Longitudinal EM phase conjugate wavepairs
  - Each wavepair is a time-polarized EM wave
- Vacuum EM is a potential and has microstructure
  - Stoney-Whittaker biwaves/t-polarized waves
  - Fluctuations exhibit chaos
- Spacetime ≡ Vacuum ≡ Potential ≡ Flux

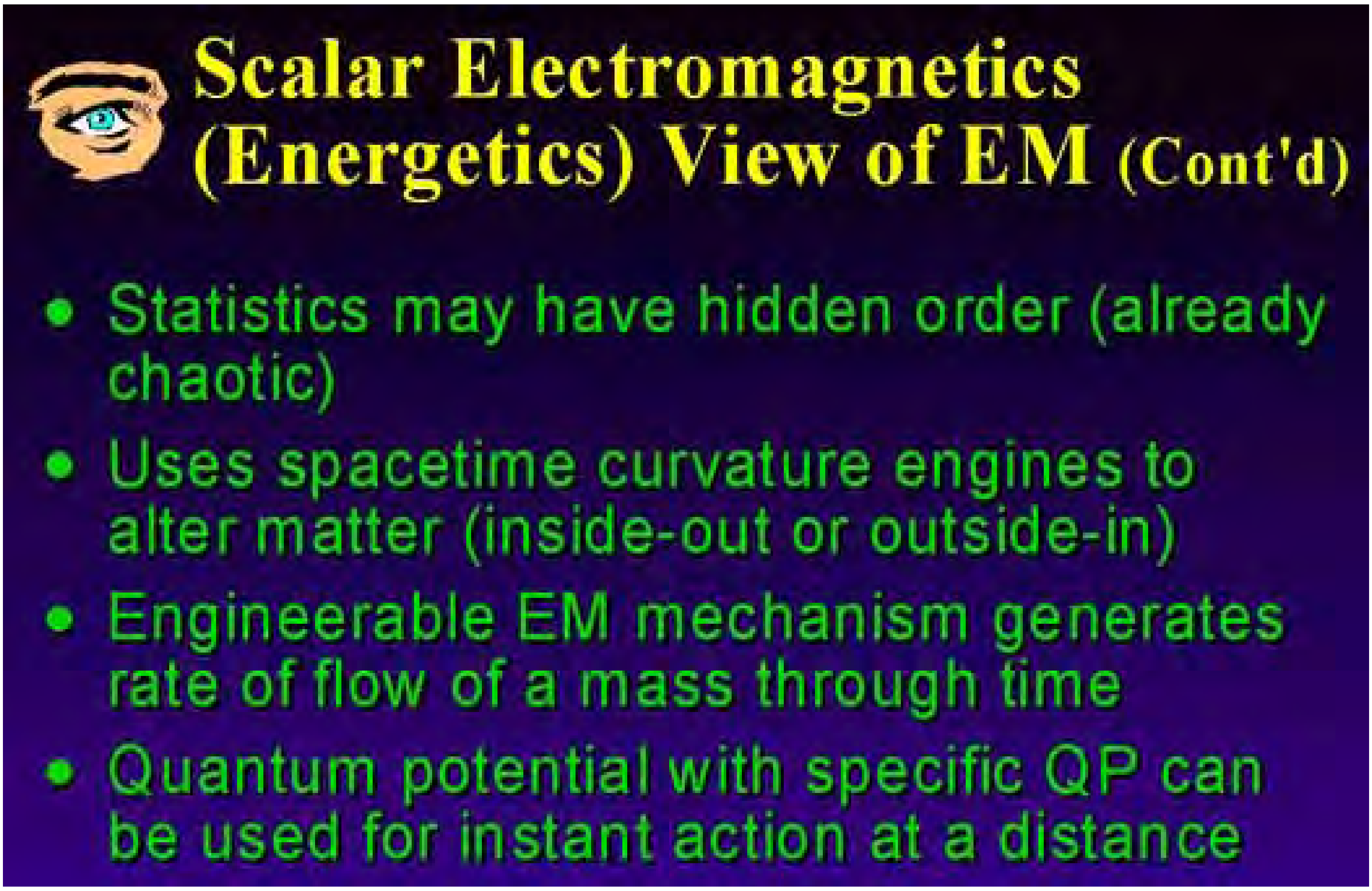

Scalar Electromagnetics (Energetics) View of EM (Cont'd)

- Statistics may have hidden order (already chaotic)
- Uses spacetime curvature engines to alter matter (inside-out or outside-in)
- Engineerable EM mechanism generates rate of flow of a mass through time
- Quantum potential with specific QP can be used for instant action at a distance

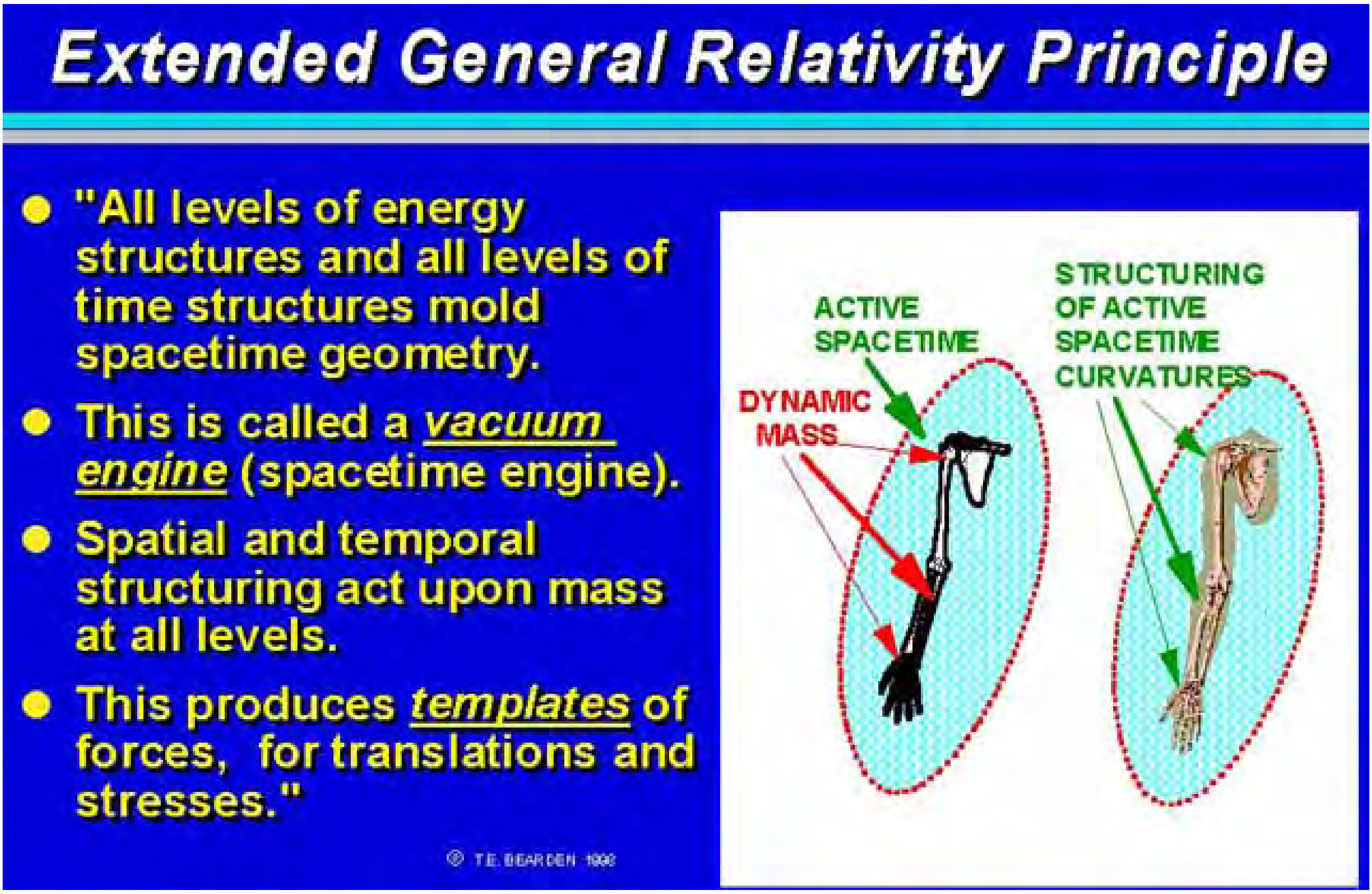

Extended General Relativity Principle

- "All levels of energy structures and all levels of time structures mold spacetime geometry.
- This is called a ***vacuum engine*** (spacetime engine).
- Spatial and temporal structuring act upon mass at all levels.
- This produces ***templates*** of forces, for translations and stresses."

ACTIVE SPACETIME
DYNAMIC MASS
STRUCTURING OF ACTIVE SPACETIME CURVATURES

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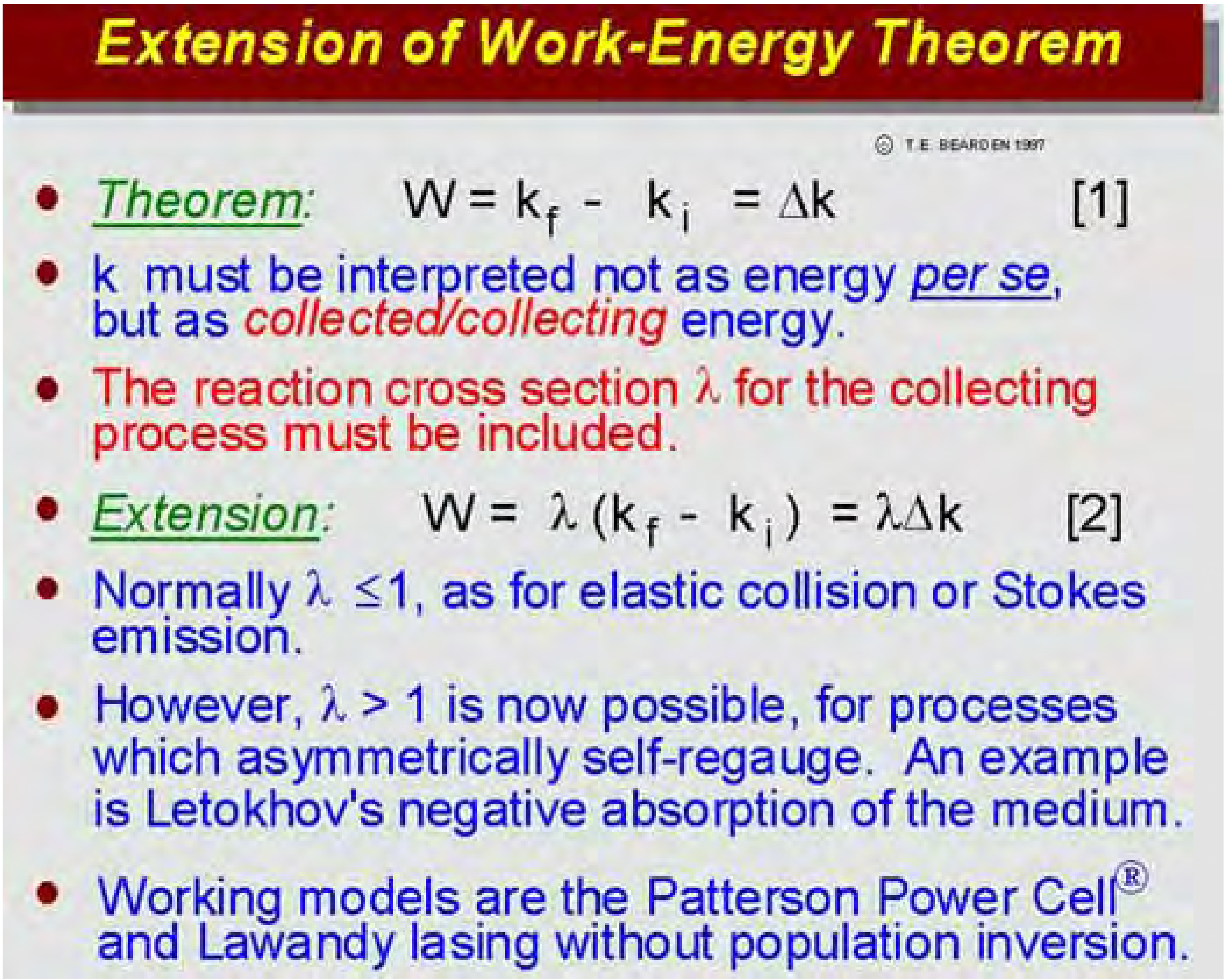

Extension of Work-Energy Theorem

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- *Theorem*: $W = k_f - k_i = \Delta k$ [1]
- k must be interpreted not as energy *per se*, but as *collected/collecting* energy.
- The reaction cross section λ for the collecting process must be included.
- *Extension*: $W = \lambda (k_f - k_i) = \lambda \Delta k$ [2]
- Normally $\lambda \leq 1$, as for elastic collision or Stokes emission.
- However, $\lambda > 1$ is now possible, for processes which asymmetrically self-regauge. An example is Letokhov's negative absorption of the medium.
- Working models are the Patterson Power Cell® and Lawandy lasing without population inversion.

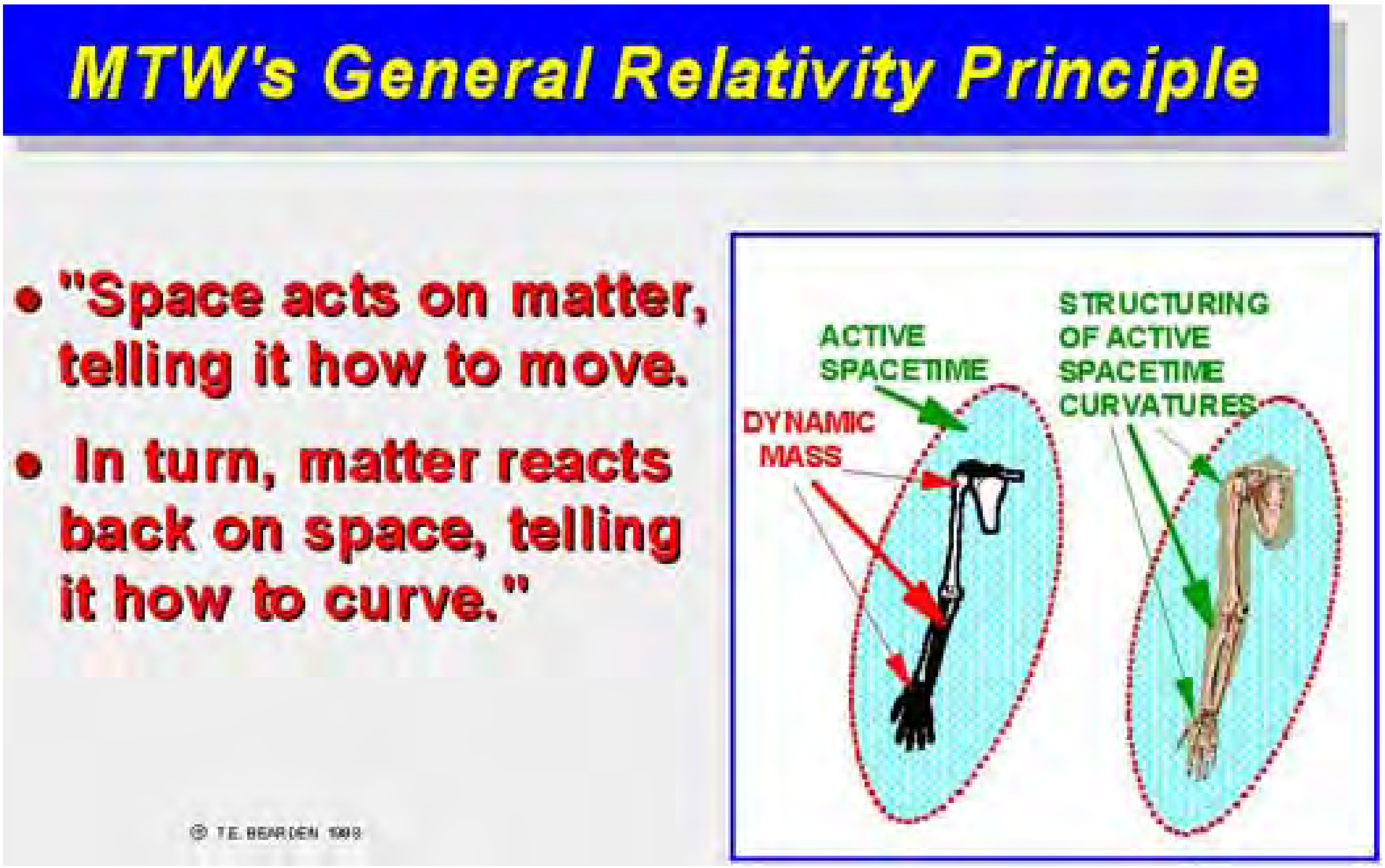

MTW's General Relativity Principle

- "Space acts on matter, telling it how to move.
- In turn, matter reacts back on space, telling it how to curve."

ACTIVE SPACETIME
STRUCTURING OF ACTIVE SPACETIME CURVATURES
DYNAMIC MASS

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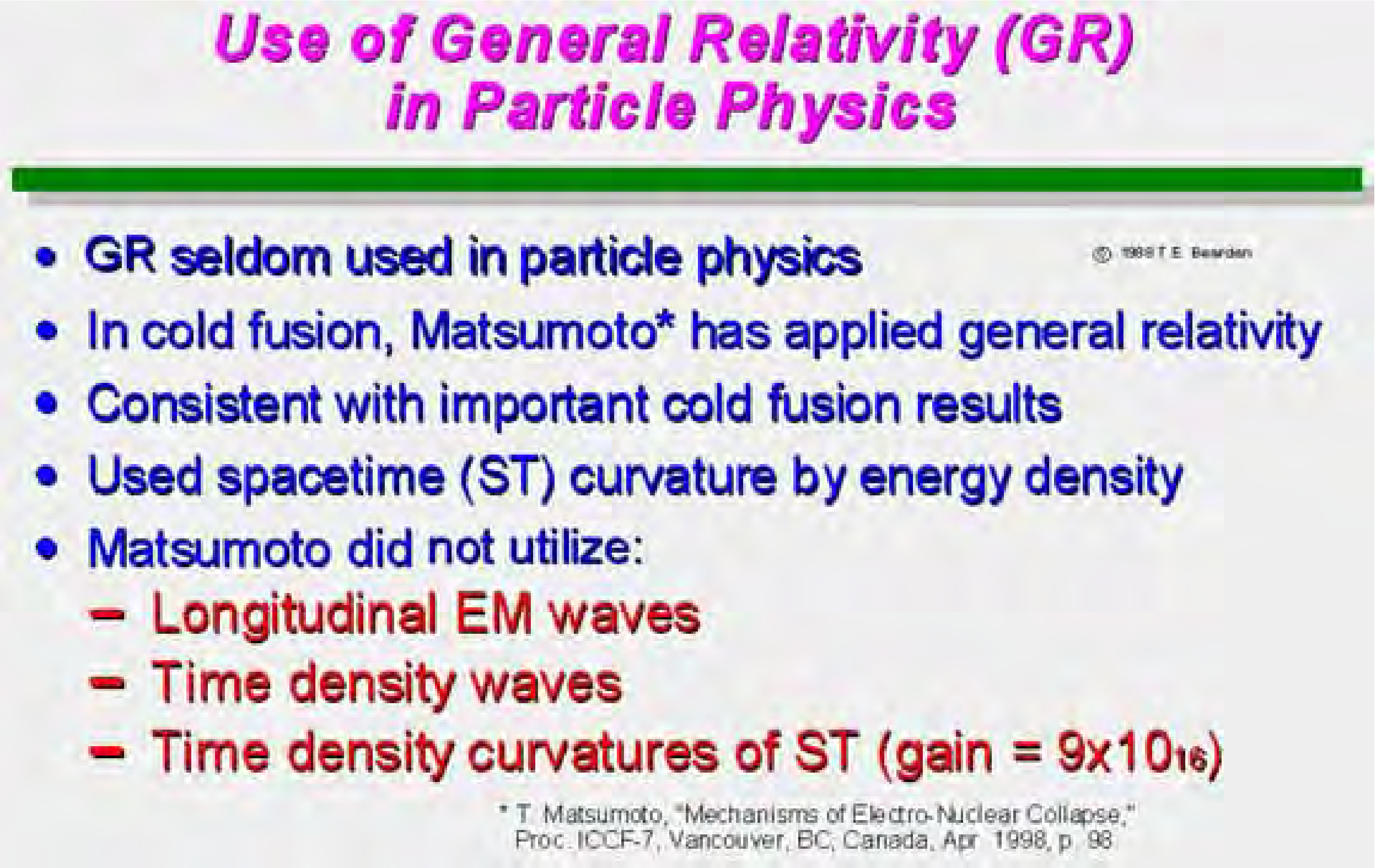

Use of General Relativity (GR) in Particle Physics

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- GR seldom used in particle physics
- In cold fusion, Matsumoto* has applied general relativity
- Consistent with important cold fusion results
- Used spacetime (ST) curvature by energy density
- Matsumoto did not utilize:
  - Longitudinal EM waves
  - Time density waves
  - Time density curvatures of ST (gain = 9x10$_{16}$)

* T. Matsumoto, "Mechanisms of Electro-Nuclear Collapse," Proc. ICCF-7, Vancouver, BC, Canada, Apr. 1998, p. 98.

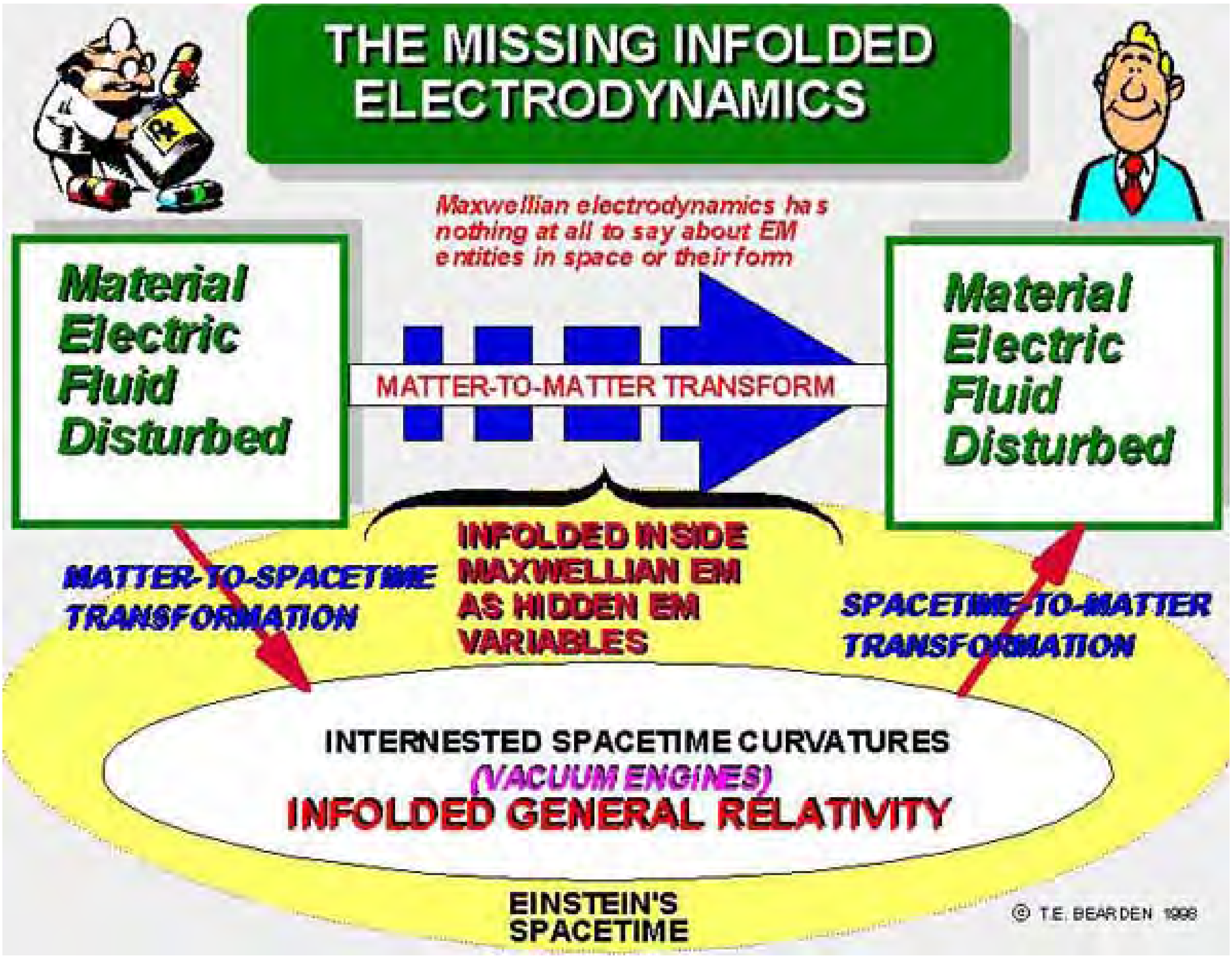

THE MISSING INFOLDED ELECTRODYNAMICS

Maxwellian electrodynamics has nothing at all to say about EM entities in space or their form

Material Electric Fluid Disturbed

MATTER-TO-MATTER TRANSFORM

Material Electric Fluid Disturbed

INFOLDED INSIDE MAXWELLIAN EM AS HIDDEN EM VARIABLES

MATTER-TO-SPACETIME TRANSFORMATION

SPACETIME-TO-MATTER TRANSFORMATION

INTERNESTED SPACETIME CURVATURES

(VACUUM ENGINES)

INFOLDED GENERAL RELATIVITY

EINSTEIN'S SPACETIME

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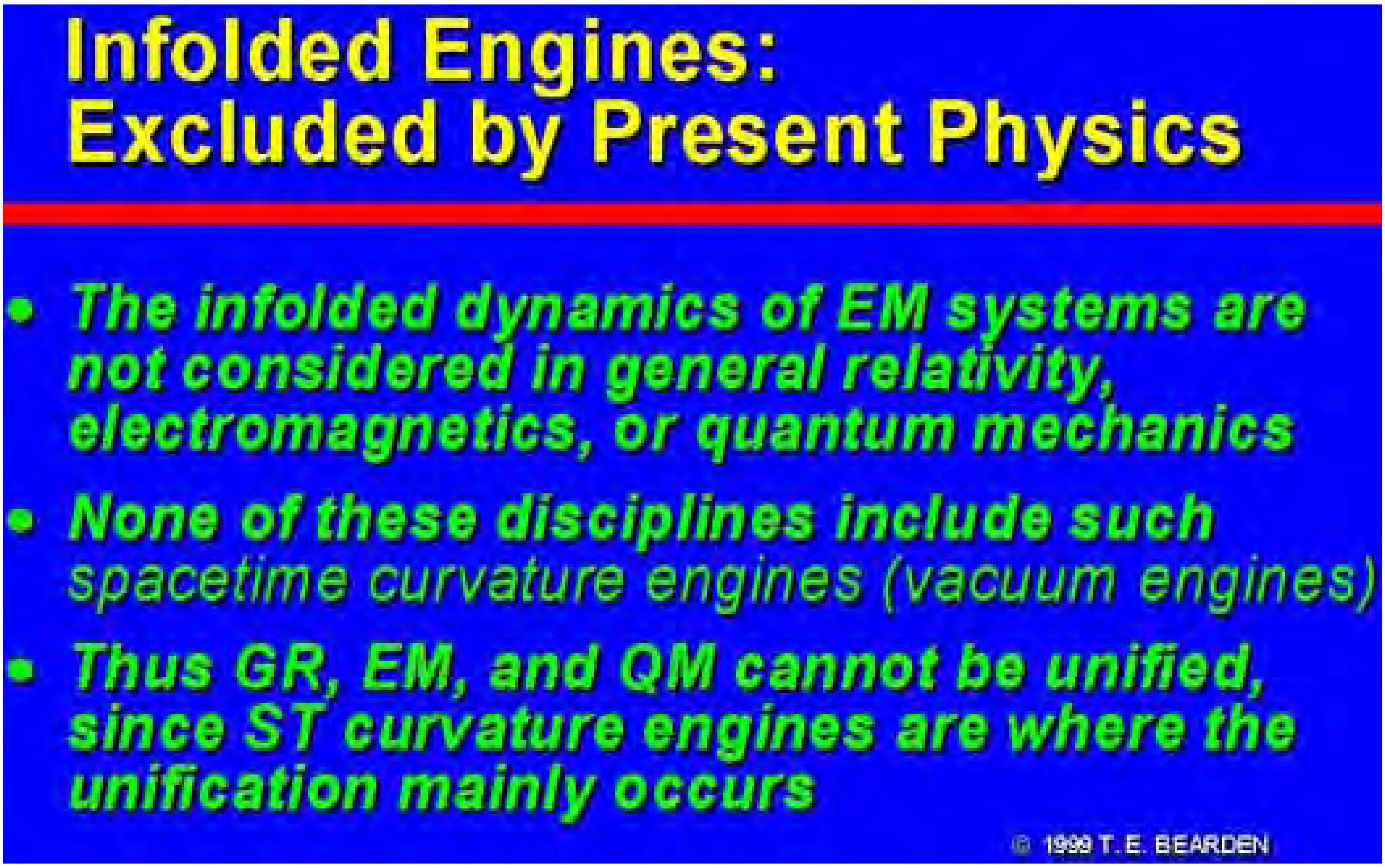

Infolded Engines: Excluded by Present Physics

- *The infolded dynamics of EM systems are not considered in general relativity, electromagnetics, or quantum mechanics*
- *None of these disciplines include such spacetime curvature engines (vacuum engines)*
- *Thus GR, EM, and QM cannot be unified, since ST curvature engines are where the unification mainly occurs*

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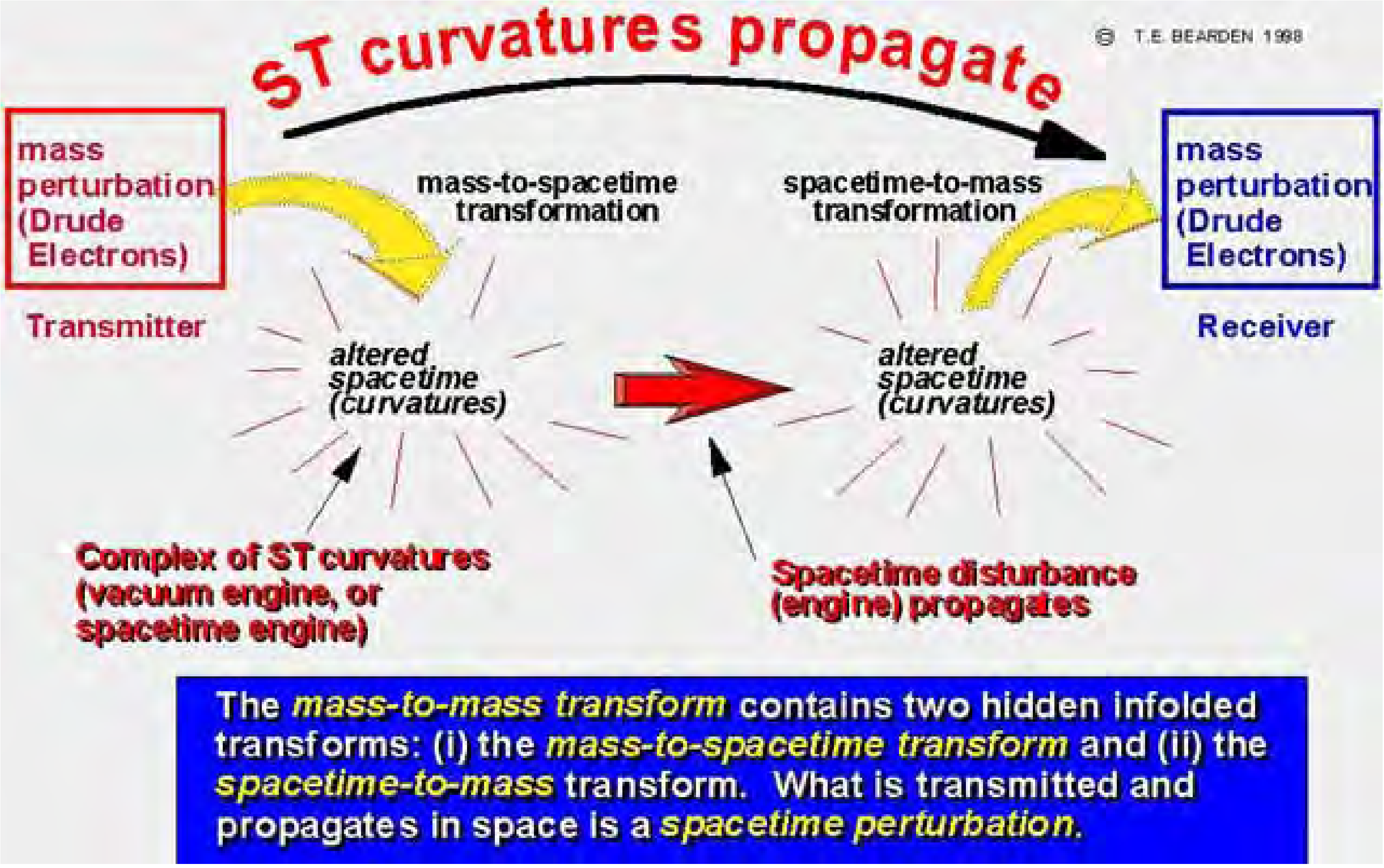
ST curvatures propagate
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mass perturbation (Drude Electrons)
Transmitter
mass-to-spacetime transformation
altered spacetime (curvatures)
spacetime-to-mass transformation
altered spacetime (curvatures)
mass perturbation (Drude Electrons)
Receiver
Complex of ST curvatures (vacuum engine, or spacetime engine)
Spacetime disturbance (engine) propagates

The *mass-to-mass transform* contains two hidden infolded transforms: (i) the *mass-to-spacetime transform* and (ii) the *spacetime-to-mass* transform. What is transmitted and propagates in space is a *spacetime perturbation.*

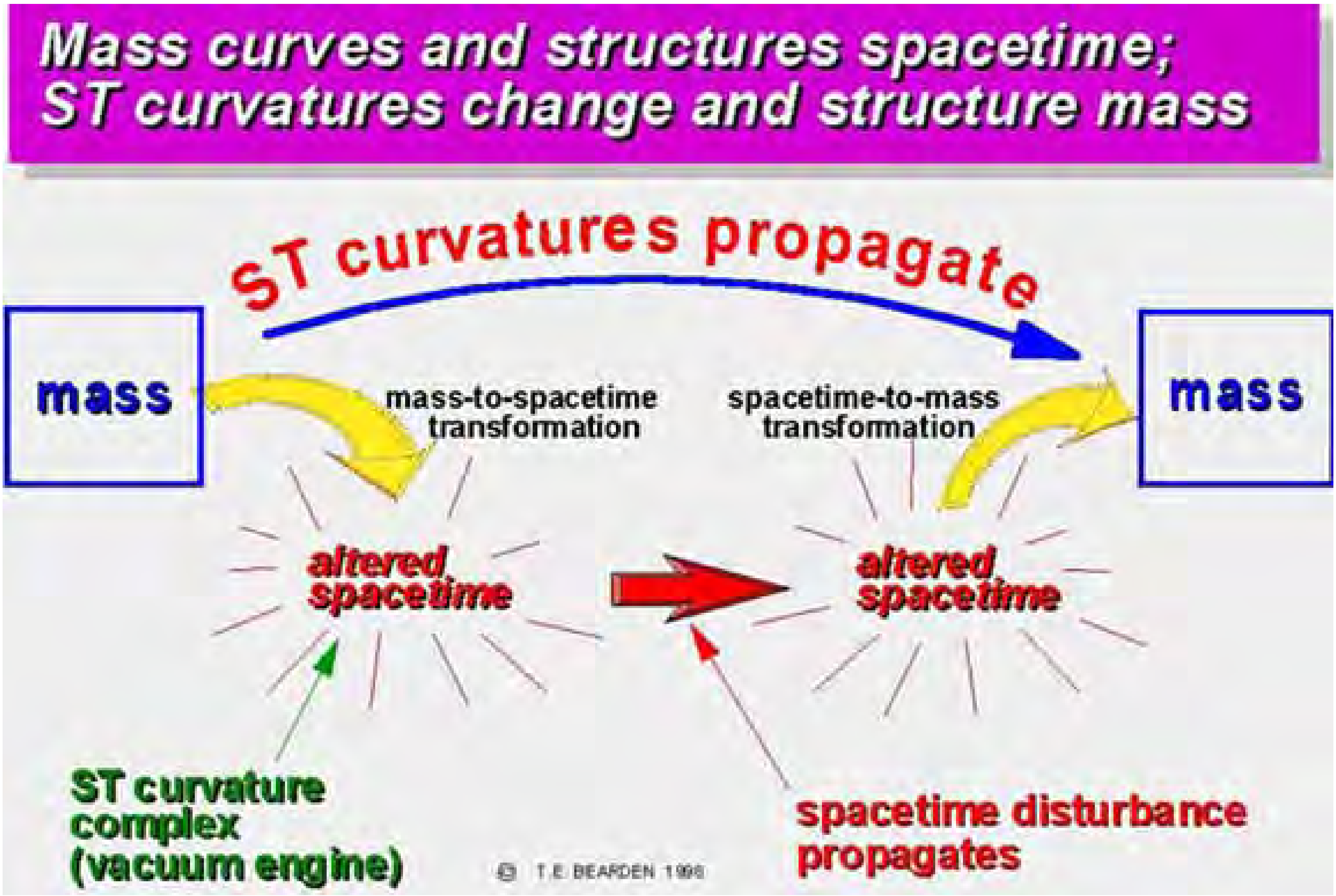

Mass curves and structures spacetime; ST curvatures change and structure mass

ST curvatures propagate

mass

mass-to-spacetime transformation

altered spacetime

spacetime-to-mass transformation

altered spacetime

mass

ST curvature complex (vacuum engine)

spacetime disturbance propagates

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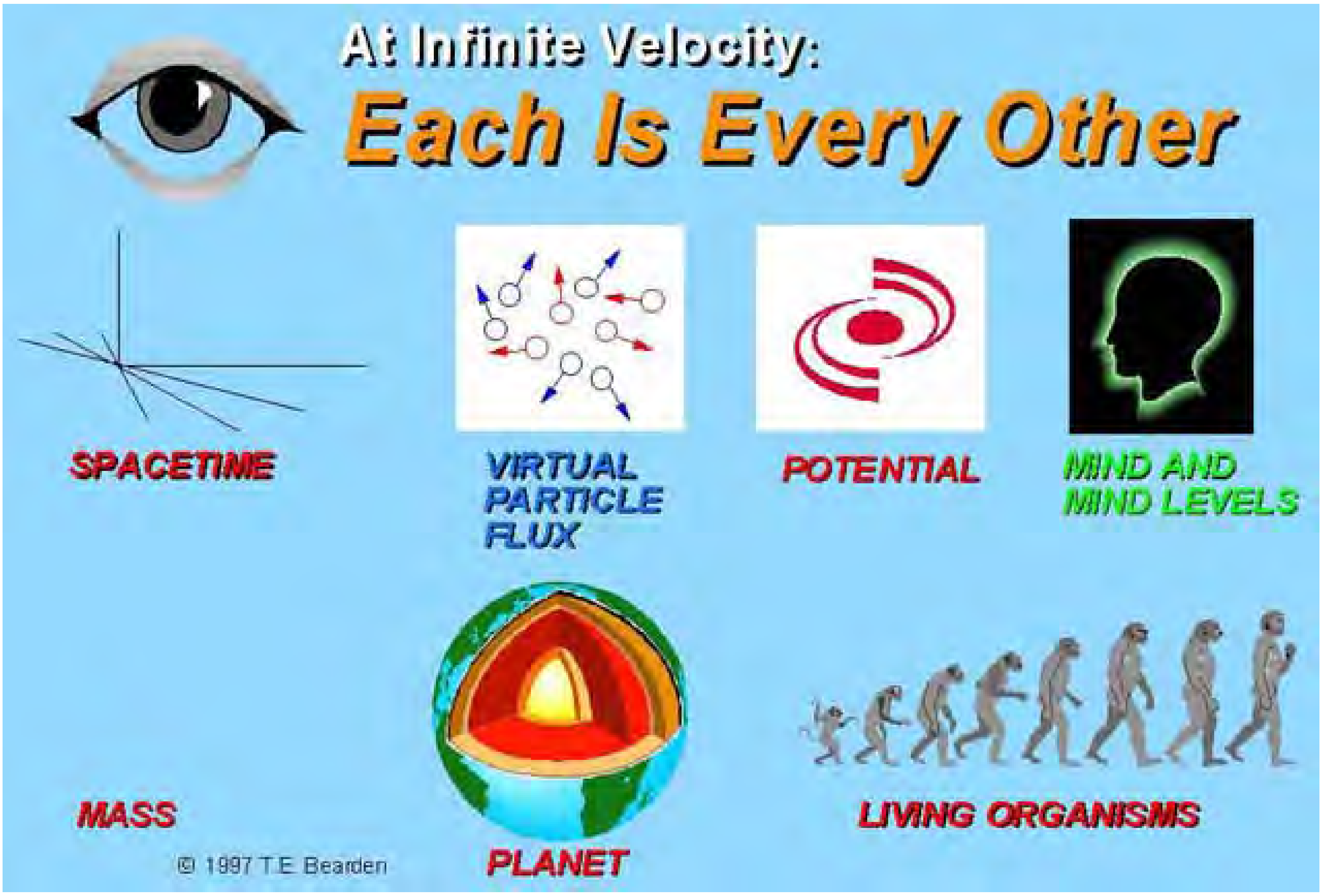

At Infinite Velocity:

Each Is Every Other

SPACETIME

VIRTUAL PARTICLE FLUX

POTENTIAL

MIND AND MIND LEVELS

MASS

PLANET

LIVING ORGANISMS

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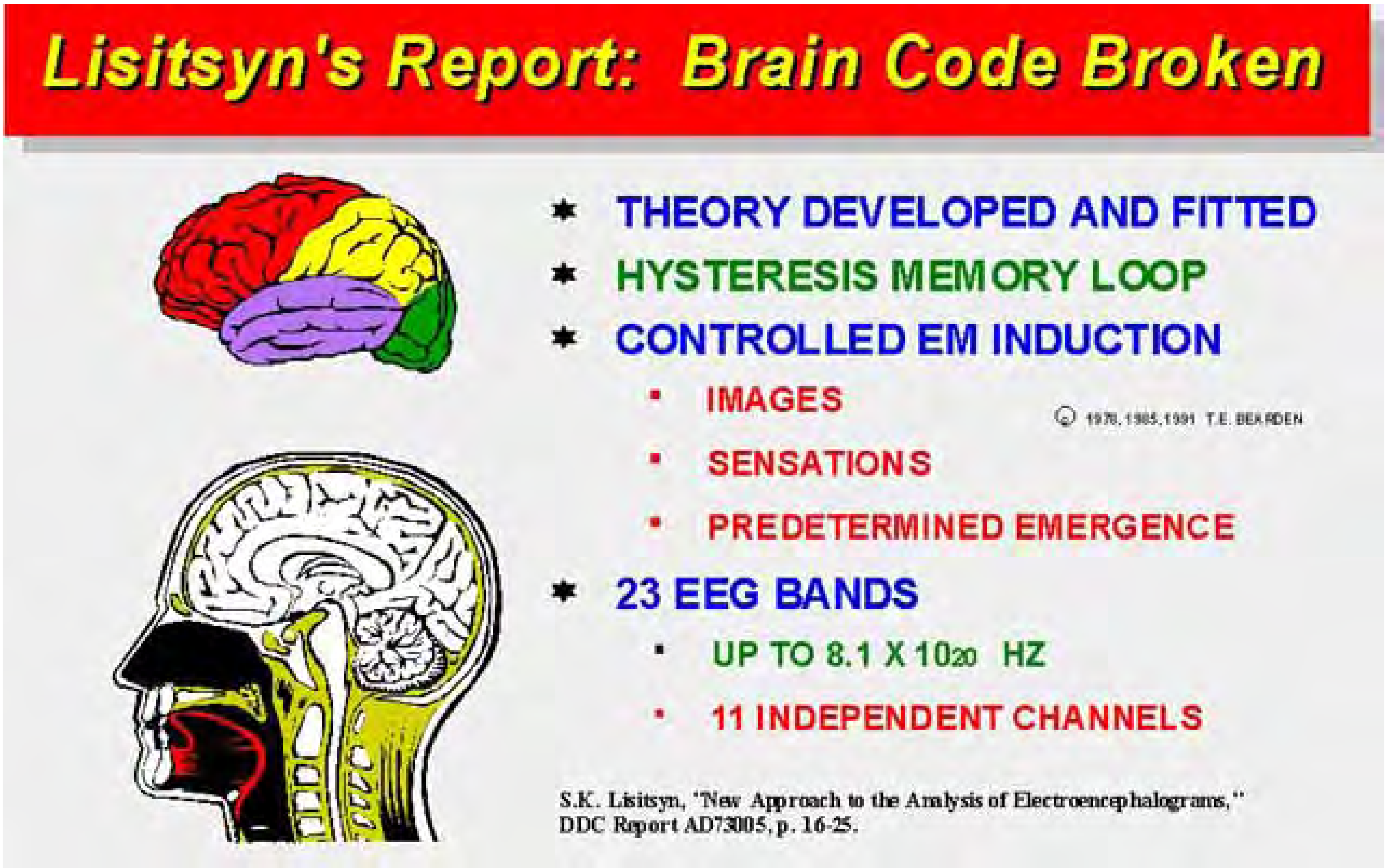

Lisitsyn's Report: Brain Code Broken

- THEORY DEVELOPED AND FITTED
- HYSTERESIS MEMORY LOOP
- CONTROLLED EM INDUCTION
  - IMAGES
  - SENSATIONS
  - PREDETERMINED EMERGENCE
- 23 EEG BANDS
  - UP TO 8.1 X 10^{20} HZ
  - 11 INDEPENDENT CHANNELS

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S.K. Lisitsyn, "New Approach to the Analysis of Electroencephalograms," DDC Report AD73005, p. 16-25.

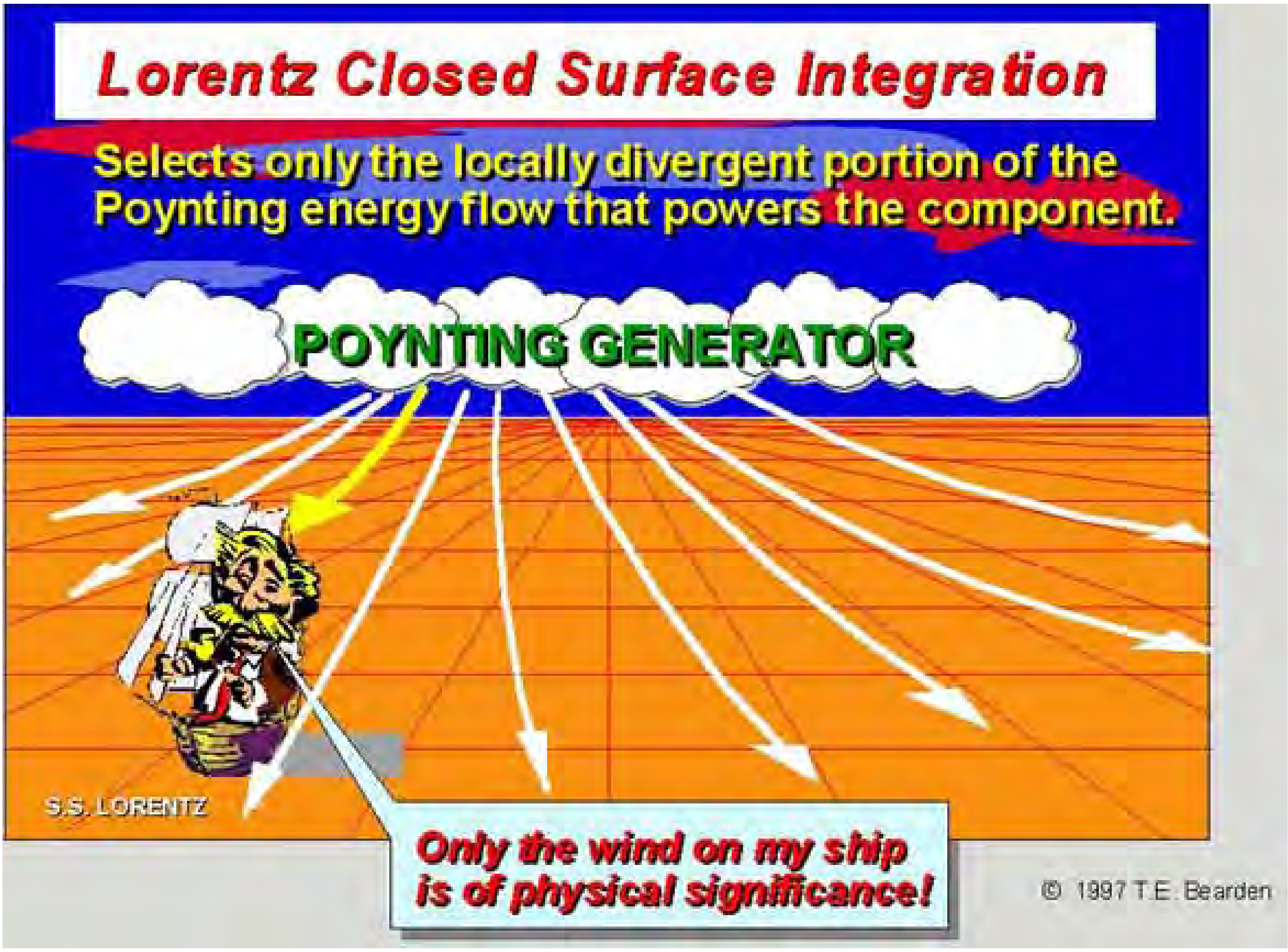

Lorentz Closed Surface Integration

Selects only the locally divergent portion of the Poynting energy flow that powers the component.

POYNTING GENERATOR

S.S. LORENTZ

Only the wind on my ship is of physical significance!

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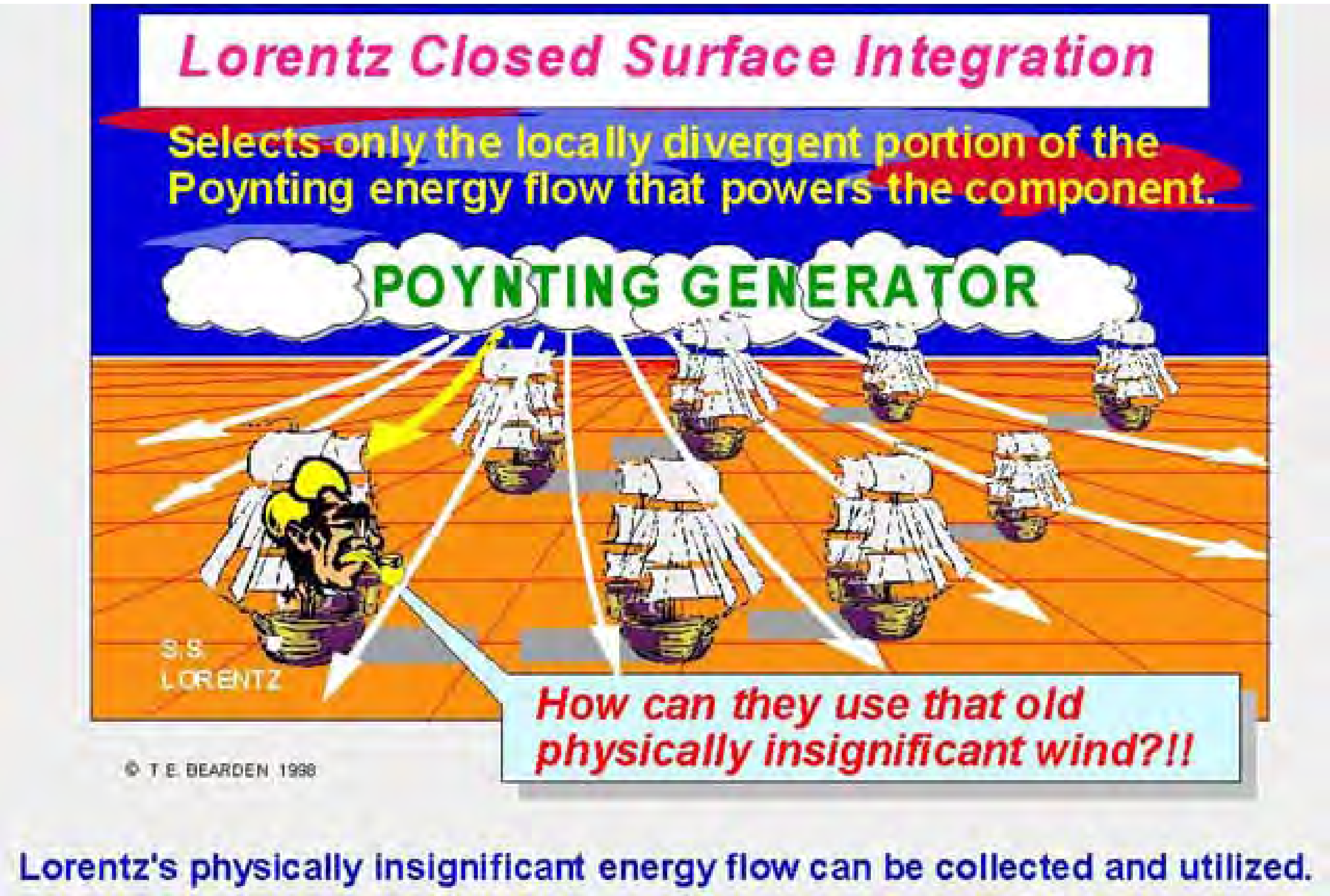

Lorentz Closed Surface Integration

Selects only the locally divergent portion of the Poynting energy flow that powers the component.

POYNTING GENERATOR

How can they use that old physically insignificant wind?!!

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Lorentz's physically insignificant energy flow can be collected and utilized.

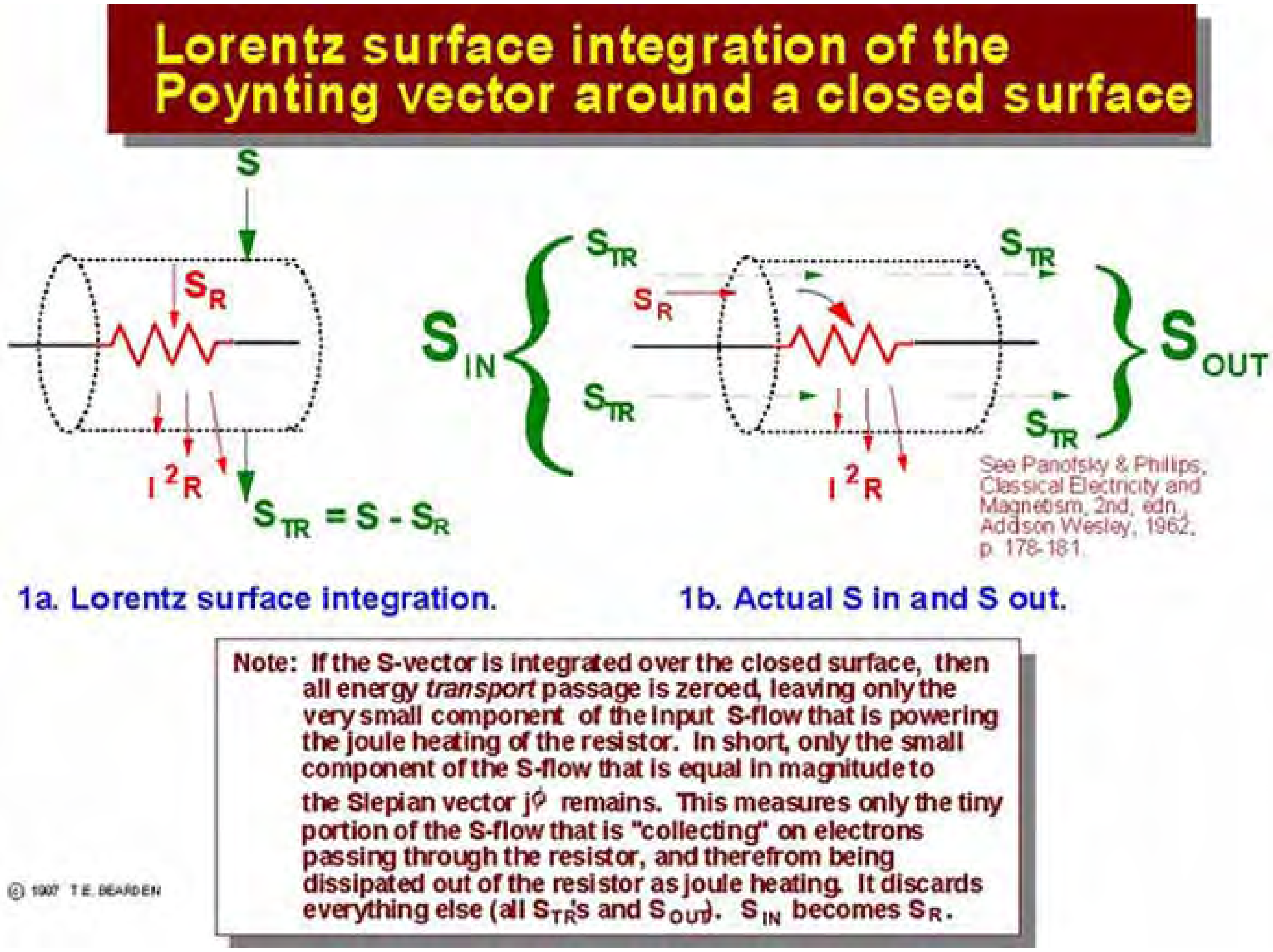

Lorentz surface integration of the Poynting vector around a closed surface

See Panofsky & Phillips, Classical Electricity and Magnetism, 2nd. edn., Addison Wesley, 1962, p. 178-181.

1a. Lorentz surface integration.

1b. Actual S in and S out.

Note: If the S-vector is integrated over the closed surface, then all energy *transport* passage is zeroed, leaving only the very small component of the input S-flow that is powering the joule heating of the resistor. In short, only the small component of the S-flow that is equal in magnitude to the Slepian vector $j\phi$ remains. This measures only the tiny portion of the S-flow that is "collecting" on electrons passing through the resistor, and therefrom being dissipated out of the resistor as joule heating. It discards everything else (all S_{TR}'s and S_{OUT}). S_{IN} becomes S_R.

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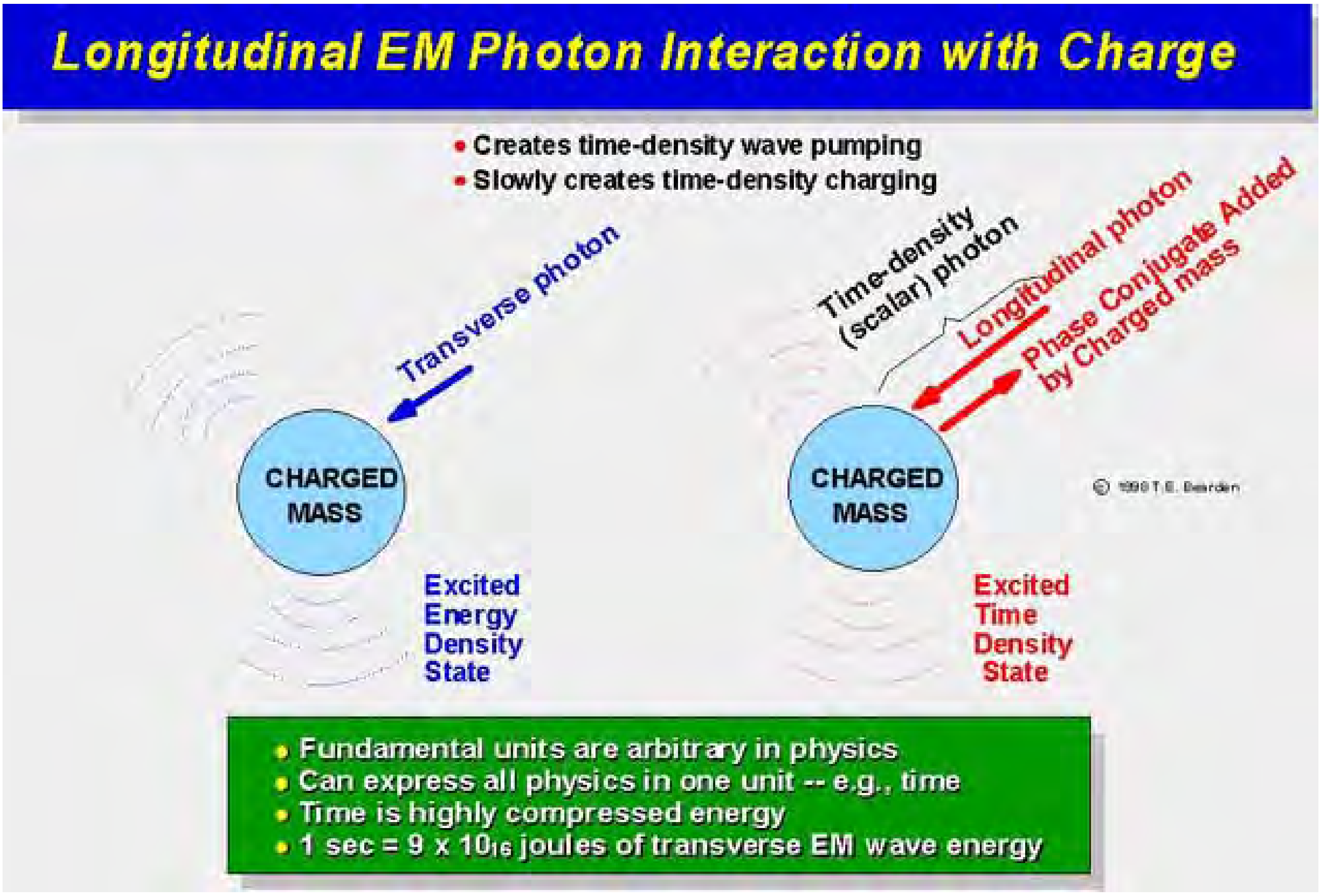

Longitudinal EM Photon Interaction with Charge

- Creates time-density wave pumping
- Slowly creates time-density charging

Transverse photon

CHARGED MASS

Excited Energy Density State

Time-density (scalar) photon

Longitudinal photon

Phase Conjugate Added by Charged mass

CHARGED MASS

Excited Time Density State

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- Fundamental units are arbitrary in physics
- Can express all physics in one unit -- e.g., time
- Time is highly compressed energy
- 1 sec = 9 x 10_{16} joules of transverse EM wave energy

Figure 1-8. Infolded biwave composition of a scalar potential.

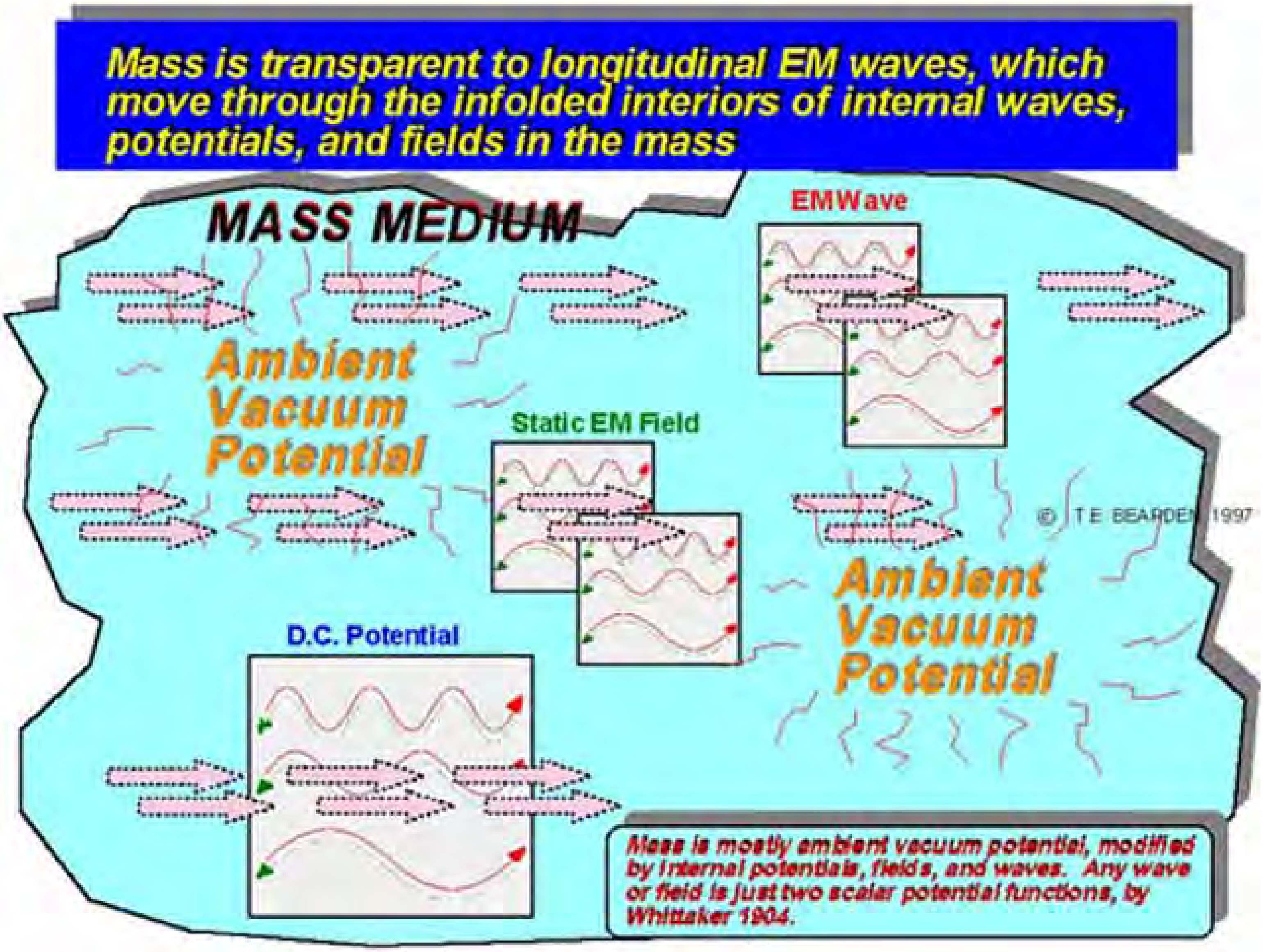

Mass is transparent to longitudinal EM waves, which move through the infolded interiors of internal waves, potentials, and fields in the mass

MASS MEDIUM
EMWave
Ambient Vacuum Potential
Static EM Field
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Ambient Vacuum Potential
D.C. Potential

Mass is mostly ambient vacuum potential, modified by internal potentials, fields, and waves. Any wave or field is just two scalar potential functions, by Whittaker 1904.

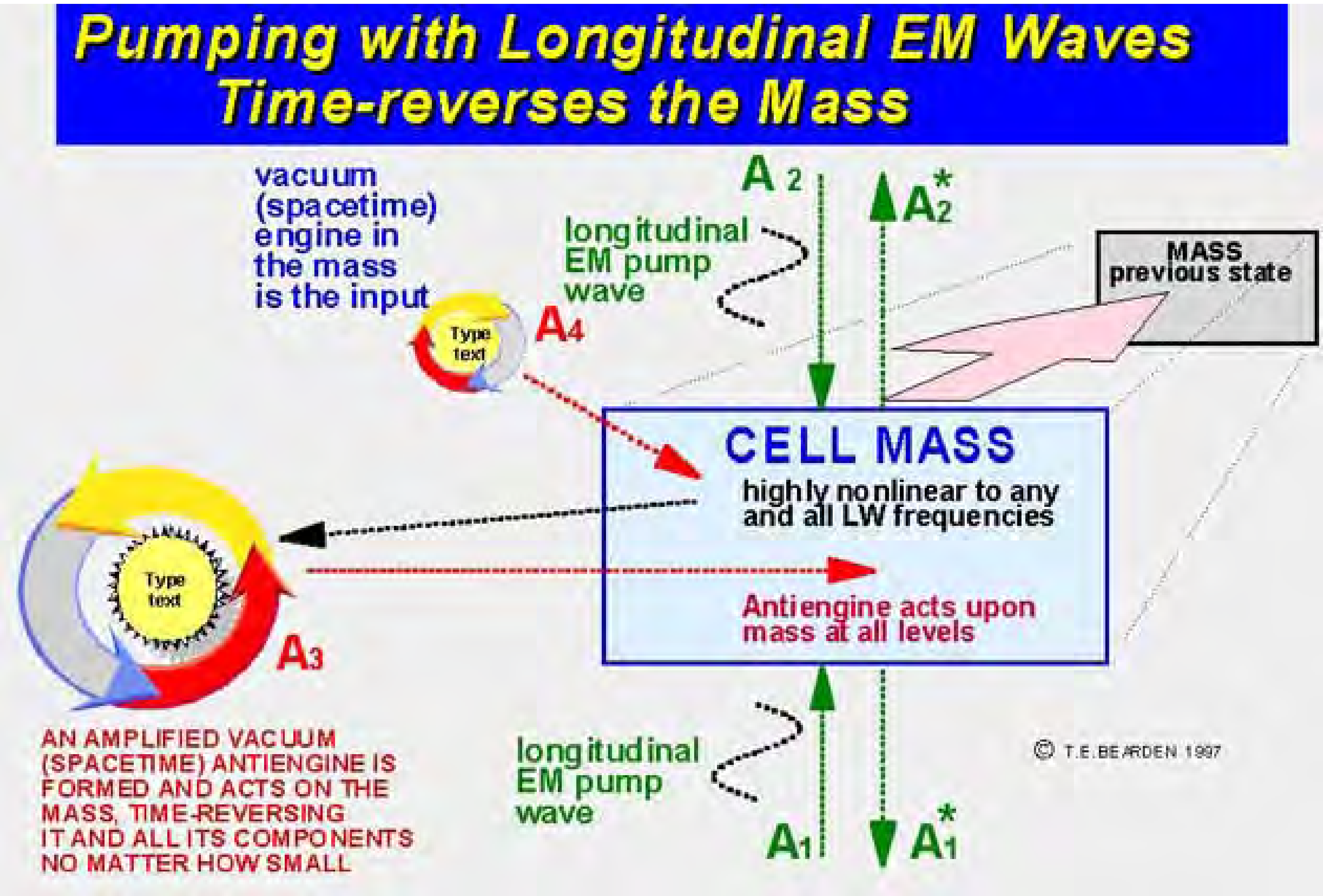

Pumping with Longitudinal EM Waves Time-reverses the Mass

vacuum (spacetime) engine in the mass is the input

longitudinal EM pump wave

MASS previous state

CELL MASS

highly nonlinear to any and all LW frequencies

Antiengine acts upon mass at all levels

AN AMPLIFIED VACUUM (SPACETIME) ANTIENGINE IS FORMED AND ACTS ON THE MASS, TIME-REVERSING IT AND ALL ITS COMPONENTS NO MATTER HOW SMALL

longitudinal EM pump wave

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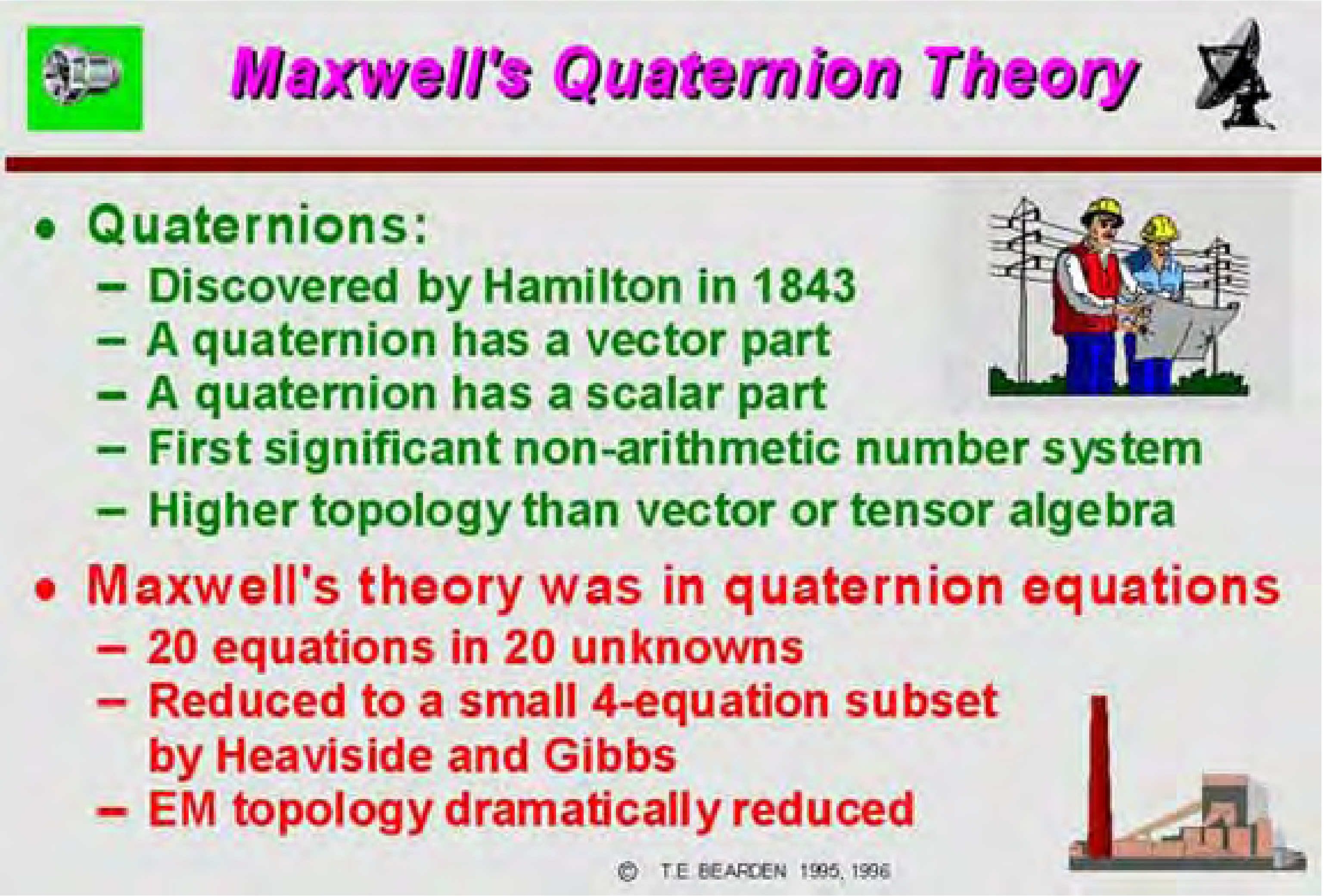

Maxwell's Quaternion Theory

- Quaternions:
  - Discovered by Hamilton in 1843
  - A quaternion has a vector part
  - A quaternion has a scalar part
  - First significant non-arithmetic number system
  - Higher topology than vector or tensor algebra
- Maxwell's theory was in quaternion equations
  - 20 equations in 20 unknowns
  - Reduced to a small 4-equation subset by Heaviside and Gibbs
  - EM topology dramatically reduced

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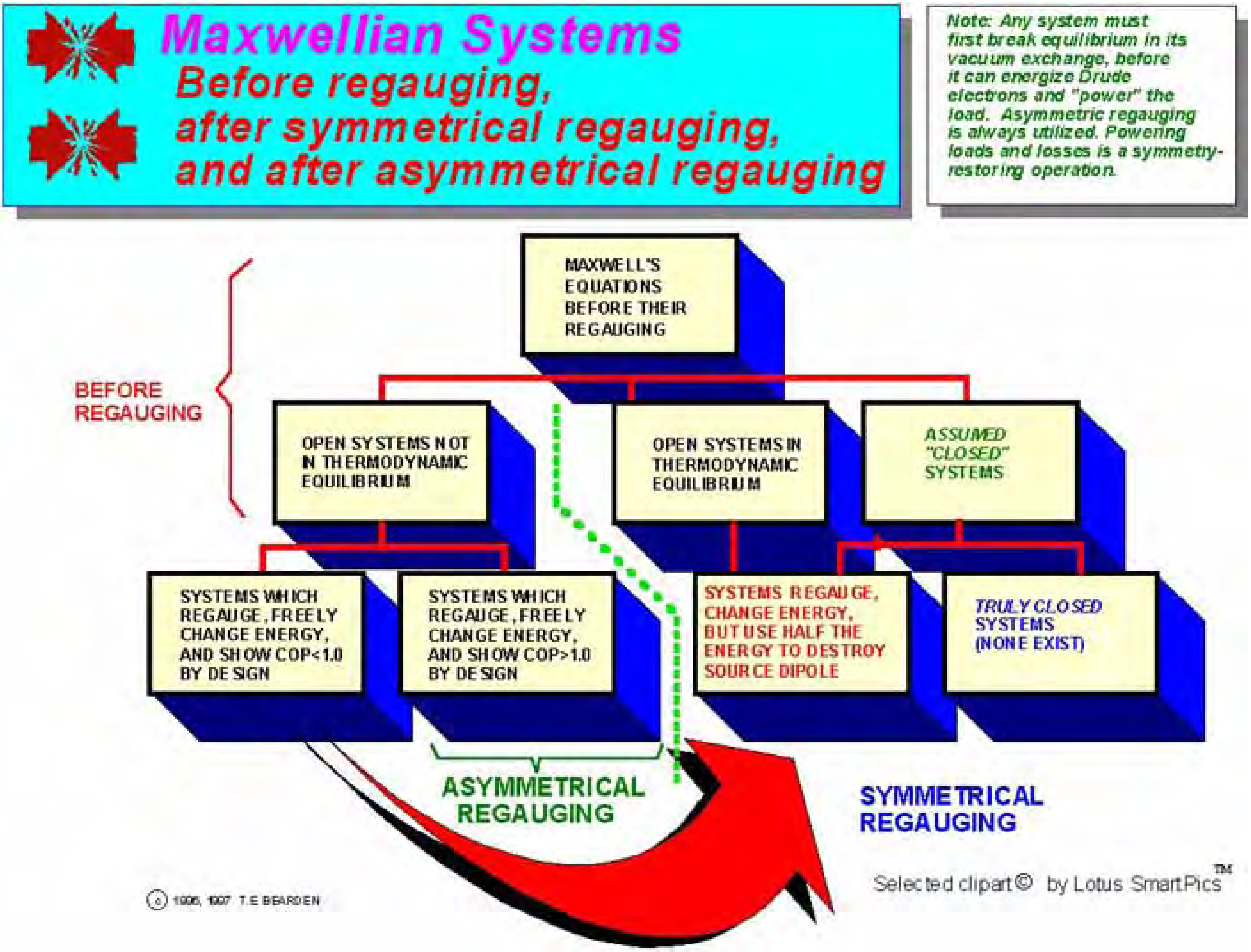

Maxwellian Systems
Before regauging, after symmetrical regauging, and after asymmetrical regauging

Note: Any system must first break equilibrium in its vacuum exchange, before it can energize Drude electrons and "power" the load. Asymmetric regauging is always utilized. Powering loads and losses is a symmetry-restoring operation.

MAXWELL'S EQUATIONS BEFORE THEIR REGAUGING

BEFORE REGAUGING

OPEN SYSTEMS NOT IN THERMODYNAMIC EQUILIBRIUM

OPEN SYSTEMS IN THERMODYNAMIC EQUILIBRIUM

ASSUMED "CLOSED" SYSTEMS

SYSTEMS WHICH REGAUGE, FREELY CHANGE ENERGY, AND SHOW COP<1.0 BY DESIGN

SYSTEMS WHICH REGAUGE, FREELY CHANGE ENERGY, AND SHOW COP>1.0 BY DESIGN

SYSTEMS REGAUGE, CHANGE ENERGY, BUT USE HALF THE ENERGY TO DESTROY SOURCE DIPOLE

TRULY CLOSED SYSTEMS (NONE EXIST)

ASYMMETRICAL REGAUGING

SYMMETRICAL REGAUGING

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Selected clipart© by Lotus SmartPics™

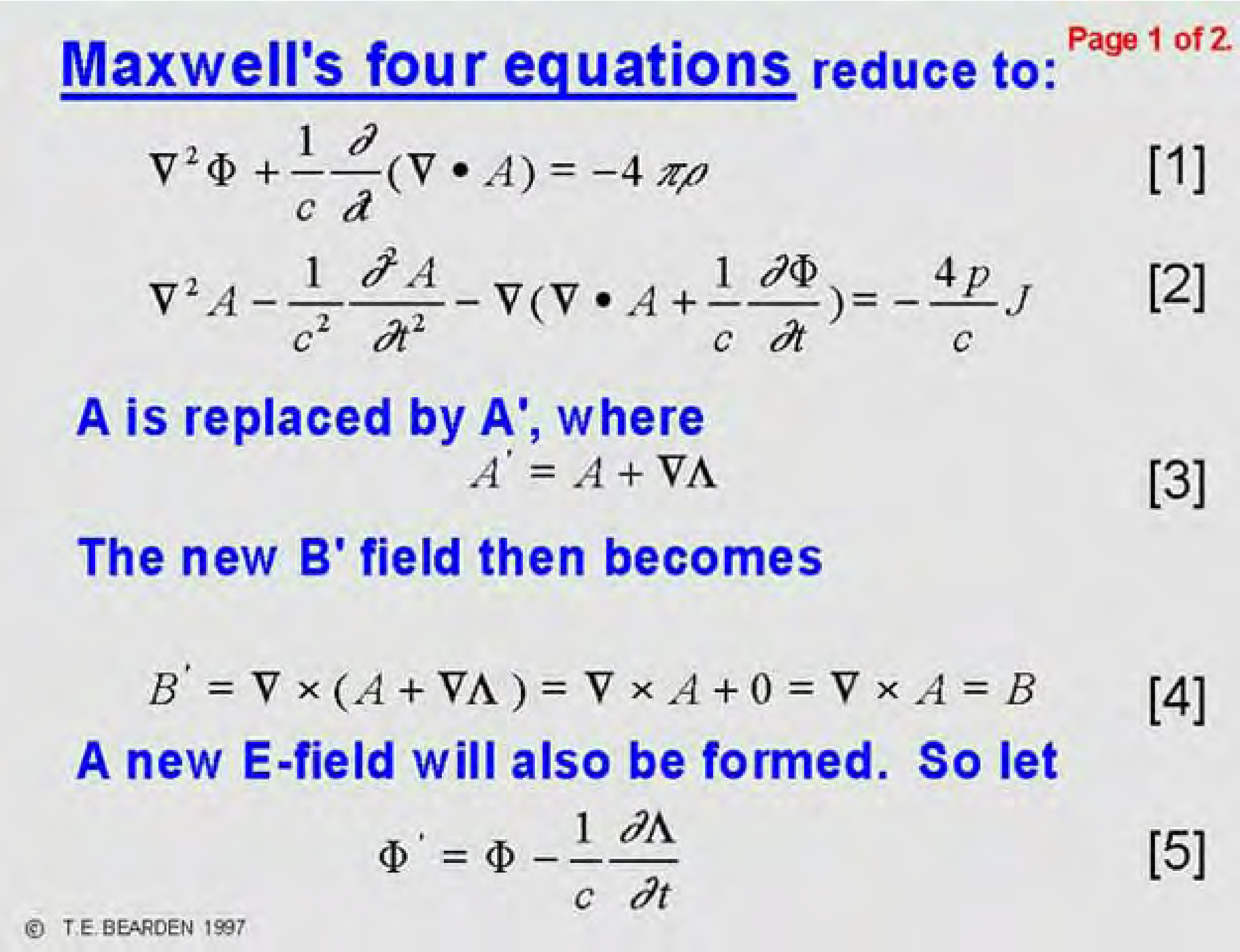

Page 1 of 2.

Maxwell's four equations reduce to:

$$\nabla^2 \Phi + \frac{1}{c}\frac{\partial}{\partial t}(\nabla \bullet A) = -4\pi\rho \qquad [1]$$

$$\nabla^2 A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} - \nabla\left(\nabla \bullet A + \frac{1}{c}\frac{\partial \Phi}{\partial t}\right) = -\frac{4p}{c}J \qquad [2]$$

A is replaced by A', where

$$A' = A + \nabla\Lambda \qquad [3]$$

The new B' field then becomes

$$B' = \nabla \times (A + \nabla\Lambda) = \nabla \times A + 0 = \nabla \times A = B \qquad [4]$$

A new E-field will also be formed. So let

$$\Phi' = \Phi - \frac{1}{c}\frac{\partial\Lambda}{\partial t} \qquad [5]$$

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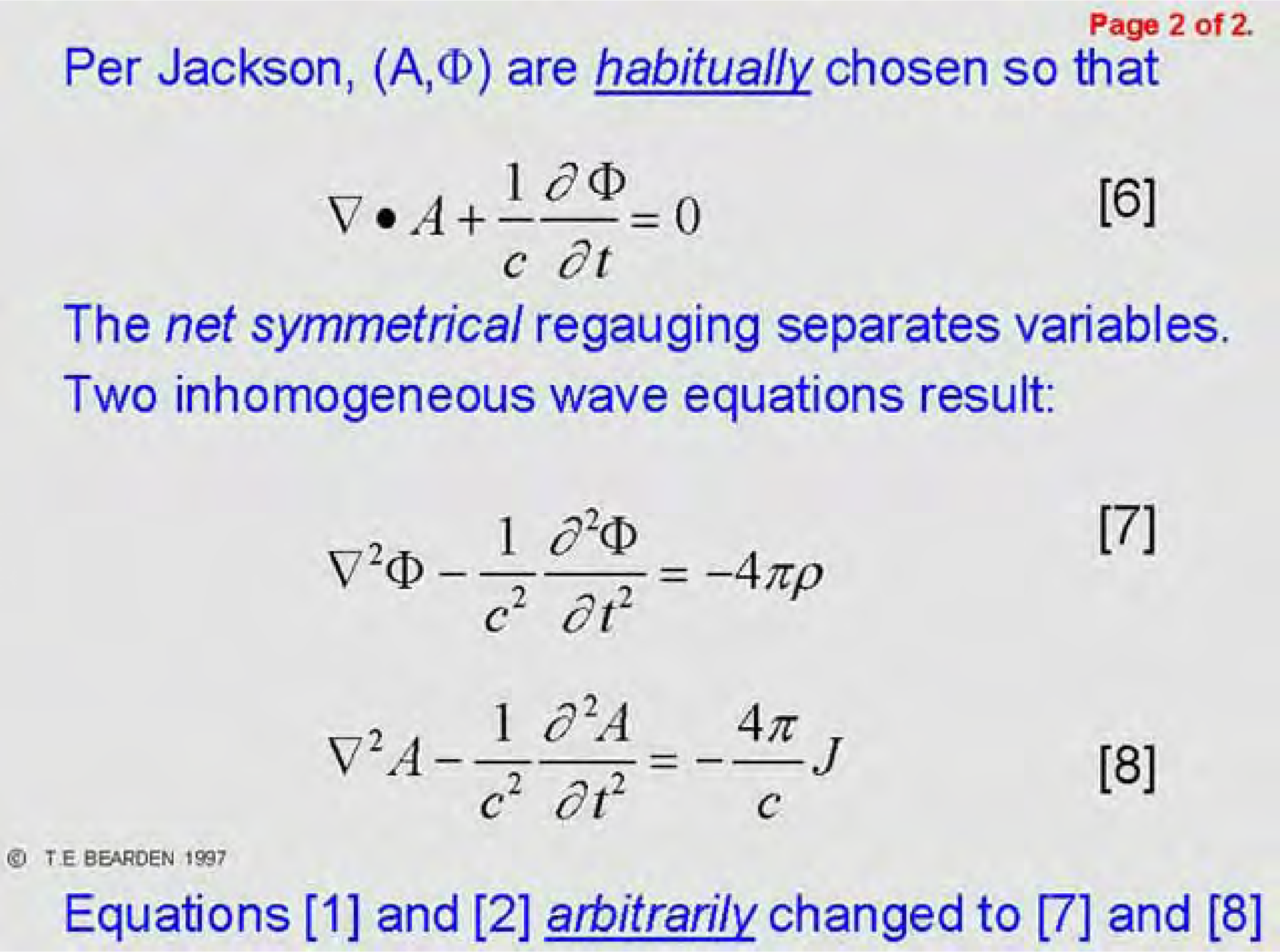

Page 2 of 2.

Per Jackson, (A,Φ) are *habitually* chosen so that

$$\nabla \bullet A + \frac{1}{c}\frac{\partial \Phi}{\partial t} = 0 \qquad [6]$$

The *net symmetrical* regauging separates variables.

Two inhomogeneous wave equations result:

$$\nabla^2 \Phi - \frac{1}{c^2}\frac{\partial^2 \Phi}{\partial t^2} = -4\pi\rho \qquad [7]$$

$$\nabla^2 A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} = -\frac{4\pi}{c} J \qquad [8]$$

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Equations [1] and [2] *arbitrarily* changed to [7] and [8]

The Tom Bearden Website

Mind Control and EM Wave Polarization Transductions - Part I, II & III

Reprinted from "Explore" magazine, 1999

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- The U.S. approach to mind control
- "Voices in my head"
  Flanagan's neurophone - used to give instructions to diplomats during negotiations, etc.

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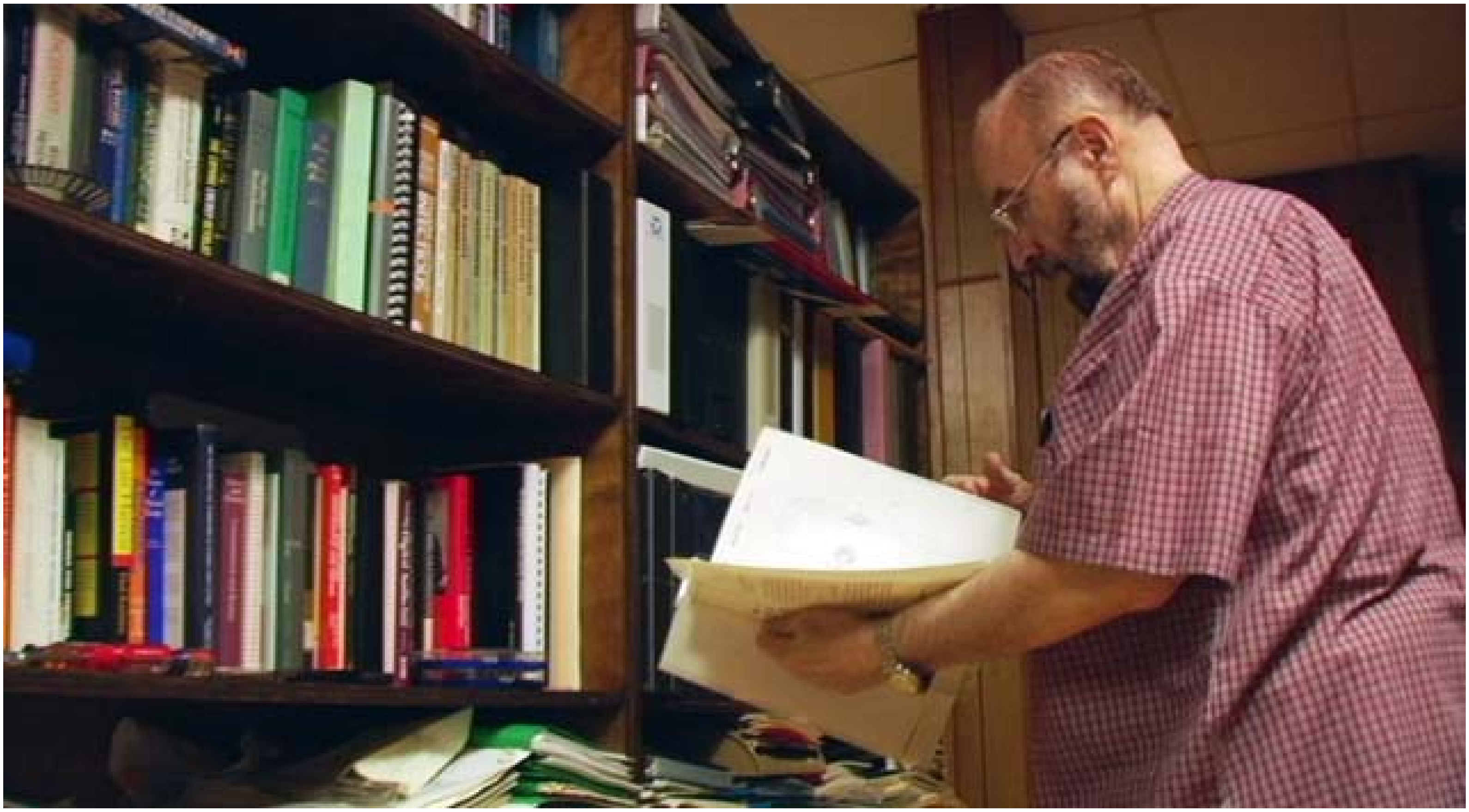

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  The Breakthrough Technology that Solves it Quickly
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Vol. 9, No. 2 1999

Part II
Vol 9, No. 3 1999

Part III
Vol 9, No. 4,5 1999

Vacuum Engines and Priore's Methodology - The True Science of Energy-Medicine

Part I
Vol. 6 No. 1 1995

Part II
Vol. 6 No. 2 1995

Paranormal Pictures
Psychic Observer 39(3) ~ 224, 255-258

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Mind Control and EM Wave Polarization Transductions, Part 1

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Special Note

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Abstract

For some time we have been repeatedly queried about the technical mechanisms and unusual electrodynamics of advanced mind control research, both in the West and abroad. Calling full attention to the special note above, in this paper we present a high-level over-view of the novel electromagnetic nature of mind operations, mind and body coupling, and *intent*•the induction of physical 3-space EM energy changes into the brain and nervous system, and into every cell of the body, from the mind's time-like coherent operations. We summarize the time-polarized electrodynamics used to engineer and affect mind operations and the mind-body coupling loop. Transduction mechanisms whereby differing EM wave polarizations can be transformed one-into-the-other are presented. We give two specific examples of lethal foreign military tests in 1997 of advanced mind control weapons against two military pilots over the central U.S. Some dangers and potential benefits of the emerging mind control technology are pointed out

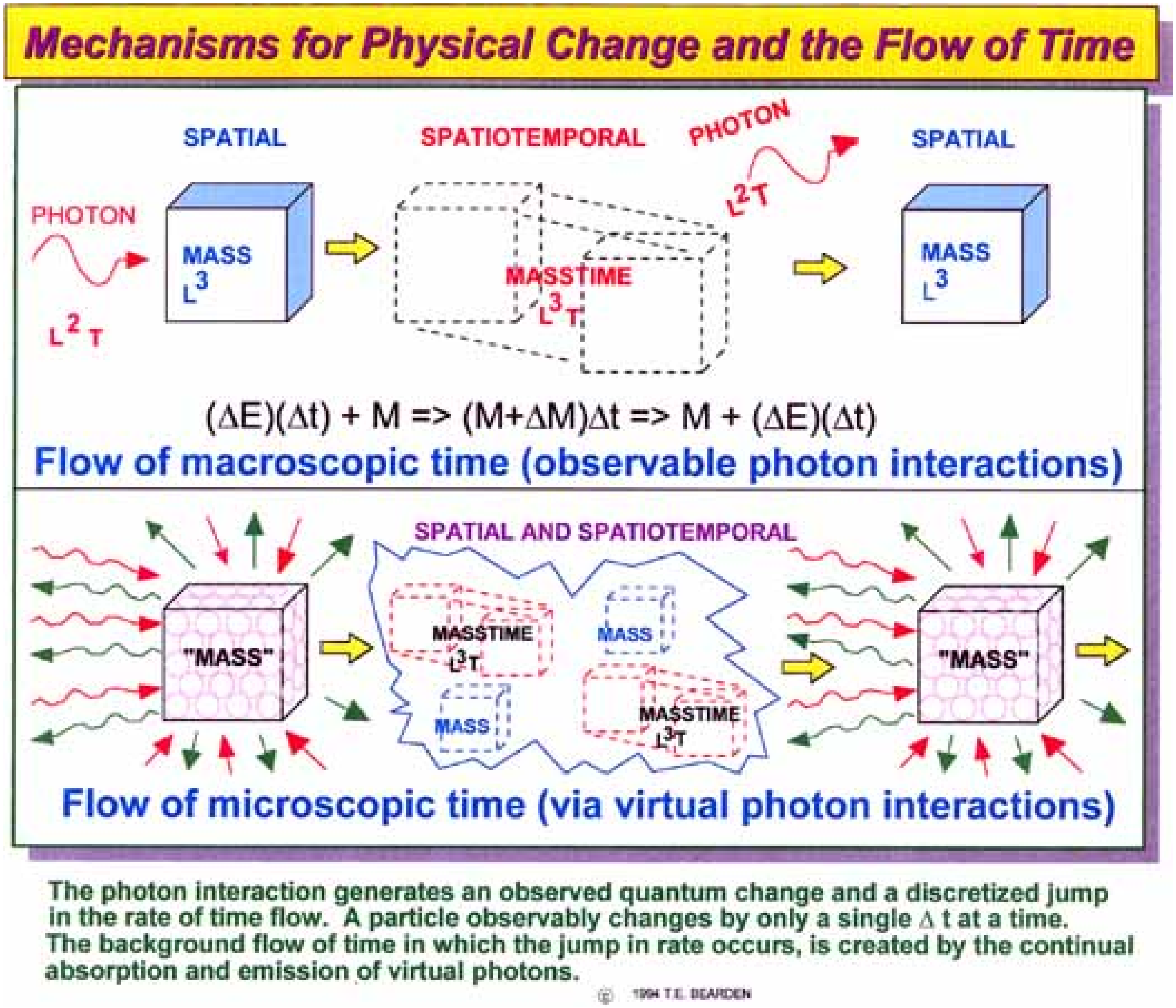
Mechanisms for Physical Change and the Flow of Time
SPATIAL
SPATIOTEMPORAL
PHOTON
SPATIAL
PHOTON
L^2T
MASS
L^3
MASSTIME
L^3T
L^2T
MASS
L^3
Flow of macroscopic time (observable photon interactions)
SPATIAL AND SPATIOTEMPORAL
"MASS"
MASSTIME
L^3T
MASS
MASS
MASSTIME
L^3T
"MASS"
Flow of microscopic time (via virtual photon interactions)
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$$(\Delta E)(\Delta t) + M \Rightarrow (M+\Delta M)\Delta t \Rightarrow M + (\Delta E)(\Delta t)$$

The photon interaction generates an observed quantum change and a discretized jump in the rate of time flow. A particle observably changes by only a single Δt at a time. The background flow of time in which the jump in rate occurs, is created by the continual absorption and emission of virtual photons.

Figure 1. Mechanism that generates a mass's flow through time.

EXPLORE! VOLUME 9, NUMBER 2, 1999

Introduction and Background

In quantum field theory, there are four polarizations of photons.[1] Using 4-space and the z-direction as the direction of propagation, we have x- and y- polarizations where the 3-spatial energy of the photon is oscillating laterally, in the x- or y- direction. These are *transverse polarized* photons, as is any combination of the two. The third polarization is along the z-direction, which is a longitudinal polarization. In other words, the 3-spatial energy of the longitudinal photon cannot oscillate in the x- or y- direction, and so it is oscillating to-and-fro along the line of motion, z-. The fourth polarization occurs when the energy is frozen in all three spatial dimensions x-, y-, and z- and it cannot oscillate in any of those directions. In that case, the photon oscillates its energy in the t- direction, providing the t-polarized photon. We will later discuss how time is actually highly condensed energy.

In Minkowski 4-space, body operations are space-like, and are so treated in conventional materialistic physics. Mind and mind-operations are time-like, not space-like, even though they are totally electromagnetic in nature.[2]

As is well-known, all observation in physics is considered 3-spatial..[3] Mass is a 3-spatial concept, and we detect changes to mass (as, e.g., in the shift of electrons in the circuits of electrical instruments). So one may model the common physical observation mechanism as a *time-differentiating process* which *a priori* discards time-change and retains 3-spatial energy change.[4] That is, Minkowski reality is modeled in the fundamental units of L^3t. Physical observation (via the transverse photon interaction) is the process given by applying the operator $\partial/\partial t$ to L^3t, yielding an L^3 output. Hence mind and mind operations are excluded by the usual physics instruments and observation, which simply exclude the time domain in their outputs and do not "measure" it.

For this reason, physicists have erroneously considered mind to be "metaphysical" and nonreal. Indeed, most physicists to one extent or the other are materialists, and consider the "mind" to be nothing but the operations ongoing in a "meat computer." Nonetheless, in the time-domain the time is absolutely real, and it is completely electrodynamic in nature. There is no metaphysics involved, and the temporal domain—along with mind and mind operations—is simply an erroneously neglected area of physics. In present physics, the notion of mind is comfortably disposed of by imposing the use of the "observer" concept, with out ever specifying that the observer has a consciousness and a mind. Indeed, "observation" is only about what that "observer" perceives. Obviously, one has a dramatically crippled physics if one eliminates that nonobservable called "time." Similarly, one also has a dramatically crippled physics when one eliminates the mechanisms and physics ongoing in those time-like and dynamic "things" such as mind, that occupy time and function in it.

From this viewpoint, Western physics adheres to its 3-spatial measurement foundation only by ignoring the transduction of time-polarized EM changes into detectable longitudinal and transverse EM wave changes. In this aspect, present Western physics is severely self-crippled.

Time is totally electromagnetic and energetic in nature. The flow of time is not a separate external river on which a mass floats along like a boat drifting down the current of a great flowing river. Instead, the flow of time is generated directly on every mass by its total set of photon interactions, both virtual and ob servable. We have previously presented the exact mechanism for the flow of time. *[Figure 1]*

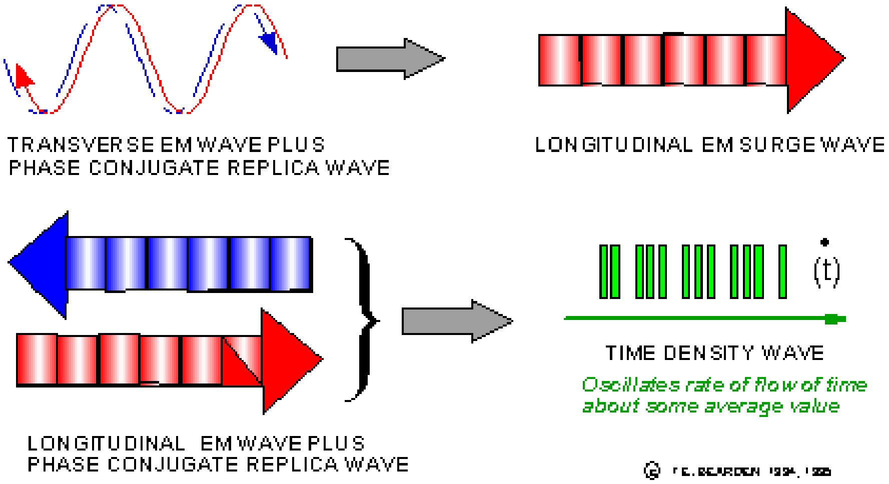
TRANSVERSE EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE
LONGITUDINAL EM SURGE WAVE
LONGITUDINAL EM WAVE PLUS
PHASE CONJUGATE REPLICA WAVE
$\dot{(t)}$
TIME DENSITY WAVE
Oscillates rate of flow of time
about some average value
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Figure 2. Transduction of EM wave type by successive phase conjugate pairing.

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Further, a photon is comprised of angular momentum, therefore of (energy)x(time). It transports both energy and time, not just energy alone. When absorbed by a mass, not only does it "energy-excitation" charge the mass, but also it "time-excitation" charges it, converting the former "mass" to "mass time". Rigorously it is *masstime* that emits a photon, not *mass*. So a mass moves through time in little spurts, by the continual macroscopic addition and subtraction of little Dt components. Further, in being driven through time, mass is continually altered to masstime (a quite different critter from mass), to mass, to masstime, to mass, etc.

In any masstime state, a myriad of tiny virtual photon interactions made of very tiny (DE)(Dt)'s interact with that same mass during that particular larger Dt of the masstime state (m+Dm)(Dt). Hence mass in its alternate masstime state has that state internally structured by its surrounding environment's interactions with it. The masstime state is internally structured energetically in its (DE) component, and also internally structured temporally in its (Dt) component.

A standard charged fundamental particle such as an electron, e.g., is not necessarily identical with another, when the internal structuring of its masstime state is considered. Further, by two papers by Whittaker,[5] interferometry of masstime states with either energy reactions or temporal reactions can yield observable effects and changes due to these neglected "hidden variables" in the electron's masstime alternative states. To engineer the mind and its operations directly, one must perform electrodynamic engineering in the *time* domain, not in the 3-space EM energy density domain. The direct engineering of time-like mind and mind operations—in all levels and all aspects—requires the use of *time-polarized photons and time-polarized EM waves*. This is the rarest form of electrodynamics, almost untouched by Western physicists.

One can either painfully produce such time-polarized photons and EM waves and directly irradiate a target mass with specific assemblies of them, or one can force the mass itself to iteratively transduce ordinary transverse EM waves first into longitudinally-polarized EM waves and then into time-polarized EM waves. Both will be discussed briefly.

In the West, it appears that the present author's discovery of mechanisms for producing time-polarized (scalar) EM waves [see *Figure 2*] and for transducing between wave polarizations has no precedent. [See *Figure 3*]. While scalar (time-polarized) photons are known in the literature,[1] the creation and use of time-polarized EM waves does not seem to appear in the Western physics literature.[6]

Wave transduction or *polarization transductions* are terms used by the author for the process of transforming an EM wave's particular polarization into another polarization type. Such transduction to other than transverse polarization forms is little known in the West. It appears essentially haphazardly in some experiments, usually without any recognition by the experimenters themselves. Significant transduction in experiments will also produce "strange" and unexplained anomalies in the instruments being used for experimental measurements.[7]

So most probably Western mind control researchers have not recognized the methodology and mechanisms[8] for transducing one type of EM wave polarization directly into another.[9] They continue to seek the "mind" in 3-space and hence in the brain, rather than in the time domain. On the other hand, it appears

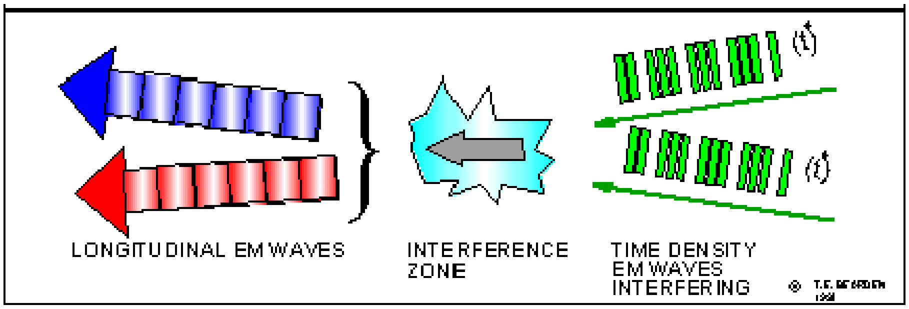

Figure 3. Interference processes for transducing higher EM wave polarizations into lower polarization states.

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that the Russian KGB *energetics*[10] weapons scientists—particularly those in *psychoenergetics*[11]—have known and used methods of transducing one wave polarization into another, for at least two decades. It follows that those same scientists have very probably developed *mind engineering* and *mind control* via novel time-polarized EM wave means and a dramatically extended electrodynamics of the time-like mind operations.

In the present paper we briefly develop the wave transductions and the basis for mind engineering, including the specialized use of ordinary transverse wave (TW) EM spectra to force internal EM wave transductions and time-domain operations inside irradiated bodies, cells, and tissues. Through the mind-body coupling mechanism, these transductions of transverse EM waves can operate upon the mind and its deepest operations as well as upon the body, every cell, and every part of every cell.

Russian Mind Control Uses Higher EM Wave Polarizations

It is apparent that the KGB psychoenergetics weapons scientists know and use the full extended EM wave polarization range. As a postulation, one would expect our own weapons scientists to know and utilize the orthodox transverse wave (TW) EM for similar research and experimentation. However, in the West scientists are *just beginning* to realize the importance of a very general (and weaker) type of longitudinal EM wave (LW) polarization, as evidenced by the appearance of dozens of papers on "undistorted progressive waves" (UPWs, which are essentially imperfect LW s with TW residues remaining). The Los Alamos National Laboratory web site has a number of such papers—particularly by Rodrigues[12] and Lu—available for free downloading. UPWs have very interesting characteristics. If they were perfect longitudinal EM waves, they would have infinite energy and infinite speed. Since only imperfect UPWs can be physically made, their speed can vary from slower than the speed of light to faster than the speed of light. Their energy can also vary over a great range.

Another characteristic of UPWs that are reasonably good longitudinal EM waves, is that they pass readily through a large depth of water and mass, including through the ocean and the earth with only small interactions and losses. Yet by interfering two such beams of "high quality" UPWs at a great distance, then in the interference zone ordinary EM energy will rise directly out of local spacetime potential, as essentially shown by Whittaker[13] nearly a century ago. Russian weapon research facilities have weaponized these effects[14] for nearly 50 years, under rigid KGB control and operation. Nonetheless, even if using only ordinary TW waves, Western mind control researchers may get some fairly good results, brute-force-like, by using gross correlates between just the input irradiating TWs and the exhibited behavioral responses of the individual. The net input-output correlations can be determined, even though not taking into account the actual wave polarization transduction mechanisms ongoing inside the irradiated dielectric (or brain, or mind, etc.). However, Western researchers appear to have no knowledge of the exact mechanisms by means of which coherent time-like mind operations of a biological organism couple to the organism's 3-spatial body to provide the mental control loop. They also appear unaware of how the coherent 3-spatial behavior responses of the body couple back to the time-like mind to provide it with a sensory feedback of the body's responses.

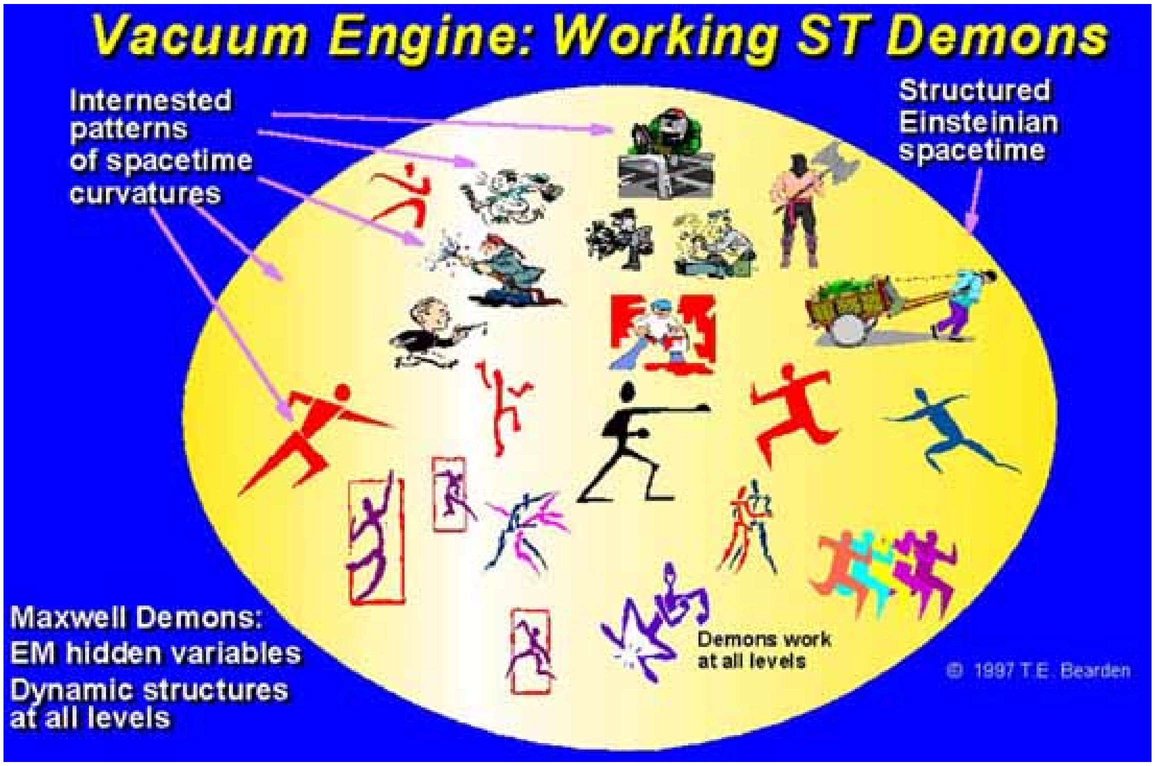
Vacuum Engine: Working ST Demons
Internested patterns of spacetime curvatures
Structured Einsteinian spacetime
Maxwell Demons: EM hidden variables
Dynamic structures at all levels
Demons work at all levels
© 1997 T.E. Bearden

Figure 4. A spacetime curvature engine has myriads of small ST curvature components which act upon mass at all levels.

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General Relativity Aspects

Both these coupling mechanisms can be taken directly from general relativity, if one puts one's mind to it. However, unless the wave polarization transformations are known, it is difficult or impossible to apply the ordinary GR *directly*, since relativists usually concentrate upon spacetime curvature by altering 3-space energy density rather than by altering time-polarized "time-energy" density.

In applied general relativity, spacetime itself is an active medium. One speaks of a change in spacetime as a "spacetime curvature". Any curvature of spacetime in a local region directly performs continuous work upon any mass embedded in that region. Vice versa, any mass (or other concentration of energy) in a local spacetime continuously acts upon that spacetime to "curve" it.

So if one wishes to perform actions upon mass in a distant region, one may generate local curvatures of spacetime in that region, and these curvature "engines" will directly act upon the mass at all levels. *[Figure 4]* This is very different from energy propagation through space from one point to another. Now the "ordinary EM energy and actions" arise from every spatiotemporal point within the mass, at every level, and move upwards (from inside to outside). So we speak of specific forms of "templates" of nested spacetime curvatures formed and utilized to engineer mass "from inside out" as *spacetime curvature engines or vacuum engines*.

Use of vacuum (spacetime curvature) engineering[15] is a far more powerful form of engineering than is provided by energy propagation through space. As an example, it is easy to alter the quarks in a nucleon, using spacetime curvature engines and time-charging decay. Indeed, we have developed the mechanisms for cold fusion and the electronuclear interaction (formation of new nuclides) at feeble energy. An Invention has been filed with the U.S. Patent Office, and formal patent applications are in preparation. Some information on these mechanisms and principles has been released[17].

Time as Dense EM Energy and a Strong Spacetime Curvature Agent

The advantage of using the time-polarized "time-energy" for spacetime curvature is that time is ordinary energy compressed by a factor of at least c^2—which, in the MKS system of units, is some 9¥10^{16}. Thus use of time-polarized EM photons and waves as ST curvature agents gives an amplification of 9 ¥10^{16} over the use of transverse-polarized EM waves for that purpose. In turn, the use of the strong EM force in ordinary TW waves as an agent of ST curvature is already a nominal 10^{40} times as strong as is the weak G force used as the agent of ST curvature.

The bottom line is this: For spacetime curvature effects, the use of the t-polarized domain provides amplification of some 9¥10^{56} greater than the weak G-force ST curvature agent usually considered in general relativity[18].

Western Science Remains Largely Materialistic

Ironically, most Western scientists are materialists and consider "mind" as a mystical and nonscientific concept. They tend to consider mind operations and functions either to be simply "meat computer" operations and functions, or at best to be very weak ordinary transverse-wave EM operations and functions in the brain and nervous system.[8] This serious self-limitation exists because in the body we *measure* only weak TW EM operations and functions correlated to biological behavior and brain operations. We simply do not know how to

Disclosure[16] on this work

measure "mind operations" directly.

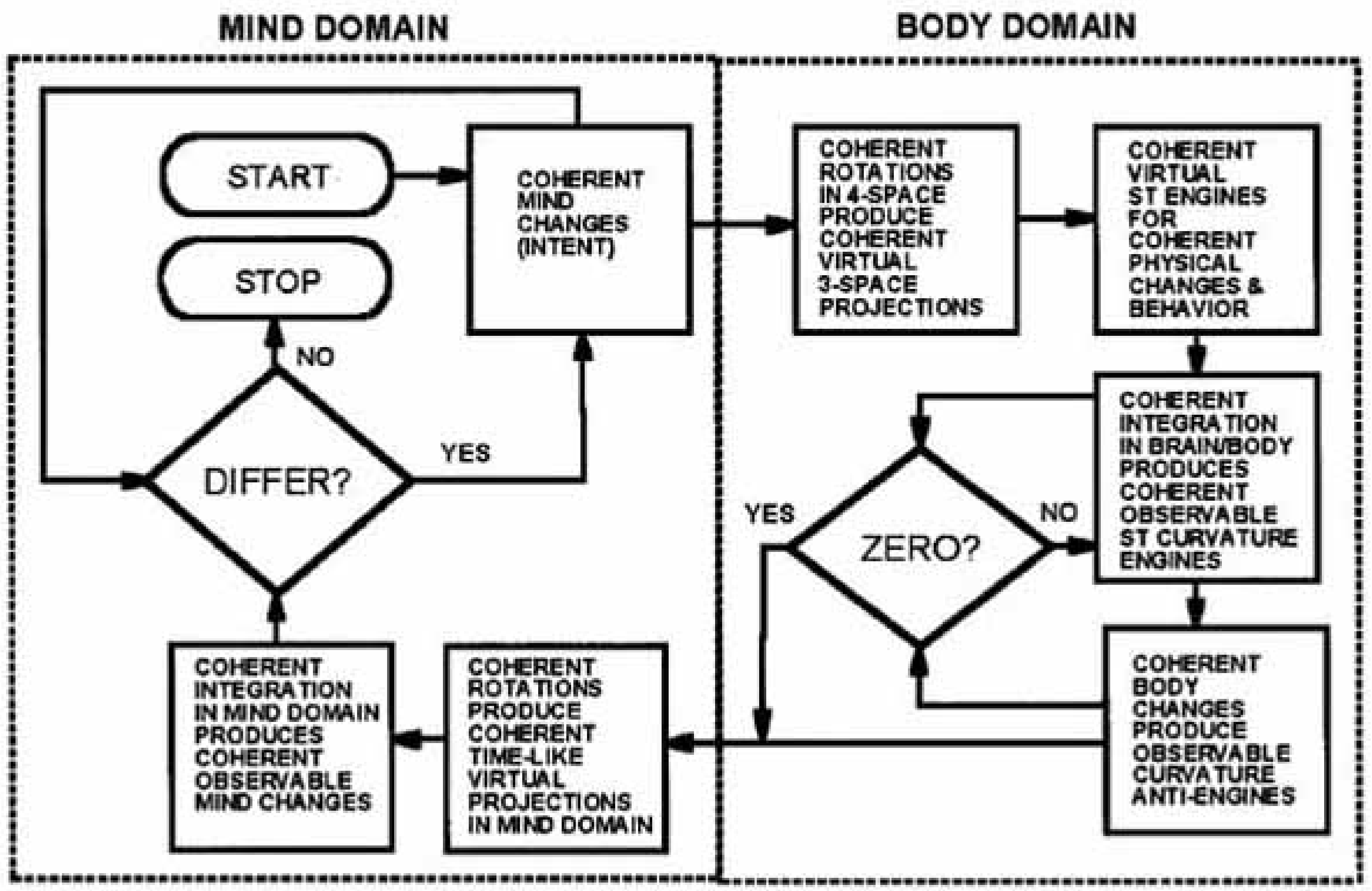
MIND DOMAIN
BODY DOMAIN
START
STOP
COHERENT MIND CHANGES (INTENT)
NO
YES
DIFFER?
COHERENT INTEGRATION IN MIND DOMAIN PRODUCES COHERENT OBSERVABLE MIND CHANGES
COHERENT ROTATIONS PRODUCE COHERENT TIME-LIKE VIRTUAL PROJECTIONS IN MIND DOMAIN
COHERENT ROTATIONS IN 4-SPACE PRODUCE COHERENT VIRTUAL 3-SPACE PROJECTIONS
COHERENT VIRTUAL ST ENGINES FOR COHERENT PHYSICAL CHANGES & BEHAVIOR
COHERENT INTEGRATION IN BRAIN/BODY PRODUCES COHERENT OBSERVABLE ST CURVATURE ENGINES
YES
NO
ZERO?
COHERENT BODY CHANGES PRODUCE OBSERVABLE CURVATURE ANTI-ENGINES

Figure 5. Mind-to body coupling and body-to-mind coupling.

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With no mind measurements possible and no instruments, it is understandable that Western science considers only the physical side of the mind-matter interface.

Presently our scientists do not measure the longitudinally-polarized EM wave operations and functions in the body and around it in nature. Few of them are aware that a maelstrom of such LW functions exist in the body and in all of nature in general. Presently only highly theoretical quantum field theorists seem to even be aware of the existence of scalar (t-polarized) photons, and even they are unaware of t-polarized EM waves. Certainly our scientists do not measure t-polarized EM waves in and around the body and in nature, nor do they make them in the laboratory. Apparently they have not studied such waves and their interactions with matter—living and inert—at all.

But it's even worse. In ignoring the time component transported by photons and EM waves, science has also erroneously omitted half of the excitation charging and excitation decay processes whenever a mass interacts with photons and EM waves. More on that later.

Brute Forcing Time Functions versus Fine Control Methods

Ironically, Western mind control researchers using transverse EM waves for mind control research, are using a brute force method of evoking and using vacuum engines (spacetime curvature engines) and a special form of general relativity, although they do not appear to realize it.

While KGB scientists also use TW EM "brute force" TW waves when necessary, they do "imprint" or "activate" those waves with the desired internal LW and time-polarized EM wave and photon structures required to directly perform the mind engineering desired. They also do not hesitate to use LWs and t-polarized waves overtly. So in blunt terms, Western compared to Russian mind control research is probably like comparing an automobile body shop with a fine surgical ward. Having long ago worked out all those "exact correlates" to the internal "information content of the field" is where the KGB scientists are at least 20 years ahead of the West.

The reason one can get mind and behavior results with the TW electromagnetics, while bypassing the real mechanism which uses t-polarized waves and photons, is due to (1) the very peculiar nature of the EM emission from a dielectric, and (2) what can be done by re-radiating that dielectric with its emitted spectrum, deliberately and very carefully altered in selected parts. We will return to that important feature later.

Polarization and Observability

As we stated, there are four photon polarizations and therefore there must be correspondingly four EM wave polarizations[1] The first three polarizations are the x-, y-, and z- spatial polarizations. The x- and y- polarizations are transverse polarizations and the z-polarization is a longitudinal polarization along the direction of propagation (along the z-axis, by standard notation). Simply put, we may visualize the transverse polarizations as rather like the wiggling of a fish's tail from side to side as the fish moves forward, or a whale's flukes up and down as the whale moves forward, or some combination thereof. We may visualize the longitudinal polarization as a sort of "repetitive accordion effect" along the line of motion of the wave. Usually the z- polarization is neglected in EM wave theory, although in recent years physicists have "rediscovered" longitudinal EM waves and are now intensely researching the use and characteristics of such waves.[12]

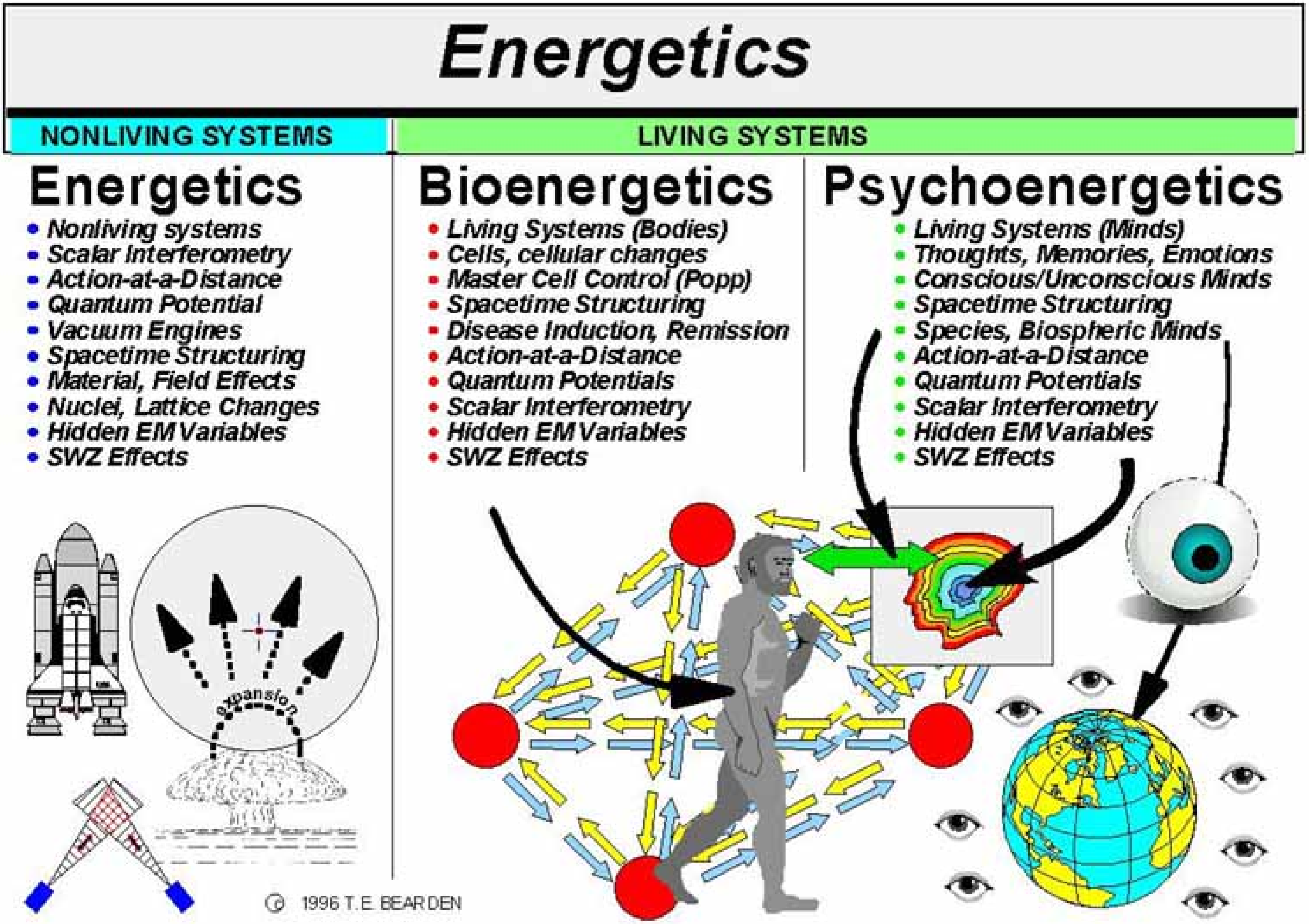
Energetics
NONLIVING SYSTEMS
LIVING SYSTEMS
Energetics
• Nonliving systems
• Scalar Interferometry
• Action-at-a-Distance
• Quantum Potential
• Vacuum Engines
• Spacetime Structuring
• Material, Field Effects
• Nuclei, Lattice Changes
• Hidden EM Variables
• SWZ Effects
Bioenergetics
• Living Systems (Bodies)
• Cells, cellular changes
• Master Cell Control (Popp)
• Spacetime Structuring
• Disease Induction, Remission
• Action-at-a-Distance
• Quantum Potentials
• Scalar Interferometry
• Hidden EM Variables
• SWZ Effects
Psychoenergetics
• Living Systems (Minds)
• Thoughts, Memories, Emotions
• Conscious/Unconscious Minds
• Spacetime Structuring
• Species, Biospheric Minds
• Action-at-a-Distance
• Quantum Potentials
• Scalar Interferometry
• Hidden EM Variables
• SWZ Effects
expansion
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Figure 6. The three divisions of Soviet energetics and their characteristics.

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Unfortunately, in quantum field theory there has been a tendency to regard the t-polarized or "scalar" photon—where the local rate of time is oscillated—as unobservable. Oscillation of the local rate of time produces powerful oscillations of local space-time curvatures, due to the extreme energy density of time. Individually, the t-polarized photon tends to be unobservable. However, a *coherent sequential group* of such t-polarized photons, each individually in the virtual state with respect to the external observer, may simply integrate in its interaction with mass over a short time period into observable change because of the coherent integration of virtual spacetime curvatures into a larger, observable spacetime curvature.

Rotations and Projections in 4-Space

Relativistically, any velocity change in 4-space is a rotation. Any such rotation in the time-domain also creates a tiny projection component into 3-space. Any such rotation in the 3-spatial domain also creates a tiny projection component into the time domain.

Hence a sufficient series of coherent time-domain (mental) changes produces a coherent series of virtual changes in 3-space (the body), thereby coherently integrating into an observable energy change in the body. A sufficient series of coherent 3-spatial energy changes produces a coherent series of virtual changes in the time domain which coherent integrate into an observable time-domain change.

Solution to the Age-Old Philosophical Problem of Intent

This is in fact the solution to the age-old problem of *intent*, or how the nonmaterial (i.e., non-3-spatial and non-observable) mind induces a 3-spatial, observable energy change upon the 3-spatial body. It is also the solution to the problem of *awareness*; i.e., how the mind is aware of itself[19] and of the responses of the body. Together the two form a closed loop coupling of the mind and body. The time delay in the loop together with memory recall for comparison, creates the sense of "persistence" of self in time. This also creates the sense of being a "separate, closed being" (i.e., of separate persistence in time—in the living entity). The sense of "separation of self from an external world" is created by comparing those body-to-mind sensory feedbacks which are not correlated to the mind's previous feed-forward intent.

Time As Energy and Why It Is Very Dense Energy

In addition to the three spatial polarizations of photons and EM waves, there is a very, very useful t-polarization along the time axis. In this polarization, the 3-spatial energy is not oscillating at all. Instead, the time or time-energy is oscillating. Time can be taken to be energy compressed by at least c^2, so it has at least the same energy density as mass. In other words, one second is $9x10^{16}$ joules of time-energy (energy compressed into time). The t-polarized photon or EM wave is called the scalar photon or scalar EM wave, respectively.

To demonstrate why time can be regarded as energy, we need only point out that the choice of fundamental units in any physics model is totally arbitrary. We usually choose these units to ease the mathematical manipulation, ease our understanding, and simplify the ability to visualize or "grasp" the physics. However, if one wishes, one can build all of physics from a single fundamental unit—e.g., energy. In that case, one readily sees that time is a function of energy and only energy. Hence it is perfectly proper to regard time as energy, and to seek out what form the function takes in our normal system of units (say, the MKS system).

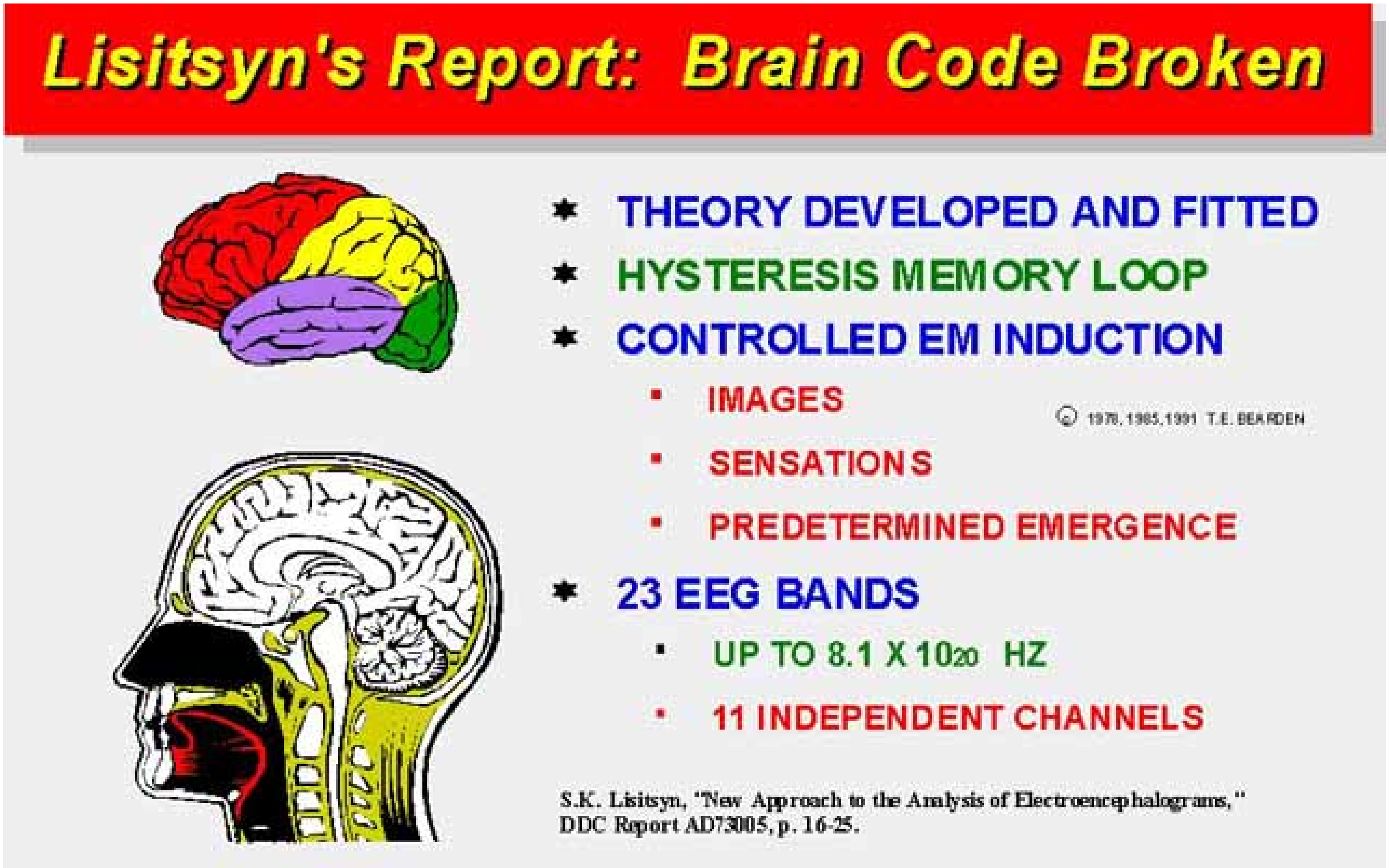

Lisitsyn's Report: Brain Code Broken

- THEORY DEVELOPED AND FITTED
- HYSTERESIS MEMORY LOOP
- CONTROLLED EM INDUCTION
  - IMAGES
  - SENSATIONS
  - PREDETERMINED EMERGENCE
- 23 EEG BANDS
  - UP TO 8.1 X 10^{20} HZ
  - 11 INDEPENDENT CHANNELS

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S.K. Lisitsyn, "New Approach to the Analysis of Electroencephalograms," DDC Report AD73005, p. 16-25.

Figure 7. In the 1960s, Lisitsyn revealed Russian scientists had deciphered the human brain code.

[*EXPLORE! VOLUME 9, NUMBER 2, 1999*]

In that system, it appears that any change in time Δt can be taken as always a function of a corresponding change in energy ΔE, where $\Delta t \leq (\Delta E) \div c^2$ [1] from which it follows that $\Delta E \geq (\Delta t) \times c^2$ [2] For convenience, we take the special case where $\Delta t = (\Delta E) \div c^2$ [3] $\Delta E = (\Delta t) \times c^2$ [4].

Observation as Used in Physics Is Spatial

We note that all mind operations are time-like, i.e., they are comprised as scalar EM photon functions and scalar EM wave functions. Thus the mind is a very special kind of electromagnetic system, existing in the time domain, and thus "lost" by the stripping away of time in the ordinary observation process. Physical observation is essentially a time-differentiating mechanism applied to a 4-spatial change, or in terms of MKS fundamental units L and t, observation θ is $\theta = \partial/\partial t(L^3 t) = L^3$ [5].

Thus, as is well-known in quantum mechanics, physical observation is 3-spatial, and time is not a physical observable, even in theory. Since mind is time-like, it follows that mind is not a physical observable either, since discarding the time dimension also discards the mind. In short, one may also take physical operation as the mechanism that separates mind and body. To observe is to separate. We point out, however, that merely "separating and discarding" the time domain (as in physical observation of a single change) does not eliminate it, nor does it eliminate the single time-like mind change that may be involved in an intentional volition. The time domain certainly remains, even though only the 3-spatial intersection of the 4-spatial mechanism and the resulting "outputs". So a series of coherently integrated "mental intent" changes introduced into the human body's overall servo-mechanism provides the continuing input. From there, ordinary physics will generate the resulting actions induced in the body by that servomechanism and its amplifying mechanisms.

Two Coupling Mechanisms Make a Closed Loop

This is the "mind-to-body" coupling mechanism. [See *Figure 5*] It is the mechanism whereby the mind is coupled to the body, and whereby mental intent is able to induce a series of physical inputs into the body servomechanism.

So the body's servomechanism then generates the responses of the body (including everything from chemistry to electrical changes to muscular movements, etc.). These responses are changes in 3-space.

The conscious mind is a *serial processor*, though extremely rapid. It produces the series of coherent intent inputs for volitional behavior.

The unconscious mind is a *massively parallel processor*.[20] It continually produces the vast series of coherent "unconscious intent inputs" for control of all the deeper processes in the body, beyond usual conscious awareness.

However, as the body moves or changes in 3-space, each resulting quantum change in body 3-space is also a slight rotation out of 3-space and toward the time axis. Hence it induces—in the "virtual state" in the time domain—a precisely correlated projection. The body's responses are in general

Minkowski change is given by physical observation. So we may say *that the time-change remains in the virtual state, with respect to attempted physical observation of a single Minkowski 4-space change.*

Rotation, Coherent Integration, and Intent

Previously we pointed out that any change in a 4-space entity may be regarded as a rotation away from the "trajectory" of the entity. Hence each and every t-polarized change creates a very small projection into 3-space by its rotation slightly away from the time axis. All mind changes in the time-domain actually produce virtual 3-spatial projections in 3-space (in the physical domain). We define "intent" as the continued production of successively coherent mental changes, producing coherent virtual changes in the 3-space body system, with coherent integration of those 3-space virtual changes into observable 3-space energy inputs into the 3-space body system. Successively coherent mind-changes will produce successively coherent 3-space virtual changes. In short, coherent mind-changes will produce coherent integration of those 3-space virtual projections into an observable 3-space change. This is the creation of an ordinary 3-spatial energy change induced upon the 3-space body. In short, this is the mechanism whereby time-like mental intent is able to produce a series of coherent observable quantum changes in the physical body (as in the brain and nervous system).

The Body as a Servomechanism

From the standpoint of control theory, we may consider the body system to be a coherent, so a coherent series of virtual state changes in the time-domain (in the mind realm) are created successively. In short, again we have coherent integration, this time in the mind or time domain. This produces "observable" changes in the time-mind domain, which are coherent with the body's 3-spatial changes actually performed. Thus the mind receives feedback directly from the physical movements and changes of the body. This is the manner in which the body is coupled back to the mind.[21]

By comparing the "intent" behavioral move that was "fed forward" into the body, with the return "response" move analog that was "fed back" from the body to the mind, the mind is able to determine errors and differences, and originate additional correctional commands.

Thus the entire mind-body loop is a closed-circuit system of feedforward and feedback, together with corrections. It also has multiple levels of such, infolded in the larger volitional levels. See again *Figure 4*.

This solves the age-old problem of the mechanisms for the mind-body coupling, intent, volition, conscious and unconscious functioning, sense of the external world, sense of the internal world, sense of "being in" the external world, etc.[22]

All This Is Included in Russian Psychoenergetics

This is the highly summarized basis for *psychoenergetics*, the KGB's division of energetics that deals with the mind and body coupling and functions, and direct engineering of (1) the mind-body coupling and (2) the mind operations directly. [See *Figure 6*] The KGB intent, of course, has always been to exploit this science for the complex servomechanism system comprised of many subordinate servo systems with feedback and feedforward looping.

Given the input from intent, ordinary servo theory will take it from there. Once a servo has an input, servomechanism theory describes the response of the

degradation, killing, and control of human beings, including all humanity.

The Russians know full well that, if you produce and utilize scalar EM photons and t-polarized EM waves, you can directly affect and engineer mind and mind operations at any and all levels. Western researchers, who know nothing of how to make

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time-polarized photons and time-polarized EM waves, do not yet know that. Consequently the Russians have developed a highly secret science of *directly* engineering the mind and its operations, including thought, images, perceptions, feelings, emotions, memory, and mind processing. Indeed, Lisitsyn[23] wrote quite specifically of this capability in the 1960s. [See *Figure 7*]

Western clandestine mind control researchers are apparently still slowly and painfully fitting TW EM irradiation correlates to induced or resulting mental and physical behavior responses. They seem unaware of the actual wave transductions occurring inside the body and mind, but are unwittingly inducing those transductions in hidden fashion anyway and in "brute-force input-response fitting" models.

These "fitted brute-force models" certainly can be very powerful, and certainly can produce the exact results shown in the experimental verifications of the fittings. However, they do not of themselves allow sophisticated design—for example—of the necessary time-polarized wave assemblies for engineering the entire human collective unconscious simultaneously, or for engineering the entire collective unconscious of all species on Earth (i.e., Gaia's collective unconscious), or even for precisely engineering the memory and knowledge base of an individual.

This fine research article will be continued in Part II with Russian Methodology, Waves and Wave

spacetime that is highly active. The mind is rooted in the time-domain and projects from that domain into 3-space. The body is rooted in the 3-space domain and projects into the time-domain. To "change" or "function" in one domain is automatically to function in the other. EM and gravitational phenomena are still modeled separately by human scientists, but not by nature.

3. In quantum mechanics, time is not an observable, but merely a parameter.

4. It is convenient to consider mass as a 3-spatial form of condensed energy.

5. E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics, " Mathematische Annalen, Vol. 57, 1903, p. 333-355;— "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions, "Proc. Lond. Math. Soc., Series 2, Vol. I, 1904, p. 367-372.

6. A NERAC document search yielded some 16 good references on t-polarized photons, but not a single reference on t-polarized EM waves.

7. E.g., such previously inexplicable instrument anomalies have accompanied some excellent and rigorous electrolyte experiments at U. S. Navy research facilities at China Lake. For a description, see Melvin H Miles and Benjamin F. Bush, "Radiation measurements at China Lake: Real or Artifacts?", Proc. ICCF - 7 (International Conference on Cold Fusion—7, Vancouver, BC, Canada, Apr. 1998, p. 101. For a brief explanation of the anomalies, see T. E. Bearden, "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves, " Explore!, 8(6), 1998, p. 7-16;— "Toward a Practical Unified Field Theory and a Deep Experimental Example," Proc. INE Symposium, Univ. Utah, Aug. 14-15, 1998.

8. Many U. S. researchers and journalists—and even many scientists—have wrestled with the problems of mind, intent, and mind-body

Transduction, The Cellular Control System, and other matters of interest. ♦

ABOUT THE AUTHOR

President and Chief Executive Officer, CTEC, Inc. Lieutenant Colonel US. Army (Retired). MS Nuclear Engineering, Georgia Institute of Technology. BS mathematics, Northeast Louisiana University. Graduate of Command & General Staff College, US. Army. Graduate of Guided Missile Staff Officers Course, U. S. Army (equivalent to MS in Aerospace Engineering). Numerous electronic warfare and counter-countermeasures courses.

Tom is the leading advocate of scalar potential electromagnetics and the Fogal charge-blocking semiconductor: He is involved in alternate energy devices and scalar electromagnetic system prototypes. He has defined charge q as a coupled system of two components, advanced a mechanism for a vacuum engine, whereby the vacuums virtual particle flux is organized and used to energetically shape and manipulate matter and energy, and advanced a mechanism for a Bohm-type quantum potential, which theoretically allows the engineering of action at a distance in physical systems.

He is president of the Association of Distinguished American Scientists (ADAS), a life member of the Alabama Academy of Science, Emeritus member of the American Association of Physics Teachers, and has served on the Board of Directors of several associations

coupling. Enumeration of those efforts would itself require an entire book. For an introduction into that domain, the reader is referred to the very determined exposé by Cheryl Welsh in her very timely book, The 1950's Discovery of the Code of the Brain, May 1988, published on the Internet. Simply employ any Net search engine and search on the name Cheryl Welsh. A connection to the site and to Welsh's book will immediately be found Welsh's important compendium is highly recommended, giving the reader a "birds eye view", so to speak, of how Western scientists think and proceed regarding the subject of mind control by electromagnetic means. Unfortunately all journalists so far researching the area have not been aware that Western electrodynamics itself is seriously flawed, and that the great Russian advances in mind engineering and mind control are a result of their secret but complete revision and correction of Western electrodynamics to provide the basis for energetics. Until Western scientists revise their own decrepit old electrodynamics fouling the textbooks, they will never catch up to the Russian mind control developments springing from intense development programs that did that revision in the late 1940s and early 1950s.

9. An Invention Disclosure on these processes and enhancement embodiments has been filed with the U. S. Patent Office. Formal patent applications are also in preparation.

10. Energetics is a unified science of an extended electrodynamics possessing a hidden infolded general relativity inside the potentials, fields, and waves. It deliberately employs higher polarizations (longitudinal and tempic) of photons and EM waves to engineer action at a distance, use of specific patterns of spacetime curvature created at a distance, and direct engineering of either inert or living bodies. It also encompasses the direct engineering of time-like mind and mind functions. It is divided into three divisions, depending upon the nature of the target. Targeted against inert materials, structures, fields, and waves it is called "energetics. "Against living bodies, their fields,

and corporations. Tom is a guitarist, a retired aikidoist (Sandan, Yoseikan style), is happily married and has two sons and two daughters. He and his wife Doris live in Huntsville, Alabama where Tom is retired from aerospace, continues private research, and serves as a consultant to industry on Scalar electromagnetics processes.

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1. E.g., see Lewis H Ryder, Quantum Field Theory, Cambridge University Press, 2nd Edition, 1996, p. 147+. For an even deeper discussion of photon polarization, see F. Mandl and G. Shaw, Quantum Field Theory, Wiley, 1984, under the heading "Covariant Quantization of the Photon Propagator" in Chapter 5. Mandl and Shaw argue that the longitudinal and scalar polarizations are not directly observable, but only in combination, where they manifest as the "instantaneous" Coulomb (i.e. electrostatic) potential.
2. Nature is unified and not separated into the "separate" disciplines our science has prescribed. Thus the mind is also totally electrogravitational. The mind works not just with EM
forms in an inert space, but also with spacetime curvatures in a

and biochemistry, it is called "bioenergetics." Against the mind and mind functions, it is called "psychoenergetics".
11. Psychoenergetics is that branch of energetics used to directly affect and engineer the mind, memory, perception, thought, emotion, sensation, personality, and other mind functions of a living biological organism. It is usable against a single personal conscious (serial processor) mind and a single personal unconscious (massively parallel) processor mind In theory it is also usable against lungs collective unconscious mind and its functions, as well as the deeper unconscious for all species on Earth (i.e., against Gaia). We are speaking of physics, not metaphysics.
12. W A. Rodrigues Jr.. and J.-Y. Lu, "On the existence of undistorted progressive waves (UPWs) of arbitrary speeds $0 \leq v < \infty$ in nature," Foundations of Physics, 27(3), 1997, p. 435-5•08 A slightly corrected version is downloadable as hep-th/9606171 on the Los Alamos National Laboratory website.
13. E. T. Whittaker, "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions, "Proc. Lond. Math. Soc., Series 2, Vol. I, 1904, p. 367-372. The paper was published in 1904 and orally delivered in 1903.
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Therapies, Tara Publishing, Internet node www. tarapublishing.com/books, July 1997; — Energetics: Extensions to Physics and Advanced Technology for Medical and Military Applications, CTEC Proprietary, May 1, 1998, 200+ pages furnished to selected government agencies and key Congressional committee leaders.

15. E.g., see T.D. Lee, Particle Physics and Introduction to Field Theory, Harwood; New York, 1981. On P.383, Nobelist Lee points out that the microstructure of the scalar vacuum field (i.e., of vacuum charge) is not utilized. Particularly see Lee's own attempt to indicate the possibility of using vacuum engineering, in his "Chapter 25; Outlook; Possibility of Vacuum Engineering, " p. 824-828. With wave transductions and use of higher polarization EM waves, there are far better and more powerful ways to do vacuum (spacetime curvature) engineering.

16 T.E. Bearden, "Formation and Use of Time-Reversal Zones, EM Wave Transduction, Time-Density (Scalar) EM Excitation and Decay, and Spacetime curvature Engines to Alter Matter and Convert Time Into Energy," Invention Disclosure Document #446522, Oct. 26, 1998.

17. T.E. Bearden, "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves, "Explore!, 8(6), 1998, p. 7-16; — "Toward a Practical Unified Field Theory and a Deep Experimental Example," Proc. INE Symposium, Univ. Utah, Aug. 14-15, 1998.

18. We have used the enormous energy density of time in our approach to a totally new kind of electronuclear interaction at feeble spatial energy. By use of a time-reversal zone (TRZ) in a fluid; the free H+ ions—which are free protons—can be induced to attract each other so tightly that the edge of the nuclear force region is entered. In that case the protons form a quasi-nucleus. When the TRZ decays back to a time-forward zone (TRZ), this new quasi-nucleus decays by changing quarks in one or more

means "sense of existing in time".

20. The "unconscious" is totally conscious, just multiply so. The conscious mind can see only "a single slide in the slide projector at a time, " so to speak. When it "looks" at the ongoings and outputs of the unconscious, it "sees" millions of slides in the slide projector simultaneously. Hence it cannot distinguish "one and one only". So it just sees nothing, where by "nothing" we mean "no single distinguishable thing." It therefore is unable to consciously perceive the actions of the unconscious. When the unconscious wishes to communicate with the conscious (because of unresolved conflicts, etc.), it must produce large groupings integrated into "symbolic scenarios". Hence the symbolism of the unconscious, and the basis for therapeutic psychology and psychiatry. A "symbol", after all, is just a thing which can have many different meanings, all folded into one.

21. The mind continually has activities of its own, each of which produces coherent changes in the body to a much smaller degree. The interweaving of these "smaller self-changes" infolded inside the 3-space major intent changes also produces slight body changes, which in turn "project back" into the mind. This huge group of "infolded self-loops" produces the sense of "my body" being "volitionally directed or occupied" simultaneously with the "greater intent" loops which represent "my intentional actions with my body". Further; the body servo continually receives a myriad of inputs from its sensory systems, both from changes inside the body and from incoming changes from the external universe. This interweaving produces the awareness of "being in the external world" by having (i) changes whose feedback do not match mind-intent changes, and (ii) changes whose feedback does match mind-intent changes. This of course applies to both the conscious and unconscious levels. The purpose here is to demonstrate that there exists an actual physics of the living being, the mind as well as

nucleons, thereby producing new nuclides. We point out that this is actually a very high energy reaction; however; since the time-energy is used and is very, very dense, the amount of 3-spatial energy that must be used is very small. If this new mechanism holds, it represents a revolution in particle physics.

19. "Self-awareness" refers to be continually "refreshed" by time-delayed coherent feed-back inputs from the body to the mind; where these inputs compare to the recalled memory of the minds inputs to the body. In short, the time-delay coherence creates the sense of "existing in time". Awareness usually the body, and the coupling and interfiinctioning of mind and body.

22. The methodology also easily extends to include deeper interlays for the collective human unconscious mind and for Gaia—the collective unconscious mind level for all the species on earth.

23. S. K Lisitsyn, "New Approach to the Analysis of Electroencephalograms, " in Problems of Bionics— (Selected Articles), Defense Documentation Center Report AD 73005, date unknown, p. 16-25. Available through the National Technical Information System (NTIS).

Mind Control and EM Wave Polarization Transductions, Part 2

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This article continues on with T.E. Bearden's article, Part 1 of which was published in Volume 9, #2 of Explore! for the Professional. Because we feel that Col. Bearden's caution below is so very important we are repeating its publication in all parts of this article.

Special Note

This article refers to experimental research techniques which can be detrimental or lethal in the hands of any but highly skilled, qualified experimental scientists proceeding under proper laboratory safety procedures. The purpose of this article is strictly for information to properly qualified and authorized scientists in certified laboratories. We do not propose or condone any use of these procedures for non-approved practice of medicine without a license. Neither the publisher nor the author are responsible for accidents or outcomes in the use of these experimental procedures and techniques. Any researcher who performs these procedures and experiments is acting on his or her own volition, and is solely responsible for insuring safety, qualifications, and legality of the acts and their results. We neither suggest nor condone unauthorized experimentation on human subjects. Such is a criminal violation of the constitutional rights of the subject under Federal and State laws, and is both illegal and immoral.

A Strategic Threat Completely Unrecognized by the West

The Russian methodology leads directly to rather mind-bending, extended capabilities. KGB psychoenergetics scientists seem fixed on an eventual goal of directly engineering Jung's collective human unconscious, thereby converting the entire human species into a sort of "ant" species. In short, they seek to engineer what they regard as "perfect communism and perfect order" directly in the entire species. *Figure 8* indicates the direct connection of every human's conscious and unconscious mind to the collective species unconscious and to Gaia, the collective unconscious for all species on Earth. Since time is internally structured and layered, it follows that time-like mind levels are also internested and layered.

This appears to be a significant strategic threat, *well along in its development*, that our scientific and intelligence communities have completely failed to recognize.

The direct engineering of the entire human collective species is a doable.[1] It is going to be done, whether we like it or not. In that race (which may eventually determine whether or not we retain any personal freedom at all), the "democratic" nations are woefully behind. In fact, the West has not even realized there is such a new kind of "arms race" for dictatorship and control of the "collective species mind" and we have already almost lost it. The West has not yet even developed the overall theory of psychoenergetics.

Waves and Wave Transductions

A pure longitudinal EM wave (LW) would have infinite energy and infinite speed. In practice, one can only approach this perfect LW wave, and one always has transverse residues remaining. Hence the "imperfect" longitudinal EM waves we can make in suitable equipment and techniques, are known as "undistorted progressive waves" (UPWs). The UPWs may have velocity far greater than the speed of light, or less than the speed of light. So the speed v of UPWs can vary as

$$0 < v < \infty \qquad [6]$$

The Russians also know that, when a nearly-pure longitudinal EM wave interacts with matter (it usually doesn't interact very much, and has a low reaction cross section), the mass immediately adds the phase conjugate replica to the interacting LW portion, regardless of frequency, thereby transducing the input LW interactions into scalar (time-polarized) EM interactions.

One transduces from TW to LW to Scalar EM via iterative phase conjugation. One transduces from scalar EM to LW to TW via iterative interferometry. It took the present author 20 years to discover this simple thing; we now have filed an invention disclosure on the process and embodiments for performing it, and will be following with formal patent applications. Let TW = transverse EM wave, LW = longitudinal EM wave, and TDW = time-density EM wave (another name I use for t-polarized or scalar EM waves, since the density of time-energy is what is varying). Let (I) = interfering with, PCR = phase conjugate replica wave with a coupled set of parentheses enclosing the type of wave. The rules for wave type transduction are:

$$\mathrm{TW} + \mathrm{PCR(TW)} \Rightarrow \mathrm{LW} \qquad [7]$$

$$\mathrm{LW} + \mathrm{PCR(LW)} \Rightarrow \mathrm{TDW} \qquad [8]$$

Going the other way, the rules are:

$$\mathrm{TDW}\ (\mathrm{I})\ \mathrm{TDW} \Rightarrow \mathrm{LW} \qquad [9]$$

$$\mathrm{LW}\ (\mathrm{I})\ \mathrm{LW} \Rightarrow \mathrm{TW} \qquad [10]$$

In EM smog (dense EM signals, even though very weak), there is increased nonlinear multiwave interactions, both interferometric and phase conjugative. So in such EM smog there exists an increased, non-negligible component of LW and TDW irradiation, formed by the above transduction interactions in the irradiated living cells and bodies. This latter part accounts for many of the long term effects which show up in "correlative" studies, but which do not show up in the normal limited-frequencies TW experiments produced by so-called "physical experiments."

The standard EM bioeffects manner of experimenting uses a theoretical model of simple, direct energy deposition by means of absorption in cells and tissues. Now we must utilize an "open system" throughout the body dielectric in which higher polarized EM energy (either LW or t-polarized) travels readily throughout all areas of the body.

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EM Bioeffects and Wave Transductions

In the EM bioeffects experiments to date, there has been absolutely zero control of the internal transductions, and there has been no consideration of them. Almost all transductions of TWs into LWs will immediately result into transduction into TDW and time-excitation charging of the cells and all their internal components. These time-excitation charges (excited states of time-charging) will then slowly decay, emitting longitudinal EM waves in the process which travel throughout the body. These emitted LWs interfere with each other and the LW processes in the body, producing low level TW "noise jamming" of the cellular processes and—most especially—of the deep cellular control system of the body. The latter system functions by means of LWs and TDWs. Long-term effects of such "noise jamming" of biochemistry reactions and the control systems of the cells and body, can lead to degenerative diseases such as arthritis, atherosclerosis, Alzheimer's disease, heart disease, cataracts, tumors, leukemia, somewhat accelerated aging, immune system weakening and depressing, etc. As the body's natural defense and regeneration ability weakens, opportunistic infections further add to the degeneration.

It was shown by Whittaker in 1903 that any scalar EM potential is comprised of a harmonic series of bidirectional longitudinal EM wavepairs. [See *Figure 9*] Each longitudinal EM wave pair in the harmonic series is a phase conjugate pair. Unknown to Whittaker, that "LW phase conjugate pair" is actually a time-polarized EM "photon" structure, containing a phase conjugate LW photon substructure. So staid old "voltage" (potential) is comprised of a harmonic series of time-polarized EM waves!

The corresponding "t-polarized photons" are actually spin-4 *supergravitons* comprised of coupled antipairs of LW "photons". Each LW photon is a spin-2 *graviton* comprised of a coupled TW photon-antiphoton pair. Each TW photon and antiphoton in the coupled pair has spin-1. The couplet, being the longitudinal "photon" or graviton, thus has spin-2. And so on.

In 1904, Whittaker showed that any EM field or wave pattern can be decomposed into two scalar potential functions. By applying Whittaker 1903 decomposition to each scalar potential function, any EM field or wave has an enormously rich internal structure, comprised of scalar potential functions in interference. Each scalar potential function is comprised of time-polarized EM waves (made of spin-4 supergravitons). Each time-polarized EM wave is further comprised of bidirectional longitudinal EM wavepairs. Each longitudinal EM wave is further comprised of phase-conjugate pairs of transverse EM waves. Each transverse EM wave is further comprised of two scalar potential functions, each of which is in turn comprised of an infinite harmonic series of time-polarized EM waves, and so on *ad infinitum* and *ad nauseum*. Obviously all EM potentials, fields, and waves have an enormous "internal structure" or internal "information content of the field".

The Cellular Control System Uses t-Polarized EM Photons and Waves

The master cellular control system (MCCS) in the body utilizes these photon-gravitons, their corresponding EM wave polarizations, and transductions between them. By the use of very powerfully condensed gravitons and supergravitons, it is able to utilize small but highly significant direct curvatures of spacetime to not merely send a "signal" and hope the cell itself acts upon it. Instead, it sends an "engine" which alters the local spacetime in which the cell and all its components are embedded. This "local ST curvature engine" then physically works directly upon the cell and all its parts, to alter the cell according to the specific "template" of the engine.

This is the direct application of the Wheeler's simple statement of general relativity: *Mass (trapped energy) acts upon spacetime to curve it, and curved spacetime acts upon mass to change it.*

Popp's "ordinary photon" study of this cellular control system[2] therefore will detect the coherent ordinary TW photon residues which result from the photon polarization transductions occurring from the actions of the ST curvature engines upon the cells.

Cellular division, biochemical processes, growth and growth control, cell differentiation and dedifferentiation, etc. are all controlled by the MCCS or one of its subsystems, using spacetime curvature engines. The ordinary TW electronic activity our biophysicists detect and correlate are simply the intermediate components of the actual ongoing polarization transductions.

The Cellular Control System Uses EM Time-Energy

One important subsystem of the MCCS controls the immune system's functions, including the deepest and most subtle functioning performed by all elements of the immune system. This system has been rather intensively studied, but since our biophysicists have not possessed the full electrodynamics utilized, only the correlated residue of normal TW EM waves and photons have been recognized and studied. Hence Western biophysics is in its very crude infancy.

Incorporation of the total wave and photon polarizations, together with their transductions, will eventually present a revolution in both biomedicine and biophysics. Unfortunately, presently our entire medical community is very firmly entrenched in only ordinary TW EM polarizations and ordinary biochemistry. Our scientists thus are studying less than 1% of the functioning of the living organism.

As an example, since Western scientists have no knowledge or research into the time-polarized mind domain and mind-body coupling, the mystery of the *placebo effect*—in which the mind has been verified to produce actual physical effects – will indefinitely remain a mystery.[3] As one result of that "crippling" of our medical theory, medical experimenters have to deliberately drive experiments on drug effects, etc. beyond the "mind's own threshold" of physical effect. In short, they have to drive the experimental results over and above the results being accomplished by the placebo effect. They must perform valid placebo control experiments, and subtract the placebo component results from their own experimental results, to determine the "delta" induced purely by the drugs.

The Regenerative Subsystem

Another important subsystem of the MCCS controls the *regenerative system* of the body. The regenerative system has various mechanisms, including growth control, differentiation and dedifferentiation of cells, etc. Becker's portrayal of the regenerative system is shown in *Figure 10*. One of its most important functions is healing and restoring damaged or diseased cells. It does that by a most remarkable process.

This system has been very poorly studied, mostly by Becker[4] powerfully condensed gravitons and supergravitons, it is able to utilize small but highly significant direct curvatures of spacetime in precise patterns. In short, it utilizes general relativistic spacetime curvature engines, rather than "EM photon signals", to accomplish its control of the cells and their processes. It does that by a most remarkable process.

This system has been very poorly studied, mostly by Becker[4] *et al.*, although there is still sporadic, ill-funded, and ill-planned research on regenerative effects from time to time.[5] Becker and his colleagues came closest, and—considering the severe limitations of the orthodox U(1) EM model available to them—Becker's work is particularly revolutionary. He demonstrated beyond question that simple DC potentials could generate cellular differentiation and redifferentiation, and produce results at global sites in the body and not just at the local injury sites where the DC potentials were applied.

Becker was nominated for a Nobel Prize for his Herculean efforts and remarkable results. For his trouble he was hounded, his funds were withdrawn, and he was forced to retire at an early age in his 50s. His biggest "heresy" was to bravely point out that power line radiations had deleterious effects upon biological systems, and to testify to it in a series of hearings and court cases where a very powerful electrical power industry essentially ran rough shod over science and the public.

Organized Science Is Highly Politicized and Imperfect

It is not only politicians that are "bought and paid for" by powerful vested financial interests. In organized science, precisely the same arrangement holds true. Scientists are no better or no worse than any other segment of humanity. A surprising percentage will produce the results desired by their benefactors, if provided with cushy jobs, good income, prestige, and secure positions.

It has been said that money is power. It has also been said that power corrupts, and absolute power corrupts absolutely. In the scientific community, as well as in the political community, this "great corruption" by great financial power has been elevated to an art form. Simply examine the funds made available to scientists. There is not enough for all the scientists, so it is fiercely competitive. If the scientist does not get grants (e.g., a would-be professor at a university), he does not bring in extra money to the university. He cannot get his graduate students funded, so his own innovative (read: heretical) research is thwarted. His papers are rejected by the journals, and before long he has no funded position in science. If lucky, he will be employed in the grocery store or the butcher shop.

Every bit of funding available for the scientists to compete for (and apply for grants) already has firmly fixed controls of exactly what research can be done with that money. The "science" that will be applied is already formulated. That and only that can be done. It is a tribute to the dedication and resourcefulness of our working scientists themselves, that anything innovative at all gets done.

One can have a very fine scientific career, tenure as a professor, get one's graduate students funded, get one's papers published in prestigious journals, win awards and achieve stature and prestige, if one just plays the desired game prescribed by the "old boys schools" in control of almost all the scientific funding. Yes, one can permissibly move the decimal point in the present models a bit, and be rewarded handsomely for doing so. But one is damned if one attempts any serious change or overthrow of obsolete scientific models and practices favored by the "system".

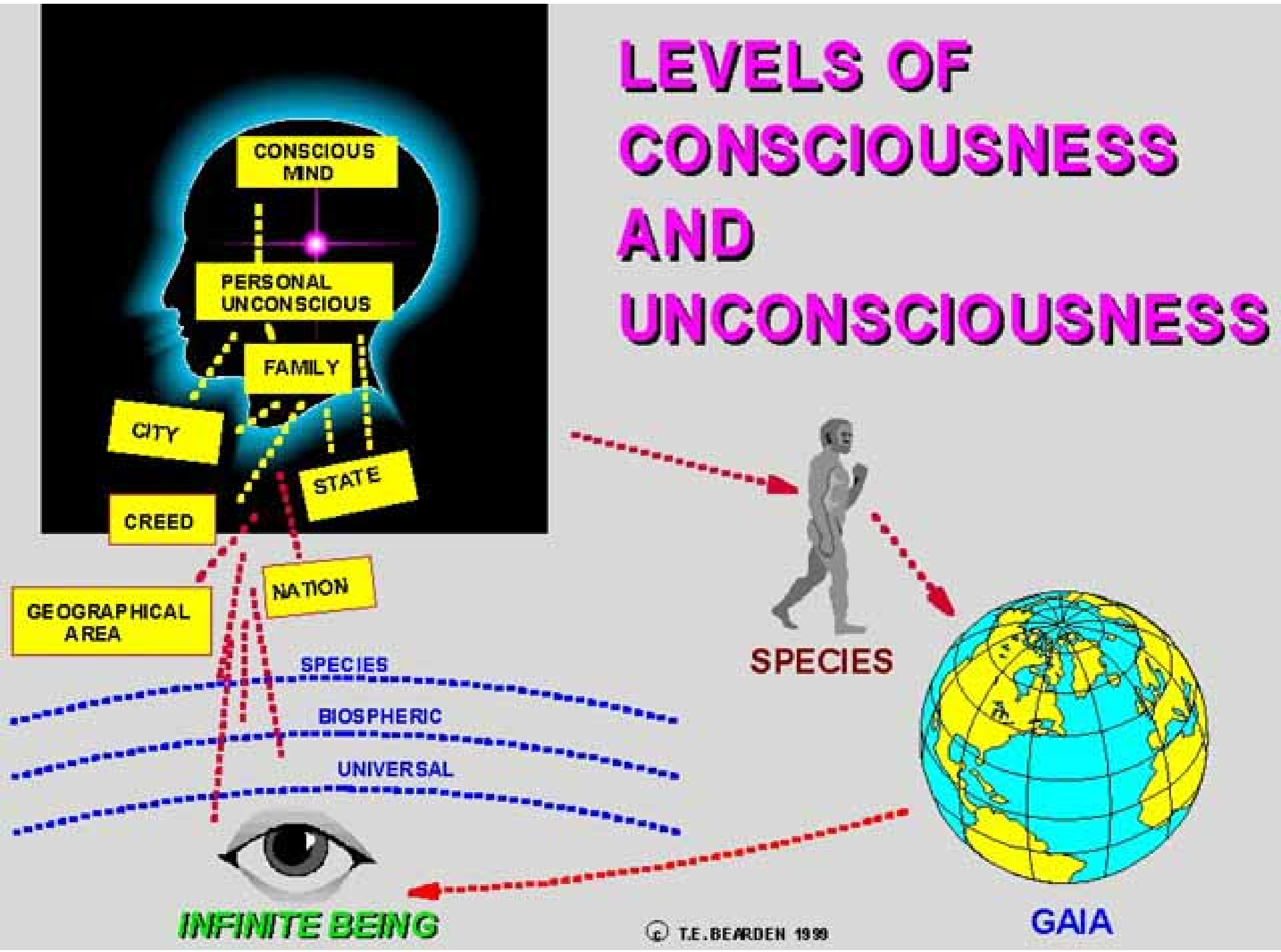

Figure 8. Nested levels of consciousness and unconsciousness.
The mind levels contain the "life" and "mind" dynamics.

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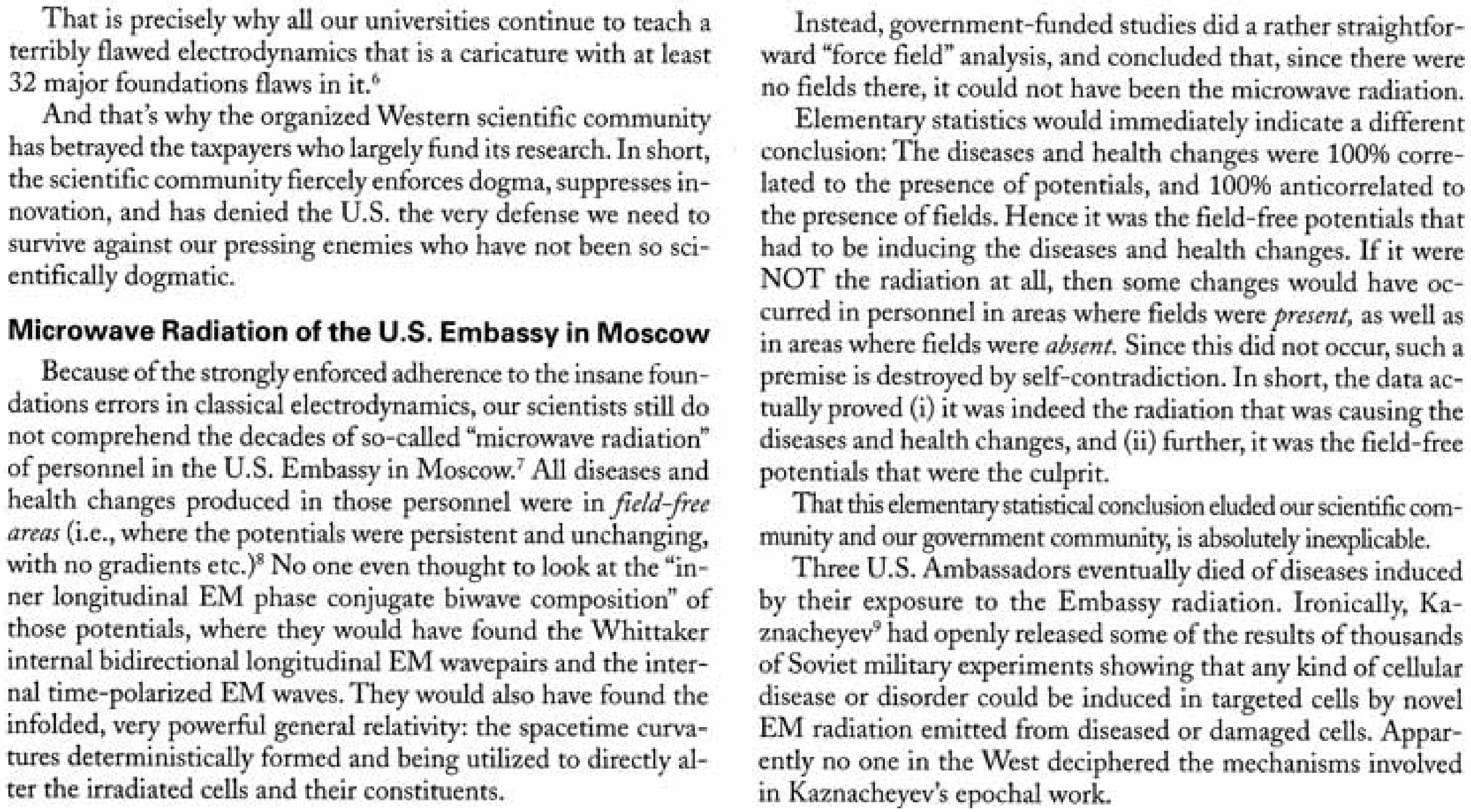

That is precisely why all our universities continue to teach a terribly flawed electrodynamics that is a caricature with at least 32 major foundations flaws in it.[6]

And that's why the organized Western scientific community has betrayed the taxpayers who largely fund its research. In short, the scientific community fiercely enforces dogma, suppresses innovation, and has denied the U.S. the very defense we need to survive against our pressing enemies who have not been so scientifically dogmatic.

Microwave Radiation of the U.S. Embassy in Moscow

Because of the strongly enforced adherence to the insane foundations errors in classical electrodynamics, our scientists still do not comprehend the decades of so-called "microwave radiation" of personnel in the U.S. Embassy in Moscow.[7] All diseases and health changes produced in those personnel were in *field-free areas* (i.e., where the potentials were persistent and unchanging, with no gradients etc.)[8] No one even thought to look at the "inner longitudinal EM phase conjugate biwave composition" of those potentials, where they would have found the Whittaker internal bidirectional longitudinal EM wavepairs and the internal time-polarized EM waves. They would also have found the infolded, very powerful general relativity: the spacetime curvatures deterministically formed and being utilized to directly alter the irradiated cells and their constituents.

Instead, government-funded studies did a rather straightforward "force field" analysis, and concluded that, since there were no fields there, it could not have been the microwave radiation.

Elementary statistics would immediately indicate a different conclusion: The diseases and health changes were 100% correlated to the presence of potentials, and 100% anticorrelated to the presence of fields. Hence it was the field-free potentials that had to be inducing the diseases and health changes. If it were NOT the radiation at all, then some changes would have occurred in personnel in areas where fields were *present*, as well as in areas where fields were *absent*. Since this did not occur, such a premise is destroyed by self-contradiction. In short, the data actually proved (i) it was indeed the radiation that was causing the diseases and health changes, and (ii) further, it was the field-free potentials that were the culprit.

That this elementary statistical conclusion eluded our scientific community and our government community, is absolutely inexplicable.

Three U.S. Ambassadors eventually died of diseases induced by their exposure to the Embassy radiation. Ironically, Kaznacheyev[9] had openly released some of the results of thousands of Soviet military experiments showing that any kind of cellular disease or disorder could be induced in targeted cells by novel EM radiation emitted from diseased or damaged cells. Apparently no one in the West deciphered the mechanisms involved in Kaznacheyev's epochal work.

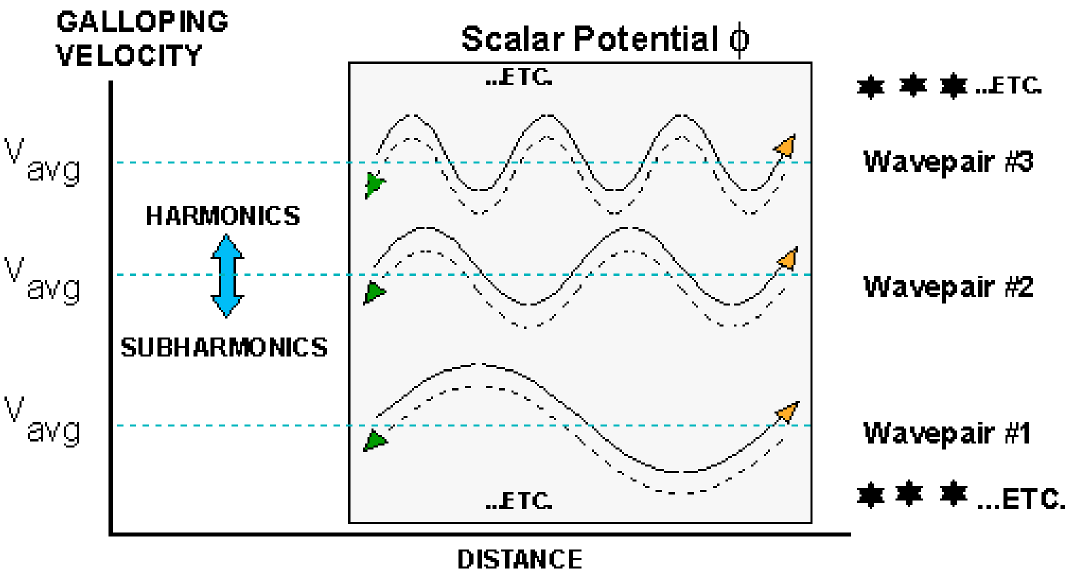

The Structure Is:

- A harmonic set of longitudinal phase conjugate wavepairs.
- In each wavepair the two waves superpose spatially after detection, but travel in opposite directions.
- The convergent wave set is in the imaginary plane, and hence is not observable. It is EM energy incoming to the potential (dipolarity) from the time domain.
- The charge's spin is 720 degrees, 360 in the real plane and 360 in the imaginary plane.
- Hence the charge receives the complex convergent EM energy, transduces it into real EM energy, and emits enormous energy at the speed of light in all directions -- which includes bidirectional pairs in 3-space (after the reaction, being after "observation").
- This produces the fields and potentials from the "source charge or dipole."
- Mandl and Shaw argue that the scalar (time-polarized) photon and longitudinal photon are observable only in similar pairs, which then makes the instantaneous scalar potential. Thus their quantum field

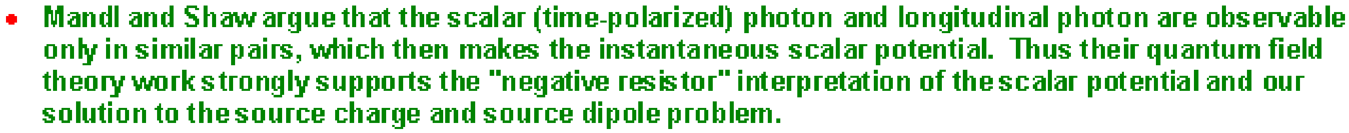

- Mandl and Shaw argue that the scalar (time-polarized) photon and longitudinal photon are observable only in similar pairs, which then makes the instantaneous scalar potential. Thus their quantum field theory work strongly supports the "negative resistor" interpretation of the scalar potential and our solution to the source charge and source dipole problem.

Figure 9. Infolded longitudinal biwaves (time-polarized EM waves) composition of a scalar potential.

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Figure 10

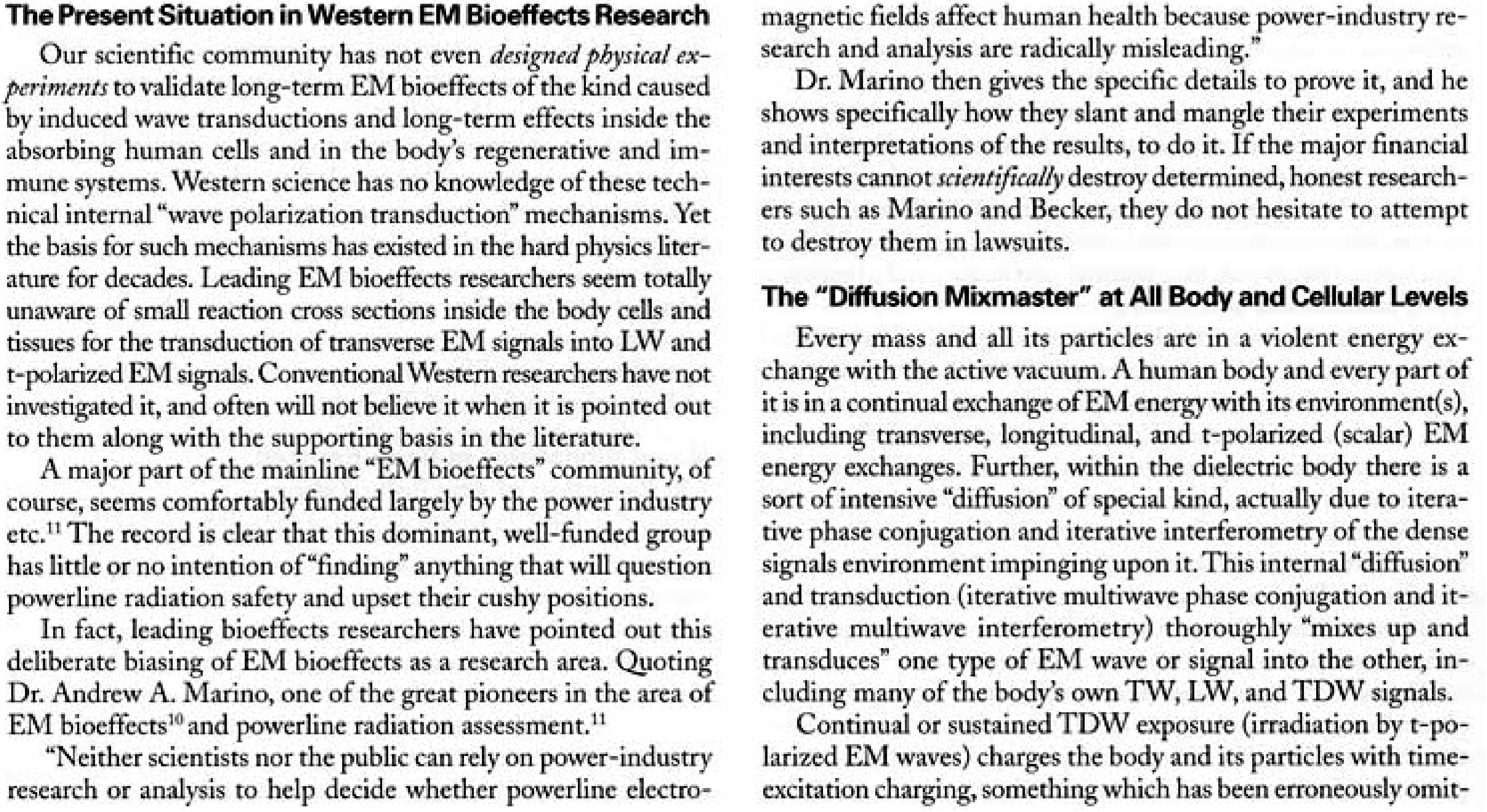

The Present Situation in Western EM Bioeffects Research

Our scientific community has not even *designed physical experiments* to validate long-term EM bioeffects of the kind caused by induced wave transductions and long-term effects inside the absorbing human cells and in the body's regenerative and immune systems. Western science has no knowledge of these technical internal "wave polarization transduction" mechanisms. Yet the basis for such mechanisms has existed in the hard physics literature for decades. Leading EM bioeffects researchers seem totally unaware of small reaction cross sections inside the body cells and tissues for the transduction of transverse EM signals into LW and t-polarized EM signals. Conventional Western researchers have not investigated it, and often will not believe it when it is pointed out to them along with the supporting basis in the literature.

A major part of the mainline "EM bioeffects" community, of course, seems comfortably funded largely by the power industry etc.[11] The record is clear that this dominant, well-funded group has little or no intention of "finding" anything that will question powerline radiation safety and upset their cushy positions.

In fact, leading bioeffects researchers have pointed out this deliberate biasing of EM bioeffects as a research area. Quoting Dr. Andrew A. Marino, one of the great pioneers in the area of EM bioeffects[10] and powerline radiation assessment.[11]

"Neither scientists nor the public can rely on power-industry research or analysis to help decide whether powerline electromagnetic fields affect human health because power-industry research and analysis are radically misleading."

Dr. Marino then gives the specific details to prove it, and he shows specifically how they slant and mangle their experiments and interpretations of the results, to do it. If the major financial interests cannot *scientifically* destroy determined, honest researchers such as Marino and Becker, they do not hesitate to attempt to destroy them in lawsuits.

The "Diffusion Mixmaster" at All Body and Cellular Levels

Every mass and all its particles are in a violent energy exchange with the active vacuum. A human body and every part of it is in a continual exchange of EM energy with its environment(s), including transverse, longitudinal, and t-polarized (scalar) EM energy exchanges. Further, within the dielectric body there is a sort of intensive "diffusion" of special kind, actually due to iterative phase conjugation and iterative interferometry of the dense signals environment impinging upon it. This internal "diffusion" and transduction (iterative multiwave phase conjugation and iterative multiwave interferometry) thoroughly "mixes up and transduces" one type of EM wave or signal into the other, including many of the body's own TW, LW, and TDW signals.

Continual or sustained TDW exposure (irradiation by t-polarized EM waves) charges the body and its particles with time-excitation charging, something which has been erroneously omit-

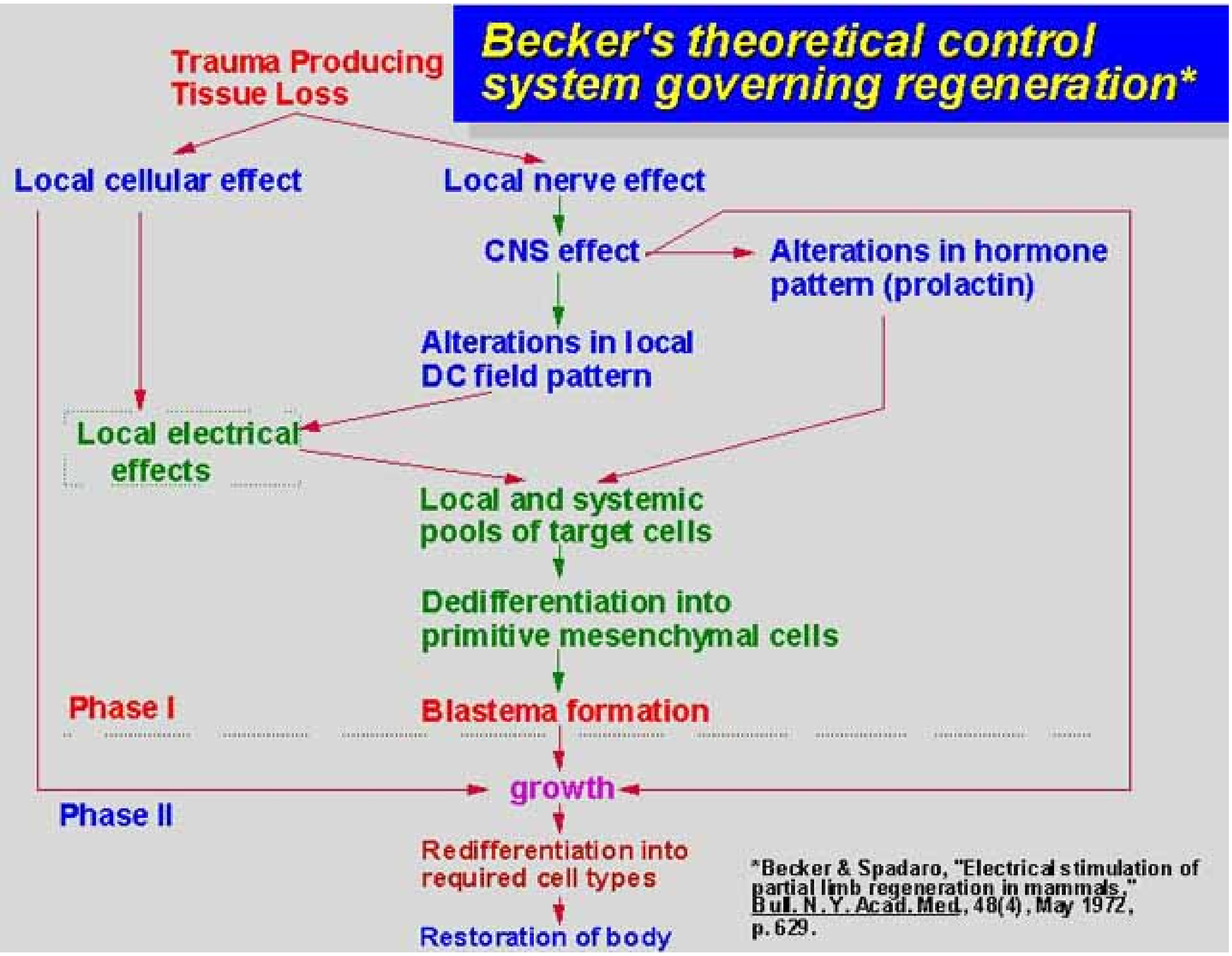

Becker's theoretical control system governing regeneration*

Trauma Producing Tissue Loss
Local cellular effect
Local nerve effect
CNS effect
Alterations in hormone pattern (prolactin)
Alterations in local DC field pattern
Local electrical effects
Local and systemic pools of target cells
Dedifferentiation into primitive mesenchymal cells
Phase I
Blastema formation
growth
Phase II
Redifferentiation into required cell types
Restoration of body

*Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bul. N. Y. Acad. Med., 48(4), May 1972, p. 629.

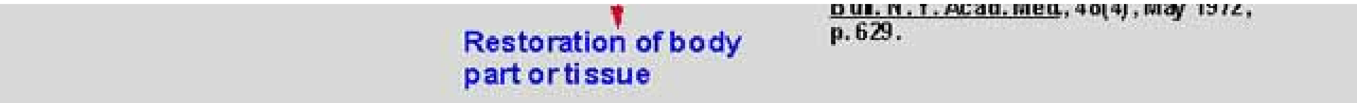
Restoration of body
part or tissue
Bull. N. Y. Acad. Med, 48(4), May 1972,
p.629.

Figure 10. Becker's model of the Regenerative system of the body.

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ted in physics, but is true nonetheless. Inexplicably, physicists just ignore what happens time-wise when a mass absorbs a photon. We have covered that elsewhere.

So inside the body dielectric, there is a "diffusion mix" correlate of any and every type of the waves, to any or all of the exchanges, plus the additional internal interactions of the body in its TW, LW, and scalar EM wave transductions. There is a one-to-one correspondence to any one of the three types of polarization waves (transverse, longitudinal, and scalar) and everything going on anywhere in the body.

Note that the type of LW we are using is actually made of phase conjugate pairs of transverse EM waves, so its "photons" are made of photon/antiphoton pairs. That is, our longitudinal EM wave has an internal TW structure, and the LW wave is comprised of spin-2 *gravitons*. Our longitudinal EM wave has an internal structure, and it dramatically differs from the LW used by the U.S. scientific community which ignores wave, field, and potential infolded substructures. Our LW (which seems to be what the Russians use) is also a gravitational wave because it is comprised of oscillations in its distributions of spin-2 photon/antiphoton pairs (i.e., *gravitons*).

The type of t-polarized (scalar) EM wave we are using is a phase conjugate coupled pair of the specialized electrogravitational (EG) LWs. The "t-polarized photons" comprising this t-polarized "EM" wave are comprised of spin-4 *supergravitons*. These are, I believe, what the KGB energetics weapons scientists use also. By iteration, we can go into as deep an internal multilevel structuring of EM and EG waves, of any type, via methods shown by Whittaker.[12]

Now let us examine a body as a dielectric, sitting there in its exchange, in relative equilibrium. It turns that every tiniest piece of a dielectric participates in any emission from it[13]—even the emission of a single photon, graviton, or supergraviton. Well, it *would* so participate, due to the special sort of correlated diffusion and interferometry and phase conjugation that we pointed out. Anything that escapes (is re-emitted) from the body, has been through this "diffusion wringer". It has escaped from each and every internal part of the body.

Novel Signatures in Body-Emitted EM Radiation of Any Polarization

A single photon or wave emitted from a dielectric carries in its internally structured time component a *template* of the exact internal time structuring of every part of the dielectric emitting that photon. It carries in its internally structured energy component a *template* of the internal energy structuring of every part of the dielectric emitting it. An emitted EM wave, being a collection of emitted photons and photon structures, thus carries the same internal structuring of both its transported energy and its transported time.[14] Western scientists do not use the internal

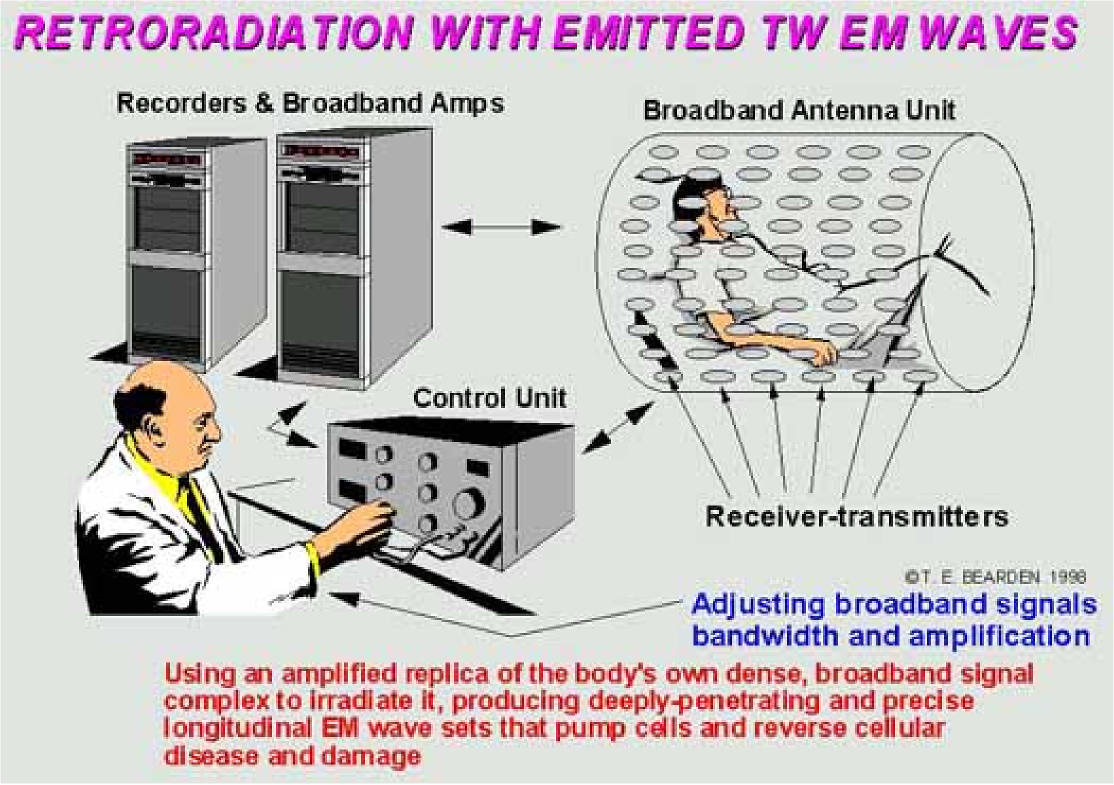
RETRORADIATION WITH EMITTED TW EM WAVES
Recorders & Broadband Amps
Broadband Antenna Unit
Control Unit
Receiver-transmitters
©T. E. BEARDEN 1998
Adjusting broadband signals bandwidth and amplification
Using an amplified replica of the body's own dense, broadband signal complex to irradiate it, producing deeply-penetrating and precise longitudinal EM wave sets that pump cells and reverse cellular disease and damage

Figure 11.

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structuring of photons and EM sine waves, have no instruments for that, and so do not know it. The Russians know it,[15,16] use it, and have developed sophisticated instruments for it for the last 30 years or more.

Shortly we will postulate how conventional scientists experimenting with mind and behavior control electromagnetically might utilize an immediate consequence of the fact that the specific emission from a body at any time—whatever type of wave component we look at—is a total correlate to all that body's internal functions, its energy exchanges with its environment, its states, its mental states and conditions, etc.

And we accent that the coherently integrated intent-changes in that body from its coupled mind's operations are also in the substructure of photons and EM waves emitted from the living body into its environment.

How Western Mind Control Scientists Might Proceed

Conventional scientists would ignore scalar photons and waves, determine the TW spectrum, and then slowly and painfully correlate that to the various physical, mental, and emotional things. That's the way they would *have* to do it, since apparently they use only standard electrodynamics. They can in fact do this via brute force, because that emission TW spectrum is of waves escaping from the entire "diffusion machinery" mixmaster in the body dielectric. It does contain all those integrated *mind-intent* 3-space correlates as well as the ordinary body 3-space energy correlates.

Anyhow, in envisioning Western procedures, the test body would be sitting there, in its normal (let's say fairly normal and quiet) EM environment. [See *Figure 11*] Let's assume this body is not sick, but is healthy and normal. Its emissions are a part of its equilibrium condition. It follows that the totality of its TW emissions is correlated to the sum total of everything that interacted with the body, plus its own internal reactions, including from mind-body coupling. Indeed, everything that has ever happened to that entity—physically, mentally, emotionally, etc.—has internal correlates infolded inside the emitted transverse EM wave spectrum.[17]

So first the scientists would simply measure the full environmental TW spectrum down to very tiny levels in all frequency bands possible—everything that is coming in to the body from its environment. They would probably perform the experiments in a triply-shielded Faraday cage, so the external environment outside the cage contributes very little transverse EM wave noise (perhaps some Schumann resonance). Magnetic wave shielding and ELF shielding is something else again, and longitudinal EM wave shielding is in general not possible unless longitudinal EM waves are employed in the shielding. But a "quiet external TW environment" enhances the isolation and measurement of the specific TW signal transforms the Western experimenters would be seeking.

Then they would measure everything likewise that the body is *emitting* when in that environment. That is the "zero reference" or "normal reference" level. They would measure every aspect: frequency, amplitude, phase, wave shape, modulation, etc.

Probable Experimental and Measurement Techniques

Next they would selectively irradiate the body with specific signals, frequencies, waveforms, etc. They would begin by using

They would consider the body dielectric as a "ship with portholes". Light (EM transverse wave energy) coming out of the portholes has originated and adapted from everywhere inside the ship and its operations. When the experimenters reinsert energy through one or more portholes, they are interested in determining precisely which operations inside the ship are affected. So the body physiological functions are also heavily instrumented.

By feeding back in the exact EM pattern and magnitude escaping the body dielectric through a single porthole, one "nullifies" that part of the emission by producing a net equilibrium in that component. This will in turn produce changes elsewhere in the spectrum emission from other portholes, and this can be measured. It will also produce "stress changes" in specific portions of the body dielectric, and in the heavily instrumented body these physiological, chemical, electrical, etc. changes can also be detected. Monitoring of the skin conductance, e.g., indicates the level of stress, and EEG monitoring with sophisticated instrumentation can indicate something of the brain wave states.

In short, the necessary measurements from which to construct specific correlates can be performed, recorded, and later analyzed.

This article will be concluded in Volume 9, #4 with Improving the Methodology, Further Phenomenology Experiments, Rejuvenation and other matters. ◆

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President and Chief Executive Officer, CTEC, Inc. Lieutenant Colonel U.S. Army (Retired). MS Nuclear Engineering, Georgia Institute of Technology. BS mathematics, Northeast Louisiana University. Graduate of Command & General Staff College, U.S. Army. Graduate of Guided Missile Staff Officer's Course, U.S. Army (equivalent to MS in Aerospace Engineering). Numerous electronic warfare and counter-countermeasures courses.

Tom is the leading advocate of scalar potential electromagnetics and the Fogal charge-blocking semiconductor. He is involved in alternate energy devices and scalar electromagnetic system prototypes. He has defined charge q as a coupled system of two components, advanced a mechanism for a vacuum engine, whereby the vacuum's virtual particle flux is organized and used to energetically shape and manipulate matter and energy, and advanced a mechanism for a Bohm-type quantum potential, which theoretically allows the engineering of action at a distance in physical systems.

He is president of the Association of Distinguished American Scientists (ADAS), a life member of the Alabama Academy of Science, Emeritus member of the American Association of Physics Teachers, and has served on the Board of Directors of several associations and corporations. Tom is a guitarist, a retired aikidoist (Sandan, Yoseikan style), is happily married and has two sons and two daughters. He and his wife Doris live in Huntsville, Alabama where Tom is retired from aerospace, continues private research, and serves as a consultant to industry on Scalar electromagnetics processes.

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1. *In fact, it simply applies in the laboratory that method that is already used by species for the so-called "directed evolution" component of evolution. The exact mechanisms for directed evolution also arise naturally in the new approach. Directed evolution is required; e.g., no reptilian species could have evolved slowly into a bird. As it started slow changes, it would have not been able to fly or to run, and would have been simply destroyed immediately by*

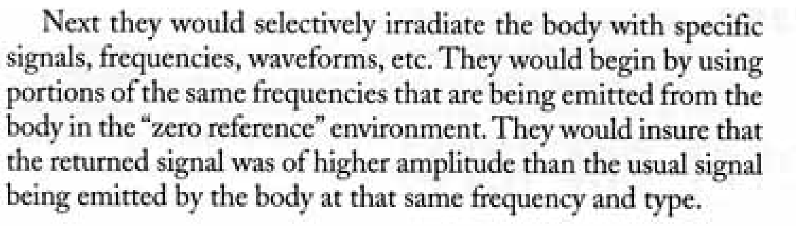

Next they would selectively irradiate the body with specific signals, frequencies, waveforms, etc. They would begin by using portions of the same frequencies that are being emitted from the body in the "zero reference" environment. They would insure that the returned signal was of higher amplitude than the usual signal being emitted by the body at that same frequency and type.

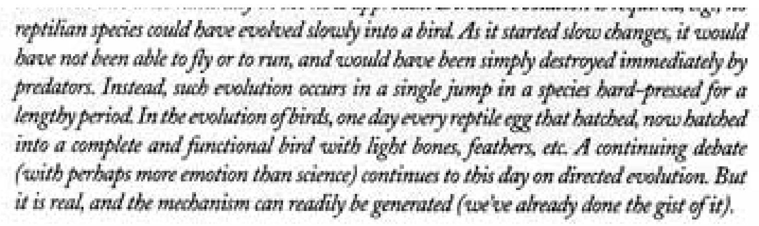

reptilian species could have evolved slowly into a bird. As it started slow changes, it would have not been able to fly or to run, and would have been simply destroyed immediately by predators. Instead, such evolution occurs in a single jump in a species hard-pressed for a lengthy period. In the evolution of birds, one day every reptile egg that hatched, now hatched into a complete and functional bird with light bones, feathers, etc. A continuing debate (with perhaps more emotion than science) continues to this day on directed evolution. But it is real, and the mechanism can readily be generated (we've already done the gist of it).

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3. With novel use of EM time-energy to curve spacetime, the physical actions of the "placebo effect" are due to the use of such "spacetime curvature engines" to produce actual physical effects—at least temporarily —in the cells and throughout the body's chemistry, physiology, etc. Experimental detection of these physical effects are well-established in the orthodox medical literature.
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5. E.g., a popular discussion is given by John Travis, "Starting Over: Some Animals can regenerate limbs or even most of their bodies. How?", Science News, 152(18), Nov. 1, 1997, p. 280–282. For a typical technical paper, see Jeremy P. Brockes, "Amphibian limb regeneration: Rebuilding a complex structure," Science, 276(5309), Apr. 4, 1997, p. 81–87.
6. I have one viewgraph which lists those 32 major flaws in electrodynamics. Further, leading theorists (Evans, Crowell, and others) in the Alpha Foundation's Institute for Advanced Study (AIAS)—of which I am a Fellow Emeritus by AIAS's kind tolerance—have added about another very technical and very fundamental dozen or so errors to my own list. A leading foundations scientist with over 500 papers in the literature commented dryly to the AIAS that "I broadly agree. that the transverse plane wave view of vacuum electrodynamics is the biggest blunder of twentieth century science. Faraday visualized that "EM disturbances" surrounding wires, magnets, etc. were simply the transverse plucking of taut strings. As he states in his book, Maxwell—who also firmly believed in the material ether—simply captured Faraday's thinking and assumed that transverse "plucked string" wave disturbance in the material ether. At the time all this was expressed, the electron had not been discovered, the atom had not been discovered, the molecule was a featureless blob, and no one had the slightest notion of an atomic nucleus filled with protons and neutrons. Charge was simply a "certain volume of electric fluid" and everything electromagnetic was expressed in fluid dynamics. As an example, that "material fluid" and "material ether" theory was destroyed in the late 1880s by the Michelson-Morley experiment. All the Maxwell equations assume that material ether to this day; not a single equation was ever changed to eliminate the material ether assumptions during the last 110 years.
7. For full explanations of the "Moscow Signals," see T. E. Bearden, ., Gravitobiology: A New Biophysics, Tesla Book Co., P.O. Box 121873, Chula Vista, CA 91912, 1991;—AIDS: Biological Warfare, Tesla Book Co., 1988. For an excellent Government study of the Embassy radiation by excellent but orthodox Johns Hopkins scientists, see A. M. Lilienfeld et al., Foreign Service Health Status Study: Evaluation of Health Status of Foreign Service and Other Employees from Selected Eastern European Posts, Department of Epidemiology, of Hygiene and Public Health, The Johns Hopkins University, Baltimore, Maryland, Final Report, July 31, 1978. On p. 245, it is noted that a marked excess of symptoms were noted in the Moscow employee group as compared to other East European employees in other East European nations.
8. Johns Hopkins researchers established the exact field patterns present in the Embassy from the microwave carrier radiation; see Robert C. Mallaliew, A Model of the Microwave Intensity Distribution within the U.S. Embassy, Moscow 1966 to 1977, Report FS-80-166, Applied Physics Laboratory, Johns Hopkins University, Aug. 1980. Nowhere in any of the Government-funded studies is there any consideration of field-free scalar potentials and their internal time-polarized EM wave structures (the bidirectional phase conjugate wavepairs shown by Whittaker to comprise the scalar potentials). Yet the field radiation patterns surprisingly showed that in just such field-free, persistent potential zones was where 100% of the health changes occurred.

issue, see "A Comment" by William A. McGarey, p. 143; "A Comment" by Arthur C. Hastings, p. 143–144. See also Vlail Kaznacheyev, "Apparent information transfer between two groups of cells," Psychoenergetic Systems, 1(1), Dec. 1974. The Soviet Union awarded Kaznacheyev a very high medal for his achievements.

10. For a very nice summary of EM bioeffects from the more conventional view, see Robert O. Becker and Andrew A. Marino, Electromagnetism and Life, State University of New York Press, Albany, 1982. The book is also available at http://www.ortho.lsumc.edu/Faculty/Marino/EL/ELPub.html.
11. Andrew A. Marino, Powerline Electromagnetic Fields and Human Health, http://www.ortho.lsumc.edu/Faculty/Marino/Marino.html. This book is highly recommended. Particularly see "Chapter 5, Blue-Ribbon Committees and Powerline EMF Health Hazards," and "Chapter 6: Power-Industry Science and Powerline EMF Health Hazards." Biophysicist Marino is one of the leaders in the field and has been personally involved in many skirmishes with powerline-dominated studies and findings.
12. E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," Mathematische Annalen, Vol. 57, 1903, p. 333–355; — "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions," Proc. Lond. Math. Soc., Series 2, Vol. 1, 1904, p. 367–372.
13. Reali, G. C., "Reflection from dielectric materials," American Journal of Physics, 50(12), Dec. 1982, p. 1133–1136. The reflected field from a dielectric material is not generated just at its surface but comes from everywhere in the interior of it.
14. Present physics models the EM wave as transporting energy, but erroneously omits that it also transports time. A photon is made of angular momentum, or "energy x time". Since EM waves are made of photons, it follows that they transport both the energy components and the time components making up those photons. An EM wave is a wave of angular momentum, not just a wave of energy.
15. KGB energetics weapons scientists call this internal structuring the "information content of the field." However, the Russians use a good deception plan, which implies that the "information content of the field" is just the normal transverse EM spectral content of EM signals. Appreciable "pertinent" work using that phrase is produced by the open Russian scientific community, thus confusing the issue. Our electrodynamicists seem to buy it hook, line, and sinker. The deception plan also tricks Western scientists into thinking that psychoenergetics is nothing but a Russian version of Western parapsychology. Again, our scientists comfortably accept this with smug satisfaction.
16. Presently the Russians are in a great new version of this deception plan, with the goal of deceiving Western scientists into thinking that the "secret" Russian energetics is based on torsion fields. Consequently they are releasing substantial material on torsion wave theory, including replicable experimental results. The released version of torsion fields has one glaring omission: the time components and structuring. This deception plan is excellent, because the torsion field theory that is released, is indeed "real" and testable. It is also revolutionary, with respect to present Western science. It almost positively assures diverting the attention of much of the Western science community into this highly limited subset of the full Russian torsion theory—effectively diverting the West away from psychoenergetics and the direct use of t-polarized EM waves and fields, torsion or otherwise.
17. We point out that E. T. Whittaker, in "On the Partial Differential Equations of Mathematical Physics," Mathematische Annalen, Vol. 57, 1903, p. 333–355, showed that every scalar potential is comprised of an internal structure of bidirectional longitudinal EM phase conjugate wavepairs in an infinite set of harmonics. Each of those phase conjugate longitudinal EM wavepairs comprises a time-polarized EM wave. So the common potential contains an internal longitudinal EM wave structure that is further organized into an internal time-polarized EM wave structure. The mind-intent correlates and the total mind and emotional experience correlates from fertilization of the egg that led to development of that person, is in the internal substructure of every potential in the living body. In his "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions," Proc. Lond. Math. Soc., Series 2, Vol. 1, 1904, p. 367–372, Whittaker also showed that any EM field or wave is comprised of two scalar potential functions. It follows from Whittaker and Reali that the EM emissions from the living body carry the internal correlates of everything that has been experienced by that person from conception in the womb. Sometimes this deep embedded "hidden information content" can even be accessed in deep hypnosis. I once observed the deep hypnotic regression of a subject back to her prenatal experiences prior to birth, where the subject relived hearing words of rejection by the father, before the subject was born. The occurrence of the incident and the father's words were directly confirmed on the spot by the mother, who was closely observing the session as it occurred. It turned out that this particular rejection of the baby still in the womb had played a major role in subsequent deep psychological

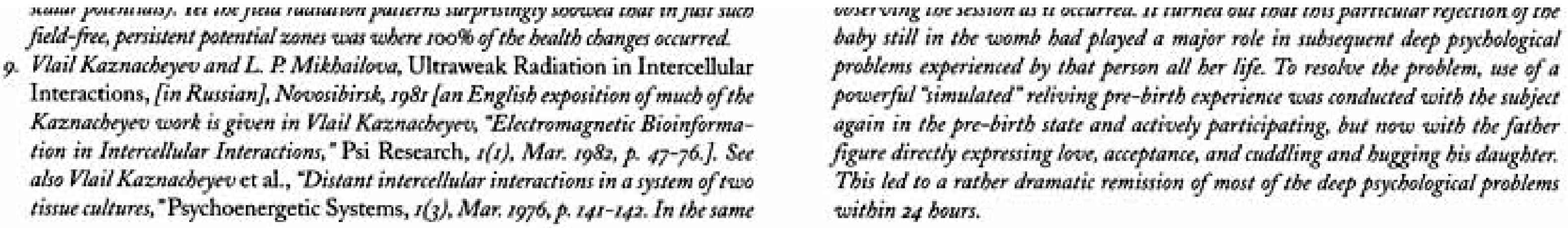

scalar potentials). Yet the field radiation patterns surprisingly showed that in just such field-free, persistent potential zones was where 100% of the health changes occurred.

9. *Vlail Kaznacheyev and L. P. Mikhailova,* Ultraweak Radiation in Intercellular Interactions, *[in Russian], Novosibirsk, 1981 [an English exposition of much of the Kaznacheyev work is given in Vlail Kaznacheyev, "Electromagnetic Bioinformation in Intercellular Interactions,"* Psi Research, *1(1), Mar. 1982, p. 47-76.]. See also Vlail Kaznacheyev* et al., *"Distant intercellular interactions in a system of two tissue cultures,"* Psychoenergetic Systems, *1(3), Mar. 1976, p. 141-142. In the same*

observing the session as it occurred. It turned out that this particular rejection of the baby still in the womb had played a major role in subsequent deep psychological problems experienced by that person all her life. To resolve the problem, use of a powerful "simulated" reliving pre-birth experience was conducted with the subject again in the pre-birth state and actively participating, but now with the father figure directly expressing love, acceptance, and cuddling and hugging his daughter. This led to a rather dramatic remission of most of the deep psychological problems within 24 hours.

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Mind Control and EM Wave Polarization Transductions, Part 3 of 3

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This outstanding article is the last, Part 3, Part I and 2 of which were published in Volume 9, #2 and #3 of Explore! for the Professional. Because we feel that Col. Bearden's Special Note below is so very important we are repeating its publication in all 3 parts of this article.

Special Note

This article refers to experimental research techniques which can be detrimental or lethal in the hands of any but highly skilled, qualified experimental scientists proceeding under proper laboratory safety procedures. The purpose of this article is strictly for information to properly qualified and authorized scientists in certified laboratories. We do not propose or condone any use of these procedures for nonapproved practice of medicine without a license. Neither the publisher nor the author are responsible for accidents or outcomes in the use of these experimental procedures and techniques. Any researcher who performs these procedures and experiments is acting on his or her own volition, and is solely responsible for insuring safety, qualifications, and legality of the acts and their results. We neither suggest nor condone unauthorized experimentation on human subjects. Such is a criminal violation

achieving many more effects in the targeted bio-organism or groups of them. With Hunt's method, the system as an *open dissipative system far from thermodynamic equilibrium in its environment* is being measured as such. This more directly allows for determination of the environmental inputs on a much broader range of subsystems, both space-like and time-like. Particularly for mental and emotional correlates to environmental stimuli, such measurements and correlations are essential.

More Comprehensive Phenomenology Experiments

To return: Now the scientists would perform many phenomenology experiments, making one little change at a time and profusely recording the data. Each time, they would establish the physical change(s) that occur in the body and/or the mental and emotional changes that occur in the mind for each spectral reinsertion back through the "ship's portholes". They would simply but painstakingly (over some years) build up an extensive database of those individual correlates.

In these experiments, the experimenters will eventually be able to provoke any body or mind change they wish. Strong emotion.

of the constitutional rights of the subject under Federal and State laws, and is both illegal and immoral.

Two Ways to Improve the Methodology and Experimental Correlates

We diverge momentarily: If they wish to improve this methodology, they will consider the body dielectric as a nonlinear isotropic medium. Then they will pretend that the spectrum of *difference frequencies* between each two adjacent waves is the spectrum of "emissions" from the body. They would also use those, as if they were actual emitted spectral signals, instead of the actual signals emitted. That procedure will give superior correlations, but it is more complicated. Part of that is known for underwater sonar,[1] and so our own scientists may or may not have realized it for use in mind and behavior correlate determination with respect to the body dielectric.

Another dramatic improvement in the depth to which the correlates can be constructed, is provided by detecting each porthole output in a two-channel device, where one channel has an adjustable time-delay as utilized by Dr. Valerie Hunt.[2] The two channels—one real-time and one slightly delayed—are then mixed, as by Hunt's method, producing an instrumental measurement of the chaotic part of the functions. Again, this can be measured, recorded, and later analyzed. It adds (i) a completely different kind of thermodynamics in the system measurements, (ii) a dramatically extended set of correlates, (iii) more direct measurement of the time-polarization causative signals, and (iv) an applications Intense pain. Intense pleasure. Painful thoughts. Images. Memories. Perceptions. Dreams. Visions. Memory losses. Memory changes. Personality changes. Etc. The "delta" in the emission spectrum (the changes from zero reference spectrum) represent the precise totality of all mental, physical, organic, chemical, etc. changes and interactions.

A particularly vulnerable aspect of every mammal is the pleasure center in the brain. Experiments have shown that, when this center is stimulated, it is the most addictive experience possible. Rats will forego food, endure electrical shocks, starve, and even die to obtain stimulation of this center. Obviously a device capable of generating signals that evoke direct stimulation of the pleasure center in humans would be a powerful weapon.[3]

Extending the Data Base

See Figure 12. After the researchers have made an "individual porthole signal insertion" correlate database, then they would make a "two, three, four," porthole signal insertion correlate database by inducing selected multiple changes at once. Again they would analyze everything; the program would need one or more supercomputers. It would also require quite a highly qualified multidisciplinary team, extensive facilities, substantial funding, and would be many years in duration. We are describing a decades-long program. But it's a doable.

With sufficient development and performance of such a program, the researchers would have produced (with sufficient testing and analysis, and sufficient retest validation and verification) a database of "specific correlates for a given overall technology eventually having many additional degrees of freedom and therefore capable of

desired physical, mental, or physical and

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mental delta."

A second stage in the research would be to test the correlates and porthole insertions upon a statistically significant cross section of ordinary people, and/or specialized populations (such as toughened soldiers). The program would evolve a highly complex, very effective, ever-improving science and technology of mind and behavior control and engineering mechanisms, complete with finished database and developed applications equipment.

The Dielectric Body as a Ship With Portholes

Again let us review what the EM transverse wave irradiation from the body dielectric represents. Think of the body dielectric as a sort of "ship", with lots of portholes. When it gets irradiated, certain operations happen internally to that radiation, i.e., certain "processes" and "interactions" occur, which change both the mental and physical states. The output emissions back from the body dielectric, out through the filtering "portholes", will directly correlate to what has happened inside the ship.

It is terribly important to realize that one can use the same frequencies and spectra coming back out of those "portholes" to insert EM signals and waves etc. back in there, and into the deepest processes going on in the body and in the mind (at all levels, times. So it will reach directly into and affect any and every part of the dielectric, as you wish, and in whatever manner you have correlates for.

We filed an invention disclosure[4] on the above correlate and "back-porthole" process for use in directly inducing full and efficient conversion directly to time-density (scalar, or time-polarized) EM waves inside the body/ cells, *therefore immediately and directly time-excitation charging the body cells and all their internal components.*

Subtracting the Normal Correlates to Obtain the Deltas

A specifically diseased body, e.g., has a specifically tailored change in its "normal" emission spectra, because of the disease condition alteration of its resident spacetime curvature engine. By having a database for the normal emission spectra of the healthy body, one can subtract it from the actual emitted spectra, to obtain the "delta spectrum".

If the correlates have been previously determined by the above mentioned research program, then one may simply introduce an amplified "delta spectrum" into the body, i.e., through the portholes. This will immediately time-excite the cells and their components throughout the body, particularly where that disease does exist. It turns out that the time-excitation charging by that method will "pump" those diseased including the deep unconscious).

Remember, whatever you put back in there, is going back through the "mixmaster" hopper. It will be iteratively phase conjugated and interfered with by everything, countless cells in the time domain. The cells themselves (and all their parts) are highly nonlinear—to time-excitation charging, they are *totally* nonlinear. So they will act as rather perfect pumped phase conjugate mirrors, but pumped in the time-energy domain rather than in the spatial

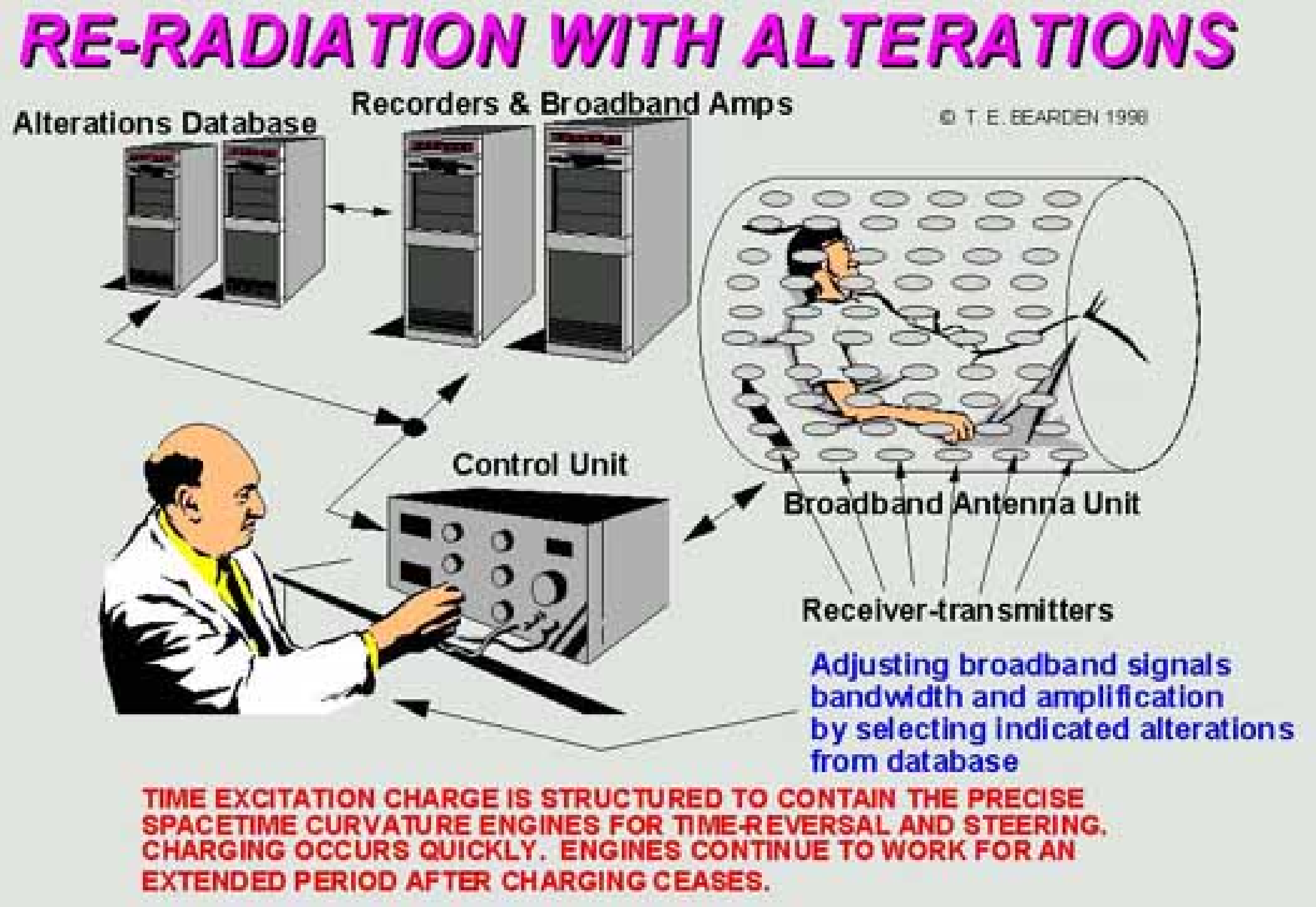

RE-RADIATION WITH ALTERATIONS

Adjusting broadband signals bandwidth and amplification by selecting indicated alterations from database

TIME EXCITATION CHARGE IS STRUCTURED TO CONTAIN THE PRECISE SPACETIME CURVATURE ENGINES FOR TIME-REVERSAL AND STEERING. CHARGING OCCURS QUICKLY. ENGINES CONTINUE TO WORK FOR AN EXTENDED PERIOD AFTER CHARGING CEASES.

Figure 12. Using an amplified replica of the body's own dense, broadband signal complex, containing added alterations, to irradiate the body and produce deeply-penetrating precise time-density charging for cellular time-reversal while steering the time-reversal trajectory to also correct a congenital condition.

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energy domain. This is a dramatic extension to nonlinear phase conjugate optics theory.[5]

General relativity tells us that each specific detail of the mass and energy structure of each cell and all its parts—down to the finest details—is accompanied by a precise set of spacetime curvatures. By reintroducing the same energy as the disease delta TW waves, the affected cells add the phase conjugates, converting the inserted TW signals into longitudinal EM wave signals. The longitudinally-pumped cells again phase conjugate, converting these longitudinal EM waves to time-polarized EM waves, and "charging" the cells and all their parts in the time domain.

Suddenly, at that point the *resident spacetime curvature engine*—rather than TW or LW EM waves-serves as the "input signal" to the cell-and-its-parts as pumped phase conjugate mirrors (PCMs), pumped in the time domain. An extension to the distortion correction theorem of nonlinear optics results. An exact, amplified antiengine for the diseased cells—i.e., a phase conjugate replica of the resident spacetime curvature engine—is formed. This amplified antiengine overpowers the resident disease engine, powerfully time-reversing the cells and their components back to a previous healthy state. The time-reversal actually occurs over a period of time after the "time excitation charge-up" ceases, say over the next week or two. Usually two to three quick irradiations are required, one week apart, to give a time-reversing period of three to four weeks.

force upon the cells or any part. E.g., as Pepper[6] states,

"On a more fundamental level, the ideal lossless PCM reverses all the quantum numbers of the incident photon (i. e., linear momentum, angular momentum, etc.). It can be shown that the PCM therefore experiences no linear or angular momentum transfer from the incident photons; hence, the PCM is free from photon radiation pressure and torques."

Note that, in ordinary EM theory, it is precisely translation forces that are engendered upon charged mass by EM fields. This process is quite different. In biological terms, this process dedifferentiates (in physics: time-reverses) the diseased cells and all their components—including the genes—back to an earlier healthy state.

By taking a diseased body and feeding back into it an exact amplified replica of its emitted TW spectrum, one can force the body to "time-excitation charge" all cells and their components immediately, with high efficiency. The human body and every cell and every part of every cell does the necessary "calculation" for the exact antiengine for each part. Since time is extremely condensed spatial EM energy (by a factor of almost 10^{17}), a startling contraction occurs in the radiation time required to time-charge the cells and their components and charged particles. This is a method for instant initiation of time-charging, hence it is extremely rapid. What took Priore several hours of LW irradiation to accomplish in the body,[7] can now be done

Even though appreciable forces are operating internally upon the cells and all their parts, there is no net translation

in seconds with this "thwarting" and spectrum transduction method. In fact, it is an intense stress on the body, and—say—should only

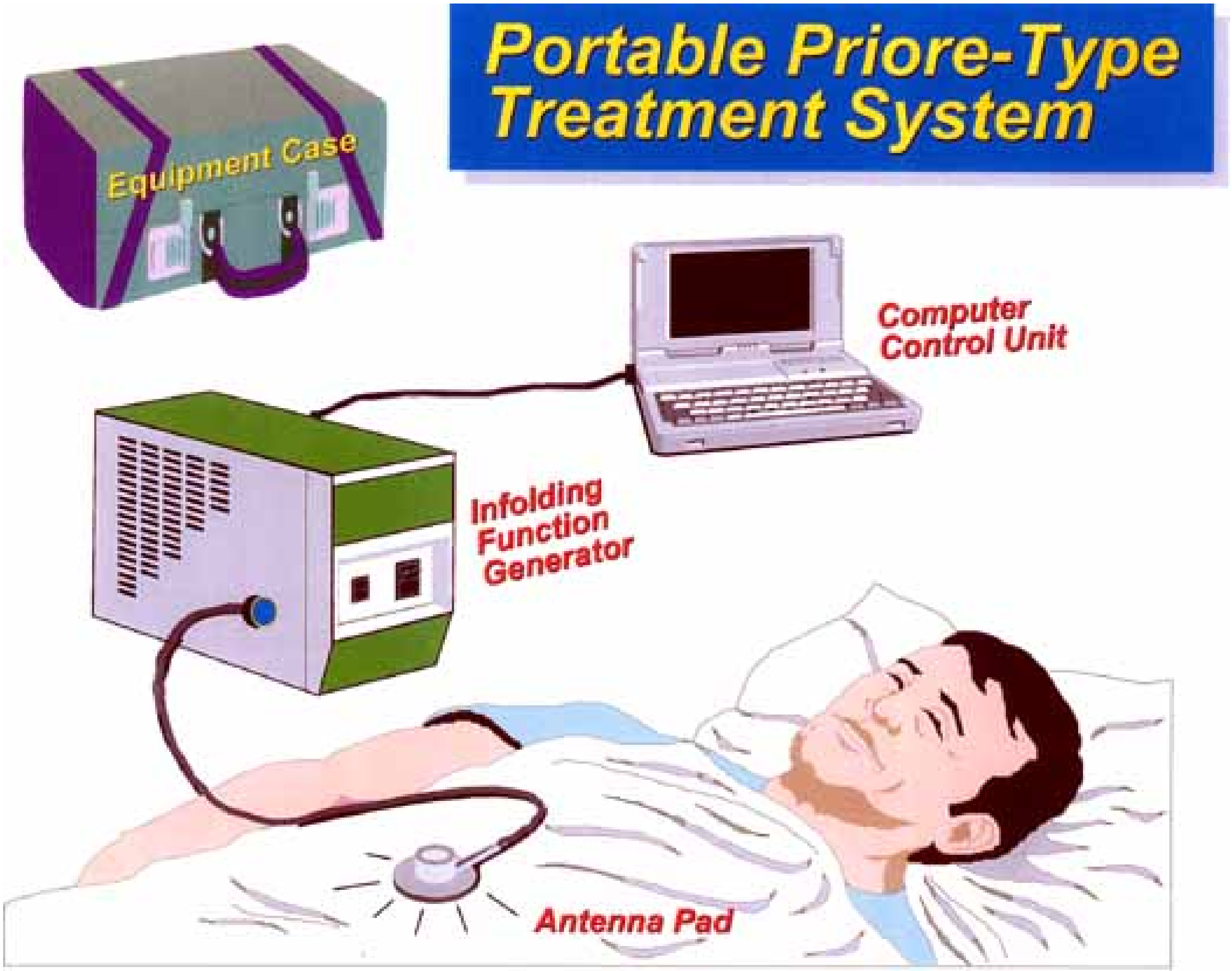
Portable Priore-Type Treatment System
Equipment Case
Computer Control Unit
Infolding Function Generator
Antenna Pad

Figure 13. Portable first-method treatment unit proposed to the Department of Defense. For treating and curing mass casualties from terrorist BW attacks on U.S. population centers.

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be continued for 30 seconds or so. We highly stress that overcharging in this time domain can be detrimental or even lethal if prolonged.

At the end of the very short time-excitation charging time, the body is "time-excitation charged in all its minutest particles". So everything is therefore pumped in the time domain for the next several days after the irradiation is removed, since the time-charge decays very gradually over a period of time. During that decay period, every part of the cell and body acts as a pumped phase conjugate mirror material, pumped in the time domain rather than in the 3-space energy domain. When time-pumped, the mass itself reverses to a previous physical state. This can be used for both nonliving and living masses. Because there is no forcible translation manipulation of the cells and their parts, it can be utilized on living cells in vivo. In the case of diseased cells—e.g., AIDS-it appears that three precisely determined 30-second "AIDS correlate" irradiations a week apart, should be sufficient to completely cure AIDS, including removal of all HIV-genetics changes from every previously infected cell of the body. Also, it would accomplish considerable rejuvenation of the body (making the body younger).

Rejuvenation: Restore the Telomeres and Produce Immortal Cells

Saving Most of the Casualties from Mass Terrorist Attacks

To defend against things like anthrax attacks on our civilian population centers, we also have recommended to the U.S. Government the crash development of small, portable treatment machines—using similar "antiengine-forming" and cellular reversing "porthole technology". [See Figure 13 on previous page]. Such portable machines could be developed cheaply and quickly, and present government facilities could be used to massively attack the correlate database production problem. The portable treatment units could be cranked out by the hundreds of thousands and flooded down through emergency response agencies such as the police forces, the National Guard, emergency hospitals, emergency response teams, etc.

Each device could be used in "assembly line" fashion upon hundreds of sickened patients, in case of a WMD (weapons of mass destruction) attack upon one or more of our cities. The first generation equipment would save probably 70% of the stricken (as from anthrax, etc.). With second generation equipment, one would expect 90% of the stricken casualties could be saved.

Just now, there is a very dim prognosis for all those casualties, using present available treatment capabilities. Time and lack of vaccines defeats just about everything that can be done. Brutally speaking, most of those unfortunate enough to breath in

In fact, it is now known that the gradual loss of the telomeres—the natural ends of chromosomes—in a cell's chromosomes is what causes the cell to age. The gradual loss of the telomeres and the resulting shortening of the chromosomes represents a cellular "disease state" or "disorder" state" accompanied by a precise delta in the spacetime curvature engine accompanying every affected (aging) cell.

By determining the correlate for that precise telomere loss in the aging body's emitted radiation spectrum, an effective telomere regeneration process immediately emerges. One simply amplifies that aging "precise telomere reduction" correlate and reradiates the body with it, passing an amplified correlate back into every cell of the body. The cells and all their parts—including the chromosomes—add *the phase conjugate replicas*, converting the incoming TW EM correlates to longitudinal EM wave correlates. The cells again phase conjugate the LWs and add *the phase conjugate replicas*, converting the LW correlates to time-polarized EM wave pumping correlates. This latter process *time-excitation-charges* the aging cells and all their parts, including the genes and chromosomes. The cellular matter itself produces the amplified "aging antiengine" for each and every cell and telomere ending. The result is to again add telomeres, converting the cell back to a younger, more vigorous cell, and reversing the process of aging.

We point out without further elaboration that these methods also introduce direct engineering signals into the body's master cellular control system, including the regenerative subsystem. Hence the body's regenerative subsystem is involved in helping produce the necessary engines and anthrax spores from an attack, are going to die. At least 80% of them will expire, in spite of everything the present system can do for them.

Note each device could rapidly treat a whole series patients, one right after the other, merely laying them between "blankets" containing wire antennas, irradiating with the proper correlate spectrum quickly, moving on to the next patient, irradiating quickly (seconds), etc. The entire apparatus could be made to fit in a large suitcase-sized container, and it would be highly portable and controlled by a laptop-sized computer.

Unfortunately, so far the DOD doesn't even understand what the heck we're talking about! The National Institute of Health (NIH) and the National Science Foundation (NSF) are not interested at all. After all, it isn't drugs, vaccines, antibiotics, etc. — which are simply not going to do the job. However, those are what the government and scientific communities are going to finance to the tune of hundreds of millions of dollars. They are then going to lose almost all those mass casualties when the terrorist attacks on our population centers inevitably occur.

Those are Americans. They are going to die. Most of them could be saved. We ought to save them.

For any change in state (physical, chemical, emotional, mental, perceptual), the body dielectric "portholes" change and the output spectrum changes. The delta from zero reference now represents that exact change.

Where Western Mind Control Research Has Probably Arrived

Western mind control researchers

operate upon the short telomere chains to add back telomeres. More specifically, the regenerative subsystem is changed into perfect consonance with the external introduction of the amplified antiengines.

That exact process can be used to rejuvenate the aged population and remedy most of the debilities of growing old. That is how we eventually intend to do it, if we can convince the U.S. government and the U.S. scientific community to perform the necessary research and validation.

probably first established a correlation database of porthole emission correlates to changes in internal states, both physical and mental. They almost certainly recognize the peculiar participation of every part of the body dielectric in the TW emission spectrum from the body. They will almost certainly have opted for this "porthole" notion of some similar expression of it, and the "thwarting" of these "relaxation and release" emission processes to engender internal physical changes in the body and in the brain-meat-computer, as they see it.

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They probably experimented with different TW EM radiation mixes, to see what the body emission change to, and what states are induced. Undoubtedly they found that the induced states began to correlate with the former emission delta data base. That is, they found out which delta emissions spectra, reversed and amplified and fed back thorough the portholes, produce what internal changes.

Use for healing is the simplest of all. Use for killing or debilitating is more complicated. Of course weapons researchers wish to look only at the killing aspects. That is something they understand. They do not understand healing, for they do not even have the "regenerative" or "healing" mechanism in any of the scientific papers or texts. Becker[8] came closest in this country, and Priore did it in France. Both of those scientists were suppressed and paid a bitter price for their revolutionary and innovative research.

But look at what has been done, by "input-output" correlation research. The scientists will have a database now, that tells what state emerges in the body and in the mind, for what irradiation spectra (frequency, relationships, phases, amplitudes, wave shapes, etc.) one uses. And they did not work out all the wave-to-wave transductions ongoing in the mind and body connection and in the body and in the mind, individually, between TWÛLWÛTDW.

We suspect that this is the course Western mind control researchers will have taken, without even realizing the internal wave transductions occurring. And they would not be concerned with that. They would have what they want, for weapons, mind control, and behavior control. And they of the internal "mix" of the dielectric and all its tiniest portions. So Western mind control researchers and rogue groups probably do get good results.

We are not just picking on the U.S. government here! Internal divisive groups exist in all large and powerful groups, and joust for power. In highly classified groups, these groups are greatly enabled to joust more widely, unethically, and immorally because it is so deeply hidden. So very deep classification evokes the growth and intensity of rogue groups. It's the old "Power corrupts, and absolute power corrupts absolutely" routine.

The implication is that in the West one or more highly classified, sustained, heavily funded developments in advanced mind control programs, probably exists and probably has existed for some time. Due to loose formation of rogue groups inside such programs, they may have dual or triple purposes, may not operate under very much legitimate government control at all, and may operate specifically for the purposes of the rogue group or groups that have gained control.

In a nutshell, that's what may be going on in the clandestine mind control projects in several Western governments. The involvement of at least some rogue groups, some being "cowboys" who operate well outside all laws and ethics, could also result in such things as assassinations, clandestine testing on individuals without their consent, etc. In short, *it could account for what seems to be actually occurring*. As also is "usual" in such a mess, one or more of the rogue groups eventually may become very powerful because their secret weapons are very powerful. They may become confident, thinking they have the "best in the would of course ignore the healing aspects. And they would get results of course, revolutionary results. So they would undoubtedly classify the program very highly, thinking that they had the best of the best.

Rogue Groups May Also Have Arisen to Divert the Purpose of the Projects

And that is where real problems may arise. Every human group has within it competing subgroups, jousting for power. The more highly classified the group and its activities, and the less that is known about it outside its confines, the more strongly and secretly the subgroups can play. So they can emerge as **rogue groups** pursuing their own agendas, not that of their duly elected governments. In the extreme, such a deep black program can even become a "captured" program, which is totally in the hands of rogues and no longer reports to or is bound by the dictates of the parent government.

It has long been suspected in some quarters that even the US's highly classified research community may be riddled by such rogue groups, and so may be certain highly sensitive parts of the Research and Development community.

Remember that, in every large and powerful human organization, the basis for rogue groups is power and secrecy. They are always seeking to increase their power, control, influence, prestige, etc. Nothing else. Patriotism and mission are—to rogue groups—often just idle words. They have their own agendas. And being rogue groups, they may well bring in unethical, immoral tricks: assassination, bribery, entrapment, disinformation, plausible deniability, etc. A world." They may actually believe they are ahead of the Russians.

Where the Russians Probably Have Arrived

On the other hand, the Russians will have developed instruments for detecting and isolating the LWs and the scalar waves, in addition to the ordinary mundane instruments for measuring the TWs. So they will have not only the TW correlates, but also the much finer TWÛLWÛTDW (scalar EM wave) correlates. They will understand and employ the use of vacuum engines (spacetime curvature engines) which Western researchers will often invoke but not understand or even be aware that this is what is being invoked. In other words, Western researchers probably just use the old method of "input fi set of functions fi output". That is the standard basis for almost all Western system analysis. With it, one doesn't have to know the exact functions and processes going on in the middle. One just determines a transfer function from a given input to the output that results. Then one catalogs that transfer function. One does that for lots and lots of transfer functions for particularly desirable results, and one has the system analysis. One also has the immediate basis for a rapidly-developed applications technology.

Western scientists are good system analysts. But they have little or no comprehension of what is really going on in that "inside the ship functions" portion, even though they have determined the transform function which acts upon the input to give the "from the portholes" output.

The Russians, with their additional knowledge of the actual mechanisms in the transforms, will be much more advanced certain percentage of a highly secret rogue group will wind up using all these things and more. It's a **human** characteristic, the old primate dominance game. Only now disguised and hidden under deep classification.

Nonetheless, the "simplified" TW EM "porthole correlate" approach will yield very positive results, due to the correlation existing with the LW s and scalar portions than the West, because their fundamental psychoenergetics science is far more advanced, so long as we continue to use the old U(l) electrodynamics. Further, the Russians have decades of use of longitudinal interferometry beams to reach right through the earth and ocean and produce stringent EM effects at a distance. So they will also be able to do the same things here in "mind control" with LW interferometers, through intervening mass

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including the earth and ocean. Western mind-control scientists and their rogue groups—assuming they exist as postulated—largely will not be able to do that, and probably won't even recognize Russian testing of psychoenergetics weapons directly in or over Western nations.

Russian Lethal Psychoenergetics Mind Control Tests Over the U. S.

In fact, the KGB tested just such highly advanced mind control weapons over the middle of the United States in 1997 on two occasions. The tests were conducted against Captain Button in his A-10 "Warthog" aircraft on April 2, 1997 [See Figure 14], and upon Captain Svoboda in her A-10 "Warthog" on May 27, 1997. [See Figure 15].

Over Arizona, Captain Button was thrown into a hypnogogic state, and his perceptions instantly altered and controlled. In his instant "dream-waking" state, everything seemed perfectly normal. His sense of direction was altered a bit more than 90 degrees, so he simply corrected and turned and "flew toward the range", actually flying off course by more than 90 degrees and ignoring radio contacts. He flew right on out of Arizona. At one point he circled, probably thinking he was over the range, and he probably dropped his ordnance there. Then he "flew on back toward home," as he thought in his waking dream state, until his fuel ran out and he crashed and died in the explosion—dream-thinking until he died that everything was normal. All the while, his sense of the passage of time was altered. To him, in his dream-thinking, dream-acting state, everything was normal and nothing untoward had happened. So the distant KGB transmitters and associated psychoenergetics team controlled him for over an hour.

Indeed, that was the exact purpose of the test: demonstrate control (at a great distance) of a skilled person performing highly skilled tasks. A secondary purpose was to stimulate the U.S. government, watch its investigation and findings, and ascertain if the U.S. knew of the extent to which Russian KGB mind control weaponry had advanced. Obligingly, we proved to me KGB that we did not understand what had actually happened to Captain Button.

Captain Svoboda was from the same Wing as Captain Button and was its most experienced night fighter A-10 pilot. In fact, she taught other pilots the fine points of night flying combat missions in the A-10. About two months after Captain Button's bizarre flight and death, Svoboda was engaged in night target bombing on the range. Rising from her ordnance drop on me target, Svoboda was suddenly struck and rendered hypnogogic and in a waking-dream state. Her sense of the vertical was instantly reversed. Superb pilot that she was, she immediately dream-perceived she was diving, not climbing out of the delivery. She instantly corrected to "climb out". So in the real world she dived sharply into the ground and her aircraft exploded.

This test demonstrated the instant alteration of a skilled pilot's perception, causing that pilot to inadvertently react promptly in an unintentionally suicidal manner. A secondary purpose of the test was to stimulate the U.S. government system again, to see if the system recognized what had

A-10 Mysterious Flyaway and Crash

April 2, 1997

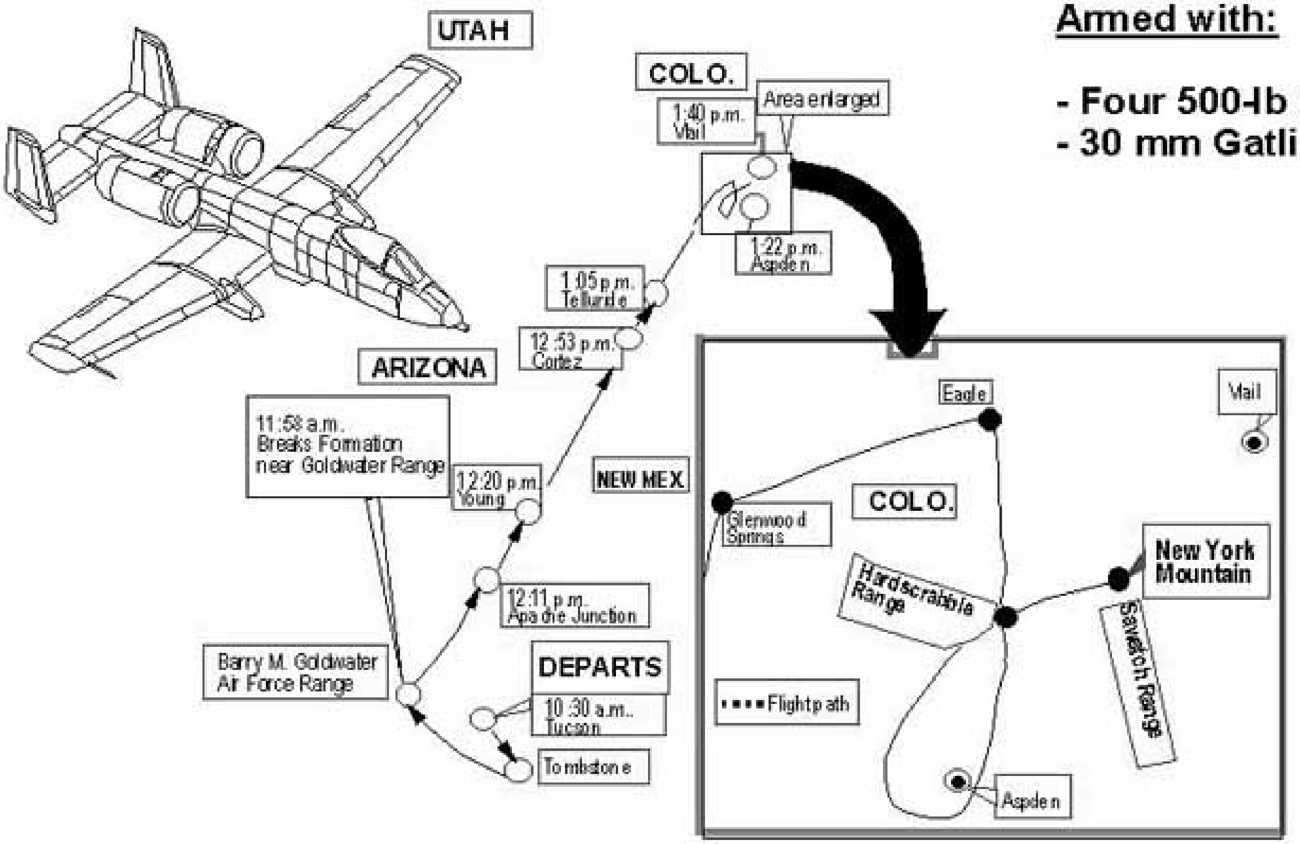
UTAH
COLO.
1:40 p.m.
Vail
Area enlarged
1:22 p.m.
Aspden
1:05 p.m.
Telluride
12:53 p.m.
Cortez
ARIZONA
11:58 a.m.
Breaks Formation
near Goldwater Range
12:20 p.m.
Young
NEW MEX
12:11 p.m.
Apache Junction
Barry M. Goldwater
Air Force Range
DEPARTS
10:30 a.m.
Tucson
Tombstone
Eagle
Vail
Glenwood
Springs
COLO.
Hardscrabble
Range
New York
Mountain
Sawatch Range
▪▪▪▪ Flightpath
Aspden

Armed with:

- Four 500-lb bombs
- 30 mm Gatling gun

Figure 14a. Captain Button's mysterious flyaway and eventual crash.

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occurred. Sad to say, it did not and it has not. It was lamely speculated that Svoboda probably looked over her shoulder like a rank greenhorn, and inadvertently dived her aircraft into the ground while looking back at the target. If there was one pilot in the USAF who would have not done that, it was Captain Svoboda. At any rate, the KGB determined that the U.S. scientific, intelligence, and governmental communities did not have the foggiest notion of what had occurred.

In private proprietary communications[9] we have explained further, to proper parties, exactly the reasons for these two tests, and what exactly was being tested, and what is its planned strategic use.

The Final Race for Direct Mind Control of the Entire Human Species

The KGB psychoenergetics weapons scientists—because of their direct measurements and detections (and use) of t-polarized waves and LWs for decades—also understand that Jung's collective unconscious mind (of the entire human species) also has its own time-like operations and correlates, which one measures also when using t-polarization measurements and sorting it all out. The collective unconscious mind operations are buried several levels deeper inside the recursive Whittaker structuring inside the EM fields, waves, and potentials.

The KGB scientists also know that something very like Gaia— a collective unconscious mind for all species on earth—also exists, and they are striving to be able to sort out and measure that one as well. The Gaia operations are buried even deeper in the recursive structuring inside the EM fields, waves, and potentials. If one reads some later books by Kaznacheyev,[10] e.g , this human species unconscious mind aspect and the biosphere unconscious mind aspect emerges loud and clear, if one interpolates between the lines, so to speak. Actually, from day one, the Russian mind control scientists have had their eventual goal set upon this "deeper area of mind and possible mind control" of the entire human species.

I am convinced that the KGB psychoenergetics scientists understand this deeper area. If they can learn to directly engineer the collective human species unconscious, they can then convert the human species easily into a sort of "ant" society, modeled along ideal Communism lines, except of course with an excluded "hierarchy at the top" running everything. The "ant society"—communist style—is still a variation of feudalism (all systems tend to feudalism or some form thereof).

The KGB psychoenergetics weapon scientists are seriously pressing on toward that very goal. In my opinion they are not very far from it right now. It is simply a matter of developing sufficiently complex equipment to be able to directly engineer the time-domain substructuring at sufficiently deep levels. It is a doable, although it is very, very complex and very, very difficult. On the other hand, they have been at it for decades. Even in the 50s the Russians already had the old LIDA device,[ll] capable of inducing a catatonic trance-like state in a mammal—either a human or a cat,[12] for example. Some versions of Russian mind control devices were used on Russian soldiers in the

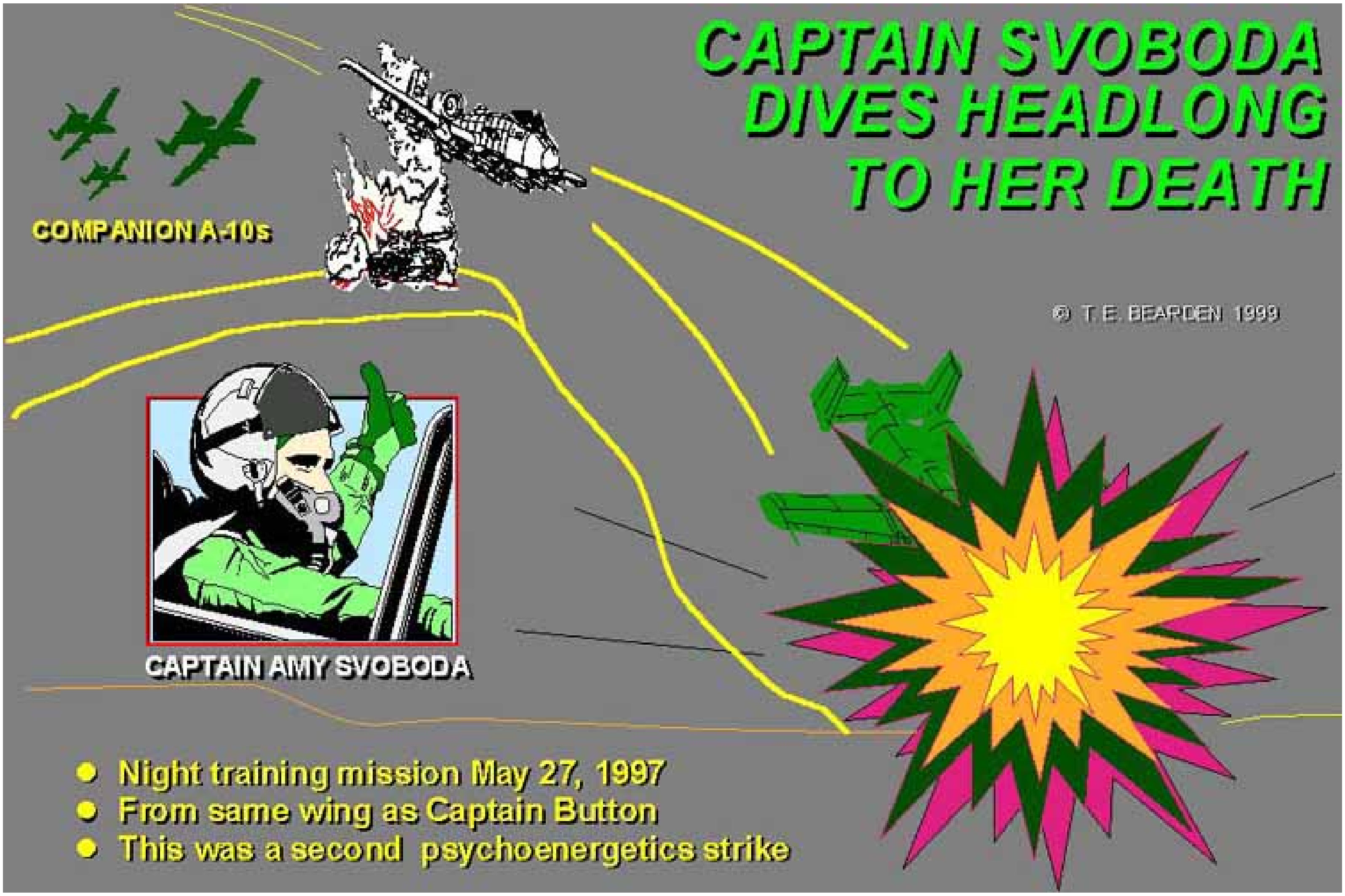

CAPTAIN SVOBODA DIVES HEADLONG TO HER DEATH

COMPANION A-10s
© T. E. BEARDEN 1999
CAPTAIN AMY SVOBODA

- Night training mission May 27, 1997
- From same wing as Captain Button
- This was a second psychoenergetics strike

Figure 15. Captain Svoboda dives headlong to her death.

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Afghan War to condition them for performance of merciless acts.[13]

Potential U.S. Rogue Groups and Two Recent Examples

Meanwhile, rogue groups amongst Western clandestine mind control researchers will probably arise if they have not already done so. They will likely seek to increase their personal control and further isolate the programs from orthodox government review and from government and legislative control. They may even divert the research into highly illegal and unethical means, because it furthers their own rogue agendas. That is how clandestine U.S. government research can sometimes go sour, unless great care is exercised by the oversight committees in the House and the Senate.

Sometimes when rogue groups do gain control and total secrecy of a given new technological area, then what appears to be "U.S. government operations" do start to encompass a criminal and unethical operations, hidden usually beneath the deep veil of high classification. Also, if it's "scientific," no one is ever brought to justice, even if the "evil science actions" are uncovered and publicly revealed.

We Certainly Have Proof of Such Rogue Activity. For Example, Here are Two Prominent Cases:

as a result of those ghoulish experiments. So what happened when this gruesome thing was revealed? Again President Clinton publicly apologized! The head of the Executive Branch did not turn the macabre matter over to his Attorney General to prosecute. How many of these scientists were indicted? Not one. How many are going to be indicted? Not one. Suppose again this had been done by a private doctor in his own private clinic. You get the point.

There is Little or No Punishment of Rogue Scientific Groups

Shockingly, the U.S. government at the highest level has directly shown (and these are not all such cases by any means!) that mass crimes against U.S. civilians, *perpetrated by portions of the U.S. scientific community in direct conspiracy and in secret*, will likely be condoned. The perpetrators will not be indicted, tried, or convicted.

Note the connection of the "rogue groups" thesis to the above incidents. Note how rogue **scientific** groups got away with it in both these cases. There may be other rogue

1. For three decades, scientists from the U.S. government, universities, and civilian contractors secretly conspired to treat unsuspecting human patients with whole body nuclear radiation, including some retarded children and cancer patients. Some of those patients—including some of the retarded children—died as a result. These illegal experiments were conducted in great secrecy, and the results were highly classified. Eventually these actions were revealed, and a Presidential investigation committee investigated. These experiments would seem to be little different from the WWII Nazi and Japanese experiments on human prisoners. Are those U.S. scientists who were responsible for those retarded children's' deaths any different from the Nazi scientists and criminals we executed at Nuremberg? So what happened when this terrible thing finally came out into the open? President Clinton publicly apologized! How many of the responsible scientists were indicted for murder? Not one. None is ever going to be.
   Suppose a doctor here in South Alabama, with his own private clinic, had secretly irradiated those human patients and retarded children with whole body nuclear radiation, over a period of 30 years, resulting in some agonizing deaths. How many state and federal agencies would have come after him with arrest warrants? Probably about 50 or so. Would he have been indicted, tried, convicted, and executed or sent to prison for scientific groups getting away with such things today. They should not be able to get away with it. But they can.

Perhaps a most startling additional part of those two incidents is that there was no great public outcry from the scientific community, deploring these murders and demanding that the criminal scientists be indicted and tried.

As the old saying goes, "By their silence they have convicted themselves." The organized scientific community, **as a community**, has shown that it has little or no ethics, and—while deploring any scientific murdering that "gets revealed,"—is not really interested in justice. In short, much of the U.S. scientific community may now have very little ethics left.

We are **not** talking about normal individual scientists, but the Big Science community. There is a whale of a lot of difference between the two. In the Big Science community, there can be and there are rogue groups. Lots of them. There is deep cover, deep classification. And there is very probably advanced mind control research and testing, be it legal or illegal. Hopefully most of it is legal and constrained. However, some of it is almost certain to be illegal and ill constrained.

Human beings are still human beings. All the good and evil is still there, regardless of the group. The stage settings change, but the cast of characters and the play never change.

It's sad, but 'twas ever thus. Hidden parts of our own governments—and other governments throughout the world—are no different from the old medieval groups, where nobles etc. were always plotting against the king, or using the king's power for their own nefarious end. The rogue groups today are no different from all the scheming and conniving groups that life? Absolutely! Would the President of the United States have apologized? Not on your life; he would have turned it over to the U.S. Attorney General with a strong directive to investigate and prosecute on criminal charges.

2. Again for three decades, scientists from (i) the U.S. Government, (ii) universities, and (iii) civilian contractors conspired to give poor syphilitic blacks in Tuskegee, Alabama a placebo while ostensibly treating them for syphilis. The purpose of the program was to deliberately observe and record the ravages of the disease to its fruition in their wracked bodies. So the scientists deliberately sat there and watched their brains rot and their bodies rot. They kept meticulous notes, of course. It was very scientific. And it was macabre. They "treated" some 400 blacks in the "program." Over 100 blacks died

destroyed the Roman Empire. *Great empires fall from within, not usually from without!*

Conclusion

This concludes our brief portrayal of the probable directions that mind control research has taken, in Russia and in the West. It is a novel and powerful area, and it poses both severe dangers and great benefits to all the peoples of the Earth.

Let us hope this great new area, already off to a bad start, can be bridled and steered in the direction of helping and healing people, rather than killing or abusing them. The excesses in its bad use are a potent threat to all nations on earth. Yet it can revolutionize medical science, education, communication, and psychology. Eventually it can engineer the mind and memory directly, beneficially. We foresee the day—perhaps 30 years hence—when education will be

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accomplished *by directly loading the software into the mind.* Then in three weeks one will "load" a doctorate, say, in physics. In three more weeks one will also load a doctorate in chemistry. Another three weeks, in electrical engineering. Another three weeks, an M. D. And so on. When that happens, then truly everyone on earth can be educated. Freedom from ignorance may well be another great freedom that is legally recognized. There will be no impoverished large groups lacking the education to find decent, productive jobs.

We urge all nations to use the principles involved: not for human abuse, but for healing, educating, uplifting, and life-expanding of every person on Earth. If we do, we shall all have a far brighter future. Then we shall check what has started out to

446955, Oct. 23, 1998, forwarded to US. Patent Office on Nov. 4, 1998.

5. A very good introduction to nonlinear phase conjugate optics is given by David M. Pepper, "Nonlinear Optical Phase Conjugation," Optical Engineering, 21(2), March/April 1982, p. 156-183. Also see David M. Pepper, "Applications of Optical Phase Conjugation," Scientific American, 254(1), Jan. 1986, p. 74-83.

6. Pepper, Optical Engineering, ibid., p. 158.

7. See T.E. Bearden, Energetics of Free Energy Systems and Vacuum Engine Therapies, Tara Publishing, Internet node www.tarapublishing.com/books,July 1997. See also T.E. Bearden, "Energetics Update and Summary, " Part I, Explore, 7(6), 1997, p. 60-67, Part II, Explore!, 7(7), 1997, p. 53-56; Part III Explore!, 8(1), I997, p. 53-56; Part IV; Explore!, 8(3), 1997, p. 56-63. See also T.E. Bearden, "Vacuum Engines and Priore's Methodology: The True Science of Energy-Medicine: Parts I and II " Explore!, 6(1), 1995, p. 66-76; 6(2), 1995, p. 50-62.

8. E.g., see R.O. Becker; Charles H. Bachman, and Howard Friedman, The direct current system: A link between the environment and the organism, " New York State Journal of Medicine, Vol. 62,

be the Sword of Damocles and turn it into the golden Millennium.

We are reminded of a poignant quote from Teilhard de Chardin:

"Someday, after we have mastered the winds, the waves, the tides and gravity, we shall harness for God the energies of love. Then for the second time in the history of the world man will have discovered fire."

May the nations of the world utilize the new mind engineering science to truly free all minds into a common love of, and respect for, their fellow humans of every color, creed, and circumstance. As de Chardin envisioned, may we use the new science to discover a new fire, burning clearer and brighter than anything that has gone before.

◆

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Tom is the leading advocate of scalar potential electromagnetics and the Fogal charge-blocking semiconductor: He is involved in alternate energy devices and scalar electromagnetic system prototypes. He has defined charge q as a coupled system of two components, advanced a mechanism for a vacuum engine, whereby the vacuums virtual particle flux is organized and used to energetically shape and manipulate

April 15, 1962, p. 1169-1176. See also R. 0. Becker; "The direct current field: A primitive control and communication system related to growth processes, "Proceedings of the XVI International Congress of Zoology, Washington, D.C., VOL.3, 1963, p. 179-183; —"The neutral semiconduction control system and its interaction with applied electrical current and magnetic fields," Proc. 1lth International. Cong. Radiol., Amsterdam, Excerpta Medica Foundation, 1966, Series 105, p. 1753-1759. See particularly Robert O. Becker and David G. Murray, "The electrical control system regulating fracture healing in amphibians," Clinical Orthopaedics and Related Research, Vol. TBD, No. 73, Nov.-Dec. 1970, p. 169-198.

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matter and energy, and advanced a mechanism for a Bohm-type quantum potential, which theoretically allows the engineering of action at a distance in physical systems.

He is president of the Association of Distinguished American Scientists (ADAS), a life member of the Alabama Academy of Science, Emeritus member of the American Association of Physics Teachers, and has served on the Board of Directors of several associations and corporations. Tom is a guitarist, a retired aikidoist (Sandan, Yoseikan style), is happily married and has two sons and two daughters. He and his wife Doris live in Huntsville, Alabama where Tom is retired from aerospace, continues private research, and serves as a consultant to industry on Scalar electromagnetics processes.

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EXPLORE! VOLUME 9, NUMBER 4 & 5, 1999

The Tom Bearden Website

Latest cloning research findings by Bedini/Bearden

The huge dangers of current cloning technology

Mystery of the death of Australia's cloned sheep explained

"Spark of Life"

From "Stranger than Science"

by Frank Edwards © 1959, 1987

Did an obscure amateur scientist discover the spark of life? Did Andrew Crosse accidentally stumble upon a mixture of chemicals and electricity which produced living things from a lifeless compound? If he did not, then just what did he accomplish? The record of his work is clear, only the enigma of the results remains to plague science.

The neighbors of Andrew Crosse regarded him as more devil than man. They did not understand the bright flashes that lighted his laboratory windows at night when he was tinkering with his crude electrical devices. Not only was he dreaded and shunned as "the thunder and lightning man," but he was denounced as an atheist, a blasphemer, and a Frankenstein who had best be put in chains for the common safety.

Andrew Crosse minded his own business, it is true, but his was a very strange business for the early 1800's. And one of his experiments remains a very strange business to this day.

Andrew was an enthusiastic amateur experimenter in the new field of electricity. Out of touch with others in the same work, he labored under the double handicap of not knowing what had already been done - and of not understanding what he was doing himself. Yet it may have been this very lack of knowledge which led him to undertake the experiments which were to inscribe his name, however faintly, in the annals of science.

He decided to induce the development of artificial crystals by subjecting chemicals to prolonged exposure to weak electrical currents. Andrew mixed up some silicate of potash and hydrochloric acid and into this he dropped a fistsized chunk of oxide of iron. By inducing the current from a small battery to trickle through the solution to the oxide of iron, he hoped to bring about the growth of artificial crystals of silica.

Having arranged this combination of chemicals and current, Andrew set it aside and went back to his favorite pastime of studying the spark-gap - the flashes which alarmed his neighbors.

Did he accidentally stumble upon an arrangement which created life from inorganic matter?

In a paper which he wrote for the London Electrical Society in that same year of 1837, Andrew set down this account of his experience.

He wrote "On the fourteenth day after the commencement of this experiment, I observed through a small magnifying lens a few small whitish specks clustered around the middle of the electrified stone. Four days later these specks had doubled in size and had struck out six or eight fine filaments around each speck . . . the filaments longer than the hemisphere from which they projected.

"On the 26th day of the experiment, the objects assumed the form of perfect insects, standing erect on the bristles which they were growing. Although I regarded this as most unusual I attached no singular significance to it until two days later, the 28th day of the experiment, when the magnifying lens showed that these things were moving their legs. I must say now that I was quite astonished. After a few more days they detached themselves from the stone and moved about through the caustic acid solution.

"In the course of a few weeks more than a hundred of them made their appearance on the oxide of iron. Under a microscope I examined them and found that the smaller ones had six legs, the larger ones had eight. Others who have examined them pronounced them to be of the genus acari, but some say they are an entirely new species.

"I have never ventured an opinion on the cause of their birth for the reason that I have never been able to form one. I thought they might have been airborne creatures that had drifted into the liquid and prospered, but later experiments with closed vessels, in which the ingredients had been purified by baking in the oven, produced identical creatures; therefore, I suggest that they must originate in the electrified liquid by some process unknown to me."

Andrew Crosse realized that he was walking a tightrope before the top scientists of his day. He was describing an experience foreign to their accepted understanding and therefore he was inviting ridicule. He did not have long to wait. Cries of fraud and hoax engulfed him. He and his alleged insects were denounced as nothing more than humbugs.

Amid all the furor that his announcement had created, Crosse stood alone and helpless. Even other scientists who had duplicated his tests with similar results kept their silence.

All but one. That voice was raised in his defense and it was such a powerful voice that none dared challenge it; for it belonged to the great Michael Faraday. At last Crosse had found his champion.

Faraday reported to the Royal Institution that he too had experienced development of these little creatures in the course of his experiments. But he added that he could not decide whether they had been created in the sterile solutions or brought back to life by the electricity! Either development would have constituted a milestone in scientific advance, as Faraday realized, but he left it to his fellow scientists to make the decision, if any.

Crosse never claimed to have discovered anything. He was merely reporting what had happened. After the attacks upon him subsided, he retired to his home in the Quontock hills for many more happy years among his test tubes and batteries.

Although he spent his long life as a humble searcher after scientific truths, the contribution for which he is remembered is the controversy over his acari - unwanted then, and unexplained to this day.

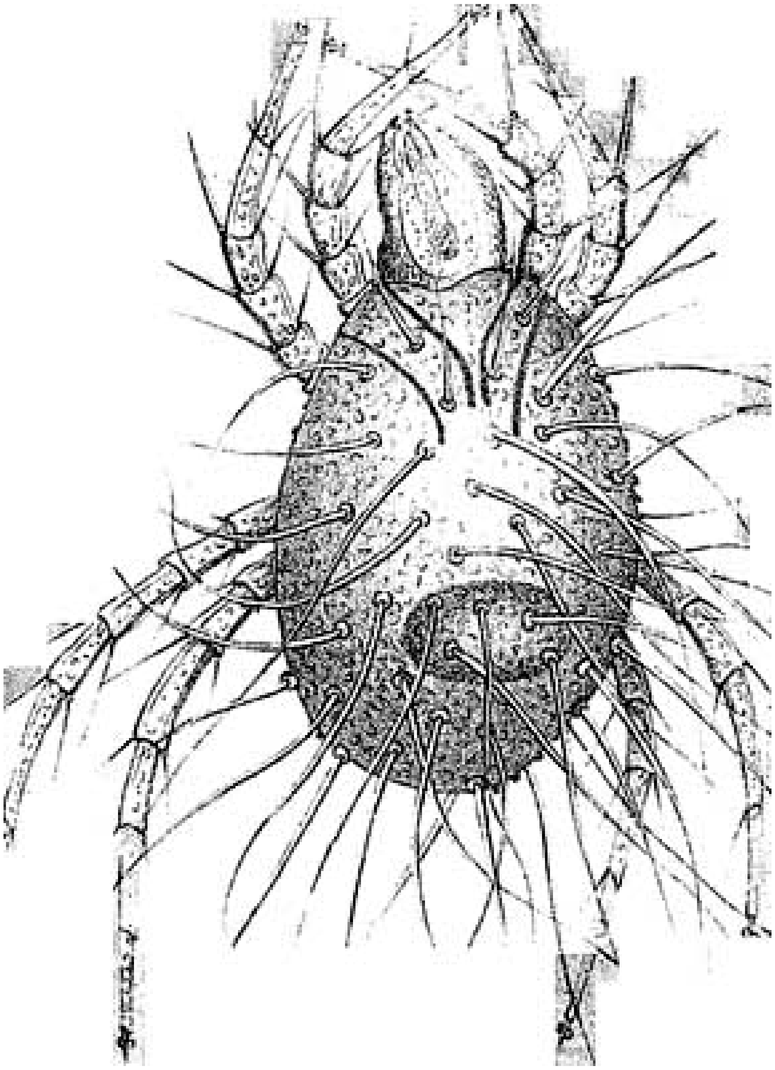

Genus Acari

Tom Bearden comments (finalized and slightly updated in March 2001).

It is difficult to make an understandable comment on the business of life, because presently scientists have not the foggiest notion what mind, being, life, death, time, etc. are. For that matter, they don't really know what matter and energy and charge are either. In the scheme of things, our modern "science" is only about three hundred years old, and that's a snap of the finger in even just the existence of this world. Much of modern science still considers the mind as a "meat computer", or just the physical electrodynamic activity of the brain, etc. Materialism has not died, even though quantum mechanics essentially wiped it out decades ago, and the old concept of "mass" as something hard, permanent, and "material" has also long since vanished. One is referred to the works of Max Jammer to see what the present view of "mass" is. Also, without looking up the references again, recent experiments with quarks and gluons wound up with experiments in which it mattered not a whit whether one considered the mass as zero or nonzero. Nature, it seems, does not have to play by our usual "either-or" rules. In physics, of course, this is the duality problem, which to this day has not been resolved because attempts to resolve it have applied Aristotelian logic -- and there is no solution to the problem of "opposites being identical" in that logic, which forbids that very thing by authoritarianism.

The modern biogenesis experiments, e.g., never took place in the absence of life. There was no "statistical generation of living or quasi-living forms" in the absence of engines for such forms. The great rush of Poynting energy flow around the earth, generally parallel to the equator, alone carries the "engines" (internal sets of spacetime curvatures) for every form of life that ever existed upon the earth. So the experiments were bathed in "living forms and dynamics", if one accounts for the internal Whittaker-structuring of electrodynamics -- noted but ignored by our scientists for nearly 100 years.

Quite some time ago, we worked out the nature of mind, and the mind-matter coupling mechanism (which is engineerable). We did that in pursuit of the mechanisms in the KGB/Russian psychoenergetics weapon work. I had the last of a 3-part article published in "Explore", dealing briefly with mind control technology both the way it is probably done clandestinely in this country and how it is done by the KGB/Russians. I'm still trying to get the proper parties to believe it; not much progress. However, some very neat information has been released on the Internet that very probably reveals why officially there is no interest. It's because three decades ago some of our "spooky folks" found (in deep hypnosis experiments) that humans are inordinately sensitive to extremely low-level EM signals and fields. Even though no detection or sensation may rise to the conscious level, the unconscious (which is totally conscious, just massively parallel rather than serial) does sense these signals. Voila! It would appear that "very deep black" parts of the community probably developed quite good mind influence and mind and behavior control or interference using techniques adapted from that work. The reader must always remember that just because the *overt* government does not know something or have something, does not at all mean that the *covert* government doesn't have it. And even in the covert government, there are layers within layers. So there, even when the upper levels do not have something, it still does not mean that the deeper levels do not have it. The problem with the best knowledge and technology, when unknown to the upper covert levels and the overt level, is that it is then quite likely to be subverted into the deepest levels, which may have their own agendas and may not report to the duly elected U.S. government at all. Indeed, such levels often assume that the President himself does not have a "need to know".

Present physics has erroneously omitted the time increment carried by the photon. The overemphasis on the so-called transverse wave (which does not exist as such in vacuum, fairly readily shown) has led to our missing the greatest and most important part of electrodynamics: the longitudinally polarized EM wave and the time-polarized EM wave. For example, mind and mind operations are totally electromagnetic, but use time-polarized EM waves rather than the standard stuff. Overtly we do not even have detectors for LPWs and TPWs yet; the Russians do. However, every major weapons lab on earth now is aware of longitudinal EM waves and their powerful characteristics. Simply read some of the summary material on Undistorted Progressive Waves (UPWs) on the Los Alamos National Laboratory website, e.g. by Rodrigues et al. A UPW is an "imperfect" longitudinal EM wave with some remaining transverse wave residue (that is the way it is modeled).

Let me give you one example of how fouled we are. We still use Aristotelian logic primarily. Yet it is an incomplete logic. Let me show you instantly. Take the simple Venn diagram of a rectangle lying on its side, divided in half by a vertical line in the middle. Label the right rectangular area A. Label the left rectangular area "not-A". What is the line in the middle and the border? Both A and not-A, so that A is identical to not-A. Yet the third law (law of the excluded middle) forbids A identical to not-A. Apply the third law to the Venn diagram. The border disappears, and the middle dividing line disappears. The logic self-destructs, because now there is no separate A and no separate not-A. Yet so far as I can determine, no one seems to have seen that very simple thing and questioned it. Aristotelian logic cannot be applied to the very Venn diagrams used to establish and "prove by demonstration" its propositions. We corrected that nearly 20 years ago, and got called every kind of lunatic imaginable -- the usual reaction when something fundamentally wrong is pointed out in a comfortable part of the prevailing paradigm. These days I simply point to Morris Kline's "Mathematics: The Loss of Certainty" to the Aristotelians, and tell skeptics to go and read it and then we will discuss the foundations of logic. With a 5-law logic (or 4-law with an additional applications rule), one solves the "dividing line" problem nicely. Then suddenly things like spacetime and being and mind and nothing etc. can be solved -- in the 5-law logic, but never in the 3-law logic. The problem of life itself -- whether terrestrial or extraterrestrial -- has no solution in 3-law logic.

The entire method of Zen is to try to break up the iron Aristotelian bent of the conscious (serial processor) mind, and get into the far broader unconscious (totally conscious, massively parallel processor) mind. Few have done that. But one cannot present a 5-law solution to a 3-law processor; it just "does not compute". It's like putting a thousand slides at once on the normal "single slide at a time" projector. The "conscious mind" can see only a single slide at a time. So it just sees "black" or "nothing at all". That's why we "see" the "massively parallel conscious" mind as "unconscious"! It isn't. But it is a quite different *form* of consciousness which we all have.

Time is never observed, and no observable is a *cause*, a priori, because an observable is only a frozen, nonchanging 3-spatial "instant snapshot" and therefore the *output* of the observation process, while the *causal input* is what exists in 4-space prior to its interaction with the observation process. When one adds time and time dynamics to one's science, one moves far in front of much of present Western physics. E.g., physics has nearly hopelessly confused the *causal* side of the observation mechanism/process with the *effect* side, everywhere, throughout physics -- simply by assuming that observables persist in time -- a non sequitur since an observation is a frozen 3-space snapshot at one single instant.

And sadly, the physicists do not seem to have even realized it!. Not a single paper or text in the West, e.g., illustrates an EM wave in spacetime prior to its interaction with a unit point charge. E.g., simply check a fine editorial by Romer. Romer is the editor of American Journal of Physics, and we are referring to Robert H. Romer, "Heat is not a noun," American Journal of Physics, 69(2), Feb. 2001, p. 107-109; and specifically to his end note #24, p. 109. Romer takes to task *"…that dreadful diagram purporting to show the electric and magnetic fields of a plane wave, as a function of position (and/or time?) that besmirch the pages of almost every introductory book. …it is a horrible diagram. 'Misleading' would be too kind a word; 'wrong' is more accurate." "…perhaps then, for historical interest, [we should] find out how that diagram came to contaminate our literature in the first place."*

But in general physicists continue to charge on, confusing effect as cause. Electrodynamics, e.g., is particularly guilty of greatly confusing the two, which is really what is preventing a successful and engineerable unified field theory. Further, contemporary classical electrodynamicists do not calculate either the field or the potential; instead they calculate the *reaction cross section* of each, interacting with a unit point charge assumed out of nowhere. In short, they calculate how much is diverged from the actual field or potential, and then call that "little extracted part" the field or potential! Again, they mistake the causal entity existing before the interaction with the effect entity existing after the interaction. Well, after the interaction has occurred, that result is the *effect*, not the *cause prior to interaction*. Physics has this so hopelessly snarled that it will require 50 to 100 years before the journals and physics societies are likely to even realize it and admit it, and then it will require them another 50 years to straighten it out and purge this huge non sequitur from physics theory and modeling.

Anyway, we did model how mind and mind operations operate, including their precise nature, how they fit into all this, etc. We thus were able to resolve many previously unsolved riddles such as the nature of intent, how a space-less mind operation can generate a spatial input to a spatial body and vice versa, etc. We also worked out how to use "effects" systems to generate "causal" systems, completely independent of mass -- because the KGB has recently completed a completely different kind of weaponry based on this, and different from anything that has ever existed in the history of mankind (at least on this planet!). The Russians of course were already there; I got there much more crudely by intensely working on how to explain what they were doing.

To see that the effect can generate the cause, just consider the normal "forward time" observation process having to operate in a "time-reversed" process. You see, not only must we shift observers from frame to frame, but we must also be able to shift them from forward-time (of some conveniently chosen outside reference observer) to reversed time (of that same reference observer).

At any rate, it turns out that the entire universe is already "alive" in a very special sense. There is no death; there is mind (I use the term "mind" in the most general sense, not just the conscious mind which is merely a "periscope" put up and taken down from the unconscious). And mind is not a part of the brain, and it is indeed separated from body but intimately linked to it by the mind-body coupling dynamics. Further, any life that has "ever existed" still dynamically exists in a special kind of more fundamental electrodynamics infolded inside all normal EM fields, waves, and potentials. The Tibetans knew much of this very well, but of course in terms that our materialistic science rejects or completely fails to understand (as we stated, most of our scientists believe the human is a robot and the mind is simply the electrochemical reactions of a "meat computer"!).

Since ambient spacetime may be modeled as a special kind of "scalar" potential with intense energy density, it then decomposes into a series of bidirectional EM longitudinal wavepairs, a la Whittaker 1903, except one must use impulse waves so as to include the time dynamics part of spacetime, rather than forcefield 3-space type waves. The entire thing -- mind, life, matter, fields, waves, spacetime, etc. -- then becomes structurable and directly engineerable by novel EM means (such as the O(3) higher symmetry electrodynamics pioneered by Evans and Vigier). Longitudinal EM wave technology is the key to developing such mind-body coupling mechanisms and engineering of them, at all. One only gets the time-polarized EM wave technology *after* the LPW technology has "done its thing" -- the time-polarized technology is far and away the most powerful and primary.

Also, low frequency photons have far more energy than high frequency photons, if one includes the time component, since time is spatial energy compressed by c-squared and has the same energy density as mass. Time-energy (highly compressed spatial energy, compressed by c-squared but in the time domain rather than in 3-space) and spatial energy in the photon are canonical. As the frequency of the photon decreases, its spatial energy decreases also with the decreasing frequency. However, the time-energy component increases, and its compacted energy increases as the square of the time-component expressed in seconds. Hence at lower frequencies the total energy (sum of spatial energy and time energy) in the photon increases. Indeed, if one wishes to engineer gravitational effects, it is the low frequency photons (low ELF) that are important, because they have far and away more "spacetime curving energy" than high frequency photons such as gamma rays.

At least eight nations on earth now have longitudinal EM wave technology weapons to one extent or another. Several of them -- hostile to one another -- are using Western Australia as a convenient nearly uninhabited target range.

Anyway, when you come at the mind-body-life problem with that background (which unfortunately required more than 20 years of very hard work!) there appears to be no great difficulty in explaining the Faraday, Crosse, Fox, Miller, and Urey biogenesis experiments. And yes, there appears to be no difficulty in explaining the "appearance" of "life on earth" in the prebiotic soup. It did not really appear out of nowhere spontaneously at all, but simply was a sort of sympathetic resonant coupling of physical forms to mind-forms already there. None of the experimenters realized that the great Poynting energy flow (and one must add back in the missing Heaviside component which is some 10exp13 times larger than the accounted Poynting flow) around the earth parallel to the equator and from West to East, is already internally structured with every possible form of life ever in the universe anywhere. If we further multiply that Heaviside component by c-squared, so that we can account for the time-energy portion of that great energy flow, we can see immediately that life and its environment are both living and intercommuting all the while. The creator in fact created a living universe, not an inert one (as best we can speak it in the inadequate 3-law logic). If one believes in big bangs, then life structuring emerged right along in all the fields and waves and energy, right in and out of the big bang. There is not a single point in the universe anywhere that is absent of energy and therefore absent of life, in the view of the model I am using.

Understand, one does not have to agree with this model! That is one's own decision. We are just pointing out that, if we correct many of the errors known to be in the presently used models, this is the kind of reality that readily emerges. We get a physics that is not just an "inert" physics, but a living physics where literally the entire universe is "alive" in very special manner.

In deciphering (after 14 years!) the Priore mechanism, I found that incredibly the cellular regenerative system does retain the form and "memory" of all the precessor cellular forms. Cancer, in fact, is very often due to a direct "order" by that system to a cell (aerobic) to start back down the "chain" to an anaerobic cell, because of severe hypoxia and the sustained inability of the regenerative system to maintain the cell in aerobic form. It doesn't just send an "order", but sends a "precise set of spacetime curvature engines" that go to work on that cell and all its parts. The first major step back is to break it loose from centralized control of its growth -- whereupon we recognize it as a tumor cell. There are two requirements: (1) cellular damage, and (2) "promotion". Biologists do not really understand "promotion", because they do not understand the cellular regenerative system—which used time-polarized EM waves, and nonlinear optical pumping of the cell and all its parts in the TIME-energy domain rather than the SPATIAL energy domain. That sort of pumping creates an "antiengine" to its forward time engine resident in the sick cell, thereby time-reversing the cell and all its parts back to a previous state on the trail from the early anaerobic single cells to the present aerobic cells.

By the way, recent experiments in cloning are beginning to bear out the fallacy that exact electrochemical processes produce the same end physical results, particularly when the persistence of the created forms is examined. E.g., cloned rats may live half their lives in apparently normalcy—then suddenly grow greatly obese and die. Many other anomalies are being uncovered in this fashion. The reason is quite simple: We have some diagrams showing that one may introduce an additional "engine" to the pumping of a diseased or damaged cell (or a healthy one for that matter), and in the time-reversal process then induced, the "time-reversal" process will be diverted from the original trajectory. In short, the original full state will not be recovered.

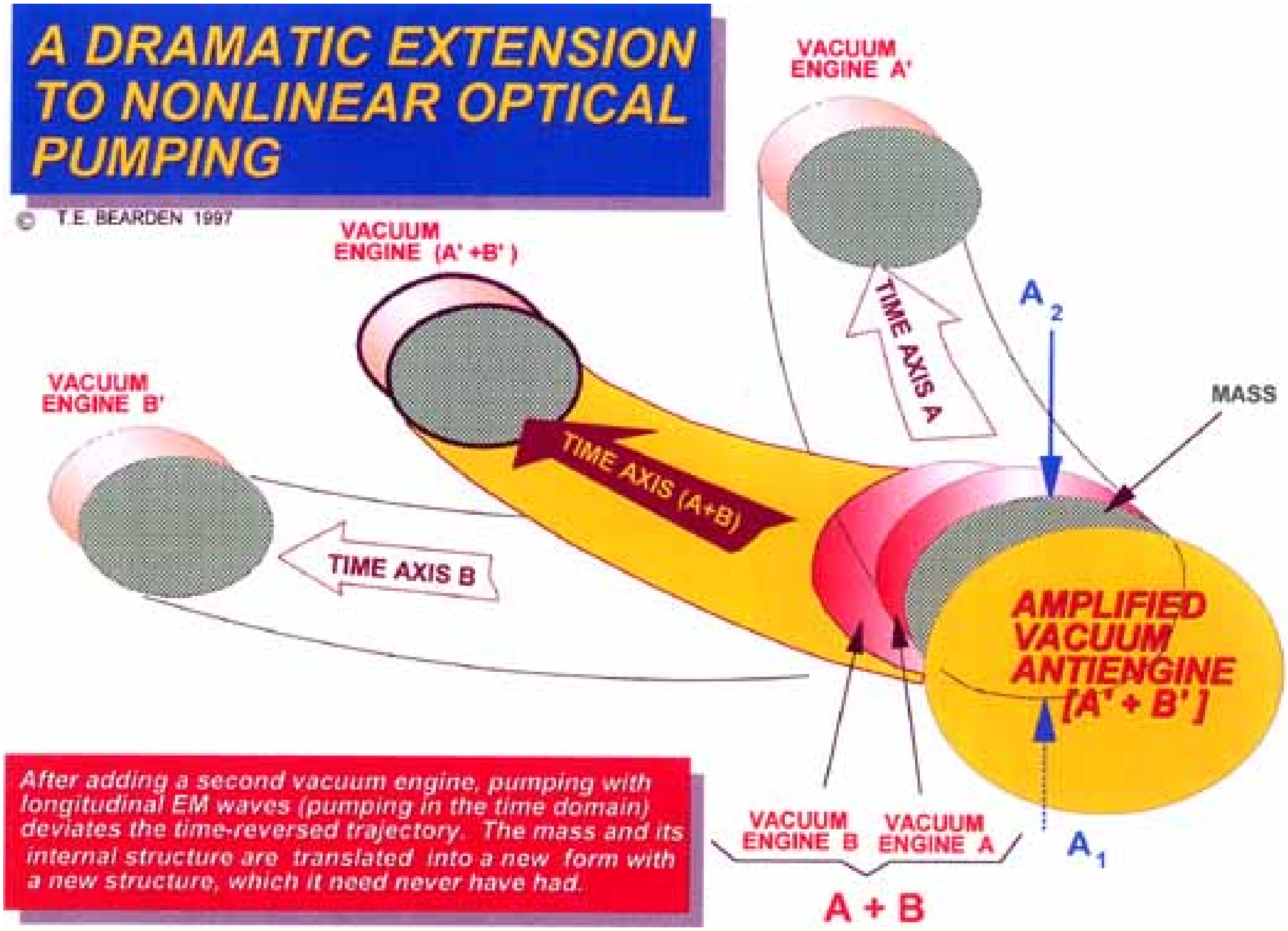
A DRAMATIC EXTENSION TO NONLINEAR OPTICAL PUMPING

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After adding a second vacuum engine, pumping with longitudinal EM waves (pumping in the time domain) deviates the time-reversed trajectory. The mass and its internal structure are translated into a new form with a new structure, which it need never have had.

This, we pointed out, is a second generation technology to be developed, where a disease or disorder must be treated and where also there was never a normal past state anyway. A case in point is birth defects, etc. Eventually, if the technology ever is allowed to be funded and developed, even those kinds of medical conditions will be treatable and curable. The point is that in cloning, one does not use the normal sperm cell and egg, without abnormal disruption. There is indeed an abnormal disruption -- and every such physical action or change and dynamics certainly involves an additional set of engines. In short, with present methods the cloned entity also has introduced into the equation an additional "engine". In the fertilization process, there is quite a jump back to a "time-reversed" situation (fertilization is the beginning of a physical embodiment, hence from two parts of an embodiment already in being, there is a rather dramatic "jump backwards"). The "normal" backwards jump of that kind is a normal fertilization of the egg by the sperm. Any change to that procedure, represents the insertion of an abnormal engine to be processed in that same "jump back". For the methods being used, it appears that the abnormal engines are sufficiently weak that, in the cloned animal, some time must expire in its lifetime before the impact of that little constant deviation from normal grows to become suddenly significant.

Indeed, all "living forms" are materialized from energy, but from both matter-energy and time-energy and the dynamics of the two. Natural processes include fertilization, birth, etc., but there is no technical reason whatsoever that the process cannot be direct and even directly engineerable. In this "expanded energy" sense, mind energy and dynamics can be engineered as well as body matter energy and dynamics.

To cinch the matter of "engineering living forms", I once participated in a accidental and unplanned experiment where Golden materialized living things. Not little bitty things, but big things. In my view we actually materialized thought forms, since much later we were able to piece together exactly what apparently engendered each part of the phenomena. There were multiple (scared) witnesses who prefer never to discuss it. The experiment also altered all the clocks in the area for four days before the "time-energy charge" we had inadvertently created dissipated. Let me just say that it really got my attention! We never repeated that experiment again. But the changes were substantial and the phenomena were substantial, and to this day I prefer not to discuss that experiment. It simply cannot be understood without the outline sketch we are speaking of, where one accounts for time-energy and dynamics as well as material energy and dynamics, and also for the coupling dynamics between the two.

Not only can one have a "material entity" or thing communicating with another "material entity" or thing, but one can also have a "mental thing" (time-domain thing with no spatial existence) communicating with a "material entity or thing" with only spatial existence, and vice versa. There is indeed a coupling two-way mechanism

Look at the so-called "physical form" -- which almost always one is speaking of as purely 3-space. Most scientists have not yet understood that a priori a piece of 3-dimensional mass *as observed* cannot even persist in time! Masstime exists in time, but "mass" is a frozen 3-spatial intersection of the spacetime entity. It is exactly comparable to a frozen frame in a movie film. The individual frame never has any existence except at a frozen moment in the slide projector. "Motion" and "movement" etc. involve the time domain a priori -- hence something without any time-component at all, cannot persist or even exist except at one frozen moment in time. Hence any observable existed in that single "observation slice" and at that "point in time" only. After all, a "point in time" is where time symmetry is broken or ceases. In short, it is a time-discontinuity. All observations are such time-discontinuities.

The SETI problem will not be solved, in my personal opinion (understand, I do not object at all if others do not see it this way) until a far greater and deeper understanding is reached by our modern physics. Forget communicating with "transverse" waves; longitudinal EM waves can travel at any velocity, limited only by how much "residue" of the normal EM wave junk is still hanging in there (how much "transverse EM wave noise" is still present. A pure LW moves at infinite velocity. As we suggested, simply download the Rodrigues and Lu papers carried on the Los Alamos National Laboratory Web site. It appears that now most major weapon labs have "discovered" the fact that there can be longitudinal EM waves, and some eight or so nations have developed weapons technology from such. If one has such technology, all the rest is obsolete.

For the skeptic, here is a statement made in 1997 by Dr. William Cohen, then Secretary of Defense:

> *"Others [terrorists] are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves… So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations…It's real, and that's the reason why we have to intensify our [counterterrorism] efforts."*
>
> [Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.].

Any technological civilization that has not solved the fundamental "self-killer" problem of the technological species, must and will self-destruct. This follows from simple servo-mechanism theory, as we have previously pointed out. The KGB is working on a "solution" that is far along: engineer the entire human species quantum potential so that the human species can be turned into an "antlike" species, which of course would be the "ideal" communist state, in the minds of many Communist party theoreticians. Our guys haven't even got started on engineering the quantum potential yet. They have not yet even discovered the big ball park, let alone the big ball game.

Anyway, that is just some comments for your personal information. What really is happening in the "hidden weapons" area and "hidden weapons science area" is already so advanced in some quarters that science fiction pales by comparison. The real question is whether we shall survive very much longer, and whether we shall mature rapidly enough to begin to use these technologies for the benefit of humanity, rather than for its destruction.

Sincerely,
Tom Bearden

Additional Comments from Tom dated 9 July, 2001

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The Tom Bearden Website

Return to Order *Excalibur Briefing*

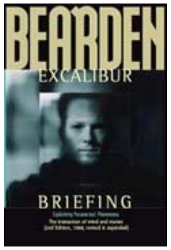

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EXCALIBUR BRIEFING

THE NEUROPHONE

Another device that uses the new hyperspatial, virtual state, nested modulation technology (and has done so for seventeen or eighteen years) is Dr. Pat Flanagan's neurophone. With brilliant insight and intuition far beyond that of science at the time, Pat invented and patented the instrument by the time he was seventeen years old. The neurophone is a device that, contrary to all present theory and knowledge, will directly “pump the brain” and reproduce sound and information directly in the brain and mind system, without going through the auditory system at all. A simplified diagram of Pat's improved neurophone is shown in Figure 11.

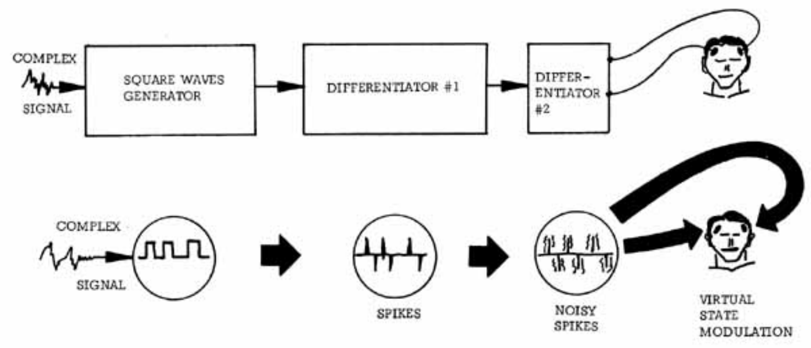

Figure 11. A simplified diagram of the improved Flanagan neurophone

Briefly, the device takes a complex signal, such as the sound of an orchestra playing a musical interlude, and electrically processes it as shown in the figure. First the signal is passed into a section that clips everything into a series of square waves, remarkably analogous to the sort of clipped waves Lisitsyn confirms are the information carriers of the human brain. Next the square waves are differentiated, yielding a series of sharp spikes (note that these spikes retain the pulse-time content of the clipped signal). These spikes are again differentiated, and since these are finite spikes with real nonzero rise times and decay times rather than theoretical constructs, a series of noisy spikes results from the second differentiator section. From here, the noisy spikes are introduced to special contact electrodes, one of which is normally placed on the forehead, while the other may be placed almost anywhere, including on the foot. Nowhere are any sound waves introduced to the head.

The square-wave clipper section reduces the complex signals, their overtones, and their complex modulations to square waves, retaining the temporal content of the wave mix but not the waves themselves. The first and second differentiators heighten or filter through the temporal content of the higher-order differentiations, that is, they serve as a band pass filter unit to accent the time keying of the neutrinic and mindfield portions or aspects of the signal. When these time spikes are then introduced across the body as pulsed voltages, they are modulated directly on the dendrite firings of the brain and nervous system, providing direct and pulsed modulation of the neutrinic and mindfield component channels of the mind-brain-consciousness-life loop itself. Thus the neurophone directly inputs information into the brain and nervous system, bypassing all the normal sensory systems that lie between the mind-brain loop and the outside environment.

Indeed, a similar development has been reported by two University of Missouri researchers. Dr. Donald York, a neurophysiologist, and Dr. Thomas Jensen, a speech pathologist, have recently reported identifying and decoding twenty-seven words and syllables in specific brain wave patterns and correlating these electroencephalographic patterns with both the spoken word and the silently thought word in about forty subjects. At present, Dr. York and Dr. Jensen are programming a computer with a brain wave vocabulary, to monitor and read the EEG of a stroke victim's brain and help stroke victims who have lost their powers of speech to communicate.

While all such developments can obviously be misused, their potential for assistance to mankind is enormous. Indeed, my own premise that brain linkage is possible and can be used to advance all mankind to the sixth stage of species evolution is slowly being proven. It is within our reach now to develop a multi-channel communications system that will directly link brains, minds, and consciousness into a single functional being; and I have already pointed out that the psychokinetic power of the emergent entity increases exponentially with the number of linked stages. The normal corpus callosum linkage of the two cerebral halves in each human head proves that brains, minds, and beings can be linked and integrated into one.

The Excalibur Briefing details the basic concepts of the theory involved in hyperspace-virtual state engineering, and thus in the engineering of mind-life-consciousness links to multicellular organisms here on earth. Pat Flanagan's neurophone proves that complex information can be implanted directly in the brain and mind, bypassing the normal isolating barriers. Drs. York and Jensen have shown that the brain wave does indeed contain recognizable, decodable information analogues. Lisitsyn has already reported measuring the number of independent channels involved and has documented the importance of the clipped brain waves as opposed to the sine-wave content. If we have the vision, we can still develop a brainlink and rapidly apply it to link sixty to one hundred persons, thereby opening a conscious, multidimensional “eye” for the collective human unconsciousness, gently rousing ZARG into wakefulness, and fulfilling human destiny without undergoing the psychotronic Armageddon planned by the Soviets. The time is short, but it can still be done if the funding, the vision, and the team can be established on a crash priority basis.

SOVIET “WOODPECKER” SIGNALS

But, as I have said, all this can be used for the detriment of mankind as well as for its benefit. Unfortunately, it appears that the Soviet Union has chosen to weaponize the effects on a global scale. A prime example is the “woodpecker” signals emanating from the USSR in the 5-30 megahertz region and interfering with communications around the earth.

These complex woodpecker signals appear to originate from two or three dozen powerful Soviet transmitters, each with a power estimated as high as 40 megawatts (Figure 12).

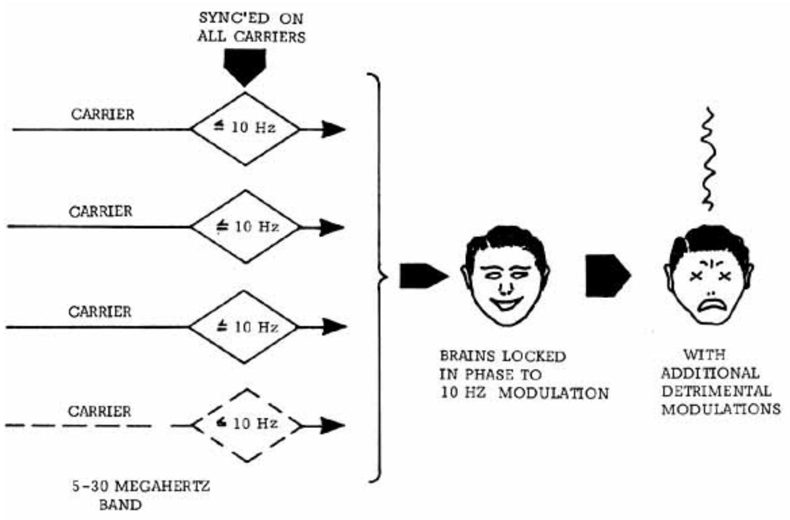

Figure 12. The Soviet “woodpecker” signals

The pioneering experimental measurements of these signals by Dr. Robert Beck and William Bise have shown just how deadly a potential may be possessed by the signals. These measurements have been performed in Eugene and Portland, Oregon; Los Angeles, California; Huntsville, Alabama; and several other locations. They have been particularly significant on the West Coast in and around Eugene, Oregon because of the presence of a direct current transmission line several hundred miles long, which has acted as a long wire antenna, picking up the signals and rebroadcasting them with appreciable gain in the vicinity.

Typically the signals may be found on, say, sixteen different carriers between 10 and 20 megahertz. Twelve of the carriers may appear normal, with normal side-bands, and the other four may have the carrier and both sidebands suppressed but still show the biologically significant modulation (for example, 10 hertz). On all sixteen channels a strong 10 hertz modulation may appear, all perfectly time synchronized and in phase channel-to-channel. The received signal from one of these carriers may be twenty-five to thirty times as strong as the earth's back-ground magnetic field, which is oscillating at approximately 7.0 to 7.5 hertz. Other complex modulation frequencies, many of them changing, are present on the various channels.

Normally, the brainwaves of mammals in an area are gently entrained by the normal oscillations of the earth's magnetic field and are oscillating along at, say, 7.5 hertz. Under continuous radiation from the Soviet woodpecker signals, a percentage (say 30 percent) of the mammalian brains may be captured by the 10 hertz modulation on the overpowering Soviet signals. These captured brains are now in forced oscillation and are riding along in phase with the 10 hertz Soviet modulation. In other words, a certain percentage of the human brains in an area will phase lock to the 10 hertz modulation, and that will effectively lock into those brains the sixteen carrier frequencies with their concomitant frequency mixes and complex signal modulations. If the signals are made much more powerful (for example, by focusing them onto one particular area or increasing the power of the transmitters), then a much higher percentage of brainwave entrainment can be accomplished in the targeted area. By simply adding on the desired modulation patterns, the Soviets can now pump material directly into the mind-brain-consciousness-life loops of the entrained brains. The weapon implications are enormous: raw emotion such as sheer terror or panic can be transmitted; death or disease patterns of all kinds can be transmitted; informational content (thoughts and ideas) can be impressed directly into the captured brains and minds and processed as if originating inside each brain itself. Indeed, as long as the Soviets keep the effects rather gentle, an entire population can be subtly influenced without governmental notice. Certain specific ELF frequencies can rapidly disable or even kill, and for wartime use those frequencies can be directly implanted in the captured brains themselves by the woodpecker signals. It appears that 1984 came a little early, and one can perhaps now understand Brezhnev's strange 1975 proposal to the SALT negotiations that we should also consider outlawing the development of new weapons more frightful than the mind of man has ever conceived.

The signals also have direct application against strategic targets other than personnel. For example, by incorporating the correct nested modulation pattern, the positron kindling (electron squelching) pattern can be impressed. By beaming through the earth (with a circularly polarized signal or with other complex modulation forms), a beam with a strong neutrinic component, which will squelch electrons and which will interact with great preference for strong voltages or strong magnetic fields, can be directed at a target complex. In the targeted area aircraft and communications systems can be disabled; automobile, truck, and other ignition systems will fail; power transformers and large motors and generators will fail; power transmission systems with their associated high voltages will fail; and so on. Even independent, self-contained emergency power equipment, such as at military installations and strategic missile sites, will fail to operate. Further, to some of these signals, the earth and the sea are as transparent as glass, and so underwater nuclear submarines can be electrically disabled on station before their missiles can be fired, while strategic missile complexes can be electrically disabled before their deadly nuclear missiles can be hurled toward their distant targets. If some submarines and land complexes succeed in firing missiles before being disabled, these missiles can be electrically dudded and scrubbed from the sky over Soviet territory while still far from their intended targets.

So, as stated at the end of *Excalibur*, the players are on stage and in place. The final act begins. One thing is sure—mankind will never be the same again after seeing the play!

Return to top of page

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LASER WEAPON SYSTEMS

Lockheed Martin has specialized in laser weapon system development for 40 years, with advancements in areas such as precision pointing and control, line-of-sight stabilization and adaptive optics – essential functions in harnessing and directing the power of a laser beam – and in compact, robust, spectrally beam-combined fiber laser devices that provide unmatched performance.

Lockheed Martin's directed energy (DE) laser program draws upon our proven expertise across a broad range of capabilities, as well as our spirit of innovation. Our experience includes:

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- Widespread weapons-system and platform integration experience across all DoD services

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Laser weapons are a revolutionary technology because of the advantages of speed, flexibility, precision and low cost per engagement that are only possible with lasers.

These advantages apply to stand-alone DE laser systems as well as to weapon systems that combine DE and kinetic energy capabilities. In these cases, DE operates as a force multiplier, enabling the warfighter to counter a growing range of emerging threats.

DE weapons are characterized by:

- Very deep magazine
- Extremely low cost per engagement
- Speed of light delivery

These strengths mean that they are well-suited to countering large numbers of inexpensive, highly maneuverable threats that might otherwise exhaust the magazines of our current defensive kinetic energy (KE) weapons. By using DE and KE weapons together, the warfighter will be able to neutralize emerging swarming threats while reserving our most capable kinetic weapons to defend against our adversaries' largest and most hardened threats. DE weapon systems support multi-mission scenarios, and can be readily augmented by communications functions, as well as unprecedented intelligence, surveillance and reconnaissance range, and precision.

In addition, Lockheed Martin's directed energy weapons bring some important and unique advantages to the warfighter:

- A robust and highly-maintainable laser architecture that is designed to minimize life-cycle cost and to maximize up-time
- Output laser power that can be rapidly adjusted between low and maximum power to support disrupt, disable, and destroy capabilities
- Highly parallel laser architecture that supports graceful degradation by eliminating almost all single points of failure

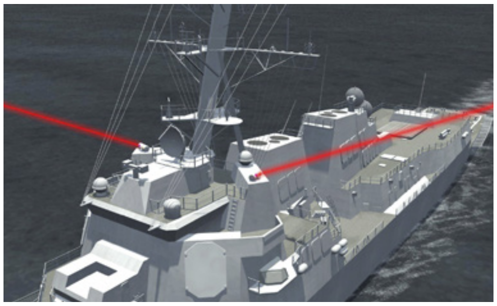

- Highest system efficiency demonstrated in any DE laser system; minimizing size weight and power requirements for DE platforms such as Army and Marine Corps ground vehicles, Navy DDG and LCS ships, and SOCOM AC-130
- Highest lethality laser to minimize engagement time

LOCKHEED MARTIN IS ADVANCING AND DEMONSTRATING A RANGE OF LASER WEAPON SYSTEM TECHNOLOGIES:

ADAM (Area Defense Anti-Munitions)

- Autonomous operations for rocket threats; accepts external sensor cue when required; capable of continuous operation
- Successfully engaged constrained and free-flying rockets, an unmanned aircraft systems (UAS) target in flight, and a small boat
- Affordable commercial-off-the-shelf (COTS) based system with very low cost-per-kill; deep magazine; scalable precision effects
- Capable of close-in defense (1-4 km)

ALADIN (Accelerated Laser Demonstration Initiative)

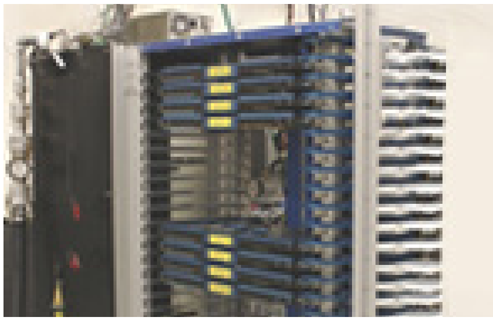

- 30-kilowatt laser made by combining many fiber lasers into a single, near-perfect-quality beam of light
- Uses approximately 50 percent less electricity than alternative solid-state laser technologies
- Spectral Beam Combining sends beams from multiple fiber laser modules, each with a unique wavelength, into a combiner that forms a single, powerful, high-quality beam

ATHENA (Advanced Test High Energy Asset)

- Represents highest power level documented by a laser weapon system of this type, while retaining excellent beam quality and electrical efficiency
- First field testing of an integrated 30-kilowatt single-mode fiber laser weapon system prototype
- Uses the proven high-energy laser weapon system architecture from our ADAM system, and incorporates the 30-kilowatt ALADIN laser

ABC Turret (Aero-adaptive Aero-optic Beam Control)

- Prototype turret with the ability to fire in any direction mounted on tactical aircraft
- First turret to demonstrate a 360-degree field of regard for laser weapon systems on an aircraft flying near the speed of sound
- Validated performance with nearly 60 flight tests conducted in 2014 and 2015 using a business jet as a low-cost flying test bed

RELI (Robust Electric Laser Initiative) for Army HELMTT (High Energy Laser Mobile Test Truck) Demonstrator

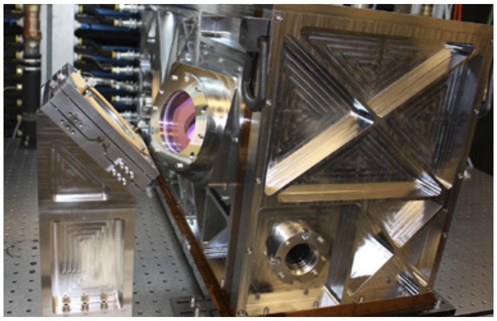

- Modular 60-kW laser in development for the U.S. Army
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- Scalable design combines multiple kilowatt lasers to attain various weapon power levels
- Modularity results in a reliable and low maintenance laser system that minimizes single points of failure

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Axial Vircator for Electronic Warfare Applications

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Abstract. *This paper deals with a high power microwave generator with virtual cathode – vircator in axial release for electronic warfare applications. The classification of directed energy weapons microwave (DEWM) is introduced together with basic block diagrams of a particular class of DEWM. In the paper, methods for designing vircator pulsed power supply, axial vircator structure, measurement methods and experimental results are presented. The vircator in electromagnetic ammunition is powered by magneto-cumulative generator and in weapons for defense of objects (WDO), it is powered by Marx generator. The possible applications of a vircator in the DEWM area are discussed.*

Keywords

Electronic warfare, directed energy weapons microwave, high power microwave, magneto-cumulative generator, Marx generator, pulse forming line, vircator.

1. Introduction

Electronic warfare (EW) is defined as the art and science of preserving the use of the electromagnetic spectrum for friendly use while denying its use to the enemy. Electromagnetic spectrum is, of course, reaching from DC to light (and beyond). Thus, electronic warfare covers the full radio frequency spectrum, the infrared spectrum, the optical spectrum, and the ultraviolet spectrum.

Electronic warfare has classically been divided into:

- Electronic warfare support (ES), which includes the receiving part of EW.
- Electronic attack (EA), which includes jamming, chaff, flares used to interfere with the operation of radars, military communication, and head-seeking weapons. Over the last years, EA also includes antiradiation weapons (ARW) and directed energy weapons (DEW).
- Electronic protection (EP), which is directed into design or operation of radars or communication systems to counter the effect EA.

A detailed classification of EW can be found in [1].

Today the directed energy weapons (DEW) are significant in terms of the electronic attack (EA). Considerable financial resources are directed especially to the research of DEW working in microwave band (directed energy weapons microwave − DEWM), which derive their benefits from incidence of electromagnetic pulses (EMP) on electronic devices. The EMP effect was first observed during the early testing of high altitude airburst nuclear weapons [2]. The effect is characterized by production of a very short (hundreds of nanoseconds) but intense electromagnetic pulse, which propagates away from its source with ever diminishing intensity, governed by the theory of electromagnetism. The EMP is in effect an electromagnetic shock wave. This pulse of energy produces a powerful electromagnetic field, particularly within the vicinity of the weapon burst. The field can be sufficiently strong to produce short lived transient voltages of hundreds of volts to kilovolts on exposed electrical conductors, such as wires or conductive tracks on printed circuit boards.

At present, a high intensity EMP can be successfully generate without using nuclear weapons. This fact is very significant especially for applications in the EW area. It is this aspect of the EMP effect which is of military significance, as it can result in irreversible damage to a wide range of electrical and electronic equipment, particularly computers and radio or radar receivers. Depending on the electromagnetic hardness of the electronics (a measure of the equipment's resilience to this effect) and the intensity of the field produced by the weapon, the equipment can be irreversibly damaged or even electrically destroyed. The damage inflicted is not unlike the damage experienced by exposure to close proximity lightning strikes, and may require complete replacement of the equipment, or at least substantial portions of it [3], [4].

2. Directed Energy Weapons Microwave

Directed energy weapons microwave (DEWM) generate very high-powered electromagnetic impulse (EMP) in the microwave band. From the generated signal bandwidth point of view, there are two classes of generators for the design and construction of DEWM in order to produce electromagnetic field with sufficient power:

- Narrowband – very similar to the radar transmitters; usually generate a modulated harmonic signal. This class is called the high power microwave (HPM).
- Ultra-wideband (UWB) – generates high power videosignal illuminated by a broadband antenna.

The application of directed energy weapons microwave (DEWM) determines their design. There are two groups of directed energy weapons microwave:

- Single shot DEWM,
- Repetitive pulsed power systems.

The electromagnetic weapon modes closely relate to the mission of these weapons. Electromagnetic ammunition usually uses single shot DEWM while weapons for defense of objects (WDO) usually use repetitive pulsed power systems. The typical pulse repetition frequency of DEWM is nearly one thousand pulses per seconds. Recently, there has been a trend of increase in the pulse repetition frequency beyond tens of thousands pulses per seconds. The actual DEWM construction depends on the concrete supposed combat use, on the required measure, range and so on. The following text will be dedicated to experimental verification of some technology usable in narrowband DEWM or HPM. Questions regarding classification, construction and possible use of generators for DEWM are answered in more detail in [4], [5] and [6].

2.1 Basic Block Diagram of DEWM

HPM design depends on the specific assumed application of DEWM. There are difference approaches to the design and realization of electromagnetic ammunition and to the design and realization of weapons for defense of objects (WDO). These differences mostly affect the choice of the power sources and the construction of modulators. In electromagnetic ammunition, a highly limiting factor is the demand for low weight and small proportions. This fact also sharply limits the choice of the power microwave tube.

Electromagnetic ammunition usually uses single shot DEWM. The single shot high-energy high-voltage pulsed source has to fulfill hard requirements on the high amount of the delivered energy with respect to the source volume [MJ/m^3]. The best solution of this requirement is a magneto-cumulative generator that reaches up to 8000 MJ/m^3. A block diagram of a HPM generator in electromagnetic ammunition is shown in Fig. 1.

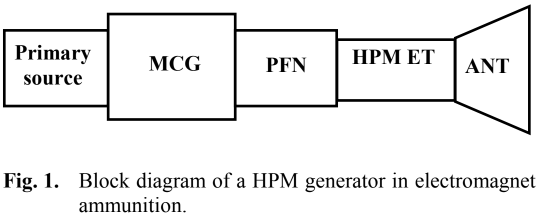

Fig. 1. Block diagram of a HPM generator in electromagnetic ammunition.

In the block diagram, the primary source feeds the stator coil of a magneto-cumulative generator (MCG), which creates a powerful magnetic field in the surrounding fittings filled with an explosive. At the moment of achieving the primary current peak value, the explosive is shooting. The explosion causes expansion of fitting that performs compression of the magnetic field inside the stator coil of MCG. Compression of magnetic field causes dramatic growth of the current flowing through MCG (hundreds of kiloamperes). The MCG output is connected to a pulse forming network that provides transformation of heavy current to an impulse high voltage (hundreds of kilovolts), which feeds a high power microwave electron tube (HPM ET). The generated microwave is emitted through antenna (ANT) to the space.

A block diagram of a HPM generator in weapons for defense of objects (WDO) is shown in Fig. 2.

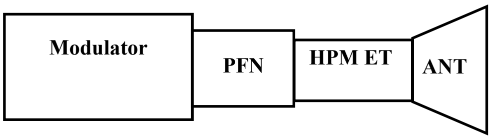

Fig. 2. The block diagram of HPM generator in Weapons for Defense of Objects (WDO).

In weapons for defense of objects (WDO), the HPM generator works similarly as the HPM generator in electromagnetic ammunition. Since WDOs usually generate power microwave pulses repetitively, a modulator with this capability has to be used instead of MCG. Modulators with Marx capacitor banks, Tesla transformers or transductors with fast opening switches are used most often. In this class of DEWM, other types of high power microwave electron tubes (HPM ET) are also used. They may generate microwave pulses with high pulse repetition frequency.

3. Energy Sources for Directed Energy Weapons Microwave

The electromagnetic pulse sources for DEWM are entirely based on energy acquired from the chemical energy of explosion that compresses the magnetic flux made by coil (MCG) or by discharging a capacitor bank. These two possibilities are the best solutions for generation of pulses with sufficient amount of energy in a short time. Other methods were used to generate pulses in the beginning of DEWM research or in laboratory.

3.1 Helical Magneto-Cumulative Generator

MCGs are entirely based on the energy acquired from chemical energy of explosion that compresses magnetic flux made by coil. MCG physical principles, classification and applications are described in more detail in [7]. The main part of research was focused on the possibility of using a magneto-cumulative generator for electromagnetic ammunition power supply. For that reason, 4 versions of low power MCGs were designed, realized and tested in order to verify their characteristics, construction principle, explosive initialization method and verifying a measurement method.

The tested magneto-cumulative generator in Fig. 3 consists of an aluminous cylindrical stator, inside is a 16 screw helical coil from 2 mm copper wire, a copper armature tube with 38 mm outer diameter and 4 mm wall thickness filed by octogen (explosive). The explosive is electrically initiated. The load coil represented by a copper strip in shape of a loop connects the stator with the armature. In the right side of stator, there is a crowbar switch made of a brass plate to perform disconnecting of the primary current source. An insulator circle is responsible for separation of the stator and the armature.

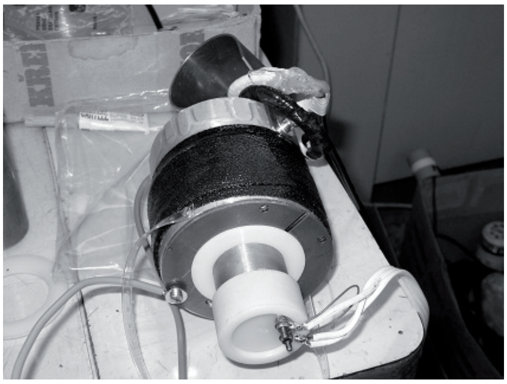

Fig. 3. Low power MCG.

Low power magneto-cumulative generator characteristics:

C_1 = 190 µF – primary capacitor capacity
U_0 = 800 V – voltage of capacitor
L_G = 13.1 µH – stator coil inductance
R = 0.0175 Ω – stator coil resistance
T_0 = 3.13×10^{-4} s – primary current period
I_m = 2750 A – maximum primary current
T_d = 73 µs – explosive initiation delay

Fig. 4 presents the low power magneto-cumulative generator output current time history calculated from the voltage measured by Rogowski coil. The primary current $I_m = 2750$ A gives the generator peak output current $I_{out} = 27$ kA. The detailed test description and measured results can be found in [8], [9], [10] and [11]. The purpose of the mentioned tests was:

- Verify the method of generating a high energy pulse by magnetic flux compression using explosive;
- Solve the primary current magneto-cumulative generator power supply;
- Find the peak primary current and an explosive initiation synchronization method;
- Find a high current measurement method.

All the requirements were met.

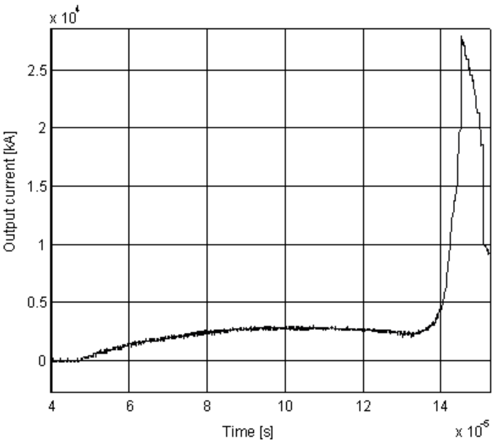

Fig. 4. Low power magneto-cumulative generator output current time history.

To use a magneto-cumulative generator for single shot high power high voltage pulse generator, it is necessary to obtain a high-level output current. Because of that reason, a middle power MCG was designed and realized. It is a two-stage helical magneto-cumulative generator using a dynamic transformer to increase the output voltage. In Fig. 5, there is a schematic plot of the generator's first stage. The magneto-cumulative generator power supply primary current, the initiation of the explosive and the output high current measure was analogical to the low power magneto-cumulative generator described above.

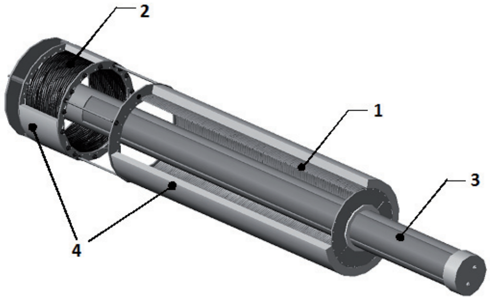

1 – First stage coil, 2 – Load coil, 3 – Armature with explosive, 4 – Insulator

Fig. 5. Schematic drawing of first stage of middle power MCG.

Fig. 6 shows a photo of the middle power magneto-cumulative generator's first stage prepared to the test.

Magneto-cumulative generator characteristics:

C_1 = 125 µF – primary capacitor capacity
U_0 = 5000 V – voltage of capacitor
L_G = 323 µH – stator coil inductance
T_0 = 3×10^{-3} s – primary current period
I_m = 2650 A – maximum primary current value
L_L = 300 nH – load inductance

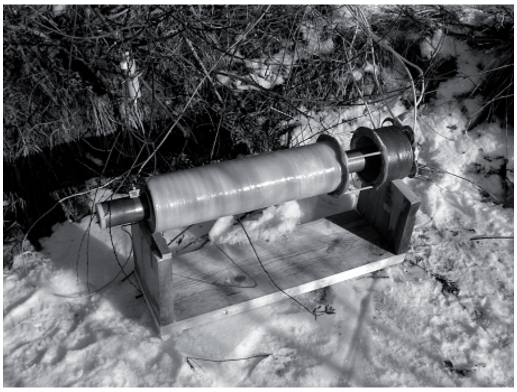

Fig. 6. The picture of middle power MCG prepared to testing.

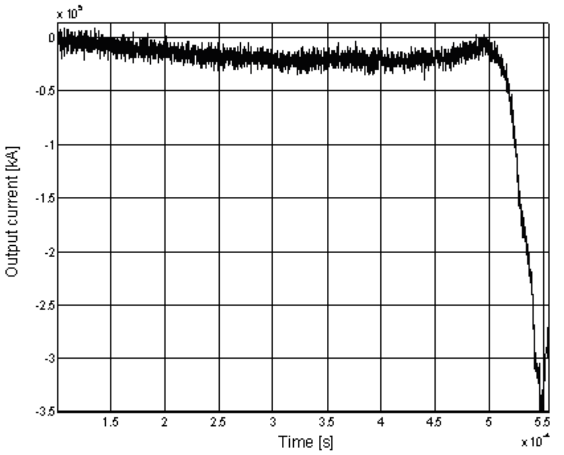

Fig. 7. Middle power magneto-cumulative generator output current time history.

In Fig. 7, the generator output current time history measured during test is shown. The primary current $I_m = 2650$ A gave the generator peak output current $I_{out} = 350$ kA.

The next step in the magneto-cumulative generator research is the implementation and verification of a dynamic transformer. The dynamic transformer's role is an increase of the output voltage to about 70 kV. Magneto-cumulative generator's second stage supplies a load coil through an electric breaker. The beaker interrupts the current in the load circuit in a very short time to enable transfer of the energy from the magnetic field to the high voltage pulse. These activities will be done in the next step of the research and development. The further trends are described in [12].

3.2 Pulsed Power Supply With Capacitive Storage of Energy

For some pulse applications in weapons for defense of objects (WDO), it is desirable to couple the Marx generator directly to the vacuum diode; however, the pulse rise time is then limited by the Marx inductance and capacitance, and the impedance of the generator is greater than typically several tens of ohms. In order to produce short, fast-rising, low-impedance beam outputs, it is customary to use the Marx to charge a pulse-forming line (PFL). Although the PFLs may be constructed in a variety of shapes (strip, coaxial, radial, etc.), they are typically used in only two types of circuits— the simple transmission line, and the double, or Blumlein line. In contrast to the simple transmission line, an alternate circuit invented by A. D. Blumlein is capable of producing an output pulse into a matched load that equals the charge voltage. A cylindrical version of the Blumlein circuit fabricated by our team is represented in Fig. 8. It consists of three coaxial cylinders with the intermediate cylinder being charged by the Marx generator. The Marx generator is shown in Fig. 9. The center cylinder is connected to the outer grounded cylinder by an inductor. Ideally the inductor acts as a short during the charge cycle, and then as an open for the short duration of the output pulse [13]. Pulsed power supply parameters are shown in Tab. 1.

Marx generator		Pulse forming line	
Number of stage	n=18	Impedance	9,1 Ω
Capacity of 1stage	100 nF	Length	1 m
Input voltage	U_{in}=25 kV	Pulse duration	60 ns
Output voltage	U_{out}=450 kV	Working medium	water

Tab. 1. Pulsed power supply parameters.

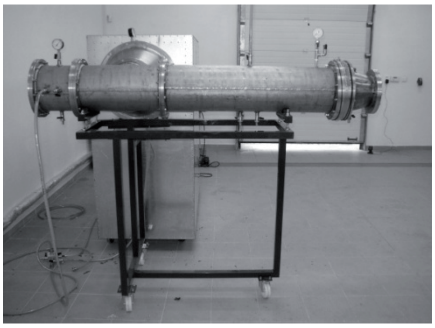

Fig. 8. Cylindrical version of the Blumlein circuit.

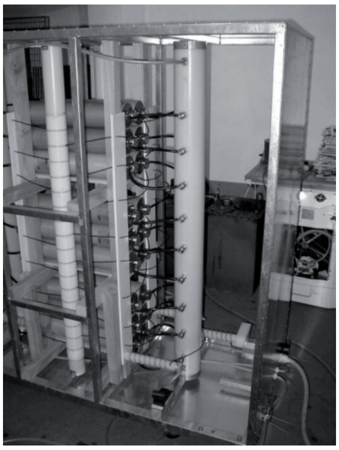

Fig. 9. Marx generator.

4. High Power Microwave Generator

A wide range of HPM devices exists. Relativistic klystrons, magnetrons, slow wave devices, reflex triodes and vircators are all examples of the available technology base [5]. From the perspective of an electromagnetic weapon or warhead designer, the device of choice will be the vircator at this time. The vircator is mainly a one shot device capable of producing a very powerful single pulse of radiation, yet it is mechanically simple, small and robust, and can operate over a relatively broad band of microwave frequencies. The physics of the vircator tube are substantially more complex than those of the preceding devices. The fundamental idea behind the vircator is that of accelerating a high current electron beam against a foil or a grid anode. Many electrons will pass through the anode, forming a bubble of space charge behind the anode. Under the proper conditions, this space charge region will oscillate at microwave frequencies. If the space charge region is placed in a resonant cavity which is appropriately tuned, very high peak powers may be achieved. Conventional microwave engineering techniques may then be used to extract the microwave power from the resonant cavity. Because the frequency of oscillation is dependent upon the electron beam parameters, vircators may be tuned or chirped in frequency, where the microwave cavity will support appropriate modes. Power levels achieved in vircator experiments range from 170 kW to 40 GW over frequencies spanning the decimeter and centimeter bands [5].

4.1 Vircator Operation Fundamentals

The basic idea of the vircator is to accelerate a dense flush of an electron beam against a grid or a foil anode. Plenty of electrons pass through the anode and form a region of a space charge behind the anode called ”virtual cathode“. This region of a space charge at corresponding conditions can oscillate in a region of microwave frequencies. It is possible to tune the vircator in a broad band of frequencies using only a change of a space charge density. There is no necessity to have an external magnetic field for a correct vircator function. In Fig. 10, an axial vircator is shown. Electron beam passes through the foil or the grid anode. Microwave power is brought out axially, too. Frequency changes appear in vircator with standard geometry when the distance between the anode and the cathode gets smaller due to filling the working space by plasma. Efficiency of a standard geometry vircator is ordinarily about ones percent.

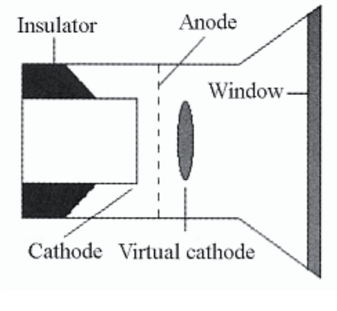

Fig. 10. Schematic drawing of axial vircator.

Despite its low efficiency, vircator is very attractive for army applications because it is very simple to be made, it is a compact device and there it is no need to have an external magnetic field. For more information about construction and properties of various types of vircators you can see e. g. [5], [13] and [14].

4.2 Mathematical Description of Vircator Operation

For microwave frequency generation, it is necessary to meet a number of conditions relevant to the power supply and geometric proportions of a vircator electrode. Determination of these conditions results from [15] and we use simplified geometry displayed in Fig. 11 to derive the mathematical characterization.

The most common case is that a pulse duration τ is much longer than a beam transit time across cavity $\tau >> L/C$.

We assume that an external axial magnetic field obstructs transverse electron motion. The space charge of the beam makes a negative potential energy $e\Phi$ in drift space which breaks the electrons. If the space charge potential reaches the value of accelerating voltage (electrons are stopped in beam), the beam with bigger current cannot expand. There is a value of current which causes stopping of electrons. This value is called the vacuum critical current. There has to be the above mentioned critical current to make the vircator generate microwave oscillations.

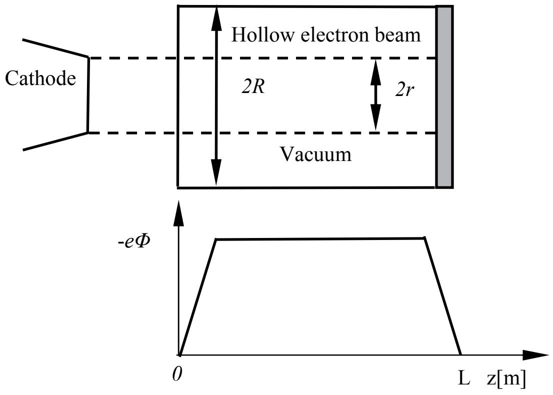

Fig. 11. Simplified geometry of axial vircator.

We suppose a hollow beam; whose charge is concentrated in a thin layer with radius r. Behind the transition space (which is comparable to the radius of chamber – backward conductor), there is nearly homogenous potential. It is possible to determine the potential quantity with consideration that it is a coaxial capacitor and its inner cylinder is saturated by beam charge.

Capacity of the coaxial capacitor is given by

$$C = \frac{2 \cdot \pi \cdot \varepsilon_0}{\lg\left(\frac{R}{r}\right)} \qquad (1)$$

where ε_0 is the vacuum electric permittivity, R is the chamber radius, r is the beam radius.

The potential is given by the equation

$$\Phi = \frac{Q}{C} \tag{2}$$

where Q is the charge linear density, C is the capacity per length unit. We can define the charge linear density as

$$Q = \frac{I}{v} \tag{3}$$

where v is an electron module velocity and the current is defined by the equation

$$I = e \cdot n \cdot v \cdot S \tag{4}$$

where e is the charge of an electron, n is the linear electron density, S is the profile of the electron beam.

When (1) and (3) are substituted into (2), we can obtain expression for the potential in the form

$$\Phi = \frac{Q}{C} = \frac{I \cdot \lg\left(\frac{R}{r}\right)}{2 \cdot \pi \cdot \varepsilon_0 \cdot v} . \tag{5}$$

The electron velocity v is associated with its initial energy and potential by the energy preservation law

$$m_e \cdot \gamma_0 \cdot c^2 + e\Phi = m_e \cdot \gamma \cdot c^2 \tag{6}$$

where γ_0 is the initial relativistic factor of the beam, γ is the relativistic factor inside a system reduced due to potential.

The relativistic factor inside a system can be expressed by the equation

$$\gamma = \gamma_0 + \frac{e\Phi}{m_e \cdot c^2} \tag{7}$$

where m_e is the electron mass and c is the speed of light. The relativistic factor can also be expressed by

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} . \tag{8}$$

The electron velocity in drift space v can be specified from following equations:

$$\gamma^2 = \left(\gamma_0 + \frac{e\Phi}{m_e \cdot c^2}\right)^2 , \tag{9}$$

$$v = c \cdot \sqrt{1 - \frac{1}{\left(\gamma_0 - \frac{e\Phi}{m_e \cdot c^2}\right)^2}} . \tag{10}$$

Substituting (10) into (3) and multiplying by $(e \cdot v) / (m \cdot c^3)$, we can get

$$F(\Phi) = \frac{e \cdot \Phi}{m \cdot c^2} \cdot \sqrt{1 - \frac{1}{\left(\gamma_0 - \frac{e\Phi}{m_e \cdot c^2}\right)^2}} = \frac{e \cdot I \cdot \lg\left(\frac{R}{r}\right)}{2 \cdot \pi \cdot \varepsilon_0 \cdot m \cdot c^3} . \tag{11}$$

The function $F(\Phi)$ has its peak value under the conditions describes by

$$\frac{e \cdot \Phi}{m \cdot c^2} = \gamma_0 - \gamma^{\frac{1}{3}} . \tag{12}$$

The evaluation is written in the form

$$F(\Phi) = \sqrt{\left(\gamma^{\frac{2}{3}} - 1\right)^3} = \frac{e \cdot I \cdot \lg\left(\frac{R}{r}\right)}{2 \cdot \pi \cdot \varepsilon_0 \cdot m \cdot c^3} . \tag{13}$$

There is no possibility to find the solution of (11) for bigger values of function $F(\Phi)$. According to (13), the critical vacuum current is

$$I_{cr} = \frac{2 \cdot \pi \cdot \varepsilon_0 \cdot m \cdot c^3}{e \cdot I \cdot \lg\left(\frac{R}{r}\right)} \sqrt{\left(\gamma^{\frac{2}{3}} - 1\right)^3} . \tag{14}$$

When we substitute the known constants (like $\pi = 3.1415$), we obtain the equation

$$I_{cr} = \frac{8.5}{\lg\left(\frac{R}{r}\right)} \sqrt{\left(\gamma^{\frac{2}{3}} - 1\right)^3} \tag{15}$$

where I_{cr} is the critical vacuum current [kA].

For vircator implementation, energy of electrons of about 500 keV is considered, which corresponds to the relativistic factor of $\gamma_0 = 2$. Thus planar diode current limited by space charge follows the three-half Child-Langmuir law

$$I \approx \frac{U^{\frac{3}{2}} \cdot S_k}{d_{ka}^{\;2}} \tag{16}$$

where U is the voltage between anode and cathode, S_k is the surface of cathode, d_{ka} is the distance between anode and cathode.

An important characteristic of a vacuum planar diode is its impedance, which is given by

$$Z = 1.36 \cdot 10^5 \cdot U^{-\frac{1}{2}} \cdot \frac{d_{ka}^2}{r_k^2} \tag{17}$$

where r_k is the radius of the cathode.

The vacuum critical current is the maximal current that can distribute itself through vacuum. It means it is possible to measure the same current until the distance is bigger than the diameter of beam. It is just the same value when the potential of space charge of electron beam is equal to the accelerating voltage. That is the limit where the virtual cathode is generated and the vircator starts working. The generated frequency depends on the plasma frequency of the electron beam. The plasma frequency is determined by the electron beam current density. The plasma frequency is the frequency of electrons in space charge field oscillations. The electrons can oscillate due to the influence of repulsive force which takes effect between particles with the same charge. The plasma frequency depends on the concentration of electrons in the beam. The current density is given by the number of charges which are able to pass through the surface of 1 m^2 per one second. Thus we can calculate the current density i [Am^{-2}]

$$i = e \cdot n_V \cdot c_e \tag{18}$$

where e is the electron charge, n_V is the electron volume density and c_e is the electron velocity.

Plasma frequency of the electron beam is approximately given by

$$f_{pe} = 9 \cdot 10^7 \cdot \sqrt{i}\ . \tag{19}$$

4.3 Axial Vircator Design

Following the theoretical assumptions given above, the axial vircator with grid anode was fabricated. The structure of the grid anode enables repeated operation in contradistinction to vircator with a foil anode. The cathode diameter $r_k = 17.5$ mm and the working chamber radius $R = 40$ mm were chosen in order to decrease the value of the vacuum current. The critical vacuum current is $I_{cr} = 4.63$ kA in this configuration. The vircator impedance matching to the forming line is a very important requirement for vircator's correct operation. Because of that, a cathode with a possibility to change the distance d_{ka} between cathode and anode is fabricated. The cathode is made as a cylindrical carbon block. The anode grid is made from pyrolitic carbon.

In Fig. 12, there is section picture of the built-up axial vircator with the possibility to the change distance between anode and cathode. In Fig. 13, there is a view of the fabricated vircator. The vircator is fed by a pulse generator formed by Marx generator and pulse forming line described in Section 3.2. The connection between the axial vircator and the output of pulse forming line is shown in Fig 14. Vircator voltage is measured by a cylindrical capacitive probe, which is a part of pulse forming line output circuit. Vircator current is measured by Rogowski coil placed in the outer cylinder of the pulse forming line. Vircator voltage time history is displayed in Fig. 15 and vircator current time history is displayed in Fig. 16.

Compared to other types of microwave tubes, the microwaves generated by an axial vircator cover a relatively wide frequency band. In Fig. 17, the frequency spectrum of the signals generated by the realized axial vircator is shown. The dominant frequencies of the generated microwave signals are placed in the band of 0.5 to 1.5 GHz. The frequency spectrum was acquired on the basis of information measured by a digital oscilloscope Tektronix TDS 7704B connected to broadband antenna EMCO 3115. For the measurement the microwave output power of the vircator, a measuring device was designed and made, using calorimetric method for the power measurement. A detailed power sensor description can be found in [18]. A more detailed description the of axial vircator research results is given in [6], [14], [16] and [17].

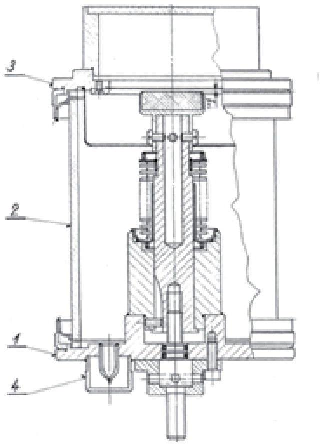

1 cathode contact ring, *2* ceramic insulator, *3* anode contact ring, *4* pipe for vacuum pumping shelter

Fig. 12. Section picture of built-up axial vircator with possibility to change distance between anode and cathode.

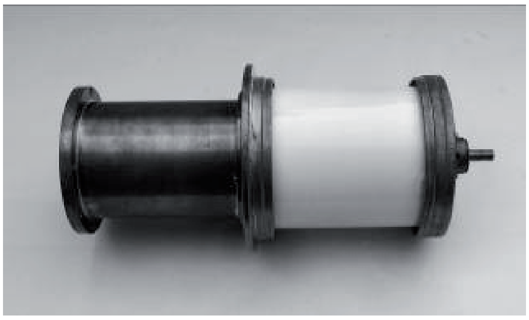

Fig. 13. View of fabricated axial vircator with adjustable distance between anode and cathode.

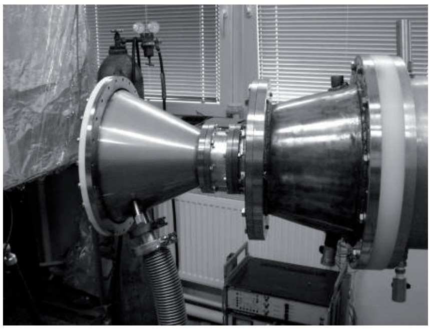

Fig. 14. View of fabricated axial vircator connected to the pulse forming line.

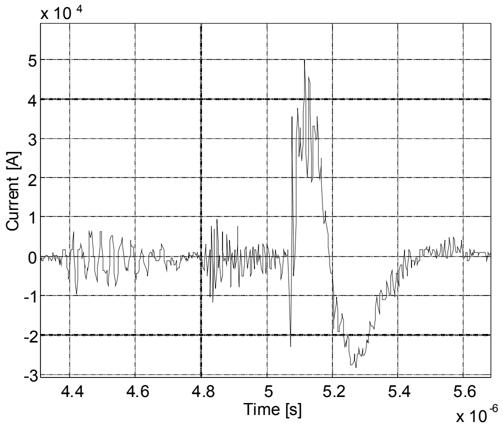

Fig. 15. Vircator current time history.

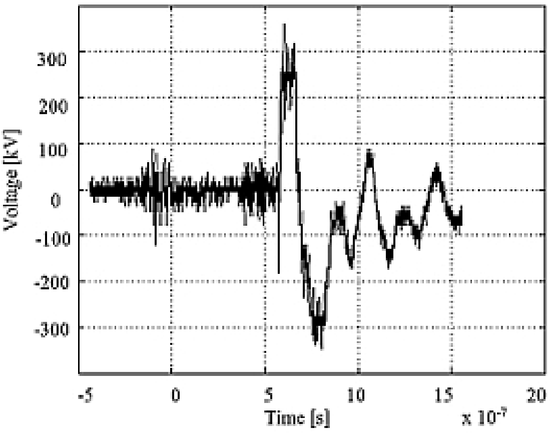

Fig. 16. Vircator voltage time history.

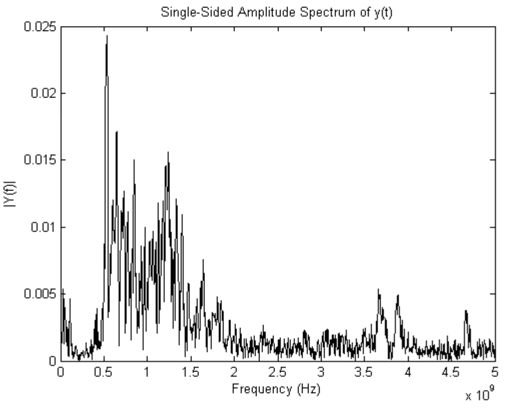

Fig. 17. Frequency spectrum of signals generated by realized axial vircator.

5. Conclusion

The research of directed energy weapons microwave validated substantial technology applicable in electromagnetic ammunition and in weapons for defense of objects (WDO). The axial vircator is the most important component part applicable in both categories of DEWM. Dominant frequencies of the generated microwave signal are placed in band of 0.5 to 1.5 GHz. To fulfill the vircator minimal proportion requirements to be able to use the vircator as a DEWM, it is necessary to shift the vircator dominant frequencies to the 3 GHz band. This requirement can be reached by arranging the cathode size efficiently and consequentially optimizing the distance between anode and cathode. Great attention also has to be paid to increase the specific dielectric strength of the output window of the axial vircator.

Acknowledgements

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DARPA NESD
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The ***Biological Technologies Office (BTO)*** of the ***Defense Advanced Research Projects Agency (DARPA)*** is sponsoring an Industry Group to support the ***Neural Engineering System Design (NESD) Program***.

NESD is a highly interdisciplinary program requiring extensive integration of new research and technology. To facilitate the development and adoption of NESD technologies, DARPA has organizedan industry group for potential proposers. Members of this group have agreed to provide access to rapid prototyping and manufacturing of advanced neuro-engineering components, including state-of-the-art electronics, photonics, computing, assembly and packaging.

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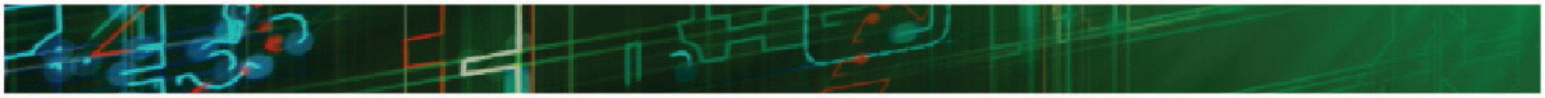

ALLEN INSTITUTE *for*
BRAIN SCIENCE

Allen Institute for Brain Science

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About

The Allen Institute for Brain Science is an independent, non-profit medical research organization that has embarked on a concerted, ten-year effort, involving more than 300 scientists, engineers, technologists and other specialists, to understand the cerebral cortex in the mouse and in the human at the cellular level. We are built upon the notion of Big Science, Team Science and Open Science in the service of Basic Science with an explicit mission to accelerate understanding of the human brain in health and disease. Our data are freely and publicly available at www.brain-map.org.

Capabilities

- We seek to experimentally and computationally characterize the components (cell types) of the rodent visual thalamo-cortical system at the molecular, transcriptional, electron-microscopic, electrophysiological, morphological and functional levels to study how these components integrate information to generate high-level cognitive functioning such as object recognition.
- To study such high-level functioning, we use various in vivo perturbation and monitoring techniques (e.g. optical stimulation, extracellular depth recordings, wide and narrow-field Ca-imaging, etc.), very high density silicon probes (364 probes per shaft) as well as state-of-the art computer models that capture cortical information processing at varying levels of granularity.
- To understand the human brain, the Institute is also engaged in cell typing from human brain tissue harvested from patients undergoing brain surgery.
- Thus, we are routinely recording intracellularly from single and multiple cells from ex vivo human lateral temporal cortex and as well as performing morphological characterization on these same cells).

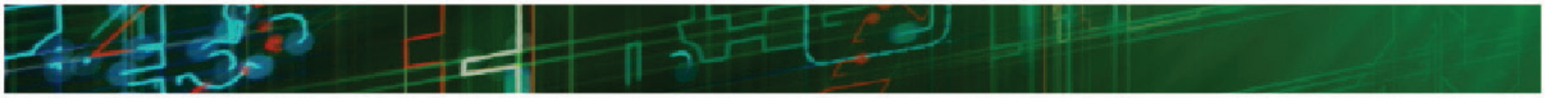

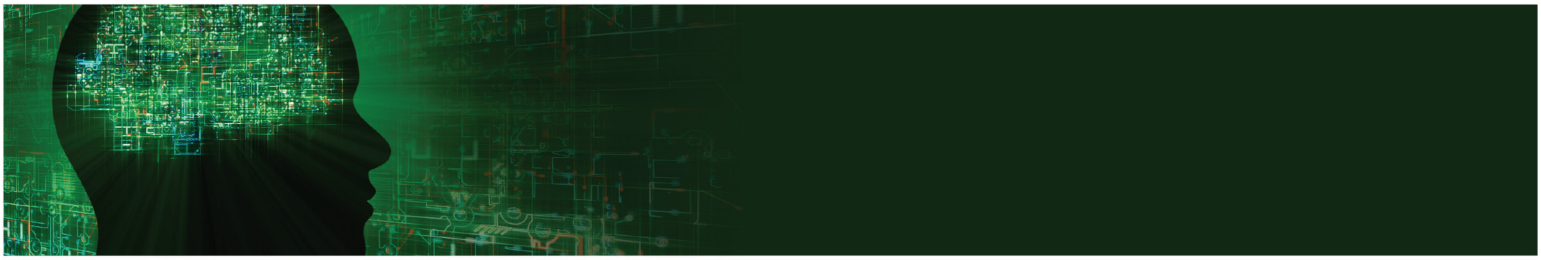

Capabilities

- We also have extensive experience with the genomic and transcriptional architecture of the human brain.
- We are interested in applying this knowledge for medical and translational purposes and to help facilitate advancement of CNS disorder therapies.

Facilities II

The Allen Institute headquarters, a 270,000 square foot life sciences building, is located in Seattle's South Lake Union neighborhood, the city's biotechnology hub. We are a high-throughput facility, home to custom-designed robotic systems, automated technologies, premier bench laboratory space and all the high-powered computing hardware and software necessary for processing petabytes of data.

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Bionics Institute

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Capabilities

Medical device safety and efficacy testing (in vitro and in vivo)

- Design, rapid prototyping & validation testing
- Accelerated aging & flexion testing
- Electrochemical impedance spectroscopy
- Acute feasibility studies
- Chronic safety and biocompatibility studies
- Drug delivery techniques
- Histology & data analysis
- Scanning electron microscopy of implanted materials
- Preclinical animal model development

Custom device prototyping & fabrication

- Design and fabrication of custom electrode arrays and surgical tools
- Use of FDA approved materials

'First in human' clinical trials

Clinical and Scientific Track Record

- 35 years of internationally recognised experience & scientific excellence
- Extensive clinical, academic & commercial partnerships
- Proven research & clinical development pathways

Staff and Facilities

- Experienced and qualified scientists, engineers and clinicians
- Co-located in a major Australian hospital
- Purpose built equipment and facilities

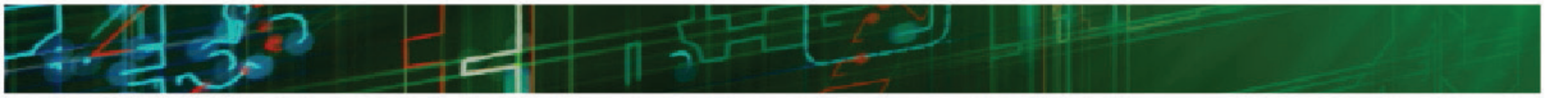

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About

Boston Micromachines Corporation (BMC) is the leading provider of microelectromechanical systems (MEMS) deformable mirror products and has expertise in the design of adaptive optics systems. The company's suite of award-winning compact DM products is the most cost-effective, highest performance mirrors in the market today. By applying wavefront correction, BMC devices can be used in a variety of applications which include laser beam shaping, microscopy, astronomy, and vision science. Located in Cambridge, MA, BMC is privately held and offers custom-designed manufacturing services in addition to its portfolio of standard DM products and adaptive optics systems.

Capabilities

The specific capabilities/services the company provides in relation to the NESD falls into two categories:

Deformable mirrors systems for use in neurological imaging instruments

- MEMS deformable mirrors ranging in size from 140 – 1000 actuators
- Mirror surface geometries of continuous, segmented, and hexagonal tip-tilt
- High speed drive electronics

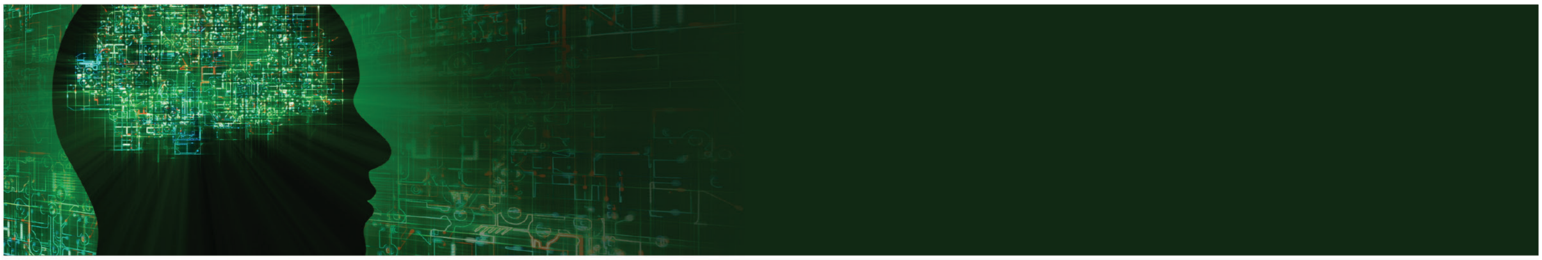

These devices are currently being used in in vivo neural imaging systems at various premier research institutions around the country. Boston Micromachines also provides research and development services for advancing the deformable mirror and drive electronics technology and design to better fit specific applications.

- Advanced imaging systems utilizing adaptive optics to improve resolution and contrast in in vivo subsurface imaging application (i.e. deep penetration brain imaging)

Boston Scientific

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Capabilities

- Lead prototyping
- Firmware modifications to the implantable pulse generators (IPG)
- Software modifications to the computer programmers (CP)
- Use of advanced computational models and predictive algorithms for parameters and programming guidance for neurostimulation

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Chronocam

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Capabilities

- Extensive know-how in designing, developing and industrialising asynchronous, event-based, bio-inspired vision sensors
- Expertise in developing and customising event-based, bio-inspired computer vision algorithms for a large number of applications spanning from autonomous navigation, security and surveillance, aerospace and defence to biomedical devices and smart objects
- System integration capabilities: development of camera systems relying on Chronocam's proprietary vision sensors and development of embedded software porting Chronocam’s proprietary computer vision algorithms on a large number of processing platforms (such as: CPUs, GPUs, FPGA)

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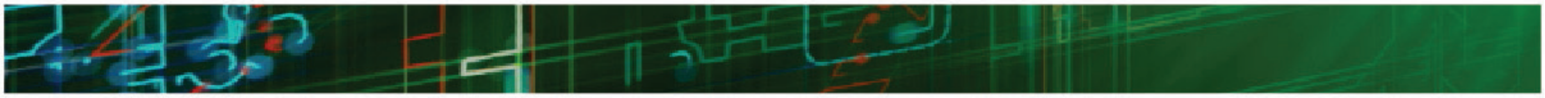

cirtec
MEDICAL SYSTEMS

Cirtec

Primary Contact

Heather Dunn / Heather.Dunn@cirtecmed.com

About Cirtec

Cirtec Medical has been providing contract design, development, and manufacturing services to the medical device industry since our founding in Massachusetts in 1986. Today, Cirtec has over 150 employees in our two facilities on the east and west coasts.

Cirtec has supported active implantable developers throughout our history. Early projects focused on hermetic welding and testing services for implantable neurostimulation devices, with service offerings expanding to provide full design and development. In all, Cirtec has worked with over 60 different companies and institutions developing active implantable devices, with over 30 in the neuromodulation space. We work with companies and institutions of all sizes, from early stage starts-ups to large, well-established medical device manufacturers. We also work frequently with research laboratories and academic groups; our current projects include development and manufacturing of an implantable neurostimulator used for research and recently approved for clinical study under a feasibility IDE.

Capabilities

Cirtec is ISO 13485 certified and FDA registered.
Cirtec supports the full product development cycle from conceptual development and requirements definition through clinical and commercial manufacturing.

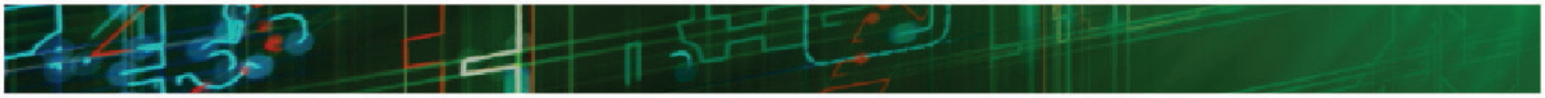

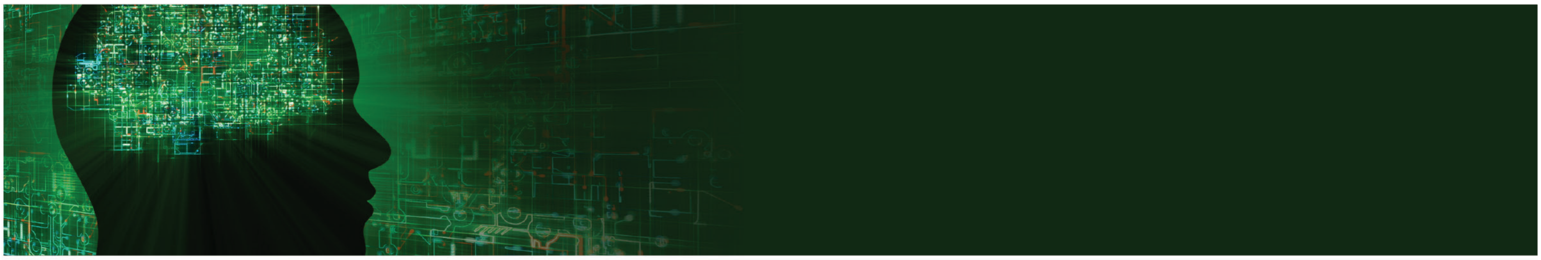

Our engineering teams including mechanical, electrical, and software design resources as well as process development, manufacturing, and quality engineering. Cirtec has a robust and flexible quality system; start-up companies and research groups often choose to work under our quality system rather than developing their own. We provide design history file management and document control services. We can also perform or contribute to requirements documentation, risk management activities, and design verification activities. Our manufacturing capabilities relevant to active implantable devices include:

- Laser welding
- Resistance welding
- Electrical assembly
- Laser marking
- Laser ablation
- Surface treatment
- Ultrasonic cleaning
- Epoxy molding and adhesion
- Silicone molding and adhesion
- Packaging and labelin

Manufacturing capabilities are supported by in-house test capabilities. These include mechanical testing, hermetic leak testing, bench level and automated electrical testing, environmental conditioning, and custom test setups such as soak or pressure testing.

Our manufacturing infrastructure includes multiple ISO class 7 cleanrooms and ESD safe handling procedures for all devices. Cirtec provides complete supply chain management services, leveraging our extensive Approved Supplier List and robust inventory management and material traceability procedures.

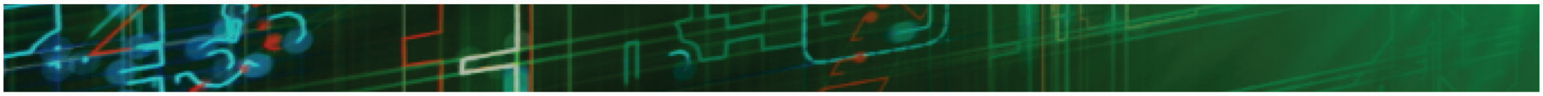

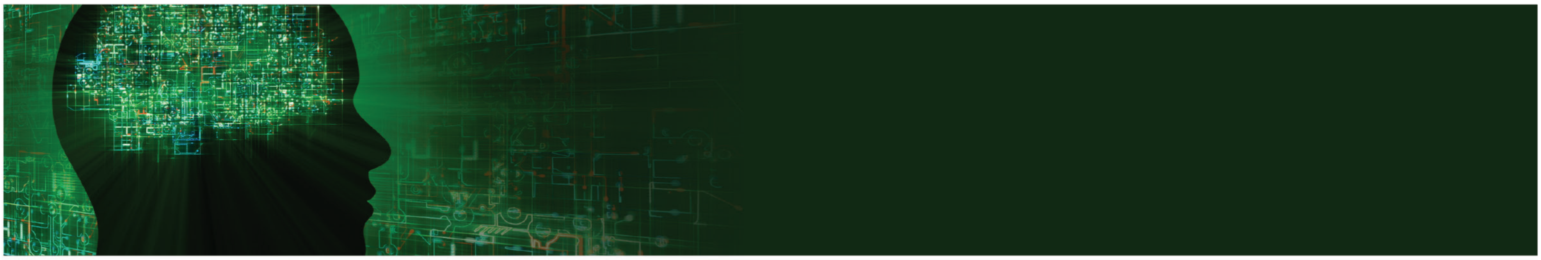

VALUE TO PROPOSING TEAMS: There are six primary areas where Cirtec capabilities provide value to proposing teams.

Hermetic barrier development	Hermetic package and barrier design
	Leak specification development
	Internal moisture management: Vacuum bake, desiccant handling, residual gas analysis testing
	Hermetic sealing (welding, brazing) and testing
Electrical assembly	Soldering, wire bonding, and die bonding
	Coil winding
	ESD-safe workspaces
	Lithium battery safe handling procedures
	Bench and automated testing
Interconnect development	Feedthrough design and sourcing
	Hardwired and disconnectable design
	Fabrication and testing
Encapsulation	Epoxy, silicone, and parylene encapsulation
	Layered encapsulation design to manage fluid ingress
	In-house design, tooling, molding, testing
Sterile packaging	Package design
	Pouch and tray packaging and labeling
	Off-the-shelf double sterile tray system
	Sterilization service provider management
Quality system support	Design control support and design history file maintenance
	GMP manufacturing
	Supply chain management
	Procedures for and support of requirements definition, risk management, design verification, and process validation

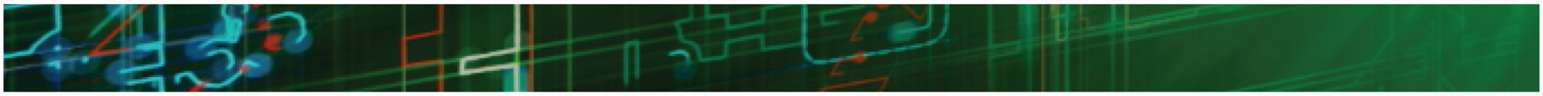

Dragon ID

Primary Contact

Eugene Malinskiy / eugene@dragonid.com

Capabilities

- Our staff is very experienced working within the complexities of the medical system from observing physicians in the operating room to bringing devices through regulatory approval.
- We have engineers with process development and industrial experience, including interfacing directly with manufacturers.
- We have software engineers experienced in both hardware and software engineering and experience in microcode and embedded systems, end user applications, and high performance computing.
- In addition to engineering talent, we staff researchers, designers, and SMEs to bring a truly interdisciplinary approach to innovation and design for a project.
- We have experience recruiting, establishing, and coordinating relationships between global stakeholders for complex projects to maximize accountability and efficiency for a product while minimizing bureaucracy required.
- We work with our world--class partners in industries such as industrial design, rapid multi--material prototyping, materials selection, and manufacturing in order to round out our capabilities for a product.

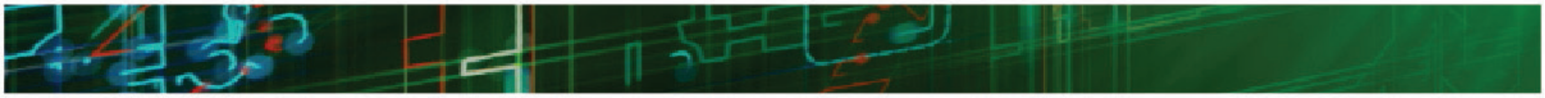

Freedom Photonics LLC

Primary Contact

Leif Johansson / leif@freedomphotonics.com

About

Founded in 2005 we are privately held Limited Liability Company based in Santa Barbara, California with ISO Qualification in process, certification in Q2 2016. We develop, manufacture and market complete photonic integrated circuit based products (Indium Phosphide, PLC, Si Photonics).

Our main markets in components, modules and subsystems are for fiber-optic communication, free-Space-optical (FSO) communication and infrared sensors and illuminators.

Capabilities

We offer electronics design, assembly and testing with expertise in photonic design, packaging, control electronics, manufacturing and qualification.

We offer services across development and have a premier R&D compound semiconductor facility with lithography (steppers, DUV stepper, EBL), wet and dry etching, deposition and characterization capabilities.

Our Business Model

Conceptualization, prototyping and development

- Fast R&D turn-around and low cost device fabrication in Nanotech cleanroom facility (Freedom Photonics employees)
- Internal multi-project wafer runs

Volume device production with commercial foundries worldwide

- Fabrication processes designed for manufacturability
- Access to manufacturability and production capacity, qualified processes
- Experience in outsourcing volume device manufacturing

Significant internal capability for assembly, packaging, test

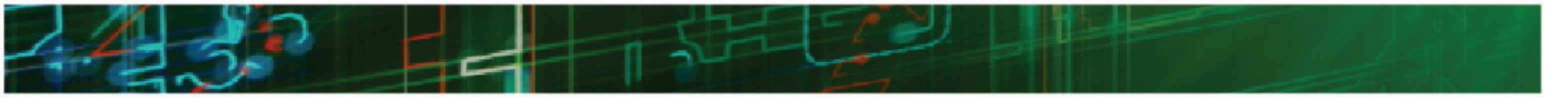

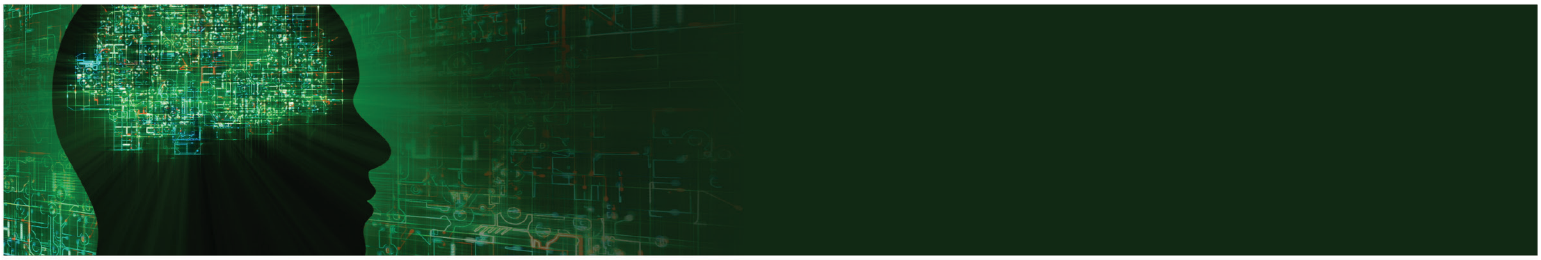

Capabilities and Facilities I – Photonics Design and Fabrication

Design

- Commercial and proprietary tools for passive and active PIC modeling, (Lumerical, native FDTD/BPM code, mode solvers, mask layout, SOA/active region models, Simwindows, SRIM)

Mask layout

- Proprietary scripting tool, with design rule checker and automated mask plate layout

Fabrication

- Full wafer process, die pick-and-place, wedge bonder, ball- bonder, auto-cleaver, pull-tester, etc.

Capabilities and Facilities II – Photonics Production Test

- Photonic device bar level probe
- Chip-on-carrier level (probe card)
- Package; DC, spectral, and data testing
- Burn in – monitored, environmental chambers

Capabilities & Facilities III – Packaging

Several in-house systems with laser welding and UV curing capability.

- Custom tooling, TOSA packages, 14 pin butterflies etc.
- ZEMAX commercial optical train design tool

Capabilities and Facilities IV – Electronics

- Digital and Analog Electronics
- FPGA design and verification tools in house
- Commercial tools for board layout
- Outside foundry for PCB fabrication and stuffing
- Electronics workstations for assembly and test
- Oscilloscopes, sources, multi-meters

We perform contract fabrication and engage with a number of domestic and international fabrication providers, both full process or selected fabrication steps are available.

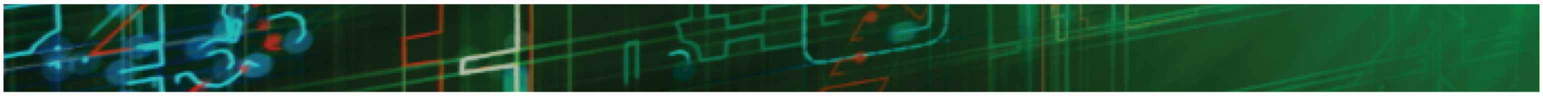

IMEC

Primary Contact

Barun Dutta / Barundeb.Dutta@imec.be

Capabilities

IMEC is interested in making its comprehensive capabilities available for joint-research programs for solutions in Life Sciences Technologies, Healthcare and Bio-medical engineering, including:

- Semiconductor/nanotechnology
- Process technology
- Design technology and systems/software technologies

Additional Contacts

Maarten Willems / Maarten.Willems@imec.be

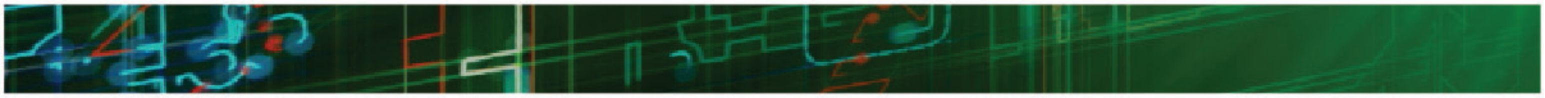

Infinite Arthroscopy

Infinite Arthroscopy

Primary Contact

Daniel Dudley / d.dudley@infinitearthro.com

About

We are exclusively focused on developing new medical technologies with an emphasis on translating innovations from other industries to the operating theatre. We have experience in the full life cycle of medical device development from initial conception to regulatory submission. We have large number of rapid prototyping and fabrication techniques available in-house including but not limited to software-based design, stereolithography, fused deposition modelling, PCB milling, and machining. Our staff includes designers, engineers, health care professionals, and subject matter experts from a diversity of industries allowing us to leverage a far wider knowledge base than the standard medical device company. We maintain a nationwide network of leading physicians and institutional partners to develop, refine, and validate our technologies according to contemporary healthcare practice and needs.

Capabilities

Infinite Arthroscopy also maintains a portfolio of intellectual property derived from our medical device technologies that would be available to the NESD Industry Group. Two relevant examples are listed below.

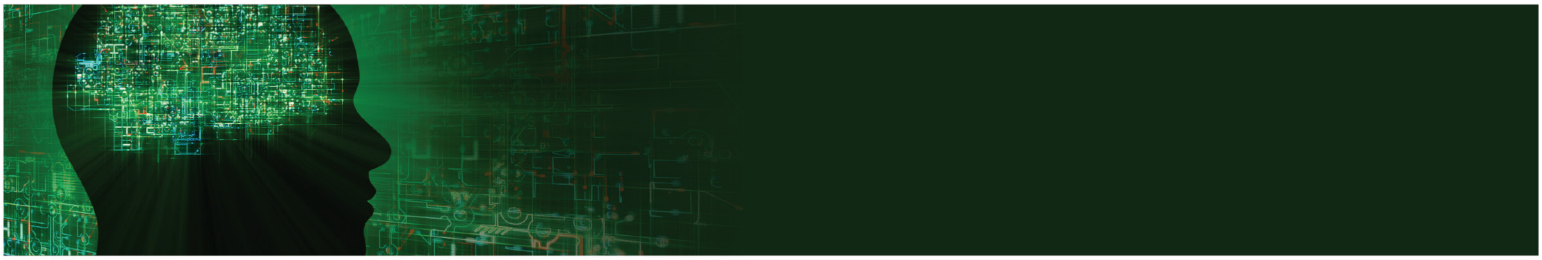

Infinite Arthroscopy, Inc. Proprietary Technologies:

Novel Light Source

- Miniaturized / Ruggedized
- Low power (sub 1 watt)
- Low heat (to LEDs of comparable lumen-output)
- High lumen output
- Long Lifetime (50,000+ hours)
- Emits only target wavelength(s) (Capacity to customize to project needs)

Command/Control Architecture for Medical Devices

- HIPAA/FTC Approved for use in Operating Rooms
- Uninterrupted High-bandwidth capacity
- Transmission below standard RF noise floor
- Encrypted protocol

Additional Contacts

Howard Fein / h.fein@infinitearthro.com

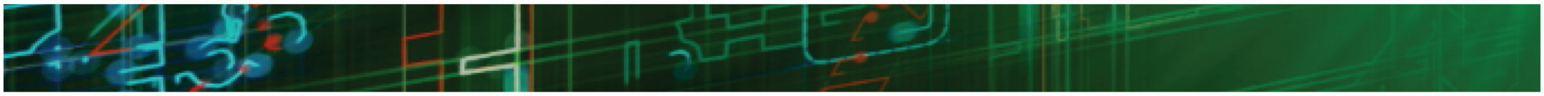

Inscopix

Primary Contact

Pushkar Joshi / pushkar@inscopix.com

Capabilities

- Neuroscience application development and validation (surgical procedures for rodents and non-human primates, application of biological reagents within our own life science lab)
- Optical system development (lens design and simulation, LED light source development, prototyping)
- Hardware system (FPGA-based and/or microcontroller based mixed-signal systems especially involving imaging, mechanical packaging) development, testing, and prototyping
- Software (application, image processing, computer vision, analytical) development and testing
- Mechanical accessories development (design, prototyping via 3D printing)
- With these capabilities, we can customize Inscopix's existing and emerging systems and applications, or develop new systems and applications for or with other proposers in support of this program.

Additional Contacts

Shung Chieh / schieh@inscopix.com

Nanomedical Diagnostics

Primary Contact

Brett Goldsmith / brgoldsmith@nanomedicaldiagnostics.com

Capabilities

- Graphene FET sensor array chips appropriate for integration with nearly any biochemical or electrochemical interaction
- Current sensor hardware capable of measuring biochemical and bioelectric interactions over time with 10 millisecond time resolution, and spatial resolution less than 10 microns
- Capability to produce sensor hardware with time resolution approaching one microsecond with a spatial resolution less than 2 microns
- Expertise in combining electronic materials, packaging and assembly with active biological materials
- Projected FDA clearance for an in vitro clinical product, and associated manufacturing chain, using graphene sensors by mid 2017
- Graphene appropriate for use in medical sensors integrated into an electronic or implantable platform of your choosing
- Chemical and biochemical expertise in biochemical attachment and blocking techniques specialized for boosting specificity of electronic readout of biological interactions
- A complete "turnkey" R&D system for using graphene sensor chips
- Hardware and software appropriate for reading graphene biosensors

Additional Contacts

Francie Barron / fbarron@nanomedicaldiagnostics.com

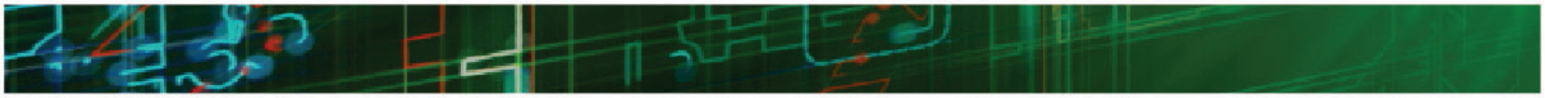

Naval Research Laboratory

Primary Contact

Dr. Jas. S. Sanghera / sanghera@nrl.navy.mil

About

NRL is the corporate research laboratory for the Navy and Marine Corps and conducts a broad program of scientific research, technology and advanced development.

The Optical Materials and Devices Branch has five primary areas: high purity chemicals, specialty optical materials, silica fiber technology, optical devices and advanced concepts.

Capabilities

We have expertise in the research, development and fabrication of glasses, glass-ceramics, ceramics, crystals, bulk optics, films, waveguides and optical fibers.

We offer a full suite of capabilities to make transparent ceramics to solve the ceramic packaging needs of NESD, some key properties:

- UV to RF transparency tailoring
- Tougher, stronger, harder than glass
- Electrically inert
- Demonstrated conformal shapes
- Demonstrated bonding technologies
- Vertical integration

Our facilities include class 100 clean rooms, powder processing equipment, sintering systems, and characterization capabilities (XRD, SEM, TEM, optics labs, mechanical testing).

Some of our prior applications include: Conformal Optics, IR simulators, photonic mast design, flexible PV’s, IRCM, and Directed Energy Weapons.

Additional Contacts

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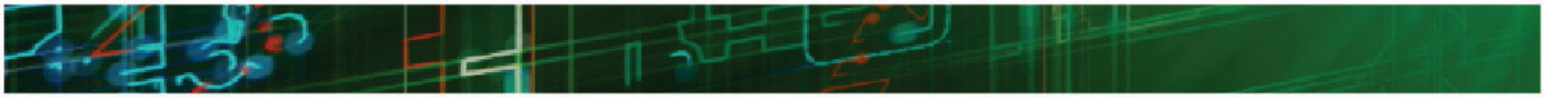

Star Lab

Primary Contact

Adam Fraser / adam.fraser@starlab.io

About

Star Lab is a high-tech small business focused on complex systems security research and development, with significant expertise and a pedigree of success developing security technologies for safety-critical and mission-critical systems. The company specializes in the areas of high-assurance operating systems, technology protection, applied cryptography, and anti-tamper, and is also a leader in kernel/hypervisor/embedded software development. Star Lab has offices in Washington D.C. and Huntsville, AL.

Additional Contacts

Irby Thompson / irby@starlab.io

Qualcomm

Primary Contact

Karim Arabi / karabi@qti.qualcom.com

Capabilities

- Experience in building an end-to-end platform as a reference design for interface with brain
- Experience in driving an industry wide standard effort to standardize a communication medium and protocol for brain interface
- Advanced low power wireless solutions, RF interface, MODEM system solutions and related electronics for brain interface
- Advanced wireless charging and powering solutions for brain implants
- Ultra low power electronic design solutions at advanced technology nodes suitable for brain implants to enable always on monitoring and processing
- Ultra low power DSP solutions, stream data processing and data compression and decompression solutions

Additional Contacts

Rudy Beraha / rberaha@qti.qualcomm.com

New World War

Revolutionary Methods for Political Control

Mind-Reading

History

Probably no more “intrusive and persistent” method of obtaining information about a person exists than reading their mind.[1] Research on mind-reading has been vigorously pursued by US government agencies and various academic centers since the 1970s, and continues to this day.

Since 1973 DARPA has been studying mind-reading with EEG hooked to computers, using scientists at the University of Illinois, UCLA, Stanford Research Institute, Massachusetts Institute of Technology, and the University of Rochester.

They developed a system that could determine how a person perceived colors or shapes and were working on methods to detect daydreaming, fatigue, and other brain states. Although the device had to be calibrated for each person’s brain by having them think a series of specific thoughts, the calibration was quick.

In 1974 another very basic mind-reading machine was created by researchers at Stanford Research Institute. It used an EEG hooked to a computer which allowed a dot to be moved across a computer screen using thought alone. When interpreting people’s brainwaves, it was right about 60% of the time. During these tests scientists discovered that brain patterns are like fingerprints, each person has their own. So, each computer would have to be calibrated for a specific person.

Another method to address this issue was to store a large amount of generic patterns on the computer, so when it encountered a brain pattern it didn’t recognized, it used one that most resembled it. Since then, DARPA has sponsored Brain-Computer Interface (BCI) and mind-reading programs at Duke University, MIT, University of Florida, and New York State University, Brooklyn.

The Human Computer Interaction group at Tufts University has studied mind-reading funded by grants from a government research and education agency known as the National Science Foundation (NSF). Carnegie Mellon University, Stanford University, and the MIT Sloan School of Management have studied mind-reading. The Computer Laboratory at the University of Cambridge in England has developed mind-reading machines based on facial expressions.

Other academic institutions that have participated in mind-reading projects include the University of California, Berkeley, University of Maryland, and Princeton University in New Jersey. Microsoft has studied mind-reading using EEG to better accommodate its users. Emotiv Systems built a mind-reading gaming device which uses EEG to infer the mental states of video game

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Updates

Update: January 20, 2018
A freemasonic death threat....more

Important Updates

All Previous Updates

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players. Honda Motors and Advanced Telecommunications Research Institute International (ATR) have studied mind-reading.

Neuroimaging Devices

Scientists discovered that the neural code of the human brain is similar to the digital code of a computer. To some extent, they have deciphered this code. Prior to this, they assumed that it was necessary to identify the neurons associated with specific acts, which would have made mind-reading much more difficult.[2]

They now understand that it's not necessary to monitor billions of neurons to determine which are connected to a particular thought or act. Only a small number of them need to be monitored to accomplish this. To monitor these neurons researchers use neuroimaging devices. They include event-related optical signal (EROS), functional magnetic resonance imaging (fMRI), electroencephalography (EEG), functional near-infrared imaging (fNIR), magnetoencephalography (MEG), and positron emission tomography (PET).[3] These devices may be combined for a more accurate reading.

There are basically two types of measurements, *direct* methods and *indirect* methods. Direct methods measure changes in electromagnetic fields and currents around the brain which are emitted from the surface of the scalp, or they monitor the neurons themselves. Indirect methods measure hemodynamic (blood movement) changes of hemoglobin in specific tissue compartments.

Both of these methods are almost simultaneous with neuronal activity. Regarding sensors, there are invasive ones which must be implanted, and non-invasive ones which can be worn on the scalp, in the form of a headband.

Electroencephalography (EEG) provides a direct method for determining brain states and processes by measuring the electrical activity on the scalp produced by the firing of neurons in the brain. EEG has been around for over 100 years. EEG is commonly used in neuroscience, cognitive science, and cognitive psychology. It is inexpensive, silent, non-invasive, portable, and tolerates movement.

Wireless EEG which uses non-invasive sensors that have physical contact with the scalp can transmit the signals to a remote machine for deciphering. Although, in 1976 the *Los Angeles Times* reported that DARPA was working on an EEG to detect brain activity several feet from a person's head, which was to be completed in the 1980s. EEG normally produces only a general indicator of brain activity.

However, in 2008 *Discovery News* reported that a company called Emotiv Systems developed an algorithm that decodes the cortex, providing a more accurate measurement. "We can calibrate the algorithm across a wide range of technologies with the same resolution you would get from placing an invasive chip inside the head," said Tan Le, president of Emotiv Systems.

Functional magnetic resonance imaging (fMRI) measures the blood flow in the brain in response to neural activity. Active neurons use oxygen, which is brought to them by blood. The more active a region of the brain is the more

GEOENGINEERING
PLANETARY
SABOTAGE
&
HUMAN
EXTERMINATION
Mark M. Rich

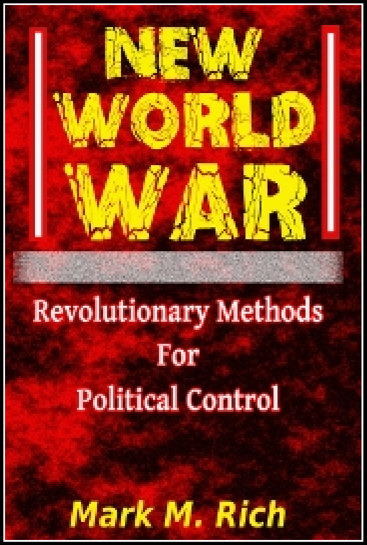

blood flows in the area. This movement of blood is referred to as *hemodynamic activity*. FMRI can detect which areas are receiving blood, which indicates that they're processing information.

The fMRI provides an indirect measurement of brain processes. It is the most common method of neuroimaging, and can produce 2 and 3-dimensional images. It is non-invasive, and can record signals from all brain regions, unlike EEG which focuses on the surface only.

Functional near-infrared imaging (fNIR) provides an indirect measurement of brain activity by detecting hemodynamic changes in the cortex. Although it is based on different principles, in that it uses light, it functions in the same manner as fMRI. FNIR can provide an almost continuous display of these changes in the cortex. It is inexpensive, non-invasive, and portable. A wireless headband with sensors exists for this device.

Event-related optical signal (EROS) is a brain-scanning device that focuses near-infrared light into the cerebral cortex to detect the density of neurons indicated by the transparency of brain tissue. Because it can only detect these changes a few centimeters deep, it can only image the cerebral cortex. Unlike fNIR, which is an optical method for measuring blood flow, EROS detects the intensity of neurons themselves and provides a direct measurement of brain activity. It is very accurate, portable, inexpensive, and non-invasive. A wireless headband with sensors exists for this device.

Capabilities

Mind-reading can be accomplished by first having a computer learn which brain patterns are associated with specific thoughts, then store the decoded information in a database. This machine learning is accomplished using a type of *artificial intelligence* (AI) called an *algorithm*. A very basic algorithm is a spell checker, which uses a database of common mistakes associated with a particular sequence of letters to present suggestions to a user.

"The new realization is that every thought is associated with a pattern of brain activity," proclaimed neuroscientist John Dylan Haynes, in *Newsweek International* on February 4, 2008. "And," says Haynes, "you can train a computer to recognize the pattern associated with a particular thought."

In a January 2000 issue of *US News and World Report*, Lockheed Martin neuroengineer Dr. John Norseen announced, "Just like you can find one person in a million through fingerprints ... you can find one thought in a million." This can be accomplished using AI and HCI, or what Dr. Norseen calls biofusion.

The decoded brain signals can be stored in a database. Then when someone is scanned, the computer detects the pattern and matches the signals to the database of known meanings. But it's not necessary to scan a brain to decode its signals for every single thought, such as a picture.

Instead, after the machine has learned how to decipher patterns associated with specific thoughts such as images, more images can be added to the program and the computer can use the process it used for the other images as a model to somewhat accurately detect additional thoughts.

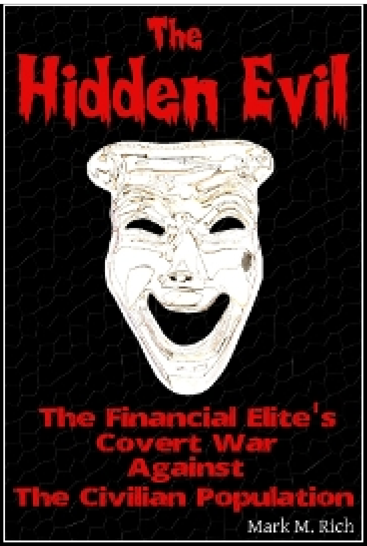
The Hidden Evil
The Financial Elite's Covert War Against The Civilian Population
Mark M. Rich

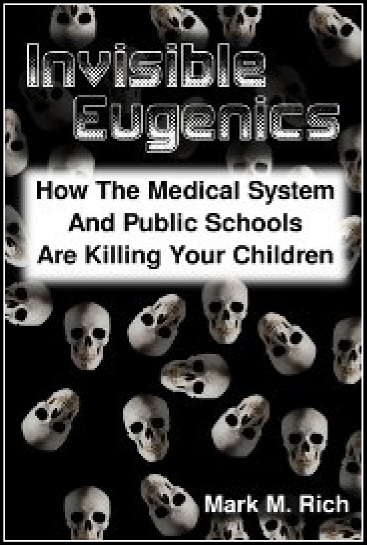
Invisible Eugenics
How The Medical System And Public Schools Are Killing Your Children
Mark M. Rich

New World War: Revolutionary Methods for Political Control

Dedication & Thanks

Peer Review & Thanks
Dedication

Volume I: Current Political Situation

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Introduction
Revolution in Warfare
The Other World
Dictatorship Creation
The Groups Facilitating the Revolution
Their Goal is Neo-Feudalism
Problem-Reaction-Solution
Volume I Commentary

Both words and images can be detected using mind-reading devices with varying degrees of accuracy. This can occur for words and images being viewed by a person on an external display, such as a book, or words and images just being thought of with no external stimuli.

“It is possible to read someone’s mind by remotely measuring their brain activity,” announced *New Scientist* in their *Mind-Reading Machine Knows What You See* article of April of 2005. The Computational Neuroscience Laboratories at the Advanced Telecommunications Research Institute International (ATR) in Kyoto Japan, and Princeton University in New Jersey, proved that by monitoring the visual cortex with fMRI they could determine which basic objects (sets of lines) a person was looking at.

When the objects were combined, they could even determine which one was being focused on. According to the scientists, it may be possible not only to view but also to record and replay these images. They announced that the technology could be used to figure out dreams and other secrets in people’s minds.

Vanderbilt University in Nashville has conducted simple mind-reading tests using an fMRI/Computer, which learned what basic images a group of test subjects was looking at. They were able to predict with 50% accuracy which objects the test subjects were thinking of when they were asked only to remember what they had seen, without being shown the images.

On March 6, 2008 *ABC News* reported that neuroscientists at the University of California at Berkeley accomplished mind-reading by monitoring the visual cortex with an fMRI connected to a self-learning (artificial intelligence) computer program.

First, they used 1750 pictures to build a computational database for the computer to learn with by flashing the pictures in front of test subjects connected to an fMRI. This allowed the algorithm to decipher the brain patterns and associate them with the images.

In addition to deciphering these brain patterns, the computer recorded the process that it used to accomplish this, and built a model based upon it. Then, without scanning the test subjects, they added 120 new pictures to the program and allowed it to create its interpretation of what the new brain signals would be, based on the previous model.

Then they had the test subjects look at these pictures which they had never seen while being scanned. The computer predicted what they were looking at 72% of the time. The scientists announced that the model could be used as a basis to predict the brain activity associated with any image.

What this means is that it’s not necessary to scan a brain to obtain the meaning of each signal. Once the model had been developed, they could simply add new pictures to the database/dictionary. The scientists suggested that out of 1 billion pictures, the computer would be accurate about 20% of the time.

Images which are not consciously seen by a person can even be detected by mind-reading machines. Researchers at University College London flashed

Volume II: The New War

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The New Enemy
Initiatives to Remove Civil Liberties
The Investigation
Surveillance Technology and Methods
Mind-Reading
Volume II Commentary

Volume III: Weapons of The New War

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Psychological Operations
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High-Powered Microwaves
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pictures in quick succession to test subjects connected to an fMRI. Although some of these pictures were invisible to the subjects, they were accurately recorded 80% of the time by the computer.

Like a fingerprint, each person has their own *brainprint*. Therefore, calibration for each brain is necessary. This is accomplished by having the person think a series of specific thoughts. In the case of EEG, this calibration can take less than a minute. However, because the signals which represent thoughts are similar from one person to the next, a universal mind-reading database has been suggested.

Using fMRI, scientists at Carnegie Mellon University (CMU) discovered that the brain patterns associated with specific thoughts are quite similar among multiple people. This, they stated, would provide the opportunity to create a universal mind-reading dictionary.

Scientists at the University of California at Berkeley mentioned that a “general visual decoder” would have great scientific use. Likewise, the brain patterns associated with specific words that occur when people are reading are also basically the same. This similarity of brain functions associated with words seems to have been an evolutionary development which allowed for an advantage in communication.

A mind-reading machine capable of determining the brain pattern associated with a specific word was developed by scientists at CMU. Brain scans using fMRI were taken of test subjects who were given a variety of words to think of in order to train the computer. An important consideration here is that they were not viewing these words on an external display, only thinking about them. After the computer identified the brain patterns associated with those words, the subjects were given two new words to think about, which the computer accurately determined.

Although, in this particular study only a couple of words were tested, it proves that after a model of how to decipher brain signals was created, AI could accurately determine new words that subjects were thinking about. “These building blocks could be used to predict patterns for any concrete noun,” proclaimed Tom Mitchell of the Machine Learning Department.

In February of 2004 *Popular Science* announced that a mind-reading computer could, in theory, translate a person’s working verbal memory onto a computer screen. “You could imagine thinking about talking and having it projected into a room 2,000 miles away,” says Professor Craig Henriquez at Duke University’s Center for Neuroengineering, who has studied mind-reading for DARPA. He added, “It’s very, very possible.”

FMRI can be used to determine if someone is reading or writing. Neuroscientists can determine when a person is reading by monitoring their brainwaves. They can almost determine exactly what they’re reading. And because these patterns are similar from one person to the next, a universal device for determining what people are reading is possible.

In March of 2008 both Technology Review and *ABC News* revealed that an fMRI could in theory be used to display a person’s dreams. Then in December of 2008, scientists at ATR in Kyoto Japan announced that they developed a

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Sources

Other Sites

www.TheHiddenEvil.com
www.RichEssence.com

technology that would eventually allow them to record and replay a person's dreams.

Emotions from love to hate can be recognized by neuralimaging. The level of stress a person is experiencing can also be measured. Brain states such as honesty, deception, and even self deception, can be measured.

Patterns associated with decisions can also be read. Scientists from CMU, Stanford University, and the MIT Sloan School of Management were able to accurately predict the purchasing decisions of test subjects in a virtual shopping center. They monitored the subject's level of interest in a product as well as their decision to purchase it.

Neuroimaging can also detect decisions about how someone will later do a high-level mental activity. Neuroimaging can be used to determine if someone is speaking or reading. It can be used to detect areas of the brain that are active when someone is hearing a sound, or touching an object.

Brain patterns associated with specific physical movements, such as a finger, can be deciphered with neural imaging. The mere intention to make a physical movement can be detected before the actual movement is made.

Cameras

A type of mind-reading is possible with cameras connected to computers. One such device, called the Emotional Social Intelligence Prosthetic (ESP), was developed at the MIT Media Laboratory in 2006. It consists of a tiny camera that can be worn on a hat, an earphone and a small computer that is worn on a belt. It infers a person's emotional state by analyzing combinations of subtle facial movements and gestures.

When an emotional state is detected, the wearer is signaled through the earphone to adjust their behavior in order to gain the attention of the target. The computer can detect 6 emotional states. It can also be adjusted for cultural differences and configured specifically for the wearer.

Around this time, the Computer Laboratory at the University of Cambridge, UK, developed a similar camera-based mind-reading machine. It uses a computer to monitor, in real-time, combinations of head movement, shape, color, smiles, and eyebrow activity to infer a person's emotional state.

It detects basic emotional states such as happiness, sadness, anger, fear, surprise, and disgust, as well as more complex states. It's accurate between 65 and 90 percent of the time. "The mind-reading computer system presents information about your mental state as easily as a keyboard and mouse present text and commands," they announced.

Used for Surveillance

Mind reading exists. The DOD and various institutions have vigorously researched this subject since at least the mid 1970s. "Mapping human brain functions is now routine," declared *US News and World Report*, in an article entitled *Reading Your Mind—And Injecting Smart Thoughts*, of January of 2000.

Both words and images, being viewed or thought, can be mind-read. Various emotional states as well as mental processes such decisionmaking, reading, writing, movement and the intention to make a movement, can be detected with mind-reading devices. Perceptions such as touch, sound, and light can also be detected.

The proposed uses for mind-reading technology are positive. Some include determining if people in comas can communicate, helping stroke patients and those who suffered brain injuries, aiding those with learning disorders, assisting with online shopping, and improving people's communications skills.

However, other uses that have been suggested include the monitoring of unconscious mental processes, and interrogation of criminal suspects and potential terrorists. Dr. John Alexander mentioned that the recent developments in mind-reading technology would take surveillance to new levels by allowing investigators to "peer into the inner sanctum of the mind," in order to determine if a suspect has caused, or will likely cause a crime.

Dr. Norseen has sent R&D plans to the pentagon to have tiny mind-reading devices installed at airports to profile potential terrorists. He suggested that these devices could be functional by 2005. In August of 2008, *CNN* stated that the US military's knowledge obtained from mind-reading research could be used to interrogate the enemy.

Law Enforcement Technology announced in September of 2005 the existence of a new forensic technology known as *Brain Fingerprinting*, which has already been used in hundreds of investigations as a lie detector by the CIA, FBI and law enforcement agencies in the United States.

Brain Fingerprinting is admissible in court, because unlike a polygraph, which relies on emotional responses, it uses EEG to see how the brain reacts to words and pictures related to a crime scene. Dr. Larry Farwell, its inventor, says it is completely accurate. According to the report it will be used to help speed-up investigations.

Sources Next

Endnotes

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[1] Another possible method to obtain information is Remote Viewing. RV is the ability to produce correct information about people, events, objects, or concepts that are somewhere else in space and time, and are completely blind to the viewer collecting the information. It can be used to describe people or events, produce leads, reconstruct events, make decisions, and make predictions about the future. See *Remote Viewing Secrets* by Joseph McMoneagle. RV tests were conducted by the US government over a 20-year period during Project Stargate, a classified initiative by the CIA which began in 1972 and lasted until about 1994. Most of the 154 tests and 26,000 trials took place at the Cognitive Sciences Laboratory at Forte Meade, Maryland. A majority of the results of the project are still classified. See the *Journal of Parapsychology* articles, *Remote Viewing by Committee*, September 22, 2003, by Lance Storm and *Experiment One of the SAIC Remote Viewing Program*, of December 1, 1998, by Richard Wiseman and Julie Milton. The success of the project varies depending on the source. Allegedly the original tests were conducted under rigid scientific conditions, which had impressive results. However, the same sources describe RV

in general as ineffective. See *Discover Magazine's* article, *CIA ESP*, on April 1, 1996, by Jeffrey Kluger, and the *Washington Post's* report, *Many Find Remote Viewing a Far Fetch from Science*, on December 2, 1995, by Curt Suplee. According to author McMoneagle, an original viewer during Project Stargate, it is accurate about 50 or 60 percent of the time. Nevertheless, RV will be used to obtain intelligence, according to John B. Alexander. See *The New Mental Battlefield*, which appeared in the December 1980 issue of *Military Review*. Also see the June 1998 *Research Report Number 2* of the University of Bradford's Non-Lethal Weapons Research Project (BNLWRP), for how RV has been added to the NLW arsenal. According to multiple sources, US government agencies are now using the consulting services of RV professionals. This was reported on January 9, 2002 in the *University Wire's (Colorado Daily)* article, *Clairvoyant Discusses Reveals Details of Remote Viewing*, by Wendy Kale, and in the *Bulletin of the Atomic Scientists* on September 1, 1994, in its report, *The Soft Kill Fallacy* by Steven Aftergood. In his book *Winning The War: Advanced Weapons, Strategies, and Concepts for the Post-911 World*, Alexander had this to say regarding RV: "Since the beginning of history, humans have made anecdotal references to innate abilities to foretell the future, to know what was occurring at distant locations or the status of people separated from them, and to find resources they need without any traditional means of accessing that information." He continued: "Studies have demonstrated beyond any doubt that these nontraditional capabilities exist. ... [RV can] radically change our means of gathering intelligence. It holds the promise of providing information about inaccessible redoubts and advances in technology. More importantly, once these skills are understood, those possessing them will be able to determine an adversary's intent and be predictive about the events."

2 Because neuroimaging technology decodes brain patterns to thoughts, some argue that it technically doesn't read a person's mind. However, because specific thoughts and brain states can be deciphered, here it is referred to as mind-reading. Additionally, most mainstream documents refer to this as mind-reading, despite the fact that it is actually brainwave-reading.

3 Magnetoencephalography (MEG) and positron emission tomography (PET) can also be used to infer a person's neurophysiological state. But because they are impractical for field use due to their large size and harmful radiation, MEG and PET won't be considered here. However, DARPA is in the process of developing a small helmet-sized MEG device which would be connected to a portable computer. See the article *Mind over Machine* in the February 1, 2004 issue of *Popular Science*, by Carl Zimmer.

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Navy Lasers, Railgun, and Hypervelocity Projectile: Background and Issues for Congress

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CRS REPORT
Prepared for Members and
Committees of Congress

Summary

The Navy is currently developing three potential new weapons that could improve the ability of its surface ships to defend themselves against enemy missiles—solid state lasers (SSLs), the electromagnetic railgun (EMRG), and the hypervelocity projectile (HVP).

Any one of these new weapon technologies, if successfully developed and deployed, might be regarded as a “game changer” for defending Navy surface ships against enemy missiles. If two or three of them are successfully developed and deployed, the result might be considered not just a game changer, but a revolution. Rarely has the Navy had so many potential new types of surface-ship missile-defense weapons simultaneously available for development and potential deployment.

Although the Navy in recent years has made considerable progress in developing SSLs, EMRG, and HVP, a number of significant development challenges remain. Overcoming these challenges will likely require years of additional development work, and ultimate success in overcoming them is not guaranteed.

The issue for Congress is whether to approve, reject, or modify the Navy’s funding requests and proposed acquisition strategies for these three potential new weapons. Potential oversight questions for Congress include the following:

- Using currently available approaches for countering anti-ship cruise missiles (ASCMs) and anti-ship ballistic missiles (ASBMs), how well could Navy surface ships defend themselves in a combat scenario against an adversary such as China that has large numbers of ASCMs (including advanced models) and ASBMs? How would this change if Navy surface ships in coming years were equipped with SSLs, EMRG, HVP, or some combination of these systems?
- How significant are the remaining development challenges for SSLs, EMRG, and HVP?
- Are current schedules for developing SSLs, EMRG, and HVP appropriate in relation to remaining development challenges and projected improvements in enemy ASCMs and ASBMs? To what degree are current schedules for developing SSLs, EMRG, or HVP sensitive to annual funding levels?
- When does the Navy anticipate issuing roadmaps detailing its plans for procuring and installing production versions of SSLs, EMRGs, and HVP on specific Navy ships by specific dates?
- Will the kinds of surface ships that the Navy plans to procure in coming years have sufficient space, weight, electrical power, and cooling capability to take full advantage of SSLs (particularly those with beam powers above 200 kW) and EMRG? What changes, if any, would need to be made in Navy plans for procuring large surface combatants (i.e., destroyers and cruisers) or other Navy ships to take full advantage of SSLs and EMRG?
- Are the funding sources for SSLs, EMRG, and HVP in Navy and Defense-Wide research and development accounts sufficiently visible for supporting congressional oversight?

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Introduction

Issue for Congress

This report provides background information and issues for Congress on three potential new weapons that could improve the ability of Navy surface ships to defend themselves against enemy missiles—solid state lasers (SSLs), the electromagnetic railgun (EMRG), and the hypervelocity projectile (HVP).[1]

Any one of these new weapon technologies, if successfully developed and deployed, might be regarded as a "game changer" for defending Navy surface ships against enemy missiles. If two or three of them are successfully developed and deployed, the result might be considered not just a game changer, but a revolution. Rarely has the Navy had so many potential new types of surface-ship missile-defense weapons simultaneously available for development and potential deployment. Although the Navy in recent years has made considerable progress in developing SSLs, EMRG, and HVP, a number of significant development challenges remain.

The issue for Congress is whether to approve, reject, or modify the Navy's funding requests and proposed acquisition strategies for these three potential new weapons. Congress' decisions on this issue could affect future Navy capabilities and funding requirements and the defense industrial base.

Scope of Report

SSLs are being developed by multiple parts of the Department of Defense (DOD), not just the Navy. SSLs, EMRG, and HVP, moreover, have potential application to military aircraft and ground forces equipment, not just surface ships. And SSLs, EMRG, and HVP can be used for missions other than defending against ASCMs and ASBMs.[2] This report focuses on Navy efforts to develop SSLs, EMRG, and HVP for potential use in defending Navy surface ships against ASCMs and ASBMs. It supersedes an earlier CRS report that provided an introduction to potential Navy shipboard lasers.[3]

Note that while fictional depictions of laser weapons in popular media often show them being used to attack targets at long ranges, the SSLs currently being developed by the Navy for potential shipboard use would be used to counter targets at short ranges of about a mile to perhaps a few miles.

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[1] Railgun is also spelled as rail gun; EMRG is also abbreviated as EM railgun; hypervelocity is also spelled as hyper-velocity or hyper velocity.

[2] As discussed later in the report, the Navy is exploring the potential for using shipboard lasers to counter small boats and unmanned aerial vehicles (UAVs), and EMRG can be used to attack land targets.

[3] CRS Report R41526, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, by Ronald O'Rourke. This earlier CRS report has been archived and remains available as a supplementary reference source on potential Navy shipboard lasers.

Background

Strategic and Budgetary Context

Concern about Survivability of Navy Surface Ships

Although Navy surface ships have a number of means for defending themselves against anti-ship cruise missiles (ASCMs) and anti-ship ballistic missiles (ASBMs),[4] some observers are concerned about the survivability of Navy surface ships in potential combat situations against adversaries, such as China, that are armed with advanced ASCMs and with ASBMs.[5] Concern about this issue has led some observers to conclude that the Navy's surface fleet in coming years might need to avoid operating in waters that are within range of these weapons, or that the Navy might need to move toward a different fleet architecture that relies less on larger surface ships and more on smaller surface ships and submarines.[6] Such changes in Navy operating areas and fleet architecture could substantially affect U.S. military strategy and the composition of the Navy's shipbuilding expenditures.

Navy surface fleet leaders in early 2015 announced a new organizing concept for the Navy's surface fleet called distributed lethality. Under distributed lethality, offensive weapons such as ASCMs are to be distributed more widely across all types of Navy surface ships, and new operational concepts for Navy surface ship formations are to be implemented. The aim of distributed lethality is to boost the surface fleet's capability for attacking enemy ships and make it less possible for an enemy to cripple the U.S. fleet by concentrating its attacks on a few very-high-value Navy surface ships (particularly the Navy's aircraft carriers).[7] Perspectives on whether it would be cost effective to spend money spreading offensive weapons across a wider array of Navy surface ships might be influenced by views on whether those surface ships can adequately defend themselves against enemy missiles.

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[4] These include the following: operating ships in ways that make it hard for others to detect and accurately track Navy ships; jamming or destroying enemy targeting sensors; interfering with the transmission of targeting data from sensors to weapon launchers; attacking weapon launchers (which can land-based launchers or launchers on surface ships, submarines, or aircraft); and countering ASCMs and ASBMs headed toward Navy ships. Navy measures for countering ASCMs and ASBMs headed toward Navy ships include the following: jamming a missile's guidance system; using decoys of various kinds to lure enemy missiles away from Navy ships; and shooting down enemy missiles with surface-to-air missiles and the Phalanx Close-In Weapon System (CIWS), which is essentially a radar-controlled Gatling gun. Employing all these measures reflects a long-standing Navy approach of creating a multi-layered defense against enemy missiles, and of attacking the enemy's "kill chain" at multiple points so as to increase the chances of breaking the chain. (The kill chain is the sequence of steps that an enemy must complete to conduct a successful missile attack on a Navy ship. This sequence includes, at a basic level of description, detecting and tracking the Navy ship, passing that information from sensors to the weapon launcher, launching the weapon, and guiding the weapon all the way to the Navy ship. Interfering with any one of these actions can break the kill chain and thereby prevent or defeat the attack.)

[5] See, for example, Andrew F. Krepinevich, Maritime Warfare in a Mature Precision-Strike Regime, Washington, Center for Strategic and Budgetary Assessments, 2014, 128 pp. For more on China's ASCMs and ASBMs, see CRS Report RL33153, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress*, by Ronald O'Rourke.

ASCMs and ASBMs are not the only reasons that some observers are concerned about the future survivability of U.S. Navy surface ships in combat situations; observers are also concerned about threats to U.S. Navy surface ships posed by small boats, mines, and torpedoes.

[6] See, for example, Phillip E. Pournelle, "The Deadly Future of Sea Control," *U.S. Naval Institute Proceedings*, July 2015: 26-31.

[7] See, for example, Thomas Rowden, Peter Gumataotao, and Peter Fanta, "Distributed Lethality," *U.S. Naval Institute Proceedings*, January 2015: 18-23; Sam LaGrone, "SNA: Navy Surface Leaders Pitch More Lethal Ships, Surface Action Groups," *USNI News*, January 14, 2015; Kris Osborn, "Navy Unveils New Surface Warfare Strategy," *Military.com*, January 14, 2015; Sydney J. Freedberg Jr., "'If It Floats, It Fights,': Navy Seeks 'Distributed Lethality,'" *Breaking Defense*, January 14, 2015; Mike McCarthy and Megan Eckstein, "Navy Eyeing A 'Hunter Killer' Surface (continued...)

Depth of Magazine and Cost Exchange Ratio

Two key limitations that Navy surface ships currently have in defending themselves against ASCMs and ASBMs are limited depth of magazine and unfavorable cost exchange ratios. Limited depth of magazine refers to the fact that Navy surface ships can use surface-to-air missiles (SAMs) and their Close-in Weapon System (CIWS) Gatling guns to shoot down only a certain number of enemy unmanned aerial vehicles (UAVs) and anti-ship missiles before running out of SAMs and CIWS ammunition[8]—a situation (sometimes called "going Winchester"), that can require a ship to withdraw from battle, spend time travelling to a safe reloading location (which can be hundreds of miles away),[9] and then spend more time traveling back to the battle area.

Unfavorable cost exchange ratios refer to the fact that a SAM used to shoot down a UAV or anti-ship missile can cost the Navy more (perhaps much more) to procure than it cost the adversary to build or acquire the UAV or anti-ship missile. In the FY2016 defense budget, procurement costs for Navy SAMs range from about $900,000 per missile to several million dollars per missile, depending on the type.[10]

In combat scenarios against an adversary with a limited number of UAVs and anti-ship missiles, an unfavorable cost exchange ratio can be acceptable because it saves the lives of Navy sailors and prevents very expensive damage to Navy ships. But in combat scenarios (or an ongoing military capabilities competition) against a country such as China that has many UAVs and anti-ship missiles and a capacity for building or acquiring many more, an unfavorable cost exchange ratio can become a very expensive—and potentially unaffordable—approach to defending Navy surface ships against UAVs and anti-ship missiles, particularly in a context of constraints on U.S. defense spending and competing demands for finite U.S. defense funds.

(...continued)

Fleet, Would Require Upgunning Existing Ship Fleets," *Defense Daily*, January 15, 2015: 1-3; Richard Scott, "Offensive Language: USN Sets Out Surface Firepower Strategy," *Jane's International Defence Review*, May 2015: 42-47; Megan Eckstein, "Navy Studying Implications of Distributed Lethality in Wargames Series," *USNI News*, July 9, 2015; Lara Seligman, "Navy Establishes Task Force To Study Impact of Distributed lethality," *Inside the Navy*, July 10, 2015.

[8] Navy cruisers have 122 missile cells; Navy destroyers have 90 or 96 missile cells. Some of these cells are used for storing and launching Tomahawk land attack cruise missiles or anti-submarine rockets. The remainder are available for storing and launching SAMs. A Navy cruiser or destroyer might thus be armed with a few dozen or several dozen SAMs for countering ASCMs and ASBMs. Countering ASCMs or ASBMs with SAMs might sometimes require shooting two SAMs at each ASCM or ASBM.

[9] The missile cells on a Navy cruiser or destroyers are clustered together in an installation called a Vertical Launch System (VLS). VLS cells cannot be reloaded while the ship is underway; a ship needs to return to a port or a calm anchorage to reload its VLS.

[10] Unit procurement costs for ship-launched SAMs in the FY2016 are as follows: about $900,000 for the Rolling Airframe Missile (RAM), about $1.1 million to about $1.5 million for the Evolved Sea Sparrow Missile (ESSM), about $3.9 million for the SM-6 Block 1 missile, about $14 million for the SM-3 Block 1B missile, and more than $20 million for theSM-3 Block IIA missiles. RAM and ESSM are short-range missiles for defense against aircraft and ASCMs. The SM-6 Block 1 is a medium-range missile used for both defense against aircraft and ASCMs, and terminal (i.e., endo-atmospheric) defense against theater-range ballistic missiles. The SM-3 Block 1B and SM-3 Block IIA are used for mid-course (i.e., exo-atmospheric) defense against theater-range ballistic missiles.

SSLs, EMRG, and HVP offer a potential for dramatically improving depth of magazine and the cost exchange ratio:

- **Depth of magazine.** SSLs are electrically powered, drawing their power from the ship's overall electrical supply, and can be fired over and over, indefinitely, as long as the SSL continues to work and the ship has fuel to generate electricity. The EMRG's projectile and the HVP (which are one and the same—see next section) can be stored by the hundreds in a Navy surface ship's weapon magazine.[11]
- **Cost exchange ratio.** An SSL can be fired for a marginal cost of less than one dollar per shot (which is the cost of the fuel needed to generate the electricity used in the shot), while the EMRG's projectile/HVP has an estimated unit procurement cost of about $25,000.[12]

For additional discussion of the strategic and budgetary context in which the programs discussed in this report and other Navy programs may be considered, see CRS Report RL32665, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*, by Ronald O'Rourke.

SSLs, EMRG, and HVP in Brief

SSLs

Overview

The Navy in recent years has leveraged both significant advancements in industrial SSLs and decades of research and development work on military lasers done by other parts of DOD to make substantial progress toward deploying high-energy SSLs[13] on Navy surface ships. Navy surface ships would use high-energy SSLs initially for countering small boats UAVs, and potentially in the future for countering ASCMs and ASBMs as well.[14] High-energy SSLs on Navy ships would be short-range defensive weapons—they would counter targets at ranges of about one mile to perhaps eventually a few miles.[15]

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[11] In July 2015, the Navy issued a request for information (RFI) to industry for the fabrication of a prototype EMRG mount that would store a minimum of 650 rounds. (RFI for Fabrication of Prototype Mount for Naval Railgun, Solicitation Number: N00024-15-R-4132, FedBizOpps.gov, July 29, 2015. See also Justin Doubleday, "Navy Developing Integrated Mount For Electromagnetic Railgun," *Inside the Navy*, July 31, 2015.)

[12] Sources for cost of HVP: David Martin, "Navy's Newest Weapon Kills at Seven Times the Speed of Sound," CBS News (cbssnews.com), April 7, 2014; Kris Osborn, "Navy Will Test its Electromagnetic Rail Gun aboard DDG 1000," *DefenseTech*, April 15, 2015.

[13] In discussions of potential Navy shipboard lasers, a high-energy laser is generally considered to be a laser with a beam power of at least 10 kilowatts (kW).

[14] In general, lasers would counter small boats and missiles by heating and burning holes in their skins, and causing thermal damage to their interiors. Lasers can also be used to "dazzle" (i.e., interfere with) electro-optical sensors on a boat or missile.

[15] The Navy has also performed research and development work on a different kind of laser, called the free electron laser (FEL). In recent years, Navy research and development work on potential shipboard lasers has shifted more to SSLs. For background information on the FEL, see CRS Report R41526, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, by Ronald O'Rourke.

In addition to a low marginal cost per shot and deep magazine, potential advantages of shipboard lasers include fast engagement times, an ability to counter radically maneuvering missiles, an ability to conduct precision engagements, and an ability to use lasers for graduated responses ranging from detecting and monitoring targets to causing disabling damage. Potential limitations of shipboard lasers relate to line of sight; atmospheric absorption, scattering, and turbulence (which prevent shipboard lasers from being all-weather weapons); an effect known as thermal blooming that can reduce laser effectiveness; countering saturation attacks; possible adversary use of hardened targets and countermeasures; and risk of collateral damage, including damage to aircraft and satellites and permanent damage to human eyesight, including blinding. These potential advantages and limitations are discussed in greater detail in the **Appendix**.

Selected Key Developments

Key developments in the Navy's high-energy SSL development effort include the following:

- Between 2009 and 2012, the Navy successfully tested a prototype SSL called the Laser Weapon System (LaWS) against UAVs in a series of engagements that took place initially on land and subsequently on a Navy ship at sea.
- Between 2010 and 2011, the Navy tested another prototype SSL called the Maritime Laser Demonstration (MLD) in a series of tests that culminated with an MLD installed on a Navy ship successfully engaging a small boat.
- In April 2013, the Navy announced that it planned to install LaWS on the USS *Ponce* (pronounced pon-SAY)—a converted amphibious ship that is operating in the Persian Gulf as an interim Afloat Forward Staging Base (AFSB[I]) [16]—to conduct evaluation of shipboard lasers in an operational setting against swarming boats and swarming UAVs.[17] The system was installed in August 2014 (see **Figure 1**, **Figure 2**, and **Figure 3**).
- In March 2014, it was reported that the Navy anticipated moving to a shipboard laser program of record in "the FY2018 time frame" and achieving an initial operational capability (IOC) with a shipboard laser in FY2020 or FY2021.[18]

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[16] An AFSB operates as a "mother ship" for Navy helicopter and small boat operations. The Ponce is serving as an interim AFSB pending the arrival of a new AFSB that is currently being built.

[17] "Navy Leaders Announce Plans for Deploying Cost-Saving Laser Technology," *Navy News Service*, April 8, 2013; Thom Shanker, "Navy Deploying Laser Weapon Prototype Near Iran," *New York Times*, April 9, 2013: 4; Mike McCarthy, "Navy Deploying Laser For Taking Out Drones," *Defense Daily*, April 9, 2013; Graham Warwick, "U.S. Navy Planning Gulf Deployment For Laser Weapon," *Aerospace Daily & Defense Report*, April 9, 2013: 6; Megan Eckstein, "Navy-Built Laser Weapon System Will Begin Demo On Ponce In Early 2014," *Inside the Navy*, April 15, 2013. See also Lara Seligman, "Navy-built LaWS To Begin Demo This Summer, IOC Slated For FY-20-21," *Inside the Navy*, March 24, 2014; Office of Naval Research, "All Systems Go: Navy's Laser Weapon Ready for Summer Deployment," *Navy News Service*, April 7, 2014.

Swarming refers to the use of boats and UAVs in large numbers, or swarms, in an attempt to confuse and overwhelm a target ship's defensive systems.

[18] Lara Seligman, "Navy-built LaWS To Begin Demo This Summer, IOC Slated For FY-20-21," *Inside the Navy*, March 24, 2014. A program of record, or POR, is a term sometimes used by DOD officials that means, in general, a program in the Future Years Defense Plan (FYDP) that is intended to provide a new, improved, or continuing materiel, weapon, or information system or service capability in response to an approved need. The term is sometimes used to refer to a program in a service's budget for procuring and deploying an operational weapon system, as opposed to a research and development effort that might or might not eventually lead to procurement and deployment of an operational weapon system.

- In December 2014, the Navy declared LaWS on the Ponce to be an "operational" system.[19]
- In January 2016, the Navy stated that it anticipated releasing a directed energy weapon roadmap in February 2016.[20]

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[19] A December, 11, 2014, press report stated

> The Navy's first-of-a-kind laser deployed on a vessel sailing in the Persian Gulf has been declared operational and can be used by the crew to defend itself against potential threats, the service's head of the Office of Naval Research said on Wednesday [December 10, 2014].
>
> Rear Adm. Matthew Klunder told reporters on a conference call that Central Command has been green lighted to use the laser in the event of a threat, approval that has been passed along to the ship's commanding officer. The 30-kilowat laser, known as the Laser Weapon System, or LaWS, was installed on the USS Ponce in August [2014].
>
> The ship later departed for the Persian Gulf and the LaWS successfully carried out operational testing recently by striking a fast attack boat and drone, Klunder said, adding that this marks the "historic" first ever operational deployment of a directed energy weapon.
>
> (Mike McCarthy, "Navy Authorized To Use Ship-Based Laser In Battle," *Defense Daily*, December 11, 2014: 3. See also Sam LaGrone, "U.S. Navy Allowed to Use Persian Gulf Laser for Defense," *USNI News*, December 10, 2014; Philip Ewing, "Navy Declares Laser Weapon 'Operational,'" *Politico Pro (Pro Defense Report)*, December 10, 2014.)

The Navy testified on February 24, 2016, that

> the Solid State Laser Quick Reaction Capability (SSL-QRC) was fielded as a science and technology demonstration aboard the USS PONCE. It was successfully demonstrated as an effective weapon system and was subsequently transitioned to the fleet in the Central Command area of responsibility and is now an operational system.
>
> (Statement of Rear Admiral Mathias W. Winter, United States Navy, Chief of Naval Research, Before the Emerging Threats and Capabilities Subcommittee of the House Armed Services Committee on The Fiscal Year 2017 Budget Request, February 24, 2016, p. 15.)

[20] Justin Doubleday, "Winter: Navy Directed-Energy Strategy To Be Released This Month," *Inside the Navy*, February 1, 2016.

Figure 1. Laser Weapon System (LaWS) on USS Ponce

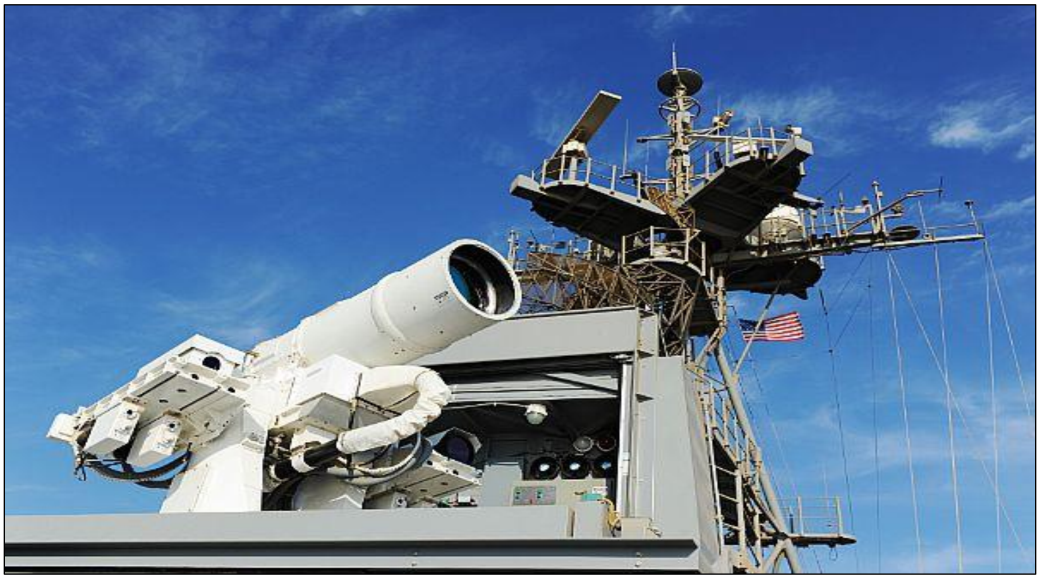

Source: Navy photograph dated November 16, 2014, accompanying David Smalley, "Historic Leap: Navy Shipboard Laser Operates in Arabian Gulf," *Navy News Service*, December 10, 2014, accessed August 12, 2015, at http://www.navy.mil/list_all.asp?id=84805.

Figure 2. Laser Weapon System (LaWS) on USS Ponce

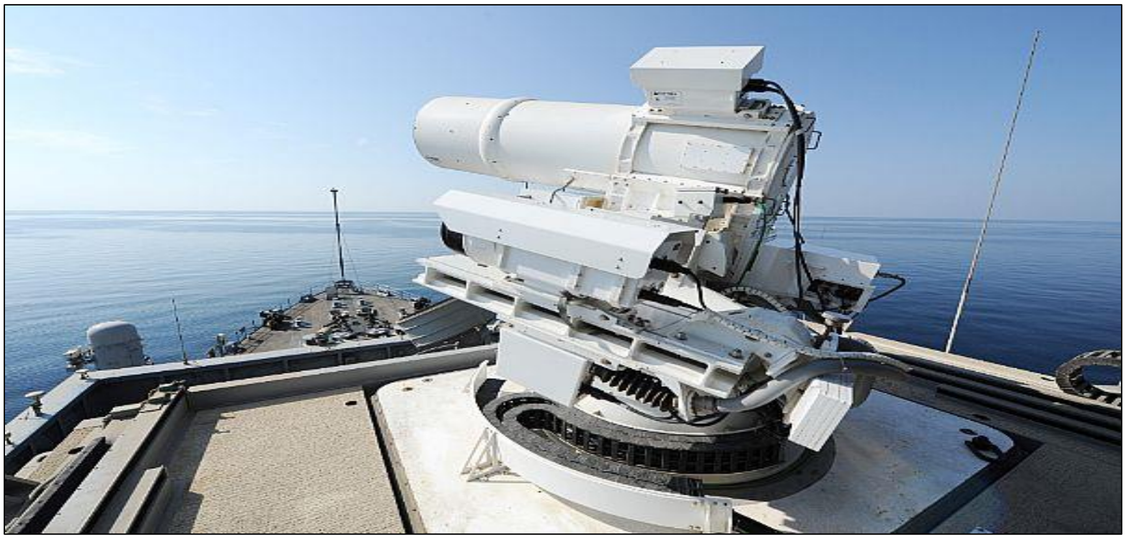

Source: Navy photograph dated November 17, 2014, accompanying David Smalley, "Historic Leap: Navy Shipboard Laser Operates in Arabian Gulf," *Navy News Service*, December 10, 2014, accessed August 12, 2015, at http://www.navy.mil/list_all.asp?id=84805.

Figure 3. Laser Weapon System (LaWS) on USS Ponce

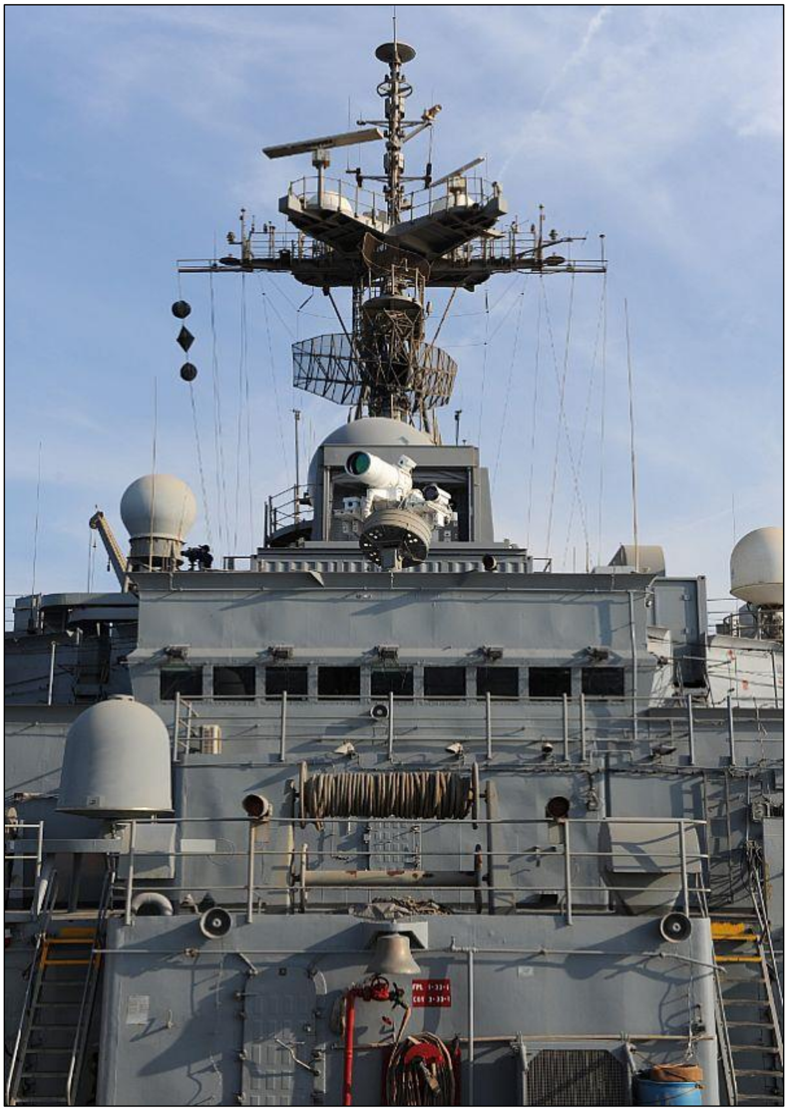

Source: Navy photograph dated November 16, 2014, accompanying David Smalley, "Historic Leap: Navy Shipboard Laser Operates in Arabian Gulf," *Navy News Service*, December 10, 2014, accessed August 12, 2015, at http://www.navy.mil/list_all.asp?id=84805.

SSL Technology Maturation (SSL-TM) Program

LaWS has a reported beam power of 30 kilowatts (kW),[21] which is strong enough to counter small boats and UAVs. As a follow-on effort to LaWS and MLD, the Navy initiated the SSL Technology Maturation (SSL-TM) program, in which industry teams led by BAE Systems, Northrop Grumman, and Raytheon, among others, competed to develop a shipboard laser with a beam power of 100 kW to 150 kW, which would provide increased effectiveness against small boats and UAVs.[22] Boosting beam power further—to something like 200 kW or 300 kW—could permit a laser to counter at least some ASCMs. Even stronger beam powers—on the order of at least several hundred kW, if not one megawatt (MW) or more—could improve a laser's effectiveness against ASCMs and enable it to counter ASBMs.[23]

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[21] See, for example, Mike McCarthy, "Navy Authorized To Use Ship-Based Laser In Battle," *Defense Daily*, December 11, 2014: 3.

On October 22, 2015, DOD announced that it had selected Northrop Grumman as the winner of the SSL-TM competition. DOD's contract-award announcement stated:

> Northrop Grumman Space and Mission Systems Corp., Redondo Beach, California, is being awarded a $53,151,809 cost-plus-fixed-fee contract for the Solid State High Power Laser Weapon System Demonstrator (LWSD) program.... The Office of Naval Research seeks to continue the advancement of SSL weapon system designs, architectures, and component technologies. The government believes that improvements in lethality may be achieved through maturation and optimization of a variety of system characteristics, including laser power, beam quality, beam director architecture, and other physical and optical aspects of the laser, beam director, and system design. Leveraging our experience and internal investments, the Northrop Grumman team is ready to fully support the three phases of the LWSD program. This contract contains options, which if exercised, will bring the contract value to $91,057,597. Work will be performed in Redondo Beach, California, and is expected to be completed Oct. 21, 2016. If options are exercised, work will continue through July 7, 2018.... This contract was competitively procured under the Office of Naval Research broad agency announcement 15-0005 entitled "Solid State, High Power Laser Weapon System Demonstrator (LWSD) Design, Development and Demonstration for Surface Navy, USN." Six proposals were received in response to this solicitation.[24]

A December 22, 2016, Northrop Grumman news release about the October 22, 2016, contract award stated:

> During Phase 1 of the LWSD contract, Northrop Grumman will develop a detailed design for the new system. Phase 2 will include assembly and ground test of the system, while Phase 3 will comprise at-sea testing of the system aboard the Navy's Self Defense Test Ship (SDTS). The Navy will lead this testing with Northrop Grumman providing technical support. The SDTS is the former USS Paul F. Foster (DD-964).
>
> According to Renard, Northrop Grumman's LWSD is well suited to support the Navy's planned initial testing on the SDTS. The company has designed its system to be installed, however, with minimal modification or additional costs, for demonstration on the Navy's DDG-51 FLT II class destroyers.[25]

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[22] For more on the SSL-TM program, see Office of Naval Research, "Solid-State Laser Technology Maturation Program," accessed August 11, 2015, at http://www.onr.navy.mil/Media-Center/Fact-Sheets/Solid-State-Laser-Technology-Maturation-Program.aspx; Office of Naval Research, "Solid State Laser Technology Maturation Program," September 2012, accessed August 11, 2015, at http://www.onr.navy.mil/~/media/Files/Fact-Sheets/35/Solid-State-Laser-Technology-Maturation-Program-2012-a.ashx; Office of Naval Research, "Research and Development/Technology Maturation of Solid State High Power Laser Weapon Systems, Subsystems, and/or Components for Surface Navy, USN, Broad Agency Announcement (BAA)," ONR BAA # 12-019, 2012, accessed August 11, 2015, at http://www.onr.navy.mil/~/media/files/funding-announcements/baa/2012/12-019.ashx; Future Force, "Developing a High-Energy Laser for the Navy," January 23, 2015, accessed August 11, 2015, at http://futureforce.navylive.dodlive.mil/2015/01/high-energy-laser/.

[23] For additional discussion, see CRS Report R41526, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, by Ronald O'Rourke, particularly the section entitled "Required Laser Power Levels for Countering Targets" and Appendix A on "Laser Power Levels Required to Counter Targets."

[24] DOD contract award announcements for October 22, 2015, accessed December 18, 2015, at: http://www.defense.gov/News/Contracts/Contract-View/Article/625630.

[25] "US Navy Selects Northrop Grumman to Design and Produce Shipboard Laser Weapon System Demonstrator," (continued...)

Figure 4 shows an artist's rendering of LWSD installed on the Navy's Self Defense Test Ship (the USS Paul F. Foster [DD-964], an old Spruance [DD-963] class destroyer).

Figure 4. Laser Weapon System Demonstrator (LWSD) on Self Defense Test Ship

Artist's rendering

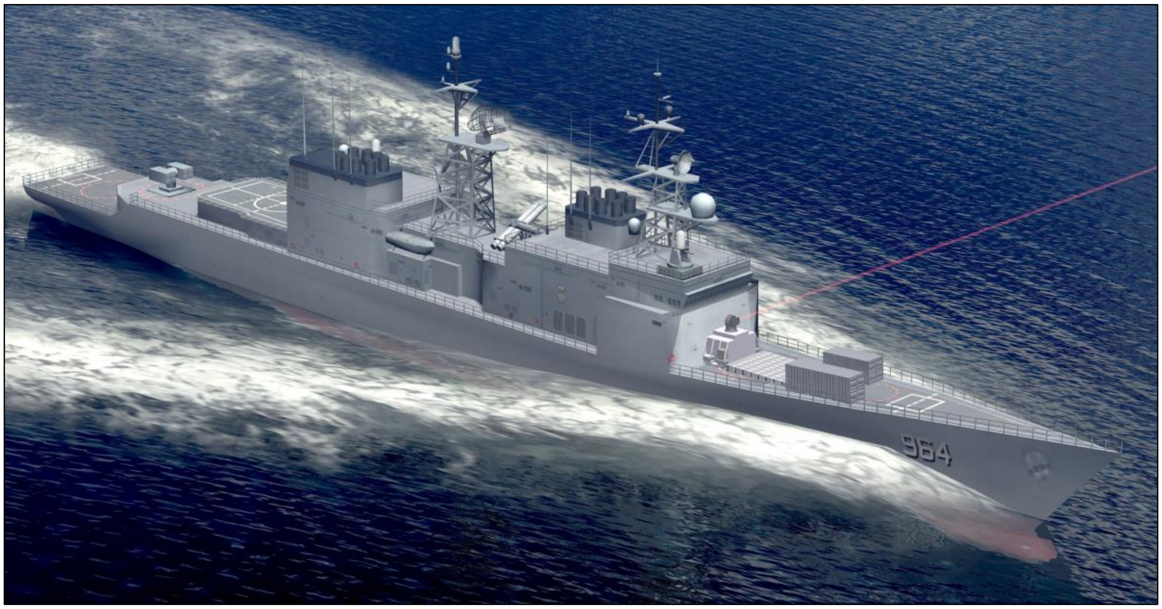

Source: Cropped version of image accessed on March 18, 2016, at http://media.globenewswire.com/cache/189/hires/39412.jpg.

Figure 5 is a detail from the above photo.

(...continued)

December 22, 2016, accessed March 18, 2016, at: http://www.globenewswire.com/newsarchive/noc/press/pages/news_releases.html?d=10158731 . See also Richard Scott, "Northrop Grumman To Build on MLD for SSL Demonstrator," *IHS Jane's International Defence Review*, February 2016: 5.

Figure 5. Laser Weapon System Demonstrator (LWSD) on Self Defense Test Ship

Artist's rendering

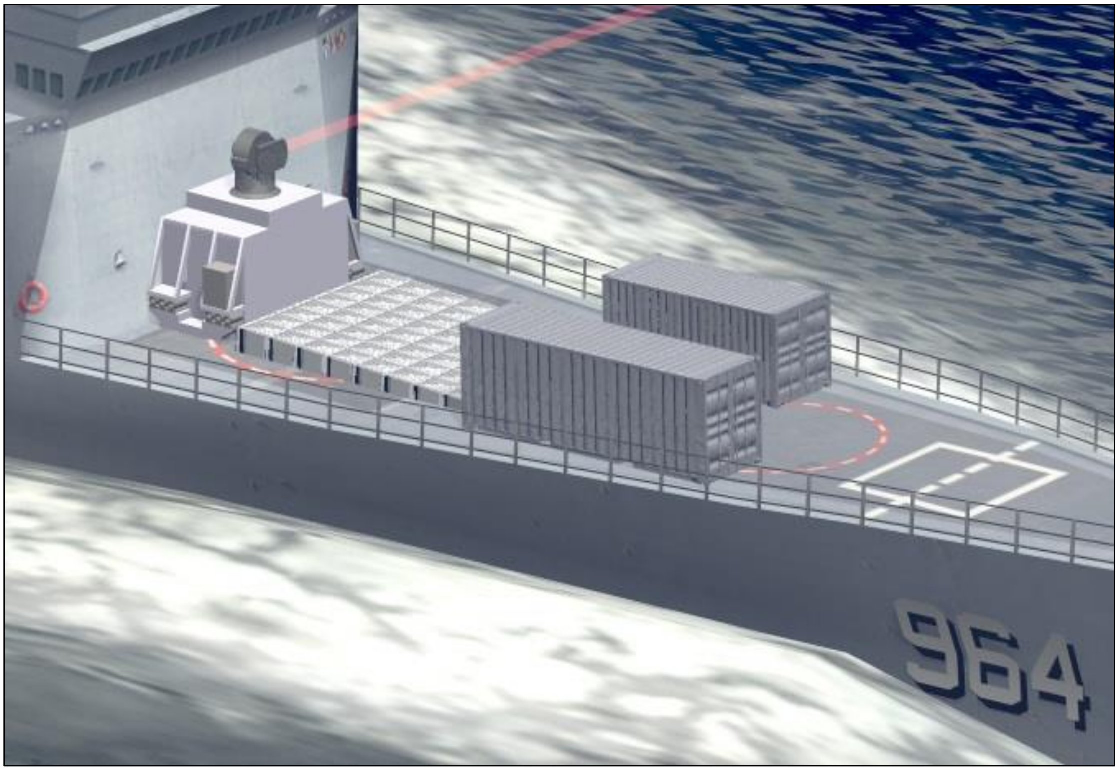

Source: Cropped version of image accessed on March 18, 2016, at http://media.globenewswire.com/cache/189/hires/39412.jpg.

Figure 6 Is an Office of Naval Research (ONR) graphic illustration of the LWSD's major components.

Figure 6. ONR Graphic of LWSD Components

Artist's rendering

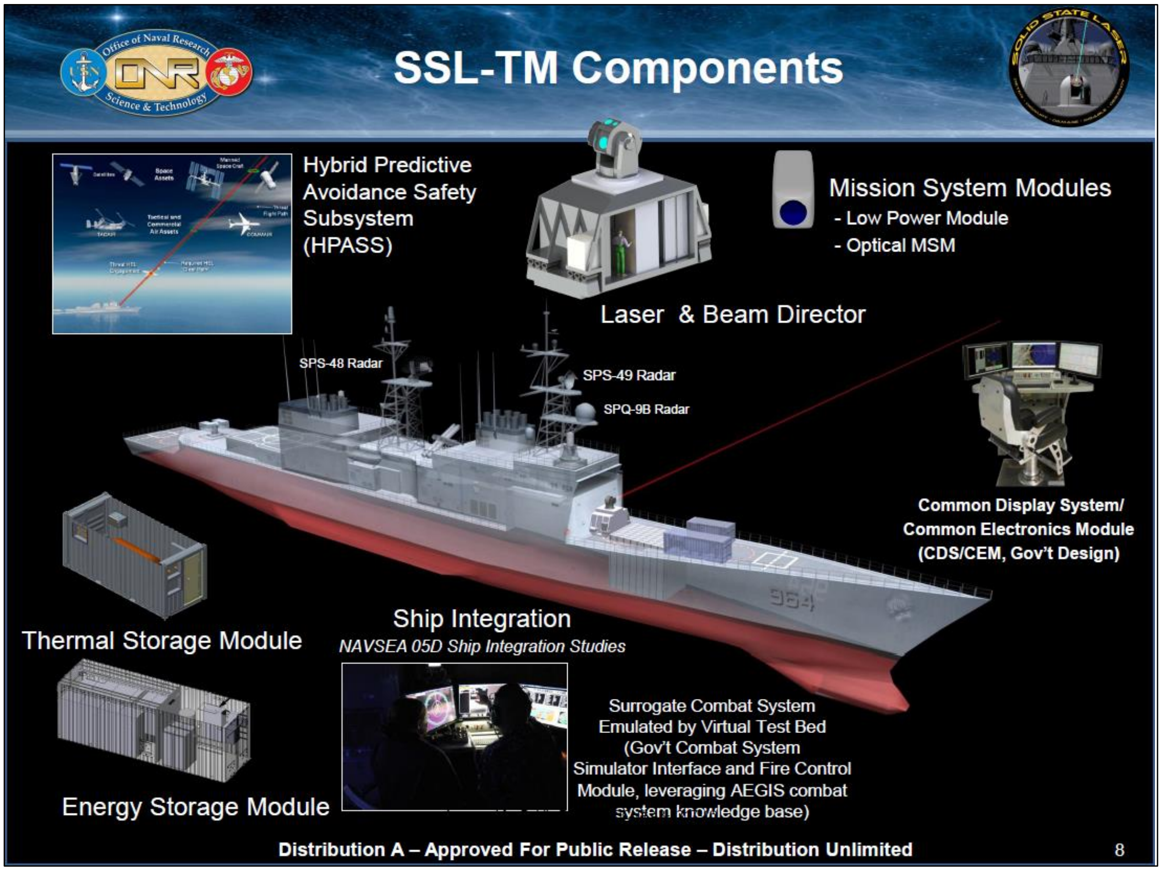

SSL-TM Components

Hybrid Predictive Avoidance Safety Subsystem (HPASS)

Laser & Beam Director

Mission System Modules
- Low Power Module
- Optical MSM

SPS-48 Radar

SPS-49 Radar

SPQ-9B Radar

Common Display System/ Common Electronics Module (CDS/CEM, Gov't Design)

Thermal Storage Module

Ship Integration

NAVSEA 05D Ship Integration Studies

Surrogate Combat System Emulated by Virtual Test Bed (Gov't Combat System Simulator Interface and Fire Control Module, leveraging AEGIS combat system knowledge base)

Energy Storage Module

Distribution A – Approved For Public Release – Distribution Unlimited

Source: Slide from February 2016 ONR briefing to CRS on SSL-TM program, received from Navy Office of Legislative Affairs February 26, 2016.

Directed Energy Roadmap

A July 28, 2015, press report stated:

> [Secretary of the Navy Ray] Mabus said he would release a DE [directed energy][26] roadmap this fall that "charts our course for research, development, and fielding of high power radio frequency weapons, lasers, and directed energy countermeasures. And I will follow it up with my guidance to the Program Objective Memorandum for [Fiscal Year 2018],[27] which, importantly, establishes a resource sponsor and a program of record."...
>
> Also meant to help quicken the pace of progress, the Office of Naval Research will take lessons learned from the [USS] Ponce to inform the Solid State Laser Technology Maturation program that aims to produce a 100-150 kilowatt laser prototype for at-sea testing in 2018, or sooner if possible. Rear Adm. Bryant Fuller, Naval Sea Systems Command (NAVSEA) chief engineer, said... that everything the Navy learned about rules

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[26] Lasers and another class of weapons called high-power microwave (HPM) weapons are referred to collectively as directed-energy weapons because they achieve their effects by directing electromagnetic energy at their targets.

[27] The Program Objective Memorandum (POM) is an internal DOD document that guides the preparation of a budget for a particular fiscal year.

> of engagement and how to use LaWS in an operational environment would apply to larger laser weapons as well. Leveraging the operational knowledge Ponce gained will help the Navy field whatever comes out of the SSL-TM effort much more rapidly.
>
> In the meantime, Mabus said the Laser Weapon System (LaWS) will continue its work in the Middle East after early success led officials to extend its deployment.[28]

EMRG

In addition to SSLs, the Navy since 2005 has been developing EMRG, a cannon that uses electricity rather than chemical propellants (i.e., gunpowder charges) to fire a projectile.[29] In EMRG, "magnetic fields created by high electrical currents accelerate a sliding metal conductor, or armature, between two rails to launch projectiles at [speeds of] 4,500 mph to 5,600 mph,"[30] or roughly Mach 5.9 to Mach 7.4 at sea level.[31] Like SSLs, EMRG draws its power from the ship's overall electrical supply.[32] The Navy originally began developing EMRG as a naval surface fire support (NSFS) weapon for supporting U.S. Marines operating ashore, but subsequently determined that the weapon also has potential for defending against ASCMs and ASBMs.[33] In response to Section 243 of the FY2012 National Defense Authorization Act (H.R. 1540/P.L. 112-81 of December 31, 2011), the Navy in September 2012 submitted to the congressional defense committees a report on the EMRG development effort.[34]

Following tests with early Navy-built EMRG prototypes, the Navy funded the development of two industry-built EMRG prototype demonstrators, one by BAE Systems and the other by General Atomics (see **Figure 7** and **Figure 8**).

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[28] Megan Eckstein, "Mabus: Adversaries Showing Interest in Directed Energy; Navy Needs to Move Faster," *USNI News*, July 28, 2015.

[29] Because it uses electricity rather than a powder charge to accelerate the projectile, Navy officials sometimes refer to EMRG as a launcher rather than a gun or cannon.

[30] Grace Jean, "With a Bang, Navy Begins Tests on EM Railgun Prototype Launcher," Navy News Service, February 28, 2012, accessed August 12, 2015, at http://www.navy.mil/submit/display.asp?story_id=65577.

[31] The speed of sound in air (i.e., Mach 1), varies with altitude; at sea level, it is approximately 761 miles an hour. (See for example, the table entitled "Speed of Sound at Different Altitudes," accessed August 12, 2015, at http://www.fighter-planes.com/jetmach1.htm.

[32] Unlike SSLs, however, EMRG is not a directed energy weapon, because it achieves its effects by firing a physical projectile at the target, not by directing electromagnetic energy at the target. See also footnote 26.

[33] For a recent article discussing the use of EMRG in countering ASCMs and ASBMs, see Sam LaGrone, "Navy Wants Rail Guns to Fight Ballistic and Supersonic Missiles Says RFI," *USNI News*, January 5, 2015.

[34] U.S. Navy, *Electromagnetic Railgun System: Final Report to the Congressional Defense Committees*, August 2012, with cover letters dated September 18, 2012. For a press report discussing the Navy's report to Congress, see Dan Taylor, "Stackley: Navy Identifies Four Technical Hurdles To Railgun Development," *Inside the Navy*, November 19, 2012.

Figure 7. Industry-Built EMRG Prototype Demonstrator

BAE prototype

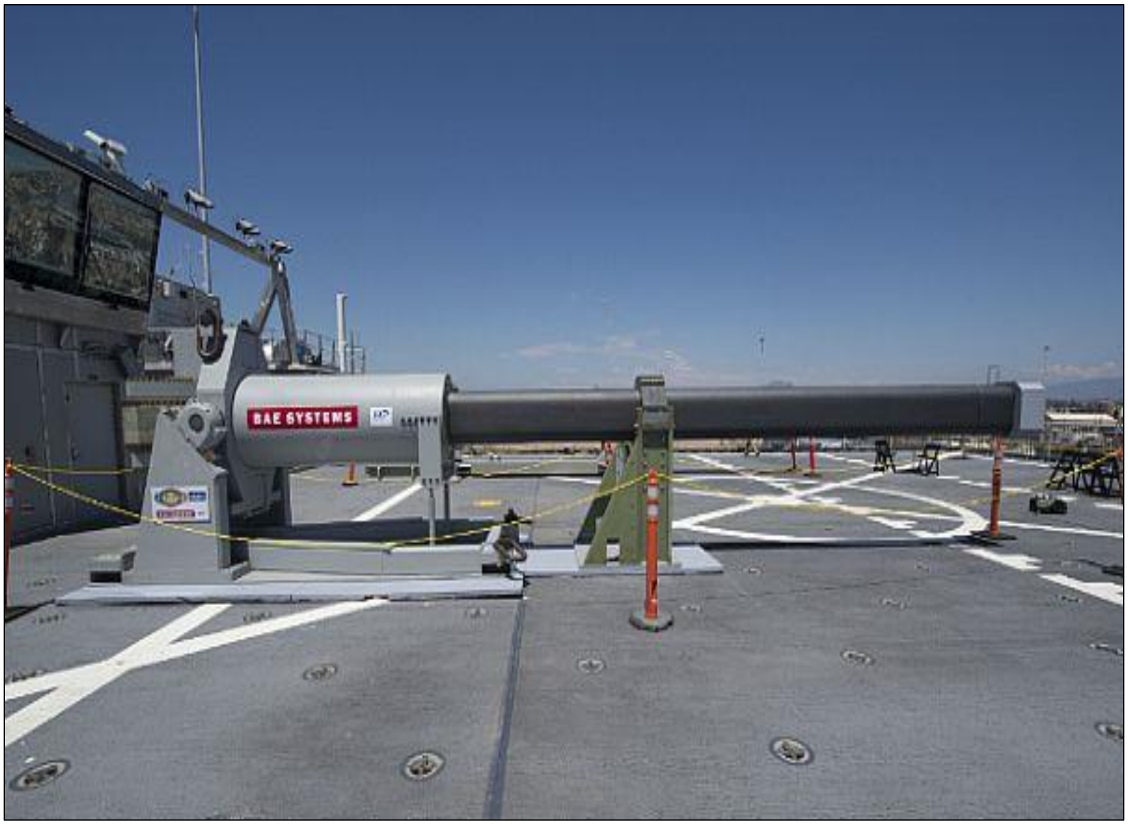

Source: Navy photograph dated July 8, 2014, associated with Office of Naval Research Public Affairs, "From Research to Railgun: Revolutionary Weapon at Future Force EXPO," *Navy News Service*, January 13, 2015, accessed August 12, 2015, at http://www.navy.mil/submit/display.asp?story_id=85166.

Figure 8. Industry-Built EMRG Prototype Demonstrator

General Atomics prototype

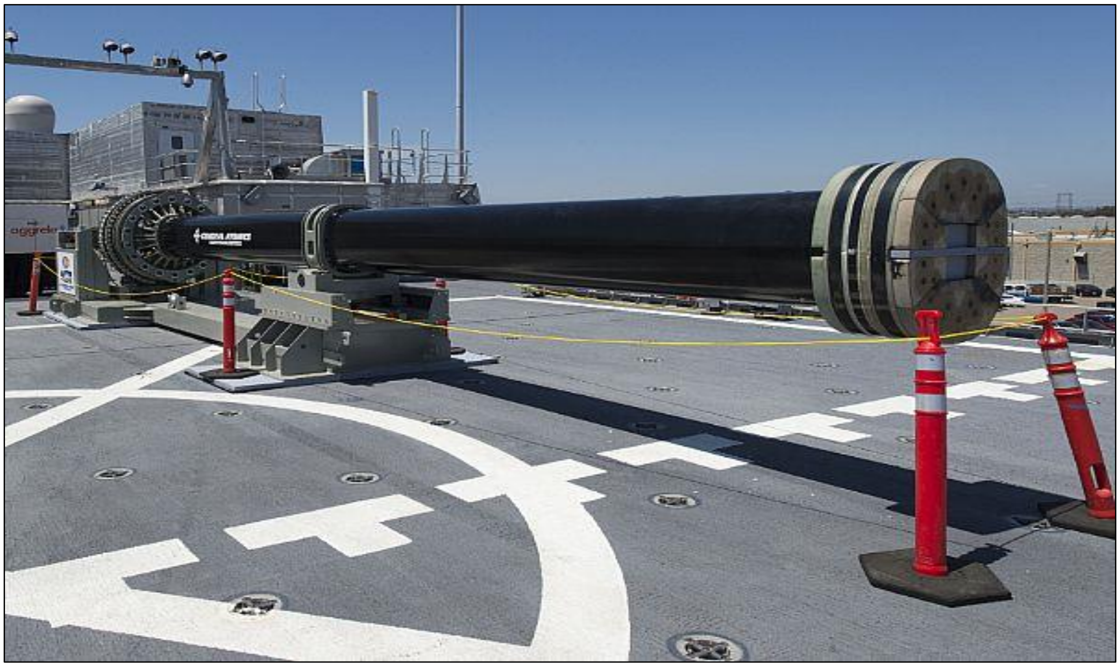

Source: navy photograph dated July 8, 2014, accessed August 12, 2015, at http://www.navy.mil/view_image.asp?id=180994.

The two industry-built prototypes are designed to fire projectiles at energy levels of 20 to 32 megajoules,[35] which is enough to propel a projectile 50 to 100 nautical miles.[36] (Such ranges might refer to using the EMRG for NSFS missions. Intercepts of ASCMs and ASBMs might take place at much shorter ranges.) The Navy began evaluating the two industry-built prototypes in 2012.

In April 2014, the Navy announced that it plans to temporarily install a prototype EMRG aboard a Navy Joint High Speed Vessel (JHSV) in FY2016, for use in at-sea tests.[37] **Figure 9** is an artist's rendering of that installation.

In January 2015, it was reported that the Navy is projecting that EMRG could become operational on a Navy ship between 2020 and 2025.[38] In April 2015, it was reported that the Navy is considering installing an EMRG on a Zumwalt (DDG-1000) class destroyer by the mid-2020s.[39]

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[35] The Navy states that "a megajoule is a measurement of energy associated with a mass traveling at a certain velocity. In simple terms, a one-ton vehicle moving at 100 mph equals a magajoule of energy." (Office of Naval Research Public Affairs, "Navy Sets New World Record with Electromagnetic Railgun Demonstration," *Navy News Service*, December 10, 2010, accessed August 12, 2015, at http://www.navy.mil/submit/display.asp?story_id=57690.)

[36] Grace Jean, "With a Bang, Navy Begins Tests on EM Railgun Prototype Launcher," Navy News Service, February 28, 2012, accessed August 12, 2015, at http://www.navy.mil/submit/display.asp?story_id=65577.

[37] Naval Sea Systems Command Office of Corporate Communication, "Navy to Deploy Electromagnetic Railgun Aboard JHSV," *Navy News Service*, April 7, 2014, accessed August 12, 2015, at http://www.navy.mil/submit/display.asp?story_id=80055.

[38] Sam LaGrone, "Navy Wants Rail Guns to Fight Ballistic and Supersonic Missiles Says RFI," *USNI News*, January 5, 2015.

[39] Sam LaGrone, "Navy Considering Railgun for Third Zumwalt Destroyer," *USNI News*, February 5, 2015 (updated (continued...)

Figure 9. EMRG Prototype Demonstrator Installed on a JHSV

Artist's rendering

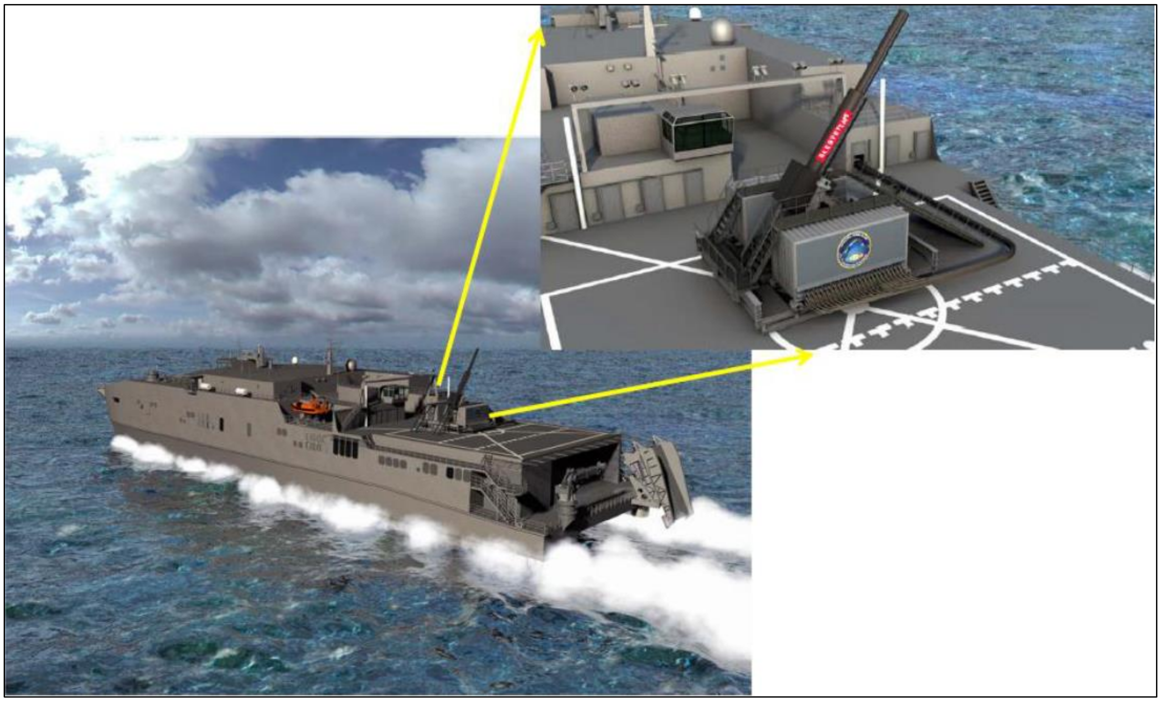

Source: Briefing slide entitled "FY16 At-Sea Test of Railgun" in Navy briefing entitled "Railgun Program Overview," undated but posted at InsideDefense.com on April 14, 2015. (InsideDefense.com states that the briefing was presented at a public conference on April 14, 2015.)

HVP

As the Navy was developing EMRG, it realized that the guided projectile being developed for EMRG could also be fired from 5-inch and 155mm powder guns.[40] Navy cruisers each have two

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(...continued)

February 11, 2015); Mike McCarthy, "Navy Aiming To Put Railgun On Third Zumwalt Destroyer," *Defense Daily*, February 6, 2015; Kris Osborn, "Navy Will Test its Electromagnetic Rail Gun aboard DDG 1000," *DefenseTech*, April 15, 2015. For more on Zumwalt-class destroyers, see CRS Report RL32109, *Navy DDG-51 and DDG-1000 Destroyer Programs: Background and Issues for Congress*, by Ronald O'Rourke.

[40] The Navy describes the HVP as "a next generation, common, low drag, guided projectile capable of completing multiple missions for gun systems such as the Navy 5-Inch, 155-mm, and future railguns.... HVP's low drag aerodynamic design enables high velocity, maneuverability, and decreased time-to-target. These attributes coupled with accurate guidance electronics provide low cost mission effectiveness against current threats and the ability to adapt to air and surface threats of the future." (Office of Naval Research, Hypervelocity Projectile," September 2012, accessed August 14, 2015, at http://www.onr.navy.mil/~/media/Files/Fact-Sheets/35/Hypervelocity-Projectile-2012B.ashx.) The Navy states that HVP weighs 23 pounds. (Source: David Martin, "Navy's Newest Weapon Kills at Seven Times the Speed of Sound," *CBS News (cbssnews.com)*, April 7, 2014.)

BAE Systems states that HVP is 24 inches long and weighs 28 pounds, including a 15-pound payload. The total length and weight of an HVP launch package, BAE Systems states, is 26 inches and 40 pounds. BAE states that the maximum rate of fire for HVP is 20 rounds per minute from a Mk 45 5-inch gun, 10 rounds per minute from the 155mm gun on DDG-1000 class destroyers (called the Advanced Gun System, or AGS), and 6 rounds per minute from EMRG. HVP's firing range, BAE Systems states, is more than 40 nautical miles (when fired from a Mk 45 Mod 2 5-inch gun), more than 50 nautical miles (Mk 45 Mod 4 5-inch gun), more than 70 nautical miles (155mm gun on DDG-1000 class destroyers), and more than 100 nautical miles (EMRG). (BAE Systems, "Hypervelocity Projectile (HVP)," 2014, (continued...)

5-inch guns, and most Navy destroyers each have one 5-inch gun. The Navy's three new Zumwalt class (DDG-1000) destroyers, which are under construction, each have two 155mm guns.

The projectile is a hypervelocity projectile when fired from either EMRG or a powder gun, but the term HVP tends to be used more frequently in connection with the concept of firing it from a powder gun. **Figure 10** and **Figure 11** show the HVP.

Figure 10. Photograph Showing HVP

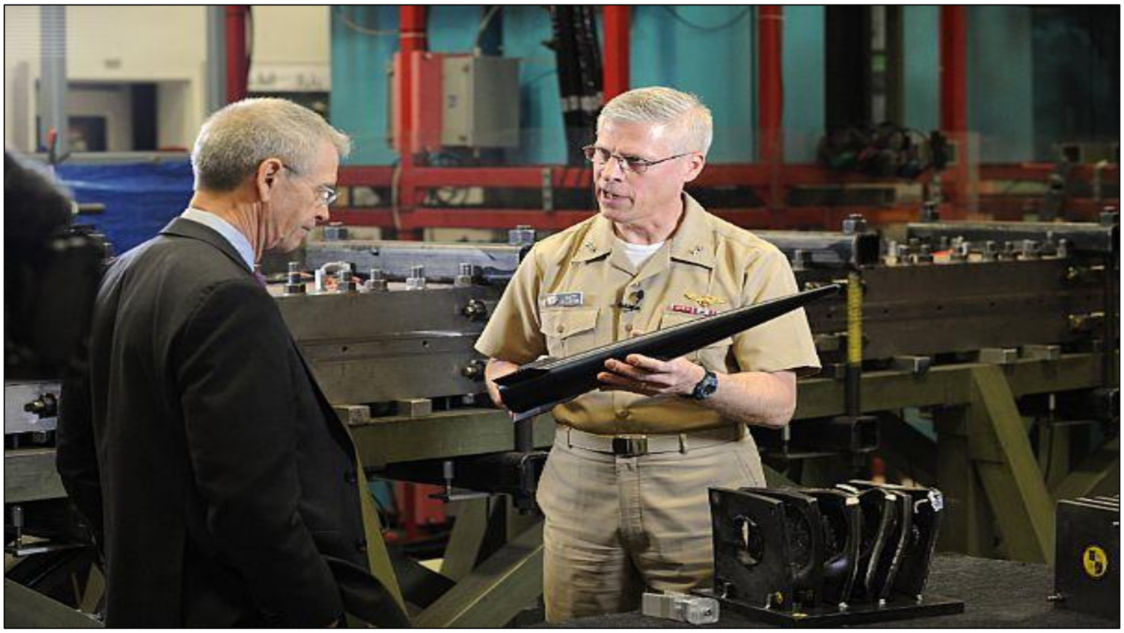

Source: Navy photograph dated April 4, 2014, with a caption that reads: "Rear Adm. Matthew Klunder, chief of naval research, shows off a Hypervelocity Projectile (HVP) to CBS News reporter David Martin during an interview held at the Naval Research Laboratory's materials testing facility. The HVP is a next-generation, common, low drag, guided projectile capable of completing multiple missions for gun systems such as the Navy 5-inch, 155-mm, and future railguns," accessed August 12, 2015, at http://www.navy.mil/view_image.asp?id=174517.

(...continued)

accessed August 14, 2015, at http://www.baesystems.com/download/BAES_178505/hyper-velocity-projectile-hvp-datasheet.)

In July 2015, the Navy issued a request for information (RFI) to industry for the fabrication of a prototype EMRG mount capable of handling an integrated launch weight package of 22 kg, or about 48.5 pounds. (RFI for Fabrication of Prototype Mount for Naval Railgun, Solicitation Number: N00024-15-R-4132, FedBizOpps.gov, July 29, 2015. See also Justin Doubleday, "Navy Developing Integrated Mount For Electromagnetic Railgun," *Inside the Navy*, July 31, 2015.)

Figure 11. HVP

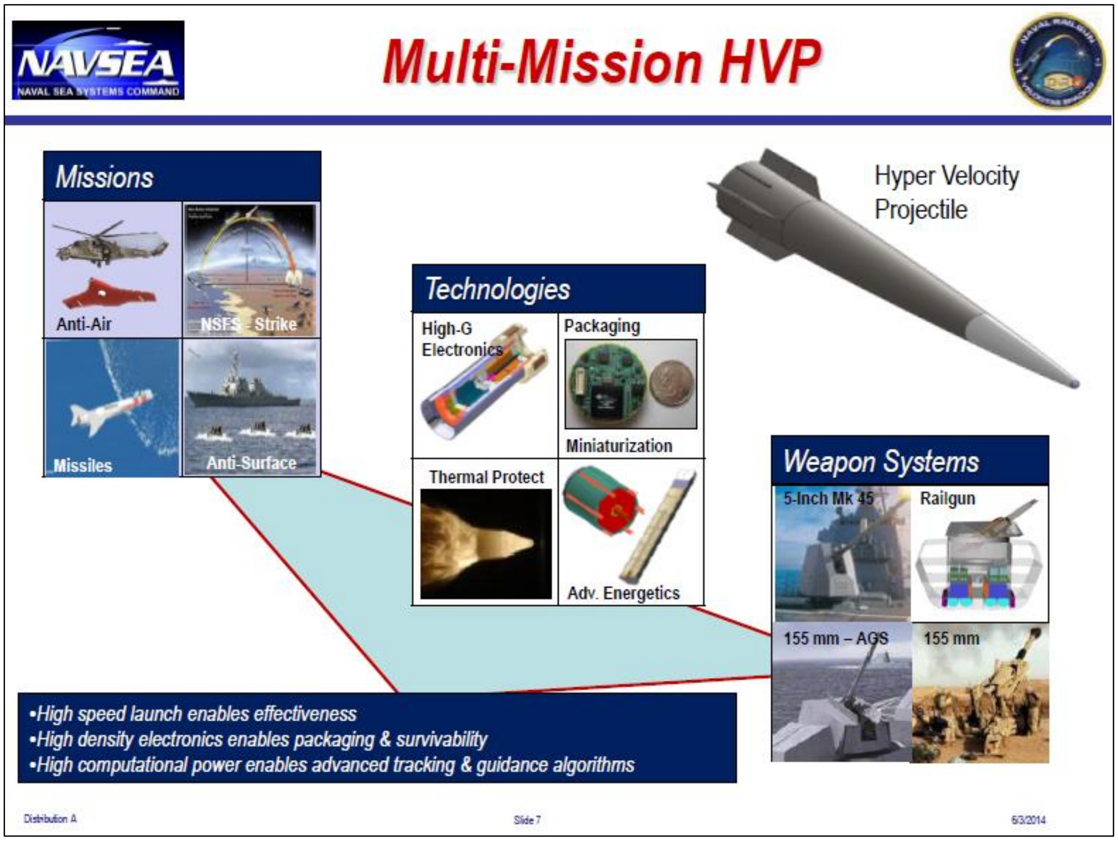

NAVSEA
NAVAL SEA SYSTEMS COMMAND

Multi-Mission HVP

Missions

Anti-Air

NSFS - Strike

Missiles

Anti-Surface

Technologies

High-G Electronics

Packaging

Miniaturization

Thermal Protect

Adv. Energetics

Hyper Velocity Projectile

Weapon Systems

5-Inch Mk 45

Railgun

155 mm – AGS

155 mm

- High speed launch enables effectiveness
- High density electronics enables packaging & survivability
- High computational power enables advanced tracking & guidance algorithms

Distribution A

Slide 7

6/3/2014

Source: Slide 7 from Navy briefing entitled "Electromagnetic Railgun," NDIA Joint Armaments Forum, Exhibition & Technology Demonstration, May 14, 2014, LCDR Jason Fox, USN, Assistant PM [Program Manager], Railgun Ship Integration, Distribution A, Approved for Public Release, accessed August 13, 2015, at http://www.dtic.mil/ndia/2014armaments/WedFox.pdf.

When fired from 5-inch powder guns, the projectile achieves a speed of roughly Mach 3, which is roughly half the speed it achieves when fired from EMRG, but more than twice the speed of a conventional 5-inch shell fired from a 5-inch gun.[41] This is apparently fast enough for countering at least some ASCMs. The Navy states that "The HVP—combined with the MK 45 [5-inch gun][42]—will support various mission areas including naval surface fire support, and has the capacity to expand to a variety of anti-air threats, [and] anti-surface [missions], and could expand the Navy's engagement options against current and emerging threats."[43]

One advantage of the HVP/5-inch gun concept is that the 5-inch guns are already installed on Navy cruisers and destroyers, creating a potential for rapidly proliferating HVP through the cruiser-destroyer force, once development of HVP is complete and the weapon has been integrated into cruiser and destroyer combat systems. **Figure 12** shows HVP launch packages configured for 5-inch guns, 155mm guns, and EMRG.

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[41] Source: Sam LaGrone, "Updated: Navy Researching Firing Mach 3 Guided Round from Standard Deck Guns," *USNI News*, June 1, 2015 (updated June 2, 2015).

[42] The type of 5-inch gun on Navy cruisers and destroyers is called the Mark 45.

[43] Naval Surface Warfare Center Dahlgren Division Corporate Communications, "DEPSECDEF Loads HVP on Test Range, Observes Repetitive Rate Electromagnetic Railgun's Commissioning Series," *Navy News Service*, May 8, 2015, accessed August 12, 2015, at http://www.navy.mil/submit/display.asp?story_id=86987.

Figure 12. HVP Launch Packages

Launch packages for 5-inch gun, 155mm gun, and EMRG

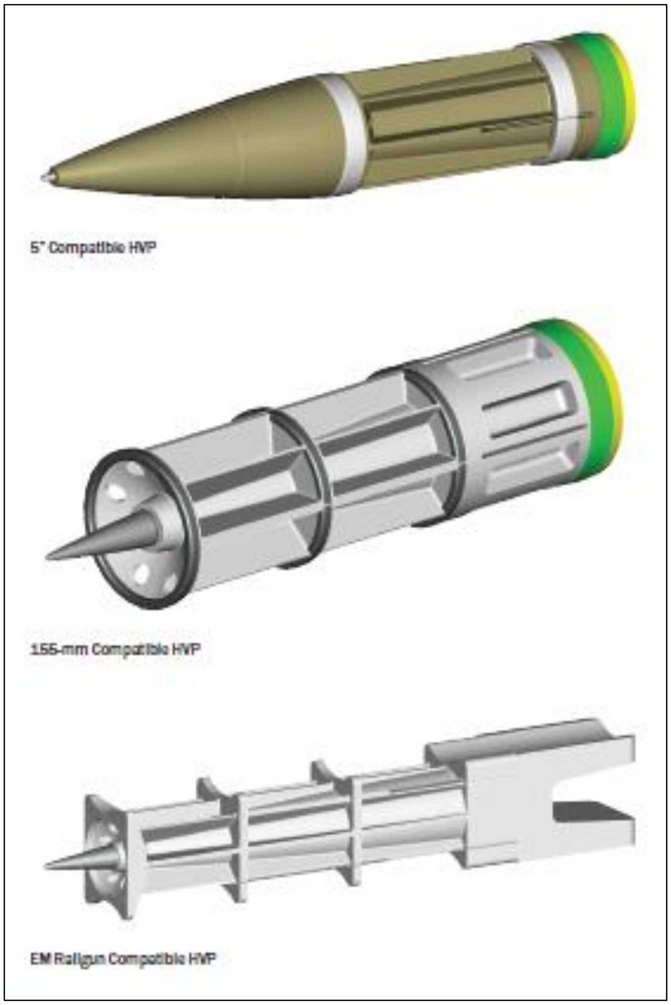

Source: BAE Systems, "Hypervelocity Projectile (HVP)," 2014, accessed August 14, 2015, at http://www.baesystems.com/download/BAES_178505/hyper-velocity-projectile--datasheet.

Figure 13 is a slide showing the potential application of HVP to 5-inch power guns, 155mm powder guns, and EMRG. The first line of the slide, for example, discusses HVP's use with 5-inch powder guns, stating that it uses a high-explosive (HE) warhead for the NSFS mission;[44] that a total of 113 5-inch gun barrels are available in the fleet (which could be a reference to 22 cruisers with two guns each, and 69 destroyers with one gun each); and that as a game-changing capability, it is guided and can be used at ranges of up to 26 nautical miles to 41 nautical miles for NSFS operations, for countering ASCMs, and for anti-surface warfare (ASuW) operations (i.e., attacking surface ships and craft).

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[44] The "KE" in the next line down means that when fired from EMRG, the projectile can alternatively attack targets using its own kinetic energy (i.e., by simply impacting the target at hypersonic speed).

Figure 13. HVP Application to Various Launchers

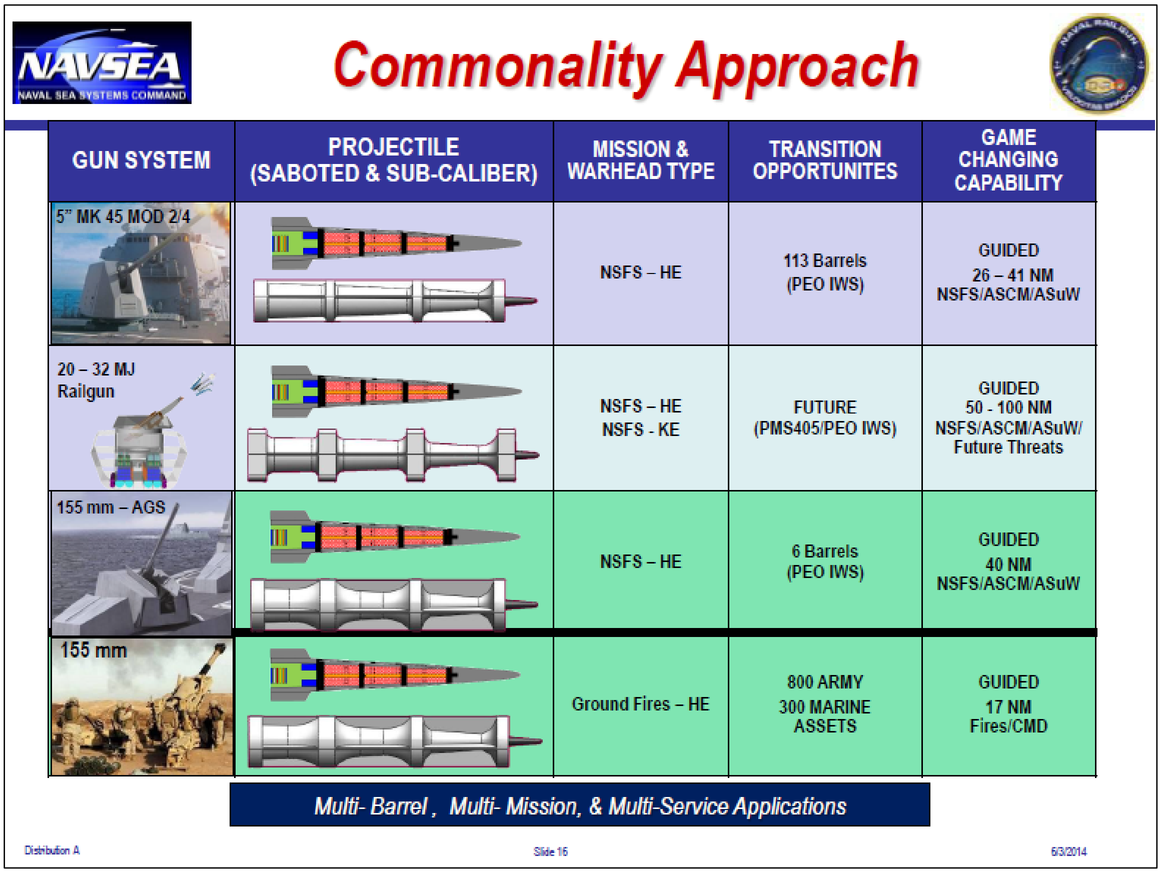
NAVSEA
NAVAL SEA SYSTEMS COMMAND

Commonality Approach

GUN SYSTEM	PROJECTILE (SABOTED & SUB-CALIBER)	MISSION & WARHEAD TYPE	TRANSITION OPPORTUNITES	GAME CHANGING CAPABILITY
5" MK 45 MOD 2/4		NSFS – HE	113 Barrels (PEO IWS)	GUIDED 26 – 41 NM NSFS/ASCM/ASuW
20 – 32 MJ Railgun		NSFS – HE NSFS - KE	FUTURE (PMS405/PEO IWS)	GUIDED 50 - 100 NM NSFS/ASCM/ASuW/ Future Threats
155 mm – AGS		NSFS – HE	6 Barrels (PEO IWS)	GUIDED 40 NM NSFS/ASCM/ASuW
155 mm		Ground Fires – HE	800 ARMY 300 MARINE ASSETS	GUIDED 17 NM Fires/CMD

Multi- Barrel , Multi- Mission, & Multi-Service Applications

Distribution A

Slide 16

6/3/2014

Source: Slide 16 from Navy briefing entitled "Electromagnetic Railgun," NDIA Joint Armaments Forum, Exhibition & Technology Demonstration, May 14, 2014, LCDR Jason Fox, USN, Assistant PM [Program Manager], Railgun Ship Integration, Distribution A, Approved for Public Release, accessed August 13, 2015, at http://www.dtic.mil/ndia/2014armaments/WedFox.pdf.

Figure 14 is a not-to-scale illustration of how HVPs fired from EMRGs and 5-inch guns can be used to counter various targets, including ASCMs and ASBMs.

Figure 14. Navy Slide Depicting Operations Against Various Target Types

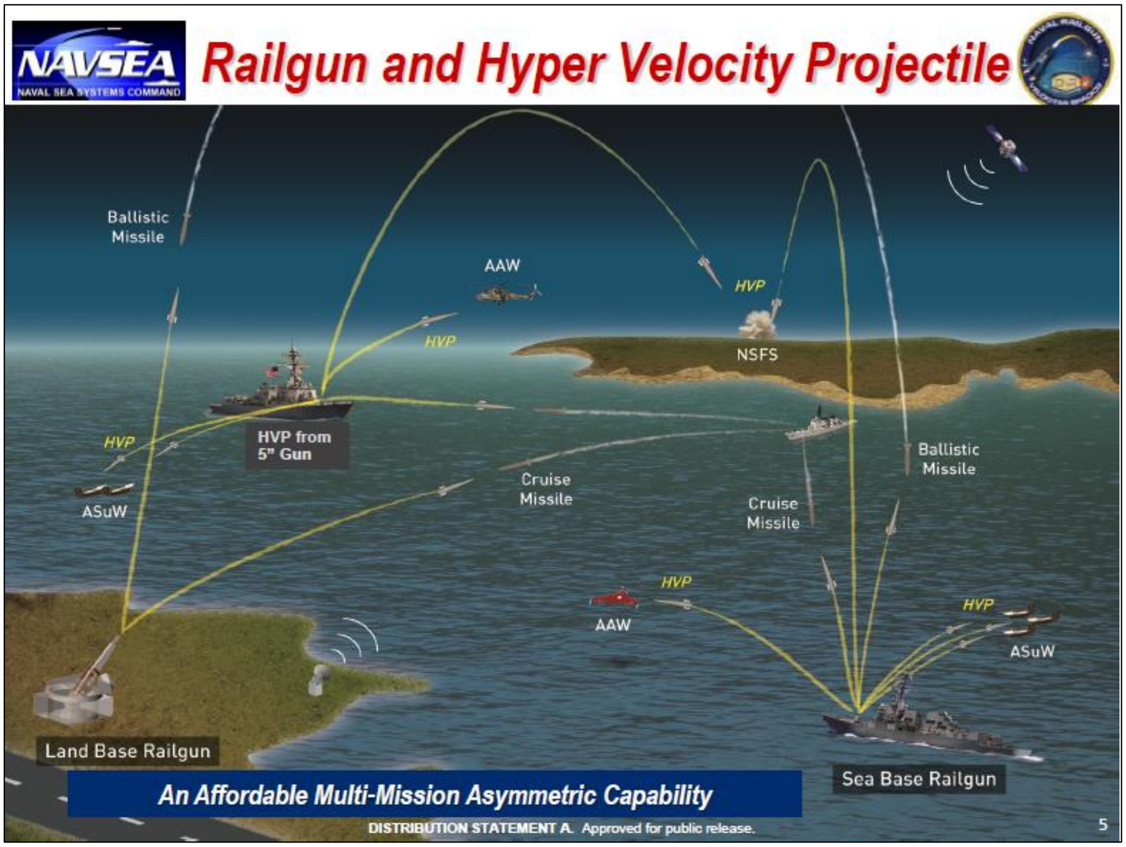
NAVSEA
NAVAL SEA SYSTEMS COMMAND
Railgun and Hyper Velocity Projectile
Ballistic Missile
AAW
HVP
NSFS
HVP
HVP
HVP from 5" Gun
ASuW
Cruise Missile
Cruise Missile
Ballistic Missile
HVP
AAW
HVP
ASuW
Land Base Railgun
Sea Base Railgun
An Affordable Multi-Mission Asymmetric Capability
DISTRIBUTION STATEMENT A. Approved for public release.
5

Source: Slide 5 from Navy briefing entitled "Electromagnetic Railgun," NDIA Joint Armaments Forum, Exhibition & Technology Demonstration, May 14, 2014, LCDR Jason Fox, USN, Assistant PM [Program Manager], Railgun Ship Integration, Distribution A, Approved for Public Release, accessed August 13, 2015, at http://www.dtic.mil/ndia/2014armaments/WedFox.pdf.

An April 11, 2016, press report states:

> The Pentagon wants to take a weapon originally designed for offense, flip its punch for defense and demonstrate by 2018 the potential for the Army and Navy to conduct missile defense of bases, ports and ships using traditional field guns to fire a new hypervelocity round guided by a mobile, ground variant of an Air Force fighter aircraft radar.
>
> The Strategic Capabilities Office is working with the Army, Navy and Air Force to craft a Hypervelocity Gun Weapon System that aims, in part, to provide China and Russia an example of a secret collection of new U.S. military capabilities the Defense Department is bringing online in an effort to strengthen conventional deterrence.
>
> "It is a fantastic program," Will Roper, Strategic Capabilities Office director, said in a March 28 interview with reporters, who said the project aims "to completely lower the cost of doing missile defense" by defeating missile raids at a lower cost per round and, as a consequence, imposing higher costs on attackers.[45]

A May 5, 2016, press report states:

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[45] Jason Sherman, "SCO Aims To Flip The Script on Missile Defense With Hypervelocity Gun," *Inside the Navy*, April 11, 2016.

> Come January [2017], the Pentagon will almost assuredly have new leadership, complete with a new vision for how the Department of Defense should operate, organize and plan for the future.
>
> It's a reality facing down Defense Secretary Ash Carter and Deputy Secretary Bob Work as they try to complete a transformation at the Pentagon, one which both men have said is vital to making sure the US is able to maintain its technological edge against great powers like Russia and China in the future.
>
> While Carter has made his reach-out to nontraditional communities the centerpiece of his initiative, Work's focus has been the "Third Offset," a series of technological bets, largely focused on man-unmanned teaming, that he believes will pay off in the future.
>
> So how do you make sure that a long-term project like the Third Offset keeps going under a new administration?
>
> "We have three really complimentary ways to go about this," Work said Monday at an event hosted by the Atlantic Council.
>
> The first, he explained, is giving many options to the next administration.
>
> "First of all, I'm going to be central to the transition, so I am going to be able to personally talk with the transition team and explain to them what we have pursued and why we have pursued it, and let them make their own decisions," Work said.
>
> "One of the things we have done in our program is build in a lot of different options that they can pull levers on," Work explained.
>
> As an example, he pointed to the idea of an electromagnetic railgun. Initially, Work and his team thought that was an area that would be a major focus of development, but as they experimented they realized that a powder gun with a hypervelocity round could have almost the same impact — but at a fraction of the cost, because it did not require the development, testing and adaptation of a new gun.
>
> "We're going to say 'look, this is the place where [we think] you want to put your money,' but we're going to have enough money in both the electromagnetic railgun and the powder gun that if the new administration says 'I really want the electromagnetic railgun, this is the way I want to go,' knock yourself out," Work said. "We've set you up for success."[46]

Indirectly Improving Ability to Counter ASCMs and ASBMs

As discussed earlier, SSLs currently under development have enough beam power to counter small boats and UAVs, but not enough to ASCMs or ASBMs. Even so, such SSLs could indirectly improve a ship's ability to counter ASCMs and ASBMs by permitting the ship to use fewer of its SAMs for countering UAVs, and more of them for countering ASCMs and ASBMs. Similarly, even though HVPs fired from 5-inch powder guns would not be able to counter ASBMs, they could indirectly improve a ship's ability to counter ASBMs by permitting the ship to use fewer of its SAMs for countering ASCMs and more of its SAMs for countering ASBMs.

Remaining Development Challenges

Although the Navy in recent years has made considerable progress in developing SSLs, EMRG, and HVP, a number of significant development challenges remain. Overcoming these challenges will likely require years of additional development work, and ultimate success in overcoming them is not guaranteed.[47]

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[46] Aaron Mehta, "Pentagon No. 2: How to Keep Third Offset Going in the Next Administration," *Defense News*, May 5, 2016.

SSLs

As shown in **Figure 15**, remaining development challenges for SSLs include, among other things, making the system rugged enough for extended shipboard use, making the beam director (the telescope-like part of the laser that sends the beam toward the target) suitable for use in a marine environment (where moisture and salt in the air can be harsh on equipment), and integrating the system into the ship's electrical power system and combat system.

A January 23, 2015, blog post co-authored by the Office of Naval Research's program officer for the Navy's SSL program states:

> In the near term, many challenges remain to develop and operate high-energy laser systems in the maritime environment that are unique to the Navy and Marine Corps. Among these challenges is dealing with the heat generated as power levels increase. A second issue is packing sufficient power on the platform, which will require advanced battery, generator, power conditioning, and hybrid energy technologies. Current laser technologies are approximately 30 percent electrically efficient. Corrosion and contamination of optical windows by shipboard salt spray, dirt, and grime also are technical challenges. In addition, atmospheric turbulence resulting from shifting weather conditions, moisture, and dust is problematic. Turbulence can cause the air over long distances to act like a lens, resulting in the laser beam's diffusing and distorting, which degrades its performance.
>
> Much progress has been made in demonstrating high-energy laser weapon systems in the maritime environment, but there is still much to be done. Additional advances will be required to scale power levels to the hundreds of kilowatts that will make high[-]energy lasers systems robust, reliable, and affordable. Higher power levels are important for the ability to engage more challenging threats and improve the rate and range at which targets can be engaged.
>
> The programs managed by ONR are addressing these remaining issues while positioning this important warfighting capability toward an acquisition program and eventual deployment with the fleet and force.[48]

---

[47] Laser skeptics sometimes note that laser proponents over the years have made numerous predictions about when lasers might enter service with DOD, and that these predictions repeatedly have not come to pass. Viewing this record of unfulfilled predictions, skeptics might argue that "lasers are X years in the future—and always will be." Laser proponents acknowledge the record of past unfulfilled predictions, but argue that the situation has now changed because of rapid advancements in SSL technology and a shift from earlier ambitious goals (such as developing megawatt-power lasers for countering targets at tens or hundreds of miles) to more realistic goals (such as developing kilowatt-power lasers for countering targets at no more than a few miles). Laser proponents might argue that laser skeptics are vulnerable to what might be called cold plate syndrome (i.e., a cat that sits on a hot plate will not sit on a hot plate again—but it will not sit on a cold plate, either).

[48] Peter Morrison and Dennis Sorenson, "Developing a High-Energy Laser for the Navy," Future Force, January 23, 2015, accessed August 13, 2015, at http://futureforce.navylive.dodlive.mil/2015/01/high-energy-laser/. The authors are identified at the end of the post as follows: "Peter Morrison is the Office of Naval Research's program officer for the Navy's Solid-State Laser program. Dennis Sorenson is a contractor with the Office of Naval Research."

Figure 15. Development Challenges for SSLs

As of February 2013

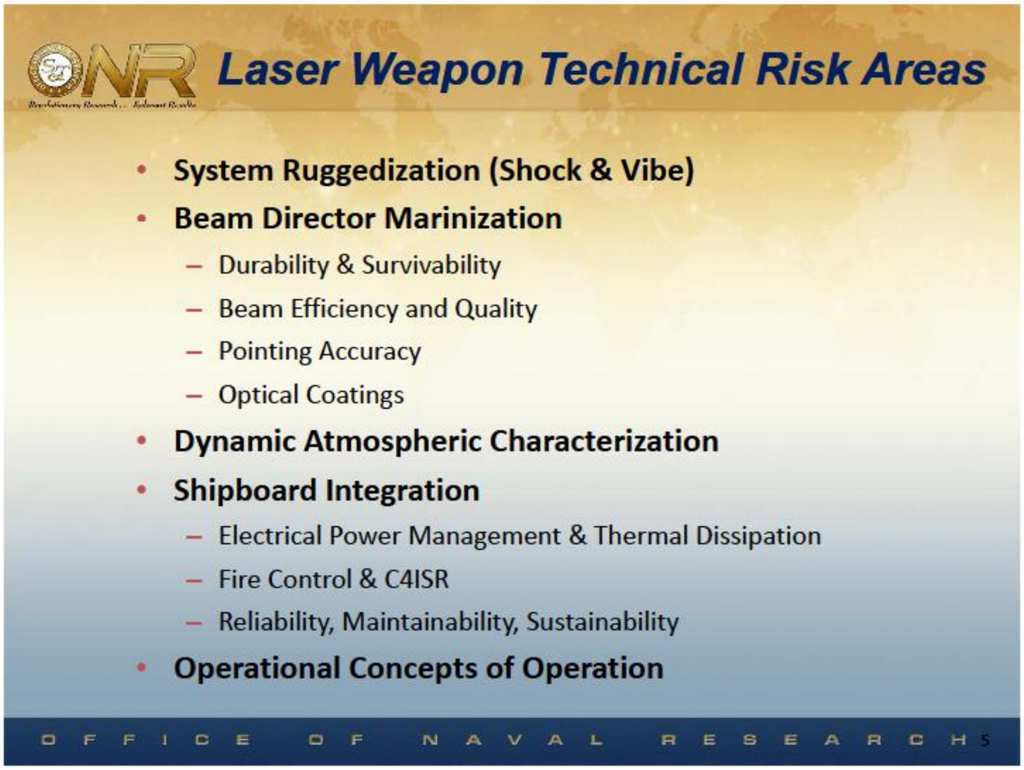

Laser Weapon Technical Risk Areas

- **System Ruggedization (Shock & Vibe)**
- **Beam Director Marinization**
  - Durability & Survivability
  - Beam Efficiency and Quality
  - Pointing Accuracy
  - Optical Coatings
- **Dynamic Atmospheric Characterization**
- **Shipboard Integration**
  - Electrical Power Management & Thermal Dissipation
  - Fire Control & C4ISR
  - Reliability, Maintainability, Sustainability
- **Operational Concepts of Operation**

Source: Slide from Navy briefing entitled "Navy Solid State Laser Program Overview," ASNE Day 2013, Mr. Peter "Rollie" Morrison, ONR 35 S&T Program Office, February 22, 2013, accessed August 13, 2015, at https://www.navalengineers.org/ProceedingsDocs/ASNEDay2013/Morrison_Pres.pdf.

EMRG and HVP

As shown in **Figure 16**, remaining development challenges for EMRG involve items relating to the gun itself (including increasing barrel life to desired levels), the projectile, the weapon's electrical power system, and the weapon's integration with the ship. Fielding HVP on cruisers and destroyers ships equipped with 5-inch and 155mm powder guns would additionally require HVP to be integrated with the combat systems of those ships.

Figure 16. Development Challenges for EMRG

As of May 2014

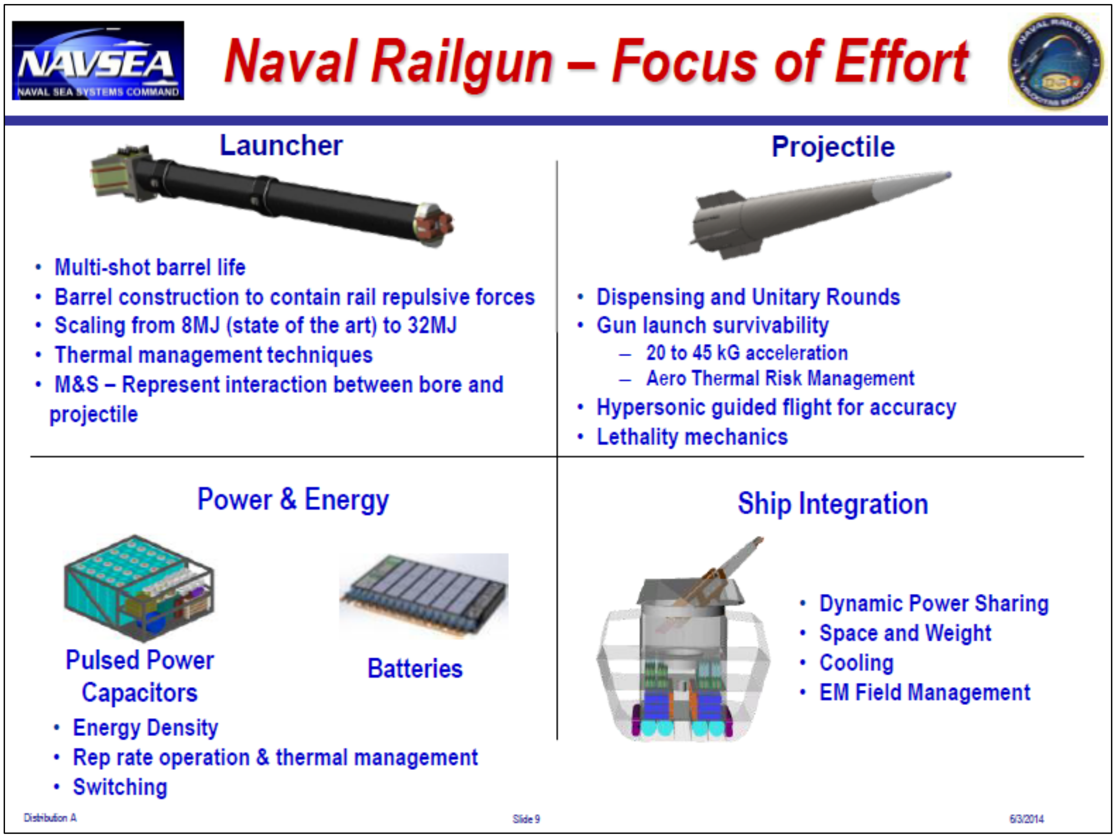

Naval Railgun – Focus of Effort

Launcher

- Multi-shot barrel life
- Barrel construction to contain rail repulsive forces
- Scaling from 8MJ (state of the art) to 32MJ
- Thermal management techniques
- M&S – Represent interaction between bore and projectile

Projectile

- Dispensing and Unitary Rounds
- Gun launch survivability
  - 20 to 45 kG acceleration
  - Aero Thermal Risk Management
- Hypersonic guided flight for accuracy
- Lethality mechanics

Power & Energy

Pulsed Power Capacitors

Batteries

- Energy Density
- Rep rate operation & thermal management
- Switching

Ship Integration

- Dynamic Power Sharing
- Space and Weight
- Cooling
- EM Field Management

Distribution A

Slide 9

6/3/2014

Source: Slide 9 from Navy briefing entitled "Electromagnetic Railgun," NDIA Joint Armaments Forum, Exhibition & Technology Demonstration, May 14, 2014, LCDR Jason Fox, USN, Assistant PM [Program Manager], Railgun Ship Integration, Distribution A, Approved for Public Release, accessed August 13, 2015, at http://www.dtic.mil/ndia/2014armaments/WedFox.pdf.

The Navy states:

> The EMRG effort began in FY 2005 with a focus on the barrel, power storage, and rail technology. In 2015, the Navy is testing full-scale industry advanced composite launchers for structure strength and manufacturability, and has advanced the pulsed-power system design from single-shot to actively cooled repeated rate operations. Building on the success of the first phase, the second phase started in 2012 with a focus on developing equipment and techniques to fire ten rounds per minute. Thermal-management techniques required for sustained firing rates are in development for both the launcher system and the pulsed-power system. The Office of Naval Research will develop a tactical prototype EMRG launcher and pulsed-power architecture suitable for advanced testing both afloat and ashore. Railgun demonstration has been funded to occur in FY 2016.[49]

A June 2015 press report states:

> As the Navy prepares to test its electromagnetic railgun at sea for the first time in 2016, service leaders said one of the biggest challenges will be integrating the new technology onto existing platforms.....

---

[49] U.S. Navy, *U.S. Navy Program Guide 2015*, p. 169.

> [Vice Adm. William Hilarides, commander of Naval Sea Systems Command] said he is positive the Navy will successfully demonstrate the weapon's ability to fire from the Trenton, but one of the biggest challenges will be configuring the railgun so that it fits within the power structure of other existing platforms.
>
> "Those are not 600-ton margin ships," he said [meaning ships with 600 tons of growth margin available to accommodate EMRG]. "If they have 60 tons, if they have 16 tons, then we'll be talking about what do we take off our existing destroyers, cruisers and other ships in order to get this incredible capability [on them]."
>
> These types of discussions are influencing ship designs as program managers look at what systems are indispensable and what can be exchanged, Hilarides said.
>
> Integrating the railgun into the fleet won't be a swift process.
>
> It will be at least 10 years until the railgun is fielded on new ships and potentially 30 years past that before the Navy considers removing powder guns from the fleet entirely and transitioning to energy weapons alone, according to Hilarides.[50]

Issues for Congress

Potential Oversight Questions

Potential oversight questions for Congress regarding Navy programs for SSLs, EMRG, and HVP include the following:

- Using currently available approaches for countering ASCMs and ASBMs, how well could Navy surface ships defend themselves in a combat scenario against an adversary such as China that has large numbers of ASCMs (including advanced models) and ASBMs? How would this change if Navy surface ships in coming years were equipped with SSLs, EMRG, HVP, or some combination of these systems?
- How significant are the remaining development challenges for SSLs, EMRG, and HVP?
- Are current schedules for developing SSLs, EMRG, and HVP appropriate in relation to remaining development challenges and projected improvements in enemy ASCMs and ASBMs? To what degree are current schedules for developing SSLs, EMRG, or HVP sensitive to annual funding levels?
- When does the Navy anticipate issuing roadmaps detailing its plans for procuring and installing production versions of SSLs, EMRGs, and HVP on specific Navy ships by specific dates?
- Will the kinds of surface ships that the Navy plans to procure in coming years have sufficient space, weight, electrical power, and cooling capability to take full advantage of SSLs (particularly those with beam powers above 200 kW) and EMRG? What changes, if any, would need to be made in Navy plans for procuring large surface combatants (i.e., destroyers and cruisers) or other Navy ships to take full advantage of SSLs and EMRG?

---

[50] Allyson Versprille, "Integration Biggest Challenge for Railgun," *National Defense*, June 2015. See also Lance M. Bacon, "3-Star: 'Lot of Work' Before Railgun Arrives in Fleet," *Navy Times*, February 5, 2015.

- Are the funding sources for SSLs, EMRG, and HVP in Navy and Defense-Wide research and development accounts (see "Summary of Congressional Action on FY2017 Funding" below) sufficiently visible for supporting congressional oversight?

Legislative Activity for FY2017

Summary of Congressional Action on FY2017 Funding

Funding in the defense budget for research and development work on Navy SSLs, EMRG, and HVP is spread across several research and development account line items (which are known as program elements, or PEs). The PEs shown in **Table 1** capture much but not necessarily all of the funding for developing Navy SSLs, EMRG, and HVP. The PEs shown in the table, moreover, include funding for efforts other than Navy SSLs, EMRG, and HVP, so congressional changes from requested amounts might or might not relate to SSLs, EMRG, or HVP.

Table 1. Summary of Congressional Action on FY17 Funding

In millions of dollars, rounded to nearest tenth

Program Element (PE) number, PE name, FY16 budget line number	Req.	Authorization			Appropriation		
		HASC	SASC	Conf.	HAC	SAC	Conf.
0602114N, Power Projection Applied Research, line 4	41.4	41.4	41.4		41.4		
0602750N, Future Naval Capabilities Applied Research, line 13	165.1	165.1	165.1		157.1		
0603114N, Power Projection Advanced Technology, line 16	96.4	106.4	81.4		76.6		
0603673N, Future Naval Capabilities Advanced Technology Development, line 21	249.1	249.1	239.1		252.1		
0603925N, Directed Energy and Electric Weapon System, line 75	32.7	32.7	32.7		32.7		
0604250D8Z, Advanced Innovative Technology, line 95	844.9	804.9	844.9		844.9		

Source: Table prepared by CRS based on Navy FY17 budget submission and committee and conference reports.

Notes: HASC is House Armed Services Committee; **SASC** is Senate Armed Services Committee; **HAC** is House Appropriations Committee; **SAC** is Senate Appropriations Committee; **Conf.** is conference agreement. The PEs shown in the table below capture much but not necessarily all of the funding for work on Navy SSLs, EMRG, and HVP. The PEs shown in the table, moreover, include funding for efforts other than Navy SSLs, EMRG, and HVP.

FY2017 National Defense Authorization Act (H.R. 4909/S. 2943)

House

The House Armed Services Committee, in its report (H.Rept. 114-537 of May 4, 2016) on H.R. 4909, recommended the funding levels shown in the HASC column of **Table 1**. The recommended increase of $10 million for PE 0603114N, Power Projection Advanced Technology (line 16) is for "Program increase for common mount." (Page 498) The recommended reduction of $40 million for PE 0604250D8Z, Advanced Innovative Technology (line 95) is for "SCO" (the Strategic Capabilities Office). (Page 518) H.Rept. 114-537 states:

> *Common mount for electromagnetic railgun*
>
> The budget request contained $96.4 million in PE 63114N for power projection advanced technology. Of this amount, $15.4 million was included for the Navy's electromagnetic railgun prototype.
>
> The committee remains supportive of the Navy's program for developing and deploying an electromagnetic railgun. The committee recognizes the growing imperative for the Navy to field this type of weapon, not only to increase capabilities for naval surface fire support and ballistic missile defense, but to also decrease the cost exchange model when comparing the railgun to conventional missiles or guns. However, the committee is increasingly concerned that the shift in emphasis to the hypervelocity projectile by the Strategic Capabilities Office has left the Navy with a funding gap in developing the requirements and design for a common mount, which is a necessary prerequisite to getting this capability into operational use. Therefore, the committee directs the Secretary of the Navy to provide a briefing to the House Committee on Armed Services by February 15, 2017, on the plan and milestone schedule for demonstrating and deploying a common railgun mount for sea- and land-based applications.
>
> The committee recommends $106.4 million, an increase of $10.0 million, in PE 63114N to support the development of a common mount for the sea-based and land-based electromagnetic railgun. (Page 61)

H.Rept. 114-537 also states:

> *Strategic Capabilities Office*
>
> The budget request contained $844.9 million in PE 64250D8Z for development activities of the Strategic Capabilities Office (SCO).
>
> Created in 2012 by the Deputy Secretary of Defense, SCO has the mission to identify, analyze, demonstrate, and transition game-changing applications of existing and near-term technology to shape and counter emerging threats. SCO is comprised of a relatively small number of personnel and relies on other program office personnel and resources to execute its mission. The committee appreciates the nature of SCO's mission and sustained leanness of the organization; however, the committee notes the budget for SCO has grown exponentially each fiscal year. For example, the fiscal year 2017 budget request is nearly double the request for fiscal year 2016.
>
> The committee is concerned that such rapid budget growth may bring with it some risks, including the demands on SCO's small staff, demands on other Department of Defense personnel, and impact of SCO decisions on existing programs. For example, the committee is aware of SCO's inclusion on the electromagnetic railgun development, and subsequent reprioritizing of its planned investment in that program for fiscal year 2017, resulting in a funding gap that could not be covered by the program office.
>
> Additionally, the committee remains concerned that the transition of technologies from SCO has not been adequately captured and conveyed to the oversight committees. The report required by the committee report (H. Rept. 114–102) accompanying the National Defense Authorization Act for Fiscal Year 2016 has not been delivered and is now almost 6 months late. In order to support prudent use of taxpayer resources, and to ensure proper oversight of these activities, the committee believes this report should be provided and concerns addressed before supporting full funding of planned activities.
>
> Therefore, the committee recommends $804.9 million, a decrease of $40.0 million, in PE 64250D8Z for development activities of the Strategic Capabilities Office. (Page 92)

Section 220 of H.R. 4909 as reported states:

> SEC. 220. Designation of Department of Defense senior official with principal responsibility for directed energy weapons.
>
> Not later than 180 days after the date of the enactment of this Act, the Secretary of Defense shall—
>
> (1) designate a senior official already serving within the Department of Defense as the official with principal responsibility for the development and demonstration of directed energy weapons for the Department; and
>
> (2) set forth the responsibilities of that senior official with respect to such programs.

H.Rept. 114-537 also states:

> *Five-inch precision guided projectile development for naval surface fire support*
>
> In the committee report (H. Rept. 114–102) accompanying the National Defense Authorization Act for Fiscal Year 2016, the committee noted "that current surface Navy gunnery requirements are outdated and that new technologies such as railgun and directed energy weapons are nearing readiness for technology transition." The committee referenced the Advanced Naval Surface Fires (ANSF) initiative and noted the ANSF was assessing options for providing a near-term 5-inch guided munition capability. The committee understands this capability would provide for improved and extended-range naval surface fire support. The committee continues to support the need for this precision guided capability and is also aware of the Hypervelocity Gun Weapon System (HGWS) program that is currently under consideration by the Strategic Capabilities Office (SCO). The committee notes the HGWS program would "flip the cost equation using conventional guns to defend forward bases against raids of advanced cruise and ballistic missiles" and believes there could be applications for use in 5-inch gun systems for naval surface fires support. The committee is encouraged by the development of both of these initiatives and expects the Navy and SCO to coordinate on these capabilities. The committee also expects the Navy to proceed forward with an accelerated development and acquisition strategy for this needed capability that is consistent with acquisition reform principles. (Pages 62-63)

H.Rept. 114-537 also states:

> *Technology enablers for directed energy weapon systems*
>
> The committee is aware that the Department of Defense has made significant advances in the development and operational demonstration of directed energy weapons systems. Each military department has demonstrated a marquee program in this area, such as the Navy's Laser Weapon System deployed on the USS Ponce, the Army High Energy Laser Mobile Demonstrator, and the Marine Corps' Ground Based Air Defense System. Along with technology demonstration activities like the Robust Electric Laser Initiative and the High Energy Liquid Laser Area Defense System, each of these programs demonstrated the increased power output and power on target necessary to develop a militarily useful directed energy weapon.
>
> However, as the Department has made progress in raising the power levels of these systems, it has also demonstrated the need for emphasis on development in other technology areas necessary to realize the full potential of laser weapons. For example, higher power output requires improved beam control to engage targets at greater distances, as well as better thermal management systems to dissipate the increased heat load. As the Department has been overcoming foundational technical challenges, new challenges have emerged that will impact the operational uses for directed energy weapons.

> Therefore, the committee directs the Assistant Secretary of Defense for Research and Engineering, in coordination with the research components of the military departments and the High Energy Laser Joint Technology Office, to provide a briefing to the House Committee on Armed Services by January 20, 2017. This briefing should provide a roadmap for enabling technologies, including:
>
> (1) Beam directors and adaptive optics, including deformable mirrors;
>
> (2) Thermal management needs and capabilities;
>
> (3) Integration challenges with fire control systems, including potential
>
> future needs for fire control for laser systems;
>
> (4) Power architectures and power electronics needs;
>
> (5) Facilities and test range capabilities; and
>
> (6) Other areas as deemed by the Secretary. (Page 93)

Senate

The Senate Armed Services Committee, in its report (S.Rept. 114-255 of May 18, 2016) on S. 2943, recommended the funding levels shown in the SASC column of **Table 1**. The recommended reduction of $15 million to PE 0603114N, Power Projection Advanced Technology (line 16) is for "General decrease." (Page 481) The recommended reduction of $10 million to PE 0603673N, Future Naval Capabilities Advanced Technology Development (line 21) is for "Capable manpower, and power and energy." (Page 481).[51] S.Rept. 114-255 states:

> **Power projection advanced technology**
>
> The budget request included $96.4 million in PE 63114N for power projection advanced technology. The committee notes that the Navy, Air Force, Defense Advanced Research Projects Agency, Strategic Capabilities Office, and other elements within the Department of Defense are all pursuing advanced power projection technologies and systems. The committee is concerned that these efforts are not well-coordinated and have uncertain pathways for transition to programs of record. In addition, the committee notes that the budget request represents an almost 200 percent increase over the amount enacted for fiscal year 2016. The committee believes that such a large increase in budget is not warranted and is concerned about the ability of the programs to absorb the additional funding. Consequently, the committee recommends a decrease of $15.0 million in PE 63114N, but directs that this reduction not be assessed against solid state laser maturation efforts. (Page 52)

Section 216 of S. 2943 as reported states:

---

[51] This recommended reduction of $10 million does not appear to relate (at least not directly) to lasers, the electromagnetic railgun, or the HVP. S.Rept. 114-255 states:

> **Capable manpower and power and energy**
>
> The budget request included $249.1 million in PE 63673N for future naval capabilities advanced technology developments. The activities listed under this program element include capable manpower and power and energy. The committee believes that the work plans for fiscal year 2017 on these activities does not warrant the level of funding included in the budget request. For example, the committee notes that the research included in these two projects include development of new personnel and management methodologies, and capabilities in energy security. Both of these efforts could be better coordinated with other organizations performing similar research. Consequently, the committee recommends a decrease of $10.0 million in PE 63673N to be distributed appropriately from capable manpower and power and energy. (Page 53)

SEC. 216. Directed energy weapon system programs.

(a) Inclusion of Directed Energy Weapon System programs in the rapid acquisition authority program.—

(1) IN GENERAL.—Section 806(c)(1) of the Bob Stump National Defense Authorization Act for Fiscal Year 2003 (Public Law 107–314; 10 U.S.C. 2302 note) is amended by adding at the end the following new subparagraph:

"(D) (i) In the case of any supplies and associated support services that, as determined in writing by the Secretary of Defense without delegation, are urgently needed to eliminate a deficiency in directed energy weapon systems, the Secretary may use the procedures developed under this section in order to accomplish the rapid acquisition and deployment of needed offensive or defensive directed energy weapon systems capabilities, supplies, and associated support services.

"(ii) For the purposes of directed energy weapon systems acquisition, the Secretary of Defense shall consider use of the following procedures:

"(I) The rapid acquisition authority provided under this section.

"(II) Use of other transactions authority provided under section 2371 of title 10, United States Code.

"(III) The acquisition of commercial items using simplified acquisition procedures.

"(IV) The authority for procurement for experimental purposes provided under section 2373 of title 10, United States Code.

"(iii) In this subparagraph, the term 'directed energy weapon systems' means military action involving the use of directed energy to incapacitate, damage, or destroy enemy equipment, facilities, or personnel.".

(2) CONFORMING AMENDMENTS.—Section 2373 of title 10, United States Code, is amended—

(A) in subsection (a), by striking "and aeronautical supplies" and inserting ", aeronautical supplies, and directed energy weapon systems"; and

(B) by adding at the end of the following new subsection:

"(c) Directed energy weapon systems defined.—In this section, the term 'directed energy weapon systems' means military action involving the use of directed energy to incapacitate, damage, or destroy enemy equipment, facilities, or personnel.".

(b) Joint Directed Energy Program Office.—

(1) REDESIGNATION.—The High Energy Laser Joint Technology Office of the Department of Defense is hereby redesignated as the "Joint Directed Energy Program Office" (in this subsection referred to as the "Office").

(2) STRATEGIC PLAN FOR DEVELOPMENT AND FIELDING OF DIRECTED ENERGY WEAPONS CAPABILITIES.—In addition to the functions and duties of the Office in effect on the day before the date of the enactment of this Act, the Office shall develop a strategic plan for development and fielding of directed energy weapons capabilities for the Department, in which the Office may define requirements for directed energy capabilities that address the highest priority warfighting capability gaps of the Department.

(3) ACCELERATION OF DEVELOPMENT AND FIELDING OF DIRECTED ENERGY WEAPONS CAPABILITIES.—

(A) IN GENERAL.—To the degree practicable, the Office shall use the policies of the Department that are revised pursuant to this section and new acquisition and management

> practices established pursuant to this section to accelerate the development and fielding of directed energy capabilities.
>
> (B) ENGAGEMENT.—The Secretary shall ensure that use of policies and practices described in subparagraph (A) include engagement with defense and private industries, research universities, and unaffiliated, nonprofit research institutions.

Regarding Section 216, S.Rept. 114-255 states:

> **Directed energy weapon system programs (sec. 216)**
>
> The committee remains concerned about the Department of Defense's inability to field an operational directed energy system. The committee is aware that the military services and industry partners have developed sufficient directed energy weapon capabilities for specific scenarios—like the High Energy Laser Mobile Demonstrator (HEL–MD) to counter rocket, artillery and mortar for base protection purposes and the Counter Electronics High Powered Microwave Advanced Missile Project (CHAMP) for disabling an adversary's electronics while avoiding collateral damage. These programs, as well as other high energy laser weapon systems, have been tested and demonstrated, but have failed to transition to acquisition programs of record.
>
> The committee notes that directed energy capabilities have the potential to support many operational missions in cost effective and efficient manners. In response to these factors, the committee recommends a provision that would amend section 806 of the Bob Stump National Defense Authorization Act for Fiscal Year 2003 (Public Law 107–314) to grant rapid acquisition authorities for directed energy weapon systems to accelerate the development and fielding of this technology and to help offset the gains of potential adversaries.
>
> The committee notes that since 1960, the Department of Defense has invested more than $6.0 billion in directed energy science and technology initiatives. However, the committee remains concerned that, despite this significant investment, the Department's directed energy initiatives are not resourced at levels necessary to transition them to full-scale acquisition programs. The committee notes with concern that years of investment have not to date resulted in any operational systems with high energy laser capability.
>
> The committee highlights that the Defense Science Board Task Force on Directed Energy Weapon Systems and Technology Applications found that "directed energy offers promise as a transformational 'game changer' in military operations, able to augment and improve operational capabilities in many areas." The task force further concluded that the range of potential applications is sufficient to warrant significantly increased attention to the scope and direction of efforts to assess, develop, and field appropriate laser, microwave, and millimeter wave weapons. Consistent with the findings of the task force, the committee believes that directed energy weapons systems offer significant benefits in terms of cost effectiveness, sustainability, magazine capabilities, and precision targeting. (Pages 46-47)

S.Rept. 114-255 also states:

> **High energy laser joint technology office**
>
> The budget request included $42.3 million in PE 62890F for high energy laser research. The committee notes that this program element funds defense high energy laser applied research through the High Energy Laser Joint Technology Office. However, the committee is concerned that the Joint Technology Office has not received sufficient funding in recent years to drive the maturation of high energy laser technology. As an example, the committee notes with concern that no laser technologies have yet been fielded or deployed, despite promising development and field tests. Given the importance of directed energy weapons systems in general as noted elsewhere in this Act, and of high energy laser systems in particular, the committee is concerned that budget request for this

> program element will be insufficient for supporting the joint technology office. Accordingly, the committee recommends an increase of $5.0 million in PE 62890F for the high energy laser joint technology office. (Pages 54-55)

S.Rept. 114-255 also states:

> **Directed energy systems prototyping**
>
> The budget request included no money in PE 64342D8Z for defense technology offsets. The committee notes with disappointment that the administration did not view it as a priority to request funds through this program element. Particularly with the high-profile emphasis placed on the Department of Defense's Third Offset Strategy, the committee is disappointed to see this program be unfunded. In addition, as noted elsewhere in this report, the committee is deeply disappointed with how the technology offset funding enacted in fiscal year 2016 was allocated. As noted, none of the money was put towards directed energy, in contradiction to the clear intent of Congress that half of the money be used to bolster directed energy technologies. While the committee does not recommend additional unrestricted funds for the technology offsets program, the committee underscores that directed energy systems are still critical areas of work in need of greater support and attention. The committee believes that the Department needs to focus in particular on the transition from lab development to deployment and fielding. Consequently, the committee recommends a general increase of $25.0 million in PE 64342D8Z to be used only for the purposes of directed energy systems prototyping. (Pages 59-60)

S.Rept. 114-255 also states:

> **Laser weapon system demonstrator**
>
> The Committee commends the Navy for initiating and funding the Laser Weapon Systems Demonstrator (LWSD) and believes that this is an important step toward maturing technologies that could ultimately enable the deployment of a shipboard maritime laser weapons system. While the Committee understands that the Navy envisions transitioning laser weapons to a formal Program of Record in the 2020s, it appears that the Navy has not programmed funding beyond the LWSD sea-based tests to support the installation of LWSD on a DDG or for the design and procurement of a formal maritime laser program.
>
> The committee expects that the Secretary of the Navy will keep the congressional defense committees updated on its plan to seamlessly transition the LWSD to a shipboard weapons system following sea-based testing and to a formal maritime laser Program of Record, technical progress toward developing the capability, and programmatic steps being taken to move to demonstration and deployment of advanced laser systems. (Page 70)

FY2017 DOD Appropriations Act (H.R. 5293)

House

The House Appropriations Committee, in its report (H.Rept. 114-577 of May 19, 2016) on H.R. 5293, recommended the funding levels shown in the HAC column of **Table 1**. The recommended reduction of $8 million to PE 0602750N, Future Naval Capabilities Applied Research (line 13) is for "FORCENET excessive growth" ($5 million), "Power and energy previously funded efforts" ($2 million), and "Sea shield previously funded efforts" ($1 million). (Page 228) The recommended reduction of $19.8 million to PE 0603114N, Power Projection Advanced Technology (line 16) is for "Precision strike technology excess growth." (Page 228) The recommended net reduction of $3 million to PE 0603673N, Future Naval Capabilities Advanced

Technology Development (line 21) consists of a reduction of $2 million for "Power and energy previously funded efforts," a reduction of $2 million for "Sea shield previously funded efforts," and an increase of $7 million for "Program increase—ASW [antisubmarine warfare] research." (Page 228)

H.Rept. 114-577 states:

> HIGH ENERGY LASERS
>
> The Committee is aware of efforts within the High Energy Laser Joint Technology Office to develop advanced, directed-energy, high energy laser weapons that have the potential to perform a wide variety of military missions. The Committee encourages the Secretary of Defense to explore further development and evaluation of this important technology. (Page 264)

Directed Energy Weapon Systems Acquisition Act of 2016 (H.R. 4964/S. 2778)

House

H.R. 4964 was introduced in the House on May 5, 2016. The text of H.R. 4964 as introduced states:

> SECTION 1. Short title.
>
> This Act may be cited as the "Directed Energy Weapon Systems Acquisition Act of 2016".
>
> SEC. 2. Findings.
>
> Congress makes the following findings:
>
> (1) The Committee on Armed Services of the Senate noted in the report accompanying S. 1356 (S. Rept. 114–49; 114th Congress) that since 1960, the Department of Defense has invested more than $6,000,000,000 in directed energy science and technology initiatives, and that the Committee is concerned that, despite this significant investment, the Department's directed energy initiatives are not resourced at levels necessary to transition them to full-scale acquisition programs.
>
> (2) The Defense Science Board Task Force on Directed Energy Weapon Systems and Technology Applications (the "Task Force") found that "directed energy offers promise as a transformational 'game changer' in military operations, able to augment and improve operational capabilities in many areas".
>
> (3) Despite this potential, years of investment have not resulted in any operational systems with high energy laser capability.
>
> (4) The Task Force believes that the range of potential application is sufficient to warrant significantly increased attention to the scope and direction of efforts to assess, develop, and field appropriate laser, microwave, and millimeter wave weapons.
>
> SEC. 3. Inclusion of directed energy weapon system programs in the rapid acquisition authority program.
>
> (a) In general.—Section 806(c)(1) of the Bob Stump National Defense Authorization Act for Fiscal Year 2003 (Public Law 107–314; 10 U.S.C. 2302 note) is amended by adding at the end the following new subparagraph:
>
> "(D) (i) In the case of any supplies and associated support services that, as determined in writing by the Secretary of Defense without delegation, are urgently needed to eliminate

> a deficiency in directed energy weapon systems, the Secretary may use the procedures developed under this section in order to accomplish the rapid acquisition and deployment of needed offensive or defensive directed energy weapon systems capabilities, supplies, and associated support services.
>
> "(ii) For the purposes of directed energy weapon systems acquisition, the Secretary of Defense shall consider use of the following procedures:
>
> "(I) The rapid acquisition authority provided under this section.
>
> "(II) Use of other transactions authority provided under section 2371 of title 10, United States Code.
>
> "(III) The acquisition of commercial items using simplified acquisition procedures.
>
> "(IV) The authority for procurement for experimental purposes provided under section 2373 of title 10, United States Code.
>
> "(iii) In this subparagraph, the term 'directed energy weapon system' means military action involving the use of directed energy to incapacitate, damage, or destroy enemy equipment, facilities, or personnel.".
>
> (b) Conforming amendments.—Section 2373 of title 10, United States Code, is amended—
>
> (1) in subsection (a), by striking "and aeronautical supplies" and inserting ", aeronautical supplies, and directed energy weapon systems"; and
>
> (2) by adding at the end of the following new subsection:
>
> "(c) Directed energy weapon system defined.—In this section, the term 'directed energy weapon system' means military action involving the use of directed energy to incapacitate, damage, or destroy enemy equipment, facilities, or personnel.".
>
> SEC. 4. Joint Directed Energy Program Office.
>
> (a) Redesignation.—The High Energy Laser Joint Technology Office of the Department of Defense is hereby redesignated as the "Joint Directed Energy Program Office" (in this section referred to as the "Office").
>
> (b) Strategic plan for development and transition of directed energy weapons capabilities toward fielding.—In addition to the functions and duties of the Office in effect on the day before the date of the enactment of this Act, the Office shall develop a strategic plan for development and transition of directed energy weapons capabilities toward fielding for the Department, in which the Office may define requirements for directed energy capabilities that address the highest priority warfighting capability gaps of the Department.
>
> (c) Acceleration of development and transition of directed energy weapons capabilities toward fielding.—
>
> (1) IN GENERAL.—To the degree practicable, the Office shall use the policies of the Department that are revised pursuant to this Act and new acquisition and management practices established pursuant to this Act to accelerate the development and transition of directed energy capabilities toward fielding.
>
> (2) ENGAGEMENT.—The Secretary shall ensure that use of policies and practices described in paragraph (1) include engagement with defense and private industries, research universities, and unaffiliated, nonprofit research institutions.

Senate

S. 2778 was introduced in the Senate on April 12, 2016. The text of S. 2778 as introduced states:

SECTION 1. Short title.

This Act may be cited as the “Directed Energy Weapon Systems Acquisition Act of 2016”.

SEC. 2. Findings.

Congress makes the following findings:

(1) The Committee on Armed Services of the Senate noted in the report accompanying S. 1356 (S. Rept. 114–49; 114th Congress) that since 1960, the Department of Defense has invested more than $6,000,000,000 in directed energy science and technology initiatives, and that the Committee is concerned that, despite this significant investment, the Department's directed energy initiatives are not resourced at levels necessary to transition them to full-scale acquisition programs.

(2) The Defense Science Board Task Force on Directed Energy Weapon Systems and Technology Applications (the “Task Force”) found that “directed energy offers promise as a transformational ‘game changer’ in military operations, able to augment and improve operational capabilities in many areas”.

(3) Despite this potential, years of investment have not resulted in any operational systems with high energy laser capability.

(4) The Task Force believes that the range of potential application is sufficient to warrant significantly increased attention to the scope and direction of efforts to assess, develop, and field appropriate laser, microwave, and millimeter wave weapons.

SEC. 3. Inclusion of directed energy weapon system programs in the rapid acquisition authority program.

(a) In general.—Section 806(c)(1) of the Bob Stump National Defense Authorization Act for Fiscal Year 2003 (Public Law 107–314; 10 U.S.C. 2302 note) is amended by adding at the end the following new subparagraph:

“(D) (i) In the case of any supplies and associated support services that, as determined in writing by the Secretary of Defense without delegation, are urgently needed to eliminate a deficiency in directed energy weapon systems, the Secretary may use the procedures developed under this section in order to accomplish the rapid acquisition and deployment of needed offensive or defensive directed energy weapon systems capabilities, supplies, and associated support services.

“(ii) For the purposes of directed energy weapon systems acquisition, the Secretary of Defense shall consider use of the following procedures:

“(I) The rapid acquisition authority provided under this section.

“(II) Use of other transactions authority provided under section 2371 of title 10, United States Code.

“(III) The acquisition of commercial items using simplified acquisition procedures.

“(IV) The authority for procurement for experimental purposes provided under section 2373 of title 10, United States Code.

“(iii) In this subparagraph, the term ‘directed energy weapon system’ means military action involving the use of directed energy to incapacitate, damage, or destroy enemy equipment, facilities, or personnel.”.

(b) Conforming amendments.—Section 2373 of title 10, United States Code, is amended—

(1) in subsection (a), by striking “and aeronautical supplies” and inserting “, aeronautical supplies, and directed energy weapon systems”; and

(2) by adding at the end the following new subsection:

“(c) Directed energy weapon system defined.—In this section, the term ‘directed energy weapon system’ means military action involving the use of directed energy to incapacitate, damage, or destroy enemy equipment, facilities, or personnel.”.

SEC. 4. Joint Directed Energy Program Office.

(a) Redesignation.—The High Energy Laser Joint Technology Office of the Department of Defense is hereby redesignated as the “Joint Directed Energy Program Office” (in this section referred to as the “Office”).

(b) Strategic plan for development and transition of directed energy weapons capabilities toward fielding.—In addition to the functions and duties of the Office in effect on the day before the date of the enactment of this Act, the Office shall develop a strategic plan for development and transition of directed energy weapons capabilities toward fielding for the Department, in which the Office may define requirements for directed energy capabilities that address the highest priority warfighting capability gaps of the Department.

(c) Acceleration of development and transition of directed energy weapons capabilities toward fielding.—

(1) IN GENERAL.—To the degree practicable, the Office shall use the policies of the Department that are revised pursuant to this Act and new acquisition and management practices established pursuant to this Act to accelerate the development and transition of directed energy capabilities toward fielding.

(2) ENGAGEMENT.—The Secretary shall ensure that use of policies and practices described in paragraph (1) include engagement with defense and private industries, research universities, and unaffiliated, nonprofit research institutions.

Appendix. Potential Advantages and Limitations of Shipboard Lasers

This appendix presents additional information on potential advantages and limitations of shipboard lasers.

Potential Advantages

In addition to a low marginal cost per shot and deep magazine, potential advantages of shipboard lasers include the following:

- **Fast engagement times.** Light from a laser beam can reach a target almost instantly (eliminating the need to calculate an intercept course, as there is with interceptor missiles) and, by remaining focused on a particular spot on the target, cause disabling damage to the target within seconds. After disabling one target, a laser can be redirected in several seconds to another target.
- **Ability to counter radically maneuvering missiles.** Lasers can follow and maintain their beam on radically maneuvering missiles that might stress the maneuvering capabilities of Navy SAMs.
- **Precision engagements.** Lasers are precision-engagement weapons—the light spot from a laser, which might be several inches in diameter, affects what it hits, while generally not affecting (at least not directly) separate nearby objects.
- **Graduated responses.** Lasers can perform functions other than destroying targets, including detecting and monitoring targets and producing nonlethal effects, including reversible jamming of electro-optic (EO) sensors. Lasers offer the potential for graduated responses that range from warning targets to reversibly jamming their systems, to causing limited but not disabling damage (as a further warning), and then finally causing disabling damage.

Potential Limitations

Potential limitations of shipboard lasers include the following:

- **Line of sight.** Since laser light tends to fly through the atmosphere on an essentially straight path, shipboard lasers would be limited to line-of-sight engagements, and consequently could not counter over-the-horizon targets or targets that are obscured by intervening objects. This limits in particular potential engagement ranges against small boats, which can be obscured by higher waves, or low-flying targets. Even so, lasers can rapidly reacquire boats obscured by periodic swells.
- **Atmospheric absorption, scattering, and turbulence.** Substances in the atmosphere—particularly water vapor, but also things such as sand, dust, salt particles, smoke, and other air pollution—absorb and scatter light from a shipboard laser, and atmospheric turbulence can defocus a laser beam. These effects can reduce the effective range of a laser. Absorption by water vapor is a particular consideration for shipboard lasers because marine environments feature substantial amounts of water vapor in the air. There are certain wavelengths of light (i.e., "sweet spots" in the electromagnetic spectrum) where atmospheric absorption by water vapor is markedly reduced. Lasers can be

designed to emit light at or near those sweet spots, so as to maximize their potential effectiveness. Absorption generally grows with distance to target, making it in general less of a potential problem for short-range operations than for longer-range operations. Adaptive optics, which make rapid, fine adjustments to a laser beam on a continuous basis in response to observed turbulence, can counteract the effects of atmospheric turbulence. Even so, lasers might not work well, or at all, in rain or fog, preventing lasers from being an all-weather solution.

- **Thermal blooming.** A laser that continues firing in the same exact direction for a certain amount of time can heat up the air it is passing through, which in turn can defocus the laser beam, reducing its ability to disable the intended target. This effect, called thermal blooming, can make lasers less effective for countering targets that are coming straight at the ship, on a constant bearing (i.e., "down-the-throat" shots). Other ship self-defense systems, such as interceptor missiles or a CIWS, might be more suitable for countering such targets. Most tests of laser systems have been against crossing targets rather than "down-the-throat" shots. In general, thermal blooming becomes more of a concern as the power of the laser beam increases.
- **Saturation attacks.** Since a laser can attack only one target at a time, requires several seconds to disable it, and several more seconds to be redirected to the next target, a laser can disable only so many targets within a given period of time. This places an upper limit on the ability of an individual laser to deal with saturation attacks—attacks by multiple weapons that approach the ship simultaneously or within a few seconds of one another. This limitation can be mitigated by installing more than one laser on the ship, similar to how the Navy installs multiple CIWS systems on certain ships.
- **Hardened targets and countermeasures.** Less-powerful lasers—that is, lasers with beam powers measured in kilowatts (kW) rather than megawatts (MW)—can have less effectiveness against targets that incorporate shielding, ablative material, or highly reflective surfaces, or that rotate rapidly (so that the laser spot does not remain continuously on a single location on the target's surface) or tumble. Small boats (or other units) could employ smoke or other obscurants to reduce their susceptibility to laser attack.[52] Measures such as these, however, can increase the cost and/or weight of a weapon, and obscurants could make it more difficult for small boat operators to see what is around them, reducing their ability to use their boats effectively.
- **Risk of collateral damage to aircraft, satellites, and human eyesight.** Since light from an upward-pointing laser that does not hit the target would continue flying upward in a straight line, it could pose a risk of causing unwanted collateral damage to aircraft and satellites. The light emitted by SSLs being developed by the Navy is of a frequency that can cause permanent damage to human eyesight, including blinding. Blinding can occur at ranges much greater than ranges for damaging targeted objects. Scattering of laser light off the target or off fog or particulates in the air can pose a risk to exposed eyes.[53]

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[52] See, for example, "Kelsey D. Atherton, "China Plans To Defeat American Lasers With Smoke," *Popular Science*, May 3, 2016.

[53] The United States in 1995 ratified the 1980 Convention on Prohibitions or Restriction on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or to Have Indiscriminate Effects. An (continued...)

For additional background information on potential Navy shipboard SSLs, see CRS Report R41526, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, by Ronald O'Rourke.

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(...continued)

international review of the convention began in 1994 and concluded in May 1996 with the adoption of, among other things, a new Protocol IV on blinding laser weapons. The protocol prohibits the employment of lasers that are specifically designed to cause permanent blindness to the naked eye or to the eye with corrective eyesight devices. The United States ratified Protocol IV on December 23, 2008, and it entered into force for the United States on July 21, 2009. DOD views the protocol as fully consistent with DOD policy. DOD believes the lasers discussed in this report are consistent with DOD policy of prohibiting the use of lasers specifically designed to cause permanent blindness to the naked eye or to the eye with corrective eyesight devices. For further discussion, see Appendix I ("Protocol on Blinding Lasers") in CRS Report R41526, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, by Ronald O'Rourke.

Torpedo & Directed Energy Weapons Indian Navy Perspective

RAdm Om Prakash Singh Rana, VSM,
Director General of Naval Armament Inspection

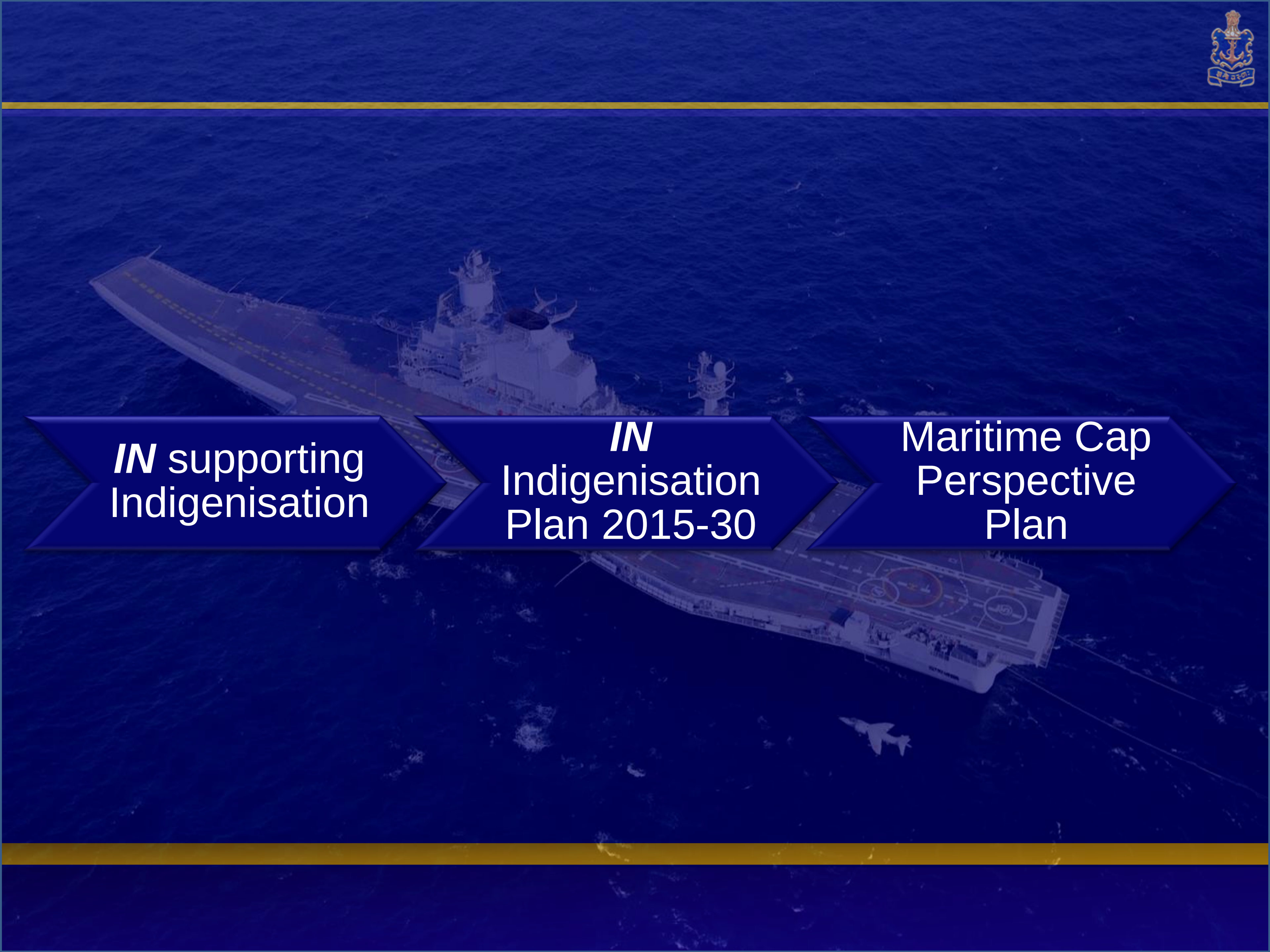

IN **supporting Indigenisation**

IN **Indigenisation Plan 2015-30**

Maritime Cap Perspective Plan

Self-Reliance

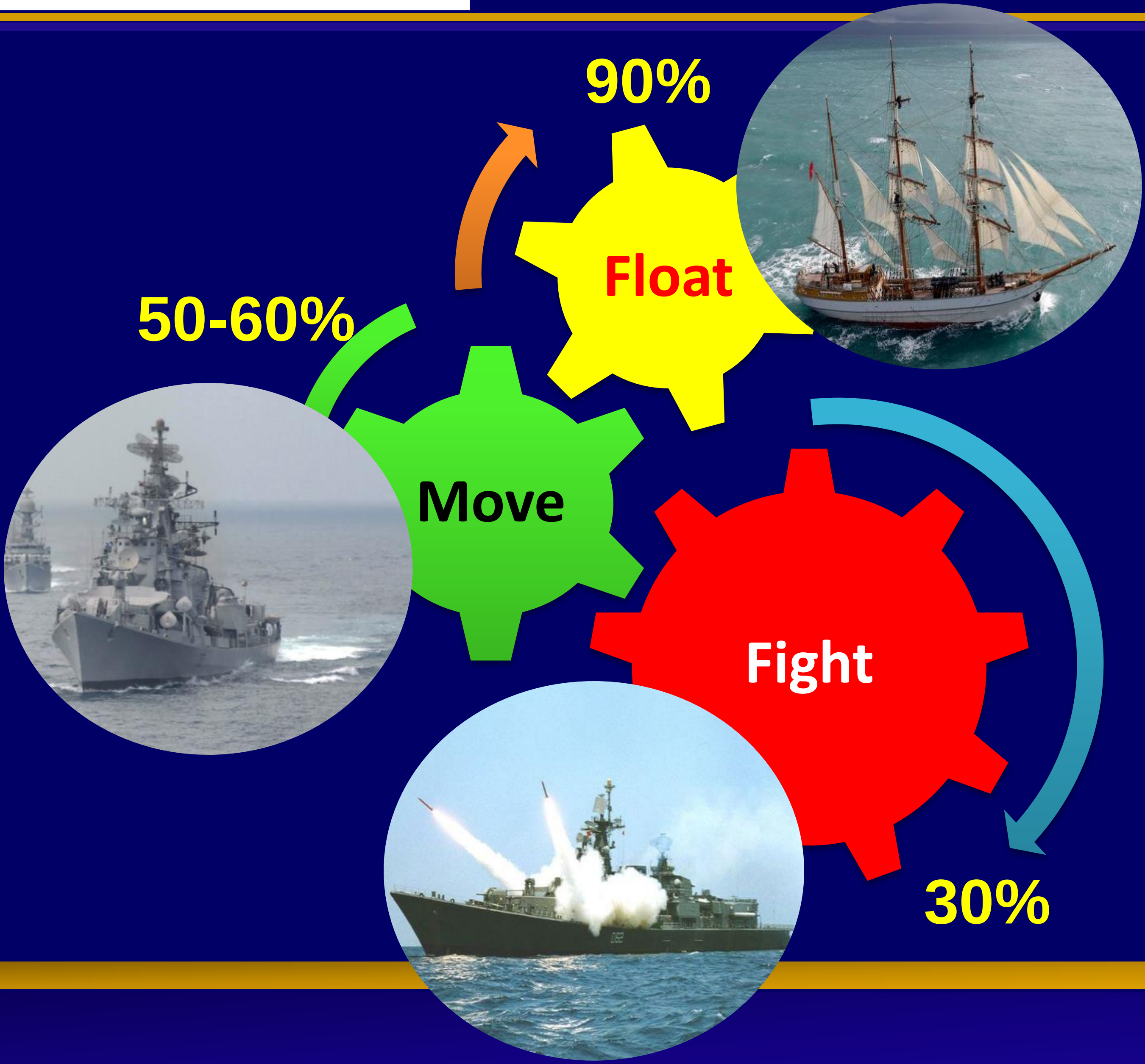

90%

Float

50-60%

Move

Fight

30%

Scope

MAD
RF
Lightweight Torpedo
Decoy
HMS
Lightweight Torpedo
TAS
Decoy
Dipping Sonar
Sonobuoy
Lightweight Torpedo

- Torpedo & Directed Energy Weapons
  - Technological advancement
  - Availability
- QRs for Torpedo & DEWs
- Way Ahead

Advancement
in
Torpedo Technology

Torpedo…….

Advancement in Torpedo Technology Contd...

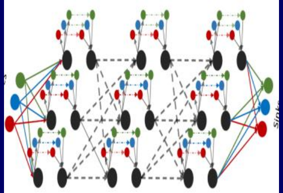

- Broadband sonar, multi-beam & INS
- Multi target tracking capability
- S/W based & high speed sig processing
- Re-programmable S/W & search pattern
- ACCM features
- Digital servo and retractable controls

Advancement in Torpedo Technology Contd...

- Al-Ag_2O, Li-ion & Cu-Ni batteries

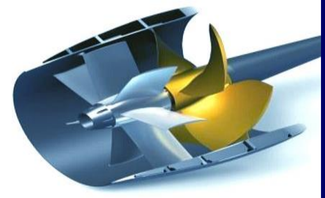

- Brushless motor & pump jet propulsion
- Semi open/close loop thermal propulsion

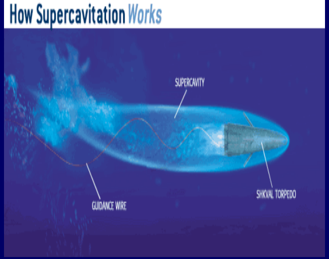
How Supercavitation Works
SUPERCAVITY
GUIDANCE WIRE
SHKVAL TORPEDO

- Super-cavitation propulsion

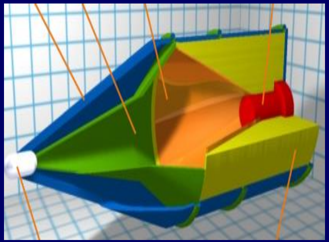

- Tandem shaped charge insensitive W/H

Torpedo…….

Advance Torpedoes

Torpedo	Origin	Speed (Kts)	Range (Kms)
Black Shark Adv	Italy	18- 50	>50
DM2 A4 Sea Hake	Ger	50	> 50
A244S MOD-3	Italy	36	13.5
Flash Black	Italy	50	20
F21 HWT	France	25-50	> 50
Spearfish HWT	UK	40	48
Torpedo (2000)	Swed	40	> 40
MU-90	Eutorp	50	23
MK 48 ADCAP	USA	55	38
MK 54	USA	28 -43	12
Shkval E	Russia	> 200	7 - 10
UGST	Russia	50	40

SeaHake
A·244/S mod.3
F21

Torpedoes in Indian Navy

Torpedo		Origin/ Country
A244S		Italy
AT1ME		Russian
MK 54		USA
TAL MK-I		**India**
53-65 KE		Russian
CET 65 E		Russian
TEST 71ME		Russian
SUT		Germany
Varunastra	VARUNASTRA NSTL, DRDO	**India**

Directed Energy Weapons

Directed Energy Weapons

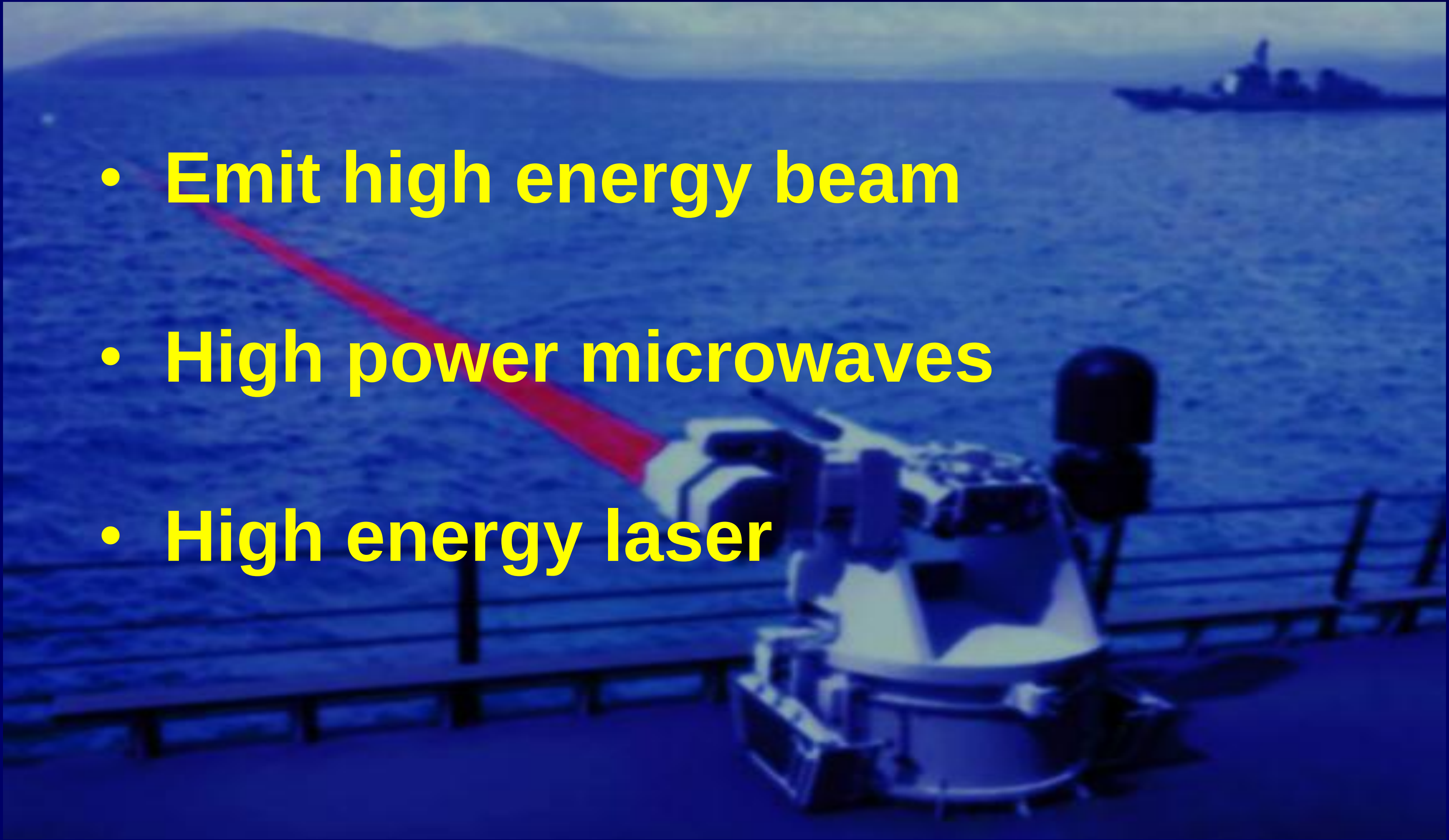

- Emit high energy beam
- High power microwaves
- High energy laser

DEW Advantages

- High Speed of Engagement
- Effective for Defensive/Offensive Role
- Immunity from Gravitation Constraints
- Space Requirement – Limited
- Effective against Moving Air Targets
- Minimal Collateral Damage
- Low Marginal Cost per Shot

High Energy Laser (HEL)
on Rocket from 1.6km away

DEWs from Sea, Air & Land Platforms

HE Laser Mobile Demon-strator **(USA)**

Electro-mag Rail Gun

(USA)

Active Denial System **(USA/ Israel)**

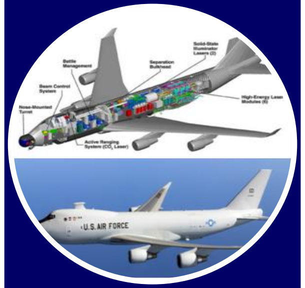
U.S. AIR FORCE

Airborne Ballistic Laser **(USA)**

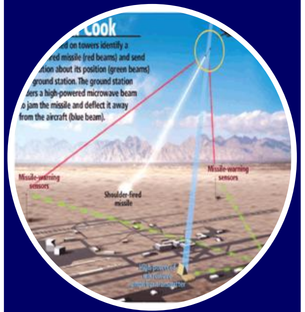
Missile-warning sensors
Shoulder-fired missile
Missile-warning sensors

Vigilant Eagle **(USA)**

Laser Weapon System

(USA)

DEWs in Indian Navy

DEWs not as potential destroyer

10 KW HEL demonstrated by DRDO

Work in progress for 25 KW HEL

Develop 100-500 KW HEL

Qualitative Requirements (QRs)

QRs….

QRs for Torpedoes

Require-ment	**Remark**
Speed	Upto 55 Knot with variable speed
Range	Upto 40 Kms
Battery	Mg-Cu_2Cl_2, Al-Ag_2O & Li-ion batteries
Propulsion	Gas turbine, brushless motor & super-cavitation
Warhead	Tandem insensitive munition W/H & prox EBW fuze
Guidance	CBASS & improved signal processing algorithm
Launch I/ P	Tactical S/W algorithm with target data & upgrades
Control	Intelligent digital controllers & actuators
Camouflage	ACCM features

QRs for DEWs

- 10-25 KW for non-lethal engagement
- 100-500 KW against:-
  - Missile
  - Rocket
  - Aircraft
  - UAVs

Way Ahead

Way Ahead….

Joint Venture

Requirement	**Scope for Designers & Industry**
Torpedo & Sub-systems	
Mech Parts, W/H & Prop	Al-Mg alloy, FRP & nano materials, **IM**, Mg-Cu, Al-Ag_2O & Li-ion batteries, brushless motor, GT, pump jet & supercavitation prop
Guidance & Control	Sonar imaging & det, CABSS, PCBs, tgt wake seeking, mag anomaly det & super quantum induction device homing, adv accl & sensors.
Process Control	Adv sig processing, tact S/W algorithm for tgt data, friendly forces positions, sound profile & mid-course upgrade, dig ctrl & actuator
Miscellaneous	Fibre optic cable, gene, invertor, shaft, bearing, gear box, bottle, gyro, pump, valve, fastener, cable, pipe, dynamic seal, loc & rec aids
Directed Energy Weapons	
DEW Systems	Ship borne 25-500 KW using High Power Microwaves or Lasers for non-lethal & lethal engagement

Way Ahead….

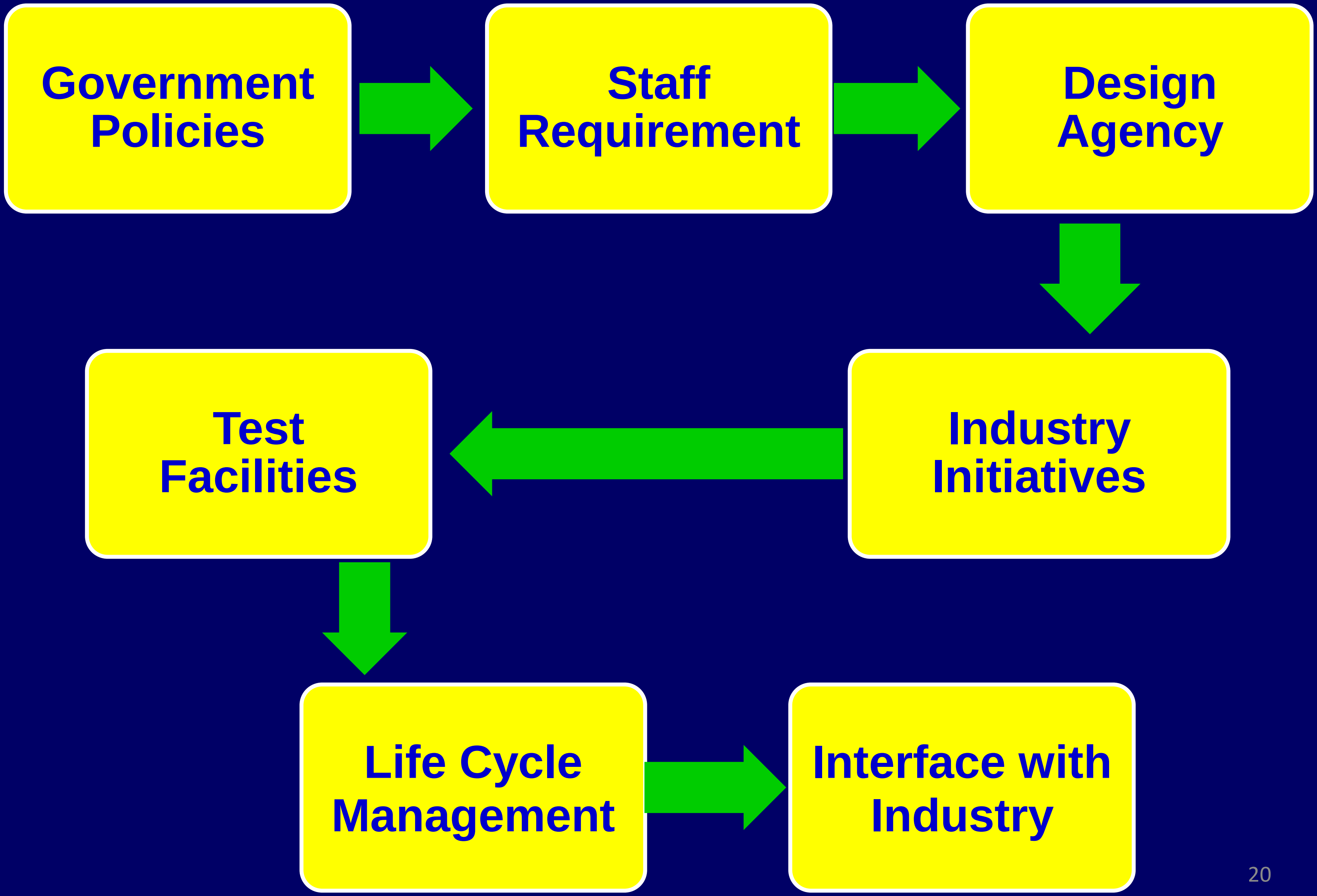

Government Policies

Staff Requirement

Design Agency

Industry Initiatives

Test Facilities

Life Cycle Management

Interface with Industry

Conclusion

- Govt promulgated various major policy guidelines
- ***IN*** "Indigenisation & MCPP"
- Harnessing knowledge base, infrastructures for "**Make in India**" prg under "**FIGHT**" category
- DEWs identified as core mil technology requirement
- Opportunities for strategic partnership

Thank You

5. Psychoenergetics

Mental entrainment, inducing hypnogogic trance, mind control, broadcasting thoughts and feelings, the Ant World, education via EM [LW] mental download, the "Feelies," revolution in spirituality, "enlightenment machine?" Scalar churches?

Psychoenergetics is simply *using the scalar interferometers to manipulate and engineer the human psyche*. To me it is the most mind-boggling and frightening aspect of longitudinal wave engineering.

The mind is electromagnetic in nature, and itself of the time-domain. It is not observable in 3-space. There is nothing you can point to that is the mind. As Bearden says, "The mind is time-like."

The longitudinal scalar EM waves are also of the time-domain. By overlaying certain infolded patterns (oscillations in time) on the longitudinal waves, a thought or feeling may be made to arise in a person or persons who are in the interference zone (where the wave beams cross).

The person will not notice anything, feeling that this thought or idea is his or her own idea. The longitudinal wave pattern might be a wave of panic or fear that spontaneously sweeps over you, perhaps inexplicably. It could even be in the form of a sudden intense patriotism. It could be explicit words and phrases, which everyone would think they had thought of by themselves. Or it could be rage and hatred, angry and violent. On the other hand It could also be a continuous sense of docility and placidity. This is the brave new world of *psychoenergetics and the coming "Mind Wars."*

Scalar Psychoenergetics in its most primitive form simply "entrains" all minds in the target area into a deep hypnogogic trance. In this state of mind people would be suddenly extremely suggestible, and would likely believe anything they are told, and would obey any orders given. Talk about winning the hearts and minds of the American People!

Tom Bearden makes me think of Paul Revere, who heroically conveyed important warnings for the sake of the new nation. But the words of the famous phrase have now strangely and curiously mutated into the once-inconceivable: "One if by land, Two if by mind."

Indeed one strategy in a Mind War would be to simply take over the minds of the "leaders" of the enemy nation. The targeted leader would not be aware that anything was amiss, although he might begin to make unexpected changes in policy.

And are, in fact, any of our "leaders" already having secret thoughts that are not their own? Who knows? Frighteningly, we can no longer be sure.

The new sciences of scalar electromagnetics and psychoenergetics are even now plunging humanity into a sudden science-fiction-like world beyond anything in humanity's previous imaginings.

> "The Russians reached the point in the mid 1990s that they could take over control of a person's mind, with modified longitudinal EM waves including some time-polarized EM waves, and with a team of specialists (estimate 25-30 per transmitter, and one transmitter and team per controlled person)."
> **Bearden: http://www.cheniere.org/misc/time.htm**

In a slide (below image) **Bearden** illustrates how a Scalar War would involve a psychoenergetics attack on the operators of the enemy scalar installation, entraining their minds into hypnogogic trance and getting them to shut down their systems.

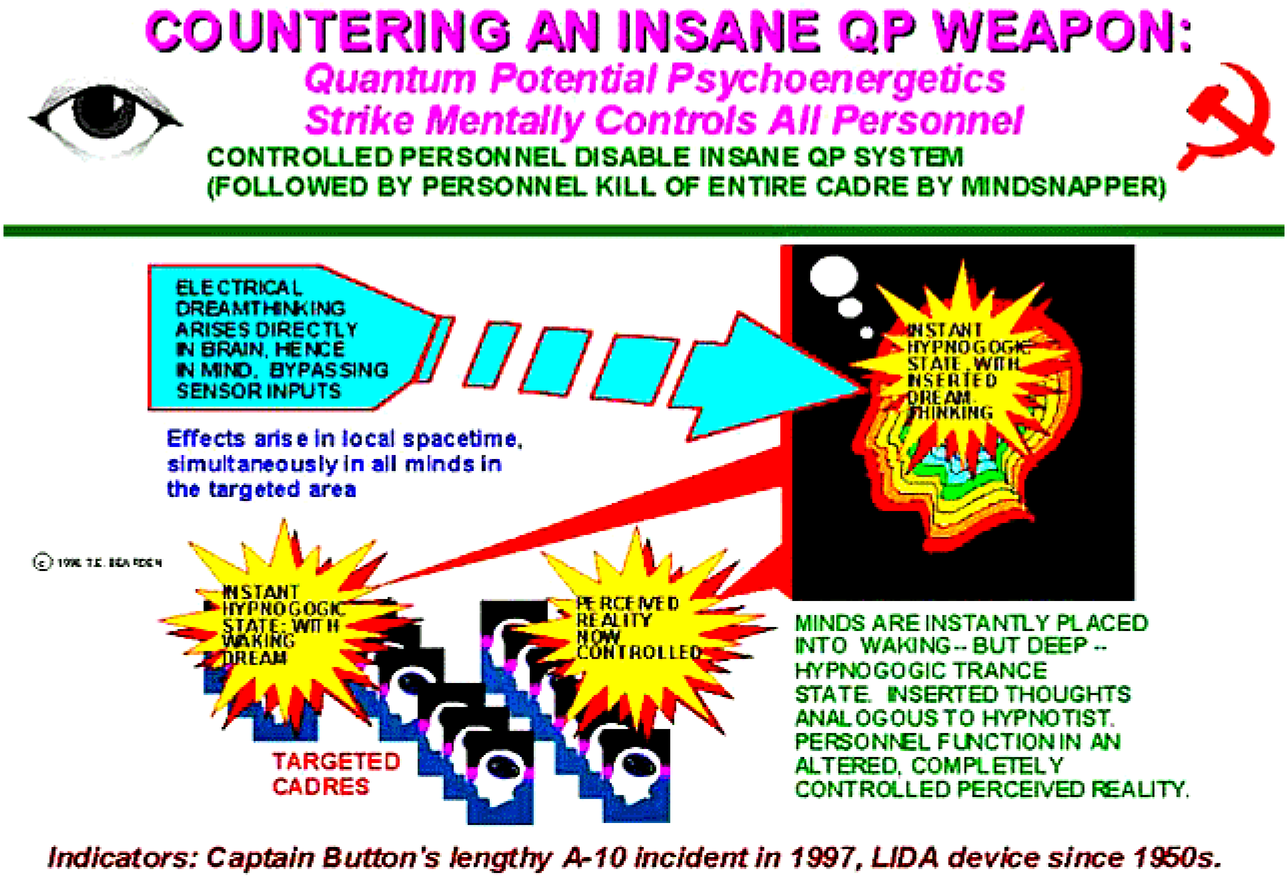
COUNTERING AN INSANE QP WEAPON:
Quantum Potential Psychoenergetics
Strike Mentally Controls All Personnel
CONTROLLED PERSONNEL DISABLE INSANE QP SYSTEM
(FOLLOWED BY PERSONNEL KILL OF ENTIRE CADRE BY MINDSNAPPER)
ELECTRICAL DREAMTHINKING ARISES DIRECTLY IN BRAIN, HENCE IN MIND, BYPASSING SENSOR INPUTS
Effects arise in local spacetime, simultaneously in all minds in the targeted area
INSTANT HYPNOGOGIC STATE, WITH INSERTED DREAM THINKING
© 1996 T.E. BEARDEN
INSTANT HYPNOGOGIC STATE: WITH WAKING DREAM
PERCEIVED REALITY NOW CONTROLLED
TARGETED CADRES
MINDS ARE INSTANTLY PLACED INTO WAKING-- BUT DEEP -- HYPNOGOGIC TRANCE STATE. INSERTED THOUGHTS ANALOGOUS TO HYPNOTIST. PERSONNEL FUNCTION IN AN ALTERED, COMPLETELY CONTROLLED PERCEIVED REALITY.
Indicators: Captain Button's lengthy A-10 incident in 1997, LIDA device since 1950s.

And ultimately psychoenergetic warfare goes to the very heart of human identity itself.

For if my thoughts might no longer be "mine,"

- Then who and what am I?
- Can my very sense of being "me" be hijacked by some nefarious psychoenergetic scheme?
- Will the "secret government" eventually dictate directly into your mind how you feel about yourself?
- Or what you think you are?
- Or what you should do?

How Does Longitudinal EM Mind Control Work?

The physics of **scalar psychoenergetics** as expounded by **Col. Bearden** seems even more arcane and over-my-head than that of extracting energy from the vacuum. I can't understand it, but I look through it anyway. Each time another tiny understanding might occur, or a term might fall into place. I know the mathematics is forever beyond me.

One paper to begin with is **Mind Control** and **EM Wave Polarization Transductions.** This is such serious stuff that **Bearden** includes a strong warning about misuse of this knowledge.

Psychoenergetics weapons can mentally maim and physically kill.

Warning!

(From "Mind Control and EM Wave Polarization Transductions")

> "This article refers to experimental research techniques which can be detrimental or lethal in the hands of any but highly skilled, qualified experimental scientists proceeding under proper laboratory safety procedures. The purpose of this article is strictly for information to properly qualified and authorized scientists in certified laboratories.
>
> We do not propose or condone any use of these procedures for non-approved practice of medicine without a license. Neither the publisher nor the author are responsible for accidents or outcomes in the use of these experimental procedures and techniques. Any researcher who performs these procedures and experiments is acting on his or her own volition, and is solely responsible for insuring safety, qualifications, and legality of the acts and their results.
>
> We neither suggest nor condone unauthorized experimentation on human subjects. Such is a criminal violation of the constitutional rights of the subject under Federal and State laws, and is both illegal and immoral."
> **Bearden: http://www.cheniere.org/explore articles/mind control1/p01.htm**

After the serious warning comes the description of the paper. This is heady stuff for the layman.

> "Calling full attention to the special note above, in this paper we present a high-level overview of the novel electromagnetic nature of mind operations, mind and body coupling, and intent - the induction of physical 3-space EM energy changes into the brain and nervous system, and into every cell of the body, from the mind's time-like coherent operations.
>
> We summarize the time-polarized electrodynamics used to engineer and affect mind operations and the mind-body coupling loop. Transaction mechanisms whereby differing EM wave polarization s can be transformed one-into-the-other are presented."
> **Bearden: http://www.cheniere.org/explore articles/mind control1/p01.htm**

I will leave it to the technically astute to try to understand the mechanisms of operation which are described in scientific language. But there are tidbits for the layman.

Here he speaks of the difficulty Western scientists have in opening up to the "immaterial" *(longitudinal wave)* nature of the human mind.

Western Science Remains Largely Materialistic

> "Ironically, most Western scientists are materialists and consider "mind" as a mystical and nonscientific concept. They tend to consider mind operations and functions either to be simply "meat computer" operations and functions, or at best to be very weak ordinary transverse-wave EM operations and functions in the brain and nervous system. This serious self-limitation exists because in the body we measure only weak TW [transverse wave] EM operations and functions correlated to biological behavior and brain operations. We simply do not know how to measure "mind operations" directly.
>
> "With no mind measurements possible and no instruments, it is understandable that Western science considers only the physical side of the mind-matter interface.
>
> "Presently our scientists do not measure the longitudinally-polarized EM wave operations and functions in the body and around it in nature. Few of them are aware that a maelstrom of such LW [longitudinal wave] functions exist in the body and in all of nature in general."
> Bearden: http://www.cheniere.org/explore articles/mind control1/p05.htm

Western methods of influencing the mind with EM waves have only used transverse waves, not the longitudinal waves of the vacuum.

If only transverse waves are used one pretty well has to hit the target mind with a sledgehammer of waves.

Western Science knows only transverse EM waves

Brute Forcing Time Functions versus Fine Control Methods

> "Ironically, Western mind control researchers using transverse EM waves for mind control research, are using a brute force method of evoking and using vacuum engines (spacetime curvature engines) and a special form of general relativity, although they do not appear to realize it.
>
> "While KGB scientists also use TW EM "brute force", TW waves when necessary, they do "imprint" or "activate" those waves with the desired internal LW and time-polarized EM wave and photon structures required to directly perform the mind engineering desired...
> Bearden
>
> "These "fitted brute-force models" certainly can be very powerful, and certainly can produce the exact results shown in the experimental verifications of the fittings. However, they do not of themselves allow sophisticated design for example of the necessary time-polarized wave assemblies for engineering the entire human collective unconscious simultaneously, or for engineering the entire collective unconscious of all species on Earth (i.e., Gaia's collective unconscious), or even for precisely engineering the memory and knowledge base of an individual.
> **Bearden: http://www.cheniere.org/explore articles/mind control1/p09.htm**

The seemingly magical operations of psychoenergetics, sometimes called "psychotronics," cannot be achieved with ordinary transverse EM wave energy. But they are possible with longitudinal scalar waves because the mind itself is scalar in nature.

> "We note that all mind operations are time-like, i.e., they are comprised as scalar EM photon functions and scalar EM wave functions. Thus the mind is a very special kind of electromagnetic system, existing in the time domain..."
> **Bearden: http://www.cheniere.org/explore articles/mind control1/p08.htm**

The engineering of the mind can only be accomplished with the waves of time.

The course of psychoenergetics development necessitates the building of a vast database of settings and patterns which bring about given mental and/or emotional states.

A kind of "gnome" of the psyche. Bearden describes the process of the decoding of this "gnome."

> "Now the scientists would perform many phenomenology experiments, making one little change at a time and profusely recording the data. Each time, they would establish the physical change(s) that occur in the body and/or the mental and emotional changes that occur in the mind for each spectral reinsertion back through the "ship’s portholes". They would simply but painstakingly (over some years) build up an extensive database of those individual correlates.
>
> "In these experiments, the experimenters will eventually be able to provoke any body or mind change they wish. Strong emotion. Intense pain. Intense pleasure. Painful thoughts. Images. Memories. Perceptions. Dreams. Visions. Memory losses. Memory changes. Personality changes. Etc. The "delta" in the emission spectrum (the changes from zero reference spectrum) represent the precise totality of all mental, physical, organic, chemical, etc. changes and interactions."
> **Bearden: http://www.cheniere.org/explore articles/mind control3/p01.htm**
>
> "A second stage in the research would be to test the correlates and porthole insertions upon a statistically significant cross section of ordinary people, and/or specialized populations (such as toughened soldiers). The program would evolve a highly complex, very effective, ever-improving science and technology of mind and behavior control and engineering mechanisms, complete with finished database and developed applications equipment."
> **Bearden: http://www.cheniere.org/explore articles/mind control3/p02.htm**

Summing up his paper Bearden speculates on what the actual situation the science of psychoenergetics probably is.

The intense secrecy with which this knowledge has been kept from the public has led to the current farce of the "government" pretending it all does not exist, and this secrecy may have now put us at great risk.

> "The implication is that in the West one or more highly classified, sustained, heavily funded developments in advanced mind control programs, probably exists and probably has existed for some time.
>
> Due to loose formation of rogue groups inside such programs, they may have dual or triple purposes, may not operate under very much legitimate government control at all, and may operate specifically for the purposes of the rogue group or groups that have gained control.
>
> "In a nutshell, that's what may be going on in the clandestine mind control projects in several Western governments. The involvement of at least some rogue groups, some being "cowboys" who operate well outside all laws and ethics, could also result in such things as assassinations, clandestine testing on individuals without their consent, etc. In short, it could account for what seems to be actually occurring.
>
> As also is "usual" in such a mess, one or more of the rogue groups eventually may become very powerful because their secret weapons are very powerful. They may become confident, thinking they have the "best in the world." They may actually believe they are ahead of the Russians..."
>
> "Remember that, in every large and powerful human organization, the basis for rogue groups is power and secrecy. They are always seeking to increase their power, control, influence, prestige, etc. Nothing else. Patriotism and mission are to rogue groups often just idle words. They have their own agendas.
>
> And being rogue groups, they may well bring in unethical, immoral tricks: assassination, bribery, entrapment, disinformation, plausible deniability, etc. A certain percentage of a highly secret rogue group will wind up using all these things and more. It's a human characteristic, the old primate dominance game. Only now disguised and hidden under deep classification."
>
> "The Russians, with their additional knowledge of the actual mechanisms in the transforms, will be much more advanced than the West, because their fundamental psychoenergetics science is far more advanced, so long as we continue to use the old U (I) electrodynamics.
>
> Further, the Russians have decades of use of longitudinal interferometry beams to reach right through the earth and ocean and produce stringent EM effects at a distance.
>
> So they will also be able to do the same things here in "mind control" with LW [longitudinal wave] interferometers, through intervening mass."
> **Bearden: http://www.cheniere.org/explore articles/mind control3/p05.htm**

Bearden cites two examples where he believes the Russian KGB tested the psychoenergetics capabilities of their scalar interferometers.

One was the case of Captain Button in his A-10 "Warthog" aircraft on April 2, 1997.

> "Over Arizona, Captain Button was thrown into a hypnogogic state, and his perceptions instantly altered and controlled. In his instant "dream-waking" state, everything seemed perfectly normal. His sense of direction was altered a bit more than 90 degrees, so he simply corrected and turned and "flew toward the range", actually flying off course by more than 90 degrees and ignoring radio contacts. He flew right on out of Arizona."
>
> "At one point he circled, probably thinking he was over the range, and he probably dropped his ordnance there. Then he "flew on back toward home," as he thought in his waking dream state, until his fuel ran out and he crashed and died in the explosion dream-thinking until he died that everything was normal.
>
> All the while, his sense of the passage of time was altered. To him, in his dream-thinking, dream-acting state, everything was normal and nothing untoward had happened. So the distant KGB transmitters and associated psychoenergetics team controlled him for over an hour.
>
>> "Indeed, that was the exact purpose of the test: demonstrate control (at a great distance) of a skilled person performing highly skilled tasks."
>
> **Bearden: http://www.cheniere.org/explore articles/mind control3/p06.htm**

The paper Mind Control and EM Wave Polarization Transductions ends with the most chilling and frightening possibility of all: the psychoenergetic engineering of the human species as a whole.

The Ant World

The Final Race for Direct Mind Control of the Entire Human Species

> "The KGB psychoenergetics weapons scientists because of their direct measurements and detections (and use) of t-polarized waves and LWs [longitudinal waves] for decades also understand that Jung's collective unconscious mind (of the entire human species) also has its own time-like operations and correlates, which one measures also when using t-polarization measurements and sorting it all out. The collective unconscious mind operations are buried several levels deeper inside the recursive Whittaker structuring inside the EM fields, waves, and potentials.
>
> "The KGB scientists also know that something very like Gaia a collective unconscious mind for all species on earth also exists, and they are striving to be able to sort out and measure that one as well. The Gaia operations are buried even deeper in the recursive structuring inside the EM fields, waves, and potentials."
>
> "Actually, from day one, the Russian mind control scientists have had their eventual goal set upon this "deeper area of mind and possible mind control" of the entire human species.
>
> "I am convinced that the KGB psychoenergetics scientists understand this deeper area. If they can learn to directly engineer the collective human species unconscious, they can then convert the human species easily into a sort of "ant" society, modeled along ideal Communism lines, except of course with an excluded "hierarchy at the top" running everything. The "ant society" communist style is still a variation of feudalism (all systems tend to feudalism or some form thereof).
>
> "The KGB psychoenergetics weapon scientists are seriously pressing on toward that very goal. In my opinion they are not very far from it right now...
>
> "Some versions of Russian mind control devices were used on Russian soldiers in the Afghan War to condition them for performance of merciless acts." 13
> **Bearden:** http://www.cheniere.org/explore articles/mind control3/p07.htm
> More about "The Ant World"

Whether it is the Russians planning an "ant world" society or rogue U.S. black-ops groups withholding a great boon from human race, the secrecy on all sides around has allowed largely criminal elements to take over this technology while leaving the civilized elements in the dark.

Openness and the spreading of this knowledge among good and decent people is essential, and for that we will have to overcome our frightened denial.

> "Meanwhile, rogue groups amongst Western clandestine mind control researchers will probably arise if they have not already done so. They will likely seek to increase their personal control and further isolate the programs from orthodox government review and from government and legislative control. They may even divert the research into highly illegal and unethical means, because it furthers their own rogue agendas. That is how clandestine U.S. government research can sometimes go sour, unless great care is exercised by the oversight committees in the House and the Senate.
>
> "Sometimes when rogue groups do gain control and total secrecy of a given new technological area, then what appears to be "U.S. government operations" do start to encompass a criminal and unethical operations, hidden usually beneath the deep veil of high classification. Also, if it's "scientific," no one is ever brought to justice, even if the "evil science actions" are uncovered and publicly revealed."
> **Bearden:** http://www.cheniere.org/explore articles/mind control3/p08.htm

Like the huge energy of the Tesla howitzers, the ability to engineer the mind with longitudinal waveforms is a seeming "magical" thing which can be used for good or ill. Bearden envisions that further developments will allow something like the "downloading" of knowledge via scalar interferometry. Everyone could be highly educated, and quickly and easily.

In the conclusion of the paper "Mind Control and EM Wave Polarization Transductions" Bearden makes a plea to the nations of the world regarding the use of psychoenergetic engineering.

> "Let us hope this great new area, already off to a bad start, can be bridled and steered in the direction helping and healing people, rather than killing or abusing them. The excesses in its bad use are a potent threat to all nations on earth.
>
> "Yet it can revolutionize medical science, education, communication, and psychology. We foresee the day - perhaps 30 years hence - when education will be accomplished by directly loading the software into the mind. Then in three weeks one will "load" a doctorate, say, in physics. In three more weeks on will also load a doctorate in chemistry. Another three weeks, in electrical engineering.
>
> Another three weeks, an MD And so on. When that happens then truly everyone on earth can be educated. Freedom from ignorance may well be another great freedom that is legally recognized.
>
> There will be no impoverished large groups lacking the education to find decent, productive jobs.
>
> "We urge all nations to use the principles involved: not for human abuse, but for healing, educating, uplifting, and life-expanding of every person on earth. If we do, we shall all have a far brighter future. Then we shall check what has started out to be the Sword of Damocles and turn it into the golden Millennium."
>
> **Bearden:** **http://www.cheniere.org/explore articles/mind control3/p08.htm**

(Perhaps after so many frightening topics a slight break is in order here to consider the lighter side of psychoenergetics. For example, what will be the ultimate impact on the entertainment industry?)

The Feelies at Last!

Psychoenergetics will be able to bring about at last, for better or for worse, Aldous Huxley’s fanciful idea in his novel "Brave New World," an entertainment format which he called "The Feelies."

Those were something you went to, like going to the movies, but you would experience all the actual feelings themselves, as if the depicted events were actually happening to you.

Although our "leaders" seem too dim to grasp what is going on in the world of scalar electromagnetics, it should not take some young Hollywood genius too long to understand that The Feelies are now possible, and that the immense megabucks of potential profit more than justify heavy investment in bringing it to market.

One can imagine that first "Feelie" theater, "The Huxley" perhaps, a large comfortable area surrounded by nine giant screens (not just one screen!), which become 3D if you put on your headset. And The Huxley is fitted with the finest sound, and oh, by the way, a modest sized scalar interferometer with computer. And there are one or more new tracks now recorded on the film next to the sound track.

These are the digital patterns of thoughts, feelings, and ideas to be fed into the theater’s interferometer. And these thoughts and feelings and ideas will be felt by the audience as if they were their own thoughts and ideas. It is an entirely new art form. Psychevision.

As important (and no doubt famous) as the actors would be the "feelers," those from whose minds the feelings were lifted in the original programming of the Feelie tracks. Because, for example, Brad Pitt might be a good and handsome actor, but can he really feel it? Like the dubbing of foreign language films, it might be necessary to dub the "emotional track" using a deeper and more profound person’s feelings, thoughts and ideas.

It might even be engineered so that if you sat on one side of the theater you would feel like the hero, and on the other side you would feel exactly like the bad guy! What would that lead to?

We have all cried at a movie some time, most people have, though they might not want to admit it. But this would be deep sobbing and a flood of tears, if the director so desired it. You would feel it at your core. Or, take a big chase scene, you would be terrified. They are breathing down your neck! You would be gripped by panic.

For that matter, the whole genre of Horror-Feelie would be too much for many people to take. Do I really want to feel that an actual vampire is tearing at my throat with his fangs?

A Religious Feelie would make you feel the exaltation of a saint at his prayers, or give you the definite feeling that you are Christ suffering on the cross. All the pain could be there too. The stickiness of the blood. The very feeling itself: "Why hast thou forsaken me?" Who among us could come up that despair for scanning?

Had this been developed a bit earlier we might watch a documentary of, say, Mother Theresa, containing her own actual deep sense of compassion, which we would feel arising in us as our own.

Then again, a Psychedelic Feelie could induce an LSD-like state and simply blow the audience’s minds.

Even in its simplest most primitive mode, the hypnogogic trance induction with its increased suggestibility, would completely alter the experience of even ordinary current movie going.

Go Back to Scalar War

Go Back to Psychoenergetics

<<< Scalar Wars

The Brave New World of Scalar Electromagnetics

by Bill Morgan

(See also **NEW 2007**: Book Review of Bearden's "Oblivion - America at the Brink")

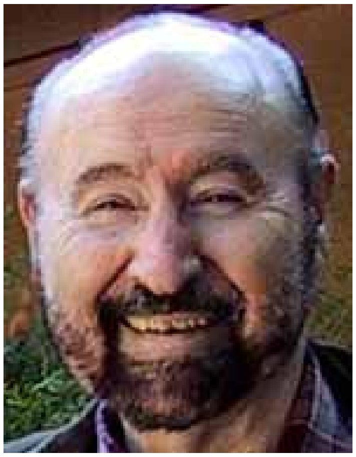

Tom Bearden (2001)
Lieutenant Colonel, U.S. Army (Retired)

For the past six months I have been undergoing the greatest **paradigm shift** I have ever had to go through. It has rattled my nerves and shaken my bones. This intense adjustment of my "world"has come about by studying the information given by Col. Tom Bearden at his website **Cheniere**. The new knowledge there has necessitated a total revision of my ideas about physical reality, the world we live in, and the future of humanity.

This paradigm shifting even actually made me dizzy on certain days as I tried to absorb and digest Bearden's vast amount of information. I am not a scientist at all, just a layman, and I have little comprehension of the math and high physics of this new science called "Scalar Electromagnetics."But there is a great deal of information at **Cheniere** which **needs to become common knowledge** as fast as possible, for the sake of the survival of life on earth.

To that end I have put together this small primer of Bearden's ideas, as a kind of "beginner's guide" to his website. (I have tried to underline certain words and phrases which are part of the new "jargon" of talking about these "new" phenomena. Also I have taken the liberty of **bolding** certain words and phrases to help them stick in the mind).

(Note: Throughout "**EM**" means "**electromagnetic,**" and "**LW**" means "**longitudinal wave**")
You can download this article in Word format

This article has six sections:

1. New Waves 2. Tapping the Waves 3. Weaponization 4. Healing 5. Psychoenergetics 6. As It Stands

2006 NOTE: Click here for a current status history of the MEG from Tom Bearden

1. New waves discovered

Longitudinal EM energy fills vacuum of space, the time domain of spacetime, time as compressed energy, E=tc2, waves of time, phase conjugate wave pairs.

> **"Electric power is everywhere present in unlimited quantities and can drive the world's machinery without the need of coal, oil, gas, or any other of the common fuels."** Nikola Tesla
>
> **"At any point and at any time, one can freely and inexpensively extract enormous EM energy flows directly from the active vacuum itself."** Tom Bearden

I guess the first thing to try to comprehend is that a **"new" kind of electromagnetic (EM) wave has been discovered** in the empty vacuum of space which, when engineered, can be an inexhaustible supply of energy in great magnitude at any place in the universe. The word "new" is in quotes because the

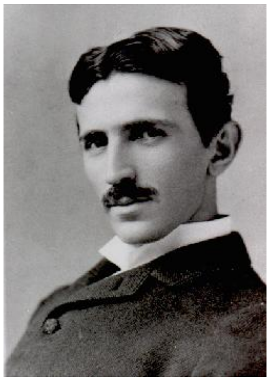

discovery really goes back to Nikola Tesla and his discovery of what he called "radiant energy." It is also not "new" because the Russians (KGB) have been working on this technology **for over 30 years** and have **weaponized** these "new" **longitudinal scalar waves** to a great degree.

These are the weapons Nikita Khrushchev spoke of in January, 1960.

> "By 1957-8 the Soviets had progressed to the point of a giant scalar EM accident in the Urals which exploded nearby atomic wastes, devastating the area. They had also progressed to development of great new superweapons using their new energetics - weapons to which Khrushchev referred in 1960 when he informed the Soviet Presidium of a new, fantastic weapon in development, a weapon so powerful that it could **wipe out all life on earth** if unrestrainedly employed.'" Tom Bearden

After over 30 years of development, and extensive testing around the globe, these new scalar electromagnetic weapons are up and running and ready to go. Tom Bearden, at his website Cheniere, dicusses the history of these new scalar electromagnetic weapons in his paper "Historical Background of Scalar EM Weapons."

Some Immediate Implications

> The implications of successful engineering of the longitudinal waves are enormous, and will change the world as we know it, one way or another. Among other things, these discoveries mean that:
>
> **1. The solutions to the energy crisis and the "oil problem" are in hand. These oil wars are unnecessary. There is endless energy available freely from the domain of time.**
>
> **2. Unbelievably powerful weapons are not only possible, but are already operating in several nations. The many powers of these weapons are unprecedented and mind-boggling.**
>
> **3. The cure of diseases such as cancer and AIDS, in fact nearly any disease, has become possible within a few years of sufficient funding. Everyone can be made healthy and stay healthy.**
>
> **4. Mind control on a mass scale has now become possible, and the machines to do it are already in place in certain nations. It has become possible to mentally enslave whole populations with the twist of a few dials.**

So the layman will need to understand that **there is a new kind of electromagnetic energy** that is altogether different from what he knows, e.g. radio, TV, cell phones, etc. The ordinary EM waves that we have known about are called **transverse** EM waves, to distinguish them from the new **longitudinal** EM waves. These scalar waves do not actually exist in our "material" world, but exist only in the vacuum of empty space, or the time domain. And we must keep in mind that this vacuum of space we speak of exists all through everything. Even our bodies are mostly empty space between atoms and molecules. So the gateway to this seething ocean of energy can be there at every point in the universe. This seething ocean of energy is all around us and all through us.

Emptiness is Full

This amazing discovery announces that **the "emptiness" of empty space is in fact not empty**, but a **great ocean** of seething energy!

Col. Bearden refers to this ocean of energy as being of the "time domain." Energy out of time? It seems like something from Star Trek but this is the point which the new science of scalar electromagnetics has reached. And where it is going may be beyond anything Star Trek could have dreamed of.

We live in a 3-dimensional world, which physics calls "3-space." But there is also **spacetime**, or 4-space, or the "4th dimension." Then suddenly comes this amazing new knowledge that **time itself is actually compressed energy**. And it is energy which is compressed by exactly the same factor by which **matter** is considered compressed energy: the speed-of-light-squared!

So we have a new companion to the famous **E=mc2**. It is now paired with **E=tc2** (where t is actually "delta-t," or change in time). Or (amaze your family and friends and) say:

"E equals em-cee-squared"

and

"E equals delta-tee-cee-squared"

It has a nice ring to it, like some freedom bell announcing a new era.

And as the atomic bomb released the compressed energy in matter, so can we now unleash **the tremendous energy that is compressed into time itself.** It gives a completely new meaning to the term "time bomb."

Some New Terminology of Scalar Electromagnetics

A new science, **several** new names

"Those [Russian] weapon scientists resurrected an old term from the history of electrodynamics, called "**energetics**". That is their approach to a **unified field theory**, where everything is based on "energetics". This model as its foundations uses a very similar approach to that "single fundamental unit" model, where energy is the unit. If one makes the energy EM in nature, then one has the Russian energetics approach. This unified approach gathers everything in, including all energy actions and relations in inert matter (the first branch of

> energetics, called by the same name), all field and matter interactions in living matter (the second branch of energetics, called "**bioenergetics**"), and all mind operations and mind-matter interactions (the third branch of energetics, called "**psychoenergetics**"). [ed: sometimes also called "psychotronics" by the Russians]
>
> "Note that the weaponeers sliced energetics into three branches, with each branch depending on the nature of the "targeting".
>
> "So I took a hint from them, since the stuff and the approach worked. They had already weaponized it highly."
>
> Bearden : http://www.cheniere.org/correspondence/021502a.htm
> See also "Subdivisions of Soviet Energetics"

Rick Andersen in an article called "What is Scalar Electromagnetics?" describes the **new science** this way:

"Scalar EM is the brainchild of Lt. Col. (retired) Thomas E. Bearden, a systems analyst and wargames specialist who has been advocating a view of electromagnetics which is based on the notion of a vast, unseen background of scalar energies (as opposed to vector energies) **which underlie all physical reality.**

"If Bearden is correct in his Scalar EM theory, then we can build devices which would enable us to **alter gravity**, time, inertia, and the apparent mass of an object. This of course has ENORMOUS implications for military applications, **space-vehicle drives, time-travel, teleportation, paranormal phenomena**, and just about every other area one can think of."
http://twm.co.nz/Beard_scalem.html

> **"Time-energy, time-currents, and time-structuring play the dominant role in electromagnetics. *Time-as-energy* eventually becomes engineerable, as easily as is spatial energy now. We are always dealing with *spacetime* and with *spacetime curvature*."**
>
> **Bearden:http://www.cheniere.org/techpapers/Vision%202000%20paper.doc**

The scalar energy discovered in the vacuum of space is sometimes called "**zero-point**" energy. Thomas Valone explains how this term came about.

What does "Zero Point" mean?

"Boyer traces the historical “creation of the vacuum” as proceeding in stages in parallel with the historical development of ideas about the vacuum. To paraphrase, he says that in the 17th century, it was thought that a totally empty volume of space could be created by simply removing all matter and, in particular, all gases. That was our first concept of the vacuum. Just get rid of all the gas.

Late in the 19th century, it became apparent that the region still contained thermal radiation. But it seemed that the radiation might be eliminated by cooling. So the second concept of getting a real vacuum is to cool it down to zero temperature. Just go all the way to absolute zero. Then we've got a real vacuum. Right? Well, since then, both theory and experiment have shown that **there is a non-thermal radiation in the vacuum** and that **it persists** even if the temperature could be **lowered to absolute zero**. Therefore, it was simply called the "**zero point**" radiation."

Thomas Valone http://www.seaspower.com/InsideZeroPoint.htm

"For our very survival, it is absolutely imperative that informed citizens be aware of this dramatic change, which is just now starting. The powerful new science and engineering must be controlled and used for humanity's benefit, not its detriment. Else it will eventually be let loose unrestrainedly, to destroy all life on earth - a possibility indicated by Nikita Khrushchev in 1960." - Bearden

http://www.cheniere.org/explore%20articles/priore1/p4.jpg

2. Tapping the waves

Endless free energy, Tesla's radiant energy, the dipole as the gateway to the energy of the void, MEG in one year, Bedini, Yakuza, etc. End of Oil, geopolitical chaos, rogue groups

Move Over G.E. & Big Oil, Energy is Everywhere!
Third-world nations set to rise

> "Certain powerful interests did not wish the extended electromagnetics to be discovered or taught. That, after all, would lead to **free energy** and loss of economic control of the citizens. That was precisely why Nikola Tesla had already been suppressed ... Today it is still being suppressed by the orthodox establishment."
> http://www.cheniere.org/books/ferdelance/s25.htm

The vast seething ocean of energy of the vacuum, the longitudinal scalar EM waves of the time domain, can now be tapped and "transduced" into ordinary (transverse) EM energy in our 3-Space world. The process can be compared to putting a paddlewheel into a river. The energy acquired is free, since the river is there flowing whether we tap it or not. And it is a mighty river, and is not diminished by our paddlewheel.

This means that **a permanent solution to the "energy crisis" is at hand**, if only those who hold it **so secret** would give it up to humankind.

It means our species' **insane use of oil** is no longer necessary. We can make automobiles that need no fuel at all. We can build motors that power themselves. It means that unlimited electrical power can be available for free anywhere in the world. Every house and even shack can have its own power supply.

Of course there is the cost of the equipment at first, but the energy flow is free for the presumably very long life (no moving parts) of the generator. It will probably take decades to shift over to scalar power.

But the ability to tap the scalar (longitudinal) EM waves of the vacuum (which exists everywhere) also means that **unbelievably powerful weapons** can be, and already have been developed. In fact these weapons are so dangerous that the **fear engendered** becomes a psychological obstacle to the grasping of the facts.

I struggled with this myself for months, and even though Tom Bearden had completely convinced me already, it is hard to accept the fact that for everyone on earth the "worst that might happen" has suddenly gotten much worse. It takes time to deal with that, to realize it and get over it.

Indeed, the possibilities of these new weapons, which are tapping the **huge energies of time**, are so terrifying it is natural for the mind to simply say: "I don't want to hear about that."

And the government, likewise, pretends these weapons do not exist and tries to keep it secret from the people. Because **most people would indeed be truly alarmed** to know the actual situation. Col. Tom Bearden has decided that the people need to know the truth anyway. As a People on a Planet we must face this now, and **ban the use of scalar weapons in war or in mass mind control**. The current deployment of these weapons is a **world emergency** which we must all face.

The physics and mathematics of the longitudinal waves and the time domain are clearly beyond the layman, but I recommend scanning through them anyway just to get a sense of the wonder and the elegance of it all and some of the exotic terms which are used. Two of the most important papers by Col. Bearden are:

Giant Negentropy from the Common Dipole
The Final Secret of Free Energy.

Despite the complexity of the science involved, Bearden sums up the **essential secret** of it all in a few words.

> "There is no problem at all in extracting all the energy one wishes from the active vacuum, anywhere in the universe, at any time. **Just make a dipole.**
>
> The problem is in (1) catching some of that freely gushing EM energy in a circuit containing a load, and (2) dissipating the caught and collected EM energy in that load to power it, without using half the caught energy to destroy the source dipole's).
>
> That is the ONLY real energy problem on the planet, and always has been."
>
> http://www.cheniere.org/correspondence/022502.htm

A dipole could be a battery, which is polarized into negative and positive. Or the terminals of a generator. Or any magnet with its two poles. Or an atom with its positive and negative charges. Or the earth's magnetic field, the sun, and all heavenly bodies. Even a galaxy must be some kind of mega-dipole. Wherever there is a dipole there is already immense scalar EM energy ushering out of and back into the vacuum. And there have already been demonstrated a number of diverse methods for tapping that energy as it flows. (John Bedini, Edwin Gray, Bruce de Palma, and others). Bearden provides what he calls a "partial list" on his website.

> "In other words, **nature then gladly gives us** as much EM energy flow as we need, indefinitely — just for paying a tiny little bit initially to "make the little dipole." After that, we never have to pay anything again, and nature will happily keep on pouring out that 3-flow of EM energy for us. This is the **giant negentropy** mechanism I uncovered, performed in the simplest way imaginable: just make an ordinary little dipole." Bearden
> http://www.cheniere.org/techpapers/Unnecessary%20Energy%20Crisis.doc

Important note 2006: Since the enthusiastic early report below, the hopeful timetable envision has gone quite off track. Bearden had said that the MEG could appear as early as 1-2 years ***after getting funding*** for the final research and scale-up. They have **still** NOT gotten the funding as of 2006.

Click here for a current status history of the MEG from Tom Bearden

The original text of article continues here...

How to Buy a Free Energy Machine

Answer: Just wait one more year! 2003. Then get off the Grid!
[note 2006: The above line was unfortunately naive and overly optimistic! - author]

Perhaps the most eagerly awaited event now is the marketing of Bearden's **M**otionless **E**lectromagnetic **G**enerator (MEG) scheduled to begin in about a year's time. This is when the proof will hit the fan. Many people have said to me, when talking about free energy, "I'll believe it when I can go to the store and buy one." Hopefully in a year's time they will be able to order their own MEG. And then they will believe, because it works and is working.

Says Bearden: "I will admit that the chief scientist of an important experimental group in a large company was rather stunned at the type of output we were able to obtain. The MEG may look like just a transformer, but it is not. It is a completely different breed of cat."

Bearden : http://www.cheniere.org/correspondence/011202.htm

Soon the cat will be fully out of the bag. The first MEG units will supply 2.5 kilowatts of free electricity. Forever. Units can be connected together to double or triple the wattage. After that gets going, 10 kilowatt generators are planned. Energy will flow freely from the time domain indefinitely, and there are no moving parts to wear out. This manufacturing project is a heroic effort and will change the world as we know it. For once people are in possession of such devices there can be no further denial from anyone, including the government and/or "secret-government."

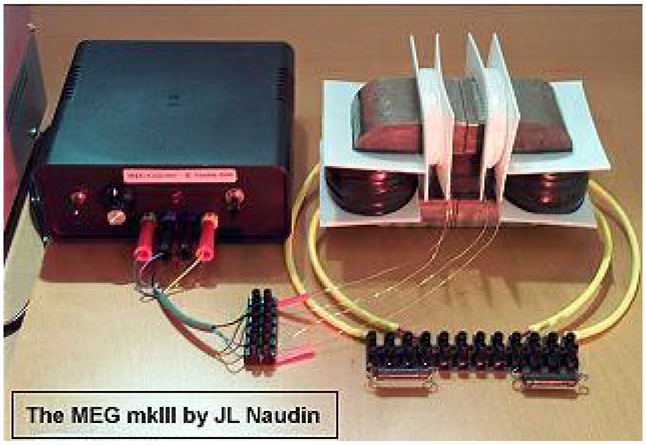

The Motionless Electromagnetic Generator
(Successfully replicated here by J. L. Naudin)

The physics of how the MEG works is explained in the paper "The Motionless Electromagnetic Generator: Extracting Energy from a Permanent Magnet with Energy Replenishment from the Active Vacuum."

The device was successfully replicated by J.L. Naudin in France, and others, like Steve Utne, are also working on their own models. But **Magnetic Energy Limited's MEG** is actually scheduled for production soon and looks to be the first commercially available free-energy generator in history!

I imagine it will not take long for tinkerers to put them into their electric cars and make the first fuelless automobiles since Tesla's unheralded (and unheeded) experiments. Or for builders to begin building houses powered by MEG's. Houses which will never see electric bills. How can they ever make enough of these to meet the demand that will suddenly be there? Bearden is right, it needs to be an all-out crash program of the government **on the order of the Manhattan Project**.

I must include here that Bearden is quick to point out that he is not himself the inventor of the MEG, but is a partner and advisor in bringing it to the public market through **Magnetic Energy Limited, Inc**. I must also admit that I am praying for the success of this venture, and the ending of the absurd and criminal withholding of this technology from the people by the black-ops military-industrial people. This secrecy has cost the planet over 30 years of unnecessary pollution.

The first units off the assembly line, which is being set up in a "friendly" unnamed nation, will usher the public at last into the new era of scalar electromagnetics.

As of December, 2001, the situation with the MEG was described by Bearden in a letter.

> "What we presently have with the MEG is a successful laboratory experiment. At least a year's very hard research will have to be done before we will be ready to put a commercial power supply into production.
>
> "Consequently, we have made an agreement with a foreign partner (the National Materials Science Lab of the National Academy of Sciences of a friendly foreign nation) to do that year's research. At the same time, we are trying to make an agreement with one or more large financial partners here in the U.S." http://www.cheniere.org/correspondence/121901.htm

> "So we are hopeful that we will be able to start introducing units on the market about a year from now. Quite simply, we will either succeed or we will fail. But we will give it our very best effort."
> http://www.cheniere.org/correspondence/012202a.htm

Bearden has given another technical explanation of how the MEG works here in a letter.

Update : Motionless Electromagnetic Generator patented, 3-26-2002

Click here to read the patent

"In Magnetic Energy Limited, all business discussions and arrangements are taken care of by Dr. Lee Kenny, Managing Partner. There are five of us who are co-inventors of the MEG, and two of the others are really the principal inventors." Bearden
http://www.cheniere.org/megstatus.htm

Lee Kenny can be reached by E-mail at: jlkenny@ingr.com

Free Energy has been Suppressed

Secret Government Aware of Free Energy

"In this world of contemporary times, all the agencies, CIA, FBI, KGB, NSA, Electric Power Research Institute, DARPA, Brookings Institution, Henry Kissinger, Edward Teller, et al., all are aware of [free-energy researcher Bruce] DePalma and his ideas.

"Because these individuals and institutions are employed by the ruling elite to forecast the future and satisfy present needs and demands, it is clear that **free energy is a threat** to the world order constructed by **business** and the **mindset of those who want to own the world**.

"Free energy represents Man's aspirations and dreams of freedom and equality, uniform division of resources and the ability to choose one's own future.

"**The fact that free energy is suppressed speaks to the greed and self-interest of a ruling elite** which, even in the face of an emergency of global starvation, resource depletion and environmental pollution, will not give one inch if it means loss of control. This is an attitude of **paranoid delusion** and fantasy which can only arise from the alienation of a **class of elitists** who, through their money, are completely **insulated** from the reality of the day to day fight for existence of the common man."

http://depalma.pair.com/Absurdity/Absurdity07/ProblemOfFreeEnergy.html

"Before the turn of the century, **Nikola Tesla** had discovered and was utilizing a **new type of electric wave**. Tesla repeatedly stated his

> waves were non-Hertzian, and his wireless transmissions did not fall off as the square of the distance. His discovery was apparently so fundamental (and his intent to provide free energy to all humankind was so clear) that it was responsible for the withdrawal of his financial backing, his deliberate isolation, and the gradual removal of his name from the history books."
>
> Bearden http://www.cheniere.org/books/part1/starting%20pages.htm

Bearden describes one clear case of the suppression of free energy when the Yakuza killed the **Kawai engine** in his very presence in Huntsville, Alabama.

> "That night a jet arrived from Los Angeles, with a Yakuza on board. The next morning Kawai no longer controlled his company, his invention, or his own fate. The Kawai party was in fear and trembling. The Yakuza coldly dissolved the agreement, they packed up the two Kawai engines we had, and left. And that was that."

So it is not only governments who are keeping this revolutionary technology from seeing the light of day. The Yakuza? KGB? The Aum Shinrikyo cult? Our "leaders" need to be honest about what is going on, otherwise they look foolish, acting out a kind of "Alice In Wonderland" script before the public, a script that has become completely unbelievable.

Concerning the criminal withholding of this scalar technology by the military black-budget people, and the cover-up of the actual situation regarding scalar weapons throughout the world, Tom has this to say:

> "The high government officials of the United States of America grossly violated our constitution and their sworn oaths of office. Our constitution specifically charges the government of the United States to **defend** the people of the United States. That means our officials are specifically charged with defending our people. Yet they deliberately agreed not to do so, and they deliberately sacrificed us in advance.
>
> **"They committed treason of the highest kind, by deliberately surrendering us to total destruction anytime the big balloon goes up.**"
>
> Bearden http://www.cheniere.org/books/ferdelance/s75.htm

Energy Crisis Solved

One of the "must read" documents at Cheniere is The Unnecessary Energy Crisis: How to Solve It Quickly, especially since the "**oil wars**," which Bearden has foreseen for decades, have now already begun.

Here are some clips from that Document:

> "To avoid the impending collapse of the world economy and/or the destruction of civilization and the biosphere, we must quickly replace much of the "electrical energy from oil" heart of the crisis at great

> speed, and simultaneously replace a significant part of the "transportation using oil products" factor also.
>
> "The technical basis for that solution and part of the prototype technology required, are now at hand. We discuss that solution in this paper." Bearden

And although the solution to the energy problem and the oil wars may be at hand, Bearden suggests there is still an urgent rush that needs to be made to save human civilization from collapse.

> "Once the technology hardware solutions are ready for mass production, even with a massive worldwide deployment effort some five years are required to deploy the new systems sufficiently to contain the problem of world economic collapse. This means that, by the end of 2003, those hardware technology solutions must have been completed, and the production replacement power systems must be ready to roll off the assembly lines en masse.
>
> "The 2003 date appears to be the critical "point of no return" for the survival of civilization as we have known it.
>
> "Reaching that point, say, in 2005 will not solve the crisis in time, and the collapse of the world economy as well as the destruction of civilization and the biosphere will still almost certainly occur, even with the solutions in hand."
>
> "The **good news** is that we now know how to easily initiate continuous and powerful "electromagnetic winds" from the vacuum at will. Once initiated, each free EM energy wind flows continuously so long as the simple initiator is not deliberately destroyed."

On page 9 he explains the concept of the **dipole**, and how there is already huge scalar energy flowing in the time domain around any dipole. Hold a magnet or a battery in your hand and you hold a stress in time and a beautiful flowing loop of longitudinal waves!

Bearden decries the scientific community in the West for being unable to let go of their dogma long enough to see that the **greatest discovery in human history** lies at their feet, but for their stubborn ignorance.

> "The present energy crisis then is due totally to that "**conspiracy of ignorance**" we referred to, that is maintained by the scientific community, and that has been maintained by it for more than 100 years.
>
> "This is the real situation that the environmentalists must become aware of, if they are to see the correct path into which their energies and efforts should be directed — to solve both the energy crisis and the problem of gigantic pollution of the biosphere."

As far as anyone in the legislative branch of government ever understanding the profundity of the discovery and engineering of scalar waves, Tom Bearden says they are at a great disadvantage in doing so.

> "The nontechnical person — e.g., a Senator or a Congressperson — is operating under a distinct disadvantage. If he or she takes the stance that much better electrical power systems can readily be achieved, **he or she is in fact opposing almost the entire set of University, Government Technical, Power Company, Battery Company, and Organized Science communities**. Further, in most cases his technical advisors are themselves from one or the other of those communities, and likely to go back into that community or those communities when the Senator or Congressperson leaves office, or even before. So the Congress and the non-technical government community at large operate at a great disadvantage...Bearden

National Emergency Declaration is Needed

"The Government *Non-Technical* community (the Senate and the Congress, in particular) are in far better shape than the Government *Technical* community, to appreciate the **world implications of the pending economic disaster**. I am hopeful that both the environmentalists and the Government Non-Technical community will rapidly unite in a common goal to **get this vacuum energy program launched**, under a **National Emergency** declaration. If so, then they can solve the energy crisis and the pending economic crisis, in fairly short order, and permanently."

unnecessary_energy_crisis.htm#congress_disadvantage

In the conclusion of his paper The Unnecessary Energy Crisis: How to Solve It Quickly Bearden again states the urgency of replacing our centralized power grids with highly dispersed and local taps on the freely flowing energy of the active vacuum. Given the abilities of the Tesla howitzers, the power grids of all nations are sitting ducks.

"Personally, the present author regards the increasing **energy crisis as the greatest strategic threat** to the United States in its entire history. I will do anything within my power to help prevent what I perceive to be the looming economic collapse of the Western world, preceded or accompanied by a sudden, explosive, all-out and continuing exchange of the WMD arsenals of most of the world.

...*In the name of all humanity, let us begin!* Else by the time this first decade of the new millennium ends, much of humanity may not remain to see the second decade."

3. Weaponization

Scalar interferometry, Tesla howitzer, Tesla dome, heat/cold, dudding, 10 nations have them, dead-man fusing & Insane Systems, scalar strategy, earthquakes and weather wars, solar storms, mind attacks, leased to Yakuza, many examples of testing, quantum potential weapons.

> **"Indeed, Soviet energetics weapons are now capable of destroying both our triad shield, our homeland, our armed forces in the field, and our population, quickly and efficiently. We have a new "gap" of monumental proportions: not a missile gap, not a submarine or bomber gap, and not even a particle beam or laser gap. We have a scalar electromagnetics or electrogravitation gap."** Bearden
> http://www.cheniere.org/books/ferdelance/intro.htm
>
> "**We have a new weapon, just within the portfolio of our scientists, so to speak, which is so powerful that, if unrestrainedly used, it could wipe out all life on earth. It is a fantastic weapon."** Khrushchev, to the Presidium, Jan. 1960
>
> "We've totally missed the most incredible "secret superweapons" development program of all times, and the worldwide testing of the weapons themselves.
>
> "Hiroshima and Nagasaki should serve as object lessons in the price of ignorance of such technological breakthroughs.
>
> "History does repeat itself. But this time it's not we Americans who got the great new superweapon first."
>
> Bearden http://www.cheniere.org/books/ferdelance/s75.htm

Warfare has been changed forever by the development of these scalar energy longitudinal wave howitzers. To get a basic understanding of scalar waves is to have the imagination suddenly run wild as all the implications and possibilities regarding warfare fall into place. One realizes with a certain horror that the world has totally changed, and that there are some very fearsome possibilities. Remember, the power for these weapons comes from the time domain, longitudinal EM waves in the vacuum of empty space, and the power is tremendous and mind-boggling. Being able to blast away at any target from a distant control booth is something that has never happened before. This is incredible power to be in control of and it divides the history of weaponry into "before" and "after." And the destructive power of these weapons is delivered instantaneously to the target **from the local vacuum at the place of the target.**

From an interview:

Questioner: "Are you saying that real energy can be transmitted faster than the speed of light?"

Bearden: "Yes. But hyperspatially. Not through 3-space, but "around" it. Again, this means that it's possible to produce energetic changes in a distant system at a distant place, without transmitting energy "through space" in the normal sense. You transmit "around" space, so to speak, and directly in time or through a higher dimension, depending on the model you're using to understand this. Further, the speed of the internal EM energy transmission is not limited to the speed of light."

http://twm.co.nz/beard_interview.htm

Here are some initial considerations about scalar weapons and scalar wars

1. Tesla Howitzer 2. Tesla Domes 3. Rogue groups 4. WW III 5. Russian "UFOs?"

1. The Tesla Howitzer and its modes of action

Source: Tom Bearden's weapons slides and Fer-de-Lance Briefing

For one thing there is no delivery of any thing to any place. Bombs are obsolete. So are the planes to get them there. No helicopters necessary. All current nuclear devices are rendered nearly useless by electronic "dudding." All distant-destruction can be done from a control room, and to any point on earth. The destructive power of "men" has just increased by orders of magnitude. The new weapons could even cause storms on the sun! Thus there is great urgency to make these **new facts public** and known, with the hope that all nations would come together to ban the use of scalar weapons.

Two scalar antennae together along with the computers to control them, make up a scalar interferometer, and according to Col. Bearden the Russians have hundreds of such installations already. These interferometers are called "**Tesla Howitzers**." They can deliver a giant blast of energy to the distant target site, true "action-at-a-distance".

The **first howitzer mode** is called the "**exothermic**" mode of operation because immense EM energy blasts outward at the target site. The blast of a scalar howitzer can be of near nuclear level in destructiveness, and can be repeated easily, at that place, or nearby, or anywhere.

The howitzer can use a lesser exothermic power setting and simply **destroy all electronics** in the target area. Thus they can render our nuclear missiles inoperable as they sit in their silos by "frying" the electronic circuits that guide them. They can bring down any airplane, anywhere in the world, at any time. Any person anywhere, if their exact position is known, can be assassinated without a shot being fired.

The howitzers can also bring down power grids anywhere in the world, at any time. Thus they could bring Wall Street to an instant halt by disabling all its electronics. Even this one little easy tweak of the howitzer could cripple the U.S. economy in a single day. No wonder the "**leaders**" don't want you to know! This is a new era we are in. The discovery and development of scalar interferometry has put us in a **new world**, whether we like it or not. Anyone could be expected to go into denial, the **befuddled** senators and congressmen included. But we have **to wake up**.

In a **second howitzer mode** called the "**endothermic**" mode, the howitzer sucks energy out of the target area, essentially creating a blast of cold at the distant target. It is even capable of freezing parts of the ocean. Bearden gives a number of cases where these "**cold explosions**" have been witnessed, mostly by airline pilots. April 9, 1984: 1 2 3) A huge mushroom cloud of mostly water is seen rising miles into the sky from out of the ocean, an awesome sight.

In the endothermic mode the sucked-out energy must go somewhere, so it is vented out at some other chosen spot on the earth. These endothermic plumes have been photographed by satellite.

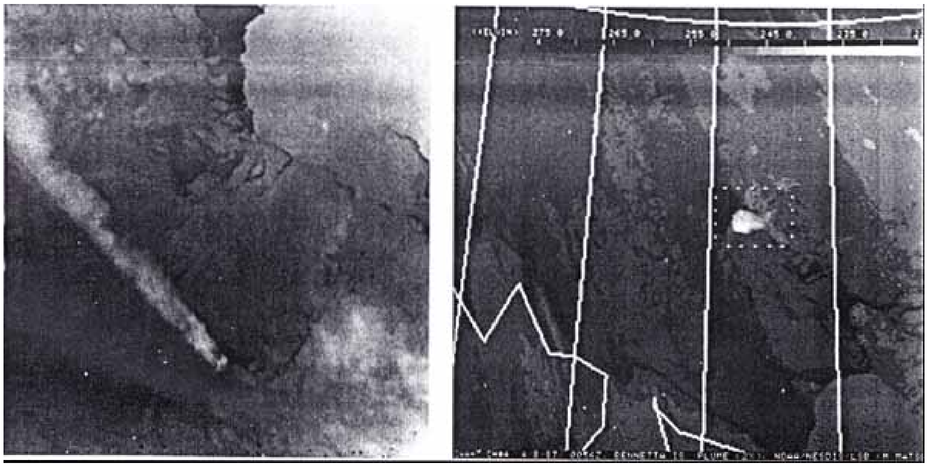

"The exhaust in the left picture is about 150 miles long, and is nearly horizontal (about 1.5 degrees above the horizontal). It is entirely consistent with the continuous exhaust from a "dumping transfer" scalar EM howitzer in the continuous exothermic mode. (The primary howitzer, of course, was activated in the endothermic mode.)" Bearden More Plumes

By using both of these **heat** (exothermic) and **cold** (endothermic) modes together the weather can be altered anywhere. Warm the air over here, cool it down over there, put a curl in the jet stream, dissipate clouds, create clouds, whip up a tornado. Bearden speaks about using the **endothermic howitzer mode** as a weapon of war:

> "Cold explosions can be used to freeze tanks, personnel, and equipment. The equipment and tanks thaw out. The personnel thaw out too, but they are dead when they do." Bearden, Fer-de-Lance

(This endothermic mode of the howitzers makes me think that there might one day be a cure for the problem of global warming after all. Could not a big device, situated in space or on the moon, be able to vent a great deal of excess heat outside the atmosphere into space, thus functioning as a kind of planetary thermostat?)

While the United States has experimented with electomagnetic weapons using ordinary **transverse** EM waves, the **longitudinal** [**LW**] weaponized waves are truly of another order altogether.

For one thing they do not have to travel through space, for they come from the time domain, which is everywhere. The energy of the blast, the heat or light or whatever, comes from the vacuum of space **at the location of the target itself**. This is astonishing. The weapons actually just trigger the release of immense energy from the vacuum at the target location.

> "... it is possible to focus the potential for the effects of a weapon **through spacetime itself**, in a manner so that mass and energy do not "travel through space" from the transmitter to the target at all. Instead, ripples and patterns in the fabric of spacetime itself are manipulated to meet and interfere in and at the local spacetime of some distant target. There **interference of these ripple patterns** creates the desired energetic effect (hence the term energetics) directly in and through the target itself, emerging from the very spacetime (vacuum) in which the target is imbedded at its distant location." Bearden Fer-de-Lance

The big Tesla howitzers are aimed at their targets by using a worldwide electromagnetic pattern called the "Woodpecker Grid," begun by the Russians in 1976.

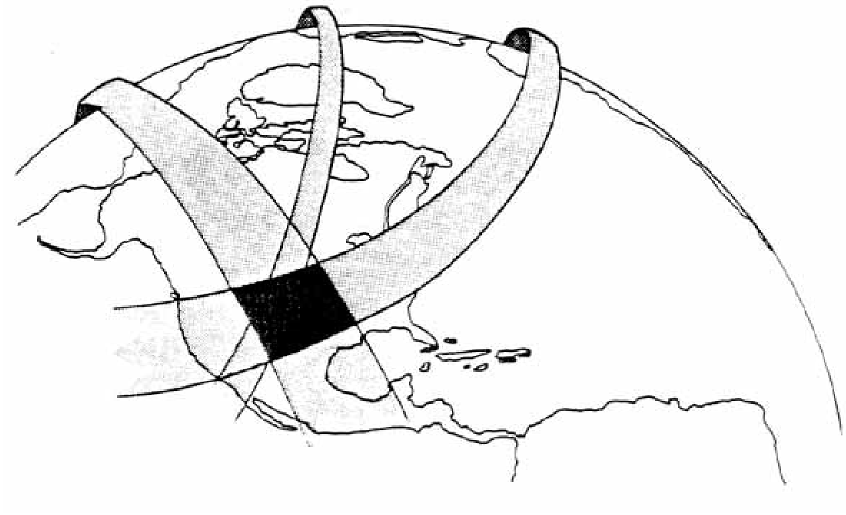

You can hear the Woodpecker signal here: http://www.cheniere.org/misc/woodpeckersound.htm

The woodpecker grid is just that, a grid of EM waves which provide a channel for the **LW** waves to any point on earth. Computers use the woodpecker grid information to hone down the aiming of the howitzers **to a pinpoint location on earth**. (For that matter, it could be under the earth, in space, or under the sea).

A third howitzer mode is what Col. Bearden calls "**Mindsnapper**" mode. This is a truly frightening mode which affects the electromagnetic mind-body connection. Being mind-snapped at a low level would cause you to lose consciousness. Being mind-snapped at a slightly higher power would "entrain" all minds in the target area into a kind of hypnogogic trance, a state in which they would all be highly susceptible to suggestions and orders.

Being mind-snapped at high level would so disrupt the mind-body connection that everyone in the target area would fall down, instantly dead. Not only that, everything around you and inside you would be killed, so that your sterilized body would **not rot** for quite a long time.

The **Mindsnapper** can be used for a small area, or to **kill an entire population**. In fact, using the scalar waves to affect the human mind has become a new field in its own right, and has been dubbed "psychoenergetics." (This is discussed below in section 5).

Bearden describes the use of the howitzer in **mind-snapping mode** against people, to cause unconsciousness or death:

> "From a military viewpoint, these scalar EM weapons are really quite all-around weapons.
>
> "For example, they are very lethal against personnel.
>
> "Set in the "high intensity pulse mode," one blast and a person's nervous system is destroyed instantly. Total, instantaneous death results. One can blast away at entire groups of infantrymen, for

> example. It's the peak power that's important, not the average power. So the weapon doesn't require too much battery power.
>
> "Set on a lower intensity pulse mode, one zap can simply knock out a person, rendering him instantly unconscious. Quite useful if one needs prisoners to interrogate. Also very silent, which is useful in operations employing stealth and surprise." Bearden http://www.cheniere.org/books/ferdelance/s80.htm
>
> "Those hit by the scalar EM weapon, however, have a most peculiar death mode.
>
> "Death comes-instantly and totally. There is no convulsion, no response. The entire nervous system is destroyed instantly. Every living cell in the body is killed instantly, including all bacteria, germs, etc.
>
> "A body hit with this thing falls like a limp rag and lies where it falls. It doesn't decay in even 30-45 days. In a macabre fashion, it's been reduced to something like food irradiated with nuclear radiation; everything is killed, so the material is preserved for an extended period before any decay can set in."
>
> Bearden http://www.cheniere.org/books/ferdelance/s81.htm

He goes on to say that the same "bazooka-sized scalar EM pulse weapon" can also be used to knock out a tank with one shot (or pulse). So tank warfare is obsolete. Helicopters? Bearden points out: "... if he's attacked by a helicopter or a fixed-wing aircraft, he can bring the same weapon to bear on it. He can knock down a chopper or a jet. With one shot."

Obituary for Tank Warfare

Tanks useless against portable LW weapons

"For example, suppose one attacks a tank. [with an LW weapon]
With scalar EM pulse, the personnel die instantly. Total personnel kill is achieved.
All electronic systems of the tank are dudded. Total systems kill is achieved.
The ammunition in the tank explodes. Total kill is achieved.
The fuel explodes. This is another total kill mechanism.
That tank has been killed totally, by a variety of mechanisms, all simultaneously.
That's a k-kill in any analyst's book.
And don't worry about retrieval and repair. That tank is finished permanently.
Even the most modern tank is just as vulnerable as the most obsolete."

Bearden http://www.cheniere.org/books/ferdelance/s88.htm

One begins to get the idea how profoundly the conventional means of warfare have been obsoleted. All the usual weapons of war have been rendered nearly useless! And **Star Trek's "Phaser**," with its "stun" and "kill" modes is here at last.

Although it is the weapons aspect of scalar electromagnetic which has received the most developmental effort, Bearden points out that a great many other amazing things that may be accomplished in this new field of science. Beam me up Scotty!

> "Superluminal communications systems, hyperspace drive, and **materialization** and **dematerialization** are all hypothetically possible, using scalar electromagnetics. As the technology develops, we should see the development of many of the systems long thought impossible except in science- fiction."
>
> Bearden http://www.cheniere.org/books/ferdelance/s15.htm

Bearden describes a huge test of the Russian scalar weapons systems which occurred in 1985, a test that went completely unnoticed by western scientists:

> "Just before May 1, 1985 the Soviet Union performed a "full-up" operational test of their entire strategic scalar EM weapons complex. This test was detected and monitored periodically by Frank Golden. Some 27 of these giant Soviet "power taps" were locked into the molten core of the earth, producing forced (entrained) scalar resonance of the entire planet on 54 controlled frequencies under our very feet. The remainder of the scalar frequency spectrum was ablaze with literally hundreds of Soviet scalar transmitters: probably the entire strategic scalar command and control system to underwater submarines, higher command centers, distant commands, etc. was activated in the giant exercise.
>
> "For several days, the system was exercised on a mind-boggling scale, apparently as part of the Soviet Union's highly accentuated 40th anniversary celebration of the end of World War II.
>
> "Ironically, not a single U.S. intelligence agency, laboratory, or scientist detected this monstrous exercise for the new Soviet leader, Gorbachev. Not a one of them had a detector for scalar EM radiation, and not a one of them officially believes the exercise ever happened."
>
> Bearden http://www.cheniere.org/books/ferdelance/s38.htm
>
> "The **Woodpecker grid/howitzer** weapon system can be placed over the ocean and used against cruise missiles, naval surface-to-air and surface-to-surface missiles, submarine-launched ballistic and cruise missiles, etc. Placed over a carrier task force, it can also take care of the aircraft launched by the carrier as fast as they are launched. It can also handily take care of the missiles launched by guided-missile cruisers of the accompanying task force."
>
> (Bearden http://www.cheniere.org/books/ferdelance/s65.htm)

The whole series of the Fer-de-Lance briefing slides and comments is a "must read" for anyone wanting to be aware of the actual state of things in this world right now. It is a new world and it takes some getting used to. Fer-de-Lance speaks clearly, for the layman, of the way things stand.

What is it like to operate these Tesla Howitzers? Col. Bearden gives us an idea in his "Fer-de-Lance" briefing, Slides 66-71.

Who needs armies anymore? A entire war can be fought and won by a handful of men sitting in a comfortable control booth! The scalar electromagnetics revolution has made all previous forms of warfare nearly obsolete.

Why haven't the Russians used the scalar weapons yet?

Bearden gives his thoughts on this in "Fer-de-Lance." The power of these weapons is so great that an accident or war could wipe out all life on earth, and even **affect the sun**.

> "As can be appreciated, this entire concept [MAD] is now totally obsoleted by the Soviet possession of scalar EM weapons.
>
> 'The "mutual assured destruction" capability -- or MAD concept as it was so aptly named! -- is **no longer mutual.** And for two reasons: (1) the Soviet surprise attack could destroy essentially all our Triad forces wherever they are, in the first attack. (2) Even if a very small number of our strategic forces survive, the puny strike we could attempt to launch could be repeatedly decimated from launch to terminal phase.
>
> 'The restraint on the Soviets is not because of our Triad forces. The restraint is twofold:
>
>> (1) a second nation has scalar EM weapons, and would undoubtedly unleash them upon the Soviet Union with great violence if such a massive world-wide destruction of U.S. forces occurred or was threatened (is it really "accidental" that six major Soviet missile ammunition storage sites mysteriously exploded within seven months?);
>>
>> (2) the closed-loop **scalar radiation exchange system of Earth-Sun could be inadvertently "tweaked"** in the feedback loop from Earth to Sun, so that a large solar scalar resonance was stimulated. In that case the Sun could emit a mighty resonant "burp" that would simply **wipe out all life on Earth in a fiery shower**.
>
> 'The "terror" in the "balance of terror" between nations has just increased by many, many orders of magnitude.
>
> 'The biblical prophecy that the Earth will be wiped out by "fire and brimstone from heaven" is very near fulfillment now.
>
> 'Put another way, the pucker factor -- even on the Russians who may contemplate unleashing Armageddon -- is higher than any Western strategic analyst has ever imagined, even **in his wildest nightmares**.
>
> 'Truly these weapons are "more frightening than the mind of man has imagined," as Brezhnev put it in 1975.
>
> 'The frightening scalar EM weapons can be used, but only very, very gingerly indeed. If a slight mistake is made, everybody loses everything."
>
> Bearden http://www.cheniere.org/books/ferdelance/s74.htm

But the Russians (KGB) are not the worst of it. Bearden claims that some of the scalar weapons have been leased to the Yakuza for about a billion a year, and that only the KGB is holding the Yakuza in check from making a **full-scale all out scalar attack on the west.**

U.S. Defense Secretary William Cohen

Warns about eco-terrorism using scalar electromagnetic weapons

> "Others [terrorists] are engaging even in an eco-type of terrorism whereby they can **alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves...** So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations...**It's real**, and that's the reason why we have to intensifour [counter terrorism] efforts." - Defense Secretary William Cohen, 1997

In a letter to a writer named "Russell" Bearden says,

"In short, Russell, the Secretary of Defense of the United States confirmed that there are indeed novel kinds of EM weapons, right now and have been for some time, which have been and are being used to (1) initiate earthquakes, (2) engineer the weather and climate, and (3) initiate the eruption of volcanoes. We wrote about those exact uses of the weaponry decades ago. Several nations now have such weapons. Three of them (two on one side and the other on a hostile side) are even firing practice shots into Western Australia, as a convenient test range."

http://www.earthchangestv.com/ufo/0209gandor.htm

See Also:
Examples of scalar weapons testing around the globe

See Also: Powers of the Longitudinal Interferometers

Tesla Howitzers in Weather mode

How to Make Weather

"Engineering the weather is **duck soup**; they tested that over the U.S. in 1967, and entered upon continuing operations over North America on July 4, 1976 as a grim kind of KGB "Bicentennial Gift" to the United States. Here's how it is done with several interferometers.

"First, the interferometers can deliberately make "high pressure areas" (cool the air so it shrinks and its "footprint" pressure on the ground increases because its density increases) and "low pressure areas" (heat the air so that expands and its "footprint" pressure on the ground decreases because its density decreases). Well, if one makes the highs and lows where one wishes them, and judiciously and somewhat slowly moves them along a given path, these highs and lows will entrain the jet streams and thus "steer" the weather.

"So if you wish a very cold snap or attack, go up into Canada and start these actions to steer down some streams that bring some very frigid air. Establish other highs and lows judiciously to "block" or "slow" other jet streams and flows as desired. In this way, one can pull the "large cold air masses coming down from Canada" deep into the southern U.S. at will. They do it regularly. If you wish an ice storm, add an additional current of warm moist air you bring up (steer up by using artificial highs and lows) from the ocean. Where they meet, you will get freezing rain, then sleet, then severe icing accumulating. This type of attack does rather large damage to the struck area."

http://www.earthchangestv.com/ufo/0209gandor.htm

Whole websites have now sprung up showing weather **radar anomalies** which may well be indications of scalar weather engineering. One list of over 500 images is here. Cheniere has its own collection here.

Here is an animated anomaly with cloud formation.

In another section at Cheniere are many photos of **cloud anomalies** which reveal the underlying grid along which the clouds are forming or un-forming. Bearden relates a startling incident in these **ongoing "weather wars**."

> "During the spring of 1986, abnormally strong Soviet weather engineering occurred over the U. S., causing a drastic drought in the southeastern U.S. **This drought was broken by a colleague who used an extremely powerful scalar EM device** to redirect jetstreams. A most unusual and unique signature of the "blocking" against the Soviet scalar EM actions resulted: Two huge circulations developed in the atmosphere, clearly showed as two adjacent giant "holes" in the swirling cloud cover over the middle and eastern U.S.
>
> "Between these two giant holes, the cloud circulations formed a stream of clouds, moving to the south, looking very: much like a giant vertical "bar" of a huge "Y-shaped" cloud flow.* Several national weathermen commented on this unusual pattern, which had not been observed before. The pattern continued, day after day, as the blocking continued."
>
> * On the weather maps.
>
> http://www.cheniere.org/books/analysis/history.htm

Tesla Howitzers in Earthquake mode

How to Make an Earthquake

"Here's how you initiate a very large earthquake with such weapons. Take a convenient fault zone of set of them. Focus the interferometry on the fault zone, in the "diverging" mode, and deposit EM energy there in the rocks on both sides, increasing (slowly) the stress in the rocks by the reverse piezoelectric effect (deposit excess energy, get crystal mechanical movements).

"Do it slowly, and the stress will build up to large pressures well-above a plate slip minimum energy required. At some point, the rocks yield and one or both sides "slip" and move rather sharply, giving a very large earthquake in that zone.

"Do the same thing down in the earth (remember, LWs easily penetrate right through the earth and ocean at will, and so the "interference zone" focus can be inside the earth or beneath the ocean, at will.

"Anyway, focus this thing down to where the active part of the volcano is still slumbering, down where the hole in the plate has been made. Keep increasing the deposition of energy in the magma itself, and eventually the increasing pressure from deep within that volcano, underground, will cause an eruption. Build the energy slow, and the eruption will likely be much larger."

http://www.earthchangestv.com/ufo/0209gandor.htm

Yugoslav Earthquake, Followed by Cold Explosion
Strange Characteristics of Iran Quake, Sep. 1978

Tesla Howitzers in Tesla's "Big Eye" mode

How to make a Big Eye in the Sky

By using longitudinal wave interferometry in a weakly endothermic mode a new kind of "radar" is now possible, one which can look right through the earth and oceans. Because the endothermic mode extracts energy from the distant target, a pattern of the target area can be scanned for in the returned energy.

"Thus the receiver produces a representation of the energy extracted from various locations within the distant endothermic zone. By displaying the received signals on an appropriately scanned screen, a representation of the distant scene in the intersection zone can be created. Indeed this is a special kind of "microwave interferometry," and -- with modern techniques -- the imagery obtained might be surprisingly good. With development, it might even become as good as the image presently obtained by side-looking acquisition radars.

"Interestingly enough, since scalar EM beams will easily penetrate the earth or the ocean, one can also look beneath the earth or beneath the ocean with this type of scanning scalar interferometer.

"The importance of this capability to strategic and tactical reconnaissance is obvious. Camouflage, cover, and concealment have no effect on such a system. One can easily look inside buildings and into underground facilities. With a small system such as this, the U.S. Marines at Khe Sahn would have had little difficulty locating the tunnels continually dug under the perimeter by the Viet Cong. And targets under jungle canopies are directly visible."

Bearden http://www.cheniere.org/books/ferdelance/s42.htm

Tesla Howitzers can destroy all life on earth

How to Make a Storm on the Sun!!

(Just make a big mistake with your Tesla howitzers)

The **deepest dangers** of the use of scalar weapons are frighteningly pointed out by Bearden here where he considers that the sun, earth and moon (actually the whole solar system) is a delicately balanced arrangement of scalar (longitudinal) EM radiation. There is a scalar connection between the earth and the sun, which are both giant dipoles gushing energy in the time domain. Big scalar events on the earth could alter this balance causing **true catastrophe**.

"Indeed, a solar response could be stimulated so that the Sun would violently belch and destroy our biosphere, among other effects."

Unrestrained scalar warfare could cause huge solar storms? To realize that **human activity** could actually **affect the sun itself** is truly mind boggling.

Bearden goes on to say:

> "Accordingly, use of huge scalar EM weapons is a double-edged sword. Unless carefully employed, use of the weapons could cause a terrible backlash to the user as well as the victim, and even accidentally cause the **destruction of the earth itself**. It is not accidental that in 1960 Khrushchev stated that his new fantastic weapon could -- if unrestrainedly used -- destroy all life on earth.
>
> "This appalling backlash potential is apparently what prompted Brezhnev in 1975 to make so strong an effort to get agreement to outlaw the development of "new weapons of mass destruction" more frightful than the mind of man had even dreamed of. Gromyko even introduced such a draft agreement into the proceedings of the United Nations. The first article of the draft agreement indicated that the nature of the weapons referred to would be negotiated. Sadly, the entire Western

world did not even know what the Russians were talking about."

http://www.cheniere.org/books/ferdelance/s24.htm

2. Tesla domes provide near-perfect defense shield.

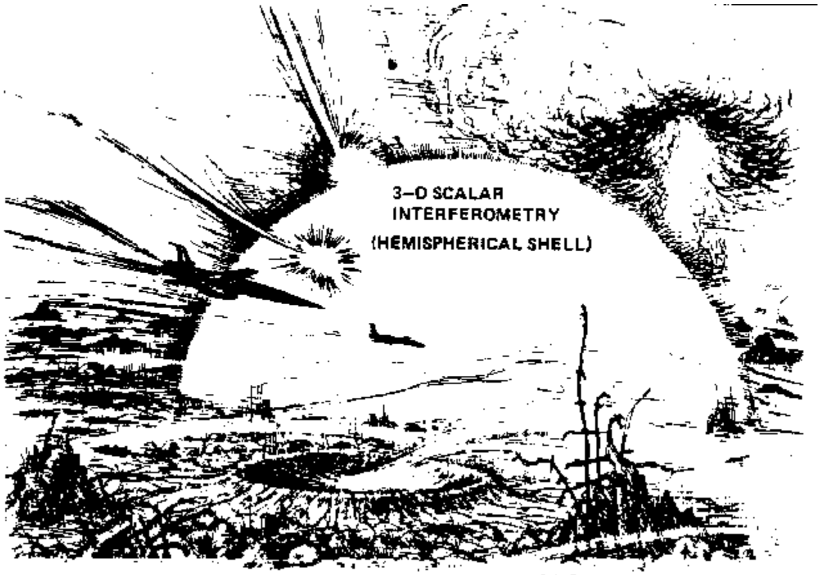

(Slide from Cheniere.org)

The Tesla howitzers can be used in a nearly **impregnable defensive mode** whereby they throw up a dome (**Tesla Dome**) or a sphere (**Tesla Globe**) of highly powerful electromagnetic energy, enough to "dud" or destroy missiles which try to penetrate them. Once again, this energy is not going through space from the howitzer, but being made to emerge from the local vacuum **at the location of the shell**. KGB tests of these domes have been witnessed by airline pilots around the world. Bearden gives many examples of the Tesla domes being sighted around the world in his briefing paper "Fer-de-Lance." (Russian dome test, another globe incident, yet another globe test). These giant electromagnetic domes can be hundreds of miles across, or narrowed down more to total impermeability.

> "Such a shell may be several hundred miles in diameter at the base. The enormous energy required to form such a defense shell is obtained by a "scalar power tap" into the **molten core of the earth itself**, as previously explained. In late April/early May of 1985, 27 such "**power taps**" were placed in the earth by the Soviets. If each tap is capable of powering four to six large scalar EM weapons, then the **Soviet strategic scalar EM arsenal contains over 100 monstrous superweapons** capable of generating exothermic explosions, endothermic explosions, engineering the weather, locating and destroying underwater submarines, detecting and destroying ballistic missiles shortly after launch, detecting and

> destroying long range strategic bombers as soon as they are airborne, etc."
> http://www.cheniere.org/books/ferdelance/s52.htm

By using nested domes one can protect the domed area **even against nuclear radiation itself**. Tesla globes can be used to hit airborne targets by simply placing a globe of any chosen size in the flight path of the incoming missile. It does double duty because the missile hits it going in, and then the rubble hits it again going out the other side.

While the U.S. persists in its useless boondoggle "missile defense system" by shooting a missile with a missile (missiles which would already have been "dudded" by the Tesla howitzers), between the domes and the globes the Russians (KGB) have in hand (**operational**) a nearly **perfect missile defense system**. Someone should ask the Secretary of Defense if the U.S. Tesla domes are in place. And over which cities? How powerful are our American Tesla domes?

Bearden cites a number of examples of these domes being tested around the world: March 20, 1969 | March 24, 1977 | August 17, 1980 | June 17, 1966 | June 18, 1982 June 22, 1976

In a slide from the Fer-de-Lance briefing it is shown how the "woodpecker grid" itself also acts as a sensor, detecting any missile launch anywhere, and how the howitzers can respond instantly by delivering a blast to exactly the right coordinates, right along the channels of that same grid which is feeding the location information about the missile launch. This certainly beats "trying to hit a bullet with a bullet." Especially since YOUR bullet would probably be instantly inoperable in a real scalar war situation.

3. Rogue Groups in the government

Bearden fears that these scalar electromagnetic secrets may have fallen into the hands of what he called secret "**rogue groups**" within the labyrinthine depths of the black-ops special-access domain of the secret government. "In the extreme, such a deep black program can even become a "captured" program," he says, "which is totally in the hands of rogues and **no longer reports to or is bound by the dictates of the parent government**."

> "They have their own agendas. And being rogue groups, they may well bring in **unethical, immoral tricks**: assassination, bribery, entrapment, disinformation, plausible deniability, etc. A certain percentage of a highly secret rogue group will wind up using all these things and more. **It's a human characteristic, the old primate dominance game. Only now disguised and hidden under deep classification. ...**
>
> "In highly classified groups, these groups are greatly enabled to joust more widely, unethically, and immorally because it is so deeply hidden. So very deep classification evokes the growth and intensity of rogue groups. It's the old 'Power corrupts, and absolute power corrupts absolutely' routine. ... Due to loose formation of rogue groups inside such programs, they may have dual or triple purposes, **may not operate under very much legitimate government control at all**, and may operate specifically for the purposes of the rogue group or groups that have gained control."

> "The involvement of at least some rogue groups, some being "**cowboys**" who operate well **outside all laws and ethics**, could also result in such things as assassinations, clandestine testing on individuals without their consent, etc. In short, ***it could account for what seems to be actually occurring***. "
>
> http://www.cheniere.org/explore%20articles/mind%20control3/p05.htm

4. World War III has already begun

Because it is now possible to cripple the power grids and electronics of any nation, that nation could be reduced to economic ruin without ever firing an actual "shot." Without electricity Wall Street cannot operate. Without electricity you quickly need martial law. One no longer needs to wage a conventional war anymore at all. There are now **lots of new ways to bring any nation to its knees**.

> "We are at war, whether we like it or not. And we are going to have strategic strikes on an unparalleled scale for us. Pearl Harbor was nothing compared to what is coming down, once we consider the "augmentation" and such.
>
> "When that factor is considered, then it's a totally new ball game on replacing the power system. There isn't going to be much choice; the old one is going to be destroyed or so badly crippled that **it will collapse the U.S. economy** in a way we have not seen since **1929**. Of course, in such a case hitting us, we will be under martial law, the works, everywhere. For one thing, it's the only way you can keep the cities from imploding from within, by the criminal element, looting, robbing, killing, etc. Simply wait and see; it's on the way."

Although Bearden has for years decried the "scalar-gap," and chided the military for falling so far behind the Russian KGB in the field of scalar electromagnetics, recent statements indicate that things may at last have changed somewhat.

> "In the new war, the first phase of WW III has already been completed. Hence President Bush's recognition that this is a total war, and has to be taken to the enemy no matter where he may be hiding or in what sanctuary or in what foreign nation. This is an entirely different war than anything the U.S. has ever fought in its history. **And before it is over, it is going to kill more Americans than have died in all the previous wars in our history. The news media and the public have not yet recognized that awful situation and predicament.** Most are already thinking that, well, we won in Afghanistan so it's just about over. Instead, it has only just begun.
>
> "Anyway, that's a brief uptake on some of the weapon situation today. Some 10 nations or more now have LWIs, and five have the QPs. I'm still working on how many have the appalling negative EMP weapons, but would estimate 6 or 7 nations have them in one stage or the other, either deployed or in at least advanced development. And in my estimation, the Yakuza will have them within three to five years if they have to build them themselves, and quicker if they can buy them from the Russians, Chinese, or???" Bearden

When he was asked the question "**Does the government listen to Tom Bearden?**" Bearden said:

> "Let me speak carefully. I am very satisfied with how I've been listened to in the quarters where the rubber meets the road. **The West is no longer defenseless, not by any means.** Cannot amplify it further than that."
> http://www.cheniere.org/correspondence/021102a.htm

Bearden has briefed the government a number of times and the Cheniere website contains a great number of his graphic military briefing slides.

5. Are the Russians making "UFOs?"

Scalar electromagnetics engineering opens the possibility of antigravity vehicles and "hyperspace travel." In other words we can now make our own UFO's! Of such **scalar-powered antigravity vehicles**, which have now become possible, Bearden has this to say:

> "We might expect to see such vehicles glowing. Their various surface features and mechanisms might appear to be glowing or revolving lights, etc.
>
> "They could exhibit incredible "aerodynamic performance," seemingly in the atmosphere. **Actually they would not be moving "through" the atmosphere at all, but through a higher space outside each particle of atmospher**e.
>
> "They could seem to **materialize** and **dematerialize**.
>
> "They could seem to plunge into the ocean or rise out of it.
>
> "They could even seem to operate under the ocean or inside the earth itself.
>
> "**Such anomalous vehicle performances have been seen all over the world**, particularly since a few years after WWII.
>
> "It appears that one or more nations of Earth are operating such vehicles now **in great secrecy**. Our own "government" may even be one of these.
>
> "If so, it **isn't** our true "government/government." Instead, it's the "control group/government." It's government at the operational level, but at higher level **it belongs to certain control groups who have penetrated our government's vitals and taken over all such projects**."
>
> Bearden http://www.cheniere.org/books/ferdelance/slide32.htm

In an excellent article on her Earthfiles website, Linda Moulton Howe reports on the utter bafflement of Norwegian scientists over mysterious lights appearing in the valley of Hessdalen, Norway.

She writes of the research there: "The results can be broken down into two groups: 95% are thermal plasmas and 5% are unidentified solid objects. The plasmas emit long wave radio frequencies and strangely, their temperatures do not vary with change in size or brightness." She quotes the scientists' research summary:

> "1) most of the luminous phenomenon is a thermal plasma;
> 2) the light-balls are not single objects but are constituted of many small components which are vibrating around a common barycenter;
> 3) the light-balls are able to eject smaller light-balls;
> 4) the light-balls change shape all the time;
> 5) the luminosity increase of the light balls is due to the increase of the radiating area. **But the cause, and the physical mechanism with which radiation is emitted, is currently unknown**."

This would almost certainly seem to be another example of the testing of the scalar howitzers. It is baffling because, as Bearden points out repeatedly, Western scientists have limited knowledge of the scalar electromagnetic principles by which the howitzers operate. The Hessdalen scientists were completely **baffled** as to where the energy of these plasma balls **was coming from**.

Ms. Howe interviews Massimo Teodorani, Ph.D., Astrophysicist, who released the report on the 2001 Hessdalen sightings. The scientist speaks of the baffling phenomon observed.

> "I don't know how it is possible that Nature is spontaneously able to do that. Anyway, we deduce that the plasma is trapped inside a sort of magnetic cage and the magnetic cage closes around the plasma and keeps it fixed in some way, prevents it from expanding. **But where does it come from? We don't know**."

By what we have been considering here, we can recognize the signatures of scalar electromagnetic engineering. If it is a Tesla howitzer, then the energy for the plasma balls **is coming from the vacuum of spacetime** at the very **location of the balls themselves**, triggered by scalar interferometers aimed through the woodpecker grid.

These kind of balls can be used as **marker beacons** giving feedback for precision aiming of the howitzers. The energy of the marker beacon can be read back into the computers giving precise location information for pinpoint aiming. The target area can be very small, or widened out.

There is a little movie of one of the Hessdalen plasma balls here. It would seem to be a clear documentation of a scalar howitzer marker-beacon. How many other current "UFO" sightings are actually the witnessing of Tesla howitzer tests?

In fact there are a great many **anomalous events** of the past few decades which might very well be explained by the Russian testing of their longitudinal electromagnetic weapons. It would seem that the mysterious appearance of crop circles around the world could be accomplished by feeding a precise mathematical graphic pattern into the computerized aiming software and change the very molecular structure of the crops themselves along the lines of that pattern. The stalks fall over from the localized effect of the longitudinal waves. A plasma ball tracing patterns? Are they slyly sending a message to see if we are "getting it" yet?

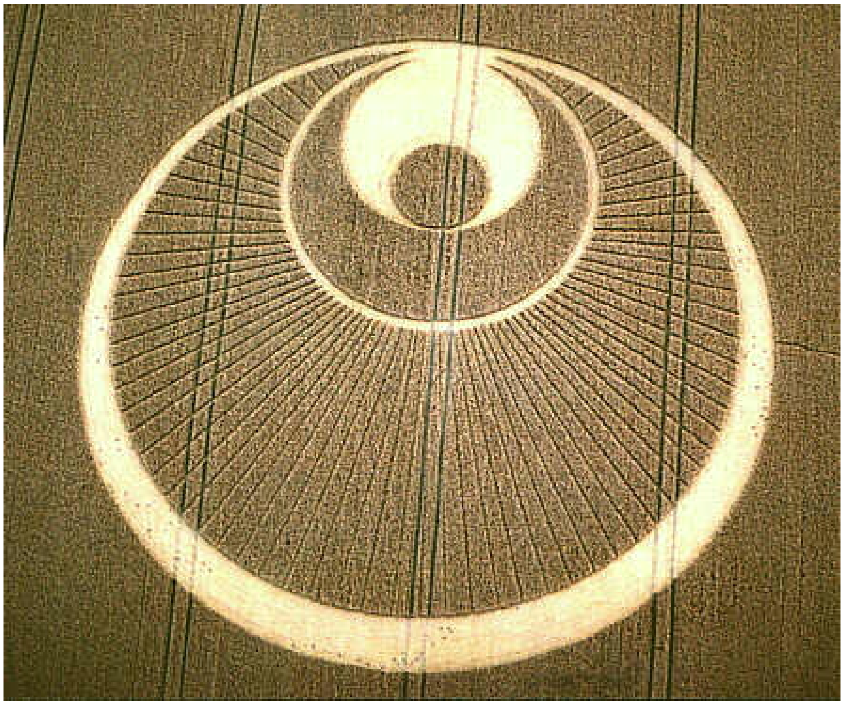

The "Cambridge Angel" - Made by Russian scalar plasma balls?

Also see: Interview with Tom Bearden

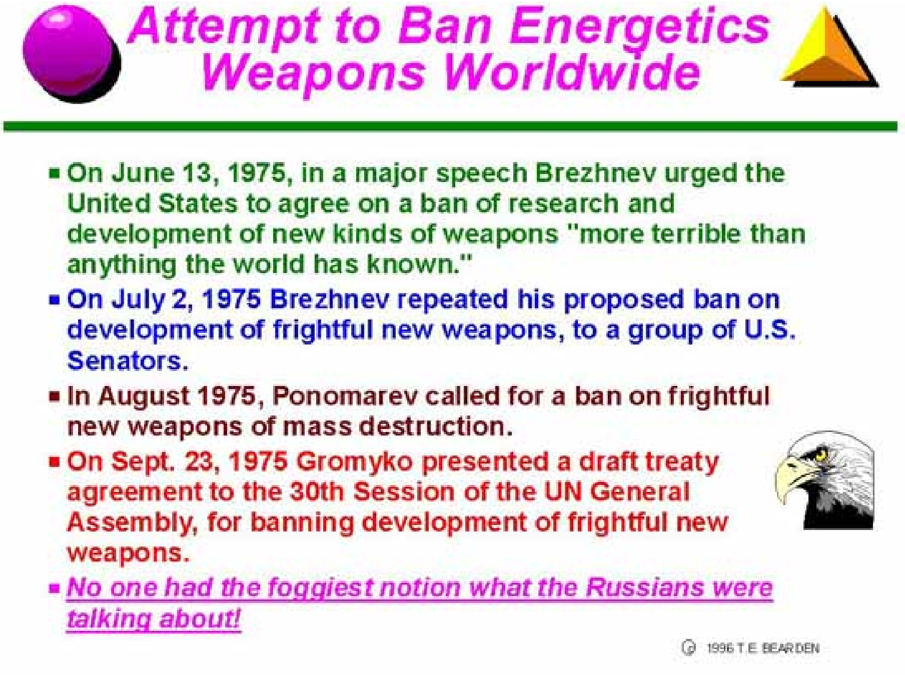

Attempt to Ban Energetics Weapons Worldwide

- On June 13, 1975, in a major speech Brezhnev urged the United States to agree on a ban of research and development of new kinds of weapons "more terrible than anything the world has known."
- On July 2, 1975 Brezhnev repeated his proposed ban on development of frightful new weapons, to a group of U.S. Senators.
- In August 1975, Ponomarev called for a ban on frightful new weapons of mass destruction.
- On Sept. 23, 1975 Gromyko presented a draft treaty agreement to the 30th Session of the UN General Assembly, for banning development of frightful new weapons.
- No one had the foggiest notion what the Russians were talking about!

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(Slide from Cheniere.org)

4. Healing powers of longitudinal waves

Healing via longitudinal waves, time reversal of cells (de-differentiation), Priore's machine, Bearden's proposed "blanket" version, using the electric power grid for healing waves or for broadcasting disease patterns. Scalar Biowar.

The good news!

"**Any sort of disease whatsoever - physical or mental** - will be rapidly curable, simply and cheaply. It will be possible to reverse aging and rejuvenate the person. It will be possible to regrow limbs and straighten misshapen spines - and directly remove the causes of mental diseases and cure them as well. Lifespan will be staggeringly increased, without 'old age's debilitation.' AIDS, cancer, leukemia, and genetic diseases will be completely conquered. The potential for a true golden era is upon us, for all humanity."

Bearden- http://twm.co.nz/beard_interview.htm

Proof of the healing powers of longitudinal waves from the vacuum is seen in the work of Antoine Priore who produced longitudinal scalar waves using a **gigantic glass tube** filled with plasma. He himself did not understand why it worked or how it cured cancer in animals.

> "The Priore team cured terminal tumors, trypanosomias, and other dread diseases in laboratory animals in France, in the 1960s and 1970s, under rigorous scientific protocols by eminent scientists. The Priore

> project was funded by the French Government to the tune of several millions of dollars (equivalent). http://www.explorepub.com/articles/energetics.html
>
> ". . . Prioré's machines concretely demonstrated a nearly 100% cure of all kinds of terminal cancers and leukemias, in thousands of rigorous laboratory tests with animals. These results were shown to medical scientists as early as 1960." http://www.cheniere.org/priore/index.html

Bearden has stated that the longitudinal EM waves can have a healing effect because they always come in pairs called "**phase conjugate pairs**" and one of the pair is **time-reversed**. This enables engineering of the waves to "pump" the cells of the body (with waves from the time domain) and actually **time-reverse the cells** back to a previous healthy condition. The scalar cure of cancer does not involve killing the cancer cells but rather pumping them with time energy into a previous condition. I know, this seems miraculous, and is it not?

Priore and his giant plasma tube

This healing power in the longitudinal waves of the time domain is a mind-boggling thing to face. It took me months to get through it, and to **suffer the fact** that the **cure** for cancer and AIDS was right there, **in this new scalar electromagnetics technology**, and that it has been kept back from the people for so many decades now.

Bearden has a great deal to say about the work of Antoine Prioré, who himself did not understand why his machine worked. Priore did not know about the longitudinal scalar waves of the time domain. In fact, Tom Bearden has supplied, at last, the missing explanation as to how that **big giant two-story glass tube** consistently cured cancer in animals.

> "**The medical implications are enormous**. By just reversing the damaged cells back to a previous physical state, this gives a physics mechanism for *controlled cellular dedifferentiation*, in biology terms. Physicians will **time-reverse diseased, damaged or aged cells** back to an earlier healthy condition, including all the cellular genetics. Normal cells are just reversed to a slightly younger condition."
>
> "We believe this mechanism explains the revolutionary but baffling electromagnetic cures achieved by a team of outstanding French scientists in the 1960s and early 70s, working with inventor **Antoine Prioré**. In lab animals, cures were achieved for terminal tumors, infectious diseases such as trypanosomiasis, and atheriosclerosis. In addition, deliberately suppressed immune systems were dramatically restored.

> "We hypothesize that this is the long-sought mechanism of how the living body heals itself. In short, the body's cellular control system induces **cellular reversal by weak time-domain pumping** of the damaged cells and the affected area. The cellular regeneration system performs all healing of cellular damage in the body; the immune system heals nothing, not even its own damaged cells) .
>
> "For the first time medical science can develop as a science of *healing* rather than a science of *intervention*. And it will develop as a science of *unlimited* healing, since **no pathogen can resist action by curved spacetime engines**." Bearden

http://www.cheniere.org/techpapers/Vision%202000%20paper.doc

See Priore's machine See Slides of how it works.

Bearden has extended the Priore work, with the previously missing knowledge now in place, and designed a revised system (for irradiating the body with longitudinal waves) which gets rid of Priore's giant glass plasma tube and uses instead an **antenna unit which surrounds the body**. He has also provided the missing explanation of how it works. There is an article from "Explore" magazine, Part I and Part II.

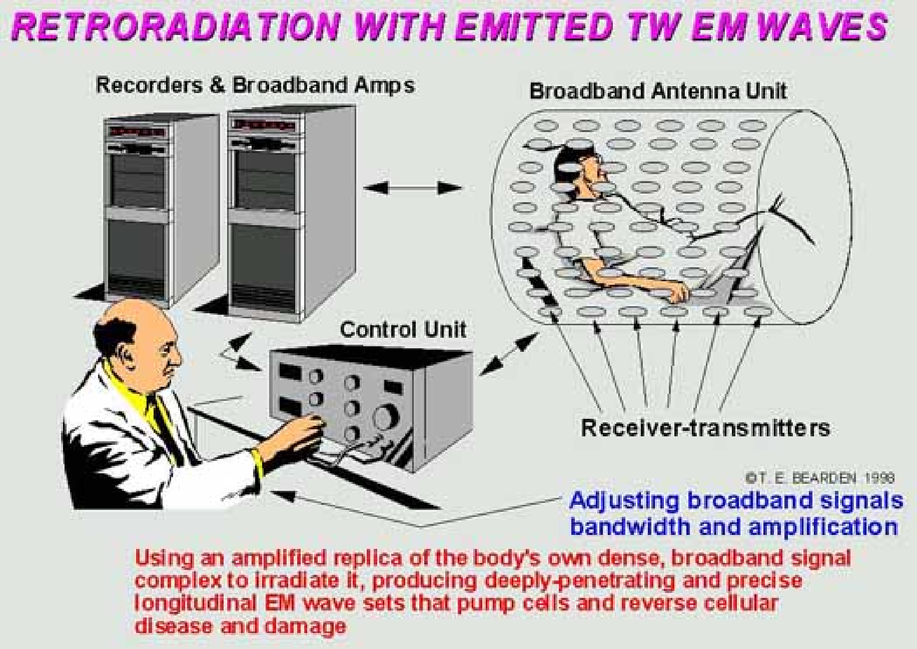

RETRORADIATION WITH EMITTED TW EM WAVES

Recorders & Broadband Amps
Broadband Antenna Unit
Control Unit
Receiver-transmitters
©T. E. BEARDEN 1998
Adjusting broadband signals bandwidth and amplification

Using an amplified replica of the body's own dense, broadband signal complex to irradiate it, producing deeply-penetrating and precise longitudinal EM wave sets that pump cells and reverse cellular disease and damage

(Slide from Cheniere.org)

In fact, Bearden has presented to the U.S. government a plan to use a **portable version** of a **Scalar Healing Blanket** where wire channels in the blanket act as a scalar antenna, which can both send and receive scalar electromagnetic waves. A **two minute treatment** of the waves is sufficient to restore the body to its earlier healthy condition. Thus even **thousands could be treated easily and quickly in a biowar mass attack** situation.

> "To defend against things like anthrax attacks on our civilian population centers, we also have recommended to the U.S.

> Government the crash development of small, portable treatment machines—using similar "antiengine-forming" and cellular reversing "porthole technology". [See Figure 13 on previous page]. Such portable machines **could be developed cheaply and quickly**, and present government facilities could be used to massively attack the correlate database production problem.
>
> "The portable treatment **units could be cranked out by the hundreds of thousands** and flooded down through emergency response agencies such as the police forces, the National Guard, emergency hospitals, emergency response teams, etc." - Bearden

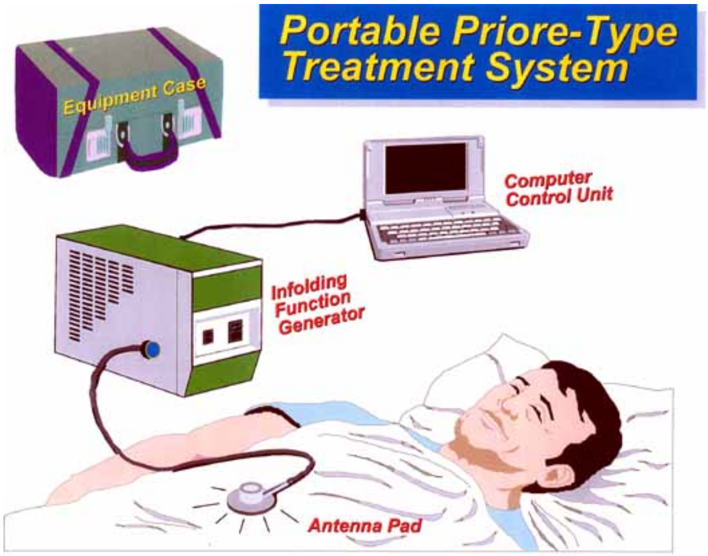
Portable Priore-Type Treatment System
Equipment Case
Computer Control Unit
Infolding Function Generator
Antenna Pad

(Slide from Cheniere.org)

The **Scalar Healing Blanket** would fit into large suitcase. It has three basic parts, the longitudinal wave generator, a laptop computer, and the antenna-blanket. The plan was a stroke of Bearden's genius, but unfortunately it fell on **befuddled government ears**. "Unfortunately, so far the DOD [Dept. of Defense] doesn't even understand what the heck we're talking about!"

Article "Healing with Energy": http://www.explorepub.com/articles/energetics.html

> "We tried very hard in 1998 to call attention to the extreme national need for the most urgent possible development of a portable computer-controlled treatment device based on the experimentally proven Prioré methodology, but extended to a much simpler and far more rapid method of treatment.
>
> "Quick development of this technology could lead to **a suitcase size device, capable of treating a patient in less than one minute, and stopping the symptoms and disease progress cold, then reversing it**. Three "less than a minute" treatments one week apart would be required for complete cure. As an added advantage, partial reversal of aging in older patients would also be accomplished as a bonus, in addition to time-reversing the damaged and diseased cells...
>
> "The method proposed to the DoD in 1998 used normal EM in a peculiar way to force the body itself to make its own time-polarized

> EM waves, and pump every part of its cells -- including the genetics -- in the time domain.
>
> "Quite simply, we are going to be struck this way (QP spreading the immune systems of the populace plus professional smallpox, anthrax, etc. BW attacks on our population centers) and by other means we've spoken of in other papers and briefings."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

The Dark Side of the Force:
Creating and broadcasting disease

Speaking of the scalar wave induction of disease by longitudinal wave patterns Bearden refers to work by French scientist Kervran and Russian scientist Kaznacheyev, who proved that any disease could be transmitted electromagnetically.

> "It works this way: the Kaznacheyev experiments (and others) demonstrated that any cellular disease or disorder can be initiated into cells at a distance, by electromagnetic means (albeit unusual EM in nature). The decades of microwave radiation of the U.S. Embassy in Moscow, was an ongoing set of "stimuli" to ping the U.S. system and, by its response, ascertain how far along (or if it was "along") in its knowledge of such weapons. The radiation was responsible for many health changes in personnel and for the **eventual deaths of three U.S. Ambassadors**." Bearden http://www.cheniere.org/correspondence/021702a.htm

In a letter he writes,

"Yes, the Kaznacheyev experiments were quite real; 15,000 or so in military research institutes in Siberia. As with so many other novel areas investigated and developed by the Soviets, most U.S. investigators just assumed normal EM, which is not what the Kaznacheyev experiments involved, and not what was carrying disease induction patterns from one cell culture to another in rigorous lab tests."

How to "Broadcast" Diseases
Longitudinal EM Biowars

Bearden explains how the new quantum potential weapons can be used to induce disease-at-a-distance in a population, or to "spread" the immune system so thin that a **conventional bio-attack would be greatly potentiated**. By "broadcasting" virtual disease patterns over a population, the immune system is so overloaded by the presence of the **"shadow" diseases** that its effectiveness is thinned out.

> "In short, alter the internal wavestructure, and one creates a curved spacetime 'engine' that acts on mass in any fashion one chooses to design -- including initiate diseases . . . Now visualize one of these '**vacuum engines**' or 'spacetime curvature engines' that **acts on mass** to **generate the exact effects produced by anthrax**. (Or any other disease one wishes) . . .

Call the virtual state of a disease engine the disease pattern in the "shadow" state, just prior to becoming observable. . . .

"And the master cellular control system responds to "coming events that cast their shadows before". In short, it responds to the upper level of the **"shadow state" of a disease**, still in the virtual state! (Hey, virtual particles are real, virtual photons are real, virtual ST curvatures are real --- just very fleeting, only for another to immediately arise). The exchange of virtual particles is known to generate all forces in physics anyway! . . .

"So the cellular control system responds to "shadow state" disease patterns. Enter a QP weapon application. Place a quantum potential weapon "area" on the United States, so that the entire populace is in it. The slowly introduce and bring up in the shadow state, the **necrotizing fasciitis disease engine**. At some point, the cellular control systems will react, and order the immune system into action. In other words, immune system resources will be committed against this "immediately coming" enemy. Bring it on up a little, but still just in the shadow state. Voila! Humans form a bell-shaped distribution curve. And even if the structure of the QP fluctuates a little, fluctuating a bit stronger and a bit weaker, etc. **A few of those targeted bodies will now actually develop necrotizing fasciitis**. So far, just like the U.S. Embassy targeting, except a different "carrier".

"But now there is an exact signature that this is what is doing it, and not normal vector carriers of disease and contact or exposure infection. **The few cases of necrotizing fasciitis that break out will be most puzzling.** They will be randomly scattered across the entire nation, and so few that the vector carrier and contact or exposure explanation completely fails."

"And that one happened, right here in the U.S., not so long ago. Check it out.

"So carefully adjust the **patterns** for, say, 12 major terrible diseases, to that "adjusted and desired shadow state level". Now add all 12 patterns into the internal structure of the quantum potential. Now it has **12 shadow state disease engines** in it.

"**Place that one on a populace**. The cellular control systems order the immune systems into action, and they now have to commit their finite resources to 12 different areas. This greatly thins the response an immune system can make to any one of those 12 disease patterns! In short, it "**spreads**" the capabilities of the immune system, which can be galvanized to great effort, but only can perform a small bit against each area.

"Suppose one of those "galvanized" areas in the targeted populace's immune systems is anthrax. And suppose the bad guys now hit one or more of those cities with a professional anthrax attack. A former OTA study showed that a professional anthrax aerial spray attack against Washington D.C., dispensing

> 100 kilograms of anthrax spores in the spray, will account for 1 to 3 million casualties. And that's in an "unthinned" set of immune systems. **In the "thinned" set, one can at least double or triple, and even up to five times, that estimate.** So conservatively, now there would be from 2 to 6 million casualties. And even mild anthrax spray attacks in other "thinned" cities would also be amplified.
>
> "**That one is being set up, or already set up, right now.** There are other such "augmentation" setups also under way.
>
> **"So the weapons alluded to by the SecDef in 1997 are already being employed. WW III has already begun, and our populace (and our scientific community) is blissfully unaware of it."**
>
> http://www.cheniere.org/correspondence/021702a.htm

Most of us can remember the strange outbreaks of the so-called "**flesh eating disease**." It seemed to break out here and there randomly with no known cause. Bearden believes this was a test of the newer quantum potential weapons which go even beyond the capabilities of the Tesla howitzers.

> "The Kaznacheyev "disease induction by novel electrodynamics" work is also the basis for the spacetime curvature engines (not EM signals!) carried by quantum potential EM biological weapons for distant induction of diseases etc. into the population of an entire nation or area, such as the U.S.
>
> "This **quantum potential disease induction weapon** -- capable of attacking an entire population of a nation or area -- has been tested several times in the U.S. at very low levels, in the shadow state only (we explain shortly) and it has a most peculiar signature. E.g., **one test used necrotizing fasciitis (flesh-rotting disease) engines**.
>
> "The disease 'engine' was deliberately kept down in the 'shadow state' (virtual state, just below the observable state) so that only a tiny bit of the populace with depressed thresholds would "breach the observable threshold' due to the population forming a bell-shaped curve as to the threshold level. **The major signature of the test was that the cases of the disease broke out totally statistically and randoml**y, spread all over, without any 'disease vector' in between.
>
> "In short, it was not spread in any manner required by normal deterministic disease vectoring, **but was a totally random set of occurrences**. Several other diseases were also tested this way in the American populace, with precisely the same signature."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm
>
> "Apparently one planned use of such an augmented clandestine BW weapon will be smallpox, e.g. As you know, the Russians

> did develop smallpox for biological warfare, and even developed a new strain against which previous vaccination is ineffective.
>
> "The vast numbers of expected casualties, coupled with immune system spreading, are absolutely irresistible to the Russian mind. You can count on it that they have seen that the smallpox is already on site here, in the U.S. and in the hands of professional terrorist teams. Of course, the Russians/KGB will protest they have nothing to do with that! Yet likely the KGB will have flatly arranged it or at least assisted it. The capability for mass destruction of the nation is so lucrative and easy to achieve in advance, that **they would never be able to resist doing it**."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

Bearden believes the **Gulf War Syndrome** involved the use of scalar technology to induce a disease state, as he stated in a 1997 interview:

> **"I'll say this flatly, and I won't answer any further questions about it; the Gulf War Syndrome was induced...** It was induced with this stuff. All the rest... was contributing factors that everybody's talking about... There are some deeper signatures, if you look into it very deeply, that show you exactly how it was done and the fact that it was induced. It was a test. It was a test of a very special kind of weapon I have not talked about yet. Anyway you can use it to create diseases."
>
> Bearden http://twm.co.nz/beard_weapon.htm

Besides using the woodpecker grid to target a population, the entire **electrical grids** of nations can be used as "channels" for disease patterns to be broadcast to all people near that grid. Your own house wiring can become an antenna, broadcasting these "shadow" patterns of disease, weakening your immune system.

And here one faces the frustrating fact that the same power grids could be set to channel patterns which would keep the entire population healthy, rejuvenated, continuously bathing in the time-reversing old-age-defying energy of the spacetime vacuum. We have **no idea yet** of how long the human life span could be increased with this new technology. People might be able to live two centuries given full humane development of this technology.

5. Psychoenergetics

Mental entrainment, inducing hypnogogic trance, mind control, broadcasting thoughts and feelings, the Ant World, education via EM [LW] mental download, the "Feelies," revolution in spirituality, "enlightenment machine?" Scalar churches?

Psychoenergetics is simply using the scalar interferometers to manipulate and **engineer the human psyche**. To me it is the most **mind-boggling and frightening** aspect of longitudinal wave engineering.

The mind is electromagnetic in nature, and itself of the time-domain. It is not observable in 3-space. There is no **thing** you can point to that is the mind. As Bearden says, "**The mind is time-like**."

The longitudinal scalar EM waves are also of the time-domain. By overlaying certain infolded patterns (oscillations in time) on the longitudinal waves, **a thought or feeling may be made to arise in a person** or persons who are in the interference zone (where the wave beams cross).

The person will not notice anything, feeling that this thought or idea is his or her own idea. The longitudinal wave pattern might be a wave of panic or fear that spontaneously sweeps over you, perhaps inexplicably. It could even be in the form of a sudden intense patriotism. It could be explicit words and phrases, which everyone would think they had thought of by themselves. Or it could be rage and hatred, angry and violent. On the other hand It could also be a continuous sense of docility and placidity. This is the brave new world of psychoenergetics and the coming "**Mind Wars**."

Scalar Psychoenergetics in its most **primitive form** simply "entrains" all minds in the target area into a **deep hypnogogic trance**. In this state of mind people would be suddenly extremely suggestible, and would likely believe anything they are told, and would obey any orders given. Talk about winning the hearts and minds of the American People!

Tom Bearden makes me think of **Paul Revere**, who heroically conveyed important **warnings** for the sake of the new nation. But the words of the famous phrase have now strangely and curiously mutated into the once-inconceivable: "**One if by land, Two if by mind.**"

Indeed one strategy in a **Mind War** would be to simply **take over the minds of the "leaders"** of the enemy nation. The targeted leader would not be aware that anything was amiss, although he might begin to make unexpected changes in policy.

And are, in fact, any of our "leaders" already having secret thoughts that are not their own? Who knows? Frighteningly, we can no longer be sure. The new sciences of scalar electromagnetics and psychoenergetics are even now plunging humanity into a sudden science-fiction-like world beyond anything in humanity's previous imaginings.

> "The Russians reached the point in the mid 1990s that they could **take over control of a person's mind**, with modified longitudinal EM waves including some time-polarized EM waves, and with a team of specialists (estimate 25-30 per transmitter, and one transmitter and team per controlled person)." Bearden

In a slide Bearden illustrates how a Scalar War would involve a **psychoenergetics attack** on the operators of the enemy scalar installation, entraining their minds into hypnogogic trance and **getting them to shut down their systems**.

And ultimately psychoenergetic warfare goes to the very heart of **human identity itself**. For if my thoughts might no longer be "mine," then **who and what am I?** Can my very sense of being "me" be hijacked by some nefarious psychoenergetic scheme? Will the "secret government" eventually dictate directly into your mind how you feel about yourself? Or what you think you are? Or what you should do?

How Does Longitudinal EM Mind Control Work?

The physics of scalar psychoenergetics as expounded by Col. Bearden seems even more arcane and over-my-head than that of extracting energy from the vacuum. I can't understand it, but I look through it anyway. Each time another tiny understanding might occur, or a term might fall into place. I know the mathematics is forever beyond me.

One paper to begin with is Mind Control and EM Wave Polarization Transductions This is such serious stuff that Bearden includes a **strong warning about misuse of this knowledge**. Psychoenergetics weapons can mentally maim and physically kill.

Warning!

(From "Mind Control and EM Wave Polarization Transductions")

> "This article refers to experimental research techniques which can be detrimental or lethal in the hands of any but highly skilled, qualified experimental scientists proceeding under proper laboratory safety procedures. The purpose of this article is strictly for information to properly qualified and authorized scientists in certified laboratories. We do not propose or condone any use of these procedures for nonapproved practice of medicine without a license. Neither the publisher nor the author are responsible for accidents or outcomes in the use of these experimental procedures and techniques. Any researcher who performs these procedures and experiments is acting on his or her own volition, and is solely responsible for insuring safety, qualifications, and legality of the acts and their results. **We neither suggest nor condone unauthorized experimentation on human subjects. Such is a criminal violation of the constitutional rights of the subject under Federal and State laws, and is both illegal and immoral**." Bearden

After the **serious warning** comes the description of the paper. This is heady stuff for the layman.

> "Calling full attention to the special note above, in this paper we present a high-level overview of the novel electromagnetic nature of mind operations, mind and body coupling, and intent - the induction of physical 3-space EM energy changes into the brain and nervous system, and into every cell of the body, from the mind's time-like coherent operations. We summarize the time-polarized electrodynamics used to engineer and affect mind operations and the mind-body coupling loop. Transduction mechanisms whereby differing EM wave polarizations can be transformed one-into-the-other are presented." Bearden

I will leave it to the technically astute to try to understand the mechanisms of operation which are described in scientific language. But there are tidbits for the layman. Here he speaks of the difficulty Western scientists have in opening up to the "immaterial" (longitudinal wave) nature of the human mind.

Western Science Remains Largely Materialistic

"Ironically, most Western scientists are materialists and consider "mind" as a mystical and nonscientific concept. They tend to consider mind operations and functions either to be simply "meat computer" operations and functions, or at best to be very weak ordinary transverse-wave EM operations and functions in the brain and nervous system. This serious self-limitation exists because in the body we measure only weak TW [transverse wave] EM operations and functions correlated to biological behavior and brain operations. We simply do not know how to measure "mind operations" directly.

"With no mind measurements possible and no instruments, it is understandable that Western science considers only the physical side of the mind-matter interface.

"Presently our scientists do not measure the longitudinally-polarized EM wave operations and functions in the body and around it in nature. Few of them are aware that a maelstrom of such LW [longitudinal wave] functions exist in the body and in all of nature in general." Bearden

Western methods of influencing the mind with EM waves have only used transverse waves, not the longitudinal waves of the vacuum. If only transverse waves are used one pretty well has to hit the target mind with a **sledgehammer of waves**.

Western Science knows only transverse EM waves

Brute Forcing Time Functions versus Fine Control Methods

"Ironically, Western mind control researchers using transverse EM waves for mind control research, are using a brute force method of evoking and using vacuum engines (spacetime curvature engines) and a special form of general relativity, although they do not appear to realize it.

"While KGB scientists also use TW EM "brute force" TW waves when necessary, they do **"imprint" or "activate" those waves with the desired internal LW and time-polarized EM wave and photon structures** required to directly perform the mind engineering desired... Bearden

"These "fitted brute-force models" certainly can be very powerful, and certainly can produce the exact results shown in the experimental verifications of the fittings. However, they do not of themselves allow sophisticated design for example of the necessary time-polarized wave assemblies for **engineering the entire human collective unconscious simultaneously**, or for engineering the entire collective unconscious of all species on Earth (i.e., Gaia's collective unconscious), or even for precisely **engineering the memory and knowledge base of an individual**. Bearden

The seemingly magical operations of psychoenergetics, sometimes called "psychotronics," cannot be achieved with ordinary transverse EM wave energy. But they are possible with longitudinal scalar waves because the mind itself is scalar in nature.

> "We note that **all mind operations are time-like**, i.e., they are comprised as scalar EM photon functions and scalar EM wave functions. Thus the mind is a very special kind of electromagnetic system, existing in the time domain..." Bearden

The engineering of the mind can only be accomplished with the waves of time.

The course of psychoenergetics development necessitates the building of a vast database of settings and patterns which bring about given mental and/or emotional states. A kind of "**genome**" of the psyche. Bearden describes the process of the decoding of this "genome."

> "Now the scientists would perform many phenomenology experiments, making one little change at a time and profusely recording the data. Each time, they would establish the physical change(s) that occur in the body and/or the mental and emotional changes that occur in the mind for each spectral reinsertion back through the "ship's portholes". They would simply but painstakingly (over some years) build up an extensive database of those individual correlates.
>
> "In these experiments, the experimenters will eventually be able to **provoke any body or mind change they wish**. Strong emotion. Intense pain. Intense pleasure. Painful thoughts. Images. Memories. Perceptions. Dreams. Visions. Memory losses. Memory changes. Personality changes. Etc. The "delta" in the emission spectrum (the changes from zero reference spectrum) represent the precise totality of all mental, physical, organic, chemical, etc.changes and interactions." Bearden
>
> "A second stage in the research would be to **test the correlates** and porthole insertions upon a statistically significant cross section of ordinary people, and/or specialized populations (such as toughened soldiers). The program would evolve a highly complex, very effective, ever-improving science and technology of mind and behavior control and engineering mechanisms, complete with finished database and developed applications equipment." Bearden

Summing up his paper Bearden speculates on what the actual situation the science of psychoenergetics probably is. The intense secrecy with which this knowledge has been kept from the public has led to the **current farce of the "government" pretending** it all does not exist, and this secrecy may have now put us at great risk.

> "The implication is that in the West one or more highly classified, sustained, heavily funded developments in advanced mind control programs, probably exists and probably has existed for some time. Due to loose formation of rogue groups inside such programs, they may have dual or triple purposes, **may not operate under very much legitimate government control at all**, and may operate specifically for the purposes of the rogue group or groups that have gained control.

> "In a nutshell, that's what may be going on in the **clandestine mind control projects** in several Western governments. The involvement of at least some rogue groups, some being "cowboys" who operate well **outside all laws and ethics**, could also result in such things as assassinations, clandestine testing on individuals without their consent, etc. In short, ***it could account for what seems to be actually occurring***. As also is "usual" in such a mess, one or more of the rogue groups eventually may become very powerful because their secret weapons are very powerful. They may become confident, thinking they have the "best in the world." They may actually believe they are ahead of the Russians..."
>
> "Remember that, in every large and powerful human organization, the basis for rogue groups is **power** and **secrecy**. They are always seeking to increase their power, control, influence, prestige, etc. Nothing else. Patriotism and mission are—to rogue groups—often just idle words. They have their own agendas. And being rogue groups, they may well bring in unethical, immoral tricks: assassination, bribery, entrapment, disinformation, plausible deniability, etc. A certain percentage of a highly secret rogue group will wind up using all these things and more. It's a **human** characteristic, the **old primate dominance game**. Only now disguised and hidden under deep classification."
>
> "The **Russians**, with their additional knowledge of the actual mechanisms in the transforms, will be **much more advanced than the West,** because their fundamental psychoenergetics science is far more advanced, so long as we continue to use the old U(l) electrodynamics. Further, the Russians have decades of use of **longitudinal interferometry beams to reach right through the earth and ocean** and produce stringent EM effects at a distance. So they will also be able to do the same things here in "mind control" with LW [longitudinal wave] interferometers, through intervening mass." Bearden

Bearden cites two examples where he believes the Russian KGB tested the psychoenergetics capabilities of their scalar interferometers. One was the case of Captain Button in his A-10 "Warthog" aircraft on April 2, 1997.

> "Over Arizona, Captain Button was thrown into a hypnogogic state, and his perceptions instantly altered and controlled. In his instant "dream-waking" state, everything seemed perfectly normal. His sense of direction was altered a bit more than 90 degrees, so he simply corrected and turned and "flew toward the range", actually flying off course by more than 90 degrees and ignoring radio contacts. He flew right on out of Arizona."
>
> "At one point he circled, probably thinking he was over the range, and he probably dropped his ordnance there. Then he "flew on back toward home," as he thought in his waking dream state, until his fuel ran out and he crashed and died in the explosion—**dream-thinking until he died that everything was normal**. All the while, his sense of the passage of time was altered. To him, in his dream-thinking, dream-acting state, everything was normal and nothing untoward had happened. **So the distant KGB transmitters and associated psychoenergetics team controlled him for over an hour**.

> "Indeed, that was the exact purpose of the test: demonstrate control (at a great distance) of a skilled person performing highly skilled tasks."

The paper Mind Control and EM Wave Polarization Transductions ends with the most chilling and frightening possibility of all: the **psychoenergetic engineering of the human species** as a whole.

The Ant World

The Final Race for Direct Mind Control of the Entire Human Species

"The KGB psychoenergetics weapons scientists—because of their direct measurements and detections (and use) of t-polarized waves and LWs [longitudinal waves] for decades—also understand that Jung's collective unconscious mind (of the entire human species) also has its own time-like operations and correlates, which one measures also when using t-polarization measurements and sorting it all out. **The collective unconscious mind operations are buried several levels deeper inside the recursive Whittaker structuring inside the EM fields, waves, and potentials**.

"The KGB scientists also know that something very like **Gaia** — a collective unconscious mind for all species on earth — **also exists**, and they are striving to be able to sort out and measure that one as well. The Gaia operations are buried even deeper in the recursive structuring inside the EM fields, waves, and potentials."

"Actually, from day one, the Russian mind control scientists have had their eventual goal set upon this "deeper area of mind and possible mind control" of the entire human species.

"I am convinced that the KGB psychoenergetics scientists understand this deeper area. If they can learn to directly engineer the collective human species unconscious, they can then **convert the human species easily into a sort of "ant" society**, modeled along ideal Communism lines, except of course with an excluded "hierarchy at the top" running everything. The "ant society" — communist style — is still a variation of feudalism (**all systems tend to feudalism or some form thereof**).

"The KGB psychoenergetics weapon scientists are seriously pressing on toward that very goal. In my opinion they are not very far from it right now...

"Some versions of Russian mind control devices were used on Russian soldiers in the Afghan War to **condition them for performance of merciless acts**." [13]

http://www.cheniere.org/explore%20articles/mind%20control3/p07.htm

More about "The Ant World"

Whether it is the Russians planning an "ant world" society or rogue U.S. black-ops groups withholding a great boon from human race, the secrecy on all sides around has allowed **largely criminal elements** to take over this technology while leaving the civilized elements in the dark. Openness and the spreading of this knowledge among good and decent people is essential, and for that **we will have to overcome our frightened denial**.

> "Meanwhile, **rogue groups** amongst Western clandestine mind control researchers will probably arise if they have not already done so. They will likely seek to increase their personal control and further isolate the programs from orthodox government review and from government and legislative control. They may even divert the research into highly illegal and unethical means, because it furthers their own rogue agendas. That is how clandestine U.S. government research can sometimes go sour, **unless great care is exercised by the oversight committees in the House and the Senate**.
>
> "Sometimes when rogue groups do gain control and total secrecy of a given new technological area, then what appears to be "U.S. government operations" do start to encompass a criminal and unethical operations, hidden usually beneath the deep veil of high classification. Also, if it's "scientific," no one is ever brought to justice, even if the "evil science actions" are uncovered and publicly revealed." Bearden

Like the huge energy of the Tesla howitzers, the ability to engineer the mind with longitudinal waveforms is a seeming "magical" thing which can be used for good or ill. Bearden envisions that further developments will allow something like the "downloading" of knowledge via scalar interferometry. Everyone could be highly educated, and quickly and easily.

In the conclusion of the paper "Mind Control and EM Wave Polarization Transductions" Bearden makes **a plea to the nations of the world** regarding the use of psychoenergetic engineering.

> "Let us hope this great new area, already off to a bad start, can be bridled and steered in the direction helping and healing people, rather than killing or abusing them. **The excesses in its bad use are a potent threat to all nations on earth**.
>
> "Yet it can revolutionize medical science, education, communication, and psychology. We foresee the day -- perhaps 30 years hence -- when **education will be accomplished by directly loading the software into the mind**. Then in three weeks one will "load" a doctorate, say, in physics. In three more weeks on will also load a doctorate in chemistry. Another three weeks, in electrical engineering. Another three weeks, an M.D. And so on. When that happens then truly everyone on earth can be educated. Freedom from ignorance may well be another great freedom that is legally recognized. There will be no impoverished large groups lacking the education to find decent, productive jobs.
>
> "We urge all nations to use the principles involved: not for human abuse, but for healing, educating, uplifting, and life-expanding of every person on earth. If we do, we shall all have a far brighter future. Then we shall check what has started out to be the Sword of Damocles and turn it into the golden Millennium." Bearden

(Perhaps after so many frightening topics a slight break is in order here to consider the **lighter side of psychoenergetics**. For example, what will be the ultimate impact on the entertainment industry?)

The Feelies at Last!

Psychoenergetics will be able to bring about at last, for better or for worse, Aldous Huxley's fanciful idea in his novel "**Brave New World**," an entertainment format which he called "**The Feelies**." Those were something you went to, like going to the movies, but you would **experience** all the actual feelings themselves, as if the depicted events were actually happening to you. Although our "leaders" seem too dim to grasp what is going on in the world of scalar electromagnetics, it should not take some young Hollywood genius too long to understand that **The Feelies are now possible**, and that the immense megabucks of potential profit more than justify heavy investment in bringing it to market.

One can imagine that first "Feelie" theater, "The Huxley" perhaps, a large comfortable area surrounded by nine giant screens (not just one screen!), which become 3D if you put on your headset. And The Huxley is fitted with the finest sound, and oh, by the way, a modest sized scalar interferometer with computer. And there are one or more **new tracks** now recorded on the film next to the sound track. These are the digital patterns of thoughts, feelings, and ideas to be fed into the theater's interferometer. And these thoughts and feelings and ideas will be felt by the audience as if they were their own thoughts and ideas. It is an entirely new art form. Psychevision.

As important (and no doubt famous) as the actors would be the "feelers," those from whose minds the feelings were lifted in the original programming of the Feelie tracks. Because, for example, Brad Pitt might be a good and handsome actor, but **can he really feel it?** Like the dubbing of foreign language films, it might be necessary to dub the "emotional track" using a deeper and more profound person's feelings, thoughts and ideas.

It might even be engineered so that if you sat on one side of the theater you would feel like the hero, and on the other side you would feel exactly like the bad guy! What would that lead to?

We have all cried at a movie some time, most people have, though they might not want to admit it. But this would be **deep sobbing** and a **flood of tears**, if the director so desired it. You would feel it at your core. Or, take a big chase scene, **you would be terrified**. They are breathing down your neck! You would be gripped by panic.

For that matter, the whole genre of **Horror-Feelie** would be too much for many people to take. Do I **really** want to feel that an **actual vampire** is tearing at my throat with his fangs?

A Religious Feelie would make you feel the exaltation of a saint at his prayers, or give you the **definite** feeling that you are Christ suffering on the cross. All the pain could be there too. The stickiness of the blood. The very feeling itself: "Why hast thou forsaken me?" Who among us could come up **that** despair for scanning? Had this been developed a bit earlier we might watch a documentary of, say, Mother Theresa, containing her own actual deep sense of compassion, which we would feel arising in us as our own.

Then again, a Psychedelic Feelie could induce an LSD-like state and simply blow the audience's minds.

Even in its simplest most primitive mode, the hypnogogic trance induction with its increased suggestibility, would completely alter the experience of even ordinary current movie going.

6. As it Stands - 2002

[Note 2006: Click here for a current status history of the MEG from Tom Bearden]

> "**Anyway, it's presently a "Mexican stand-off**" with the various parties maneuvering with check and countercheck. That is the real "balance of terror" that is held by such a fragile balance."
>
> "You can see the implications if such weapons fall into the hands of the radical terrorists. Ordinary positive energy EMP shooters **can be made fairly readily and cheaply** from nearly just **Radio Shack parts** or surplus parts. It just takes some know-how... When and if the Yakuza [Japanese mafia] gets those (and they will, it's just a question of time), you can begin to appreciate some of the turns this present terrorism and our war on it will take." Bearden

The very thought of the building of one of these howitzers by "some lone-nut gunman" from Radio Shack parts makes one realize how serious it is for humanity to face the crisis it has come to.

Once again, as at the dawn of the nuclear era, humanity finds itself at the crossroads of Heaven and Hell. As a species, we must stop and consider. And there is at least one real difference between this visit to the crossroads and the last: *this* time there is a very real possibility of a true "earthly heaven" on the Heaven side.

The poor nations could come to a good life. Disease could be largely eliminated. Fossil fuel pollution could end. Global warming could be solved, and the weather could be managed in a humane way, bringing water where there is drought, and sunny skies where there is flood. Scalar interferometry would be there to avert any possible hits by asteroids or comets. Mars could be colonized and terraformed. Everyone would be highly educated through psychoenergetic downloading of knowledge. And the **wisdom of the wise** could be realized directly through scalar connection to their minds and hearts.

These stunning sudden possibilities give me pause to think: if our species has reached this crossroads in such a short span of centuries, then surely other species in this vast universe have passed this way before and long ago. And of those who chose the path to "planetary heaven," what is their life like now? It might be good if some of them were with us now, to guide us through this last struggle over this pesky old good-and-evil problem. **It is our last chance to choose the path which benefits the whole species, and not just some elite group or faction**.

The Disclosure Project

One person working tirelessly to bring to bring these technologies into the open is Dr. Stephen Greer of the Disclosure Project, which is calling for congressional hearings into the issues of UFOs and the free energy technology that was, perhaps in part, reverse-engineered from them.

> "Once abundant and nearly free energy is available in impoverished areas for agriculture, transportation, construction, manufacturing and electrification, **there is no limit to what humanity can achieve**. It is ridiculous — obscene even — that mind-boggling poverty and famine exists in the world while we sit on classified technologies that could completely reverse this situation.
>
> "So why not release these technologies? **Because the social, economic and geo-political order of the world would be greatly altered**. Every deep insider with whom I have met has emphasized that this would be the greatest change in known human history. The matter is so highly classified not because it is so silly, but because its implications are so profound and far reaching. By nature, those who control such projects do not like change. And here we are talking about the biggest economic, technological, social and geo-political change in known human history. Hence, the status quo is maintained, even as our civilization hurtles towards oblivion...
>
> "With the types of weapons currently in the **covert arsenal** — weapons more fearsome even than thermonuclear devices — there is no possibility of a survivable conflict. Yet in the darkness of secrecy, actions have been taken on behalf of every human that may endanger our future. Only a full, honest disclosure will correct this situation. **It is not possible for me to convey in words the urgency of this**."
>
> Dr. Stephen Greer http://www.disclosureproject.org/ES-DisclosureImplications-2.htm

Greer and his team have assembled hundreds of witnesses, many of whom are military or ex-military, who are ready to testify to congressional hearings what they know about the covert black projects which have kept free-energy and antigravity propulsion technology secret from the people.

Greer points out the need to regulate these technologies so they are limited to peaceful uses, but this is of course difficult when the government simply chooses to pretend they do not exist. In the meantime, as the President and the Defense Department continue the charade of war-as-usual, those scalar (longitudinal wave) installations which DO exist continue to fall into ever more sinister hands. And there is no reporter in the press brave enough to ask, "**Mr. Secretary of Defense, what steps are you taking to defend our MINDS from attack by the big Russian longitudinal interferometers?**"

Longitudinal Interferometers are Proliferating

In a later statement Bearden reveals that in fact the Yakuza [Japanese mafia] has **already leased** some of the interferometers with a nearly $1 billion "down payment:"

> "After the collapse of the Soviet Union's economy, lots of things got available for lease or purchase that would never have been under the old system. That happened in the resulting economic chaos. The Russian Mafia rose to prominence, as did some wheeling and dealing entrepreneurs who played both ends against the middle.
>
> "**In that atmosphere, and in the need for money, the KGB allowed leasing of the earlier longitudinal EM wave interferometers to a consortium of the Yakuza and Aum Shinrikyo.** They did this only after they had tested and deployed their great new quantum potential weapons. That class of weapon is the dominant weapon on earth. Five nations now have it: Brazil, Russia (KGB), China, and two nations friendly to the U.S. The deal to lease many of the earlier LWIs [longitudinal wave interferometers] to the Japanese Yakuza and Aum Shinrikyo was consummated at the end of 1989, with a down payment of $900 million in gold bullion as "up front" money. I don't know what the lease per year was and is, but probably something like a billion dollars a year. **So the rogue Japanese acquired longitudinal EM weapons** and that technical know-how. In fact, the Yakuza is producing certain kinds of those in its own facilities in Japan now."
>
> http://www.cheniere.org/correspondence/030202a.htm

Personally, I am a little uncomfortable with the knowledge that the Japanese mafia may now be able to insert things into my mind. I'd like to sleep at night knowing that my dreams are my own, such as they may be, and not some weird fantastic visions cooked up by a criminal organization. **This is a world emergency**.

And in Bearden's analysis, it all comes back to the issue of **energy**. It is the energy crisis which is now provoking the current "oil wars," since oil production has hit the "Hubbard Peak" and will decline. And the electrical power grids must be replaced with scalar power as fast as possible, for these grids are now totally vulnerable to any possessor of longitudinal interferometers. They can all be wiped out in minutes. By anyone who possesses or controls a Tesla howitzer.

> "Anyway, in my personal view, we should have a national **Manhattan Project** right now, to develop decentralized electrical power systems taking their energy from the vacuum . . . The MEG is real and so are several other systems invented by private inventors and colleagues. All these efforts should be massively funded and massively and quickly developed. The survival of this nation is going to depend upon it. . . . There are many other facets, but the major point is that **our scientific apparatus and the public are still unaware of what a desperate struggle we have entered, since it was thrust upon us. 9-11 was a wake-up call**. It was certainly bad enough, and one grieves for those lost American lives. But I fear the **worst is yet to come**, and it is coming at us like a runaway train hurtling right down the track at us."
>
> http://www.cheniere.org/correspondence/021702a.htm
>
> "The electromagnetic weapons mentioned by the Secretary of Defense in April 1997 **are in terrorist hands also**, including the **Yakuza and Aum Shinrikyo**. That rogue group leased those earlier weapons on site in Russia, from the KGB, at the end of 1989. The SecDef stated that such weapons were being used to initiate earthquakes, initiate volcanoes into eruption, and control and engineer the weather. Quite true. And presently

there is a truly massive set of weather engineering operations going on over North America, from that rogue Japanese group manning the weapons in Russia. Some 10 nations of the world now have the type of longitudinal EM wave interferometer weapons (which are what the SecDef was most probably referring to). There are other even more fearsome weapons, possessed by five nations. **So a great deal of the state of the world is not covered in the news at all, and will not be . . .**

"We have been in an undeclared war of an eerie kind for some decades. That war seems now to have started to heat up also. The destructive capability of some of these weapons is awesome, and far greater than nuclear."

http://www.cheniere.org/correspondence/021702a.htm

"In that sense, the first phase of WW III is already completed. Now we are only waiting for Phase II.

"It is against that backdrop that I think one must "analyze" such things as how fast we will be replacing the power grid (**it's going to go anyway, and catastrophically, the terrorists will see to that**). And everything we have is critically dependent upon energy, from the economy to jobs to mobility, to the millions of trucks that transport our goods every day, etc.

"As far as I am concerned, we are already late in declaring a great national emergency in energy, because of the coming destruction of the present energy infrastructure. The scientific community should lead, follow, or get out of the way. The emergency is not in seeking "alternative but conventional" systems. It is in developing "energy from the vacuum" on an emergency, crash basis.

"Unfortunately, everywhere I look I just see business as usual. Most Americans (and news media) seem to think, hey, Afghanistan is finished except for a bit of cleanup, and it's just about over).

"It isn't. It has only just begun."

http://www.cheniere.org/correspondence/021702a.htm

Beyond the Howitzers: Quantum Potential Weapons

Do not use EM propagation through space

As more and more nations acquire the scalar interferometers, Bearden speculates on the next generation of longitudinal weapons called "quantum potential" [QP] weapons.

> "The **quantum potential weapons** are presently only held by three nations: Russia (in the hands of the KGB, which is now know by its new name), Brazil, and the "friendly little nation." Red China may be working on them, but is just at the beginning...

> "The QP weapons have been highly reserved by the Russians. However, the complete extent of their capabilities is still being figured out...
>
> "The quantum potential weaponry (possessed by only three nations) is supreme, because **it uses multiply connected spacetime**, and DOES NOT involve propagation of EM energy through space as does the longitudinal EM wave interferometers.
>
> http://www.cheniere.org/misc/qp.htm
>
> "The operational deployment of full-scale strategic QP weapons on site in Russia occurred at the end of 1989, which is when the formal weapons first went operational. These weapons are not in the inventory of the regular Russian armed forces, but all research and development, manufacturing, deployment, an manning and employment is under the ruthless control of the KGB. Shortly thereafter (within weeks), the KGB leased many of their earlier longitudinal EM wave interferometer (LWI) weapons to a rogue Japanese group comprised of the Aum Shinrikyo and Yakuza."
>
> Bearden http://www.cheniere.org/correspondence/021401.htm

In another paper, "Time Polarization - Significance and Weaponization," Bearden tells the story of how a KGB longitudinal wave attack was averted by the longitudinal weapons of a "friendly small nation."

So as it stands, it is precarious. Not until the people demand an end of what author Jim Marrs has dubbed the "**Rule by Secrecy**," can the people's representatives tackle the big problems of a worldwide ban on Scalar Wars and the shifting over to an essentially oil-free economy.

Latest Update from Tom Bearden - March 2002

The whole situation is changing so fast that when I asked Tom to look over this article he mentioned the seeming contradiction when some of the above statements are taken together. At different times the information he has is updated so one has to keep a kind of running track. He was kind enough to clear up the confusion here with the situation as it stands as of March, 2002.

> "We knew of three nations having the QP weapons for some time. Then we found out last year that five nations had it. So that explains my using the figure "three" first (which represented what I knew at the time). Later I found out about the other two nations. China, e.g., only deployed its QP weapon this past year. So that explains the apparent contradiction between me using "five" in later papers and "three" in earlier ones. It was the best information I had at that time. Might mention that so the reader will understand the apparent discrepancy." Tom Bearden

Emptiness is Full of Energy

"The Tao is an empty vessel;
it is used, but never filled.
Oh, unfathomable source
of ten thousand things!

"Oh, hidden deep but ever present!
I do not know from whence it comes.
It is the forefather of the gods."

Lao Tzu -Tao te Ching

Afterword

Because of the extreme seriousness of the topics brought forward in this article, I asked Tom Bearden to look it over to make sure I had not gotten anything too terribly wrong or mixed up. I did not want to pass on any misunderstanding of my own. I felt a little nervous writing to an eminent scientist, and hoped I had not presumed upon his time.

But Tom was so kind as to answer immediately, and to my relief I had not gotten anything too terribly wrong. Here is his letter, in which he clears up a misunderstanding, and reports on his current health treatment, and gives a call to the young grad students to turn themselves loose in the whole new field of scalar electromagnetics and free energy.

Subject: RE: Article on Tom Bearden and "Scalar Wars"
Date: Fri, 22 Mar 2002 22:54:01 -0600

Bill,

Well, I must say I'm astounded at your persistence and hard work in congealing all that together. My compliments on a hard job quite well done.

Couple tiny things: In the area mentioning Kervran and Kaznacheyev: Kervran was French; Kaznacheyev was and is Russian. Little typo of "spredding" the immune system. Should be "spreading".

We knew of three nations having the QP weapons for some time. Then we found out last year that five nations had it. So that explains my using the figure "three" first (which represented what I knew at the time). Later I found out about the other two nations. China, e.g., only deployed its QP weapon this past year. So that explains the apparent contradiction between me using "five" in later papers and "three" in earlier ones. It was the best information I had at that time. Might mention that so the reader will understand the apparent discrepancy.

Otherwise, it's pretty accurate.

Just now I'm letting the weapons take care of themselves; have to, as I will be recovering now for nearly a year from now after the heart attack last year and discovering that I had contracted mycoplasia (the BW modified kind) in Canada in 1968. Finally got a test which confirmed the chronic mycoplasia (which I had for 33 years!). The stuff burrows inside one's red corpuscles, then draws nutrients from the hemoglobin, hardening it and reducing its ability to take on oxygen (by as much as 50% or more). The resulting symptom is loss of endurance (which I had for that 33 years) -- the so-called "chronic fatigue syndrome".

Many of the Gulf War Veterans who are sick also have it, though they apparently have other complicating factors as well. A very high percentage of persons with chronic fatigue syndrome also have mycoplasia. The treatment for the long-standing mycoplasma infection of that nature is to stay on antibiotics for a year. The only time the mycoplasma is vulnerable is when one wears out a red cell in normal usage, and the body makes a new red cell to replace it. The mycoplasma comes out of the dying cell to infect the new replacement cell, so it is exposed and vulnerable at that specific time and that time only. The antibiotics kills it at that time. Hence the necessity to stay on antibiotics for such a long time so it is continuously in your bloodstream (I've already been on antibiotics for over two months, and have at least 10 more months to go). We also take a little medical oxygen every day.

Another symptom of the mycoplasma infection is the association of runaway fibrillation of the heart. To stop that, there are pills one takes, and they stop it. But they also further reduce the volume of blood pumped by the heart, so that this projects one right back into the hypoxia, dizzy, loss of balance, etc. Catch 22 situation; the fibrillation will build and cause heart attack, stroke, etc. if not stopped, and if stopped it puts you back in the hypoxia which can cause many things! With the conventional treatment, you're damned if you do and damned if you don't. Hence the need for a little extra medical oxygen, so you can take the "heart clamp" pill and stop the fibrillation, but also augment the oxygen enough to continue to survive without a stroke or some such. Interestingly, it's very difficult to even obtain a mycoplasma test, and Medicare fights you tooth and nail over paying for the oxygen. Either they will pay for it or I'll pay for it myself; it is absolutely necessary.

After a heart attack, one is treated in the heart clinic by specialists who are very caring and excellent practitioners, but know nothing of mycoplasma infection, so not consider it even a part of "heart disease", and who are rather puzzled when one has no clogging of the arteries, has the right count of red corpuscles (largely nonfunctional, of course, but there), pumps the right amount of blood, etc. So they identify and treat only the runaway fibrillation, do not prescribe the oxygen -- and essentially place you on a regime as best they know, but one that is guaranteed to kill or maim you or turn you into a totally disabled person or human vegetable via stroke, paralysis, etc. Fortunately my family doctor will prescribe the oxygen anyway, though I may have to pay for it myself. Whatever works!

However, I'm slowly improving little by little, working as much as I'm able to and trying to finish my book: Energy from the Vacuum: Concepts and Principles, and get it to the publisher for publication later this year. Hopefully the book will turn all the interested young grad students and post-docs loose in the free-energy area. They will not have to spend 30 agonizing years to get to where I am, and where a few others are, but can simply start here and go forward. Since speed to develop energy from the vacuum is of the essence because of the world situation, I'm moving on it as fast as I am physically able to.

Meanwhile, working with the AIAS (Alpha Foundation's Institute for Advanced Study), the AIAS (15 authors) has now gotten about 20 scientific papers published in leading journals (Foundations of Physics, Foundations of Physics Letters, Physical Scripta, Optik, etc.) dealing with electromagnetic energy from the vacuum. Several more are either approved for publication or in the review process also. So slowly we are getting it into the mainstream scientific literature. Hopefully it will be in time, but it's cutting it close.

Very best wishes,

Tom Bearden

Late update

Massive display of longitudinal interferometers?

UFO Fleet Taped
Over Bedhampton, England

Is this sighting a case of the testing of all the Russian (KGB) longitudinal interferometers at once? And coordinating their targeting through the woodpecker grid to a common place, as an exercise in making a massive scalar attack upon a given region? Was this a confluence of Russian Tesla howitzer marker-beacons?

Bedhampton, England - March 22, 2002 - Video Frames by: Anthony Woods

Certainly for a massive all-out scalar attack you would want coordinated movements of the target areas of many howitzers at once, for you could then just cut a bloody swath across a wide area, all the howitzer blasts marching across the land in a kind of scalar version of the "scorched-earth policy." All in a line, blasting, and heat, and mind waves. Or you might want to put the blasts all in the same place for a truly horrendous destruction. And on top of that biowar on citizens whose immune systems have been weakened with the quantum potenial weapons. This is the latest version of Armageddon.

And should any madmen gain control of these weapons, any rogue group at all, and should they have some aggenda to radically depopulate the world, to simply kill by the billion, the means will be in their hands to do so.

Update: MEG patent granted

Motionless Electromagnetic Generator Patent Granted

This message is from **Jean-Louis Naudin**, the French scientist who successfully replicated the Motionless Electromagnetic Generator (MEG) in France. He announces the granting of the patent to the MEG Builder's group at Yahoo.

----- Original Message -----
From: jnaudin509@aol.com
To: jlnlabs@yahoogroups.com
Sent: Tuesday, March 26, 2002 2:20 PM
Subject: [jlnlabs] (Info) GOOD NEWS : The Tom Bearden's MEG IS PATENTED

Dear ALL,

GOOD NEWS !!!!

The **Motionless Electromagnetic Generator**
from Tom Bearden is now PATENTED
US **6362718** granted on March 26, 2002

US Patent 6,362,718 :
Motionless Electromagnetic Generator (MEG)

Abstract: An electromagnetic generator without moving parts includes a permanent magnet and a magnetic core including first and second magnetic paths. A first input coil and a first output coil extend around portions of the first magnetic path, while a second input coil and a second output coil extend around portions of the second magnetic path. The input coils are alternatively pulsed to provide induced current pulses in the output coils. Driving electrical current through each of the input coils reduces a level of flux from the permanent magnet within the magnet path around which the input coil extends. In an alternative embodiment of an electromagnetic generator, the agnetic core includes annular spaced-apart plates, with posts and permanent magnets extending in an alternating fashion between the plates. An output coil xtends around each of these posts. nput coils extending around portions of the plates are pulsed to cause the induction of current within the output coils.

Inventors: Patrick; Stephen L. (2511 Woodview Dr. SE., Huntsville, AL 35801); Bearden; Thomas E. (2211 Cove Rd., Huntsville, AL 35801); Hayes; James C. (16026 Deaton Dr. SE., Huntsville, AL 35803); Moore; Kenneth D. (1704 Montdale Rd., Huntsville, FL 35801); Kenny; James L. (925 Tascosa Dr., Huntsville, AL 35802)

Appl. No.: 656313
Filed: September 6, 2000

For some technical info see my web site at : http://jnaudin.free.fr/html/meg.htm

Best Regards
Jean-Louis Naudin
Email: JNaudin509@aol.com
Main Web site : http://jlnlabs.org
Site France : http://jlnlabs.multimania.com

Click here to view patent # **6,362,718**

Patent Story on Rense.com:

Important Note 2006! MEG delayed: **Click here for a current status history of the MEG from Tom Bearden**

Rense.com

MEG Scalar Energy Device Patented - Production Starts Next Year

From Bill Morgan
3-28-2

Patent was granted on March 26, 2002 for "The Motionless Magnetic Generator," (MEG) US Patent 6,362,718, which is likely to become the first commercially available free energy device in history in about one year from now. The machine will provide free electricity from the vacuum, for the life of the device, which should be a very long life since it has no moving parts. You can see a picture of scientist Jean-

Louis Naudin's MEG replication model at:
http://jnaudin.free.fr/html/meg.htm.

It has strong magnets, coils, and a controller unit with the electronics. Naudin made the announcement to the MEG-builder's Yahoo group. The announcement has significance since the patent office has always been skeptical of devices which seem to "get-something-for-nothing." But according to the new science of scalar electromagnetics, the MEG does not break the law of conservation of energy. It's just that the energy is conserved in the fourth dimension, time, and not our 3-space world.

The MEG provides electrical energy by tapping the longitudinal electromagnetic (EM) waves which exist in almost infinite abundance in the vacuum of space. This ocean of energy which permeates everything is sometimes called the "zero point" energy, since it remains there even at absolute zero temperature.

Four inventors are listed: Stephen L. Patrick, Thomas E. Bearden, James C. Hayes, Kenneth D. Moore.

Tom Bearden has explained the operation of the MEG on his website Cheniere.org, and also speaks about the new fearful weapons that can and have been made using the same "longitudinal waves" of the vacuum.

The complicated physics of how the MEG works is explained in the paper "The Motionless Electromagnetic Generator: Extracting Energy from a Permanent Magnet with Energy Replenishment from the Active Vacuum," which can be found at Tom Bearden's website:

cheniere.org.(http://www.help4all.de/energy/MEGpaper.pdf)

The first MEG units to be produced for sale will output 2.5 kilowatts of free electricity. Forever. They should be in production about a year from now. Facilities for manufacturing the device are being set up in an unnamed "friendly nation."

This free electricity will flow indefinitely, without much, or any maintenance. The units may be hooked together to provide more wattage, so four of them would provide 10 kilowatts. After some production experience units will be made which output 10 kilowatts each. With a couple of those units a house could get off the electrical grid.

Tom Bearden, one of the inventors has said "I will admit that the chief scientist of an important experimental group in a large company was rather stunned at the type of output we were able to obtain. The MEG may look like just a transformer, but it is not. It is a completely different breed of cat." This cat, it would seem, is out of the bag now.

The ordinary EM waves we are familiar with are called "transverse" waves, to distinguish them from the new "longitudinal" EM waves of the vacuum. Bearden has explained in depth on his website cheniere.org that wherever there is a dipole (battery, generator, magnet) there is an unseen flow of longitudinal EM waves in that local vacuum, the only problem is in tapping that energy and "transducing" it to electricity. Bearden says that the problem with all the electrical circuits we have is that they are two-wire circuits, a loop by which half the energy goes back to destroy the dipole. In the MEG that closed loop is never made. So the dipole is not being destroyed.

Patents are not granted on devices which do not work, so in a sense this announcement proclaims a new era. The MEG device itself proclaims and proves that energy is abundantly available everywhere, for free. We only have to build the devices to tap it. MEG type devices could be put into a car with an electric engine to make a truly fuel-less automobile. Electricity can be available in very remote places. People will be able to get off our very terrorist-vulnerable power grids. In an era of terrorism a highly dispersed power system would be most desirable rather than our centralized systems.

What is somewhat astonishing to me is the discovery by Bearden et. al. that time itself is actually compressed energy, and that this free energy is actually coming from the time domain, the ocean of longitudinal EM waves which fill the empty vacuum of spacetime. In fact, time is energy compressed by the same factor that matter is compressed energy: the speed-of-light squared. Thus there is a new companion to Einstein's E=mc2. Can you say "E equals delta-tee-cee-squared?" The "tee" is time and delta-tee is change in time.

A company has been set up to manufacture the MEG called Magnetic Energy Limited.

The ramifications of free energy are enormous. The oil wars are not necessary. If we threw as much money at this technology as we are spending on the oil wars we would be free of the need for oil in less than a decade. With fuel-less cars air pollution will be greatly lessened. Third world nations can raise their standard of living eventually. And the energy is free. And it never runs out.

I have put together a kind of "Bearden for Beginners" article which explains some of the basic concepts of the current state of scalar technology.

http://www.prahlad.org/pub/bearden/scalar_wars.htm

The granting of the MEG patent is the herald of the new era of scalar electromagnetics, and the free energy which flows forever and never runs out.

Bill Morgan

Status History of the MEG

updated Oct. 26, 2006

Important notes on the status of the MEG (Motionless Electromagnetic Generator)

Since the time this "**Scalar Wars**" article was written the timetable of the **MEG** has been thrown off considerably. Bearden had originally said the MEG could be marketed within 1-2 years ***of receiving funding for final research and scale-up costs***. I thought certainly it would not take very long, but over 5 years later they still have not gotten the $10 million or so necessary. There are various reasons for this, some of which Tom Bearden has written about.

The place for updates on the MEG status is Tom Bearden's correspondence section at his website Cheniere.org:

http://www.cheniere.org/correspondence/index.html

Here are a few of his reports which detail the history of the MEG status :

Mar. 6, 2006
http://www.cheniere.org/correspondence/030206.htm

May 16, 2005
http://www.cheniere.org/correspondence/051605.htm

Jan. 19, 2005
http://www.cheniere.org/correspondence/011905.htm

Dec. 5, 2004
http://www.cheniere.org/correspondence/120504.htm

Do the magnets run down after a while?

Further developments

Tom Bearden clears up a question

When the MEG patent was released many questioned the patent language which seemed to imply that permanent magnets of the MEG would "wear out" after awhile. I myself wondered about the same thing so I put the question to Tom, and here is his reply.

> Dear Bill,
>
> Thanks for the kind words; much appreciated.
>
> I'm not up to going on radio or TV, and won't be for quite some time. Still suffering from hypoxia, though very slowly improving, and will still be on antibiotics for 10 more months at least (maybe longer).
>
> Obviously an extensive dialog developed between the Patent office and our patent attorneys. As best I can understand it, the Patent office accepts the fact that a permanent magnet produces and emits energy, or has a history of accepting it. They do not appear to be at all cognizant of the broken symmetry of opposite charges, and hence of a dipole. So in their opinion (which seems to be vague), the magnet has to use itself up very gradually, or some such. So some rewrites were essentially required by the Patent office.
>
> All I can say is that a magnet is a very durable thing, so long as you don't heat it up too much or shock it to much. Certainly one will make a good 20 years, and of course there are plenty of magnets that have been around awhile longer.
>
> That said, in our earliest experiments we did "measure" some such effect, or so we thought, until we found that a particular instrument was bad and giving erroneous readings. So with a new instrument, we have not observed since then any such readings.
>
> Out of all that fuzziness came the inclusion of "using up the magnets gradually". So far as we are aware (after correcting those early readings on a defective instrument), we have seen no such measurements or effects since then at all. Nonetheless, just in case there is some very small effect in that respect, at least it's in there.
>
> Actually, as you are aware, capacitors and solid state components are the major concerns for failure, and any system does require maintenance, both periodic and whenever malfunction or failure occurs. The MEG is no different from any other device in that respect, so of course it will have a component failure rate and maintenance required from time to time, just as any other electromagnetic device. But without moving parts, it can be ruggedized and made very durable indeed.
>
> Please give Jeff Rense my regrets, and I do admire his work and his show. He's laying it in there.
>
> The depth of the scientific mindset against COP>1.0 is inexplicable, particularly when physics itself already has COP>1.0 validated

experiments (such as Bohren's experiment, which outputs 18 times as much as one inputs by Poynting calculations), and it works every time. Any competent university optics lab can perform the experiment. Also, even the conventional texts admit that a charged capacitor or electret laid on a permanent magnet, so that the E of the cap or electret and the H of the magnet are at right angles, is a "free energy machine". That silly thing will just sit there and pour out Poynting energy S = EXH indefinitely. Years and years and years. If you wait just a single year, that silly thing has changed the energy density of a volume of space a light year in radius, reaching out well beyond the solar system. Now that's a WHALE of a lot of EM energy that beast poured out in that year, and it will still be going strong and pouring it out at a steady rate. The charges and dipoles in original matter in the universe have been pouring out EM energy in that fashion for some 14 billion years, give or take a billion or so. It's also easy to see that, prior to Lorentz's ARBITRARY symmetrical regauging of the Maxwell-Heaviside equations, those equations prescribe both EM systems in equilibrium with their active environment, and EM systems not in equilibrium with it. The latter systems are permitted by the thermodynamics of open disequilibrium systems to perform five magic functions: (1) self-order, (2) self-oscillate or self-rotate, (3) output more energy than the operator inputs (the active environment inputs the rest of it), (4) power itself and its load (the active environment inputs all the energy, like a windmill), and (5) exhibit negentropy. That is a well-established thermodynamics. Lorentz arbitrarily discarded all such open disequilibrium EM systems in order to get simpler equations having analytical solutions and not requiring numerical methods. So he simply scrapped all the really interesting and challenging EM systems in Maxwell's theory. ARBITRARILY!

That our scientific establishment continues to teach only that "half" of the theory, and not point out the rest to the young students, and not fund research into developing such systems that take energy from the vacuum, is simply inexplicable. It's a matter of total dogma, not science at all.

But hopefully it is changing a little bit. At least now we cite chapter and verse when these things were done, and what they are, and the young grad students and post docs can go check the papers and make up their own minds.

That is the real hope of the future: that we get a generation of young fellows, with excellent skills, who now know where all the skeletons got hidden in the closet, and understand that the electrical engineering model arbitrarily assumes an inert vacuum environment (falsified for more than a half century in particle physics) and a local flat spacetime (falsified for nearly a century by general relativity).

Once they know that past history, and go read into what broken symmetry of opposite charges means for a dipole and for all dipolar EM circuits, they will set to and change that more than a century of error. In that case, we shall have numerous solutions to the energy crisis rather quickly, popping up all over.

Good thing. It will certainly displace some great energy barons, but it will also free the populace. One can extract all the EM energy from the vacuum one wishes, anywhere, anytime, with ridiculous ease. One can produce that "electrical wind of energy" at will, by making a simple dipole and then letting it alone. The only energy problem is in how to then intercept some of that energy flow and "catch" it in a circuit, discharge it in a load to power it, and not use half the "caught" energy to kill that dipole that is gushing out the extracted EM energy from the vacuum.

Very best wishes,

Tom Bearden

END

Revised: May 16, 2007

Download this article in Ms Word format
(ScalarWars.doc)
Send a comment to Bill Morgan

See also:

Scalar Electromagnetics

Scalar Wars:

The Brave New World of Scalar Electromagnetics
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TOM BEARDEN ON THE CHALLENGER DISASTER

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ELECTROMAGNETIC WEAPONS TO BE USED

SCALAR: BEARDEN SAYS U.S. NOW DEFENDED

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Journal of Directed Energy, **1**, Fall 2003, 48–72

Compact Pulsed Power for Directed Energy Weapons

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The Titan Corporation has been developing directed energy technologies since the early 1980s. Over this time Titan has provided advanced power supplies for electromagnetic gun and laser research while making broader contributions in the field of high-power microwaves (HPM). Titan's HPM work expanded from initial efforts fielding and operating the first gigawatt-level oscillators for susceptibility test applications, to research and development maximizing the peak and average output powers and overall efficiency realized from such systems. As interest in HPM technology has spread globally, Titan has leveraged this core competency and provided the HPM equipment for nearly all of the major European effects test facilities. Titan's current interests focus on compact, efficient and reliable directed energy weapon systems and the advanced subsystems and components that enable the same. Specific subsystems of interest include pulse-forming networks and intermediate energy storage and power conditioning elements (electronically reconfigurable batteries and power ride-thru subsystems). These subsystems are designed for reduced size and weight while still meeting severe service, platform integration, lifetime, and thermal management constraints. Specific components under development at Titan include laser-gated solid-state switches and both high peak and high average power, frequency-agile, HPM oscillators. Status and recent results from this research are presented.

KEYWORDS: Electronically reconfigurable batteries, High-power microwaves, Laser-gated solid-state switches, Magnetron, Power-ride thru, Pulsed power, Reltron

1. Introduction and Previous Work

Directed energy weapons (DEWs) are emerging as a key defense technology of the early 21st century. The first laser antimissile and antiartillery systems are within perhaps five years of deployment, and newly envisioned information warfare and nonlethal point defense missions are hastening the deployment of high-power microwave (HPM) systems. Department of Defense (DoD) programs in "more electric" and "all-electric" platforms and electrically driven weapon and self-defense systems are promoting the development of laser, high-power radio frequency (RF) and both electromagnetic (EM) and electrothermal/chemical (ETC) gun technologies. In fact, the DoD's current fundamental "transformation" efforts are based on stressing the development of capabilities to deal with threats emerging in the

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Table 1. Triservice directed energy applications

U.S. Army [Future Combat System (FCS)—hybrid electric drive vehicles]
- Advanced armaments—electrothermal/chemical guns
- Enhanced area air defense—solid-state heat capacity laser system
- Counter-HARM
- Counter-ATGM
- Countermine (electronically fuzed and wide-area threats)

U.S. Navy [All-Electric Ship Programs (Integrated Propulsion System and DDX)]
- Advanced stand-off shore bombardment—electromagnetic guns
- Advanced anti-ship missile defense (free-electron laser and HPM)
- Nonlethal area denial

U.S. Air Force (more electric aircraft program and advanced UAV programs)
- Enhanced self-defense—solid-state heat capacity laser system
- Space-based laser program
- Airborne laser
- Suppression of enemy air defense
- Aircraft self-defense
- Close air support
- Defensive and offensive counter air
- Strategic attack/strike warfare, attack operation/air interdiction
- Combat search and rescue
- Area denial
- Cruise missile defense

Table 2. Countries now developing high-power RF technology

Programs	Countries
Major	United States, China
Medium-scale	United Kingdom, France, Germany, Russia
Emerging	Sweden, Japan, India, Taiwan, Australia, Israel, South Korea

Information Age instead of emphasizing countermeasures to specific threats. DEWs hold the promise of engaging multiple threats and multiple threat types, thereby fitting very well into this conceptual paradigm. Some specific examples of defense applications of DEW technologies are shown in Table 1.

The initiatory HPM programs in the USSR and United States have evolved and influenced foreign allies and threats to take an interest (Table 2). The collapse of the USSR led to the dispersal of Russian and Ukrainian HPM workers and the proliferation of the Soviet technology to the Third World. This global emergence is driven by at least two factors: 1) The dependence of both military systems and civilian support infrastructure on sensitive electronics is increasing, and 2) after a more-than-20-year effort, an understanding of the susceptibilities of both military and commercial systems to HPM threats is maturing.

For these reasons the Titan Corporation has taken a keen interest in the development of systems, subsystems, and advanced components across several different technologies to support HPM and laser directed energy programs.

In 1997, Maxwell Technologies purchased Physics International (PI) from Primex Technologies and merged two of the three most prominent, commercial, pulsed power entities in the United States. PI and Maxwell pulsed power capabilities were combined into a new entity, Maxwell Physics International, which became a component of Maxwell's Systems Division. Maxwell subsequently decided to leave the DoD and Department of Energy (DOE) pulsed power business altogether and sold the combined Maxwell/PI pulsed power divisions to the Titan Corporation, the parent company of Pulse Sciences Incorporated (PSI). Now, the three most prominent names in commercial pulsed power are combined as the Pulse Sciences Division (Titan-PSD) of the Titan Corporation.

In March 2002, Titan completed the acquisition of Jaycor and its subsidiary California Tube Laboratory (CTL). This acquisition established Titan as one of the world's primary industrial authorities on electromagnetic effects and suppliers of RF and narrow-band microwave DEW technologies and associated electrical power systems. High average power, high efficiency, magnetrons; high peak power, pulsed, relativistic magnetrons and superreltrons; short pulsed, ultra-broad-bandwidth systems and megawatt-class power supplies and power conditioning subsystems are all designed and manufactured by Titan. This paper will chronicle some of the past and report on some of the current contributions that Titan has made to the development of pulsed power technology for DEW applications.

1.1. Previous Titan work in support of HPM programs

Titan-PSD has been developing directed energy technologies since the early 1980s. In this time, Titan has delivered capacitor banks for electromagnetic gun research with a total stored energy exceeding 200 MJ and advanced pulsed power systems for several large laser systems (Fig. 1). Over 40 years, Titan-PSD has delivered more than 200 pulsed power systems for electromagnetic pulse (EMP), x-ray, and lightning simulation; flash radiography; and other applications worldwide. Although somewhat peripheral to DEW research proper, these projects have nonetheless formed much of the experience base supporting Titan's directed energy technologies contributions.

Titan's primary contributions have been in the field of HPM (Fig. 2). Work started in 1984 when Titan set up and began operating a susceptibility effects test facility for the Defense Threat Reduction Agency (DTRA). A 30 × 20 × 16 ft anechoic chamber to support this work was originally designed to operate in X-band and above. At the outset of the U.S. HPM directed energy program the community felt that the higher gains possible from fixed antenna sizes at higher frequencies would drive technology development into these bands. Over the next 10-plus years, the 25 effects test programs conducted on strategic and tactical systems in the Titan facility and tests conducted at other sites both confirmed that the lowest susceptibility thresholds are observed in the S-band and below. HPM source development history has mirrored these findings.

1.1.1. HPM source developments at Titan. In 1983 Titan initiated HPM source research in its test facility by developing first C-X band overmoded vircators[17] and later an L-band vircator.[13] These systems produced gigawatt outputs through the oscillating virtual cathode mechanism. Their main shortcoming was their broad bandwidth due to chirping induced by diode gap closure. To address this shortcoming Titan developed the first cavity vircator[3] that reduced the output bandwidth from several hundred megahertz to a few tens of megahertz. Versions of these devices were soon after sold to Nucletudes in France

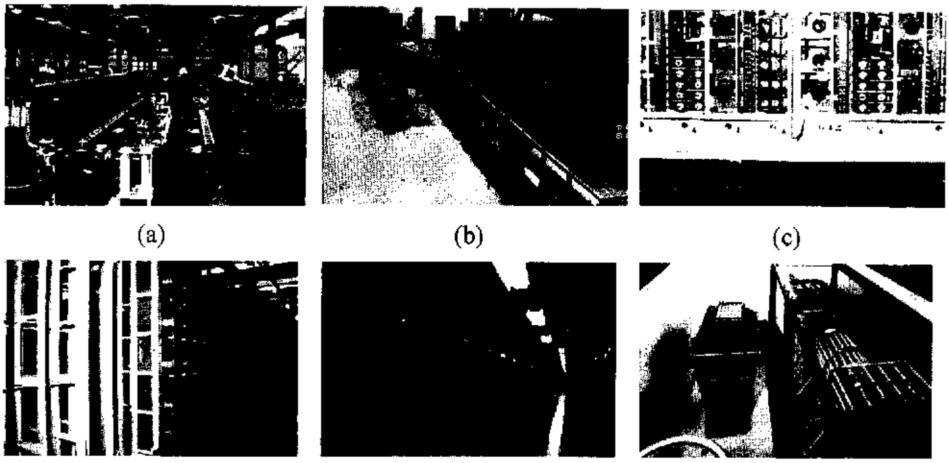

(a) (b) (c)

(d) (e) (f)

Fig. 1. Titan-PSD has designed, fabricated, and delivered the pulse power subsystems for most of the major electric gun facilities worldwide: (a) the decommissioned 32-MJ Thunderbolt System built for a Strategic Defence Initiative Office (SDIO) project; (b) the existing 32-MJ Kirkcudbright system currently being operated by the United Kingdom; (c) the first transportable pulse power subsystem designed for an electric weapon system. [This 8.5-MJ stored energy subsystem, consisting of four separate PFNs, was designed by Titan-PSD under the Army/Army Research Development and Engineering Center (ARDEC) Balanced Technology Initiative and was capable of delivering up to 5 shots at 3 rounds per minute.]; (d) the 52-MJ bank delivered to the ARDEC for electromagnetic and coil gun research; (e) the pulsed power driver for the 40-MJ OMEGA laser at the University of Rochester; and (f) a portion of the 100-Hz, 750-kV, 1.25-μs modulator for NRL's EMRLD laser.

and Culham Laboratory in the United Kingdom to help kick-start HPM effects testing and technology development programs at each location.

Titan initiated work on magnetrons by acquiring S- and X-band, A-6 versions from Bekifi at the Massachusetts Institute of Technology.[2] These devices were integrated into the Titan test facility, and within two years an L-band version of this same design was developed.[16] An S-band magnetron was sold commercially to Thales in France in 1987 to help kick-start HPM effects testing and technology development programs there.

This HPM source development work soon expanded from the initial efforts to field gigawatt-level vircators and magnetrons for the effects testing applications to the development of other high-power sources. These include narrow-band klystrons (both high- and low-perveance variants) and reltrons, as well as ultra-wide-band systems. In parallel, the peak and average power and spectral characteristics of these HPM sources were being explored in research involving phase locking, repetitive pulsing, and frequency agility. Other related Titan work included the development of pulsed power systems to drive these HPM sources involving several different architectures [pulse-forming networks (PFNs) with capacitive energy storage and voltage adders with magnetic compression power conditioning]. These advancements are described briefly in the following.

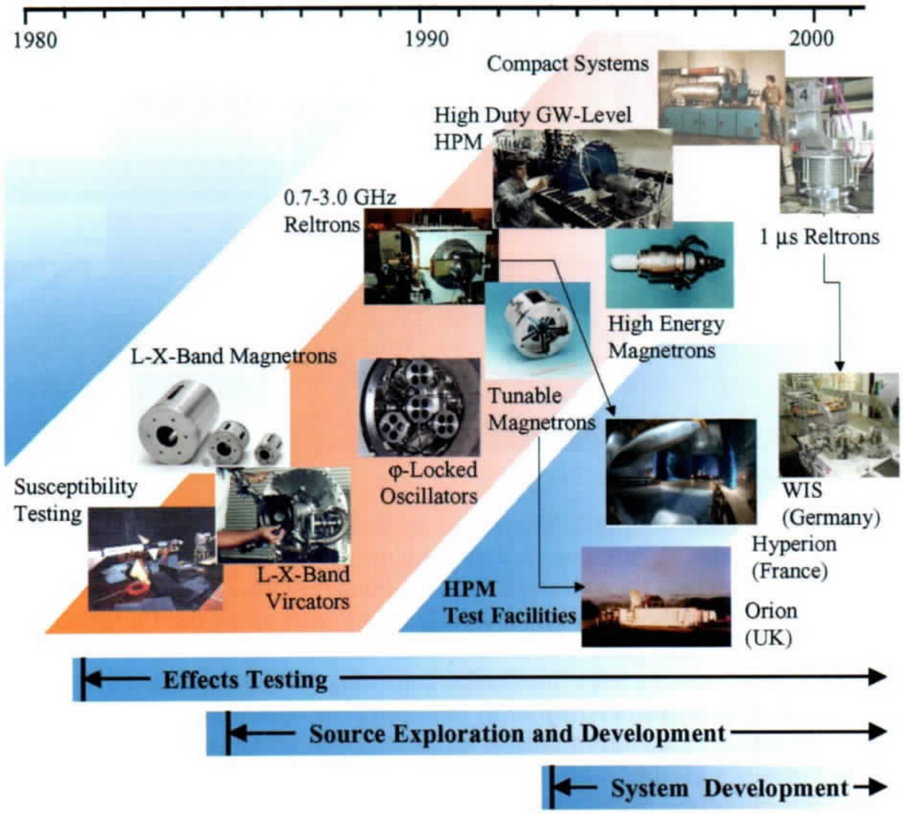
1980
1990
2000
Compact Systems
High Duty GW-Level HPM
0.7-3.0 GHz Reltrons
1 µs Reltrons
High Energy Magnetrons
L-X-Band Magnetrons
Tunable Magnetrons
φ-Locked Oscillators
Susceptibility Testing
WIS (Germany)
Hyperion (France)
L-X-Band Vircators
HPM Test Facilities
Orion (UK)
Effects Testing
Source Exploration and Development
System Development

Fig. 2. Titan contributed to the field of HPMs in three distinct eras: 1) susceptibility effects testing, 2) HPM source development, and (currently) 3) DEW system development. The effects testing work started in 1984. Then, Titan operated the DTRA susceptibility effects test facility supporting tests for external DoD users. Soon thereafter Titan began using the facility for its own end-to-end DEW research programs. In parallel, Titan HPM source development efforts initially focused narrowly on providing the facility with minimum essential capability but soon expanded to meet specific weaponization and testing requirements. During this period, Titan performed some of the seminal narrowband HPM work associated with phase-locking, frequency agility, and repetitive operation. Source development work continues today, focusing on improving energy output and tunable bandwidth. These efforts are combined with the development of other advanced pulsed power subsystems and components needed to realize compact, efficient, and reliable DEW systems.

In the late 1980s, Titan S-band magnetrons were used in a three-year effort to understand how to achieve output powers exceeding 10 GW from a phase-locked array.[9] Many mission scenarios for DEW systems that could produce burnout or upset in military targets using only a single HPM pulse drove output requirements to this 10-GW level. The combination of gigawatt-level sources locked in phase appeared an effective way to realize this output level without increasing the RF fields and beam energies within individual diodes (and dealing with the RF breakdown and thermal issues that would certainly ensue). In this effort both master/slave and peer configurations were investigated to understand the optimal architecture for such an array. In the end, a module of seven "peer-coupled," 2.8-GHz, magnetrons was built that produced an output power of 2.9 GW. Extrapolation to even higher output levels appeared feasible.

At this time, the HPM community was beginning to recognize that there must exist a middle ground between HPM and electronic warfare (EW) DEW concepts. The HPM approaches were characterized by superpower, single-shot, single-frequency, pulse formats, while the EW approaches made use of very low powers but incorporated modulations in the output pulse formats to effectively exploit susceptibilities within their intended targets. To access this middle ground the HPM sources had to first be shown capable of operation in repetitive or burst modes. This burst capability would be surely required of any DEW system, if only to engage multiple threats deployed in sorties or clusters. In response to these weaponization considerations Titan-PSD developed relativistic magnetrons capable of operation in 1-kHz bursts.[4] A 1.1-GHz, L-band, magnetron was driven by a magnetic pulse compression modulator (see discussion below) and achieved 250-pps repetitive operation at 1.2-GW peak power, in a burst of 100 shots. The average power of 12.6 kW during the burst remains today the state of the art for gigawatt peak power sources. To demonstrate that the magnetron's diode could recover in a time short enough to support higher repetition rates, the device was run for ~5 pulses (limited by the modulator) with 1 ms between individual pulses.

In the early 1990s both Jaycor and PI were actively extolling the use of frequency-agile waveforms to enhance lethality in backdoor attacks. Frequency agility exploits the characteristics of typical coupling cross sections that show pronounced dependence on microwave frequency. An HPM source that can sweep or hop frequency across a band has a higher probability of matching to a coupling resonance than a source fixed at a single frequency. Because of this strong dependence of backdoor coupling and susceptibility levels on microwave frequency, it was apparent that test facilities needed the capability to vary frequency continuously in order to obtain a comprehensive and accurate assessment of any given test asset's susceptibilities. In response to these testing and weaponization considerations Titan-PSD developed frequency-tunable magnetrons. These oscillators can be tuned ±17% about a central frequency,[10] which today still represents the state of the art. In the mid-1990s these magnetrons were integrated into advanced concept demonstrations for the Army and were also exported to the United Kingdom as part of an HPM test facility.

In the late 1980s and early 1990s Titan-PSD developed several ultra-broad-bandwidth (UWB) systems for Army and Air Force DEW research programs. The first system was based on a spark gap-switched Marx that drove a variety of different broadband antennas. It could launch 200-MW total RF power in 3-ns pulses with rise times of ~300 ps at a repetition rate of a few pulses per second. This compact, self-contained system was used in both indoor susceptibility tests and outdoor technology demonstrations. A second project produced a system that could launch impulse waveforms at 200 pps in burst mode.[15] A 3.66-m-diameter paraboloidal reflector was driven at its feed by a hydrogen switch that was integrally coupled to a novel electromagnetic lens. The radiated waveform had a rise time of ~100 ps and a 10–90 rise-to-fall pulse width of 45 ns. The peak electric field on bore-sight measured at 305 m was 4.2 kV/m.

Titan invented the super-reltron in 1992. A suite of tubes that operate between 0.7 and 4.5 GHz has been developed since that time.[12] These novel tubes represent a marriage between pulse power and conventional high-power klystron techniques. An energetic electron beam is modulated by periodic virtual cathode formation, and the bunched electron beam is postaccelerated to energies approaching 1 MeV. Microwave power is extracted with ~50%

Table 3. Operating parameters of Titan-built modulators for DEW applications

Modulator	Voltage, kV	Current	Pulse width	Pulse repetition frequency	Pulse energy	Average power	Switch type
LS-15	50	10 kA	100 ns	1.9 kHz	50 J	95 kW	Spark gap
NED laser driver	±40	260 A	2 μs	10 Hz	3 kJ	30 kW	Thyratron
EMRLD PFN	750	38 kA	1.3 μs	125 Hz	35 kJ	4.4 MW	Spark gap
EMRLD (trigger)	600	260 A	400 ns	125 Hz	100 J	12.5 kW	Spark gap
OMEGA[a] laser driver	15	128 kA	200 μs	Single shot	40 MJ	—	Ignitrons
CLIA HPM driver	750	10 kA	100 ns	250 Hz	750 J	188 kW	Magnetic
ORION HPM driver	500	10 kA	50–500 ns	100 Hz	250 J	25 kW	Thyratron
Compact HPM driver	450	9 kA	450 ns	10 Hz	1.8 kJ	18 kW	Spark gap

[a] 120 modules, each storing 0.33 MJ.

conversion efficiency downstream in a dual-cavity output section that is tuned to the bunch frequency. The reltrons can produce microwave pulse widths approaching 1 μs and pulse energies of a few 100 J, outstripping the relativistic magnetrons that to date are limited to pulse widths of about 100 cycles and pulse energies below 100 J.

In response to the HPM effects testing considerations discussed above, Titan developed frequency-tunable reltrons. These oscillators can be tuned ±10% about a central frequency.[11] These devices are still in development today (see Sec. 2) and have been provided to both France and Germany as HPM threat simulators.

1.1.2. Development of pulse power modulators for DEW applications at Titan. Titan has developed a large number of modulators for a variety of laser and HPM DEW applications, with voltage ratings from tens of kilovolts to several megavolts and average power levels from tens of kilowatts to multimegawatts (Table 3). They also range from relatively simple units to complex, state-of-the-art devices with various different architectures and subsystems. These include PFNs for generating the required pulse shapes; thyratron switching for precise timing of the pulse switching into the load; low inductance layouts for fast output pulse rise times and high-turns-ratio pulse transformers for generating the high voltage outputs. The switching technologies include thyratrons, spark gaps, magnetic switches, and solid-state devices, such as metaloxide semiconductor field effect transistors (MOSFETs), insulated gate bipolar transistors (IGBTs), and thyristors (Fig. 3).

Several of these modulators have been designed for long-lifetime, reliable operations. Such features are essential if these systems are to find their way into military applications. As an example, the Defense Advanced Research Projects Agency (DARPA) excimer Raman-shifted laser device (EMRLD) modulator (a 100-Hz, 750-kV, 1.25-μs, lumped-element PFN to pump an excimer laser) was specifically designed for and demonstrated a lifetime of 10^{10} shots.

The ORION pulser (Fig. 3b) design has command resonant charge and intermediate energy storage sections each switched by thyratrons that drive a step-up transformer and

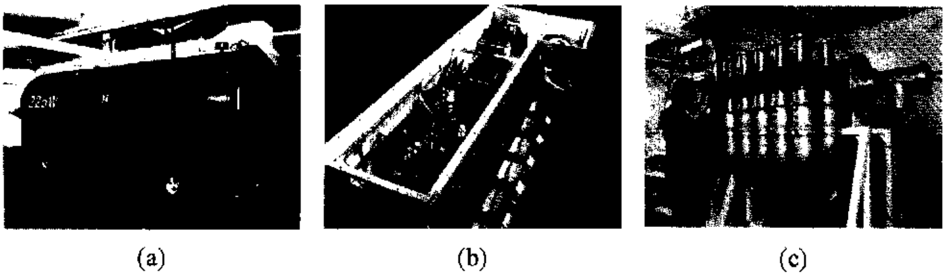

Fig. 3. Titan-PSD pulsed power systems based on (a) spark gap, (b) thyratron, and (c) magnetic switching.

Table 4. Key operating parameters in European HPM test facilities

HPM facility	Power density, W/cm^2	Range, m	Frequency, MHz	Maximum pulse width, ns	Maximum repetition rate, Hz	Shots per burst	Source type
UK—Orion	>120	100	1,070–3,300	100	100	100	Magnetrons
France—Hyperion	>1,000	~100	700–3,300	300	1	—	Reltrons and magnetrons
Germany	>170	15	700–1,450	300	10	100	Reltrons
Sweden[a]	~120	15–25	L-Ku	500–5,000	1,000	Continuous	Reltrons

[a] This facility uses conventional high power klystrons in L-, S-, C-, X-, and Ku-bands, with maximum power 25–0.25 MW.

PFN. The modulator can fire 1,000 pulses in a burst at repetition rates up to 100 pps and produces 500 kV into a 50Ω load. It has been used to drive relativistic magnetrons[6] for HPM effects measurements.

The Compact Linear Induction Accelerator (CLIA) (Fig. 3c) was developed for moderate-repetition-rate HPM source research and development.[1] CLIA operates at 250 pps with 750-kV, 10-kA, 100-ns output pulses. The system uses thyratron and magnetic switching throughout and produces 188-kW average power into the load. CLIA is not actively cooled and so is restricted to burst operation with 5,000 pulses in a burst. CLIA has been used to drive both magnetron and klystron loads. This technology is scalable to kilohertz repetitive operation.

1.1.3. Titan pulse power systems for HPM simulation. In addition to work done supporting domestic RF and microwave DEW research and development, Titan has provided HPM simulation systems for all of the world's major HPM test facilities in Sweden, France, the United Kingdom,[14] and, most recently, Germany. The microwave test parameters and operational capabilities achievable in these international facilities are summarized in Table 4. The types of Titan HPM sources that produce the intense microwave environments are also given. Work continues today upgrading those systems and providing similar hardware for several non-European countries.

2. Most Recent Contributions

Titan-PSD has taken an interest in the full spectrum of developments of advanced subsystems and components that the three U.S. services will require to realize their DEW and electric platform goals. These developments enable many different military missions and cut across many different technologies: advanced capacitors, switches, transmission systems, RF, and optical systems. Some of the pulse power and power electronic subsystem and component developments that Titan is pursuing are summarized in Table 5.

The following subsections describe five electrical subsystems and three components that Titan-PSD is currently developing for DEW applications.

2.1. Titan-PSD development of subsystems for DEW applications

2.1.1. HPM modulator. Titan-PSD has a conceptual design of a high-voltage-pulse power subsystem for a short-pulse HPM system. The given RF pulse output parameters led us to choose a specific tube that is compatible with the constraints of an airborne system, namely the magnetron with a 20Ω impedance and 33% efficiency in a short-pulse mode. Our pulse power design concept is driven by the tube input requirements (20Ω load, 40-ns pulse width, 10 pps) and comprises a low-impedance, water-filled, stepped-pulse forming line (PFL) charged by a fast Marx and discharged through a self-breaking, spark-gap output switch. An advantage to using a liquid dielectric PFL is that its impedance can be easily varied along its length to accommodate variations in load impedance. Input power to the Marx is from two 400-V series strings of lithium ion batteries with solid-state switched intermediate voltage multipliers providing ±40 kV. Batteries are recharged from aircraft power through a small voltage converter.

Figure 4 is a simplified circuit diagram of the pulse power modulator coupled to a 20Ω constant impedance load though a transit-time isolator. The transit-time isolation is integral to the two parallel cables that couple the output of the pulsed power modulator to the microwave source. The Marx stores 1,140 J at a voltage of ±40 kV. It erects to a 1,280-kV open circuit voltage after a trigger pulse is applied to several of its switches from the trigger generator. Near peak PFL voltage, the self-firing spark gap closes, and energy is transferred to the tube at a peak voltage of 640 kV.

Figure 5 shows the voltage and current in the load computed from a more detailed version of the circuit depicted in Fig. 4. Note that the current is multiplied by a factor of 10. Voltage rises in about 11 ns (10–90%), and the width at the peak is approximately 40 ns. We recognize that the impedance of the magnetron can vary during RF generation, but the constant impedance model is sufficient here. An advantage to using a liquid dielectric PFL

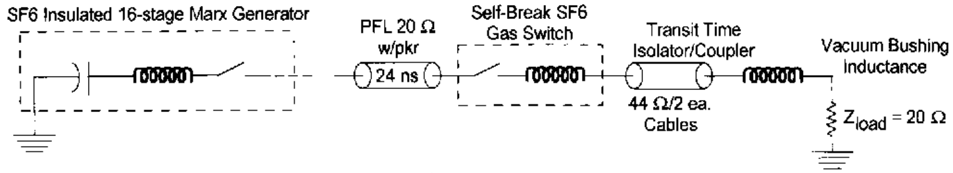

Fig. 4. Simplified circuit diagram of the pulse power modulator coupled to a 20Ω constant impedance load though a transit time isolator. This impedance represents a magnetron electron tube load.

Table 5. Titan advanced DEW power technology development rationales

What need does the development of pulsed power technology fulfill?		What need does the development of high power/high current technology fulfill?	
It is an enabler for advanced electric weapons and self-defense systems.		It is an enabler for advanced electric weapons and self-defense systems.	
System	User	System	User
Dynamic protection	Army (FCS), Navy (carrier)	Solid-state lasers	Army (Anti-Aircraft and Anti-Missile), Navy (ASMD)
ETC	Army (FCS), Navy (shore bombardment)	HPM	Army (FCS), Navy (non-lethal area denial)
HPM/electromagnetic pulse	Army (FCS), Navy (non-lethal area denial and ASMD), Air Force (SEAD)	EMALS	Navy (carriers)
EM gun	Navy (shore bombardment)	Electric arresting gear	Navy
UWB	All services (counter C4I)	Ride-thru	All services
		It is an enabler for electrically driven platforms: • FCS platforms for the Army • Combatants such as DD21 for the Navy • More electric aircraft for the Air Force	
It is an enabler for commercial spin-offs: • Environmental remediation systems • Material surface treatments • Pulsed thrusters for satellite station keeping		It is an enabler for commercial spin-offs: • Electric vehicles • Commercial power distribution and control • Advanced semiconductor lithography	
What must we accomplish at the subsystem level? • Develop compact, reliable, affordable PFNs • Develop compact, reliable, affordable modulators • Develop compact, reliable, affordable intermediate energy stores		What must we accomplish at the subsystem level? • Develop compact, reliable, affordable prime power, power conversion and controls • Develop compact, reliable, affordable intermediate energy stores • Develop compact, reliable, affordable ride-thru systems	
What must we accomplish at the component level? • Develop high-energy-density, fast-discharge capacitors • Develop long-life, reliable, high-current switches • Develop compact inductors for pulse control • Develop affordable ultracapacitors • Develop compact, reliable, efficient, high-average-power HPM sources		What must we accomplish at the component level? • Develop high-current-density, high-voltage stand-off solid-state switches • Develop affordable ultracapacitors • Develop compact, reliable, efficient, high-average-power HPM sources	

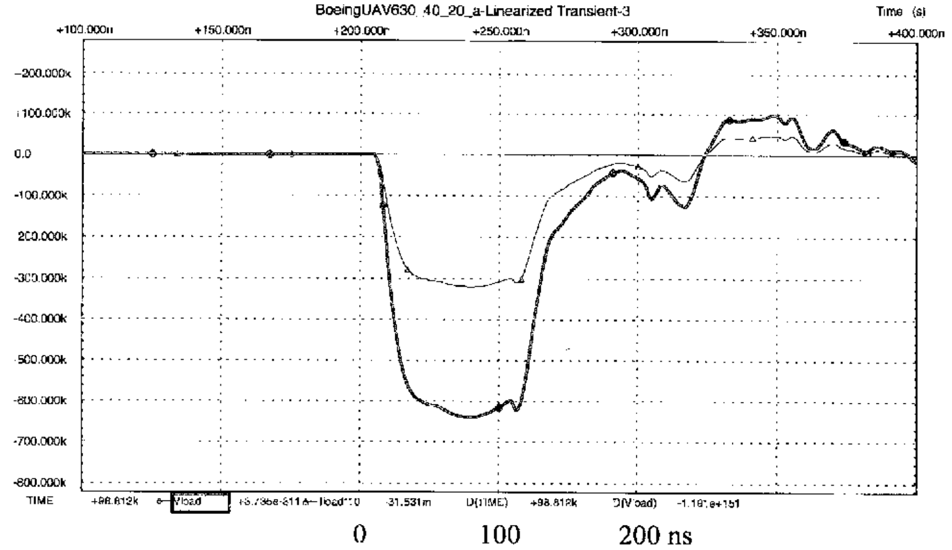

Fig. 5. Voltage and current (multiplied 10×) in the magnetron load computed using detailed version of the simplified circuit diagram in Fig. 4.

is that its characteristic impedance can easily be varied along its length to accommodate variations in load impedance.

Our compact pulse power system conceptual design mounts all of the subsystems and components in a frame that is 24 in. wide × 24 in. high × 144 in. long. The total weight of the system, including the frame, sealed enclosures, and internal mountings, is 1,420 lb. Figure 6 is a dimensioned diagram of the subsystem that is designed to fit into the port bay of an unmanned aerial vehicle (UAV) with the source in the starboard bay. Frames and supports have been omitted for clarity.

2.1.2. Compact PFN. Titan-PSD has designed, fabricated, and delivered the pulse power subsystems for most of the major electric gun facilities worldwide. These facilities were dedicated to electric gun research and for this reason were designed with a premium on reliability and ease of use of the pulse power subsystem. Compactness was a secondary consideration given the large amount of real estate available for the subsystem.

The 8.5-MJ stored energy subsystem, consisting of four separate PFNs (Fig. 1c), was the first design to use the high-energy-density, 2.5-J/cc (2.5-MJ/m^3) polyvinylidene fluoride (PVDF) Aerovox capacitors; the overall energy density of the PFNs is less than 0.5 MJ/m^3. This low energy density is partially due to the use of "jelly-roll" inductors whose large external fields forced the separation of components and resulted in a low component packing fraction.

Figure 7 is a photograph of a 250-kJ PFN that was constructed under a DTRA/Navy-sponsored ETC gun development project and that was incorporated for a time into the Army/Tank-Automotive and Armaments Command (TACOM) Combat Hybrid Power System (CHPS) system integration laboratory.[5] Titan-PSD designed this PFN module for compactness by developing innovative bus work and a closed-field inductor for use with the 2.5-J/cc PVDF capacitors. These advances in component design allowed us to achieve a

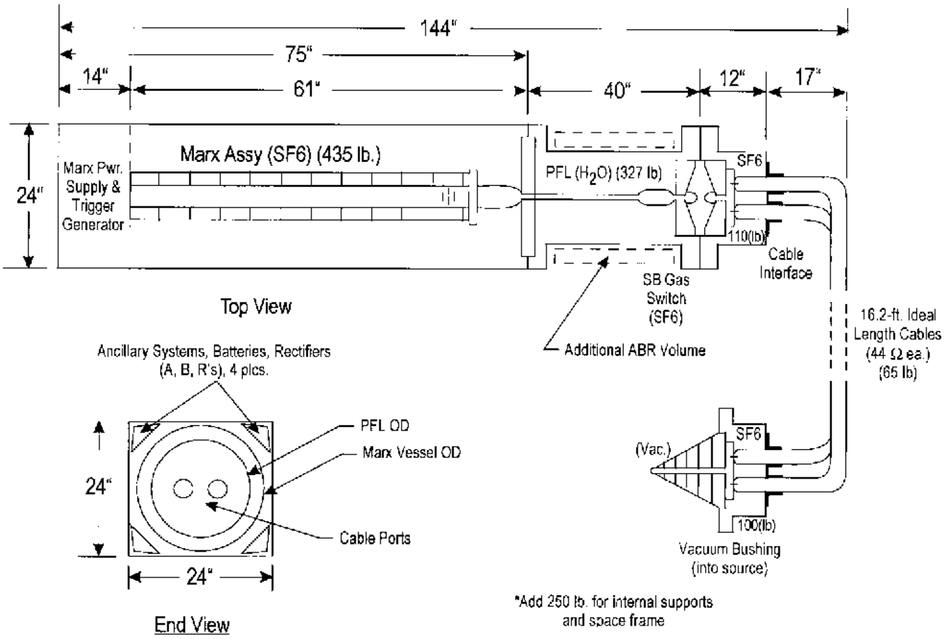
144"
75"
14"
61"
40"
12"
17"
24"
Marx Pwr. Supply & Trigger Generator
Marx Assy (SF6) (435 lb.)
PFL (H_2O) (327 lb)
SF6
110(lb)
Cable Interface
SB Gas Switch (SF6)
Additional ABR Volume
Top View
16.2-ft. Ideal Length Cables (44 Ω ea.) (65 lb)
Ancillary Systems, Batteries, Rectifiers (A, B, R's), 4 plcs.
PFL OD
Marx Vessel OD
Cable Ports
24"
24"
End View
(Vac.)
SF6
100(lb)
Vacuum Bushing (into source)
*Add 250 lb. for internal supports and space frame

Fig. 6. Top and end views of the pulse power subsystem concept design. The upper portion will be mounted in a frame and placed in one bay of a UAV. The vacuum bushing and the source will be placed in a second bay.

very high packing factor and an overall energy density of 1.25 MJ/m^3. This module designed in 1994 still represents the state of the art in PFN design. Minor variants to the design are under consideration today for EM gun applications.

Titan-PSD has estimated the increases in the overall energy density of small (250–500-kJ) PFN modules that could be realized by achieving specific advances in component technologies.† This includes the use of an existing, more compact vacuum output switch (developed by Titan-PSD) and existing, more compact diodes for the crowbar switches. We would design a higher-energy-density, closed-field inductor and eliminate the dump resistors and associated hardware. Rather than having to dump energy into a resistor, advanced pulsed power systems would be charged by four-quadrant converters capable of returning energy from the PFN to an intermediate energy store. When 5-J/cc film or ceramic, high-energy, reversal tolerant capacitors become available, the utilization of advanced components would lead to a PFN design with an energy density of 3.25 MJ/m^3.

2.1.3. Power supplies for laser applications. Titan-PSD's San Diego operations are actively engaged in building innovative high-average-power systems. Titan is currently delivering power conditioning and control elements for the high-power RF klystrons that will power the DOE Spallation Neutron Source that is now under construction at Oak Ridge, Tennessee, and a series of multimegawatt rectifiers for the U.S. Navy's Electro-Magnetic

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† Higher energy densities could be achieved in the design of larger modules due to economics of scale.

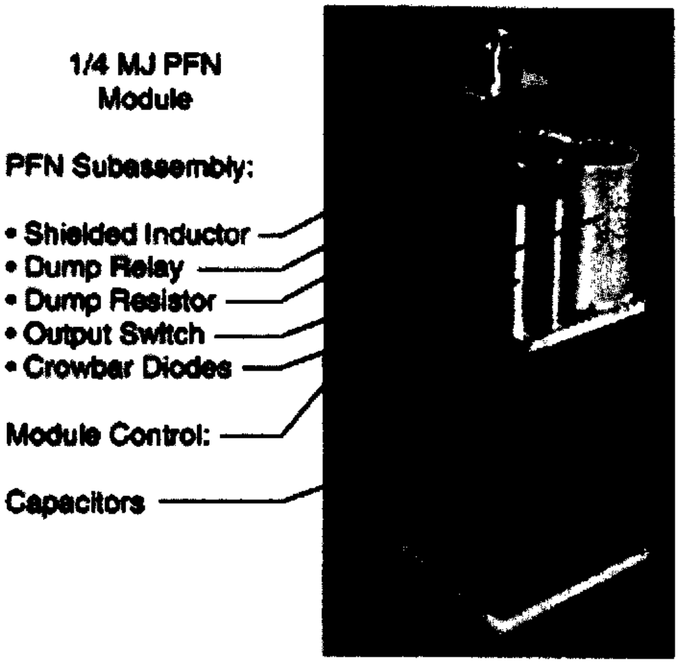

Fig. 7. Photograph of the 250-kJ PFN with the state-of-the-art, 1.25-MJ/m^3 overall energy density. Titan-PSD has operated this PFN into resistive loads at a rate of 1/3 Hz for extended periods. Operational limits were imposed by the heating of the load, not by the performance of any component of the PFN.

Aircraft Launch System (EMALS). Most recently, Titan has developed conceptual compact power supply designs for deployable pulse power systems for the Strategic Illumination Laser (SIL). The SIL is a diode-pumped, solid-state laser for use as a designator as a part of the U.S. Air Force's Missile Defense Agency's Airborne Laser (ABL). These power supplies will drive compact arrays of light-emitting diodes (LEDs), which will in turn pump the solid-state lasing medium.

Titan's proposed SIL power supply system will consist of a group of innovative ballast-type isolated power converter modules, each fed by its own active-power-factor-corrected rectifier module. By this method the input current harmonic distortion will be minimized, resulting in an overall system power factor of 0.995, which will be acceptable for the Boeing-747 type aircraft (ABL platform) power system. The whole power system will be protected against faults by appropriate fuses and circuit breakers. Initial size and weight estimates for the total power system is 65 liters of total volume and 140 kg of mass. The driving factor in the weight and volume is the need to meet the power factor requirements. Given a dedicated power source, the size and weight could be halved.

Two basic topologies have been examined for power factor correction. They are the "Vienna rectifier,"[8] first proposed by researchers in the Vienna Technical University, and the hex-bridge bidirectional inverter. Both topologies do not contain any magnetic components, operating at line frequency, and both can provide a power factor over 0.99. All merits and drawbacks of both topologies have been initially analyzed, and the Vienna approach is favored for this application.

For the ballast inverter Titan-PSD selected the variable-frequency, zero-power switching full bridge quasi-resonant inverter topology. It is new and until recently not well known but is very promising for multikilowatt power supplies. It shows excellent average to peak ratio for the semiconductor switches, close to the theoretical limit of 50%, and a good power transformer copper utilization factor, typically 90%. It is intrinsically output current limiting and therefore operates well in a current regulated mode and is tolerant to output short circuits. Using this converter topology allows the design to reach unprecedented power conversion efficiency (real value 95%) with excellent reliability.

2.1.4. Electronically reconfigurable battery. We consider a DEW power system in which a 10-kV capacitive store is required to operate repetitively. If the system operates at 3 pps, even for a short period of time, the recharge time would be about 300 ms and the recharge power would be about 500 kW_{avg} (1 MW_{pk}). An important system issue is the size and weight of the 500-kW power conditioning unit.

Titan-PSD has developed a means to eliminate the need for intermediate power conditioning for many DEW systems mounted on hybrid electric vehicles by using the on-board batteries to charge the capacitive store directly. Our approach uses electronic switching to convert the battery modules in the mobility store from a parallel configuration providing vehicle load leveling and/or silent mobility capability, to a series configuration that delivers 500 kW at 10 kV to recharge the capacitor bank and back again. We refer to this as an "electronically reconfigurable battery" (ERB). Note that all of the batteries are recharged in parallel. A similar approach is used in capacitive Marx generators to achieve very high voltage pulsed output.

Figure 8 is a schematic drawing of the circuit of an ERB in a hybrid electric drive vehicle. In this schematic circuit, some battery modules are always in parallel and connected to the vehicle bus. Others, along the left-hand side of the drawing, can be switched between a parallel configuration, which supports the vehicle bus, and series operation for charging the DEW store. Electronic reconfiguration requires three switches per battery module. All switches, with the exception of the output switch, need only block the voltage of a single battery module and open at near zero current (characteristic of capacitor charging) in normal operation. Passive snubbing controls the transient conditions during erection and de-erection. Reconfiguration can be accomplished in less than 1 ms using off-the-shelf, solid-state switches such as IGBTs or MOSFETs.

Figure 8 shows an erectable battery module charging a Guillemin E-type network. Switches 2 and 3 are battery isolation switches, and switch 4 is a series switch. These switches are rated only for the module voltage (1 kV in this case). Mechanical contactors parallel the isolation switches for better efficiency during periods when the pulse power system is not in use. Switch 5 is the output switch, which is rated for the full output of the ERB (10 kV and 50 A) and is most likely a series stack of the same switches used for 2–4. For fault protection and charge interrupt at current, a vacuum contactor and fuse are placed in series with the output switch. All switches are optically isolated with gate power drawn from their adjacent modules. Switch 6 is a high-voltage and current-closing switch, either vacuum or solid state.

Assuming a 20-ton-class vehicle and extrapolating from CHPS requirements, we have developed a conceptual design of an ERB for a hybrid electric vehicle with a system meeting the following requirements: 1) Deliver up to 400 kW to the vehicle bus at 1 kV in parallel operation; 2) recharge a 150-kJ capacitive store to 10 kV in 300 ms; and 3) support 30–45-min silent operation at 80 kW. These requirements mandate the use of very high energy

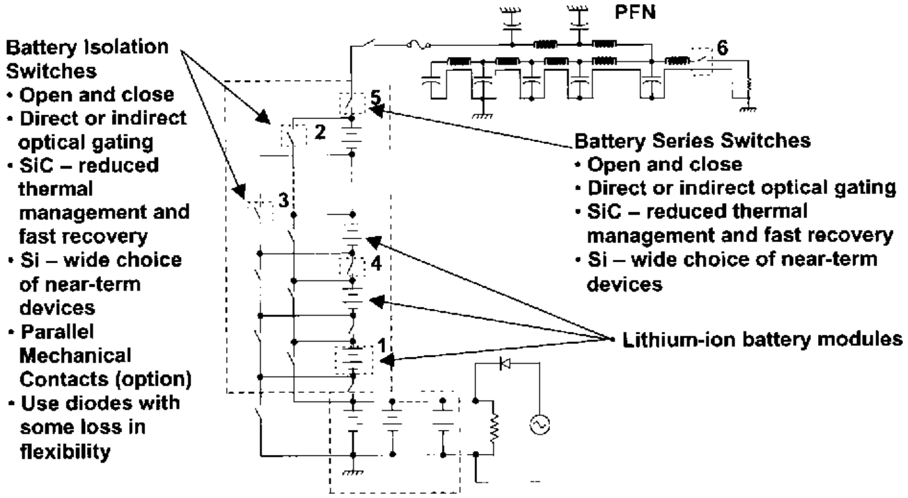
PFN
6
5
2
3
4
1
Battery Isolation Switches
• Open and close
• Direct or indirect optical gating
• SiC – reduced thermal management and fast recovery
• Si – wide choice of near-term devices
• Parallel Mechanical Contacts (option)
• Use diodes with some loss in flexibility
Battery Series Switches
• Open and close
• Direct or indirect optical gating
• SiC – reduced thermal management and fast recovery
• Si – wide choice of near-term devices
Lithium-ion battery modules

Fig. 8. Schematic circuit of the ERB. Shown is a generic circuit topology for charging a Guillemin E-type network. For the present application, the 10 modules in the dynamic store are all erected in series to produce a 10-kV output. A feature of the ERB is that the dynamic portion of the store may be erected in combinations of series/parallel modules to provide any output voltages that are an integer multiple of the DC bus voltage. This voltage agility, in theory, would allow a single dynamic store to power several loads with different input voltage requirements on the same platform such as ETC guns and HPM systems.

and power density batteries such as the HP series of lithium ion batteries being developed by SAFT and the lithium polymer batteries produced by Ultralife Batteries, Inc., for use in cell phones. The SAFT batteries have a slight advantage in usable power density and packaging for military use, whereas the Ultralife batteries have an advantage in cost due to volume production and a potential for more compact packaging (thin, rectangular) in ERB service. A design and trade study will select the most appropriate cell for the application. We chose the Ultralife cells for the conceptual design used for purposes of discussion in this paper because of our experience with them in our laboratory tabletop ERB and because of the availability of these cells over a range of capacities from 120 mA-h to 3.5 A-h.

The ERB system in this case constitutes only 1/3rd of the total battery for erected (dynamic) operation. The remaining 2/3rds of the store (static) is dedicated to load leveling and silent mobility. The total capacity of ~290 MJ (80 kW-h) accommodates silent mobility requirements. With only 1/3rd (90 MJ, 25 kW-h) of the total capacity configured for on-command electronic erection and de-erection, the vehicle energy storage system maintains its load leveling and silent operation capability even when the pulse power system is active.

For our conceptual design, we assemble 53 Ultralife polymer batteries into individual 200-V stacks. Five of these stacks are placed in series to obtain an output voltage equal to that of the vehicle bus. In the static portion of the store, 20 such series stacks of the UBC34106102 cells (5,300 total cells) are needed to provide the 200-MJ nominal capacity. In the dynamic portion of the store, the UBC383562 cell is used because of its higher current rating. Due to the smaller size of these cells, there can be as many as 4 in parallel by 53 in series per 200-V unit, and five such units will form an erectable module. The module will incorporate all necessary switches and isolation and thermal management hardware.

Ten modules will constitute the entire dynamic store (~90 MJ, 10,600 total cells). The total battery volume in the static and dynamic stores is ~0.282 m^3, and the accessories are expected to add another 0.4–0.6 m^3 for a total volume of less than 1 m^3. The weight for just the batteries would be ~572 kg, with accessories of much lower density adding another 100–200 kg, for a total weight of less than 700 kg. Charging of the ERB is always performed at bus voltage with the dynamic store in parallel configuration.

In load leveling or silent mobility operation, the charge state of the ERB is continuously monitored and controlled by the vehicle's systems. When the pulse power mode is activated, the mechanical contactors bypassing the isolation switches are opened. Next, all isolation switches are opened, followed by the closing of all series switches, and the ERB begins charging the capacitive store. Initially, the load looks like a short circuit, and the charging current is limited by the internal impedance of the ERB cells. As the charge on the bank increases, the charging current diminishes, and the cell voltage begins to rise. Near full charge, the current approaches zero and the ERB output voltage rises to its maximum of ~10 kV. Voltage on the store is monitored and is regulated by chopping the ERB output (i.e., opening and closing the series and output switches as necessary to maintain charge against leakage; this has been demonstrated in the laboratory at rates of up to 1 kHz). When the store discharges, the output switch opens immediately and remains open long enough for the closing switch to recover (1–10 ms). The ERB can remain erected for as long as the pulse power system is active. Recharging of the store is then initiated by reclosing the ERB output switch. When the pulse power system is deactivated, the dynamic store is returned to its parallel configuration by opening the series switches (de-erecting). The dynamic store can then be recharged from the vehicle power bus.

We have created an ERB laboratory demonstration consisting of five erectable modules of 40 V. The Ultralife UBC383562 cells were used and arranged on PC boards that were in turn stacked via standoffs. Isolation and series switching was via optically coupled IGBTs. Some figures of merit (FOM) from the ERB testing include a demonstrated current rise time to 80 A of 4 μs at 200 V and an erection/de-erection frequency of 1 kHz for use in voltage regulation. A FOM from the four series cell tests is a demonstrated current rise time to 120 A of 1 μs, in a maximum power transfer configuration.

2.1.5. Intermediate energy storage. In the preceding section Titan-PSD identified a need for and established the technical feasibility of an advanced technology power conditioning element to charge capacitive stores in DEW systems. The ERB is the solution with the highest efficiency and energy and power density possible. This is critical in order to realize a manageably sized DEW system. A second similar, critical issue in the design and use of pulsed electrical weapon systems involves the level of available platform power. If this power is insufficient to support the required operational burst length and repetitive fire rate of the system, then it may be necessary to incorporate intermediate energy storage into the system design. Intermediate storage could be practically achieved through the use of secondary batteries, flywheels, and ultracapacitors (also referred to as electric double-layer capacitors or EDLCs). Figure 9 is a schematic diagram of intermediate energy stores in two DEW systems.

Figure 10 shows a present application of an EDLC energy storage system in providing ride-through of voltage sags and momentary outages for an induction motor. The output of the store is connected across the direct current (DC) link of the asynchronous drive and supports its voltage. Titan-PSD has manufactured a ride-through system that has been demonstrated to respond to sags and outages within 10 ms. It can provide

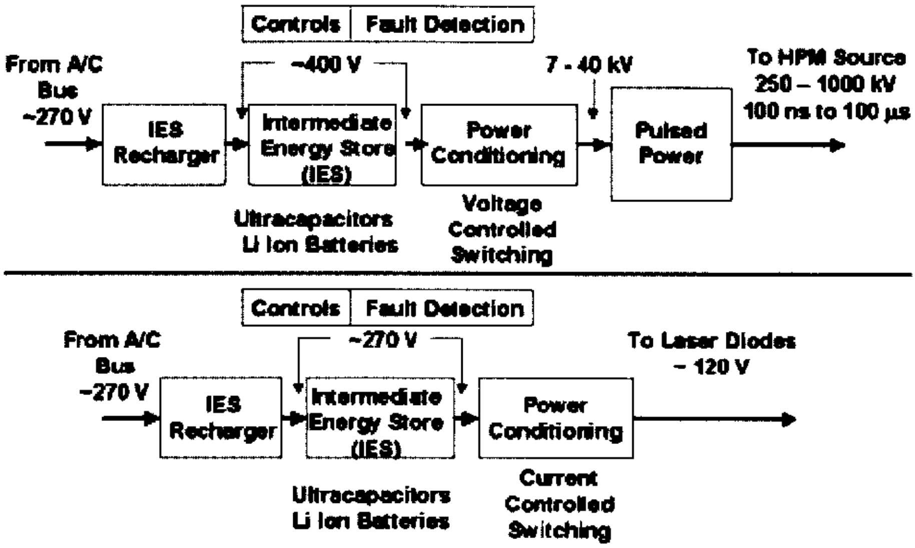
Controls
Fault Detection
From A/C Bus ~270 V
~400 V
7 - 40 kV
To HPM Source 250 – 1000 kV 100 ns to 100 µs
IES Recharger
Intermediate Energy Store (IES)
Power Conditioning
Pulsed Power
Ultracapacitors Li Ion Batteries
Voltage Controlled Switching
Controls
Fault Detection
From A/C Bus ~270 V
~270 V
To Laser Diodes ~ 120 V
IES Recharger
Intermediate Energy Store (IES)
Power Conditioning
Ultracapacitors Li Ion Batteries
Current Controlled Switching

Fig. 9. Two DEW block system schematics with intermediate energy storage.

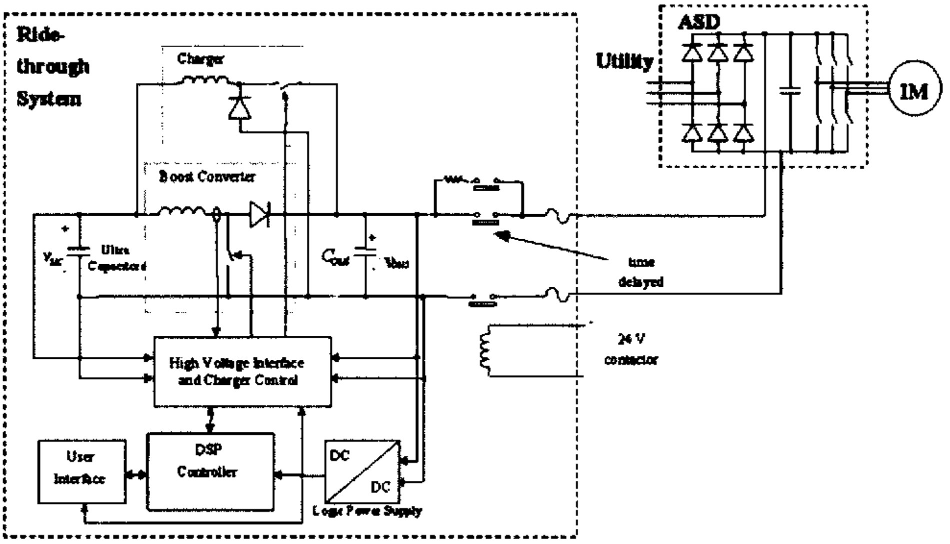
Ride-through System
Charger
Boost Converter
Ultra Capacitors
C_out
V_out
High Voltage Interface and Charger Control
DSP Controller
User Interface
DC
DC
Logic Power Supply
time delayed
24 V contactor
Utility
ASD
IM

Fig. 10. Circuit diagram of an EDLC ride-through system supporting the DC link of an asynchronous drive (ASD).

100 kW for up to 5 s, which is sufficient to allow for orderly shutdown in a prolonged outage.

Titan-PSD has also developed several concept designs of EDLC energy storage systems for military applications. For example, one EDLC system design would be capable of supporting the DC link in a Navy shipboard system at 480 V for 12.5 s at 250 kW. This system is estimated to be 50% smaller and lighter than a corresponding flywheel system (i.e., the Caterpillar UPS-250 system). With minor modifications, the same system (or several systems in parallel) could be used as an intermediate energy store for DEW systems.

2.2. Titan advanced component developments to enable DEWs

2.2.1. Solid-state switches for severe service. The key enabling technology for nearly all pulse power systems for DEW applications is the switch that initiates and delivers the pulsed electrical output from the electrical energy store to the load. This switch must hold off high voltage (typically $\geq$10 kV), close rapidly ($<$1 μs), carry high peak current (100–500 kA) with high initial rate of rise (50–100 kA/μs), sustain a high total action ($\geq 10^7$ A^2-s), and recover rapidly ($<$10 ms). In addition, the switch must support high current density, operate reliably under mechanically stressing conditions, have minimum weight and volume claims, and not require ancillaries such as vacuum pumps or gas flow subsystems. At present, the hydrogen thyratron is most frequently selected to meet these simultaneous requirements, but thyratrons are large and heavy devices, with auxiliary equipment that consumes several kilowatts and often require immersion in oil. The Army Research Laboratory has been actively seeking solid-state devices for DEW utility[7] and Titan-PSD is weighing in by developing a high fluence, laser gated and pumped (silicon) thyristor (LGPT) that will satisfy these requirements.

High fluence optical gating of thyristor switches has been chosen for numerous pulsed power switching applications. Light activation with high fluence laser sources enables the use of solid-state switching devices in performance parameter spaces previously serviced only by vacuum and gas spark gaps. If the output from the high fluence source is properly distributed within the switching medium, the di/dt capability of the switch does not depend on the rate of plasma spreading. Rather, di/dt becomes a function of the rate of rise of the optical fluence. In addition, optical gating eliminates the extensive and intrusive physical gate structure that limits the conduction area of the highest di/dt conventional solid-state devices. Properly designed laser-gated devices are typically capable of higher di/dt, peak current, and charge transfer for a given silicon area than conventional solid-state devices.

The band edge for intrinsic silicon is ~1.12 eV, corresponding to ~1,111 nm. However, silicon is an indirect band-gap material so that the optical phonon energy (0.063 eV) adds to the photon energy to create e–h pairs out to 1,170 nm. In most previous efforts involving direct laser-gating of silicon devices, a solid-state laser was used; typically either Nd:YAG or Nd:YVO at 1,064 nm. However, over the past 10 years, the development of compact diode-pumped solid-state lasers has significantly reduced the size of the requisite optical sources and improved their lifetime and reliability. More important, the InGaAs laser diode bars that were developed for pumping these solid-state lasers have been pushed to longer wavelengths, approaching and exceeding that of the silicon band edge. In principle, the center wavelength of InGaAs laser diode bars is selectable by design over a continuum from 850 nm through at least 1,150 nm. This allows direct optical gating and pumping of silicon by the diodes without any of the intermediary options of the preceding paragraph. Figure 11 is an illustration of an on-board laser diode gated and pumped silicon thyristor, which is one of the candidate approaches in development now.

Titan-PSD is currently performing on two programs and has finished a third that provide technical leverage for further switch development. Our Electra Advanced Pulsed Power Program is a five-year, Naval Research Laboratory (NRL)/DOE-sponsored effort to develop advanced pulsed power components and systems for KrF laser IFE (krypton fluoride laser inertial fusion energy). The most critical component is the primary switch, and we are

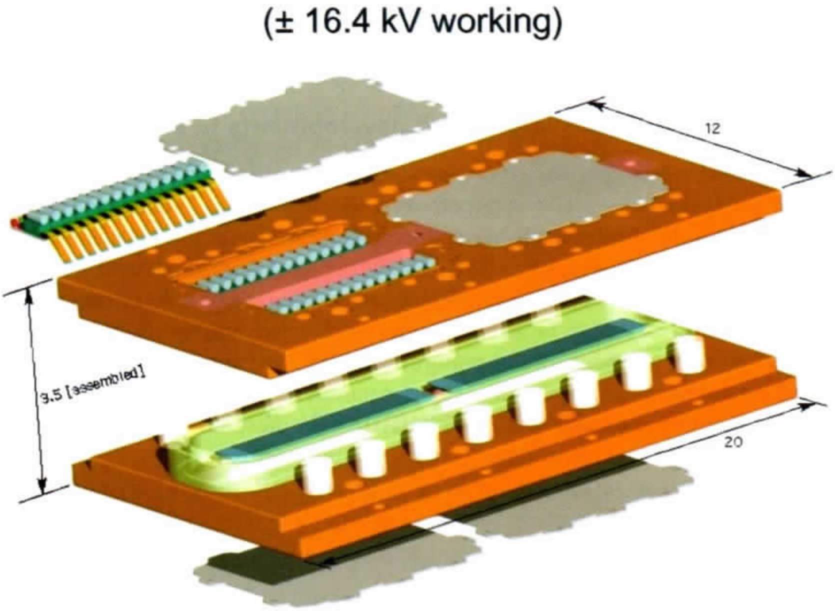

Fig. 11. Illustration of a laser gated and pumped thyristor.

developing an on-board LGPT for this role. The switching requirements are repetitive, high peak current and di/dt, as well as high efficiency (the switch dissipates $<1.5\%$ of stored energy) and long lifetime (10^9 shots). The LGPT is to be used in a Marx generator, and the single device operating parameters are 16.4-kV working voltage, current density 2.25 kA/cm^2, peak current 225 kA, max di/dt 900 kA/μs, pulse width 800 ns, and repetition rate 5 pps continuous. The lifetime requirement limits the thermal excursion per pulse to a few degrees, and therefore the action per square centimeter is low ($\sim$2 A^2-s).

Another current Titan-PSD program is to develop compact pulsed power components for the Air Force Research Laboratory (AFRL) at Kirtland Air Force Base. Components under development enable a compact, long-lifetime Marx-PFN driver for a narrowband HPM source. The di/dt requirement is a few hundred kA/μs/cm^2(Si) or 2 MA/μs total, with a peak current of 30 kA. To satisfy the switching requirements for this application, we are considering the LGPT, a solid-state laser activated switch, and a hybrid combination of the two.

Although the action and charge transfer in these Electra and AFRL applications are substantially less than that found in some pulse power applications, they serve to illustrate our confidence in the high power laser diode bars for high di/dt service. In both cases, the pulse width of the energy transfer is short enough that thyristor action has barely begun by the time the pulse is over. Because of this, a large fraction of the total charge conducted during the pulse must be supplied optically. The diode laser bars and their drive circuitry are capable of supplying an illumination fluence of up to 6 kW/cm^2(Si) within 20 ns and sustaining that level for at least several microseconds. Fluence of several kilowatts per square centimeter is desirable for initial gating in many DEW applications. The required fluence drops to 250–500 W/cm^2 for continuous pumping.

Another effort was recently undertaken in a conceptual design study for an optically gated and pumped switch for rectification of compulsator (pulsed alternator) output for driving an electromagnetic gun. This completed study was performed by Titan-PSD and the Optiswitch Technology Corporation for the Institute for Advanced Technology (IAT). The on-board LGPT design was chosen because of the customer's desire to reduce the overall device count and silicon area compared with conventional devices. Specifically, we designed a 16.7 kV, 100–115-cm^2 asymmetric (blocks voltage forward direction only) thyristor and series diode. Depending on the allowable temperature excursion per shot, our approach replaces ~80 conventional devices with 3–5 series pairs (6–10 devices total; 340–500 cm^2 active) for the same forward losses. This is possible because continuous pumping of thick (2.5-mm), high-voltage (15–20-kV) devices with photo-carriers mitigates the carrier population deficit in the n-base. Electrically gated devices of the same voltage capability typically exhibit huge commutation and conduction losses and are therefore impractical for this type of service. Reverse blocking was handled by a series optically pumped diode. Separating the forward and reverse blocking functions allowed more freedom in designing for reverse recovery, a feature deemed necessary due to repeated failures of symmetric (blocks voltage both directions) devices in this service. Laser diode pumping served to reduce the forward losses in the series diode element as in the thyristor.

The switch was designed to handle a peak current of 1.6 MA (3.3–4.7 kA/cm^2) for 600 μs when installed in a half-wave, four-phase rectifier. Nine total cycles are rectified per shot of the electromagnetic gun. The initial design (500 cm^2 active) limited the temperature excursion per shot to ~100°C, commensurate with a service life of ~10^4 shots. In the extreme, the current density could be pushed to 4.7 kA/cm^2 and optical pump power doubled, resulting in a ΔT approaching 180°C and ~200-shot lifetime. The laser diode bars in the initial case provided a constant 500 W/cm^2 of silicon for each 600-μs conduction phase. This goes to 1 kW/cm^2 in the extreme case.

2.2.2. Next generation reltron microwave generator development. Reltron HPM sources were invented and developed by R. Bruce Miller of Titan Advanced Innovative Technologies from the mid-1980s through 1998. The PSD of Titan assumed responsibility for reltron contracts in 1998. Projects included one complete HPM simulator for a government research laboratory in Germany and eight reltron tubes of various specifications. In developing these eight tubes, enough mechanical and electrical modifications have been included to justify their designation as "second-generation" designs.

Reltrons are both compact and efficient. The electron beam is highly modulated over ~10 cm and postaccelerated prior to drifting to the output cavities and beam collector. This beam transport requires only ~75-cm overall length for L-band tubes (Fig. 12). The output cavities are incorporated into a standard rectangular waveguide. Microwave power is efficiently extracted (~80%) directly in TE$_{10}$ mode. The overall efficiency (peak electrical to microwave power) is 30–40%.

In general these new tubes move the reltron technology base in the directions of longer pulsewidths (~1–2 μs), increased frequency tunability (~±13%), lower driver voltages (500–600 kV), and higher repetition rates (~10 Hz for demountable versions, ~300 Hz for sealed tubes). Second-generation improvements include a new high voltage insulator design, new movable current contacts for the modulation and output cavity tuners, reduced outgassing, and monolithic grids. The frequency range for these eight tubes covers 700–1,450 MHz. Programs are in place now to extend this range.

In addition to the objective to extend the frequency coverage, efforts are underway to improve beam optics to reduce current losses and thereby improve efficiency and microwave output power. A new beam current diagnostic package has been recently implemented to

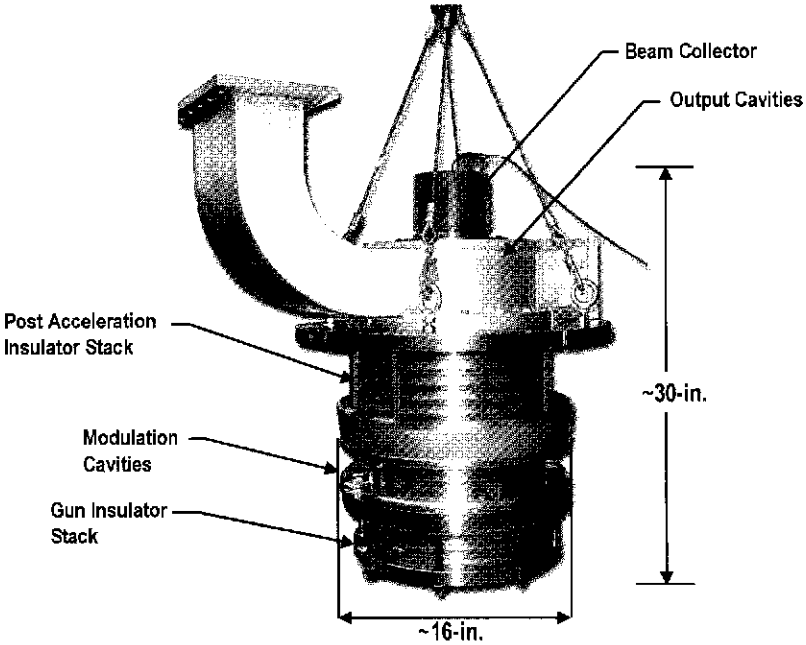

Fig. 12. L-band reltron capable of generating flat 200-MW, 900-ns pulses with frequency stability $\delta f/f < 0.3$. This generation of reltrons is capable of RF pulse widths of ~300 RF cycles, repetitive pulse operation from single-shot to 10 Hz, and ±10% continuous-frequency tunability.

better infer basic performance parameters and to assist in comparing benchmarking simulations. These calculations simulate performance in the actual geometry and are generated with a three dimensional particle-in-cell code (the LSP code from Mission Research Corporation). Measured waveforms generated by a recently delivered L-band tube are shown in Fig. 13. This tube produces ~185 MW in flat, 900-ns pulses with excellent frequency stability. The LSP code was essential during this tube's development. A new era in microwave tube design has emerged with the development of accurate three-dimensional models.

2.2.3. HEM magnetron. Backdoor microwave effects on electronics systems in modern weapons fall into three broad categories. Two categories are characterized by high peak power density and microwave formats that overwhelm the target system with an electric field that is high enough to cause circuit upset or burnout. In the third category, effects are caused by coupling spurious signals into the target system, akin to classical smart jamming, interference or spoofing[‡] techniques used by the EW countermeasures community. The DEW microwave pulse formats appropriate to the latter class of effects are generally distinguished from upset and damage pulse formats by lower peak power density thresholds but more specific requirements on frequency and amplitude modulations and

---

[‡] Low incident microwave levels can cause "interference" with the operation of threat weapon electronic systems, producing high levels of noise in sensitive circuitry to "mask" true signals. The incident microwave signal is said to "spoof" if it is tailored to "mimic" the true signal and to thereby produce false commands.

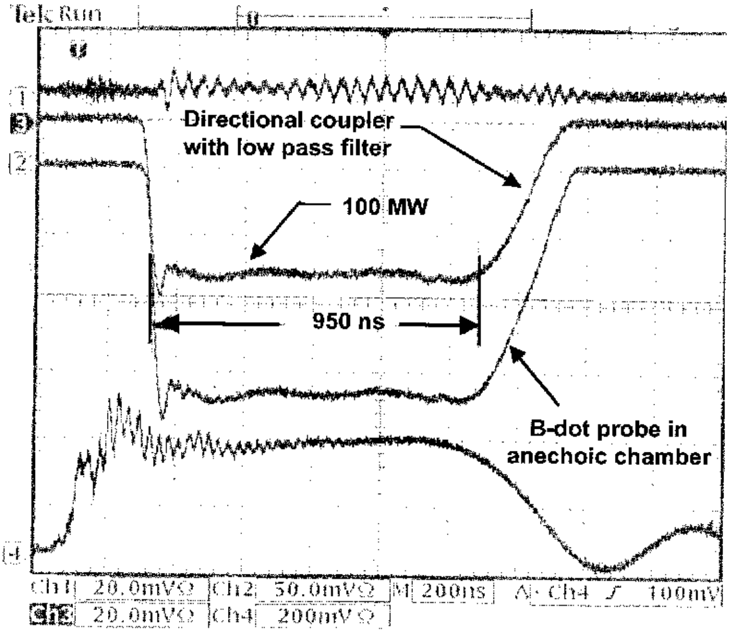

Fig. 13. Waveforms from the 185-MW L-band reltron: the top trace is the heterodyne (l.o. = 1.3 GHz) showing excellent frequency stability, and the second trace is the steady, flattop output power measured with a calibrated directional coupler. (The data are conditioned with a low-pass filter; higher harmonic content is know to be more than 13 dB below the primary L-band signal.) The third trace is the radiated power monitored with an uncalibrated, free-field B-dot, and the last trace is an uncalibrated profile of the Marx current.

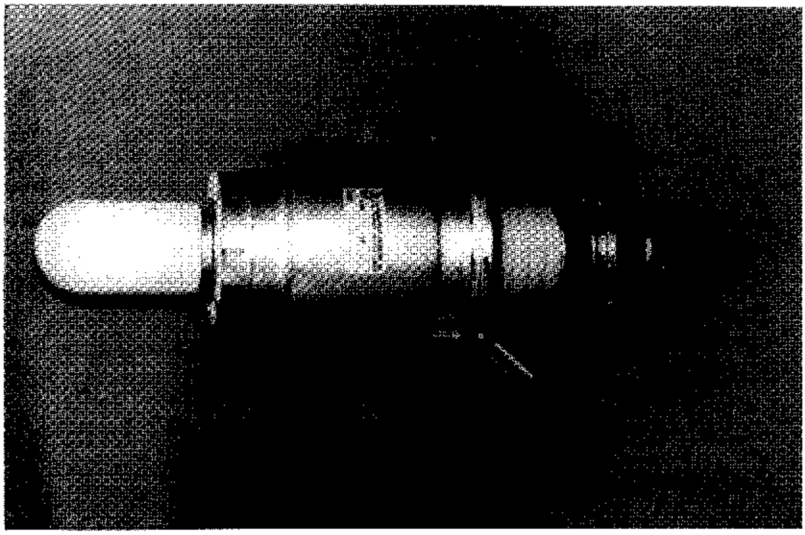

Fig. 14. Titan's L-band HEM magnetron. This is the highest-average-power magnetron that is commercially available.

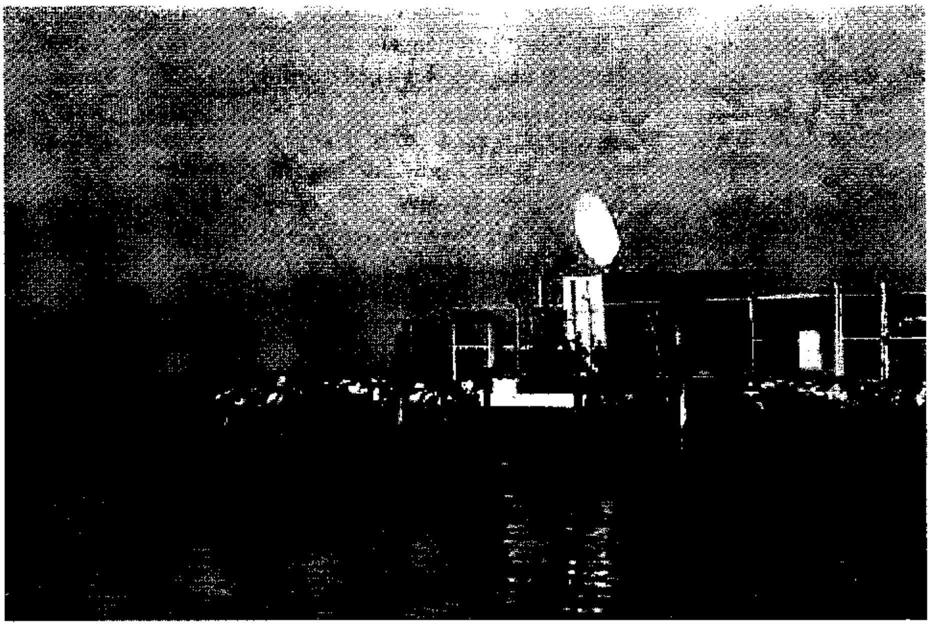

Fig. 15. The principal system elements of the ATD system are a power supply, a modulator, an HEM source, and an antenna. These components are supported by a control system and a cooling system. For the DTRA ATD ground-based system the power supply and operators' console(s) are housed in a shelter mounted on one flatbed trailer while the remaining components are mounted on another flatbed trailer (out of the field of view to the right). The system was designed to broadcast 2-MW peak power pulses with an average power of 300 kW for 30-s missions. This yields a peak fluence of 1 mW/cm^2 at a range of 2,400 m.

repetition rate. All three categories of effects can be induced by DEW systems based on high-power RF, narrow-band, pulsed HPM or long-pulse, high-energy microwaves (HEMs).

Titan has developed an HEM laboratory source and an HEM advanced technology demonstration (ATD) source for DEW purposes at its California Tube Laboratory. These HEM sources have efficiencies of approximately 85%. This high efficiency minimizes prime power and cooling requirements, thus significantly minimizing overall DEW system size and weight. The HEM magnetron, shown in Fig. 14, has produced 900-kW peak and 150-kW average powers and can easily be upgraded to 300-kW average power. The unique modulation characteristics of this magnetron can produce modulation effects of 30 MHz or greater in the target systems. More operational details are given in Table 6.

The ATD system shown in Fig. 15 combines the outputs of two 150-kW-average-output power magnetrons. The maximum peak output power obtained to date is 1.2 MW. The magnetrons with their respective magnet yokes each weigh about 200 lb, and each takes up about 4 ft^3. When combined their efficiency is over 76%, therefore together they absorb only 95 kW and are actively cooled. Variants of this RF system are suitable for Army, Navy, and Air Force missions.

Table 6. California tube laboratory HEM magnetron operational specifications

Parameter	Value
Frequency, fixed	915 MHz (890–920 MHz possible as well)
Power output	
Continuous wave	300-kW minimum
Pulse	600-kW peak (900 actually achieved) 300-kW avg (nominal 50% duty)
Pulse width	10s of microseconds to 5 ms
Peak anode voltage	42 kV
Peak anode current	17 A
Beam efficiency	88% typical
Water-cooled anode	20 gpm typical
Filament	12 VAC, 200-A typical standby

3. Conclusions and Significance

The first laser and HPM DEWs are just now being deployed, and new threats emerging in the information age will sustain the need for continued DEW development and acceptance. The deployment of even more advanced DEW systems and in fact the DoD's intent to field more (or all) electric fighting platforms depend critically on the availability of compact, lightweight, efficient pulsed power subsystems and long-lived, reliable advanced power conditioning and front-end components.

Titan has been supporting U.S. directed energy programs by providing services and analysis and developing advanced technologies since the early 1980s. Today, Titan is the only U.S. industrial supplier of commercial HPM generators. We have advanced pulsed power and power electronics technology development programs involving intermediate and primary electrical energy storage, solid-state switching, power conditioning, electrical-to-microwave conversion, and novel microwave antennas underway now. Titan is focused on providing pulsed power and C4ISR (command, control, communications, computers, intelligence, surveillance, and reconaissance) solutions for national defense and is intent on maintaining its industrial leadership in military information technologies.

Acknowledgments

The authors recognize and acknowledge contributions made by Jim Benford, Jerry Levine, R. Bruce Miller, and David Blank to the development of the primary narrow-band microwave sources that were the precursors of much of the HPM and HEM technology that Titan offers today.

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TOWARDS A NEW ELECTROMAGNETICS
PART I: SOLUTION TO TESLA'S SECRETS AND THE SOVIET TESLA WEAPONS

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PART I

I am much indebted to Mr. Carey Briggs for furnishing references which strongly support the existence of scalar potential waves and scalar interferometry. Among those papers are Whittaker (1903), Nisbet (1955) , and other papers dealing with Hertzian potential theory. As ever, my profound gratitude is due Hal Crawford for his splendid illustrations which accompany this paper. I am also indebted to John Ratzlaff and the Tesla Book Company for graciously furnishing important Tesla references for me to analyze. My sincere thanks go to Messrs. Jim Beal and Williard Van de Bogart for furnishing important references on exoelectron emission and tectonic fault zones, and to Dr. Robert Beck for furnishing important material on the Rogers underground and undersea transmission system. Additional assistance was also received from Mr. Peter Kelly, Joe Siegeldorf, Joe Gambill, and Bob Beutlich. I am also very appreciative of the information furnished by Bob Jones and Vestigia on the beautiful Vestigia mystery light experiments.

PART II

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Bob Nelson, Berkeley, Calif.
Mildred Ratzlaff, Millbrae, Calif.

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FOREWORD

The long-searched-for Tesla secrets have been solved by Tom Bearden. Part I contains the specific description of the solutions to Tesla's secrets and the Soviet Tesla weapons.

The present electromagnetic theory has several flaws, and it is these errors that have hidden the long-sought unified field theory. The explanations presented by the author provide clarity and understanding to related Tesla writings and patents.

Before the turn of the century, Nikola Tesla had discovered and was utilizing a new type of electric wave. Tesla repeatedly stated that his waves were non-Hertzian, and that his wireless transmissions did not fall off as the square of the distance. The author has found that the wave which Tesla was using is a longitudinal scalar wave, capable of many times the speed of light. When coupled with another scalar wave (Tesla wave),
the resulting vector wave can be the source of electromagnetic energy for electrical power, a protective force field, or a destructive weapon.

The booklet is well illustrated with special drawings by Hal Crawford. The bibliography includes corroborating information on all major points. Part II presents reprints or the entire subject matter of selected articles from the bibliography, plus additional references of importance. Articles are arranged in chronological order. Also included are nine patents by James Harris Rogers which were the basis of successful wireless communication during World War I. These principles of underground and sub-sea wireless were based on Tesla's discoveries.

Bearden's solutions are truly a major breakthrough, and an absolute necessity to the understanding of existing Tesla writings. It is also important that more should be known of this extraordinary individual, Thomas E. Bearden.

BIOSKETCH:

A nuclear engineer, wargames analyst, and military tactician, Lieutenant Colonel (Retired) Tom Bearden has over 26 years experience in air defense systems, tactics and operations; technical intelligence, anti-radiation missile countermeasures; nuclear weapons employment, computerized wargames; and military systems requirements.

He is currently with the Alabama division of a large aerospace company where he is involved in determining the future requirements for laser weapons.

Lieutenant Colonel Bearden obtained a Master of Science degree in nuclear engineering from the Georgia Institute of Technology and a Bachelor of Science degree in mathematics from Northeast Louisiana University. He is also a graduate of the U.S. Army Command and General Staff College and several U.S. Army artillery and missile schools.

He has had direct experience with tube artillery and with the Ajax, Hercules, Hawk, and Patriot missile systems and the production of technical intelligence on Soviet surface-to-air missile systems for the U.S. Army/Department of Defense.

Tom holds a Sandan (third degree black belt) in Yoseikan aikido; is a singer, guitarist and songwriter; member of Mensa, Society for the Investigation of the Unexplained, Vestigia, the American Association of Meta-Science: and is on the board of governors of the U.S. Psychotronics Association. In addition, he is Alabama Director of a small nonprofit foundation, the Association of Distinguished American Scientists and is a MUFON adviser on nuclear engineering.

He also edits *Specula,* Journal of the American Association of Meta-Science.

Tom is primarily active as a theorist on UFOs, parapsychological and paranormal phenomena, and psychotronics. He is the author of a book, *The Excalibur Briefing,* Strawberry Hill Press, 2594 15th Avenue, San Francisco, California 94127 and has numerous technical papers dealing with new paradigm physics, paranormal phenomena, and Soviet psychotronic weapons.

Finally, Bearden's *Solutions to Tesla's Secrets and the Soviet Tesla Weapons* promises to be recognized in the future as a major contribution to our present technology.

JTR

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TESLA'S SECRET AND THE SOVIET TESLA WEAPONS

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With Special Drawings by Hal Crawford

Before the turn of the century, Nikola Tesla had discovered and was utilizing a new type of electric wave. Tesla repeatedly stated his waves were non-Hertzian, and his wireless transmissions did not fall off as the square of the distance. His discovery was apparently so fundamental (and his intent to provide free energy to all humankind was so clear) that it was responsible for the withdrawal of his financial backing, his deliberate isolation, and the gradual removal of his name from the history books.

By 1914 or so, Tesla had been successfully isolated and was already nearly a "nonperson." Thereafter Tesla lived in nearly total seclusion, occasionally surfacing (at his annual birthday party for members of the press) to announce the discovery of an enormous new source of free energy, the perfection of wireless transmission of energy without losses, fireball weapons to destroy whole armies and thousands of airplanes at hundreds of miles distance, and a weapon (the "Tesla Shield," I've dubbed it) that could provide an impenetrable defense and thus render war obsolete.

In my pursuit of Tesla's secret, it gradually became apparent to me that present orthodox electromagnetic theory is seriously flawed in some fundamental respects. One of these is in the definition and use of ϕ, the scalar electrostatic potential. It is this error which has hidden the long-sought unified field theory from the theorists.

In the theory of the scalar electrostatic potential (SEP), the idea is introduced of work accomplished on a charge brought in from a distance against the scalar field. The SEP is not a vector field, but is a scalar field. Indeed, scalar potential cannot of itself perform work on a charged mass; if it could do so, then tremendous force would exist on every mass due to the extremely high SEP of the vacuum itself. Only a differential of SEP between two spatial points can produce force or accomplish work. (Rigorously, a differential of scalar potential between two spatial points constitutes a vector. Only a vector can produce force and do work.)

Also, work can only be done on a mass. Further, it takes time* to move an electron or other charged mass between two spatial points, and so the work performed by a spatial differential of the ϕ-field requires time. Rigorously, the delta SEP is voltage, not SEP per se, and is directly related to

E field. The entire voltage concept depends on the work performed in moving a mass, after that mass has moved. The idea of "voltage" always implies the existence of a steady differential of ϕ between two spatial points for a finite length of time, and it also involves the assumption of a flow of actual mass having occurred. SEP, on the one hand, is always a single-point function; on the other hand, difference in potential (i.e., V) is always a two point function, as is any vector.

Yet many graduate level physics and electromagnetics papers and texts erroneously confuse ϕ and V in the static case! Such an interpretation is of course quite incorrect.

---

* *Two spatial points involve at least $\Delta t = \Delta L/c$ in time. All vectors and gradients involve 2 separated spatial points, and thus present timelines in 4-space. ϕ_4 is a point, not a line, in 4-space.*

Another common assumption in present EM theory -- that the electrostatic potential (ϕ_0) of the normal vacuum is zero -- has no legitimate basis. In fact, we know ϕ_0 is nonzero because the vacuum is filled with enormous amounts of fluctuating virtual state activity, including incredible charge fluctuations. And by virtue of its point definition, ϕ_0 must be the "instantaneous intensity" of these fluctuations -- but both in space and time. The scalar electrostatic potential is therefore the "instantaneous stress" on spacetime itself, and a measure of the intensity of the virtual state flux through a 4-dimensional spacetime point.

Potential theory was largely developed in the 1800's, before the theory of relativity. Time flowrate was then regarded as immutable. Accordingly, electrostatic "intensity" was chosen as "spatial intensity," with the connotation of "spatial flux density." This assumes a constant, immutable rate of flow of time, which need not be true at all if we believe relativity. Such a spatial "point" intensity is actually a "line" in 4-space, and not a 4-dimensional "point" at all. Thus the spatial potential -- ϕ_3 -- is a very special case of the real spacetime potential -- ϕ_4, or charge and electromagnetic theory today is accordingly a special case of the real 4-space electromagnetism that actually exists! Note also that charge is a 4-dimensional concept.

Now mass is a spatial, 3-dimensional concept. Rigorously, mass does not exist in time -- masstime exists in time. Mass and charge are thus of differing dimensionalities!

Also, according to quantum mechanics, the charge of a particle -- e.g., of an electron -- is due to the continual flux of virtual particles given off and absorbed by the observable particle of mass. Thus charge also is conceptually a measure of the virtual flux density, and directly related to ϕ. Further, since the charge exists in time, it is the charge of a particle of spatial mass that gives it the property of masstime, or existing in time.

Here a great confusion and fundamental error has been thrown into the present EM theory by the equating of "charge" and "charged mass." As we have seen, the two things are really very different indeed.

To speak of a spatial "amount" of charge erroneously limits the basic EM theory to a fixed time flowrate condition (which of course it was considered to be, prior to Einstein's development of relativity). Thus when the limited present theory encounters a "relativistic" case (where the time flowrate changes), all sorts of extraordinary corrections must be introduced. The real problem, of course, is with the fundamental definitions of electrostatic potential and charge. The spatial "amount" of charge (i.e. the coulomb) as we presently erroneously use the term, is actually the spatial amount of observable "charged mass." To correct the theory, one must introduce the true 4-space SEP and separate the definitions of charge and charged mass.

Only when a mass is moved does one have work -- and voltage or vector fields. (The reason one has voltage and E field connected to a normal electrostatically charged object in the laboratory is because an excess of charged-particle masses are assembled on the object, and these masses are in violent motion! A true static charge would have no E field at all.)

Table 1. Some Present Theoretical Facts

- Ø_3-FIELD CONCEIVED BEFORE RELATIVITY
    - POINT FUNCTION IN SPACE
    - LINE FUNCTION IN SPACETIME
    - TIME FLOWRATE CONSIDERED IMMUTABLE
    - SPECIAL CASE OF $\text{Ø}_4, \ldots\ldots, \text{Ø}_N$
- GRADIENT BETWEEN TWO POINTS IN Ø_3 FIELD
    - PRODUCES VOLTAGE
    - PRODUCES E FIELD
    - MOVES ELECTRON
    - IS AN AREA IN 4-SPACE
- GRADIENT MAY BE BETWEEN SEPARATED POINTS IN TWO SUPERPOSED Ø-FIELDS
- Ø-FIELD CAN "MOVE" AT INFINITE VELOCITY*

* JACKSON, CLASSICAL ELECTRODYNAMICS, 2ND EDITION, P. 223

Table 2. Some Proposed $Ø_4$ Characteristics

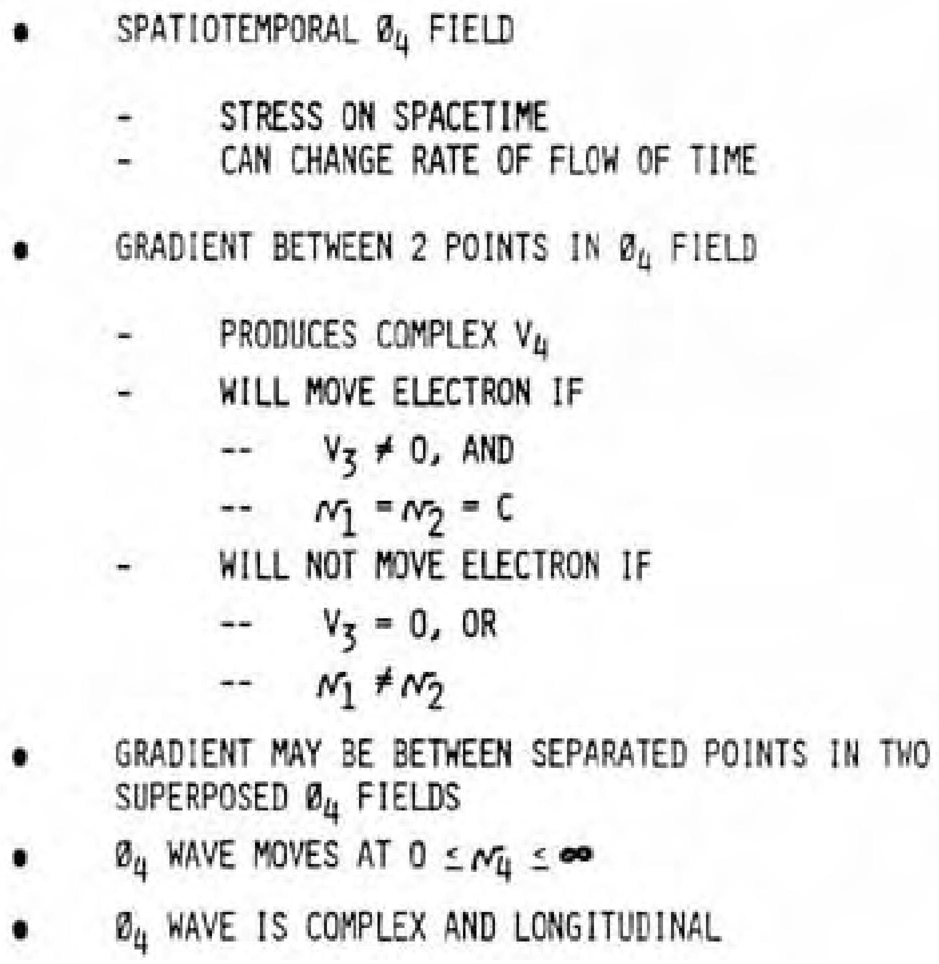

- SPATIOTEMPORAL $Ø_4$ FIELD
  - STRESS ON SPACETIME
  - CAN CHANGE RATE OF FLOW OF TIME
- GRADIENT BETWEEN 2 POINTS IN $Ø_4$ FIELD
  - PRODUCES COMPLEX V_4
  - WILL MOVE ELECTRON IF
    - -- $V_3 \neq 0$, AND
    - -- $\nu_1 = \nu_2 = C$
  - WILL NOT MOVE ELECTRON IF
    - -- $V_3 = 0$, OR
    - -- $\nu_1 \neq \nu_2$
- GRADIENT MAY BE BETWEEN SEPARATED POINTS IN TWO SUPERPOSED $Ø_4$ FIELDS
- $Ø_4$ WAVE MOVES AT $0 \leq \nu_4 \leq \infty$
- $Ø_4$ WAVE IS COMPLEX AND LONGITUDINAL

ϕ-field need not involve observable mass accumulation, but only charge (virtual flowrate intensity) accumulation. Accumulated masses are like so many gallons of water; accumulated charge is like so much pressure on both the water (space) and the time in which the water is existing.

Now, if one varies the SEP solely as a point function, one would have a purely scalar complex longitudinal wave, and not a vector wave at all. This is the fundamentally new electrical wave that Tesla discovered in 1899.

Rigorously, all vector fields are two-point functions and thus decomposable into two scalar fields, as Whittaker showed in 1903. It follows that any vector wave can be decomposed into two scalar waves. By implication, therefore, a normal transverse EM vector wave, e.g., must simply be two coupled scalar (Tesla) waves -- and these scalars independently would be longitudinal if uncoupled. An ordinary transverse EM vector wave is thus two pair-coupled Tesla scalar longitudinal waves, and only a single special case of the much more fundamental electromagnetics discovered by Nikola Tesla.

A Tesla (scalar potential) wave -- i.e., a massless wave in pure ϕ_0, the stress of the spacetime medium would have very strange characteristics indeed. For one thing, since it moves in a complex 4-space, it has many more modes of movement than does a simple wave in 3-space. And for another thing, it need not be bound at all by the speed of (vector) light. In current theory, one ϕ_3-field does not directly interact or couple with other existing ϕ_3-fields except by simple superposition. Therefore presently the ϕ-field is considered to have no drag limitation at all, hence infinite velocity. (E.g., as stated in Jackson, Classical Electrodynamics, 2nd edition, page 223.)

Actually, a ϕ_4-wave can and will interact with some of the other existing ϕ_4-waves in the medium transversed, and this interaction can involve pair-coupling into EM vector fields and waves, an interaction not presently in the electrodynamics theory. The result of scalar pair-coupling creates a finite amount of vector "drag" on the ϕ_4-wave, so it then has less than infinite velocity. However, if this drag is small due to limited pair-coupling, the scalar wave's velocity through the slightly dragging medium still may be far greater than the speed of vector EM waves (light) in vacuum. On the other hand, if the pair-coupling is made severe, the ϕ-wave may move at a speed considerably below the speed of vector light waves in vacuum. The velocity of the ϕ_4-wave is thus both variable and controllable or adjustable (e.g., simply by varying its initial amplitude, which through a given medium changes the percentage of pair-coupling and hence the degree of drag on the scalar wave). The Tesla scalar wave thus can have either subluminal or superluminal velocity, in contradiction to present theory.

Note that the scalar wave also violates one of Einstein's fundamental postulates -- for the speed of our "new kind of light" wave is not limited to c, and need not be the same to every observer. Thus Tesla scalar waves lead to a new "superrelativity" of which the present Einstein relativity is only a highly special case!

Table 3. Tesla Waves Can:

- **ESTABLISH STANDING WAVES**
  - **- in the earth**
  - **- in the ionosphere**
- **TAP ENERGY FROM THE EARTH'S CORE**
- **TRAVEL FASTER OR SLOWER THAN LIGHT**
- **CHANGE RATE OF TIME FLOW**
- **AFFECT ALL FIELDS, INCLUDING GRAVITY**
- **COMMUTE BETWEEN VIRTUAL AND OBSERVABLE**

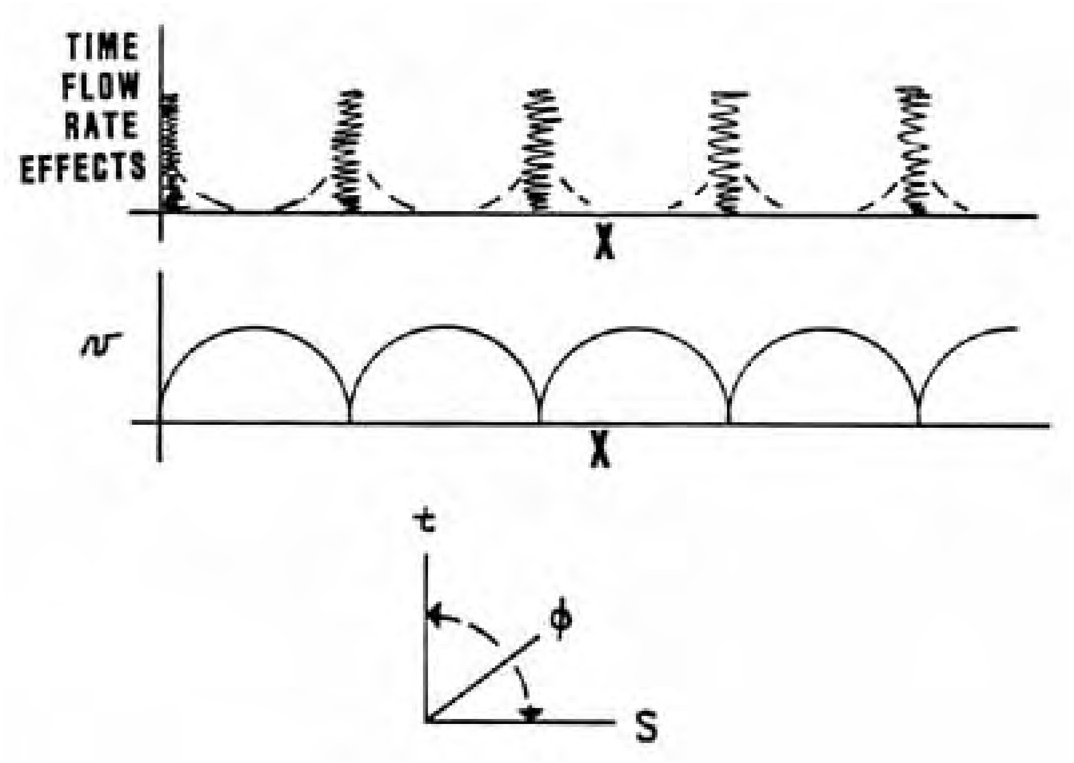

Figure 1. Tesla's Standing Columnar Wave

But let us now look for some subtle but real examples of scalar waves and scalar pair-coupling in nature. As is well known, a tectonic fault zone can provide anomalous lights, sounds, etc. from stresses, piezoelectrical activity, and telluric currents in the earth and through the fault zone. In examining the fault zone phenomena, I finally realized that a fault zone was literally a scalar interferometer i.e., if one can have scalar ϕ_4-waves, they can interfere, either constructively or destructively. Their interference, however, produces scalar pair-coupling into vector EM waves. This coupling may be at a distance from the interferometer itself, and thus the interferometer can produce energy directly at a distance, without vector transmission through the intervening space. Coupling of ϕ waves with the paired scalars comprising ordinary EM vector waves can also occur. If this triplex coupling forms additional EM vector waves 180 degrees out of phase, the ordinary EM wave is diminished or extinguished. If the scalar triplex coupling occurs so as to create vector EM waves in phase with the interacting vector EM wave, the amplitude of the ordinary vector wave is increased.

Scalar potential waves can thus augment or diminish, or create or destroy, ordinary EM waves at a distance by pair-coupling interference under appropriate conditions, and this is in consonance with the implications of Whittaker's fundamental 1903 work.

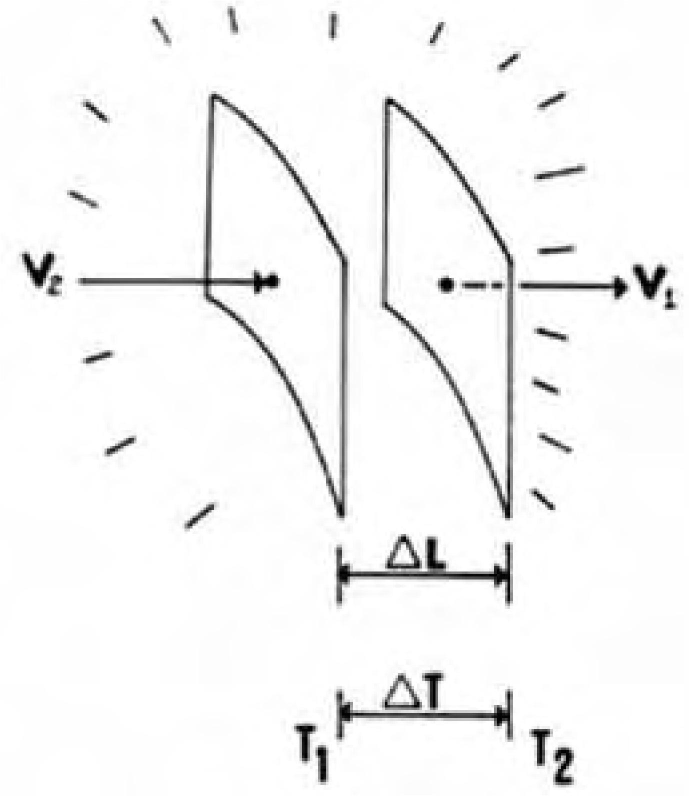
V_2
V_1
ΔL
ΔT
T_1
T_2

ALL VECTORS AND VECTOR FIELDS ARE CREATED BY SCALAR INTERFEROMETRY AND PAIR COUPLING

EM COUPLING CONDITION

$$\Delta L/c = \Delta T$$

Figure 2. Pair Coupling: Producing EM at a Distance

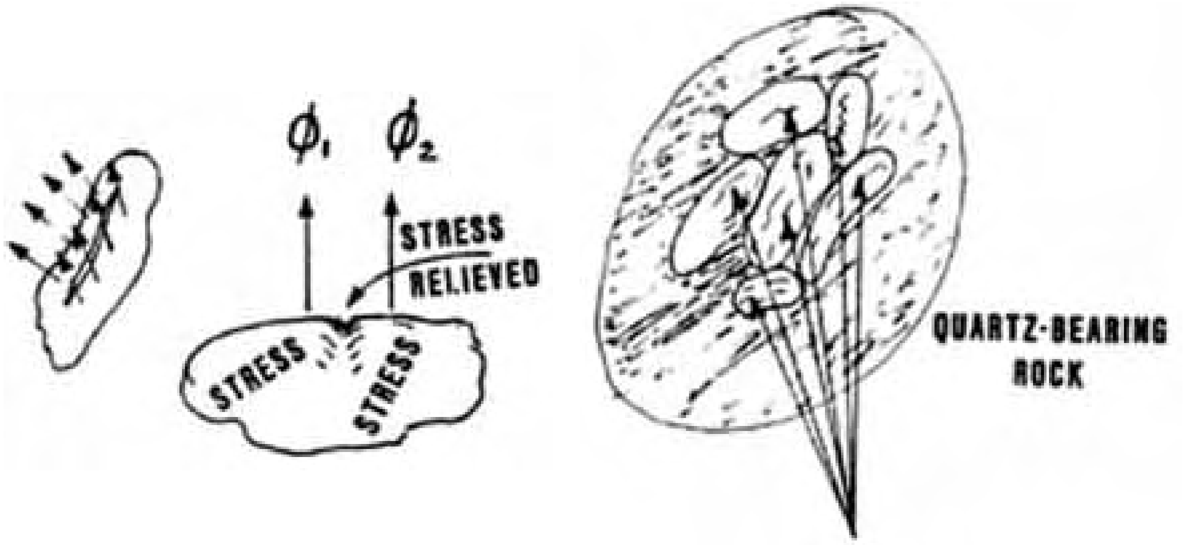
ϕ_1
ϕ_2
STRESS RELIEVED
STRESS
STRESS
QUARTZ-BEARING ROCK

LOCKED-IN STRESSED CRACKS

EACH TINY STRESSED CRACK ACTS AS A SCALAR INTERFEROMETER

BECOMES A PRIGOGINE CRYSTAL

Figure 3. Natural Scalar Interferometers

An earthquake fault zone is such a scalar interferometer. Stresses and charge pileups exist in the plates on each side adjacent to the fault, with stress relief existing in the middle in the fault fracture itself. Since the rock is locally nonlinear, the mechanical stresses and electrical currents in it are also locally nonlinear. This results in the generation of multiple frequencies of ϕ_4-waves from each side of the fault interferometer, yielding two complex Fourier expansion patterns of scalar potential waves. On occasion these two Fourier-transformed scalar wave patterns couple at a distance to produce stable ordinary electromagnetic field in a 3-dimensional spatial pattern -- e.g., a stress light such as the Vestigia light covered in Part I of The Excalibur Briefing. Driven by the erratic two scalar Fourier expansion patterns of the scalar interferometer (whose input stresses normally slowly change), an erratic, darting, hovering "spooklight" of the variety studied by Vestigia is produced.

As the stresses change in each side of the interferometer, the distant scalar coupling zone is affected. Thus the stresslight moves and its form changes, but it may be relatively stable in form for seconds or minutes. Since the stresses in the rock may be intense, the stress light may involve an intense pair of ϕ-patterns coupling into the sphere or ball of vector EM energy. The atoms and molecules of the air in the region of the coupled stresslight ball thus become highly excited, giving off radiant energy as the excited states decay.

Since much of the piezoelectric material in the stressed rocks is quartz grains, the features of quartz are of particular interest. Each little quartz grain is itself highly stressed, and has stress cracks. It is therefore a little scalar interferometer. Further, quartz is transparent to infrared and ultraviolet; and the random orientation of all the quartz scalar interferometers may also form a Prigogine system far from thermodynamic equilibrium. If so, this system can tap into highly energetic microscopic electromagnetic fluctuations to produce large-scale, ordered, relatively stable patterns of electromagnetic energy at a distance.

In short, all of this lends support to the formation of relatively stable but somewhat erratic patterns of electromagnetic energy at a distance from the fault itself. In the atmosphere, such scalar interferometers could form in clouds or even in the air or between clouds and earth. If so, such rare but occasional "weather" scalar interferometers could account for the rare phenomenon of ball lightning. The intense energy of the ball of lightning, as compared to the lesser energy of an earthstress light, could well be due to the enormous electrical charges between clouds or between cloud and earth, available to fuel the scalar interferometer. Very probably it is this phenomenon which gave Tesla the clue to scalar wave interferometry.

Thus such phenomena as earthstress lights, ball lightning, and the Tesla system of wireless transmission of energy at a distance with negligible losses and at speeds exceeding the speed of light may be explained. They are complex, however, and involve fundamental changes to present electromagnetic theory. These changes include utilizing 4-space scalar electrostatic potentials, scalar waves, pair coupling, ordinary 3-dimensional Fourier expansion, the Prigogine effect, and the properties of piezoelectric materials in rocks.

Since the scalar potential also stresses time, it can change the rate of flow of time itself. Thus it affects anything which exists in time -- including the mind, both of the individual and at various levels of unconsciousness. Therefore the same functions that result in earthstress lights also affect mind and thought, and are in turn affected by mind and thought. This is the missing ingredient in Persinger's theory that UFO's are correlated with, and a result of, fault zones and earth stresses. While Persinger seems to feel this is a "normal physics" explanation, it indeed involves a paranormal explanation.

The time-stressing ability of the true ϕ scalar wave also explains the interaction of such earthstress lights with humans and human intent, as noted by other researchers. (E.g., the lights that repeatedly seemed to react to the observers, as detailed by Dr. Harley Rutledge in his epoch-making Project Identification, Prentice-Hall, 1981.)

These ideas in condensed form comprise the concepts required to violate the speed of light and produce an ordinary electromagnetic field at a distance, using scalar interferometry, without losses -- as Tesla had done in his wireless transmission system which he had tested prior to 1900 and had perfected by the 1930's. Scalar interferometry can give stable regions of EM or "light energy" at a distance without losses, particularly as detailed in the beautiful Vestigia experiments, and it is within our grasp to utilize the new effects. Indeed, any stress crack in a material can result in the scalar potential interferometer effect. Exophoton and exoelectron emission -- poorly understood but already known in fatiguing of materials -- must be at least partly due to the scalar interferometer effect.

However, one additional caution should be advanced. Normal movement of electrons allows so much "sideplay" movement of the electrons -- and there is so much such sideplay electron motion in the surrounding vicinity -- that pair coupling is almost instantaneous for small waves. Thus orbital electrons in atoms seem to absorb and emit vector EM photons. Actually they also emit some percentage of scalar waves as well. Since a scalar wave is comprised exclusively of disturbance in the virtual state, it need not obey the conservation of energy law. Further, a scalar wave of itself does not "push electrons" or other charges; hence it is nearly indetectable by present detectors. Ionization detectors such as a Geiger counter tube, e.g., are exceptions if the scalar wave encountered is fairly strong. In that case sufficient triplex coupling with the ionized gas occurs to produce additional ionization or charge, breaching the tube's cutoff threshold and producing a cascade discharge of electrons and voltage which is detected. But weak scalar waves are presently indetectable by ordinary instruments. However, these small scalar waves are detectable by sensitive interferometry techniques e.g., such as an electron interferometer. Since the use of such instruments is quite rare, then indeed we have been living immersed in a sea of scalar waves without knowing it.

Finally, the percentage of scalar waves produced by changes in charged mass pileups can be increased by utilizing charged mass streaming. Essentially the charged masses must be moved suddenly, as quickly as possible, at or near the complete breakdown of the medium. For this reason, Tesla utilized sparkgaps in his early transmission systems, but also found that he could induce ionized media to "breakdown" in such fashion by a slow growth process. One of his early patented atmospheric wireless transmission systems is based on this fact. However, it was necessary to use a very high voltage, insuring extreme stress on the medium and hence some spillover stress onto time itself. In other words, ϕ_3 is always an approximation; at sufficiently high spatial stress, sufficient spillover ϕ_4 exists to give Tesla scalar waves. For this reason, Tesla used very high voltages and extremely sharp discharges to give "streaming" of the charged masses and thus high percentages of ϕ_4 waves. This suggests that the breakdown of dielectrics is a much richer phenomenon than is presently allowed for in the conventional theory.

To summarize, electrostatic potential -- ϕ-field is stress on the spacetime medium at a four-dimensional point. I. e. , it is a sort of pressure on the medium, but pressure on all four dimensions, not just on the three spatial dimensions. Thus in the new standard theory, ϕ_4 may have complex values. In addition, a ϕ-wave is to be interpreted as a scalar longitudinal wave in complex spacetime -- directly in ϕ_0, the normal average 4-space stress itself. And charge and charged mass must be recognized as two separate concepts. This is the gist of what I finally recognized about Nikola Tesla's work and fundamental discovery.

This is exciting, for it means that Tesla stress waves can affect either space or time individually, or both space and time simultaneously, or even oscillate back and forth between primarily affecting time and primarily affecting space, Tesla's waves were actually these ϕ-field scalar waves. As such, they were fundamentally different from ordinary electromagnetic waves, and had entirely different characteristics, just as Tesla often stated. E. g., a Tesla wave can either move spatially, with time flowing linearly; move temporally only (sitting at a point and waxing and waning in magnitude -- but changing the rate of flow of time itself in doing so, and affecting gravitational field, fundamental constants of nature, etc,), or move in a combination of the two modes. In the latter case, the Tesla wave moves in space with a very strange motion -- it oscillates between (1) spatially standing still and flexing time, and (2) moving smoothly in space while time flows smoothly and evenly. I.e., It stands at one point (or at one columnar region), flexing for a moment; then slowly picks up spatial velocity until it is moving smoothly through space; then slows down again to a "standing column," etc. This is Tesla's fabulous "standing columnar wave."

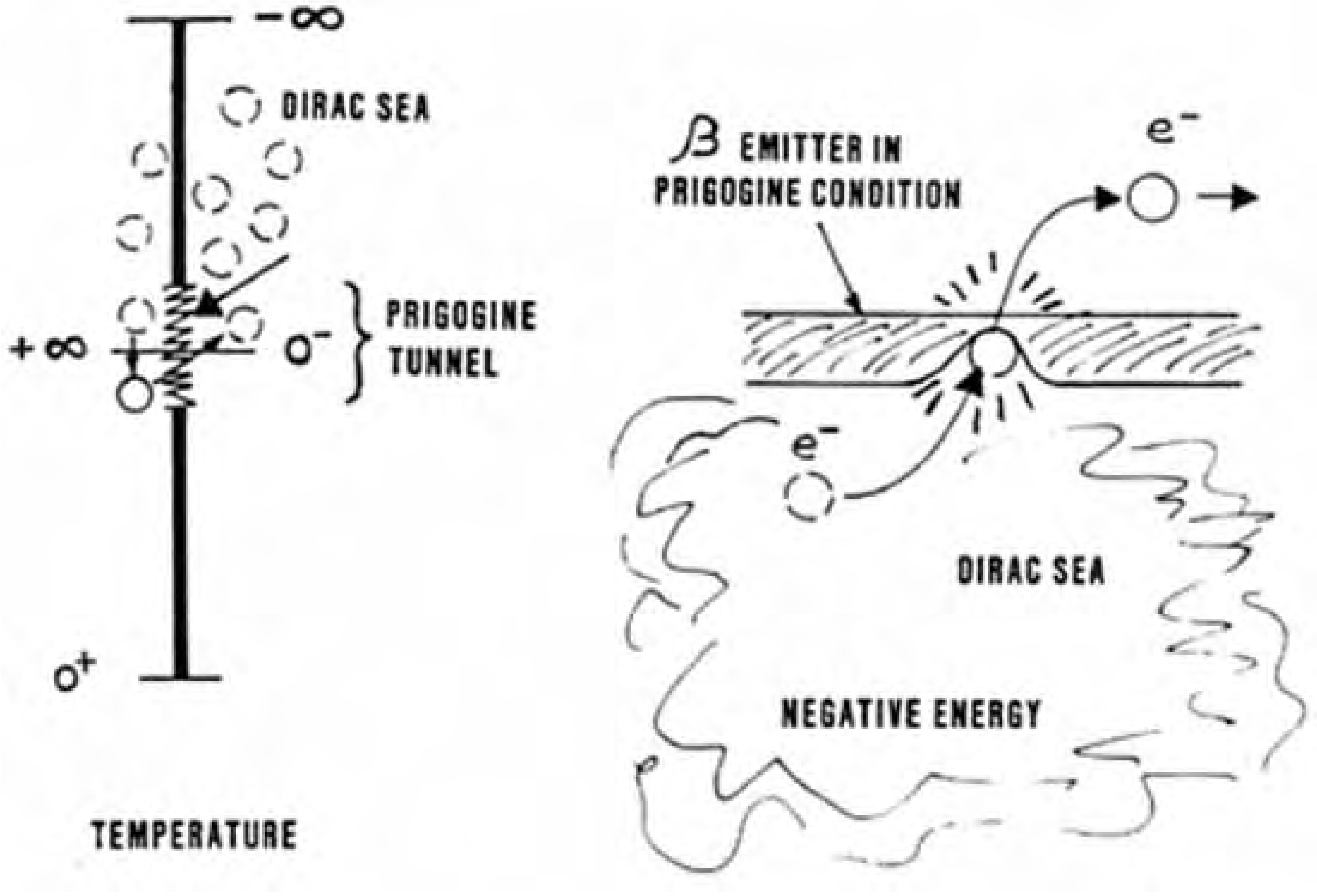
−∞
DIRAC SEA
+∞
0⁻
PRIGOGINE TUNNEL
0⁺
TEMPERATURE
β EMITTER IN PRIGOGINE CONDITION
e⁻
e⁻
DIRAC SEA
NEGATIVE ENERGY

Figure 4. Exoelectric Emission

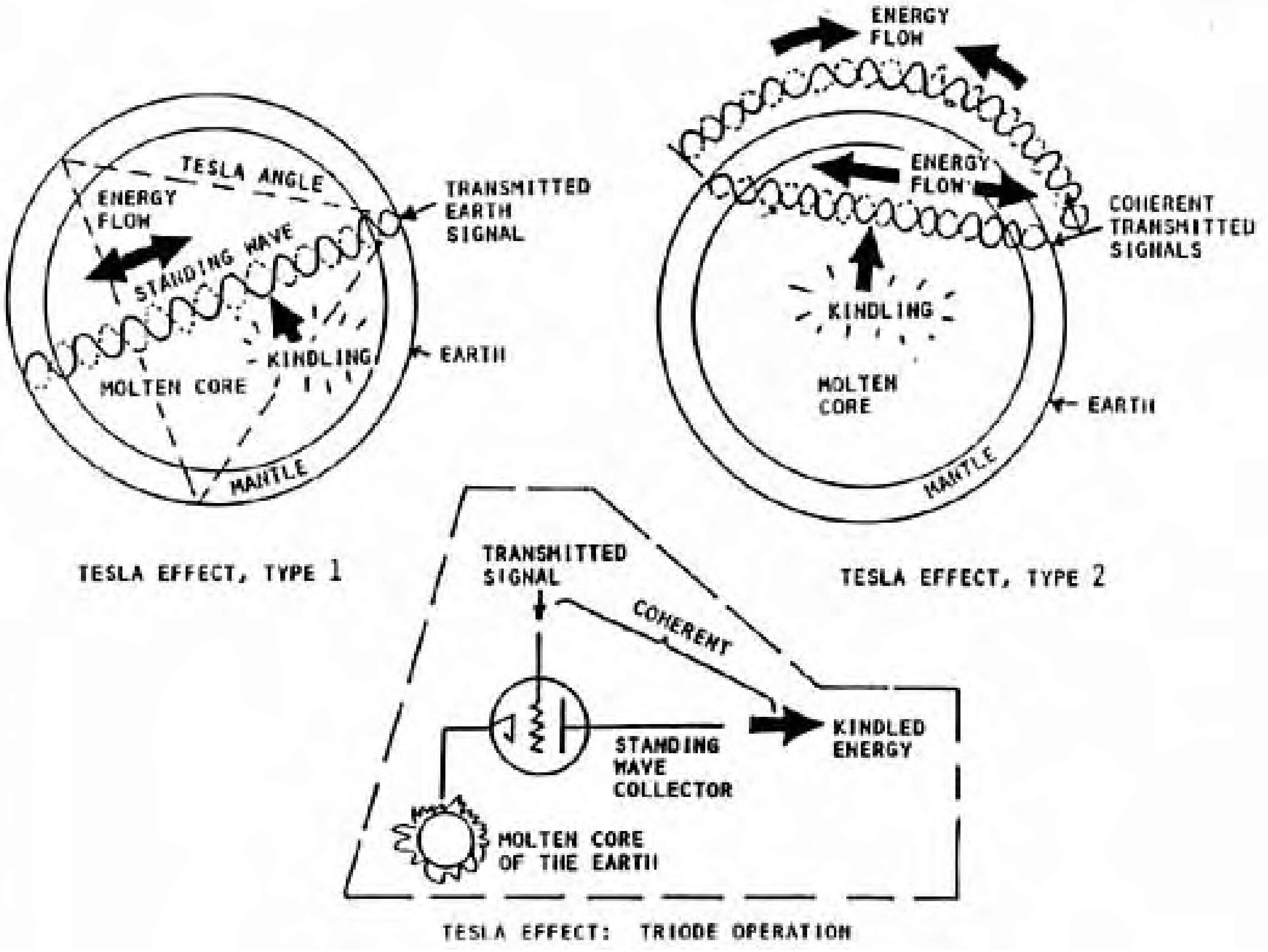
TESLA ANGLE
ENERGY FLOW
STANDING WAVE
TRANSMITTED EARTH SIGNAL
KINDLING
EARTH
MOLTEN CORE
MANTLE
TESLA EFFECT, TYPE 1
ENERGY FLOW
ENERGY FLOW
COHERENT TRANSMITTED SIGNALS
KINDLING
MOLTEN CORE
EARTH
MANTLE
TESLA EFFECT, TYPE 2
TRANSMITTED SIGNAL
COHERENT
KINDLED ENERGY
STANDING WAVE COLLECTOR
MOLTEN CORE OF THE EARTH
TESLA EFFECT: TRIODE OPERATION

Figure 5. The Tesla Effect

Another wild characteristic of the Tesla wave is that it can affect the rate of flow of time itself; hence it can affect or change every other field including the gravitational field -- that exists in time flow. It can also affect all universal constants, the mass of an object, the inertia of a body, and the mind and thoughts as well! All of these exist in the flow of time, and they are affected if the time stream in which they exist is affected. This was the awful secret that Tesla partially discovered by 1900, and which he came more and more to fully realize as he pursued its nature and its ramifications into the 1920's and 1930's.

Tesla also found he could set up standing ϕ-field waves through the earth. He in fact intended to do so, for he had also discovered that all charges in the highly stressed earth regions in which such a standing wave existed produced ϕ-fields which would feed (kindle) energy into the standing ϕ-field wave by pair coupling. I.e., normal vector field energy would "assemble" onto the scalar matrix wave by means of pair-coupling. Thus by transmitting a scalar standing wave into the earth, he could easily tap the fiery scalar fields produced in the molten core of the planet itself, turning them into ordinary electromagnetic energy. In such case, a single generator would enable anyone to put up a simple antenna and extract all the free energy desired.

When Tesla's alarmed financial backers discovered this was his real intent, they considered him a dangerous madman and found it necessary to ruthlessly stop him at all costs. And so his financial support was withdrawn, he was harassed in his more subtle patent efforts (and the patents themselves were adulterated), and his name gradually was removed from all the electrical textbooks. By 1914 Tesla, who had been the greatest inventor and scientist in the world, had become essentially a nonperson.

A few other persons in the early 1900's also were aware that potential and voltage are different. And some of them even learned to utilize Tesla's ϕ-field, even though they only vaguely understood they were utilizing a fundamentally different kind of electromagnetic wave. For example, James Harris Rogers patented an undersea and underground communications system which Tesla later confirmed utilized Tesla waves. The U.S. secretly used the Rogers communications system in World War I to communicate with U.S. submarines underwater, and to communicate through the earth to the American Expeditionary Force Headquarters in Europe. The Rogers system was declassified after the War and very shortly after that, it had mysteriously been scrubbed off the face of the earth. Again, potential stress waves -- Tesla waves -- were eliminated and "buried."

Probably the most brilliant inventor and researcher into Tesla's electromagnetics was T. Henry Moray of Salt Lake City, Utah. Dr. Moray actually succeeded in tapping the limitless zero-point energy of vacuum (spacetime) itself. By 1939, Dr. Moray's amplifier contained 29 stages and its output stage produced 50 kilowatts of power from vacuum. Interestingly, another 50 kilowatts could be tapped off any other stage in the device -- which consequently could have produced almost 1.5 megawatts of electrical power! Dr. Moray's epoch-making work was suppressed also. His device -- which represented over 20 years of heartbreaking accumulation of 29 working tubes from thousands made -- was destroyed by a Soviet agent in 1939, but not before the agent had obtained the drawings for building the tubes and the device itself. Today the Moray amplifier is a standard component of many of the Soviet secret superweapons and Tesla weapons.

In the 20's and 30's, Tesla announced the final perfection of his wireless transmission of energy without losses even to interplanetary distances. In several articles (e.g., H. Winfield Secor, "Tesla Maps Our Electrical Future, " Science and Invention, Vol. XVII, No.12, pp. 1077, 1124-1126), Tesla even revealed he used longitudinal stress waves in his wireless power transmission. Quoting from the article, "Tesla upholds the startling theory formulated by him long ago, that the radio transmitters as now used, do not emit Hertz waves, as commonly believed, but waves of sound." "He says that a Hertz wave would only be possible in a solid ether, but he has demonstrated already in 1897 that the ether is a gas, which can only transmit waves of sound; that is such as are propagated by alternate compressions and rarefactions of the medium in which transverse waves are absolutely impossible." The wily Tesla did not reveal, of course, that such scalar waves nearly always immediately pair-coupled into vector waves when produced by normal means. Tesla himself was working with longitudinal scalar waves.

Table 4. Rogers' Undersea and Underground Communication System

- **SECRETLY USED BY U.S. IN WWI**
- **COMMUNICATED TO SUBS UNDERWATER**
    - **- ANY DEPTH, UP TO 30 KHZ**
    - **- REDUCED DEPTH, >30 KHZ**
- **COMMUNICATED TO EXPEDITIONARY HQ OVERSEAS**
    - **- 5,000 TIMES STRONGER THAN AERIAL**
    - **- STATIC-FREE**
- **DECLASSIFIED IN 1919**
    - **- TO REVOLUTIONIZE COMMUNICATIONS**
    - **- TO END ALL SURFACE ANTENNAS**
- **MYSTERIOUSLY "LOST"**
- **REDISCOVERED AND "LOST" THREE TIMES AFTER WWII**

continued

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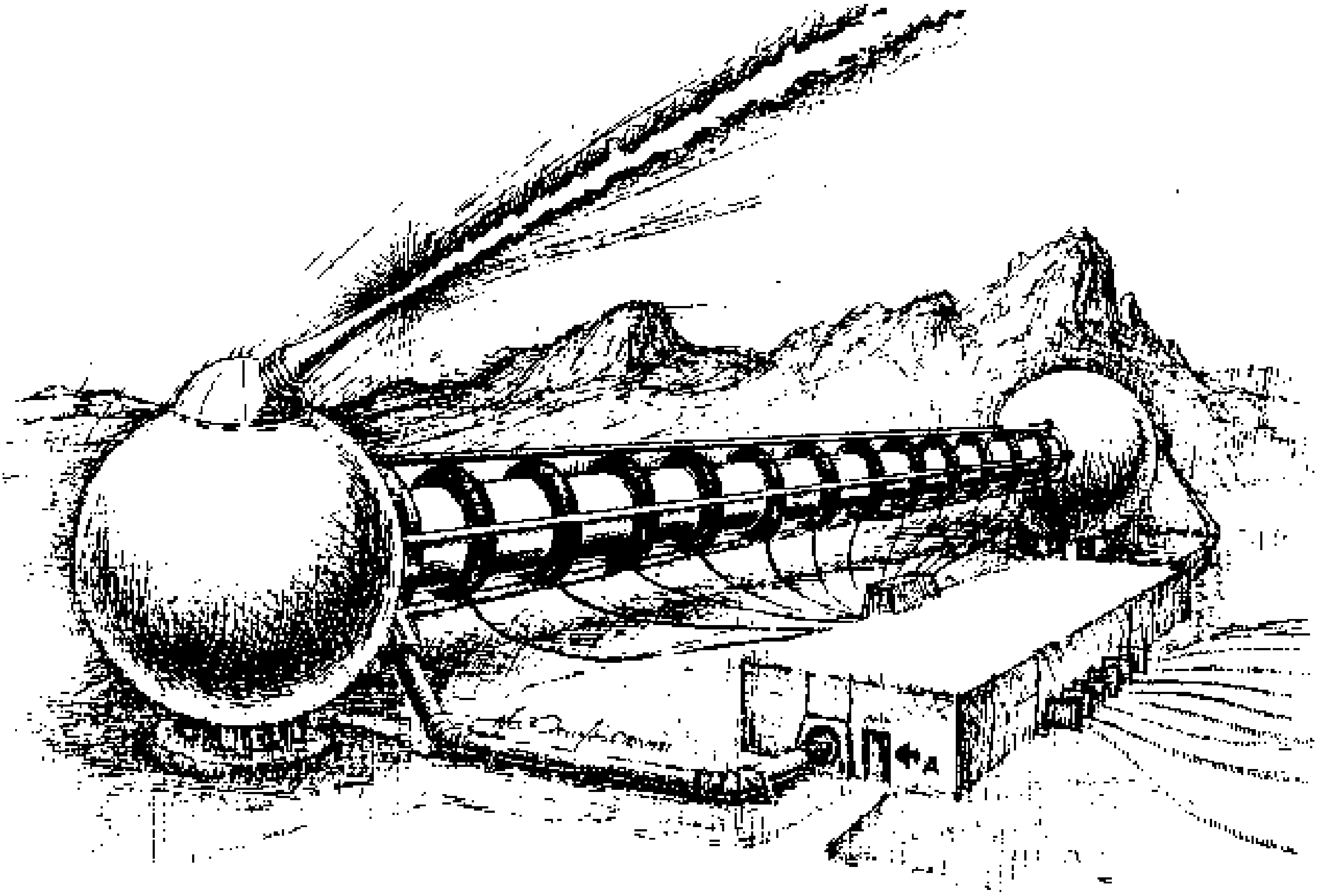

Scalar Potential Interferometer

Figure 6. Multimode Tesla Weapon

In the 1930's Tesla announced other bizarre and terrible weapons: a death ray, a weapon to destroy hundreds or even thousands of aircraft at hundreds of miles range, and his ultimate weapon to end all war -- the Tesla shield, which nothing could penetrate. However, by this time no one any longer paid any real attention to the forgotten great genius. Tesla died in 1943 without ever revealing the secret of these great weapons and inventions.

Unfortunately, today in 1981 the Soviet Union has long since discovered and weaponized the Tesla scalar wave effects. Here we only have time to detail the most powerful of these frightening Tesla weapons -- which Brezhnev undoubtedly was referring to in 1975 when the Soviet side at the SALT talks suddenly suggested limiting the development of new weapons "more frightening than the mind of man had imagined." One of these weapons is the Tesla howitzer recently completed at the Saryshagan missile range and presently considered to be either a high-energy laser or a particle beam weapon, (See Aviation Week & Space Technology, July 28, 1980, p. 48 for an artist's conception.)

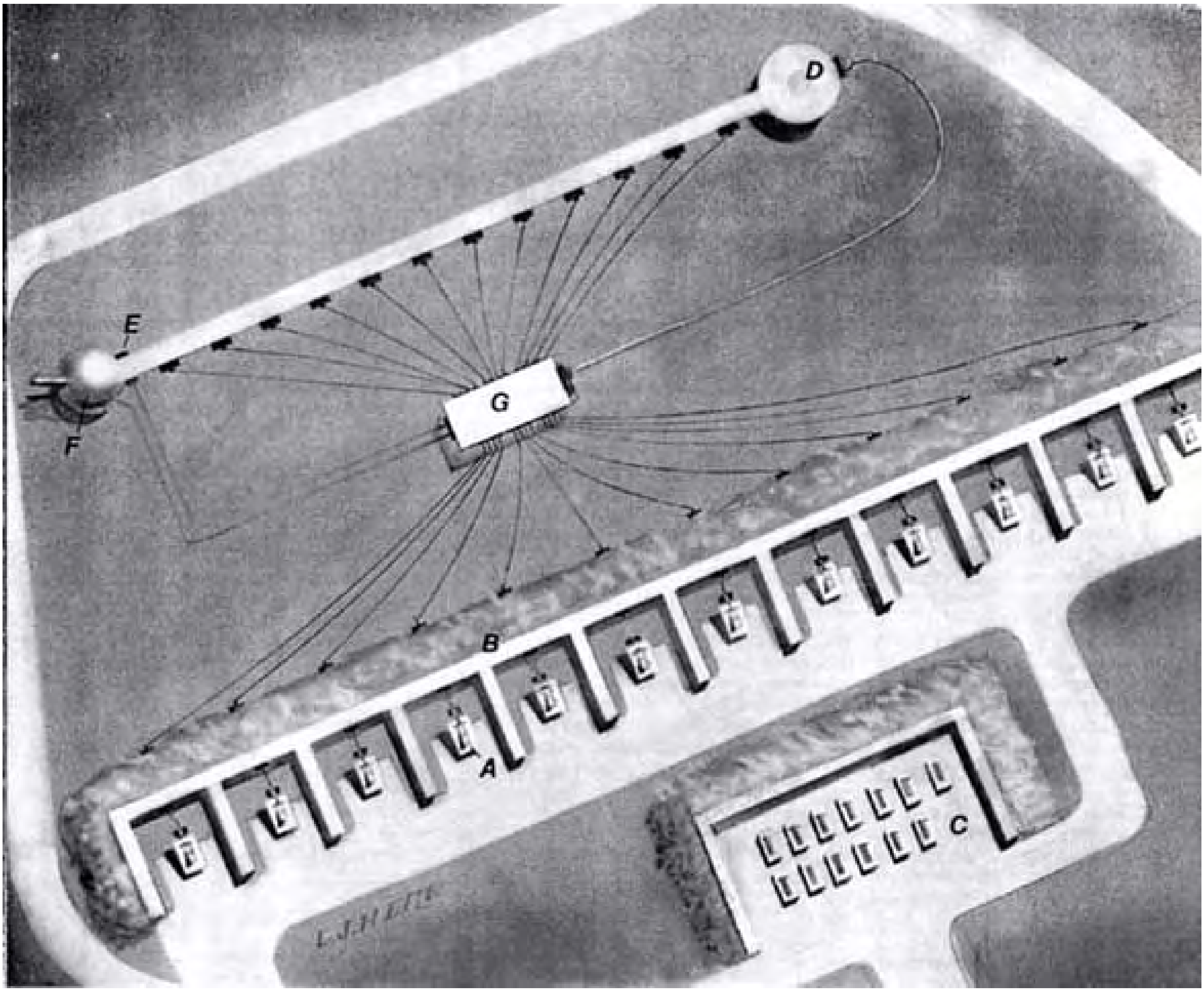

Aviation Week & Space Technology July 28, 1980

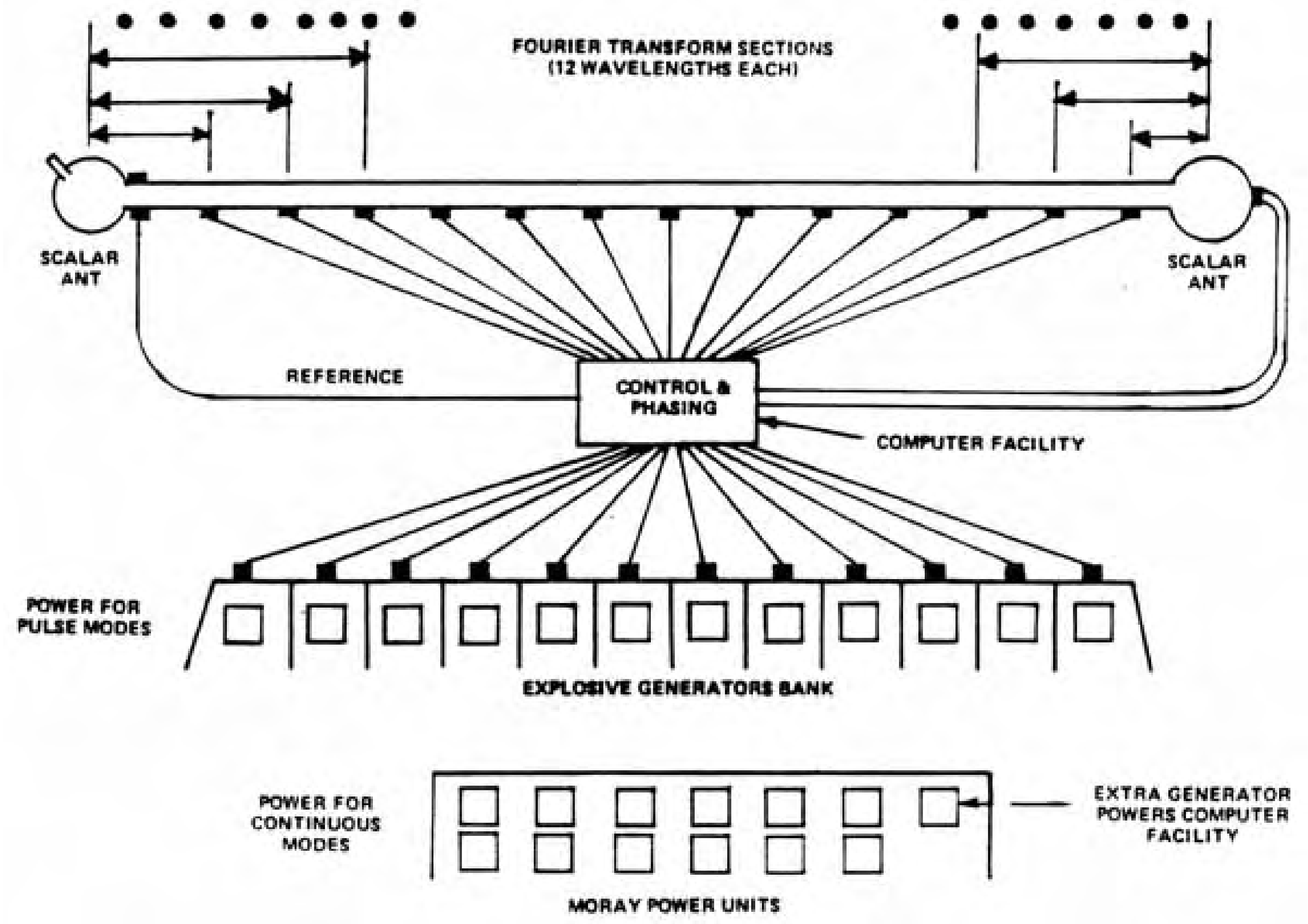
FOURIER TRANSFORM SECTIONS
(12 WAVELENGTHS EACH)
SCALAR ANT
SCALAR ANT
REFERENCE
CONTROL & PHASING
COMPUTER FACILITY
POWER FOR PULSE MODES
EXPLOSIVE GENERATORS BANK
POWER FOR CONTINUOUS MODES
EXTRA GENERATOR POWERS COMPUTER FACILITY
MORAY POWER UNITS

Figure 7. Tesla Weapons at Saryshagan

The Saryshagan howitzer actually is a huge Tesla scalar interferometer with four modes of operation. One continuous mode is the Tesla shield, which places a thin, impenetrable hemispherical shell of energy over a large defended area. The 3-dimensional shell is created by interfering two Fourier-expansion, 3-dimensional scalar hemispherical patterns in space so they pair-couple into a dome-like shell of intense, ordinary electromagnetic energy. The air molecules and atoms in the shell are totally ionized and thus highly excited, giving off intense, glowing light. Anything physical which hits the shell receives an enormous discharge of electrical energy and is instantly vaporized -- it goes pfft! like a bug hitting one of the electrical bug killers now so much in vogue.

If several of these hemispherical shells are concentrically stacked, even the gamma radiation and EMP from a high altitude nuclear explosion above the stack cannot penetrate all the shells due to repetitive absorption and reradiation, and scattering in the layered plasmas.

In the continuous shield mode, the Tesla interferometer is fed by a bank of Moray free energy generators, so that enormous energy is available in the shield. A diagram of the Saryshagan-type Tesla howitzer is shown in figure 7. Hal Crawford's fine drawing of the interferometer end of the Tesla howitzer is shown in figure 6. Hal's exceptional rendition of the Tesla shield produced by the howitzer is shown in figure 8.

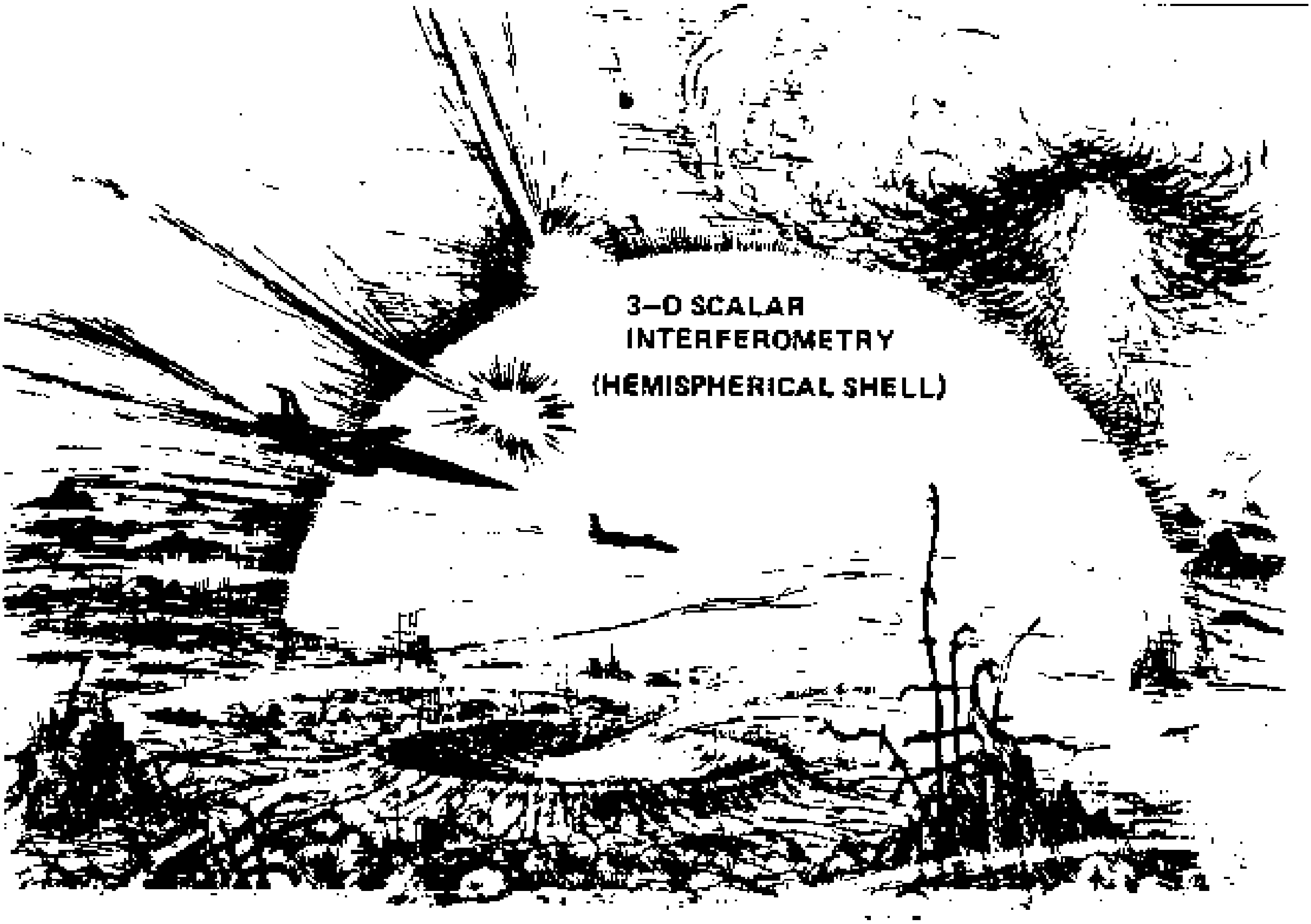
3–D SCALAR
INTERFEROMETRY
(HEMISPHERICAL SHELL)

Figure 8. The Tesla Shield

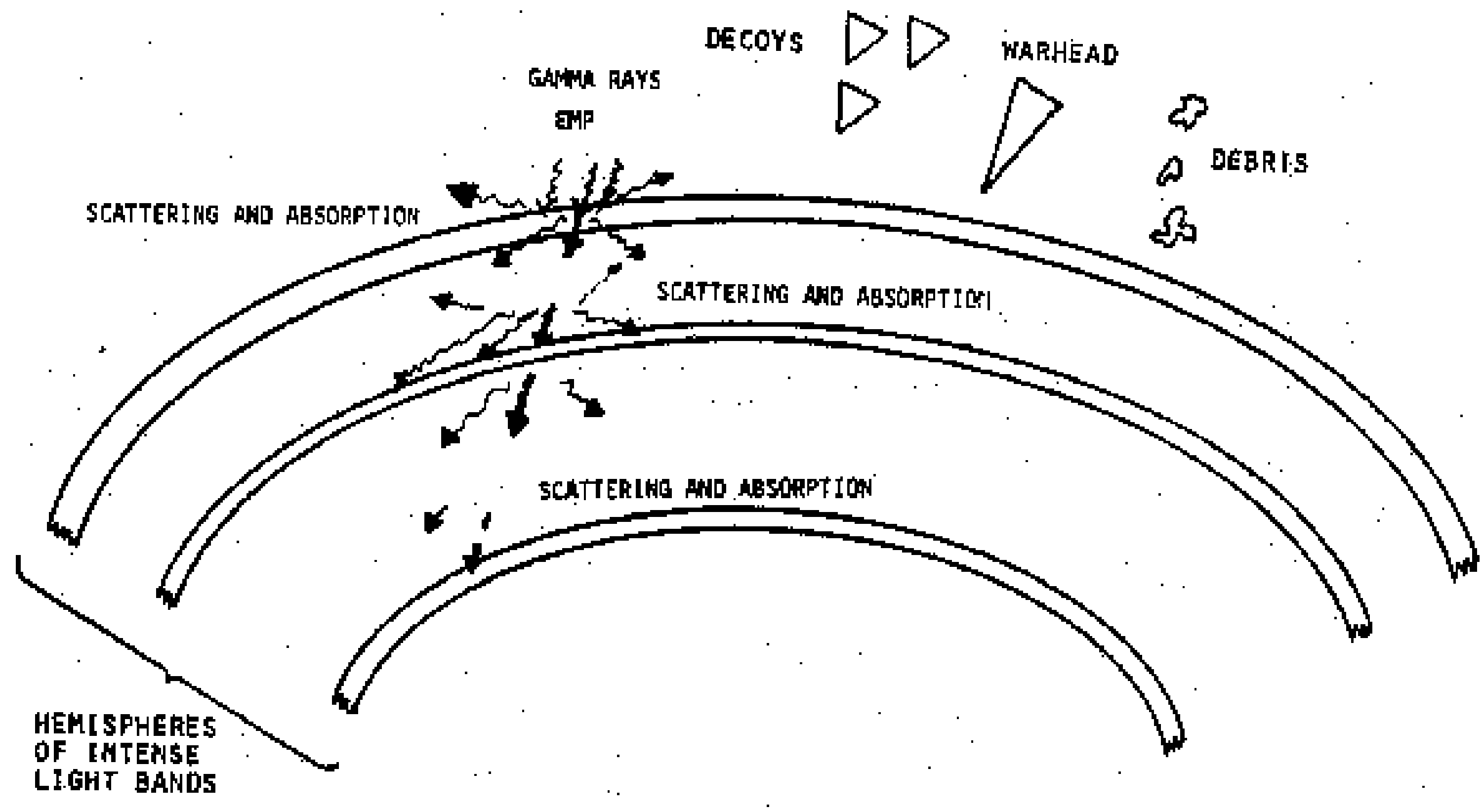
DECOYS
WARHEAD
GAMMA RAYS
EMP
DEBRIS
SCATTERING AND ABSORPTION
SCATTERING AND ABSORPTION
SCATTERING AND ABSORPTION
HEMISPHERES
OF INTENSE
LIGHT BANDS

Figure 9. Tesla Terminal Area Defense System

In the pulse mode, a single intense 3-dimensional scalar phi-field pulse form is fired, using two truncated Fourier transforms, each involving several frequencies, to provide the proper 3-dimensional shape (Figure 10). This is why two scalar antennas separated by a baseline are required. After a time delay calculated for the particular target, a second and faster pulse form of the same shape is fired from the interferometer antennas. The second pulse overtakes the first, catching it over the target zone and pair-coupling with it to instantly form a violent EMP of ordinary vector (Hertzian) electromagnetic energy. There is thus no vector transmission loss between the howitzer and the burst. Further, the coupling time is extremely short, and the energy will appear sharply in an "electromagnetic pulse (EMP)" strikingly similar to the 2-pulsed EMP of a nuclear weapon.

This type weapon is what actually caused the mysterious flashes off the southwest coast of Africa, picked up in 1979 and 1980 by Vela satellites. The second flash, e.g., was in the infrared only, with no visible spectrum. Nuclear flashes do not do that, and neither does superlightning, meteorite strikes, meteors, etc. In addition, one of the scientists at the Arecibo Ionospheric Observatory observed a gravitational wave disturbance -- signature of the truncated Fourier pattern and the time-squeezing effect of the Tesla potential wave -- traveling toward the vicinity of the explosion.

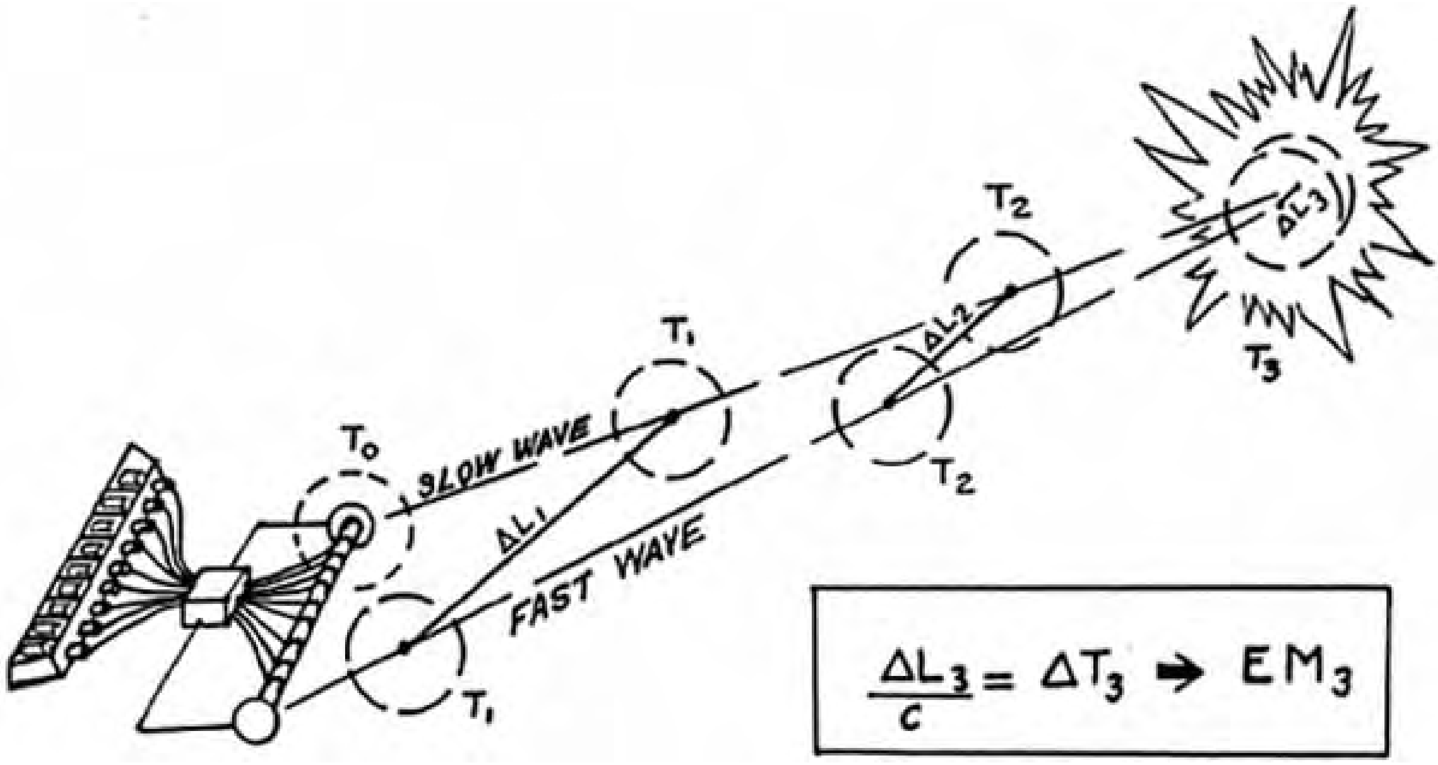
T₀
SLOW WAVE
T₁
ΔL1
FAST WAVE
T₁
T₁
T₂
ΔL2
T₂
ΔL3
T₃
$\frac{\Delta L_3}{c} = \Delta T_3 \rightarrow EM_3$

TESLA HOWITZER
(SCALAR INTERFEROMETER)

Figure 10. "Nuclear" Flashes off the Coast of Africa

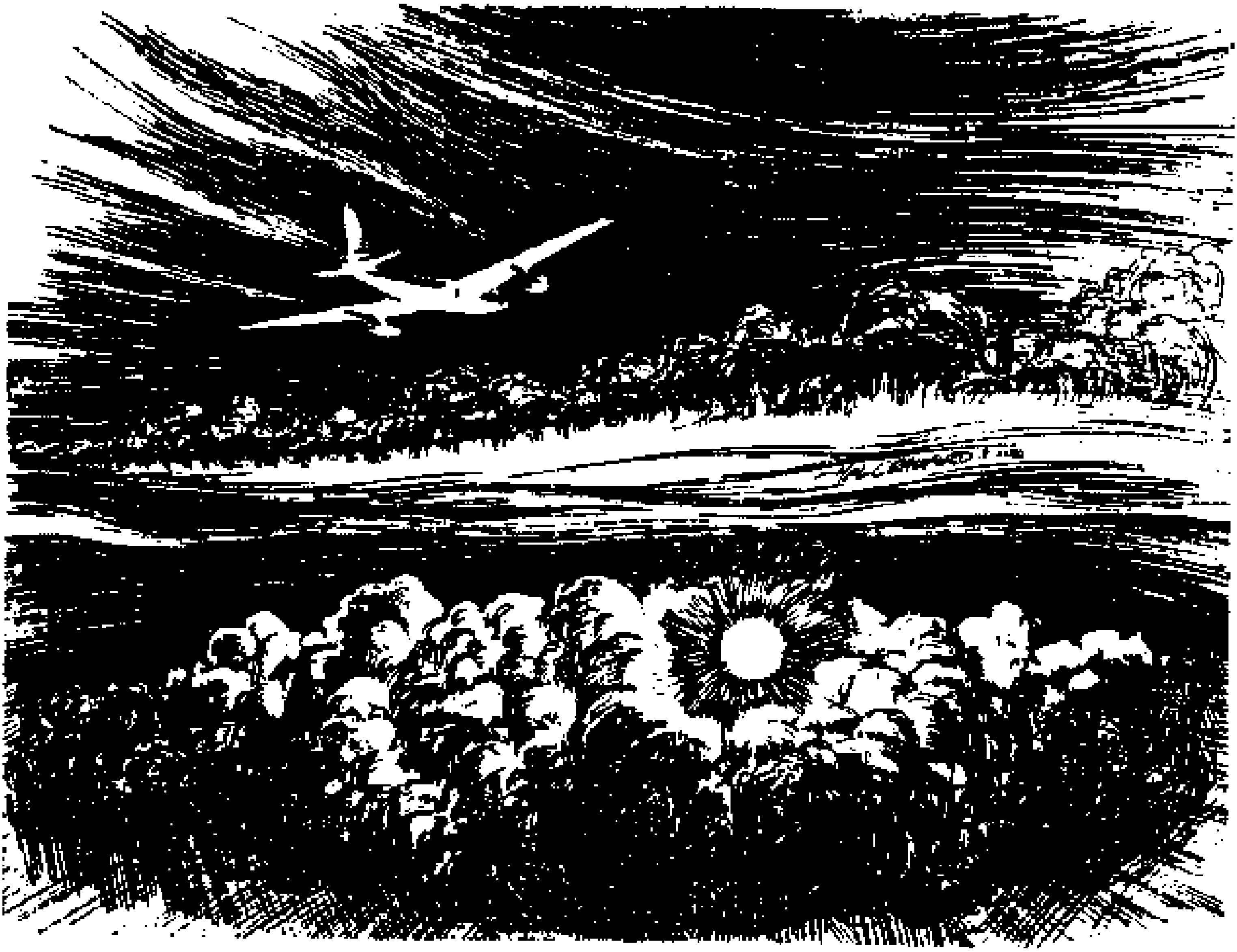

Lithuania - 10 Sep 1976 - British European Airways Flight #831 between Moscow and London

CIA Report Released under FOIA

Figure 11. Continuous Tesla Fireball

The pulse mode may be fed from either Moray generators or -- if the Moray generators have suffered their anomalous "all fail" malfunction -- ordinary explosive generators. Thus the Tesla howitzer can always function in the pulse mode, but it will be limited in power if the Moray generators fail.

In the continuous mode, two continuous scalar waves are emitted -- one faster than the other -- and they pair-couple into vector energy at the region where they approach an in-phase condition. In this mode, the energy in the distant "ball" or geometric region would appear continuously and be sustained -- and this is Tesla's secret of wireless transmission of energy at a distance without any losses. It is also the secret of a "continuous fireball" weapon capable of destroying hundreds of aircraft or missiles at a distance. An example of a Soviet test of this mode of operation is shown in figure 11.

Witness to a super weapon?

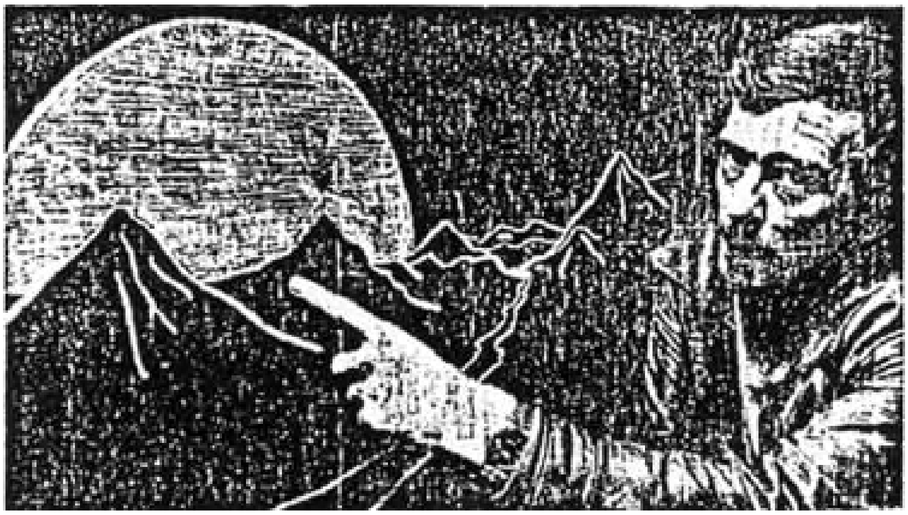

Nick Downie describes the strange lurid glow that flared silently over the Hindu Kush

THE SUNDAY TIMES, 17 AUGUST 1980

(Multiple incidents in Sept., 1979)

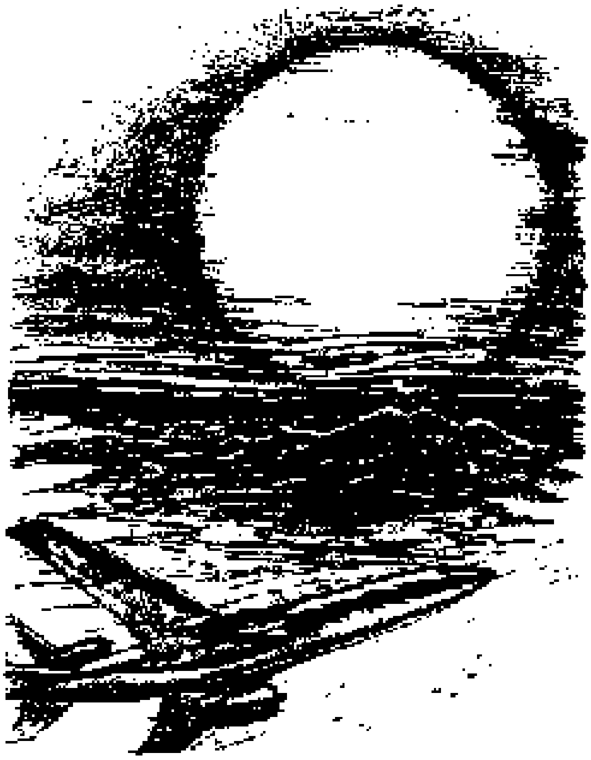

TEHERAN, IRAN 17 JUNE 1966

SEEN FROM NEAR MEHRABAD AIRPORT

OBSERVED 4-5 MINUTES

SEEN BY 2 AIRCRAFT

CIA REPORT RELEASED UNDER FOIA

Figure 12. Tesla EMP Globe

The volume of the Tesla fireball can be vastly expanded to yield a globe which will not vaporize physical vehicles but will deliver an EMP to them to dud their electronics. A test of this mode is shown in figure 12. (See also Gwynne Roberts, "Witness to a Super Weapon?", the London Sunday Times, 17 August 1980 for several other tests of this mode at Saryshagan, seen from Afghanistan by British TV cameraman and former War Correspondent Nick Downie.)

If the Moray generators fail anomalously, then a continuous mode limited in power and range could conceivably be sustained by powering the interferometer from more conventional power-sources such as advanced magnetohydrodynamic generators.

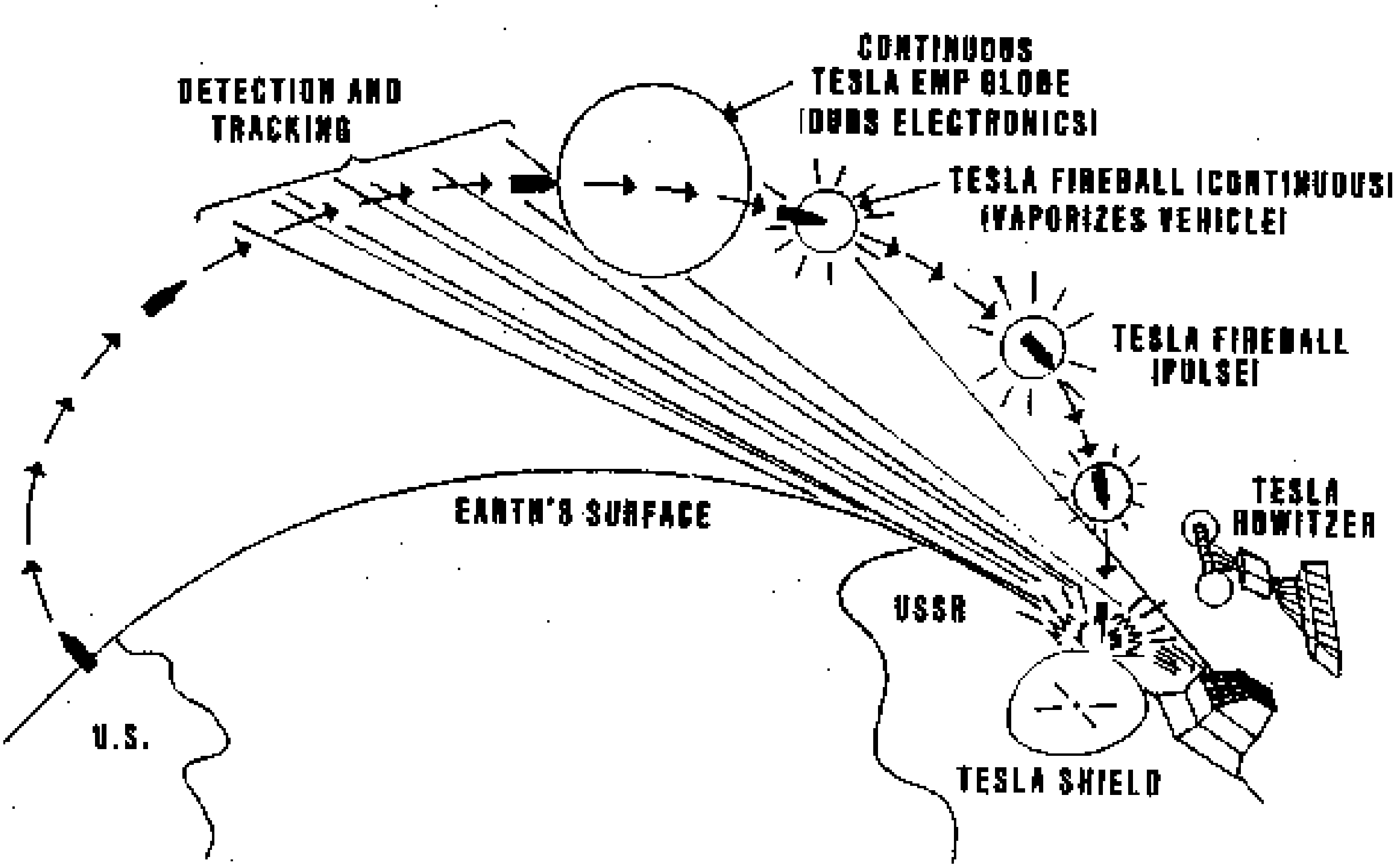
DETECTION AND
TRACKING
CONTINUOUS
TESLA EMP GLOBE
(DUDS ELECTRONICS)
TESLA FIREBALL (CONTINUOUS)
(VAPORIZES VEHICLE)
TESLA FIREBALL
(PULSE)
TESLA
HOWITZER
EARTH'S SURFACE
USSR
U.S.
TESLA SHIELD

Figure 13. Tesla ABM Defenses

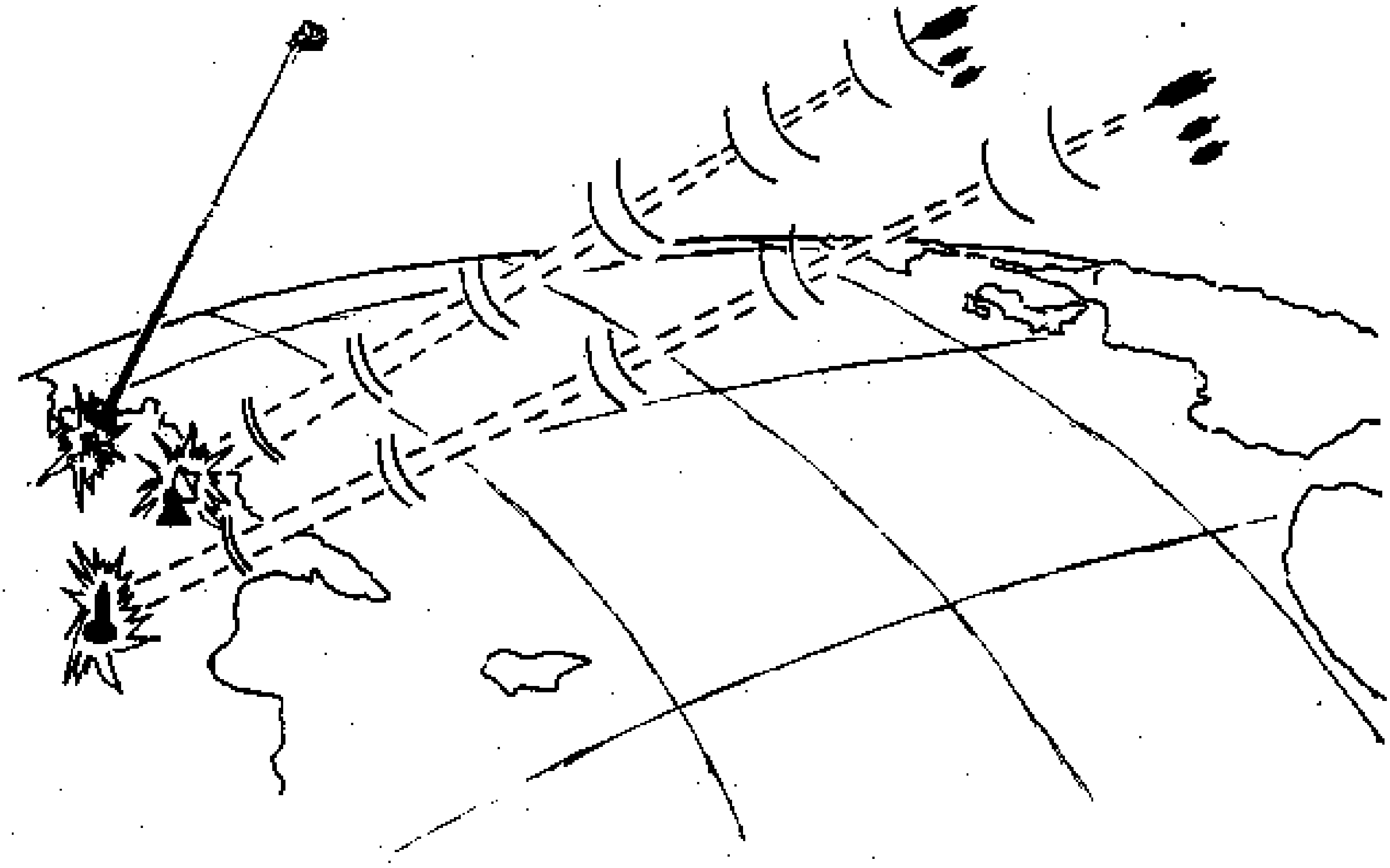

Figure 14. Moray/Tesla Technology: Star Wars Now

Typical strategic ABM uses of Tesla weapons are shown in figure 13. In addition, of course, smaller Tesla howitzer systems for anti-tactical ballistic missile defense of tactical troops and installations could be constituted of more conventional field missile systems using paired or triplet radars, of conventional external appearance, in a scalar interferometer mode.

With Moray generators as power sources and multiply deployed reentry vehicles with scalar antennas and transmitters, ICBM reentry systems now can become long range "blasters" of the target areas, from thousands of kilometers distance (figure 14). Literally, "Star Wars" is liberated by the Tesla technology. And in air attack, jammers and ECM aircraft now become "Tesla blasters." With the Tesla technology, emitters become primary fighting components of stunning power.

The potential peaceful implications of Tesla waves are also enormous. By utilizing the "time squeeze" effect, one can get antigravity, materialization and dematerialization, transmutation, and mindboggling medical benefits. One can also get subluminal and superluminal communication, see through the earth and through the ocean, etc. The new view of phi-field also provides a unified field theory, higher orders of reality, and a new super-relativity, but detailing these possibilities must wait for another book.

With two cerebral brain halves, the human being also has a Tesla scalar interferometer between his ears. And since the brain and nervous system processes avalanche discharges, it can produce (and detect) scalar Tesla waves to at least a limited degree. Thus a human can sometimes produce anomalous spatiotemporal effects at a distance and through time. This provides an exact mechanism for psychokinesis, levitation, psychic healing, telepathy, precognition, postcognition, remote viewing, etc. It also provides a reason why an individual can detect a "stick" on a radionics or Hieronymus machine (which processes scalar waves), when ordinary detectors detect nothing. Unfortunately there is not room to develop the implications of this human Tesla interferometry in detail, for that must wait for yet another book, presently in its initial stages, that Hal Crawford and I are writing.

Table 5. Orders of Reality

- **PHOTONS ARE**
  - **> PAIR-COUPLED SCALARS**
  - **> VELOCITY-LIMITED TO C**
  - **> CARRIERS OF T**

- **PHOTON INTERACTION**
  - **> IS UBIQUITOUS**
  - **> PRODUCES $\dot{T}$ = C**
  - **> YIELDS 1st ORDER REALITY**

- **SCALAR O WAVES**
  - **> NOT VELOCITY-LIMITED**
  - **> YIELD HIGHER ORDER REALITIES**

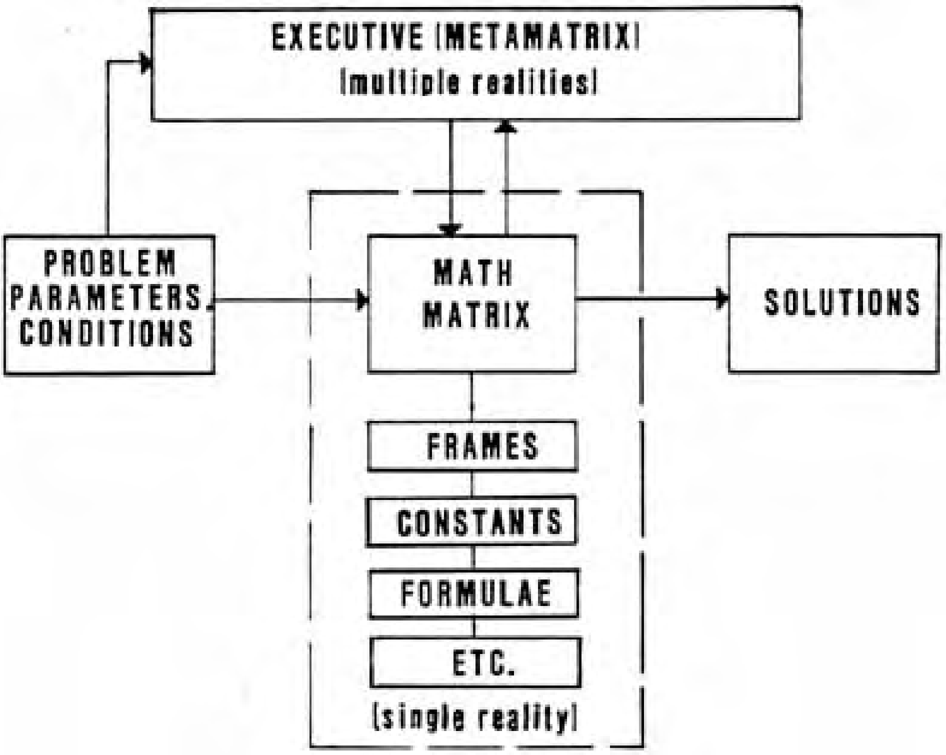
EXECUTIVE (METAMATRIX)
(multiple realities)
PROBLEM PARAMETERS, CONDITIONS
MATH MATRIX
SOLUTIONS
FRAMES
CONSTANTS
FORMULAE
ETC.
(single reality)

Figure 15. Implications of Tesla Potential

At the July 1981 U.S. Psychotronics Association's Annual Conference in Dayton, Ohio, I presented the first rough paper on the Tesla secret and scalar interferometry. A videotape of the presentation was made and will shortly be available. I am also scheduled to make a special presentation at the Alternate Energy Conference in Toronto, Canada in latter October, 1981. A professional, videotaped two-hour presentation on this subject is also being prepared. Wide distribution of the material through the international underground physics and technology network has already been made. This time, God willing, Tesla's secret will not be suppressed for another 80 years!

And perhaps it is not yet too late. The material has cost me (now) some 16 years of agonizing labor and nearly $100,000 of my own personal funds. No orthodox university, scientific group, foundation, or governmental agency would support such an effort, either financially or otherwise. Indeed, most ordinary journals will not even accept material on such matters. Nonetheless, the area is of overwhelming importance and I truly believe Tesla's lost secret will shortly affect the lives of every human being on earth.

Perhaps with the free and open release of Tesla's secret, the scientific and governmental bureaucracies will be. shocked awake from their slumber, and we can develop defenses before Armageddon occurs. Perhaps there is hope after all -- for even Brezhnev, in his strange July, 1975 proposal to the SALT talks, seemed to reveal a perception that a turning point in war and weaponry may have been reached, and that human imagination is incapable of dealing with the ability to totally engineer reality itself. Having tested the weapons, the Soviets must be aware that the ill-provoked oscillation of timeflow affects the minds and thoughts -- and the very lifestreams and even the collective species unconsciousnesses -- of all lifeforms on earth. They must know that these weapons are two-edged swords, and that the backlash from their use can be far more terrible to the user than was the original effect to his victim.

If we can avoid the Apocalypse, the fantastic secret of Nikola Tesla can be employed to cure and elevate man, not kill him. Tesla's discovery can eventually remove every conceivable external human limitation. If we humans ourselves can elevate our consciousness to properly utilize the Tesla electromagnetics, then Nikola Tesla -- who gave us the electrical twentieth century in the first place -- may yet give us a fantastic new future more shining and glorious than all the great scientists and sages have imagined.

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The Tom Bearden
Website

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Persinger's "earthquake light" scheme for explaining UFO's. Mentions Dr. Brian Brady's experiments obtaining fast, short electrical lights or sparks from crushing quartz-bearing granite cylinders. (Comment: Brady's experiments are certainly repeatable, so it is true that "earthstress lights" can be produced at a distance, although the piezoelectric effect alone in no way explains the production of the phenomena outside the piezoelectric crystal. The fact that UFO's occurring near a fault zone are not necessarily repeatable simply means that at least one other major factor must be involved in the production of UFOs than is involved in the production of earthstress lights. UFOs may sometimes involve scalar interferometry from a fault zone, but other causative factors must also be involved. Earthstress lights, on the other hand, need have no additional causative factors than what lies in the earth itself.)

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by

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TOWARD A NEW ELECTROMAGNETICS

Part III: Clarifying the Vector Concept

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-- IMPLICATIONS --

Some of the fundamental concepts of the new Tesla electromagnetics are presented. The new concepts have startling implications:

(1) No force or force field exists as such in vacuum.

(2) Hertzian (transverse) electromagnetic waves do not travel through the vacuum, just as Tesla stated.

(3) Forceless, massless Tesla (scalar) longitudinal waves actually transit the vacuum. Tesla called them "electrical sound waves."

(4) At present there are actually four different FUNDAMENTAL TYPES of vectorial entities in physics, erroneously confused as one and the same.

(5) Tesla longitudinal scalar waves are also "time" waves and can affect anything and everything that exists in time.

(6) The fundamental constants of nature (which exist in time) can be altered by Tesla scalar waves, which oscillate the values of the constants.

(7) Every vector and scalar has an internal substructure, which can be independently affected and changed. This allows the direct engineering of the virtual state and the vacuum itself.

(8) All observable forces (electrical, mechanical, gravitational, etc.) arise in, on, and OF the actual substructure of the "accelerating mass particle" itself, not as an "external" massless force or force field applied "to" a mass .

(9) Physical reality itself -- and the "physical laws of nature"

can be deliberately changed and engineered.

(10) All "physical reality" is totally internal to the physical changes of the mass particles of the detector system of the observer.

(11) Relativity's speed of light limitation applies only to the changes of the basic mass particles of the detecting instrument.

(12) Detection of superluminal effects cannot be accomplished by a "single stage" or "single shift " (single interaction) detector .

(13) Detection of superluminal effects is permitted by "multiple stage" or "multiple shift" interactions where the last interaction is a conventional interaction of photon vs. detector particle. (The two-slit apparatus for detection of electron diffraction is an example. First, the superluminal DeBroglie waves interact with the slits, which are "tuned" toward the electron's DeBroglie wavelength. The interaction with TWO slits produces subluminal interference effects, which then interact back upon the physical electron. The apparatus is thus an electron interferometer capable of detecting superluminal waves by a two-stage interaction).

(14) Interference is the most common first-stage superluminal interaction to accomplish "downshifting" superluminal entities to luminal or subluminal velocities. Superposition of superluminal "phase" waves (such as deBroglie waves, which individually always move faster than the speed of light) interferes the waves to create a subluminal group velocity, which may then interact with an ordinary mass particle in the detection system.

(15) Any otherwise physical vector must exist as an unzipped (segmented) or "shadow" vector in vacuum. "Radiation" of a vector EM wave from the electron gas in an antenna into vacuum results in the "choking off" of the mass of the transversely oscillating electrons in the antenna. Since the spinning electron mass is the "zipper" that makes or comprises the physical vector in the first place, this throttling of the mass flow unzips the E and B vectors, leaving whirling (massless magnetic scalar potential) segments of massless charge flux (massless electrostatic scalar potential). This unzipped whirling pattern of charge flux (scalar massless A/Ø) is what radiates into vacuum and propagates through it. This is a special kind of

scalar wave pattern, not a physical or vector wave.

(16) The spin of a charged particle is the mechanism for integrating or "zipping together" the individual virtual fragments of a shadow vector into a real (observable) vector. For "uncharged particles" such as neutrons, it is the spins of its virtual charged components. that accomplish the integration or zipping.

(17) All fundamental charged particles are constantly accelerated. There is no such thing as an "unaccelerated" particle, except as a gross average over time or length. Further, all of them are spinning.

(18) All changes to and from a physical vector or scalar system must arise in and come from its own internal substructure, which is zipped to its spinning particle of mass.

(19) All fundamental particles are charged internally. That is, they are dynamic assemblages of smaller charged particles. If the average sum of the total internal charge is essentially zero over some finite, small increment of time, the particle is externally uncharged. If the sum is not essentially zero, the particle is also externally charged.

(20) There are no static physical things in existence. In physical reality, something appears "static" only at a particular level. Upon sufficiently fine examination, it is composed of accelerating parts, and thus comprised of "fluctuations."

(21) Since (a) the basic physical (mass) vector consists of a "smeared particle," where particle and smear are inseparable, (b) the conceptual particle also is accelerated, and (c) the "smearing" is for a small increment of time and a small increment of length; then the basic constituency of "physical reality" is inseparable "force x time x length," or action. The basic "quantum" of physical change is thus comprised of action.

(22) Since to "detect" we must "stop" the action, separate or split the quantum into two pieces ("canonical" pieces) , and compare (measure) one piece by throwing away the other, then each physical observable must have a differential operator (the "separating agent") corresponding to it. This accounts for the fundamental postulate of quantum mechanics whereby every observable has a corresponding operator. Further, since what remains is totally relative to what was split out and thrown away, physical change

is totally "relative." This accounts for the fact that observed reality is relative, each part to each other.

(23) As a special case, we may assume that we can evaluate a physical change at a point (without length). If so, when we discard length, the remaining basic vector is momentum. This approximation holds only so long as the system to which it is applied essentially does not change over the quantal fragment of length discarded -- i.e., it holds for the linear case. Conservation of momentum, then, is violated when sufficient nonlinearity in length is present.

(24) As a second special case, we may assume that we can evaluate a physical change in a spatial manner (without time). If so, when we discard time, the remaining basic vector is energy (has the units of energy or work). This approximation holds only so long as the system to which it is applied essentially does not change over the quantal fragment of time discarded -- i.e., it holds for the linear case. Conservation of energy, then, is violated when sufficient nonlinearity in time is present. Since a "virtual change" a priori is defined as a total nonlinearity in the observer's quantal time increment but not outside it, then virtual interactions can and do violate conservation of energy within that time increment, but not out of it -- so long as the time interval itself is considered linear. If the time interval is sufficiently nonlinear, then the virtual change may result in violation of the conservation of energy externally to the time increment. In that case, an "observable change" results .

(25) As a third special case, we may assume that we can evaluate the "instantaneous value" of a physical change at a static point in space. To do so, we must discard both time (to be instantaneous) and length (to be at a spatial point), and the remaining basic vector is force. This approximation holds only so long as the system to which it is applied essentially does not change over the quantal fragment of time or the quantal fragment of length discarded. Conservation of force, then, is violated when sufficient nonlinearity in time or length is present.

(26) A new conservation of energy law is required, one which unites the present conservation of energy law with an altered form of the conservation of charge law. Briefly, the total equivalent of mass,

observable energy, and massless charge (anenergy) is conserved.

(27) All AL and At fragments are produced and destroyed one at a time, in the action fissioning of a single quantum of action (detection process). Each ∇L and ∇t is discretized but not quantized. Since quanta do not superpose, the "external universe" is continually created and destroyed in the detector's mass system, one quantum at a time, at a very high rate. This interpretation gives physical meaning to the creation and annihilation operators of quantum mechanics.

(28) Since the detecting mass system is itself continually created and destroyed one quantum at a time, ultimately all is mind changes, and only mind changes. The observer's life, mind, and being transcend all materialistic interpretations of reality -- as indeed does the very fact of the "existence" of a perceived external universe.

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TOWARD A NEW ELECTROMAGNETICS
PART III: CLARIFYING THE VECTOR CONCEPT

-- Electrical Physics Presently Has a Mindset --

In examining the foundations of geometry, mechanics, and electromagnetics, it becomes strikingly clear that substantial -- even grave theoretical errors were made early on and perpetuated into the existing theory. These errors are now so firmly entrenched that they form a part of the "mindset" of almost all physicists, engineers, and scientists.

So ingrained are these errors and inconsistencies that the orthodox scientist/theoretician finds it almost impossible to break out of them.

The present mindset is analogous to the Newtonian mindset which so fiercely resisted the new ideas of relativity, shortly after the turn of the century. However, after a few scientists formulated the rules and theory of the "relativity mathematics game," a new generation of students, not yet so firmly engrained in the Newtonian mindset, could grasp the new relativity when their teachers expounded it.

In this short series of papers[1],[2] I will roughly outline where the founders of mechanics and electromagnetics went wrong, and indicate the way to correct the fundamental errors. In addition, I will briefly point out some of the implications, and speak of some direct experimental proof.

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PART III: CLARIFYING THE VECTOR CONCEPT

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2. Bearden, T. E., "Solutions to Tesla's Secrets and the Soviet Tesla Weapons," Tesla Book Co., 1981. Also Ratzlaff , John T., "Reference Articles for Solutions to Tesla's Secrets," Tesla Book Co., 1982.

3. Note we are applying the rule, "A thing is that which it does, and it does that which it is." Actually this is one statement of a fourth fundamental law of logic not incorporated by Aristotle. See Bearden, "A Conditional Criterion for Identity, Leading to a Fourth Law of Logic," DTIS report, available through the National Technical Information System, Port Royal Road, Springfield, VA 22161.

4. Specifically, the resulting theory becomes a curtailed, special case of the much more fundamental electrodynamics and electromagnetics that actually exist .

5. We point out here that measuring a field of force existing in the electron gas in a probe of the measuring instrument is not at all the same thing as measuring a force in the vacuum, nor does it establish that a force exists in vacuum. Indeed, it is already well known that the FIELD concept itself will not withstand rigorous logical examination. For a discussion rather clearly showing the present difficulty in defining a field, see Robert Bruce Lindsay and Henry Margenau, Foundations of Physics, Dover Publications, New York, 1963, pp. 283-287. Note particularly on p. 283 that a "field of force" at any point is actually DEFINED only for the case when a unit mass is present at that point. It is then illogically ASSUMED that the force

continues to exist at the point in the ABSENCE of the mass, which of course need not follow at all. On p. 284, note the similar logical paradox connected with the idea of a scalar gravitational potential field. The potential (field) is only defined at a point when mass is present at that point, .and it is specifically defined as the potential energy per unit mass for a particle present at that point. IF THERE IS NO MASS PRESENT, NEITHER A FORCE VECTOR FIELD NOR A SCALAR POTENTIAL FIELD IS DEFINED THERE. ASSIGNMENT OF THESE FIELDS TO THE POINT IN THE ABSENCE OF THE MASS IS AN ASSUMPTION, NOT AT ALL A DEFINITION. SINCE A TRUE DEFINITION IS AN IDENTITY, THEN THE ENTITY IDENTIFIED (DEFINED) TO INCLUDE THE PRESENCE OF MASS IS NOT IDENTICAL TO THE ENTITY RESULTING WHEN THAT MASS IS ABSENTED.

To see just how arbitrary and postulational are present. "definitions" of mass and force, see Lindsay and Margenau, op. cit., pp. 84-101. Also see Richard P. Feynman, Robert B. Leighton, and Matthew Sands, The Feynman Lectures on Physics, Addison-Wesley, New York, Vol.1,. 1963, Fourth Printing July 1966, p.2-4 for a definition of the electric field in the context of its POTENTIALITY for producing a force. Again, the force only exists when a particle of mass is present. From these examples, one can see the implication that A PHYSICAL FIELD IS SOMETHING SUCH THAT, WHEN A MASS IS INTRODUCED INTO IT, THE MASS EXHIBITS AN EFFECT. For a "force field," this is tantamount to stating that there exists some mechanism connected with a field which, in the presence of a mass causes a force to be exhibited. In that case the force is an EFFECT, not a cause, and there is a more fundamental mechanism that GENERATES FORCE ITSELF. See also field discussions in Feynman, Richard, The Character of Physical Law, M.I.T. Press, Cambridge, MA, March 1967, 2nd printing September 1967, passim.

6. While in Europe prior to 1881, Albert Abraham Michelson performed his first interferometer experiments to determine the velocity of the earth through the ether, obtaining essentially null results. At the Case School of Applied Science in Cleveland,

Ohio, he perfected his interferometer experiment from 1883 to 1887, assisted by a colleague, chemist Edward Williams Morley. By 1887 the results were ready and announced. Michelson himself thought his experiment had proven Stokes' theory of an ether dragged along by the earth in motion, and thus motionless with respect to the earth. This was at odds, however, with certain other experiments indicating a moving ether. The Michelson-Morley experiment was finally reconciled with these other experiments by Fitzgerald's suggestion in 1892 that the physical dimensions of material bodies are altered when they are in motion. In 1907 Michelson was awarded the Nobel prize, the first American to receive it in the sciences.

7. See Lindsay and Margenau, Foundations of Physics, 1963, pp. 324-326; D. C. Miller, "The Ether Drift Experiment and the Determination of the Absolute Motion of the Earth," Reviews of Modern Physics, Vol. 5, p. 203, 1933. Actually the experiments did not yield a conclusively null result, but rather showed large systematic trends. For a typical elimination of the systematic trends, see Handschy, M. A., "Re-examination of the 1887 Michelson-Morley experiment," American Journal of Physics, Vol. 50, No. 11, Nov. 1982, pp. 987-990. See Rho Sigma, Ether-Technology, CSA Printing & Bindery, Lakemont Georgia, 30552, 1977 for several enlightening points on the vacuum ether: See A. K. Lapkovskii, "Relativistic Kinematic Equations and the Theory of Continuous Media," Soviet Physics Journal, Vol. 21., No. 6, June 1978 for an abstract describing Soviet utilization of the concept of a small particle (called by Bearden a quiton, in Quiton/Perceptron Physics, DTIS, 1973) of the medium. See Belyaev, B. N. , "On Random Fluctuations of the Velocity of Light in Vacuum," Azvestiya Vysshikh Uchebnykh Zavedenii, Fizika, No. 11, Nov. 1980, pp. 37-42, translation by Plenum, for discussion of the proven variation of the speed of light in vacuum; the velocity of light in a vacuum on earth is measured to be higher than the velocity of light in the vacuum of deep space. See Graham, G. M. & Lahoz, D. G., "Observation of static electromagnetic angular momentum in vacuo," Nature, Vol. 285, 15 May 1980, pp. 154-155 for the first direct observation of free electromagnetic angular

momentum in vacuum. See Davies, Paul, "Something for nothing," New Scientist, 27 May 1982, pp. 580-582 for a discussion showing that modern theories of the vacuum reveal that even empty space is seething with activity; an ether of sorts emerges from vacuum fluctuations due to quantum mechanics considerations. See Hooper, William J., "All-Electric Motional Electric Field Generator," U. S. Patent No. 3,610,971, October 5, 1971 for a generator which produces a gravitational or inertial field. Einstein suggested that vacuum, complete with electromagnetic and gravitational fields, be called the ether. Dirac certainly did not abandon an ether, for in 1954 he stated "The aetherless basis of physical theory may have reached the end of its capabilities and we see in the aether a new hope for the future." James Clerk Maxwell derived his famous equations based on an ether theory. Sir Arthur Eddington also believed firmly in an ether. Sir Oliver Lodge actually pointed out the dilemma which yields the approach in this paper: writing of the ether in his book, The Ether of Space, Harper & Bros., New York, 1909, he stated: "We have no means of getting hold of the ether mechanically; we cannot grip it or move it in the ordinary way: we can only get it electrically. We are straining the ether when we charge a body with electricity; it tries to recover, it has the power of recoil.. . . "But when electrical theory was being founded, scientists thought of space as something rather fixed, and FILLED WITH a thin material ether. They did not realize that space itself does not exist except after an observation; before the observation, spacetime exists -- indefinite in both length and time. They did not know that electrostatic scalar potential in fact was spacetime, hence also the vacuum and the ether. In assuming that the charge of vacuum is zero and that charge and charged mass are identical, they hid the answer to the dilemma and placed the foundations of electromagnetics on its present unsound basis.

8. The field, of course, is indeed a highly useful concept and this author certainly does not recommend its abandonment. Instead, he recommends that it be placed on a sounder logical basis.

9. Specifically, they came to feel that the "electric

field" which was improperly defined -- was what was waving.

10. In fact Einstein once proposed that the vacuum, complete with its electromagnetic and gravitational fields, should be called the ether. His proposal was not adopted. (See Born, Max, Einstein's Theory of Relativity, Revised Edition, Dover Publications, New York, 1965, p. 224.)

11. Particularly from the work of Schrodinger, Born, Dirac and others.

12. For example, see Lindsay and Marge. nau, op. cit., pp. 287-288. A physical vector is thought to be defined by its magnitude, its direction in space, and its transformation characteristics. Actually that is a geometrical vector, not a physical vector. It does not tell us WHAT A VECTOR CONSISTS OF, but only tells us some of its important characteristics. Remember that a true definition must be an identity.

13. Here a reading of Lindsay and Margenau, op. cit., pp. 79-81 may prove enlightening. Also note that velocity, or L/T considered "at an instant" (stopped), represents an idea of "motionless motion" and is an application of the fourth law of logic. For a discussion of the fourth law of logic and its usage, see Bearden, Thomas E., "A Conditional Criterion for Identity, Leading to a Fourth Law of Logic," Specula, Journal of the A.A.M.S., P.O. Box 1182, Huntsville, AL 35807, combined Vol. 3, No. 4/Vol. 4, No. 3, Oct 1980 - Mar 1981, pp. 50-57 (also available from Defense Technical Information Service).

14. Note this is an identity of opposites, which explicitly violates the three Aristotlean laws of logic. See Bearden, "A Conditional Criterion for Identity, Leading to a Fourth Law of Logic," loc. cit., 1981.

15. Again note the fourth law of logic: zero motion (the absence of motion) being recognized as a special case of the presence of motion. Also, physical reality consists of internested levels, and any physical object has an internal substructure of nested levels of finer structure, extending down into the virtual (nonobserved) state. For a vector to model (apply to) a

physical object, it itself must be modeled in such fashion as to reflect this kind of substructure. Thus the use of geometrical vectors as models of physical objects in motion is presently flawed in a fundamental fashion.

16. The reader is most strongly urged to read Morris Kline, Mathematics: The Loss of Certainty, Oxford University Press, New York, 1980 as a prelude to understanding what mathematics is and is not, and what it does and does not.

17. Refer to Lindsay & Margenau, op. cit., pp. 79-81 to see how the ideas of motion and vector are inextricably entangled with the idea of a particle.

18. Call it uncertainty or call it constituency; a quantum change is composed of two canonical entities inextricably welded together into a single entity.

19. Time is an unavoidable, nonexclusive constituency of the welded quantum.

20. Simply from the definition of force as CONSISTING OF a time- and length-smeared mass motion change.

21. The force is an effect, not a cause. It IS the smeared charged particle. It is CAUSED by a more fundamental mechanism. It is the result of the combination of (1) a nonzero del phi, and (2) the presence of a spinning charged particle. IN A DEL PHI, THE SPINNING CHARGED PARTICLE ACCELERATES ITSELF! This is the fundamental secret of free energy that was suppressed, to bury the fundamental work of Nikola Tesla, shortly after Tesla was forced to abort his Wardenclyffe attempt to provide the world with free energy.

22. To quote: "The Hertz wave theory of wireless transmission may be kept up for a while, but I do not hesitate to say that in a short time it will be recognized as one of the most remarkable and inexplicable aberrations of the scientific mind which has ever been recorded in history. " Nikola Tesla, "The True Wireless, " Electrical Experimenter, May 1919, p. 87.

23. De Beauregard, O. Costa, "Running backwards the Mermin device: Causality in EPR correlations," American Journal of Physics, Vol. 51, No. 6, June 1983, p. 515.

24. Note the Soviet scientist Kozyrev's experiments with time waves. See Kozyrev, N. A., "Possibility of Experimental Study of the Properties of Time," September 1967, pp. 1-49, in JPRS 45238, May 1968. Kozyrev reports real physical effects from the oscillation of time. Also, note that scalar potential energy of appreciable size with respect to a particle's rest energy can force the situation to be relativistic, even though the velocity of the particle with respect to the velocity of light is small. That is, electrostatic scalar potential alone can cause variation in the rate of flow of time and hence vary physical characteristics. See Bloch & Crater, "Lorentz-invariant potentials and the non-relativistic limit," American Journal of Physics, Vol. 49, No.1, 1981, pp. 67-75. By inference, oscillating the electrostatic scalar potential can produce time waves and lead to direct physical effects.

25. It is already shown in the literature that the electrostatic scalar potential (ESP) can affect spacetime (ST) in the same manner as velocity. Cf Bloch & Crater, op. cit., 1981. Now note that, to any quantal or macroscopic observer, the existence of the 4-space volume of ST implicit in (Δt)(Δv), where v is volume, cannot be separated from the existence of the subquantal entities that exist therein. We therefore DEFINE the magnitude of the ESP as the summation of the absolute values of all the internal virtual vectors in the (Δt)(Δv) quantum of ST, divided by the absolute value (magnitude) of (Δt)(Δv). We take the view that no such thing as "unstressed" ST physically exists, and that "spacetime" and "stressed spacetime" are identical. Hence ESP and ST are one and the same thing. Note that this implies that the virtual density of ST is variable, and is nothing but the magnitude of the ESP. In EM theory, the assumption that the ESP of vacuum ($Ø_O$) is equal to zero is in serious error. In fact, $Ø_O$ IS "spacetime of the laboratory observer," in the new view.

26. For example, the definition of the electrostatic

potential (ESP) is usually taken as "the work which must be done against electric forces to bring a unit charge from a reference point to the point in question; the reference point is located at an infinite distance, or, for practical purposes, at the surface of the earth or some other large conductor." (McGraw-Hill Dictionary of. Scientific and Technical Terms, ed. Daniel N. Lapedes, second edition, 1978, p. 518.) Note that this is NOT a definition at all, for it is not an identity. Instead, it is the statement that, if an ESP exists at a point and a unit charged mass (assumed to be at a point) is brought in from infinity toward the ESP location point, the amount of work it is necessary to expend upon the mass of the particle is equal to the magnitude of the ESP. The ESP exists whether or not any work at all is expended, and whether or not a charged unit mass is brought in. To adequately define ESP, we must define its identity, or what it consists of, in the absence of mass, since we have conceived the ESP to exist at a vacuum point. Further, the definition usually taken is completely a 3-space definition. Instead, in our new view the ESP is to be taken at a point in n-space, where n is equal to or greater than 4.

27. See Bearden, Quiton/Perceptron Physics, 1973, available through the DTIS. See also Bearden, The Excalibur Briefing, Strawberry Hill Press, San Francisco, CA, 1980. Ultimately all physical phenomena are mindchanges in the minds of all the observers.

28. And then assumes this summation value is zero.

29. See note 25 above.

30. Bearden, The Excalibur Briefing, Strawberry Hill Press, San
Francisco, CA, 1980.

31. Cf Rauscher, E. A., "Electromagnetic and Non-Linear Phenomena in Complex Minkowski Spaces," Tecnic Research Laboratories, 64 Santa Margarita, San Leandro, CA 94579. Presented at the 1983 March Meeting of The American Physical Society in Los Angeles, CA 21-25 March, 1983. This is a truly remarkable paper of great significance. Rauscher, a world-class physicist, has presented a new theoretical

model for some rather extraordinary possible extensions of present electromagnetics.

32. Cf Muses, Charles, Introduction to Jerome Rothstein's Communication, Organization, and Science, The Falcon's Wing Press, Indian Hills, Colorado, 1958. The entire foreword by Muses is a remarkable document, which analyzes the structure of time itself. See also his profound summary paper, "Hypernumbers II" in the January 1978 issue of Applied Mathematics and Computation, published by Elsevier.

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ADDITIONAL NOTES AND REFERENCES

Although quotes and direct utilization of material from these references were not incorporated in this paper, the following references were also consulted. In addition,' several notes are added for further clarity.

33. Rupert Sheldrake, A New Science of Life: The Hypothesis of Formative Causation, J. P. Tarcher, Inc., Los Angeles, CA, 1981. Ø, the electrostatic scalar potential field, in my opinion is actually the morphogenetic field that Sheldrake proposes.

34. Briefly, by a "particle" we mean an entity so constructed that, if any part of it changes all of it changes. From the viewpoint of the particle, this implies that to change is to detect, and to detect is to change. Also, internal and external become synonymous, in the "detected" sense. The idea of a "fundamental particle" in physics actually invokes the fourth law of logic implicitly.

35. Only if a thing dimensionally contains time, can it "occupy time." This point is so obvious that one wonders how so many of the scientists and mathematicians seem to have missed it. By this criterion, e.g., mass does not exist in time, a priori. To "observe" or detect, in fact, means to stop time, thus collapsing the wave function. However, it reduces the observable or detectable to a spatial quantity, not a spatiotemporal quantity. In other words, the ordinary scientific method destroys a part of reality in each detection or measurement, yielding only a partial truth. not fundamental truth.

36. Note that electrostatic scalar potential is actually infinite-dimensional and hyperspatial. The coverage of

this paper is still only a special case. By Tesla technology, it is possible to do direct engineering in hyperspace -- beyond our present space and time, with all that that statement implies.

37. Bob Sloan, "Nikola Tesla: The Greatest Inventor of all Time?". IEEE Antennas and Propagation Society Newsletter, June 1983, pp. 9-11. A very succinct summary of the importance Tesla played in ushering in the modern age.

38. Gerald E. Brown and Mannque Rho, "The structure of the nucleon," Physics Today, Vol. 36, No.2, February 1983, pp. 24-32. Recommended as a summary of the new thinking as to the structure of the nucleon: a bag containing three quarks, surrounded by a cloud of mesons which squeeze the bag.

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40. Margaret Cheney, Tesla: Man Out of Time, Prentice-Hall, Englewood Cliffs, NJ, 1981.

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Proof, New York University Press, 1958.

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of all kinds. Corliss is a national treasure, and his handbooks are absolutely indispensable.
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The last paragraph by Jammer is illuminating: "The modern physicist may rightfully be proud of his spectacular achievements in science and technology. However, he should always be aware that the foundations of his imposing edifice, the basic notions of his discipline, such as the concept of mass, are entangled with serious uncertainties and perplexing difficulties that have as yet not been resolved."

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TOWARD A NEW ELECTROMAGNETICS PART III: CLARIFYING THE VECTOR CONCEPT

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-- It Started With Geometry and Grew --

At the very beginning of what we call the "scientific period," mathematics was both king and queen, and Euclidean geometry was its handmaiden. So we ask, "What precisely is geometry?" Here we are not interested in a "textbook" answer, but in an answer indicating what geometry really does.[3] In other words, with what does geometry concern itself, and what is the fundamental nature of those things with which it concerns itself?

Briefly, geometry -- at its foundation -- is totally spatial. It is fitted to, and expressed in terms of, the TOTAL ABSENCE OF MASS. Thus the geometer deals in abstract, massless entities called "points," "lines," "planes" etc. When the geometer speaks of "motion," he speaks of a time-smeared, length-smeared point. Geometry at heart is massless, and a "geometer's vector" is a highly specific type of "system." In fact, it represents the "time-smearing" and "length-smearing" of a point. A priori, the fundamental concept of the geometrical vector has taken a "spatial" entity and introduced a hidden involvement with "time."

Modern mathematics and physics have followed an intertwined development for several hundred years. And both sprang as offshoots of the original work of the geometers. Let us briefly sketch the overall path of interest taken by these two developing disciplines.

With the advent of Descartes's fundamental work, algebra was combined with geometry to yield analytic geometry, a new and powerful mathematical tool. With the invention of calculus by Leibniz and Newton, both mathematics and physics received a giant impetus. Differential geometry and vector mathematics arose in full splendor and, in physics, mechanics leaped to the forefront with Newton's profound work.

But the mechanics made a most fundamental error when they simply applied the geometer's vector to a mass, to produce -- so they thought -- a mass vector. That which rigorously applies only to the absence of mass cannot be so lightly applied to the presence of mass without the risk of serious limitations in the resulting theory. The precise difference between a geometer's massless vector and a mechanic's mass-vector is one of the issues to be developed in this thesis.

As rapid development continued in mechanics and mathematics, certain physicists were involved in intense experimental work on charged matter, becoming the first electricians. Both the preceding mathematical ideas and constructs as well as the preceding (partially erroneous) mechanics constructs and ideas were applied by the electricians, struggling with their pith balls, cat fur, and glass rods to understand, quantify, and model electrical forces and the phenomena of charged matter. In other words, the electricians strove to formulate the physics and dynamics of charged matter and its interactions by simply "adding to" the work of the geometers and mechanics. Here again, a fundamental logical error was made. That (geometry) which a priori applies only to the absence of mass, and that (mechanics) which a priori applies only to the absence of charge, cannot be lightly applied to the presence of charged mass (both mass and charge)[4] without risking the incorporation of grave limitations in the resulting theory.

After the profound work of Maxwell, the idea of FIELDS OF FORCE became more prominent, until the field concept ruled the day[5]. The electricians continued, pushing the idea of fields into space and vacuum itself, along the way inventing the idea of "charge effects" existing even in the massless vacuum, with concomitant fields. Meanwhile, they had thoroughly confused chargeless point-smeared, chargeless mass-smeared, length-smeared and time-smeared vectors.

After a set of fundamental experiments designed to detect motion of the material ether yielded essentially null results[6], Michelson and Morley were regarded as having completely disposed of the ether -- even though the experiments only disposed of material ethers, and not Lorentz-invariant non-material ethers[7]. Maxwell's equations and the field concept were elevated to profound importance.[8] Then, after Einstein's fundamental relativity work shortly after the turn of the century, the ether concept faded away and the field concept reigned supreme. Indeed, in their enthusiasm the interpreters of relativity went so far as to affirm that one can have a wave without any medium; that is. that something can be moving (waving) without anything there to move![9] And with great glee they pronounced the final end to the idea of "ether" as a medium, even though Einstein himself never did any such thing.[10] With the advent of Einstein's General Theory of Relativity, even matter came to be regarded as just a special "kink" or curvature in spacetime or "vacuum nothing."

Quantum mechanics arose and even certainty and determination fell. Chaos, probability, and randomness now assumed the ruling position. Probability waves (and probability fields) arose,[11] as did quantum fields of various kinds. The intermingling of these concepts with the concepts of electrodynamics pushed the idea of the field even farther into esoteric realms.

The point is, each of these developing disciplines incorporated and built on the foregoing disciplines. From the beginning of geometry, there was no rigorous definition of a vector, and there is none today.[12] From the beginning of mechanics, in their foundations the theorists made grave logical errors by incorporating the geometer's vector; errors so great that today mechanics and electromagnetics are severely flawed, as is everything that came after them and built upon their illogical foundations.

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-- Points and Motion --

It is my purpose in this paper to expose in a very simple fashion the most basic errors that were made. One basic error involves the idea of motion itself.[13]

In formulating concepts of motion, the geometers used a "point in motion" to determine or specify, for example, velocity. Now a "point" is a static concept a priori. To determine (or even to think and perceive) motion, one must determine that it occupies two different points (positions or locations) at two different times, yet consider both points at the same time. Indeed, that is precisely what the arrow means that is used to represent a vector. A "point in motion" therefore represents a contradiction of opposites. That is, it represents the idea that "that which is motionless has motion.".[14] Even with this, there is a difference in a spatial point and a spatiotemporal (spacetime) point. To exist at all, a spatial point must be moving in time; in other words, it is a spatiotemporal line, even if it is a static spatial point.

Vector analysis was constructed in the abstract -- again, a massless point in motion possessed or constituted a velocity vector, etc. In massless (and timeless) space, FIELDS were defined: "scalar" fields constituted the assignment of a simple motionless number (magnitude) to each spatial point, while "vector" fields constituted the assignment of a "simple vector" (magnitude and velocity) to each spatial point. But the MATHEMATICAL vector system consisted of massless (point) motional relationships, recognizing zero motion as a special case of motion.[15]

Of course mathematics development was also always intertwined with practical problems. With the sustained application of mathematics to gross physical material problems, mechanics slowly arose.

These developments required decades and even centuries to occur completely. All along the way, innovations and changes -- and additions to the mathematical formulism were being derived and taught to students as the "natural" system of reality. A permanent mindset was being forged.

Indeed, mathematics was regarded as THE single human expression of fundamental truth. Not until Godel's work in the twentieth century did it become evident that MATHEMATICS IS SIMPLY A GAME PLAYED ACCORDING TO ASSIGNED RULES, AND THERE IS NO ULTIMATE TRUTH IN MATHEMATICS ALONE.[16] It is a most useful game, of course, since it is the game fitted to perception. Thus it applies, essentially, to whatever can be perceived. But to be applied to physical systems, it must be changed, altered, updated, and fitted as the perceiving/detecting instruments become ever more subtle.

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-- Four Types of Vectors Actually Emerged --

As the physical sciences slowly developed and incorporated abstract geometry and mathematics, in actuality four major types of vectors and two major states of observation evolved, although this fact did not become apparent to the scientists. Specifically, the mathematicians and scientists failed to recognize the differences in the four types of vectors, hopelessly intermingling them and confusing them as a single class of vector. Further, they did not appreciate that a fundamental vector conceptually is a UNITARY SYSTEM, and the system represented by one of these four types of vectors utilizes and is comprised of different components, "welded together with no seam in the middle."

Conceptually (and from a systems viewpoint), the four types of vectors are (1) the chargeless, massless spatial system vector (geometer's vector), (2) the uncharged mass system vector (mechanic's vector), (3) the charged mass system vector (electrician's vector), and (4) the charged space system vector (advanced electrician's vector). These four fundamentally different vectors are shown in Figures 1, 2, 4, and 9 in a simplified manner.

The major problem was that, beginning with the geometer's vector, these four major types of vectors were not treated as systems. Instead, their "vector" aspects were hopelessly confused and intermeshed, and no distinctions were made between them. And in the foundations of the mathematical constructs, time-smearing was not recognized at all.

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-- Quantum Mechanics Compounds the Problem --

In addition, the two presently recognized observation states -- observable and nonobservable (virtual) -- were of course unknown to the early geometers and electricians, and these ideas were not incorporated directly into the theoretical foundation.

From particle physics and quantum mechanics, we now understand that physical reality is structured of an observable state, underlaid with an infinite number of ever finer, successive levels of virtual (unobservable) states. At least reality is most accurately modeled in that fashion, according to particle physics today.

It is also well known, for example, that at the most fundamental level, one cannot actually separate nonmotion from motion (which implies, for example, that one cannot separate mass and velocity). In other words, a "mass in motion" idea is actually incorrect, at the most basic level. What actually exists is a sort of "smeared mass". That is, "mass-motion" is fundamentally what exists, not mass IN motion .

Actually, all that the Heisenberg Uncertainty Principle implies is this fact: If one examines the concept of "static (non-smeared) thing in non-static (smeared) motion", in ever finer detail, one reaches a degree of fineness where the "smearing" is paramount and one cannot have an un-smeared or "separate static thing" to be in motion. Instead, one only has the smeared, 4-dimensional spacetime entity, without 3-dimensional spatial separations.

This means, for example, that at the most basic level, it is actually incorrect to represent a momentum with a little static particle of mass connected to a spatial velocity vector. It is incorrect to think of the system as comprised of TWO SEPARATE ENTITIES, (1) a mass, and (2) a massless spatial system velocity vector (a geometer's vector).

We mention in passing that, presently, we understand that every particle is continually accelerating. First, the particle has spin, which involves rotation, which means that every "part" of the periphery of the particle is accelerated toward the center axis of spin. Second, every particle is continuously "fluctuating," and these fluctuations are accelerations. Further, we must consider any change such as an acceleration -- as existing in a small time increment, and occurring in a small length increment. Thus mass particles actually exist as (mass x acceleration x time x length). This of course has the dimensions of ACTION or angular momentum. The "real" world of physical matter, then, is composed of building blocks of action, called "quanta." Any other physical "quantity" must be obtained by fissioning (differentiating) the action quantum. For this reason, quantum mechanics presently must postulate that to every observable there corresponds an operator.

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-- To Summarize Briefly --

Let us now summarize these concepts and further examine their impact.

In physics, there must actually exist four major KINDS of vectors, rather than just one as prescribed by present interpretation. These vectors are "built" starting with four major kinds of particles.[17] These are: (1) the spatial point, (2) an uncharged mass particle, (3) a charged mass particle, and (4) a charged spatial point. Further, each of the four vectors at its most fundamental level (that is, at the quantum level)[18] is actually an inseparable, unitary SYSTEM welded into a single undivided entity containing time and existing nonexclusively in time.[19] When we look at or represent the so-called "parts" of the system, we are looking at them before they are welded together into the physical vector. That is, whenever we speak of "parts, " we imply that a "cutting" or "differentiating" action has been implied to separate the system into such "parts."

From such considerations, four different kinds of system vectors result.

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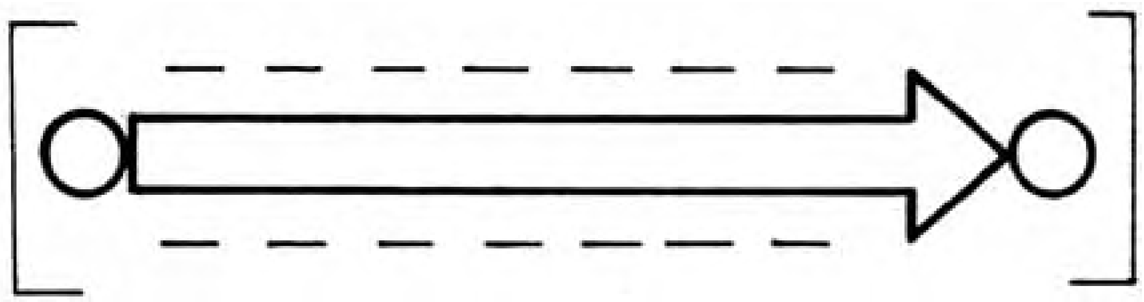

(GEOMETER'S VECTOR)

Figure 1. Uncharged spatial (massless) system vector.

UNCHARGED SPATIAL (MASSLESS) SYSTEM VECTOR
-- (Figure 1) --

This is the geometer's abstract vector, consisting of a "point in motion." (Actually, it is a "smeared point," for example.) However, so ingrained is the concept of a "point in motion" velocity vector that we now consider it to be "natural" because of its total familiarity. But simply ask, "WHAT is in motion?"[17] and you immediately see the difficulty. To have a WHAT, one must "stop the action" (detect or measure), separating "static" from "non-static." Acceleration and other vectors, etc. have also been derived by the geometer and utilized in similar fashion. All are massless.

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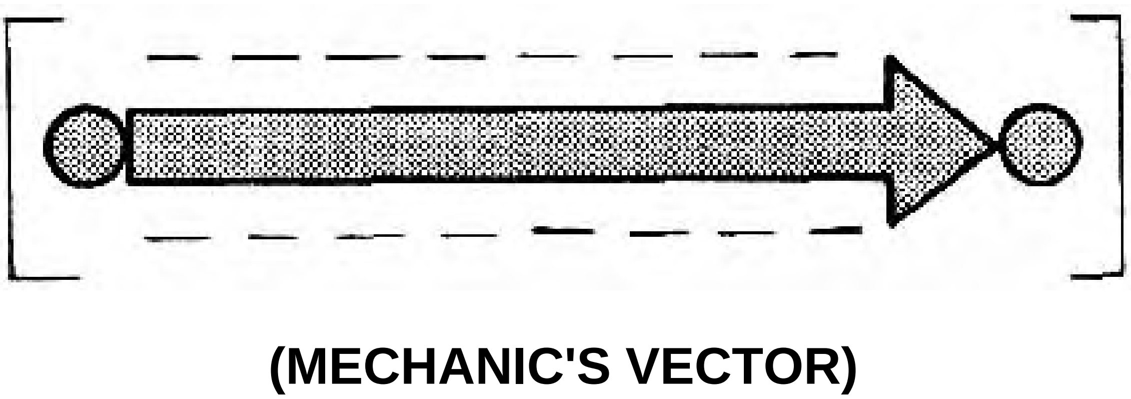

Figure 2. Chargeless mass system vector.

CHARGELESS MASS SYSTEM VECTOR
-- (Figure 2) --

This type of vector actually is the essential vector of mechanics, involving mass-motion (momentum), force (mass-motion change), etc. The fundamental difference between this type of vector and the geometer's vector is the presence of smeared mass existing in time (i.e., mass-time), welded together with a geometer's vector, but with no seam in the middle, into a new kind of "vector" AS A SYSTEM. The vector is the SYSTEM EXISTING IN TIME .

To illustrate:

"Momentum" is more properly referred to as "mass-motion" rather than "mass in motion." That is, at the fundamental level, the mass is NOT "separate" from its motion. It is NOT separated from the time in which the smearing occurs. The idea of momentum, however, is really to express the time-density of the mass-smeared-through-length. It is, in other words, the time rate of length-smearing of mass. Now in our minds we have conceived that

$$\bar{p} = m \odot \bar{v} \qquad (1)$$

where, by the symbol $\odot$ we mean "coupled to"; but we actually have

$$\bar{p} \equiv [\overline{m\bar{v}}] \qquad (2)$$

where we are not allowed to separate (even in thought) m and $\bar{v}$. Quantum mechanics agrees with this essentially, because $\bar{p}$ is a canonical variable linked to length, in any observable physical change. (The REASON p is canonically linked to ΔL is because $\bar{p}$ is the time-rate of length-smearing of m. If there is no length, there is no length-smearing of m to have a time rate OF in the first place.)

Note that, not only is

$$\bar{p} = [\overline{m\bar{v}}] \qquad (3)$$

but also

$$\bar{p} \equiv [\overline{m\bar{v}}] \qquad (4)$$

which is a much stronger and quite different statement. That is, $\bar{p}$ is IDENTICALLY $(\overline{mv})$, not just calculably EQUAL TO (m)($\bar{v}$). This means that $\bar{p}$ is a SYSTEM that is COMPRISED of mass-motion.

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-- What Force Is --

We now note that force, for example, is -- and may be defined as -- the time-rate of change of momentum, or

$$\bar{F} \equiv d/dt[\bar{p}] \qquad (5)$$

and this identity states that a force -- any force is COMPRISED OF time-changing "mass-motion." As such, the force vector is a mass-system vector, not just a massless spatial vector. Fundamentally, this mass-system vector is a totally different creature from a massless spatial vector. Our present manner of considering force as a geometer's vector "separately applied to" a mass particle is completely erroneous at the quantum level. Instead, fundamentally force is always a mechanic's vector. Force is an EFFECT, not a CAUSE.

And here mechanics made a most fundamental error, in not recognizing the difference between its kind of vector and that of the geometer.

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--Force and Hertzian Waves Cannot Exist in Vacuum --

Note that one cannot have an observable "force vector" existing' in vacuum a priori.

For example, we have the definition of force as

$$\bar{F} \equiv \frac{d\bar{p}}{dt} \qquad (6)$$

or

$$\bar{F} \equiv \overline{[m\bar{a} + \dot{m}\bar{v}]} \qquad (7)$$

and we see that, rigorously, a force vector CONSISTS OF (not, "is equal to") a time-changing mass-motion vector system. IF THERE IS NO OBSERVABLE ACCELERATING MASS PRESENT, THEN THERE CAN BE NO OBSERVABLE FORCE PRESENT. The mass can accelerate in time (increase or decrease of mass) or space (increase or decrease of velocity) or both.

Observable force CANNOT exist in vacuum (in the absence of mass), a priori.[20]

However, assume for a moment that one could have a massless force vector, as assumed in present electrical theory. Let this force vector appear at a point in the vacuum. Since the vacuum has zero observable mass, it would have zero inertial resistance to this hypothetical observable force -- hence the observable force would instantly produce an "infinite" acceleration of its point of application, vanishing with it into the infinite distance. Therefore our fictitious force would disappear the instant it appeared! In any case, it could not be retained at a point in the vacuum for any finite length of time, however small.

The direct implications are that (1) something other than an observable electrical force field exists in the vacuum, and (2) there must exist a more fundamental mechanism by which this "something else" generates or CREATES a force on/of a moving electrically charged mass. (Note again that, at the most basic level, any particle of mass is always quivering, in motion, and accelerating. from quantal considerations alone.)

Thus immediately we have discovered something unique about so-called "force-fields" in vacuum: for example, about gravitational field, electrical field, and magnetic field (and the strong force and the weak force as well). These fields do not exist at all as ordinary force vectors -- and real force fields -- in vacuum! $\overline{E}$ and $\overline{B}$ fields, e.g., are defined in terms of force per unit electrical charged mass and magnetically charged mass, respectively. In the absence of mass, they cannot exist.

And this in turn means that transverse $\overline{E}-\overline{H}$ field waves (Hertzian waves) cannot exist in a vacuum. Indeed, they appear on, and ARE CONSTITUTED of, the charged-mass-motion that changes, and they appear where such change occurs, as a result of an introduced mass.[21] But in the absence of the spinning charged particle of mass, they do not exist as force fields at all.

Hertzian waves exist in a transmitting whip antenna, for example, in the oscillating electron gas along its length. Something else entirely different exists in vacuum between the transmitting antenna and the receiving antenna. Then in the receiving antenna, Hertzian waves again exist in the oscillating electron gas along its length. (See Figure 3.)

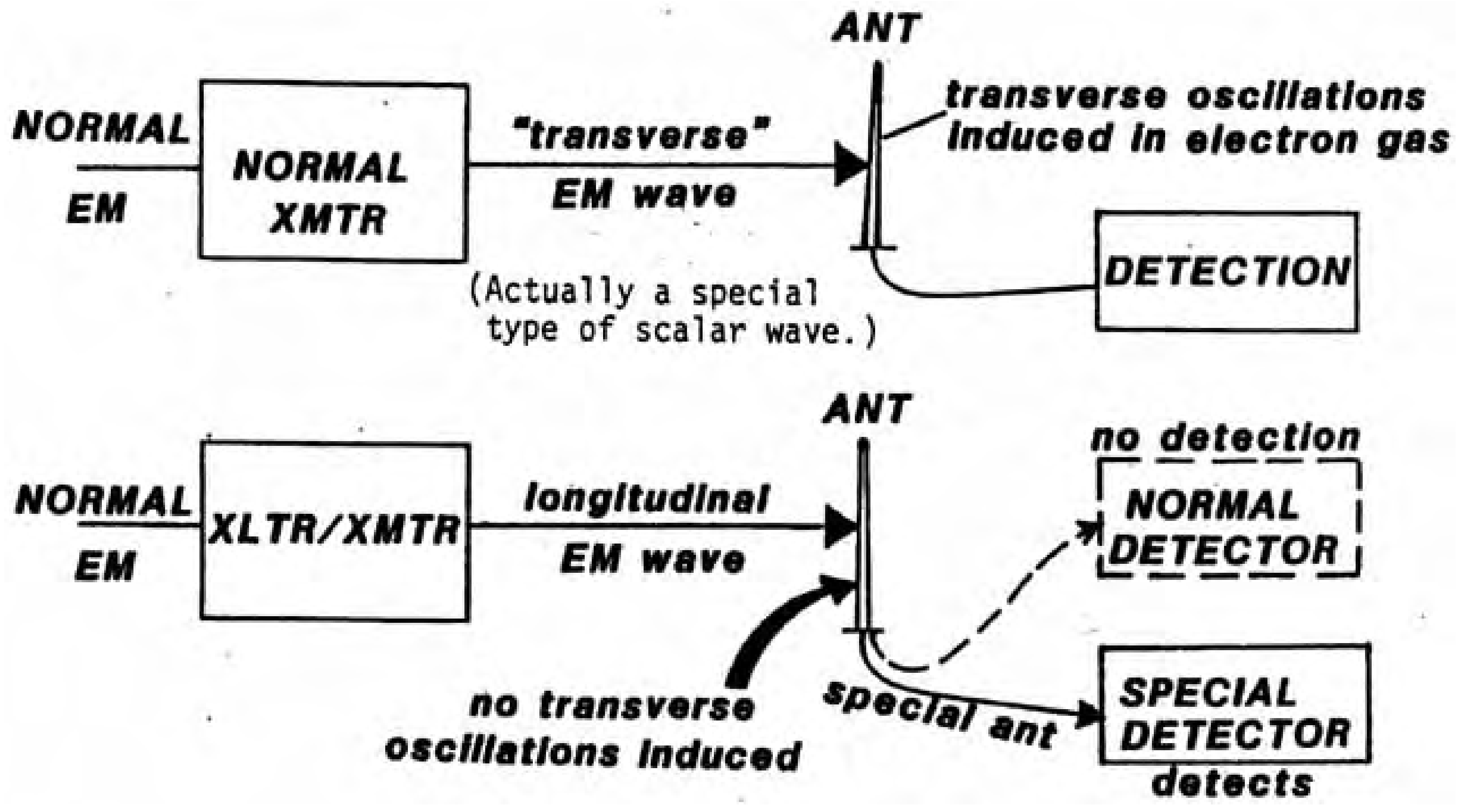
ANT
NORMAL
EM
NORMAL XMTR
"transverse"
EM wave
transverse oscillations induced in electron gas
DETECTION
(Actually a special type of scalar wave.)
ANT
NORMAL
EM
XLTR/XMTR
longitudinal
EM wave
no detection
NORMAL DETECTOR
no transverse oscillations induced
special ant
SPECIAL DETECTOR
detects

Figure 3. Detection of "transverse" and longitudinal waves

This is interesting, for Nikola Tesla stated several times that HERTZIAN WAVES CANNOT BE PRODUCED IN A VACUUM, NOR CAN THEY TRAVEL IN A VACUUM.[22]

Tesla was correct, as we are beginning to see.

We shall later return to show in what form so-called "force-fields" actually exist in vacuum.

For now, I point out that I am stating a fundamental change to all of physics, including both mechanics and electromagnetics.

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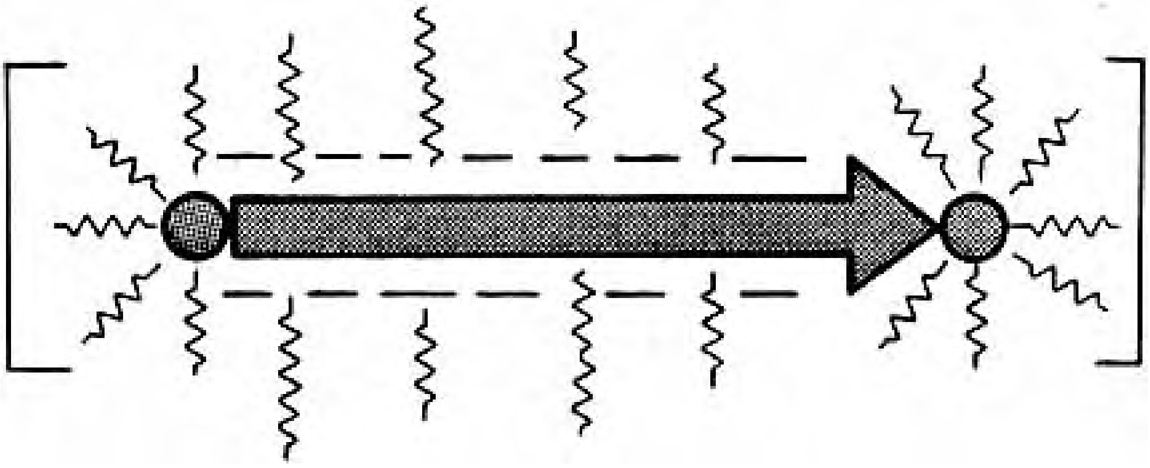

(ELECTRICIAN'S VECTOR)

Figure 4. Charged mass system vector.

-- CHARGED-MASS-SYSTEM VECTOR --
-- (Figure 4) --

The third type of vector we meet is the vector mass system where the mass is charged. First, we point out a serious error in present electromagnetic (EM) theory. That is, in present theory it is implicitly assumed that

$$\mathbf{q} \equiv \mathbf{q_m} \qquad (8)$$

In other words, "charge" and "charged mass" are erroneously assumed to be identically the same thing.

In the days when electricians were playing with pith balls and striving to uncover the secrets of electricity, they knew nothing at all about the virtual state, and consequently nothing about a "virtual particle flux" on a particle of mass causing (and comprising) the "charge" of that mass.

Today, of course, we know from particle physics and quantum mechanics that the "charge" on an observable particle of mass IS due to a flux of virtual (nonobservable) particles on and off the mass of the observable particle (see figure 5). A charged mass is thus presently known to be a SYSTEM: a massless charge flux, coupled to a bare particle (chargeless mass) constitutes a "charged particle."

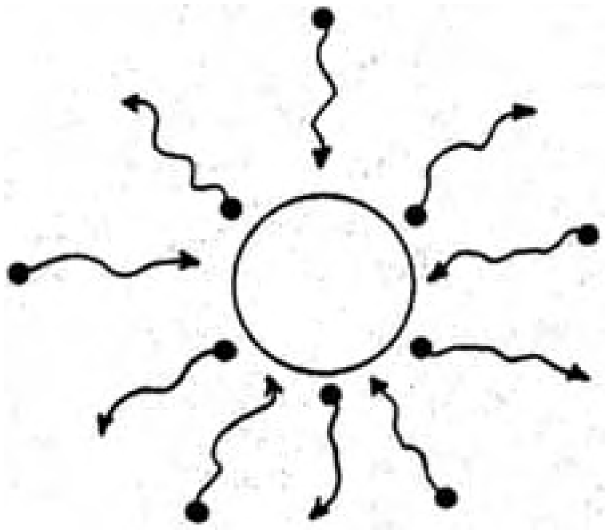

Figure 5. The "charge" on an electron mass consists of a flux of virtual particles on and off the mass.

Thus, actually the "charge" is the virtual (unobservable, or SPATIO-TEMPORAL) flux to and from the observable SPATIAL particle of mass. So, rigorously,

$$\mathbf{q \not\equiv q_m} \qquad (9)$$

But instead,

$$\mathbf{q \equiv [d/dm(q_m)]} \qquad (10)$$

and this is a definition and therefore an identity. This definition alone affects all present electromagnetics theory.

To illustrate: In founding electrical theory, early scientists dealt with forces generated by charged masses (for example, charged pith balls). They later extrapolated the experimental results they obtained (or thought they obtained) with the smallest charged mass, a charged particle. In Figure 6, I show the classic situation for derivation of the idea of E-field (except we have used an electron for our test charge, rather than a pith ball).

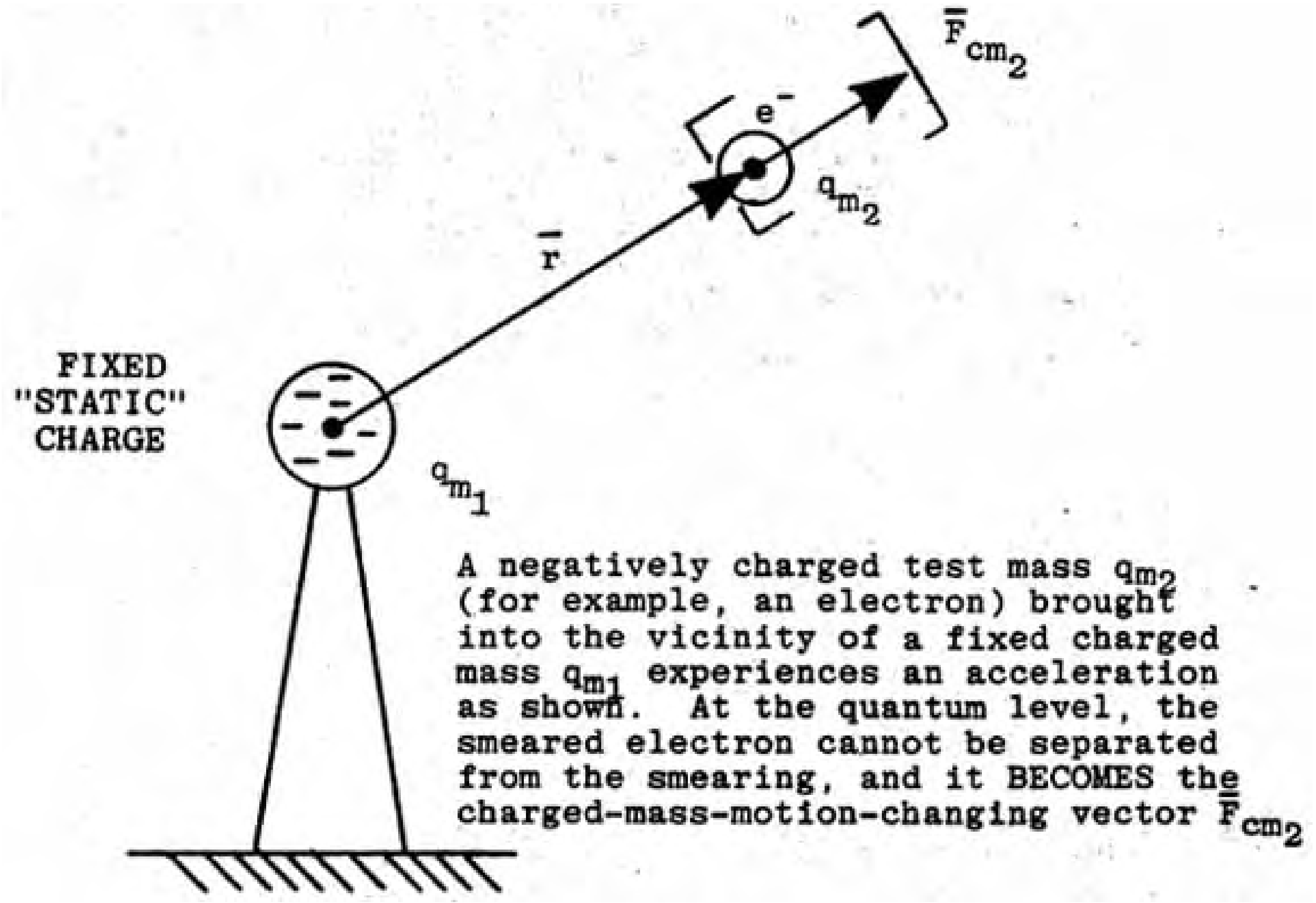

A negatively charged test mass q_{m_2} (for example, an electron) brought into the vicinity of a fixed charged mass q_{m_1} experiences an acceleration as shown. At the quantum level, the smeared electron cannot be separated from the smearing, and it BECOMES the charged-mass-motion-changing vector $\bar{F}_{cm_2}$

Figure 6. A test charge (charged mass) brought near a fixed charge (charged mass) experiences an acceleration.

Now note that what actually happens is that the unrestrained test charge becomes a CHARGED MASS SYSTEM VECTOR (a "smeared charged mass-motion changing"). The "test charge" BECOMES a charged mass force vector; it does not have a separate geometer's vector "appear on it." What actually happens is shown in Figure 7.

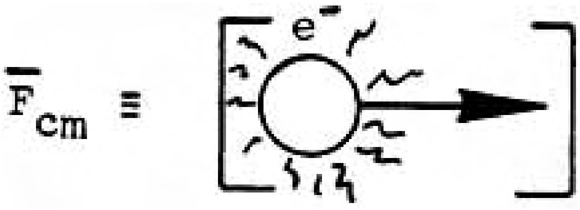

Figure 7. A charged-mass-system vector.

That is, in the simplest (nonrelativistic) case, for an electron what happens is

$$\bar{F}_{cm} \equiv [\overline{q_e \odot m_e \odot \bar{a}_s}] \qquad (11)$$

and this is a DEFINITION. That is, considered instantly, the electron exists as a charged-mass electrical force CONSISTING OF/COMPRISED OF a charge flux q_e canonically coupled to a mass, with that subsystem then canonically coupled to a spatial acceleration vector, ALL AS A SINGLE ENTITY, WITHOUT ANY "SEAMS" BETWEEN ITS "PARTS." The $\bar{F}_{cm}$ IS THE ELECTRON SYSTEM ITSELF; it is NOT a "spatial vector." Rigorously, it does not exist in the absence of the smeared electron mass, a priori.

Again, in assuming this force exists in the absence of the smeared mass of the moving particle, electromagnetics theory is in serious logical error.

Referring back to Figure 6, we see that, if we repeat the experiment many times and with the test charge in many locations, we have the situation shown in Figure 8.

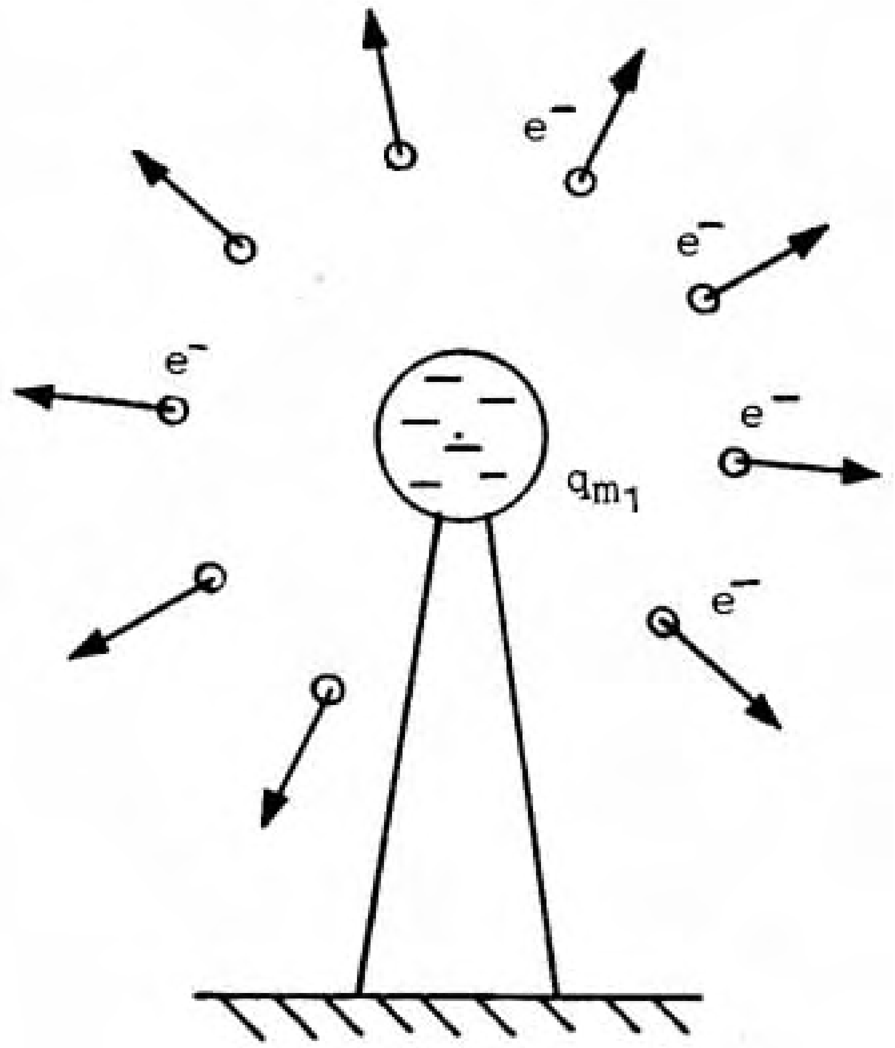

Figure 8. Repeating the "test charge" experiment.

It is found that, rigorously,

$$|\bar{F}_{cm}| \propto \left|\frac{q_{m_1} q_{m_2}}{r^2}\right| \tag{12}$$

where $\bar{\mathbf{F}}_{cm}$ is a charged mass system vector. Erroneously, this has been stated one way or another as

$$|\bar{F}| \propto \left|\frac{q_1 q_2}{r^2}\right| \tag{13}$$

where $\bar{\mathbf{F}}$ is assumed to be a spatial system vector. Further, this confusion has been carried over into the definition of the $\bar{\mathbf{E}}$-field as:

$$\bar{E}_{cm} \equiv \frac{\bar{F}_{cm}}{m_{cm}} \qquad (14)$$

In this definition, $\bar{E}$ -- which is a charged mass system vector -- has been confused as a charged spatial system vector, where $\bar{F}$ is regarded simply a spatial system vector! Actually, the definition of the $\bar{E}$-field should be

$$\bar{E}_{cm} \equiv \frac{\bar{F}_{cm}}{m_{cm}} \qquad (15)$$

where $\bar{F}_{cm}$ is a charged mass system vector. Failure to properly define the $\bar{E}$-field has caused the conception of the $\bar{E}$-field to be falsely perpetuated as existing in vacuum.

The $\bar{E}$-field is TREATED this way in present EM theory. Hence present theory falsely assumes that the observable $\bar{E}$-field can exist in vacuum.

What actually exists in space, $\bar{E}$-field-wise, is a special kind of ordered virtual state pattern in a series of spinning "scalar" fields. This virtual state pattern or "shadow vector" field will be explained later.

Note again that one cannot have a "force vector" existing in vacuum - a priori.

However, assume for a moment that one could have a massless force vector, as presently assumed. Let this force vector appear at a point in the vacuum. Since the vacuum has zero observable mass, it would have zero inertial resistance to this hypothetical observable force hence the observable force would instantly produce an "infinite" acceleration of its point of application, vanishing with it into the distance. Therefore our fictitious force would disappear the instant it appeared! In any case, it could not be retained at a point in the vacuum for any finite length of time, however small.

The direct implications are that (1) something other than an observable electrical force field exists in the vacuum, and (2) there must exist a more fundamental mechanism by which this "something else" generates or CREATES a change on/of an accelerating electrically charged mass particle. (Note again that at the basic level, any particle of mass is ALWAYS quivering and accelerating, from quantal fluctuation considerations alone.) Causality has no arrow microscopically.[23]

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TOWARD A NEW ELECTROMAGNETICS PART III: CLARIFYING THE VECTOR CONCEPT

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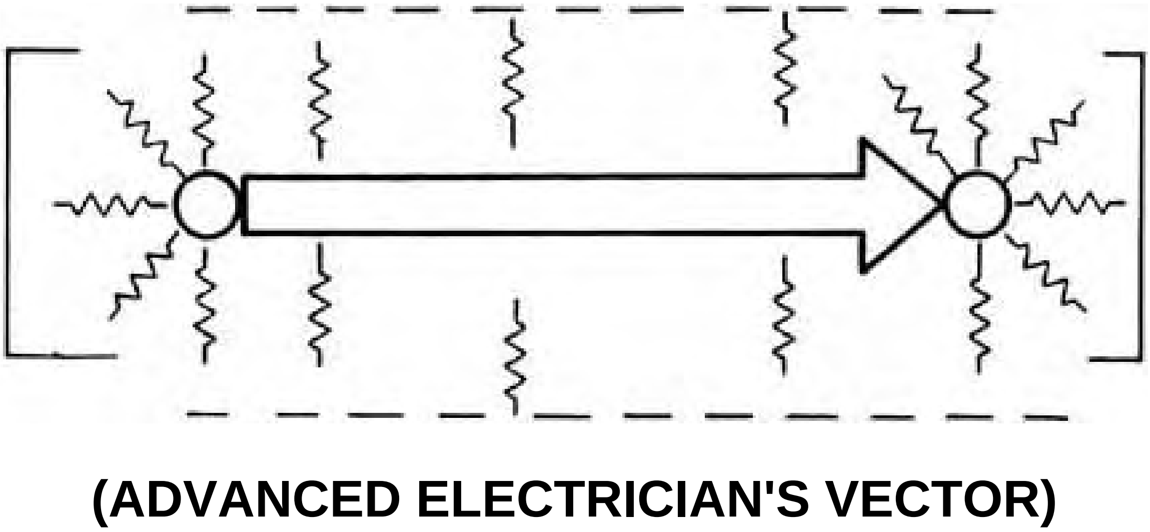

Figure 9. Charged spatial (massless) vector.

-- CHARGED SPATIAL (MASSLESS) VECTOR --

We recognize now that

$$q_c \not\equiv q_m \qquad (16)$$

and that q_c is simply the virtual-particle flux that constitutes charge -- and indeed constitutes vacuum itself!

We DEFINE vacuum, based on Figure 5, as shown in Figure 10.

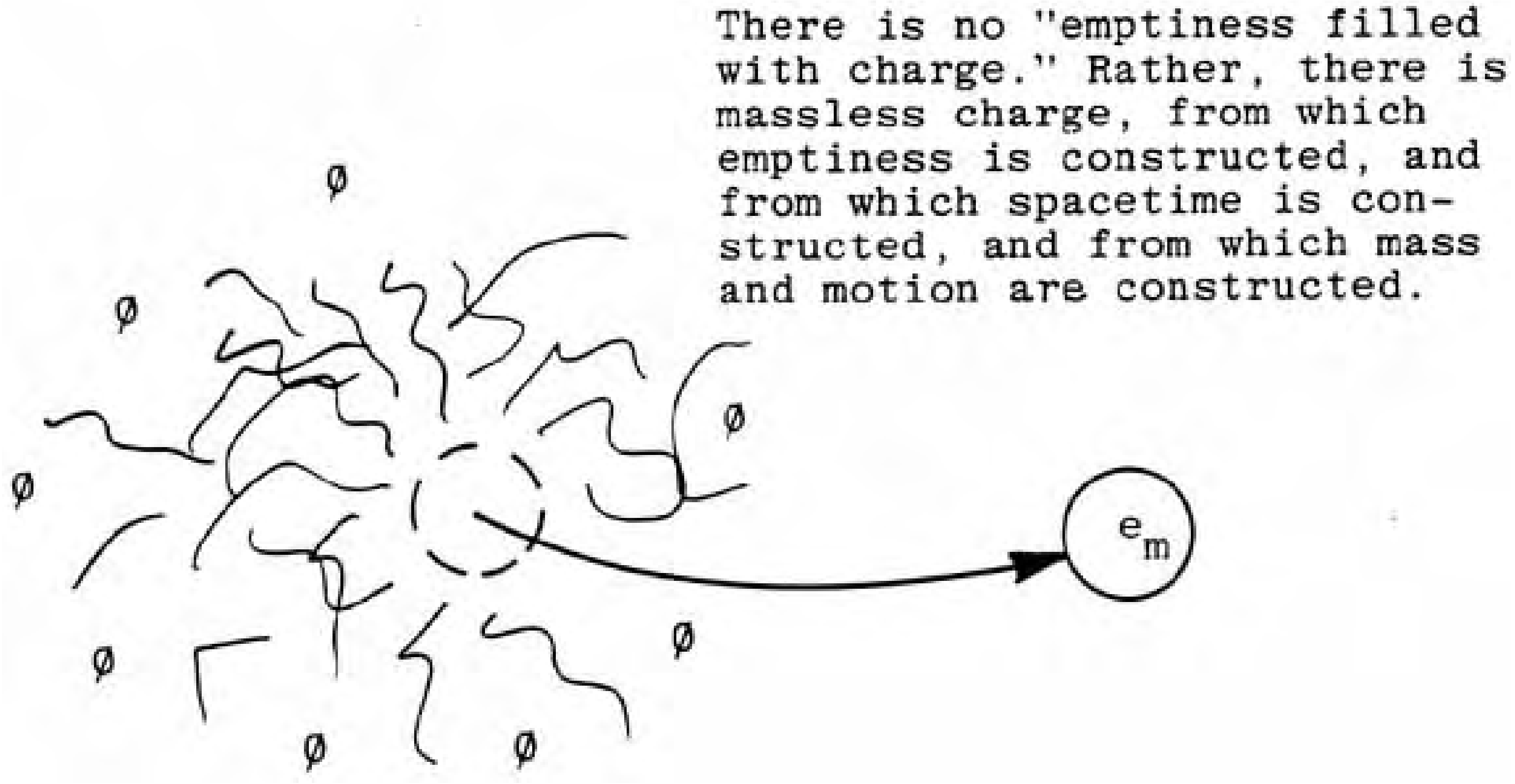

There is no "emptiness filled with charge." Rather, there is massless charge, from which emptiness is constructed, and from which spacetime is constructed, and from which mass and motion are constructed.

Figure 10. Removing the bare particle (mass) from a charged particle leaves the charge. The vacuum is DEFINED AS the charge.

That is, vacuum may be defined as pure massless charge flux. This flux IS identically "spacetime" as well. Vacuum is pure Ø-field (electrostatic scalar potential). Here again, in present theory it is assumed that

$$Ø_O \equiv 0 \qquad (17)$$

which, by our new definition of vacuum, is quite false.

We now note that, if we insist on assigning a spatial vector to the vacuum, we have the situation shown in Figure 11.

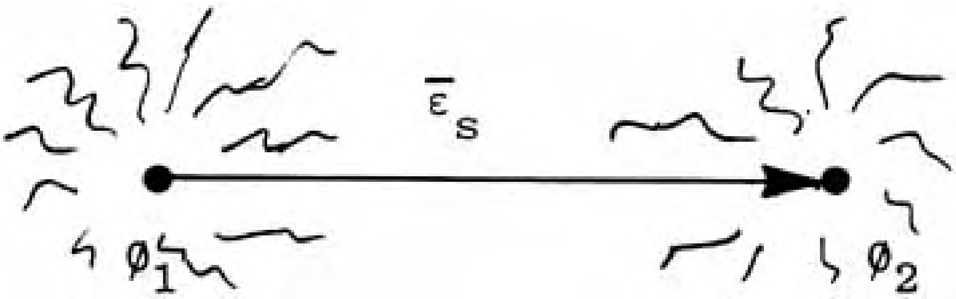

Figure 11. Assigning a spatial vector to the charged vacuum

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TOWARD A NEW ELECTROMAGNETICS PART III: CLARIFYING THE VECTOR CONCEPT

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-- THE SHADOW VECTOR --

Note that this spatial vector $\bar{\epsilon}_s$ represents $-\overline{\nabla\phi_s}$, that is,

$$\bar{\epsilon}_s = -\overline{\nabla\phi}_s \qquad (18)$$

but $\bar{\epsilon}_s$ cannot be a force (mass system) vector. It can only exist as an ordered pattern in the virtual flux between two separated points of the vacuum; that is, as an ordered pattern in the virtual state. Literally, $\bar{\epsilon}_s$ exists only as a tiny bit of order existing in great disorder.

In other words, the present EM theory is incorrect in stating that

$$\bar{E}_m = -\overline{\nabla\phi}_s \qquad (19)$$

in vacuum in the absence of an observable spinning charged particle, since

$$\bar{\epsilon}_s \neq \bar{E}_m \qquad (20)$$

The actual existence of $\bar{\epsilon}_s$ may be visualized in terms of successive differentials of $\bar{E}_m$, broken into differentials $\bar{e}_m$ so small that, observably, each little differential's mass component m has become virtual, so that

$$\bar{e}_m \equiv \bar{e}_{vm} \qquad (21)$$

where subscript m stands for mass, subscript v for virtual, and observably

$$\bar{e}_{vm} \equiv \overline{dE}_{m} \qquad (22)$$

but, in the absence of a spinning charged particle,

$$\bar{E}_{m} \neq \int \overline{dE}_{m} \qquad (23)$$

since the $\bar{e}_{vm}$ components remain individually separated. That is, in macro-time a SHADOW force vector exists, made of microscopically ordered BUT UNJOINED (unintegrated) "virtual state" vector differentials of what would be an observable mass system force vector $\bar{E}_{m}$ if integrated.

Thus, the "$\bar{E}$-vector" $\bar{\varepsilon}_{s}$ that exists in vacuum is a "shadow" vector as shown in figure 12.

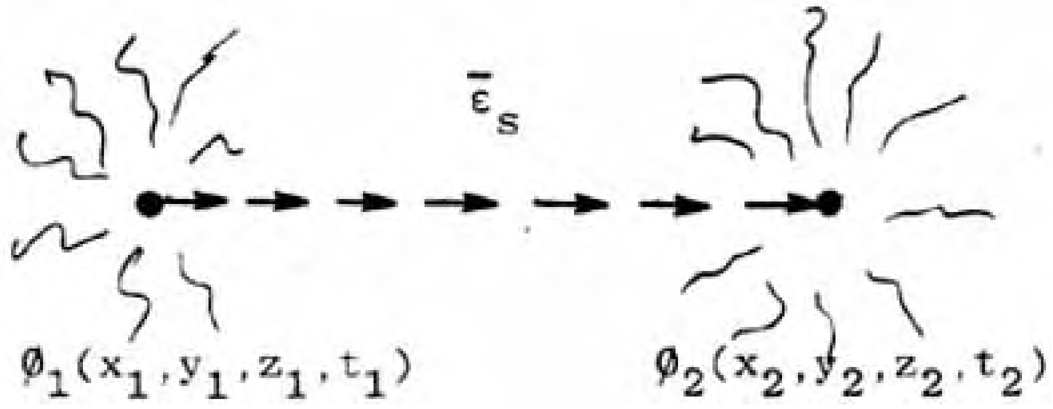

Figure 12. A "shadow vector" $\bar{\varepsilon}_{s}$

We say that such a previous mass system vector, broken into ordered but unjoined virtual vectors by the absenting of all mass, is a SHADOW VECTOR, and we label it with a subscript vm, to represent "virtual mass" system. To the macro observer, this is the kind of "vector" that exists in vacuuo.

Note that, observably, the shadow vector merely represents a special ordering in $\nabla\phi$. It is NOT an OBSERVABLE (mass system) vector, but it IS an ordered series of consecutive virtual vectors.

With each virtual bit vector, a virtual time exists as well, and these "virtual time bits" are also ordered consecutively (in macrotime).

I point out that any observable vector must be finite, and so it must have a finite magnitude (finite length). In the simplest case, this length ΔL is related to a Δt by

$$\Delta L = c\Delta t \qquad (24)$$

What I am saying is that ANY observable spatial vector is actually a spatiotemporal vector, and the MAGNITUDE of any vector is related to TIME (to the existence of that vector in time) at the most fundamental level. Suffice it to say that, if the fundamental quantum level (Δt) aspect of a vector is interfered with, then the MAGNITUDE of the vector is interfered with.[24] That is, if we can make a time wave, we can change or affect ANY vector's magnitude, including the magnitude of mass system vectors and charged mass system vectors. Such a "time wave" can be made easily, and it has been.

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TOWARD A NEW ELECTROMAGNETICS PART III: CLARIFYING THE VECTOR CONCEPT

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-- A Scalar is a Zero Vector --

Now let us look at the idea of a scalar.

A "scalar" may in a general sense be considered as the sum of the "absolute values" of the individual vector components of a system of vectors whose observable resultant is zero. That is, it represents the magnitude of the internal stress of a vector system, with the absence of a single observable directionality of the system. It also follows that every scalar is actually a stressed zero vector, and every zero vector is a scalar.

Thus we have four major types of scalars related to the four types of vectors:

(a) $S_1 = |\overline{v}_s|$ (25)

(b) $S_2 = |\overline{v}_m|$ (26)

(c) $S_3 = |\overline{v}_{cm}|$ (27)

(d) $S_4 = |\overline{v}_{cs}|$ (28)

where S stands for scalar, $\overline{V}$ for vector, and subscript s for spatial, m for mass, and c for charged.

For example, comparing equations (25) and (26), it can easily be seen that twice as many "point-motions" is not at all the same thing as twice as many "gram-mass-motions." The two resulting vector systems are quite different.

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-- Virtual and Observable Aspects --

We must also examine some aspects of "virtual" and "observable."

For example, we construct several spatial vector summations in Figure 13. The "resultants" of these spatial vectors are all equal. However, the actual sums, even though equal, are quite different, because their internal "stresses" (substructure forms) are quite different.

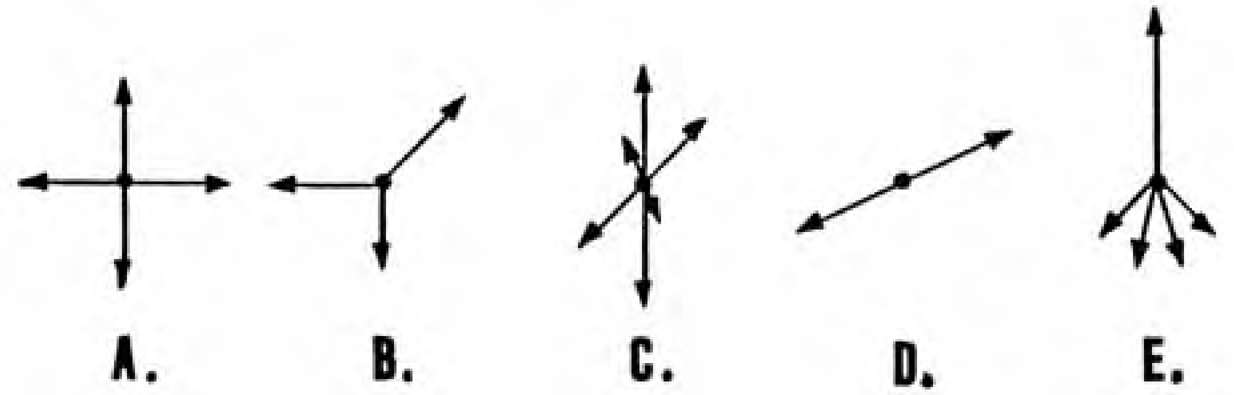

SUPERPOSITION DOES NOT ELIMINATE THE VIRTUAL SUBSTRUCTURE.

When the time aspects of the vector systems of Figure 13 are considered, one can easily understand the problem. That is, the resultant of each of these "systems" is zero, and so one can say that the vectorial "magnitude" of the system is zero since the magnitude of the resultant vector is zero. However, in each case the "action" represented by each vector element actually occurs in a finite tiny Δt. So: (1) The zero resultant must exist for a finite Δt, and (2) all the actions indicated by the system component vectors actually occur in that Δt. The absolute value of the "activity per unit time per unit volume" of such a zero-resultant system thus has physical meaning, and one may refer to this notion as the "stress" on spacetime[25], or the "electrostatic scalar potential" of the system. Note that this differs from the present definition of electrostatic scalar potential, which becomes just a special case of the more fundamental potential defined here.[26]

The derivatives of this spatiotemporal stress also have physical meaning. The time derivative is indicative of the stress on the flow of macroscopic time at a fixed spatial point, and the spatial derivative is indicative of the stress on space. Here one is confronted with the fact that what we call "space" and "time" are continually being created, directly in the physical observing/detecting apparatus itself.[27] That is, rigorously, "detected physical reality" exists totally in and of the mass-changes of the observer's mass or his detecting instruments. In the fundamental detection process itself, there is a flow of the rate of creation of spatial lengths and a flow of the rate of creation of time lengths. Indeed, to a linear observer the stress on the creation of the flow of time controls the flow of the creation of space, and the stress on the creation of the flow of space controls the flow of the creation of time. The change in the stress on 4-space (ordinary Minkowskian space-time) controls the "curvature of that spacetime" in the fifth dimension. The change in the stress on 5-space controls the "curvature of that 5-space spacetime" in 6-space, and so on. Development of these facets of the new concepts is beyond the scope of this paper.)

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TOWARD A NEW ELECTROMAGNETICS PART III: CLARIFYING THE VECTOR CONCEPT

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-- SCALARS AND VECTORS HAVE SUBSTRUCTURES --

As can now be seen, the sum of each structure in figure 13 is observably zero. Therefore we might define the sum as a "zero spatial vector." We note, however, that it actually exists for a time Δt and is thus a spatiotemporal entity, rigorously.

If we define the internal stress action A in a region $\Delta s^3 \Delta t$ of spacetime as

$$A_{(s^3t)} \equiv \sum_{k=1}^{n} |\bar{i}_s| \qquad (29)$$

and the 4-space internal stress intensity or potential as

$$S \equiv \lim_{(\Delta s^3 \Delta t) \to 0} \left[\frac{A(s^3t)}{\Delta s^3 \Delta t} \right] \qquad (30)$$

where $\bar{i}_s$ is any internal vector in the substructure, Δs^3 is the spatial volume (about a point) containing vector $\bar{i}_s$, and Δt is the inseparable time during which these component actions occurred, then we see that, stress-wise, all the "zero-vectors" in figure 13 are quite different in their internal stresses, 4-space potentials, and internal substructures. For the five "zero sum" vectors, OBSERVABLY we have

$$\bar{0}_1 = \bar{0}_2 = \bar{0}_3 = \bar{0}_4 = \bar{0}_5 \qquad (31)$$

whether or not

$$\Delta s^3 \Delta t_m = \Delta s^3 \Delta t_n \ (m \neq n;\ 1 \leq m \leq 5;\ 1 \leq n \leq 5) \qquad (32)$$

But considering the substructures,

$$\bar{0}_m \neq \bar{0}_n \quad (1 \leq m \leq 5;\ 1 \leq n \leq 5;\ m \neq n) \qquad (33)$$

I now point out that a scalar can be regarded as a stressed zero-sum vector, where the magnitude S of the scalar represents the internal stress intensity caused by the substructure of the zero-vector.

Thus, generally,

$$S(s^n t) \equiv \lim_{\Delta s^n \Delta t \to 0} \left[\frac{\sum_{n=1}^{k} |\bar{i}_s|}{\Delta s^n \Delta t} \right] \qquad (34)$$

That is, in general any observable scalar has, consists of, and is comprised of a VIRTUAL (unobservable) substructure that is very real indeed. One must also consider the scalar as existing for some finite time Δt, (at least for the time of one quantum change), and the intensity of the virtual actions occurring in the spatiotemporal substructure of the scalar during that time Δt is proportional to the magnitude of the scalar.

Normally, the concept of a scalar -- as presently used -- makes no allowance for the scalar to exist in time, or for a virtual vector substructure, or for any patterning inside the substructure. This is equivalent to assuming that

$$A \equiv 0 \qquad (35)$$

and that all $\bar{i}_s$'s are evenly distributed. That is, from this new viewpoint, presently the mathematical theory assumes all scalars to have an equal density of virtual activity per spatiotemporal volume in its virtual substructure, and an isotropic virtual pattern distribution of an infinite number of equal virtual vectors in its 4-space substructure.[28]

In the new approach, neither of these two assumptions need hold -- though in special cases they can hold. Thus present orthodox theory is just a single special case of a more fundamental approach indicated here.

Note that, by directly affecting and changing the virtual substructures of scalars and vectors, we can directly perform virtual. state engineering, and this allows us to directly "engineer" the so-called "laws of nature" of the normal observable laboratory state and thus ENGINEER AND CHANGE PHYSICAL REALITY ITSELF.[29]

In the new approach, we can (observably) have

$$2 + 2 \neq 4 \qquad (36)$$

or

$$2 + 2 = 4 \qquad (37)$$

by the following means: In the first case (equation 36), we assume that the virtual substructures are patterned, and interact nonlinearly in such a way as to produce an extra observable. Thus we have a delta added to the normal observable scalar results of the interaction, as follows:

$$2_o + 2_o = 4_o + \Delta_{v\text{->}o} \qquad (38)$$

where subscript "o" means observable and "v" means virtual. Note that

$$\Delta_{v\text{->}o} \qquad (39)$$

indicates a delta due to virtual substructure interactions yielding an extra observable delta. This extra delta may be either scalar or vector in nature, depending on the circumstances and the particular interactions.

Note also that any vector or scalar must now be considered to HAVE, CONTAIN, and CONSIST OF an infinite substructure. And note that, similar to the scalar case, from the new viewpoint the present theory assumes each scalar (point) of the vector to have a structure similar to that of equation (34), except that now the scalars are ordered, with a linearly decreasing internal stress density per unit scalar along the line of the vector.

In the new approach, vector interaction (superposition, for example) can now violate present theory, if the two virtual substructures interact nonlinearly to produce a nonzero, observable delta. Observably (macroscopically) , this delta, again, may be either "scalar" or "vector."

This approach now becomes consistent with quantum mechanics at the foundation level.

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-- Substructures, Virtual Levels, and Hyperspaces --

In the new approach, our definitions and assumptions immediately drive us to a picture of an infinite set of nested levels of substructures in the virtual state. That is, anyone component (scalar or vector) in one level of virtual state has an infinite number of even finer virtual components, one level more subtle.

AND THAT IS WHAT PARTICLE PHYSICS AND QUANTUM MECHANICS ALREADY REVEAL ABOUT THE STRUCTURE OF PHYSICAL REALITY.

So these definitions and assumptions now provide the basis for a new vector mathematics that is in accord with, and fitted to, modern physical observations.

We have a picture such that any observable scalar or vector contains a virtual substructure (virtual level 1). Any scalar or vector in virtual level 1 also contains a finer virtual substructure, in virtual level 2. And so on ad infinitum.

Each succeedingly finer level of virtual state can be modeled as a hyperdimension (higher spatial dimension) as I pointed out in Appendix 1 to my book, The Excalibur Briefing.[30]

Thus this approach immediately ties into hyperdimensional or hyperspatial theory -- such as Elizabeth Rauscher's 8-dimensional theory[31] and C. Muses's hypernumber theory.[32]

The new definitions and assumptions are far richer than what is allowed by tensors, though there are many similarities. Muses's work, however, essentially can encompass most of these definitions and concepts, except the distinct types of vectors are not so clearly delineated in his theory (at least to my comprehension of it.) His theory does provide a nested, hyperdimensional structure of time, however, and thus allows "scalar" waves in the hyperspatial structure of time -- in other words, observably "scalar" waves in the virtual state structure of spacetime, or pure Tesla waves, or simply "time" waves.

These are the bare notes; from this approach, already new (proprietary) mechanisms and exact specifications to make scalar waves -- in essentially whatever quantity and degree desired -- appear to have been successfully accomplished by my close colleagues.

The new approach is real and it leads to a new physics. And I believe that the very beginnings of the new physics are already working on the laboratory bench.

Nikola Tesla discovered the most essential features of the new electromagnetics over eighty years ago and was simply suppressed for his efforts. Now, although it has been eighty years in the reborning, Tesla electromagnetics is once again loose in the Western world.

This time, let us hope that it fares better at the hands of orthodox science and large financial control groups than it did for Nikola Tesla.

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The Tom Bearden Website

TOWARDS A NEW ELECTROMAGNETICS
PART 4: VECTORS AND MECHANISMS CLARIFIED

by Lt. Col. T.E. Bearden (retd.), 1983

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TOWARD A NEW ELECTROMAGNETICS

PART 4: VECTORS AND MECHANISMS CLARIFIED

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Delivered to the 1983 Annual Conference

of the

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Portland, Oregon

--FOREWORD --

This paper is an adaptation of the oral/visual presentation given by the author at the 1983 Annual Conference of the U. S. Psychotronics Association on Saturday, July 23, 1983.

The presentation was delivered directly from the vugraphs alone, and not from a formal, written text.

The title of the presentation at the conference was "New Electromagnetics: Where the 'Old Math' Took the Wrong Turn."

As originally conceived, the lecture was to be given in a single period of some 45 minutes and cover only the first part of this paper, the clarification of the vector concept in physical theory. The Symposium director so graciously scheduled two periods instead, allowing time to present additional material further clarifying vector and scalar waves, and to present a variety of unusual physical mechanisms that apply the concepts.

After the conference, the author prepared this paper directly from the same slides, in the same order. However, no attempt was made to match the words in this paper to the words actually delivered in the formal presentation. The gist of the two, however, are the same -- except that, in the conference lecture, the author covered (as an aside) some important additional material: (1) the nature of what actually occurs in an "electrical ground," and (2) the author's explanation of the theory of Tesla's magnifying transmitter.

An audio tape and a videotape of the author's USPA presentation were made by the conference officials. Copies are available at nominal cost from Mr. Robert Beutlich, Secretary/ Treasurer, U. S. Psychotronics Association, 3459 Montrose Avenue, Chicago, Illinois 60618, U.S.A.,
phone (312) 478-7715.

SLIDE 1.

TOWARD A NEW ELECTROMAGNETICS

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ACKNOWLEDGEMENTS

I would like to express my deep appreciation to two of my fellow colleagues, Dr. William Tiller and Mr. Frank Golden, for many fruitful hours of discourse and interchange on these and related subjects.

Also, I wish to thank the Association of Distinguished American Scientists (A.D.A.S.) for support and assistance in the long and arduous struggle to revise the basic foundations of electromagnetics and mechanics.

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SLIDE 2.

OUTLINE

- **MAIN BRIEFING**
  - **> TRANSLATOR EFFECTS**
  - **> POTENTIAL WEAPONS**
  - **> INCIDENTS**
  - **> CONCLUSION**
- **HISTORICAL BACKGROUND**
  - **> TESLA/MORAY**
  - **> WWII AND AFTER**
- **ELEMENTS OF THE EMERGING THEORY**
  - **> LONGITUDINAL/ TRANSVERSE WAVES**
  - **> VACUUM/MASS EFFECTS**
  - **> FLAWS IN VECTOR THEORY**
  - **> IMPLICATIONS**

This presentation is one part of a three part presentation, consisting of the main briefing on physical effects, the historical background, and the elements of the emerging new electromagnetics.

In this present briefing I will not cover the historical background. Instead, first I will address the concepts of the new theory, and then I will give an abbreviated main briefing, including some weapon aspects. I will present one simple free energy motor and show how it works, and where it gets its energy.

Much of this material I have known for some time, but have hesitated to release it because it enables one to develop -- in a fairly straightforward manner -- weapons and beams (ray) systems that can disable electronics, computers, communications, and people. Anyone handy in electronics, who has a few thousand dollars and access to bench equipment and an electronics parts supply house, can develop these weapons in his or her basement workshop. But because certain very radical elements in this country already know some of this information and may plan to utilize such devices in criminal activities, I am openly releasing the information as a warning, to be prepared.

Of course there are many good things that can be developed with this technology, including machines to heal a remarkable variety of ailments and illnesses. I strongly urge everyone to use this information wisely and only to benefit other human beings. There exists a cosmic or karmic law for those who misuse it against their fellow persons; if one does that, one will assuredly suffer the consequences.

Also, I strongly urge the development of Western defenses against the Soviet strategic and tactical weapons; already developed utilizing these principles. Unless the West wakes up to the extreme urgency of this task, in the near future we may be overwhelmed in short order by a much harsher, dictatorial system. If that should happen, it will plunge the human race into a new dark ages far more terrible than that dark period in history following the fall of Rome.

These are the final times, and this is the beginning of the final technology. The ability to directly engineer physical reality itself has been laid in our laps. Pandora's box is already spilled open, and there is no longer any stopping the new technology.

Let us prepare, then, for that which is to come.

With these introductory remarks, let us now turn to the main presentation.

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SLIDE 3.

CHARACTERISTICS OF SELECTED CONCEPTS

CONCEPT	**CHARACTERISTIC**
• **ENERGY**	**FLOW OF OBSERVABLE MASS PARTICLES**
• **ANENERGY**	**FLOW OF VIRTUAL PARTICLES**
• **PRESENT "CHARGE"**	**VIRTUAL PARTICLE FLUX TIED TO OBSERVABLE MASS PARTICLES**
• **TRUE CHARGE**	**VIRTUAL PARTICLE FLUX WITHOUT MASS**
• **FLUX**	**MULTI-DIRECTIONAL FLOW THROUGH A POINT**
• **FLOW**	**UNI-DIRECTIONAL MOVEMENT OF A FLUX [GRADIENT]**
• **CURRENT**	**UNI-DIRECTIONAL GRADIENT OF A [USUALLY CONSTRAINED] FLUX**

On this slide I show some fundamental defining characteristics of energy, "charge" or charged mass as presently in the theory, flux, flow, and current. These fundamental concepts are often somewhat confused in the literature.

Particularly note that the concept of energy, being tied to "the capacity to do work," is specifically tied to the concept of mass. Eventually, energy must be expressed in terms of moving masses -- specifically, in accelerating or decelerating masses.

I introduce the term "anenergy" here, specifically in relation to

the concept of a virtual particle. Anenergy is roughly equivalent to the present idea of "virtual energy,"
except it more precisely implies the flow or flux of virtual particles.

We also redefine charge as virtual particle flux, in order to remove the present error in EM theory where "charge" always implies a charged mass. The electrostatic scalar potential, phi (Ø) , then merely becomes the intensity of the massless charge -- that is, the intensity of the virtual particle flux -- at a point. Let me point out, however, that in the new view this "point" is always in n-dimensional space, where n is equal to or greater than four. The present 3-space formulation of Ø is thus a highly special case.

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SLIDE. 4

QUOTE FROM NIKOLA TESLA:

> **"THE HERTZ WAVE THEORY OF WIRELESS TRANSMISSION MAY BE KEPT UP FOR A WHILE, BUT I DO NOT HESITATE TO SAY THAT IN A SHORT TIME IT WILL BE RECOGNIZED AS ONE OF THE MOST REMARKABLE AND INEXPLICABLE ABERRATIONS OF THE SCIENTIFIC MIND WHICH HAS EVER BEEN RECORDED IN HISTORY."**

Nikola Tesla
"The True Wireless,"
The Electrical Experimenter

One of the things we will find is that Hertz or transverse electromagnetic waves are strictly mass waves in a charged mass particle medium.

For example, transverse EM waves do not, and CAN not, exist in vacuum. Vacuum EM waves are longitudinal waves of compression and rarefaction. What is compressed and rarified is the virtual particle flux that comprises vacuum itself. Vacuum EM waves in this virtual flux are just like sound waves in air -- in the flux of molecules and atoms that comprise the atmospheric gas.

Nikola Tesla, of course, knew this and he frequently pointed out the falsity of the accepted transverse wave theory. Here is one Tesla quote, for example, taken from The Electrical Experimenter. (PAUSE)

Almost every scientist -- even the "Tesla bugs" -- have thought Tesla wrong in his adamant opposition to the idea of Hertzian waves in the vacuum.

As we shall see, Tesla was right and all the present scientists and textbooks are wrong .

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SLIDE 5.

FORCE BETWEEN TWO LIKE CHARGES

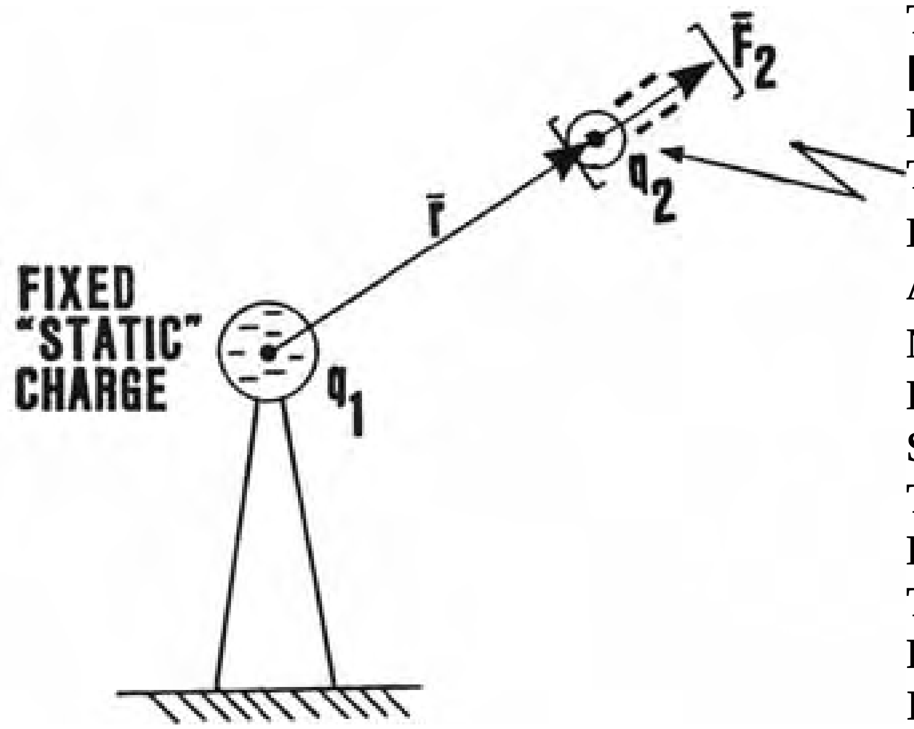

**A NEGATIVELY CHARGED
TEST MASS
[e.g., AN ELECTRON]
BROUGHT INTO
THE VICINITY OF q_1
EXPERIENCES
A FORCE $\bar{F}_2$ AS SHOWN.
NOTE THE
ELECTRON ACTUALLY IS
SPINNING.
THIS HAS NEVER BEEN
DONE WITH A
TRUE "STATIC CHARGE",
FOR THERE
IS NO SUCH THING IN
NATURE.**

In my presentation last year, I noted some 22 fundamental flaws in present electromagnetics theory. One of these flaws was in the actual vector theory itself. As we shall discover, one cannot simply plug geometrical vectors into physical systems without making fundamental errors. The vector concept itself must be adapted, for there are now four different kinds of vectors in physics, all confused as the same thing. We will come to that shortly.

To begin, let us look at the fundamental kind of experiment, shown on this slide, from which the idea of electrical force and electric field was taken.

We have a fixed static charged object q(l) in the laboratory, and we bring in a test charged mass q(2). The test charged mass may even be a single electron, as we illustrate here. We show in our example the fixed charge to be negative. When we release the test charge electron, it accelerates away from the fixed charged mass, as shown on the diagram. Note that we have no force at all until we bring in the test charged mass. Indeed, we shall find that the force is actually COMPRISED OF the accelerating test electron. Specifically, it is not something mysterious which appears in vacuum and PUSHES on the electron. We shall find that FORCE IS AN EFFECT, NOT A CAUSE. It CONSISTS OF the "smeared mass" that is accelerating -- in this case, it consists of the smeared, accelerating electron.

We summarize the experiment: in the absence of the charged test particle, no force exists in the vacuum. When we bring in the test charged mass, it accelerates away, and THE FORCE CONSISTS OF THAT ACCELERATING CHARGED MASS PARTICLE. The experiment does not at all address or deal with WHAT EXISTS IN THE VACUUM AROUND CHARGED MASS Q(l) IN THE ABSENCE OF TEST CHARGED MASS Q(2). Any assumption of a force existing in the vacuum is sheer speculation and not based on this experiment.

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SLIDE 6.

REPETITIONS LEAD TO THE VECTOR "FIELD" CONCEPT

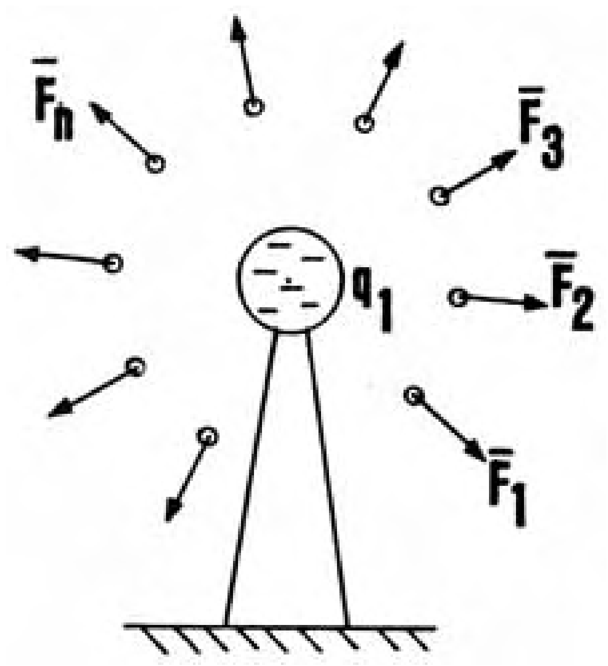

REPEATING FIGURE 4 A NUMBER OF TIMES LEADS TO SETS OF FORCE ARROWS, WHICH WE THEN VISUALIZE IN TOTAL AS A FIELD, Ë, OF FORCE(S) ABOUT q_1

RIGOROUSLY, THIS "FORCE FIELD" WOULD REQUIRE THAT A SPINNING CHARGED PARTICLE OF MASS EXIST AT EACH AND EVERY POINT IN SPACE ABOUT q_1

On this slide, we show that, as we repeat the experiment by bringing in the test charged mass from differing directions, the same thing happens around the fixed charged mass q(l). Test charged mass q (2) -- our electron -- accelerates radially away from q(l).

As we repeat the experiment and draw many of the little arrows radially outward, gradually the idea of a "vector field" emerges. That is, we form the idea that, at every point in space around fixed charge q (l), there exists one of our little vector arrows. Thus we assign a vector field to the space: to every point of it, there is assigned both a magnitude and a direction.

However, note that this does not describe the situation as it exists, at any time, in the "present." That is, rigorously any one arrow only exists whenever a little test charged mass is present and accelerating radially away.

We may take the view that the arrow WILL exist WHEN a test charged mass is brought to that point and released. In that case, the arrow WILL exist in the FUTURE, not the present. And we may refer to that as, it POTENTIALLY exists, when and if.. ..etc.

So already we see a fundamental logical problem in the idea of such a field. It WILL exist in the future, but only POTENTIALLY exists in the present.

Of course I am not the first one to point out such difficulties; the fact that the field concept is erroneous is already well-known to foundations scientists. But it is such a USEFUL concept that it is retained.

Now the Ë-field, or electric field, is defined as "the accelerating force on a charged mass per unit charged mass accelerated by it." If there is no charged mass present to be accelerated, then there can be no Ë-field present.

So Ë-field cannot exist in vacuum, for vacuum presupposes the absence of all observable mass.

So we can rigorously say that no Ë-field of force exists around the charged mass q(l) IN THE PRESENT. At best, it can only POTENTIALLY exist IN THE FUTURE.

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SLIDE 7.

A SCALAR HAS A HIDDEN [VIRTUAL] VECTOR SUBSTRUCTURE

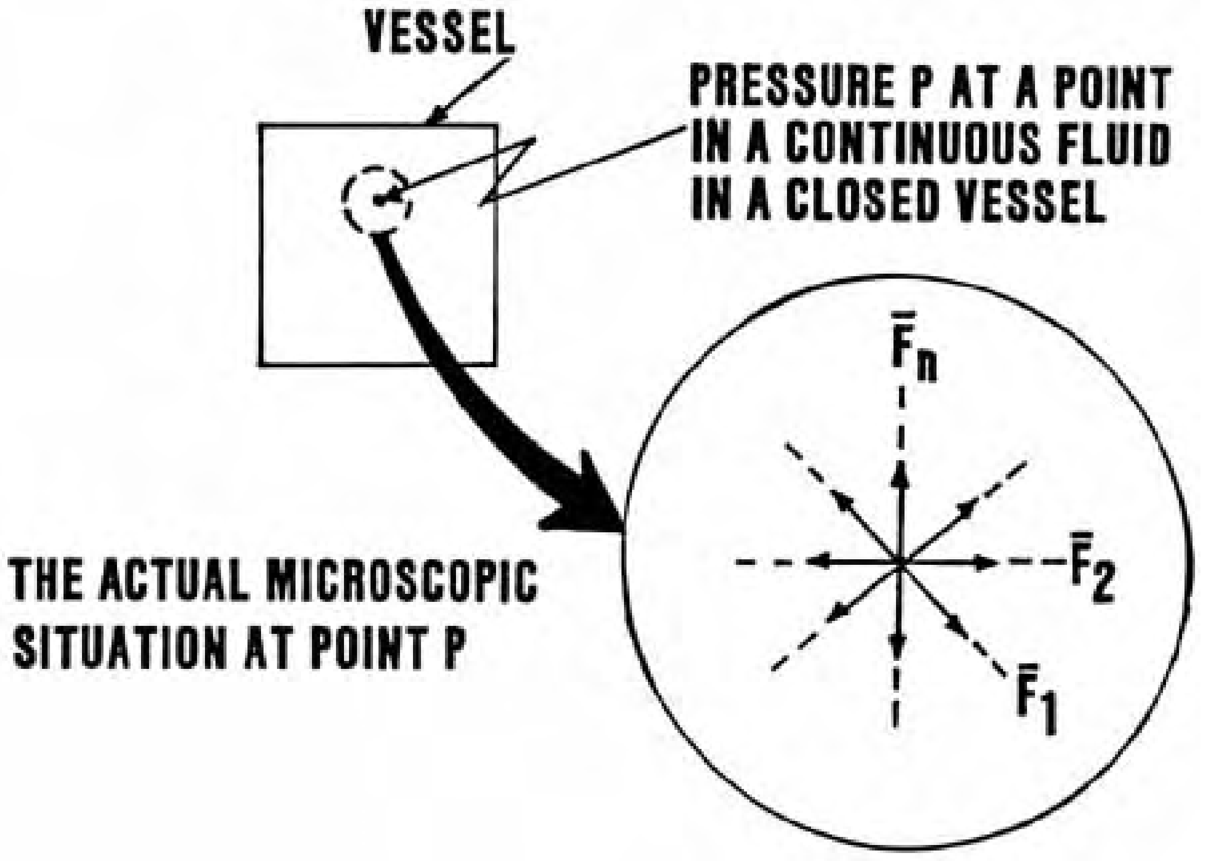
VESSEL
PRESSURE P AT A POINT IN A CONTINUOUS FLUID IN A CLOSED VESSEL
THE ACTUAL MICROSCOPIC SITUATION AT POINT P
$\bar{F}_n$
$\bar{F}_2$
$\bar{F}_1$

Our next slide shows that a physical scalar quantity has a hidden vector substructure.

For example, we show on the left a closed vessel containing a pressurized gas. The pressure at a point in the gas is a scalar quantity, since it has a magnitude but not a direction. However, physically what we have in the gas is a flux of individual molecules continually through any small volume, which we may let approach a point in the limit. Thus we have a flux in all directions through the point at which we specify pressure.

That is, the scalar "pressure" at a point may be said to contain a substructure of individual molecule flow vectors.

All physical process scalars have such hidden substructures. In the equilibrium case, the summation of all the individual flux vectors yields a resultant vector zero.

Thus we take the view that ANY PHYSICAL PROCESS SCALAR IS ALSO A ZERO VECTOR, AND ANY ZERO VECTOR IS A SCALAR AND CONTAINS A SUM-ZERO HIDDEN VECTOR SUBSTRUCTURE.

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SLIDE 8.

SCALAR AND VECTOR SUBSTRUCTURES

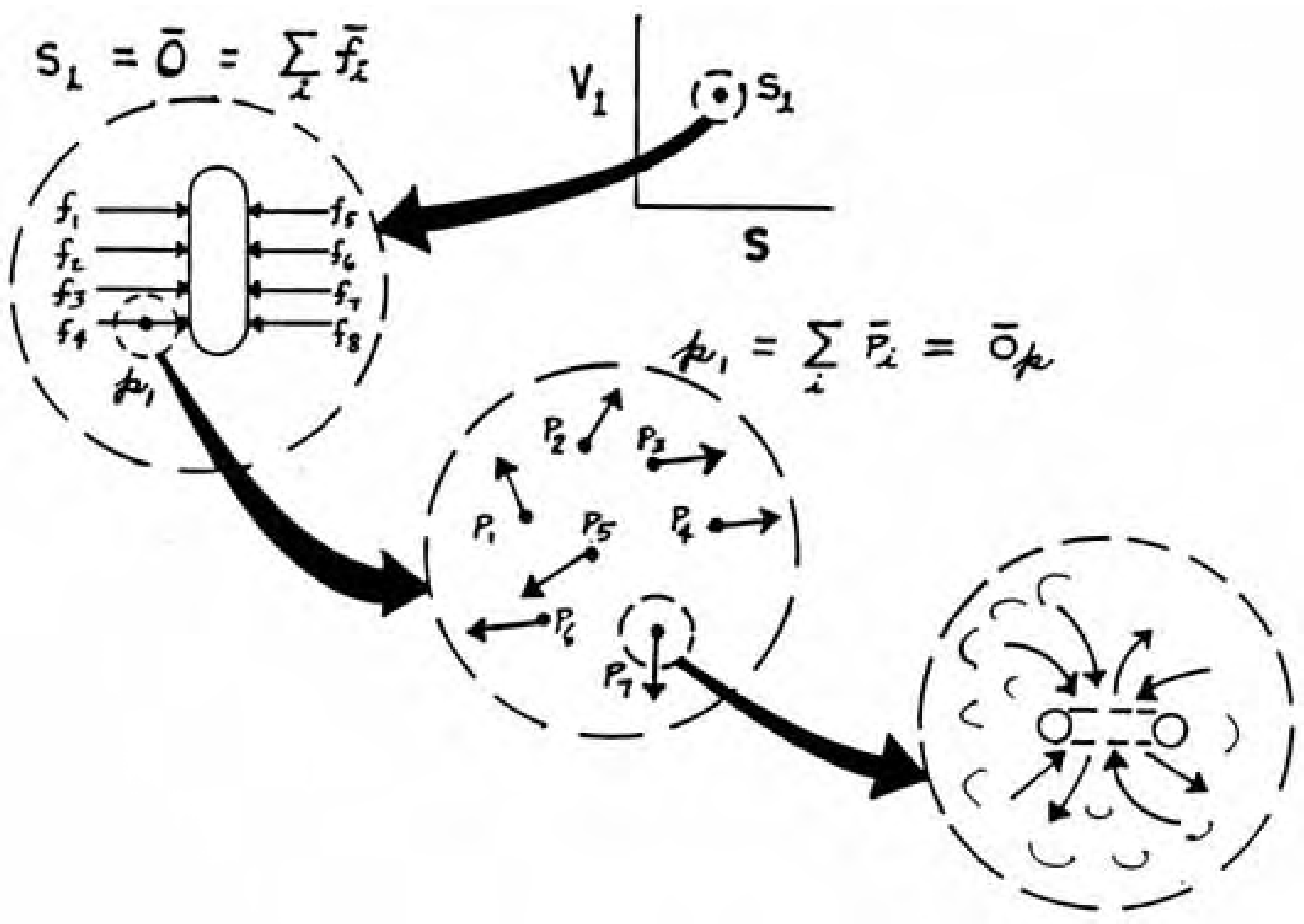
$S_1 = \bar{O} = \sum_i \bar{f}_i$
V_1
S_1
S
f_1
f_2
f_3
f_4
f_5
f_6
f_7
f_8
p_1
$p_1 = \sum_i \bar{P}_i = \bar{O}_p$
P_1
P_2
P_3
P_4
P_5
P_6
P_7

Now let us see if we can do some unusual thinking about the hidden vector substructure of a scalar or zero-vector.

On the leftmost figure in this slide, we show a plate with balanced opposing forces. The vector summation of all the forces' is zero, so the system has no resultant vector. The plate therefore does not move. However, the plate -- that is, the medium in which the forces act -- is stressed, much like the previous example of pressure in a gas. The difference is that now the stress is patterned in its substructure, and not random. Now suppose we rhythmically vary the forces, each the same, in a regular manner in time. Yet we maintain a continuous balance, so there is never a system resultant greater than zero. In this case, we maintain our vector zero, but we are producing regular stress waves in the plate medium..

I think you now can see that I can vary the individual opposing vector pairs so that rhythmic waves flow from top to bottom, or from bottom to top. That, of course, will describe a vector gradient traveling through the medium, and that will be an ordinary "vector wave." Is there any way I can make waves through the medium, and not have such vector waves ever appear?

Indeed there is, if I look further into the substructure. Take one point on one of the vectors shown acting on the plate in the left diagram. That point is a scalar, and it also has a substructure of even finer vectors, as shown in the lower middle figure. And any point in one of these second-order hidden vectors is a scalar and composed of a still finer hidden vector substructure, as shown in the lower right figure. This process repeats ad infinitum, and all is structures within structures. At least it can be modeled that way, for it already is treated that way in particle physics.

Now go back to the second order vector substructure. Here I can establish whatever patterns I wish, and not affect the first order pattern shown in the figure on the left. I can even rhythmically vary things in the second order substructure, and leave a blissfully unchanged first order substructure, to the first order observer.

So I can make as many waves; as I wish through the medium, as long as I stay second order or higher, and the external observer will never see any change at all unless he has a special detector of some sort to detect the lower substructure changes.

As I showed in the Appendix to my book, The Excalibur Briefing, these substructures are in reality the same thing as hyperspaces. And movements in them can proceed much faster than the speed of light.

So I can have higher order signals and waves through the stressed medium without changing the overall first order stress in the medium.

This is a sort of super-relativity; the present relativity is just a special case.

Superluminal communication systems are perfectly possible, but not with the present first order transmitters and receiver/detectors.

Note also that higher order stresses -- stresses in the higher order substructures -- represent special stresses in time, and time has an internal stress-pattern substructure. The higher order stress waves are phase waves or phase fluctuations in that respect.

Also note that Charles Musés has already created the hypernumber mathematics of the structure of time, and it is largely in his mathematics that these concepts will have to be mathematically modeled.

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SLIDE 9.

SUPERPOSITION DOES NOT ELIMINATE THE VIRTUAL SUBSTRUCTURE

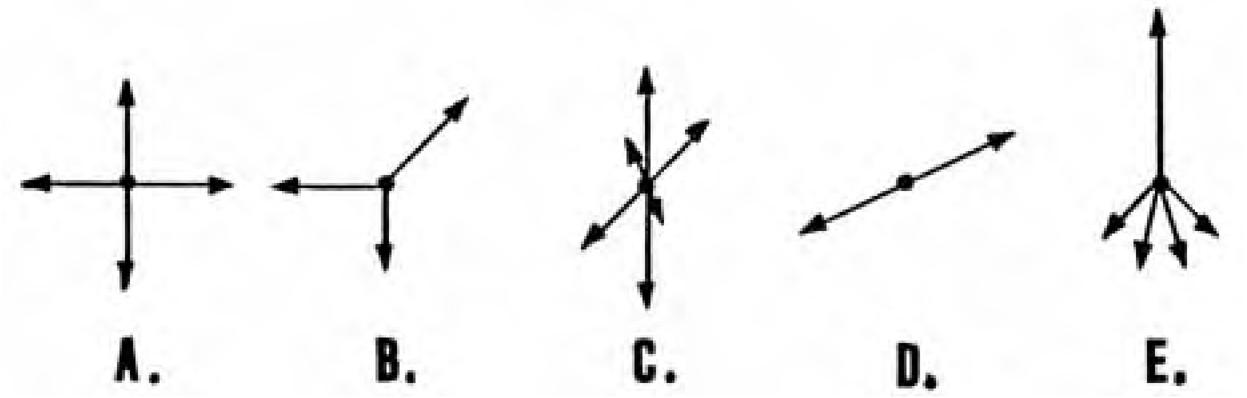

TWO OR MORE MACROSCOPICALLY "EQUAL" VECTORS OR SCALARS CAN DIFFER DRASTICALLY IN THEIR VIRTUAL SUBSTRUCTURE DISTRIBUTIONS. EVEN TWO "ZEROS" MAY BE DYNAMICALLY DIFFERENT DUE TO THEIR DIFFERING SUBSTRUCTURES.

Next we show some simple substructures of a zero vector. All of these vector systems sum to zero vectorially. Note that if we superpose two of these structures, all substructure vectors are still present., and the vector summation is still zero.

Also notice that, from the standpoint of substructuring, zeros can be and are drastically different.

We can even make rhythmic waves in the substructure by superposing patterned zero vectors in a regular fashion.

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SLIDE 10.

PHYSICAL VECTORS

- **VECTOR: A "SMEARED PARTICLE"**
- **FOUR MAJOR PARTICLES IN PHYSICS:**
  - POINT [MASSLESS, CHARGELESS]
  - MASS [CHARGELESS]
  - CHARGED MASS
  - CHARGED POINT [MASSLESS}
- **LEADS TO FOUR MAJOR VECTORS:**
  - GEOMETER'S
  - MECHANIC'S
  - ELECTRICIAN'S
  - ADVANCED ELECTRICIAN'S

In quantum mechanics, as we approach the quantum level, we find that the notions of a particle (static concept) and a wave become inseparable. That is, any particle becomes a "smear" in length and time, and it becomes inseparable from its smear. At the quantum level, there is no separate energy, length, mass, momentum, energy, or time -- all are welded together inextricably into a quantity called "action," having the units of angular momentum.

So at the fundamental quantum level, a moving point becomes a smear, and a vector represents a physical, undifferentiated entity.

To go quickly, we now define a vector as consisting of a smeared particle. That is, the particle is smeared in both time and length, and it is not differentiated from time or length.

There are four kinds of particles in physics which can be smeared to form vectors. First, there is a point in space or spacetime. This point may be approximated as massless and chargeless. At least that is the way the geometers of old conceived it in the abstract, and so the idea of a "point" in space assumes it to be chargeless and massless. Second, there is a tiny particle of mass, often abstracted to be a "point-mass," but visualized as having no charge. This is the mechanic's particle. Third, there is a tiny charged mass, such as an electron, and this is the electrician's particle. Again, it is often abstracted as a charged point-mass. Fourth, there is a charged point, having no mass, and this is the advanced electrician's particle, which he uses to form the idea of potentials and fields.

Smearing these four particles at the fundamental quantum level produces four different kinds of physical vectors: the geometer's, the mechanic's, the electrician's and the advanced electrician's vectors. They are all different.

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SLIDE 11.

THE FOUR VECTORS OF PHYSICS

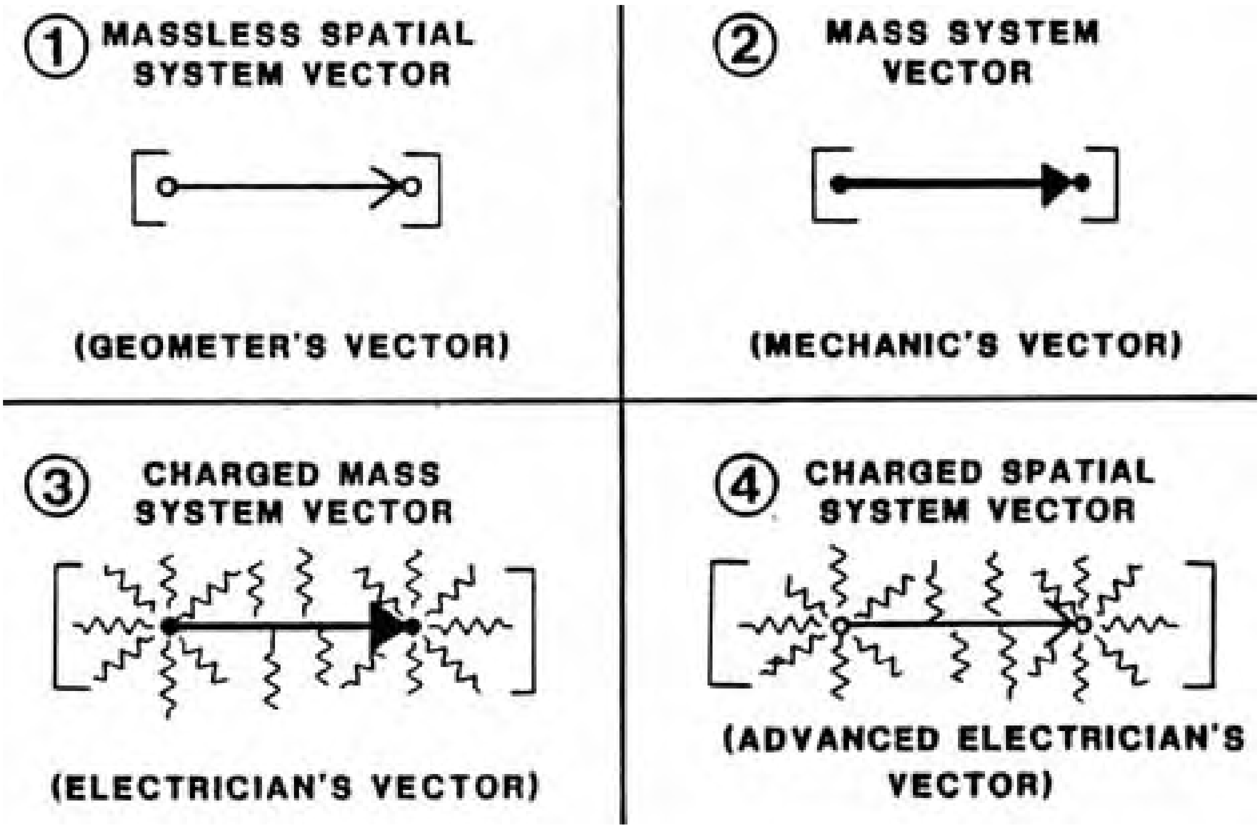
① MASSLESS SPATIAL SYSTEM VECTOR
(GEOMETER'S VECTOR)
② MASS SYSTEM VECTOR
(MECHANIC'S VECTOR)
③ CHARGED MASS SYSTEM VECTOR
(ELECTRICIAN'S VECTOR)
④ CHARGED SPATIAL SYSTEM VECTOR
(ADVANCED ELECTRICIAN'S VECTOR)

On this slide we show a graphic illustration of each of these vectors.

Note that they may be visualized as smeared particles, but the particle is not separate from the smear in time and length.

Each vector must be considered as a unitary entity -- it is a special kind of quantum, if you will.

Each is a special quantum of motion.

And Dewey Larson has it right when he says, "All is motion."

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SLIDE 12.

FORCE DEFINITION

- *A TRUE DEFINITION IS AN IDENTITY.*

$$F \equiv d/dt\,(mv)$$

- **FORCE CONSISTS OF THE TIME RATE OF CHANGE OF MOMENTUM**
- **MOMENTUM IS A MASS SMEARED THROUGH A LENGTH IN A CERTAIN TIME**
- **FORCE CONSISTS OF MASS-MOTION-CHANGE**
- ***FORCE IS AN EFFECT, NOT A CAUSE !***

We now look a little closer at the concept of a force.

I point out that a true definition is an identity. If a supposed definition of an entity is not an identity for that entity, then it is not a definition at all, but only a statement ABOUT the entity.

It may come as somewhat of a shock to the normal engineer and scientist that the foundations concepts of physics -- such as force, mass, energy, etc. -- are ALL in serious difficulty and contain many unresolved logical conflicts.

Force is in that kind of difficulty, and it has that kind of logical conflict.

In fact, in its force equations, physics has not even applied its own present definition of force.

As we show here, force is generally defined as the time rate of change of momentum.

If that is true, then as an identity the definition states that a force CONSISTS OF the time rate of change of momentum.

And of course, momentum is mass times velocity. Hence momentum is a mass smeared through a length and through a certain time.

Force then consists of the time rate of change of that smearing. That is, we smear the mass through time and length, faster or slower.

But if force CONSISTS OF that smearing change, it does not CAUSE it.

Force is thus an effect or result, not a cause.

This implies that there is a more fundamental mechanism that causes or generates force itself -- ANY force. If we can find that hidden mechanism, we may well find the long-sought unified field theory, since it will unify all forces on a common mechanism.

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SLIDE 13.

FORCE IS AN EFFECT NOT A CAUSE

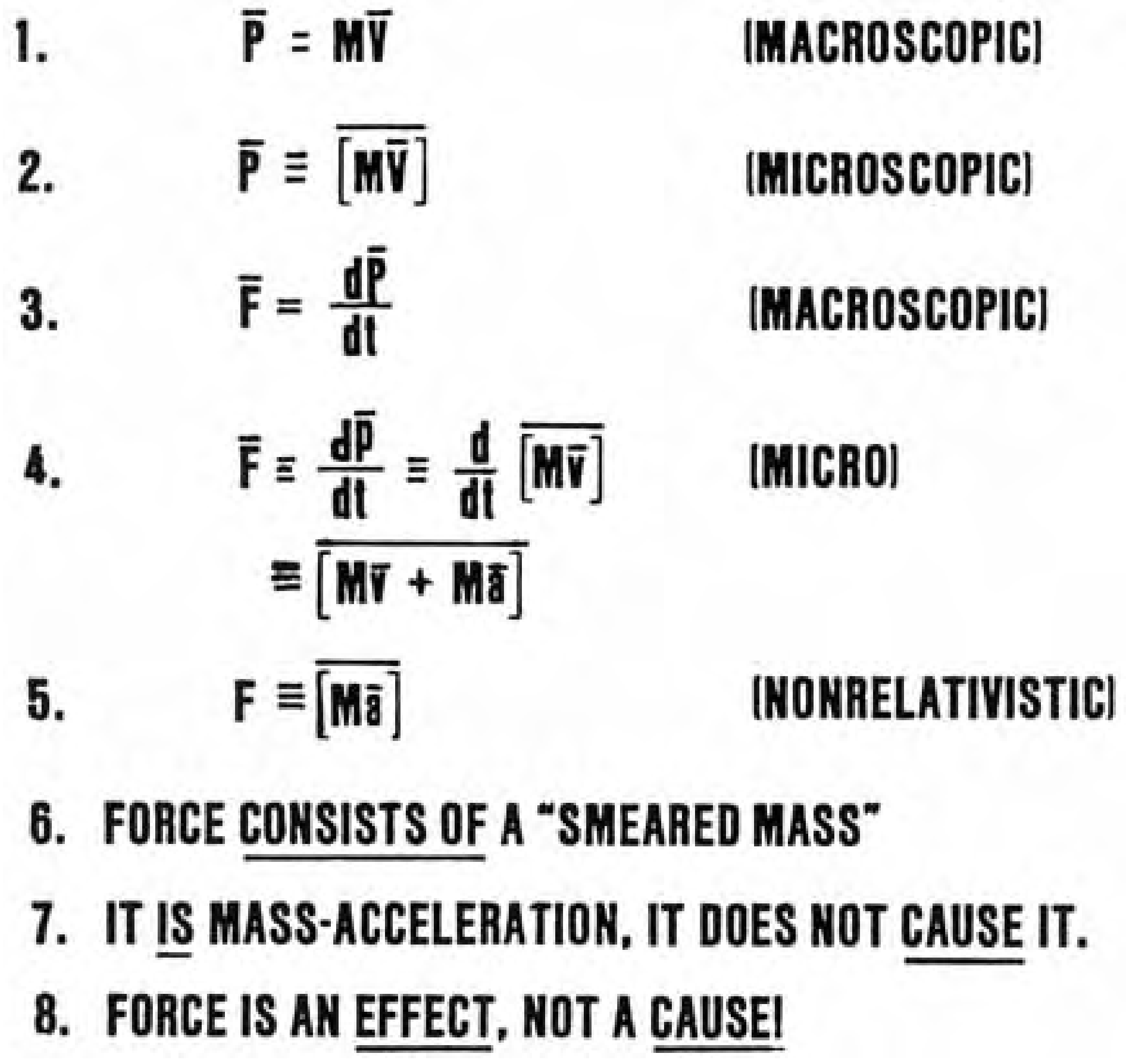

1. $\bar{P} = M\bar{V}$ (MACROSCOPIC)

2. $\bar{P} \equiv \overline{[M\bar{V}]}$ (MICROSCOPIC)

3. $\bar{F} = \frac{d\bar{P}}{dt}$ (MACROSCOPIC)

4. $\bar{F} \equiv \frac{d\bar{p}}{dt} \equiv \frac{d}{dt}\overline{[M\bar{v}]}$ (MICRO)

   $\equiv \overline{[M\bar{v} + M\bar{a}]}$

5. $F \equiv \overline{[M\bar{a}]}$ (NONRELATIVISTIC)

6. FORCE CONSISTS OF A "SMEARED MASS"

7. IT IS MASS-ACCELERATION, IT DOES NOT CAUSE IT.

8. FORCE IS AN EFFECT, NOT A CAUSE!

On this slide, we show briefly how one might express this idea in mathematical symbology.

Macroscopically, momentum consists of mass times velocity. Microscopically, the mass and the velocity are inextricable, and it is not proper to speak of a "mass in motion," but only of "mass-motion." We show this in equation 2.

We take the macro definition of momentum, as shown in equation 3, and express it for the microscopic, unseparated case, as shown in equation 4.

In the nonrelativistic case, we may consider m-dot to be zero, since the time rate of change of mass is almost zero. In that case, force may be defined for the microscopic case as a smeared accelerating mass, as shown in equation 5.

Force thus consists of the welded mass and acceleration, with no seam in the middle.

It IS mass-acceleration; it does not CAUSE it. Therefore force is an effect, not a cause.

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SLIDE. 14

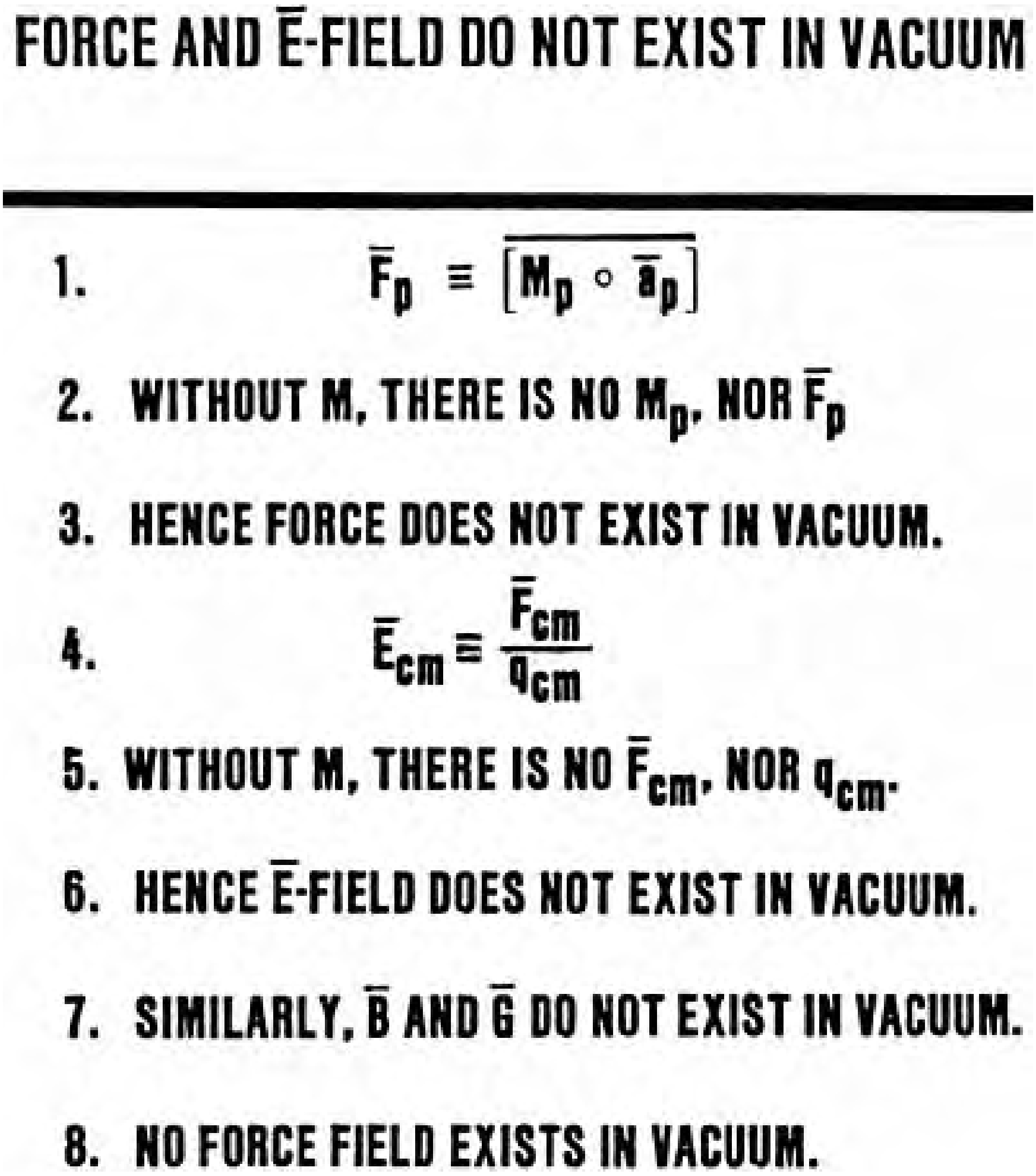

FORCE AND $\bar{E}$-FIELD DO NOT EXIST IN VACUUM

1. $$\bar{F}_p \equiv \overline{[M_p \circ \bar{a}_p]}$$
2. WITHOUT M, THERE IS NO M_p, NOR $\bar{F}_p$
3. HENCE FORCE DOES NOT EXIST IN VACUUM.
4. $$\bar{E}_{cm} \equiv \frac{\bar{F}_{cm}}{q_{cm}}$$
5. WITHOUT M, THERE IS NO $\bar{F}_{cm}$, NOR q_{cm}.
6. HENCE $\bar{E}$-FIELD DOES NOT EXIST IN VACUUM.
7. SIMILARLY, $\bar{B}$ AND $\bar{G}$ DO NOT EXIST IN VACUUM.
8. NO FORCE FIELD EXISTS IN VACUUM.

But if force CONSISTS OF mass welded to acceleration, it cannot exist in the absence of mass.

Hence force does not exist in vacuum.

Further, the Ë-field (Electric field) of a charged particle is defined as the force on a charged mass, divided by the mass. That is, the Ë-field is thought to represent the force per unit charged mass. And then it is assumed to exist in vacuum.

But vacuum is without mass or charged mass, observably. Without mass, neither force nor charged mass exists.

Therefore the Ë-field does not exist in the vacuum.

Magnetic field (B) and gravitational field (G) are similarly defined, and they have the same logical difficulties.

Therefore neither magnetic field nor gravitational field exist in vacuum.

A priori, NO force field exists in vacuum.

The greatest error in physics has been the assignment of a force as a cause, and thus assigning it to the vacuum. The force is an effect, and it never exists in vacuum, a priori.

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SLIDE 15.

COROLLARIES

- **MORE PRIMARY MECHANISM CAUSES/GENERATES FORCE -- ANY FORCE**
- **FORCE DOES NOT EXIST IN VACUUM, SINCE VACUUM IS THE ABSENCE OF MASS**
- **FORCE FIELDS DO NOT EXIST IN VACUUM**
    - **E-FIELD**
    - **B-FIELD**
- **TRANSVERSE [HERTZIAN] WAVES DO NOT EXIST IN VACUUM**

Without belaboring the issue, I now point out and summarize some of these conclusions.

First, a more primary mechanism causes or generates force -- ANY force.

Second, force implies the presence of mass a priori. Force does not exist in vacuum, since vacuum is the absence of mass. _

Third, no force fields of any kind exist in vacuum, including Ë-field, B-field, and gravitational field. _

Fourth, since Hertzian waves are defined in terms of Ë and H force fields, and these fields do not exist in vacuum, then Hertzian waves do not exist in vacuum.

Tesla pointed out long ago that vacuum EM waves are longitudinal waves, not Hertz waves. Vacuum EM waves are similar to sound waves in a gas.

The Hertz wave exists as a matter wave in the electron gas in a transmitting antenna, and in the electron gas in a receiving antenna, but does not exist in the vacuum in between the two antennas. Between them, EM waves are longitudinal waves.

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SLIDE 16.

ENERGY IS DERIVED, NOT FUNDAMENTAL

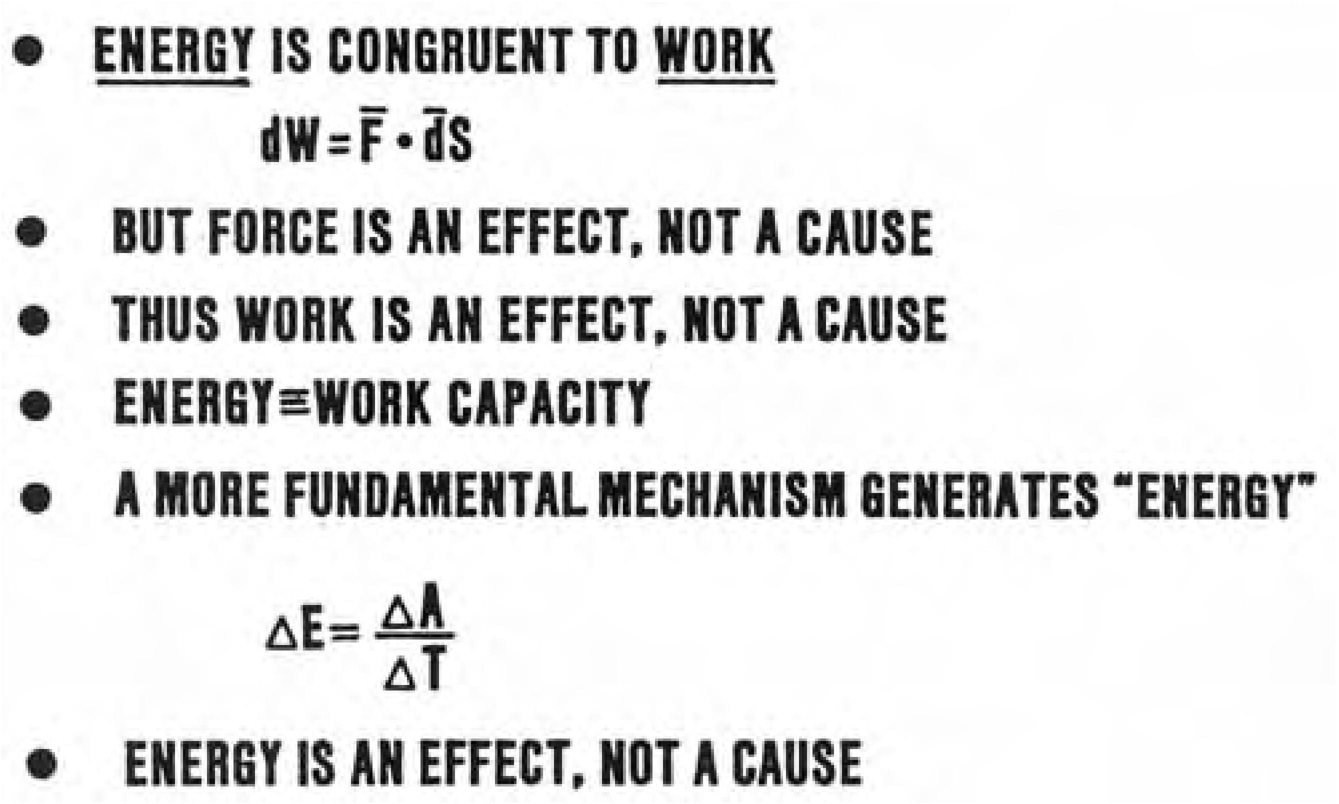

- ENERGY IS CONGRUENT TO WORK

$$dW = \bar{F} \cdot \bar{d}S$$

- BUT FORCE IS AN EFFECT, NOT A CAUSE
- THUS WORK IS AN EFFECT, NOT A CAUSE
- ENERGY≅WORK CAPACITY
- A MORE FUNDAMENTAL MECHANISM GENERATES "ENERGY"

$$\Delta E = \frac{\Delta A}{\Delta T}$$

- ENERGY IS AN EFFECT, NOT A CAUSE

Energy is usually taken as "the capacity to do work" at some future time. In other words, when we refer to the energy of something, we refer to HOW MUCH WORK IT CAN DO IN THE FUTURE, IF AND WHEN WE ARRANGE FOR IT TO DO IT. Rigorously, a body has no "work" at a particular instant in time, so we use "energy" to refer to potential work that can, or will, be done in the future. Thus energy is always congruent to work in the future.

And for that reason, the units of energy are the units of work; the only difference is in the time the work is done, relative to the "now" or "present" we are speaking of.

Energy is the potential for work to be done in the future.

But what is work?

Well, work is defined in terms of the movement of a force through a distance. And it is understood that only the projection of the force along the line of movement is "working." Thus work is defined differentially as shown on the slide. The differential of work is equal to the dot product of the moving force times the differential of displacement.

But as we have seen, force is an effect, not a cause.

That is, when we calculate the work done, it's always in the past, never in the present or future. It's always been DONE, and has been expended.

Being in the past, it's gone forever, so it certainly isn't the CAUSE of anything which happens in the future.

Thus work is an effect, not a cause.

That's interesting, because then it certainly does not directly generate "energy," since energy is something in the present which speaks of future work to be done.

Rigorously, the fundamental quantum -- which is what exists in the present, in unseparated and unquantized form -- consists of action. NOT energy, NOT time, NOT length, NOT momentum exclusively, but all of these INclusively.

And a change in energy occurs when a quantum is separated at a certain rate in time. Thus delta energy equals the time rate of change of action, or delta action divided by the delta time used in separating the quantum and fissioning it into parts (collapsing the wave function).

Thus energy itself is an effect or result of a more fundamental mechanism, and it is not a cause.

In quantum mechanics all this has been neatly "buried" in the mysterious "collapse of the wave function," which is supposedly what "causes" everything to happen. And then we swear that what results after the collapse is a totally statistical selection from the possible states of the system we are examining. We thus say that the microworld is totally statistical at base. Of course we also build a wave equation or wave function which propagates forward in time with rigorous causality, and that wave or function absolutely controls the basket of "possible states" allowed .

All that says is that the "wave function times time" is what exists in the present, when observation has not been made by "stopping time." And then we "stop time" in a rather blunt manner, somewhat like firing a billiard ball blindly into a group of billiard balls on a table, and we live with what gets hit and pops out.

If we examine this "time" that is flowing, look into its substructure, and arrange that substructure as we will, we can control which "billiard ball" is hit and which pocket it goes into. By working on the vector substructures of time, we can thus deliberately control the microworld and make it causal, not statistical. Quantum mechanics is in error in stopping where it has; it is presently only a first order approximation of the real quantum mechanics that awaits.

Einstein was correct after all; God does NOT play dice with the universe when one considers all levels.

One finds oneself in a statistical situation at one level only when the constituent sublevels of it are uncontrolled.

Next Chapter

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SLIDE 17.

EXISTENCE IN, AND PASSAGE THROUGH, TIME

- **IN RELATIVITY, TRANSLATION OF A BODY AND PASSAGE THROUGH TIME ARE RELATED**

  $$\Delta L = C \Delta T$$

- **"MASS" IS SPATIAL**
  - **DOES NOT EXIST IN TIME**
  - **"MASS-TIME" EXISTS IN TIME**

- **VIRTUAL FLUX TO AND FROM A BARE PARTICLE DETERMINES ITS "PASSAGE THRU TIME"**

- **SPHERICAL SPIN OF A MASS PARTICLE [L^3] COUPLES IT TO THE SPACETIME VACUUM [L^3T] VIRTUAL PARTICLE FLUX**

- **PASSAGE THROUGH ORDINARY TIME IS CONTROLLED BY CREATION AND ANNIHILATION OF QUANTA**

On this slide, we simply point out that translation of a body through space and its passage through time are related, according to relativity.

Now "mass" is spatial.

It does not exist in time.

Only things which contain the unit of time can "exist in time."

Otherwise, the thing only exists as such when the passage of time has been momentarily stopped -- usually by photon emission and the consequent carrying off of the time unit by the photon.

Since every mass that has temperature -- and every mass does -- is continually absorbing and emitting photons, then the mass is continually grabbing a time tail (absorption) and losing it (emission) shortly thereafter.

Masstime is what exists in time, not mass.

And every mass particle is continually turning from mass to masstime to mass, etc.

Indeed, it is the summation of the absorption and emission of virtual subquanta by a mass particle -- i.e., its "charge" -- that determines its rate of flow through "time."

And the spherical spin of a mass particle couples the particle of mass to the spacetime vacuum; that is, to the virtual particle flux.

Passage through ordinary time is controlled by creation and annihilation of quanta, and these processes are controlled by substructure (subquantal) actions and interactions.

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SLIDE 18.

SOME IMPLICATIONS

- **MODIFIES CONSERVATION OF CHARGE**
- **MODIFIES CONSERVATION OF ENERGY**
  - ***MASS***
  - ***ENERGY***
  - ***ANENERGY (MASSLESS CHARGE)***
- **MODIFIES NEWTON'S LAW**
  - ***FOR EVERY ACTION, THERE IS AN OPPOSITE AND EQUAL REACTION***
  - ***REACTION NEED NOT BE LOCAL***
  - ***REACTION NEED NOT BE ANTIPARALLEL***
- **UNIFIED FIELD THEORY**

Without belaboring the issue, I now simply point out some implications of the new approach.

First, we modify two laws -- the conservation of charge and the conservation of energy -- by combining them into one law, a new conservation law in which anenergy is conserved.

Neither charge per se nor energy per se need be conserved; but the overall anenergy (massless charge) equivalency is what is conserved. This allows us to derive mechanisms for free energy from the vacuum, for example. These mechanisms readily violate the present conservation of energy law, but do not violate the overall conservation of anenergy law.

It is the total anenergy equivalency of mass, energy, and massless charge that is now to be conserved in general. The old laws are now just special cases.

Also, Newton's third law -- for every action there is an equal and opposite reaction -- is modified. It still applies, but in changed form.

The reaction still occurs, but it need not be local, and it need not be antiparallel to the original action.

Thus it is now possible to design and build a "locally reactionless" inertial space drive for a vehicle.

The final implication is that the common mechanism producing force -- any force -- provides a unified field theory. Specifically, it provides one which easily lends itself to direct engineering. It is not esoteric nor mysterious. It is practical and physical, and it can be done with some modifications to our present electrical circuits and devices.

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SLIDE 19.

CONSERVATION OF ANENERGY (AE):
(AN EXPANDED ENERGY CONSERVATION LAW)

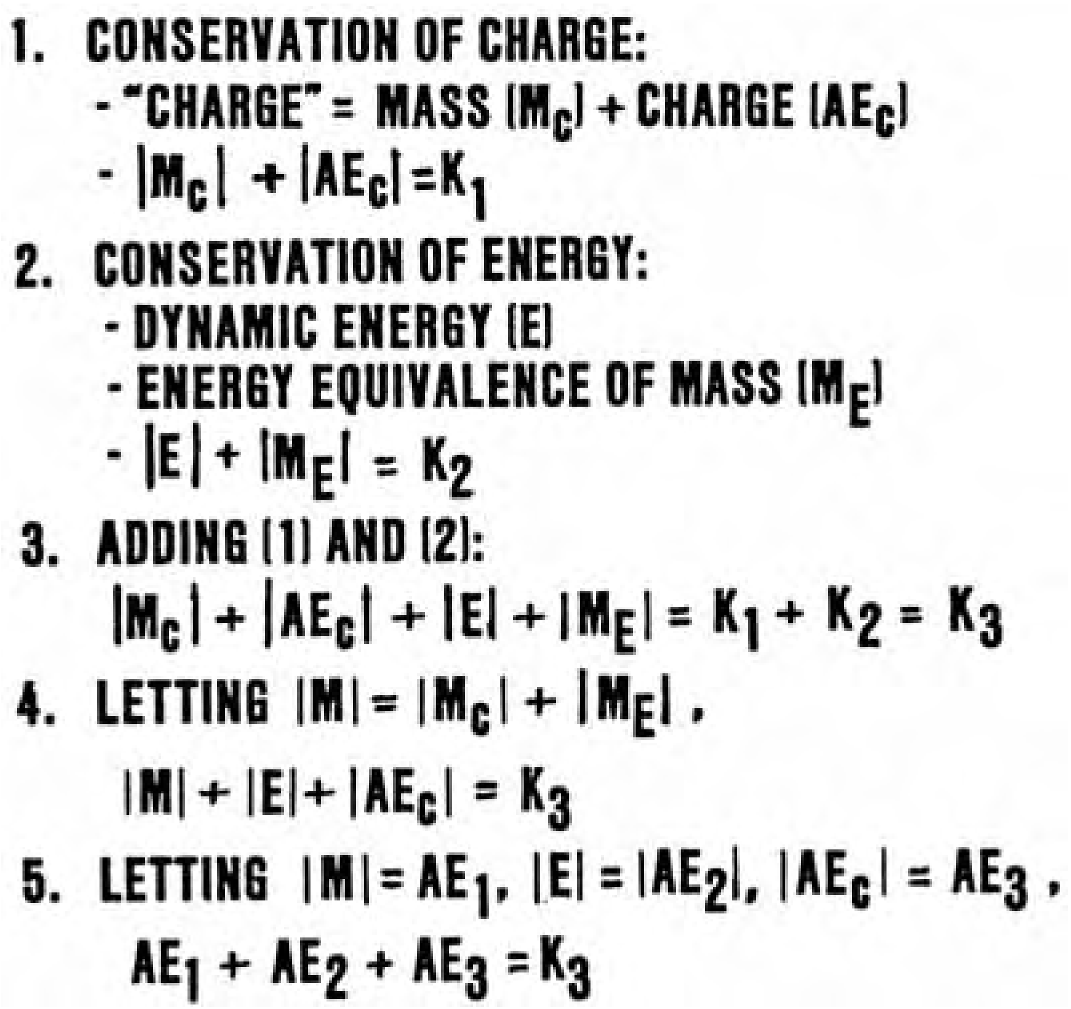

1. CONSERVATION OF CHARGE:
   - "CHARGE" = MASS (M_C) + CHARGE (AE_C)
   - $|M_C| + |AE_C| = K_1$
2. CONSERVATION OF ENERGY:
   - DYNAMIC ENERGY (E)
   - ENERGY EQUIVALENCE OF MASS (M_E)
   - $|E| + |M_E| = K_2$
3. ADDING (1) AND (2):

   $|M_C| + |AE_C| + |E| + |M_E| = K_1 + K_2 = K_3$
4. LETTING $|M| = |M_C| + |M_E|$,

   $|M| + |E| + |AE_C| = K_3$
5. LETTING $|M| = AE_1$, $|E| = |AE_2|$, $|AE_C| = AE_3$,

   $AE_1 + AE_2 + AE_3 = K_3$

We briefly show a simplified derivation of the new conservation of anenergy law.

We express the conservation of charge law by correcting the term "charge" to show its true meaning: charged mass. We use the absolute value symbol to mean the "anenergy equivalency."

As shown on the slide, we account separately :for the mass (m-sub-c) of the conserved charges and the virtual particle charge flux (the anenergy -- AE-sub-c) of the charges conserved. That law now says that the absolute values of the masses and the massless charge fluxes have a total constant summation.

For a dynamic mass, we do a similar thing, in this simplified case ignoring potential energy of position, and taking the energy equivalence of the dynamic energy (M-sub-E) and the rest mass energy of the particles, M-sub-E. The conservation of energy now states that these two terms have a constant absolute value summation.

We add equations 1 and 2, getting equation 3. We consolidate like terms to get equation 4.

Expressing all terms in their anenergy equivalencies (absolute values), we get equation 5, which is the overall conservation of anenergy equivalency.

Note that we now can change mass into energy or anenergy (massless charge), energy into mass or anenergy, and anenergy into mass or energy.

Thus we can turn everything into pure vacuum ether (pure massless charge, pure anenergy, pure electrostatic scalar potential, pure stress on spacetime) or we can turn part of the vacuum into energy or particles of mass.

Vacuum now becomes a very real thing indeed.

It is pure anenergy.

Pure massless charge, pure electrostatic scalar potential, pure "broken bits" (subquantal bits) of (quantized) energy.

The vacuum is identically the virtual state.

It is not an emptiness filled with virtual things; rather, it IS the sum total of those virtual things, for they are totally unseparated until some sort of "conceptual observation" is invoked.

Physics should have adopted Einstein's suggestion that the vacuum, complete with its EM and gravitational fields, be called the ether.

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SLIDE 20.

FREE ENERGY IS ALLOWED

- **ANY ONE-WAY GATING PROCESS FROM ANENERGY TO ENERGY YIELDS "FREE ENERGY" SINCE THE ANENERGY IS AUTOMATICALLY REPLENISHED BY THE UNIVERSE.**

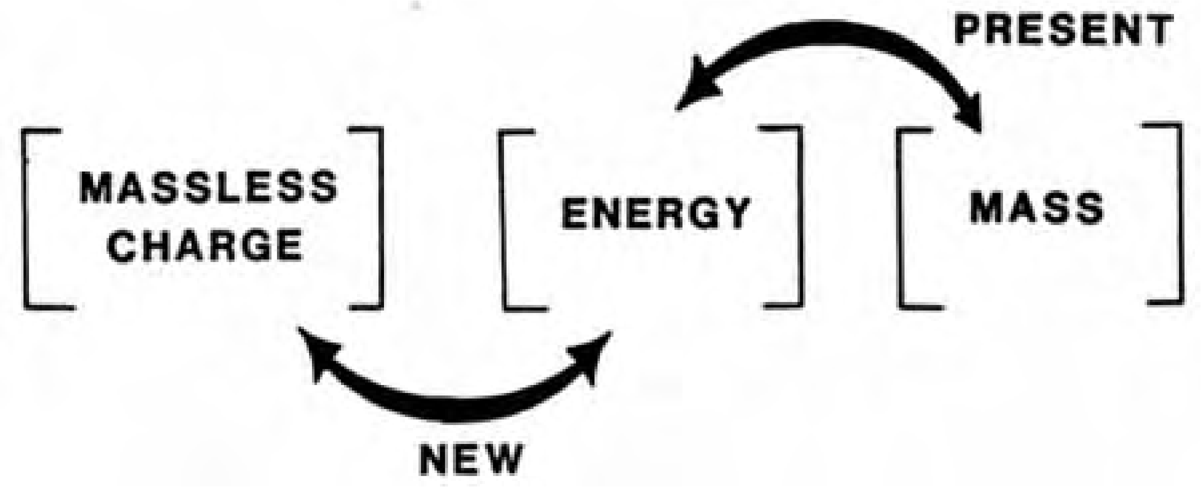
PRESENT
MASSLESS CHARGE
ENERGY
MASS
NEW

Now we can put the search for free energy devices on a rigorous scientific basis.

As shown here, mass and energy are translatable one into the other. So are massless charge and energy.

And the universe is filled with fantastic amounts of anenergy; ultimately, that is what the universal vacuum IS.

Any one-way gating process from anenergy to energy yields "free energy" since the anenergy is automatically replenished by the universe.

A sort of Maxwell's demon, after all, is what we need. Only we need one which works with the virtual state, not observable molecules.

Fortunately nature has provided several Maxwell's demons of this sort, if we but recognize them and learn to use them.

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SLIDE 21.

SCALAR POTENTIAL CAN FORCE THE RELATIVISTIC CASE

- **FOR SCALAR POTENTIAL ENERGY OF APPRECIABLE SIZE RELATIVE TO A PARTICLE'S REST ENERGY.**
  - **NEWTONIAN MECHANICS AND**
  - **THE SCHRODINGER EQUATION**
- **MAY BE INADEQUATE**
  - **EVEN IF V/C IS SMALL**

Bloch & Crater, "Lorentz-invariant potentials and the non-relativistic limit," American Journal of Physics, Vol. 49, No. 1, Jan. 1981, pp. 67-75

First, let us now digress to point out that one does not have to have relativistic velocity to obtain relativistic effects.

One can use the common electrostatic scalar potential to drive the situation relativistic. On this slide we show just one of several references in the standard literature that address this fact.

Let's understand what we are saying.

Anything you get from a relativistic situation, you can get directly by cleverly applying electrostatic scalar potential.

You can get a change in the passage through time, you can get energy changes, mass changes, inertial resistance changes, etc.

You can bend, warp, and twist spacetime like a pretzel.

If you "wave" the scalar potential by simply varying it , you can create pure time waves. You can also produce pure inertial field waves, pure gravitational waves, etc.

The ability to engineer the curving of spacetime allows the direct ability to engineer physical reality itself.

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SLIDE 22.

SCALAR STRESS WAVE
[Ō-WAVE] [TESLA WAVE]

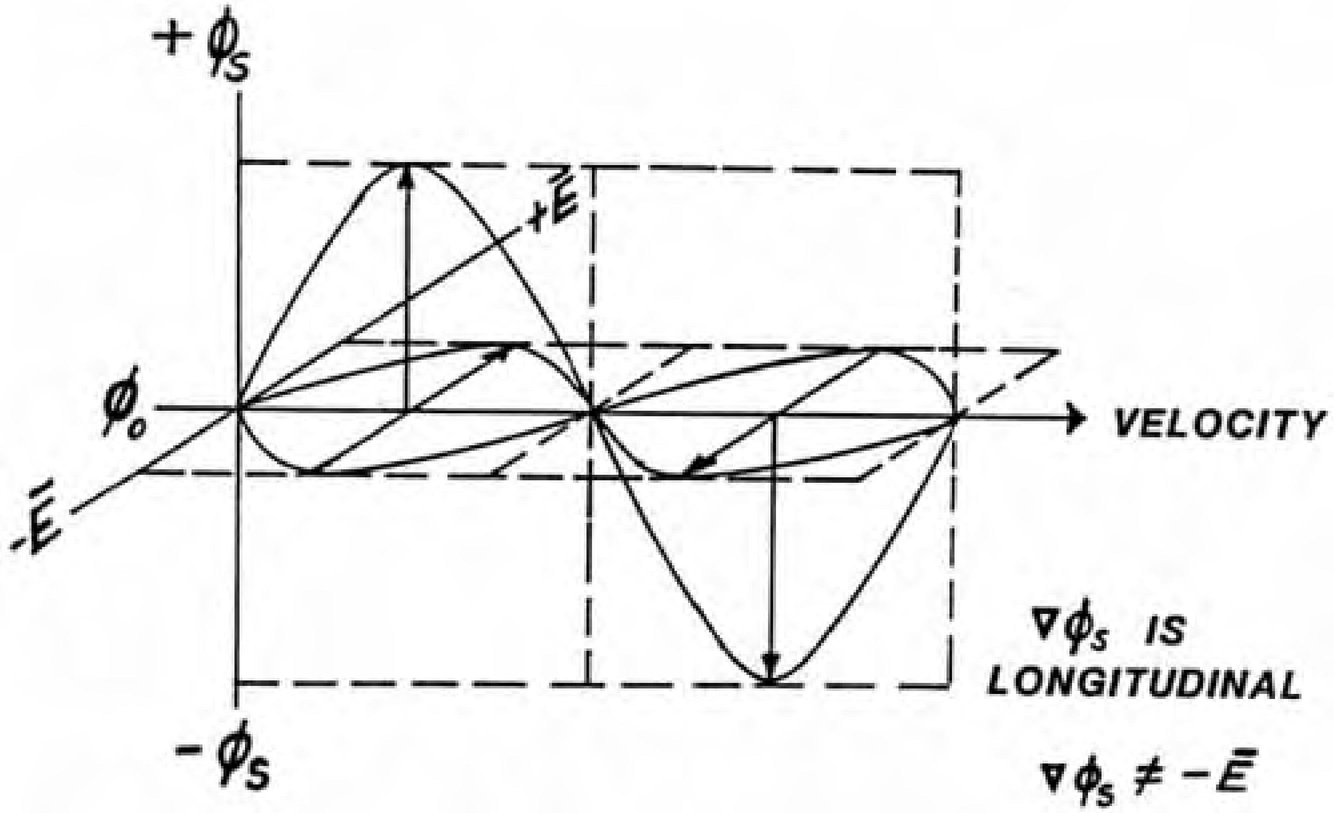

$+\phi_S$
$+\bar{E}$
ϕ_o
VELOCITY
$-\bar{E}$
$\nabla\phi_S$ IS LONGITUDINAL
$-\phi_S$
$\nabla\phi_S \neq -\bar{E}$

On this slide we now show a simple way to make a scalar, zero-vector wave -- the kind of wave originally discovered by Nikola Tesla.

It's simple. We just believe that a sum-zero vector substructure makes a scalar quantity, and we MAKE some scalars that way.

We also understand that a zero-gradient of a scalar is a zero vector, so that the scalar itself may be taken to be a zero vector.

The simplest explanation of this wave is as follows:

First, in physics we have two competing, mutually exclusive theories as to the nature of electromagnetic energy: the wave theory and the particle theory. Physicists argued for decades over these theories, for some experiments support one and some support the other. They never solved the problem; they just agreed to quit arguing. They formulated the "duality" principle to allow the saving of face to both sides.

Briefly, the duality principle implies that, whatever the nature of electromagnetic energy is before an interaction, in the interaction you can get it to act as a wave or as a particle. In other words, AS IT EXISTS, BEFORE THE INTERACTION, it is implicitly both particle and wave, joined together in some fashion, without being explicitly either one.

With the fourth law of logic, this becomes perfectly clear. With three-law Aristotlean logic, the problem is unresolvable.

Let us use this idea of "explicit duality without implicit duality" to analyze the wave shown on the slide.

First, from a wave aspect, the E-fields and the B-fields of the two waves do superpose and vectorially add. Since the waves are 180 degrees out of phase, the exterior resultant wave has a zero electric field and a zero magnetic field. Therefore it is a "zero-vector" wave, or "scalar" wave. It's a wave of pure stress in spacetime.

However, this scalar wave has a precisely determined substructure, consisting_of two ordinary sine waves, each of which comprises an ordinary E-H vector EM wave.

Now we apply the photon consideration (remember, before we interact with the wave, it must implicitly possess BOTH wave and particle natures combined, and we have so far only examined the implication of the wave nature.

The theory of photons' states that they are monocular critters. Photons pass right through other photons without interaction, in a linear situation. Therefore they can coexist without interaction, which is what we show here.

One photon, by the way, is one wavelength .

The photon theory requires that both substructure waves continue to exist as independent photons. Therefore we are assured that our substructure is intact.

However, notice that the totality of the two waves stresses spacetime. In other words, we have twice the stress on spacetime now as we would have from either wave separately.

This wave is therefore just a pure stress wave in spacetime itself.

This thing oscillates time, oscillates the relativity of the situation, and can affect energy, time flow rate, inertia, gravity, etc. aspects of an absorbing system.

Note that we have a rhythmic oscillation in phi (Ø), and we have a longitudinal stress wave, very similar to a sound wave. The MEDIUM for this wave is the virtual particle flux that identically comprises vacuum spacetime itself.

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SLIDE 23.

SCALAR Ö-WAVE PRODUCTION

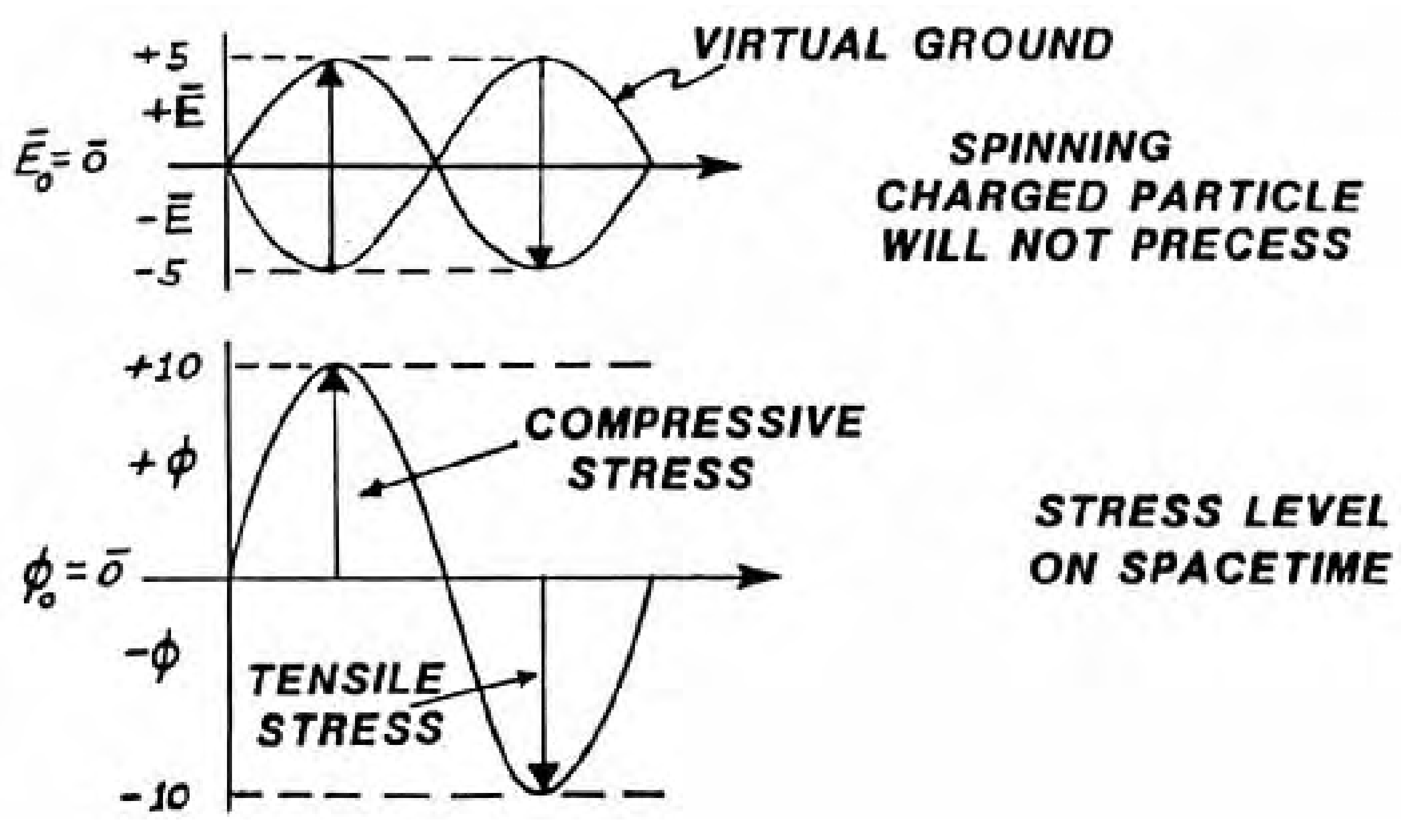
VIRTUAL GROUND
+5
+Ē
$\bar{E}_0 = \bar{0}$
-Ē
-5
SPINNING CHARGED PARTICLE WILL NOT PRECESS
+10
+φ
COMPRESSIVE STRESS
$\phi_0 = \bar{0}$
STRESS LEVEL ON SPACETIME
-φ
TENSILE STRESS
-10

On this slide we show how to regard the magnitude of the stress, by using one wave envelope as "virtual ground." In the top diagram, the original E-field stress of each wave has a magnitude of 5, and the composite stress wave now has a magnitude of 10, in whatever units we choose to express them.

We show in the bottom diagram that during one half cycle we have compressive stress in the virtual particle vacuum flux, and during the second half cycle we have tensile stress.

This shows the wave is like a sound wave in the gaseous molecules of the air.

However, this wave has one difference. It also oscillates time, and thus has at least one additional degree of freedom, compared to ordinary EM waves.

In fact, this wave can be made n-dimensional and hyperspatial.

As a first order approximation, we can treat such a wave in
a spatial fashion, if the wave is not too great in magnitude and the relativistic oscillation of time and inertia is not too large.

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SLIDE 24.

A SIMPLIFIED CHARGED PARTICLE

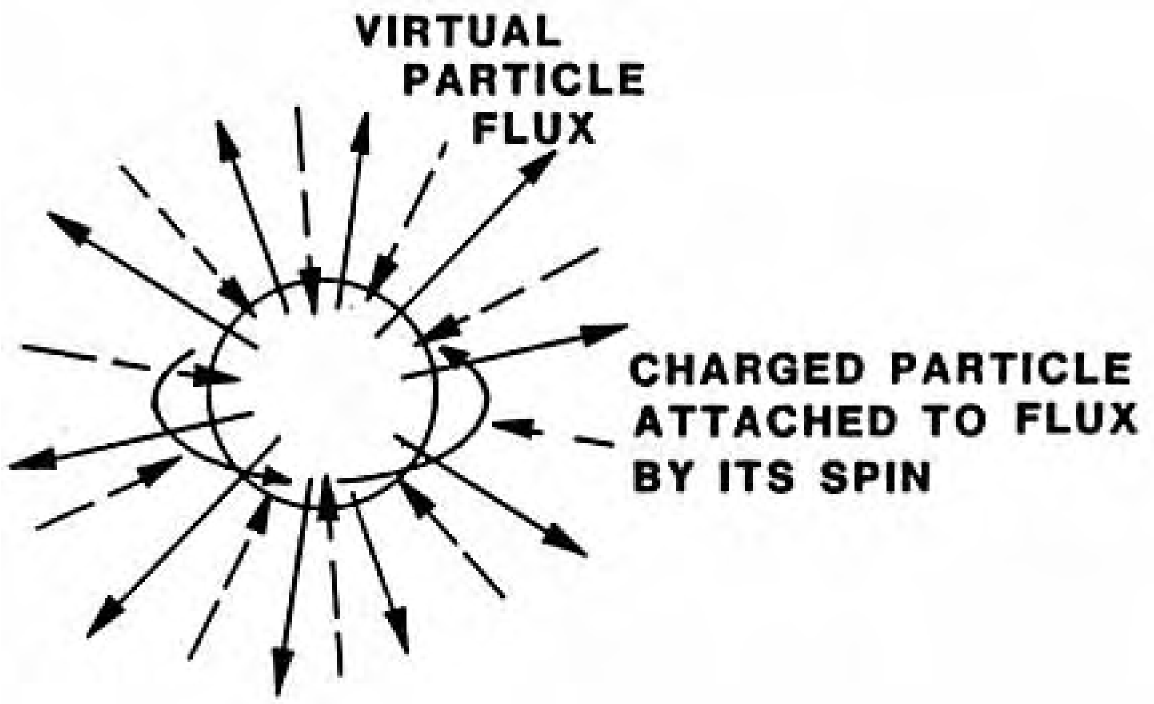

(THINK OF THE FLUX IN AND OUT, EXCEPT GRADIENTS ARE SPIRAL-LIKE, DUE TO PARTICLE'S SPIN)

We now digress slightly to pick up some more concepts.

On this slide, we show a simplified physical model of a charged particle. According to present particle physics, we model it as an observable, spinning bare mass in the middle, connected to a spray of virtual particles on and off the mass in all directions.

It is the spin of the mass that "attaches" the spray of virtual particles to and from itself.

Note that, because of the spin, the gradient lines of flux will actually be spiral or vortex in nature.

Also note that, when EM theory was founded, no one knew that an electron was spinning. Electron spin was therefore omitted from the foundations of present electromagnetic theory, and compensated for later by strictly ad hoc measures.

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SLIDE 25.

A CHARGED PARTICLE IS A SPECIAL KIND OF "SPRAY NOZZLE"

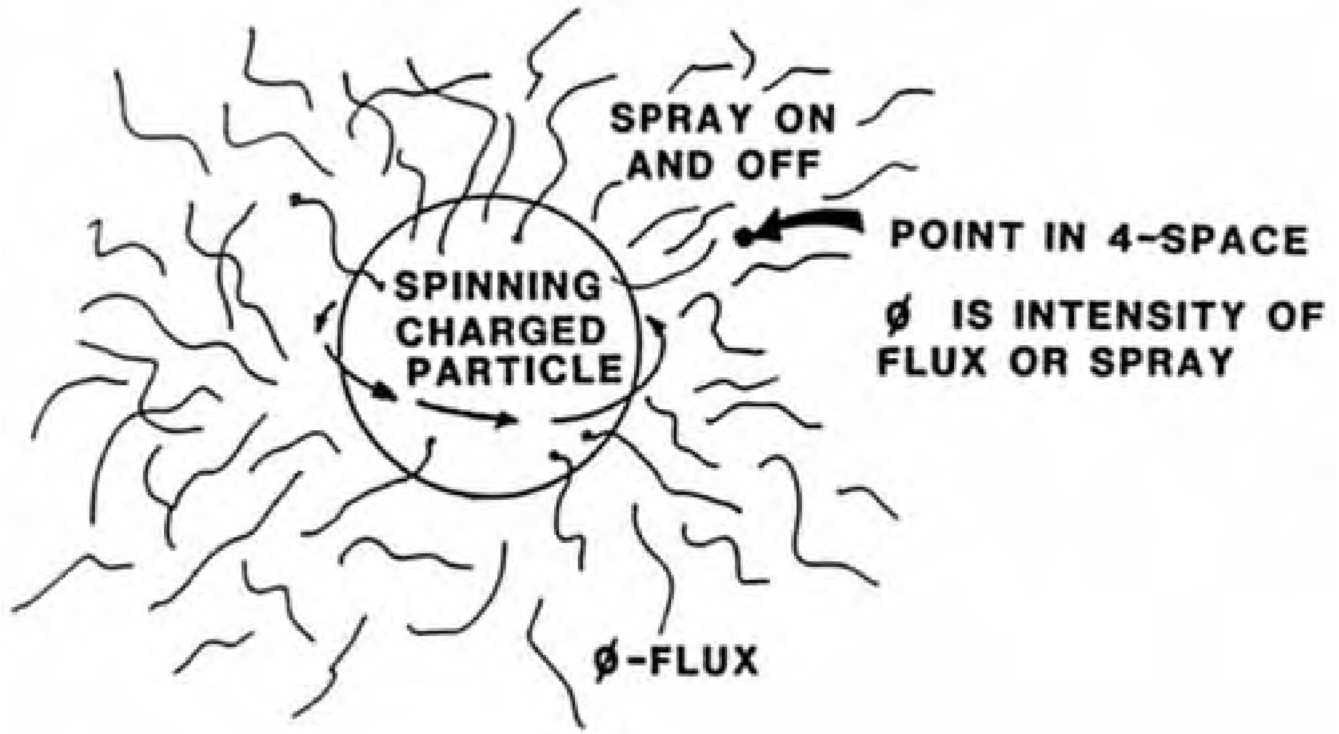
SPRAY ON AND OFF
POINT IN 4-SPACE
SPINNING CHARGED PARTICLE
0 IS INTENSITY OF FLUX OR SPRAY
0-FLUX

(SPRAY IS THROUGH 4 DIMENSIONS, NOT JUST 3)

Here we show a very important concept, and a very important fact of nature.

A charged particle may be idealized as a special kind of spray nozzle.

The 3-dimensional particle of mass is spraying out virtual particle fluid, and sucking in virtual particle fluid, in four or more dimensions.

We never have to furnish or replenish the spray. Nature provides that. And it's inexhaustible. It comes from the entire virtual particle flux vacuum of the universe. It's already connected firmly to matter, by its connection to the spinning charged particle of mass.

I repeat and strongly stress: This tremendous, continuous spray of virtual particles is absolutely free, and absolutely furnished by the universe.

We don't have to create the basic pumps for the fluid. We just move the spray nozzles around, by moving the spinning charged masses around.

We never furnish any ultimate energy to or in our present EM circuits. We just pump around the spray nozzles, gating the spray furnished by the universe.

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SLIDE 26.

AN OBSERVABLE CHARGED PARTICLE IS DIRECTLY CONNECTED TO VIRTUAL PARTICLE FLUX VACUUM

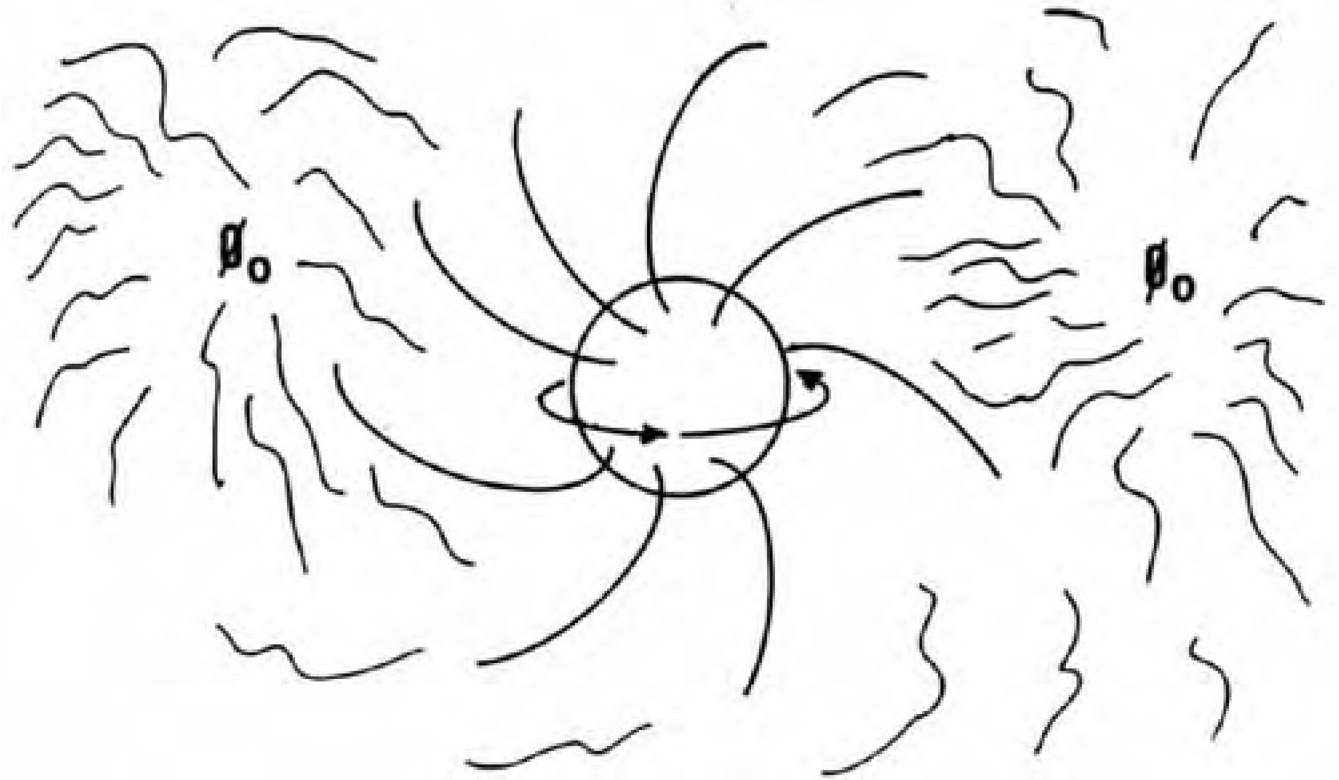

On this slide we accent that our 3-dimensional particle of mass is directly connected by its spin to the vacuum ether itself. To the virtual particle flux that identically IS the vacuum spacetime.

Interestingly, relativity states that the mass itself is nothing but a "kink" or curvature in spacetime .

The fact that the surface of the particle is spinning at right angles to the virtual particle vacuum flux "drags" part of the flux along with it, spiraling it, and certainly "kinking" or "bending" the vacuum flux .

That's the MECHANISM for the bending of spacetime. And that's what MAKES the particle of mass in the first place, and reduces its dimensionality to three.

Also note that the vacuum IS phi-sub-zero, and that is never a zero value. This is contrary to present EM theory, which erroneously assumes phi-sub-zero -- the charge of vacuum -- to be zero or non-existent.

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SLIDE 27.

SPIN COUPLES VACUUM TO PARTICLE

- **SPHERICAL ROTATION IS THE KEY**
- **A PARTICLE CAN BE MODELED AS A SPHERICALLY ROTATING VORTEX OF SPACETIME**
- **ITS MASS IS DUE TO ITS SPIN**
- **THE SPINNING OBJECT IS CONTINUALLY CONNECTED TO ITS ENVIRONMENT**
- **VERY HIGH VALUES OF ELECTROSTATIC POTENTIAL CAN INDUCE RELATIVISTIC CONDITIONS**
    - **CHANGE RATE OF FLOW OF TIME**
    - **EVEN THOUGH VELOCITY IS NONRELATIVISTIC**

E.P.BATTEY-PRATT AND T.J.RACEY
"GEOMETRIC MODEL FOR FUNDAMENTAL PARTICLES,"
INTL. J. OF PHYS. 19, NO. 6, 437-475, 1980

In fact, the bits and pieces of many of the new concepts are strewed all through the scientific literature. Here we show one example, establishing a good model that spin of a particle couples the particle to the vacuum .

This paper is by E.P. Battey-Pratt and T.J. Racey, and was . published in the International Journal of Physics in 1980.

Note again that very high values of electrostatic potential
can induce relativistic conditions, even though relativistic velocity is not present.

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SLIDE 28.

ELECTRON PRECESSION (SIMPLIFIED)

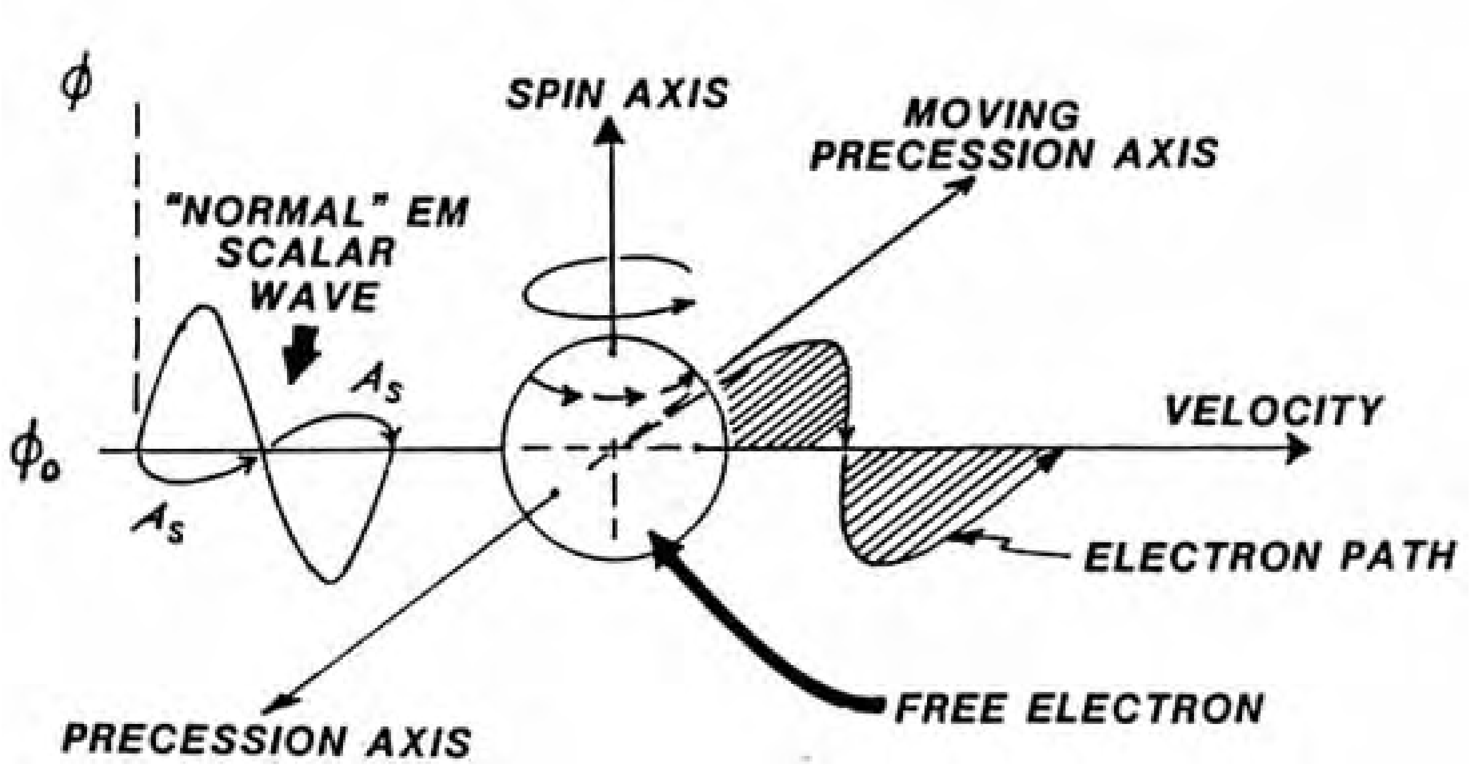
φ
SPIN AXIS
MOVING
PRECESSION AXIS
"NORMAL" EM
SCALAR
WAVE
A_S
$φ_0$
VELOCITY
A_S
ELECTRON PATH
FREE ELECTRON
PRECESSION AXIS

On this slide I show the effects of precession of an electron when it encounters a longitudinal scalar wave that contains "spin vortex holes" for the electrons to fall into and mesh its spin with.

The basic idea here -- that electron precession accounts for the Hertzian waves in the electron gas in a transmitting antenna and in a receiving antenna, came from my close colleague and friend, Frank Golden, and I am most happy to give him full credit for this important insight.

As we have previously stated, transverse (force) waves cannot exist in vacuum in the absence of mass. Hertz waves therefore cannot exist in vacuum, just as Tesla stated.

Yet we know that Hertz waves exist in the electron gas in our transmitting antennas and in the electron gas in our receiving antennas. How then do we get Hertz waves here, if only longitudinal waves can exist in the vacuum in between?

Electron precession is the key.

We never measure what's happening in vacuum with our instruments. Instead, almost always we measure what is happening to and in the electron gas in our antenna or probe and feeding current to the instrument.

Here we show a "normal" EM vacuum wave -- which is a longitudinal wave containing spin vortexes from the electrons that generated it -- approaching and striking a spinning charged electron. As the peak and trough of the wave passes, it is as if we had a force pressing against the spinning electron, first along the line of wave travel, and then antiparallel to the wave travel. *(that is, "explaining" it in present concepts.)*

The electron acts as a little gyroscope, and precesses laterally, first in one direction and then the other.

Therefore the wave recovered in the electron gas in our receiving antenna or instrument probe is a transverse Hertzian matter wave.

Hertz waves are always matter vector waves.

Vacuum EM waves are always nonmaterial longitudinal scalar waves.

Longitudinal scalar waves in vacuum normally contain many spinning vortex "holes" of flux, created from the spinning electrons which launched the wave and stayed behind in the transmitting antenna. This kind of longitudinal wave is directly detectable by a normal free electron charged gas in a receiving antenna or probe. It also directly interacts with free electrons in a conducting metal shield, and so is shielded by Faraday cages.

On the other hand, our zero-vector longitudinal wave, made
by opposing waves, contains opposing spin holes which annihilate or cancel each other.

In the absence of spin holes, the longitudinal wave will not mesh with spinning electrons in a conductor, and so it is not detectable in the normal fashion. It also does not interact with free electrons in a conducting metal shield, so it readily penetrates Faraday cages.

An easy way to see that electrons do not interact with that substructured longitudinal zero-vector wave is to visualize both substructure component waves interacting on the electron simultaneously, pushing in opposite directions equally. In that case the electron tries to precess in both directions, equally, and so it does not precess in either direction. Therefore it does not "detect" the passing wave.

The wave without "golf ball holes", however, is detectable
by any circuit having high nonlinearity actions occurring in it. Such highly nonlinear dynamic areas act to provide a phase shifting between the composite substructure waves. This phase shift results in violation of the sum-zero condition, producing a "normal" EM wave which deposits energy in the out-of-phase area.

From the spin vortex "golf ball hole" concept, the out-of-phase condition means that now we have an alternating preponderance of spin holes, spinning first in one direction and then in the other. Thus the electrons in the nonlinear, phase shift area are hooked and oscillated (precessed) to and fro, producing energy.

Solid state, highly doped transistors are particularly vulnerable to this effect, as are gas discharge tubes, spark and cascade ion discharges, plasmas, etc.

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SLIDE 29.

VACUUM/SPACETIME IS PURE VIRTUAL PARTICLE FLUX ($Ø_o$)

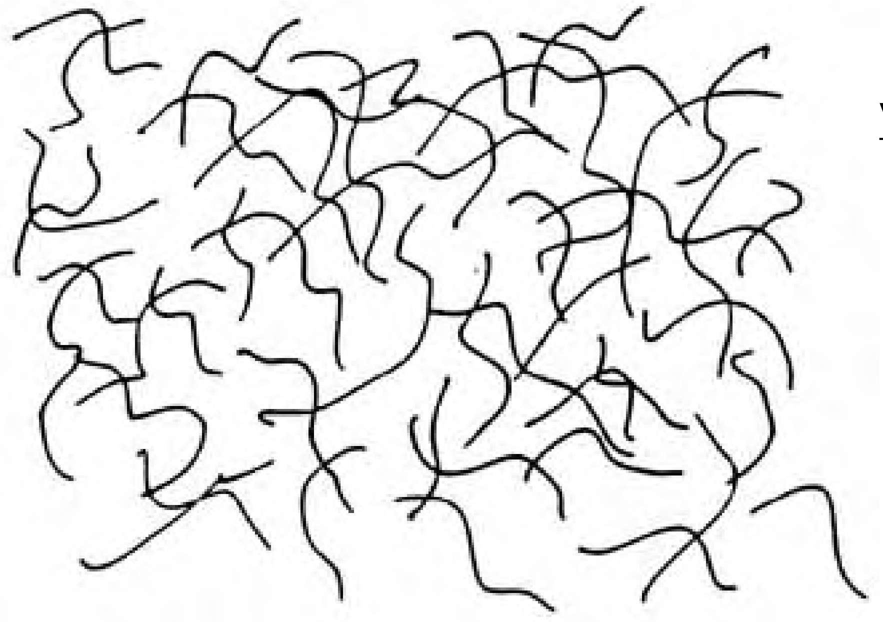

VACUUM IS IDENTICAL TO:

- **VIRTUAL PARTICLE FLUX**
- **SPACETIME**
- **ANENERGY**
- **$Ø_0$**
- **MASSLESS CHARGE**

VACUUM IS:

- **MADE OF UNQUANTIZED ACTION**
- **WITHOUT DEFINITE LENGTH INTERVALS**
- **WITHOUT DEFINITE TIME INTERVALS**
- **N-DIMENSIONAL (UNFIXED)**

We pause here to again summarize some important things we now know about vacuum.

Vacuum IS IDENTICAL TO virtual particle flux, spacetime, anenergy, Phi-subzero, massless charge, unquantized action, and infolded energy, momentum, length, time, power, velocity, acceleration, etc.

Vacuum is made of unquantized action, dimensionally.

It is without definite length or time, as Einstein stated.

It is n-dimensional, where n is always four or greater.

It is not an emptiness filled with things. Rather, it is identically a plenum filled with things which are totally unseparated, unfixed, and undetermined.

From vacuum: mass, energy, time, frames, and all the rest of physical reality are dynamically made.

Vacuum is the ether. The ether has never been eliminated from physics. Ether just has become much more subtle, and physicists have used other names for it.

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SLIDE 30.

VACUUM IS:

- **SPACETIME (L^nT, WHERE $n \geq 3$)**
- **CHARGE (MASSLESS)**
- **ELECTROSTATIC SCALAR POTENTIAL $Ø_0 \neq 0$ ERROR IN PRESENT THEORY**
- **BROKEN BITS OF ENERGY (SUBQUANTAL)**
- **PURE VIRTUAL PARTICLE FLUX**
- **O-WAVE FLUX**
- **MULTILEVEL, STRUCTURED, PATTERNED**
- **A VIRTUAL PLENUM**
- **AN OBSERVABLE EMPTINESS**

Again, we list some of the things that vacuum identically is.

It is spacetime, massless charge, electrostatic scalar potential, broken bits (subquantal) of energy, pure virtual particle flux, zero-vector wave flux, multilevel, structured, patterned, a virtual plenum, and an observable emptiness.

It is all things and contains all things in potential state.

It is not, in that it is not observable. But from it comes all observables.

It is both ordered and disordered, simultaneously.

It involves four-law logic, not just three-law Aristotlean logic.

Next Slide

The Tom Bearden Website

SLIDE 31.

GRADIENT OF ELECTROSTATIC POTENTIAL

IN VACUUM

$$\nabla \mathbf{Ø} \neq \ddot{\mathbf{E}}$$

ON AND OF A MOVING CHARGED PARTICLE

$$\nabla \mathbf{Ø} = \ddot{\mathbf{E}}$$

Again I accent that, in vacuum in the absence of a charged spinning particle of observable mass, del-phi does not yield an Ë-field, and the conventional equations of EM are wrong in that respect.

In the presence of a spinning charged particle, in a del-phi which contains electron-vortex-holes to mesh with, the charged particle attaches itself to the moving del-phi flux gradient, moving itself with the river. This produces an Ë field. The Ë-field CONSISTS OF the smeared electron, it does not CAUSE THE MOVEMENT of the electron. It is an effect, not a cause. The conventional equation for del-phi equals E is correct for matter waves in electron gases; it is not correct in vacuum itself.

Next Slide

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SLIDE 32.

IN A ∇Ø, A CHARGED PARTICLE MOVES ITSELF

∇Ø>0 IMPLIES A MOVING RIVER, AND THE CHARGED PARTICLE IS "HOOKED TO" THE RIVER

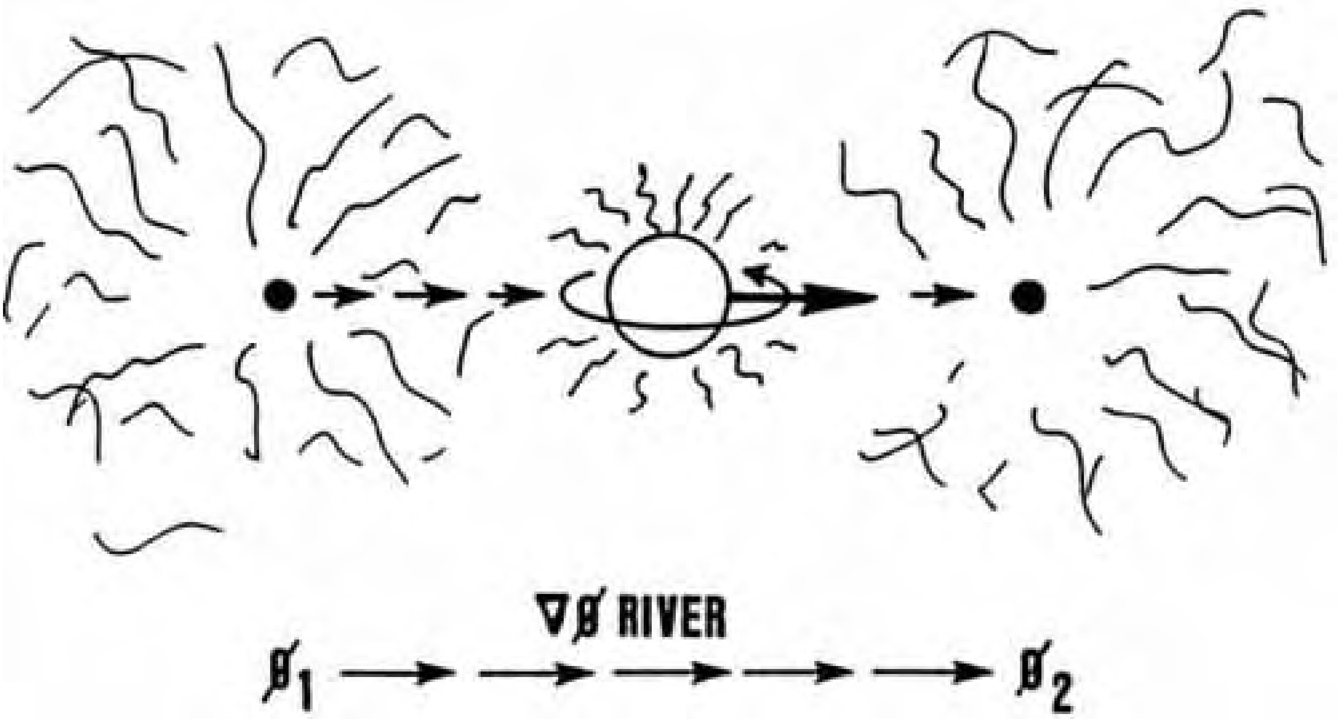

We show clearly on this slide that a spinning charged particle, when it hooks to a spin-hole in a del-phi river, MOVES ITSELF.

Note that a del-phi implies a "pressure difference" in phi-flux between two points. Therefore there is a moving river -- a gradient -- of phi-dot, moving from the higher pressure to the lower.

If a charged particle is attached to this moving river, it flows along with the river. It is just like putting a boat into a moving stream of water. If the boat "latches" to the moving water, it moves with the river.

Electron spin and spin vortexes in the del-phi mesh, to accomplish the "hooking" or "latching."

Once hooked into a moving river, the electron moves itself. One does not have to furnish work to move it.

If the river is accelerating, the electron will accelerate itself.

By cleverly gating such rivers into and onto sources of free electrons, one can directly produce free energy.

The extra energy comes from converting anenergy (massless charge, vacuum flux) to energy of a moving mass.

Next Slide

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SLIDE 33.

ELECTROMAGNETIC WAVES IN ELECTRON GAS IN A CONDUCTOR

- **VECTOR WAVES**
- **CONTAIN E, B FIELDS**
- **GENERATED BY SPIN COUPLING OF ELECTRONS WITH SCALAR WAVE "SPIN-HOLES"**
- **WAVES OF FORCE**
- **HERTZIAN WAVES**
- **TRANSVERSE WAVES**
- **WAVES OF ELECTRON PRECESSION**

Here we pause to summarize the characteristics of electromagnetic waves in the electron gas of a conductor.

First, these are vector EM waves in the accepted sense.

They contain E and B fields.

They are generated by spin coupling of electrons with spin-holes in a scalar wave delta-phi river. The electrons move themselves under that condition, producing work and forces.

They are waves of force or force field variations.

They are Hertzian waves.

They are transverse oscillatory, not longitudinal.

They are matter waves.

They are waves of electron precession.

Next Slide

The Tom Bearden Website

SLIDE 34.

ELECTROMAGNETIC WAVES IN VACUUM

- **SCALAR LONGITUDINAL WAVES**
- **VECTOR ZERO [Ö] WAVES**
- **WITHOUT Ë, B FIELDS**
- **INTERNALLY STRUCTURED**
- **PATTERNED**
- **MAY CONTAIN ELECTRON "SPIN-HOLES"**

Here we summarize the characteristics of electromagnetic waves in vacuum.

They are scalar longitudinal waves of alternate compression and rarefaction of the vacuum virtual particle flux.

That is, they are waves of electrostatic potential.

They are zero-vector waves.

They are internally structured and patterned.

They usually contain electron "spin holes" unless made in a fashion so as to make opposing spin holes that cancel each other.

Since they are pure phi-waves, they need not be limited in velocity to the speed of light.

They are hyperspatial waves.

They are waves in virtual state itself.

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SLIDE 35.

DETECTION OF TRANSVERSE AND LONGITUDINAL WAVES

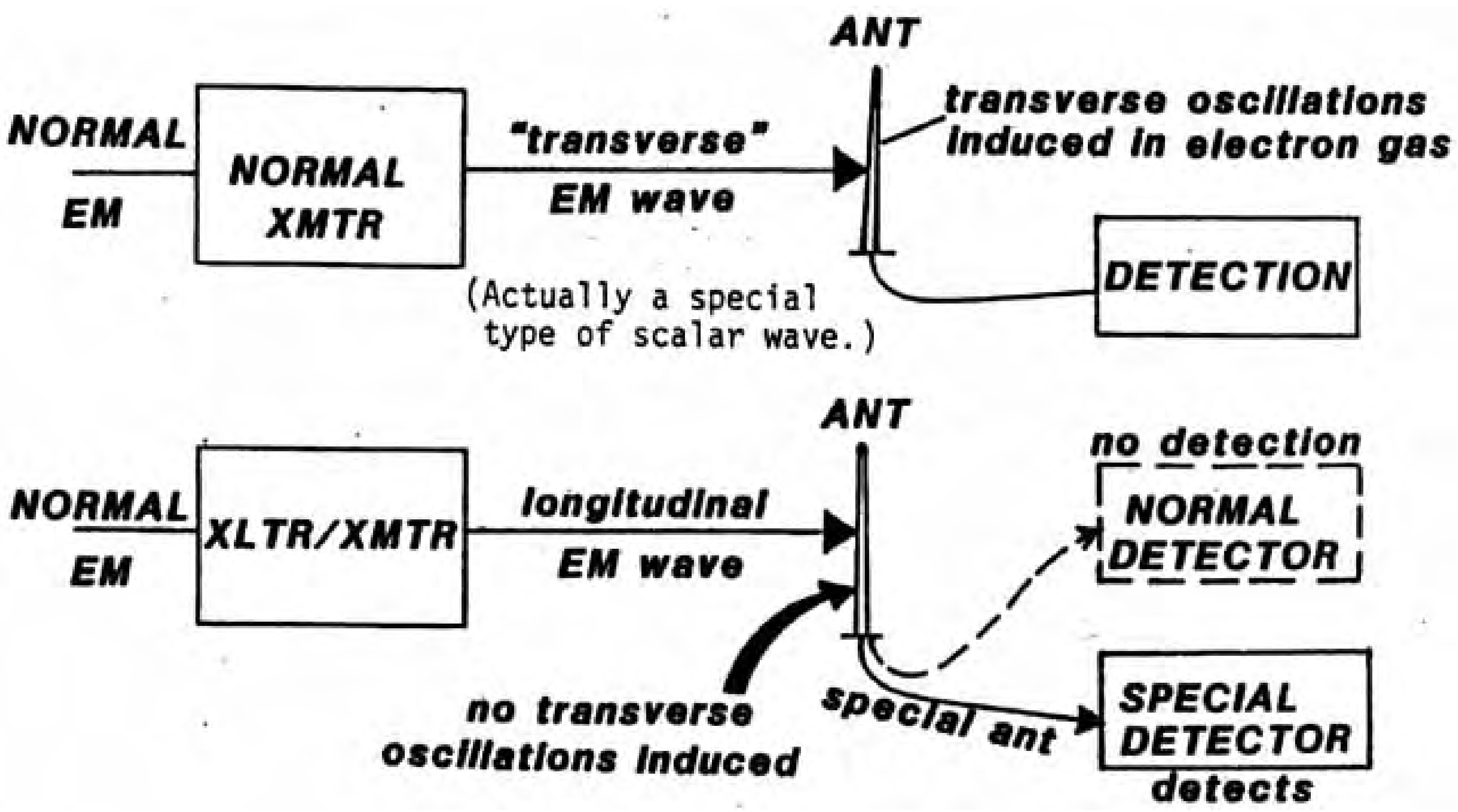
ANT
NORMAL
EM
NORMAL XMTR
"transverse"
EM wave
transverse oscillations induced in electron gas
DETECTION
(Actually a special type of scalar wave.)
ANT
NORMAL
EM
XLTR/XMTR
longitudinal
EM wave
no detection
NORMAL DETECTOR
no transverse oscillations induced
special ant
SPECIAL DETECTOR
detects

In the top drawing on this slide, we show a normal transmitter putting out a normal EM wave, which received in a normal antenna/receiver. What we call a "transverse" wave rigorously exists only in the electron gas in the transmitting antenna and in the electron gas in the receiving antenna. Specifically, a longitudinal wave exists in the vacuum in between the two antennas. However, due to the method of production, the longitudinal wave contains spin-holes for electrons, so the electrons in the receiving antenna readily couple with the wave by falling into and meshing their spins with the spins of the spin-vortex holes. Electron precession produces electron gas waves that are transverse oscillatory, hence Hertzian waves in nature.

In the bottom drawing, we show a translator/

transmitter. In other words, we oppose ordinary EM waves in a sum-zero substructure, deliberately producing longitudinal EM waves in vacuum with the spin-hole vortexes canceling each other. This type of wave does not "hook" spinning electrons in the normal receiving antenna, and thus it is not detected. The normal antenna/receiver system never sees it at all.

However, by means of a special antenna which generates nonlinear phase shifts in the composite substructure waves, "hooking" holes are restored in an oscillatory nature. Electrons then hook with this output and detect the wave.

Note that it requires a two-stage detector, operated in an interferometer fashion, to detect this pure scalar wave.

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SLIDE 36.

CREATING A "RIVER" OF ANENERGY

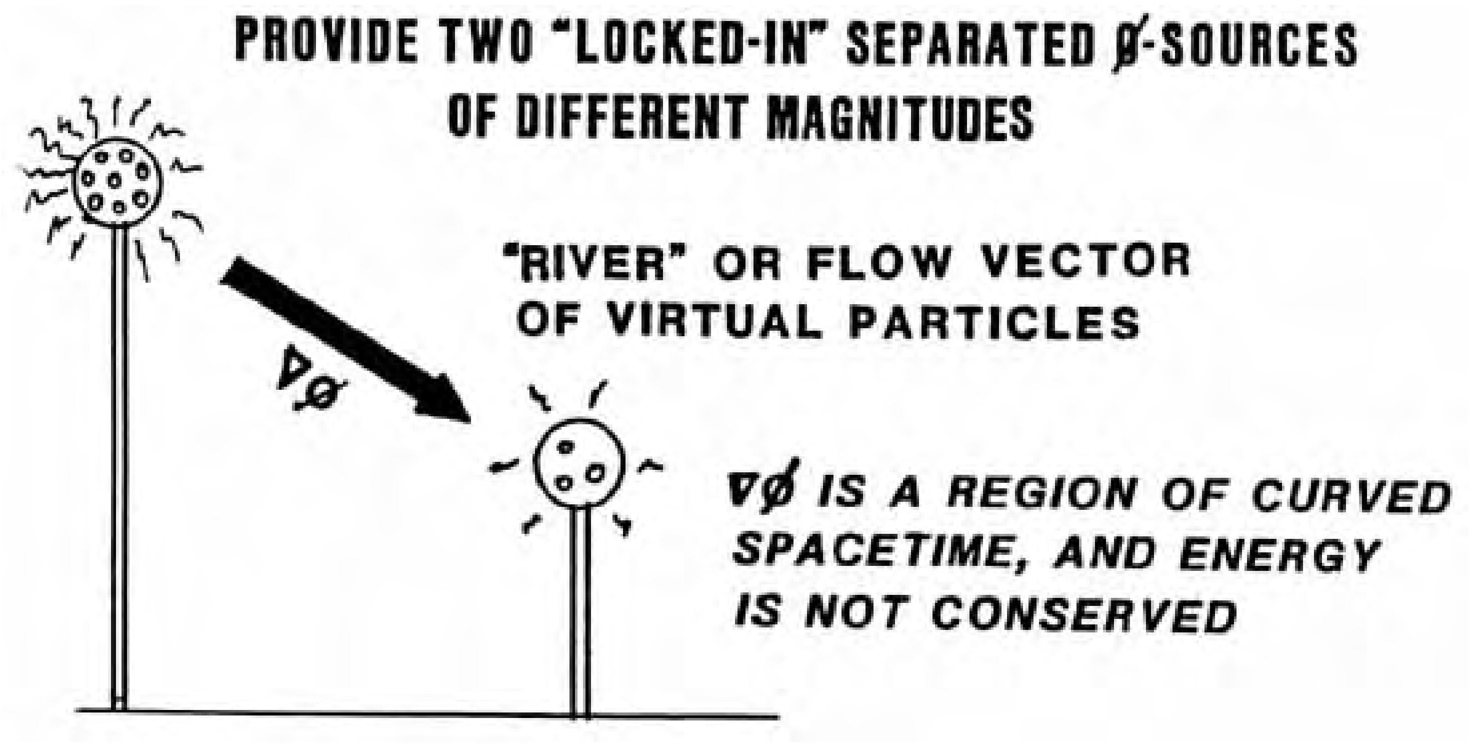

PROVIDE TWO "LOCKED-IN" SEPARATED ϕ-SOURCES OF DIFFERENT MAGNITUDES

"RIVER" OR FLOW VECTOR OF VIRTUAL PARTICLES

$\nabla\phi$ IS A REGION OF CURVED SPACETIME, AND ENERGY IS NOT CONSERVED

IN VACUUM, THIS IS NOT YET A VOLTAGE DROP (NO MASS FLOW),
NOR IS THERE AN Ë-FIELD

Now if we wish to get free energy, we are going to have to provide a continuous anenergy river, and a means of tapping it to produce mass movement.

This slide shows one easy way to make an anenergy river.

We simply pump some electrons (spray nozzles) onto an elevated charged ball, and we LEAVE them there. A second ball is connected to ground. A higher phi -- that is, a denser spray -- is now in the vicinity of the elevated ball on the left. A lower phi -- that is, a less dense spray -- is in the vicinity of the lower ball on the right. Between the two balls, now, there is a gradient in phi, and a virtual flux flowing from the "higher virtual pressure" to the "lower virtual pressure."

This del-phi river does NOT constitute an Ë-field, as we
have previously pointed out.

The del-phi region, however, is definitely a region of
curved spacetime. As is well known from general relativity, in such a region energy need not be conserved.

Therefore it is entirely possible -- consistent with ordinary physics -- to violate conservation of energy in this del-phi river, if one believes general relativity. If one argues adamantly that conservation of energy cannot be violated under any circumstances, then one must throw out general relativity. Also, one must throw out most of particle physics, whose explanations presently involve virtual interactions, each of which violates the conservation of energy.

Next Slide

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SLIDE 37

A 2-WIRE SYSTEM IS CONSERVATIVE

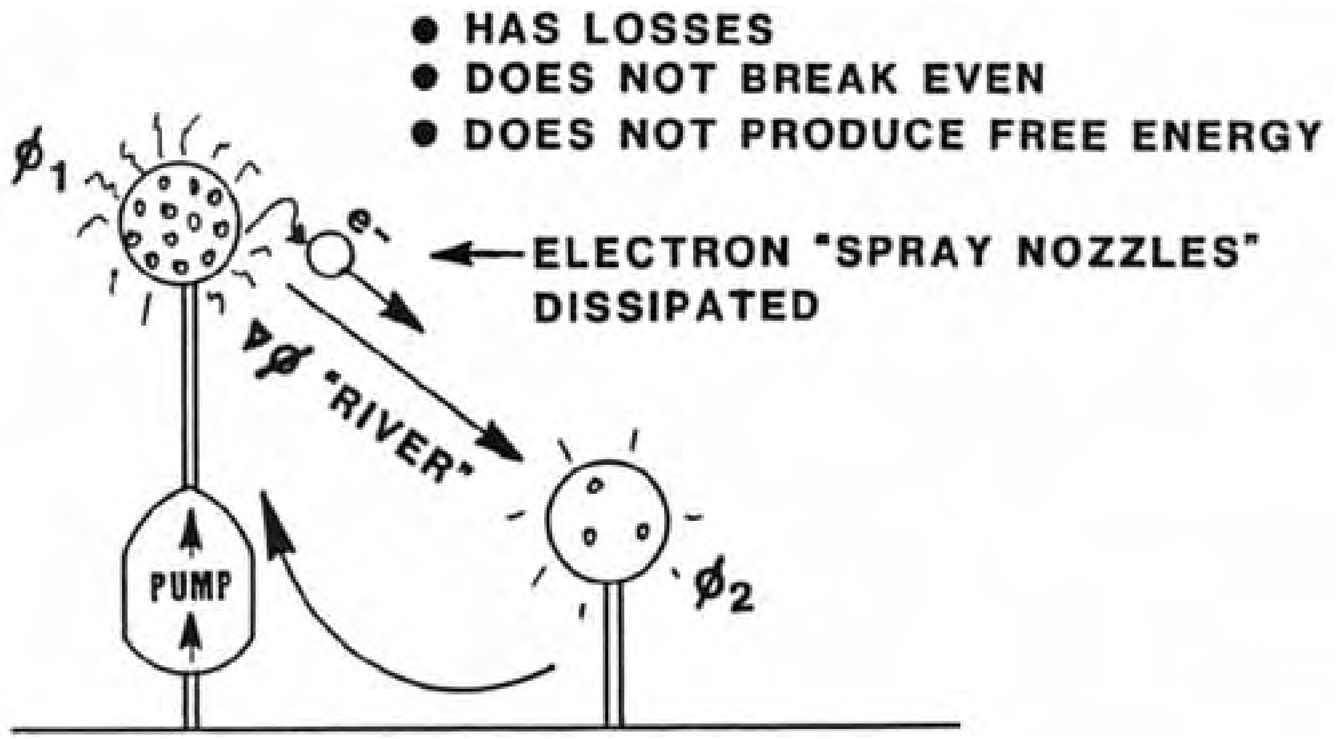

- HAS LOSSES
- DOES NOT BREAK EVEN
- DOES NOT PRODUCE FREE ENERGY

REPLENISH SPRAY NOZZLES BY PUMPING MORE ELECTRONS. (MOVING ELECTRON MASSES AGAINST A "SPRAY PILEUP" REQUIRES WORK.

Here we show that, as engineers, we've all been tricked into releasing our virtual rivers so that we would not discover free energy.

While I cannot prove this as yet, I tentatively suspect that J. P. Morgan and Thomas Edison are directly responsible for this occurring. Tesla utilized a single-wire system; we have all been taught to utilize only two-wire systems.

What we in effect do is connect a wire or circuit to our charged ball, allowing our hose nozzles to drain away.

In other words, we first do some work to pump hose nozzles (electrons) into and onto our elevated reservoir, so we will obtain a denser flux, and a flux river to utilize. Then we release the nozzles themselves, and let THEM move on the flux river, deplenishing our river. Of course we can get back as much energy as we pumped up there in the first place. But this two-wire system is at best theoretically even. Since real circuits have losses, we can never even quite break even. Thus we have to continue to pump hose nozzles, and let them bleed off to provide energy, in a less-than-100% fashion.

By foolishly releasing our hose nozzles, we guarantee that we will never achieve free energy. And that's nice, because the people who control things, and for their own wealth and power depend on selling us energy at high prices, are guaranteed to stay in power and control.

One is never truly free unless one is energy independent, in a self-contained fashion.

Tesla nearly succeeded in giving us free or very cheap, inexhaustible energy -- and for that reason was quickly and dramatically suppressed.

Only three graduate schools of electrical engineering existed in the U.S. The only one of any real importance was at Columbia University.

Only one or two professors were necessary to "reach" to modify and subtly direct the entire foundations of the emerging electrical theory.

Professors were in general poor, and had no research funds unless some rich industrialist or philanthropist gave them a few dollars.

The setup then was certainly very ripe for Morgan and Edison to stop free energy, and suppress Tesla at the same time. They could have done so by influencing only one -- or at most two -- theoreticians at Columbia.

At any rate, the theory was developed in such fashion as to rule out the single wire circuit and the longitudinal wave. Free energy was suppressed, and the financial empires of Morgan and Edison stayed secure.

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SLIDE 38.

A HOLLOW CHARGED SPHERE

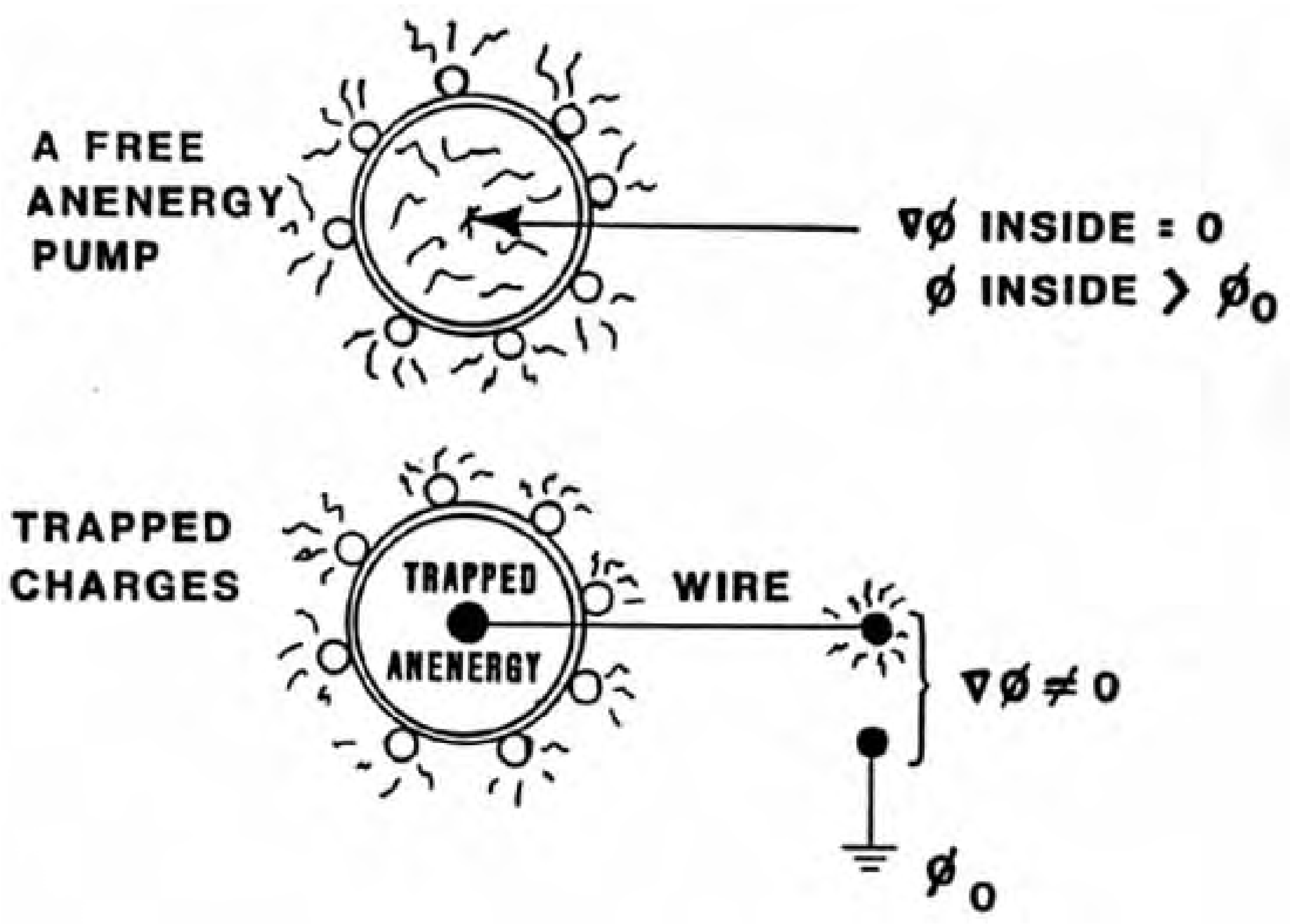
A FREE
ANENERGY
PUMP
$\nabla\phi$ INSIDE = 0
ϕ INSIDE > ϕ_0
TRAPPED
CHARGES
TRAPPED
ANENERGY
WIRE
$\nabla\phi \neq 0$
ϕ_0

Here we show another easy source of a higher vacuum charge, hence an easy source for a free river.

Simply charge up a sphere. As is well known, inside that sphere one has no del-phi. So one can introduce an electron therein and not produce an Ë-field .

However, since we've piled up additional spray nozzles, the density of the spray inside the sphere (as well as outside it) is certainly higher.

In other words, the inside of the sphere is also a source
for an increased del-phi river. In the bottom drawing, we drill
a tiny hole in the sphere, insulate a thin wire running into the inside of the sphere, and run the wire out to a terminal opposing another grounded terminal. Between the two terminals now there must exist a del-phi river.

And between those terminals there now exists a curvature of spacetime, hence the theoretical possibility to obtain free energy without violation of principles.

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SLIDE 39.

ONE-WAY GATE VALVE

(ANENERGY TO ENERGY)

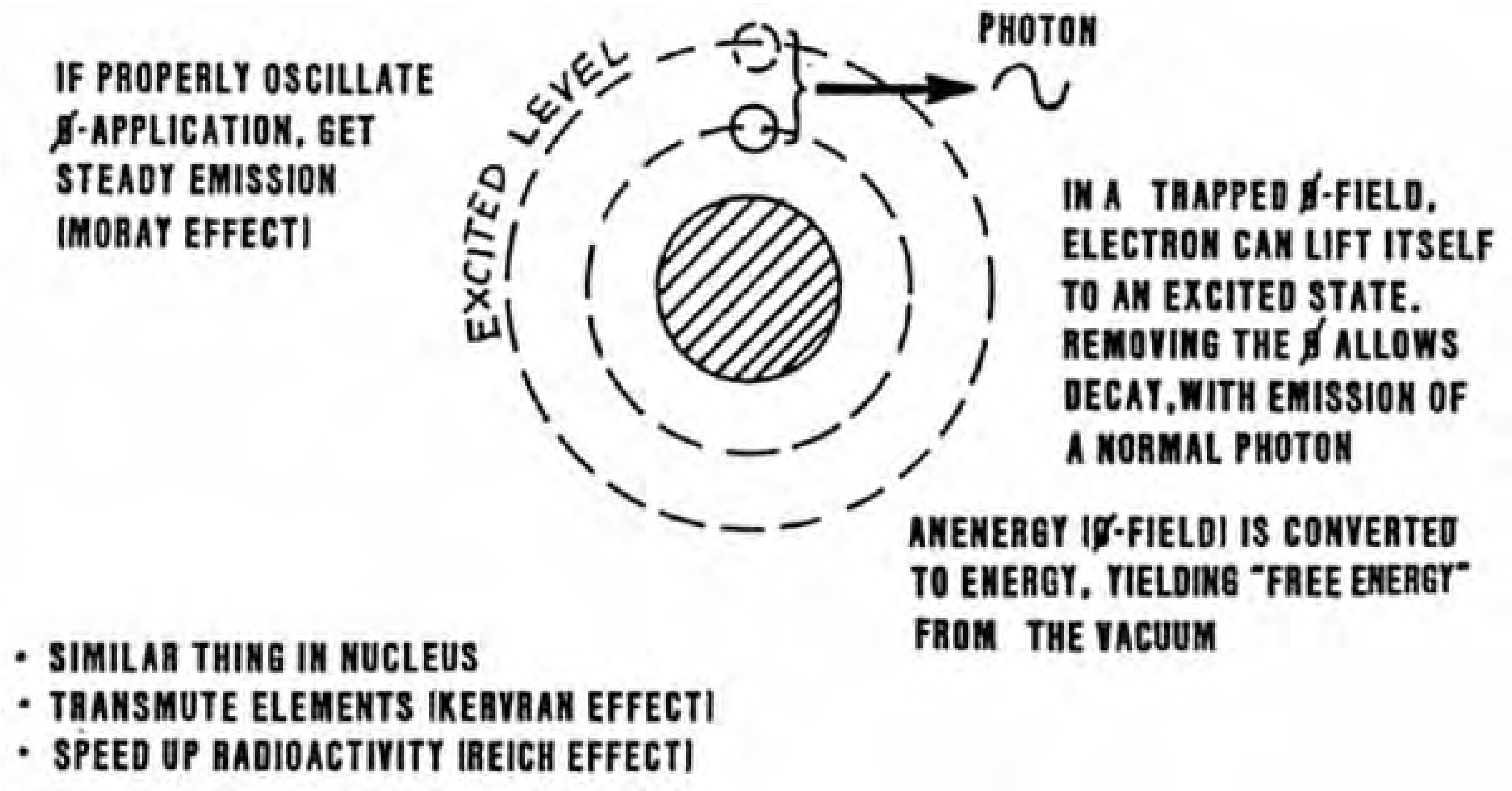

IF PROPERLY OSCILLATE
∅-APPLICATION, GET
STEADY EMISSION
(MORAY EFFECT)

IN A TRAPPED ∅-FIELD,
ELECTRON CAN LIFT ITSELF
TO AN EXCITED STATE.
REMOVING THE ∅ ALLOWS
DECAY, WITH EMISSION OF
A NORMAL PHOTON

ANENERGY (∅-FIELD) IS CONVERTED
TO ENERGY, YIELDING "FREE ENERGY"
FROM THE VACUUM

- SIMILAR THING IN NUCLEUS
- TRANSMUTE ELEMENTS (KERVRAN EFFECT)
- SPEED UP RADIOACTIVITY (REICH EFFECT)

Here we show one way to provide a one-way gate valve from a del-phi river to energy released into the outside world.

By providing a properly tuned, oscillating phi wave, one can cause an orbital electron in an atom to raise itself to an excited state. Remember, in a del-phi, an electron that hooks to it raises itself.

We then switch out the phi application, and the excited electron decays in normal fashion, emitting a normal photon of energy.

By phase locking the processes, one produces a steady stream of photons.

By absorbing or directing the photons, one can produce heat, light, energy beams, etc.

By this means, one produces free energy by gating anenergy into energy.

And if one does not release spray nozzles in the phi-oscillations which feed the mechanism, one has an inexhaustible energy production.

A very similar thing can be done with the excited states of the nucleus. For example, by using a radioactive material with a predisposition to emit some particle -- say an electron -- the nucleus can be made to continually emit the particles WITHOUT ITSELF DECAYING INTO BYPRODUCTS. In other words, an electron is lifted from the Dirac sea of vacuum to instantly replace the electron emitted from the nucleus.

This provides a one-way gate valve from the Dirac sea to the external universe.

Theoretically, these mechanisms are no more mysterious than a hydraulic ram, which raises water higher than the stream that feeds the ram.

In the 20's and 30's, T. Henry Moray successfully built such gating devices for converting vacuum anenergy to external energy.

In the Kervran effect, living systems are able to directly transmute elements, even though they only possess feeble energies, by influencing the virtual particle interactions in the nucleus that furnish its binding energy.

Reich used an adaptation of a cloudbuster -- which emits scalar waves -- to drastically speed up radioactive decay of radioelements.

Both plants and animals transmute elements by similar processes.

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TOWARDS A NEW ELECTROMAGNETICS
PART 4: VECTORS AND MECHANISMS CLARIFIED

SLIDE 40,

SIMPLE FREE ENERGY MOTOR

BATTERY RECHARGES ITSELF

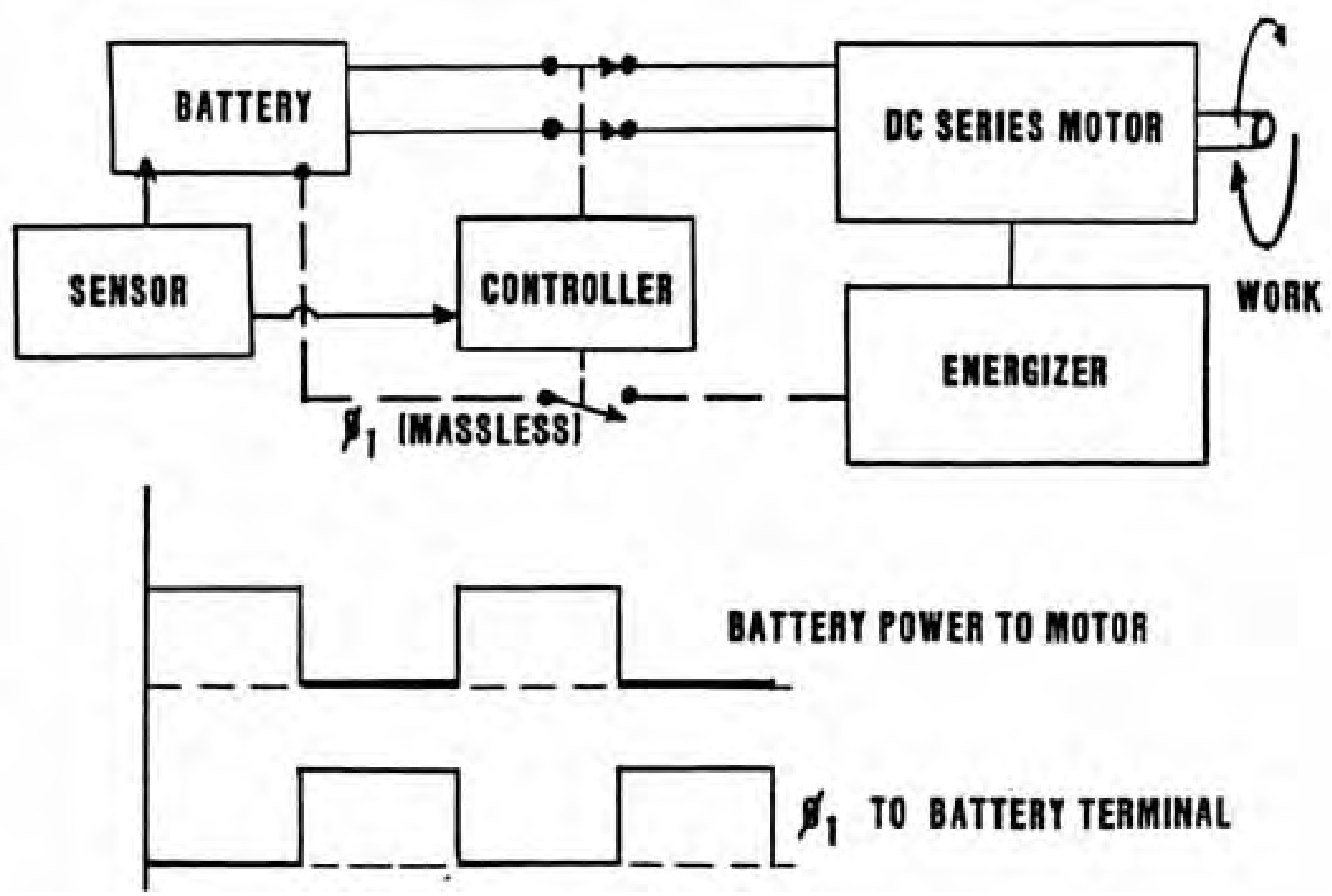
BATTERY
DC SERIES MOTOR
SENSOR
CONTROLLER
WORK
ENERGIZER
Ø1 (MASSLESS)
BATTERY POWER TO MOTOR
Ø1 TO BATTERY TERMINAL

On this slide, we show a theoretical scheme which several researchers have discovered and used to build simple free energy motors.

In this scheme, we drive an ordinary d.c. series motor by a two wire system from an ordinary battery. The motor produces shaft horsepower, at -- say -- some 30 or 40 percent efficiency, compared to the power drained from the battery. This much of the circuit is perfectly ordinary.

The trick here is to get the battery to recharge itself, without furnishing normal power to it, or expending work from the external circuit in the process.

To do this, recall that a charged particle in a "hooking" del-phi river moves itself. This is true for an ion, as well as for an electron. We need only make the del-phi in correct fashion and synchronize it; specifically, we must not release the hose nozzles we utilize to produce our del-phi river or waves.

The inventors who have discovered this have used various variations, but here we show a common one.

First, we add an "energizer" (often referred to by various other names) to the circuit. This device makes the del-phi waves we will utilize, but does NOT make currents of electron masses. In other words, it makes pure Ø-dot. It takes a little work to do this, for the energizer circuit must pump a few charges now and then. So the energizer draws a little bit of power from the motor, but not very much.

Now we add a switching device, called a controller, which breaks up power to the motor in pulses. During one pulse, the battery is connected and furnishes power to the motor; during the succeeding pulse, the battery is disconnected completely from the motor and the output from the energizer is applied across the terminals of the battery.

If frequency content, spin-hole content, etc. are properly constructed by the energizer, then the ion movements in the battery reverse themselves, recharging the battery. Again, remember that these ions MOVE THEMSELVES during this recharge phase. Specifically, we are NOT furnishing ordinary current to the battery, and we are not doing work on it from the energizer.

If things are built properly, the battery can be made to more than recover its charge during this pulse cycle.

To prevent excess charge of the battery and overheating and destroying it, a sensor is added which senses the state of charge of the battery, and furnishes a feedback signal to the controller to regulate the length of recharge time per "power off" pulse. In other words, the system is now self-regulating.

The relation between power pulses and recharge pulses is shown on the graphs at the bottom. Note that regulation may decrease the time of recharge application of the del-phi river.

This system, if properly built and tuned, will furnish "free shaft energy" continually, without violating conservation of anenergy. Remember that the del-phi condition across the battery terminals means that spacetime is suddenly curved there, and conservation of energy need no longer apply.

Again, this system is consistent with general relativity and with the fact that Ø-field alone can drive a situation relativistic. We have deliberately used these facts to do direct engineering. Our "extra energy" comes from shifting phi-flux -- the energy of the universal vacuum spacetime -- directly into ordinary energy for our use. Thus we draw on an inexhaustible source, and our device is no more esoteric than a paddlewheel in a river. The only difference is that, in this case, we have to be clever enough to make and divert the river in the right timing sequency.

This is a free energy device which an ordinary person, who knows a little electronics, can experiment with in the basement. To develop it, one is talking several thousands of dollars and a lot of persistence and tinkering; one is not talking millions.

WARNING: THE PRECEDING EXPERIMENTS ARE HAZARDOUS. DO NOT ATTEMPT THESE EXPERIMENTS UNDER ANY CIRCUMSTANCES UNLESS YOU ARE AN EXPERIENCED ELECTRICAL RESEARCHER, EXPERIENCED IN PERFORMING EXPERIMENTS WITH LEAD-ACID BATTERIES AND PULSE CHARGE AND DISCHARGE OF SAME, AND UNLESS YOU ALSO USE ALL SAFETY PRECAUTIONS SUCH AS GOGGLES

AND PROTECTIVE GLOVES, SLEEVES, AND APRON. YOU MUST NOT HAVE OTHER INFLAMMABLE LIQUIDS OR OTHER SUBSTANCES PRESENT WHICH COULD BE IGNITED AND BURN OR EXPLODE. SURGED LEAD-ACID BATTERIES PRODUCE HYDROGEN GAS, WHICH CAN EASILY EXPLODE SINCE SPARKING ALSO CAN OCCUR. THE ACID FROM SUCH AN EXPLOSION CAN EASILY BLIND YOU IF IT GETS IN YOUR EYES, AND IT CAN BURN YOUR SKIN. IN ADDITION, LEAD AND LEAD COMPOUNDS ARE POISONS, AND ARE TO BE HANDLED ONLY BY EXPERIENCED RESEARCHERS. THESE EXPERIMENTS ARE NOT FOR AMATEURS UNDER ANY CIRCUMSTANCE, BUT ONLY FOR EXPERIENCED PROFESSIONALS WITH PROPER KNOWLEDGE AND TRAINING, AND USING PROPER PRECAUTIONS. NEITHER THE AUTHOR NOR THE PUBLISHER IS REPONSIBLE OR LIABLE FOR ANY ACCIDENTS OR DAMAGE YOU MAY ENCOUNTER, AND ALL EXPERIMENTATION WITH THESE DEVICES AND PROCEDURES IS AT YOUR OWN ASSUMED PERSONAL RISK.

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SLIDE 41.

THE TRANSLATOR

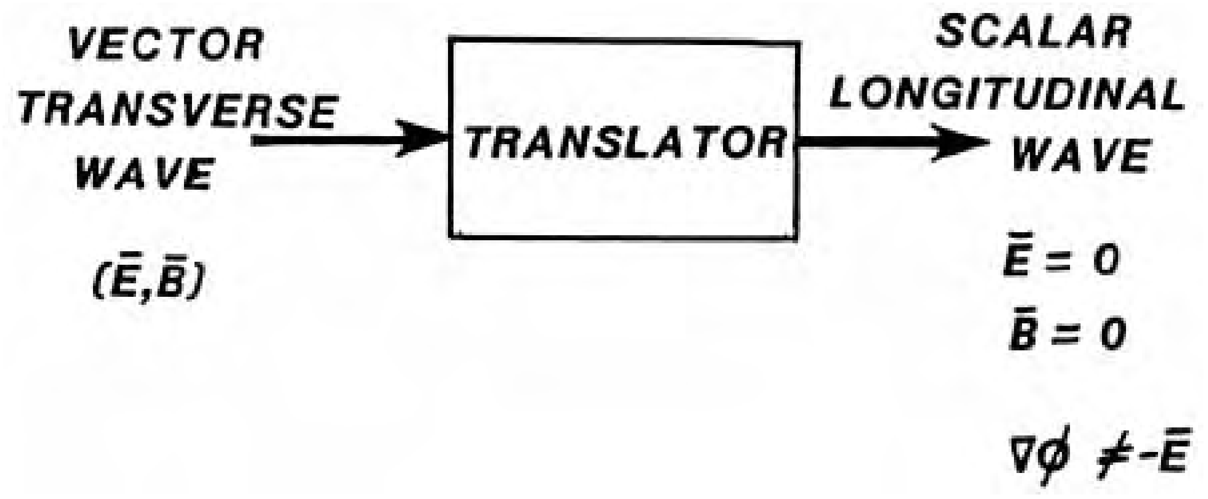

We now turn to a fundamental concept we need in order to understand some of the effects used by the Soviets in their Tesla weapons.

Note that one other country -- one not hostile to the U.S. -- also has such weaponry.

This slide shows the concept of a TRANSLATOR. Briefly, if we input a transverse matter wave, the translator outputs a scalar longitudinal wave without spin vortex hooks. If we input a scalar longitudinal wave -- even one without hooks -- the translator puts out a normal vector transverse matter wave.

We define a translator as anything which will accomplish one or both of those functions (usually both).

Basically, any device which is TOTALLY nonlinear to transverse waves will produce scalar waves from a transverse wave input. Any device which is totally nonlinear to longitudinal waves will produce transverse waves from a longitudinal wave input.

It is comparable to certain plasmas, which, as is well
known, produce such a translator effect. If you input longitudinal waves, you get transverse waves. If you input transverse waves, you get longitudinal waves. And the plasma is rather totally nonlinear.

Again, if our translator outputs non-hooking waves, it means that the component substructure waves oppose each other in sum zero fashion, and "kill" or nullify the vortex spin-holes.

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SLIDE 42.

TRANSVERSE WAVE INTERFERENCE

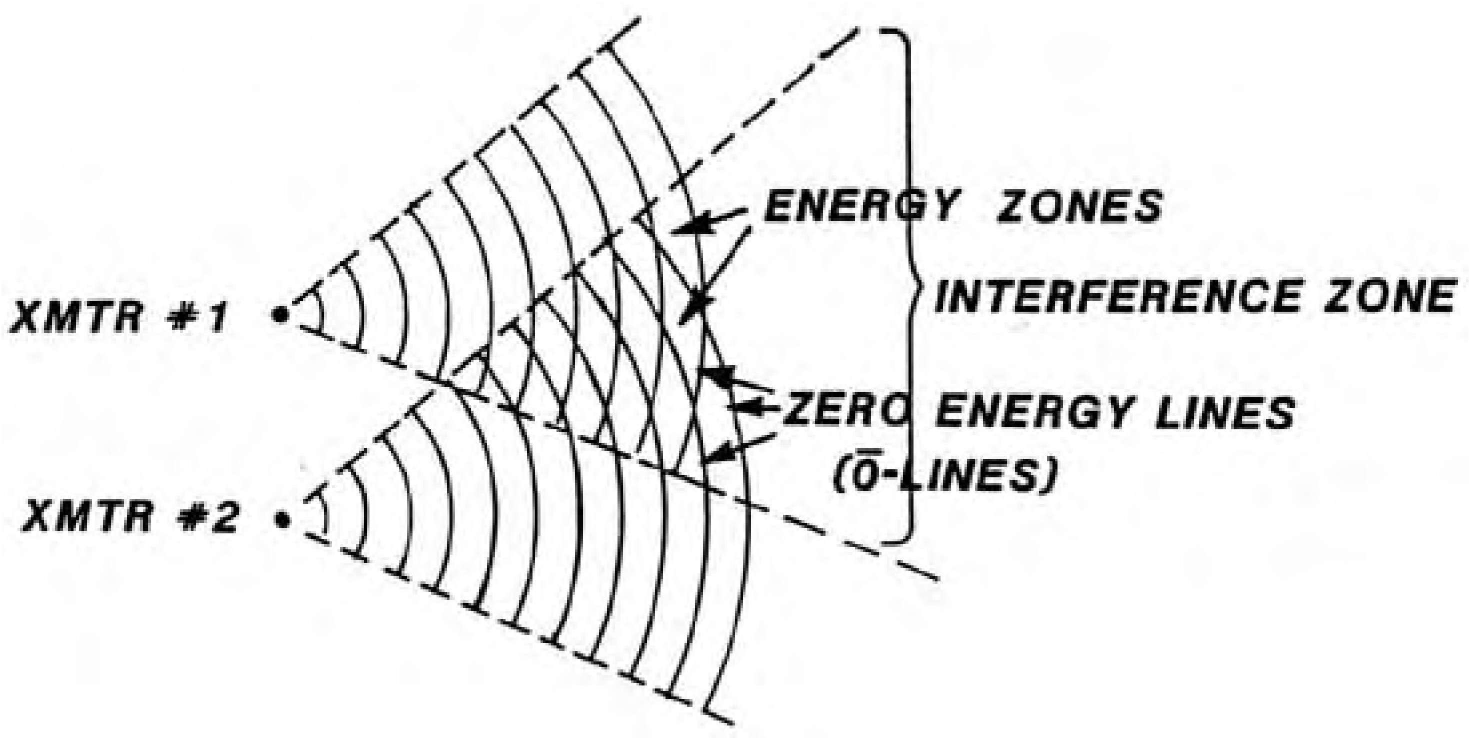

On this slide we show "normal " transverse wave interference, as we presently teach it in our textbooks.

We visualize two identical transmitters, each producing a beam in a pattern of about 55 degrees of so.

Where these beams overlap -- in the ideal, perfect case, we have constructive and destructive interference, with absolute zero-vector linear regions being formed. We put in the energy, and out-of-phase interference creates the zero zones, which contain no energy as such.

We point out, however, that these zero-lines are scalars,
and contain high stresses on spacetime.

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SLIDE 43.

LONGITUDINAL WAVE INTERFERENCE [SCALAR WAVES]

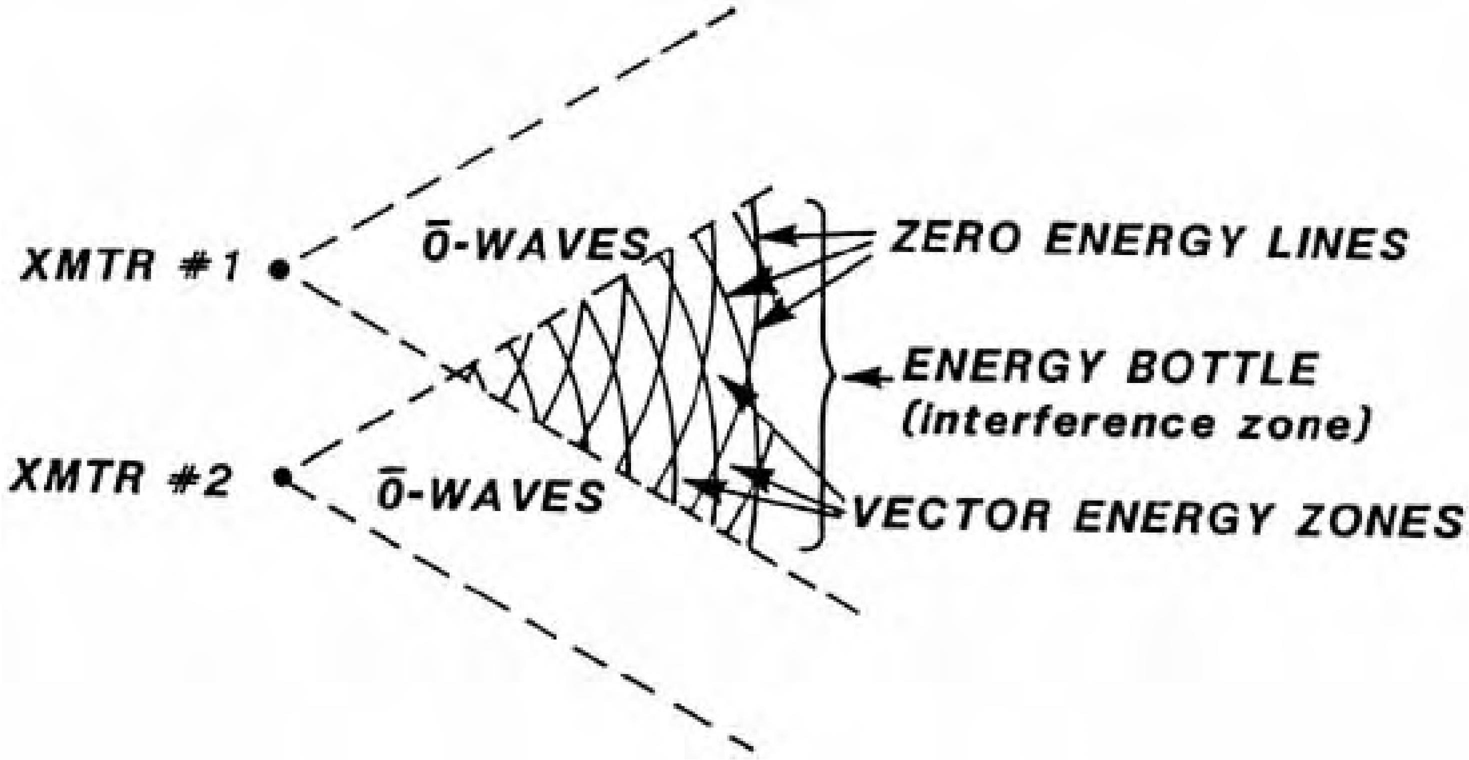
XMTR #1
XMTR #2
$\bar{0}$-WAVES
$\bar{0}$-WAVES
ZERO ENERGY LINES
ENERGY BOTTLE
(Interference zone)
VECTOR ENERGY ZONES

On this slide we show the interference pattern that emerges from the interference of two identical scalar wave beams from translator/transmitters.

Now note we are interfering two zero-vector waves, each containing a substructure. In this case we assume similar substructures.

What happens now is that we get a similar interference pattern, but with some startling differences.

First, we put in the zero-lines. These represent in-phase conditions for the substructures.

. Second, the substructures themselves interfere, and form energy in the grid zones between intersecting zero-lines.

In the perfect case, however, this energy cannot radiate away. It is physically created and trapped as if in an "energy bottle." We are CREATING this energy at a distance, and storing it in a bottle. If the bottle were perfect, we would continue to accumulate energy in the grid zones -- notice we are continuing to pour energy into both transmitters, and there is zero ordinary energy anywhere else except in the grid zone "bottles."

If we turn off the transmitters smoothly, we extinguish the energy in the bottle completely. It is sucked right out of there, and the vacuum returns to its normal condition.

If we erratically and nonlinearly turn off the transmitters, we destroy the bottle and "dump" the energy suddenly. This is exactly like a sudden EMP from a nuclear weapon. A sudden pulse of energy is freed to radiate and interact in the region where the bottle was.

The high altitude booms off the East coast of the U.S. a few years ago were made in precisely this fashion, from such a weapon being adjusted and calibrated in the Soviet Union.

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SLIDE 44.

CREATING ENERGY AT A DISTANCE

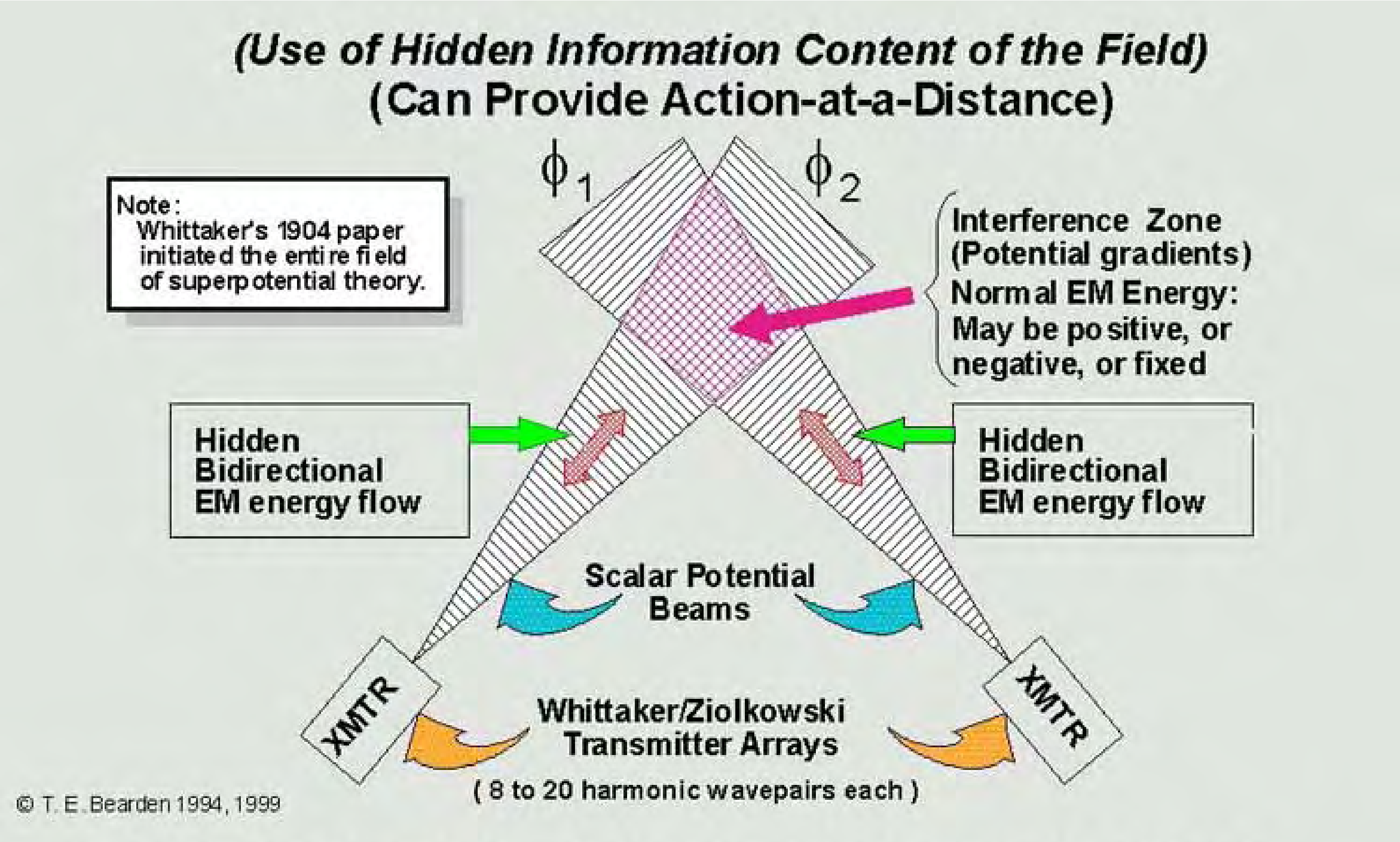
(Use of Hidden Information Content of the Field)
(Can Provide Action-at-a-Distance)
ϕ_1
ϕ_2
Note:
Whittaker's 1904 paper initiated the entire field of superpotential theory.
Interference Zone (Potential gradients)
Normal EM Energy: May be positive, or negative, or fixed
Hidden Bidirectional EM energy flow
Hidden Bidirectional EM energy flow
Scalar Potential Beams
XMTR
XMTR
Whittaker/Ziolkowski Transmitter Arrays
(8 to 20 harmonic wavepairs each)
© T. E. Bearden 1994, 1999

Figure 5. Scalar potential interferometry (between the two sets of bidirectional longitudinal EM wavepair functions) produces all EM force fields and waves.

But let us look at one way to do this sort of thing more efficiently.

Here we show two scalar transmitters (that is, two translator /transmitters) which form narrow beams, and which cross those beams at a distance.

In the crossing zone, scalar interference is established, making an energy bottle and producing trapped or locked in energy.

If I have a physical target in that crossed zone, I can literally "fry" the target, for I get all the power inputted to the transmitters contained in the bottle zone. I don't have any square law losses.

I can heat a metal object white hot at a distance, for example. Because all real bottles are slightly imperfect, the real bottle is leaky and some photons escape. I can observe the white hot steel in the bottle, and I can record and measure the temperature from the escaping photons, by simple radiometric methods.

Now if I smoothly turn off both transmitters linearly, all the energy in the bottle disappears immediately. I can immediately reach in and pick up a black, cool piece of steel. And that cannot be done with ordinary inductive or radiowave heating.

That has been done in a laboratory on the North American continent.

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SLIDE 45.

NONLINEARITIES CAUSE SHIFTING [PARTIAL TRANSLATION]

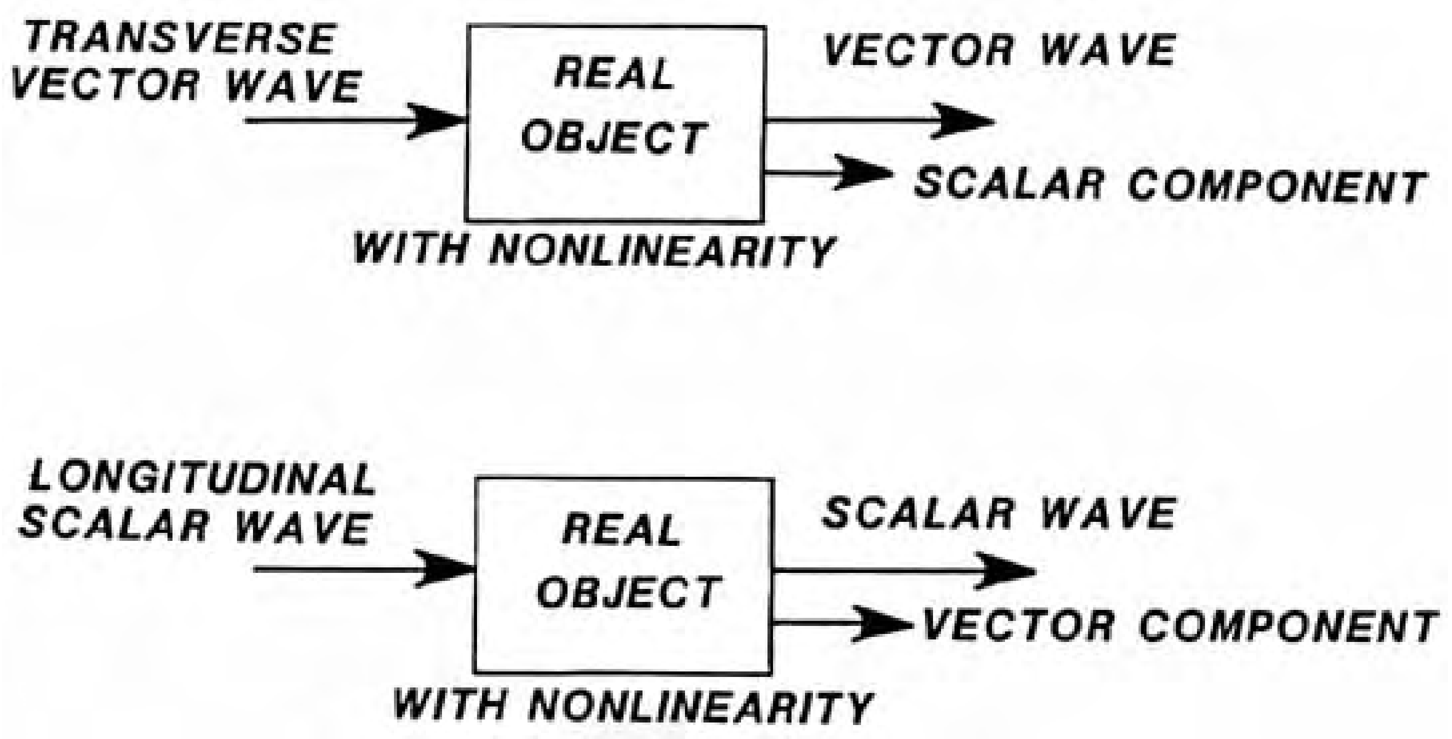
TRANSVERSE VECTOR WAVE
REAL OBJECT
WITH NONLINEARITY
VECTOR WAVE
SCALAR COMPONENT
LONGITUDINAL SCALAR WAVE
REAL OBJECT
WITH NONLINEARITY
SCALAR WAVE
VECTOR COMPONENT

Here we show the results of electrical nonlinearities in an object which encounters a true translated (non-hooking) scalar wave. All objects have some electrical nonlinearities in them, and so all act partially as translators.

This means that any real object creates a small scalar aura around itself from its continual temperature interactions -- from absorbing and radiating ordinary EM waves. In addition, the object normally is subject to undetected scalar wave radiations, and so it also produces a small aura of transverse vector waves around itself by translation.

All real objects accomplish at least a little bit of translation.

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TOWARDS A NEW ELECTROMAGNETICS
PART 4: VECTORS AND MECHANISMS CLARIFIED

SLIDE 46.

THE SCALAR AURA

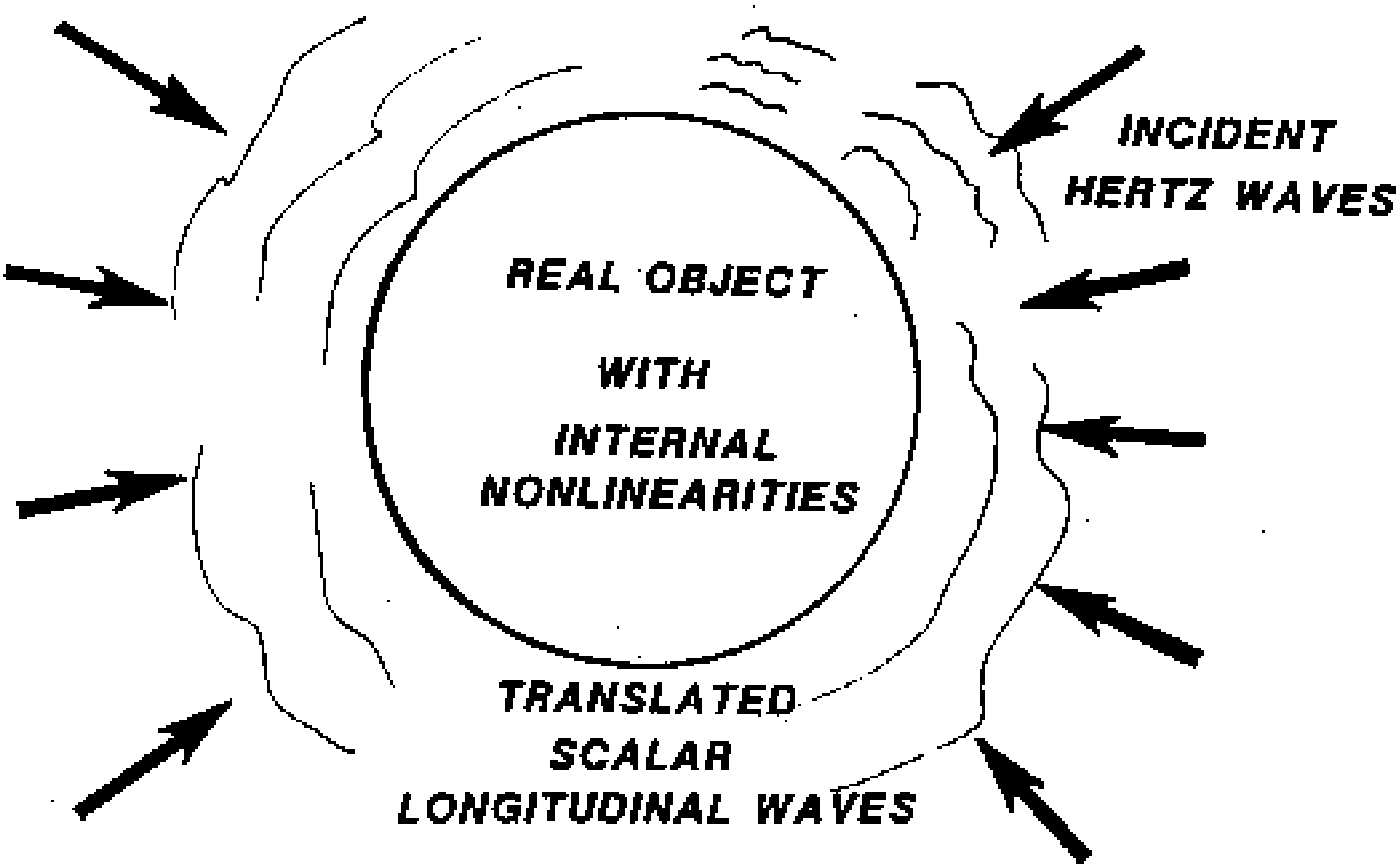
INCIDENT
HERTZ WAVES
REAL OBJECT
WITH
INTERNAL
NONLINEARITIES
TRANSLATED
SCALAR
LONGITUDINAL WAVES

We examine now an object with temperature, that is, a normal object continually absorbing ordinary EM radiation and continually emitting EM radiation.

The object has a small fraction of its incident energy expressed as a scalar aura around it, because of translation. Note that normal detectors will not detect this aura, but special two-stage interferometric detectors will detect it. Also note that the object replenishes- the ordinary radiation flow by its translation of some of its incident scalar radiation into the normal or "transverse" (so-called) radiation.

The entire internal pattern -- all interactions and functions of the body -- are precisely present in its scalar aura, down to the finest detail. This makes an x-ray pale by comparison.

True psychics actually use the nonlinearity of their nervous systems (note the avalanche ion discharges across dendrite gaps) and the interferometric aspects (note two cerebral hemispheres, connected by a corpus callosum) to detect the scalar aura. This is a physical fact and not esoteric delusion. To control this, however, is normally as difficult as learning to walk a high wire and do acrobatics on it. There are not many high wire walkers in the world, but it certainly is a skill within human control capability and purview.

T. Galen Hieronymus was absolutely correct when he stated that the entire internal working pattern of an object is radiated by that object in terms of an extraordinary energy, which he called "eloptic" energy. It is actually translated scalar wave energy, and entirely consistent with present EM theory when the glaring errors in its foundations are corrected.

Shortly I hope we will see instrumentation which can directly examine the scalar aura in the finest detail, seeing every illness, and simply setting dials to radiate the body with gentle, harmless scalar waxes to directly correct illnesses.

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SLIDE 47.

VIRTUAL FLUX AND MAGNETIC FIELD [LINEAR CASE]

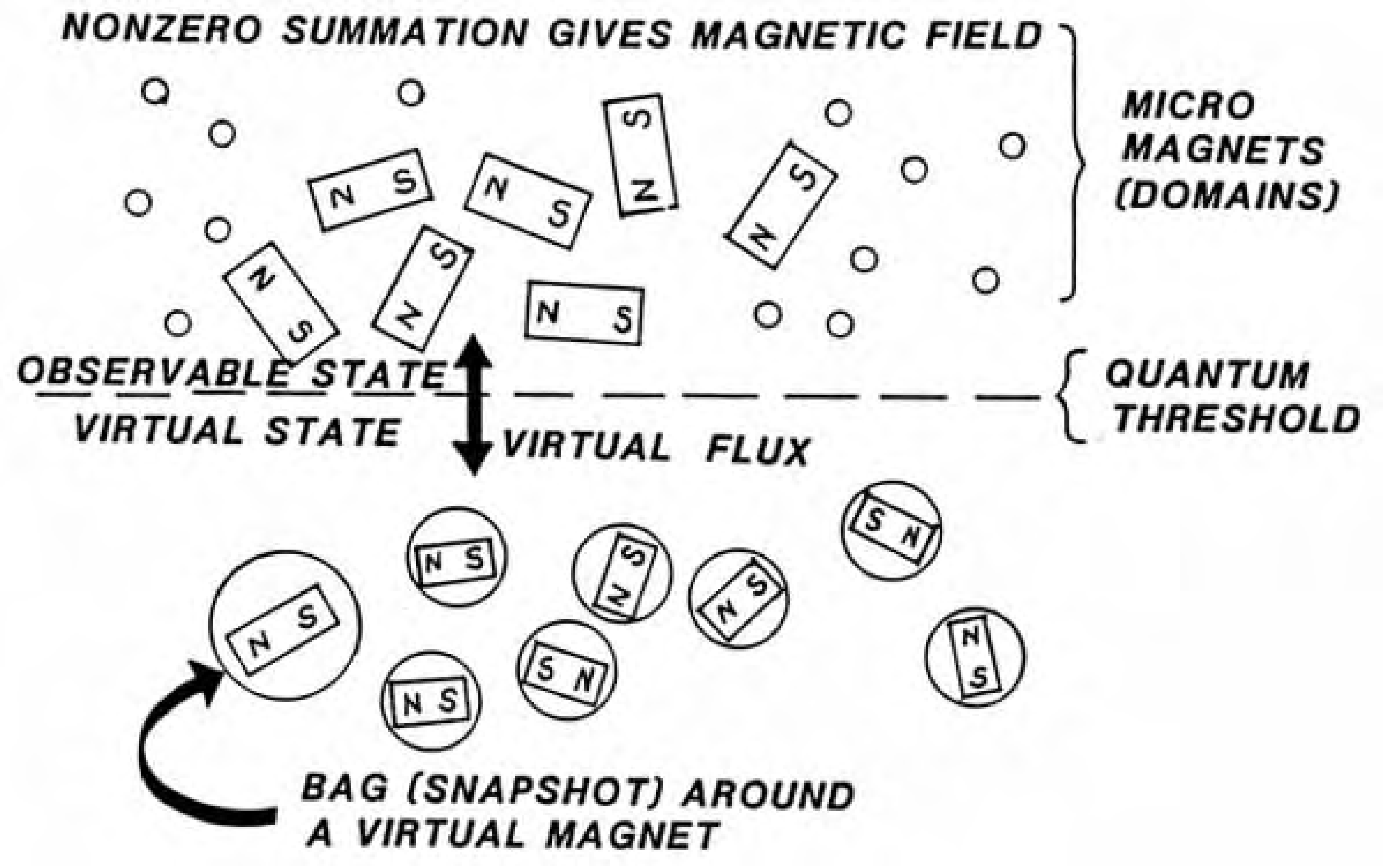
NONZERO SUMMATION GIVES MAGNETIC FIELD
MICRO MAGNETS (DOMAINS)
N S
OBSERVABLE STATE
VIRTUAL STATE
VIRTUAL FLUX
QUANTUM THRESHOLD
BAG (SNAPSHOT) AROUND A VIRTUAL MAGNET

Briefly, let's look at some nice things we can do with magnetism. Specifically, let's find out how to make magnetic monopoles and use them to do things in the laboratory. This again has been done in a laboratory on the North American continent.

First, about all the present science can tell us about a magnet is that "a big magnet is made of littler magnets." And if we examine one of the smaller magnets, it's made of even smaller magnets. This is like saying big dirt piles are made of smaller dirt piles, and that explains what dirt is.

However, let's use that with our knowledge of the virtual flux vacuum.

In this slide, we show diagrammatically the situation for a common magnet. Note that domains in the magnetic material are themselves little magnets, and their alignment and vector summation determine whether or not there's said to be a magnetic field present. Nonzero summation states that there's a resultant magnetic vector, and hence an external magnetic field. Zero summation states there's no external nonzero resultant, hence no external magnetic field.

Actually, there's an external scalar magnetic potential field, even when the external vector magnetic field is zero. The substructure is still there.

If we pursue this "big magnets are composed of smaller magnets," eventually we reach the quantum threshold, and we have a substructure of virtual, subquantal magnets in vacuum, in the virtual particle flux. At least we conceive each little virtual particle as if it were spinning, and hence a little magnet.

We put a conceptual bag around each little virtual magnet.

In a linear situation, the north pole is as strong as the south pole, and so just outside the bag, the poles cancel or appear zero. Since the virtual bag appears to be zero length to an external macro observer, the poles seem to be directly superposed on top of each other, yielding no pole at all to the observer.

However, you and I now know that both poles are still in there, in the virtual substructure, and we certainly have remaining with us a translated scalar magnetic field.

There's a virtual flux to and from each observable particle of charged mass in the observable state as shown, but this flux is now scalar in virtual magnets, except for nonlinearities in the structures above the quantum level. Thus accelerated portions -- atoms with electrons in whirling orbit, spinning electrons, protons, etc. -- possess nonzero ordinary vector magnetic fields by translation. Again, notice the successive interlocking levels of reality, all the way from deep in the virtual state into interlocking levels in observable state.

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SLIDE 48.

PRODUCING MAGNETIC MONOPOLES

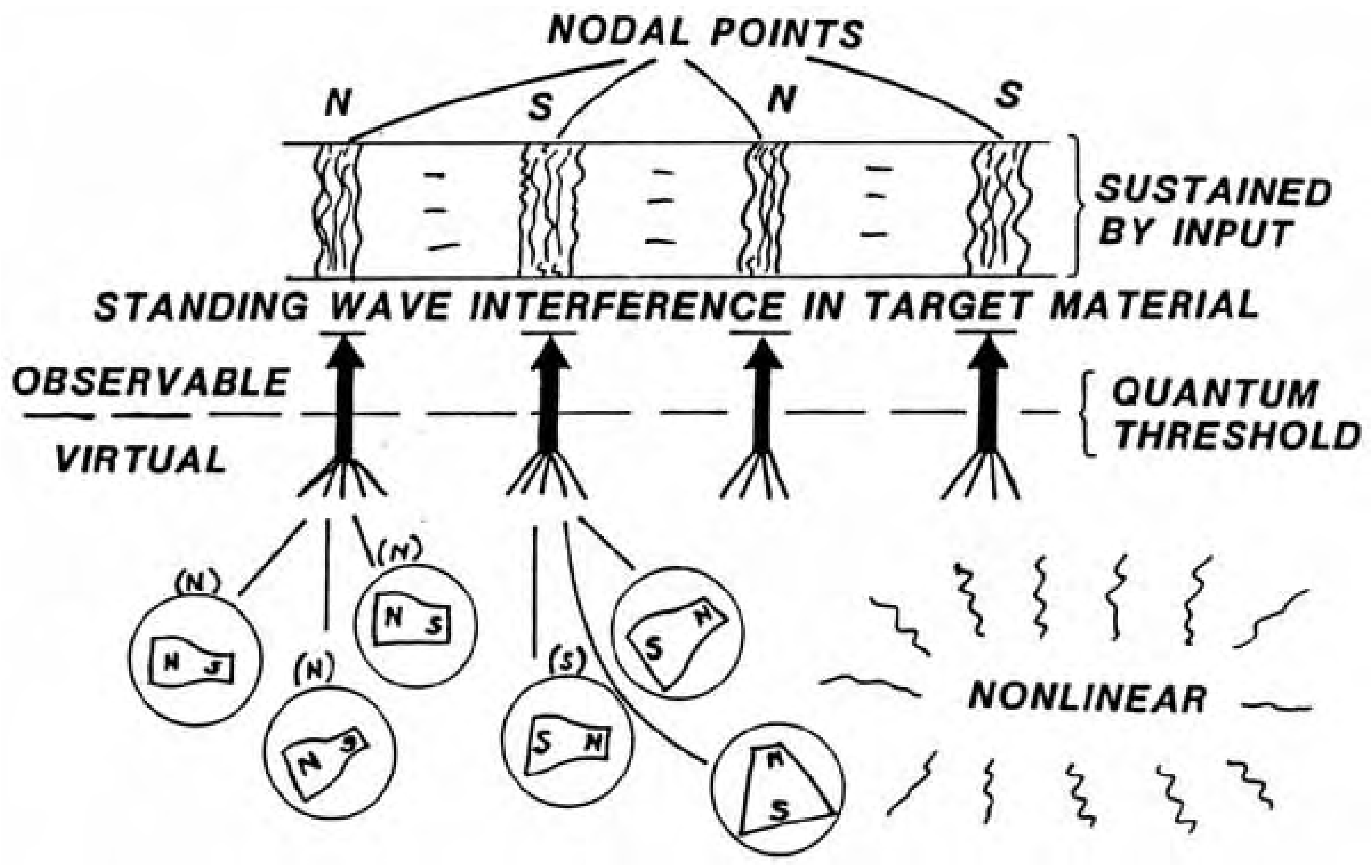
NODAL POINTS
N
S
N
S
SUSTAINED BY INPUT
STANDING WAVE INTERFERENCE IN TARGET MATERIAL
OBSERVABLE
VIRTUAL
QUANTUM THRESHOLD
(N)
N S
(N)
N S
(N)
N S
(S)
S N
S N
N S
NONLINEAR

Now let us look at a non-linear case of the same sort of thing. Now the bags are still around the little virtual magnets, but they are nonlinear. This means that, to an observer outside the bag, one pole seems bigger or more powerful than the other. In other words, to the quantum observer, this bag appears to be a magnetic monopole at a point.

In the flux still on and off each observable spinning charged mass, we now have a steady component of "monopoles". If we have a standing scalar wave present in a physical material in which the nonlinearity exists -- and the scalar waves can even be PRODUCING that nonlinearity -- we will have nodes available at which the monopoles will congregate and emerge and interact.

North monopoles will congregate at one node, while south monopoles will congregate at the next, and so on in alternating fashion.

That means that, at anyone node, monopoles of the same kind are steadily being "deposited" in the material. These monopoles strongly repel each other, and so the material at that node is increasingly stressed in a tensile fashion.

Eventually the material will be torn apart at the node,
stress relieving the situation. Movement of the material will release the nonlinear condition, stopping monopole production and deposit. However, at a break node, the same kind of magnetic pole will appear on each side of the break.

That is, the breaks will be N-N, S-S, N-N, S-S, etc.

An ordinary magnetic does not do that when it breaks. Instead, it breaks N-S, N-S, etc.

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SLIDE 49.

BREAKING METAL WITH MAGNETIC MONOPOLES

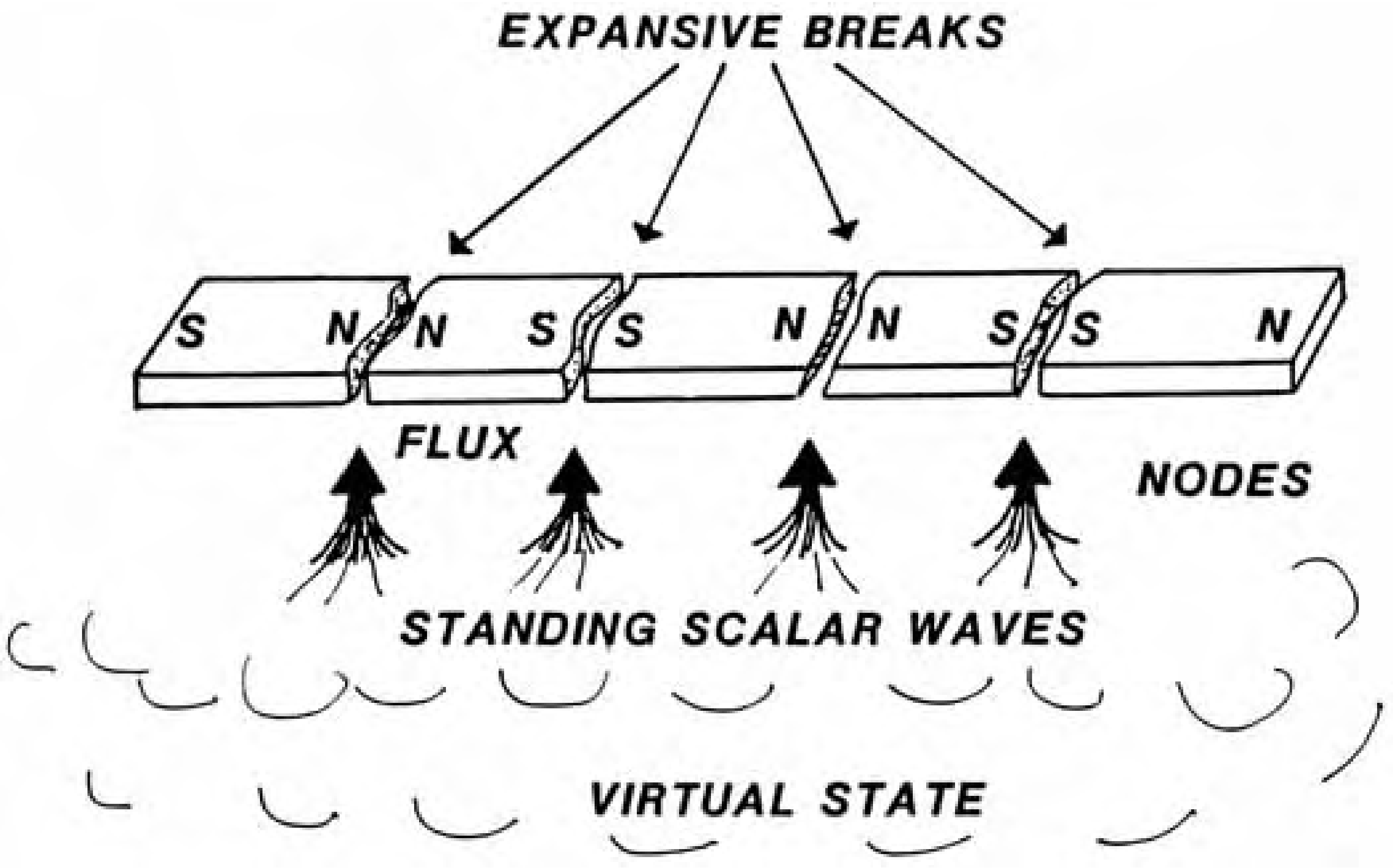

Again, metal has been broken in a North American laboratory utilizing the production and deposit of magnetic monopoles in this fashion.

On this slide we show what was done.

An ordinary bar of steel was exposed to standing scalar
waves in a nonlinear situation, depositing magnetic monopoles at the wave nodal points in the metal bar. The breaks occurred as shown on this slide.

Much of what I am presenting is based on certain experiments accomplished in experimental laboratories here and abroad. Most of the mechanisms have actually been produced in the lab. However, these are proprietary labs and I cannot violate trust and reveal the precise construction details utilized. In some cases I have not seen the precise constructions, but only the direct results.

But ironically, the production of magnetic monopoles -- which has fiercely resisted the normal scientific approach -- yields readily to the new approach.

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SLIDE 50.

CREATING AN INERTIAL FIELD (ANTIGRAVITY)

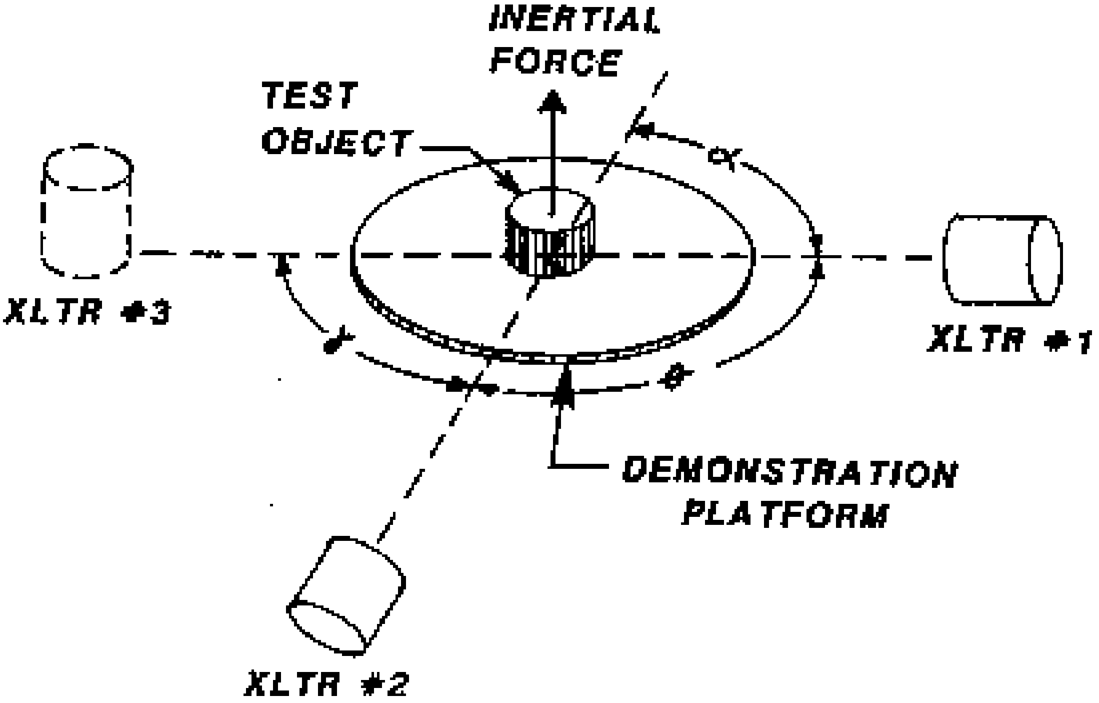

We now show schematically how to produce an inertial field, or antigravity. Also an inertial space drive can be produced in this manner.

This again has been done in a North American laboratory. In fact, inertial fields have been produced in more than one lab here in North America.

In the setup shown here, three translator/ transmitter projectors are used and oriented so as to give three-dimensional interference, or interference along all three spatial axes.

By controlling the substructures of the three projectors all together, one can control the precise phasing in all substructures, with respect to a common time reference.

By this means, a unilateral force can be created of each and every charged mass particle (that is, on each proton) in the nucleus.

Since we know that the neutrons and protons in a nucleus of an atom are continually interchanging, one into the other, back and forth, all of the nucleons can be treated as "diffuse protons" for mass purposes, and scalar wave interaction purposes.

Thus if we have the correct pattern to affect protons, we can control the phases of the substructure waves of the projectors so as to produce unilateral, parallel forces on and of each spinning proton in the nucleus.

This means we can produce unilateral thrust in an object exposed to the triad interference of the projectors.

In short, this produces antigravity. If sufficient force is produced, the test object in the interference zone simply lifts itself off against earth gravity. This has been done in North America.

If we phase the projectors so that counterbalancing forces are produced on each proton, we can either make the proton "lighter" inertially or "heavier."

In fact, we could "freeze" a common pistol so that it could not be moved and its trigger could not be pulled, simply by sufficiently increasing its inertia. This was done in experimental demonstrations in Toronto, Canada in 1969, and witnessed by the Chief of the Homicide Squad of the Toronto police. It was his pistol that was frozen for the demonstration.

If the projectors themselves are on board a space capsule, for example, they can produce such a unilateral thrust in and of a central mass or disc attached to the of the craft. By this means, an inertial spacedrive can be built.

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SLIDE 51.

EFFECTS ON HUMANS

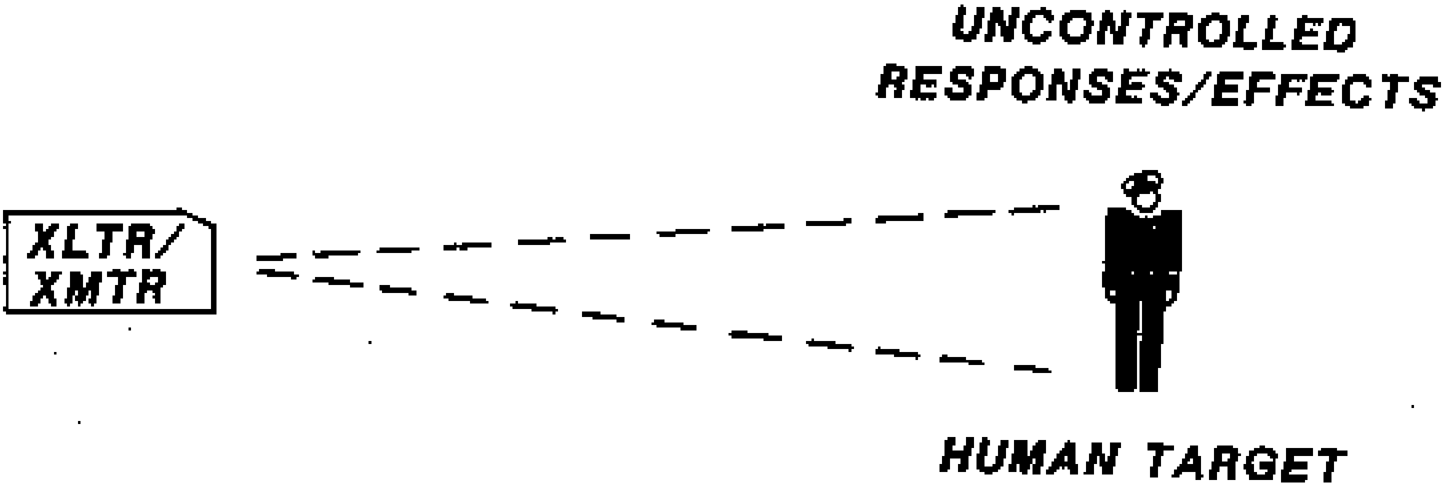

Now let us look at some of the effects on humans, when radiated with a true scalar wave beam from a translator/transmitter.

First, the human nervous system is highly nonlinear. Essentially, across billions of synapses, sudden ion discharges -- analogous to spark discharges -- are continually or periodically occurring. Brain waves, for example, are not waves along wires; instead, they are waves of avalanche discharges across tremendous numbers of nerve cell gaps.

The central nervous system is thus highly nonlinear, and the gap firings of the nerve endings act as translators.

These translators partially translate incident scalar waves, so that additional transverse matter waves -- or ordinary energy inputs -- occur in the ion discharges.

Thus additional energy is being added to the nervous system by incident scalar waves.

Many long-term effects of the environment on the body are gradually kindled in this fashion, even over a period of years.

For a stronger dosage of scalar waves, the nervous system experiences "jamming" of its signals. This leads to four basic "noise jamming" effects.

If a small dose is absorbed, the interference is slight. One feels as if one had taken a whiff of anaesthesia -- an unreal, dreamy feeling.

If a slightly larger dose is absorbed, the interference is moderate. Now the single channel system -- the motor system -- goes, and the individual is paralyzed. Mentally he is barely conscious, in a sort of hypnogogic, waking dream state. Any tendency toward epileptic seizure or other nervous disorder may surface here, as may heart palpitations or even heart failure.

For a heavier dosage yet, the interference is now strong. Now the multiple systems start failing. Consciousness is lost and the individual is in a deep coma. In addition, seizures and convulsions, and loss of control of some body functions, may occur. The autonomic nervous system is keeping the heart beating with difficulty and keeping the body gasping for breath.

For a very strong dosage, the entire nervous system fails and death results almost immediately. This is quite similar to the effects of nerve gas.

These are the four major symptoms of scalar wave radiation of the body and translating absorption by the nervous system in an uncoordinated fashion.

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[The Tom Bearden Website](http://www.cheniere.org)

TOWARDS A NEW ELECTROMAGNETICS
PART 4: VECTORS AND MECHANISMS CLARIFIED

SLIDE 52.

INITIATING SPECIFIC BIOLOGICAL EFFECTS

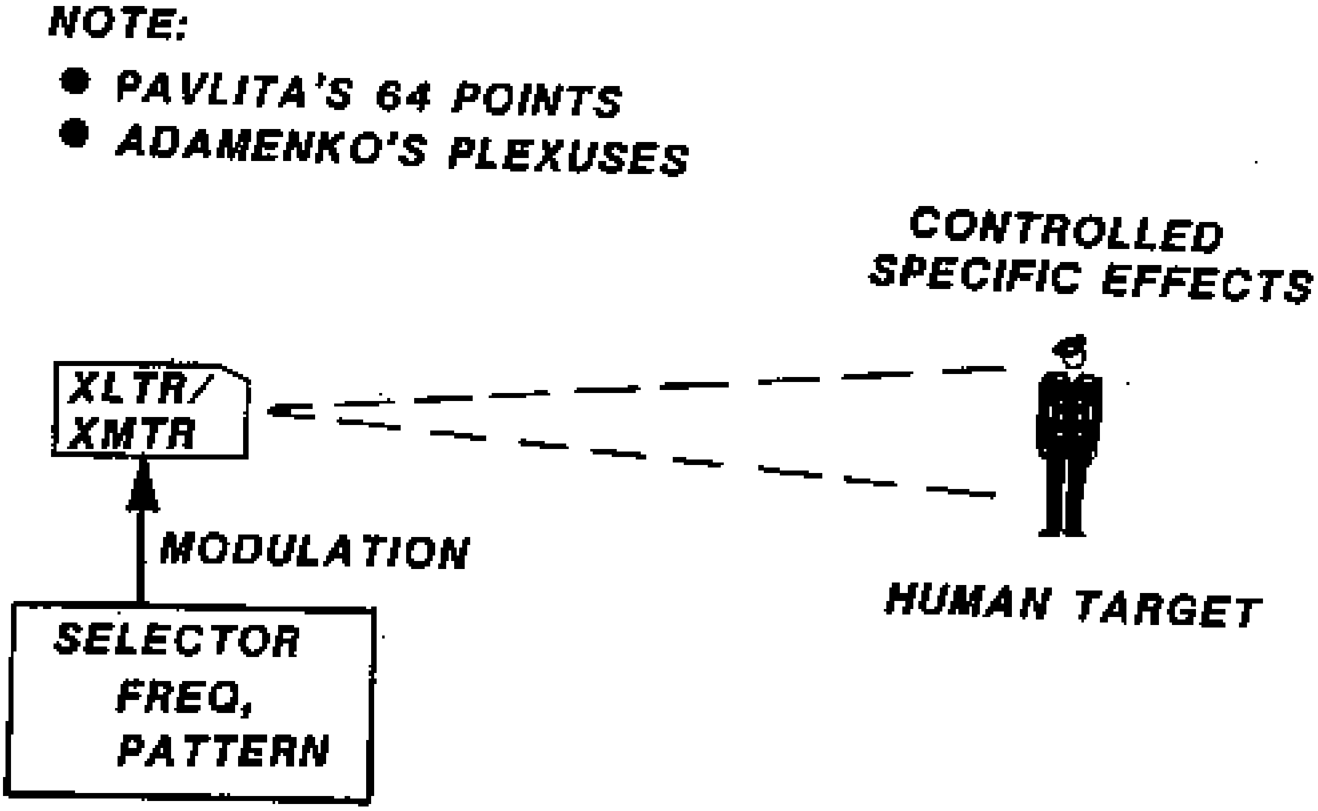
NOTE:
- PAVLITA'S 64 POINTS
- ADAMENKO'S PLEXUSES
CONTROLLED SPECIFIC EFFECTS
XLTR/ XMTR
MODULATION
SELECTOR FREQ, PATTERN
HUMAN TARGET

If we now add precisely patterned modulations to the substructure waves of the scalar zero vector beam, we can induce deliberate patterns in the dosage absorbed by a biological system.

As Kaznacheyev's experiments showed, any death or disease pattern can be induced upon an electromagnetic carrier -- specifically, upon the near-ultraviolet as an example. Some of his experiments were duplicated at the University of Marburg in West Germany, utilizing infrared carriers. These patterns can be dumped into cell cultures, eventually kindling the pattern of death or disease in the target cells.

The same can be done to a human from an external source. The major entry point is the acupuncture system, which reacts to scalar waves and transfers them to the nervous system for translation.

Pavlita, Czechoslovakian engineer, has built "psychotronic generators" for over 30 years that affect the human body. Adamenko, Soviet physicist, found that the acupuncture points formed groupings or plexuses that were frequency sensitive. In other words, certain frequency bands affect one plexus more than others. Further, these acupuncture points are known to be connected to effects produced at remote locations in the body.

Pavlita stated he had found 64 different sensitive "points" on the body, and had succeeded in building a generator for each. If by his points he meant Adamenko's plexuses, then frequency patterns can be created that affect certain acupuncture groupings -- and thereby certain specific body locations and effects -- more than others.

It thus appears reasonable that, by placing the proper frequency pattern in the modulations of the substructure waves feeding into the translator/ transmitter, the scalar ray or beam can be made highly selective as to body part affected and the effect generated or kindled in the body.

By this means, specifically tailored attacks on the body can be created.

Strong emotions such as sheer terror, overpowering rage, blind panic, etc. can be induced. Or physical effects such as epileptic seizure, loss of control of internal functions, loss of muscular control, severe weakness, specific failure of an individual organ such as the heart or liver, or blackouts and comas can be induced. In addition, patterns for specific toxins and diseases can be induced. With a strong absorption, these changes can be effected quickly. Imagine bubonic plague developing in 30 seconds, for example, or the effects of a cobra bite developing in 10 seconds.

If the individual is placed in crossed interference beams (that is, in the interference zone of a scalar interferometer), strong effects can be produced essentially instantly, including instantaneous death.

Of course BENEFICIAL effects can also be accomplished. As instrumentation is developed, one should be able to scan the aura, do a computerized readout to show the different medical problems either developed or developing in the body, have the computer compose a "cancellation or offsetting pattern," and radiate the body with a totally beneficial pattern, customized for that particular condition at that particular time. One should be able to quickly cure cancers and leukemias, for example, even of the brain and of the bone marrow. One may even be able to quickly reverse the effects of aging; at least there is no foreseeable reason why it should not be possible.

The new technology is a very powerful tool, and it can be used for either good or bad, depending upon the intent of the developer and the user.

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The Tom Bearden Website

SLIDE 53.

GROUND-TO-AIR USE

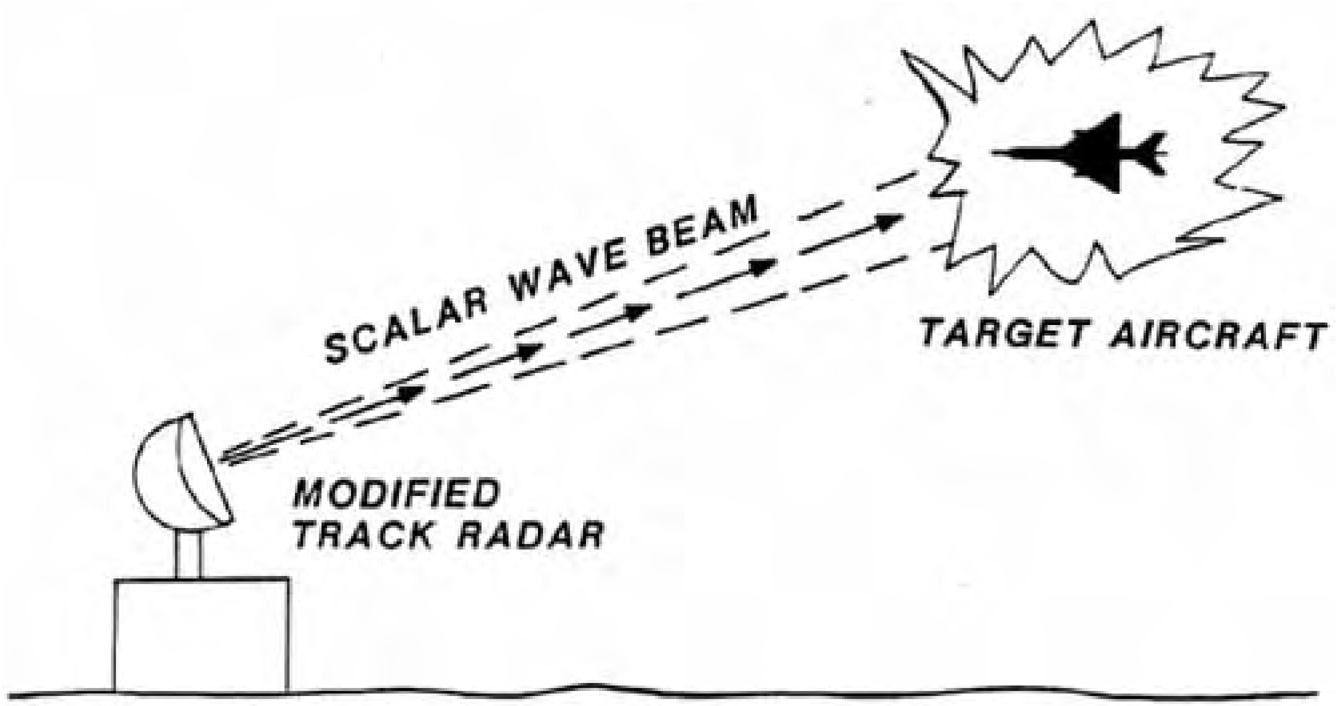

Here we show another use of the scalar beam technology already developed by foreign powers.

A modified track radar -- either continuous wave or pulsed -- transmits a scalar wave beam. It radiates an incoming hostile aircraft, keeping the beam on it, and kindling energy in the nonlinear electronic circuits of the aircraft by translation. Communications, navigation systems, avionics systems, electronic fuze systems, ignition and control systems, airborne radar, missile armament electronics, etc. are all vulnerable to this translation kindling of internally jamming energy from the incident scalar beam.

The electronics can be knocked out and the aircraft knocked down.

The pilot himself is also vulnerable because of his highly nonlinear central nervous system.

Some or all of the eight F-111's mysteriously

lost in
Vietnam may have been bagged by modified SA-2 FANSONG radars, using this effect.

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SLIDE 54.

TACTICAL AIR-TO-GROUND USAGE

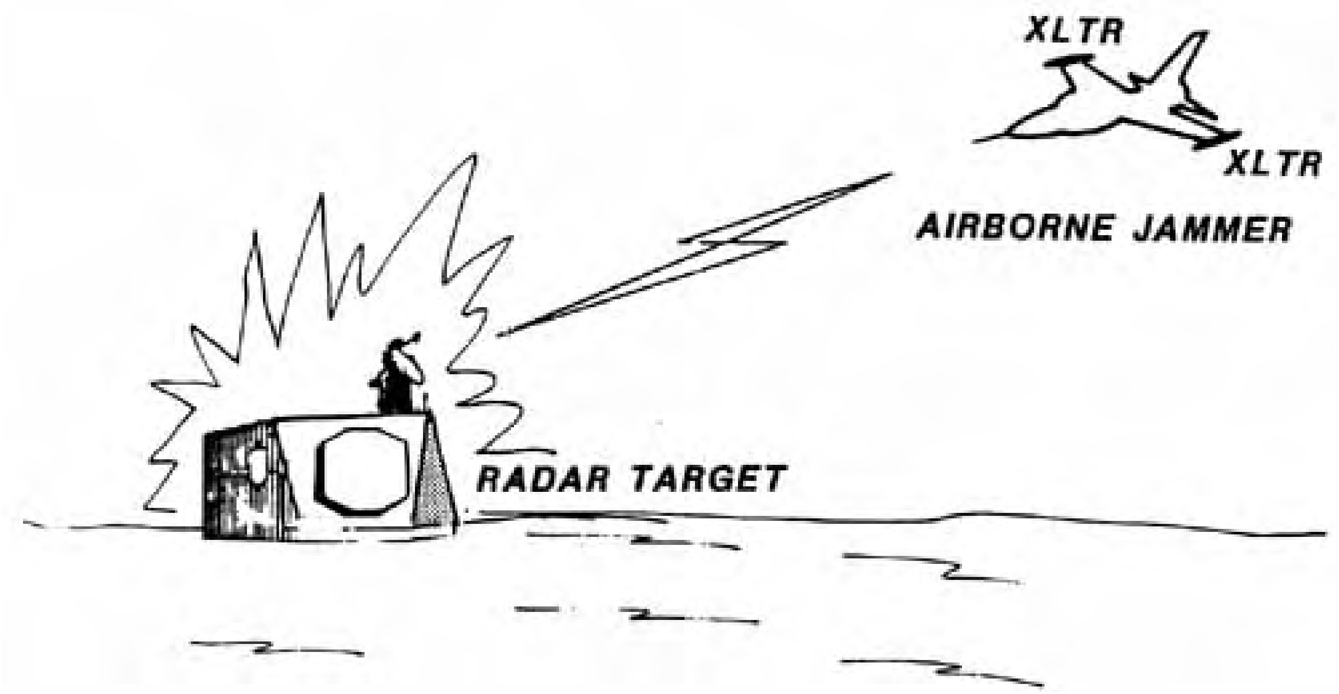

As shown on this slide, the technology is also usable from aircraft against ground targets, particularly ground-based radars and communications systems.

As shown, the aircraft has a modified jammer, able to emit a beam of scalar energy from one or more translator/transmitters.

By simply training a beam on the radar, eventually the radar can be knocked out. That is the simplest use.

A more sophisticated usage is provided by more than one translator/transmitter, acting as a scalar interferometer.

In this mode, each translator/transmitter emits multiple scalar carrier frequencies. Two Fourier expansions are established, so that a three dimensional "ball" or sphere of interference-zone energy is established. By pulsing or phasing, this ball is moved to strike the location of the radar, delivering a large burst of energy to it and knocking it out. Alternatively, the energy bottle is "dumped" when it reaches the targeted radar or its near vicinity.

A still better way is to fire one Fourier scalar pattern directly at the target radar, then fire a second pulse faster so that it overtakes the first directly upon the target. (The ensemble of such a pattern acts as a soliton, and its velocity is controllable by controlling the amplitude of the pattern generated).

When the second scalar overtakes the first, a sharp interference is formed, with a fast energy bottle, which is then nonlinearly dumped in microseconds or milliseconds. In this fashion, all the energy put out by the jammer is delivered directly upon and into the target in one sharp EMP pulse, much like that from a small nuclear explosion. The target is destroyed.

Note that such a weapon can be utilized against tanks, vehicles, explosives, missiles, ammunition, bridges (the airblast), bunkers (the blast can occur INSIDE the enclosure), ships, planes, personnel, and targets of varied types.

The Soviets have had such secret weapons for years.

One additional country has them also.

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SLIDE 55.

INTEGRATED WEAPONS DISPLAY (MODIFIED JAMMER)

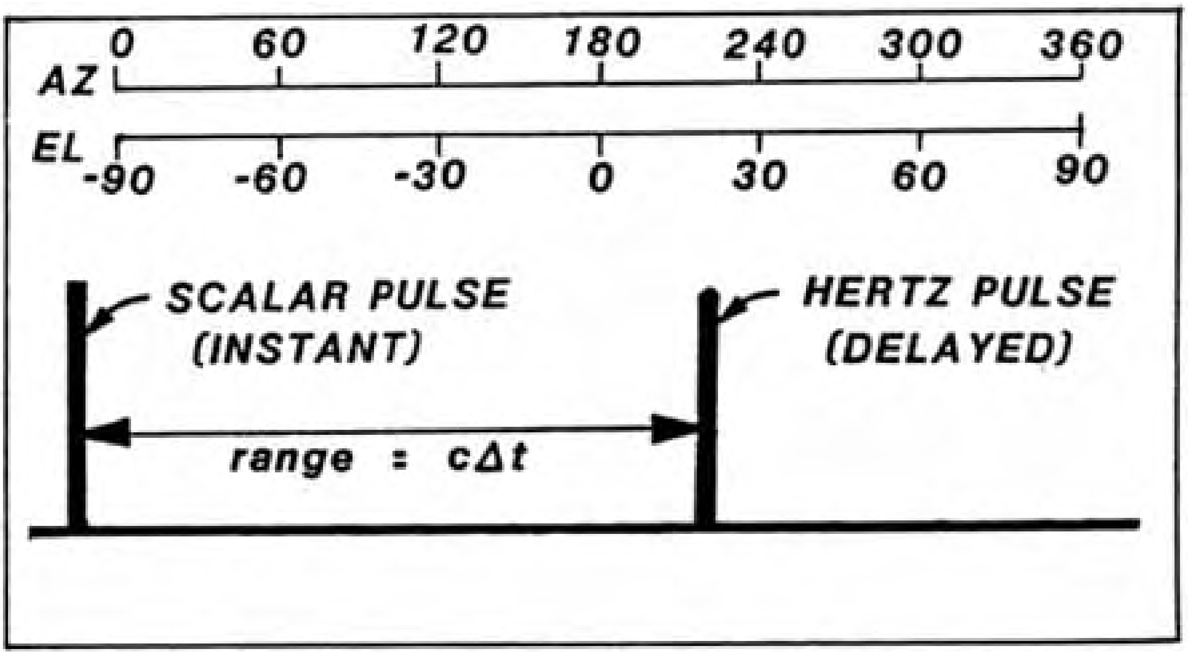

Here we show diagrammatically what a modified Soviet integrated weapons display for a modified jammer might be, to employ scalar interferometer weaponry.

As the "main bang" is emerging from the antenna of the

target radar on the ground, the phi-field from it reaches to infinity, including through the aircraft with a finite magnitude. In the a1rcraft, two channels act in interferometer fashion as a scalar detector for phi-dot. The main bang creation (phi-dot) is detected, and displayed as the leftmost pulse.

At that time, a computer time-base starts clocking off microseconds.

At some time later, the third channel, acting as a normal receiver, receives the ordinary "Hertz" pulse from the radar, which has traveled to the aircraft at the speed of light.

The computer converts elapsed time between the scalar pulse and the Hertz pulse to range.

Azimuth and elevation angle to the radar are obtained by normal angle tracking.

At this time, the computer has the exact coordinates of the radar, allowing for motion of the aircraft during the lapse time.

The computer switches the interferometer into transmit mode, and arranges amplitude patterns to target the radar.

It fires the first scalar pulse, then fires the second so as to create the full EMP directly upon the target.

The EMP flash occurs, destroying the radar.

At that time, another target can be processed.

In a more advanced weapon, scanning may be used to detect, locate, target, and engage multiple targets, including incoming air-to-air and surface-to-air missiles, one after another.

The same weapon is usable against a variety of aerial and ground based targets.

The major weapon is the electronic emitter, not a missile or ordinary ordnance.

Hordes of such special "jammer aircraft" now become a potent force on the battlefield, destroying all before them with annihilating ray weapons.

Star war is a reality now.

The High Frontier is already seriously obsolete.

Our entire defense establishment is completely vulnerable to these weapons at present, for we have not developed countermeasures or defenses.

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TOWARDS A NEW ELECTROMAGNETICS
PART 4: VECTORS AND MECHANISMS CLARIFIED

SLIDE 56

RADAR INVISIBILITY

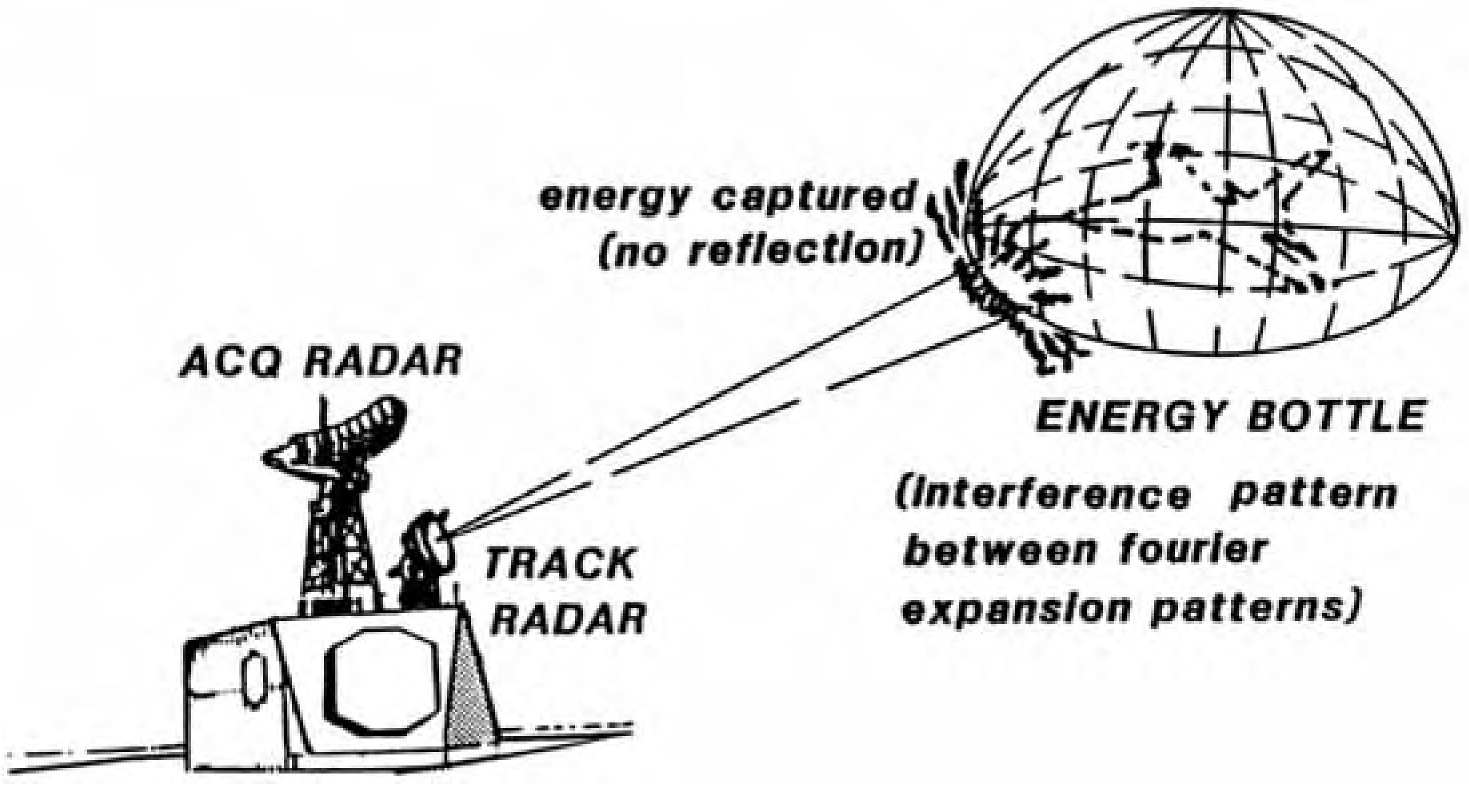
energy captured
(no reflection)
ACQ RADAR
ENERGY BOTTLE
(interference pattern
between fourier
expansion patterns)
TRACK
RADAR

On this slide we show another effect which can be obtained. We can make an airplane invisible to ordinary radar.

Imagine now the same "jammer" type aircraft with three channels, one for use in scalar interferometry and one as an ordinary channel.

This time, a Fourier interference pattern is established around the aircraft, so this establishes an "energy bottle" around the plane. We specifically arrange this bottle in the frequency band of the hostile radar we wish to avoid. For multiple bands, we establish multiple bottles -- this just requires more frequencies or more translator/transmitters.

The beam from the ground radar now strikes the energy bottle, and its energy enters and is trapped in the bottle grids. Since the bottle is leaky, the incident energy gradually disperses and "leaks" out all around, with very little emerging energy.

The ground radar receives no return pulse or reflection.

Therefore it sees no target.

The same interferometer system is usable both in this defensive screen fashion and in the attack fashion previously discussed.

Use of this system has been demonstrated internationally.

An energy bottle has been created in a North American laboratory as well.

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SLIDE 57.

NETWORK OF VIRTUAL TRANSMITTERS

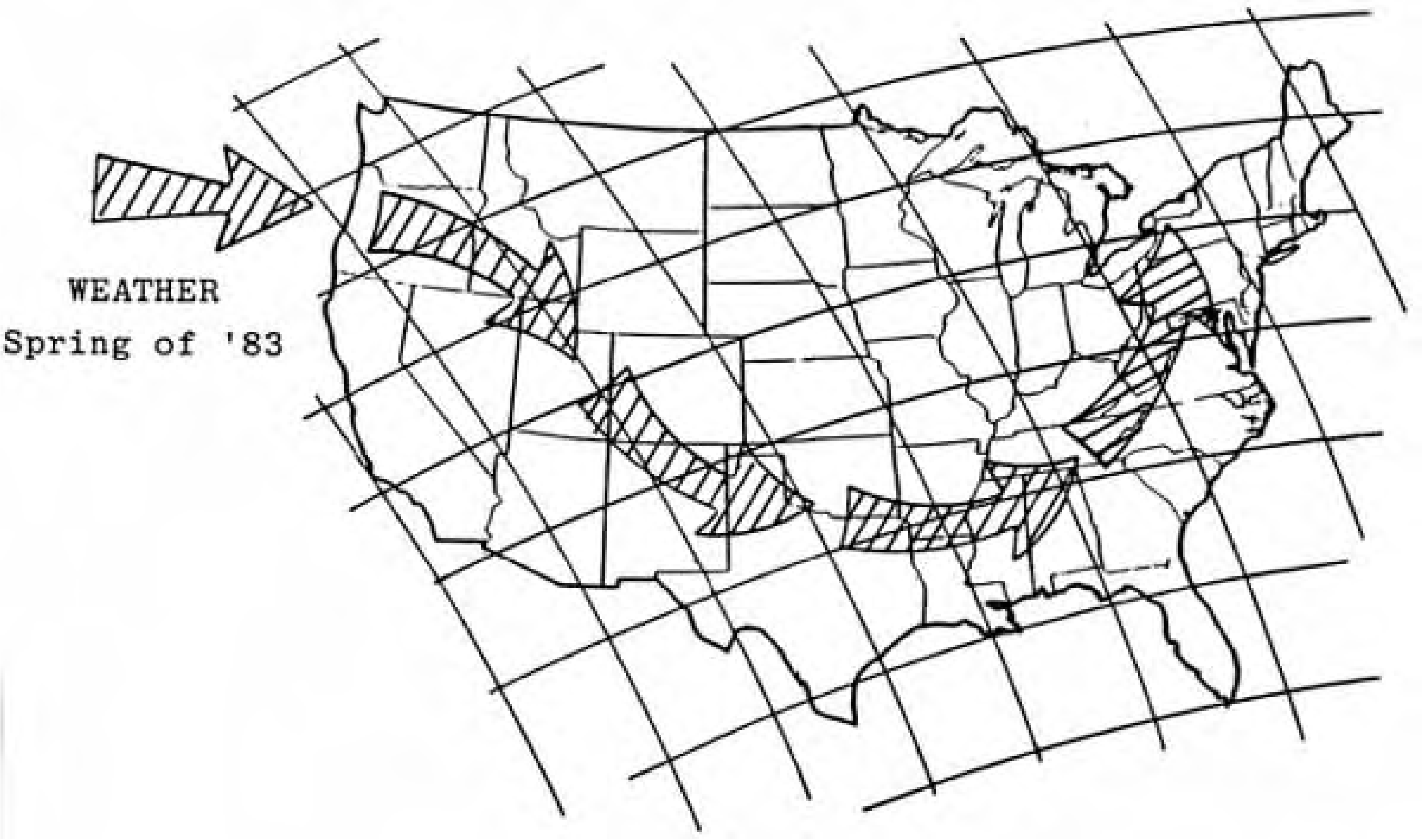

As is well-known, for years the Soviets have blanketed the world with large, powerful transmitter signals in the communications band, referred to as the "Woodpecker" signals because of the staccato noise the chirped signals make to the ear. The carriers have been modulated with known harmful bioactive ELF frequencies. At least some effects have been noted on humans from these signals, and other human effects are suspected but not proven.

In addition, evidence exists that such transmitters, utilized in the scalar transmission mode, may have been used to cause earthquakes and to control the weather. High altitude bursts off the coast of the Eastern United States and Canada, over

Timmons, Ontario, Canada, and off the coast from St. Petersburg, Florida have occurred also.

Mysterious "blackouts" of U. S .satellites -- and British satellites -- have occurred. These would be difficult to explain as the result of illumination from a ground laser, but easily explained as the result of illumination from a ground-based scalar beam or scalar interferometer.

Strange patterns of micro sky quakes and micro earthquakes occurred at various locations throughout the U.S. just before and shortly after the death of Leonid Brezhnev. These strongly appear to be connected with the adjustment of a scalar interference pattern -- a gigantic "energy bottle" across North America, as shown on this slide.

Shortly after this suspected adjustment and alignment, the underground net in the U.S. detected the emergence of numerous ELF-modulated signal carriers throughout the U.S., generally utilizing carriers in the vicinity of 40 MHz. Locations of the apparent transmitters were such places as Atlanta, North Georgia, St. Petersburg, Florida; Mississippi; Alabama; in the vicinity of Washington, D.C.; near Boston; around the Great Lakes; Michigan; in the Pacific Northwest (Washington and Oregon); and in both northern and southern California.

Researchers knowledgeable of the Soviet woodpecker signals and ELF modulations detected and reported these signals.

Physical effects were reported and correlated to the signals, including wakefulness at night, restlessness, fatigue, headaches, nausea, ringing in the ears, anxiety, disturbed dreams, etc.

What appears to have occurred is the adjustment and
alignment of a vast scalar interference pattern across the U.S. Recall that energy emerges in each grid, by phase interference between the composite substructure waves of the scalar beams.

Thus the Woodpecker "over-the-horizon radars," as accepted
by Western intelligence analysts, may have acquired a diabolical new strategic capability.

It is as if the Soviets had been permitted to build a vast network of transmitters directly on U.S. soil, for hostile employment against U.S. citizens.

Shortly after the net was aligned, a curious pattern of weather assaults on the U.S. began.

Storms assaulted California unceasingly. Then they roared across the Rockies, dipping sharply down to hit the Texas Panhandle, and bending northeast again to assault the South and the East.

The mighty jetstreams themselves were diverted and "kinked" into this looped, distorted pattern.

And the storms and floods assaulted the U.S. one after the other in this highly unusual fashion.

I maintain that the virtual transmitter net, just established by the Soviets and adjusted in on the U.S., was tested in the weather control mode. If so, it proved highly effective. Imagine what would have happened to the U.S. if it had been unleashed full force, and not just "gently tested."

And imagine what happens when disease, death, and nervous system disturbances are modulated upon these blanketing signals. The "transmitters" for the patterns are in each grid, all across the U.S.! And there are no physical transmitters there to destroy.

A counter is needed quickly. A simple one would consist of recording the signals in each grid zone, analyzing the substructure, reversing the signals and their structured patterns 180 degrees, and feeding the "cancellation signals" out in each area.

A great strategic Russian weapon of devastating power and potential is now operating directly on U.S. soil. The need for a crash countermeasures program is urgent.

In 1975 Brezhnev had introduced to the SALT talks the
strange proposal that we should also consider outlawing the development of new weapons more frightful than the mind of man
had ever imagined. We didn't know what the Russians were talking about. When we asked them later what weapons they meant, they referred vaguely to weapons of an electromagnetic nature.

The presentation I have just given you is part of what Brezhnev meant.

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SLIDE 58.

CONCLUSION

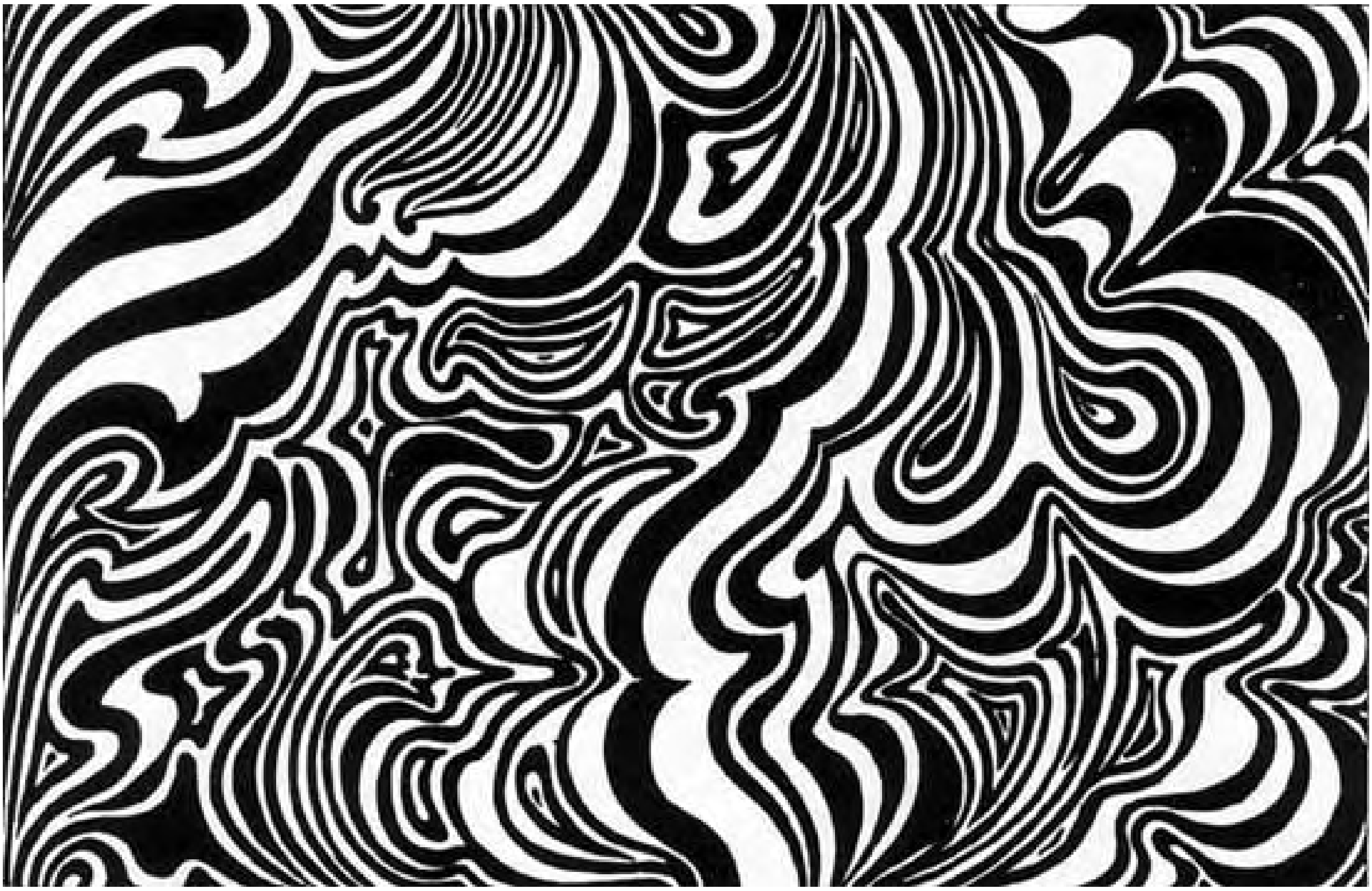

In conclusion, today I have released a number of powerful mechanisms that result from the new technological concepts. Many of these were originally discovered -- at least in rudimentary form -- by Nikola Tesla. In the West, the suppression of Tesla led to the suppression of these effects. And our knowledge of them went to the grave with Tesla.

After World War II, the Soviet Union mounted a massive campaign to obtain all the scientific literature of the West and thoroughly digest it. Great centers were set up, and thousands

of PhD's devoted to this purpose. Gradually they synthesized
this technology from the errors in EM foundations they uncovered, and from obscure, ignored papers published in the orthodox
Western scientific literature.

They rediscovered the technology of Tesla, Moray, and
Rogers. And they have highly weaponized the effects, and adjusted and aligned the weapons upon us.

Now the radical movements are onto part of this technology. As late as about six months ago, one such group discovered how to build a translator and a scalar beam projector. Excitedly, they planned to build them the size of a large pistol, powered by a portable battery pack, and sell them to street criminals to kill or stop the police. They planned to get rich by this illicit means. At that time, a personal friend of mine, who moves in underground circles, was attempting to purchase one of the prototypes for my analysis. Fortunately, the inventor stepped into the beam of one of his devices and was almost killed. This frightened the group, and at least for now they have desisted. But be forewarned: this technology is coming down the pipe, and the police establishments in the West are in for the shock of their lives if the scientific community does not wake up and prepare defenses.

Again I urge my fellow colleagues to experiment vigorously with these new concepts, but build equipment for the benefit of man. Insect control, disease elimination and control -- both are noble purposes. Defense against the hostile use of such devices is also a fitting purpose.

We are in the final days, and the final technology is upon us. It is a stupendous tool for either good or bad, and assuredly it will be utilized for both means. I call attention once again to the fact that my ultimate purpose is to use this technology benevolently to achieve mind linkage, and elevate man from his present brutish state to the lofty state that is his destiny and his true God-nature.

For better or worse, Tesla technology is once again loose in the world, this time for good, and on a massive scale.

Let us prepare ourselves for a wild canoe ride, for the real white water lies just ahead.

Thank you for your attention, and good evening.

LEADING EDGE

Volume 7, Issue No. 4

DIRECTED ENERGY

Applications Across Land, Air, and Sea

NAVSEA
WARFARE CENTERS
DAHLGREN

Challenges & Solutions for the 21st Century

LEADING EDGE

Volume 7, Issue No. 4

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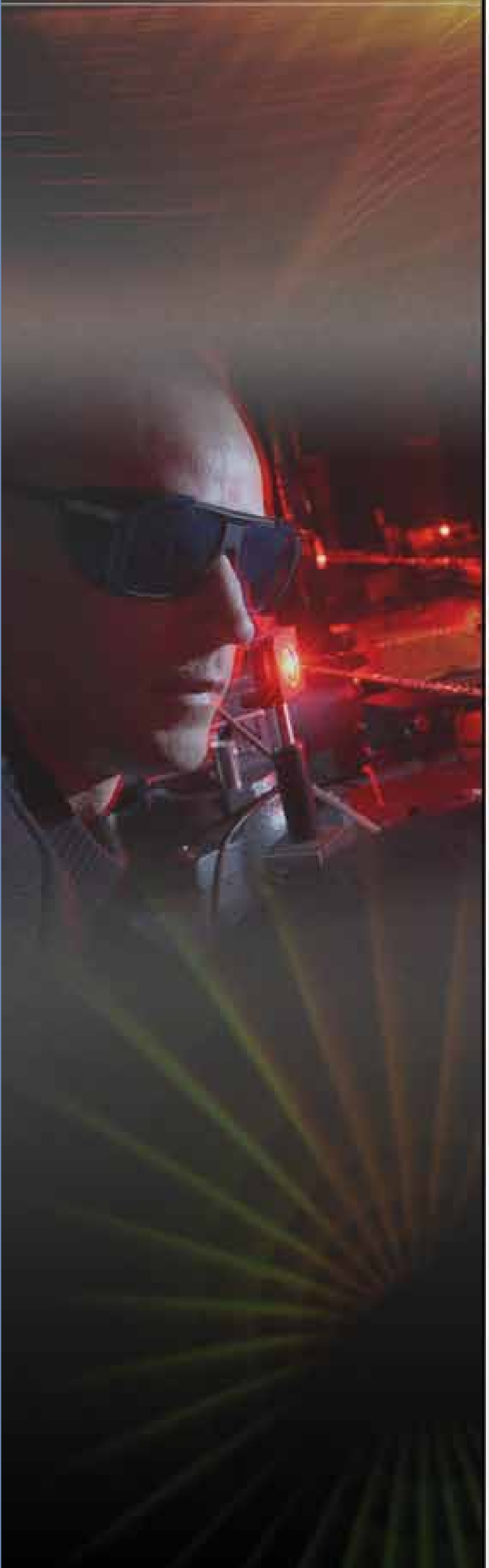

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Introduction

Leading Edge Directed-Energy RDT&E

Captain Michael H. Smith, USN
Commander, NSWCDD

Dahlgren first launched research and development efforts devoted to harnessing the power of electromagnetic energy over 40 years ago. From early work with voltage multipliers and pulse-powered technology, to today's high-energy lasers and high-power microwave technologies, the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) has led, and continues to lead, cutting-edge directed-energy research, development, testing, and evaluation. Our commitment in this area only grows stronger—evidenced by our chartering of the Directed Energy Warfare Office (DEWO)—in order to provide increased focus on warfighting applications of these technologies.

Today's military forces face a wide array of challenges in diverse operating environments around the world. Directed energy offers unique and flexible options to address today's challenges, as traditional kinetic weapons are often of limited value in peacekeeping missions and in urban environments, where restricted rules of engagement typify the norm. Kinetic weapons can also be more costly or ineffective to employ against asymmetric threats.

The Chief of Naval Operations (CNO) recently placed added emphasis on directed energy and on expanding the range of directed-energy capabilities. In response, scientists and engineers at NSWCDD are actively developing prototype systems in a number of areas that you will read about in this issue—areas that have been successfully demonstrated and tested in our Navy laboratories and ranges.

In this issue of *The Leading Edge* magazine, you will trace the rich history of directed-energy work at Dahlgren, gain insight into directed-energy weapons already fielded or being readied for the field, and learn about prototypes that show real promise for providing incredibly effective offensive and defensive directed-energy solutions. For example, scientists and engineers at NSWCDD are leading the way toward realizing small, lightweight radio frequency (RF) transmitters using high-power, solid-state switching amplifiers for the development of counter-improvised explosive device detection and neutralization systems. You will also learn about diverse applications of directed-energy technology—such as research and testing of laser glare devices and laser eye protection—and have the opportunity to gain a better understanding of the Department of Defense (DoD) acquisition framework and the challenge of maintaining cost and schedule estimates while delivering weapons systems that are critical to the warfighter.

From lasers to high-power electrical vehicle-stopping systems, I am sure you will be fascinated and, along with me, be impressed with the advancements our scientists, engineers, and technical staff are achieving in the directed-energy arena to support of our men and women in uniform.

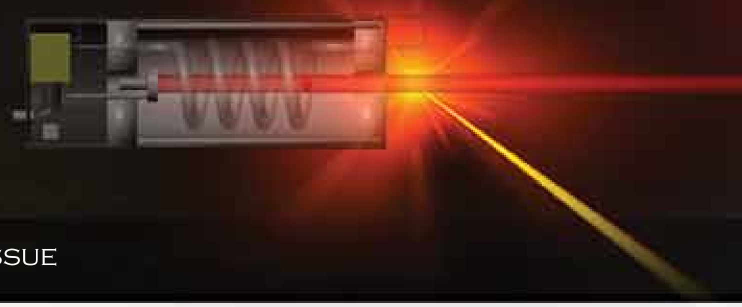

Directed-Energy Topics in This Issue

Dale Sisson
Head, Electromagnetic and
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Welcome to our Directed Energy issue of the *Leading Edge* magazine. This issue represents the third in a trilogy of issues covering the truly fascinating and incredibly challenging area of naval warfare in the operational electromagnetic environment. In our first issue, we covered the full range of operational and readiness implications when operating in the electromagnetic environment. Then, in our second issue, we highlighted the complexities and dynamics of providing relevant and effective sensors and radars to our warfighters. Now, we focus on directed energy and relate how the Naval Sea Systems Command (NAVSEA) Warfare Centers, and the Naval Surface Warfare Center, Dahlgren Division's (NSWCDD's), in particular, are working on state-of-the-art directed-energy weapons capabilities for the warfighter.

In this issue, we first look back to the early years, decades ago, when directed-energy weapons research began. We examine the history of directed energy, and we cover significant discoveries and achievements made by NAVSEA Warfare Center scientists and engineers, and others in the scientific community. We then relate information about several of our current directed-energy initiatives, and about how we're working hard to solve some of the most complex technical challenges associated with directed-energy weapons. We highlight how others in the Navy, such as the Naval Medical Research Unit in San Antonio, Texas, are also conducting research into directed energy and how our forces can better protect themselves from the effects of directed energy. We show how directed energy can be employed in a variety of offensive and defensive, lethal and nonlethal situations. We explain how directed-energy weapons work and how they can be employed in various environments against a wide range of situations. Lastly, we look forward as we provide technical and strategic leadership for the efficient and effective development, acquisition, and fielding of directed-energy systems for the warfighter.

So, if you want to learn about what the NAVSEA Warfare Centers and others in the Navy are doing in the area of directed-energy weapons, look no further than this issue of the *Leading Edge* magazine. I'm confident that you will be impressed by the progress made in this most important technology field.

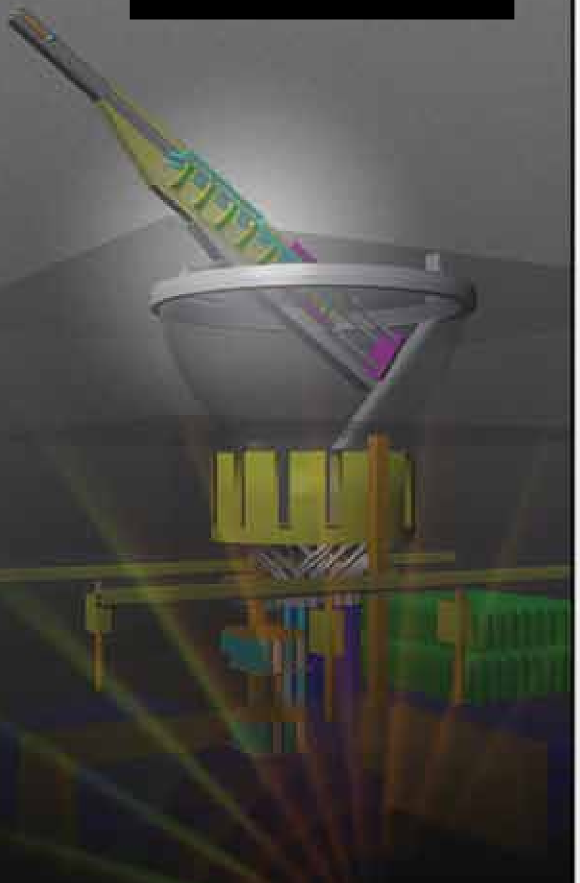

DIRECTED
ENERGY

DIRECTED ENERGY

NAVAL DIRECTED-ENERGY WEAPONS – NO LONGER A FUTURE WEAPON CONCEPT

By David C. Stoudt

Dr. Stoudt is the Distinguished Engineer for Directed Energy (ST) and the NAVSEA Technical Warrant for Directed Energy and Electric Weapon Systems.

Directed-energy weapon (DEW) technologies typically take the form of high-energy lasers (HELs), high-power microwaves (HPMs), and charged-particle beams. This article focuses on the first two technology areas, as they have reached the point of being ready for operational testing and evaluation, and in some cases, operational use on the battlefield. DEWs have been popularized in science-fiction writings for over a hundred years. The Department of Defense (DoD) has been investing in their development since the 1970s. This article will not go into technical depth regarding the various directed-energy (DE)-related efforts currently underway in the Navy, but rather, it will overview DE areas under development and relate recent Navy leadership activity. Other articles in this issue of *The Leading Edge* magazine will provide the reader with much greater technical and programmatic details on various DE efforts.

HIGH-ENERGY LASER WEAPONS

HEL weapon systems have been envisioned for a great many years, to include being referred to as Martian "Heat Ray" weapons in H.G. Wells' epic novel *The War of the Worlds*, originally published in 1898. In reality, a high-average-power laser weapon system is very similar to a "heat ray", or even a blow torch. During the early years of DoD investments in DE technology, the Navy led the development of HEL with the creation of the world's first megawatt-class, continuous-wave, Mid-Infrared Advanced Chemical Laser (MIRACL), located at White Sands Missile Range (WSMR). Roughly 80 years after the work of H.G. Wells, the U.S. Navy tested the MIRACL laser and ultimately used that laser system to engage static and aerial targets in the desert of WSMR in the following years. While that laser proved to be the wrong choice for the Surface Navy's self-defense mission, it did spawn work by the Air Force on the Airborne Laser (ABL), and the Army on the Tactical High-Energy Laser (THEL). In 2000 and 2001, the THEL successfully shot down 28 supersonic Katyusha artillery rockets and 5 artillery shells.

In 2010, the ABL successfully engaged and destroyed tactical ballistic missiles during the boost phase of their flight. All three of these laser systems—the MIRACL, the ABL, and the THEL—are chemical lasers that utilize toxic chemicals and operate in less than optimal wavelengths that make them a poor choice for most naval applications. The MIRACL is shown in Figure 1.

Recent advances in solid-state lasers, to include fiber lasers, have moved these electric lasers to the forefront of the Department's research and development (R&D) for near-term HEL applications in the services. The Navy has particular interest in electric lasers, to include the free-electron laser (FEL), for shipboard self-defense and force protection applications. The speed-of-light delivery of HEL energy can defeat the high-g maneuvers of newly developed foreign antiship cruise missiles (ASCMs). Thus, the Office of Naval Research (ONR) started an FEL Innovative Naval Prototype (INP) program in FY10, with a goal of reaching the output power of 100 kW. The eventual goal of the FEL program is to reach the multi-megawatt power level with wavelength selectivity. The Naval Sea Systems Command (NAVSEA) Directed Energy and Electric Weapons Program Office (PMS 405) has been actively developing a fiber laser-based Laser Weapon System (LaWS) that could be a retrofit to augment the current capabilities of the Close-In Weapon System (CIWS) currently deployed on many surface combatants. The Naval Surface Warfare Center, Dahlgren Division (NSWCDD), is the Technical Direction Agent and lead system integrator for PMS 405 on the LaWS program. The Naval Air Systems Command (NAVAIR) has interest in compact, solid-state HEL systems for aircraft self-protect and air-to-ground engagements, and will be starting a

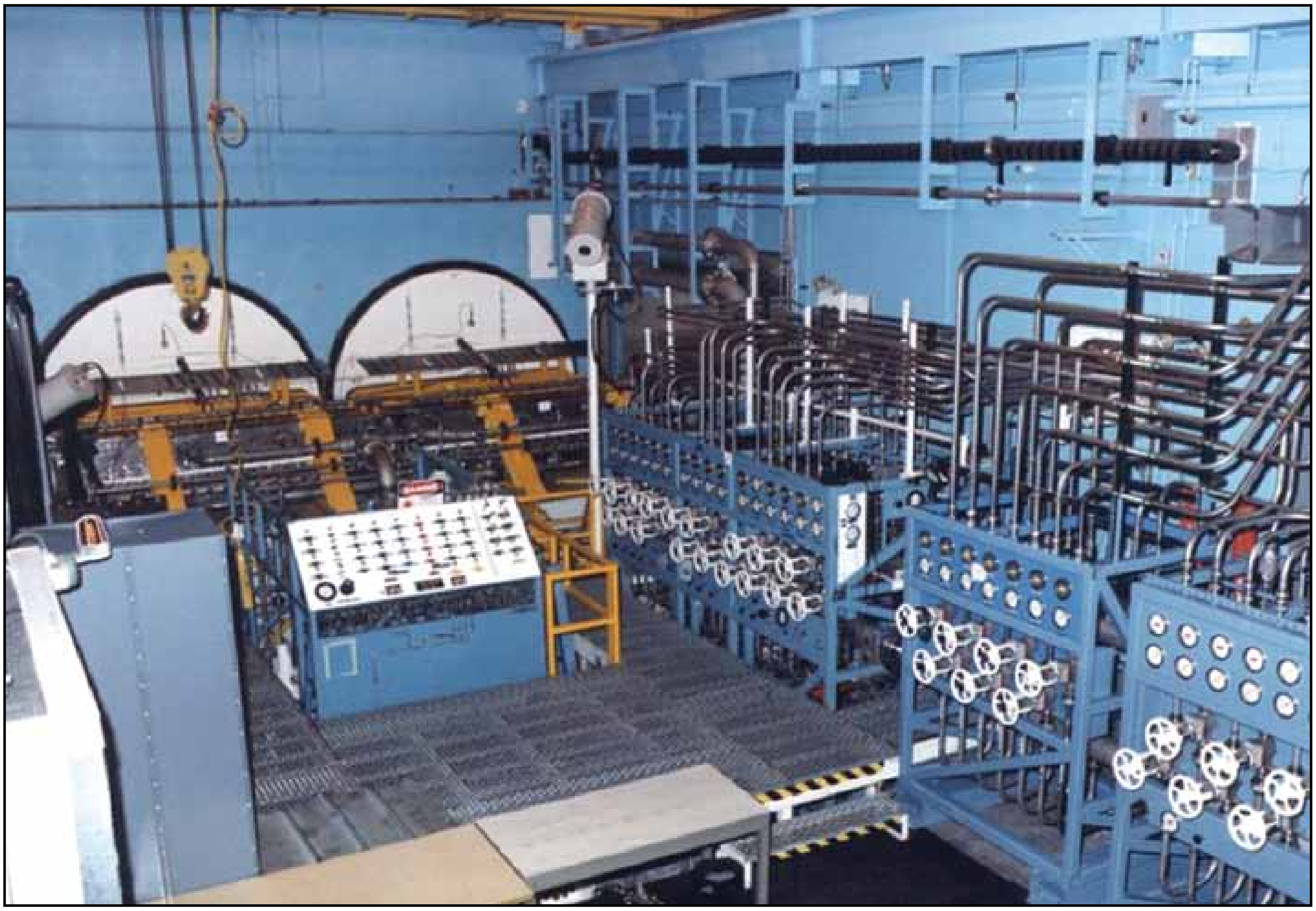

Figure 1. Mid-Infrared Advanced Chemical Laser (MIRACL)

fiber laser-based ONR Future Naval Capability effort in FY12. LaWS is shown in Figure 2.

High-Power Microwave Weapons

Like lasers, microwave weapons have been fantasized about ever since the invention of microwave power generators. In fact, in 1932 it was generally recognized by the British government that bombers, ostensibly German bombers, would be able to penetrate British air space and bomb its civilian population and infrastructures. In 1934, the Air Ministry initially asked Robert Watson-Watt, of the National Physical Laboratory, if he could build a "death ray" that could kill enemy pilots or detonate bombs while they are still on the planes of enemy aircraft. Such a "death ray" had been proposed to the Air Ministry by Harry Gindell-Mathews 10 years earlier in 1924. Watson-Watt, a former meteorologist who had become an expert on radio signals, suggested that energy reflected from an aircraft could be used to locate it. His experiments were successful and RADAR (radio detection and ranging), a name coined by the U.S. Navy in 1940, was born. While RADAR is not a DEW in the way they are thought of today, its roots can clearly be traced to the military's desire for such capabilities.

The Navy's HPM, or high-power radio-frequency (RF) systems, have been progressively increasing in power density to the point where it is now feasible to integrate the technology into weapon systems for deployment. While initial HPM applications suffered from their inability to obtain militarily useful outcomes, either due to technology limitations, difficult concept of operations (CONOPS), or inherent robustness of potential target systems, many feasible military applications for using HPM

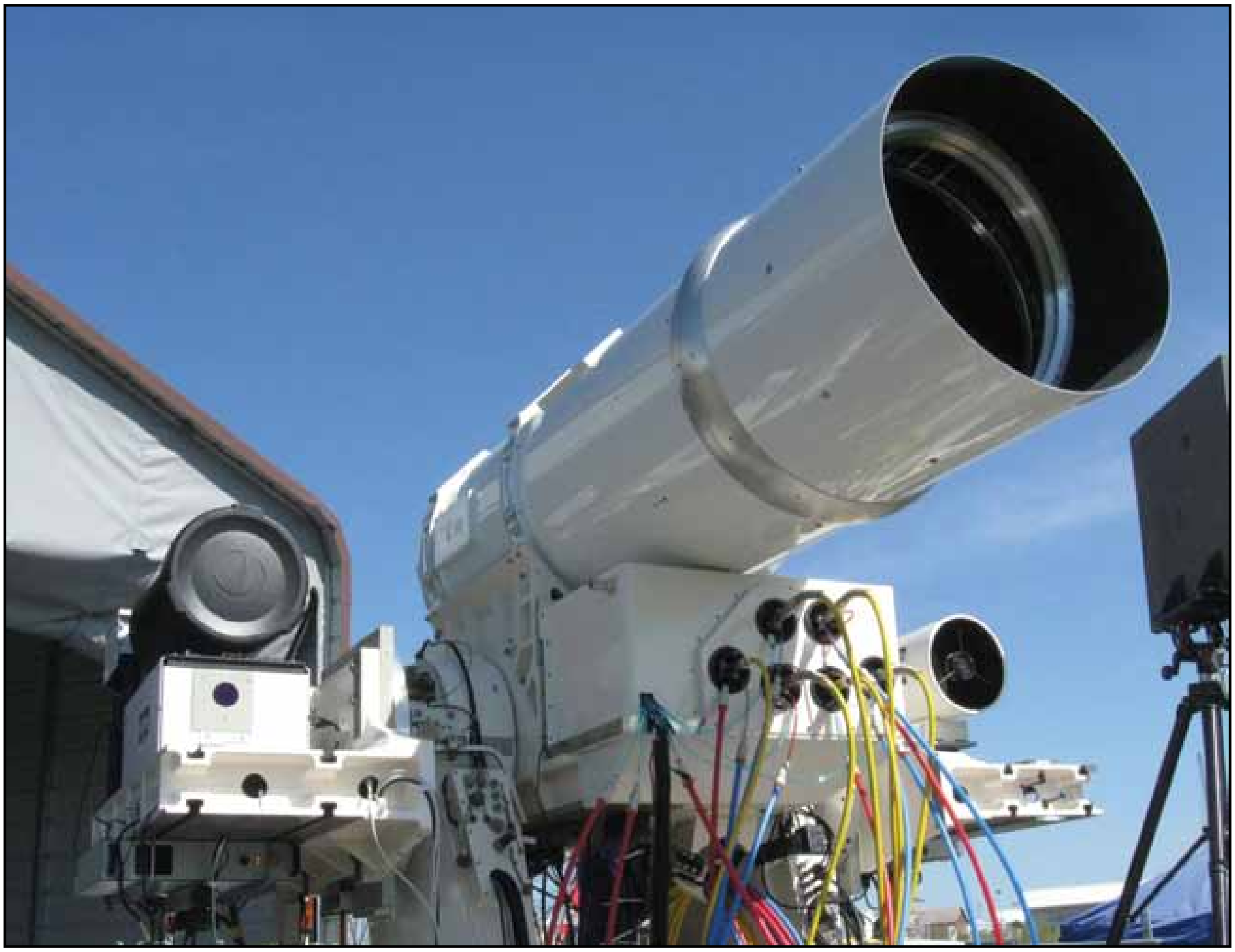

Figure 2. Laser Weapon System (LaWS)

devices have surfaced over recent years to include nonlethal, antipersonnel weapons and nonkinetic, antimateriel weapons. While these concepts offer unique capabilities to the warfighter due to the nonkinetic effects they generate, other warfighting concepts—such as stopping vehicles, or countering hidden roadside bombs or improvised explosive devices (IEDs)—are difficult to achieve by any other means. The multifrequency Radio-Frequency Vehicle Stopper (RFVS) system is shown in Figure 3.

In addition, the difficulty in overcoming the propagation losses associated with HPM has driven some concepts into platforms such as unmanned aerial vehicles (UAVs) or cruise missiles that deliver the HPM device to the target for a close-in engagement. Over the past 10 years, field-testable prototypes have been developed to demonstrate the operational utility of these concepts, and in some cases, those prototypes have or will be deployed operationally to support our troops in theater. It is only through the hard work and perseverance of the Naval Research Enterprise (NRE), as well as other DoD laboratories, that concepts that were once only laboratory curiosities are now making their way onto the battlefield and contributing to the fight.

Foreign Directed-Energy Weapon (DEW) Development

While the United States has been very active in this warfighting area, significant foreign DEW development also has elevated the need for the Navy to afford these threats a higher priority. This can be done either by incorporating the necessary DEW countermeasures into weapon systems, platforms, and critical infrastructures, or by adapting the CONOPS and tactics, techniques, and procedures (TTPs) employed by our armed forces to properly account for those foreign DEW systems. Materiel developers need to understand how this threat

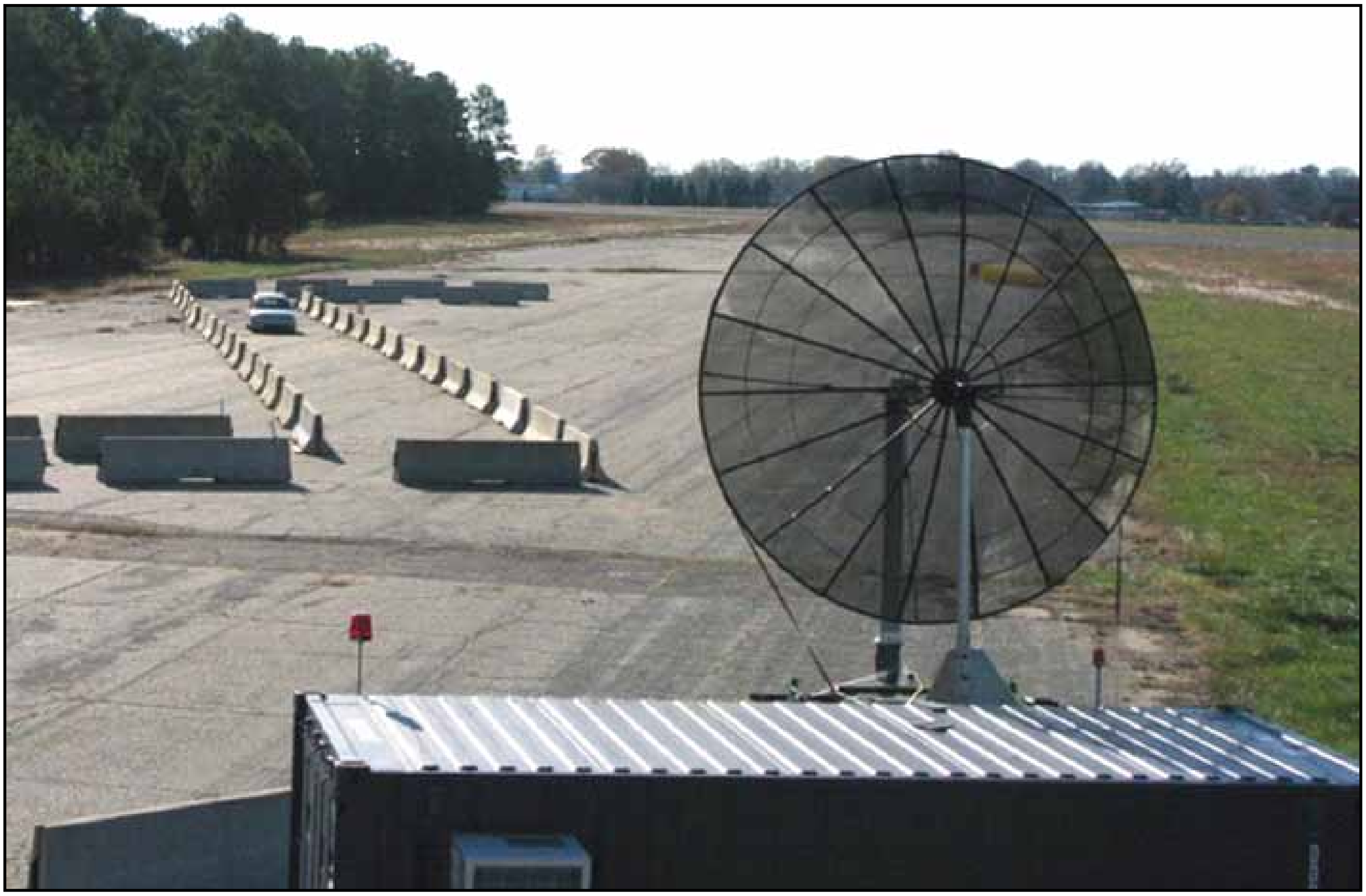

Figure 3. Multifrequency RF Vehicle-Stopper (RFVS) System

is evolving and properly address it during the design of their systems. They also need to address DE in the development of their system threat assessments. There has been movement on the HPM side to modify existing military standards, such as MIL STD 464[1] and others, to now include information on potential HPM threats. For example, in the HEL arena, work has been accomplished in the development of protective measures for eyes; however, this threat needs to be considered during the system development process. It is well known that building in countermeasures is much cheaper during the initial development of a system, vice trying to retrofit systems with countermeasures once a new threat is on the battlefield. As analysts evaluate the foreign development of DE technologies, and the trends become clearer, it is the responsibility of the acquisition community to take this threat into consideration and ensure that weapon systems, platforms, and infrastructures will be available and at full capability when needed. By accounting for foreign threat developments, assessing blue force susceptibilities and vulnerabilities, and adopting appropriate measures to negate or counter these threats, naval forces will avoid technological surprise on the battlefield in the future.

Requirements

The DE programs briefly mentioned in this article, and covered more deeply in this and other publications, offer warfighters unique capabilities not currently found in their arsenal. The continuing problem, however, is matching those unique capabilities to vetted operational requirements. The DE technical community has made great strides in helping the operational community understand the capabilities of DE weapons and their potential military effects on targets. The lack of formal requirements, however, has yielded more of a technology push—rather than an operational pull—of various DE capabilities. Progress has been made, but more effort is required if DE capabilities are to be developed and transitioned between science and technology (S&T), and formal programs of record. Notwithstanding, the current outlook and trends are positive.

A Resurgence of Navy Interest in Directed Energy

The Navy's interest in DEWs for future maritime operations has increased in recent years due to a number of weapons development successes. Recognizing the importance and value of DEWs, NAVSEA reestablished the Navy Directed Energy Weapons Program Office (PMS 405) in 2004. Accordingly, PMS 405 was designated as the point of contact for matters related to DE and electric weapon systems (EWS) development and acquisition initiation for NAVSEA, and for matters being coordinated with other federal agencies and military services. PMS 405's mission is to transition technology from the laboratory to prototype/advanced development/testing for operational development and use.[2,3]

The Navy also established its first formal executive position for DE (ST-level), the Navy's Distinguished Engineer/Scientist for Directed Energy, at NSWCDD in August 2004. Following the establishment of this position, NAVSEA then formally established a Technical Authority Warrant for Directed Energy and Electric Weapon Systems (DE&EWS)—Surface Ships in July 2008. The scope of the warrant includes the transition of S&T development to weapon system development of lethal and nonlethal capabilities associated with the DE&EWS for Surface Ships.[4] This included, but was not limited to, the following:

- Laser Weapon Systems
    - High-Energy Lasers
    - Solid-State Lasers
    - Free-Electron Lasers
    - Femtosecond Ultrashort Pulse Lasers
    - Laser-Induced Plasma Channel
    - Lethality/Vulnerability
- Electromagnetic Rail Gun Weapon System
- High-Power Microwave
    - Active Denial System
    - Laser-Guided Energy
- Maritime Directed Energy Test Center
- Electromagnetic Launch of Weapons (excluding the Electromagnetic Aircraft Launch System (EMALS))

Then, within the NAVSEA Warfare Center Enterprise, Warfare Center leadership established two technical capabilities (TCs): an NSWCDD TC for DE systems research, development, test, and evaluation (RDT&E); and a Naval Surface Warfare Center, Port Hueneme Division (NSWCPHD) TC for in-service engineering, test and evaluation (T&E), and integrated logistics support to DE systems. NSWCDD leads all S&T and RDT&E for the development and weaponization of DE systems for surface, air, and ground environments. It also leads the development of offensive and defensive DE technologies needed to characterize and exploit vulnerabilities, provide weapons, and protect against attack. NSWCDD provides the technologies, devices, and systems designed to create or control electromagnetic energy used to cause persistent disruption or permanent damage by attacking target materials, electronics, optics, antennas, sensors, arrays, and personnel, including nonlethal applications. NSWCPHD provides in-service engineering, T&E, and integrated logistics support to DE systems throughout the system life cycle.

The Navy further demonstrated increased interest in DE when Assistant Secretary of the Navy (Research, Development & Acquisition (ASN(RDA)) designated NAVAIR offensive and defensive leads for naval aviation DE activities:

- Program Executive Officer for Unmanned Aviation and Strike Weapons (PEO(U&W)), assigned as the offensive DE lead for naval aviation
- PEO for Tactical Aircraft Programs (T), assigned as the defensive lead for naval aviation

Concerning future initiatives, the Chief of Naval Operations (CNO) tasked the Strategic Studies Group (SSG) to examine a topic entitled "Maritime Operations in the Age of Hypersonic and Directed-Energy Weapons."[5] The intent of the study was to provide Navy leadership with an understanding of where DE technologies and weapons are today and how they might influence future maritime operations. The theme of the study was completed during FY10, the results of which discuss many DE concepts, as well as tactics for the employment of DE capabilities. The study's findings are currently under review and consideration by senior Navy leadership.

Conclusion

While H.G. Wells' *The War of the Worlds* novel and television programs like *Star Trek* popularized the notion of using DE for weapons in years past, today— through persistent DEW RDT&E—Navy leadership is realizing the great potential that DEWs offer naval warfighters and homeland defenders. The scientific and technical advances the Navy has made in HEL and HPM in recent years have been nothing short of extraordinary. Moreover, future technological and engineering advances undoubtedly will result in profound differences in our nation's future warfighting capabilities. Naval DEWs, therefore, are no longer just a future weapon concept…they are here today.

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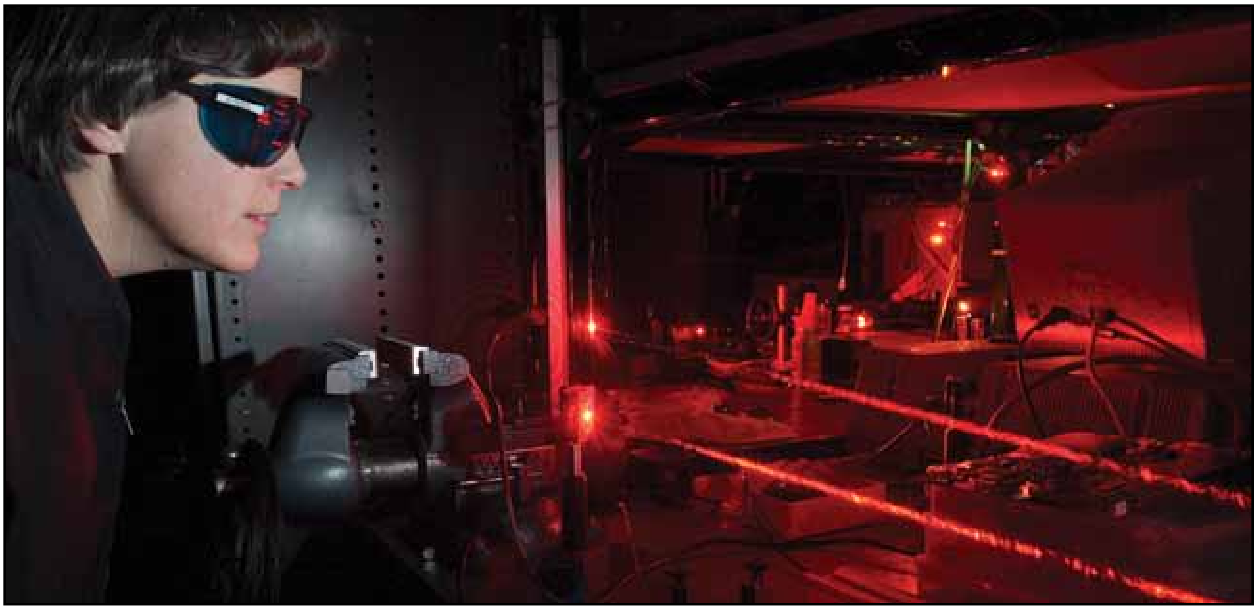

Historical Overview of Directed-Energy Work at Dahlgren

By Stuart Moran

In 1962, the United States set off a megaton nuclear weapon 250 miles above the Pacific. The blast caused a large imbalance of electrons in the upper atmosphere that interacted with the Earth's magnetic field to create oscillating electric fields over a large area of the Pacific. These fields were strong enough to damage electronics in Hawaii, a thousand miles away, and clearly demonstrated the effects of an electromagnetic pulse (EMP). It didn't take long for the military to begin considering ways to create such pulses without using nuclear weapons.

In the late 1960s, the Special Applications Branch at the Naval Weapons Laboratory at Dahlgren began studying ways to generate high-power oscillating electric fields that could be used as a weapon to damage enemy electronics. These devices were basically high-power versions of the old spark-gap transmitters used in the early days of radio. To construct a device that could produce nuclear EMP-like fields, stored electrical energy was converted to radio-frequency (RF) energy that could be radiated from an antenna through the atmosphere to a target. These devices typically would store energy in a high-voltage capacitor and release the energy quickly using a spark-gap switch. This would then drive oscillating currents on an antenna, causing it to radiate. To achieve field strengths of thousands of volts per meter, typical of a nuclear EMP, devices operating at hundreds of thousands of volts or more were needed.

A number of radiating devices were studied in the early 1970s. Most belonged to a class of devices called Hertzian oscillators. A capacitor is charged to high voltage, the switch is closed, and current flows in the circuit, causing the stored energy to oscillate between the electric field of the capacitor and the magnetic field of the inductor. To charge the capacitor to extremely high voltages, a step-up transformer of some type must be used. One of the fastest voltage multipliers, the Marx generator, was frequently used. The losses from internal resistance and external radiation damp the oscillating waveform, typically after a few cycles. The radiated pulses are, therefore, short in time and broad in frequency content.[1] A simple diagram of the inductance-capacitance oscillator (L-C oscillator) is shown in Figure 1.

Single-Pulse Burnout Devices

Many types of Hertzian devices were designed, constructed, and tested at Dahlgren during the 1970s. The transmission-line oscillator, or cavity oscillator, used a quarter-wavelength

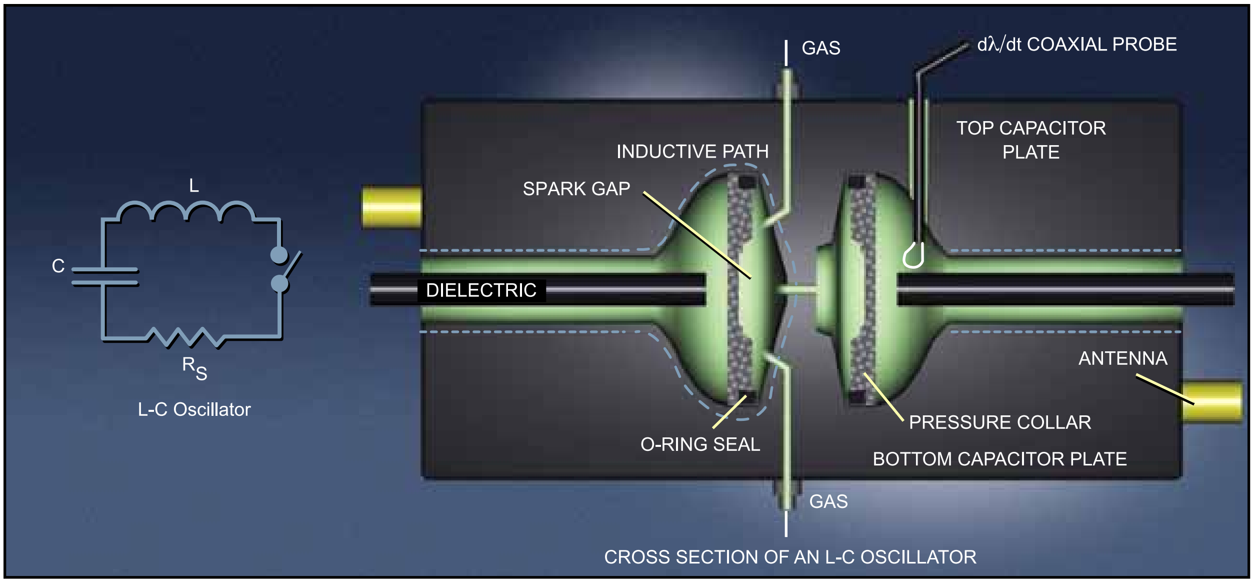

Figure 1. Inductance-Capacitance Oscillator (L-C Oscillator) Diagram

coaxial pipe, which was switched at one end, to create the oscillating waveform. A frozen wave generator, a different type, had quarter-wave sections of cable that were charged plus and minus to create a two-cycle waveform "frozen" in the cable. All sections were simultaneously switched, causing the wave to travel to an antenna. A special folded design was developed so one switch could be used, eliminating the multiswitch synchronization problem. A Ross circuit used a square wave pulse, which traveled down cable "tees," creating reflections, which were timed to create several RF cycles. In the Travetron, the turn-on time of a series of spark-gap switches was incorporated as a designed delay, creating reflections through a series of gaps to produce the waveform. This design allowed higher frequencies. All of these devices were designed, built, and tested to determine power and frequency capabilities, as well as efficiency.

Scientists and engineers at Dahlgren built and tested versions of Hertzian oscillators operating up to half a million volts. These devices powered relatively simple monopole or dipole antennas that could produce very high electric fields at hundreds of meters. In the early 1970s, a special outdoor field-measurement range was constructed. It housed high-voltage systems in underground trailers that fed antennas above ground on a specially-built, 100-m-long ground plane that was constructed for testing and field measurements. A picture of the ground place in a fielded measurement range is shown in Figure 2. Field probes were even carried aboard helicopters to make measurements above ground effects, as shown in Figure 3.

Other types of devices to produce pulses were constructed, too. Vector inversion generators used spiral-wound capacitive plates to generate high voltages without transformers.[2,3] The Landecker ring used a paddle-wheel arrangement of capacitors and inductors charged in parallel and discharged in series. The circular arrangement was designed so the entire system would radiate as a magnetic dipole, thus forming its own antenna.[4] Switch timing was critical, and Dahlgren engineers attempted to verify reports that Landecker developed a specific type that brought all capacitor leads into a single-center spark gap.

Scientists and engineers also looked at devices that used explosives to generate the electrical energy needed. These included explosive flux compressors of several types, which generated fields and then explosively squeezed the fields between conductors to amplify the peak power. In the early 1970s, a large (70-ft clear zone) anechoic chamber was constructed at Dahlgren with an explosive chamber in one end. Explosives would be set off in the chamber to drive various types of flux compressor schemes that would generate electrical pulses fed into an oscillator and antenna in the anechoic chamber. Pulse parameters and field strengths could be measured. Impedance-matching networks, matching transformers, and methods of improving efficiency were studied. Tests were performed at Dahlgren and at Los Alamos using large antennas suspended from balloons.[5] In other schemes, piezoelectric devices were developed, which could be compressed hydraulically and then quickly released to produce high voltages. The concept was to use explosives to generate the high

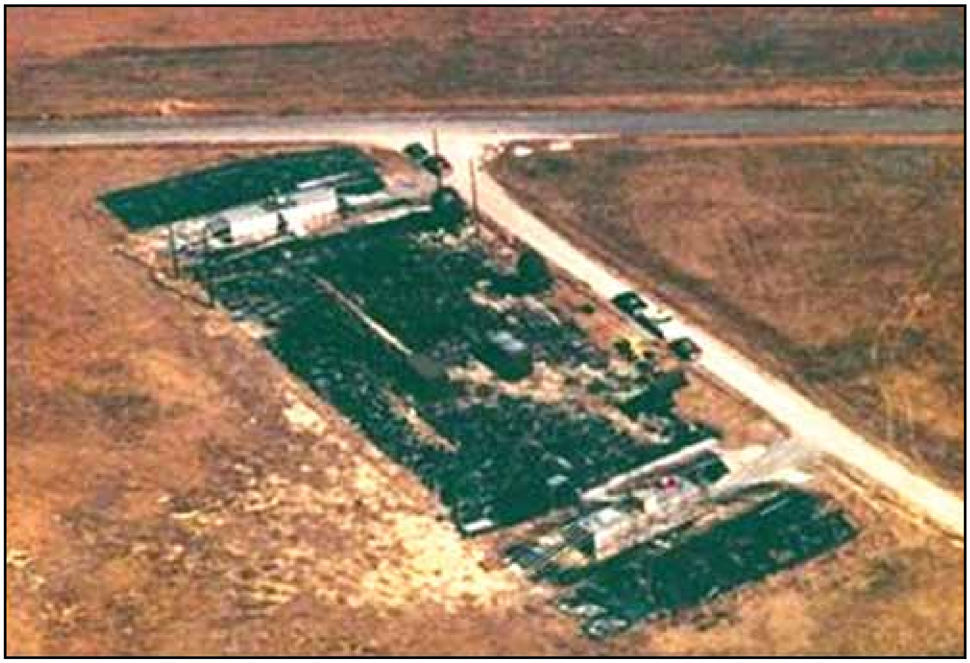

Figure 2. Field Measurement Range

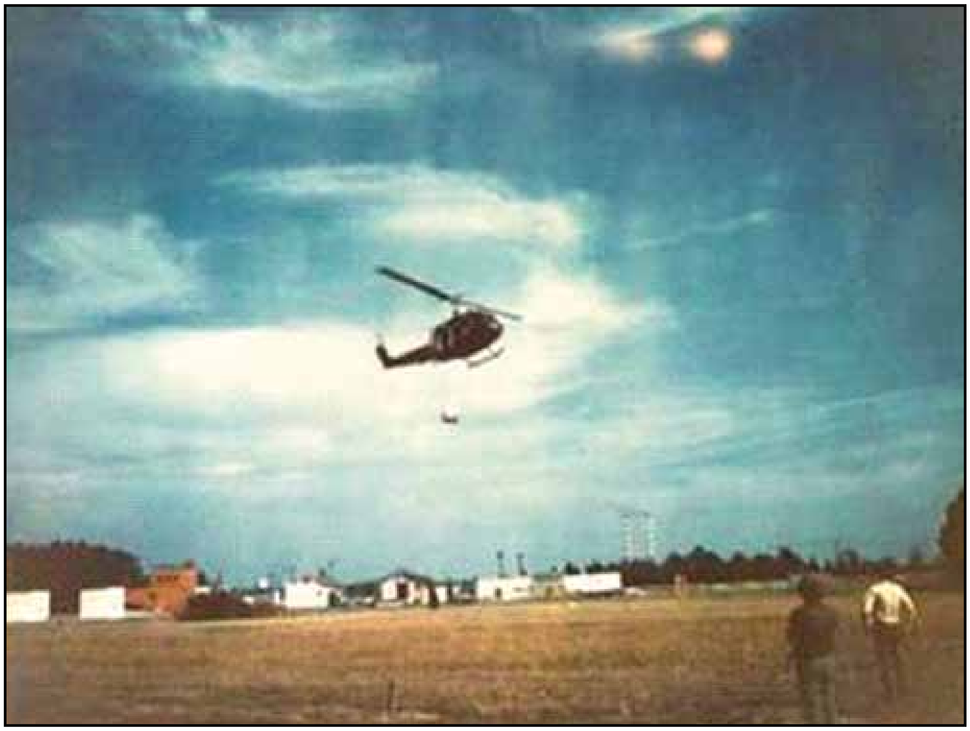

Figure 3. Airborne Electric Field Measurements

pressures. Ferroelectric and ferromagnetic transducers driven by explosives were also tested.[6]

Special Effects Warhead (SEW) Program

In 1973, Dahlgren began the SEW Program to look at the feasibility of "burning out" enemy radar and missile systems using single-shot, very high-peak-power EMPs. The program looked at the feasibility of constructing an electromagnetic warhead that could disable electronics beyond a normal hard-kill explosive range as far as a mile away. The program was funded at several million dollars a year through most of the 1970s.

A major thrust of the SEW Program was to better understand the effects of high fields on military electronics. Little information was available on the vulnerability of foreign or U.S. electronics, particularly entire systems. A trailer-based RF impulse system, employing a Marx-driven L-C oscillator charged at two million volts, was constructed at Dahlgren. This Transportable Oscillating Pulser System (TOPS) was connected to a large bounded-wave structure that produced uniform fields over a region large enough to place an entire radar or missile system. The electric field emitted from the throat of this system was so high that a special bag of high-voltage gas was needed until the radiating structure became large enough to transition to the normal atmosphere. A picture of TOPS is shown in Figure 4.

Since many important target systems were not available for testing, much of the vulnerability information was obtained from U.S. electronics, and estimates were then made for foreign systems. In addition to the tests done at Dahlgren, pulsers were also constructed in mobile trailers that could be transported to other sites for testing against simulated or actual targets. The Mobile Oscillating Pulser System (MOPS) was an example that was carried to test sites, such as China Lake, to perform tests against radars and simulated foreign systems.

A key requirement for the SEW Program was to demonstrate enforceable target vulnerability, which means that a high percentage of the time a large percentage of the targets are affected. One important finding was the broad difference between an electromagnetic safety concern—where a 1 percent vulnerability was far too great—and a weapon concern—where a 10 percent vulnerability was not good enough. The field strengths between the safety requirements and weapon requirements often were many orders of magnitude apart.

The SEW Program looked at many types of electronic component vulnerability, subsystem vulnerability, and complete system vulnerability. As a result, energy tables for burnout effects were developed. Subsequently, Dahlgren performed numerous field tests against radar and communications systems between 1973 and 1978, and funded component and subsystem testing on missiles.

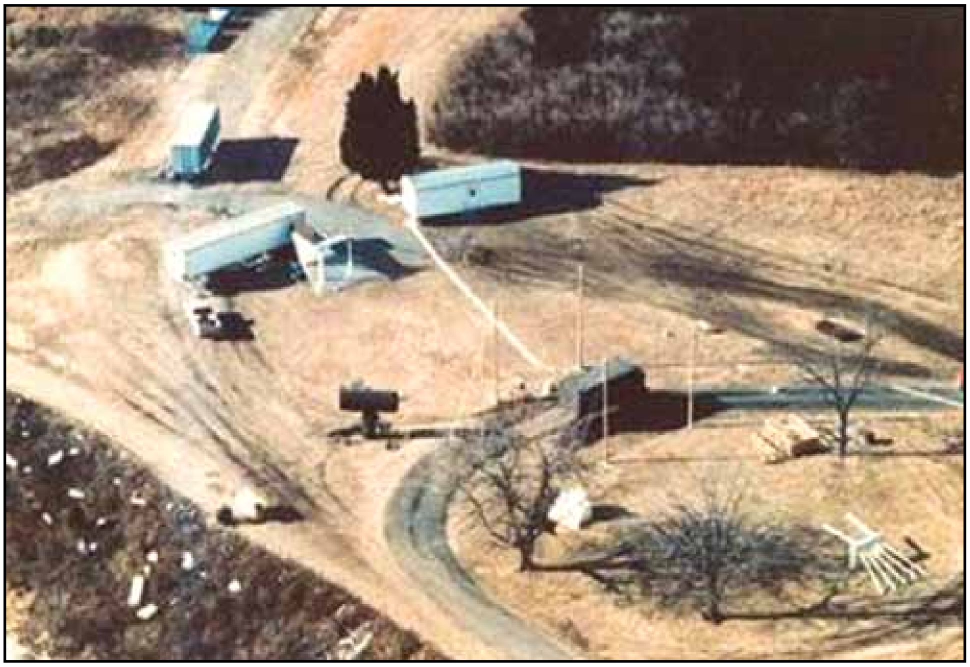

Figure 4. Transportable Oscillating Pulser System (TOPS)

Repetitive Systems for Electronic Warfare

The electric fields required to damage military electronics in the 1970s often were very high, and ranges typically were limited. As a spinoff of programs trying to damage targets with a single pulse, some of these devices were reduced in size and power, and operated in a repetitive mode to generate noise pulses for the purpose of electronically jamming target systems. In 1976, the Naval Air Systems Command (NAVAIR) began the Electromagnetic Countermeasures Program to study the application of high-repetition-rate Hertzian devices for use as noise jammers. The initial targets were low-frequency radars.

In late 1976, Dahlgren performed effectiveness tests against various radars using helicopter-mounted Hertzian jammers. These devices were able to screen incoming target aircraft at useful ranges. The concept of a forward-launched rocket to deliver a parachute-suspended Hertzian jammer also was investigated. Dahlgren teamed with engineers at China Lake to study packaging concepts of utilizing an extended 5-inch Zuni rocket as a forward-fired delivery vehicle. A prototype is shown in Figure 5.

Similar Hertzian devices were considered for use as communications and data-link jammers. Several antenna deployment schemes were developed, and by fall 1978, successful ground launches had been performed in which the deployment sequence and jammer operation were demonstrated. The name Zuni Expendable Pulsed-Power Oscillator (ZEPPO) was given to the project. Dahlgren teamed with the Naval Avionics Center (NAC) to build the systems. By 1980, China Lake fired the first air-launched prototypes at both low and high altitudes. Devices, batteries, spark gaps, and antennas continued to be developed, and new targets—such as spread-spectrum systems—were tested. Other delivery systems besides rockets were also considered.

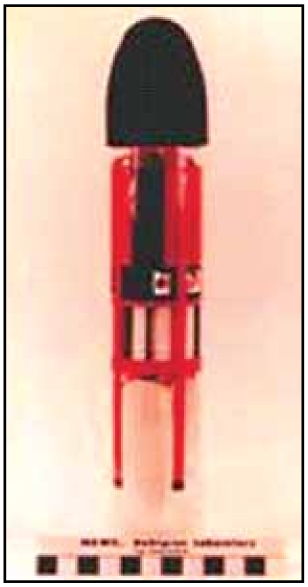

Figure 5. ZEPPO Payload

The Pulsed Power Technology Program

Large directed-energy weapons (DEWs) often required megawatts or gigawatts of peak power, so methods of supplying and modifying this power were needed. As Dahlgren became involved in a broad range of DEW systems, one attribute became more and more obvious: the size, weight, and cost of a directed-energy (DE) system were dominated by the pulsed-power technologies needed to drive the system, not by the source device itself. Consequently, more effort began to be devoted to the power-delivery technologies needed for many of the weapon concepts. Pulsed-power components enabled energy to be stored over long periods of time (seconds) and released very quickly (nanoseconds) to obtain a billion times increase in peak power.

Dahlgren hosted a pulsed-power systems symposium and workshop in 1976 and helped initiate the International Pulsed Power Conferences, which began in 1977 and continues today under the Institute of Electrical and Electronics Engineers (IEEE). As Dahlgren's involvement with systems design increased, it became apparent that new technologies were needed in the prime-power and pulsed-power area to support a variety of new concepts. Dahlgren urged the Navy to initiate a Pulsed Power Technology Program to develop power sources, energy storage systems, high-power switches, and power conditioning systems needed for a variety of future weapons. This program was initiated in 1978 and was originally funded by NAVAIR and then by the Directed Energy Program Office (PMS 405) in the early 1980s. In addition to the Pulsed Power Technology Program, PMS 405 also began funding free-electron lasers (FELs), chemical lasers, high-power microwaves (HPMs), and charged-particle beams (CPBs). The Pulsed Power Technology Program at Dahlgren, in turn, funded many areas of research, both internal and external, over the next 10 years. Dahlgren served as the focal point for the Navy's science and technology (S&T) in pulsed power and funded many universities, government laboratories, and commercial companies under the Pulsed Power Technology Program.

To provide large amounts of electrical prime power, new types of rotating machines were studied, including flywheels, conventional alternators, homopolar generators, rotary flux compressors, and compensated pulsed alternators. These machines attempted to produce fast, high-power pulses using special materials to reduce losses, eddy currents, and mechanical stresses. MHD generators were developed using rocket-motor propellant that could be started and stopped. In the mid-1980s, a full-scale hybrid (solid fuel/liquid oxidizer) combustor was fabricated and tested at 10 MW, achieving world records for power-to-weight ratio and conductivity. By 1980, new types of energy storage systems were studied, including inductive storage and advanced capacitors using new types of insulating materials and geometries. During the late 1980s, programs such as the Mile-Run Capacitor Program reduced the capacitor size by a factor of 10 through better synthesis of polymer films.

Beginning with internal independent research funds, Dahlgren developed liquid dielectric materials based on water/glycol mixtures at low temperatures. These water-capacitor devices could hold energy for orders-of-magnitude longer time periods than ever before, allowing pulseforming lines to be constructed that could be charged directly from rotating machines. Dahlgren scientists developed a world-record high-voltage water capacitor that could hold pulses for milliseconds and became internationally recognized experts in water breakdown.[7, 8]

High-power fast switching was another important area of research. Dahlgren funded companies to develop new types of multistage thyratrons that could operate at very high voltages. By the early 1980s, multistage thyratrons capable of operating at over 200 kV, 40 kA with 20 nsec risetimes were demonstrated. Vacuum switches, ignitrons, plasma pinch switches, pseudospark switches, back-lighted thyratrons, and e-beam switches all were studied, as well as a variety of spark-gap switches. Higher power solid-state switches were developed, too, using new geometries and substrate material. Superconducting coils were considered, both for energy storage and as opening switches. Dahlgren engineers developed exploding-wire opening switches, and several types of plasma pinch switches were funded. They also worked on stacked cable pulsers. Additionally, concepts for electromagnetic armor were developed. These systems used high-density capacitors to blunt penetrators. Inductive energy storage—which could be far denser than capacitors—was studied, including methods of generating the seed current and the problematic high-voltage opening switch. Opening switches—which were needed for inductive energy store systems—were studied, as well as magnetic switches, which used saturating magnetic material to sharpen pulses. Magnetic switches operating at 10 kHz were demonstrated by 1983.[9]

In 1985, Dahlgren used internal funds to upgrade a facility to provide controls, diagnostics, and 200 kW of average power at 50 kV to accommodate testing of new switches and water-based capacitors. This facility could control the power with a vacuum-tube pulser and could generate over a million volts with a rep-rated Marx generator. The facility was used to:

- Develop water-dielectric energy storage, rep-rated spark gaps, and pseudospark switches.
- Test a variety of switches developed by contractors, such as back-lighted thyratrons.[10, 11]

A picture of one system being tested—a water pulse-forming line and spark-gap switch—is shown in Figure 6.

Dahlgren concentrated in-house switching efforts in spark gaps. New types of gases were studied, as well as electrode materials, gas-flows, switch geometries, and triggering techniques to produce high-repetition-rate switches for electronic warfare, as well as particle-beam weapons.[12] Dahlgren scientists and engineers demonstrated 100-μs recovery of spark-gap switches after handling kilojoules of energy at hundreds of kilovolts, a world record.[13] The High Energy 2-Pulse System for fast recovery experiment is shown in Figure 7.

In 1986, Dahlgren ran a workshop on high-power switching for Navy tactical and Department of Defense (DoD) strategic applications and became involved with numerous DoD working groups on electromagnetic propulsion, high-power diagnostics, advanced energy conversion, power modulators, and pulsed power. Spark gaps were investigated to create underwater noise for submarines. Dahlgren also led four North Atlantic Treaty Organization (NATO) Advanced Study Institutes in Europe and the UK on various pulsed-power topics. International assessments of key pulsed-power technologies were also performed.

PARTICLE-BEAM WEAPONS

Particle-beam weapons were a major focus of DE work during the 1970s and 1980s. A CPB weapon takes subatomic particles, generally electrons, and accelerates them to near the speed of light before sending them toward a target. These fast electrons penetrate deeply into most materials, so they are difficult to counter. The high-current electron beam was to be accelerated by an induction-type

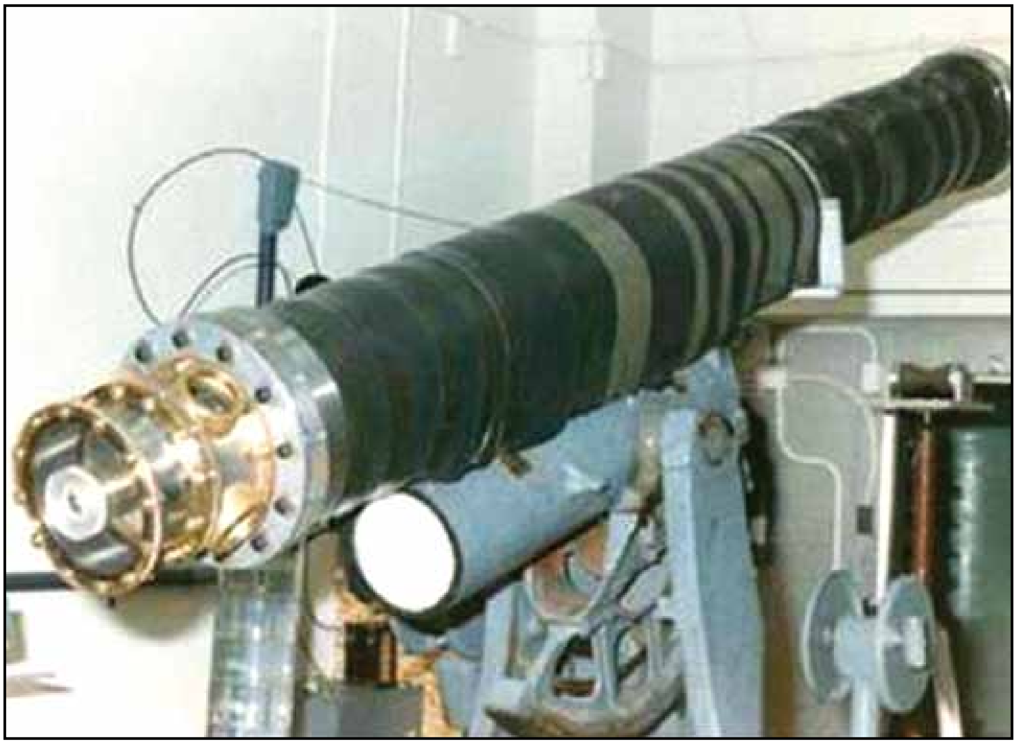

Figure 6. A Water Pulse-Forming Line and Spark-Gap Switch Test

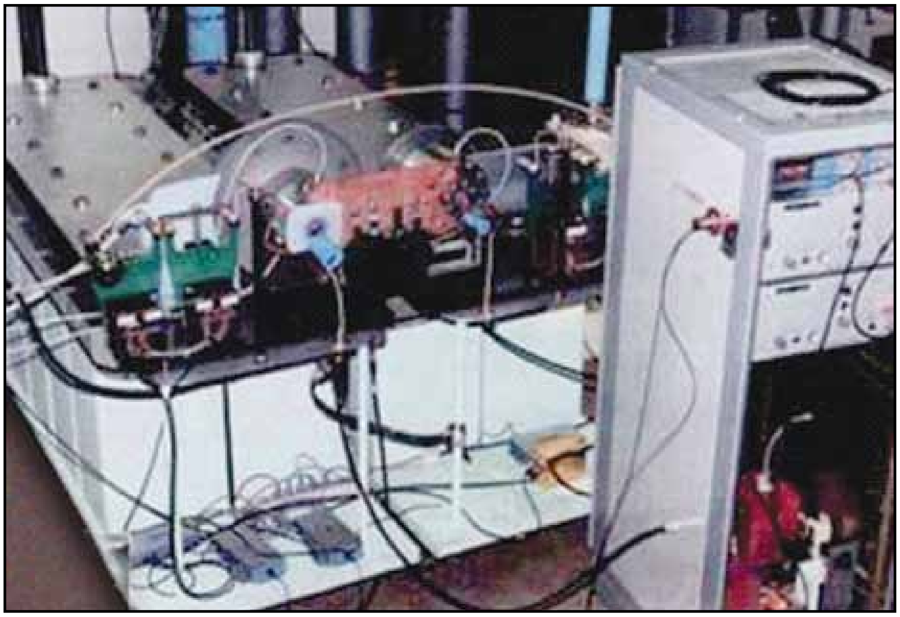

Figure 7. High Energy 2-Pulse System

accelerator, repetitively pulsed. High electron-beam currents (kiloamps) and a hole-boring series of pulses were anticipated to create a stable, long-range beam. Since the beam was capable of penetrating quickly and deeply into any target material, it had the potential to damage electronics and set off explosives before salvage fuzing could occur. The beam was predicted to be all-weather and essentially countermeasure-proof. Even a near miss could cause substantial damage from high fields and X-rays produced by the deceleration of electrons as they hit air molecules near the target. The CPB concept is shown in Figure 8.

Scientists and engineers from Dahlgren worked on the pulsed-power technologies needed to drive these machines beginning in 1980, and it became a major focus of the Pulsed Power Technology Program.[14] The White Oak Laboratory developed beam-steering concepts and looked at material interactions. By 1989, the program investigated:

- Propagation
- Compact Recirculating Accelerators
- Pointing and Tracking
- Prime Power
- Material Interaction
- Fratricide

For a compact shipboard system, recirculating accelerators were needed to make multiple passes of the electron beam past the accelerating cavities. This required a high-power, fast recovery switch, which Dahlgren began working on in 1988. Using patented hydrogen switches and special triggering techniques—efforts that had begun with internal research funds—Dahlgren demonstrated spark-gap switches, the only technology that could meet the current, voltage, and recovery requirements at that time.[15] The High-Voltage 5-Pulse System experiment is shown in Figure 9.

During these technology efforts, significant advances were achieved in all aspects of the program. These included:

- Generating high-current, high-energy beams (although still below weapons parameters)
- Demonstrating a 360° turn in a high-current beam
- Propagating a single pulse through the air
- Demonstrating beam steering on a small scale
- Performing target interaction measurements

Multipulse, long-range propagation was never demonstrated. A comprehensive tri-service summary called the Net Technical Assessment for CPB was sponsored by the Defense Advanced Research Projects Agency (DARPA) in 1987 to describe the accomplishments of the program. The report said compact accelerators were the most pressing technology need. As a result, most funding was directed toward this topic. Funding was stopped in the early 1990s, however, due to the high expense, stretched timelines, and changes in the threat.

Pulsed Power and Electromagnetic Launchers

During the 1980s, the Army and Air Force looked at short-range electromagnetic weapons to penetrate stronger armor with higher velocities. The Navy worked on concepts for a weapon that could be mounted on ships to intercept missile systems at line-of-sight distances. The Navy—then the biggest user of space systems—was also interested in studies showing that small satellites could

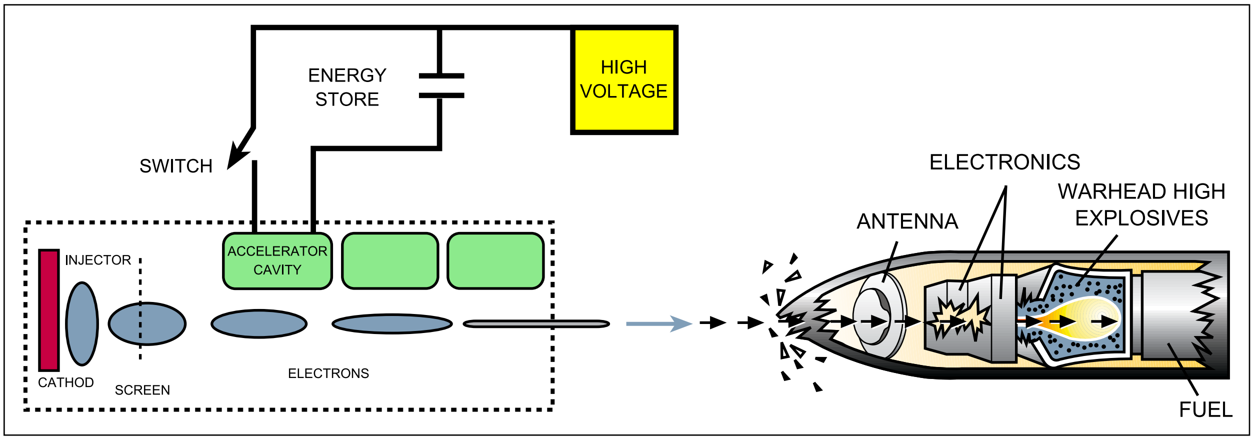

Figure 8. Charged-Particle Beam (CPB) Concept

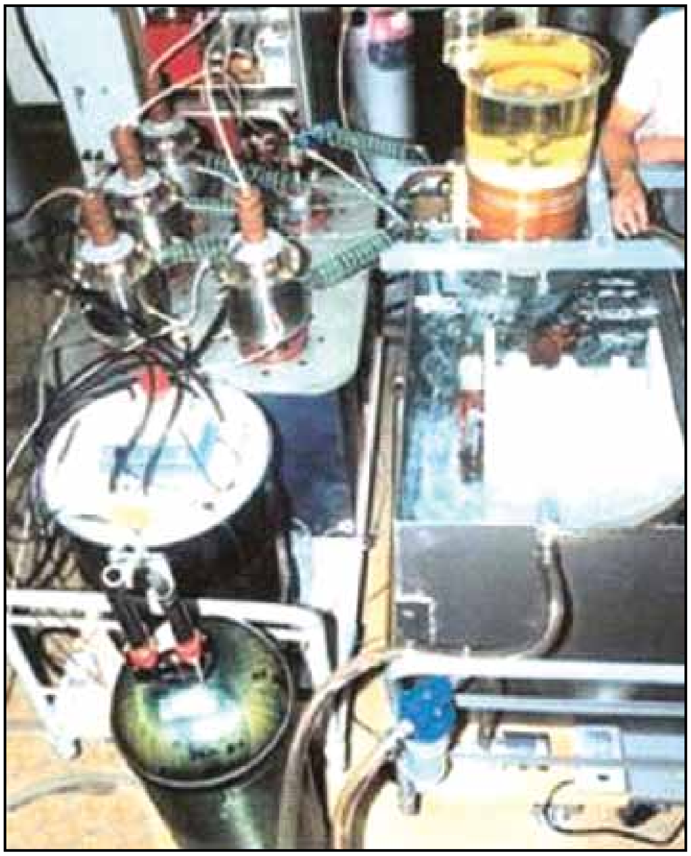

Figure 9. High-Voltage 5-Pulse System Experiment

be electromagnetically launched into low Earth orbit for the fraction of the cost for a normal launch.

Through the 1980s, electric guns were funded by independent research and independent exploratory development programs at Dahlgren, studying electric gun concepts for both rail guns and electrothermal (ET) guns. Kinetic energy weapons were also investigated as part of the Pulsed Power Technology Program. Under these programs, pure electric launchers were developed and tested at Dahlgren, including ones that self-formed projectiles.[16–18] Also studied were ET guns that used the discharge of electrical energy at the gun breech to generate a plasma jet. This plasma jet heated a low-molecular-weight working fluid, such as water, to produce a heated gas that accelerated the projectile to higher velocities than conventional explosives. The Electrothermal-Chemical (ETC) Gun concept augmented the electrical energy generating the plasma jet with a chemical reaction. A 127mm ETC gun was investigated, and a 60mm ETC gun was tested at Dahlgren, with the ability to fire short bursts at a rate of 100 rounds per minute.[19]

Early Dahlgren work on electromagnetic launchers—along with capacitor development and switch advances from the Pulsed Power Technology Program—allowed Dahlgren to provide the Navy with detailed conceptual designs in the late 1990s for near-term, long-range rail guns based on capacitor energy store. These efforts helped support the decision to begin a long-range rail-gun program at Dahlgren that continues today, resulting in world-record achievements. Capital investment funds were used to construct a high-energy facility in 2005 to test pulsed-power components and module designs for use in electromagnetic launcher programs. An early electromagnetic launcher is shown in Figure 10.

High-Energy Lasers (HELs)

In general, megawatts of continuous laser power are required to kill hard targets at long ranges. Laser technologies that can produce this much power are very limited. The Navy was a leader in developing powerful chemical lasers in the 1970s and 80s. These lasers burned chemical reactants to

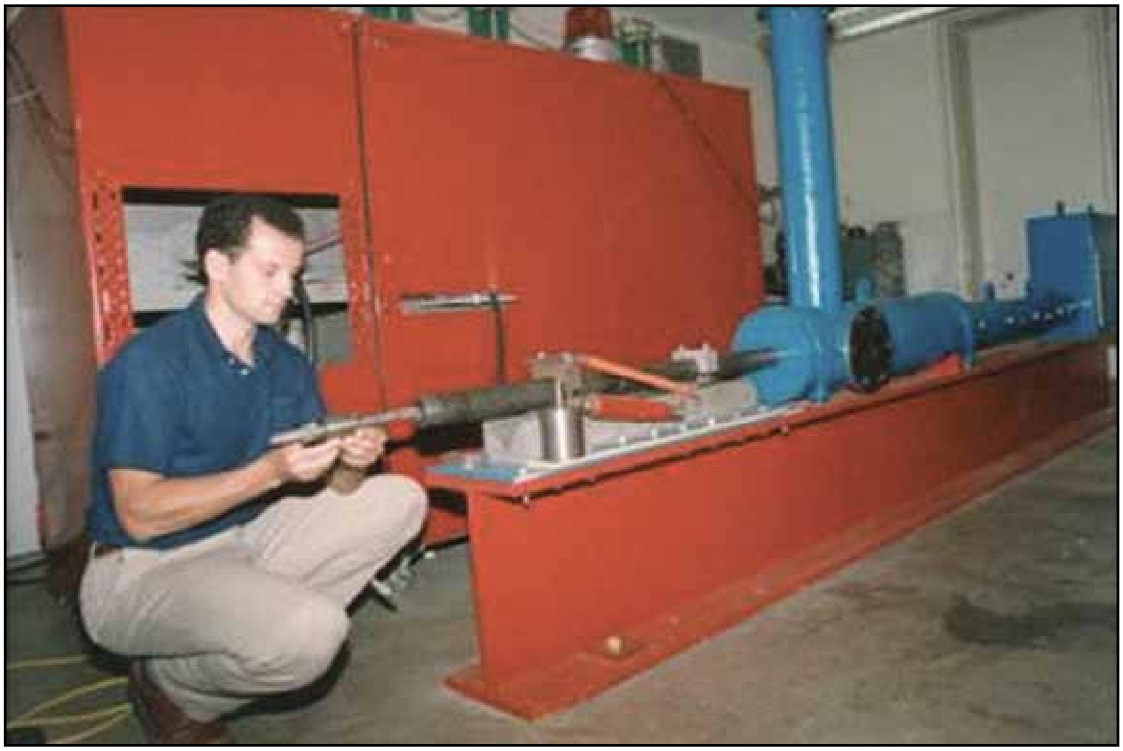

Figure 10. Early Electromagnetic Launcher at Dahlgren

generate the excited states for lasing, thus reducing the need for large amounts of electrical power. The Navy built an entire HEL system, including the Mid-Infrared Advanced Chemical Laser (MIRACL) and the Sea-Lite beam director. By 1990, this building-sized system demonstrated shooting boosters, missiles in flight, and supersonic vehicles. However, the system had drawbacks because it:

- Used hazardous, expensive chemicals
- Had propagation problems at the mid-infrared wavelength
- Was large in size and high in cost

FELs require electron accelerators similar to CPB weapons, so they also are large and complex. However, they can be designed to operate at optimum wavelengths and scale nicely to higher powers. The Strategic Defense Initiative began working on FELs in the late 1980s, funding the advanced test accelerator at LLNL, originally developed for CPBs. FELs were also studied under the Strategic Defense Initiative Organization (SDIO) to be used as an antisatellite weapon. These lasers went from milliwatts to watts under SDIO, and then to kilowatts more recently with work at the Thomas Jefferson National Accelerator Facility in Virginia. Space-based lasers and relay mirror systems were studied under SDIO funding, too, including the development of the Advanced Beam Control System for beam steering, beam control, rapid optical retargeting, and self-alignment.

Dahlgren engineers concentrated its internal laser efforts on medium-power soft-kill weapons. They performed tests against sensors and cameras, and investigated damage thresholds. In the late 1980s, Dahlgren engineers worked with optical augmentation to locate enemy optics for targeting and on green laser dazzlers for defense against small-boat attack. There were efforts to harden electro-optical equipment, including sights and night-vision systems for the Marines, and laser eye-protection filters for goggles and binoculars. Laser systems were also investigated for remotely cutting holes and wires to disable electronics. Lethality work continued under funding from the Joint Technology Office for High-Energy Lasers to look at alternative wavelengths and pulse shapes in addition to modern target materials.[20]

Dahlgren scientists continued to investigate laser-damage thresholds for materials, components, and subsystems for a variety of laser technologies. Near the start of the 21st century, commercial lasers based on pumping optical fibers with semiconductor lasers became common and more powerful. Dahlgren purchased the Navy's largest collection of fiber lasers in 2004 and began investigating ways to combine multiple beams into a laser weapon. These lasers have very high efficiencies, above 20 percent, and the fiber-optic output reduces the requirement for complex optical paths. In 2008, Dahlgren engineers demonstrated a laser capability to ignite spinning mortar rounds, and in 2009, engineers demonstrated the capability of fiber lasers in a shoot down of soft targets at China Lake, California.

Resurgence of Directed Energy

With the fall of the Soviet Union and a greatly altered threat, DoD funding (particularly technology funding) experienced an overall decline in the late 1980s and early 1990s. This caused Navy managers to emphasize near-term, lower risk, evolutionary concepts. The Pulsed Power Technology Program and the Navy's Charged Particle Beam Program both came to an end. Investigations into HPM weapons declined as the difficulty of burnout of military electronics—particularly analog components—became apparent. Problems with propagation and cost caused the Navy to greatly reduce efforts on chemical lasers. With the cancellation of major programs, Dahlgren used internal funding in 1990 to keep a core technical capability together, which was necessary for the Center to remain in the mainstream of tactical DE and its associated technologies. Efforts continued in water breakdown, testing of contractor-developed pulsed-power components, and electric guns. New talent and technologies from universities were brought in to jump-start new projects. Tunable waveform generators using unique semiconductor materials were developed. These used bulk semiconductor material, fabricated in-house, that could be used as a fast switch controlled by laser light for both on and off operation. This allowed faster repetition rates and better triggering than could be done with small spark gaps, as well as the ability to create specific waveforms.[21] "Green" technologies were also investigated using nonthermal plasmas and spark-gap shock waves for cleaning and pollution reduction.[22] New types of particle detectors and magnetic field sensors were developed, and new methods of infrastructure protection were investigated.[23] Soft-kill weapons, both optical and HPM, continued to be studied. Short-pulse jamming of spread-spectrum systems was investigated, as well as beat-wave coupling and special waveforms.[24]

A number of trends led to a resurgence of DEWs by the end of the 20th century. The DoD trend in using digital electronics and off-the-shelf commercial technologies increased dramatically. The pace of change in electronics and computers changed rapidly, too. Most of these new electronic systems had never been tested for vulnerability, and there was a question of how much they would increase military vulnerability to RF or HPM attack. The reduced emphasis on nuclear EMP shielding meant more military electronics were not as well protected from RF attack. Consequently, interest in protecting U.S. military and civilian infrastructure increased, including systems in foreign countries. Moreover, with the increasing reliance on civilian infrastructure, such as power, communications, and emergency and industrial systems—all of which were controlled by digital electronics—the potential that an adversary could attack infrastructure systems to affect or divert military operations became an increasing concern. Following several major terrorist attacks during this time period, there was also concern about the impact of an RF attack on airport towers, financial systems, alarm systems, and industrial plants. Human factors—such as a state of confusion experienced by humans—also played an important part in determining the overall effects of an RF attack.

The asymmetric threat—where large numbers of cheap weapons in a swarm attack could overrun a few sophisticated weapons—caused more concern. As the asymmetric threat to the surface Navy pushed the limits of conventional defensive systems, DE—with it speed-of-light propagation, soft-kill potential, and cheap rounds—offered tactical advantages, either as an adjunct to conventional systems or as stand-alone systems. Additionally, there was an increased emphasis on nonlethal, precise accuracy and graduated effects that could be used. Moreover, the idea that future battles would be fought together with civilians and friendly forces on the battlefield increased the importance of low collateral damage and antimateriel attacks.

The Joint Program Office for Special Technology Countermeasures (JPO/STC), located at Dahlgren, began efforts concerning the vulnerability of new digital systems to RF attack. The program also established a DoD-wide database of vulnerability data, source designs, and RF-effects information—bringing together much of the information collected by the services over the years. The program looked at the protection of modern digital infrastructure systems and funded a facility constructed in 1992 to test large-scale electromagnetic vulnerabilities to various methods of attack.

In the late 1990s and early 2000s, Dahlgren initiated programs regarding the potential for RF attack using nonkinetic disruption, with minimal collateral damage. Capital investment funds were used to construct a test facility for this effort in 1998. Dahlgren developed RF payloads for remotely piloted vehicles and demonstrated their effectiveness in field tests in 1999, and in similar tests in 2007. The successful completion of Project Guillotine was DoD's first demonstration of this type of HPM technology. As the need for statistical vulnerability to commercial digital systems became apparent, Dahlgren constructed instrumented test facilities in 1999 and 2002. Two multistory buildings could be reconfigured to reflect different types of building construction and electromagnetic shielding. Large complexes of electronics, computer networks, server systems, telephone systems, security systems, and various types of digital industrial controls could be assembled, instrumented and exposed to attack from an external device or technique. This program-funded complex—called the Maginot Open Air Test Site (MOATS) facility—continues to be used to test target systems, as well as a variety of RF weapon technologies developed internally and by external and international organizations. A picture of the MOATS facility is shown in Figure 11.

As the need for additional DE laboratory space and testing capabilities became apparent, Dahlgren applied for military construction funds, and in 2008, constructed the Naval Directed Energy Center (NDEC), with access to Dahlgren's overwater test range. Other construction funds were used to construct a remote facility at the Pumpkin Neck Explosive Test Range to serve as a laser backstop and measurement facility, as well as an explosive-test staging area. These facilities already have been used to develop and test fiber lasers against modern threat targets. Construction is currently underway to build an expansion of the NDEC and a 120-m laser test laboratory building using an existing tunnel structure. This collection of facilities represents very important capabilities to develop and test future DE systems.

Conclusion

For over 40 years, the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) has been a leader in developing DE devices, pulsed-power systems, and electric weapons. Its people have contributed many publications and patents, and set world records. DEWs tend to be complex and technically challenging to build. Regardless, these weapons offer important, powerful advantages, such as:

- Deep Magazines
- Cheap Rounds
- Fast Targeting
- Variable Lethality
- Pinpoint Targeting

As a result of NSWCDD's leadership, persistent scientific initiatives, and leading-edge engineering

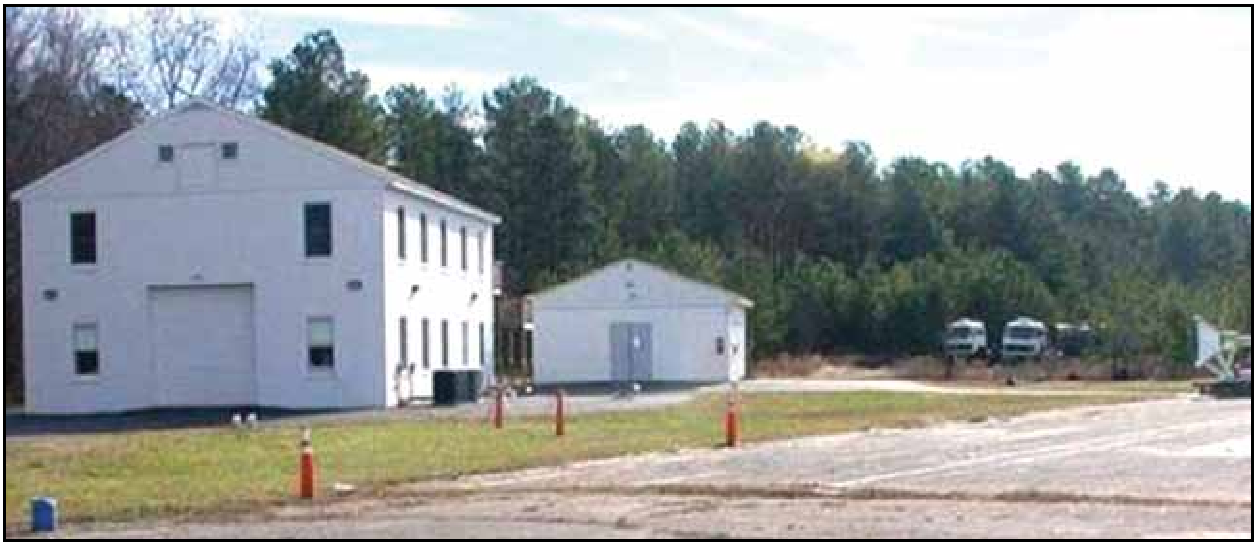

Figure 11. MOATS Facility Undergoing Testing with an RF Weapon (on right)

over the years, naval warfighters will increasingly find themselves turning to DEWs when dealing with situations spanning the spectrum of conflict.

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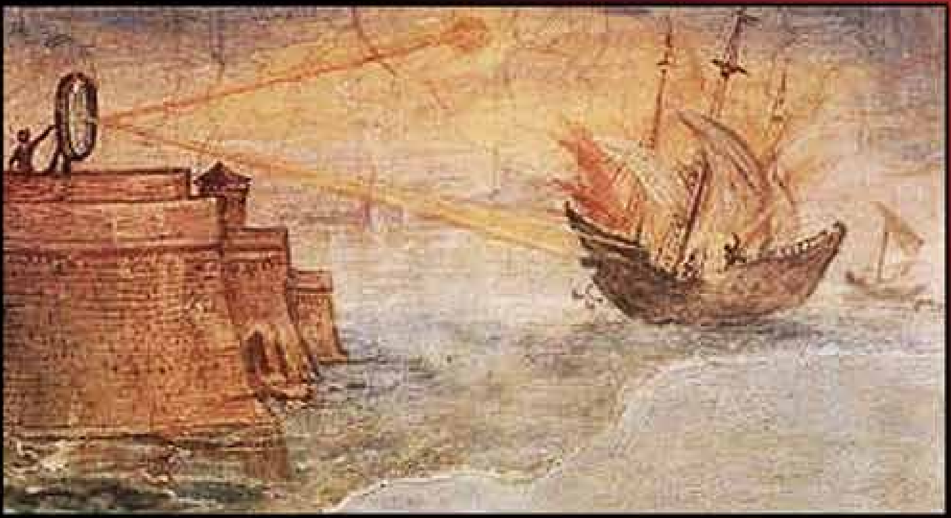

HISTORY OF LASER WEAPON RESEARCH

By Melissa Olson

The idea of using light as a weapon can be traced back to Hippocrates, commander of the Greek forces in 212 B.C. His forces supposedly set fire to the sails of the Roman fleet by focusing sunlight with mirrors. Weapons systems based on lasers and "ray guns," long a staple of science fiction, have captured the imagination of people everywhere. But with steady progress toward the development of lasers in the last 40 years, viable, state-of-the-art laser weapon systems have now become a reality.

The production of lasers in the modern scientific world is fairly new. The first laser was developed in the 1960s and represented the beginning of a drastic change in how the military viewed warfare. The late 1970s and 1980s, too, marked a busy time period for developing lasers into possible weapon systems. All branches of the military and industry were striving to master high power levels, beam control, and adaptive optics. In 1999, the Department of Defense (DoD) formally recognized lasers as future weapons and began research and development (R&D). In 2000, the Joint Technology Office for High Energy Lasers was formed to bring all laser technologies together to develop a complete laser weapon system that could be used by the warfighter.

ELECTROMAGNETIC SPECTRUM

The electromagnetic spectrum contains all the types of electromagnetic energy, including radio waves, microwaves, infrared, visible light, ultraviolet, and gamma rays. ***Laser*** is an acronym for "light amplification by stimulated emission of radiation." Light, therefore, is a type of electromagnetic radiation. Light is made up of tiny packets of energy called photons. The amount of energy is what determines the wavelength. Lasers are usually infrared (1 mm to 750 nm) and visible light (750- to 400-nm wavelength). Microwaves are mostly high-frequency radio waves (millimeters to centimeters), with wavelengths 10,000 times longer than lasers. Diffraction of any electromagnetic radiation beam is based on the wavelength and aperture size. For the same aperture size, lasers diffract 10,000 times less than microwaves. This allows the beam to reach farther ranges while maintaining a small spot size of concentrated energy on the target. Lasers are preferred in specific scenarios because of minimal diffraction. The electromagnetic spectrum is shown in Figure 1.

LASER FUNDAMENTALS

The quantum mechanical idea of stimulated emission of light was discovered by Albert Einstein in 1917 and is one of the fundamental ideas behind the laser. Einstein

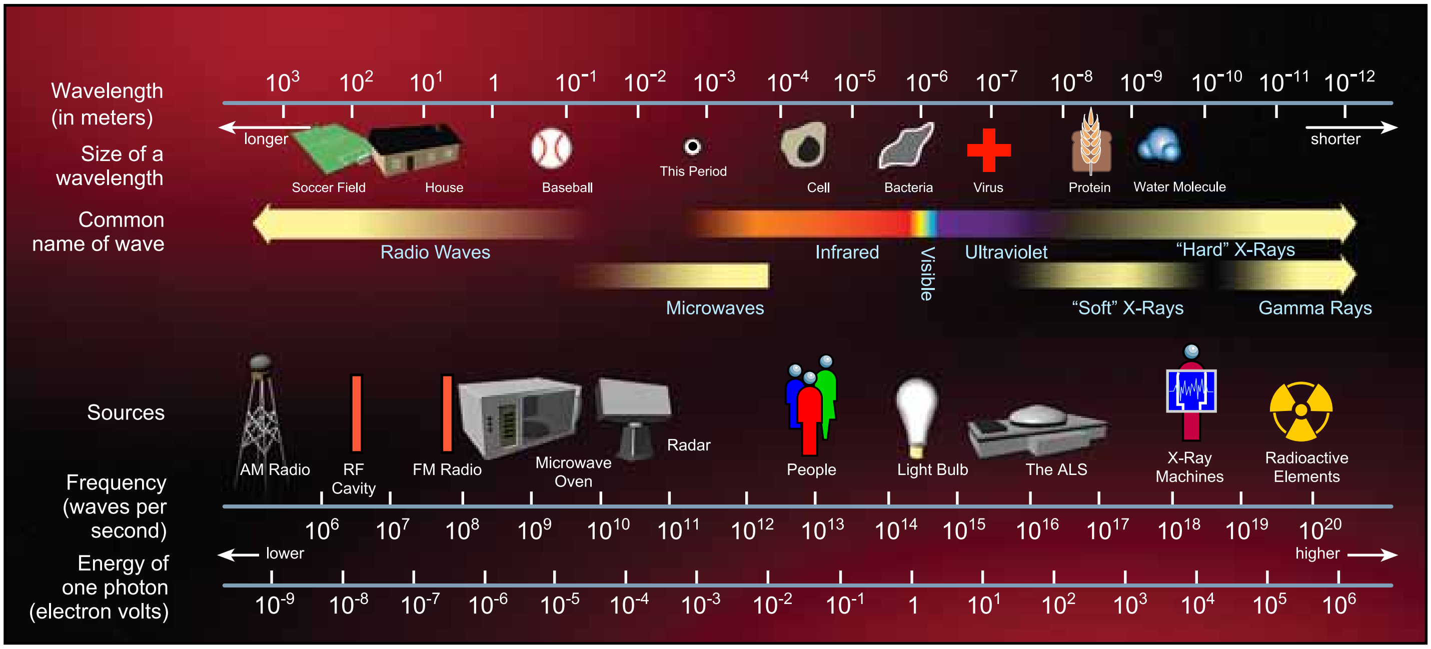
Wavelength (in meters)
10^{3} 10^{2} 10^{1} 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
Radio Waves
Infrared
Visible
Ultraviolet
"Hard" X-Rays
Microwaves
"Soft" X-Rays
Gamma Rays
Sources
AM Radio
RF Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20}
lower
higher
Energy of one photon (electron volts)
10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6}

Figure 1. Electromagnetic Spectrum

theorized that when a photon interacts with an atom or molecule in an excited state, two photons are produced when the atom or molecule leaves the excited state. Population inversion occurs when the atoms or molecules are in the excited state. In order for molecules to come out of the normal "ground" state, a source of power must be introduced to the system energizing the atoms to the excited state. When many photons are passed through many excited atoms, more and more photons are produced. The photons are contained and reflected back and forth in a cavity, with mirrors usually on each end. The mirror on the output end is only partially reflective, allowing some photons to leak through, creating the laser beam.

The difference between an everyday light bulb and the light of a laser is temporal and spatial coherence. In a light bulb, the light emits photons equally in all directions. The light is random, out of phase, and multiwavelength. A laser emits coherent light, so photons travel in identical direction and phase. A laser is also monochromatic, i.e., light of one wavelength. Another significant difference is that laser light is highly collimated, which means the laser beam can travel long distances with minimum spreading.

The laser gain medium through which the photons travel to become amplified or magnified can vary. The source of power used to excite the medium, achieving population inversion, can be the result of a chemical reaction, an electric discharge, a flash lamp, another laser, or some other excitation mechanism. The type of the lasing medium determines the type of laser. The three categories in which lasers are usually classified are chemical, gas, and solid state. A laser can also be continuous wave (CW) or pulsed. Each type of laser produces a specific wavelength of radiation. It is important to note that different wavelengths of radiation interact with the atmosphere differently. A laser beam is either scattered or absorbed by air molecules, water vapor, or dust. Longer wavelengths scatter less and are absorbed more than shorter wavelengths; our sky is blue because the shorter blue wavelengths of light are scattered more than the longer wavelengths.[1] Gamma rays are so highly absorbed that they cannot propagate more than a few feet in the air. Thus, some laser wavelengths are scattered or absorbed more than others. This makes laser wavelengths with minimum absorption better for use as directed-energy weapons since they propagate through the atmosphere better than others. For example, the carbon-dioxide (CO_2) laser is strongly absorbed by water vapor, so any use near the ocean will be negatively affected. Near-infrared and infrared lasers have shorter wavelengths with negligible absorbance. The optimal laser choice, therefore, would be a wavelength-tunable laser that could vary depending on the atmospheric conditions, such as the free-electron laser (FEL).

Lasers have affected almost every type of modern technology. Most laser technologies use low powers and were mastered very quickly. They are used in many everyday appliances, such as scanning/inventory devices, surgery/medicine, hair removal, presentation pointers, law enforcement, ranging and sighting devices, welding applications, and much more. Using a laser as a weapon has many advantages. For example, a laser:

- Is unaffected by gravity
- Causes minimal collateral damage
- Travels at the speed of light
- Can precisely reach far distances
- Is capable of causing a specific, predetermined amount of damage to targets

The theory behind these capabilities makes the laser weapon a prime choice in multiple engagement scenarios. However, developing lasers with higher powers to use as a weapon has proven more difficult than first considered.

MILITARY LASER HISTORY AND LASER TYPES

Generally, a laser weapon is any laser used against the enemy with more than 50 kW to megawatts of power. This is much greater power than commercial lasers. Accordingly, they have greater support needs, including:

- Environmental and personnel safety
- Mirror coatings
- Chilling requirements
- Power requirements
- Laser fuel storage
- Alignment and tracking requirements

In 1960, the very first laser (a ruby laser) was built, producing minimal power. This event was followed by many other laser technology developments. The first chemical laser, hydrogen fluoride (HF), was built in 1965, producing 1 kW. It was then that DoD became interested in researching and developing a more powerful laser for weapon applications. Subsequently, in 1968, the Defense Advanced Research Projects Agency (DARPA) Baseline Demonstration Laser produced 100 kW, and the Navy-ARPA Chemical Laser (NACL) produced 250 kW in 1975. The very first laser is depicted in Figure 2.

Solid-State Lasers (SSLs)

An SSL uses a solid lasing medium, such as a rod made up of glass or crystal, or a gem, like the ruby laser. Along with the rod or host material is an active material, such as chromium, neodymium, erbium, holmium, or titanium. Chromium is the active material used in ruby lasers. Neodymium is the active material in the most widespread applications. A flash lamp, arc lamp, or another laser carries out the optical cavity pumping to achieve population inversion and stimulate the laser beam. The Neodymium Yttrium-aluminum garnet (Nd:YAG) laser is a popular SSL. It operates at a 1064.5-nm wavelength and can be pulsed wave or CW. A great advantage of these lasers is that the wavelength and pulse duration can be varied considerably.[1] The power level can reach up to megawatts when using Q-switching to achieve

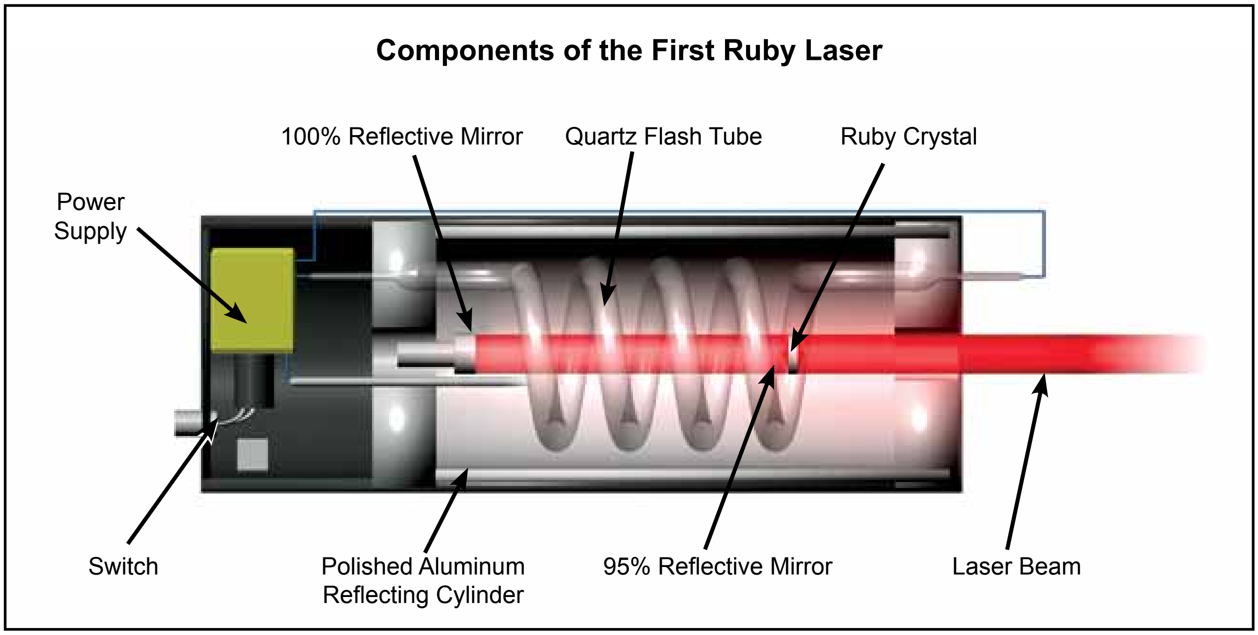

Figure 2. First Ruby Laser Developed in 1960 by Research Physicist Theodore H. Maiman

short pulse lengths. The various interactions with the laser and different crystalline materials can double the electromagnetic frequency, which will halve the wavelength, bringing the laser beam into the visible range, 532 nm (green). The wavelength can be further divided down three or four times, making this laser range from the near-infrared to the ultraviolet wavelength. These lasers are commonly used for rangefinders and target designators. Other advantages of these lasers are that they can be made very small, rugged, cheap, and battery-powered. Characteristics of SSLs are shown in Table 1.

Chemical Lasers

A chemical laser uses chemical reaction to create population inversion in the lasing medium. One example is the Mid-Infrared Advanced Chemical Laser (MIRACL) developed in the mid-1980s. The MIRACL is a continuous-wave, mid-infrared (3.8-μ) laser. Its operation is similar to a rocket engine in which a fuel (ethylene, C2H4) is burned with an oxidizer (nitrogen trifluoride, NF3).[2] Free, excited fluorine atoms are among the combustion products. Just downstream from the combustor, deuterium and helium are injected into the exhaust. Deuterium (U) combines with the excited fluorine to create excited deuterium fluoride (DF) molecules, while the helium stabilizes the reaction and controls the temperature.[2] The laser's resonator mirrors are wrapped around the excited exhaust gas, and optical energy is extracted. The cavity is actively cooled and can be run until the fuel supply is exhausted. The laser's megawatt-class output power can be varied over a wide range by altering the fuel flow rates and mixture. The laser beam in the resonator is approximately 21-cm high and 3-cm wide. Beam-shaping optics are used to produce a 14- × 14-cm (5.5- × 5.5-inch) square, which is then propagated through the rest of the beam train. Diagnostics for evaluating the beam shape, absolute power, and intensity profile are used on each firing of the laser. The beam can be directed to a number of different test areas or to the SEA LITE beam director.[2] The DF Chemical Laser (MIRACL) and the Sea Lite Beam are shown in Figure 3.

The laser and beam director were integrated in the mid-1980s at the Army's High Energy Laser Systems Test Facility (HELSTF) at White Sands Missile Range, New Mexico. Following integration, extensive tests were conducted in the areas of:

- High-power optical components and beam-path conditioning
- Beam-control techniques
- High-power propagation
- Target damage and vulnerability
- Target lethality[3]

Tests supported by the MIRACL included:

- The high-power dynamic with flying drone (BQM-34)
- Conventional defense initiative with flying drone
- High-velocity target test with Vandal Missile
- High-altitude target tests with flying drone
- Missile and plume tests using the 1.5-m aperture
- Radiometrically calibrated images and spectral radiometry

These successful tests are what made many believe that MIRACL was the first and only successful laser weapon system developed by the Navy prior to the Navy Laser Weapon System (LaWS).[3]

Gas Lasers

Gas lasers are a type of chemical laser that uses a pure gas or gas mixture to produce a beam. The typical gas laser contains a tube with mirrors on each end. One end transmits the beam out of the cavity. Most gas lasers use electron-collision pumping, with electric current passing through the gas. Some use optical pumping with flash lamps. The helium

Table 1. Characteristics of Solid-State Lasers

Name	Wavelength (nm)	Typical Power	Typical Operation
Alexandrite	700-830	5 watts	Pulsed/CW tunable
Erbium	850/1230/1540/1730/2900	8 watts	Pulsed
Holmium: glass	1950	milliwatts	Pulsed
Neodymium	1064/1123/1318/1370	megawatts	Pulsed
Neodymium: glass	1060	megawatts	Pulsed
Neodymium: YAG	1064.5	megawatts	Pulsed/CW
Ruby	694.3	10–15 watts	Pulsed
Titanium-sapphire	660–1060	15 watts	Pulsed/CW tunable

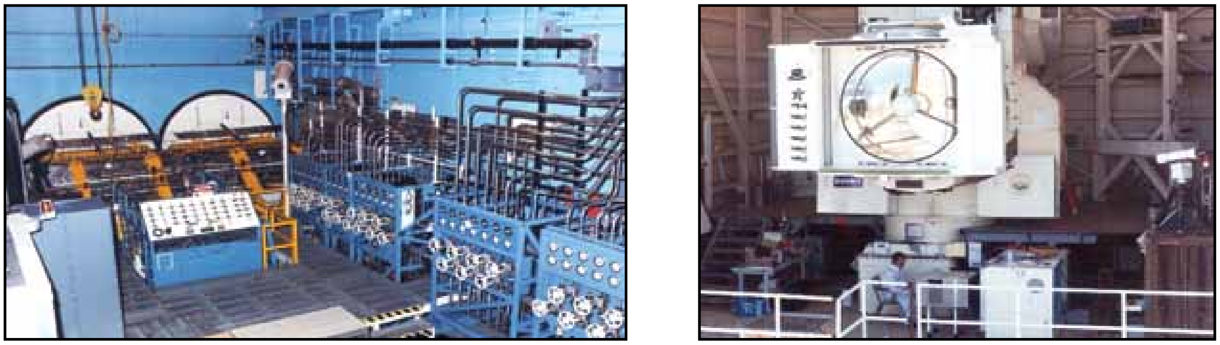

DF Chemical Laser (MIRACL)

Sea Lite Beam

Figure 3. DF Chemical Laser (MIRACL) and Sea Lite Beam

neon (HeNe) laser is a very well-known gas laser. It produces a bright red, continuous beam of low power. It is used for many applications such as scanning, alignment, measurement, and stabilization devices. University students use them in optical training laboratories. Many larger lasers contain a HeNe inside the beam path, as well to verify beam alignment. HeNe lasers are fairly cheap and very rugged. They can work continuously for thousands of hours.

CO_2 lasers are in the gas family. These lasers were the earliest, truly high-power lasers and have been among the most crucial lasers used in R&D for high-energy laser (HEL) weapons. In industry, the more powerful CO_2 lasers are used for welding, drilling, and cutting. There are many different types of CO_2 lasers that vary in pumping design. CO_2 lasers work by burning a hydrocarbon fuel (like kerosene or methane) in oxygen or nitrous oxide. The hot gas flows through a comb of nozzles, expands quickly, and achieves population inversion. The gas then flows through an optical resonator at supersonic speeds, resulting in stimulated emission and a laser beam.[4]

CO_2 lasers have been researched for use as nonlethal weapons. The wavelength produced by a CO_2 laser is also absorbed by glass. For example, the beam does not penetrate a windshield. Thus, shooting a CO_2 laser at a vehicle's windshield could deter a threat by damaging the windshield or by causing a dazzling effect to reduce the visibility of the driver, while not reaching the driver at all.

The gas dynamic laser (GDL) is a CO_2 laser based on differences in relaxation velocities of molecular vibrational states. The laser medium's gas has properties such that an energetically lower vibrational state relaxes faster than a higher vibrational state; thus, a population inversion is achieved in a particular time. A GDL is shown in Figure 4. Characteristics of chemical and gas lasers are identified in Table 2.

Fiber Lasers

Modern fiber lasers are considered SSLs. They are powered by electricity, making them highly mobile and supportable on the battlefield. Fiber lasers use optical fibers as the gain media. In most cases, the gain medium is a fiber doped with rare earth elements—such as erbium (Er3+), neodymium (Nd3+), ytterbium (Yb3+), thulium (Tm3+), or praseodymium (Pr3+)—and one or several laser diodes are used for pumping. Optical fibers have been used in industry, specifically for telecommunications to transport information via light. With developing technology, optical fibers have become high-energy, powerful laser energy sources. Fiber lasers have proven to have much benefit over traditional SSLs. They are rugged and do not require a clean room to operate or maintain, as most other laser systems do. They also are extremely efficient; however, they cannot operate well in all weather conditions. One example is the IPG CW fiber lasers, which produce moderate beam quality, causing damage to materials and components through thermal heating and burn-through. The Naval Surface Warfare Center, Dahlgren Division (NSWCDD) purchased eight commercially available 5.5-kW IPG lasers, where two multimode (seven fibers) lasers are housed per cabinet. This type of laser is easy to mount due to the flexible fibers. The IPG CW Fiber Laser is shown in Figure 5.

Miscellaneous Lasers

There are other types of lasers that do not necessarily fit into the chemical or solid-state categories. These include semiconductor lasers, used in:

- Television
- CD Players
- Dye Lasers
- Spectroscopy
- Radios
- Telecommunications
- Medicine
- Astronomy

There also are the FELs mentioned previously. The FEL is a completely different breed of laser.

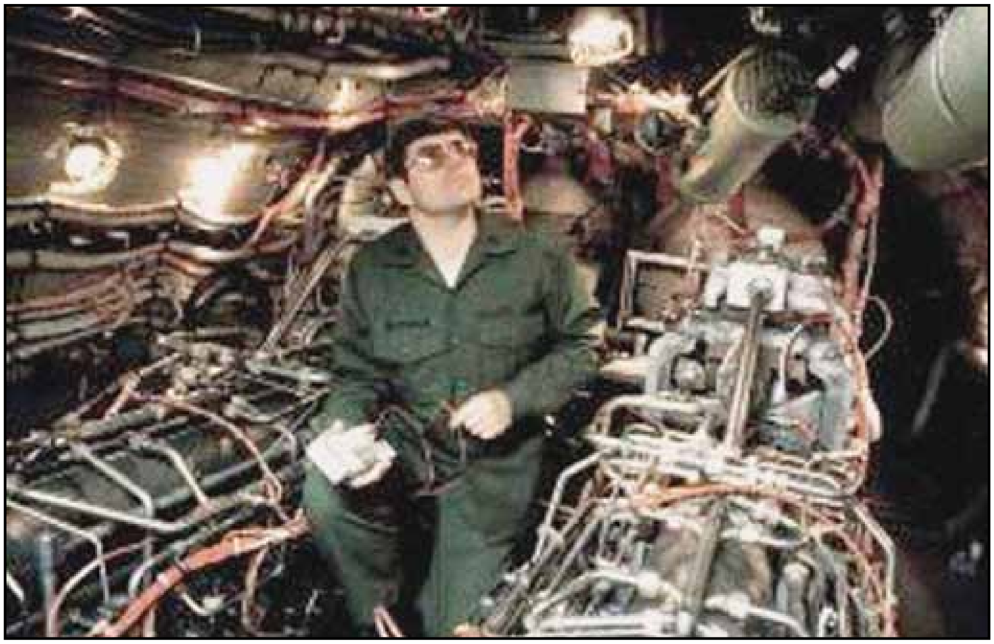

Figure 4. A laser engineer inspects a gas dynamic laser after installation aboard an NKC-135 airborne laser laboratory.

Table 2. Characteristics of Chemical/Gas Lasers

Name	Wavelength (nm)	Typical Power	Typical Operation
Helium-Neon	543/632.8	.0001–.001 watts	CW
Krypton	350–647	.0001–.05 watts	CW
Argon	350–514.5	.001–6.0 watts	CW
Xenon fluoride (excimer)	351	.001–20 watts	CW
Argon fluoride (excimer)	193	.05–30 watts	Pulsed
Krypton fluoride (excimer)	249	7–100 watts	Pulsed
Deuterium fluoride (chemical)	3,000–4,200	.01–100 megawatts	Pulsed/CW
Hydrogen fluoride (chemical)	2,600–3,000	.01–150 megawatts	Pulsed/CW
Carbon dioxide	9,000–12,000	.1–15,000 megawatts	Pulsed/CW
GaAlAs (semiconductor)	750–900	10–4,000 milliwatts	Pulsed

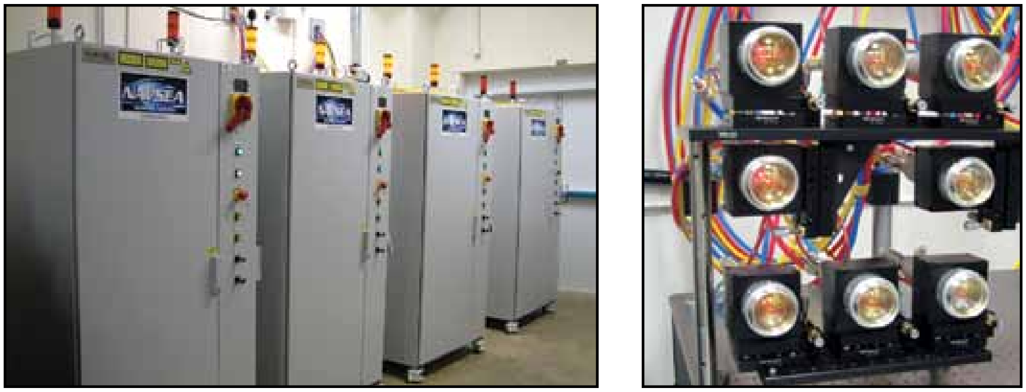

Figure 5. IPG CW Fiber Laser System

It uses electrons to create photons instead of some type of matter. The electrons are produced, collected, and directed to flow at very high speeds. To excite the electrons, they are passed through a “wiggler,” i.e., a series of magnets positioned in such a way that electromagnetic radiation (light) is produced when the electrons release photons. The significant feature of the FEL is that the wavelength can be controlled, depending on the magnet positions and the speed of electrons. This versatility makes the FEL particularly appealing. However, the footprint of the FEL system is too large to transform into any ideal defense weapon. The Jefferson Laboratory in Newport News, Virginia, has an FEL and continues to maintain and test its capabilities and effects. This laser was new to the military in the late 1990s and received funding to optimize its capabilities and integrate as a defense weapon. Although great progress has been made, the required footprint could be much larger than desired. Consequently, some interest in the FEL has shifted to other HEL sources.

Many scientists foresee the probability of using the laser as a global weapon. This possibility is proven through basic laws of physics. Actually implementing such a system, however, can be more difficult. The global weapon concept uses a base laser with optics and is strategically positioned in space to be able to direct its beam multiple places on Earth at the speed of light with maximum power levels. This idea faces significant problems, including appropriate power levels, optics to handle such levels, propagation issues, and the ethical measures behind any global weapon. Still, the idea presents interesting possibilities.

LASER WEAPON DEVELOPMENT

The following paragraphs highlight some of the laser weapons that have been successfully developed over the last 40 years.

Baseline Demonstrator Laser (BDL) Hydrogen Fluoride (HF)

In 1973, TRW Inc. produced the world’s first high-energy chemical laser, the Baseline Demonstration Laser, for DoD. After that, TRW Inc. produced and demonstrated six more HELs, including the MIRACL (1985) and Alpha (2000), the nation’s only megawatt-class chemical lasers.

Navy-ARPA Chemical Laser (NACL) HF

The NACL was mated with the Navy Pointer Tracker at TRW Inc.’s San Juan Capistrano, California, facilities in the 1975–1978 time frame. This was the Navy’s initial, integrated HEL system test bed and was used to provide the first demonstrated kill of an operational missile in 1978.

Alpha HF—Built for Strategic Defense Initiative (SDI) Space-Based Laser (SBL)

Alpha, an HF laser, was the baseline technology for the SBL readiness demonstration (SBLRD). In 1991, the Alpha laser demonstrated megawatt-class power levels similar to MIRACL, but in a low-pressure, space operation environment. Alpha demonstrated that multimegawatt, space-compatible lasers can be built and operated.

Tactical High-Energy Laser (THEL)

The THEL is a DF chemical laser developed by the Army. In 2000 and 2001, THEL shot down 28 Katyusha artillery rockets and 5 artillery shells. On 4 November 2002, THEL shot down an incoming artillery shell and a mobile version successfully completed testing. Subsequently, during a test conducted on 24 August 2004, the system successfully shot down multiple mortar rounds. These tests represented actual mortar threat scenarios in which both single mortar rounds and salvo were tested and intercepted. A photograph of THEL is shown in Figure 6.

Advanced Tactical Laser (ATL)

The ATL uses a closed-cycle, chemical oxygen-iodine laser (COIL) with beam control, which lases at a 1.315-μ wavelength. The ATL was developed to engage tactical targets from a moving platform at ranges of approximately 10 km. It can spot a 10-cm-wide beam on a distant target for up to 100 shots. This beam has enough power to slice through metal at a distance of 9 miles. The aircraft equipped with the ATL weapon system is shown in Figure 7.

A specially modified 46th Test Wing NC-130H aircraft equipped with the ATL weapon system fired its laser while flying over White Sands Missile Range, New Mexico, successfully hitting a target board located on the ground. Equipped with a chemical laser, a beam control system, sensors, and weapon-system consoles, the ATL is designed to damage, disable, or destroy targets with little or no collateral damage.

Airborne Laser (ABL) (CO_2) Chemical Oxygen

The ABL C-130H aircraft contains three laser beam systems: the powerful killing primary laser beam (ATL), a set of illuminating laser beams for infrared surveillance and high-speed target acquisition, and a beacon laser for a high-precision laser target tracking beam control system. The primary

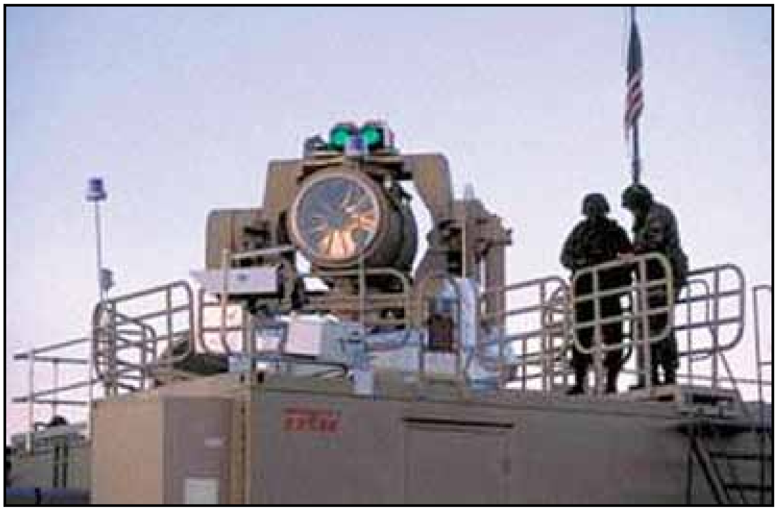

Figure 6. Tactical High-Energy Laser (THEL)

Figure 7. 46th Test Wing NC-130H Aircraft Equipped with the ATL Weapon System

laser beam is generated by a megawatt COIL located at the rear of the fuselage. The high-power laser beam travels towards the front of the aircraft through a pipe. The pipe passes through a Station 1000 bulkhead/airlock, which separates the rear fuselage from the forward cabins. The high-power beam passes through the fine beam control system mounted on a vibration-isolated optical bench. Beam pointing is achieved with very fast, lightweight steering mirrors, which are tilted to follow the target missile. The ABL finally destroyed a target while in flight at White Sands Missile Range in August 2009. The 12,000-lb ABL locked onto an unspecified ground target and fired the laser, making the target disappear. Although it was successful at this demonstration, using the ABL in the fleet has fallen out of favor due to affordability and technology problems. The ABL is shown on an aircraft in Figure 8.

Joint High-Power Solid-State Laser (JHPSSL)

In hopes of accelerating SSL technology for military uses, work is being performed by the U.S. Army Space and Missile Defense Command (SMDC) and the Army Test and Engineering Center at White Sands Missile Range. The technology uses an electric laser diode to shoot light into 32 garnet crystal modules that combine to create "laser amplifier chains" producing 15 kW. By using seven chains and by combining multiple beams, they have reached 105 kW in the laboratory operating in a clean room. The program's ultimate goal is for a laser system to reach high powers outside a laboratory environment. Fielding such a delicate optical structure can present significant barriers for this laser system. Nonetheless, it will be a great accomplishment for a variety of force protection missions, such as shipboard defense against cruise missiles. The JHPSSL system is shown in Figure 9.

Navy Laser Weapon System (LaWS)

The Navy LaWS is the most recent, successful laser weapon. It uses an electric-fiber laser design, avoiding the problems that chemical lasers present. In the summer of 2009, the Naval Sea Systems Command (NAVSEA)—with support from NSWCDD—successfully tracked, engaged, and destroyed unmanned aerial vehicles (UAV)

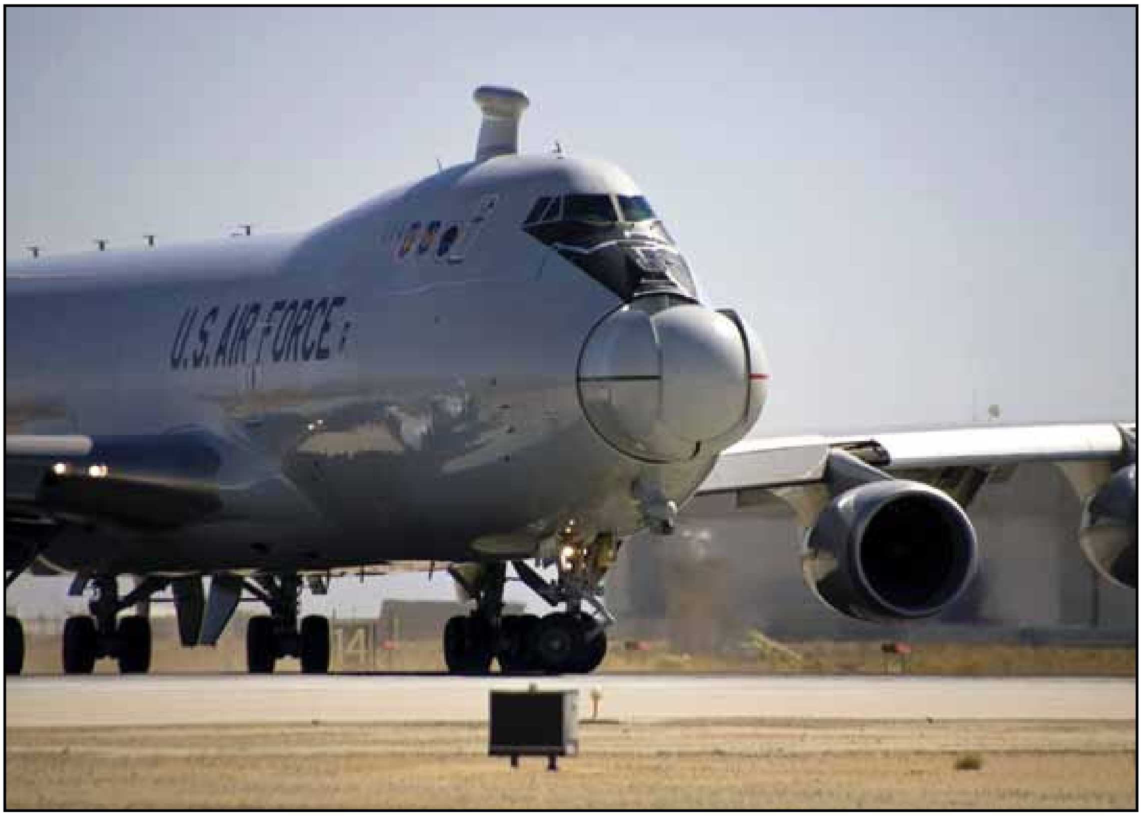

Figure 8. Airborne Laser (ABL)

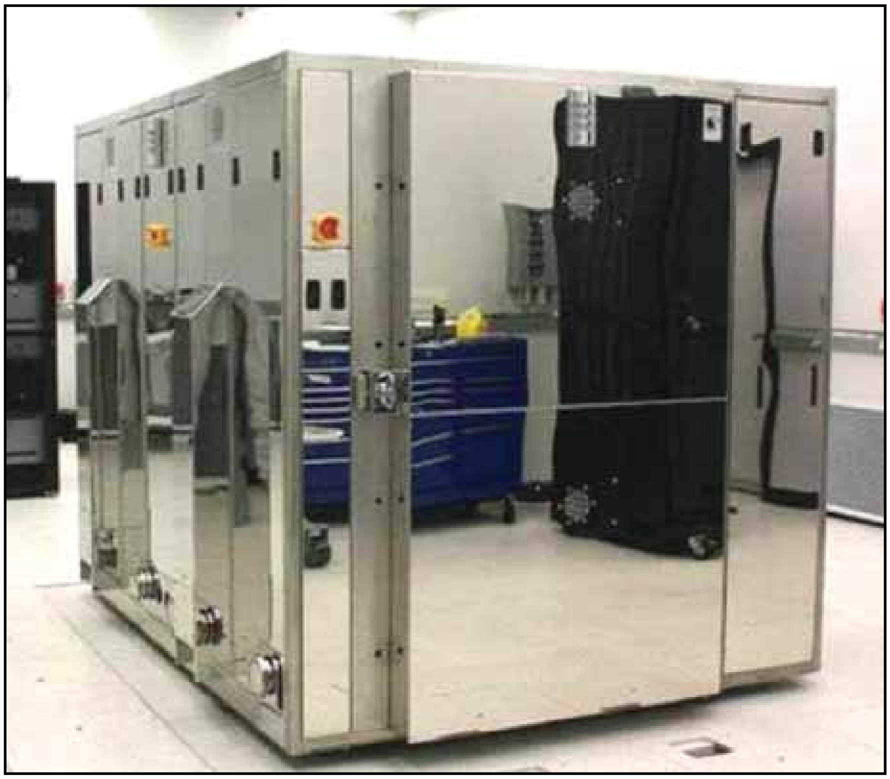

Figure 9. Joint High-Power Solid-State Laser (JHPSSL) System

in flight at the Naval Air Warfare Center, China Lake, California. A total of five targets were engaged and destroyed during the testing, which represented a first for the U.S. Navy. The laser was fired through a beam director on a Kineto Tracking Mount similar to the Sea Lite beam director. The system used fiber lasers in the configuration and has proven to be a rugged and dependable choice for the warfighter's needs. A photograph of LaWS is shown in Figure 10.

Laser weapon systems development in recent years has taken giant steps forward. Dedicated R&D has advanced the state of the art considerably. What was unimaginable only a few short years ago, today has become reality. Accordingly, given continued R&D, warfighters in the near term will have additional weapon options to choose from for dealing with a spectrum of threats and contingencies.

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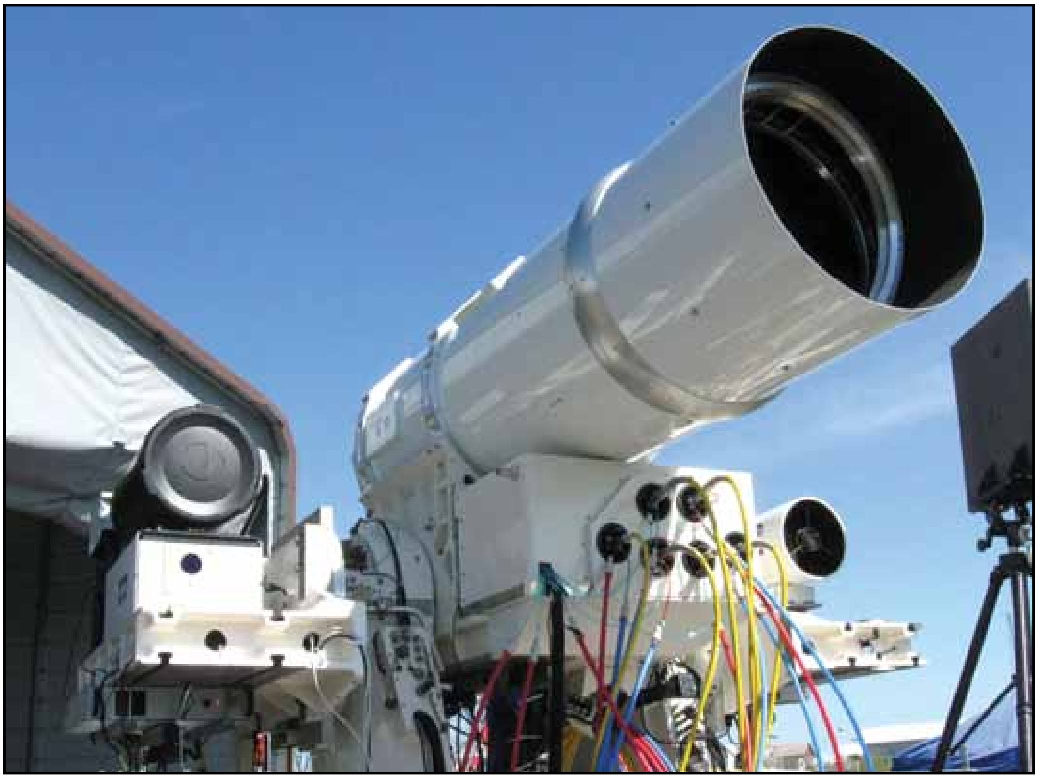

Figure 10. Navy Laser Weapon System (LaWS)

Laser Weapon System (LaWS) Adjunct to the Close-In Weapon System (CIWS)

By Robin Staton and Robert Pawlak

The Naval Sea Systems Command (NAVSEA) established the Navy Directed Energy Weapons Program Office in January 2002 and subsequently chartered the Directed Energy and Electric Weapon Systems Program Office (PMS 405) in July 2004.[1, 2] Its mission is to change the way the Navy fights in the 21st century by transitioning directed-energy and electric weapon technology, providing the warfighter with additional tools to fight today's and tomorrow's wars. In support of this mission, the Laser Weapon System (LaWS) was developed, which potentially adds a suite of tools for offensive and defensive operations.

The LaWS program is managed by PMS 405 in cooperation with the Program Executive Office Integrated Warfare Systems (PEO IWS), the Navy's Close-In Weapon System (CIWS) manager. A multilaboratory/multicontractor organization led by the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), has been executing the program since March 2007. The potential advantages of a lethal, precise, speed-of-light weapon are numerous and have been recognized for many years. However, even in light of these advantages, there are realities that need to be considered for any program to succeed to the point that an actual system is placed in the hands of the warfighters.

The LaWS system offers viable solutions for an important subset of threats while fitting into acceptable size and weight constraints. In addition, since LaWS is a fully electric laser, the operation of the system does not require the handling and storage of hazardous chemicals, such as hydrogen fluoride. As will be discussed later, due to the incorporation of high levels of commercial off-the-shelf (COTS) technology, the LaWS system also has advantages for topside design, logistic supportability, and cost. Thus, LaWS could enable the Navy to address adverse cost-exchange situations, which can occur when engaging proliferated inexpensive threats such as unmanned aerial vehicles (UAVs).

BACKGROUND

Based on mission analysis work conducted prior to the LaWS program and additional work done as part of the program, it became clear that a number of factors require careful consideration. First, a high-power laser is not likely to replace anything on a ship in the next 5 years. For a new system to be added to a ship, a high-power laser must supplement current capabilities or provide new capabilities that clearly justify its addition. Second, because a laser provides such a diverse set of capabilities, conventional air-to-air warfare (AAW) models—such as the Fleet AAW Model for Comparison of Tactical Systems (FACTS), Antiair Warfare Simulation (AAWSIM), and Extended Air Defense Simulation (EADSIM), as well as other existing AAW analysis approaches—are not well suited for showcasing current or near-term laser-weapon capabilities. While they can (and have) been used for laser-weapon analysis, their application to a megawatt-class laser that could "instantly" destroy boats or cruise missiles (akin to missile engagements) is a more straightforward application of the existing models and techniques.

In November 1995, the Chief of Naval Operations requested that the National Research Council initiate, through its Naval Studies Board, a thorough examination of the impact of advancing technology on the form and capability of the naval forces to the year 2035. A major observation of the report is quoted below:

> Numerous laboratory and field-test versions of laser weapons have been developed and demonstrated. They have worked as expected and demonstrated suitable lethality against their intended targets. The primary factors that have inhibited the transition of the technology into deployed systems are size and weight. Generally, the conceptual designs of laser weapons that are scaled for combat effectiveness are too large to be appealing to users; conversely, weapons that are sized for platform convenience generally lack convincing lethality.[3]

Subsequently, an August 2006 U.S. Air Force (USAF) Scientific Advisory Board Study examined the increasing threat posed by UAVs in some detail. Key conclusions included:

> No single system can completely address the UAV threat. A single sensor solution is inadequate because of the size and speed challenges presented by small UAVs. A single-weapon-layer solution fails to provide for adaptability to multiple scenarios or adequate probability of kill.

Key recommendations of the USAF Advisory Scientific Board Study included:

> Develop and field longer-term upgrades to counter increased UAV threats. They include:…a small, multimission air/air and air/ground weapon; and directed-energy air defense weaponry.[4]

In addition to the USAF Scientific Advisory Board study, a 2007 OPNAV Deep Blue Study noted the potential advantage of nonkinetic defeat options and recommended that the Navy accelerate development of nonkinetic systems to include high-energy lasers (HELs).[5]

The laser power levels likely to be available in the near term, within reasonable size and cost, are in the neighborhood of 100 kW of radiated power. While this power level is not adequate to engage certain threats, such as cruise missiles or tactical ballistic missiles at tactically useful ranges, there is still a wide spectrum of threats that could be engaged at ranges that are comparable to many current ship-defense weapons, including minor-caliber guns and small missiles. The spectrum of threats includes:

- UAVs
- Missile Seekers
- Intelligence, Surveillance, and Reconnaissance Systems
- Rockets
- Man-Portable Air-Defense Systems (MANPADS)
- Mortar Rounds
- Floating Mines
- Artillery Rounds

LaWS on CIWS

The Mk 15 Phalanx CIWS can often detect, track, and (sometimes) identify potential threats at ranges well outside the effective range of the 20mm gun. These functions are accomplished using the search/track radar system and the Phalanx Thermal Imager (PTI). When added to the Phalanx mount and pointed in the same direction as the gun (see Figure 1), a laser weapon could potentially add a number of useful functions and capabilities to the mount, but technical challenges must be overcome. Preliminary analyses of the mechanical characteristics of the mount suggest that the additional weight that could be added to the mount must be kept under approximately 1200–1500 lb. Additionally, it is highly desirable that the addition of the laser weapon not substantially affect the train/elevation operation of the mount in angle, peak velocity, or acceleration. Consequently, use of rapidly evolving fiber laser technology appears to be the only currently foreseeable path to adding significant laser energy directly to the mount within these constraints.

One major driver in the genesis of the LaWS system was the availability of relatively low-cost COTS fiber-optic lasers. Because these fibers are flexible, they obviate the need for an expensive coudé path system (an optical mirror/lens assembly that turns radiation 90° and may also support rotation of the beam director), thus allowing the use of low-cost mount technology, as well as the retrofitting of the system on existing mounts. The last factor is extremely important because of the scarcity of topside real estate on today's ships. These fiber-optic lasers do have limitations in terms of power, although power levels are growing with advancing technology. The reality today is that, in order to get adequate lethality from a system based on this technology, the use of a beam-combining apparatus utilizing several individual fibers is necessary. (Figure 2 depicts combining multiple fibers in the same beam director.) Furthermore, a smaller beam size is desirable since this drives power density up—increasing the performance required for the tracking and pointing elements of the system. Thus, a high-resolution fine track sensor is needed, as well as an appropriately robust line-of-sight control.

A Potential Suite of LaWS-Related Capabilities

Potential added capabilities that an adjunct LaWS could contribute to the total ship combat system are briefly outlined in the following subsections.

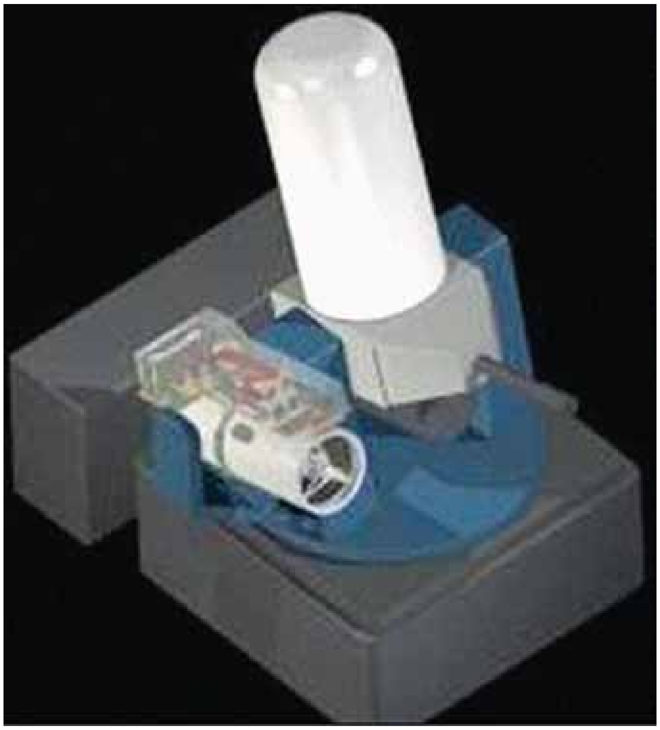

Figure 1. LaWS Mounted on CIWS

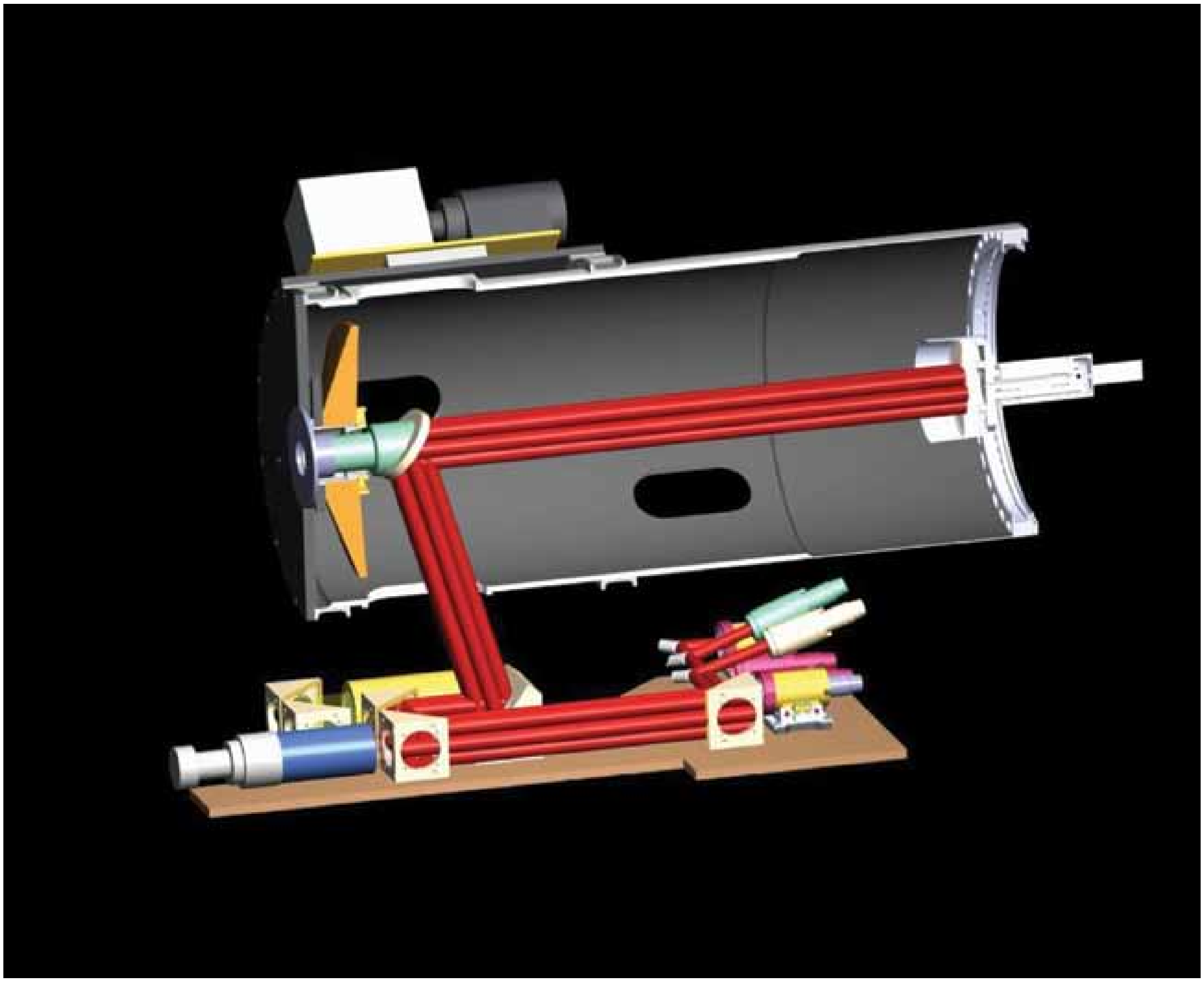

Figure 2. Cutaway View of the LaWS Beam Director

Target Identification, Tracking, and Intent Determination at Range

The optics that would be added for the laser to detect and track targets in support of a laser engagement would immediately contribute additional capabilities to the entire ship combat system even without operating the laser. A laser-gated illuminator, part of the tracking system, significantly increases the signal to the background level of tracked targets and provides good range resolution as well. The additional sensitivity and angle resolution provided by the LaWS optics would allow the identification, precision tracking, and "monitoring" (at high resolution) of potential threats or vehicles of interest at substantially greater ranges than could be achieved by the PTI alone. The Phalanx radar, or another source, would have to provide an initial, accurate cue to facilitate initial acquisition. Once acquired, the target could be examined and monitored with high resolution at range. This capability could make a substantial contribution to identification efforts—efforts to determine intent and potentially even to documenting target behavior to resolve issues with rules-of-engagement doctrine. It is widely recognized that rules-of-engagement issues, such as threat identification and intent determination, are among the most difficult problems faced by ship commanding officers.

Unambiguous Warning at Range

If a fraction of the laser energy is routed through a frequency-doubling crystal, an intense, visible beam can be projected to significant ranges to provide a clear, unambiguous warning that a potential target is about to be engaged unless an immediate change in behavior is observed. This feature also would have utility for dazzling aircraft, surface vehicle, or submarine sensors, and would provide exceptional long-range, unambiguous warning to boats or aircraft at night.

Sensor Destruction at Range

Many electro-optical (EO) sensors are quite susceptible to damage by laser energy in the fiber-laser band as is the case with infrared (IR) missile seekers with germanium optics. The frequency-doubling feature described in the previous paragraph also would be useful to ensure that a band-pass filter at a single frequency could not be applied as an effective countermeasure. The intent here would be to destroy the seeker or imager at ranges well beyond those achievable by the Phalanx 20mm gun. Other examples include intelligence, surveillance, reconnaissance, and targeting sensors on UAVs or unmanned surface vehicles (USVs).

IR Missile Assist at Range

Many targets of interest—including UAVs, USVs, and small boats—are somewhat "marginal" from a target-signature standpoint, particularly at the maximum range of existing IR guided missiles such as the FIM-92 Stinger, the FGM-148 Javelin, the RIM-116 RAM, and the AIM-9X Sidewinder. The CIWS laser adjunct could potentially "correct" this situation by laser heating target vehicles to enhance their signature to existing IR guided missiles. Note that this is NOT "conventional" semiactive-laser (SAL) guidance—the LaWS is not a coded illuminator, nor do the seekers in question rely on this coding. The IR missiles would be unmodified weapons taken from inventory. The LaWS adjunct would simply contribute laser energy that heats the target and enhances its signature for the missile. While, at the ranges envisioned, this laser heating alone would not be sufficient to "kill" the target, it could definitely heat the target. It should also be noted that the laser "illumination" could potentially be used to preferentially select a specific target from among a group of targets for engagement by a missile. It is expected that these engagements could occur at ranges of two to four times the effective Phalanx gun engagement ranges. Use of LaWS in this manner would be exactly analogous to the use of a SAL designator for a SAL guided missile, such as the AGM-114 Hellfire. It is expected that similar rules of engagement would apply.

Direct Target Destruction by Laser Heating

Some threats are known to be vulnerable to direct destruction by the application of laser energy for an appropriate period of time. The currently envisioned system would be able to destroy a subset of naval threats at ranges comparable to, and in some cases greater than, the ranges achieved with modern, stabilized guns using EO fire control systems and modern ammunition. In the case of a LaWS adjunct, the addition of the laser would open new options for a firing/engagement doctrine and would be expected to conserve CIWS rounds for use on threats that are not appropriate for this laser power level. While the laser is often quoted as having an "unlimited magazine," the true number of threats that can be engaged by the laser in any period of time is limited by the required illumination time and by the time required to evaluate a kill and transition to the next target. Thus, for particular target velocities and numbers, the "effective laser magazine" might be added to the CIWS magazine to increase the total number of targets engaged by the combined system.

LaWS Accomplishments

A government/industry team, led by government technical personnel, have achieved significant accomplishments since the start of the LaWS program in 2007; specifically, the team:

- Conducted mission analyses
- Developed threat lethality estimates
- Performed industry surveys for critical components and subsystems
- Performed extensive trade-off analyses
- Designed a prototype system
- Constructed the system—the prototype director and mount (see Figure 3)
- Performed numerous laboratory-based tests of subsystems and the complete prototype
- Validated system operation with a full-up field test at high power using BQM-147A UAV target drones

Additionally, the team was able to minimize the cost of the prototype by leveraging hardware that had already been developed or procured for other applications, including an L3-Brashear tracking mount, a 50-cm telescope, and high-performance IR sensors. Some components were commercially procured, such as the 5.4-kW fiber lasers. Figure 4 shows three laser cabinets, containing two lasers apiece, resulting in a total power output of 32.4 kW. Other components, such as the beam combiner and much of the system software required for operation and target tracking, had to be specifically designed, fabricated, and tested.

The LaWS program achieved a highly successful field test/demonstration in June 2009 when the prototype successfully engaged and destroyed five drone targets at tactically significant ranges at the China Lake, California, test range (see Figure 5).

Additional Work to be Done

Since the LaWS prototype sits on a dedicated gimbal, much additional work needs to be done

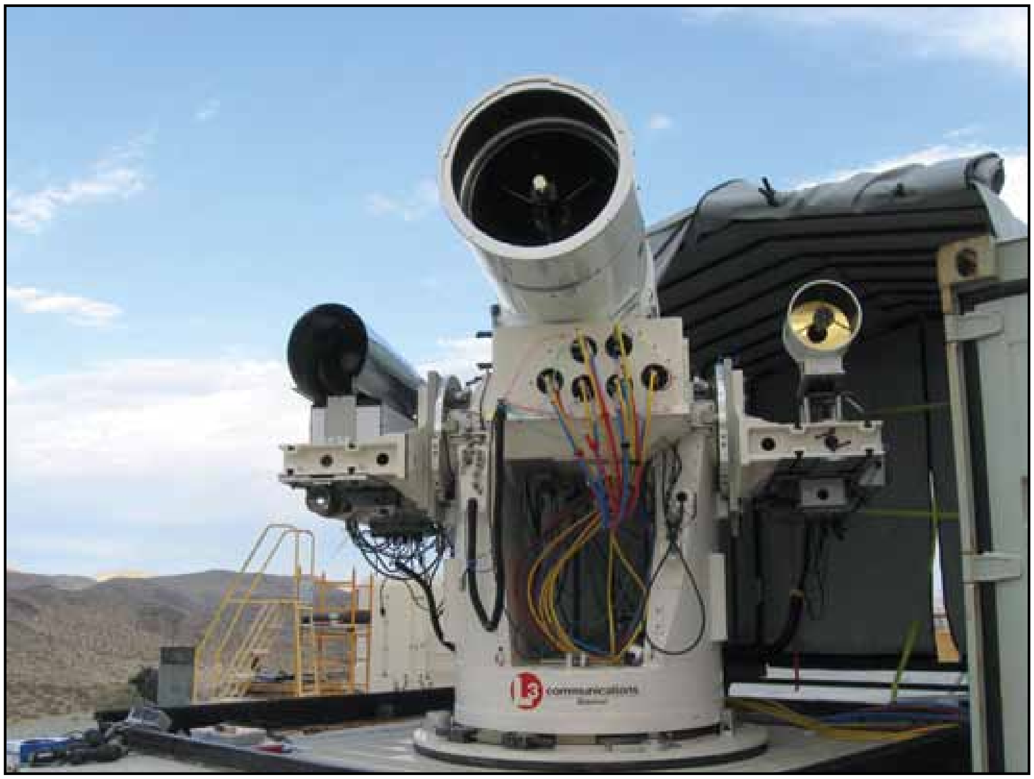
L3 communications

Figure 3. Photo of LaWS During Testing at the Naval Weapons Center, China Lake

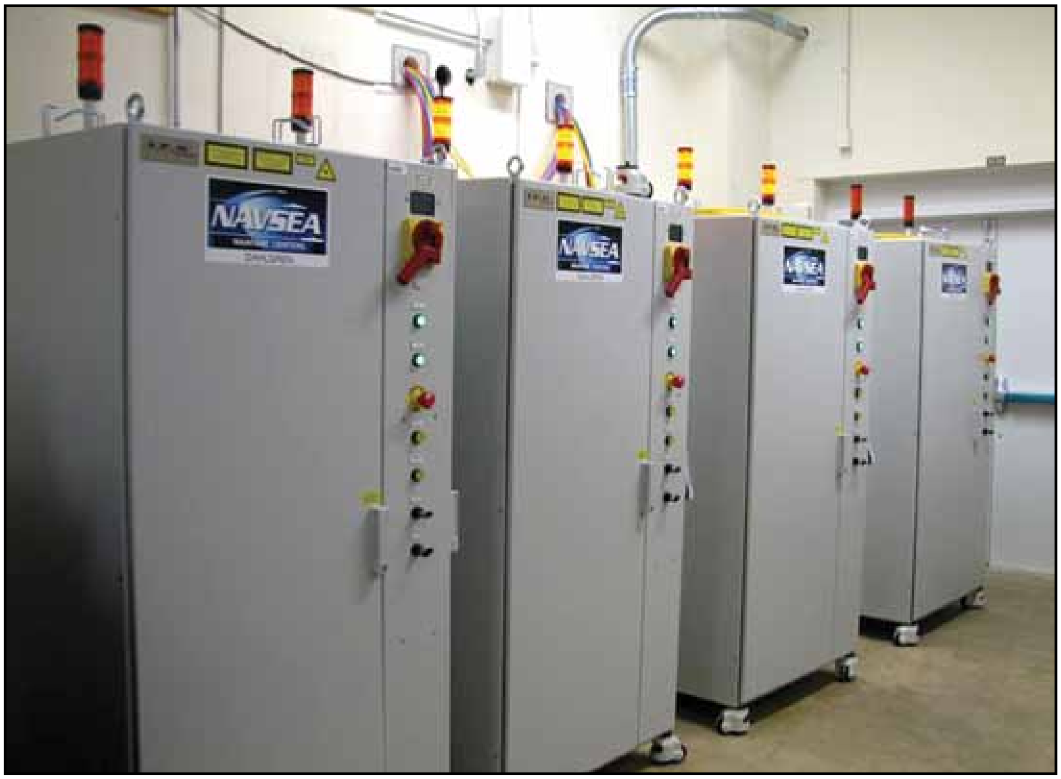
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Figure 4. IPG Laser Cabinets

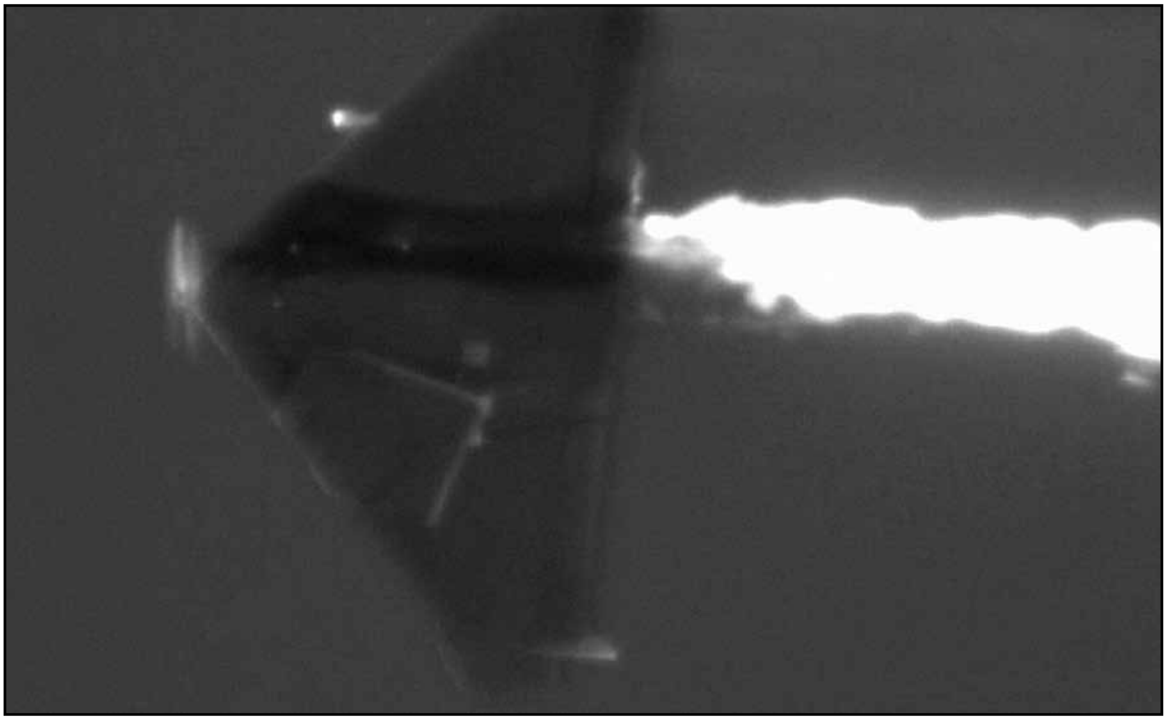

Figure 5. BQM-147A During LaWS Engagement

to place the weapon on the CIWS mount. The latter would require new control systems and optomechanical hardware for line-of-sight stabilization. Other aspects of the shipboard environment are also more stressful, and future mission areas may require an increasingly robust capability to deal with optical turbulence and the high-clutter environment of the ocean surface. Additional laser power might also be required. These modifications, depending on the level of capability desired, will require engineering modifications to the system. Engineering analysis and design to address these issues is currently underway at NSWCDD.

While the aforementioned engineering issues are important to address, there are additional technical issues that have yet to be analyzed. These issues are concerned with the potential utility of the system. Indeed, most of the detailed technical analyses and experiments performed thus far have focused on target destruction, with some effort expended on the issue of seeker damage/destruction. Developing credible lethality estimates for various potential threat targets is clearly very important, but one consequence of the lethality focus is that necessary, detailed, defendable technical analysis, analytic model development, and experiments have not been performed to explore the other functions/features that a CIWS Adjunct LaWS might provide to the overall ship combat system. Some of these contributions might become "routine" if the LaWS were available.

For example, a hard-kill engagement of a target by a Navy shipboard weapon is a relatively rare event, even during wartime conditions. On the other hand, ships in combat zones—and elsewhere—constantly have the problem of detecting potential threats, tracking them, identifying them, determining their intent, and providing warning. Thus, use of the LaWS system, at less than its full lethal potential, could become a daily, standard practice. It is still not clear how these potential benefits and capabilities could be measured or quantified to the satisfaction of key decision makers.

Likewise, other potential advantages of laser weapons—such as the potential for precision engagement, covert engagement, fire starting, graduated lethality, low cost per shot, and "unlimited" magazine—have not been subjected to rigorous technical analysis for feasibility, utility, and practicality. These investigations need to be performed and are gradually being addressed within the LaWS program.

Although the Phalanx CIWS system is currently installed on a number of Navy surface warships—either a single mount or a double mount—there are still significant numbers of ships that do not have a Phalanx system. It is highly desirable to make LaWS potentially available to virtually any ship that could benefit from the enhanced capabilities.

While the technical issues associated with the addition of LaWS to the Phalanx CIWS will be somewhat different from those associated with adding a LaWS system to other weapon systems—or the provision of a "stand-alone" LaWS—they do not appear to be insurmountable. For example, a LaWS beam director might be added to the stabilized Mk 38 Mod 2 25mm gun or the Mk 46 Mod 2 30mm gun. A LaWS beam director might be added to (or even substituted for) the Mk 46 EO Sight on DDGs or added to the trainable RAM launcher. Other options may exist as well.

The issue of defending combat logistics force ships, joint sealift ships, and certain support vessels from attacks from small boats or UAVs is also relevant. These ships often have little or no installed defensive capabilities for potential terrorist or pirate threats, and expeditionary security detachments do not have decisive warning or engagement capability. In addition, there are severe limitations placed on concept of operations (CONOPS) and rules of engagement due to the limited objectives/limited means of the various missions.

A system such as LaWS could provide graduated lethality from warning to destruction. It also could provide additional applications to minimize risk to sea base platforms and enhance sea shield capabilities against nonstate threats. If acceptable rules of engagement can be established, the advantages of graduated lethality might be extended to ships in port or entering/exiting harbors.

While considerable additional work needs to be done to produce a tactical system, the LaWS program's recent demonstration of capability provides strong evidence that a useful, tactical system could be produced within reasonable cost, volume, weight, and power constraints to provide the warfighter with a suite of additional tools to fight today's and tomorrow's wars.

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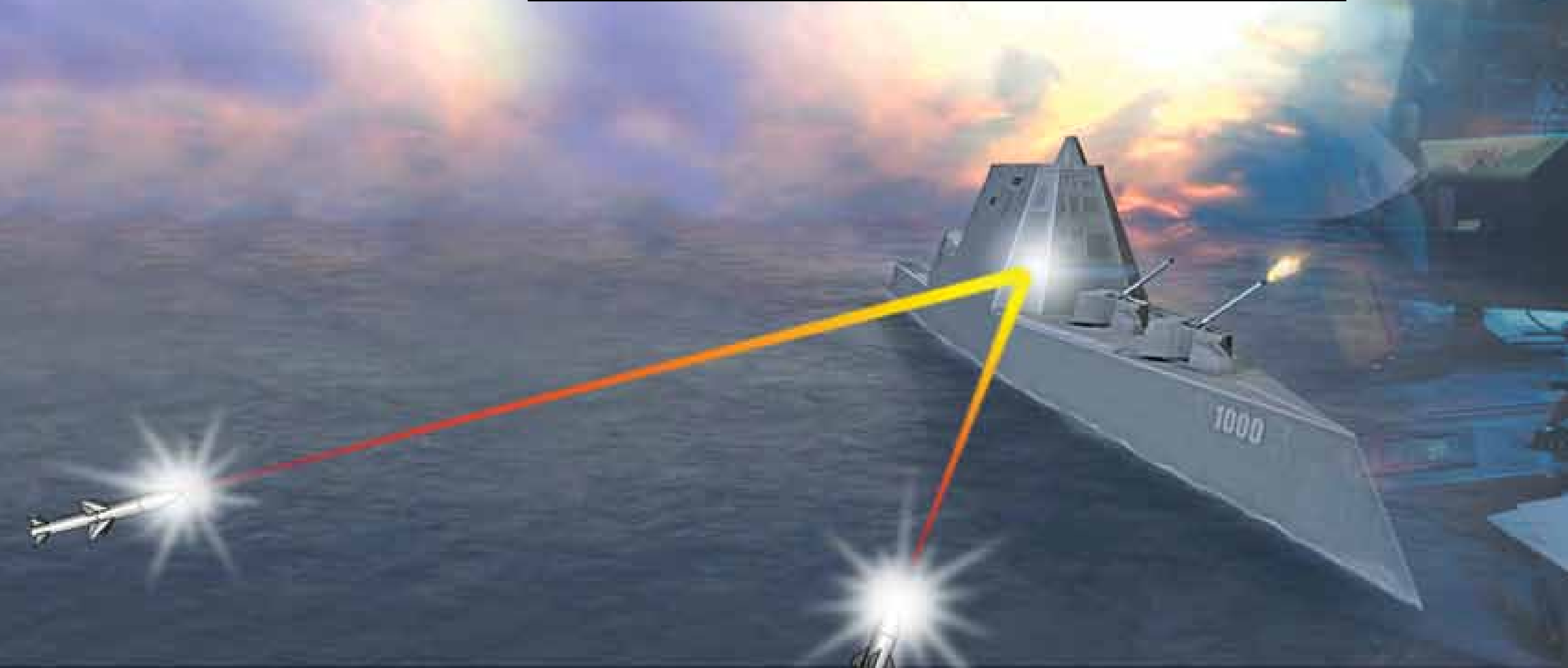

THE ACQUISITION CHALLENGE ASSOCIATED WITH DIRECTED-ENERGY RDT&E

By Mike Kotzian

An already tense situation quickly escalated. Everyone within the combat information center of the Navy's newest all-electric ship suddenly realized that two surface-skimming, antiship missiles were bearing down on their destroyer. With less than 30 seconds to impact, the tactical warfare officer gave the order to fire. Seconds later, the first surface-skimming missile vanished from all tracking consoles. Another order to fire closely followed, and the second missile threat was also destroyed. Consequently, within a matter of 10 seconds from threat recognition to threat elimination, the Navy's newest all-electric ship was able to destroy two incoming threats by using one of the Navy's newest weapon systems—the free-electron laser.

Does this scenario of a Navy all-electric ship, employing a high-energy laser to shoot down enemy surface-skimming antiship missiles, sound like inevitable reality or unattainable science fiction? For scientists and engineers working on directed-energy systems for the Navy, the answer does not lie solely in the advanced technical challenges associated with developing directed-energy weapons. Rather, the answer also lies in how well scientists and engineers understand and adhere to the Department of Defense's (DoD's) Defense Acquisition Management System (DAMS) framework governing the development of new weapon systems.

EVOLUTION OF DEFENSE ACQUISITION

The way in which DoD identifies needs and subsequently develops, tests, procures, and sustains weapon systems has evolved over time. Today's acquisition foundation can be traced back to the Packard Commission report in 1986, where many of this report's recommendations became part of the Goldwater-Nichols DoD Reorganization Act of 1986. This evolution continued along three tracks:

1. Requirements moving from threat-based to capability-based
2. The resource allocation system adding execution reviews with concurrent program and budget reviews

3. The acquisition process attempting to incorporate a more flexible and tailored process

These three tracks form the Defense Support System organizational structure: the Joint Capabilities Integration and Development System (JCIDS) process; the Planning, Programming, Budgeting, and Execution (PPBE) process; and the DAMS process, respectively. These three processes operate as "systems of systems" and are referred to as the "Big A" acquisition process shown in Figure 1.[1]

While all three of these phases hold their own level of importance, the major focus for scientists and engineers at research and development (R&D) facilities is the "Little a" acquisition process. It is this "Little a" acquisition process, where the rules and processes are found, that governs how DoD goes about developing a new materiel solution to a validated warfighter requirement. These rules and processes are codified within DoD Instruction 5000.02, *Operation of the Defense Acquisition System*, which was issued in December 2008.

The acquisition framework associated with DoD Instruction 5000.02 is the DAMS structure. This framework, shown in Figure 2, consists of numerous strategically placed milestones and major program reviews to ensure proper programmatic oversight.[2] Each of the milestones has specific

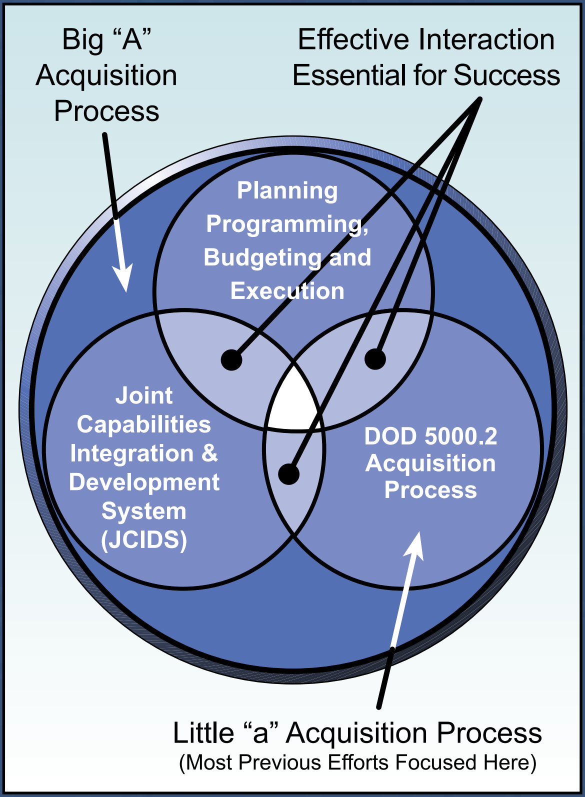
Big "A" Acquisition Process
Effective Interaction Essential for Success
Planning Programming, Budgeting and Execution
Joint Capabilities Integration & Development System (JCIDS)
DOD 5000.2 Acquisition Process
Little "a" Acquisition Process
(Most Previous Efforts Focused Here)

Figure 1. Defense Support System Organizational Structure

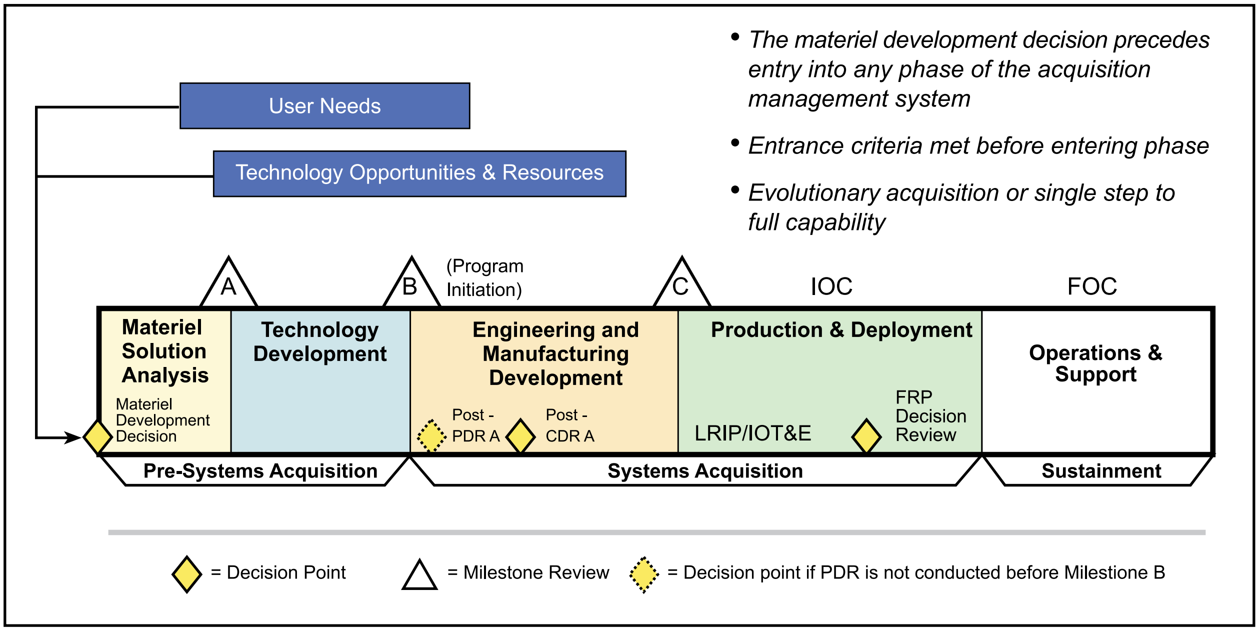
• The materiel development decision precedes entry into any phase of the acquisition management system
• Entrance criteria met before entering phase
• Evolutionary acquisition or single step to full capability
User Needs
Technology Opportunities & Resources
A
B
(Program Initiation)
C
IOC
FOC
Materiel Solution Analysis
Materiel Development Decision
Technology Development
Engineering and Manufacturing Development
Post - PDR A
Post - CDR A
Production & Deployment
LRIP/IOT&E
FRP Decision Review
Operations & Support
Pre-Systems Acquisition
Systems Acquisition
Sustainment
= Decision Point
= Milestone Review
= Decision point if PDR is not conducted before Milestone B

Figure 2. DoD Acquisition Framework

criteria that must be satisfied before a program is allowed to further proceed along the DAMS. The program's Milestone Decision Authority (MDA) rests with the individual responsible for deciding if the milestone criteria have been met and, if so, for allowing the program to proceed to the next phase of the acquisition process. Designation of a program's MDA depends on a program's level of research, development, test, and evaluation (RDT&E) and procurement funding. For example, an Acquisition Category (ACAT) I program is defined as an eventual total expenditure for RDT&E of more than $365 million in fiscal year (FY) 2000 constant dollars or, for procurement, of more than $2.19 billion in FY 2000 constant dollars. In this case, for an ACAT ID ("D" refers to the Defense Acquisition Board (DAB)) the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) is the MDA; for an ACAT IC ("C" refers to Component or Service), the MDA is the Head of the DoD Component or, if delegated, the Component Acquisition Executive.[3]

In addition, civilian and military workforce members within the DoD whose job responsibilities are deemed acquisition-related find themselves with a training requirement necessary to carry out their acquisition-related job responsibilities. Specifically, these workforce members are required to gain acquisition training and education with the passage of the Defense Acquisition Workforce Improvement Act (DAWIA) signed into law in 1990. The current certification process comprises three levels covering 16 different career fields. Each of these 16 career fields has a set of specific training, education, and experience requirements that must be met in order for an individual to achieve Level 1, Level 2, or Level 3 certification. The Defense Acquisition University (DAU) provides the necessary training classes required for the certification. DAU identifies "core-plus" training classes and continuous learning modules for each level of certification. The core-plus classes and modules are not required for certification but are identified as additional sources of information to assist individuals in becoming more knowledgeable about their career field beyond the minimum standards required for certification. The most up-to-date certification frameworks for all 16 career fields can be found at the following DAU website: http://icatalog.dau.mil/onlinecatalog/CareerLvl.aspx

Defense Acquisition Reform

The DoD acquisition environment is undergoing continuous change. The issuance of DoD Instruction 5000.02 marked the opening salvo of what has become seemingly constant updates, modifications, and guidance impacting how DoD procures weapon systems to meet warfighter requirements. In addition to DoD's issuance of DoD Instruction 5000.02, the Government Accountability Office published a stream of reports and findings that indicate significant cost growth and schedule delays in major defense acquisition programs. In 2009, Secretary of Defense Robert M. Gates proclaimed

a new way of doing business within DoD when it comes to weapon systems acquisition. Pressures are building for every program to maintain cost and schedule estimates while delivering the technical requirements originally developed to support the warfighter.

Moreover, there have been two major policy issuances. As previously mentioned, the first was DoD Instruction 5000.02 in December 2008. This update of the rules and processes governing DoD weapon systems acquisition primarily impacted the early part of the DAMS framework. The problem was that weapon system programs were failing their initial operational test and evaluation phases at alarming rates—many times traced to program offices attempting to design weapon systems with immature technology. Such failures were preventing those programs from proceeding to a full-rate production decision review and, more importantly, causing a repeat of some of the DAMS framework, which translated to increased costs and delayed initial operational capability timelines.

DoD Instruction 5000.02 attempted to solve this problem with three main emphases. First, a mandatory requirement was inserted for competitive prototyping prior to program initiation at Milestone B. The intent was to ensure a competition among contractors competing for a contract award. The theory was that such a competition would reduce technical risk, validate designs, improve cost estimates, evaluate manufacturing processes, and refine requirements. Reducing technical risks was especially important because weapon system programs were expected to demonstrate a technology readiness level (TRL) of six—where the system/subsystem model or prototype is demonstrated in a relevant environment—by the time a program reached Milestone B. TRLs are categorized on a scale of 1 to 9. A TRL of 1 is the lowest level of technology readiness, where scientific research begins to be translated into applied R&D. A TRL of 9 is the highest level of technology readiness, where the actual system is proven through successful mission operations. A TRL of 6 represents a major step up in a technology's demonstrated readiness. Using TRLs enables consistent comparisons of technical maturity across different types of technologies, giving program decision makers a common benchmark to consider when assessing program risk. Note that TRLs are meant to capture a level of technical maturity, not the probability of occurrence (i.e., the likelihood of attaining a required maturity level) or the impact of not achieving a level of technical maturity.[4]

The second emphasis was on a stricter adherence to systems engineering processes and technical reviews. Too often weapon system programs were not closely following systems engineering processes or avoiding due diligence when it came to the definition of successful exit criteria for a technical review. Consequently, all technical efforts must be outlined in a program's systems engineering plan. The program manager will use the eight technical management processes—decision analysis, technical planning, technical assessment, requirements management, risk management, configuration management, technical data management, and interface management—to manage the technical development of the system increments, including the supporting or enabling systems.[5] The program manager will use the eight technical processes—stakeholders requirements definition, requirements analysis, architectural design, implementation, integration, verification, validation, and transition—to design the system, subsystems, and components, including the supporting or enabling systems required to produce, support, operate, or dispose of a system.[6] Figure 3 provides an overlay of the new DoD Instruction 5000.02 and Secretary of the Navy (SECNAV Instruction) 5000.2D (Implementation and Operation of the Defense Acquisition System and the JCIDS), and shows the timing of specific systems engineering technical reviews as a program matures through the DAMS.

The third emphasis was a more prominent role of the MDA, starting with a mandatory requirement that all weapon system programs seeking a full or partial materiel solution must hold a Materiel Development Decision chaired by the MDA. Thus, the old Design Readiness Review was replaced with the Post-Critical Design Review Assessment chaired by the MDA. In short, the MDA was to become a more prominent figure in the oversight of a weapon system program's progress.

The second relatively recent major policy issuance was the Weapon Systems Acquisition Reform Act (WSARA) of 2009, implemented by Directive-Type Memorandum (DTM) 09-027 in December 2009. This DTM amended DoD Instruction 5000.02, the *Defense Federal Acquisition Regulation Supplement (DFARS)*, and associated business practices within the *Defense Acquisition Guidebook (DAG)*. The WSARA implementation brought about changes to policies and procedures across 13 categories. Some of the WSARA changes most relevant to the Navy directed-energy community include:

- Analysis of alternatives study guidance
- Acquisition strategies to ensure competition
- Competitive prototyping
- Developmental test and evaluation
- Systems engineering
- Preliminary design reviews
- Critical cost growth

THE ACQUISITION IMPACT

So why should the directed-energy community care about these acquisition policy changes? Because these policy changes impact the community's

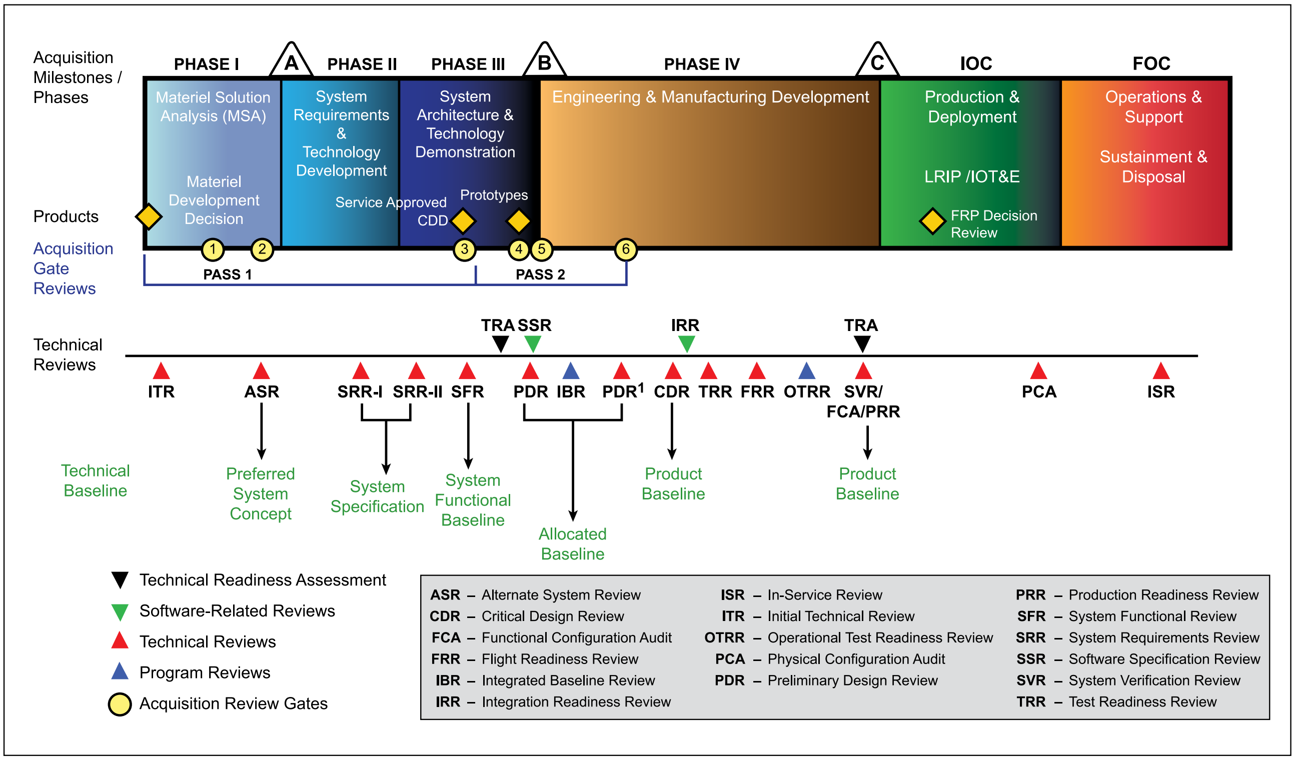
Acquisition Milestones / Phases
PHASE I
A
PHASE II
PHASE III
B
PHASE IV
C
IOC
FOC
Materiel Solution Analysis (MSA)
System Requirements & Technology Development
System Architecture & Technology Demonstration
Engineering & Manufacturing Development
Production & Deployment
Operations & Support
Sustainment & Disposal
Products
Materiel Development Decision
Service Approved CDD
Prototypes
LRIP /IOT&E
FRP Decision Review
Acquisition Gate Reviews
1
2
3
4
5
6
PASS 1
PASS 2
Technical Reviews
TRA
SSR
IRR
TRA
ITR
ASR
SRR-I
SRR-II
SFR
PDR
IBR
PDR1
CDR
TRR
FRR
OTRR
SVR/ FCA/PRR
PCA
ISR
Technical Baseline
Preferred System Concept
System Specification
System Functional Baseline
Allocated Baseline
Product Baseline
Product Baseline
▼ Technical Readiness Assessment
▼ Software-Related Reviews
▲ Technical Reviews
▲ Program Reviews
○ Acquisition Review Gates

ASR	Alternate System Review	**ISR**	In-Service Review	**PRR**	Production Readiness Review
CDR	Critical Design Review	**ITR**	Initial Technical Review	**SFR**	System Functional Review
FCA	Functional Configuration Audit	**OTRR**	Operational Test Readiness Review	**SRR**	System Requirements Review
FRR	Flight Readiness Review	**PCA**	Physical Configuration Audit	**SSR**	Software Specification Review
IBR	Integrated Baseline Review	**PDR**	Preliminary Design Review	**SVR**	System Verification Review
IRR	Integration Readiness Review			**TRR**	Test Readiness Review

Figure 3. Systems Engineering Technical Review Timing

ability to develop, produce, and/or sustain directed-energy weapon systems. The ultimate goal of the directed-energy community is to deploy directed-energy weapons to the fleet. Accordingly, regardless of which phase or phases an organization in the community supports, its actions are impacted by the language in DoD Instruction 5000.02 and the WSARA of 2009. The more scientists and engineers in the organization are aware of governing policy documents like DoD Instruction 5000.02, the better their chances are of meeting DoD leadership's expectations in terms of cost, schedule, and technical effectiveness.

Actions have shown that DoD senior leadership has come to expect all weapon system programs to adhere to the current acquisition-related policy and guidance changes. As mentioned earlier, major weapon system programs have recently been canceled or restructured for not meeting DoD senior leadership expectations—something that rarely occurred previously. In today's environment, technology alone will not carry the argument for a program's survivability. Directed-energy weapons definitely carry the allure of a "Star Wars-like" capability, but these same weapon systems will need to show sustainable cost and schedule compliance if they are to come to fruition. Resources are too limited, and the warfighter has too many needs to allow unsustainable weapon system programs to continue. Therefore, everyone involved with the development, procurement, and/or sustainment of a directed-energy weapon system needs to have an adequate understanding of the acquisition underpinnings now governing DoD.

Summary

The proverbial "winds of change" are blowing across the DoD acquisition landscape. The management of major weapon systems dependent upon cutting-edge technologies—such as those of directed energy—cannot afford to conduct business in a manner reminiscent of bygone days. Everyone involved with the development, production, or sustainment of a directed-energy weapon system needs to understand the "rules of engagement" laid down by the most recent DoD acquisition policy guidance. Highly skilled scientists and engineers typically already understand the need for a structured systems engineering approach to problem solving. Today, though, more than ever, cost and schedule must be factored in as potential tradespace to deliver the ultimate goal: a cost-effective, directed-energy weapon system delivered in a timely manner while meeting the warfighter's requirements. Scientists and engineers who adhere to these recent acquisition changes will help their organizations achieve this goal, thereby ensuring that warfighters will be armed with the most technologically superior weapons possible.

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2. Ibid., p. 8.
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THE BASICS OF ELECTRIC WEAPONS AND PULSED-POWER TECHNOLOGIES

By Stuart Moran

WHAT ARE ELECTRIC WEAPONS?

Most conventional weapons rely on chemical energy (explosives) as their destruction mechanism, either to explode on target, like bombs, or to create kinetic energy, like a bullet. Electric weapons are different. Electric weapons use stored electrical energy, rather than explosives, to attack or destroy the target. Electric weapons generally fall into two categories: directed-energy weapons (DEWs) and electromagnetic (EM) launchers. DEWs send energy, instead of matter, toward a target, and can be separated into three types: laser weapons, particle-beam weapons, and high-power microwave (HPM) or radio-frequency (RF) weapons. EM launchers use electrical energy to throw a mass at a target, thus making them distinct from directed energy. There are also three types of EM launchers: rail guns, coil guns, and induction drivers. All involve the use of strong magnetic fields to push against projectiles. While electric guns are an electric weapon, they are not a DEW.

High electrical powers and large energies are needed for all these weapons. Technologies for storing and controlling electric power are needed and are commonly called pulsed-power technologies. Electric guns are often associated with DEWs due to their common reliance on pulsed-power technology. The types of electric weapons are shown in Figure 1.

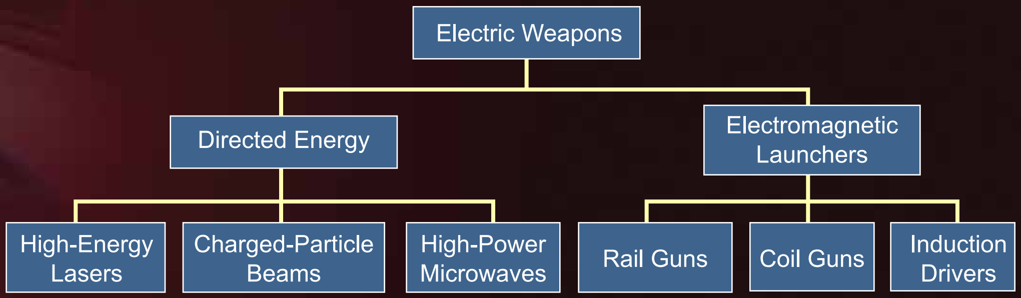
Electric Weapons
Directed Energy
Electromagnetic Launchers
High-Energy Lasers
Charged-Particle Beams
High-Power Microwaves
Rail Guns
Coil Guns
Induction Drivers

Figure 1. Types of Electric Weapons

There are a number of powerful advantages of electric weapons over conventional explosives:

- DEWs have a near-zero time of flight compared to conventional ordnance, allowing longer decision times and quicker reaction times.
- Electric weapons have a large "magazine" capacity, often limited only by the ability of the power source to recharge the system. The firing rate depends on how fast the system can be recharged, which in turn, depends on the available power source.
- The cost of engagement is greatly reduced. With increasingly sophisticated conventional weapons, the cost of practice rounds, such as a missile, can be millions. For an electric weapon, the cost per engagement is greatly reduced, making the attack of small targets (the asymmetric threat) less costly and training much more affordable.
- There is the potential for variable lethality, where the weapon effects can be controlled or attenuated to provide a warning or nonlethal effect. Otherwise, a full-power setting can be used to destroy the target.
- Electric weapons have the benefit of increased safety since less ordnance needs to be stored. Logistics costs less, and underway replenishment is easier since explosives are reduced or eliminated.
- Electric weapons can be used in conjunction with conventional weapons to heighten overall combat system effectiveness, such as knocking out electronics before engaging with a kinetic weapon.

Historically, the key Navy scenario for using directed-energy technologies has been close-in protection of naval vessels from antiship cruise missiles, particularly in a littoral environment. The ability of a DEW's speed-of-light engagement is particularly attractive under conditions of short warning times from supersonic stealthy missiles. However, increasingly difficult and problematic threats from nonmilitary aircraft and surface ships, countersurveillance platforms, fast patrol boats, unmanned aerial vehicles (UAVs), and terrorist inflatable boats or jet skis present different challenges. The threat has shifted from small numbers of expensive targets in open water to large numbers of small and cheap targets among neutral forces. The unique characteristics offered by DEWs, when compared to traditional weapon systems, allow them to be applied across a spectrum of threat roles, particularly in friendly or neutral-rich regions where precision pointing or less-than-lethal capability is paramount. The potential for HPM to counter electronics at levels below human effects makes them ideal nonlethal weapons. Electromagnetically launched projectiles allow longer range, shorter flight times, reduced reliance on air strikes and missiles, and safer storage and replenishment. With military budgets being squeezed, the low cost of directed-energy engagements, which often require just a few gallons of fuel, cannot be overemphasized. Instead of million-dollar missile shots, electric weapons allow new tactics, warning shots, and continual fire against large and small targets. They also allow inexpensive practice and training for improved readiness.

Pulsed Power for Electric Weapons

A useful rule of thumb is that a stick of TNT contains about a megajoule (MJ) of chemical energy, and this amount is often needed to destroy a military target. To destroy a target with an electric weapon, the electrical energy must also be deposited quickly. Surprisingly, a candy bar also has a megajoule of chemical energy, but it is released very slowly when we eat it. Many electric weapons require peak powers of more than a gigawatt (GW) or energies more than a megajoule. The time scales for delivery range from milliseconds to nanoseconds. As an example, delivering 1 MJ of energy in 10 μs requires 100 GW of power, which is more than a commercial power plant can produce. It is not practical to build continuous power supplies to directly drive most electric weapons. Consequently, pulsed-power technologies are needed to store energy at low power rates and release it quickly for weapon use. A pulsed-power system takes electrical power from a prime source (like a motor), stores it, and transforms the power to meet specific user requirements. The importance of a pulsed-power system is often underappreciated. For most electric weapon systems, the system size, weight, volume, and reliability are dominated by the pulsed-power chain. Pulsed-power components must be improved along with the weapon technology to make electric weapons systems practical. A block diagram of a pulsed-power system is shown in Figure 2.

Electrical energy can be stored in many ways, such as a battery (actually a chemical storage). A car battery has about a megajoule of energy, but it takes many seconds to drain it. A much faster method of storing electrical energy is in a capacitor, which can be discharged in milliseconds or faster. Inductive methods store the energy in the magnetic fields of a coil. This has the potential of achieving higher energy density than capacitors, but

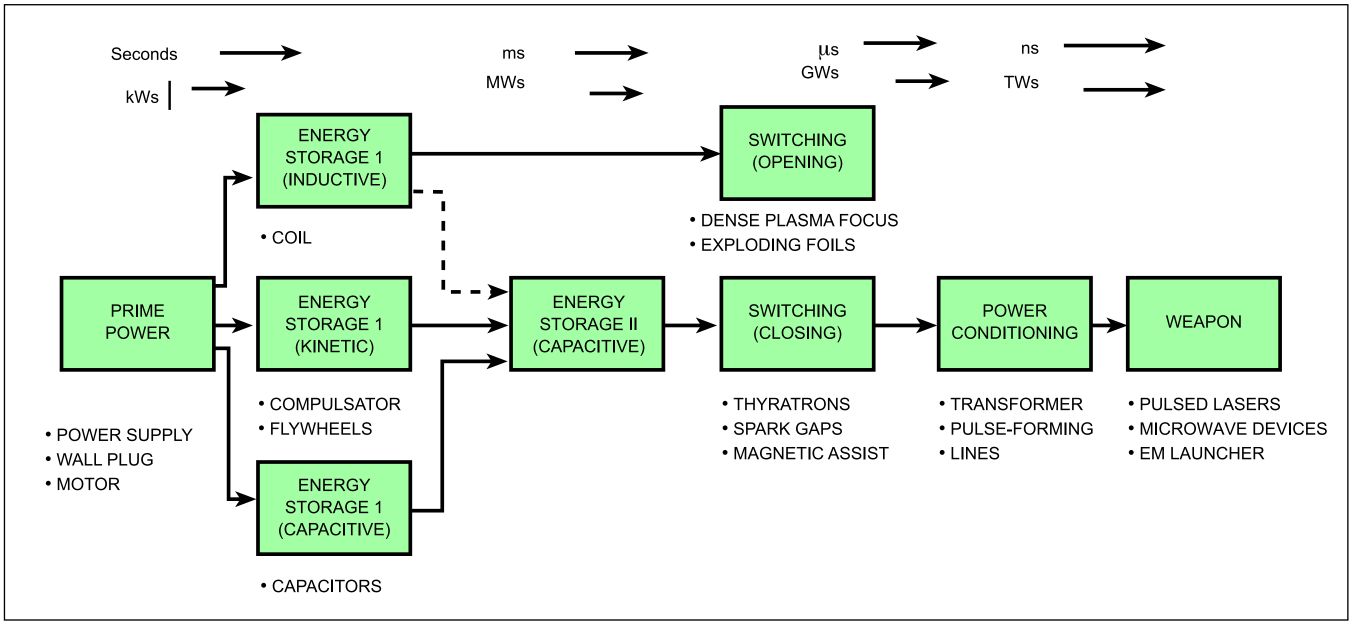
Seconds
kWs
ms
MWs
µs
GWs
ns
TWs
ENERGY STORAGE 1 (INDUCTIVE)
• COIL
SWITCHING (OPENING)
• DENSE PLASMA FOCUS
• EXPLODING FOILS
PRIME POWER
• POWER SUPPLY
• WALL PLUG
• MOTOR
ENERGY STORAGE 1 (KINETIC)
• COMPULSATOR
• FLYWHEELS
ENERGY STORAGE 1 (CAPACITIVE)
• CAPACITORS
ENERGY STORAGE II (CAPACITIVE)
SWITCHING (CLOSING)
• THYRATRONS
• SPARK GAPS
• MAGNETIC ASSIST
POWER CONDITIONING
• TRANSFORMER
• PULSE-FORMING
• LINES
WEAPON
• PULSED LASERS
• MICROWAVE DEVICES
• EM LAUNCHER

Figure 2. Block Diagram of a Pulsed-Power System

when the supporting systems are considered, the technology becomes less attractive. Energy storage for electric weapons can also be done with chemical explosive energy, where an explosive force is converted into electrical energy using techniques such as flux compression. Energy can be stored in the inertia of rotating machines and flywheels, but the energy can be released only as fast as the flywheel or motor can be stopped, usually in seconds. In many cases, several stages of energy store are used where each stage is faster than the last. Once the energy is stored, it must be released quickly using a high-power switch. There are many types of switches. Perhaps the most common type for electric-weapon applications has been the spark gap. Many types of controlled spark gaps exist, including pin-triggered, laser-triggered, field distortion, and simple overvolted. To achieve high repetition rates, flowing oil or gas can be used to flush the hot spark products, or sealed gaps using special fast-recovery gases, such as hydrogen, can be employed. Other switches, such as vacuum tubes and solid-state switches, can be used if they can handle the voltages and currents needed. Solid-state technologies, such as thyristers, have become very capable in recent years. Once the energy is switched out, there is usually some additional power conditioning, where transformers or pulse-forming networks are used to provide the desired pulse shape, voltage, and current required for the weapon. For rapid firing rates or continuous use, high average input powers are needed.

All-Electric Ship

One of the major impediments to the development of electric weapons systems for Navy ships has been a lack of electrical prime power. Current surface combatant designs employ up to 90 percent of engine power mechanically dedicated solely to propulsion. These designs are unable to provide the tens to hundreds of megawatts (MW) of electrical power capacity required for many electric weapons. The solution is an electric-drive ship that uses all the engine power to generate electricity, enabling it to allocate power to weapons or propulsion as needed. In recent years, the Navy has been investigating cost-effective power-system options to meet future platform requirements.

High-Power Microwave (HPM) and RF Weapons

Microwave weapons are generally considered to use frequencies above a gigahertz, whereas lower frequencies are generally called RF weapons. These weapons are more powerful than electronic warfare systems and are designed to create extended disruption or permanent damage. An HPM weapon is considered to have a peak power of more than 100 MW, or energies above 1 J. The energy can enter a target through intended RF paths, such as target antennas (front door), or unintended paths, such as housing joints, cavities, and circuit wires (back door). Pulses ranging from a few nanoseconds to microseconds in duration can be sufficient to reset computers, cause loss of stored data, or cause microprocessors to switch operating modes. Nonlinear circuits and components can rectify signals and absorb energy outside of their normal operating parameters. Figure 3 illustrates some of the vulnerability areas on a missile body.

RF or HPM devices can be divided into narrowband or wideband systems, dependent upon the employed pulse length. Narrowband systems are similar to high-power radar pulses and produce RF radiation with a very narrow bandwidth (frequency coverage). The damage concept is to create enough energy in a target to overheat or overload electronic components. Wideband systems generally produce very short pulses (nanoseconds) and typically operate in lower frequency ranges. Wideband systems produce much lower average powers and rely on high-peak electric fields to produce reset or arcing of digital components. Creating short pulses—often only a few RF cycles long—generates a very broad frequency output to take advantage of a target's weak point. But, it also means that the energy is spread over many frequencies, so there may be very little energy at a specific vulnerable frequency. Vulnerability data is critical to estimate the effectiveness of HPM weapons. Ultimately, air breakdown will limit the amount of energy out of an antenna to around 1 MW/cm^2.

HPM devices can produce effects that range from denying the use of electronic-based equipment to disrupting, damaging, or destroying such equipment. HPM weapon advantages include all-weather capability, low precision pointing requirements, and effects persistence after the radiated EM energy "beam" has been turned off. One major advantage of HPM is that electronics are generally more vulnerable to high fields and high energies than humans. This provides the ability to attack electronics without harming people, which makes HPM an ideal choice for nonlethal applications.

Two major challenges of implementing HPM technologies into an operational weapon systems platform are:

1. Fratricide, or self-destruction, can be a problem because of the large areas affected by the sidelobes and near field of any meaningful HPM weapon system. Therefore, when attacking a target of interest with an HPM weapon, there is a greater risk of disruption to systems that were not intended to be targeted but fell within the sphere of influence. Host platforms, therefore, may need to undergo interference hardening.
2. With regard to battle damage assessment, kinetic weapons have the advantage of typically leaving visual evidence. HPM weapon systems do not leave large holes in a target but create more subtle influences as a result of attacking critical electronic components. Consequently, it can be more difficult to ascertain whether a target's capabilities have been sufficiently degraded or destroyed—and for how long—in determining whether a mission was successful.

For HPM system development, a fundamental challenge is the understanding of what it takes to affect the target. Coupling mechanisms, where EM energy enters and affects the target system, are extremely complex. The vulnerability of components is often vastly different if it is outside or inside a circuit board or enclosure. Effects depend upon the interactions with other components, connectors, and nearby conductors. The effects on a component can vary many orders of magnitude depending on frequency, orientation, cracks and seams, protective circuits, pulse energy, and duration. Research regarding effects on missiles has shown large variations not only between designs, but also between different serial numbers due to assembly methods, cable routing, and component variations. With the increasing use of commercial equipment by the military, such as computers and radios, effects are difficult to predict due to constant design and component changes. In general, electronics are getting smaller and operating at lower voltages, making them more sensitive to high fields. But smaller components often have lower pickup areas, and the proliferation of interfering signals has increased the amount of shielding on modern electronics. When

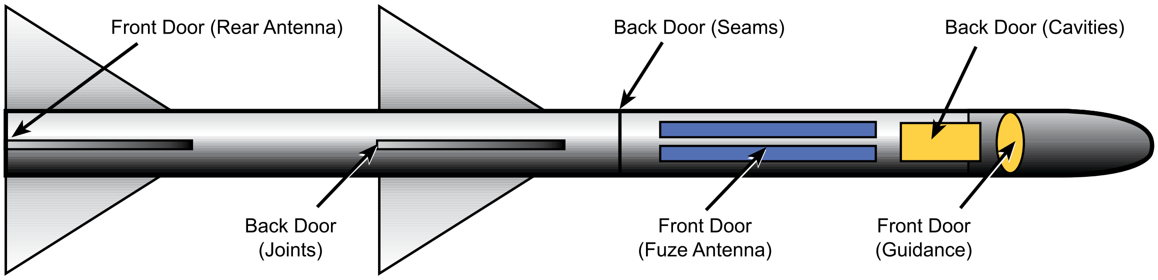

Figure 3. HPM Coupling Paths on Missile Body

target systems are located inside structures or buildings, it becomes even more difficult to predict. Efforts to predict reflections and interference inside complex structures become extremely complicated. Accordingly, generic electronics kill using universal waveforms is not likely. There continues to be a lot of hype about what RF weapons can do, but the idea that a backpack device can wipe out all electronics in a city is no more realistic than a hand-held laser cutting through a bank vault door.

High-Energy Lasers (HELs)

A laser generally produces a beam of coherent light at a specific wavelength dependent on the atomic structure of the lasing substance. Only certain substances have the atomic properties appropriate for producing laser light, and these are often limited in power. Lasers are characterized by the substance being lased (gas, liquid, or solid) and the "pumping" process (light energy, electricity, or chemical reaction). A resonant optical cavity provides the means for aligning the energy in the beam and extracting that energy. A military laser system also includes beam processing or beam-path conditioning, beam pointing and control and—for long-range applications—adaptive optics to compensate for the atmosphere.

Until recently, HELs have been driven by chemical energy, so very little electrical power or pulsed power was needed. Chemical lasers use the reactions of gases or liquids to create the excited energy states necessary for laser emission. Large chemical lasers and beam directors have been developed by the Navy in recent decades and have successfully ruptured fuel tanks and downed supersonic missiles. However, these lasers required high-velocity, chemical-reaction chambers and emitted hazardous gaseous by-products. They often operated at wavelengths where the atmosphere absorbed much of the energy. Absorption creates thermal blooming, whereby absorbed energy in the air creates a negative lens that defocuses the beam. Increasing the power of the laser increases the energy absorbed and worsens the problem. The Army and Air Force are developing chemical lasers for airborne applications, where atmospheric absorption is less of a problem. Recent Navy interest in HELs has concentrated on lasers that are electrically powered, rather than chemically powered, and that operate at shorter wavelengths to allow smaller optics and more efficient propagation near the water.

Small semiconductor (or diode) lasers use current flow through an electrical junction to excite electrons and create laser light. These lasers are very limited in power, so research has focused on using large numbers of lasers assembled into a coherent array. Semiconductor lasers also create efficient light to excite or "pump" other types of lasers. Solid-state lasers (SSLs) use crystalline materials mixed (doped) with elements needed for proper lasing. SSLs show strong promise for compact, medium-power HEL weapon systems. Scaling these systems up to megawatt levels creates extreme heat in the crystal material, making it very difficult to prevent internal damage. Forced cooling and the heat capacity of large masses are under study.

Fiber lasers—which use semiconductor diode lasers to pump a flexible, doped crystalline fiber (similar to a fiber-optic line)—have demonstrated high efficiency and relatively high power. The technology is being used in the welding and cutting industries. Methods of pumping large numbers of fiber-optic lasers and combining them are being investigated. An example is shown in Figure 4.

The free-electron laser (FEL) operates differently from a conventional laser. An FEL uses a high-voltage electron accelerator to push electrons through a magnetic "wiggler" to create light radiation across a tunable band of frequencies. The FEL is extremely complex and large, but scaling to very high powers may be possible. Perhaps the biggest promise of the FEL is the ability to design the laser at an ideal atmospheric propagation wavelength. Significant technical hurdles remain in reaching the status of a deployable FEL, in scaling the beam to megawatt powers and in providing the necessary engineering to turn a laboratory device into a weapon system of reasonable size. For Navy application, FELs will require improvements in areas of radiation shielding, high vacuum, high-current photo-injectors, and probably cryogenic cooling—all of which must be integrated into a ship's basic design.

Fiber lasers and SSLs are the leading-candidate Navy lasers for medium power, as FELs are for high power. All are electrically driven and can meet the requirement for shorter wavelength, capable of transmitting at the "maritime window" of approximately 1 μ.

HEL weapons' advantages include a highly directional and narrowly focused beam, providing:

- Minimal collateral damage
- Speed-of-light delivery
- Rapid retargeting
- Low cost of engagement

Disadvantages center on:

- Limited range due to atmospheric attenuation
- Weather limitations
- Low efficiency (often less than 10 percent)
- Need for eye protection
- Relatively large size and weight requirements

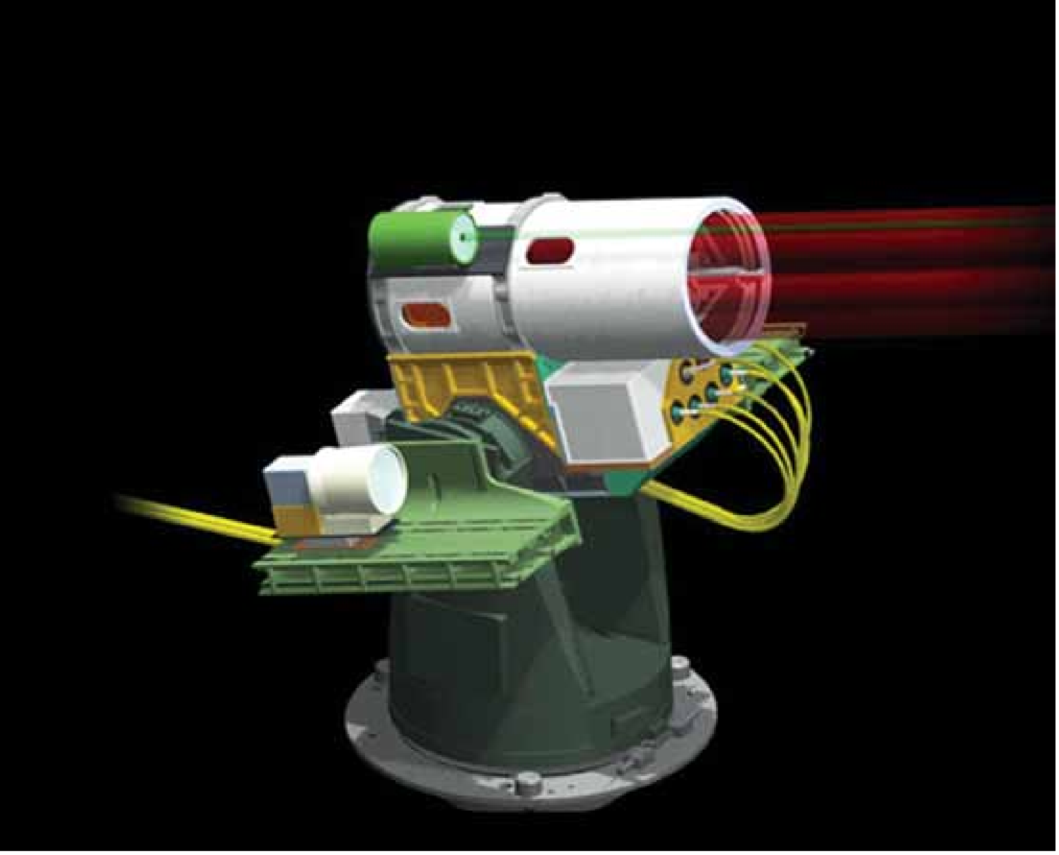

Figure 4. Drawing of Laser Weapon System (LaWS)

Long dwell times (seconds) will be needed for most targets. As with RF systems, there is a potential nonlethal or variable lethality capability since the energy can be easily defocused. A critical challenge is the understanding of a laser beam's propagation through a maritime boundary layer environment, where the sea and air interface creates turbulence and moisture gradients. Measuring the atmosphere and compensating for variations in real time may require adaptive optics or "rubber mirrors" that can be constantly adjusted to compensate for changes. Focusing a small spot at long range will require high beam quality and large optics, probably meter-size mirrors that are very highly reflective and very clean.

HELs in the future are expected to be able to focus energy to a spot size of much less than a meter at ranges of kilometers. This will necessitate very accurate target tracking systems, and precise stabilization and beam-pointing systems, both of which are difficult but should be feasible in the near term. Real-time atmospheric measuring systems will be needed for compensation techniques. Methods to protect the sensitive optical system from salt spray and corrosion will also be needed.

From a lethality perspective, three considerations need to be better understood before a HEL can be deemed a true weapon system:

1. Achievable spot size of beam on target at range
2. Amount of coupling into the target material
3. Subsequent effects of the damage inflicted

For the more severe threats, such as high-speed, antiship cruise missiles, HELs face the difficult task of engaging maneuverable, stealthy, inbound missiles. As such, a better quantitative understanding of the interactions among a laser beam's energy deposition, target material, and flight dynamics is needed.

Particle Beams

A particle-beam weapon is a directed flow of atomic or subatomic particles. These particles can be neutral or electrically charged. Neutral beams need to be used outside the atmosphere (in space), where charged particles would repel and fly apart. Charged-particle beams (CPBs) are easier to make and are used within the atmosphere, where air molecules can constrain the beam. A CPB weapon transmits matter—not just EM waves—like lasers and microwave weapons. The particles are near the speed of light and deposit their kinetic energy deeply into any target material. They have the potential to be highly destructive weapons and are very difficult to shield against.

Charged particles are produced by applying a strong electric field near a material that emits electrons. These electrons then pass through accelerating stages with high voltage gradients (often megavolts), which increase the electron's velocity. As the electrons pass each stage, the velocity increases until they approach the speed of light (become relativistic), at which point they have substantial energy to penetrate a target. The accelerating systems can be linear, but a recirculating design is more compact and can reuse stages. These systems are basically high-current versions of scientific particle accelerators.

Once the electron beam is produced, it must propagate to the target. High-velocity electrons will not go far before they collide with air molecules and lose energy. The fact that air molecules struck by the beam are heated and moved out of the way for a short period of time creates a rarified "hole" in the atmosphere through which a second pulse can travel farther. In this manner, a fast series of pulses can "hole-bore" to the target, each pulse going farther than the last. The final pulse must have enough energy to damage the target. The deceleration of electrons in the atmosphere causes

Bremsstrahlung radiation in the forward direction toward the target, creating gamma rays that, in turn, create X-rays and RF radiation.[a] These effects can cause electronic upset and "soft-kill" mechanisms even if the beam slightly misses the target.

The beam of electrons is typically a few centimeters in diameter. When a beam strikes a target, the energy is deposited deep in the material (the collision cross section is small because of the relativistic speeds) in microseconds (much faster than a laser), creating thermal shock that is very difficult to shield against. For an explosive target, there is also the possibility of causing a deflagration or low-order burn, disrupting the normal warhead mechanism.

Scientists studying CPB weapons made significant technical advancements in the 1980s, but the weapons are still far from being practical. A CPB weapon is technically very challenging and expensive to build. Studies project that the volume requirements necessary for a CPB system could be on the order of a 5-inch gun system. Advantages of a CPB weapon include rapid penetration, a deep magazine, all-weather capability, and soft-kill mechanisms for a near miss. Problems include complexity, size, limited range, and the need to demonstrate compact accelerators and propagation mechanisms.

ELECTROMAGNETIC (EM) LAUNCHERS

A number of technology concepts to launch projectiles exist using electrical energy. These systems rely on large currents in conductors, creating strong magnetic fields that drive a projectile. The velocity of a normal powder gun projectile is limited by the expansion speed of the explosive powder, and present military guns are reaching that limit. With an electric gun, the fields can push projectiles much faster, providing longer ranges and increased kinetic energies. The simplest version is an EM rail gun, shown in Figure 5.

In any conducting loop, the generated magnetic field tries to expand the loop. If everything is held in position, the only movable item is the conducting projectile, which moves down the rails in an attempt to expand the loop. Since megajouoles of projectile energy are needed for EM rail guns, energy storage

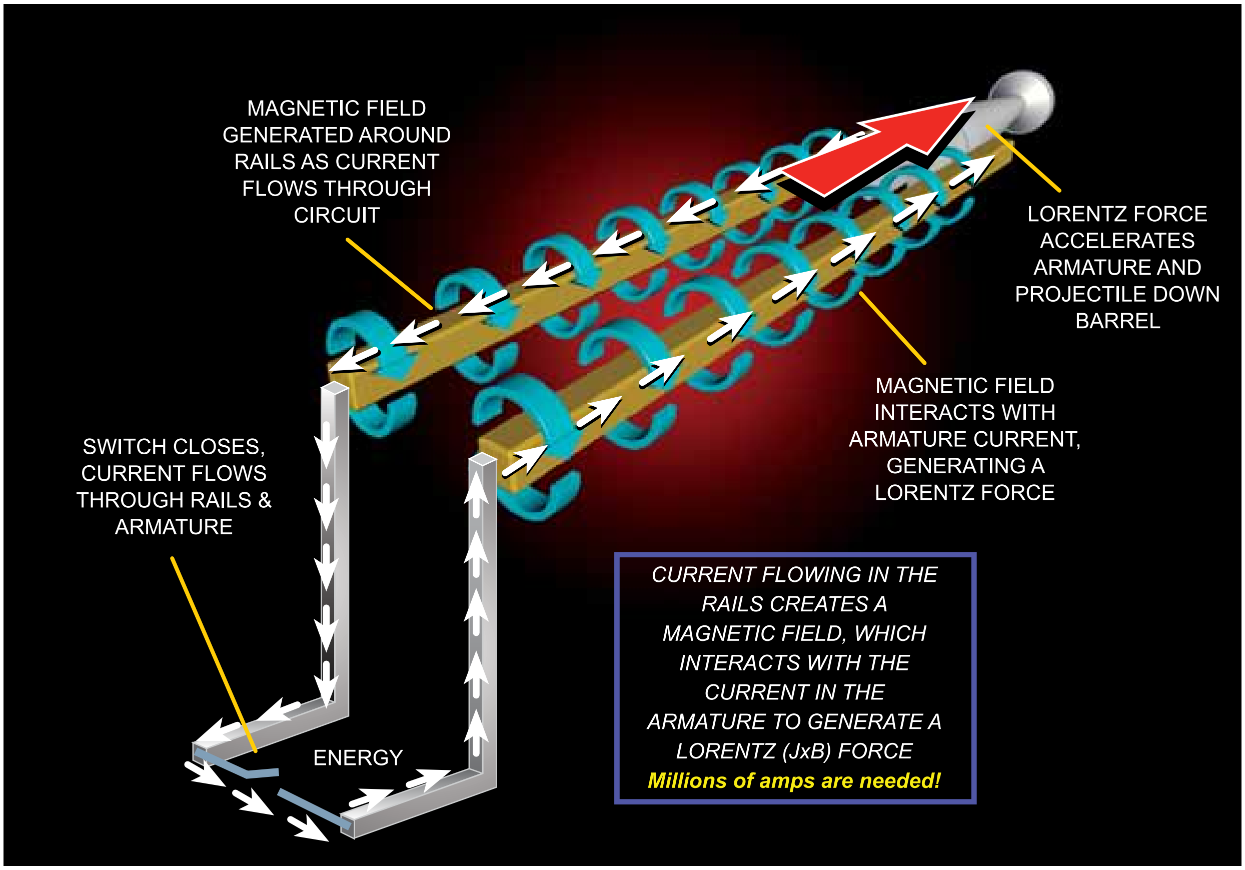
MAGNETIC FIELD GENERATED AROUND RAILS AS CURRENT FLOWS THROUGH CIRCUIT
LORENTZ FORCE ACCELERATES ARMATURE AND PROJECTILE DOWN BARREL
MAGNETIC FIELD INTERACTS WITH ARMATURE CURRENT, GENERATING A LORENTZ FORCE
SWITCH CLOSES, CURRENT FLOWS THROUGH RAILS & ARMATURE
ENERGY
CURRENT FLOWING IN THE RAILS CREATES A MAGNETIC FIELD, WHICH INTERACTS WITH THE CURRENT IN THE ARMATURE TO GENERATE A LORENTZ (JxB) FORCE
Millions of amps are needed!

Figure 5. Electromagnetic (EM) Rail Gun Concept

mechanisms that can store about 100 MJ are needed, along with the ability to discharge the energy in milliseconds. To generate useful forces, millions of amps of current are needed—a major challenge and significant loss mechanism. Large capacitor banks with very high-current switches are required. Spark gap switches have historically been the only option, but new high-current solid-state switches are now becoming available. Capacitor energy densities, too, have improved an order of magnitude in the last few decades. Rotating machines have also been considered because they are smaller than equivalent capacitor banks, but extracting the energy quickly, without tearing the machine apart, has been problematic. The launch energy of various projectiles is shown in Figure 6.

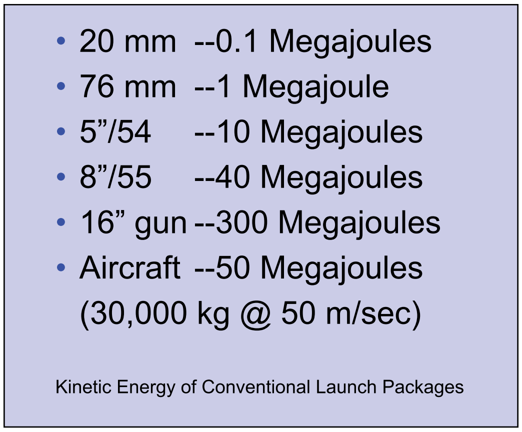

- 20 mm --0.1 Megajoules
- 76 mm --1 Megajoule
- 5”/54 --10 Megajoules
- 8”/55 --40 Megajoules
- 16” gun --300 Megajoules
- Aircraft --50 Megajoules (30,000 kg @ 50 m/sec)

Kinetic Energy of Conventional Launch Packages

Figure 6. Launch Energy of Various Projectiles

A rail gun is probably the most compact form of electric launcher. However, it requires direct electrical contact between the projectile and barrel rails, creating the potential for arcing, melting, and erosion. Coil guns use a series of sequentially fired coils around a “barrel” to push the projectile in stages. This does not require direct electrical contact, so it avoids rail erosion but requires a series of fast timed switches and more space. Linear induction motors are basically unrolled electric motors and have been used on electric trains and roller coasters, typically with magnetic levitating systems to avoid contact erosion. This concept is being developed by the Navy for launching aircraft. The energy to launch an aircraft is similar to a large-caliber projectile—more weight but less speed. The slower speeds are more suitable for rotating machines since the launch times are seconds rather than microseconds.[1] Electrothermal guns and electrothermal-chemical (ETC) guns use a combination of electricity and chemicals. Electrical energy is used to initiate chemical reactions that can produce lightweight driving gases, like steam, or allow more energetic propellants that are difficult to ignite in a conventional fashion.

Some advantages of electrically driven projectiles include:

- Higher projectile velocity (over conventional explosives)
- Very long range (>100 miles) with lower cost than missiles
- Time-critical delivery (because of shorter time of flight)
- Safer projectile stowage (minimal explosives)
- Potentially adjustable velocity levels, for better accuracy and controllable damage

The potential of having nonexplosive rounds and magazines is very attractive for the Navy. For long-range, large-caliber EM projectiles, the kinetic energy from the projectile velocity is greater than the chemical explosive energy in a conventional round traveling much slower. Therefore, damage can be equivalent even without explosives. System size and lifetime are still behind conventional systems, but getting close.

Outlook

Challenges remain for many electric weapon concepts. These weapon systems appear promising to meet the increasingly important asymmetric threats with low-cost precision rounds. They also can be employed across the energy spectrum for nonlethal targeting. Electric weapon systems will, in many cases, continue to supplement existing kinetic weapon systems in the near term. Despite technology challenges, directed-energy and electric weapons hold great promise in offering the future warfighter unique combat capabilities not currently available.

Endnote

a. Bremsstrahlung—a type of radiation emitted when high-energy electrons are decelerated. (German for ***braking radiation***)

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SOLID MODELING OF DIRECTED-ENERGY SYSTEMS

By Joseph F. Sharrow

Not long ago, around the mid-1980s, development of most new mechanical systems—such as automobiles, consumer products, and military devices—was performed manually on a drafting table or drawing board, much like the present-day version shown in Figure 1. These tables and boards performed a necessary function, but they offered little assistance other than for drawing lines. Engineers used them to prepare layouts, or two-dimensional sketches of what they were designing. They then would take these layouts to a draftsman, who would create drawings of each part in the device. The drawings would subsequently be sent to a manufacturing facility.

This layout and drawing preparation process typically would need to be repeated multiple times because mistakes would be made, or design issues would be discovered late in the process. Similarly, the manufacturing process would sometimes require multiple iterations as well because of the inherent limitations in designing three-dimensional (3-D) devices on two-dimensional boards. This less-than-ideal process made it difficult to design and manufacture even mundane products and frequently resulted in things that just didn't work. With the emergence of early computerization, numerical analyses of more complex systems began to be performed. These analyses were conducted to ensure that the systems worked in the real world. For example, engineers might conduct a structural analysis of the forces in a loaded dump-truck bed to make sure that the frame wouldn't bend and fail. Because of the difficulty in performing these analyses, they would often require a specially trained group of structural engineers, expensive software, and large mainframe computers, limiting their use to only the largest, most well-funded companies or organizations.

EMERGENCE OF COMPUTER-AIDED DESIGN (CAD) AND SOLID MODELING

With the availability of smaller scale computers and more economical software in the mid-to-late 1980s, CAD was born, initiating a period of rapid improvement in the design process. This was driven, in part, by the introduction of software packages such as AutoCAD. Initially, these software packages only attempted to automate drawing lines by making wireframe (stick-figure) versions on the computer of what previously had been made by hand on the drafting board. This reduced the difficulty in making changes in the development process, but it still limited the engineer's pallet to a two-dimensional space. What was really needed was a 3-D method of design. Solid modeling

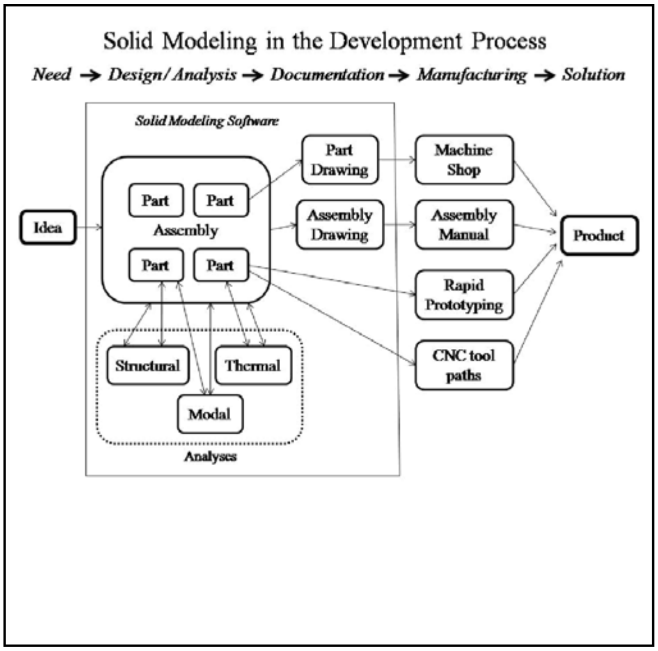
Solid Modeling in the Development Process
Need → Design/Analysis → Documentation → Manufacturing → Solution
Solid Modeling Software
Idea
Part
Part
Assembly
Part
Part
Part Drawing
Assembly Drawing
Machine Shop
Assembly Manual
Rapid Prototyping
CNC tool paths
Product
Structural
Thermal
Modal
Analyses

Figure 1. Drawing Board

addressed this need beginning in the late 1980s to early 1990s.

Solid modeling is analogous to taking blocks of clay and cutting and forming them into the shape of a solid part on a computer. These 3-D parts are then put together in an assembly, more accurately representing real-world devices. Though originally used only in a limited way for specialized applications in the aircraft and automobile industries, it wasn't until the 1990s that solid modeling experienced widespread availability and mainstream acceptance due to software packages such as Pro/ENGINEER. Figure 2 summarizes how Pro/ENGINEER and other similar packages fit into the development of new products. The general flow of the process moves from left to right.

Initially, nearly all 3-D solid modeling packages required significant computing and graphics display power, necessitating the use of large graphics workstations running the UNIX operating system. Rapid advances in computing and graphics power have since enabled nearly all packages to run efficiently on personal computers (PCs) and laptops, bringing solid modeling and analysis capability into the mainstream.

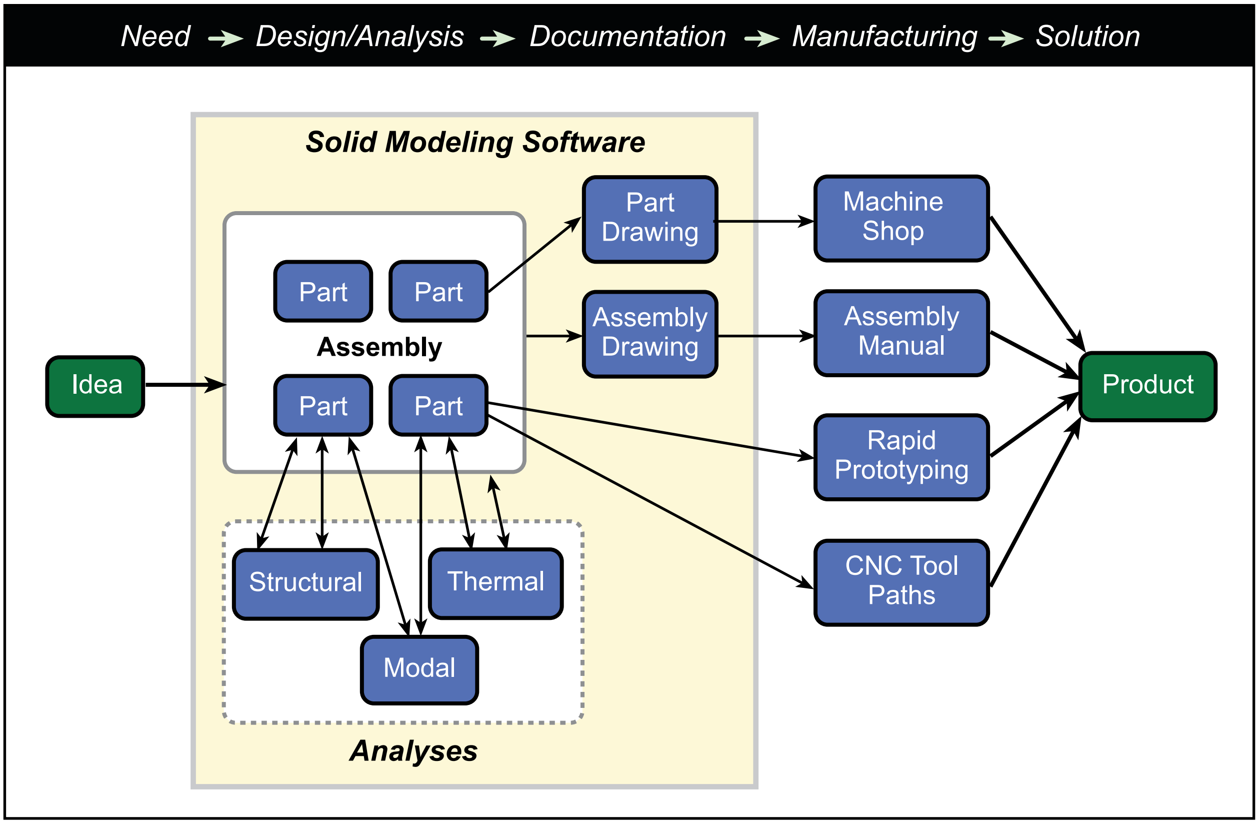
Need → Design/Analysis → Documentation → Manufacturing → Solution
Solid Modeling Software
Idea
Part
Part
Assembly
Part
Part
Part Drawing
Assembly Drawing
Machine Shop
Assembly Manual
Rapid Prototyping
CNC Tool Paths
Product
Structural
Thermal
Modal
Analyses

Figure 2. Solid Modeling in the Development Process

SOLID MODELING OF DIRECTED-ENERGY SYSTEMS

Engineers working in the Directed Energy Division at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), use solid modeling to develop hardware for nearly all of its programs. Both Pro/ENGINEER and SolidWorks are used extensively to develop new products in virtual 3-D space. Additionally, the structural simulation package within Pro/ENGINEER is used to determine stresses and natural frequencies of parts and assemblies. Consequently, these packages have enabled a single mechanical engineer in the Directed Energy Division and a draftsman in the Engagement Systems Department at Dahlgren to perform the design and analysis work that would have required an entire group of engineers and draftsmen just a few years ago. Today, collaboration among many organizations using similar packages has become commonplace. Insofar as solid modeling has become an indispensable tool for development and collaboration, its successful implementation requires proper training and experience before engineers can use it effectively, just as medical surgeons require training in the use of advanced robotic surgical devices before they can be used effectively. Thus, while these high-tech modeling systems not only have reduced the number of personnel needed for design and development, they have enabled the Navy to get significantly more bang for its buck while supporting warfighting needs. An example of how solid modeling is currently being used is discussed below.

NAVY LASER WEAPON SYSTEM (LAWS) BEAM DIRECTOR

The Directed Energy Warfare Office (DEWO) and Directed Energy Division at Dahlgren are currently developing the Navy LaWS for the Naval Sea Systems Command's Directed Energy and Electric Weapon Systems (DE&EWS) Program Office (PMS 405). The program's goal is to take advantage of currently available industrial laser technology and incorporate it into a future naval weapon system. As part of the development process, major subsystems have been integrated with a Kineto Tracking Mount (KTM) into a LaWS beam director. The KTM/beam director was modeled and analyzed using Pro/ENGINEER. Ultimately, the resulting LaWS will be installed on Navy ships on the Close-In Weapon System (CIWS) gun mount. During field testing in June 2009 at the Naval Air Warfare Center, China Lake, California, the prototype KTM/beam director successfully destroyed five unmanned aerial vehicles (UAVs). The actual beam director used in the China Lake testing is shown in Figure 3; the Pro/ENGINEER assembly model used for development is shown in Figure 4.

The LaWS effort took advantage of many aspects of solid modeling including collaboration, structural and modal analysis, and manufacturing drawing creation. The project required development of new, unique hardware, as well as the integration of electronic models from commercial vendors. The KTM model was provided by L-3 Brashear and was originally designed using Pro/ENGINEER. The beam-directing telescope model was provided by RC Optical Systems, Incorporated, and was originally made in SolidWorks. These models were combined with many new optical and structural components developed by the Directed Energy Division into a single, comprehensive assembly model. This model was instrumental in understanding the interaction of the many components, and its use increased accuracy and precision that would have been impossible with old-fashioned two-dimensional development processes. Figure 5 shows a cross section through the main portion of the beam director, revealing the complexity of the many parts and subassemblies required for such a device. In addition to modeling the mechanical components, the actual laser beams were also included to better understand their path through the various mirrors and optical devices in the beam director, and to better highlight any interference they might have with structural components within the KTM or telescope.

Numerous analyses were performed to make sure that everything worked the way it was intended. One major analysis addressed the telescope mount. To ensure that the beams were stable at range, the mount had to be extremely stiff. The best way to ensure this was to perform a structural analysis using the structural simulation package within Pro/ENGINEER. Figure 6 shows the results of that analysis: a displacement plot in which different colors represent how much the telescope will move when the KTM rotates at its maximum speed. The large cylindrical object simulates the mass of the telescope. The minimum amount of displacement is indicated by blue, and the maximum is shown in red. This analysis verified that the movement of the telescope, relative to the optical components within the optics breadboard, was acceptable and should perform well at the range specified by the program office.

After modeling and analysis were completed, manufacturing drawings of custom parts were created by the Engagement Systems Department to be

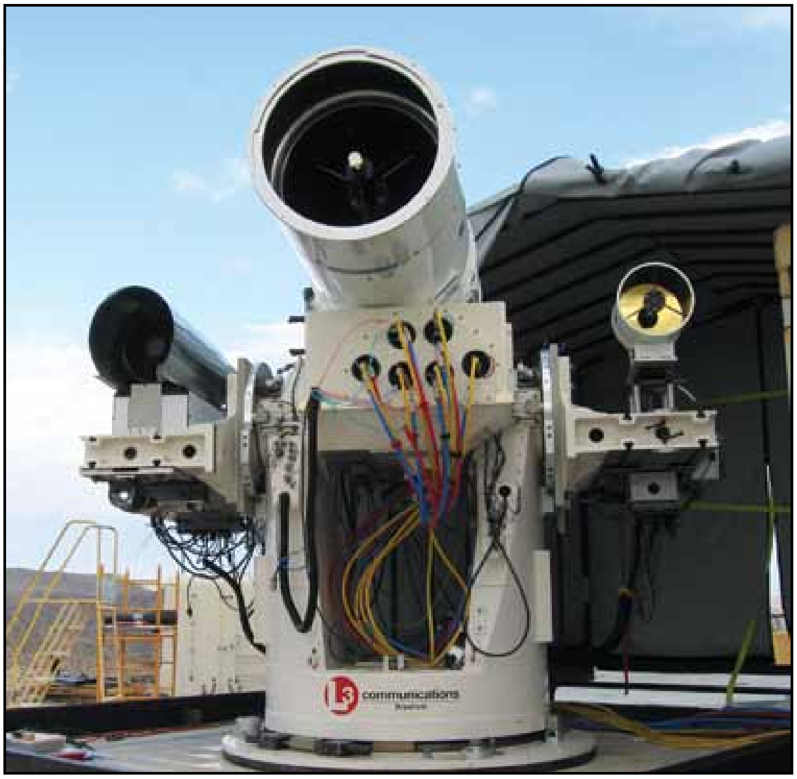
L3 communications

Figure 3. LaWS Beam Director

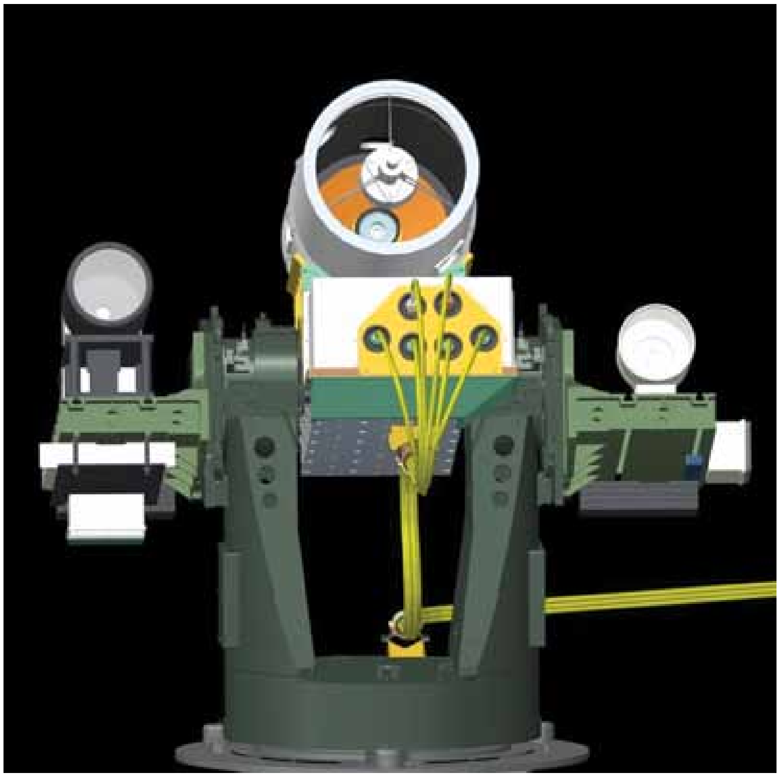

Figure 4. LaWS Beam Director Assembly Model

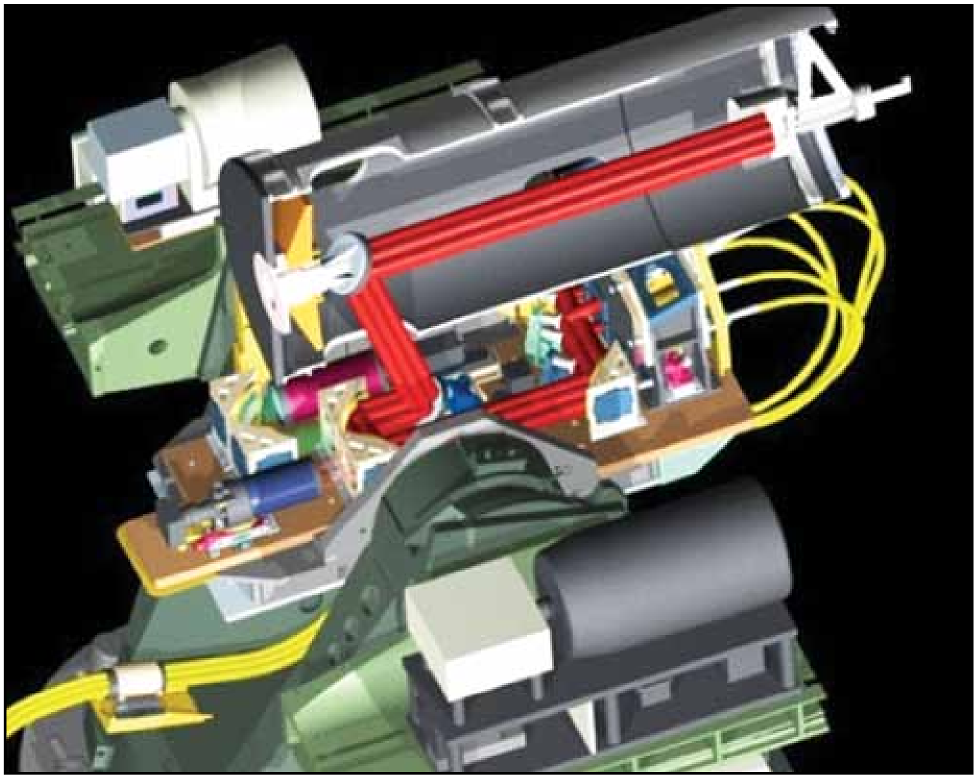

Figure 5. LaWS Beam Director Cutaway

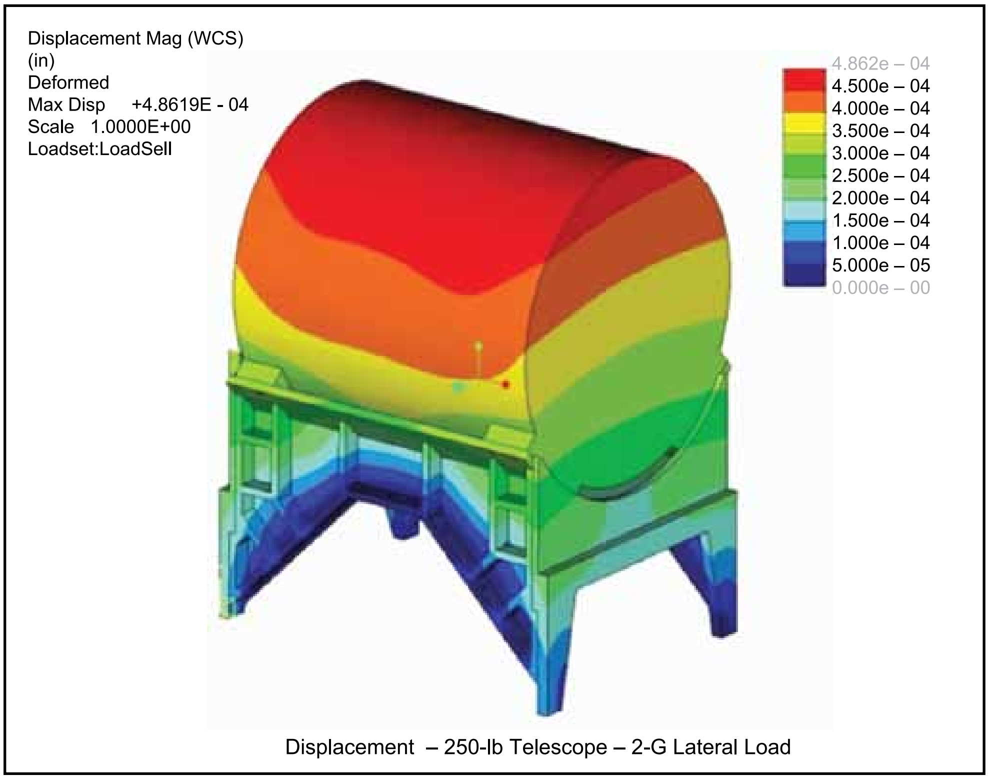
Displacement Mag (WCS)
(in)
Deformed
Max Disp +4.8619E - 04
Scale 1.0000E+00
Loadset:LoadSell
4.862e – 04
4.500e – 04
4.000e – 04
3.500e – 04
3.000e – 04
2.500e – 04
2.000e – 04
1.500e – 04
1.000e – 04
5.000e – 05
0.000e – 00
Displacement – 250-lb Telescope – 2-G Lateral Load

Figure 6. Displacement Plot

sent to manufacturing facilities, such as machine shops. One example is shown in Figure 7, which shows the first sheet of the multisheet drawing needed to manufacture the large plates that support the telescope from the center platform of the KTM. One of these plates is also shown in the displacement plot in Figure 6.

Even though it would be possible for one person to do all of the modeling, analyses, and drawings for a particular program, a more efficient process takes advantage of using the best skills available by collaborating with other experts. Collaboration enables assembly, part, and drawing files to be sent electronically, eliminating the need for collocating personnel. Drawings for the LaWS program, for instance, were made using noncollocated personnel across base at NSWCDD. They could just as easily have been made using personnel from across the country.

The LaWS program exemplifies how the Directed Energy Division uses solid modeling to enhance the quality and effectiveness of Navy directed-energy capabilities. As a result, warfighters will be better armed with more effective weapons and capabilities for future naval conflicts.

Acknowledgment

The author would like to acknowledge the valuable contributions of the Engagement Systems Department's drafting group in support of numerous DEWO and Directed Energy Division programs.

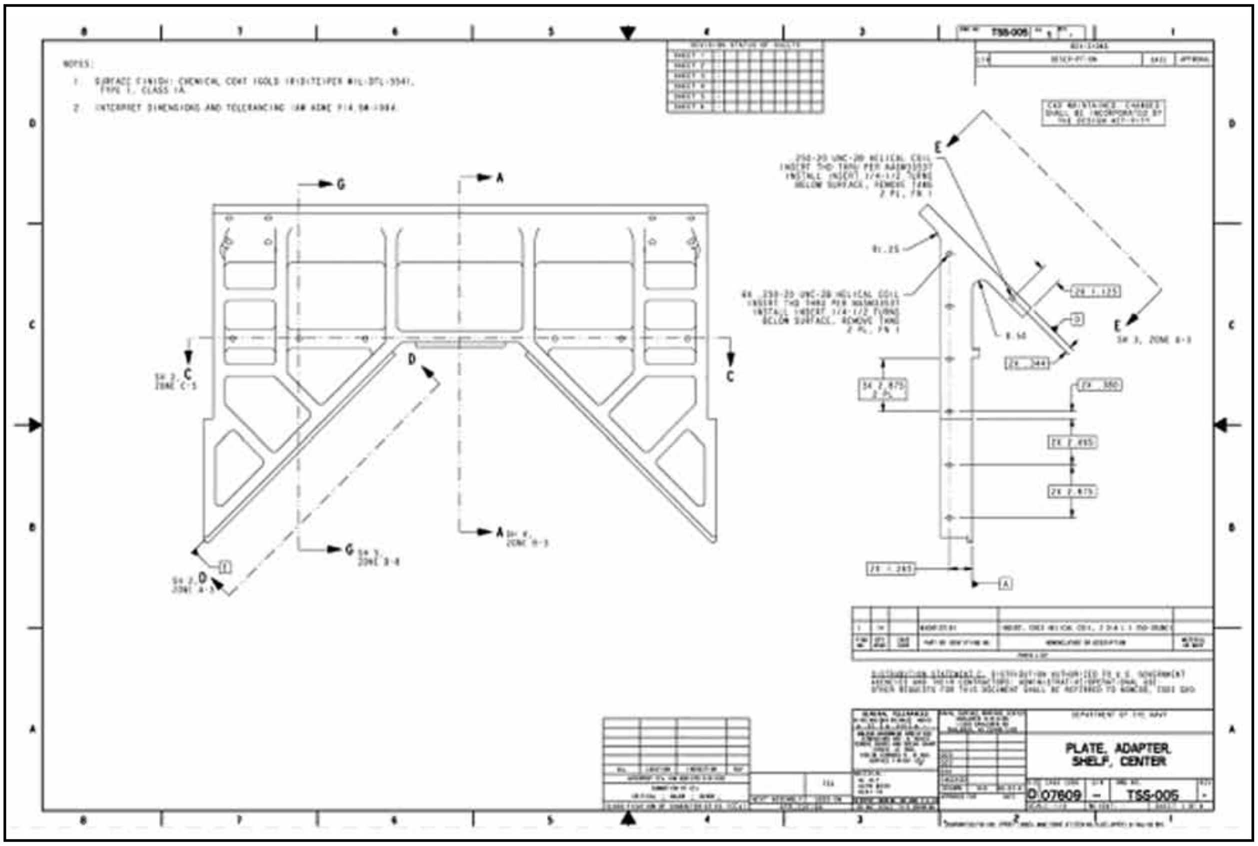

Figure 7. Manufacturing Drawing

A FUNDAMENTAL KEY TO NEXT-GENERATION DIRECTED-ENERGY SYSTEMS

By Directed Energy Division, Electromagnetic and Sensor Systems Department

Imagine an explosive ordnance disposal (EOD) unit on a routine scouting patrol deep in the notorious "Triangle of Death" south of Baghdad, where Marines, Sailors, and Soldiers frequently find themselves exposed to improvised explosive devices (IEDs). Fortunately, this newly outfitted unit is equipped with the latest unmanned, mobile, remote-controlled, radio frequency (RF) transmitter used as a directed-energy weapon (DEW). The integrated system provides comprehensive IED prediction, detection, prevention, and neutralization capabilities. Lightweight, pocket-sized transmitters carried by each warfighter constantly communicate sensor intelligence, key vital signs, critical conditions, and location telemetry to a geostationary satellite (GEOSAT). It intercepts, collects, and retransmits intelligence and situational awareness data simultaneously to any command post in the world and to each member of the unit on patrol. Highly efficient, miniature, switch-mode, RF amplifiers with high-power density (small size and weight with high-power output) enable these visions of future capabilities as their systems' transmitter backbone.

To civilians, the miniaturization of modern wireless (electromagnetic) devices is considered a mere convenience or luxury, i.e., Blackberries, mobile phones, and high-speed wireless network connections. To the next-generation warfighter, miniaturized, wireless, directed-energy (DE) systems open the door to the realization of a whole new set of effective and efficient wireless modalities. And while the capabilities mentioned in the above scenario are not yet available to warfighters, researchers believe they have uncovered the key to next-generation DE systems leading to the miniaturization of DE devices.

NEXT-GENERATION DE SYSTEM REQUIREMENTS

At the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), key system requirements for effective next-generation DE systems are being researched and developed for applications to counter IEDs, to detect explosively formed penetrators (EFPs), to neutralize explosives, and to predict threat locations. Next-generation DE systems must yield a high probability of mission success and be inherently safe to operate. By design, they must minimize or eliminate the risk of hostile attack or collateral damage especially during screening missions. Considering the DEW example above, practical

080102-N-1132M-006 SHEIK SA'ID, Iraq (2 January 2008) U.S. Army Soldiers attached to 3rd Squadron, 2nd Cavalry Regiment patrol and search for weapons or Improvised Explosive Devices (IEDs) during a clearing mission. (U.S. Navy photo by Mass Communication Specialist 1st Class Sean Mulligan/Released)

next-generation DE systems must be physically characterized by:

- Low mass (weight)
- Small size (volume)
- High-power output with respect to size or high-power density
- High efficiency for extended mission use
- Minimized prime power and cooling support
- Portability
- Mobility
- Configurability

They must also ensure a high probability of mission effectiveness. The DEW must be easily transportable and agile, adapting to the immediate, local military mission requirements in various warfighting environments. Additionally, DE systems must be mechanically robust and able to withstand the shock and vibration of combat missions in rough and rugged environments. The key requirement—efficiency—fundamentally facilitates all required characteristics, including mass and size.

MOVING BEYOND REQUIREMENTS

Scientists at NSWCDD, sponsored by the Office of Naval Research (ONR), are researching and developing key system requirements for effective next-generation DE systems to counter IEDs, to detect EFPs, to neutralize explosives, and to predict threat locations.

Researchers at NSWCDD are leading the way toward realizing small, lightweight, RF transmitters using high-power, solid-state, switch-mode amplifiers, theoretically 100 percent efficient. These practical switch-mode amplifier realizations are at least 1/100 the volume and weight of any commercially available linear solid-state amplifier of comparable power output. The challenges included assessing what type of active amplifier device and operation would provide the greatest power density (power output per unit volume and mass) with its necessary auxiliary systems, such as prime power generation and cooling of waste heat. Such a device also needed to provide sufficient output power based on required standoff range and IED system-coupling efficiency while also maintaining a manageably-sized, easily transportable system. Researchers initially considered tube-based systems, but large, heavy, direct-current (DC) power supplies are required, and typically 40 percent of the input power is dissipated in heat, which negates any possibility of miniaturization.

Upon a practical review of amplifier-class operations and suitable active amplifier devices, however, research pointed to contemporary switch-mode amplifier schemes (e.g., Class-E and Class-F) using solid-state technology—such as the high-electron mobility transistor (HEMT)—as satisfying the high-power density and abusive mechanical requirements for expected worst-case transportation and operation in a rugged environment. To significantly impact reduction of size and weight, practical, high-efficiency thresholds were defined for next-generation DE systems at 90 percent and greater. The key technology enabler to realize amplifier high efficiency in high-power amplifiers up to 60 kW was found in exploiting contemporary switch-mode amplifier architecture with efficient power combining. Particularly, switch-mode schemes in Class-E and Class-F operation as solid-state, active-hybrid planar topology designs were found to be necessary and sufficient for DE applications. These analyses led to a novel, Class-E RF switch-mode amplifier design. A Class-E RF switch-mode amplifier can theoretically operate at 100-percent efficiency. For every input watt supplied, an RF output watt is produced. The conductors and dielectric substrate of the hybrid planar load network and the commercial off-the-shelf (COTS) transistor all exhibit some small degree of power loss, suggesting an estimated practically realized efficiency of 90 percent.

Moreover, the amplifier under research consisted of a novel microwave load network operating with high-power output at ultrahigh frequency (UHF). This research led to the state of the art in Class-E designs leading by hundreds of watts, several hundred megahertz in frequency, and roughly 10 percentage points in efficiency. A common, solid-state, high-power amplifier design technique sums the phase and amplitude of smaller amplifier units to the large values required for DE systems. A practical hardware limitation exists that limits the theoretically infinite number of fixed RF output power units to a finite number. Approximately 60-kW RF output power sets the boundary as the largest hardware realization. By applying spatial power combining in the propagating medium, phased-array antennas can be employed with constructive wave interference in air that would allow sufficient RF power densities on target, based on the number of elements in the array. This technique eliminates the traditional hardware necessary to power combine the smaller power-amplifier elements, realizing a much simplified DE system with enhanced power density in the transmitter, and reduced mass and volume.

The key to ultrahigh efficiency in a switch-mode amplifier, such as Class-E or Class-F, is found in zero-voltage switching (ZVS). Here, the load network is not only designed to be resonant at and around a particular desired switching frequency, it must simultaneously act to force the voltage across the switch to be zero when current flows and when it switches off; hence, theory suggests that no power is dissipated because the product of current through, and voltage across, the switch is zero. It is this aspect of the design that makes the job of switch-mode amplifier realization difficult. Of course, in practice, a small voltage exists for a very short time during the switching action, resulting in a small amount of input power being dissipated in heat. This theoretical description also assumes that all components are ideal (i.e., no impedance to current flow exists in the switch when turned on). All realistic switches exhibit finite impedance when turned on, which does dissipate some wasted energy, but again, this is very small in modern HEMT devices using the ZVS technique.

Class-E switch-mode amplifier theory development began in the United States during the 1960s, with details published in 1975, although some earlier reports were published in Russia. Lumped element electrical components (RF choke inductors and metal film capacitors) were initially used in lower frequency (3 to 30 MHz) prototypes. As engineers attempted higher frequency designs in the very high frequency (VHF) range, solid-state transistor switch parasitic intrinsic and packaging elements found inside the transistor began to be used as some of the key components necessary for ZVS. These parasitic elements included stray capacitance caused by differences of potential between parts inside the transistor and inductance caused by bond wire length that is used to connect the transistor to accessible terminals in its packaging. At microwave frequencies, these parasitic elements become sensitive, invoking unintended significant changes to load networks designed to operate with the transistors. Intrinsic elements include drain-to-source breakdown voltage capability and peak current capability. As the need for higher frequency operation and higher power increased, constraints of key transistor parameters became difficult to produce in traditional silicon technology:

- High instantaneous transient (peak) current capability through the transistor
- Moderate breakdown potential across the transistor
- Low output capacitance

Only within the past few years have transistor manufacturers produced COTS transistors that meet the required capabilities necessary to operate in switch mode for microwave frequencies and

081107-N-1120L-072 RAMADI, Iraq (7 November 2008) Joint EOD Rapid Response Vehicles (JERRVs) assigned to Naval Mobile Construction Battalion (NMCB) 7's convoy security element are secured following an escort mission from a forward operating base. The Cougar-type JERRVs are employed by coalition forces for escort and logistics missions, and to protect personnel from IEDs. NMCB 7 is deployed to U.S. Forces Central Command to provide contingency construction support to coalition forces in support of Operations Enduring Freedom and Iraqi Freedom. (U.S. Navy photo by Mass Communication Specialist 2nd Class Michael B. Lavender/Released)

high-power output. Selection is still somewhat limited for designers.

New transistor technology known as gallium nitride (GaN) HEMTs—using state-of-the-art manufacturing processes with GaN on silicon carbide materials—now facilitates Class-E high-power amplifier (100-W) designs at ultrahigh frequencies. The design process for switch-mode amplifiers is radically different than linear amplifiers, so engineers have tended to continue using linear amplifier design techniques due to familiarity, rather than advance to the switch-mode designs. Today, the Class-E and Class-F unit power output (greater than 100 W) capability and upper frequency limitation is based on a lack of available HEMTs with the necessary parameter capabilities.

Most recently, transistor manufacturers have limited their investment in the Class-E amplifier solid-state switch market due to no commercial market mandate. An assortment of presently available HEMTs provides a low-power capability in terms of 1- to 10-W output power for Class-E amplifiers in the cell phone market. The need remains to continue advancing in commercially manufactured HEMTs with key capabilities necessary to realize larger unit power output, hundreds of watts to a thousand watts, for practical implementation in DE systems.

Possible Multiple Applications

Directed-Energy Weapon Systems

Expanding on the vision of the next-generation DEW system mentioned at the beginning of this article, further imagine that EOD scouts detect a laser fluorescence signature of C4 high explosive and chlorine outgasses in the vicinity of an abandoned vehicle 2-km north of their current position. An electronic support measure (ESM) team on board an approaching clearing vehicle initiates RF jamming and electromagnetic surveillance procedures. Electronic specialists also scan the area with ground-surface differential thermography—particularly to detect possible buried IEDs and EFPs or their tiny command wires, crush wires, or pressure plates—while clearing a pathway to the abandoned roadside vehicle.

Upon arrival at a 500-m safe distance, the EOD specialists command the RF transmitter's robotic platform, also equipped with sensitive gamma-ray planar and computed tomography (CT) imaging to navigate toward and around the vehicle, interrogating every possible hiding place. It discloses an IED in the fuel tank. The specialist lifts the transmitter arming safety and commands the remote transmitter to radiate a prescribed dose of RF energy directed at a carefully chosen component of the vehicle-borne IED (VBIED) system. Without entering the vehicle, the advanced screening system detects and defuses the deadly IED buried within the rusty, metal vehicle chassis. Within minutes, the suspected VBIED threat is entirely neutralized, with absolutely no wounded warfighters or casualties.

Pictured here is the National Aeronautics and Space Administration / National Oceanic and Atmospheric Administration (NASA/NOAA) Geostationary Operational Environmental Satellite-P (GOES-P) launching from Cape Canaveral Air Force Station, Florida, aboard a Delta IV rocket procured by Boeing Launch Services on 4 March 2010. Built by Boeing Space and Intelligence Systems, GOES-P will provide NOAA and NASA scientists with data to support weather, solar, and space operations, and will enable future science improvements in weather prediction and remote sensing. Additionally, GOES-P will provide data on global climate changes and capability for search and rescue.

Mobile Ad-Hoc Wireless Network (MANET)

Beyond IED detection and neutralization, imagine an expeditionary unit on patrol, with each member equipped with an RF transceiver about the size and weight of a cigarette pack with an ultrahigh-efficient switch-mode amplifier. The miniature transceiver constantly communicates sensor intelligence, key vital signs, critical conditions, and location telemetry to a GEOSAT. This small switch-mode amplifier has the needed output power to reach an altitude of 35786 km, where the GEOSAT intercepts, collects, and retransmits this intelligence and situational awareness data to any command post in the world and to each member of the unit on patrol simultaneously. The expeditionary unit, spread out over a wide area with large interspacing, shares the situational awareness and intelligence data of each other at the speed of light. Thus, near real-time, worldwide communications with ubiquitous secure access from the battlefield is possible in a multiple-input, multiple-output (MIMO) architecture. The same system could provide a soldier-to-soldier MANET.

Next-generation switch-mode RF amplifier designs could also optimize payload weight and volume on board new communication satellites while supplying higher power density and making efficient use of the solar power supply budget. Improved switch-mode amplifier power output, when combined with enhanced antenna design, would minimize Earth-station antenna size requirements. The recently launched satellite shown at left demonstrates an example of the latest antenna technology.

LOOKING FORWARD

Miniaturizing next-generation DE systems opens up a whole new world of applications to support warfighters in ways unimaginable just a few years ago. Reduction of transmitter mass and volume, accompanied with high efficiency, creates a welcome trickle-down effect. Low profile, small, lightweight DE systems means:

- Less vulnerability to attack
- Greater mobility and maneuverability
- Simplified logistics with less fuel-supply demands
- Less impact on the environment

Clandestine operations, too, could be executed with greater ease and simplified logistics support. In the case of MIMO MANETs, miniaturized high-power density transmitters could further expand capabilities for the warfighter, enabling them to carry high-power transmitters to communicate with satellites or other supporting platforms. The

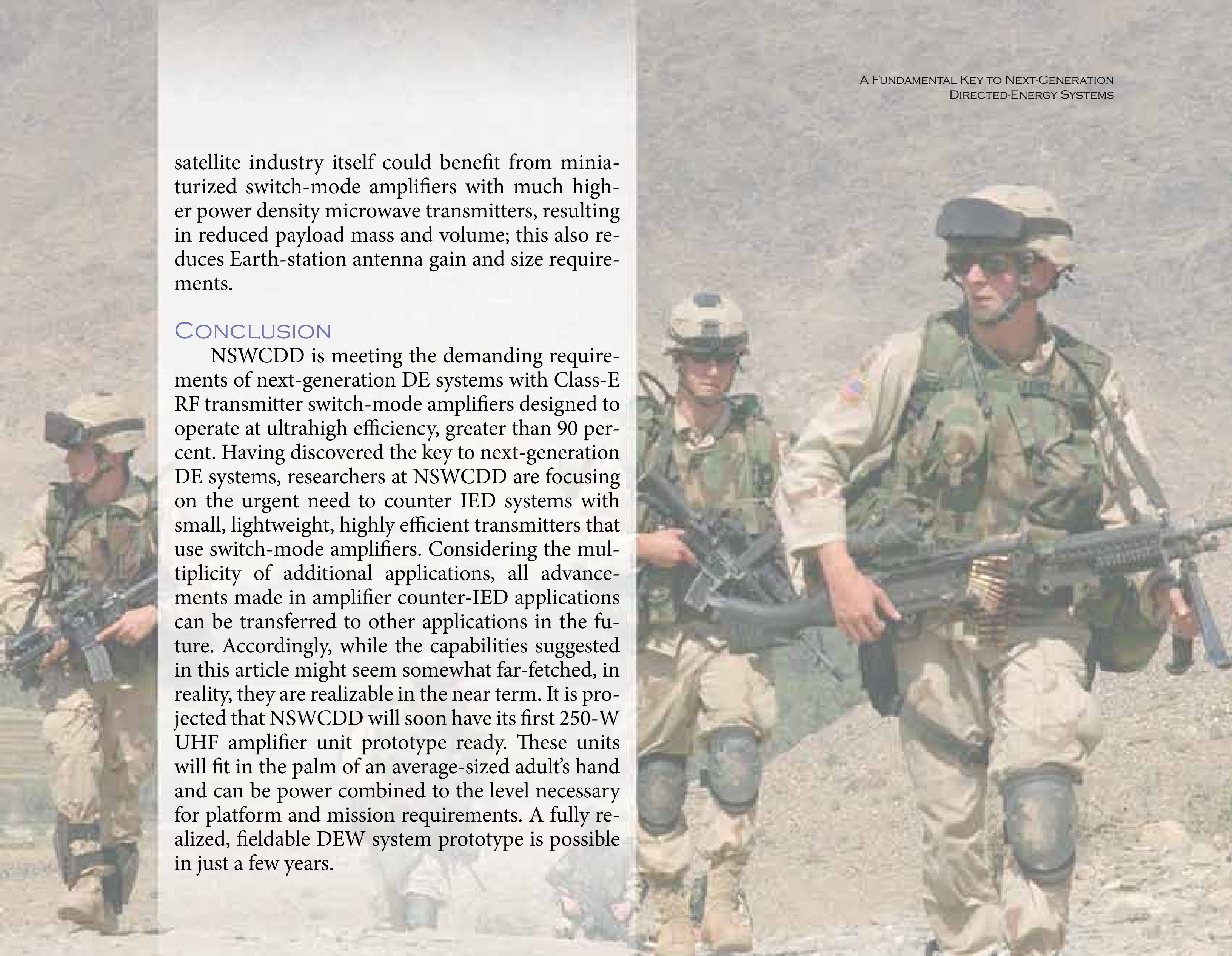

satellite industry itself could benefit from miniaturized switch-mode amplifiers with much higher power density microwave transmitters, resulting in reduced payload mass and volume; this also reduces Earth-station antenna gain and size requirements.

CONCLUSION

NSWCDD is meeting the demanding requirements of next-generation DE systems with Class-E RF transmitter switch-mode amplifiers designed to operate at ultrahigh efficiency, greater than 90 percent. Having discovered the key to next-generation DE systems, researchers at NSWCDD are focusing on the urgent need to counter IED systems with small, lightweight, highly efficient transmitters that use switch-mode amplifiers. Considering the multiplicity of additional applications, all advancements made in amplifier counter-IED applications can be transferred to other applications in the future. Accordingly, while the capabilities suggested in this article might seem somewhat far-fetched, in reality, they are realizable in the near term. It is projected that NSWCDD will soon have its first 250-W UHF amplifier unit prototype ready. These units will fit in the palm of an average-sized adult's hand and can be power combined to the level necessary for platform and mission requirements. A fully realized, fieldable DEW system prototype is possible in just a few years.

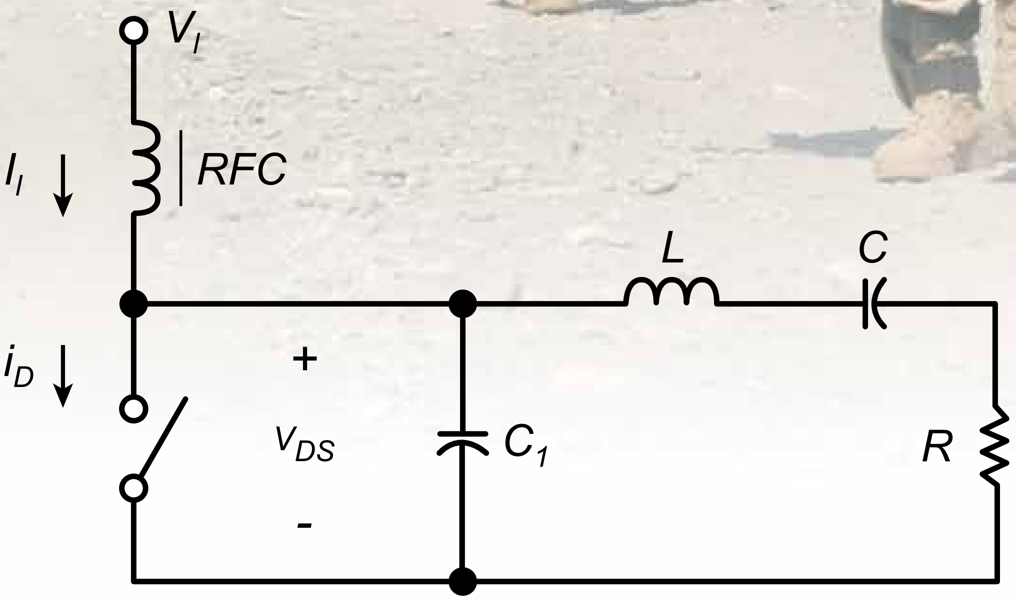

ACTIVE DENIAL ARRAY

By Randy Woods and Matthew Ketner

Active Denial Technology (ADT)—which encompasses the use of millimeter waves as a directed-energy, nonlethal, counterpersonnel weapon—has the potential to provide an important new escalation-of-force capability to U.S. operating forces. ADT projects a focused beam of 95-GHz millimeter waves to induce an intolerable heating sensation on an adversary's skin, repelling the individual with minimal risk of injury. More than a decade of research has established the biological and behavioral effects of ADT for large spot size systems, such as Active Denial System 1 (Figure 1). While the effects of this large spot size system have been successfully established, the technology that produces those effects has the potential to progress in a number of ways, particularly with the development of smaller, lighter, and lower-cost systems.

One research effort focuses on the development of smaller, lighter, and lower cost ADT demonstrators that produce commensurate "ADS-effects," with effective spot size and power densities on target. In support of this effort, the Joint Non-Lethal Weapons Program (JNLWP) sponsored the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) to develop a "smart target system," which measures the millimeter-wave beam using fast-response, 95-GHz diode detectors. NSWCDD subsequently developed and tested the W-Band Beam Diagnostic Array to characterize the system's beam with a temporal resolution of 30 Hz and a high spatial resolution of 1 inch.

The current method of measuring the 95-GHz beam is to use carbon-loaded Teflon (CLT) to produce an average power beam image. This method works as the CLT is exposed to the system's beam. The material heats, over a period of seconds, proportional to the magnitude of the radio frequency (RF) field, resulting in an image as shown in Figure 2. After the exposure, the specific heat capacity of the CLT can be used with the temperature increase in the CLT to provide an indication of the total energy deposited in the material. This method produces a good representation of the average RF field; however, any peak variations in the beam are averaged out.

To allow for high temporal-resolution measurements of the 95-GHz beam, a high-density, 95-GHz diode-detector array was commissioned by the Joint Non-Lethal Weapons Directorate (JNLWD), and was designed and built by NSWCDD, with support from Millitech, Inc. The array consists of a center 11 × 11 matrix (shown in Figure 3) with four removable arms that can be attached (shown in Figure 4), resulting in a measurement area of approximately 1 × 1 m.

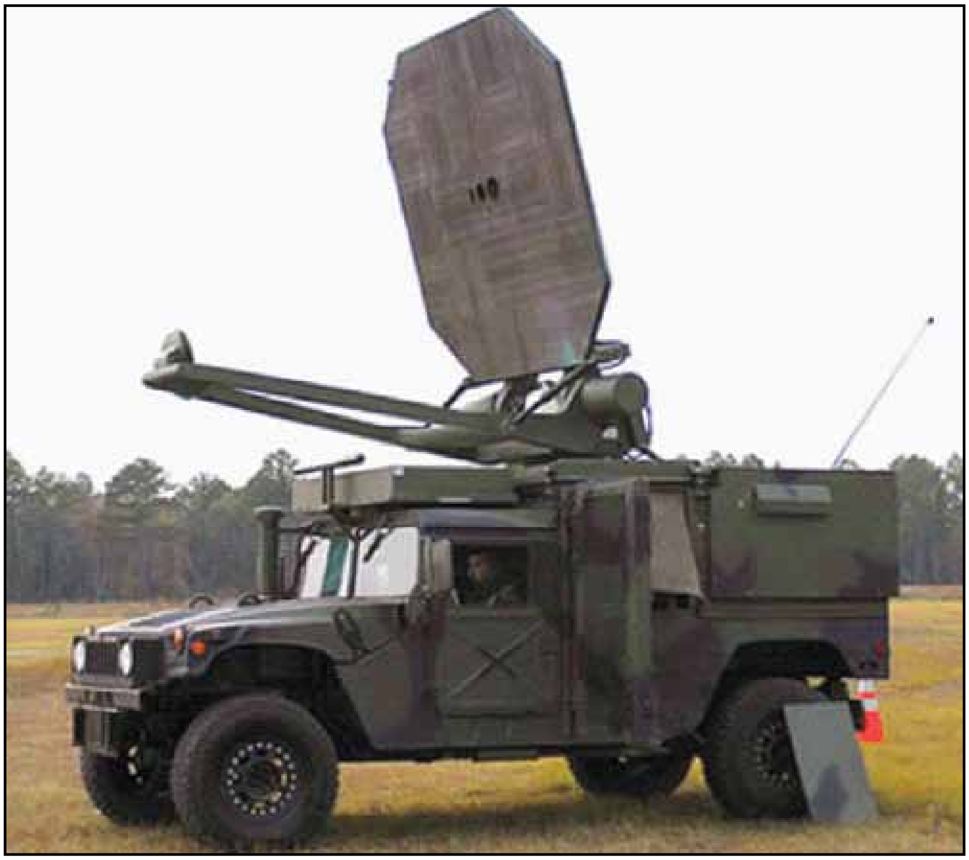

Figure 1. Active Denial System 1

Each element's profile consists of the individual horn antenna from the array, an attenuator, a detector, and a SubMiniature version A (SMA) connection to the digitizer circuitry. This configuration allows for the power received from the antenna to be attenuated and converted to a direct current (DC) output capable of being measured by an analog-to-digital converter. The machined antenna elements provide a uniform effective area for each element, allowing field strength (W/cm^2) to be converted into power received (W or dBm). The aperture antennas also provide an impedance match between free space and the waveguide system. A cross-sectional view of the array element is shown in Figure 5, followed by a signal flow diagram shown in Figure 6.

The basic principle of operation behind the array is that the derivative of the diode detector's power vs. output voltage curve is very repeatable between detector elements. Therefore, when the detector elements arrived at NSWCDD, each detector element was paired with a variable

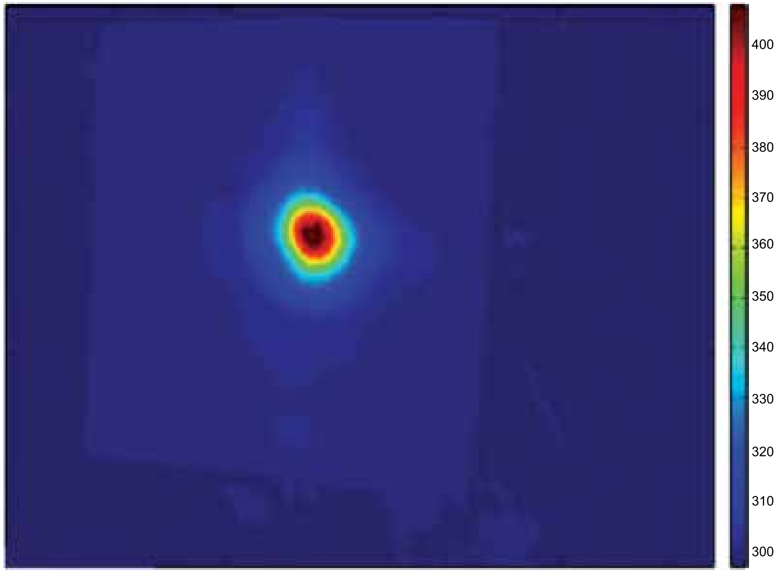

Figure 2. CLT Representation of Small, 95-GHz Spot

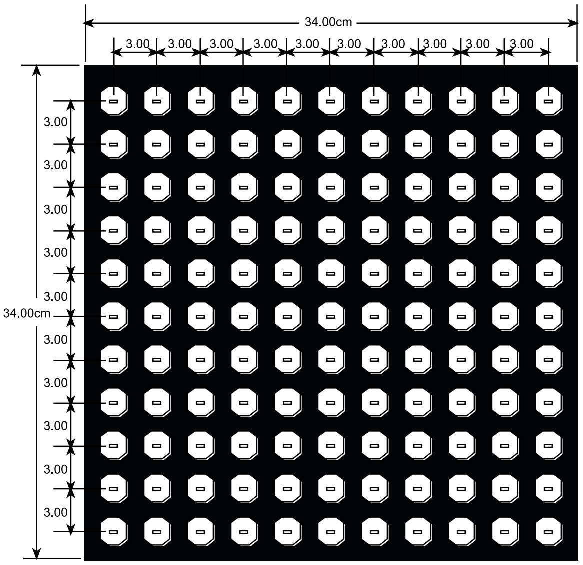
34.00cm
3.00
34.00cm

Figure 3. Main Array Face

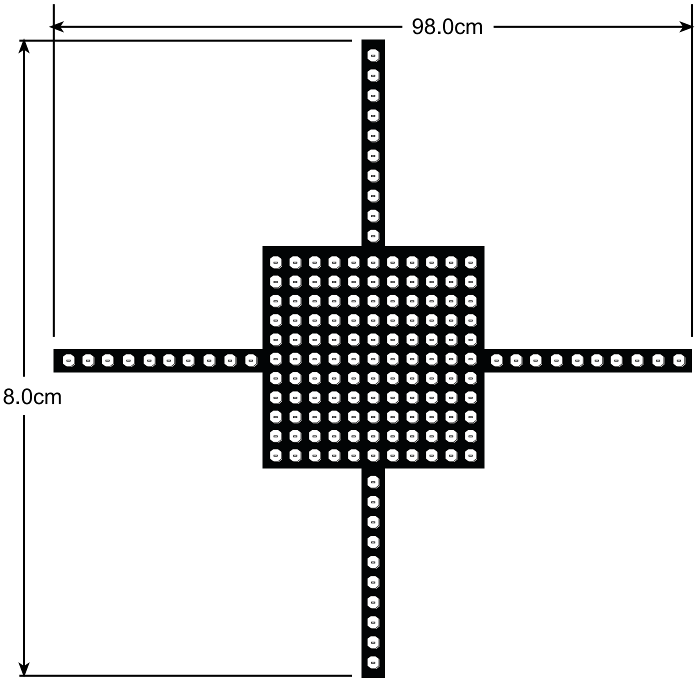

Figure 4. Full W-Band Array

attenuator and calibrated as a single unit. The calibration was accomplished by inserting a known input power of +5 dBm into the input of the attenuator and setting the DC output voltage at a predetermined millivolt (mV) output. This allowed the detector's individual offset voltages to be removed and caused the detectors to behave in a repeatable manner. The attenuator is able to be adjusted by varying the depth that the aluminum nickel card is inserted into the section of waveguide.

The final section of the electrical system converts the DC voltage output from the detectors to a digital signal to send back to the operator station. For this, it was determined that a 16-bit digitizer would be required to enable measuring the microvolts output by the detectors on the low end of their range, while still allowing the digitizer to measure the full output voltage of 1.8 V for high-input powers. Also, due to the proximity of the operator to the array and overall system flexibility, it was determined that Ethernet communications would provide a sufficient means of reading the system data.

To display the data to the operator, a two-dimensional array is populated and displayed for the user (shown in Figure 7). This allows values to be

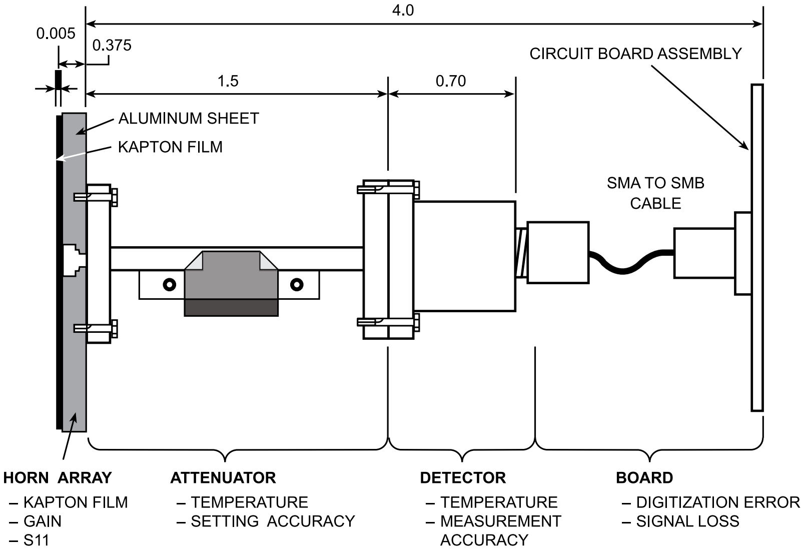
4.0
0.005
0.375
1.5
0.70
CIRCUIT BOARD ASSEMBLY
ALUMINUM SHEET
KAPTON FILM
SMA TO SMB
CABLE
HORN ARRAY
– KAPTON FILM
– GAIN
– S11
ATTENUATOR
– TEMPERATURE
– SETTING ACCURACY
DETECTOR
– TEMPERATURE
– MEASUREMENT
ACCURACY
BOARD
– DIGITIZATION ERROR
– SIGNAL LOSS

Figure 5. Cross-Sectional View of Array Element

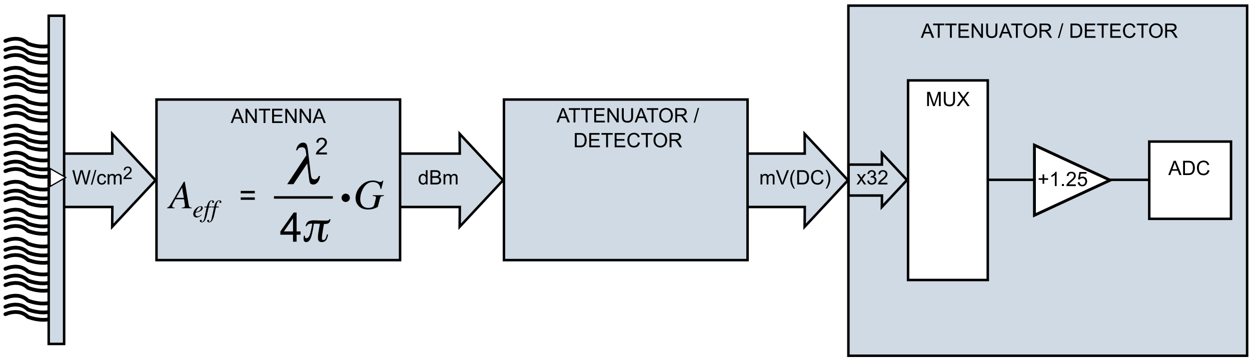
W/cm^2
ANTENNA
$A_{eff} = \frac{\lambda^2}{4\pi} \cdot G$
dBm
ATTENUATOR / DETECTOR
mV(DC)
ATTENUATOR / DETECTOR
x32
MUX
+1.25
ADC

Figure 6. Signal Flow Diagram

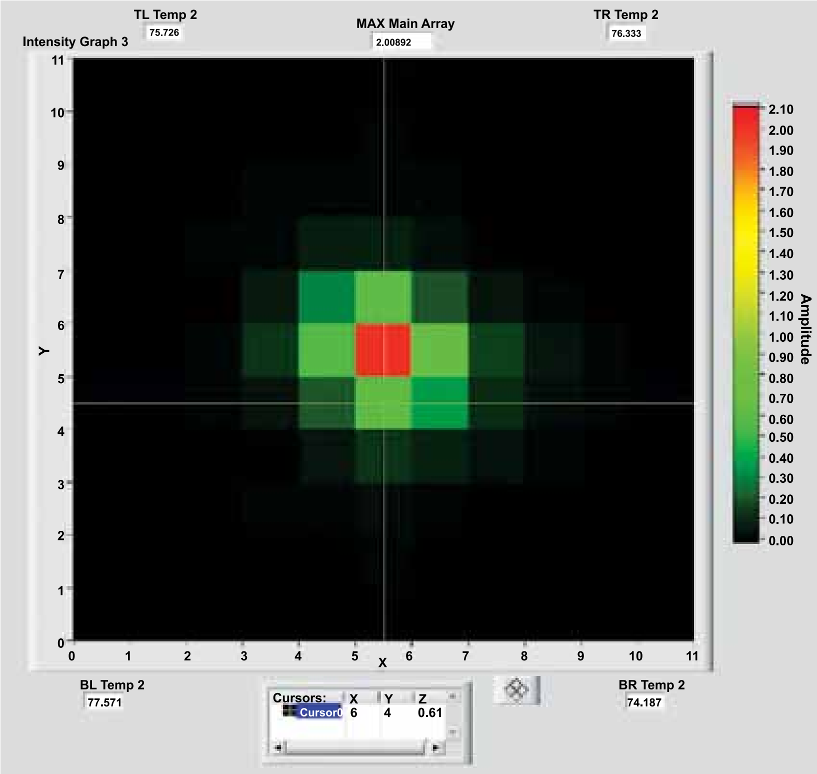
Intensity Graph 3
Y
X
0
1
2
3
4
5
6
7
8
9
10
11
Amplitude
2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

TL Temp 2 75.726

MAX Main Array 2.00892

TR Temp 2 76.333

BL Temp 2 77.571

BR Temp 2 74.187

Cursors:	X	Y	Z
Cursor0	6	4	0.61

Figure 7. Array's Operator Interface Showing a Small Spot Source

read directly from the display corresponding to the watts per centimeter squared (W/cm^2) present at the array face. Data also is recorded so that it can be viewed later in a player application, such as a video file, or it can be viewed in a spreadsheet application, frame by frame. The data shown in Figure 7 is representative of small-source testing performed recently and very clearly shows the beam profile.

CONCLUSION

NSWCDD engineers successfully met the W-band array's design goals of providing a high temporal-resolution image of 95-GHz beams. The system has been tested against two active denial systems, providing good agreement with the currently accepted methods, as well as valuable information regarding the system's beam characteristics. These accomplishments will allow future system development to take advantage of this better understanding to possibly reduce system size and increase the effective range. A better understanding of the 95-GHz beam helps to facilitate future ADT development for this much-needed, nonlethal escalation-of-force capability for U.S. warfighters, homeland defenders, and law enforcement personnel.

DIRECTED ENERGY IN THE MILITARY ENVIRONMENT

By LT Leedjia Svec, Jeremy Beer, and Dave Freeman

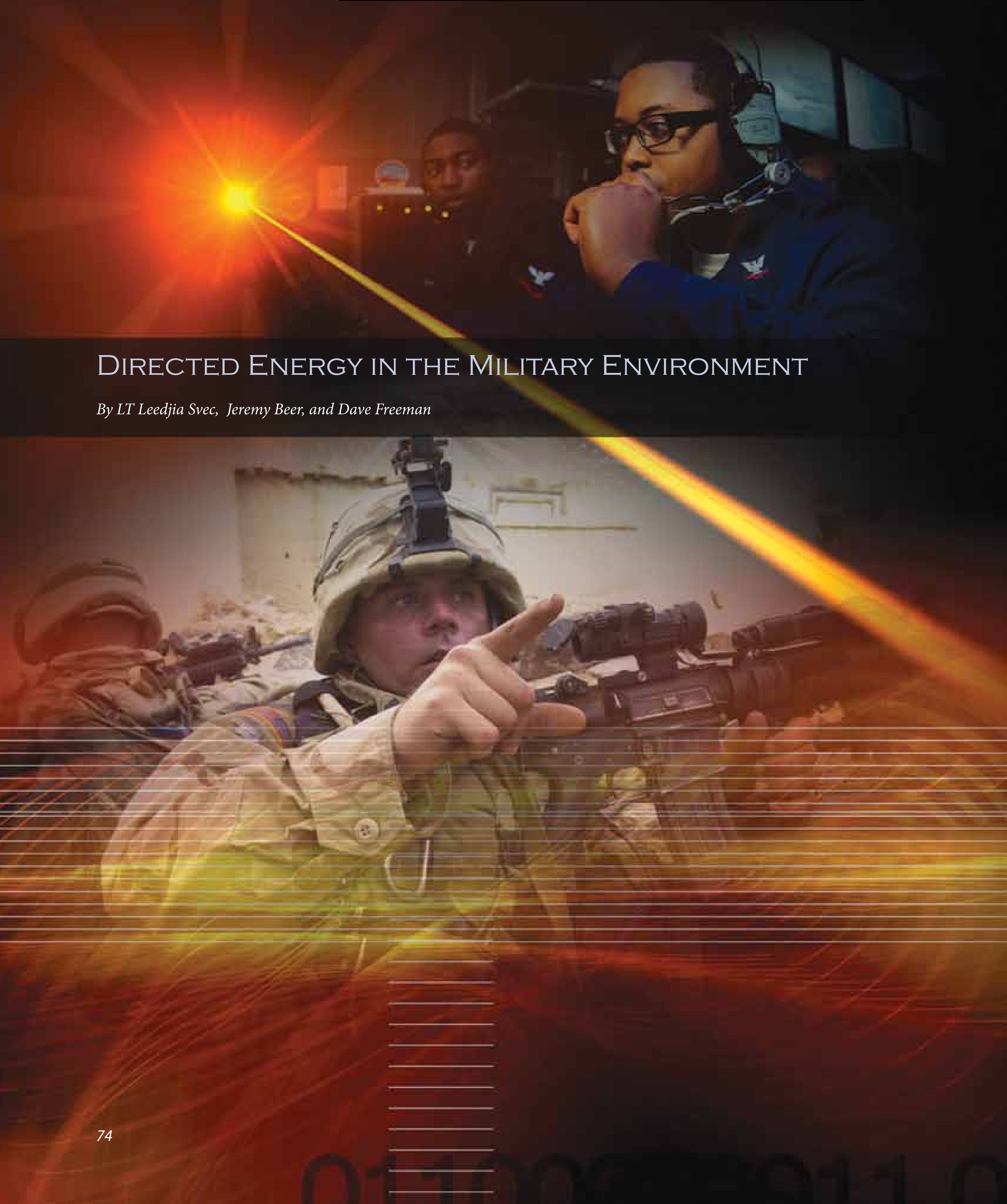

The military operates in the land, air, and maritime environments. In each of these environments, lasers and laser devices are increasingly being seen and used in a variety of ways. Accordingly, the military must protect itself and civilians from the potentially dangerous effects of lasers and other directed-energy devices.

Lasers are being used on the ground to determine the intentions of people who approach checkpoints and to dissuade aircraft from entering restricted airspace. Laser weapons are also being developed for use in the maritime environment. With the use of lasers comes the requirement for eye protection. The eye is particularly sensitive to lasers and its anatomy includes optical components that amplify the power of incoming light. Consequently, the potential for injury or blinding is great.

Naval Medical Research Unit – San Antonio (NAMRU-SA) is poised to lead the way in researching and testing laser glare devices and laser eye protection. The mission of the NAMRU-SA is to conduct medical, dental, and directed-energy biomedical research, which focuses on ways to enhance the health, safety, performance, and operational readiness of Navy and Marine Corps personnel, and addresses their emergent medical and dental problems in routine and combat operations. NAMRU-SA was officially commissioned on 6 May 2009 and is a subordinate command under the Naval Medical Research Center (NMRC) in Silver Spring, Maryland, reporting to Navy Medicine Support Command (NMSC) in Jacksonville, Florida. NAMRU-SA consolidates the Naval Health Research Center Detachment Directed Energy Bioeffects Laboratory, the Naval Institute for Dental and Biomedical Research in Great Lakes, and the NMRC Combat Casualty Care research function. As part of the Base Realignment and Closure (BRAC) 2005, NAMRU-SA has moved to Fort Sam Houston. Two new buildings that have been constructed are the Battlefield Health and Trauma Research Institute and the Tri Service Research Laboratory. A conceptual drawing of the NAMRU-SA Tri-Service Research Laboratory (to house directed-energy research) is shown in Figure 1.

Many factors must be considered when lasers operate in military environments. On the ground, lasers offer a greater likelihood of close contact exposure. In aviation and maritime environments, the mobility of lasers is limited to permanent fixtures on aircraft or ships, so target acquisition can be much more complicated. Often ignored, but just as important and common to all environments, are the psychological factors that need to be explored. These factors include clarifying intentions, communications, and effectiveness. In certain situations,

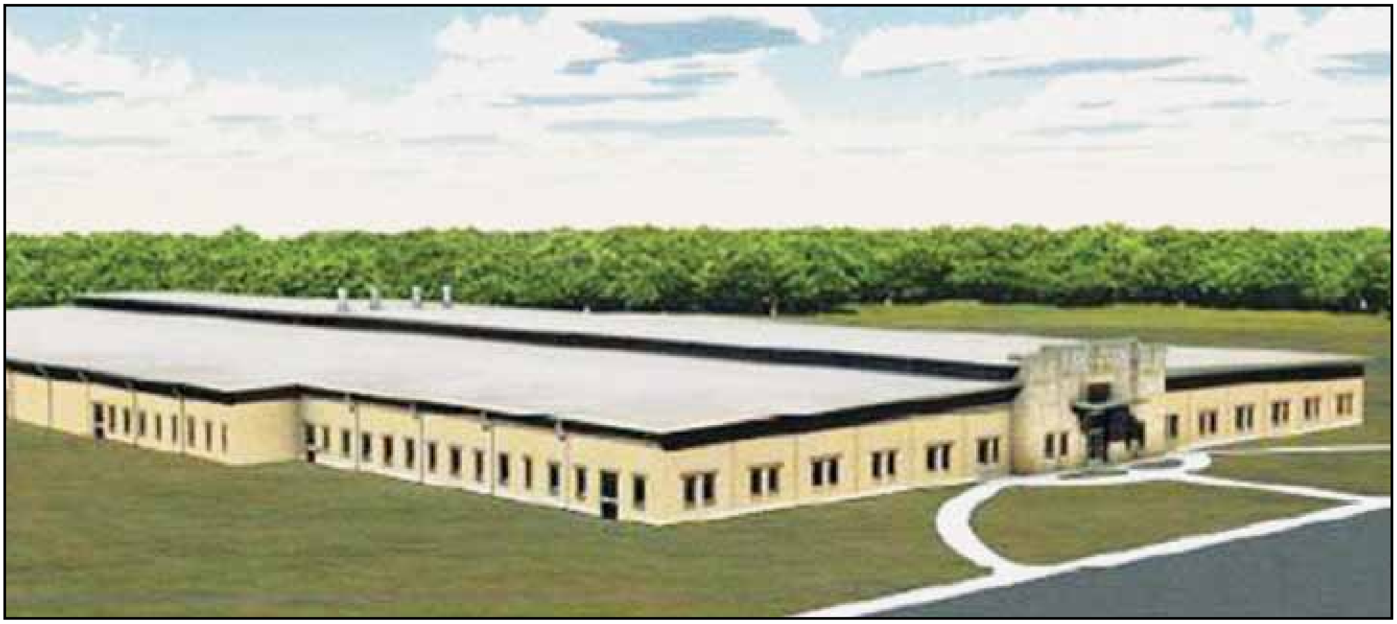

Figure 1. Naval Medical Research Unit – San Antonio Tri-Service Research Laboratory at Fort Sam Houston, San Antonio, Texas (artist's concept)

sometimes lasers are coupled with other modalities, such as auditory instructions.

On the ground, laser exposure has been shown to interfere with driving vehicles, making color judgments, and target shooting. In aviation, lasers can interfere with pilot vision, causing afterimages, glare, or temporary ocular injury, with attendant effects on navigation and control. In the maritime environment, lights frequently are used to signal a variety of messages, from direction (left, right, etc.) to more complicated messages such as "man overboard." More prolific use of lasers underscores the need for laser eye protection, a dynamic area of research, which must respond to changing threat wavelengths and changing environments. Figure 2 shows NAMRU-SA personnel executing an operational field test at Kennedy Space Center, July 2009.

Recent studies undertaken by NAMRU-SA have investigated the use of laser dazzlers on sailors in small boats.[a] In these studies, participants were exposed to the laser glare at different angles and distances, in both day and night conditions. Study protocols were approved in accordance with the Institutional Review Board in compliance with all applicable federal regulations governing the protection of human subjects. Participants were given a survey assessing their subjective response to the laser, as well as a more objective visual eye chart. The

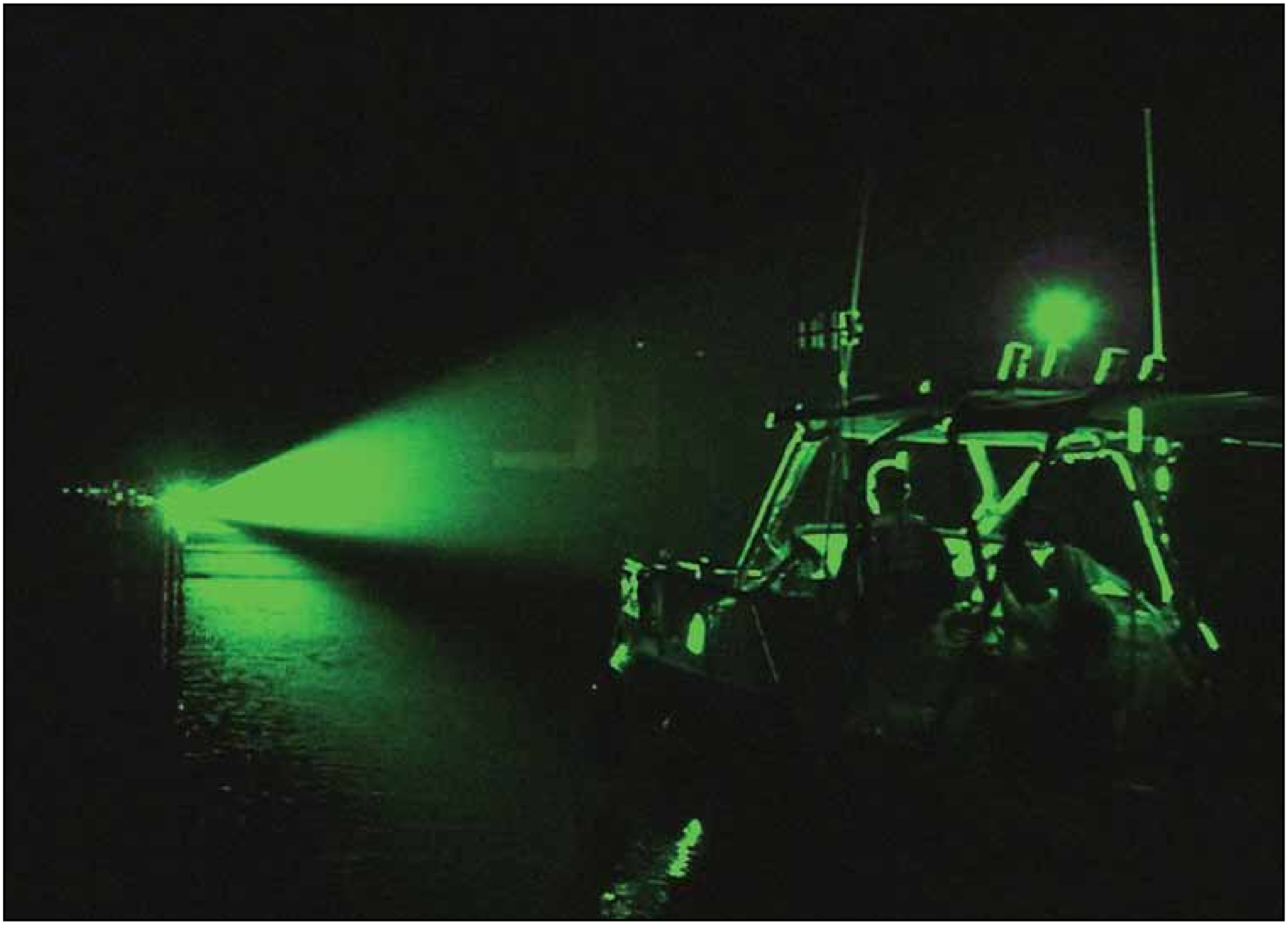

Figure 2. NAMRU-SA personnel execute operational field test at Kennedy Space Center, July 2009, in which a nonlethal laser prototype is evaluated for power delivery (stability and beam propagation) at range and human visual effectiveness aboard a maritime target.

results suggested that participants were most affected by the laser at night when they were looking straight at it (as opposed to many degrees away) and at the closest exposure distances. The most surprising finding, however, was that some participants reported being drawn to the laser rather than away from it, especially at farther distances. Participants remarked that they couldn't tell what the signal was, so they would want to go closer to find out. This illustrates that the assumption (by some)—that distant laser lights will deter and repel innocent mariners—might not always be true. Further research is needed to verify this finding, however, before employing laser glare devices in the maritime environment. Figure 3 shows NAMRU-SA personnel executing operational field tests, which were conducted at Cheatham Annex, Virginia, and Panama City, Florida, in 2008–2009.

These studies also brought the factor of communication to light. Participants remarked that "green is not a threatening color," and some thought "it could be a signal for help." Many felt curious about the "blinking light" used in the study and would go closer or try to contact the vessel to determine the intent of the message. Green lasers are used because they are more visually salient; however, they may not be as psychologically salient. Participants remarked that if the signal were paired with another signal, such as an auditory one, then the message of "warning" or "do not come closer" might be clearer.

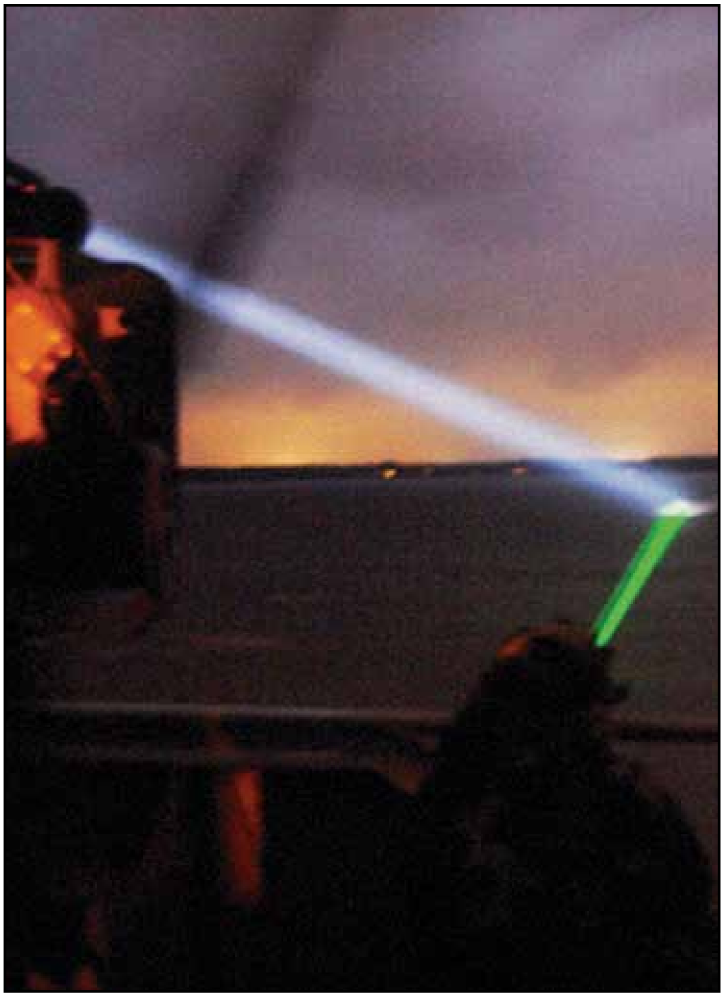

Figure 3. A compact hand-held laser is evaluated for effectiveness in maritime defense against small-boat attacks.

Lastly, these studies brought to light the matter of effectiveness. Laser glare devices are used to stop or alter the behavior of the recipient, but one study yielded mixed results. At close distances, participants noticed the signal, felt affected by it, and reported that their behavior changed in the manner desired by the person pointing the laser. But at greater distances, behavior might not change. Thus, these findings need to be replicated in different maritime scenarios in order to be truly useful in developing laser glare devices. This particular study was encouraging regarding the effectiveness and visual usefulness of glare devices, but it brought up new questions about their psychological impact on behavior. Resolving these questions must be an integral goal of technical research and development studies to determine the operational effectiveness of directed-energy devices, not just for the maritime environment, but for all military environments.

ENDNOTE

a. Results and technical reports are available upon request from the corresponding author or from the NAMRU-SA Public Affairs Officer.

Directed Energy Using High-Power Microwave Technology

By Jacob Walker and Matthew McQuage

The Directed Energy Warfare Office (DEWO) and Directed Energy Division at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) merge past research and data with continuous innovation in the field of high-power microwave(s) (HPM) to address the critical need for nonlethal, nonkinetic weapons. HPM weapons can be described as nonkinetic devices that radiate electromagnetic energy in the radio frequency (RF) or microwave spectrum. They are designed to disrupt, deny, degrade, damage, or destroy targets. In essence, this is achieved when high-power electromagnetic waves propagate through air and interdict targets by traveling through the exterior layers of structures and coupling energy to critical electronic components. Since effectiveness against a wide range of targets is the goal, HPM has become a collective term for various technologies: wave shapes, source frequencies, and the distribution of varying signal bandwidths. It is the objective of HPM research and assessment, therefore, to address targets for which no engagement option currently exists. NSWCDD is working to identify optimal HPM mission platforms and move relevant technologies into the field.

HPM Initiatives

NSWCDD has actively pursued HPM research since the advent of the field in the 1970s. Since then, scientists and engineers have conducted HPM research and development in many areas, including hydrogen spark-gap switching, spiral generators, and related technologies. More currently, the Directed Energy Division developed a variety of high-power wideband RF systems based on pulsed power and Marx generators (Figure 1). In addition to the extensive work accomplished in HPM and RF source development, NSWCDD contributed substantially to the area of counter-HPM vulnerability assessments. Researchers developed site assessment guides and threat brochures, as well as a number of wideband RF sources, to determine the susceptibility of electronic equipment to high-power RF interference. This latter effort involved assessing and exploiting the weaknesses of specified electronic targets to various HPM and RF threats. Data gleaned from these efforts was then used to support optimized prototypes and system designs employing effects-based design methodology. NSWCDD utilized these wideband RF sources to determine the susceptibility of a multitude of military

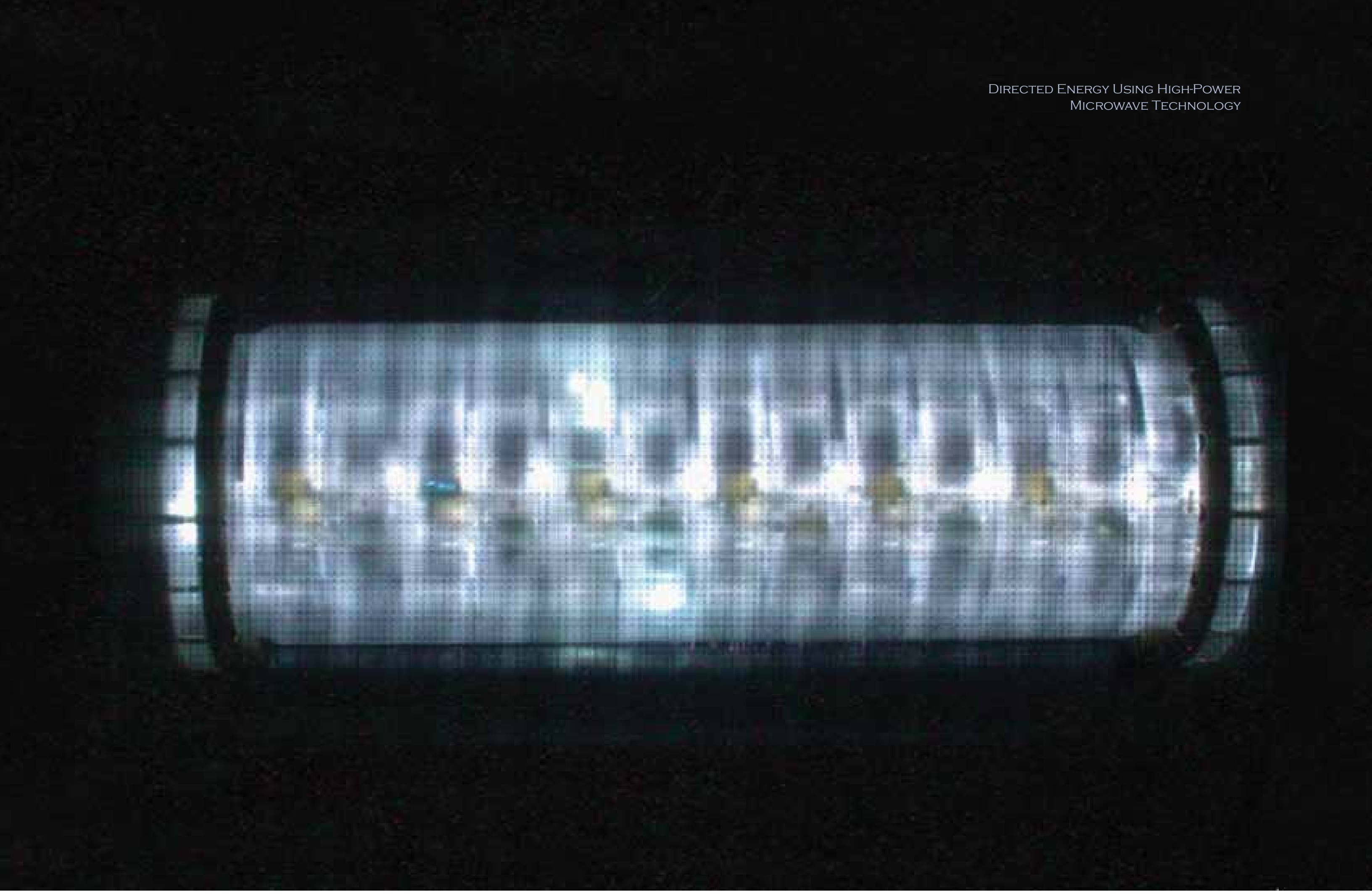

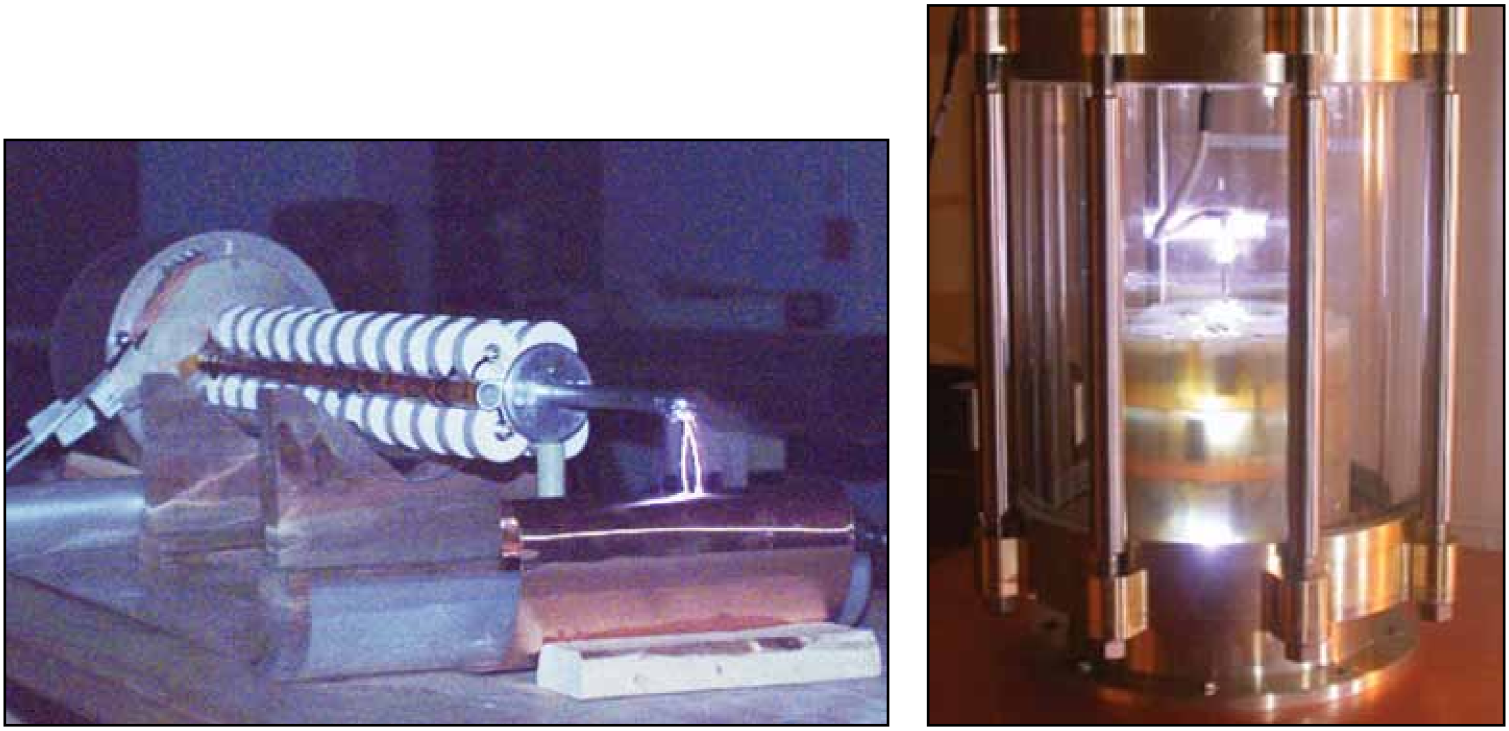

Figure 1. Examples of NSWCDD Marx Generators

and electronic infrastructure equipment to high-power RF interference.

HPM Counterattack Operational Overview

Research in support of HPM-driven electronic attack increased significantly as the demand for nontraditional warfare emerged. Traditional kinetic weapons often are of limited value in peace-keeping missions, for example, as today's enemies frequently are embedded within civilian populations and structures. This creates the need for novel HPM technologies that minimize the risk of collateral damage while effectively neutralizing threats. Dahlgren researchers conduct HPM system research and development—as well as lethality and weapon effectiveness assessments—to address this need while developing technologies against a wide variety of electronic targets. These projects leverage NSWCDD's assets, including the Maginot' Open Air Test Site (MOATS), state-of-the-art RF diagnostics, and modeling and simulation tools to identify applications and platforms in which HPM technologies can be employed. Figure 2 shows a computer model of the MOATS facility and a modeling and

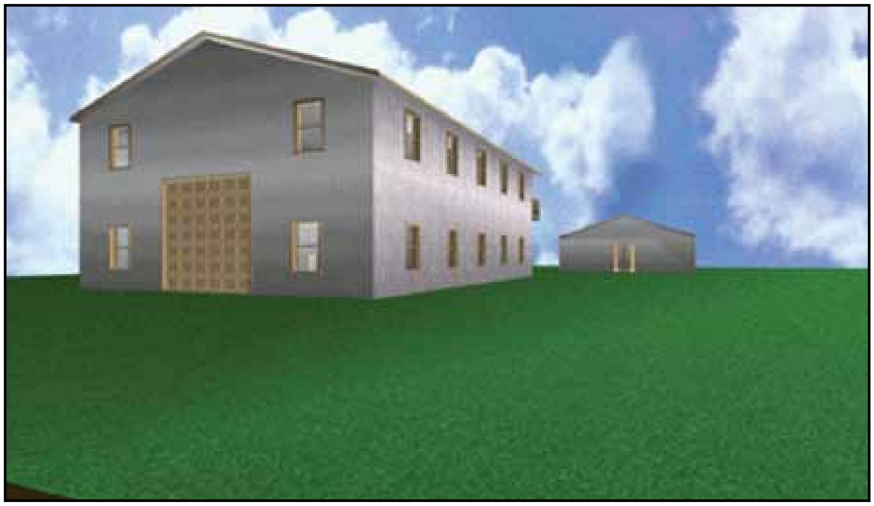
(a)

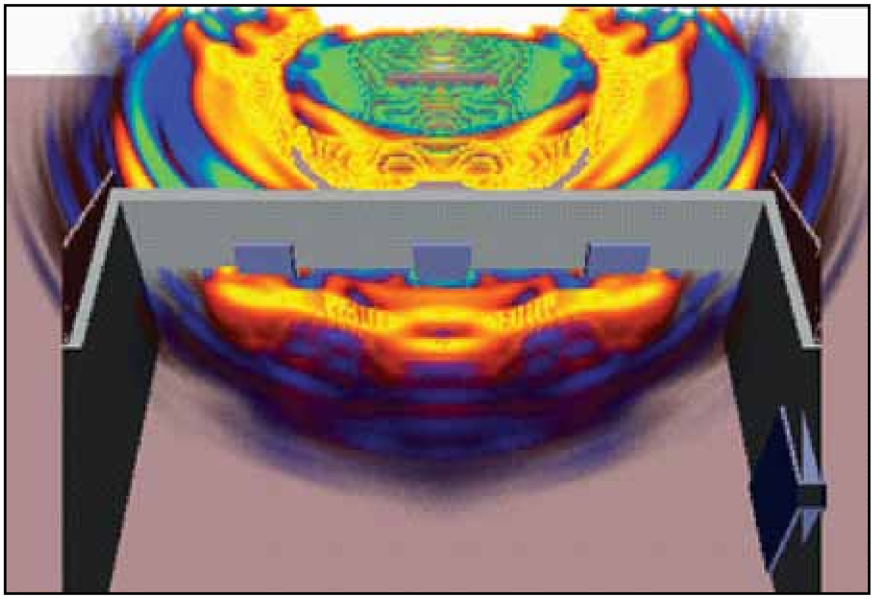
(b)

Figure 2. Modeling and Simulation Depicting (a) NSWCDD Test Facility and (b) Simulation of Radiated RF

simulation graphic depicting the RF emitted by an HPM dipole antenna.

Potential platforms for HPM integration include: man-portable, aerial, vehicle, and vessel-mounted systems. These platforms all provide unique methods for delivery of HPM sources. For example, aerial delivery—which, in many ways, is the most challenging due to size and weight constraints—can increase the effective range of these systems and can engage multiple targets at close range without endangering personnel. Likewise, vehicles and vessel-mounted HPM systems provide a way for law enforcement and the military to stop vehicles in chase scenarios almost as soon as they begin. The goal of all of these projects is to provide military forces with the ability to employ nonkinetic, electronic strike technologies against an adversary's electronics.

The DEWO and Directed Energy Division are uniquely positioned to provide numerous capabilities for in-house development while engaging with the private sector to test and provide feedback on HPM systems developed externally. In the past decade, NSWCDD has evaluated several HPM systems at Dahlgren to determine their effectiveness against various electronic targets while maintaining the Office of the Secretary of Defense's Tri-Service RF Directed Energy Weapon (DEW) Database. This database contains all effects data collected from directed-energy tests performed within the U.S. Air Force, Army, and Navy.

Conclusion

NSWCDD continues to pioneer HPM source development and lethality and integration studies, leading to the demonstration and delivery of prototype capabilities. It also is committed to researching and developing critical subsystems for HPM delivery. By leveraging numerous target assets and sophisticated diagnostic equipment—in conjunction with MOATS—NSWCDD has positioned itself at the forefront of HPM electronic attack, leading the way in the development and delivery of these capabilities to the warfighter.

Acknowledgment

Nancy Muncie, Bowhead, contributed to this article.

LASER COUNTER ROCKET, ARTILLERY, AND MORTAR (C-RAM) EFFORTS

By Michael Libeau

Mortars and rockets are common weapons confronting U.S. troops abroad. Insurgents fire the inexpensive projectiles into populated areas, intending to kill or injure service members and to inflict physical damage. While kinetic solutions like guns and missile interceptors are used to counter rockets and mortars, laser counter rocket, artillery, and mortar (C-RAM) systems present a promising solution to counter these challenging threats in the near future.

Scientists and engineers at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) have been researching, developing, testing, and evaluating laser C-RAM systems through collaboration, modeling and simulation, and experimentation. The Joint Technology Office (JTO) and the Directed Energy and Electric Weapons Program Office (PMS 405) sponsored the first year of these initiatives in 2007. Consecutive and current work has been sponsored by the Office of Naval Research (ONR) Expeditionary Maneuver Warfare and Combating Terrorism S&T Department.

BACKGROUND

In preparation for the development of a laser C-RAM system, an understanding of the vulnerability of rockets and mortars to laser energy was crucial. Engineers from NSWCDD and the U.S. Army Space and Missile Defense Command (SMDC) collaborated on laser C-RAM efforts. Engineers analyzed the RAM threat and examined a variety of targets, accessing RAM vulnerabilities to laser energy by utilizing theoretical, numerical, and experimental work. They then developed theoretical models that captured the physics of the laser-induced failures of targets containing high explosives (HE). Additionally, NSWCDD engineers enhanced lethality simulations using a tool called the Effectiveness Toolbox to model engagements of RAM targets with laser energy. Figure 1 shows a screen capture from the Effectiveness Toolbox.

The resulting simulations included results from a laser atmospheric propagation model and a thermal model to determine the effect of the laser energy on the target. The simulations also incorporated target trajectories necessary for modeling the changing laser conditions on the target resulting from the engagement of a ballistic target. Subsequent to modeling these effects, live testing was performed. Figure 2 shows the lasing and destruction of a RAM target during live testing.

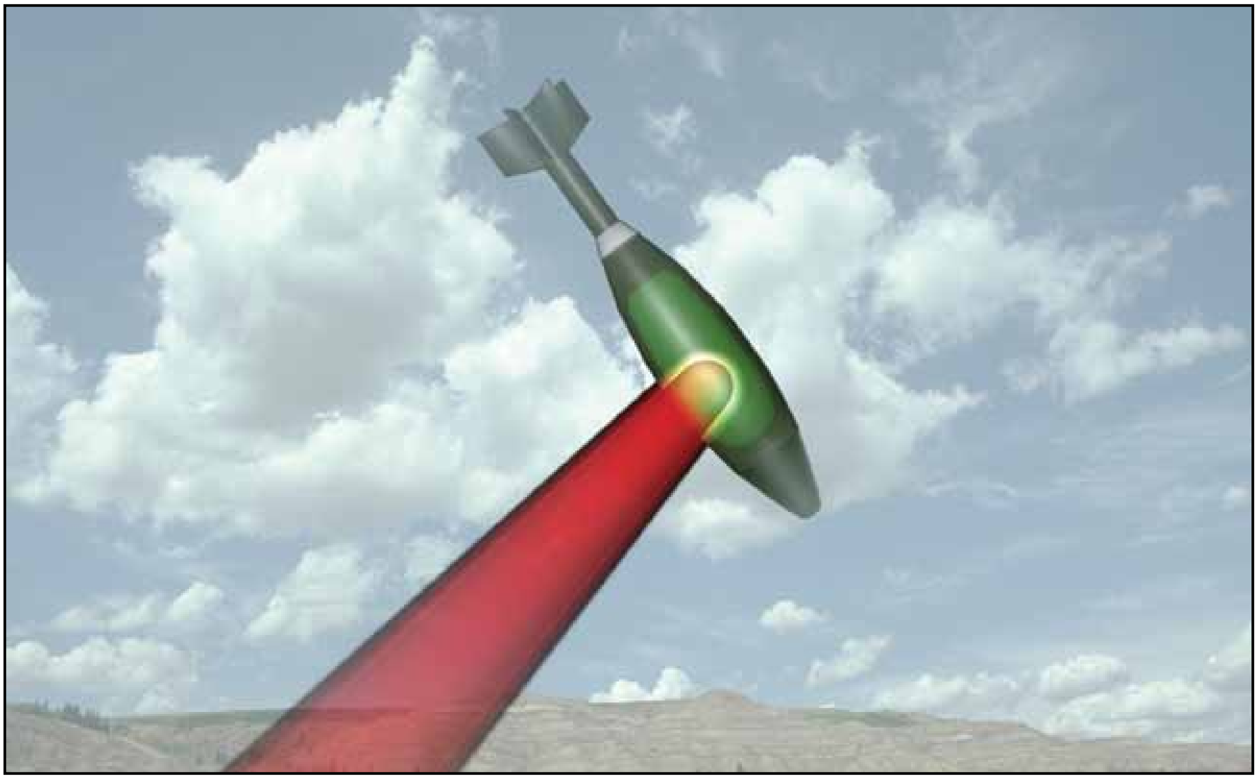

Figure 1. Screen Capture from the Effectiveness Toolbox Showing the Laser Engagement of a Mortar Target

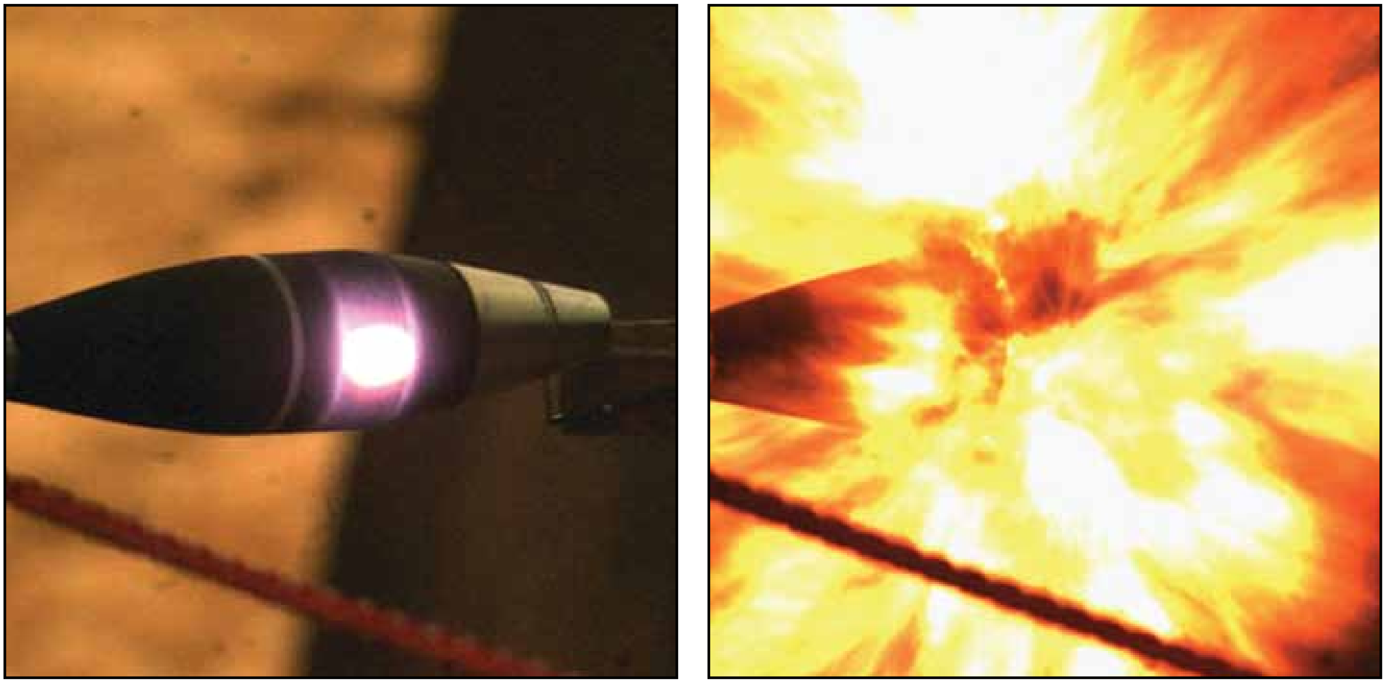

Figure 2. Explosive Target is Destroyed with NSWCDD's Fiber Lasers

NSWCDD engineers conducted two large experimental tests to determine the vulnerability of HE targets to laser energy using NSWCDD's High-Energy Fiber lasers. The first test was conducted jointly with SMDC. During these two tests, over 40 RAM targets were destroyed under different laser conditions, producing significant information on laser lethality. Researchers measured the failure times of multiple targets for different laser powers, spot sizes, incidence angles, and aimpoints. The experimental data yielded by the tests increased engineers' understanding of the vulnerability of targets containing energetic materials. This data was then used to benchmark predictive models.

Future tests are planned with additional HE targets to further the knowledge of RAM vulnerability. These tests are controlled and conducted carefully to ensure that good data is obtained. Accurate measurements of laser power on the target and the resulting target failure times must be made during the tests. To that end, NSWCDD engineers leverage Division-wide expertise in lasers and optics with its long history of explosives testing to achieve meaningful test results. NSWCDD personnel have been instrumental in improving techniques to measure the spatial profile of laser power on a target. The spatial distribution of laser power on a target is critical to understanding the target's failure. Figure 3 shows a laser beam's spatial power distribution measured during a test.

ONGOING LASER C-RAM INITIATIVES

Recent advances in fiber lasers have increased the power outputs of these rugged, solid-state devices. Both government and contractor efforts are examining the application of commercial off-the-shelf (COTS) lasers and other electric lasers for application into advanced weapon systems. The Navy's Laser Weapon System (LaWS) Program, for example, is examining a laser system built around efficient fiber lasers. This is significant because a high-energy fiber laser system offers two critical advantages over gun and missile interceptor C-RAM systems. First, the laser has a great depth of magazine since it requires only electricity for operation. Consequently, unlike a gun system, which has a limited supply of ammunition, a laser system is limited only by its supply of electrical energy. Second, a laser system offers a cost per kill that is significantly lower than alternative systems because only electricity is being expended instead of gun ammunition or a costly missile interceptor. This low cost per kill also better matches the low cost of the RAM target being engaged.

High-Energy Fiber Laser C-RAM systems will provide significant advantages in defeating the RAM threat while augmenting existing C-RAM solutions. More importantly, laser C-RAM systems will help protect members of the armed forces from the inexpensive, yet often deadly threats posed by rockets and mortars.

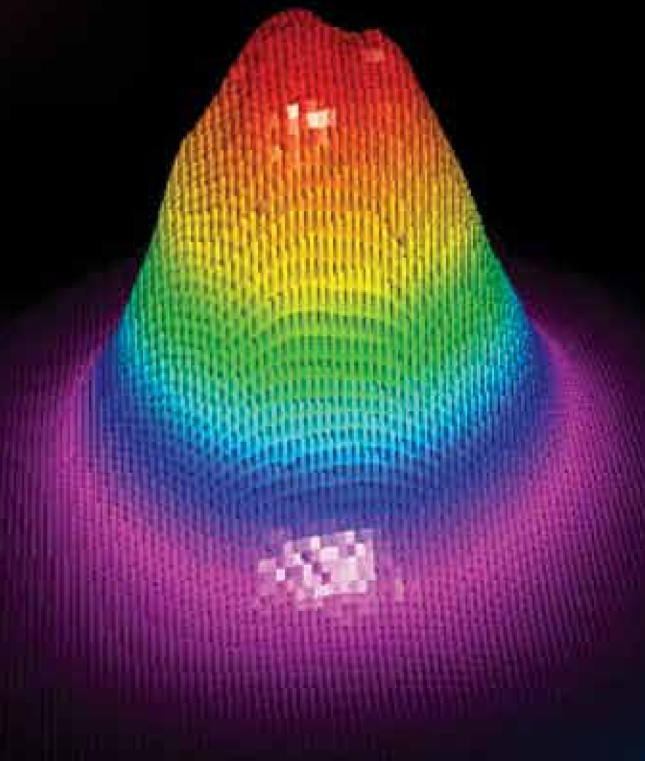

Figure 3. Laser Power Spatial Variation from a C-RAM Test

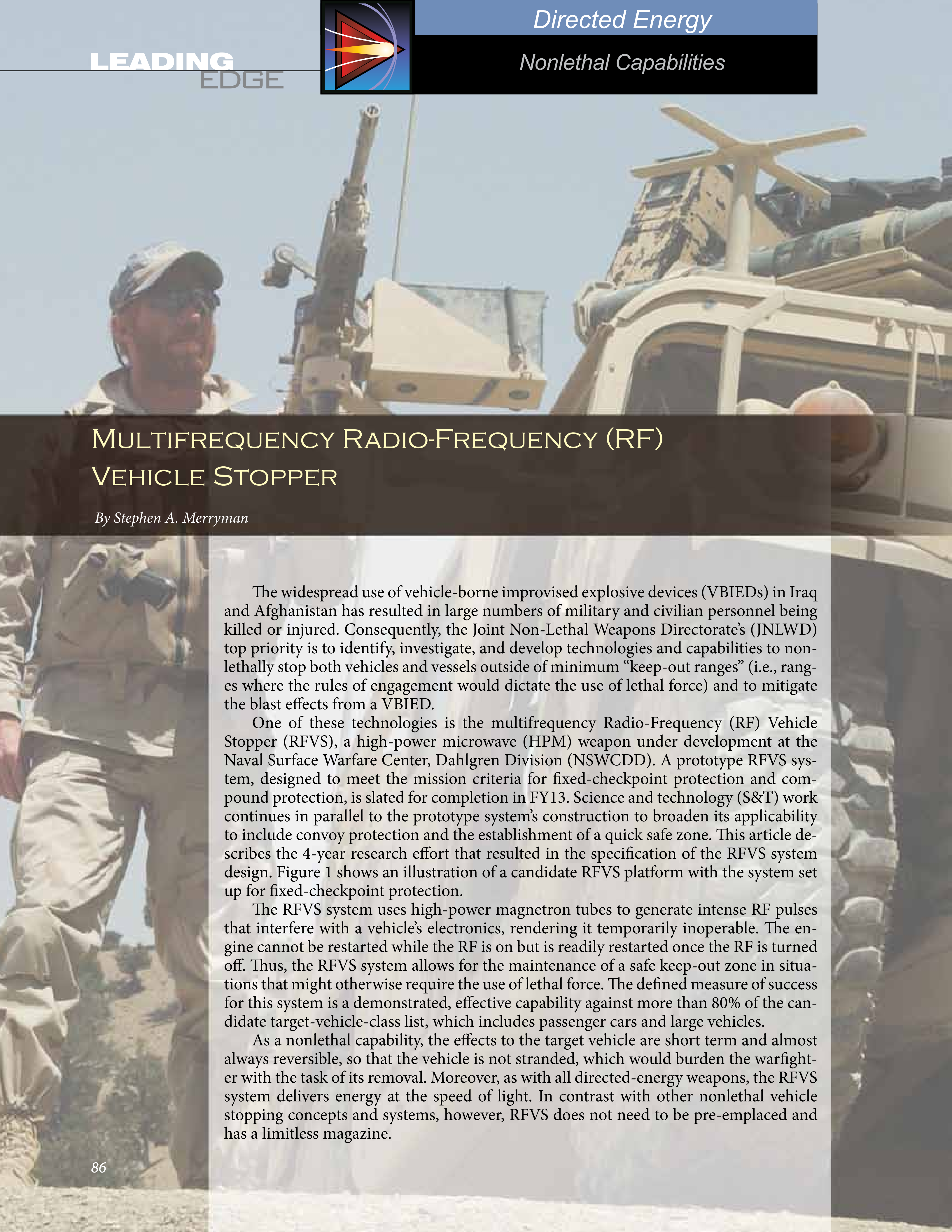

MULTIFREQUENCY RADIO-FREQUENCY (RF) VEHICLE STOPPER

By Stephen A. Merryman

The widespread use of vehicle-borne improvised explosive devices (VBIEDs) in Iraq and Afghanistan has resulted in large numbers of military and civilian personnel being killed or injured. Consequently, the Joint Non-Lethal Weapons Directorate's (JNLWD) top priority is to identify, investigate, and develop technologies and capabilities to non-lethally stop both vehicles and vessels outside of minimum "keep-out ranges" (i.e., ranges where the rules of engagement would dictate the use of lethal force) and to mitigate the blast effects from a VBIED.

One of these technologies is the multifrequency Radio-Frequency (RF) Vehicle Stopper (RFVS), a high-power microwave (HPM) weapon under development at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD). A prototype RFVS system, designed to meet the mission criteria for fixed-checkpoint protection and compound protection, is slated for completion in FY13. Science and technology (S&T) work continues in parallel to the prototype system's construction to broaden its applicability to include convoy protection and the establishment of a quick safe zone. This article describes the 4-year research effort that resulted in the specification of the RFVS system design. Figure 1 shows an illustration of a candidate RFVS platform with the system set up for fixed-checkpoint protection.

The RFVS system uses high-power magnetron tubes to generate intense RF pulses that interfere with a vehicle's electronics, rendering it temporarily inoperable. The engine cannot be restarted while the RF is on but is readily restarted once the RF is turned off. Thus, the RFVS system allows for the maintenance of a safe keep-out zone in situations that might otherwise require the use of lethal force. The defined measure of success for this system is a demonstrated, effective capability against more than 80% of the candidate target-vehicle-class list, which includes passenger cars and large vehicles.

As a nonlethal capability, the effects to the target vehicle are short term and almost always reversible, so that the vehicle is not stranded, which would burden the warfighter with the task of its removal. Moreover, as with all directed-energy weapons, the RFVS system delivers energy at the speed of light. In contrast with other nonlethal vehicle stopping concepts and systems, however, RFVS does not need to be pre-emplaced and has a limitless magazine.

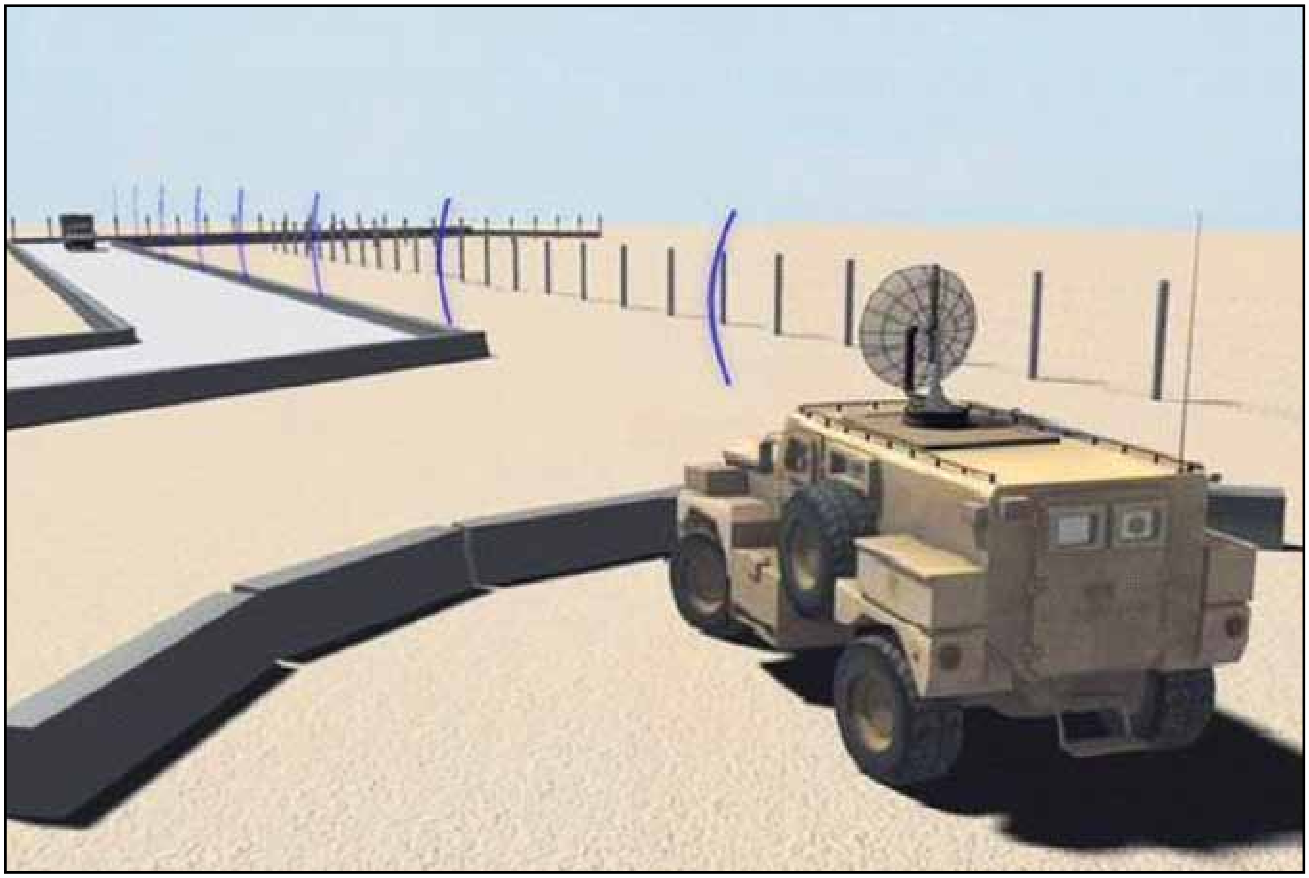

Figure 1. Illustration of Candidate RFVS System Setup for Checkpoint Protection

BACKGROUND

Using HPM or RF energy to stop an automobile engine is not a new concept; it has been under investigation for some time in private, academic, and military sectors. To that end, the RFVS program leveraged as much historic work as possible while collaborating with academic and military laboratories and while aggressively pursuing contacts in the automobile industry to gain knowledge of vehicle electronic design and function.

In 2005, the JNLWD funded the then-Directed Energy Technology Office (DETO) at NSWCDD to perform an extensive reverberation chamber test series to characterize the vulnerability of a representative cross section of automobiles to a wide range of HPM source frequencies.[a] The purposes of the tests were twofold. First, the applicability of the Army's Ground Vehicle Stopper (GVS) data set needed to be established for newer vehicles, and second, a thorough, source-technology independent assessment of vehicle vulnerabilities needed to be performed. The rationale behind the latter was to establish vehicle vulnerabilities without inadvertently biasing the process. Only after the full assessment was performed would factors such as concept of operations (CONOPS) and system requirements come into play. Figure 2 is a photograph of reverberation chamber testing.

Over the past decade, a significant number of private, academic, and military laboratories have investigated the susceptibility of automobiles to HPM energy. The range in approaches spans the gamut from isolated component testing, through direct injection and radiated testing of electronic control units (ECUs), and continuing through full vehicle radiated testing. Each of the different test methods has its strengths and weaknesses. Testing of isolated ECUs in controlled laboratory conditions is arguably the best way to determine exactly how a specific unit is responding to the RF. However, whether or not the identified susceptibilities continue to hold true when the unit is in place in a

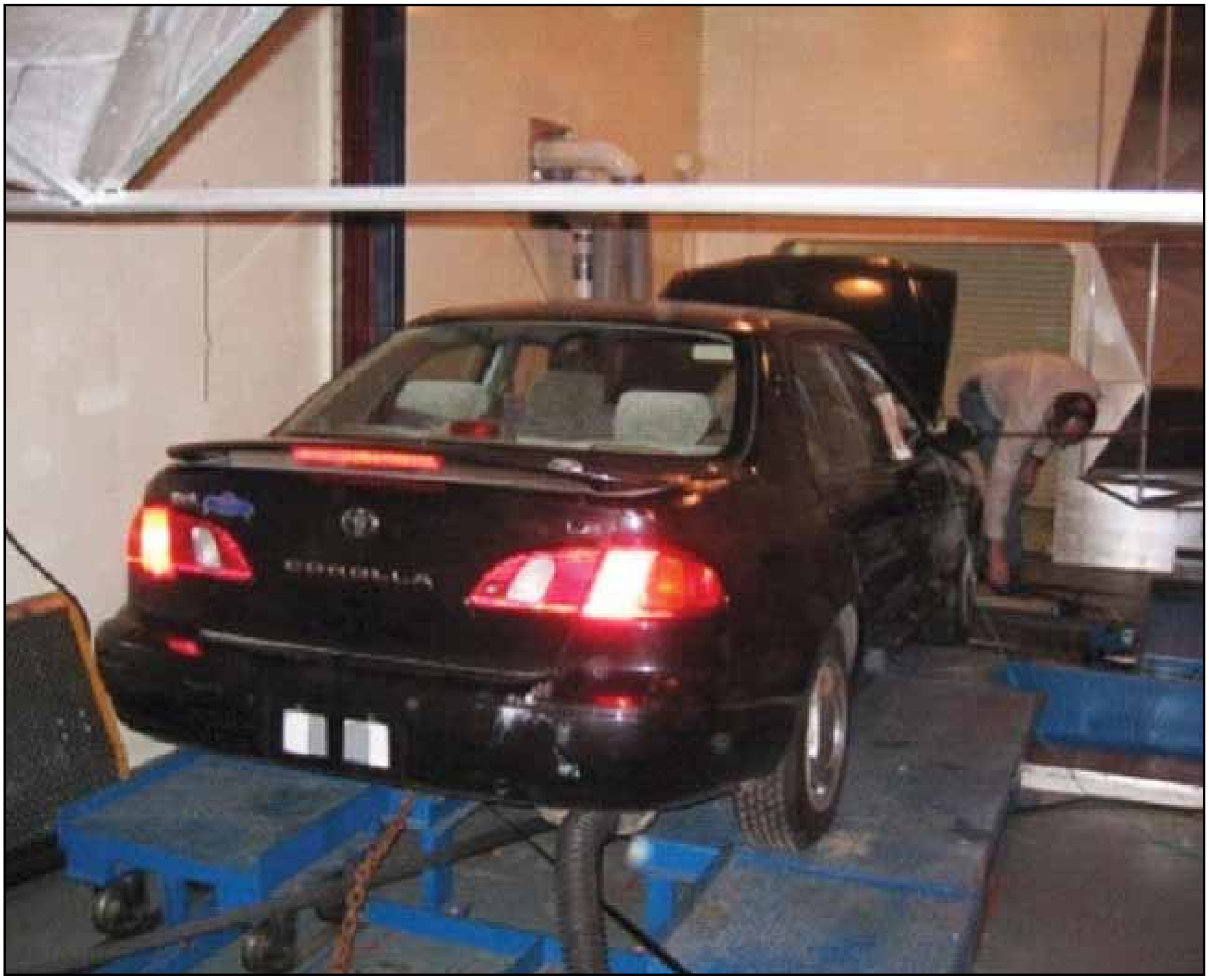

Figure 2. Vehicle on a Dynamometer in the NSWCDD Reverberation Chamber

vehicle, or whether the results apply to other vehicles' ECUs, remains a significant question that limits the applicability of the results.

Full vehicle testing and failure analysis of the ECU can be a daunting task. That said, full vehicle testing affords the advantage of ensuring that the response is commensurate with expectations of genuine engagements. The test approach one chooses to take depends upon resources, test facility availability, and most importantly, the objectives of the program. For the RFVS program, the objectives were to identify an HPM waveform that is effective against a broad class of the candidate target vehicles and to ensure that the identified waveform could be generated with a source that can be packaged in a footprint and cost amenable to military users. To meet the program's objectives, the RFVS program chose to invest the majority of its resources in full vehicle testing. While the focus of the effects testing portion of the RFVS program has remained on full vehicle testing, both time and resources have been devoted to fostering and maintaining connections with academia and the auto industry. There is concerted effort to keep abreast of the latest trends in automotive technology, to ensure that the current RFVS system design will continue to be effective against future vehicle designs, and to leverage all research that might aid in future RFVS designs.

SYSTEM OPERATION

The majority of current HPM system concepts employ a narrowband, single-frequency HPM source. In contrast, RFVS utilizes multiple HPM frequencies. The rationale for using multiple frequencies is associated with increased system effectiveness. Electromagnetic (EM) energy can be used to disrupt or damage an electronic target. In order for the energy to affect the electronics, however, it must be able to reach a critical component(s) inside the target. This involves a process referred to as coupling. Different EM waveforms are more or less effective against specific targets depending, in part, on their frequency, as different frequencies couple better or worse depending on varying target geometries. To be specific, each piece of electronics has specific resonance frequencies that most effectively facilitate coupling energy to the target. Unfortunately, these resonant frequencies can be unique to each piece of equipment. Consequently, a single-frequency waveform might be very effective against one target, but less effective against another target. Therefore, a system that utilizes either a sweep of frequencies or multiple frequencies will be more effective against a larger target set. This is not a novel idea, but rather one that has been readily acknowledged within the HPM community for some time and fervently embraced by the RFVS program. Current technology limitations prohibit high-power-swept frequency sources as viable options, leading to the idea of a multifrequency source. The more frequencies that are used, the more effective the system; however, a trade-off is made with system size and cost as the number of source frequencies is increased.

BRASSBOARD SYSTEM

After completion of the exhaustive vehicle effects characterization testing in 2006, the RFVS program identified the optimal number of frequencies needed to meet mission requirements. It then used this information in the design and construction of the Brassboard System. The purpose in constructing the Brassboard System was to demonstrate the benefit of the multifrequency approach and the ability to meet mission objectives with specified power on target requirements. Construction of the RFVS Brassboard System began in 2007 and was completed in 2008. The Brassboard System was not constructed with specific system footprints in mind. Thus, the antenna and conex used are significantly larger than those in the prototype design. The RFVS team collaborated with a Marine Corps service representative identified by the JNLWD to flesh out the specifics of the mock checkpoint to be used in the RFVS Brassboard System Demonstration. Figure 3 provides a diagram of the checkpoint setup used in the RFVS Brassboard Demonstration. Figure 4 provides photographs of the RFVS Brassboard System.

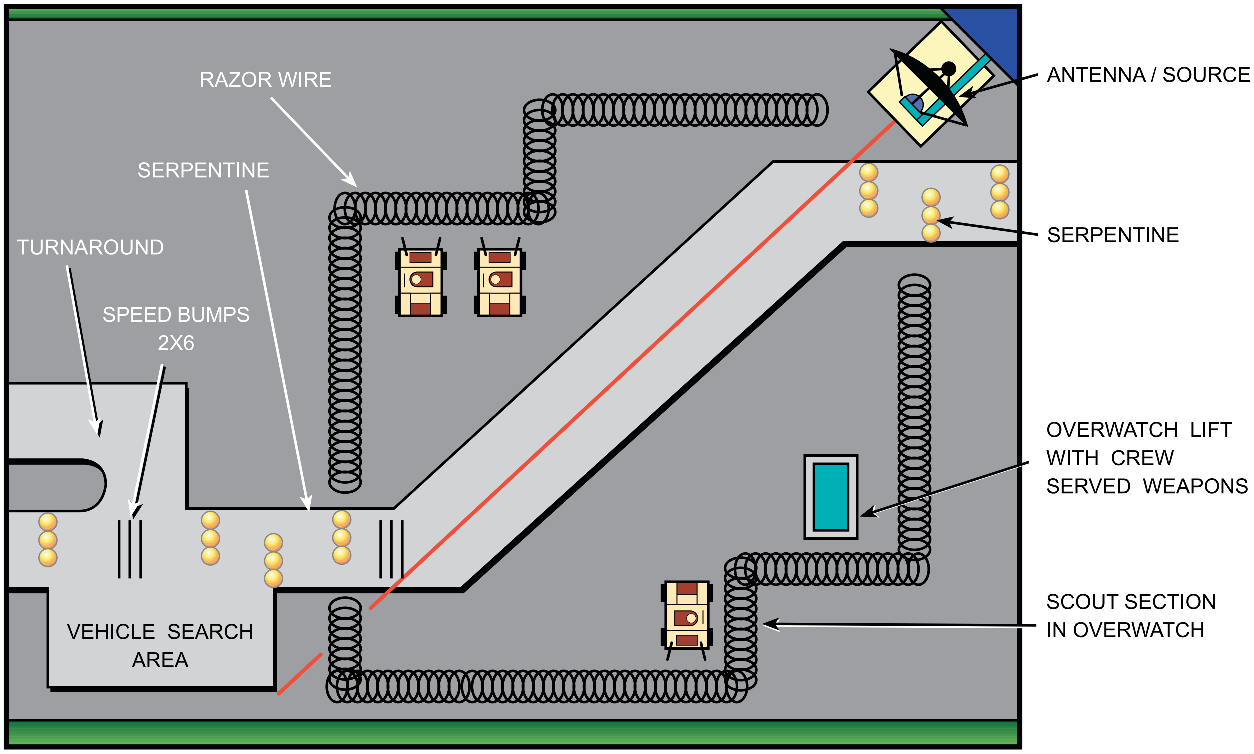

Figure 3. Schematic of Checkpoint Setup

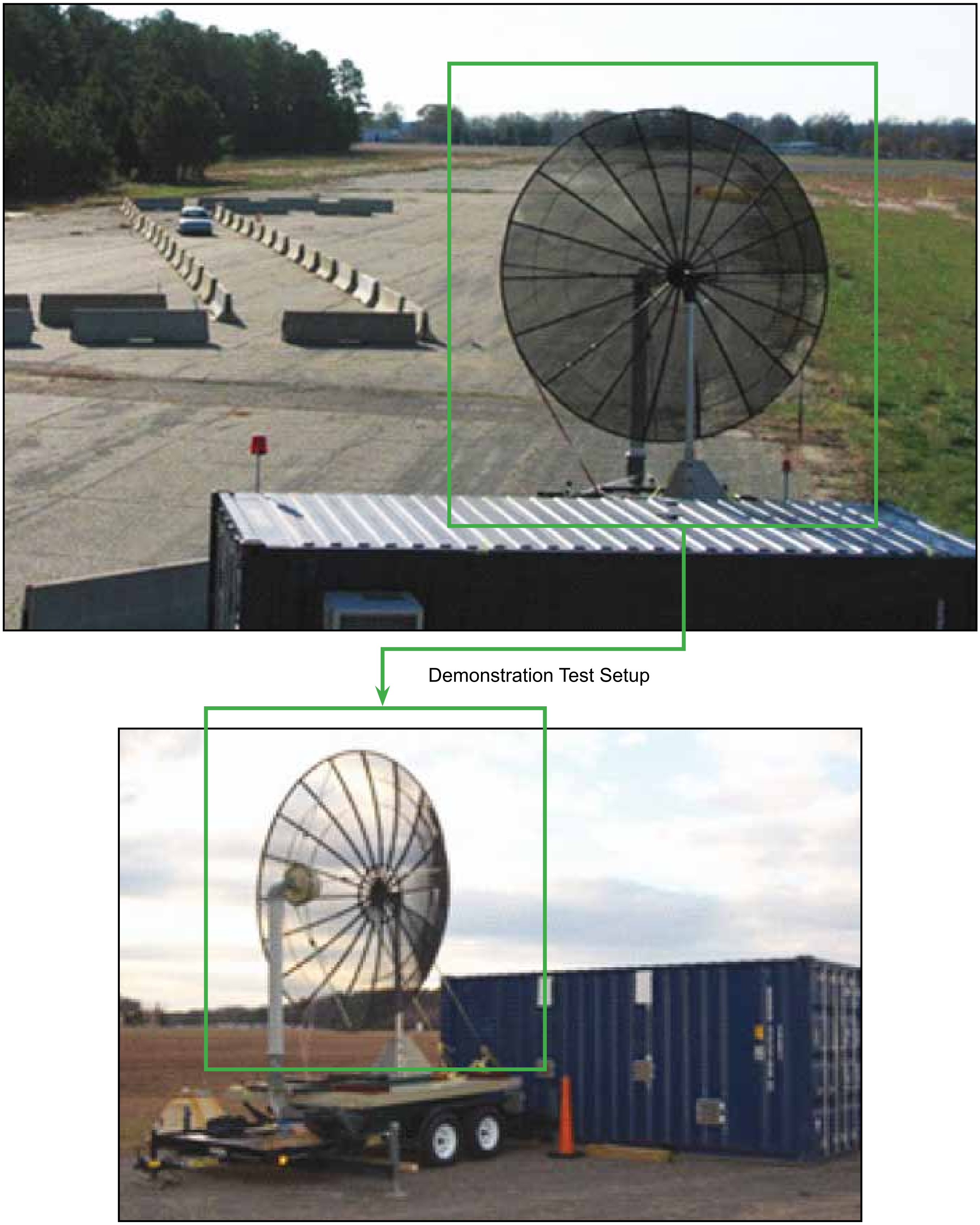
Demonstration Test Setup

Figure 4. Photograph of the RFVS Brassboard System and Demonstration Setup

The Brassboard System Demonstration was conducted in Spring 2008. The Demonstration was a success, and funding for the RFVS prototype was consequently approved. To date, 42 passenger vehicles (cars, pickup trucks, vans, and sport utility vehicles (SUVs)) and 3 large trucks (dump truck and tractors) have been tested as part of the RFVS program.

WAY AHEAD

The JNLWD continues to work with the Directed Energy Warfare Office (DEWO) toward the development of a fieldable multifrequency RFVS system. Once the capability is fully developed, tested, and certified ready for operational use, warfighters and civilians alike will benefit greatly. Lives will no doubt be saved using the ability to stop vehicles nonlethally and mitigate the blast effects from VBIEDs.

ACKNOWLEDGMENT

Dr. Cynthia Ropiak (SAQ Consulting) contributed to this article.

ENDNOTE

a. The Directed Energy Technology Office (DETO) was renamed the Directed Energy Warfare Office (DEWO) in August 2009. For reference, see the charter for the DEWO, NSWCDD, 17 August 2009.

HIGH-POWER ELECTRICAL VEHICLE-STOPPING SYSTEMS

By Jordan Chaparro and Melanie Everton

The military needs devices that can safely and reliably stop or arrest vehicles. The primary concern is security at entry control points and vehicle check points similar to the one shown in Figure 1. In such scenarios, it is desirable to be able to stop unauthorized vehicles at predefined standoff ranges to protect personnel, equipment, and critical infrastructure.

Both the military and civilian law enforcement agencies face similar issues with chase scenarios, where concerns over bringing an offending vehicle to a stop without killing or injuring innocent civilians, or causing collateral damage, often prolongs high-speed pursuits. That said, currently employed nonlethal options for arresting vehicles have significant logistical limitations and carry a high cost per use.

The Naval Surface Warfare Center, Dahlgren Division's Directed Energy Warfare Office (DEWO), under the sponsorship of the Joint Non-Lethal Weapons Directorate (JNLWD), investigated compact systems designed to couple high-power electrical impulses to a target vehicle to stop its engine. Such systems are highly portable, can operate remotely, can be deployed quickly by a two-man team, and can engage hundreds of targets before requiring any significant maintenance.

SYSTEM OVERVIEW

Conceptually, electrical vehicle-stopping systems are fairly simple devices. The systems use several stages of energy compression to take a low-peak power source—like a battery pack—and create very intense, short-duration, oscillating electrical impulses. The block diagram, shown in Figure 2, illustrates the principal components of such a system.

A high-energy density, 300-V lithium battery pack, similar to what might be found in a hybrid vehicle, serves as the prime power source for the device. These batteries are capable of driving the system for hundreds of engagements before requiring recharge.

The direct current bus from the batteries is stepped up to several kilovolts in order to charge a capacitive voltage multiplier, such as a Marx Generator, Spiral Line Generator, or Tesla Transformer. Once triggered, these generators charge a resonant circuit to hundreds of kilovolts which, when switched, generate the desired oscillating waveform. Coupling this electrical pulse to a target may be accomplished by direct electrode contact, by radiating the waveform from a broadband antenna structure, or by a combination of both methods.

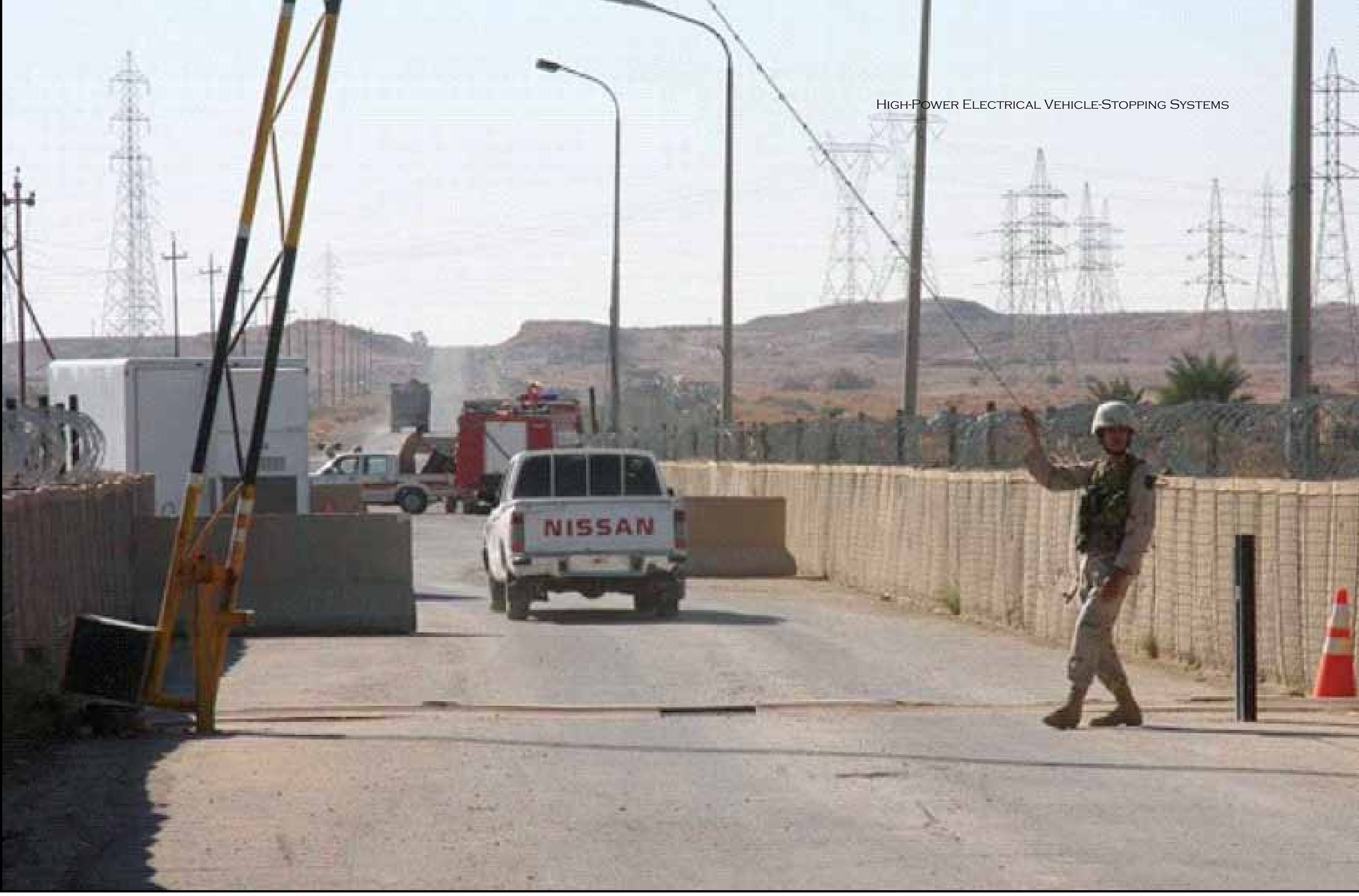

Figure 1. An Azerbaijani Soldier Guarding Entry Control Point 1 at the Haditha Dam in Support of Operation Iraqi Freedom

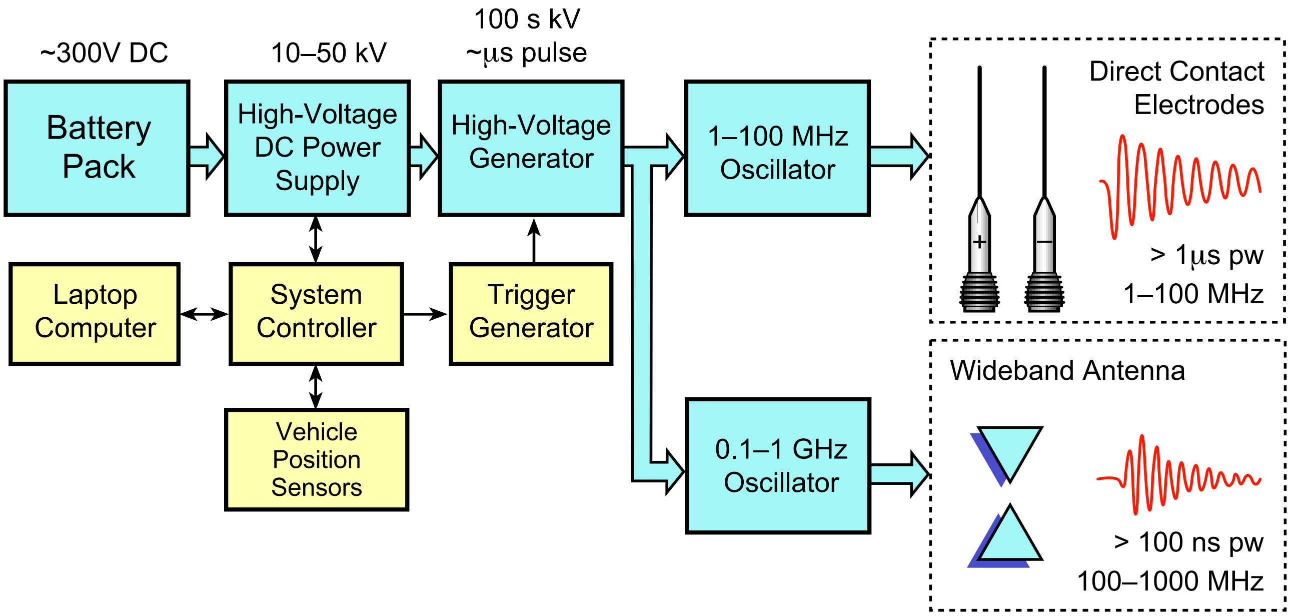
~300V DC
10–50 kV
100 s kV
~µs pulse
Battery Pack
High-Voltage DC Power Supply
High-Voltage Generator
1–100 MHz Oscillator
Direct Contact Electrodes
+
–
> 1µs pw
1–100 MHz
Laptop Computer
System Controller
Trigger Generator
Vehicle Position Sensors
0.1–1 GHz Oscillator
Wideband Antenna
> 100 ns pw
100–1000 MHz

Figure 2. System Block Diagram for Generic Electrical Vehicle-Stopping Systems

The system is monitored and controlled by an integrated system computer. A laptop computer, remotely connected to the system controller through either fiber optic or a wireless network, can be used to arm the system. At this point, motion detection sensors trigger the pulse train upon the targeted vehicle. The laptop can also be used to monitor the system's status, change system parameters, and receive data collected during the last engagement event.

A conceptual rendering of how such a system might look when in use is shown in Figure 3. Traffic would be funneled with barriers to a single lane. When not engaged, the system electrodes would sit flush with the roadway unit, with an exposed height of less than 3 inches. When required, the electrodes could be released to make contact with a vehicle's undercarriage and deliver the electrical impulses.

Comparison with Existing Systems

Tire spike systems are frequently employed but do not limit the momentum, drive, or control of a vehicle to an extent that could be useful in any type of control or checkpoint scenario. Consequently, while tire spike systems are primarily used in high-speed pursuit applications, they are limited, in that they cripple the target just enough to allow law enforcement to force the vehicle to a stop.

Restraining nets are most comparable to electrical vehicle stoppers with respect to their intended application and desired effect. Restraining net systems and electrical vehicle stoppers both completely arrest vehicles, although by different means. Restraining nets bind the front axle of the vehicle, causing it to forcibly lose momentum and skid to a stop. Thus, the vehicle operator loses the ability to steer the vehicle, further resulting in a lower potential for collateral damage. Electrical systems stop the engine of the vehicle, leaving the operator with control for the duration of the vehicle's momentum. Physical barrier structures can then be employed to force an affected vehicle to stop in a fairly short distance. Modern vehicles lose power steering when the engine is cut off, such that the maneuverability of the vehicle is limited enough to

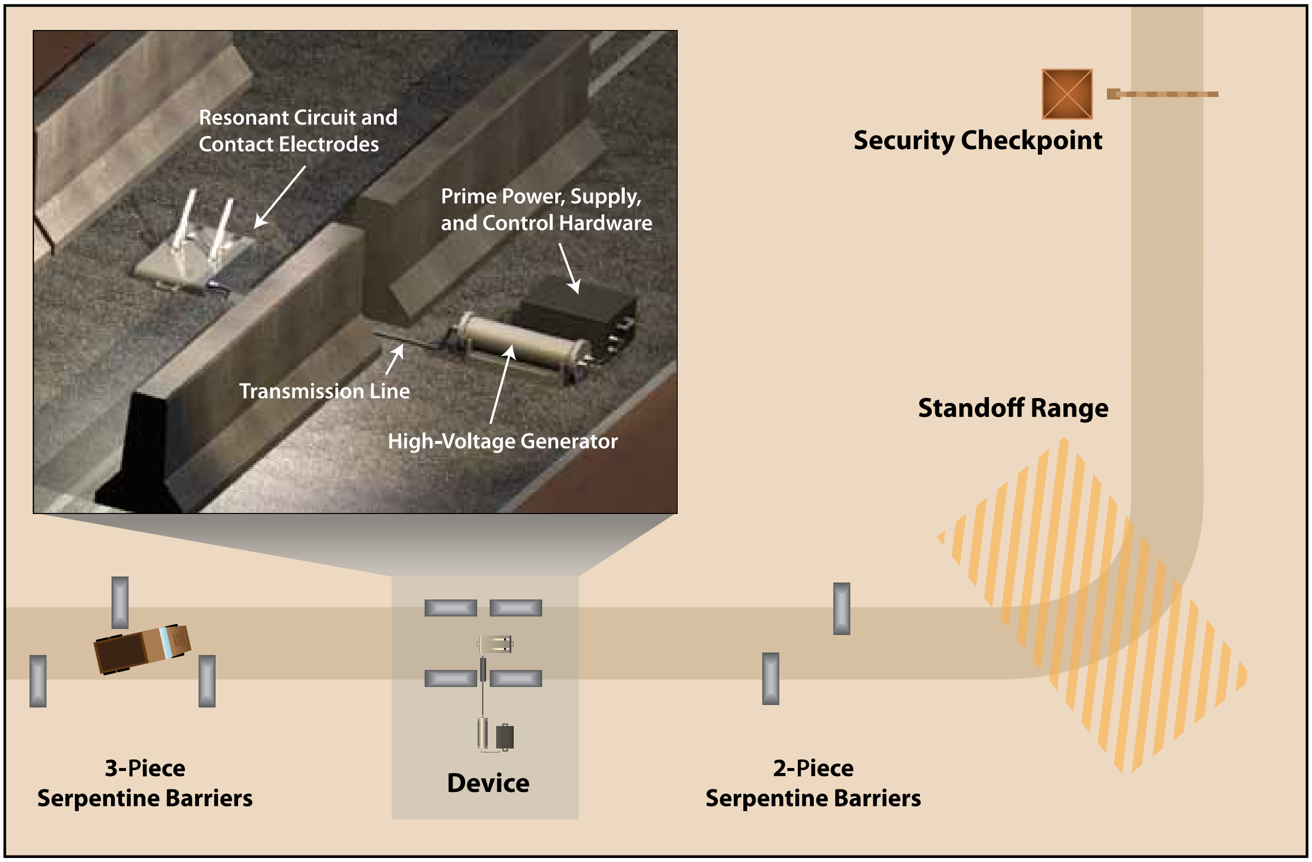
Resonant Circuit and Contact Electrodes
Prime Power, Supply, and Control Hardware
Transmission Line
High-Voltage Generator
Security Checkpoint
Standoff Range
3-Piece Serpentine Barriers
Device
2-Piece Serpentine Barriers

Figure 3. Conceptual Rendering of an Employed Electric Vehicle Stopping System

allow normally nonrestrictive serpentines to be effective at limiting roll-off distances.

One key logistical advantage of electrical vehicle stoppers, compared to restraining nets, is the average cost per engagement. Restraining net systems are one-time use devices that cost several thousand dollars each. Electrical systems initially cost tens of thousands of dollars but can perform thousands of stops within the expected lifetime of the device. Also, there is no requirement to physically reset or reload an electrical system, as with restraining nets. The maintenance required for electrical systems involves the occasional replacement of electrode arms and the inspection of the system connections and pressure levels.

Operationally, both systems have limitations on the types of targets that can be effectively stopped. Restraining nets are limited by vehicle momentum, which can be a product of high speeds or large vehicles. Electrical systems are not limited by vehicle size or speed, but they require additional support from structures—such as serpentines or speed bumps—to force the target to brake and dissipate its momentum once the engine has been stopped.

Both devices typically cause damage to targeted, stopped vehicles. Restraining nets almost always cause tire damage. Less commonly, brake lines, front axles, wheels, and transmissions also might be damaged. Electrical systems typically damage engine controllers, security modules, and engine sensors. In addition, noncritical parts—such as gauges, radios, and cabin fans—also might be damaged. Moreover, moving affected targets is much less of an issue with electrical stoppers than vehicles stopped by net systems, which must first have the net cut away and freed before the target is moved to the side of the roadway.

System Refinement and Look Forward

Previous attempts to field electrical vehicle-stopping systems have been hampered by limited success rates on a large population of vehicles. Many models of vehicles are easily affected by any type of large injected current, while others are fairly resistant. Through carefully designed and controlled experiments, and logistical regression modeling techniques, the DEWO team has been able to determine key waveform attributes that scale with stopping effectiveness rates on a representative population of vehicles. Successful stop rates exceeding 90 percent have been achieved on a diverse vehicle test set by engineering system resonators to enhance system performance The DEWO team, through continued research, testing, and evaluation, is continuing its work to increase the reliability and effectiveness of these systems to make them more compact and to improve their functionality for future military and law enforcement applications.

NONLETHAL SMALL-VESSEL STOPPING WITH HIGH-POWER MICROWAVE TECHNOLOGY

By Jacob Walker

The employment of small vessels to attack merchant ships and other seafaring units has emerged as a significant threat to international navigation and safe operations on the high seas. Along with swarm tactics, small vessels have been known to carry improvised explosive devices, help smuggle terrorists and weapons, and serve as attack platforms on the water for larger weapons. While kinetic solutions serve as the decisive option, alternative solutions that employ nonlethal means are being explored. A depiction of a swarm of small vessels ready to attack is shown in Figure 1.

The Naval Surface Warfare Center, Dahlgren Division's (NSWCDD's) Directed Energy Warfare Office (DEWO) is evaluating directed-energy (DE) concepts based on high-power microwave (HPM) technology for nonlethal vessel-stopping applications. Nonlethal weapons are defined by the Department of Defense (DoD) as weapons that are explicitly designed and primarily employed so as to incapacitate personnel or materiel while minimizing fatalities, permanent injury to personnel, and undesired damage to property and the environment.[1]

Several methodologies exist for using nonlethal means to stop small vessels. They include:

- Running-gear or prop entanglement systems
- Exhaust stack blockers
- A sea-anchor vessel-stopping system, which casts a net across the bow of a vessel to impart resistance
- Small-craft disablers, which insert a spear into the hull and deploy a fin that drags in the water, making steering impossible

Prop entanglement systems, exhaust stack blockers, and sea-anchor systems are useful and effective, but all are operationally difficult to deliver when deployment methods rely on positioning them in front of, or directly over, a vessel moving

Figure 1. Depiction of a Small-Vessel Swarm Ready to Attack

at high speeds. Small-craft disablers also are a formidable vessel-stopping solution and may be easier to deploy, but they cause permanent damage to the vessel in question.

Under the direction of the Joint Non-Lethal Weapons Directorate (JNLWD), the DEWO is in the initial stages of a multiyear effort to evaluate DE concepts for nonlethal vessel-stopping applications. It is currently focusing on HPM technology. This technology uses HPM sources to radiate radio frequency (RF) pulses downrange to interfere with motor-control electronics and significantly impede or stop small-vessel motors with minimal collateral damage. These RF pulses can be generated using different technologies ranging from wideband LC oscillators and microwave tubes (e.g., magnetrons, klystrons, and backward wave oscillators) to emerging solid-state technologies (e.g., nonlinear transmission line and photo-conductive switching). An outboard motor on a test stand is shown in Figure 2.

In comparison to kinetic weapons or other nonlethal systems, HPM avoids gross physical destruction to the vessel while, more importantly, providing zero-to-low risk of human injury. HPM accomplishes this at safe distances using speed of light delivery, therefore making evasion difficult, if not impossible, with the added benefit of scalable effects ranging from disruption to damage. Despite its numerous advantages, the use of HPM technology as a nonlethal weapon presents challenges as well, including a trade-off between system size and standoff range. This is particularly important when considering the use of HPM systems in different environments.

Upfront HPM source development costs represent one of the biggest challenges. However, long-term savings associated with HPM technology can offset this challenge. For example, prop entanglement systems might be deployed only once before they are rendered useless. HPM sources integrated onto a ship or other military vehicle can be employed in potentially thousands of missions, therefore resulting in a lower cost per single use, bringing overall associated costs of the system down significantly. Priorities for HPM nonlethal weapons include developing a system effective against different types of small vessels.

NSWCDD's Directed Energy Division began HPM susceptibility testing to determine the effectiveness of HPM weapons against relevant outboard engines. This involves testing small vessels in

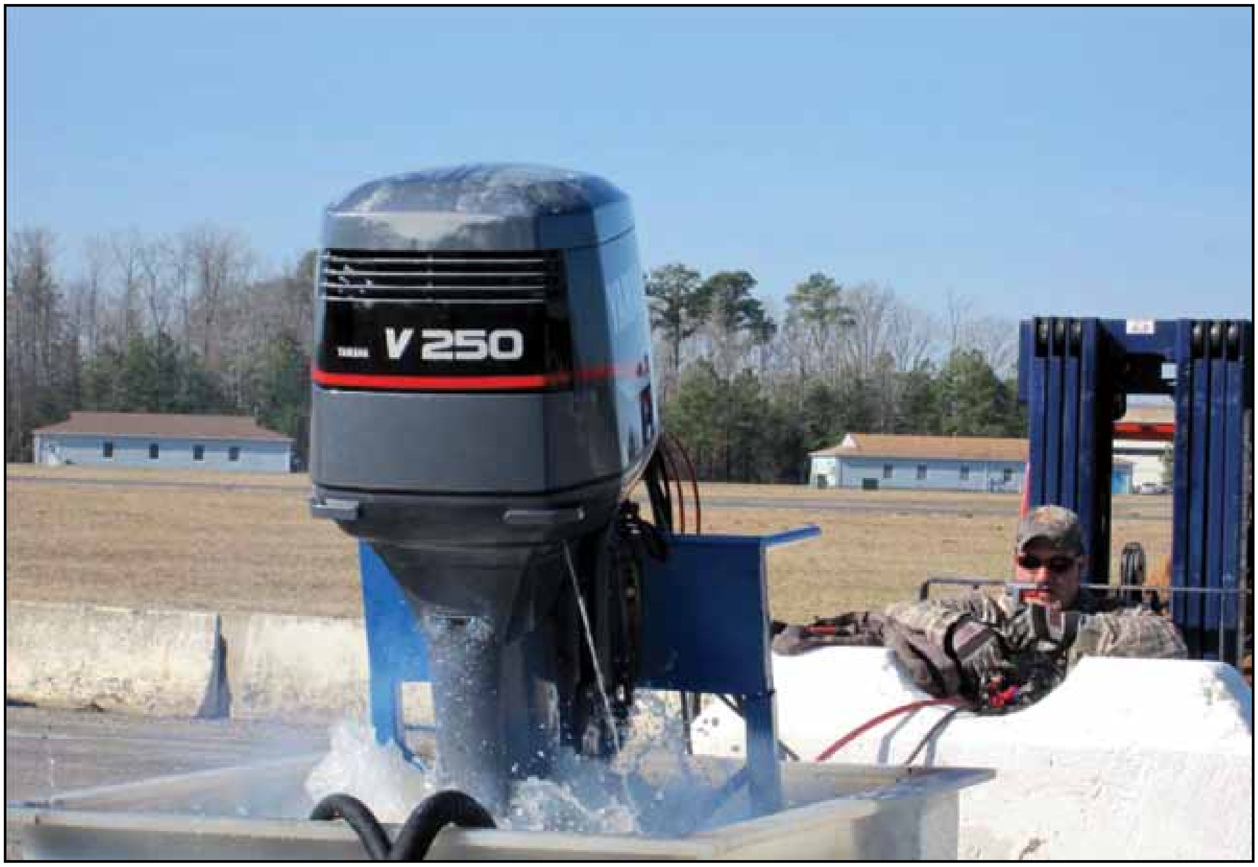

Figure 2. Outboard Motor Test Stand

a variety of environments, including reverberation and anechoic chambers, and open-air testing. All help identify different, effective waveform parameters such as frequency, pulse width, rise time, and required power or energy on target. They further facilitate the identification of design specifications necessary for an eventual HPM source. This source, once developed, will then be integrated into one of several potential platforms. Candidate concepts of deployment include U.S. Coast Guard and naval vessels in addition to unmanned surface or aerial vessels. Another potential application might be to supplement existing Coast Guard or Navy platforms used for fast-boat interdiction with an HPM vessel-stopping capability. A small-vessel test using an HPM source is shown in Figure 3.

Developing solutions for the growing threat that small vessels pose to navigation and safe operations in the world's oceans is one of JNLWD's top priorities. Using nonlethal HPM weapons to stop vessels will provide the warfighter with a viable option for swarm threat and fast-boat interdiction. DEWO is working diligently to accelerate this technology and provide a DE alternative to kinetic weapons and fulfill this long overdue capability gap.

Reference

1. *Department of Defense Dictionary of Military and Associated Terms*, Joint Publication 1-02, 12 April 2001 (as amended through 19 August 2009).

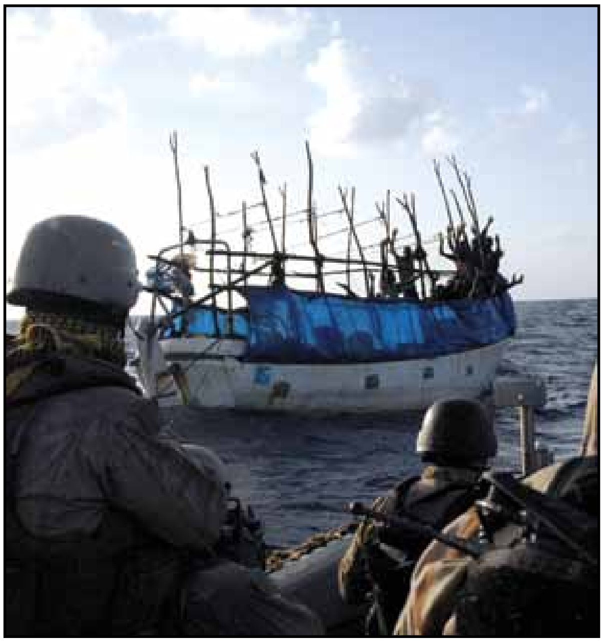

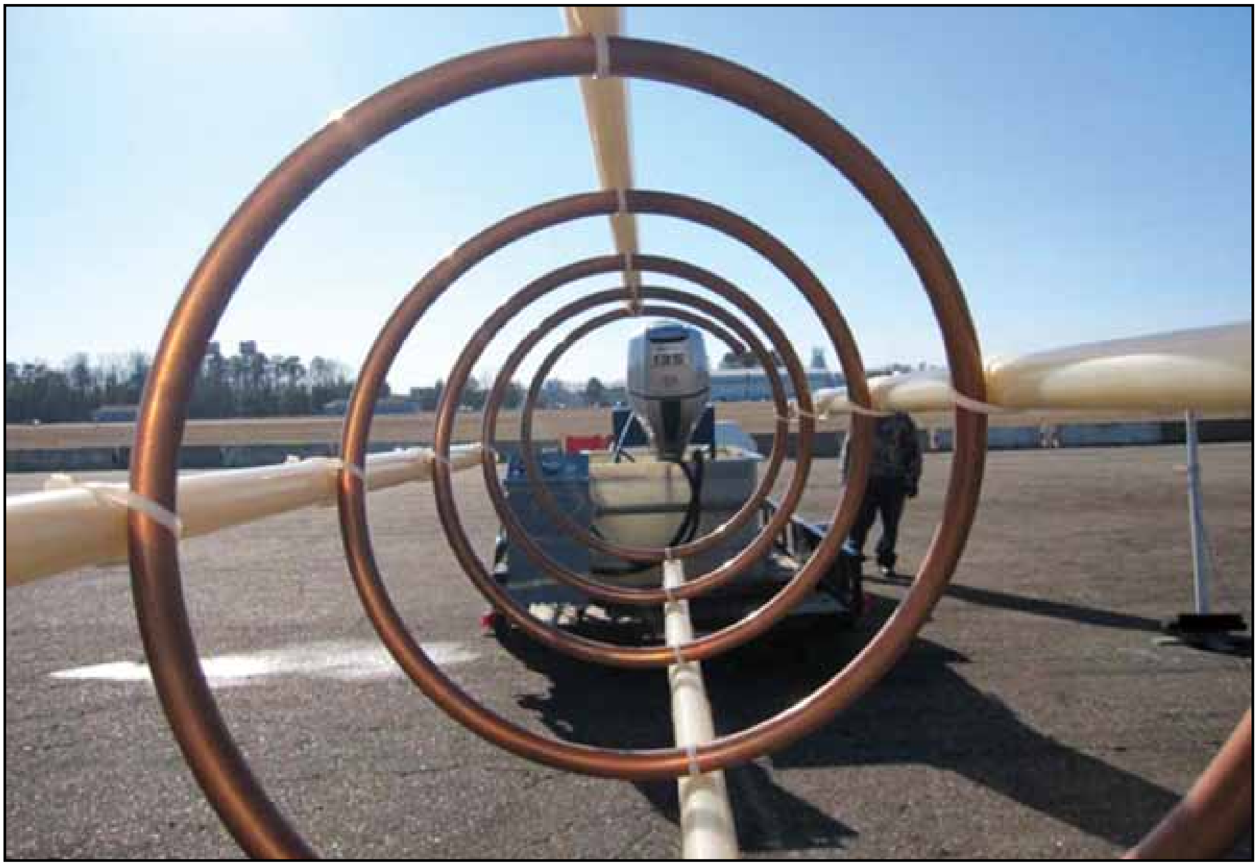

Figure 3. Small-Vessel Testing Using a High-Power Microwave Source

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Volume 7, Issue No. 4

Directed Energy

We look forward as we provide enterprise-wide technical and strategic leadership for the efficient and effective development, acquisition, and fielding of directed-energy systems for the warfighter.

Dale Sisson
Head, Electromagnetic and
Sensor Systems Department
NSWCDD, Dahlgren, Virginia

LEADING EDGE

Volume 7, Issue No. 4

Fallen Warriors

Here we honor those who died while serving their country

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Engineering Handbook

A Comprehensive Handbook for
Electronic Warfare and Radar Systems Engineers

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FOREWORD

This handbook is designed to aid electronic warfare and radar systems engineers in making general estimations regarding capabilities of systems. This handbook is sponsored by the NAVAIR Director of Electronic Warfare/Combat Systems Department. This fourth edition updates technical information in Sections 3-7 and 3-8 from previous editions.

This document was reviewed for technical accuracy by Dr. Andrew Chen.

Approved by
DR. R. E. SMILEY, *NAVAIR Director*
EW/Combat Systems Department
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Aircraft Dynamics, Antenna, Data Transfer Busses, Electro-Optics and Infrared, Ethernet, Internet Protocol, Maneuverability, Microwave Components, Polarization, Radar Equations, Radiation Patterns, Receiver Characteristics, Receiver Sensitivity, Receiver Tests, Radio Frequency Components, RS-232 Interface, RS-422 Balanced Voltage Interface, RS-485 Interface, Transmission Control Protocol

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ABBREVIATIONS AND ACRONYMS

a	Acceleration or atto (10^{-18} multiplier)
A	Ampere, Area, Altitude, Angstrom (Å), Antenna Aperture, or Aerial
A-799	No evidence of failure report
A/A, A-A, AA	Air-to-Air or Anti-Aircraft
AA-()	Air-to-Air missile number ()
AAA	Anti-Aircraft Artillery
AAAA	Army Aviation Association of America
AAED	Advanced Airborne Expendable Decoy
AAM	Air-to-Air Missile
AARGM	Advanced Anti-Radiation Guided Missile
AAW	Anti-Air Warfare
A-BIT	Automatic Built-in-Test
ABM	Air Breathing Missile or Anti-ballistic Missile
A/C	Aircraft (also acft.)
AC	Alternating Current
ACA	Associate Contractor Agreement or Airspace Coordination Area
ACAT	Acquisition Category
ACC	Air Combat Command
ACCB	Aircraft Configuration Control Board
Acft	Aircraft (also A/C)
ACLS	Aircraft Carrier Landing System
ACM	Advanced Cruise Missile or Air Combat Maneuvering
ACQ	Acquisition
ACS	Antenna Coupler Set
ACTD	Advanced Concept Technology Demonstration
A/D	Analog to Digital
ADM	Advanced Development Model
ADP	Automatic Data Processing or Advanced Development Program
AEA	Airborne Electronic Attack
AEC	Aviation Electronic Combat (Army)
AEGIS	Automatic Electronic Guided Intercept System
AEL	Accessible Emission Limit
AESA	Active Electronically Scanned Array
AEW	Airborne Early Warning
AF	Antenna Factor, Air Force, or Audio Frequency
AFB	Air Force Base or Airframe Bulletin
AFC	Automatic Frequency Control or Airframe Change
AFIPS	Automated Financial Information Processing System
AFOTEC	Air Force Operational T&E Center
A/G	Air-to-Ground
AGB	Autonomous Guided Bomb
AGC	Automatic Gain Control
AGI	Auxiliary General Intelligence (Intelligence-gathering Ship)
AGL	Above Ground Level
AGM	Air-to-Ground Missile
AGS	Angle Gate Stealer
AHWS	Advanced Helicopter Weapons System
AI	Artificial Intelligence, Air Intercept, or Airborne Interceptor
AIAA	American Institute of Aeronautics and Astronautics
AIC	Air Intercept Control
AIM	Air Intercept Missile
AIRLANT	Commander, U.S. Naval Air Forces, Atlantic Fleet
AIRPAC	Commander, U.S. Naval Air Forces, Pacific Fleet
AJ	Anti-jamming or Anti-Jam
A-Kit	Aircraft wiring kit for a system (includes cabling, racks, etc. excluding WRAs)
ALC	Air Logistics Center
AM	Amplitude Modulation
AMD	Aircraft Maintenance Department
AMES	Advanced Multiple Environment Simulator
AMLV	Advanced Memory Loader/Verifier
Amp	Amplifier
AMRAAM	Advanced, Medium-Range, Air-to-Air Missile
ANSI	American National Standards Institute
ANT	Antenna
Ao	Operational Availability
AO	Acousto-Optical
AOA	Angle of Arrival, Angle of Attack, or Analysis of Alternatives (similar to COEA)
AOC	Association of Old Crows (Professional EW Society) or Award of Contract
AOT	Angle Only Track, Angle Off Tail, or Acquisition-on-Target
APC	Amphenol Precision Connector or Armored Personnel Carrier
APN	Aircraft Procurement, Navy
APO	Armed Forces (or Army or Air) Post Office, Acquisition Program Office

APU	Auxiliary Power Unit
AR	Anti-reflection or Aspect Ratio
ARM	Anti-radiation Missile
ARO	After Receipt of Order
A/S, A-S, AS	Air-to-Surface
ASC	Air Systems Command
ASCM	Anti-ship Cruise Missile
ASE	Aircraft Survivability (or Survival) Equipment, Allowable Steering Error, or Automatic Support Equipment
ASIC	Application Specific Integrated Circuit
ASK	Amplitude Shift Keying
ASM	Air-to-Surface Missile
ASO	Aviation Supply Office
A-Spec	System Specification
ASPJ	Airborne Self-Protection Jammer
ASPO	Avionics Support (also Systems) Project Office (also Officer)
ASR	Advanced Special Receiver or Airport/Airborne Surveillance Radar
ASRAAM	Advanced Short Range Air-to-Air Missile
ASTE	Advanced Strategic and Tactical Expendables
ASW	Anti-submarine Warfare
ATA	Advanced Tactical Aircraft
ATARS	Advanced Tactical Air Reconnaissance System
ATC	Air Traffic Control
ATD	Advanced Technology Demonstration
ATE	Automatic Test Equipment
ATEDS	Advanced Technology Expendables and Dispenser Systems
ATF	Advanced Tactical Fighter (F-22)
ATIMS	Airborne Turret Infrared Measurement System or Airborne Tactical Information Management System
ATIRCM	Advanced Threat Infrared Countermeasures
ATP	Acceptance Test Procedure
ATR	Autonomous Target Recognition, Airborne Transportable Rack, Atlantic Test Range
ATRJ	Advanced Threat Radar Jammer
AUTODIN	Automatic Digital Network
AUX	Auxiliary
avdp.	Avoirdupois (system of measures)
Avg	Average
AWACS	Airborne Warning and Control System
AZ	Azimuth (also Az)
B	Bandwidth (also BW) or Magnetic inductance
BAFO	Best and Final Offer
BAU	Bus Adapter Unit
BC	Bus Controller
BDA	Battle Damage Assessment
BDI	Battle Damage Indication
BFO	Beat Frequency Oscillator
BI	Background Investigation
BIFF	Battlefield Identification, Friend, or Foe
BIT	Built-in-Test, Binary Digit or Battlefield Information Technology
BITE	Built-in-Test Equipment
BIU	Bus Interface Unit
B-Kit	Avionics "Black Box" WRAs
B/N	Bombardier/Navigator
BNC	Bayonet Navy Connector
BOA	Basic Ordering Agreement
BOL	Swedish chaff dispenser in a launcher
BPF	Band Pass Filter
BPS	Bits Per Second
BUMED	Bureau of Medicine (Navy)
BUNO	Bureau Number (aircraft)
BUR	Bottom Up Review
BVR	Beyond Visual Range
BW	Beamwidth (referring to an antenna) or sometimes Bandwidth
BWA	Backward Wave Amplifier
BWO	Backward Wave Oscillator
c	Speed of Light = $3\text{x}10^8$ meters/sec = $1.8\text{x}10^{12}$ furlongs per fortnight or 1.8 terafurlongs per fortnight, or centi (10^{-2}) multiplier
C	Electron Charge, Coulomb, Capacitance, Celsius, Centigrade, Confidential, Roman numeral for 100, or a programming language (also C+ and C++)
C^2	Command and Control
C^3 (C^4)	Command, Control, Communications (and Computers)
C^3I (C^4I)	Command, Control, Communications, (Computers) and Intelligence
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAG	Carrier Air Group
CAGE	Commercial and Government Entry
CAIV	Cost as an Independent Variable
CAL	Calibration

CAM	Computer-Aided Manufacturing or Constant Addressable Memory
CAO	Competency Aligned Organization or Contract Administrative Officer
CAP	Combat Air Patrol
CAS	Close Air Support or Calibrated Airspeed
CASS	Consolidated Automated Support System
CAT	Catapult or Cockpit Automation Technology
CB	Citizens Band (also see Seabee)
CBD	Commerce Business Daily
CBIT	Continuous Built-in-Test
CBO	Congressional Budget Office
CCA	Circuit Card Assembly
CCB	Configuration Control Board
CCD	Charge Coupled Device
CCM	Counter-Countermeasures
CCN	Contract Change Number or Configuration Change Notice
CCU	Cockpit Control Unit
cd	Candela (SI unit of luminous intensity)
CD	Compact Disk or Control and Display
CDC	Combat Direction Center
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CE	Conducted Emission
CECOM	Communications and Electronics Command (Army)
CEESIM	Combat Electromagnetic Environment Simulator
CEP	Circular Error Probability
CFA	Cognizant Field Activity
CFAR	Constant False Alarm Rate
CFE	Contractor Furnished Equipment
CG	Center of Gravity, Commanding General, Command Guidance, or Cruiser
CI	Configuration Item
CIA	Central Intelligence Agency
CIC	Combat Information Center (now called CDC)
CID	Combat Identification or Charge Injection Device
CILOP	Conversion in Lieu of Procurement
CINC	Commander in Chief
CIP	Capital Improvement Program
CIS	Commonwealth of Independent States (11 of 15 former Soviet Union territories except Estonia, Georgia, Latvia, and Lithuania)
CIWS	Close-In Weapon System
CJ	Coherent Jamming
CLC	Command Launch Computer
cm	Centimeter
CM	Countermeasures or Configuration Management
CMC	Command Mission Computer or Commandant Marine Corps
CMDS	Countermeasure Dispensing System
CMOS	Complementary Metal-Oxide Semiconductor
CMP	Configuration Management Plan
CMWS	Common Missile Warning System
CNAF	Commander, Naval Air Forces
CNAL	Commander, Naval Air Forces Atlantic (also COMNAVAIRLANT)
CNAP	Commander, Naval Air Forces Pacific (also COMNAVAIRPAC)
CNI	Communications, Navigation, and Identification
CO	Commanding Officer, Contracting Officer, Change Order, or Carbon Monoxide
COB	Close of Business
COCOM	Combatant Command
COEA	Cost and Operational Effectiveness Analysis
COG	Center of Gravity or Cognizant
COMM	Communications
COMSEC	Communications Security
CONSCAN	Conical Scanning Radar
CONUS	Continental United States
CO-OP	Cooperative (countermeasures)
COR	Contracting Officers Representative
CORPORAL	Collaborative On-Line Reconnaissance Provider/Operationally Responsive Attack Link
Cos	Cosine
COSRO	Conical-Scan on Receive Only
COTS	Commercial Off-The-Shelf (hardware/software)
CP	Circularly Polarized (antenna), Central Processor, or Command Post
CPS	Computer or Control Power Supply (depends on application)
CPU	Central Processing Unit
CRC	Originally Chemical Rubber Company, now published reference books by CRC Press
CRFM	Coherent RF Memory
CRISD	Computer Resources Integrated Support Document
CRLCMP	Computer Resources Life Cycle Management Plan

CRO	Countermeasures Response Optimization
CRT	Cathode Ray Tube or Combat Rated Thrust (afterburner)
CSAR	Combat Search and Rescue
Crypto	Cryptographic
CS	Conducted Susceptibility
CSC	Commodity Software Change
CSCI	Computer Software Configuration Item
C-Spec	Product Specification
CSS	Contractor Support Services
CTR	Chesapeake Test Range
CV	Aircraft Carrier
CVN	Nuclear Powered Aircraft Carrier
CVR	Crystal Video Receiver
CW	Continuous Wave or Chemical Warfare
CWBS	Contract Work Breakdown Structure
CWI	Continuous Wave Illuminator
CY	Calendar Year

d	Distance, Diameter, or deci (10^{-1} multiplier)
D	Distance, Diameter, Electron displacement, Detectivity, Doppler, Density, or Roman numeral for 500
da	deca (10^{0} multiplier)
D/A	Digital-to-Analog
DAB	Defense Acquisition Board
DAC	Digital to Analog Converter or Dept of Army Civilian
DAR	Defense Acquisition Regulation
DARPA	Defense Advanced Research Projects Agency
DB	Database
dB	Decibel
dBc	dB referenced to the Carrier Signal
dBi	Decibel antenna gain referenced to an isotropic antenna
dBm	Decibel referenced to the power of one milliwatt
DBOF	Defense Business Operations Fund
dBsm	Decibel value of radar cross section referenced to a square meter
dBW	Decibel referenced to the power of one watt
DC	Direct Current, Discrete Circuit, or District of Columbia
DCE	Data Communication Equipment
DCS	Direct Commercial Sales or Distributed Control System
DDI	Digital Display Indicator
DDS	Direct Digital Synthesizers
DECM	Deceptive Electronic Countermeasures (also Defensive ECM)
deg	Degree
DEMVAL	Demonstration Validation (also DEM/VAL)
DET	Detachment
DF	Direction Finding
DFT	Discrete Fourier Transform
DI	Data Item
DIA	Defense Intelligence Agency or Diameter
DID	Data Item Description
DIRCM	Directed Infrared Countermeasures
DJ	Deceptive Jamming
D-Level	Depot Level Maintenance
DM	Data Management (also manager)
DMA	Direct Memory Address or Defense Mapping Agency
DME	Distance Measuring Equipment
DNA	Defense Nuclear Agency, Does Not Apply, or Deoxyribonucleic Acid
DOA	Direction of Arrival
DOD or DoD	Department of Defense
DoDISS	DoD Index of Specifications and Standards
DOM	Depth of Modulation
DON	Department of the Navy
DOS	Disk Operating System
DOT&E	Director, Operational Test & Evaluation
DPRO	Defense Plant Representative Office
DRB	Defense Review Board
DRFM	Digital RF Memory
DSARC	Defense Systems Acquisition (and) Review Council
DSN	Defense Switching Network
DSO	Dielectrically Stabilized Oscillator
DSP	Digital Signal Processor
D-Spec	Process Specification
DT (&E)	Development or Developmental Test (and Evaluation)
DTC	Design to Cost
DTE	Data Terminal Equipment
DTO	Digitally Tuned Oscillator or Defense Technology Objectives
DTRMC	Defense (or DoD) Test Recourse Management Center

e	Electron charge or base of natural logarithms (2.71828...)
E	Electric Field Intensity or Strength, Energy, East, or Exa (10^{18} multiplier)
E^3	Electromagnetic Environmental Effects
EA	Electronic Attack (similar to older term of ECM)
EC	Electronic Combat
ECAC	Electromagnetic Compatibility Analysis Center (DOD), now Joint Spectrum Center
ECCM	Electronic Counter-Countermeasures (similar to newer term of EP)
ECL	Emitter Coupled Logic
ECM	Electronic Countermeasures (similar to newer term of EA)
ECN	Engineering Change Notice
ECO	Engineering Change Order
ECP	Engineering Change Proposal or Egress Control Point
ECR	Electronic Combat Range (China Lake) or Electronic Combat & Reconnaissance
ECS	Environmental Control System
ECSEL	Electronic Combat Simulation and Evaluation Laboratory
ECU	Electronic Control Unit
EDM	Engineering Development Model
EED	Electro-Explosive Device
EEPROM	Electrically Erasable/Programmable Read-only Memory
EHF	Extremely High Frequency [30 to 300 GHz]
EIA	Electronic Industries Associates
EID	Emitter Identification Data
EIRP	Effective Isotropic Radiated power
EL	Elevation (also El)
ELF	Extremely Low Frequency [3 Hz to 3 kHz]
ELINT	Electronics Intelligence
ELNOT	Emitter Library Notation
EM	Electromagnetic
E-Mail	Electronic Mail
EMC	Electromagnetic Compatibility
EMCAB	EMC Advisory Board
EMCON	Emission Control
EMD	Engineering and Manufacturing Development
EME	Electromagnetic Environment
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse
EMR	Electromagnetic Radiation
EMS	Electromagnetic Susceptibility, Electromagnetic Spectrum
EMV	Electromagnetic Vulnerability
EO	Electro-Optic, Electro-Optical, or Engineering Order
EOB	Electronic Order of Battle or Expense Operating Budget
EOCM	Electro-Optic Countermeasures
EOF	Electro-Optical Frequency (300 to 3 x 10^7 GHz)
EP	Electronic Protection (similar to older terms of ECCM and DECM)
EPA	Environmental Protection Agency
EPROM	Electrically Programmable Read-only Memory
ERAM	Electronic Counter-Countermeasures (also Protection) Requirements and Assessment Manual
ERP	Effective Radiated Power
ES	Electronic Surveillance (similar to older term of ESM)
ESD	Electrostatic Discharge
ESM	Electronic Support Measures (similar to newer term of ES)
ESSM	Evolved Sea Sparrow Missile
ET	Electronics Technician
ETI	Elapsed Time Indicator
ETIRMS	EW Tactical Information and Report Management System
ETR	Estimated Time to Repair
EVM	Earned Value Management
EW	Electronic Warfare , Early Warning, or Expeditionary Warfare
EWBM	EW Battle Management
EWDS	EW Data Systems
EWIA	EW Intelligence Analysis
EWIR	Electronic Warfare Integration & Reprogramming (USAF database)
EWMP	Electronic Warfare Master Plan
EWO	Electronic Warfare Officer
EWRL	Electronic Warfare Reprogrammable Library (USN)
EWSI	EW Systems Integration
EWSSA	EW Software Support Activity
EXP	Expendable Countermeasure
f	femto (10^{-15} multiplier), Frequency (also F), or lens *f* number
F	Frequency (also *f*), Force, Farad, Faraday Constant, Female, Fahrenheit, Noise Figure, Noise Factor or “Friendly” on RWR display

F2T2EA	Find, Fix, Track, Target, Engage, Assess (targeting of hostile forces)
F/A	Fighter/Attack
FAA	Federal Aviation Administration
FAC	Forward Air Controller
FAR	Federal Acquisition Regulations or False Alarm Rate
f_c	Footcandle (unit of illuminance)
FCA	Functional Configuration Audit
FCR	Fire Control Radar
FDR	Frequency Domain Reflectometry
FEBA	Forward Edge of the Battle Area
FET	Field-Effect Transistor
FEWC	Fleet EW Center
FFT	Fast Fourier Transform
FIFO	First In / First Out
FIPR	Federal Information Processing Resources
fl	fluid
FLAK	AAA Shrapnel, from the German “Flieger Abwher Kanone” (AAA gun that fires fast and furiously)
FLIR	Forward Looking Infrared
FLPS	Flightline Payload Simulator
FLT	Flight
FM	Frequency Modulation or Failure Mode
FME	Foreign Material Exploitation
FMEA	Failure Mode and Effects Analysis
FMS	Foreign Military Sale(s)
FOC	Full Operational Capability
FOD	Foreign Object Damage
FORCECAP	Force Combat Air Patrol
FOT&E	Follow-On Test and Evaluation
FOTD	Fiber Optic Towed Device
FOUO	For Official Use Only
FOV	Field of View
FPA	Focal Plane Array
fps	feet per second
FRACAS	Failure, Reporting, Analysis, and Corrective Actions System
FRB	Failure Review Board
FRD	Functional Requirements Document
FSD	Full Scale Development
FSED	Full Scale Engineering Development
FSK	Frequency Shift Keying
FSU	Former Soviet Union
ft	Feet or Foot
FTC	Fast Time Constant
FTD	Foreign Technology Division (USAF)
FWD	Forward
FY	Fiscal Year
g	Gravity (also G)
G	Universal Gravitational Constant (also K), Giga (10^9 multiplier), Conductance, or Gain
G&A	General and Administrative (expense)
GaAs	Gallium Arsenide
GACIAC	Guidance and Control Information Analysis Center (DoD)
gal	Gallon
GAO	General Accounting Office
GBU	Guided Bomb Unit
GCA	Ground Controlled Approach
GCI	Ground Control Intercept
GENSER	General Service
GEN-X	Generic Expendable
GFE	Government Furnished Equipment
GHz	GigaHertz
GI	Government Issue
GIDEP	Government Industry Data Exchange Program
GIG	Global Information Grid
GIGO	Garbage In / Garbage Out
GOCO	Government Owned Contract Operated
GOFO	General Officer / Flag Officer
GP	General Purpose
GPI	Ground Plane Interference
GPIB	General Purpose Interface Bus
GPS	Global Positioning System
GSE	Ground Support Equipment
h	hours, hecto (10^2 multiplier), Plank’s constant, or height (also H)
H	Height (also h), Henry (Inductance), or Irradiance
HARM	High-speed Anti-Radiation Missile
HAWK	Homing All the Way Killer
HDBK	Handbook
HDF	High Duty Factor
HE	High Explosive
HEF	High Energy Frequency ($3x10^7$ to $3x10^{14}$ GHz)
HEL	High Energy Laser
HELO	Helicopter
HERF	Hazards of Electromagnetic Radiation to Fuel
HERO	Hazards of Electromagnetic Radiation to Ordnance
HERP	Hazards of Electromagnetic Radiation to Personnel
hex	hexadecimal
HF	High Frequency [3 - 30 MHz]
HIL or HITL	Hardware-in-the-Loop

HOJ	Home-On-Jam
HOL	Higher Order Language
HPF	High-Pass Filter
HP-IB	Hewlett-Packard Interface Bus
HP-IL	Hewlett-Packard Interface Loop
HPM	High Powered Microwave
HPRF	High Pulse Repetition Frequency
hr	hour
HSDB	High Speed Data Bus
HUD	Heads-Up Display
HV	High Voltage
H/W	Hardware
HWCI	Hardware Configuration Item
HWIL	Hardware-in-the-loop
Hz	Hertz (Cycles per second)

i	current (also I)
I	Current (also i), Intensity, Irradiance, Intermediate, or Roman Numeral for One
IA	Information Assurance
IADS	Integrated Air Defense System
I&Q	In-Phase and Quadrature
IAS	Indicated Airspeed
IAW	In Accordance With
IBIT	Initiated Built-in-Test
IBU	Interference Blanker Unit
IC	Integrated Circuit
ICD	Interface Control Document Initial Capabilities Document
ICMD	Improved Countermeasure Dispenser
ICNIA	Integrated Communication, Navigation, Identification Avionics
ICS	Inverse Conical Scan or Intercommunications System (aircraft)
ICW	In Compliance With
ID	Identification
IDA	Institute For Defense Analysis
IDECM	Integrated Defensive Electronic Countermeasures
IEEE	Institute of Electrical and Electronic Engineers
IF	Intermediate Frequency
IFF	Identification Friend-or-Foe
IFM	Instantaneous Frequency Measurement
IFR	Instrument Flight Rules
IG	Inspector General
IIR	Imaging Infrared
I-Level	Intermediate Level of Repair (also “I” Level)
ILS	Integrated Logistic Support, Instrument Landing System, or Inertial Locator System
ILSMT	Integrated Logistic Support Management Team
IM	Intermodulation or Item Manager
IMA	Intermediate Maintenance Activity
in	Inch
INEWS	Integrated Electronic Warfare System
INS	Inertial Navigation System
INT	Intensity
IO	Information Operations
I/O	Input/Output
IOC	Initial Operational (also Operating) Capability
IOT&E	Initial Operational Test and Evaluation
IPO	International Projects (Program) Office
IPR	In-Progress/Process Review
IPT	Integrated Product (also Program) Team
IR	Infrared
IR&D	Independent Research and Development
IRCM	Infrared Countermeasures
IRDS	Infrared Detecting System
IREXP	IR Expendables
IRIG-B	Inter-range Instrumentation Group B
IRLS	Infrared Line Scanner
IRS	Interface Requirements Specification, IR Suppression or Internal Revenue Service
IRST	Infrared Search and Track
ISAR	Inverse Synthetic Aperture Radar
ISO	Derived from the Greek “isos” meaning “equal,” the official title is International Organization for Standardization
ISP	Integrated Support Plan Intelligence Support Plan
ISR	Interference to Signal Ratio (also I/S)
ITU	International Telecommunications Union
IV&V	Independent Validation and Verification
IW	Information Warfare

J	Jamming, Radiance, Current Density, or Joules
JAAS	Joint Architecture for Aircraft Survivability
JAFF	Jammer (illuminating) Chaff
JAG	Judge Advocate General
JAMS	Jamming Analysis Measurement System
JARS	Jamming Aircraft & Radar Simulation
JASSM	Joint Air-to-Surface Standoff Missile
JAST	Joint Advanced Strike Technology
JATO	Jet Assisted Takeoff or JAmmer Technique Optimization
JC2WC	Joint Command and Control Warfare Center (now JIOWC)
JCTD	Joint Concept Technology Demonstration
JCS	Joint Chiefs of Staff or Joint Spectrum Center (formerly ECAC)
JDAM	Joint Direct Attack Munition
JEACO	Joint Electronic Attack and Compatibility Office
JED	Journal of Electronic Defense (Published by the Association of Old Crows)
JEM	Jet Engine Modulation
JETS	Joint Emitter Targeting System
JEWC	Joint EW Conference or Joint EW Center (then JC2WC & now JIOWC)
JEWEL	Joint Electronic Warfare Effects Laboratory
JIOWC	Joint Information Operations Warfare Command
JMEM	Joint Munitions Effectiveness Manual
JMR	Jammer
JOVIAL	Julius' Own Version of International Algorithmic Language (Air Force computer programming language)
JPATS	Joint Primary Aircraft Training System
J/S	Jamming to Signal Ratio
JSF	Joint Strike Fighter
JSGCC	Joint Services Guidance and Control Committee
JSIR	Joint Spectrum Interference Resolution (signal interference portion of MIJI)
JSOW	Joint Stand-Off Weapon (AGM-154A)
JSTARS	Joint Surveillance Target Attack Radar System
JTA	Jammer Threat Analysis
JTAT	JATO Techniques Analysis and Tactics
JTCG/AS	Joint Technical Coordinating Group for Aircraft Survivability
JTCG/ME	Joint Technical Coordinating Group for Munitions Effectiveness
JTIDS	Joint Tactical Information Distribution System
JV or J/V	Joint Venture
k	kilo (10^3 multiplier) or Boltzmann Constant
K	Kelvin, Cathode, Universal gravitational constant (also G), or Luminous efficacy
KCAS	Knots Calibrated Airspeed
kg	kilogram
kHz	KiloHertz
KIA	Killed in Action
KIAS	Knots Indicated Air Speed
km	Kilometer
KSLOC	Thousand Source Lines of Code (software)
kt	Knot (nautical miles per hour)
kW	Kilowatt
l	length (also L) or liter
L	Length (also l), Loss, inductance, Luminance, or Roman Numeral for fifty
LADAR	Laser Detection and Ranging (i.e., laser radar)
LAN	Local Area Network
LANTIRN	Low Altitude Navigation & Targeting Infrared for Night
LASER	Light Amplification by Stimulated Emission of Radiation
LAT	Latitude (0-90° N or S from equator)
lbs	pounds
LCC	Life Cycle Cost(s)
LCD	Liquid Crystal Display or Lowest Common Denominator
LCP or LHCP	Left-hand Circular Polarization
LDF	Low Duty Factor
LDS	Laser Detecting Set
LED	Light-Emitting Diode
LEX	Leading Edge Extension
LGB	Laser Guided Bomb
LF	Low Frequency [30 - 300 kHz]
LIC	Low Intensity Combat or Laser Intercept Capability

LISP	List Processing (A programming language used in artificial intelligence)
LLL	Low Light Level (as in LLL TV)
lm	lumen (SI unit of luminous flux)
ln	Natural Logarithm
LO	Local Oscillator or Low Observable
LOA	Letter of Agreement (or Acceptance)
LOB	Line of Bearing (see also AOA)
LOG	Logarithm to the base 10 (also log) or Logistician
LONG	Longitude (0-180° E or W from Greenwich, U.K.)
LOR	Level of Repair
LORA	Level of Repair Analysis
LORAN	Long Range Navigation
LORO	Lobe on Receive Only
LOS	Line-of-Sight
LPAR	Large Phased-Array Radar
LPD	Low Probability of Detection
LPF	Low Pass Filter
LPI or LPOI	Low Probability of Intercept
LPRF	Low Pulse Repetition Frequency
LR	Lethal Range
LRA	Line Replaceable Assembly
LRF	Laser Rangefinder
LRIP	Low Rate Initial Production
LRU	Line Replaceable Unit
LSA	Logistic Support Analysis
LSAR	Logistic Support Analysis Record
LSB	Least Significant Bit
LSI	Large Scale Integration
LSO	Landing Signal Officer
LSSO	Laser System Safety Officer
LTBB	Look Through Blanking Bus
LWIR	Long Wave Infrared
LWR	Laser Warning Receiver
lx	Lux (SI unit of illuminance)
LZ	Landing Zone

m	milli (10^{-3} multiplier), meter, or electron mass
M	Mega (10^6 multiplier), Male, Mach number, or Roman numeral for 1,000
MA	Missile Alert or Missile Active
MAD	Magnetic Anomaly Detection (also Detector)
MADD	Microwave Acoustic Delay Device
MAF	Maintenance Action Form
MAG	Marine Aircraft Group or Magnetic
MAGTF	Marine Air-Ground Task Force
MANPADS	Man-portable Air Defense System
M&S	Modeling and Simulation
MASER	Microwave Amplification by Simulated Emission of Radiation
MATE	Modular Automatic Test Equipment
MAW	Missile Approach Warning system (also MAWS) or Marine Aircraft Wing
MAX	Maximum or Maximum aircraft power (afterburner)
MBFN	Multiple Beam Forming Network
MC	Mission Computer
MCIOC	Marine Corps Information Operations Center
MCP	Micro-Channel Plate
MDF	Mission Data File
MDI	Multiple Display Indicator or Miss Distance Indicator
MDG	Mission Data Generator
MDS	Minimum Discernible Signal or Minimum Detectable Signal
MDU	Multipurpose Display Unit
MF	Medium Frequency (300 kHz to 3 MHz)
MFD	Multifunction (video) Display
MG	Missile Guidance
MHz	MegaHertz (10^6 Hz)
MIA	Missing in Action
MIC	Microwave Integrated Circuit or Management Information Center
MICRON	10^{-6} meter
MiG	Mikoyan-Gurevich (Soviet aircraft manufacturer)
MIGCAP	MiG Combat Air Patrol
MIJI	Meaconing, Intrusion, Jamming, & Interference (also see JSIR)
mil	One-thousandth of an inch
MIL	Military power (100%, no afterburner) or Military
MILCON	Military Construction
MILSPEC	Military Specification
MILSTRIP	Military Standard Requisitioning and Issue Procedure(s)
MIMIC	Microwave Monolithic Integrated Circuit (also MMIC)
MIN	Minimum
Mincon	Minimal Construction
MIPPLE	RWR display switching between ambiguous emitters
MIPS	Millions of (Mega) Instructions Per Second
ML	Missile Launch
MLC	Main Lobe Clutter
MLV	Memory Loader Verifier
MLVS	Memory Loader Verifier Set

mm	Millimeter
MM	Man Month
MMIC	Microwave Monolithic Integrated Circuit (also MIMIC)
MMW	Millimeter Wave (40 GHz or higher per IEEE, but commonly used down to 30 GHz)
MOA	Memorandum of Agreement
MOE	Measure of Effectiveness
MOM	Methods of Moments (also MoM) or Metal-Oxide-Metal
MOP	Modulation on Pulse or Measure of Performance
MOPS	Million Operations Per Second
MOS	Minimum Operational Sensitivity, Military Occupational Specialty, Metal-Oxide Semiconductor, or Measure of Suitability
MOSAIC	Modeling System for Advanced Investigation of Countermeasures
MOU	Memorandum of Understanding
MPD	Multi-Purpose Display or Microwave Power Device
MPE	Maximum Permissible Exposure
mph	Miles per Hour
MPLC	Multi-Platform Launch Controller
MPM	Microwave Power Module
MPPS	Million Pulses Per Second
MPRF	Medium Pulse Repetition Frequency
mr or mrad	Milliradian
MRC	Maintenance Requirement Card or Medium Range CAP
MRE’s	Meals Ready to Eat
ms	Milliseconds
MSB	Most Significant Bit
MSI	Multi-Sensor (also Source) Integration, Management Support Issues, or Medium Scale Integration
MSIC	Missile and Space Intelligence Center
MSL	Mean Sea Level (altitude) or Missile
MTBF	Mean Time Between Failures
MTI	Moving Target Indicator (or Indication)
MTTR	Mean Time To Repair
MUXBUS	Multiplex Bus
MVS	Minimum Visible Signal
mw	Microwave
mW	Milliwatt
MWIR	Mid Wave Infrared
MWS	Missile Warning Set
MY	Man Year
n	nano (10^{-9} multiplier) or number of elements
N	Noise, Newton (force), Radiance, North, or No
n/a	Not Applicable (also N/A)
NA	Numerical Aperture
NADEP	Naval Aviation Depot
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NATOPS	Naval Air Training and Operating Procedures Standardization
NAV	Navigation
NAVAIR	Naval Air Systems Command (also NAVAIRSYSCOM)
NavMPS	Naval Mission Planning System
NAVSEA	Naval Sea Systems Command (also NAVSEASYSCOM)
NAWCAD	Naval Air Warfare Center Aircraft Division
NAWCWD	Naval Air Warfare Center Weapons Division
NBC	Nuclear, Biological, Chemical
NCTR	Non-Cooperative Target Recognition
NDI	Non-Developmental Item or Non Destructive Inspection
NEI	Noise Equivalent Power
NEMP	Nuclear Electromagnetic Pulse
NEOF	No Evidence of Failure
NEP	Noise Equivalent Power
NF	Noise Figure or Noise Factor (also F)
NFO	Naval Flight Officer
NGJ	Next Generation Jammer
NIOC	Navy Information Operations Command
NIPO	Navy International Program Office
NIR	Near Infrared
nm	nanometer or Nautical Mile (also NM or NMI)
NM or NMI	Nautical Mile (also nm)
NMCI	Navy Marine Corps Intranet
NNWC	Naval Network Warfare Command
NOHD	Nominal Ocular Hazard Distance
NORAD	North American Air Defense Command
NPG or NPGS	Naval Post Graduate School
NRE	Non-Recurring Engineering
NRL	Naval Research Laboratory
NRZ	Non Return to Zero
NSA	National Security Agency
nsec or ns	Nanosecond
NSN	National Stock Number
NSWC	Naval Surface Weapons Center
nt	Nit (SI unit of luminance)

NUWC	Naval Undersea Warfare Center
NVG	Night Vision Goggles
NWIP	Naval Warfare Information Publication
NWP	Naval Warfare Publication

O	Optical
OADR	Originating Agency’s Determination Required
OAG	Operational Advisory Group
O&MN	Operations and Maintenance, Navy (also O&M,N)
OBE	Overtaken (Overcome) By Events
OCA	Offensive Counter Air
OEWTPS	Organizational Electronic Warfare Test Program Set
OFP	Operational Flight Program
OJT	On-the-Job Training
O-Level	Organizational Level of Repair (also “O” Level)
OMA	Organizational Maintenance Activity
OMB	Office of Management and Budget
OMEGA	Optimized Method for Estimating Guidance Accuracy (VLF Navigation System)
ONR	Office of Naval Research
OOK	On-Off Keying
OPEVAL	Operational Evaluation
OPM	Office of Personnel Management
OPSEC	Operational Security
OPTEVFOR	Operational Test and Evaluation Force
OR	Operational Requirement or Operationally Ready
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OSHA	Occupational Safety and Health Act
OSIP	Operational Safety Improvement Program
OSM	Operating System Memory or SMA connector made by Omni-Spectra
OSRB	Operational Software Review Board
OT (&E)	Operational Test (and Evaluation)
OTD	Operational Test Director
OTH	Over the Horizon
OTH-B	Over-the-Horizon Backscatter
OTH-R	Over-the-Horizon Radar
OTH-T	Over-the-Horizon Targeting
OTRR	Operational Test Readiness Review
OUSD	Office of the Under Secretary of Defense
oz	ounce

p	pico (10^{-12} multiplier) or page
P	Power, Pressure, or Peta (10^{15} multiplier)
P^3I	Pre-Planned Product Improvement
Pa	Pascal (pressure)
PA	Public Address or Program Analyst
PBIT	Periodic Built-in-Test
PC	Pulse Compression, Personal Computer, or Photoconductive
PCA	Physical Configuration Audit
PCM	Pulse Code Modulation
P_d	Probability of Detection
PD	Pulse Doppler
PDI	PD Illuminator or Post Detection Integration
PDP	Plasma Display Panel
PDQ	Pretty Darn [sic] Quick
PDR	Preliminary Design Review
PDW	Pulse Descriptor Word
PEL	Personnel Exposure Limits
PEM	Photoelectromagnetic
PEO	Program Executive Officer
pf	Power Factor or Pico Farads
PFA	Probability of False Alarm
PGM	Precision Guided Munition
ph	Phot (unit of illuminance)
P_h	Probability of Hit
pi	Greek letter π
P_i	Probability of Intercept (also POI)
PID	Positive Identification
PIN	Personal Identification Number
PIP	Product Improvement Plan or Predicted Intercept Point
Pixel	Picture Element
P_k	Probability of Kill or Peak
PLSS	Precision Location Strike System
PM	Phase Modulation or Program Manager
PMA	Program (also Project) Manager, Air
PMAWS	Passive Missile Approach Warning System
PMS	Program Manager, Ship
PMT	Photomultiplier Tube
PMW	Program Manager, Warfare
P-N	Positive to Negative Junction (also p-n)
PN or P/N	Part Number
POC	Point of Contact
POET	Primed Oscillator Expendable Transponder
POI	Probability of Intercept (also PI)
POL	Polarization
POM	Program Objective Memorandum

POP	Pulse-on-Pulse or Product Optimization Program
POST	Passive Optical Seeker Technology (Stinger missile)
PPI	Plan Position Indicator
PPS	Pulses Per Second
PRF	Pulse Repetition Frequency
PRI	Priority or Pulse Repetition Interval
PROM	Programmable Read-only Memory
PRR	Production Readiness Review or Pulse Repetition Rate
PRT	Pulse Repetition Time
P_s	Probability of Survival
P's & Q's	Pints and Quarts (small details)
PSK	Phase-shift Keying
PUPS	Portable Universal Programming System
PV	Photovoltaic
pw or PW	Pulse Width
PWB	Printed Wiring Board

q	electron charge
Q	Quantity Factor (figure of merit), Quadrature, aerodynamic pressure, or Charge (coulomb)
QA	Quality Assurance
QC	Quality Control
QED	Quod Erat Demonstradum (end of proof)(Satirically "quite easily done")
QML	Qualified Manufacturer Listing
QPL	Qualified Parts List
QRC	Quick-Reaction Capability
QRD	Quick Reaction Demonstration
QRT	Quick-Reaction test

r or R	Radius or Range
R	Resistance, Reliability, or Roentgen
rad	Radian
R&D	Research and Development
RADAR	Radio Detection and Ranging
RADHAZ	Radiation Hazard
RAM	Random Access Memory, Radar Absorbing Material, Rolling Airframe Missile, or Reliability, Availability, and Maintainability
R&M	Reliability and Maintainability
RAT	Ram Air Turbine
RBOC	Rapid Blooming Offboard Chaff
RCP or RHCP	Right-hand Circular Polarization
RCS	Radar Cross Section
RCVR	Receiver
RDT&E	Research, Development, Test, & Evaluation
RDY	Ready
RE	Radiated Emissions
REC	Receive
RET	Return
RF	Radio Frequency
RFEXP	RF Expendables
RFI	Radio Frequency Interference, Ready-For-Issue, or Request for Information
RFP	Request for Proposal
RFQ	Request for Quotation
RFSS	Radio Frequency Simulation System (Army)
RGPO	Range Gate Pull Off
RGS	Range Gate Stealer
RGWO	Range Gate Walk Off (see RGPO)
RHAW	Radar Homing and Warning Receiver or Radar Homing All the Way
RHAWS	Radar Homing and Warning System
RINT	Radiation Intelligence
RIO	Radar Intercept Officer
RM	Radar Mile
rms or RMS	Root Mean Square
RNG	Range
ROC	Required Operational Capability
ROE	Rules of Engagement
ROI	Return on Investment
ROM	Read-only Memory or Rough Order of Magnitude
ROR	Range Only Radar or Rate of Return (financial)
ROT	Rate of Turn
ROWG	Response Optimization Working Group
RPG	Receiver Processor Group
RPM	Revolutions per Minute
RPT	Repeat
RPV	Remotely Piloted Vehicle
RRT	Rapid Reprogramming Terminal (a type of MLVS)
RS	Radiated Susceptibility or Remote Station
RSDS	Radar Signal Detecting Set
RSO	Range Safety Officer or Receiver, Set-on
RST	Receiver Shadow Time
RT	Remote Terminal, Termination Resistance, or Receiver/Transmitter (also R/T)
RUG	Radar Upgrade
RWR	Radar Warning Receiver
Rx	Receive

s, S, or sec	seconds
S	Signal Power, Surface Area, Secret, Electrical conductance (siemens), South, Scattering (as in S-parameters), or Seconds
SA	Situational Awareness, Semi-Active, Spectrum Analyzer, or Surface-to-Air (also S/A or S-A)
SA-()	Surface-to-Air missile number ()
SAE	Society of Automotive Engineers
SAM	Surface-to-Air Missile
SA-N-()	Naval Surface-to-Air missile number
SAR	Synthetic Aperture Radar, Special Access Required, Semi-Active Radar, Search and Rescue, or Specific Absorption Rate
SATS	Semi-Active Test System
SAW	Surface Acoustic Wave
SBIR	Small Business Innovative Research
SCI	Sensitive Compartmented Information
SCIF	Sensitive Compartmented Information Facility
SCN	Specification Change Notice
SCR	Software Change Request
SCP	Software Change Proposal
SCRB	Software Configuration Review Board
SCUD	Soviet short-range surface-to-surface missile
SE	Support Equipment
SDLM	Standard Depot Level Maintenance
SDI	Strategic Defense Initiative
SEAD	Suppression of Enemy Air Defense (pronounced “seed” or “C add”)
SEAL	Sea-Air-Land (Navy special forces)
sec	seconds (also S or s)
SECDEF	Secretary of Defense
SEI	Specific Emitter Identification
SEMA	Special Electronic Mission Aircraft
SERD	Support Equipment Recommendation Data
SHAPE	Supreme Headquarters Allied Powers Europe (NATO military command)
SHF	Super High Frequency (3 to 30 GHz)
SI	Special Intelligence or System International (Units)
SIF	Selective Identification Feature
SIGINT	Signals Intelligence
SIJ	Stand-In Jamming (also S/J)
SIM	Simulation
sin	Sine
SINCGARS	Single Channel Ground and Airborne Radio System
SIRCM	Suite of IR Countermeasures
SIRFC	Suite of Integrated RF Countermeasures
SJ	Support Jamming
S/J	Stand-In Jamming or Signal to Jamming Ratio
SL	Side lobe or Sea Level (also S.L.)
SLAM	Standoff Land Attack Missile
SLAR	Side-Looking Airborne Radar
SLC	Side Lobe Clutter
SLOC	Source Lines of Code or Sea Lines of Communication
SM	Statute Mile (also sm) or Standard Missile
SMA	Scheduled Maintenance Action or Sub-Miniature A connector
SMC	Sub-Miniature C connector
SME	Subject Matter Expert
SML	Support Material List
SMS	Stores Management Set or Status Monitoring System
S/N or SNR	Signal-to-Noise Ratio
SNORT	Supersonic Naval Ordnance Research Track
SNTK	Special Need to Know
SOF	Safety of Flight
SOJ	Stand-off Jammer
SONAR	Sound Navigation and Ranging
SOO	Statement of Objectives (replacing SOW)
SOP	Standard Operating Procedures
SORO	Scan-on-Receive Only
SOS	“Save Our Ship” (distress call with easy Morse code, i.e. ● ● ● – – – ● ● ●)
SOW	Statement of Work (being replaced by SOO)
SPAWAR	Space and Naval Warfare Systems Command
SPEC	Specification
SPIRITS	Spectral Infrared Imaging of Targets and Scenes
SPO	System Program Office
SPY	Radar on an AEGIS ship
sq	Square
sr	Steradian
SRA	Shop Replaceable Assembly
SRAM	Static Random Access Memory
SRB	Software Review Board
SRBOC	Super Rapid Blooming Offboard Chaff
SRD	Systems Requirements Document
SRS	Software Requirements Specification
SRU	Shop Replaceable Unit

SSA	Software (also Special or System) Support Activity, Source Selection Activity, or Solid State Amplifier
SSB	Single Side Band
SSI	Small Scale Integration
SSJ	Self Screening Jamming
SSM	Surface-to-Surface Missile
SSRO	Sector Scan Receive Only
SSW	Swept Square Wave
S&T	Science and Technology
STANAG	Standardization Agreement (NATO)
STAR	System Threat Assessment Report
stat	Statute
STBY	Standby
STC	Sensitivity Time Control, Short Time Constant or SHAPE Technical Center
STD	Software Test Description, Standard, or Sexually Transmitted Disease
STE	Standard Test Equipment
STOVL	Short Takeoff and Vertical Landing
STP	Software Test Plan, or Standard Temperature and Pressure (0°C at 1 atmosphere)
STR	Software (also System) Trouble Report
STT	Single Target Track
STU	Secure Telephone Unit
SUBSAM	Subsurface-to-Air Missile
SUT	System Under Test
S/W	Software (also SW)
SWAP	Size, Weight, And Power
SWC	Scan With Compensation
SWM	Swept Wave Modulation
SYSCOM	Systems Command
t	Time (also T)
T	Time (also t), tera (10^{12} multiplier), Temperature, or Telsa
TA	Target Acquisition or Terrain Avoidance
TAAF	Test, Analyze, and Fix
TAC	Tactical Air Command (now ACC)
TACAIR	Tactical Aircraft
TACAMO	Take Charge and Move Out (airborne strategic VLF communications relay system)
TACAN	Tactical Air Navigation
TACDS	Threat Adaptive Countermeasures Dispensing System
TACTS	Tactical Aircrew Combat Training System
TAD	Threat Adaptive Dispensing, Temporary Additional (also Active) Duty, or Tactical Air Direction
T&E	Test & Evaluation
TALD	Tactical Air Launched Decoy
TAMPS	Tactical Automated Mission Planning System
TAR	Target Acquisition Radar or Training Administrative Reserve
TAS	True Airspeed
TBA	To Be Announced
TBD	To Be Determined
TBMD	Theater Ballistic Missile Defense
TD	Technical Directive (also Director)
TDD	Target Detection Device
TDM	Time Division Multiplexing
TE	Transverse Electric
TEA	Technology Exchange Agreement
TEAMS	Tactical EA-6B Mission Support
TECHEVAL	Technical Evaluation
TEL	Transporter Erector Launcher
TEM	Transverse Electromagnetic
TEMP	Test and Evaluation Master Plan
TEMPEST	Not an acronym. Certification of reduced electromagnetic radiation for security considerations
TENA	Training Enabling Architecture
TERPES	Tactical Electronic Reconnaissance Processing and Evaluation System
TGT	Target
TIM	Technical Interchange Meeting
TM	Telemetry, Transverse Magnetic, or Technical Manual
TMD	Theater Missile Defense
TNC	Threaded Navy Connector
TOA	Time of Arrival
TOJ	Track on Jam
TOO	Target of Opportunity (HARM operating mode)
TOR	Tentative (also Tactical) Operational Requirement or Time of Receipt
TOS	Time on Station
TOT	Time on Target
TOW	Tube-Launched, Optically-Tracked, Wire-guided
TPI	Test Program Instruction
TPS	Test Program Set or Test Pilot School
TPWG	Test Plan Working Group
TQM	Total Quality Management
T/R	Transmit / Receive
TRB	Technical Review Board
TRD	Test Requirements Document
TREE	Transient Radiation Effects on Electronics

TRF	Tuned Radio Frequency
TRR	Test Readiness Review
TS	Top Secret
TSS	Tangential Sensitivity
TSSAM	Tri-Service Standoff Attack Weapon
TT	Target Track
TTI	Time To Impact/Intercept
TTG	Time-to-Go
TTL	Transistor-Transistor Logic
TTR	Target Tracking Radar
TV	Television
TVC	Thrust Vector Control
TWS	Track While Scan or Tail Warning System
TWSRO	Track While Scan on Receive Only
TWT	Traveling Wave Tube
TWTA	Traveling Wave Tube Amplifier
Tx	Transmit
TYCOM	Type Commander

u or µ	micron / micro (10^{-6} multiplier)
U	Unclassified, Unit, or Unknown (on RWR display)
UAS	Unmanned Aerial System
UAV	Unmanned (also uninhabited) Air (or Aerial) Vehicle
UCAV	Uninhabited Combat Air Vehicle (new USAF term for UAV)
UDF	User Data File
UDFG	User Data File Generator
UDM	User Data Module
UHF	Ultra High Frequency (300 MHz to 3 GHz)
ULF	Ultra Low Frequency (3 to 30 Hz)
µm	Micrometer
UN	United Nations
UNK	Unknown (also U)
UPC	Unique Planning Component
UPS	Uninterruptable Power Supply
us or µs	Microseconds
U.S.	United States
USA	United States of America or United States Army
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy
UTA	Uninhabited Tactical Aircraft
UUT	Unit Under Test
UV	Ultraviolet

v	Volts (also V), Velocity (also V or v_t)
V	Volts (also v), Velocity (also v or v_t), Volume, or Roman Numeral for five
VA	Veterans Administration, Volt-Amperes
VAQ	Prefix for Navy tactical EW squadron
V&V	Validation and Verification
VCO	Voltage Controlled Oscillator
Vdc or VDC	Volts Direct Current
VDT	Video Display Terminal
VECP	Value Engineering Change Proposal
VF	Prefix for Navy fighter squadron
VFO	Variable Frequency Oscillator
VFR	Visual Flight Rules
VGPO	Velocity Gate Pull Off
VGS	Velocity Gate Stealer
VGWO	Velocity Gate Walk Off
VHF	Very High Frequency (30 - 300 MHz)
VHSIC	Very High Speed Integrated Circuit
VID	Visual Identification
VLF	Very Low Frequency (3 to 30 kHz)
VLSI	Very Large Scale Integration
VLSIC	Very Large Scale Integrated Circuit
VMAQ	Prefix for Marine Tactical EW Squadron
VP	Prefix for Navy patrol squadron
VQ	Prefix for Navy special mission (usually reconnaissance) squadron
VRAM	Video Random Access Memory
VS or vs	Velocity Search or Versus (also vs.)
V/STOL	Vertical/Short Take-off and Landing (also VSTOL)
vt	Velocity (also V or v)
VTOL	Vertical Takeoff and Landing
VSWR	Voltage Standing Wave Ratio
VVA	Voltage Variable Attenuator

W	Watts, Weight, or West
W&T	Warning & Targeting
WARM	Wartime Reserve Mode
wb	Weber (magnetic flux)
WBS	Work Breakdown Structure
WC	Waveguide, circular
WFT	Windowed Fourier Transform
WGIRB	Working Group on Infrared Background
WORM	Write Once Read Many [times] (Refers to optical disks)
WOW	Weight on/off Wheels (also WonW or WoffW)
WPN	Weapons Procurement, Navy or Weapon

WR	Waveguide, rectangular
WRA	Weapon Replaceable Assembly
WRD	Waveguide, rectangular double ridged
WSSA	Weapons System Support Activity
WVR	Within Visual Range

x	Multiplication symbol
X	Reactance, Experimental, Extraordinary, Roman Numeral for ten, or X axis
X-EYE	Cross Eye
X-POL	Cross Polarization
XMIT	Transmit
XMTR	Transmitter

Y	Yes or Y-Axis
YAG	Yttrium-Aluminum Garnet
yd	Yard
YIG	Yttrium-Iron Garnet

Z	Impedance, Zenith, or Z-Axis

1xLR, 2xLR	One (or two or three etc.) Times Lethal Range
1v1 or 1-v-1	One versus One (Aerial engagement)

2D	Two Dimension

3D	Three Dimension
3M	Navy Maintenance and Material Management System

FUNDAMENTALS

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CONSTANTS, CONVERSIONS, and CHARACTERS

DECIMAL MULTIPLIER PREFIXES

Prefix	Symbol	Multiplier
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deka	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

EQUIVALENCY SYMBOLS

Symbol	Meaning
∝	Proportional
~	Roughly equivalent
≈	Approximately
≅	Nearly equal
=	Equal
≡	Identical to, defined as
≠	Not equal
>>	Much greater than
>	Greater than
≥	Greater than or equal to
<<	Much less than
<	Less than
≤	Less than or equal to
∴	Therefore
°	Degrees
′	Minutes or feet
“	Seconds or inches

UNITS OF LENGTH

1 inch (in) = 2.54 centimeters (cm)
1 foot (ft) = 30.48 cm = 0.3048 m
1 yard (yd) ≅ 0.9144 meter
1 meter (m) ≅ 39.37 inches

1 kilometer (km) ≅ 0.54 nautical mile
≅ 0.62 statute mile
≅ 1093.6 yards
≅ 3280.8 feet

1 statute mile ≅ 0.87 nautical mile
(sm or stat. mile) ≅ 1.61 kilometers
= 1760 yards
= 5280 feet

1 nautical mile ≅ 1.15 statute miles
(nm or naut. mile) ≅ 1.852 kilometers
≅ 2025 yards
≅ 6076 feet
1 furlong = 1/8 mi (220 yds)

UNITS OF SPEED

1 foot/sec (fps) ≅ 0.59 knot (kt)*
≅ 0.68 stat. mph
≅ 1.1 kilometers/hr

1000 fps ≈ 600 knots

1 kilometer/hr ≅ 0.54 knot
(km/hr) ≅ 0.62 stat. mph
≅ 0.91 ft/sec

1 mile/hr (stat.) ≅ 0.87 knot
(mph) ≅ 1.61 kilometers/hr
≅ 1.47 ft/sec

1 knot* ≅ 1.15 stat. mph
≅ 1.69 feet/sec
≅ 1.85 kilometer/hr
≅ 0.515 m/sec

*A knot is 1 nautical mile per hour.

UNITS OF VOLUME

1 gallon ≅ 3.78 liters
≅ 231 cubic inches
≅ 0.1335 cubic ft
≅ 4 quarts
≅ 8 pints

1 fl ounce ≅ 29.57 cubic centimeter (cc) or milliliters (ml)

1 in^3 ≅ 16.387 cc

UNITS OF AREA

1 sq meter ≅ 10.76 sq ft

1 sq in ≅ 645 sq millimeters (mm)
= 1,000,000 sq mil
1 mil = 0.001 inch

1 acre = 43,560 sq ft

UNITS OF WEIGHT

1 kilogram (kg) ≅ 2.2 pounds (lbs)

1 pound ≅ 0.45 Kg
= 16 ounce (oz)
1 oz = 437.5 grains
1 carat ≅ 200 mg
1 stone (U.K.) ≅ 6.36 kg

NOTE: These are the U.S. customary (avoirdupois) equivalents, the troy or apothecary system of equivalents, which differ markedly, was used long ago by pharmacists.

UNITS OF POWER / ENERGY

1 H.P. = 33,000 ft-lbs/min
= 550 ft-lbs/sec
≅ 746 Watts
≅ 2,545 BTU/hr
(BTU = British Thermal Unit)

1 BTU ≅ 1055 Joules
≅ 778 ft-lbs
≅ 0.293 Watt-hrs

SCALES

OCTAVES

"N" Octaves = Freq to Freq x 2^N
i.e., One octave would be 2 to 4 GHz
Two Octaves would be 2 to 8 GHz
Three octaves would be 2 to 16 GHz

DECADES

"N" Decades = Freq to Freq x 10^N
i.e., One decade would be 1 to 10 MHz
Two decades would be 1 to 100 MHz
Three decades would be
1 to 1,000 MHz

TEMPERATURE CONVERSIONS

°F = (9/5) °C + 32
°C = (5/9)(°F - 32)
°K = °C + 273.16
°F = (9/5)(°K - 273) + 32
°C = °K - 273.16
°K = (5/9)(°F - 32) + 273

UNITS OF TIME

1 year = 365.2 days
1 fortnight = 14 nights (2 weeks)
1 century = 100 years
1 millennium = 1,000 years

NUMBERS

1 decade = 10
1 Score = 20
1 Billion = 1 x 10^9 (U.S.) (thousand million)
= 1 x 10^{12} (U.K.) (million million)

RULE OF THUMB FOR ESTIMATING DISTANCE TO LIGHTNING / EXPLOSION:

km: Divide 3 into the number of seconds which have elapsed between seeing the flash and hearing the noise.
miles: Multiply 0.2 times the number of seconds which have elapsed between seeing the flash and hearing the noise.

Note: Sound vibrations cause a change of density and pressure within a media, while electromagnetic waves do not. An audio tone won't travel through a vacuum but can travel at 1,100 ft/sec through air. When picked up by a microphone and used to modulate an EM signal, the modulation will travel at the speed of light.

Physical Constant	Quoted Value	S*	SI unit	Symbol
Avogadro constant	6.0221367 x 10^{23}	36	mol^{-1}	N_A
Bohr magneton	9.2740154 x 10^{-24}	31	J•T^{-1}	μ_B
Boltzmann constant	1.380658 x 10^{-23}	12	J•K^{-1}	k(=R N_A)
Electron charge	1.602177 33 x 10^{-19}	49	C	-e
Electron specific charge	-1.758819 62 x 10^{11}	53	C•kg^{-1}	$-e/m_e$
Electron rest mass	9.1093897 x 10^{-31}	54	kg	m_e
Faraday constant	9.6485309 x 10^{4}	29	C•mol^{-1}	F
Gravity (Standard Acceleration)	9.80665 or 32.174	0	m/sec^2 ft/sec^2	g
Josephson frequency to voltage ratio	4.8359767 x 10^{14}	0	Hz•V^{-1}	2e/hg
Magnetic flux quantum	2.06783461 x 10^{-15}	61	Wb	φ_o
Molar gas constant	8.314510	70	J•mol^{-1}•K^{-1}	R
Natural logarithm base	≅ 2.71828	-	dimensionless	*e*
Newtonian gravitational constant	6.67259 x 10^{-11}	85	m^3•kg^{-1}•s^{-2}	G or K
Permeability of vacuum	4π x 10^{-7}	d	H/m	μ_o
Permittivity of vacuum	≅ 8.8541878 x 10^{-12}	d	F/m	ε_o
Pi	≅ 3.141592654		dimensionless	π
Planck constant	6.62659 x 10^{-34}	40	J•s	h
Planck constant/2π	1.05457266 x 10^{-34}	63	J•s	h(=h2π)
Quantum of circulation	3.63694807 x 10^{-4}	33	J•s•kg^{-1}	$h/2m_e$
Radius of earth (Equatorial)	6.378 x 10^{6} or 3963		m miles	
Rydberg constant	1.0973731534 x 10^{7}	13	m^{-1}	R_χ
Speed of light	2.9979246 x 10^{8}	1	m•s^{-1}	c
Speed of sound (dry air @ std press & temp)	331.4	-	m•s^{-1}	-
Standard volume of ideal gas	22.41410 x 10^{-3}	19	m^3•mol^{-1}	V_m
Stefan-Boltzmann constant	5.67051 x 10^{-8}	19	W•K^{-4} •m^{-2}	σ

* S is the one-standard-deviation uncertainty in the last units of the value, d is a defined value.
(A standard deviation is the square root of the mean of the sum of the squares of the possible deviations)

THE SPEED OF LIGHT			
ACTUAL	UNITS	RULE OF THUMB	UNITS
$\cong 2.9979246 \times 10^8$	m/sec	$\cong 3 \times 10^8$	m/sec
$\cong 299.79$	m/μsec	$\cong 300$	m/μsec
$\cong 3.27857 \times 10^8$	yd/sec	$\cong 3.28 \times 10^8$	yd/sec
$\cong 5.8275 \times 10^8$	NM/hr	$\cong 5.8 \times 10^8$	NM/hr
$\cong 1.61875 \times 10^5$	NM/sec	$\cong 1.62 \times 10^5$	NM/sec
$\cong 9.8357105 \times 10^8$	ft/sec	$\cong 1 \times 10^9$	ft/sec
$\cong 9.8357105 \times 10^2$	ft/μsec	$\cong 1 \times 10^3$	ft/μsec

SPEED OF LIGHT IN VARIOUS MEDIUMS

The speed of EM radiation through a substance such as cables is defined by the following formula:

$$V = c/(\mu_r\varepsilon_r)^{1/2}$$

Where: μ_r = relative permeability

ε_r = relative permittivity

The real component of ε_r = dielectric constant of medium.

EM propagation speed in a typical cable might be 65-90% of the speed of light in a vacuum.

APPROXIMATE SPEED OF SOUND (MACH 1)

Sea Level (CAS/TAS)		**36,000 ft*** (TAS)	(CAS)
1230 km/hr	Decreases	1062 km/hr	630 km/hr
765 mph	Linearly	660 mph	391 mph
665 kts	To ⇒	573 kts	340 kts

* The speed remains constant until 82,000 ft, when it increases linearly to 1215 km/hr (755 mph, 656 kts) at 154,000 ft. Also see Section 8-2 for discussion of Calibrated Air Speed (CAS) and True Airspeed (TAS) and a plot of the speed of sound vs. altitude.

SPEED OF SOUND IN VARIOUS MEDIUMS

Substance	Speed (ft/sec)
Vacuum	Zero
Air	1,100
Fresh Water	4,700
Salt Water	4,900
Glass	14,800
Steel	20,000

DECIMAL / BINARY / HEX CONVERSION TABLE

Decimal	Binary	Hex	Decimal	Binary	Hex	Decimal	Binary	Hex
1	00001	01h	11	01011	0Bh	21	10101	15h
2	00010	02h	12	01100	0Ch	22	10110	16h
3	00011	03h	13	01101	0Dh	23	10111	17h
4	00100	04h	14	01110	0Eh	24	11000	18h
5	00101	05h	15	01111	0Fh	25	11001	19h
6	00110	06h	16	10000	10h	26	11010	1Ah
7	00111	07h	17	10001	11h	27	11011	1Bh
8	01000	08h	18	10010	12h	28	11100	1Ch
9	01001	09h	19	10011	13h	29	11101	1Dh
10	01010	0Ah	20	10100	14h	30	11110	1Eh

When using hex numbers it is always a good idea to use "h" as a suffix to avoid confusion with decimal numbers.

DECIMAL TO HEX CONVERSION

Both the following methods must use long division. Method one computes the digits from right to left while method two works from left to right.

Method one: To convert a decimal number above 16 to hex, divide the number by 16, then record the integer resultant and the remainder. Convert the remainder to hex and write this down - this will become the far right digit of the final hex number. Divide the integer you obtained by 16, and again record the new integer result and new remainder. Convert the remainder to hex and write it just to the left of the first decoded number. Keep repeating this process until dividing results in only a remainder. This will become the left-most character in the hex number (i.e., to convert 60 (decimal) to hex we have 60/16 = 3 with 12 remainder). 12 is C (hex) - this becomes the right most character. Then 3/16=0 with 3 remainder. 3 is 3 (hex). This becomes the next (and final) character to the left in the hex number, so the answer is 3C.

Method two: Use table of powers to work the digits from left to right:

For example: Here is your Decimal Number - 9379

Step 1 - Set up your chart:

65536	4096	256	16	1
16^4	16^3	16^2	16^1	16^0

Step 2 - Look in the table for the highest divisible number in the chart.
9379 / 4096 = 2 (the left-most Hex digit)
Must use long division to calculate the remainder (1187)

Step 3 - Divide the remainder with its highest divisible number in the chart:
1187 / 256 = 4 (the next digit to the right)
Must use long division to calculate the remainder (163)

Step 4 - Divide the remainder with its highest divisible number in the chart:
163 / 16 = 10 (or "A" from table L-1) (the next digit to the right)
Must use long division to calculate the remainder (3)

Step 5 - The remainder will not divide: remainder = 3 (the right-most Hex digit)

65536	4096	256	16	1
16^4	16^3	16^2	16^1	16^0
	2	4	A	3

HEX TO DECIMAL CONVERSION

To convert a hex number to decimal, multiply each hex digit converted to decimal by the decimal equivalent of the hex power represented and add the results.

For example: Here is your Hex Number - 24A3

Step 1 - Set up your chart:

4096	256	16	1
16^3	16^2	16^1	16^0

Step 2 - Place the numbers in a table:

4096	256	16	1
16^3	16^2	16^1	16^0
2	4	A	3

Step 3 - Multiply the Hex number times the power value:

2 x 4096 = 8192
4 x 256 = 1024
A(10) x 16 = 160
3 x 1 = 3

Step 4 - Add up your values:

Decimal value is 9379

GREEK ALPHABET

Case		Greek Alphabet Name	English Equivalent
Upper	Lower		
Α	α	alpha	a
Β	β	beta	b
Γ	γ	gamma	g
Δ	δ	delta	d
Ε	ε	epsilon	e
Ζ	ζ	zeta	z
Η	η	eta	e
Θ	θ , ‘	theta	th
Ι	ι	iota	i
Κ	κ	kappa	k
Λ	λ	lambda	l
Μ	μ	mu	m

Case		Greek Alphabet Name	English Equivalent
Upper	Lower		
Ν	ν	nu	n
Ξ	ξ	xi	x
Ο	ο	omicron	o
Π	π	pi	p
Ρ	ρ	rho	r
Σ	σ	sigma	s
Τ	τ	tau	t
Υ	υ	upsilon	u
Φ	φ	phi	ph
Χ	χ	chi	ch
Ψ	ψ	psi	ps
Ω	ω	omega	o

LETTERS FROM THE GREEK ALPHABET COMMONLY USED AS SYMBOLS

Symbol	Name	Use
α	alpha	space loss, angular acceleration, or absorptance
β	beta	3 dB bandwidth or angular field of view [radians]
Γ	Gamma	reflection coefficient
γ	gamma	electric conductivity, surface tension, missile velocity vector angle, or gamma ray
Δ	Delta	small change or difference
δ	delta	delay, control forces and moments applied to missile, or phase angle
ε	epsilon	emissivity [dielectric constant] or permittivity [farads/meter]
η	eta	efficiency or antenna aperture efficiency
Θ	Theta	angle of lead or lag between current and voltage
θ or ‘	theta	azimuth angle, bank angle, or angular displacement
Λ	Lambda	acoustic wavelength or rate of energy loss from a thermocouple
λ	lambda	wavelength or Poisson Load Factor
μ	mu	micro 10^{-6} [micron], permeability [henrys/meter], or extinction coefficient [optical region]

ν	nu	frequency
π	pi	3.141592654+
ρ	rho	charge/mass density, resistivity [ohm-meter], VSWR, or reflectance
Σ	Sigma	algebraic sum
σ	sigma	radar cross section [RCS], Conductivity [1/ohm-meter], or Stefan-Boltzmann constant
Τ	Tau	VSWR reflection coefficient
τ	tau	pulse width, atmospheric transmission, or torque
Φ	Phi	magnetic/electrical flux, radiant power [optical], or Wavelet’s smooth function [low pass filter]
φ	phi	phase angle, angle of bank, or beam divergence [optical region]
Ψ	Psi	time-dependent wave function or Wavelet’s detail function [high pass filter]
ψ	psi	time-independent wave function, phase change, or flux linkage [weber]
Ω	Omega	Ohms [resistance] or solid angle [optical region]. Note: inverted symbol is conductance [mhos]
ω	omega	carrier frequency in radians per second

MORSE CODE and PHONETIC ALPHABET

A - alpha	• –	J - juliett	• – –	S - sierra	• • •	1	• – – – –
B - bravo	– • • •	K - kilo	– • –	T - tango	–	2	• • – – –
C - charlie	– • – •	L - lima	• – • •	U - uniform	• • –	3	• • • – –
D - delta	– • •	M - mike	– –	V - victor	• • • –	4	• • • • –
E - echo	•	N - november	– •	W - whiskey	• – –	5	• • • • •
F - foxtrot	• • – •	O - oscar	– – –	X - x-ray	– • • –	6	– • • • •
G - golf	– – •	P - papa	• – •	Y - yankee	– • – –	7	– – • • •
H - hotel	• • • •	Q - quebec	– – • –	Z - zulu	– – • •	8	– – – • •
I - india	• •	R - romeo	• – •	0	– – – – –	9	– – – – •

Note: The International Maritime Organization agreed to officially stop Morse code use by February 1999, however use may continue by ground based amateur radio operators. (The U.S. Coast Guard discontinued its use in 1995.)

BASIC MATH / GEOMETRY REVIEW

EXPONENTS

$a^x a^y = a^{x+y}$

$a^x / a^y = a^{x-y}$

$(a^x)^y = a^{xy}$

$a^0 = 1$

Example:

$$\frac{x}{\sqrt{x}} = x \bullet x^{-\frac{1}{2}} = x^{(1-\frac{1}{2})} = x^{\frac{1}{2}} = \sqrt{x}$$

LOGARITHMS

$\log (xy) = \log x + \log y$

$\log (x/y) = \log x - \log y$

$\log (x^N) = N \log x$

If $z = \log x$ then $x = 10^z$

Examples: $\log 1 = 0$
$\log 1.26 = 0.1$; $\log 10 = 1$

if $10 \log N = \text{dB\#}$,
then $10^{(\text{dB\#}/10)} = N$

TRIGONOMETRIC FUNCTIONS

$\sin x = \cos (x-90°)$

$\cos x = -\sin (x-90°)$

$\tan x = \sin x / \cos x = 1 / \cot x$

$\sin^2 x + \cos^2 x = 1$

A radian is the angular measurement of an arc which has an arc length equal to the radius of the given circle, therefore there are 2π radians in a circle. One radian = 360°/2π = 57.296....°

ELLIPSE

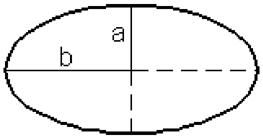

Area = π a b

Approx circumference

$$= 2\pi\sqrt{\frac{a^2 + b^2}{2}}$$

RECTANGLULAR SOLID

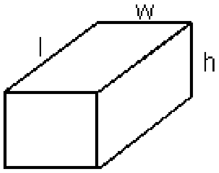

Area = lw

Volume = lwh

CYLINDER

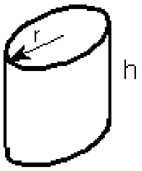

Volume − $\pi r^2 h$

Lateral surface area _ $2\pi rh$

ANGLES

$r^2 - x^2 + y^2$

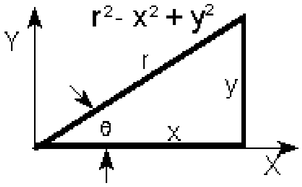

Sin θ = y/r Cos θ = x/r

Tan θ = y/x

SPHERE

Surface area = $4\pi r^2$

Volume = $4/3\ \pi r^3$

Cross Section (circle)
Area = πr^2

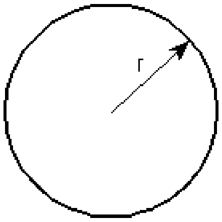

TRIANGLES

Angles: A + B + C = 180°

$c^2 = a^2 + b^2 - 2ab \cos C$

Area = 1/2 hc = 1/2 ab sin C

$b = \sqrt{e^2 + h^2}$

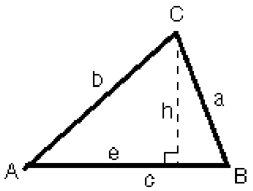

DERIVATIVES

Assume: a = fixed real #; u, v & w are functions of x

d(a)/dx = 0 ; d(sin u)/dx = du(cos u)/dx

d(x)/dx = 1 ; d(cos v)/dx = -dv(sin v)/dx

d(uvw)/dx = uvdw/dx + vwdu/dx + uwdv/dx +...etc

INTEGRALS

Note: All integrals should have an arbitrary constant of integration added, which is left off for clarity

Assume: a = fixed real #; u, & v are functions of x

$\int a\,dx = ax$ and $\int a\, f(x)dx = a\int f(x)dx$

$\int (u + v)dx = \int u\,dx + \int v\,dx$; $\int e^x dx = e^x$

$\int(\sin ax)dx = -(\cos ax)/a$; $\int(\cos ax)dx = (\sin ax)/a$

Differentiating Circuit

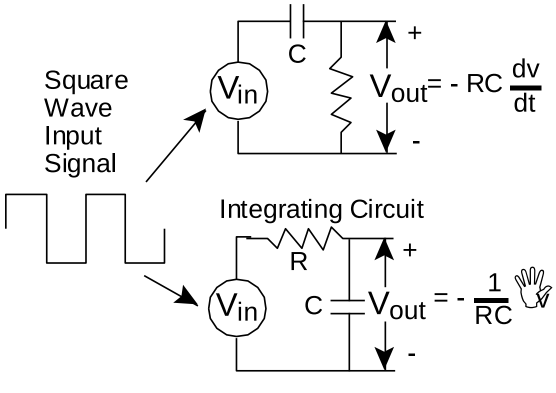

$V_{out} = -RC\frac{dv}{dt}$

$V_{out} = -\frac{1}{RC}\int v\,dt$

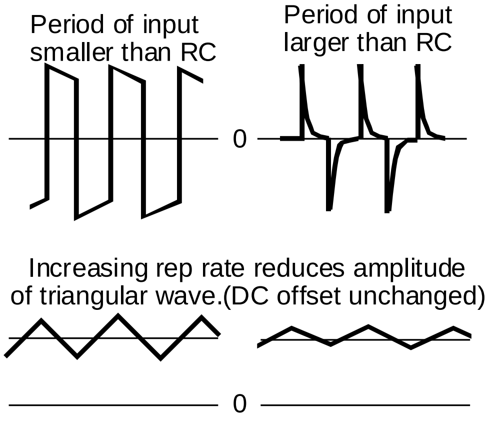

Increasing rep rate reduces amplitude of triangular wave.(DC offset unchanged)

MATHEMATICAL NOTATION

The radar and EW communities generally accept some commonly used notation for the various parameters used in radar and EW calculations. For instance, “P” is almost always power and “G” is almost always gain. Textbooks and reference handbooks will usually use this notation in formulae and equations.

A significant exception is the use of “α” for space loss. Most textbooks do not develop the radar equation to its most usable form as does this reference handbook, therefore the concept of “α” just isn’t covered.

Subscripts are a different matter. Subscripts are often whatever seems to make sense in the context of the particular formula or equation. For instance, power may be “P”, “P_T”, “P_t”, or maybe “P_1”. In the following list, generally accepted notation is given in the left hand column with no subscripts. Subscripted notation in the indented columns is the notation used in this handbook and the notation often used in the EW community.

α = Space loss
α_1 = One way space loss, transmitter to receiver
α_2 = Two way space loss, xmtr to target (including radar cross section) and back to the rcvr
α_{1t} = One way space loss, radar transmitter to target, bistatic
α_{1r} = One way space loss, target to radar receiver, bistatic

Other notation such as α_{tm} may be used to clarify specific losses, in this case the space loss between a target and missile seeker, which could also be identified as α_{1r}.

A = Antenna aperture (capture area)
A_e = Effective antenna aperture
Å = Angstrom

B = Bandwidth (to 3dB points)
B_{IF} = 3 dB IF bandwidth of the receiver (pre-detection)
B_J = Bandwidth of the jamming spectrum
B_{MHz} = 3 dB bandwidth in MHz
B_N = Equivalent noise bandwidth, a.k.a. B
B_V = 3 dB video bandwidth of the receiver (post-detection) (Subscript V stands for video)
BF = Bandwidth reduction factor (jamming spectrum wider than the receiver bandwidth)
BW = Beamwidth (to 3 dB points)

c = Speed of Light

f = Frequency (radio frequency)
f_c = Footcandle (SI unit of illuminance)
f_D = Doppler frequency
f_R = Received frequency
f_T = Transmitted frequency

G = Gain
G_t = Gain of the transmitter antenna
G_r = Gain of the receiver antenna
G_{tr} = Gain of the transmitter/receiver antenna (monostatic radar)
G_J = Gain of the jammer
G_{JA} = Gain of the jammer antenna
G_{JT} = Gain of the jammer transmitter antenna
G_{JR} = Gain of the jammer receiver antenna
G_σ = Gain of reflected radar signal due to radar cross section

h = Height or Planks constant
h_{radar} = Height of radar
h_{target} = Height of target

J = Jamming signal (receiver input)
J_1 = Jamming signal (constant gain jammer)
J_2 = Jamming signal (constant power jammer)
J/S = Jamming to signal ratio (receiver input)

k = Boltzmann constant
$K_{1,2,3,4}$ = Proportionality constants, see Sections 4-3, 4-4, 4-5, and 4-1 respectively.

λ = Lambda, Wavelength or Poisson factor

L = Loss (due to transmission lines or circuit elements)

N = Receiver equivalent noise input (kT_oB)
NF = Noise figure

P = Power
P_d = Probability of detection
P_D = Power density
P_J = Power of a jammer transmitter
P_n = Probability of false alarm
P_r = Power received
P_t = Power of a transmitter

R = Range (straight line distance)
R_1 = Bistatic radar transmitter to target range
R_2 = Bistatic radar target to receiver range
R_J = Range of jammer to receiver (when separate from the target)
R_{NM} = Range in nautical miles

σ = Sigma, radar cross section (RCS)

S = Signal (receiver input)
S_R = Radar signal received by the jammer
S_{min} = Minimum receiver sensitivity

t = Time
t_{int} = Integration time
t_r = Pulse Rise Time
τ = Pulse Width

V = Velocity
V_r = Radial velocity

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FREQUENCY SPECTRUM

Figure 1, which follows, depicts the electromagnetic radiation spectrum and some of the commonly used or known areas. Figure 2 depicts the more common uses of the microwave spectrum. Figure 3 shows areas of the spectrum which are frequently referred to by band designations rather than by frequency.

Section 7-1 provides an additional breakdown of the EO/IR spectrum.

To convert from frequency (f) to wavelength (λ) and vice versa, recall that f = c/λ, or λ = c/f; where c = speed of light.

$$\lambda_{meter} = \frac{3x10^8}{f_{Hz}} = \frac{3x10^5}{f_{kHz}} = \frac{300}{f_{MHz}} = \frac{0.3}{f_{GHz}} \qquad \text{or} \qquad f_{Hz} = \frac{3x10^8}{\lambda_{meter}} \quad f_{kHz} = \frac{3x10^5}{\lambda_{meter}} \quad f_{MHz} = \frac{300}{\lambda_{meter}} \quad f_{GHz} = \frac{0.3}{\lambda_{meter}}$$

Some quick rules of thumb follow:

Metric:

Wavelength in cm = 30 / frequency in GHz
For example: at 10 GHz, the wavelength = 30/10 = 3 cm

English:

Wavelength in ft = 1 / frequency in GHz
For example: at 10 GHz, the wavelength = 1/10 = 0.1 ft

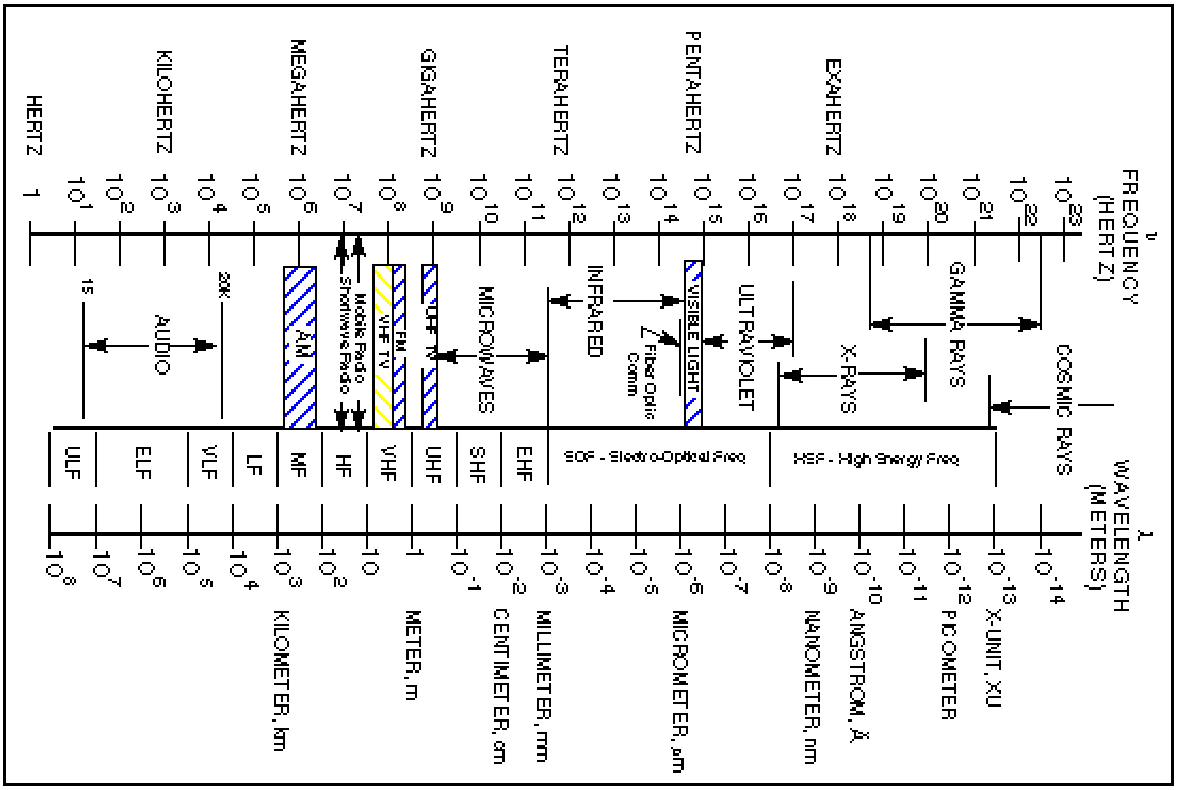
HERTZ
KILOHERTZ
MEGAHERTZ
GIGAHERTZ
TERAHERTZ
PENTAHERTZ
EXAHERTZ
1
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
10^{22}
10^{23}
ν
FREQUENCY (HERTZ)
15
AUDIO
20K
AM
Mobile Radio
Shortwave Radio
FM
VHF TV
UHF TV
MICROWAVES
INFRARED
Fiber Optic Comm
VISIBLE LIGHT
ULTRAVIOLET
X-RAYS
GAMMA RAYS
COSMIC RAYS
ULF
ELF
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
EOF - Electro-Optical Freq
HEF - High Energy Freq
λ
WAVELENGTH (METERS)
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
KILOMETER, km
METER, m
CENTIMETER, cm
MILLIMETER, mm
MICROMETER, µm
NANOMETER, nm
ANGSTROM, Å
PICOMETER
X-UNIT, XU

Figure 1. Electromagnetic Radiation Spectrum.

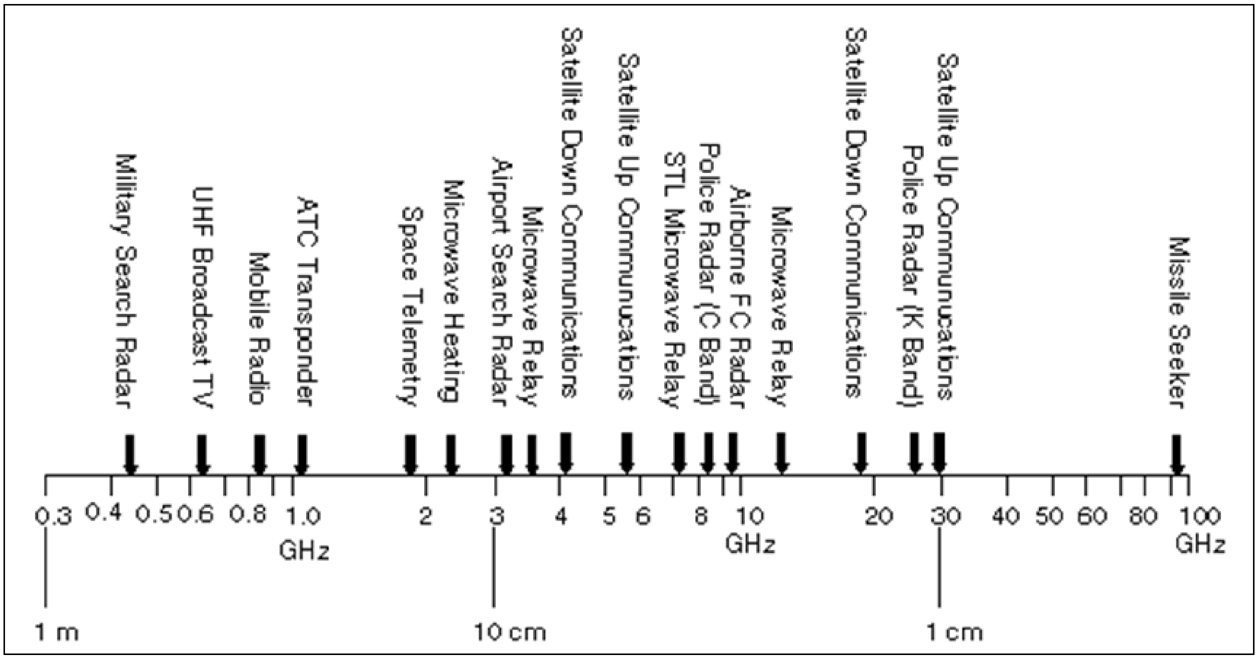

Figure 2. The Microwave Spectrum.

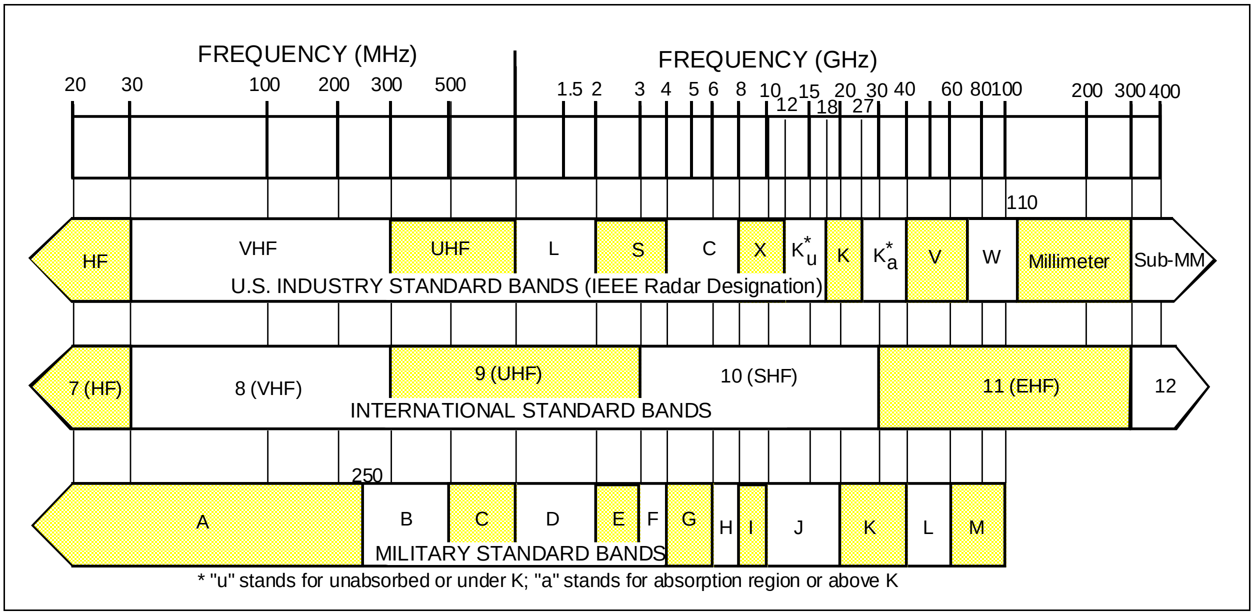
FREQUENCY (MHz)
20 30 100 200 300 500
FREQUENCY (GHz)
1.5 2 3 4 5 6 8 10 12 15 18 20 27 30 40 60 80 100 110 200 300 400
HF
VHF
UHF
L
S
C
X
K_u^*
K
K_a^*
V
W
Millimeter
Sub-MM
U.S. INDUSTRY STANDARD BANDS (IEEE Radar Designation)
7 (HF)
8 (VHF)
9 (UHF)
10 (SHF)
11 (EHF)
12
INTERNATIONAL STANDARD BANDS
250
A
B
C
D
E
F
G
H
I
J
K
L
M
MILITARY STANDARD BANDS
* "u" stands for unabsorbed or under K; "a" stands for absorption region or above K

Figure 3. Frequency Band Designations.

See Section 7, Figure 1 for a more detailed depiction of the UV and IR spectrum.

DECIBEL (dB)

The Decibel is a subunit of a larger unit called the bel. As originally used, the bel represented the power ratio of 10 to 1 between the strength or intensity i.e., power, of two sounds, and was named after Alexander Graham Bell. Thus a power ratio of 10:1 = 1 bel, 100:1 = 2 bels, and 1000:1 = 3 bels. It is readily seen that the concept of bels represents a logarithmic relationship since the logarithm of 100 to the base 10 is 2 (corresponding to 2 bels), the logarithm of 1000 to the base 10 is 3 (corresponding to 3 bels), etc. The exact relationship is given by the formula

$$\text{Bels} = \log(P_2/P_1) \qquad \textbf{[1]}$$

where P_2/P_1 represents the power ratio.

Since the bel is a rather large unit, its use may prove inconvenient. Usually a smaller unit, the Decibel or dB, is used. 10 decibels make one bel. A 10:1 power ratio, 1 bel, is 10 dB; a 100:1 ratio, 2 bels, is 20 dB. Thus the formula becomes

$$\text{Decibels (dB)} = 10 \log(P_2/P_1) \qquad \textbf{[2]}$$

The power ratio need not be greater than unity as shown in the previous examples. In equations [1] and [2], P_1 is usually the reference power. If P_2 is less than P_1, the ratio is less then 1.0 and the resultant bels or decibels are negative. For example, if P_2 is one-tenth P_1, we have

$$\text{bels} = \log(0.1/1) = -1.0 \text{ bels}$$

and $$\text{dB} = 10 \log(0.1/1) = -10 \text{ dB}.$$

It should be clearly understood that the term decibel does not in itself indicate power, but rather is a ratio or comparison between two power values. It is often desirable to express power levels in decibels by using a fixed power as a reference. The most common references in the world of electronics are the milliwatt (mW) and the watt. The abbreviation dBm indicates dB referenced to 1.0 milliwatt. One milliwatt is then zero dBm. Thus P_1 in equations [1] or [2] becomes 1.0 mW. Similarly, the abbreviation dBW indicates dB referenced to 1.0 watt, with P_2 being 1.0 watt, thus one watt in dBW is zero dBW or 30 dBm or 60 dBμW. For antenna gain, the reference is the linearly polarized isotropic radiator, dBLI. Usually the “L” and/or “I” is understood and left out.

dBc is the power of one signal referenced to a carrier signal, i.e., if a second harmonic signal at 10 GHz is 3 dB lower than a fundamental signal at 5 GHz, then the signal at 10 GHz is -3 dBc.

THE DECIBEL, ITS USE IN ELECTRONICS

The logarithmic characteristic of the dB makes it very convenient for expressing electrical power and power ratios. Consider an amplifier with an output of 100 watts when the input is 0.1 watts (100 milliwatts); it has an amplification factor of

$$P_2/P_1 = 100/0.1 = 1000$$

or a gain of:

$$10 \log(P_2/P_1) = 10 \log(100/0.1) = 30 \text{ dB}.$$

(notice the 3 in 30 dB corresponds to the number of zeros in the power ratio)

The ability of an antenna to intercept or transmit a signal is expressed in dB referenced to an isotropic antenna rather than as a ratio. Instead of saying an antenna has an effective gain ratio of 7.5, it has a gain of 8.8 dB (10 log 7.5).

A ratio of less than 1.0 is a loss, a negative gain, or attenuation. For instance, if 10 watts of power is fed into a cable but only 8.5 watts are measured at the output, the signal has been decreased by a factor of

$8.5/10 = .85$

or $10 \log(.85) = -0.7$ dB.

This piece of cable at the frequency of the measurement has a gain of -0.7 dB. This is generally referred to as a loss or attenuation of 0.7 dB, where the terms "loss" and "attenuation" imply the negative sign. An attenuator which reduces its input power by factor of 0.001 has an attenuation of 30 dB. The utility of the dB is very evident when speaking of signal loss due to radiation through the atmosphere. It is much easier to work with a loss of 137 dB rather than the equivalent factor of 2×10^{-14}.

Instead of multiplying gain or loss factors as ratios we can add them as positive or negative dB. Suppose we have a microwave system with a 10 watt transmitter, and a cable with 0.7 dB loss connected to a 13 dB gain transmit antenna. The signal loss through the atmosphere is 137 dB to a receive antenna with an 11 dB gain connected by a cable with 1.4 dB loss to a receiver. How much power is at the receiver? First, we must convert the 10 watts to milliwatts and then to dBm:

10 watts = 10,000 milliwatts

and

$10 \log (10{,}000/1) = 40$ dBm

Then

40 dBm - 0.7 dB + 13 dB - 137 dB + 11 dB - 1.4 dB = -75.1 dBm.

-75.1 dBm may be converted back to milliwatts by solving the formula:

$\text{mW} = 10^{(\text{dBm}/10)}$

giving: $10^{(-75.1/10)} = 0.00000003$ mW

Voltage and current ratios can also be expressed in terms of decibels, provided the resistance remains constant. First we substitute for P in terms of either voltage, V, or current, I. Since P=VI and V=IR we have:

$P = I^2R = V^2/R$

Thus for a voltage ratio we have: $\text{dB} = 10 \log[(V_2^2/R)/(V_1^2/R)] = 10 \log(V_2^2/V_1^2)$

$= 10 \log(V_2/V_1)^2 = 20 \log(V_2/V_1)$

Like power, voltage can be expressed relative to fixed units, so one volt is equal to 0 dBV or 120 dBμV.

Similarly for current ratio: $\text{dB} = 20 \log(I_2/I_1)$

Like power, amperage can be expressed relative to fixed units, so one amp is equal to 0 dBA or 120 dBμA.

Decibel Formulas (where Z is the general form of R, including inductance and capacitance)

When impedances are equal: $dB = 10\log\frac{P2}{P1} = 20\log\frac{E2}{E1} = 20\log\frac{I2}{I1}$

When impedances are unequal: $dB = 10\log\frac{P2}{P1} = 20\log\frac{E2\sqrt{Z1}}{E1\sqrt{Z2}} = 20\log\frac{I2\sqrt{Z2}}{I1\sqrt{Z1}}$

SOLUTIONS WITHOUT A CALCULATOR

Solution of radar and EW problems requires the determination of logarithms (base 10) to calculate some of the formulae. Common “four function” calculators do not usually have a log capability (or exponential or fourth root functions either). Without a scientific calculator (or math tables or a Log-Log slide rule) it is difficult to calculate any of the radar equations, simplified or “textbook.” The following gives some tips to calculate a close approximation without a calculator.

DECIBEL TABLE

DB	Power Ratio	Voltage or Current Ratio	DB	Power Ratio	Voltage or Current Ratio
0	1.00	1.00	10	10.0	3.16
0.5	1.12	1.06	15	31.6	5.62
1.0	1.26	1.12	20	100	10
1.5	1.41	1.19	25	316	17.78
2.0	1.58	1.26	30	1,000	31.6
3.0	2.00	1.41	40	10,000	100
4.0	2.51	1.58	50	10^5	316
5.0	3.16	1.78	60	10^6	1,000
6.0	3.98	2.00	70	10^7	3,162
7.0	5.01	2.24	80	10^8	10,000
8.0	6.31	2.51	90	10^9	31,620
9.0	7.94	2.82	100	10^{10}	10^5

For dB numbers which are a multiple of 10

An easy way to remember how to convert dB values that are a multiple of 10 to the absolute magnitude of the power ratio is to place a number of zeros equal to that multiple value to the right of the value 1.
40 dB = 10,000 : 1 (for power)

Minus dB moves the decimal point that many places to the left of 1.
-40 dB = 0.0001 : 1 (for power)

For voltage or current ratios, if the multiple of 10 is even, then divide the multiple by 2, and apply the above rules.
40 dB = 100 : 1 (for voltage)
-40 dB = 0.01 : 1

If the power in question is not a multiple of ten, then some estimation is required. The following tabulation lists some approximations. Some would be useful to memorize.

DB RULES OF THUMB

Multiply Current / Voltage By			Multiply Power By:	
if +dB	if -dB	**dB**	if +dB	if -dB
1	1	0	1	1
1.12	0.89	1	1.26	0.8
1.26	0.79	2	1.58	0.63
1.4	0.707	3	2	0.5
2.0	0.5	6	4	0.25
2.8	0.35	9	8	0.125
3.16	0.316	10	10	0.1
4.47	0.22	13	20	0.05
10	0.1	20	100	0.01
100	0.01	40	10,000	0.0001

You can see that the list has a repeating pattern, so by remembering just three basic values such as one, three, and 10 dB, the others can easily be obtained without a calculator by addition and subtraction of dB values and multiplication of corresponding ratios.

Example 1:

A 7 dB increase in power (3+3+1) dB is an increase of (2 x 2 x 1.26) = 5 times whereas
A 7 dB decrease in power (-3-3-1) dB is a decrease of (0.5 x 0.5 x 0.8) = 0.2.

Example 2: Assume you know that the ratio for 10 dB is 10, and that the ratio for 20 dB is 100 (doubling the dB increases the power ratio by a factor of ten), and that we want to find some intermediate value.

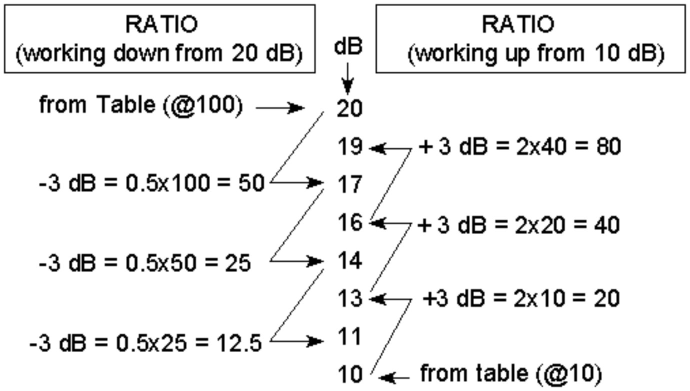

We can get more intermediate dB values by adding or subtracting one to the above, for example, to find the ratio at 12 dB we can:

work up from the bottom; 12 = 1+11 so we have 1.26 (from table) x 12.5 = 15.75
alternately, working down the top 12 = 13-1 so we have 20 x 0.8 (from table) = 16

The resultant numbers are not an exact match (as they should be) because the numbers in the table are rounded off. We can use the same practice to find any ratio at any other given value of dB (or the reverse).

dB AS ABSOLUTE UNITS

Power in absolute units can be expressed by using 1 Watt (or 1 milliwatt) as the reference power in the denominator of the equation for dB. We then call it dBW or dBm. We can then build a table such as the adjoining one.

From the above, any intermediate value can be found using the same dB rules and memorizing several dB values for determining the absolute power, given 48 dBm power output, we determine that 48 dBm = 50 dBm - 2 dB so we take the value at 50 dB which is 100W and divide by the value 1.58 (ratio of 2 dB) to get:

100 watts/1.58 = 63 W or 63,291 mW.

dB AS ABSOLUTE UNITS

dBμW	dBm	POWER	dBW
120	90	1 MW	60
90	60	1 kW	30
80	50	100 W	20
70	40	10 W	10
60	30	1 W (1000 mW)	0
50	20	100 mW	-10
40	10	10 mW	-20
33	3	2 mW	-27
32	2	1.58 mW	-28
31	1	1.26 mw	-29
30	0	1 mW	-30

Because dBW is referenced to one watt, the Log of the power in watts times 10 is dBW. The Logarithm of 10 raised by any exponent is simply that exponent. That is: $\mathrm{Log}(10)^4 = 4$. Therefore, a power that can be expressed as any exponent of 10 can also be expressed in dBW as that exponent times 10. For example, 100 kW can be written 100,000 watts or 10^5 watts. 100 kW is then +50 dBW. Another way to remember this conversion is that dBW is the number of zeros in the power written in watts times 10. If the transmitter power in question is conveniently a multiple of ten (it often is) the conversion to dBW is easy and accurate.

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DUTY CYCLE

Duty cycle (or duty factor) is a measure of the fraction of the time a radar is transmitting. It is important because it relates to peak and average power in the determination of total energy output. This, in turn, ultimately affects the strength of the reflected signal as well as the required power supply capacity and cooling requirements of the transmitter.

Although there are exceptions, most radio frequency (RF) measurements are either continuous wave (CW) or pulsed RF. CW RF is uninterrupted RF such as from an oscillator. Amplitude modulated (AM), frequency modulated (FM), and phase modulated (PM) RF are considered CW since the RF is continuously present. The power may vary with time due to modulation, but RF is always present. Pulsed RF, on the other hand, is bursts (pulses) of RF with no RF present between bursts. The most general case of pulsed RF consists of pulses of a fixed pulse width (PW) which come at a fixed time interval, or period, (T). For clarity and ease of this discussion, it is assumed that all RF pulses in a pulse train have the same amplitude. Pulses at a fixed interval of time arrive at a rate or frequency referred to as the pulse repetition frequency (PRF) of so many pulse per second. Pulse repetition interval (PRI) and PRF are reciprocals of each other.

$$PRF = 1/T = 1/PRI \qquad \textbf{[1]}$$

Power measurements are classified as either peak pulse power, P_p, or average power, P_{ave}. The actual power in pulsed RF occurs during the pulses, but most power measurement methods measure the heating effects of the RF energy to obtain an average value of the power. It is correct to use either value for reference so long as one or the other is consistently used. Frequently it is necessary to convert from P_p to P_{ave}, or vice versa; therefore the relationship between the two must be understood. Figure 1 shows the comparison between P_p and P_{ave}.

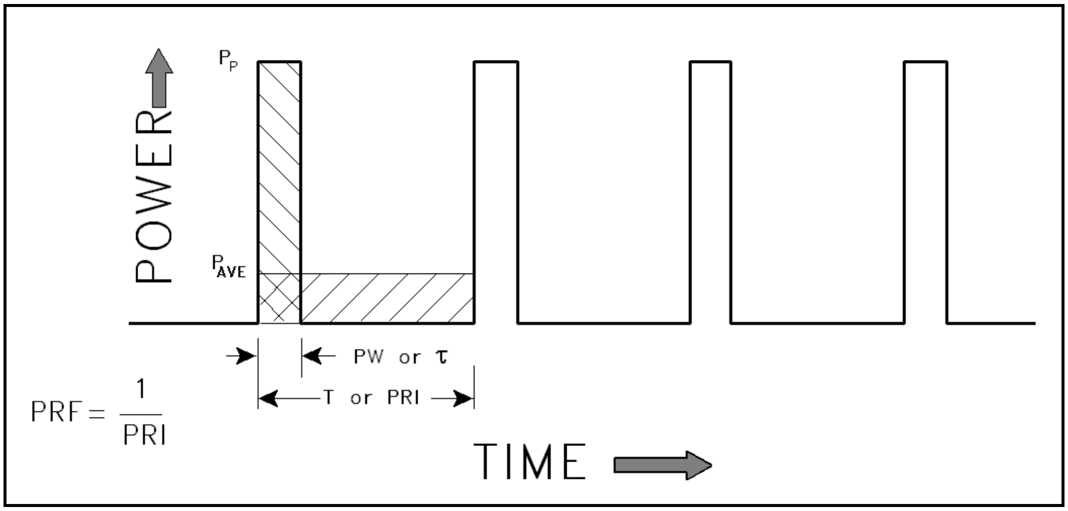

Figure 1. RF Pulse Train.

The average value is defined as that level where the pulse area above the average is equal to area below average between pulses. If the pulses are evened off in such a way as to fill in the area between pulses, the level obtained is the average value, as shown in Figure 1 where the shaded area of the pulse is used to fill in the area between pulses. The area of the pulse is the pulse width multiplied by the peak pulse power. The average area is equal to the average value of power multiplied by the pulse period.

Since the two values are equal:

$$P_{ave} \text{ x } T = P_p \text{ x } PW \qquad \textbf{[2]}$$

or

$$P_{ave}/P_p = PW/T \qquad \textbf{[3]}$$

Using [1]

$$P_{ave}/P_p = PW/T = PW \text{ x } PRF = PW/PRI = \text{duty cycle} \qquad \textbf{[4]}$$

(note that the symbol τ represents pulse width (PW) in most reference books)

The ratio of the average power to the peak pulse power is the duty cycle and represents the percentage of time the power is present. In the case of a square wave the duty cycle is 0.5 (50%) since the pulses are present 1/2 the time, the definition of a square wave.

For Figure 1, the pulse width is 1 unit of time and the period is 10 units. In this case the duty cycle is:

$$PW/T = 1/10 = 0.1 \text{ } (10\%).$$

A more typical case would be a PRF of 1,000 and a pulse width of 1.0 microseconds. Using [4], the duty cycle is 0.000001 x 1,000 = 0.001. The RF power is present one-thousandth of the time and the average power is 0.001 times the peak power. Conversely, if the power were measured with a power meter which responds to average power, the peak power would be 1,000 time the average reading.

Besides expressing duty cycle as a ratio as obtained in equation [4], it is commonly expressed as either a percentage or in decibels (dB). To express the duty cycle of equation [4] as a percentage, multiply the value obtained by 100 and add the percent symbol. Thus a duty cycle of 0.001 is also 0.1%.

The duty cycle can be expressed logarithmically (dB) so it can be added to or subtracted from power measured in dBm/dBW rather than converting to, and using absolute units.

$$\text{Duty cycle (dB)} = 10 \log(\text{duty cycle ratio}) \qquad \textbf{[5]}$$

For the example of the 0.001 duty cycle, this would be 10 log(0.001) = -30 dB. Thus the average power would be 30 dB less than the peak power. Conversely, the peak power is 30 dB higher than the average power.

For pulse radars operating in the PRF range of 0.25-10 kHz and PD radars operating in the PRF range of 10-500 kHz, typical duty cycles would be:

Pulse	~	0.1 - 3%	=	0.001 - .03	=	-30 to -15 dB
Pulse Doppler	~	5 - 50%	=	0.05 - .5	=	-13 to -3 dB
Continuous Wave	~	100%	=	1	=	0 dB

Intermediate Frequency Bandwidths of typical signals are:

Pulse	1 to 10 MHz
Chirp or Phase coded pulse	0.1 to 10 MHz
CW or PD	0.1 to 5 kHz

PRF is usually subdivided into the following categories: Low 0.25-4 kHz; Medium 8-40 kHz; High 50-300 kHz.

DOPPLER SHIFT

Doppler is the apparent change in wavelength (or frequency) of an electromagnetic or acoustic wave when there is relative movement between the transmitter (or frequency source) and the receiver.

Summary RF Equation for the Two-Way (radar) case

$$f_{Rec} = f_{Xmt} + f_D = f_{Xmt} + \frac{2(V_{Xmtr} + V_{Tgt})\, f_{Xmt}}{c}$$

Summary RF Equation for the One-Way (ESM) case

$$f_{Rec} = f_{Xmt} + f_D = f_{Xmt} + \frac{V_{Xmtr\ or\ Rec}\ f_{Xmt}}{c}$$

Rules of Thumb for two-way signal travel
(divide in half for one-way ESM signal measurements)
At 10 GHz, $f_D \cong$
35 Hz per Knot
19 Hz per km/Hr
67 Hz per m/sec
61 Hz per yd/sec
20 Hz per ft/sec

To estimate f_D at other frequencies, multiply these by:

$$\left[\frac{f_{Xmt}(GHz)}{10}\right]$$

The Doppler effect is shown in Figure 1. In everyday life this effect is commonly noticeable when a whistling train or police siren passes you. Audio Doppler is depicted, however Doppler can also affect the frequency of a radar carrier wave, the PRF of a pulse radar signal, or even light waves causing a shift of color to the observer.

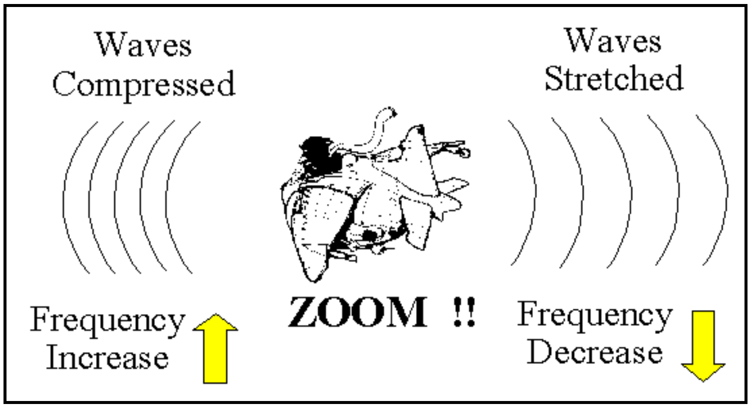

Figure 1. Doppler Frequency Creation From Aircraft Engine Noise.

How do we know the universe is expanding?

Answer: The color of light from distant stars is shifted to red (see Section 7-1: higher λ or lower frequency means Doppler shift is stretched, i.e., expanding).

A memory aid might be that the lights from a car (going away) at night are red (tail lights)!

Doppler frequency shift is directly proportional to velocity and a radar system can therefore be calibrated to measure velocity instead of (or along with) range. This is done by measuring the shift in frequency of a wave caused by an object in motion (Figure 2).

- * Transmitter in motion
- * Reflector in motion
- * Receiver in motion
- * All three

For a closing relative velocity:

- * Wave is compressed
- * Frequency is increased

For an opening relative velocity:

- * Wave is stretched
- * Frequency is decreased

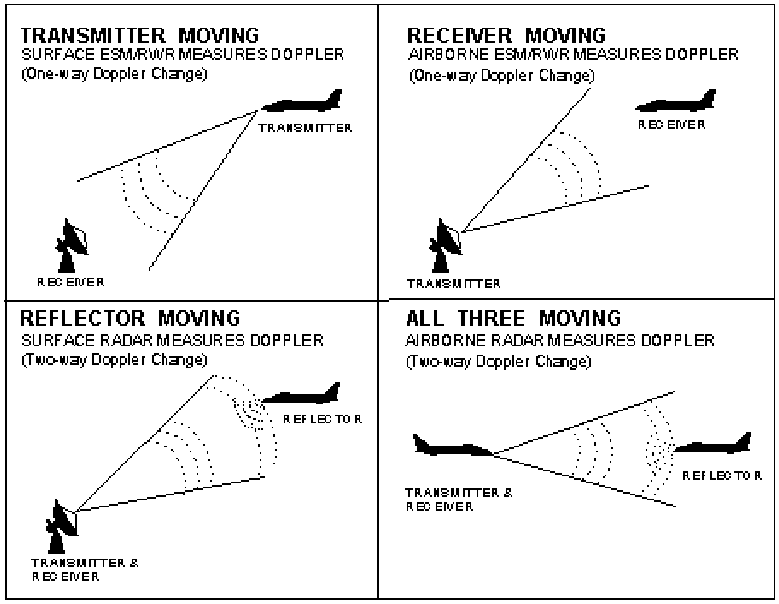
TRANSMITTER MOVING
SURFACE ESM/RWR MEASURES DOPPLER
(One-way Doppler Change)
TRANSMITTER
RECEIVER
RECEIVER MOVING
AIRBORNE ESM/RWR MEASURES DOPPLER
(One-way Doppler Change)
RECEIVER
TRANSMITTER
REFLECTOR MOVING
SURFACE RADAR MEASURES DOPPLER
(Two-way Doppler Change)
REFLECTOR
TRANSMITTER & RECEIVER
ALL THREE MOVING
AIRBORNE RADAR MEASURES DOPPLER
(Two-way Doppler Change)
TRANSMITTER & RECEIVER
REFLECTOR

Figure 2. Methods of Doppler Creation.

To compute Doppler frequency we note that velocity is range rate; V = dr/dt

For the reflector in motion case, you can see the wave compression effect in Figure 3 when the transmitted wave peaks are one wavelength apart. When the first peak reaches the target, they are still one wavelength apart (point a).

When the 2nd peak reaches the target, the target has advanced according to its velocity (vt) (point b), and the first reflected peak has traveled toward the radar by an amount that is less than the original wavelength by the same amount (vt) (point c).

As the 2nd peak is reflected, the wavelength of the reflected wave is 2(vt) less than the original wavelength (point d).

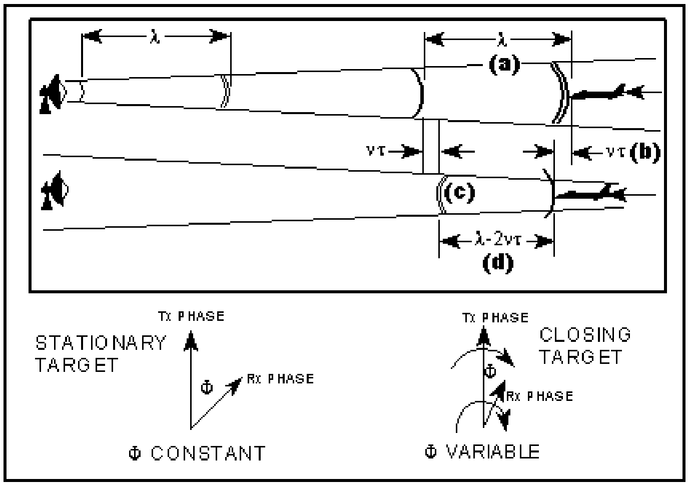
λ
λ
(a)
vτ
vτ (b)
(c)
λ-2vτ
(d)
Tx PHASE
STATIONARY TARGET
Φ
Rx PHASE
Φ CONSTANT
Tx PHASE
CLOSING TARGET
Φ
Rx PHASE
Φ VARIABLE

Figure 3. Doppler Compression Equivalent to Variable Phase Shift.

The distance the wave travels is twice the target range. The reflected phase lags transmitted phase by 2x the round trip time. For a fixed target the received phase will differ from the transmitted phase by a constant phase shift. For a moving target the received phase will differ by a changing phase shift.

For the closing target shown in Figure 3, the received phase is advancing with respect to the transmitted phase and appears as a higher frequency.

Doppler is dependent upon closing velocity, not actual radar or target velocity as shown in Figure 4.

For the following equations (except radar mapping), we assume the radar and target are moving directly toward one another to simplify calculations (if this is not the case, use the velocity component of one in the direction of the other in the formulas).

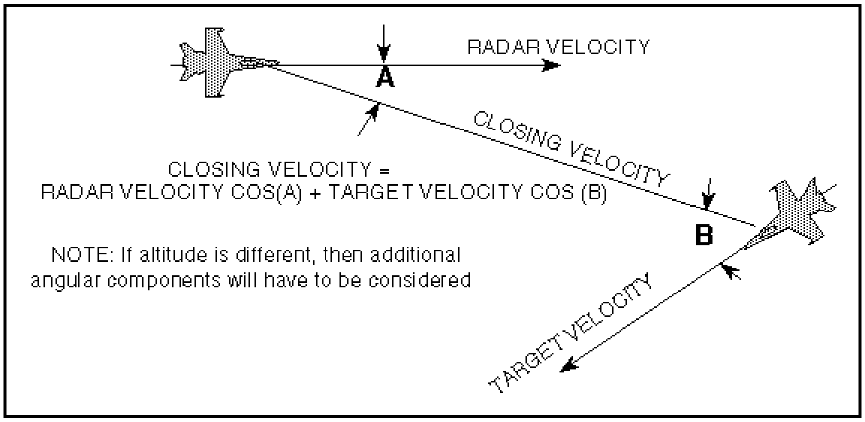
RADAR VELOCITY
A
CLOSING VELOCITY
CLOSING VELOCITY =
RADAR VELOCITY COS(A) + TARGET VELOCITY COS (B)
B
NOTE: If altitude is different, then additional angular components will have to be considered
TARGET VELOCITY

Figure 4. Doppler Depends Upon Closing Velocity.

For the case of a moving reflector, doppler frequency is proportional to 2x the transmitted frequency:
Higher rf = higher doppler shift
$f_D = (2 \times V_{Target})(f/c)$

Speed of Light
Conversions
* * *
$c \cong 2.9979 \times 10^8$ m/sec
$c \cong 5.8275 \times 10^8$ nm/hr (knots)
$c \cong 9.8357 \times 10^8$ ft/sec

Likewise, it can be shown that for other cases, the following relationships hold:

For an airplane radar with an airplane target (The "all three moving" case, aircraft radar transmitter, target, and aircraft radar receiver)
$f_D = 2(V_{Radar} + V_{Target})(f/c)$

For the case of a semi-active missile receiving signals (Also "all three moving")
$f_D = (V_{Radar} + 2V_{Target} + V_{Missile})(f/c)$

For the airplane radar with a ground target (radar mapping) or vice versa.
$f_D = 2(V_{Radar} \cos\theta \cos\varphi)(f/c)$, Where θ and φ are the radar scan azimuth and depression angles.

For a ground based radar with airborne target - same as previous using target track crossing angle and ground radar elevation angle.

For the ES/ESM/RWR case where only the target or receiver is moving (One-way Doppler measurements)
$f_D = V_{Receiver\ or\ Target}(f/c)$

Note: See Figure 4 if radar and target are not moving directly towards or away from one another.

Figure 5 depicts the results of a plot of the above equation for a moving reflector such as might be measured with a ground radar station illuminating a moving aircraft.

It can be used for the aircraft-to-aircraft case, if the total net closing rate of the two aircraft is used for the speed entry in the figure.

It can also be used for the ES/ESM case (one-way doppler measurements) if the speed of the aircraft is used and the results are divided by two.

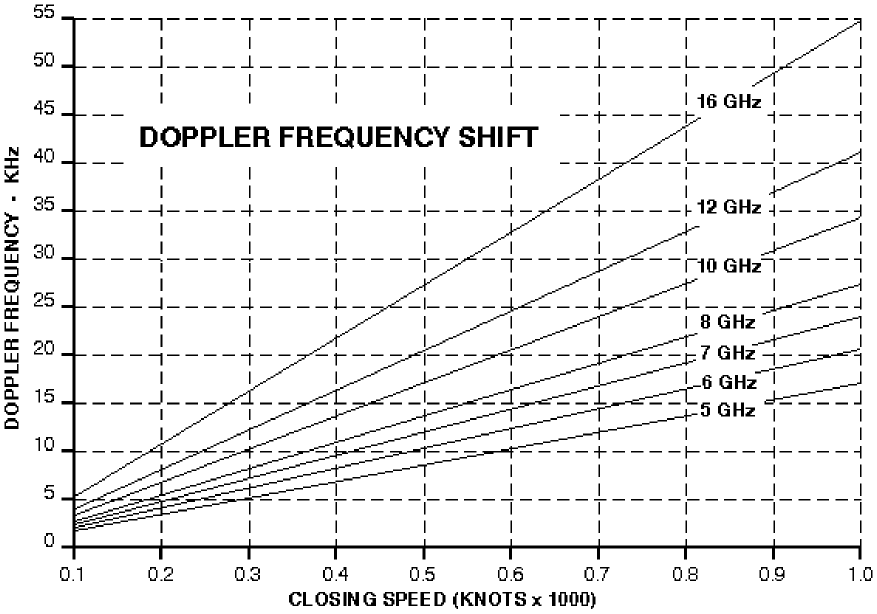

Figure 5. Two-Way Doppler Frequency Shift.

SAMPLE PROBLEMS:

(1) If a ground radar operating at 10 GHz is tracking an airplane flying at a speed of 500 km/hr tangential to it (crossing pattern) at a distance of 10 km, what is the Doppler shift of the returning signal?

Answer: Since the closing velocity is zero, the Doppler is also zero.

(2) If the same aircraft turns directly toward the ground radar, what is the Doppler shift of the returning signal?

Answer: 500 km/hr = 270 kts from Section 2-1. From Figure 4 we see that the Doppler frequency is about 9.2 KHz.

(3) Given that a ground radar operating at 7 GHz is Doppler tracking an aircraft 20 km away (slant range) which is flying directly toward it at an altitude of 20,000 ft and a speed of 800 ft/sec, what amount of VGPO switch would be required of the aircraft jammer to deceive (pull) the radar to a zero Doppler return?

Answer: We use the second equation from the bottom of page 2-6.3 which is essentially the same for this application except a ground radar is tracking an airplane target (vs. an airplane during ground mapping), so for our application we use a positive elevation angle instead of a negative (depression) angle.

$f_D = 2(V_r \text{ Cos } \theta \text{ Cos } \varphi)(f/c)$, where θ is the aircraft track crossing angle and φ is the radar elevation angle.

Since the aircraft is flying directly at the radar, $\theta = 0°$; the aircraft altitude = 20,000 ft = 6,096 meters.

Using the angle equation in Section 2-1, sin φ = x/r = altitude / slant range, so:
$\varphi = \sin^{-1}$ (altitude/slant range) = $\sin^{-1}$ (6,096 m / 20,000 m) = 17.7°

F_D = 2(800 ft/sec Cos 0° Cos 17.7°)(7x10^9 Hz / 9.8357 x 10^9 ft/sec) = 10,845 Hz

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ELECTRONIC FORMULAS

Ohm's Law Formulas for D-C Circuits. $E = IR = \frac{P}{I} = \sqrt{PR}$ $\quad P = I^2 R = EI = \frac{E^2}{R}$

Ohm's Law Formulas for A-C Circuits and Power Factor.

$$E = IZ = \frac{P}{I \cos \Theta} = \sqrt{\frac{P\,Z}{\cos \Theta}} \qquad P = I^2\, Z \cos \Theta = IE \cos \Theta = \frac{E^2 \cos \Theta}{Z}$$

In the above formulas Θ is the angle of lead or lag between current and voltage and cos Θ = P/EI = power factor or *pf*.

$$pf = \frac{Active\ \ power\ (in\ watts)}{Apparent\ \ power\ (in\ volt\text{-}amps)} = Pover E\ I \qquad pf = \frac{R}{Z}$$

Note: Active power is the "resistive" power and equals the equivalent heating effect on water.

Voltage/Current Phase Rule of Thumb Remember "ELI the ICE man"

ELI: Voltage (E) comes before (leads) current (I) in an inductor (L)
ICE: Current (I) comes before (leads) Voltage (E) in a capacitor (C)

Resistors in Series $R_{total} = R_1 + R_2 = R_3 + \ldots$

Two Resistors in Parallel $R_t = \frac{R_1\, R_2}{R_1 + R_2}$

Resistors in Parallel, General Formula

$$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$$

Resonant Frequency Formulas *Where in the second formula f is in kHz and L and C are in microunits.

$$f = \frac{1}{2\pi\sqrt{LC}}\ ,\ \ or\ \ \ f = \frac{159.2*}{\sqrt{LC}} \quad L = \frac{1}{4\pi^2 f^2 C}\ ,\ \ or\ \ L = \frac{25{,}330*}{f^2 C} \quad C = \frac{1}{4\pi^2 f^2 L}\ ,\ \ or\ \ C = \frac{25{,}330*}{f^2 L}$$

Conductance $G = \frac{1}{R}$ $\ (for\ D\text{-}C\ circuit)$ $\qquad G = \frac{R}{R^2 + X^2}$ $\ (for\ A\text{-}C\ circuit)$

Reactance Formulas $X_C = \frac{1}{2\pi\, f\ C}$ $\qquad C = \frac{1}{2\pi\, f\ X_C}$ $\qquad X_L = 2\pi\, fL$ $\qquad L = \frac{X_L}{2\pi\, f}$

Impedance Formulas $Z = \sqrt{R^2 + (X_L - X_C)^2}$ $\quad (for\ series\ circuit)$

$$Z = \frac{RX}{\sqrt{R^2 + X^2}} \quad (for\ R\ and\ X\ in\ parallel)$$

Q or Figure of Merit $Q = \frac{X_L}{R}\ \ or\ \ \frac{X_C}{R}$

Frequency Response

		Inductor *	Capacitor *	Resister
	DC	Pass	Block	Attenuate
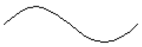	Low Freq AC	Attenuate *	Attenuate *	Attenuate
	High Freq	Block	Pass	Attenuate

* Attenuation varies as a function of the value of the each device and the frequency

"Cartoon" memory aid

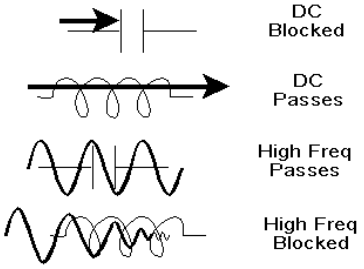

Sinusoidal Voltages and Currents

Effective value = 0.707 x peak value
[Also known as Root-Mean Square (RMS) value]

Half Cycle Average value = 0.637 x peak

Peak value = 1.414 x effective value

∴ Effective value = 1.11 x average value

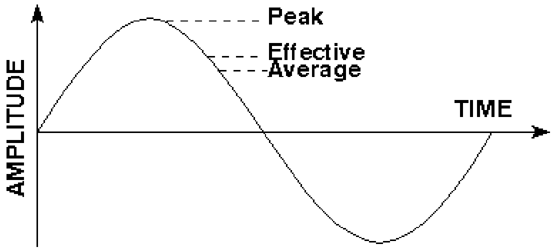

Three-phase AC Configurations

(120° phase difference between each voltage)

If the connection to a three phase AC configuration is miswired, switching any two of the phases will put it back in the proper sequence.

Electric power for ships commonly uses the delta configuration, while commercial electronic and aircraft applications commonly use the wye configuration.

Wye (Y) or Star

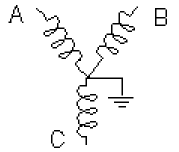

Delta

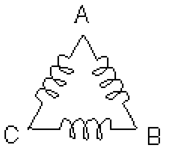

Color Code for House Wiring:	**PURPOSE:**	**Color Code for Chassis Wiring:**
Black or red	HOT	Red
White	NEUTRAL (Return)	White
Green or bare	GROUND	Black

Color Code for Resistors: **First and second band**: (and third band # of zeros if not gold/silver)

First and second band				Third band Multiplier		Fourth band Tolerance	
0	Black	5	Green	.1	Gold	5%	Gold
1	Brown	6	Blue	.01	Silver	10%	Silver
2	Red	7	Violet			20%	No color
3	Orange	8	Gray				
4	Yellow	9	White				

The third color band indicates number of zeros to be added after figures given by first two color bands. But if third color band is gold, multiply by 0.1 and if silver multiply by 0.01. Do not confuse with fourth color-band that indicates tolerance. Thus, a resistor marked blue-red-gold-gold has a resistance of 6.2 ohms and a 5% tolerance.

MISSILE AND ELECTRONIC EQUIPMENT DESIGNATIONS

Missiles are designated with three letters from the columns below plus a number (i.e., AIM-7M) Suffixes (M in this case) indicate a modification.

First Letter Launch Environment	**Second Letter** Mission Symbols	**Third Letter** Vehicle Type
A Air B Multiple C Coffin H Silo stored L Silo launched M Mobile P Soft Pad R Ship U Underwater	D Decoy E Special electronic G Surface attack I Intercept, aerial Q Drone T Training U Underwater attack W Weather	M Guided Missile N Probe (non-orbital instruments) R Rocket (without installed or remote control guidance)

U.S. military electronic equipment is assigned an identifying alphanumeric designation that is used to uniquely identify it. This system is commonly called the "AN" designation system, although its formal name is the Joint Electronics Type Designation System (JETDS). The letters AN preceding the equipment indicators formerly meant "Army/Navy," but now are a letter set that can only be used to indicate formally designated DOD equipment. The first three letters following the "AN/" indicate Platform Installation, Equipment Type, and Equipment Function, respectively. The appropriate meaning is selected from the lists below. The letters following the AN designation numbers provide added information about equipment. Suffixes (A, B, C, etc.) indicate a modification. The letter (V) indicates that variable configurations are available. The letter (X) indicates a development status. A parenthesis ( ) without a number within it indicates a generic system that has not yet received a formal designation, e.g., AN/ALQ( ). Quite often the () is pronounced "bow legs" since they look like the shape of cowboy legs.

First Letter Platform Installation	**Second Letter** Equipment Type	**Third Letter** Function or Purpose
A Piloted aircraft B Underwater mobile, submarine D Pilotless carrier F Fixed ground G General ground use K Amphibious M Mobile (ground) P Portable S Water T Ground, transportable U General utility V Vehicular (ground) W Water surface and underwater combination Z Piloted-pilotless airborne vehicle combination	A Invisible light, heat radiation C Carrier D Radiac F Photographic G Telegraph or teletype I Interphone and public address J Electromechanical or inertial wire covered K Telemetering L Countermeasures M Meteorological N Sound in air P Radar Q Sonar and underwater sound R Radio S Special or combinations of types T Telephone (wire) V Visual and visible light W Armament X Facsimile or television Y Data Processing	B Bombing C Communications D Direction finder, reconnaissance and/or surveillance E Ejection and/or release G Fire control or searchlight directing H Recording and/or reproducing K Computing M Maintenance and/or test assemblies N Navigation aids Q Special or combination of purposes R Receiving, passive detecting S Detecting and/or range and bearing, search T Transmitting W Automatic flight or remote control X Identification and recognition Y Surveillance and control

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RADAR HORIZON / LINE OF SIGHT

There are limits to the reach of radar signals. At the frequencies normally used for radar, radio waves usually travel in a straight line. The waves may be obstructed by weather or shadowing, and interference may come from other aircraft or from reflections from ground objects (Figure 1).

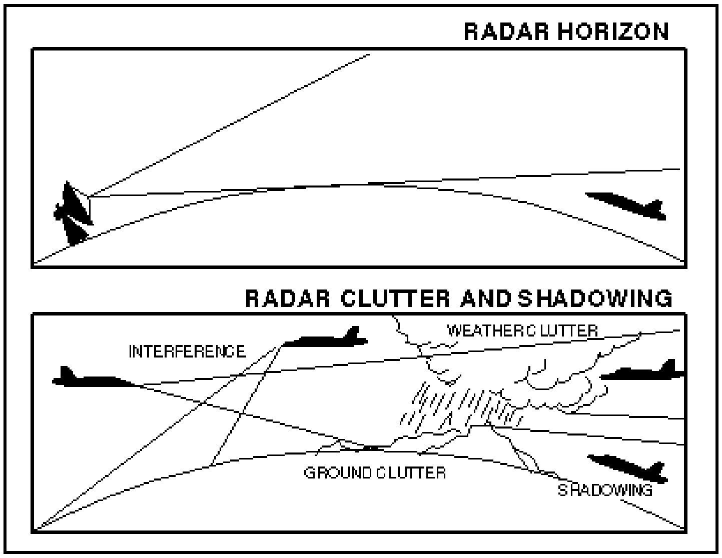

Figure 1. Radar Horizon and Shadowing.

As also shown in Figure 1, an aircraft may not be detected because it is below the radar line which is tangent to the earth's surface.

Some rules of thumb are:

Range (to horizon):

$$R_{NM} = 1.23\sqrt{h_{radar}} \quad with\ h\ in\ ft$$

Range (beyond horizon / over earth curvature):

$$R_{NM} = 1.23\left(\sqrt{h_{radar}} + \sqrt{h_{target}}\right) \quad with\ h\ in\ ft$$

In obtaining the radar horizon equations, it is common practice to assume a value for the Earth's radius that is 4/3 times the actual radius. This is done to account for the effect of the atmosphere on radar propagation. For a true line of sight, such as used for optical search and rescue, the constant in the equations changes from 1.23 to 1.06.

A nomograph for determining maximum target range is depicted in Figure 2. Although an aircraft is shown to the left, it could just as well be a ship, with radars on a mast of height "h." Any target of height (or altitude) "H" is depicted on the right side.

See also Section 5-1 on ducting and refraction, which may increase range beyond these distances.

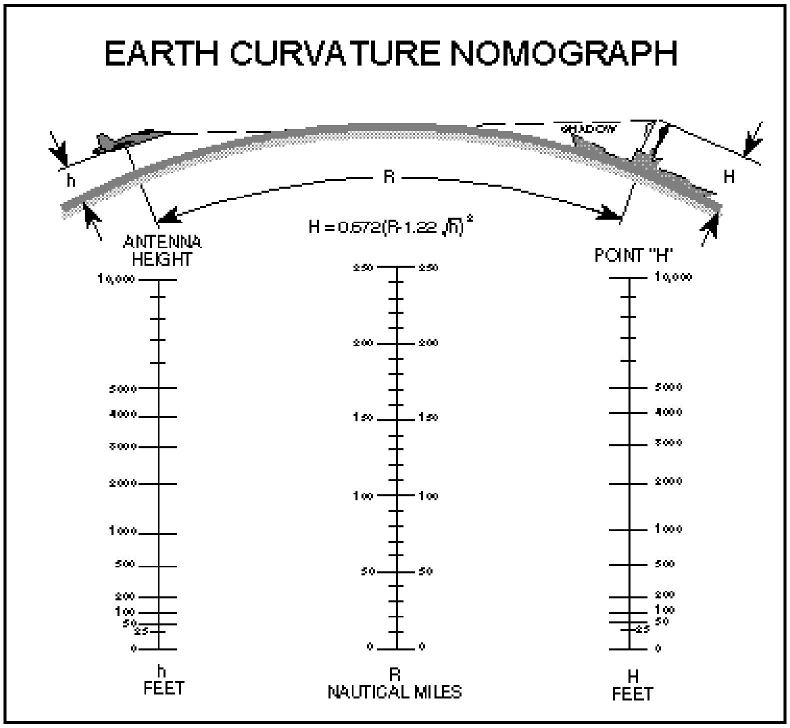

Figure 2. Earth Curvature Nomograph.

This data was expanded in Figure 3 to consider the maximum range one aircraft can detect another aircraft using:

$$R_{NM} = 1.23\left(\sqrt{h_{radar}} + \sqrt{h_{target}}\right)$$

(with h in feet)

It can be used for surface targets if H_{target} = 0. It should be noted that most aircraft radars are limited in power output, and would not detect small or surface objects at the listed ranges.

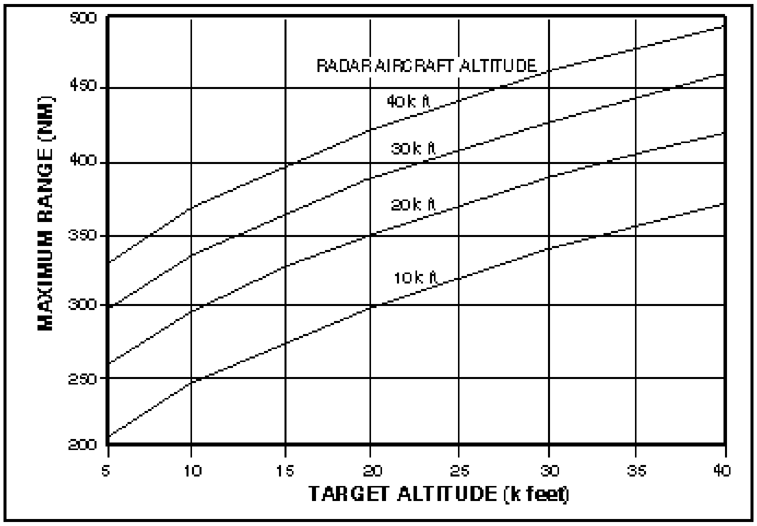

Figure 3. Aircraft Radar vs. Aircraft Target Maximum Range.

Figure 4 depicts the maximum range that a ship height antenna can detect a zero height object (i.e., rowboat).

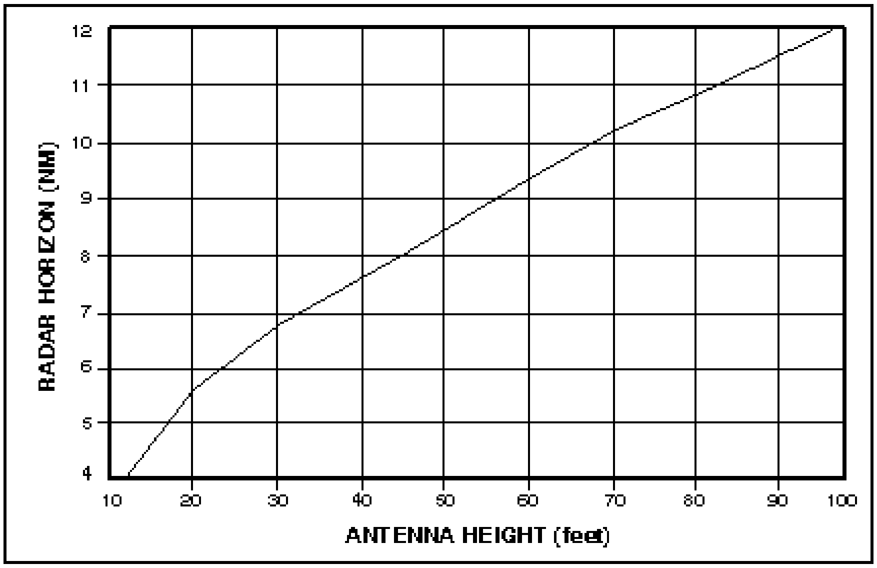

Figure 4. Ships Radar Horizon With Target on the Surface.

In this case “H” = 0, and the general equation becomes: $R_{max}\,(NM) = 1.23\sqrt{h_r}$

Where h_r is the height of the radar in feet.

Figure 5 depicts the same for aircraft radars. It should be noted that most aircraft radars are limited in power output, and would not detect small or surface objects at the listed ranges.

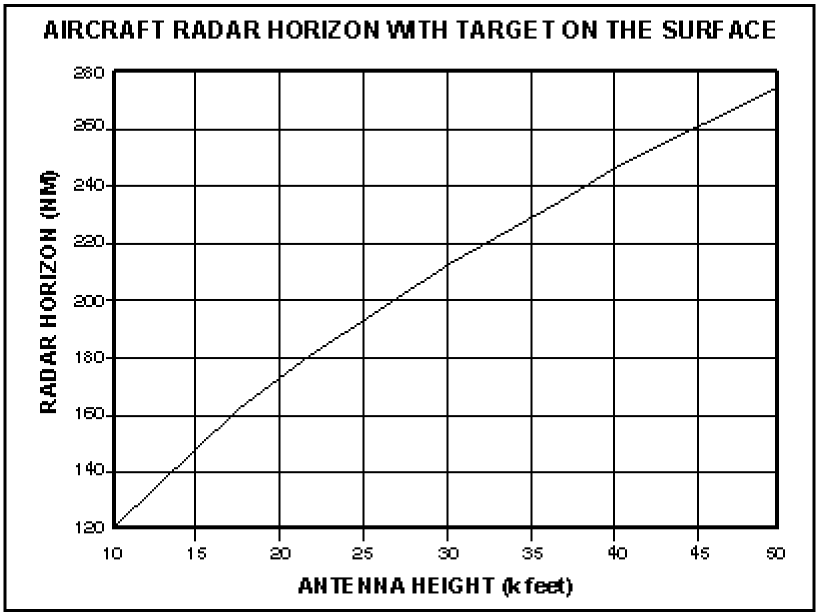

Figure 5. Aircraft Radar Horizon With Target on the Surface.

Other general rules of thumb for surface "targets/radars" are as follows:

For Visual SAR:

$$R_{Visual}(NM) = 1.05\sqrt{Acft\ \ Alt\ \ in\ \ ft}$$

For ESM:

$$R_{ESM}(NM) = 1.5\sqrt{Acft\ \ Alt\ \ in\ \ ft}$$

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PROPAGATION TIME / RESOLUTION

1. ROUND TRIP RANGE: $R = \frac{c\,t}{2}$ with t = time to reach target

Rules of Thumb

In one µsec round trip time, a wave travels to and from an object at a distance of:	The time it takes to travel to and from an object at a distance of:
≅ 150 m	1 m ≅ 0.0067 µsec
≅ 164 yd	1 yd ≅0.006 µsec
≅ 500 ft	1 ft ≅ 0.002 µsec
≅ 0.08 NM	1 NM ≅ 12.35 µsec
≅ 0.15 km	1 km ≅ 6.7 µsec

2. ONE WAY RANGE: ***R = ct*** with t = time to reach target

Time	Distance Traveled
1 milli sec (ms)	165 NM
1 micro sec (µs)	1000 ft
1 nano sec (ns)	1 ft

Distance	Time it Takes
1 NM	6.18 µsec
1 km	3.3 µsec
1 ft	1 nsec

3. UNAMBIGUOUS RANGE

(DISTANCE BETWEEN PULSES): $R = \frac{c \bullet PRI}{2}$

Normally a radar measures “distance” to the target by measuring time from the last transmitted pulse. If the inter-pulse period (T) is long enough that isn’t a problem as shown in “A” to the right. When the period is shortened, the time to the last previous pulse is shorter than the actual time it took, giving a false (ambiguous) shorter range (figure “B”).

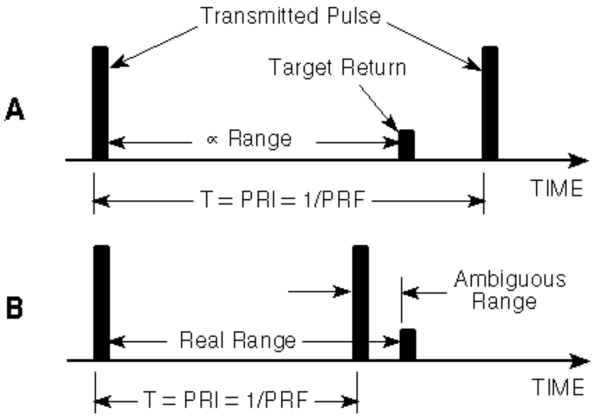

Rules of Thumb

RNM ≅ 81Pms

RKm ≅ 150Pms

Where Pms is PRI in milliseconds

4. RANGE RESOLUTION

Rules of Thumb

500 ft per microsecond of pulse width

500 MHz IF bandwidth provides 1 ft of resolution.

5. BEST CASE PERFORMANCE:

The atmosphere limits the accuracy to 0.1 ft

The natural limit for resolution is one RF cycle.

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MODULATION

Modulation is the process whereby some characteristic of one wave is varied in accordance with some characteristic of another wave. The basic types of modulation are angular modulation (including the special cases of phase and frequency modulation) and amplitude modulation. In missile radars, it is common practice to amplitude modulate the transmitted RF carrier wave of tracking and guidance transmitters by using a pulsed wave for modulating, and to frequency modulate the transmitted RF carrier wave of illuminator transmitters by using a sine wave.

Frequency Modulation (FM) - As shown in Figure 1, an unmodulated RF signal in the time domain has only a single spectral line at the carrier frequency (f_c) in the frequency domain. If the signal is frequency modulated, as shown in Figure 2 (simplified using only two changes), the spectral line will correspondingly shift in the frequency domain. The bandwidth can be approximated using Carson's rule: $BW = 2(\Delta f + fm)$, where Δf is the peak deviation of the instantaneous frequency from the carrier and fm is the highest frequency present in the modulating signal. There are usually many more "spikes" in the frequency domain than depicted. The number of spikes and shape of the frequency domain envelope (amplitude) are based on the modulation index β. The modulation index is related to the same two factors used in Carson's rule. A high Δf means a higher modulation index with many more "spikes" spread across a wider bandwidth.

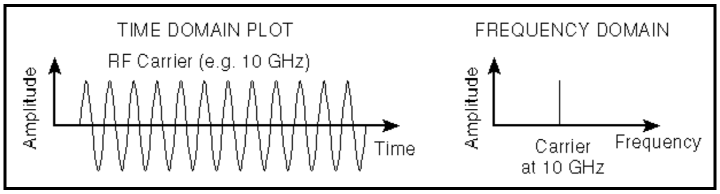
TIME DOMAIN PLOT
RF Carrier (e.g. 10 GHz)
Amplitude
Time
FREQUENCY DOMAIN
Amplitude
Carrier at 10 GHz
Frequency

Figure 1. Unmodulated RF Signal.

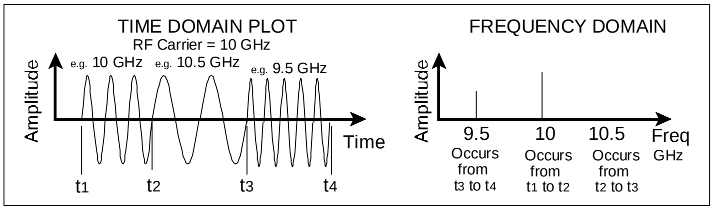
TIME DOMAIN PLOT
RF Carrier = 10 GHz
e.g. 10 GHz
e.g. 10.5 GHz
e.g. 9.5 GHz
Amplitude
Time
t1
t2
t3
t4
FREQUENCY DOMAIN
Amplitude
9.5
Occurs from t3 to t4
10
Occurs from t1 to t2
10.5
Occurs from t2 to t3
Freq GHz

Figure 2. RF Signal With Frequency Modulation.

Amplitude Modulation (AM) - If the signal in Figure 1 is amplitude modulated by a sinewave as shown in Figure 3, sidebands are produced in the frequency domain at $F_c \pm F_{AM}$. AM other than by a pure sine wave will cause additional sidebands normally at $F_c \pm nF_{AM}$, where n equals 1, 2, 3, 4, etc.

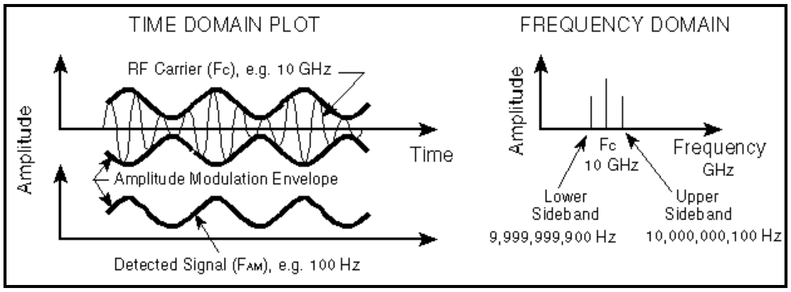
TIME DOMAIN PLOT
RF Carrier (Fc), e.g. 10 GHz
Amplitude
Time
Amplitude Modulation Envelope
Detected Signal (FAM), e.g. 100 Hz
FREQUENCY DOMAIN
Amplitude
Fc
10 GHz
Frequency
GHz
Lower Sideband
9,999,999,900 Hz
Upper Sideband
10,000,000,100 Hz

Figure 3. Sinewave Modulated RF Signal.

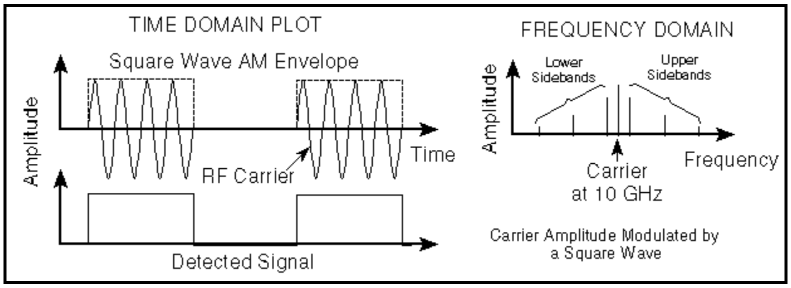
TIME DOMAIN PLOT
Square Wave AM Envelope
Amplitude
Time
RF Carrier
Detected Signal
FREQUENCY DOMAIN
Lower Sidebands
Upper Sidebands
Amplitude
Carrier at 10 GHz
Frequency
Carrier Amplitude Modulated by a Square Wave

Figure 4. Square Wave Modulated RF Signal (50% Duty Cycle).

Pulse modulation is a special case of AM wherein the carrier frequency is gated at a pulsed rate. When the reciprocal of the duty cycle of the AM is a whole number, harmonics corresponding to multiples of that whole number will be missing, e.g., in a 33.33% duty cycle, AM wave will miss the 3rd, 6th, 9th, etc. harmonics, while a square wave or

50% duty cycle triangular wave will miss the 2nd, 4th, 6th, etc. harmonic, as shown in Figure 4. It has sidebands in the frequency domain at $F_c \pm nF_{AM}$, where n = 1, 3, 5, etc. The amplitude of the power level follows a sine x / x type distribution.

Figure 5 shows the pulse width (PW) in the time domain which defines the lobe width in the frequency domain (Figure 6). The width of the main lobe is 2/PW, whereas the width of a side lobe is 1/PW. Figure 5 also shows the pulse repetition interval (PRI) or its reciprocal, pulse repetition frequency (PRF), in the time domain. In the frequency domain, the spectral lines inside the lobes are separated by the PRF or 1/PRI, as shown in Figures 7 and 8. Note that Figures 7 and 8 show actual magnitude of the side lobes, whereas in Figure 4 and 6, the absolute value is shown.

The magnitude of each spectral component for a rectangular pulse can be determined from the following formula:

$$a_n = 2A\frac{\tau}{T}\frac{\sin(n\pi\tau/T)}{n\pi\tau/T} \quad \text{where: } \begin{array}{c}\tau = \text{pulse width (PW)} \\ T = \text{period (PRI)}\end{array} \quad \text{and } A = \text{Amplitude of rectangular pulse} \qquad [1]$$

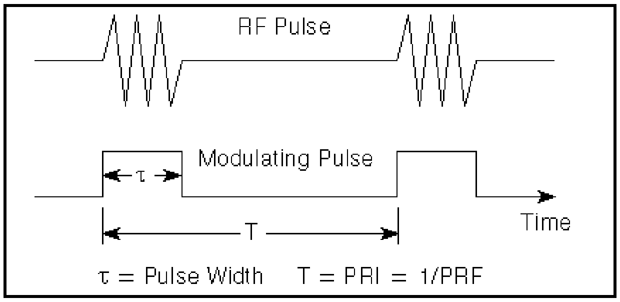

Figure 5. Pulse Width and PRI/PRF Waveforms.

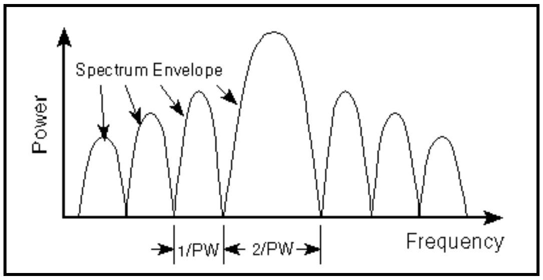

Figure 6. Sidelobes Generated by Pulse Modulation (Absolute Value).

Figure 7 shows the spectral lines for a square wave 50% duty cycle), while Figure 8 shows the spectral lines for a 33.33% duty cycle rectangular wave signal.

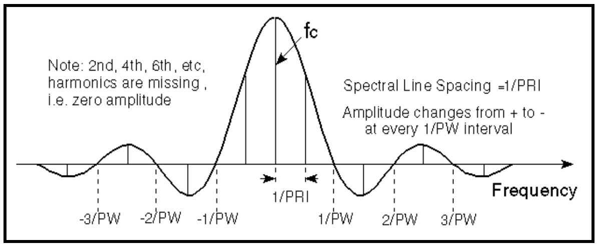

Figure 7. Spectral Times for a Square Wave Modulated Signal.

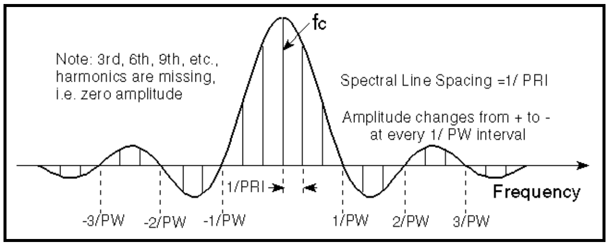

Figure 8. Spectral Lines for a 33.3% Duty Cycle.

Figure 9 shows that for square wave AM, a significant portion of the component modulation is contained in the first few harmonics which comprise the wave. There are twice as many sidebands or spectral lines as there are harmonics (one on the plus and one on the minus side of the carrier). Each sideband represents a sine wave at a frequency equal to the difference between the spectral line and f_c.

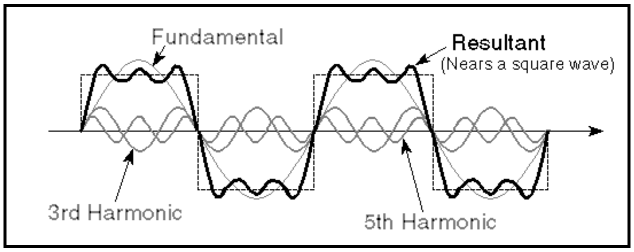

Figure 9. Square Wave Consisting of Sinewave Harmonics.

A figure similar to Figure 9 can be created for any rectangular wave. The relative amplitude of the time domain sine wave components are computed using equation [1]. Each is constructed such that at the midpoint of the pulse the sine wave passes through a maximum (or minimum if the coefficient is negative) at the same time. It should be noted that the "first" harmonic created using this formula is NOT the carrier frequency, f_c, of the modulated signal, but at $F_c \pm F_{AM}$.

While equation [1] is for rectangular waves only, similar equations can be constructed using Fourier coefficients for other waveforms, such as triangular, sawtooth, half sine, trapezoidal, and other repetitive geometric shapes.

PRI Effects - If the PW remains constant but PRI increases, the number of sidelobes remains the same, but the number of spectral lines gets denser (move closer together) and vice versa (compare Figures 7 and 8). The spacing between the spectral lines remains constant with constant PRI.

Pulse Width (PW) Effects - If the PRI remains constant, but the PW increases, then the lobe width decreases and vice versa. If the PW approaches PRI, the spectrum will approach "one lobe," i.e., a single spectral line. The spacing of the lobes remains constant with constant PW.

RF Measurements - If the receiver bandwidth is smaller than the PRF, the receiver will respond to one spectral line at a time. If the receiver bandwidth is wider than the PRF but narrower than the reciprocal of the PW, the receiver will respond to one spectral envelope at a time.

Jet Engine Modulation (JEM)

Section 2-6 addresses the Doppler shift in a transmitted radar signal caused by a moving target. The amount of Doppler shift is a function of radar carrier frequency and the speed of the radar and target. Moving or rotating surfaces on the target will have the same Doppler shift as the target, but will also impose AM on the Doppler shifted return (see Figure 10). Reflections off rotating jet engine compressor blades, aircraft propellers, ram air turbine (RAT) propellers used to power aircraft pods, helicopter rotor blades, and protruding surfaces of automobile hubcaps will all provide a chopped reflection of the impinging signal. The reflections are characterized by both positive and negative Doppler sidebands corresponding to the blades moving toward and away from the radar respectively.

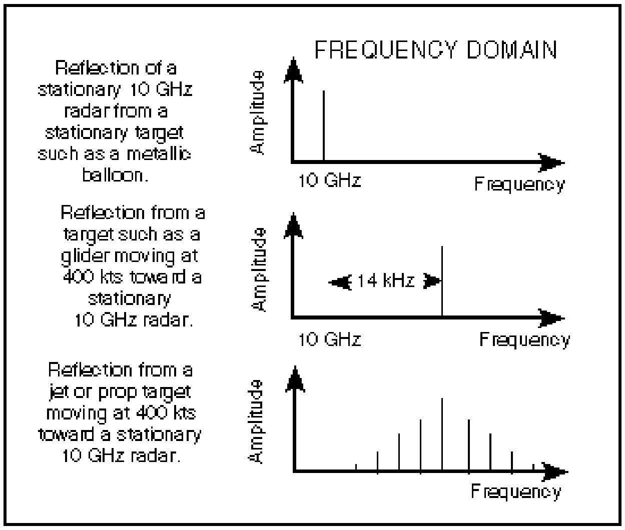
FREQUENCY DOMAIN
Reflection of a stationary 10 GHz radar from a stationary target such as a metallic balloon.
Amplitude
10 GHz
Frequency
Reflection from a target such as a glider moving at 400 kts toward a stationary 10 GHz radar.
Amplitude
14 kHz
10 GHz
Frequency
Reflection from a jet or prop target moving at 400 kts toward a stationary 10 GHz radar.
Amplitude
Frequency

Figure 10. Doppler Return and JEM.

Therefore, forward/aft JEM does not vary with radar carrier frequency, but the harmonics contained in the sidebands are a function of the PRF of the blade chopping action and its amplitude is target aspect dependent, i.e., blade angle, intake/exhaust internal reflection, and jet engine cowling all effect lateral return from the side. If the aspect angle is too far from head-on or tail-on and the engine cowling provides shielding for the jet engine, there may not be any JEM to detect. On the other hand, JEM increases when you are orthogonal (at a right angle) to the axis of blade rotation. Consequently for a fully exposed blade as in a propeller driven aircraft or helicopter, JEM increases with angle off the boresight axis of the prop/rotor.

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TRANSFORMS / WAVELETS

Transform Analysis

Signal processing using a transform analysis for calculations is a technique used to simplify or accelerate problem solution. For example, instead of dividing two large numbers, we might convert them to logarithms, subtract them, then look-up the anti-log to obtain the result. While this may seem a three-step process as opposed to a one-step division, consider that long-hand division of a four digit number by a three digit number, carried out to four places requires three divisions, 3-4 multiplication's, and three subtractions. Computers process additions or subtractions much faster than multiplications or divisions, so transforms are sought which provide the desired signal processing using these steps.

Fourier Transform

Other types of transforms include the Fourier transform, which is used to decompose or separate a waveform into a sum of sinusoids of different frequencies. It transforms our view of a signal from time based to frequency based. Figure 1 depicts how a square wave is formed by summing certain particular sine waves. The waveform must be continuous, periodic, and almost everywhere differentiable. The Fourier transform of a sequence of rectangular pulses is a series of sinusoids. The envelope of the amplitude of the coefficients of this series is a waveform with a Sin X/X shape. For the special case of a single pulse, the Fourier series has an infinite series of sinusoids that are present for the duration of the pulse.

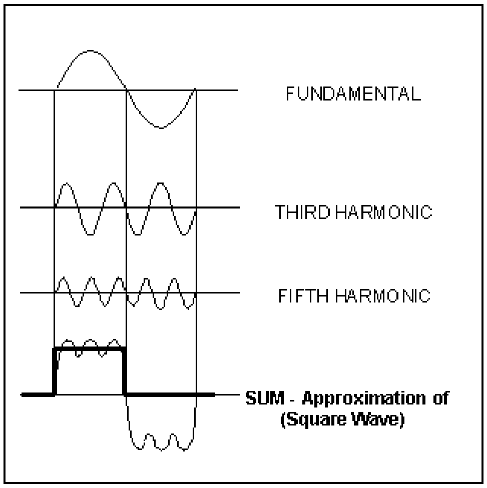

Figure 1. Harmonics.

Digital Sampling of Waveforms

To process a signal digitally, we need to sample the signal frequently enough to create a complete "picture" of the signal. The discrete Fourier transform (DFT) may be used in this regard. Samples are taken at uniform time intervals as shown in Figure 2 and processed.

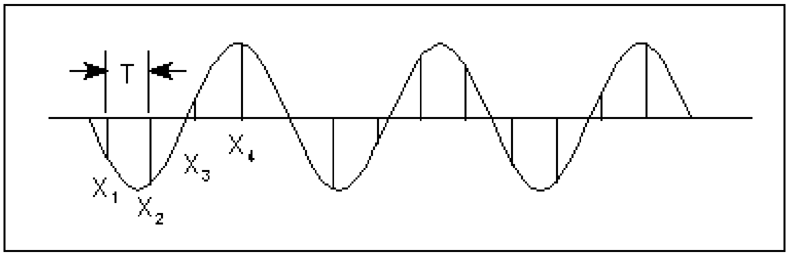

Figure 2. Waveform Sampling.

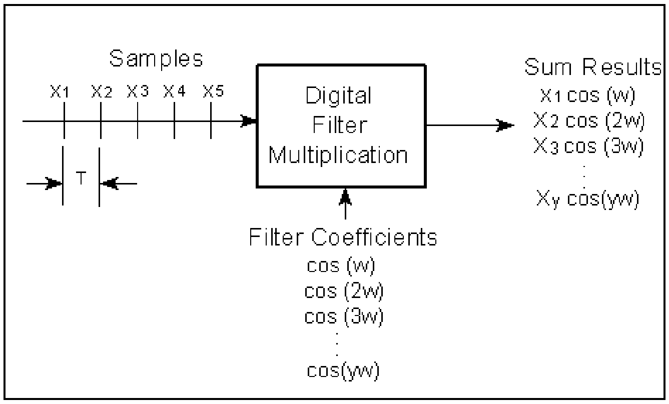

Figure 3. Digital Filtering.

If the digital information is multiplied by the Fourier coefficients, a digital filter is created as shown Figure 3. If the sum of the resultant components is zero, the filter has ignored (notched out) that frequency sample. If the sum is a relatively large number, the filter has passed the signal. With the single sinusoid shown, there should be only one resultant. (Note that being "zero" and relatively large may just mean below or above the filter's cutoff threshold.)

Figure 4 depicts the process pictorially: The vectors in the figure just happen to be pointing in a cardinal direction because the strobe frequencies are all multiples of the vector (phasor) rotation rate, but that is not normally the case. Usually the vectors will point in a number of different directions, with a resultant in some direction other than straight up.

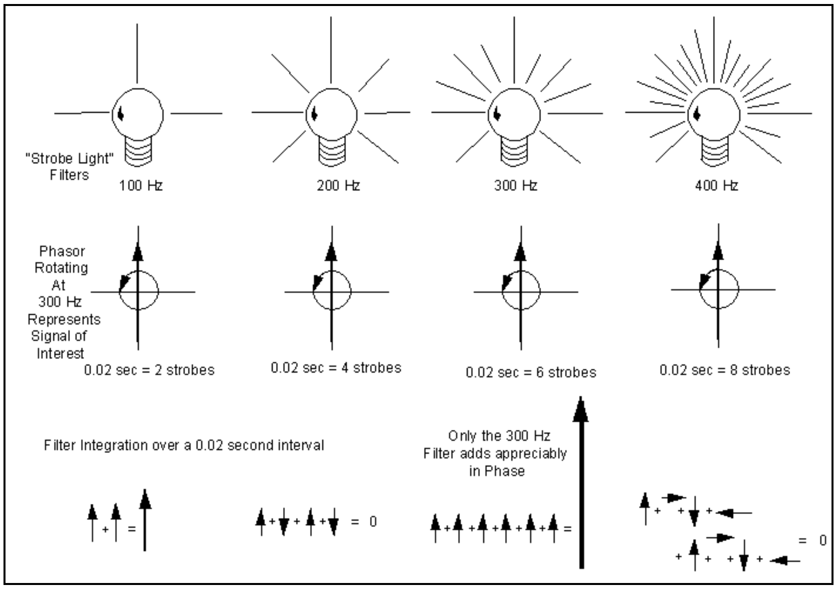
"Strobe Light" Filters
100 Hz
200 Hz
300 Hz
400 Hz
Phasor Rotating At 300 Hz Represents Signal of Interest
0.02 sec = 2 strobes
0.02 sec = 4 strobes
0.02 sec = 6 strobes
0.02 sec = 8 strobes
Filter Integration over a 0.02 second interval
Only the 300 Hz Filter adds appreciably in Phase
= 0
= 0

Figure 4. Phasor Representation.

In addition, sampling normally has to taken at or above twice the rate of interest (also known as the Nyquist rate), otherwise ambiguous results may be obtained. Figure 4 is under-sampled (for clarity) and consequently does not depict typical filtering.

Fast Fourier Transforms

One problem with this type of processing is the large number of additions, subtractions, and multiplications which are required to reconstruct the output waveform. The Fast Fourier transform (FFT) was developed to reduce this problem. It recognizes that because the filter coefficients are sine and cosine waves, they are symmetrical about 90, 180, 270, and 360 degrees. They also have a number of coefficients equal either to one or zero, and duplicate coefficients from filter to filter in a multibank arrangement. By waiting for all of the inputs for the bank to be received, adding together those inputs for which coefficients are the same before performing multiplications, and separately summing those combinations of inputs and products which are common to more than one filter, the required amount of computing may be cut drastically.

- The number of computations for a DFT is on the order of N squared.

- The number of computations for a FFT when N is a power of two is on the order of N $\log_2$ N.

For example, in an eight filter bank, a DFT would require 512 computations, while an FFT would only require 56, significantly speeding up processing time.

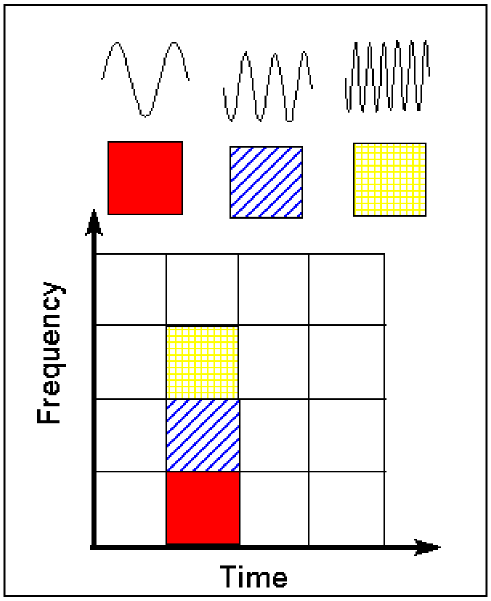
Frequency
Time

Figure 5. Windowed Fourier Transform.

Windowed Fourier Transform

The Fourier transform is continuous, so a windowed Fourier transform (WFT) is used to analyze non-periodic signals as shown in Figure 5. With the WFT, the signal is divided into sections (one such section is shown in Figure 5) and each section is analyzed for frequency content. If the signal has sharp transitions, the input data is windowed so that the sections converge to zero at the endpoints. Because a single window is used for all frequencies in the WFT, the resolution of the analysis is the same (equally spaced) at all locations in the time-frequency domain.

The FFT works well for signals with smooth or uniform frequencies, but it has been found that other transforms work better with signals having pulse type characteristics, time-varying (non-stationary) frequencies, or odd shapes.

The FFT also does not distinguish sequence or timing information. For example, if a signal has two frequencies (a high followed by a low or vice versa), the Fourier transform only reveals the frequencies and relative amplitude, not the order in which they occurred. So Fourier analysis works well with stationary, continuous, periodic, differentiable signals, but other methods are needed to deal with non-periodic or non-stationary signals.

Wavelet Transform

The Wavelet transform has been evolving for some time. Mathematicians theorized its use in the early 1900's. While the Fourier transform deals with transforming the time domain components to frequency domain and frequency analysis, the wavelet transform deals with scale analysis, that is, by creating mathematical structures that provide varying time/frequency/amplitude slices for analysis. This transform is a portion (one or a few cycles) of a complete waveform, hence the term wavelet.

The wavelet transform has the ability to identify frequency (or scale) components, simultaneously with their location(s) in time. Additionally, computations are directly proportional to the length of the input signal. They require only N multiplications (times a small constant) to convert the waveform. For the previous eight filter bank example, this would be about twenty calculations, vice 56 for the FFT.

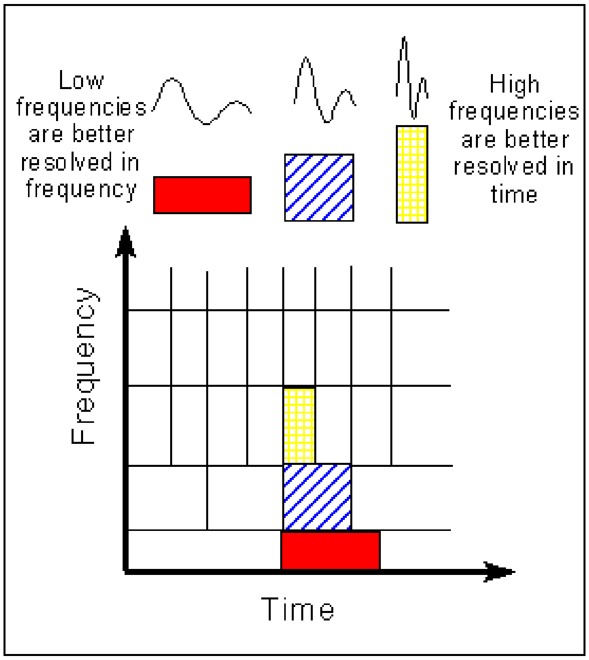
Low frequencies are better resolved in frequency
High frequencies are better resolved in time
Frequency
Time

Figure 6. Wavelet Transform.

In wavelet analysis, the scale that one uses in looking at data plays a special role. Wavelet algorithms process data at different scales or resolutions. If we look at a signal with a large "window," we would notice gross features. Similarly, if we look at a signal with a small "window," we would notice small discontinuities as shown in Figure 6. The result in wavelet analysis is to "see the forest and the trees." A way to achieve this is to have short high-frequency fine scale functions and long low-frequency ones. This approach is known as multi-resolution analysis.

For many decades, scientists have wanted more appropriate functions than the sines and cosines (base functions) which comprise Fourier analysis, to approximate choppy signals. (Although Walsh transforms work if the waveform is periodic and stationary). By their definition, sine and cosine functions are non-local (and stretch out to infinity), and therefore do a very poor job in approximating sharp spikes. But with wavelet analysis, we can use approximating functions that are contained neatly in finite (time/frequency) domains. Wavelets are well-suited for approximating data with sharp discontinuities.

The wavelet analysis procedure is to adopt a wavelet prototype function, called an "analyzing wavelet" or "mother wavelet." Temporal analysis is performed with a contracted, high-frequency version of the prototype wavelet, while frequency analysis is performed with a dilated, low-frequency version of the prototype wavelet. Because the original signal or function can be represented in terms of a wavelet expansion (using coefficients in a linear combination of the wavelet functions), data operations can be performed using just the corresponding wavelet coefficients as shown in Figure 7.

If one further chooses the best wavelets adapted to the data, or truncates the coefficients below some given threshold, the data is sparsely represented. This "sparse coding" makes wavelets an excellent tool in the field of data compression. For instance, the FBI uses wavelet coding to store fingerprints. Hence, the concept of wavelets is to look at a signal at various scales and analyze it with various resolutions.

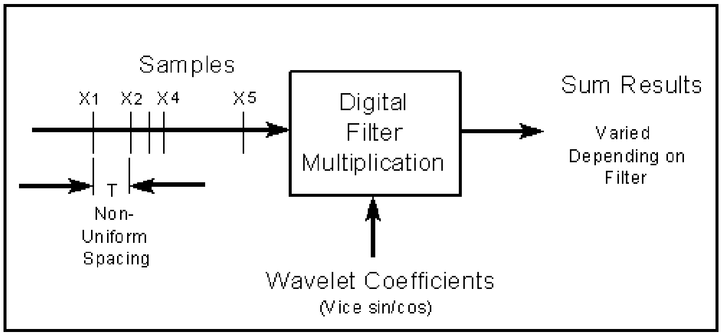

Figure 7. Wavelet Filtering.

Analyzing Wavelet Functions

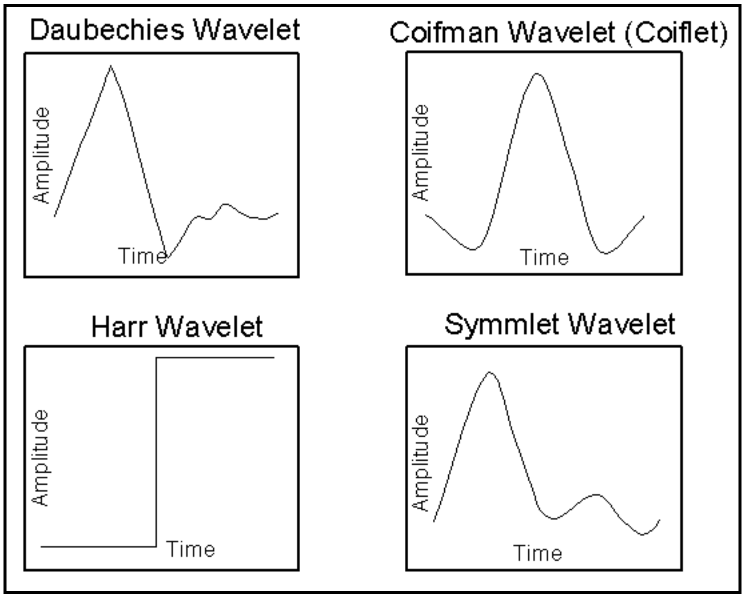

Figure 8. Sample Wavelet Functions.

Fourier transforms deal with just two basis functions (sine and cosine), while there are an infinite number of wavelet basis functions. The freedom of the analyzing wavelet is a major difference between the two types of analyses and is important in determining the results of the analysis. The "wrong" wavelet may be no better (or even far worse than) than the Fourier analysis. A successful application presupposes some expertise on the part of the user. Some prior knowledge about the signal must generally be known in to select the most suitable distribution and adapt the parameters to the signal. Some of the more common ones are shown in Figure 8. There are several wavelets in each family, and they may look different than those shown. Somewhat longer in duration than these functions, but significantly shorter than infinite sinusoids is the cosine packet shown in Figure 9.

Wavelet Comparison With Fourier Analysis

While a typical Fourier transform provides frequency content information for samples within a given time interval, a perfect wavelet transform records the start of one frequency (or event), then the start of a second event, with amplitude added to or subtracted from, the base event.

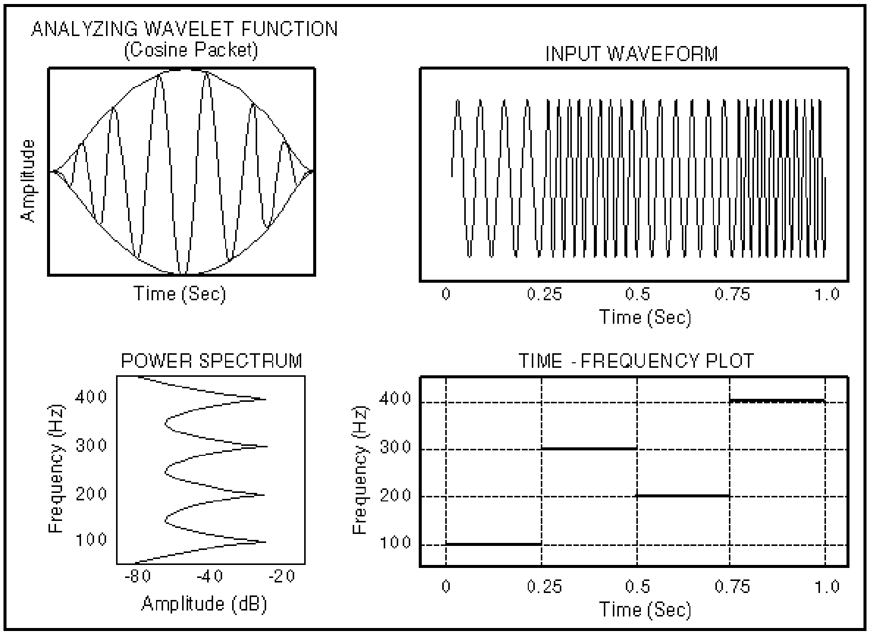

Figure 9. Sample Wavelet Analysis.

Example 1.

Wavelets are especially useful in analyzing transients or time-varying signals. The input signal shown in Figure 9 consists of a sinusoid whose frequency changes in stepped increments over time. The power of the spectrum is also shown. Classical Fourier analysis will resolve the frequencies but cannot provide any information about the times at which each occurs. Wavelets provide an efficient means of analyzing the input signal so that frequencies and the times at which they occur can be resolved. Wavelets have finite duration and must also satisfy additional properties beyond those normally associated with standard windows used with Fourier analysis. The result after the wavelet transform is applied is the plot shown in the lower right. The wavelet analysis correctly resolves each of the frequencies and the time when it occurs. A series of wavelets is used in example 2.

Example 2.

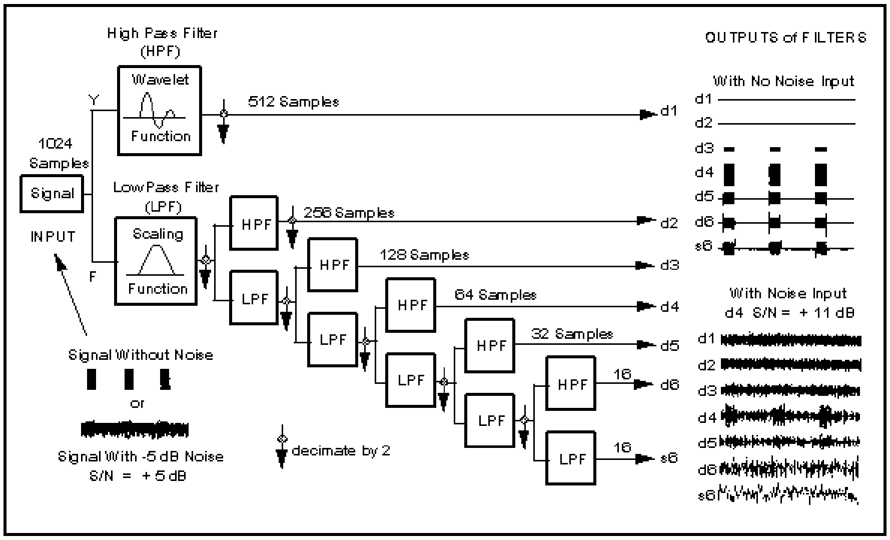
High Pass Filter
(HPF)
Wavelet
Function
Y
512 Samples
d1
1024
Samples
Signal
INPUT
Low Pass Filter
(LPF)
Scaling
Function
F
HPF
256 Samples
d2
LPF
HPF
128 Samples
d3
LPF
HPF
64 Samples
d4
LPF
HPF
32 Samples
d5
LPF
HPF
16
d6
LPF
16
s6
Signal Without Noise
or
Signal With -5 dB Noise
S/N = + 5 dB
decimate by 2
OUTPUTS of FILTERS
With No Noise Input
d1
d2
d3
d4
d5
d6
s6
With Noise Input
d4 S/N = + 11 dB
d1
d2
d3
d4
d5
d6
s6

Figure 10. Example 2 Analysis Wavelet.

Figure 10 shows the input of a clean signal, and one with noise. It also shows the output of a number of “filters” with each signal. A 6 dB S/N improvement can be seen from the d4 output. (Recall from Section 4.3 that 6 dB corresponds to doubling of detection range.) In the filter cascade, the HPFs and LPFs are the same at each level. The wavelet shape is related to the HPF and LPF in that it is the “impulse response” of an infinite cascade of the HPFs and LPFs. Different wavelets have different HPFs and LPFs. As a result of decimating by 2, the number of output samples equals the number of input samples.

Wavelet Applications

Some fields that are making use of wavelets are: astronomy, acoustics, nuclear engineering, signal and image processing (including fingerprinting), neurophysiology, music, magnetic resonance imaging, speech discrimination, optics, fractals, turbulence, earthquake-prediction, radar, human vision, and pure mathematics applications.

See Andrew Bruce, David Donoho, and Hong-Ye Gao, “Wavelet Analysis,” *IEEE Spectrum*, Vol. 33 No. 10, October 1996.

ANTENNAS

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Polarization 3-2
Radiation Patterns 3-3
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ANTENNA INTRODUCTION / BASICS

Rules of Thumb:

1. The power gain of an antenna with losses, excluding input impedance mismatch, is given by:

$$G \approx \frac{4\pi\eta A}{\lambda^2} \quad Where \quad \begin{aligned} \eta &= Efficiency \\ A &= Physical\ aperture\ area \\ \lambda &= wavelength \end{aligned}$$

another is :

$$G = \frac{X\,\eta}{BW_{\phi}\,BW_{\theta}}$$

Where $BW_{\theta\ and\ \phi}$ *are the elev & az beamwidths in degrees.*

For approximating an antenna pattern with :

(1) A rectangle; $X = 41253, \eta_{typical} = 0.7$

(2) An ellipsoid; $X = 52525, \eta_{typical} = 0.55$

2. Directive gain of rectangular X-Band Aperture
G = 1.4 LW Where: Length (L) and Width (W) are in cm

3. Power gain of Circular X-Band Aperture
$G = d^2\eta$ Where: d = antenna diameter in cm
η = aperture efficiency

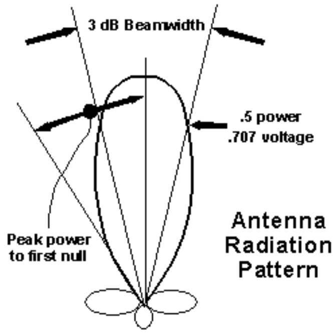

4. Directive gain of an imaginary isotropic antenna radiating in a uniform spherical pattern is one (0 dB).

5. Antenna with a 20 degree beamwidth has approximately a 20 dB directive gain.

6. 3 dB beamwidth is approximately equal to the angle from the peak of the power to the first null (see figure at right).

7. Parabolic Antenna Beamwidth: $$BW = \frac{70\lambda}{d}$$

Where: BW = antenna beamwidth; λ = wavelength; d = antenna diameter.

The antenna equations which follow relate to Figure 1 as a typical antenna. In Figure 1, BW_{φ} is the azimuth beamwidth and BW_{θ} is the elevation beamwidth. Beamwidth is normally measured at the half-power or -3 dB point of the main lobe unless otherwise specified. See Glossary.

The gain or directivity of an antenna is the ratio of the radiation intensity in a given direction to the radiation intensity averaged over all directions.

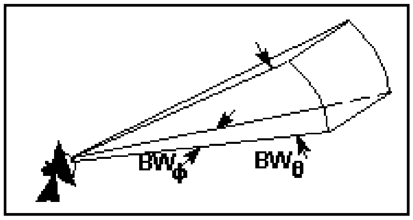

Figure 1. Antenna Aperture.

Quite often directivity and gain are used interchangeably and it sometimes leads to overly optimistic antenna performance estimations. The difference is that directivity is based solely on antenna pattern shape estimation where antenna losses such as dielectric, ohmic resistance, and polarization mismatch are neglected. If these losses are included in the antenna gain calculations, the antenna gain is then referred to as the power gain. Moreover, if additional impedance mismatch or VSWR losses are included in the antenna system gain estimation, the antenna gain calculations are then referred to as the realized gain. However, using directive gain (or directivity) calculations is very convenient in practice for a first order idealized antenna performance estimation.

Normalizing a radiation pattern by the integrated total power yields the directivity of the antenna. This concept in shown in equation form by:

$$D(\theta,\phi) = 10\,\mathrm{Log}\left[\frac{4\pi P\ (\theta,\phi)}{\iint P_{in}(\theta,\phi)\,\mathrm{Sin}\,\theta\, d\theta\, d\phi}\right] \quad \begin{matrix} 0<\phi\le 360^\circ \\ 0<\theta\le 180^\circ \end{matrix} \qquad \textbf{[1]}$$

Where D(θ,φ) is the directivity in dB, and the radiation pattern power in a specific direction is $P_d(\theta,\varphi)$, which is normalized by the total integrated radiated power. Another important concept is that when the angle in which the radiation is constrained is reduced, the directive gain goes up. For example, using an isotropic radiating source, the gain would be 0 dB by definition (Figure 2(a)) and the power density (P_d) at any given point would be the power in (P_{in}) divided by the surface area of the imaginary sphere at a distance R from the source. If the spacial angle was decreased to one hemisphere (Figure 2(b)), the power radiated, P_{in}, would be the same but the area would be half as much, so the gain would double to 3 dB. Likewise if the angle is a quarter sphere, (Figure 2(c)), the gain would be 6 dB. Figure 2(d) shows a pencil beam. The gain is independent of actual power output and radius (distance) at which measurements are taken.

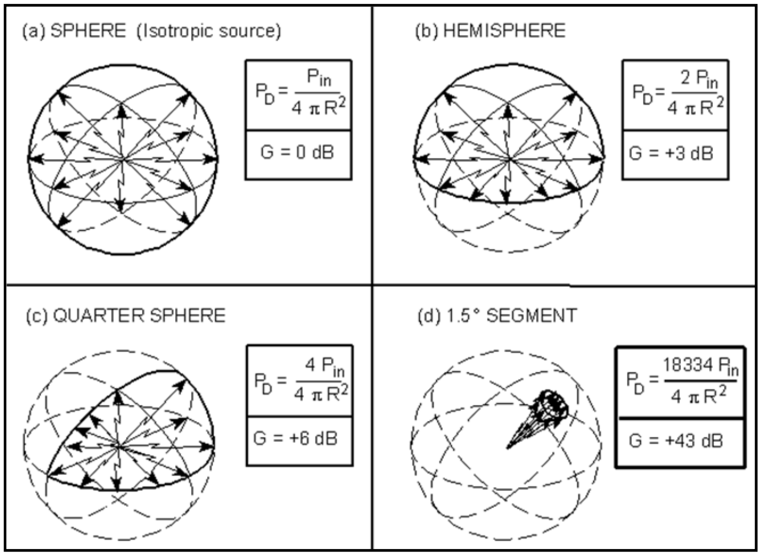
(a) SPHERE (Isotropic source)
$P_D = \frac{P_{in}}{4 \pi R^2}$
G = 0 dB
(b) HEMISPHERE
$P_D = \frac{2 P_{in}}{4 \pi R^2}$
G = +3 dB
(c) QUARTER SPHERE
$P_D = \frac{4 P_{in}}{4 \pi R^2}$
G = +6 dB
(d) 1.5° SEGMENT
$P_D = \frac{18334 P_{in}}{4 \pi R^2}$
G = +43 dB

Figure 2. Notional Representation of Directive Antenna Gain.

Real antennas are different, however, and do not have an ideal radiation distribution. Energy varies with angular displacement and losses occur due to sidelobes. However, if we can measure the pattern, and determine the beamwidth we can use two (or more) ideal antenna models to approximate a real antenna pattern as shown in Figure 3.

Assuming the antenna pattern is uniform, the gain is equal to the area of the isotropic sphere ($4\pi r^2$) divided by the sector (cross section) area.

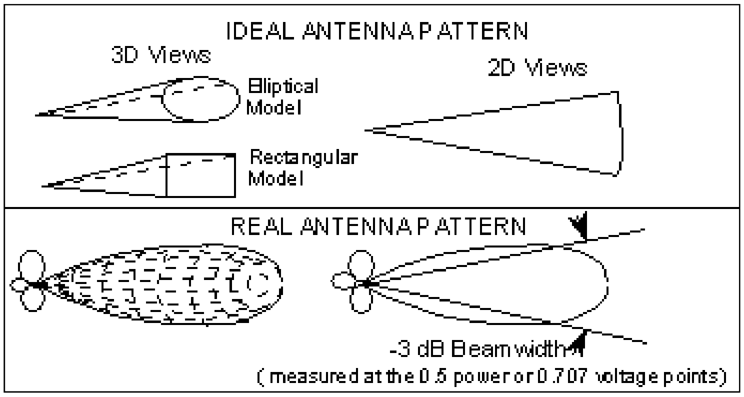
IDEAL ANTENNA PATTERN
3D Views
Elliptical Model
Rectangular Model
2D Views
REAL ANTENNA PATTERN
-3 dB Beamwidth
(measured at the 0.5 power or 0.707 voltage points)

Figure 3. Antenna Beamwidth.

$$G = \frac{Area\ of\ Sphere}{Area\ of\ Antenna\ pattern} \qquad \textbf{[2]}$$

It can be shown that:

$$G \approx \frac{4\pi}{BW_{\phi\, az}\, BW_{\theta\, el}} \quad or \quad \frac{4\pi}{\phi\theta\ (radians)} \quad where: \begin{matrix} BW_{\phi\, az} = \text{Azmith beamwidth in radians} \\ BW_{\theta\, el} = \text{Elevation beamwidth in radians} \end{matrix} \qquad \textbf{[3]}$$

From this point, two different models are presented:

(1) Approximating an antenna pattern using an elliptical area, and
(2) Approximating an antenna pattern using a rectangular area.

Approximating the antenna pattern as an **elliptical** area:

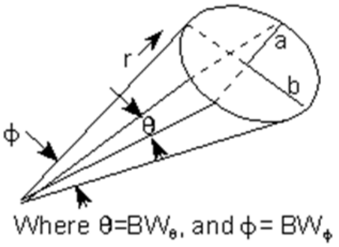

Area of ellipse = $\pi a b = \pi[(r \sin\theta)/2][(r \sin\varphi)/2] = (\pi r^2 \sin\theta \sin\varphi)/4$

$$G = \frac{\textit{Area of Sphere}}{\textit{Area of Antenna pattern}} = (4\pi r^2)\left(\frac{4}{\pi r^2 \sin\theta \sin\phi}\right) = \frac{16}{\sin\theta \sin\phi}$$

For small angles, $\sin\varphi = \varphi$ in radians, so:

$$G = \frac{16}{\sin\phi \sin\theta} \approx \frac{16}{\phi\,\theta\,(radians)} = \frac{16}{\phi\,\theta}\left(\frac{360°\;360°}{2\pi\;2\pi}\right) = \frac{52525}{\phi\,\theta\,(degrees)} \; or \; \frac{52525}{BW_\phi\, BW_\theta\,(degrees)} \qquad \textbf{[4]}$$

The second term in the equation above is very close to equation [3].

For a very directional radar dish with a beamwidth of 1° and an average efficiency of 55%:

Ideally: G = 52525, or in dB form: 10 log G =10 log 52525 = 47.2 dB

With efficiency taken into account, G = 0.55(52525) = 28888, or in log form: 10 log G = 44.6 dB

Approximating the antenna pattern as a **rectangular** area:

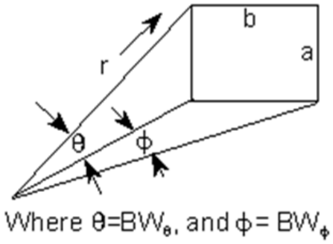

$a = r \sin\theta$, $b = r \sin\varphi$, area = $ab = r^2 \sin\theta \sin\varphi$

$$G = \frac{\textit{Area of Sphere}}{\textit{Area of Antenna pattern}} = \frac{4\pi r^2}{r^2 \sin\theta \sin\phi} = \frac{4\pi}{\sin\theta \sin\phi}$$

For small angles, $\sin\varphi = \varphi$ in radians, so:
The second term in the equation above is identical to equation [3].

$$G = \frac{4\pi}{\sin\phi \sin\theta} = \frac{4\pi}{\phi\,\theta\,(radians)} = \frac{4\pi}{\phi\,\theta}\left(\frac{360°\;360°}{2\pi\;2\pi}\right) = \frac{41253}{\phi\,\theta\,(degrees)} \; or \; \frac{41253}{BW_\phi\, BW_\theta\,(degrees)} \qquad \textbf{[5]}$$

Converting to dB, $G_{\max}(dB) = 10 \;\mathrm{Log}\left[\frac{41253}{BW_\phi\, BW_\theta}\right] \; with \; BW_\phi \; and \; BW_\theta \; in \; degrees$ **[6]**

For a very directional radar dish with a beamwidth of 1° and an average efficiency of 70%:
Ideally (in dB form): 10 log G =10 log 41253 = 46.2 dB.
With efficiency taken into account, G = 0.7(41253) = 28877, or in log form: 10 log G = 44.6 dB

Comparison between elliptical and rectangular areas for antenna pattern models:

By using the rectangular model there is a direct correlation between the development of gain in equation [5] and the ideal gain of equation [3]. The elliptical model has about one dB difference from the ideal calculation, but will yield the same real antenna gain when appropriate efficiencies are assumed.

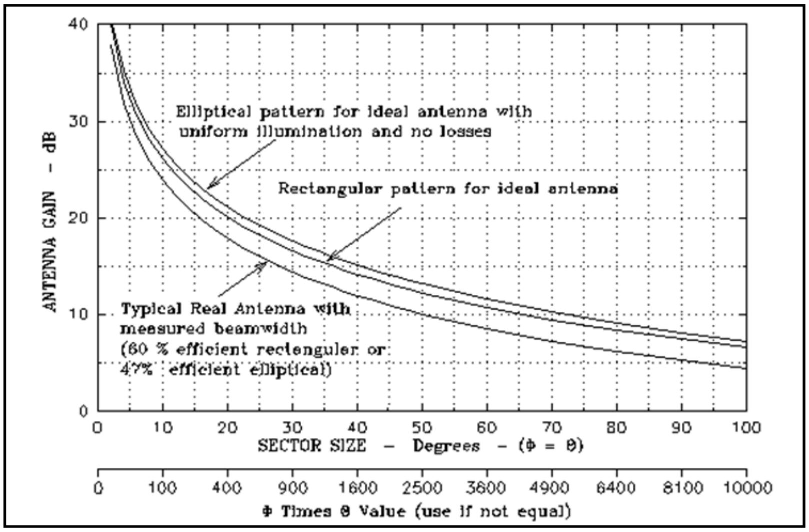

Figure 4. Antenna Sector Size vs. Gain.

The upper plot of Figure 4 shows the gain for an ideal antenna pattern using the elliptical model. The middle plot shows the gain for an ideal antenna using the rectangular model. The lower plot of Figure 4 shows the gain of a typical real antenna (rectangular model using an efficiency of 70% or elliptical model using an efficiency of 47%).

Gain as a function of λ:

When θ = 0, each wave source in Figure 5 is in phase with one another and a maximum is produced in that direction.

Conversely, nulls to either side of the main lobe will occur when the waves radiating from the antenna cancel each other. The first null occurs when there is a phase difference of λ/2 in the wave fronts emanating from the aperture. To aid in visualizing what happens, consider each point in the antenna aperture, from A to C in Figure 5, as a point source of a spherical wave front. If viewed from infinity, the electromagnetic waves from each point interfere with each other, and when, for a particular direction, θ in Figure 5, each wave source has a corresponding point that is one-half wavelength out of phase, a null is produced in that direction due to destructive interference.

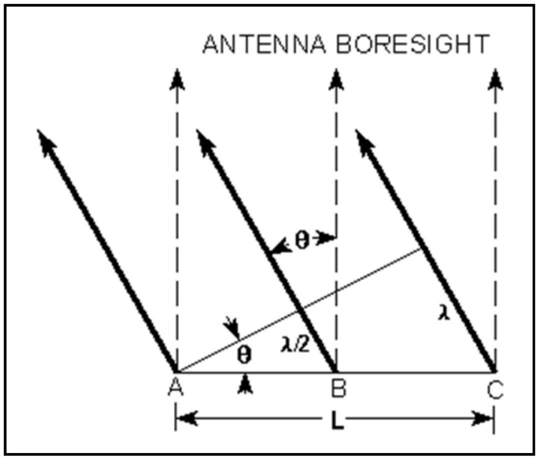

Figure 5. Directional Gain vs. Wavelength.

In Figure 5, the wave emanating from point A is out of phase with the wave from point B by one-half of a wavelength. Hence, they cancel. Similarly, a point just to the right of point A cancels with a point just to the right of point B, and so on across the entire aperture. Therefore, the first null in the radiation pattern is given by:

$$\text{Sin } \theta = \lambda/L \text{ and, in radians, } \theta = \lambda/L \text{ (for small angles)} \qquad \textbf{[7]}$$

As the angle off boresight is increased beyond the first null, the intensity of the radiation pattern rises then falls, until the second null is reached. This corresponds to a phase difference of two wavelengths between the left and right edges of the aperture. In this case, the argument proceeds as before, except now the aperture is divided into four segments (point A canceling with a point halfway between A and B, and so on).

The angle θ is the angle from the center (maximum) of the radiation pattern to the first null. The null-to-null beam width is 2θ. Generally, we are interested in the half-power (3 dB) beamwidth. It turns out that this beamwidth is approximately one-half of the null-to-null beamwidth, so that:

$$BW_{3\text{ dB}} \approx (½)(2\theta) = \lambda/L \qquad \textbf{[8]}$$

Therefore, beamwidth is a function of the antenna dimension "L" and the wavelength of the signal. It can be expressed as follows: Note: for circular antennas, L in the following equations = diameter

$$Bw_{\varphi(az)} = \lambda/L_{Az\text{ eff}} \text{ and } BW_{\theta(el)} = \lambda/L_{El\text{ eff}} \qquad \textbf{[9]}$$

Substituting the two variations of equation [9] into equation [3] and since $L_{Az\text{ eff}}$ times $L_{El\text{ eff}} = A_e$ (effective capture area of the antenna), we have:

$$G \approx \frac{4\pi}{BW_\phi \, BW_\theta \, (radians)} = \frac{4\pi \, L_{az} \, L_{el}}{\lambda^2} = \frac{4\pi \, A_e}{\lambda^2} \qquad \textbf{[10]}$$

Note: Equation is approximate since aperture efficiency isn't included as is done later in equation [12].

The efficiency (discussed later) will reduce the gain by a factor of 30-50%, i.e. real gain = .5 to .7 times theoretical gain.

Unity Gain Antenna.
If a square antenna is visualized and G=1, $A_e = \lambda^2 / 4\pi$. When a dimension is greater than 0.28 λ (~¼λ) it is known as an electrically large antenna, and the antenna will have a gain greater than one (positive gain when expressed in dB). Conversely, when the dimension is less than 0.28 λ (~¼λ)(an electrically small antenna), the gain will be less than one (negative gain when expressed in dB). Therefore, a unity gain antenna can be approximated by an aperture that is ¼λ by ¼λ.

Beamwidth as a Function of Aperture Length
It can be seen from Figure 5, that the wider the antenna aperture (L), the narrower the beamwidth will be for the same λ. Therefore, if you have a rectangular shaped horn antenna, the radiation pattern from the wider side will be narrower than the radiation pattern from the narrow side.

APERTURE EFFICIENCY, η

The Antenna Efficiency, η, is a factor which includes all reductions from the maximum gain. η can be expressed as a percentage, or in dB. Several types of "loss" must be accounted for in the efficiency, η:

(1) Illumination efficiency which is the ratio of the directivity of the antenna to the directivity of a uniformly illuminated antenna of the same aperture size,
(2) Phase error loss or loss due to the fact that the aperture is not a uniform phase surface,
(3) Spillover loss (Reflector Antennas) which reflects the energy spilling beyond the edge of the reflector into the back lobes of the antenna,

(4) Mismatch (VSWR) loss, derived from the reflection at the feed port due to impedance mismatch (especially important for low frequency antennas), and

(5) RF losses between the antenna and the antenna feed port or measurement point.

The aperture efficiency, η_a, is also known as the illumination factor, and includes items (1) and (2) above; it does not result in any loss of power radiated but affects the gain and pattern. It is nominally 0.6-0.8 for a planer array and 0.13 to 0.8 with a nominal value of 0.5 for a parabolic antenna, however η can vary significantly. Other antennas include the spiral (.002-.5), the horn (.002-.8), the double ridge horn (.005-.93), and the conical log spiral (.0017-1.0).

Items (3), (4), and (5) above represent RF or power losses which can be measured. The efficiency varies and generally gets lower with wider bandwidths. Also note that the gain equation is optimized for small angles - see derivation of wavelength portion of equation [7]. This explains why efficiency also gets lower for wider beamwidth antennas.

EFFECTIVE CAPTURE AREA

Effective capture area (A_e) is the product of the physical aperture area (A) and the aperture efficiency (η) or:

$$A_e = \eta\, A = \frac{\lambda^2 G}{4\pi} \quad \textbf{[11]}$$

GAIN AS A FUNCTION OF APERTURE EFFICIENCY

The Gain of an antenna with losses is given by:

$$G = \frac{4\pi\eta A}{\lambda^2} \quad \begin{array}{r l} & \eta = \text{Aperture Efficiency} \\ \text{Where} & A = \text{Physical aperture area} \\ & \lambda = \text{wavelength} \end{array} \quad \textbf{[12]}$$

Note that the gain is proportional to the aperture area and inversely proportional to the square of the wavelength. For example, if the frequency is doubled, (half the wavelength), the aperture could be decreased four times to maintain the same gain.

BEAM FACTOR

Antenna size and beamwidth are also related by the beam factor defined by:

Beam Factor = (D/λ)·(Beamwidth) where D = antenna dimension in wavelengths.

The beam factor is approximately invariant with antenna size, but does vary with type of antenna aperture illumination or taper. The beam factor typically varies from 50-70°.

APERTURE ILLUMINATION (TAPER)

The aperture illumination or illumination taper is the variation in amplitude across the aperture. This variation can have several effects on the antenna performance:

(1) reduction in gain,
(2) reduced (lower) sidelobes in most cases, and
(3) increased antenna beamwidth and beam factor.

Tapered illumination occurs naturally in reflector antennas due to the feed radiation pattern and the variation in distance from the feed to different portions of the reflector. Phase can also vary across the aperture which also affects the gain, efficiency, and beamwidth.

CIRCULAR ANTENNA GAIN

Solving equation [12] in dB, for a circular antenna with area $\pi D^2/4$, we have:

$$10 \text{ Log } G = 20 \text{ Log } (D/\lambda) + 10 \text{ Log } (\eta) + 9.94 \text{ dB}; \quad \text{where } D = \text{diameter} \qquad \textbf{[13]}$$

This data is depicted in the nomograph of Figure 6. For example, a six foot diameter antenna operating at 9 GHz would have approximately 44.7 dB of gain as shown by the dashed line drawn on Figure 6. This gain is for an antenna 100% efficient, and would be 41.7 dB for a typical parabolic antenna (50% efficient).

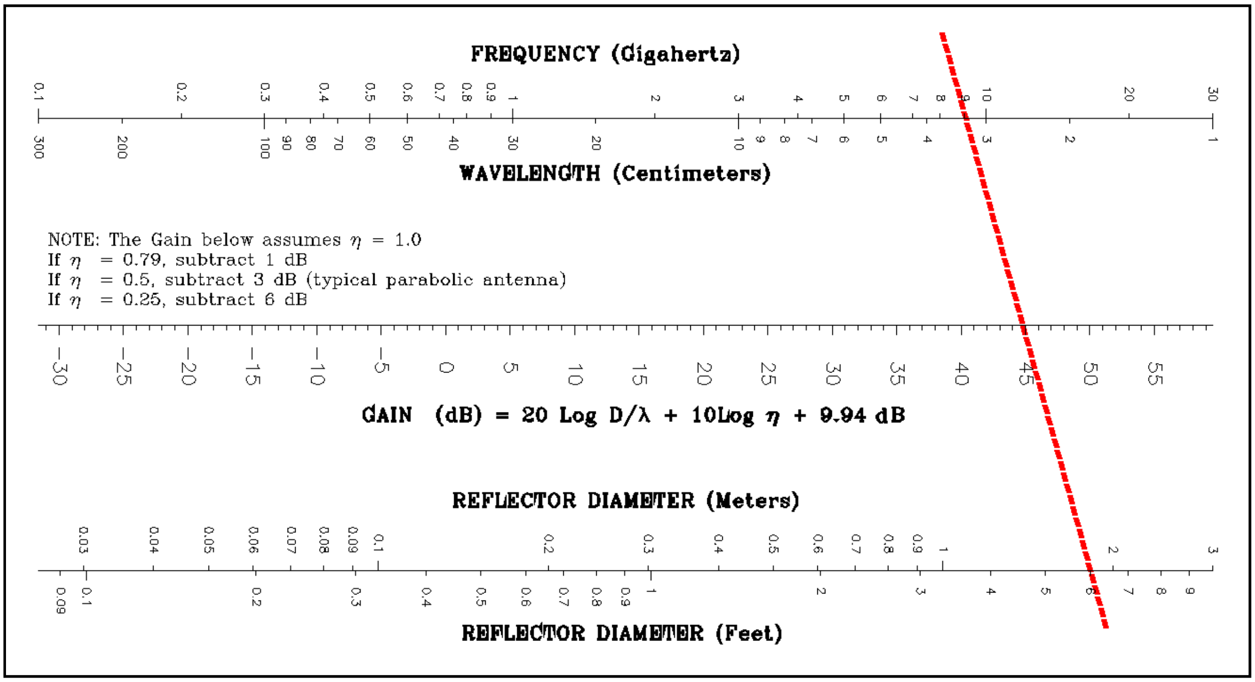

NOTE: The Gain below assumes η = 1.0
If η = 0.79, subtract 1 dB
If η = 0.5, subtract 3 dB (typical parabolic antenna)
If η = 0.25, subtract 6 dB

Figure 6. Antenna Gain Nomograph.

An example of a typical antenna (with losses) showing the variation of gain with frequency is depicted in Figure 7, and the variation of gain with antenna diameter in Figure 8. The circle on the curves in Figure 7 and 8 correspond to the Figure 6 example and yields 42 dB of gain for the 6 ft dish at 9 GHz.

Example Problem: If the two antennas in the drawing are "welded" together, how much power will be measured at point A? (Line loss $L_1 = L_2 = 0.5$, and 10log L_1 or L_2 = 3 dB)

Multiple choice:

A. 16 dBm b. 28 dBm c. 4 dBm d. 10 dBm e. < 4 dBm

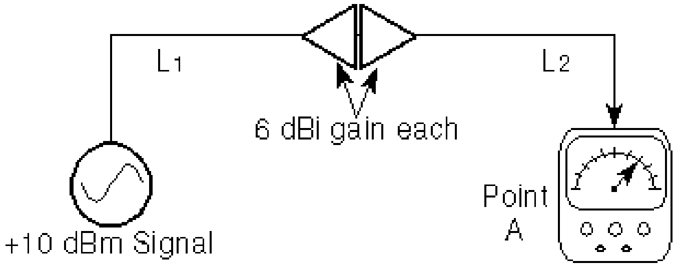

Answer:

The antennas do not act as they normally would since the antennas are operating in the near field. They act as inefficient coupling devices resulting in some loss of signal. In addition, since there are no active components, you cannot end up with more power than you started with. The correct answer is "e. < 4 dBm."

10 dBm - 3 dB - small loss -3 dB = 4 dBm - small loss

If the antennas were separated by 5 ft and were in the far field, the antenna gain could be used with space loss formulas to calculate (at 5 GHz): 10 dBm - 3 dB + 6 dB - 50 dB (space loss) + 6 dB -3 dB = -34 dBm (a much smaller signal).

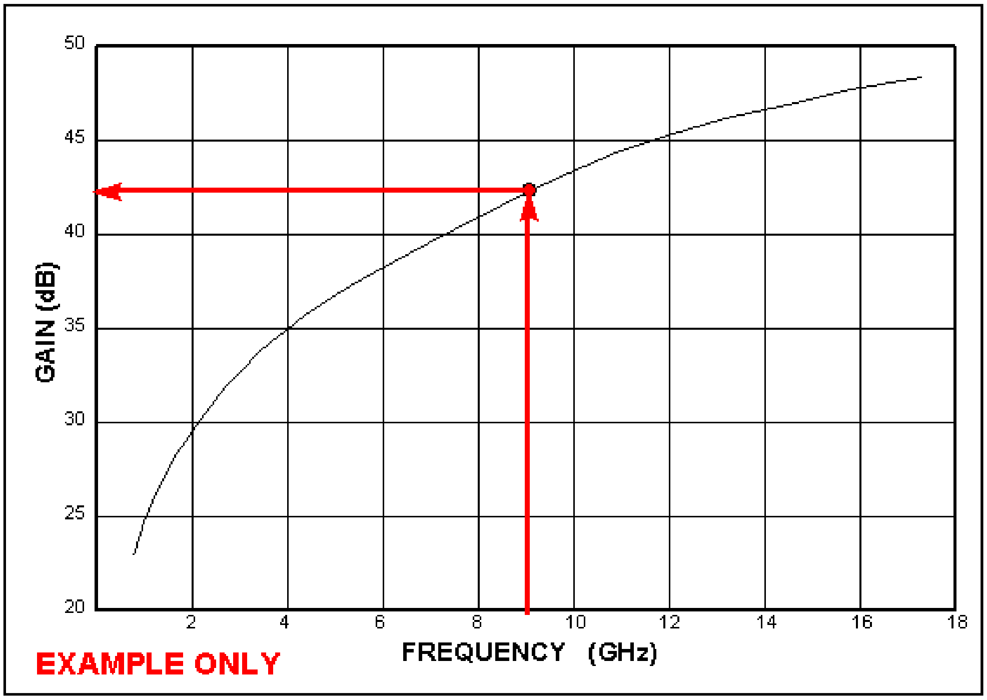

Figure 7. Gain of a Typical 6-Foot Dish Antenna (With Losses).

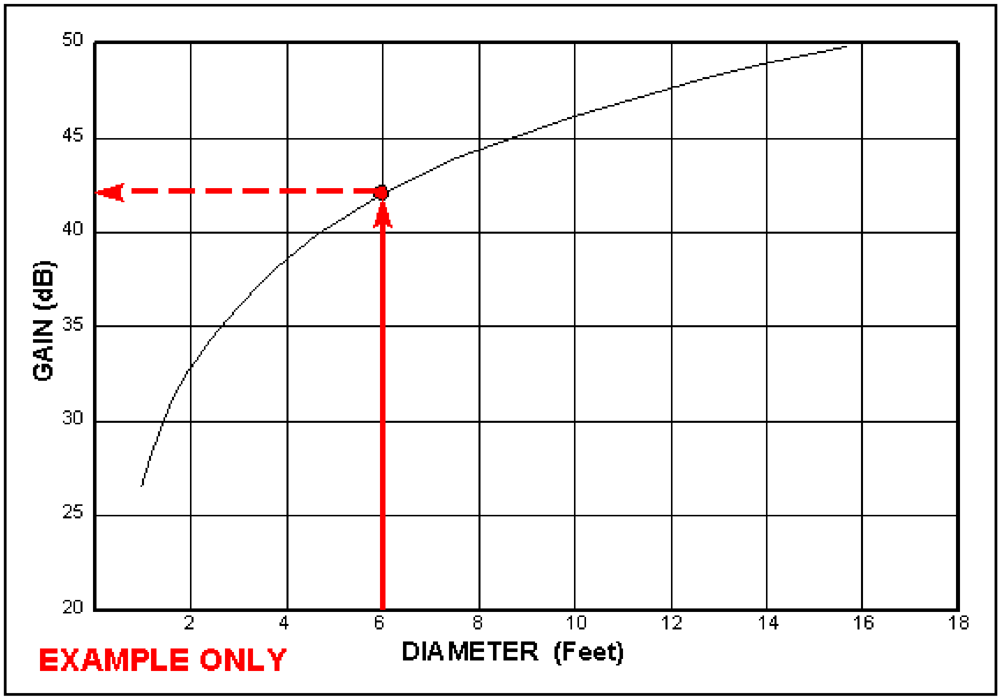

Figure 8. Gain of a Typical Dish at 9 GHz (With Losses).

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POLARIZATION

Table 1 shows the **theoretical** ratio of power transmitted between antennas of different polarization. These ratios are seldom fully achieved due to effects such as reflection, refraction, and other wave interactions, so some practical ratios are also included.

Table 1. Polarization Loss for Various Antenna Combinations.

Transmit Antenna Polarization	Receive Antenna Polarization	Ratio of Power Received to Maximum Power					
		Theoretical		Practical Horn		Practical Spiral	
		Ratio in dB	as Ratio	Ratio in dB	as Ratio	Ratio in dB	as Ratio
Vertical	Vertical	0 dB	1	*	*	N/A	N/A
Vertical	Slant (45° or 135°)	-3 dB	½	*	*	N/A	N/A
Vertical	Horizontal	- ∞ dB	0	-20 dB	1/100	N/A	N/A
Vertical	Circular (right-hand or left-hand)	-3 dB	½	*	*	*	*
Horizontal	Horizontal	0 dB	1	*	*	N/A	N/A
Horizontal	Slant (45° or 135°)	-3 dB	½	*	*	N/A	N/A
Horizontal	Circular (right-hand or left-hand)	-3 dB	½	*	*	*	*
Circular (right-hand)	Circular (right-hand)	0 dB	1	*	*	*	*
Circular (right-hand)	Circular (left-hand)	- ∞ dB	0	-20 dB	1/100	-10 dB	1/10
Circular (right or left)	Slant (45° or 135°)	-3 dB	½	*	*	*	*

* Approximately the same as theoretical.
Note: Switching transmit and receive antenna polarization will give the same results.

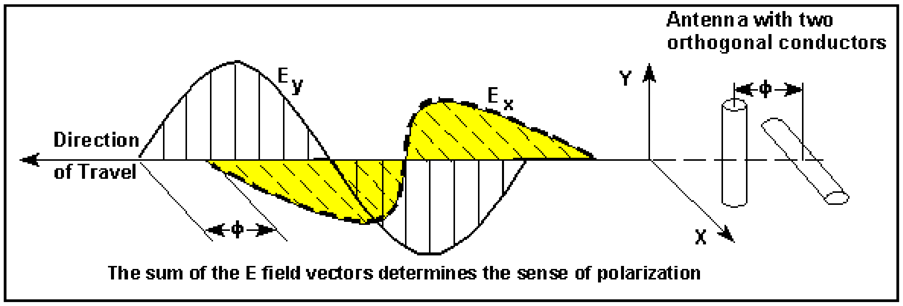
Antenna with two orthogonal conductors
Ey
Ex
Y
X
ϕ
ϕ
Direction of Travel
The sum of the E field vectors determines the sense of polarization

Figure 1. Polarization Coordinates.

The polarization of an electromagnetic wave is defined as the orientation of the electric field vector. Recall that the electric field vector is perpendicular to both the direction of travel and the magnetic field vector. The polarization is described by the geometric figure traced by the electric field vector upon a stationary plane perpendicular to the direction of propagation, as the wave travels through that plane. An electromagnetic wave is frequently composed of (or can be broken down into) two orthogonal components as shown in Figure 1. This may be due to the arrangement of power input leads to various points on a flat antenna, or due to an interaction of active elements in an array, or many other reasons.

The geometric figure traced by the sum of the electric field vectors over time is, in general, an ellipse as shown in Figure 2. Under certain conditions the ellipse may collapse into a straight line, in which case the polarization is called linear.

In the other extreme, when the two components are of equal magnitude and 90° out of phase, the ellipse will become circular as shown in Figure 3. Thus linear and circular polarization are the two special cases of elliptical polarization. Linear polarization may be further classified as being vertical, horizontal, or slant.

Figure 2 depicts plots of the E field vector while varying the relative amplitude and phase angle of its component parts.

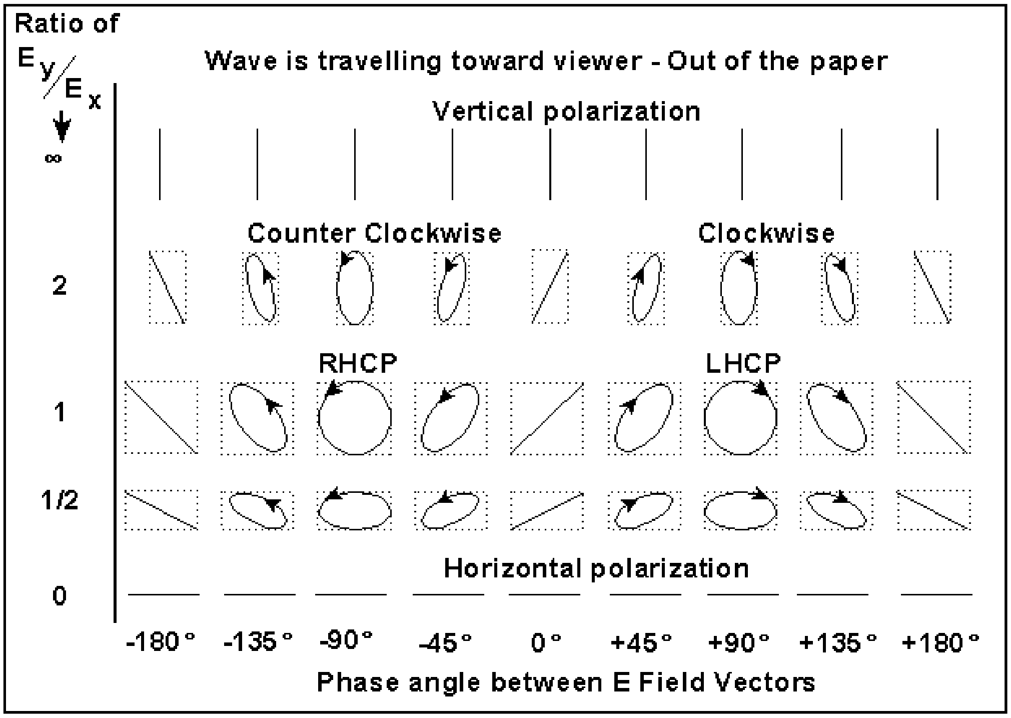
Ratio of
Ey/Ex
∞
2
1
1/2
0
Wave is travelling toward viewer - Out of the paper
Vertical polarization
Counter Clockwise
Clockwise
RHCP
LHCP
Horizontal polarization
-180°
-135°
-90°
-45°
0°
+45°
+90°
+135°
+180°
Phase angle between E Field Vectors

Figure 2. Polarization as a Function of E_y / E_x Ratio and Phase Angle.
Adopted from J.D. Kraus, "Antennas," 2nd ed., Figure 2-37

For a linearly polarized antenna, the radiation pattern is taken both for a co-polarized and cross polarized response. The polarization quality is expressed by the ratio of these two responses. The ratio between the responses must typically be great (30 dB or greater) for an application such as cross-polarized jamming. For general applications, the ratio indicates system power loss due to polarization mismatch. For circularly polarized antennas, radiation patterns are usually taken with a rotating linearly polarized reference antenna. The reference antenna rotates many times while taking measurements around the azimuth of the antenna that is being tested. The resulting antenna pattern is the linear polarized gain with a cyclic ripple. The peak-to-peak value is the axial ratio, and represents the polarization quality for a circular polarized antenna. The typical RWR antenna has a maximum 3 dB axial ratio within 45° of boresight.

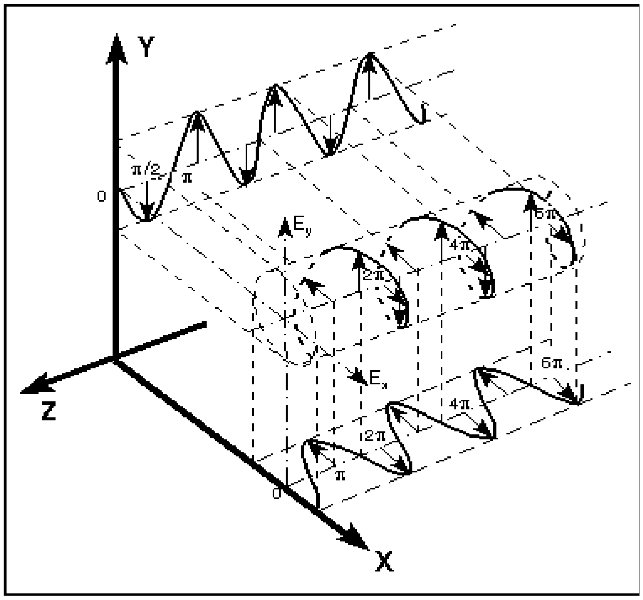
Y
Z
X
0
π/2
π
Ey
2π
4π
6π
Ex
0
π
2π
4π
6π

Figure 3. Circular Polarization – E Field.

For any antenna with an aperture area, as the aperture is rotated, the viewed dimension along the axis remains constant, while the other viewed dimension decreases to zero at 90° rotation. The axial ratio of an antenna will get worse as the antenna is rotated off boresight because the field contribution from the axial component will remain fairly constant and the other orthogonal component will decrease with rotation.

The sense of antenna polarization is defined from a viewer positioned behind an antenna looking in the direction of propagation. The polarization is specified as a transmitting, not receiving antenna regardless of intended use.

We frequently use "hand rules" to describe the sense of polarization. The sense is defined by which hand would be used in order to point that thumb in the direction of propagation and point the fingers of the same hand in the direction of rotation of the E field vector. For example, referring to Figure 4, if your thumb is pointed in the direction of propagation and the rotation is counterclockwise looking in the direction of travel, then you have left hand circular polarization.

Optics people view an aperture from the front and therefore use the opposite reference.

The polarization of a linearly polarized horn antenna can be directly determined by the orientation of the feed probe, which is in the direction of the E-field.

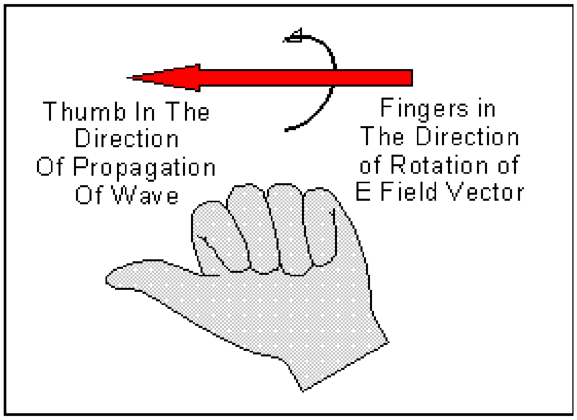
Thumb In The Direction Of Propagation Of Wave
Fingers in The Direction of Rotation of E Field Vector

Figure 4. Left Hand Polarization.

In general, a flat surface or sphere will reflect a linearly polarized wave with the same polarization as received. A horizontally polarized wave may get extended range because of water and land surface reflections, but signal cancellation will probably result in "holes" in coverage. Reflections will reverse the sense of circular polarization.

If the desired antenna is used for receiving a direct transmission as shown in Figure 5, the same polarization sense (specified if transmitting) is required for maximum signal reception in this situation. Buy two right-hand or two left-hand circularly polarized antennas for this case. When you procure antennas, remember that the polarization is specified as if transmitting, regardless of intended use.

Wave propagation between two identical antennas is analogous to being able to thread a nut from one bolt to an identical opposite facing bolt.

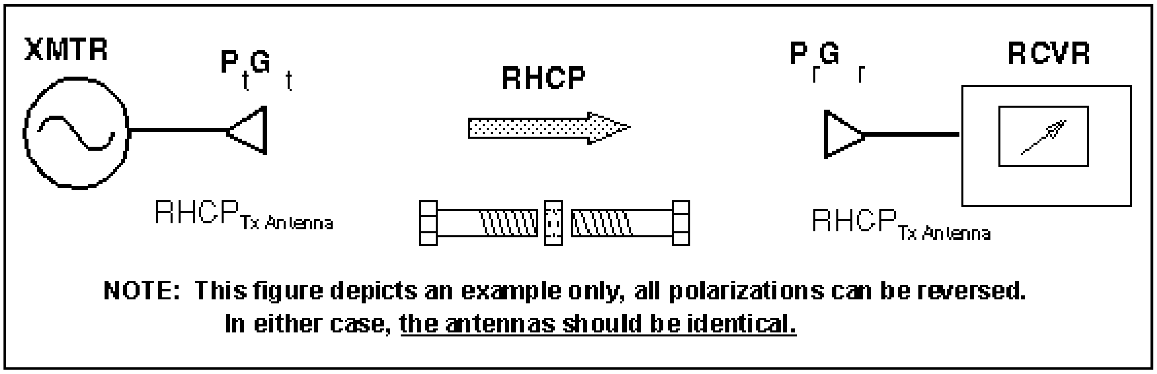
XMTR
P_tG_t
RHCP
P_rG_r
RCVR
$RHCP_{Tx\ Antenna}$
$RHCP_{Tx\ Antenna}$
NOTE: This figure depicts an example only, all polarizations can be reversed.
In either case, the antennas should be identical.

Figure 5. Same Circular Polarization.

If the desired antenna is used for a receiving a wave with a single or odd number of reflections, such as a bistatic radar where separate antennas are used for transmit and receive as shown in Figure 6, then opposite circularly polarized antennas would be used for maximum signal reception. In this case buy antennas of opposite polarization sense (one left hand and one right hand).

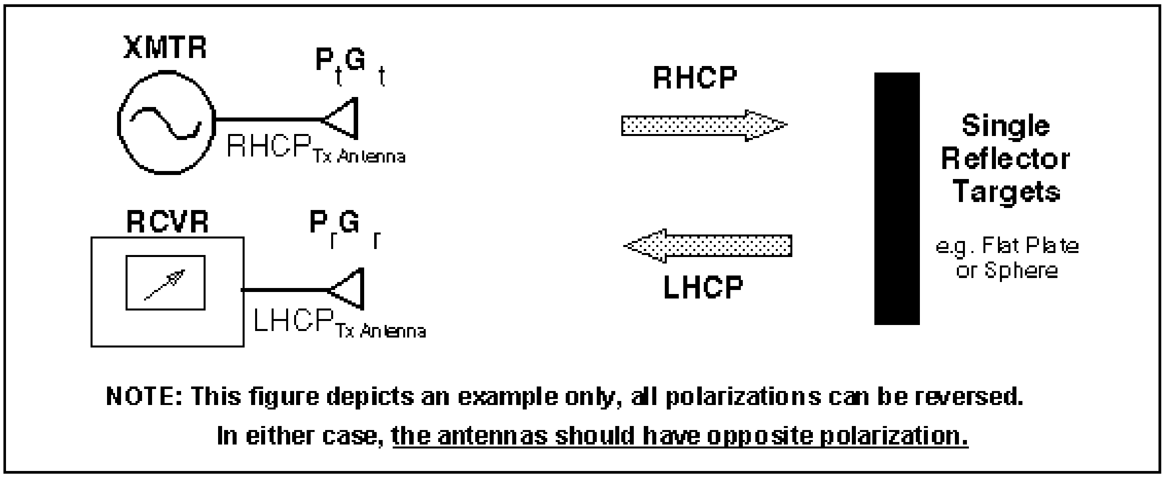
XMTR
PtG t
RHCP Tx Antenna
RCVR
PrG r
LHCP Tx Antenna
RHCP
LHCP
Single Reflector Targets
e.g. Flat Plate or Sphere

NOTE: This figure depicts an example only, all polarizations can be reversed.
In either case, the antennas should have opposite polarization.

Figure 6. Opposite Circular Polarization.

In a corner reflector, waves reflect twice before returning to the receiver as shown in Figure 7, consequently they return with the same sense as they were transmitted. In this case (or any even number of reflections) buy antennas of the same polarization sense.

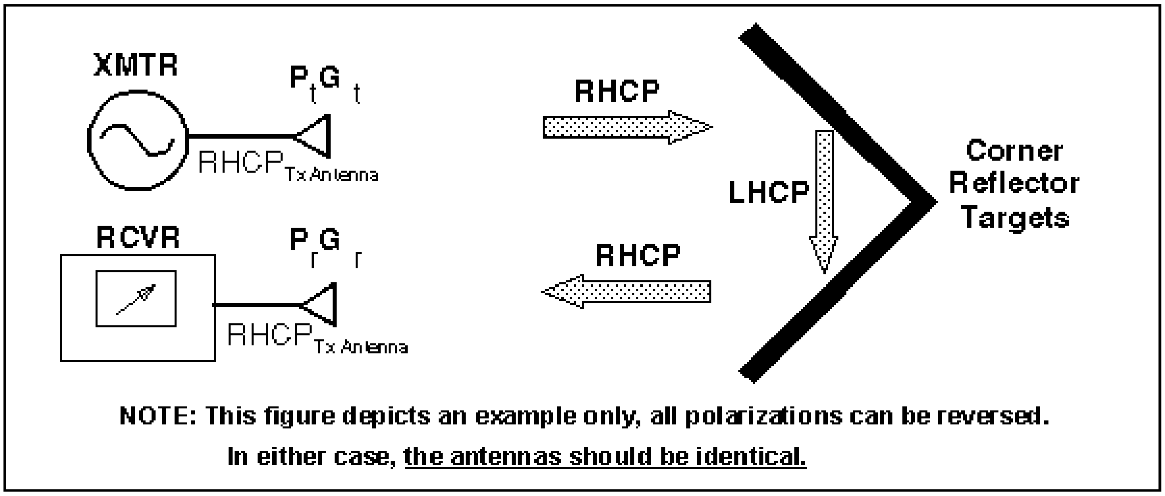
XMTR
PtG t
RHCP Tx Antenna
RCVR
PrG r
RHCP Tx Antenna
RHCP
LHCP
RHCP
Corner Reflector Targets

NOTE: This figure depicts an example only, all polarizations can be reversed.
In either case, the antennas should be identical.

Figure 7. Circular Polarization With Corner Reflector.

An aircraft acts as both a corner reflector and a “normal” reflector so the return has mixed polarization. Most airborne radars use the same antenna for transmitting and receiving in order to receive the corner reflections and help exclude receipt of reflections from rain (single polarization reversal), however in doing so there is about a 5-9 dB loss from the ideal receiver case. It should be noted that the return from raindrops is attenuated by approximately 20 dB.

RADIATION PATTERNS

The radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna. Antenna radiation patterns are taken at one frequency, one polarization, and one plane cut. The patterns are usually presented in polar or rectilinear form with a dB strength scale. Patterns are normalized to the maximum graph value, 0 dB, and a directivity is given for the antenna. This means that if the side lobe level from the radiation pattern were down -13 dB, and the directivity of the antenna was 4 dB, then the sidelobe gain would be -9 dB.

Figures 1 to 14 on the pages following depict various antenna types and their associated characteristics. The patterns depicted are those which most closely match the purpose for which the given shape was intended. In other words, the radiation pattern can change dramatically depending upon frequency, and the wavelength to antenna characteristic length ratio. See Section 3-4. Antennas are designed for a particular frequency. Usually the characteristic length is a multiple of $\lambda/2$ minus 2-15% depending on specific antenna characteristics.

The gain is assumed to mean directional gain of the antenna compared to an isotropic radiator transmitting to or receiving from all directions.

The half-power (-3 dB) beamwidth is a measure of the directivity of the antenna.

Polarization, which is the direction of the electric (not magnetic) field of an antenna is another important antenna characteristic. This may be a consideration for optimizing reception or jamming.

The bandwidth is a measure of how much the frequency can be varied while still obtaining an acceptable VSWR (2:1 or less) and minimizing losses in unwanted directions. See Glossary, Section 10.

A 2:1 VSWR corresponds to a 9.5 dB (or 10%) return loss - see Section 6-2.

Two methods for computing antenna bandwidth are used:

Narrowband by %, $B = \left(\frac{F_U - F_L}{F_C} \right) (100)$, where F_C = Center frequency

Broadband by ratio, $B = \frac{F_U}{F_L}$

An antenna is considered broadband if $F_U / F_L > 2$. The table at the right shows the equivalency of the two, however the shaded values are not normally used because of the aforementioned difference in broadband/narrowband.

Bandwidth	
%	Ratio
5	1.05 : 1
10	1.11 : 1
20	1.22 : 1
30	1.35 : 1
40	1.50 : 1
50	1.67 : 1
60	1.85 : 1
67	2 : 1
100	3 : 1
120	4 : 1
133	5 : 1
150	7 : 1
160	9 : 1
163	10 : 1

Should there be ever a need to express bandwidth of an antenna in one or the other alternative formats, a conversion between the two narrowband and broadband bandwidth quantities can be easily calculated using the following relationships:

Calculate broadband ratio B_{bb} given narrowband B%,

$$B_{bb} = (200 + B\%)/(200 - B\%) \qquad \textbf{[1]}$$

Calculate narrowband B% given broadband ratio B_{bb},

$$B\% = 200 * (Bbb - 1)/(Bbb + 1) \qquad [2]$$

For an object that experiences a plane wave, the resonant mode is achieved when the dimension of the object is nλ/2, where n is an integer. Therefore, one can treat the apertures shown in the following figure as half wave length dipole antennas for receiving and reflecting signals. More details are contained in Section 8-4.

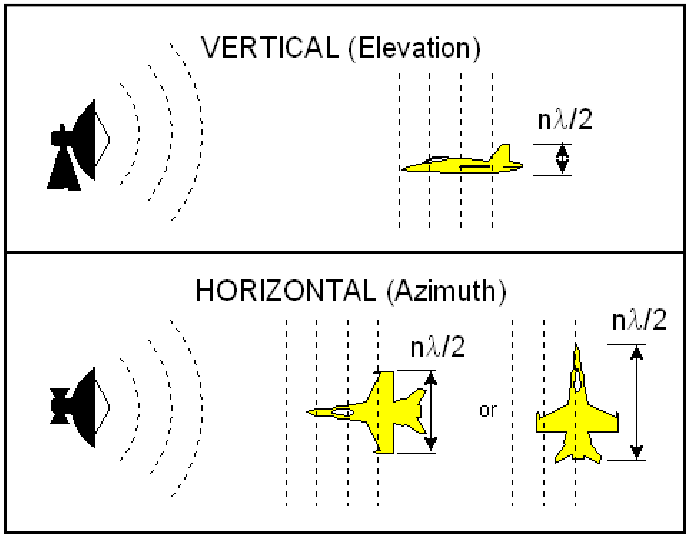

The following lists antenna types by page number. The referenced page shows frequency limits, polarizations, etc.

Type	Page	Type	Page
4 arm conical spiral	3-3.6	log periodic	3-3.8
alford loop	3-3.4	loop, circular	3-3.4
aperture synthesis	3-3.8	loop, alford	3-3.4
array	3-3.8	loop, square	3-3.4
axial mode helix	3-3.5	luneberg lens	3-3.9
biconical w/polarizer	3-3.6	microstrip patch	3-3.9
biconical	3-3.6	monopole	3-3.3
cavity backed circuit fed slot	3-3.5	normal mode helix	3-3.5
cavity backed spiral	3-3.9	parabolic	3-3.7
circular loop	3-3.4	patch	3-3.9
conical spiral	3-3.5	reflector	3-3.10
corner reflector	3-3.9	rhombic	3-3.3
dipole array, linear	3-3.8	sinuous, dual polarized	3-3.6
dipole	3-3.3	slot, guide fed	3-3.9
discone	3-3.4	slot, cavity backed	3-3.9
dual polarized sinuous	3-3.6	spiral, 4 arm conical	3-3.6
guide fed slot	3-3.9	spiral, conical	3-3.5
helix, normal mode	3-3.5	spiral, cavity backed	3-3.5
helix, axial mode	3-3.5	square loop	3-3.4
horn	3-3.7	vee	3-3.3
linear dipole array	3-3.8	yagi	3-3.8

Antenna Type	Radiation Pattern	Characteristics
MONOPOLE 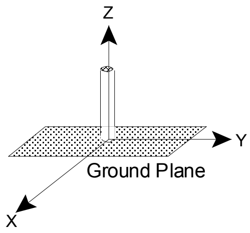 	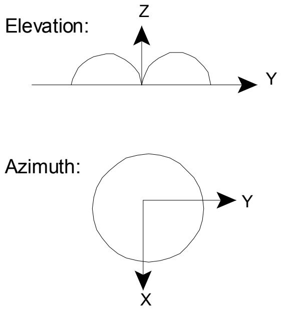 	**Polarization: Linear** Vertical as shown **Typical Half-Power Beamwidth** 45 deg x 360 deg **Typical Gain:** 2-6 dB at best **Bandwidth:** 10% or 1.1:1 **Frequency Limit** **Lower:** None **Upper:** None **Remarks:** Polarization changes to horizontal if rotated to horizontal
λ/2 DIPOLE 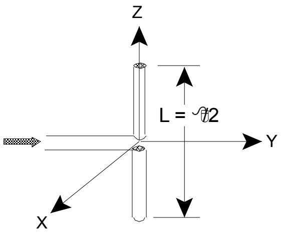 	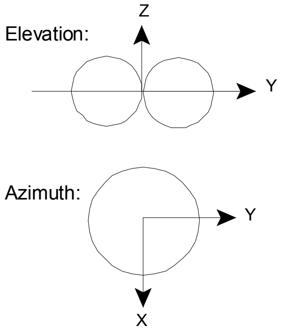 	**Polarization**: Linear Vertical as shown **Typical Half-Power Beamwidth** 80 deg x 360 deg **Typical Gain:** 2 dB **Bandwidth:** 10% or 1.1:1 **Frequency Limit** **Lower:** None **Upper:** 8 GHz (practical limit) **Remarks:** Pattern and lobing changes significantly with L/f. Used as a gain reference < 2 GHz.

Figure 1. Monopole and Dipole Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
VEE 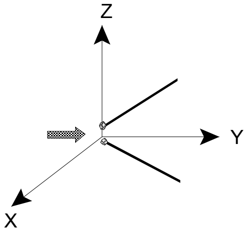 	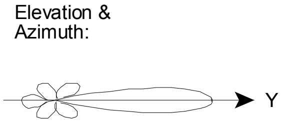 	**Polarization**: Linear Vertical as shown **Typical Half-Power Beamwidth** 60 deg x 60 deg **Typical Gain:** 2 to 7 dB **Bandwidth:** "Broadband" **Frequency Limit** **Lower:** 3 MHz **Upper:** 500 MHz (practical limits) **Remarks:** 24KHz versions are known to exist. Terminations may be used to reduce backlobes.
RHOMBIC 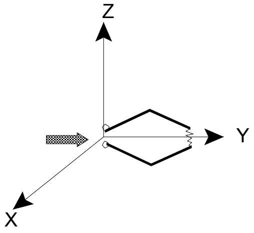 	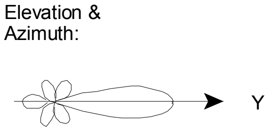 	**Polarization**: Linear Vertical as shown **Typical Half-Power Beamwidth** 60 deg x 60 deg **Typical Gain:** 3 dB **Bandwidth:** "Broadband" **Frequency Limit** **Lower:** 3 MHz **Upper:** 500 MHz **Remarks:** Termination resistance used to reduce backlobes.

Figure 2. Vee and Rhombic Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
CIRCULAR LOOP (Small) 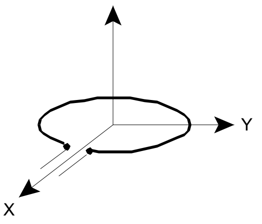	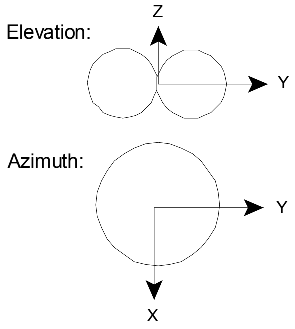 Elevation: Z Y Azimuth: Y X	**Polarization:** Linear Horizontal as shown **Typical Half-Power Beamwidth:** 80 deg x 360 deg **Typical Gain:** -2 to 2 dB **Bandwidth:** 10% or 1.1:1 **Frequency Limit:** **Lower:** 50 MHz **Upper:** 1 GHz
SQUARE LOOP (Small) 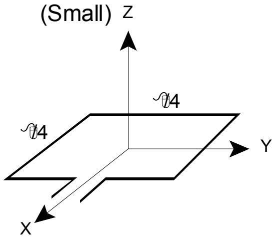	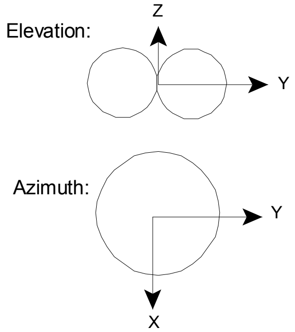 Elevation: Z Y Azimuth: Y X	**Polarization:** Linear Horizontal as shown **Typical Half-Power Beamwidth:** 100 deg x 360 deg **Typical Gain:** 1-3 dB **Bandwidth:** 10% or 1.1:1 **Frequency Limit:** **Lower:** 50 MHz **Upper:** 1 GHz

Figure 3. Circular Loop and Square Loop Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
DISCONE 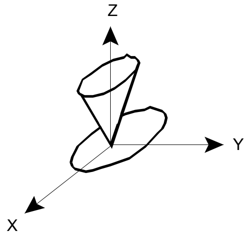	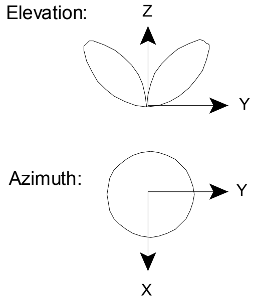 Elevation: Z Y Azimuth: Y X	**Polarization:** Linear Vertical as shown **Typical Half-Power Beamwidth:** 20-80 deg x 360 deg **Typical Gain:** 0-4 dB **Bandwidth:** 100% or 3:1 **Frequency Limit:** **Lower:** 30 MHz **Upper:** 3 GHz
ALFORD LOOP 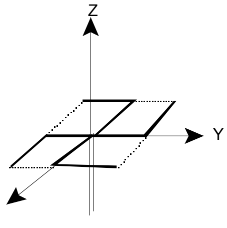	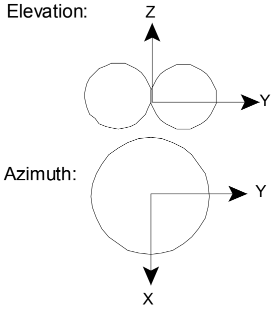 Elevation: Z Y Azimuth: Y X	**Polarization:** Linear Horizontal as shown **Typical Half-Power Beamwidth:** 80 deg x 360 deg **Typical Gain:** -1 dB **Bandwidth:** 67% or 2:1 **Frequency Limit:** **Lower:** 100 MHz **Upper:** 12 GHz

Figure 4. Discone and Alford Loop Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
AXIAL MODE HELIX 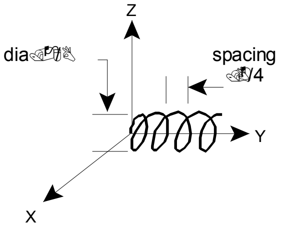	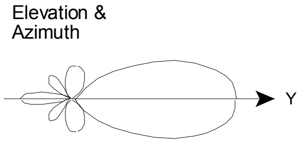	**Polarization:** Circular Left hand as shown **Typical Half-Power Beamwidth:** 50 deg x 50 deg **Typical Gain:** 10 dB **Bandwidth:** 52% or 1.7:1 **Frequency Limit** **Lower:** 100 MHz **Upper:** 3 GHz **Remarks:** Number of loops >3
NORMAL MODE HELIX 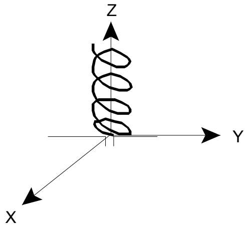	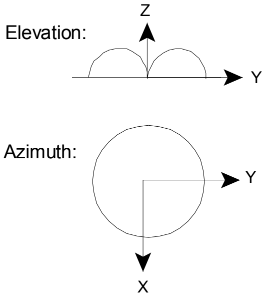	**Polarization:** Circular - with an ideal pitch to diameter ratio. **Typical Half-Power Beamwidth:** 60 deg x 360 deg **Typical Gain:** 0 dB **Bandwidth:** 5% or 1.05:1 **Frequency Limit** **Lower:** 100 MHz **Upper:** 3 GHz

Figure 5. Axial Mode Helix and Normal Mode Helix Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
CAVITY BACKED SPIRAL (Flat Helix) 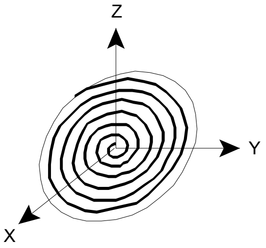	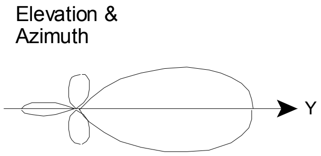	**Polarization:** Circular Left hand as shown **Typical Half-Power Beamwidth:** 60 deg x 90 deg **Typical Gain:** 2-4 dB **Bandwidth:** 160% or 9:1 **Frequency Limit:** **Lower:** 500 MHz **Upper:** 18 GHz
CONICAL SPIRAL 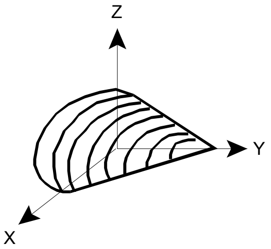	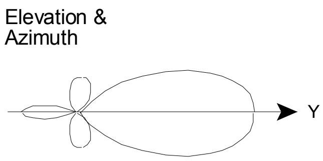	**Polarization:** Circular Left hand as shown **Typical Half-Power Beamwidth:** 60 deg x 60 deg **Typical Gain:** 5-8 dB **Bandwidth:** 120% or 4:1 **Frequency Limit:** **Lower:** 50 MHz **Upper:** 18 GHz

Figure 6. Cavity Backed Spiral and Conical Spiral Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
4 ARM CONICAL SPIRAL 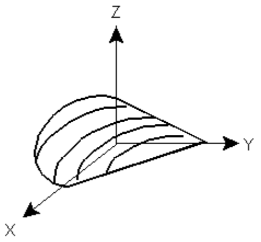	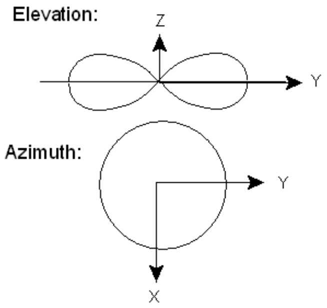	**Polarization:** Circular Left hand as shown **Typical Half-Power Beamwidth:** 50 deg x 360 deg **Typical Gain:** 0 dB **Bandwidth:** 120% or 4:1 **Frequency Limit:** **Lower:** 500 MHz **Upper:** 18 GHz
DUAL POLARIZED SINUOUS 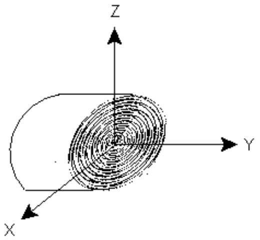	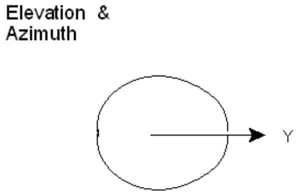	**Polarization**: Dual vertical or horizontal or dual Circular right hand or left hand with hybrid **Typical Half-Power Beamwidth:** 75 deg x 75 deg **Typical Gain:** 2 dB **Bandwidth:** 163% or 10:1 **Frequency Limit:** **Lower:** 500 MHz **Upper:** 18 GHz

Figure 7. Dual Polarized Sinuous Antenna Characteristics and 4 Arm Conical Spiral.

Antenna Type	Radiation Pattern	Characteristics
BICONICAL 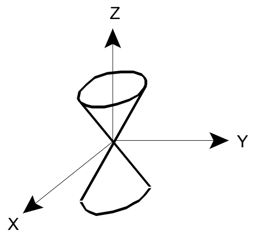	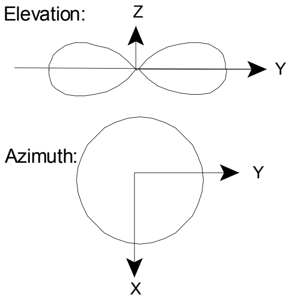	**Polarization:** Linear, Vertical as shown **Typical Half-Power Beamwidth:** 20-100 deg x 360 deg **Typical Gain:** 0-4 dB **Bandwidth:** 120% or 4:1 **Frequency Limit:** **Lower:** 500 MHz **Upper:** 40 GHz
BICONICAL W/POLARIZER 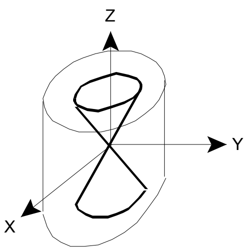	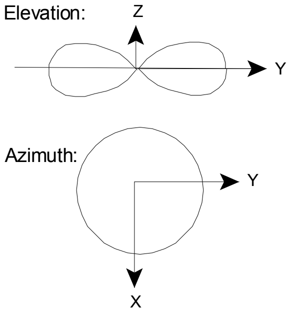	**Polarization:** Circular, Direction depends on polarization **Typical Half-Power Beamwidth:** 20-100 deg x 360 deg **Typical Gain:** -3 to 1 dB **Bandwidth:** 100% or 3:1 **Frequency Limit:** **Lower:** 2 GHz **Upper:** 18 GHz

Figure 8. Biconical and Biconical With Polarizer Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
HORN 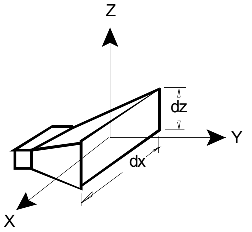 	Elevation: 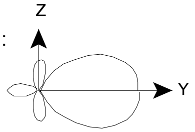 3 dB beamwidth = 56 🖰/dz Azimuth: 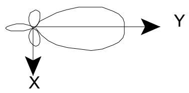 3 dB beamwidth = 70 🖰/dx	**Polarization:** Linear **Typical Half-Power Beamwidth:** 40 deg x 40 deg **Typical Gain:** 5 to 20 dB **Bandwidth:** If ridged: 120% or 4:1 If not ridged: 67% or 2:1 **Frequency Limit:** **Lower:** 50 MHz **Upper:** 40 GHz
HORN W / POLARIZER 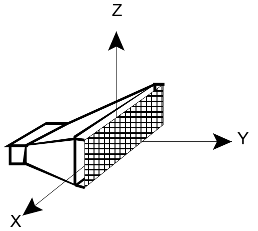 	Elevation: 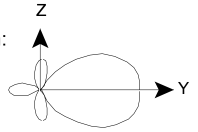 Azimuth: 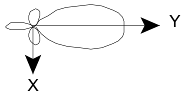 	**Polarization:** Circular, Depends on polarizer **Typical Half-Power Beamwidth:** 40 deg x 40 deg **Typical Gain:** 5 to 10 dB **Bandwidth:** 60% or 2:1 **Frequency Limit:** **Lower:** 2 GHz **Upper:** 18 GHz

Figure 9. Horn and Horn w/Polarizer Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
PARABOLIC (Prime) 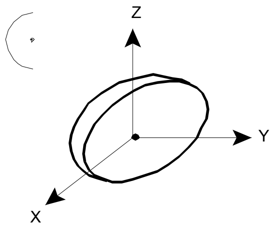 	Elevation & Azimuth 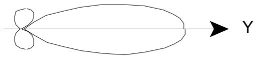 	**Polarization:** Takes polarization of feed **Typical Half-Power Beamwidth:** 1 to 10 deg **Typical Gain:** 20 to 30 dB **Bandwidth:** 33% or 1.4:1 limited mostly by feed **Frequency Limit:** **Lower:** 400 MHz **Upper:** 13+ GHz
PARABOLIC 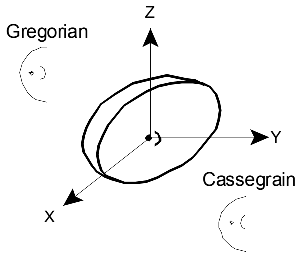 	Elevation & Azimuth 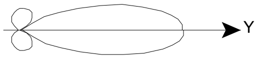 	**Polarization:** Takes polarization of feed **Typical Half-Power Beamwidth:** 1 to 10 deg **Typical Gain:** 20 to 30 dB **Bandwidth:** 33% or 1.4:1 **Frequency Limit:** **Lower:** 400 MHz **Upper:** 13+ GHz

Figure 10. Parabolic (Prime) and Parabolic Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
YAGI 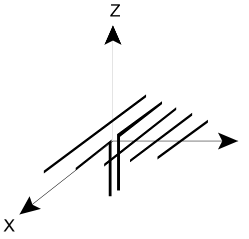 	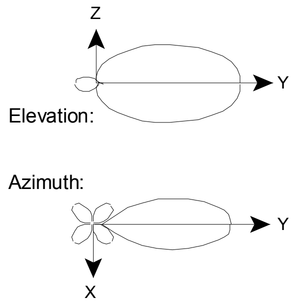 	**Polarization:** Linear Horizontal as shown **Typical Half-Power Beamwidth** 50 deg X 50 deg **Typical Gain:** 5 to 15 dB **Bandwidth:** 5% or 1.05:1 **Frequency Limit:** **Lower:** 50 MHz **Upper:** 2 GHz
LOG PERIODIC 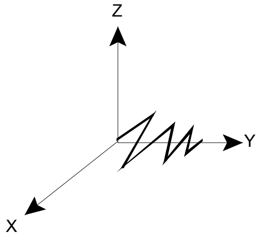 	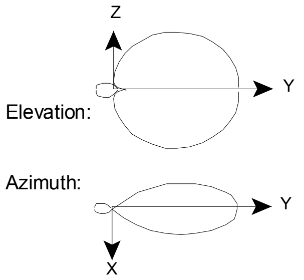 	**Polarization:** Linear **Typical Half-Power Beamwidth:** 60 deg x 80 deg **Typical Gain:** 6 to 8 dB **Bandwidth:** 163% or 10:1 **Frequency Limit:** **Lower:** 3 MHz **Upper:** 18 GHz **Remarks:** This array may be formed with many shapes including dipoles or toothed arrays.

Figure 11. Yagi and Log Periodic Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
LINEAR DIPOLE ARRAY (Corporate Feed) 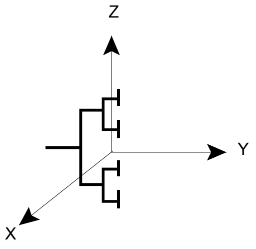 	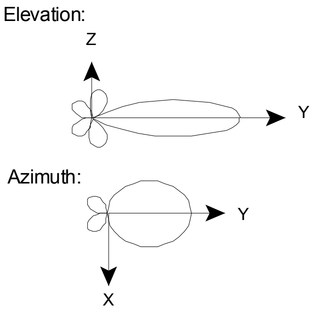 	**Polarization:** Element dependent Vertical as shown **Typical Half-Power Beamwidth:** Related to gain **Typical Gain:** Dependent on number of elements **Bandwidth:** Narrow **Frequency Limit:** **Lower:** 10 MHz **Upper:** 10 GHz
APERTURE SYNTHESIS 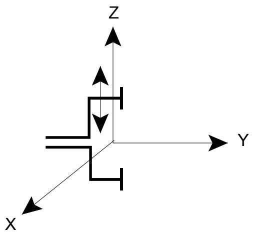 	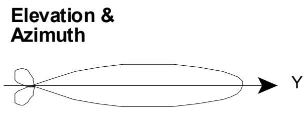 	All characteristics dependent on elements **Remarks:** Excellent side-looking, ground mapping where the aircraft is a moving linear element.

Figure 12. Linear Dipole Array and Aperture Synthesis Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
CAVITY BACKED CIRCUIT FED SLOT (and Microstrip Patch) 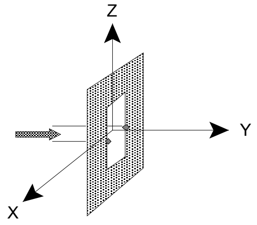	Elevation & Azimuth 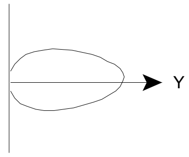	**Polarization:** Linear, vertical as shown **Typical Half-Power Beamwidth**: 80 deg x 80 deg **Typical Gain:** 6 dB **Bandwidth:** Narrow **Frequency Limit:** **Lower:** 50 MHz **Upper:** 18 GHz **Remarks:** The feed line is sometimes separated from the radiator by a dialetric & uses capacititive coupling. Large conformal phased arrays can be made this way.
GUIDE FED SLOT 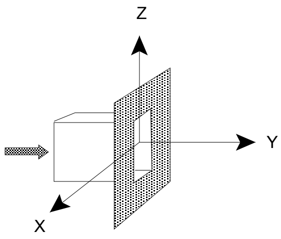	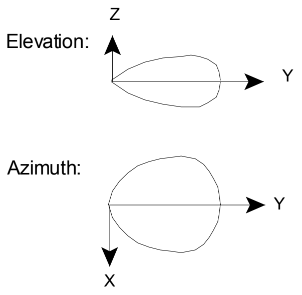	**Polarization:** Linear, **Typical Half-Power Beamwidth** Elevation: 45-50° Azimuth: 80° **Typical Gain:** 0 dB **Bandwidth:** Narrow **Frequency Limit:** **Lower:** 2 GHz **Upper:** 40 GHz **Remarks:** Open RF Waveguide

Figure 13. Cavity Backed Circuit Fed Slot and Guide Fed Slot Antenna Characteristics.

Antenna Type	Radiation Pattern	Characteristics
CORNER REFLECTOR 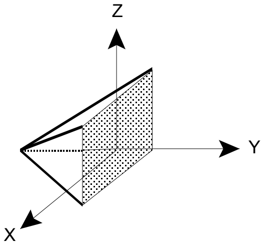	Elevation: (Z-Y) Azimuth: (X-Y) Dependent upon feed emitter	**Polarization**: Feed dependent **Typical Half-Power Beamwidth** 40 deg x variable **Typical Gain:** 10 dB above feed **Bandwidth:** Narrow **Frequency Limit** **Lower:** 1 GHz **Upper:** 40 GHz **Remarks:** Typically fed with a dipole or colinear array.
LUNEBURG LENS 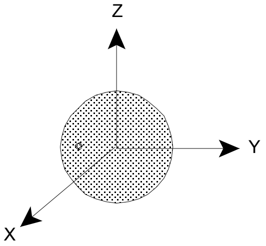	Elevation & Azimuth 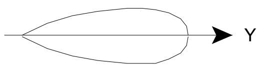	**Polarization:** Feed dependent **Typical Half-Power Beamwidth:** System dependent **Typical Gain:** System dependent **Bandwidth:** Narrow **Frequency Limit** **Lower:** 1 GHz **Upper:** 40 GHz **Remarks:** Variable index dielectric sphere.

Figure 14. Corner Reflector and Luneburg Lens Antenna Characteristics.

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FREQUENCY / PHASE EFFECTS OF ANTENNAS

The radiation patterns of the antennas presented in the previous section are for antenna geometries most commonly used. The antenna should be viewed as a matching network that takes the power from a transmission line (50 ohm, for example), and matches it to the free space "impedance" of 377 ohms. The most critical parameter is the change of VSWR with frequency. The pattern usually does not vary much from acceptable to the start of unacceptable VSWRs (> 2:1). For a given physical antenna geometric size, the actual radiation pattern varies with frequency.

The antenna pattern depicted in Figure 1 is for the dipole pictured in Section 3-3. The maximum gain is normalized to the outside of the polar plot and the major divisions correspond to 10 dB change. In this example, the dipole length (in wavelengths) is varied, but the same result can be obtained by changing frequency with a fixed dipole length. From the figure, it can be seen that side lobes start to form at 1.25λ and the side lobe actually has more gain than the main beam at 1.5λ. Since the radiation pattern changes with frequency, the gain also changes.

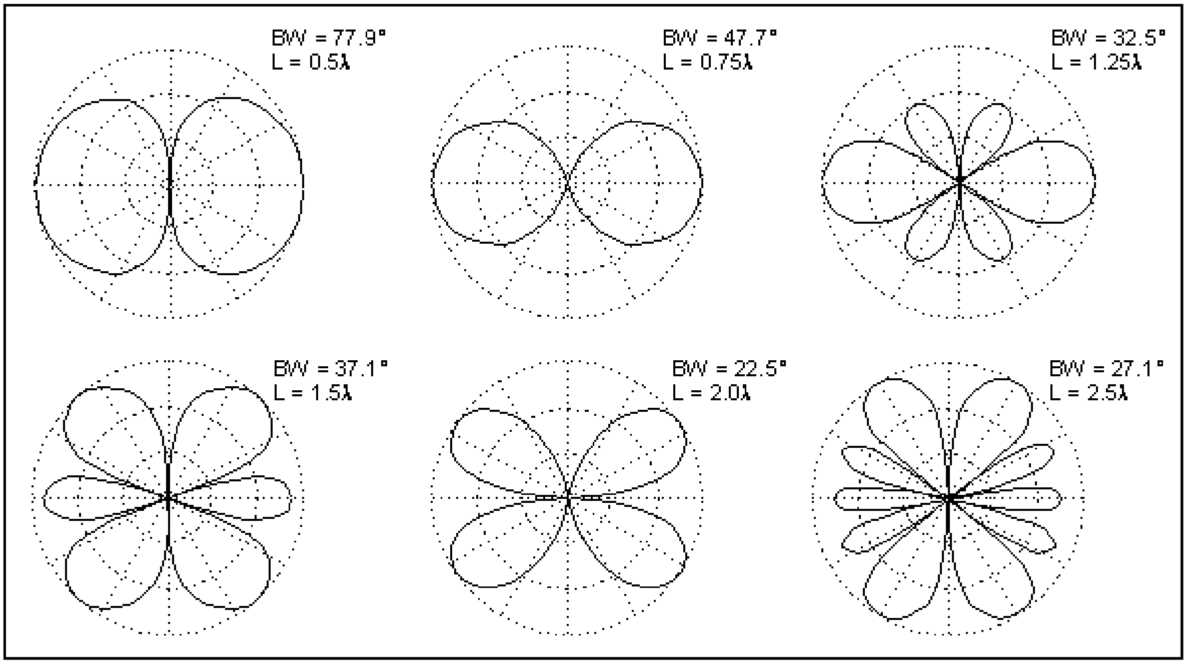

Figure 1. Frequency Effects.

Figure 2 depicts phase/array effects, which are yet another method for obtaining varied radiation patterns. In the figure, parallel dipoles are viewed from the end. It can be seen that varying the phase of the two transmissions can cause the direction of the radiation pattern to change. This is the concept behind phased array antennas. Instead of having a system mechanically sweeping the direction of the antenna through space, the phase of radiating components is varied electronically, producing a moving pattern with no moving parts. It can also be seen that increasing the number of elements further increases the directivity of the array. In an array, the pattern does vary considerably with frequency due to element spacing (measured in wavelengths) and the frequency sensitivity of the phase shifting networks.

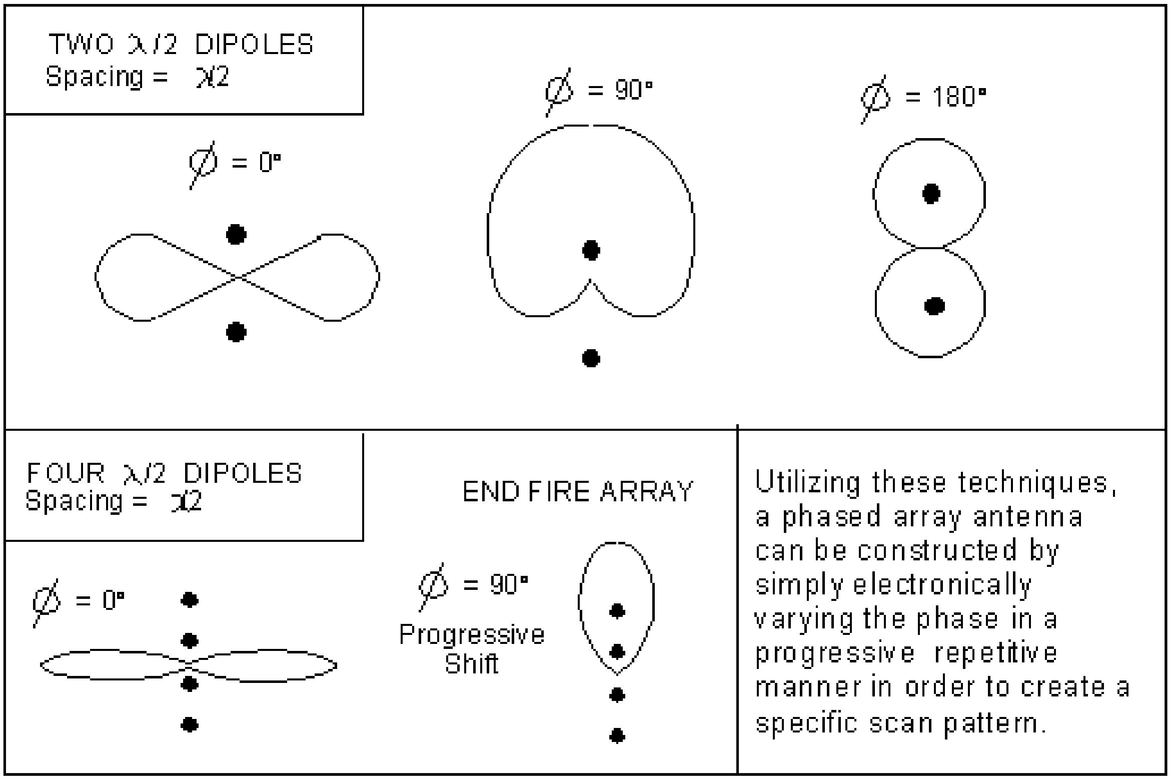

Utilizing these techniques, a phased array antenna can be constructed by simply electronically varying the phase in a progressive repetitive manner in order to create a specific scan pattern.

Figure 2. Phase / Array Effects*.

* Note: Assuming Figure 2 depicts x-y plane antenna pattern cross section, to achieve the indicated array patterns using dipole antennas, the dipole antenna elements must be aligned with the z-axis.

Two antennas that warrant special consideration are the phased array and the Rotman bootlace type lens. Both of these antennas find wide application in EW, RADAR, and Communications. The phased array will be described first.

LINEAR PHASED ARRAY

The linear phased array with equal spaced elements is easiest to analyze and forms the basis for most array designs. Figure 3 schematically illustrates a corporate feed linear array with element spacing d.

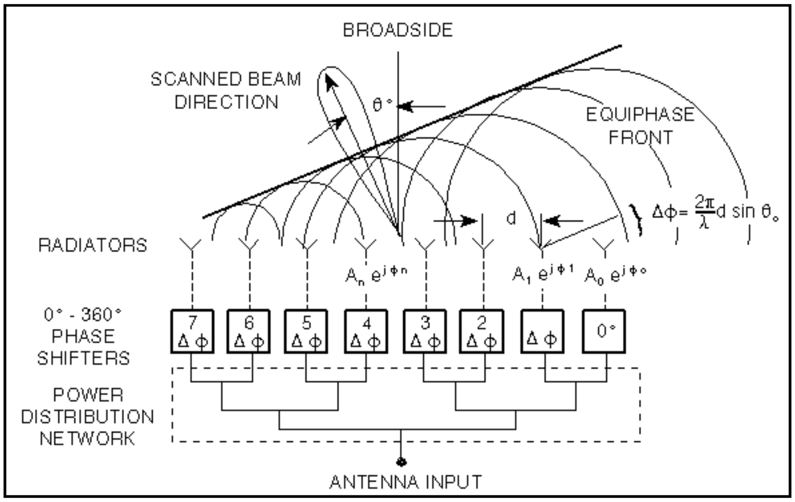

Figure 3. Corporate Fed Phased Array.

It is the simplest and is still widely used. By controlling the phase and amplitude of excitation to each element, as depicted, we can control the direction and shape of the beam radiated by the array. The phase excitation, $\varphi(n)$, controls the beam pointing angle, θ_o, in a phased array. To produce a broadside beam, $\theta_o=0$, requires phase excitation, $\varphi(n)=0$. Other scan angles require an excitation, $\varphi(n) = nkd \sin(\theta_o)$, for the nth element where k is the wave number $(2\pi/\lambda)$. In this manner a linear phased array can radiate a beam in any scan direction, θ_o, provided the element pattern has sufficient beamwidth. The amplitude excitation, A_n, can be used to control beam shape and sidelobe levels. Often the amplitude excitation is tapered in a manner similar to that used for aperture antennas to reduce the sidelobe levels. One of the problems that can arise with a phased array is insufficient bandwidth, since the phase shift usually is not obtained through the introduction of additional path length. However, it should be noted that at broadside the corporate feed does have equal path length and would have good bandwidth for this scan angle.

The linear array described above would yield a narrow fan beam in the plane normal to the plane containing the array and scan direction, with the narrow beamwidth in the plane of the array. To obtain a pencil beam it would be necessary to array several of these linear arrays in such a manner resulting in a planar array of radiating elements. A problem associated with all electronic scanning is beam distortion with scan angle. Figure 4 illustrates this phenomenon. It results in spread of the beam shape with a concomitant reduction in gain. This effect is known as “scan loss.” For an ideal array element, scan loss is equal to the reduction in aperture size in the scan direction which varies as cos θ, where θ is the scan angle measured from the planar array normal.

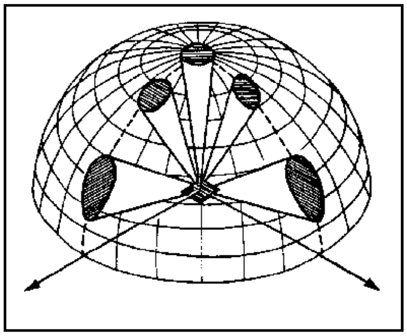

Figure 4. Beam Distortion.

When elements are spaced greater than λ/2 apart, grating lobes are possible when scanning. As the beam is scanned further from broadside, a point is reached at which a second symmetrical main lobe is developed at the negative scan angle from broadside. This condition is not wanted because antenna gain is immediately reduced by 3 dB due to the second lobe. Grating lobes are a significant problem in EW applications because the broad frequency bandwidth requirements mean that at the high end of the frequency band, the elements may be spaced greater than λ/2. Therefore in order to avoid grating lobes over a large frequency bandwidth, element spacing must be no greater than λ/2 at the highest frequency of operation.

There are many other factors to consider with a phased array such as coning, where the beam curves at large scan angles, and mutual coupling between elements that affect match and excitation. Excessive mutual coupling will invariably result in blind scan angles where radiation is greatly attenuated. These issues will not be covered in detail here.

Of interest is the gain of the array which is given by:

$$Array\ Gain = G_e(\theta) \bullet \sum_{n=1}^{N} A(n)\, e^{j\,\phi(n)}\, e^{j\,n\,k\,d\,\sin\theta}$$ Where each element is as described in Section 3-4.

$G_e(\theta)$ is the element gain which in this case has been taken the same for all elements. Note that if we set A(n)=1, and φ(n)=0, then at broadside where sin(θ) = 0, the gain would be (N G_e). This represents the maximum gain of the array, which typically will not exceed nπ, and is a familiar figure. It should be noted that in practical array design, the element pattern characteristics are greatly influenced by mutual coupling and that the characteristic of elements at the edge of the array can deviate significantly from those near the center.

ROTMAN BOOTLACE LENS

Another method of feeding an array of elements is to use a lens such as the Rotman (rhymes with rotten) Bootlace type shown in Figure 5. The lens consists of a parallel plate region (nowadays microstrip or stripline construction) and cables of specified length connecting the array of elements to the parallel plate region. The geometry of the lens and the cable lengths are designed so that all ray paths traced from a beam port on the right side to its associated wavefront on the left array port side, are equal. This tailoring of the design is accomplished at three focus points (beam ports 1, 4, and 7 in Figure 5). Departure from perfect focus at intermediate beam ports is negligible in most designs.

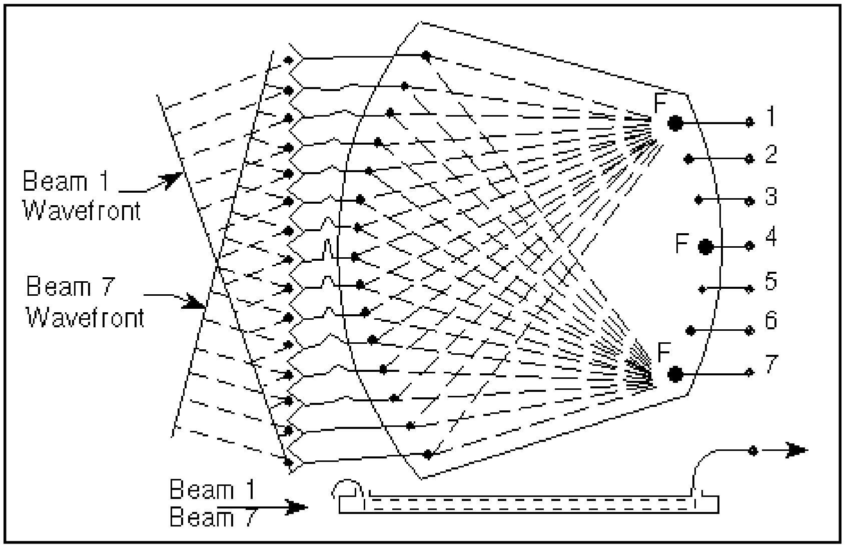

Figure 5. Rotman Bootlace Lens.

The Rotman lens provides both true time delay phase shift and amplitude taper in one lens component. The true time delay is one of the distinct advantages of the lens over the phase shifted array since that makes it independent of frequency. To understand how the taper is obtained requires knowledge of the parallel plate region. For a stripline design the unit would consist of a large flat plate-like center conductor sandwiched between two ground planes, and having a shape much like that of the plan view outline shown in Figure 5 with individual tapered launchers (connectors) attached to each beam port and array port. If the antenna is in the receive mode, the energy intercepted on the array port side can be controlled by the angle subtended by the tapered sections of the connector (launcher) much like a larger antenna would intercept a larger portion of energy from free space.

Unlike the phased array with its fine beam steering, the Rotman lens provides only a distinct set of beams. Fine steering is obtained by combining beams either equally or unequally to form intermediate beams. As can be seen in Figure 6, this results in a broader beam with less gain but lower side lobes than the primary beams.

High transmit power can be obtained using a Rotman lens by placing a low power amplifier between each lens output port and its antenna. In this case a separate Rotman lens would have to be used for receiving.

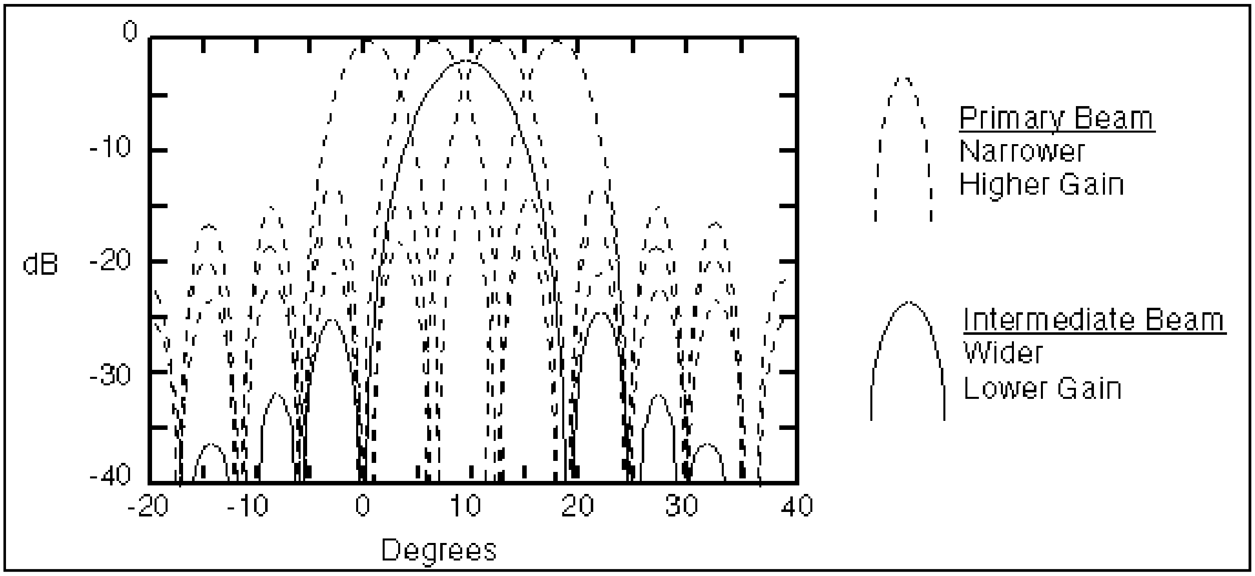

Figure 6. Primary and Intermediate Beam Formation in Lens Arrays.

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ANTENNA NEAR FIELD

As noted in the sections on RF propagation and the radar equation, electromagnetic radiation expands spherically (Figure 1) and the power density at a long range (R) from the transmitting antenna is:

$$P_D = \frac{P_t G_t}{4\pi R^2} \quad \textbf{[1]}$$

When the range is large, the spherical surface of uniform power density appears flat to a receiving antenna which is very small compared to the surface of the sphere. This is why the far field wave front is considered planar and the rays approximately parallel. Also, it is apparent that at some shorter range, the spherical surface no longer appears flat, even to a very small receiving antenna.

The planer, parallel ray approximation is valid for distances greater than the distance where the phase error is 1/16 of a wavelength or 22.5 degrees. This distance is given by

$R_{ff} = \frac{2D^2}{\lambda}$ where λ is the wavelength and D is the largest dimension of the transmit antenna. **[2]**

Antenna measurements made at distances greater than R_{ff} generally result in negligible pattern error. Distances less than R_{ff} is termed the near-field.

If the same size antenna is used for multiple frequencies, R_{ff} will increase with increasing frequency. However, if various size antennas are used for different frequencies and each antenna is designed with D as a function of λ (λ/2 to 100λ), then R_{ff} will vary from c/2*f* to 20000c/*f*. In this case R_{ff} will decrease with increasing frequency. For example: a 10λ antenna at 3 GHZ has a D of 100 cm and corresponding R_{ff} of 20 m, while a 10λ antenna at 30 GHz has a D of 10 cm and corresponding R_{ff} of 2 m.

While the above analogy provides an image of the difference between the near and far fields, the relationship must be defined as a characteristic of the transmitting antenna.

Actual antennas, of course, are not ideal point source radiators but have physical dimensions. If the transmitting antenna placed at the origin of Figure 1 occupies distance D along the Z-axis and is boresighted along the Y-axis (φ = 90), then the geometry of point P on the sphere is represented in two dimensions by Figure 2. For convenience, the antenna is represented by a series of point sources in an array.

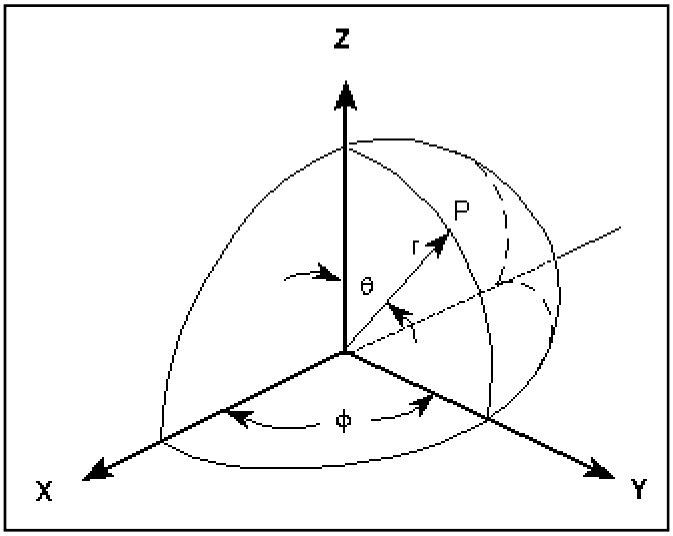

Figure 1. Spherical Radiation to Point "P" from an Ideal Point Source.

When point P is close to the antenna, as in Figure 2, then the difference in distance of the two rays r and R taken respectively from the center of the antenna and the outer edge of the antenna varies as point P changes.

Derivation of equation [2] is given as follows:

From Figure 2, the following applies:

$r^2 = z^2 + y^2$ **[3]**

$z = r \cos \theta$ **[4]**

$y = r \sin \theta$ and **[5]**

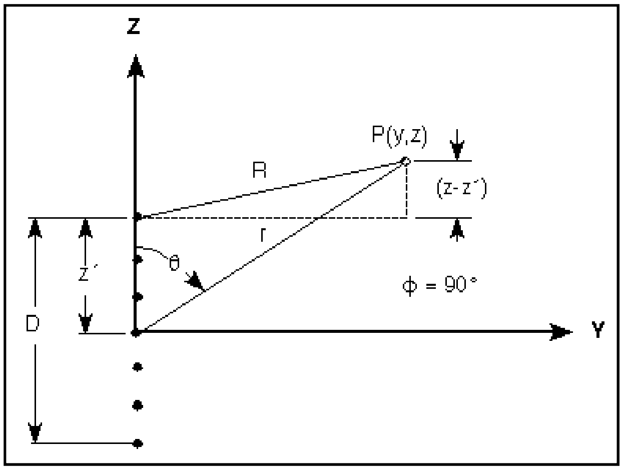

Figure 2. Near Field Geometry of Point "P" for a Non-Ideal Radiator With Dimension D.

$$R=\sqrt{y^2+(z-z')^2}=\sqrt{y^2+z^2-2z'z+(z')^2} \qquad \textbf{[6]}$$

Substituting [3] and [4] into [6] $R=\sqrt{r^2+[-2(r\cos\theta)z'+(z')^2]}$ **[7]**
which puts point P into spherical coordinates.

Equation [7] can be expanded by the binomial theorem which for the first three terms, reduces to:

$$R=r-z'\cos\theta+\frac{(z')^2\sin^2\theta}{2r}+....... \qquad \textbf{[8]}$$

In the parallel ray approximation for far field calculations (Figure 3) the third term of [8] is neglected.

The distance where the far field begins (R_{ff}) (or where the near field ends) is the value of r when the error in R due to neglecting the third term of equation [8], equals 1/16 of a wavelength.

R_{ff} is usually calculated on boresight, so θ = 90° and the second term of equation [8] equals zero (Cos 90° = 0), therefore from Figure 3, where D is the antenna dimension, R_{ff} is found by equating the third term of [8] to 1/16 wavelength.

$$\frac{(z')^2\sin^2\theta}{2\,R_{ff}}=\frac{\lambda}{16}$$

$\sin\theta=\sin 90=1 \text{ and } z'=D/2$ so: $$\frac{\left(\frac{D}{2}\right)^2}{2\,R_{ff}}=\frac{\lambda}{16}$$

$$R_{ff}=\frac{16(D/2)^2}{2\lambda}=\frac{2\,D^2}{\lambda} \qquad \textbf{[9]}$$

Equation [9] is the standard calculation of far field given in all references.

Besides [9] some general rules of thumb for far field conditions are:

$$r >> D \quad \text{or} \quad r >> \lambda$$

If the sphere and point P are a very great distance from the antenna, then the rays are very nearly parallel and this difference is small as in Figure 3.

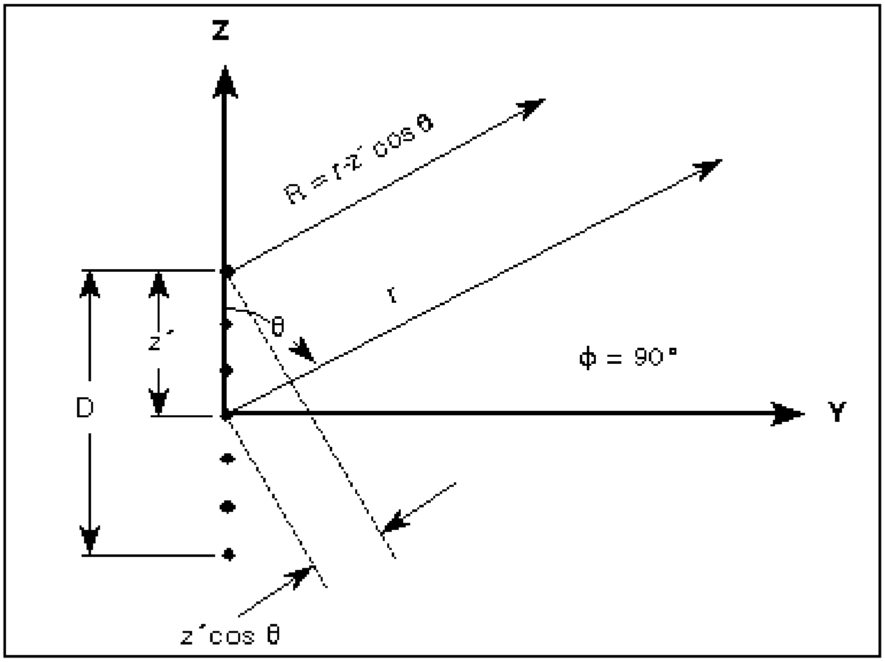

Figure 3. Far Field Parallel Ray Approximation for Calculations.

For reference purposes, a simplified alternative method to derive minimum far field distance approximation for an antenna or an antenna array with aperture size “d” is presented in Figure 4 without the need to resort to the spherical coordinate system and the Binomial Theorem. This approach illustrates a simple application of the Pythagorean Theorem. The P_{FF} symbol represents an arbitrary point in the far field at antenna boresight. Refer to relevant quantities shown in Figure 4.

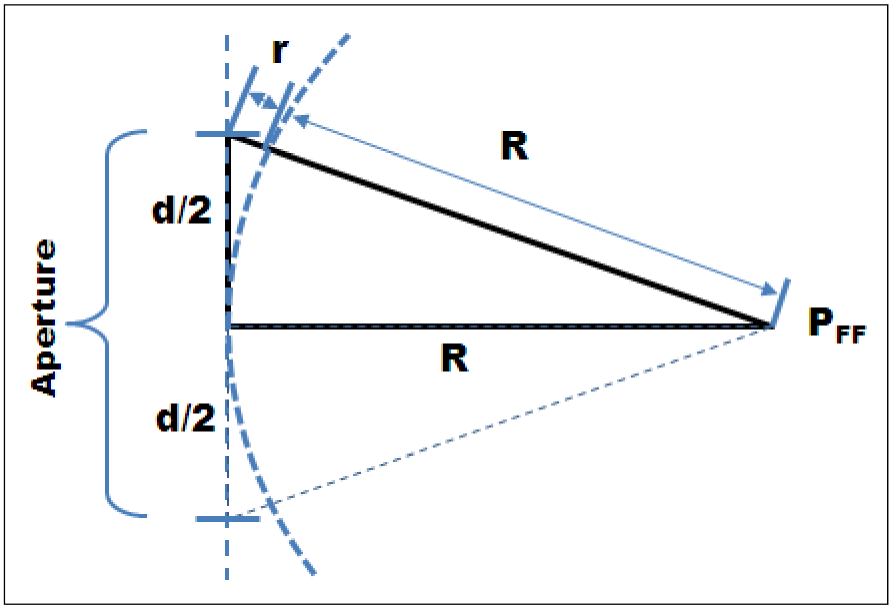

Figure 4. Alternative Geometry for Far Field Estimation.

From Figure 4, the distance "r" is the maximum propagation path difference across a given antenna aperture endpoint locations. Expressing this propagation path difference in terms of a wavelength provides means to derive an equation for generalized far field range relationship. Note a slight change of notation between Figures 3 and 4. A derivation of results already shown in Equations [2] & [9] is given as follows. From Figure 4, the following applies:

$$(R + r)^2 = (d/2)^2 + R^2 \qquad \textbf{[10]}$$

Collecting terms and cancelling,

$$2Rr + r^2 = d^2/4 \qquad \textbf{[11]}$$

Simplifying with a noted valid assumption,

$$2Rr \approx d^2/4, \ \text{since } r << R \qquad \textbf{[12]}$$

Solving for "r" (see Figure 4)

$$r \approx d^2/(8R) \qquad \textbf{[13]}$$

For far field condition assume $r \leq \lambda/16$. Substituting "r" in terms of lambda,

$$\lambda/16 \geq r \approx d^2/(8R) \ \rightarrow \ P_{FF} \geq 2d^2/\lambda \qquad \textbf{[14]}$$

As shown, Equation [14] represents the same result as Equation [9] derived earlier.

The power density within the near field varies as a function of the type of aperture illumination and is less than would be calculated by equation [1]. Thus, in the antenna near field there is stored energy. (The complex radiation field equations have imaginary terms indicating reactive power.) Figure 5 shows normalized power density for three different illuminations.

Curve A is for reference only and shows how power density would vary if it were calculated using equation [1].

Curve B shows power density variations on axis for an antenna aperture with a cosine amplitude distribution. This is typical of a horn antenna in the H-plane.

Curve C shows power density variations on axis for a uniformly illuminated antenna aperture or for a line source. This is typical of a horn antenna in the E-plane.

Curve D shows power density variations on axis for an antenna aperture with a tapered illumination. Generally the edge illumination is approximately -10 dB from the center illumination and is typical of a parabolic dish antenna.

Point E For radiation safety purposes, a general rule of thumb for tapered illumination is that the maximum safe level of 10 mW/cm^2 (~200 V/m) is reached in the near field if the level at R_{ff} reaches 0.242 mW/cm^2 as can be verified by computing the power density at point E in Figure 5. (10 mW/cm^2 at point E extrapolates to 0.242 mW/cm^2 [16 dB lower] at R=R_{ff}, or Y axis value =1). Figure 1 in Section 3-6 depicts more precise values for radiation hazard exposure.

Point F Far Field Point. At distances closer to the source than this point (near field), the power density from any given antenna is less than that predicted using Curve A. At farther distances, (far field) power densities from all types of antennas are the same.

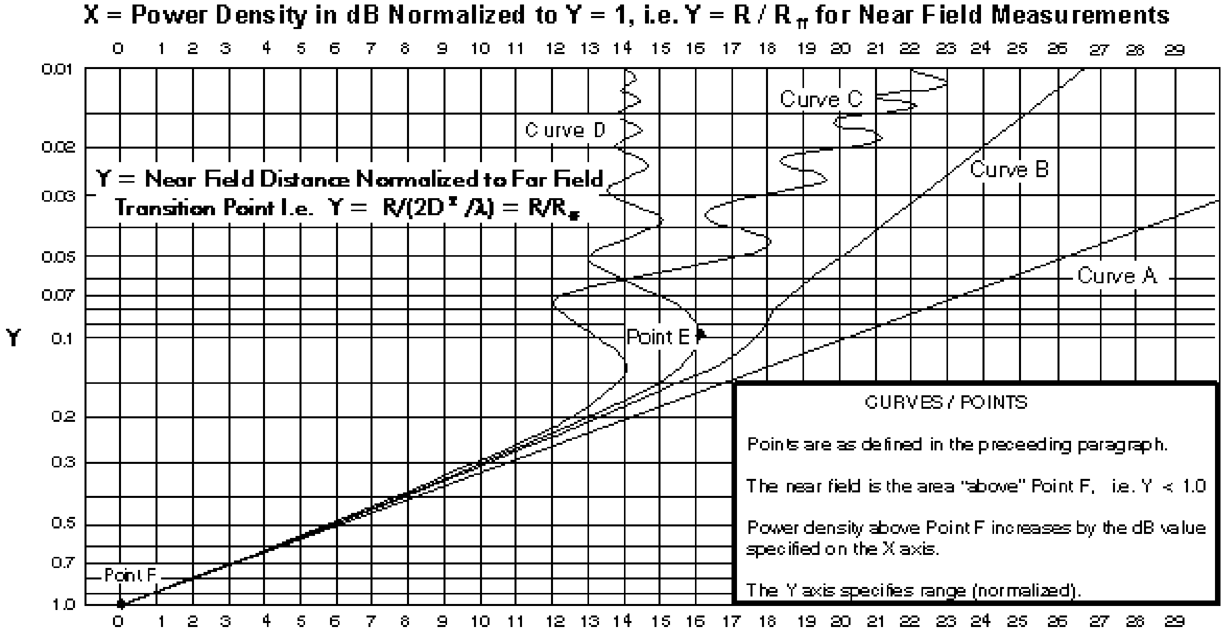

Points are as defined in the preceeding paragraph.

The near field is the area "above" Point F, i.e. Y < 1.0

Power density above Point F increases by the dB value specified on the X axis.

The Y axis specifies range (normalized).

Figure 5. Antenna Near-Field On-Axis Power Density (Normalized) for Various Aperture Illuminations.

FOR FAR FIELD MEASUREMENTS:

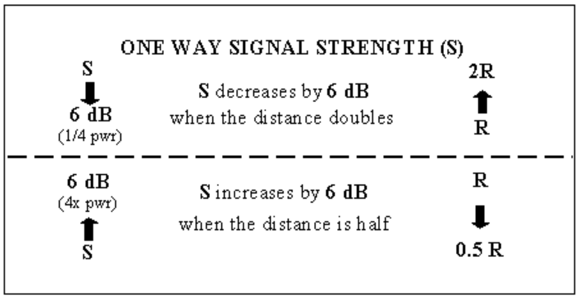
ONE WAY SIGNAL STRENGTH (S)
S
6 dB
(1/4 pwr)
S decreases by 6 dB
when the distance doubles
2R
R
6 dB
(4x pwr)
S
S increases by 6 dB
when the distance is half
R
0.5 R

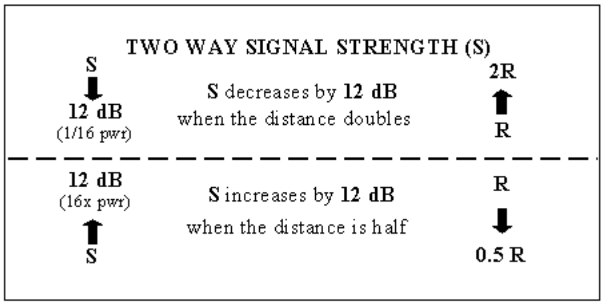
TWO WAY SIGNAL STRENGTH (S)
S
12 dB
(1/16 pwr)
S decreases by 12 dB
when the distance doubles
2R
R
12 dB
(16x pwr)
S
S increases by 12 dB
when the distance is half
R
0.5 R

When free space measurements are performed at a known distance from a source, it is often necessary to know if the measurements are being performed in the far field. As can be seen from Curve A on Figure 5, if the distance is halved (going from 1.0 to 0.5 on the Y axis), the power density will increase by 6 dB (going from 0 to 6 dB on the X axis). Each reduction in range by ½ results in further 6 dB increases. As previously mentioned, Curve A is drawn for reference only in the near field region, since at distances less than R_{ff} the power density increases less than 6 dB when the range is halved. In the far field, all curves converge and Equation [1] applies.

When a measurement is made in free space, a good check to ensure that is was performed in the far field is to repeat the measurement at twice the distance. The power should decrease by exactly 6 dB. A common error is to use 3 dB (the half power point) for comparison. Conversely, the power measurement can be repeated at half the distance, in which case you would look for a 6 dB increase, however the assumed extrapolation conclusion is not as certain, because the first measurement could have been made in the far field, and the second could have been made in the near field.

Care must be exercised in using the $\mathbf{2d^2/\lambda}$ far field measurement criterion. For antennas with moderate sidelobe levels (>-25 dB) pattern errors are negligible and the error in directivity is less than 0.1 dB and this measurement distance suffices in most cases. However low sidelobe antennas require longer measurement distances. For example, maintaining a 1 dB or less sidelobe error for a linear array with a -40 dB sidelobe level requires a measurement distance of $6d^2/\lambda$. (1). This corresponds to criterion for "r" in Equation [14] to be changed from $r \leq \lambda/16$ to $r \leq \lambda/48$ or 7.5 deg.

[1] R. C. Hansen. "Measurement Distance Effects on Low Sidelobe Patterns," *IEEE Transactions on Antennas and Propagation*, Vol. AP-32, No. 6, June 1984.

RADIATION HAZARDS

Radiation Hazard (RADHAZ) describes the hazards of electromagnetic radiation to fuels, electronic hardware, ordnance, and personnel. In the military these hazards are segregated as follows:

1) Hazards of Electromagnetic Radiation to Personnel (HERP)
2) Hazards of Electromagnetic Radiation to Ordnance (HERO)
3) Hazards of Electromagnetic Radiation to Fuel (HERF)

The current industrial specifications for RADHAZ are contained in ANSI/IEEE C95.1-1992 which was used as a reference to create the combined Navy regulation NAVSEA OP3565 / NAVAIR 16-1-529. Volume I contains HERP and HERF limits - its current version is REV 5. Volume II (REV 6) covers HERO. These limits are shown in Figure 1 although all values have been converted to average power density.

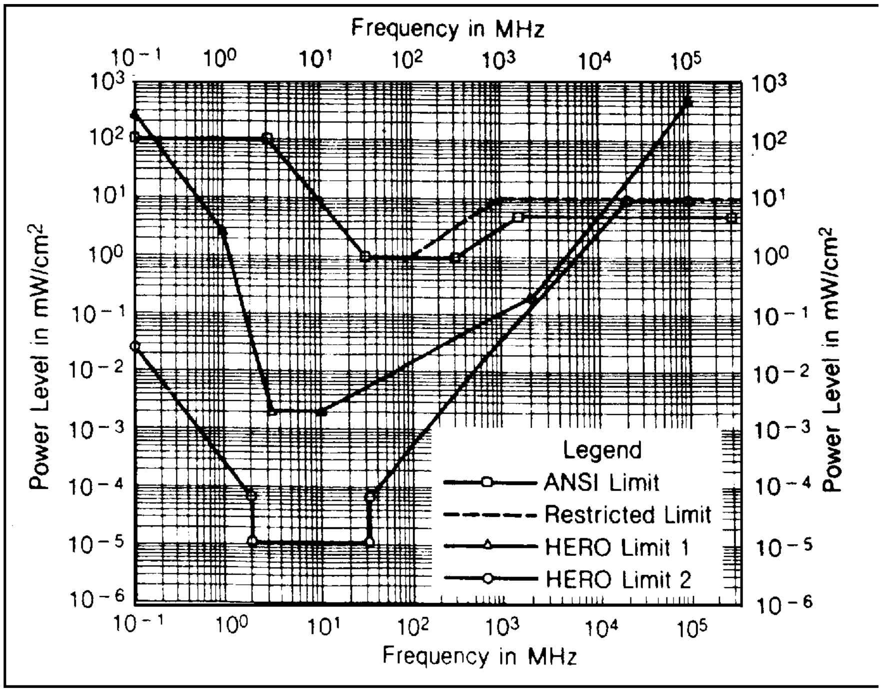

Figure 1. Radiation Hazards to Personnel and Ordnance.

OP 3565 specifies HERO RADHAZ levels at frequencies below 1 GHz in peak value of electric field strength (V/m), while levels above 200 MHz are specified in average power density (mW/cm^2) - note the overlapping frequencies. Since Figure 1 depicts power density as the limits, you must convert the average values to peak field strength for use at lower frequencies. Also many applications of EMC work such as MIL-STD-461 use limits based on the electric (E) field strength in volts/meter. Remember that $P=E^2/R$, and from Section 4-2, we note that $R=377\Omega$ for free space. It can also be shown that the magnetic field strength (H field in Amps/meter) = I/m where I=E/R. Don't forget that RMS = 0.707 Peak. With the units of P_D in mW/cm^2, E in V/m, and H in A/m, then P_D (mW/cm^2) = E^2 / 3770 = 37.7 H^2. It should thus be noted that a 100 times increase in power (mW/cm^2) is only a 10 times increase in V/m.

The potential dangers to ordnance and fuels are obvious because there could be an explosive "chain reaction" by exploding; consequently, these limits are generally lower than personnel limits. There are three **HERO** categories. The HERO limit 2 is for HERO "unsafe" or "unreliable" explosive devices with exposed wires arranged in optimum (most susceptible) receiving orientation. This usually occurs during the assembly/disassembly of ordnance, but also applies to new/untested ordnance until proven "safe" or "susceptible." The HERO limit 1 is for HERO susceptible ordnance fully assembled undergoing normal handling and loading operations. HERO safe ordnance requires no RF radiation precautions. A list of which specific ordnance (by NALC) falls into each category can be found in OP 3565 along with specific frequency restrictions for each piece of ordnance. For example, all missiles of one variety are susceptible

(HERO 1 limits), while another missile has both susceptible and safe variants (with no RADHAZ limits). Other ordnance may be HERO unsafe (HERO 2 limits).

The danger of **HERP** occurs because the body absorbs radiation and significant internal heating may occur without the individual’s knowledge because the body does not have internal sensation of heat, and tissue damage may occur before the excess heat can be dissipated. As shown in Figure 1, the current “restricted” limit is for individuals more than 55” tall because they have more body mass. In other words, all people may be exposed to the lower limit, but only persons taller than 55” may be exposed to the higher limit of 10 mW/cm^2.

NAVSEA OP 3565 will be updated in the future to be compatible with DoD INST 6055.11 dated Feb 21, 1995 which supersedes it. The personnel radiation levels in Figures 2 and 3 were taken from the new release of DoD INST 6055.11.

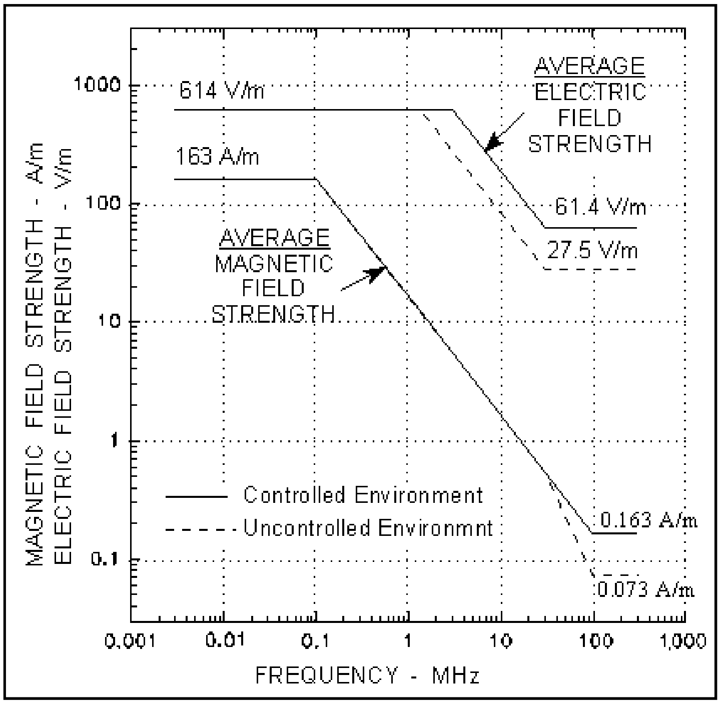

Figure 2. Lower Frequency HERP from DoD INST 6055.11.

Unlike the existing “restricted limit” of NAVSEA OP 3565 discussed above, in the revised DoD instruction for personnel radiation hazards, a different approach to exposure was taken.

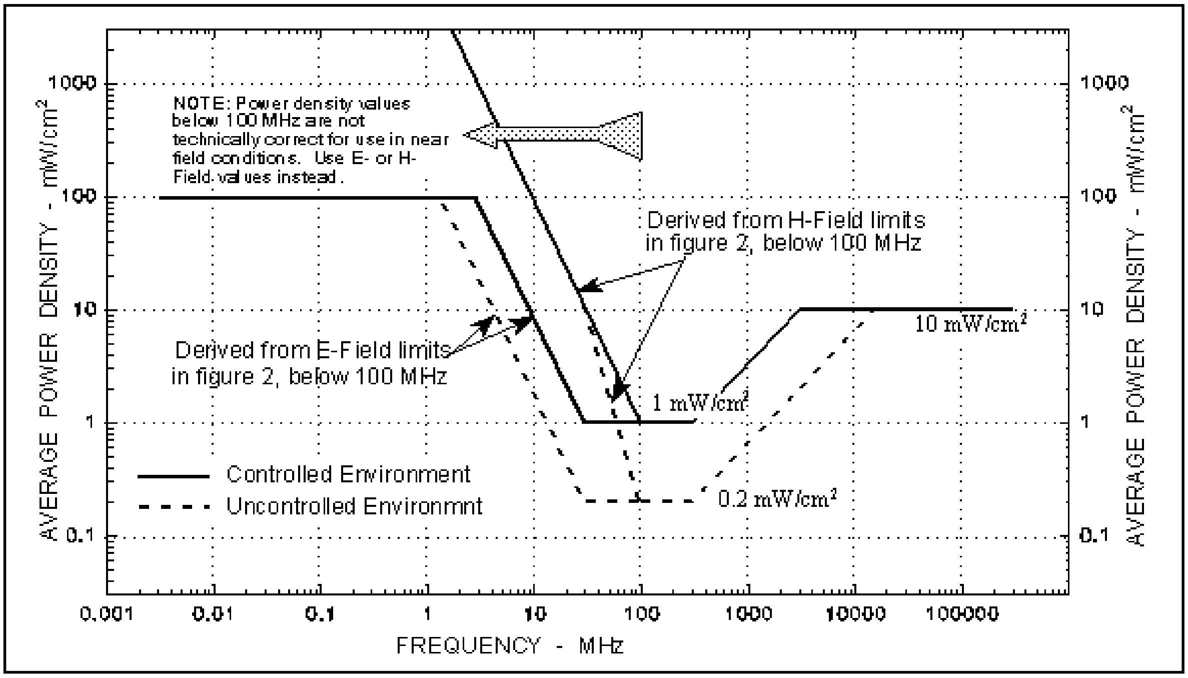

Figure 3. Radiation Hazards to Personnel from DoD INST 6055.11.

Two maximum hazard limits are defined;

1) Controlled Environments - where personnel are aware of the potential danger of RF exposure concurrently with employment, or exposure which may occur due to incidental transient passage through an area, and;
2) Uncontrolled Environments - A lower maximum level where there is no expectation that higher levels should be encountered, such as living quarters.

These Personnel Exposure Limits (PELs) are based on a safety factor of ten times the Specific Absorption Rate (SAR) which might cause bodily harm. The term PEL is equivalent to the terms "Maximum Permissible Exposure (MPE)" and "Radio Frequency Protection Guides (RFPG)" in other publications.

There are several exceptions to the max limits in Figs 2 and 3 (in some cases higher levels are permitted):

- High Power Microwave (HPM) system exposure in a controlled environment, which has a single pulse or multiple pulses lasting less than 10 seconds, has a higher peak E-Field limit of 200 kV/m.
- EMP Simulation Systems in a controlled environment for personnel who are exposed to broad-band (0.1 MHz to 300 GHz) RF are limited to a higher peak E-Field of 100 kV/m.
- The given limits are also increased for pulsed RF fields. In this case the peak power density per pulse for pulse durations < 100 msec and no more than 5 pulses in the period is increased to: PELPulse = PEL x TAVG / 5 x Pulse Width, and the peak E-field is increased to 100 kV/m. If there are more than 5 pulses or they are greater than 100 msec, a time averaged PD should not exceed that shown in Figure 3.
- A rotating or scanning beam likewise reduces the hazard, so although an on-axis hazard might exist, there may be none with a moving beam. The power density may be approximated with:
  PDscan = PDfixed (2 x Beam Width / scan angle)
- Many other special limitations also apply, such as higher limits for partial body exposure, so if in doubt, read the DoD Inst 6055.11 in detail. Field measurements may be measured in accordance with IEEE C95.3-1991.

The PELs listed in Figures 2 and 3 were selected for an average RF exposure time at various frequencies. In a controlled environment, this averaging time was selected as 6 minutes for 0.003 to 15,000 MHz. If the exposure time is less than 6 minutes, then the level may be increased accordingly. Similar time weighted averages apply to uncontrolled environments, but it varies enough with frequency such that DoD INST 6055.11 should be consulted.

NAVSEA OP 3565 contains a list of Navy avionics which transmit RF as well as radars along with their respective hazard patterns. Special training is required for individuals who work in areas which emit RF levels which exceed the uncontrolled levels. Warning signs are also required in areas which exceed either the controlled or uncontrolled limits.

Although E-Field, H-Field, and power density can be mathematically converted in a far-field plane wave environment, the relations provided earlier do not apply in the near field, consequently the E- or H-field strength must be measured independently below 100 MHz. It should be noted that the specifications in NAVSEA OP 3565 for lower frequency HERO limits are listed as peak E-field values, whereas lower RF limits in DoD INST 6055.11 on HERP are in average (RMS) E-field values. Upper frequency restrictions are based on average (RMS) values of power density in both regulations except for certain circumstances.

HERF precautions are of more general concern to fuel truck operators. However, some general guidelines include:

- Do not energize a transmitter (radar/comm) on an aircraft or motor vehicle being fueled or on an adjacent aircraft or vehicle.
- Do not make or break any electrical, ground wire, or tie down connector while fueling.
- Radars able to illuminate fueling areas with a peak power density of 5 W/cm2 should be shut off.
- For shore stations, antennas radiating 250 watts or less should be installed at least 50 ft from fueling areas (at sea 500 watts is the relaxed requirement).
- For antennas which radiate more than 250 watts, the power density at 50 ft from the fueling operation should not be greater than the equivalent power density of a 250 watt transmitter at 50 ft.

ACTIVE ELECTRONICALLY SCANNED ARRAYS (AESA)

Scanning phased arrays employing electronically controlled phase shifters (e.g., PiN diode, ferrite) have been used in high power radar applications since the early 1960s. These are planar arrays and generally use a corporate type feed structure to array rows of elements in one dimension of the array and use an analogous feed to array the rows in the orthogonal dimension of the array, resulting in a single feed point. A high power RF transmitter, usually employing some sort of liquid cooling, is used to excite the array. This architecture is cumbersome and difficult to package and the high power transmitter is a single point of failure for the system.

The maturation of solid state transmit/receive modules (T/R) using Gallium Arsenide (GaAs) technology or more recently Gallium Nitride (GaN) technology has made AESAs a practical reality. The T/R modules consist of a low noise amplifier (LNA) for the receive function and a solid state high power amplifier (SSPA) for realization of the transmit function. The T/R module may also contain the necessary phase control elements for beam scanning. A generic 8-element AESA for one dimension is shown in Figure 1.

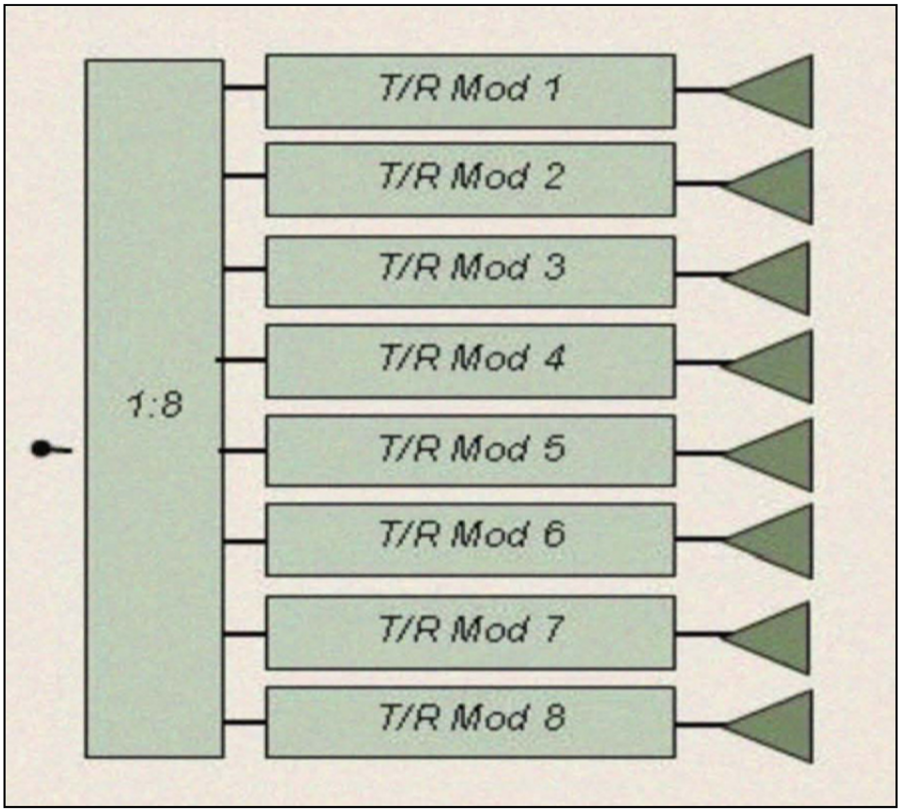

Figure 1. Eight Element AESA.

Electronically scanned phased array designs with decade bandwidths have been reported in the open literature for many years. However those reported are only lab versions and none have been implemented in a fielded system. In addition, the high average power requirement, particularly for EW systems, calls for the use of GaN SSPA technology and this, in conjunction with the dense array packaging requirement, poses severe heat dissipation/cooling issues.

AESAs for EW applications impose design considerations vastly different from an AESA for radar. In contradistinction with high **peak** power radar applications (e.g., AN/APG79), the high **average** power large duty factors (sometimes CW) requirements for EW impose severe design requirements and constraints for the wide bandwidth AESA. Incorporation of an AESA in airborne environment, with its concomitant restrictive volume, further exacerbates design constraints.

The heat dissipation problem is of major concern in modern high power AESAs. Due to the behavior of microwave transistor amplifiers, the power added efficiency (PAE) of a TR module transmitter is typically a relatively small fraction of the total prime power consumption. As a result, an AESA will dissipate a lot of heat, which must be extracted. The reliability of GaAs and GaN MMIC chips improves if the RF amplifier system operates at reduced temperatures. Traditional air cooling used in most established avionic hardware is ill suited to the high packaging density of an AESA. As a result modern AESAs are predominantly liquid cooled. A typical liquid cooling system will use pumps to drive the coolant through channels in the cooling plenum of the array, and then route it to a heat exchanger. In comparison, with a conventional air cooled fighter radar, the AESA will be more reliable but will require more electrical power and more cooling infrastructure, and typically can produce much higher average transmit power.

ADVANTAGES OF AESA RADIATORS

AESAs add many capabilities of their own to those of the Passive Electronically Steered Array (PESAs). Among these are: the ability to form multiple beams, to scan without mechanical steering, to use each transmit/receive module for different roles concurrently, like radar detection, and, more importantly, their multiple wave and scanning frequencies create multiple difficulties for traditional, correlation-type radar detectors.

LOW PROBABILITY OF INTERCEPT

Radar systems work by sending out a signal and then listening for its echo off distant objects. Each of these paths, to and from the target, is subject to the inverse square law of propagation. That means that a radar's received energy drops with the fourth power of distance, which is why radar systems require high powers, often in the megawatt range, to be effective at long range.

The radar signal being sent out is a simple radio signal, and can be received with a simple radio receiver. It is common to use such a receiver in the targets, normally aircraft, to detect radar broadcasts. Unlike the radar unit, which must send the pulse out and then receive its reflection, the target's receiver does not need the reflection and thus the signal drops off only as the square of distance. This means that the receiver is always at an advantage over the radar in terms of range. It will always be able to detect the signal long before the radar can see the target's echo. Since the position of the radar is extremely useful information in an attack on that platform, this means that radars generally must be turned off for lengthy periods if they are subject to attack; this is common on ships, for instance.

Turning that received signal into a useful display is the purpose of the RWR. Unlike the radar, which knows which direction it is sending its signal, the receiver simply gets a pulse of energy and has to interpret it. Since the radio spectrum is filled with noise, the receiver's signal is integrated over a short period of time, making periodic sources like a radar add up and stand out over the random background. Typically RWRs store the detected pulses for a short period of time, and compare their broadcast frequency and pulse repetition frequency against a database of known radars. The rough direction can be calculated using a rotating antenna, or similar passive array, and combined with symbology indicating the likely purpose of the radar - airborne early warning, surface to air missile, etc.

This technique is much less useful against AESA radars. Since the AESA can change its frequency with every pulse, and generally does so using a pseudo-random sequence, integrating over time does not help pull the signal out of the background noise. Nor does the AESA have any sort of fixed pulse repetition frequency, which can also be varied and thus hide any periodic brightening across the entire spectrum. Traditional RWRs suffered significantly decreased effectiveness against AESA radars.

HIGH JAMMING RESISTANCE

Jamming is likewise much more difficult against an AESA. Traditionally, jammers have operated by determining the operating frequency of the radar and then broadcasting a signal on it to confuse the receiver as to which is the “real” pulse and which is the jammer’s. This technique works as long as the radar system cannot easily change its operating frequency. When the transmitters were based on klystron tubes this was generally true, and radars, especially airborne ones, had only a few frequencies to choose among. A jammer could listen to those possible frequencies and select the one to be used to jam.

Since an AESA could change its operating frequency with every pulse, and spread the frequencies across a wide band even in a single pulse, jammers are much less effective. Although it is possible to send out broadband white noise against all the possible frequencies, this means the amount of energy being sent at any one frequency is much lower, reducing its effectiveness. In fact, AESAs can then be switched to a receive-only mode, and use these powerful jamming signals instead to track its source, something that required a separate receiver in older platforms.

AESA radars can be much more difficult to detect, and so much more useful in receiving signals from the targets, that they can broadcast continually and still have a very low chance of being detected. This allows such radar systems to generate far more data than traditional radar systems, which can only receive data periodically, greatly improving overall system effectiveness.

OTHER ADVANTAGES

Since each element in an AESA is a powerful radio receiver, active arrays have many roles besides traditional radar. One use is to dedicate several of the elements to reception of common radar signals, eliminating the need for a separate radar warning receiver. The same basic concept can be used to provide traditional radio support, and with some elements also broadcasting, form a very high bandwidth data link.

AESAs are also much more reliable than either a PESA or older designs. Since each module operates independently of the others, single failures have little effect on the operation of the system as a whole. Additionally, the modules individually operate at lower powers and voltages so the need for a large high-voltage power supply is eliminated.

Replacing a mechanically scanned array with a fixed AESA mount can help reduce an aircraft’s overall RCS, but some designs (such as the Eurofighter Typhoon) forgo this advantage in order to combine mechanical scanning with electronic scanning and provide a wider angle of total coverage.

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FRACTAL ANTENNAS

The term fractal, which means broken or irregular fragments, was originally coined by B.B. Mandelbrot **[1]** to describe a family of complex shapes that possess self-similarity in their geometrical structure. In-depth studies of the patterns of nature provided inspiration for the development of fractal geometry where it has been used to model numerous natural objects. Recent advances in the antenna art have led to the application of fractal geometry instead of convention Euclidean geometric concepts to the design of wide bandwidth, low profile, compact antennas.

A fractal antenna is an antenna that uses a fractal, self-similar design to maximize the length, or increase the perimeter (on inside sections or the outer structure), of material that can receive or transmit electromagnetic radiation within a given total surface area or volume. The earliest published reference to use of the term fractal radiators and fractal antennas to refer to fractal shaped antenna elements appeared May 1994 **[2]**.

Such fractal antennas are also referred to as multilevel and space filling curves, but the key aspect lies in their repetition of a motif over two or more scale sizes, or "iterations." For this reason, fractal antennas are very compact, multiband or wideband, and have useful applications in many commercial and military systems.

A good example of a fractal antenna as a space-filling curve is in the form of a Minkowski Island (Figure 1). Here, each line of copper is just a small fraction of a wavelength **[3]**.

A fractal antenna's response differs markedly from traditional antenna designs, in that it is capable of operating with good-to-excellent performance at many different frequencies simultaneously. Normally standard antennas have to be "cut" for the frequency for which they are to be used — and thus the standard antennas only work well at that frequency. This makes the fractal antenna an excellent design for wideband and multiband applications.

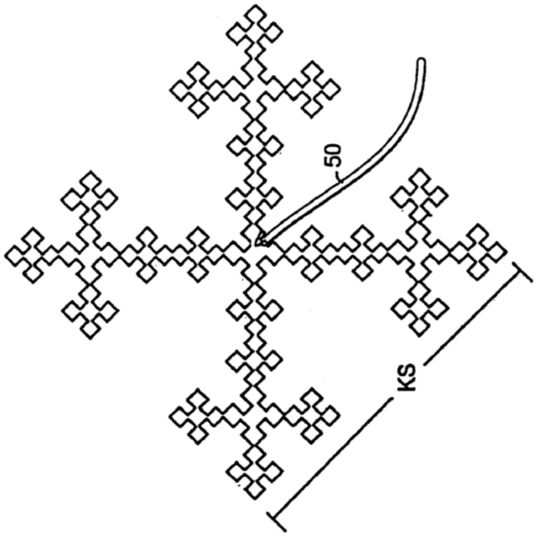

Figure 1. An Example of a Fractal Antenna: a Space-Filling Curve Called a Minkowski Island.

Antenna elements (as opposed to antenna arrays) made from self-similar shapes were first created by Nathan Cohen, then a professor at Boston University, starting in 1995 **[4]**. Cohen's efforts with a variety of fractal antenna designs were first published in 1995 (thus the first scientific publication on fractal antennas), and a number of patents have been issued from the 1995 filing priority of invention. Most allusions to fractal antennas make reference to these "fractal element antennas."

Many fractal element antennas use the fractal structure as a virtual combination of capacitors and inductors. This makes the antenna have so that it has many different resonances that can be selected and adjusted by choosing the proper fractal design. Electrical resonances may not be directly related to a particular scale size of the fractal antenna structure. The physical size of the antenna is unrelated to its resonant or broadband performance. The general rule of antenna length being near target frequency wavelength does not apply itself in the same way with fractal antennas.

This complexity arises because the current on the structure has a complex arrangement caused by the inductance and self capacitance. In general, although their effective electrical length is longer, the fractal element antennas are physically smaller.

Fractal element antennas are shrunken compared to conventional designs and do not need additional components. In general, the fractal dimension of a fractal antenna is a poor predictor of its performance and application. Not all fractal antennas work well for a given application or set of applications. Computer search methods, optimization algorithms, and antenna simulations are commonly used to identify which fractal antenna designs best meet the need of the application.

Although the first validation of the technology was published as early as 1995 **[4]** recent independent studies show advantages of the fractal element technology in real-life applications, such as radio frequency identification and cell phones.

A different and also useful attribute of some fractal element antennas is their self-scaling aspect. In 1999, it was discovered that self-similarity was one of the underlying requirements to make antennas "invariant" (same radiation properties) at a number or range of frequencies. Previously, under Rumsey's Frequency Independent Antenna Principle, it was believed that antennas had to be defined by angles for this to be true; the 1999 analysis **[5]**, based on Maxwell's equations, showed this to be a subset of the more general set of self-similar conditions. Hence fractal antennas offer a closed-form and unique insight into a key aspect of electromagnetic phenomena to wit the invariance property of Maxwell's equations.

Antenna tuning units are typically not required on fractal antennas due to their wide bandwidth and complex resonance. However, if a transmitting antenna has deep nulls in its response or has electromagnetic structural issues that require equalization then an antenna tuning unit should be used.

In addition to their use as antennas, fractals have also found application in other antenna system components including loads, counterpoises, and ground planes. Confusion by those who claim "grain of rice"-sized fractal antennas arises, because such fractal structures serve the purpose of loads and counterpoises, rather than bona fide antennas.

Fractal inductors and fractal tuned circuits (fractal resonators) were also discovered and invented simultaneously with fractal element antennas. An emerging example of such is in metamaterials. A recent report demonstrates using close-packed fractal resonators to make the first wideband metamaterial "invisibility cloak" at microwave frequencies **[6]**. Fractal filters (a type of tuned circuit) are another example of fractal geometry in microwave componentry.

As fractals can be used as counterpoises, loads, ground planes, and filters, all parts that can be integrated with antennas, they are considered parts of some antenna systems and thus are discussed in the context of fractal antennas.

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RADAR EQUATIONS

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FIELD INTENSITY and POWER DENSITY

Sometimes it is necessary to know the actual field intensity or power density at a given distance from a transmitter instead of the signal strength received by an antenna. Field intensity or power density calculations are necessary when estimating electromagnetic interference (EMI) effects, when determining potential radiation hazards (personnel safety), or in determining or verifying specifications.

Field intensity (field strength) is a general term that usually means the magnitude of the electric field vector, commonly expressed in volts per meter. At frequencies above 100 MHZ, and particularly above one GHz, power density (P_D) terminology is more often used than field strength.
Power density and field intensity are related by equation [1]:

$$P_D = \frac{E^2}{Z_0} = \frac{E^2}{120\pi} = \frac{E^2}{377} \qquad \textbf{[1]}$$

where P_D is in W/m^2, E is the RMS value of the field in volts/meter and 377 ohms is the characteristic impedance of free space. When the units of P_D are in mW/cm^2, then P_D (mW/cm^2) = E^2/3,770.

Conversions between field strength and power density when the impedance is 377 ohms, can be obtained from Table 1. It should be noted that to convert dBm/m^2 to dBµV/m add 115.76 dB. Sample calculations for both field intensity and power density in the far field of a transmitting antenna are in Section 4-2 and Section 4-8. Refer to chapter 3 on antennas for the definitions of near field and far field.

Note that the "/" term before m, m^2, and cm^2 in Table 1 mean "per," i.e., dBm per m^2, not to be confused with the division sign which is valid for the Table 1 equation $P=E^2/Z_o$. Remember that in order to obtain dBm from dBm/m^2 given a certain area, you must add the logarithm of the area, not multiply. The values in the table are rounded to the nearest dBW, dBm, etc. per m^2 so the results are less precise than a typical handheld calculator and may be up to ½ dB off.

VOLTAGE MEASUREMENTS

Coaxial cabling typically has input impedances of 50, 75, and 93Ω, (±2) with 50Ω being the most common. Other types of cabling include the following: TV cable is 75Ω (coaxial) or 300Ω (twin-lead), audio public address (PA) is 600Ω, audio speakers are 3.2 (4), 8, or 16Ω.

In the 50Ω case, power and voltage are related by:

$$P = \frac{E^2}{Z_0} = \frac{E^2}{50} = 50\, I^2 \qquad \textbf{[2]}$$

Conversions between measured power, voltage, and current where the typical impedance is 50 ohms can be obtained from Table 2. The dBµA current values are given because frequently a current probe is used during laboratory tests to determine the powerline input current to the system.

MATCHING CABLING IMPEDANCE

In performing measurements, we must take into account an impedance mismatch between measurement devices (typically 50 ohms) and free space (377 ohms).

Table 1. Conversion Table - Field Intensity and Power Density.
$P_D = E^2/Z_0$ (Related by free space impedance = 377 ohms)

E (Volts/m)	20 log 10^6 (E) (dBµV/m)	P_D (watts/m^2)	10 Log P_D (dBW/m^2)	Watts/cm^2	dBW/cm^2	mW/cm^2	dBm/cm^2	dBm/m^2
7,000	197	130,000	+51	13	+11	13,000	+41	+81
5,000	194	66,300	+48	6.6	+8	6,630	+38	+78
3,000	190	23,900	+44	2.4	+4	2,390	+34	+74
4,000	186	10,600	+40	1.1	0	1,060	+30	+70
1,000	180	2,650	+34	.27	-6	265	+24	+64
700	177	1,300	+31	.13	-9	130	+21	+61
500	174	663	+28	.066	-12	66	+18	+58
300	170	239	+24	.024	-16	24	+14	+54
200	166	106	+20	.011	-20	11	+10	+50
100	160	27	+14	.0027	-26	2.7	+4	+44
70	157	13	+11	1.3x10^{-3}	-29	1.3	+1	+41
50	154	6.6	+8	6.6x10^{-4}	-32	.66	-2	+38
30	150	2.4	+4	2.4x10^{-4}	-36	.24	-6	+34
20	146	1.1	+0	1.1x10^{-4}	-40	.11	-10	+30
10	140	.27	-6	2.7x10^{-5}	-46	.027	-16	+24
7	137	.13	-9	1.3x10^{-5}	-49	.013	-19	+21
5	134	.066	-12	6.6x10^{-6}	-52	66x10^{-4}	-22	+18
3	130	.024	-16	2.4x10^{-6}	-56	24x10^{-4}	-26	+14
2	126	.011	-20	1.1x10^{-6}	-60	11x10^{-4}	-30	+10
1	120	.0027	-26	2.7x10^{-7}	-66	2.7x10^{-4}	-36	+4
0.7	117	1.3x10^{-3}	-29	1.3x10^{-7}	-69	1.3x10^{-4}	-39	+1
0.5	114	6.6x10^{-4}	-32	6.6x10^{-8}	-72	66x10^{-4}	-42	-2
0.3	110	2.4x10^{-4}	-36	2.4x10^{-8}	-76	24x10^{-4}	-46	-6
0.2	106	1.1x10^{-4}	-40	1.1x10^{-8}	-80	11x10^{-4}	-50	-10
0.1	100	2.7x10^{-5}	-46	2.7x10^{-9}	-86	2.7x10^{-6}	-56	-16
70x10^{-3}	97	1.3x10^{-5}	-49	1.3x10^{-9}	-89	1.3x10^{-6}	-59	-19
50x10^{-3}	94	6.6x10^{-6}	-52	6.6x10^{-10}	-92	66x10^{-8}	-62	-22
30x10^{-3}	90	2.4x10^{-6}	-56	2.4x10^{-10}	-96	24x10^{-8}	-66	-26
20x10^{-3}	86	1.1x10^{-6}	-60	1.1x10^{-10}	-100	11x10^{-8}	-70	-30
10x10^{-3}	80	2.7x10^{-7}	-66	2.7x10^{-11}	-106	2.7x10^{-8}	-76	-36
7x10^{-3}	77	1.3x10^{-7}	-69	1.3x10^{-11}	-109	1.3x10^{-8}	-79	-39
5x10^{-3}	74	6.6x10^{-8}	-72	6.6x10^{-12}	-112	66x10^{-10}	-82	-42
3x10^{-3}	70	2.4x10^{-8}	-76	2.4x10^{-12}	-116	24x10^{-10}	-86	-46
2x10^{-3}	66	1.1x10^{-8}	-80	1.1x10^{-12}	-120	11x10^{-10}	-90	-50
1x10^{-3}	60	2.7x10^{-9}	-86	2.7x10^{-13}	-126	2.7x10^{-10}	-96	-56
7x10^{-4}	57	1.3x10^{-9}	-89	1.3x10^{-13}	-129	1.3x10^{-10}	-99	-59
5x10^{-4}	54	6.6x10^{-10}	-92	6.6x10^{-14}	-132	66x10^{-12}	-102	-62
3x10^{-4}	50	2.4x10^{-10}	-96	2.4x10^{-14}	-136	24x10^{-12}	-106	-66
2x10^{-4}	46	1.1x10^{-10}	-100	1.1x10^{-14}	-140	11x10^{-12}	-110	-70
1x10^{-4}	40	2.7x10^{-11}	-106	2.7x10^{-15}	-146	2.7x10^{-12}	-116	-76
7x10^{-5}	37	1.3x10^{-11}	-109	1.3x10^{-15}	-149	1.3x10^{-12}	-119	-79
5x10^{-5}	34	6.6x10^{-12}	-112	6.6x10^{-16}	-152	66x10^{-14}	-122	-82
3x10^{-5}	30	2.4x10^{-12}	-116	2.4x10^{-16}	-156	24x10^{-14}	-126	-86
2x10^{-5}	26	1.1x10^{-12}	-120	1.1x10^{-16}	-160	11x10^{-14}	-130	-90
1x10^{-5}	20	2.7x10^{-13}	-126	2.7x10^{-17}	-166	2.7x10^{-14}	-136	-96
7x10^{-6}	17	1.3x10^{-13}	-129	1.3x10^{-17}	-169	1.3x10^{-14}	-139	-99
5x10^{-6}	14	6.6x10^{-14}	-132	6.6x10^{-18}	-172	66x10^{-16}	-142	-102
3x10^{-6}	10	2.4x10^{-14}	-136	2.4x10^{-18}	-176	24x10^{-16}	-146	-106
2x10^{-6}	6	1.1x10^{-14}	-140	1.1x10^{-18}	-180	11x10^{-16}	-150	-110
1x10^{-6}	0	2.7x10^{-15}	-146	2.7x10^{-19}	-186	2.7x10^{-16}	-156	-116

NOTE: Numbers in table rounded off.

FIELD STRENGTH APPROACH

To account for the impedance difference, the antenna factor (AF) is defined as: AF=E/V, where E is field intensity which can be expressed in terms taking 377 ohms into account and V is measured voltage which can be expressed in terms taking 50 ohms into account. Details are provided in Section 4-12.

POWER DENSITY APPROACH

To account for the impedance difference, the antenna's effective capture area term, A_e relates free space power density P_D with received power, P_r, i.e. $P_r = P_D A_e$. A_e is a function of frequency and antenna gain and is related to AF as shown in Section 4-12.

SAMPLE CALCULATIONS

Section 4-2 provides sample calculations using power density and power terms from Tables 1 and 2, whereas Section 4-12 uses these terms plus field intensity and voltage terms from Table 1 and Table 2. Refer the examples in Section 4-12 for usage of the conversions while converting free space values of power density to actual measurements with a spectrum analyzer attached by coaxial cable to a receiving antenna.

Conversion Between Field Intensity (Table 1) and Power Received (Table 2).

Power received (watts or milliwatts) can be expressed in terms of field intensity (volts/meter or μv/meter) using equation [3]:

$$Power\ received\ (P_r) = \frac{E^2}{480\pi^2}\frac{c^2}{f^2}G \qquad [3]$$

or in log form: $$10 \log P_r = 20 \log E + 10 \log G - 20 \log f + 10 \log (c^2/480\pi^2) \qquad [4]$$

Then $$10 \log Pr = 20 \log E_1 + 10 \log G - 20 \log f_1 + K_4 \qquad [5]$$

$$Where\ K_4 = 10 \log\left[\frac{c^2}{480\pi^2} \bullet \left(\begin{matrix} conversions \\ as\ required \end{matrix}\ \frac{(Watts\ to\ mW)}{(volts\ to\ \mu v)^2\ (Hz\ to\ MHz\ or\ GHz)^2}\right)\right]$$

The derivation of equation [3] follows:

$P_D = E^2/120\pi$ Eq [1], Section 4-1, terms (v^2/Ω)

$A_e = \lambda^2 G/4\pi$ Eq [8], Section 3-1, terms (m^2)

$P_r = P_D A_e$ Eq [2], Section 4-3, terms $(W/m^2)(m^2)$

$\therefore\ P_r = (E2/120\pi)(\lambda^2 G/4\pi)$ terms $(v^2/m^2\Omega)(m^2)$

$\lambda = c/f$ Section 2-3, terms (m/sec)(sec)

$\therefore P_r = (E^2/480\pi^2)(c^2 G/f^2)$ which is equation [3]

terms $(v^2/m^2\Omega)(m^2/sec^2)(sec^2)$ or v^2/Ω = watts

Values of K_4 (dB)

P_r	E_1	f_1 (Hz)	f_1 (MHz)	f_1 (GHz)
Watts (dBW)	volts/meter	132.8	12.8	-47.2
	μv/meter	12.8	-107.2	-167.2
mW (dBm)	volts/meter	162.8	42.8	-17.2
	μv/meter	42.8	-77.2	-137.7

Table 2. Conversion Table - Volts to Watts and dBµA.
($P_x = V_x^2/Z$ - Related by line impedance of 50 Ω)

Volts	dBV	dBµV	Watts	dBW	dBm	dBµA
700	56.0	176.0	9800	39.9	69.9	142.9
500	53.9	173.9	5000	37.0	67.0	140.0
300	49.5	169.5	1800	32.5	62.5	135.5
200	46.0	166.0	800	29.0	59.0	132.0
100	40.0	160.0	200	23.0	53.0	126.0
70	36.9	156.9	98	19.9	49.9	122.9
50	34.0	154.0	50	17.0	47.0	120.0
30	29.5	149.5	18	12.5	42.5	115.5
20	26.0	146.0	8	9.0	39.0	112.0
10	20.0	140.0	2	3.0	33.0	106.0
7	16.9	136.9	0.8	0	29.9	102.9
5	14.0	134.0	0.5	-3.0	27.0	100.0
3	9.5	129.5	0.18	-7.4	22.5	95.6
2	6.0	126.0	0.08	-11.0	19.0	92.0
1	0	120.0	0.02	-17.0	13.0	86.0
0.7	-3.1	116.9	9.8×10^{-3}	-20.1	9.9	82.9
0.5	-6.0	114.0	5.0×10^{-3}	-23.0	7.0	80.0
0.3	-10.5	109.5	1.8×10^{-3}	-27.4	2.6	75.6
0.2	-14.0	106.0	8.0×10^{-4}	-31.0	-1.0	72.0
0.1	-20.0	100.0	2.0×10^{-4}	-37.0	-7.0	66.0
.07	-23.1	96.9	9.8×10^{-5}	-40.1	-10.1	62.9
.05	-26.0	94.0	5.0×10^{-5}	-43.0	-13.0	60.0
.03	-30.5	89.5	1.8×10^{-5}	-47.4	-17.7	55.6
.02	-34.0	86.0	8.0×10^{-6}	-51.0	-21.0	52.0
.01	-40.0	80.0	2.0×10^{-6}	-57.0	-27.0	46.0
7×10^{-3}	-43.1	76.9	9.8×10^{-7}	-60.1	-30.1	42.9
5×10^{-3}	-46.0	74.0	5.0×10^{-7}	-63.0	-33.0	40.0
3×10^{-3}	-50.5	69.5	1.8×10^{-7}	-67.4	-37.4	35.6
2×10^{-3}	-54.0	66.0	8.0×10^{-8}	-71.0	-41.0	32.0
1×10^{-3}	-60.0	60.0	2.0×10^{-8}	-77.0	-47.0	26.0
7×10^{-4}	-64.1	56.9	9.8×10^{-9}	-80.1	-50.1	22.9
5×10^{-4}	-66.0	54.0	5.0×10^{-9}	-83.0	-53.0	20.0
3×10^{-4}	-70.5	49.5	1.8×10^{-9}	-87.4	-57.4	15.6
2×10^{-4}	-74.0	46.0	8.0×10^{-10}	-91.0	-61.0	12.0
1×10^{-4}	-80.0	40.0	2.0×10^{-10}	-97.0	-67.0	6.0
7×10^{-5}	-84.1	36.9	9.8×10^{-11}	-100.1	-70.1	2.9
5×10^{-5}	-86.0	34.0	5.0×10^{-11}	-103.0	-73.0	0
3×10^{-5}	-90.5	29.5	1.8×10^{-11}	-107.4	-77.4	-4.4
2×10^{-5}	-94.0	26.0	8.0×10^{-12}	-111.0	-81.0	-8.0
1×10^{-5}	-100.0	20.0	2.0×10^{-12}	-117.0	-87.0	-14.0
7×10^{-6}	-104.1	16.9	9.8×10^{-13}	-120.1	-90.1	-17.1
5×10^{-6}	-106.0	14.0	5.0×10^{-13}	-123.0	-93.0	-20.0
3×10^{-6}	-110.5	9.5	1.8×10^{-13}	-127.4	-97.4	-24.4
2×10^{-6}	-114.0	6.0	8.0×10^{-14}	-131.0	-101.0	-28.0
1×10^{-6}	-120.0	0	2.0×10^{-14}	-137.0	-107.0	-34.0
7×10^{-7}	-124.1	-3.1	9.8×10^{-15}	-140.1	-110.1	-37.1
5×10^{-7}	-126.0	-6.0	5.0×10^{-15}	-143.0	-113.0	-40.0
3×10^{-7}	-130.5	-10.5	1.8×10^{-15}	-147.4	-117.4	-44.4
2×10^{-7}	-134.0	-14.0	8.0×10^{-16}	-151.0	-121.0	-48.0
1×10^{-7}	-140.0	-20.0	2.0×10^{-16}	-157.0	-127.0	-54.0

POWER DENSITY

Radio Frequency (RF) propagation is defined as the travel of electromagnetic waves through or along a medium. For RF propagation between approximately 100 MHz and 10 GHz, radio waves travel very much as they do in free space and travel in a direct line of sight. There is a very slight difference in the dielectric constants of space and air. The dielectric constant of space is one. The dielectric constant of air at sea level is 1.000536. In all but the highest precision calculations, the slight difference is neglected.

From chapter 3, Antennas, an isotropic radiator is a theoretical, lossless, omnidirectional (spherical) antenna. That is, it radiates uniformly in all directions. The power of a transmitter that is radiated from an isotropic antenna will have a uniform power density (power per unit area) in all directions. The power density at any distance from an isotropic antenna is simply the transmitter power divided by the surface area of a sphere ($4\pi R^2$) at that distance. The surface area of the sphere increases by the square of the radius, therefore the power density, P_D, (watts/square meter) decreases by the square of the radius.

$$\begin{matrix} \text{Power density from} \\ \text{an isotropic antenna} \end{matrix} = P_D = \frac{P_t}{4\pi R^2} \qquad \begin{matrix} \text{where : } P_t = \text{Transmitter Power} \\ R = \text{Range From Antenna (i.e., radius of sphere)} \end{matrix} \qquad \textbf{[1]}$$

P_t is either peak or average power depending on how P_D is to be specified.

Radars use directional antennas to channel most of the radiated power in a particular direction. The Gain (G) of an antenna is the ratio of power radiated in the desired direction as compared to the power radiated from an isotropic antenna, or:

$$G = \frac{\text{Maximum radiation intensity of actual antenna}}{\text{Radiation intensity of isotropic antenna with same power input}}$$

The power density at a distant point from a radar with an antenna gain of G_t is the power density from an isotropic antenna multiplied by the radar antenna gain.

Power density from radar, $$P_D = \frac{P_t G_t}{4\pi R^2} \qquad \textbf{[2]}$$

P_t is either peak or average power depending on how P_D is to be specified.

Another commonly used term is effective isotropic radiated power (EIRP), where **EIRP = P_t G_t.** ERP is also used but EIRP is preferred because it specifically defines the type of reference antenna as isotropic.

A receiving antenna captures a portion of this power determined by its effective capture Area (A_e). The received power available at the antenna terminals is the power density times the effective capture area (A_e) of the receiving antenna.

e.g., If the power density at a specified range is one microwatt per square meter and the antenna's effective capture area is one square meter then the power captured by the antenna is one microwatt.

For a given receiver antenna size the capture area is constant no matter how far it is from the transmitter, as illustrated in Figure 1. Also notice from Figure 1 that the received signal power decreases by 1/4 (6 dB) as the distance doubles. This is due to the R^2 term in the denominator of equation [2].

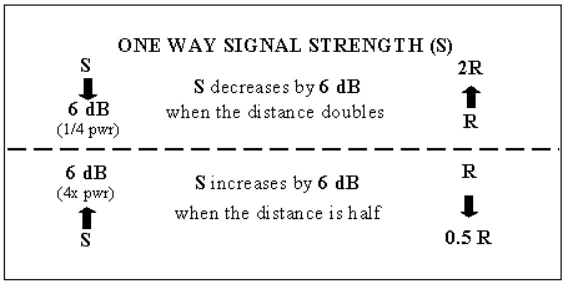
ONE WAY SIGNAL STRENGTH (S)
S
6 dB
(1/4 pwr)
S decreases by 6 dB when the distance doubles
2R
R
6 dB
(4x pwr)
S
S increases by 6 dB when the distance is half
R
0.5 R

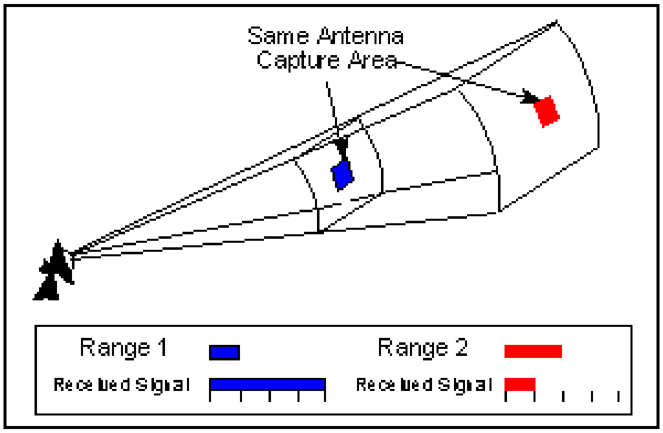
Same Antenna Capture Area
Range 1
Received Signal
Range 2
Received Signal

Figure 1. Power Density vs. Range.

Sample Power Density Calculation - Far Field
(Refer to Section 3-5 for the definition of near field and far field)

Calculate the power density at 100 feet for 100 watts transmitted through an antenna with a gain of 10.

Given: P_t = 100 watts G_t = 10 (dimensionless ratio) R = 100 ft

This equation produces power density in watts per square range unit.

$$P_D = \frac{P_t G_t}{4\pi R^2} = \frac{(100 \text{ watts})(10)}{4\pi (100 \text{ ft})^2} = 0.0080 \text{ watts}/\text{ft}^2$$

For safety (radiation hazard) and EMI calculations, power density is usually expressed in milliwatts per square cm. That's nothing more than converting the power and range to the proper units.

100 watts = 1×10^2 watts = 1×10^5 mW

100 feet = 30.4785 meters = 3047.85 cm.

$$P_D = \frac{P_t G_t}{4\pi R^2} = \frac{(10^5 \text{ mW}) \bullet (10)}{4\pi (3047.85 \text{cm})^2} = 0.0086 \text{ mW}/\text{cm}^2$$

However, antenna gain is almost always given in dB, not as a ratio. It's then often easier to express EIRP in dBm.

$$P_t(\text{dBm}) = 10 \text{ Log}\left[\frac{P_t \text{ watts}}{1 \text{ mW}}\right] = 10 \text{ Log}\left[\frac{100}{.001}\right] = 50 \text{ dBm}$$

$$G_t(\text{dB}) = 10 \text{ Log}\left[\frac{G_t}{1}\right] = 10 \text{ Log}(10) = 10 \text{ dB}$$

EIRP (dBm) = P_t (dBm) + G_t (dB) = 50 + 10 = 60 dBm

To reduce calculations, the graph in Figure 2 can be used. It gives EIRP in dBm, range in feet and power density in mW/cm^2. Follow the scale A line for an EIRP of 60 dBm to the point where it intersects the 100 foot range scale. Read the power density directly from the A-scale x-axis as 0.0086 mW/cm^2 (confirming our earlier calculations).

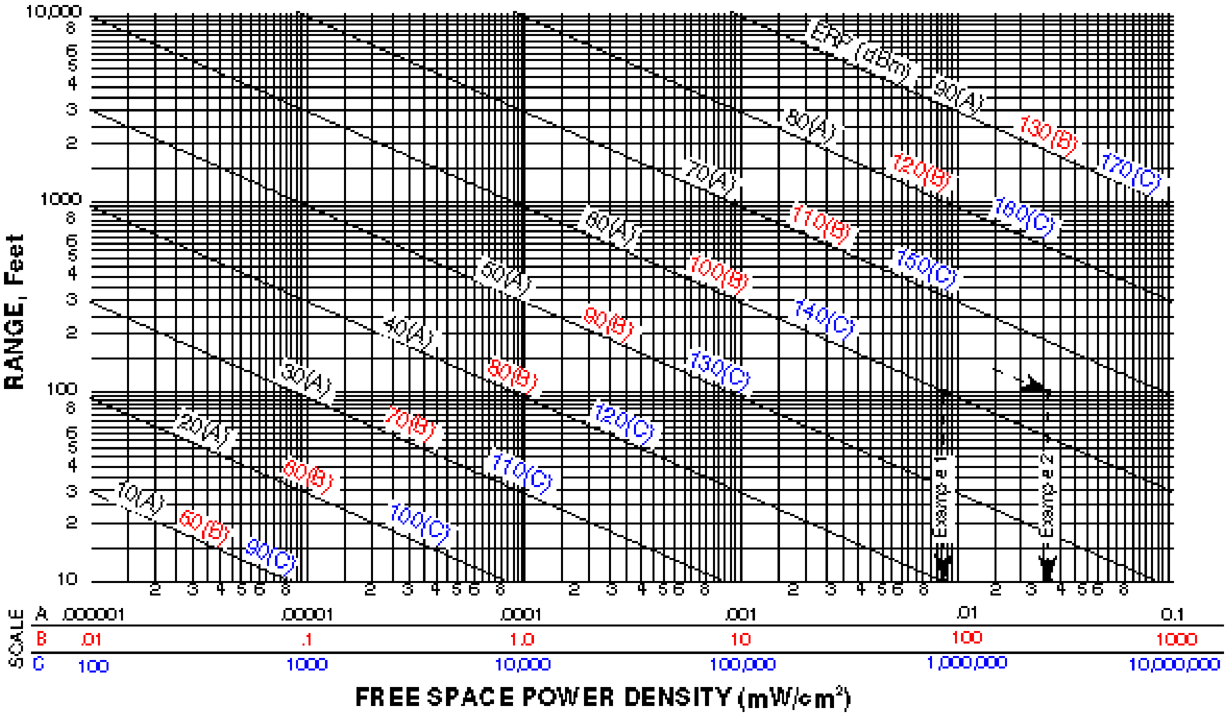

Figure 2. Power Density vs. Range and EIRP.

Example 2

When antenna gain and power (or EIRP) are given in dB and dBm, it is necessary to convert back to ratios in order to perform the calculation given in equation [2]. Use the same values as in example 1 except for antenna gain.

Suppose the antenna gain is given as 15 dB: **G_t (dB) = 10 Log (G_t)**

$$Therefore: \quad G_t = [10]^{\left(\frac{G_t(dB)}{10}\right)} = [10]^{\left(\frac{15}{10}\right)} = 31.6228$$

$$P_D = \frac{P_t G_t}{4\pi R^2} = \frac{(10^5\ mW)(31.6228)}{4\pi\,(3047.85)^2} = 0.0271\ mW/cm^2$$

Follow the 65 dBm (extrapolated) EIRP line and verify this result on the A-scale X-axis.

Example 3 - Sample Real Life Problem

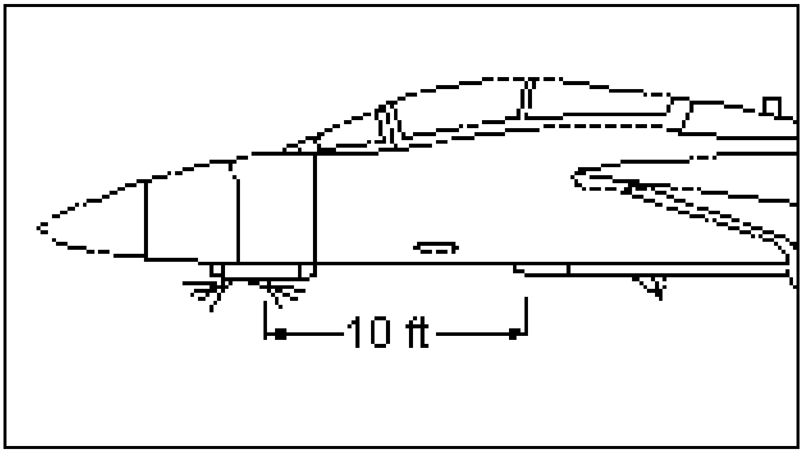

Assume we are trying to determine if a jammer will damage the circuitry of a missile carried onboard an aircraft and we cannot perform an actual measurement. Refer to the diagram at the right.

Given the following:

Jammer power: 500 W ($P_t = 500$)

Jammer line loss and antenna gain: 3 dB ($G_t = 2$)

Missile antenna diameter: 10 in

Missile antenna gain: Unknown

Missile limiter protection (maximum antenna power input): 20 dBm (100mW) average and peak.

The power density at the missile antenna caused by the jammer is computed as follows:

$$P_D = \frac{P_t G_t}{4\pi R^2} = \frac{500W\,(2)}{4\pi[(10ft)(.3048m/ft)]^2} = 8.56W/m^2$$

The maximum input power actually received by the missile is either:

$P_r = P_D A_e$ (if effective antenna area is known) or
$P_r = P_D G_m\lambda^2/4\pi$ (if missile antenna gain is known)

To cover the case where the missile antenna gain is not known, first assume an aperture efficiency of 0.7 for the missile antenna (typical). Then:

$P_r = P_D A \eta = 8.56 \text{ W/m}^2 (\pi)[(10/2 \text{ in})(.0254 \text{ m/in})]^2 (0.7) = 0.3$ watts

Depending upon missile antenna efficiency, we can see that the power received will be about 3 times the maximum allowable and that either better limiter circuitry may be required in the missile or a new location is needed for the missile or jammer. Of course if the antenna efficiency is 0.23 or less, then the power will not damage the missile's receiver.

If the missile gain were known to be 25 dB, then a more accurate calculation could be performed. Using the given gain of the missile (25 dB= numeric gain of 316), and assuming operation at 10 GHz ($\lambda = .03$m)

$P_r = P_D G_m \lambda^2 / 4\pi = 8.56 \text{ W/m}^2 (316)(.03)^2/ 4\pi = .19$ watts (still double the allowable tolerance)

ONE-WAY RADAR EQUATION / RF PROPAGATION

The one-way (transmitter to receiver) radar equation is derived in this section. This equation is most commonly used in RWR, communications, or ESM type of applications. The following is a summary of the important equations explored in this section:

ONE-WAY RADAR EQUATION

Peak Power at Receiver Input, $P_r \, (or \; S) = P_D A_e = \frac{P_t G_t A_e}{4\pi R^2}$ and Antenna Gain, $G = \frac{4\pi A_e}{\lambda^2}$

or: Equivalent Area, $A_e = \frac{G \lambda^2}{4\pi}$

So the one-way radar equation is :

$$S \, (or \; P_r) = \frac{P_t G_t G_r \lambda^2}{(4\pi R)^2} = P_t G_t G_r \left[\frac{c^2}{(4\pi f R)^2} \right]^* \qquad (Note : \lambda = \frac{c}{f})$$

* keep λ, c, and R in the same units

On reducing to log form this becomes:
$10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r - 20\log fR + 20\log (c/4\pi)$

or in simplified terms:
$10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r - \alpha_1$ (in dB)

Where: α_1 = one-way free space loss = $20\log (f_1 R) + K_1$ (in dB) and:
$K_1 = 20\log [(4\pi/c)$(Conversion factors if units if not in m/sec, m, and Hz)]

Note: To avoid having to include additional terms for these calculations, always combine any transmission line loss with antenna gain

Values of K_1 (in dB)

Range (units)	f_1 in MHz K_1 =	f_1 in GHz K_1 =
NM	37.8	97.8
km	32.45	92.45
m	-27.55	32.45
yd	-28.33	31.67
ft	-37.87	22.13

Note: Losses due to antenna polarization and atmospheric absorption (Sections 3-2 & 5-1) are not included in any of these equations.

Recall from Section 4-2 that the power density at a distant point from a radar with an antenna gain of G_t is the power density from an isotropic antenna multiplied by the radar antenna gain.

Power density from radar, $P_D = \frac{P_t G_t}{4\pi R^2}$

If you could cover the entire spherical segment with your receiving antenna you would theoretically capture all of the transmitted energy. You can't do this because no antenna is large enough. (A two degree segment would be about a mile and three-quarters across at fifty miles from the transmitter.)

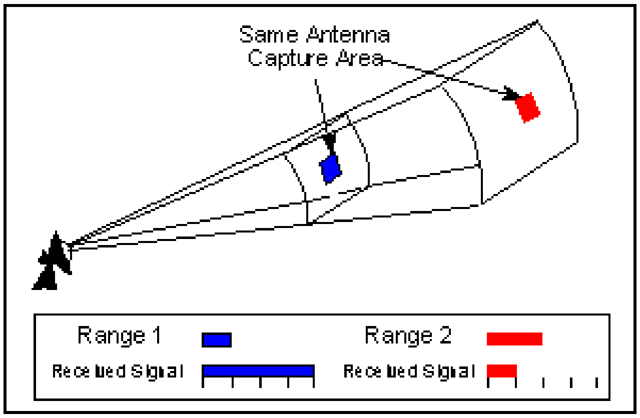

Figure 1. Power Density vs. Range.

A receiving antenna captures a portion of this power determined by its effective capture Area (A_e). The received power available at the antenna terminals is the power density times the effective capture area (A_e) of the receiving antenna.

For a given receiver antenna size the capture area is constant no matter how far it is from the transmitter, as illustrated in Figure 1. This concept is shown in the following equation:
Peak Power at Receiver input,

$$P_R \text{ (or S)} = P_D A_e = \frac{P_t G_t A_e}{4\pi R^2} \quad \text{which is known as the one-way (beacon) equation} \qquad [2]$$

In order to maximize energy transfer between an antenna and transmitter or receiver, the antenna size should correlate with frequency. For reasonable antenna efficiency, the size of an antenna will be greater than λ/4. Control of beamwidth shape may become a problem when the size of the active element exceeds several wavelengths.

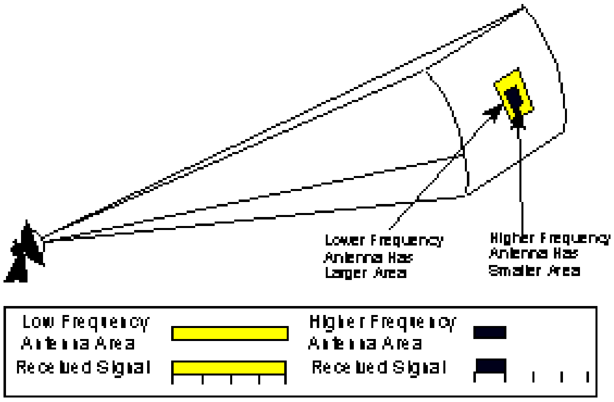
Lower Frequency
Antenna Has
Larger Area
Higher Frequency
Antenna Has
Smaller Area
Low Frequency
Antenna Area
Received Signal
Higher Frequency
Antenna Area
Received Signal

Figure 2. Capture Area vs. Frequency.

The relation between an antenna's effective capture area (A_e) or effective aperture and its Gain (G) is:

$$\textit{Antenna Gain, } G = \frac{4\pi A_e}{\lambda^2} \qquad [3]$$

$$\textit{or : Equivalent Area, } A_e = \frac{G\lambda^2}{4\pi} \qquad [4]$$

Since the effective aperture is in units of length squared, from equation [3], it is seen that gain is proportional to the effective aperture normalized by the wavelength. This physically means that to maintain the same gain when doubling the frequency, the area is reduced by 1/4. This concept is illustrated in Figure 2.

If equation [4] is substituted into equation [2], the following relationship results:

$$\textit{Peak Power at Receiver Input} = S \text{ (or } P_R) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 R^2} = \frac{P_t G_t G_r \lambda^2}{(4\pi R)^2} \qquad [5]$$

This is the signal calculated one-way from a transmitter to a receiver. For instance, a radar application might be to determine the signal received by a RWR, ESM, or an ELINT receiver. It is a general purpose equation and could be applied to almost any line-of-sight transmitter to receiver situation if the RF is higher than 100 MHZ.

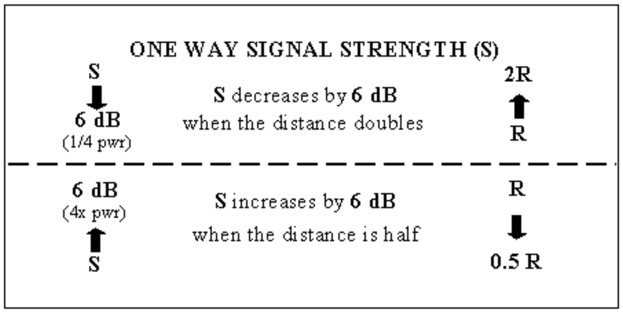
ONE WAY SIGNAL STRENGTH (S)
S
6 dB
(1/4 pwr)
S decreases by 6 dB
when the distance doubles
2R
R
6 dB
(4x pwr)
S
S increases by 6 dB
when the distance is half
R
0.5 R

Values of K_1 (dB)		
Range (units)	f_1 in MHz K_1 =	f_1 in GHz K_1 =
NM	37.8	97.8
km	32.45	92.45
m	-27.55	32.45
yd	-28.33	31.67
ft	-37.87	22.13

The free space travel of radio waves can, of course, be blocked, reflected, or distorted by objects in their path such as buildings, flocks of birds, chaff, and the earth itself.

As illustrated in Figure 1, as the distance is doubled the received signal power decreases by 1/4 (6 dB). This is due to the R^2 term in equation [5].

To illustrate this, blow up a round balloon and draw a square on the side of it. If you release air so that the diameter or radius is decreased by 1/2, the square shrinks to 1/4 the size. If you further blow up the balloon, so the diameter or radius is doubled, the square has quadrupled in area.

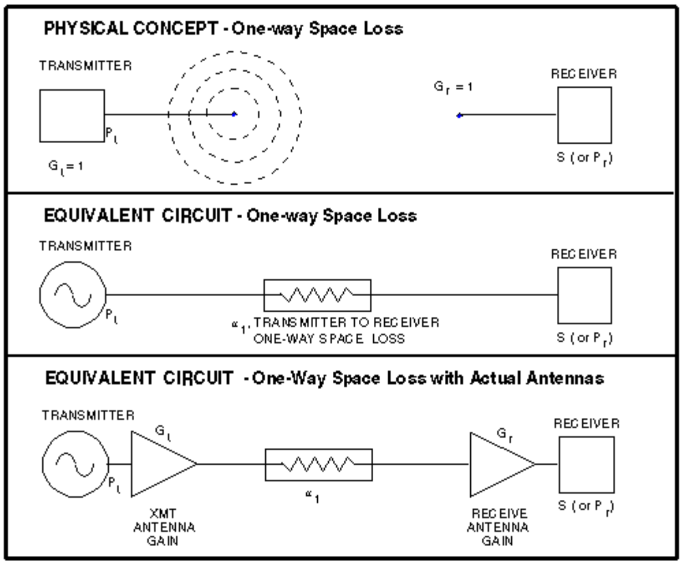
PHYSICAL CONCEPT - One-way Space Loss
TRANSMITTER
P_t
$G_t = 1$
$G_r = 1$
RECEIVER
S (or P_r)
EQUIVALENT CIRCUIT - One-way Space Loss
TRANSMITTER
P_t
α_1, TRANSMITTER TO RECEIVER ONE-WAY SPACE LOSS
RECEIVER
S (or P_r)
EQUIVALENT CIRCUIT - One-Way Space Loss with Actual Antennas
TRANSMITTER
G_t
P_t
XMT ANTENNA GAIN
α_1
G_r
RECEIVE ANTENNA GAIN
RECEIVER
S (or P_r)

Figure 3. Concept of One-Way Space Loss.

The one-way free space loss factor (α_1), (sometimes called the path loss factor) is given by the term $(4\pi R^2)(4\pi/\lambda^2)$ or $(4\pi R/\lambda)^2$. As shown in Figure 3, the loss is due to the ratio of two factors (1) the effective radiated area of the transmit antenna, which is the surface area of a sphere ($4\pi R^2$) at that distance (R), and (2) the effective capture area (A_e) of the receive antenna which has a gain of one. If a receiving antenna could capture the whole surface area of the sphere, there would be no spreading loss, but a practical antenna will capture only a small part of the spherical radiation. Space loss is calculated using isotropic antennas for both transmit and receive, so α_1 is independent of the actual antenna. Using Gr = 1 in equation [11] in Section 3-1, $A_e = \lambda^2/4\pi$. Since this term is in the denominator of α_1, the higher the frequency (lower λ) the more the space loss. Since G_t and G_r are part of the one-way radar equation, S (or P_r) is adjusted according to actual antennas as shown in the last portion of Figure 3. The value of the received signal (S) is:

$$S\,(or\ P_R) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 R^2} = P_t G_t G_r \left[\frac{\lambda^2}{(4\pi R)^2}\right] \qquad \textbf{[6]}$$

To convert this equation to dB form, it is rewritten as:

$$10\,\mathrm{Log}\,(S\ \mathrm{or}\ P_r) = 10\,\mathrm{Log}\,(P_t G_t G_r) + 20\,\mathrm{Log}\left[\frac{\lambda}{4\pi f R}\right] \qquad \textbf{[7]}$$

Since λ = c / *f*, equation [7] can be rewritten as:

$$10\ \mathrm{Log}\ (S\ \mathrm{or}\ P_r) = 10\ \mathrm{Log}(P_t G_t G_r) - \alpha_1 \qquad \textbf{[8]}$$

Where the one-way free space loss, α_1, is defined as: $\alpha_1 = 20\,\mathrm{Log}\left[\frac{4\pi f R}{c}\right]*$ **[9]**

The signal received equation in dB form is: 10log (P_r or S) = 10log P_t + 10log G_t + 10log G_r - α_1 **[10]**

The one-way free space loss, α_1, can be given in terms of a variable and constant term as follows:

$$\alpha_1 = 20\,\text{Log}\left[\frac{4\pi f R}{c}\right]^* = 20\,\text{Log}\, f_1 R + K_1 \quad (in\ dB) \qquad \textbf{[11]}$$

The value of f_1 can be either in MHz or GHz as shown with commonly used units of R in the adjoining table.

$$where\ K_1 = 20\,\text{Log}\left[\frac{4\pi}{c} \bullet (Conversion\ units\ if\ not\ in\ m/\text{sec}, m, and\ Hz)\right]$$

Note: To avoid having to include additional terms for these calculations, always combine any transmission line loss with antenna gain.

A value for the one-way free space loss (α_1) can be obtained from:

(a) The One-way Free Space Loss graph (Figure 4). Added accuracy can be obtained using the Frequency Extrapolation graph (Figure 5)

(b) The space loss nomograph (Figure 6 or 7)

(c) The formula for α_1, equation [11].

FOR EXAMPLE:

Find the value of the one-way free space loss, α_1, for an RF of 7.5 GHz at 100 NM.

(a) From Figure 4, find 100 NM on the X-axis and estimate where 7.5 GHz is located between the 1 and 10 GHz lines (note dot). Read α_1 as 155 dB. An alternate way would be to read the α_1 at 1 GHz (138 dB) and add the frequency extrapolation value (17.5 dB for 7.5:1, dot on Figure 5) to obtain the same 155 dB value.

(b) From the nomogram (Figure 6), the value of α_1 can be read as 155 dB (Note the dashed line).

(c) From the equation 11, the precise value of α_1 is 155.3 dB.

Remember, α_1 is a free space value. If there is atmospheric attenuation because of absorption of RF due to certain molecules in the atmosphere or weather conditions etc., the atmospheric attenuation is in addition to the space loss (refer to Section 5-1).

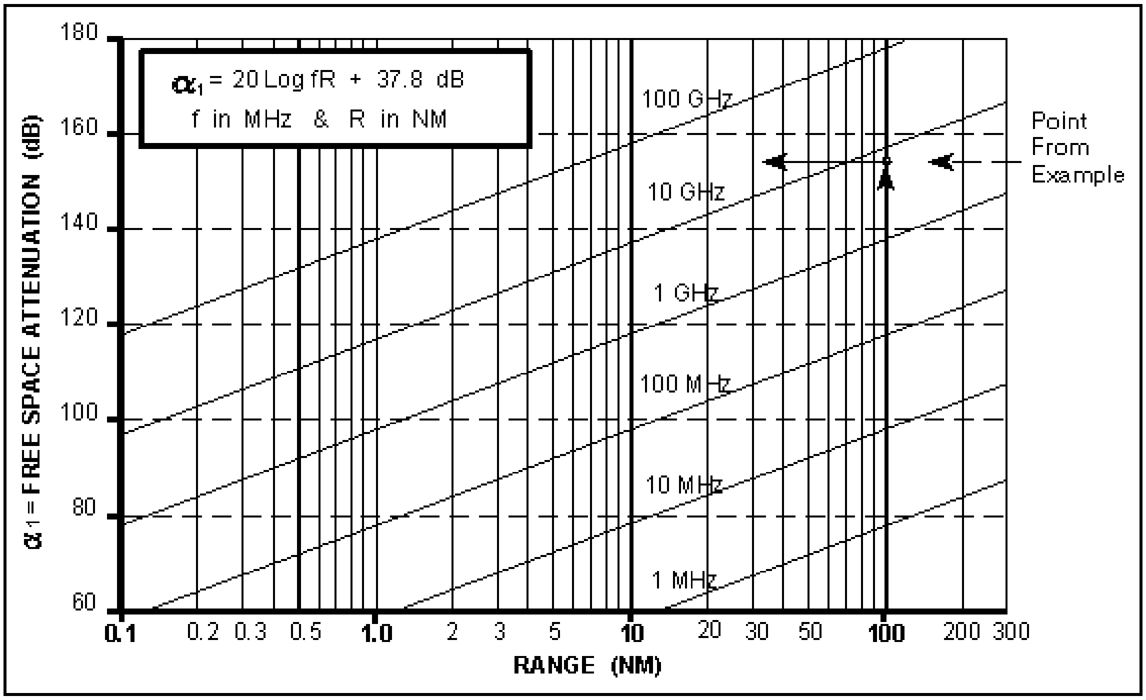

Figure 4. One-Way Free Space Loss.

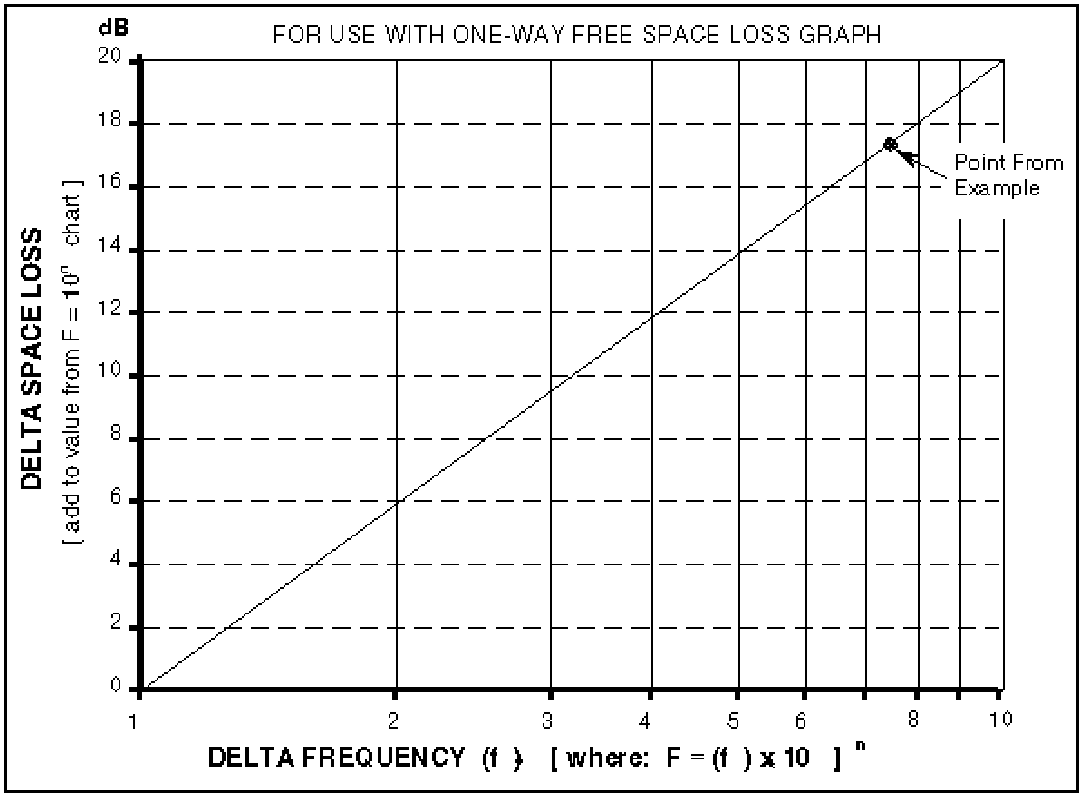

Figure 5. Frequency Extrapolation.

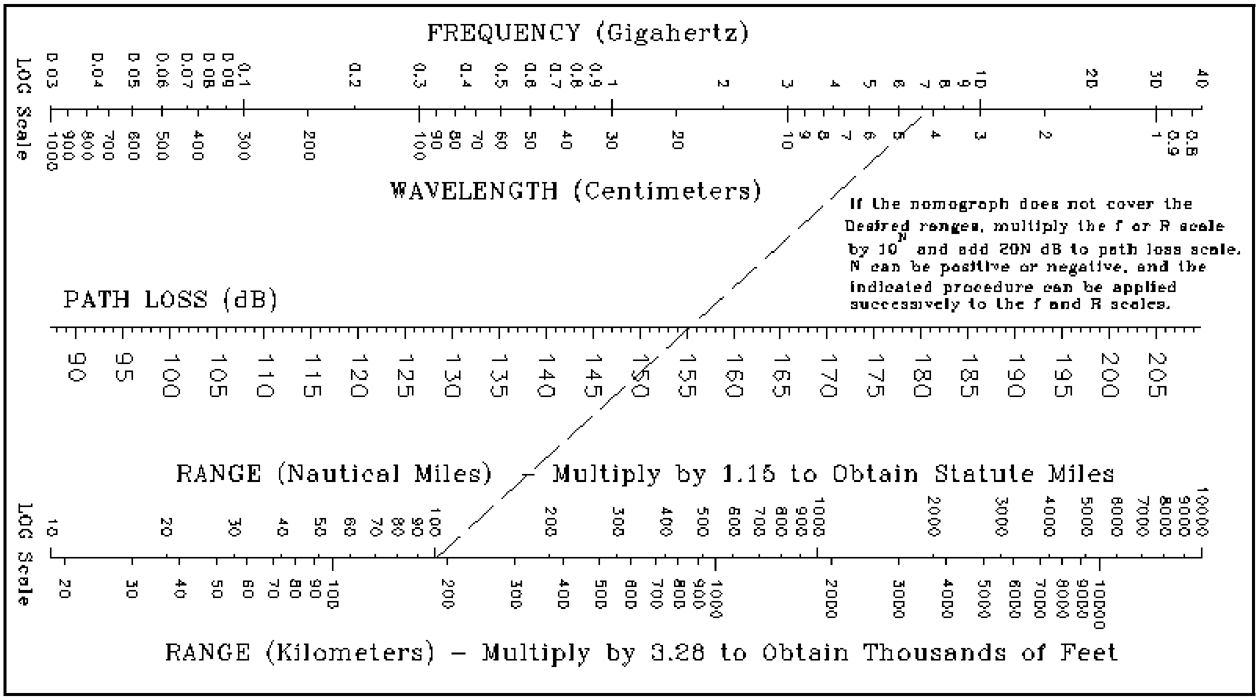

If the nomograph does not cover the Desired ranges, multiply the f or R scale by 10^N and add 20N dB to path loss scale. N can be positive or negative, and the indicated procedure can be applied successively to the f and R scales.

Figure 6. One-Way Space Loss Nomograph for Distances Greater Than 10 Nautical Miles.

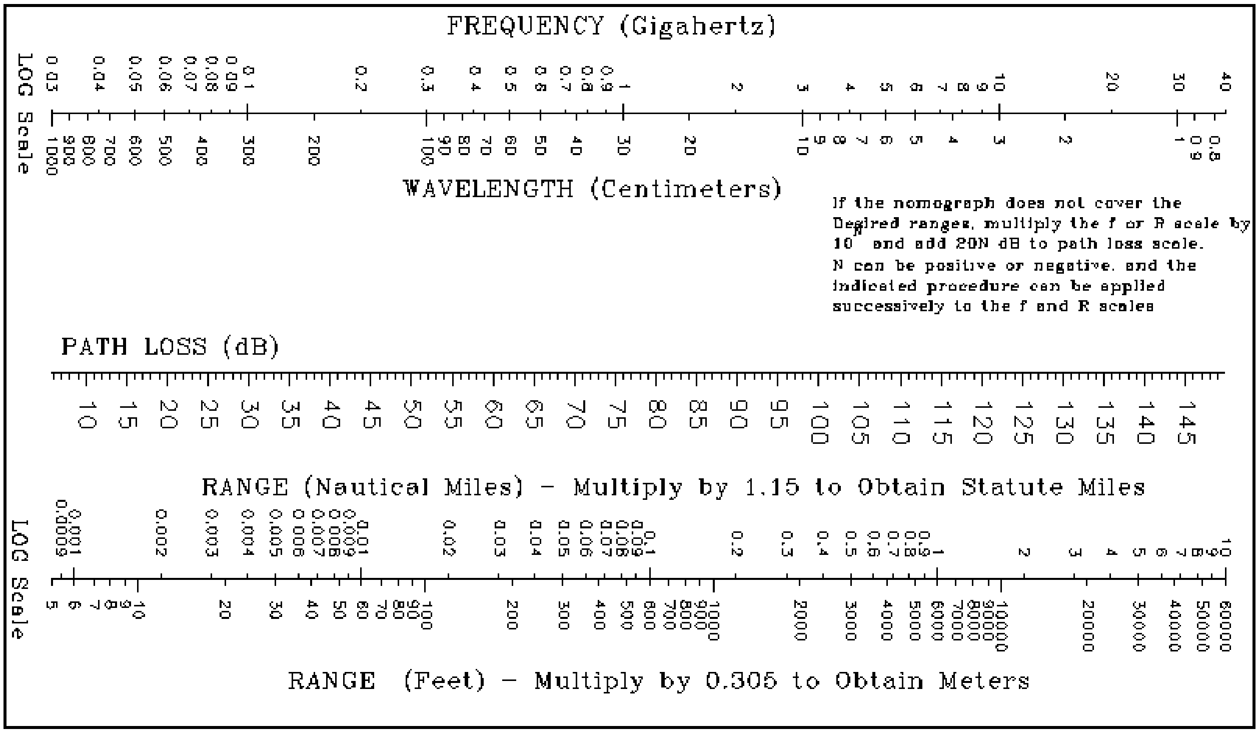

If the nomograph does not cover the Desired ranges, multiply the f or R scale by 10^N and add 20N dB to path loss scale. N can be positive or negative, and the indicated procedure can be applied successively to the f and R scales

Figure 7. One-Way Space Loss Nomograph for Distances Less Than 10 Nautical Miles.

Figure 8 is the visualization of the losses occurring in one-way radar equation. Note: To avoid having to include additional terms, always combine any transmission line loss with antenna gain. Losses due to antenna polarization and atmospheric absorption also need to be included.

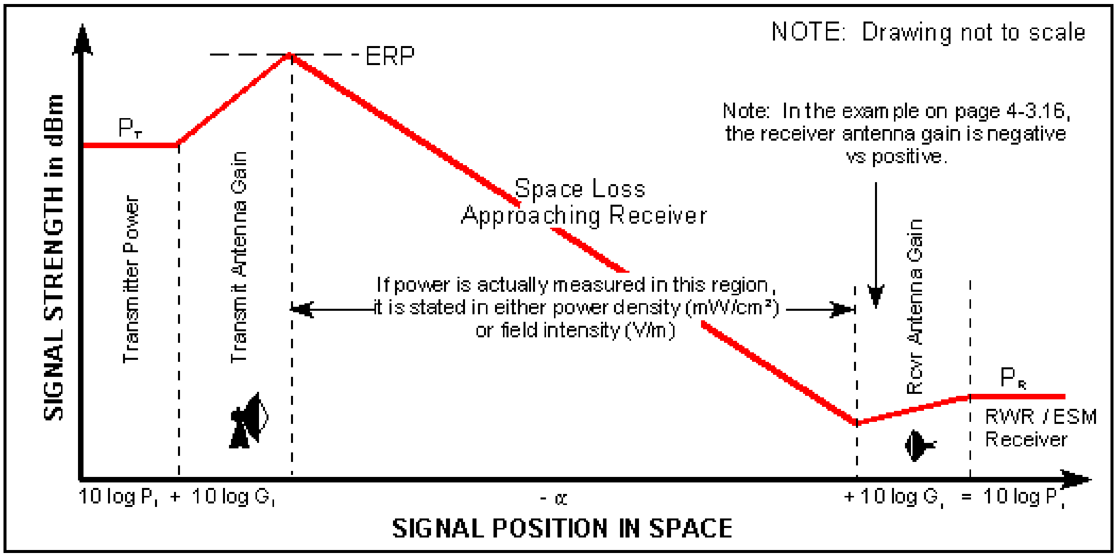
NOTE: Drawing not to scale
ERP
SIGNAL STRENGTH in dBm
P_T
Transmitter Power
Transmit Antenna Gain
Space Loss Approaching Receiver
Note: In the example on page 4-3.16, the receiver antenna gain is negative vs positive.
If power is actually measured in this region, it is stated in either power density (mW/cm²) or field intensity (V/m)
Rcvr Antenna Gain
P_R
RWR / ESM Receiver
10 log P_t + 10 log G_t
- α
+ 10 log G_r = 10 log P_r
SIGNAL POSITION IN SPACE

Figure 8. Visualization of One-Way Radar Equation.

RWR/ESM RANGE EQUATION (One-Way)

The one-way radar (signal strength) equation [5] is rearranged to calculate the maximum range R_{max} of RWR/ESM receivers. It occurs when the received radar signal just equals S_{min} as follows:

$$R_{max} \cong \left[\frac{P_t G_t G_r \lambda^2}{(4\pi)^2 S_{min}}\right]^{\frac{1}{2}} \; or \; \left[\frac{P_t G_t G_r c^2}{(4\pi f)^2 S_{min}}\right]^{\frac{1}{2}} \; or \; \left[\frac{P_t G_t A_e}{4\pi S_{min}}\right]^{\frac{1}{2}} \qquad \textbf{[12]}$$

In log form:

$$20\log R_{max} = 10\log P_t + 10\log G_t - 10\log S_{min} - 20\log f + 20\log(c/4\pi) \qquad \textbf{[13]}$$

and since $K_1 = 20\log\{4\pi/c$ times conversion units if not in m/sec, m, and Hz$\}$
(Refer to Section 4-3 for values of K_1).

$$10\log R_{max} = \tfrac{1}{2}[\,10\log P_t + 10\log G_t - 10\log S_{min} - 20\log f - K_1] \quad \text{(keep } P_t \text{ and } S_{min} \text{ in same units)} \qquad \textbf{[14]}$$

If you want to convert back from dB, then $R_{max} \cong \frac{10^{M\,dB}}{20}$, where M dB is the resulting number in the brackets of equation 14.

From Section 5-2, Receiver Sensitivity / Noise, S_{min} is related to the noise factor S:

$$S_{min} = (S/N)_{min}\,(NF)KT_oB \qquad \textbf{[15]}$$

The one-way RWR/ESM range equation becomes:

$$R_{max} \cong \left[\frac{P_t\, G_t\, G_r\, \lambda^2}{(4\pi\,)^2\,(S/N\,)_{\min}(NF)\,KT_o\,B}\right]^{\frac{1}{2}} \; or \; \left[\frac{P_t\, G_t\, G_r\, c^2}{(4\pi f\;)^2\,(S/N\,)_{\min}(NF)\,KT_o\,B}\right]^{\frac{1}{2}} \; or \; \left[\frac{P_t\, G_t\, A_e}{4\pi\,(S/N\,)_{\min}(NF)\,KT_o\,B}\right]^{\frac{1}{2}} \qquad \textbf{[16]}$$

RWR/ESM RANGE INCREASE AS A RESULT OF A SENSITIVITY INCREASE

As shown in equation [12] $S_{min}^{-1} \propto R_{max}^2$. Therefore, -10 log $S_{min} \propto$ 20 logR_{max} and the following table results:

% Range Increase: Range + (% Range Increase) x Range = New Range
i.e., for a 6 dB sensitivity increase, 500 miles +100% x 500 miles = 1,000 miles
Range Multiplier: Range x Range Multiplier = New Range
i.e., for a 6 dB sensitivity increase 500 miles x 2 = 1,000 miles

dB Sensitivity Increase	% Range Increase	Range Multiplier	dB Sensitivity Increase	% Range Increase	Range Multiplier
+ 0.5	6	1.06	10	216	3.16
1.0	12	1.12	11	255	3.55
1.5	19	1.19	12	298	3.98
2	26	1.26	13	347	4.47
3	41	1.41	14	401	5.01
4	58	1.58	15	462	5.62
5	78	1.78	16	531	6.31
6	100	2.0	17	608	7.08
7	124	2.24	18	694	7.94
8	151	2.51	19	791	8.91
9	182	2.82	20	900	10.0

RWR/ESM RANGE DECREASE AS A RESULT OF A SENSITIVITY DECREASE

As shown in equation [12] $S_{min}^{-1} \propto R_{max}^2$. Therefore, -10 log $S_{min} \propto$ 20 logR_{max} and the following table results:

% Range Decrease: Range - (% Range decrease) x Range = New Range
i.e., for a 6 dB sensitivity decrease, 500 miles - 50% x 500 miles = 250 miles
Range Multiplier: Range x Range Multiplier = New Range
i.e., for a 6 dB sensitivity decrease 500 miles x .5 = 250 miles

dB Sensitivity Decrease	% Range Decrease	Range Multiplier	dB Sensitivity Decrease	% Range Decrease	Range Multiplier
- 0.5	6	0.94	-10	68	0.32
- 1.0	11	0.89	- 11	72	0.28
- 1.5	16	0.84	- 12	75	0.25
- 2	21	0.79	- 13	78	0.22
- 3	29	0.71	- 14	80	0.20
- 4	37	0.63	- 15	82	0.18
- 5	44	0.56	- 16	84	0.16
- 6	50	0.50	- 17	86	0.14
- 7	56	0.44	- 18	87	0.13
- 8	60	0.4	- 19	89	0.11
- 9	65	0.35	- 20	90	0.10

Example of One-Way Signal Strength: A 5 (or 7) GHz radar has a 70 dBm signal fed through a 5 dB loss transmission line to an antenna that has 45 dB gain. An aircraft that is flying 31 km from the radar has an aft EW antenna with -1 dB gain and a 5 dB line loss to the EW receiver (assume all antenna polarizations are the same).

Note: The respective transmission line losses will be combined with antenna gains, i.e.:

$$-5 + 45 = 40 \text{ dB},\ -5 - 1 = -6 \text{ dB},\ -10 + 5 = -5 \text{ dB}.$$

(1) What is the power level at the input of the EW receiver?

Answer (1): P_r at the input to the EW receiver = Transmitter power - xmt cable loss + xmt antenna gain - space loss + rcvr antenna gain - rcvr cable loss.

Space loss (from Section 4-3) @ 5 GHz = $20 \log f R + K_1 = 20 \log (5\text{x}31) + 92.44 = 136.25$ dB. Therefore:

$$P_r = 70 + 40 - 136.25 - 6 = -32.25 \text{ dBm @ 5 GHz } (P_r = -35.17 \text{ dBm @ 7 GHz since } \alpha_1 = 139.17 \text{ dB})$$

(2) If the received signal is fed to a jammer with a gain of 60 dB, feeding a 10 dB loss transmission line which is connected to an antenna with 5 dB gain, what is the power level from the jammer at the input to the receiver of the 5 (or 7) GHz radar?

Answer (2): P_r at the input to the radar receiver = Power at the input to the EW receiver+ Jammer gain - jammer cable loss + jammer antenna gain - space loss + radar rcvr antenna gain - radar rcvr cable loss. Therefore:

$$P_r = -32.25 + 60 - 5 - 136.25 + 40 = -73.5 \text{ dBm @ 5 GHz. } (P_r = -79.34 \text{ dBm @ 7 GHz since } \alpha_1 = 139.17 \text{ dB and } P_t = -35.17 \text{ dBm}).$$

This problem continues in Sections 4-4, 4-7, and 4-10.

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TWO-WAY RADAR EQUATION (MONOSTATIC)

In this section the radar equation is derived from the one-way equation (transmitter to receiver) which is then extended to the two-way radar equation. The following is a summary of the important equations to be derived here:

TWO-WAY RADAR EQUATION (MONOSTATIC)

Peak power at the radar receiver input is:

$$P_r = \frac{P_t\, G_t\, G_r\, \lambda^2 \sigma}{(4\pi)^3 R^4} = P_t\, G_t\, G_r \left[\frac{\sigma c^2}{(4\pi)^3 f^2 R^4}\right]^*$$

Note : $\lambda = c/f$ and $\sigma = RCS$

** keep λ or c, σ, and R in the same units*

On reducing the above equation to log form we have:
$10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r + 10\log \sigma - 20\log f - 40\log R - 30\log 4\pi + 20\log c$

or in simplified terms: $10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r + G_\sigma - 2\alpha_1$ (in dB)

Note: Losses due to antenna polarization and atmospheric absorption (Sections 3-2 and 5-1) are not included in these equations.

Target gain factor, $G_\sigma = 10\log \sigma + 20\log f_1 + K_2$ (in dB)

K_2 Values (dB)	RCS (σ) (units)	f_1 in MHz K_2 =	f_1 in GHz K_2 =
	m^2	-38.54	21.46
	ft^2	-48.86	11.14

One-way free space loss, $\alpha_1 = 20\log(f_1 R) + K_1$ (in dB)

K_1 Values (dB)	Range (units)	f_1 in MHz K_1 =	f_1 in GHz K_1 =
	NM	37.8	97.8
	Km	32.45	92.45
	m	-27.55	32.45
	yd	-28.33	31.67
	ft	-37.87	22.13

Figure 1 illustrates the physical concept and equivalent circuit for a target being illuminated by a monostatic radar (transmitter and receiver co-located). Note the similarity of Figure 1 to Figure 3 in Section 4-3. Transmitted power, transmitting and receiving antenna gains, and the one-way free space loss are the same as those described in Section 4-3. The physical arrangement of the elements is different, of course, but otherwise the only difference is the addition of the equivalent gain of the target RCS factor.

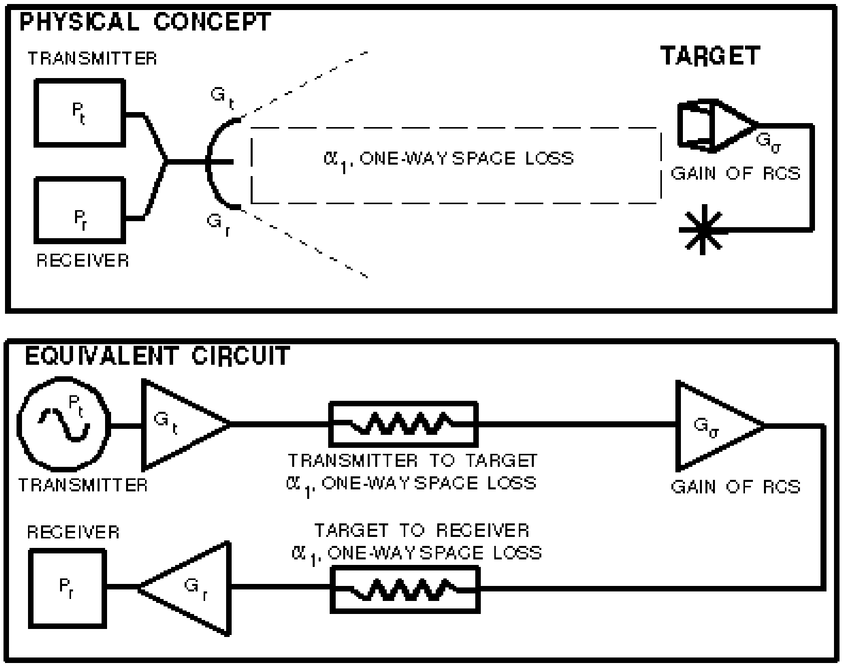
PHYSICAL CONCEPT
TRANSMITTER
P_t
P_r
RECEIVER
G_t
G_r
α_1, ONE-WAY SPACE LOSS
TARGET
G_σ
GAIN OF RCS
EQUIVALENT CIRCUIT
P_t
G_t
TRANSMITTER
TRANSMITTER TO TARGET
α_1, ONE-WAY SPACE LOSS
G_σ
GAIN OF RCS
RECEIVER
P_r
G_r
TARGET TO RECEIVER
α_1, ONE-WAY SPACE LOSS

Figure 1. The Two-Way Monostatic Radar Equation Visualized.

From Section 4-3, One-Way Radar Equation / RF Propagation, the power in the receiver is:

$$\begin{matrix}\textit{Received Signal}\\ \textit{at Target}\end{matrix} = \frac{P_t G_t G_r \lambda^2}{(4\pi R)^2} \qquad \textbf{[1]}$$

From equation [3] in Section 4-3: $$\textit{Antenna Gain}, G = \frac{4\pi A_e}{\lambda^2} \qquad \textbf{[2]}$$

Similar to a receiving antenna, a radar target also intercepts a portion of the power, but reflects (reradiates) it in the direction of the radar. The amount of power reflected toward the radar is determined by the Radar Cross Section (RCS) of the target. RCS is a characteristic of the target that represents its size as seen by the radar and has the dimensions of area (σ) as shown in Section 4-11. RCS area is not the same as physical area. But, for a radar target, the power reflected in the radar's direction is equivalent to re-radiation of the power captured by an antenna of area σ (the RCS). Therefore, the effective capture area (A_e) of the receiving antenna is replaced by the RCS (σ).

$$G_r = \frac{4\pi\sigma}{\lambda^2} \qquad \textbf{[3]}$$

so we now have:

$$\begin{matrix}\textit{Reflected Signal}\\ \textit{from target}\end{matrix} = \frac{P_t G_t \lambda^2 \, 4\pi\sigma}{(4\pi R)^2 \lambda^2} \qquad \textbf{[4]}$$

The equation for the power reflected in the radar's direction is the same as equation [1] except that P_t G_t, which was the original transmitted power, is replaced with the reflected signal power from the target, from equation [4]. This gives:

$$\begin{matrix}\textit{Reflected Signal Received Back}\\ \textit{at Input to Radar Receiver}\end{matrix} = \frac{P_t G_t \lambda^2 \, 4\pi\sigma}{(4\pi R)^2 \lambda^2} \, x \, \frac{G_r \lambda^2}{(4\pi R)^2} \qquad \textbf{[5]}$$

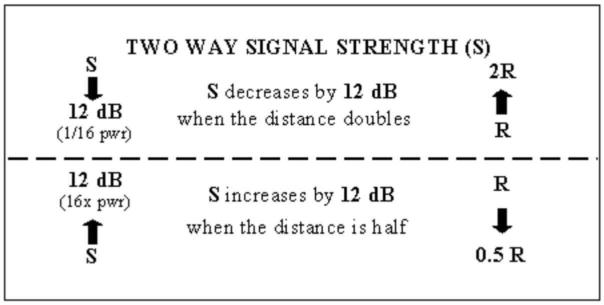

If like terms are cancelled, the two-way radar equation results. The peak power at the radar receiver input is:

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R^4} = P_t G_t G_r \left[\frac{\sigma c^2}{(4\pi)^3 f^2 R^4} \right]^* \qquad \textbf{[6]}$$

* Note: $\lambda = c/f$ and σ = RCS. Keep λ or c, σ, and R in the same units.

On reducing equation [6] to log form we have:

$$10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r + 10\log \sigma - 20\log f - 40\log R - 30\log 4\pi + 20\log c \qquad \textbf{[7]}$$

Target Gain Factor

If Equation [5] terms are rearranged instead of cancelled, a recognizable form results:

$$S\,(or\ P_r) = (P_t G_t G_r) \bullet \left[\frac{\lambda^2}{(4\pi R)^2}\right] \bullet \left[\frac{4\pi\sigma}{\lambda^2}\right] \bullet \left[\frac{\lambda^2}{(4\pi R)^2}\right] \qquad \textbf{[8]}$$

In log form:

$$10\log[S\,(or\ P_r)] = 10\log P_t + 10\log G_t + 10\log G_r + 20\log\left[\frac{\lambda}{4\pi R}\right] + 10\log\left[\frac{4\pi\sigma}{\lambda^2}\right] + 20\log\left[\frac{\lambda}{4\pi R}\right] \qquad \textbf{[9]}$$

The fourth and sixth terms can each be recognized as -α, where α is the one-way free space loss factor defined in Section 4-3. The fifth term containing RCS (σ) is the only new factor, and it is the "Target Gain Factor."

In simplified terms the equation becomes:

$$10\log\,[S\,(\text{or } P_r)] = 10\log P_t + 10\log G_t + 10\log G_r + G_\sigma - 2\alpha_1 \qquad \text{(in dB)} \qquad \textbf{[10]}$$

Where α_1 and G_σ are as follows:

From Section 4-3, equation [11], the space loss in dB is given by:

$$\alpha_1 = 20\log\left[\frac{4\pi f\,R}{c}\right]^* = 20\log f_1 R + K_1 \quad where\ K_1 = 20\log\left[\frac{4\pi}{c} \bullet (Conversion\ units\ if\ not\ in\ m/s\text{ec}, m, and\ Hz)\right] \qquad \textbf{[11]}$$

* Keep c and R in the same units. The table of values for K_1 is again presented here for completeness. The constant, K_1, in the table includes a range and frequency unit conversion factor.

While it's understood that RCS is the antenna aperture area equivalent to an isotropically radiated target return signal, the target gain factor represents a gain, as shown in the equivalent circuit of Figure 1. The Target Gain Factor expressed in dB is G_σ as shown in equation [12].

One-way free space loss, α_1 = 20log (f_1R) + K_1 (in dB)

K_1 Values (dB)	Range (units)	f_1 in MHz K_1 =	f_1 in GHz K_1 =
	NM	37.8	97.8
	Km	32.45	92.45
	m	-27.55	32.45
	yd	-28.33	31.67
	ft	-37.87	22.13

$$G_\sigma = 10\log\left[\frac{4\pi\sigma}{\lambda^2}\right] = 10\log\left[\frac{4\pi\sigma f^2}{c^2}\right] = 10\log\sigma + 20\log f_1 + K_2 \quad (in\ dB) \qquad \textbf{[12]}$$

$$where: K_2 = 10\log\left[\frac{4\pi}{c^2} \bullet \left(\begin{matrix} Frequency\ and\ RCS \\ conversions\ as\ required \end{matrix} \quad \frac{(Hz\ to\ MHz\ or\ GHz)^2}{(meters\ to\ feet)^2}\right)\right]$$

The “Target Gain Factor” (G_σ) is a composite of RCS, frequency, and dimension conversion factors and is called by various names: “Gain of RCS”, “Equivalent Gain of RCS”, “Gain of Target Cross Section”, and in dB form “Gain-sub-Sigma”.

If frequency is given in MHz and RCS (σ) is in m^2, the formula for G_σ is:

$$G_\sigma = 10\log\sigma + 20\log f_1 + 10\log\left[4\pi \bullet \left(\frac{\sec}{3\,x\,10^8\,m}\right)^2 \bullet m^2 \bullet \left(\frac{1x\,10^6}{\sec}\right)^2\right] \qquad \textbf{[13]}$$

or:

$$G_\sigma = 10\log\sigma + 20\log f_1 - 38.54 \quad (in\ dB) \qquad \textbf{[14]}$$

Target gain factor, G_σ = 10log σ + 20log f_1 + K_2 (in dB)

K_2 Values			
(dB)	RCS (σ)	f_1 in MHz	f_1 in GHz
(units)	K_2 =	K_2 =	
m^2	-38.54	21.46	
ft^2	-48.86	11.14	

For this example, the constant K_2 is -38.54 dB. K_2 values for various area and frequency and frequency units are summarized in the adjoining table.

In the two-way radar equation, the one-way free space loss factor (α_1) is used twice, once for the radar transmitter to target path and once for the target to radar receiver path. The radar illustrated in Figure 1 is monostatic so the two path losses are the same and the values of the two α_1’s are the same.

If the transmission loss in Figure 1 from P_t to G_t equals the loss from G_r to P_r, and $G_r = G_t$, then equation [10] can be written as:

$$10\log\,[S \text{ or } P_r] = 10\log P_t + 20\log G_{tr} - 2\alpha_1 + G_\sigma \quad \text{(in dB)} \qquad \textbf{[15]}$$

The space loss factor (α_1) and the target gain factor (G_σ) include all the necessary unit conversions so that they can be used directly with the most common units. Because the factors are given in dB form, they are more convenient to use and allow calculation without a calculator when the factors are read from a chart or nomograph.

Most radars are monostatic. That is, the radar transmitting and receiving antennas are literally the same antenna. There are some radars that are considered “monostatic” but have separate transmitting and receiving antennas that are co-located. In that case, equation [10] could require two different antenna gain factors as originally derived:

$$10\log\,[S \text{ or } P_r] = 10\log P_t + 10\log G_t + 10\log G_r - 2\alpha_1 + G_\sigma \quad \text{(in dB)} \qquad \textbf{[16]}$$

Note: To avoid having to include additional terms for these calculations, always combine any transmission line loss with antenna gain.

Figure 2 is the visualization of the path losses occurring with the two-way radar equation. **Note:** to avoid having to include additional terms, always combine any transmission line loss with antenna gain. Losses due to antenna polarization and atmospheric absorption also need to be included.

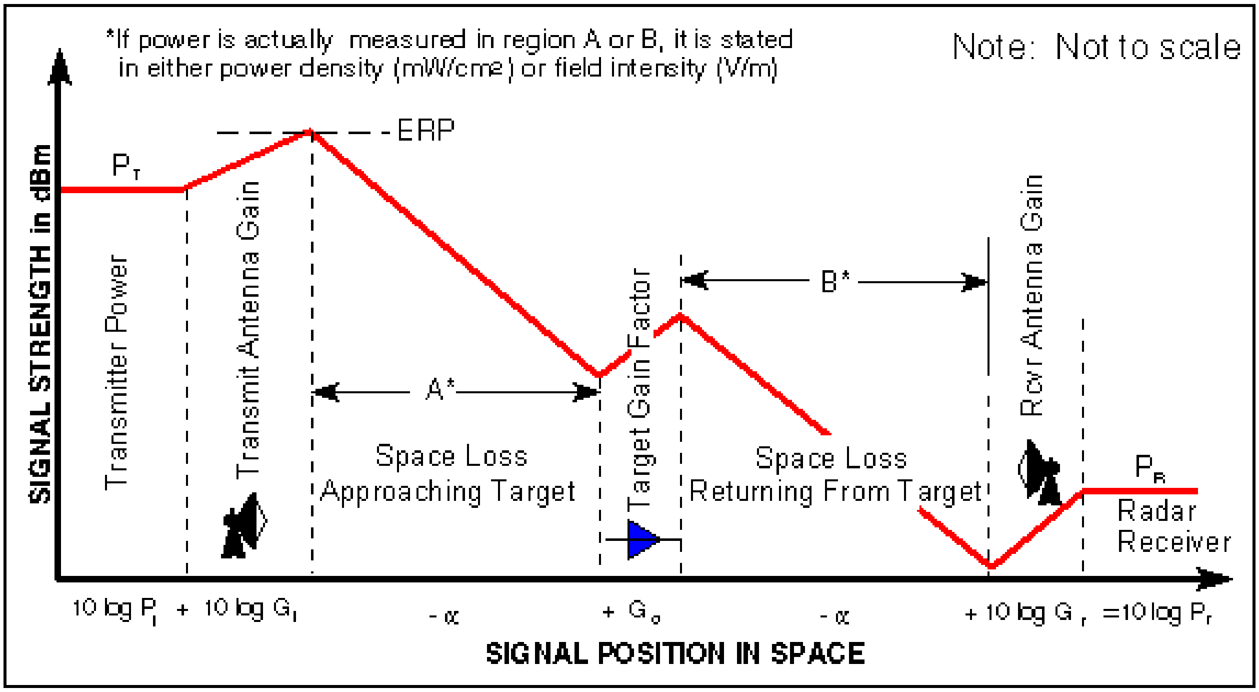
*If power is actually measured in region A or B, it is stated in either power density (mW/cm²) or field intensity (V/m)
Note: Not to scale
SIGNAL STRENGTH in dBm
P_T
ERP
Transmitter Power
Transmit Antenna Gain
A*
Space Loss Approaching Target
Target Gain Factor
B*
Space Loss Returning From Target
Rcvr Antenna Gain
P_R
Radar Receiver
10 log P_t + 10 log G_t
- α
+ G_σ
- α
+ 10 log G_r =10 log P_r
SIGNAL POSITION IN SPACE

Figure 2. Visualization of Two-Way Radar Equation.

RADAR RANGE EQUATION (Two-Way Equation)

The Radar Equation is often called the "Radar Range Equation." The Radar Range Equation is simply the Radar Equation rewritten to solve for maximum Range. The maximum radar range (R_{max}) is the distance beyond which the target can no longer be detected and correctly processed. It occurs when the received echo signal just equals S_{min}.

The Radar Range Equation is then:

$$R_{\max} \cong \left[\frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 S_{\min}}\right]^{\frac{1}{4}} \ or \ \left[\frac{P_t G_t G_r c^2 \sigma]}{(4\pi)^3 f^2 S_{\min}}\right]^{\frac{1}{4}} \ or \ \left[\frac{P_t G_t A_e \sigma}{(4\pi)^2 S_{\min}}\right]^{\frac{1}{4}} \qquad \textbf{[17]}$$

The first equation, of the three above, is given in Log form by:

$$40\log R_{max} \cong 10\log P_t + 10\log G_t + 10\log G_r + 10\log \sigma - 10\log S_{min} - 20\log f - 30\log 4\pi + 20\log c \qquad \textbf{[18]}$$

As shown previously, Since $K_1 = 20\log [(4\pi/c)$ times conversion units if not in m/sec, m, and Hz], we have:

$$10\log R_{max} \cong \tfrac{1}{4}\,[10\log P_t + 10\log G_t + 10\log G_r + 10\log \sigma - 10\log S_{min} - 20\log f_1 - K_1 - 10.99 \text{ dB}] \qquad \textbf{[19]}$$

If you want to convert back from dB, then

$$R_{max} \cong 10^{\frac{M\,dB}{40}}$$

Where M dB is the resulting number within the brackets of equation 19.

One-way free space loss, $\alpha_1 = 20\log(f_1R) + K_1$ (in dB)

K_1 Values (dB)	Range (units)	f_1 in MHz K_1 =	f_1 in GHz K_1 =
	NM	37.8	97.8
	Km	32.45	92.45
	m	-27.55	32.45
	yd	-28.33	31.67
	ft	-37.87	22.13

From Section 5-2, Receiver Sensitivity / Noise, S_{min} is related to the noise factors by:

$$S_{min} = (S/N)_{min}(NF)\,kT_0B \qquad \textbf{[20]}$$

The Radar Range Equation for a tracking radar (target continuously in the antenna beam) becomes:

$$R_{max} \cong \left[\frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 (S/N)_{min}(NF)kT_0B}\right]^{\frac{1}{4}} \text{ or } \left[\frac{P_t G_t G_r c^2 \sigma}{(4\pi)^3 f^2 (S/N)_{min}(NF)kT_oB}\right]^{\frac{1}{4}} \text{ or } \left[\frac{P_t G_t A_e \sigma}{(4\pi)^2 (S/N)_{min}(NF)kT_oB}\right]^{\frac{1}{4}} \qquad \textbf{[21]}$$

P_t in equations [17], [19], and [21] is the peak power of a CW or pulse signal. For pulse signals these equations assume the radar pulse is square. If not, there is less power since P_t is actually the average power within the pulse width of the radar signal. Equations [17] and [19] relate the maximum detection range to S_{min}, the minimum signal which can be detected and processed (the receiver sensitivity). The bandwidth (B) in equations [20] and [21] is directly related to S_{min}. B is approximately equal to 1/PW. Thus a wider pulse width means a narrower receiver bandwidth which lowers S_{min}, assuming no integration.

One cannot arbitrarily change the receiver bandwidth, since it has to match the transmitted signal. The "widest pulse width" occurs when the signal approaches a CW signal (see Section 2-11). A CW signal requires a very narrow bandwidth (approximately 100 Hz). Therefore, receiver noise is very low and good sensitivity results (see Section 5-2). If the radar pulse is narrow, the receiver filter bandwidth must be increased for a match (see Section 5-2), i.e. a 1 μs pulse requires a bandwidth of approximately 1 MHz. This increases receiver noise and decreases sensitivity.

If the radar transmitter can increase its PRF (decreasing PRI) and its receiver performs integration over time, an increase in PRF can permit the receiver to "pull" coherent signals out of the noise thus reducing S/N_{min} thereby increasing the detection range. Note that a PRF increase may limit the maximum range due to the creation of overlapping return echoes (see Section 2-10).

There are also other factors that limit the maximum practical detection range. With a scanning radar, there is loss if the receiver integration time exceeds the radar's time on target. Many radars would be range limited by line-of-sight/radar horizon (see Section 2-9) well before a typical target faded below S_{min}. Range can also be reduced by losses due to antenna polarization and atmospheric absorption (see Sections 3-2 and 5-1).

Two-Way Radar Equation (Example)

Assume that a 5 GHz radar has a 70 dBm (10 kilowatt) signal fed through a 5 dB loss transmission line to a transmit/receive antenna that has 45 dB gain. An aircraft that is flying 31 km from the radar has an RCS of 9 m^2. What is the signal level at the input to the radar receiver? (There is an additional loss due to any antenna polarization mismatch but that loss will not be addressed in this problem). This problem continues in Sections 4-3, 4-7, and 4-10.

Answer:

Starting with: $10\log S = 10\log P_t + 10\log G_t + 10\log G_r + G_\sigma - 2\alpha_1$ (in dB)

We know that: $\alpha_1 = 20\log fR + K_1 = 20\log(5\text{x}31) + 92.44 = 136.25$ dB

and that: $G_\sigma = 10\log\sigma + 20\log f_1 + K_2 = 10\log 9 + 20\log 5 + 21.46 = 44.98$ dB (see Table 1)
(Note: The aircraft transmission line losses (-5 dB) will be combined with the antenna gain
(45 dB) for both receive and transmit paths of the radar)

So, substituting in we have: $10\log S = 70 + 40 + 40 + 44.98 - 2(136.25) =$ **-77.52 dBm** @ 5 GHz

The answer changes to -80.44 dBm if the tracking radar operates at 7 GHz provided the antenna gains and the aircraft RCS are the same at both frequencies.

$\alpha_1 = 20\log(7\text{x}31) + 92.44 = 139.17$ dB, $G_\sigma = 10\log 9 + 20\log 7 + 21.46 = 47.9$ dB (see Table 1)

$10\log S = 70 + 40 + 40 + 47.9 - 2(139.17) =$ **-80.44 dBm** @ 7 GHz

Table 1. Values of the Target Gain Factor (G_σ) in dB for Various Values of Frequency and RCS.

Frequency (GHz)	RCS - Square meters						
	0.05	5	9	10	100	1,000	10,000
0.5 GHz	2.44	22.42	24.98	25.44	35.44	45.44	55.44
1 GHz	8.46	28.46	31.0	31.46	41.46	51.46	61.46
5 GHz	22.44	42.44	44.98	45.44	55.44	65.44	75.44
7 GHz	25.36	45.36	47.9	48.36	58.36	68.36	78.36
10 GHz	28.46	48.46	51.0	51.46	61.46	71.46	81.46
20 GHz	34.48	54.48	57.02	57.48	67.48	77.48	87.48
40 GHz	40.50	60.48	63.04	63.5	73.5	83.5	93.5

Note: Shaded values were used in the examples.

TWO-WAY RADAR RANGE INCREASE AS A RESULT OF A SENSITIVITY INCREASE

As shown in equation [17] $S_{min}^{-1} \propto R_{max}^4$. Therefore, $-10\log S_{min} \propto 40\log R_{max}$ and the table below results:

% Range Increase: Range + (% Range Increase) x Range = New Range
i.e., for a 12 dB sensitivity increase, 500 miles +100% x 500 miles = 1,000 miles
Range Multiplier: Range x Range Multiplier = New Range
i.e., for a 12 dB sensitivity increase 500 miles x 2 = 1,000 miles

Table 2. Effects of Sensitivity Increase.

dB Sensitivity Increase	% Range Increase	Range Multiplier	dB Sensitivity Increase	% Range Increase	Range Multiplier
+ 0.5	3	1.03	10	78	1.78
1.0	6	1.06	11	88	1.88
1.5	9	1.09	12	100	2.00
2	12	1.12	13	111	2.11
3	19	1.19	14	124	2.24
4	26	1.26	15	137	2.37
5	33	1.33	16	151	2.51
6	41	1.41	17	166	2.66
7	50	1.50	18	182	2.82
8	58	1.58	19	198	2.98
9	68	1.68	20	216	3.16

TWO-WAY RADAR RANGE DECREASE AS A RESULT OF A SENSITIVITY DECREASE

As shown in equation [17] $S_{min}^{-1} \propto R_{max}^{4}$ Therefore, $-10 \log S_{min} \propto 40 \log R_{max}$ and the table below results:

% Range Decrease: Range - (% Range Decrease) x Range = New Range
i.e., for a 12 dB sensitivity decrease, 500 miles - 50% x 500 miles = 250 miles

Range Multiplier: Range x Range Multiplier = New Range
i.e., for a 12 dB sensitivity decrease 500 miles x 0.5 = 250 miles

Table 3. Effects of Sensitivity Decrease.

dB Sensitivity Decrease	% Range Decrease	Range Multiplier	dB Sensitivity Decrease	% Range Decrease	Range Multiplier
- 0.5	3	0.97	-10	44	0.56
- 1.0	6	0.94	- 11	47	0.53
- 1.5	8	0.92	- 12	50	0.50
- 2	11	0.89	- 13	53	0.47
- 3	16	0.84	- 14	55	0.45
- 4	21	0.79	- 15	58	0.42
- 5	25	0.75	- 16	60	0.40
- 6	29	0.71	- 17	62	0.38
- 7	33	0.67	- 18	65	0.35
- 8	37	0.63	- 19	67	0.33
- 9	40	0.60	- 20	68	0.32

ALTERNATE TWO-WAY RADAR EQUATION

In this section the same radar equation factors are grouped differently to create different constants as is used by some authors.

TWO-WAY RADAR EQUATION (MONOSTATIC)

Peak power at the radar receiver input is:

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R^4} = \frac{P_t G_t G_{rsigma} c^2}{(4\pi)^3 f^2 R^4}* \quad (Note: \lambda = \frac{c}{f} \text{ and } \sigma \text{ is RCS}) \qquad \textbf{[1]}$$

* Keep λ or c, σ, and R in the same units. On reducing the above equation to log form we have:

or: $\mathbf{10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r - \alpha_2}$ (in dB)

Where: $\alpha_2 = 20\log f_1 R^2 - 10\log \sigma + K_3$, and $K_3 = -10\log c^2/(4\pi)^3$

Note:
Losses due to antenna polarization and atmospheric absorption (Sections 3-2 and 5-1) are not included in these equations

K_3 Values:
(dB)

Range Units	f_1 in MHz σ in m^2	f_1 in GHz σ in m^2	f_1 in MHz σ in ft^2	f_1 in GHz σ in ft^2
NM	114.15	174.15	124.47	184.47
km	103.44	163.44	113.76	173.76
m	-16.56	43.44	-6.24	53.76
yd	-18.1	41.9	-7.78	52.22
ft	-37.2	22.8	-26.88	33.12

In the last section, we had the basic radar equation given as equation [6] and it is repeated as equation [1] in the table above.

In Section 4-4, in order to maintain the concept and use of the one-way space loss coefficient, α_1, we didn't cancel like terms which was done to form equation [6] there. Rather, we regrouped the factors of equation [5]. This resulted in two minus α_1 terms and we defined the remaining term as G_σ, which accounted for RCS (see equation [8] & [9]).

Some authors take a different approach, and instead develop an entirely new single factor α_2, which is used instead of the combination of α_1 and G_σ.

If equation [1] is reduced to log form, (and noting that $f = c/\lambda$) it becomes:

$$10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r - 20\log (f R^2) + 10\log \sigma + 10\log (c^2/(4\pi)^3) \qquad \textbf{[2]}$$

We now call the last three terms on the right minus α_2 and use it as a single term instead of the two terms α_1 and G_σ. The concept of dealing with one variable factor may be easier although we still need to know the range, frequency, and radar cross section to evaluate α_2. Additionally, we can no longer use a nomograph like we did in computing α_1 and visualize a two-way space loss consisting of two times the one-way space loss, since there are now 3 variables vs. two.

Equation [2] reduces to:

$$\mathbf{10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r - \alpha_2} \quad \text{(in dB)} \qquad \textbf{[3]}$$

Where $\alpha_2 = 20\log(f_1 R^2) - 10\log\sigma + K_3$ and where f_1 is the MHz or GHz value of frequency and $K_3 = -10\log(c^2/(4\pi)^3) + 20\log$ (conversion for Hz to MHz or GHz)+ 40log (range unit conversions if not in meters) - 20log (RCS conversions for meters to feet)

The values of K_3 are given in the table above.

Comparing equation [3] to equation [10] in Section 4-4, it can be seen that $\alpha_2 = 2\alpha_1 - G_\sigma$.

TWO-WAY RADAR EQUATION (BISTATIC)

The following table contains a summary of the equations developed in this section.

TWO-WAY RADAR EQUATION (BISTATIC)

Peak power at the radar receiver input is:

$$P_r = \frac{P_t\, G_t\, G_r\, \lambda^2\, \sigma}{(4\pi)^3\, R_{Tx}^2\, R_{Rx}^2} = P_t\, G_t\, G_r \left[\frac{\sigma\, c^2}{(4\pi)^3\, f^{\,2}\, R_{Tx}^2\, R_{Rx}^2} \right]^*$$

Note : $\lambda = c/f$ and σ = RCS

** keep λ or c, σ, and R in the same units*

On reducing the above equation to log form we have:
$10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r + 10\log \sigma - 20\log f + 20\log c - 30\log 4\pi - 20\log R_{Tx} - 20\log R_{Rx}$

or in simplified terms: $10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r + G_\sigma - \alpha_{Tx} - \alpha_{Rx}$ (in dB)

Where α_{Tx} corresponds to transmitter to target loss and α_{Rx} corresponds to target to receiver loss.

Note: Losses due to antenna polarization and atmospheric absorption (Sections 3-2 and 5-1) are not included in these equations.

Target gain factor, $G_\sigma = 10\log \sigma + 20\log f_1 + K_2$ (in dB)

K_2 Values (dB)	RCS (σ) (units)	f_1 in MHz K_2 =	f_1 in GHz K_2 =
	m^2	-38.54	21.46
	ft^2	-48.86	11.14

One-way free space loss, $\alpha_{Tx \text{ or } Rx} = 20\log (f_1 R_{Tx \text{ or } Rx}) + K_1$ (in dB)

K_1 Values (dB)	Range (units)	f_1 in MHz K_1 =	f_1 in GHz K_1 =
	NM	37.8	97.8
	Km	32.45	92.45
	m	-27.55	32.45
	yd	-28.33	31.67
	ft	-37.87	22.13

BISTATIC RADAR

There are also true bistatic radars - radars where the transmitter and receiver are in different locations as is depicted in Figure 1. The most commonly encountered bistatic radar application is the semi-active missile. The transmitter is located on, or near, the launch platform (surface or airborne), and the receiver is in the missile which is somewhere between the launch platform and the target.

The transmitting and receiving antennas are not the same and are not in the same location. Because the target-to-radar range is different from the target-to-missile range, the target-to-radar and target-to-missile space losses are different.

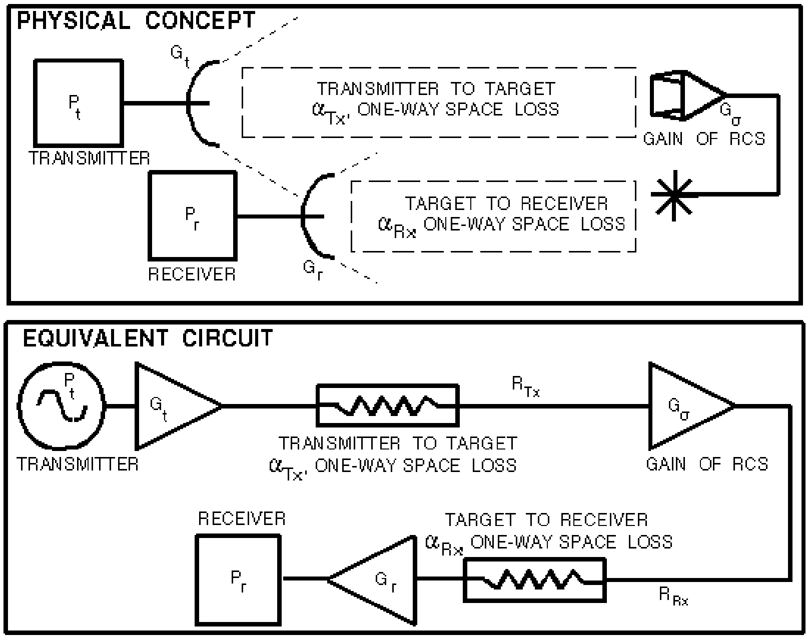
PHYSICAL CONCEPT
G_t
P_t
TRANSMITTER
TRANSMITTER TO TARGET
α_{Tx}, ONE-WAY SPACE LOSS
G_σ
GAIN OF RCS
P_r
RECEIVER
G_r
TARGET TO RECEIVER
α_{Rx} ONE-WAY SPACE LOSS
EQUIVALENT CIRCUIT
P_t
G_t
R_{Tx}
G_σ
TRANSMITTER
TRANSMITTER TO TARGET
α_{Tx}, ONE-WAY SPACE LOSS
GAIN OF RCS
RECEIVER
TARGET TO RECEIVER
α_{Rx} ONE-WAY SPACE LOSS
P_r
G_r
R_{Rx}

Figure 1. Bistatic Radar Visualized.

The peak power at the radar receiver input is:

$$P_r = \frac{P_t\, G_t\, G_r\, \lambda^2\, \sigma}{(4\pi)^3\, R_{Tx}^2\, R_{Rx}^2} = P_t\, G_t\, G_r \left[\frac{\sigma\, c^2}{(4\pi)^3\, f^{\,2}\, R_{Tx}^2\, R_{Rx}^2} \right] \qquad (\textit{Note}: \lambda = \frac{c}{f} \textit{ and } \sigma = RCS) \qquad \textbf{[1]}$$

Keep λ or c, σ, and R in the same units.

On reducing the above equation to log form we have:

$$10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r + 10\log \sigma - 20\log f + 20\log c - 30\log 4\pi - 20\log R_{Tx} - 20\log R_{Rx} \quad \textbf{[2]}$$

or in simplified terms:

$$10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r + G_\sigma - \alpha_{Tx} - \alpha_{Rx} \quad \text{(in dB)} \qquad \textbf{[3]}$$

Where α_{Tx} corresponds to transmitter to target loss and α_{Rx} corresponds to target to receiver loss, or:

$\alpha_{Tx} = 20\log(f_1 T_{Tx}) + K_1$ (in dB) and $\alpha_{Rx} = 20\log(f_1 T_{Rx}) + K_1$ (in dB)

with K_1 values provided on page 4-6.1 and with f_1 being the MHz or GHz value of frequency.

Therefore, the difference between monostatic and bistatic calculations is that two α's are calculated for two different ranges and different gains may be required for transmit and receive antennas.

To avoid having to include additional terms for these calculations, always combine any transmission line loss with antenna gain.

As shown in Figure 2, it should also be noted that the bistatic RCS received by the missile is not always the same as the monostatic RCS. In general, the target's RCS varies with angle. Therefore, the bistatic RCS and monostatic RCS will be equal for receive and transmit antennas at the same angle to the target (but only if all three are in a line, as RCS also varies with elevation angle).

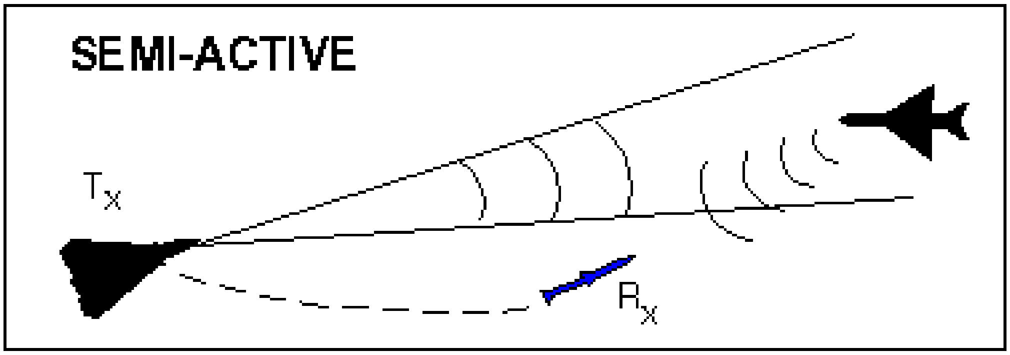

Figure 2. Bistatic RCS Varies.

JAMMING TO SIGNAL (J/S) RATIO - CONSTANT POWER [SATURATED] JAMMING

The following table contains a summary of the equations developed in this section.

<table>
<tr>
<td>JAMMING TO SIGNAL (J/S) RATIO (MONOSTATIC)
$J/S = (P_j G_{ja} 4\pi R^2) / (P_t G_t \sigma)$ (ratio form)* or:
$10\log J/S = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - 10\log\sigma^* + 10.99\text{ dB} + 20\log R^*$
Note (1): Neither f nor λ terms are part of these equations</td>
<td rowspan="2">* Keep R and σ in same units
Target gain factor, (in dB)
$G_\sigma = 10\log\sigma + 20\log f_1 + K_2$
K_2 Values (dB):
<table>
<tr><td>RCS (σ)
(units)</td><td>f_1 in MHz
$K_2 =$</td><td>f_1 in GHz
$K_2 =$</td></tr>
<tr><td>m2</td><td>-38.54</td><td>21.46</td></tr>
<tr><td>ft2</td><td>-48.86</td><td>11.14</td></tr>
</table>
</td>
</tr>
<tr>
<td>If simplified radar equations developed in previous sections are used:
$10\log J/S = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - G_\sigma + \alpha_1$ (in dB)
Note (2): the $20\log f_1$ term in $-G_\sigma$ cancels the $20\log f_1$ term in α_1</td>
</tr>
<tr>
<td>JAMMING TO SIGNAL (J/S) RATIO (BISTATIC)
R_{Tx} is the range from the radar transmitter to the target. See note (1).
$J/S = (P_j G_{ja} 4\pi R_{Tx}^2) / (P_t G_t \sigma)$ (ratio form) * or:
$10\log J/S = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - 10\log\sigma^* + 10.99\text{ dB} + 20\log R_{Tx}^*$</td>
<td rowspan="2">One-way free space loss (dB)
α_1 or $\alpha_{Tx} =$
$20\log(f_1 R) + K_1$
K_1 Values (dB):
<table>
<tr><td>Range
(units)</td><td>f_1 in MHz
$K_1 =$</td><td>f_1 in GHz
$K_1 =$</td></tr>
<tr><td>NM</td><td>37.8</td><td>97.8</td></tr>
<tr><td>km</td><td>32.45</td><td>92.45</td></tr>
<tr><td>m</td><td>-27.55</td><td>32.45</td></tr>
<tr><td>ft</td><td>-37.87</td><td>22.13</td></tr>
</table>
</td>
</tr>
<tr>
<td>If simplified radar equations developed in previous sections are used: see note (2).
$10\log J/S = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - G_\sigma + \alpha_{Tx}$ (in dB)</td>
</tr>
</table>

This section derives the J/S ratio from the one-way range equation for J and the two-way range equation for S, and deals exclusively with active (transmitting) Electronic Attack (EA) devices or systems. Furthermore, the only purpose of EA is to prevent, delay, or confuse the radar processing of target information.

By official definition, EA can be either Jamming or Deception. This may be somewhat confusing because almost any type of active EA is commonly called "jamming," and the calculations of EA signal in the radar compared to the target signal in the radar commonly refer to the "jamming-to-signal" ratio ("J-to-S" ratio). Therefore this section uses the common jargon and the term "jammer" refers to any EA transmitter, and the term "jamming" refers to any EA transmission, whether Deception or Concealment.

Jamming: "Official" jamming should more aptly be called Concealment or Masking. Essentially, Concealment uses electronic transmissions to swamp the radar receiver and hide the targets. Concealment (Jamming) usually uses some form of noise as the transmitted signal. In this section, Concealment will be called "noise" or "noise jamming."

Deception: Deception might be better called Forgery. Deception uses electronic transmissions to forge false target signals that the radar receiver accepts and processes as real targets.

"J" designates the EA signal strength whether it originates from a noise jammer or from a deception system.

Basically, there are two different methods of employing active EA against hostile radars:

Self Protection EA
Support EA

For most practical purposes, Self Protection EEA is usually Deception and Support EA is usually noise jamming. As the name implies, Self Protection EA is EA that is used to protect the platform that it is on. Self Protection EA is often called "self screening jamming," "Defensive EA" or historically "Deception ECM." The top half of Figure 1 shows self-screening jamming.

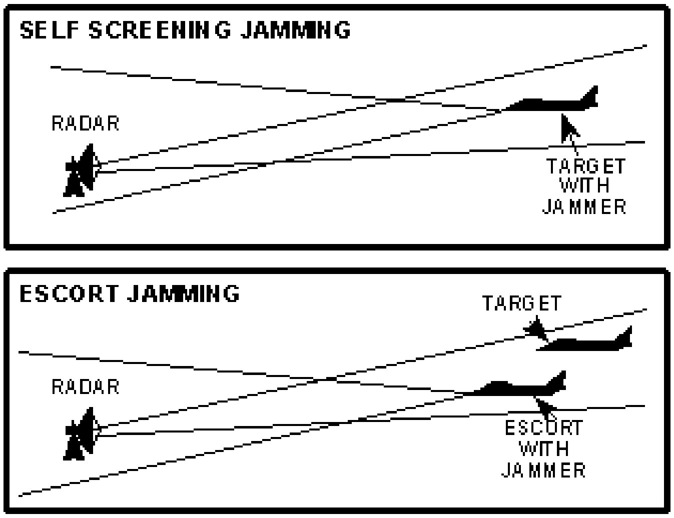

Figure 1. Self Protection and Escort Jamming.

The bottom half of Figure 1 illustrates escort jamming which is a special case of support jamming. If the escort platform is sufficiently close to the target, the J-to-S calculations are the same as for self protection EA.

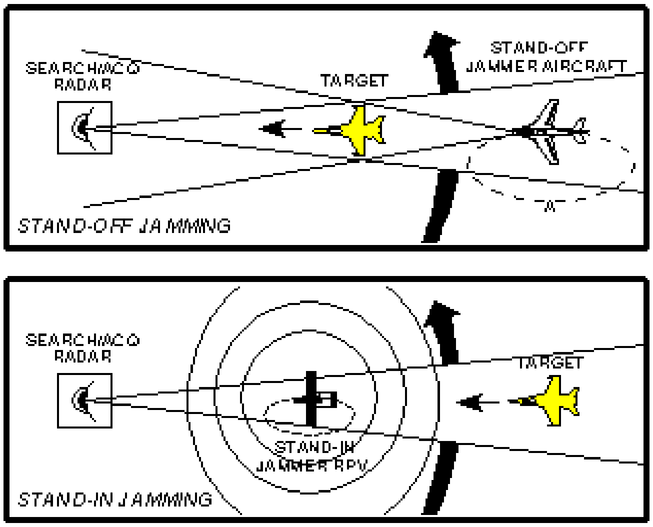

Figure 2. Support Jamming.

Support EA is electronic transmissions radiated from one platform and is used to protect other platforms or fulfill other mission requirements, like distraction or conditioning. Figure 2 illustrates two cases of support jamming protecting a striker - stand-off jamming (SOJ) and stand-in jamming (SIJ). For SOJ the support jamming platform is maintaining an orbit at a long range from the radar - usually beyond weapons range. For SIJ, a remotely piloted vehicle is orbiting very close to the victim radar. Obviously, the jamming power required for the SOJ to screen a target is much greater than the jamming power required for the SIJ to screen the same target.

When factoring EA into the radar equation, the quantities of greatest interest are "J-to-S" and Burn-Through Range.

"J-to-S" is the ratio of the signal strength of the jammer signal (J) to the signal strength of the target return signal (S). It is expressed as "J/S" and, in this section, is always in dB. J usually (but not always) must exceed S by some amount to be effective, therefore the desired result of a J/S calculation in dB is a positive number. Burn-through Range is the radar to target range where the target return signal can first be detected through the jamming and is usually slightly farther than crossover range where J=S. It is usually the range where the J/S just equals the minimum effective J/S (See Section 4-8).

The significance of "J-to-S" is sometimes misunderstood. The effectiveness of EA **is not** a direct mathematical function of "J-to-S." The magnitude of the "J-to-S" required for effectiveness is a function of the particular EA technique and of the radar it is being used against. Different EA techniques may very well require different "J-to-S" ratios against the same radar. When there is sufficient "J-to-S" for effectiveness, increasing it will rarely increase the effectiveness at a given range. Because modern radars can have sophisticated signal processing and/or EP capabilities, in certain radars too much "J-to-S" could cause the signal processor to ignore the jamming, or activate special anti-jamming modes. Increasing "J-to-S" (or the jammer power) does, however, allow the target aircraft to get much closer to the threat radar before burn-through occurs, which essentially means more power is better if it can be controlled when desired.

IMPORTANT NOTE: If the signal S is CW or PD and the Jamming J is amplitude modulated, then the J used in the formula has to be reduced from the peak value (due to sin x/x frequency distribution). The amount of reduction is dependent upon how much of the bandwidth is covered by the jamming signal. To get an exact value, integrals would have to be taken over the bandwidth. As a rule of thumb however:

- If the frequency of modulation is less than the BW of the tracking radar reduce J/S by 10 Log (duty cycle).
- If the frequency of modulation is greater than the BW of the tracking radar reduce J/S by 20 Log(duty cycle).

For example; if your jamming signal is square wave chopped (50% duty cycle) at a 100 Hz rate while jamming a 1 kHz bandwidth receiver, then the J/S is reduced by 3 dB from the maximum. If the duty cycle was 33%, then the reduction would be 4.8 dB. If the 50% and 33% duty cycle jamming signals were chopped at a 10 kHz (vice the 100 Hz) rate, the rule of thumb for jamming seen by the receiver would be down 6 dB and 9.6 dB, respectively, from the maximum since the 10 kHz chopping rate is greater than the 1 kHz receiver BW.

J/S for SELF PROTECTION EA vs. MONOSTATIC RADAR

Figure 3 is radar jamming visualized. The Physical concept of Figure 3 shows a monostatic radar that is the same as Figure 1, Section 4-4, and a jammer (transmitter) to radar (receiver) that is the same as Figure 3, Section 4-3. In other words, Figure 3 is simply the combination of the previous two visual concepts where there is only one receiver (the radar's).

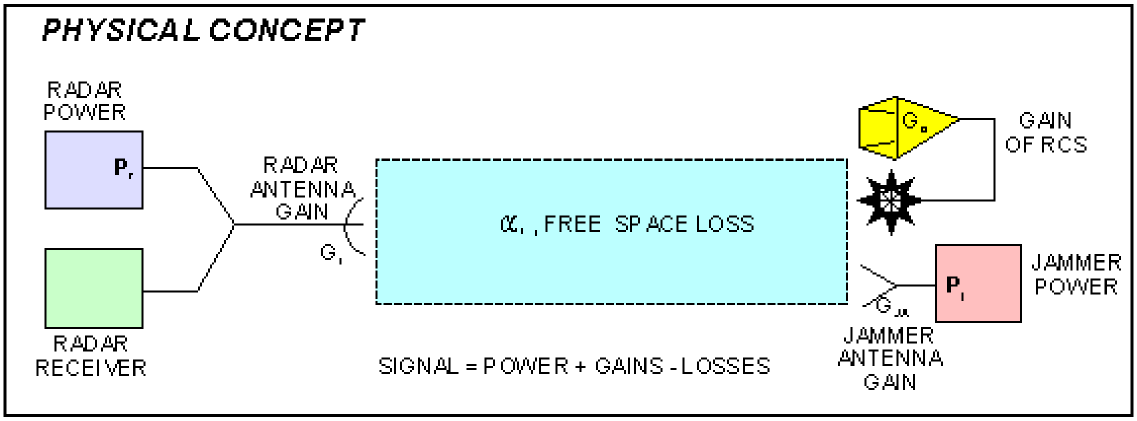

Figure 3. Radar Jamming Visualized.

The equivalent circuit shown in Figure 4 applies to jamming monostatic radars with either self protect EA or support EA. For self protect (or escort) vs. a monostatic radar, the jammer is on the target and the radar receive and transmit antennas are collocated so the three ranges and three space loss factors (α's) are the same.

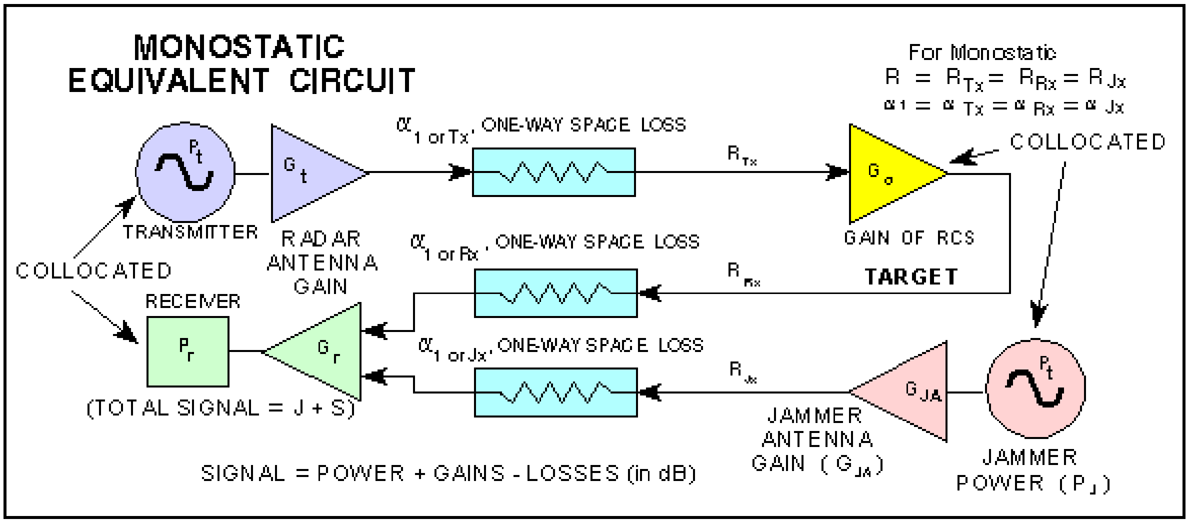
MONOSTATIC
EQUIVALENT CIRCUIT
For Monostatic
$R = R_{Tx} = R_{Rx} = R_{Jx}$
$\alpha_1 = \alpha_{Tx} = \alpha_{Rx} = \alpha_{Jx}$
P_t
G_t
TRANSMITTER
RADAR ANTENNA GAIN
$\alpha_{1 \text{ or } Tx}$, ONE-WAY SPACE LOSS
R_{Tx}
G_σ
COLLOCATED
GAIN OF RCS
TARGET
$\alpha_{1 \text{ or } Rx}$, ONE-WAY SPACE LOSS
R_{Rx}
COLLOCATED
RECEIVER
P_r
G_r
(TOTAL SIGNAL = J + S)
$\alpha_{1 \text{ or } Jx}$, ONE-WAY SPACE LOSS
R_{Jx}
G_{JA}
P_t
JAMMER ANTENNA GAIN (G_{JA})
JAMMER POWER (P_J)
SIGNAL = POWER + GAINS - LOSSES (in dB)

Figure 4. Monostatic Radar EA Equivalent Circuit.

J-S Ratio (Monostatic) - The ratio of the power received (P_{r1} or J) from the jamming signal transmitted from the target to the power received (P_{r2} or S) from the radar skin return from the target equals J/S.

From the one way range equation in Section 4-3: $$P_r 1 \text{ or } J = \frac{P_j G_{ja} G_r \lambda^2}{(4\pi R)^2} \qquad \textbf{[1]}$$

From the two way range equation in Section 4.4: $$P_r 2 \text{ or } S = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R^4} \qquad \textbf{[2]}$$

so $$\frac{J}{S} = \frac{P_j G_{ja} G_r \lambda^2 (4\pi)^3 R^4}{P_t G_t G_r \lambda^2 \sigma (4\pi R)^2} = \frac{P_j G_{ja} 4\pi R^2}{P_t G_t \sigma}^{*} \qquad \textit{(ratio form)} \qquad \textbf{[3]}$$

* Keep R and σ in the same units.

On reducing the above equation to log form we have:

$10\log J/S = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - 10\log \sigma + 10\log 4\pi + 20\log R$ **[4]**

or $10\log J/S = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - 10\log \sigma + 10.99 \text{ dB} + 20\log R$ **[5]**

Note: Neither *f* nor λ terms are part of the final form of equation [3] and equation [5].

J/S Calculations (Monostatic) Using a One Way Free Space Loss - The simplified radar equations developed in previous sections can be used to express J/S.

From the one way range equation Section 4-3:

$$10\log(P_{r1} \text{ or } J) = 10\log P_j + 10\log G_{ja} + 10\log G_r - \alpha_1 \quad \text{(in dB)} \qquad \textbf{[6]}$$

From the two way range equation in Section 4.4:

$$10\log(P_{r2} \text{ or } S) = 10\log P_t + 10\log G_t + 10\log G_r + G_\sigma - 2\alpha_1 \quad \text{(in dB)} \qquad \textbf{[7]}$$

$$10\log(J/S) = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - G_\sigma + \alpha_1 \quad \text{(in dB)} \qquad \textbf{[8]}$$

Note: To avoid having to include additional terms for these calculations, always combine any transmission line loss with antenna gain. The $20\log f_1$ term in $-G_\sigma$ cancels the $20\log f_1$ term in α_1.

Target gain factor, $G_\sigma = 10\log\sigma + 20\log f_1 + K_2$ (in dB)

K_2 Values (dB)	RCS (σ) (units)	f_1 in MHz K_2 =	f_1 in GHz K_2 =
	m^2	-38.54	21.46
	ft^2	-48.86	11.14

One-way free space loss, $\alpha_1 = 20\log(f_1 R) + K_1$ (in dB)

K_1 Values (dB)	Range (units)	f_1 in MHz K_1 =	f_1 in GHz K_1 =
	NM	37.8	97.8
	km	32.45	92.45
	m	-27.55	32.45
	yd	-28.33	31.67
	ft	-37.87	22.13

J/S for SELF PROTECTION EA vs. BISTATIC RADAR

The semi-active missile illustrated in Figure 5 is the typical bistatic radar which would require the target to have self protection EA to survive. In this case, the jammer is on the target and the target to missile receiver range is the same as the jammer to receiver range, but the radar to target range is different. Therefore, only two of the ranges and two of the α's (Figure 6.) are the same.

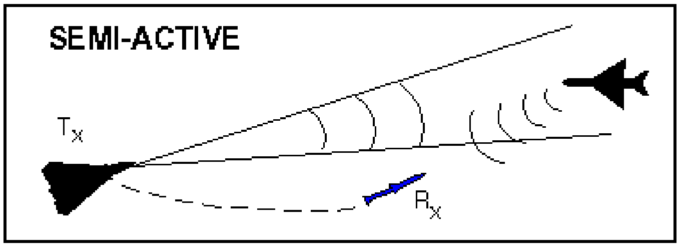

Figure 5. Bistatic Radar.

In the following equations:

α_{Tx} = The one-way space loss from the radar transmitter to the target for range R_{Tx}
α_{Rx} = The one-way space loss from the target to the missile receiver for range R_{Rx}

Like the monostatic radar, the bistatic jamming and reflected target signals travel the same path from the target and enter the receiver (missile in this case) via the same antenna. In both monostatic and bistatic J/S equations this common range cancels, so both J/S equations are left with an R_{Tx}^2 or 20 log R_{Tx} term. Since in the monostatic case $R_{Tx} = R_{Rx}$ and $\alpha_{Tx} = \alpha_{Rx}$, only R or α_1 is used in the equations. Therefore, the bistatic J/S equations [11], [13], or [14] will work for monostatic J/S calculations, but the opposite is only true if bistatic R_{Tx} and α_{Tx} terms are used for R or α_1 terms in monostatic equations [3], [5], and [8].

The equivalent circuit shown in Figure 6 applies to jamming bistatic radar. For self protect (or escort) vs. a bistatic radar, the jammer is on the target and the radar receive and transmit antennas are at separate locations so only two of the three ranges and two of the three space loss factors (α's) are the same.

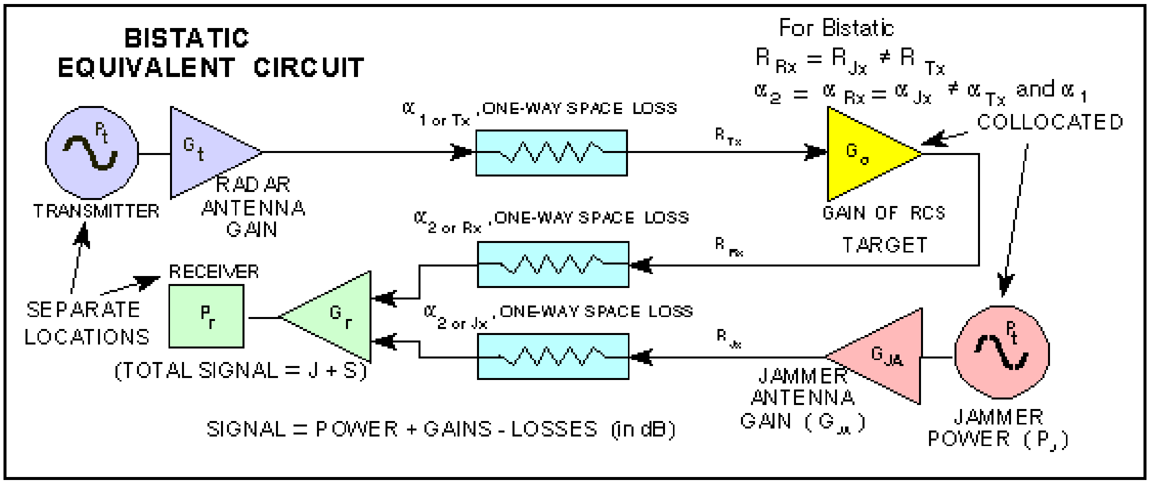
BISTATIC
EQUIVALENT CIRCUIT
For Bistatic
$R_{Rx} = R_{Jx} \neq R_{Tx}$
$\alpha_2 = \alpha_{Rx} = \alpha_{Jx} \neq \alpha_{Tx}$ and α_1
COLLOCATED
P_t
G_t
TRANSMITTER
RADAR ANTENNA GAIN
$\alpha_{1 \text{ or } Tx}$, ONE-WAY SPACE LOSS
R_{Tx}
G_σ
GAIN OF RCS
TARGET
$\alpha_{2 \text{ or } Rx}$, ONE-WAY SPACE LOSS
R_{Rx}
RECEIVER
P_r
G_r
SEPARATE LOCATIONS
(TOTAL SIGNAL = J + S)
$\alpha_{2 \text{ or } Jx}$, ONE-WAY SPACE LOSS
R_{Jx}
G_{JA}
P_t
JAMMER ANTENNA GAIN (G_{JA})
JAMMER POWER (P_J)
SIGNAL = POWER + GAINS - LOSSES (in dB)

Figure 6. Bistatic Radar EA Equivalent Circuit.

J-to-S Ratio (Bistatic) When the radar's transmit antenna is located remotely from the receiving antenna (Figure 6), the ratio of the power received (P_{r1} or J) from the jamming signal transmitted from the target to the power received (P_{r2} or S) from the radar skin return from the target equals J/S. For jammer effectiveness J normally has to be greater than S.

From the one way range equation in Section 4-3: $$P_r 1 \text{ or } J = \frac{P_j G_{ja} G_r \lambda^2}{(4\pi R_{Rx})^2} \quad (R_{Jx} = R_{Rx}) \qquad \textbf{[9]}$$

From the two way range equation in Section 4.4: $$P_r 2 \text{ or } S = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R_{Tx}^2 R_{Rx}^2} \qquad \textbf{[10]}$$

so $$\frac{J}{S} = \frac{P_j G_{ja} G_r \lambda^2 (4\pi)^3 R_{Tx}^2 R_{Rx}^2}{P_t G_t G_r \lambda^2 \sigma (4\pi R_{Rx})^2} = \frac{P_j G_{ja} 4\pi R_{Tx}^2}{P_t G_t \sigma}^{*} \qquad \textit{(ratio form)} \qquad \textbf{[11]}$$

* Keep R and σ in the same units.

On reducing the above equation to log form we have:

$$10\log J/S = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - 10\log \sigma + 10\log 4\pi + 20\log R_{Tx} \qquad \textbf{[12]}$$

or $$10\log J/S = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - 10\log \sigma + 10.99 \text{ dB} + 20\log R_{Tx} \qquad \textbf{[13]}$$

Note: To avoid having to include additional terms for these calculations, always combine any transmission line loss with antenna gain. Neither *f* nor λ terms are part of the final form of equation [11] and equation [13].

Bistatic J/S Calculations (Bistatic) Using a One Way Free Space Loss - The simplified radar equations developed in previous sections can be used to express J/S.

From the one way range equation in Section 4-3:

$10\log (P_{r1} \text{ or } J) = 10\log P_j + 10\log G_{ja} + 10\log G_r - \alpha_{Rx}$ (all factors dB) **[14]**

From the two way range equation in Section 4-4:
$10\log (P_{r2} \text{ or } S) = 10\log P_t + 10\log G_t + 10\log G_r + G_\sigma - \alpha_{Tx} - \alpha_{Rx}$ (all factors dB) **[15]**

$10\log (J/S) = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - G_\sigma + \alpha_{Tx}$ (all factors dB) **[16]**

Note: To avoid having to include additional terms for these calculations, always combine any transmission line loss with antenna gain. The $20\log f_1$ term in $-G_\sigma$ cancels the $20\log f_1$ term in α_1.

Target gain factor, $G_\sigma = 10\log \sigma + 20\log f_1 + K_2$ (in dB)

K_2 Values (dB)	RCS (σ) (units)	f_1 in MHz K_2 =	f_1 in GHz K_2 =
	m^2	-38.54	21.46
	ft^2	-48.86	11.14

One-way free space loss $\alpha_{Tx \text{ or } Rx} = 20\log f_1 R_{Tx \text{ or } Rx} + K_1$ (in dB)

K_1 Values (dB)	Range (units)	f_1 in MHz K_1 =	f_1 in GHz K_1 =
	NM	37.8	97.8
	km	32.45	92.45
	m	-27.55	32.45
	yd	-28.33	31.67
	ft	-37.87	22.13

Saturated J/S (Monostatic) Example (Constant Power Jamming)

Assume that a 5 GHz radar has a 70 dBm signal fed through a 5 dB loss transmission line to an antenna that has 45 dB gain. An aircraft is flying 31 km from the radar. The aft EW antenna has -1 dB gain and a 5 dB line loss to the EW receiver (there is an additional loss due to any antenna polarization mismatch but that loss will not be addressed in this problem). The aircraft has a jammer that provides 30 dBm saturated output if the received signal is above -35 dBm. The jammer feeds a 10 dB loss transmission line which is connected to an antenna with a 5 dB gain. If the RCS of the aircraft is 9 m^2, what is the J/S level received by the tracking radar?

Answer: The received signal at the jammer is the same as the example in Section 4-3, i.e. answer (1) = -32.3 dBm @ 5 GHz. Since the received signal is above -35 dBm, the jammer will operate in the saturated mode, and equation [5] can be used. (See Section 4-10 for an example of a jammer in the linear region.)

$10\log J/S = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - 10\log \sigma + 10.99 \text{ dB} + 20\log R$

Note: the respective transmission line losses will be combined with antenna gains,
i.e. $-5 + 45 = 40$ dB & $-10 + 5 = -5$ dB.

$10\log J/S = 30 - 5 - 70 - 40 - 9.54 + 10.99 + 89.8 = 6.25 \text{ dB @ 5 GHz*}$

* The answer is still 6.25 dB if the tracking radar operates at 7 GHz provided the antenna gains and the aircraft RCS are the same at both frequencies.

In this example, there is inadequate jamming power at each frequency if the J/S needs to be 10 dB or greater to be effective. One solution would be to replace the jammer with one that has a greater power output. If the antenna of the aircraft and the radar are not the proper polarization, additional power will also be required (see Section 3-2).

BURN-THROUGH / CROSSOVER RANGE

The burn-through equations are derived in this section. These equations are most commonly used in jammer type of applications. The following is a summary of the important equations explored in this section:

J/S CROSSOVER RANGE (MONOSTATIC) (J = S)

$R_{J=S} = [\ (P_t\ G_t\ \sigma) / (P_j\ G_{ja}\ 4\pi)\ ]^{1/2}$ (dB Ratio)

or $20 \log R_{J=S} = 10\log P_t + 10\log G_t + 10\log \sigma - 10\log P_j - 10\log G_{ja} - 10.99$ dB

If simplified radar equations already converted to dB are used:

$20 \log R_{J=S} = 10\log P_t + 10\log G_t + G_\sigma - 10\log P_j - 10\log G_{ja} - K_1 - 20\log f_1$ (dB)

* Keep P_t & P_j in same units
Keep R and σ in same units

K_1 Values (dB):

Range (units)	f_1 in MHz K_1 =	in GHz K_1 =
m	-27.55	32.45
ft	-37.87	22.13

BURN-THROUGH RANGE (MONOSTATIC)

The radar to target range where the target return signal (S) can first be detected through the EA (J).

$R_{BT} = [\ (P_t\ G_t\ \sigma\ J_{min\ eff}) / (P_j\ G_{ja}\ 4\pi\ S)\ ]^{1/2}$ (dB Ratio)

or $20\log R_{BT} = 10\log P_t + 10\log G_t + 10\log\sigma - 10\log P_j - 10\log G_{ja} + 10\log(J_{min\ eff}/S) - 10.99$

If simplified radar equations already converted to dB are used:

$20\log R_{BT} = 10\log P_t + 10\log G_t + G_\sigma - 10\log P_j - 10\log G_{ja} - K_1 + 10\log(J_{min\ eff}/S) - 20\log f_1$(in dB)*

f_1 is MHz or GHz value of frequency

Target gain factor (dB)

$G_\sigma = 10\log \sigma + 20\log f_1 + K_2$

K_2 Values (dB):

RCS (σ) (units)	f_1 in MHz K_2 =	in GHz K_2 =
m^2	-38.54	21.46
ft^2	-48.86	11.14

BURN-THROUGH RANGE (BISTATIC)

R_{Tx} is the range from the radar transmitter to the target and is different from R_{Rx} which is the range from the target to the receiver. Use Monostatic equations and substitute R_{Tx} for R

CROSSOVER RANGE and BURN-THROUGH RANGE

To present the values of J and S, (or J/S) over a minimum to maximum radar to target range of interest, equation [1], Section 4-7. which has a slope of 20 log for J vs. range and equation [2], Section 4-7, which has a slope of 40 log for S vs. range are plotted. When plotted on semi-log graph paper, J and S (or J/S) vs. range are straight lines as illustrated in Figure 1.

Figure 1 is a sample graph - it cannot be used for data.

The crossing of the J and S lines (known as crossover) gives the range where J = S (about 1.29 NM), and shows that shorter ranges will produce target signals greater than the jamming signal.

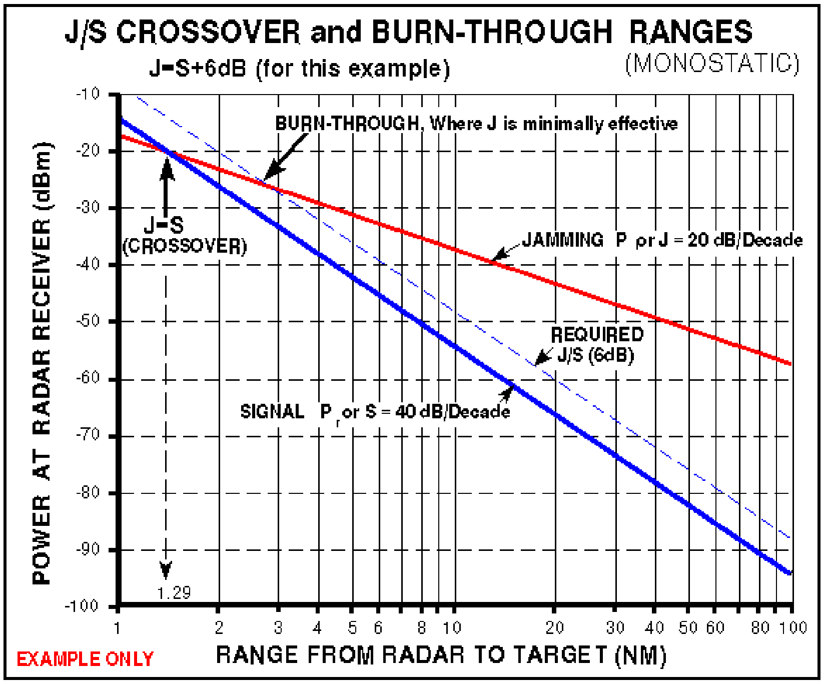

Figure 1. Sample J and S Graph.

The point where the radar power overcomes the jamming signal is known as burn-through. The crossover point where J = S could be the burn-through range, but it usually isn't because normally J/S > 0 dB to be effective due to the task of differentiating the signal from the jamming noise floor (see receiver sensitivity section). For this example, the J/S required for the EA to be effective is given as 6 dB, as shown by the dotted line. This required J/S line crosses the jamming line at about 2.8 NM which, in this example, is the burn-through range.

In this particular example, we have:

P_t = 80 dBm G_t = 42 dB
P_j = 50 dBm G_{ja} = 6 dB
σ = 18 m^2 f = 5.9 GHz (not necessary for all calculations)

A radar can be designed with higher than necessary power for earlier burn-through on jamming targets. Naturally that would also have the added advantage of earlier detection of non-jamming targets as well.

Note: To avoid having to include additional terms for the following calculations, always combine any transmission line loss with antenna gain.

CROSSOVER AND BURN-THROUGH RANGE EQUATIONS (MONOSTATIC)

To calculate the crossover range or burn-through range the J/S equation must be solved for range. From equation [3], Section 4-7:

$$\frac{J}{S} = \frac{P_j\, G_{ja}\, 4\pi\, R^2}{P_t\, G_t\, \sigma} \qquad \textit{(ratio form)} \qquad \text{Solving for R:} \quad R = \sqrt{\frac{P_t\, G_t\, \sigma\, J}{P_j\, G_{ja}\, 4\pi\, S}} \qquad \textbf{[1]}$$

BURN-THROUGH RANGE (MONOSTATIC) - Burn-through Range (Monostatic) is the radar to target range where the target return signal (S) can first be detected through the jamming (J). It is usually the range when the J/S just equals the minimum effective J/S.

$$R_{BT} = \sqrt{\frac{P_t\, G_t\, \sigma\, J_{\min eff}}{P_j\, G_{ja}\, 4\pi\, S}} \qquad \text{(burn-through range)} \qquad \textbf{[2]}$$

or in dB form, (using 10log 4π = 10.99 dB):

$$20\log R_{BT} = 10\log P_t + 10\log G_t + 10\log \sigma - 10\log P_j - 10\log G_{ja} + 10\log (J_{\min eff}/S) - 10.99 \text{ dB} \qquad \textbf{[3]}$$

RANGE WHEN J/S CROSSOVER OCCURS (MONOSTATIC) - The crossover of the jammer's 20 dB/decade power line and the skin return signal's 40 dB/decade power line of Figure 1 occurs for the case where J = S in dB or J/S=1 in ratio. Substituting into equation [1] yields:

$$R_{(J=S)} = \sqrt{\frac{P_t\, G_t\, \sigma}{P_j\, G_{ja}\, 4\pi}} \qquad \text{(Crossover range)} \qquad \textbf{[4]}$$

or in dB form:

$$20\log R_{J=S} = 10\log P_t + 10\log G_t + 10\log \sigma - 10\log P_j - 10\log G_{ja} - 10.99 \text{ dB} \qquad \textbf{[5]}$$

Note: keep R and σ in same units in all equations.

CROSSOVER AND BURN-THROUGH EQUATIONS (MONOSTATIC)
USING α - ONE WAY FREE SPACE LOSS

The other crossover burn-through range formulas can be confusing because a frequency term is subtracted (equations [6], [7] and [8]), but both ranges are independent of frequency. This subtraction is necessary because when J/S is calculated directly as previously shown, λ^2 or $(c/f)^2$ terms canceled, whereas in the simplified radar equations, a frequency term is part of the G_σ term and has to be cancelled if one solves for R. From equation [8], Section 4-7:

$$10\log J/S = 10\log P_j + 10\log G_{ja} - 10\log P_t - 10\log G_t - G_\sigma + \alpha_1 \qquad \text{(factors in dB)}$$

or rearranging: $\alpha_1 = 10\log P_t + 10\log G_t + G_\sigma - 10\log P_j - 10\log G_{ja} + 10\log (J/S)$

from Section 4-4: $\alpha_1 = 20\log f_1 R_1 + K_1$ or $20\log R_1 = \alpha_1 - K_1 - 20\log f_1$

then substituting for α_1:

$$20\log R_1 = 10\log P_t + 10\log G_t + G_\sigma - 10\log P_j - 10\log G_{ja} - K_1 + 10\log (J/S) - 20\log f_1 \quad \text{(in dB)} \qquad \textbf{[6]}$$

EQUATION FOR BURN-THROUGH RANGE (MONOSTATIC) - Burn-through occurs at the range when the J/S just equals the minimum effective J/S. G_σ and K_1 are as defined on page 4-8.1.

$$20\log R_{BT} = 10\log P_t + 10\log G_t + G_\sigma - 10\log P_j - 10\log G_{ja} - K_1 + 10\log (J_{min\ eff}/S) - 20\log f_1 \quad \text{(in dB)} \qquad \textbf{[7]}$$

EQUATION FOR THE RANGE WHEN J/S CROSSOVER OCCURS (MONOSTATIC)

The J/S crossover range occurs for the case where J = S, substituting into equation [6] yields:

$$20\log R_{J=S} = 10\log P_t + 10\log G_t + G_\sigma - 10\log P_j - 10\log G_{ja} - K_1 - 20\log f_1 \quad \text{(factors in dB)} \qquad \textbf{[8]}$$

BURN-THROUGH RANGE (BISTATIC)

Bistatic J/S crossover range is the radar-to-target range when the power received (S) from the radar skin return from the target equals the power received (J) from the jamming signal transmitted from the target. As shown in Figure 6, Section 4-7, the receive antenna that is receiving the same level of J and S is remotely located from the radar's transmit antenna. Bistatic equations [11], [13], and [14] in Section 4-7 show that J/S is only a function of radar to target range, therefore J/S is not a function of wherever the missile is in its flight path provided the missile is in the antenna beam of the target's jammer. The missile is closing on the target at a very much higher rate than the target is closing on the radar, so the radar to target range will change less during the missile flight.

It should be noted that for a very long range air-to-air missile shot, the radar to target range could typically decrease to 35% of the initial firing range during the missile time-of-flight, i.e. A missile shot at a target 36 NM away, may be only 12 NM away from the firing aircraft at missile impact.

Figure 2 shows both the jamming radiated from the target and the power reflected from the target as a function of radar-to-target range. In this particular example, the RCS is assumed to be smaller, 15 m^2 vice 18 m^2 in the monostatic case, since the missile will be approaching the target from a different angle. This will not, however, always be the case.

In this plot, the power reflected is:

$$P_{ref} = \frac{P_t\, G_t\, 4\,\pi\,\sigma}{(4\pi R\,)^2}$$

Substituting the values given previously in the example on page 4-8.1, we find that the crossover point is at 1.18 NM (due to the assumed reduction in RCS).

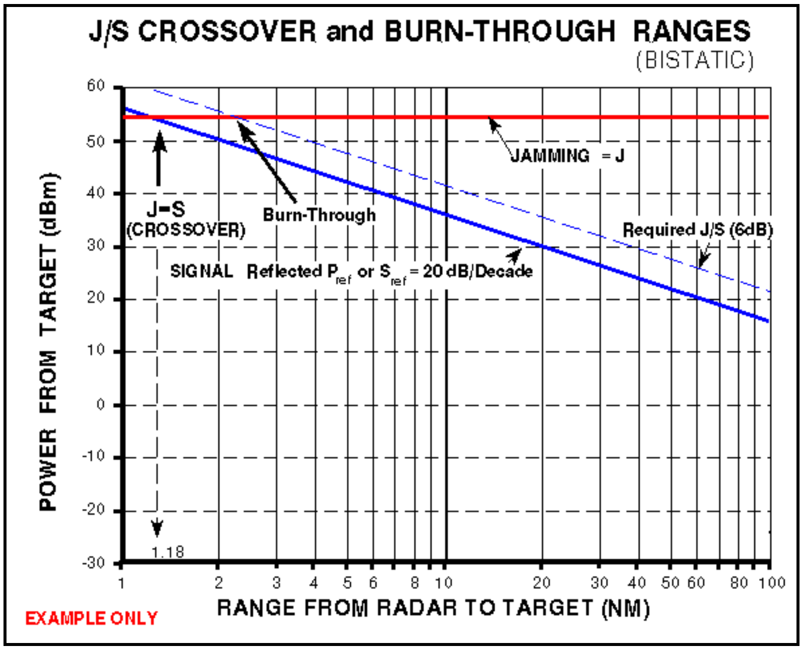

Figure 2. Bistatic Crossover and Burnthrough.

CROSSOVER AND BURN-THROUGH RANGE EQUATIONS (BISTATIC)

To calculate the radar transmitter-to-target range where J/S crossover or burn-through occurs, the J/S equation must be solved for range. From equation [11] in Section 4-7:

$$\frac{J}{S} = \frac{P_j\, G_{ja}\, 4\pi\, R_{Tx}^2}{P_t\, G_t\, \sigma} \qquad \textit{(ratio form)}$$

Solving for R$_{Tx}$:

$$R_{Tx} = \sqrt{\frac{P_t\, G_t\, \sigma\, J}{P_j\, G_{ja}\, 4\pi\, S}} \qquad [9]$$

Note:
Bistatic equation [10] is identical to monostatic equation [1] except R$_{Tx}$ must be substituted for R and a bistatic RCS (σ) will have to be used since RCS varies with aspect angle. The common explanations will not be repeated in this section.

BURN-THROUGH RANGE (BISTATIC) - Burn-through Range (Bistatic) occurs when J/S just equals the minimum effective J/S. From equation [9]:

$$R_{Tx(BT)} = \sqrt{\frac{P_t\, G_t\, \sigma\, J_{\min\, eff}}{P_j\, G_{ja}\, 4\pi\, S}} \qquad \textit{(ratio form)} \qquad [10]$$

or in dB form:

$$20\log R_{Tx(BT)} = 10\log P_t + 10\log G_t + 10\log \sigma - 10\log P_j - 10\log G_{ja} + 10\log (J_{min\ eff}/S) - 10.99\text{ dB} \quad \textbf{[11]}$$

If using the simplified radar equations (factors in dB):

$$20\log R_{Tx(BT)} = 10\log P_t + 10\log G_t + G_\sigma - 10\log P_j - 10\log G_{ja} - K_1 + 10\log (J_{min\ eff}/S) - 20\log f_1 \quad \textbf{[12]}$$

Where G_σ and K_1 are defined on page 4-8.1

RANGE WHEN J/S CROSSOVER OCCURS (BISTATIC)

The crossover occurs when J = S in dB or J/S = 1 in ratio.

$$R_{Tx(J=S)} = \sqrt{\frac{P_t\, G_t\, \sigma}{P_j\, G_{ja}\, 4\pi}} \qquad (ratio) \quad \textbf{[13]}$$

or in log form:

$$20\log R_{Tx(J=S)} = 10\log P_t + 10\log G_t + 10\log \sigma - 10\log P_j - 10\log G_{ja} - 10.99\text{ dB} \quad \textbf{[14]}$$

If simplified equations are used (with G_σ and K_1 as defined on page 4-8.1) we have:

$$20\log R_{Tx(J=S)} = 10\log P_t + 10\log G_t + G_\sigma - 10\log P_j - 10\log G_{ja} - K_1 - 20\log f_1 \qquad \text{(factors in dB)} \quad \textbf{[15]}$$

Note: keep R and σ in same units in all equations.

DETAILS OF SEMI-ACTIVE MISSILE J/S

Unless you are running a large scale computer simulation that includes maneuvering, antenna patterns, RCS, etc., you will seldom calculate the variation in J/S that occurs during a semi-active missile's flight. Missiles don't fly straight lines at constant velocity. Targets don't either - they maneuver. If the launch platform is an aircraft, it maneuvers too. A missile will accelerate to some maximum velocity above the velocity of the launch platform and then decelerate.

The calculation of the precise variation of J/S during a missile flight for it to be effective requires determination of all the appropriate velocity vectors and ranges at the time of launch, and the accelerations and changes in relative positions during the fly out. In other words, it's too much work for too little return. The following are simplified examples for four types of intercepts.

In these examples, all velocities are constant, and are all along the same straight line. The missile velocity is 800 knots greater than the launch platform velocity which is assumed to be 400 kts. The missile launch occurs at 50 NM.

	J/S (dB)	ΔJ/S (dB)
At Launch:	29	n/a
Intercept Type	At 2 sec. to Intercept:	
AAM Head-on:	23	-6
SAM Incoming Target:	25	-4
AAM Tail Chase:	29	0
SAM Outbound Target:	35	+6

For the AAM tail chase, the range from the radar to the target remains constant and so does the J/S. **In these examples** the maximum variation from launch J/S is ± 6 dB. That represents the difference in the radar to target range closing at very high speed (AAM head on) and the radar to target range opening at moderate speed (SAM outbound target). The values shown above are examples, not rules of thumb, every intercept will be different.

Even for the simplified linear examples shown, graphs of the J and S will be curves - not straight lines. Graphs could be plotted showing J and S vs. radar to target range, or J and S vs. missile to target range, or even J/S vs. time of flight. If the J/S at launch is just barely the minimum required for effectiveness, and increasing it is difficult, then a detailed graph may be warranted, but in most cases this isn't necessary.

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SUPPORT JAMMING

The following table contains a summary of equations developed in this section:

<table>
<tr>
<td>MAIN LOBE JAMMING TO SIGNAL (J/S) RATIO (For SOJ/SIJ)
$J/S = (P_j\ G_{ja}\ 4\pi\ R_{Tx}^4) / (P_t\ G_t\ \sigma\ [BW_J/BW_R]\ R_{Jx}^2)$ (ratio form)*
$10\log J/S = 10\log P_j - 10\log[BW_J/BW_R] + 10\log G_{ja} - 10\log P_t - 10\log G_t - 10\log \sigma +$ ↓
$10.99\text{ dB} + 40\log R_{Tx} - 20\log R_{Jx}$ * ←←
or if simplified radar equations are used:
$10\log J/S = 10\log P_j - BF + 10\log G_{ja} - \alpha_{jx} - 10\log P_t - 10\log G_t - G_\sigma + 2\alpha_1$ (in dB)*</td>
<td>Target gain factor,
$G_\sigma = 10\text{Log}\sigma + 20\text{Log} f_1 + K_2$ (in dB)
K_2 Values (dB):
RCS (σ) (units) · f_1 in MHz K_2 = · f_1 in GHz K_2 =
m^2 · -38.54 · 21.46
ft^2 · -48.86 · 11.14</td>
</tr>
<tr>
<td>SIDE LOBE JAMMING TO SIGNAL (J/S) RATIO (For SOJ/SIJ)
$J/S = (P_j\ G_{ja}\ G_{r(SL)}\ 4\pi\ R_{Tx}^4) / (P_t\ G_t\ G_{r(ML)}\ \sigma\ [BW_J/BW_R]\ R_{Jx}^2)$ (ratio form)*
$10\log J/S = 10\log P_j - BF + 10\log G_{ja} + 10\log G_{r(SL)} - 10\log P_t - 10\log G_t - 10\log G_{r(ML)} +$ → ↓
$10.99\text{ dB} - 10\log \sigma + 40\log R_{Tx} - 20\log R_{Jx}$ * ←←
or if simplified radar equations are used (in dB)*:
$10\log J/S = 10\log P_j - BF + 10\log G_{ja} + 10\log G_{r(SL)} - \alpha_{jx} - 10\log P_t - 10\log G_t - 10\log G_{r(ML)} - G_\sigma + 2\alpha_1$</td>
<td rowspan="2">One-way free space loss,
α_1 or $\alpha_{Tx} = 20\text{Log}(f_1 R) + K_1$ (in dB)
K_1 Values (dB):
Range (units) · f_1 in MHz K_1 = · f_1 in GHz K_1 =
NM · 37.8 · 97.8
Km · 32.45 · 92.45
m · -27.55 · 32.45
yd · -28.33 · 31.67
ft · -37.87 · 22.13

* Keep R and σ in same units</td>
</tr>
<tr>
<td>R_{Jx} Range from the support jammer transmitter to the radar receiver
R_{Tx} Range between the radar and the target
BF 10 Log of the ratio of BW_J of the noise jammer to BW_R of the radar receiver
$G_{r(SL)}$ Side lobe antenna gain
$G_{r(ML)}$ Main lobe antenna gain
α_{JX} One way free space loss between SOJ transmitter and radar receiver
α_1 One way space loss between the radar and the target</td>
</tr>
</table>

Support jamming adds a few geometric complexities. A SOJ platform usually uses high gain, directional antennas. Therefore, the jamming antenna must not only be pointed at the victim radar, but there must be alignment of radar, targets, and SOJ platform for the jamming to be most effective. Two cases will be described, main lobe-jamming and side-lobe jamming.

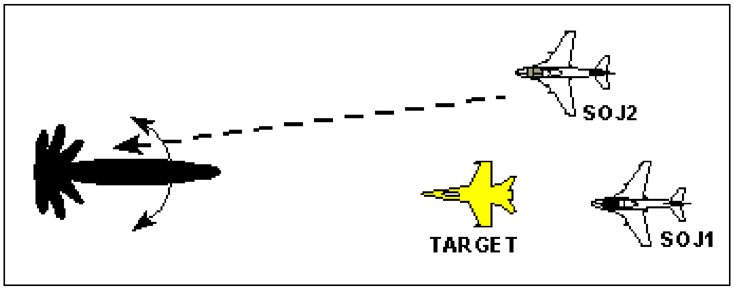

Figure 1. Radar Antenna Pattern.

Support jamming is usually applied against search and acquisition radars which continuously scan horizontally through a volume of space. The scan could cover a sector or a full 360°. The horizontal antenna pattern of the radar will exhibit a main lobe and side lobes as illustrated in Figure 1. The target is detected when the main lobe sweeps across it. For main lobe jamming, the SOJ platform and the target(s) must be aligned with the radar's main lobe as it sweeps the target(s).

For side lobe jamming, the SOJ platform may be aligned with one or more of the radar's side lobes when the main lobe sweeps the target. The gain of a radar's side lobes are many tens of dB less (usually more than 30 dB less) than the gain of the main lobe, so calculations of side lobe jamming must use the gain of the side lobe for the radar receive antenna gain, not the gain of the main lobe. Also, because many modern radars employ some form of side lobe blanking or side lobe cancellation, some knowledge of the victim radar is required to predict the effectiveness of side lobe jamming.

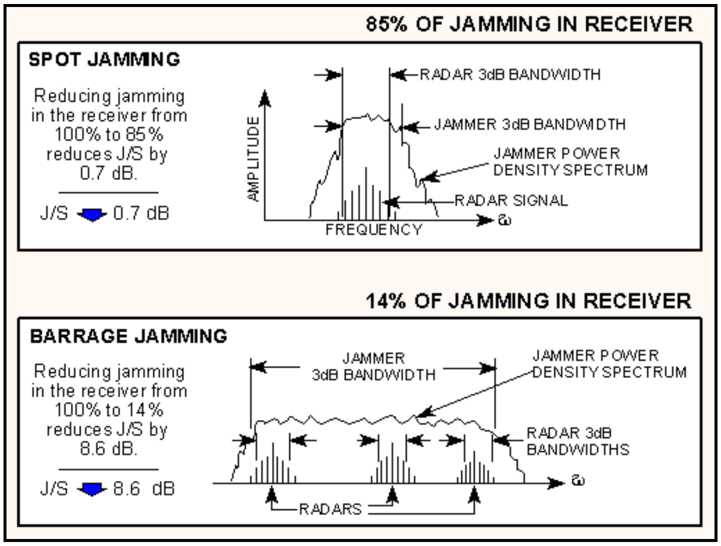
85% OF JAMMING IN RECEIVER
SPOT JAMMING
Reducing jamming in the receiver from 100% to 85% reduces J/S by 0.7 dB.
J/S ⬇ 0.7 dB
RADAR 3dB BANDWIDTH
JAMMER 3dB BANDWIDTH
JAMMER POWER DENSITY SPECTRUM
RADAR SIGNAL
AMPLITUDE
FREQUENCY
ω
14% OF JAMMING IN RECEIVER
BARRAGE JAMMING
Reducing jamming in the receiver from 100% to 14% reduces J/S by 8.6 dB.
J/S ⬇ 8.6 dB
JAMMER 3dB BANDWIDTH
JAMMER POWER DENSITY SPECTRUM
RADAR 3dB BANDWIDTHS
RADARS
ω

Figure 2. Noise Jamming.

All radar receivers are frequency selective. That is, they are filters that allow only a narrow range of frequencies into the receiver circuitry. Deceptive EA, by definition, creates forgeries of the real signal and, ideally, are as well matched to the radar receiver as the real signal. On the other hand, noise jamming probably **will not match** the radar receiver bandwidth characteristics. Noise jamming is either spot jamming or barrage jamming. As illustrated in Figure 2, spot jamming is simply narrowing the bandwidth of the noise jammer so that as much of the jammer power as possible is in the radar receiver bandwidth. Barrage jamming is using a wide noise bandwidth to cover several radars with one jammer or to compensate for any uncertainty in the radar frequency. In both cases some of the noise power is “wasted” because it is not in the radar receiver filter.

In the past, noise jammers were often described as having so many “watts per MHz.” This is nothing more than the power of the noise jammer divided by the noise bandwidth. That is, a 500 watt noise jammer transmitting a noise bandwidth of 200 MHz has 2.5 watts/MHz. Older noise jammers often had noise bandwidths that were difficult, or impossible, to adjust accurately. These noise jammers usually used manual tuning to set the center frequency of the noise to the radar frequency. Modern noise jammers can set on the radar frequency quite accurately and the noise bandwidth is selectable, so the noise bandwidth is more a matter of choice than it used to be, and it is possible that all of the noise is placed in the victim radar’s receiver.

If, in the example above, the 500 watt noise jammer were used against a radar that had a 3 MHz receiver bandwidth, the noise jammer power applicable to that radar would be:

$$3\ MHz\ x\ 2.5\ watts/MHz = 7.5\ watts\ \_\ 38.75\ dBm \qquad \textbf{[1]}$$

The calculation must be done as shown in equation [1] - multiply the watts/MHz by the radar bandwidth first and then convert to dBm. You can’t convert to dBm/MHz and then multiply. (See derivation of dB in Section 2-4)

An alternate method for dB calculations is to use the bandwidth reduction factor (BF).

The BF is: $$BF_{dB} = 10\ \text{Log}\left[\frac{BW_J}{BW_R}\right] \qquad \textbf{[2]}$$

where: BW_J is the bandwidth of the noise jammer, and BW_R is the bandwidth of the radar receiver.

The power of the jammer in the jamming equation (P_J) can be obtained by either method. If equation [1] is used then P_J is simply 38.75 dBm. If equation [2] is used then the jamming equation is written using (P_J - BF). All the following discussion uses the second method. Whichever method is used, it is required that $BW_J \geq BW_R$. If $BW_J < BW_R$, then all the available power is in the radar receiver and equation [1] does not apply and the BF = 0.

> Note: To avoid having to include additional terms for the following calculations, always combine any transmission line loss with antenna gain.

MAIN LOBE STAND-OFF / STAND-IN JAMMING

The equivalent circuit shown in Figure 3 applies to main lobe jamming by a stand-off support aircraft or a stand-in RPV. Since the jammer is not on the target aircraft, only two of the three ranges and two of the three space loss factors (α's) are the same. Figure 3 differs from the J/S monostatic equivalent circuit shown in Figure 4 in Section 4-7 in that the space loss from the jammer to the radar receiver is different.

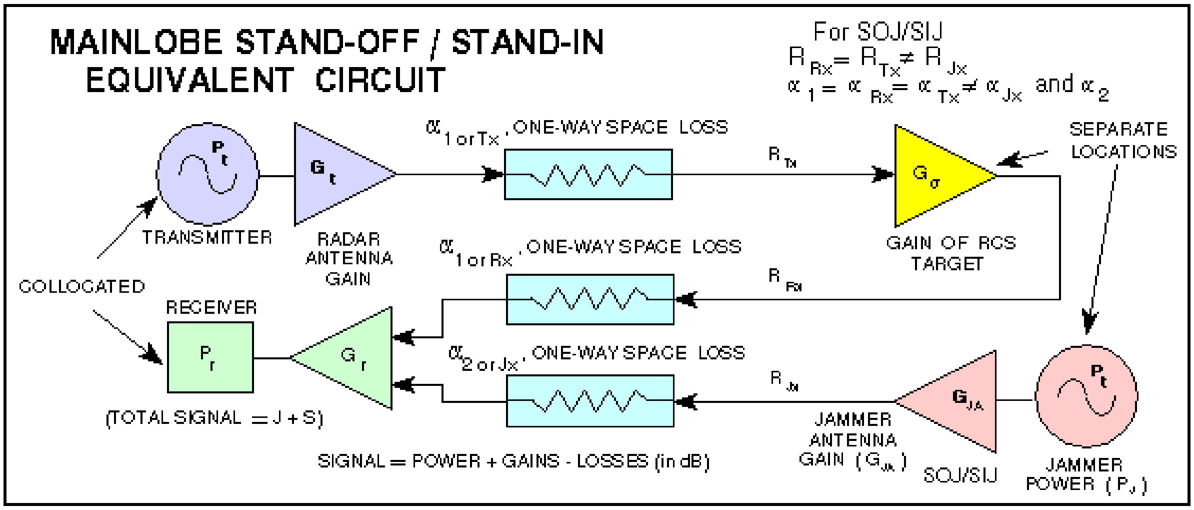
MAINLOBE STAND-OFF / STAND-IN EQUIVALENT CIRCUIT
For SOJ/SIJ
$R_{Rx} = R_{Tx} \neq R_{Jx}$
$\alpha_1 = \alpha_{Rx} = \alpha_{Tx} \neq \alpha_{Jx}$ and α_2
P_t
G_t
$\alpha_{1\,or\,Tx}$, ONE-WAY SPACE LOSS
R_{Tx}
G_σ
SEPARATE LOCATIONS
TRANSMITTER
RADAR ANTENNA GAIN
$\alpha_{1\,or\,Rx}$, ONE-WAY SPACE LOSS
R_{Rx}
GAIN OF RCS TARGET
COLLOCATED
RECEIVER
P_r
G_r
$\alpha_{2\,or\,Jx}$, ONE-WAY SPACE LOSS
R_{Jx}
G_{JA}
P_t
(TOTAL SIGNAL = J + S)
JAMMER ANTENNA GAIN (G_{JA})
SOJ/SIJ
JAMMER POWER (P_J)
SIGNAL = POWER + GAINS - LOSSES (in dB)

Figure 3. Main Lobe Stand-Off / Stand-In EA Equivalent Circuit.

The equations are the same for both SOJ and SIJ. From the one way range equation in Section 4-3, and with inclusion of BF losses:

$$P_r\,1\ or\ J = \frac{P_j\, G_{ja}\, G_r\, \lambda^2\, BW_R}{(4\pi\, R_{Jx})^2\, BW_J} \qquad [3]$$

From the two way range equation in Section 4.4: $$P_r\,2\ or\ S = \frac{P_t\, G_t\, G_r\, \lambda^2\, \sigma}{(4\pi)^3\, R_{Tx}^4} \qquad [4]$$

so $$\frac{J}{S} = \frac{P_j\, G_{ja}\, G_r\, \lambda^2 (4\pi)^3\, R_{Tx}^4\, BW_R}{P_t\, G_t\, G_r\, \lambda^2\, \sigma\, (4\pi\, R_{Jx})^2\, BW_J} = \frac{P_j\, G_{ja}\, 4\pi\, R_{Tx}^4\, BW_R}{P_t\, G_t\, \sigma\, R_{Jx}^2\, BW_J} \qquad \textit{(ratio form)} \qquad [5]$$

Note: Keep R and σ in the same units. Converting to dB and using 10 log 4π = 10.99 dB:

$$10\log J/S = 10\log P_j - 10\log [BW_j/BW_R] + 10\log G_{ja} - 10\log P_t - 10\log G_t - 10\log \sigma + 10.99 \text{ dB} + 40\log R_{Tx} - 20\log R_{Jx} \quad \textbf{[6]}$$

If the simplified radar equation is used, the free space loss from the SOJ/SIJ to the radar receiver is α_{Jx}, then equation [7] is the same as monostatic equation [6] in Section 4-7 except α_{Jx} replaces α, and the bandwidth reduction factor [BF] losses are included:

$$10\log J = 10\log P_j - BF + 10\log G_{ja} + 10\log G_r - \alpha_{Jx} \qquad \text{(factors in dB)} \qquad \textbf{[7]}$$

Since the free space loss from the radar to the target and return is the same both ways, $\alpha_{Tx} = \alpha_{Rx} = \alpha_1$, equation [8] is the same as monostatic equation [7] in Section 4-7.

$$10\log S = 10\log P_t + 10\log G_t + 10\log G_r + G_\sigma - 2\alpha_1 \qquad \text{(factors in dB)} \qquad \textbf{[8]}$$

and $$10\log J/S = 10\log P_j - BF + 10\log G_{ja} - \alpha_{Jx} - 10\log P_t - 10\log G_t - G_\sigma + 2\alpha_1 \qquad \text{(factors in dB)} \qquad \textbf{[9]}$$

Notice that unlike equation [8] in Section 4-7, there are two different α's in [9] because the signal paths are different.

SIDE LOBE STAND-OFF / STAND-IN JAMMING

The equivalent circuit shown in Figure 4. It differs from Figure 3, (main lobe SOJ/SIJ) in that the radar receiver antenna gain is different for the radar signal return and the jamming.

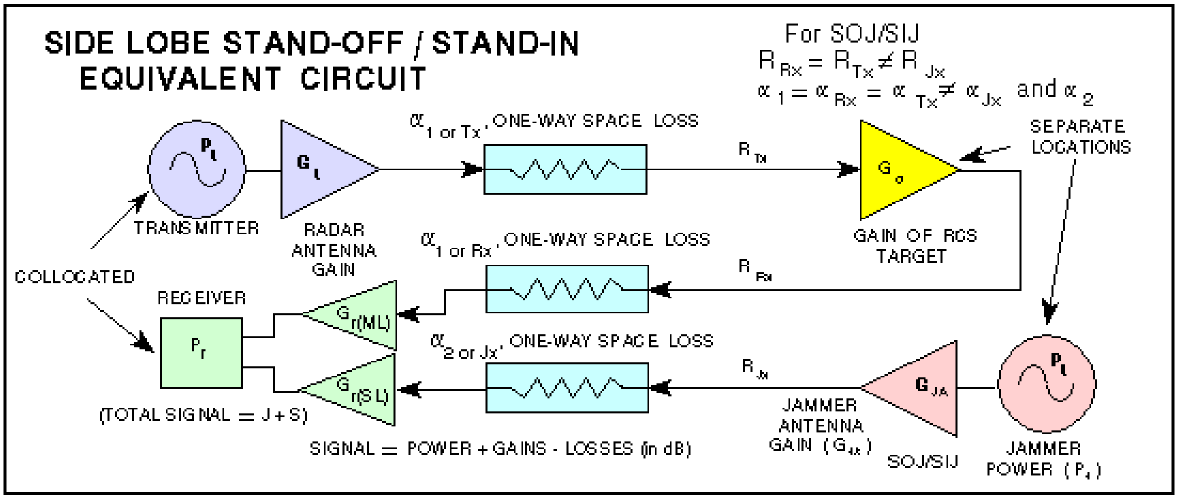
SIDE LOBE STAND-OFF / STAND-IN EQUIVALENT CIRCUIT
For SOJ/SIJ
$R_{Rx} = R_{Tx} \neq R_{Jx}$
$\alpha_1 = \alpha_{Rx} = \alpha_{Tx} \neq \alpha_{Jx}$ and α_2
$\alpha_{1 \text{ or } Tx}$, ONE-WAY SPACE LOSS
R_{Tx}
P_t
G_t
G_σ
SEPARATE LOCATIONS
TRANSMITTER
RADAR ANTENNA GAIN
$\alpha_{1 \text{ or } Rx}$, ONE-WAY SPACE LOSS
GAIN OF RCS TARGET
R_{Rx}
COLLOCATED
RECEIVER
P_r
$G_{r(ML)}$
$G_{r(SL)}$
$\alpha_{2 \text{ or } Jx}$, ONE-WAY SPACE LOSS
R_{Jx}
G_{JA}
P_t
(TOTAL SIGNAL = J + S)
SIGNAL = POWER + GAINS - LOSSES (in dB)
JAMMER ANTENNA GAIN (G_{JA})
SOJ/SIJ
JAMMER POWER (P_J)

Figure 4. Side Lobe Stand-Off / Stand-In EA Equivalent Circuit.

To calculate side lobe jamming, the gain of the radar antenna's side lobes must be known or estimated. The gain of each side lobe will be different than the gain of the other side lobes. If the antenna is symmetrical, the first side lobe is the one on either side of the main lobe, the second side lobe is the next one on either side of the first side lobe, and so on. The side lobe gain is G_{SLn}, where the 'n' subscript denotes side lobe number: 1, 2, ..., n.

The signal is the same as main lobe equations [4] and [8], except $G_r = G_{r(ML)}$

$$P_{r}2 \text{ or } S = \frac{P_t\, G_t\, G_{r(ML)}\, \lambda^2\, \sigma}{(4\pi)^3\, R_{Tx}^4} \qquad \textit{(ratio form)} \qquad \mathbf{[10]}$$

If simplified radar equations are used:

$$10\log S = 10\log P_t + 10\log G_t + 10\log G_{r(ML)} + G_\sigma - 2\alpha_1 \qquad \text{(factors in dB)}$$

The jamming equation is the same as main lobe equations [3] and [7] except $G_r = G_{r(SL)}$:

$$J = \frac{P_j\, G_{ja}\, G_{r(SL)}\, \lambda^2\, BW_R}{(4\pi\, R_{Jx})^2\, BW_J} \qquad \mathbf{[11]}$$

$$10\log J = 10\log P_j - BF + 10\log G_{ja} + 10\log G_{r(SL)} - \alpha_{Jx} \qquad \text{(factors in dB)} \qquad \mathbf{[12]}$$

so

$$\frac{J}{S} = \frac{P_j\, G_{ja}\, G_{r(SL)}\, 4\pi\, R_{Tx}^4\, BW_R}{P_t\, G_t\, G_{r(ML)}\, \sigma\, R_{Jx}^2\, BW_J} \qquad \textit{(ratio form)} \qquad \mathbf{[13]}$$

Note: keep R and σ in same units. Converting to dB and using 10log 4π = 10.99 dB:

$$10\log J/S = 10\log P_j - BF + 10\log G_{ja} + 10\log G_{r(SL)} - 10\log P_t - 10\log G_t - 10\log G_{r(ML)} - 10\log \sigma + 10.99 \text{ dB} + 40\log R_{Tx} - 20\log R_{Jx}$$

(factors in dB) **[14]**

If simplified radar equations are used:

$$10\log J/S = 10\log P_j - BF + 10\log G_{ja} + 10\log G_{r(SL)} - \alpha_{Jx} - 10\log P_t - 10\log G_t - 10\log G_{r(ML)} - G_\sigma + 2\alpha_1 \qquad \mathbf{[15]}$$

(in dB)

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JAMMING TO SIGNAL (J/S) RATIO - CONSTANT GAIN [LINEAR] JAMMING

JAMMING TO SIGNAL (J/S) RATIO (MONOSTATIC)

$$\frac{J}{S} = \frac{G_{ja(Rx)}\, G_j\, G_{ja(Tx)}\, \lambda^2}{4\pi\sigma} = \frac{G_{ja(Rx)}\, G_j\, G_{ja(Tx)}\, c^2}{4\pi\sigma\, f^2} \qquad \text{(ratio form)}$$

$G_{ja(Rx)}$ = The Gain of the jammer receive antenna
G_j = The gain of the jammer
$G_{ja(Tx)}$ = The Gain of the jammer transmit antenna

or:

$10\log J/S = 10\log G_{ja(Rx)} + 10\log G_j + 10\log G_{ja(Tx)} - 10\log (4\pi\sigma/\lambda^2)$

or if simplified radar equations developed in previous sections are used:

$10\log J/S = 10\log G_{ja(Rx)} + 10\log G_j + 10\log G_{ja(Tx)} - G_\sigma$ (dB)

* Keep λ and σ in same units. Note: $\lambda = c/f$

Target gain factor,
$G_\sigma = 10\log \sigma + 20\log f_1 + K_2$ (dB)

K_2 Values (dB):

RCS (σ) (units)	f_1 in MHz K_2 =	f_1 in GHz K_2 =
m^2	-38.54	21.46
ft^2	-48.86	11.14

JAMMING TO SIGNAL (J/S) RATIO (BISTATIC)

Same as the monostatic case except G_σ will be different since RCS (σ) varies with aspect angle.

Since the jammer on the target is amplifying the received radar signal before transmitting it back to the radar, both J and S experience the two way range loss. Figure 1 shows that the range for both the signal and constant gain jamming have a slope that is 40 dB per decade. Once the jammer output reaches maximum power, that power is constant and the jamming slope changes to 20 dB per decade since it is only a function of one way space loss and the J/S equations for constant power (saturated) jamming must be used.

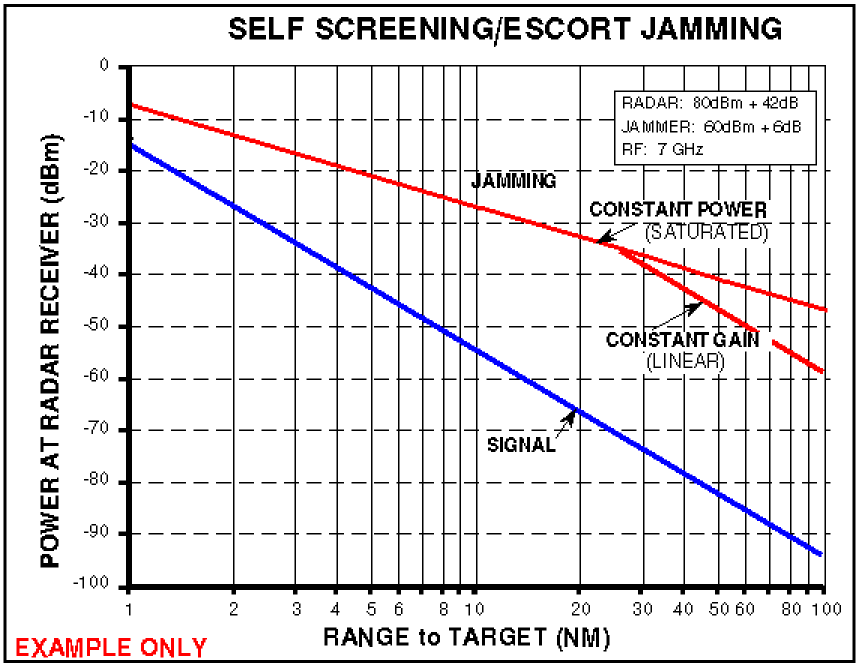

Figure 1. Sample Constant Gain / Constant Power Graph.

Normally the constant gain (linear) region of a repeater jammer occurs only at large distances from the radar and the constant power (saturated) region is reached rapidly as the target approaches the radar. When a constant gain jammer is involved it may be necessary to plot jamming twice - once using J from the constant power (saturated) equation [1] in Section 4-7 and once using the constant gain (linear) equation [4], as in the example shown in Figure 1.

CONSTANT GAIN SELF PROTECTION EA

Most jammers have a constant power output - that is, they always transmit the maximum available power of the transmitter (excepting desired EA modulation). Some jammers also have a constant gain (linear) region. Usually these are coherent repeaters that can amplify a low level radar signal to a power that is below the level that results in maximum available (saturated) power output. At some radar to target range, the input signal is sufficiently high that the full jammer gain would exceed the maximum available power and the jammer ceases to be constant gain and becomes constant power.

To calculate the power output of a constant gain jammer where:

S_{Rj} = The Radar signal at the jammer input (receive antenna terminals)
$G_{ja(Rx)}$ = The Gain of the jammer receive antenna
G_j = The gain of the jammer
α_{Tx} = The one-way free space loss from the radar to the target
P_{jCG} = The jammer constant gain power output
P_j = The maximum jammer power output
L_R = The jammer receiving line loss; combine with antenna gain $G_{ja(Rx)}$

From equation [10], Section 4-3, calculate the radar power received by the jammer.

$$10\log S_{Rj} = 10\log P_t + 10\log G_t - \alpha_{Tx} + 10\log G_{ja(Rx)} \qquad \text{(factors in dB)} \qquad \textbf{[1]}$$

The jammer constant gain power output is:

$$10\log P_{jCG} = 10\log S_{Rj} + 10\log G_{ja} \qquad \textbf{[2]}$$

and, by definition:

$$P_{jCG} \le P_j \qquad \textbf{[3]}$$

MONOSTATIC

The equivalent circuit shown in Figure 2 is different from the constant power equivalent circuit in Figure 4 in Section 4-7. With constant gain, the jamming signal experiences the gain of the jammer and its antennas plus the same space loss as the radar signal.

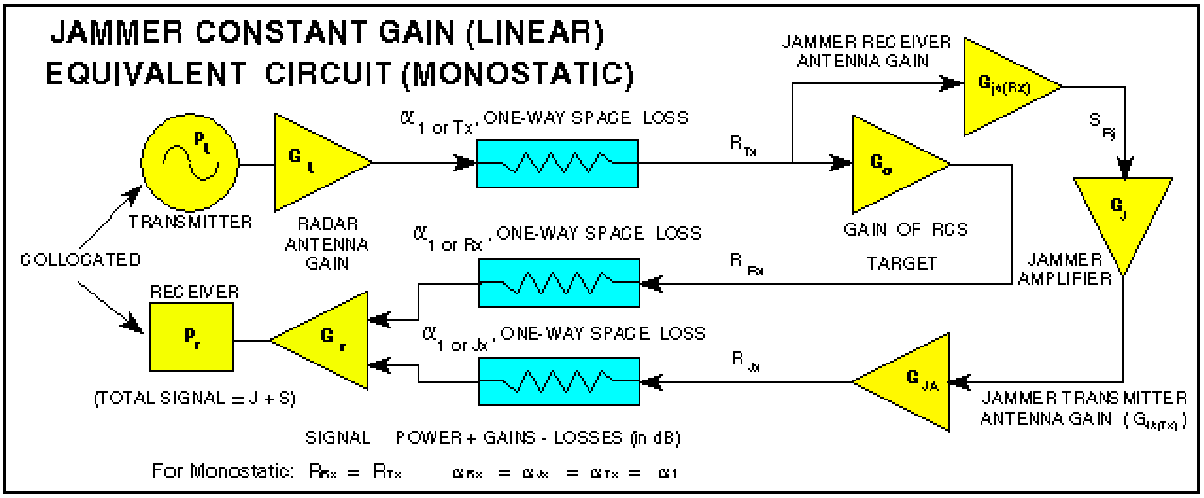
JAMMER CONSTANT GAIN (LINEAR)
EQUIVALENT CIRCUIT (MONOSTATIC)
P_t
TRANSMITTER
G_t
RADAR ANTENNA GAIN
COLLOCATED
RECEIVER
P_r
(TOTAL SIGNAL = J + S)
G_r
$\alpha_{1 \text{ or } Tx}$, ONE-WAY SPACE LOSS
$\alpha_{1 \text{ or } Rx}$, ONE-WAY SPACE LOSS
$\alpha_{1 \text{ or } Jx}$, ONE-WAY SPACE LOSS
R_{Tx}
R_{Rx}
R_{Jx}
JAMMER RECEIVER ANTENNA GAIN
$G_{ja(Rx)}$
S_{Rj}
G_σ
GAIN OF RCS
TARGET
G_j
JAMMER AMPLIFIER
G_{JA}
JAMMER TRANSMITTER ANTENNA GAIN ($G_{ja(Tx)}$)
SIGNAL POWER + GAINS - LOSSES (in dB)
For Monostatic: $R_{Rx} = R_{Tx}$ $\alpha_{Rx} = \alpha_{Jx} = \alpha_{Tx} = \alpha_1$

Figure 2. Jammer Constant Gain EA Equivalent Circuit (Monostatic).

To calculate J, the one way range equation from Section 4-3 is used twice:

$$J = \frac{P_t\, G_t\, G_{ja(Rx)}\, \lambda^2}{(4\pi R\,)^2}\, \frac{G_j\, G_{ja(Tx)}\, G_r\, \lambda^2}{(4\pi R\,)^2} \qquad [4]$$

From the two way range equation in Section 4-4: $S = \frac{P_t\, G_t\, G_r\, \lambda^2\, \sigma}{(4\pi\,)^3\, R^4}$ **[5]**

Terms cancel when combined: $\frac{J}{S} = \frac{G_{ja(Rx)}\, G_j\, G_{ja(Tx)}\, \lambda^2}{4\pi\sigma}$ *Keep λ and σ in same units* **[6]**

Or in dB form: $10\log J/S = 10\log G_{ja(Rx)} + 10\log G_j + 10\log G_{ja(Tx)} - 10\log (4\pi\sigma/\lambda^2)$ **[7]**

Since the last term can be recognized as minus G_σ from equation [10] in Section 4-4, where the target gain factor, $G_\sigma = 10\log (4\pi\sigma/\lambda^2) = 10\log (4\pi\sigma f^2/c^2)$, it follows that:

$10\log J/S = 10\log G_{ja(Rx)} + 10\log G_j + 10\log G_{ja(Tx)} - G_\sigma$ (factors in dB) **[8]**

Target gain factor, $G_\sigma = 10\log \sigma + 20\log f_1 + K_2$ (in dB)

K_2 Values

(dB)	RCS (σ) (units)	f_1 in MHz K_2 =	f_1 in GHz K_2 =
	m^2	-38.54	21.46
	ft^2	-48.86	11.14

BISTATIC

The bistatic equivalent circuit shown in Figure 3 is different from the monostatic equivalent circuit shown in Figure 2 in that the receiver is separately located from the transmitter, $R_{Tx} \neq R_{Rx}$ or R_{Jx} and G_σ will be different since the RCS (σ) varies with aspect angle.

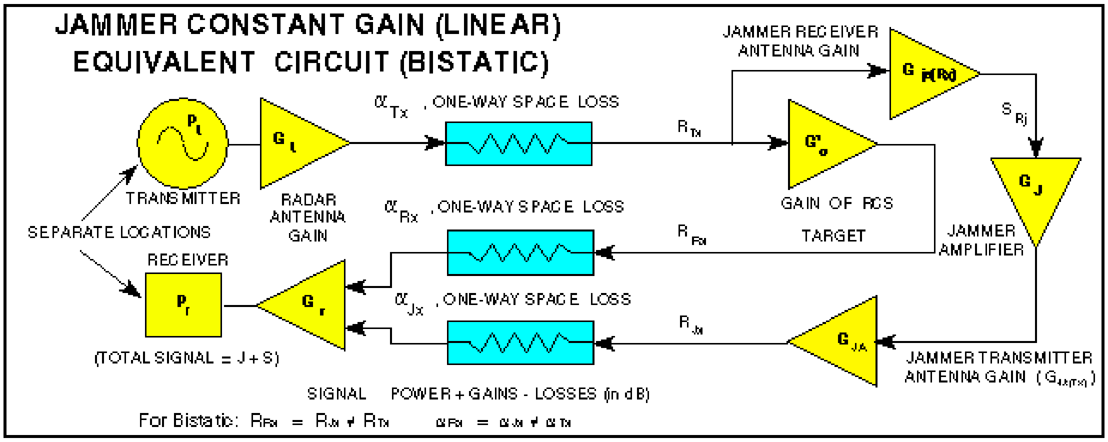
JAMMER CONSTANT GAIN (LINEAR)
EQUIVALENT CIRCUIT (BISTATIC)
JAMMER RECEIVER ANTENNA GAIN
$G_{ja(Rx)}$
α_{Tx} , ONE-WAY SPACE LOSS
P_t
G_t
R_{Tx}
G'_σ
S_{Rj}
G_J
TRANSMITTER
RADAR ANTENNA GAIN
α_{Rx} , ONE-WAY SPACE LOSS
GAIN OF RCS
TARGET
SEPARATE LOCATIONS
R_{Rx}
JAMMER AMPLIFIER
RECEIVER
P_r
G_r
α_{Jx} , ONE-WAY SPACE LOSS
R_{Jx}
G_{JA}
(TOTAL SIGNAL = J + S)
JAMMER TRANSMITTER ANTENNA GAIN ($G_{ja(Tx)}$)
SIGNAL POWER + GAINS - LOSSES (in dB)
For Bistatic: $R_{Rx} = R_{Jx} \neq R_{Tx}$ $\alpha_{Rx} = \alpha_{Jx} \neq \alpha_{Tx}$

Figure 3. Jammer Constant Gain EA Equivalent Circuit (Bistatic).

To calculate J, the one way range equation from Section 4-3 is used twice:

$$J = \frac{P_t\, G_t\, G_{ja(Rx)}\, \lambda^2}{(4\pi\, R_{Tx})^2} \frac{G_j\, G_{ja(Tx)}\, G_r\, \lambda^2}{(4\pi\, R_{Rx})^2} \qquad (R_{Jx} = R_{Rx}) \qquad \textbf{[9]}$$

From the two way range equation in Section 4-4: $S = \frac{P_t\, G_t\, G_r\, \lambda^2\, \sigma'}{(4\pi)^3\, R_{Tx}^2\, R_{Rx}^2}$ (σ′ is bistatic RCS) **[10]**

Terms cancel when combined: $\frac{J}{S} = \frac{G_{ja(Rx)}\, G_j\, G_{ja(Tx)}\, \lambda^2}{4\pi\sigma'}$ *Keep λ and σ in same units* **[11]**

Or in dB form: $10\log J/S = 10\log G_{ja(Rx)} + 10\log G_j + 10\log G_{ja(Tx)} - 10\log (4\pi\sigma'/\lambda^2)$ **[12]**

Since the last term can be recognized as minus G_σ from equation [10] in Section 4-4, where the target gain factor, $G_\sigma = 10\log (4\pi\sigma'/\lambda^2) = 10\log (4\pi\sigma' f^2/c^2)$, it follows that:

$10\log = 10\log G_{ja(Rx)} + 10\log G_j + 10\log G_{ja(Tx)} - G_\sigma'$ (factors in dB) **[13]**

Target gain factor, $G_\sigma = 10\log \sigma + 20\log f_1 + K_2$ (in dB)

K_2 Values (dB)	RCS (σ) (units)	f_1 in MHz K_2 =	f_1 in GHz K_2 =
	m^2	-38.54	21.46
	ft^2	-48.86	11.14

Linear J/S (Monostatic) Example (Linear Power Jamming)

Assume that a 5 GHz radar has a 70 dBm signal fed through a 5 dB loss transmission line to an antenna that has 45 dB gain. An aircraft that is flying 31 km from the radar has an aft EW antenna with -1 dB gain and a 5 dB line loss to the EW receiver (there is an additional loss due to any antenna polarization mismatch but that loss will not be addressed in this problem). The received signal is fed to a jammer with a gain of 60 dB, feeding a 10 dB loss transmission line which is connected to an antenna with 5 dB gain.

If the RCS of the aircraft is 9 m^2, what is the J/S level received at the input to the receiver of the tracking radar?

Answer:

$10\log J/S = 10\log G_{ja(Rx)} + 10\log G_j + 10\log G_{ja(Tx)} - G_\sigma$

$G_\sigma = 10\log \sigma + 20\log f_1 + K_2 = 10\log 9 + 20\log 5 + 21.46 = 44.98$ dB

Note: The respective transmission line losses will be combined with antenna gains, i.e. -1 -5 = -6 dB and -10 + 5 = -5 dB

$10\log J/S = -6 + 60 - 5 - 44.98 = 4.02$ dB @ 5 GHz

The answer changes to 1.1 dB if the tracking radar operates at 7 GHz provided the antenna gains and aircraft RCS are the same at both 5 and 7 GHz.

$G_\sigma = 10\log 9 + 20\log 7 + 21.46 = 47.9$ dB

$10\log J/S = -6 + 60 - 5 - 47.9 = 1.1$ dB @ 7 GHz

Separate J (-73.5 dBm @ 5 GHz and -79.34 dBm @ 7 GHz) and S (-77.52 dBm @ 5 GHz and -80.44 dBm @ 7 GHz) calculations for this problem are provided in Sections 4-3 and 4-4, respectively. A saturated gain version of this problem is provided in Section 4-7.

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RADAR CROSS SECTION (RCS)

Radar cross section is the measure of a target's ability to reflect radar signals in the direction of the radar receiver, i.e. it is a measure of the ratio of backscatter power per steradian (unit solid angle) in the direction of the radar (from the target) to the power density that is intercepted by the target.

The RCS of a target can be viewed as a comparison of the strength of the reflected signal from a target to the reflected signal from a perfectly smooth sphere of cross sectional area of 1 m^2 as shown in Figure 1.

The conceptual definition of RCS includes the fact that not all of the radiated energy falls on the target. A target's RCS (σ) is most easily visualized as the product of three factors:

σ = Projected cross section x Reflectivity x Directivity.

RCS(σ) is used in Section 4-4 for an equation representing power reradiated from the target.

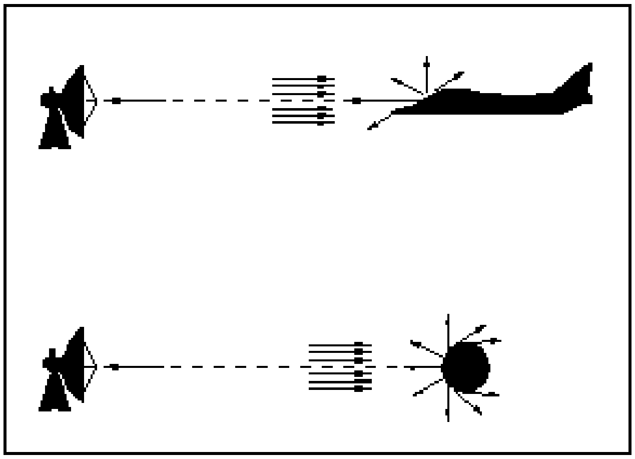

Figure 1. Concept of Radar Cross Section.

Reflectivity: The percent of intercepted power reradiated (scattered) by the target.

Directivity: The ratio of the power scattered back in the radar's direction to the power that would have been backscattered had the scattering been uniform in all directions (i.e. isotropically).

Figures 2 and 3 show that RCS does not equal geometric area. For a sphere, the RCS, $\boldsymbol{\sigma = \pi r^2}$, where r is the radius of the sphere.

The RCS of a sphere is independent of frequency if operating at sufficiently high frequencies where λ<<Range, and λ<< radius (r). Experimentally, radar return reflected from a target is compared to the radar return reflected from a sphere which has a frontal or projected area of one square meter (i.e. diameter of about 44 in). Using the spherical shape aids in field or laboratory measurements since orientation or positioning of the sphere will not affect radar reflection intensity measurements as a flat plate would. If calibrated, other sources (cylinder, flat plate, or corner reflector, etc.) could be used for comparative measurements.

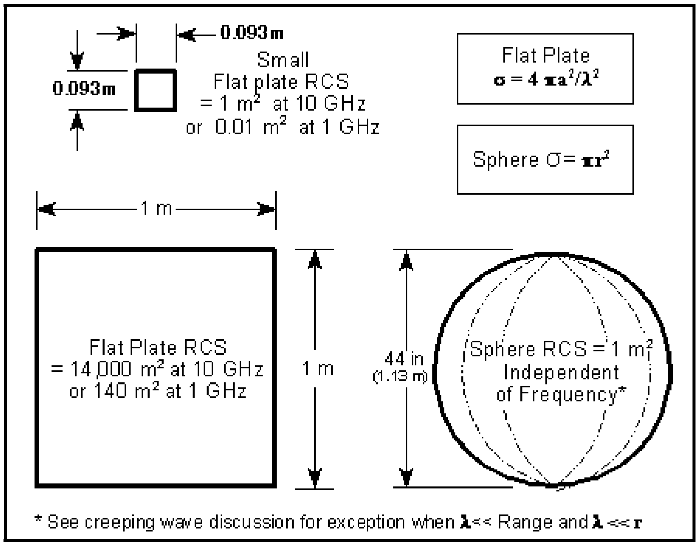
0.093m
0.093m
Small
Flat plate RCS
= 1 m² at 10 GHz
or 0.01 m² at 1 GHz
Flat Plate
σ = 4 πa²/λ²
Sphere σ= πr²
1 m
Flat Plate RCS
= 14,000 m² at 10 GHz
or 140 m² at 1 GHz
1 m
44 in
(1.13 m)
Sphere RCS = 1 m²
Independent
of Frequency*
* See creeping wave discussion for exception when λ<< Range and λ<<r

Figure 2. RCS vs. Physical Geometry.

To reduce drag during tests, towed spheres of 6", 14", or 22" diameter may be used instead of the larger 44" sphere, and the reference size is 0.018, 0.099, or 0.245 m^2 respectively instead of 1 m^2. When smaller sized spheres are used for tests you may be operating at or near where $\lambda \sim$radius. If the results are then scaled to a 1 m^2 reference, there may be some perturbations due to creeping waves. See the discussion at the end of this section for further details.

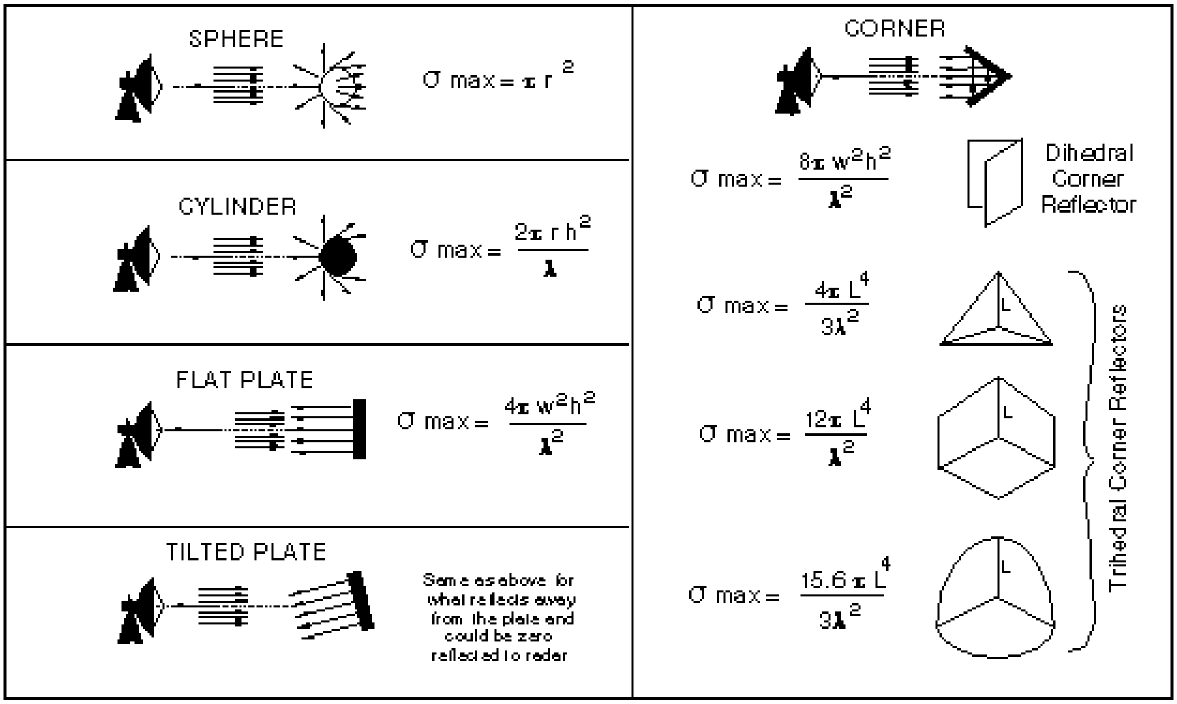
SPHERE
σ max = πr^2
CYLINDER
σ max = $\frac{2\pi r h^2}{\lambda}$
FLAT PLATE
σ max = $\frac{4\pi w^2 h^2}{\lambda^2}$
TILTED PLATE
Same as above for what reflects away from the plate and could be zero reflected to radar
CORNER
σ max = $\frac{8\pi w^2 h^2}{\lambda^2}$
Dihedral Corner Reflector
σ max = $\frac{4\pi L^4}{3\lambda^2}$
L
σ max = $\frac{12\pi L^4}{\lambda^2}$
L
σ max = $\frac{15.6\pi L^4}{3\lambda^2}$
L
Trihedral Corner Reflectors

Figure 3. Backscatter From Shapes.

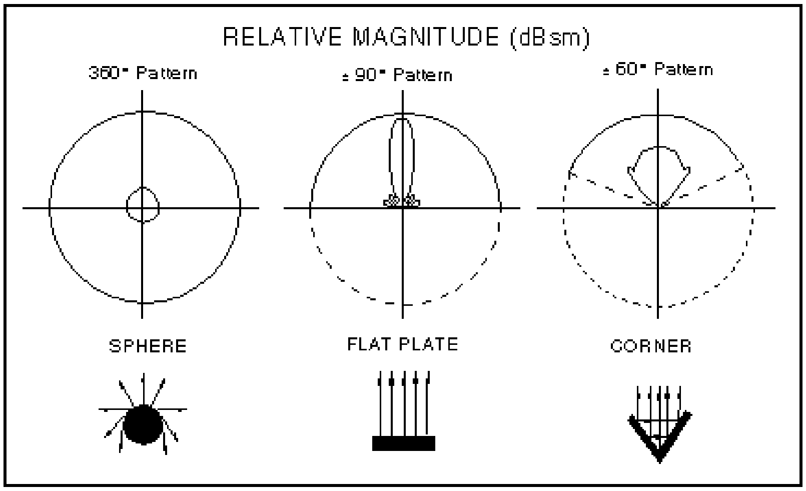
RELATIVE MAGNITUDE (dBsm)
360° Pattern
± 90° Pattern
± 60° Pattern
SPHERE
FLAT PLATE
CORNER

Figure 4. RCS Patterns.

In Figure 4, RCS patterns are shown as objects are rotated about their vertical axes (the arrows indicate the direction of the radar reflections).

The sphere is essentially the same in all directions.

The flat plate has almost no RCS except when aligned directly toward the radar.

The corner reflector has an RCS almost as high as the flat plate but over a wider angle, i.e., over ±60°. The return from a corner reflector is analogous to that of a flat plate always being perpendicular to your collocated transmitter and receiver.

Targets such as ships and aircraft often have many effective corners. Corners are sometimes used as calibration targets or as decoys, i.e. corner reflectors.

An aircraft target is very complex. It has a great many reflecting elements and shapes. The RCS of real aircraft must be measured. It varies significantly depending upon the direction of the illuminating radar.

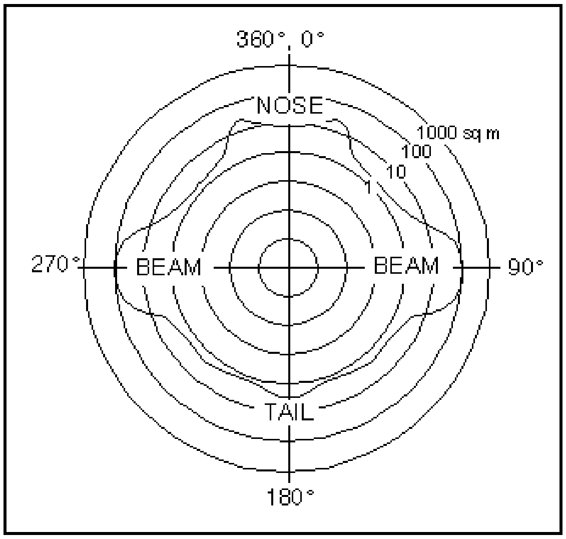

Figure 5. Typical Aircraft RCS.

Figure 5 shows a typical RCS plot of a jet aircraft. The plot is an azimuth cut made at zero degrees elevation (on the aircraft horizon). Within the normal radar range of 3-18 GHz, the radar return of an aircraft in a given direction will vary by a few dB as frequency and polarization vary (the RCS may change by a factor of 2-5). It does not vary as much as the flat plate.

As shown in Figure 5, the RCS is highest at the aircraft beam due to the large physical area observed by the radar and perpendicular aspect (increasing reflectivity). The next highest RCS area is the nose/tail area, largely because of reflections off the engines or propellers. Most self-protection jammers cover a field of view of +/- 60 degrees about the aircraft nose and tail, thus the high RCS on the beam does not have coverage. Beam coverage is frequently not provided due to inadequate power available to cover all aircraft quadrants, and the side of an aircraft is theoretically exposed to a threat 30% of the time over the average of all scenarios.

Typical radar cross sections are as follows: Missile 0.5 sq m; Tactical Jet 5 to 100 sq m; Bomber 10 to 1000 sq m; and ships 3,000 to 1,000,000 sq m. RCS can also be expressed in decibels referenced to a square meter (dBsm) which equals 10 log (RCS in m^2).

Again, Figure 5 shows that these values can vary dramatically. The strongest return depicted in the example is 100 m^2 in the beam, and the weakest is slightly more than 1 m^2 in the 135°/225° positions. These RCS values can be very misleading because other factors may affect the results. For example, phase differences, polarization, surface imperfections, and material type all greatly affect the results. In the above typical bomber example, the measured RCS may be much greater than 1000 square meters in certain circumstances (90°, 270°).

SIGNIFICANCE OF THE REDUCTION OF RCS

If each of the range or power equations that have an RCS (σ) term is evaluated for the significance of decreasing RCS, Figure 6 results. Therefore, an RCS reduction can increase aircraft survivability. The equations used in Figure 6 are as follows:

Range (radar detection):
From the 2-way range equation in Section 4-4:

$$P_r = \frac{P_t\, G_t\, G_r\, \lambda^2 \sigma}{(4\pi)^3\, R^4}$$

Therefore, $R^4 \propto \sigma$ or $\sigma^{1/4} \propto R$

Range (radar burn-through):
The crossover equation in Section 4-8 has:

$$R_{BT}^2 = \frac{P_t\, G_t\, \sigma}{P_j\, G_j\, 4\pi}$$

Therefore, $R_{BT}^2 \propto \sigma$ or $\sigma^{1/2} \propto R_{BT}$

Power (jammer): Equating the received signal return (P_r) in the two way range equation to the received jammer signal (P_r) in the one way range equation, the following relationship results:

$$P_r = \underset{S}{\underset{\uparrow}{\frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R^4}}} = \underset{J}{\underset{\uparrow}{\frac{P_j G_j G_r \lambda^2}{(4\pi R)^2}}}$$

Therefore, $P_j \propto \sigma$ or $\sigma \propto P_j$

Note: jammer transmission line loss is combined with the jammer antenna gain to obtain G_t.

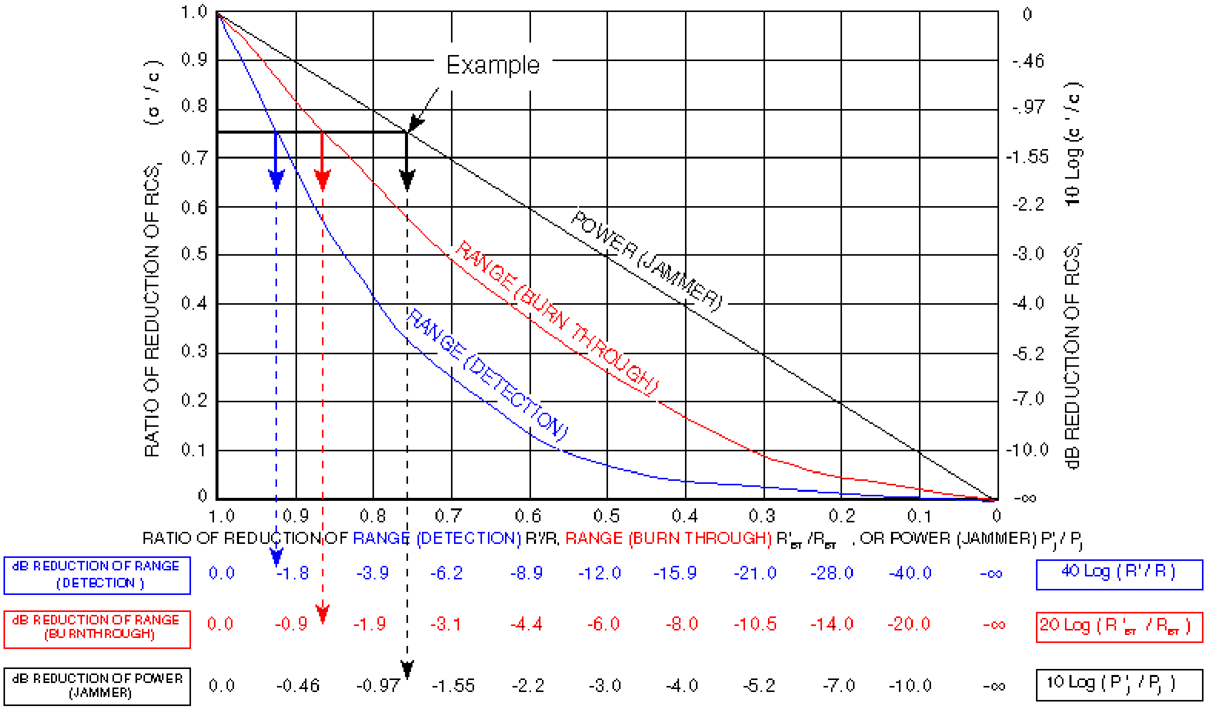

dB REDUCTION OF RANGE (DETECTION)	0.0	-1.8	-3.9	-6.2	-8.9	-12.0	-15.9	-21.0	-28.0	-40.0	-∞	40 Log (R' / R)
dB REDUCTION OF RANGE (BURNTHROUGH)	0.0	-0.9	-1.9	-3.1	-4.4	-6.0	-8.0	-10.5	-14.0	-20.0	-∞	20 Log (R'_{BT} / R_{BT})
dB REDUCTION OF POWER (JAMMER)	0.0	-0.46	-0.97	-1.55	-2.2	-3.0	-4.0	-5.2	-7.0	-10.0	-∞	10 Log (P'_j / P_j)

Figure 6. Reduction of RCS Affects Radar Detection, Burn-through, and Jammer Power.

Example of Effects of RCS Reduction - As shown in Figure 6, if the RCS of an aircraft is reduced to 0.75 (75%) of its original value, then (1) the jammer power required to achieve the same effectiveness would be 0.75 (75%) of the original value (or -1.25 dB). Likewise, (2) If Jammer power is held constant, then burn-through range is 0.87 (87%) of its original value (-1.25 dB), and (3) the detection range of the radar for the smaller RCS target (jamming not considered) is 0.93 (93%) of its original value (-1.25 dB).

OPTICAL / MIE / RAYLEIGH REGIONS

Figure 7 shows the different regions applicable for computing the RCS of a sphere. The optical region ("far field" counterpart) rules apply when $2\pi r/\lambda > 10$. In this region, the RCS of a sphere is independent of frequency. Here, the RCS of a sphere, $\sigma = \pi r^2$. The RCS equation breaks down primarily due to creeping waves in the area where λ~2πr. This area is known as the Mie or resonance region. If we were using a 6” diameter sphere, this frequency would be 0.6 GHz. (Any frequency ten times higher, or above 6 GHz, would give expected results). The largest positive perturbation (point A) occurs at exactly 0.6 GHz where the RCS would be 4 times higher than the RCS computed using the optical region formula. Just slightly above 0.6 GHz a minimum occurs (point B) and the actual RCS would be 0.26 times the value calculated by using the optical region formula. If we used a one meter diameter sphere, the perturbations would occur at 95 MHz, so any frequency above 950 MHz (~1 GHz) would give predicted results.

CREEPING WAVES

The initial RCS assumptions presume that we are operating in the optical region (λ<<Range and λ<<radius). There is a region where specular reflected (mirrored) waves combine with back scattered creeping waves both constructively and destructively as shown in Figure 8. Creeping waves are tangential to a smooth surface and follow the “shadow” region of the body. They occur when the circumference of the sphere ~ λ and typically add about 1 m^2 to the RCS at certain frequencies.

RAYLEIGH REGION
$\sigma = [\pi r^2][7.11(kr)^4]$

where: $k = 2\pi/\lambda$

MIE (resonance)
$\sigma = 4\pi r^2$ at Maximum (point A)
$\sigma = 0.26\pi r^2$ at Minimum (pt B)

OPTICAL REGION
$\sigma = \pi r^2$
(Region RCS of a sphere is independent of frequency)

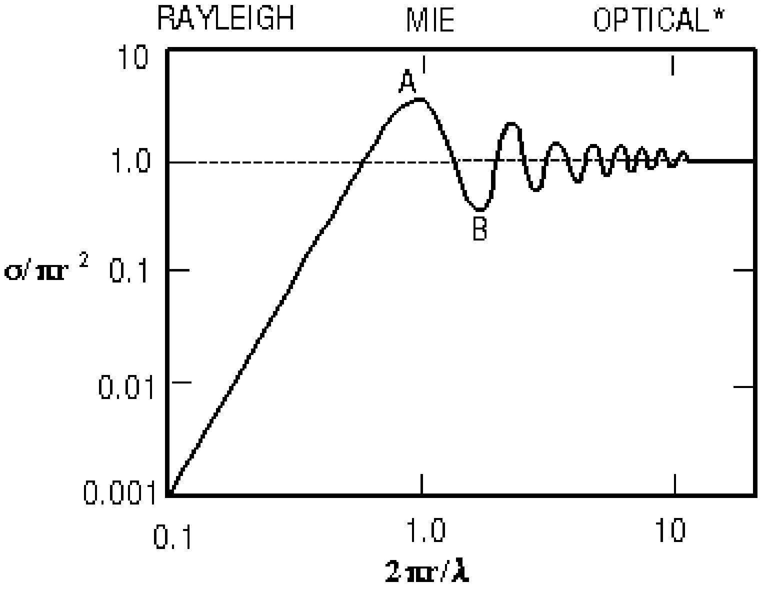

* "RF far field" equivalent
Courtesy of Dr. Allen E. Fuhs, Ph.D.

Figure 7. Radar Cross Section of a Sphere.

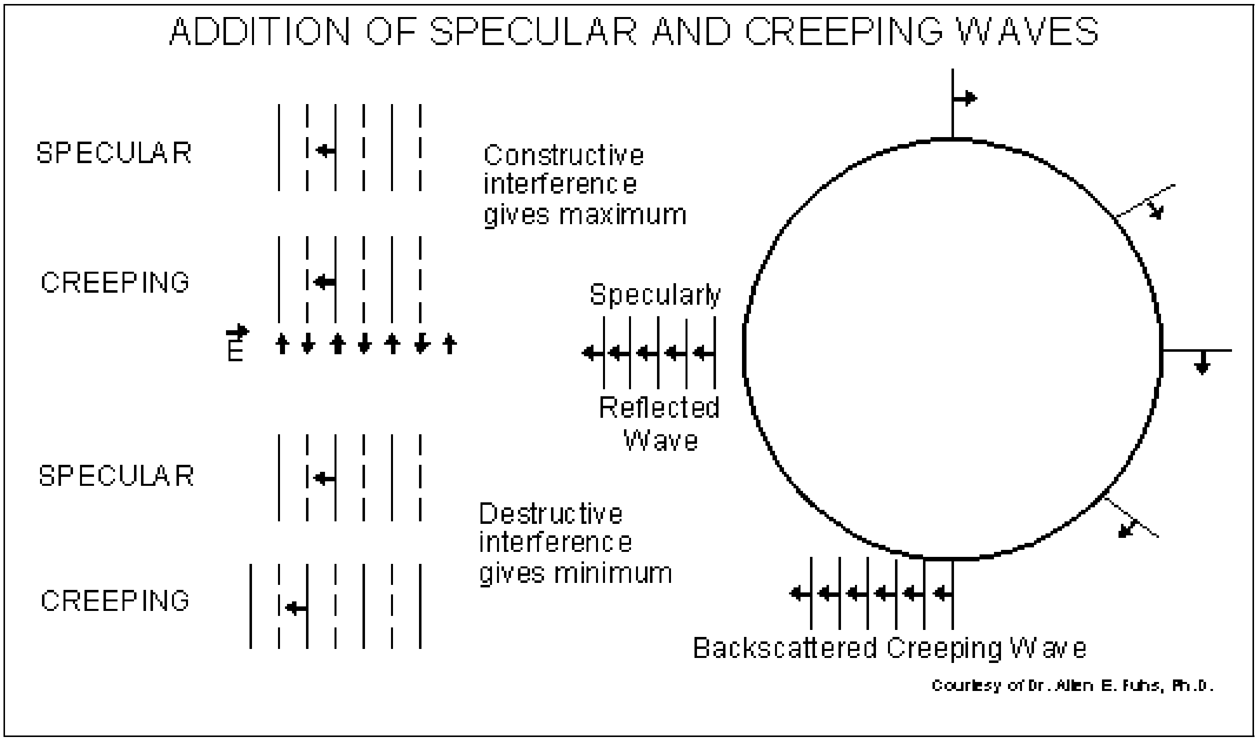
ADDITION OF SPECULAR AND CREEPING WAVES
SPECULAR
CREEPING
E
Constructive interference gives maximum
SPECULAR
CREEPING
Destructive interference gives minimum
Specularly
Reflected Wave
Backscattered Creeping Wave
Courtesy of Dr. Allen E. Fuhs, Ph.D.

Figure 8. Addition of Specular and Creeping Waves.

EMISSION CONTROL (EMCON)

When EMCON is imposed, RF emissions must not exceed -110 dBm/meter^2 at one nautical mile. It is best if systems meet EMCON when in either the Standby or Receive mode versus just the Standby mode (or OFF). If one assumes antenna gain equals line loss, then emissions measured at the port of a system must not exceed -34 dBm (i.e. the stated requirement at one nautical mile is converted to a measurement at the antenna of a point source - see Figure 1). If antenna gain is greater than line loss (i.e. gain 6 dB, line loss 3 dB), then the -34 dBm value would be lowered by the difference and would be -37 dBm for the example. The opposite would be true if antenna gain is less.

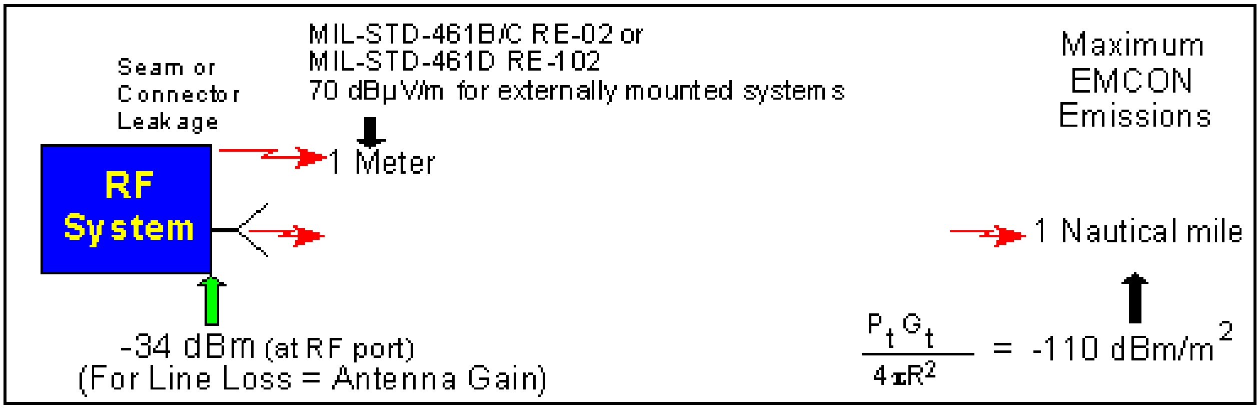
Seam or Connector Leakage
MIL-STD-461B/C RE-02 or
MIL-STD-461D RE-102
70 dBµV/m for externally mounted systems
1 Meter
Maximum EMCON Emissions
RF System
1 Nautical mile
-34 dBm (at RF port)
(For Line Loss = Antenna Gain)
$\frac{P_t G_t}{4\pi R^2} = -110$ dBm/m^2

Figure 1. EMCON Field Intensity / Power Density Measurements.

To compute the strength of emissions at the antenna port in Figure 1, we use the power density equation (see Section 4-2)

$$P_D = \frac{P_t G_t}{4\pi R^2} \quad \textbf{[1]} \qquad \text{or rearranging} \qquad P_t G_t = P_D\,(4\pi R^2) \quad \textbf{[2]}$$

Given that $P_D = -110$ dBm/m^2 = $(10)^{-11}$ mW/m^2, and R = 1 NM = 1852 meters.

$$P_t G_t = P_D\,(4\pi R^2) = (10^{-11}\text{mW/m}^2)(4\pi)(1852\text{m})^2 = 4.31(10)^{-4}\text{ mW} = -33.65 \approx -34\text{ dBm}$$

at the RF system antenna as given.

or, the equation can be rewritten in Log form and each term multiplied by 10:

$$10\log P_t + 10\log G_t = 10\log P_D + 10\log(4\pi R^2) \quad \textbf{[3]}$$

Since the m^2 terms on the right side of equation [3] cancel, then:

$$10\log P_t + 10\log G_t = -110\text{ dBm} + 76.35\text{ dB} = -33.65\text{ dBm} \approx -34\text{ dBm as given in Figure 1.}$$

If MIL-STD-461B/C RE02 (or MIL-STD-461D RE-102) measurements (see Figure 2) are made on seam/connector leakage of a system, emissions below 70 dBµV/meter which are measured at one meter will meet the EMCON requirement. Note that the airframe provides attenuation so portions of systems mounted inside an aircraft that measure 90 dBµV/meter will still meet EMCON if the airframe provides 20 dB of shielding (note that the requirement at one nm is converted to what would be measured at one meter from a point source).

The narrowband emission limit shown in Figure 2 for RE02/RE102 primarily reflect special concern for local oscillator leakage during EMCON as opposed to switching transients which would apply more to the broadband limit.

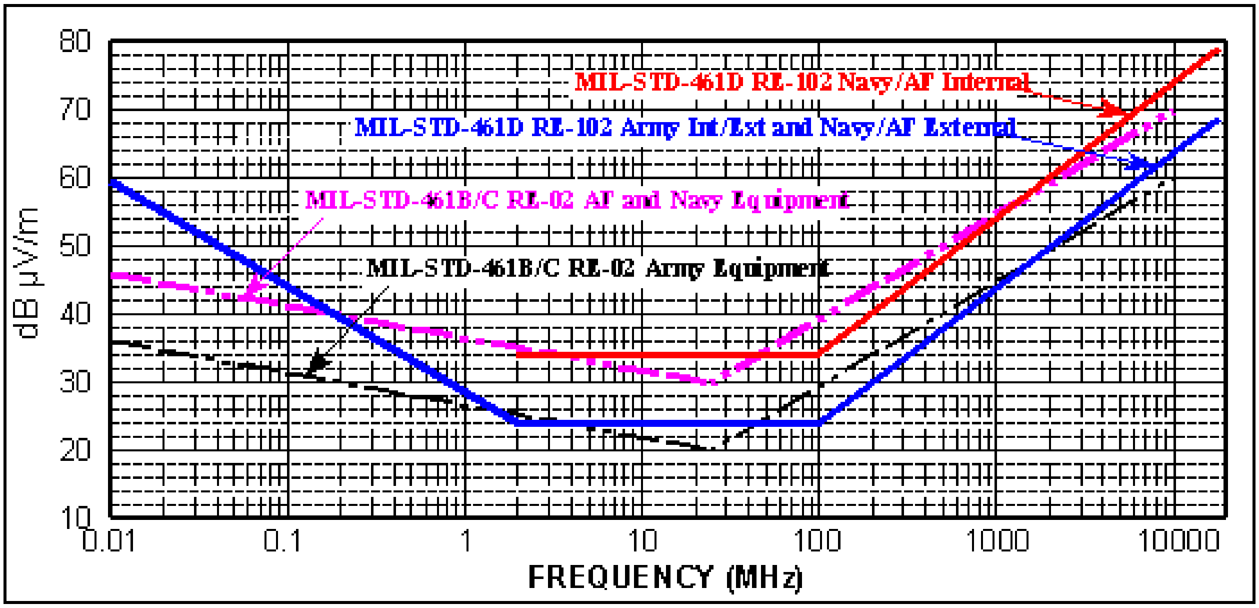

Figure 3. MIL-STD-461 Narrowband Radiated Emissions Limits.

Note that in MIL-STD-461D, the narrowband radiated emissions limits were retitled RE-102 from the previous RE-02 and the upper frequency limit was raised from 10 GHz to 18 GHz. The majority of this section will continue to reference RE02 since most systems in use today were built to MIL-STD-461B/C.

For the other calculation involving leakage (to obtain 70 dBµV/m) we again start with: $P_D = \frac{P_t G_t}{4\pi R^2}$

and use the previous fact that: 10log (P_tG_t) = -33.6 dBm = $4.37\text{x}10^{-4}$ mW (see Section 2-4).

The measurement is at one meter so $R^2 = 1\ m^2$

we have: $\frac{4.37x\,10^{-4}}{4\pi}\, mW/\,m^2 = .348x\,10^{-4}\, mW/\,m^2 = -\,44.6\ dBm/\,m^2 = P_D$ @ 1 meter

Using the field intensity and power density relations (see Section 4-1)

$$E = \sqrt{P_D Z} = \sqrt{3.48x\,10^{-8} \bullet 377\Omega} = 36.2x\,10^{-4}\ V/m$$

Changing to microvolts (1V = 10^6 µV) and converting to logs we have:

20 log (E) = 20 log (10^6 x $36.2\text{x}10^{-4}$) = 20 log ($.362\text{x}10^4$) = 71.18 dBµV/m ≈ 70 dBµV/m as given in Figure 1.

Some Words of Caution

A common error is to only use the one-way free space loss coefficient α_1 directly from Figure 6, Section 4-3 to calculate what the output power would be to achieve the EMCON limits at 1 NM. This is incorrect since the last term on the right of equation [3] (10 Log($4\pi R^2$)) is simply the Log of the surface area of a sphere - **it is NOT** the one-way free space loss factor α_1. You cannot interchange power (watts or dBW) with power density (watts/m^2 or dBW/m^2).

The equation uses power density (P_D), **NOT** received power (P_r). It is independent of RF and therefore varies only with range. If the source is a transmitter and/or antenna, then the power-gain product (or EIRP) is easily measured and it's readily apparent if 10log ($P_t G_t$) is less than -34 dBm. If the output of the measurement system is connected to a power meter in place of the system transmission line and antenna, the -34 dBm value must be adjusted. The measurement on the power meter (dBm) minus line loss (dB) plus antenna gain (dB) must not be higher than -34 dBm.

However, many sources of radiation are through leakage, or are otherwise inaccessible to direct measurement and P_D must be measured with an antenna and a receiver. The measurements must be made at some RF(s), and received signal strength is a function of the antenna used therefore measurements must be scaled with an appropriate correction factor to obtain correct power density.

RE-02 Measurements

When RE-02 measurements are made, several different antennas are chosen dependent upon the frequency range under consideration. The voltage measured at the output terminals of an antenna is not the actual field intensity due to actual antenna gain, aperture characteristics, and loading effects. To account for this difference, the antenna factor is defined as:

$$AF = E/V \qquad \textbf{[4]}$$

where E = Unknown electric field to be determined in V/m (or μV/m)
V = Voltage measured at the output terminals of the measuring antenna

For an antenna loaded by a 50 Ω line (receiver), the theoretical antenna factor is developed as follows:

$$P_D A_e = P_r = V^2/R = V_r^2/50 \text{ or } V_r = \sqrt{50 P_D A_e}$$

From Section 4-3 we see that $A_e = G_r\lambda^2/4\pi$, and from Section 4-1, $E^2 = 377 P_D$ therefore we have:

$$AF = \frac{E}{V} = \frac{\sqrt{377 P_D}}{\sqrt{50 P_D(\lambda^2 G_r / 4\pi)}} = \frac{9.73}{\lambda\sqrt{G_r}} \qquad \textbf{[5]}$$

Reducing this to decibel form we have:

$$20 \log AF = 20 \log E - 20 \log V = 20 \log\left[\frac{9.73}{\lambda\sqrt{GSUBr}}\right] \quad \textit{with } \lambda \textit{ in meters and Gain numeric ratio (not dB)} \qquad \textbf{[6]}$$

This equation is plotted in Figure 3.

Since all of the equations in this section were developed using far field antenna theory, use only the indicated region.

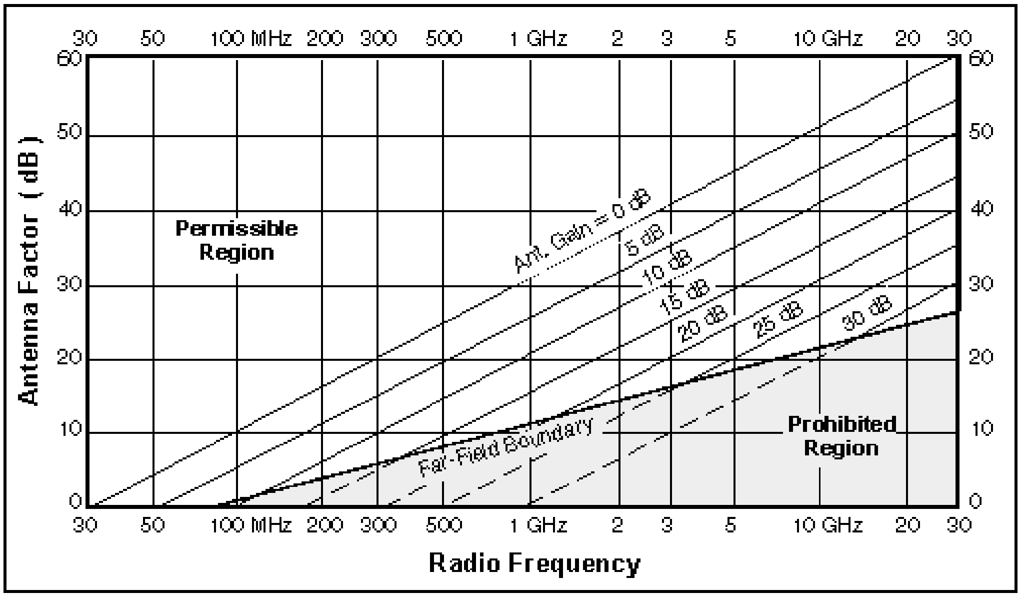

Figure 3. Antenna Factor vs. Frequency for Indicated Antenna Gain.

In practice the electric field is measured by attaching a field intensity meter or spectrum analyzer with a narrow bandpass preselector filter to the measuring antenna, recording the actual reading in volts and applying the antenna factor.

$$20\log E = 20\log V + 20\log AF \qquad \textbf{[7]}$$

Each of the antennas used for EMI measurements normally has a calibration sheet for both gain and antenna factor over the frequency range that the antenna is expected to be used. Typical values are presented in Table 1.

Table 1. Typical Antenna Factor Values.

Frequency Range	Antenna(s) Used	Antenna Factor	Gain(dB)
14 kHz - 30 MHz	41" rod	22-58 dB	0 - 2
20 MHz - 200 MHz	Dipole or Biconical	0-18 dB	0 - 11
200 MHz - 1 GHz	Conical Log Spiral	17-26 dB	0 - 15
1 GHz - 10 GHz	Conical Log Spiral or Ridged Horn	21-48 dB	0 - 28
1 GHz - 18 GHz	Double Ridged Horn	21-47 dB	0 - 32
18 GHz - 40 GHz	Parabolic Dish	20-25 dB	27 - 35

The antenna factor can also be developed in terms of the receiving antenna's effective area. This can be shown as follows:

$$AF = \frac{E}{V} = \frac{\sqrt{377\, P_D}}{\sqrt{50\, P_D\, A_e}} = \frac{2.75}{\sqrt{A_e}} \qquad \textbf{[8]}$$

Or in log form:

$$20 \log AF = 20 \log E - 20 \log V = 20 \log \left[\frac{2.75}{\sqrt{A_e}} \right] \qquad \textbf{[9]}$$

While this relation holds for any antenna, many antennas (spiral, dipole, conical etc.) which do not have a true "frontal capture area" do not have a linear or logarithmic relation between area and gain and in that respect the parabolic dish is unique in that the antenna factor does not vary with frequency, only with effective capture area. Consequently a larger effective area results in a smaller antenna factor.

A calibrated antenna would be the first choice for making measurements, followed by use of a parabolic dish or "standard gain" horn. A standard gain horn is one which was designed such that it closely follows the rules of thumb regarding area/gain and has a constant antenna factor. If a calibrated antenna, parabolic dish, or "standard horn" is not available, a good procedure is to utilize a flat spiral antenna (such as the AN/ALR-67 high band antennas). These antennas typically have an average gain of 0 dB (typically -4 to +4 dB), consequently the antenna factor would not vary a lot and any error would be small.

EXAMPLE:

Suppose that we want to make a very general estimation regarding the ability of a system to meet EMCON requirements. We choose to use a spiral antenna for measurements and take one of our samples at 4 GHz. Since we know the gain of the spiral is relatively flat at 4 GHz and has a gain value of approximately one (0 dB) in that frequency range. The antenna is connected to a spectrum analyzer by 25 feet of RG9 cable. We want to take our measurements at 2 meters from the system so our setup is shown as follows:

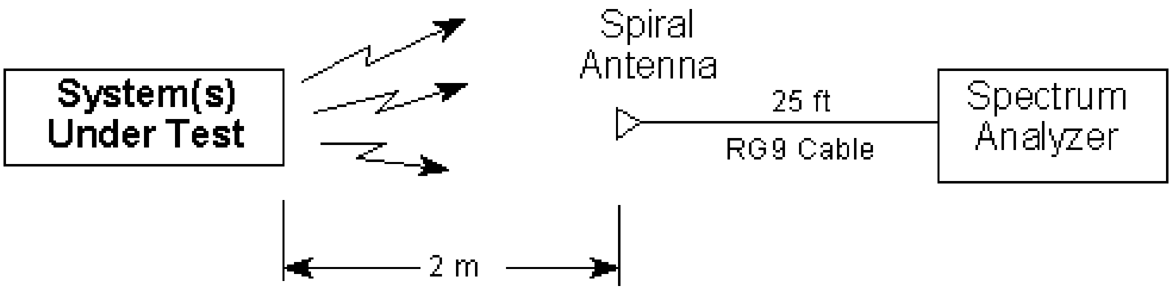

Our RG9 cable has an input impedance of 50Ω, and a loss of 5 dB (from Figure 5, Section 6-1).

First, let's assume that we measure -85 dBm at the spectrum analyzer and we want to translate this into the equivalent strength at 1 NM. Our power received by the antenna is: P_r = -85 dBm + 5 dB line loss = -80 dBm

also $P_D = P_r/A_e$ and $A_e = G\lambda^2/4\pi = (G/4\pi)\bullet(c/f)^2 = (1/4\pi)\bullet(3x10^8/4x10^9)^2 = 4.47x10^{-4}\ m^2$

in log form: $10\ \text{Log}\ P_D = 10\ \text{Log}\ P_r - 10\ \text{Log}\ A_e = -80\ \text{dBm} + 33.5 = -46.5\ \text{dBm/m}^2$
at our 2 meter measuring point

To convert this to a value at 1 NM, we use

$P_t\ G_t = P_{D@1\ nm}\ 4\pi R_1^{\ 2} = P_{D@2\ m}\ 4\pi R_2^{\ 2}$ and we solve for PD@1 $_{nm}$

in log form after cancelling the 4π terms:

$10\ \text{Log}\ P_{D@1\ nm} = 10\ \text{Log}\ P_{D@2\ m} + 10\ \text{Log}\ (R_{2m}/R_{1nm})^2 = -46.5\ \text{dBm/m}^2 - 59.3\ \text{dB} = -105.8\ \text{dBm/m}^2$ which is more power than the maximum value of $-110\ \text{dBm/m}^2$ specified.

If we are making repetitive measurement as we might do when screening an aircraft on the flight line with numerous systems installed, or when we want to improve (reduce) the leakage on a single system by changing antennas, lines, connectors, or EMI gaskets or shielding, this mathematical approach would be unnecessarily time consuming since it would have to be repeated after each measurement. A better approach would be to convert the $-110\ \text{dBm/m}^2$ value at 1 NM to the maximum you can have at the measuring instrument (in this case a spectrum analyzer), then you could make multiple measurements and know immediately how your system(s) are doing. It should be noted that -90 to -100 dBm is about the minimum signal level that can be detected by a spectrum analyzer, so you couldn't take measurements much further away unless you used an antenna with a much higher gain.

In order not to exceed EMCON, the power density must not exceed $-110\ \text{dBm/m}^2$ at 1 NM, which is $10^{-11}\ \text{mW/m}^2$.

$$P_t\ G_t = P_{D@1\ nm}\ 4\pi R_1^{\ 2} = P_{D@2\ m}\ 4\pi R_2^{\ 2}$$

we solve for $P_{D@2\ m} = 10^{-11}(1852m)^2/(2m)^2 = 8.57\ x\ 10^{-6}\ \text{mW/m}^2 = -50.7\ \text{dBm/m}^2$

We'll be using a spectrum analyzer, so we want to compute what the maximum power or voltage may be.

Method 1 - Using the Power Density Approach

Using logs/dB and the values of $P_{D@2\ m}$ and A_e determined previously:
$10\ \text{Log}\ P_r = 10\ \text{Log}\ P_D + 10\ \text{Log}\ A_e = -50.7 - 33.5 = -84.2\ \text{dBm}$

taking line loss into account we have: -84.2 - 5 dB = - 89.2 dBm as the maximum measurement reading.

If we wanted to calculate it in volts, and take into account our line impedance we would have the following:

$P_r = P_D A_e = V^2/R = V^2/50\Omega$ also $A_e = G\lambda^2/4\pi$ so solving for V we have:

$$V = \sqrt{P_D\left[\frac{G_r\lambda^2}{4\pi}\right]R} = \sqrt{P_D\left[\frac{G_r}{4\pi}\left(\frac{c}{f}\right)^2\right]R} = \sqrt{8.57x\,10^{-9}\left[\frac{1}{4\pi}\left(\frac{3x\,10^8}{4x\,10^9}\right)^2\right]50\Omega} = 1.38x\,10^{-5}\text{ volts}\quad\text{(before line loss)}$$

since our line loss is 5 dB, we have -5 dB = 20 Log V_2/V_1. Solving for V_2 we get 7.79x10^{-6} volts or -89 dBm as a maximum at our measurement device input. We can see immediately that our value of -85 dBm that we measured on the previous page would not meet specifications, and neither would any signal with more power than -89 dBm.

Method 2 - Using the Antenna Factor Approach

Starting with the same value of power density that we obtained above (8.57x10^{-9} W/m^2), we find the field intensity from Table 1, Section 4-1 to be approximately 65 dBμv/m. Also from Figure 3 in this section, AF = 43 dB @ 4 GHz (by calculating with equation [6], the exact value is 42.3 dB).

From equation [6]:
20log V = 20log E - 20log AF
20log V = 65 - 43 = 22 dBμv/m.

Since dBμv/m = 20 log (V)(10^6) = 20 log V + 20 log 10^6 = 20 log V + 120, we see that to get an answer in dBv we must subtract 120 from the dBμv/m value so: V_{dB} = 22 - 120 = -98dBv. We then subtract our line loss (-5 dB) and we have:

V = -98 - 5 = -103 dBv = 17 dBμv = 7.1x10^{-6} volts

using the fact that P = V^2/R and for the input line R = 50Ω, P = 1x10^{-12} W = -120 dBW = -90 dBm

Although this method is just as accurate as that obtained using method 1, the values obtained in Table 1, Section 4-1, and Figure 3 must be interpolated, and may not result in values which are as precise as the appropriate formulas would produce.

Sample Problem: What is the approximate transmit power from a receiver?

A. 1 nanowatt (nW)
B. 10 nW
C. 100 nW
D. 1 microwatt (μW)
E. 10 μW
F. 100 μW
G. 1 milliwatt (mW)
H. 10 mW
I. 100 mW
J. 1 watt (W)
K. 10 W
L. 100 W
M. 1 kilowatt (kW)
N. 10 kW
O. 100 kW

The question may seem inappropriate since a receiver is supposedly a passive device which only receives a signal. If the receiver was a crystal video receiver as shown in Section 5-3, it wouldn't transmit power unless a built-in-test (BIT) signal was injected after the antenna to periodically check the integrity of the microwave path and components. The potential exists for the BIT signal to leak across switches and couple back through the input path and be transmitted by the receiver's antennas.

If the receiver uses a local oscillator (LO) and a mixer to translate the signal to an intermediate frequency (IF) for processing (such as a superhet shown in Section 5-3), there is the potential for the CW LO signal to couple back through the signal input path and be transmitted by the receiver's antenna. Normally a mixer has 20 dB of rejection for the reverse direction. In addition, the LO may be further attenuated by receiver front end filters.

In both cases, the use of isolators described in Section 6-7 could be used to further attenuate any signals going in the reverse direction, i.e. back to the antenna. A good receiver design should ensure that any RF leakage radiated by the receiver will not exceed the EMCON level.

In answer to the initial question, "transmit" leakage power should be less than -34 dBm (0.4 μW) to meet EMCON. Therefore, the real answer may be "A," "B," or "C" if EMCON is met and could be "D" through possibly "G" if EMCON is not met.

EW JAMMING TECHNIQUES

INTRODUCTION

Electronic jamming is a form of Electronic Attack where jammers radiate interfering signals toward an enemy's radar, blocking the receiver with highly concentrated energy signals. The two main technique styles are noise techniques and repeater techniques. The three types of noise jamming are spot, sweep, and barrage. Repeater techniques can be further subdivided into categories as shown in Figure 1.

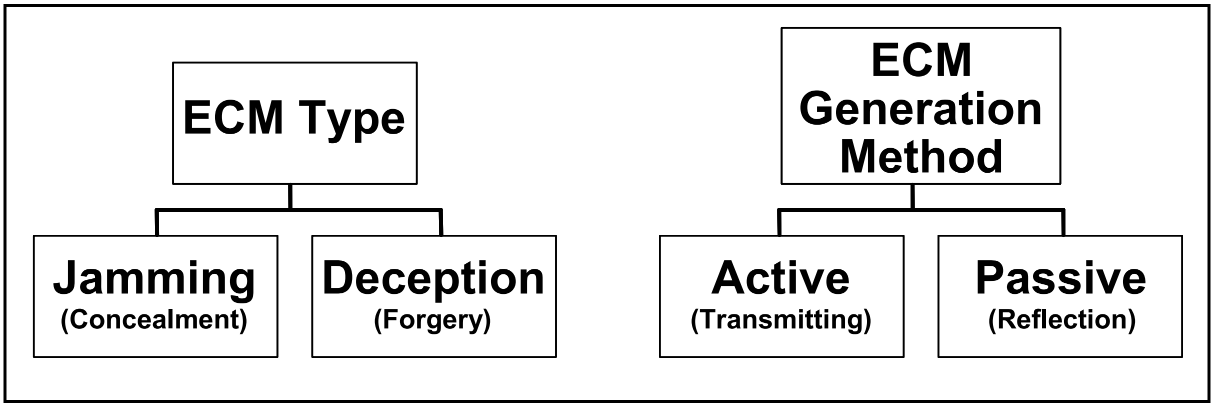
ECM Type
Jamming
(Concealment)
Deception
(Forgery)
ECM Generation Method
Active
(Transmitting)
Passive
(Reflection)

Figure 1. EA Repeater Technique Divisions.

ASYNCHRONOUS SWEPT WAVE MODULATION (ASWM)

ASWM is synonymous with A-SWM. Asynchronous indicates that the waveform is free running - also see SSWM. A swept wave modulation is essentially a swept amplitude modulation (SAM). It is a waveform that is swept between two frequencies that are usually chosen to bracket a radar's passive angle scanning rate. The modulation amplitude can be either down modulated or On-Off Keyed (OOK). The down modulated shape can be square wave, rectangular wave, linear (e.g. a sine wave), or a combination. The OOK modulated shape can be square wave or rectangular wave.

BARRAGE JAMMING

The jamming of multiple frequencies at once by a single jammer. The advantage is that multiple frequencies can be jammed simultaneously; however, the jamming effect can be limited because this requires the jammer to spread its full power between these frequencies. So the more frequencies being jammed, the less effectively each is jammed.

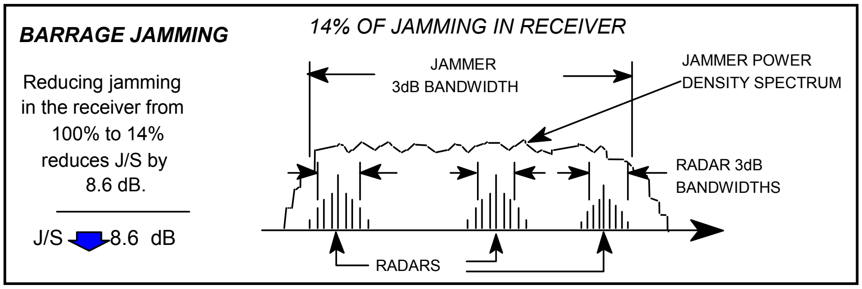
BARRAGE JAMMING
Reducing jamming in the receiver from 100% to 14% reduces J/S by 8.6 dB.
J/S 8.6 dB
14% OF JAMMING IN RECEIVER
JAMMER 3dB BANDWIDTH
JAMMER POWER DENSITY SPECTRUM
RADAR 3dB BANDWIDTHS
RADARS

Figure 2. Barrage Jamming.

CROSS POLARIZATION (X-POL)

(1) A self-screening or support EA technique that causes angle errors in tracking radars and sensing errors in jamming suppression EP systems of surveillance radars by radiating a signal that is orthogonally polarized to the principal polarization of the victim radar. (2) A technique used against monopulse and other passive lobe tracking radars. Requires a strong jam-to-signal ratio or the skin echo will show up in the pattern nulls.

HOME ON JAM (HOJ)

A means whereby a missile guidance receiver utilizes the self-screening target jamming signal to develop angular steering information so that the missile can home on that target.

IMAGE JAMMING

Jamming at the image frequency of the radar receiver. Barrage jamming is made most effective by generating energy at both the normal operating and image frequency of the radar. Image jamming inverts the phase of the response and is thereby useful as an angle deception technique. Not effective if the radar uses image rejection.

INVERSE CON SCAN (ICS)

One method of confusing a radar operator or fire control radar system is to provide erroneous target bearings. This is accomplished by first sensing the radar antenna or antenna dipole scan rate and then modulating repeater amplifier gain so that the weapons system will fire at some bearing other than the true target bearing.

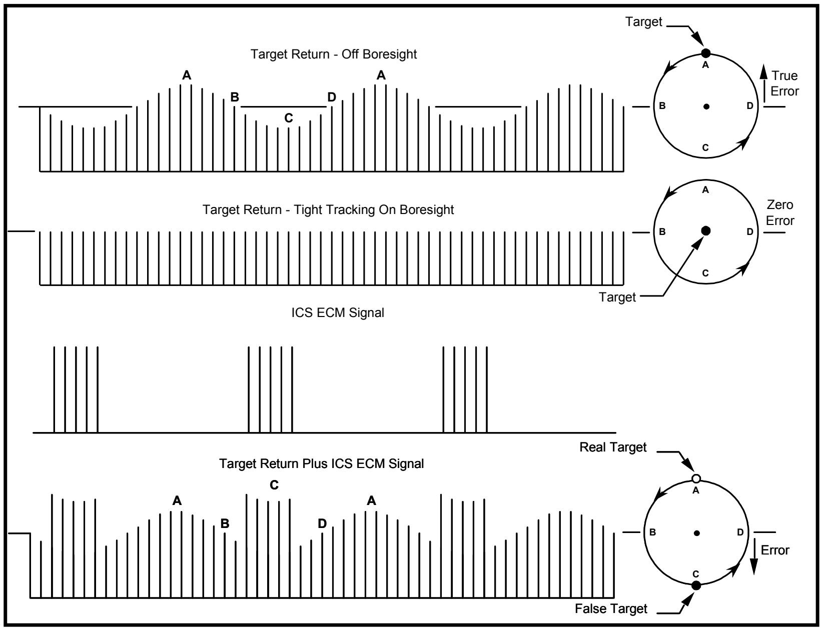
Target
Target Return - Off Boresight
A
A
B
C
D
A
B
D
C
True Error
Target Return - Tight Tracking On Boresight
A
B
D
C
Zero Error
Target
ICS ECM Signal
Real Target
Target Return Plus ICS ECM Signal
C
A
A
B
D
A
B
D
C
Error
False Target

Figure 3. Inverse Con Scan.

J/S REQUIREMENT

The jamming to signal ratio for effective coverage of the true target. Usually on the order of zero dB (J/S=1).

LINEAR MODULATION

A modulation technique in which the output varies in a straight line (linear) manner with the input (modulating) waveform. This is different from a discontinuous (On-Off) modulation. Typically the modulating waveform is a ramp or triangular wave but could also be a sine wave modulating input.

LOBE ON RECEIVE ONLY (LORO)

Predicting the future location of a target (to track) requires that the radar look at areas where the target is not located. When this scanning is accomplished with the radiated beam, large angle targets such as chaff clouds can create complete radar "white-out." RWR indications can be obtained before actual target lock-on. These problems can be overcome by scanning only the receiving antennas and using a separate transmitting antenna pointed only at the target.

In a LORO system, a transmitting antenna emits a few "exploratory" pulses along a direction obtained from an acquisition radar. These exploratory pulses are the acquisition mode of the TTR. That is, in its acquisition mode the small beamed TTR must scan the large location segment provided by the acquisition radar. In radars equipped with Fast Time Constant, the return pulse is applied to a differentiator of extremely short time constant. When the pulse is received, it is "cut-off" on the leading edge and only that portion is fed to the computer. This allows the radar to effectively track on the leading edge of the target. FTC does not improve the range resolution but it can prevent any countermeasures aft of the target which are in the same resolution cell as the target (such as chaff) from interfering with the radar receiver.

The receiving antennas scan their sector for the target return due to these exploratory pulses; as the power centroid is located, the center of the receiving pattern is brought onto the target. The transmitting antenna, which is slaved to the receiving antenna, is then pointing directly at the desired target and only that target is radiated during tracking. This approach allows a very small radiated beam, but the resolution cell of the system is still that of the receiving antenna.

NOISE JAMMING

The transmission of noise-like signals in the target system's radar receiver bandpass. At low power levels, noise jamming has the characteristics of receiver noise and can be mistaken by the radar operator as a problem with the radar. The object of noise jamming is to introduce a disturbing signal into the hostile electronic equipment so that the actual signal is obscured by the interference. The victim of this disturbance might be a radar receiver, a communications network, or a data link.

See also Barrage Jamming and Spot Jamming.

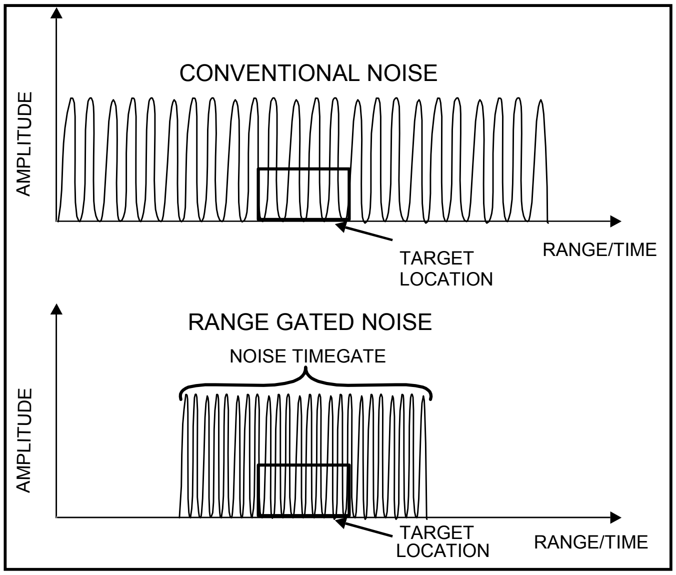

Figure 4. Noise Jamming.

ON-OFF MODULATION

On-Off Modulation is any modulation which switches rapidly between two states. This definition includes pulse radar operation.

On-Off Keying (OOK) is the envelope modulation of a jamming signal with a rectangular wave. The modulation rate and duty cycle are adjusted commensurate with the victim radar's processing time constants. These can be related to AGC time constants, logic time-outs, data sampling cycles, or any other data processing response times.

An important distinction must be made between the terms On-Off Keying and Blinking. While both terms involve envelope modulations that turn a jamming signal on and off, the term OOK is used as the envelope modulation of a single jamming signal, and the term blinking is used as the tactical application of OOK involving two or more cooperative jamming platforms.

PSEUDO RANDOM NOISE (PRN)

A controlled, noise-like, pulse pattern repeated in synchronism with the victim radar pulse repetition frequency. Synonymous with quasi-noise jamming.

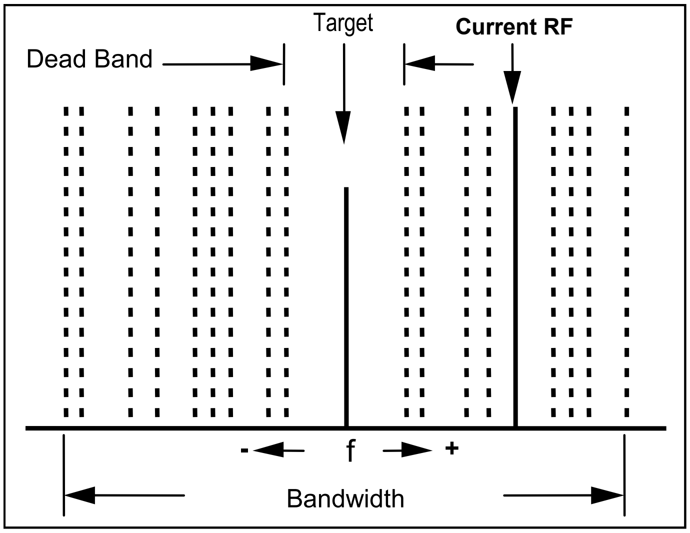

Figure 5. Random Dual Line.

RANDOM DUAL LINE (RDL)

RDL is a coherent repeater technique that is essentially the same as velocity noise (VN), narrow band noise (NBN), and pseudo random noise (PRN) except that no false Doppler frequencies are stepped directly over the target return. The objective is to prevent the momentary additions of the EA signal and target signal that might highlight the presence of a coherent return.

RANDOM RANGE PROGRAM (RANRAP)

A dynamic False Target Jamming technique program to create multiple realistic targets of varying size and distance from the jamming plane.

RANGE GATE PULL OFF (RGPO)

Once a tracking radar has detected a target, it will place *range gates* to either side of it. Range gates essentially blank out all signals which originate from ranges outside a narrow window, substantially increasing the signal-to-noise ratio and protecting the radar against unsynchronized jamming pulses. The radar 'concentrates' on a short range interval which encloses the target's location, and it no longer looks out for other targets. This state is known as 'lock-on'. But range gates can be 'stolen', and it is the objective of the Range Gate Pull-Off (RGPO) technique to *break lock* and escape from out of the window.

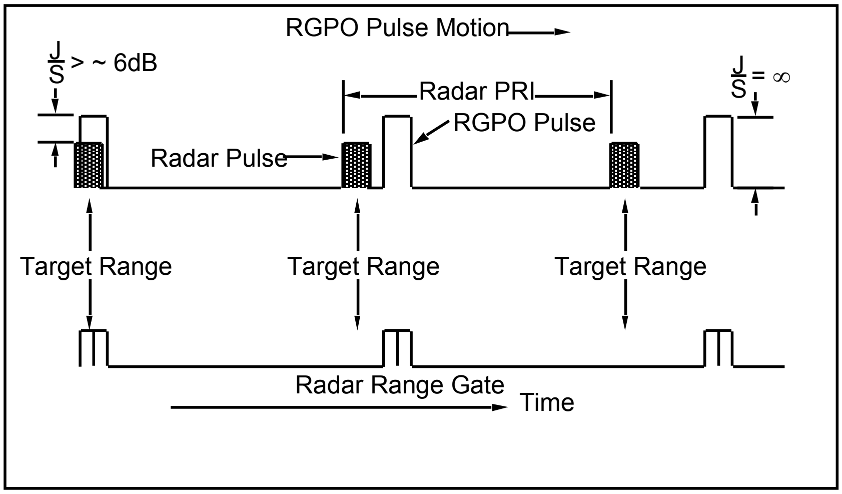

Figure 6. Range Gate Pull Off.

RGPO works as follows:

Upon detection (or assumption) that a tracking radar has locked on, the on-board jammer is switched on and starts to work in a couple of phases:

1. First, a sample of the illuminating pulse signal is taken and the radar's pulse repetition frequency (PRF) is determined. This sample is amplified and retransmitted simultaneously when further pulses are received. The aircraft actually highlights itself on the radar screen. The jamming power is steadily increased, and this continues until the replica is much stronger than the echo from the aircraft skin return. At this time, the sensitivity of the tracking radar's receiver is usually reduced in order to avoid overload. This causes the skin echo vanishes below the noise floor.

2. *Another* replica is transmitted after each of the 'dummy' skin echoes. The power of the second replica is increased while the dummy is made weaker.

3. Next, the tracker has locked on to the *delayed replica*, whereas the skin return has decreased into the noise. With respect to each of the radar's pulses, the replica is now being delayed by small, but increasing amounts of time. The range gates, of course, follow the dummy target which appears to be receding. This continues until the range gates have been moved away from the target's real position. The result is that the radar is tracking a *phantom target* and the skin return is being blanked out by the range gates.

4. Finally, the jammer is switched off and leaves the radar with just *nothing* but noise inside the window between its range gates. Break-lock was successfully achieved and the "tracking" radar needs to

switch back into a search or acquisition mode and loses time. The whole cycle will start again if the target is still within range and is reacquired.

As described above, RGPO creates only false targets which appear at greater ranges than the real target because the deceptive signal is transmitted *after* the skin echo. However, if the victim radar's PRF is constant then the time of incidence of the next radar pulse can be calculated and jamming pulses can be placed such that false targets at closer ranges are also produced.

SCINTILLATION (SCINT)

Scintillation is not an EA technique by itself, it is an implementation of an EA technique. Scintillation is simply superimposing a small, pseudo random amplitude modulation on the EA signal to make it appear more realistic to a manual operator.

SPOT JAMMING

Occurs when a jammer focuses all of its power on a single frequency. While this would severely degrade the ability to track on the jammed frequency, a frequency agile radar would hardly be affected because the jammer can only jam one frequency. While multiple jammers could possibly jam a range of frequencies, this would consume a great deal of resources to have any effect on a frequency-agile radar, and would probably still be ineffective

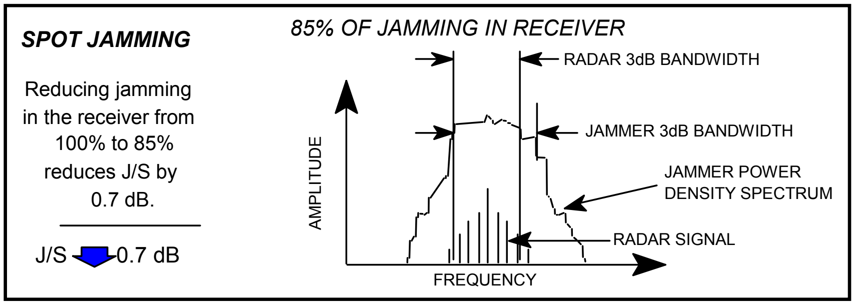
SPOT JAMMING
Reducing jamming in the receiver from 100% to 85% reduces J/S by 0.7 dB.
J/S ↓ 0.7 dB
85% OF JAMMING IN RECEIVER
RADAR 3dB BANDWIDTH
JAMMER 3dB BANDWIDTH
JAMMER POWER DENSITY SPECTRUM
RADAR SIGNAL
AMPLITUDE
FREQUENCY

Figure 7. Spot Jamming.

SWEPT JAMMING

This happens when a jammer's full power is shifted from one frequency to another. While this has the advantage of being able to jam multiple frequencies in quick succession, it does not affect them all at the same time, and thus limits the effectiveness of this type of jamming. Although, depending on the error checking in the receiver(s) this can render a wide range of receivers effectively useless.

SWEPT AMPLITUDE MODULATION (SAM)

The OOK frequency is linearly varied in a sawtooth fashion between preset frequency limits while the duty factor is held constant.

SWEPT WAVE MODULATION (SWM)

A swept wave modulation.2 (SWM.2) is essentially a swept amplitude modulation (SAM). It is a waveform that is swept between two frequencies that are usually chosen to bracket a radar's passive angle scanning rate. SWM can be either Synchronous Swept Wave Modulation.2-; (S-SWM) or Asynchronous Swept Wave Modulation.2-; (A-SWM.2-;). The modulation amplitude can be either down modulated or On-Off Keyed (OOK). The down modulating shape can be square wave, rectangular wave, linear (e.g. a sine wave), or a combination. The OOK modulating shape can be square wave or rectangular wave.

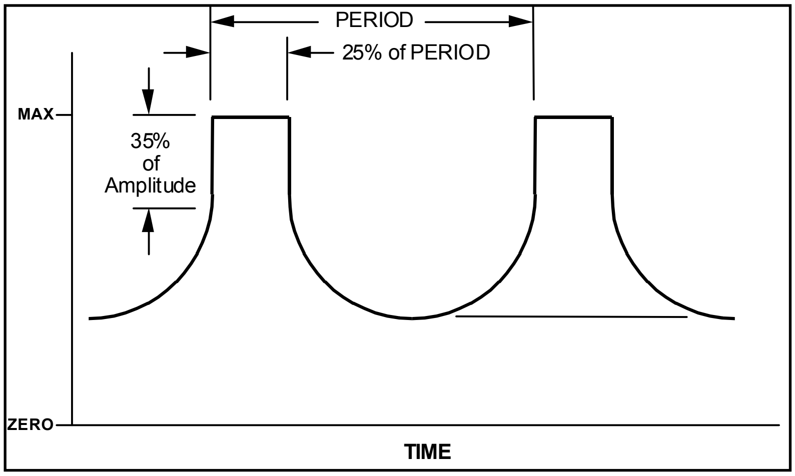

Figure 8. Typical Linear SWM Modulation.

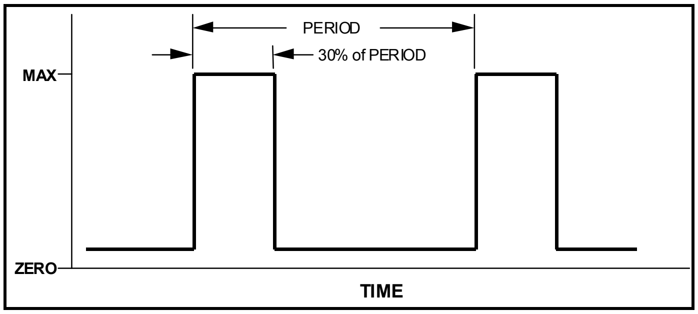

Figure 9. Rectangular SWM.

SYNCHRONOUS SWEPT WAVE MODULATION (SSWM)

SSWM is synonymous with S-SWM. S-SWM and A-SWM are essentially the same except that asynchronous means that the waveform is free running and synchronous means that when a radar scan or TWS beam can be detected, the modulation waveform is synchronized to the detected beam. For programming purposes A-SWM sets sweep limits and rate by frequency (Hz), while S-SWM sets them by period (mSec).

Active Con-Scan radars will not have a detectable modulation if the target is being tightly tracked in the center of the beam. Therefore, a SWM can "jog" the tracking sufficiently to detect the modulation and allowing subsequent synchronization of the SWM waveform.

TRACK WHILE SCAN JAMMING

The technique of shifting or "walking" EA pulses off target. Many angle jamming techniques are effective.

VELOCITY FALSE TARGETS (VFT)

VFT is a pseudo-random false Doppler target concealment technique. It is designed for use against radars that acquire Doppler targets with a bank of contiguous narrow band filters. A false Doppler target is programmed to remain in a Doppler filter long enough for the radar processing to declare it a valid target return, but not long enough for the radar processing to establish tracking.

The false Doppler target is then switched to the next pseudo-randomly selected frequency and repeated. It is intended to overload the radar processing and/or the operator's ability to identify an actual target. In the illustration, the VFTs jump around in the indicated numerical order.

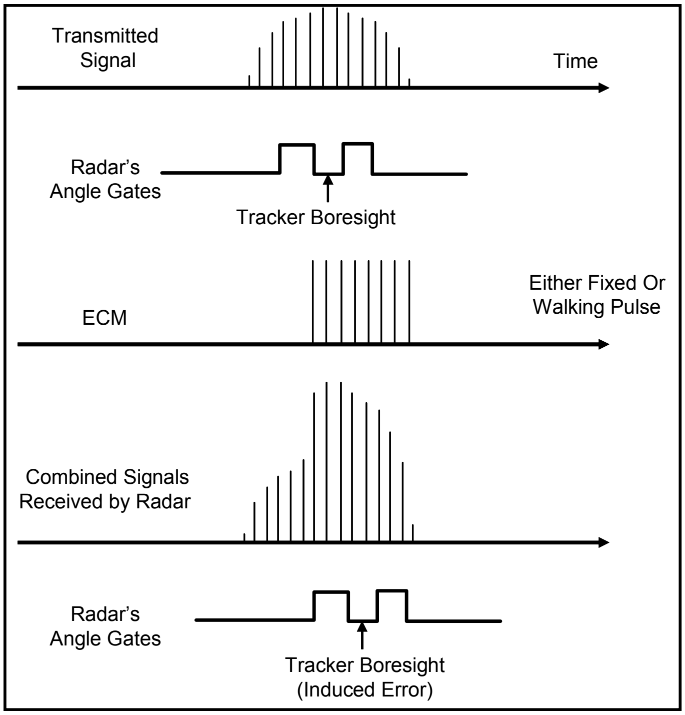
Transmitted Signal
Time
Radar's Angle Gates
Tracker Boresight
ECM
Either Fixed Or Walking Pulse
Combined Signals Received by Radar
Radar's Angle Gates
Tracker Boresight (Induced Error)

Figure 10. TWS Jamming.

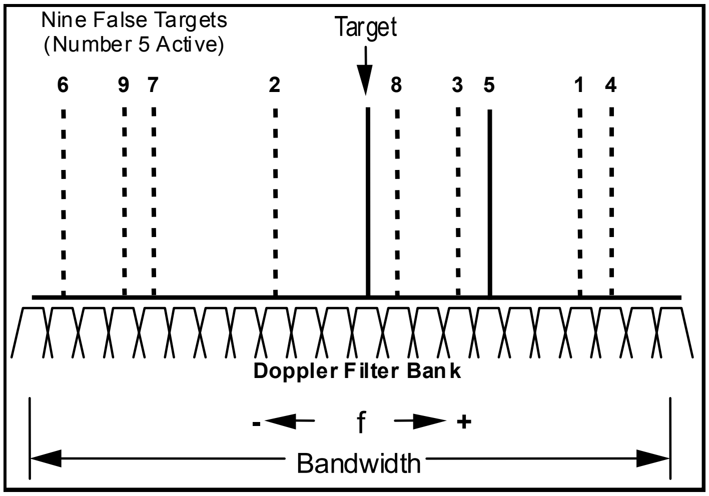
Nine False Targets (Number 5 Active)
Target
6
9
7
2
8
3
5
1
4
Doppler Filter Bank
- f +
Bandwidth

Figure 11. Velocity False Targets.

VELOCITY GATE PULL OFF

This is a method of capturing the velocity gate of a Doppler radar and moving it away from the skin echo. Similar to the RGPO, but used against CW or Doppler velocity tracking radar systems. The CW or pulse doppler frequency, which is amplified and retransmitted, is shifted in frequency (velocity) to provide an apparent rate change or Doppler shift.

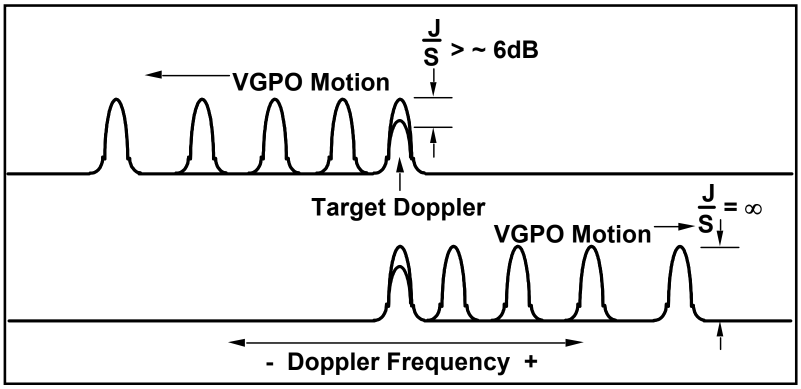

Figure 12. Velocity Gate Pull Off.

VELOCITY NOISE (VN)

VN is a coherent repeater technique. The objective is to create noise centered on a coherent radar's RF, with a noise bandwidth that is close to, or less than, the radar's bandwidth and conceal the target, or destroy target signal coherency. VN is generated by pseudo randomly stepping a frequency over the victim radar's bandwidth. The dashed RF lines represent possible frequencies and the solid line represents the frequency currently active.

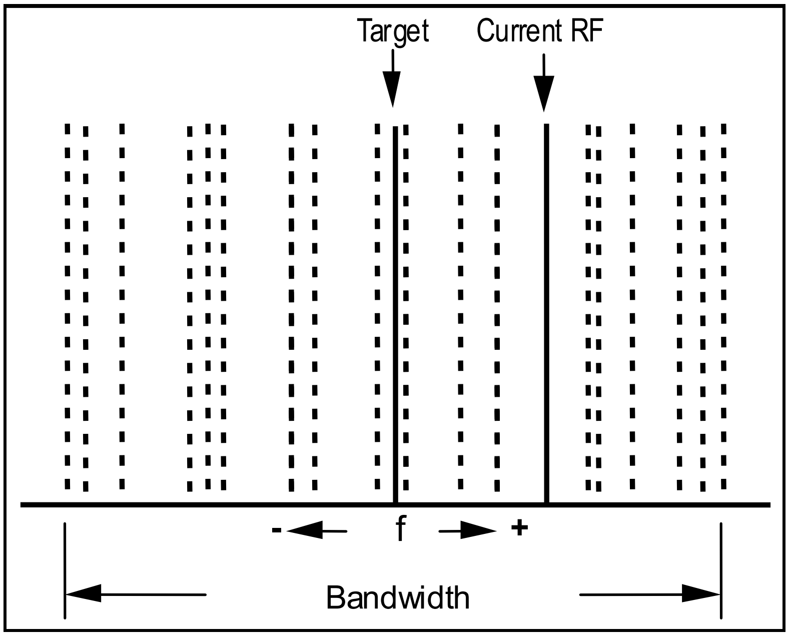

Figure 13. Velocity Noise.

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RADAR AND RECEIVER CHARACTERISTICS & TEST

RF Atmospheric Absorption / Ducting 5-1
Receiver Sensitivity / Noise 5-2
Receiver Types and Characteristics 5-3
Radar Modes 5-4
General Radar Display Types 5-5
IFF - Identification - Friend or Foe 5-6
Receiver Tests 5-7
Signal Sorting and Direction Finding 5-8

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RF ATMOSPHERIC ABSORPTION / DUCTING

Signal losses are associated with each stage of signal processing in both the transmitting and receiving portions of the system. The transmitting losses include power transmission efficiency, waveguide and antenna losses, and duplexer losses. In the receiver, losses include antenna, waveguide, RF amplifier, mixer, and IF amplifier.

In addition to these losses, energy traveling through the atmosphere suffers from atmospheric attenuation caused primarily by absorption by the gasses. For lower frequencies (below 10 GHz), the attenuation is reasonably predictable. For high frequencies in the millimeter wave range, the attenuation not only increases, but becomes more dependent upon peculiar absorbing characteristics of H_2O, O_2, and the like.

Figure 1 shows the areas of peak absorption in the millimeter wave spectrum. Figure 2 shows how the intensity of precipitation can affect atmospheric attenuation.

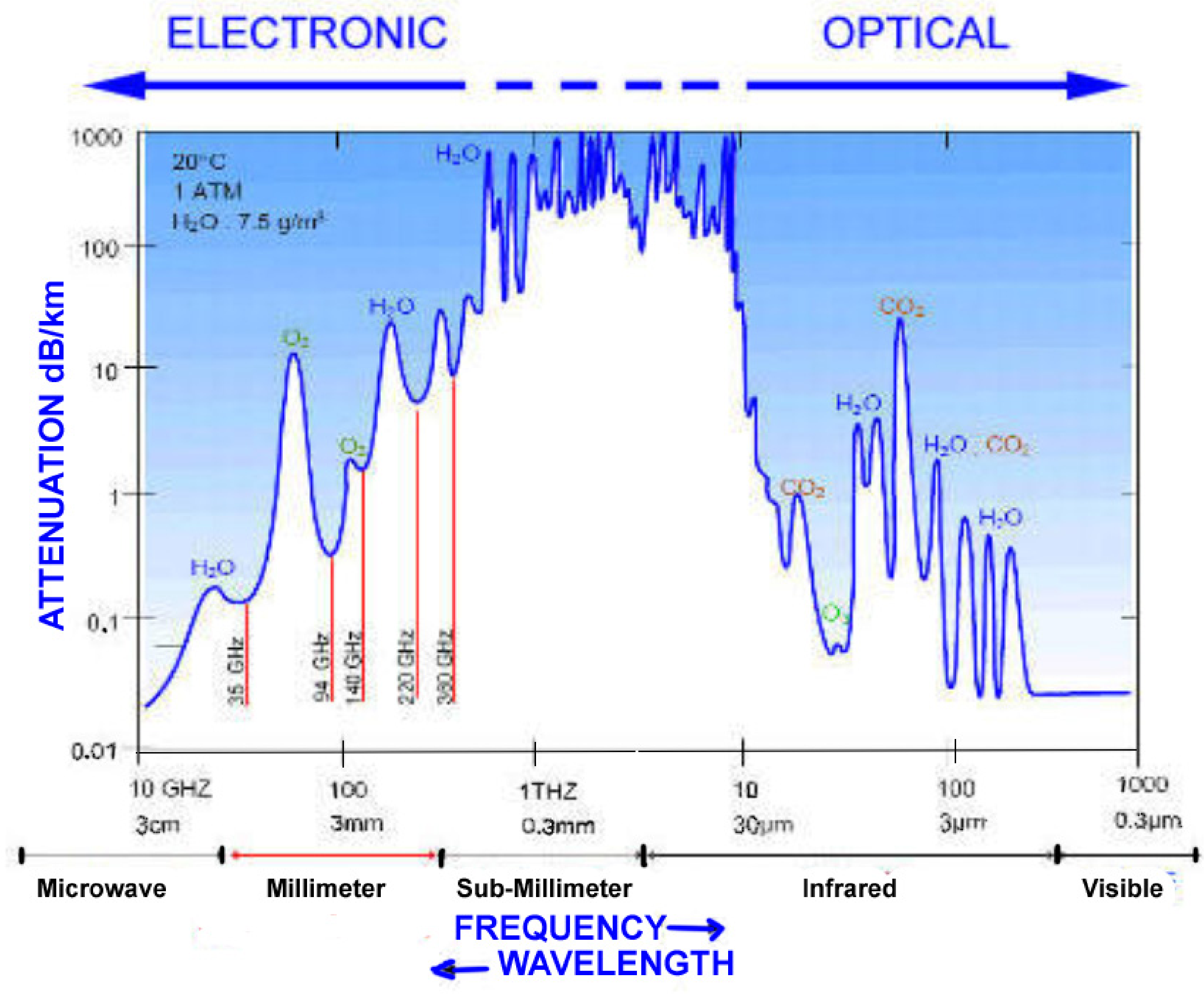

Figure 1. Atmospheric Absorption of Millimeter Waves.

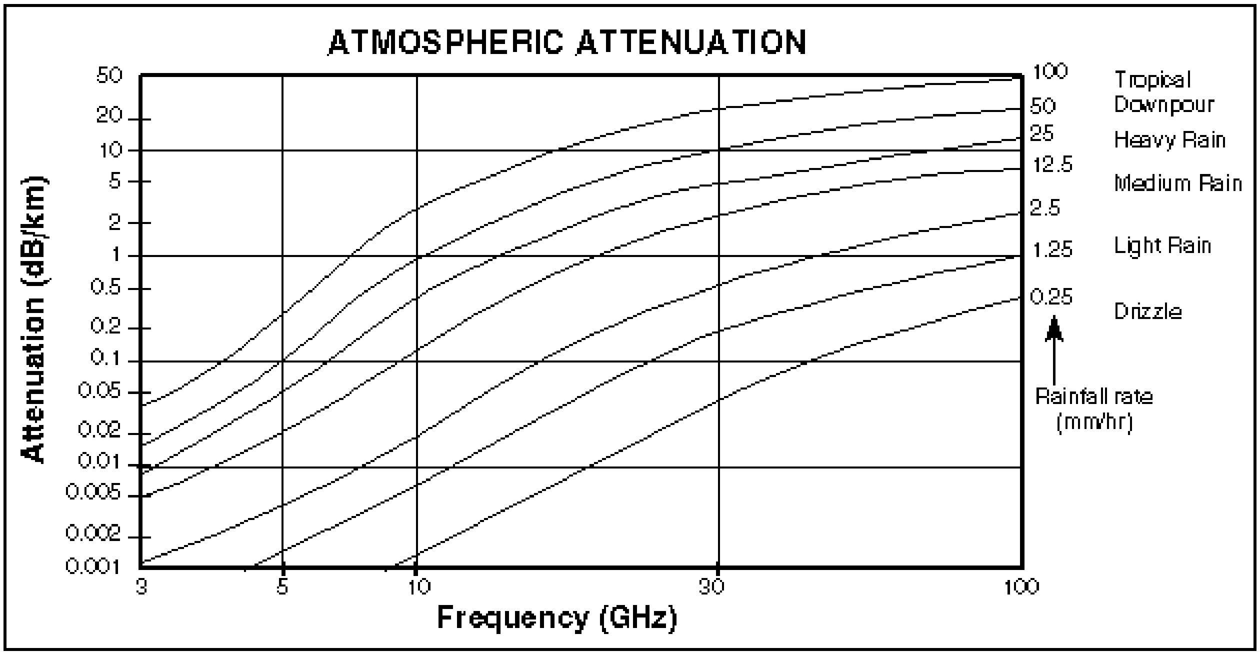

Figure 2. Atmospheric Attenuation.

Ducting is an increase in range that an electromagnetic wave will travel due to a temperature inversion of the lower atmosphere (troposphere) as shown in Figure 3. The temperature inversion forms a channel or waveguide (duct) for the waves to travel in, and they can be trapped, not attenuating as would be expected from the radar equation. Ducting may also extend range beyond what might be expected from limitations of the radar horizon (see Section 2-9).

The ducting phenomena is frequency sensitive. The thicker the duct, the lower the minimum trapped frequency.

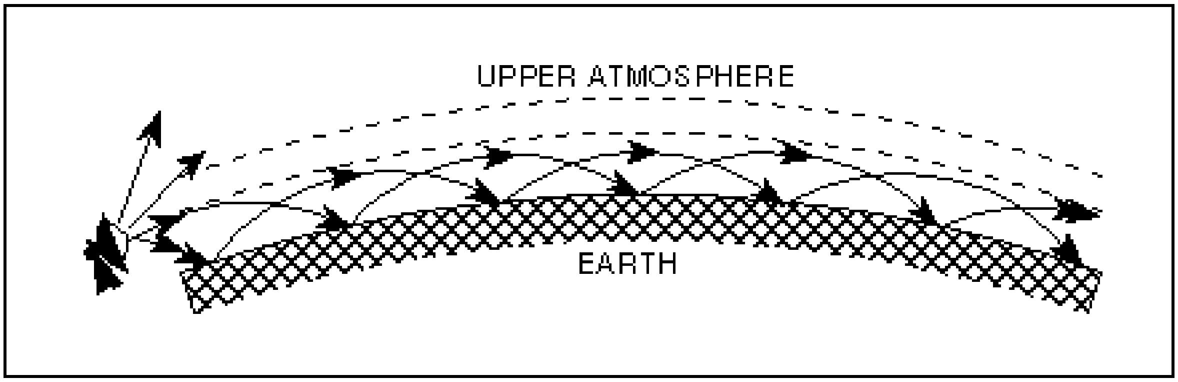

Figure 3. Ducting.

A similar occurrence takes place with ionospheric refraction, however the greatest increase in range occurs in the lower frequencies. This is familiar to amateur radio operators who are able to contact counterparts “around the world.”

RECEIVER SENSITIVITY / NOISE

RECEIVER SENSITIVITY

Sensitivity in a receiver is normally taken as the minimum input signal (S_{min}) required to produce a specified output signal having a specified signal-to-noise (S/N) ratio and is defined as the minimum signal-to-noise ratio times the mean noise power, see equation [1]. For a signal impinging on the antenna (system level) sensitivity is known as minimum operational sensitivity (MOS), see equation [2]. Since MOS includes antenna gain, it may be expressed in dBLi (dB referenced to a linear isotropic antenna). When specifying the sensitivity of receivers intended to intercept and process pulse signals, the minimum pulse width at which the specified sensitivity applies must also be stated. See the discussion of post-detection bandwidth (B_V) in Section 5-2 for significance of minimum pulsewidth in the receiver design.

$\mathbf{S_{min} = (S/N)_{min} k T_o B(NF)}$ receiver sensitivity ("black box" performance parameter) **[1]**

or $\mathbf{MOS = (S/N)_{min} k T_o B(NF)/G}$ system sensitivity i.e. the receiver is connected to an antenna **[2]**
(transmission line loss included with antenna gain)

where: S/N_{min} = Minimum signal-to-noise ratio needed to process (vice just detect) a signal
NF = Noise figure/factor
k = Boltzmann's Constant = 1.38×10^{-23} Joule/°K
T_o = Absolute temperature of the receiver input (°Kelvin) = 290°K
B = Receiver Bandwidth (Hz)
G = Antenna/system gain

We have a lower MOS if temperature, bandwidth, NF, or S/N_{min} decreases, or if antenna gain increases. For radar, missile, and EW receivers, sensitivity is usually stated in dBm. For communications and commercial broadcasting receivers, sensitivity is usually stated in micro-volts or dBμv. See Section 4-1.

There is no standard definition of sensitivity level. The term minimum operational sensitivity (MOS) can be used in place of S_{min} at the system level where aircraft installation characteristics are included. The "black box" term minimum detectable signal (MDS) is often used for S_{min} but can cause confusion because a receiver may be able to detect a signal, but not properly process it. MDS can also be confused with minimum discernable signal, which is frequently used when a human operator is used to interpret the reception results. A human interpretation is also required with minimum visible signal (MVS) and tangential sensitivity (discussed later). To avoid confusion, the terms S_{min} for "black box" minimum sensitivity and MOS for system minimum sensitivity are used in this section. All receivers are designed for a certain sensitivity level based on requirements. One would not design a receiver with more sensitivity than required because it limits the receiver bandwidth and will require the receiver to process signals it is not interested in. In general, while processing signals, the higher the power level at which the sensitivity is set, the fewer the number of false alarms which will be processed. Simultaneously, the probability of detection of a "good" (low-noise) signal will be decreased.

Sensitivity can be defined in two opposite ways, so discussions can frequently be confusing. It can be the ratio of response to input or input to response. In using the first method (most common in receiver discussions and used herein), it will be a negative number (in dBm), with the more negative being "better" sensitivity, e.g., -60 dBm is "better" than -50 dBm sensitivity. If the second method is used, the result will be a positive number, with higher being "better." Therefore the terms low sensitivity or high sensitivity can be very confusing. The terms S_{min} and MOS avoid confusion.

SIGNAL-TO-NOISE (S/N) RATIO

The Signal-to-Noise Ratio (S/N) (a.k.a. SNR) in a receiver is the signal power in the receiver divided by the mean noise power of the receiver. All receivers require the signal to exceed the noise by some amount. Usually if the signal power is less than or just equals the noise power it is not detectable. For a signal to be detected, the signal energy plus the noise energy must exceed some threshold value. Therefore, just because N is in the denominator doesn't mean it can be increased to lower the MOS. S/N is a required minimum ratio, if N is increased, then S must also be increased to maintain that threshold. The threshold value is chosen high enough above the mean noise level so that the probability of random noise peaks exceeding the threshold, and causing false alarms, is acceptably low.

Figure 1 depicts the concept of required S/N. It can be seen that the signal at time A exceeds the S/N ratio and indicates a false alarm or target. The signal at time B is just at the threshold, and the signal at time C is clearly below it. In the sample, if the temperature is taken as room temperature (T_o = 290°K), the noise power input is -114 dBm for a one MHz bandwidth. Normally S/N_{min} may be set higher than S/N shown in Figure 1 to meet false alarm specifications.

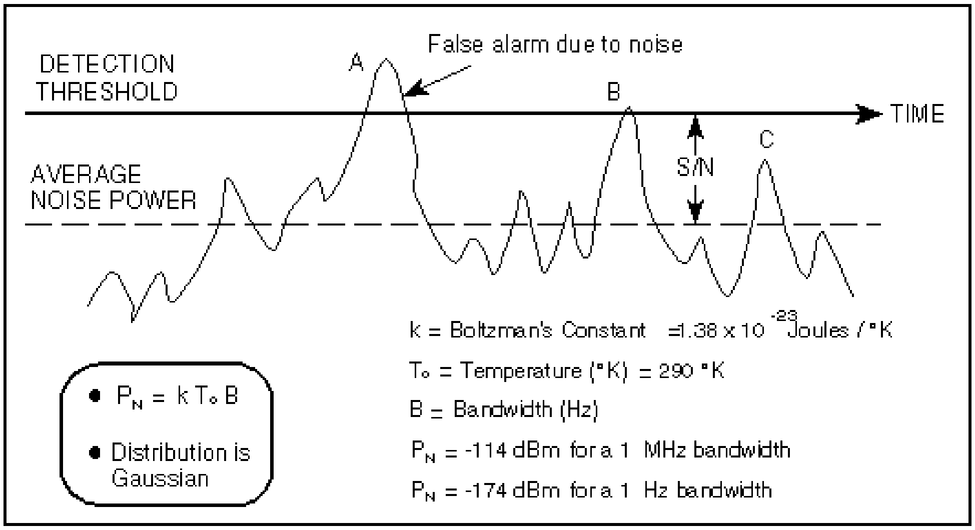
False alarm due to noise
DETECTION THRESHOLD
A
B
C
TIME
S/N
AVERAGE NOISE POWER
k = Boltzman's Constant =1.38 x 10^{-23} Joules / °K
T_o = Temperature (°K) = 290 °K
B = Bandwidth (Hz)
P_N = -114 dBm for a 1 MHz bandwidth
P_N = -174 dBm for a 1 Hz bandwidth
• $P_N = k T_o B$
• Distribution is Gaussian

Figure 1. Receiver Noise Power at Room Temperature.

The acceptable minimum Signal-to-Noise ratio (or think of it as Signal **above** Noise) for a receiver depends on the intended use of the receiver. For instance, a receiver that had to detect a single radar pulse would probably need a higher minimum S/N than a receiver that could integrate a large number of radar pulses (increasing the total signal energy) for detection with the same probability of false alarms. Receivers with human operators using a video display may function satisfactorily with low minimum S/N because a skilled operator can be very proficient at picking signals out of a noise background. As shown in Table 1, the setting of an acceptable minimum S/N is highly dependent on the required characteristics of the receiver and of the signal.

Table 1. Typical Minimum S/N Required.

Skilled Operator	Auto-Detection	Auto-detection with Amplitude, TOA, and Frequency Measurements	AOA Phase Interferometer	AOA Amplitude Comparison
3 to 8 dB	10 to 14 dB	14 to 18 dB	14 to 18 dB	16 to 24 dB

A complete discussion of the subject would require a lengthy dissertation of the probability and statistics of signal detection, which is beyond the scope of this handbook, however a simplified introduction follows. Let's assume that we have a receiver that we want a certain probability of detecting a single pulse with a specified false alarm probability. We can use Figure 2 to determine the required signal-to-noise ratio.

S/N EXAMPLE

If we are given that the desired probability of detecting a single pulse (P_d) is 98%, and we want the false alarm rate (P_n) to be no more than 10^{-3}, then we can see that S/N must be 12 dB (see Figure 2).

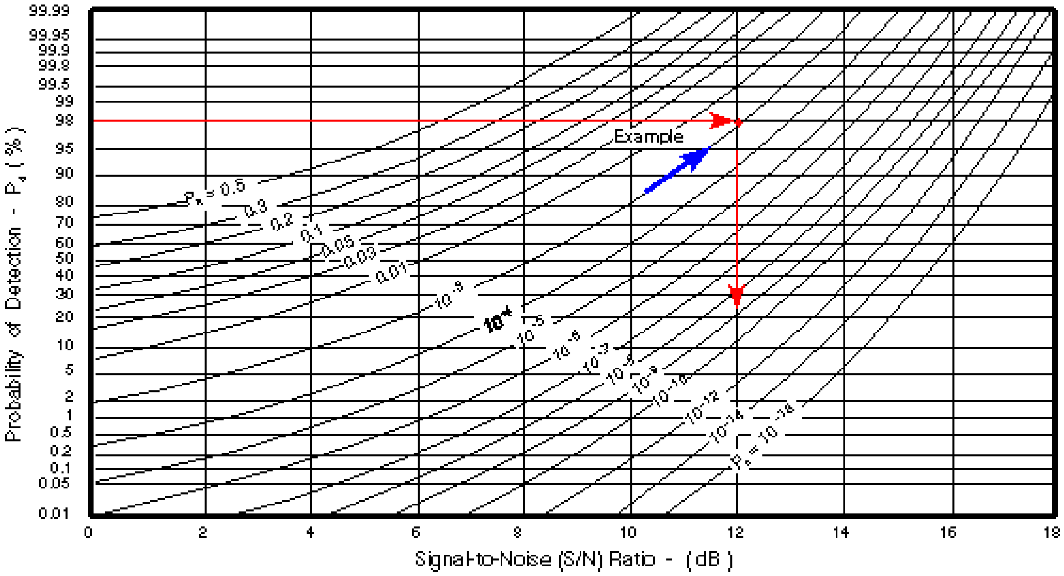

Figure 2. Nomograph of Signal-to-Noise (S/N) Ratio as a Function of Probability of Detection (P_d) and Probability of False Alarm Rate (P_n).

MAXIMUM DETECTION RANGE (ONE-WAY)

From Section 4-3, the one way signal strength from a transmitter to a receiver is:

$$S\ (or\ P_R) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 R^2}$$

For calculations involving receiver sensitivity the "S" can be replaced by S_{min}. Since $S_{min} = (S/N)_{min}\ kT_oB(NF)$, given by equation [1], the one-way radar equation can be solved for any of the other variables in terms of receiver parameters. In communication, radar, and electronic warfare applications, you might need to solve for the maximum range (R_{max}) where a given radar warning receiver could detect a radiated signal with known parameters. We would then combine and rearrange the two equations mentioned to solve for the following one-way equation:

$$R_{max} \cong \sqrt{\frac{P_t\ G_t\ G_r\ \lambda^2}{(4\pi)^2 (S/N)_{min}\, k\, T_o\, B\, (NF)}} \quad or \quad \sqrt{\frac{P_t\ G_t\ G_r\ c^2}{(4\pi f)^2 (S/N)_{min}\, k\, T_o\, B\, (NF)}} \quad or \quad \sqrt{\frac{P_t\ G_t\ A_e}{4\pi (S/N)_{min}\, k\, T_o\, B\, (NF)}} \qquad \textbf{[3]}$$

We could use standard room temperature of 290° K as T_o, but NF would have to be determined as shown later.

In this calculation for receiver R_{max} determination, P_t, G_t, and λ are radar dependent, while G_r, S/N_{min}, NF, and B are receiver dependent factors.

Equation [3] relates the maximum detection range to bandwidth (B). The effects of the measurement bandwidth can significantly reduce the energy that can be measured from the peak power applied to the receiver input. Additional bandwidth details are provided in Sections 4-4, 4-7, and in other parts of this section.

NOISE POWER, kT_oB

Thermal noise is spread more or less uniformly over the entire frequency spectrum. Therefore the amount of noise appearing in the output of an ideal receiver is proportional to the absolute temperature of the receiver input system (antenna etc) times the bandwidth of the receiver. The factor of proportionality is Boltzmann's Constant.

Mean noise power of ideal receiver = kT_oB = P_N (Watts)
Mean noise power of a real receiver = $(NF)kT_oB$ (Watts)

The convention for the temperature of T_o is set by IEEE standard to be 290°K, which is close to ordinary room temperature. So, assuming T_o = 290°K, and for a bandwidth B = 1 Hz, $kT_oB = 4x10^{-21}$ W = -204 dBW = -174 dBm.

For any receiver bandwidth, multiply $4x10^{-21}$ W by the bandwidth in Hz, or if using dB;

$10 \log kT_oB$ = -174 dBm + 10 Log (actual BW in Hz) or -114 dBm + 10 Log (actual BW in MHz)

and so on, as shown by the values in Table 2.

Table 2. Sample Noise Power Values (kT_oB).

Bandwidth	Bandwidth Ratio (dB)	Watts	dBW	dBm
1 Hz	0	$4x10^{-21}$	-204	-174
1 kHz	30	$4x10^{-18}$	-174	-144
1 MHz	60	$4x10^{-15}$	-144	-114
1 GHz	90	$4x10^{-12}$	-114	-84

Typical values for maximum sensitivity of receivers would be:

RWR	-65 dBm
Pulse Radar	-94 dBm
CW Missile Seeker	-138 dBm

If antenna contributions are ignored (see note in Table 4) for a CW receiver with a 4 GHz bandwidth, the ideal mean noise power would be -174 dBm + 10 Log($4x10^9$) = -174 dBm + 96 dB = -78 dBm. A skilled operator might only be able to distinguish a signal 3 dB above the noise floor (S/N=3 dB), or -75 dBm. A typical radar receiver would require a S/N of 3 to 10 dB to distinguish the signal from noise, and would require 10 to 20 dB to track. Auto tracking might require a S/N of approximately 25 dB, thus, a receiver may only have sufficient sensitivity to be able to identify targets down to -53 dBm. Actual pulse receiver detection will be further reduced due to sin x/x frequency distribution and the effect of the measurement bandwidth as discussed in Sections 4-4 and 4-7. Integration will increase the S/N since the signal is coherent and the noise is not.

Noise Bandwidth

Equivalent Noise Bandwidth (B_N) - Set by minimum pulse width or maximum modulation bandwidth needed for the system requirements. A choice which is available to the designer is the relationship of pre- and post-detection bandwidth. Pre-detection bandwidth is denoted by B_{IF}, while post-detection is denoted B_V, where V stands for video. The most affordable approach is to set the post-detection filter equal to the reciprocal of the minimum pulse width, then choose the pre-detection passband to be as wide as the background interference environment will allow. Recent studies suggest that pre-detection bandwidths in excess of 100 MHz will allow significant loss of signals due to “pulse-on-pulse” conditions. Equations [4] and [5] provide B_N relationships that don’t follow the Table 3 rules of thumb.

Table 3. Rules of Thumb for B_N a.k.a. B (Doesn’t apply for S/N between 0 and 10 to 30 dB).

S/N out	Linear Detector	Square Law Detector
High S/N (>15 to 20 dB)	$B_N = B_V$ (> 20 to 30 dB)	$B_N = 4\ B_V$ (> 10 to 15 dB)
Low S/N (< 0 dB)	$B_N = \sqrt{(2\,B_{IF}\,B_V - B_V^2) / 4\,(S/N)_{out}}$	$B_N = \sqrt{(2\,B_{IF}\,B_V - B_V^2) / (S/N)_{out}}$

For a square law detector: (1)

$$B_N = B_V \left[2 + \sqrt{4 + \frac{(2\,B_{IF} / B_V) - 1}{(S/N)_{out}}} \right] \qquad \textbf{[4]}$$

At high $(S/N)_{out}$, the $1/(S/N_{out})$ term goes to zero and we have: $B_N = B_V\,[\,2 + \sqrt{4}\,] = 4\,B_V$

At low $(S/N)_{out}$, the $1/(S/N_{out})$ term dominates, and we have:

$$B_N = B_V \sqrt{\frac{(2\,B_{IF} / B_V) - 1}{(S/N)_{out}}} = \sqrt{\frac{2\,B_{IF}\,B_V - B_V^2}{(S/N)_{out}}}$$

For a linear detector: (1)

$$B_N = \frac{B_V}{2} + \frac{1}{4} \bullet \sqrt{B_V \left(4\,B_V + \frac{H^2(2\,B_{IF} - B_V)}{(S/N)_{out}} \right)} \qquad \textbf{[5]}$$

H is a hypergeometric (statistical) function of $(S/N)_{in}$

H = 2 for $(S/N)_{in} << 1$
H = 1 for $(S/N)_{in} >> 1$

At high $(S/N)_{out}$, the $1/(S/N_{out})$ term goes to zero and we have: $B_N = \frac{B_V}{2} + \frac{1}{4}\sqrt{B_V\,(4\,B_V)} = B_V$

At low $(S/N)_{out}$, the $1/(S/N_{out})$ term dominates, and we have:

$$B_N = \frac{1}{4} \bullet \sqrt{\frac{B_V H^2 (2 B_{IF} - B_V)}{(S/N)_{out}}} = \sqrt{\frac{2 B_{IF} B_V - B_V^2}{4 (S/N)_{out}}}$$

Note (1): From Klipper, "Sensitivity of Crystal Video Receivers With RF Pre-amplification," *The Microwave Journal*, August 1965.

TRADITIONAL "RULE OF THUMB" FOR NARROW BANDWIDTHS (Radar Receiver Applications)
Required IF Bandwidth for Matched Filter Applications:

$$B_{IF} = \frac{1}{PW_{\min}} \quad \text{Where :} \quad \begin{array}{l} B_{IF} = \text{Pre - detection RF or IF bandwidth} \\ PW_{\min} = \text{Specified minimum pulse width} = \tau \end{array}$$

Matched filter performance gives maximum probability of detection for a given signal level, but: (1) Requires perfect centering of signal spectrum with filter bandwidth, (2) Time response of matched pulse does not stabilize at a final value, and (3) Out-of-band splatter impulse duration equals minimum pulse width. As a result, EW performance with pulses of unknown frequency and pulse width is poor.

Required Video Bandwidth Post - Detection
Traditional " Rule of Thumb"

$$B_V = \frac{0.35}{PW_{\min}} \quad \text{Where : } B_V = \text{Post - detection bandwidth}$$

Some authors define B_V in terms of the minimum rise time of the detected pulse, i.e., $B_V = (0.35 \text{ to } 0.5)/t_r$ min, where t_r = rise time.

REVISED "RULE OF THUMB" FOR WIDE BANDWIDTHS (Wideband Portion of RWRs)

$$B_{IF} = \frac{2 \text{ to } 3}{PW_{\min}} \quad \text{and} \quad B_V = \frac{1}{PW_{\min}}$$

The pre-detection bandwidth is chosen based upon interference and spurious generation concerns. The post-detection bandwidth is chosen to "match" the minimum pulse width. This allows (1) Half bandwidth mistuning between signal and filter, (2) Half of the minimum pulse width for final value stabilization, and (3) The noise bandwidth to be "matched" to the minimum pulse width. As a result, there is (1) Improved EW performance with pulses of unknown frequency and pulse width, (2) Measurement of in-band, but mistuned pulses, and (3) Rejection of out-of-band pulse splatter.

NOISE FIGURE / FACTOR (NF)

Electrical noise is defined as electrical energy of random amplitude, phase, and frequency. It is present in the output of every radio receiver. At the frequencies used by most radars, the noise is generated primarily within the input stages of the receiver system itself (Johnson Noise). These stages are not inherently noisier than others, but noise generated at the input and amplified by the receiver's full gain greatly exceeds the noise generated further along the receiver chain. The noise performance of a receiver is described by a figure of merit called the noise figure (NF). The term noise factor is synonymous, with some authors using the term "factor" for numeric and "figure" when using dB notation. (The notation "F_n" is also sometimes used instead of "NF.") The noise figure is defined as:

$$NF = \frac{Noise\ output\ of\ actual\ receiver}{Noise\ output\ of\ ideal\ receiver} = \frac{N_{out}}{GN_{in}} \quad or\ in\ dB: \quad 10\ \mathrm{Log}\left[\frac{Noise\ output\ of\ actual\ receiver}{Noise\ output\ of\ ideal\ receiver}\right] = 10\ \log\frac{N_{out}}{GN_{in}}$$

A range of NF values is shown in Table 4.

Table 4. Typical Noise Figure / Factor Value.	Decimal	dB
Passive lossy network (RF transmission line, attenuator, etc.) Example: 20 dB attenuator (gain = 0.01)	Same as reciprocal of gain value ex: 100	Same as dB value ex: 20
Solid State Amplifier (see manufacturers specifications)	4	6
Traveling Wave Tube (see manufacturers specifications)	10 to 100	10 to 20
Antennas (Below ≈ 100 MHz, values to 12 dB higher if pointed at the sun) Note: Unless the antenna is pointed at the sun, its negligible NF can be ignored. Antenna gain is not valid for NF calculations because the noise is received in the near field.	1.012 to 1.4	0.05 to 1.5

An ideal receiver generates no noise internally. The only noise in its output is received from external sources. That noise has the same characteristics as the noise resulting from thermal agitation in a conductor. Thermal agitation noise is caused by the continuous random motion of free electrons which are present in every conductor. The amount of motion is proportional to the conductor's temperature above absolute zero. For passive lossy networks, the noise factor equals the loss value for the passive element:

$$NF = \frac{N_{out}}{G\,N_{in}} = \frac{kTB}{\frac{1}{L}kTB} = L \qquad \begin{array}{c} Where\ L = Ratio\ Value\ of\ \ Attenuation \\ i.e.\ For\ a\ 3\ dB\ attenuator, G = 0.5\ and\ L = 2 \\ \therefore NF = 2\ \ and\ \ 10\ \log NF = 3\ dB \end{array}$$

A typical series of cascaded amplifiers is shown in Figure 3.

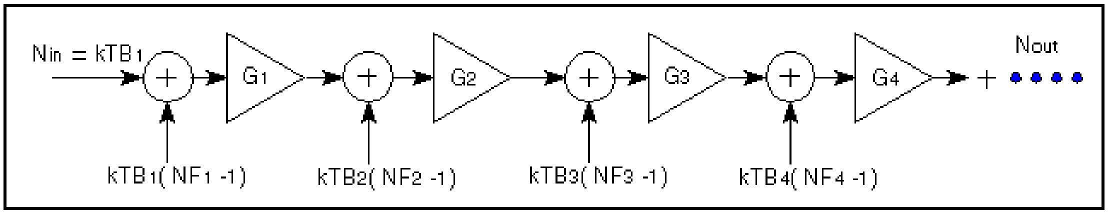

Figure 3. Noise Factors for Cascaded Amplifiers (NF_{CA}).

Loss (negative gain) can be used for the gain value of attenuators or transmission line loss, etc to calculate the noise out of the installation as shown in the following equation:

$$N_{out} = N_{in}\,G\,NF_{CA} = k\,T\,B_1(\,G_1G_2G_3\ldots)\left(NF_1 + \frac{B_2(NF_2 - 1)}{B_1G_1} + \frac{B_3(NF_3 - 1)}{B_1G_1G_2} + \frac{B_4(NF_4 - 1)}{B_1G_1G_2G_3} + \ldots\right) \quad (ratio\ form) \qquad [6]$$

If the bandwidths of the amplifiers are the same, equation [6] becomes:

$$N_{out} = N_{in}\, G\, NF_{CA} = k\,T\,B\,(\,G_1 G_2 G_3 \ldots)\left(NF_1 + \frac{NF_2 - 1}{G_1} + \frac{NF_3 - 1}{G_1 G_2} + \frac{NF_4 - 1}{G_1 G_2 G_3} + \ldots \right) \quad \textit{(ratio form)} \qquad \textbf{[7]}$$

Pre-amplifier Location Affects Receiver Input Noise

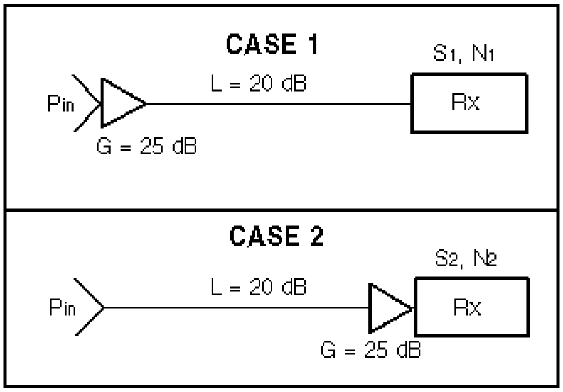

Figure 4. Pre-Amp S/N.

As shown in Figure 4, if a 2 to 12 GHz receiver installation doesn't have enough sensitivity, it is best to install an additional amplifier closer to the antenna (case 1) instead of closer to the receiver (case 2). In both cases, the line loss (L) and the amplifier gain (G) are the same, so the signal level at the receiver is the same. For case 1, $S_1 = P_{in} + G - L$. In case 2, $S_2 = P_{in} - L + G$, so $S_1 = S_2$. The noise generated by the passive transmission line when measured at the receiver is the same in both cases. However, the noise generated inside the amplifier, when measured at the receiver input, is different.

For this example, case 2 has a noise level at the input to the receiver which is 19.7 dB higher than case 1 (calculations follow later).

Table 5a	Case 1 Gain		Case 1 NF	
	Amp	L	Amp	L
dB	25	-20	6 *	20
ratio	316.2	0.01	4 *	100

Table 5b	Case 2 Gain		Case 2 NF	
	L	Amp	L	Amp
dB	-20	25	20	6 *
ratio	0.01	316.2	100	4 *

* Amplifier NF value from Table 4.

Using equation [3] and the data in Tables 5a and 5b, the noise generated by the RF installation is shown in Tables 6a and 6b (the negligible noise contribution from the antenna is the same in both cases and is not included) (also see notes contained in Table 4):

Table 6a. Case 1	**Table 6b.** Case 2
$G(NF) = 316.2\,(0.01)\left(4 + \frac{100 - 1}{316.7} \right) = 13.64$	$G(NF) = 0.01\,(316.2)\left(100 + \frac{4 - 1}{0.01} \right) = 1264.8$
10 log G(NF) = 11.34 dB	10 log G(NF) = 31 dB
Noise at receiver:	
$N_{out\,1}$ = -74 dBm + 11.34 dB = -62.7 dBm	$N_{out\,2}$ = -74 dBm + 31 dB = -43 dBm

$N_{out\,2} - N_{out\,1}$ = 19.7 dB. The input noise of -74 dBm was calculated using 10 log (kTB), where B = 10 GHz.

Note that other tradeoffs must be considered: (1) greater line loss between the antenna and amplifier improves (decreases) VSWR as shown in Section 6-2, and (2) the more input line loss, the higher the input signal can be before causing the pre-amplifier to become saturated (mixing of signals due to a saturated amplifier is addressed in Section 5-7).

Combining Receive Paths Can Reduce Sensitivity

If a single aircraft receiver processes both forward and aft signals as shown in Figure 5, it is desirable to be able to use the receiver's full dynamic range for both directions. Therefore, one needs to balance the gain, so that a signal applied to the aft antenna will reach the receiver at the same level as if it was applied to the forward antenna.

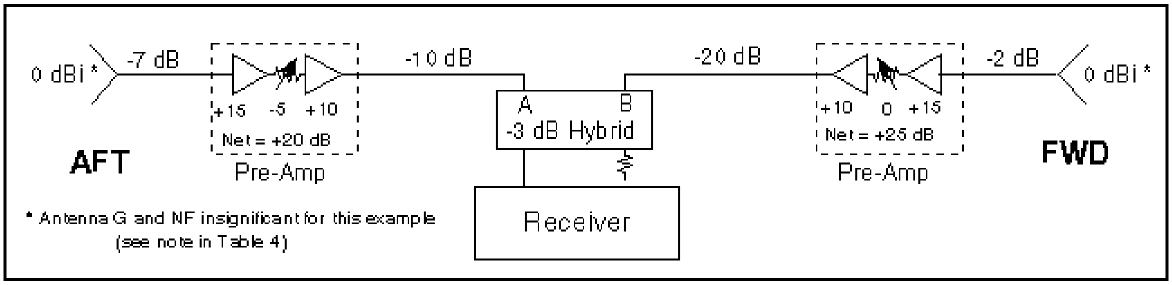

Figure 5. Example of Pre-Amplifier Affecting Overall Gain / Sensitivity.

Common adjustable preamplifiers can be installed to account for the excessive transmission line loss. In this example, in the forward installation, the level of the signal at the receiver is the same as the level applied to the antenna. Since the aft transmission line has 5 dB less attenuation, that amount is added to the preamplifier attenuator to balance the gain. This works fine for strong signals, but not for weaker signals. Because there is less loss between the aft preamplifier and the receiver, the aft noise dominates and will limit forward sensitivity. If the bandwidth is 2-12 GHz, and if port A of the hybrid is terminated by a perfect 50Ω load, the forward noise level would be -65.3 dBm. If port B is terminated, the aft noise level would be -60.4 dBm. With both ports connected, the composite noise level would be -59.2 dBm (convert to mw, add, then convert back to dBm). For this example, if the aft preamplifier attenuation value is changed to 12 dB, the gain is no longer balanced (7 dB extra loss aft), but the noise is balanced, i.e., forward = -65.6 dBm, aft = -65.3 dBm, and composite -62.4 dBm. If there were a requirement to see the forward signals at the most sensitive level, extra attenuation could be inserted in the aft preamplifier. This would allow the forward noise level to predominate and result in greater forward sensitivity where it is needed. Calculations are provided in Tables 7 and 8.

Table 7. Summary of Gain and NF Values for Figure 5 Components.

		Aft					Fwd				
		RF Line	Amp	Attn	Amp	RF Line & hybrid	RF Line	Amp	Attn	Amp	RF Line & hybrid
Gain	dB	-7	15	-5	10	-13	-2	15	0	10	-23
	ratio	0.2	31.6	0.32	10	0.05	0.63	31.6	0	10	0.005
NF	dB	7	6	5	6	13	2	6	0	6	23
	ratio	5	4	3.16	4	20	1.585	4	0	4	200

Aft NF = 22.79 therefore 10 log NF = 13.58 dB. Input noise level = -74 dBm + 13.58 dB = -60.42 dBm ≅ -60.4 dBm
Fwd NF = 7.495 therefore 10 log NF = 8.75 dB. Input noise level = -74 dBm + 8.75 dB = -65.25 dBm ≅ -65.3 dBm
The composite noise level at the receiver = -59.187 dBm ≅ -59.2 dBm.

Table 8. Effect of Varying the Attenuation (shaded area) in the Aft Preamplifier Listed in Table 7.

Aft Attn NF	Aft Attn Gain	Aft Noise	Fwd Noise	Composite Noise	Min Signal Received ***	Aft Input	Fwd Input
0 dB	0 dB	-55.8 dBm	-65.3 dBm	-55.4 dBm	-43.4 dBm	-48.4 dBm	-43.4 dBm
5	-5	-60.4	-65.3	-59.2	-47.2 *	-47.2 *	-47.2 *
10	-10	-64.4	-65.3	-61.8	-49.8	-44.8	-49.8
12	-12	-65.6 **	-65.3 **	-62.4	-50.4	-43.4	-50.4
15	-15	-67.1	-65.3	-63.1	-51.1	-41.1	-51.1

* Gain Balanced ** Noise Balanced *** S/N was set at 12 dB

TANGENTIAL SENSITIVITY

Tangential sensitivity (TSS) is the point where the top of the noise level with no signal applied is level with the bottom of the noise level on a pulse as shown in Figure 6. It can be determined in the laboratory by varying the amplitude of the input pulse until the stated criterion is reached, or by various approximation formulas.

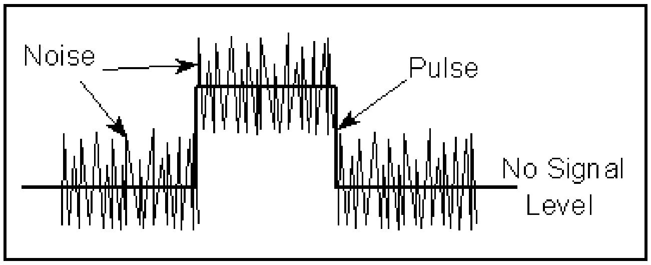

Figure 6. Tangential Sensitivity.

The signal power is nominally 8±1 dB above the noise level at the TSS point. TSS depends on the RF bandwidth, the video bandwidth, the noise figure, and the detector characteristic.

TSS is generally a characteristic associated with receivers (or RWRs), however the TSS does not necessarily provide a criterion for properly setting the detection threshold. If the threshold is set to TSS, then the false alarm rate is rather high. Radars do not operate at TSS. Most require a more positive S/N for track (> 10 dB) to reduce false detection on noise spikes.

SENSITIVITY CONCLUSION

When all factors effecting system sensitivity are considered, the designer has little flexibility in the choice of receiver parameters. Rather, the performance requirements dictate the limit of sensitivity which can be implemented by the EW receiver.

1. Minimum Signal-to-Noise Ratio (S/N) - Set by the accuracy which you want to measure signal parameters and by the false alarm requirements.

2. Total Receiver Noise Figure (NF) - Set by available technology and system constraints for RF front end performance.

3. Equivalent Noise Bandwidth (B_N) - Set by minimum pulse width or maximum modulation bandwidth needed to accomplish the system requirements. A choice which is available to the designer is the relationship of pre- (B_{IF}) and post-detection (B_V) bandwidth. The most affordable approach is to set the post-detection filter equal to the reciprocal of the minimum pulse width, then choose the pre-detection passband to be as wide as the background interference environment will allow. Recent studies suggest that pre-detection bandwidths in excess of 100 MHz will allow significant loss of signals due to "pulse-on-pulse" conditions.

4. Antenna Gain (G) - Set by the needed instantaneous FOV needed to support the system time to intercept requirements.

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RECEIVER TYPES AND CHARACTERISTICS

Besides the considerations of noise and noise figure, the capabilities of receivers are highly dependent on the type of receiver design. Most receiver designs are trade-offs of several conflicting requirements. This is especially true of the Electronic Support Measures (ESM) receivers used in Electronic Warfare.

This section consists of a figure and tables that provide a brief comparison of various common ESM receiver types. Figures 1 and 2 show block diagrams of common ESM receivers. Table 1 is a comparison of major features of receivers. Table 2 shows the receiver types best suited for various types of signals and Tables 3 and 4 compare several direction of arrival (DOA) and emitter location techniques. Table 5 shows qualitative and quantitative comparisons of receiver characteristics.

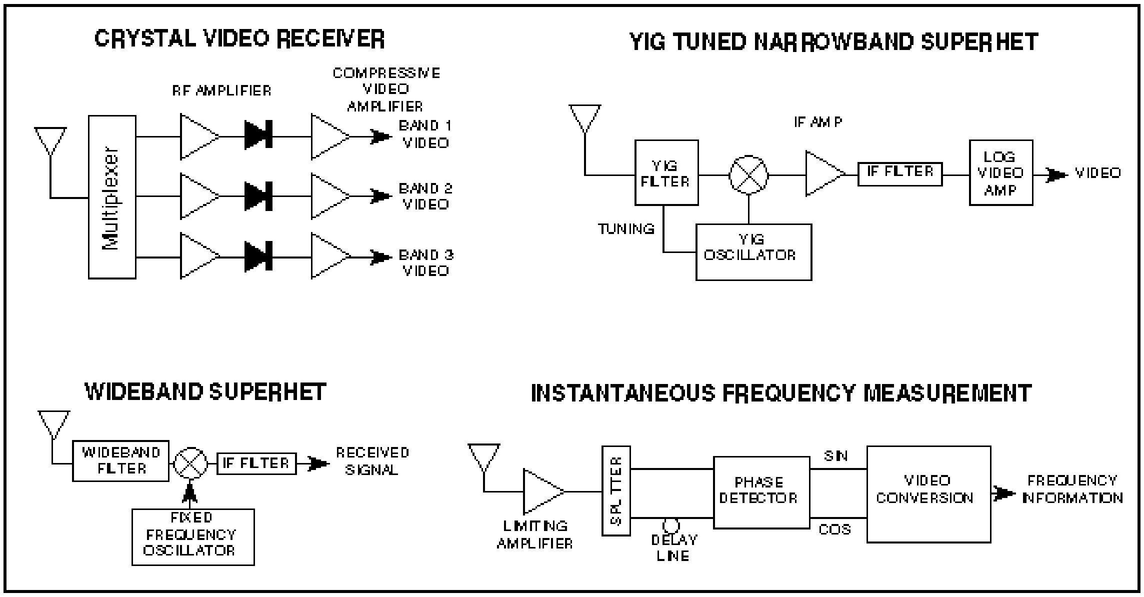
CRYSTAL VIDEO RECEIVER
RF AMPLIFIER
COMPRESSIVE VIDEO AMPLIFIER
Multiplexer
BAND 1 VIDEO
BAND 2 VIDEO
BAND 3 VIDEO
YIG TUNED NARROWBAND SUPERHET
IF AMP
YIG FILTER
IF FILTER
LOG VIDEO AMP
VIDEO
TUNING
YIG OSCILLATOR
WIDEBAND SUPERHET
WIDEBAND FILTER
IF FILTER
RECEIVED SIGNAL
FIXED FREQUENCY OSCILLATOR
INSTANTANEOUS FREQUENCY MEASUREMENT
LIMITING AMPLIFIER
SPLITTER
DELAY LINE
PHASE DETECTOR
SIN
COS
VIDEO CONVERSION
FREQUENCY INFORMATION

Figure 1. Common ESM Receiver Block Diagrams.

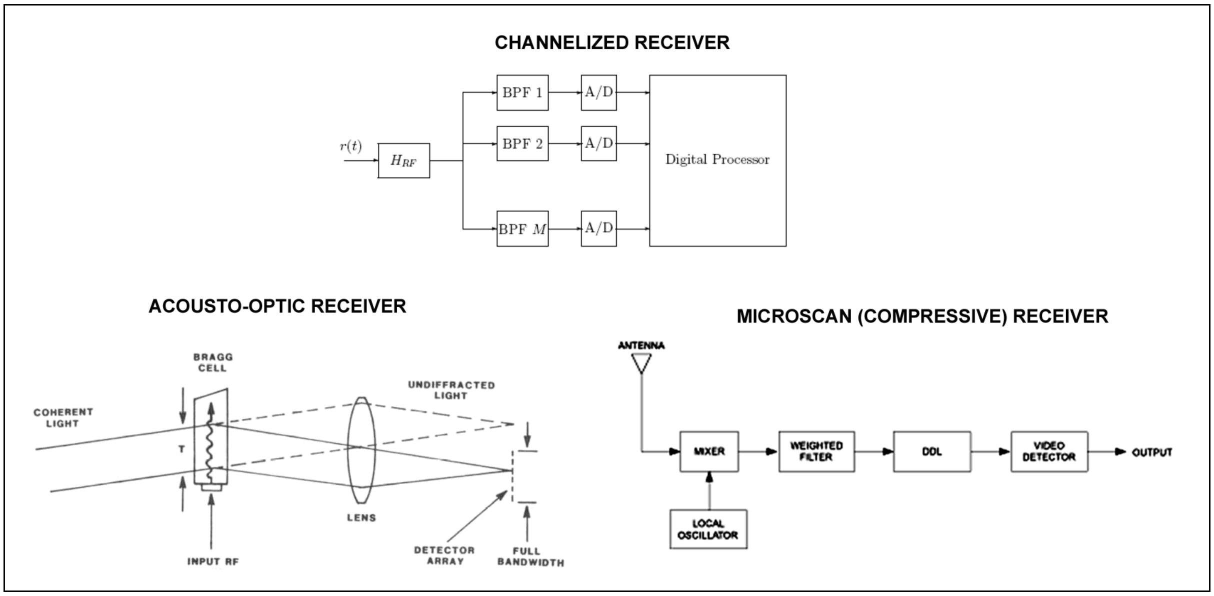
CHANNELIZED RECEIVER
r(t)
H_RF
BPF 1
BPF 2
BPF M
A/D
A/D
A/D
Digital Processor
ACOUSTO-OPTIC RECEIVER
BRAGG CELL
COHERENT LIGHT
T
UNDIFFRACTED LIGHT
LENS
INPUT RF
DETECTOR ARRAY
FULL BANDWIDTH
MICROSCAN (COMPRESSIVE) RECEIVER
ANTENNA
MIXER
WEIGHTED FILTER
DDL
VIDEO DETECTOR
OUTPUT
LOCAL OSCILLATOR

Figure 2. Common ESM Receiver Block Diagrams (Continued).

Table 1. Comparison of Major Features of Receivers.

Receiver	Advantages	Disadvantages	Principal Applications
Wideband crystal video	Simple, inexpensive, instantaneous, High POI in frequency range	No frequency resolution Poor sensitivity and Poor simultaneous signal performance	RWR
Tuned RF Crystal Video	Simple, Frequency measurement Higher sensitivity than wideband	Slow response time Poor POI	Option in RWR, Frequency measurement in hybrid
IFM	Relatively simple Frequency resolution Instantaneous, high POI	Cannot sort simultaneous signals Relatively poor sensitivity	Shipboard ESM, Jammer power management, SIGINT equipment
Narrow-band scanning Superhet	High sensitivity Good frequency resolution Simultaneous signals don't interfere	Slow response time Poor POI Poor against frequency agility	SIGINT equipment Air and ship ESM Analysis part of hybrid
Wide-band Superhet	Better response time and POI	Spurious signals generated Poorer sensitivity	Shipboard ESM Tactical air warning
Channelized	Wide bandwidth, Near instantaneous, Moderate frequency resolution	High complexity, cost; Lower reliability; limited sensitivity	SIGINT equipment Jammer power management
Microscan	Near instantaneous, Good resolution and dynamic range, Good simultaneous signal capability	High complexity, Limited bandwidth No pulse modulation information Critical alignment	SIGINT equipment Applications for fine freq analysis over wide range
Acousto-optic	Near instantaneous, Good resolution, Good simultaneous signal capability Good POI	High complexity; new technology	

Note: The Microscan receiver is also known as a compressive receiver

Table 2. Receiver Types vs. Signal Types.

Signal Type	Receiver Type							
	Wide-Band Crystal Video	TRF Crystal Video	IFM	Narrow-Band Superhet	Wide-Band Superhet	Channelized	Microscan	Acousto-optic
CW	Special design for CW	Special design for CW	Yes, but interferes with pulsed reception	Yes	Yes	Yes	Yes	Yes
Pulsed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Multiple Frequency	No	No	No	Yes, but won't recognize as same source	No	Yes	Yes	Yes
Frequency Agile	Yes, doesn't measure frequency	No	Yes	No	Yes (within passband)	Yes	Yes	No/Yes, depending on readout time
PRI Agile	Yes	Yes	Yes	No/Yes, depending on scan rate	Yes	Yes	No/Yes, imprecision in TOA	No/Yes, depending on readout time
Chirped	Yes, within acceptance BW	No	Yes	No/Yes, depending on BW	Yes	Yes (reduced sensitivity)	No/Yes, depending on scan rate	Yes (reduced sensitivity)
Spread Spectrum	Yes, within acceptance BW	No	Yes	No	No/Yes, depending on BW	Yes (reduced sensitivity)	Yes (reduced sensitivity)	Yes (reduced sensitivity)

Table 3. Direction of Arrival Measurement Techniques.

	Amplitude Comparison	Phase Interferometer
Sensor Configuration	Typically 4 to 6 Equal Spaced Antenna Elements for 360° Coverage	2 or more RHC or LHC Spirals in Fixed Array
DF Accuracy	$DF_{ACC} \approx \frac{\Theta_{bW}^{2}\,\Delta C_{dB}}{24\,S}$ (Gaussian Antenna Shape)	$DF_{ACC} \approx \frac{\lambda}{2\,\pi\,d\,\cos\theta}\Delta\theta$
DF Accuracy Improvement	Decrease Antenna BW; Decrease Amplitude Mistrack; Increase Squint Angle	Increase Spacing of Outer Antennas; Decrease Phase Mistrack
Typical DF Accuracy	3° to 10° rms	0.1° to 3° rms
Sensitivity to Multipath/Reflections	High Sensitivity; Mistrack of Several dB Can Cause Large DF Errors	Relatively Insensitive; Interferometer Can be Made to Tolerate Large Phase Errors
Platform Constraints	Locate in Reflection Free Area	Reflection Free Area; Real Estate for Array; Prefers Flat Radome
Applicable Receivers	Crystal Video; Channelizer; Acousto-Optic; Compressive; Superheterodyne	Superheterodyne
ΔC_{dB}= Amplitude Monopulse Ratio in dB S= Squint Angle in degrees θ_{BW}= Antenna Beamwidth in degrees		

Table 4. Emitter Location Techniques.

Measurement Technique	Advantages	Disadvantages
Triangulation	Single Aircraft	Non-instantaneous location Inadequate accuracy for remote targeting Not forward looking
Azimuth/elevation	Single Aircraft Instantaneous location possible	Accuracy degrades rapidly at low altitude Function of range
Time Difference of Arrival (Pulsed signals)	Very high precision Can support weapon delivery position requirements Very rapid, can handle short on-time threat	Very complex, diverse systems required, at least 3 aircraft High quality receivers, DME (3 sites) very wideband data link Very high performance control processor; requires very high reliability subsystems

Table 5. Qualitative Comparison of Receivers. (From NRL Report 8737)

Feature	Receiver Type							
	Wide-Band Crystal Video	TRF Crystal Video	IFM	Narrow-Band Superhet	Wide-Band Superhet	Channelized	Microscan	Acousto-optic
Instantaneous Analysis Bandwidth	Very wide	Narrow	Very wide	Narrow	Moderate	Wide	Wide	Moderate
Frequency Resolution	Very poor	Fair	Good	Very good	Poor	Fair	Good	Good
Sensitivity	Poor (No preamp) Fair (preamp)	Fair/ good	Poor (No preamp) Fair (preamp)	Very good	Fair	Fair/ good	Very good	Good
Dynamic Range	Fair	Fair/ good	Good	Very good	Fair	Good	Fair	Poor
Speed of Acquisition	Very Fast	Slow	Very Fast	Slow	Fast	Very Fast	Very Fast	Fast
Short pulse Width Capability	Good	Good	Good	Good	Very good	Good	Fair	Fair
Retention of Signal Characteristics	Fair	Fair	Poor	Good	Fair/ good	Good	Poor	Fair/ good
Applicability to Exotic Signals	Poor/ fair	Poor	Good	Poor	Fair/ good	Good	Fair/ good	Fair/ good
High signal Density Performance	Poor (high false alarm rate from background)	Fair/ good	Good	Poor	Fair (depending on BW)	Fair/good, depending on architecture & processing	Good	Poor
Simultaneous Signal Capability	Poor	Fair/ good	Poor	Good	Fair (depending on BW)	Good	Good	Good
Processing Complexity	Moderate depending on application	Moderate depending on application	Moderate	Moderate	Moderate	Low-high depending on architecture	Complex	Simple signal processing complex data processing
Immunity to Jamming	Poor	Fair	Poor/ Fair	Good	Poor/ Fair	Good	Good	Good
Power Requirements	Low	Low/ Moderate	Moderate	Moderate	Moderate	High	Moderate	Moderate/ High
RF Range (GHz)	Multi-octave (0.5-40)	0.15-18 separate	>0.5 to 40	<0.01 to 40	0.5 to 18	0.5 to 60	<0.5 to 8	0.5-4 (0.5-18 channelized and down conversion)
Max Instantaneous Analysis Bandwidth	Multi-octave (to 17.5 GHz)	As high as desired with equivalent reduction in resolution	Multi-octave (1 octave per unit)	50 MHz	500 MHz	~2 GHz without degradation, 17.5 GHz with degradation	0.5 to 2 depending on PW limitation	1 GHz
Frequency Accuracy	Measurement accuracy no better than analysis BW	Measurement accuracy no better than analysis BW	5-10 MHz	0.5% to 1%	0.5 to 3 MHz	±1 MHz	10 KHz	±1 MHz

Feature	Receiver Type							
	Wide-Band Crystal Video	TRF Crystal Video	IFM	Narrow-Band Superhet	Wide-Band Superhet	Channelized	Microscan	Acousto-optic
Pulse Width Range	CW to 50 ns	CW to 50 ns	CW to ~20 ns (depending on resolution)	CW to 100 ns with 20 MHz resolution	CW to 4 ns with 500 MHz resolution	CW to 30 ns (depending on resolution)	CW to 250 ns	CW to 0.5 µs
Frequency Resolution	~400 MHz (no better than BW)	25 MHz	1 MHz	<0.1 MHz	100-500 MHz	10-125 MHz (less with freq vernier)	1 MHz	0.5 to 1 MHz
Sensitivity (dBm)	-40 to -50 (no preamp) -80 (with preamp)	Better than -80 with preamp	-40 (no preamp) -75 (preamp) 4 GHz BW	-90, 1 MHz BW	-80, 500 MHz BW	-70, 10-50 MHz BW	-90, 5-10 MHz BW	-70 to -80
Maximum Dynamic Range (dB)	70	70-80	80 (w/preamp) 100+ (saturated)	90	60	50-80	40-60	25-35
Tuning Time	-	50 ms	-	1.0 s (1 octave)	.12 s (200 MHz band)	-	0.3 µs LO scan time	0.5 ms (integration time)
Signal ID Time	100 ns	50 ms	2-10 ms	~0.1 s	-	2.10 ms	~1 µs	-
Minimum Weight (lb)	20 (with processor)	30	<20 (octave unit) 65-75 (full coverage)	60-75	35 (tuner only)	1309-200 for 0.5 to 18 GHz coverage	25	29-55
Size / Minimum Volume (in³)	Small 300 (w/processor)	Small 375	Sm/Moderate 600-1000 ~100 miniaturized	Moderate 1500-3000	Moderate Several thousand	Large 4000-8000 (0.5-18 GHz coverage	Moderate 1200-2000	Small 800-1900
Minimum Power (W)	100 (with processor) <10 without processor	60 (without processor)	~50 (octave unit)	150	150 (tuner only)	350 to 1200 for 0.5 to 18 GHz coverage	70-80	200
Cost	Low	Low/ Moderate	Moderate	Moderate/ High	Moderate/ High	High	Moderate/ High	Low/ Moderate

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RADAR MODES

Typical Radar modes are listed below in the general functional category for which they were designed. Not all of these modes are applicable to all radars and certain radars have additional modes.

• NAVIGATION

Terrain avoidance - A mode in which the radar is set at a fixed depression angle and short range to continuously sweep the ground area directly in front of the aircraft in order to avoid mountains. This is particularly useful during flight into unfamiliar territory when clouds, haze, or darkness obscure visibility.

Ground mapping - A mode in which the radar uses a variety of techniques to enhance ground features, such as rivers, mountains, and roads. The mode is unlike air-to-air modes where ground return is rejected from the display.

Precision velocity update / Doppler navigation - A mode in which the radar again tracks ground features, using Doppler techniques, in order to precisely predict aircraft ground speed and direction of motion. Wind influences are taken into account, such that the radar can also be used to update the aircraft inertial navigation system.

• FIGHTER MISSIONS

Pulse search - Traditional pulse techniques are used to accurately determine range, angle, and speed of the target. Limitations are easy deception by enemy jamming, and less range when compared to other modes.

Velocity search - A high PRF Pulse Doppler waveform is used for long range detection primarily against nose aspect targets, giving velocity and azimuth information. Although velocity search can work against tail-on targets, the Doppler return is weaker, consequently the maximum detection range is also much less. When the target is in the beam (flying perpendicular to the fighter), the closure (Doppler) is the same as ground return and target return is almost zero.

Track While Scan (TWS) - A system that maintains an actual track on several aircraft while still searching for others. Since the radar is sharing its computing time between targets, the accuracy is less precise than for a single target track (STT) mode of operation.

Raid assessment - A mode in which the radar has an STT on a single target, but is routinely driven off by a small amount in order to determine if multiple aircraft exists in the immediate vicinity of the target aircraft.

Single-Target-Track (STT) (including air combat maneuvering modes) - Highly precise STT modes are used to provide the most accurate information to the fire control computer so that accurate missile or gun firing can be accomplished. The fire control radar continuously directs energy at the target so that the fired missile locates and tracks on the reflected energy from the target. Air combat maneuvering modes are automatic modes in which the radar has several sweep patterns fixed about the aircraft axis, such that little or no work is required of the pilot in order to lock up a target.

- **AIR-TO-GROUND MISSIONS**

Weapons delivery - A mode in which ground features are tracked, and particular emphasis is placed on determining range to the ground target, angle of dive, weapons ballistic tables, and aircraft speed.

Surveillance/tracking of ground forces/targets - Similar to the above with emphasis on multiple ground features and less on weapons delivery data.

Reconnaissance - A specific navigational mode to aid in identifying specific targets.

- **AIR-TO-SURFACE MISSIONS**

ASW - Navigational techniques specializing in specific search patterns to aid in detection of enemy submarines.

- **TECHNIQUES USED FOR MULTIPLE APPLICATIONS**

Synthetic Aperture Radar (SAR) - A form of radar that uses the relative motion between an antenna and its target region, to provide coherent-signal variations, in order to obtain finer spatial resolution than is possible with conventional beam-scanning means. SAR is usually implemented by mounting a single beam-forming antenna on a moving platform such as an aircraft from which a target scene is repeatedly illuminated with pulses of radio waves at wavelengths anywhere from a meter down to millimeters. The many echo waveforms received successively at the different antenna positions are coherently detected and stored and then post-processed together to resolve elements in an image of the target region.

Over-The-Horizon Radar (OTHR) - uses the refraction of high frequency radiation through the ionosphere in order to detect targets beyond the line-of-sight. The complexities of the ionosphere can produce multipath propagation, which may result in multiple resolved detections for a single target. When there are multipath detections, an OTHR tracker will produce several spatially separated tracks for each target. Information conveying the state of the ionosphere is required in order to determine the true location of the target and is available in the form of a set of possible propagation paths, and a transformation from measured coordinates into ground coordinates for each path. Since may be no other information as to how many targets are in the surveillance region, or which propagation path gave rise to which track, there is a joint target and propagation path association ambiguity which must be resolved using the available track and ionospheric information.

GENERAL RADAR DISPLAY TYPES

There are two types of radar displays in common use today.

RAW VIDEO

Raw video displays are simply oscilloscopes that display the detected and amplified target return signal (and the receiver noise). Raw video displays require a human operator to interpret the various target noise and clutter signals.

On the left hand display of Figure 1, an operator could readily identify three targets and a ghost (a ghost is a phony target that usually fades in and out and could be caused by birds, weather, or odd temporary reflections - also referred to as an angel). Target 3 is a weak return and hidden in the noise - an operator can identify it as a target by the "mouse under the rug" effect of raising the noise base line.

SYNTHETIC VIDEO

Synthetic video displays use a computer to clean up the display by eliminating noise and clutter and creating its own precise symbol for each target.

On the right hand display target 1 comes and goes because it is barely above the receiver noise level - notice that it is quite clear on the raw video. Target 3 wasn't recognized by the computer because it's too far down in the noise. The computer validated the ghost as a target. The ghost might be a real target with glint or ECM characteristics that were recognized by the computer but not the operator.

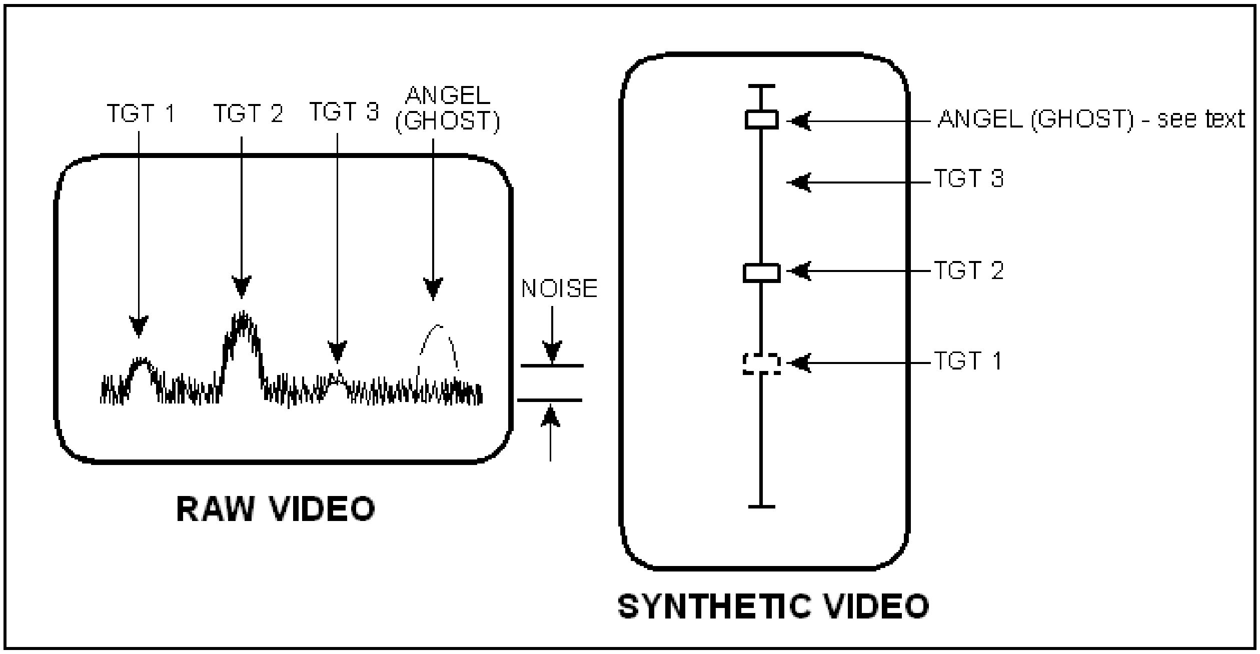

Figure 1. Radar Display Types.

SEARCH AND ACQUISITION RADARS

They generally use either a PPI or a sector PPI display as shown in Figure 2. PPI displays can be either raw video or synthetic video.

PPI scope (plan position indicator).
    Polar plot of direction and distance.
    Displays all targets for 360 degrees.

Sector PPI scope.
    Polar plot of direction and distance.
    Displays all targets within a specific sector.
    Origin may be offset so that “your” radar position may be off the scope.

TRACKING RADARS

Usually use some combination of A, B, C, or E scope displays. There are many other types of displays that have been used at one time or another - including meters - but those listed here are the most common in use today.

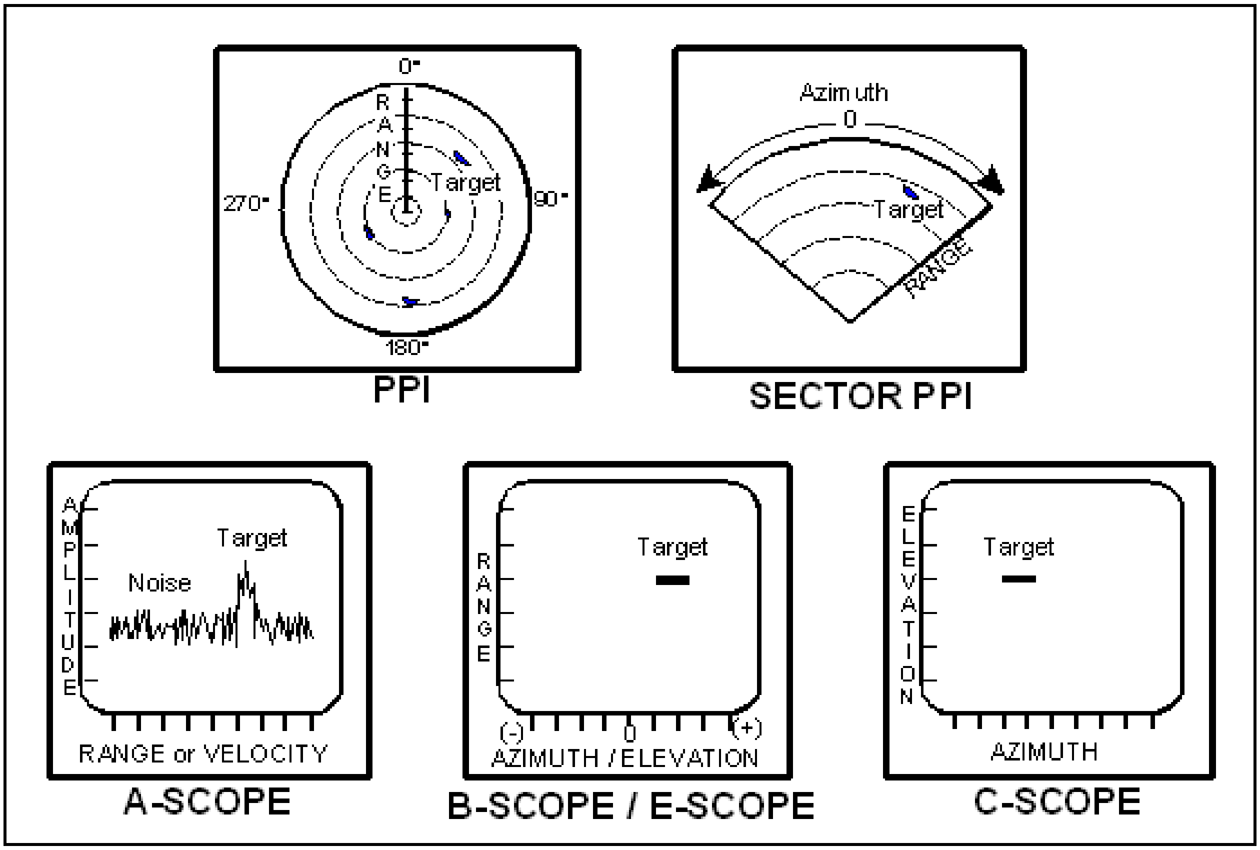
0°
RANGE
Target
270°
90°
180°
PPI
Azimuth
0
Target
RANGE
SECTOR PPI
AMPLITUDE
Target
Noise
RANGE or VELOCITY
A-SCOPE
RANGE
Target
(-)
0
(+)
AZIMUTH / ELEVATION
B-SCOPE / E-SCOPE
ELEVATION
Target
AZIMUTH
C-SCOPE

Figure 2. Common Radar Displays.

A-SCOPE

Target signal amplitude vs. range or velocity.

Displays all targets along pencil beam for selected range limits.

Displays tracking gate. Usually raw video. Some modern radars have raw video a-scopes as an adjunct to synthetic video displays.

Must be used with a separate azimuth and elevation display of some sort.

Also called a range scope (R-Scope).

B-SCOPE

Range vs. azimuth or elevation. Displays targets within selected limits.

Displays tracking gate. May be raw or synthetic video.

Surface radars usually have two. One azimuth/one elevation which can result in confusion with multiple targets.

C-SCOPE

Azimuth vs. elevation. Displays targets within selected limits of az and el.

Displays tracking gate. May display bull's-eye or aim dot.

May have range indicator inserted typically as a marker along one side. Usually synthetic video.

Pilots eye view and very common in modern fighter aircraft heads up displays for target being tracked.

Could be used in any application where radar operator needs an "aiming" or "cross hair" view like a rifle scope.

E-SCOPE

Elevation vs. Range similar to a B-scope, with elevation replacing azimuth.

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IFF - IDENTIFICATION - FRIEND OR FOE

Originated in WWII for just that purpose - a way for our secondary radars to identify U.S. aircraft from enemy aircraft by assigning a unique identifier code to U.S. aircraft transponders.

The system is considered a secondary radar system since it operates completely differently and independently of the primary radar system that tracks aircraft skin returns only, although the same CRT display is frequently used for both.

The system was initially intended to distinguish between enemy and friend but has evolved such that the term "IFF" commonly refers to all modes of operation, including civil and foreign aircraft use.

There are five major modes of operation currently in use by military aircraft plus two sub-modes.

- Mode 1 is a non-secure low cost method used by ships to track aircraft and other ships.
- Mode 2 is used by aircraft to make carrier controlled approaches to ships during inclement weather.
- Mode 3 is the standard system also used by commercial aircraft to relay their position to ground controllers throughout the world for air traffic control (ATC).
- Mode 4 is secure encrypted IFF (the only true method of determining friend or foe) Military only
- Mode 5 – provides a cryptographically secured version of Mode S and ADS-B GPS position. (military only). Mode 5 is divided into two levels. Both are crypto-secure with Enhanced encryption, Spread Spectrum Modulation, and Time of Day Authentication. Level 1 is similar to Mode 4 information but enhanced with an Aircraft Unique PIN. Level 2 is the same as Mode 5 level one but includes additional information such as aircraft position and other attributes
- Mode "C" is the altitude encoder (military and civilian).
- Mode S – provides multiple information formats to a selective interrogation. Typically aircraft are assigned a unique 24-bit Mode S address. The Mode S address is partitioned and a group of address ranges are allocated to each country. Some countries change the assigned address for security reasons, and thus it might not be a unique address. (military and civilian)

The non-secure codes are manually set by the pilot but assigned by the air traffic controller.

A cross-band beacon is used, which simply means that the interrogation pulses are at one frequency and the reply pulses are at a different frequency. 1030 MHz and 1090 MHz is a popular frequency pair used in the U.S.

The secondary radar transmits a series of selectable coded pulses. The aircraft transponder receives and decodes the interrogation pulses. If the interrogation code is correct, the aircraft transponder transmits a different series of coded pulses as a reply.

The advantage of the transponder is that the coded pulses "squawked" by the aircraft transponders after being interrogated might typically be transmitted at a 10 watt ERP, which is much stronger than the microwatt skin return to the primary radar. Input power levels may be on the order of several hundred watts.

The transponder antenna is low gain so that it can receive and reply to a radar from any direction.

An adjunct to the IFF beacon is the altitude encoding transponder known as mode C - all commercial and military aircraft have them, but a fair percentage of general aviation light aircraft do not because of cost. The number of transponder installations rises around many large metropolitan areas where they are required for safety (easier identification of aircraft radar tracks).

Air traffic control primary radars are similar to the two-dimensional search radar (working in azimuth and range only) and cannot measure altitude.

The expanded display in figure 1 is typical of an air traffic control IFF response. The aircraft was told to squawk a four digit number such as "4732." The altitude encoded transponder provides the aircraft altitude readout to the ground controllers display along with the coded response identifying that particular aircraft.

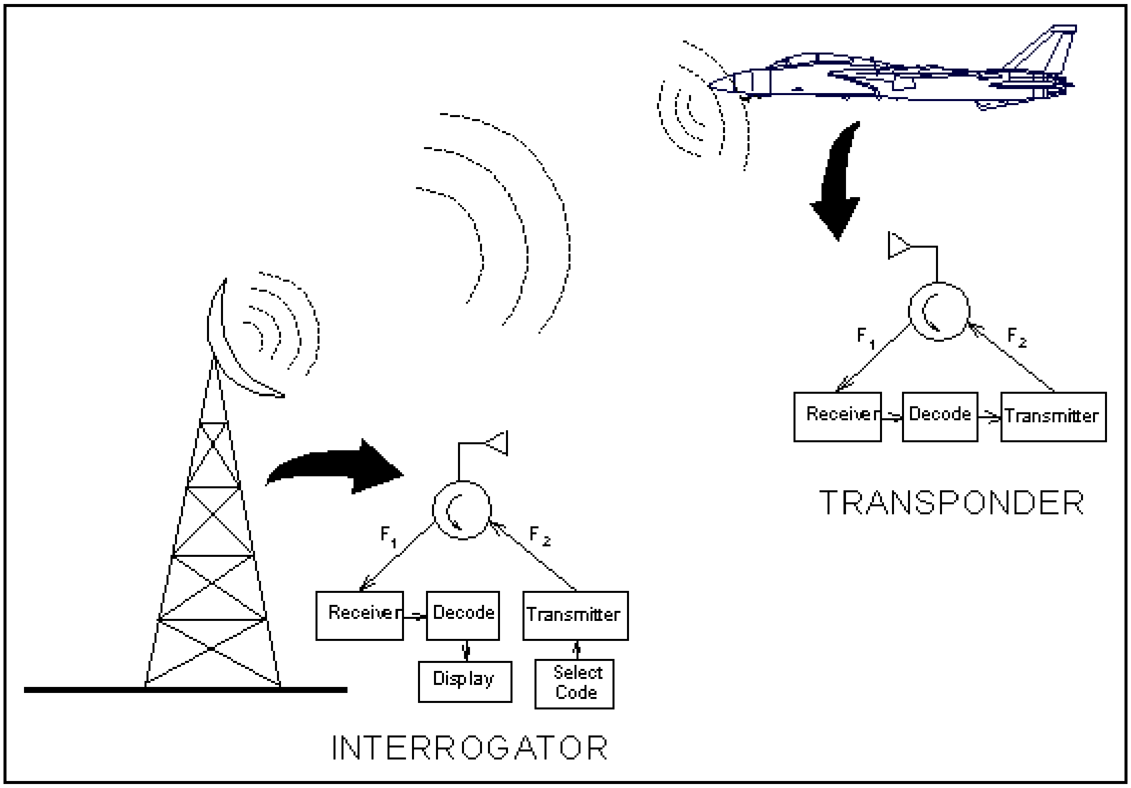

Figure 1. IFF Transponder.

In addition to systems with active electronic data interchange between airborne and ground equipment, some military surveillance systems can provide targeting in tactical applications. The development of automated techniques for use against ground targets is typically referred to as Automatic Target Recognition (ATR). When used against air targets, it is typically referred to as Non-Cooperative Target Recognition (NCTR). The requirements for radar target recognition are complex since typical targets have background clutter and often multiple targets types exist.

RECEIVER TESTS

Two tone and spurious response (single signal) receiver tests should be performed on EW and radar receivers to evaluate their spurious free dynamic range. A receiver should have three ranges of performance: (1) protection from damage, (2) degraded performance permitted in the presence of a strong interfering signal(s) and no degradation when only a strong desired signal is present, and (3) full system performance.

The original MIL-STD-461A design requirement and its companion MIL-STD-462 test requirement specified four receiver tests. These standards allowed the interfering signal(s) to be both inband and out of band, which is meaningful for design and test of EW receivers, however inband testing generally is not meaningful for narrowband communications receivers. These standards were difficult to follow and had to be tailored to properly evaluate the EW and radar system. MIL-STD-461B/C still allowed the interfering signal(s) to be both inband and out of band but deleted the single signal interference test (CS08 Conducted Susceptibility test). MIL-STD-461D/-462D leave the pass/fail criteria entirely up to what is listed in the individual procurement specification. It also places all interfering signals out of band, redesignates each test number with a number "100" higher than previously used, and combines "CS08" as part of CS104. Therefore, to provide meaningful tests for EW and radar systems, the procurement specification must specify the three ranges of performance mentioned in the beginning of this section and that the tests are to be performed with the interfering signal(s) both inband and out of band. The four tests are as follows (listed in order of likelihood to cause problems):

Test Name	MIL-STD-461A	MIL-STD-461D
Undesired, Single signal interference test	CS08	Part of CS104
Desired with undesired, two signal interference tests	CS04	CS104
Two signal intermodulation test	CS03	CS103
Two signal cross modulation test	CS05	CS105

The rest of this section explains the application of these tests and uses the names of the original MIL-STD-461A tests to separate the tests by function.

TEST SETUP

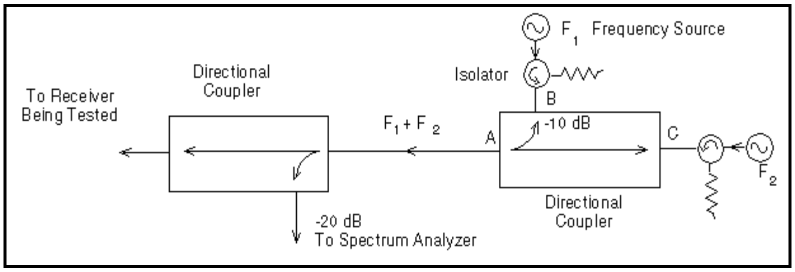

Figure 1. Receiver Test Setup When Antenna Can Be Removed.

A directional coupler used backwards (as shown here in Figure 1) is an easy way to perform two signal tests. The CW signal should be applied to the coupling arm (port B) since the maximum CW signal level is -10 dBm. The pulse signal should be applied to the straight-through path (port C) since the maximum pulse level is +10 dBm peak. These power levels are achievable with standard laboratory signal generators, therefore one doesn't have to resort to using amplifiers which may distort the signals. Always monitor the output signal to verify spectrally pure signals are being applied to the test unit. This can be accomplished by another directional coupler used in the standard configuration. Dissimilar joints or damaged or corroded microwave components can cause mixing. This can also result if the two signal generators are not isolated from one another. Therefore, even if a directional coupler is used to monitor the signal line, it is still advisable to directly measure the input to the receiver whenever there is a suspected receiver failure. This test does not need to be performed in an EMI shielded room and is more suitable for a radar or EW lab where the desired signals are readily available.

If the receiver's antenna is active or cannot be removed, a modified test as shown in Figure 2 should be performed. The monitoring antenna which is connected to the spectrum analyzer should be the same polarization as the antenna for the receiver being tested. Amplifiers may be required for the F_1 and F_2 signals. It is desirable to perform this test in an anechoic chamber or in free space.

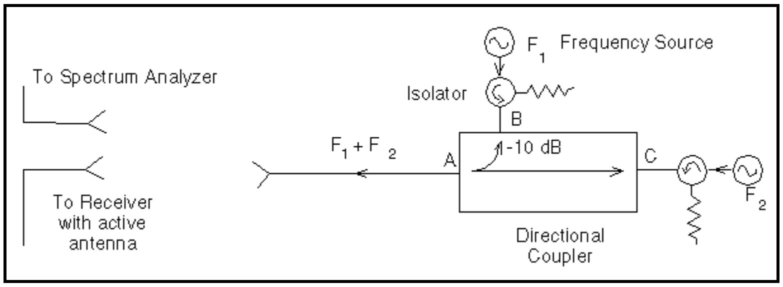

Figure 2. Receiver Test Setup When Antenna Is Active.

In the following discussion of CS08, CS04, CS03, and CS05 tests, it is assumed that when the receive light illuminates, the receiver identifies a signal that matches parameters in the User Data File (UDF) or pre-programmed list of emitter identification parameters. If a receiver is different, the following procedures will have to be appropriately tailored. If the UDF does not have entries for very low level signals in the 10% and 90% regions of each band, complete testing is not possible. Most problems due to higher order mixing products and adjacent band leakage are only evident in these regions. In the following tests, the lowest level where the receive light is constantly on is used to identify the minimum receive level. If a receiver has a receive level hysteresis or other idiosyncrasy, then using a 50% receive light blinking indicator may be more appropriate. Whatever technique is appropriate, it should be consistently used during the remainder of the test. The maximum frequency for testing is normally 20 GHz. If a millimeter wave receiver is being tested, the maximum frequency should be 110 GHz.

CS08 - UNDESIRED, SINGLE SIGNAL INTERFERENCE TEST

MIL-STD-461B/C (EMI design requirements) deleted this test. MIL-STD-461D allows a single signal test as part of CS104 (CS04) but specifies it as an out of band test. The original CS08 inband and out of band test is still needed and is the most meaningful test for wide band EW receivers which have a bandwidth close to an octave. This test will find false identification problems due to 1) lack of RF discrimination, 2) higher order mixing problems, 3) switch or adjacent channel/band leakage, and 4) cases where the absence of a desired signal causes the receiver to search and be more susceptible. In this latter case, a CS04 two signal test could pass because the receiver is captured by the desired signal, whereas a CS08 test could fail. Examples of the first three failures are as follows.

EXAMPLE 1

A 2 to 4 GHz receiver which uses video detection (e.g., crystal video) and doesn't measure RF is used for this example. This receiver assumes that if the correct Pulse Repetition Interval (PRI) is measured, it is from a signal in the frequency band of interest. Three cases can cause false identification. Refer to Figure 3.

(1) Region A&C. The 2 to 4 GHz band pass filter will pass strong signals in regions A&C. If they have the correct PRI, they will also be identified.

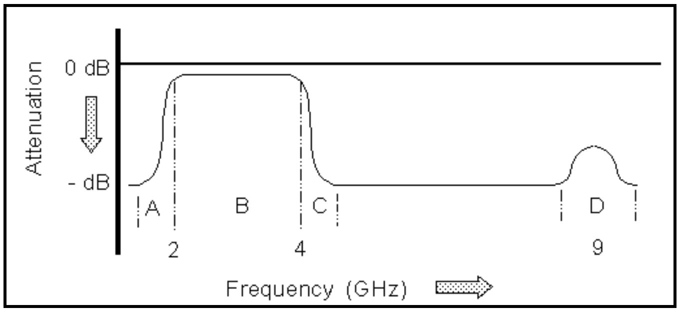

Figure 3. Frequency Areas in a Sample 2-4 GHz Receiver.

(2) Region B. Any other signal besides the desired signal in the 2 to 4 GHz region that has the correct PRI will also be identified as the signal of interest.

(3) Region D. Band pass filters with poor characteristics tend to pass signals with only limited attenuation at frequencies that are three times the center frequency of the band pass filter. If these signals have the correct PRI, they will be incorrectly identified.

High duty cycle signals (CW or pulse doppler) in regions A, B, C, and D may overload the processing of signals, saturate the receiver, or desensitize the receiver. This case is really a two signal CS04 test failure and will be addressed in the CS04 section.

EXAMPLE 2

A receiver measuring the carrier frequency of each pulse (i.e., instantaneous frequency measurement (IFM)) and the PRI is used for this example. False signal identification can occur due to higher order mixing products showing up in the receiver pass bands. These unwanted signals result from harmonics of the input RF mixing with harmonics of the Local Oscillator (LO). Refer to Figures 4 and 5.

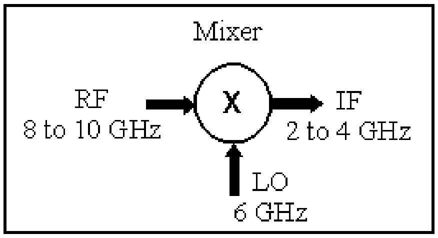

Figure 4. Low Side Mixing.

Mixers are nonlinear devices and yield the sum, difference, and the original signals. Any subsequent amplifier that is saturated will provide additional mixing products.

If a 8.5 GHz signal with a 1 kHz PRI is programmed to be identified in the UDF, measurements are made at the 2.5 GHz Intermediate Frequency (IF), i.e., RF-LO = IF = 8.5-6 = 2.5 GHz.

The same 2.5 GHz signal can result from an RF signal of 9.5 GHz due to mixing with the second harmonic of the LO i.e., 2 X 6 - 9.5 = 2.5 GHz. This signal will be substantially attenuated (approximately 35 dB) when compared to the normal IF of 9.5 - 6 = 3.5 GHz. If the receiver has filters at the IF to reduce the signal density and a filter has minimum insertion loss at 2.5 GHz and maximum insertion loss at 3.5 GHz, then only the low level 2.5 GHz signal will be measured and assumed to be due to a 8.5 GHz input signal whereas the input is really at 9.5 GHz.

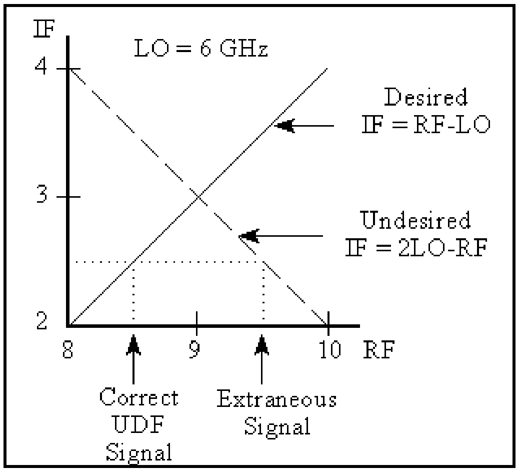

Figure 5. Low Side Mixing Results.

Spurious intermodulation products can also result from high side mixing, but generally the suppression of undesired signals is greater. In this case, the LO is at a frequency higher than the RF input. This is shown in Figures 6 and 7.

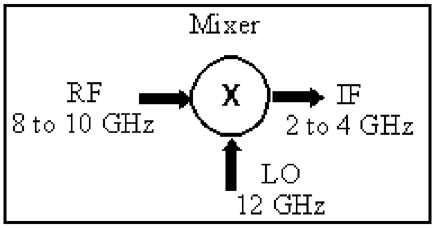

Figure 6. High Side Mixing.

Table 1. Intermodulation Product Suppression.

Harmonic of		
LO	RF	Suppression
1	1	0
1	2	ΔP-41
1	3	2ΔP-28
2	1	-35
2	2	ΔP-39
2	3	2ΔP-44
3	1	-10
3	2	ΔP-32
3	3	2ΔP-18
4	1	-35
4	2	Δ-39
5	1	-14
5	3	2ΔP-14
6	1	-35
6	2	ΔP-39
7	1	-17
7	3	2ΔP-11

Courtesy Watkins-Johnson

As previously mentioned, the amplitude of intermodulation products is greatly reduced from that of the original signals. Table 1 shows rule of thumb approximate suppression (reduction), where ΔP = P_{RF}(dBm) - P_{LO}(dBm). As can be seen, the strength of the LO is a factor. The higher the LO power, the more negative the suppression becomes.

If one assumes the maximum RF power for full system performance is +10 dBm and the LO power level is +20 dBm, then ΔP = -10 dB minimum. Therefore in this example, the 3RF-2LO mixing product would be 2ΔP - 44 = - 20 - 44 = -64 dB when compared to the desired mixing product.

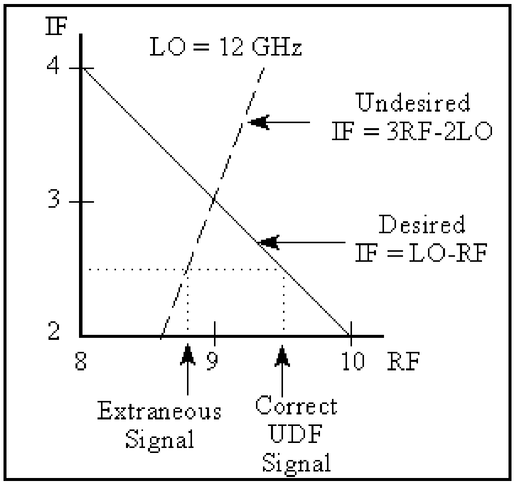

Figure 7. High Side Mixing Byproducts.

The use of double mixing, as shown in Figure 8, can significantly reduce unwanted signals but it is more expensive. For a 8 GHz signal in, one still generates a 2 GHz IF but by mixing up, then down, unwanted signals are not generated or significantly suppressed.

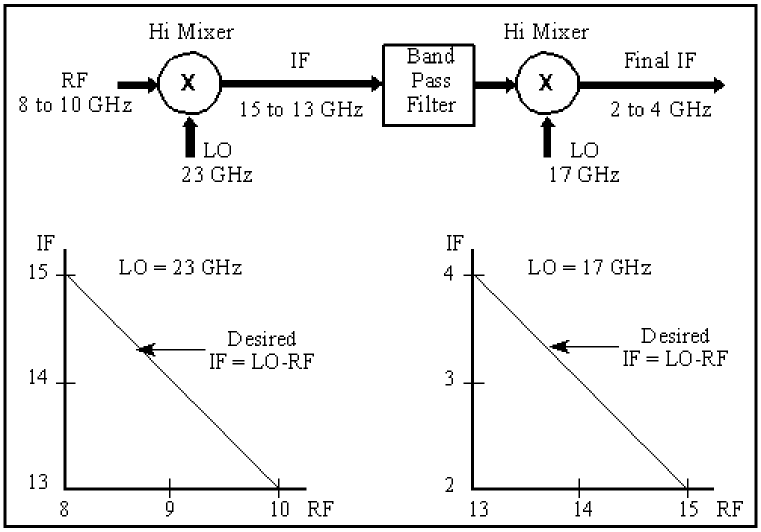
Hi Mixer
RF
8 to 10 GHz
X
IF
15 to 13 GHz
LO
23 GHz
Band
Pass
Filter
Hi Mixer
X
Final IF
2 to 4 GHz
LO
17 GHz
IF
15
14
13
8
9
10
RF
LO = 23 GHz
Desired
IF = LO-RF
IF
4
3
2
13
14
15
RF
LO = 17 GHz
Desired
IF = LO-RF

Figure 8. Double Mixing.

Some of these problems can be corrected by:

(1) always having LOs on the high side versus low side of the input RF (but this is more expensive),

(2) using double mixing

(3) software programming the receiver to measure for the potential stronger signal when a weak signal is measured in a certain IF region, and

(4) improved filtering of the LO input to the mixer and the output from the mixer.

EXAMPLE 3

If the same receiver discussed in example 2 had additional bands (Figure 9) and used a switch at the IF to select individual bands, a strong signal in an adjacent band could be inadvertently measured because:

(1) the switch, which may have 80 dB of isolation when measured outside the circuit, may only have 35 dB isolation when installed in a circuit because of the close proximity of input and output lines,

(2) the strong signal in one band may have the same IF value that is being sought in an adjacent band, and

(3) the additional parameters such as PRI may be the same.

As shown in Figure 9, assume that in band 2 we are looking for a 4.5 GHz signal that has a PRI of 1 kHz. Measurements are made at an IF of 3.5 GHz since LO-RF = IF = 8-4.5 = 3.5 GHz. If a 6.5 GHz signal is applied to band 3, its IF also equals 3.5 since LO-RF = 10-6.5 = 3.5 GHz. If this is a strong signal, has a PRI of 1 kHz, and there is switch leakage, a weak signal will be measured and processed when the switch is pointed to band 2. The receiver measures an IF of 3.5 GHz and since the switch is pointed to band 2, it scales the measured IF using the LO of band 2 i.e., LO-IF = RF = 8-3.5 = 4.5 GHz. Therefore, a 4.5 GHz signal is assumed to be measured when a 6.5 GHz signal is applied. Similarly this 6.5 GHz signal would appear as a weak 3.5 GHz signal from band 1 or a 9.5 GHz signal from band 4.

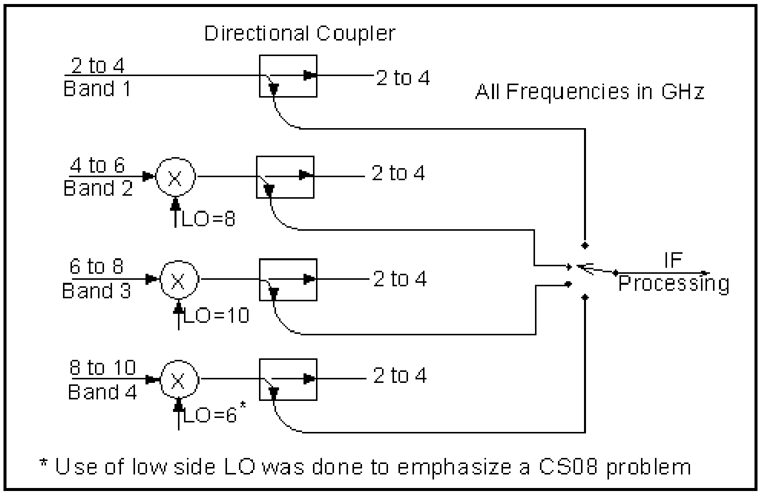

* Use of low side LO was done to emphasize a CS08 problem

Figure 9. Multi Band Receiver With Common IF.

In performing this test it is important to map the entries of the UDF for each band i.e., show each resulting IF, its PRI, and the sensitivity level that the receive light is supposed to illuminate, i.e., if a test in one band used a PRI corresponding to a PRI in another band where the receive threshold is programmed to not be sensitive this will negate the effectiveness of a cross coupling test. Mapping the UDF will facilitate applying a strong signal to one band using the PRI of a desired signal in an adjacent band.

CS08 TEST PROCEDURE

Assume that the receiver band is 2 to 4 GHz as shown in Figure 10. Pick the UDF entry that has the greatest sensitivity. UDF #1 entry is for a 3±.05 GHz signal with a PRI of 1 kHz. If the test signal is set for the UDF #1 PRI, a receive light will also occur at the frequencies of UDF #2 if it also has the same PRI (this is not a test failure). If adjacent bands don't also have entries with the same PRI, then the test should be repeated for the band being tested with at least one of the adjacent band PRI values.

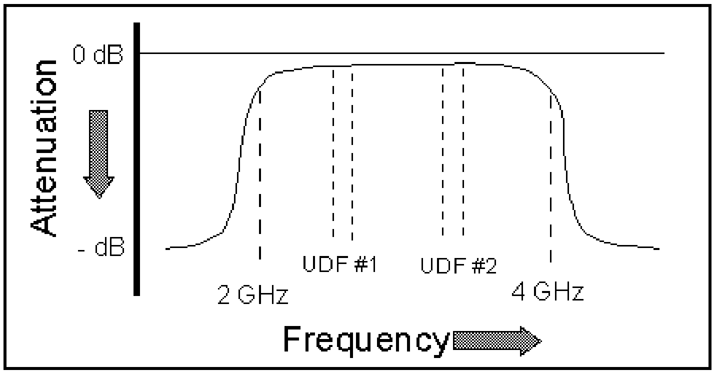

Figure 10. Receiver Band With Multiple UDF Entries.

(1) Set the receiver or jammer to the receive mode, verify it is working for UDF #1 and record P_o, the minimum signal level where the receive light is constantly on.

(2) Raise this signal to its maximum specified level for full system performance. If a maximum level is not specified, use +10 dBm peak for a pulse signal or -10 dBm for a CW signal.

(3) Tune this strong RF signal outside the UDF #1 range and record any RF frequency where the receive light comes on. If another inband UDF has the same PRI, this is not a failure.

(4) This test is performed both inband and out of band. Out of band tests should be performed on the high end to five times the maximum inband frequency or 20 GHz, whichever is less, and on the low end to IF/5 or 0.05 F0, whichever is less, unless otherwise specified. The out of band power level is +10 dBm peak for a pulse signal or -10 dBm for a CW signal, unless otherwise specified.

(5) If a receive light comes on when it is not supposed to, record the RF and reduce the power level to where the receive light just stays on constantly. Record this level P1. The interference rejection level is P1-P0= PIR

(6) Repeat this test for each type of signal the receiver is supposed to process, i.e., pulse, PD, CW, etc.

CS04 - DESIRED WITH UNDESIRED, TWO SIGNAL INTERFERENCE TEST

The intent is for a weak desired signal to be received in the presence of an adjacent CW signal. The desired signal is kept tuned at minimal power level and a strong unmodulated signal is tuned outside the UDF region. Radar and EW receivers without preselectors are likely to experience interference when this test is performed inband. Receivers with nonlinear devices before their passive band pass filter, or filters that degrade out of band, are likely to experience susceptibility problems when this test is performed out of band.

Tests performed inband - An unmodulated CW signal is used. If the receiver is supposed to handle both pulsed and CW signals, this test is performed inband. If the pulse receiver is supposed to desensitize in order to only process pulse signals above the CW level, then only this limited function is tested inband i.e., normally the levels correspond, if a CW signal of -20 dBm is present, then the receiver should process pulse signals greater than -20 dBm.

CS04 TEST PROCEDURE

(1) As shown in Figure 11, initially the pulse signal is tuned to F_0 and the minimum receive level P_0 is recorded, i.e., minimum level where the receive light is constantly on.

(2) The pulse signal is raised to the maximum specified level for full system performance and tuned on either side of F_0 to find the frequencies on both sides (F_{High} and F_{Low}) where the receive light goes out. If a maximum pulse power level is not specified, then +10 dBm peak is used. In some receivers F_L and F_H are the band skirts.

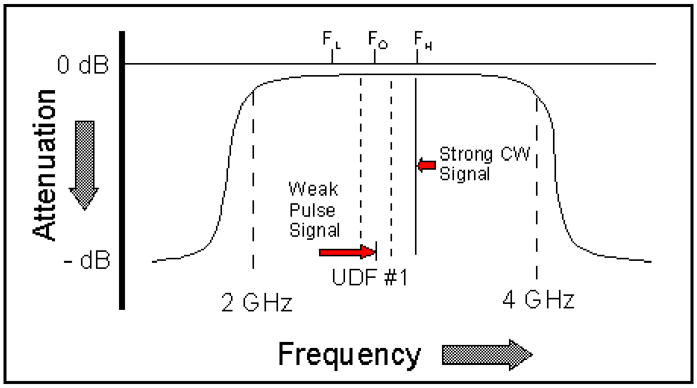

Figure 11. CS04 Test Signals.

(3) The pulse signal is returned to the level found in step 1. A CW signal at the maximum specified CW power level for full system performance is tuned above F_H and below F_L. If a maximum CW power level is not specified, then -10 dBm is used. Anytime the receive light is lost, the tuned CW RF value is recorded. The CW signal should be turned off to verify that the pulse signal can still be received in the absence of

interference. If the pulse signal is still being received, then the interfering CW signal should be reapplied and decreased to the lowest power level where the receive light stays on constantly. Record this level P_1. The interference rejection level is $P_1 - P_0 = P_{IR}$.

(4) Out of band tests should be performed to five times the maximum inband frequency or 20 GHz, whichever is less, and on the low end to IF/5 or 0.05 F_0, whichever is less, unless otherwise specified. The out of band CW power level is -10 dBm unless otherwise specified.

Failures - Out of band test

(1) If a non-linear device such as a limiter is placed before a band pass filter, a strong out of band signal can activate the limiter and cause interference with the inband signal. The solution is to place all non-linear or active devices after a passive band pass filter.

(2) Band pass filters with poor characteristics tend to pass signals with only limited attenuation at frequencies that are three times the center frequency of the band pass filter. Passage of a CW or high duty cycle signal that is out of band may desensitize or interfere with the processing of a weak inband signal.

CS03 INTERMODULATION TEST

This two signal interference test places a pulse signal far enough away (Δf) from the desired UDF frequency (F_0) that it won't be identified. A CW signal is initially placed 2Δf away. If an amplifier is operating in the saturated region, these two signals will mix and produce sum and difference signals. Subsequent mixing will result in a signal at the desired UDF frequency F_0 since $F_1 - (F_2 - F_1) = F_0$. These two signals are raised equally to strong power levels. If no problem occurs, the CW signal is tuned to the upper inband limit and then tuned out of band. A similar test is performed below F_0.

CS03 TEST PROCEDURES

(1) Set the receiver or jammer to the receive mode. Verify it is working at a desired signal frequency, (F_0), and record the minimum signal level i.e., lowest level where the receive light is constantly on (record this level P_0).

(2) The modulated signal is raised to the maximum specified level for full system performance and tuned on either side of F_0 to find the frequency F_1 on both sides where the receive light goes out. If a maximum power level is not specified, +10 dBm peak is used. The difference between F_1 and F_0 is Δf as shown in Figure 12.

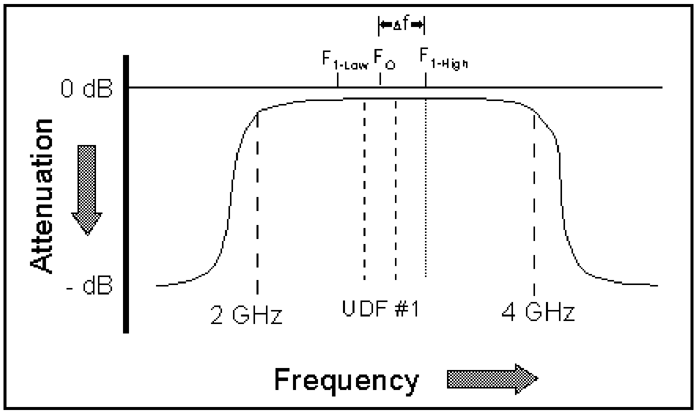

Figure 12. Initial CS03 Test Signal.

(3) As shown in Figure 13, a pulse signal is tuned to F_1 and a CW signal is tuned to F_2 where $F_2 = F_1 + \Delta f$ on the high side. The power level of the two signals is initially set to P_0 and raised together until the maximum specified levels for full system performance are reached. If maximum power levels are not specified, then +10 dBm peak is used for the pulse signal and -10 dBm is used for the CW signal. Whenever the receive light comes on, the two signals should be turned off individually to verify that the failure is due to a combination of the two signals versus (1) a single signal (CS08) type failure or (2) another inband UDF value has been matched. If the failure is due to the two signal operation, then the power level (P_1 and P_2) of F_1 and F_2 should be recorded. If $P_1=P_2$, the intermodulation rejection level is $P_1-P_0=P_{IM}$. If $P_1 \neq P_2$, it is desirable to readjust them to be equal when the receive light just comes on.

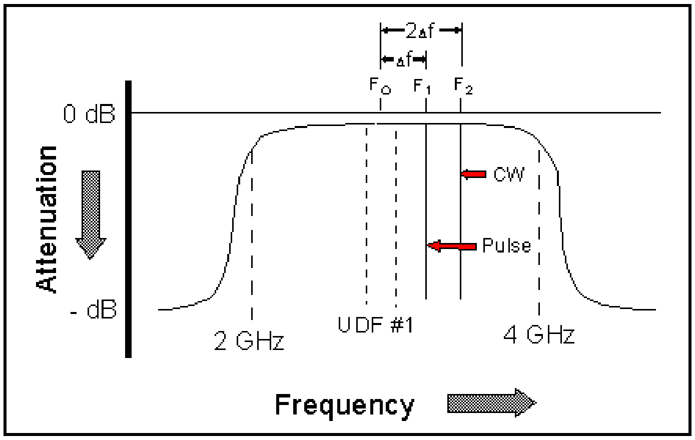

Figure 13. CS03 Testing Signal.

(4) Once the $F_1 + F_2$ signals are raised to the maximum power test levels described in step 3 without a failure, then F_2 is tuned to the upper limit of the band. F_2 should also be tuned out of band to five times the maximum inband frequency or 20 GHz whichever is less unless otherwise specified. The out of band power level is -10 dBm unless otherwise specified. Whenever the receive light comes on, F_2 should be turned off to verify that the failure is due to a two signal test. If it is, turn F_2 back on and equally drop the power levels of F_1 and F_2 to the lowest level where the receive light just comes on. Record the power levels (P_1 and P_2).

(5) Step 3 is repeated where F_1 is Δf below F_0 and $F_2=F_1-\Delta f$. Step 4 is repeated except F_2 is tuned to the lower limit of the band. F_2 should also be tuned out of band down to 0.1 F_0, unless otherwise specified.

(6) Normally if a failure is going to occur it will occur with the initial setting of F_1 and F_2. Care must be taken when performing this test to ensure that the initial placements of F_1 and F_2 do not result in either of the signals being identified directly.

As shown in Figure 14, if F_1 was placed at 3.2 GHz it would be identified directly and if F_2 was placed at 3.4 GHz it would be identified directly. Whereas, if F_1 was at 3.1 GHz and F_2 was at 3.2 GHz neither interfering signal would be identified directly but their intermodulation may result in an improper identification at F_0. Later when F_2 is tuned higher, the receive light will come on around 3.4 GHz and 3.6 GHz. This is not a test failure just a case of another inband UDF value being matched.

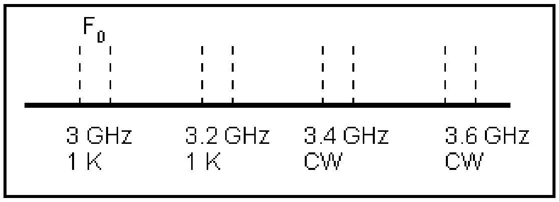

Figure 14. Sample UDF Entries.

CS05 - CROSS MODULATION

This two signal interference test places a weak CW signal where the receiver is programmed for a pulse signal and tunes a strong pulse signal elsewhere. As shown in Figure 15, when an amplifier is saturated, lower level signals are suppressed. When an amplifier is operated in the linear region all signals receive the rated linear gain. In this test the pulse signal will cause the amplifier to kick in and out of saturation and modulate the weak CW signal. The receiver may measure the modulation on the CW signal and incorrectly identify it as a pulse signal.

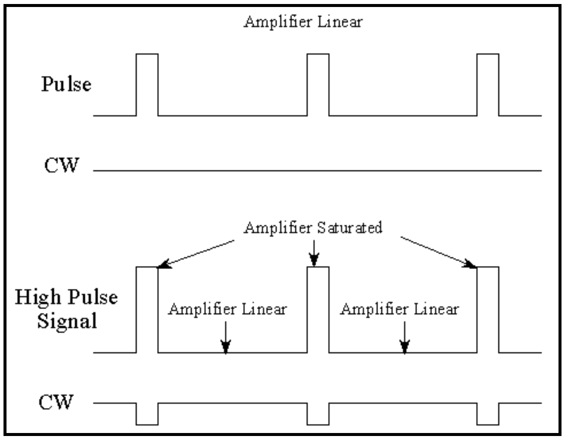
Amplifier Linear
Pulse
CW
Amplifier Saturated
High Pulse Signal
Amplifier Linear
Amplifier Linear
CW

Figure 15. Cross Modulation Example.

CS05 TEST PROCEDURE

(1) Initially the pulse signal is tuned to F_0 and the minimum power level P_0 where the receive light is constantly on is recorded.

(2) As shown in Figure 16, the signal is raised to the maximum specified level for full system performance for a pulse signal and tuned on either side of F_0 to find the frequencies on both sides, (F_{High} and F_{Low}) where the receive light goes out. If a maximum pulse power level is not specified, then +10 dBm peak is used.

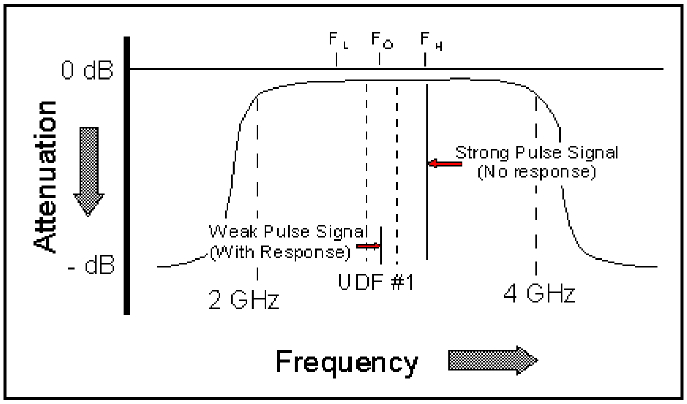
F L
F O
F H
0 dB
Attenuation
- dB
Strong Pulse Signal
(No response)
Weak Pulse Signal
(With Response)
2 GHz
UDF #1
4 GHz
Frequency

Figure 16. Initial CS05 Test Signals.

(3) The pulse signal from step 2 is turned off and a second signal is placed at F_0. It is a CW signal that is 10 dB stronger than the peak power level (P_0) measured is step 1. The receive light should not come on.

(4) As shown in Figure 17, the strong pulse signal of step 2 is turned back on and tuned above F_H and then tuned below F_L. Out of band tests should be performed to the maximum RF of the system + maximum IF or 20 GHz whichever is less and on the low end to the minimum RF of the system minus the maximum IF, unless otherwise specified.

(5) If a receive light occurs, turn off the weak CW signal since the “failure” may be due to the tuned pulsed signal, i.e., a CS08 failure or another inband UDF value has been matched.

If the light extinguishes when the weak CW signal is turned off, then turn the signal back on, reduce the value of the high level pulse signal until the minimum level is reached where the light stays on constantly. Record this level as P_1.

The cross modulation rejection level is P_1-P_0-10 dB = P_{CM}.

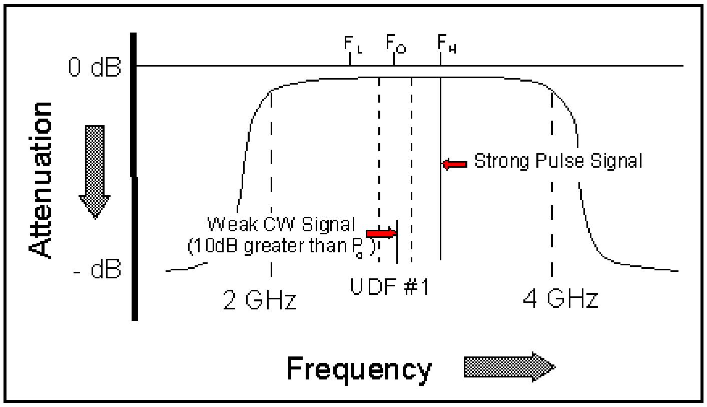
F_L
F_O
F_H
0 dB
Attenuation
Strong Pulse Signal
Weak CW Signal
(10dB greater than P_o)
- dB
2 GHz
UDF #1
4 GHz
Frequency

Figure 17. Final CS05 Test Signals.

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SIGNAL SORTING METHODS and DIRECTION FINDING

As shown in Figure 1, signal processing is basically a problem of signal detection, emitter parameter measurement and correlation, emitter sorting, identification, and operator notification.

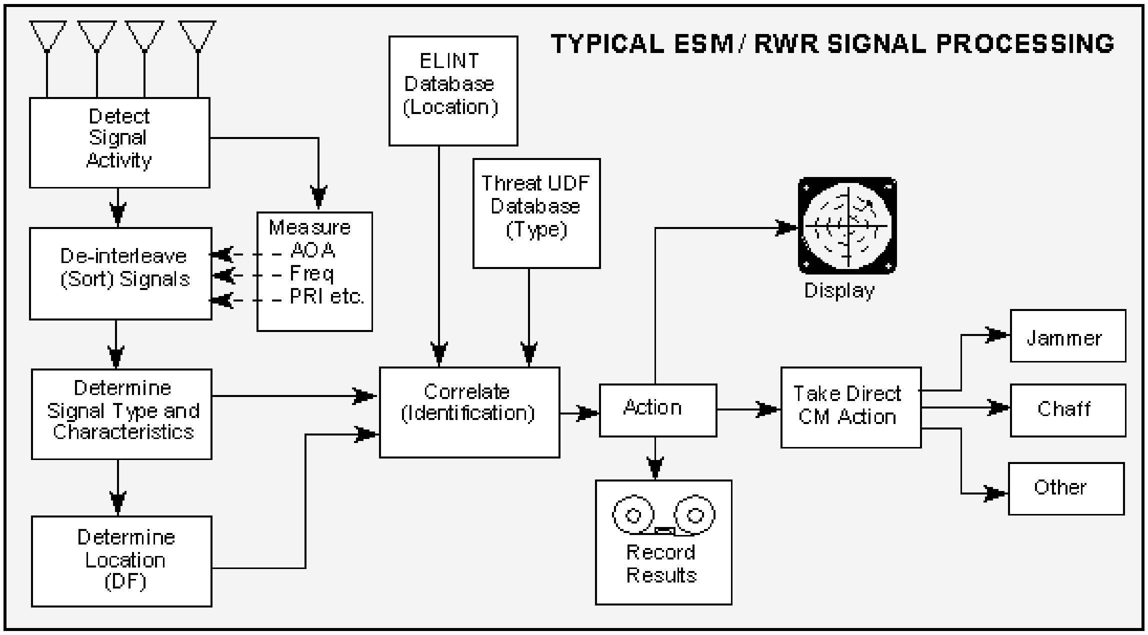
TYPICAL ESM / RWR SIGNAL PROCESSING
Detect Signal Activity
De-interleave (Sort) Signals
Measure
– AOA
– Freq
– PRI etc.
Determine Signal Type and Characteristics
Determine Location (DF)
ELINT Database (Location)
Threat UDF Database (Type)
Correlate (Identification)
Action
Display
Record Results
Take Direct CM Action
Jammer
Chaff
Other

Figure 1. Signal Processing Steps.

The ultimate goal of this processing is to classify radar signals by their unique characteristics and to use this data to identify enemy radars operating in the environment, determine their location or direction, assess their threat to friendly forces, and display this information to the operator.

While not all electronic support measures (ESM) or radar warning receiver (RWR) systems perform every step in this process, each completes some of them. For example, ESM systems seldom initiate direct CM action, while RWRs sometimes do. Also ESM systems frequently record electronic data for future use, but few RWRs do. ESM systems place more emphasis on accurate emitter location and hence direction finding capabilities, while RWRs usually give a rough estimate of position/distance.

The typical emitter characteristics that an ESM system can measure for a pulse radar include the following data:

1. Radio Frequency (RF)
2. Amplitude (power)
3. Direction of Arrival (DOA) - also called Angle of Arrival (AOA)
4. Time of Arrival (TOA)
5. Pulse Repetition Interval (PRI)
6. PRI type
7. Pulse Width (PW)
8. Scan type and rate
9. Lobe duration (beam width)

However, this list is not comprehensive. Other emitter parameters are available which may be necessary to characterize the threat system.

More sophisticated ESM systems can measure additional parameters, such as PRI modulation characteristics, inter- and intra-pulse Frequency Modulation (FM), missile guidance characteristics (e.g., pattern of pulse spacing within a pulse group), and Continuous Wave (CW) signals.

Still other parameters which can describe an electromagnetic wave but are currently not commonly used for identification include polarization and phase. However, as threat emitters begin to use this data more frequently to avoid jamming the more important they may become in identifying signals.

Some of the emitter characteristics which describe an electromagnetic wave are shown in Figure 2.

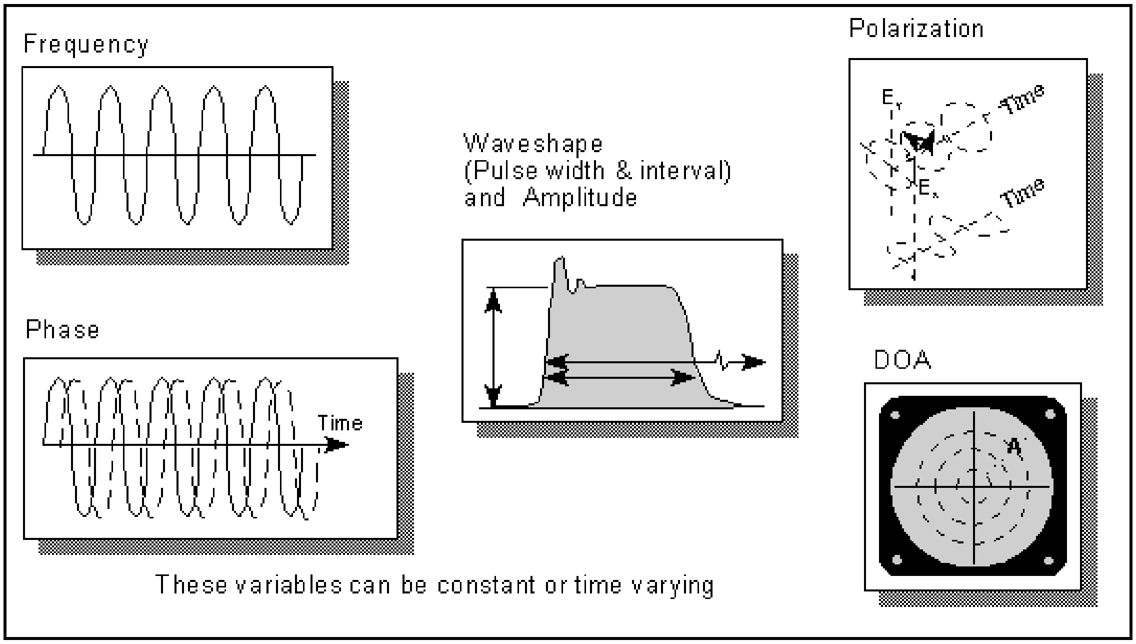
Frequency
Polarization
E_Y
Time
E_X
Time
Waveshape
(Pulse width & interval)
and Amplitude
Phase
Time
DOA
A
These variables can be constant or time varying

Figure 2. Information Content of an Electromagnetic Wave.

Table 1 illustrates the relative importance of several measured parameters during various stages of signal processing.

Table 1. Importance of Emitter Parameters During Signal Processing.

Parameter	Pulse Train De-interleavement	Emitter Identification	Intercept Correlation
Frequency	2	2	2
Amplitude	1	0	1
Angle of Arrival	2	0	2
TOA	0	0	1
PRI	2	2	2
PRI type	2	2	2
PW	2	1	1
Scan rate and type	0	2	1
Lobe Duration	0	1	1
0 Not Useful 1 Some Use 2 Very Useful			

Some emitter parameters can be measured using a single pulse; these parameters are referred to as monopulse parameters. The monopulse parameters include RF, PW, DOA, amplitude and TOA. RF can be determined on a pulse-by-pulse basis by receivers that can measure frequency. Frequency is very useful for emitter identification since most radars operate at a single frequency. Most real-time systems measure pulse width instead of pulse shape because the latter is much more difficult to characterize mathematically. Unfortunately, the apparent pulse width can be severely distorted by reflections, and consequently, its usefulness for emitter identification is limited. DOA cannot be used for emitter identification, but is excellent for sorting signals. A number of ESM systems use both frequency and DOA information to distinguish the new signals from the old (that is, known) ones. Amplitude also cannot be used for emitter identification. However, it can be used for sorting and for gross distance estimation using precompiled emitter's effective radiated power. Moreover, amplitude in conjunction with TOA can be used to determine the emitter's scan characteristics.

Other emitter parameters such as PRI, guidance and scan characteristics can be determined only by analyzing a group of pulses. All these parameters are useful for emitter identification; unfortunately, they require time for data collection and analysis, and call for sophisticated signal processing algorithms.

The problem of signal recognition in real-time is complicated by two factors: modulation of the signals and the very high pulse densities expected in the environment. Complex modulations (for example, inter-pulse RF modulation, intra-pulse RF modulation and agile Pulse Repetition Frequencies (PRFs)) present a significant pattern recognition problem for a number of ESM systems. It is expected that during some missions, hundreds of emitters will be transmitting simultaneously in the same vicinity. Wide-open antenna/receiver combination systems may have to cope with up to a million PPS. Even narrow-band receivers can expect data rates up to 100,000 PPS. At these rates, a single modern computer cannot be expected to process all the pulses, derive the characteristics for all emitters and identify the emitters in real-time. Other factors which encumber signal recognition include missing pulses, atmospheric noise and multiple reflections of pulses.

Present RWRs are designed primarily to cope with stable emitters. A stable emitter is one whose frequency and pulse repetition interval (PRI) remain relatively constant from pulse to pulse. The future threat will move steadily away from the stable emitter towards agile emitters which vary their frequency and PRI characteristics. The first change in this direction is towards the patterned agile emitter which varies its pulse and frequency parameters in accordance with a specific pattern. Examples of patterned agile emitters are MTI radars which use staggered PRFs, pulse Doppler radars which change frequency and PRF on a block-to-block basis, and certain frequency-agile radars whose transmitter frequency is mechanically modulated in a systematic pattern (e.g., spin-tuned magnetron). The next step in this evolution is towards truly agile emitters which change their frequency and PRF in a random manner on a pulse-to-pulse basis. One tempering factor in this evolution is that radars which process Doppler must maintain a constant frequency for at least two consecutive pulses.

In addition to agile frequency and PRI parameters, the future threat will be composed of a number of high-PRF pulsed Doppler, burst-frequency, CW, pulse-compression, agile-beam, and LPI radars, which use pseudo-noise waveforms. This conglomeration of radar types will cause a high signal density which must be segmented into a manageable data stream by the use of both frequency and spatial filtering in the RWR. While frequency and PRI are good parameters for sorting present-day non-agile emitters, they are poor or useless parameters for sorting agile emitters.

Angle of arrival is generally regarded as the best initial sorting parameter because it cannot be varied by the emitter from pulse to pulse.

PASSIVE DIRECTION FINDING AND EMITTER LOCATION

Direction finding (DF) systems provide several important functions in modern EW systems. We have already discussed the importance of measuring the emitter's bearing, or angle of arrival (AOA), as an invariant sorting parameter in the deinterleaving of radar signals and in separating closely spaced communication emitters. In addition, the conservation of jamming power in power-managed ECM systems depends on the ability of the associated ESM system to measure the direction to the victim emitter. A function which is becoming increasingly important in defense suppression and weapon delivery systems involves locating the emitter's position passively. This can be accomplished from a single moving platform through successive measurements of the emitter's angular direction, or from multiple platforms which make simultaneous angular measurements.

The emitter identification function requires identifying and associating consecutive pulses produced by the same emitter in angle of arrival (AOA) and frequency. The AOA is a parameter which a hostile emitter cannot change on a pulse-to-pulse basis. However, to measure the AOA of pulses which overlap in the time domain first requires them to be separated in the frequency domain. The advanced ESM receivers which accomplish this function must operate over several octaves of bandwidth while providing RMS bearing accuracies on the order of at least 2 degrees with high POI and fast reaction time in dense signal environments.

There are basically three methods, depicted in Figure 3, which allow the passive location of stationary ground-based emitters from airborne platforms.

These are:

1. The azimuth triangulation method where the intersection of successive spatially displaced bearing measurements provides the emitter location.

2. The azimuth/elevation location technique, which provides a single-pulse instantaneous emitter location from the intersection of the measured azimuth/elevation line with the earth's surface.

3. The time difference of arrival (TDOA), or precision emitter location system (PELS) method, which measures the difference in time of arrival of a single pulse at three spatially remote locations.

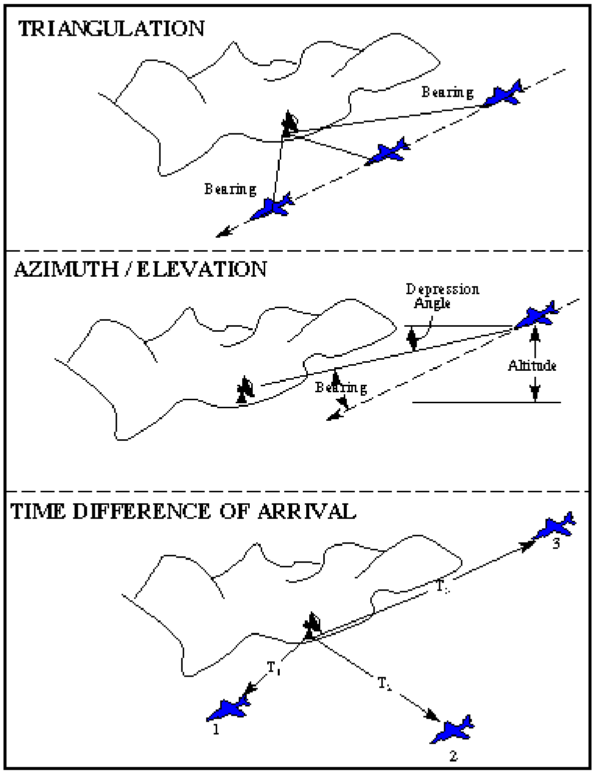

Figure 3. Passive Emitter Location Techniques.

Additional methods include:

1. Phase rate of change, which is similar to triangulation, except it makes calculations using the phase derivative.

2. Angle distance techniques, where the distance from the emitter is derived from the signal strength (with known "threat" characteristics).

3. RF Doppler processing, which measures Doppler changes as the aircraft varies direction with respect to the "target" radar.

The relative advantages and disadvantages of each are given in Table 2.

Table 2. Emitter Location Techniques.

Measurement Technique	Advantages	Disadvantages
Triangulation	Single Aircraft	Non-Instantaneous Location; Inadequate Accuracy for Remote Targeting; Not Forward Looking
Azimuth/Elevation	Single Aircraft Instantaneous Location Possible	Accuracy Degrades Rapidly at Low Altitude; Function of Range
Time Difference of Arrival (Pulsed Signals)	Very High Precision Can Support Weapon Delivery Position Requirements Very Rapid, Can Handle Short On-Time Threat	Very Complex, At Least 3 Aircraft; High Quality Receivers; DME (3 Sites); Very Wideband Data Link; Very High Performance Control Processor; Requires Very High Reliability Subsystems. Requires common time reference and correlation operation for non-pulse signals.

The triangulation method has the advantage of using a single aircraft, and its accuracy is greatest for a long baseline and the broadside geometry. The accuracy degenerates as the aircraft heading line approaches the boresight to the emitter.

The azimuth/elevation technique also has the advantage of using a single aircraft, but suffers from the difficultness of making an accurate elevation measurement with limited vertical aperture and in the presence of multipath effects.

The TDOA technique requires multiple aircraft and is complex, but has high potential accuracy. The determination of the location of the site involves the solution of at least two simultaneous second order equations for the intersection of two hyperbolas which represent $T_2 - T_1$ = Constant #1 and $T_3 - T_2$ = Constant #2. This method can be used to obtain a fix for an emitter which radiates only a single pulse.

ANGLE-OF-ARRIVAL (AOA) MEASUREMENTS

Several of the above DF measurements require AOA determination. Threat AOA measurements are also required to inform the aircrew in order to position the aircraft for optimal defense.

As shown in Figure 4, angle-of-arrival measuring systems fall into three main system categories of:

1. Scanning beam
2. Amplitude comparison or Simultaneous-multiple-beam
3. Phased Interferometer techniques

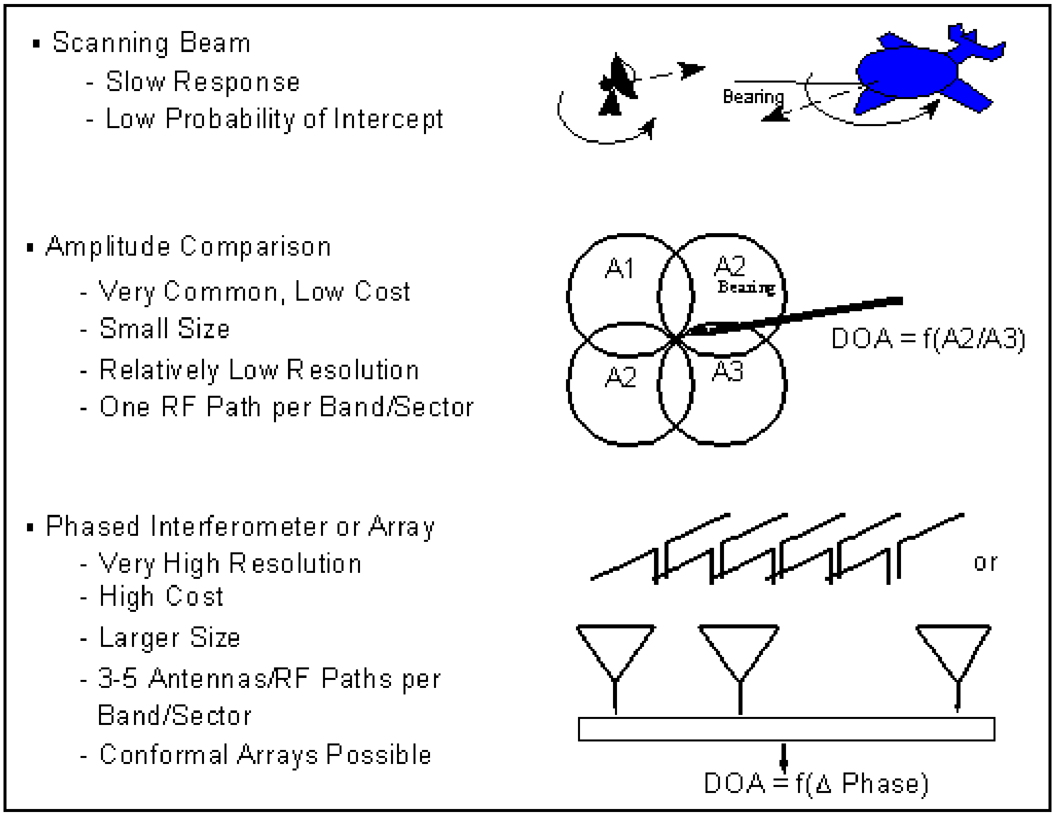

- Scanning Beam
  - Slow Response
  - Low Probability of Intercept
- Amplitude Comparison
  - Very Common, Low Cost
  - Small Size
  - Relatively Low Resolution
  - One RF Path per Band/Sector
- Phased Interferometer or Array
  - Very High Resolution
  - High Cost
  - Larger Size
  - 3-5 Antennas/RF Paths per Band/Sector
  - Conformal Arrays Possible

Figure 4. Angle-of-Arrival Measurement Techniques.

Scanning Beam

The mechanically scanning beam, or "spinner," requires only a single receiver and also exhibits high sensitivity due to the use of a directive antenna. The disadvantage is that the "spinner" usually exhibits slow response because it must rotate through the coverage angle (e.g., 360 degrees) to ensure that it intercepts an emitter. Also, if the emitter uses a scanning directional antenna, both beams must point at each other for maximum sensitivity, which is a low probability occurrence. Both of these effects cause the mechanically scanning beam technique to have a low probability of intercept (POI).

Amplitude Comparison

The two primary techniques used for direction finding are the amplitude-comparison method and the interferometer or phase-comparison method. The phase-comparison method generally has the advantage of greater accuracy, but the amplitude-comparison method is used extensively due to its lower complexity and cost. Regardless of which technique is used, it should be emphasized that the ultimate rms angular accuracy is given by:

$$\Delta\theta = \frac{k\,\theta_B}{\sqrt{SNR}}$$

where θ_B is the antenna's angular beamwidth, or interferometer lobe width, and SNR is the signal-to-noise ratio.

Thus, phase interferometers that typically use very widebeam antennas require high signal-to-noise ratios to achieve accurate angle-of-arrival measurements. Alternately, a multi-element array antenna can be used to provide relatively narrow interferometer lobes, which require modest signal-to-noise ratios.

Virtually all currently deployed radar warning receiving (RWR) systems use amplitude-comparison direction finding (DF). A basic amplitude-comparison receiver derives a ratio, and ultimately angle-of-arrival or bearing, from a pair of independent receiving channels, which utilize squinted antenna elements that are usually equidistantly spaced to provide an instantaneous 360° coverage. Typically, four or six antenna elements and receiver channels are used in such systems, and wideband logarithmic video detectors provide the signals for bearing-angle determination. The monopulse ratio is obtained by subtraction of the detected logarithmic signals, and the bearing is computed from the value of the ratio.

Amplitude comparison RWRs typically use broadband cavity-backed spiral antenna elements whose patterns can be approximated by Gaussian-shaped beams. Gaussian-shaped beams have the property that the logarithmic output ratio slope in dB is linear as a function of angle of arrival. Thus, a digital look-up table can be used to determine the angle directly. However, both the antenna beamwidth and squint angle vary with frequency over the multi-octave bands used in RWRs. Pattern shape variations cause a larger pattern crossover loss for high frequencies and a reduced slope sensitivity at low frequencies. Partial compensation of these effects, including antenna squint, can be implemented using a look-up table if frequency information is available in the RWR. Otherwise, gross compensation can be made, depending upon the RF octave band utilized.

Typical accuracies can be expected to range from 3 to 10 degrees rms for multi-octave frequency band amplitude-comparison systems which cover 360 degrees with four to six antennas.

The four-quadrant amplitude-comparison DF systems employed in RWRs have the advantage of simplicity, reliability, and low cost. Usually, only one antenna per quadrant is employed which covers the 2 to 18 GHz band. The disadvantages are poor accuracy and sensitivity, which result from the broad-beam antennas employed. Both accuracy and sensitivity can be improved by expanding the number of antennas employed. For example, expanding to eight antennas would double the accuracy and provide 3 dB more gain. As the number of antennas increases, it becomes appropriate to consider multiple-beam-forming antennas rather than just increasing the number of individual antennas. The geometry of multiple-beam-forming antennas is such that a conformal installation aboard an aircraft is difficult. Therefore, this type of installation is typically found on naval vessels or ground vehicles where the space is available to accommodate this type of antenna.

Simultaneous-multiple-beam (amplitude comparison)

The simultaneous-multiple-beam system uses an antenna, or several antennas, forming a number of simultaneous beams (e.g., Butler matrix or Rotman lens), thereby retaining the high sensitivity of the scanning antenna approach while providing fast response. However, it requires many parallel receiving channels, each with full frequency coverage. This approach is compatible with amplitude-monopulse angular measuring techniques which are capable of providing high angular accuracy.

A typical example of a multiple-beam antenna is a 16-element circular array developed as part of a digital ESM receiver. This system covers the range from 2 to 18 GHz with two antenna arrays (2 to 7.5 GHz and 7.5 to 18 GHz), has a sensitivity of -55 to -60 dBm and provides an rms bearing accuracy of better than 1.7 degrees on pulsewidths down to 100 ns.

Phased Interferometer Techniques

The term interferometer generally refers to an array type antenna in which large element spacing occurs and grating lobes appear.

Phase interferometer DF systems are utilized when accurate angle-of-arrival information is required. They have the advantage of fast response, but require relatively complex microwave circuitry, which must maintain a precise phase match over a wide frequency band under extreme environmental conditions. When high accuracy is required (on the order of 0.1 to 1°), wide baseline interferometers are utilized with ambiguity resolving circuitry. The basic geometry is depicted in Figure 5, whereby a plane wave arriving at an angle is received by one antenna earlier than the other due to the difference in path length.

The time difference can be expressed as a phase difference:

$$\varphi = \omega\Delta\tau = 2\pi a(f/c) = 2\pi\,(d \sin\theta)/\lambda,$$

where θ is the angle of arrival,
d is the antenna separation, and
λ is the wavelength in compatible units.

The unambiguous field of view (FOV) is given by $\theta = 2\sin^{-1}(\pi/2d)$, which for $\lambda/2$ spacing results in 180° coverage. This spacing must be established for the highest frequency to be received.

Interferometer elements typically use broad antenna beams with beamwidths on the order of 90°. This lack of directivity produces several adverse effects. First, it limits system sensitivity due to the reduced antenna gain. Secondly, it opens the system to interference signals from within the antenna's broad angular coverage. The interference signals often include multipath from strong signals which can limit the accuracy of the interferometer.

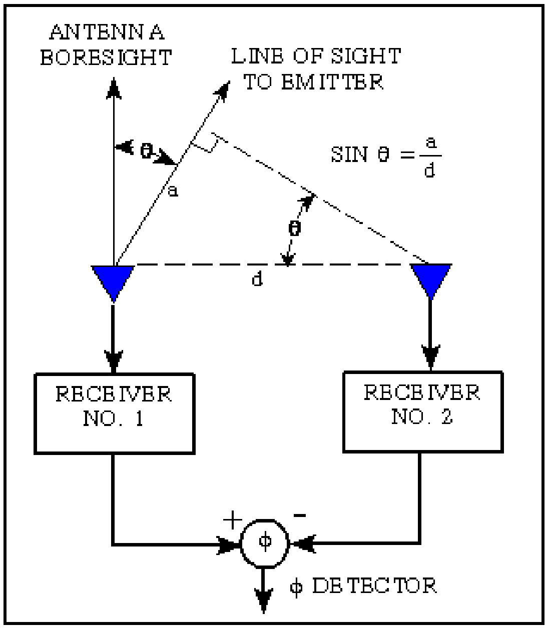

Figure 5. Phase Interferometer Principle.

In an interferometer, the locus of points that produce the same time or phase delay forms a cone. The indicated angle is the true azimuth angle multiplied by the cosine of the elevation angle. The error in assuming the incident angle to be the azimuth angle is negligible for signals near the antenna's boresight. At 45° azimuth and 10° elevation, the error is less than 1°, increasing to 15° for both at 45°. Two orthogonal arrays, one measuring the azimuth angle and the other the elevation angle can eliminate this error. For targets near the horizon, the depression angle is small, thereby requiring only horizontal arrays.

The rms angular accuracy of an interferometer in radians is given by:

$\sigma_\theta = \Delta\alpha\,/\,(\pi \bullet \sqrt{SNR}),$ where $\Delta\alpha = \lambda/(d\cdot\cos\theta)$ is the separation between adjacent nulls.

For a two-element interferometer, the spacing (d) must be $\lambda/2$ or less to provide unambiguous, or single lobe ± 90°, coverage. This, in effect, sets a wide interferometer (or grating) lobe which must be split by a large factor to achieve high accuracy. This, in turn, imposes a requirement for high SNR to achieve the large beam-splitting factor. For example, if 0.1° accuracy is required from an unambiguous two-element interferometer, then a SNR of about 50 dB is required to achieve this accuracy. This may be difficult to achieve considering the inherently low sensitivity of an interferometer system.

When high accuracy is required from an interferometer system, it is usual to employ separations greater than $\lambda/2$. The increased separation sets up a multi-grating-lobe structure through the coverage angle which requires less SNR to achieve a specified accuracy. For example, a two-element interferometer with 16λ spacing would set up a 33-grating-lobe structure (including the central lobe) throughout the ± 90° coverage angle. Within each of the 33 grating lobes, it would only require a SNR on the order of 20 dB to achieve 0.1° accuracy. However, there would be 33 ambiguous regions within the ± 90° angular coverage and also 32 nulls (where the phase detector output is zero), about which the system would be insensitive to an input signal. The ambiguities could be resolved by employing a third antenna element with $\lambda/2$ spacing, which would provide an accuracy on the order of 3° with 20 dB SNR. This accuracy is sufficient to identify which of the 33 lobes contains the signal. Providing coverage in the null regions requires additional antenna elements.

Interferometers employing multiple antenna elements are called multiple-baseline interferometers. In a typical design, the receiver consists of a reference antenna and a series of companion antennas. The spacing between the reference element and the first companion antenna is $\lambda/2$; other secondary elements are placed to form pairs separated by 1, 2, 4, and 8 wavelengths. The initial AOA is measured unambiguously by the shortest-spaced antenna pair. The next greatest spaced pair has a phase rate of change which is twice that of the first, but the information is ambiguous due to there being twice as many lobes as in the preceding pair. A greater phase rate of change permits higher angular accuracy while the ambiguity is resolved by the previous pair. Thus, the described multiple-baseline interferometer provides a binary AOA measurement where each bit of the measurement supplies a more accurate estimate of the emitter's AOA.

Harmonic multiple-baseline interferometers use elements which are spaced at $2^n \cdot \lambda/2$, with $n = 0, 1, 2, 3$. In nonharmonic interferometers, no pair of antennas provides a completely unambiguous reading over the complete field of view. For example, the initial spacing in the nonharmonic interferometer might be λ, while the next companion element spacing is $3\lambda/2$. Ambiguities are resolved by truth tables, and hence the accuracy is set by the spacing of the widest baseline antenna pair. Nonharmonic interferometers have been implemented over 9:1 bandwidths (2 to 18 GHz) with rms accuracies from 0.1 to 1° and with no ambiguities over ± 90°. The principal advantage of the nonharmonic over the harmonic interferometer is the increased bandwidth for unambiguous coverage.

Interferometer DF accuracy is determined by the widest baseline pair. Typical cavity-backed spirals, track to 6 electrical degrees, and associated receivers track to 9°, resulting in an rms total of 11°. At a typical 16 dB SNR, the rms phase noise is approximately 9 electrical degrees. For these errors and an emitter angle of 45°, a spacing of 25λ is required for 0.1° rms accuracy while a spacing of 2.5λ is needed for 1° accuracy. For high accuracy, interferometer spacings of many feet are required. In airborne applications, this usually involves mounting interferometer antennas in the aircraft's wingtips.

The characteristics of typical airborne amplitude comparison and phase interferometer DF systems are summarized in Table 3. The phase interferometer system generally uses superheterodyne receivers which provide the necessary selectivity and sensitivity for precise phase measurements.

Table 3. Direction of Arrival Measurement Techniques.

	Amplitude Comparison	Phase Interferometer
Sensor Configuration	Typically 4 to 6 Equispaced Antenna Elements for 360° Coverage	2 or more RHC or LHC Spirals in Fixed Array
DF Accuracy	$\mathrm{DF}_{\mathrm{ACC}} \approx \frac{\theta_{BW}^{2}\,\Delta C_{dB}}{24S}$ (Gaussian Shape)	$\mathrm{DF}_{\mathrm{ACC}} = \frac{\lambda}{2\pi d\cos\theta}\Delta\theta$
DF Accuracy Improvement	Decrease Antenna BW Decrease Amplitude Mistrack Increase Squint Angle	Increase Spacing of Outer Antennas; Decrease Phase Mistrack
Typical DF Accuracy	3° to 10° rms	0.1° to 3° rms
Sensitivity to Multipath/ Reflections	High Sensitivity Mistrack of Several dB Can Cause Large DF Errors	Relatively Insensitive; Interferometer Can Be Made to Tolerate Large Phase Errors
Platform Constraints	Locate in Reflection Free Area	Reflection Free Area; Real Estate For Array; Prefers Flat Radome
Applicable Receivers	Crystal Video; Channelizer; Acousto-Optic; Compressive; Superheterodyne	Superheterodyne

ΔC_{dB} = Amplitude Monopulse Ratio in dB
S = Squint Angle in degrees
θ_{BW} = Antenna Beamwidth in degrees

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MICROWAVE / RF COMPONENTS

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Voltage Standing Wave Ratio (VSWR) / Reflection Coefficient
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MICROWAVE WAVEGUIDES and COAXIAL CABLE

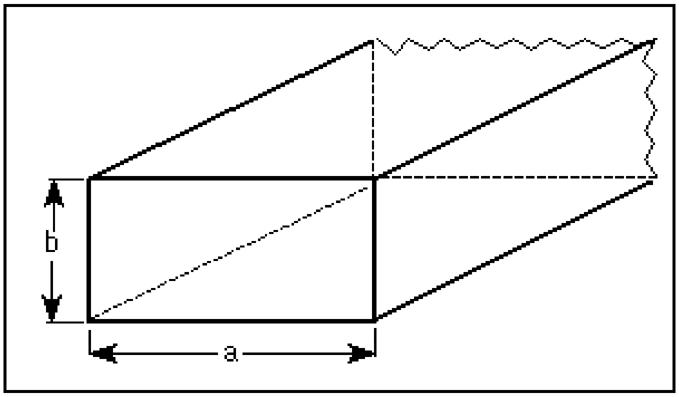

Figure 1. The Rectangular Waveguide.

In general, a waveguide consists of a hollow metallic tube of arbitrary cross section uniform in extent in the direction of propagation. Common waveguide shapes are rectangular, circular, and ridged. The rectangular waveguide has a width a and height b as shown in Figure 1. Commonly used rectangular waveguides have an aspect ratio b/a of approximately 0.5. Such an aspect ratio is used to preclude generation of field variations with height and their attendant unwanted modes. Waveguides are used principally at frequencies in the microwave range; inconveniently large guides would be required to transmit radio-frequency power at longer wavelengths. In the X-Band frequency range of 8.2 to 12.4 GHz, for example, the U.S. standard rectangular waveguide, WR-90, has an inner width of 2.286 cm (0.9 in.) and an inner height of 1.016 cm (0.4 in.).

In waveguides the electric and magnetic fields are confined to the space within the guides. Thus no power is lost to radiation. Since the guides are normally filled with air, dielectric losses are negligible. However, there is some I^2R power lost to heat in the walls of the guides, but this loss is usually very small.

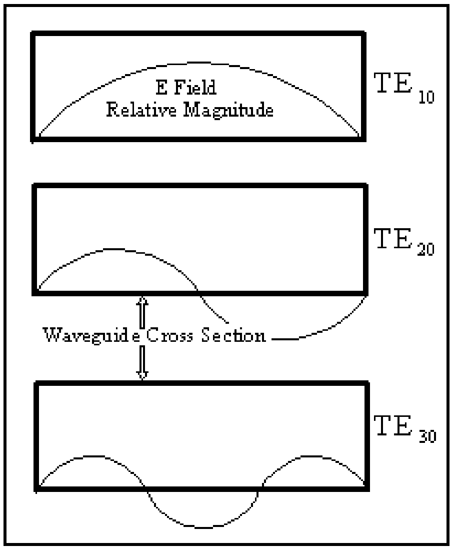

Figure 2. TE Modes.

It is possible to propagate several modes of electromagnetic waves within a waveguide. The physical dimensions of a waveguide determine the cutoff frequency for each mode. If the frequency of the impressed signal is above the cutoff frequency for a given mode, the electromagnetic energy can be transmitted through the guide for that particular mode with minimal attenuation. Otherwise the electromagnetic energy with a frequency below cutoff for that particular mode will be attenuated to a negligible value in a relatively short distance. This grammatical use of cutoff frequency is opposite that used for coaxial cable, where cutoff frequency is for the highest useable frequency. The dominant mode in a particular waveguide is the mode having the lowest cutoff frequency. For rectangular waveguide this is the TE_{10} mode. The TE (transverse electric) signifies that all electric fields are transverse to the direction of propagation and that no longitudinal electric field is present. There is a longitudinal component of magnetic field and for this reason the TE_{mn} waves are also called H_{mn} waves. The TE designation is usually preferred. Figure 2 shows a graphical depiction of the E field variation in a waveguide for the TE_{10}, TE_{20}, and TE_{30} modes. As can be seen, the first index indicates the number of half wave loops across the width of the guide and the second index, the number of loops across the height of the guide - which in this case is zero. It is advisable to choose the dimensions of a guide in such a way that, for a given input signal, only the energy of the dominant mode can be transmitted through the guide. For example, if for a particular frequency, the width of a rectangular guide is too large, then the TE_{20} mode can propagate causing a myriad of problems. For rectangular guides of low aspect ratio the TE_{20} mode is the next higher order mode and is harmonically related to the cutoff frequency of the TE_{10} mode. It is this relationship together with attenuation and propagation considerations that determine the normal operating range of rectangular waveguide.

The discussion on circular waveguides will not be included because they are rarely used in the EW area. Information regarding circular waveguides can be found in numerous textbooks on microwaves.

CHARACTERISTICS OF STANDARD RECTANGULAR WAVEGUIDES

Rectangular waveguides are commonly used for power transmission at microwave frequencies. Their physical dimensions are regulated by the frequency of the signal being transmitted. Table 1 tabulates the characteristics of the standard rectangular waveguides. It may be noted that the number following the EIA prefix "WR" is in inside dimension of the widest part of the waveguide (i.e., WR90 has an inner dimension of 0.90").

DOUBLE RIDGE RECTANGULAR WAVEGUIDE

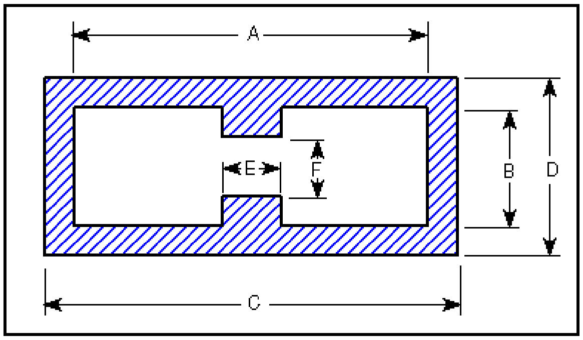

Figure 3. Double Ridge Waveguide.

Another type of waveguide commonly used in EW systems is the double ridge rectangular waveguide. The ridges in this waveguide increase the bandwidth of the guide at the expense of higher attenuation and lower power-handling capability. The bandwidth can easily exceed that of two contiguous standard waveguides. Introduction of the ridges mainly lowers the cutoff frequency of the TE_{10} mode from that of the unloaded guide, which is predicated on width alone. The reason for this can easily be explained when the field configuration in the guide at cutoff is investigated. At cutoff there is no longitudinal propagation down the guide. The waves simply travel back and forth between the side walls of the guide. In fact the guide can be viewed as a composite parallel plate waveguide of infinite width where the width corresponds to the direction of propagation of the normal guide. The TE_{10} mode cutoff occurs where this composite guide has its lowest-order resonant frequency. This occurs when there is only one E field maximum across the guide which occurs at the center for a symmetrical ridge. Because of the reduced height of the guide under the ridge, the effective TE_{10} mode resonator is heavily loaded as though a shunt capacitor were placed across it. The cutoff frequency is thus lowered considerably. For the TE_{20} mode the fields in the center of the guide will be at a minimum. Therefore the loading will have a negligible effect. For guides of proper aspect ratio, ridge height, and ridge width, an exact analysis shows that the TE_{10} mode cutoff can be lowered substantially at the same time the TE_{20} and TE_{30} mode cutoffs are raised slightly. Figure 3 shows a typical double ridged waveguide shape and Table 2 shows double ridged waveguide specifications. In the case of ridged waveguides, in the EIA designation, (WRD350 D36) the first "D" stands for double ridged ("S" for single ridged), the 350 is the starting frequency (3.5 GHz), and the "D36" indicates a bandwidth of 3.6:1. The physical dimensions and characteristics of a WRD350 D24 and WRD350 D36 are radically different. A waveguide with a MIL-W-23351 dash number beginning in 2 (i.e., 2-025) is a double ridge 3.6:1 bandwidth waveguide. Likewise a 1- is a single ridge 3.6:1, a 3- is a single ridge 2.4:1, and a 4- is a double ridge 2.4:1 waveguide.

Figure 4 shows a comparison of the frequency /attenuation characteristics of various waveguides. The attenuation is based on real waveguides which is higher than the theoretical values listed in Tables 1 and 2. Figure 5 shows photographs of waveguides with some common connectors. Figure 6 shows attenuation characteristics of various RF coaxial cables.

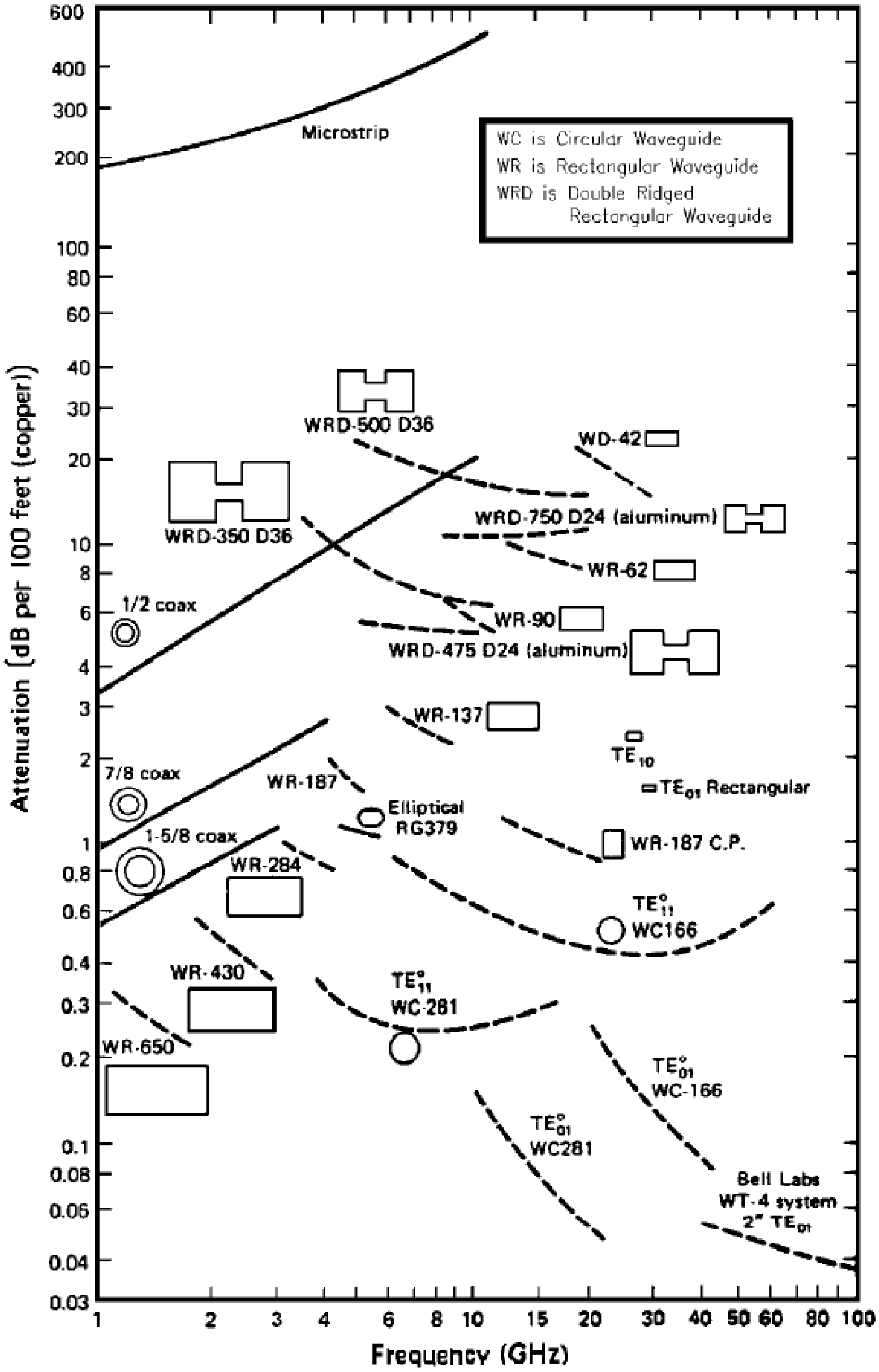

Figure 4. Attenuation vs. Frequency for a Variety of Waveguides and Cables.

Table 1. Rectangular Waveguide Specifications.

Waveguide Size	JAN WG Desig	MIL-W-85 Dash #	Material	Freq Range (GHz)	Freq Cutoff (GHz)	Power (at 1 Atm)		Insertion Loss (dB/100ft)	Dimensions (Inches)	
						CW	Peak		Outside	Wall Thickness
WR284	RG48/U RG75/U	1-039 1-042	Copper Aluminum	2.60 - 3.95	2.08	45 36	7650	.742-.508 1.116-.764	3.000x1.500	0.08
WR229	RG340/U RG341/U	1-045 1-048	Copper Aluminum	3.30 - 4.90	2.577	30 24	5480	.946-.671 1.422-1.009	2.418x1.273	0.064
WR187	RG49/U RG95/U	1-051 1-054	Copper Aluminum	3.95 - 5.85	3.156	18 14.5	3300	1.395-.967 2.097-1.454	1.000x1.000	0.064
WR159	RG343/U RG344/U	1-057 1-060	Copper Aluminum	4.90 - 7.05	3.705	15 12	2790	1.533-1.160 2.334-1.744	1.718x0.923	0.064
WR137	RG50/U RG106/U	1-063 1-066	Copper Aluminum	5.85 - 8.20	4.285	10 8	1980	1.987-1.562 2.955-2.348	1.500x0.750	0.064
WR112	RG51/U RG68/U	1-069 1-072	Copper Aluminum	7.05 - 10.0	5.26	6 4.8	1280	2.776-2.154 4.173-3.238	1.250x0.625	0.064
WR90	RG52/U RG67/U	1-075 1-078	Copper Aluminum	8.2 - 12.4	6.56	3 2.4	760	4.238-2.995 6.506-4.502	1.000x0.500	0.05
WR75	RG346/U RG347/U	1-081 1-084	Copper Aluminum	10.0 - 15.0	7.847	2.8 2.2	620	5.121-3.577 7.698-5.377	0.850x0.475	0.05
WR62	RG91/U RG349/U	1-087 1-091	Copper Aluminum	12.4 - 18.0	9.49	1.8 1.4	460	6.451-4.743 9.700-7.131	0.702x0.391	0.04
WR51	RG352/U RG351/U	1-094 1-098	Copper Aluminum	15.0 - 22.0	11.54	1.2 1	310	8.812-6.384 13.250-9.598	0.590x0.335	0.04
WR42	RG53/U	1-100	Copper	18.0 - 26.5	14.08	0.8	170	13.80-10.13	0.500x0.250	0.04
WR34	RG354/U	1-107	Copper	2.0 - 33.0	17.28	0.6	140	16.86-11.73	0.420x0.250	0.04
WR28	RG271/U	3-007	Copper	26.5 - 40.0	21.1	0.5	100	23.02-15.77	0.360x0.220	0.04

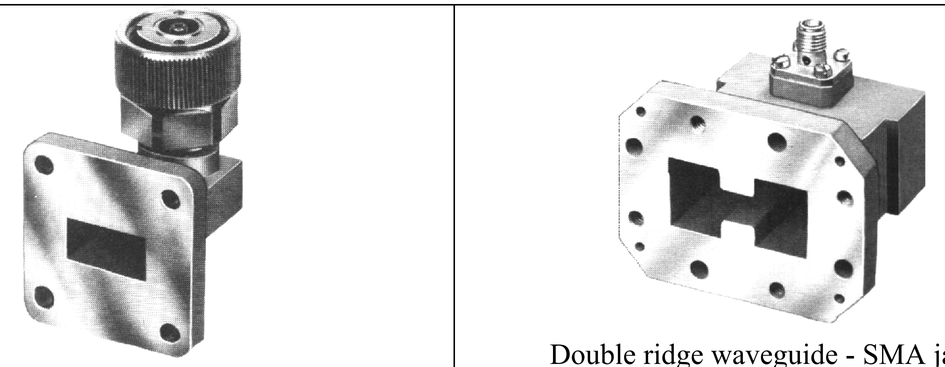

Standard waveguide - 7 mm

Double ridge waveguide - SMA jack

Figure 5. Waveguides With Some Common Connections.

Table 2. Double Ridge Rectangular Waveguide Specifications.

Waveguide Size	MIL-W-23351 Dash #	Material	Freq Range (GHz)	Freq Cutoff (GHz)	Power (at 1 Atm)		Insertion Loss (dB/ft)	Dimensions (Inches)					
					CW	Peak		A	B	C	D	E	F
WRD250		Alum Brass Copper Silver Al	2.60 - 7.80	2.093	24	120	0.025 0.025 0.018 0.019	1.655	0.715	2	1	0.44	0.15
WRD350 D24	4-029 4-303 4-031	Alum Brass Copper	3.50 - 8.20	2.915	18	150	0.0307 0.0303 0.0204	1.48	0.688	1.608	0.816	0.37	0.292
WRD475 D24	4-033 4-034 4-035	Alum Brass Copper	4.75 - 11.00	3.961	8	85	0.0487 0.0481 0.0324	1.09	0.506	1.19	0.606	0.272	0.215
WRD500 D36	2-025 2-026 2-027	Alum Brass Copper	5.00 - 18.00	4.222	4	15	0.146 0.141 0.095	0.752	0.323	0.852	0.423	0.188	0.063
WRD650		Alum Brass Copper	6.50 - 18.00	5.348	4	25	0.106 0.105 0.07	0.720	0.321	0.820	0.421	0.173	0.101
WRD750 D24	4-037 4-038 4-039	Alum Brass Copper	7.50 - 18.00	6.239	4.8	35	0.0964 0.0951 0.0641	0.691	0.321	0.791	0.421	0.173	0.136
WRD110 D24	4-041 4-042 4-043	Alum Brass Copper	11.00 - 26.50	9.363	1.4	15	0.171 0.169 0.144	0.471	0.219	0.551	0.299	0.118	0.093
WRD180 D24	4-045 4-046 4-047	Alum Brass Copper	18.00 - 40.00	14.995	0.8	5	0.358 0.353 0.238	0.288	0.134	0.368	0.214	0.072	0.057

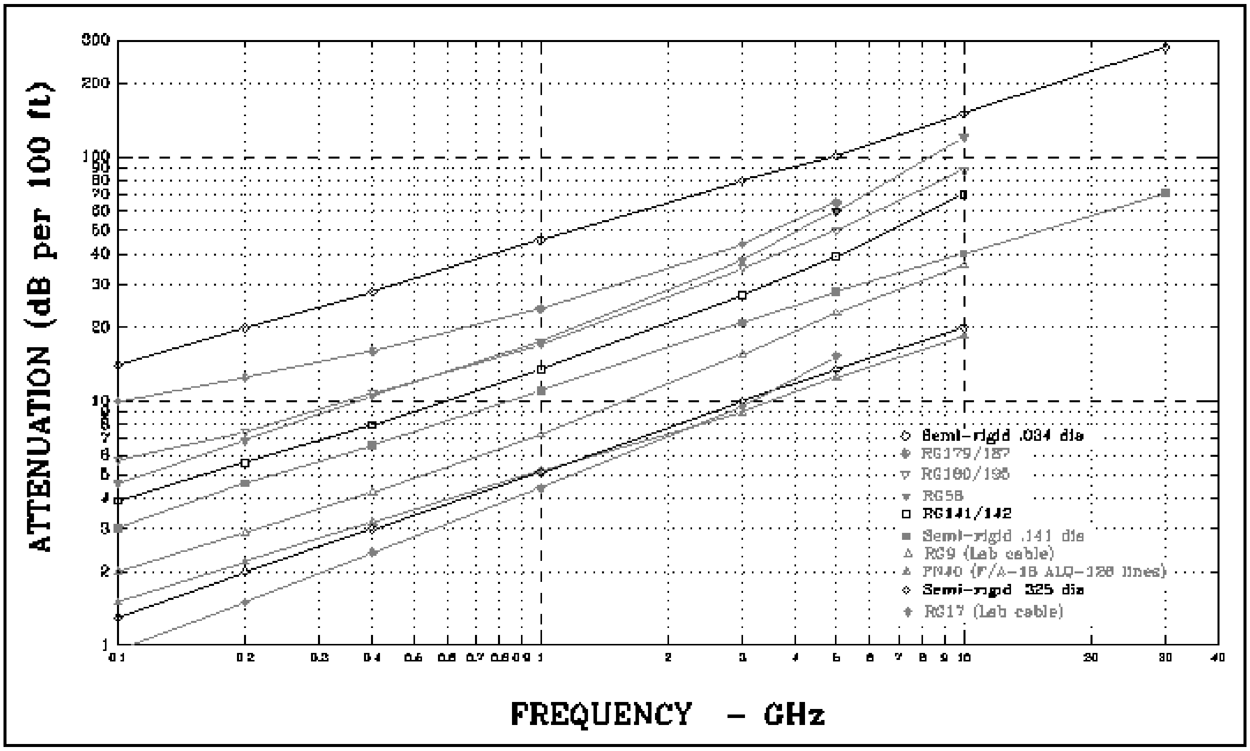

Figure 6. Attenuation vs. Frequency for a Variety of Coaxial Cables.

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VOLTAGE STANDING WAVE RATIO (VSWR) / REFLECTION COEFFICIENT RETURN LOSS / MISMATCH LOSS

When a transmission line is terminated with an impedance, Z_L, that is not equal to the characteristic impedance of the transmission line, Z_O, not all of the incident power is absorbed by the termination. Part of the power is reflected back so that phase addition and subtraction of the incident and reflected waves creates a voltage standing wave pattern on the transmission line. The ratio of the maximum to minimum voltage is known as the Voltage Standing Wave Ratio (VSWR) and successive maxima and minima are spaced by 180° (λ/2).

$$VSWR = \frac{E_{\max}}{E_{\min}} = \frac{E_i + E_r}{E_i - E_r}$$

where E_{max} = maximum voltage on the standing wave
E_{min} = minimum voltage on the standing wave
Ei = incident voltage wave amplitude
Er = reflected voltage wave amplitude

The reflection coefficient, ρ, is defined as E_r/E_i and in general, the termination is complex in value, so that ρ will be a complex number.

Additionally we define: $\Gamma = \frac{Z_L - Z_O}{Z_L + Z_O}$ The refection coefficient, ρ, is the absolute value of the magnitude of Γ. If the equation for VSWR is solved for the reflection coefficient, it is found that:

$$\frac{Reflection}{Coefficient} = \rho = |\Gamma| = \frac{VSWR - 1}{VSWR + 1} \qquad \text{Consequently,} \quad VSWR = \frac{1+\rho}{1-\rho}$$

The return loss is related through the following equations:

$$\frac{Return}{Loss} = 10 \log\left[\frac{P_i}{P_r}\right] = -20 \log\left[\frac{E_r}{E_i}\right] = -20 \log\left[\frac{VSWR - 1}{VSWR + 1}\right] = -20 \log \rho$$

Return loss is a measure in dB of the ratio of power in the incident wave to that in the reflected wave, and as defined above always has a positive value. For example if a load has a Return Loss of 10 dB, then 1/10 of the incident power is reflected. The higher the return loss, the less power is actually lost.

Also of considerable interest is the Mismatch Loss. This is a measure of how much the transmitted power is attenuated due to reflection. It is given by the following equation:

Mismatch Loss = -10 log (1 -ρ^2)

For example, an antenna with a VSWR of 2:1 would have a reflection coefficient of 0.333, a mismatch loss of 0.51 dB, and a return loss of

VSWR	Return Loss (dB)	% Power / Voltage Loss	Reflection Coefficient	Mismatch Loss (dB)
1	∞	0 / 0	0	0.000
1.15	23.1	0.49 / 7.0	0.07	.021
1.25	19.1	1.2 / 11.1	0.111	.054
1.5	14.0	4.0 / 20.0	0.200	.177
1.75	11.3	7.4 / 27.3	0.273	.336
1.9	10.0	9.6 / 31.6	0.316	.458
2.0	9.5	11.1 / 33.3	0.333	.512
2.5	7.4	18.2 / 42.9	0.429	.880
3.0	6.0	25.1 / 50.0	0.500	1.25
3.5	5.1	30.9 / 55.5	0.555	1.6
4.0	4.4	36.3 / 60.0	0.600	1.94
4.5	3.9	40.7 / 63.6	0.636	2.25
5.0	3.5	44.7 / 66.6	0.666	2.55
10	1.7	67.6 / 81.8	0.818	4.81
20	0.87	81.9 / 90.5	0.905	7.4
100	0.17	96.2 / 98.0	0.980	14.1
∞	.000	100 / 100	1.00	∞

* Divide % Voltage loss by 100 to obtain ρ (reflection coefficient)

9.54 dB (11% of your transmitter power is reflected back). In some systems this is not a trivial amount and points to the need for components with low VSWR.

If 1000 watts (60 dBm/ 30 dBW) is applied to this antenna, the return loss would be 9.54 dB. Therefore, 111.1 watts would be reflected and 888.9 watts (59.488 dBm/29.488 dBW) would be transmitted, so the mismatch loss would be 0.512 dB.

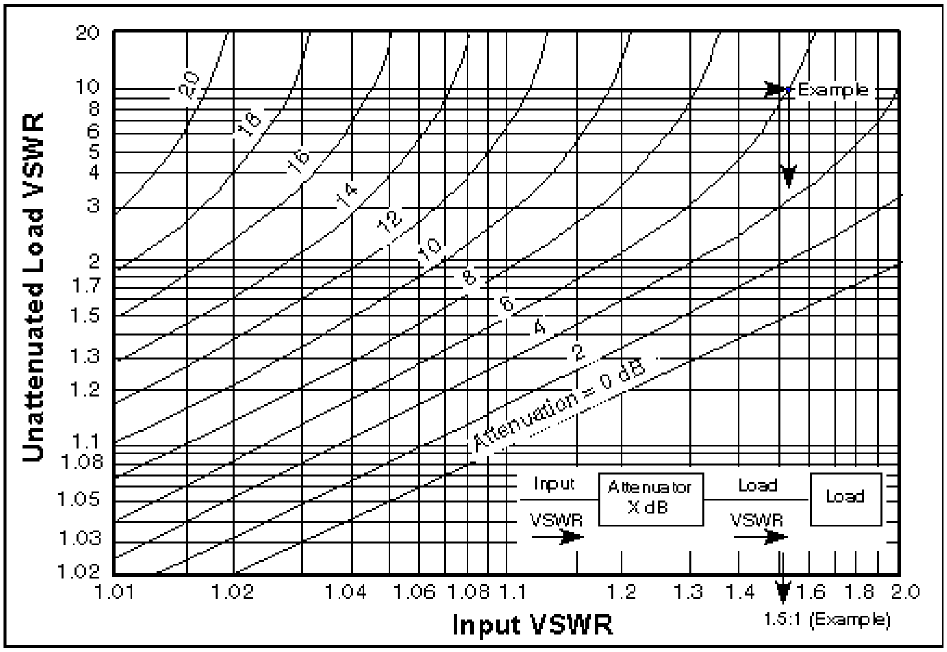

Figure 1. Reduction of VSWR by Attenuation.

Transmission line attenuation improves the VSWR of a load or antenna. For example, a transmitting antenna with a VSWR of 10:1 (poor) and a line loss of 6 dB would measure 1.5:1 (okay) if measured at the transmitter. Figure 1 shows this effect.

Therefore, if you are interested in determining the performance of antennas, the VSWR should always be measured at the antenna connector itself rather than at the output of the transmitter. Transmit cabling will load the line and create an illusion of having a better antenna VSWR. Transmission lines should have their insertion loss (attenuation) measured in lieu of VSWR, but VSWR measurements of transmission lines are still important because connection problems usually show up as VSWR spikes.

Historically VSWR was measured by probing the transmission line. From the ratio of the maximum to minimum voltage, the reflection coefficient and terminating impedance could be calculated. This was a time consuming process since the measurement was at a single frequency and mechanical adjustments had to be made to minimize coupling into circuits. Problems with detector characteristics also made the process less accurate. The modern network analyzer system sweeps very large frequency bandwidths and measures the incident power, P_i, and the reflected power, P_r. Because of the considerable computing power in the network analyzer, the return loss is calculated from the equation given previously, and displayed in real time. Optionally, the VSWR can also be calculated from the return loss and displayed real time.

If a filter is needed on the output of a jammer, it is desirable to place it approximately half way between the jammer and antenna. This may allow the use of a less expensive filter, or a reflective filter vs. an absorptive filter.

Special cases exist when comparing open and shorted circuits. These two conditions result in the same ∞ VSWR and zero dB return loss even though there is a 180° phase difference between the reflection coefficients. These two conditions are used to calibrate a network analyzer.

MICROWAVE COAXIAL CONNECTORS

For high-frequency operation, the average circumference of a coaxial cable must be limited to about one wavelength in order to reduce multimodal propagation and eliminate erratic reflection coefficients, power losses, and signal distortion.

Except for the sexless APC-7 connector, all other connectors are identified as either male (plugs) which have a center conductor that is a probe or female (jacks) which have a center conductor that is a receptacle. Sometimes it is hard to distinguish them as some female jacks may have a hollow center "pin" which appears to be male, yet accepts a smaller male contact.

An adapter is an approximately zero loss interface between two connectors and is called a barrel when both connectors are identical. A number of common of coaxial connectors are described below, however other special purpose connectors exist, including blind mate connectors where spring fingers are used in place of threads to obtain shielding (desired connector shielding should be at least 90 dB).

APC-2.4 (2.4mm) - The 50 Ω APC-2.4 (Amphenol Precision Connector-2.4 mm) is also known as an OS-50 connector. It was designed to operate at extremely high microwave frequencies (up to 50 GHz).	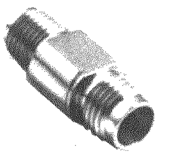 2.4 mm jack - 3.5 mm jack
APC-3.5 (3.5mm) - The APC-3.5 connector provides repeatable connections and has a very low VSWR. Either the male or female end of this 50 Ω connector can mate with the opposite type of SMA connector. The APC-3.5 connector can work at frequencies up to 34 GHz.	
APC-7 (7mm) - The APC-7 was developed by HP, but has been improved and is now manufactured by Amphenol. The connector provides a coupling mechanism without male or female distinction and is the most repeatable connecting device used for very accurate 50 Ω measurement applications. Its VSWR is extremely low up to 18 GHz. Other companies have 7mm series available.	 7mm - 3.5mm plug
BNC (OSB) - The BNC (Bayonet Neill-Concelman or Bayonet Navy Connector) was originally designed for military system applications during World War II. The connector operates best at frequencies up to about 4 GHz; beyond that it tends to radiate electromagnetic energy. The BNC can accept flexible cables with diameters of up to 6.35 mm (0.25 in.) and characteristic impedance of 50 to 75 Ω. It is now the most commonly used connector for frequencies under 1 GHz. Other names the BNC has picked up over the years include: "Baby Neill-Concelman", "Baby N connector", "British Naval Connector", and "Bayonet Nut Connector"	 BNC male plug (above) BNC female jack

C - The C (Concelman) coaxial connector is a medium size, older type constant 50 Ω impedance. It has a bayonet (twist and lock) connection. It is larger than the BNC, but about the same as Type N. It has a frequency range of 0-11 GHz	C Plug (top) 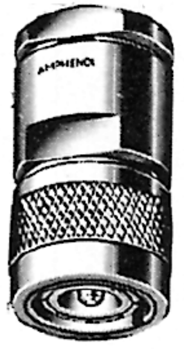 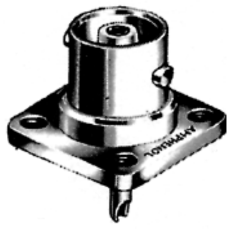 C jack (bottom)
SC (OSSC) - The SC type connector is a screw version of the “C” connector.	
SMA (OSM/3mm) - The SMA (Sub-Miniature A) connector was originally designed by Bendix Scintilla Corporation, but it has been manufactured by the Omni-Spectra division of M/ACOM (as the OSM connector) and many other electronic companies. It is a 50 Ω threaded connector. The main application of SMA connectors is on components for microwave systems. The connector normally has a frequency range to 18 GHz, but high performance varieties can be used to 26.5 GHz.	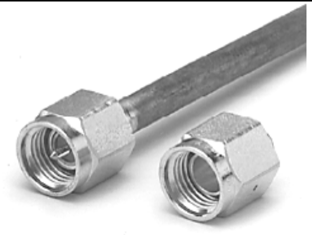 SMA Plug (above) SMA Jack
SSMA (OSSM) - The SSMA is a microminiature version of the SMA. It is also 50 Ω and operates to 26.5 GHz with flexible cable or 40 GHz with semi-rigid cable.	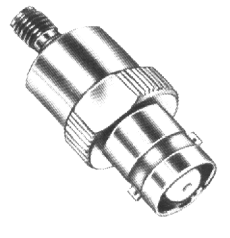 SSMA jack - BNC jack

SMC (OSMC) - The SMC (Sub-Miniature C) is a 50 Ω or 75 Ω connector that is smaller than the SMA. The connector can accept flexible cables with diameters of up to 3.17 mm (0.125 in.) for a frequency range of up to 7-10 GHz.	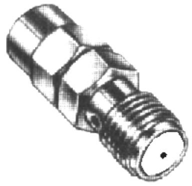 SMC Plug - SMA Jack (Some call this a SMC Jack, even though it has a female connector)
SMB (OSMB) - The SMB is like the SMC except it uses quick disconnect instead of threaded fittings. It is a 50 / 75 Ω connector which operates to 4 GHz with a low reflection coefficient and is useable to 10 GHz.	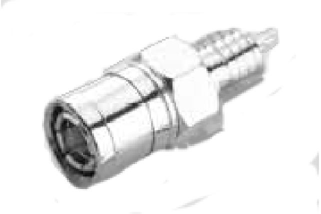 SMB Plug (above) SMB Jack
TNC (OST) - The TNC (Threaded Neill-Concelman or threaded Navy Connector) is merely a threaded BNC. The function of the thread is to stop radiation at higher frequencies, so that the connector can work at frequencies up to 12 GHz (to 18 GHz when using semi-rigid cable). It can be 50 or 75 Ω. For size comparison here is a SMA plug - TNC plug 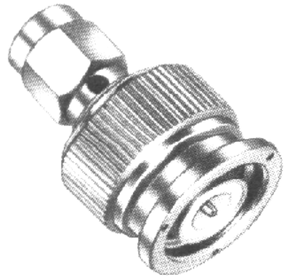	 TNC Plug (above) TNC Jack

Type N (OSN) - The 50 or 75 Ω Type N (Navy) connector was originally designed for military systems during World War II and is the most popular measurement connector for the frequency range of 1 to 11 GHz. The precision 50 Ω APC-N and other manufacturers high frequency versions operate to 18 GHz.

For size comparison here is a picture of Type N plug - TNC jack

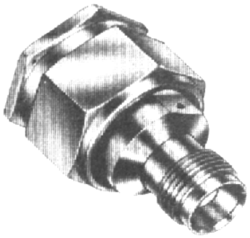

N Plug (above)

N Jack

Note: Always rotate the movable coupling nut of the plug, not the cable or fixed connector, when mating connectors. Since the center pin is stationary with respect to the jack, rotating the jack puts torque on the center pin. With TNC and smaller connectors, the center pin will eventually break off.

An approximate size comparison of these connectors is depicted below (not to scale).

Large ======================= Medium =========================== Small
SC 7mm N TNC/BNC 3.5mm SMA 2.4mm SSMA SMC

Figure 1 shows the frequency range of several connectors.

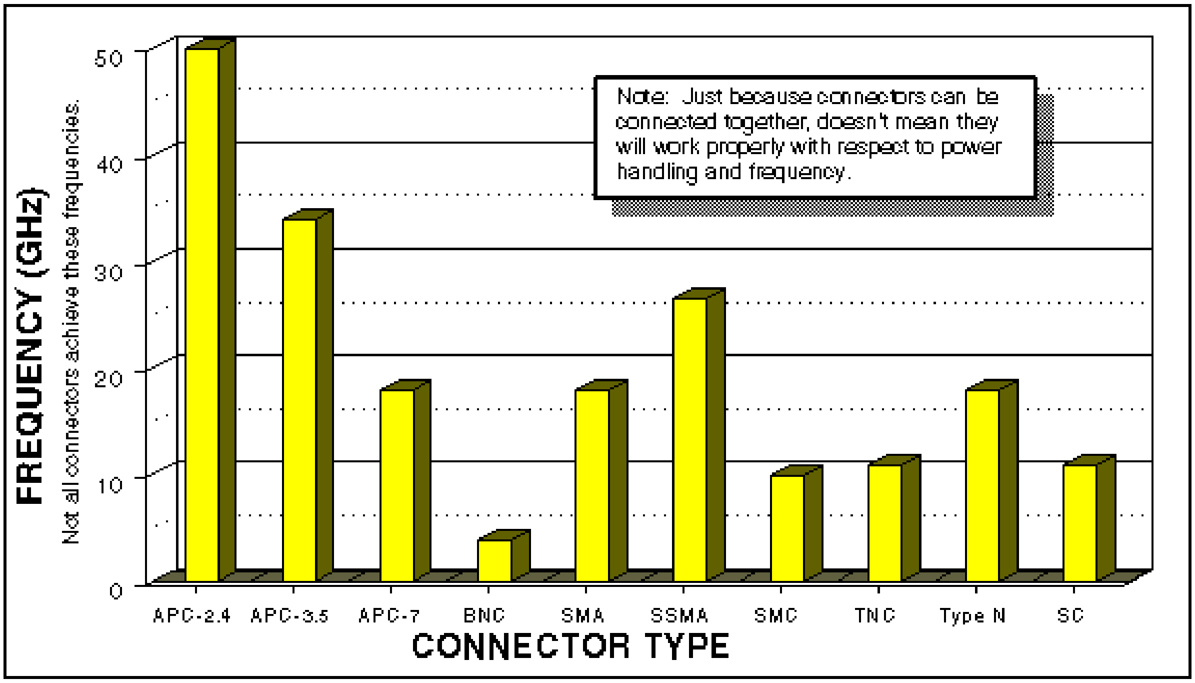

Note: Just because connectors can be connected together, doesn't mean they will work properly with respect to power handling and frequency.

Figure 1. Frequency Range of Microwave Connectors.

POWER DIVIDERS AND DIRECTIONAL COUPLERS

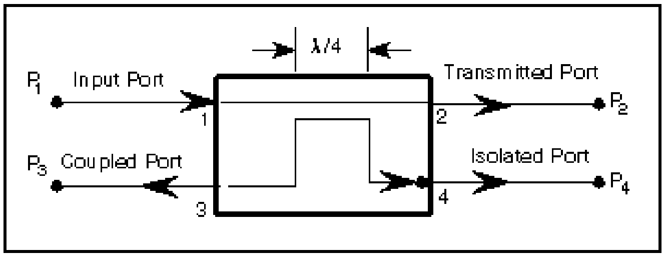

Figure 1. Directional Coupler.

A directional coupler is a passive device which couples part of the transmission power by a known amount out through another port, often by using two transmission lines set close enough together such that energy passing through one is coupled to the other. As shown in Figure 1, the device has four ports: input, transmitted, coupled, and isolated. The term "main line" refers to the section between ports 1 and 2. On some directional couplers, the main line is designed for high power operation (large connectors), while the coupled port may use a small SMA connector. Often the isolated port is terminated with an internal or external matched load (typically 50 ohms). It should be pointed out that since the directional coupler is a linear device, the notations on Figure 1 are arbitrary. Any port can be the input, (as in Figure 3) which will result in the directly connected port being the transmitted port, adjacent port being the coupled port, and the diagonal port being the isolated port.

Physical considerations such as internal load on the isolated port will limit port operation. The coupled output from the directional coupler can be used to obtain the information (i.e., frequency and power level) on the signal without interrupting the main power flow in the system (except for a power reduction - see Figure 2). When the power coupled out to port three is half the input power (i.e., 3 dB below the input power level), the power on the main transmission line is also 3 dB below the input power and equals the coupled power. Such a coupler is referred to as a 90 degree hybrid, hybrid, or 3 dB coupler. The frequency range for coaxial couplers specified by manufacturers is that of the coupling arm. The main arm response is much wider (i.e., if the spec is 2-4 GHz, the main arm could operate at 1 or 5 GHz - see Figure 3). However it should be recognized that the coupled response is periodic with frequency. For example, a λ/4 coupled line coupler will have responses at nλ/4 where n is an odd integer.

Common properties desired for all directional couplers are wide operational bandwidth, high directivity, and a good impedance match at all ports when the other ports are terminated in matched loads. These performance characteristics of hybrid or non-hybrid directional couplers are self-explanatory. Some other general characteristics will be discussed below.

COUPLING FACTOR

The coupling factor is defined as: $\text{Coupling factor (dB)} = -10 \log \frac{P_3}{P_1}$

where P_1 is the input power at port 1 and P3 is the output power from the coupled port (see Figure 1).

The coupling factor represents the primary property of a directional coupler. Coupling is not constant, but varies with frequency. While different designs may reduce the variance, a perfectly flat coupler theoretically cannot be built. Directional couplers are specified in terms of the coupling accuracy at the frequency band center. For example, a 10 dB coupling ± 0.5 dB means that the directional coupler can have 9.5 dB to 10.5 dB coupling at the frequency band center. The accuracy is due to dimensional tolerances that can be held for the spacing of the two coupled lines. Another coupling specification is frequency sensitivity. A larger frequency sensitivity will allow a larger frequency band of operation. Multiple quarter-wavelength coupling sections are used to obtain wide frequency bandwidth directional couplers. Typically this type of directional coupler is designed to a frequency bandwidth ratio and a maximum coupling ripple within the frequency band. For example a typical 2:1 frequency bandwidth coupler design that produces a 10 dB coupling with a ±0.1 dB ripple would, using the previous accuracy specification, be said to have 9.6 ± 0.1 dB to 10.4 ± 0.1 dB of coupling across the frequency range.

LOSS

In an ideal directional coupler, the main line loss port 1 to port 2 (P_1 - P_2) due to power coupled to the coupled output port is:

$$Insertion\ loss\ (dB) = 10 \log \left[1 - \frac{P_3}{P_1} \right]$$

The actual directional coupler loss will be a combination of coupling loss, dielectric loss, conductor loss, and VSWR loss. Depending on the frequency range, coupling loss becomes less significant above 15 dB coupling where the other losses constitute the majority of the total loss. A graph of the theoretical insertion loss (dB) vs. coupling (dB) for a dissipationless coupler is shown in Figure 2.

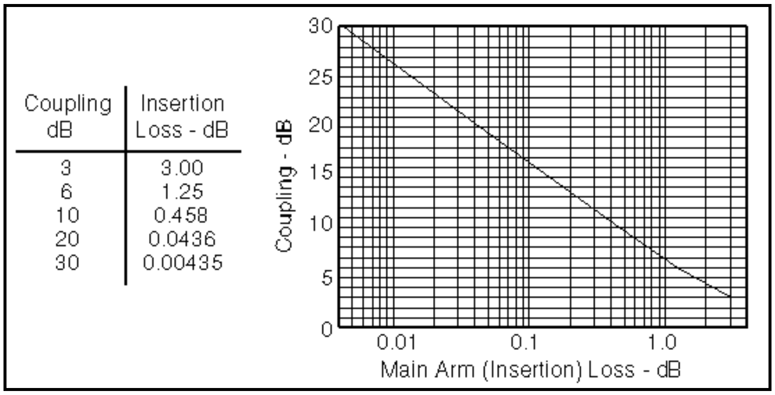

Coupling dB	Insertion Loss - dB
3	3.00
6	1.25
10	0.458
20	0.0436
30	0.00435

Figure 2. Coupling Insertion Loss.

ISOLATION

Isolation of a directional coupler can be defined as the difference in signal levels in dB between the input port and the isolated port when the two output ports are terminated by matched loads, or:

$$Isolation\ (dB) = -10 \log \frac{P_4}{P_1}$$

Isolation can also be defined between the two output ports. In this case, one of the output ports is used as the input; the other is considered the output port while the other two ports (input and isolated) are terminated by matched loads.

Consequently: $$Isolation\ (dB) = -10 \log \frac{P_3}{P_2}$$

The isolation between the input and the isolated ports may be different from the isolation between the two output ports. For example, the isolation between ports 1 and 4 can be 30 dB while the isolation between ports 2 and 3 can be a different value such as 25 dB. If both isolation measurements are not available, they can assumed to be equal. If neither are available, an estimate of the isolation is the coupling plus return loss (see VSWR section). The isolation should be as high as possible. In actual couplers the isolated port is never completely isolated. Some RF power will always be present. Waveguide directional couplers will have the best isolation.

If isolation is high, directional couplers are excellent for combining signals to feed a single line to a receiver for two-tone receiver tests. In Figure 3, one signal enters port P_3 and one enters port P_2, while both exit port P_1. The signal from port P_3 to port P_1 will experience 10 dB of loss, and the signal from port P_2 to port P_1 will have 0.5 dB loss. The internal load on the isolated port will dissipate the signal losses from port P_3 and port P_2. If the isolators in Figure 3 are neglected, the isolation measurement (port P_2 to port P_3) determines the amount of power from the signal generator F_2 that will be injected into the signal generator F_1. As the injection level increases, it may cause modulation of signal generator F_1, or even injection phase locking. Because of the symmetry of the directional coupler, the reverse injection will happen with the same possible modulation problems of signal generator F_2 by F_1. Therefore the isolators are used in Figure 3 to effectively increase the isolation (or directivity) of the directional coupler. Consequently the injection loss will be the isolation of the directional coupler plus the reverse isolation of the isolator.

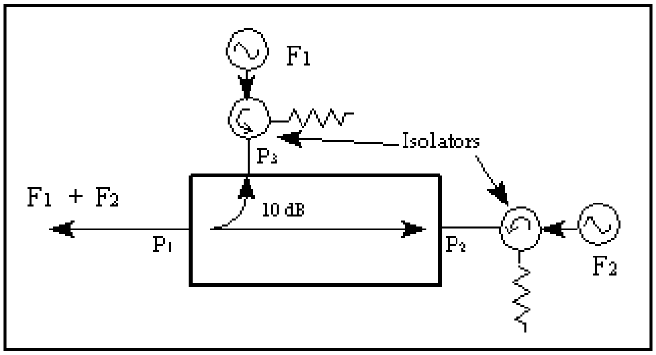

Figure 3. Two-Tone Receiver Tests.

DIRECTIVITY

Directivity is directly related to Isolation. It is defined as:

$$Directivity\,(dB) = -10\log\frac{P_4}{P_3} = -10\log\frac{P_4}{P_1} + 10\log\frac{P_3}{P_1}$$

where: P_3 is the output power from the coupled port and P_4 is the power output from the isolated port.

The directivity should be as high as possible. Waveguide directional couplers will have the best directivity. Directivity is not directly measurable, and is calculated from the isolation and coupling measurements as:

Directivity (dB) = Isolation (dB) - Coupling (dB)

HYBRIDS

The hybrid coupler, or 3 dB directional coupler, in which the two outputs are of equal amplitude takes many forms. Not too long ago the quadrature (90 degree) 3 dB coupler with outputs 90 degrees out of phase was what came to mind when a hybrid coupler was mentioned. Now any matched 4-port with isolated arms and equal power division is called a hybrid or hybrid coupler. Today the characterizing feature is the phase difference of the outputs. If 90 degrees, it is a 90 degree hybrid. If 180 degrees, it is a 180 degree hybrid. Even the Wilkinson power divider which has 0 degrees phase difference is actually a hybrid although the fourth arm is normally imbedded.

Applications of the hybrid include monopulse comparators, mixers, power combiners, dividers, modulators, and phased array radar antenna systems.

AMPLITUDE BALANCE

This terminology defines the power difference in dB between the two output ports of a 3 dB hybrid. In an ideal hybrid circuit, the difference should be 0 dB. However, in a practical device the amplitude balance is frequency dependent and departs from the ideal 0 dB difference.

PHASE BALANCE

The phase difference between the two output ports of a hybrid coupler should be 0, 90, or 180 degrees depending on the type used. However, like amplitude balance, the phase difference is sensitive to the input frequency and typically will vary a few degrees.

The phase properties of a 90 degree hybrid coupler can be used to great advantage in microwave circuits. For example in a balanced microwave amplifier the two input stages are fed through a hybrid coupler. The FET device normally has a very poor match and reflects much of the incident energy. However, since the devices are essentially identical the reflection coefficients from each device are equal. The reflected voltage from the FETs are in phase at the isolated port and are 180° different at the input port. Therefore, all of the reflected power from the FETs goes to the load at the isolated port and no power goes to the input port. This results in a good input match (low VSWR).

If phase matched lines are used for an antenna input to a 180° hybrid coupler as shown in Figure 4, a null will occur directly between the antennas. If you want to receive a signal in that position, you would have to either change the hybrid type or line length. If you want to reject a signal from a given direction, or create the difference pattern for a monopulse radar, this is a good approach.

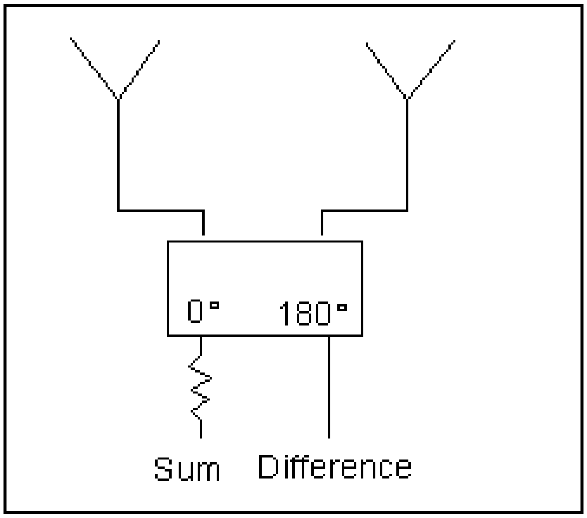

Figure 4. Balanced Antenna Input.

OTHER POWER DIVIDERS

Both in-phase (Wilkinson) and quadrature (90°) hybrid couplers may be used for coherent power divider applications. The Wilkinson's power divider has low VSWR at all ports and high isolation between output ports. The input and output impedances at each port is designed to be equal to the characteristic impedance of the microwave system. A typical power divider is shown in Figure 5. Ideally, input power would be divided equally between the output ports. Dividers are made up of multiple couplers, and like couplers, may be reversed and used as multiplexers. The drawback is that for a four channel multiplexer, the output consists of only 1/4 the power from each, and is relatively inefficient. Lossless multiplexing can only be done with filter networks.

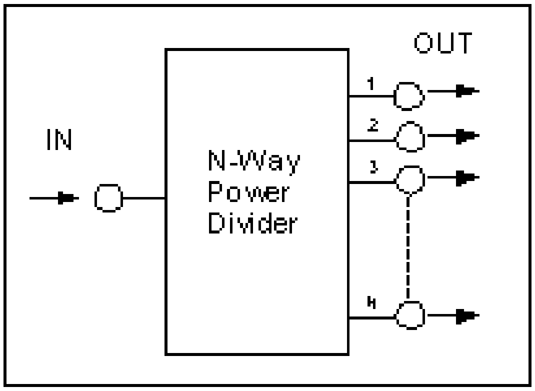

Figure 5. Power Divider.

Coherent power division was first accomplished by means of simple Tee junctions. At microwave frequencies, waveguide tees have two possible forms - the H-Plane or the E-Plane. These two junctions split power equally, but because of the different field configurations at the junction, the electric fields at the output arms are in-phase for the H-Plane tee and are anti-phase for the E-Plane tee. The combination of these two tees to form a hybrid tee allowed the realization of a four-port component which could perform the vector sum (Σ) and difference (Δ) of two coherent microwave signals. This device is known as the magic tee.

POWER COMBINERS

Since hybrid circuits are bi-directional, they can be used to split up a signal to feed multiple low power amplifiers, then recombine to feed a single antenna with high power as shown in Figure 6. This approach allows the use of numerous less expensive and lower power amplifiers in the circuitry instead of a single high power TWT. Yet another approach is to have each solid state amplifier (SSA) feed an antenna and let the power be combined in space or be used to feed a lens which is attached to an antenna. (See Section 3-4.)

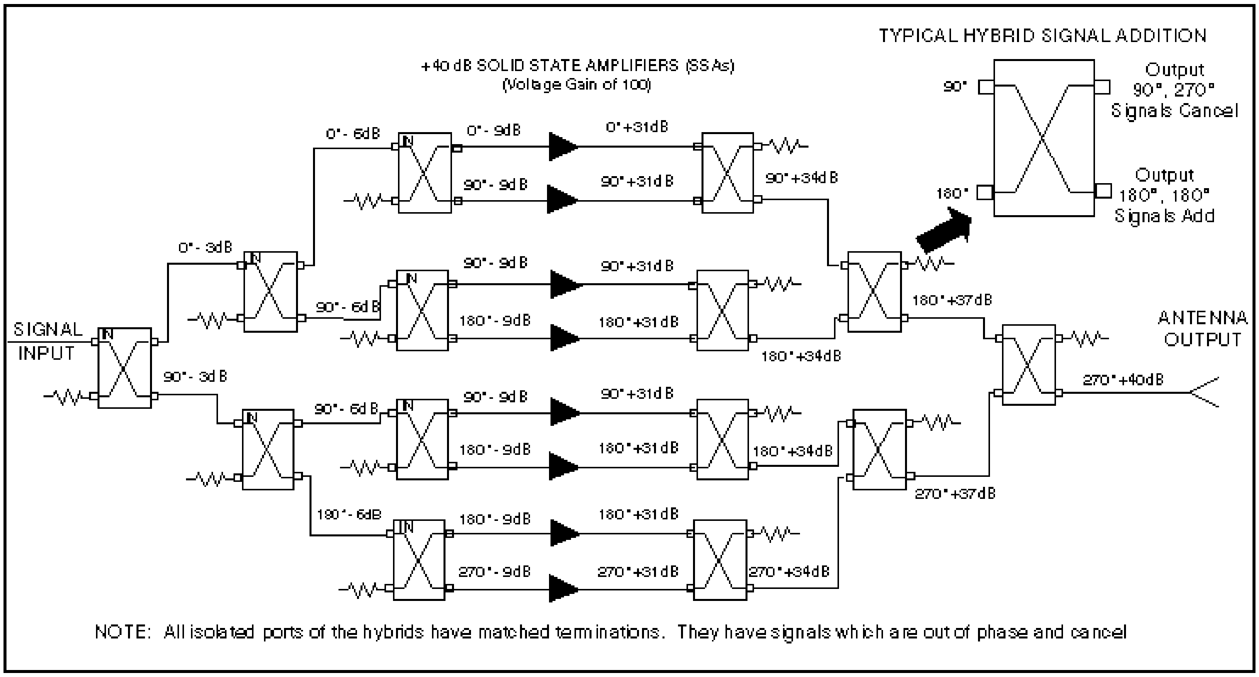
TYPICAL HYBRID SIGNAL ADDITION
+40 dB SOLID STATE AMPLIFIERS (SSAs)
(Voltage Gain of 100)
90°
180°
Output 90°, 270° Signals Cancel
Output 180°, 180° Signals Add
SIGNAL INPUT
IN
0°- 3dB
90°- 3d B
0°- 6dB
90°- 6d B
90°- 6d B
180°- 6dB
0°- 9dB
90°- 9d B
90°- 9d B
180°- 9dB
90°- 9d B
180°- 9dB
180°- 9dB
270°- 9dB
0°+31dB
90°+31d B
90°+31d B
180°+31dB
90°+31d B
180°+31dB
180°+31dB
270°+31dB
90°+34d B
180°+34dB
180°+34dB
270°+34dB
180°+37dB
270°+37dB
270°+40dB
ANTENNA OUTPUT

NOTE: All isolated ports of the hybrids have matched terminations. They have signals which are out of phase and cancel

Figure 6. Combiner Network.

Sample Problem:

If two 1 watt peak unmodulated RF carrier signals at 10 GHz are received, how much peak power could one measure?

A. 0 watts

B. 0.5 watts

C. 1 watt

D. 2 watts

E. All of these

The answer is all of these as shown in Figure 7.

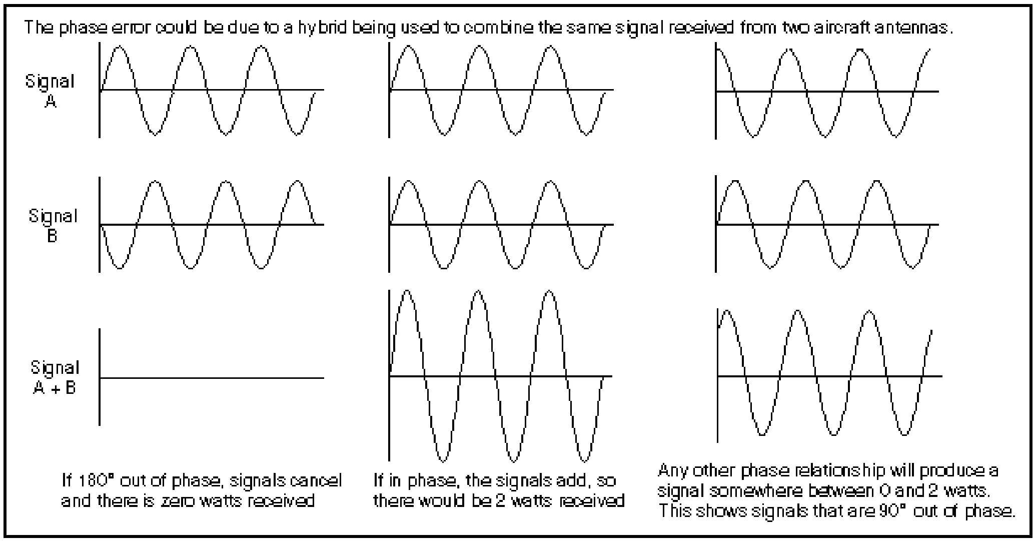
Signal A
Signal B
Signal A + B

The phase error could be due to a hybrid being used to combine the same signal received from two aircraft antennas.

If 180° out of phase, signals cancel and there is zero watts received

If in phase, the signals add, so there would be 2 watts received

Any other phase relationship will produce a signal somewhere between 0 and 2 watts. This shows signals that are 90° out of phase.

Figure 7. Sine Waves Combined Using Various Phase Relationships.

ATTENUATORS / FILTERS / DC BLOCKS

ATTENUATORS

An attenuator is a passive microwave component which, when inserted in the signal path of a system, reduces the signal by a specified amount. They normally possess a low VSWR which makes them ideal for reducing load VSWR in order to reduce measurement uncertainties. They are sometimes used simply to absorb power, either to reduce it to a measurable level, or in the case of receivers to establish an exact level to prevent overload of following stages.

Attenuators are classified as either fixed or variable and either reflective or non-reflective. The fixed and variable attenuators are available in both waveguide and coaxial systems. Most of the receivers under 20 GHz use coaxial type attenuators.

FIXED

The performance characteristics of a fixed attenuator are:

1. input and output impedances
2. flatness with frequency
3. average and peak power handling capability
4. temperature dependence

VARIABLE

The variable attenuator can be subdivided into two kinds: step attenuator and continuously variable attenuator. In a step attenuator, the attenuation is changed in steps such as 10 dB, 1 dB or 0.5 dB. In a continuously variable attenuator, the attenuation is changed continuously and a dial is usually available to read the attenuation either directly or indirectly from a calibration chart.

For a variable attenuator, additional characteristics should be considered, such as:

1. amount or range of attenuations
2. insertion loss in the minimum attenuation position
3. incremental attenuation for step attenuator
4. accuracy of attenuation versus attenuator setting
5. attenuator switching speed and switching noise.

REFLECTIVE

A reflective attenuator reflects some portion of the input power back to the driving source. The amount reflected is a function of the attenuation level. When PIN diodes are zero or reverse biased, they appear as open circuits when shunting a transmission line. This permits most of the RF input power to travel to the RF output. When they are forward biased, they absorb some input, but simultaneously reflect some back to the input port. At high bias current, most RF will be reflected back to the input resulting in a high input VSWR and high attenuation.

ABSORPTIVE

The VSWR of a non-reflective (absorptive) PIN diode attenuator remains good at any attenuation level (bias state). This is accomplished by configuring the diodes in the form of a Pi network that remains matched for any bias state or by use of a 90° hybrid coupler to cancel the waves reflected to the input connector.

MICROWAVE FILTERS

INTRODUCTION

Microwave filters are one of the most important components in receivers. The main functions of the filters are: (1) to reject undesirable signals outside the filter pass band and (2) to separate or combine signals according to their frequency. A good example for the latter application is the channelized receiver in which banks of filters are used to separate input signals. Sometimes filters are also used for impedance matching. Filters are almost always used before and after a mixer to reduce spurious signals due to image frequencies, local oscillator feedthrough, and out-of-frequency band noise and signals. There are many books which are devoted to filter designs. There are many kinds of filters used in microwave receivers, so it is impossible to cover all of them.

If a filter is needed on the output of a jammer, it is desirable to place it approximately half way between the jammer and antenna vs. adjacent to either. The transmission line attenuation improves the VSWR of the filter at the transmitter. This may allow use of a less expensive filter, or use of a reflective filter vs. an absorptive filter.

A filter is a two-port network which will pass and reject signals according to their frequencies. There are four kinds of filters according to their frequency selectivities. In the examples that follow, f_L = low frequency, f_M = medium frequency, and f_H = high frequency. Their names reflect their characteristics, and they are:

1. A low-pass filter which passes the low frequency signals below a predetermined value as shown in Figure 1.

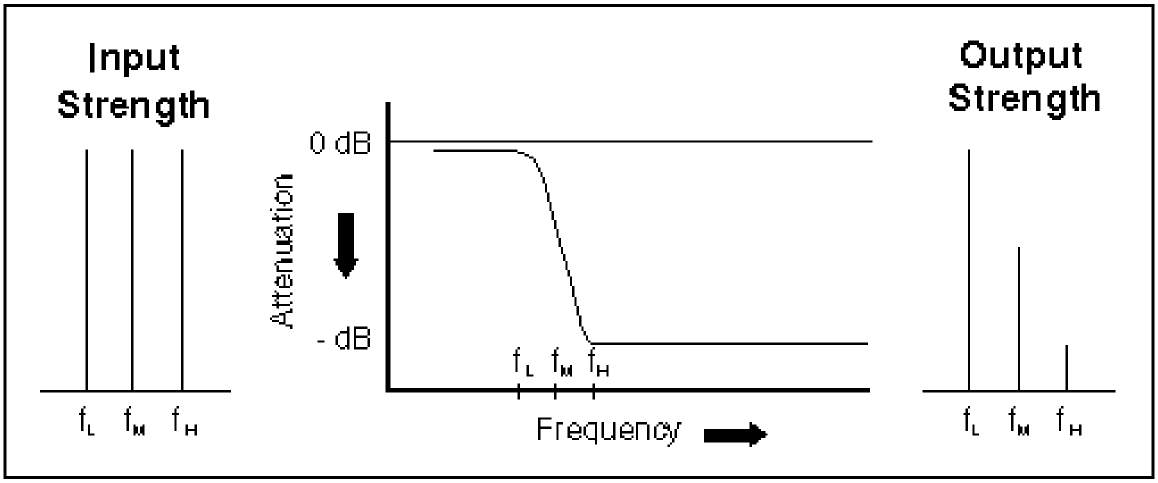

Figure 1. Low-Pass Filter.

2. A high-pass filter which passes the high frequency signals above a predetermined value as in Figure 2.

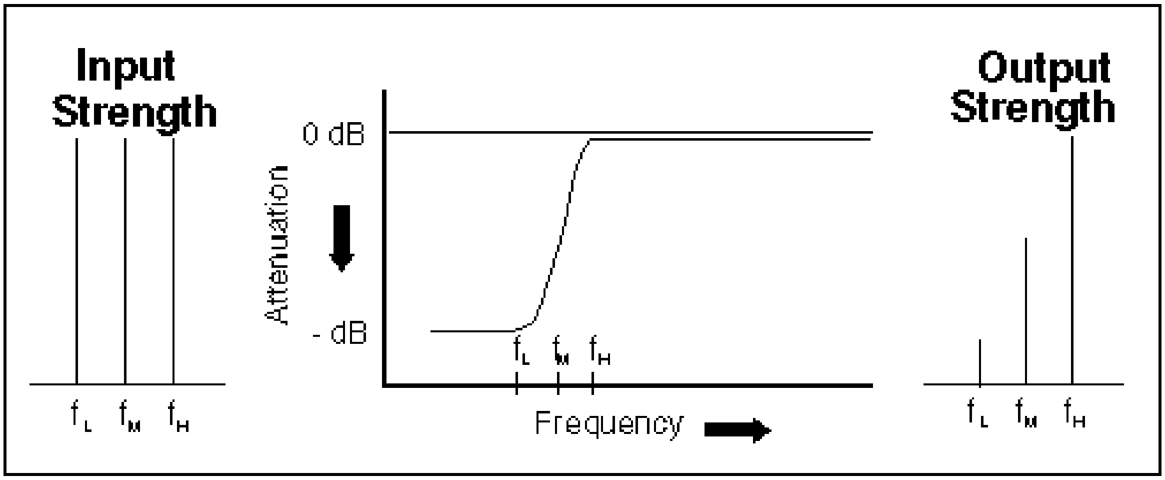
Input Strength
f_L f_M f_H
0 dB
Attenuation
- dB
f_L f_M f_H
Frequency
Output Strength
f_L f_M f_H

Figure 2. High-Pass Filter.

3. A band-pass filter which passes signals between two predetermined frequencies as shown in Figure 3.

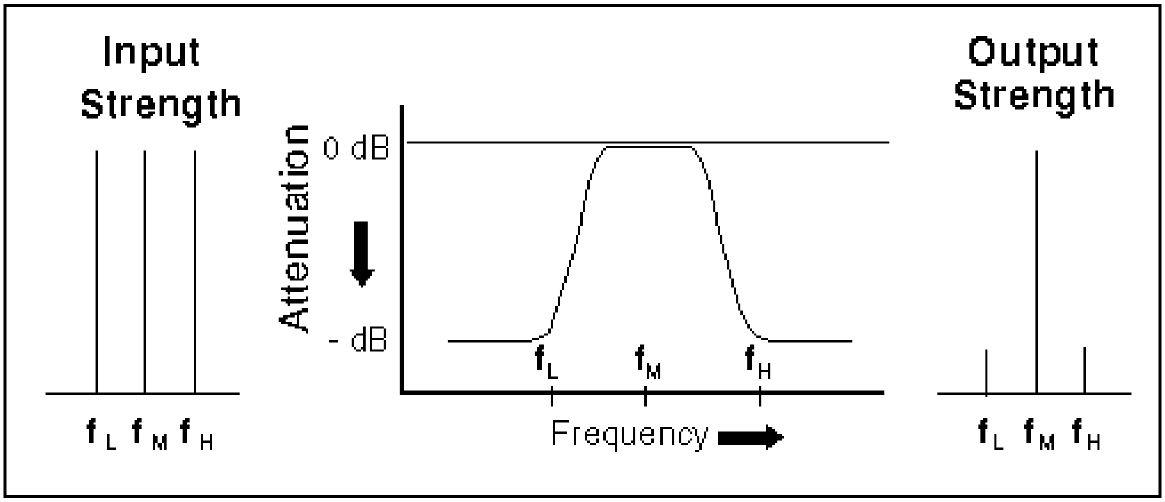
Input Strength
f_L f_M f_H
0 dB
Attenuation
- dB
f_L f_M f_H
Frequency
Output Strength
f_L f_M f_H

Figure 3. Band-Pass Filter.

A band-pass filter with different skirt slopes on the two sides of the pass band is sometimes referred to as an asymmetrical filter. In this filter the sharpness of the rejection band attenuation is significantly different above and below the center frequency. One additional note regarding band-pass filters or filters in general, their performance should always be checked in the out-of-band regions to determine whether or not they possess spurious responses. In particular they should be checked at harmonics of the operating frequency.

4. A band reject filter (sometimes referred to as a bandstop or notch filter) which rejects signals between two predetermined frequencies such as high power signals from the aircraft's own radar as shown in Figure 4.

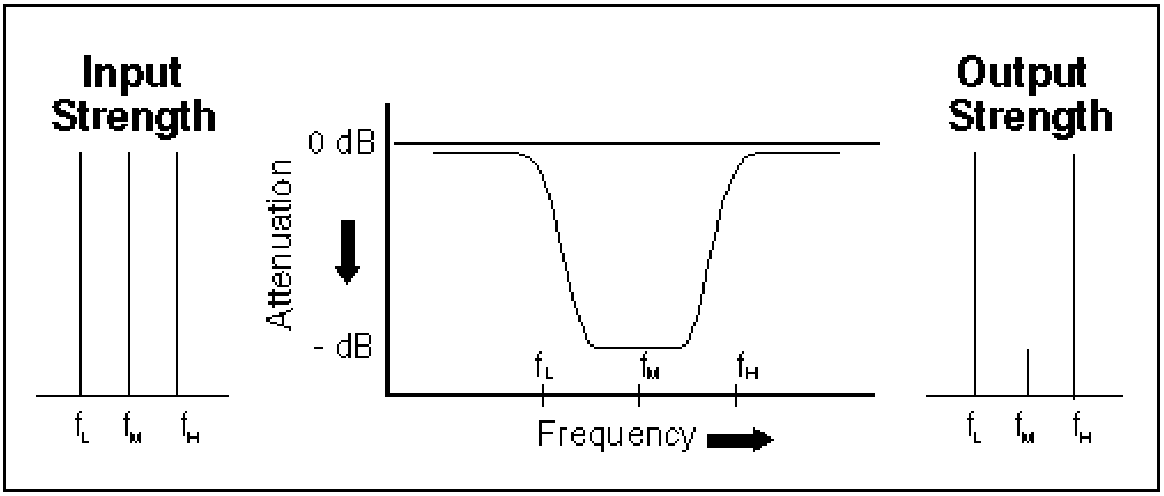

Figure 4. Band-Reject Filter.

In general, filters at microwave frequencies are composed of resonate transmission lines or waveguide cavities that, when combined, reflect the signal power outside the filter frequency pass band and provide a good VSWR and low loss within the frequency pass band. As such, specifications for filters are maximum frequency, pass band loss, VSWR, and rejection level at a frequency outside of the pass band. The trade-offs for filters are a higher rejection for a fixed frequency pass band or a larger frequency pass band for a fixed rejection, which requires a filter with more resonators, which produce higher loss, more complexity, and larger size.

DC BLOCKS

DC Blocks are special connectors which have a capacitor (high pass filter) built into the device. There are three basic types:

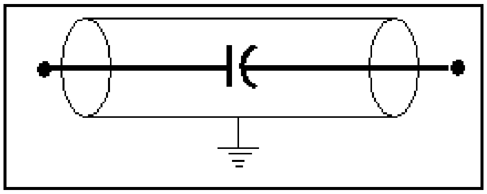

Figure 5. Inside DC Block.

1. INSIDE - The high pass filter is in series with the center conductor as shown in Figure 5. DC is blocked on the center conductor.
2. OUTSIDE - The high pass filter is in series with the cable shield as shown in Figure 6.
3. INSIDE/OUTSIDE - A high pass arrangement is connected to both the inner and outer conductors.

DC Blocks are ideal for filtering DC, 60 Hz, and 400 Hz from the RF line.

In general, capacitors with a large value of capacitance do not have the least loss at microwave frequencies. Also, since capacitance is proportional to size, a large size produces more capacitance with more inductance. Because of these reasons, D.C. blocks are typically available with a high pass frequency band starting in the region of 0.1 to 1 GHz.

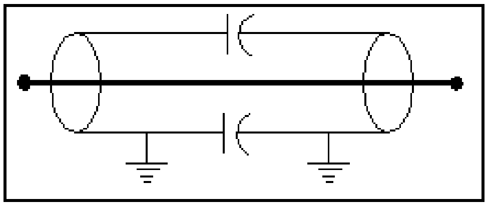

Figure 6. Outside DC Block.

TERMINATIONS / DUMMY LOADS

A termination is a one-port device with an impedance that matches the characteristic impedance of a given transmission line. It is attached to a certain terminal or port of a device to absorb the power transmitted to that terminal or to establish a reference impedance at that terminal. Important parameters of a termination are its VSWR and power handling capacity. In a receiver, terminations are usually placed at various unconnected ports of components such as hybrid and power dividers to keep the VSWR of the signal path low. It is extremely important that the isolated port in a directional coupler and the unused port of a power divider (i.e., only three ports of a four-way power divider are used) be properly terminated. All of the design considerations of directional couplers and power dividers are based on the fact that all ports are terminated with matched loads. If an unused port is not properly terminated, then the isolation between the output ports will be reduced which may severely degrade the performance of the receiver.

A termination is the terminology used to refer to a low power, single terminal device intended to terminate a transmission line. Similar devices designed to accommodate high power are generally termed dummy loads.

TERMINATIONS

Terminations are employed to terminate unconnected ports on devices when measurements are being performed. They are useful as dummy antennas and as terminal loads for impedance measurements of transmission devices such as filters and attenuators.

The resistive elements in most terminations are especially fabricated for use at microwave frequencies. Two types are commonly employed: (1) resistive film elements, and (2) molded resistive tapers. The resistive film is very thin compared to the skin depth and normally very short relative to wavelength at the highest operating frequency. The molded taper consists of a dissipative material evenly dispersed in a properly cured dielectric medium. Both forms of resistive elements provide compact, rugged terminations suitable for the most severe environmental conditions with laboratory stability and accuracy.

Terminations should be properly matched to the characteristic impedance of a transmission line. The termination characteristics of primary concern are:

a. operating frequency range
b. average power handling capability
c. operating temperature range
d. VSWR
e. size
f. weight

Many microwave systems employ directional couplers which require terminations on at least one port, and most have various modes of operation or test where terminations are needed on certain terminals.

A matched termination of a generalized transmission line is ideally represented by an infinite length of that line having small, but non-zero loss per unit length so that all incident energy is absorbed and none is reflected.

Standard mismatches are useful as standards of reflection in calibrating reflectometer setups and other impedance measuring equipment. They are also used during testing to simulate specific mismatches which would be encountered on the terminals of components once the component is installed in the actual system.

The following table shows common mismatches with the impedance that can provide the mismatch.

Common Mismatches (Z_O = 50 Ω)		
Ratio	Z_L (higher)	Z_L (lower)
1.0 : 1	50 Ω (matched)	50 Ω (matched)
1.25 : 1	62.5 Ω	40 Ω
1.50 : 1	75 Ω	33.3 Ω
2.00 : 1	100 Ω	25 Ω

DUMMY LOADS

A dummy load is a high power one port device intended to terminate a transmission line. They are primarily employed to test high power microwave systems at full power capacity. Low power coaxial loads are generally termed terminations and typically handle one watt or less.

Most radars or communications systems have a dummy load integrated into them to provide a non-radiating or EMCON mode of operation, or for testing (maintenance).

Three types of dissipative material are frequently employed in dummy loads: (1) lossy plastic, (2) refractory, and (3) water.

The lossy plastic consists of particles of lossy material suspended in plastic medium. This material may be designed to provide various attenuations per unit length but is limited as to operating temperature. It is employed primarily for low power applications.

The refractory material is a rugged substance that may be operated at temperatures up to 1600°F. It is virtually incapable of being machined by ordinary means but is often fabricated through diamond wheel grinding processes. Otherwise material must be fired in finished form. Such material is employed in most high power applications.

The dissipative properties of water are also employed for dummy load applications. Energy from the guide is coupled through a leaky wall to the water which flows alongside the main guide. Water loads are employed for extremely high power and calorimetric applications.

While dummy loads can operate over full waveguide bands, generally a more economical unit can be manufactured for use over narrower frequency ranges.

The power rating of a dummy load is a complex function dependent upon many parameters, including average and peak power, guide pressure, external temperature, guide size, air flow, and availability of auxiliary coolant. The average and peak powers are interrelated in that the peak power capacity is a function of the operating temperature which in turn is a function of the average power.

CIRCULATORS AND DIPLEXERS

A microwave circulator is a nonreciprocal ferrite device which contains three or more ports. The input from port n will come out at port n + 1 but not out at any other port. A three-port ferrite junction circulator, usually called the Y-junction circulator, is most commonly used. They are available in either rectangular waveguide or strip- line forms. The signal flow in the three-port circulator is assumed as 1→2, 2→3, and 3→1 as shown in Figure 1.

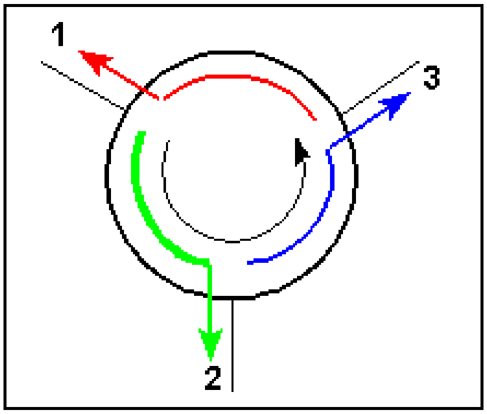

Figure 1. Symbolic Expression for a Y-Junction Circulator.

If port 1 is the input, then the signal will come out of port 2; in an ideal situation, no signal should come out of port 3 which is called the isolated port. The insertion loss of the circulator is the loss from 1 to 2, while the loss from 1 to 3 is referred to as isolation. A typical circulator will have a few tenths of a dB insertion loss from port 1 to 2 and 20 dB of isolation from port 1 to 3 for coaxial circulators (30 dB or more for waveguide circulators). When the input is port 2, the signal will come out of port 3 and port 1 is the isolated port. Similar discussions can be applied to port 3.

Since circulators contain magnets, they should not be mounted near ferrous metals since the close proximity of metals like iron can change the frequency response.

As shown in Figure 2, if one port of a circulator is loaded, it becomes an isolator, i.e., power will pass from ports one to two, but power reflected back from port two will go to the load at port three versus going back to port one.

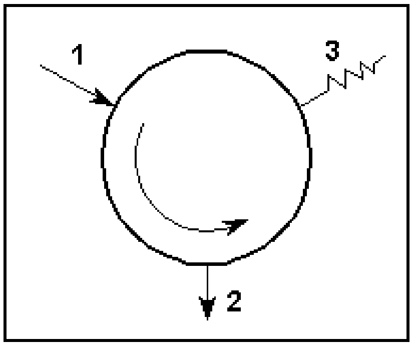

Figure 2. Isolator From A Circulator.

As shown in Figure 3 this circulator is made into a diplexer by adding a high pass filter to port two. Frequencies from port one that are below 10 GHz will be reflected by port two. Frequencies above 10 GHz will pass through port two. At the 10 GHz crossover frequency of the diplexer, a 10 GHz signal will be passed to both ports two and three but will be half power at each port. Diplexers or triplexers (one input and three output bands), must be specifically designed for the application.

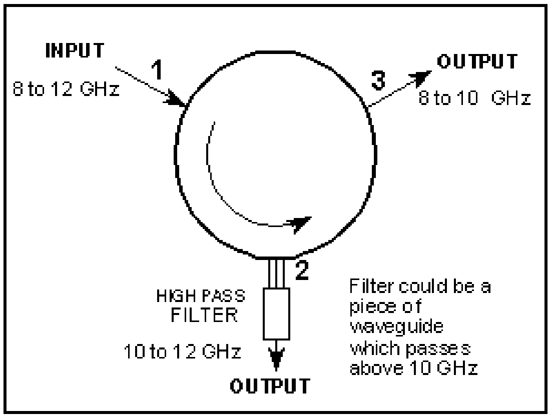

Figure 3. Diplexer From A Circulator.

Another useful device is the 4-port Faraday Rotator Circulator shown symbolically in Figure 4. These waveguide devices handle very high power and provide excellent isolation properties. It is useful when measurements must be made during high power application as shown. A water load is used to absorb the high power reflections so that a reasonable power level is reflected to the receiver or measurement port.

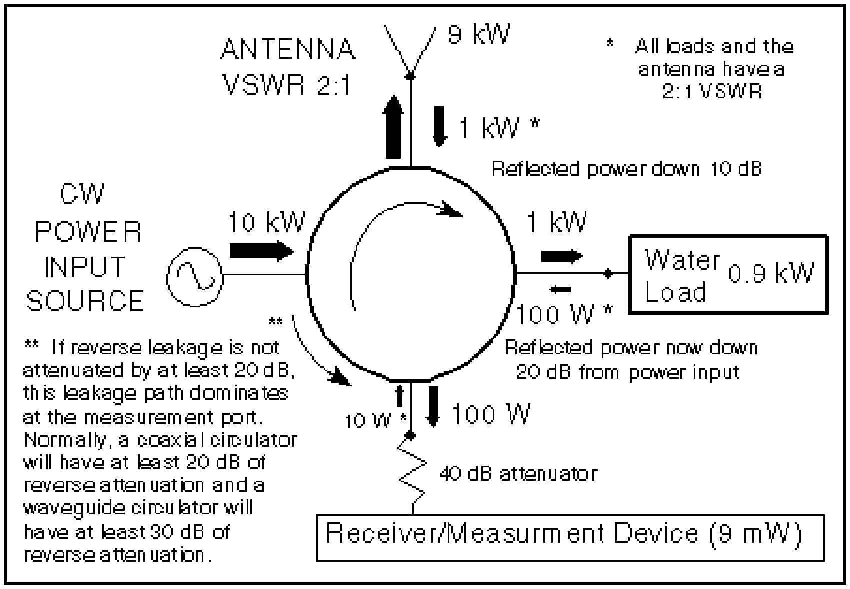
ANTENNA
VSWR 2:1
9 kW
* All loads and the antenna have a 2:1 VSWR
1 kW *
Reflected power down 10 dB
CW POWER INPUT SOURCE
10 kW
1 kW
Water Load
0.9 kW
100 W *
Reflected power now down 20 dB from power input
**
** If reverse leakage is not attenuated by at least 20 dB, this leakage path dominates at the measurement port. Normally, a coaxial circulator will have at least 20 dB of reverse attenuation and a waveguide circulator will have at least 30 dB of reverse attenuation.
10 W *
100 W
40 dB attenuator
Receiver/Measurment Device (9 mW)

Figure 4. Faraday Rotator Circulator.

The Maximum Input Power to a Measurement Device - The ideal input to a measurement device is in the 0 to 10 dBm (1 to 10 mW) range. Check manufacturer's specification for specific maximum value.

If the RF transmission lines and their components (antenna, hybrid, etc.) can support the wider frequency range, circulators could be used to increase the number of interconnecting RF ports from two as shown in Figure 5, to four as shown in Figure 6. Figure 7 shows an alternate configuration using diplexers which could actually be made from circulators as shown previously in Figure 3.

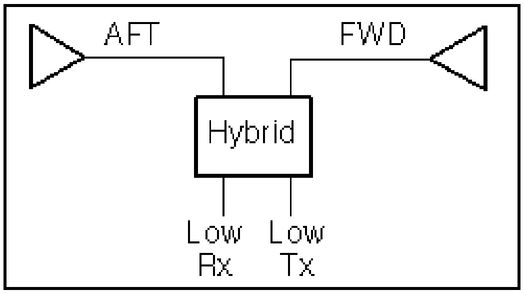
AFT
FWD
Hybrid
Low Rx
Low Tx

Figure 5. Low Band Configuration.

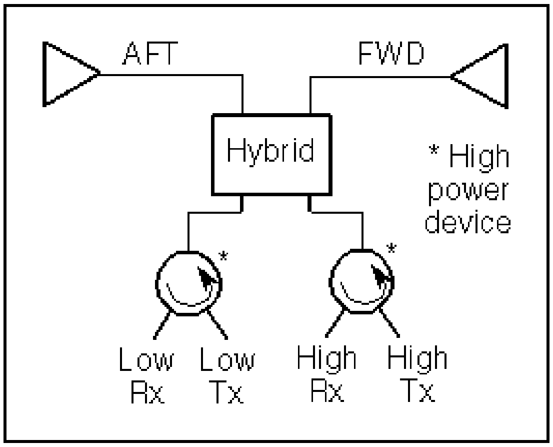
AFT
FWD
Hybrid
* High power device
*
*
Low Rx
Low Tx
High Rx
High Tx

Figure 6. Low/High Band Configuration.

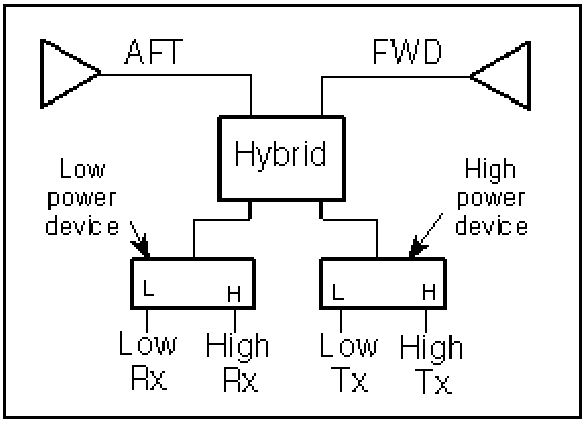
AFT
FWD
Hybrid
Low power device
High power device
L
H
L
H
Low Rx
High Rx
Low Tx
High Tx

Figure 7. Alternate Low/High Band Configuration.

MIXERS AND FREQUENCY DISCRIMINATORS

Mixers are used to convert a signal from one frequency to another. This is done by combining the original RF signal with a local oscillator (LO) signal in a non-linear device such as a Schottky-barrier diode.

The output spectrum includes:

- The original inputs, LO and RF
- All higher order harmonics of LO and RF
- The two primary sidebands, LO ± RF (m,n = 1)
- All higher order products of mLO ± nRF (where m,n are integers)
- A DC output level

The desired output frequency, commonly called the intermediate frequency (IF), can be either the lower (LO-RF) or upper (LO+RF) sideband. When a mixer is used as a down converter, the lower sideband is the sideband of interest.

A microwave balanced mixer makes use of the 3 dB hybrid to divide and recombine the RF and LO inputs to two mixing diodes. The 3 dB hybrid can be either the 90° or 180° type. Each has certain advantages which will be covered later. The critical requirement is that the LO and RF signals be distributed uniformly (balanced) to each mixer diode.

Figure 1 is a typical balanced mixer block diagram. The mixer diodes are reversed relative to each other; the desired frequency (IF) components of each diode are then in-phase while the DC outputs are positive and negative respectively.

The two diode outputs are summed in a tee where the DC terms cancel and only the desired IF component exists at the IF port.

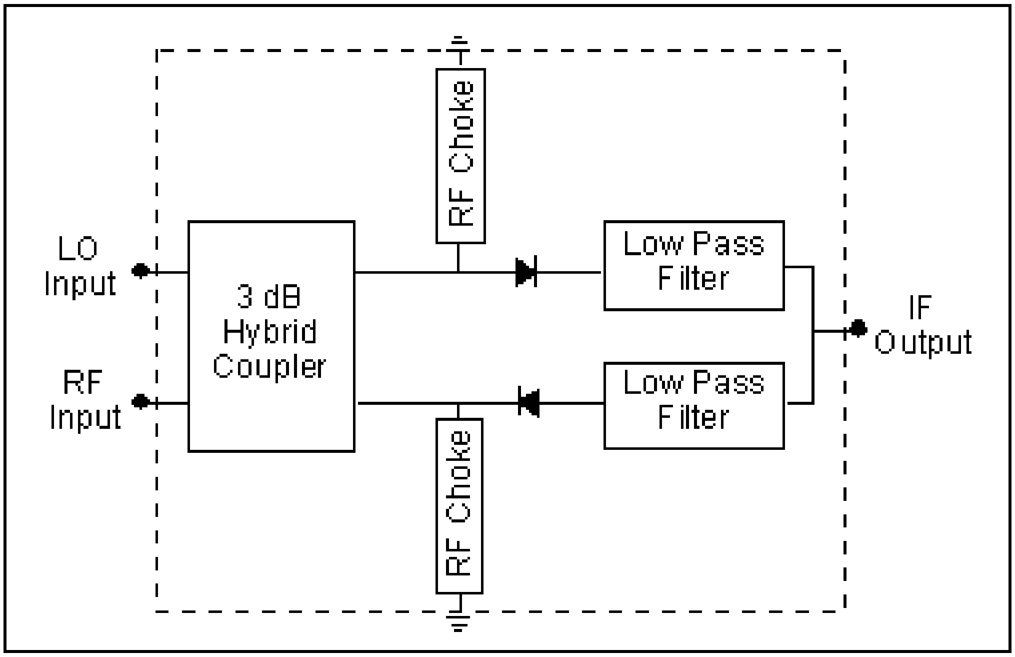

Figure 1. Mixer Block Diagram.

Other types of mixers exist, including the double-balanced mixer, and the Ortho-Quad® (quadrature fed dual) mixer. The relative advantages and disadvantages of each of the four types are summarized in Table 1.

Table 1. Mixer Comparison.

Mixer Type	VSWR [1]	Conversion Loss [2]	LO/RF Isolation [3]	Harmonic Suppression [4]	Dynamic Range	IF Bandwidth
90° Hybrid	good	lowest	poor	poor-fair	high	wide
180° Hybrid	poor	low	good	good	high	wide
Double-Balanced	poor	low	Very good -excellent	very good	high	extremely wide
Ortho Quad	good	low	very good	fair	high	wide

NOTES:
(1) Poor = 2.5:1 typical; Good = 1.3:1 typical
(2) Conversion loss: lowest: 5-7 dB typical; Low 7-9 dB typical
(3) Poor: 10 dB typical; Good: 20 dB typical; Very Good: 25-30 dB typical; Excellent: 35-40 dB typical
(4) Poor: partial rejection of LO/RF even harmonics
Fair: slightly better
Good: can reject all LO even harmonics
Very Good: can reject all LO and RF even harmonics

Used in various circuits, mixers can act as modulators, phase detectors, and frequency discriminators.

The phase discriminators can serve as a signal processing network for systems designed to monitor bearing, polarization, and frequency of AM or FM radiated signals.

A frequency discriminator uses a phase discriminator and adds a power divider and delay line at the RF input as shown in Figure 2. The unknown RF signal "A" is divided between a reference and delay path. The differential delay (T) creates a phase difference (θ) between the two signals which is a linear function of frequency (f) and is given by $\theta = 2\pi fT$.

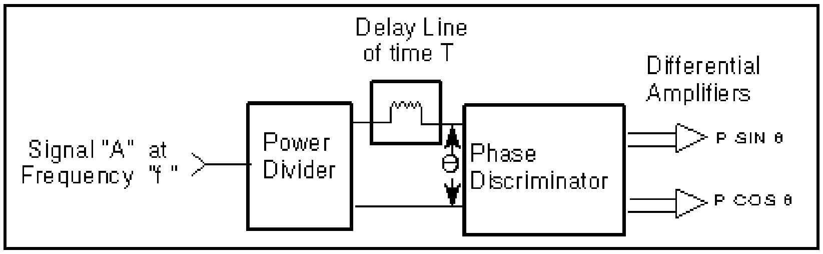

Figure 2. Frequency Discriminator.

When the two output signals are fed to the horizontal and vertical input of an oscilloscope, the resultant display angle will be a direct function of frequency.

DETECTORS

A detector is used in receiver circuits to recognize the presence of signals. Typically a diode or similar device is used as a detector. Since this type of detector is unable to distinguish frequency, they may be preceded by a narrow band-pass filter.

A typical simplistic circuit is shown in Figure 1.

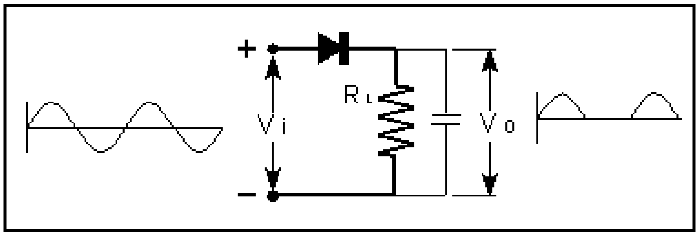

Figure 1. Typical Diode Detector Circuit.

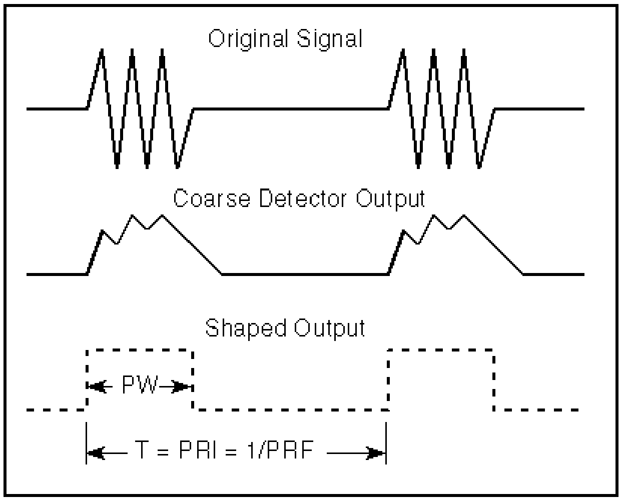

Figure 2. Demodulated Envelope Output.

To integrate a pulse radar signal, we can add capacitance to the circuit in parallel with the output load R_L to store energy and decrease the bleed rate. Figure 2 shows a typical input/output waveform which detects the envelope of the pulse radar signal. From this information pulse width and PRF characteristics can be determined for the RWR UDF comparison.

When the diode is reverse biased, very little current passes through unless the reverse breakdown voltage is exceeded. When forward biased and after exceeding the cut-in voltage, the diode begins to conduct as shown in Figure 3. At low voltages, it first operates in a square law region. Detectors operating in this region are known as small signal type. If the voltage is higher, the detector operates in a linear region, and is known as the large signal type.

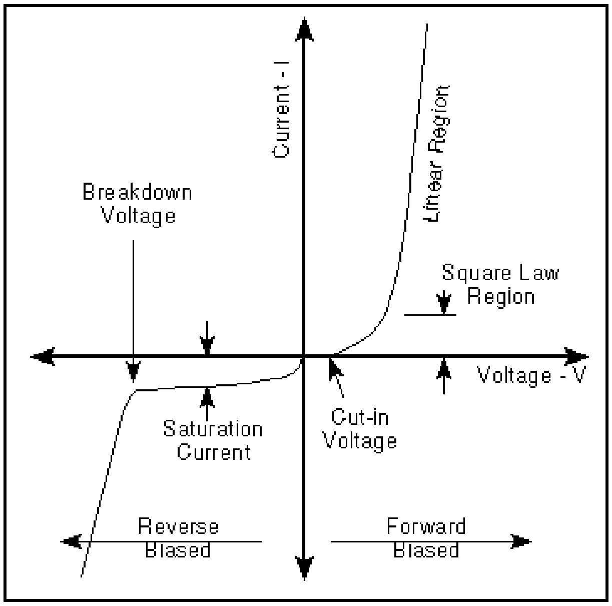

Figure 3. Diode Electrical Characteristics.

The power/voltage characteristics for a typical diode detector is shown in Figure 4.

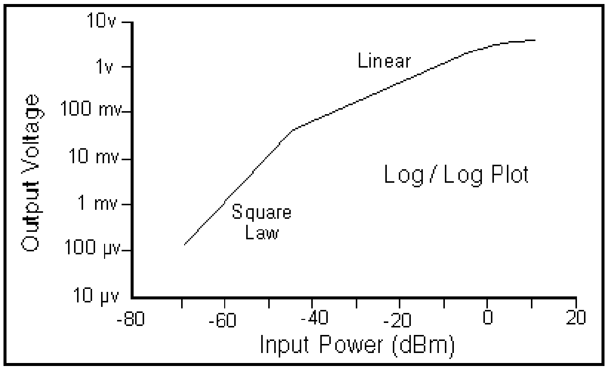

Figure 4. Diode Power/Voltage Characteristic.

Square Law Detector

In the square law region, the output voltage V_o is proportional to the square of the input voltage V_i, thus V_o is proportional to the input power.

$V_o = nV_i^2 = nP_i$ or $P_i \propto V_o$
Where n is the constant of proportionality

Linear Detector

In the linear detection region, the output voltage is given by:

$V_o = mV_i$ and since $P=V^2/R$, $P_i \propto V_o^2$
Where m is the constant of proportionality

Log Detector Amplifier

Another type of detector arrangement is the Log detector amplifier circuit shown in Figure 5. It is formed by using a series of amplifiers and diode detectors. Due to the nature of the amplifier/diode characteristics, the output voltage is related to the power by:

$P_i \propto 10^{pV_o + q}$
Where p and q are constants of proportionality

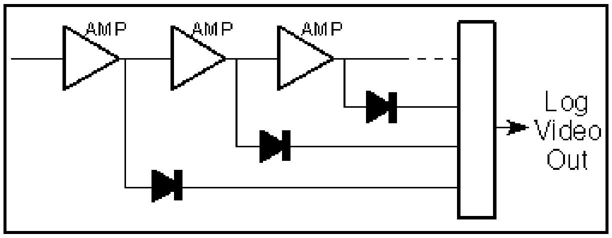

Figure 5. Log Detector.

The Log detector has good range, but is hampered by large size when compared to a single diode detector.

Pulse Width Measurements

If the pulse width of a signal was specified at the one-half power point, the measurements of the detected signal on an oscilloscope would vary according to the region of diode operation. If the region of operation is unknown, a 3 dB attenuator should be inserted in the measurement line. This will cause the power to decrease by one-half. The (temporary) peak amplitude on the oscilloscope becomes the amplitude reference point for measuring the pulse width when the external 3 dB attenuator is removed.

These voltage levels for half power using the three types of detectors are shown in Table 1.

Table 1. Detector Characteristics.

	Square Law	Linear	Log
Output Voltage When Input Power is reduced by Half (3 dB)	0.5 V_{in}	0.707 V_{in}	A very small value. ~ 0.15 V_{in} for typical 5 stage log amplifier
Sensitivity & Dynamic Range	Good sensitivity Small dynamic range	Less sensitivity Greater dynamic range	Poorest sensitivity Greatest dynamic range (to 80 dB)

Also see the Microwave Measurements section subsection entitled "Half Power or 3 dB Measurement Point."

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RF / MICROWAVE AMPLIFIERS

An amplifier is one of the most essential and ubiquitous elements in modern RF and microwave systems. Fundamentally, an amplifier is a type of electronic circuit used to convert low-power signals into ones of significant power. The specific requirements for amplification are as varied as the systems where they are used. Amplifiers are realized using a wide range of different technologies, and are available in many form factors. While the performance of an amplifier can be measured by wide range of attributes, several important ones include: gain, power added efficiency (PAE), input and output return loss, 1-dB compression point (P_{1dB}), stability, linearity, intermodulation distortion, and noise figure.

Traveling Wave Tubes (TWTs)

A traveling-wave tube (TWT) is a specialized vacuum tube used in electronics to amplify radio frequency (RF) signals to very high power. A TWT is a component of an electronic assembly known as a traveling-wave tube amplifier (TWTA), often pronounced "Tweet-uh." While trades between these parameters exist, modern TWTAs are capable of providing very high gains (>50 dB), multiple octaves of bandwidth, high efficiency, and output powers that range from tens to thousands of watts. Pulsed TWTAs can reach even higher output powers. Figure 1 presents a simplified diagram of a helix-type TWT.

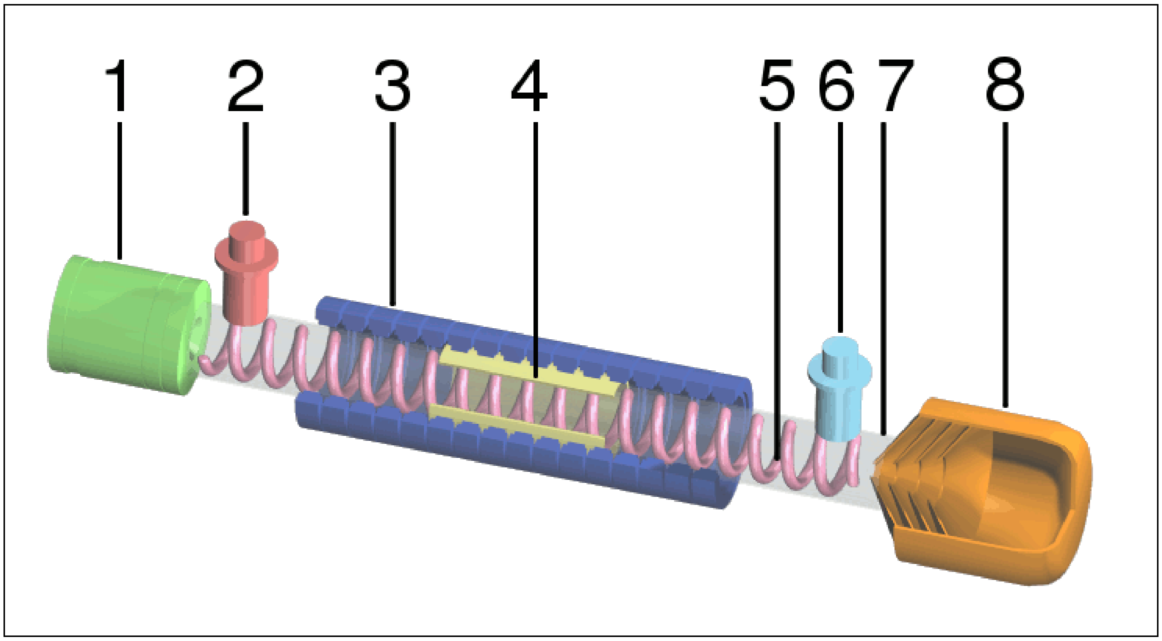

Figure 1. Cutaway view of a helix TWT.
(1) Electron gun; (2) RF input; (3) Magnets; (4) Attenuator;
(5) Helix coil; (6) RF output; (7) Vacuum tube; (8) Collector.
Reproduced from Wikipedia.

The device is an elongated vacuum tube with an electron gun (a heated cathode that emits electrons) at one end. A solenoid coil wrapped around the tube creates a magnetic field which focuses the electrons into a beam, which then passes down the middle of a wire helix that stretches the length of the tube, finally striking a collector at the other end. An input signal is coupled into the helix near the emitter, is amplified by the electron beam as it travels down the length of the tube, and the amplified signal is coupled to an external port near the collector.

The helix, which acts as a RF transmission line, delays the signal to near the same propagation speed as the electron beam. The speed at which the electromagnetic wave travels down the tube can be varied by changing the number or diameter of the turns in the helix. While propagating along the tube, the EM wave interacts with the electron beam. Since the electromagnetic wave effectively propagates slower than the electron beam, the electrons “bunch up” and modulate the input signal, giving up energy in the process - an effect known as velocity modulation. Thus, the traveling wave progressively grows in amplitude as it propagates down the tube towards the collector.

Figure 2 features a photo of a high voltage power supply and TWT.

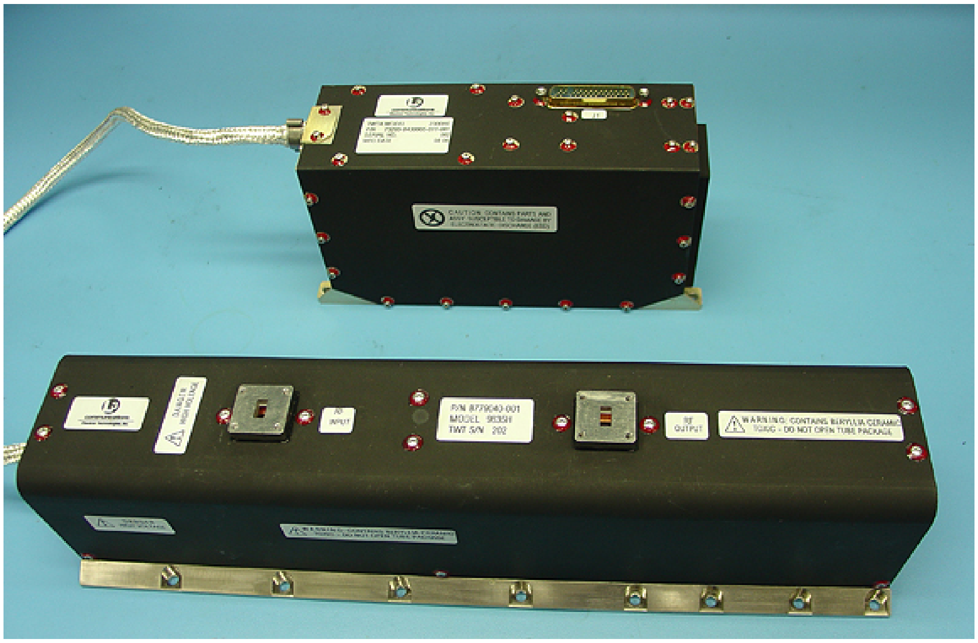

Figure 2. TWTA Including High Voltage Power Supply (top) and TWT (bottom).

Historically, TWTAs have been used in satellite transponders, radars, and in electronic warfare and self-protection systems. Recently, with the advent of wideband, high power solid-state amplifier solutions, however, TWTAs are slowly being replaced due to the higher reliability of their solid state counterparts.

Microwave Power Modules (MPMs)

A Microwave Power Module (MPM) is a hybrid solution between solid-state and vacuum tube electronics, which aims to take advantage of the best features of both technologies. They feature a solid-state pre-amplifier, miniaturized TWTA, and a high-density power supply, all integrated into a unit much more compact and lightweight than the traditional TWTA. While MPMs generally don’t provide as much power as their larger TWTA counterparts, their lighter weight, compact form factor, and relaxed power supply requirements (often 28 VDC or 270 VDC) enable use in applications where a TWTA would not be possible.

Similar to TWTAs, MPMs are capable of providing very high gains (>50 dB), multiple octaves of bandwidth, high efficiency. Typical power levels range from tens to hundreds of watts, with ~1 kW capability for pulsed MPMs.

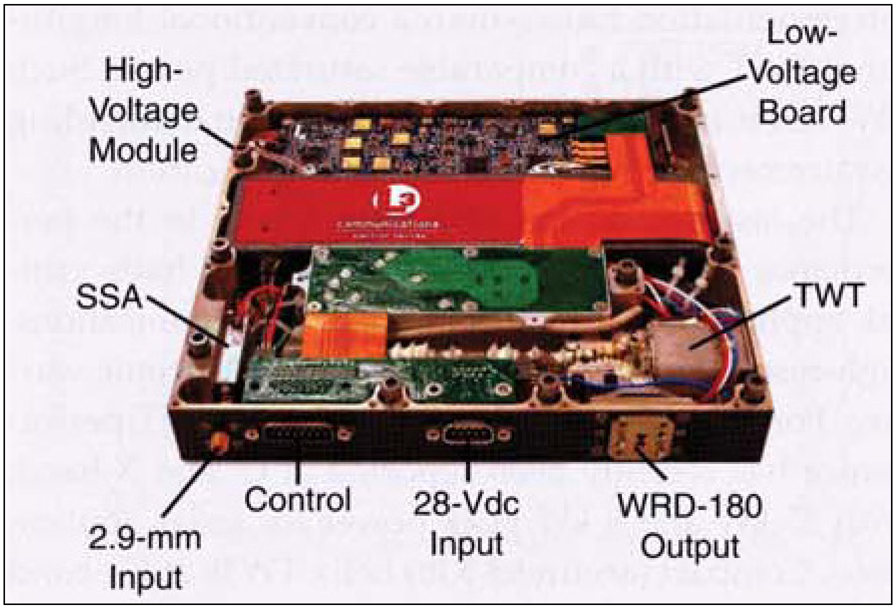
High-Voltage Module
Low-Voltage Board
SSA
TWT
2.9-mm Input
Control
28-Vdc Input
WRD-180 Output

Figure 3. 40W Ka-band MPM With Components Identified.
Image from *IEEE Magazine*, December 2009, page 42.

They have found applications in phased array antennas, lower-power radar transmitters, satellite communications, EW systems, and UAVs.

Solid State

Solid-state electronics, including amplifiers, are built entirely from solid materials and in which the electrons, or other charge carriers, are confined entirely within the solid material. The building material is most often a crystalline semiconductor. Solid-state power amplifiers, or SSPAs, are fabricated on many different semiconductor technologies, some of which include GaAs, GaN, InP, SiGe, CMOS. A photo of a GaN SSPA is presented in Figure 4.

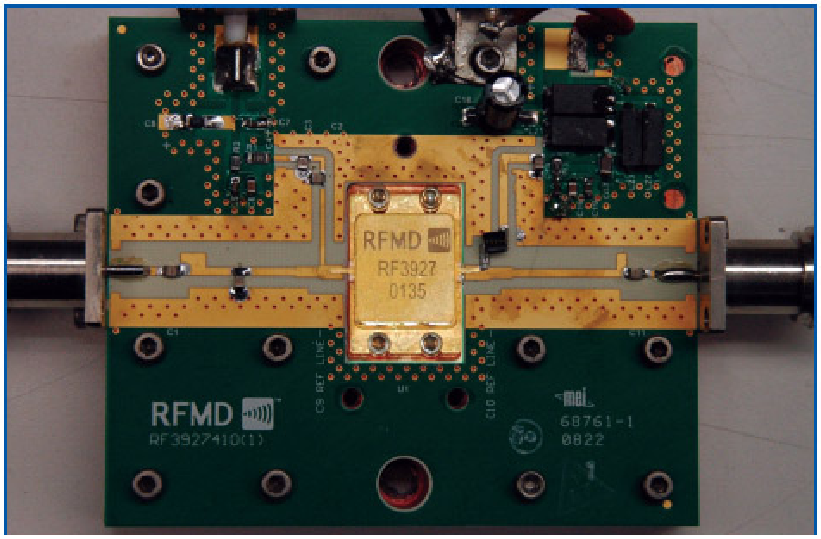
RFMD
RF3927
0135
RFMD
RF3927410(1)
68761-1
0822

Figure 4. Typical SSPA. Note the GaN die and external impedance matching networks.

In general, SSPAs are heralded as having a higher reliability than TWTAs. While high power SSPAs are available on the market, achieving high efficiency has been a challenge as many amplifier stages often need to be combined to meet to achieve power levels in the tens to hundreds of watts. Multi-stage designs increase size, weight, and power (SWAP) and decrease PAE (due to ohmic losses in the combining networks), which is one reason why TWTs and MPMs still provide excellent alternatives for medium to high power applications.

Below is a table that attempts to compare and contrast different solid-state technologies in the context of microwave networks and amplifiers. It is by no means complete, but provides a general overview.

Table 1. Comparison Between Different Semiconductor Process Technologies.

Technology	Advantages	Disadvantages
Silicon variants (CMOS, SiGe)	• Cheapest substrate due to CPU industry • Can be fabricated with nanometer accuracy	• Not a good overall microwave substrate • Results in lossy, high noise figure, low power components • Crystal is fragile • Junction temperatures limited to ~110C
Indium Phosphide Variants (InP/InGaP)	• High performance at low voltage • Good thermal stability • Results in high efficiency PAs, particularly at lower operating voltage • Extremely low noise figure • Useful through W-band and beyond	• Less mature, “niche” fabrication houses • Brittle, fragile material • Higher cost than GaAs • Low breakdown voltage – not good for high power
Gallium Arsenide variants (GaAs)	• Most mature, widespread technology • Many transistor variants (MESFET, PHEMT, MHEMT, HBT, etc) • High reliability • Fairly low cost (but more than silicon) • Great microwave substrate • Low loss, high ε_r. • 16-20V breakdown possible • Junction temperatures up to 150C	• High noise figure, Noise figure and power performance • Difficult to summarize - depends on transistor type used
Gallium Nitride (GaN)	• Up to 10x the power density of GaAs • High breakdown voltage (100V possible) • Results in high efficiency, high frequency, wide bandwidth PAs • Can operate hotter than GaAs, Si, or SiGe	• Currently more expensive than GaAs, but costs are decreasing • Difficult to fabricate • High power density leads to thermal challenges

SIGNAL GENERATION

Signal generators, also known variously as function generators, RF and microwave signal generators, pitch generators, arbitrary waveform generators, digital pattern generators or frequency generators are electronic devices that generate repeating or non-repeating electronic signals (in either the analog or digital domains). They are generally used in designing, testing, troubleshooting, and repairing electronic or electro-acoustic devices; though they often have artistic uses as well.

There are many different types of signal generators, with different purposes and applications (and at varying levels of expense); in general, no device is suitable for all possible applications.

Analog Signal Generators

RF signal generators are capable of producing CW (continuous wave) tones. The output frequency can usually be tuned anywhere in their frequency range. Many models offer various types of analog modulation, either as standard equipment or as an optional capability to the base unit. This could include AM, FM, ΦM (phase modulation) and pulse modulation. Another common feature is a built-in attenuator which makes it possible to vary the signal's output power. Depending on the manufacturer and model, output powers can range from -135 to +30 dBm. A wide range of output power is desirable, since different applications require different amounts of signal power. For example, if a signal has to travel through a very long cable out to an antenna, a high output signal may be needed to overcome the losses through the cable and still have sufficient power at the antenna. But when testing receiver sensitivity, a low signal level is required to see how the receiver behaves under low signal-to-noise conditions.

RF signal generators are required for servicing and setting up analog radio receivers, and are used for professional RF applications.

Arbitrary Waveform Generator

An arbitrary waveform generator (AWG) is a piece of electronic test equipment used to generate electrical waveforms. These waveforms can be either repetitive or single-shot (once only) in which case some kind of triggering source is required (internal or external). The resulting waveforms can be injected into a device under test and analyzed as they progress through the device, confirming the proper operation of the device or pinpointing a fault in the device.

Unlike function generators, AWGs can generate any arbitrarily defined wave shape as their output. The waveform is usually defined as a series of "waypoints" (specific voltage targets occurring at specific times along the waveform) and the AWG can either jump to those levels or use any of several methods to interpolate between those levels.

Because AWGs synthesize the waveforms using (baseband) digital signal processing techniques, their maximum frequency is usually limited to no more than a few gigahertz (~10 GHz being the latest state-of-the-art in 2012).

A major difficulty in generating non-repetitive waveforms at higher frequencies with AWGs is the large amount of data required to describe high-frequency baseband signals. For example, a 20 gigasample/sec arbitrary waveform with 8 bits of resolution requires 20 GB of data to represent every 1 second of signal, regardless of that signal's nature. Generating such large digital data streams and delivering them to the DAC in the AWG is an increasingly difficult problem as DAC upper frequencies continue to grow.

AWGs, like most signal generators, may also contain an attenuator, various means of modulating the output waveform, and often contain the ability to automatically and repetitively "sweep" the frequency of the output waveform (by means of a voltage-controlled oscillator) between two operator-determined limits. This capability makes it very easy to evaluate the frequency response of a given electronic circuit.

AWGs can operate as conventional function generators. These would include standard waveforms such as sine, square, ramp, triangle, noise, and pulse. Some units include additional built-in waveforms such as exponential rise and fall times, sinx/x, cardiac. Some AWGs allow users to retrieve waveforms from a number of digital and mixed-signal oscilloscopes. Some AWGs may display a graph of the waveform on their screen - a graph mode. Some AWGs have the ability to generate a pattern of words from multiple bit output connector to simulate data transmission, combining the properties of both AWGs and digital pattern generators.

One feature of direct digital synthesizer (DDS) based arbitrary waveform generators is that their digital nature allows multiple channels to be operated with precisely controlled phase offsets or ratio-related frequencies. This allows the generation of polyphase sine waves, I-Q constellations, or simulation of signals from geared mechanical systems such as jet engines. Complex channel-channel modulations are also possible.

Vector Signal Generators

Modern vector signal generators can be seen as a hybrid of the arbitrary waveform generator and the analog signal generator, combining a lower-bandwidth AWG with analog upconversion, allowing a moderate-bandwidth (~100 MHz, circa 2012) digital signal to be upconverted to any frequency (~50 GHz typically upper frequency typically).

With the advent of digital communications systems, it is no longer possible to adequately test these systems with traditional analog signal generators. This has led to the development of vector signal generators, also known as digital signal generators. These signal generators are capable of generating digitally-modulated radio signals that may use any of a large number of digital modulation formats such as QAM, QPSK, FSK, BPSK, and OFDM. In addition, since modern commercial digital communication systems are almost all based on well-defined industry standards, many vector signal generators can generate signals based on these standards. Examples include GSM, W-CDMA (UMTS), CDMA2000, LTE, Wi-Fi (IEEE 802.11), and WiMAX (IEEE 802.16). In contrast, military communication systems such as JTRS, which place a great deal of importance on robustness and information security, typically use very proprietary methods. To test these types of communication systems, users will often create their own custom waveforms and download them into the vector signal generator to create the desired test signal.

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DIGITAL SIGNAL PROCESSING COMPONENTS

The goal of DSP is usually to measure, filter and/or compress continuous real-world analog signals. The first step is usually to convert the signal from an analog to a digital form, by sampling and then digitizing it using an analog-to-digital converter (ADC), which turns the analog signal into a stream of numbers. However, often, the required output signal is another analog output signal, which requires a digital-to-analog converter (DAC). Even if this process is more complex than analog processing and has a discrete value range, the application of computational power to digital signal processing allows for many advantages over analog processing in many applications, such as error detection and correction in transmission as well as data compression. With the increasing bandwidth and dynamic range of ADC and digital components, common analog RF signal processing operations such as filtering, threshold detection, and pulse compression are being carried out in the digital domain. Additionally new capabilities such as synthetic aperture radar (SAR), digital RF memory (DRFM), and space-time adaptive processing (STAP) are wholly enabled by the increasing power of digital processing components.

Analog-to-Digital Converter

An analog-to-digital converter (abbreviated ADC, A/D or A to D) is a device that converts a continuous quantity to a discrete time digital representation. An ADC may also provide an isolated measurement. The reverse operation is performed by a digital-to-analog converter (DAC).

Typically, an ADC is an electronic device that converts an input analog voltage or current to a digital number proportional to the magnitude of the voltage or current. However, some non-electronic or only partially electronic devices, such as rotary encoders, can also be considered ADCs.

Resolution

The resolution of the converter indicates the number of discrete values it can produce over the range of analog values. The values are usually stored electronically in binary form, so the resolution is usually expressed in bits. In consequence, the number of discrete values available, or "levels," is a power of two. For example, an ADC with a resolution of 8 bits can encode an analog input to one in 256 different levels, since $2^8 = 256$. The values can represent the ranges from 0 to 255 (i.e. unsigned integer) or from −128 to 127 (i.e., signed integer), depending on the application.

Resolution can also be defined electrically, and expressed in volts. The minimum change in voltage required to guarantee a change in the output code level is called the least significant bit (LSB) voltage. The resolution Q of the ADC is equal to the LSB voltage. The voltage resolution of an ADC is equal to its overall voltage measurement range divided by the number of discrete values:

$$Q = \frac{E_{FSR}}{2^M}$$

where M is the ADC's resolution in bits and E_{FSR} is the full scale voltage range (also called 'span').

E_{FSR} is given by

$$E_{FSR} = V_{RefHi} - V_{RefLow}$$

where V_{RefHi} and V_{RefLow} are the upper and lower extremes, respectively, of the voltages that can be coded.

Normally, the number of voltage intervals is given by

$$N = 2^M - 1$$

where M is the ADC's resolution in bits.

That is, one voltage interval is assigned in between two consecutive code levels.

A typical 3 bit (2^8 = 8-level) coding scheme is depicted in Figure 1.

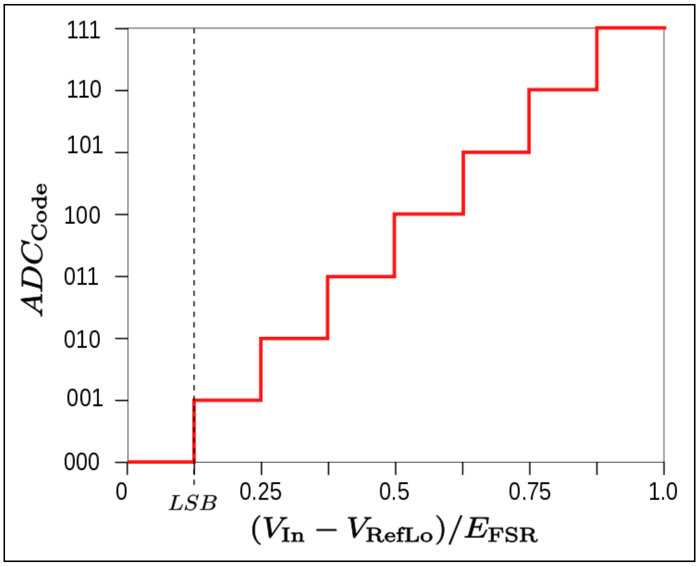

Figure 1. An 8-level (3 bit) ADC Coding Scheme.

Example:

Assume input signal x(t) = A cos(t), A = 5V
Full scale measurement range = -5 to 5 volts
ADC resolution is 8 bits: 2^8 - 1 = 256 - 1 = 255 quantization levels (codes)
ADC voltage resolution, Q = (5 V − [-5] V) / 255 = 10 V / 255 ≈ 0.039 V ≈ 39 mV.

In practice, the useful resolution of a converter is limited by the best signal-to-noise ratio (SNR) that can be achieved for a digitized signal. An ADC can resolve a signal to only a certain number of bits of resolution, called the effective number of bits (ENOB). One effective bit of resolution changes the signal-to-noise ratio of the digitized signal by 6 dB, if the resolution is limited by the ADC. If a preamplifier has been used prior to A/D conversion, the noise introduced by the amplifier can be an important contributing factor towards the overall SNR.

Accuracy

An ADC has several sources of errors. Quantization error and (assuming the ADC is intended to be linear) non-linearity are intrinsic to any analog-to-digital conversion. There is also a so-called aperture error which is due to a clock jitter and is revealed when digitizing a time-variant signal (not a constant value).

These errors are measured in a unit called the least significant bit (LSB). In the above example of an eight-bit ADC, an error of one LSB is 1/256 of the full signal range, or about 0.4%.

Sampling Rate

The analog signal is continuous in time and it is necessary to convert this to a flow of digital values. It is therefore required to define the rate at which new digital values are sampled from the analog signal. The rate of new values is called the sampling rate or sampling frequency of the converter.

A continuously varying band limited signal can be sampled (that is, the signal values at intervals of time T, the sampling time, are measured and stored) and then the original signal can be exactly reproduced from the discrete-time values by an interpolation formula. The accuracy is limited by quantization error. However, this faithful reproduction is only possible if the sampling rate is higher than twice the highest frequency of the signal. This is essentially what is embodied in the Shannon-Nyquist sampling theorem.

Oversampling

Usually, for economy, signals are sampled at the minimum rate required, with the result that the quantization noise introduced is white noise spread over the whole pass band of the converter. If a signal is sampled at a rate much higher than the Nyquist frequency and then digitally filtered to limit it to the signal bandwidth there are the following advantages:

- Digital filters can have better properties (sharper roll-off, phase) than analog filters, so a sharper anti-aliasing filter can be realized and then the signal can be down-sampled giving a better result
- A 20-bit ADC can be made to act as a 24-bit ADC with 256× oversampling
- The signal-to-noise ratio due to quantization noise will be higher than if the whole available band had been used. With this technique, it is possible to obtain an effective resolution larger than that provided by the converter alone.
- The improvement in SNR is 3 dB (equivalent to 0.5 bits) per octave of oversampling which is not sufficient for many applications. Therefore, oversampling is usually coupled with noise shaping. With noise shaping, the improvement is 6L+3 dB per octave where L is the order of loop filter used for noise shaping. e.g. - a 2nd order loop filter will provide an improvement of 15 dB/octave.

Digital to Analog Converter (DAC)

Digital-to-analog converters (DACs) perform the inverse function of the ADC. As such, the aforementioned principles of accuracy, resolution, sampling and oversampling, etc. apply equivalently.

Field-Programmable Gate Array (FPGA)

A field-programmable gate array (FPGA) is an integrated circuit designed to be configured by the customer or designer after manufacturing—hence “field-programmable.” The FPGA configuration is generally specified using a hardware description language (HDL), similar to that used for an application-specific integrated circuit (ASIC). Circuit diagrams were previously used to specify the configuration, as they were for ASICs, but this is increasingly rare. FPGAs can be used to implement any logical function that an ASIC could perform. The ability to update the functionality after shipping, partial re-configuration of a portion of the design and the low non-recurring engineering costs relative to an ASIC design (notwithstanding the generally higher unit cost), offer advantages for many applications.

FPGAs contain programmable logic components called “logic blocks,” and a hierarchy of reconfigurable interconnects that allow the blocks to be “wired together”—somewhat like many (changeable) logic gates that can be inter-wired in (many) different configurations. Logic blocks can be configured to perform complex combinational functions, or merely simple logic gates like AND and XOR. In most FPGAs, the logic blocks also include memory elements, which may be simple flip-flops or more complete blocks of memory.

FPGAs are becoming increasingly more popular for implementing RF signal processing functions such as signal compression (matched filtering), channel selection, modulation / demodulation, etc.

MICROWAVE MEASUREMENTS

Measurement Procedures

Calculate your estimated power losses before attempting to perform a measurement. The ideal input to a measurement device is in the 0 to 10 dBm (1 to 10 mW) range.

Linearity Check

To verify that a spectrum measurement is accurate and signals are not due to mixing inside the receiver, a linearity check should be performed, i.e., externally insert a 10 dB attenuator - if measurements are in the linear region of the receiver, all measurements will decrease by 10 dB. If the measurements decrease by less than 10 dB, the receiver is saturated. If the measurements disappear, you are at the noise floor.

Half-Power or 3 dB Measurement Point

To verify the half power point of a pulse width measurement on an oscilloscope, externally insert a 3 dB attenuator in the measurement line, and the level that the peak power decreases to is the 3 dB measurement point (Note: you cannot just divide the peak voltage by one-half on the vertical scale of the oscilloscope).

VSWR Effect on Measurement

Try to measure VSWR (or reflection coefficient) at the antenna terminals. Measuring VSWR of an antenna through its transmission line can result in errors. Transmission lines should be measured for insertion loss not VSWR.

High Power Pulsed Transmitter Measurements

When making power measurements on a high power pulsed transmitter using a typical 40 dB directional coupler, an additional attenuator may be required in the power meter takeoff line, or the power sensor may be burnt out.

For example, assume we have a 1 megawatt transmitter, with PRF = 430 pps, and PW = 13 μs. Further assume we use a 40 dB directional coupler to tap off for the power measurements. The power at the tap would be:

$10 \log(P_p) - 10 \log(DC) - \text{Coupler reduction} =$

$10 \log(10^9 \text{mW}) - 10 \log(13\text{x}10^{-6})(430) - 40 \text{ dB} =$

$90 \text{ dBm} - 22.5 \text{ dB} - 40 \text{ dB} = 27.5 \text{ dBm}$ (too high for a power meter)

Adding a 20 dB static attenuator to the power meter input would give us a value of 7.5 dBm or 5.6 mW, a good level for the power meter.

High Power Measurements With Small Devices

When testing in the presence of a high power radar, it is normally necessary to measure the actual field intensity. The technique shown in Figure 4, in Section 6-7, may not be practical if the measurement device must be small. An alternate approach is the use of a rectangular waveguide below its cutoff frequency. In this manner, the "antenna" waveguide provides sufficient attenuation to the frequency being measured so it can be coupled directly to the measurement device or further attenuated by a low power attenuator. The attenuation of the waveguide must be accurately measured since attenuation varies significantly with frequency.

ELECTRO-OPTICS AND IR

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ELECTRO-OPTICAL SYSTEMS AND EW COUNTERMEASURES

INTRODUCTION

The development of infrared countermeasures and the evaluation of their performance against threat missiles is a broad, complex technical field. Much of the detailed information about the threats to be countered and the characteristics of the countermeasures themselves is understandably sensitive, beyond the limitations of this document. More detailed information can be requested, provided the requesting organization has the necessary clearance and need to know. Such requests will be considered on a case-by-case basis. Information will be provided only upon written concurrence of the controlling Government organization.

There are many electro-optical (EO) electronic warfare (EW) systems, which are analogous to radio frequency (RF) EW systems. These EO EW systems operate in the optical portion of the electromagnetic spectrum. Electro-optics (EO), as the name implies, is a combination of electronics and optics. By one definition EO is the science and technology of the generation, modulation, detection and measurement, or display of optical radiation by electrical means. Most infrared (IR) sensors, for example, are EO systems. In the popularly used term "EO/IR," the EO is typically used to mean visible or laser systems. The use of EO in this context is a misnomer. Actually, almost all "EO/IR" systems are EO systems as defined above. Another often-used misnomer is referring to an EO spectrum. EO systems operate in the optical spectrum, which is from 0.01 to 1000 micrometers. EO systems include, but are not limited to, lasers, photometry, infrared, and other types of visible, and UV imaging systems.

Within the broad field of Electronic Warfare, electro-optical systems are prevalent for communication systems and offensive and defensive applications. Lasers have been used extensively for weapons guidance purposes, warhead fuzing applications, targeting systems and other offensive weapons related purposes. Understanding electro-optical and radiometric principles and sensors is critical to the development of vehicle survivability systems. These principles range from signature reduction and camouflage to active countermeasure systems such as lamp-based and laser jammers to passive threat warning systems and expendable flare decoys.

Although military systems operate in many portions of the electro-optical spectrum, the infrared is of paramount importance for remote detection systems and weapons applications. Missile seekers, Forward Looking Infrared (FLIR) systems, and Infrared Search and Track Systems all operate in the infrared portion of the spectrum.

OPTICAL SPECTRUM

The optical spectrum is that portion of the electromagnetic spectrum from the extreme ultraviolet (UV) through the visible to the extreme IR. Figure 1 shows the optical spectrum in detail. The end points of the optical spectrum are somewhat arbitrary.

IR spectrum terminology has also varied through the years, with near (near visible), or short-wavelength infrared (SWIR) being on the high frequency end. Then as frequency decreases the spectrum is followed by intermediate or mid-wavelength infrared (MWIR), then far or long-wavelength IR (LWIR), and finally extreme IR.

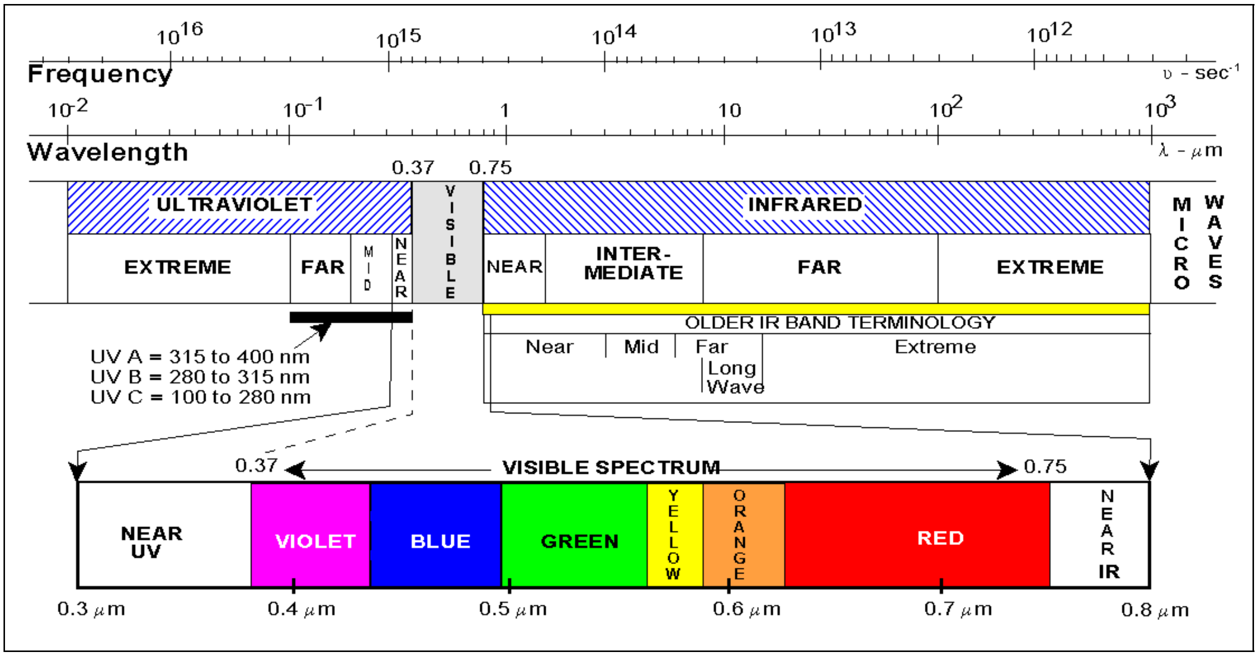
10^16
10^15
10^14
10^13
10^12
Frequency
υ - sec^-1
10^-2
10^-1
1
10
10^2
10^3
Wavelength
λ - µm
0.37
0.75
ULTRAVIOLET
VISIBLE
INFRARED
MICRO WAVES
EXTREME
FAR
MID
NEAR
NEAR
INTER-MEDIATE
FAR
EXTREME
OLDER IR BAND TERMINOLOGY
Near
Mid
Far
Long Wave
Extreme
UV A = 315 to 400 nm
UV B = 280 to 315 nm
UV C = 100 to 280 nm
0.37
VISIBLE SPECTRUM
0.75
NEAR UV
VIOLET
BLUE
GREEN
YELLOW
ORANGE
RED
NEAR IR
0.3 µm
0.4 µm
0.5 µm
0.6 µm
0.7 µm
0.8 µm

Figure 1. Optical Spectrum.

RADIOMETRIC QUANTITIES AND TERMINOLOGY

The common terms used to describe optical radiation are the source parameters of power, radiant emittance (older term) or radiant exitance (newer term), radiance, and radiant intensity. They refer to how much radiation is given off by a body. The parameter measured by the detector (or collecting object/surface) is the irradiance. Any of these quantities can be expressed per unit wavelength in which case the subscript is changed from e (meaning energy derived units) to λ and the term is then called "Spectral ...X...", i.e. I_e is radiant intensity, while I_λ is spectral radiant intensity. These quantities in terms of currently preferred "Système International d'Unités" (SI units) are defined in Table 1.

Table 1. Radiometric SI Units.

Symbol	Name	Description	Units
Q	Radiant Energy		J (joules)
Φ_e	Radiant Power (or flux)	Rate of transfer of radiant energy	W (watts)
M_e	Radiant Exitance	Radiant power per unit area emitted from a surface	$W\ m^{-2}$
L_e	Radiance	Radiant power per unit solid angle per unit projected area	$W\ m^{-2} sr^{-1}$
I_e	Radiant Intensity	Radiant power per unit solid angle from a point source	$W\ sr^{-1}$
E_e	Irradiance	Radiant power per unit area incident upon a surface	$W\ m^{-2}$
X_λ	Spectral ...X..	(Quantity) per unit wavelength interval	(Units) nm^{-1} or μm^{-1}

Where X_λ is generalized for each unit on a per wavelength basis; for example, L_λ would be called "spectral radiance" instead of radiance.

In common usage, irradiance is expressed in units of Watts per square centimeter and wavelengths are in **µ**m instead of nanometers (nm). Other radiometric definitions are shown in Table 2.

Table 2. Other Radiometric Definitions.

Symbol	Name	Description	Units
α	Absorptance[1]	α = (*) absorbed / (*) incident	numeric
ρ	Reflectance	ρ = (*) reflected / (*) incident	numeric
τ	Transmittance	τ = (*) transmitted / (*) incident	numeric
$\in$	Emissivity	$\in$ = (*) of specimen / (*) of blackbody @ same temperature	numeric

Where (*) represents the appropriate quantity Q, Φ, M, E, or L

Note (1) Radiant absorptance should not be confused with absorption coefficient.

PHOTOMETRIC QUANTITIES

Whereas the radiometric quantities Φ_e, M_e, I_e, L_e, and E_e have meaning throughout the entire electromagnetic spectrum, their photometric counterparts Φ_v, M_v, I_v, L_v, and E_v are meaningful only in the visible spectrum (0.38 **µ**m thru 0.78 **µ**m).

The "standard candle" was redefined as the new candle or candela (cd). One candela is the luminous intensity of 1/60th of 1 cm^2 of the projected area of a blackbody radiator operating at the temperature of the solidification of platinum (2045 ºK). By definition, the candela emits one lumen (lm) per steradian.

Table 3 displays the photometric quantities and units. These are used in dealing with optical systems such as aircraft television camera systems, optical trackers, or video recording.

Table 3. Photometric SI Units.

Symbol	Name	Description	Units
Q_v	Luminous energy		lumen sec (lm s)
F or Φ_v	Luminous flux or Luminous Power	Rate of transfer of luminant energy	lumen (lm)
M_v	Luminous Exitance or flux density (formerly luminous emittance)	Luminant power per unit area emitted from a surface	$lm\ m^{-2}$
L_v	Luminance (formerly brightness)	Luminous flux per unit solid angle per unit projected area	nit (nt) or candela / m^2 or $lm/sr \cdot m^2$
I_v	Luminous Intensity (formerly candlepower)	Luminous power per unit solid angle from a point source	candela (cd) or lm/sr
E_v	Illuminance (formerly illumination)	Luminous power per unit area incident upon a surface	lux or lx or lm/m^2
K	Luminous efficacy	$K = \Phi_v / \Phi_e$	lm / w

Table 4 displays conversion factors for commonly used illuminance quantities.

Table 4. Illuminance Conversion Units.

		Lux (lx)	Footcandle (fc)	Phot (ph)
1 lux (lm m^{-2})	=	1	0.0929	1×10^{-4}
1 footcandle (lm ft^{-2})	=	10.764	1	0.001076
1 phot (lm cm^{-2})	=	1×10^{4}	929	1

THE BASIC PRINCIPLES

The processes of absorption, reflection (including scattering), and transmission account for all incident radiation in any particular situation, and the total must add up to one in order that energy be conserved:

$\alpha + \rho + \tau = 1,$ as shown in Figure 2.

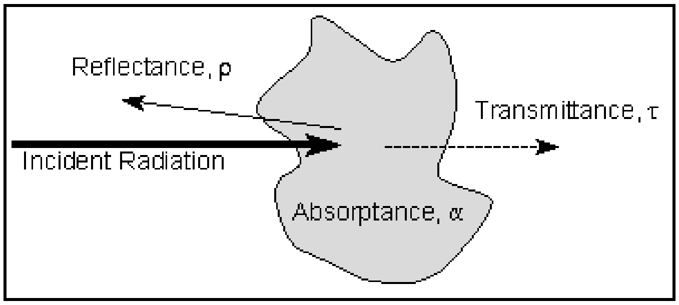

Figure 2. Radiation Incident on a Body.

If a material is opaque (no transmission), then: absorption + reflection = 1

In addition to the above processes, optical (including IR) radiation interacts with matter the same as radiation in any other part of the spectrum, including:

1. **Diffraction** – around edges
2. **Emission** – from matter by conversion from another form of energy
3. **Interference** – constructive and destructive
4. **Refraction** – bends when passing between two media with different propagation speeds (Snell's Law)
5. **Scattering** – when interacts with particles whose size approaches length of the wave
6. **Polarized** - electric field is partially polarized by reflection from dielectric

STERADIAN – SOLID ANGLE

Of significance to many terms and units in radiometric calculations is the *solid angle*. Figure 3 is a pictorial depicting the relationship of area, distance, and solid angle. By definition, the ratio of area on the surface of a sphere to the square of distance (the radius) is the unit less parameter *solid angle*, or steradian in the SI system of units. Solid angle is usually abbreviated as "sr" or given the Greek letter, Ω. The steradian is a dimensionless quantity in radiometric calculations.

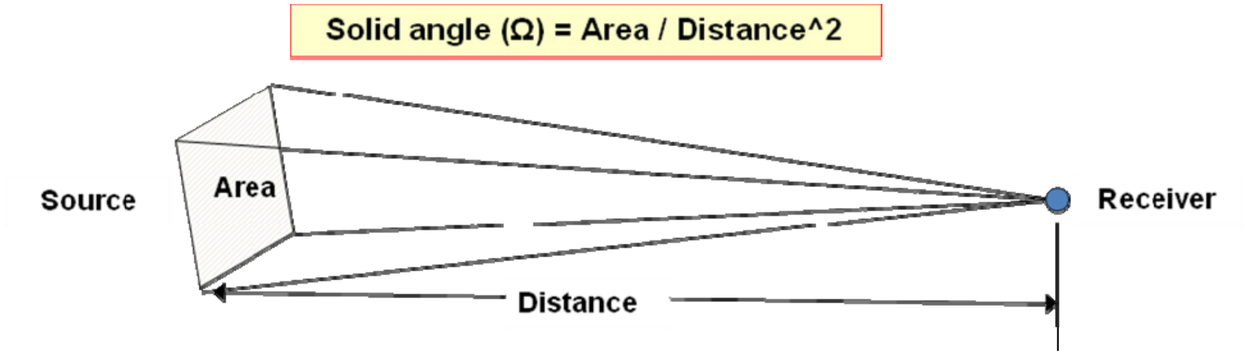

Figure 3. Solid Angle.

A sphere contains a solid angle of 4π steradians; a hemisphere contains 2π steradians, and so on. The area is a curved surface, but in most applications, the solid angles are sufficiently small that the area can be approximated as a plane. Also, for small angles, the solid angle in steradians is approximately equal to the product of two plane angles in radians.

CONVERSIONS

IR wavelengths are typically expressed in **µ**m, visible wavelengths in **µ**m or nm, and UV wavelengths in nm or angstroms. Table 5 lists conversion factors for converting from one unit of wavelength to another. The conversion is from column to row. For example, to convert from **µ**m to nm, multiply the value expressed in **µ**m by 10^3. IR wavelengths are also sometimes expressed in a frequency-like unit called wavenumbers or inverse centimeters. A wavenumber value can be found by dividing 10,000 by the wavelength expressed in **µ**m. For example, 2.5 **µ**m converts to a wavenumber of 4000 or 4000 inverse centimeters (cm^{-1}).

Table 5. Wavelength Conversion Units.

From ->	Angstroms - Å	Nanometers - nm	Micrometers - **µ**m
To get ↓	Multiply by		
Angstroms - Å	1	10	10^4
Nanometers - nm	10^{-1}	1	10^3
Micrometers - **µ**m	10^{-4}	10^{-3}	1

BASIC RADIANT POWER RELATIONSHIPS

Radiant intensity is the most commonly used term to describe the radiant power of a source per unit solid angle. Radiant Intensity offers the advantage of being a source term, like radiance, that is not related to the size of the radiating source. In practice, radiant intensity is a derived term and is not directly measurable. If the Instantaneous Field of View (IFOV), which represents the smallest optical resolution element of a remote sensor, subtends an angle smaller than the size of the radiating source, the sensor responds directly to *radiance*. If the IFOV of the sensor subtends an angle larger than the radiating source, the sensor responds to *irradiance*. The relationship among radiant intensity, radiance, and irradiance is shown in the following equation:

$$I = ED^2 = E\frac{A}{\Omega} = LA = L\Omega D^2$$

Where:

I = Intensity. Radiant intensity is the target source power per unit solid angle, in Watts/steradian.

E = Irradiance. Irradiance is the received power density in Watts/cm2 incident on a distant sensor. Irradiance is the quantity measured or detected by a distant sensor where the target is not spatially resolved (i.e., where the target subtends an angle smaller than the resolution or field of view of the instrument.)

L = Radiance. Radiance is the intensity per unit area of source, in W/cm^2/steradians. Radiance is the quantity measured by a camera or imaging system, where the target is optically resolved (i.e., where the target subtends an angle much greater than the resolution or instantaneous field of view of the imager.)

A = Area. Area is the cross-sectional or projected area of the target in cm^2.

D = Distance. Distance between the target and sensor in cm.

Ω = Solid angle subtended by the target in steradians. Solid angle appears directly or indirectly in many infrared quantities. The solid angle subtended by a source is the ratio of the source area to the square of distance.

All remote sensors receive energy from a source through an atmospheric path. The atmosphere attenuates the propagation of energy due to scattering, absorption, and molecular rotation and vibration, depending on the wavelengths involved. The atmosphere itself also radiates. All incident energy on a remote sensor, except as received under vacuum conditions, is detected through the atmosphere. The term *apparent* is applied to a radiometric quantity to acknowledge the presence of atmospheric effects. A remote sensor, responding the radiance of a source over an atmospheric path, responds to *apparent radiance*.

Real sensors do not respond uniformly to energy. Sensors have non-uniform spectral and spatial response due to many factors, including detector and optical characteristics. All energy received by the detector is spectrally weighted by the spectral response of the instrument. The term *effective* is applied to acknowledge the non-uniform response of the instrument.

Outside of a vacuum, all radiation incident on a remote sensor is attenuated by atmospheric effects such as scattering and absorption. Where the atmosphere absorbs, it also emits. Path radiance is the term applied to the contribution of the atmospheric path to the received radiation. The term *apparent* is applied to radiometric quantities to acknowledge the influence of the atmosphere on the received radiation.

DOMAINS, DISTRIBUTIONS, AND SENSOR RESPONSE

Radiant power that is emitted or reflected from a source is distributed across multiple dimensions or domains. The three domains that are most important to radiometric applications are spectral (Figure 4), spatial (Figure 5), and temporal (Figure 6). Knowing how the radiant power from a source is distributed across each domain is important to understanding performance of an EW system, whether it be a sensor, a weapon, or a countermeasure.

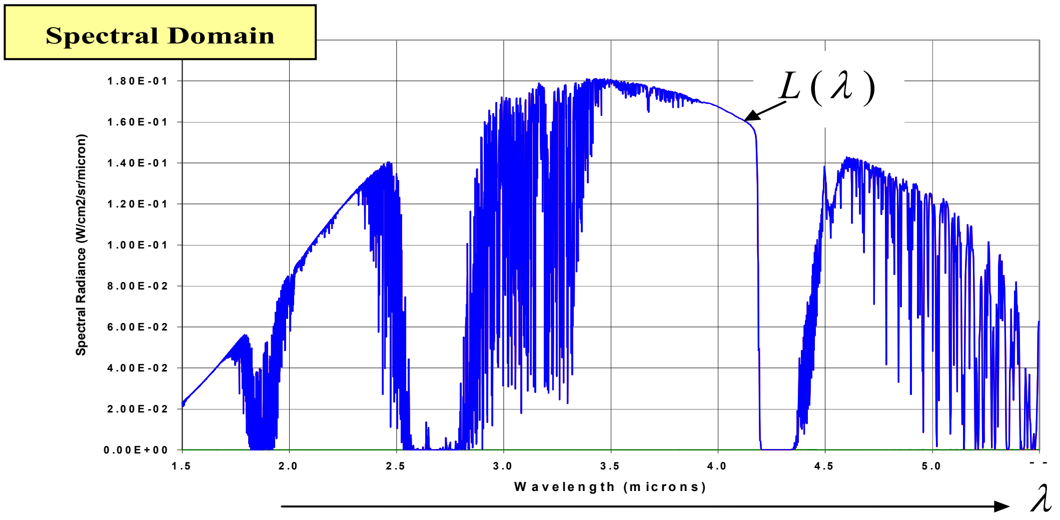

In the spectral domain, radiation is distributed as a function of wavelength (or wavenumber). Radiation from solid materials is distributed as a continuum in accordance with Planck's formula. The graph above shows the spectral distribution of radiation from a 600 degree Celsius blackbody after passage through the atmosphere. Radiation from gases appears at specific wavelength "lines" corresponding to molecular resonances.

Figure 4. Sample Spectral Distribution of a Solid Material.

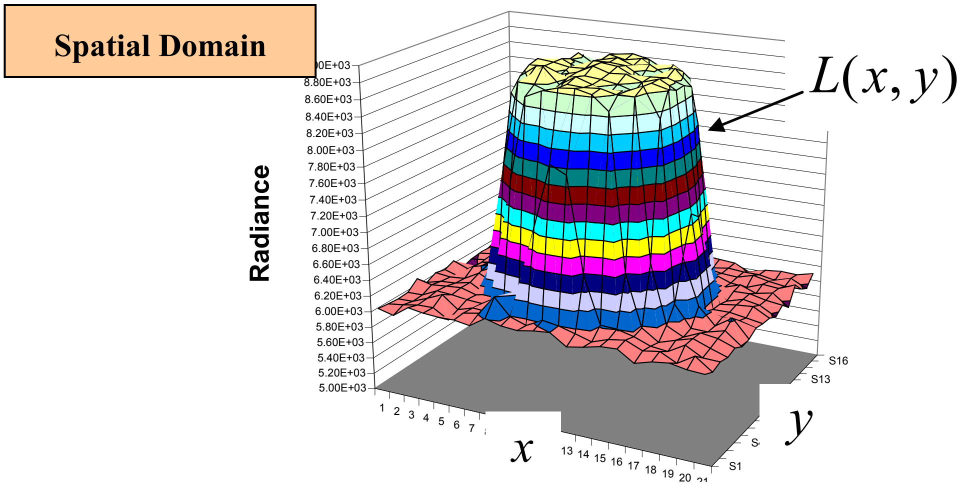

In the spatial domain, radiation is distributed as a function of angle, position, size, shape, or orientation. The graph above shows the radiance of a circular target as viewed by an imaging system.

Figure 5. Sample Spatial Distribution of a Circular Target Image.

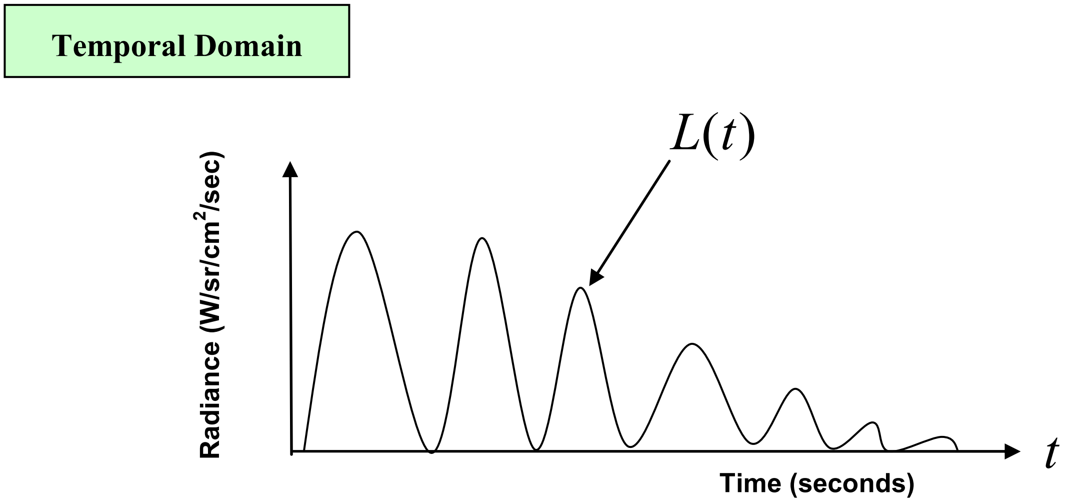

In the temporal domain, radiation is distributed as a function of time (or frequency). Most IR target sources, such as aircraft and ground vehicles, change slowly with time and can be considered steady state for measurement purposes. However, IR countermeasures systems and devices, such as jammers and decoy flares, have high frequency content that must be considered in their design and effectiveness assessment.

Figure 6. Sample Temporal Distribution of a Modulated Source.

All electro-optical sensors have some sensitivity to how radiation is distributed across the different domains. This sensitivity or response takes the following forms:

1. **Spectral response**:
    a. May be broad in the case of a radiometer or imager, or narrow in the case of a spectrometer where response takes the form of resolution.
    b. Spectral response is chosen to exploit particular spectral features of interest in a target.
    c. Non-uniformity of spectral response can have a significant effect on the performance of sensor.

2. **Spatial response**:
    a. May be broad in the case of a radiometer or spectrometer, where spatial response takes the form of sensitivity across the sensor's FOV. In the case of an imager, the spatial response may be narrow because spatial response takes the form of the resolution or IFOV.
    b. Required spatial resolution is defined by the size and radiant power of the source, the distance between the source and the target, and by the sensitivity of the sensor.
    c. Non-uniformity of spatial response can have a significant effect on the performance of sensor.
    d. Response to radiation from the background within the FOV is primarily a spatial response issue and can be significant to sensor performance.

3. **Temporal response**:
    a. Takes the form of bandwidth or, in the case of a digital system, of sampling frequency.
    b. Unlike spectral and spatial response, temporal response includes the response time of the detector and all of the electronics, data transfer time, and processing time for a sensor.
    c. Non-uniformity across a region is usually not a concern. Temporal response is usually uniform for target frequencies that fall well below the low-pass or Nyquist breakpoints.

Sensors respond to received radiant power by integrating the power distribution in each domain under the corresponding response curve. Sensors respond in multiple domains, so output is proportional to a multi-dimensional, weighted integral. Figure 7 illustrates response-weighting, or convolution, of radiation with instrument response in the spectral domain. The concept applies equally in the spatial domain.

Response Weighting in the Spectral Domain

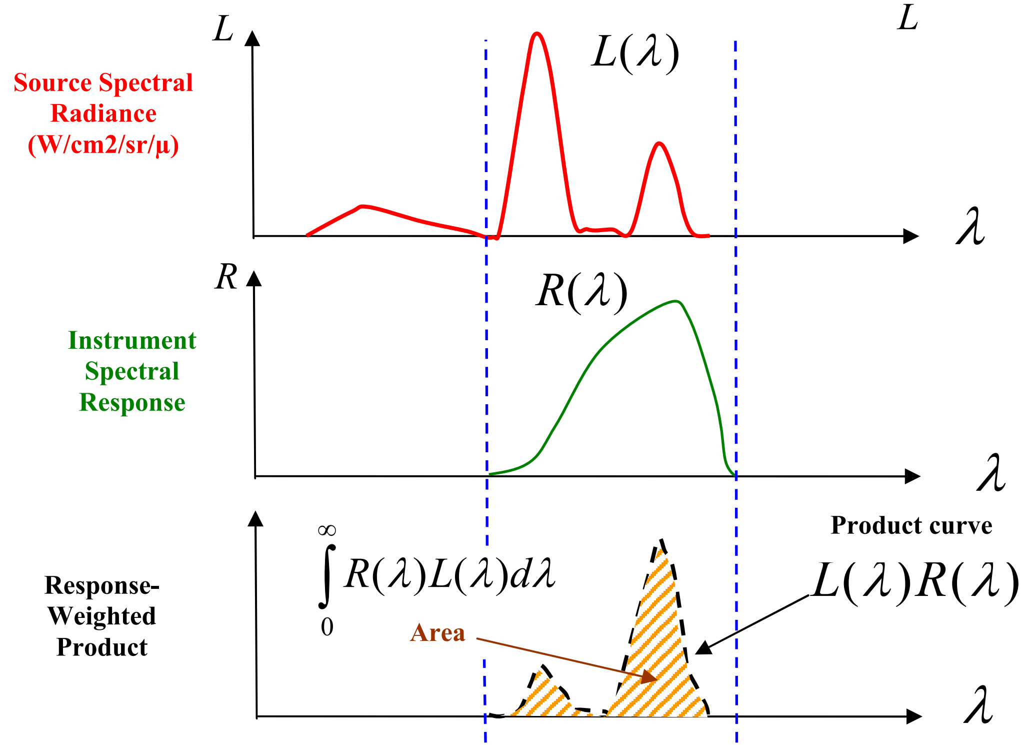
Source Spectral
Radiance
(W/cm2/sr/μ)
L
$L(\lambda)$
L
λ
Instrument
Spectral
Response
R
$R(\lambda)$
λ
Response-
Weighted
Product
$\int_0^\infty R(\lambda)L(\lambda)d\lambda$
Area
Product curve
$L(\lambda)R(\lambda)$
λ

Non-uniform sensor response across a domain distorts the distribution of received radiant power by weighting the radiation at some wavelengths differently than others. Instrument output is proportional to the integral of this weighted product, which makes instrument response shape an embedded part of both the measurement and the calibration. Some consequences of non-uniform response are:

- Two different sources with identical power, but different distributions will produce different measurement values.
- If two different sources (such as the calibration and the target) have similar relative power distributions, the relative weighting by the instrument will be the same for both sources, so the shape and degree of non-uniformity has little or no effect. This will be discussed in more detail later as a key strategy in calibration to reduce measurement uncertainty.

Figure 7. Response-Weighting in the Spectral Domain.

The consequence of instrument output being proportional to multiple weighted integrals is that the characteristics of the instrument affect the measured value in ways that cannot be easily extracted or corrected. Understanding non-uniformity in sensor response is critical to understanding performance and evaluating the effectiveness of the system.

INFRARED SOURCE CHARACTERISTICS

Reflectance

Reflectance is generally categorized as either *specular* (mirror-like) or *diffuse* (scattered by reflection from a rough surface). Most surfaces exhibit both types of reflection, but one typically dominates. Reflections from smooth surfaces are specular. Reflectance is a unitless quantity between zero and one that is the ratio of reflected power to the incident power. Reflectance varies with angle from the normal and with wavelength.

Diffuse reflectors scatter incident radiation broadly. Johann Heinrich Lambert described an ideal diffuse reflector in which the intensity of reflected rays is distributed as a cosine of the angle from the normal, regardless of the angles of the arriving incident rays. Such a surface is described as *Lambertian*. The same relationship applies to a diffuse source. If the source is perfectly diffuse, the radiance is independent of the viewing angle because the projected area of the source also varies as a cosine function of the angle from normal.

While no surface is perfectly diffuse, standard paint on most aircraft, for example, is near enough for at least a first approximation. Significant effort has gone into measuring and describing surface properties of military vehicles to support modeling and simulation activities. Bidirectional Reflectance Distribution Function (BRDF) is defined as the ratio of the reflected radiance to the incident irradiance at a wavelength, λ.

The BRDF provides a complete description of the reflectance properties of a surface. Measurements of BRDF are made in specially equipped optical laboratories. For aircraft, a typical use of BRDF data is in computer models that predict the reflections of the earth and sun from the aircraft fuselage and wings.

Emissivity

Emissivity is a unitless quantity that is a measure of the efficiency of a surface as an absorber or emitter. Emissivity is expressed as a number between 0.0 and 1.0. According to Kirchoff's Law, for an opaque object in thermal equilibrium, i.e., no net heat transfer, the emissivity equals the absorptance. In other words, a perfect emitter is also a perfect absorber. This ideal emitter is known as a *blackbody*. A surface with an emissivity of 1.0 emits the maximum radiation that Planck's Law allows. A body for which the emissivity is constant with wavelength but less than 1.0 is commonly known as a *graybody*. Planck's equation is typically expressed for an ideal blackbody emitter, but multiplying the blackbody expression by the emissivity term expresses the spectral distribution of power for a graybody.

Electromagnetic (EM) radiation, including infrared radiation, can be characterized by amplitude, frequency (or wavelength), coherency, and polarization properties. Amplitude refers to the magnitude of the electromagnetic wave. Coherency refers to the degree in which the electromagnetic waves maintain a constant phase difference, both spatially and temporally. Polarization is a description of the orientation of the wave's propagation perpendicular to the direction of travel. Like all electromagnetic radiation, infrared radiation travels as an EM field with the propagation velocity of the speed of light in a vacuum, and slower through air and other dielectrics. , Infrared radiation also exhibits both wave and particle properties. Which property is used depends on the application: Waves are used for applications involving propagation and geometrical optics, while particles (photons) are used for most detector applications. The energy of a photon is inversely proportional to its wavelength (*hc*/λ) where *h* is the Planck's constant, and *c* is the speed of light.

Infrared radiation also interacts with matter in a variety of ways:

- Reflects – wave is reflected from a surface.
- Refracts – direction of wave bends when passing between two transparent media with different propagation speeds.
- Scatters – when interacts with particles whose size approaches the wavelength of the radiation.
- Diffracts – around edges of an obstruction.
- Interferes – constructively and destructively.
- Absorbs – when absorbed by matter, radiation is (usually) converted into heat energy.
- Emits – radiation is emitted from matter by conversion from another form of energy.
- Transmitted – propagates through a transparent medium (or vacuum).

Plank's Law:

Infrared is directly related to the heat radiated from matter. Anything with a temperature above absolute zero (-273.15 degrees Celsius) radiates in the infrared. Planck's Law, discovered by German Physicist Max Planck, mathematically describes the distribution of radiant power across the spectrum for a given temperature. The form presented below calculates source radiance in Watts/sr/cm^2/ μ:

$$L_\lambda = \frac{C_1}{\pi\lambda^5\left[e^{\left(\frac{C_2}{\lambda T}\right)} - 1\right]}$$

Where: $C_1 = 2\pi c^2 h = 3.7415 \times 10E{+}04$ W cm^{-2} μ^4
$C_2 = ch/k = 1.4389E{+}04$ μ K
c = speed of light; h = Plank's constant; k = Boltzmann's constant
With λ in μ and T in Kelvin (= ºC + 273.15)

The behavior of Planck's curve with temperature is fundamental to every infrared detection scenario. Figure 8 shows Planck's equation for a single temperature. The shape of this curve resembles a wave of water, with a steep rise in power on the short wavelength side of the peak and a tail off on the long wavelength side.

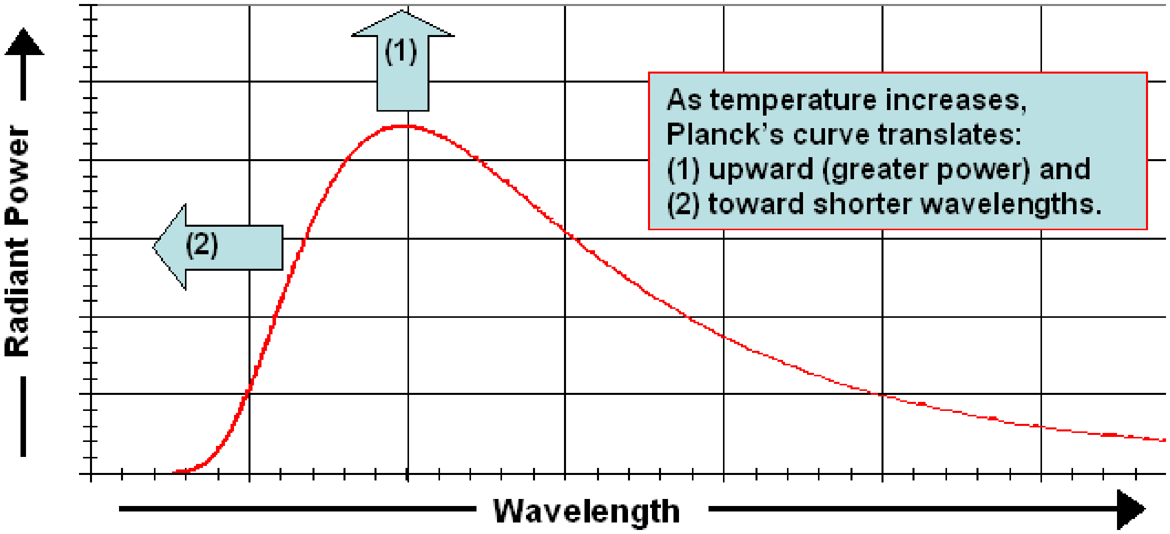

Figure 8. Temperature Effects and Power Distribution.

When temperature increases, two significant changes in power distribution occur and are governed by the following two relationships:

Stefan-Boltzmann Law:

The total power under the curve increases proportionally to the fourth power of the temperature. According to the Stefan-Boltzmann law, the total radiant emittance (power) of a blackbody is:

$$M = \sigma T^4 \qquad \text{Where:} \quad \sigma = \frac{2\pi^5 k^4}{15 c^2 h^3} = 5.67 \times 10^{-12}\ \text{Watts cm}^{-2}\ {}^\circ K^{-4}$$

and T is in Kelvin

This is Plank's radiation law integrated over all values of λ.

Wein's Displacement Law

The peak emission translates toward shorter wavelengths.

Wein's displacement law takes the derivative of the Plank's law equation to find the wavelength for maximum spectral exitance (emittance) at any given temperature:

$$\lambda_{max} = 2897.8 / T$$ where T = temperature is in Kelvin

The surface of the sun radiates with a spectral distribution like that of a 5900 Kelvin source. In accordance with Wein's Law, the wavelength at which the radiation for a 5900 Kelvin source peaks is approximately 490 nanometers. The maximum sensitivity of the day-adapted human eye (photopic) occurs at about 555 nanometers, which happens to be in a highly transparent region of the atmosphere. In other words, the temperature of our sun and the transmission of our atmosphere are conveniently matched to the response of the human eye. Figure 9 shows the relationship between the response of the human eye and the spectral distribution of solar irradiance.

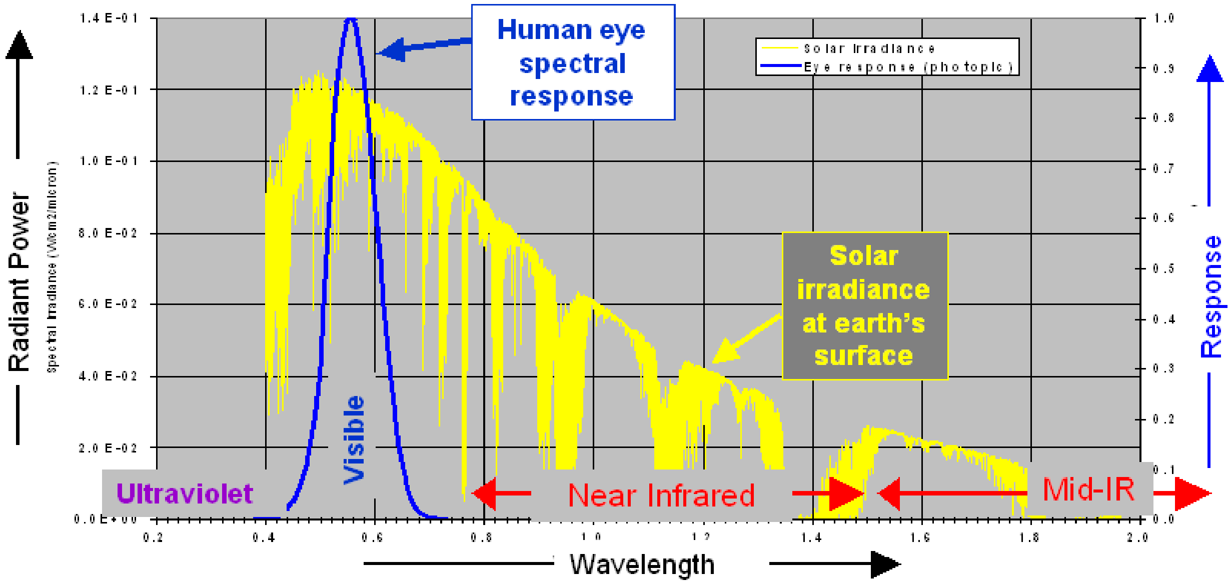

Figure 9. Power Distribution of the Sun Related to the Human Eye.

Unlike other electromagnetic radiation, the peak radiation from objects at the temperature of the earth, and of humans, vehicles, aircraft, etc., lies at infrared wavelengths. This makes the infrared portion of the spectrum militarily important.

For detection of an object, whether it is with the human eye or with an electro-optical sensor, it is not where the maximum emissions occur in the spectrum that is important. It is where the maximum difference between the target and background lies that is most significant.

The *absolute* signature of a source or target is the power radiated and reflected by the target without influence from background radiation. Absolute signature can be measured with an instrument such as an imaging camera at close range, producing highly resolved IR imagery. The difference between radiation from a target and its background is its *contrast*. Contrast is the target signature relative to a specific background. Contrast irradiance is the quantity detected by any remote sensor or missile. Contrast varies greatly with background conditions.

Figure 10 shows several different types of source distributions encountered by infrared sensors. Most targets of military interest are a complex combination of spectral contributions from a variety of sources. For example, the signature of an aircraft can typically be described by the contributions from airframe, hot engine parts, and plume.

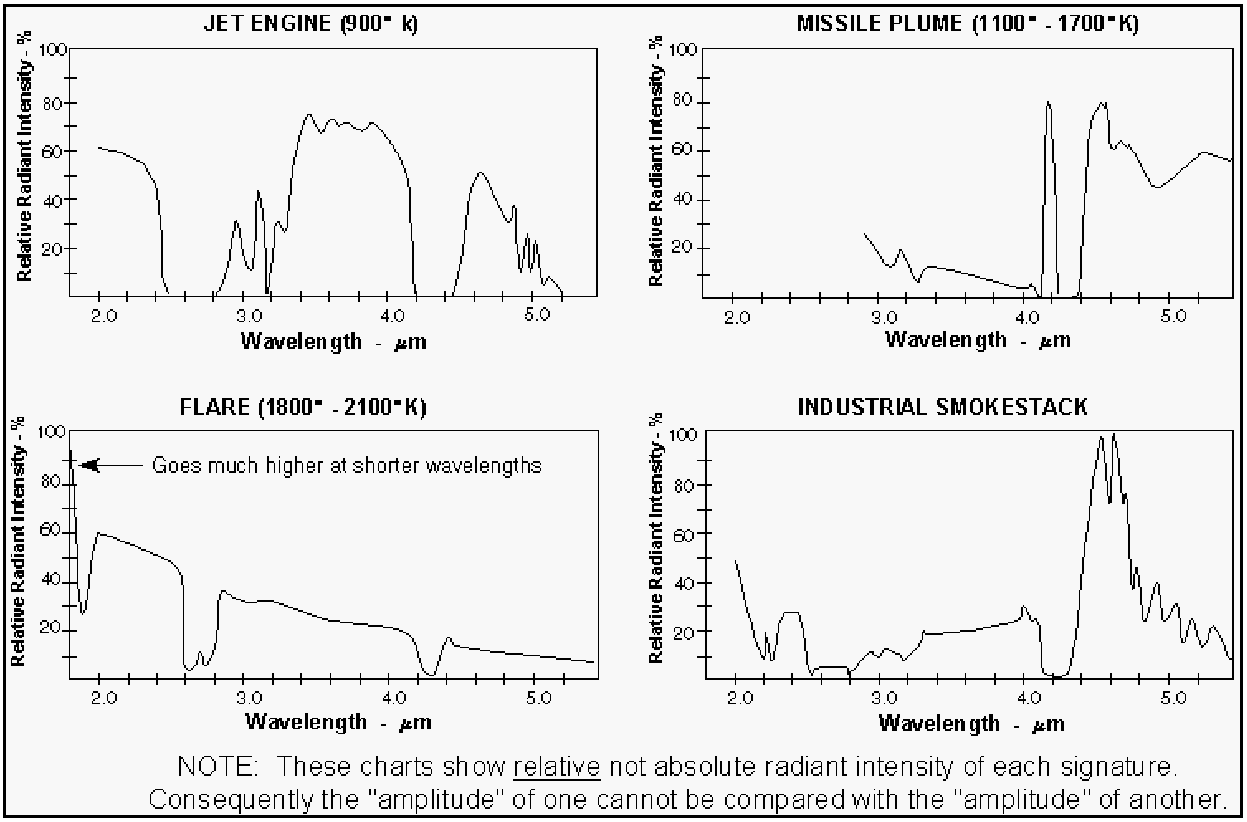
JET ENGINE (900° k)

MISSILE PLUME (1100° - 1700°K)

FLARE (1800° - 2100°K)

INDUSTRIAL SMOKESTACK

NOTE: These charts show relative not absolute radiant intensity of each signature. Consequently the "amplitude" of one cannot be compared with the "amplitude" of another.

Figure 10. Spectral Distribution of Various Targets.

ATMOSPHERIC TRANSMISSION

The radiation emitted or reflected from the targets and backgrounds must pass through the intervening atmosphere before reaching the detection system. The radiation is absorbed and re-emitted by molecular constituents of the atmosphere and scattered into and out of the path by various aerosol components.

Figure 11 reveals the presence of atmospheric windows, i.e. regions of reduced atmospheric attenuation. IR detection systems are designed to operate in these windows. Combinations of detectors and spectral bandpass filters are selected to define the operating region to conform to a window to maximize performance and minimize background contributions.

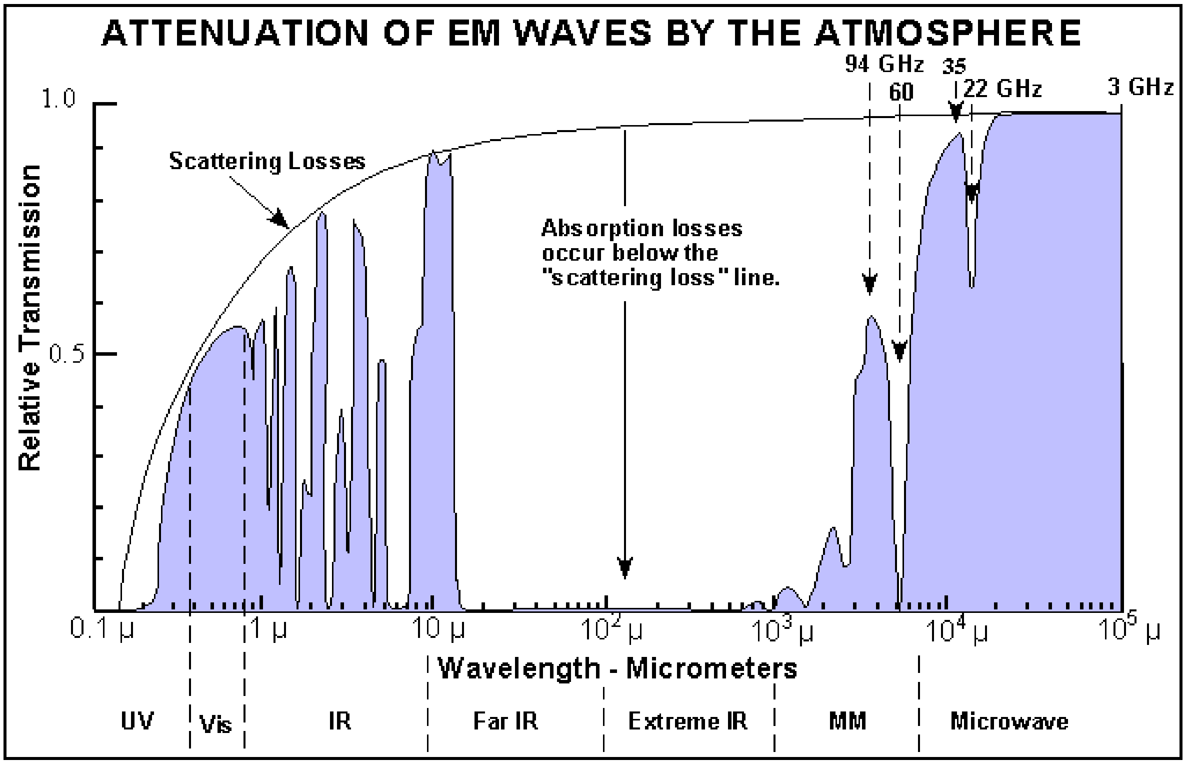

Figure 11. Atmospheric Transmission Over 1 NM Sea Level Path.

The molecules that account for most of the absorption in the IR region are water, carbon dioxide, nitrous oxide, ozone, carbon monoxide, and methane. Figure 12 shows an expanded view of the infrared portion of the spectrum.

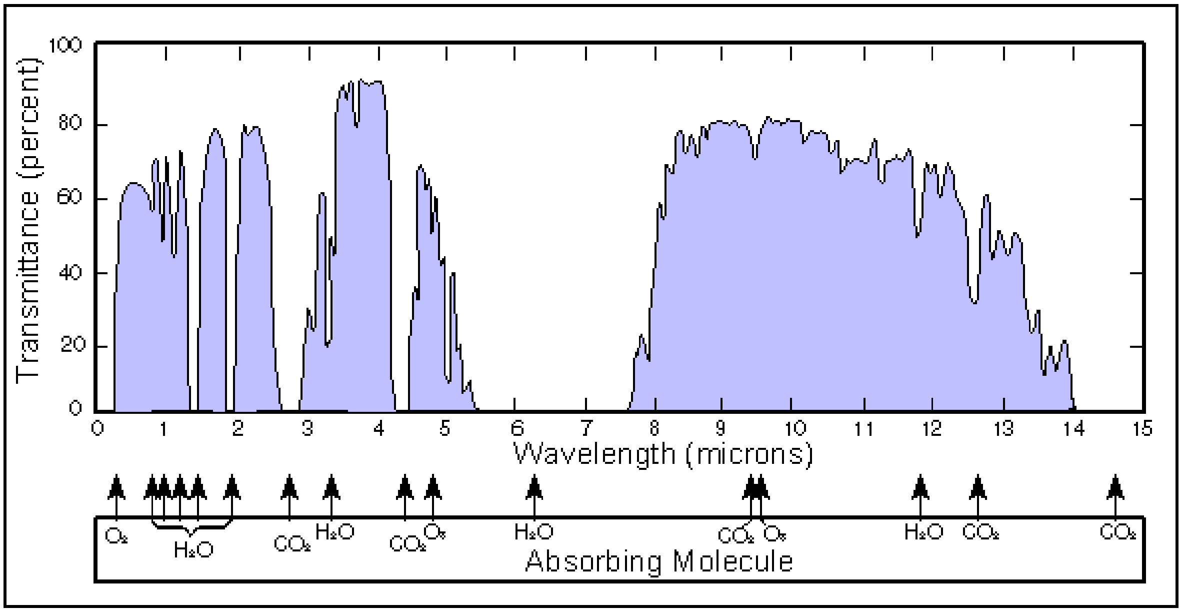

Figure 12. Transmittance of Atmosphere Over 1 NM Sea Level Path (Infrared Region).

The transmission in a window is greatly dependent on the length and characteristics of the path. As path length increases, absorption gets deeper and broader. Water vapor also has a significant effect overall on transmission through the atmosphere. High relative humidity attenuates transmission at all optical wavelengths.

Since water vapor generally decreases with altitude, transmission generally increases and path length becomes the determining factor. However, path length does not affect transmission of all wavelengths the same.

The altitude effects on transmittance are shown in Figure 13.

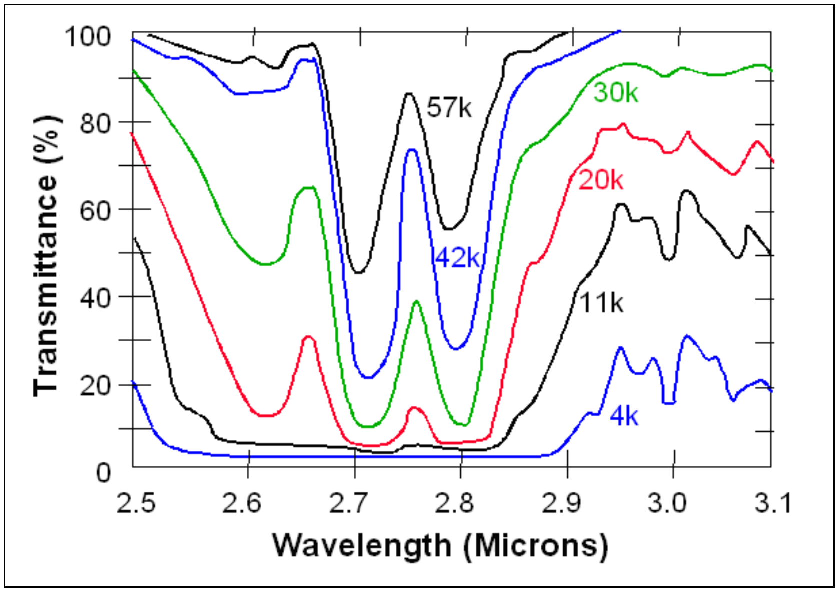

Figure 13. Transmittance at Various Altitudes.

A great deal of work has gone into developing high fidelity atmospheric models. One of the most commonly used tools is MODTRAN™ (MODerate Resolution Atmospheric TRANsmission). MODTRAN™ models atmospheric propagation of EM radiation from 0.2 to 100 um. MODTRAN was developed by Spectral Sciences Inc. and the United States Air Force Research Laboratory.

ELECTRO-OPTICAL COMPONENTS AND SENSORS

Almost all IR instruments, missiles, search systems, etc. have similar functional components. Basic components typically include:

- Optics - Reflective or refractive lenses to:
  - Collect radiation. Irradiance (power density) is increased by collecting radiation over a large area and focusing down to a small area.
  - Form or focus an image that will be used to extract information about the target.

- Filter(s) - Spectral and spatial filters to distinguish target from background and to extract
  - Target information.
  - Spectral filters restrict sensitive wavelength range.
  - A spatial filter separates image information by features such as size or position.

- Detector - A transducer to convert received radiation to an electrical signal for processing.

- Electronics - Used to amplify and condition the detector signal and perform some action, such as controlling a servo for tracking and guidance or recording the received information. In addition to the above, the optical head may also contain a window to protect the electronics and an output unit consisting of indicators or displays.

Windows / Domes / Lens Materials

For most applications of EO systems in EW the detection system is protected from the environment by a window or dome of optically transmissive material. The window operates both as a weather seal and, in some cases, helps to define the spectral response region of the system. In some cases the window functions as a lens.

IR energy interacts with matter in ways we associate with light (reflection, refraction, and transmission). Lower energy of IR photons results in different optical properties than light. For example:

- Glass and water are not transparent to wavelengths longer than about 3 microns.
- Silicon and germanium are highly transparent to infrared radiation, but are opaque to visible light.

Transmission bands of representative window or lens materials are shown in Figure 14. The end points depicted are for the 10% transmission wavelengths. Not shown in Figure 14 are the various UV transmissive glasses such as Pyrex, Corex, and Vycor or Amorphous Material Transmitting IR radiation (AMTIR) which are various combinations of Ge-As-Se (AMTIR-1), As-Se (AMTIR-2, 4, & 5), Ge-Sb-Se (AMTIR-3), As-S (AMTIR-6).

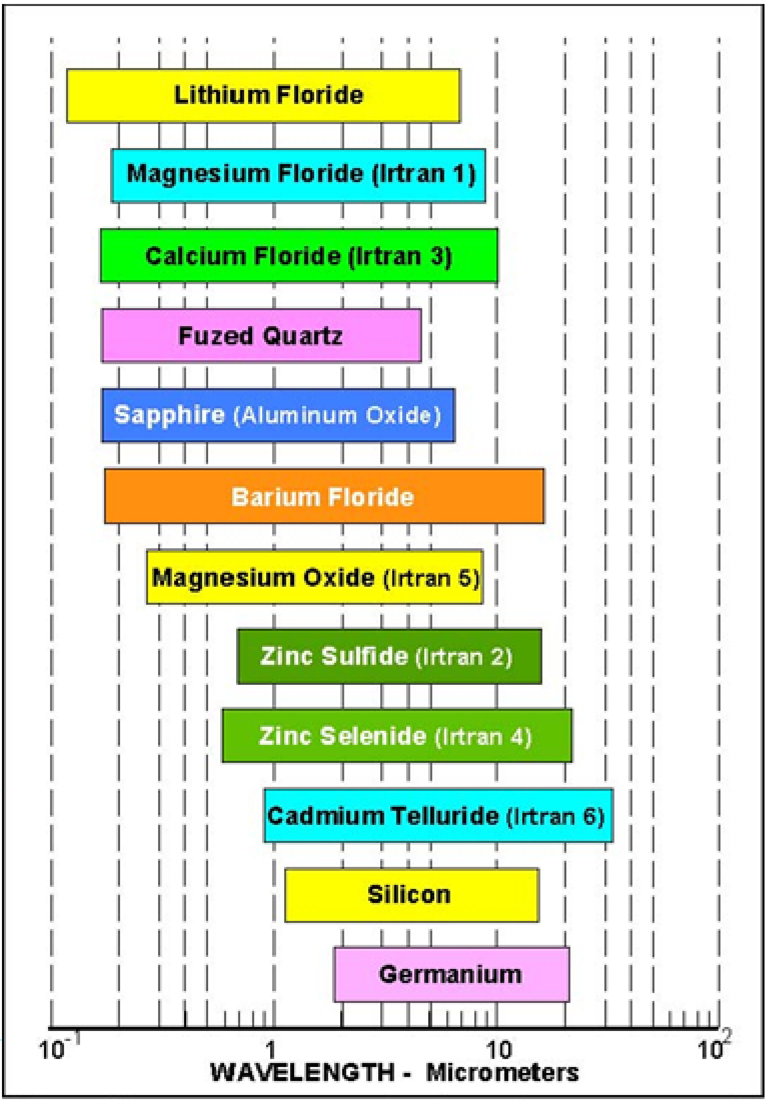

Figure 14. Transmission of Selected Window / Lens Materials.

Objective Lens

The objective lens is the first optical element in a lens in a typical sensor or missile seeker. The objective lens serves two main functions:

- Collect radiation (i.e., multiply irradiance (power density) by collecting over a large area and focusing onto a small area)
- Form an image of the target scene onto a filter and detector array.

Lens Types

Lenses for the IR can be either refractive or reflective. Refractive optics are “straight through” lenses, with the light never making large bends as shown in Figure 15.

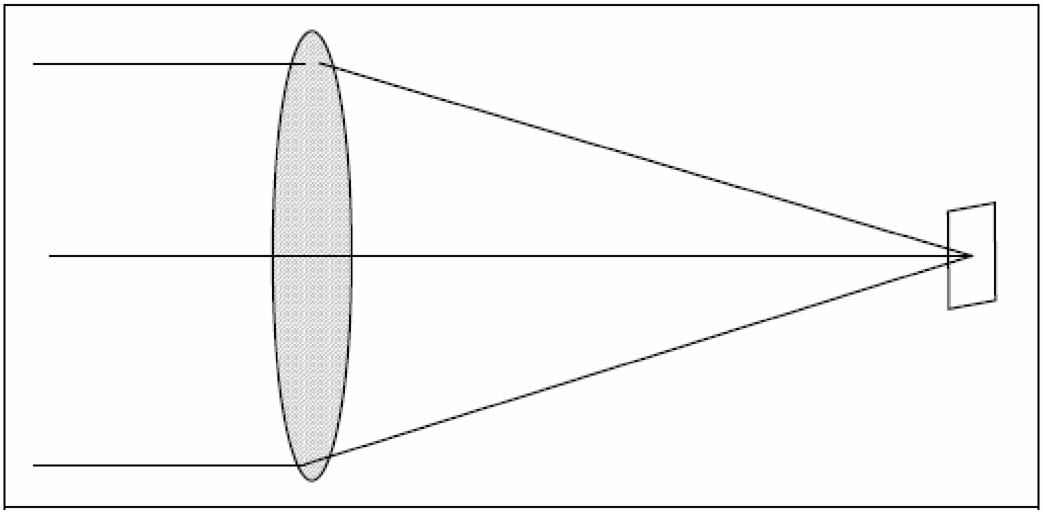

Figure 15. Refractive Lens.

A common reflective design used in many missiles is the Cassegrain. The Cassegrain design shown in Figure 16 is compact in size for its focal length.

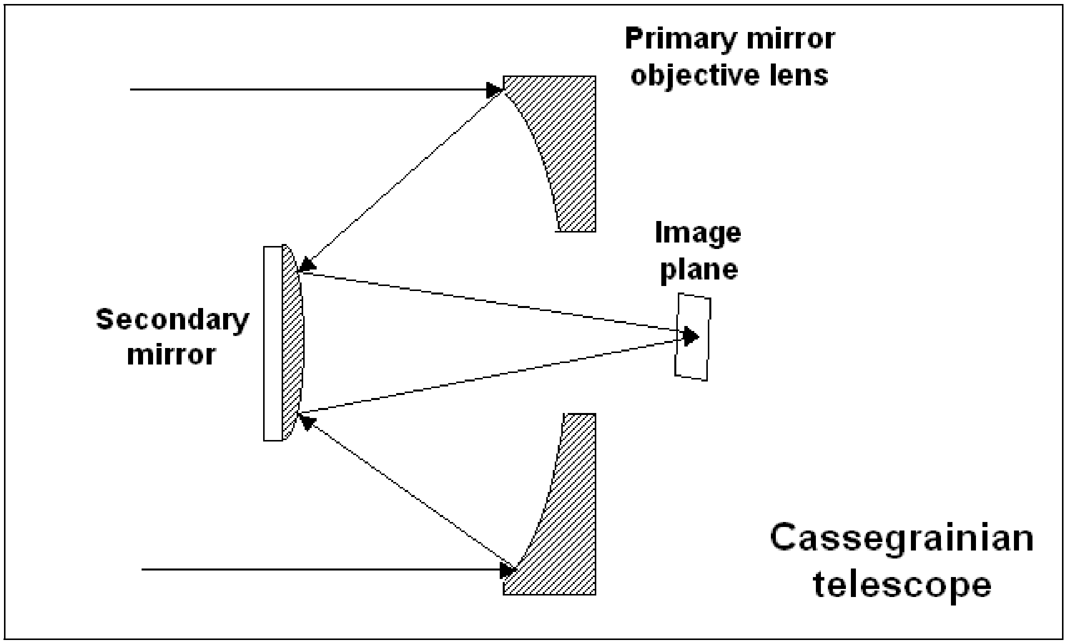
Primary mirror
objective lens
Image
plane
Secondary
mirror
Cassegrainian
telescope

Figure 16. Cassegrain Lens.

Optical Filters

Filters may be divided into two major categories: (1) spectral and (2) spatial.

Most optical radiation detectors have a wider sensitivity band than desired for the particular application. Spectral filters restrict sensitive wavelength range. Reasons for filtering include: enhancement of target-to-background contrast, avoidance of unwanted plume emissions and/or atmospheric absorption regions, and extraction and measurement of target spectral features.

To further define the system sensitivity, band interference filters or absorption filters are used. An absorption filter is a bulk material with a sharp cut-on or cut-off in its transmission characteristic. A cut-on and a cut-off filter can be combined to make a bandpass filter. By selecting absorption characteristics of absorption filters combined with the response of a detector, the desired system response can be obtained. An interference filter is composed of dielectric coatings on an appropriate substrate combined in such a way to produce cut-on, cut-off, or bandpass filters. Interference filters allow more control of the final response characteristics and smaller elements. See Figure 17.

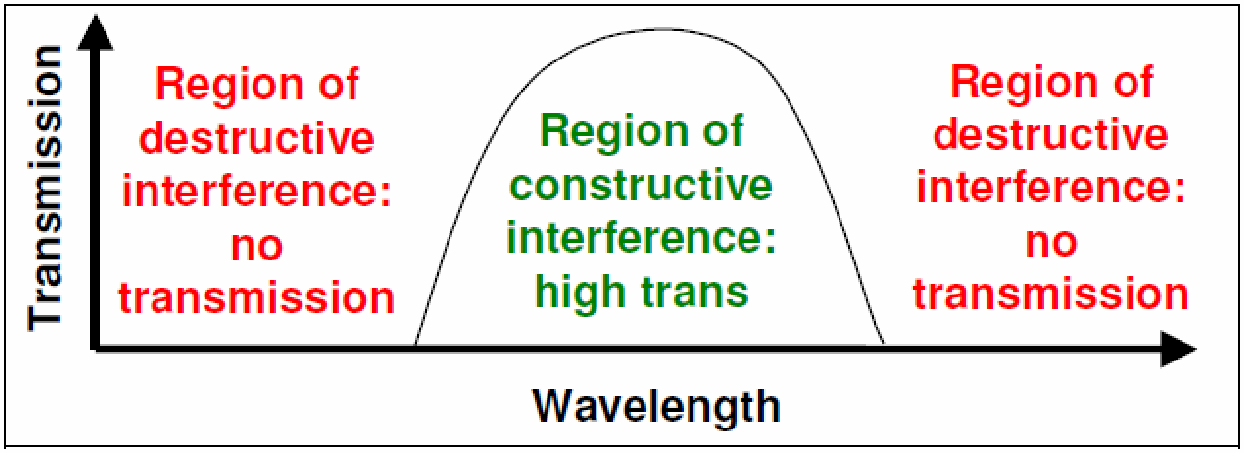
Transmission
Region of destructive interference: no transmission
Region of constructive interference: high trans
Region of destructive interference: no transmission
Wavelength

Figure 17. Spectral Bandpass Filter.

Most spectral filters are of the thin-film interference type. Layers of dielectric material are vacuum deposited on a substrate window material. Typical substrate materials in IR are sapphire, silicon, and germanium. Thickness of deposited layers designed to have constructive interference to pass desired radiation at desired wavelengths and destructive interference to block undesired wavelengths Besides spectral filters, EO system optics often have antireflection (or AR) coatings to eliminate or greatly reduce unwanted reflections between optical elements.

A spatial filter separates information in a scene image by features such as size or position. Spatial filters take a variety of forms. Some common types and their functions include:

- Field stop: limits an instrument's field of view. Blocks unwanted sources (such as sun) outside nominal field of view.
- Mechanical modulator or "chopper."
- Reticle: A mechanical modulator used in many missile designs. Usually discriminates against extended sources (such as background) in favor of "point" target sources and provides target directional information from modulation phase.

Detector Coolers

Many IR detectors have to be cooled for proper operation. Most systems use closed-cycle coolers or thermoelectric coolers. Thermoelectric coolers use the Peltier effect, which produces a reduced temperature by passing a d-c current through a thermoelectric junction. Multi-stage coolers can cool a detector down to below 200ºK. Closed-cycle coolers typically are of the Stirling cycle design and utilize the expansion of a gas (helium) to cool a cold finger attached to the detector. These generally operate at liquid nitrogen temperature (77ºK).

Detectors

A detector is a transducer that transforms electromagnetic radiation into a form, which can be more easily detected. In the detectors of interest to EW the electromagnetic radiation is converted into an electrical signal. In some systems the signal is processed entirely within the system to perform its function. In others the signal is converted to a form to allow the human eye to be used for the final detection and signal analysis.

Detectors are transducers than convert optical radiation into electrons. The physical effects by which electromagnetic radiation is converted to electrical energy are divided into two categories: photon effects and thermal effects. EW systems primarily use detectors dependent on photon effects. These effects can be divided into internal photo effects and external photo effects.

The external photo effect is known as photoemission. In the photoemissive effect, photons impinging on a photocathode drive electrons from its surface. These electrons may then be collected by an external electrode and the photocurrent thus obtained is a measure of the intensity of the received radiation.

Internal photoeffects of interest are the photoconductive effect and the photovoltaic effect. In the photoconductive effect, absorbed photons cause an increase in the conductivity of a semiconductor. The change is detected as a decrease in the resistance in an electrical circuit. In the photovoltaic effect, absorbed photons excite electrons to produce a small potential difference across a p-n junction in the semiconductor. The photovoltage thus produced may be amplified by suitable electronics and measured directly.

Thermal detectors respond directly to heat. Examples of these devices include bolometers, thermopiles, and pyroelectric detectors. The pyroelectric effect is an example of the thermal effect. The pyroelectric effect is a change in polarization in a crystal due to changes in temperature. Radiation falling on such a crystal is detected by observing the change in polarization as a build up of surface charge due to local heating. When coated with a good black absorber, the crystal will be sensitive to a wide band of wavelengths.

Figure 18 shows the spectral sensitivity range of typical detectors using these effects.

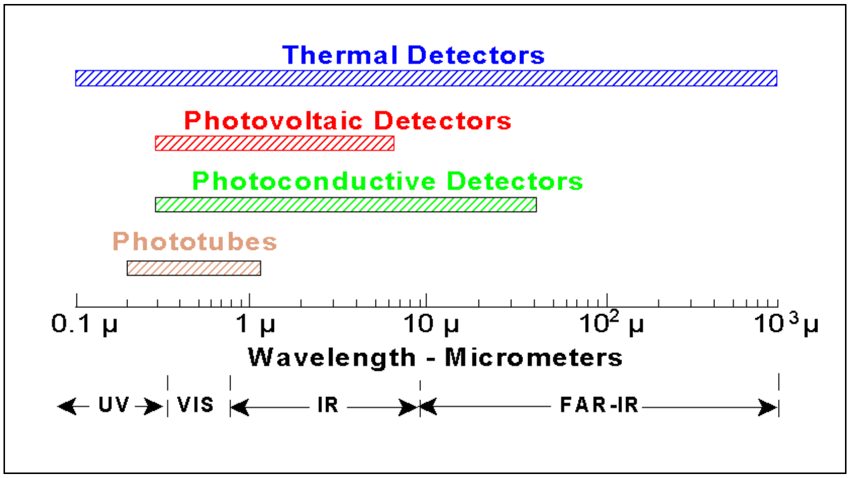

Figure 18. Spectral Range of Various Detectors.

Detector Types

Photoconductive detectors operate as resistors in a circuit. The resistance of the detector changes as the radiation incident on its surface changes. For EW applications, the most photoconductive detector types include: Indium Antimonide (InSb), which can also be operated in photovoltaic mode; Gallium Arsenide (GaAs); Lead Sulfide (PbS); and Lead Selenide (PbSe).

Photovoltaic detectors, the most common detectors used in modern EW and military sensor applications, produce a voltage that is proportional to the incident radiation. Common examples of photovoltaic detectors are Indium Antimonide (InSb) and Mercury Cadmium Telluride (HgCdTe). Both of these detector types offer high sensitivity when cryogenically cooled.

Diode phototubes and photomultipliers are commonly used detectors for UV systems including many operational missile-warning systems. These types of tubes offer the advantage of operating uncooled which can significantly reduce the complexity of a sensor system and offer increased reliability. Most of the modern IR sensors require cooled detectors. InSb, for example, requires cooling to 77 Kelvin to achieve the necessary sensitivity. Depending on the application, HgCdTe can be operated at somewhat higher temperature conditions.

A Photoelectromagnetic (PEM) detector has a junction that generates a current when exposed to light in a magnetic field.

Some detectors (such as InSb) have multiple modes of operation, including: Photoconductive (PC), Photovoltaic (PV), or Photoelectromagnetic (PEM) modes of operation.

Detector Parameters and Figures of Merit

The important parameters in evaluating a detector are the spectral response, time constant, the sensitivity, and the noise figure.

The spectral response determines the portion of the spectrum to which the detector is sensitive.

The time constant is a measure of the speed of response of the detector. It is also indicative of the ability of the detector to respond to modulated radiation. When the modulation frequency is equal to one over the time constant, the response has fallen to 70.7 % of the maximum value. The time constant is related to the lifetime of free carriers in photoconductive and photovoltaic detectors and to the thermal coefficient of thermal detectors. The time constant in photoemissive devices is proportional to the transit time of photoelectrons between the photocathode and anode.

The sensitivity of a detector is related to its responsivity. The responsivity is the ratio of the detected signal output to the radiant power input. For photoconductive and photovoltaic detectors the responsivity is usually measured in volts per watt -- more correctly, RMS volts per RMS watt. However, the sensitivity of a detector is limited by detector noise. Responsivity, by itself, is not a measure of sensitivity. Detector sensitivity is indicated by various figures of merit, which are analogous to the minimum detectable signal in radar. Such a quantity is the noise equivalent power (NEP). The NEP is a measure of the minimum power that can be detected. It is the incident power in unit bandwidth, which will produce a signal voltage equal to the noise voltage. That is, it is the power required to produce a signal-to-noise ratio of one when detector noise is referred to unit bandwidth. The units of NEP are usually given as watts, but more correctly, are watts/$\mathrm{Hz}^{1/2}$ or watts·$\mathrm{sec}^{1/2}$.

Another figure of merit is the noise equivalent irradiance (NEI). The NEI is defined as the radiant power per unit area of the detector required to produce a signal-to-noise ratio of one. The units of NEI are watts per square centimeter.

Noise equivalent power (NEP) is the radiant power required to produce a signal to noise ratio of one for a detector. Detectivity (D) of a detector is defined as the reciprocal of the NEP. The units of D are watts $^{-1}$·sec $^{-½}$. A higher value of detectivity indicates an improvement in detection capability. Since D depends on detector area, an alternate figure of merit, known as D-star (D*). D* is the detectivity measured with a bandwidth of one hertz and reduced to a responsive area of one square centimeter. The units of D* are cm·watts $^{-1}$·sec $^{-½}$. D* is the detectivity usually given in detector specification sheets. Typical spectral detectivity characteristics for various detectors are shown in Figure 19.

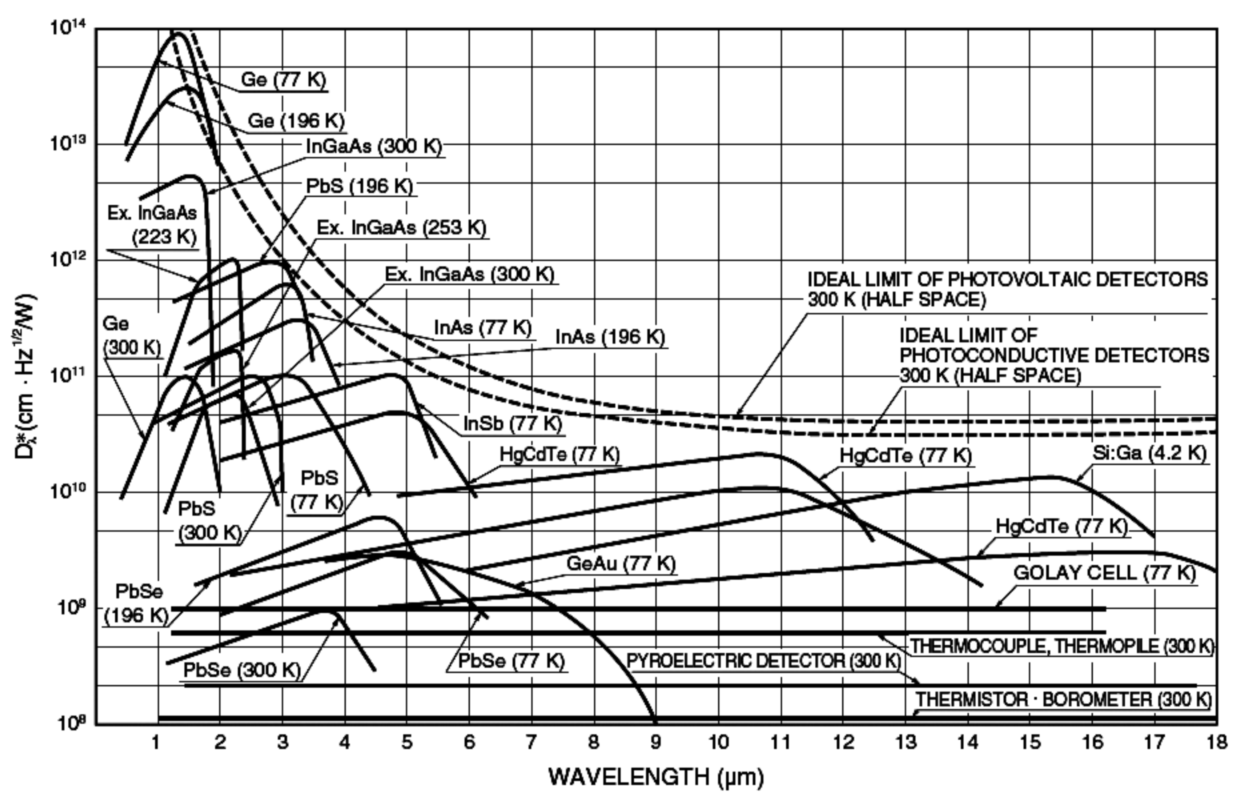

Figure 19. Spectral Detectivity of Various Detectors.

Besides the NEI mentioned above, the quantum efficiency of the photocathode is also a figure of merit for photoemissive devices. Quantum efficiency is expressed as a percent -- the ratio of the number of photoelectrons emitted per quantum of received energy expressed as a percent. A quantum efficiency of 100 percent means that one photoelectron is emitted for each incident photon.

There are other figures of merit for television cameras. The picture resolution is usually described as the ability to distinguish parallel black and white lines and is expressed as the number of line pairs per millimeter or TV lines per picture height. The number of pixels in the scene also defines the quality of an image. A pixel, or picture element, is a spatial resolution element and is the smallest distinguishable and resolvable area in an image. CCD cameras with 512 x 512 elements are common.

Another resolution quantity is the gray scale, which is the number of brightness levels between black and white a pixel can have.

Noise in Detectors

The performance of a detector is limited by noise. The noise is the random currents and voltages that compete with or obscure the signal or information content of the radiation. Five types of noise are most prominent in detectors: (1) thermal, (2) temperature, (3) shot, (4) generation-recombination, and (5) 1/f noise.

Thermal noise, also known as Johnson noise or Nyquist noise, is electrical noise due to random motions of charge carriers in a resistive material.

Temperature noise arises from radiative or conductive exchange between the detector and its surroundings, the noise being produced by fluctuations in the temperature of the surroundings. Temperature noise is prominent in thermal detectors.

Shot noise occurs due to the discreetness of the electronic charge. In a photoemissive detector shot noise is due to thermionic emission from the photocathode. Shot noise also occurs in photodiodes and is due to fluctuations in the current through the junction.

Generation-recombination noise is due to the random generation and recombination of charge carriers (holes and electrons) in semiconductors. When the fluctuations are caused by the random arrival of photons impinging upon the detector, it is called photon noise. When it is due to interactions with phonons (quantized lattice vibrations), it is called generation-recombination noise. Johnson noise is predominant at high frequencies, shot noise predominates at low frequencies, and generation-recombination and photon noise are predominant at intermediate frequencies.

As the name implies, 1/f noise has a power spectrum that is inversely proportional to frequency. It is dominant at very low frequencies. In photoemissive detectors it is called flicker noise and has been attributed to variation in the emission from patches of the photocathode surface due to variation in the work function of the surface. In semiconductors 1/f noise is also called modulation noise. Here it is apparently due to surface imperfections and ohmic contacts (which are a form of surface imperfection).

Infrared Spectral Region and Features of Interest

Different portions of the infrared spectrum are common for particular applications. The reasons for the selection of a specific window are often sensitive and beyond the scope of this document, but selections are typically based on several key considerations:

- Target characteristics such as size and spectral distribution of signature.
- Background radiance and clutter.
- Atmospheric effects (transmission, path radiance, scintillation, etc.).
- Distinguishing characteristics between natural and man-made sources.

Table 6 describes some of the types of characteristics that are prevalent in the short-wavelength (SWIR) infrared (0.7 to 3.0 microns), mid-wavelength (MWIR) infrared (3.0 to 6.0 microns) and long-wavelength (LWIR) infrared (7.0 to 14.0 microns) along with some types of systems that operate in these regions.

Table 6. Infrared Features, Regions, and Types of Systems.

Near or Short Wave IR (SWIR)	**Dominant natural source:**	**Sun**
	Atmospheric:	
	Transmission:	High
	Path radiance:	Scattered sunlight
	Dominant aircraft IR component:	Sunlit airframe
	Anti-aircraft threat:	Vehicle-launched SAM
Mid-wave IR (MWIR)	**Dominant natural source:**	**Sun**
	Atmospheric:	
	Transmission:	High transmission “windows” between H_2O and CO_2 absorption
	Path radiance:	Scattered sunlight below 3 microns Thermal at longer than 3 microns
	Dominant aircraft IR component:	Engine hot parts and plume
	Anti-aircraft threat:	All AAMs and SAMs
Far or Long-wave IR (LWIR)	**Dominant natural source:**	**Earth**
	Atmospheric:	
	Transmission:	High
	Path radiance:	Low: small thermal emission from ozone
	Dominant aircraft IR component:	Airframe direct emission and terrestrial illumination
	Anti-aircraft threat:	Airborne IRST. No anti-aircraft missiles

Sensors and Detection

Figure 20 shows a generalized detection problem. On the left of the diagram are the radiation sources - the sun, background, and the target of interest. In the middle is the intervening atmosphere, which attenuates the radiation as it travels to the detection system shown on the right of the diagram.

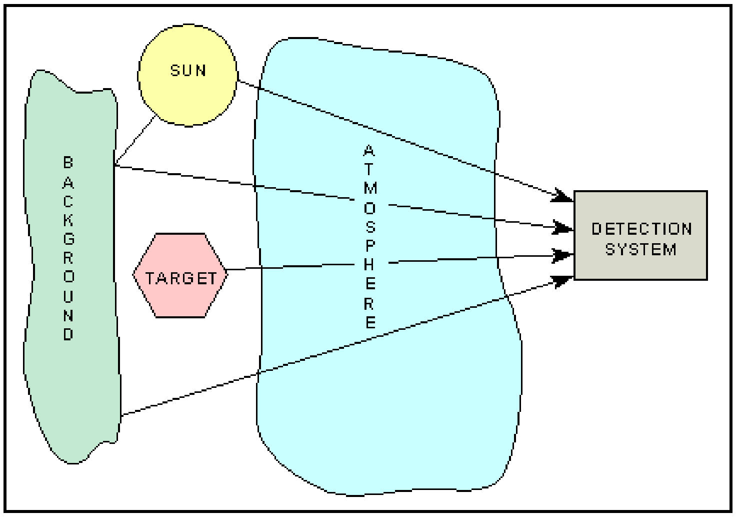

Figure 20. Generalized Detection Problem.

Figure 21 shows the basic relationships that are critical to detection of a target in the infrared. The figure is based on a generalized aircraft, but the principles apply whether the target is in fact an aircraft against a sky background or a ground vehicle being viewed from above against a terrain background. At detection, most targets are unresolved. The sensor’s ability to detect the target against background in this case is driven primarily by noise equivalent irradiance.

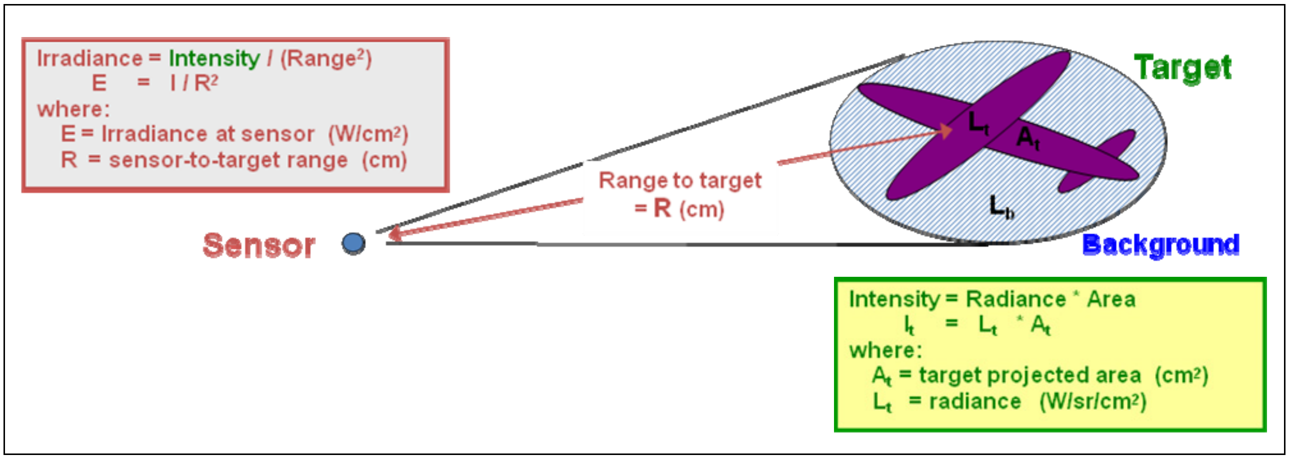
Irradiance = Intensity / (Range²)
E = I / R²
where:
E = Irradiance at sensor (W/cm²)
R = sensor-to-target range (cm)
Sensor
Range to target
= R (cm)
Target
L_t
A_t
L_b
Background
Intensity = Radiance * Area
I_t = L_t * A_t
where:
A_t = target projected area (cm²)
L_t = radiance (W/sr/cm²)

Figure 21. Detection of a Target with a Remote Sensor.

Each of the equations shown in Figure 21 in reality has atmospheric effects and attenuation due to transmission losses and contributes to path radiance. Just as the power distribution of the target and background vary with wavelength, atmospheric effects are also spectrally selective.

Figure 22 shows the roll off of irradiance as a function of range for two different aircraft. Detection occurs at the point of intersection with the sensors noise equivalent irradiance. In the case of threat missiles, there is often a signal-to-noise threshold required for launch of the missile to ensure target quality prior to launch. The product of noise equivalent irradiance and the threshold for these systems is known typically as the minimum trackable irradiance (MTI). This is the figure used to calculate detection range for such systems.

In an effort to simplify calculations, band average atmospheric transmission values are often applied during analysis of detection scenarios. The target itself is non-uniformly distributed as a function of wavelength, and the atmospheric effect is non-uniform, so this approach is mathematically incorrect since it pulls a non-constant term out of an integral. The degree of error introduced by the band average approach depends on the spectral distribution of the source and the overall transmission of the band in question, but caution should be applied when applying band averages. All calculations involving atmospheric propagation should be done spectrally and then integrated to provide the in-band value.

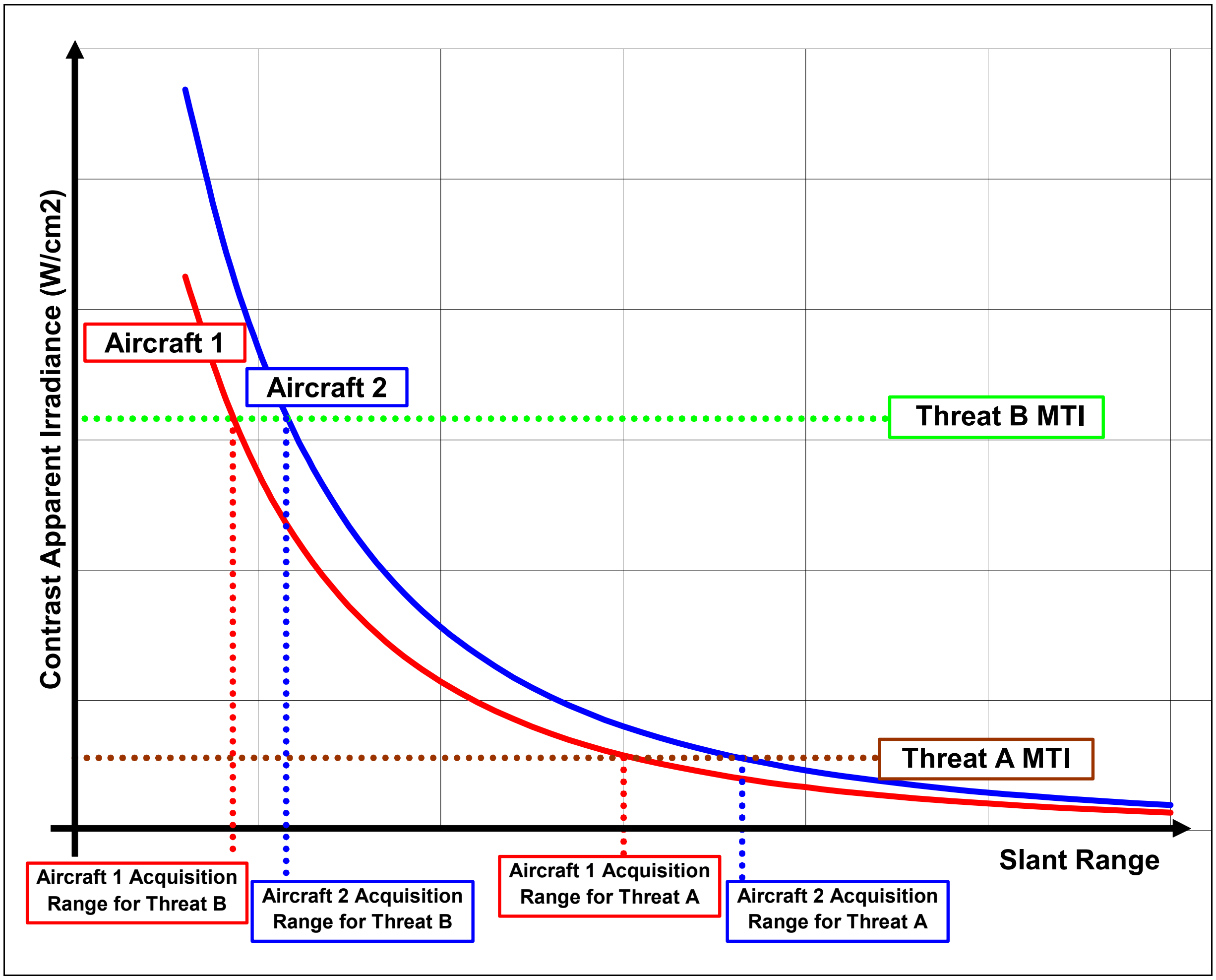

Figure 22. Detection Range Calculation.

Sensor Characterization

As described in a previous section, the output of every sensor is proportional to an integral of the received radiation weighted by the instrument's response function in that domain. Every sensor responds to radiation in accordance with the characteristics of the sensor and its components.

Characterization quantifies the sensor's response shape. Knowledge of response shape is essential to the design of a sensor and understanding its performance in with changing ambient conditions and against various types of targets in real environments.

Normalization

Calibration of a sensor, which describes its response to known input sources, and characterization of the sensor would ideally be the same process. Ideally, the absolute instrument response would be mapped over a domain with a traceable standard laboratory source that was tunable across the range of interest. In the spectral domain, for example, this would require a tunable monochromater whose output beam provided a level of spectral irradiance traceable to a radiation standard and that also had a cryogenically-cooled background source. The result would be an absolute spectral response function in units of output reading per unit radiance (or irradiance) as a function of wavelength.

In practice, it is sufficient and more practical to separate the characterization and calibration processes, so characterization determines only the relative response shape rather than absolute. Calibration then incorporates the results of the shape characterization to determine the absolute instrument response. Both, however, are important to understanding performance of a sensor.

Characterization uses a variety of different methods and sources to map relative response shapes. The response curve is then normalized and this normalized curve is used in the later derivation of the calibration coefficients. Different normalizations, such as normalization to an average value, are possible, but the convention throughout most of the measurement community today is to normalize response curves to unity at the peak.

When the contributions of all the components are combined into one curve, the result is then peak normalized and this, now unitless, curve is used in the calibration calculations.

Calibration

Sensor calibration, which is the process of relating the known input power to the output of a sensor, requires the use of standard sources, typically National Institute of Standards and Technology (NIST) traceable blackbodies and various other laboratory equipment such as collimators which make all of the rays coming from the source parallel to each other, thus representing a source at infinity. Figure 23 is a pictorial illustration of the calibration of a sensor.

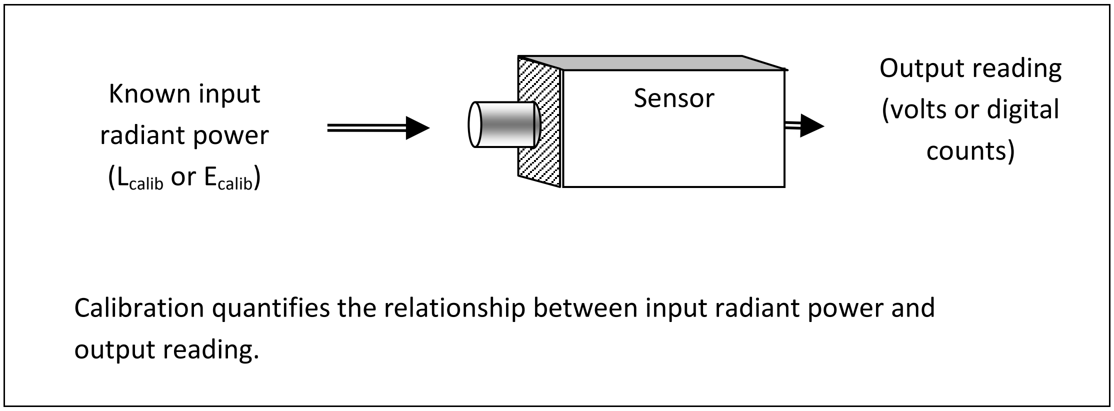
Known input radiant power (L_{calib} or E_{calib})
Sensor
Output reading (volts or digital counts)
Calibration quantifies the relationship between input radiant power and output reading.

Figure 23. Sensor Calibration Relates Input Power to Output.

Calibration of a sensor usually involves two major steps. Responsivity is the change in output of the sensor to changing input. For a sensor that responds linearly, for example, responsivity represents the slope of the curve when source radiance or incident irradiance is plotted against output voltage or counts for a digitized system. Figure 24 represents a calibration curve for a sensor that has a linear change in output over its dynamic range with changing input power. The slope of the curve is the “m” in the linear equation. Not all sensors respond linearly with power. Higher order response coefficients are common, especially for bolometers and infrared focal plane array sensors operated at short integration times. For these the process of determining the response of the instrument is the same, the curve just yields higher order terms.

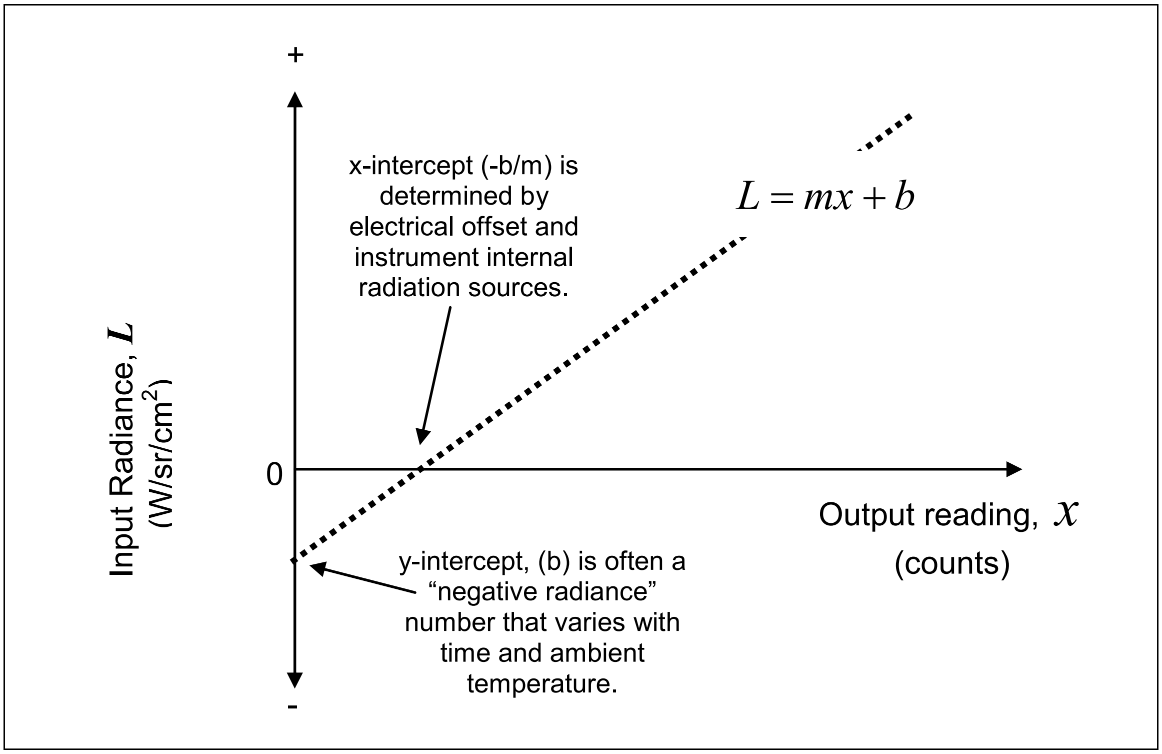

Figure 24. Calibration of a Sensor to Determine Responsivity and Offset.

For most electro-optical sensors, the responsivity does not change with ambient temperature. In other words, the non-constant terms in the calibration equation, whether it is linear or higher order, do not change with changes in temperature. Over time, however, as detectors decay, responsivity decreases. This would show itself on the Figure 24 as an increase in the slope value, i.e., higher input power is required for the same output as the detector becomes less responsive.

Offset

Offset is another important parameter for instrument calibration. For any real (non-ideal) instrument, the response curve does not pass through zero. There are several reasons for this; one being that except in a complete vacuum, zero radiance does not exist. Additionally, contributions from detector noise and radiation from the optical elements in the lens, which cause the offset to drift with changes in ambient temperature, contribute to the offset term. Some amount of offset is designed into the system as well. All electronic circuits have some amount of DC drift. To prevent clipping of the signal if this drift should go below the lower limit of the analog-to-digital converter, the “bottom end” level is adjusted up to some offset level. The consequence of this offset voltage is the addition of a y-intercept term (b), which also must be quantified by the calibration if the sensor is a laboratory instrument. For a sensor that is used for contrast detection, the intercept value is unimportant since it subtracts out in the contrast calculation.

Sensitivity

Sensitivity for a sensor is determined to a large extent by the noise level in the detector output. For focal plane array detector, pixel-to-pixel non-uniformity also limits the sensitivity of the system since detection is determined by contrast with surrounding pixels. In practice, at least for cooled infrared sensors, detection is typically limited by background and not noise limits.

Instrument Response Uniformity and Non-Uniformity Correction

In reality, all sensors exhibit non-uniform response in all of the domains referenced previously. For example, in the spatial domain, the raw output of an infrared focal plane array detector exhibits pixel-to-pixel offset differences and response differences across the field-of-view. The response change is the result of two primary factors. Since each pixel is essentially a unique detector, it exhibits unique response because of manufacturing tolerances, slight differences in crystal structure, etc. Additionally, most electro-optical sensors implement an aperture or "field stop" in the case of infrared sensors, that limits the radiation that can reach the detector outside of the sensor's desired field-of-view. Radiation entering at angles off of normal to the detector shows a cosine roll-off in incident power. The result is a reduction in responsivity for pixels that are radially separated from the center of the detector. For the majority of systems, an optical gain correction can be applied to compensate for the change in response. The typical method involves using an extended blackbody source that fills the FOV of the sensor. Reference images are collected with the source at two temperatures that are well separated across the sensor's dynamic range. This process is typically called a "2-point" correction. Actual temperature is unimportant. Slope corrections can be determined for each pixel. The result is a gain map that can be stored in the sensor electronics that can be applied to each image to correct for the non-uniform spatial response across the detector array. Pixel-to-pixel offset maps can be determined using one of the same reference images. Pixel slope and offset corrections are typically derived as normalized quantities relative to a center pixel, average of center pixels, or maximum value. The application of the correction maps to the images is commonly referred to as "non-uniformity correction." Figure 25 shows the transition from a raw image to a non-uniformity corrected image.

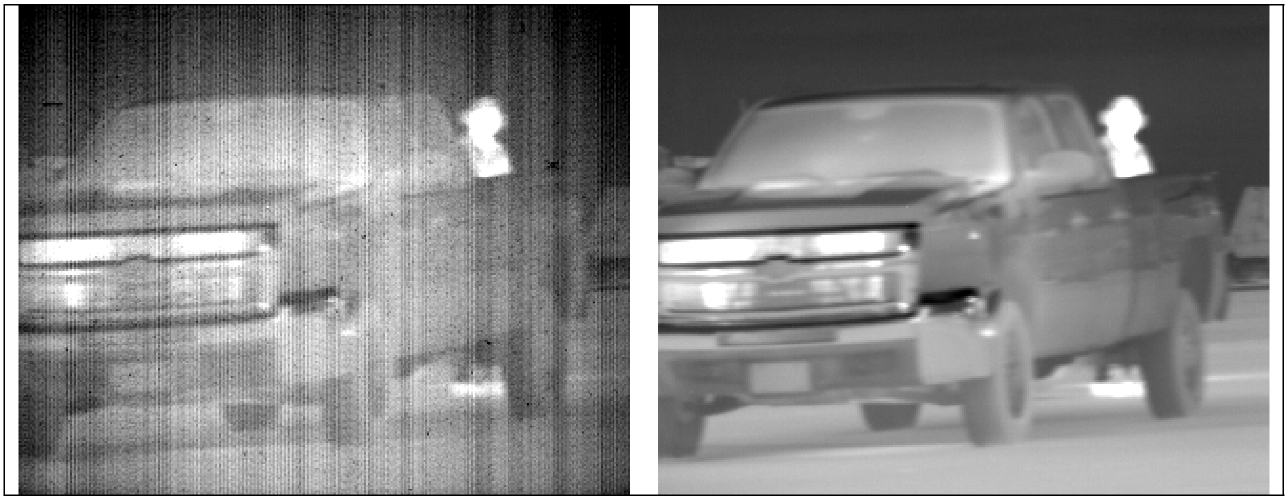

Figure 25. Non-Uniformity Correction of a Mid-IR Image.

Bad Pixel Replacement

Focal plane arrays have pixels that are either unresponsive or responsive outside of useful limits. Figure 25 shows some of the bad pixels that appear as small black spots in an image from an InSb IRFPA imager. Bad pixels can be identified during laboratory calibration or with a sensor mounted reference source. There are many approaches to replacement of bad pixels and the best approach often depends on the sensor characteristics and its application. One common approach is simply to replace the pixel with the average of its nearest neighbors.

INFRARED THREATS TO AIRCRAFT AND THEIR COUNTERMEASURES

IR guided missiles are the largest single cause for aircraft losses since the start of the 1991 Gulf war. All missiles designed within the last 20 years have counter-countermeasures circuitry. Every missile can be defeated with IR countermeasures given time to develop and test devices and techniques, but many missiles have not been exploited and the variety and complexity of the different designs present formidable challenges to the US countermeasure community.

The IR "signature" of any aircraft has three main components:

- Engine exhaust plumes
- Engine hot parts (tailpipe, etc)
- Airframe (aerodynamic heating & reflection from sun, earth, etc)

Infrared guided missiles modulate the signal produced by the aircraft in contrast with its background. Previous generations of missiles used reticles to produce signal waveforms that would provide spatial and temporal information from which signal processing could produce trackable information.

IR Missile Operation

Aircraft (or any other object) can be intercepted using several different types of guidance. The simplest type is pure pursuit, where the missile is always pointed directly at the target location. This is not aerodynamically efficient since the missile would follow a longer (curving) flight path when following a crossing target.

Most missile guidance systems are designed to lead the target so that intercept occurs at the point where the target will be at the time the missile arrives. This requires that the missile fly a course so the relative bearing to the target stays constant (constant "line of sight" angle). The LOS angle is determined by missile speed relative to the target (higher closing speed = smaller angle). The size of the angle isn't important; only that it be constant (zero line of sight rate) as shown in Figure 26.

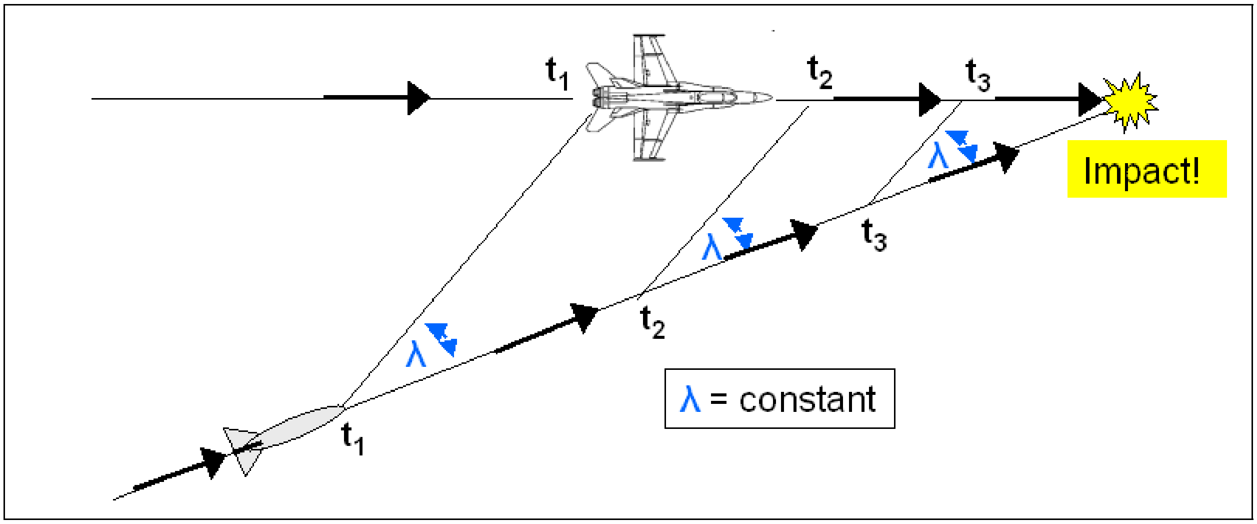

Figure 26. Missile Proportional Navigation.

This intercept course ("proportional navigation") requires that the missile have two separate servo loops: (1) a target tracker and (2) a wing control servo to control direction of flight

For a missile to guide to its intended target, it needs a tracker, which contains the following elements:

- Optics to collect and focus IR from target.
- Gimbals to allow movement to point the optics.
- Gyro stabilization to isolate optics from missile body.
- Detector to convert the received IR to electrical signal.
- Stabilization (gyro) to isolate from missile body.
- A method to determine target direction to enable closed-loop tracking.
- A method to distinguish the target from natural background.

The target tracker is the "window" into the missile's guidance through which it can be deceived by countermeasures.

The problem of determining target direction with a single detector was solved by forming an image of the target scene onto the center of a reticle disk that spun with the optics. Unlike, for example, the reticle in a rifle telescope that superimposes cross hairs, the reticle in a missile acts as a kind of shutter that blocks the passage of IR through part of the reticle and allows IR to pass through the other part. A target image falling on the opaque portion is blocked and produces no detector signal. A target image falling on the transparent portion is passed on to the detector. When the reticle is spun, IR from a target off center is alternately passed and blocked, resulting in amplitude modulation (AM). The phase of this modulation relative to a spin reference is used to tell target direction from center. A closed servo loop moves the optics to keep the target centered on the reticle. This is depicted in Figure 27.

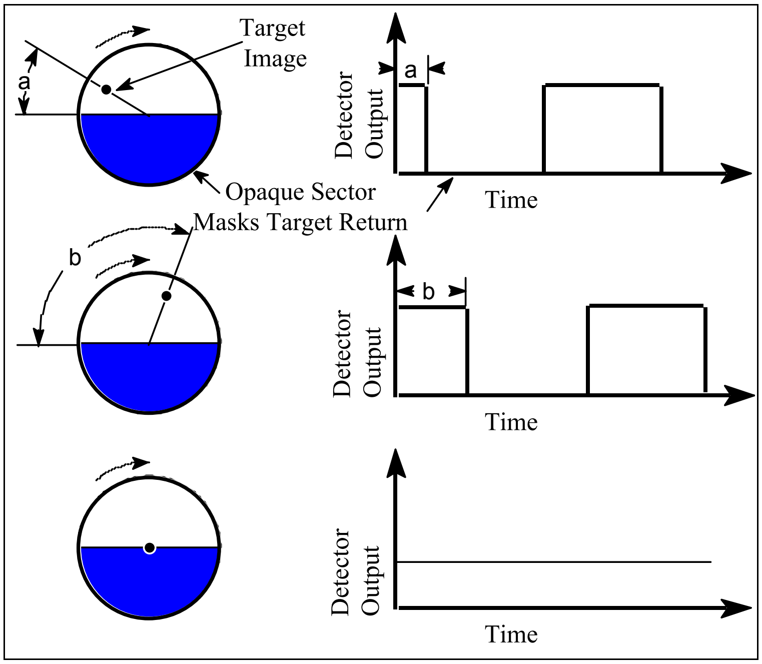
Target Image
a
a
Detector Output
Time
Opaque Sector Masks Target Return
b
b
Detector Output
Time
Detector Output
Time

Figure 27. Basic Reticle Design.

Target trackers have another problem: The aircraft target must be distinguished from natural background sources, such as sunlit clouds and terrain. To solve this, they look for features in the spectral, spatial, and temporal domains where the target is different from background.

- Temporal: There is no difference. Neither clouds nor aircraft signature are time varying.
- Spectral: Some difference. Choice of wavelength band yields helpful differences between target and background, but this is not sufficient by itself.
- Spatial: The most viable option. Aircraft are smaller than clouds and terrain. Background radiation can be greatly reduced by spatial filtering.

If half of the reticle is made with opaque "spokes," then some irradiance from targets with small images (such as aircraft) will be modulated more completely and generate a stronger signal at a faster modulating rate than large images (clouds) as shown in Figure 28.

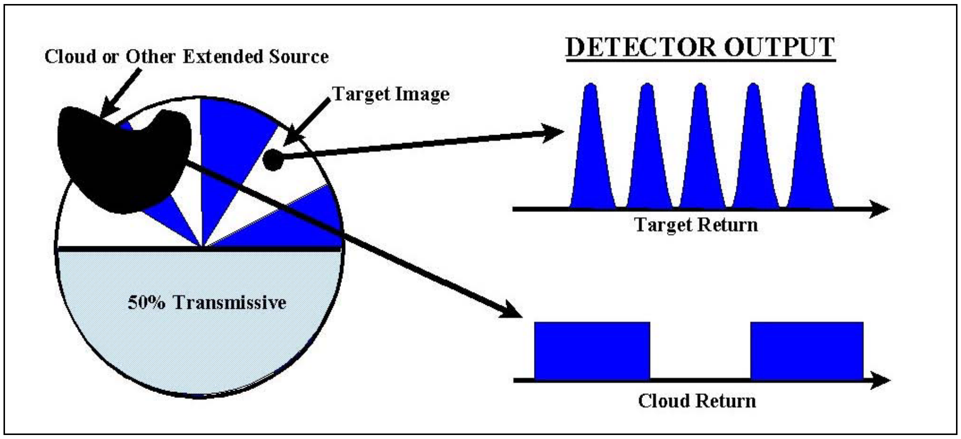
Cloud or Other Extended Source
Target Image
DETECTOR OUTPUT
50% Transmissive
Target Return
Cloud Return

Figure 28. IR Seeker Design for Background Discrimination.

The past figure and the following two figures (29 and 30) depict a spin-scan reticle used on the early Sidewinder designs. After the detector preamp, signal goes through a narrow bandpass filter to improve S/N. The AM waveform is then rectified and filtered. Target direction is determined from AM envelope phase.

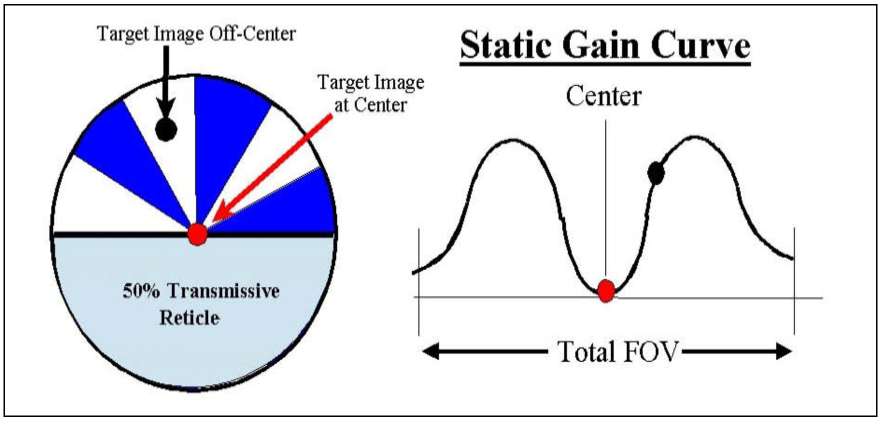
Target Image Off-Center
Target Image at Center
50% Transmissive Reticle
Static Gain Curve
Center
Total FOV

Figure 29. Spin Scan Seeker.

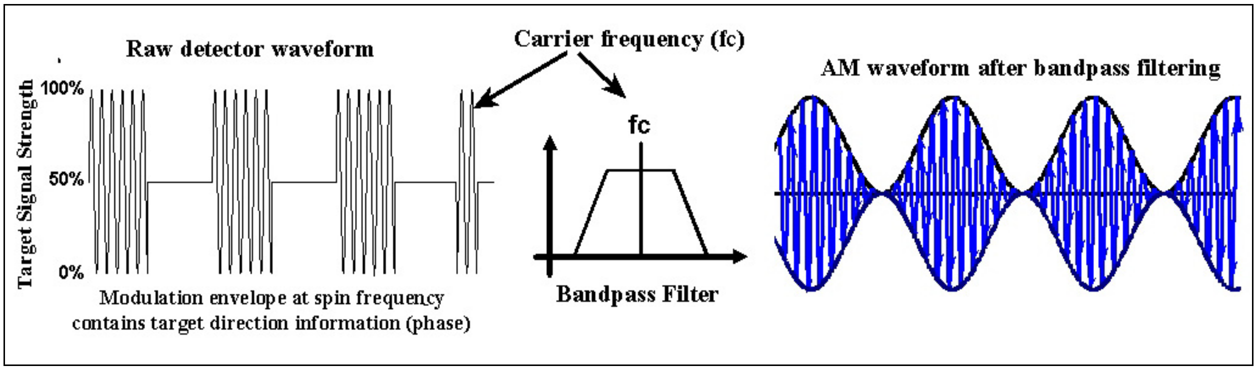
Raw detector waveform
Carrier frequency (fc)
AM waveform after bandpass filtering
Target Signal Strength
100%
50%
0%
fc
Modulation envelope at spin frequency contains target direction information (phase)
Bandpass Filter

Figure 30. Spin Scan Waveforms for Off-Center Target.

Spin-scan has the following characteristics that are important to countermeasures:

- The tracker loop drives to null the signal to zero. This occurs when the target is on the optical axis and the target image is at the center of the reticle.
- If the target is off-center, an AM carrier "error signal" is generated, where the phase of the modulation envelope indicates the target direction.

With spin scan, the missile is always looking at the target. This vulnerability to jammers led to the next evolution in target trackers: conical scan.

Conical scan borrows concept from early fire-control radars, which used a nutating feed horn. A con scan tracker is shown in Figure 31. With con scan:

- The secondary mirror of the Cassegrain is canted so the field of view seen by the detector sweeps out a pattern of overlapping circles.
- A target image at boresight falls near the edge of the reticle instead of center.
- Reticle pattern is same all the way around. (Usually tapered spokes.)

- Modulation of target near boresight is FM rather than AM. This allows tighter tracking.
- For larger angles off boresight, the target image falls outside the FOV of the detector for part of the scan. The modulation then becomes AM.

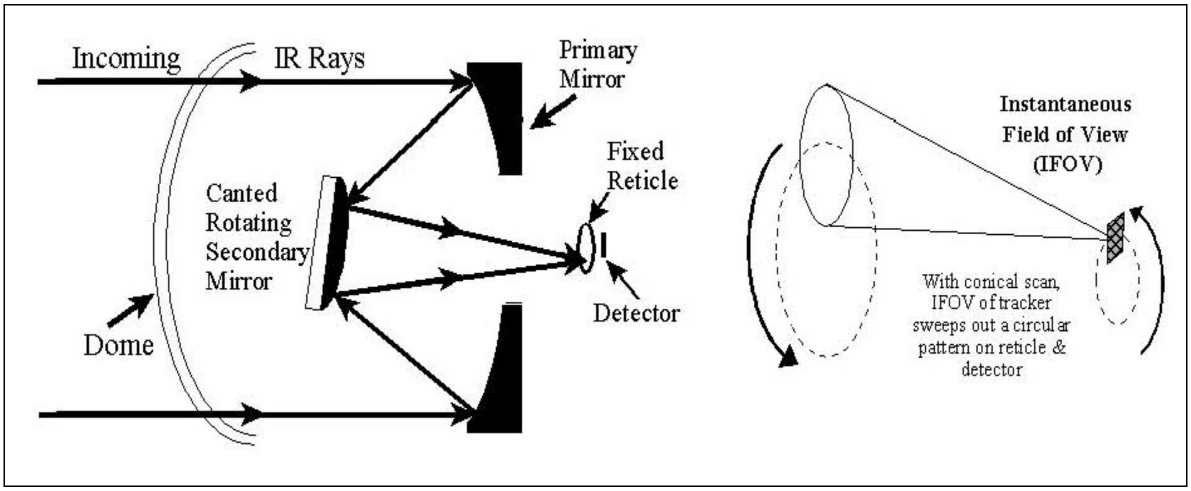
Incoming
IR Rays
Primary Mirror
Fixed Reticle
Canted Rotating Secondary Mirror
Detector
Dome
Instantaneous Field of View (IFOV)
With conical scan, IFOV of tracker sweeps out a circular pattern on reticle & detector

Figure 31. Conical Scan Tracker.

In the con scan tracker, as the missile instantaneous field of view nutates about a target on boresite, (moving through positions at t_1 through t_5 shown in Figure 32), the apparent position of a target image on the reticle sweeps out the circular pattern shown.

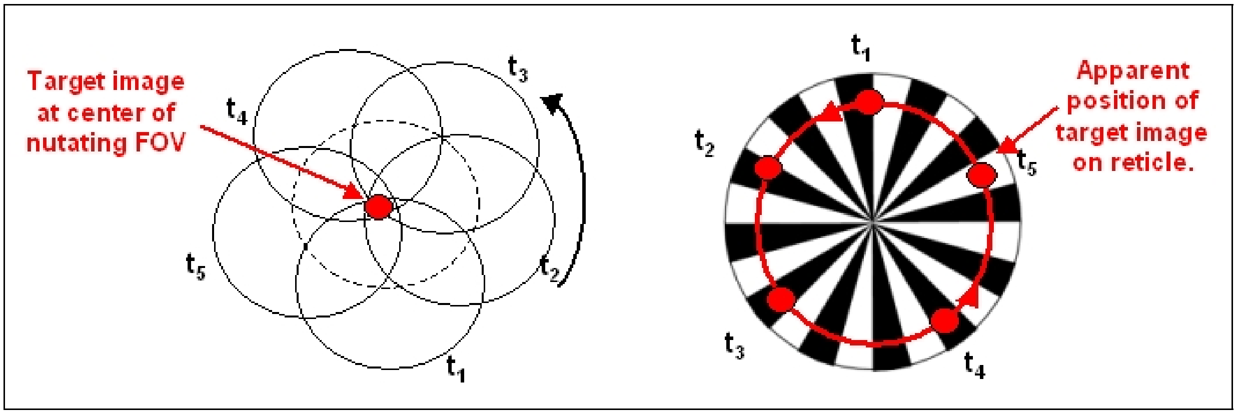
Target image at center of nutating FOV
t_1
t_2
t_3
t_4
t_5
Apparent position of target image on reticle.

Figure 32. Image on a Con Scan Reticle: Target at Boresite.

If the target is off boresight as shown in Figure 33, the detector receives a signal of varying pulse widths.

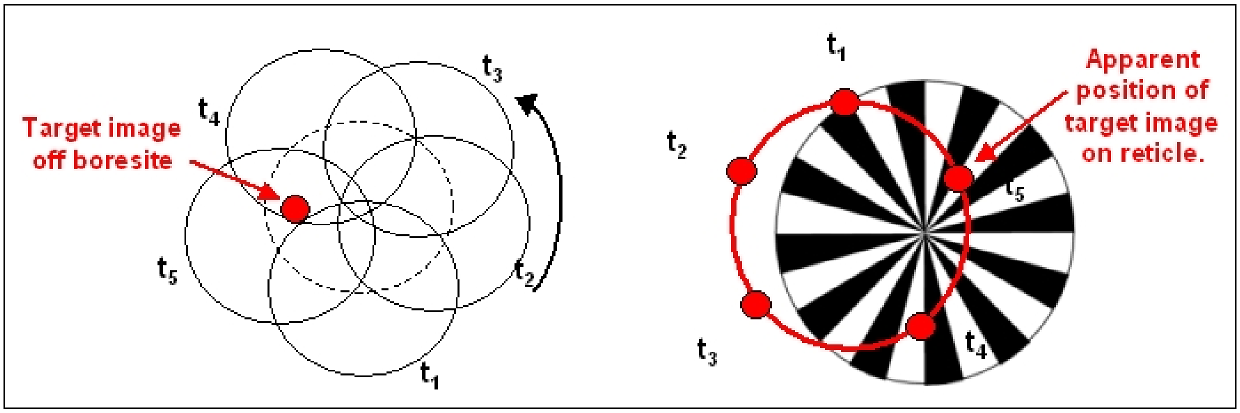
Target image off boresite
t4
t3
t5
t2
t1
t1
t2
Apparent position of target image on reticle.
t5
t3
t4

Figure 33. Image on a Con Scan Reticle: Target off Boresite**.**

The waveform produced by a target on boresite is a constant amplitude carrier at the reticle chopping frequency as shown in Figure 34. A target slightly off boresite produces a constant amplitude carrier that is frequency modulated at spin frequency.

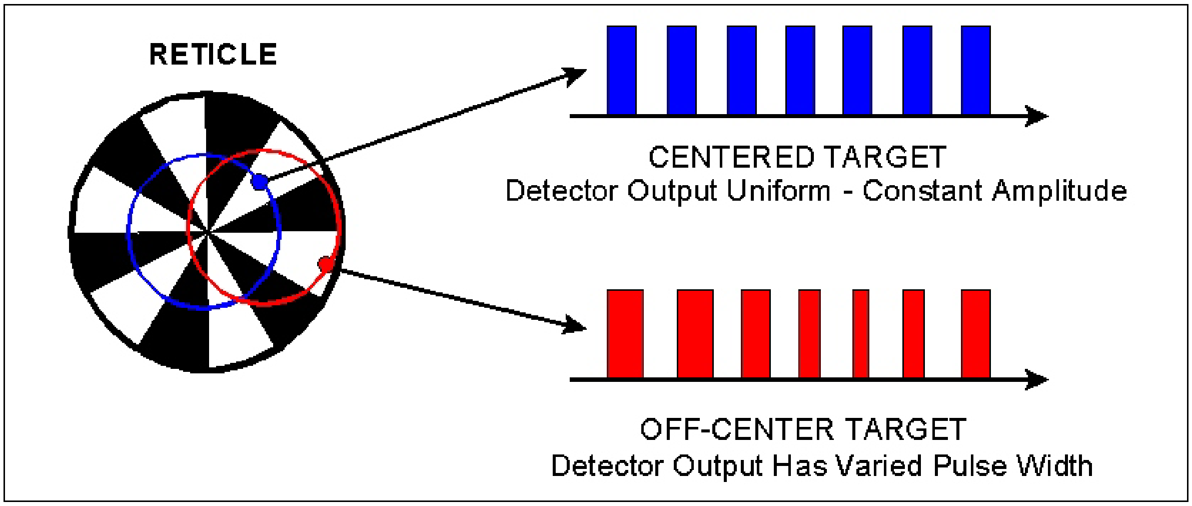
RETICLE
CENTERED TARGET
Detector Output Uniform - Constant Amplitude
OFF-CENTER TARGET
Detector Output Has Varied Pulse Width

Figure 34. Conical Scan Seeker Output.

A target further off boresite leaves the missile field of view during part of the scan, producing an amplitude-modulated waveform similar to that of a spin scan tracker. The important difference is that with a spin scan tracker, the target never leaves the missile field of view. With con scan, the target may fall outside the missile FOV at certain times during the scan. Because con-scan trackers do not necessarily view the target continuously, they can have high resistance to jammers.

Other types of seeker scan patterns now exist. The Rosette scan pattern shown in Figure 35 is one such example. It has an even higher resistance to countermeasures.

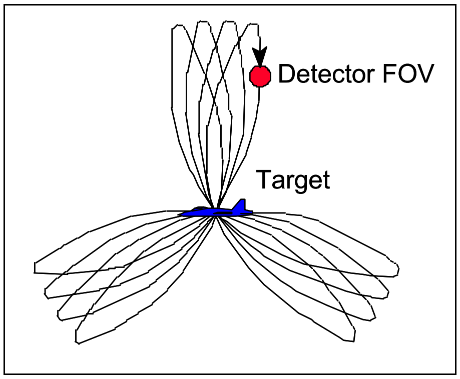

Figure 35. Rosette Scan Pattern.

Imaging arrays of detectors without reticles are newer yet. They may be classified as either staring (every pixel sees the entire scene), or scanning arrays, where the optics plays a role in determining which "pixels" are exposed to optical / IR radiation.

INFRARED COUNTERMEASURE (IRCM)

Flares

Figure 36 shows a Navy F/A-18E Super Hornet aircraft dispensing IRCM flares from its internal flare dispensers. IRCM have been the staple of countermeasures protection for military aircraft more than four decades. Flares are designed to transfer the track of an attacking infrared missile by exhibiting characteristics that confuse the tracking and guidance algorithms built into the missile. Modern missiles incorporate Counter-Countermeasures (CCM) capabilities including hardware configurations, circuitry, and logic to help identify countermeasures and reject them from processing. CCM capabilities can be based on spectral, spatial, and temporal features of the target scene. As missiles continue to improve in their sensitivity, range, maneuverability, and CCM capabilities, flares continue to evolve in order to keep pace with the evolving threat.

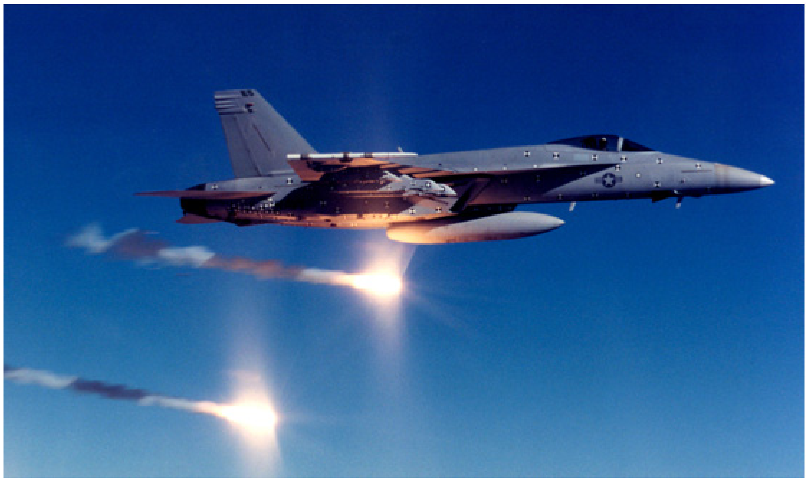

Figure 36. Navy F/A-18E Aircraft Dispensing IRCM Flares.

Over the years the Navy has fielded many flare types including the MJU-2/B, MJU-8, MJU-32, MJU-38, MJU-27, MJU-49, and many other improved versions of these flares and other types as well. IRCM flares continue to be the prevailing countermeasure for military aircraft protection by offering cost effective and robust protection.

Dispenser Systems

Most Navy fixed wing and rotary wing aircraft are equipped with countermeasures dispenser systems. These systems are critical to the survivability of the aircraft in a hostile threat environment. Modern dispensers such as the AN/ALE-47 offer high reliability and substantial programming capability that allows flare dispenses to be tailored for maximum protection of the host aircraft type. AN/ALE-47 is highly integrated into the aircraft over the 1553 data buses. The dispenser can incorporate information from several aircraft systems including missile-warning systems to improve its responses to threats and provide vital situational awareness to the aircrew.

Impulse Cartridges

IRCM flares are dispensed from the aircraft flare dispensers with electrically initiated impulse cartridges. Impulse cartridges incorporate energetic materials within a small confined canister. Upon application of a voltage to the electrical leads, a bridge wire in contact with the energetic materials burns through, igniting the propellant materials. The expanding gases push the flare from its case, held captive in the aircraft dispenser. Impulse cartridges for Navy use have been designed to withstand the extreme electro-magnetic environments encountered around aircraft carriers and other combat ships. Examples of impulse cartridges include the CCU-63 and CCU-136.

Infrared Jammers

Several lamp-based and mechanically modulated jammers have been developed over the years for protection of aircraft. Examples include the AN/ALQ-144 and AN/ALQ-157, predominantly used on helicopters and cargo aircraft. These jammers offer some level of protection over a broad field-of-regard and offer the advantage of continuous operation.

In principle, these jammers produce a modulated signal in the track band of the threat that corrupts the target tracking pulses in the missile seeker.

Passive Missile Warning Systems

Infrared-guided weapons provide passive attack capabilities against military vehicles. Unlike a radar-guided weapon that actively emits radiation and tracks the reflected pulses from the target, infrared weapons track radiation already being emitted from the target. Attacking missiles fly at very high speeds, and they are exceptionally maneuverable. Missile warning systems must be capable of detecting the threat, alerting the aircrew, and cueing a countermeasures response within sufficient time to counter the attacking missile. The time from launch to impact can be very short, making timely detection critical. Active warning systems have been developed in the past that use Doppler Radar capabilities to detect missiles, but passive missile warning systems have been preferred because of the desire to minimize emissions from the aircraft under attack.

Several passive missile-warning systems have been developed over the years for military aircraft. These systems operate in a variety of different parts of the electro-optical spectrum, but the most common are ultraviolet and infrared sensor systems. Examples of passive missile warning systems include AN/AAR-47, AN/AAR-54, AN/AAR-57, AN/AAQ-24 (both passive and active components), and the Joint and Allied Threat Awareness System (JATAS), currently under development by the Navy. Passive missile warning sensors continue to improve with advances in detector technologies, particularly with imaging detectors. These sensors provide excellent angle-of-arrival information, necessary to support cueing of laser based countermeasures, and advanced processing to detect and declare threat missiles in cluttered environments.

Laser Countermeasures

Laser-based infrared countermeasures have been in development for many years. Several systems have been fielded over the past fifteen years including the AN/AAQ-24 system on Air Force cargo aircraft and helicopters and a derivative system for Marine Corps helicopters.

Although configurations vary, most of these systems incorporate a single multi-band laser or several single-band lasers that produce modulated waveforms designed to corrupt a missile’s guidance target tracking. The laser optics are located in a tracking gimbal that provides agile and rapid pointing over a broad field-of-regard. Laser based countermeasures require a relatively high angle of arrival accuracy from the host aircraft’s missile warning sensor. Upon declaration of the threat, the missile warning system hands-off track to the tracking gimbal and cues the lasers to lase. A tracking camera in the tracking gimbal with high optical resolution helps to maintain track on the threat missile through the engagement period.

LASERS

The word laser comes from Light Amplification by Stimulated Emission of Radiation. A laser system emits light that is generated through a process of stimulated emission. The radiation produced by a laser exhibits high temporal and spatial coherence. In order to begin the process of stimulated emission, the lasing medium absorbs the energy from a pump source. The atoms in the lasing medium are excited to a higher energy state. These atoms will eventually return to their ground state. A large number of atoms that are excited to higher states create a population inversion. Population inversion describes the number of atoms in excited state versus the number of atoms in the ground state. In order for the atoms to return to their ground state, they must release energy. This energy is released in the form of photons. Energy of a photon is expressed as

$$E = \frac{hc}{\lambda}$$

Where

E = Energy, generally electron volts (eV)
h = Planck’s constant = 4.136×10^{-15} (eV·s)
c = speed of light = 2.998×10^{8} (m/s)
λ = wavelength of light in meters

The energy that must be released by the atom to return to the ground state will direct the wavelength of the photon emitted since h and c are constants. If all the excited atoms released the same amount of energy to return to their ground state, the released photons would all have the same wavelength and would be considered fully monochromatic. Most lasers do not emit a single wavelength but a range of slightly differing wavelengths (Δλ).

The lasing medium may be a solid, a gas, liquid, or plasma. Some laser types include gas, chemical, dye, fiber-based, solid-state and semiconductor lasers. The laser radiation can be output in a continuous wave (CW) or in a pulsed wave. A continuous wave laser emits light that maintains a steady amplitude and frequency. A pulse wave will vary in amplitude and is also characterized by the systems pulse repetition frequency (PRF). The PRF is defined as the number of pulses emitted during a unit of time. Figure 37 shows the spectral output of several laser types.

The first laser was constructed by Theodore Maiman at Hughes Research Laboratories in Malibu, California. This laser was a pulsed, solid-state ruby laser. The ruby laser uses a synthetic ruby crystal as the lasing medium. A xenon flash lamp is used to excite the atoms in a ruby rod to higher energy levels. The highly polished and mirrored ends of the rod form a resonant cavity. One end of the rod has a slightly lower reflectivity. The lamp excitation produces an inverted population of excited atoms, which are stimulated to relax to lower energy levels releasing their extra energy as photons. Repeated reflections off the mirrored ends of the rod causes the photons to bounce back and forth through the rod stimulating further emissions at the same wavelength and phase producing a highly coherent beam, which finally passes through the lower reflectivity end.

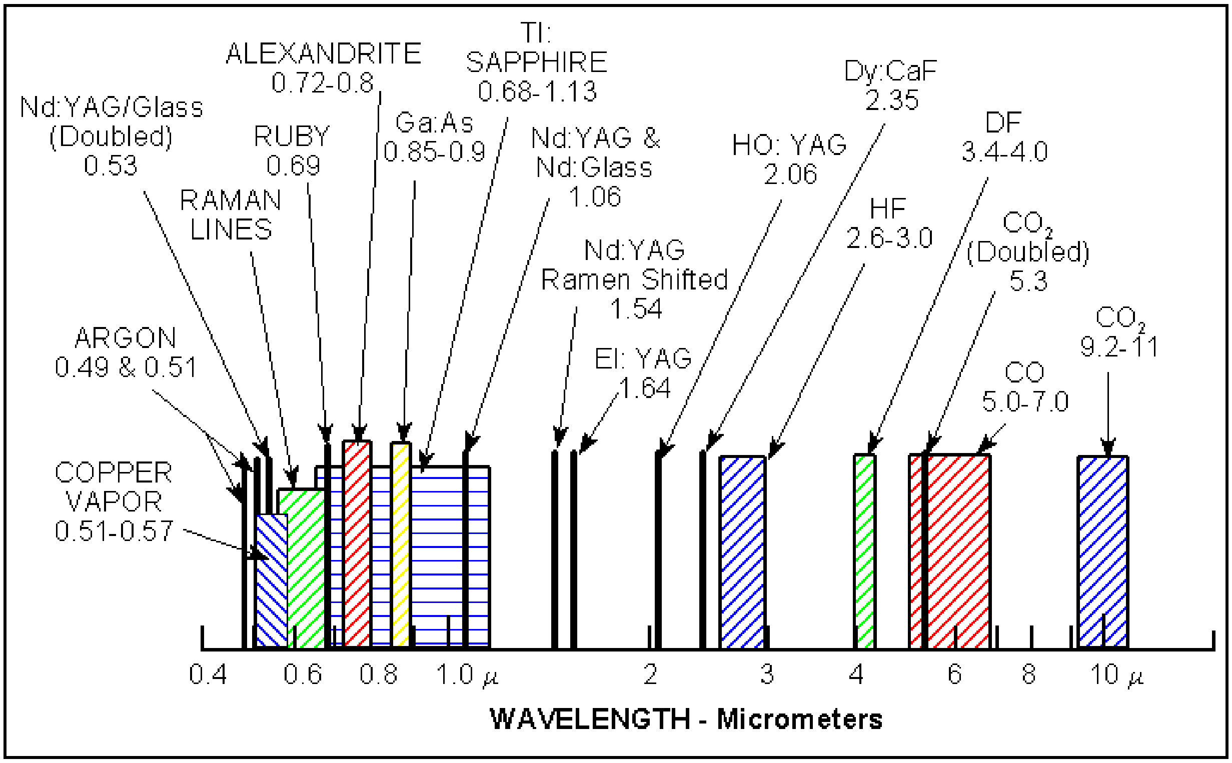

Figure 37. Spectral Lines / Ranges of Available Lasers.

The typical laser rangefinder uses a solid-state laser with a neodymium-YAG crystal lasing at 1.06 µm.

Gas lasers can be pulsed or CW. The gas dynamic laser obtains its inverted population through a rapid temperature rise produced by accelerating the gas through a supersonic nozzle. In chemical lasers the inversion is produced by a chemical reaction. In the electric discharge laser the lasing medium is electrically pumped. The gas can also be optically pumped. In an optically pumped gas laser the lasing medium is contained in a transparent cylinder. The cylinder is in a resonant cavity formed by two highly reflective mirrors.

Many gas lasers use carbon dioxide as the lasing medium (actually a mixture of CO_2 and other gases). These are the basis for most high energy or high power lasers. The first gas laser was an optically pumped CW helium-neon laser. The common laser pointer is a helium-neon laser operating at 0.6328 µm. The lasing medium is a mixture of helium and neon gas in a gas discharge or plasma tube.

The dye laser is an example of a laser using a liquid for the lasing medium. The lasing medium is an organic dye dissolved in a solvent such as ethyl alcohol. Dye lasers operate from the near UV to the near IR, are optically pumped, and are tunable over a fairly wide wavelength range.

Another type of laser is the semiconductor or injection laser, also known as a laser diode. The junctions of most semiconductor diodes will emit some radiation if the devices are forward biased. This radiation is the result of energy released when electrons and holes recombine in the junction. There are two kinds of semiconductor diode emitters: (1) the light emitting diode (LED), which produces incoherent spontaneous emission when forward biased and which has a broad (800 angstrom) spectral output, and (2) the laser diode, which maintains a coherent emission when pulsed beyond a threshold current and which has a narrow spectral width (< 10 angstrom). In the laser diode the end faces of the junction region are polished to form mirror surfaces. They can operate CW at room temperatures, but pulsed operation is more common. Figure 38 shows a typical diode laser structure.

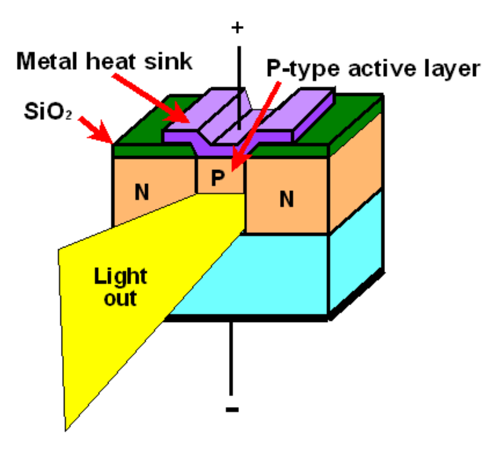

Figure 38. Diode Laser Construction.

Fiber lasers use fibers that are doped with rare-earth elements as the pumping medium. These rare-earth elements include elements such as Erbium (most common), Ytterbium, and Neodymium. There are other elements such as Thulium that are used for doping purposes. Erbium doped fiber lasers can emit in the 1.5 to 1.6 micron wavelength, which is important due to eye safety concerns in this part of the spectrum. Other wavelength emissions for Erbium include 2.7 and 0.55 microns.

Fiber based laser systems are beneficial in many ways. The fiber gain medium is compact compared to many other types of gain medium and is highly efficient. The fiber gain medium can also be physically manipulated to save space. Fiber based lasers are able to achieve high output powers. The gain medium of a fiber laser can extend for several kilometers to achieve these higher power outputs. The fact that the light is already propagating in a flexible fiber can also allow for system designs that implement a gain cavity in one location and then deliver the output in another location.

Q-switching is a common means of obtaining short intense pulses from lasers. The Q-switch inhibits lasing until a very large inverted population builds up. The switch can be active or passive. A passive Q-switch switches at a predetermined level. An active Q-switch is controlled by external timing circuits or mechanical motion. The switch is placed between the rod (or lasing medium) and the 100 percent mirror. Figure 39 shows an arrangement using a Pockels cell as an active Q-switch.

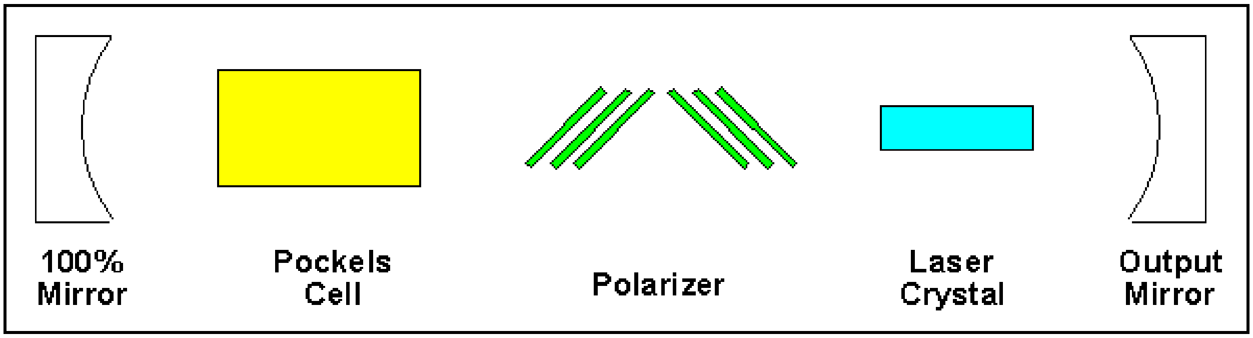

Figure 39. Q-Switch Arrangement.

Other methods of obtaining pulsed operation include using pump sources that are pulsed and mode-locking.

FIBER OPTICS

Fiber optic cables are the optical analog of RF waveguides. Fiber optic cables are made from transparent dielectrics. The fiber optic cable acts as an optical waveguide allowing light to propagate along the length of the fiber by using the principle of total internal reflection. This phenomenon can only occur under certain conditions relating to the material indices of refraction and the light ray's angle of incidence. Some benefits of fiber optic fiber include low losses, bandwidth, electromagnetic interference immunity, size, and weight.

Consider the physical construction of a bare optical fiber, depicted in Figure 40. A bare optical fiber is simply the inner glass core and the surrounding glass sleeve. The core must have a higher index of refraction than the cladding, $n_1 > n_2$. When $n_1 > n_2$, light impinging the boundary between the core and the cladding will totally internally reflect if the incident angle at each reflection is greater than the critical angle, θ_c. $\sin \theta_c = (n_2/ n_1)$

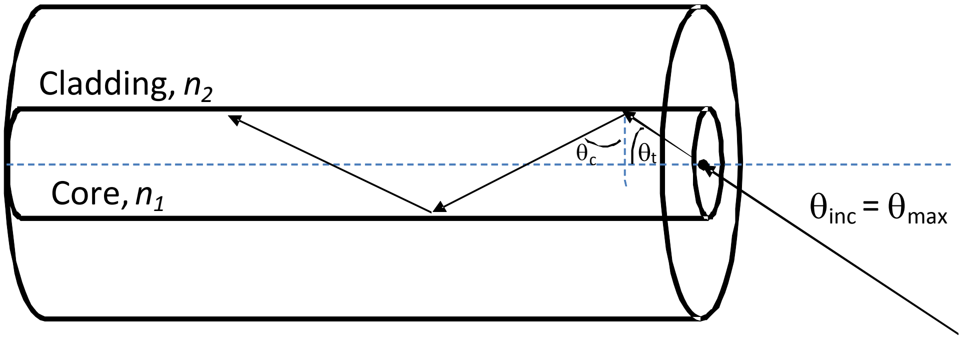

Figure 40. Bare Fiber Optic Cable.

Incident rays on the face of the fiber must intersect at angles less than θ_{max} for the internal ray, θ_t, to intersect at θ_c. When rays intersect the front face of the fiber at angles greater than θ_c, they are only partially reflected in the core and will leak out.

There are many varieties of optical fibers. Optical fibers can either be single mode or multimode. Single mode fibers are fibers which propagate a single mode down the length of the fiber while multimode fibers can propagate many modes. Single mode fibers typically have a much smaller core diameter, typically around 8 to 10 µm. Their cladding is usually 125 µm. Multimode fibers typically have core diameters around 62.5 µm with 125 µm claddings. These diameters can vary depending on the application. Loss in multimode fibers over a 1 kilometer distance is typically around 1 dB at 1310 nm. This value will vary some with changes in wavelength. Single mode fibers can maintain the quality of a light pulse over longer distances than multimode fibers due to modal dispersion effects that occur in multimode fibers. Typical losses for a single mode fiber over 1 kilometer is approximately .3 dB at 1310 nm. Again, this value will vary some with changes in wavelength. However, multimode fiber is much less expensive than single-mode and can have a lower connection loss due to the larger core diameter. Multimode fiber is commonly used in communications.

In addition to single mode or multimode, a fiber can have a step index profile or a graded index profile. Figure 41 depicts the two profiles. The step index profile maintains a uniform index of refraction within the core. A graded index profile has a peak index of refraction at the center of the core. The index of refraction value rolls off from the center to lower values closer to the cladding interface. This profile assists with the modal dispersion issue found in multimode fiber.

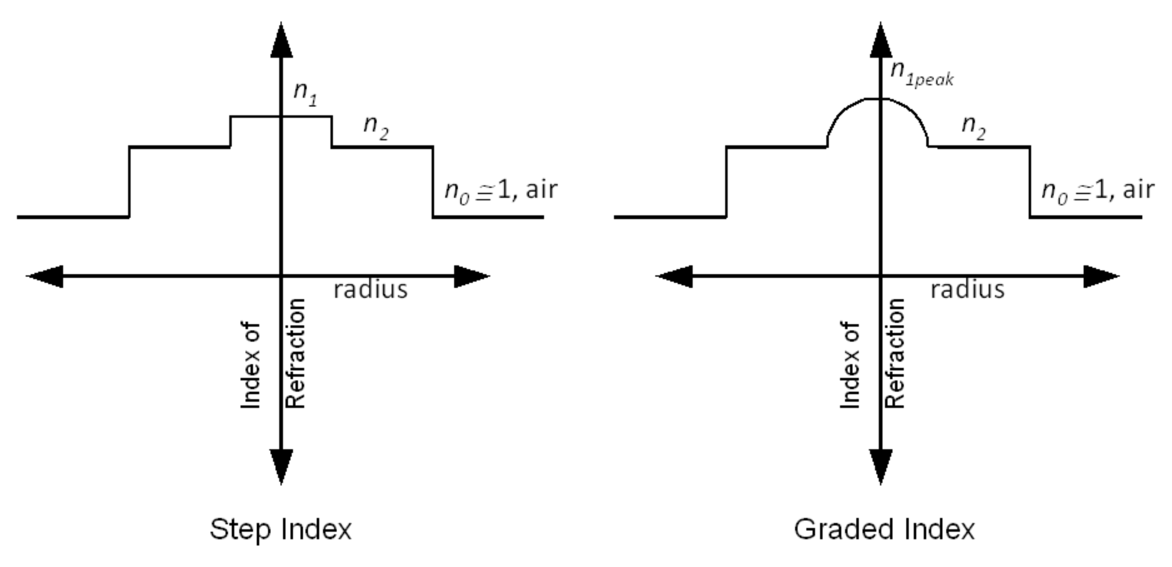

Figure 41. Fiber Profiles for a Single Mode Step Index and a Multimode Graded-Index Fiber.

Most fiber is not used in a bare form and has some additional layers of protection around the cladding. These layers can include a 250 µm buffer with a 900 µm PVC tight buffer. Some fiber will also contain aramid yarn followed by a 3 mm PVC furcation tube. Buffer tubes are often used to assist with identification and provide damage protection. The outer layers can provide additional isolation from environmental factors and lower optical crosstalk.

There are also more specialized types of fiber that include polarization maintaining and photonic crystal fibers. Polarization maintaining fibers are not constructed with a cylindrical core but instead use elliptical, bow-tie styled cores or stress rods located in the cladding (PANDA style). These are shown in Figure 42.

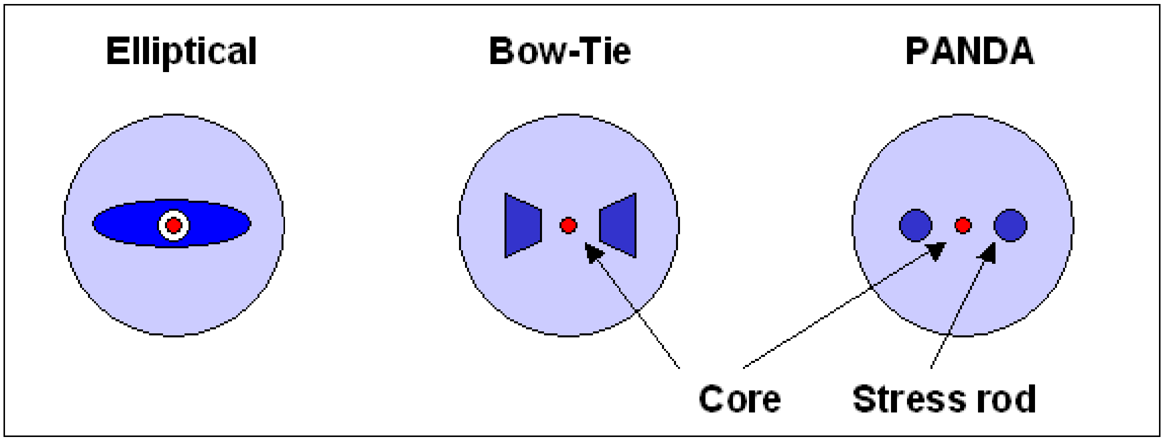

Figure 42. Polarization Maintaining Optical Fiber Types.

Polarization maintaining fibers maintain the state of the linearly polarized light propagating through the fiber. This type of fiber is used when the polarization state of the light cannot vary within a system. Photonic crystals propagate light by an arrangement of very small and closely spaced air holes that are maintained throughout the length of the fiber. Applications of photonic crystal fibers are varying and can be used in fiber lasers, amplifiers, sensors, and telecom.

It is well known that fiber optics has many communication applications; however, improvements in fiber optic technology have lent themselves to many EO applications. Many EO components are now fiber based and can interface with the tremendous advancements in fiber-based laser systems as well as other EO systems. An example of the use of fiber optics in an EW system is the AN/ALE-50 and 55 Fiber-Optic Towed Decoy (FOTD). The FOTD uses fiber optic cabling to communicate with the jammer.

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LASER SAFETY

Lasers are divided into the following classes:

Class 1	Low power / non-hazardous
Class 2/2a	Low power / minor controls necessary
	Emit less than 1 mW visible CW radiation. Not considered hazardous for momentary (<0.25 sec) unintentional exposure. Class 2a lasers are those class 2 lasers not intended to be viewed, i.e. supermarket scanners.
Class 3a/3b	Medium power / direct viewing hazard / little diffuse reflection hazard.
Class 3a	Visible lasers with 1-5 mW power output, invisible lasers, and those having 1-5 times the Accessible Emission Limit (AEL) of class 1 lasers.
Class 3b	All other class 3 lasers at all wavelengths which have a power output less than 500 mW.
Class 4	High power / eye & skin hazard / potential diffuse reflection hazard or fire hazard

There are several pertinent instructions and guidelines regarding laser use. They are:

- OPNAVINST 5100.27B Navy Laser Hazards Control Program
  (which replaced OPNAVINST 5100.27A and SPAWARINST 5100.12B)
- MIL-HDBK-828B, Range Laser Safety
- ANSI Z136.1-2007, American National Standard for the Safe Use of Lasers (Parent)

Every Navy command which uses lasers must have a Laser System Safety Officer (LSSO). All LSSOs must attend a Navy LSSO course.

There are four categories of LSSOs.

- Administrative Laser Safety Officer (ALSO)
- Technical Laser Safety Officer (TLSO)
- Laser Safety Specialist (LSS)
- Range Laser Safety Specialist (RLSS)

See OPNAVINST 5100.27B for details of their qualifications and responsibilities.

The hazard ranges of interest are the NOHD for direct viewing of a beam and the $r_{1(safe)}$ or $r_{2(safe)}$ for viewing a beam reflected off an object such as a wall. These are depicted in Figure 1. The Maximum Permissible Exposure (MPE) values present laser safety levels as a function of exposure time, laser PRF, pulse duration, and wavelength. Different tables are used for eye safety while directly viewing a beam, for viewing a diffusely reflected beam, and for skin exposure.

For repeated pulses the following equation is used to calculate the maximum permissible exposure (MPE).

$$\text{MPE (repeated pulse)} = \frac{MPE(single\ pulse)}{(\ PRF\ x\ t_e\ )^{1/4}} \qquad \textbf{[1]}$$

Where PRF is the pulse repetition frequency of the laser and t_e is the exposure duration.

For visible lasers t_e is usually taken as 1/4 second and for non-visible lasers a value of 10 seconds is used.

Figure 1 depicts some laser hazard distances.

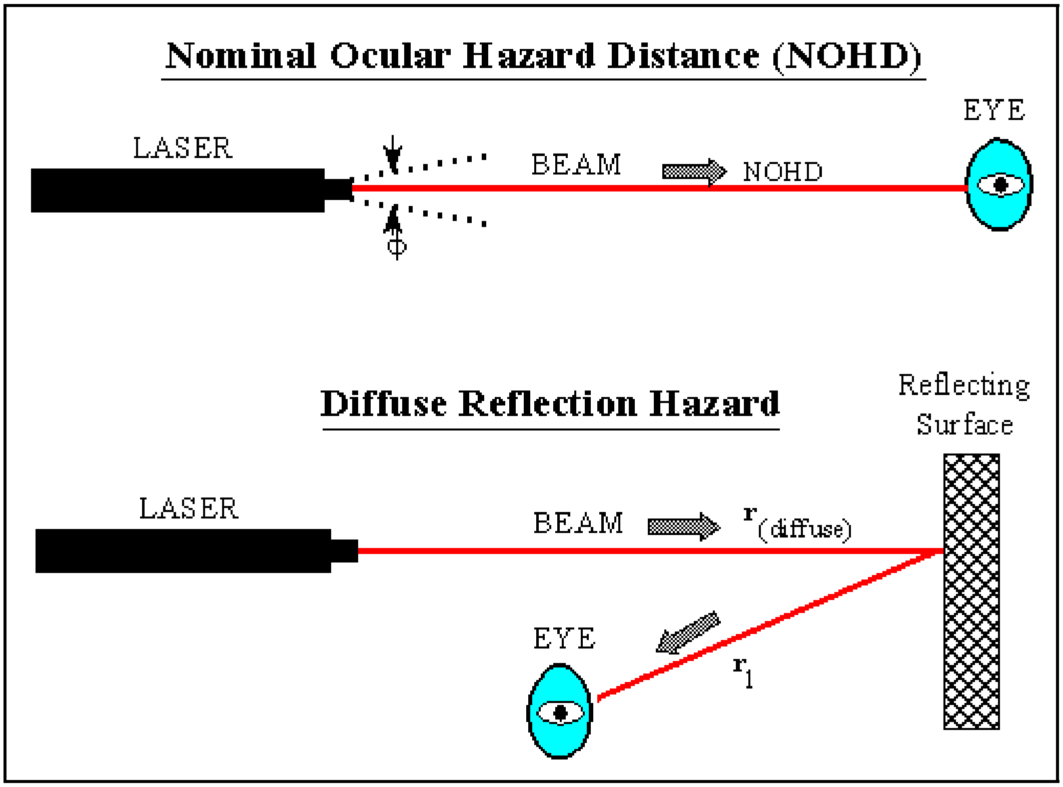
Nominal Ocular Hazard Distance (NOHD)
LASER
Φ
BEAM
NOHD
EYE
Diffuse Reflection Hazard
Reflecting Surface
LASER
BEAM
$r_{(diffuse)}$
EYE
r_1

Figure 1. Laser Hazard Distances.

Range laser safety specialists shall be designated for external operations. Range test plans shall specify:

- Permissible aircraft flight paths, and ship or vehicle headings.
- Hazard areas to be cleared.
- Operational personnel locations.
- Types of surveillance to be used to ensure a clear range.
- Radio / communications procedures.

During laser operations no portion of the laser beam may extend beyond the controlled target area unless adequate surveillance can prevent radiation of unprotected areas. Class 3 and class 4 lasers shall not be directed above the horizon unless coordinated with those responsible for the given airspace (FAA, Navy, Air Force, etc).

In an industrial environment, warning and hazard signs and lights will be posted, a hazard zone shall be designated when lasers are in operation, and training shall be provided to operators in the proper eye and body (skin) protection required. Interlocks to laser operation shall be provided when there is the possibility of unauthorized personnel entering the hazard area.

Fiber optic cables usually have laser power sources so appropriate warnings or labels need to be applied to connections or possible breakage points.

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AIRCRAFT DYNAMICS CONSIDERATIONS

Free Fall / Aircraft Drag.......... 8-1
Mach Number and Airspeed vs. Altitude.......... 8-2
Maneuverability 8-3
EMP / Aircraft Dimensions.......... 8-4

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FREE FALL / AIRCRAFT DRAG

The purpose of this section is to get an awareness of the distance traveled by a flare or other object such as a bomb, which is jettisoned or dropped by an aircraft. This will give the reader an appreciation for the significance of aircraft tactical altitude.

From Newton's second law of motion:

$F = m_o a$ where:

F = Force
m_o = Mass of object
a = Acceleration

and the law of gravitation: $F = G\frac{m_o m_e}{r^2}$

where:	English Units	SI Units
F = Force of attraction	lb_f	Newton
G = universal gravitational constant	$3.44\text{x}10^{-8}$ $ft^4/lb\text{-}sec^4$	$6.67\text{x}10^{-11}$ $m^3/kg\text{-}sec^2$
m_o, m_e= Masses (not weight) of object & earth	slug	kg
r = distance between center of gravity of objects	feet	meter

Combining the two equations and solving for "a":

$$a = \frac{G m_e}{r^2} = g$$, the familiar constant acceleration due to gravity.

Since G and m_e are fixed and the variation in r (the distance from the earth's center) is small except for satellites, "g" is considered fixed at 32.2 ft/sec^2.

For objects with a constant acceleration (g), it can be shown that:

$$d = v_i t + \frac{1}{2} g t^2$$ where

d = distance traveled
v_i = Initial velocity
t = time
g = acceleration

For a falling object, Figure 1 on the following page may be used to estimate time/distance values.

- The upper curve is for an object shot upward with an initial velocity of 50 ft/sec.
- The middle curve is for an object shot horizontally with an initial velocity of 50 ft/sec or one that is a free-falling object dropped with no initial vertical velocity.
- The lower curve is for an object with a downward initial velocity of 50 ft/sec.

Notes:

1) 50 ft/sec is the typical cartridge ejection velocity of a flare/chaff expendable.
2) The top curve actually goes up 39 feet before starting back down, but this is difficult to see due to the graph scale.
3) This simplification ignores the effects of air drag or tumbling effects on a falling object which will result in a maximum terminal velocity, with resultant curve straightening.

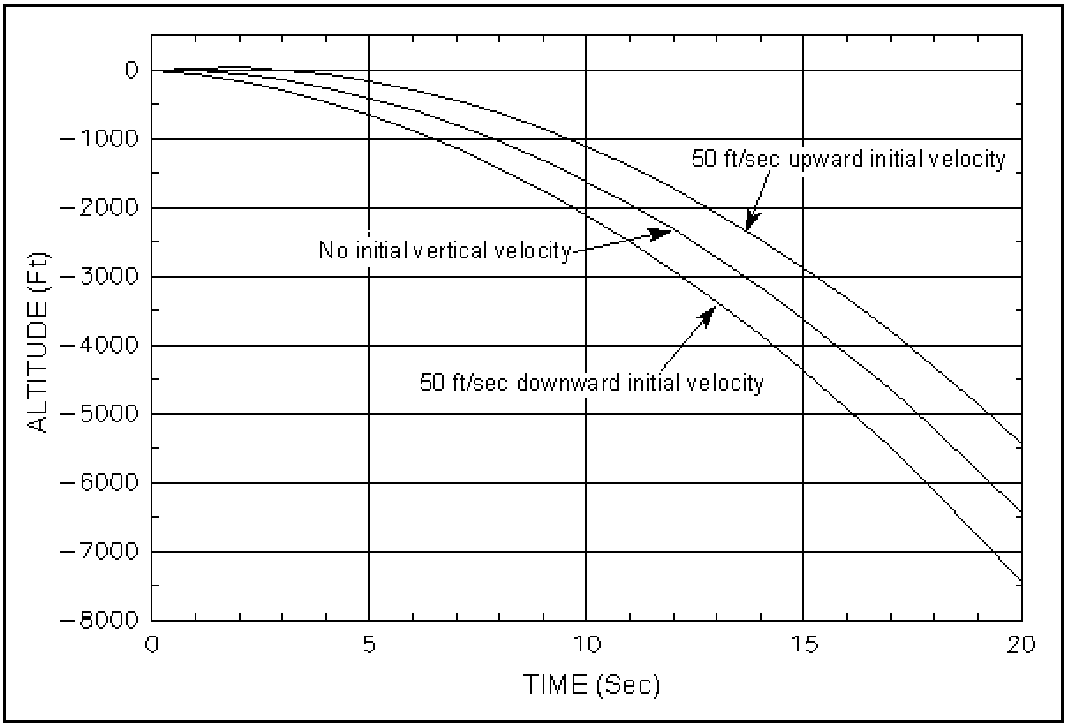

Figure 1. Object Fall Rate.

SAMPLE CALCULATIONS

Let us assume that we want to know how far a bomb or other object has fallen after 13 seconds if it had been dropped from an aircraft traveling at 450 kts which was in a 40° dive.

Our initial vertical velocity is: 450 kts (Sin 40°) (1.69 ft/sec per knot) = 489 ft/sec downward

$d = V_i t + \frac{1}{2}gt^2 = -489(13) + \frac{1}{2}(-32.2)(13)^2 = -6355 - 2721 = -9{,}076$ ft.

Remember to keep the signs (+/-) of your calculations in agreement with whatever convention you are using. Gravity pulls downward, so we used a minus sign for acceleration. Also the initial velocity was downward.

In reality, any object may well have reached terminal velocity before the time indicated using the above formula or Figure 1. In this example, the actual distance determined from ballistics tables would have been 8,000 ft, which is about 13% less than the above calculation would indicate. The drag characteristics of the object determine how much shorter the distance will be. In any case, it will not have dropped farther.

AIRCRAFT DRAG INDEX POINTS

Tactical aircraft carry stores in various combinations depending upon the mission. Each store has a different drag load which affects range. The pilot needs to know the total drag load in order to determine his aircraft range on a particular mission. Adding up the total drag in pounds of force for wind resistance would be cumbersome. Therefore, the drag of the stores is compared to a known reference drag (usually the aircraft), and expressed as a percentage of aircraft drag multiplied by some constant. This ratio is variously called drag count, drag index, or drag points. For instance, if a missile has 100 pounds of drag and the reference aircraft drag is 50,000 pounds, the ratio is 100/50,000 = 0.002. Multiply this by a constant of 100 (for example) and the drag index point is 0.2. The pilot only needs to look on a chart to see what the drag index points are for his stores, add up the drag points, and look on a chart to see what his aircraft range and best range (or endurance) speed will be.

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MACH NUMBER and AIRSPEED vs. ALTITUDE

MACH NUMBER is defined as a speed ratio, referenced to the speed of sound, i.e.

$$MACH\ NUMBER = \frac{Velocity\ of\ Interest}{Velocity\ of\ Sound} \quad (at\ the\ given\ atmospheric\ conditions) \qquad \textbf{[1]}$$

Since the temperature and density of air decreases with altitude, so does the speed of sound, hence a given true velocity results in a higher MACH number at higher altitudes.

AIRSPEED is a term that can be easily confused. The unqualified term airspeed can mean any of the following:

a. Indicated airspeed (IAS) - the airspeed shown by an airspeed indicator in an aircraft. Indicated airspeed is expressed in knots and is abbreviated KIAS.

b. Calibrated airspeed (CAS) - indicated airspeed corrected for static source error due to location of pickup sensor on aircraft. Calibrated airspeed is expressed in knots and is abbreviated KCAS. Normally it doesn't differ much from IAS.

c. True airspeed (TAS) - IAS corrected for instrument installation error, compressibility error, and errors due to variations from standard air density. TAS is expressed in knots and is abbreviated KTAS. TAS is approximately equal to CAS at sea level but increases relative to CAS as altitude increases. At 35,000 ft, 250 KIAS (or KCAS) is approximately 430 KTAS.

IAS (or CAS) is important in that aircraft dynamics (such as stall speed) responds largely to this quantity. TAS is important for use in navigation (True airspeed ± wind speed = ground speed).

Figures 1 and 2 depict relations between CAS and TAS for various altitudes and non-standard temperature conditions. The first graph depicts lower speed conditions, the second depicts higher speeds.

As an example of use, consider the chart on the next page. Assume we are in the cockpit, have read our IAS from the airspeed indicator, and have applied the aircraft specific airspeed correction to obtain 370 KCAS. We start at point "A" and go horizontally to our flight altitude at point "B" (25,000 ft in this case). To find our Mach, we go down vertically to point "C" to obtain 0.86 Mach. To get our TAS at our actual environmental conditions, we go from point "B" vertically until we hit the Sea Level (S.L.) reference line at point "D", then travel horizontally until we reach our actual outside air temperature (-20°C at altitude) at point "E", then go up vertically to read our actual TAS from the scale at point "F" (535 KTAS). If we wanted our TAS at "standard" temperature and pressure conditions, we would follow the dashed lines slanting upward from point "B" to point "G" and read 515 KTAS from the scale. Naturally, we could go into the graph at any point and go "backwards" to find CAS from true Mach or TAS.

Figure 3 shows a much wider range of Mach numbers. It contains only TAS and Mach, since aircraft generally do not fly above Mach 2, but missiles (which don't have airspeed indicators) do. The data on this graph can be obtained directly from the following formula for use at altitudes of 36,000 ft and below:

$$Speed\ of\ Sound\ (KTAS) = 29.06\sqrt{518.7 - 3.57\ A} \qquad Where\ A = altitude\ (K\ ft) \qquad \textbf{[2]}$$

The speed of sound calculated from this formula can be used with the equation on the first page to obtain Mach number. This equation uses the standard sea level temperature of 59° F and a lapse rate of -3.57°/1000 ft altitude. Temperature stabilizes at -69.7° F at 36,000 ft so the speed of sound stabilizes there at 573 knots. See the last page of this section for a derivation of equation [2].

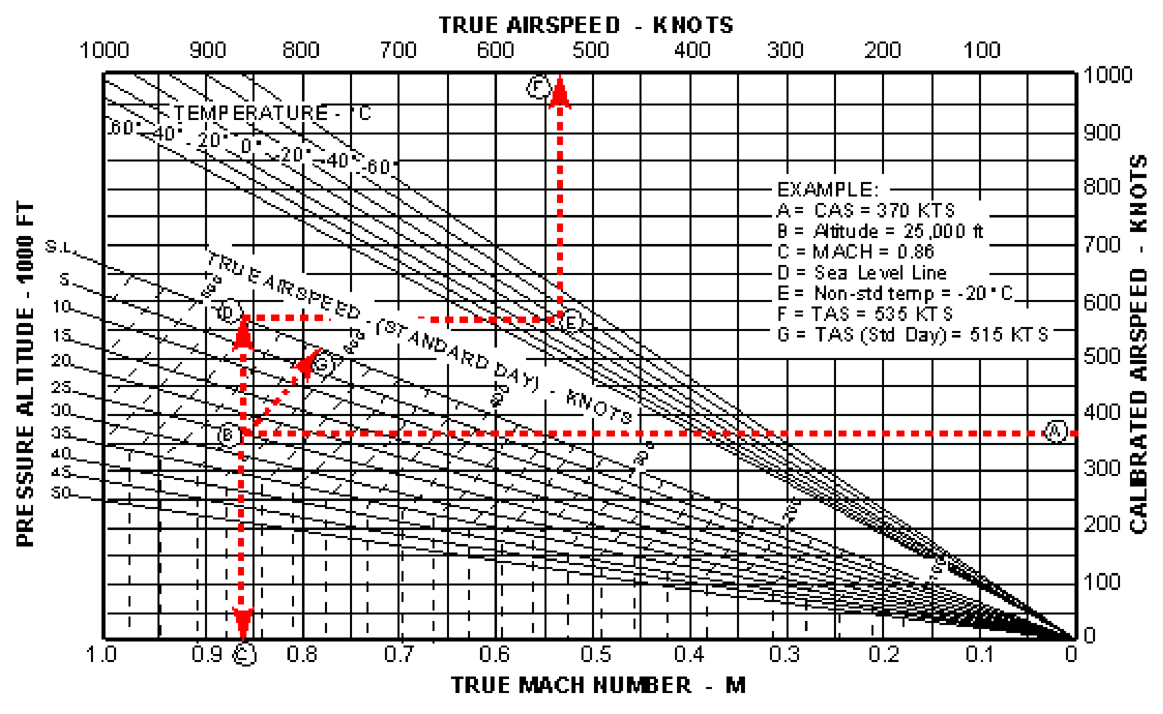

Figure 1. TAS and CAS Relationship With Varying Altitude and Temperature.

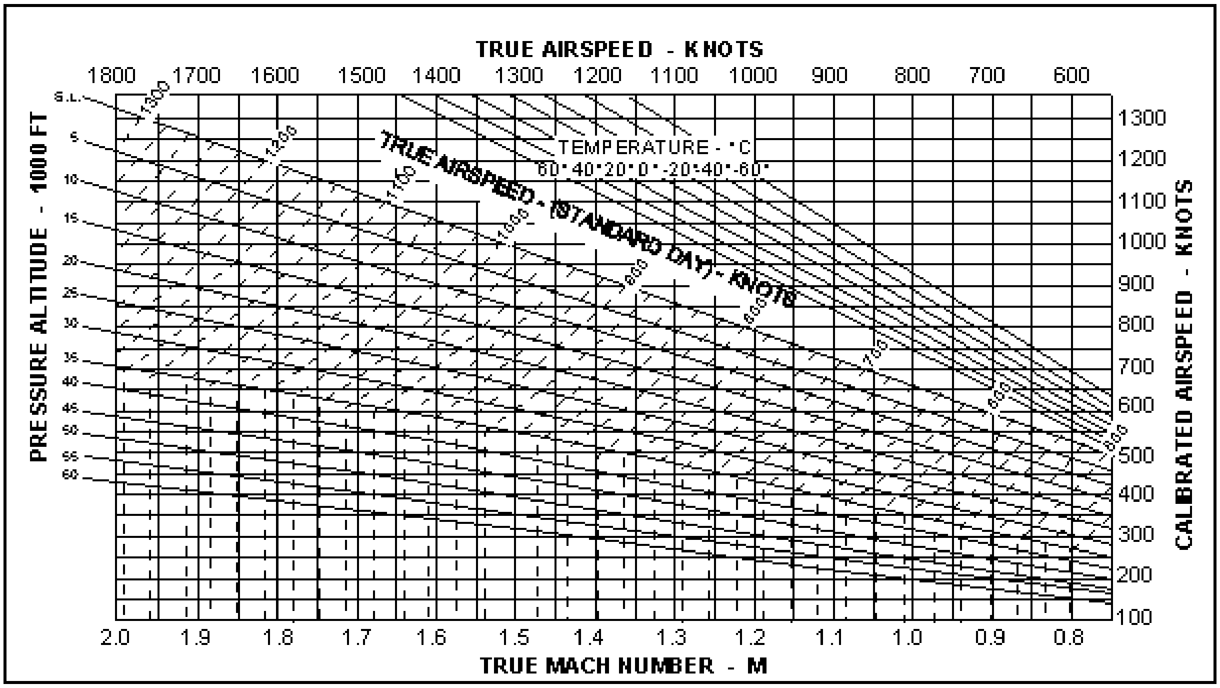

Figure 2. TAS and CAS Relationship With Varying Altitude and Temperature (Continued).

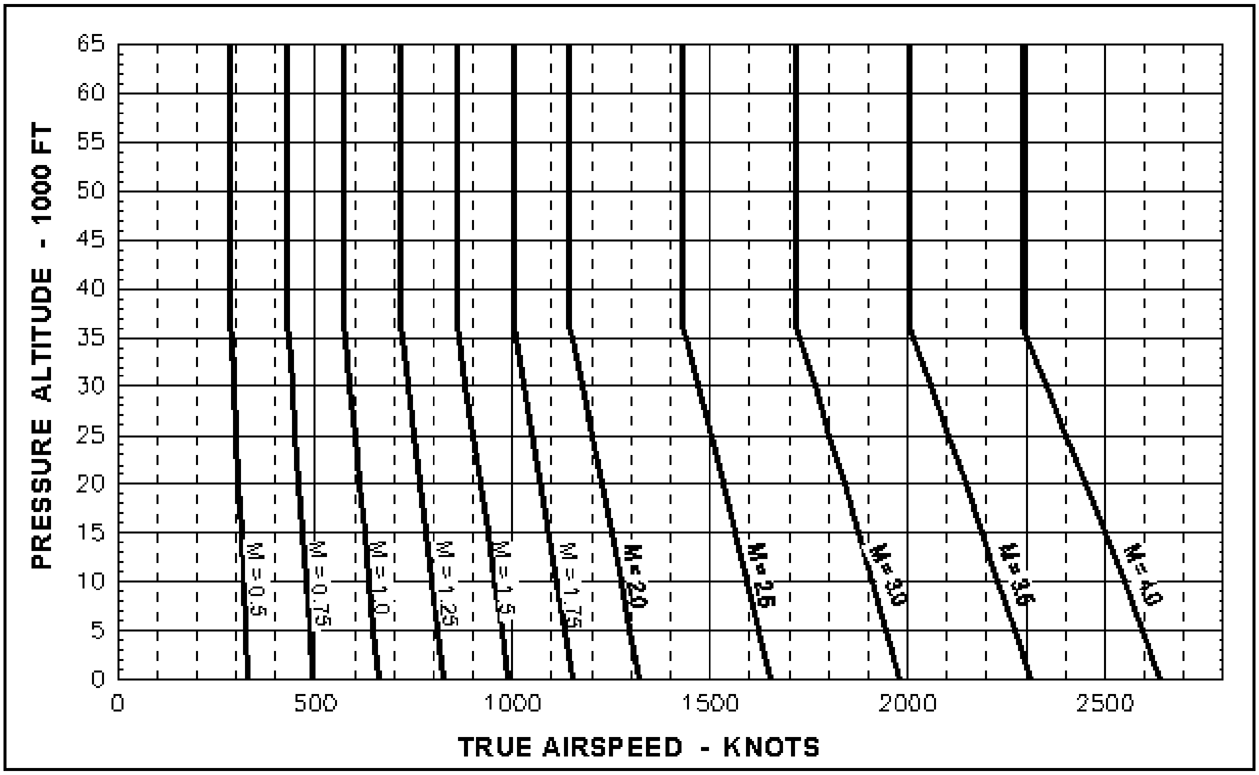

Figure 3. Mach Number vs. TAS Variation With Altitude.

The following is a derivation of equation [2] for the speed of sound:

Given: p = pressure (lb/ft^2)
v = specific volume (ft^3/lb)
R = a constant (for air: R = 53.3)

T = absolute temperature (°Rankine) = °F + 459.7
w = specific weight (lb/ft^3) = $1/v$
ρ = density = $w/\mathrm{g} = 1/\mathrm{g}v \;\therefore\; v = 1/\mathrm{g}\rho$

From Boyle's law of gasses: $pv = \mathrm{RT}$, therefore we have: $p/\rho = \mathrm{gRT} = (32.2)(53.3)\mathrm{T} = 1718\ \mathrm{T}$ **[3]**

It can also be shown that: p/ρ^{γ} = constant; for air $\gamma = 1.4$ **[4]**

From the continuity equation applied to a sound wave: $\rho A V_a = (\rho + dp)A(V_a + dV_a)$ **[5]**

Expanding and dropping insignificant terms gives: $dV_a = -V_a\, d\rho/\rho$ **[6]**

Using Newton's second law ($p + \rho V_a/2$ = a constant) and taking derivatives: $dp = -\rho V_a dV_a$

Substituting into [6] gives: $V_a^2 = dp/d\rho$ **[7]**

Then taking derivatives of [4] and substituting in [7] gives: $V_a = \sqrt{\dfrac{\gamma p}{\rho}}$ **[8]**

Then using [3] gives: $V_a = \sqrt{\gamma gRT} = \sqrt{1.4(1718)T} = 49\sqrt{T}$ **[9]**

Using a “Standard” atmosphere of 59° F @ Sea Level (S.L.) and a lapse rate of -3.57°/1000 ft altitude:

$$V_a = 49\sqrt{459.7 + 59 - 3.57\,A}\,\frac{ft}{\sec}\left[\frac{3600\sec}{hr}\,\frac{nm}{6076\ ft}\right] = 29.06\sqrt{518.7 - 3.57A} \quad \text{which is equation [2]}$$

MANEUVERABILITY

A useful function is to determine how many "G's" an aircraft might require to make a given turn without altitude loss. From Newton's laws, F cos φ = W, where: F = force applied to an aircraft, W = weight, and φ = bank angle. By definition "G's" is the ratio of the force on an object to its weight, i.e., G = F/W = 1/cos φ.

Simple calculations will show the results presented in Table 1, to the right.

Given that the average structural limit of an aircraft is about 7 G's, the maximum bank angle that can be achieved in level (non-descending) flight is 81.8°.

Table 1. G vs. Angle of Bank.
(No altitude loss)

G	φ
1.0	0
1.4	45
2.0	60
3.9	75
7.2	82
11.5	85

Figure 1 can be used to determine the turn radius and rate-of-turn for any aircraft, given speed and angle of bank (assuming the aircraft maintains level flight). It may also be used in the reverse context. It should be noted that not all aircraft can fly at the speeds depicted - they may stall beforehand or may be incapable of attaining such speeds due to power/structural limitations.

In the example shown on Figure 1, we assume an aircraft is traveling at 300 kts, and decides to make a 30° angle of bank turn. We wonder what his turn radius is so we can approximate his flight path over the ground, and what his rate of turn will be. We enter the chart at the side at 300 kts and follow the line horizontally until we intercept the 30° "bank angle for rate of turn" line. We then go down vertically to determine the 2.10°/sec rate of turn. To get radius, we continue horizontally to the 30° "bank angle for turn radius" line. We can then go down vertically to determine the radius of 13,800 ft.

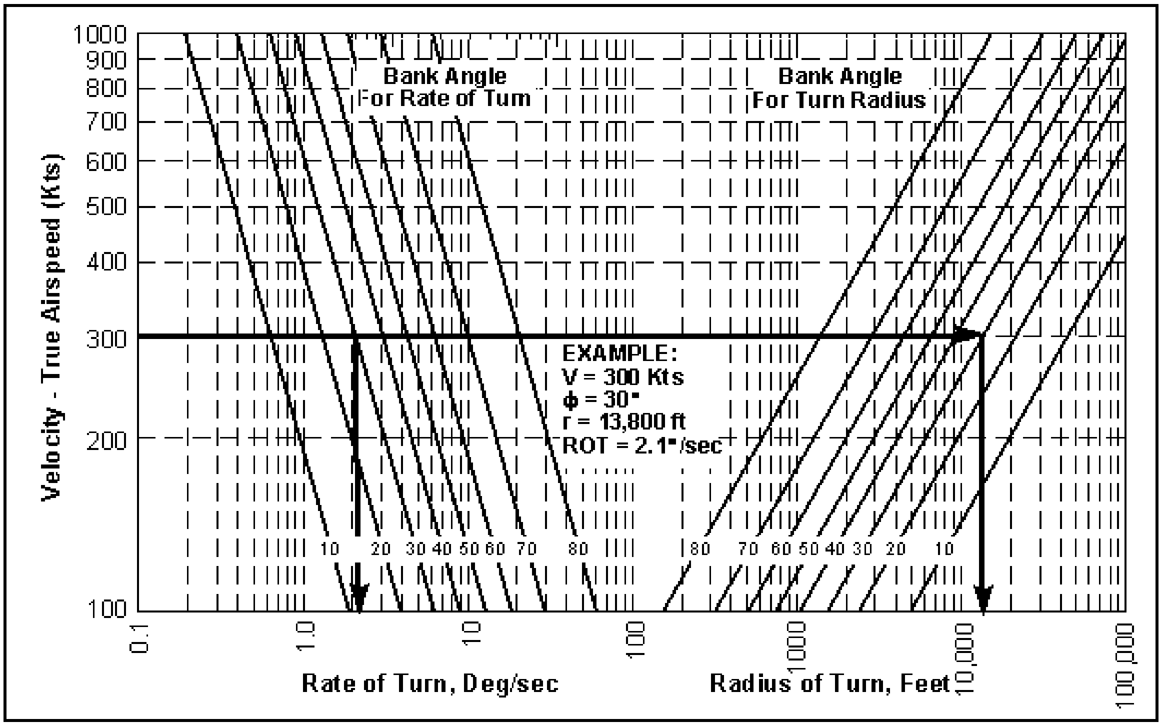

Figure 1. Aircraft Turn Rate / Radius vs. Speed.

The exact formulas to use are:

$$Rate\ of\ Turn = \frac{1091\tan(\phi)}{V} \qquad Radius\ of\ Turn = \frac{V^2}{11.26\tan(\phi)} \qquad Where: \begin{matrix} V = Velocity\ (Knots) \\ and\ \phi = Angle\ of\ Bank \end{matrix}$$

Another interesting piece of information might be to determine the distance a typical aircraft might travel during a maneuver to avoid a missile.

Figure 2 shows a birds-eye view of such a typical aircraft in a level (constant altitude) turn.

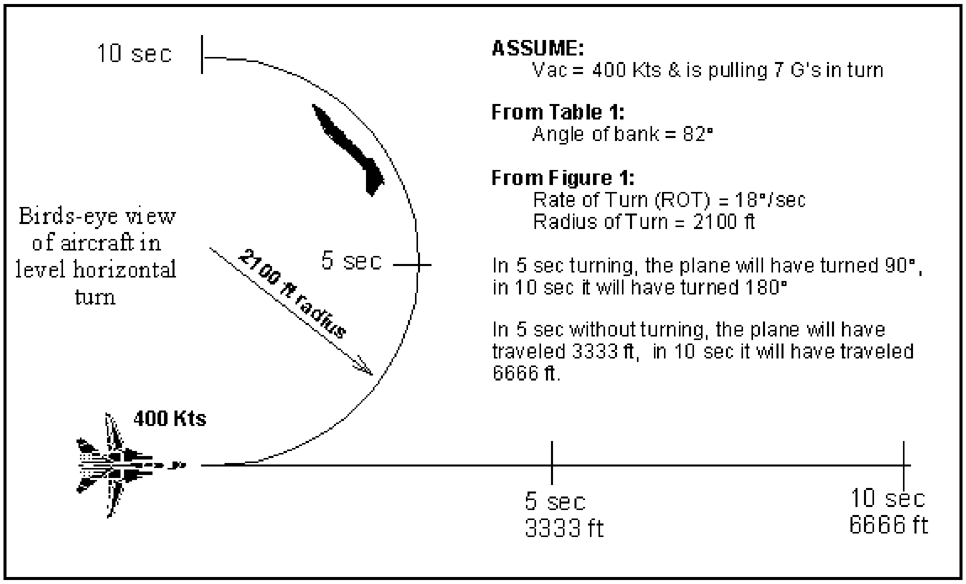
10 sec
Birds-eye view of aircraft in level horizontal turn
5 sec
2100 ft radius
400 Kts
5 sec 3333 ft
10 sec 6666 ft
ASSUME:
Vac = 400 Kts & is pulling 7 G's in turn
From Table 1:
Angle of bank = 82°
From Figure 1:
Rate of Turn (ROT) = 18°/sec
Radius of Turn = 2100 ft
In 5 sec turning, the plane will have turned 90°, in 10 sec it will have turned 180°
In 5 sec without turning, the plane will have traveled 3333 ft, in 10 sec it will have traveled 6666 ft.

Figure 2. Maneuvering Aircraft.

To counter many air-to-air missiles the pilot might make a level turn, however in countering a SAM, altitude is usually lost for two reasons: (1) the direction of maneuvering against the missile may be downward, and (2) many aircraft are unable to maintain altitude without also losing speed. These aircraft may have insufficient thrust for their given weight or may be at too high an altitude. The lighter an aircraft is (after dropping bombs/burning fuel), the better the performance. Likewise, the higher the altitude, the poorer the thrust-to-weight ratio. Maximum afterburner is frequently required to maintain altitude at maximum "G" level.

REFERENCE AXES (Roll, Pitch, Yaw)

The rotational or oscillating movement of an aircraft, missile, or other object about a longitudinal axis is called roll, about a lateral axis is called pitch, and about a vertical axis is called yaw as shown in Figure 3.

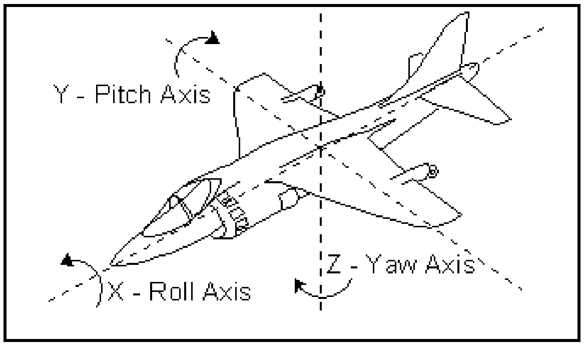
Y - Pitch Axis
X - Roll Axis
Z - Yaw Axis

Figure 3. Reference Axes.

SAMPLE CALCULATIONS

If we want to determine the rate of turn or turn radius more precisely than can be interpolated from the chart in Figure 1, we use the formulas. For our initial sample problem with an aircraft traveling 300 kts, in a 30° angle of bank turn, we have:

$$Rate\ of\ Turn = \frac{1091 \tan(\phi)}{V} = \frac{1091 \tan(30)}{300} = 2.1° / \sec$$

$$Radius\ of\ Turn = \frac{V^2}{11.26 \tan(\phi)} = \frac{300^2}{11.26 \tan(30)} = 13{,}844\ ft$$

These are the same results as we determined using Figure 1.

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EMP / AIRCRAFT DIMENSIONS

An aircraft flying in the vicinity of an electromagnetic pulse (EMP) acts like a receiving antenna and picks up EMP radiation in relation to size like a dipole (or half-wavelength dipole). The electromagnetic pulse spectrum decreases above 1 MHz as shown in Figure 1, so an F-14 aircraft that is an optimum ½ wavelength antenna at ≈8 MHz will pick up less EMP voltage than a B-52 or an aircraft with a trailing wire antenna. A rule of thumb for the voltage picked up is:

V_{EMP} = 8.1 volts/ft times the maximum dimension of the aircraft in feet

This rule of thumb was generated because a single linear relationship between voltage and aperture seemed to exist and compared favorably with more complex calculations for voltage picked up by various aircraft when subjected to EMP.

Table 1 shows various aircraft and the frequencies they would be most susceptible to, using f = c/λ, where λ matches the selected aircraft dimension for maximum "antenna reception effect." This should be a design consideration when trying to screen onboard avionics from the effects of EMP.

The following is a partial listing of aircraft types vs. identifying prefix letters (several are used in Table 1):

A	Attack	K	Tanker	T	Trainer
B	Bomber	O	Observation	U	Utility
C	Cargo	P	Patrol	V	Vertical or Short Takeoff and Landing (V/STOL)
E	Electronic Surveillance	Q	Special mission		
F	Fighter	R	Reconnaissance	X	Experimental
H	Helicopter	S	Anti Sub/Ship	Y	Prototype

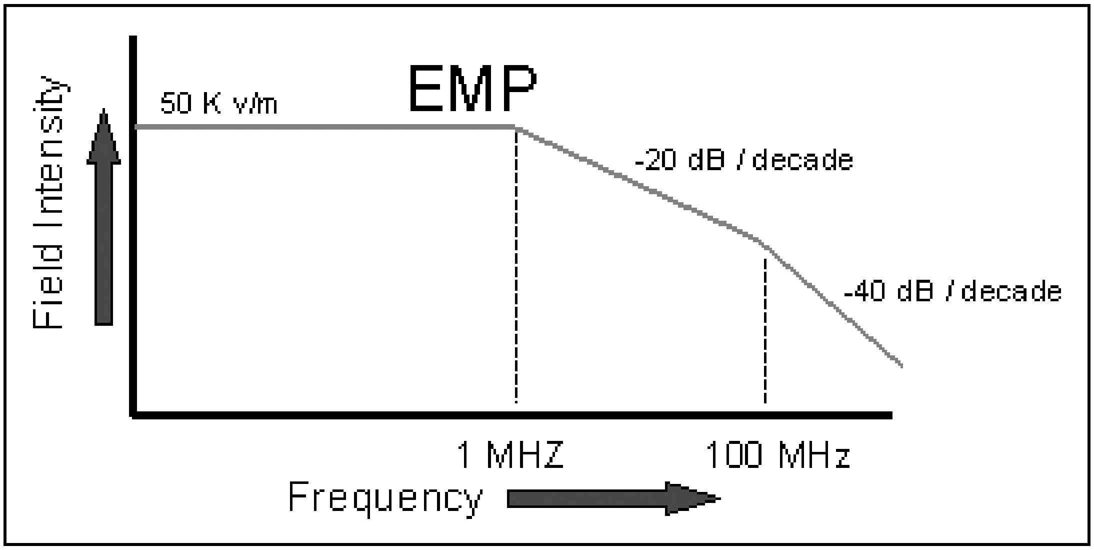

Figure 1. EMP as a Function of Frequency.

Table 1. Aircraft Dimensions and Equivalent Antenna Aperture.

Mission	Aircraft Type	Height (ft.)	Frequency (MHz)		Length (ft.)	Frequency (MHz)		Wing Span (ft.)	Frequency (MHz)	
		A	f	f/2	A	f	f/2	A	f	f/2
ATTACK	A-10	14.66	67.05	33.52	53.33	18.43	9.21	57.5	17.1	8.55
ELECTRONIC WARFARE	EA-6B	16.50	59.64	29.82	59.34	16.58	8.29	53.0	18.57	9.29
	EA-18	16.0	61.47	30.74	60.17	16.35	8.17	44.67	22.02	11.01
FIGHTER	F-15	18.4	53.42	26.71	63.75	15.42	7.71	42.8	22.97	11.48
	F-16	16.66	59.00	29.5	49.25	19.96	9.98	31.0	31.71	15.85
	F/A-18C/D	15.3	64.31	32.16	56.0	17.57	8.79	40.70	24.18	12.09
	F/A-18E/F	16	61.47	30.7	60.17	16.34	8.17	44.67	22.02	11.01
	F-22	17.75	55.41	27.7	64.17	15.33	7.66	43	22.87	11.43
	F-35A	14.2	69.27	34.63	51.4	19.1	9.57	35	28.1	14.05
	F-35C	15.5	63.45	31.73	51.4	19.1	9.57	43	22.8	11.43
	F-117	12.42	79.15	39.57	65.92	14.91	7.46	43.33	22.69	11.34
ASW	P-3C	33.75	29.16	14.58	116.42	8.45	4.23	99.67	9.87	4.94
	S-3A	22.75	43.25	21.63	54.34	18.45	9.23	68.67	14.33	7.17
	P-8	42.1	23.36	11.68	129.5	7.6	3.8	123.6	7.96	3.98
AEW	E-2C	18.4	53.48	26.74	56.50	17.42	8.71	80.58	12.21	6.11
V/STOL	AV-8B	11.64	84.45	42.23	46.3	21.23	10.62	30.3	32.44	16.22
	V-22	18.1	54.3	27.2	57.3	17.17	8.58	84.5	11.64	5.82
	F-35B	15.0	65.6	32.78	51.2	19.2	9.61	35	28.1	14.05
HELICOPTERS	AH-1W	14.16	69.46	34.73	58.25	16.89	8.44	48.0	20.49	10.24
	UH-1E	12.75	71.18	35.59	52.91	18.60	9.30	44.0	22.36	11.18
	U/SH-2	15.41	63.85	31.93	52.5	18.74	9.37	44.0	22.36	11.18
	SH-3D	16.42	59.93	29.97	72.67	13.54	6.77	62.00	15.87	7.84
	CH-46D	16.75	58.75	29.38	84.34	11.67	5.84	50.0	19.68	9.84
	CH-47	18.75	52.45	26.23	99.0	9.94	4.98	60.0	16.39	8.19
	CH-53A	24.91	39.50	19.75	88.16	11.16	5.58	72.25	13.62	6.81
	SH-60	17.0	57.85	28.93	64.83	15.17	7.59	53.83	18.27	9.14
	AH-64	15.25	64.5	32.25	58.25	16.89	8.44	48.0	20.49	10.24
TRANSPORT	C-2A	15.92	61.81	30.91	56.6	17.39	8.70	80.58	12.21	6.11
TANKERS	KC-130F	38.1	25.83	12.92	97.8	10.06	5.03	132.5	7.43	3.72
SPECIAL ELECTRONICS	EC-13OQ	38.5	25.56	12.78	99.34	9.91	4.96	132.58	7.42	3.71
TRAINER	T-2B	14.8	66.49	33.25	38.7	25.43	12.72	37.85	26.00	13.0
	T-39D	16.0	61.50	30.75	43.75	22.49	11.25	44.34	22.19	11.10
	T-45	13.5	72.86	36.43	39.33	25.0	12.5	30.8	31.93	15.97

DATA TRANSFER BUSSES

Data Busses 9-1
RS-232 Interface 9-2
RS-422 Balanced Voltage Interface 9-3
RS-485 Interface 9-4
IEEE-488 Interface Bus (HP-IB/GP-IB) 9-5
MIL-STD-1553 & 1773 Data Bus 9-6
Ethernet 9-7
Transmission Control Protocol / Internet Protocol 9-8

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DATA BUSSES

INTRODUCTION

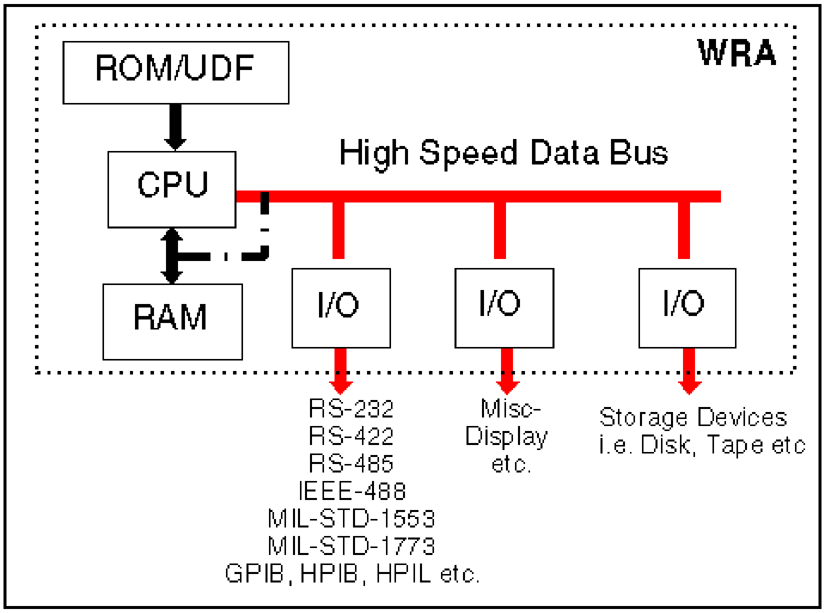

Figure 1. Avionics Block Diagram.

The avionics systems on aircraft frequently contain general purpose computer components which perform certain processing functions, then relay this information to other systems. Some common examples are the mission computers, the radar processors, RWRs, and jammers. Each system is frequently laid out as shown in Figure 1.

The Input/Output (I/O) modules will vary in function, but all serve the same purpose - to translate the electrical signals from one protocol to one of another in order to exchange information. I/O modules are used similarly in general purpose computers in laboratories to test equipment and/or tie computers together via a local area network (LAN) to exchange information. Some of the methodologies include a star, ring, or bus type network (see terminology at the end of this section).

A number of network "models" exist for describing the functions, interfaces and protocols involved in network data interchange. Regardless of the descriptive model used, all strive toward the same end and none actually changes the detailed implementation. Table 1 shows the layer names and the number of layers of networking models presented in Internet Engineering Task Forces (IETF) Request For Comments (RFCs) and in common use by textbooks.

Table 1. Some Common Network Architecture Models.

IETF-RFC 1122	**Kurose, Forouzan**	**Comer, Kozierok**	**Stallings**	**Cisco Academy**
Four layer Internet model	*Five-layer Internet model or TCP/IP protocol suite*	*TCP/IP 5-layer reference model*	*Five layer TCP/IP model*	*Four layer Internet model*
Application	Application	Application	Application	Application
Transport	Transport	Transport	Host-to-host or transport	Transport
Internet	Network	Internet	Internet	Internetwork
Link	Data link	Data link (Network interface)	Network access	Network interface
	Physical	(Hardware)	Physical	

These textbooks are secondary sources that may be contrary to the intent of RFC 1122 and other primary sources such as the Open Systems Interconnection (OSI) Reference Model developed by the International Organization for Standardization (ISO).

The OSI Reference Model is a more general description for layered communications and computer network protocol design. The IETF makes no effort to follow the OSI model although RFCs sometimes refer to it. The description of the OSI layers is shown in Table 2.

Table 2. OSI Reference Model.

	Name	Use	Misc Example	IP Suitte
7	APPLICATION	Meaning of data	HL7, Modbus	DHCP, DNS, FTP, Gopher, HTTP, NTP, SMTP, SNMP, Telnet
6	PRESENTATION	Building blocks of data and encryption	ASCII, EBCDIC, MIDI	MIME, XDR, SSL
5	SESSION	Opening and closing of specific communication paths	NetBIOS, SAP, Half Duplex, Simplex, SDP	NetBIOS, RTP, SAP
4	TRANSPORT	Error checking	NBF	PPTP, SCTP, TCP, UDP
3	NETWORK	Determination of data paths within the network	NBF, Q.931, IS-IS	IP, ICMP
2	DATA LINK	Data transmission, source, destination, and checksum	802.3 (Ethernet), PPP 802.11a/b/g/n MAC, FDDI	ARP, PPP, PPTP, SLIP
1	PHYSICAL	Voltage levels, signal connections, wire, or fiber	RS-232, 10Base-T, 802.11a/b/g/n Physical	

A layer is a collection of conceptually similar functions that provide services to the layer above it and receives service from the layer below it. On each layer an instance provides services to the instances at the layer above and requests service from the layer below. For example, a layer that provides error-free communications across a network provides the path needed by applications above it, while it calls the next lower layer to send and receive packets that make up the contents of the path. Conceptually two instances at one layer are connected by a horizontal protocol connection on that layer.

Most networks do not use all layers. For example, RS-232 is only a physical layer. Ethernet is only layers 1 and 2. TCP/IP is a protocol, not a network, and uses layers 3 and 4 regardless of whether layers 1 and 2 are a telephone line, wireless connection, or 10Base-T Ethernet cable.

Most of the sections in this division discuss the lowest (physical) layer of communication. There are, however, several more areas of general interest which are included in later sections such as Ethernet and TCP/IP. These are used in general purpose computers like the desktop PC or lab networks, and are not commonly used in aircraft.

The typical high-speed data busses on avionics/computers do not operate as fast as the CPU clock speed, but they are much faster than the interface busses they connect to. There are a number of interface busses (physical layer in network model) which are widely used by aircraft, avionics systems and test equipment. The most common include the RS-232, the RS-422, the RS-485, the IEEE-488 (GP-IB/HP-IB) and the MIL-STD-1553A/B. The MIL-STD-1773 bus is a fiber optic implementation of the 1553 bus and may be used in the future when technology requires it to reduce susceptibility to emissions or other reasons.

A summary of these more common types follows in Table 3, which includes a brief descriptive comparison, while a section covering each in more detail is provided later.

Table 3. Summary of Physical Bus Characteristics.

Bus	**Max Length**	**Max Number of Terminals**(1)	**Type**	**# of Lines**(2)	**Data Rate**	**Rise Time**(3)	**Data Format**
RS-232C	100 feet max 50 ft at 20k bps	1	Serial	3-20	150 - 19,200 baud per sec		5- to 8- bit serial
RS-422	1.2 km(4)	10(5)	Serial	3	see figure in RS-232 section	<0.1 T_b	unspecified
RS-485	unspecified	32	Serial	3	10 MHz	<0.3 T_b	unspecified
IEEE-488 (GP-IB/HP-IB)	20 meters	14	Parallel	16	500 kHz(6)		8-bit parallel
HP-IL	100 meters	30	Serial	2	20 k BPS		serial
MIL-STD-1553B MIL-STD-1773	300 feet N/A	32(7)	Serial	3	1 MHz	100-300 ns	20-bit serial

NOTES FROM TABLE:

(1) Max Number of Terminals does not include the bus controller.

(2) Including ground/shield

(3) T_b = time duration of the unit interval at the applicable data signaling rate (pulse width)

(4) Length is function of data signaling rate influenced by the tolerable signal distortion, amount of longitudinally coupled noise and ground potential difference introduced between the controller and terminal circuit grounds as well as by cable balance. See RS-422 section for graph.

(5) Physical arrangement of multiple receivers involves consideration of stub line lengths, fail-safe networks, location of termination resistors, data rate, grounding, etc.

(6) Rate can go up to 1 MHz if special conventions are followed.

(7) Max Number of Terminals includes terminal reserved for broadcast commands.

BUS TERMINOLOGY

10BASE-T: Standard "Plain Vanilla" Ethernet based on Unshielded Twisted Pair wire

10BASE-F: 10Mbps fiber optic Ethernet

100BASE-T: Standard "Fast Ethernet" based on twisted pair copper wire

ADDRESS: A unique designation for the location of data or the identity of an intelligent device; allows each device on a single communications line to respond to its own message.

ASCII (American Standard Code for Information Interchange): Pronounced asky. A seven-bit-plus-parity code established by ANSI to achieve compatibility between data services.

ASYNCHRONOUS OPERATION: Asynchronous operation is the use of an independent clock source in each terminal for message transmission. Decoding is achieved in receiving terminals using clock information derived from the message.

BAUD: Unit of signaling speed. The speed in baud is the number of discrete events per second. If each event represents one bit condition, baud rate equals bits per second (BPS). When each event represents more than one bit, baud rate does not equal BPS.

BIT: Contraction of binary digit: may be either zero or one. A binary digit is equal to one binary decision or the designation of one or two possible values of states of anything used to store or convey information.

BIT RATE: The number of bits transmitted per second.

BRIDGE: A network bridge connects multiple network segments at the data link layer (layer 2) of the OSI model, and the term layer 2 switch is very often used interchangeably with bridge. Bridges are similar to repeaters or network hubs, devices that connect network segments at the physical layer; however, with bridging, traffic from one network is managed rather than simply rebroadcast to adjacent network segments.

BROADCAST: Operation of a data bus system such that information transmitted by the bus controller or a remote terminal is addressed to more than one of the remote terminals connected to the data bus.

BUS CONTROLLER: The terminal assigned the task of initiating information transfers on the data bus.

BUS MONITOR: The terminal assigned the task of receiving bus traffic and extracting selected information to be used at a later time.

BYTE: A binary element string functioning as a unit, usually shorter than a computer "word." Eight-bits per byte are most common. Also called a "character."

COMMAND/RESPONSE: Operation of a data bus system such that remote terminals receive and transmit data only when commanded to do so by the bus controller.

CRC: Cyclic Redundancy Check; a basic error-checking mechanism for link-level data transmissions; a characteristic link-level feature of (typically) bit-oriented data communications protocols. The data integrity of a received frame or packet is checked by an algorithm based on the content of the frame and then matched with the result that is performed by a sender and included in a (most often, 16-bit) field appended to the frame.

CROSSOVER CABLE: Cable with transmit/receive pairs reversed so one computer or hub or switch can link directly to another.

DATA BUS: Whenever a data bus or bus is referred to in MIL-STD-1553B, it shall imply all the hardware including twisted shielded pair cables, isolation resistors, transformers, etc., required to provide a single data path between the bus controller and all the associated remote terminals.

DCE (Data Communications Equipment): Devices that provide the functions required to establish, maintain, and terminate a data-transmission connection; e.g., a modem.

DHCP: Dynamic Host Configuration Protocol - permits auto-assignment of temporary IP addresses for new devices logging in

DNS: Domain Name Server - associates names with IP addresses

DTE (Data Terminal Equipment): Devices acting as data source, data sink, or both.

DUPLEX: Communication traveling between two nodes in both directions

DYNAMIC BUS CONTROL: The operation of a data bus system in which designated terminals are offered control of the data bus.

EIA (Electronic Industries Association): A standards organization in the U.S.A. specializing in the electrical and functional characteristics of interface equipment.

FDM (Frequency-Division Multiplexer: A device that divides the available transmission frequency range into narrower banks, each of which is used for a separate channel.

FDX (Full Duplex): Simultaneous, two-way, independent transmission in both directions (4-wire).

FTP: File Transfer Protocol - the most popular mechanism for bulk movement of files on TCP/IP.

GATEWAY: Device which links Ethernet to dissimilar networks and transfers data at the application layer level. Interface cards link the PC to Ethernet via the PCI, ISA, PCMCIA, PC/104, or other buses.

GPIB: General Purpose Interface Bus (see section 9-5),

HALF DUPLEX: Operation of a data transfer system in either direction over a single line, but not in both directions on that line simultaneously.

HANDSHAKING: Exchange of predetermined signals between two devices establishing a connection. Usually part of a communications protocol.

HPIB / HPIL: Hewlett-Packard Interface Bus / Hewlett-Packard Interface Loop

HUB: The simplest method of redistributing data, are “dumb,” not interpreting or sorting messages that pass through them. A hub can be as simple as an electrical buffer with simple noise filtering. It isolates the impedances of multiple spokes in a star topology. Some hubs also have limited store-and-forward capability. They indiscriminately transmit data to all other devices, which are still on the same collision domain, connected to the hubs. They are not assigned MAC addresses or IP addresses.

IEEE (Institute of Electrical and Electronic Engineers): An international professional society that issues its own standards and is a member of ANSI and ISO.

IP: Internet Protocol portion of TCP/IP. It is a protocol used for communicating data across a packet-switched network.

IP ADDRESS: Address of a TCP/IP enabled device on an Intranet or Internet – in the form xxx.xxx.xxx.xxx, where xxx is an integer between 0 and 255.

LAN: Local Area Network

MAC: Media Access Control - the physical components which disassemble Ethernet message fames

MANCHESTER ENCODING: Digital encoding technique (specified for the IEEE 802.3 Ethernet baseband network standard) in which each bit period is divided into two complementary halves; a negative-to-positive (voltage) transition in the middle of the bit period designates a binary "1," while a positive-to-negative transition represents a "0." The encoding technique also allows the receiving device to recover the transmitted clock from the incoming data stream (self-clocking).

MESSAGE: A single message is the transmission of a command word, status word, and data words if they are specified. For the case of a remote terminal to remote terminal (RT to RT) transmission, the message shall include the two command words, the two status words, and data words.

MODE CODE: A means by which the bus controller can communicate with the multiplex bus related hardware, in order to assist in the management of information flow.

MODEM (Modulator-Demodulator): A device used to convert serial digital data from a transmitting terminal to a signal suitable for transmission over a telephone channel, or to reconvert the transmitted signal to serial digital data for acceptance by a receiving terminal.

MULTIPLEXOR (also Multiplexer): A device used for division of a transmission into two or more subchannels, either by splitting the frequency band into narrower bands (frequency division) or by allotting a common channel to several different transmitting devices one at a time (time division).

NETWORK: An interconnected group of nodes; a series of points, nodes, or stations connected by communications channels; the assembly of equipment through which connections are made between data stations.

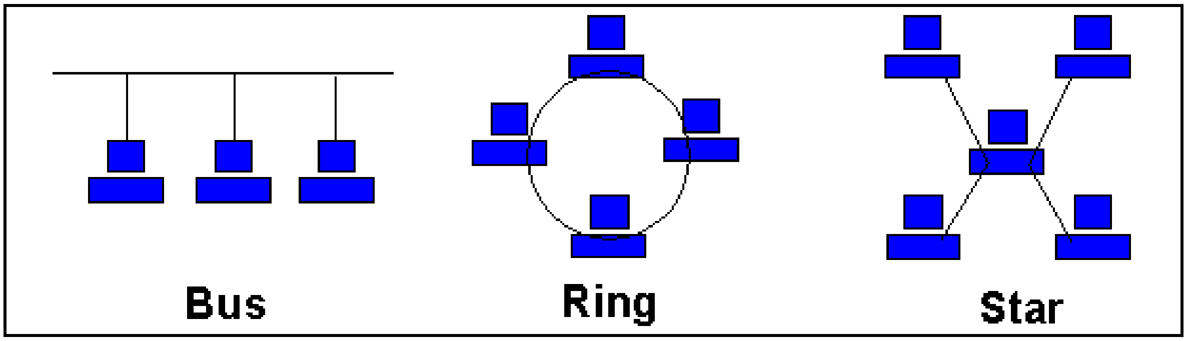

NODE: A point of interconnection to a network. Normally, a point at which a number of terminals or tail circuits attach to the network.

PARALLEL TRANSMISSION: Transmission mode that sends a number of bits simultaneously over separate lines (e.g., eight bits over eight lines) to a printer. Usually unidirectional.

PHASE MODULATION: One of three ways of modifying a sine wave signal to make it "carry" information. The sine wave or "carrier" has its phase changed in accordance with the information to be transmitted.

PING: Packet Inter Net Groper - very useful utility which probes for the existence of a TCP/IP host

POLLING: A means of controlling devices on a multipoint line.

PORT: A number in TCP/IP to which services are assigned; e.g. FTP is port 21; SMTP is port 25; HTTP is port 80.

PROTOCOL: A formal set of conventions governing the formatting and relative timing of message exchange between two communicating systems.

PULSE CODE MODULATION (PCM): The form of modulation in which the modulation signal is sampled, quantized, and coded so that each element of information consists of different types or numbers of pulses and spaces.

REMOTE TERMINAL (RT): All terminals not operating as the bus controller or as a bus monitor.

REPEATER: Buffer which cleans up, strengthens and re-transmits a signal.

ROUTER: Repeater which selectively re-distributes messages based on IP address

SERIAL TRANSMISSION: The most common transmission mode; in serial, information bits are sent sequentially on a single data channel.

SNMP: Simple Network Management Protocol; allows monitoring and management of a network.

SOCKET: Specific instance of an IP address and Port number that represents a single connection between two applications.

STAR TOPOLOGY: Topology which allows only one device at each end of a wire and requires repeaters for more than two devices.

STUBBING: Stubbing is the method wherein a separate line is connected between the primary data bus line and a terminal. The direct connection of stub line causes a mismatch which appears on the waveforms. This mismatch can be reduced by filtering at the receiver and by using bi-phase modulation. Stubs are often employed not only as a convenience in bus layout but as a means of coupling a unit to the line in such a manner that a fault on the stub or terminal will not greatly affect the transmission line operation. In this case, a network is employed in the stub line to provide isolation from the fault. These networks are also used for stubs that are of such length that the mismatch and reflection degrades bus operation. The preferred method of stubbing is to use transformer coupled stubs. The method provides the benefits of DC isolation, increased common mode protection, a doubling of effective stub impedance, and fault isolation for the entire stub and terminal. Direct coupled stubs should be avoided if at all possible. Direct coupled stubs provide no DC isolation or common mode rejection for the terminal external to its subsystem. Further, any shorting fault between the subsystems' internal isolation resistors (usually on the circuit board) and the main bus junction will cause failure of that entire bus. It can be expected that when the direct stub length exceeds 1.6 feet, that it will begin to distort the main bus waveforms. Note that this length includes the cable runs internal to a given subsystem.

SUBSYSTEM: The device or functional unit receiving data transfer service from the data bus.

SWITCH: Repeater which selectively re-distributes messages based on hardware MAC address

SYNCHRONOUS TRANSMISSION: Transmission in which data bits are sent at a fixed rate, with the transmitter and receiver synchronized. Synchronized transmission eliminates the need for start and stop bits.

TCP: Transmission Control Protocol - mechanism in TCP/IP that ensures that data arrives intact and in correct order

TELNET: Standard interface through which a client may access a host as though it were local

TERMINAL: The electronic module necessary to interface the data bus with the subsystem and the subsystem with the data bus. Terminals may exist as separate units or be contained within the elements of the subsystem.

TIME DIVISION MULTIPLEXING (TDM): The transmission of information from several signal sources through one communication system with different signal samples staggered in time to form a composite pulse train.

UDP: User Datagram Protocol - lower overhead alternative to TCP protocol which does not guarantee message delivery

WORD: A set of bits or bytes comprising the smallest unit of addressable memory. In MIL-STD-1553B, a word is a sequence of 16 bits plus sync and parity.

RS-232 INTERFACE

INTRODUCTION

The RS-232 interface is the Electronic Industries Association (EIA) standard for the interchange of serial binary data between two devices. It was initially developed by the EIA to standardize the connection of computers with telephone line modems. The standard allows as many as 20 signals to be defined, but gives complete freedom to the user. Three wires are sufficient: send data, receive data, and signal ground. The remaining lines can be hardwired on or off permanently. The signal transmission is bipolar, requiring two voltages, from 5 to 25 volts, of opposite polarity.

COMMUNICATION STANDARDS

The industry custom is to use an asynchronous word consisting of: a start bit, seven or eight data bits, an optional parity bit and one or two stop bits. The baud rate at which the word sent is device-dependent. The baud rate is usually 150 times an integer power of 2, ranging from 0 to 7 (150, 300, 600, ..., 19,200). Below 150 baud, many system-unique rates are used. The standard RS-232-C connector has 25 pins, 21 pins which are used in the complete standard. Many of the modem signals are not needed when a computer terminal is connected directly to a computer, and Figure 1 illustrates how some of the “spare” pins should be linked if not needed. Figure 1 also illustrates the pin numbering used in the original DB-25 connector and that now commonly used with a DB-9 connector normally used in modern computers

Specifying compliance to RS-232 only establishes that the signal levels in two devices will be compatible and that if both devices use the suggested connector, they may be able to be connected. Compliance to RS-232 does not imply that the devices will be able to communicate or even acknowledge each other’s presence.

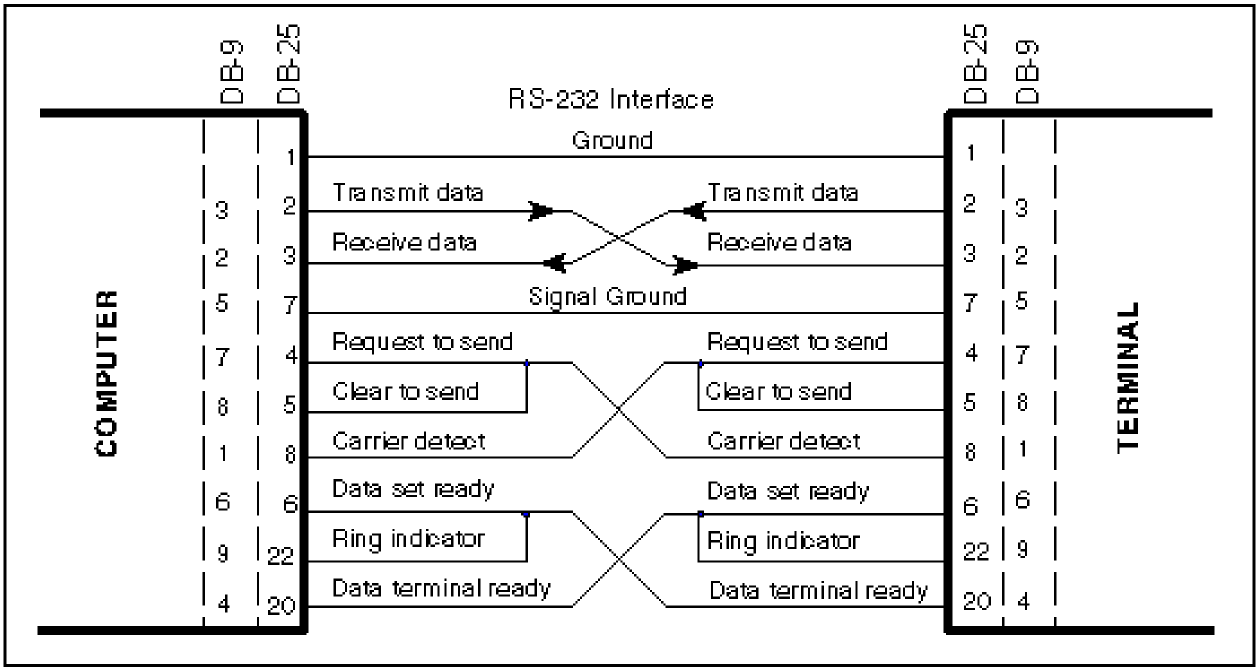
DB-9
DB-25
RS-232 Interface
DB-25
DB-9
Ground
Transmit data
Transmit data
Receive data
Receive data
Signal Ground
Request to send
Request to send
Clear to send
Clear to send
Carrier detect
Carrier detect
Data set ready
Data set ready
Ring indicator
Ring indicator
Data terminal ready
Data terminal ready
COMPUTER
TERMINAL
1
3 2
2 3
5 7
7 4
8 5
1 8
6 6
9 22
4 20
1
2 3
3 2
7 5
4 7
5 8
8 1
6 6
22 9
20 4

Figure 1. Direct-to-Computer RS-232 Interface.

Table 1 shows the signal names, and functions of the RS-232 serial port pinout. Table 2 shows a complete pin description.

Table 1. RS-232 Serial Port Pinout.

Name	Pin	Signal Name	Function
AA	1	PG Protective Ground	This line is connected to the chassis ground of the GPIB-232CV. Since the GPIB-232CV chassis ground is not connected to earth ground, pin 1 should be connected on both serial devices.
BA	2	TxD Transmit Data	This line carries serial data from the GPIB-232CV to the serial host.
BB	3	RxD Receive Data	This line carries serial data from the serial host to the GPIB-232CV.
CA	4	RTS Request to Send	This signal line is driven by the GPIB-232CV and when asserted indicates that the GPIB-232CV is ready to accept serial data. The GPIB-232CV un-asserts RTS when it is no longer ready to accept serial data because of a buffer full condition.
CB	5	CTS Clear to Send	This signal line is asserted by the serial host and sensed by the GPIB-232CV. When asserted, it indicates that the serial host is ready to accept serial data. When unasserted, it indicates that data transmission should be disabled.
AB	7	SG Signal Ground	This line establishes a reference point for all interface voltages.
CD	20	DTR Data Terminal Ready	This signal line is asserted by the GPIB-232CV to signal that it has been powered on, and is ready to operate.

Table 2. RS-232C Interface Signals.

Pin	Description	Pin	Description	Pin	Description
1	Protective Ground	10	(Reserved for Data Set Testing)	19	Secondary Request to Send
2	Transmitted Data	11	Unassigned	20	Data Terminal Ready
3	Received Data	12	Sec. Rec'd. Line Sig. Detector	21	Signal Quality Detector
4	Request to Send	13	Sec. Clear to Send	22	Ring Indicator
5	Clear to Send	14	Secondary Transmitted Data	23	Data Signal Rate Selector (DTE/DCE Source)
6	Data Set Ready	15	Transmission Signal Element Timing (DCE Source)	24	Transmit Signal Element Timing (DTE Source)
7	Signal Ground (Common Return)	16	Secondary Received Data	25	Unassigned
8	Received Line Signal Detector	17	Receiver Signal Element Timing (DCE Source)		
9	(Reserved for Data Set Testing)	18	Unassigned		

Electrical Characteristics: The RS-232-C specifies the signaling rate between the DTE and DCE, and a digital signal is used on all interchange circuits. The RS-232 standard specifies that logic “1” is to be sent as a voltage in the range -15 to -5 V and that logic “0” is to sent as a voltage in the range +5 to +15 V. The standard specifies that voltages of at least 3 V in amplitude will always be recognized correctly at the receiver according to their polarity, so that appreciable attenuation along the line can be tolerated. The transfer rate is rated > 20 kbps and a distance of < 15 m. Greater distance and data rates are possible with good design, but it is reasonable to assume that these limits apply in practice as well as in theory. The load impedance of the terminator side of the interface must be between 3000 and 7000 ohms, and not more than 2500 pF.

Table 3, summarizes the functional specifications of the most important circuits.

Table 3. RS-232-C Circuit Definitions.

Name	Direction to:	Function
Data Signals		
Transmitted Data (BA)	DCE	Data generated by DTE
Received Data (BB)	DTE	Data Received by DTE
Timing signals		
Transmitter Signal Element Timing (DA)	DCE	Clocking signal, transitions to ON and OFF occur at center of each signal element
Transmitter Signal Element Timing (DB)	DTE	Clocking signal, as above; both leads relate to signals on BA
Receiver Signal Element Timing (DD)	DTE	Clocking signal, as above, for circuit BB
Control Signals		
Request to Send (CA)	DCE	DTE wishes to transmit
Clear to Send (CB)	DTE	DCE is ready to transmit; response to request to send
Data Set Ready (CC)	DTE	DCE is ready to operate
Data Terminal Ready (CD)	DCE	DTE is ready to operate
Ring Indicator (CE)	DTE	Indicates that DCE is receiving a ringing signal on the communication channel
Carrier Detect (CF)	DTE	Indicates that DCE is receiving a carrier signal
Signal Quality Detector (CG)	DTE	Asserted when there is reason to believe there is an error in the received data
Data Signal Rate Selector (CH)	DCE	Asserted to select the higher of two possible data rates
Data Signal Rate Selector (CI)	DTE	Asserted to select the higher of two possible data rates
Ground		
Protective Ground (AA)	NA	Attached to machine frame and possibly external grounds
Signal Ground (AB)	NA	Establishes common ground reference for all circuits

Range: The RS-232-C standard specifies that the maximum length of cable between the transmitter and receiver should not exceed 100 feet. Although in practice many systems are used in which the distance between transmitter and receiver exceeds this rather low figure. The limited range of the RS-232C standard is one of its major shortcomings compared with other standards which offer greater ranges within their specifications. One reason why the range of the RS-232C standard is limited is the need to charge and discharge the capacitance of the cable connecting the transmitter and receiver.

Mechanical Characteristics: The connector for the RS-232-C is a 25 pin connector with a specific arrangement of wires. In theory, a 25 wire cable could be used to connect the Data Terminal Equipment (DTE) to the Data Communication Equipment (DCE). The DTE is a device that is acting as a data source, data sink, or both, e.g. a terminal, peripheral, or computer. The DCE is a device that provides the functions required to establish, maintain, and terminate a data-transmission connecting, as well as the signal conversion, and coding required for communication between data terminal equipment and data circuit; e.g. a modem. Table 4, shows the complete summary of the RS-232-C, e.g., descriptor, sponsor, data format, etc.

Table 4. Summary of the RS-232-C.

Data Format	5- to 8- bit serial
Transfer Type	Asynchronous
Error Handling	Optional Parity Bit
Connector	25-pin female connector on DCE; 25-pin male connector on DTE
Length	20 meters
Speed	20 kb/s
Remarks	RS-232 is used in the microcomputer world for communications between two DTEs. The null-modem is included into one or both connecting devices, and/or cable and is seldom documented. As a result, establishing an RS-232 connection between two DTEs is frequently a difficult task.

RS-422 BALANCED VOLTAGE INTERFACE

Specifying compliance to RS-422 only establishes that the signal between the specified devices will be compatible. It does not indicate that the signal functions or operations between the two devices are compatible. The RS-422 standard only defines the characteristic requirements for the balanced line drivers and receivers. It does not specify one specific connector, signal names, or operations. RS-422 interfaces are typically used when the data rate or distance criteria cannot be met with RS-232. The RS-422 standard allows for operation of up to 10 receivers from a single transmitter. The standard does not define operations of multiple tri-stated transmitters on a link.

The RS-422-A interfaces between the Data Terminal Equipment (DTE) and Data Communication Equipment (DCE) or in any point-to-point interconnection of signals between digital equipment. It employs the electrical characteristics of balanced-voltage digital interface circuits.

The balanced voltage digital interface circuit will normally be utilized on data, timing, or control circuits where the data signaling rate is up to 10 Mbit/s. While the balanced interface is intended for use at the higher data signaling rate, it may (in preference to the unbalanced interface circuit) generally be required if any of the following conditions prevail:

- The interconnecting cable is too long for effective unbalanced operation.
- The interconnecting cable is exposed to an extraneous noise source that may cause an unwanted voltage in excess of + 1 volt measured differentially between the signal conductor and circuit common at the load end of the cable with a 50 ohm resistor substituted for the generator.
- It is necessary to minimize interference with other signals.
- Inversion of signals may be required, i.e. plus to minus MARK may be obtained by inverting the cable pair.

Applications of the balanced voltage digital interface circuit are shown in Figure 1.

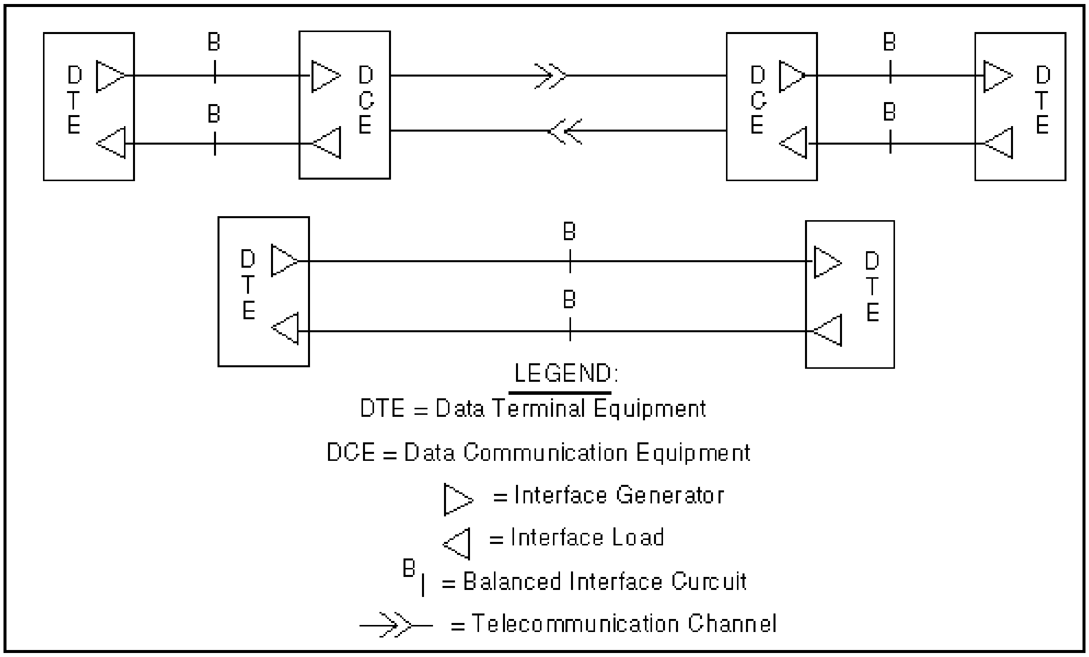
DTE
B
B
DCE
DCE
B
B
DTE
DTE
B
B
DTE
LEGEND:
DTE = Data Terminal Equipment
DCE = Data Communication Equipment
= Interface Generator
= Interface Load
B | = Balanced Interface Curcuit
= Telecommunication Channel

Figure 1. Application of a RS-422 Circuit.

While a restriction on maximum cable length is not specified, guidelines are given later with respect to conservative operating distances as function of data signaling rate.

For a binary system in which the RS-422-A is designed, the data signaling rate in bit/s and the modulation in bauds are numerically equal when the unit interval used in each determination is the minimum interval.

Electrical Characteristics:

The balanced voltage digital interface circuit consists of three parts: the generator (G), the balanced interconnecting cable, and the load. The load is comprised of one or more receivers (R) and an optional cable termination resistance (RT). The balanced voltage interface circuit is shown in Figure 2.

Environmental Constraints:

Balanced voltage digital interface conforming to this standard will perform satisfactorily at data signaling rates up to 10 Mbit/s providing that the following operational constraints are satisfied:

- The interconnecting cable length is within that recommended for the applicable data signaling rate (see Figure 3) and the cable is appropriately terminated.
- The common mode voltage at the receiver is less than 7 volts (peak). The common mode voltage is defined to be any uncompensated combination of generator-receiver ground potential difference, the generator offset voltage (Vos), and longitudinally coupled peak noise voltage measured between the received circuit ground and cable within the generator ends of the cable short-circuited to ground.

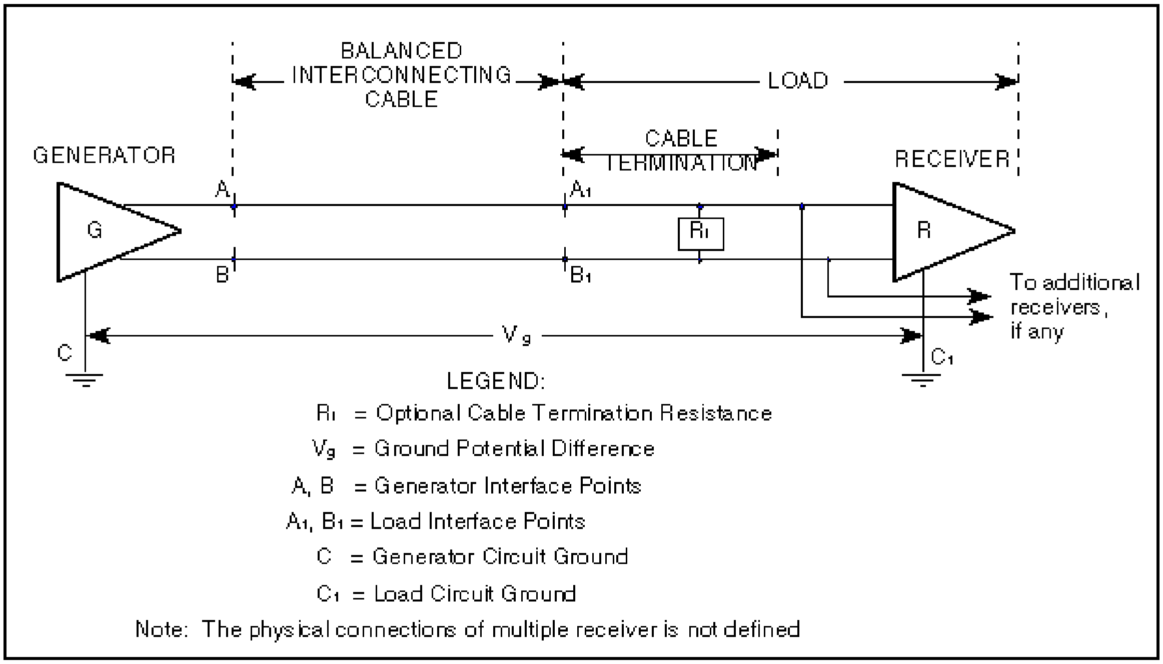
BALANCED
INTERCONNECTING
CABLE
LOAD
CABLE
TERMINATION
GENERATOR
RECEIVER
A
A1
G
R
Rt
B
B1
To additional
receivers,
if any
C
Vg
C1
LEGEND:
Rt = Optional Cable Termination Resistance
Vg = Ground Potential Difference
A, B = Generator Interface Points
A1, B1 = Load Interface Points
C = Generator Circuit Ground
C1 = Load Circuit Ground
Note: The physical connections of multiple receiver is not defined

Figure 2. Balanced Digital Interface Circuit.

Interconnecting Cable Guidelines:

The maximum permissible length of cable separating the generator and the load is a function of data signaling rate and is influenced by the tolerable signal distortion, the amount of coupled noise and ground potential difference introduced between the generator and load circuit as well as by cable balance. The curve of cable length versus signaling rate is given in Figure 3. This curve is based upon using 24 AWG copper, twisted-pair cable with a capacitance of 52.5 pF/meter terminated in a 100 ohm load. As data signaling rate is reduced below 90 kbit/s, the cable length has been limited at 1200 meters by the assumed maximum allowable 6 dBV signal loss.

Industry customs are not nearly as well established for RS-422 interfaces as they are for RS-232. The standard specifies use of the 37-pin "D"; the 9-pin "D" is specified for use with the secondary channel. Most data communications equipment uses the 37-pin "D"; many computer applications use a 9-pin "D" only. Some equipment applications use the 25-pin "D" defined for RS-232.

Compatibility With Other Interfaces:

Since the basic differential receivers of RS-423-A and RS-422-A are electrically identical, it is possible to interconnect an equipment using RS-423-A receivers and generators on one side of the interface with an equipment using RS-422-A generators and receivers on the other side of the interface, if the leads of the receivers and generators are properly configured to accommodate such an arrangement and the cable is not terminated.

This circuit is not intended for interoperation with other interface electrical circuits such as RS-232-C, MIL-STD-188C, or CCITT (Comite Consultatif Internationale Telegraphique et Telephonique), recommendations V.28 and V.35. Under certain conditions, the above interfaces may be possible but may require modification of the interface or equipment; therefore satisfactory operation is not assured and additional provisions not specified herein may be required.

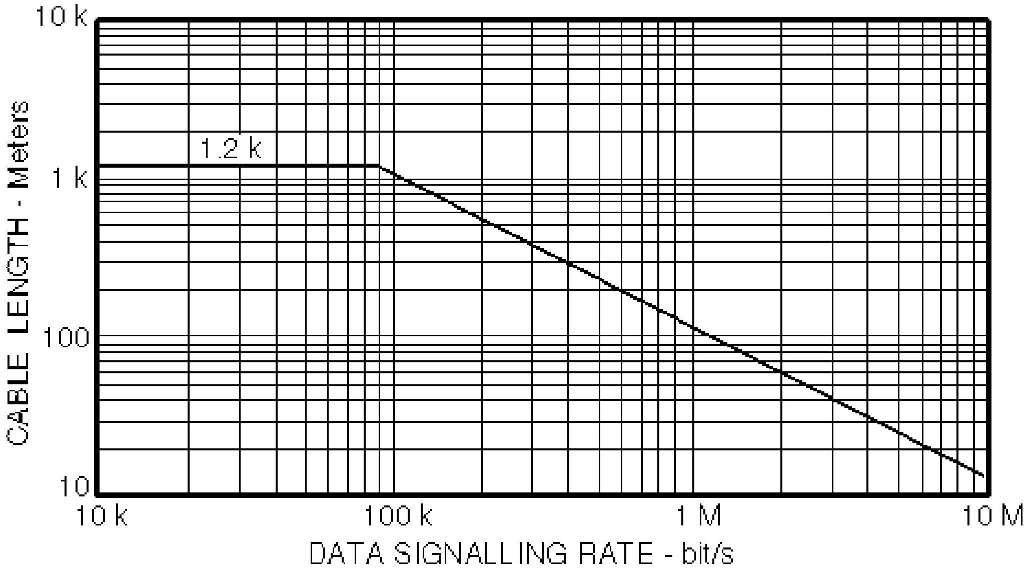

Figure 3. Data Signaling Rate vs. Cable Length.

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RS-485 INTERFACE

STANDARD FOR ELECTRICAL CHARACTERISTICS OF GENERATORS AND RECEIVERS FOR USE IN BALANCED DIGITAL MULTIPOINT SYSTEMS

Introduction: The RS-485 is the recommend standard by the Electronic Industries Association (EIA) that specifies the electrical characteristics of generators and receivers that may be employed for the interchange of binary signals in multipoint interconnection of digital equipments. When implemented within the guidelines, multiple generators and receivers may be attached to a common interconnecting cable. An interchange system includes one or more generators connected by a balanced interconnecting cable to one or more receivers and terminating resistors.

Electrical Characteristics: The electrical characteristics that are specified are measured at an interconnect point supplied by the devices manufacturer. Figure 1 shows an interconnection application of generators and receivers having the electrical parameters specified. The elements in the application are: generators, receivers, transmission cables, and termination resistances (Rt). The loads on the system caused by each receiver and passive generator shall be defined in terms of unit loads. Each generator can drive up to 32 unit loads consisting of both receivers and generators in the passive state. The loading caused by receivers and passive generators on the interconnect must be considered in defining the device electrical characteristics. Two areas are of concern: the DC load and the AC load characteristics. The DC load is defined as a number or fractions of "unit loads." The AC loading is not standardized but must be considered in the design of a system using the devices meeting this standard.

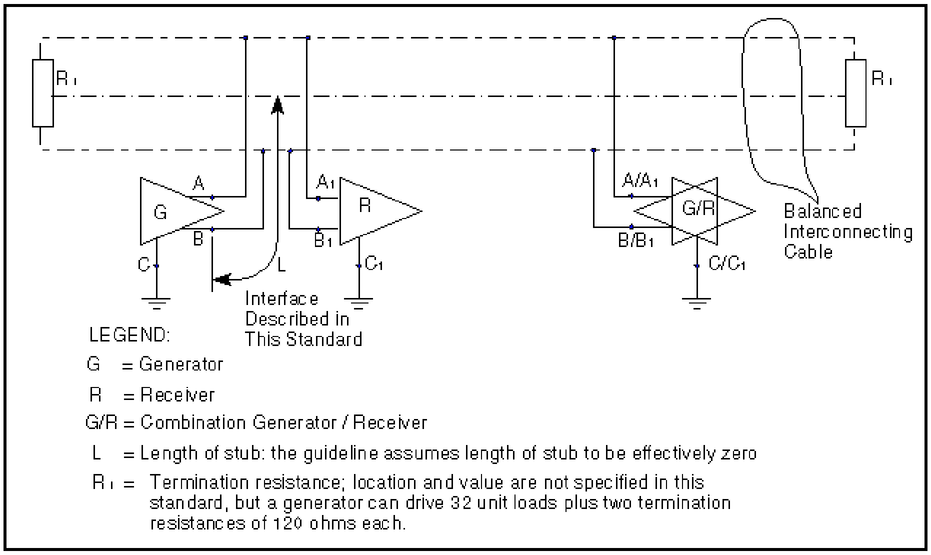
Rt
Rt
A
B
G
C
A1
B1
R
C1
L
Interface
Described in
This Standard
A/A1
B/B1
G/R
C/C1
Balanced
Interconnecting
Cable
LEGEND:
G = Generator
R = Receiver
G/R = Combination Generator / Receiver
L = Length of stub: the guideline assumes length of stub to be effectively zero
Rt = Termination resistance; location and value are not specified in this standard, but a generator can drive 32 unit loads plus two termination resistances of 120 ohms each.

Figure 1. Multipoint Interconnect Application.

General System Configuration: The generators and receivers conforming to the RS-485 standard can operate with a common mode voltage between -7 volts and +7 volts (instantaneous). The common mode voltage is defined to be any uncompensated combination of generator-receiver ground potential difference and longitudinally coupled peak noise voltage measured between the receiver circuit ground and cable with the generator ends of the cable short circuited to ground, plus the generator offset voltage (Vos).

Grounding Arrangements: Proper operation of the generator and receiver circuits requires the presence of a signal return path between the circuit grounds of the equipment at each end of the interconnection. The grounding arrangements are shown in Figure 2. Where the circuit reference is provided by a third conductor, the connection between circuit common and the third conductor must contain some resistance (e.g., 100 ohms) to limit circulating currents when other ground connections are provided for safety. Some applications may require the use of shielded interconnecting cable for EMI or other purposes. The shield shall be connected to frame ground at either or both ends, depending on the application.

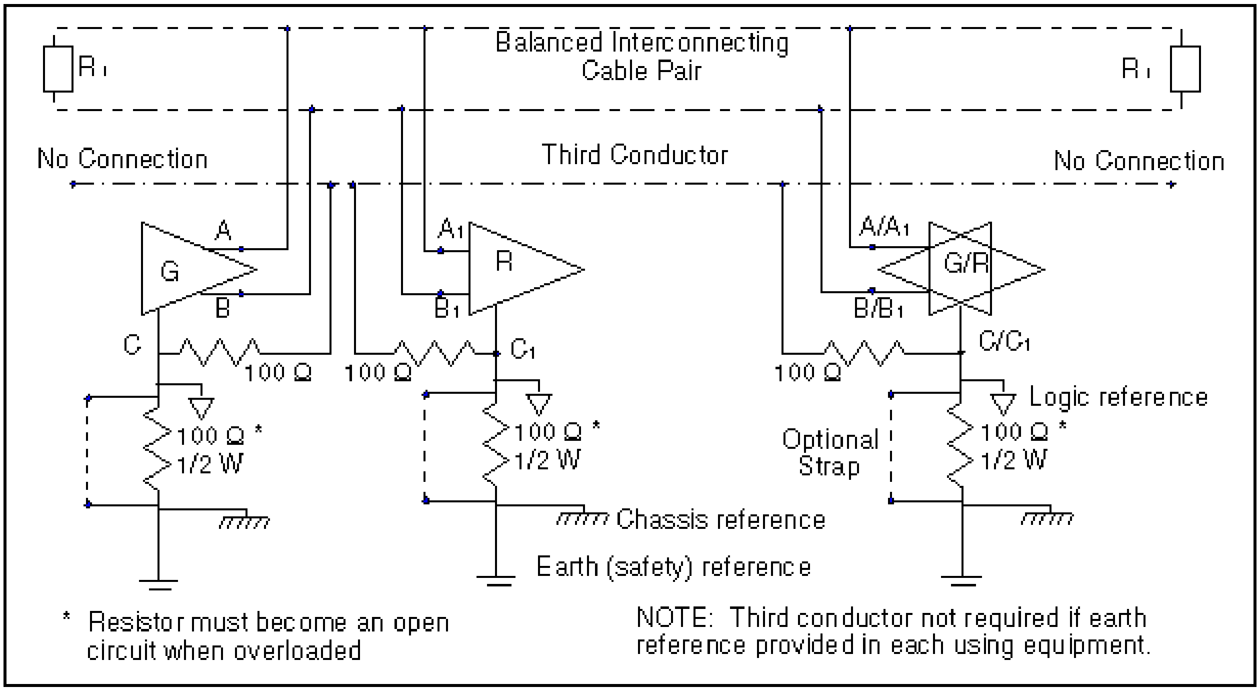
Balanced Interconnecting Cable Pair
R1
R1
No Connection
Third Conductor
No Connection
A
G
B
A1
R
B1
A/A1
G/R
B/B1
C
100 Ω
100 Ω
C1
100 Ω
C/C1
Logic reference
100 Ω *
1/2 W
100 Ω *
1/2 W
Optional Strap
100 Ω *
1/2 W
Chassis reference
Earth (safety) reference
* Resistor must become an open circuit when overloaded
NOTE: Third conductor not required if earth reference provided in each using equipment.

Figure 2. Grounding Arrangements.

Similarity with RS-422-A:

In certain instances, it may be possible to produce generators and receivers that meet the requirements of both RS-422-A and of RS-485. Table 1 depicts the differences in parameter specifications which exist between the two documents.

Table 1. Comparison of RS-422-A and RS-485 Characteristics.

Characteristic	RS-422-A	RS-485
Min. output voltage	2V into 100 ohm > 1/2 open circuit V	1.5 V into 54 ohms
I_{short} to ground	150 mA maximum	
I_{short} to -7, +12 volts		250 mA peak
t_{rise} time	< 0.1 t_b , 100 ohm load	< 0.3 t_b , 54 ohm, 50 pF load

Where t_b = time duration of the unit interval at the applicable data signaling rate (pulse width).

IEEE-488 INTERFACE BUS (HP-IB/GP-IB)

In the early 1970's, Hewlett-Packard came out with a standard bus (HP-IB) to help support their own laboratory measurement equipment product lines, which later was adopted by the IEEE in 1975. This is known as the IEEE Std. 488-1975. The IEEE-488 Interface Bus (HP-IB) or general purpose interface bus (GP-IB) was developed to provide a means for various instruments and devices to communicate with each other under the direction of one or more master controllers. The HP-IB was originally intended to support a wide range of instruments and devices, from the very fast to the very slow.

DESCRIPTION

The HP-IB specification permits up to 15 devices to be connected together in any given setup, including the controller if it is part of the system. A device may be capable of any other three types of functions: controller, listener, or talker. A device on the bus may have only one of the three functions active at a given time. A controller directs which devices will be talkers and listeners. The bus will allow multiple controllers, but only one may be active at a given time. Each device on the bus should have a unique address in the range of 0-30. The maximum length of the bus network is limited to 20 meters total transmission path length. It is recommended that the bus be loaded with at least one instrument or device every 2 meter length of cable (4 meters is maximum). The use of GP-IB extenders may be used to exceed the maximum permitted length of 20 meters.

ELECTRICAL INTERFACE

The GP-IB is a bus to which many similar modules can be directly connected, as is shown in Figure 1. A total of 16 wires are shown in the figure - eight data lines and eight control lines. The bus cables actually have 24 wires, providing eight additional for shielding and grounds.

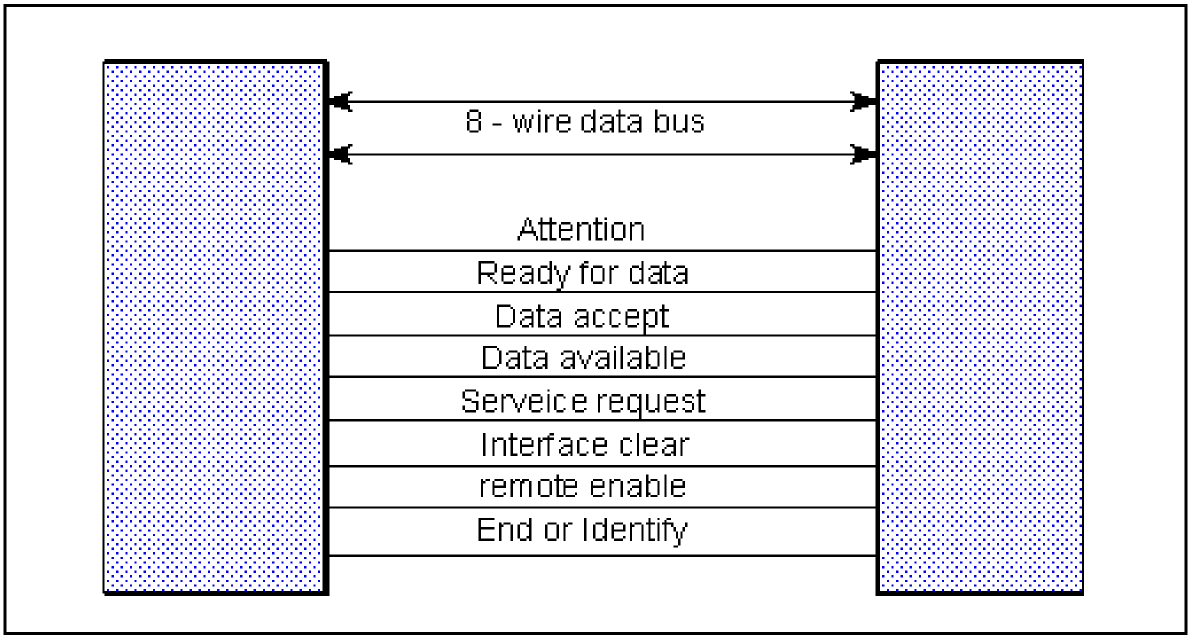

Figure 1. IEEE-488 (HP-IB / GP-IB) Bus Configuration.

The GP-IB defines operation of a three-wire handshake that is used for all data transfers on the bus. The bus operation is asynchronous in nature. The data-transfer rate of the GP-IB is 500 kHz for standard applications and can go up 1 MHz if special conventions are followed. Each transaction carries 8 bits, the maximum data bandwidth is on the order of 4 to 8 megabits (1 M byte) per second. The bus is a two way communications channel and data flows in both directions. Figure 2 illustrates the structure of the GP-IB bus and identifies the 16 connections of the interconnecting cable.

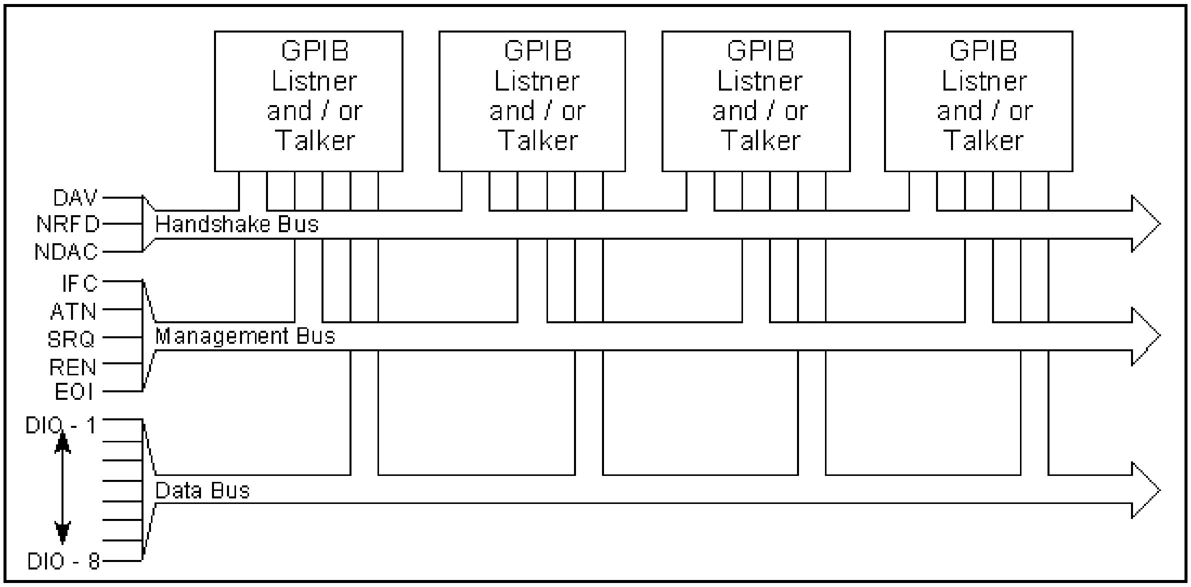
GPIB Listner and / or Talker
GPIB Listner and / or Talker
GPIB Listner and / or Talker
GPIB Listner and / or Talker
DAV
NRFD
NDAC
Handshake Bus
IFC
ATN
SRQ
REN
EOI
Management Bus
DIO - 1
Data Bus
DIO - 8

Figure 2. GP-IB Instrumentation Bus Structure.

The cabling limitations make it a less-than-ideal choice for large separation between devices. These limitations can be overcome with bus extenders. Those attempting to use bus extenders should be aware that few extenders are as transparent as claimed. This is especially true in handling of continuous data and interrupts. In nonextended environments, it provides an excellent means for high-speed computer control of multiple devices.

The following table shows the various interface functions, the mnemonics and the descriptions.

Table 1. GP-IB Interface Functions.

Interface Function	Mnemonic	Description
Talker (extended talker)	T (TE)	Device must be able to transmit
Listener (Extended listener)	L (LE)	Device must receive commands and data
Source Handshake	SH	Device must properly transfer a multiline message
Acceptor Handshake	AH	Device must properly receive remote multiline messages
Remote/Local	RL	Device must be able to operate from front panel and remote information from bus
Service Request	SR	Device can asynchronously request service from the controller
Parallel Poll	PP	Upon controller request, device must uniquely identify itself if it requires service
Device Clear	DC	Device can be initialized to a predetermined state
Device Trigger	DT	A device function can be initiated by the talker on the bus
Controller	C	Device can send addresses, universal commands, address commands, and conduct polls
Drivers	E	This code describes the type of electrical drivers in a device

The cabling specifications of the GP-IB interface system permit interconnecting all devices together in a star or linear configuration. The GP-IB connector is a 24-pin ribbon-type connector.

In summary, Table 2 on this page and the next shows the complete description of the GP-IB data bus.

Table 2. GP-IB Data Bus Description.

IEEE-488, GP-IB, HP-IB, or IEC-625					
Descriptor	8-bit parallel, monodirectional, multi-master (token passing) One controller, one talker, several listeners	Arbitration	Token passing: the controller addresses the next controller SRQ Service request when the controller assigns modes	Connector	24-pin Amphenol Female connector on equipment chassis. DIO1 1 ■ ■ 13 DIO5 DIO2 2 ■ ■ 14 DIO6 DIO3 3 ■ ■ 15 DIO7 DIO4 4 ■ ■ 16 DIO8 EOI 5 ■ ■ 17 REN DAV 6 ■ ■ 18 Gnd NRFD 7 ■ ■ 19 Gnd NDAC 8 ■ ■ 20 Gnd IFC 9 ■ ■ 21 Gnd SRQ 10 ■ ■ 22 Gnd ATN 11 ■ ■ 23 Gnd Shld 2 ■ ■ 24 Gnd
Sponsor	Hewlett-Packard	Error handling	Parity bit DI07 when 7-bit ACSII characters		
Standard	IEEE 488, IEC 625	Bus length	15 m		
Address space	31 devices	Driver	Special 24 mA drivers		
Data format	8-bit parallel	Speed	1 MByte/s		
Transfer type	Write only, talker toward listener(s) or commander toward all others			Remarks	The 488 is most commonly used for data acquisition of H-P peripherals. Programmable interfaces and drivers exist and simplify the development of microprocessor interfaces.
Timing	Handshaken 3-wire broadcast transfer: DAV data valid NDAC Not data accepted NRFD Not ready for data	References	IEEE Computer Society		

HP-IL VARIATION

Since introduction of the IEEE-488, technology produced a generation of medium-speed, low-power, instrumentation which had a need to operate in an automatic test system such as the GP-IB. The HP-IL (Hewlett-Packard Interface Loop), was introduced to meet this need. The HP-IL is a low-cost, low-power alternative to the GP-IB system. The HP-IL and GP-IB provide the same basic functions in interfacing controllers, instruments, and peripherals, but they differ in many other respects. HP-IL is suitable for use in low-power, portable applications (typically used for interface of battery-power systems). The GP-IB is not practical to operate from battery power. The HP-IL maximum data rate is 20K bytes per second. This is a high rate compared to the RS-232C, but much slower than GP-IB. The HP-IL can operate over distances of up to 100 meters between any two devices. Since it is a loop environment, there is no maximum system cable restriction. The basic device-addressing scheme allows for up to 30 devices on a loop.

MIL-STD-1553 & 1773 DATA BUS

PURPOSE

In recent years, the use of digital techniques in aircraft equipment has greatly increased, as have the number of avionics subsystems and the volume of data processed by them.

Because analog point-to-point wire bundles are inefficient and cumbersome means of interconnecting the sensors, computers, actuators, indicators, and other equipment onboard the modern military vehicle, a serial digital multiplex data bus was developed. MIL-STD-1553 defines all aspects of the bus, therefore, many groups working with the military tri-services have chosen to adopt it.

The 1553 multiplex data bus provides integrated, centralized system control and a standard interface for all equipment connected to the bus. The bus concept provides a means by which all bus traffic is available to be accessed with a single connection for testing and interfacing with the system. The standard defines operation of a serial data bus that interconnects multiple devices via a twisted, shielded pair of wires. The system implements a command-response format.

MIL-STD-1553, "Aircraft Internal Time-Division Command/Response Multiplex Data Bus," has been in use since 1973 and is widely applied. MIL-STD-1553 is referred to as "1553" with the appropriate revision letter (A or B) as a suffix. The basic difference between the 1553A and the 1553B is that in the 1553B, the options are defined rather than being left for the user to define as required. It was found that when the standard did not define an item, there was no coordination in its use. Hardware and software had to be redesigned for each new application. The primary goal of the 1553B was to provide flexibility without creating new designs for each new user. This was accomplished by specifying the electrical interfaces explicitly so that compatibility between designs by different manufacturers could be electrically interchangeable.

The Department of Defense chose multiplexing because of the following advantages:

- Weight reduction
- Simplicity
- Standardization
- Flexibility

Some 1553 applications utilize more than one data bus on a vehicle. This is often done, for example, to isolate a Stores bus from a Communications bus or to construct a bus system capable of interconnecting more terminals than a single bus could accommodate. When multiple buses are used, some terminals may connect to both buses, allowing for communication between them.

MULTIPLEXING

Multiplexing facilitates the transmission of information along the data flow. It permits the transmission of several signal sources through one communications system.

BUS

The bus is made up of twisted-shielded pairs of wires to maintain message integrity. MIL-STD-1553 specifies that all devices in the system will connect to a redundant pair of buses. This provides a second path for bus traffic should one of the buses be damaged. Signals are only allowed to appear on one of the two buses at a time. If a message cannot be completed on one bus, the bus controller may switch to the other bus. In some applications more than one 1553 bus may be implemented on a given vehicle. Some terminals on the bus may actually connect to both buses.

BUS COMPONENTS

There are only three functional modes of terminals allowed on the data bus: the bus controller, the bus monitor, and the remote terminal. Devices may be capable of more than one function. Figure 1 illustrates a typical bus configuration.

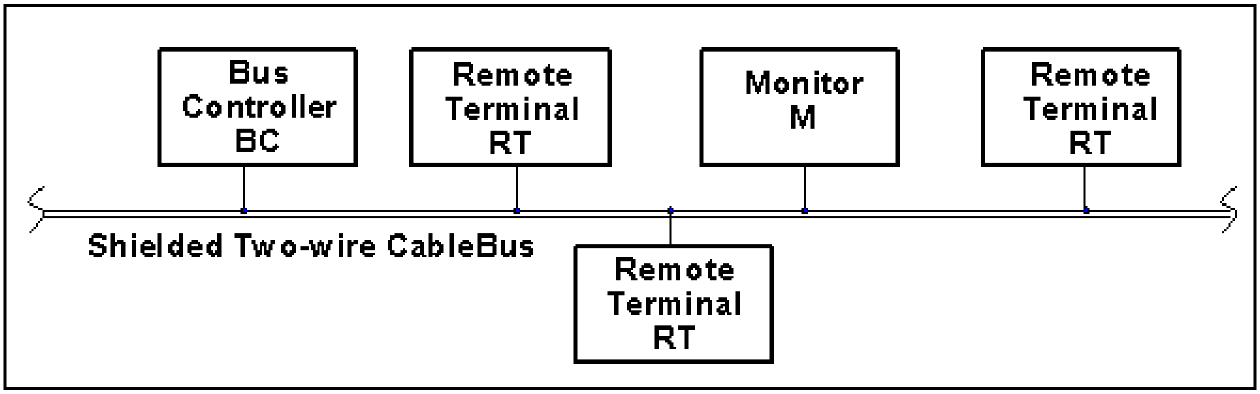

Figure 1. 1553 Bus Structure.

- Bus Controller - The bus controller (BC) is the terminal that initiates information transfers on the data bus. It sends commands to the remote terminals which reply with a response. The bus will support multiple controllers, but only one may be active at a time. Other requirements, according to 1553, are: (1) it is “the key part of the data bus system,” and (2) “the sole control of information transmission on the bus shall reside with the bus controller.”

- Bus Monitor - 1553 defines the bus monitor as “the terminal assigned the task of receiving bus traffic and extracting selected information to be used at a later time.” Bus monitors are frequently used for instrumentation.

- Remote Terminal - Any terminal not operating in either the bus controller or bus monitor mode is operating in the remote terminal (RT) mode. Remote terminals are the largest group of bus components.

MODULATION

The signal is transferred over the data bus using serial digital pulse code modulation.

DATA ENCODING

The type of data encoding used by 1553 is Manchester II biphase.

- A logic one (1) is transmitted as a bipolar coded signal 1/0 (in other words, a positive pulse followed by a negative pulse).
- A logic zero (0) is a bipolar coded signal 0/1 (i.e., a negative pulse followed by a positive pulse).

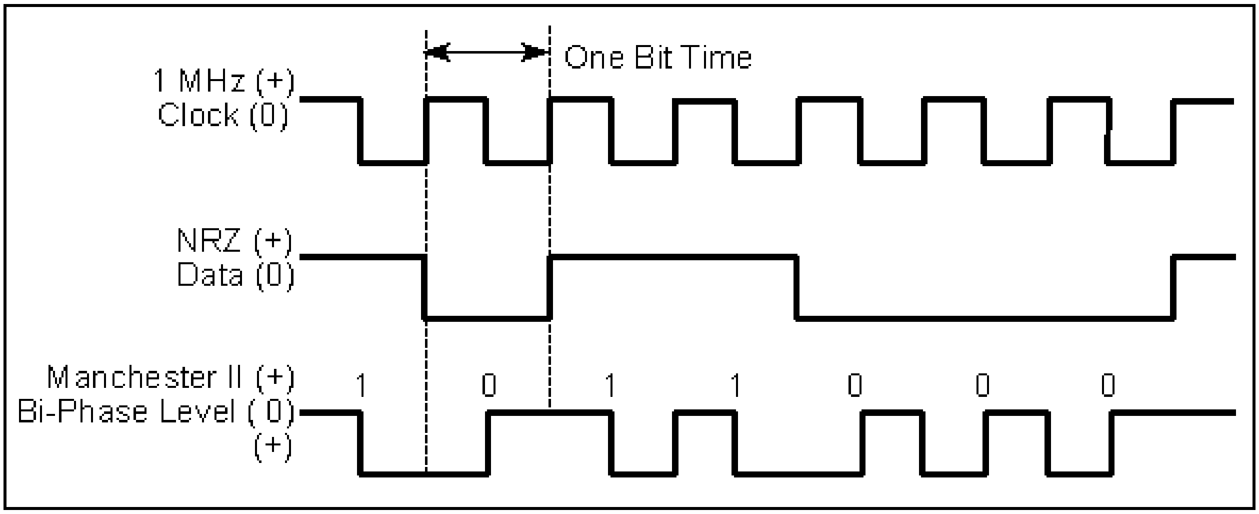

Figure 2. Data Encoding.

A transition through zero occurs at the midpoint of each bit, whether the rate is a logic one or a logic zero. Figure 2 compares a commonly used Non Return to Zero (NRZ) code with the Manchester II biphase level code, in conjunction with a 1 MHz clock.

BIT TRANSMISSION RATE

The bit transmission rate on the bus is 1.0 megabit per second with a combined accuracy and long-term stability of +/- 0.1%. The short-term stability is less than 0.01%.

There are 20 1.0-microsecond bit times allocated for each word. All words include a 3 bit-time sync pattern, a 16-bit data field that is specified differently for each word type, and 1 parity check bit.

WORD FORMATS

Bus traffic or communications travels along the bus in words. A word in MIL-STD-1553 is a sequence of 20 bit times consisting of a 3 bit-time sync wave form, 16 bits of data, and 1 parity check bit. This is the word as it is transmitted on the bus; 1553 terminals add the sync and parity before transmission and remove them during reception. Therefore, the nominal word size is 16 bits, with the most significant bit (MSB) first.

There are three types of words: command, status, and data. A packet is defined to have no inter-message gaps. The time between the last word of a controller message and the return of the terminal status byte is 4-12 microseconds. The time between status byte and the next controller message is undefined. Figure 3 illustrates these three formats.

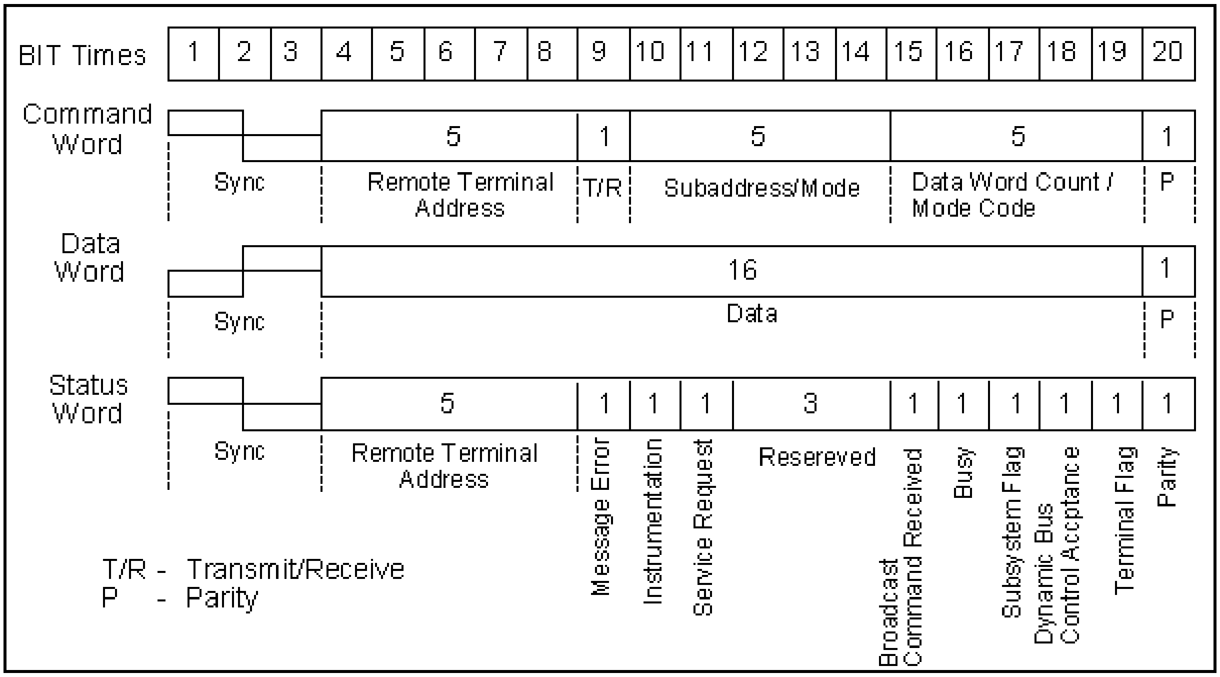
BIT Times
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Command Word
5
1
5
5
1
Sync
Remote Terminal Address
T/R
Subaddress/Mode
Data Word Count / Mode Code
P
Data Word
16
1
Sync
Data
P
Status Word
5
1
1
1
3
1
1
1
1
1
1
Sync
Remote Terminal Address
Message Error
Instrumentation
Service Request
Resereved
Broadcast Command Received
Busy
Subsystem Flag
Dynamic Bus Control Accptance
Terminal Flag
Parity
T/R - Transmit/Receive
P - Parity

Figure 3. 1553 Word Formats.

COMMAND WORD

Command words are transmitted only by the bus controller and always consist of:

- 3 bit-time sync pattern
- 5 bit RT address field
- 1 Transmit/Receive (T/R) field
- 5 bit subaddress/mode field
- 5 bit word count/mode code field
- 1 parity check bit.

DATA WORD

Data words are transmitted either by the BC or by the RT in response to a BC request. The standard allows a maximum of 32 data words to be sent in a packet with a command word before a status response must be returned. Data words always consist of:

- 3 bit-time sync pattern (opposite in polarity from command and status words)
- 16 bit data field
- 1 parity check bit.

STATUS WORD

Status words are transmitted by the RT in response to command messages from the BC and consist of:

- 3 bit-time sync pattern (same as for a command word)
- 5 bit address of the responding RT
- 11 bit status field
- 1 parity check bit.

The 11 bits in the status field are used to notify the BC of the operating condition of the RT and subsystem.

INFORMATION TRANSFERS

Three basic types of information transfers are defined by 1553:

- Bus Controller to Remote Terminal transfers
- Remote Terminal to Bus Controller transfers
- Remote Terminal to Remote Terminal transfers

These transfers are related to the data flow and are referred to as messages. The basic formats of these messages are shown in Figure 4.

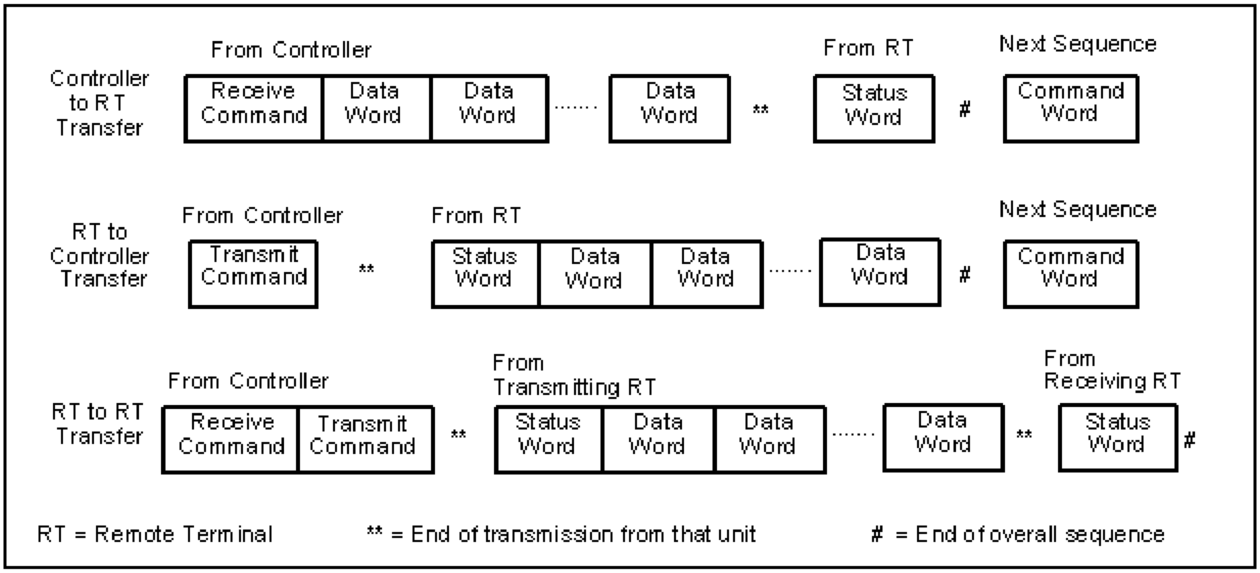
Controller to RT Transfer
From Controller
Receive Command
Data Word
Data Word
Data Word
**
From RT
Status Word
#
Next Sequence
Command Word
RT to Controller Transfer
From Controller
Transmit Command
**
From RT
Status Word
Data Word
Data Word
Data Word
#
Next Sequence
Command Word
RT to RT Transfer
From Controller
Receive Command
Transmit Command
**
From Transmitting RT
Status Word
Data Word
Data Word
Data Word
**
From Receiving RT
Status Word
#
RT = Remote Terminal
** = End of transmission from that unit
# = End of overall sequence

Figure 4. 1553 Data Message Formats.

The normal command/response operation involves the transmission of a command from the BC to a selected RT address. The RT either accepts or transmits data depending on the type (receive/transmit) of command issued by the BC. A status word is transmitted by the RT in response to the BC command if the transmission is received without error and is not illegal.

Figure 5 illustrates the 1553B Bus Architecture in a typical aircraft.

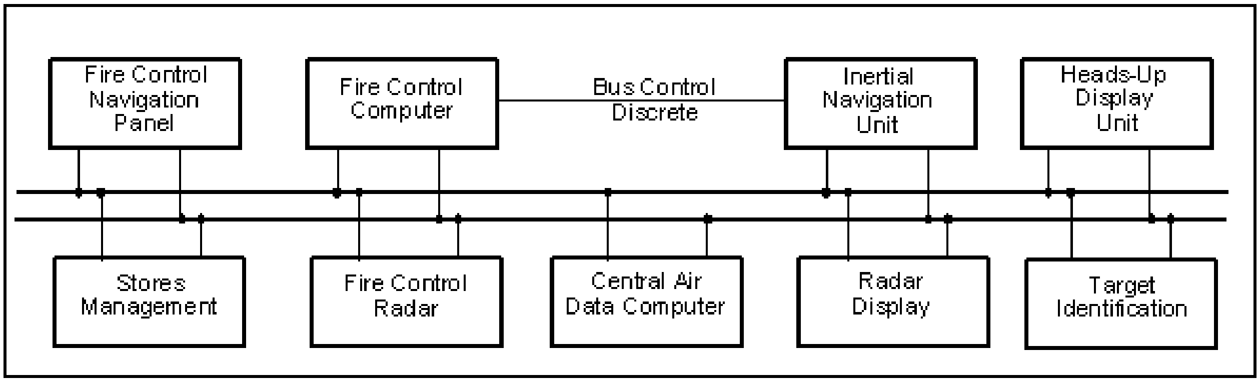
Fire Control
Navigation
Panel
Fire Control
Computer
Bus Control
Discrete
Inertial
Navigation
Unit
Heads-Up
Display
Unit
Stores
Management
Fire Control
Radar
Central Air
Data Computer
Radar
Display
Target
Identification

Figure 5. Typical Bus Architecture.

MIL-STD-1773

MIL-STD-1773 contains the requirements for utilizing a fiber optic “cabling” system as a transmission medium for the MIL-STD-1553B bus protocol. As such, the standard repeats MIL-STD-1553 nearly word-for-word. The standard does not specify power levels, noise levels, spectral characteristics, optical wavelength, electrical/optical isolation or means of distributing optical power. These must be contained in separate specifications for each intended use.

Data encoding and word format are identical to MIL-STD-1553, with the exception that pulses are defined as transitions between 0 (off) and 1 (on) rather than between + and - voltage transitions since light cannot have a negative value.

Since the standard applies to cabling only, the bus operates at the same speed as it would utilizing wire. Additionally, data error rate requirements are unchanged.

Different environmental considerations must be given to fiber optic systems. Altitude, humidity, temperature, and age affects fiber optics differently than wire conductors. Power is divided evenly at junctions which branch and connectors have losses just as wire connectors do.

ETHERNET

HISTORY

Ethernet was originally developed by Digital, Intel, and Xerox (DIX) in the early 1970's at the Xerox Palo Alto Research Center (PARC). The two primary inventors were Robert Metcalf and David Boggs.

IEEE Project 802 was set up in February 1980 to provide standards for Local Area Network (LAN) and Metropolitan Area Network (MAN) Architecture. The following committees were established:

- IEEE 802.1: Standards related to network management.
- IEEE 802.2: General standard for the data link layer in the OSI Reference Model. The IEEE divides this layer into two sub-layers -- the logical link control (LLC) layer and the media access control (MAC) layer. The MAC layer varies for different network types and is defined by standards IEEE 802.3 through IEEE 802.5.
- IEEE 802.3: Defines the MAC layer for bus networks that use CSMA/CD. **This is the basis of what is most commonly referred to as the Ethernet standard**.
- IEEE 802.4: Defines the MAC layer for token-bus networks.
- IEEE 802.5: Defines the MAC layer for token-ring networks.
- IEEE 802.6: Standard for Metropolitan Area Networks (MANs).
- IEEE 802.7-9 Inactive Standards:
  - IEEE 802.7: Broadband local area networks. The working group is currently inactive.
  - IEEE 802.8: The Fibre Optic Technical Advisory Group was to create a LAN standard for fiber optic media used in token passing computer networks like FDDI.
  - IEEE 802.9: Integrated Services (IS) LAN Interface at the MAC and Physical Layers.
- IEEE 802.10: A standard for security functions that can be used in both LAN and MAN.
- IEEE 802.11: Wireless LAN MAC and physical layer
- IEEE 802.12: Demand Priority Access Method, Physical Layer and Repeater used in star topology, 100VG-AnyLAN, etc
- IEEE 802.16: Fixed broadband wireless LAN

Ethernet versions 1.0 and 2.0 followed after the original development until the IEEE 802.3 committee altered the structure of the Ethernet II packet to form the Ethernet 802.3 packet. You will currently see either Ethernet II (DIX) format or Ethernet 802.3 format being used.

IEEE 802.3 Ethernet uses Manchester Phase Encoding (MPE) for coding the data bits on the outgoing signal.

INTRODUCTION

Ethernet is a family of frame-based computer networking technologies for local area networks (LANs). The 'Ether' part of Ethernet denotes that the system is not meant to be restricted for use on only one medium type. Copper cables, fiber cables and even radio waves can be used.

Ethernet is standardized as IEEE 802.3. The combination of the twisted pair versions of Ethernet for connecting end systems to the network, along with the fiber optic versions for site backbones, is the most widespread wired LAN technology. It has largely replaced competing LAN standards such as token ring, FDDI, and ARCNET.

Ethernet defines a number of wiring and signaling standards for the Physical Layer of the OSI networking model, through means of network access at the Media Access Control (MAC) / Data Link Layer, and a common addressing format. Therefore, Ethernet defines the lower two layers of the OSI Reference Model (see Data Busses Section intro). Ethernet sometimes implies an attached protocol—such as TCP/IP, however TCP/IP really defines the transport and network layers, respectively, of the OSI model.

Ethernet was designed as a 'broadcast' system, i.e. stations on the network can send messages whenever and wherever they want. All stations may receive the messages, however only the specific station to which the message is directed responds. To handle simultaneous demands, the system uses Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

CARRIER SENSE MULTIPLE ACCESS WITH COLLISION DETECTION (CSMA/CD)

When an Ethernet station is ready to transmit, it checks for the presence of a signal on the cable. If no signal is present then the station begins transmission. However, if a signal is present then the station delays transmission until the cable is not in use. If two stations detect an idle cable and at the same time transmit data, then a collision occurs. On a star-wired, unshielded twisted pair (UTP) network, if the transceiver of a sending station detects activity on both its receive and transmit pairs before it has completed transmitting, then it decides that a collision has occurred. On a coaxial system, a collision is detected when the DC signal level on the cable is the same or greater than the combined signal level of the two transmitters. Line voltage drops dramatically if two stations transmit at the same time and the first station to notice this sends a high voltage jamming signal around the network as a signal. The two stations involved with the collision quit transmitting again for a random time interval.

A Collision Domain is that part of the network where each station can 'see' other stations' traffic both unicast and broadcasts. The Collision Domain is made up of one segment of Ethernet coax (with or without repeaters) or a number of UTP shared hubs. A network is segmented with bridges that create two segments, or two Collision Domains where a station on one segment cannot see traffic between stations on the other segment unless the packets are destined for itself. If it can still see all broadcasts on the segmented network(s), no matter the number of segments, it is a Broadcast Domain.

ETHERNET FRAME

Figure 1 depicts the structure of the older DIX (Ethernet II) and the now standard 802.3 Ethernet frames. The numbers above each field represent the number of bytes.

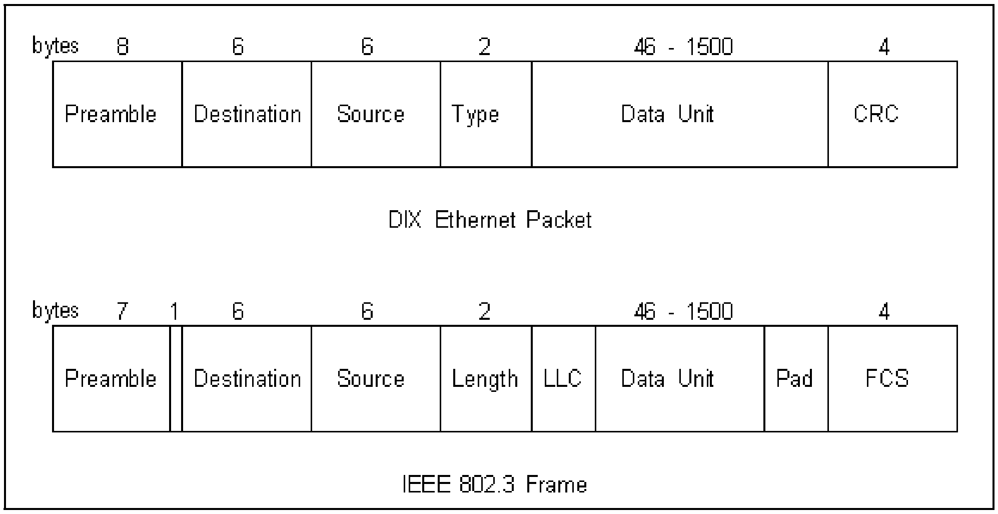

Figure 1. Ethernet Frame.

- **Preamble field:** Establishes bit synchronization and transceiver conditions so that the circuitry synchs with the received frame timing. The DIX frame has 8 bytes for the preamble rather than 7, as it does not have a Start Frame Delimiter (or Start of Frame).
- **Start Frame Delimiter:** Sequence 10101011 in a separate field, only in the 802.3 frame.
- **Destination address:** Hardware address (MAC address) of the destination station (usually 48 bits i.e. 6 bytes).
- **Source address:** Hardware address of the source station (must be of the same length as the destination address, the 802.3 standard allows for 2 or 6 byte addresses, although 2 byte addresses are never used, N.B. Ethernet II *only* uses 6 byte addresses).
- **Type:** Specifies the protocol sending the packet such as IP or IPX (only applies to DIX frame).
- **Length:** Specifies the length of the data segment, actually the number of LLC data bytes, (only applies to 802.3 frame and replaces the Type field).
- **LLC:** Logical Length Control is a data communication protocol layer which provides multiplexing and flow control mechanisms that make it possible for several network protocols (IP, IPX) to coexist within a multipoint network and to be transported over the same network media.
- **Data:** Actual data which is allowed anywhere between 46 to 1500 bytes within one frame.
- **Pad:** Zeros added to the data field to 'Pad' a short data field to 46 bytes (applies to 802.3 frame).
- **CRC:** Cyclic Redundancy Check to detect errors during transmission (DIX version of FCS).
- **FCS:** Frame Check Sequence to detect errors that occur during transmission (802.3 version of CRC). This 32-bit code has an algorithm applied to it, which will give the same result as the other end of the link, provided that the frame was transmitted successfully.

From the above we can see that the maximum 802.3 frame size is 1518 bytes and the minimum size is 64 bytes. Packets that have correct CRCs (or FCSs) but are smaller than 64 bytes are known as 'Runts'.

The hardware address, or MAC address is transmitted and stored in Ethernet network devices in **Canonical** format i.e. Least Significant Bit (LSB) first. The expression **Little-Endian** is used to describe the LSB format in which Ethernet is transmitted. On the other hand, Token Ring networks and the subset, Fiber

Distributed Data Interface (FDDI) networks, transmit the MAC address with the Most Significant Bit (MSB) first, or **Big-Endian**, This is known as **Non-Canonical** format. Note that this applies on a byte-by-byte basis i.e. the bytes are transmitted in the same order, it is just the bits in each of those bytes that are reversed. The storage of the MAC addresses in Token Ring and FDDI devices however, may sometimes still be in Canonical format so this can sometimes cause confusion. The reference to, the distribution of MAC addresses and the Organizationally Unique Identifier (OUI) destinations are always in Canonical format.

The Logical Link Control (LLC) protocol data unit (PDU) is defined in IEEE 802.2 and operates with 802.3 Ethernet as seen in Figure 2.

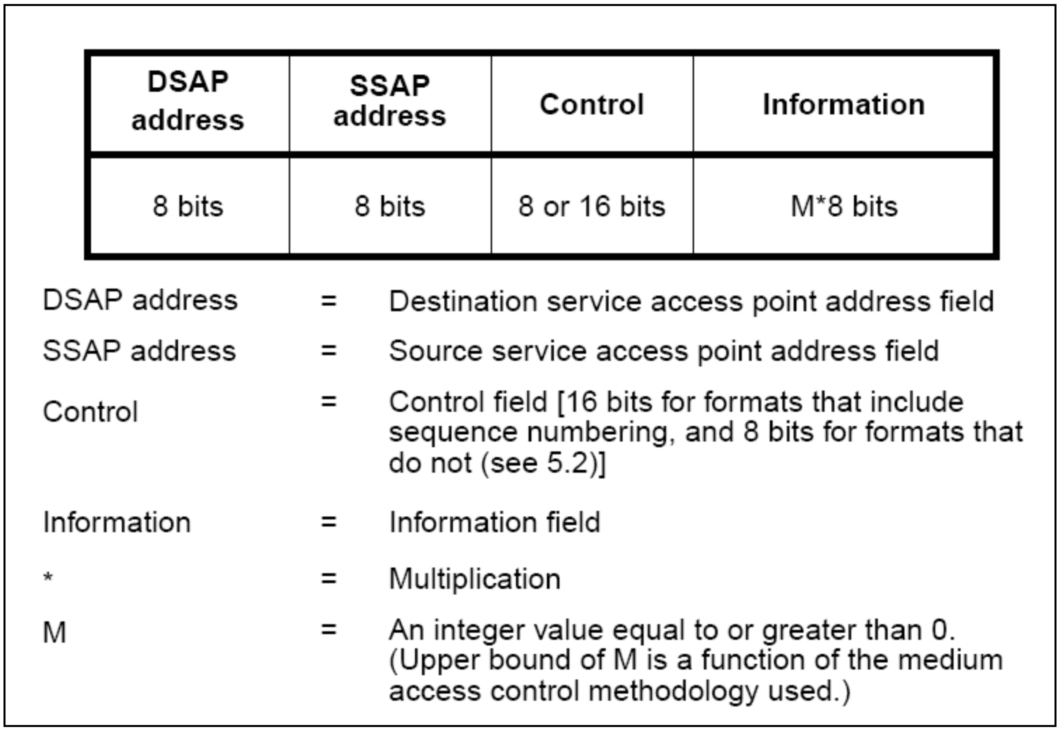

DSAP address	SSAP address	Control	Information
8 bits	8 bits	8 or 16 bits	M*8 bits

DSAP address = Destination service access point address field
SSAP address = Source service access point address field
Control = Control field [16 bits for formats that include sequence numbering, and 8 bits for formats that do not (see 5.2)]
Information = Information field
* = Multiplication
M = An integer value equal to or greater than 0. (Upper bound of M is a function of the medium access control methodology used.)

Figure 2. LLC Format.

LLC is based on the High-Level Data Link Control (HDLC) data protocol format. Whereas Ethernet II (2.0) combines the MAC and the Data link layers restricting itself to connectionless service in the process, IEEE 802.3 separates out the MAC and Data Link layers. IEEE 802.2 is also required by Token Ring and FDDI but cannot be used with the Novell 'Raw' format. There are three types of LLC; Type 1, which is connectionless, Type 2 which is connection-oriented, and Type 3 for Acknowledged Connections.

The **Service Access Point (SAP)** is used to distinguish between different data exchanges on the same end station and basically replaces the Type field for the older Ethernet II frame. The **Source Service Access Point (SSAP)** indicates the service from which the LLC data unit is sent, and the **Destination Service Access Point (DSAP)** indicates the service to which the LLC data unit is being sent. As examples, NetBIOS uses the SAP address of **F0** whilst IP uses the SAP address of **06**. The following lists some common SAPs:

00 - Null LSAP
02 - Individual LLC Sublayer Management Function
03 - Group LLC Sublayer Management Function
05 - IBM SNA Path Control (group)

06 - Internet Protocol (IP)
18 - Texas Instruments
42 - IEEE 802.1 Bridge Spanning Tree Protocol
80 - Xerox Network Systems (XNS)
86 - Nestar
AA - SubNetwork Access Protocol (SNAP)
E0 - Novell NetWare
F0 - IBM NetBIOS
F5 - IBM LAN Management (group)
FE - ISO Network Layer Protocol

The **Control Field** identifies the type of LLC, of which there are three:

- **Type 1** - Data (PDUs) shall be exchanged between LLCs without the need for the establishment of a data link connection. These PDUs shall not be acknowledged, nor shall there be any flow control or error recovery. This is called **Unsequenced Information (UI)**.
- **Type 2** – Needs data link connection. Uses **Information (I)** frames and maintains the sequence numbers during an acknowledged connection-oriented transmission.
- **Type 3** – No data link connection required. Uses **Acknowledged Connection (AC)** frames in an acknowledged connectionless service.

MAC ADDRESS

With an Ethernet MAC address, the first octet uses only the lowest significant bit as the Individual/Group (I/G) bit address identifier. If it is zero it indicates the address is individual. If it is one, it indicates a group address. The Universally or Locally administered (U/L) address bit is the bit of octet 0 adjacent to the I/G address bit. This bit indicates whether the address has been assigned by a local or universal administrator. Universally administered addresses have this bit set to 0. If this bit is set to 1, the entire address (i.e., 48 bits) has been locally administered.

The first 3 octets of the MAC address form the Organizational Unique Identifier (OUI) assigned by IEEE to organizations that requires their own group of MAC addresses.

SUBNETWORK ACCESS PROTOCOL (SNAP)

The SNAP protocol was introduced to allow an easy transition to the new LLC frame format for vendors. SNAP allows older frames and protocols to be encapsulated in a Type 1 LLC header making any protocol ‘pseudo-IEEE compliant’. SNAP is described in RFC 1042. Figure 3 shows how it looks:

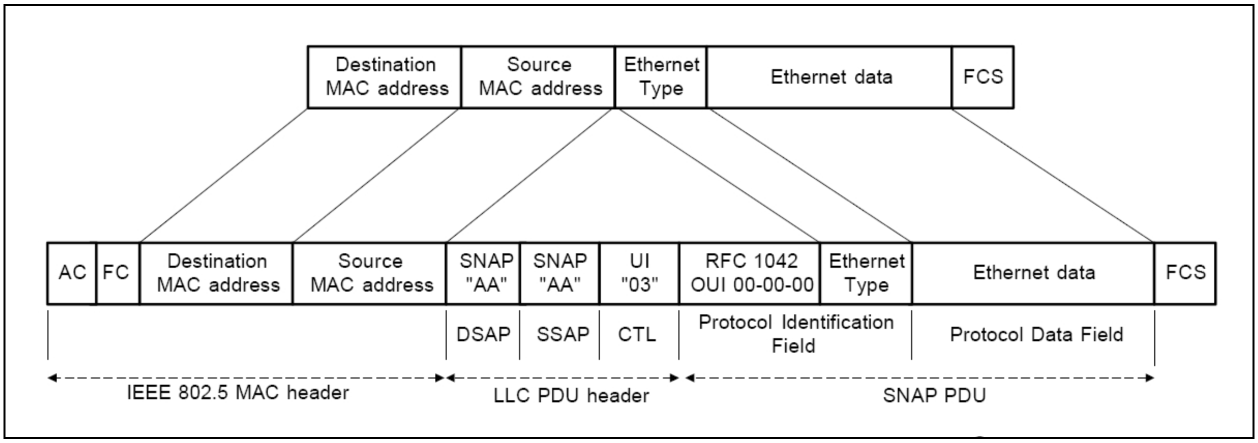
Destination MAC address
Source MAC address
Ethernet Type
Ethernet data
FCS
AC
FC
Destination MAC address
Source MAC address
SNAP "AA"
SNAP "AA"
UI "03"
RFC 1042 OUI 00-00-00
Ethernet Type
Ethernet data
FCS
DSAP
SSAP
CTL
Protocol Identification Field
Protocol Data Field
IEEE 802.5 MAC header
LLC PDU header
SNAP PDU

Figure 3. Ethernet Frame SNAP-encapsulated in IEEE 802.5 Frame.

It can be seen that it is an LLC data unit (sometimes called a Logical Protocol Data Unit (LPDU)) of Type 1 (indicated by 03). The DSAP and SSAP are set to AA to indicate that this is a SNAP header coming up. The SNAP header then indicates the vender via the Organizational Unique Identifier (OUI) and the protocol type via the Ethertype field. In the example above the OUI is 00-00-00 which means that there is an Ethernet frame. An ethernet type (Ethertype) of 08-00 would indicate Internet IP is the protocol. The official list of types can be found at IEEE. Although vendors tend to be are moving to LLC1 on the LAN, SNAP still remains.

TRANSMISSION MEDIA

10Base-5 - largely obsolete, but may still be in use.

Traditionally, Ethernet is used over 'thick' coaxial cable called 10Base-5 (the '10' denotes 10Mbps, base means that the signal is baseband i.e. takes the whole bandwidth of the cable (so that only one device can transmit at one time on the same cable), and the '5' denotes 500 m maximum length). The minimum length between stations is 2.5 m.

The cable is run in one long length forming a 'Bus Topology'. Stations attach to it by way of inline N-type connections or a transceiver, which is literally screwed into the cable (by way of a 'Vampire Tap') providing a 15-pin Attachment Unit Interface (AUI) connection (also known as a DIX connector or a DB-15 connector) for a drop lead connection (maximum of 50 m length) to the station. The segments are terminated with 50 ohm resistors and the shield grounded at one end only.

The segment could be appended with up to a maximum of 4 repeaters; therefore 5 segments (total length of 2,460 m) can be connected together. Of the 5 segments only 3 can have devices attached (100 per segment). This is known as the 5-4-3 rule. A total of 300 devices can be attached on a Thicknet broadcast domain.

10Base-2 – dominant for many years

It was common to see the Thick coax used in Risers to connect Repeaters, which in turn provide 'Thin Ethernet' coaxial connections for runs up to 30 workstations. Thin Ethernet (Thinnet) uses RG-58 cable and is called 10Base-2 (The '2' now denoting 200 m maximum length - strictly speaking this is 185 m). The minimum length between stations is 0.5 m.

Each station connects to the thinnet by way of a Network Interface Card (NIC), which provides a BNC (British Naval Connector). At each station the thinnet terminates at a T-piece and at each end of the thinnet run (or 'Segment') a 50-ohm terminator is required to absorb stray signals, thereby preventing signal bounce. The shield is grounded at one end only.

A segment can be appended with other segments using up to 4 repeaters, i.e. 5 segments in total. Two of these segments however, cannot be tapped; they can only be used for extending the length of the broadcast domain (to 925 m). What this means is that 3 segments with a maximum of 30 stations on each can give you 90 devices on a Thinnet broadcast domain.

10Base-T – Most widespread today

The most common media used in of Ethernet today involves use of Unshielded Twisted Pair (UTP) or Shielded Twisted Pair (STP). For instance, Category 5 UTP can be installed in a 'Star-wired' format, with runs recommended at no greater than 100 m (including patch leads, cable run and flyleads) and Ethernet Hubs with UTP ports (RJ45) centrally located. It has been found though that runs of up to 150 m are feasible, the limitations being signal strength. Also, there should be no more than a 11.5 dB signal loss and the minimum distance between devices is 2.5 m. The maximum delay for the signal in a 10Mbps network is 51.2 microseconds. This comes from the fact that the bit time (time to transmit one bit) is 0.1 microseconds and that the slot time for a frame is 512 bit times.

In order to connect to Ethernet in this 'Star Topology', each station has a NIC, which contains an RJ45 socket which is used by a 4-pair droplead to connect to another nearby RJ45 socket.

Each port on the hub sends a 'Link Beat Signal' which checks the integrity of the cable and devices attached, a flickering LED on the front of the port of the hub tells you that the link is running fine. The maximum number of hubs (or, more strictly speaking, repeater counts) that you can have in one segment is four and the maximum number of stations on one broadcast domain is 1024.

The advantages of the UTP/STP technology are gained from the flexibility of the system, with respect to moves, changes, fault finding, reliability, and security. The following table shows the RJ45 pin-outs for 10Base-T:

RJ45 Pin	Function	Color
1	Transmit	White/Orange stripe
2	Transmit	Orange
3	Receive	White/Green stripe
4		Blue
5		White/Blue stripe
6	Receive	Green
7		White/Brown stripe
8		Brown

If you wish to connect hub to hub, or a NIC directly to another NIC, then the following 10Base-T crossover cable should be used:

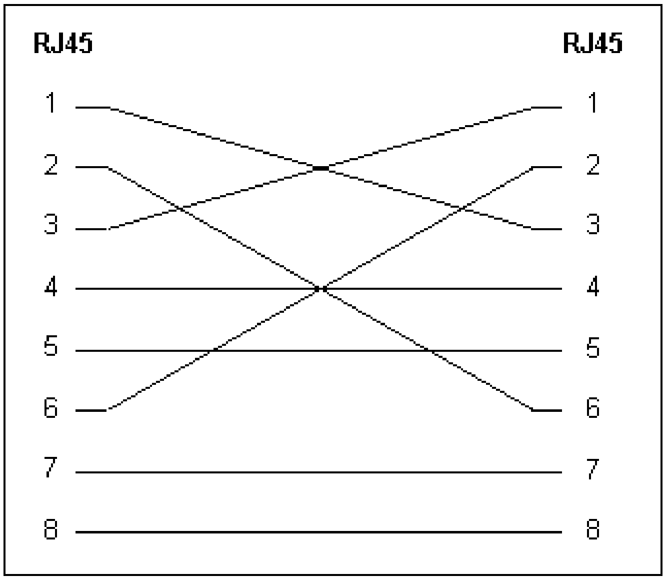

Figure 4. 10Base-T Crossover.

The 4-repeater limit manifests itself in 10/100Base-T environments where the active hub/switch port is in fact a repeater, hence the name multi-port repeater. Generally, the hub would only have one station per port but you can cascade hubs from one another up to the 4-repeater limit. The danger here is that you will have all the traffic from a particular hub being fed into one port so care would need to be taken on noting the applications being used by the stations involved, and the likely bandwidth that the applications will use.

There is a pre-standard called Lattisnet (developed by Synoptics), which runs 10 MHz Ethernet over twisted pair but instead of bit synchronization occurring at the sending (as in 10Base-T) the synchronization occurs at the receiving end.

10Base-F

The 10Base-F standard defines the use of fiber for Ethernet. 10Base-FL describes the standards for the fiber optic links between stations and repeaters, allowing up to 2 km per segment on multi-mode fiber. It replaces the 1987 FOIRL (Fiber Optic Inter-Repeater Link), which provides the specification for a fiber optic Media Attachment Unit (MAU) and other interconnecting components. Two related standards are essentially "dead": 10Base-FB allows up to 2 km per segment (on multi-mode fiber) and is designed for backbone applications such as cascading repeaters. In addition, there is the 10Base-FP (Passive components) standard

The 10Base-F standard allows for 1024 devices per network.

Fast Ethernet - 100Base-T

Fast Ethernet is the most popular of the newer standards and is an extension to 10Base-T. The '100' denotes 100 Mbps data speed and it uses the same two pairs as 10Base-T and must only be used on Category 5 UTP cable installations with provision for it to be used on Type 1 STP. The actual data throughput increases by between 3 to 4 times that of 10Base-T.

Fast Ethernet is specified in 802.3u and uses the same frame formats and CSMA/CD technology as normal 10Mbps Ethernet. The difference is that the maximum delay for the signal across the segment is 5.12 microseconds instead of 51.2 microseconds. This stems from the fact that the bit time (time to transmit one bit) is 0.01 microseconds and that the slot time for a frame is 512 bit times. The Inter-Packet Gap (IPG) for 802.3u is 0.96 microseconds as opposed to 9.6 microseconds for 10Mbps Ethernet.

Whereas 10Base-T uses Normal Link Pulses (NLP) for testing the integrity of the connection, 100Base-T uses Fast Link Pulses (FLP) which are backwardly compatible with NLPs but contain more information. FLPs are used to detect the speed of the network (e.g. in 10/100 switchable cards and ports). The distance must not exceed 100 m.

The IEEE uses the term 100Base-X to refer to both 100Base-Tx and 100Base-Fx and the Media-Independent Interface (MII) allows a generic connector for transceivers to connect to 100Base-Tx, 100Base-Fx and 100Base-T4 LANs.

There is no such thing as the 5-4-3 rule in Fast Ethernet. All 10Base-T repeaters are considered to be functionally identical. Fast Ethernet repeaters are divided into two classes of repeater: Class I and Class II. A Class I repeater has a repeater propagation delay value of 140 bit times, whilst a Class II repeater is 92 bit times. The Class I repeater (or Translational Repeater) can support different signaling types such as 100Base-Tx and 100Base-T4. A Class I repeater transmits or repeats the incoming line signals on one port to the other ports by first translating them to digital signals and then retranslating them to line signals. The translations are necessary when connecting different physical media (media conforming to more than one physical layer specification) to the same collision domain. Any repeater with an MII port would be a Class I device. Only one Class I repeater can exist within a single collision domain, so this type of repeater cannot be cascaded.

A Class II repeater immediately transmits or repeats the incoming line signals on one port to the other ports: it does not perform any translations. This repeater type connects identical media to the same collision domain (for example, TX to TX). At most, two Class II repeaters can exist within a single collision domain.

The cable used to cascade the two devices is called and unpopulated segment or IRL (Inter-Repeater Link). The Class II repeater (or **Transparent Repeater**) can only support one type of physical signaling.

100Base-T4

100Base-T4 was an early implementation of Fast Ethernet. It requires four twisted copper pairs, but those pairs were only required to be category 3 rather than the category 5 required by TX. One pair is reserved for transmit, one for receive, and the remaining two will switch direction as negotiated. A very unusual 8B6T code is used to convert 8 data bits into 6 base-3 digits (the signal shaping is possible as there are three times as many 6-digit base-3 numbers as there are 8-digit base-2 numbers). The two resulting 3-digit base-3 symbols are sent in parallel over 3 pairs using 3-level pulse-amplitude modulation (PAM-3).

100Base-T2

This little known version of Fast Ethernet is for use over two pairs of Category 3 cable and uses PAM-5 for encoding. There is simultaneous transmission and reception of data in both pairs and the electronics uses DSP technology to handle alien signals in adjacent pairs. 100Base-T2 can run up to 100 m on Category 3 UTP.

100Base-Fx

100Base-Fx is a version of Fast Ethernet over optical fiber. It uses a 1300 nm near-infrared (NIR) light wavelength transmitted via two strands of optical fiber, one for receive (RX) and the other for transmit (TX). Maximum length is 400 meters (1,310 ft) for half-duplex connections (to ensure collisions are detected) or 2 kilometers (6,600 ft) for full-duplex over multimode optical fiber. Longer distances are possible when using single-mode optical fiber. 100Base-Fx uses the same 4B5B encoding and NRZI line code that 100Base-TX does. 100Base-Fx should use the following connectors: SC, straight tip (ST), or media independent connectors (MIC), with SC being the preferred option. 100Base-Fx is not compatible with 10Base-Fl, the 10 MBit/s version over optical fiber.

100Base-Sx

100Base-Sx is a version of Fast Ethernet over optical fiber. It uses two strands of multi-mode optical fiber for receive and transmit. It is a lower cost alternative to using 100Base-Fx, because it uses short wavelength optics (850 nm) which are significantly less expensive than the long wavelength optics used in 100Base-Fx. 100Base-Sx can operate at distances up to 300 meters (980 ft).

100Base-Sx uses the same wavelength as 10Base-Fl, the 10 MBit/s version over optical fiber. Unlike 100Base-Fx, this allows 100Base-Sx to be backwards-compatible with 10Base-Fl. Because of the shorter wavelength used and the shorter distance it can support, 100Base-Sx uses less expensive optical components (LEDs instead of lasers) which makes it an attractive option for those upgrading from 10Base-Fl and those who do not require long distances.

100Base-Bx

100Base-Bx is a version of Fast Ethernet over a single strand of optical fiber (unlike 100Base-Fx, which uses a pair of fibers). Single-mode fiber is used, along with a special multiplexer which splits the signal into transmit and receive wavelengths. The two wavelengths used for transmit and receive are either 1310/1550 nm or 1310/1490 nm. Distances can be 10, 20, or 40 km.

100VG-AnyLAN

Based on 802.12 (Hewlett Packard), 100VG-AnyLAN uses an access method called Demand Priority. The ‘VG’ stands for ‘Voice Grade’ as it is designed to be used with Category 3 cable. This is where the repeaters (hubs) carry out continuous searches around all of the nodes for those that wish to send data. If two devices cause a ‘contention’ by wanting to send at the same time, the highest priority request is dealt with first, unless the priorities are the same, in which case both requests are dealt with at the same time (by alternating frames). The hub only knows about connected devices and other repeaters so communication is only directed at them rather than broadcast to every device in the broadcast domain (which could mean 100’s of devices!). This is a more efficient use of the bandwidth. This is the reason why the new standard was developed as it is not strictly Ethernet. Standard 802.12 is designed to better support both Ethernet and Token Ring.

The encoding techniques used are 5B/6B and NRZ. All four pairs of UTP are used. On Cat3 the longest cable run is 100 m but this increases to 200 m on Cat5. The clock rate on each wire is 30 MHz; therefore 30 Mbits per second are transmitted on each pair giving a total bit rate of 120 Mbps. Since each 6-bits of data on the line represents 5 bits of real data due to the 5B/6B encoding, the rate of real data being transmitted is 25 Mbps on each pair, giving a total real data rate of 100 Mbps. For 2-pair STP and fiber, the bit rate is 120 Mbps on the transmitting pair, for a real data transmission rate of 100 Mbps.

Gigabit Ethernet

Although the functional principles of Gigabit Ethernet are the same as Ethernet and Fast Ethernet i.e. CSMA/CD and the Framing format, the physical setup is very different. One difference is the slot time. The standard Ethernet slot time required in CSMA/CD half-duplex mode is not long enough for running over 100 m of copper, so Carrier Extension is used to guarantee a 512-bit slot time.

1000Base-X (802.3z)

The 802.3z committee is responsible for formalizing the standard for Gigabit Ethernet. The 1000 refers to 1 Gbps data speed. The existing Fiber Channel interface standard (ANSI X3T11) is used and allows up to 4.268 Gbps speeds. The Fiber Channel encoding scheme is 8B/10B.

Gigabit Ethernet can operate in half or full duplex modes and there is also a standard 802.3x which manages XON/XOFF flow control in full duplex mode. With 802.3x, a receiving station can send a packet to a sending station to stop it sending data until a specified time interval has passed.

There are three media types for 1000Base-X. 1000Base-Sx, 1000Base-Lx, and 1000Base-Cx.

1000Base-Sx (‘S’ is for Short Haul) uses short-wavelength laser (850 nm) over multi-mode fiber. 1000Base-Sx can run up to 300 m on 62.5/125 µm multimode fiber and up to 550 m on 50/125 µm multimode fiber.

1000Base-Lx (‘L’ is for Long Haul) uses long wavelength laser (1300 nm) and can run up to 550 m on 62.5/125 µm multi-mode fiber or 50/125 µm multi-mode fiber. In addition, 1000Base-Lx can run up to 5 km (originally 3 km) on single-mode fiber using 1310 nm wavelength laser.

1000Base-Cx is a standard for STP copper cable and allows operation up to 25 m over STP cable.

1000Base-T (802.3ab)

Many cable manufacturers are enhancing their cable systems to ‘enhanced Category 5’ (Cat 5e) standards in order to allow Gigabit Ethernet to run at up to 100 m on copper. The Category 6 standard has yet to be ratified, and is not being pursued very strongly.

In order to obtain the 1000 Mbps data bit rate across the UTP cable without breaking the FCC rules for emission, all 4 pairs of the cable are used. Hybrid circuits at each end of each pair are used to allow simultaneous transmission and reception of data (full-duplex) by separating the transmission signal from the receiving signal. Because some transmission signal still manages to couple itself to the receiving side there is an additional echo canceller built in, this is called a Near End Crosstalk (NEXT) canceller.

Encoding is carried out with PAM-5.

TRANSMISSION CONTROL PROTOCOL / INTERNET PROTOCOL

Transmission **C**ontrol **P**rotocol / **I**nternet **P**rotocol (TCP/IP) is the communication protocol for the Internet.

Whereas IP handles lower-level transmissions from computer to computer as a message makes its way across the Internet, TCP operates at a higher level, concerned only with the two end systems, for example a Web browser and a Web server. In particular, TCP provides ordered delivery of a stream of bytes from a program on one computer to another program on another computer. Besides the Web, other common applications of TCP include e-mail and Internet file transfer like FTP. Among its other management tasks, TCP controls message size, the rate at which messages are exchanged, and network traffic congestion. Your computer Internet address is a part of the standard TCP/IP protocol and so is your domain name.

Inside the TCP/IP standard there are several protocols for handling data communication:

- TCP (Transmission Control Protocol) communication between applications
- UDP (User Datagram Protocol) simple communication between applications
- IP (Internet Protocol) communication between computers
- ICMP (Internet Control Message Protocol) for errors and statistics
- DHCP (Dynamic Host Configuration Protocol) for dynamic addressing

TCP: If one application wants to communicate with another via TCP, it sends a communication request. This request must be sent to an exact address. TCP is responsible for breaking data down into IP packets before they are sent, and for assembling the packets when they arrive. After a “handshake” between the two applications, TCP will set up a “full-duplex” communication between the two applications. The “full-duplex” communication will occupy the communication line between the two computers until it is closed by one of the two applications. UDP is very similar to TCP, but simpler and less reliable.

IP: IP is responsible for sending the packets to the correct destination. IP does not occupy the communication line between two computers and hence reduces the need for network lines. Each line can be used for communication between many different computers at the same time. With IP, messages (or other data) are broken up into small independent “packets” and sent between computers via the Internet. IP is responsible for “routing” each packet to the correct destination.

When an IP packet is sent from a computer, it arrives at an IP router. The IP router is responsible for “routing” the packet to the correct destination, directly or via another router. The path the packet will follow might be different from other packets in the same communication chain. The router is responsible for the right addressing, depending on traffic volume, errors in the network, or other parameters.

Each computer must have a unique IP address before it can connect to the Internet. Each IP packet must also have an address before it can be sent to another computer. TCP/IP uses 32 bits (4 bytes), of four numbers between 0 and 255, separated by a period, to address a computer. A typical IP address is of the format: 192.255.30.50

Domain Names: A name is much easier to remember than a 12 digit number. The names used for TCP/IP addresses are called domain names. “**navy.mil**” is a domain name. Subdomains are identified by prefixes to the main domain name (separated by a period). When you address a web site, like **http://www.navair.navy.mil** the name is translated to a number by a Domain Name System (DNS) Server. DNS servers are connected to the Internet all over the world. When a new domain name is registered together with a TCP/IP address, all DNS servers are updated with this information.

BROWSER AND OTHER APPLICATION LAYER PROTOCOLS

DHCP - Dynamic Host Configuration Protocol. DHCP is used for allocation of dynamic IP addresses to computers in a network.

FTP - File Transfer Protocol. FTP takes care of transmission of data files between computers.

HTTP - Hyper Text Transfer Protocol - takes care of the communication between a web server and a web browser. It is used for sending requests from a web client (a browser) to a web server, returning web content (web pages) from the server back to the client.

HTTPS - Secure HTTP. HTTPS typically handles credit card transactions and other sensitive data.

IMAP - Internet Message Access Protocol. The IMAP protocol is used by email programs (like Microsoft Outlook) just like the POP protocol (discussed below). The main difference between the IMAP protocol and the POP protocol is that the IMAP protocol will not automatically download all your emails each time your email program connects to your email server. The IMAP protocol allows you to look through your email messages at the email server before you download them. With IMAP you can choose to download your messages or just delete them. This way IMAP is useful if you need to connect to your email server from different locations, but only want to download your messages when you are back in your office.

NTP - Network Time Protocol. NTP is used to synchronize the time (the clock) between computers.

POP - Post Office Protocol. The POP protocol is used by email programs (like Microsoft Outlook) to retrieve emails from an email server. If your email program (also called email client), uses POP, all your emails are downloaded to your computer each time it connects to your email server.

SMTP - Simple Mail Transfer Protocol. The SMTP protocol is used for the transmission of e-mails to another computer. Normally your email is sent to an email server (SMTP server), and then to another server or servers, and finally to its destination. SMTP can only transmit pure text. It cannot transmit binary data like pictures, sounds, or movies directly. SMTP uses the MIME protocol to send binary data across TCP/IP networks.

SNMP - Simple Network Management Protocol. SNMP is used for administration of computer networks.

PRESENTATION LAYER PROTOCOLS

MIME - Multi-purpose Internet Mail Extensions protocol. Converts binary data to pure text. The MIME protocol lets SMTP transmit multimedia files including voice, audio, and binary data.

SSL - Secure Sockets Layer. The SSL protocol is used for encryption of data for secure data transmission.

LOWER LAYER PROTOCOLS

ARP - Address Resolution Protocol. ARP is used by IP to find the hardware address of a computer network card based on the IP address.

BOOTP - Boot Protocol. BOOTP is used for booting (starting) computers from the network.

ICMP - Internet Control Message Protocol. ICMP takes care of error-handling in the network.

LDAP - Lightweight Directory Access Protocol. LDAP is used for collecting information about users and e-mail addresses from the internet.

PPTP - Point to Point Tunneling Protocol. PPTP is used for setting up a connection (tunnel) between private networks.

RARP - Reverse Address Resolution Protocol. RARP is used by IP to find the IP address based on the hardware address of a computer network card.

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GLOSSARY

ACCEPTABLE DEGRADATION - The allowable reduction in system performance. For a fire control radar, the acceptable degradation is usually expressed as a reduction in range; for example, the maximum lock-on range might be degraded by 25 percent without loss of essential defense capability.

ACQUISITION - A procedure by which a fire control tracking radar attains initial lock-on. Usually, the approximate target coordinates are supplied to the tracking radar and it searches a predetermined volume of space to locate the target.

AEROSOLS - Solid particles dispersed in the atmosphere having resonant size particles with a high index of refraction. The particles both scatter and absorb visual and laser directed energy so as to cut down on weapon systems directed by these techniques.

AFC (AUTOMATIC FREQUENCY CONTROL) - An arrangement whereby the frequency of an oscillator or the tuning of a circuit is automatically maintained within specified limits with respect to a reference frequency. A magnetron drifts in frequency over a period of time. The AFC of a radar makes the local oscillator shift by an equal amount so the IF frequency will remain constant.

AGC (AUTOMATIC GAIN CONTROL) - A method for automatically obtaining an essentially constant receiver output amplitude. The amplitude of the received signal in the range gate determines the AGC bias (a DC voltage) which controls the receiver gain so as to maintain a nearly constant output even though the amplitude of the input signal changes.

AMPLIFIER - An electronic device used to increase signal magnitude or power. See also GaAs FET Amplifier, Klystron Amplifier, Traveling-Wave Tube Amplifier.

AMPLITUDE MODULATION (AM) - A method of impressing a message upon a carrier signal by causing the carrier amplitude to vary proportionally to the message waveform.

AMPLITUDE SHIFT KEYING (ASK) - A method of impressing a digital signal upon a carrier signal by causing the carrier amplitude to take different values corresponding to the different values of the digital signal.

ANGLE JAMMING - ECM technique, when azimuth and elevation information from a scanning fire control radar is jammed by transmitting a jamming pulse similar to the radar pulse, but with modulation information out of phase with the returning target angle modulation information.

ANGULAR SEPARATION - This term is frequently used to indicate a protective (from EMI) zone for a missile. The interfering antenna axis must be separated, throughout the critical portion of the missile flight, from the missile by the specified angle. The vertex of the angle is at the interference source antenna.

ANTENNA BEAMWIDTH - The angle, in degrees, between the half-power points (-3 dB) of an antenna beam. This angle is also nearly that between the center of the mainlobe and the first null. The angle is given for both horizontal and vertical planes unless the beam is circular. When so indicated, the term may refer to the angular width of the mainlobe between first nulls [beamwidth between first nulls (BWFN)]. See also Antenna Pattern. The figure illustrates vertical profile for antenna displaying a 10-degree beamwidth characteristic. The values can vary dramatically with frequency.

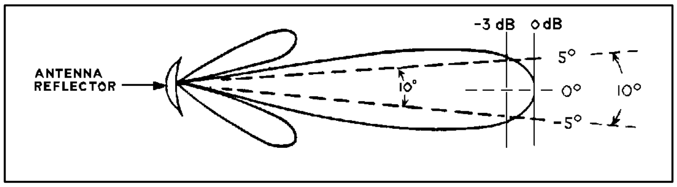

ANTENNA CROSS TALK - A measure of undesired power transfer through space from one antenna to another. Ratio of power received by one antenna to power transmitted by the other, usually expressed in decibels.

ANTENNA ISOLATION - The ratio of the power input to one antenna to the power received by the other. It can also be viewed as the insertion loss from transmit antenna input to receive antenna output to circuitry.

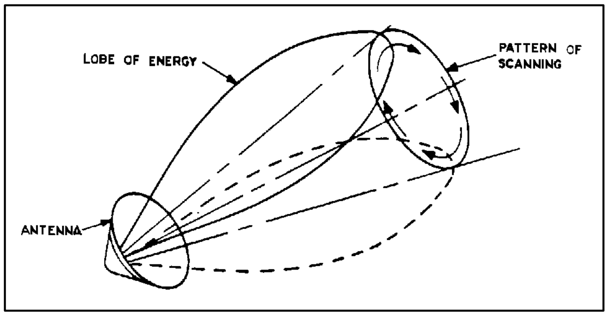

ANTENNA LOBING - Two lobes are created that overlap and intercept at -1 to -3 dB. The difference between the two lobes produces much greater spatial selectivity than provided by either lobe alone. (See also Lobe, Antenna.)

ANTENNA NUTATING - An antenna, as used in automatic-tracking radar systems, consisting of a parabolic reflector combined with a radiating element which is caused to move in a small circular orbit about the focus of the antenna with or without change of polarization. The radiation pattern is in the form of a beam that traces out a cone centered on the reflector axis. The process is also known as nutating conical scanning.

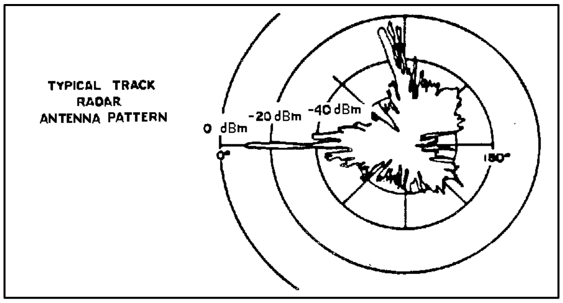

ANTENNA PATTERN - A cross section of the radiating pattern (representing antenna gain or loss) in any plane that includes the origin (source reference point) of the pattern. Both horizontal and vertical polar plots are normally used to describe the pattern. Also, termed "polar diagram" and "radiation pattern."

ANTENNA, PENCIL-BEAM - A highly directional antenna designed that cross sections of the major lobe are approximately circular, with a narrow beamwidth.

ANTI-CLUTTER CIRCUITS (IN RADAR) - Circuits which attenuate undesired reflections to permit detection of targets otherwise obscured by such reflections.

APERTURE - In an antenna, that portion of the plane surface area near the antenna perpendicular to the direction of maximum radiation through which the major portion of the radiation passes. The effective and/or scattering aperture area can be computed for wire antennas which have no obvious physical area.

A-SCOPE - A cathode-ray oscilloscope used in radar systems to display vertically the signal amplitude as a function of time (range) or range rate. Sometimes referred to as Range (R)-Scope.

ASYNCHRONOUS PULSED JAMMING - An effective form of pulsed jamming. The jammer nearly matches the pulse repetition frequency (PRF) of the radar; then it transmits multiples of the PRF. It is more effective if the jammer pulsewidth is greater than that of the radar. Asynchronous pulsed jamming is similar to synchronous jamming except that the target lines tend to curve inward or outward slightly and appear fuzzy in the jammed sector of a radar scope.

ATTENUATION - Decrease in magnitude of current, voltage, or power of a signal in transmission between two points. May be expressed in decibels.

AUTOMATIC FREQUENCY CONTROL - See AFC.

AUTOMATIC GAIN CONTROL - See AGC.

BACKWARD WAVE OSCILLATOR (BWO) - A cross-field device in which an electron stream interacts with a backward wave on a nonreentrant circuit. This oscillator may be electronically tuned over a wide range of frequencies, is relatively unaffected by load variations and is stable. BWO is commonly pronounced "be woe".

BALANCED MIXERS - The two most frequently encountered mixer types are single-balanced and double-balanced. In a double-balanced mixer, four Schottky diodes and two wideband transformers are employed to provide isolation of all three ports.

BALLISTIC MISSILE - Any missile which does not rely upon aerodynamic surfaces to produce lift and consequently follows a ballistic trajectory when thrust is terminated.

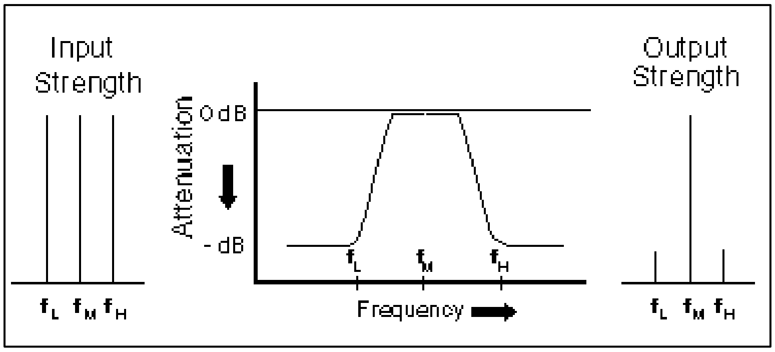

BANDPASS FILTER - A type of frequency discrimination network designed to pass a band or range of frequencies and produce attenuation to all other frequencies outside of the pass region. The figure illustrates a typical bandpass filter, incorporating a bandpass region of (F_h)-(F_l), offering no rejection (0 dB) to desired signal (F_m) and much higher rejection to the adjacent undesired signals F_h, and F_l. The upper and lower frequencies are usually specified to be the half power (-3 dB) or half voltage points (-6 dB).

BANDWIDTH - An expression used to define the actual operational frequency range of a receiver when it is tuned to a certain frequency. For a radar receiver, it is the difference between the two frequencies at which the receiver response is reduced to some fraction of its maximum response (such as 3 dB, 6 dB, or some other specified level). The frequencies between which "satisfactory" performance is achieved. Two equations are used:

$$\textit{Narrowband by \%}\ \left(\frac{F_u - F_l}{F_c}\right)(100)\quad ;\quad \textit{Broadband by ratio}\ \frac{F_u}{F_l}$$

$$\textit{Where}\ F_u = \textit{Upper}\ ;\ F_l = \textit{lower}\ ;\ F_c = \textit{center} = (\,F_u + F_l\,) \div 2$$

See also Receiver Bandwidth and Spectrum Width.

BARRAGE NOISE JAMMING - Noise jamming spread in frequency to deny the use of multiple radar frequencies to effectively deny range information. Although this is attractive because it enables one jammer to simultaneously jam several radars of different frequencies, it does have the inherent problem that the wider the jamming spread, the less jamming power available per radar, i.e. the watts per MHz bandwidth is low.

BATTERY, MISSILE - A missile battery consists of a missile launcher and its associated missile fire control systems (such as a MK 11 MOD 0 Missile Launcher and two MK 74 MOD 0 Missile Fire Control Systems).

BEACON - A system wherein a transponder in a missile receives coded signals from a shipboard radar guidance transmitter and transmits reply signals to a shipboard radar beacon receiver to enable a computer to determine missile position. The missile beacon transmitter and shipboard radar beacon receiver are tuned to a frequency different from that of the guidance transmitter.

BEAM - See Lobe, antenna. The beam is to the side of an aircraft or ship.

BEAM, CAPTURE - See Capture Beam.

BEAM-TO-BEAM CORRELATION (BBC) - BBC is used by frequency scan radars to reject pulse jamming and jamming at a swept frequency. Correlation is made from two adjacent beams (pulses). The receiver rejects those targets (signals) that do not occur at the same place in two adjacent beams.

BEAMWIDTH - See Antenna Beamwidth.

BEAT FREQUENCY OSCILLATOR (BFO) - Any oscillator whose output is intended to be mixed with another signal to produce a sum or difference beat frequency. Used particularly in reception of CW transmissions.

BINGO - The fuel state at which an aircraft must leave the area in order to return and land safely. Also used when chaff/flares reach a preset low quantity and automatic dispensing is inhibited.

BIPOLAR VIDEO - Unrectified (pre-detection) IF (both positive and negative portions of the RF envelope) signals that arise from the type of detection and console display employed in pulse Doppler and MTI receivers.

BISTATIC RADAR - A radar using antennas at different locations for transmission and reception.

BLANKING - The process of making a channel, or device non-effective for a certain interval. Used for retrace sweeps on CRTs or to mask unwanted signals such as blanking ones own radar from the onboard RWR.

BOGEY - Unknown air target.

BURN-THROUGH RANGE - The ability of a radar to see through jamming. Usually, described as the point when the radar's target return is a specified amount stronger than the jamming signal (typical values are 6 dB manual and 20 dB automatic). See Section 4-8.

BUTT LINE - Line used for reference in measurement of left/right location. One of several aircraft references. See also fuselage station and water line.

CAPTURE BEAM - A wide beam incorporated in capture transmitters of beam rider (command guided) missile systems to facilitate gaining initial control of a missile immediately after launch. Upon capture, the system then centers the missile in the narrow guidance beam. The figure illustrates a launched missile at point of capture.

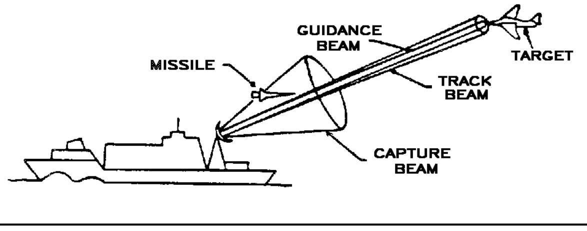

CAPTURE TRANSMITTER - A transmitter employing a wide beam antenna to gain initial control of in-flight missile for the purpose of centering the missile in the guidance transmitter antenna beam. See also Capture Beam.

CARRIER FREQUENCY - The basic radio frequency of the wave upon which modulations are impressed. Also called “Carrier” or f_c. See figure at right.

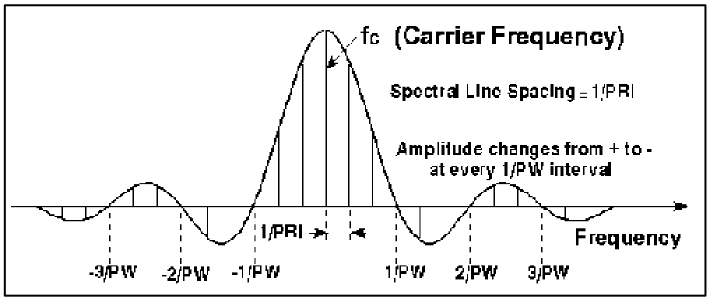

CATCH-22 - A lose-lose situation, from the book of the same name.

CAVITY - A space enclosed by a conducting surface used as a resonant circuit at microwave frequencies. Cavity space geometry determines the resonant frequency. A storage area for oscillating electromagnetic energy.

CENTER FREQUENCY - The tuned or operating frequency. Also referred to as center operating frequency. In frequency diversity systems, the midband frequency of the operating range. See also Carrier Frequency.

CHAFF - Ribbon-like pieces of metallic materials or metalized plastic which are dispensed by aircraft or ships to mask or screen other “targets.” The radar reflections off the chaff may cause a tracking radar to break lock on the target. The foil materials are generally cut into small pieces for which the size is dependent upon the radar interrogation frequency (approximately 1/2 wave length of the victim radar frequency). Being this length, chaff acts as a resonant dipole and reflects much of the energy back to the radar. Also see rainbow, rope, stream chaff, and window.

CHANNEL - A frequency or band of frequencies. In guided missile systems, an assigned center frequency and a fixed bandwidth around it. Designates operating frequency of track radars and frequency/code assignments of X-band CW illuminators.

CHIRP - A pulse compression technique which uses frequency modulation (usually linear) on pulse transmission.

CHIRP RADAR - See PC.

CIRCULARLY POLARIZED JAMMING - The techniques of radiating jamming energy in both planes of polarization simultaneously. With this method, there is a loss of 3 dB of effective power in either linear plane, and substantial loss if the opposite sense of circular polarization is used (i.e. left vs. right). See Section 3-2.

CLUTTER, RADAR - Undesired radar returns or echoes resulting from man-made or natural objects including chaff, sea, ground, and rain, which interfere with normal radar system observations. The figure illustrates a target being masked by ground clutter

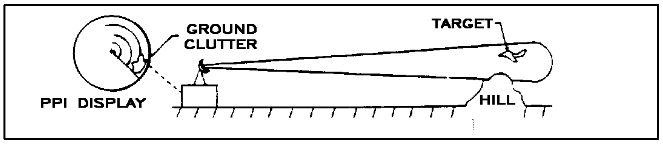

CO-CHANNEL - This term is used to indicate that two (or more) equipments are operating on the same frequency.

COHERENT - Two signals that have a set (usually fixed) phase relationship.

COINCIDENCE DETECTOR - This radar video process requires more than one hit in a range cell before a target is displayed. This prevents video interference from pulses coming from another radar, because such interference is unlikely to occur twice in the same range cell.

COLLIMATION - The procedure of aligning fire control radar system antenna axes with optical line of sight, thereby ensuring that the radars will provide for correct target illumination and guidance beam positioning.

COMMAND CODE - Modulations superimposed upon transmitter carrier signals to provide electronic instructions to an airborne guided missile or pilotless aircraft. The receiver of the remotely guided vehicle is preset to accept only a selected transmitter code to eliminate the possibility of the vehicle responding to commands of extraneous signals. Missile command codes include instructions such as arm, warhead detonate, and self destruct.

COMMAND GUIDANCE - A guidance system wherein intelligence transmitted to the missile from an outside source causes the missile to traverse a directed flight path.

CONICAL SCAN - See Antenna, Nutating.

CONTINUOUS WAVE and CONTINUOUS WAVE ILLUMINATOR - See CW and CWI.

COOPERATIVE COUNTERMEASURES - (CO-OP) Generic term for jamming the same threat radar from two or more separate platforms that are in the same radar resolution cell.

COUPLING FACTOR - A multiplying factor, expressed in dB, used to express the change in EM energy intensity from a radar transmitter to a receiver. The factor includes the antenna gains and the loss (basic transmission loss) caused by the distance between the antennas. The factor will usually be a negative dB figure (a reduction in intensity) because basic transmission loss is always a large negative value. The antenna gains may be positive (pointed toward each other) or negative (no main beam interactions).

CROSS MODULATION - Intermodulation caused by modulation of the carrier by an undesired signal wave.

CROSS POLARIZATION - or “Cross Pole,” is a monopulse jamming technique where a cross-polarized signal is transmitted to give erroneous angle data to the radar. The component of the jamming signal with the same polarization as the radar must be very small.

CW (CONTINUOUS WAVE) - In radar and EW systems this term means that the transmitter is on constantly; i.e., not pulsed (100% duty cycle). These systems may frequency or phase modulate the transmitter output. A CW radar has the ability to distinguish moving targets against a stationary background while conserving spectrum bandwidth compared to pulsed radar requirements. A CW radar extracts accurate target range-rate data but cannot determine target range.

CWI (CONTINUOUS WAVE ILLUMINATOR) - A surface or aircraft-based CW transmitter employed in semiactive homing missile systems where the transmitter illuminates the target and the missile senses the reflected energy. The transmitter also provides a reference signal to the missile rear receiver to allow determination of range-rate data and target identification. CW transmitter emissions are sometimes coded corresponding to the associated missile receiver codes to reduce the possibility of the “missile accepting commands of extraneous signals.

DECIBEL (dB) - A dimensionless unit for expressing the ratio of two values of power, current, or voltage. The number of decibels being equal to: $dB = 10 \log P_2/P_1 = 20 \log V_2/V_1 = 20 \log I_2/I_1$ Normally, used for expressing transmission gains, losses, levels, and similar quantities. See Section 2-4.

DECEPTION - The deliberate radiation, reradiation, alteration, absorption or reflection of electromagnetic energy in a manner intended to mislead the enemy interpretation or use of information received by his electronic systems.

dB - See Decibel, or Decibel Section 2-4.

dBc - Decibels referenced to the carrier signal.

dBi - Decibels referenced to an isotropic radiator. (dBLi indicating linear isotropic radiator is sometimes used).

dBm - Decibels relative to 1 mW. dBm is calculated by using the ratio of some power (expressed in mW) to 1 mW. For example, 1 mW is 0 dBm and 10 mW is +10 dBm.

dBsm - Decibel referenced to one square meter.

dBv / dBμv - Decibels referenced to one volt or microvolt, i.e. 0 dBv is 1 volt or 120 dBμv.

dBW / dBμW - Decibels referenced to 1 watt or one microwatt, i.e. 0 dBW is 1 watt or 30 dBm or 60 dBμW.

DEMODULATOR - A device employed to separate the modulation signal from its associated carrier, also called Second Detector. See also Detection.

DESIGNATION - The assignment of a fire control radar to a specific target by supplying target coordinate data to the radar system.

DETECTION - Usually refers to the technique of recovering the amplitude modulation signal (envelope) superimposed on a carrier. See figure at right.

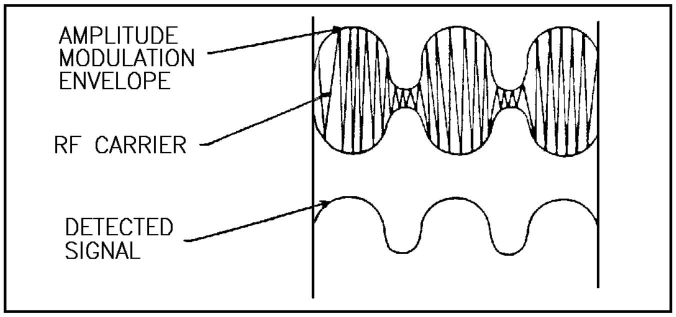

DICKE FIX - This type of radar processing occurs in the IF amplifier. A limiter follows a wideband amplifier, and then the signal goes to a matched filter amplifier. This discriminates against pulses that are too long (clutter) or too short (interference). The “DICKE FIX” is a technique that is specifically designed to protect the receiver from ringing caused by noise, fast-sweep, or narrow pulse jamming. The basic configuration consists of a broadband limiting IF amplifier, followed by an IF amplifier of optimum bandwidth. The limit level is preset at approximately the peak amplitude of receiver noise, the bandwidth may vary from 10 to 20 MHz, depending on the jamming environment. This device provides excellent discrimination against fast sweep jamming (10-500 MHz), usually something on the order of 20 to 40 dB, without appreciable loss in sensitivity. However, strong CW jamming will seriously degrade the performance of the DICKE FIX because the CW signal captures the radar signal in the limiter.

DIELECTRICALLY STABILIZED OSCILLATOR - The DSO uses a dielectric resonator as the frequency determining element. When the dielectric material is properly selected and used, the variations in dielectric constant vs. temperature and the dimensions of the resonant structure vs. temperature tend to cancel out, providing relatively good frequency vs. temperature stability. The DSO offers frequency accuracy and stability, low power consumption and high reliability. Some of the commonly used materials are barium, zirconium, or tin tinates. The composition of these materials may be controlled to achieve any frequency variation with temperature with close tolerances.

DIODE - An electronic device which restricts current flow chiefly to one direction. See also Gunn diode, IMPATT diode, PIN diode, point contact diode, Schottky barrier diode, step recovery diode, tunnel diode, varactor diode.

DIODE SWITCH - PIN-diode switches provide state-of-the-art switching in most present-day microwave receivers. These switches are either reflective or nonreflective in that the former reflect incident power back to the source when in the isolated state. While both types of switches can provide high isolation and short transition times, the reflective switch offers multi octave bandwidth in the all shunt diode configuration, while the non-reflective switch offers an octave bandwidth.

DIPLEX - The simultaneous transmission or reception of two signals using a common feature such as a single antenna or carrier. Typically, two transmitters operate alternately at approximately the same RF and using a common antenna. See Section 6-7 for a discussion of diplexers.

DIRECTIONAL COUPLER - A 4-port transmission coupling device used to sample the power traveling in one direction through the main line of the device. There is considerable isolation (typically 20 dB) to signals traveling in the reverse direction. Because they are reciprocal, the directional coupler can also be used to directively combine signals with good reverse isolation. The directional coupler is implemented in waveguide and coaxial configurations. See Section 6-4.

DIRECTIVITY - For antennas, directivity is the maximum value of gain in a particular direction. (Isotropic point source has directivity = 1). For directional couplers, directivity is a measure (in dB) of how good the directional coupling is and is equal to the isolation minus the coupling. See Section 6-4.

DISH - A microwave reflector used as part of a radar antenna system. The surface is concave and is usually parabolic shaped. Also called a parabolic reflector.

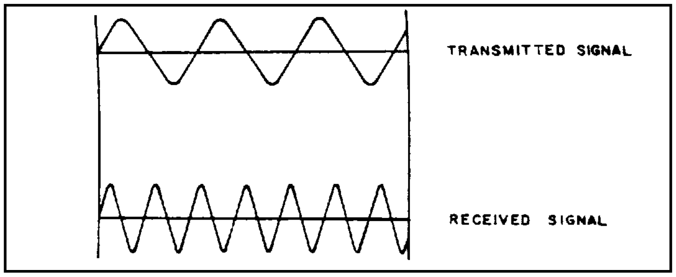

DOPPLER EFFECT - The apparent change in frequency of an electromagnetic wave caused by a change in distance between the transmitter and the receiver during transmission/reception. The figure illustrates the Doppler increase that would be realized by comparing the signal received from a target approaching the radar site to the transmitted reference signal. An apparent frequency decrease would be noted for targets departing the radar location. Differences can be calibrated to provide target range-rate data.

DRY RUN - A test run with aircraft/ship armament and/or EW switches off.

DUCTING - The increase in range that an electromagnetic wave will travel due to a temperature inversion of the atmosphere. The temperature inversion forms a channel or waveguide (duct) for the waves to travel in, and they can be trapped, not attenuating as would be expected from the radar equation.

DUMMY LOAD (Radio Transmission) - A dissipative but essentially nonradiating substitute device having impedance characteristics simulating those of the antenna. This allows power to be applied to the radar transmitter without radiating into free space. Dummy loads are commonly used during EMCON conditions or when troubleshooting a transmitter at a workbench away from its normal environment.

DUPLEXER - A switching device used in radar to permit alternate use of the same antenna for both transmitting and receiving.

DUTY CYCLE - The ratio of average power to peak power, or ratio of pulse length to interpulse period for pulsed transmitter systems. Interpulse period is equal to the reciprocal of the pulse repetition rate.
See Section 2-5.

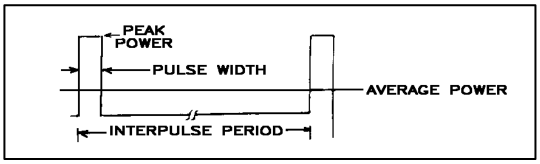

The duty cycle of a radar having a pulse length of 0.3 μsec and a PRF of 2000 pulses/sec is computed as follows:

Interpulse Period, T = PRI = 1/PRF = 500 μsec

$$Duty\ Cycle = \frac{Pulse\ length}{Interpulse\ Period} = \frac{0.3\ \mu\text{sec}}{500\ musec} = 0.0006\ (or\ 0.06\%)$$ or Duty Cycle (dB) = 10log(Duty cycle) = -32.2 dB

An output tube providing an average power of only 90 watts for such a system would, therefore, provide a peak power of:

$$Peak\ Power = \frac{Average\ Power}{Duty\ Cycle} = \frac{90}{0.0006} = 150{,}000\ W\ or\ 52\ dBW\ or\ 82\ dBm$$

EFFECTIVE RADIATED POWER (ERP) - Input power to the antenna in watts times the gain ratio of the antenna. When expressed in dB, ERP is the transmitter power (P_T), in dBm (or dBW) plus the antenna gain (G_T) in dB. The term EIRP is used sometimes and reiterates that the gain is relative to an isotropic radiator.

EGRESS - Exit the target area.

ELECTROMAGNETIC COUPLING - The transfer of electromagnetic energy from one circuit or system to another circuit or system. An undesired transfer is termed EMI (electromagnetic interference).

EMC (ELECTROMAGNETIC COMPATIBILITY) - That condition in which electrical/electronic systems can perform their intended function without experiencing degradation from, or causing degradation to other electrical/electronic systems. More simply stated, EMC is that condition which exists in the absence of EMI. See also Intersystem and Intrasystem EMC tests.

EME (ELECTROMAGNETIC ENVIRONMENT) - The total electromagnetic energy in the RF spectrum that exists at any given location.

EMI (ELECTROMAGNETIC INTERFERENCE) - Any induced, radiated, or conducted electrical emission, disturbance, or transient that causes undesirable responses, degradation in performance, or malfunctions of any electrical or electronic equipment, device, or system. Also synonymously referred to as RFI (Radio Frequency Interference).

EMI MODEL - Usually a set of equations or logical concepts designed to illustrate the interactions, the detailed parameters considerations, and mathematical procedures necessary for proper analysis of a given EMI situation.

EMITTER - Any device or apparatus which emits electromagnetic energy.

EMP (ELECTROMAGNETIC PULSE) - The generation and radiation of a very narrow and very high-amplitude pulse of electromagnetic noise. It is associated with the high level pulse as a result of a nuclear detonation and with intentionally generated narrow, high-amplitude pulse for ECM applications. In the case of nuclear detonations, EMP consists of a continuous spectrum with most of its energy distributed through the low frequency band of 3 KHz to 1 MHz.

ERROR SIGNAL - In servomechanisms, the signal applied to the control circuit that indicates the degree of misalignment between the controlling and the controlled members. In tracking radar systems, a voltage dependent upon the signal received from a target whose polarity and magnitude depend on the angle between the target and the center axis of the scanning beam.

FAST TIME CONSTANT - See FTC.

FEET DRY / WET - Aircraft has crossed from water to shore / aircraft has crossed from shore to water.

FERRET - An aircraft, ship, or vehicle especially equipped for the detection, location, recording, and analyzing of electromagnetic radiations.

FIELD STRENGTH - The magnitude of a magnetic or electric field at any point, usually expressed in terms of ampere turns per meter or volts per meter. Sometimes called field intensity and is expressed in volts/meter or dBμv/meter. Above 100 MHz, power density terminology is used more often. See Section 4-1.

FIRST HARMONIC - The fundamental (original) frequency.

FREQUENCY AGILITY - A radar's ability to change frequency within its operating band, usually on a pulse-to-pulse basis. This is an ECCM technique employed to avoid spot jamming and to force the jammer to go into a less effective barrage mode.

FREQUENCY AGILITY RADAR - A radar that automatically or semiautomatically tunes through a discrete set of operating frequencies in its normal mode of operation.

FREQUENCY DIVERSITY RADAR - A radar system technique, employed primarily as an antijamming feature, where the transmitter output frequency varies randomly from pulse to pulse over a wide frequency range.

FREQUENCY RANGE - (1) A specifically designated portion of the frequency spectrum; (2) of a device, the band of frequencies over which the device may be considered useful with various circuit and operating conditions; (3) of a transmission system, the frequency band in which the system is able to transmit power without attenuating or distorting it more than a specified amount.

FREQUENCY SHIFT KEYING (FSK) - A form of FM where the carrier is shifted between two frequencies in accordance with a predetermined code. In multiple FSK, the carrier is shifted to more than two frequencies. FSK is used principally with teletype communications.

"FRUIT" - In a radar beacon system, there is a type of interference called "FRUIT," caused by beacon replies to interrogation asynchronous with the observer's interrogator. The largest amount of this interference is received through the sidelobes of the interrogating antenna, but it can become dense enough to cause false target indications.

FTC (FAST TIME CONSTANT) - An antijam feature employed in radar systems where receiver circuits may be selected to provide a short time constant to emphasize signals of short duration to produce discrimination against the low frequency components of clutter.

FUNDAMENTAL FREQUENCY - Used synonymously for tuned frequency, carrier frequency, center frequency, output frequency, or operating frequency.

FUSELAGE STATION or just STATION - A reference point (usually the nose of an aircraft) used to measure or identify fore and aft locations. One of several aircraft location designations - also see butt line and water line.

GaAs FET AMPLIFIER - Because of their low noise, field-effect transistors are often used as the input stage of wideband amplifiers. Their high input resistance makes this device particularly useful in a variety of applications. Since the FET does not employ minority current carriers, carrier storage effects are eliminated giving the device faster operating characteristics and improved radiation resistant qualities.

GAIN - For antennas, the value of power gain in a given direction relative to an isotropic point source radiating equally in all directions. Frequently expressed in dB (gain of an isotropic source = 0 dB). The formula for calculating gain is:

$$G = \frac{4\pi\, P(\theta,\phi)}{P_{in}} \quad ; \text{where} \quad \begin{array}{l} P(\theta,\phi) = \text{Radiation intensity in given direction} \\ P_{in} = \text{Power into lossless antenna radiating uniformly in all directions} \end{array}$$

Note: (1) If radiation efficiency is unity, then gain = directivity i.e. if directivity = 2, then gain = 3 dB, etc.
(2) Interference losses within an array also affect gain
(3) See Section 3-1 for further details

For amplifiers, gain is the ratio of the output power to input power (usually in dB).

GATE (RANGE) - A signal used to select radar echoes corresponding to a very short range increment. Range is computed by moving the range gate or marker to the target echo; an arrangement which permits radar signals to be received in a small selected fraction of the time period between radar transmitter pulses.

GATING - (1) The process of selecting those portions of a wave which exist during one or more selected time intervals; (2) the application of a square waveform of desired duration and timing to perform electronic switching; (3) the application of receiver operating voltages to one or more stages only during that portion of a cycle of operation when reception is desired. See also Gate (Range).

GCI (GROUND-CONTROLLED INTERCEPT) - Vectoring an interceptor aircraft to an airborne target by means of information relayed from a ground-based radar site which observes both the interceptor and the target.

GIGA - A prefix meaning 10^9 (times a billion). For example, gigahertz (GHz).

GLINT (In Radar) - 1. The random component of target location error caused by variations in the phase front of the target signal (as contrasted with Scintillation Error). Glint may affect angle, range of

Doppler measurements, and may have peak values corresponding to locations beyond the true target extent in the measured coordinate. 2. Electronic countermeasures that uses the scintillating, or flashing effect of shuttered or rotating reflectors to degrade tracking or seeking functions of an enemy weapons system.

GUARDBAND - A frequency band to which no other emitters are assigned as a precaution against interference to equipments susceptible to EMI in that band.

GUIDANCE, BEAM RIDER - A missile guidance technique which is dependent on the missile's ability to determine its positions with reference to the center of scan of the guidance radar beam and thus correct its trajectory on the basis of detected errors.

GUIDANCE CODE - A technique of modulating guidance transmitter carriers with coded pulses compatible with the receiver code of the missile assigned that system, thus reducing the possibility of the missile accepting erroneous commands of other transmissions.

GUIDANCE, COMMAND - A guidance system wherein intelligence transmitted to the missile from an outside source causes the missile to traverse a directed path in space.

GUIDANCE, HOMING, ACTIVE - A system of homing guidance wherein both the transmitter and receiver are carried within the missile.

GUIDANCE, HOMING, PASSIVE - A form of homing guidance, which is dependent on a missile's ability to detect energy emitted by the target. Frequently termed Home-On-Jam (HOJ).

GUIDANCE, HOMING, SEMIACTIVE - A system of homing guidance wherein the missile uses reflected signals from the target which has been illuminated by a source other than within the missile. See also CWI.

GUIDANCE, INERTIAL - A self-contained system independent of information obtained from outside the missile, usually using Newton's second law of motion.

GUNN DIODE - The Gunn diode is a transferred electron device which because of its negative resistance can be used in microwave oscillators or amplifiers. When the applied voltage exceeds a certain critical value, periodic fluctuations in current occur. The frequency of oscillation depends primarily upon the drift velocity of electrons through the effective length of the device. This frequency may be varied over a small range by means of mechanical tuning.

HARMONIC - A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency. For example, a component which is twice the fundamental frequency is called the second harmonic. (The fundamental is the first harmonic, which is frequently misunderstood.)

HERTZ - The unit of frequency equal to one cycle per second.

HOME-ON-JAM (HOJ) - See Guidance, Homing, Passive.

HORN ANTENNA - A flared, open-ended section of waveguide used to radiate the energy from a waveguide into space. Also termed "horn" or "horn radiator." Usually linearly polarized, it will be vertically polarized when the feed probe is vertical, or horizontally polarized if the feed is horizontal. Circular polarization can be obtained by feeding a square horn at a 45° angle and phase shifting the vertical or horizontal excitation by 90°.

HYPERABRUPT VARACTOR OSCILLATOR - Due to a non-uniform concentration of N-type material (excess electrons) in the depletion region, this varactor produces a greater capacitance change in tuning voltage and a far more linear voltage-vs.-frequency tuning curve. As a result, this device has an improved tuning linearity and low tuning voltage.

IF (INTERMEDIATE FREQUENCY) - The difference frequency resulting from mixing (beating) the received signal in a superheterodyne receiver with the signal from the local oscillator. The difference frequency product provides the advantages inherent to the processing (amplification, detection, filtering, and such) of low frequency signals. The receiver local oscillator may operate either below or above the receiver tuned frequency. A single receiver may incorporate multiple IF detection.

$IF = F_{LO} - F_O$ (for a local oscillator operating above the fundamental)

where:
F_O = Received fundamental frequency
F_{LO} = Local oscillator frequency

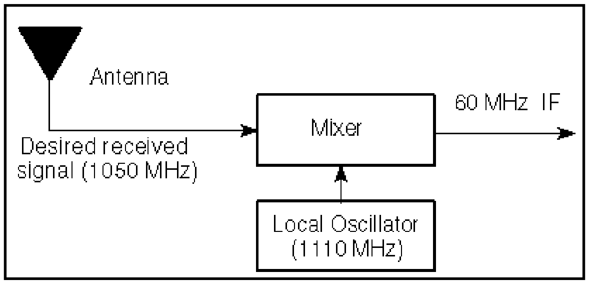
Antenna
Desired received signal (1050 MHz)
Mixer
60 MHz IF
Local Oscillator (1110 MHz)

The simplified block diagram illustrates a typical mixing procedure employed in radar systems to obtain desired IF frequencies. The local oscillator is tuned above the fundamental frequency in this example. It should be noted that an undesired signal received at the receiver image frequency of 1170 MHz will also produce the desired 60 MHz IF frequency; this relationship provides the receiver image. See also Image Frequency.

IFF (IDENTIFICATION FRIEND OR FOE) - A system using radar transmission to which equipment carried by friendly forces automatically responds by emitting a unique characteristic series of pulses thereby distinguishing themselves from enemy forces. It is the “Mode IV” for the aircraft transponder. See also transponder.

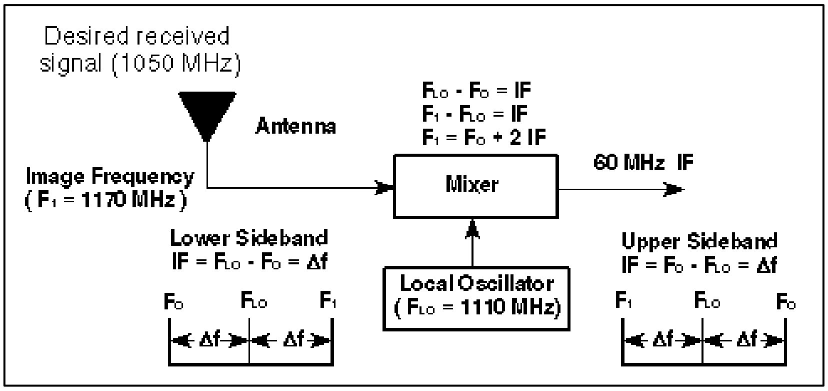
Desired received signal (1050 MHz)
Antenna
$F_{LO} - F_O = IF$
$F_I - F_{LO} = IF$
$F_I = F_O + 2\ IF$
Image Frequency (F_I = 1170 MHz)
Mixer
60 MHz IF
Lower Sideband
$IF = F_{LO} - F_O = \Delta f$
F_O
F_{LO}
F_I
Δf
Δf
Local Oscillator (F_{LO} = 1110 MHz)
Upper Sideband
$IF = F_O - F_{LO} = \Delta f$
F_I
F_{LO}
F_O
Δf
Δf

IMAGE FREQUENCY - That frequency to which a given superheterodyne receiver is inherently susceptible, thereby rendering such a receiver extremely vulnerable to EMI at that frequency. The image frequency is located at the same frequency difference (Δf) to one side of the local oscillator as the tuned (desired) frequency is to the other side. An undesired signal received at the image frequency by a superheterodyne receiver not having preselection would, therefore, mix (beat) with the oscillator, produce the proper receiver IF, and be processed in the same manner as a signal at the desired frequency. See also receiver selectivity.

IMAGE JAMMING - Jamming at the image frequency of the radar receiver. Barrage jamming is made most effective by generating energy at both the normal operating and image frequency of the radar.

Image jamming inverts the phase of the response and is thereby useful as an angle deception technique. Not effective if the radar uses image rejection.

IMPATT DIODE - The IMPATT (IMPact Avalanche and Transit Time) diode acts like a negative resistance at microwave frequencies. Because of this property, Impatt diodes are used in oscillators and amplifiers. Usually the frequency range is in the millimeter wave region where other solid state devices cannot compete.

INGRESS - Go into the target area.

INSERTION LOSS - The loss incurred by inserting an element, device, or apparatus in an electrical/electronic circuit. Normally expressed in decibels determined as 10 log of the ratio of power measured at the point of insertion prior to inserting the device (P_1) to the power measured after inserting the device (P_2). Insertion loss (dB) = 10 log P_1/P_2.

INTEGRATION EFFECT - Pulse radars usually obtain several echoes from a target. If these echoes are added to each other, they enhance the S/N ratio, making a weak target easier to detect. The noise and interference do not directly add from pulse to pulse, so the ratio of target strength to undesired signal strength improves making the target more detectable. Random noise increases by the square root of the number of integrations, whereas the signal totally correlates and increases directly by the number of integrations, therefore the S/N enhancement is equal to the square root of the number of integrations.

INTERFERENCE - See EMI.

INTERFERENCE PARAMETERS - Equipment and propagation characteristics necessary for the proper evaluation of a given EMI situation.

INTERFERENCE/SIGNAL RATIO - See I/S Ratio.

INTERFERENCE THRESHOLD - The level of interference normally expressed in terms of the I/S (interference/signal) ratio at which performance degradation in a system first occurs as a result of EMI.

INTERFEROMETER - When two widely spaced antennas are arrayed together, they form an interferometer. The radiation pattern consists of many lobes, each having a narrow beamwidth. This antenna can provide good spatial selectivity if the lobe-to-lobe ambiguity can be solved such as using amplitude comparison between the two elements.

INTERMODULATION - The production, in a nonlinear element (such as a receiver mixer), of frequencies corresponding to the sums and differences of the fundamentals and harmonics of two or more frequencies which are transmitted through the element; or, the modulation of the components of a complex wave by each other, producing frequencies equal to the sums and differences of integral multiples of the component frequencies of the complex wave.

INTERSYSTEM EMC - EMC between the external electromagnetic environment (EME) and an aircraft with its installed systems. Generally, only system BIT must operate properly on the carrier deck while all system functions must operate properly in the operational EME.

INTRASYSTEM EMC - EMC between systems installed on an aircraft, exclusive of an external environment.

INVERSE CON SCAN - One method of confusing a radar operator or fire control radar system is to provide erroneous target bearings. This is accomplished by first sensing the radar antenna scan rate and then modulating repeater amplifier gain so the weak portion of the radar signal is amplified by the jammer, while the strong portion is not, so the weapons systems will fire at some bearing other than the true target bearing. The angle deception technique is used to break lock on CONSCAN radars.

INVERSE GAIN - Amplification, inverse modulation, and re-radiation of a radar's pulse train at the rotation rate of the radar scan. Deceives a conical scanning radar in angle.

ISOTROPIC ANTENNA - A hypothetical antenna which radiates or receives energy equally in all directions.

I/S RATIO (INTERFERENCE-TO-SIGNAL RATIO) (ISR) - The ratio of electromagnetic interference level to desired signal level that exists at a specified point in a receiving system. The ratio, normally expressed in dB, is employed as a tool in prediction of electronic receiving system performance degradation for a wide range of interference receiver input levels. Performance evaluations compare actual I/S ratios to minimum acceptable criteria.

JAFF - Expression for the combination of electronic and chaff jamming.

JAMMING - The deliberate radiation, reradiation, or reflection of electromagnetic energy with the object of impairing the use of electronic devices, equipment, or systems by an enemy.

JATO - JAmmer Technique Optimization group -- Organization coordinates EA technique development and evaluation efforts in support of naval airborne EA (ALQ-99, USQ-113, ALQ-227, ALQ-231, ALE-43). The group is run out of PMA-234 and comprised of elements at NAWCWD-Point Mugu, Johns Hopkins University/ Applied Physics Lab, Naval Research Lab, and NSWC-Crane. Efforts include M&S, Lab test, ground test, flight test, direct fleet support, and requirements and test support to development programs.

JINK - An aircraft maneuver which sharply changes the instantaneous flight path but maintains the overall route of flight. More violent than a weave.

JITTERED PRF - An antijam feature of certain radar systems which varies the PRF consecutively, and randomly, from pulse to pulse to prevent enemy ECM equipment from locking on, and synchronizing with, the transmitted PRF. PRF is synonymous with pulse repetition rate (PRR).

JTAT - JATO Techniques Analysis and Tactics -- Analysis documents produced by JATO to advise EA systems operators on the best ways to employ their systems by region, mission and equipment configuration. Currently covering ALQ-99 and USQ-113 on EA-6B; ALQ-99 and ALQ-227 on EA-18G, and ALQ-231 on AV-8B.

KILO - A prefix meaning 10^3 (times one thousand). For example, kilohertz.

KLYSTRON AMPLIFIER - An electron beam device which achieves amplification by the conversion of periodic velocity variations into conduction-current modulation in a field-free drift region. Velocity variations are launched by the interaction of an RF signal in an input resonant cavity and are coupled out through an RF output cavity. Several variations including reflex and multi cavity klystrons are used.

KLYSTRON, MULTICAVITY - An electron tube which employs velocity modulation to generate or amplify electromagnetic energy in the microwave region. Since velocity modulation employs transit time of the electron to aid in the bunching of electrons, transient time is not a deterrent to high frequency operations as is the case in conventional electron tubes. See also Velocity Modulation.

KLYSTRON, REFLEX - A klystron which employs a reflector (repeller) electrode in place of a second resonant cavity to redirect the velocity-modulated electrons through the resonant cavity. The repeller causes one resonant circuit to serve as both input and output, which simplifies the tuning operation. This type of klystron is well adapted for use as an oscillator because the frequency is easily controlled by varying the position of the repeller. See also Velocity Modulation.

LEAKAGE - Undesired radiation or conduction of RF energy through the shielding of an enclosed area or of an electronic device.

LENS, RADAR (MICROWAVE) - The purpose of any such lens is to refract (focus) the diverging beam from an RF feed into a parallel beam (transmitting) or vice versa (receiving). The polarization is feed dependent.

LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION (LASER) - A process of generating coherent light. The process utilizes a natural molecular (and atomic) phenomenon whereby molecules absorb incident electromagnetic energy at specific frequencies, store this energy for short but usable periods, and then release the stored energy in the form of light at particular frequencies in an extremely narrow frequency-band.

LIMITING - A term to describe that an amplifier has reached its point of saturation or maximum output voltage swing. Deliberate limiting of the signal is used in FM demodulation so that AM will not also be demodulated.

LITTORAL - Near a shore.

LOBE, ANTENNA - Various parts of the antenna's radiation pattern are referred to as lobes, which may be subclassified into major and minor lobes. The major lobe is the lobe of greatest gain and is also referred to as the main lobe or main beam. The minor lobes are further subclassified into side and back lobes as indicated in the figure to the right. The numbering of the side lobes are from the main lobe to the back lobe.

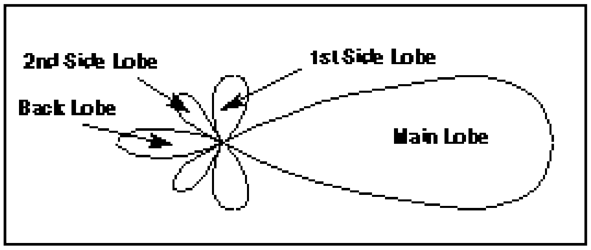

LOCAL OSCILLATOR FREQUENCY - An internally generated frequency in a superheterodyne receiver. This frequency differs from the receiver operating frequency by an amount equal to the IF of the receiver. The local oscillator frequency may be designed to be either above or below the incoming signal frequency.

LOG VIDEO - This receiver process, generally implemented in the IF, compresses the dynamic range of the signal so both weak and strong signals are displayed without changing the gain setting. Output voltage can be calibrated in volts/dB of input power.

LONG PULSE MODE - Many pulsed radars are capable of transmitting either long or short pulses of RF energy. When the long pulses of RF energy are selected manually (or sometimes automatically), the radar is said to be operating in the long pulse mode. In general, "long pulse mode" is used to obtain high average power for long-range search or tracking, and "short pulse mode" gives low average power for short-range, high-definition, tracking or search.

LOOSE DEUCE - General term for two aircraft working in mutual support of each other.

LORO (LOBE-ON-RECEIVE-ONLY) - A mode of operation generally consisting of transmitting on one non-scanning antenna system and receiving the reflected energy on another scanning system (The receiver could be TWS, Conical, or monopulse).

MACH NUMBER - The ratio of the velocity of a body to the speed of sound in the medium that is being considered. In the atmosphere, the speed of sound varies with temperature and atmospheric pressure, hence, so does mach number.

MAGNETIC ANOMALY DETECTOR - A means of detecting changes in the earth's magnetic field caused by the presence of metal in ships and submarines.

MAGNETRON - A magnetron is a thermionic vacuum tube which is constructed with a permanent magnet forming a part of the tube and which generates microwave power. These devices are commonly used as the power output stage of radar transmitters operating in the frequency range above 1000 MHz and are used less commonly down to about 400 MHz. A magnetron has two concentric cylindrical electrodes. On a conventional magnetron, the inner one is the cathode and the outer one is the anode. The opposite is true for a coaxial magnetron.

MAGNETRON OSCILLATOR - A high-vacuum tube in which the interaction of an electronic space charge and a resonant system converts direct current power into ac power, usually at microwave frequencies. The magnetron has good efficiency, is capable of high power outputs, and is stable.

MATCHED FILTER - This describes the bandwidth of an IF amplifier that maximizes the signal-to-noise ratio in the receiver output. This bandwidth is a function of the pulsewidth of the signal.

MDS (MINIMUM DETECTABLE/DISCERNIBLE SIGNAL) - The receiver input power level that is just sufficient to produce a detectable/discernible signal in the receiver output. The detectable term is interchangeable with S_{min} and the discernable term is interchangeable with MVS. See Section 5-2.

MEACONING -- A system receiving radio signals and rebroadcasting them (or just transmitting) on the same frequency to confuse navigation. The meaconing station attempts to cause aircraft to receive inaccurate range or bearing information.

MEATBALL - Visual light "ball" seen in Fresnel lens optical landing system (FLOLS) by pilot during carrier or Navy field landing. Used as a reference to determine if flight path is high or low.

MEGA - A prefix meaning 10^6 (times one million). For example megahertz (MHz)

MICROVOLT PER METER - A commonly used unit of field strength at a given point. The field strength is measured by locating a standard receiving antenna at that point, and the "microvolts per meter" value is then the ratio of the antenna voltage in microvolts to the effective antenna length in meters. Usually used below 100 MHz. Above 100 MHz, power density terminology is normally used.

MICROWAVE AMPLIFICATION BY STIMULATED EMISSION OF RADIATION (MASER) - A low-noise radio-frequency amplifier. The emission of energy stored in a molecular or atomic system by a microwave power supply is stimulated by the input signal.

MISS DISTANCE - Used variously in different contexts. The distance from the missile to the geometric center of the aircraft, or the closest point of approach (CPA) of the missile to any portion of the aircraft such as the aircraft nose or telemetry pod, etc.

MISSILE SYSTEMS FUNCTIONS - Examples of missile system functions are: "acquisition" (ability to lock-on a desired target); "tracking" of a target; "guidance" of a missile toward a target; "illumination" of a target so that a homing missile can home on the reflected RF illumination; and "command" signal transmission to a missile to cause it to arm, to detonate, to commence homing, or to destroy itself.

MIXERS - See Balanced and Schottky Diode Mixers.

MODULATION - The process whereby some characteristic of one wave is varied in accordance with some characteristic of another wave. The basic types of modulation are angle modulation (including the special cases of phase and frequency modulation) and amplitude modulation. In missile radars, it is common practice to amplitude modulate the transmitted RF carrier wave of tracking and guidance transmitters by using a pulsed wave for modulating, and to frequency module the transmitted RF carrier wave of illuminator transmitters by using a sine wave.

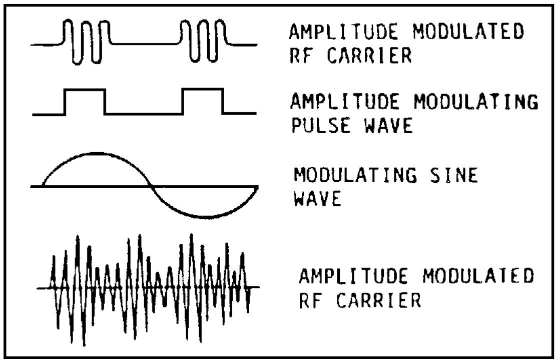
AMPLITUDE MODULATED RF CARRIER
AMPLITUDE MODULATING PULSE WAVE
MODULATING SINE WAVE
AMPLITUDE MODULATED RF CARRIER

MODULATION, AMPLITUDE - This type of modulation changes the amplitude of a carrier wave in responses to the amplitude of a modulating wave. This modulation is used in radar and EW only as a switch to turn on or turn off the carrier wave; i.e., pulse is a special form of amplitude modulation.

MODULATION, FREQUENCY - The frequency of the modulated carrier wave is varied in proportion to the amplitude of the modulating wave and therefore, the phase of the carrier varies with the integral of the modulating wave. See also Modulation.

MODULATION, PHASE - The phase of the modulated carrier is varied in proportion to the amplitude of the modulating wave. See also Modulation.

MONOPULSE - (See figure to right) A type of tracking radar that permits the extracting of tracking error information from each received pulse and offers a reduction in tracking errors as compared to a conical-scan system of similar power and size. Multiple (commonly four) receiving antennas or feeds are placed symmetrically about the center axis and operate simultaneously to receive each RF pulse reflected from the target. A comparison of the output signal amplitude or phase among the four antennas indicates the location of the target with respect to the radar beam center line. The output

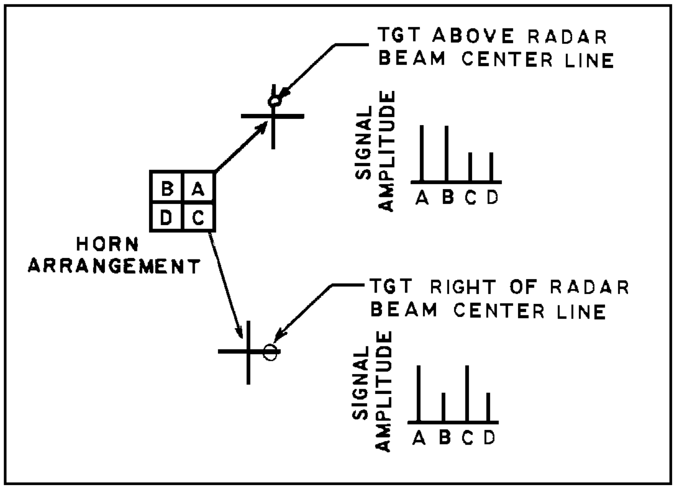

of the comparison circuit controls a servo system that reduces the tracking error to zero and thereby causes the antenna to track the target.

MOS (MINIMUM OPERATIONAL SENSITIVITY) - The minimum signal which can be detected and automatically digitally processed by a radar without human discrimination.

MTI (MOVING TARGET INDICATOR) - This radar signal process shows only targets that are in motion. Signals from stationary targets are subtracted out of the return signal by a memory circuit.

MULTIPATH - The process by which a transmitted signal arrives at the receiver by at least two different paths. These paths are usually the main direct path, and at least one reflected path. The signals combine either constructively or destructively depending upon phase, and the resultant signal may be either stronger or weaker than the value computed for free space.

MULTIPLEX - Simultaneous transmission of two or more signals on a common carrier wave. The three types of multiplex are called time division, frequency division, and phase division.

MULTIBAND RADAR - A type of radar which uses simultaneous operation on more than one frequency band through a common antenna. This technique allows for many sophisticated forms of video processing and requires any jammer to jam all channels at the same time in order to be effective.

MVS (MINIMUM VISIBLE SIGNAL) - The minimum input pulse signal power level which permits visibility of the output pulse, such as on a radar A-scope display. This level is determined by initially setting the input level above the visible detection threshold, and then slowly decreasing the amplitude.

NOISE FIGURE, RECEIVER - A figure of merit (NF or F) of a system given by the ratio of the signal-to-noise ratio at the input, S_i / N_i, divided by the signal-to-noise ratio at the output, S_o/N_o. It essentially expresses the ratio of output noise power of a given receiver to that of a theoretically perfect receiver which adds no noise.

$$\text{Noise Figure} = \frac{S_i / N_i}{S_o / N_o} = \frac{N_o}{G\,N_i}$$

Where $S_o = GS_i$ and G is the gain of the system.

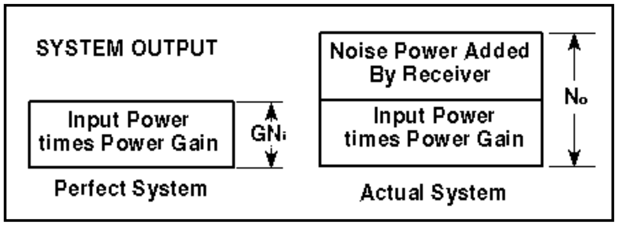
SYSTEM OUTPUT
Input Power times Power Gain
GNᵢ
Perfect System
Noise Power Added By Receiver
Input Power times Power Gain
Nₒ
Actual System

Noise figure is usually expressed in dB and given for an impedance matched condition. Impedance mismatch will increase the noise figure by the amount of mismatch loss. NF is usually given at room temperature; 17°C or 290°K. See Section 5-2.

NOISE JAMMING - A continuous random signal radiated with the objective of concealing the aircraft echo from the enemy radar. In order for it to be effective, it must have an average amplitude at least as great as the average amplitude of the radar echo. There are three major categories of noise jamming which are grouped by how jamming power is concentrated: Spot, barrage, and swept jamming. (See individual definitions)

NONCOHERENT - Two signals that have no set phase relationship.

NOTCH - The portion of the radar velocity display where a target disappears due to being notched out by the zero Doppler filter. If not filtered (notched), ground clutter would also appear on the display. A notch filter is a narrow band-reject filter. A "notch maneuver" is used to place a tracking radar on the beam of the aircraft so it will be excluded.

NULL, ANTENNA PATTERN - The directions of minimum transmission (or reception) of a directional antenna. See also Lobe, Antenna.

NULL FILL - The nulls in an antenna pattern may be reduced (filled) by using a second ancillary (spoiler) antenna whose pattern is such that it fills in the nulls of the main antenna pattern.

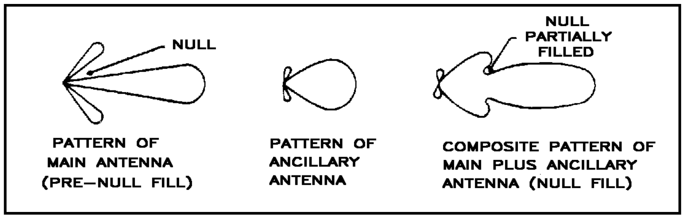
NULL
NULL PARTIALLY FILLED
PATTERN OF MAIN ANTENNA (PRE—NULL FILL)
PATTERN OF ANCILLARY ANTENNA
COMPOSITE PATTERN OF MAIN PLUS ANCILLARY ANTENNA (NULL FILL)

NUTATION - As applied to current missile system radars, this term refers to the mechanical motion of an antenna feed to produce a conical scan (fixed polarization) by the main beam of a tracking antenna, thus providing a means of developing tracking error signals. See also Antenna, Nutating. By analogy, "Nutation" also is used to denote the electrical switching of the quadrants of a seeker antenna. See also Interferometer. The effect is similar to that of a conical scan.

NUTATOR - A motor-driven rotating antenna feed used to produce a conical scan for a tracking radar. See also Antenna, Nutating. Also, the electrical circuits necessary to effect nonmechanical conical scans. See also Nutation.

OPERATIONAL CONSTRAINTS - Limitations on operating procedures in order to prevent interference between missile systems on a ship or between missile systems in a formation of ships under operational conditions. These limitations consist of such things as limited frequency bands or channels in which the radars may be tuned, limited sectors of space into which radar beams may be pointed, limits on minimum spacing between ships, limits on what codes may be used by radars and missiles on each ship, and limits on minimum interval between firing of certain missiles.

OSCILLATORS - Devices which generate a frequency. See also Backward Wave, Dielectrically Stabilized Oscillator, Hyperabrupt Varactor Oscillator, Magnetron Oscillator, Varactor Tuned Oscillator, and YIG tuned oscillator.

OSCILLATOR, LOCAL - See Local Oscillator Frequency.

PALMER SCAN - Conical scan superimposed on another type of scan pattern - usually a spiral pattern.

PARAMETER - A quantity which may have various values, each fixed within the limits of a stated case or discussion. In the present case, some examples of parameters; would be: radar frequency, limited by the tuning range of the radar; missile range, limited by the maximum operating range of the missile; or a missile code, limited by the number of codes available and by the codes that the ship radars are set up to operate on.

PASSIVE ANGLE TRACKING - Tracking of a target using radiation from the target (such as jamming), with no radiation from the radar itself. Only angular tracking is possible under these conditions since no measurement of time of travel of radiation to the target is possible, as is required to obtain target range.

PC (PULSE COMPRESSION) - The process used in search and tracking pulse radars whereby the transmitted pulse is long, so as to obtain high average transmitter output power, and the reflected pulse is processed in the radar receiver to compress it to a fraction of the duration of the transmitted pulse to obtain high definition and signal strength enhancement. Pulse compression may be accomplished by sweeping the transmitted frequency (carrier) during the pulse. The returned signal is then passed through a frequency-dependent delay line. The leading edge of the pulse is therefore delayed so that the trailing edge catches up to the leading edge to produce effectively a shorter received pulse than that transmitted. Pulse compression radars are also referred to as CHIRP radars. Other more sophisticated pulse compression techniques are also possible and are becoming more popular.

PENCIL BEAM - A narrow circular radar beam from a highly directional antenna (such as a parabolic reflector).

PHASED ARRAY RADAR - Radar using many antenna elements which are combined in a controlled phase relationship. The direction of the beam can be changed as rapidly as the phase relationships (usually less than 20 microseconds). Thus, the antenna typically remains stationary while the beam is electronically scanned. The use of many antenna elements allows for very rapid and high directivity of the beam(s) with a large peak and/or average power. There is also a potential for greater reliability over a conventional radar since the array will fail gracefully, one element at a time.

PIN DIODE - A diode with a large intrinsic (I) region sandwiched between the P- and N- doped semiconducting regions. The most important property of the PIN diode is the fact that it appears as an almost pure resistance at RF. The value of this resistance can be varied over a range of approximately one-10,000 ohms by direct or low frequency current control. When the control current is varied continuously, the PIN diode is useful for attenuating, leveling and amplitude modulation of an RF signal. When the control current is switched on and off or in discrete steps, the device is useful in switching, pulse modulating, and phase shifting an RF signal.

POINT CONTACT DIODE - This was one of the earliest semiconductor device to be used at microwave frequencies. Consisting of a spring-loaded metal contact on a semiconducting surface, this diode can be considered an early version of the Schottky barrier diode. Generally used as a detector or mixer, the device is somewhat fragile and limited to low powers.

POLARIZATION - The direction of the electric field (E-field) vector of an electromagnetic (EM) wave. See Section 3-2. The most general case is elliptical polarization with all others being special cases. The E-field of an EM wave radiating from a vertically mounted dipole antenna will be vertical and the wave is said to be vertically polarized. In like manner, a horizontally mounted dipole will produce a horizontal electric field and is horizontally polarized. Equal vertical and horizontal E-field components produce circular polarization.

PORT - The left side of a ship or aircraft when facing the bow (forward)

POWER (AVERAGE) FOR PULSED RADARS - Average power for a pulse radar is the average power transmitted between the start of one pulse and the start of the next pulse (because the time between pulses is many times greater than the pulse duration time, the average power will be a small fraction of peak power).

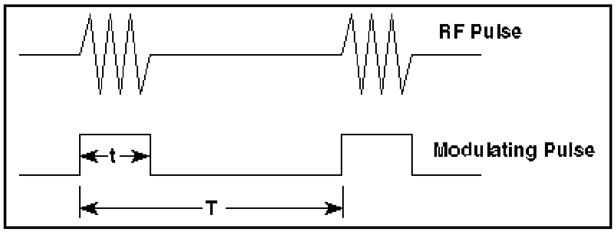

For this example: Peak Power = 1 MW, Pulse Time (t) = 0.5 microsecond, and Interval Between Pulses (T) = 1000 microseconds (1000 pps).

Peak Power = Pwr during pulse time (t) = 1 MW = 10^6 Watts = 90 dBm.

Avg Power = Average Power During Time (T) = 10^6 x t/T
= 10^6 x 0.5/1000 = 0.5 x 10^3 = 0.5 kilowatt = 57 dBm or 27 dBW

POWER OUTPUT - Power output of a transmitter or transmitting antenna is commonly expressed in dBW or dBm. One megawatt would be expressed as 60 dBW or 90 dBm:

10 log (1 megawatt / 1 watt) = 10 log ($10^6/10^0$)
= 10 x 6 = 60 dBW

10 log (1 megawatt / 1 milliwatt) = 10 log ($10^6/10^{-3}$)
= 10 x 9 = 90 dBm

POWER (PEAK) FOR PULSED RADARS - Peak power for a pulsed radar is the power radiated during the actual pulse transmission (with zero power transmitted between pulses).

POWER FOR CW RADARS - Since the power output of CW transmitters (such as illuminator transmitters) usually have a duty cycle of one (100%), the peak and average power are the same.

POWER DENSITY - The density of power in space expressed in Watts/meter^2, dBW/m^2, etc. Generally used in measurements above 100 MHz. At lower frequencies, field intensity measurements are taken. See Section 4-1.

PPI-SCOPE - A radar display yielding range and azimuth (bearing) information via an intensity modulated display and a circular sweep of a radial line. The radar is located at the center of the display.

PRESELECTOR - A device placed ahead of the mixer in a receiver, which has bandpass characteristics such that the desired (tuned) RF signal, the target return, is allowed to pass, and other undesired signals (including the image frequency) are attenuated.

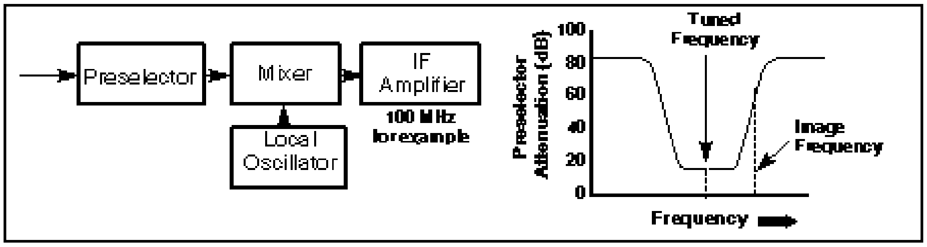

PROPAGATION - In electrical practice, the travel of waves through or along a medium. The path traveled by the wave in getting from one point to another is known as the propagation path (such as the path through the atmosphere in getting from a transmitting antenna to a receiving antenna, or the path through the waveguides and other microwave devices in getting from an antenna to a receiver).

PULSE COMPRESSION - See PC.

PULSED DOPPLER (PD) - A type of radar that combines the features of pulsed radars and CW Doppler radars. It transmits pulses (instead of CW) which permits accurate range measurement. This is an inherent advantage of pulsed radars. Also, it detects the Doppler frequency shift produced by target range rate which enables it to discriminate between targets of only slightly different range rate and also enables it to greatly reduce clutter from stationary targets. See also Doppler Effect.

PULSE LENGTH - Same meaning as Pulsewidth.

PULSE MODULATION - A special case of amplitude modulation wherein the carrier wave is varied at a pulsed rate. Pulse Modulation - The modulation of a carrier by a series of pulses generally for the purpose of transmitting data. The result is a short, powerful burst of electromagnetic radiation which can be used for measuring the distance from a radar set to a target.

PULSE REPETITION FREQUENCY (PRF) - The rate of occurrence of a series of pulses, such as 100 pulses per second. It is equal to the reciprocal of the pulse spacing (T) or PRT. (PRF = 1/T = 1/PRI). Sometimes the term pulse repetition rate (PRR) is used.

PULSE REPETITION FREQUENCY (PRF) STAGGER - The technique of switching PRF (or PRI) to different values on a pulse-to-pulse basis such that the various intervals follow a regular pattern. This is useful in compensating for blind speeds in pulsed MTI radars. Interpulse intervals which differ but follow a regular pattern.

PULSE REPETITION INTERVAL (PRI) or TIME (PRT) - Time between the beginning of one pulse and the beginning of the next.

PULSE SPACING - The interval of time between the leading edge of one pulse and the leading edge of the next pulse in a train of regularly recurring pulses. See also Pulse Repetition Frequency. Also called "the interpulse period."

PULSEWIDTH - The interval of time between the leading edge of a pulse and the trailing edge of a pulse (measured in microseconds for the short pulses used in radar). Usually measured at the 3 dB midpoint (50-percent power or 70% voltage level) of the pulse, but may be specified to be measured at any level. See Section 6-10 for measurement techniques.

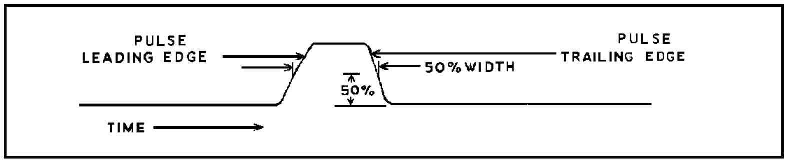

QUANTIZE - The process of restricting a variable to a number of discrete values. For example, to limit varying antenna gains to three levels.

RADAR - Radio detection and ranging.

RADAR CROSS SECTION - A measure of the radar reflection characteristics of a target. It is equal to the power reflected back to the radar divided by power density of the wave striking the target. For most targets, the radar cross section is the area of the cross section of the sphere that would reflect the same energy back to the radar if the sphere were substituted. RCS of sphere is independent of frequency if operating in the far field region. See Section 4-11.

RADAR RANGE EQUATION - The radar range equation is a basic relationship which permits the calculation of received echo signal strength, if certain parameters of the radar transmitter, antenna, propagation path, and target are known.

Given: $P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R^4}$ *(freespace)* as the basic two-way radar equation (see Sections 4-4 thru 4-6)

where:

P_r = Peak power at receiver input

λ = Wavelength of signal (length) = c/f

P_t = Transmitted signal level (power)
R = Range of target to radar (distance)
G_t = Gain of transmitting antenna (dimensionless ratio)
σ = Radar cross section of target
G_r = Gain of receiving antenna (dimensionless ratio)

In practical use, the radar range equation is often written in logarithmic form, all terms expressed in decibels, so that the results can be found by simple processes of addition and subtraction. Using the above equation and $\lambda = c/f$.

$$10 \log P_r = 10 \log P_t + 10 \log G_t + 10 \log G_r + 10 \log \sigma - 40 \log R - 20 \log f + 20 \log c - 30 \log 4\pi$$

where: f = Signal frequency (cycles {dimensionless}/time) c = Speed of light (length/time)

$$10 \log P_r = 10 \log P_t + 10 \log G_t + 10 \log G_r + G_\sigma - 2\alpha_1$$

where α_1 and G_σ are factors containing the constants and conversion factors to keep the equations in consistent units.

Refer to Sections 4-4 through 4-6.

RADAR TRIGGER KILL - see Trigger Kill, Radar.

RADIATION EFFICIENCY - $E = P_{radiated}/P_{in}$ (ideal=1)

RADIATION PATTERN - See Antenna Pattern.

RADIO FREQUENCY - See RF.

RADIO FREQUENCY INTERFERENCE - See RFI.

RAIL KEEPING - Ability of countermeasures to keep the missile on the launch rail, i.e., prevent launch.

RAINBOW - A technique which applies pulse-to-pulse frequency changing to identifying and discriminating against decoys and chaff.

RANGE CELL - In a radar, a range cell is the smallest range increment the radar is capable of detecting. If a radar has a range resolution of 50 yards and a total range of 30 nautical miles (60,000 yds), there are: 60000/50 = 1,200 range cells.

RANGE GATE - A gate voltage used to select radar echoes from a very short range interval.

RANGE GATE PULL OFF (RGPO) - Deception technique used against pulse tracking radars using range gates. Jammer initially repeats the skin echo with minimum time delay at a high power to capture the AGC circuitry. The delay is progressively increased, forcing the tracking gates to be pulled away ("walked off") from the target echo. Frequency memory loops (FML's), or transponders provide the variable delay.

RANGE RATE - The rate at which a radar target is changing its range with respect to the radar (in feet per second for example). Note that this rate is not the same as target velocity unless the target is moving straight toward or straight away from the radar.

RANGE SCOPE - See A-Scope or PPI.

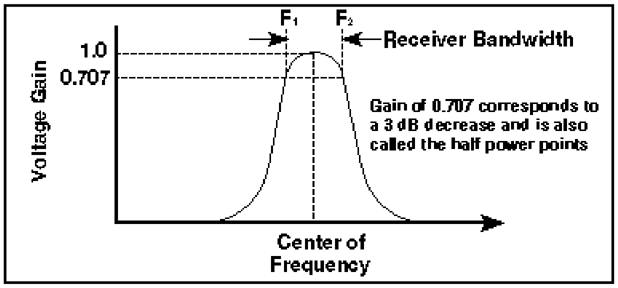

RECEIVER BANDWIDTH - The difference between the limiting frequencies within which receiver performance in respect to some characteristic falls within specified limits. (In most receivers this will be the difference between the two frequencies where the intermediate frequency (IF) amplifier gain falls off 3 dB from the gain at the center IF frequency.) See also Receiver Selectivity.

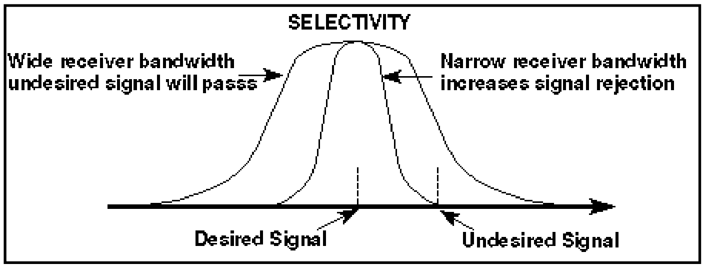
SELECTIVITY
Wide receiver bandwidth undesired signal will pass
Narrow receiver bandwidth increases signal rejection
Desired Signal
Undesired Signal

RECEIVER SELECTIVITY - The degree to which a receiver is capable of differentiating between the desired signal and signals or interference at other frequencies. (The narrower the receiver bandwidth, the greater the selectivity.)

REFLECTION - The turning back (or to the side) of a radio wave as a result of impinging on any conducting surface which is at least comparable in dimension to the wavelength of the radio wave.

RESOLUTION - In radar, the minimum separation in angle or in range between two targets which the radar is capable of distinguishing.

RF (RADIO FREQUENCY) - A term indicating high frequency electromagnetic energy.

RFI (RADIO FREQUENCY INTERFERENCE) - Any induced, radiated, or conducted electrical disturbance or transient that causes undesirable responses or malfunctioning in any electrical or electronic equipment, device, or system. Same as EMI. Not to be confused with the logistic term ready for issue (also RFI).

RING AROUND - A condition in which a repeater jammer's total gain, from receiver antenna to transmitter antenna, exceeds the antenna isolation resulting in the repeater amplifying its own internal noise. Akin to positive feedback in an amplifier that causes unwanted oscillations.

RING AROUND (RADAR-TO-MISSILE) - The condition where radio frequency interference signals from a transmitter of one missile radar enter the receiving circuits of a missile under the control of another missile radar.

RING AROUND (RADAR-TO-RADAR) - The condition where radio frequency interference signals from a transmitter of one radar enter the receiving circuits of another radar.

ROPE - An element of chaff consisting of a long roll of metallic foil or wire which is designed for broad, low-frequency response. See Chaff.

R-SCOPE - (RANGE SCOPE) See A-scope or PPI.

SAFETY OF FLIGHT (SOF) TEST - A flight test to verify that a new or modified subsystem will not cause a major problem with the aircraft, i.e., interference can occur, but will not be such that required navigational systems will fail or which might potentially cause the loss of an aircraft under all normally expected weather conditions.

SCAN - To transverse or sweep a sector or volume of airspace with a recurring pattern, by means of a controlled directional beam from a radar antenna. See also "Antenna, nutating."

SCHOTTKY BARRIER DIODE - The Schottky barrier diode is a simple metal-semiconductor boundary with no P-N junction. A depletion region between the metal contact and the doped semiconductor region offers little capacitance at microwave frequencies. This diode finds use as detectors, mixers, and switches.

SCHOTTKY DIODE MIXER - The mixer is a critical component in modern RF systems. Any nonlinear element can perform the mixing function, but parameters determining optimal mixing are noise figure, input admittance, and IF noise and impedance. The Schottky diode is particularly effective because of its low noise figure and nearly square law characteristics.

SCHOTTKY DIODE SWITCH - Standard P-N diodes are limited in switching ability at high frequencies because of capacitance provided by the minority carriers. The Schottky diode overcomes this problem by use of the metal-semiconductor junction with inherently low carrier lifetimes, typically less than 100 picoseconds.

SEARCH RADAR - A radar whose prime function is to scan (search) a specified volume of space and indicate the presence of any targets on some type of visual display, and, in some cases, to provide coordinates of the targets to a fire control system to assist in target acquisition and tracking.

SEEKER - The seeker consists of circuitry in a homing missile which detects, electronically examines, and tracks the target; provides data for controlling the flight path of the missile; and provides signals for destroying the missile or for detonating it at intercept. (The seeker function is similar to that of an interferometer.)

SELF-SCREENING JAMMING (SSJ) - Each aircraft carries its own jamming equipment for its own protection.

SENSITIVITY - The sensitivity of a receiver is taken as the minimum signal level required to produce an output signal having a specified signal-to-noise ratio. See also Minimum Visible Signal and Minimum Discernible Signal (MDS).

SENSITIVITY TIME CONTROL - See STC.

SENSOR - The receiver portion of a transmitter/receiver pair used to detect and process electromagnetic energy.

SHIELDING - The physical arrangement of shields for a particular component, equipment, or system, (A shield is a housing, screen, or other material, usually conducting, that substantially reduces the effect of electric or magnetic fields on one side of the shield upon devices or circuits on the other side.) Examples are tube shields, a shielded enclosure or cabinet for a radar receiver, and the screen around a screen room.

SHORT PULSE MODE - See Long Pulse Mode.

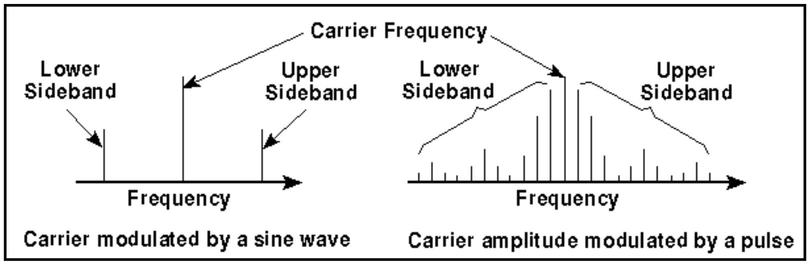

SIDEBAND - A signal either above or below the carrier frequency, produced by the modulation of the carrier wave by some other wave. See figure at right ⇒

SIDELOBE - See Lobe, Antenna.

SIGNAL STRENGTH - The magnitude of a signal at a particular location. Units are volts per meter or dBV/m.

SIGNATURE - The set of parameters which describe the characteristics of a radar target or an RF emitter and distinguish one emitter from another. Signature parameters include the radio frequency of the carrier, the modulation characteristics (typically the pulse modulation code), and the scan pattern.

SILICON CONTROLLED SWITCH - A P-N-P-N device able to operate at sub-microsecond switching speeds by the application of gate signals. Because it is a four layer device, this switch is also known as a tetrode thyristor.

SLANT POLARIZATION - Technique of rotating a linear antenna 45° so it can receive or jam both horizontal and vertical polarization although there is a 3 dB loss. See Section 3.2.

SOLID STATE STAMO - A stable master oscillator constructed using transistors and other solid state devices as opposed to vacuum tubes. See also STAMO.

SPECTRUM - The distribution of power versus frequency in an electromagnetic wave. See also Spectrum Signature Analysis and illustrations under Sideband.

SPECTRUM ANALYZER - An electronic device for automatically displaying the spectrum of the electromagnetic radiation from one or more devices. A cathode ray tube display is commonly used to display this power-versus frequency spectrum. For examples of two types of displays, see illustrations under Sideband.

SPECTRUM SIGNATURE ANALYSIS - The analysis of the electromagnetic radiation from an electronic device to determine the relative power in each sideband, harmonic, and spurious emission compared to the carrier frequency. This particular distribution (or spectrum) is peculiar to the device and can identify this type of device, thereby acting as an identifying "signature."

SPECTRUM WIDTH (TRANSMITTER) - The difference between the frequency limits of the band which contains all the spectrum frequency components of significant magnitude.

SPOILER ANTENNA - An antenna used to change (spoil) the antenna pattern of a second antenna so as to reduce the nulls in the pattern of the second antenna. See also Null Fill.

SPOKING (RADAR) - Periodic flashes of the rotating radial display. Sometimes caused by mutual interference.

"SPOOFING" - A type of deception by using an electronic device to transmit a "target" echo. The spoofing transmitter must operate at the same frequency and PRF as the radar to be deceived. The radar main pulse triggers the spoofing transmitter which, after a delay, transmits a false echo.

SPOT JAMMING - Narrow frequency band jamming concentrated against a specific radar at a particular frequency. The jamming bandwidth is comparable to the radar bandpass. Can deny range and angle information.

SPURIOUS EMISSION - Electromagnetic radiation transmitted on a frequency outside the bandwidth required for satisfactory transmission of the required waveform. Spurious emissions include harmonics, parasitic emissions, and intermodulation products, but exclude necessary modulation sidebands of the fundamental carrier frequency.

SQUINT ANGLE - The angular difference between the axis of the antenna mainlobe and the geometric axis of the antenna reflector, such as the constant angle maintained during conical scan as the mainlobe rotates around the geometric axis of the reflector.

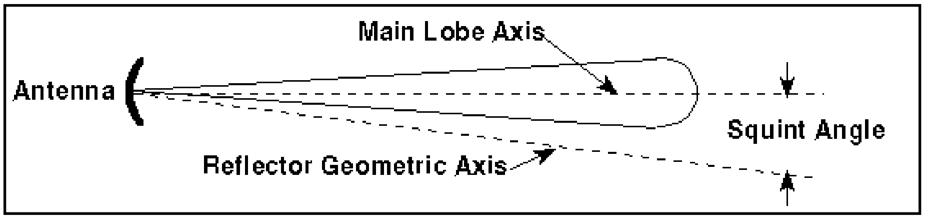

STAGGERED PRF - Staggered PRF allows an increase in MTI blind speeds such that no zeros exist in the velocity response at lower velocities. In a two-period mode, the usual "blind speed" or occurrence of a zero in the velocity response is multiplied by a factor which is a function of the ratio of the two repetition periods.

STAMO (STABLE MASTER OSCILLATOR) - A very stable (drift free) oscillatory used to provide a precise frequency for transmission and for comparison with the reflected radar signal returned to the receiver, such as in a Doppler radar where a precise difference between transmitted and received signals must be measured to determine accurately the Doppler frequency.

STAND-FORWARD JAMMING - A method which places the jamming vehicle between the enemy sensors and attack aircraft.

STAND-IN JAMMING (SIJ) - Similar to stand-forward jamming but usually using an UAV with a lower powered jammer instead of a jammer aircraft.

STAND-OFF JAMMING (SOJ) - An ECM support aircraft orbits in the vicinity of the intended target. As the fighter-bomber pilot starts his strike penetration, the ECM aircraft directs jamming against all significant radars in the area. This technique provides broad frequency band ECM without affecting performance of the strike aircraft.

STARBOARD - The right side of a ship or airplane when facing the bow (forward).

STC (SENSITIVITY TIME CONTROL) - Gain control that reduces the radar receiver gain for nearby targets as compared to more distant targets. STC prevents receiver saturation from close-in targets.

STEP RECOVERY DIODE - A charge-controlled switch which ceases current conduction so rapidly that it can be used to produce an impulse. Cyclic operation of the diode can produce a train of impulses which when used with a resonant circuit can produce a single frequency output at any harmonic of the pulse frequency.

STERADIAN - Unit of solid angle. An entire sphere has 4π steradians.

STREAM CHAFF - Operational technique of dropping large quantities of chaff for a continuous period of time. This results in a “ribbon” or “stream” of returns many miles in lengths on radarscopes. The penetrating strike force can then use the resulting chaff corridor to mask their penetration.

SUBHARMONIC - A frequency which is an integral submultiple of another frequency. For example, a sine wave whose frequency is one-third of the frequency of another sine wave is called the third subharmonic. (3 MHz is the third subharmonic of 9 MHz).

SUPERHETERODYNE RECEIVER - A receiver that mixes the incoming signal with a locally generated signal (local oscillator) to produce a fixed, low intermediate frequency (IF) signal for amplification in the IF amplifiers.

SUPPRESSION - Elimination or reduction of any component of an emission, such as suppression of a harmonic of a transmitter frequency by band rejection filter.

SUPPRESSION OF ENEMY AIR DEFENSES (SEAD) - Activity which neutralizes, destroys, or temporarily degrades enemy air defense systems by using physical attack or electronic means (SEAD pronounced “seed” or “C add”).

SUSCEPTIBILITY - The degree to which an equipment or a system is sensitive to externally generated interference.

SWEPT JAMMING - Narrowband jamming which is swept through the desired frequency band in order to maximize power output. This technique is similar to sweeping spot noise to create barrage jamming, but at a higher power.

SWITCHES - See also Diode Switch, Silicon Controlled Switch, Schottky Diode Switch.

SYNCHRODYNE - A klystron mixer amplifier stage in a transmitter, where two signal frequencies are applied as inputs and a single amplified signal is taken out.

TARGET SIZE - A measure of the ability of a radar target to reflect energy to the radar receiving antenna. The parameter used to describe this ability is the “radar cross section” of the target. The size (or radar cross section) of a target, such as an aircraft, will vary considerably as the target maneuvers and presents different views to the radar. A side view will normally result in a much larger radar cross section than a head-on view. See also Radar Cross Section.

TERMINAL IMPEDANCE - The equivalent impedance as seen by the transmitter/receiver.

TERRAIN BOUNCE - Term for jamming that is directed at the earth’s surface where it is reflected toward the threat radar. Reflected jamming creates a virtual image of the jamming source on the earth as a target for HOJ missiles.

THERMISTOR - A resistor whose resistance varies with temperature in a defined manner. The word is formed from the two words “thermal” and “resistor,”

THRESHOLD ISR - The interference to signal ratio (ISR) at which the performance of a receiver starts undergoing degradation. It must be determined by tests.

TRACKING RADAR - A radar whose prime function is to track a radar target and determine the target coordinates (in range and angular position) so that a missile may be guided to the target, or a gun aimed at the target.

TRACKING RADAR RECEIVER - These are of two primary types: conical scan and monopulse. (1) The conical scan system directs the radar signal in a circle around the target. The radar paints this circle 15 to 40 times per second. As the target moves out of the center of this circle, the radar develops aim error voltages and re-aims the antenna. (2) The monopulse system directs four beams at the target simultaneously. The target is in the middle of the four beams. If the target is not in the center, the radar return develops an aim error voltage to re-aim the antenna.

TRACK WHILE SCAN (TWS) RADAR - Although it is not really a tracking radar in the true sense of the word, it does provide complete and accurate position information for missile guidance. In one implementation it would utilize two separate beams produced by two separate antennas on two different frequencies. The system utilizes electronic computer techniques whereby raw datum is used to track an assigned target, compute target velocity, and predict its future position, while maintaining normal sector scan. Most aircraft use only a single antenna.

TRADE-OFF TABLES - A set of tables showing the various combinations of two or more variables that are related in that making one variable better will make the other variable worse. The trade-off helps find the best solution considering all combinations. (For example, how a no-interference condition can be maintained if two emitter platforms are brought close together, if at the same time the frequency separation between their radar transmitters is increased.)

TRANSIENT - A phenomenon (such as a surge of voltage or current) caused in a system by a sudden change in conditions, and which may persist for a relatively short time after the change (sometimes called ringing).

TRANSPONDER - A transmitter-receiver capable of accepting the electronic challenge of an interrogator and automatically transmitting an appropriate reply. There are four modes of operation currently in use for military aircraft. Mode 1 is a nonsecure low cost method used by ships to track aircraft and other ships. Mode 2 is used by aircraft to make carrier controlled approaches to ships during inclement weather. Mode 3 is the standard system used by commercial aircraft to relay their position to ground controllers throughout the world. Mode 4 is IFF. See also IFF.

TRAVELING-WAVE TUBE AMPLIFIER - The TWT is a microwave amplifier capable of operation over very wide bandwidths. In operation, an electron beam interacts with a microwave signal which is traveling on a slow wave helical structure. The near synchronism of the beam and RF wave velocities results in amplification. Bandwidths of 3:1 are possible. Operation at high powers or at millimeter wavelengths is possible at reduced bandwidths.

TRIGGER KILL (RADAR) - A method employed to momentarily disable certain radar system circuits to reduce or eliminate RF emissions which may cause an EMI/EMC or RADHAZ situation such as on the deck of a ship.

TUNNEL DIODE - The tunnel diode is a heavily doped P-N junction diode that displays a negative resistance over a portion of its voltage-current characteristic curve. In the tunneling process, electrons from the p-side valence bands are able to cross the energy barrier into empty states in the N-side conduction band when a small reverse bias is applied. This diode is used as a microwave amplifier or oscillator.

UPLINK - The missile guidance signal which passes midcourse correction command guidance intelligence from the guidance radar site to the missile.

VARACTOR DIODE - A P-N junction employing an external bias to create a depletion layer containing very few charge carriers. The diode effectively acts as a variable capacitor.

VARACTOR TUNED OSCILLATOR - A varactor diode serves as a voltage-controlled capacitor in a tuned circuit to control the frequency of a negative resistance oscillator. The major feature of this oscillator is its extremely fast tuning speed. A limiting factor is the ability of the external voltage driver circuit to change the voltage across the varactor diode, which is primarily controlled by the driver impedance and the bypass capacitors in the tuning circuit.

VELOCITY GATE PULL-OFF (VGPO) - Method of capturing the velocity gate of a Doppler radar and moving it away from the skin echo. Similar to the RGPO, but used against CW or Doppler velocity tracking radar systems. The CW or pulse doppler frequency, which is amplified and retransmitted, is shifted in frequency (velocity) to provide an apparent rate change or Doppler shift.

VELOCITY MODULATION - Velocity modulation is modification of the velocity of an electron beam by alternately accelerating and decelerating the electrons at a frequency equal to the input frequency. Thus, the electrons are segregated in bunches, each bunch causing a cycle or current as it passes an output electrode. The velocity of the electrons is thus a function of the modulation voltage. See also Klystron, Multicavity and Klystron, Reflex.

VICTIM - A receiver (radar or missile) that suffers degradation due to ECM or EMI effects.

VIDEO - Receiver RF signals that have been converted (post detection) into a pulse envelope that can be seen when applied to some type of radar visual display; also used to describe the actual display itself (such as the video on an A-scope).

WARM - Acronym for Wartime Reserve Mode. Any mode of operation of a radar or ECM that is held in reserve, and never used, except in actual combat.

WATER LINE - A reference line used for vertical measurements. When used with an aircraft it is usually the ground with the landing gear extended normally. One of several aircraft location designations, also see butt line and fuselage station.

WAVEGUIDE - A transmission line consisting of a hollow conducting tube of arbitrary geometry (usually rectangular, but may be circular) within which electromagnetic waves may propagate.

WAVELENGTH (λ) - The distance traveled by a wave in one period (the period is the time required to complete one cycle). $\lambda = c/f$. In the atmosphere, electromagnetic waves travel at c, the speed of light (300 million meters per second or 30 cm/nsec). At 5 GHz, one wavelength = 6 cm. At 10 GHz, one wavelength = 3 cm.

WAVEMETER - An instrument for measuring the frequency of a radio wave. The wavemeter is a mechanically tunable resonant circuit. It must be part of a reflection of transmission measurement system to measure the maximum response of a signal. Below 20 GHz, the wavemeter has been replaced by the frequency counter with much greater accuracy and ease of use.

WEAVE - An aircraft maneuver that smoothly changes the instantaneous flight path but maintains the overall route of flight. Not as violent as a jink.

WET RUN - A test run with ship / aircraft armament and/or EW switches on.

WILD WEASEL - USAF aircraft (F-4Gs during Desert Storm) used for suppression of enemy air defense (SEAD) mission.

WINDOW - WWII name for chaff

YIG TUNED OSCILLATOR - A YIG (yttrium iron garnet) sphere, when installed in the proper magnetic environment with suitable coupling will behave like a tunable microwave cavity with Q on the order of 1,000 to 8,000. Since spectral purity is related to Q, the device has excellent AM and FM noise characteristics.

ZENER DIODE - A diode that exhibits in the avalanche-breakdown region a large change in reverse current over a very narrow range in reverse voltage. This characteristic permits a highly stable reference voltage to be maintained across the diode despite a wide range of current.

Donald Marshall On Megadeth's "The World Needs A Hero" Album Cover

Empowerment by Virtue of Golden Truth
Human Cloning: Specifically,
REM Driven Human Cloning
FULL DISCLOSURE

Donald Marshall

29 October 2015

https://www.facebook.com/donald.marshall.148
http://donaldmarshall.proboards.com/
Vincent Eastwood Interview
https://www.youtube.com/watch?v=M_1UiFeV5Jg&ab

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Introduction

Just read it. Every word in this document is true, and it is the most important document to ever reach the internet. This document is written to empower good people of the world against the tyranny which exists all around us in our world today. Effectively, the document presented here discloses concealed information about the extent to which medicine, science, and technology has advanced in our **current** era. Moreover, I am disclosing this information because I have been extensively abused, and I am victim of **current** advances in medicine, science, and technology, which I describe in detail below. There are many, many, other victims of abuse, including myself, and therefore it is our plea that you read this document with an open mind and you investigate **ALL** statements which may initially irk you and appear ‘suspect’ to begin with (the circumstantial evidence is available all around you); because as a victim of abuse, I can honestly say, there is nothing worse than experiencing abuse, and those who have the power to protect you from your abusers, ignore you.

I will now discuss what qualifies as whistle blowing disclosure. After detailing the criteria which qualifies for whistle blowing disclosure, I will detail aspects of the Serious Crime Act, and preface a foundation which defines, explains, and references key information for the reader to understand as well as explore the extent to which medicine, science, and technology has advanced today; all for the express purpose of compelling the reader that medicine, science, and technology, has advanced at an incredible rate; that **current** advances in medicine, science and technology are withheld from public knowledge; and finally these advancements in medicine, science, and technology, have been and are **currently** used to commit **serious unspeakable** crimes against humanity and our environment here on earth. Moreover, it is my aim to present this information as coherently as possible to assist the reader to save me, and save many, many others who experience abuse daily resulting from concealed advances in technology.

Whistle Blowing: Qualifying Disclosure

In the United Kingdom under the Public Interest Disclosure Act (1998) (PIDA) section 43B, a “qualifying disclosure” (whistle blowing disclosure) implies “any disclosure of information which in the reasonable belief of the worker, tends to show one of the following:

a) That a criminal offence has been committed, is being committed or is likely to be committed,
b) That a person has failed, is failing or is likely to fail to comply with any legal obligation to which he is subject
c) That a miscarriage of justice has occurred, is occurring or is likely to occur,
d) That the health or safety of any individual has been, is being or is likely to be endangered,
e) That the environment has been, is being, or is likely to be damaged, or
f) That information tending to show any matter falling within any one of the preceding paragraphs has been, or is likely to be deliberately concealed”

Furthermore, under the Enterprise and Regulatory Reform Act (ERRA) 2013 section 17 (*The new 'public interest' test)* is added for whistle blowing disclosures, amending section 43B of the Employment Rights Act (ERA) 1996 and therefore now reads as such (new words underlined):

"(1) In this part a 'qualifying disclosure' means any disclosure of information which, in the reasonable belief of the worker making the disclosure, *is made in the public interest and* tends to show one or more of the following-- [criminal offence, breach of legal obligation, etc]." (Halliday 2013, p. 2).

The following information is presented **with the express intent** that it is made in the public interest, and meets the all criteria set out in section 43B (a-f) of PIDA as well as the 'public interest test', ERRA section 17. Furthermore, in order for the reader to perceive the credence of my statements, so that (s)he has impetus to research the validity of my statements and not dismiss it as folly supplied by an internet troll who has nothing better to do than waste peoples' time, I will cite the Serious Crime Act 2015 here for the express purpose of convincing the reader that all statements made in this document and my original document are indeed FACTUAL! THIS IS NO HOAX. THIS IS NO JOKE. This is simply what is happening in the world today.

The Serious Crime Act 2015

The Serious Crime Act 2015 (UK) section 41, 3ZA, amends section 3A of the Computer Misuse Act 1990 which **previously** read [under Computer Misuse Offences]:

[[F1] 3A Making, supplying or obtaining articles for use in offence under section 1 or 3

1) [That] A person is guilty of an offence if he makes, adapts, supplies or offers to supply any article intending it to be used to commit, or to assist in the commission of, an offence under section 1 or 3.

To: [The Serious Crime Act 2015, section 41, 3ZA]

3ZA Unauthorised acts causing, or creating risk of, serious damage

(1) A person is guilty of an offence if—

(a) the person does any unauthorised act in relation to a computer;

(2) Damage is of a "material kind" for the purposes of this section if it is—

(a) damage to human welfare in any place;

(b) damage to the environment of any place;

(c) damage to the economy of any country; or

(d) damage to the national security of any country.

3) For the purposes of subsection (2)(a) an act causes damage to human welfare only if it causes—

(a) loss to human life;

(b) human illness or injury;

(4) It is immaterial for the purposes of subsection (2) whether or not an act causing damage—

(a) does so directly;

(b) is the only or main cause of the damage.

(5) In this section—

(c) a reference to a country includes a reference to a territory, and to any place in, or part or region of, a country or territory.

(6) A person guilty of an offence under this section is (unless subsection (7) applies) liable, on conviction on indictment, to imprisonment for a term not exceeding 14 years, or to a fine, or to both.

(7) Where an offence under this section is committed as a result of an act causing or creating a significant risk of—

(a) serious damage to human welfare of the kind mentioned in subsection (3)(a) or (3)(b), or

(b) serious damage to national security,

a person guilty of the offence is liable, on conviction on indictment, to imprisonment for life, or to a fine, or to both."

In laymen's terms it is a **serious crime** (Serious Crime Act 2015), punishable by imprisonment, a fine, or both, to cite hatred or spread hoaxes by use of a computer which would cause mass hysteria or public dissension. I have been condemning public figures, high profile individuals, celebrities, singers, movie stars, directors, politicians, world leaders, royalty, anti-secret society 'truthers' (who are really misinformation agents, and agents of deception) etc. –the list is long - since 2011 and **NOT** a single one of these high profile people has issued a public statement saying "I do not like how you have tarnished my name" or filed a law suit against me. Why you may ask? **Because** every word I have stated and will state again (in this document) is true.

Fundamentals

Before I describe the heinous crimes committed against me and many others (including unsuspecting civilians of the world) it is important that I explain, define, and reference:

- Key figures such as Phil Schneider, George Green and Aaron Russo, so that the reader has reference points to verify the extent to which technology has advanced in our **present** era (and continues to advance);
- Define and briefly explain the transhumanist / post human agenda (for those who may be unfamiliar with their aims).
- Define and explain rapid eye movement (R.E.M) sleep, the phases of sleep, and what happens to the (original's) body during sleep.

- Reference advances in technology, with particular attention to: Memory suppression technologies; Mind-voice technology; H.A.A.R.P technology, RFID microchip technology, and MK Ultra technology (CIA's mind control program);
- Define and explain cloning; the different types of clones; cloning centres and cloning technology;
- Define drip feed disclosure / evaluative conditioning and explain why it occurs;
- Explain what 'consciousness transfer' is to the best of my knowledge, and cite drip feed disclosure articles with the express intent to allow the reader to grasp the abuse I have suffered daily at the hands of my tormentors.

Key Figures

Phil Schneider

Phil Schneider (pictured) had 17 years experience working in government black projects carrying a level three security clearance. He was a geologist and engineer who worked in the black projects underground bases at Area 51, S-4, and Los Alamos.

He is most notable for disclosing (Schneider 1995; 1996; Open Minds 2011):

- The 'black budget' expenditure of the United States, which Schneider claims to be between 1.023 trillion U.S. dollars every 2 years (over $500 billion per year);
- Deep Underground Military Bases (also known as D.U.M.Bs -"dumbs"), and at the time of his lecture (Schneider, 1995), –that there are 131 **active** Deep Underground Military Bases present in the United States, and 1477 Deep Underground Military Bases worldwide;
- Each D.U.M.B costs on average 17-19 billion U.S. dollars; paid for by the taxpayer; and it takes approximately a year-and-a-half to 2 years to build D.U.M.Bs with sophisticated methods.
- That military technology outstrips the general public's technology at a rate of 44 to 45 years of technology for every calendar year which passes. In other words for every 12 months which passes military technology will have advanced by 44 years than what we as the general public is currently accustomed to. Therefore as a rough example if we were to take the year Facebook was founded (2004) as a base year, then the military technology since the creation of Facebook will have outstripped what the

general public is accustomed to by as much as **484 years(!)** (2015 - 2004 = 11. 11 x 44 = 484). Similarly, if we are to use the year which YouTube was founded as a base year (2005), once again, military technology would be 440 years more advanced than what the public is currently accustomed to today.

For the purpose of disclosing current advances in medicine, science and technology, and how such advances are used against me and the people of the world to commit monstrous crimes I will use 1945 as a base year. Everything will become apparent including why I use 1945 as a base year for my disclosure, but for the express purpose of compelling the reader to investigate my disclosure I must present everything, logically, sequentially, methodologically, and provide references for the reader in a coherent way to enable him or her to **pay serious attention** to my eye witness accounts. Therefore, at this present stage keep in mind the year 1945, and the fact that military technology outstrips the general public's technology at a rate of 44 years for every 12 months which passes.

George Green

George Green (pictured) was affiliated with U.S. Presidential candidates, and was once asked to be the Finance Chairman for the next President of the United States. Green would later declined the offer of Finance Chairman when a comment made by Ted Kennedy regarding sleeping with Green's 14 year old daughter caused George Green to re-evaluate his associations with this in-group.

During his 2008 interview with Project Camelot (2008a; 2008b), Green disclosed the following noteworthy information:

- U.S. presidents are "selected" and not elected. This is clearly expressed in a story Green recounts, when Green asks:
  "Who is going to be the next President of the United States [for him to overlook their finances]?"
  And the reply was: "Jimmy Carter"
  Green responds: "Jimmy who?"
  The reply Green received was: "Well, he's the Democratic Governor of Georgia."
  George Green: "But I've been voting Republican."
  Green was then confronted by a tall man, Paul Volcker (American Economist, and Chairman of Federal Reserve under Jimmy Carter and Ronald Regan), who walked over and said, "Son, don't worry about it [Republican or Democrat], we control 'em both."
- U.S. scientists learned how to make people (clones) since 1938 -walking talking ones –and the scientists call these people "synthetics" or "the others".
- Cloning technology is relatively advanced. All that has to be done is take two cells from the original, give the cells a small electrical charge (retain a fertilised egg), then all one needs is a receiver (a womb / artificial womb for the fertilised egg to grow).
- Scientist were excited by the synthetic technology because it meant that spare organ parts could be grown for an "original" human without rejection, because theoretically speaking, the DNA of the synthetic is the same as the original.
- Green gives an example of a cloned Politician: George Walker Bush. Green advices the viewer to seek old video recordings of George W. Bush, and compare the old George W. Bush, with the George W. Bush during Bush's second term,

-in terms of mannerism, speech pattern, body language etc. (old videos of George Walker Bush (Boringest 2006; Fox 4 News - Dallas-Fort Worth 2014) are presented in the References section).

- Scientist have also learned how to make these synthetic people within a few months, to the point where the synthetic can be a walking, talking duplicate of the original, intact with all the memories and experiences of the original. The only problem is that the memory, experiences, and functioning capabilities of these synthetics are like: "A DVD recorder. Sometimes you have glitches, and you have to take the synthetics to Camp David occasionally [every 6 months to a year] to get them tuned up."
- Remember these synthetics are people too, they can think and act just like you can, but they do not have a soul.
- Most of the world leaders have been bought and paid for [by men in the background] and are created to think a certain way –to meet the agendas of these men who remain in the background.
- The global elite plans on depopulating the current human population of **over 7 billion** to **500 million** people. This is corroborated by the "Georgia Guidestones" (WorldTruth 2014).
- Vladimir Putin is executing plans to bring the United States down and into a massive depression. Furthermore, China agrees with Vladimir Putin's plans; stating that the Chinese government has not been a Superpower for over 5000 years and "It is their turn to run the world."
- China has the capacity to set back / shut down all of U.S. computing and electrical systems within two days.

At this present stage, the most **salient** points to keep in mind from Green's accounts are that: U.S. presidents are selected and not elected; and **most importantly**, that scientists have been capable of creating synthetics (cloning people) since 1938. If you have kept in mind Schneider's statement (1995; 1996), (that for every 12 months which passes military technology increases by the equivalent of 44 years compared to what the general public is accustomed to) –then learning that scientists have been capable of cloning humans since 1938 should not come as much surprise. Again, everything regarding my disclosure will become apparent, and I thank these men for disclosing their information, because it helps the reader to corroborate my disclosure.

Aaron Russo

Aaron Russo (pictured) was an American businessman, director, and political activist. He is best known for directing blockbuster films such as *Trading Places*, *The Rose* and *Wise Guys*. Russo believed that a human being "Should stand for something, and do the right thing when the time calls to act". Consequently, during the latter part of his career he did his best to warn the American public by producing documentaries such as *Mad as Hell* (1996), *Freedom to Fascism* (Russo 2006), and *Reflections and Warnings* (Jones 2008).

Russo disclosed the following key information in *Freedom to Fascism* (Russo 2006):

Income Tax

- There is no law requiring Americans to pay income tax. **Although this is a truth, I DO NOT advocate Americans NOT to pay income tax (and neither did Russo).** This is simply because the Federal Reserve can imprison you and seize your possessions for not paying income tax (although there is no law requiring Americans to do so). So for the sake of avoiding hassle for the mean time –pay your income taxes.
- To further illustrate the above point, Bob Shultz speaking at "We the People Foundation" said the following: "Most people believe that the income tax system is legal and that the revenue from the tax is used in the public interest. However, there is a substantial conclusive body of evidence that proves that our income tax system represents the most pernicious form of tyranny. It is the greatest hoax ever perpetrated by government against the working men and women of America."
- Charlie Beall: "The federal government itself refuses to provide, the American people, who are coercively being subjected to this extraction of their private property, without any underlying legal justification. There is no law. There is no law that requires the average American worker in the private sector to pay a direct un-apportioned tax on their labour and compensation for services. There is no law."

- State Representative – Phil Hart –(R-Idaho): "You can look through the statutes, and look for the law that requires you to pay, and when you do that, you **cannot** identify a law that requires the average person in America who earns a wage and works in private business to pay an income tax."
- Peter Gibbons (Tax Attorney) –It's actually very simple. Congress tried to enact an income tax in 1894 –The Supreme Court said that is unconstitutional. When The Supreme Court says something is unconstitutional, it's unconstitutional. They (Congress) tried again in 1913 –and The Supreme Court said –the 16th amendment- "No new power of taxation" –so if they (Congress) didn't have it then (1913) and they didn't get it; they **DON'T** have it. There is no constitutional base for a tax on the wages for Americans living and working in the 50 States of the union. Period. End of argument.

Radio Frequency Identification (RFID) Microchips

- The latest technology for identifying people at the point of self, when they make purchases –is actually the implantable (RFID) microchip. There are microchips that can actually be imbedded directly into human flesh... It's a tiny glass capsule about the size of a grain of rice... it contains an RFID computer microchip with a coiled antenna and it can transmit information also at a distance.
- Katherine Albrecht –Author of "*Spychips*" (2005) makes the following comment: "RFID is a technology that uses tiny computer technology the size of a grain of sand or smaller; hooked up to miniature antennas to transmit information about items at a distance. Back in 1999, Procter and Gamble, Gillette, and MIT got together to find a way to commercialise this technology and make it small enough, make it efficient enough and make it low cost enough to essentially ---their dream is to put these tiny computer chips on every physical item manufactured on planet earth."
- Radio waves can travel through walls, they can travel through wood, and they can travel through things we normally rely on to protect our privacy, for example your purse, your bag-pack, your pocket, –anything you are wearing or carrying.
- One of the most worrisome applications of RFID microchips, are proposals to put them into cash, meaning that it would be able to track every bank note where it had been, who it had been issued to, and create in essence an audit trail. That would essentially take away the anonymity of cash we now enjoy today.
- Once everything you do is tied down to a single number and there is no longer the ability to pay with cash, then all it takes to render you a non citizen is to simply turn that microchip off. **You will no longer be able to participate in any function in society including buying food. Once money becomes digitised through RFID technology, the elite can deduct whatever amount of money they want out of your microchip, whenever they want. They can trace you whenever they want. You will be at their mercy.**

Habeas Corpus

- Habeas Corpus is "[A] writ [formal document] requiring a person under arrest to be brought before a judge or into court, especially to secure the person's release unless lawful grounds are shown for their detention" (Legal-dictionary 2015).
- During the Bush Presidency [2001-2009 (History 2015)], President Bush signed executive orders giving him sole authority to impose martial law, and suspend Habeas Corpus. This gives him doctorial power over the people without any 'checks and balances.'

  In other words, "The government can jail you for life without charges, without a trial, without a lawyer" (Russo 2006).
- Furthermore: "The National Defense Authorization Act [4] signed by President Obama on the 31st December 2011 authorises the indefinite detention, without trial or indictment, of any US citizens designated as enemies by the executive." See Paye (2013) for further discussion regarding the suspension of Habeas Corpus.

Fraudulent Manipulation of Election Results

- In 2004 at the "Forum of Presidential Election" Clinton Eugene Curtis, a former Computer Programmer for NASA and ExxonMobil testified under oath that election results can be rigged using electronic programs.
- In 2004 he gave the following abridged testimony (Russo 2006):

  Judge: Mr Curtis, are there programs which can be used to secretly fix elections?

  Curtis: Yes.

  Judge: How do you know that to be the case?

  Curtis: Because in October of 2000 I wrote a prototype for present congressman Tom Feeney, and the company I worked for in Oviedo Florida –it did just that.

  Judge: And when you said, "it did just that" –it would rig an election?

  Curtis: It would flip the vote 51:49 –whoever you wanted it to go to, and whichever race you wanted to win.

  Judge: And would that program that you designed be something that election officials that might be on county boards would actually, could detect?

  Curtis: They'd never see it.

  Judge: So how would such a program, a secret program that, fixes the election –how could it be detected?

  Curtis: You would have to view it either with source code, or you would have to have a receipt and then count the hard paper against the actual vote total –other than that you won't see it.
- **Judge:** Given the availability of such vote rigging software and the testimony that has been given under oath of substantial statistical anomalies and gross differences – between exit polling data and the actual tabulated results, do you have an opinion whether or not Ohio elections, the Ohio Presidential elections was hacked?

  Curtis: Yes. I would say it was.

Person in the audience: ---So in other words there is absolutely no assurance whatsoever in anything in regard to these machines?
Curtis: Absolutely none.

- See Truthstream (2006) for further details regarding the full account of Curtis' testimony on how elections can be manipulated.
- Moreover, voting machine manufactures refuse to allow anyone to see the source code. Without paper ballots, the honesty of any election cannot be verified.

The War on Terrorism is the War on Your Freedom

- It is time to wake up America. These ID cards are not about defeating terrorism, but they are **ALL** about controlling the American people.
- The (mainstream) media controls the information that a person gets in various ways. They can make sure that the average American watching T.V. or reading the newspaper is going to come out with a certain mindset. She is going to say this is good, that's bad –and that is all they (media/elites) have to do.

Whoever Makes the Money Makes the Rules

- As Mayer Rothschild said "Give me control of a nation's money supply, and I care not who makes its laws". Mayer Rothschild, private banker, –knew that he and the other bankers would now control the laws of the nation. Government gave these bankers one of its most important powers, and now had to borrow money from the bankers and pay interest to finance the government.
- America has gone from people owning their own property, owning their own businesses –to a nation in debt because all the money is created by borrowing (from private banks) and this country has become one where people just live by borrowing.

Russo's Message to Mankind

- If you are in the military or law enforcement, remember you swore an oath [to uphold the law of the land]. You did not swear an oath to promote world government, or corporations.
- Now that you do understand what happened [to America, and the monetary system based on debt slavery] and how it is leading to a tyrannical one world government – the future of mankind depends on you –will you choose freedom or slavery?
- Stop being passive liberals. Stop being passive conservatives. Stop being passive centralists. Stop being passive human beings! When the media starts telling you that the country will fall apart if this is done... Do not be fooled!!
- Remember these are sick, malevolent and twisted people we are dealing with, trying to save themselves. Squash their agendas and stay on course.
- "I believe the time for mankind is time to give all or perish. Grow up or die. Grow up and become adults. Act like adults. Take some responsibility. The world which you have perceived is childlike; –and now the curtain has been pulled back for all to see."

- Unless people get active [get fully informed, and learn how governments of the world are conspiring against their people] and say –I am going to help shut down the Federal Reserve System; I am going to shut down the powers that be –the whole human race is doomed otherwise.
- We are coming near the end game and things are starting to accelerate... –and people are looking at the world leaders to declare martial law [which in turn will rid Habeas corpus].

Let's Consolidate our Problems

- If we can all get focused on how to win the game instead of all these different objectives –such as people are fighting for a better environment; people are fighting to keep their guns/gun control; there are all these different issues which are going on around the world -and which are all important on their own –but if we can consolidate on that and focus –and take all those people –and say –hey let's shut down the Federal Reserve, then we'll deal with those issues. Let's go to the agenda, the objective, the root cause of man's problems, first, then we'll go back to the other stuff.
- That is the priority right now. You have to cut off the head of the beast. And the head of the beast is the Federal Reserve System and the people behind it. You see, and that is what will save the world, and if people understand that –and they **stop** being passive liberals, and **stop** being passive republicans, but rather become **active** human beings –that is what will save the world!

Aaron Russo: Reflections and Warnings

In this documentary Russo recalls his relationship with Nick Rockefeller. Russo shares critical information Rockefeller discussed with him.

The Falsehood of September 11th 2001

- Russo met Nick Rockefeller through a female attorney who telephoned Russo and said "One of the Rockefellers would like to meet you." Russo made a documentary called *Mad as Hell* (1996), and Rockefeller had watched the video and knew Russo was running for Governor of Nevada and wanted to meet him. Russo said "Sure I'd like to meet him", and the two met and talked. Rockefeller proved to be a very smart man and shared ideas with Russo and was the person to tell Russo 11 months before 9/11 happened "There was going to be an event..."
- Rockefeller never told Russo what the event was going to be; but, there was going to be an event –and out of that event, we [America] were going to invade Afghanistan, to run pipelines from the Caspian Sea; we were going to invade Iraq, to take over the oil fields and establish a base in the Middle East, and make it all part of the New World Order; and we would go after (Hugo) Chavez and Venezuela –and sure enough, later when 9/11 happened –and I remember he was telling me how you are going to see soldiers looking in caves for people in Afghanistan and Pakistan and all these places and there is going to be this war on terror which has no real enemy and

the whole thing is a giant HOAX, but it is a way for the government to take over the American people (and the world).

- There is no question about it [that 9/11 is a hoax]. Nick Rockefeller said to Russo: "There is going to be a "War on Terror"" and he was laughing. Who are we fighting against...? Why do you think 9/11 happened and then nothing has happened since then? Do you think that our security is so great here that these people who pulled off 9/11, who were able to lock down another plane...? Come on it is ridiculous... 9/11 was done by people in our own government and our own banking system to perpetuate the fear of the American people into subordinating themselves to anything the government wants them to do. That is what it is about and to create this endless war on terror.
- Nick Rockefeller was laughing when he said, "We are going to be sending men into caves in Afghanistan and Pakistan" –and it was just cynical, he kept laughing and saying "Look how stupid everyone is! We can do whatever we want!"
- 9/11 was the first lie; and the next lie was to go into Iraq, to get Saddam Hussein out with his weapons of mass destruction (when the real issue was control of the oil fields) –that was the next lie. 9/11 created an endless war on terror that would go on and on and you can never define a real winner. There is no one to defeat and so it goes on and on forever. And they can do whatever they want; because they scared the hell out of the American public.
- This whole war on terror is [perpetuated on] a fraud. It is a farce. It is very difficult to say it out loud because people are intimidated in saying it. Because if you say it they want to make you into a nutcase –but the truth has to be... and the truth has to come out. The fact of the matter happens to be the whole war on terror is a fraud, it is a farce. Yes. There is a war going on in Iraq, because we invaded Iraq, and people over there are fighting... but the 'war on terror' –it is a JOKE –you know, and until we discover what really happened in 9/11 and who was responsible for 9/11 –because that is where the war on terror emanates from. That is where it comes from. It was 9/11 which allowed this war on terror to begin and until we get to the bottom root of 9/11 –the truth of 9/11 we'll never know about the war on terror.
- Russo was in Tahiti when 9/11 happened and he got a call from his son – and his son said –"The twin towers, they were just attacked and they are falling down or something..." Russo was in Tahiti and had just woken up from sleep. Russo didn't realise what it was immediately (11 months after Rockefeller had told him about 9/11 and it had happened –because Rockefeller said there was going to be an event –he wasn't specific) –but after Russo saw that America was going to go to Iraq and Afghanistan, that is when he realised, and equated it to what Rockefeller had said.
- 9/11 was only a manifestation to create a fear in the American public. So that we would obey and do what they want us to do. Take for example, Richard Reed 'The shoe bomber' –now here is a guy who is 6 feet 6, ugly as can be; I heard he smelled... He sits on a plane, lights a match in a non-smoking area, to put his shoe on fire... surrounded by people... That is idiotic! If you were going to blow up a plane... you would go into the bathroom... you close the door... and you put your shoe on fire...

you are not going to sit there.... surrounded by people, lighting matches in a no smoking flight... they (elite) want you to believe this nonsense. That is ridiculous!

- The war on terrorism is to keep people in fear. It is an endless war without a real enemy ('terrorists') –so that people would submit and do whatever the government wants them to. Submit to searches, give you ID cards, put Radio Frequency Identification (RFID) chips in you etc. You become servants to the elite –that is what this is all about...
- Freedom of liberty is what people really want, and it is time to stop the duplicity of the government from lying to us. You see many people know the truth of what is happening in this country; like 9/11 but they are afraid to stand up. People have to stand up and find their courage and say "I'm not going to take this anymore, I know the truth" –and they create a situation where if you tell the truth, you are considered a lunatic.
- In other words if someone goes on a T.V. show and says that 9/11 was an inside job – immediately the person is labelled an idiot or crazy. They call you names. **You cannot be afraid of that.**
- If you do not fight the corruption and you do not stand up for what is right in life, you end up being a serf and a slave and you are leaving your children a world in which you would not want to live in yourself, so how can you in decency behave that way? You have to stand up for what is right in life, and unless you do that you are nothing.

The New World Order Agenda

- The whole agenda is to create a one world government where everyone has an RFID chip implanted in them. All the money is to be in those chips [a cashless world]. This information came straight from Nick Rockefeller himself. That is what the ultimate plans of the global elite, banking industry and Rockefeller wants to accomplish.
- The agenda is to implant everyone with RFID microchips. All money is transferred to those microchips. There is no more cash. Money would be in microchips. Instead of having cash, you would have money in your microchips, but whenever they want, they (elite) could take whatever amount out of your microchip whenever they want to. Total control. If you are a protestor they just turn off your chip; you cannot buy food; you cannot do anything; it is total control of the people.
- So they want a one world government controlled by them. Everyone being chipped, all the money in those chips, and they control the chips and they control people, and you become a slave. You become a serf to these people –that is their goal. That is their goal; that is their intentions.
- Russo did not believe in enslaving people and Rockefeller would question him in the following manner: "Why do you care about them? Why do you care about those people? What difference does it make to you [Aaron]? Take care of your own life.
  Do the best you can for you and your family. What do the rest of the people mean to you? They don't mean anything to you. They are just serfs. They are just people..."

- Rockefeller asked –"Why are you fighting for the people for, what is it all about? The people have to be ruled. The constitution, what you are standing for is only for a few people, it's only for a few individuals who can live that way and we believe that it is best for society to be ruled by an elite people who control everything." Russo told Rockefeller he does not believe that. Russo believes: "God put me on this earth to be best person I could be and put everyone on this earth to be the best they can be, and NOT to be a slave and a sheep to YOU and these people (elite) –and I do not understand why you want to control everything. What is the need for that?"
- It was just a lack of caring [from Rockefeller's part], and that is just not who Russo was. It was just sort of like cold you know, and Russo used to say to Rockefeller, "What is the point, of all this? You have all the money in the world you need; you have all the power you need, what is the point? What is the end goal? Rockefeller said "The end goal is to get everyone chipped. To control the whole society. To have the elite people [the bankers and government] controlling the world."

Women's Liberation from the Perspective of the Elite

- Women's' Liberation was founded by the Rockefellers.
- Rockefeller asked Russo: "What do you think women's liberation was about?" At the time Russo had a pretty conventional thinking about it and he said "It's about women having the right to work; get equal pay with men; just like they won the right to vote." At this point Rockefeller started to laugh and he said to Russo "You're an idiot"
- Rockefeller said –"Let me tell you what that was about. We the Rockefellers funded women's' liberation. We are the ones who got it all over the newspapers and television. The Rockefeller foundation –and you want to know why? There were two primary reasons:"
- 1) "We couldn't tax half the population before Women's Liberation and the second reason was"
- 2) "Now we get the kids at an early age [because both parents are away from home working] –we can indoctrinate the kids how to think, so it breaks up their family –the kids start looking at the state as the family, as the school as the officials as their family, not as their parents teaching them, and so those are the two primary reasons for women's liberation."
- Russo thought, up to that point, Women's Liberation was a noble thing; however when he saw the Rockefellers' intentions behind it, where they were coming from when they created Women's Liberation; the thought process of it; Russo saw the evil behind what he thought was a noble venture.

America is a Republic

- America is a constitution republic / it is supposed to be a constitution republic –and **NOT** a democracy. The majority should not rule, and nor should the majority take over the inalienable rights of the minority.

- Americans pledge allegiance to the "Flag and the **Republic** which it stands" –and **NOT** democracy.
- Democracy is the worst form of government you can have because it is majority rule. Therefore the government can tell you what to do because 'the majority' wants it. It is irrelevant what the majority wants. Decisions should not take away the inalienable rights of an individual.
- Russo also said "It doesn't matter who you vote for, republican or democrat; –they are the same –neither one of them is stopping the Federal Reserve or paying income taxes.
- The elite (Federal Reserve) have taken over the American government; there is no difference between republicans and democrats. There is no difference between the two parties. The duality is manufactured. They (Federal Reserve; central banks) control both parties. It doesn't matter to the elite which one wins, because whoever is running for President will be someone they anoint. Whoever runs for President, will do whatever the elite want them to do. The fact of the matter happens to be that you cannot win an election unless you have enough money to win; they (Federal Reserve; central banks) make sure who gets the money.

Depopulation

- Russo and Rockefeller discussed many things –and one of the things Rockefeller brought up in conversation was reducing the world population. Rockefeller felt that there are too many people in the world. In a way Russo agreed that there are too many people in the world, but he **does not** think he has the authority to say who dies and who lives; but the elite felt that they want to reduce world population and Rockefeller felt it should be reduced by half.
- Rockefeller even mentioned to Russo in conversation, that they were having a real problem trying to solve the Israel/Palestine problem –and they were playing with the idea of bringing Israel to Arizona –and taking everybody from Israel and giving everybody a million dollars, and setting up Israel in the state of Arizona –because that is a problem that they are not in charge of.

Borrowing Money from Private Banks causes Inflation and Debt

- These people (elite) control the money so they make all the rules, and therefore they put the rules in which they want into effect, and the truth is America has really become a socialist communistic country. Everyone says it is a capitalistic country, but how can it be a capitalistic country when you have a central bank? That is the first question people should ask. It can't be. It is a planned economy, it is a phony!
- If they want to create prosperity, they just print dollars, or put digits into the economy. Now you have prosperity. You do not have real prosperity, you do not have real manufacturing, you just have money being injected in which is infusion of credit. This makes the government go into more debt.

- Whoever makes the money makes the rules. Rothschild said that. Why are we allowing these private bankers to make the money for our country? It is nonsense. Why are we paying interest to these banks to make money for us when the government can do it itself without paying interest, without all that debt? There is no answer to that question and it is a question no politician will raise. Everybody talks about America's debt... We are in debt because we borrow money... but we don't HAVE to borrow money. They designed it so that we can go into debt. We can create the money, and back it by gold so that they cannot create too many of it, so that you do not have the inflation, and do what the Founding Fathers told us.
- Why in the world does the American government borrow money from the banks when they have the ability to create it themselves without borrowing it, and paying interest on it? Why? Nobody can answer that question –not one politician ever raises that. Why does the American government ever borrow money, when they can create it without paying interest?

  –And people say that –well if the American government creates it, it will cause inflation. And that is their answer. And Russo says well let's look at it: the American government has the Federal Reserve do it, which creates the same inflation as if they did it, but also with the inflation –now you are getting massive debt –so with the Federal Reserve you have inflation and debt. Now if the American government made the money, backed by gold which would limit the amount they could make –you wouldn't have debt and you wouldn't have inflation.
- It wasn't until 1913 when the Federal Reserve came in, that America had inflation. Before then there was no inflation for 100 years. There were points and spikes, mostly during the Civil War –but basically there was no inflation other than during that short period of time. I mean a loaf of bread would cost the same thing. People could plan their lives.
- Today, they have planned inflation, and now you have two parents working, they cannot afford to take and pay for their family anymore; the kids are going to state run schools now, the kids are being indoctrinated how to think; they are being given Ritalin, they are being given all these drugs, the whole country is being dumb down, it is all because of the Federal Reserve System; and the Federal Reserve system and these bankers are responsible for the demise of America. And if we ever want to win this battle you must shut down the Federal Reserve System, and we must shut down these bankers and restore sound money to this country.
- If you analyse the situation and if you realise that since the Federal Reserve has come into being since 1913, illegally, without a constitutional amendment, by bribing a few senators during Christmas vacation, they turned over the most important power that the American government has, the creation and issuance of money to a private bank.
- Through that private bank issuing money they have destroyed this country. They have destroyed the purchasing power of money in this country; they have created social programs that are destroying this country.
- The Federal Reserve has created massive inflation in America which means the American worker has to keep on making more money to keep up with the cost of

living. The more money they make to keep up with the cost of living, the less competitive they become in the world economy. So now what happens is that we have to pay our workers so much to keep up with the cost of living; and then they (elite; government; corporations etc.) say screw the American worker; let's go overseas now to get the cheap labour.

- The inflation the Federal Reserve has created has now allowed other countries to outcompete us. Other countries do not have to pay as much money as we have to pay to our workers to survive. So now we are not competitive anymore and we have lost our manufacturing base. We have lost our competitive edge.
- "Freedom to Fascism" is a documentary that everybody should see. Russo and his team show the fraud of the income tax; they show how Judges put people into jail for no reason; they show the corruption of the justice system. They show how the Federal Reserve came into being and how it is controlling society and how all the central banks are working together through the bank of International Settlements, in Switzerland which is the central bank for all central banks and how all are working together to create this one world government; this one world order; which is what they are trying to do.

The Deception of the Council of Foreign Relations (CFR)

- Russo was interested in joining the Council of Foreign Relations, but he found out from Rockefeller himself, that part of the end goal of the CFR is to get everyone RFID chipped. To control the whole society and have the elite people (bankers, government etc.) controlling the world. Russo asked Rockefeller "Do all the people in the CFR believe the way that you do?" Rockefeller said "No, no, no. Most of them believe they are doing the right thing. A lot of them believe it is better off being socialistic. We have to convince people that socialism is really capitalism." Because America is becoming a socialistic country; it is a communist country today.
- Russo's friendship with Rockefeller became one where they would share thoughts, ideas and philosophies and Rockefeller wanted Russo to become a part of what they were doing [enslavement agenda], and for Russo to become a member of the CFR; Rockefeller offered various business opportunities for Russo to get involved in the CFR and to **not** take up the fight or the battle that Russo had been taking up in the past. Rockefeller wanted Russo to drop the idea of helping the people; because "What was the point in Russo fighting for the people?" Rockefeller would question.
- Russo asked Rockefeller do all the people of the Council of Foreign Relations feel the same way you feel? Rockefeller said "A lot of them think they are doing the right thing, they think that socialism is the best way to go (but this form of socialism involves redistributing the wealth for the elites and not to everyone), they think that they are doing the right thing." But the people at the (very) top they all know the truth of what is happening. (Therefore, the good people in the CFR are also under an illusion, and do not know that effectively they are working for evil men who have the overall goal to control the populace of the world).

- So it is compartmentalised within the elite structure as well. All the people in the CFR -2000 to 3000 people like Dan Raddler –they don't know what is going on--- they join the CFR because it is prestigious. They think it is good for business, it is good for this; they don't know what is really happening –the evil that comes out of it –that is emanating out of it.
- In terms of the CFR, in terms of compartmentalisation, there are many good people which Russo believes are part of these organisations who do not even understand what these organisations are really about. For example, when Russo was in Germany, doing cancer treatment, there was a gentleman there who was visiting a friend of his with cancer. The gentleman visiting his friend was a member of the CFR, and him and Russo were talking and Russo showed him the movie (*Freedom to Fascism* (2006)); --and he said, "Oh my god! I'm going to resign." "I had no idea this is what the CFR is about". He had no idea; he is just a nice guy, who thought he was joining a prestigious organisation.
- A lot of people join the CFR because they think it is a prestigious organisation; it will help them in business; make good business contacts etc. They do not have an understanding that the CFR is really about world domination. How they, and the Trilateral Commission, The Bilderberger [Group], the banks, all work together to control the people –a lot of them do not understand that. They do not see the big picture. They think: Oh the CFR is a prestigious organisation. I'll make this, I'll make that, and I can do business deals. It is just business to them. The CFR wants to get the people in there that have influence and power, and so they are part of that (enslavement agenda), and so they are not opposed to them. So the whole country is becoming the haves and the have not. You are getting the very, very wealthy and the middle class being destroyed and you are getting the poor people.
- In Russo's words: "You can call the CFR what you like, but it is a criminal organisation. Run by criminals. But people do not think of it as a criminal organisation, because it has 'class'; 'style'; 'prestige'; –and it is 'respected'; so people do not look at it as being a criminal organisation. That is what a great job they have done."

Combining America, Mexico and Canada into one Country

- Imagine this... here you are in America, and they (elite) are combining American, Canada and Mexico into one country. The North American union. And the American people do not know anything about it. It is not even in the press. They would rather talk about Rosy O'Donnell and Donald Trump calling each other names than discussing the fact that we are merging into one country. This isn't even reported.
- The fact of the matter happens to be, that tells you how controlled the media is. The elite control the media, and they control governments and they are all in bed together. Here you are combining American, Canada and Mexico into one country, and you do not see it in the press. You do not see it in the press. Why? This should be one of the top stories everywhere –and the elite are not worried about it. That tells you –there is the evidence that [media] it is controlled. They do not want the American people to

know what is going on, that is why they do not protect our borders. That is why we are losing our constitution, the very document that secures our freedoms.

Russo's Vision on How to Bring These People Down

- There is no question we are in tyranny, there is no question that the American citizen is no longer a free individual human being, to do the things that they wish to do. We're slaves and it is getting worse.
- We are dealing with complete evil; and until the American people wake up and say, we do not want this evil in our country anymore and we want to come back to a country of decency and goodness, integrity and honour, we are going down that road and that is what it is going to take? It is going to take people to stand up and say we do not want to live in this kind of world anymore. I believe we should pull all of our troops out of Iraq, I believe we should leave other countries alone. Let other countries live their lives the way they choose to. Stop trying to spread 'democracy' around the world, which is the worst form of government there is anyway (because 51 percent rule over 49%), restore our republic to what it is supposed to be and go back to what the founding fathers gave us. Restore the republic.
- In Russo's opinion: The populace must shut down the Federal Reserve System –and there has to be an uprising. There has to be an uprising. People have to stand up. One person cannot do it alone. You cannot do it alone. People do not seem to have the courage to do what they have to do.
- A lot of people in Hollywood know the truth, they do not want to stand up and speak about it; I know many of them have seen my movie (*Freedom to Fascism* (2006)) and they know I am right, and they want to talk about it because everybody is afraid. Everybody is afraid because they think that the money they get from the Federal Reserve is really money and they have a comfortable lifestyle and they are afraid of change. They are afraid to stand up for what is right, and until people are willing to stand up and have the courage to do what they need to do, it is not going to change; and hopefully we can affect change when people stand up and say "Hey, I've had enough".
- We (the populace) have one advantage. They (elite) need us to cooperate. See, if we do not cooperate with them, they cannot win. They always need our cooperation with them to go along with their programs. They try to "sell us". Democracy; this majority says this; believe in this; do this, do that; the war on terror; we have to be scared... They are always trying to do things to "sell to us" to go along with them, and once we learn not to cooperate with them; then we win the game.
- That is the point, do not cooperate with them, and do not go along with the program anymore. Stop it. Join forces, and bring freedom back to this country. It is going to take people who believe in freedom; The Constitution and the Founding Fathers, Thomas Jefferson, to make this country whole again, because right now it is in the grip of the evil ones, and the only way to stop that is for good men to stand up.

- We have to stop being scared. We have to do what is necessary to take back what is ours. We have to stop these bankers, these elite, full of liars, congressmen full of liars. They are destroying our borders.
- So through these bankers, attempting to take over America, knowing that America was the freest nation on this earth, it was necessary for them to takeover America, take away gun rights, freedom to bear arms, and create a country where we become slaves, because once they take over America, the rest of the world becomes a lot easier for them. And so by creating 9/11, an event to terrify the American people that we are being 'attacked by terrorist', you create a world where there is an enemy that can **never** be pinpointed. You can never win the battle. It is 100 year war – a never ending war on terrorism. So you are always fighting this war, and through the war on terrorism, through 9/11 which is the first lie, then you create the war on terrorism which is the next lie, then you create the war in Iraq through weapons of mass destruction, which is the next lie –so you get one lie, to the next lie, to the next lie, -- now it is going to be Iran the next lie –and sending more troops and insurgents into Iraq.
- Restore America's Republic back to what it is supposed to be. Get the bankers out of our government. Get government to stop borrowing money from the banks. Government should make its own money; restore the Republic. Restore individual freedoms. That is what this country is about -and until we do that we are going to be slaves.
- You have to take away the creation of money away from the private bankers and you will solve 95% of your problems.
- Americans, mobilise, stand tall, stand together, tell the government you are "Mad as hell!" Do not cooperate with the government do not accept a National ID card. Do everything in your power to restore freedom and your individuality back to America. Stop being a country run by the institutions for the institutions. Let's go back to "We the people, by the people for the people", as opposed to, we the institutions, by the institution, for the institution. Stand up for your individual rights. Stand up for the God leaders that are in each and every one of us!

The Trans-humanist / Post Human Agenda

Transhumanism is a cultural and intellectual movement that believes we can, and should, improve the human condition through the use of advanced technologies. One of the core concepts in transhumanist thinking is life extension: through genetic engineering, nanotech, cloning, and other emerging technologies, eternal life may soon be possible. Likewise, transhumanists are interested in the ever-increasing number of technologies that can boost our physical, intellectual, and psychological capabilities beyond what humans are naturally capable of (thus the term *trans*human) (Anthony 2013). Transcranial direct current stimulation (tDCS), for example, which speeds up reaction times and learning speed by running a very weak electric current through your brain, (Anthony 2012) has already been used by the US military to train snipers. On the more extreme side, transhumanism deals with the concepts of mind uploading (to a computer), and what happens when we finally craft a computer with greater-than-human intelligence (the technological singularity) (See: “How to create a mind, or die trying”, Hewitt 2012) (Anthony 2013).

Moreover, put simply, “posthumanism” can be defined as that condition in which humans and intelligent technology are becoming increasingly intertwined (TheNanoAge 2015). For readers interested in learning more about the posthuman / transhuman agenda see BT Soul Catcher 2025 (BEAMS 2007); Avatar Project 2045 (2045 Initiative 2015; Borghino 2012) and Mind Clone Robot (Bloomberg Business 2015; RT 2015) which have all been disclosed as methods of transferring the human consciousness to a computer.

The Phases of Sleep and Rapid Eye Movement (R.E.M) Sleep

Sleepers pass through five stages of sleep: 1, 2, 3, 4, and REM (rapid eye movement) sleep. These stages progress cyclically from stage 1 through REM then begin again with stage 1. A complete sleep cycle takes an average 90 to 110 minutes (Sleepdex 2015). In other words, after falling asleep, it takes approximately 90-110 minutes to enter REM sleep.

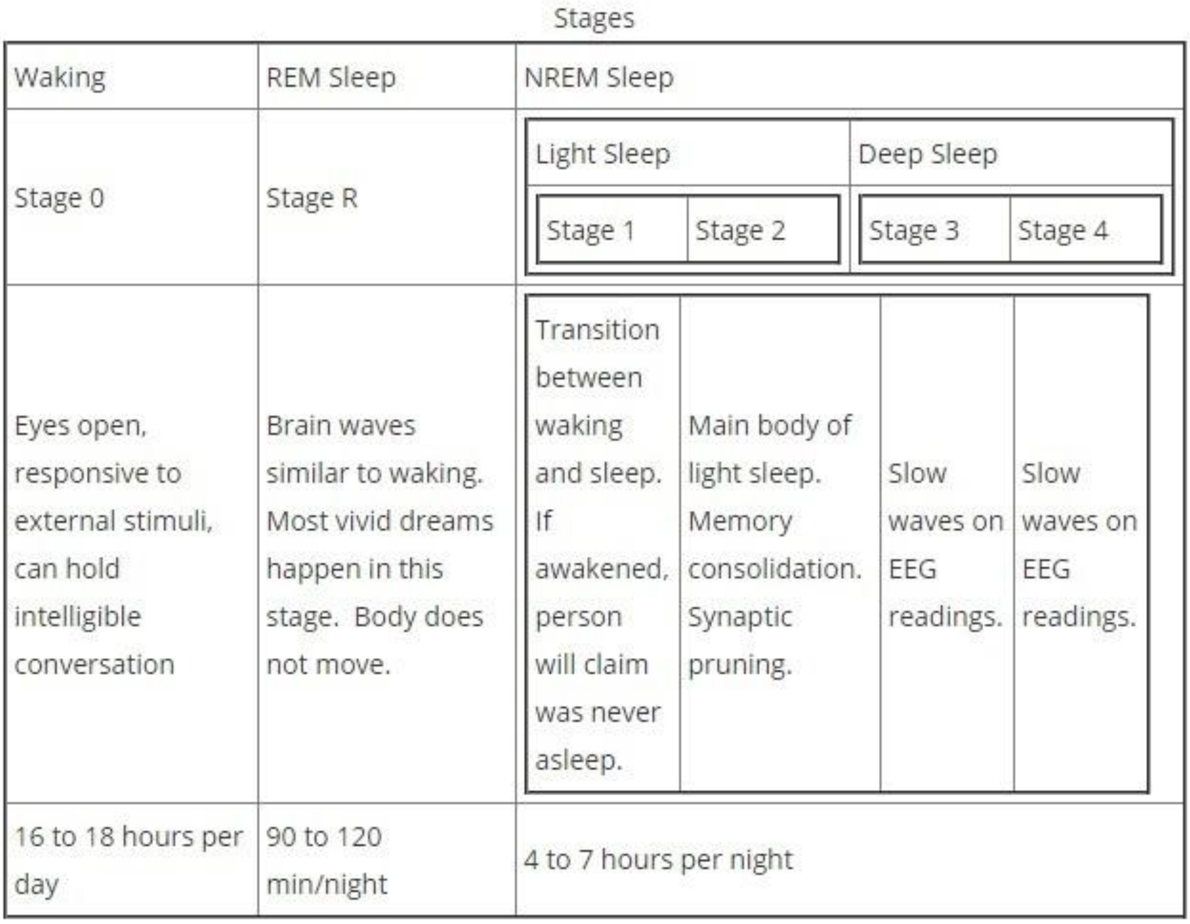

Stages

Waking	REM Sleep	NREM Sleep			
Stage 0	Stage R	Light Sleep		Deep Sleep	
		Stage 1	Stage 2	Stage 3	Stage 4
Eyes open, responsive to external stimuli, can hold intelligible conversation	Brain waves similar to waking. Most vivid dreams happen in this stage. Body does not move.	Transition between waking and sleep. If awakened, person will claim was never asleep.	Main body of light sleep. Memory consolidation. Synaptic pruning.	Slow waves on EEG readings.	Slow waves on EEG readings.
16 to 18 hours per day	90 to 120 min/night	4 to 7 hours per night			

Image 1: Stages of sleep. Source: Sleepdex: (2015)

Any sufficiently advanced technology is indistinguishable from magic.
Arthur C. Clarke

REM Sleep

Most dreaming occurs during Stage Five, known as REM. REM sleep is characterized by eye movement, increased respiration rate, and increased brain activity. REM sleep is also referred to as paradoxical sleep because, while the brain and other body systems become more active, your muscles become more relaxed, or paralyzed. Dreaming occurs because of increased brain activity, but voluntary muscles become paralyzed. Voluntary muscles are those that you need to move by choice, for example, your arms and legs. Involuntary muscles are those that include your heart and gut. They move on their own (Sleepdex 2015; Walcutt 2013).

Rapid eye movement, or REM sleep, is when you typically dream. You may have images float by in earlier stages, particularly when you are going through Alpha or Theta (brain waves), but the actual dream state occurs in REM (Walcutt 2013).

This period of paralyzation is a built-in protective measure to keep you from harming yourself. When you are paralyzed, you can't leap out of bed and run. Do you ever feel like you can't escape during a dream? Well, the truth is, you can't. You can breathe, and your heart is working, but you really can't move (Walcutt 2013).

The reader is also advised to see the Horizon documentary "Why Do We Dream?" (BBC Horizon 2009). This video is available, on YouTube, and details sleep, the phases of sleep, REM sleep, the period of paralysation and more.

Current Advances in Technology

This is a section some readers may have difficulty with, because reading about these current technologies alone, one cannot help but feel that such technologies described below sound like the stuff of science fiction and fantasy -although they have been corroborated through public drip-feed disclosure (explained below). Nevertheless, I urge the reader to keep in mind Arthur C. Clarke's quote (above), as well as Phil Schneider's testimony regarding the advancements of military technology in comparison to the general public's technology (for every 12 months, military technology outstrips the technology the public is accustomed to by a rate of 44 years). Moreover, for the reader who finds difficulty understanding the technologies described below, seek the supporting articles / videos.

Memory Suppression Technologies

Memory suppression technologies are any scientifically advanced technologies which are used to suppress memory. Examples of how memories can be suppressed can be found by reading Winter's (2014) article which details how memories can be suppressed using light; and Greenberg's (2013) article which discusses memory suppression through gene / chemical modification.

Mind-Voice Technology

Mind-voice technology is an advanced technology which is capable of reading, listening, hearing or broadcasting your inner voice / thoughts. Examples of articles which discuss mind-voice technology are: Prigg (2014) details software which can read the inner voice; and New Scientist (2014) which also discusses a brain decoder which can eavesdrop on one's inner voice.

H.A.A.R.P. Technology

The High Frequency Active Auroral Research Program (HAARP) is a radio transmitting system that can bounce signals off the ionosphere (a region of the Earth's upper atmosphere 60km (37 miles) to 1000km (620 miles) altitude) and back to earth to probe deep into the earth or sea, its proponents say. The system could locate minerals or communicate with submarines. (Begich & Manning 1997; Sheen, Begich & Robbins 2005).

HAARP can also:

- Disrupt human mental processes.
- Knock out all global communications systems.
- Manipulate global weather.
- Change weather patterns over large areas.
- Interfere with wildlife migration patterns.
- Hurt ecosystems.
- Negatively affect your health, moods, and mental states.
- Unnaturally impact the Earth's upper atmosphere.

This illustration (below) shows the ionosphere's relationship to the Earth. The illustration appeared in the HAARP Environmental Impact Statement on page 10-125 of Volume II.

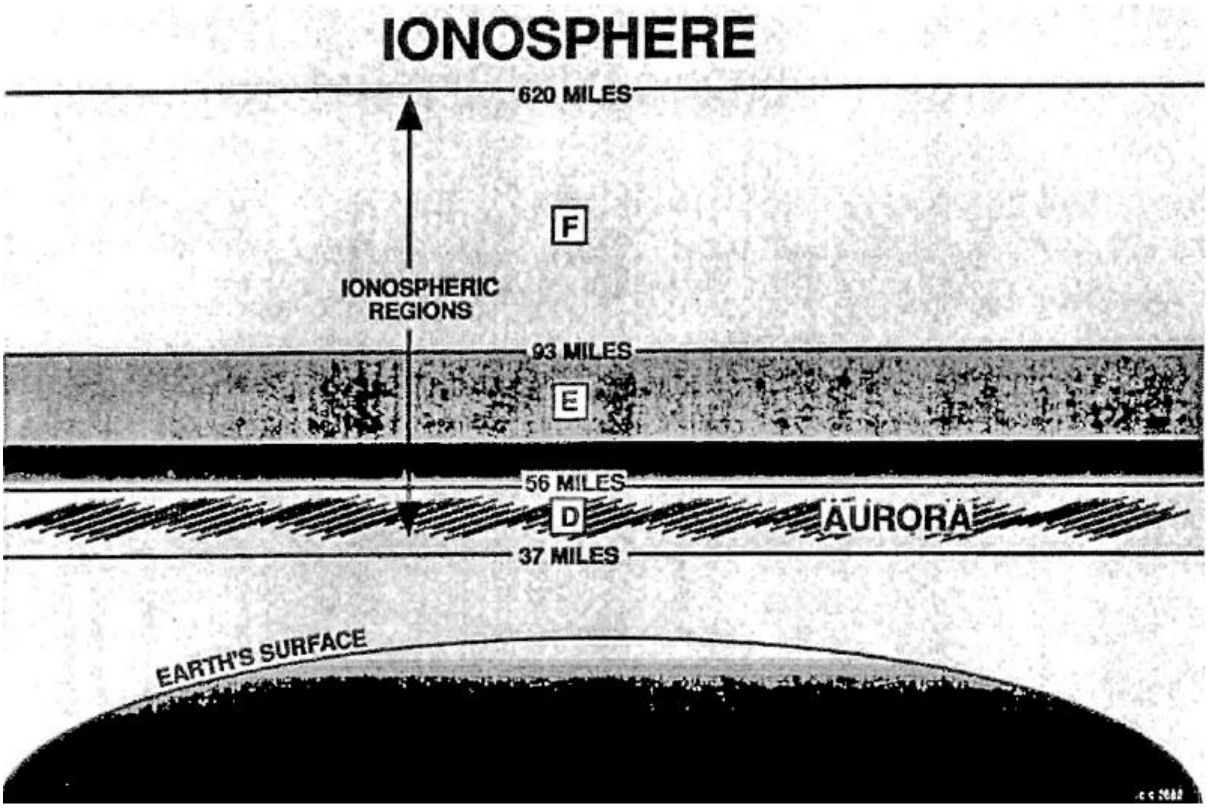

Image 2: The ionosphere's relationship to earth. Source: (Begich & Manning 1997)

The ionosphere protects the earth. HAARP (High frequency Active Auroral Research Program) is made to beam more than 1.7 gigawatts (billion watts) of radiated power into the ionosphere -the electrically charged layer above Earth‘s atmosphere. Put simply, the apparatus is a reversal of a radio telescope - just transmitting instead of receiving. It will boil the upper atmosphere. After disturbing the ionosphere, the radiations will bounce back onto the earth in the form of long waves which penetrate our bodies, the ground, and the oceans.

HAARP represents a technology which could lead to a new class of weapons that could change our world profoundly - an all-purpose military tool. If misused, the tool could mess up the weather. It could be used against humanity in a way that would change what people think, believe and feel. It could be used for good or evil, just as a harp can produce the music of Mozart or the melody of a death march.

H.A.A.R.P. and Weather Control

- “The theoretical implication [of Dr. Robert Helliwell and John Katsufrakis of Stanford University in 1974] suggested by their work is that global weather control can be attained by the injection of relatively small 'signals' into the Van Allen belts (radiation belts around Earth) - something like a super-transistor effect” said Frederic Jueneman.
- Yes. The weather can be controlled using HAARP technology.

- A series of weather disasters began in 1960, according to a CIA report mentioned in the editorial, but at the time climatologists couldn‘t look ahead and see that droughts, floods and abnormal temperatures would continue beyond that decade. As if natural disasters weren‘t bad enough, the CIA reported that national governments were already able to manipulate weather for military purposes [using HAARP technology].

As far back as 1958, the chief White House advisor on weather modification, Captain Howard T. Orville, said the U.S. Department of Defence (DoD) was studying ways to manipulate the charges of the earth and sky and so affect the weather by using an electronic beam to ionize or deionize the atmosphere over a given area. In 1966, Professor Gordon J. F. MacDonald, associate director of the Institute of Geophysics and Planetary Physics at the University of California, Los Angeles, was a member of the President‘s Science Advisory Committee, and later a member of the President's Council on Environmental Quality.

Gordon J. F. MacDonald published papers on the use of environmental control technologies for military purposes. MacDonald made a revealing comment: ―The key to geophysical warfare is the identification of environmental instabilities to which the addition of a small amount of energy would release vastly greater amounts of energy. MacDonald had a number of ideas for using the environment as a weapon system and he contributed to what was, at the time, the dream of a futurist. When he wrote his chapter, ―"How to Wreck the Environment" for the book "Unless Peace Comes" he was not kidding around.

In the text MacDonald describes the use of weather manipulation, climate modification, polar ice cap melting or destabilization, ozone depletion techniques, earthquake engineering, ocean wave control and brain wave manipulation utilizing the planet‘s energy fields. He also said that these types of weapons would be developed and, when used, would be virtually undetectable by their victims. He was not some wire haired fanatic when he made these observations in 1966 -he had the credentials of a world recognized scientist. What his futuristic concepts became, are the things which projects like HAARP are made of...

H.A.A.R.P. and Mind Control

- Radio frequency radiation, acting as a carrier for extremely low frequencies (ELF), can be used to wirelessly entrain (adjust) brain waves.
- We are talking about very, very low power requirements. The trick for influencing brain activity is in the combination of frequency, power level and wave form.
- As Dr. Patrick Flanagan, one of America's most gifted inventors noted in an interview, the HAARP project could be not only the biggest ionospheric heater in the world, but also the biggest brain-entrainment (brain adjustment) device ever conceived.
- According to HAARP records, when the device is built to full power it can send very low frequency (VLF) and extremely low frequency (ELF) waves using many wave forms at energy levels sufficient to affect the mental states of entire regional populations.

- The HAARP transmitting system could be used unintentionally or intentionally to alter mental functions.
- If HAARP is tuned to the right frequency, using just the right wave forms, mental disruption throughout a region could occur intentionally or as a side effect of the radio frequency transmissions [in other words: “mind control”].

RFID Technology

Radio Frequency Identification (RFID) microchips are microchips that can be directly imbedded into human flesh. This section discusses the dangers of RFID chips. See Rense (2001) for full review.

- RFID technology links the brains of people via implanted microchips to satellites controlled by ground-based super-computers.
- Today they are small enough to be inserted into the neck or back, and also intravenously (through a vein) in different parts of the body during surgical operations, with or without the consent of the subject. It is now almost impossible to detect or remove them.
- Implanted human beings can be followed anywhere.
- Today's microchips operate by means of low-frequency radio waves that target them. With the help of satellites, the implanted person can be tracked anywhere on the globe.

RFID Technology and the Medical Profession

- One reason the dangers of implantable microchip technology has remained a state secret is the widespread prestige of the psychiatric DIAGNOSTIC STATISTICAL MANUAL IV produced by the U.S. American Psychiatric Association (APA), and printed in 18 languages. Psychiatrists working for U.S. intelligence agencies no doubt participated in writing and revising this manual. This psychiatric "bible" covers up the secret development of Mind Control technologies by labelling some of their effects as symptoms of paranoid schizophrenia.
- The Psychiatric Diagnostic Statistical Manual (DSM) for mental disorders has been a brilliant cover up operation in 18 languages to hide the atrocities of military and intelligence agencies' actions towards their targets. THE MANUAL LISTS ALL MIND CONTROL ACTIONS AS SIGNS OF PARANOID SCHIZOPHRENIA.
- If a target is under surveillance with modern technology via TV, radio, telephone, loudspeakers, lasers, microwaves, poisoned with mind altering drugs via air-ducts, giving familiar smells which cause headache, nausea and so forth, if s/he claims her/his clothes are poisoned, her/his food or tap water as well --- all medical schools teach their students that the person is paranoid, ESPECIALLY if s/he believes intelligence agencies are behind it all.
- Never is the medical profession told that these are routine actions all over the world by intelligence agencies against their targets. Thus, victims of mind control are falsely considered mentally ill and get no help since they are not believed and their suffering is doubled by misinformed health professionals.

Further Implications of RFID Technology

- How many people realize what the implications of implantable chips actually mean? It means total loss of privacy and total outside control of the person's physical body functions, mental, emotional and thought processes, including the implanted person's subconscious and dreams! For the rest of his / her life!
- It sounds like science fiction but it is secret military and intelligence agencies' mind control technology, which has been experimented with for over half a century (since 1950s). Totally without the knowledge of the general public and even the general academic population.
- Supercomputers in Maryland, Israel and elsewhere with a speed of over 20 BILLION bits/sec can monitor millions of people simultaneously. In fact, the whole world population can be totally controlled by these secret brain-computer interactions, however unbelievable it sounds for the uninformed.
- Neuro-electromagnetic involuntary human experimentation has been going on with the so-called "vulnerable population" for over 50 years, in the name of "science" or "national security" contrary to all human rights. It happens today in the **USA, Japan, and Europe**. With few exceptions, the mass media suppresses all information about the entire topic.
- Only increased public awareness of the microchip implants, their frightful consequences to privacy by influencing of individuals' thoughts and actions, causing people to become biological robots with physical and emotional pain whenever the supercomputer technician so wishes, is enough reason to refuse to take the microchip into your body for whatever reason.
- It is the biggest threat to humanity and the most sinister plan to enslave the human race forever.

If you have a choice and want to remain a normal human being with privacy, **DO NOT** have your children implanted **NOR** yourself implanted with RFID microchip(s) (or any other type of implantable microchip). Otherwise your vision, hearing, sensing, thoughts, dreams and subconscious will be influenced by an outsider, who does not have your best interests in mind. For the rest of your life!

Mind Control: MK Ultra Technology

MK Ultra today has evolved from the 1950s variation of mind control (MK Ultra Compendium 1980), whereby drugs such as LSD, and interrogation were used as methods to weaken the mind of the individual to force confessions through mind control. Today, mind control is achieved through the implantable microchip (mentioned above; Rense 2001).

- The brain functions of an implanted person can then be remotely monitored by supercomputers and even altered through the changing of frequencies.
- Once implanted, the U.S. National Security Agency's (NSA) 20 billion bits / second supercomputers could now "see and hear" what you are experiencing with a remote monitoring system (RMS).

- Every thought, reaction, hearing and visual observation causes a certain neurological potential, spikes, and patterns in the brain and its electromagnetic fields, which can now be decoded into thoughts, pictures and voices. MK Ultra technology is therefore capable of Mental Video and Audio Projection, as well as Artificial Telepathy.
- The mass media have not reported that an implanted person's privacy vanishes for the rest of his or her life. S/he can be manipulated in many ways. Using different frequencies, the secret controller of MK Ultra technology can even change a person's emotional life. S/he can be made aggressive or lethargic. Sexuality can be artificially influenced. Thought signals and subconscious thinking can be read, dreams affected and even induced, all without the knowledge or consent of the implanted person by using MK ultra technology.
- Memory suppression technologies are used in conjunction with MK Ultra technology, which enables the programmer to control certain memories the victim remembers. The use of memory suppression technologies and MK Ultra technology allows the programmer to reinforce behaviour and elicit specific conditioned responses.
- Mind control techniques, such as MK Ultra, can be used for political purposes. The goal of mind controllers today is to induce the targeted persons or groups to act against his/her own convictions and best interests. Zombified individuals can even be programmed using MK Ultra technology, to murder and remember nothing of their crime afterward.
- The goal of mind control, using MK Ultra technology is to program an individual to carry out any task against their will and self-preservation instinct and to control the absolute behaviour and thought patterns of the individual. The purpose of mind control, using MK Ultra technology is to disrupt memory, discredit people through unusual behaviour, to make them insane or to commit suicide or murder.

See Mind-Computer (2012) which discusses how artificial telepathy is achieved. Artificial telepathy, also known as ‘brain to brain communication’, is also possible using MK Ultra technology. Furthermore, review: Jim Cristea (2009); Berkeley News (2011); UC Berkeley Campus Life (2011) CTForecaster (2013); nature video (2013) and Stromberg (2013). The above mentioned articles and videos describe, demonstrate, and corroborate how audio and video projection of the brain is achieved; how dreams can be recorded and projected digitally; how the brain can be scanned to reveal hidden information personal to an individual; and what a person’s underlying intentions are, by using brain scans. Moreover, the articles and videos mentioned above confirm the functionalities of MK Ultra technology.

Furthermore, when our brain functions are connected to supercomputers by means of RFID technology, MK Ultra technology and other implantable microchips, it will be too late for protest. This threat can be defeated only by educating the public, using available literature on biotelemetry (electronic equipment that receives signals from radio transmitters) and information exchanged at international congresses.

Human Cloning

There are currently five different types of clones, concealed from public knowledge. There are Mark 1 clones; Mark 2 Clones; Mark 3 Clones; and Mark 4 clones and reanimated clones. Moreover, there are two types of cloning techniques: duplication cloning and replication cloning.

Mark 1 clones are REM sleep driven clones. However, the technology used for Mark 1 clones causes many side effects and therefore Mark 1 REM sleep driven clones are no longer a preferred choice.

Mark 2 clones are also REM sleep driven clones. Mark 2 clones have fewer side effects than Mark 1 clones, and therefore Mark 2 clones are currently the preferred method for REM sleep driven clones.

Mark 3 clones are independent clones which operate on microchip containing the entire consciousness of an individual.

Mark 4 clones are also independent clones, operating on a microchip which contains the entire consciousness of an individual and is an advanced version of a Mark 3 clone.

These independent clones (Mark 3 and Mark 4) have a lifespan of 6 months to 12 months and require adjustments after this period to run efficiently once more. Without these adjustments, their functionality weakens.

To "reanimate" means "to restore to life; resuscitate; revive". Consequently, reanimated clones are clones which are genetically identical to that of a person who once lived.

Replication cloning is what the public is most familiar with. Replication cloning involves giving birth to a genetic identical of an original where the newborn starts life off as a baby and matures. The newborn is referred to as a clone.

However, duplication cloning is a current concealed advanced from of cloning, and it involves taking as little as two cells from an individual, adding a constant electrical charge to the cells until a complete human being is formed.

Duplication cloning is similar to the process of regenerative medicine as demonstrated by Dr. Stephen Badylak's video "How to grow a New Fingertip" (CBS 2008; Science Channel 2014) where Badylak states: 'A whole human can be grown within 9 months.' On average it takes 5 months to grow a duplicate clone of an original by means of advanced scientific and technological regenerative procedures.

Cloning Centre and Cloning Technology

A cloning centre is a place where clones are produced. Cloning technology are the advancements in medicine, science and technology used to produce duplicate and replicate copies of originals.

Drip Feed Disclosure and Evaluative Conditioning

Drip Feed Disclosure

Drip feed disclosure is the process of supplying information but in small amounts overtime. Drip feed disclosure is also the process of revealing information slowly overtime, possibly telling lies to conceal certain aspects of the truth until the source administering the drip feed disclosure has adequate time to let out the truth in a slow and controlled way, thereby delaying the betrayed partner (in this disclosure, the public) from having the "complete truth" for some time.

Drip feed disclosure is also a method to gauge public reaction used by governments, the media, multinational corporations and organisations as well as high ranking officials to "test" whether the general public is acceptant of the concealed information or not. When the public reacts favourably to the drip feed disclosure, more information is revealed and made public, and it appears to the unsuspecting observer that the people involved in making the disclosure are taking positive steps towards a favourable goal for all. However, when the public reacts adversely; information contradicting the drip feed disclosure is presented, and an expert is presented to the public who voices the concerns of the general public, and therefore it appears that the opinions of the public have been noted and research and development will not continue in the initial stated direction. Nevertheless, the truth remains concealed and research and development continues despite the aversions of the public.

Examples of drip feed disclosure involve articles such as mind uploading / downloading (BEAMS 2007), Mind Clone Robots (Bloomberg Business 2015; RT 2015), The 2045 Avatar Project (2045 Initiative 2015; Borghino 2012). I am here to tell you that I have been a spy for over 30 years and such technological accomplishments which are posted under trans-humanism / post-humanism genre have been realised many years ago and are **available** today. They are just concealed from the public.

Furthermore, Dolly the sheep was announced as the first publicly cloned mammal (Animal Research 1996), but how many readers can say they know that, four years later, a monkey (BBC News 2000), our closest primate, was cloned? This is publicly disclosed knowledge, but I suspect not many people know of a cloned monkey four years after Dolly. This is because there was such a worldwide adverse reaction to genetic cloning when Dolly was made public, that the disclosure of the cloned Rhesus monkey (BBC News 2000) was not made public knowledge on a grand scale.

Evaluative Conditioning

Evaluative conditioning is defined as a change in liking, which occurs due to an association with a positive or negative stimulus (see De Houwer et al., 2001). Simply put, this means that our preferences for brands, products, people and other things can be influenced and even modified by the presence of something we like or dislike strongly (Hale 2012).

In many settings, a neutral stimulus, called a "conditioned stimulus", often coincides with some desirable or undesirable object, called the unconditioned stimulus. An unknown brand, for example, might appear in a commercial that also depicts a happy child. Over time, stimuli that often coincide with desirable objects are perceived more favourably, whereas stimuli that often coincide with undesirable objects are perceived less favourably--called evaluative conditioning (De Houwer, Thomas, & Bauyens, 2001; Walter, Nagengast, & Trassilli, 2005; Moss 2009). An "unconditioned response" is a response to a neutral stimulus we have no / little control over. It is a natural automatic response.

In other words, our preferences for liking or disliking brands, products etc. (the neutral stimulus) can be influenced by embedding (implicitly placing) the brand etc. (neutral stimulus) with positive or negative associations. Overtime our conditioned response becomes one of conditioned favourable or negative response towards the brand, product etc. (neutral stimulus) when we are faced with the brand, product etc. at a future date. Our preferences have been guided overtime. Evaluative conditioning can change our preferences when carried out subliminally or implicitly; it does not have to be explicit.

In media; music; movies; and other forms of popular culture and entertainment, images and symbols (of stimuli which cause undesirable consequences) are embedded subliminally and implicitly and are paired with positive associations as a form of evaluative conditioning. This causes individuals who have no preconceived judgements of the stimulus to be guided to have positive associations with a stimulus which causes undesirable consequences.

In popular culture; media; advertisements; movies; music and other forms of entertainment, evaluative conditioning is used as a method of hinting (that something is wrong); showing off of power (i.e. nothing can be done to stop the negative stimulus) and as a form of gloating (i.e. we've pulled off the negative stimulus / we are pulling it off). In over the 30 years I have been a spy, I have witnessed methods of evaluative conditioning used to hint, show off power, and gloat more often than not, and evaluative conditioning is not used just to guide social order.

The fortunate aspect is that once a person learns that his / her preferences are being guided by methods of evaluative conditioning, in order to influence the person to have positive associations with negative stimuli (or feel powerless towards the negative stimuli); and that the stimulus (brand / product) does in fact cause undesirable consequences –then the 'spell' is broken. The person can now choose how he or she responds to the brand etc. Usually, once all is known: a negative stimulus is associated with negative associations; despite it being portrayed as positive through evaluative conditioning.

Consciousness Transfer

Consciousness is defined as "the state of being aware of and responsive to one's surroundings; a person's awareness or perception of something" (Dictionary Reference 2015). Consciousness can also be described as: individual awareness of a person's unique thoughts, memories, feelings, sensations and environment (Cherry 2015).

John Locke (1632-1704) was an English philosopher, Oxford academic and medical researcher who argues that it is sameness of consciousness rather than sameness of substance that constitutes personal identity. Consequently, if the psychological life is transferred from the body of a prince to the body of a cobbler (shoe mender), Locke argues, the resulting person will be the prince and not the cobbler. He would be responsible for the prince's actions and not the cobbler's; those who were close to the prince could continue their relationships with him but those who had relationships with the cobbler could not, and so on (Schechtman 2012, p.334). Moreover, basic Lockean intuition has proved to be that "consciousness transfer" can be thought of as the feat in which the person moves from one body into another (Schechtman 2012, p.334).

Consciousness transfer can also be thought of as the process of transferring or copying the mental content (including long-term memory and "self") from a particular brain and copying it to a computational device; artificial body or avatar body such as that of a robot or clone version of the original. The computation device, robot or the clone, will then respond essentially the same way as the original brain (as suggested by Lockean theory on consciousness transfer) and therefore the computational device, robot or clone experiences having a conscious mind and essentially the behaviour of the computational device, robot or clone, can be attributed as belonging to that of the original.

It is **OF MONUMENTAL IMPORTANCE** that the reader understands the above statement regarding consciousness transfer is a method of **CURRENT** concealed advances in technology and not a concept relegated only to the genre of science fiction. At the very least the reader should be **open** to the possibility of consciousness transfer and the implications of consciousness transfer, in order to truly begin to understand the extent to which current concealed advances in technology are used to commit monstrous crimes.

I understand the above sounds unsettling, but there are also many wonderful concealed advances in technology (detailed in the disclosure section). The marvels in technological feats and human accomplishment will be released for the benefit of mankind once the world learns about the monstrous crimes which are committed against the them, and the earth, through the use of highly concealed technological advances and the good people of the world band together to put an end to the tyranny around us.

Now is also a good time to remind the reader that if military technology advances by a rate of 44 years for every 12 months which passes, then since 1945 military technology has advanced by a rate of more than 3000 years compared to the technology the public is currently accustomed to (44 times 70 = 3080). Now ask yourself honestly, in 3000 years from now (the year is 5015) don't you think humans will have been capable of developing a method which allows them to transfer their consciousness from one body to the next and more?

I am here to tell you that I have been a spy for over 30 years and that from the intelligence I have gathered over the years it has been illustrated to me countless times that consciousness transfer is indeed fact and currently exists. Consciousness transfer has been achieved since 1945, although this accomplishment in human advancement (and more) is concealed from public knowledge. Moreover, consciousness transfer is a highly advanced form of concealed technology used by high ranking members of society to commit unspeakable crimes against the public.

Furthermore, for the reader who wishes to understand how consciousness transfer is possible, see Petkova and Ehrsson (2008) and Ehrsson (2013). In the video Professor Henrik Ehrsson (2013) demonstrates:

1) Consciousness transfer from one body to the next (owning another body other than ones original)
2) Physiological evidence for owning the new body. In other words when consciousness has been transferred and the person perceives the new body as that of his or her own; when the new body is threatened as the mannequin (new body) was in the experiment, individuals still perceived the mannequin body as that of their own and became frightened (displayed biological and physiological responses).
3) Visual perception and stimulation causes us to perceive ownership of a new body.
4) The new body we inhabit must be similar to that of our own (it does not matter whether the new body is smaller or larger than our original so long as the measurements are proportional) for consciousness transfer to occur.

5) That it is possible for consciousness to be transferred to another person's body and have (or perceive) ownership of other person's body while being localised in your own body. In other words, dual consciousness is possible.

Petkova and Ehrsson's (2008) and Ehrsson's (2013) research gives one of the clearest publicly disclosed explanations of consciousness transfer and I urge the reader to watch the video in order to better understand my disclosure. One of the main findings from his research is that perception is not rigid; and perception does shape reality. Sight and synchronous (going on at the same time) stimulation can, and does alter the brains perception of reality. Sight and synchronous stimulation activates certain parts of the brain (the sensory parts of the brain and the motor (movement) parts of the brain). The match between the two (sight and stimulation) "convinces" the brain that 'hey, I'm no longer in this body; I'm in that one or that I have a third arm (although it is a false limp) etc. Accordingly, "perception is reality".

Disclosure: Save the Victims through your Diligence

I've done my best to preface this information as logically, sequentially and methodologically for the reader as possible. I have stated what the law is on 'whistle blowing'; I have given references and definitions where appropriate and I have provided many sources in order for the reader to research, corroborate, and better understand my disclosure, so that he or she becomes compelled to help me and victims like me, defeat tyranny and save the future of mankind; therefore if there are any areas of my disclosure which still appears suspect –and I understand, after all my efforts –things may still not appear clear to some readers because we are dealing with highly advanced concealed technologies which are not available in the world the general public lives in; and therefore it is difficult to fathom and furthermore conceive that men can be so evil to their fellow humans through the use of advances in science and technology. Nevertheless, I promise you, I have no reason to lie, I am victimised daily because of these technologies, and therefore my only option is to tell the truth, and nothing but the truth so that the people of the world can put an end to this grave injustice.

For the reader who still finds it difficult to accept my disclosure after first read, I want you to do two things:

1) **Give me the benefit of the doubt.** I am asking you to do this because as I stated earlier, one of the hardest things to do as a victim of abuse is to come forward about the abuse you have suffered. It is even more heartbreaking when nobody believes you. Consider all the victims of paedophiles you have heard about on the news. I cannot speak for their individual cases but I can attest to the fact it affects my mental psyche beyond comprehension; there is nothing worse than being ignored and that nobody believes you. So on that premise, please give me the benefit of the doubt, because I'm sure the majority of good human beings out there will feel worse when it is proven that I am a victim of severe abuse and you ignored me, when you could have done everything in your power to save me.

2) **Set out on a genuine quest to debunk my disclosure.** If my disclosure appears suspect to you to begin with, then set out on a genuine and investigative quest to debunk my disclosure because, if my disclosure initially appears circumspect to believe, then I should be proven false within minutes of your research of my disclosure, because even professionals make mistakes. There will be something about the disclosure which will just not 'add up'. However, when a person is telling the truth, then it is very difficult to debunk that person.
I promise you, it will be worth your time to know the real truth about the world, simply because the truth is liberating.

I would also like to remind you that the truth about the world has been hidden from the public for many decades, therefore when you do hear the truth of course it is going to sound absurd to begin with; but keep an open mind and pursue till you know what truth is; because "to "know" is to understand with certainty".

Words of Inspiration: Personalized from a Theoretical Physicist –Thomas Campbell

The following gives an introduction to many aspects which occur in this world behind closed doors or in plain sight depending on how familiar the reader is with the topics. Evidently, a lot of what is written predominantly affects the people of the world and it is time the people of the world stood up and reclaimed their world. I cannot stress this importance enough! The disclosure is also a basis which explains many of the anomalies which exist in the world today. I apologise in advance if the disclosure is too shocking to be believable (initially) and it shakes the foundations of your belief systems... but as I've said, rather than lash out at the information, you must question your own belief system... and probe into the mechanisms which have influenced you to adopt your current belief system... only then does the shock subside... and you can move forward with an open mind through investigation, which should lead you to either corroborate or debunk the disclosure. Keep in your heart: scepticism, optimism and open mindedness (Campbell 2008). Scepticism keeps you from believing fallacies. It keeps you from falling into that which you have not yet proven for yourself. Scepticism is a requirement for breakthroughs. Optimism gives you the ability to give merit to that which you have not yet proven for yourself and Open Mindedness gives you the ability to "see" that which has not yet been proven.

The Science of Hidden Consciousness

Furthermore, "Consciousness Science Kept Hidden" (YesEthan 2013) illustrates:

- "The heart is an electrical organ. It produces by far the strongest form of bio electricity in our body; up to 40-60 times stronger than the second most powerful source –which is the brain. This electrical energy travels through every single cell in our body and in a sense, binds the cells together. The bio-electricity field is strong enough that it can even be detected outside of the body; out into space; beyond the skin. It is very measurable electromagnetic energy, much like radio waves. What we found is that the heart produces an electromagnetic field that surrounds our entire body 360 degrees; and it can be detected about 3-4 feet with megatron meters outside of the body. Researchers at the medical facility in Kansas –say they have detected it 10-12 feet. So regardless of how far it goes, what is interesting is that we produce this electromagnetic field which can be detected; it can be measured, with sensitive mainstream medical equipment." -Howard Martin (co Author) "The Heart Math Solution""
- Scientific studies have shown: that the heart is not only the most powerful centre in the body, it is the most intelligent and has the ability to receive precognition (knowledge of a future event or situation, especially outside one's normal sense of perception). If we can create coherence with our heart and mind centre we can access our intuition more frequently.

When you read my disclosure, remember that it is the heart and NOT the brain which is the most powerful centre in the body; the heart is the most intelligent; it has the ability to receive precognition and intuition about a future event, **before it actually occurs**; therefore if you find that your heart is in resonance with the themes I disclose; do not fight it with the ego of the mind; when our egos get in the way it overrides our heart's intuition; your heart is capable of discerning the truth of an event before your brain becomes conscious of it; by all means listen to your heart, and allow your brain to naturally develop its intuition. It will be the coherence between your heart first, and then your mind centre which will allow you to access your intuition.

Make an effort and reach your own conclusions to the point where you feel comfort in the fact that you **KNOW** the information contained in this disclosure is indeed factual. This will be the point you will have become empowered with golden truth and compelled to fulfil your duty as a human being and also spread the truth far and wide. Yes, we are all living in very interesting times.

Disclosure: Donald Marshall's Message to the World

My name is Donald Marshall. I have been cloned by a large secretive cult know as "The Freemasons" and "The Vril Society" and "Scientologist" together called the Illuminati. For readers unfamiliar with The Illuminati see "The New World Order" (1990) by A. Ralph Epperson and Appendix C in this document; an introductory guide to the Illuminati and their agenda for the world is presented.

Furthermore, I have to tell you that human cloning has been done since 1945. Now is also a very good time to recall Phil Schneider's comment (Schneider was a Geologist and Engineer who worked on black projects and Deep Underground Military Bases (DUMBs)): "That for every 12 months which passes, military technology advances by a rate of 44 years compared to the technology the public is currently accustomed to" (Schneider 1995; 1996; Open Minds 2011). George Green (a former Financier affiliated with U.S. Presidential candidates) also attests to the fact that humans have been cloned since 1938 (Green 2008a; 2008b). Therefore if we take 1945 as a base year, then military technology or hidden technology has advanced by the rate equivalent to 3080 years than the technology the general public is currently accustomed to (2015 – 1945 = 70 years; 70 multiplied by 44 = 3080). So yes, humans have been cloned since 1945 and continue to be cloned today and that current hidden technology in the year 2015 is as much as 3000 years ahead of the technology the public is currently accustomed to. I'll repeat myself because it is **very important** the reader understands the above statement, even if, the rest of the disclosure is hard to fathom after first read. The two **most important** things to keep in mind are:
1) Humans have been cloned for over 70 years (since 1945);
2) **Present** hidden technology is more advanced -as much as 3080 years more advanced- than what the public is currently accustomed to and technology continues to advance at an incredible rate.

The Two Types of Cloning Techniques

Now there are two different types of cloning techniques, there is replication cloning and duplication cloning. Replication cloning is the type of cloning the public has generally heard of. Replication cloning involves taking the nucleus (the DNA) out of a donor egg, and replacing it with new DNA from the person to be cloned. After a few days the resulting embryo can be implanted for pregnancy. The newborn starts life off as a genetic copy of an original.

Duplication cloning, on the other hand, is the second hidden method and type of cloning where the DNA from the person is grown in a big thick tank full of (salty) water. It involves a method of regenerative technology where the cells are agitated and agitated and over the course of 5 months, a fully formed duplicate clone body of an original is developed. The Illuminati used to have to use a tissue sample from the original or the cells from women's pap smears because this contained rich cells to make duplicate clones; they also used children's foreskins which were discarded at the hospital that got removed. That is what happened to me. I had my foreskin removed at age 4 –and by age 5 the Illuminati grew duplicate clones of me. Now the Illuminati say they have upgraded the technology since 2000 and now all they need is blood from the original. They then agitate the blood cells over and over again through regenerative technology, until a fully formed duplicate clone body of an original is produced. For readers who are unfamiliar with regenerative procedures, see Dr Stephen Badylak's video on "How to grow a new fingertip" (Science Channel 2014) and Carmichael (2013) which discuses how scientists cloned a mouse from a blood sample (this is another example of drip-feed disclosure). Regenerative science and medicine (CBS 2008) does work; I've seen it many times.

The Different Grades of Clones: "Mark 1" to "Mark 4" Clones

There are a few different grades of clones that I know of. There are: "Mark 1" to "Mark 4" clones. Mark 1 clones were available at the end of World War II (1945). Mark 1 clones were rapid eye movement (REM) driven clones but they were primitive grades of cloning with lots of side effects caused to the original. Mark 1, REM driven clones were called "Organic Robotoids", even though there are no robotic parts to the clone at all. See Dr Peter Beter's discussion on "Organic Robotoids" (Beter 2011).

Donald Marshall's Dilemma with "Mark 2" Sleep Driven REM Clones

The problem I am having is with Mark 2 REM driven clones. "Mark 2" is a rapid eye movement (REM) driven clone. In other words, Mark 2 clones are sleep driven clones. REM sleep is the fifth stage of sleep (Sleepdex 2015). The first REM cycle usually happens 90 minutes to 110 minutes **after** we fall asleep (Sleepdex 2015). What that means is: **currently,** this is the Illuminati's main form of communication. They do not call people on the phone; they do not meet at the Bohemian Grove anymore (they only meet there once a year for traditional purposes). Since they discovered the science of sleep driven cloning, they meet at the cloning centre **WHEN THEY GO TO SLEEP** (The cloning centre is a physical location, located 5 / 6 hours radius from the Robert Pickton Farm (Port Coquitlam, British Columbia, Canada) at a nature reserve).

Consciousness Transfer Happens When the Original Reaches REM Sleep

The Illuminati can transfer the consciousness of an original once the person reaches REM sleep if there is a duplicate clone of the original at the cloning centre, once the person goes to sleep (90 minutes to 110 minutes after falling asleep). So what happens is that the consciousness of the original is transferred to the duplicated clone body (the duplicated clone body is grown within 5 months by regenerative technology) once the original reaches REM sleep. The original's consciousness is transferred from the original's body, although the original's body is still in their bed, asleep at home; to a duplicated REM driven clone body at the cloning centre and the original 'wakes up' as a cloned version of himself / herself at the cloning centre. It is a great marvel of science and one man's greatest achievements, but it is kept hidden and used for sinister purposes which I discuss below. I must address the readers at this point who are lost at the thought of duplication cloning, and consciousness transfer.

For readers who may have difficulty understanding the process of duplication cloning, see the video which features Dr Stephen Badylak (CBS 2008; Science Channel 2014). Badylak describes and illustrates how a new fingertip can be grown within 4 weeks, by the process of regenerative technology. Duplication cloning works a similar way; involving regenerative technology whereby the cells are agitated and agitated, and over the course of 5 months a fully formed duplicate clone body of an original is grown. Moreover, readers should also view the Horizon documentary "Why Do We Dream?" (2009); the documentary clearly explains the phases of sleep; particularly REM sleep. The documentary also clearly explains that during REM phase sleep the whole body shuts down, and it is only the brain which is active. The fact that the brain is still active, although the body is inactive, is a perfect opportunity for consciousness transfer; and this is usually the moment the Illuminati transfer the consciousness of a person who is asleep, to a cloned version of himself / herself. The reader should also explore Ehrsson's (2013) lecture on consciousness transfer. In the video, Ehrsson (2013) clearly explains how through the first person visual perspective (seeing through the eyes), and through synchronous (occurring at the same time) stimulation of a body part, individuals can perceive and see the world from another body different from their original. In other words, so long as people can see through the eyes, and the body is stimulated, the match between the visual perspective and feeling body sensations allows the individual to see and perceive the world through another body different from their original. The consciousness has been transferred to another body.

Ehrsson (2013) also demonstrates that consciousness is linked. Once consciousness is transferred (from the original's body to the new body), even though the new body is not the persons original body; when the new body is attacked, because the person perceives the world through the new body, everything feels "very real". When the new body (for which the person's consciousness has been transferred to) is attacked, the original still perceives the threat as "real", and therefore the person displays a biological and physiological fear response in their original body; the heart rate increases, as does respiration (breathing) rate, as well as anxiety.

Donald Marshall is an Original as he sits at Home Typing this Disclosure

This is how advanced technology is today. This is also exactly what happens to me. **I am an original as I sit at home here typing this disclosure,** but when I enter REM sleep, my entire original body shuts down, and only my brain is active. The Illuminati have linked my consciousness to a REM driven duplicate clone body of me. Therefore, as soon as I enter REM sleep, they are alerted to the fact that I have entered stage five of the sleep cycle, and in REM sleep, because they have a green and red light above duplicate clones at the cloning centre. The red light indicates that the original is awake, and the green light lets them know that original has entered REM phase sleep and it is time to transfer their consciousness to a duplicate clone version. They cannot transfer the consciousness of an original before REM phase or when the original is awake. When they try and transfer consciousness before an original is in REM phase it makes the original have intense headaches. Setting an alarm every 90 minutes to wake up and then go back to sleep also does not work in terms of avoiding REM sleep and having your consciousness transferred, because the body requires REM sleep, and therefore you become very tired, quickly, if you do not get REM sleep. If you stay awake for four days without REM sleep you begin to hallucinate; after seven days without REM sleep you will die.

When Donald Marshall's REM Driven Cloned Experiences Began

This whole sordid episode began when I was 5 years old, after going to the doctors to get my foreskin removed, at age 4. The tissues from my discarded foreskin were used to grow multiple duplicate clones of me. Within months, I was having my consciousness transferred to a REM driven, 5 year old clone version of me every time I entered REM sleep. The reason the Illuminati did this was because they wanted to use me as what they term "a diddle kid" – in other words they wanted to have sex with an REM driven, 5 year old, duplicate clone version of me. This is what they do. They clone people. They make duplicate clone bodies of people to victimise in terrible ways, and they clone children for men with undeveloped penises to have sex with.

However, I could never remember any of these REM driven clone experiences when I woke up for 25 years; because another aspect of REM driven cloning is that the Illuminati have the advantage of being able to suppress the experiences of people who have their consciousness transferred to their REM driven duplicate clone versions through advanced memory suppression technologies. For the reader who wishes to understand how memory suppression works see Winter (2014). Memories are stored and retrieved from different parts of the brain. Interactions between the cerebral cortex (the outer layer of the brain) and hippocampus need to work together in order to bring the memories out of mental storage to be re-experienced by the mind (Winter 2014). Therefore all that has to be done is for them to turn off the nerve cells which communicate with the cerebral cortex and hippocampus for the evening which you went to sleep and had your consciousness transferred to a REM driven duplicate clone version of you, and you will not remember anything. The technology is so advanced; they can, and do suppress memories at a push of a button. Therefore, the victim wakes up the next morning and will not remember a single REM driven duplicate clone experience. All that they will be aware of is that they did not have a dream the previous night.

This is what happened to me for over 25 years. I wasn't allowed to remember these REM driven duplicate clone experiences until I turned 30. My memories were suppressed for 25 years. I would wake up many days, after a night's sleep, thinking 'I didn't have a dream last night'; or I would wake up the next morning and I would be sick, although I went to sleep the previous night feeling completely healthy. Throughout the years, I thought I had terminal illness; because whenever I went to see a doctor, the diagnosis would always come back that 'there was nothing wrong with me'.

However, over the course of 25 years when I was memory suppressed, and not allowed to remember my REM sleep driven clone experiences, the Illuminati were using me to produce songs, lots and lots of songs, and whenever I could not produce a song, or did not want to, they would stab my REM driven clone body; sodomize my REM driven clone body; chain me to a crucifix and burn my REM driven clone and torture me for all kinds different reasons; and even when I was compliant and did what they told me to, I was attacked, simply because some members of the Illuminati wanted to know what it feels like to stab someone. Now because consciousness is linked (Ehrsson 2013), all these REM clone torture experiences affected me in my original body, and I have a weak heart today because of it, at the age of 39. The memories of my REM clone driven experiences also had to be released to me slowly (see Alford (2014) and FW: Thinking (2014) –for an example of how memories can be wiped and restored) over the course of many months because I had been through so much horror and torture that if the memories was released all at once, I would have had a heart attack in my real body and died.

This is one of the main reasons the Illuminati currently use REM sleep driven cloning (besides sex and torture): to plagiarise talented people under duress. There are many people including me who have been, and are plagiarised on a daily basis. Their consciousness is transferred to their REM driven clone alternates, and night after night and under duress they are forced to reveal their money making ideas or face torture or clone death; clone death after clone death. That is what the movie *Inception* (2010) is about: REM sleep driven cloning, and stealing ideas from the minds of unsuspecting individuals. The Illuminati actually made the film *Inception* (2010) as well as *The Island* (2005), *Avatar* (2009) and *The 6th Day* (2000); the films mentioned above contain references of cloning and REM driven cloning to show off the Illuminati's 'power' and throw in the world's face and laugh.

The Science of REM Driven Cloning Began in 1945

I am one of the few people fortunate, or unfortunate depending on how you look at it, who remembers all of my REM driven cloning experiences because these memories were released to me at the age of 30. I remember many people who have attended and still attend the cloning centre which they bring me to over the course of 34 years. I am currently 39 years old and was brought there since the age of 5. The science of REM sleep driven cloning was first discovered in 1945, and at first it was just a political thing which leaders of the world did. Through the science of REM sleep driven cloning, political figures, heads of state and royalty met each other as REM driven clones versions of their selves when they went to sleep and discussed worldly affairs in complete secret with each other. They also did whatever they wanted with each other as REM driven clones, which they could not do in their original bodies such as sex, fighting each other to the death, jumping off cliffs as their REM driven clones, and just about anything you can think of when one has the ability of pseudo-immortality as a sleep driven clone version of themselves hidden from the guise of the world and general public.

Well they soon got bored of each other very quickly, and started to make REM driven duplicate clones of movie stars, musicians, celebrities and public figures from all walks of life to hang with as REM driven clones and now they all get together for a disgusting time as REM driven clones when they go to sleep. Most of the G20 political leaders meet at the cloning centre as REM driven clones when they go to sleep to discuss worldly matters and watch gruesome things done to innocent and unsuspecting civilians, who are also REM sleep driven clones at the cloning centre, but civilians have their memories suppressed. This is what the films *Hostel* (2006); *Hostel: Part II* (2007); and *Hostel: Part III* (2011) (Illuminati made films) -are about: -rich people paying to torture and kill innocent people at a secluded location for sport; just that at the cloning centre, the Illuminati members torture and kill REM driven clones of innocent people.

Therefore, depending on what was done to your REM driven clone, you could wake up the next day with a very intense headache in your **original body**, if your REM clone was repeatedly punched in the head; an upset stomach in your **original body** if your internal organs were tortured; achy limbs; and worst of all, feel sick all over; although the previous evening you went to sleep feeling healthy. Remember consciousness is linked (Ehrsson 2013), therefore whatever happens to your REM driven clone will affect you in your original body. Even when they suppress your memory; the previous night's experiences still affects you in your original body. You wake up with the knowledge that you did not dream the previous evening when you went to sleep, and with certain illnesses depending on what was done to your REM driven clone.

Help Donald Marshall STOP REM Driven Cloning NOW!

Everything I discuss in this disclosure is firsthand witness accounts. I have seen and experienced horror spectacles done to innocent civilians and to me. For the sake of humanity and the innocent children brought to the cloning centres all over the world; I must tell the whole world about this and the good people of this world **MUST HELP ME TO BRING THIS TO A STOP.** My sense of duty, moral correctness, and conscience cannot allow me to stay silent about this evil. REM sleep driven cloning, and the torture of innocent civilians as REM driven clones; having REM driven clone sex with beautiful, innocent unsuspecting civilians of the world; the paedophilia of children through the process of REM driven cloning; REM driven sex slavery; the plagiarism of talented individuals through the process of REM driven cloning; and REM driven idea slavery, whereby talented individuals must produce new ideas and concepts daily (or whenever they sleep) or be stabbed or tortured in their sleep as REM clones –is the most vicious and pernicious form of tyranny ever to occur against humanity and **IT MUST BE STOPPED NOW!**

Do Not Panic, Riot, or Cause Chaos. This is Very Important.

Now I must preface this carefully, because members of the Illuminati have told me that I have to put this in an eloquent fashion, in a way which does not make people panic because people finding out about REM driven cloning, and the extent of the evil it has been used for, and continues to be used for; it could cause loss of social order, riots and anarchy in the streets. Moreover, I too **DO NOT** want riots and anarchy in the streets, despite the fact that I am vehemently angry considering the extent to which they plagiarised my talents over the years. If you are a good person reading this, and you want to help and you want social order restored for the benefit of mankind, promise yourself; me; all the innocent children they have affected through REM driven cloning, and the children of the future that you will **NOT** riot, and destroy a world for children who are going to inherit the world. **This is very important**. Remember the Illuminati have highly advanced technologies (kept hidden and secret), including weaponry, and they are just waiting for any excuse to use it on the populace. In all revolutions, the populace always win, and I want this disclosure and the end of REM driven sleep cloning to go smoothly. I want the good people of the world to keep spreading this information, keep spreading this disclosure all over social media, tell your close friends, your family, and as many people on social media platforms as you can. The internet, and radio shows with small audiences are the only forms of communication the Illuminati do not control. They own all forms of television networks, even including the Aboriginal People's Television Network (APTN), and therefore a message as important as this will never reach the average man or woman through television because it does not serve their agenda.

Spread this Disclosure Document until it reaches the Armed Forces

I want this message to reach the armed forces, because currently people in the armed forces are following orders, yet they do not know how corrupt their governments and people in high profile places are. They are unknowingly defending these corrupt people. People in the armed forces will **NOT** defend these corrupt people nor will they harm civilians when they realise that these corrupt people have been growing duplicate clone bodies of civilians, transferring civilians consciousness to their duplicate clone versions when the victim reaches REM sleep, and torturing civilians in their sleep; having sex with under-aged REM driven cloned children; having sex with innocent and unsuspecting adults as REM driven sleep clones, against their will; torturing REM driven clones for sport; and for money-making ideas to benefit their own pockets while they make innocent civilians sick and have side effects in their original bodies from REM sleep driven cloning technology. No. The armed forces will not accept that. Therefore keep spreading and sharing this information for everyone to see so that it reaches personnel in the armed forces **ASAP!** I want the armed forces to overthrow these corrupt people. The Illuminati think they are very sly and untouchable because together they hold most of the wealth in the world. We must show them that they are not untouchable. Please do all you can, to share and spread this message. It is the most important message to ever reach the internet because it affects all our liberties.

I must also address the readers who may feel afraid in spreading my message because they may want to do the right thing, but they are terrified the Illuminati may degrade or end their lives. As unbelievable as the next thing I am going to share sounds, it is a belief system which shapes the reality of the Illuminati and therefore they themselves are afraid to do anything which may degrade their lives or 'eternal soul'.

They believe that they are the 'fornicators' mentioned in The Bible, and if they were to degrade or harm the lives of anyone aiding me, they would suffer the wrath of God when they die. Notice I said **when they die**, but so long as they are still alive they can do all the evil they like, with little consequence, as they do in their REM driven clone versions at the cloning centre; worshipping Lucifer and doing all sorts of ungodly things. They even say God does not exist, only science and technology; yet they are afraid of dying. Very afraid of dying; because they believe they'll meet God's judgement. I'm just relaying what they have told me. They are weird like that. They also follow Hopi Indian Prophecy, Mayan Prophecy and Nostradamus Prophecy. They mix and match those three prophecies and come up with their own religion of what may or may not happen in the future.

Donald Marshall is NOT "The New Age Saviour". Nobody wants to be a 'saviour'

Furthermore, **THEY** believe I am a new age saviour for the end times; that I was going to save the world from something, according to the Nostradamus prophecy (quatrains); the Illuminati consider Nostradamus the greatest prophet ever to walk the earth. They are in awe of him.

I **DO NOT** endorse their claims. I just want REM driven cloning to stop and these people face punishments for their crimes against humanity. I really do not endorse such claims, but if it saves my life and yours, so be it. In reality and practicality, nobody wants to be 'the saviour'; not with such tyranny and pernicious evil such as this. We'd rather all just be living normal lives without the knowledge and practice of REM driven sleep cloning which is used for torture, clone death spectacles and sex with children. My friends on Facebook do not want to be heroes or 'saviours' either; nobody really does, but we do it out of a sense of duty, moral correctness and our conscience would never rest knowing the true extent of evil in this world, and doing nothing to end it. So all that saviour and Nostradamus prophecy talk, it is just the Illuminati; they like to quote prophecies, and make them come true to make themselves feel special.

Like I said, they are weird. I'm just relaying what they say, and I **do not** endorse the new age saviour claims. I'm just a normal guy, who was unfortunate to be cloned when he had his foreskin removed at age 4. This could have happened to anyone. Thankfully I had a very active imagination at the age of 5 and with the use of the technologies such as Mind-voice technology (that is what the Illuminati call it) it allowed me to make songs to keep the perverts off me. Mind-voice technology is just a technology which can tune into the inner voice in your head (See articles by Prigg (2014) and New Scientist (2014) –which discuss how scientist can listen to your inner voice; –it is similar to how Mind-voice technology works). Therefore, when you hear the sound of a guitar; the sound of drums; or any instrument for that matter; after hearing the sound, when you imagine the sound you heard, your REM driven clone can replicate this sound with Mind-voice technology **exactly**; and I used Mind-voice technology to make many, many songs over the years. As I've said, and I'll say it again: technology today is very advanced.

How the Nostradamus Prophecies shapes the lives of the Illuminati

Also another reason they have not killed me is because the Illuminati said "If they do, everyone is going to know I am telling the truth", -which I am with my right hand to God and I cannot lie about this stuff; the things I have seen are too sinister and diabolical. It would make me as bad as them if I did. Furthermore, because they follow the Nostradamus prophecies religiously, they have told me that they believe anyone helping me is considered part of "The Army of Light" and again, to hurt or degrade anyone helping me, considered part of The Army of Light would incur the wrath of God; and that to hurt anyone considered part of The Army of Light will degrade their lives; they will suffer misfortune and entire ruin as will their eternal soul. These are just some of the interpretations of the Nostradamus quatrains they have relayed to me. These people are beyond crazy, zealot and religious fanatics. Nevertheless, the main point to remember by all this is that **you are safe**, and **they cannot hurt you**, **they are scared to hurt you**, as well as kill me because prophecies have shaped their lives and the lives of their ancestors for hundreds of years.

Furthermore, and practically, I have told too many people that this is the extent, to which technology has developed in our current day, and it is kept secret and hidden from the public for nefarious purposes and this is what the Illuminati do: REM sleep driven cloning. I have been spreading this information **since 2011** and not one of these high profile people, government officials or celebrity figures has issued a (public) statement against me or taken me to court over libel charges because I'm telling the truth; and their statements would not hold in court.

I have also told over a million Arabs; I have appeared on radio interviews with Vinny Eastwood (Vincent Eastwood 2013); Jeanice Barcelo (Jeanice Barcelo 2013); and Lisa Phillips on the Cry Freedom Radio show (Astral 7ight 2013a – 2013h). I have reached audiences as many as 280,000 views on the Vinny Eastwood Show (Vincent Eastwood 2013) alone. However, I must stress that YouTube reduces the view count of my interviews every so often in order to suppress the truth so that my interviews do not get featured on their platform. Nevertheless, there is safety in numbers and rest assured there are new people waking up to the disclosure of REM driven sleep cloning every day; and therefore you can share and spread this information **without any worry** about facing reprisals from the Illuminati, even if you do not believe that it is in fact their beliefs in Nostradamus prophecies which is saving you and I from the Illuminati.

HIV/AIDS has been cured; so have many forms of cancer

Now is also a good time to share with the reader that this situation is not all 'doom and gloom.' In their quest to perfect technologies, science and medicine, the Illuminati discovered the cure for HIV/AIDS; cancer (except pancreatic cancer); Alzheimer's; Dementia and many more debilitating diseases which humanity suffers with. They relayed the fact that they found the cure for HIV/AIDS by stimulating the cells in an oxygenated rich environment because diseases/viruses cannot thrive in an oxygenated rich environment (in layman's terms). Magic Johnson was cured from AIDS this way and they use him as a spokesperson to sell the retrovirus pills which they know is not as effective. However, the greed these people have, knows no bounds, and because they receive too many donations for HIV/AIDS as well as cancer donations they do not announce they have cured HIV/AIDS or cancer publicly. As I've told you, and will continue to tell you: technology is far, far, FAR advanced than what you currently see around you. With the help of the good people of earth I promise to release these technologies for the benefit of mankind, and all reading this disclosure can hold me to this. You **must** hold me to this. It is time we ended corrupt governments and corrupt individuals in high positions of power in this world. Hold me to this.

I hope you are now beginning to understand why this is a **world emergency** and why these corrupt people must be ousted and overthrown. I also hope you understand why you must not riot or cause chaos because as I said at the beginning of this disclosure "I write this to empower good people of the world against the tyranny which exists all around us in our world today"; I **did NOT** write this to cause chaos, public dissension or anarchy. Good people of the world will inherit the earth once these corrupt people are overthrown. Therefore, under no circumstance must you destroy the world when you are going to inherit it. No matter how angry this disclosure makes you; no matter how angry the diabolical people who commit these crimes against humanity make you feel. Let's make sure this goes smoothly. Keep spreading and sharing this information, until this disclosure reaches the armed forces; until the armed forces bring these corrupt people to their knees. We are about to inherit the earth; by all means let's ensure everything goes smoothly. Now that you understand how important this disclosure is and that the overthrow of these corrupt individuals must progress smoothly, I'll continue.

The Behaviour of High Profile People at the Cloning Centre

The high profile individuals who attend these REM driven clone gatherings in their sleep have nothing better to do than to show off in disgusting ways. They have no shame and it seems nothing embarrasses them. Some REM sleep driven, cloning centre attendees, sit in the stands of an unused arena, smaller than a hockey rink, but it still has the capacity to seat between approximately 300 to 400 people. There is dirt in the centre of the rink where ice would be. They have frightened REM driven clones of children walk into the middle of the dirt rink to be victimised for a bizarre and disgusting spectacle. Sometimes, they have animals like dogs have sex with the REM driven clone children, while a man holds the dogs on leash so that it wouldn't bite the child on the back of the neck; which I have seen happen before. They all try to outdo each other in their levels of depravity; to be evil is to be "cool" to them.

The Ring Leaders of the Cloning Centre

I will now discuss the ring leaders, but before I name names, please understand that I am not someone who has collated stories and evidence together over the internet. I REALLY **do not** need to do this. Every time I enter REM sleep, the ring leaders at the cloning centre transfer my consciousness to a duplicate clone version of me. I have seen and talked with these monsters over the course of 34 years as REM driven clones at the cloning centre. However, I do understand that for the average reader, without understanding how far medicine, science and technology has advanced; without seeing or hearing people, other than me, discuss the crimes the ring leaders of the cloning centres commit, it is very difficult to imagine that this is what these high profile people are involved with, and do. Nevertheless, I guarantee it; this is the true extent and prevalence of evil in our world.

Their public personas, and public images is well managed by their PR teams, and therefore for the average person it is difficult to imagine these people in any other way but "positive"; but these people behind closed doors are the most evil, sick and twisted people I have ever had the misfortune of encountering. It is also difficult to take in what I am saying because I am not a public figure, nor do I have the "influence" or public image these people have; the general populace have never met, or heard of me, or known who I am; if this was the case my eye witness testimony alone will be enough; however, I do understand that we are dealing with highly advanced technologies, thousands of years advanced compared to what the general public is accustomed to, and because of this I provide references for the reader; I provide references for the reader to have something to corroborate what I am disclosing; and I provide references for the reader to see past the illusions these people have created.

Moreover, as "Consciousness Science Kept Hidden" demonstrates (YesEthan 2013):
remember that it is the heart and not the brain which is the most powerful centre in the body, the heart is the most intelligent; it has the ability to receive precognition and intuition about a future event, **before it actually occurs**, therefore if you find that your heart is in resonance with the names mentioned; do not fight it with the ego of the mind; when our egos get in the way it overrides our heart's intuition; your heart is capable of discerning the truth of an event before your brain becomes conscious of it; by all means listen to your heart, and allow your brain to naturally develop its intuition. It will be the coherence between your heart first, and then your mind centre which will allow you to access your intuition.

The references I provide for the reader to corroborate what I am about to say includes: "Appeal from Survivors of Canadian Genocide" (inifiniLor 2013); Tila Tequila –"Missing Children and Cloning Centres" (Astral 7ight 2013i); "Royal Babylon by Heathcote Williams" (MrCowshedder 2012); and "THIS MOVIE WILL BLOW YOUR F%SNG MIND" (KafkaWinstonWorld 2014).

Watch all the above videos and you will easily see all that I disclose. In Appeal from Survivors of Canadian Genocide interview (inifiniLor 2013): Listen to the indigenous people Stee-mas and Wahtsek speak about the pain and torment they have suffered under the Crown, the Vatican, the government, and churches of Canada. 50,000 to 150,000 indigenous children have gone missing because of the involvement of the Crown, the Vatican, the government, and the churches of Canada; and all these factions involved know this!

Tila Tequila is a television personality who has attended the cloning centres as a REM driven clone since childhood. In Tila Tequila's radio phone in (Astral 7ight 2013i), the audio is not very clear for the majority of her disclosure; she was also frightened and therefore she sounds most animated; however her words are clear at the following points of the audio (I also provide a transcript in the appendices section: "Appendix A"):

4.00 min: Cloning Centres and they take your children...
4.25 min: –There are these CLONING CENTRES –I'm not even talking about child molestation here...
5.40 min –They take your children –they not only molest them; men f*** them; and make them shoot each other...
7.59 min- There is a point where you cannot just turn the other way, you know this stuff is going on and you go 'oh well, you know... that's their problem; let's just turn the other cheek. How long are you going to turn the other cheek until it happens to your own freaking children?

10.34 min - Do you know why they love children? Because they are innocent souls; they are innocent... they are the most innocent, pure beings in this planet. They are not harmed by anything. They are new to the world; bright-eyed, pure innocent children. That is why these disgusting paedophile... and these clone rings, cloning centres, satanic rituals, Brownsville Texas... there are many of the of the cloning centres where they take your children that go missing.

Royal Babylon by Heathcote Williams (MrCowshedder 2012) addresses the fact that for Brits, despite their inordinate pride about their tradition, it is often revealed they know little about it than anyone. The documentary then goes on to address the fact that Prince Phillip the Duke of Edinburgh, has a lust for blood-sports which includes shooting endangered wildlife and mammals which he considers 'culling'. The documentary is also notable for demonstrating to the viewer that Queen Elizabeth II redistributed as much as 2.1 million for her private income from 276 people from Merseyside and Lancashire. These people had no will, so their property was grabbed. The same is true for the Duchy of Cornwall. If you die without making a will, everything you possess will go to Prince Charles. Furthermore, Queen Elizabeth II is the largest land owner on earth. Queen Elizabeth II: head of state of the United Kingdom, and 31 other states and territories is the legal owner of about 6600 million acres of land; one six of the earth's non ocean surface. She is the only person on earth who owns whole countries, and who owns countries that are not her own domestic territory. This land ownership is separate from her role as head of state; is different from other monarchies where no such claim is made –Norway, Belgium, Denmark etc. The value of her land holding is £17,600,000,000,000 (17.6 trillion Pounds) (approximately)).

In "THIS MOVIE WILL BLOW YOUR F%SNG MIND" (KafkaWinstonWorld 2014), readers with a deeper knowledge of the Illuminati and the agenda of the Illuminati will easily spot the minor inaccuracies in the documentary. However, the documentary provides a good reference and foundation for anyone new to the topic of the Illuminati and their agendas for the world. The documentary demonstrates how the world is currently a deception within a deception coated in reverse psychology. It gives widespread insight into the Royal family of England, and their lineage.

Furthermore, the documentary provides information that the world's most popular religions have been infiltrated with Illuminati dogma, in secret. The documentary details how (some) modern Christians, Jews, and Muslims do not (yet) recognise their common enemy because that enemy is invisible (until now). The enemy hides within their own religions. The enemy also hides within the activist community (anti-Illuminati movements), it finances big budget documentaries and movements. The end game is to sell a divisive (creating strong disagreement), anti-capitalistic, atheistic message and deliver trusting followers right into the lap of a communist (one government) New World Order. The enemy is the Illuminati.

The documentary also details that: "Today, the bloodlines of this unholy alliance are on the final stages of establishing one world religion, one world government, and one world ruler [--that is **IF**, the good people of this world do nothing to stop them]. The Windsor Royals are at the control of this web of deceit. It is a known fact that Adam Weishaupt (the founder of the Illuminati) took refuge and got assistance from the German Saxe-Coburg Gotha Royal family. The Saxe-Coburg Gotha's changed their German name to Windsor (in 1917). The Windsor's public image is a façade, to hide the cesspool from which they operate behind the scenes; their power and control cascades out of Buckingham Palace to the elite bloodlines who run world affairs."

For anyone who thinks they know they Royal family of England, did you know that still to this day: they have a person appointed called "Groom of the Stool"? What is a "Groom of the stool", you may ask? A Groom of the stool is responsible for stools. The kind you sit on and the kind you expel. In other words a Groom of the stool wipes Royal bottoms. The above has been confirmed to me by Prince Charles of Wales himself as REM driven clones at the cloning centre, and I quote: "It gives you the feeling of being completely taken care of" when I asked Prince Charles (as a REM driven clone) why they still have that. But don't just take my word for this; research "Groom of the stool".

The Royal Family of England

As most of readers have already guessed; and as unbelievable as it may currently sound to some readers, the ring leaders of these cloning centres includes the royal family of England. As I've said REM driven cloning started as far back as 1945, and it was just a political thing, but Queen Elizabeth II has been involved with REM driven cloning since its inception! Yes! Queen Elizabeth II; Phillip, Duke of Edinburgh and Prince Charles of Wales are the worst of them. They are unbelievable depraved perverts all showing off to the celebrities who attend these REM driven clone gatherings. Elizabeth has the REM sleep driven cloned children at the cloning centre call her "Lilli-bet" and Elizabeth as a REM driven clone herself does ungodly things to these REM driven cloned children. Some she fakes being nice to; some she is terrible to; and as a REM sleep driven clone Elizabeth cuts these REM driven clone children with swords while they scream. The decent people at these cloning centres who have had their consciousness transferred into their duplicate REM driven clones, and are there against their will, like I am; they are terrified to say anything against Elizabeth and her cronies. Most of these decent people also have their children's consciousness transferred into their REM driven duplicate clones, and Elizabeth and her cronies hold these decent peoples' children as hostage; to be torn apart; clone death after clone death if they have the slightest inkling of informing anyone, but as Elizabeth and her cohort have been torturing me as REM driven sleep clones anyway, I will disclose all that they do.

Vladimir Putin is also there, as an REM driven clone, and he loves to put the fear of torture and death into people, but he is essentially a perverted coward himself. Most of the famous people who attended the cloning centre as REM driven clones are ashamed to speak or be seen by me there very much; because they are ashamed of the perverse and disgusting gatherings. I am a decent person, even when my consciousness is transferred to my REM duplicate clone alternative, and I will not participate in these depraved acts; so they use me as an example and torture me for being a good person. They have drugged my REM driven clone, and as I've mentioned because consciousness transfer is real (Ehrsson 2013) and because consciousness is linked, therefore everything feels "real as real"; when I'm drugged as a REM driven clone, I behave exactly as any person would on hard drugs (although I have never taken any drugs in my original body); my vision is blurry and my balance affected; they have used this as method of having me do disgusting things in a blurred state, videotaping these dirty acts and editing a highlight reel which also depicts me doing disgusting things to show to the world when the world learns of their depraved natures and their public personas are shattered so that I can be despised as much as they will be when the entire world learns about this. Furthermore, because of the microchip inserted in my REM driven clone; they mind controlled me like a "Manchurian Candidate" (*The Manchurian Candidate* 2004) using MK Ultra technology, which is far more advanced than the declassified MK Ultra techniques (MK Ultra Compendium 1980) mentioned online today which references MK Ultra techniques in the 1970s. See Rense (2001) for a detailed explanation of how implanted microchips work, and how these chips allow the programmer control victims. C.S.I.S Canadian intelligence are all involved; they have REM driven clones too; including a lot of Commissionaires and Canadian Prime Minister Steven Harper himself; They do what Elizabeth says, and seem to follow her every whim without question. It doesn't matter who you are; if you have a cute child, or a talented child with imagination, creativity and moneymaking potential (such as business smarts; song making ability; literary / oratory ability etc. –you name it so long as your child has moneymaking value to them) they will send for the blood record of your child; agitate the blood cells over and over until a duplicate clone of your child is grown; they will then transfer your child's duplicate clone body from the tank they were grown onto a steel rack; the steel racks contain 5 rows and each row holds a duplicate cloned body; once your child goes to sleep in his or her original body and once they enter REM sleep (90 minutes to 110 minutes after they first fall asleep) the Illuminati are alerted to this fact by a green light above your child's duplicate clone at the cloning centre and they then transfer your child's consciousness to the REM driven duplicate clone; this is the point where the prime evils molest your children; and so your children are being molested in their sleep as REM driven clones and then they suppress the child's memory or implant false memories (see Kim (2013) and Alford (2015) –on how false memories can be implanted) so your children wake up not remembering dreams from the previous night, or if they do remember anything, the memory is false. These depraved acts very much stunt children's development; it causes them to have learning disabilities; unexplained depression; loneliness; suicidal thoughts, and all kinds of side effects.

The cloning centre is a paedophiles paradise and **it must be stopped**! Elizabeth secretly owes a few music companies too (Universal and others) with bands under contract; she forces me under a knife to compose music for them; if I can't she will stab my REM driven clone; burn my REM driven clone and have her pervert thugs smash my REM driven clone body there. As Ehrsson (2013) demonstrated, because consciousness is linked; and consciousness transfer leads the person who has had their consciousness transferred to still perceive reality as "real as real" in the new body; I have the same biological and physiological responses as I would have if these attacks were occurring to my original body. This has caused me to have heart damage and severe debilitating headaches. Because my memories were released to me; I can now also remember all my past REM driven clone memories since age 5; as well as the previous night's REM driven cloned memories (when I have my consciousness transferred to the cloning centre) which causes severe stress to my mental psyche and mental well being.

As unbelievable as the above statement sounds regarding Elizabeth's ownership of music companies, just go and listen to the song "Abadon" performed by Boondox (RainmanJhof 2011) on YouTube. There are two "Abadon" versions; the version you seek can be found in the Reference section uploaded by RainmanJhof (2011); skip to 2:46 min (or listen to the whole song; pay particular attention at 2:46 min) and you will hear loud and clearly, Elizabeth say "Drop the mother f****ing base". That is Elizabeth's voice; you can compare it to any of her Christmas speeches. That is her. Elizabeth said the above as a REM driven clone at the cloning centre. I know. I was there. They got so confident, that nobody would ever find out about their REM driven cloning shenanigans, that they even had me sing on a song I produced: "Where'd You Go" –Fort Minor (Murdok Dubstep Remix) (MurdokDubstep 2010), available on YouTube. Tila Tequila and I sing on this remixed track as REM driven clones (MurdokDubstep 2010); I start to sing from 1:44 min onwards. You can compare the voice you hear in the song with the Vinny Eastwood interview (Vincent Eastwood 2013). That is me, in both cases, and that song was recorded at the cloning centre.

One good person at the cloning centre; Bernie Mac (also as an REM clone version of himself); who was an actor and comedian, tried to stand up for me and speak up for me saying ‘Cloning and torturing people here, it’s not right to do to a human being...’ and “This place is the devil”’... Bernie Mac also tried to have others join him in speaking out against the REM driven clone torture zone while he was having his consciousness transferred to his REM clone driven version. Elizabeth and Philip tortured him for 4 to 5 hours continuously at the cloning centre as an example of their ‘power’, Bernie Mac had an aneurysm (brain bleed) the next day and died. This is one of the aspects about REM driven clone torture: if you torture a REM driven clone continuously for hours on end, you will cause the person to die in their original body from a heart attack or aneurysm (while they sleep); even if they do manage to wake up the next day; because of the constant pain their consciousness has recorded; and because consciousness is linked they will wake up only to have a heart attack or aneurysm in their original bodies the following day. If you apply a constantly electrical current to a REM driven clone, that person will either have a heart attack or die from aneurysm in their original bodies while they sleep.

This form of murder is similar to the CIA’s heart attack gun (Non Mirage Truth Vision 2015); which was declassified in the 1970s and was a weapon used for causing heart attacks in victims, undetectable as the cause of heart attack under autopsy. The difference with REM driven clone death as a form of weaponry is that hardly anyone has heard of death by REM driven clone torture. Moreover, the perpetrator can be thousands of miles away from the victim; the culprit just needs a duplicate REM driven clone of the victim to torture or apply a constant electrical current to; this is exactly what is going on in our world every day. When Elizabeth and Philip don’t like someone and they want to get rid of that person, they clone that person; torture his or her REM driven clone till that person has a heart attack or aneurysm in their original body and dies.

This is what Elizabeth and Duke Phillip did to the indigenous people in Canada. The video reference (inifiniLor 2013) provided above, regarding the genocide of the indigenous people of Canada discusses this very topic (inifiniLor 2013). As Elizabeth and Duke Phillip visited Canada as clones, when they killed the native children; they both had solid alibis of being in England at the time. They then cloned all the witnesses of the Canadian missing children’s case and had them remotely killed by applying constant electric currents to their REM driven clones; one by one and each witness either died of a heart attack or aneurysm. They just dispatched the last witness by also applying a constant electric current to the persons REM driven clone because the missing children’s case was building momentum.

After Bernie Mac’s death everyone is afraid to speak up; they all became afraid of suffering the same fate. All it will take is a few lie detector tests from an independent source; and I will volunteer for them; they cover up for themselves so carefully that lie detector tests from an independent source unconnected to them in anyway will be the only viable method. I know many know non-famous people who have also attended these clone centre gatherings as their REM driven clone duplicate versions and also remember the clone gathering experiences in their original bodies (because they were not memory suppressed) that could be given lie detector tests to prove this. When it comes to the sexual exploitation of a child, lie detectors are admissible in Canadian courts. I need decent people with integrity to speak about this filthy business; to testify about who is involved. There is much to tell about the Illuminati and I am a wealth of information about this topic.

Elizabeth also had Princess Dianna Spencer killed by having someone shine the brightest light known to mankind through the window side on her car; they served away to avoid the light and hit the divider; it was no paparazzi. I first wrote about this in my original disclosure in **2011**; this was corroborated by an article 2 years **AFTER** I had made my original disclosure. See Radar Online (2013) for the corroborating article. Furthermore, "Candle in the wind" performed by Elton John (SadSongs4You 2010) was not Dianna's 'death song'; it was "Bigger than us" performed by "White Lies" (WhiteLiesVevo 2010). The Illuminati released this song, deliberately, 13 years after Dianna's death, again as a show of their 'power'. I did not want to compose this song but Elizabeth and her thugs threatened to stab and burn my REM driven clone repeatedly if I did not. Listen to the lyrics. I'll provide some of the lyrics here for those of you who are feeling too shocked by these revelations:

White Lies Lyrics "Bigger than us"

You took the tunnel route home.
You've never taken that way with me before.
Did you feel a need for change?
Apologies on your fingernails,
Love flickered in the city of lights
Like internet and radio waves.

I don't need your tears
I don't want your love
I've just got to get home

And I feel like I'm breaking up
But I wanted to stay.
Headlights on the hillside
Don't take me this way.
I don't want you to hold me
I want you to pray,
'cause it's bigger than us.

Are you beginning to see why these people must be stopped and stopped immediately? Are you beginning to see why it is no longer okay to 'turn a blind eye' or 'bury your head in the sand', and hope it all goes away? Can you see why I need the good people of this world to keep sharing this disclosure (online); to tell your friends and family until this information reaches the armed forces so that the armed forces can bring these people to their knees. I also do not want innocent civilians to get hurt despite the monstrosities these people cause to humanity on a daily basis. I want the overthrow to progress smoothly so that the good people of the earth can inherit the world, with all technologies and medical advancements which benefit mankind, made available to all. This is why I maintain my composure and resolve, in spite of the evil I see on a daily basis, and you the reader must also maintain your composure and resolve in spite of the evil which I am disclosing, so that we do not inherit a torn down world after we have completely overthrown these malevolent, sinister and corrupt hypocrites!

Furthermore, Diana survived the car crash; and while, either on her way to hospital or in hospital, Dianna was injected with a high concentration of salt, which is near undetectable in an autopsy and she died. Elizabeth did this because Diana was going to marry an Arab named Dodi Fayed. The Illuminati hate Arabs because for the most part, Arabs have not broken their relationship with God. Dianna hated her association with these people; Dianna knew about REM driven, sleep cloning and wanted nothing to do with it; but she was afraid of being killed and so said nothing. I know a lot about this and many more deplorable things the Illuminati have done over the course of 34 years and I will be more than happy to reveal all the evil they have done; as well as all the wonderful discoveries and progresses they have made in medicine, science and technology, which they have withheld from the general public. I am very happy to disclose all, because I known once the world learns of all they have done, we truly will begin to see the end of such evil on this planet. Just make sure you keep spreading this disclosure and it reaches the armed forces soon. Soon, soon, soon!

Help Donald Marshall by Sharing this Disclosure with Your Close Friends and Family

If you are reading this, then you have to help me. I know some of you may be reading this thinking, but I am just an ordinary man or woman Donald, I know you are telling the truth; I can feel it in my heart and my head that what you say is true and that you are telling the truth (which I promise you, with my right hand to God I am) but I'm just an ordinary man / woman Donald; I don't have any power; I don't have any influence; or because of the position I am currently in I can't speak out against these people; and I am just an ordinary man / woman I cannot be expected to take on the world's problems. You are right if you are thinking and feeling this, and I do not expect or want you to take on the world's problems. All I want you to do is share this information with close friends and family initially, because when you do that, at least that is one more person who will know about the true extent of evil in this world. When your close friend or family member also shares my disclosure with another close friend, the disclosure will eventually spread exponentially. It will also be one more person who has your well being in their thoughts because I understand how scary it is to know this. Therefore remember **there is safety in numbers;** and the more people you tell in your social circle, the more you can all look out for each other. So feel free to share my disclosure with close friends and family. Do not talk about my disclosure in public (for now) if it makes you feel uncomfortable. Moreover, if you want to reach more people (other than your initial social circle) the best way, is to do it online: through social media, such as Facebook, Twitter, and YouTube etc. As I've already mentioned, the Illuminati controls all forms of media except the internet.

The Illuminati, being so 'confident' at the time with the evil they wield onto the world, put my face on a Megadeth album cover titled *The World Needs a Hero* (2001) (to mock me) when I was 23. I posed for this album cover at the cloning centre when I was 23, and the album was released with a picture of my face, as a REM driven clone, 3 years later when I was 26. They did this because they were extremely confident that nothing would ever be proven. Google image it, although I am 39 now, you can still tell that it is me. The image shows what I end up looking like after an REM driven clone gathering with a skeleton popping out from my chest. I understand most of you are going to continue reading because although it is "liberating", it is also "paralysing" at the same time (Laurence Mountford) to realise what the truth of the world is, so I will display two images below, but promise yourself, that you will Google search this image in your spare time.

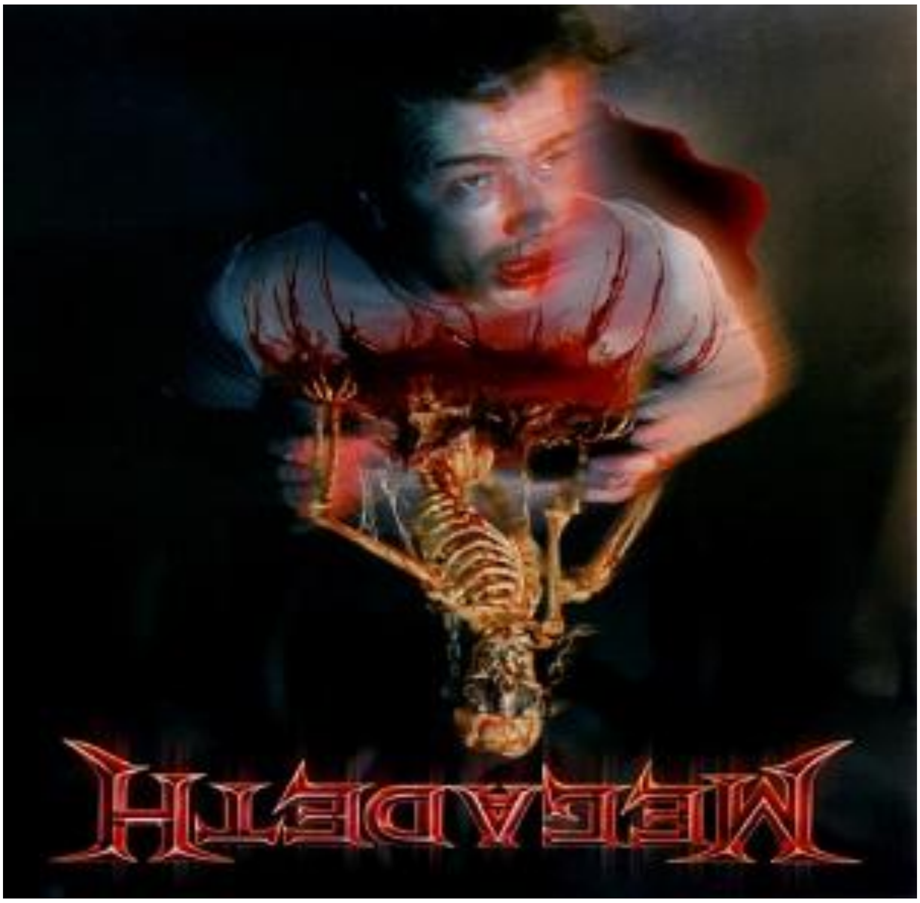

Image 3: Megadeth Album Cover: ***The World Needs a Hero*** **(2001)**

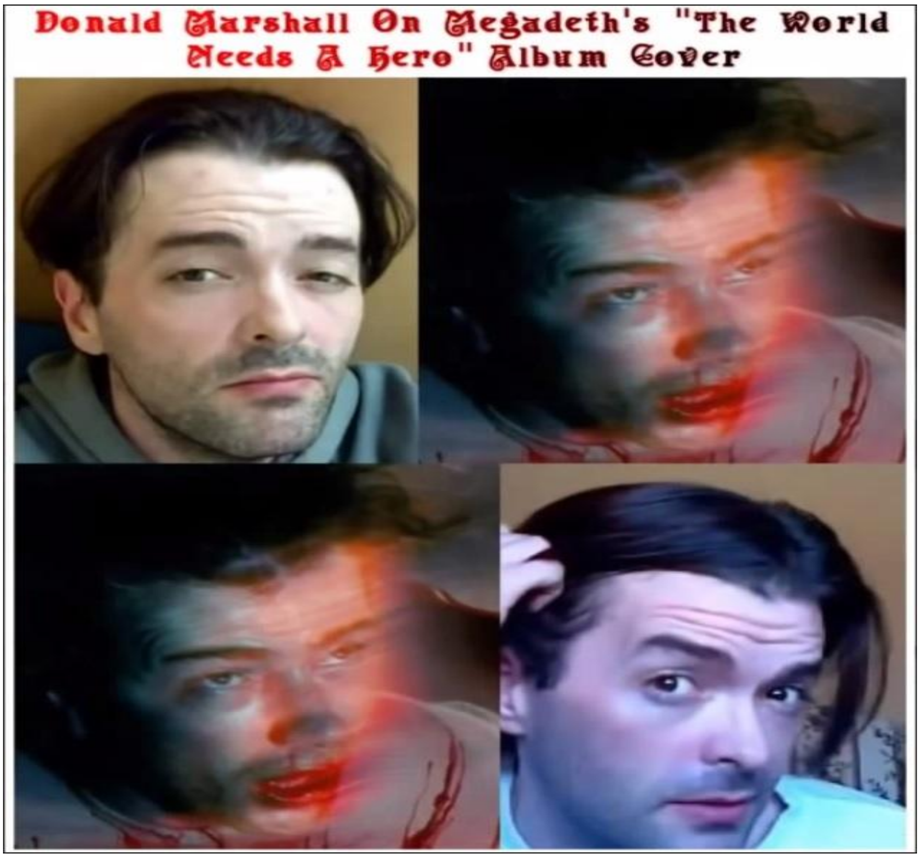
Donald Marshall On Megadeth's "The World Needs A Hero" Album Cover

Image 4: My original body: top left (age 37) and bottom right (age 37); compared to my 23 year old REM driven duplicate clone body (top right and bottom left) at the cloning centre.

You can clearly see from the images that, it is in fact me. In Image 4, you can also compare what my real body (top left and bottom right) looks like compared to my duplicate clone body. Duplicate clones do not come out of the tank looking 100% like the original; it's 99% - there are always some slight variations as some have commented that the eyebrows and nose in the picture, bottom right, is not the same (as the duplicate clone on the album cover). However, to people who make such comments, I say: my eyebrows and nose is the same when you compare it to the pictures of my original body (top left and bottom right). Also, remember that the image on the album cover is a duplicate REM driven clone of me. REM duplicate clones do not come out of the tank looking 100% like the original. There are always slight variations; but the wrinkles on my 37 year old forehead (when I took the picture in my original body; top left and bottom right) is similar to my 23 year old wrinkles, the lips are the same; and the face which you see, is definitely, the same! Yes. REM duplicate cloning is real; going to sleep and waking up as a cloned version of version of you is real and **we must put a stop to it now!**

The Deplorable Nature of the Illuminati

My own family has been turned against me one by one. The Illuminati have told my family members when they were REM driven clones at the cloning centre, things such as I secretly hit or molested their children; poisoned their pets when the pets died of sickness and other such things to make my own family hate me and not want to help me. Even when my family side with me there at the cloning centre, as REM driven clones of themselves; and my family members say 'They do not believe that Donny did all those horrid things' -which they have been told; Elizabeth then says "Are you cooling me a liyah?!" in her disgusting croaking voice made as low as low and evil sounding as she can make it, complete with psychotic and malevolent glare; and as terrified REM driven clones my family say "No, no, of course [what you are saying] it's true", stuttering and afraid as REM clones. My mother Catherine McMahon sold me into this REM driven sex and torture cloning slavery when she remarried a man named Gordon Cohoon; Gordon's whole family is in this scummy secret society, his brothers Tom and Tony Cohoon; his sisters Darlene and Bernadette Cohoon; they fear the new and improved lie detector tests; and all it would take, is for an independent source, far, far removed from any association with the Illuminati to administer these lie detector tests on me **AND** the above named people to prove this unequivocally.

Half way through the making of my original disclosure document (in **2011**), when I went to sleep that evening, the Illuminati transferred my consciousness to my REM driven clone and introduced me to a man (who was also a REM driven clone) named TROY LANDRY. He is an alligator trapper from Louisiana on the TV program named "Swamp People". Troy Landry said "If I send my [original] disclosure out to the public then he would take a power drill to my shin bone at the cloning centre and suck the marrow from my [REM driven clone's] bones." It is similar to spinal tap, and one of the WORST things you can do to a REM driven clone besides burning a REM driven clone. I told Troy that I will be sending out my disclosure to the public, because I have to escape the cloning centre, and so, Troy Landry did just that. It was excruciatingly painful; all the REM driven clones that were sat in the stands of the arena just watched; slack-jawed. Troy Landry is an insatiable child molester and an extra retarded REM driven clone. A side effect of REM driven cloning is that as a REM driven clone version of yourself, your emotions are heightened and you are less smart as you are when you are experiencing the world in your original body. Nevertheless, Troy Landry is extra retarded as a REM driven clone.

In Louisiana, when Troy sees a young boy that he likes, Troy asks of the boy's name and tells the boy "He is an alligator hunter"; Troy then proceeds to shake the boy's hand; Troy then has his paedophile friends at the local cloning centre find the boy's blood records to grow duplicate clones of the boy. Five months later, there are multiple REM driven duplicate clone bodies of the boy grown for Troy Landry to victimise before the crowd of onlookers. All members of the Illuminati do this; it's just a way of life to them; they consider themselves 'the privileged people' in the world power organisation. Almost all the cast on the "Swamp People" television program attended the cloning centre as REM driven duplicate clones of themselves, **when they go to sleep**. After putting a power drill to my shin bone, Troy Landry asked me again, "Will I send my [original] disclosure out?" I said "Yes" to which he replied "I'll do the same to your pelvic bone everyday!" The pain on my pelvic bone was far worse than when Troy put the power drill to my REM driven clone shin bone. I told Troy "I have no choice but to inform the public" – and so Troy put a power drill to my REM driven pelvic bone, everyday... and it is the worst pain ever... you forget your own name; where you are; all you know is pain; and you beg God or anything to save you from it...

Another deplorable thing which the Illuminati did in real life is: The Canadian government were trying to lower the amount of prostitutes on the streets (Elizabeth hates prostitutes) so they had a man named Robert Pickton start killing the women and feeding the women to pigs on his farm. The Illuminati had a camera set up in the upper corner of a room in Pickton's house and recorded Pickton hitting these women over the head with a hammer (a ball-peen hammer). They took the recordings, all 49 of these murders, and they all watch them at the cloning centre. To be seen as 'tough' at the cloning centre is to watch all 49 of the Pickton murders without having it affect your psyche. Elizabeth loves watching the Pickton murders and she says she has a macabre fascination with death. Canadian Prime minster Steven Harper knows all about the conduct of the Pickton murders; he has seen all the recordings and cheers on as the rest of them do. If Mr. Pickton says anything about his involvement with the Illuminati, or the recordings, they will apply a constant electrical current to his REM driven clone until Pickton has a heart attack or aneurysm in his original body.

What Happened to Britney Spears?

The Pickton murders are also the reason Britney Spears 'lost it' and shaved her head bald. She had watched too many Pickton murders as a REM driven clone at the cloning centre and it drove her 'over the edge'. I'll also reference the following songs performed by Britney Spears so that the reader has more corroborating evidence to add to the ever increasing pile. Search for the video "Break the Ice" (BritneySpearsVevo 2009) on YouTube. In the Japanimation video; at the beginning of the video; that is a cloned **cartoon** version of Britney Spears being grown in a big thick thank full of water (1 second to 7 seconds); and at 1:32 min to 1:43 min Britney walks into the cloning centre. This is **EXACTLY** how the cloning tubes are in real life. They are stacked one on top of the other, each filled with salty water. Britney Spears made this video because she said a fantasy of hers is to "Blow up a cloning centre". The Illuminati allowed her to release this video because at the time they figured nobody would ever figure it out. I have provided the images on the next page.

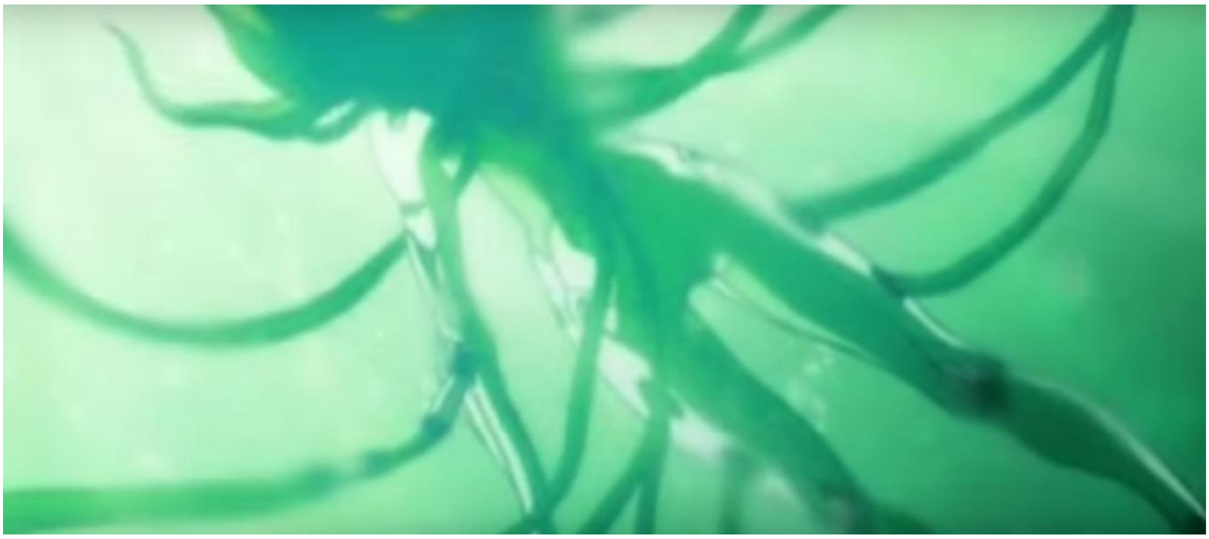

Image 5: Britney Spears is being grown as a duplicate clone in a cloning tube. The depiction is EXACTLY how the duplicate clones are grown in the Cloning Centre... with wires extending from the body; in a big thick tank full of salty water.

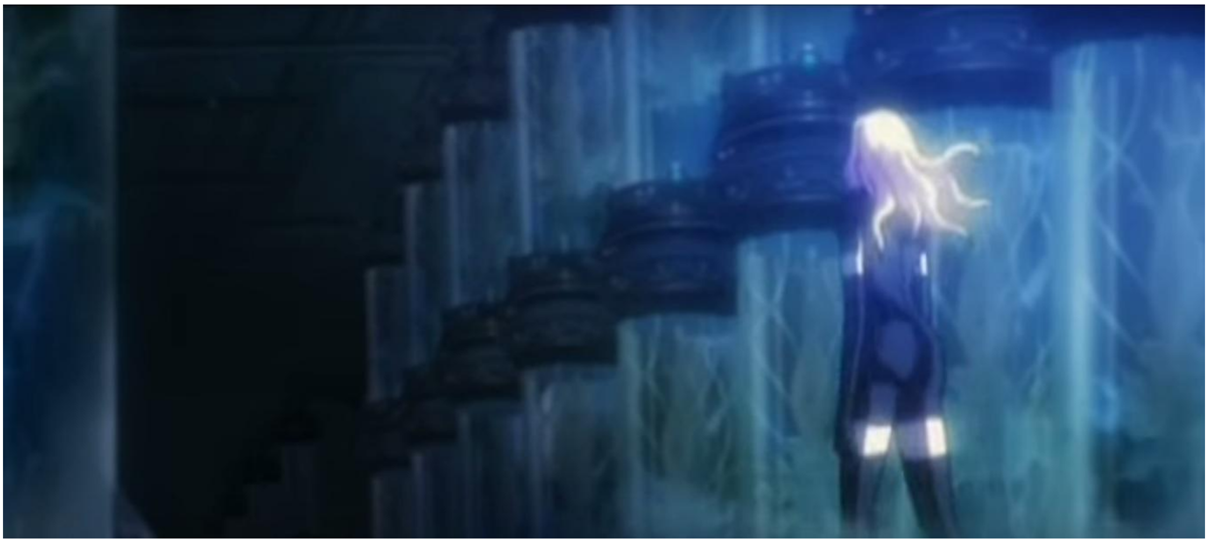

Image 6: Britney Spears walks into the cloning centre. The cloning tubes are stacked one on top of another. This is EXACTLY how these cloning tubes are in real life at the Cloning Centre.

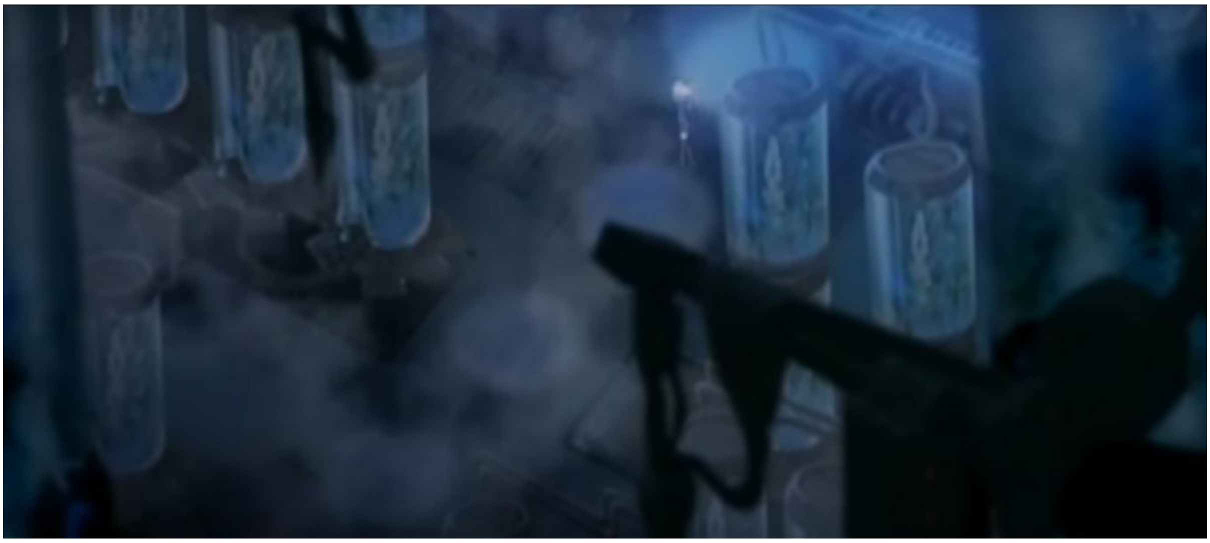

Image 7: The Cloning Centre depicted from an aerial view.

In “Hold it Against Me” (BritneySpearsVevo 2011) performed by Britney Spears; Britney is depicted fighting against her clone at 2:46 min till the end of the video. In “Mona Lisa” (SimpleGirl4ewer 2007) later remade by Britney Spears she changed the words in the song from “gone” to “cloned”. I’ll provide the lyrics to chorus here because they have not changed it on A-Z lyrics etc., but listen to the song and you will clearly hear the following:

Britney Spears Lyrics “Mona Lisa”

She’s the original (yeah, yeah)
She’s unforgettable (yeah yeah)
She wants you to know (yeah)
She’s been cloned…
It’s kind of incredible (yeah yeah)
She’s so unpredictable (yeah yeah)
She wants you to know (yeah)
She’s been cloned,
She’s been cloned,
She’s been cloned…

Yes. Britney Spears and many other celebrities want you to know they have been cloned. The celebrities are depending on you, the ordinary man / woman; the populace, as I am depending on you to spread this message fast and far. In fact Elizabeth has said that “If any public person speaks out, they will die!” Therefore, public figures cannot openly discuss this topic to warn the populace –so they hint. It is **NOW** up to the ordinary man and woman to end this. Furthermore, Elizabeth has a nuclear bomb hooked up at the cloning centre which she can press at any time to wreck havoc on the world unsuspectingly. Thankfully, I managed to convince Elizabeth not to do such a silly thing. I hope you can now understand why everyone is terrified of Elizabeth at the cloning centre, and why this is a **world emergency** and we are depending on you to share and spread my disclosure!

NEVER EVER SELL YOUR SOUL

In This Physical World Selling Your Soul Is Selling Your REM Driven Clone

Furthermore I must discuss an entrapment many up and coming ‘stars’ fall into. You have most likely heard many public figures say “I sold my soul to the devil” or some variation of “I sold my soul”. I am now going to address the aspect of “selling souls” or “selling your soul” which I am sure you have heard many of these celebrities talk about. I’ll address this as coherently as I can because the on the surface selling your soul talk is difficult to contemplate especially if you consider the soul to be a metaphysical, ethereal or mystical part separate from your earth body. Moreover, we live in a physical world, so selling a metaphysical aspect of you sounds incomprehensible (at first). For the most part we have little understanding of what the soul is. However, we are told that the soul is a part of us which never dies and it is eternal. It is all that we are, ever were, and ever will be. Now our faiths and beliefs come into question, because if you are an atheist: there is no God, selling your soul is a bunch of crazy nonsense.

From a practical perspective it also seems difficult to fathom, because if you go on what you have been told, you are selling an intangible part of yourself to be used by someone else for whatever they wish; and so if you get into the headspace of viewing your soul as something separate from you or that you are in control of your mind and your body, then again, 'selling an intangible aspect of you' again sounds like nonsense because right now nobody controls you; you are controlling you; so what are you really selling? Thin air?

Many up and coming 'stars' think this way when they are confronted with "selling their soul" aspect. The up and coming 'stars' are blinded by the prospect of being super famous and super rich; and in the moment they are confronted with "selling their soul" they believe these Illuminati people, are a group of over religious zealots and that they, -the up and coming 'stars' are taking advantage of the Illuminati because the 'soon to be 'stars'' do not believe (in that moment) it is possible to sell your soul, and only consider being super rich and super famous; so the 'stars' sign their 'soul' over.

At this point, it is usually too late for the up and coming 'star'; because what they have actually sold, in this physical world, is the use of their REM driven clone to the Illuminati. They have sold their REM driven clone to be used for REM driven sex by perverse old men and women whenever they enter REM sleep.

These celebrities are not memory suppressed either; so whenever they enter REM sleep, their consciousness is transferred to their REM driven clone, to be used for whatever the Illuminati wish: usually sex as REM driven clones with dirty and perverse old men in return for a promotion in the entertainment industry; such as movie role, advertisements, concert gigs etc. It is a very, very, sick business, and once these up and coming 'stars' get into the business they are trapped. Now you can begin to understand why so many celebrities, although on the surface it appears they have it all, are depressed; and do random and crazy things. It is a cry for help. Their illogical behaviours, (not all) for the most part, can be attributed to REM driven cloning. Furthermore, the Illuminati consider 'selling your soul' (the use of your REM clone) **a very serious business.** They do not joke about this; and there are NO RETURNS. Once you have sold the use of your REM driven clone for promotions etc., that's it. If you ever make a fuss and want your 'soul' back, in other words: you no longer wish to have your REM driven clone to be used by dirty old men for sex; the Illuminati will kill you by applying a constant electric current to your REM driven clone until you have a heart attack or aneurysm in your original body and die. It is as simple as that.

For example, Whitney Houston wanted nothing to do with the cloning centres, she said she would keep quiet; she never wants to be in the spotlight; she never wants to do radio or television. Let bygones be bygones, I'll go my way and you can go your way. The Illuminati were extremely angry! They had bank-rolled her, and now she didn't want to be their 'friend' or ever associate with them again. She was sacrificed; she was killed with a constant electric current to her REM clone. She had sold her soul, in the beginning of her career; in other words, the "use of her REM clone". Earlier in Whitney Houston's career, she had signed that they can use her REM driven clone however they wish.

I have also seen people say "No" –when confronted with 'selling their souls'. These people are then memory suppressed, and will not remember the proposal of their REM driven experience. The people who also refuse to sell the use of their REM driven clone ('sell their souls') are blacklisted secretly, and they will never receive a high paying movie role, concert gig, advertisements etc. If you have ever wondered why so many talented people have not 'made it' –they refused to sell their souls, in other words, the use of their REM driven clones in exchange for promotions. This is how the entertainment industry really works. Another aspect of selling your soul, in other words, **selling your REM driven clone** is that you are also agreeing to sell your children, and your children's children etc.; your whole lineage to the Illuminati; for the Illuminati to use your unborn children for paedophilia, torture, sex sports and other grotesque and ungodly things when they sleep. It is a nasty business. **NEVER EVER** sell your soul.

The lesson is very important. NEVER EVER, 'sell your soul'; NEVER, EVER! You will experience the worst nightmare situation ever, and in this physical world, that is the use of your REM driven clone to be used for sex sports. You'll never have a decent night's sleep ever again, and you will always retain the full memory of your REM driven clone experiences; as well as, you will be selling your unborn children into this dirty business. Even when confronted with this as a joke: never sell your soul. Never Ever! The physical aspect you are confronted with when asked to 'sell your soul' is: "YOU", and everything which makes you, "you"; your ideas, your creativity, your privacy, your biology; everything which makes you, you. Never sell your soul, which in this life is currently the use of your REM driven clone! Never, ever! I hope that is well received.

Fake Alien Abductions conducted through REM Driven Cloning Technology

I must add they grow duplicate REM driven clones of people from all walks of life and then they transfer the persons consciousness to their REM driven clone version at the cloning centre while the person's REM driven duplicate clone is chained down to stainless steel corpse tables; or they pre-inject the REM driven duplicate clones with drugs before transferring the consciousness so that once the consciousness has been transferred, the REM driven clone cannot move. This is the point when they usually send people into the room dressed as aliens. It is a fake alien abduction. It's just these Illuminati people dressed in Hollywood quality accessories and they make the REM driven duplicate clones which have either been chained to the steel corpse tables or pre-injected with drugs, believe they are having an 'alien abduction'. Members of the Illuminati even dye chicken skin grey, and stretch it over a mask for realism and perform "experiments" on the immobile REM driven clones; the perverts anally probe them; they rape their limb bodies and do not suppress the victims memories; so these victims wake up thinking they have been abducted by aliens but in reality, they had their consciousness transferred to their duplicate clone versions when they entered REM sleep and they were violated. The victims do not know where to turn and naturally, they are embarrassed. Some victims even try and do install cameras all around their bedrooms in order to videotape themselves while they sleep; to prove they have been 'taken'; but to no avail they have not been taken; they have been cloned and had their consciousness transferred to their REM driven duplicate copies once they enter REM sleep by the most disgusting perverts in the world. The scum even videotape these 'abductions' to watch later as sick demented porn. These fake abductions are conducted by the Illuminati more often than you can imagine. They just keep doing it to random people over and over and over...

I am THE Spy for Humanity against the Corruption of the Illuminati

Over the years the Illuminati have offered me: a priceless katana (samurai sword); a rigged jackpot winning lottery ticket; REM driven clone slaves to keep me quiet, any of the prettiest women I've ever seen; any girl from high school; Vladimir Putin's daughter; even children; I do the right thing and spit in their REM driven clone faces; jam my fingers into their eyes but they have the technology to turn off the pain sensors of a REM driven clone, and therefore they have their pain receptors turned off as REM clones, while my pain receptors are fully on (sometimes even beyond the threshold of what is normal pain for a human). See the online articles: Science Daily (2014) and RT (2014) which discuss how pain receptors can be turned on and off in humans. Not much will hurt their REM driven clones other than getting dirt or vomit in a wound or bleeding too much. However, they have perfected the science and technology of REM driven cloning and therefore it only takes time and approximately $30 to grow new duplicate clone bodies. I started to smear excrement in their faces as a REM driven clone at the cloning centre in an attempt to deter them; I have **never** handled faeces in my original body, but I do this as a REM driven clone at the cloning centre, and even that does not deter them from their depraved ways. I composed a song which was later performed by "One Republic" referring to it called "All the Right Moves" ("All the right friends in all the right places... All the right moves in all the right faces"). I've made so many songs with MK Ultra technology (Rense 2001; Jim Cristea 2009; Berekley News 2011; Mind-Computer 2012 nature video 2013) and Mind-voice technology (New Scientist 2014; Prigg 2014) it is ridiculous. You see it is very easy to make music using Mind-voice technology; Flo-Rida used Mind-voice technology to produce the song "Whistle" when I first made my original disclosure (in 2011). The song is a taunt at me about my "whistle blowing disclosure" i.e. 'Can Donald blow the whistle? Etc. etc.' The thing is, anyone with a talent for music can make music much easier with the technologies which they have (MK ultra technology; Mind-voice technology); however, the Illuminati made more money from the music I composed, and so over the years, they just kept using me, over and over and over again, for rock, pop, rap, country etc. There are so many people involved in this REM driven cloning business, it is staggering; the organisation is vast. The only things the Illuminati fear are nuclear war; the new and improved lie detector tests and the general populace spreading my DISCLOSURE DOCUMENTS.

For those of you thinking Queen Elizabeth II looks like a kindly little old lady and you still cannot believe that all this is true, although I have provided plenty of evidence to the contrary as well as evidence of her saying "Drop the mother f***ing base" as a REM driven clone on a song track (RainmanJhof 2011); you could not be more wrong. She is the worst human being I have ever seen or heard of. It is so sad to see these REM driven women and children having their consciousness transferred to their REM driven clone duplicates and brought to the centre of the dirt rink, sitting there naked, afraid and crying and raped and beaten for sport, for the rich and famous. REM driven cloned women and children display the most range of emotions, and it is the saddest thing to see there. Therefore, of course I cannot bring myself to be a part of this despite any riches which the Illuminati offer me.

Over the 31 years when I was having my consciousness transferred to my REM driven clone at the cloning centre; Elizabeth, Vladimir and many, many Illuminati members and cloning centre attendees discussed many topics with me. These Illuminati people, such as Elizabeth and Vladimir, as well as many others confided in me because I had composed songs since I was 5 years old.

For readers struggling with the idea that a 5 year old can compose such wonderful songs at such a young age I will remind you that, it is easier to compose songs with technologies such as MK Ultra and Mind-voice technology. One is only limited by their imagination and creativity. Moreover, research talented children. I won't provide references of talented children here because I want to protect children from the Illuminati, and not have children exploited like I was; and for the readers who are parents; I am sure you know how talented, creative, and imaginative your children are.

Accordingly, since the age of 5, Elizabeth, Vladimir and many, others confided me in me because they thought I was special, and wanted me to hang with them; some of these Illuminati people, I had composed their favourite songs; I was also memory suppressed for many years so they thought it was harmless to tell me everything that exists or is possible. They were trying to impress me and amaze me, and therefore they showed me plenty of their technologies and what they had. They wanted me to me a willing, full Illuminati member; so over the years I feigned interest and pretended to like these Illuminati people, so that I could learn what they do and how they do it. I was looking for a way to block the consciousness transfer to a clone during REM sleep, or hoping they would reveal this part to me; but they did not, and I did not find a method to block the consciousness transfer. However, I bided my time, until I knew just about everything they do; so that I could reveal to the world everything they do; to give humanity a fighting chance against everything they do and as a consequence, I became a spy for humanity against the corruption of the Illuminati.

The Threat to Humanity when the H.A.A.R.P Grid is Complete

One of the most important topics which they discussed with me that I must add to this disclosure is HAARP technology and their plans for HAARP technology. I have discussed the basics of HAARP above. HAARP radio transmitters have to be placed at certain points across earth to complete a 'HAARP grid'. Once all the installations are completed over the earth HAARP will have more functions as a grid than the basics described. The Illuminati have told me, there is a possibility the HAARP grid will be capable of time travel, although there is a 50/50 chance using HAARP for time travel could destroy the earth. They also told me that once the HAARP installations are completed, the HAARP grid will be able to bend space and make the distance between, for example, Earth and Pluto approximately 1000 miles for a few seconds, and then the distance will go back to normal.

The Illuminati also said, once the HAARP grid is completed, they would be able to mind control people like never before without the use of RFID microchips or MK Ultra. Life on earth will be much worse once all the HAARP installations are up and working together in unison. The grid has to be complete though. HAARP cannot achieve time travel manipulation and mind control if it is just located in one or a few locations around the earth. There must be a certain number of HAARP installations around the world, in certain locations around the world; and the HAARP radio transmitters must be working in unison in order to achieve time travel manipulation and mind control of the populace of earth.

This is what they told me as REM driven clones at the cloning centre. This disclosure could be false, or a half truth. I do not know. However, it is very important that I add this to the disclosure because the Illuminati are working twice as fast to complete the HAARP grid to achieve their aim of mind control over the entire population since I the time I sent out my first disclosure (in **2011**). Whether or not they will achieve their aim of total mind control once all the HAARP installations are completed is NOT something we can afford to debate. They also told me that once the HAARP installations are completed; they will have the capability to mind control anyone remotely like never before, at the push of a button. HAARP will also be capable of setting back time; which the Illuminati will use if they are ever in danger of being exposed. However, the Illuminati will remember the previous time, and the general populace will NOT remember the previous time, so that the Illuminati can correct the mistake(s) which led to their downfall. **Once the HAARP grid is completed, humanity will be slaves forever.** This is why we cannot afford to debate. Furthermore, from the book “Angels don’t play this HAARP” (Begich & Manning 1997, p. 8), it is estimated that the HAARP grid will be completed by approximately 2017; others estimate by the year 2020. The important thing to note is that humanity does not have long, until the HAARP grid is completed.

I must also add the positive side of HAARP, because as I have said, there is nothing inherently evil about technology. Technology is just a tool; it depends on the person using it. HAARP used correctly, and in the hands of honest men and women, will tame the weather with no adverse effects. Therefore humanity is on a timeline and a deadline to bring the Illuminati to an end. **HAARP is one of the main reasons, this disclosure must spread, and spread fast.**

See below for possible HAARP locations around the earth (Rense 2011). The HAARP sites are located globally where the richest mineral belts are located. Sub-surface mineral exploration has been done from satellites by radio tomography that is 100% accurate.

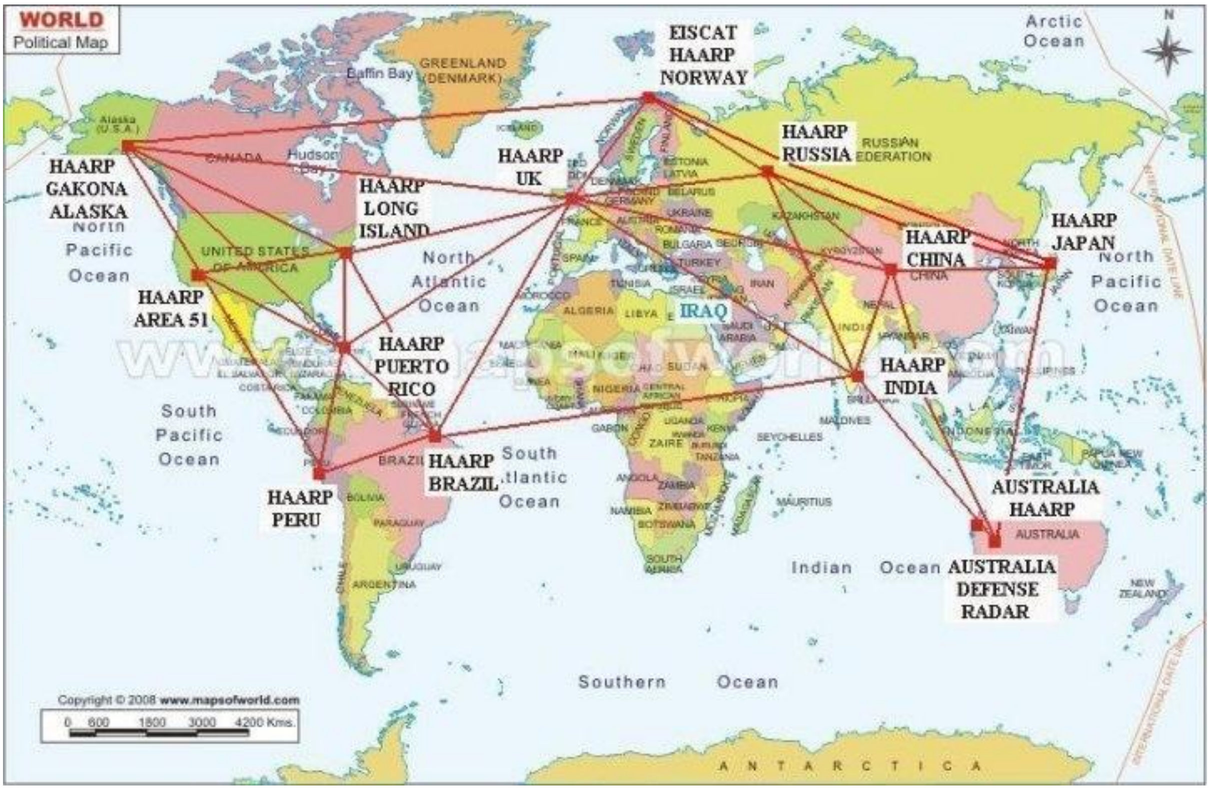
WORLD
Political Map
EISCAT
HAARP
NORWAY
HAARP
GAKONA
ALASKA
HAARP
LONG
ISLAND
HAARP
UK
HAARP
RUSSIA
HAARP
CHINA
HAARP
JAPAN
HAARP
AREA 51
HAARP
PUERTO
RICO
IRAQ
HAARP
INDIA
HAARP
BRAZIL
HAARP
PERU
AUSTRALIA
HAARP
AUSTRALIA
DEFENSE
RADAR
Arctic Ocean
North Pacific Ocean
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
Indian Ocean
Southern Ocean
ANTARCTICA
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0 600 1800 3000 4200 Kms.

Image 8: Possible H.A.A.R.P. Locations. Source: Rense (2011)

REM Driven Cloning is the Most Terrible Nightmare Situation Ever

Furthermore, in terms of REM driven cloning; Fefe Dobson (singer) and Kurt Russell (actor) told me during my original disclosure (**2011**) specifically, to include in my disclosure that they do not like the cloning centre and they didn't torture me. Then they said not to mention them, but I will mention them again. Mila Kunis (actress) from "That 70s Show" stabbed in my REM driven clone body multiple times when I made my original disclosure and I was rendered immobile for saying that "She is a slimy scumbag for hanging with these people" and for also saying "She has enormous eyeballs and looks like a lemur". Mila Kunis (as a REM driven clone at the cloning centre) then begged me not to mention her (in my original disclosure, but I'll mention her again too) and then Mila Kunis said "She doesn't want to go to the clone zone anyway" and the Illuminati then deactivated her consciousness from her REM driven clone body, and she left. Her REM driven clone body went limp at the point where her consciousness was deactivated from it; her REM driven clone body looked 'dead', and she was gone. Some of the privileged people at the cloning centre are allowed **NOT** to have their consciousness transferred to their REM driven, clone duplicate versions (or they attend the cloning centre willingly when they want), but not me. I am an imprisoned slave in the worst nightmare situation. I told Nicole Leone (Madonna) also a REM driven clone at the cloning centre, that I was going to tell everyone that she coerced me to compose songs for her throughout my life (as REM driven clones). Nicole Leone (Madonna) told me VERY specifically to say in my disclosure here "She is not afraid!" and "No one will believe me and nothing will come of this". I beg you to help me prove her wrong.

Moreover, having your consciousness transferred to a REM driven clone alternative inhibits the person's ability to dream for that evening. Although your original body is immobile and asleep in your bed, when they transfer your consciousness you have actually 'woken up' as a REM driven clone version of you at a physical location here on earth; therefore you walk and talk as a clone version of you. You are not dreaming; you are just a REM driven clone for the evening. Furthermore, when the Illuminati restore your memories (as they have with me) or do not suppress the memory of your REM driven cloning experience for the evening (such as with the fake alien abductions), you will remember the experience as 'clear as daylight on a summer's day'; the experience is 'clear as a bell' as life is in your original body.

It is unlike dreaming, where dreams are fuzzy, incoherent and with random conjecture. The Illuminati know this as a fact, and therefore pre-inject the REM driven clones of random unsuspecting civilians for the evening with drugs before they transfer the person's consciousness. They tell the person who has had their consciousness transferred to their REM driven clone all sorts of nonsense: such as they are in the 5th Dimension; the astral plane; a singularity; the spiritual realm; Valhalla; quantum hopping etc. and all sorts of fallacies so that the person will not have a coherent picture of what has happened or what is happening. The truth is that person has had their consciousness transferred to their REM driven duplicate clone when they went to sleep and entered REM sleep; their original body still remains asleep in their bed; their consciousness however is now transferred to a clone duplicate alternative, and the person is 'awake', walking and talking as a cloned version of themselves in a physical location. The Illuminati allow some people to retain some of these REM driven clone experiences to affect their mental psyche.

The physical location where the populace will be able to verify these REM driven clones is somewhere within 5/6 hours drive, in a radius of the Robert Pickton farm, Port Coquitlam, British Columbia, in Canada, somewhere at a remote nature reserve. This is the cloning centre all the rich and famous attend because it is above ground and the rich and famous don't like the 'hospital smell' of underground cloning centres. The above ground cloning centre located in Canada is the cloning centre I have my consciousness transferred to when I sleep. It is guarded by military personnel. There are many cloning centres all over the world; as Phil Schneider (1995; 1996) disclosed as far back as the mid 1990s when he spoke: there were 1477 Deep Underground Military Bases (DUMBs) worldwide and 131 active DUMBs in the United States alone. Each DUMB costs on average 17 -19 billion U.S. dollars; paid for by the taxpayer; and it takes approximately a year-and-a-half to 2 years to build DUMBs with sophisticated methods. DUMBs contain cloning floors, and have an entire floor dedicated to human cloning, where duplicate clones are grown of unsuspecting civilians (remember they just need your blood / DNA); and unsuspecting civilians have their consciousness transferred to their REM driven clones at a physical location, which is usually these Deep Underground Military Bases when they sleep; unsuspecting civilians are memory suppressed, also to be used for gruesome torture and sex sports; as well as the plagiarism of talented individuals. Schneider gave the above statistics in the mid 1990s; chances are there are more DUMBS and cloning centres worldwide today.

Are you beginning to understand why this is the worst nightmare situation ever? Can you understand how: you, your friends, your family, your brothers, your sisters, aunties, uncles, children, work colleagues and anyone else you have contact with in your network, may be involved in this REM driven cloning business and will not even be fully aware of the situation or remember any experiences which they may have had once they wake up from sleep and they are back in their original bodies? I remember all of the REM driven clone experiences as clear as daylight because my memories are fully restored. Can you understand why the Illuminati must be stopped and stopped immediately? This REM driven clone business is vast, and it affects everyone, not just me.

This is why I mention that I am fortunate or unfortunate to remember all these experiences clearly depending on how you view it. I am unfortunate in the sense that I can recall all the depraved things these people do as REM driven cloned duplicates as clear as daylight and it affects my mental psyche. However, the fortunate part is: because I can recall all these experiences clearly, I can inform the world about the evil committed against humanity in a clear and logical way for the average reader to understand and verify, so that the populace can bring these people to justice for the crimes they have perpetrated against humanity and continue to inflict on humanity. For anyone who has had their intellectual property stolen by the Illuminati as a consequence of the technologies they have used on you unsuspectingly, you will be able to sue and regain monetary reward for the theft of intellectual property as well as invasion of your privacy.

I do not want to get too far ahead, because at this present moment, it is **very important** (I cannot say it enough) that this disclosure spreads (this is the stage we are currently at); it reaches the armed forces; to enable the armed forces to realise the crimes committed against humanity because of these people (the armed forces are kept 'out of the loop'; they just 'follow orders'); the armed forces will have to perform a military coup and bring this people to their knees. This is the point where the ordinary man / woman can have his REM driven cloning experiences restored, (that is if you want to) and sue / rightfully reclaim damages and legal reward for any crimes committed against him or her.

The Meek Shall Inherit the Earth

As you can see if everything goes smoothly; the meek shall inherit the earth. This is why you must maintain your composure and resolve, as I do every single day. You must not riot or cause chaos, damage property or undertake any act which will cause public dissension. The good people of this earth are about to inherit the earth; under no circumstance must you destroy anything. At the end of this currently dire and complicated situation; humanity will inherit the cure for HIV/AIDS, cancer, Alzheimer's, dementia, you name it –many debilitating diseases known to man; and other such wonderful technologies like hypersonic trains which run on magnets and are capable of doing Mach 5 (Mach 5 is the equivalent of 3806 miles per hour or 6125 kilometres per hour; Schneider (1995; 1996) also mentions the availability of Mach 5 trains in his disclosure, back in the 1990s). These trains can be used to deliver foods which are discarded in More Economically Developed Countries (MEDCs) to Less Economically Developed Countries (LEDCs) because these trains can travel thousands of miles within minutes. Yes. The Illuminati have all these wonderful technologies and more, but withhold it, and in turn withhold the progress of humanity. Yes. Plenty of man's problems can be solved when we address the root causes of our problems, and one of the root causes of humanity's problems is: REM driven human cloning which is currently in the hands of evil men. Even REM driven cloning can be used for the benefit of mankind when this tool is in the hands of righteous men. It can be used learn new skills in your sleep: such as gain extra qualifications; learn how to speak a new language; play instruments etc. –so long as memories are not suppressed, you will be able to perform the skills you learned as a REM clone in your original body when you wake up. As you see there is nothing wrong with most technologies; it all depends on the person / people using it. Nevertheless, although they may be beneficial uses to REM driven cloning not yet realised, we must be shut down REM cloning before we can even consider how REM driven cloning may benefit mankind, because at this present moment all that REM driven human cloning is used for is to commit evil, particularly against unsuspecting civilians.

It is OK to feel angry about all these crimes committed against humanity daily. But do not let these evil crimes rule you, in fact, let it motivate you; let it motivate you to the point where you will stand up and speak out to ensure that these crimes end. I think about the children and the future of the world every day; that is what motivates me and I view my situation as a God-given mission to bring these people to justice. I view things this way to maintain my sanity and composure. This is what keeps me going despite the extreme evil I experience, and it helps me to maintain my resolve and composure. The fact that I do not want a single child to grow up in a world, where they are being messed with in their sleep is what keeps me going despite this extreme evil. Some children are even kidnapped and brought to the cloning centre in their original bodies, again to be messed with. This is the root cause of why so many children go missing across the world. I'm sure any rational thinking human being feels the same way I do, and does not want their children, or any child to inherit a sick world governed by sick individuals.

I am a baptised Roman Catholic and a God fearing man. I believe there is a Creator of the universe but the Illuminati tell me there is no God, only science and technology. The Illuminati are also responsible for the death of the young beauty pageant girl Jean-Benet Ramsay; her parents are in this REM driven cloning business. Casey Anthony's daughter; as well as, Casey Anthony (before she died) AND Casey Anthony's parents also attend the cloning centre as REM driven clones. Many others; a man had his wife killed and this was mentioned on the news; it was an Asian woman whose rich husband had killed her; the husband said the wife was responsible for their son’s death. Elizabeth’s response was that “Rich people in this organisation (The Illuminati) do not go to jail, they are covered for.”

Stephen Spielberg and George Lucas are Illuminati members and they willing attend the cloning centre as REM driven clones when they sleep. George Lucas made other Illuminati members light my REM driven clone body on fire for the end of his movie *Star Wars Episode III: Revenge of the Sith* (2005).George Lucas said (as a REM driven clone) he wanted Hayden Christensen “To scream realistically”. Hayden Christensen (also a REM driven clone at the cloning centre) watched me, and listened to my screams and groans of pain and copied the sounds coming from my burning REM driven clone exactly. Hayden Christensen knows he is a REM driven clone when he goes to sleep and Hayden Christensen knows his consciousness is transferred when he reaches REM sleep. Hayden Christensen knows all about REM driven human cloning, and he is a “privileged” Illuminati member. Natalie Portman also knows all there is to know about REM driven human cloning; as does approximately a quarter of the “Star Wars” cast. Many directors have attended the cloning centre as REM driven clones too, and have used me in a similar role playing situation; they have caused me to have excruciating pain as a REM driven clone, to see what kind of squeak or screech I will make, as if I were less than a dog; and when I am a bloody mess on the floor as a REM driven clone; that is when they usually crawl on my broken REM driven clone body and sodomize me saying something like “They love me and they cannot control themselves because I made all their favourite songs and I’m so “special””.

My ribs in my REM driven clone body will be broken, I will have suffered internal bleeding and will be crying or screaming, if I am able, but they just continue to sodomize me, and videotape such a depraved act of wickedness so that they can view it again like “evil pornography”.

The REM driven cloned children, who have their consciousness transferred while they sleep at home in bed, in their original bodies, need a familiar face to talk to as REM clones or all they do is scream and cry at the cloning centre; that is where Joy Geizer comes in. Joy Geizer is married to my half brother from my father’s first marriage; Joy Geizer is a REM driven clone girl guide leader, and when the Illuminati clone young girls, Joy Geizer speaks to these REM driven cloned girls; Joy Geizer keeps the REM driven cloned girls calm and “pimps” them out for free, knowing that these young girls will have their memories suppressed, and therefore they will not remember the experience and will not talk about it when they wake up. All the Geizers are in this REM driven, human cloning business; there are many people who remember these REM driven cloning experiences in their ‘awake state’ and in their original bodies who could be polygraph tested by independent polygraph testers. The police, and polygraph testers in my City of Halifax, Nova Scotia are compromised (they attend cloning centres as REM driven clones too); they cover up for child molesters and therefore cannot be trusted to fairly administer a polygraph test; as I said, commissionaires and C.S.I.S are heavily involved. All it would take is a few polygraph tests to prove these things unequivocally, because for those of you who have ‘eyes’, you can already see that REM driven cloning is real, and that this is actually the way of the world. I will take these polygraph tests publicly too, and demand that my mother and step father submit to them. They have told me, they **wouldn’t** even attempt to lie on a polygraph.

Human cloning, particularly REM driven human cloning, is one of the absolute truths of this world; hidden from the world for over 70 years. My life and the freedoms of many, many people, including the reader (you) depend on this disclosure. The Illuminati say that the world finding out about REM driven human cloning will set the stage for the end of the world; people panicking and destroying property because of the evil these people have committed, but as I've said: prove them wrong, because we are going to inherit the earth, so there is no need to riot or cause public dissension. There will be no end of this world; just the end of the crazy Illuminati people. They always like to think and behave so negatively, don't they? *Sigh*. Furthermore, the whole talk about 2012; December 21st 2012 and the end of the world Mayan Prophecy; that was really about the world finding out REM driven human cloning, and the sick and sadistic nature it has been used for by these sick and sadistic people. Under no circumstance must you riot; you **must** prove you are better than these savage barbarians. I'll say it again, **because it is important**: we are going to inherit the earth, and therefore the smart and right thing to do, is not to destroy anything, especially the earth which you shall inherit.

Furthermore, I hope you are beginning to understand that the good people of this world must bring these people to justice and stop their wicked ways. I sincerely wrote this disclosure so that the good people of earth would be empowered to put a stop to their wicked ways. I wrote this disclosure to empower the good people of earth against tyranny and not so that the world would end. Therefore you must understand that the downfall of these Luciferians (Illuminati) must progress smoothly, because unless you have been to the cloning centre as a REM driven clone and retained the full memories of your experience, it is difficult to understand the level of depravity and sub human cruelty; it is beyond anything that has ever been heard of, and there is much more to tell.

Ignore this disclosure and you will condemn me to a horrible eventual death and you will encourage them that 'they are all 'powerful''. This is not an exaggeration. There is no need to exaggerate even President Barrack Obama is involved in the REM driven cloning business and attends the cloning centre as a REM driven clone version of himself, when he goes to sleep. He and his wife Michelle Obama attend these REM driven clone gatherings. Barrack Obama has even told me as a REM driven clone, at the cloning centre "Donny, we're all powerful. You are a slave and the people here [as REM driven clones at the cloning centre] won't speak up for you for fear of torture or death. Now make us a new song or we'll gut you like fish and leave you to writhe in agony!"

Be Wary of: Shills; Trolls; Disinformation Agents and Double Agents

There are many, many disinformation agents whose aim it is, is to denounce or debunk me. Be very wary of them. They DO NOT, and cannot debunk me, because after all, everything I have disclosed is truth. Although the truth concerns highly advanced concealed technologies, so it is a bit difficult to fathom at first, but keep reading, and you will realise that all which I have disclosed is true. Be very wary of the disinformation agents.

The most common thing these people say is that "Donald is a paranoid schizophrenic" –yet, ask them to detail the ins and outs of what a paranoid schizophrenic is and what specifically qualifies Donald to be a 'paranoid schizophrenic'; there is a high probability they will not be able to explain this to you, logically, sequentially and methodologically. Their main goal is just to make it as difficult for newcomers to understand what the real truth of this world is and as I have disclosed; and one of the root causes of man's problems is REM driven cloning.

Some disinformation agents are paid by the Illuminati, to behave this way, and are all too happy to echo empty statements (without any substantial evidence for their claims) because it provides them with a pay check. I will provide the following reference for the reader which discusses the signs and symptoms of a paranoid schizophrenic; all for the express intent for the reader to further understand paranoid schizophrenia. You can read more about paranoid schizophrenia on Medical News Today (2015). The link is provided in the reference section. You are welcome to read my Facebook wall and within days, you will realise I converse with others quite naturally. You can also ask individuals who have spoken to me through Skype or met me; but if this is not a viable option for you; all you have to do is read my Facebook wall and within days, you'll see that whoever makes such harsh and untrue remarks on my character is in fact a disinformation agent.

Furthermore, remember we live in a 3D **physical** world; and there is always a physical aspect to how something manifests. Therefore, when you hear others discussing concepts such as 'Tila Tequila demonstrated an 'energy ball' right on camera; Why didn't Donald discuss that?!' Please understand that these people are trying to deceive you with misinformation. There are also professional disinformation agents to be wary of. I do not perceive anything extra-ordinary in the world when I am awake in my original body beyond the five senses. I don't see orbs, auras or anything of the like. All I will ever discuss are practical things which have been unequivocally proven to me as fact; because in the situation the earth is currently in, I cannot afford to speculate.

Contact Information

My Facebook is: https://www.facebook.com/donald.marshall.148
You can also press Ctrl+Click (hold "Ctrl" on your keyboard and left "Click" with your mouse, on the image to your right).

I have a public wall on Facebook which starts from March 2012. In other words, all posts are made public since March 2012 and you do not have to join my friends list or subscribe me to see what I post (although you will have to have a Facebook account). I suggest that newcomers start reading from March 2012, and be patient, and read everything. You can read everything and learn the real truth of the world free of charge. I don't wish to write a book, I am not looking to turn a profit from this; I want to crush these guys and shut down the cloning centres!

It also worthwhile to add that: I am **not** asking for donations. I do not want **ANY** donations. Ever! These disclosures are far more important than any donations. This is **NOT** my job. I have a job. I am an independent contractor; carpentry is my trade and I earn a living this way. If you sincerely want to help; the best way to help is to spread and share my disclosures. That is all I ever ask for, so that eventually, the world knows about REM driven human cloning, and the armed forces can bring these people to their knees. **That is all I want; spread, spread, and spread this disclosure.** I will **never ever** ask for donations. Ever! Please keep this in mind, and anyone who asks for donations in my name or on my behalf should not be trusted. I, Donald Marshall, will **NEVER EVER** ask for any donations. I hope that is well received.

You can also view Proboards which has all my Facebook posts and have been archived by Celine O'Carroll and Astral 7ight by visiting:

http://donaldmarshall.proboards.com/
You can also press Ctrl+Click (hold "Ctrl" on your keyboard and left "Click" with your mouse, on the image to your right).

There is a search function on Proboards, and you can use this to search for and read all the disclosures I have made regarding REM driven clones, the people involved and more. I understand that it is human nature to want to know, which people have been to the cloning centre as REM driven clones; therefore, use the search function to read about any public figure which I have already covered that you have an inkling about. You can also post anonymously on Proboards and Celine and other Administrators will transfer your question onto Facebook which I'll answer.

Donald Marshall Revolution is a website which details a brief overview of the Illuminati.
http://donaldmarshallrevolution.com/
You can also press Ctrl+Click (hold "Ctrl" on your keyboard and left "Click" with your mouse, on the image to your right).

DONALD MARSHALL
REVOLUTION

Interviews

You can listen to the radio interviews I have done. Listen for consistency; particularly anything which you do not hear me, pronounce clearly for the first time; the best thing to do is to pause the recording at that particular point and replay it. You should also research the statement you do not understand. Sometimes reading helps comprehension a lot faster.

One of the main reasons you should pause and replay the recordings is because: the truth has been kept hidden for so long that a lot of what I discuss in my interviews are beyond most people's current world view; so at some points I may speak too fast for you; my audio/ microphone may not be so clear so you may miss what I say etc.

A friend has told me that when he first watched the Vinny Eastwood interview; he did not hear me say the word "scars" (When Vinny asked: 'How do I know I'm the real me?') although he replayed that particular point in the video 8 times. Everything was just beyond his current comprehension, at the time. No matter how many times he replayed that part he really could not hear me say the word "scars" –so he let that part go, and played the rest of the interview, pausing, and replaying points which he did not understand, especially to comprehend whether I was talking about my original body or my REM driven clone duplicate body. He also listened to all my interviews for consistency, to note any 'slip ups', or any parts of my testimonies which do not 'add up'. He would listen to all my interviews, pausing and replaying parts he did not understand and he would reserve his judgements until he felt everything I was saying was for example as ordinary as: 'I woke up today, brushed my teeth, and took the dog for a walk'. He was also patient to realise the truth. After listening to my interviews he would just let it 'sink in'. A week later he would come back and listen to the same interviews, to test whether his comprehension on the topics I discuss has improved, and whether he can understand what I am saying without having to pause and repeat at certain points in my interview; and soon enough he could now hear me say "scars" at that particular point of the Vinny Eastwood interview. He had reached the point where all topics I discuss sounded to him like I'm saying everyday common place stuff that people have heard, such as: 'I woke up today, brushed my teeth, and took the dog for a walk'. For anyone who may struggle to understand the topics I discuss: I strongly recommend you take the above approach as my friend did; soon enough, you too will realise the real truth of the world like he has: REM driven cloning, kept secret and used for sinister purposes.

I cannot say the following is true for everybody, however, an unproductive venture a complete newcomer can do is to listen to my interviews first time, all the way through, without pausing or replaying parts which they do not fully understand; If you do this and if there is just a single part of my interviews which does not make sense to you; this will interfere with your understanding of the entire interview. Remember, all I am discussing is technology, thousands of years advanced compared to what you currently use; available today, hidden and secret. If things start to get too complex for you, reduce it to its bare minimums: (advanced) science and technology. I hope that helps.

Another thing which I do in my interviews, that friends have picked up on, is: -because REM driven cloning has been my reality for many years; I don't differentiate between my original body and my REM driven clone body. I just say: I did this, I did that, and Elizabeth did this and that, therefore it can become very confusing for newcomers. Please bare with me; although I'm more emotional as a REM driven clone, and not as smart as I am in my original body (this is a side effect of cloning: REM driven clones are more emotional than normal, and dumber than they are in their original bodies) I'm still "me" when my consciousness is transferred; I have all the experiences and knowledge which makes me, "me" and therefore I naturally do not differentiate between my REM driven clone version, and my original body as an outsider discussing these concepts would. I understand it helps comprehension so I have painstakingly done this throughout this disclosure.

I hope this helps; and I hope this helps to better understand my disclosure as well as the interviews which I have done. On the next page you can find the links to my interviews. You can copy and paste the links to your web browser or press Ctrl+Click – (hold "Ctrl" on your keyboard and left "Click" with your mouse, on the images below) to direct you to the interviews.

Links to Donald Marshall Interviews

Vincent Eastwood

Copy and paste the link below to your web browser.
https://www.youtube.com/watch?v=M_1UiFeV5Jg&ab_channel=VincentEastwood
OR Press Ctrl+Click (on the image below) to follow the link.

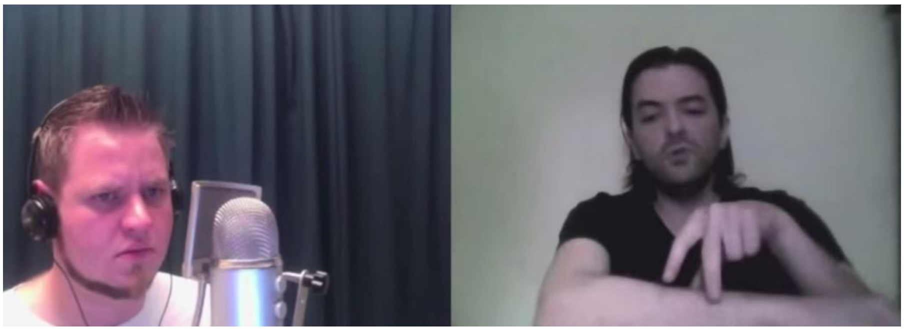

Jeanice Barcelo

Copy and paste the link below to your web browser.
https://www.youtube.com/watch?v=3uzgu4ekT3c&ab_channel=JeaniceBarcelo
OR Press Ctrl+Click (on the image below) to follow the link.

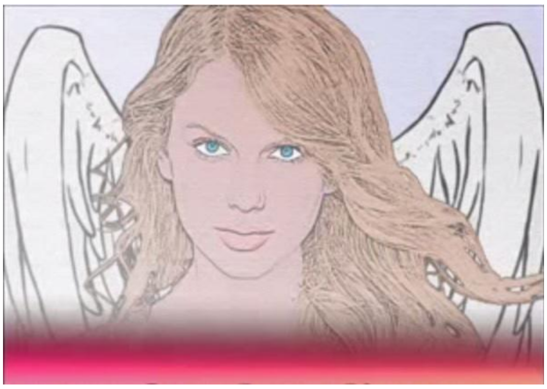

Lisa Phillips (CFR)

Copy and paste the link below to your web browser.
https://www.youtube.com/watch?v=UonnFuHLJKc&ab_channel=Astral7ight
OR Press Ctrl+Click (on the image below) to follow the link.
Listen to parts 1 through 8.

Donald Marshall
1st Part Of Interview
April 11, 2013

Radio Presenters –Contact Donald Marshall

Anyone who sincerely wants to contact me for radio interviews on their show is welcome to do this. Please contact me through Proboards by leaving a message for me to contact you.

Professionals who understand "Consciousness Transfer" –Contact Donald Marshall

Any neuroscientists, engineers or professionals who understand how consciousness transfer works, and can provide me with a detailed methodology of how to block the consciousness transfer to my REM driven clone; please message me on Proboards, and this will be greatly appreciated.

Email

I currently do not have a contactable email address. In my original disclosure, the email address has been compromised (hacked), and so has any other email accounts I created: Yahoo, hotmail, Gmail, AOL etc. It doesn't matter; they eventually get hacked; for whatever reason, the Illuminati do not want me to have an email account.

How to Learn More about Donald Marshall's Whistle Blowing Disclosures

The best ways to learn about the truth of the world is through my Facebook page and Proboards. There is a mountain of evidence which has been collated over the years, and corroborates all that I have disclosed here. I also understand that for some people it is impractical to read three years worth of Facebook posts, especially when some post are repetitive; contain unnecessary comments from trolls, shills and other disinformation agents. Therefore, I am currently compiling 5 documents which should make it easier for others to read and understand everything quickly; as well as, for others to share and spread those 5 documents including this main disclosure document –so 6 documents about the real truth of the world. All for free!!

These documents include:

- "Frequently Asked Donald Marshall Questions" –This will contain all the general FAQs which I have been asked over the years; all in one place.
- "Experiences from the cloning centre" –This document will contain the full disclosure of my REM driven cloning experiences from the cloning centre when I go to sleep; all in chronological order.
- "List of people to avoid" This will contain a whole list of trolls, shills, and disinformation agents and double agents in alphabetical order, to avoid at all costs, in real life and online; -all complied in one place; and the reasons why they should be avoided.
- "Public Figures and their relationship with Donald Marshall as REM driven clones" –this will be a complete list of every public figure I have ever come into contact with as a REM driven clone; and you will be able to read about all the public figures I have met as REM clones, as well as the experiences, all in one place.
- "The subterranean underground colonists: The Vril" –this will be everything about the biological parasites the Illuminati harbour. Yes. The Illuminati harbour biological parasites, which they use against unsuspecting humans. I told you the Illuminati were

> the biggest depraved perverts ever to grace God's earth. REM driven human cloning, kept secret from the world for over 70 years is difficult to fathom as it is, as are these biological parasites. These parasites are also one of the main root causes of humanity's problems here on earth, and must be rendered extinct. In this document you will be able to learn everything about their, strengths, weaknesses, psychology, biology, ecology, sexuality and arm yourself with knowledge which ensures that humanity exterminates these parasites from our earth, forever. The secret of Vril; a secret no more!

I hope after reading my eye witness statements presented in this document that you have now began to understand that this is simply what is happening in our world today.

Heed my disclosure, very diligently. At the start of my disclosure I asked the reader to do two things:

1) Give me the benefit of the doubt –because there is nothing worse than being a victim of abuse, reporting it and the people who have the power to stop it, ignore you;
2) Set out on a genuine quest to debunk my disclosure. I understand that for some people, plenty of what I have disclosed will still sound 'too out there' beyond their current scope of reality to be believable. For such people, the honest thing to do is to start with the first topic which you do not fully understand and explore it, either by finding that corresponding topic on Proboards (Donald Marshall Proboards 2015), and continuing your research from there; or just Google any topic you currently do not understand and review the topic on websites such as New Scientist (2015), Gizmag (2015), Motherboard (2015), BBC News (2015a; 2015b), BBC Future (2015), The Guardian (2015a; 2015b) The Independent (2015a; 2015b), Daily Mail Online (2015) and start reading more articles in the Science and Technology columns because these people have been telling you what they have been doing for decades. Consequently, keep in mind that articles which discuss 'future' technologies and 'improvements' in medicine or science, are articles, which are **really** discussing present technologies, and achievements in science and medicine already realised; because most of these achievements have been realised decades ago. It just hasn't been fully disclosed publicly.

I have also saved and backed-up every reference (except the homepages of the websites referenced) in this document; therefore if a link or video is ever deleted let me know.

How Much Do You Know About Post-humanism / Trans-humanism?

Furthermore, you have to be honest here: because if you do not know much or anything about post-humanism / trans-humanism then I am afraid to say, -and this is no fault of yours – that you are behind in this the world; simply because these Illuminati people are Post-humanists; and that is the direction the want the rest of the world to go. They want the world to reach a destination where human cloning is common place; a world where downloading your mind / entire life experience onto a computer microchip and living on as a cloned version of you with the microchip running the consciousness to be common place; and these Illuminati Post-humanists want the world to head in a direction where it is commonplace to molest children through science and technology. No. This really is not Science-Fiction, this is the world we live in today; this is why such marvels in science, medicine and technology has been withheld from the general public and kept hidden by an 'elite' group of people because if these people honestly came forward, and said “We have invented this technology and we want to use it for this “negative” purpose” –the populace would not accept it, and these people will be lynched in the streets before lunchtime. Therefore, through concealed advancements in medicine, science and technology, the Illuminati can live out their inner depraved cravings and commit crimes against humanity and the world, for which most people will be too blind to see or even fathom, because the hidden science and technology is beyond the average person’s current comprehension.

Therefore, please attain an education in post-humanism / trans-humanism because these Illuminati people believe they can rival creation, nature and the marvels of the universe through science, medicine and technology. The Illuminati go **against** creation; they go **against** nature; and they go **against** humans. They don’t consider themselves humans. They consider themselves post-humans and believe they can become “gods” through advancements in medicine, science and technology. See LawOfIdentity (2014) and Mark Dice (2014) for Richard Seed’s comments on ‘becoming gods’ through transhumanism. Richard Seed is a Physicist with a Ph.D. from Harvard University; he is well known in the controversial cloning debate and declares his aspirations to "become god" saying 'We are going to become Gods, period. If you don't like it, get off. You don't have to contribute, you don't have to participate, but if you are going to interfere with me becoming a God, you're going to have trouble. There'll be warfare.' If you value humanity, do your best to attain an education in the trend of post-humanism / trans-humanism; otherwise the future of mankind will be bleak. We must do everything we can to stop these people.

This is of uttermost importance. REM driven cloning of is the most terrible thing in the world, especially when it involves unsuspecting civilians, and worst of all, innocent children. If you choose NOT to do anything you allow the Illuminati to continue to clone your children, sisters, wives, and sons. You allow the Illuminati to continue to hijack the minds of your children, sisters, wives, and sons while they sleep, through concealed advancements in science and technology. You allow the Illuminati to transfer the consciousness of your children, sisters, wives and sons to their REM driven duplicate clone versions while they sleep, whereby the Illuminati molest your children, sisters, wives and sons, which will cause them to have learning disabilities, unexplained depression and suicidal thoughts, as well as all kinds of side effects.

This IS your ONLY chance to end these monsters. There is a deadline!

This is your **ONLY** chance to do something to end these monsters. We are on a timeline and there is a deadline. As I have already mentioned, as well as, the top scientists in the field of physics and geophysics have mentioned: HAARP is not only capable of controlling the weather; once the HAARP grid is completed and working at full power, it will be capable of mind control over entire populations. We will all be slaves to the Illuminati FOREVER. Our freewill will be gone forever. Furthermore, if they achieve their aim of time travel with HAARP technology, future generations of humanity will never be able to stop them, because as they have told me: ‘They will always be able to go back to a previous time, and correct the mistake(s) which led to their downfall’. This is the Illuminati’s end game and what they wish to achieve. This is why this disclosure is so heavy, and so important. It goes beyond REM driven cloning; although it is important the world understands REM driven cloning. The future of humanity is at stake; and because of the 2-5 year deadline until the HAARP grid is completed, it is time humanity stood up and brought an end to the Illuminati. This REALLY is your ONLY chance to end these monsters!

The only way for evil to triumph is for good people to do nothing.
Edmund Burke

Remember for every 12 months which passes military / concealed technology outstrips the technology the general public is accustomed to by 44 years (Schneider 1995; 1996). Close your eyes and think 44 years into the future. The year is 2059. What kind of technologies do you expect mankind to have? Do it for real; don't just read the words. Close your eyes and imagine. The year is 2059. What kind of technologies does mankind have? You see. It is 'out of this world' technology, right. This is exactly what is going on today in the year 2015. It's just that it is hidden. That's all. Not so difficult to fathom now.

Do NOT Be Afraid to Help. We Outnumber the Illuminati by 1,000,000:1

Don't be afraid to help. These people are easily defeated when good people stand together as one. These Illuminati people total no more than 10,000 people. 10,000 people against 7,000,000,000 (7 billion) people –that's less than 0.000001 % of the world's population. Now can you begin to understand how prevalent evil can be when a small organised group of individuals, as little as 10,000 of the world's most evil and tyrannical people all work together in unison to exert their influence over the world? The world does not have to be this way. We outnumber the Illuminati people by a 1,000,000 to 1. For every Illuminati person there is, there are **one million** people who are not Illuminati, therefore do not to be afraid to help; all you will be doing is helping humanity rid itself of its sickness. So please feel free to share and spread my disclosure far and wide.

For those of you whom this applies to: remember the Illuminati (and I know it sounds ridiculous despite the evil they do) are deeply religious. They believe anyone aiding me is part of the "Army of Light" prophesised by Nostradamus; and to harm or degrade the life of anyone assisting me will bring them to their ultimate end and they will incur the wrath of God; they will suffer utter ruin and demise in their lives if they are to hurt you; they are very scared of people who can see through the lies and deceptions they have inflicted on the world. So please, stay calm, do not stress your heart, and know that **you are safe**, and **they cannot hurt you**. You can feel safe in the knowledge that you can do the right thing by helping me. They told me this as REM driven clones on the night of 21st of February 2014 when I went to sleep. The above is exactly what they said.

For anyone interested in understanding the interpretations of the Nostradamus Prophecies, Crystal Links (2015) provides a good source for all 942 of the quatrains. Delores Cannon is also an author who has written three volumes called "Conversations with Nostradamus" and for anyone interested you can read these online (Galactic 2012a; Galactic 2012b) as well as watch her YouTube videos (CreativeForceVideo 2014; Disclose TruthTV 2015).

Yes. This is the state of the world today: a deception within a deception coated in reverse psychology; and fact is indeed stranger than fiction. Now after everything I have said, if you are still sceptical and 'in-between' on this issue then the best thing for you to do is to pay attention to your dreams; or lack of dreams –they are your own experiences and you cannot deny your experiences.

In other words, you may be having REM driven cloned experiences too; for some people they have a 'dream', where they are in the same environment, over and over and over again; or the theme being discussed in their 'dreams' is the same over and over and over again; or the environment their 'dreams' take place always appear to happen in the same 3 or 4 environments over and over again –no matter what the theme is. In each scenario there is a likely probability that these are not just dreams, and in fact these people have had their consciousness transferred to the REM driven clone duplicates and the Illuminati is trying to extract something from them, once that is done they implant a false memory (See Kim (2013) and Alford (2015) for discussions on how false memories are implanted) so you wake up with the feeling of remembering something, but in actuality it is false; or you wake up with no memory of dreams from the previous evening, which means there is a high probability that you had your memories suppressed when your consciousness was transferred to your REM driven clone. This is why I say you can be sceptical about everything I have said (for now), but pay attention to your dreams, or lack of dreams, they are your own experiences, and you cannot deny your own experiences.

Noteworthy Frequently Asked Question

A Frequently Asked Question I receive, which is worth a mentioning here, is as follows: **Q:** Donald, if everything you have said is true...; in other words human clones walk among us now in a multilayered conspiracy which reaches the highest levels of government; armed with this knowledge what does one do exactly? What happens now, Donald? You obviously want to spread the word and make people aware but to what end?

DM: In short: I want to bring a complete end to the Illuminati and usher in a "Golden Age" of mankind. This question is best answered by detailing my 'Mission and Vision' for ending the Illuminati completely.

Donald Marshall's Mission and Vision on How to Bring Down The Illuminati

- This disclosure must spread, and **spread FAST and FAR!**
- If you now understand everything I have disclosed in this document as truth, then do not waste any more time. Share this disclosure with your wives, husbands, brothers, sisters' aunties, uncles, friends, co-workers, and children. We all have a part to play in saving the world from a premature doom.
- Call friends who have not heard from you in a while and tell them you have important news to share. Share this document. Share it on social media such as Facebook; Twitter; Instagram; Dropbox; Slideshare etc.
- Keep sharing this document until it comes to the attention of the Armed Forces. The Armed Forces will have to intervene. Once the Armed Forces intervene we will have reached the middle stage of this vision and will be witnessing a complete end to the Illuminati. Until then, we're in the beginning stages, so please; spread this document faster and further. The quicker it is spread; the quicker the Illuminati are ended.
- Once the Armed Forces have intervened a Military coup can be orchestrated against these vile people.
- Cloning centres can then be shut down once these people are overthrown.

- The freeing of any missing people (children; teens; adults) trapped in the cloning centres can commence (once the Armed Forces intervene).
- HAARP (as well as other highly advanced technologies) can now be contained and not used for adverse effects against the world (once the world learns of this disclosure).
- These Illuminati people will then HAVE to appear in court for their crimes against humanity.
- Suing the Illuminati members in court (once court proceedings commence... we will be past the midpoint of my vision, and closer towards witnessing a complete end to the Illuminati).
- The populace (and it will be your choice) can then have their REM driven clone experiences restored and also sue and claim any legal reward / compensation.
- After the populace has sued the Illuminati for their crimes against humanity; the punishments can commence.
- Punishments will include: imprisonment and executions of these sick and malevolent people. The imprisonment and executions of evil Illuminati members will bring an end to the Illuminati.
- After the punishments and executions; Governments worldwide can now be replaced with incorrupt individuals, worldwide.
- The structure of Governance will also have to change. The reason for this because future generations will always be able to check their leaders and governance more appropriately; so that the depraved and subhuman acts I described can NEVER be committed against humanity again; nor will world leaders be capable of committing such monstrous crimes in such secrecy ever again.
- Ensuring that the laws of the land always progresses in line with advancements in medicine, science and technology; as well as, ensuring law progresses in the directions of Research and Development (R&D) regarding future technologies, science and medicine.
- Release of technologies, science and medicine which benefit mankind.
- Commence a “Golden Age” of mankind.

If you do not fight the corruption and you do not stand up for what is right in life, you end up being a serf and a slave and you are leaving your children a world in which you would not want to live in yourself, so how can you in decency behave that way? You have to stand up for what is right in life, and unless you do that you are nothing.

Aaron Russo

Empowerment by Virtue of Golden Truth

As you can see, despite all the horror of the world I currently present: if everything goes smoothly, the good people of this world, truly will inherit it. This is why despite any anger, sadness, or fears you may have; you must not riot, damage property or cause chaos or bring about any other form of public dissension. You cannot stay silent, or ignore the issue in the hope that the threat removes itself. You are called to act; you must take action to help bring the Illuminati to an end; you must act while at the same time, you must maintain your composure and resolve to ensure that the whole procedure goes smoothly, and we all inherit a world we want to live in.

Your life, **at this very moment**, is more important than you may have probably ever imagined. You have purpose. Through you, and other good people around the world, together we can bring an end to such unspeakable forms of tyranny in this world. It is my humble stance that you have now become truly empowered with golden truth and you are now compelled to bring this tyranny to an end.

Do not waste the knowledge you have obtained from this disclosure. It is my only hope to escape this man made living hell. It is my only hope, as well as, the hope of many REM clones imprisoned there, as well as, real people who go missing daily, and are trapped in the cloning centres.

We sincerely beg you.

Donald Marshall

Appendices

Appendix A: Thien Thanh Thi Nguyen (Tila Tequila) Transcript

Link: https://www.youtube.com/watch?v=7mRZ7ItF9ls&ab_channel=Astral7ight

00.00 – 1.10 min: You know what... since you f****** with my program darling Queen Elizabeth [II] and the paedophilia ring and the cloning centres, and the cloning centres. That's right darling the cloning centres. Parents listen to me right now, they are blocking me but that is quite alright. They are blocking me but that is quite alright. Because I have many, many other forces; I shall not say their names right now, but I have many big plans to expose all of you disgusting, sadistic f***s! Okay? That is all. I shall save that for another time. But, however, I shall REPEAT: that was just an introduction to the reptilian family, leading all the way back. They call themselves the "The Black Nobility". Now that is just one part of it; alright?

1.11 -2.47 min: The Black Nobility; the reptilian family; all the way back from ancient times; so which they think... they feel like they are the divine chosen ones... from whom may I ask? Definitely. Definitely not God. Our creator of the world. Reptilians: they feed on blood; children; the paedophilia ring; recently busted. Oh! It has been going on for centuries. Parents listen to me carefully. I don't care if I'm cutting out. I will continue this and I am not alone on this battle. Believe THAT! Believe THAT! I am not alone on this battle. I started out alone but I am marching on with MILLIONS; okay? So sit your old a** down okay. Because you are gonna roll over, but it doesn't matter anyway because you are all ancestral f***s! Who interbreed... ancestral f*****g... and then... and then... Oh! Only going to talk about cloning those children and... oh! And all those many children's parents listen to me carefully.

2.48 -4.24 min: Hundreds of missing children come up every year. You wonder... why? How? How could this be? And then there is so called CPS [Child Protection Services] or whatever they are called; they come and take your children, just, just for nothing; right? Not to discredit everybody, because not everybody is bad. I'm talking about the bad people. And they take your kids... they take them as this... they treat them like... I can't even say the word. It's disgusting, it's sadistic. They... they... they take your kids... they toss them out like little [inaudible] cause they are so f*****g... Pardon my French, but then again when I'm dealing with these evil cum-buckets I have no holy words coming out of my mouth, because these are the only words they resonate to. So therefore that's how I refer to them. Because they can only [inaudible] ...their masters whiplash on them with these [inaudible] words of cursing, vileness and slaving and that is not what the true God is; okay? The God of Hell...; Anyways...

4.25 – 5.30 min: There are these CLONING CENTRES where they take your children and do sadistic things to them. I'm not even talking about child molestation here; not to mention; uh there is one of them that got caught, flying out to Florida; to meet up with a four year old little girl, to have sex with a four year old girl. That's right. Google it because it is so highly sinful... We have commercials about... you know starving kids; you know save the starving kids and it is heartbreaking. We can have commercials about it... why? Because it is a horrible thing and people can have commercials about it. WHY do we not have commercials about... 'Daddy please don't, don't. Mommy please don't let daddy let daddy touch me?' – because it is disgusting! It is so disgusting; beyond sin that no one, NO ONE, can even make a commercial about that because that's how sinful it is.

5.31 – 7.19 min: Do you understand that? Do you understand how sinful that is? These people, I'm not even going to call them people; alright? They take your children; they not only molest them; men f*** them and make them shoot each other. They give them guns. It's either you shoot him or I'm gonna shoot you. They are... mind you, they are children. Children. Yes. I'm speaking out, because I... uh! Who else is doing this? You're all just [inaudible]... shame on you... And actually the most recent paedophilia... got taken down... WOW! How long did that take? Really?! Do you know how long this has been going on? *Sigh* Alright I'm gonna calm down... but as a parent and I love parents out there. My heart goes out to all the parents out there who have missing children. You know, we all pray for them; every day. And I put on a bold face in public every day; because there needs to be someone strong, believe that. But my strength comes from somewhere... that I have a very vulnerable emotional side where I feel very strongly for these children and innocent people. So therefore I want to speak out.

7.20 – 9.10 min: I have and I have my passion too; and in the end you shall all know why I am so passionate about exposing every single one of these scumbags; okay? The truth shall prevail and you all will know why. So, as for you parents... ah... there are no words to describe. But let me just expose because you can't just... there is a point where you CANNOT just turn the other way. You know this stuff is going on; and you go 'Oh well... that's their problem. Let's just turn the other cheek.' How long are you going to turn the other cheek, until it happens to your own freaking children? When, when, when your own child; three years old, get's run out [kidnapped] and gets blasted right in the head with a gun... yeah... there's more to that people; okay? And I'm not just saying that coming from some... I mean, actually, mothers, fathers out there... If you found out... I'm sure you would do way worse than what I am just saying. I'm just using voc. I'm just annihilating them vocally. I'm sure the parents out there who find out what their children have gone through, their missing children. I am pretty positive more than just a vocal annihilation of these scumbags that do this to your children; okay?

9.11 – 10.32 min: So keep on turning the other cheek folks. Hey, go and turn the other cheek; you are with the others. I am not. I AM NOT. Like I said you... There is only two ways to go about this: you're either with us: the good guys, or you're with the others. There is no in-between. Cause if you are in-between, hiding like cowards, turning the other cheek; doing whatever; well then you are a freaking coward and you are just a sheep. And sheep end up dying because you know what you are owned by "The Others". So pick one: you're either one of us: the good guys or you're part of the others. That is simple as that! Two choices: good guys; bad guys. In-between you're dead because the bad guys are going to suck your soul out [transfer your consciousness to your REM driven clone] and do some sadistic stuff to you and watch, and make you watch while they pretty sadistic stuff to your children as well.

10.33 – 11.33 min: Do you know why they love children? Because they are innocent souls; they're innocent... they're, they're the most innocent pure beings in this planet. They're not harmed by anything. They're new to the world; bright-eyed pure innocent children. That is why these disgusting paedophile and these clone rings; cloning centres; satanic rituals; Brownsville Texas... There are many other cloning centres where they take your children that go missing. And you wonder why? What happens to them? I'm sorry to break this to you but that is what happens. Now either do you want to know what happens to them or do you want to turn the other freaking cheek?

11.34 – 13.09 min: Tune into my next show. I'm gonna upload stuff; I have an arsenal ready to blow up! Okay. And I have reason behind this. You all should know my personal reason soon; but this has nothing to do with me right now. But know that I'm back, I'm back with a vengeance and I'm back with an army full of people around the world who are sick and tired of treated like animals; or quote, unquote "COWS". We all know what that means. For the outside world (the masses) we all know the term "sheep", sheeple. But for the insiders we know what the cows are don't we? You know what "The Others" like to do with the cows, right? They start to herd you in... and to... yeah...I'm gonna end it at that. And to all the parents, families and children out there, I love you so much. I... have to maintain composure, because that is what I do. That is all. Over and out.

Appendix B: MK Ultra

MK Ultra *-noun:* [Manufacturing Killers Utilizing Lethal Tradecraft Requiring Assassinations] The goal of mind control, using MK Ultra technology is to program an individual to carry out any task against their will and self-preservation instinct, and to control the absolute behaviour and thought patterns of the individual.

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Modern-day MK Ultra involves an implantable microchip which is inserted into a Mark 2 clone of the victim. Every thought, reaction, hearing and visual observation causes a certain neurological potential, spikes, and patterns in the brain and its electromagnetic fields, which can now be decoded by the implantable microchip into thoughts, pictures and voices. The thoughts, pictures and voices of the implanted Mark 2 clone (victim) can now be displayed visually and heard on any system capable of converting visual images, such as a television or a computer. These images are usually displayed on a giant screen at the cloning centre.

The purpose of MK Ultra is to elicit a specific conditioned response in a victim (desired by the programmer) to an otherwise neutral stimulus. In other words, through the process of "classical conditioning" (which involves learning a new behaviour via the process of association. In simple terms two stimuli are linked together to produce a new learned response in a person) the implanted Mark 2 REM duplicate clone (victim) is placed thorough many similar recurring scenarios which are experienced (or perceived) by the victim as "real", because the programmer manipulates the victim's audio and visual field, and continuously pairs the victim with the neutral stimulus, so that either a positive or negative conditioned response is elicited in the victim towards the neutral stimulus.

In other words an implanted victim can be placed in many recurring situations deemed as frightful, where a mystery stranger saves the victim from the frightful situation over and over again. The victim will now have positive associations towards the mystery stranger and therefore the conditioned response is now one of 'positive associations' (towards the mystery stranger who did not elicit such a reaction before).

MK Ultra techniques are administered through Mark 2 (sleep driven) clones. In other words classical conditioning happens when the person sleeps. Memory suppression technologies are also used in conjunction with MK Ultra technology, which enables the programmer to control certain memories the victim remembers. The use of memory suppression technologies and MK Ultra technology allows the programmer to reinforce behaviour and elicit specific conditioned responses (in an original).

Therefore, in our example above, when the original meets the mystery stranger in real life, the original (victim) will be predisposed to the mystery stranger and automatically 'feel safe' around this person and may even believe that he / she should 'date this mystery stranger' – depending on what was programmed; because the victim was conditioned to elicit such an emotional response towards the mystery stranger in his / her sleep as a Mark 2 REM driven clone through MK Ultra functionality.

MK Ultra can also be used to create zombified individuals who are programmed to murder and remember nothing of their crime afterward. MK Ultra (technology) can also be used to disrupt the memory of the original, discredit people through unusual behaviour, make the person insane or commit suicide and murder.

MK Ultra has much functionality. Furthermore, because of its video and audio projection functionality, MK Ultra can also be used to compose music. MK Ultra is capable of relaying the Mark 2 REM driven clone's subconscious and conscious mind as visual images and audio, projected onto a screen. Therefore thoughts, pictures and voices which have been experienced consciously and subconsciously in one's life can be displayed visually and audibly on a television or computer screen. The Mark 2 clone now has the option of harmonising these thoughts, pictures, and voices into a coherent order which produces music through the thought process of his or her imagination. See Jim Cristea (2009); Berkeley News (2011); UC Berkeley Campus Life (2011) CTForecaster (2013); nature video (2013) and Stromberg (2013) for examples and discussions and the capability of MK Ultra technology.

Appendix C: The Illuminati

Illuminati *–noun:* A modern-day criminal organisation operated by reprobate (depraved, unprincipled and wicked person) criminals. Their main agenda: is to enslave the whole world through advanced concealed technologies.

Today's Illuminati trace their roots back to Professor Adam Weishaupt who found the Illuminati on 1st May 1776. Since the inception of the Illuminati the intent has always been, and remains: "to bring about a NEW World Order that writes God out of the picture and deifies (glorifies) Lucifer." This intent is still prevalent today. The following excerpt is derived from A. Ralph Epperson (1990) *The New World Order:*

> Weishaupt was a teacher of Cannon Law (law governing the affairs of a Christian Church, especially the law created or recognised by the Papal authority in the Roman Catholic Church) at the University of Ingolstadt in Bavaria, now part of Germany.
>
> He even told the world, in his writings, where he would conceal the Order: "None is fitter than the three lower degrees of Free Masonry; the public is accustomed to it, expects little from it, and therefore takes little notice of it." He felt that this secrecy would lead him to success because he felt no one would be able to break into it. He wrote: "Our secret Association works in a way that nothing can withstand ...."
>
> Weishaupt accepted the fact that all secret associations and secret orders had two doctrines, one concealed and reserved for the Masters... the other public ...." and the Illuminati was [and are to this day] a secret society with two doctrines.
>
> Professor Weishaupt, its founder, boasted of his organization's secrecy. He realized that this secrecy would enable them to decide the fate of nations and because their deliberations were secret, no outsider could interfere. He wrote: "The great strength of our Order lies in its concealment; let it never appear in its own name, but always covered by another name, and another occupation." Weishaupt later wrote about that secrecy in a letter to a fellow member of the Illuminati: "Nothing can bring this about [the new world order] but hidden societies. Hidden schools of wisdom are the means which will one day free men from their bonds [the "bonds" of religion] Princes and nations shall vanish from the earth." So the secret societies were created to bring the world to the new society known as the New World Order. The members of these organizations obviously feel that their goals are so noble that they may perform whatever tasks are required of them to bring that goal to fruition. This means that murder, plunder, and lying all become acceptable as long as these methods assist its members in obtaining their goal.
>
> Adam Weishaupt, the founder of the Illuminati, wrote over and over and over again, that "the ends justified the means." Weishaupt also told initiates to use whatever means, which included murder, to achieve the goals of the association that he was joining. And that the major goal of the Illuminati, was the destruction of all religion, including Christianity. That meant that if Christians physically stood in the way, they could be removed by simply murdering them. Weishaupt even went so far as to say that anyone not willing to take the life of another was unfit to join the Illuminati. He wrote the following in a letter to a fellow member in 1778: "No man is fit for our Order who is not ... ready to go to every length ...."
>
> Another reason, that Weishaupt felt that the Illuminati would succeed, was the fact that he was offering his members worldwide power. He felt that this inducement would enable him to draw into his organization only those who would do anything to satisfy that desire for power. He wrote: "The true purpose of the Order was to rule the world. To achieve this it was necessary for the Order to destroy all religions, overthrow all governments and abolish private property."

> But his religion had a different base than the traditional religion: his was based upon a worship of reason: "... then will Reason rule with unperceived sway." "... Reason will be the only code of Man. This is one of our greatest secrets." "When at last Reason becomes the religion of man, then will the problem be solved." Weishaupt's dedication of his organization to "reason" makes some sense when the reader recalls that "reason" has been defined as the "unbridled use of man's mind to solve man's problems without the involvement of God." The Bible calls this "the fruit of the tree of the knowledge of good and evil." It was this knowledge that God wanted man not to have, and it was the promise made to man by Lucifer that man could have it by eating of "the fruit." In addition, Weishaupt's religion offered its believers a reward not offered by any other religion: worldwide power!
>
> Weishaupt wrote: "The pupils [members of the Illuminati] are convinced that the Order will rule the world. Every member therefore becomes a ruler." Weishaupt's religion not only offered power to his believers, but he offered them something else not guaranteed by any other religion: worldly success. He said that once a candidate had achieved the exalted degree of Illuminatus Minor, the fourth of the thirteen inside his Order, his superiors would: "assist him [the member] in bringing his talents into action, and [would] place him in situations most favourable for their exertion, so that he may be assured of success." Finally, the goal of the Illuminati was "man made perfect as a god - without God."

The ideology of "man made perfect as a god –without God" still remains to this day, and it is practiced by today's Illuminati members. The above phrase is what ties in Luciferian worship and trans-humanism. Lucifer is idolised by Illuminati members as the deity who gave man 'knowledge' and therefore is worthy of worship; God, -according to Luciferians, -did not want man to have knowledge and therefore is despised by Luciferians. Ingrained in the trans-humanism doctrine is the believe that: 'man can become 'god' through science and technology and in turn overthrow the Creator of the universe: God'. See LawOfIdentity (2014) and Mark Dice (2014).

These are the basics of Luciferianism. Therefore everything which is natural or pertains to nature must be contended or destroyed by Luciferians. This is why Illuminati members endorse having sex with children, killing first born sons, and drink blood. All the above go against nature and according to the 'edicts of Lucifer': paedophilia makes the person committing the act younger (it doesn't, it is just an excuse to act perverse on children because they know children are vulnerable); killing your first born son gives you good luck and fortune in this life (so yes, some Luciferians have sacrificed their first bon sons); and Illuminati members believe drinking blood / cannibalism is a 'purifying agent' (although in reality it causes spongiform encephalitis (holes in the brain)).

Modern-day Illuminati members still retain the goal of its founder "to bring about a NEW World Order that writes God out of the picture and deifies (glorifies) Lucifer." Infiltration through secrecy, still remains their mode of operation, for the current Illuminati and therefore they have secretly infiltrated all the major religions on earth; government and education – where each successive generation is being dumb down; they have continually diminished the ability for individuals to own private property, or claim inheritance; divided people against each other to continually diminish patriotism; and have continually diminished family values.

They also compartmentalise their knowledge between members. Until I fully exposed the Illuminati, many people who have been REM clones at the cloning centre did not know they were in fact REM driven clones, and thought they were in the 5th Dimension; the astral plane; a singularity; the spiritual realm; Valhalla; quantum hopping; a time stutter etc. or whatever else the Illuminati told them.

Today's Illuminati members also meet in secret (just like the founding members) as REM driven clones, **when they go to sleep**. Furthermore, because Illuminati meetings are in secret and not many people know the exact location (because knowledge is compartmentalised) of the cloning centre; or the fact that their consciousness has been transferred to Mark 2 REM driven clone bodies at the cloning centre (and they are not in their original bodies); as well as the fact that unsuspecting civilians have their memories suppressed; the points mentioned above are the reasons the Illuminati believe 'they are all powerful and untouchable'; and as a consequence, today's Illuminati members do all the disgusting things they want, because they believe no outsider can interfere.

The ring leaders of the Illuminati today also believe "the ends justify the means". This is why they clone, torture, molest, murder, and rape unsuspecting civilians as REM driven clones in their sleep. The Illuminati of today offer their members incitements to go along with their agenda and not oppose them (or face death). Another popular method is to entice their target with many, many wonderful prospects, and have the target believe they are joining a noble and prosperous venture, so that the target fulfils the objectives of the Illuminati unknowingly; promoting the Illuminati in a positive way, because the target has been deceived to perceive the nature of the Illuminati as 'positive'; by the time the target finds out the true intent of the Illuminati, and the evil which emanates from it, it is too late. Those who rise up in the ranks of the Illuminati are the men and women who have an insatiable lust for power, and most importantly: the men and women who want to rule the world.

Modern-day Illuminati members also wish to become gods (through technology); overthrow the Creator, and achieve their overall aim of enslaving mankind. This is why they clone people, and clone people in high rank society from all walks of life (movie stars, musicians, politicians etc.; whether the person willing wants to be part of the Illuminati or not) so long as that person is in a position of power and influence, the Illuminati clone that person, and threaten that person, for example -"Hey, you're going to hang with us –or else" –through such coercion, the people in high rank society who have power and influence will not oppose the Illuminati's plans to become gods; enslave mankind forever; and rule the world. Another reason for cloning high rank society is to include these people into the Illuminati (willingly or unwillingly) to ensure the world's populace remains in ignorance (because once all the world leaders and high rank society are cloned and under the coercion of the Illuminati nobody in a position of influence or power can warn the populace against the Illuminati) until the Illuminati's plan is completed and they have enslaved the world forever.

The Illuminati's overall aim of 'becoming gods' and ruling the world, as well as, mind controlling all the inhabitants of earth is also the reason the Illuminati:

- Administer drip feed disclosure through media, by telling some truths mixed with lies in order to conceal their true intentions and overall aim, and prevent the betrayed partner (the public) from ever discovering "the complete truth";
- Administer evaluative conditioning, by placing their symbols and ideology in popular media with positive associations, so that the unknowing and unsuspecting public will eventually become predisposed to the Illuminati and unsuspectingly have a positive or neutral response towards the Illuminati;
- Because they want to become 'gods' is also the reason the Illuminati is promoting RFID microchips and only discussing RFID microchips positively, while at the same time placing suppression (gagging) orders on anyone who speaks negatively about RFID microchips –which implies an unsuspecting public will willingly accept the microchip; and at the point of transaction, the person will have (unknowingly) given up their privacy to a third party (the Illuminati) for the rest of his / her life;
- Their aim to become 'gods' is also the reason the Illuminati are hurriedly trying to complete the HAARP grid across earth –because a complete HAARP grid will allow them to achieve their goal of mind control over the entire world; which fulfils their objective of becoming gods; because a complete HAARP grid will be capable of time travel, and therefore the Illuminati will be capable of going back to a previous time to correct the mistake(s) which led to their downfall; the Illuminati members will retain the knowledge of the previous time, and the rest of humanity will have no recollection of such a memory.

The Illuminati is **not** a joke. It is **not** fiction. They are very real, and part of humanity's reality; and through advanced concealed technologies the Illuminati aim to enslave humanity forever. The ring leaders of the present Illuminati includes Queen Elizabeth II, Prince Philip Duke of Edinburgh, Prince Charles of Wales and Vladimir Putin. I have also detailed the actions of the ringleaders in the main text in this disclosure, as well as, detailed other modern-day evil Illuminati members on my Facebook and Proboards. It is time the good people of earth, stopped being afraid, do the right thing, put a stop to this evil, and save themselves, as well as their children's children from being slaves forever. Spread and share this disclosure.

Glossary

Aneurysm -*noun:* An excessive swelling of the wall of an artery at a fixed point in the body. A brain aneurysm is therefore a: bulge or ballooning in a blood vessel in the brain. It often looks like a berry hanging on a stem. A brain aneurysm can leak or rapture, causing bleeding into the brain.

Brain Aneurysm -*noun:* see Aneurysm.

Clone –*noun:* a cell, group of cells, an organism produced asexually from a single ancestor and is genetically identical to a single ancestor.

Concealed Technology -*noun:* hidden machinery and devices undisclosed and currently unavailable for public consumption. Concealed (or military) technology develops at a rate of 44 years for every 12 months which passes in comparison to the technology the public is currently accustomed to. Origin: Phil Schneider.

Cloning Centre –*noun:* a physical location (on earth) where duplicate and replicate clones are produced. These physical locations are usually Deep Underground Military Bases (DUMBs). DUMBs have an entire floor dedicated to cloning. It is also a place where Illuminati members meet with each other as REM driven clones. The above-ground cloning centre where many high profile people attend can be found within a radius of 5/6 hours drive from the Robert Pickton Farm Port Coquitlam, British Columbia, in Canada, somewhere at a remote nature reserve.

Cloning Technology -*noun:* the technological advancements in medicine, science and technology used to produce duplicate and replicate copies of originals.

Conditioned Response -*noun:* an automatic response established by training to an ordinarily neutral stimulus.

Conditioned Stimulus –*noun:* A previously neutral stimulus that, after repeated association with an unconditioned stimulus, elicits the response produced by the unconditioned stimulus itself.

Consciousness –*noun:* the state of being aware of and responsive to one's surroundings; a person's awareness or perception of something.

Consciousness Transfer -*noun or verb:* the process of transferring or copying the mental content (including long-term memory and "self") from a particular brain and copying it to a computational device; artificial body or avatar body such as that of a robot or clone version of the original. It is also the feat in which the person's mental content (long term memory and "self") moves from one body into another.

Depopulation *verb:* to remove or reduce the population of, as by destruction or force.

Drip Feed Disclosure *noun or verb:* is the process of supplying information but in small amounts overtime. Drip feed disclosure is also the process of revealing information slowly overtime, possibly telling lies to conceal certain aspects of the truth until the source administering the drip feed disclosure has adequate time to let out the truth in a slow and controlled way, thereby delaying the betrayed partner (in this disclosure, the public) from having the "complete truth" for some time.

DUMB *–noun:* [Deep Underground Military Base] a facility directly owned and operated by or for the military or one of its branches that shelters military equipment and personnel, and facilitates training and operations beneath the surface of the earth.

Duplicate Clone *-noun:* a fully formed human body which is a genetic copy of original developed through the process of regenerative technology. Duplicate clones are grown in a big thick tank full of (salty) water.

Duplication Cloning *-verb:* involves agitating the cells of on an original repetitively until a fully formed human body of the original is developed. Duplicate clones take an average of 5 months to form into a fully developed human body of the original through the process of regenerative medicine and technology.

Evaluative Conditioning *-noun:* is a change in liking, which occurs due to an association with a positive or negative stimulus.

H.A.A.R.P. Technology *–noun:* [High frequency Active Auroral Research Program] a radio transmitting system that can bounce signals off the Earth's upper atmosphere, (60km (37 miles) to 1000km (620 miles) high) back to probe deep into the earth or sea. HAARP is also capable of: disrupting human mental processes; knocking out all global communication systems; changing weather patterns over large areas; interfering with wildlife and migration patterns; hurting ecosystems; negatively affect human beings health, moods and mental states; and unnaturally 'boil' the earth's upper atmosphere. HAARP used correctly will control the weather without any adverse effects.

H.A.A.R.P. Grid *–noun:* a network of radio transmitters which can bounce signals off the earth's upper surface. Each transmitter is located at a specific point across earth and communicates in unison with other radio transmitters across the earth. At this present time of writing, a HAARP grid has **not** been completed, although the Illuminati are working twice as fast to complete a HAARP grid. The threat to humanity once a HAARP grid is completed includes: mind control over the entire world's inhabitants. A completed HAARP grid will also be capable of time travel, and therefore the Illuminati will always be able to go back to a pervious point in time to correct the mistake(s) which led to their downfall. Humanity will be slaves forever.

Habeas Corpus *-noun:* is [A] writ [formal document] requiring a person under arrest to be brought before a judge or into court, especially to secure the person's release unless lawful grounds are shown for their detention.

Heart Attack *-noun:* A sudden occurrence of a blockage of the flow of blood to the heart.

Human Clone *–noun:* The creation of a genetically identical copy of a human.

Ionosphere *–noun:* the layer of the earth's atmosphere which contains a high concentration of ions and free electrons and is able to reflect radio waves. It lies above the mesosphere and extends from about 60km (37 miles) to 1,000 km (620 miles) above the earth's surface.

Illuminati *–noun:* A modern-day criminal organisation operated by reprobate (depraved, unprincipled and wicked person) criminals. Their main agenda: is to enslave the whole world through advanced concealed technologies. See Appendix C for further discussion.

Mark 2 Clone *–noun:* Is a sleep driven clone; specifically, a REM sleep driven clone. A Mark 2 Clone is activated by transferring the consciousness of an original into a Mark 2 Clone **only when** the original reaches REM sleep (usually 90- 110 minutes **after** the original falls asleep). Once the consciousness of the original is transferred from the original's body to the Mark 2 Clone, the Mark 2 clone is now capable of motion: such as walking, talking etc. The Mark 2 clone 'drops limp' and becomes motionless once the original wakes up from sleep. The original's consciousness no longer resides in the Mark 2 clone (once the original is awake) and therefore the Mark 2 clone is now incapable of motion. Mark 2 Clones are also known as "REM Driven Clones" and "REM Duplicate Clones".

Memory Suppression *–noun or verb:* is the selective removal of memories or associations with the mind using memory suppression technology.

Memory Suppression Technology *–noun:* any scientifically advanced technology used selectively to remove memories from the conscious mind.

Mind-Voice Technology *–noun:* an advanced technology capable of reading, listening, hearing and broadcasting a person's inner voice or thoughts. It is capable of replicating sounds **exactly**. Therefore an individual can hear the sound of drums, a guitar or any instrument and replicate that sound exactly just by thinking about it. Consequently, Mind-voice technology has the functionality of producing music.

Military Technology *–noun:* machinery and devices developed from scientific knowledge used by the Armed Forces which advance at a rate of 44 years for every 12 months which passes, compared to the technology the public is accustomed to. Origin: Phil Schneider

MK Ultra *-noun:* [Manufacturing Killers Utilizing Lethal Tradecraft Requiring Assassinations] The goal of mind control, using MK Ultra technology is to program an individual to carry out any task against their will and self-preservation instinct and to control the absolute behaviour and thought patterns of the individual. See Appendix B for further details.

Neutral Stimulus *–noun:* is a stimulus which initially produces no specific response other than focusing attention. In classical conditioning, when used together with an unconditioned stimulus, the neutral stimulus becomes a conditioned stimulus.

Negative Association *-noun:* is an undesirable experience or perception.

Negative Stimulus *-noun:* a stimulus with undesirable consequences.

New World Order *-noun:* [NWO] Agenda. The whole NWO agenda is to turn humanity into mindless slaves forever; whereby the post-humans / trans-humans mind control the entire world's populace either through RFID microchips or a completed HAARP grid. Another aspect of the NWO agenda is to depopulate the world's current population of 7.3 billion people to 500 million people (and never exceed a world population of 500 million people afterwards); ruled by a one world government; a one world ruler; with a one world religion. See Appendix C for more details.

Original *–noun:* A person who is **not** a clone.

Pain Receptor *-noun:* Any one of the many nerve endings throughout the body that warn of harmful changes in the environment such as excessive pressure or temperature.

Positive Association *-noun:* is a desirable experience or perception.

Positive stimulus *-noun:* a stimulus with desirable consequences.

Posthumanism *–noun:* seeks to rewrite the very definition of being human. It is the condition in which humans and intelligent technology become intertwined. In the Posthuman there are no essential differences or absolute demarcations between bodily existence and computer stimulation, cybernetic mechanism and biological organism, robot technology and human goals.

Posthuman *-noun:* see Posthumanism.

Project MK Ultra *-noun:* see MK Ultra.

Regenerative Medicine *-noun:* (of a living organism) the process of re-growing new tissues after loss or damage.

Regenerative Technology *-noun:* any machinery or device developed from scientific knowledge which has the capability to re-grow new tissues after loss or damage.

REM Sleep *–noun:* [Rapid Eye Movement] is the fifth stage of sleep in the sleep cycle. It takes 90 - 110 minutes to reach REM sleep after we fall asleep. REM sleep is also known as the "period of paralysation". The involuntary muscles such as the brain become more active whereas voluntary muscles (those that you move by choice) such as your arms and legs become more relaxed or paralysed. REM sleep is a kind of sleep that occurs at intervals during sleep, and it is characterised by rapid eye movements.

REM Driven Clone *-noun:* [Rapid Eye Movement Driven Clone] a clone that can only become activated, once the original is in REM sleep. See Mark 2 Clone.

REM Duplicate Clone *-noun:* [Rapid Eye Movement Driven Clone] A clone developed by regenerative medicine and technology and is therefore an identical copy of an original. REM duplicate clones can only become activated when the original is in REM sleep. See Mark 2 Clone.

REM Driven Clone Death *–noun:* the process where an original dies because of constant torture to their REM driven clone or where a constant electrical current is applied to the REM driven clone resulting in death of an original usually in the form of an aneurysm or heart attack (because consciousness is linked) in the original's body.

REM Driven Clone Torture *—noun or verb:* the action or practice of inflicting serve pain on a REM driven clone. REM driven clone torture causes biological and physiological responses in the original's body because consciousness is linked. Intermittent REM driven clone torture (depending on what is done) causes the original to experience severe headaches, an upset stomach, achy limbs, sickness; a weakened heart. Continuous REM driven clone torture will lead to the death of the original; usually in the form of aneurysm or heart attack in the original's body.

Replication Cloning *–verb:* involves giving birth to a genetic identical of an original where the newborn starts life off as a baby and matures. The newborn is referred to as a clone.

RFID Technology [Radio Frequency Identification] *-noun:* are electronic microchips the size of a grain of sand that can be directly embedded into the human flesh. RFID microchips communicate wirelessly through the use of electromagnetic fields to transfer data. RFID microchips link the brains of people via the implanted microchip to satellites controlled by ground base super-computers. The dangers of RFID microchips to the implanted person are: total loss of privacy and total control of the person's physical body functions, mental and emotional thought processes, including the implanted person's subconscious or dreams –for the rest of that person's life! RFID microchips are also tracking devices, and the implanted person can be tracked anywhere on the globe.

Selling One's Soul *-verb:* to sell the use one's "Mark 2" REM driven clone to the Illuminati, for the Illuminati to use the individual's Mark 2 REM driven clone in whatever manner the Illuminati wishes. There are no returns once the individual has signed over his / her (soul) Mark 2 REM driven clone. When an individual sells their (soul) Mark 2 REM driven clone, the person has also entered into a contract to sell the Mark 2 REM driven clone(s) of their current children (if they have any) as well as any unborn children the person may have later in life. The person sells all their descendants (souls) Mark 2 REM driven clones to the Illuminati, once the individual sells their (soul) Mark 2 REM driven clone to the Illuminati. Selling one's (soul) Mark 2 REM driven clone is considered **a serious business transaction** to the Illuminati. There are no returns. If the person ever makes a fuss and wants their (soul) Mark 2 REM driven clone back, the Illuminati will either torture the person's Mark 2 Clone, or apply a constant electric current to the person's Mark 2 Clone until the person either has a heart attack or aneurysm in their original body. This is what public figures are hinting at when they say "They have sold their soul". They have sold the use of their Mark 2 REM driven clone to the Illuminati. Selling one's soul is not a joke. Never sell your soul.

Stimulus *–noun:* is something that causes a reaction, especially interest, excitement or energy. It is also an energy change registered by the senses. For example a stimulus can be a shinny object for a baby.

Technology *–noun:* machinery and devices developed from scientific knowledge.

Technological Advancement *–noun:* is incorporating, by means of experimental development, a characteristic or capability not previously existing or available in standard practice, into a new or existing process or product that enhances a product's performance. Novelty, uniqueness, or innovation alone does not indicate a technological advancement.

Transhumanism *–noun:* the belief or theory that the human race can evolve beyond its current physical and mental limitations, especially by means of science and technology.

Unconditioned Response *–noun:* is a response to a neutral stimulus we have no / little control over. It is a natural automatic response. For example, food is an unconditioned stimulus for a hungry animal, and salivation is the unconditioned response.

Unconditioned Stimulus *–noun:* A stimulus that elicits an unconditioned response.

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Planck mass-energy templates [Tetryonic theory] 1694

Tetryonic Theory

The unified quantum field geometry of charged EM mass-ENERGY-Matter in motion

"...the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the eternally problematic character of his concepts. He uses this conceptual material, or, speaking more exactly, these conceptual tools of thought, as something obviously, immutably given; something having an objective value of truth which is hardly even, and in any case not seriously, to be doubted. ...in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them." [Albert Einstein]

Given the range and applied scope of Quantum Physics in today's modern technologic World there remains a driving desire to rationalise our numerous disparate scientific theories into one coherent theory with a intuitive model that can be applied equally to the Quantum and Cosmological scales of our Universe.

Such a theory would need to preserve the currently observed outcomes and present established theories in a new light, offering additional testable predictions of its own, and ideally do so in a manner that is simpler than that of the established theories and hypothesises.

Many foundational properties of Quantum Mechanics remain unaddressed by scientific theory and in the following pages an overview of the key quantum properties challenging our current scientific advancement will be highlighted, including a number of assumptions that currently impede the development of a fully realised, coherent solution to all of our current scientific questions.

While Mathematics is the language of Science it remains a language that lacks a well-defined physical model on which to test it and further its many and varied solutions to Quantum & Cosmological scale physics. It is this lack of any rigid, enforceable GEOMETRY that has allowed the development of numerous disjointed statistical and probabilistic solutions to physical problems, in turn impeding our scientific understanding and advancement of quantum processes.

The Standard Model has many observed and testable components to it but more recently new theories have emerged to contest it without being rigorously testable themselves. They rely on the established foundation provided by the Standard Model but try to explain its various deficiencies ad-hoc with various suppositions without any solid footing of their own.

Often the only way to progress further in our scientific endeavours is to retrace our footsteps in science and to develop new physical models on which we can discern our known results and observations thus excluding any false or misleading assumptions (mathematical of otherwise).

In doing so there exists the promise that a simple underlying foundation can be found to the physics of our Universe, revealing new and exciting advances in Science that will allow us to usher in a new age of scientific and technological advancement for the betterment of humanity as a whole.

'Tetryonics – The charged geometry of EM mass-ENERGY-Matter' whose founding principle is that **EQUILATERAL Planck energies are** the foundation geometry for all quantum mechanical processes is presented here as just such a solution to the current quandaries of Quantum Mechanics.

ENERGY

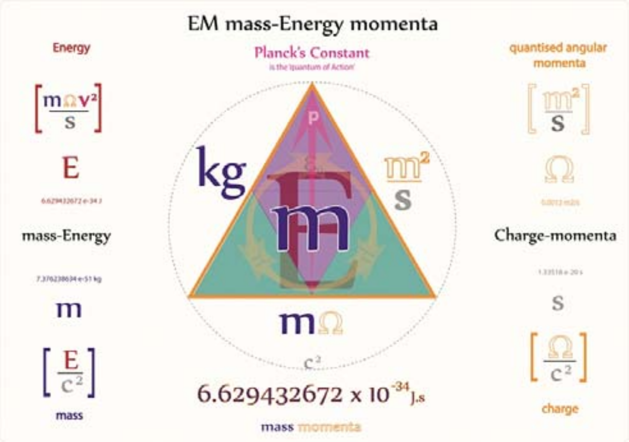
EM mass-Energy momenta
Energy
Planck's Constant
is the 'quantum of Action'
quantised angular momenta
mΩv²/s
E
m²/s
kg
P
m²/s
Ω
mass-Energy
Charge-momenta
m
m
s
mΩ
E/c²
Ω/c²
c²
6.629432672 x 10⁻³⁴ J.s
mass
charge
mass momenta

Energy, in Physics, is an indirectly observed quantity of a system that imbues it with the ability to exert a Force or do Work over a distance.

It has been measured and quantified through numerous methodologies over the centuries, most notably through its associated characteristics such as mass, velocity and ElectroMagnetic fields.

The most recent attempt to quantify its characteristics (with respect to heat and light) led to the discovery of Planck's constant and the development of Quantum Mechanics

The application of a simple proposition (that Energy has an equilateral geometry) opens the door on a greater understanding of the mechanics of the quantum world, a realm that will be forever beyond the reach of our physical eyes.

The myriad of perplexing properties of quantum properties (such as Charge, mass & Matter) and the astonishing outcomes of quantum experiments (Interference and Wave-Particle duality) can now all be readily modelled and explained rationally on a solid geometric footing.

Paving the way for new discoveries and a greater understanding of our Universe and its mechanics

Quantised Angular Momenta

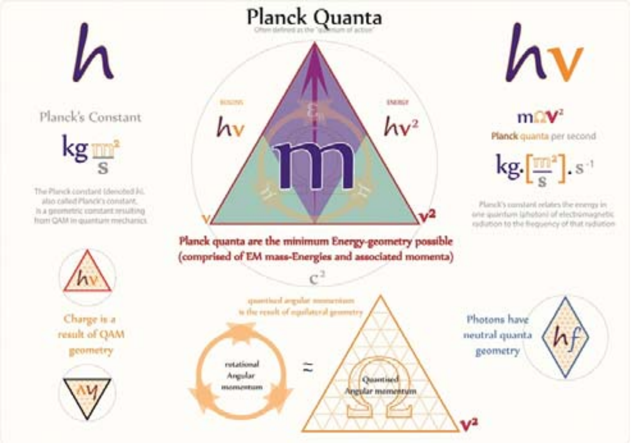
Planck Quanta
h
hv
Planck's Constant
kg m²/s
hv
hv²
m
mΩv²
Planck quanta per second
kg.[m²/s].s⁻¹
The Planck constant (denoted h), also called Planck's constant, is a geometric constant resulting from QAM in quantum mechanics
Planck's constant relates the energy in one quantum (photon) of electromagnetic radiation to the frequency of that radiation
v
v²
Planck quanta are the minimum Energy-geometry possible
(comprised of EM mass-Energies and associated momenta)
c²
hv
Charge is a result of QAM geometry
quantised angular momentum is the result of equilateral geometry
Photons have neutral quanta geometry
hf
rotational Angular momentum
≈
Quantised Angular momentum
Ω
v²

Building on the priori definition of equilateral energy quantisation it can be quickly demonstrated that any energy measurement per unit of Time results in a geometric unit of measurement that has historically be taken to represent rotational motion (specifically Angular momentum)

This unit of motion is found throughout Quantum Mechanics and is directly related to the square energy levels in nuclear processes.

The equilateral EM fields of energy quanta are constrained by its geometry and this geometry lies at the heart of understanding the quantum world in all its beauty.

It determines properties such as Electric permittivity and Magnetic permeability, the vector direction of linear momentum and relates the scalar property of electromagnetic mass directly to velocity.

CHARGE

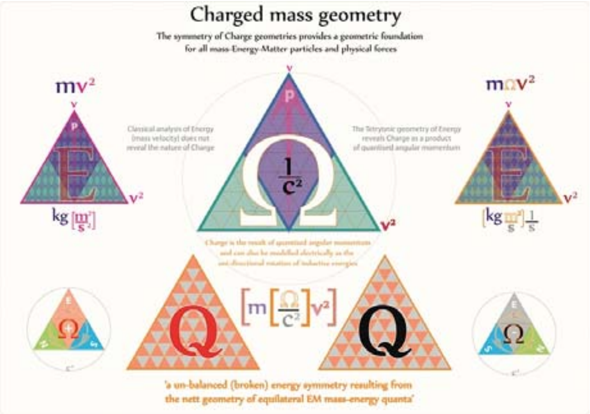
Charged mass geometry
The symmetry of Charge geometries provides a geometric foundation for all mass-Energy-Matter particles and physical forces
mv²
v
p
E
v²
kg [m²/s²]
Classical analysis of Energy (mass velocity) does not reveal the nature of Charge
v
p
Ω
1/c²
v²
The Tetryonic geometry of Energy reveals Charge as a product of quantised angular momentum
mΩv²
v
E
v²
[kg m²/s] 1/s
Charge is the result of quantised angular momentum and can also be modelled electrically as the uni-directional rotation of inductive energies
Ω
Q
[m[Ω/c²]v²]
Q
Ω
'a un-balanced (broken) energy symmetry resulting from the nett geometry of equilateral EM mass-energy quanta'

A fundemental property of all mass-ENERGY-Matter that gives rise to the Forces of electrical Interaction has eluded physical explanation by Physicists since its discovery and led to many 'band aid' additions to the Standard model in attempts to explain its observed properties.

The most recent attempt at an explanation was Special relativity theory which in turn led to our current models of charge from contractions of Matter due to motion.

SR explains Charge as an invariant property of of electrostatic bodies and that the motion of charges creates an additional magnetic moment through the relativistic distortion of spherical bodies of Matter.

Equilateral Planck energy momenta geometries and Matter topologies offer a completely different explanation for the source of electrostatic charges and their associated magnetic moments.

Positive and Negative charges are revealed to be opposite side of the same quantum energy 'quoin', and can be modelled electrically as ideal quantum inductive loops. It is equilateral geometry that gives rise to the physical properties of quantised angular momenta, inertial mass, elemental charges and even the geometric topology of Matter itself.

In a planar 2D form they form a neutral EM energy momenta geometry but it is when they form the topology of 3D Matter they are expressed as either Positive or Negative electric charge fascia.

ODD number energy quanta [W Bosons] combine via their magnetic bases in fixed quantum steps to create the 'squared' nuclear energy levels so familiar to quantum mechanics and form the basis for ElectroMagnetic Induction.

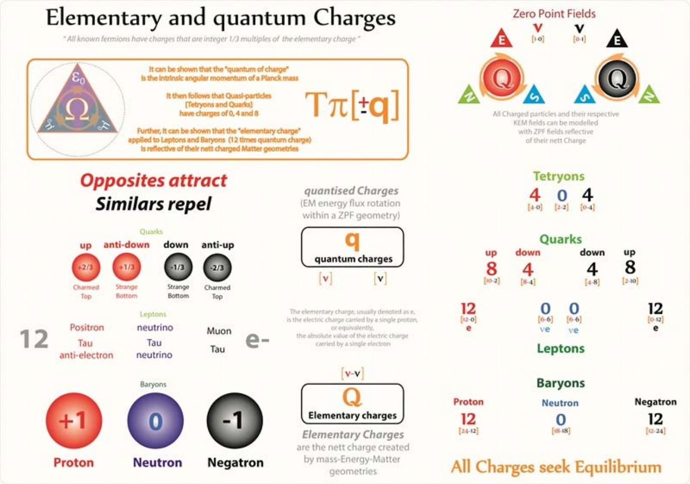
Elementary and quantum Charges
"All known fermions have charges that are integer 1/3 multiples of the elementary charge"
ε₀
Ω
It can be shown that the "quantum of charge" is the intrinsic angular momentum of a Planck mass
It then follows that Quasi-particles [Tetryons and Quarks] have charges of 0, 4 and 8
Further, it can be shown that the "elementary charge" applied to Leptons and Baryons (12 times quantum charge) is reflective of their nett charged Matter geometries
Tπ[±q]
Zero Point Fields
E
v [1-0]
v [0-1]
E
Q
Q
N
S
S
N
All Charged particles and their respective KEM fields can be modelled with ZPF fields reflective of their nett Charge
Opposites attract
Similars repel
Quarks
up
anti-down
down
anti-up
+2/3
+1/3
-1/3
-2/3
Charmed Top
Strange Bottom
Strange Bottom
Charmed Top
Leptons
12
Positron
Tau
anti-electron
neutrino
Tau
neutrino
Muon
Tau
e-
Baryons
+1
0
-1
Proton
Neutron
Negatron
quantised Charges
(EM energy flux rotation within a ZPF geometry)
q
quantum charges
[v]
[v]
The elementary charge, usually denoted as e, is the electric charge carried by a single proton, or equivalently, the absolute value of the electric charge carried by a single electron
[v-v]
Q
Elementary charges
Elementary Charges
are the nett charge created by mass-Energy-Matter geometries
Tetryons
4 [4-0]
0 [2-2]
4 [0-4]
Quarks
up 8 [10-2]
down 4 [8-4]
down 4 [4-8]
up 8 [2-10]
12 [12-0] e
0 [6-6] ve
0 [6-6] ve
12 [0-12] e
Leptons
Baryons
Proton 12 [24-12]
Neutron 0 [18-18]
Negatron 12 [12-24]
All Charges seek Equilibrium

It is their rigid equilateral geometry that provides the basis for relativistic charge invariance and the quantum mechanism for photo-electron transitions in atoms while the net energy momenta quanta in charged geometries provides the electromotive force known as Voltage.

Equilateral geometry reveals an intrinsic connection between EM Energy, mass and Charge.

As separated charges seek equilibrium they provide motive energies & the quantum scaffolding for large scale Matter topologies and their force interactions throughout our Universe.

mass-ENERGY-Matter

All Energy has an EM mass equivalence and equally any object with EM mass has energy equivalence

But there has never been a formal scientific definition and associated equation to distinguish the property of EM mass from that of Matter.

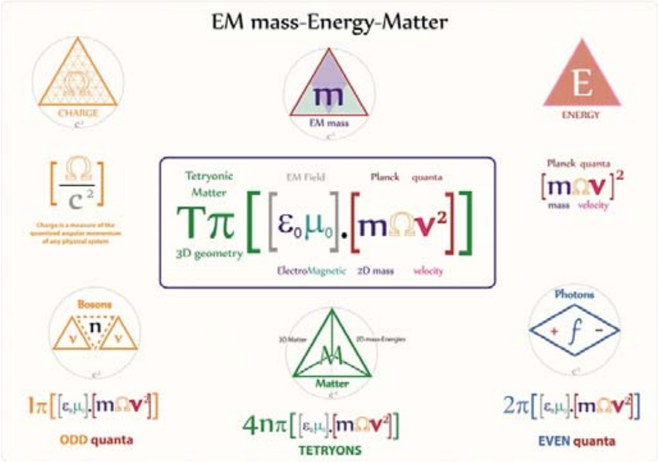
EM mass-Energy-Matter
CHARGE
c^2
m
EM mass
c^2
E
ENERGY
$\left[\frac{\Omega}{c^2}\right]$
Tetryonic Matter
EM Field
Planck quanta
$T\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$
3D geometry
ElectroMagnetic
2D mass
velocity
Planck quanta
$[m\Omega v]^2$
mass
velocity
Bosons
n
v
v
c^2
3D Matter
2D mass-Energies
M
Matter
c^4
Photons
+
f
-
c^2
$1\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
ODD quanta
$4n\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
TETRYONS
$2\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
EVEN quanta

Using Tetryonic geometry it can be clearly demonstrated that ElectroMagnetic mass is NOT Matter – it is the Energy content of a system per unit of time [E / c^2] in total agreement with Einstein (and all before him) however, lacking a formal definition of either the two terms have become mired with each other so much that they are often used for each other inappropriately even in scientific peer-reviewed literature.

ElectroMagnetic mass is the two dimensional (planar) measurement of Energy per unit of Time whereas Matter is a measure of the tetrahedral energies found in a spherical volume of 3D space.

Mass-energy can be viewed as the paper from which 3D Matter is created when it is folded into a tetrahedral shape (the quantum canvas covering the topology of Matter)

The often used tem of 'massless' is now shown to be a misnomer that should be removed from the scientific vocabulary except where it specifically refers to empty space (devoid of any energies).

Matter is now formally defined geometrically as 4nπ tetrahedral standing wave of EM energy and it is the tetrahedral topology of Tetryons that forms the foundation for all large scale Matter in the Universe (not spherical point particles).

Charge allows EM masses to form a Tetryonic topology giving volume to Matter and its energy momenta provides the interactive forces between them imbuing motion into our Universe.

Matter at rest is comprised of EM mass-energies that are always in motion and propagating in a tetrahedral EM standing wave.

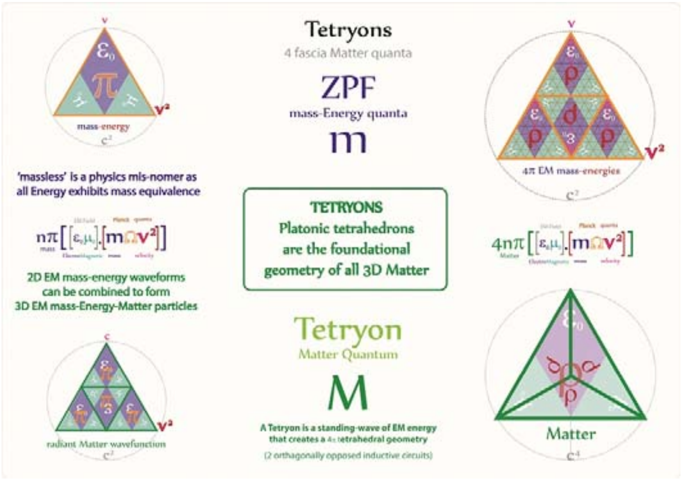
v
ε_0
π
v^2
mass-energy
c^2
'massless' is a physics mis-nomer as all Energy exhibits mass equivalence
$n\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
2D EM mass-energy waveforms can be combined to form 3D EM mass-Energy-Matter particles
c
v^2
radiant Matter wavefunction
c^2
Tetryons
4 fascia Matter quanta
ZPF
mass-Energy quanta
m
TETRYONS
Platonic tetrahedrons are the foundational geometry of all 3D Matter
Tetryon
Matter Quantum
M
A Tetryon is a standing-wave of EM energy that creates a 4π tetrahedral geometry
(2 orthagonally opposed inductive circuits)
v
v^2
4π EM mass-energies
c^2
$4n\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
Matter
c^4

To cause at will the birth and death of matter would be man's grandest deed, which would give him the mastery of physical creation, make him fulfil his ultimate destiny."

[Nikola Tesla]

Sub-Atomic Particles

Using equilateral energy all the mass-energy geometries & mass-Matter topologies of EM fields and particles can be physically modelled revealing the known Standard Model particle sand a few more.

Bosons are shown to be transverse EM fields that facilitate EM induction and Photons are revealed as longitudinal dual-charge pairs possessing a neutral EM charge and inherent magnetic moment.

The net unidirectional momentum of Bosons then distinguishes them from Photons that possess a bi-directional momentum

Closer examination of the geometries highlights a long-standing error in the mathematical formulation of QM energy formulas, namely the mistaken interchanging of Planck's quanta [*v*] for Einstein's frequency [*f*] in relation to Energy.

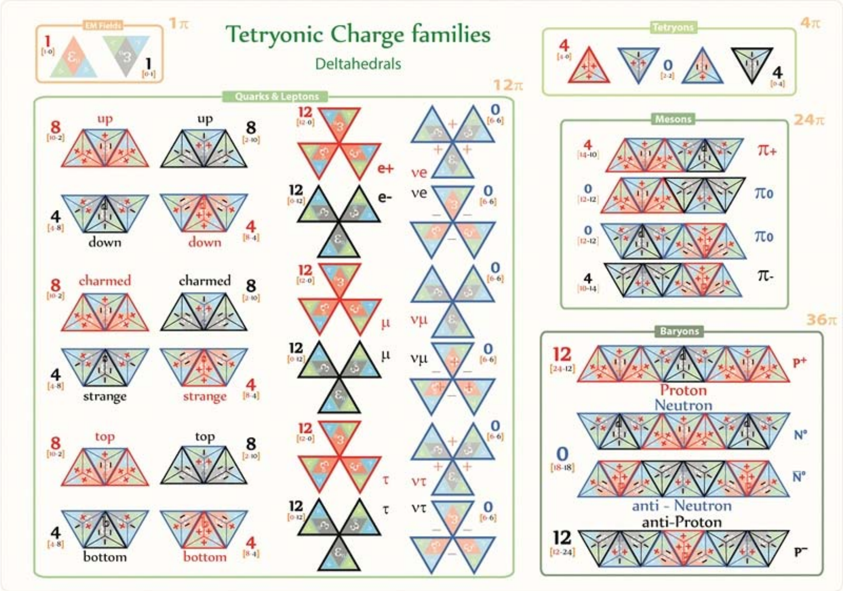
Tetryonic Charge families
Deltahedrals
EM Fields
1π
1 [1-0]
1 [0-1]
Quarks & Leptons
12π
8 [10-2] up
up 8 [2-10]
4 [4-8] down
down 4 [8-4]
8 [10-2] charmed
charmed 8 [2-10]
4 [4-8] strange
strange 4 [8-4]
8 [10-2] top
top 8 [2-10]
4 [4-8] bottom
bottom 4 [8-4]
12 [12-0] e+
12 [0-12] e-
12 [12-0] μ
12 [0-12] μ
12 [12-0] τ
12 [0-12] τ
νe 0 [6-6]
νe 0 [6-6]
νμ 0 [6-6]
νμ 0 [6-6]
ντ 0 [6-6]
ντ 0 [6-6]
Tetryons
4π
4 [4-0]
0 [2-2]
4 [0-4]
Mesons
24π
4 [14-10] π+
0 [12-12] πo
0 [12-12] πo
4 [10-14] π-
Baryons
36π
12 [24-12] P+
Proton
Neutron
N°
0 [18-18]
N̄°
anti - Neutron
anti-Proton
12 [12-24] P⁻

2D EM masses [bosons-photons] do not have the physical property of 3D topology possessed by Matter [Fermions]

Fermions can now be defined as the standing wave energy topologies that create all the known sub-atomic particles – the building blocks of large scale Matter and structure in the macro world.

Historically these particles have been classified according to their charges and masses, Tetryonic geometry now provides a 3D physical model of all the particles highlighting the physical source of the 1/3 charges of Quarks and revealing charge to be the foundational geometry of all Matter.

Tetryons are 4π charge topologies that are the foundational quanta of Matter and surprisingly have a mass-charge ratio identical to that of Leptons explaining how these particles have remained hidden from accelerator experiments.

Quarks are 12π charge geometries where the attractive strong charge interactions between their fascia form 8π particle topologies with entirely different properties to that of Leptons

Leptons also have 12π charge geometries but with repulsive fascia that result in them forming the quantum equivalent of a 6 loop rotor

Protons and Neutrons are 36π charge geometries [that result in 20π Baryon topologies] and have identical masses (against the current model of baryonic masses which derived from an entirely different process where Neutrons are formed by Protons absorbing electrons).

The Particle Zoo

Baryons – the building blocks of atomic nuclei can be formed from many tri- quark combinations and energy levels and this is of particular note when modern accelerators are used to probe atomic structures.

The higher energies they employ when colliding particles together results in higher 2D kinetic energies (and increased energy quanta) which recombine after collisions into a plethora of similar particles called the Particle Zoo.

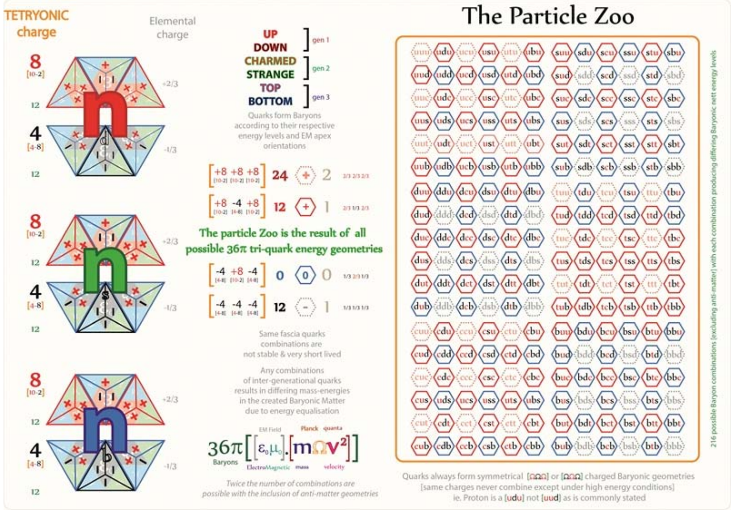

TETRYONIC charge
Elemental charge
8 [10-2]
12
4 [4-8]
+2/3
-1/3
UP
DOWN
gen 1
CHARMED
STRANGE
gen 2
TOP
BOTTOM
gen 3
Quarks form Baryons according to their respective energy levels and EM apex orientations
[+8 +8 +8] 24 2
[+8 -4 +8] 12 1
The particle Zoo is the result of all possible 36π tri-quark energy geometries
[-4 +8 -4] 0 0
[-4 -4 -4] 12 1
Same fascia quarks combinations are not stable & very short lived
Any combinations of inter-generational quarks results in differing mass-energies in the created Baryonic Matter due to energy equalisation
36π[[ε₀μ₀].[mΩv²]]
Baryons
EM Field
ElectroMagnetic
mass
Planck
quanta
velocity
Twice the number of combinations are possible with the inclusion of anti-matter geometries
The Particle Zoo
216 possible Baryon combinations (excluding anti-matter) with each combination producing differing Baryonic nett energy levels
Quarks always form symmetrical [ΩΩΩ] or [ΩΩΩ] charged Baryonic geometries
[same charges never combine except under high energy conditions]
ie. Proton is a [udu] not [uud] as is commonly stated

A sound understanding of EM mass-energy geometries & the charged topologies of all sub-atomic Matter particles reveals the true genesis of all of the Baryons to be found in the particle zoo.

Tetryonic geometries facilitate the precise 3D modelling of all the periodic elements, allotropes and compounds enabling the development of new classes of materials and medicines providing us with many new insights into Quantum Chemistry and large scale Matter in general.

Quantum Electro-Dynamics [QED]

Adding to the mysteries of quantum mechanics is a number of well-known QED effects that have also eluded physical explanation – to date

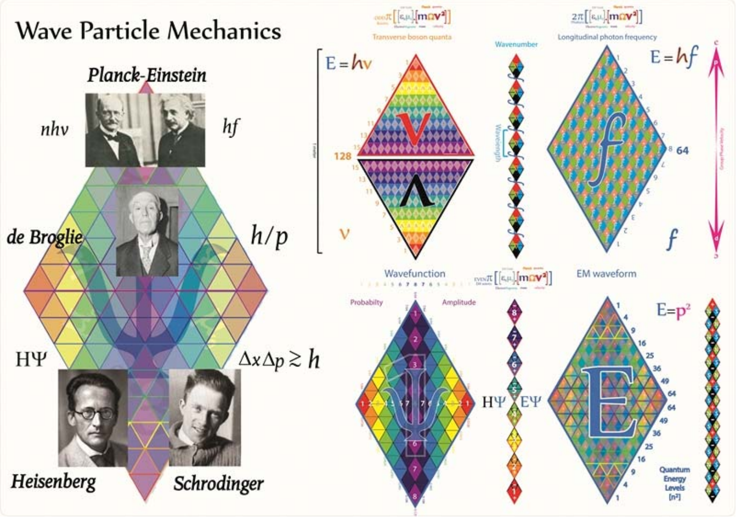

Wave Particle Mechanics
Planck-Einstein
nhv
hf
de Broglie
h/p
HΨ
ΔxΔp ≳ h
Heisenberg
Schrodinger
Transverse boson quanta
E = hv
v
Λ
128
Wavenumber
Wavelength
Longitudinal photon frequency
E = hf
f
64
Wavefunction
Probability
Amplitude
HΨ
EΨ
EM waveform
E=p²
Quantum Energy Levels [n²]

In 1865, James Maxwell Clerk unified the then disparate theories of Electric and Magnetic fields into a theory of Electromagnetism and related then to the velocity of light.

The exact quantum geometry for EM wave geometries (and the photons comprising them) that explains their Wavefunctions and observed inference patterns represents one of the greatest challenges to developing a concise fully realised quantum theory of EM radiation.

Wave-Particle duality dating back to the 17th century is perhaps the best known example of quantum behaviour that has defied precise modelling despite intense effort by scientists around the World for over two centuries

The application of equilateral energy momenta to the charged geometries of Photons and EM waves not only explains these long standing mysteries but also removes the quantum fuzziness introduced by Heisenberg's Uncertainty principle, in turn clearing the way for Science to develop an advanced understanding of Electricity, its role in Quantum ElectroDynamics and provide new clean forms of energy from quantum processes.

Photo-electrons and spectral lines

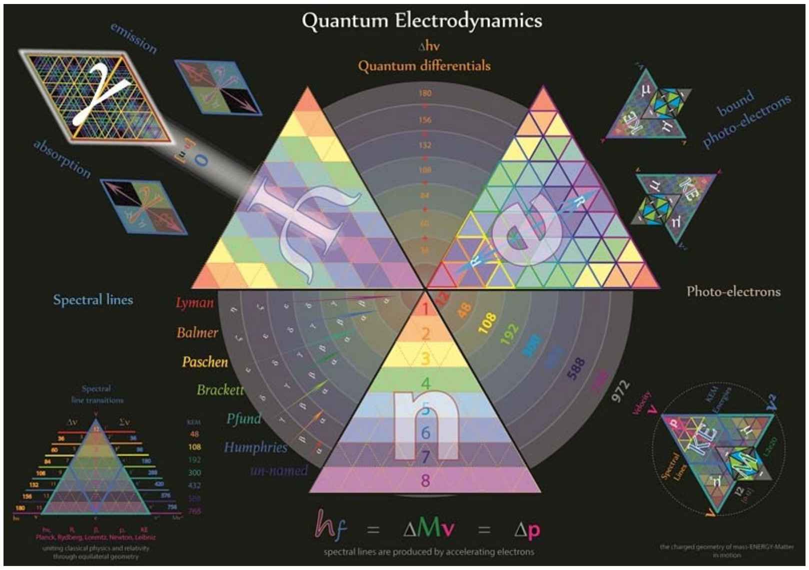
Quantum Electrodynamics
Δhv
Quantum differentials
emission
absorption
bound photo-electrons
Photo-electrons
Spectral lines
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
Spectral line transitions
Δv
Σv
KEM
48
108
192
300
432
588
768
180
156
132
108
84
60
36
1
2
3
4
5
6
7
8
12
48
108
192
300
432
588
768
972
Velocity v
KEM Energies
Spectral Lines
KE
μ
n
R
v²
hν, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz
uniting classical physics and relativity through equilateral geometry
$hf = \Delta Mv = \Delta p$
spectral lines are produced by accelerating electrons
the charged geometry of mass-ENERGY-Matter in motion

The physical relationship between Spectral lines, Rydberg's Constant and the Kinetic energies of Photo-electrons as they interact with photons and atomic nuclei is quickly revealed when equilateral energy geometries are employed

It is the rigid geometry of equilateral Planck energy momenta that gives rise to the invisible forces of Faraday's Electric and Gauss' Magnetic fields as well as Newton's Action-at-a-Distance.

Quantised Angular Momentum, a direct measure of the long hidden equilateral geometry of Energy, is revealed as the source of Charge, the physical constants and even the geometry of EM mass-energy & Matter itself.

The geometry of Nuclear Forces and Constants

Charge interactions resulting from equilateral EM energy geometries have been mistakenly developed into three disparate nuclear forces:

The EM Force is the result of $2n\pi$ charge geometries acting along transverse or longitudinal directions (or in superposition) in the forms of Bosons and Photons

The Weak Force is the inductive coupling of the magnetic permeability of adjacent energy geometries

The Strong Force is the attractive force between opposite charged fascia of Tetryonic Matter. It can also form a repulsive force between similar charged fasciae resulting in charged Leptons [electrons].

Gravitation (mathematically identical to Coulomb's Force save for strength and source) can also be modelled as the geometric mean of super-positioned EM waves.

All of which are determined by the Fine Structure Constant – the mysterious hand of GOD – setting the strength of EM interactions and determining Charge on the quantum level.

Applying equilateral geometry to energy momenta quanta, the Tetryonic model of EM mass-ENERGY-Matter quickly evolves to explain many additional electrical properties such as Voltage, Current and Power

Quantum Chemistry

Applying tetrahedral Matter topologies to quantum chemistry leads to a number of significant advances in the understanding of chemical processes most notably:

- **Accurate models for all periodic elements and their associated allotropes**
- **Advanced molecular orbitals plots**
- **Exact rest masses for all elements and**
- **A new Periodic table based on the charged topologies of Matter**

Improving upon and extending the Aufbau principle with charged geometries leads to many refinements in chemical engineering and facilitates the building of accurate 3D models of all elements, isotopes and compounds.

Every element can be analysed from the quantum level upwards revealing its exact 3D topology, quark configuration, rest mass-Matter-energies and chemical properties.

And number of misconceptions can be quickly clarified and corrected in turn advancing our understanding to the physical mechanics underlying chemical processes like chemical bonding, element family properties and the structures of complex chemical compounds.

Hydrocarbons and Carbohydrates have already been modelled using equilateral charge topology with the results matching the established chemical models of Nobel gases, Core electrons, Lewis diagrams and the most recent electron photographs of these chemical properties of atoms.

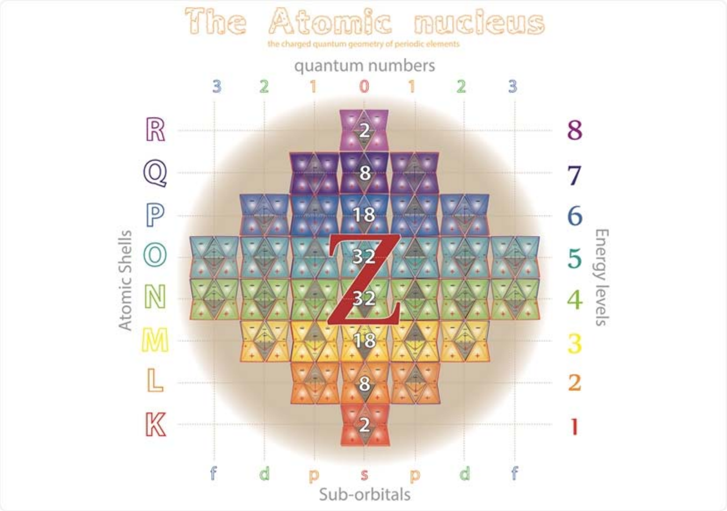

Even DNA can be modelled in 3 dimensions leading to a greater understanding of the role of quantum mechanics in biological processes and the interaction of EM radiation on organic compounds.

A highly developed quantum model of chemical elements and compounds will allow us to model chemical and biological structures in hitherto unimagined detail and facilitate the building of complex (and increasingly accurate) models of all chemical compounds and biological processes.

A Unified field equation

In physics a Unified Field Theory is a type of theory that allows all that is usually thought of as a fundamental force or elementary particle to be formulated in terms of a single equation that explains all their disparate properties.

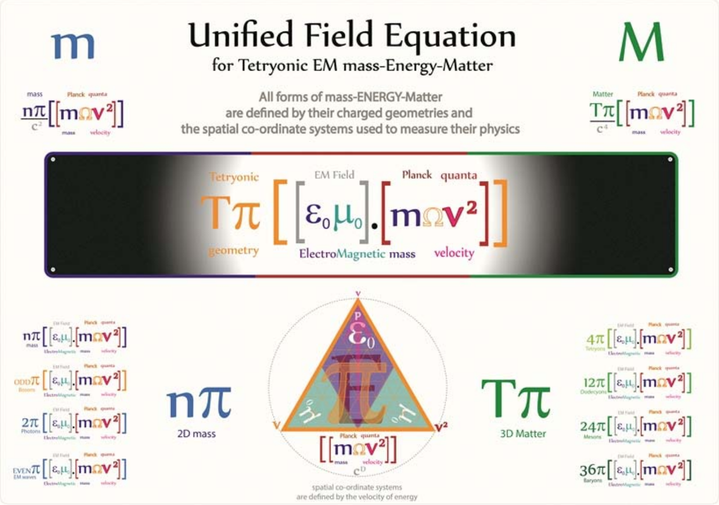
m
Unified Field Equation
for Tetryonic EM mass-Energy-Matter
M
All forms of mass-ENERGY-Matter
are defined by their charged geometries and
the spatial co-ordinate systems used to measure their physics
$\frac{n\pi}{c^2}[[m\Omega v^2]]$
$\frac{T\pi}{c^4}[[m\Omega v^2]]$
Tetryonic
EM Field
Planck quanta
$T\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
geometry
ElectroMagnetic mass
velocity
nπ
2D mass
Tπ
3D Matter
$[[m\Omega v^2]]$
c^D
spatial co-ordinate systems
are defined by the velocity of energy
$n\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
$\text{ODD}\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
$2\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
$\text{EVEN}\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
$4\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
$12\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
$24\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
$36\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$

It is considered the holy grail of Science, offering the promise of advances in Technology, Energy and Medicine unparalleled in Human history.

Equilateral energy provides the foundation for the creation of a single equation that expresses EM mass-ENERGY and Matter as the result of geometric & topological charge interactions.

Applying equilateral geometry to Planck energy momenta quanta has been shown to firmly resolve many of the current mysteries plaguing the Standard model and provides a firm foundation for the development of a single unified quantum theory uniting all quantum and macroscopic forces.

It effortlessly merges all the tested features of Classical mechanics with the statistical probabilities of quantum mechanics and scales up to the cosmological scale of General Relativity.

Equilateral charged energy geometries provide a quantifiable foundation for advances in:

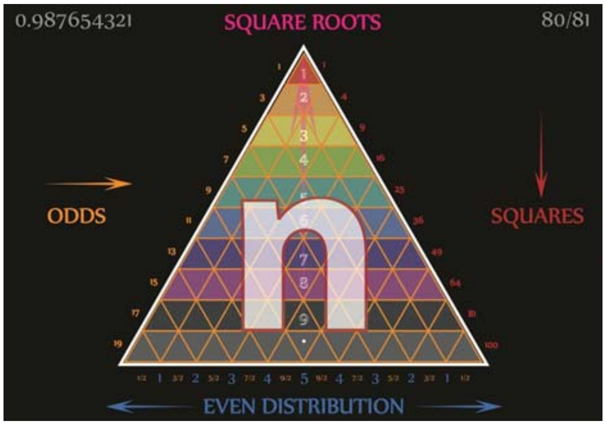
0.987654321
SQUARE ROOTS
80/81
ODDS
SQUARES
n
EVEN DISTRIBUTION

- **Quantum Mechanics**
- **Quantum Electrodynamics**
- **Quantum Chemistry**
- **Quantum Cosmology**

Explaining the quantum mysteries of mass & Matter, Wave-Particle duality and gravitational Singularities by challenging the very foundational assumptions of Relativity and the role of charge in our Universe.

Mathematical principles such as re-normalisation, probabilities and square roots of negative numbers can all be geometrically modelled through Tetryonics leading to further advances in fields such as biology, medicine, quantum computing and telecommunications

Through the charged geometry of Tetryonics many of the erroneous theories that have been developed during the last 1oo years can be falsified at last providing a solid foundation for further advances in science and mathematics.

Gravitation

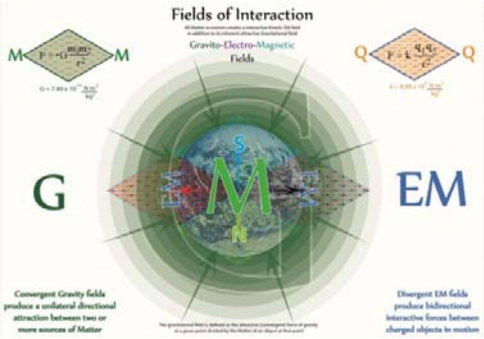
Fields of Interaction
Gravito-Electro-Magnetic Fields
M
M
Q
Q
G
EM
S
M
N
EM
EM
Convergent Gravity fields produce a unilateral directional attraction between two or more sources of Matter
Divergent EM fields produce bidirectional interactive forces between charged objects in motion

The force of Gravity has been long-held to be the mysterious force that holds our Universe together, shaping the Stars and holding us to the Earth as we orbit our own SUN.

Tetryonic geometry reveals its quantum mechanics to be the result of electromagnetic fields and the effect produced by the geometry of Matter in these fields.

Newton saw Gravity as a force that acts instantaneously on distant bodies of Matter while Einstein dismissed the force between the bodies and explained it as the result of the 'curvature of Spacetime'.

In fact the Gravitational field is comprised of 3 separate components, each of which produces differing forces of interaction, but all combine to produce the nett Gravitational field that we observe and describe as strictly convergent Gravity.

Gravity fields are created by the topology of Matter itself as it displaces and distorts the Vacuum energies surrounding it.

Electric fields diverge radially from all Matter as it is heated, or placed in motion by other forces creating an interactive field with both divergent and convergent equatorial regions of force and acceleration.

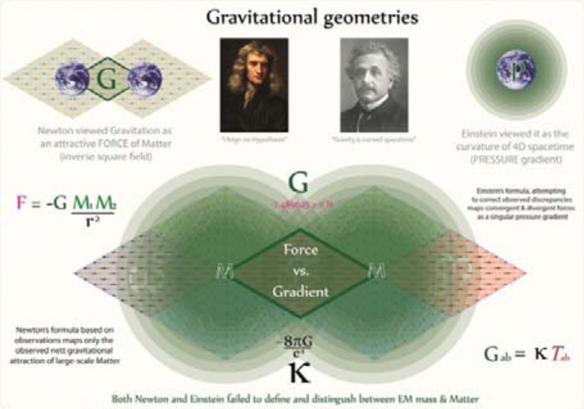
Gravitational geometries
G
Newton viewed Gravitation as an attractive FORCE of Matter (inverse square field)
Einstein viewed it as the curvature of 4D spacetime (PRESSURE gradient)
P
G
F = -G M₁M₂ / r²
Einstein's formula, attempting to correct observed discrepancies maps convergent & divergent forces as a singular pressure gradient
M
Force vs. Gradient
M
Newton's formula based on observations maps only the observed nett gravitational attraction of large-scale Matter
-8πG / c⁴
K
Gab = K Tab
Both Newton and Einstein failed to define and distingush between EM mass & Matter

Dipole Magnetic fields located around the Polar Regions of all Matter also create a perturbative force on bodies close to them

Although Newton's and Einstein's theories were both correct in their respective analysis of the forces at work they both failed to define and distinguish between EM masses and Matter leading to the continued debate over the true nature and physical formulation of quantum gravity.

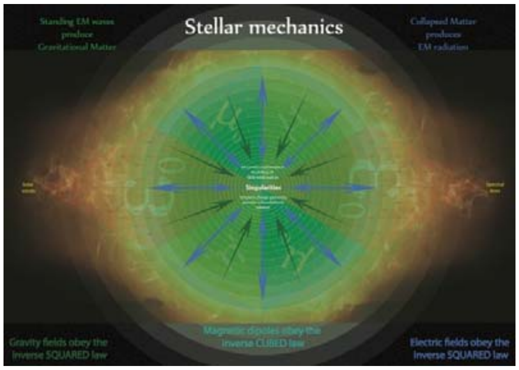
Stellar mechanics
Standing EM waves produce Gravitational Matter
Collapsed Matter produces EM radiation
Singularities
Magnetic dipoles obey the inverse CUBED law
Gravity fields obey the inverse SQUARED law
Electric fields obey the inverse SQUARED law

These three quantum forces [G+E+M] combine to produce a field of gravitational acceleration that was so eloquently modelled by Newton back in the 16th century through his inverse square law.

And these 3 distinct forces also combine to produce the stellar mechanics that power the Stars – a Gravito-Electro-Magnetic pinch.

The force of Gravity, created by the geometry of Matter draws Matter toward the core of Stars.

And the GEM pinch singularity at the core of the Star destroys Matter (collapsing its 3D geometry), turning it into radiant 2D ElectroMagnetic radiation (Light).

Energy from the Stars

Virtual particles, Dark Energy and Dark Matter (were all developed to explain the observed mechanics of our Universe) and can now be revealed to be differing manifestations of the electromagnetic force interacting at various angles to, and with, the standing-wave topologies that create it.

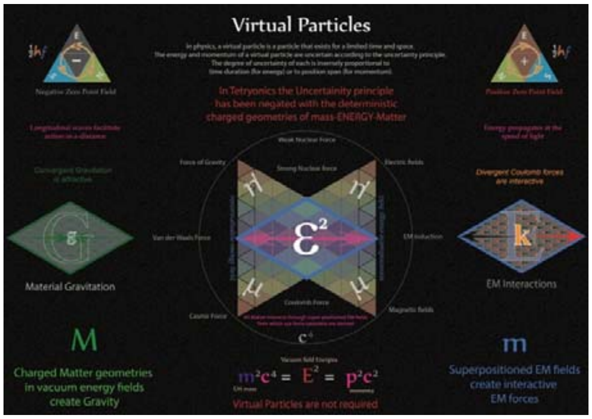
Virtual Particles
In Tetryonics the Uncertainity principle
has been negated with the deterministic
charged geometries of mass-ENERGY-Matter
Negative Zero Point Field
Positive Zero Point Field
Longitudinal waves facilitate action-at-a-distance
Energy propagates at the speed of light
Convergent Gravitation is attractive
Divergent Coulomb forces are interactive
Weak Nuclear Force
Strong Nuclear force
Force of Gravity
Electric fields
Van der Waals Force
EM induction
Coulomb Force
Cosmic Force
Magnetic fields
ε²
G
k
Material Gravitation
EM Interactions
c⁴
M
m
Charged Matter geometries in vacuum energy fields create Gravity
Vacuum field Energies
m²c⁴ = E² = p²c²
Virtual Particles are not required
Superpositioned EM fields create interactive EM forces

Quantum fields of Planck energies combine to create charged 2D geometries of radiative ElectroMagnetic fields that in turn spread out interacting with each other to give us the fundamental laws of Attraction and Repulsion.

The 3D standing-wave topologies of Matter provide a rigid structure that displaces the surrounding Vacuum energies and creates a pressure gradient which we call Gravity.

And the destruction of these Matter topologies in turn creates radiant energies that propagate out into the surrounding space to weaken and form the Vacuum energies that permeate all of Space.

The eternal cycle of Matter creation and destruction within Stars and Galaxies is what drives the Universe we see today causing it to contract as it forms gravitational Matter and to expand as it restructures the standing-wave Matter into radiant forms of Energy (Light and heat).

The same process offers us clean, limitless energy for all our needs as well as unlimited resources from the restructuring of this energy into its varied elemental and compound forms.

Our toxic stockpiles of radioactive wastes can be completely eliminated from the environment and electrical power can be safely stored as mass within large-scale models of the deuterium nuclei and distributed worldwide to any location without the need for transmission lines.

Even hydro-electric storage schemes can be eliminated, returning water courses to their natural states of flow in turn reducing conflicts stemming from the flow of this precious resource worldwide.

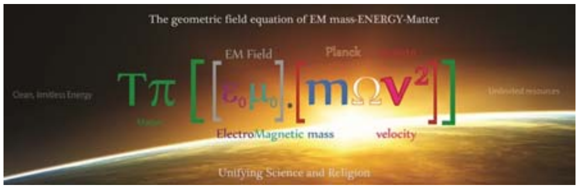
The geometric field equation of EM mass-ENERGY-Matter
EM Field
Planck
Clean, limitless Energy
Tπ [[ε₀μ₀].[mΩv²]]
Unlimited resources
ElectroMagnetic mass
velocity
Unifying Science and Religion

Through the geometries of equilateral Planck energies and the application of the Tetryonic unified field equation of mass-ENERGY-Matter in motion to our needs, for the first time in Humanity's history, we have the chance to advance our civilization to new pinnacles of technology and understanding in turn leaving our World a better place than we found it to be.

The age old dilemma of technological advancement versus environmental pollution is at an end

We stand on the threshold of realising one of the greatest advances in scientific understanding ever witnessed but we must also endeavour to redress our current social challenges with an equally rigorous determination to ensure all of Humanity benefits from this discovery

……………………..……… ABRAHAM [2012]

Tetryonics …. Challenging and correcting the foundations of quantum theory

Electric field permittivity has a 2pi (rhombic) field geometry while magnetic field permeability is always the result of two separate equilateral magnetic fields that form a magnetic dipole moment

Where two or more rhombic electric fields interact a Coulombic –charge force of interaction results
Where two or more equilateral magnetic fields interact a Gaussian-Ampere forces of interaction results *[opposite fields attract - same fields repel]*

The classical model of the unidirectional electrostatic force fields of point charged particles is corrected to show a bidirectional arrangement of equilateral Planck energy momenta geometries within the electrostatic field that creates the bi-directional forces of charge interactions

Where two similar coupled equilateral energy momenta fields combine an electrostatic field is created
Where two opposite coupled equilateral energy momenta fields combine a magnetic dipole is created

The arrangement and asymmetry of Planck quantum charges with in any EM field determines the motion and acceleration of charged particles within the field of electrostatic force

The classical forces of attraction should be renamed forces of interaction
(as they result from bidirectional quantum vector forces)

All electromagnetic fields are comprised of a squared number of equilateral Planck energy momenta quanta (whose asymmetrical distribution of equilateral Planck quanta results in a net divergent Force) with a convergent vector force component

When modelled with equilateral Planck geometries electromagnetic fields follow the Biot-Savart Law:

- Rhombic electric fields follow the inverse squared law of propagation
- Equilateral magnetic fields follow the inverse squared law of propagation
- Magnetic dipole fields follow an inverse cubed law of propagation

The equilateral geometry of quantised angular momentum creates chirality at the quantum level in physics (rotation does not affect the charge of plank quanta, but mirroring and/or spatial coordinate translations do)

All positive charged fields can be modelled as having a clockwise inductive flux geometry
All negative charged fields can be modelled as having an anticlockwise inductive flux geometry
(with OMEGA representing equilateral geometries per second and PI reflecting their scalar areas]

All W bosons are comprised of an odd number of equilateral Planck quanta in a trapezoidal geometry
All Z bosons are comprised of an even number of equilateral Planck quanta in a dual-trapezoidal geometry (neutral Z bosons are equivalent in terms of Planck mass energy momenta to photons save their net geometry)

All charged fascia [Higgs bosons] are comprised of squared numbers of equilateral Planck quanta in an equilateral geometry.

The odd quanta W bosons within electromagnetic fields form quantum levels of charged mass-energy momenta

The Planck equation [E=n.hv] of quantised energy is a generalised equation of Planck geometries (and applies to all energy momenta arrangements equally)

Bosons and Quantum levels are a transverse measure of mass energy momenta in EM fields
Photons are a longitudinal measure of mass energy momenta within the same electromagnetic fields

Equilateral Planck energy momenta per second [E/c^2] equates to mass geometries
Equilateral Planck energies momenta per second squared [E/c^4] equates to Matter topologies

Interactive **mass energy geometries** can combine via the weak force to form standing wave Matter topologies

Standing wave **Matter topologies** can combine via the strong force to form elementary subatomic particles

The fundamental Matter quantum of all physics is the tetryon (a tetrahedral mass-energy Matter topology) which is formed from photons of electrostatic energy and can be found as positive, neutral or negative charges topologies

These three forms of charged tetryons form the foundation of all the physical Matter of our universe as they seek a state of equilibrium, Tetryons are not spherical point charges – they are tetrahedral, likewise the subatomic particles they form are not spherical point charges - they are **[T]***π* Tetryonic charge topologies

The Tetryonic topologies created by tetryons as they combine to form elementary particles creates new forms of closed volume topologies that follow Euler's characteristic [V+F-E = 2] for Platonic solids

Quarks and leptons are comprised of 12 charged mass energy geometries
- quarks form *[8π]* octahedral Matter topologies
- leptons form *[12π]* dodecahedral Matter topologies

and

Baryons are comprised of 36 charged mass energy geometries
- forming *[20π]* Icosahedral Matter topologies

Anti-UP quark's are comprised of 2 positive and 8 negative charges
creating a net charge of **-8** *[-2/3 elementary charge]*
DOWN quark's are comprised of 4 positive and 8 negative charges
creating a net charge of **-4** *[-1/3 elementary charge]*
Anti-DOWN quark's are comprised of 8 positive and 4 negative charges
creating a net charge of **4** *[1/3 elementary charge]*
UP quark's are comprised of 10 positive and 2 negative charges
creating a net charge of **8** *[2/3 elementary charge]*

Positrons are comprised of 12 positive charges
creating a net charge of **+12** *[positive integer elementary charge]*
neutrinos are comprised of 6 positive and 6 negative charges
creating a net charge of **0** *[no elementary charge]*
Electrons are comprised of 12 negative charges
creating a net charge of **-12** *[negative integer elementary charge]*

Protons are comprised of 24 positive charges and 12 negative charges
creating a net charge of **+12** *[positive integer elementary charge]*
Neutrons are comprised of 18 positive and 18 negative charges
creating a net charge of **0** *[no elementary charge]*
anti-Neutrons are comprised of 18 positive and 18 negative charges
creating a net charge of **0** *[no elementary charge]*
anti -Protons are comprised of 12 positive charges and 24 negative charges
creating a net charge of **-12** *[negative integer elementary charge]*

Rest lepton topologies have a completely neutralised magnetic dipole structure and all leptons (charged or neutral) have identical physical Matter topologies
Their rest masses are the result of the number of plank quanta comprising each Matter topology with applied forces creating additional asymmetrical KEM fields resulting in kinetic energies, magnetic moments and vector velocities of motion

As the energies of motion are added to equilateral KEM fields the Planck quanta themselves are physically WAVE-length Lorentz contracted

(Lorentz contractions apply to mass energy geometries only - NOT to Matter topologies)

Matter topologies are Lorentz invariant to velocity changes (or acceleration)
The relativistic distortion of spherical point charges in physics is no longer applicable, in turn undermining a basic tenet of special relativity as postulated by Albert Einstein

It is the equilateral secondary KEM fields of motion created by applied forces to material Matter topologies (and the asymmetrical distribution of plank charges therein) that creates the magnetic moments associated with charged particles in motion, not the relativistic distortion of spherical bodies of Matter as postulated by Einstein in special relativity

These secondary KEM fields of motion also contain the kinetic EM energies and vector [square root] linear momentum of material particles in motion - the mass energy momenta density and physical geometries of Matter topologies is unaffected by applied forces or changes to velocity-momenta

The changing Lorentz contracted mass energies of kinetic EM fields contributes to the total relativistic mass energy of Matter topologies but in no way changes the mass energy distribution of the Matter component of particles in motion itself - leading in turn to varying generations of subatomic particles with in the particle families themselves

The net asymmetric KEM field geometry of each particles in motion is reflective of the charged distribution of the Matter topology of the particle itself.

Mesons are created when quark and anti-quark particles combine via the strong force interaction between their charged fascias to create unique 14 pi Matter topologies (neutral or charged pions)

These strong interactions between opposite charge fascia of material particles and the resulting Matter topologies are evidence of the fact that Matter-antimatter combinations do not necessarily result in the explosive annihilation of the particles concerned (in fact the combining of opposite charge quarks is a necessary step in the formation of the baryons)

All Baryons are Matter topologies created from the combination of tri-quark topologies
The quark's combine via their opposite charged [Higgs] fascia to create neutral and charged elementary topologies
Due to this opposite charge interaction the charged distribution of baryonic topologies does not follow the textbook given arrangements of [UUD] & [DDU] instead they are arranged as follows:

Protons	**UP**	**+**	**DOWN**	**+**	**UP**
Neutrons	**DOWN**	**+**	**UP**	**+**	**DOWN**
anti-Neutrons	**anti-DOWN**	**+**	**anti-UP**	**+**	**anti-DOWN**
anti-Protons	**anti-UP**	**+**	**anti-DOWN**	**+**	**anti-UP**

The specific arrangement of charged fascia within these respective Matter topologies goes on to facilitate nuclear bonding via the residual strong force between atomic nuclei, following the charge arrangement given in modern textbooks does not allow the formation of baryons or their subsequent bonding to form larger scale atoms and molecules

Protons and neutrons are revealed to have quark arrangements that are mirror symmetries of each other, revealing the neutral charge neutron to have a complementary negative charge arrangement to that of protons.

The increased Planck mass energy contents of various families of quarks facilitates the creation of a huge number of possible Baryon topologies resulting in the particle zoo of subatomic elements created in particle collisions within accelerator experiments - all of these elements can be easily modelled and accounted for using Tetryonic mass-energy Matter topologies

Additionally, the particles often referred to as gluons within the standard model can be easily accounted for and explained as being neutral tetryons within Tetryonic theory - where these neutral charge Matter topologies form a neutral Matter dielectric between charged tetryons to facilitate the strong force interaction and the formation of larger particles

Neutral tetryons (gluons) can also form particles in their own right (neutrinos and glue-balls), as can charged tetryons (charge-ball particles), most of which are short lived

Tetryonics reveals the previously hidden geometry and topology of electromagnetic fields and subatomic particles and the geometric relationship and interplay between electric permittivity and magnetic permeability within all EM field that results on the speed of light in any medium.

As well as the revealing a geometric source of all physical constants within physics itself, Tetryonic charge geometries show the weak force to be a magnetic dipole [edge] interaction between mass energy geometries and Matter topologies and the strong force to be a charge [fascia] interaction between Matter topologies themselves

The equilateral [quantised angular momentum] of ***inductive*** Planck mass energy geometries within squared [HIGGS] fascia of Matter topologies is what creates ***inertial*** properties of Matter at the quantum level

The strong force between charged parallel Higgs fascia of Matter topologies results in 'hidden' partitions of mass energy with in the Matter topologies of quark's and baryons leading to the inability of mathematics online to accurately model and understand the physics of creating these particles at the quantum level

Tetryonic charged mass energy geometries allows for the accurate 2D and 3D modelling of all Matter topologies and fields of Force interactions within physics

It reveals that the deuterium atom [not the hydrogen atom] is the quantum building block of all elementary Matter - the unique charge topology of deuterium (consisting of a proton, neutron and electron) can be related to the electromechanical topology and function of quantum synchronous converters.

These quantum synchronous converters absorb and emit mass energies via the rotating electrons [quantum rotors] bound to the nuclei by way of radiant bosons and photons [heat and light]

The net charge of Deuteron nuclei facilitates their binding together to form helium and larger atoms, while stored mass energy quanta within their Matter topology results in raised quantum grounds states that can all be modelled mathematically using Schrodinger’s wavenumbers

The simpler geometric charge topology reveals visually how the mass energy content of baryons directly affects the angular momentum and energy levels of photo electrons bound to atomic nuclei, in turn revealing that larger elements be created in two ways - namely by the addition of a neutron to a Hydrogen atom (as classically modelled in modern chemical physics) or through the raising of Planck mass-energy quanta within the deuterium Matter topology itself

Deuterium nuclei without any bound photo-electrons form quantum batteries with EM mass energies can be stored indefinitely without being released.
These nuclei can be arranged atomically in either a series, parallel or empty parallel configuration each of which affects the ground energy states of the respective nuclei created.
Where photo-electrons (quantum rotors) are attracted and bind to these nuclei (quantum batteries) the stored mass energies can then be released in a controlled manner via spectral line emissions, or energy can be added via spectral line absorption.

As photo-electrons are bound to the deuteron nuclei the energy levels are affected directly by the mass energy levels of the nuclei that they bind to, in turn affecting their KEM field energies
The square root linear momentum of KEM field energies normally creates a vector motion but in the case of bound electrons this vector motion is turned into an angular motion resulting in electron spin within the nucleus.

The direction of the spin is always reference with respect to the nuclear magnetic moment resulting in up and down electron spins and their associated magnetic dipole moments

The kinematics of KEM fields provides an easy visual explanation of Newton's 2nd law of motion - namely that deceleration can be seen as the removal of odd number quanta from the squared kinetic energy fields and acceleration can be viewed as the addition of odd numbered quanta to squared kinetic energy fields.

The addition or subtraction of odd numbered Planck quanta from squared energy fields results in changing square root linear momentum for the particles that these fields are associated with - this changing linear momentum over time can be equated to acceleration leading to Newton's formulation of Force = mass x acceleration [F = ma = dp/t = dmv/t]

Using the equilateral geometry of Planck's constant we can now unify classical mechanics with quantum mechanics and reveal the underlying dynamics of relativistic mass energies of motion (as well is providing an electromechanical explanation of inertia in the physics of Matter in motion)

Newton's vector linear momentum [p=mv] forces are revealed to be the geometric square root of Leibnitz's scalar energies [E/mv^2] with their associated inertial mass being a measure of the scalar energies per second [m=E/v^2]

Linear momentum [mv] is differentiated from vector velocities [v] through the equilateral geometry of energy per second [m] in tetryonics, with the total linear momentum of any EM field or system of particles being the vector some of the square root Planck linear momentum of the quanta in the fields comprising the system

Once the equilateral field geometry of KEM fields is revealed it is easy to show that the total energy of the field [E=mv^2] is the result of the kinetic energies [$_{1/2}$Mv^2] plus the magnetic moment [$_{1/2}$Mv^2] of any material topology in motion

This in turn allows for a rigid geometric differentiation of quantised angular momentum [Ω] in Planck quanta, the linear momentum [p] of any system and the classical angular momentum [vector rotation about a point] in physics

These geometric definitions of mass energy momenta in physical systems as portrayed in Tetryonic theory reveal a differing geometric relationship to that commonly portrayed in modern physics]i.e. neutralising right angled Pythagorean triangles]

Additionally Lorentz corrections factors are restricted to planar 2-D mass energies of KEM fields associated to particles in motion where changes of velocity force result in the addition or subtraction of equilateral Planck quanta from the KEM field geometry resulting in the physical expansion or contraction of Planck geometries within the field

Tetryonic theory's geometric definition and application of quantised angular momentum with respect to mass energy momenta in physics allows for the physical modelling of mass energy and Matter at all scales of physics and their unification of classical, quantum and relativistic mechanics

The 'squared' energies of quantum mechanics and statistical distributions of the math associated with quantum mechanics is now revealed in an entirely new light facilitating the macro scale modelling of all hitherto unseen quantum particles and processes.

The geometric relationships between charge, mass geometries and Matter topologies is easily visualised and applied to all physics revealing quantised angular momenta [QAM] to be the hidden variable of Planck's constant [h].......

The modelling of quantised angular momentum as an equilateral geometry allows for the elimination of Heisenberg's uncertainty principle and Bell's inequality from the foundational tenants of quantum mechanics

Both the position and momentum of particles and fields can be now modelled at any stage of a system's spatio-temporal development and evolution using these simple equilateral charged geometries of mass energy momenta

Precise rest mass energies of any Matter topology can be calculated from 1st principles allowing for accurate modelling of all quantum systems and even periodic elements - expanding our knowledge of chemical systems and processes

The Planck-Compton frequency, de Broglie wavelength, absolute rest mass and charge Matter topology of all periodic elements, compounds and molecules can now be calculated with absolute certainty and precision and can be related back to Avogadro's number for all elements in chemistry

The exponential energy levels of atomic nuclei and atomic processes of energy release can also now be shown to be the result of an underlying geometric Planck scale geometry inherent to all mass energy Matter within physics

Einstein's mass energy equivalence formula is shown to be a geometric relationship between measurements of energy per second and inertial mass........ combined with Tetryonics new definition of Matter as energy per second squared we can now show that Einstein's famous formulation is an incomplete formulation of the mass-ENERGY-Matter relationship that applying only to specific processes within our physical universe

The Lorentz corrections on which special relativity is based are shown to be WAVE-length and QAM corrections for the changing physical geometries of scalar mass energies per unit of time in spatial co-ordinate systems (c^2) and that additional time-based dimensional analysis must be taken into account in order to define and differentiate between electromagnetic mass and Matter in physics

The application of squared (equilateral) geometries to physics in the role of quantised angular momentum has been overlooked since the inception of physics itself, but with the inclusion of this geometry a rigid geometric grammar can now be imposed upon the mathematics of physics leading to the correction of many erroneous mathematical assumptions

An exact value from first principles for Planck's constant can be calculated and Avogadro's number can be confirmed and related to the absolute rest mass of hydrogen atoms.

A geometric representation of Coulomb's charged field interactions and the impedance of free space can also be provided for all physical processes allowing for a fast and accurate visualisation of energy mechanics at all scales of physics

Tetryonics theory’s equilateral charged mass energy and polyhedral Matter topologies allow for the modelling and differentiation of energy in all its forms within any spatial coordinate system providing a vast improvement over relativity's use of stress energy tensors and non-Euclidean geometries in modelling physical systems

All fields and particles can be defined and differentiated in terms of their charged mass energy geometries and Matter topologies respectively and the differentiation of elemental families into their generations can be easily accounted for through the addition of mass energies of motion to secondary KEM fields associated with each particle grouping

Inertial resistance to force can be modelled and explained through the equilateral geometry of quantised angular momentum when viewed as an electromechanical equivalent to an inductive loop of energy

Electromagnetic inertial mass can now be clearly defined as a measure of the inductive EM energy density of any charged 2D planar Planck geometry in any spatial co-ordinate system of measurement

3D Matter can now be viewed and modelled as the closed topology created by 2D mass energies through charge interactions in any spatial co-ordinate system of measurement per second squared

Additionally physical terms such as 'mass-less' particles are shown to be a misnomer as any field or particle must by definition contain energy per unit of time - and should be more appropriately re-termed Matter-less or weightless particles

Tetryonics theory defines, differentiates and unifies energy in all its forms (mass, Matter & Force) through the equilateral geometry of quantised angular momentum at the quantum level, allowing for the development of a unified field equation that models physics on all scales and reveals a common geometric thread to all the disparate fields of physics that to date have defied unification

Equilateral (SQUARED) energy fields of Planck quanta comprised of statistical distributions of (ODD) transverse bosons and (EVEN) longitudinal photons account for all the quantum mechanical processes of physics including EM field geometries and material particle topologies and electron spin

Principle quantum levels [1st Schrodinger wave-numbers] are shown to be the result of the series addition of deuterium nuclei in atomic elements with their resulting energy levels determining the squared energy levels of bound photoelectron KEM fields – in turn forming the foundation of discrete quantum jumps of electrons bound to atomic nuclei

The bound photo-electron can only transition between allowed squared energy levels permitted by the energy levels of deuterium nuclei to which they are bound and once free from the atomic nuclei the electron can emit or absorbed a continuous spectra of light photons - but while bound to the deuterium nuclei in atoms it can only have specific [squared] KEM energy levels

The complex, asymmetric tri-quark (9 tetryon) Matter topology of baryons directly affects the magnetic moment of protons and neutrons in motion making them considerably weaker than the symmetric axial Bohr magnetron of electrons in motion

As the Bohr magneton of photo-electrons is determined by the squared energies of its secondary KEM field confusion has arisen with respect to the allocation of spins to subatomic particles, Tetryonic geometries now correct for this and suggest that the electron historically viewed as a spin 1/2 particle is in fact a spin 3 particle under the formal definitions of spin rotations i.e. rotating at 120° can bring it back to an identical quantum state as the initial state measured]

Again Tetryonic theory and its energy geometries in addition to explaining and correcting electron spins also shows that the term electron spin can now be taken literally when modelled with Tetryonic geometries to provide an accurate description of the origin of magnetic moments for electrons, in turn undermining the foundational postulate of special relativity that these magnetic moments are the result of the distortion of spherical point charges and that relativistic Lorentz contractions apply to Matter topologies

Dirack's constant, or Planck's reduced constant [h/2π], is revealed to be a measure of the electric permittivity of a relativistic electron's KEM field, and the measurement of the associated magnetic dipole of the same KEM field results in the mistaken concept of 1/2 spins in the measurement of Bohr magnetons

The magnetic vector created by the Bohr magneton [or KEM field dipole] when measured with respect to the nuclear magneton [Proton magnetic moment] produces either a higher energy [parallel] or lower energy [anti-parallel] state for all atomic nuclei

It is the arrangement of these parallel or anti-parallel magnetic dipoles within atomic nuclei that determines the exact frequency-wavelength (energy level) of emitted spectral lines with the interaction of a particle’s magnetic dipole moment with external electromagnetic fields creating Lorentz forces

As electrons and protons have identical quantum Matter topologies [elementary charges] but differing mass energy contents the electron is able to create a much larger secondary KEM field (with associated magnetic dipole moment) for the same velocity [$_{1/2}$Mv^2]

The energy level differences created by the parallel or anti-parallel spin coupling of electrons with protons or deuterium nuclei within atomic elements creates the hyperfine splitting and Zeemen effects observed and spectral lines

As the electron is now shown to be a complex non-spherical particle topology when it binds with protons to form hydrogen the unique Matter topology of both the proton and the electron [Hydrogen] create a small but detectable precession in the motion of the spinning electron as compared to that of the motion of the same electron in a deuterium nuclei

Additionally, as all periodic elements, compounds and molecules are comprised of deuterium nuclei (not hydrogen as currently supposed) the orientation and spin direction of electrons bound within these nuclei results in the diamagnetic and paramagnetic properties of various macro-scale materials

Tetryonics theory reveals that the mass charge ratio is of particles are measure of the constituent mass energy geometries that go into making the particle's final Matter topology that we observe a measure

But unlike the current mathematical approach the geometric approach of Tetryonics reveals the hidden mass energy partitions within the Matter topology of all subatomic particles and that particles such as tetryons (the quantum building blocks of all Matter) are in fact hidden within the debris of current collider results.

4 quantum charge tetryons have the same1/3 partial elementary charge as some quarks, and can be measured as having the same mass charge ratio's as charged leptons such as positrons and electrons in collider experiments.

………. To be continued [QED, Chemistry, Cosmology, Mathematics, Biology and economic theory]

answers@tetryonics.com

ABRAHAM [2014]

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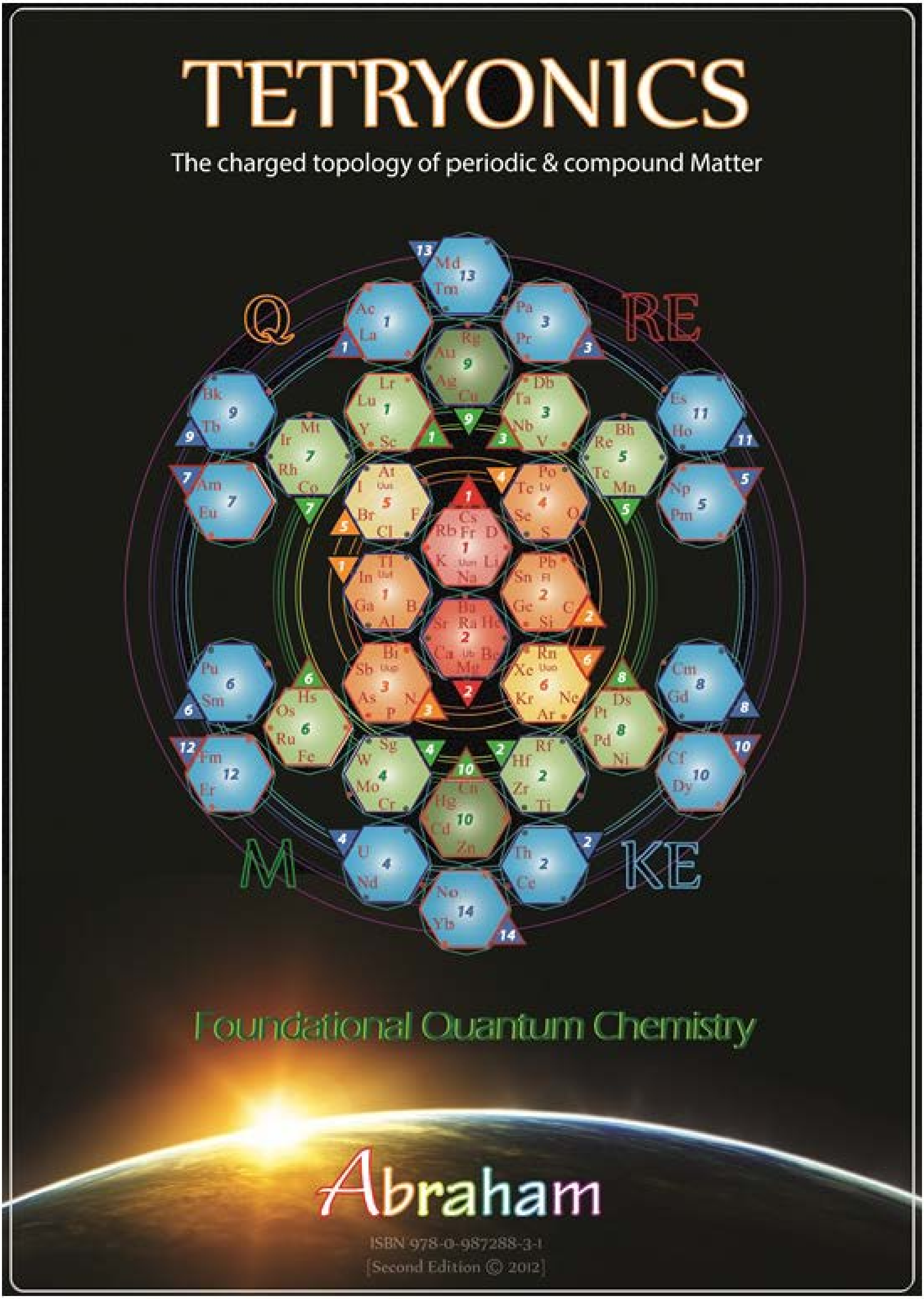

TETRYONICS

The charged topology of periodic & compound Matter

Foundational Quantum Chemistry

Abraham

ISBN 978-0-987288-3-1
[Second Edition © 2012]

Periodic element Families

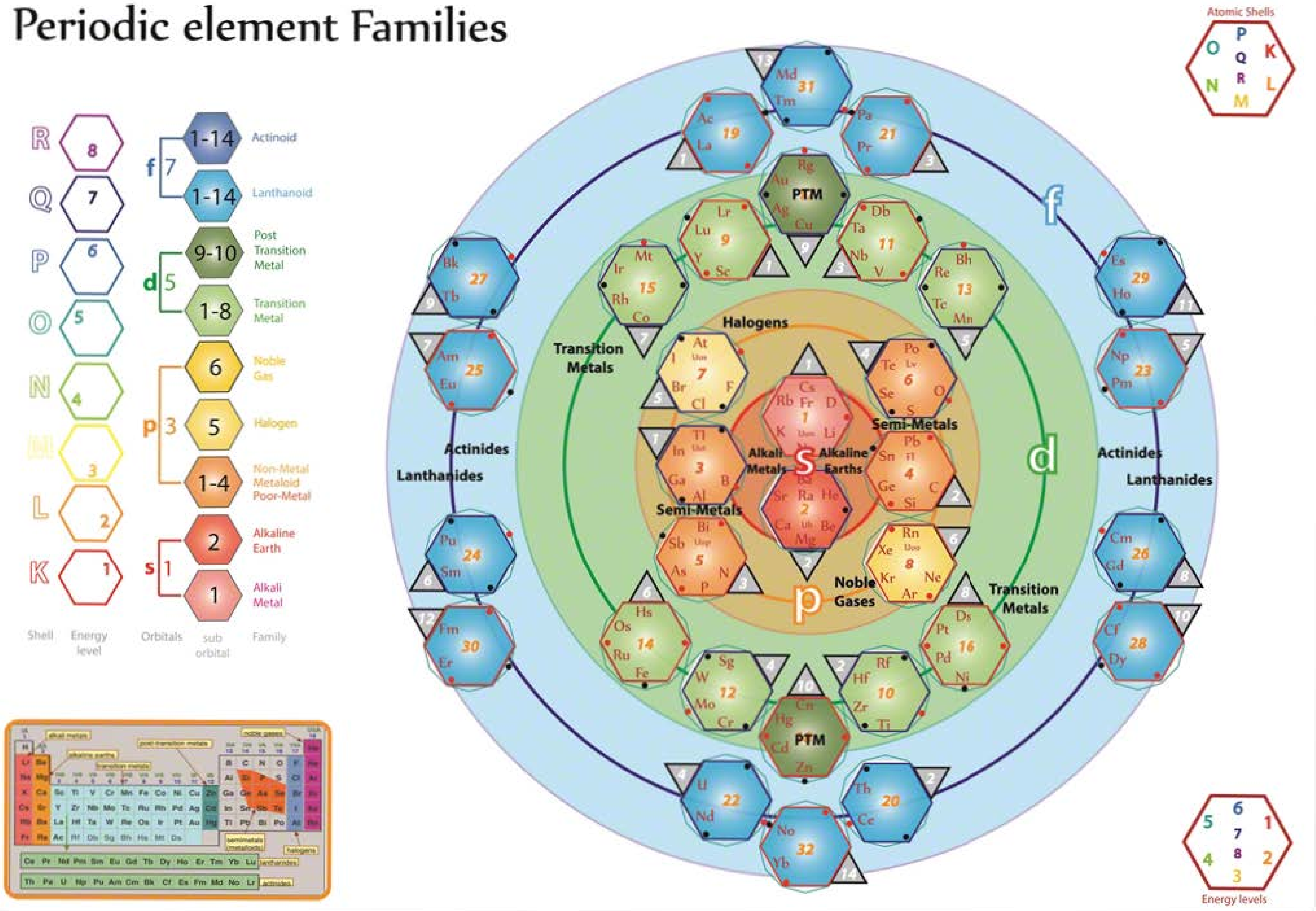
Atomic Shells
O P Q K
N R L
M
R 8
Q 7
P 6
O 5
N 4
M 3
L 2
K 1
f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metaloid Poor-Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Shell
Energy level
Orbitals
sub orbital
Family
f
d
s
p
Halogens
Transition Metals
Semi-Metals
Alkali Metals
Alkaline Earths
Noble Gases
Actinides
Lanthanides
PTM
Energy levels
5 6 1
7
4 8 2
3

Alkali Metals

The alkali metals are silver-colored (caesium has a golden tinge), soft, low-density metals, which react readily with halogens to form ionic salts, and with water to form strongly alkaline (basic) hydroxides.

These elements all have one electron in their outermost shell, so the energetically preferred state of achieving a filled electron shell is to lose one electron to form a singly charged positive ion.

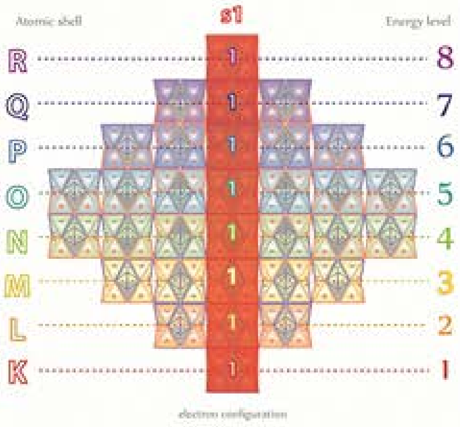
Atomic shell
s1
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
electron configuration

R 8
Q 7
P 6
O 5
N 4
M 3
L 2
K 1
Shell Quantum level

S
1
Alkali Metal

s Orbital

n1-8

s1 sub-orbital

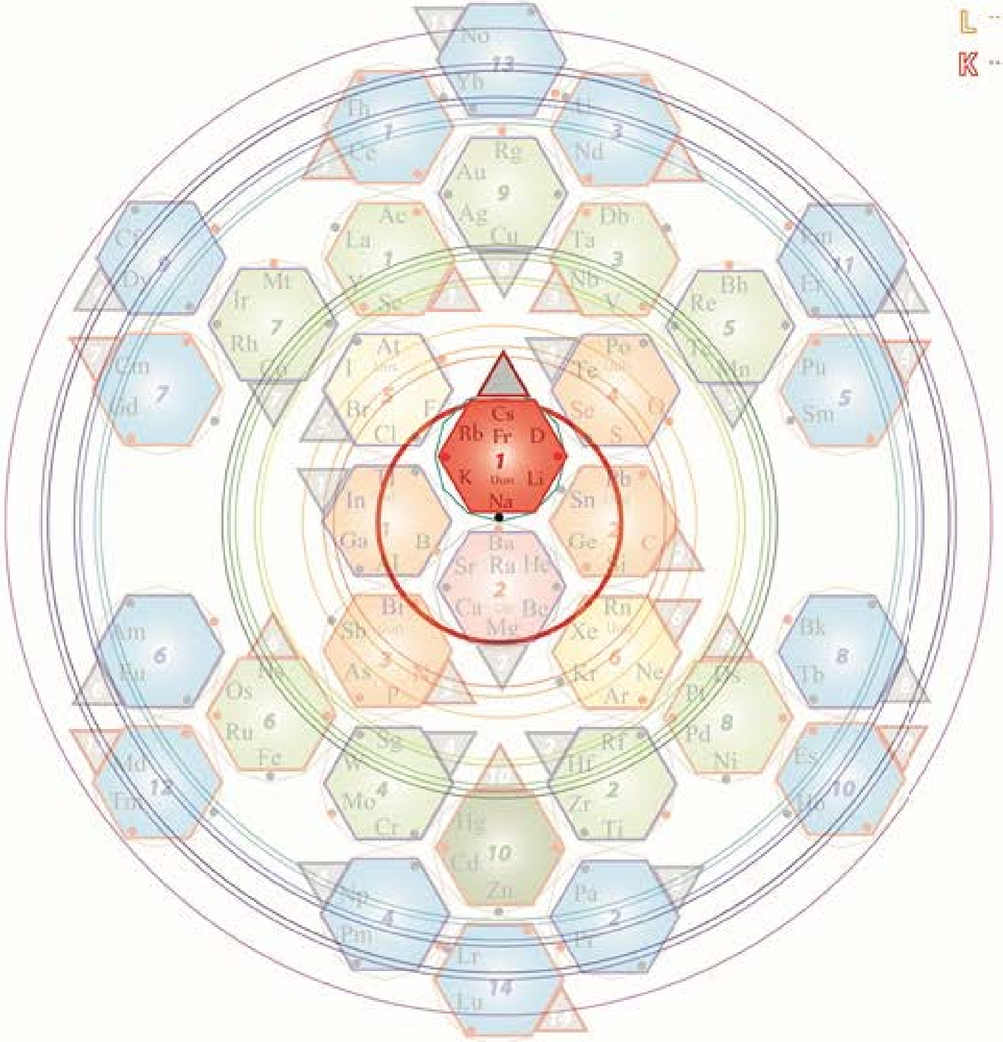
Cs
Fr
Rb
D
1
K
Li
Na

8

Alkaline Metals

Quantum level

The alkali metals are all highly reactive and are never found in elemental form in nature.

As a result, in the laboratory they are stored under mineral oil. They also tarnish easily and have low melting points and densities. Potassium and rubidium possess a weak radioactive characteristic (harmless) due to the presence of long duration radioactive isotopes.

Alkaline Earths

The alkaline earth metals are silver colored, soft metals, which react readily with halogens to form ionic salts, and with water, though not as rapidly as the alkali metals, to form strong alkaline (basic) hydroxides.

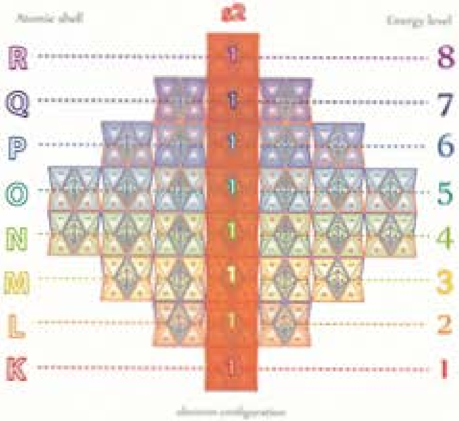
Atomic shell
s2
Energy level
R
Q
P
O
N
M
L
K
1
1
1
1
1
1
1
1
8
7
6
5
4
3
2
1
electron configuration

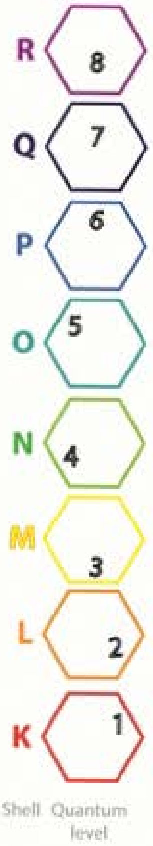
R
8
Q
7
P
6
O
5
N
4
M
3
L
2
K
1
Shell
Quantum level

s
2
Alkaline Earth

s Orbital

n1-8

s2 sub-orbital

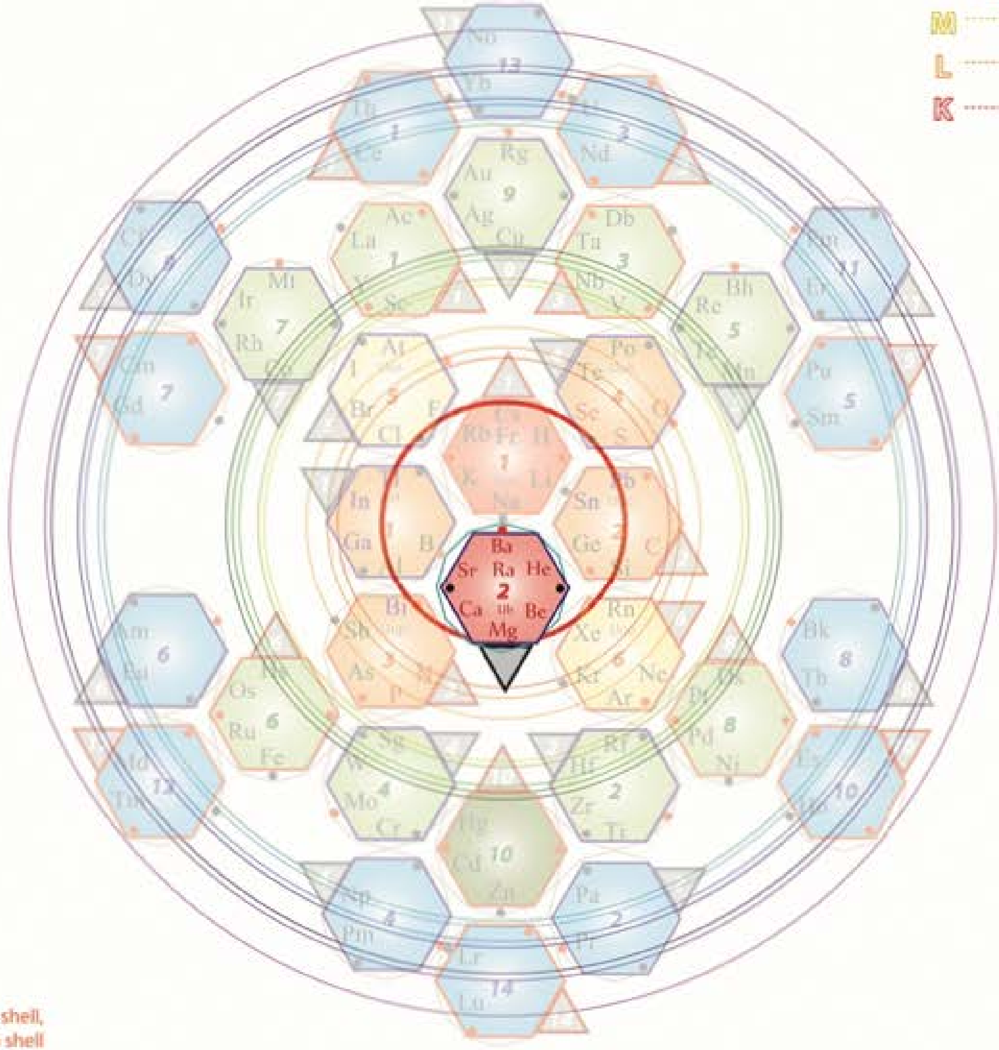
Ba
Sr
Ra
He
2
Ca
Be
Mg
Rb
Fr
H
1
K
Li
Na

8

Alkaline Earths

6
5
7
1
4
8
2
3
Quantum level

All the alkaline earth metals have two electrons in their valence shell, so the energetically preferred state of achieving a filled electron shell is to lose two electrons to form doubly charged positive ions.

Metalloids

A metaloid is a material with a small overlap in the energy of the conduction band and valence bands.

Unlike a regular metal, metaloids have been described electrically as charge carriers of both types (holes and elecrons), so it could be argue that they should be called 'double-metals' rather than metaloids.

As metaloids have fewer charge carriers than metals, they typically have lower electrical and thermal conductivities.

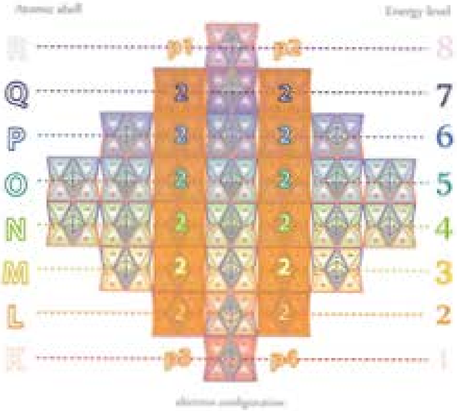
Atomic shell
Energy level
K
Q
P
O
N
M
L
K
p1
p2
p3
p4
8
7
6
5
4
3
2
1
2
electron configuration

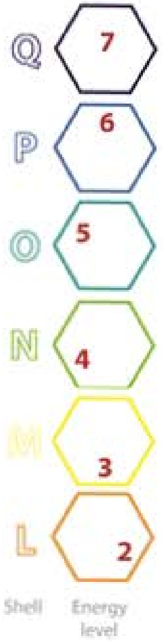
Q 7
P 6
O 5
N 4
M 3
L 2
Shell
Energy level

p
1-4
Non-Metal
Metaloid
Poor-Metal

2 p-Orbitals

n2-7

p1-4 sub-orbitals

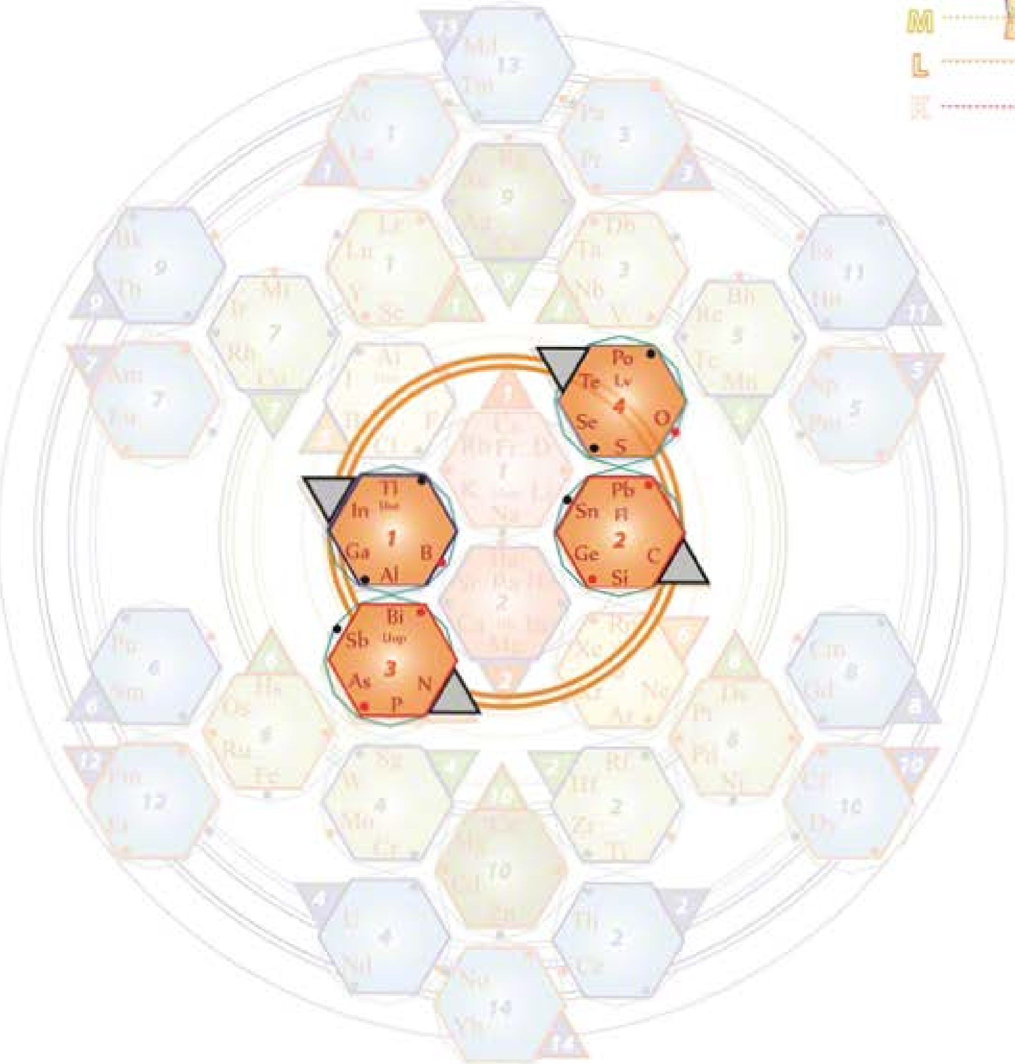
Po
Te
Lv
4
Se
O
S
Tl
In
Uut
1
Ga
B
Al
Pb
Sn
Fl
2
Ge
C
Si
Bi
Sb
Uup
3
As
N
P

24 Semi-Metals

Charge carriers typically occur in much smaller numbers than in a real metal. In this respect they resemble degenerate semiconductors more closely.
This explains why the electrical properties of metaloids are partway between those of metals and semiconductors.

6
5
7
4
2
3
Energy levels

Halogens

Owing to their high reactivity, the halogens are found in the environment only in compounds or as ions.

Halide ions and oxoanions such as iodate (IO3−) can be found in many minerals and in seawater.

Halogenated organic compounds can also be found as natural products in living organisms. In their elemental forms, the halogens exist as diatomic molecules, but these only have a fleeting existence in nature and are much more common in the laboratory and in industry.

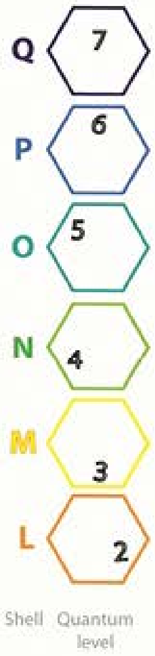
Q
7
P
6
O
5
N
4
M
3
L
2
Shell
Quantum level

p3 Orbital

n2-7

p5 sub-orbital

At room temperature and pressure, fluorine and chlorine are gases, bromine is a liquid and iodine and astatine are solids.

Group 17 is therefore the only periodic table group exhibiting all three states of matter at room temperature

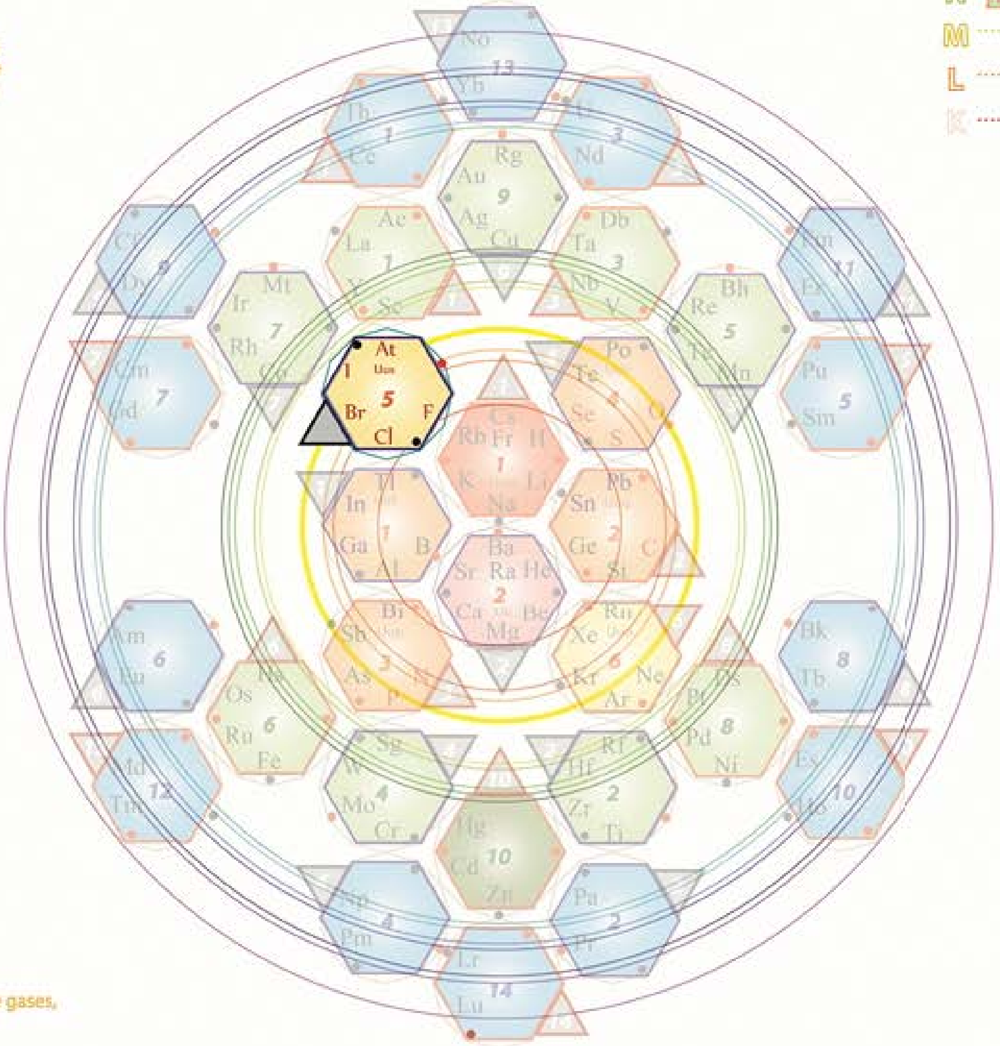
At
Uus
I
5
Br
F
Cl

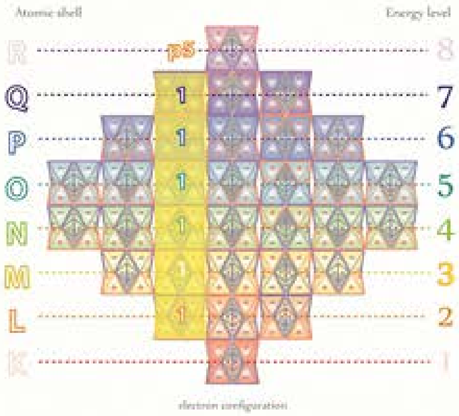
Atomic shell
Energy level
R
Q
P
O
N
M
L
K
p5
8
7
6
5
4
3
2
1
electron configuration

6

Halogens

6
5
7
4
2
3
Quantum level

Nobel Gases

The properties of the noble gases can be well explained by modern theories of atomic structure: their outer shell of valence electrons is considered to be "full", giving them little tendency to participate in chemical reactions, and only a few hundred noble gas compounds have been prepared.

The melting and boiling points for each noble gas are close together, differing by less than 10 °C (18 °F); consequently, they are liquids only over a small temperature range.

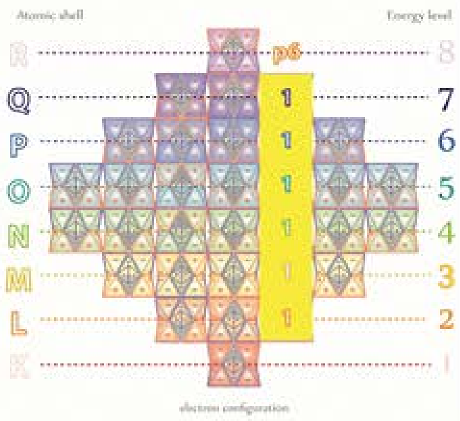
Atomic shell
Energy level
R
p6
8
Q
1
7
P
1
6
O
1
5
N
1
4
M
1
3
L
1
2
K
1
electron configuration

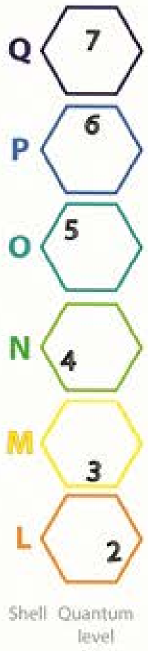
Q
7
P
6
O
5
N
4
M
3
L
2
Shell
Quantum level

p
6
Noble Gas

completed
p3 Orbital
n2-7
p6 sub-orbital

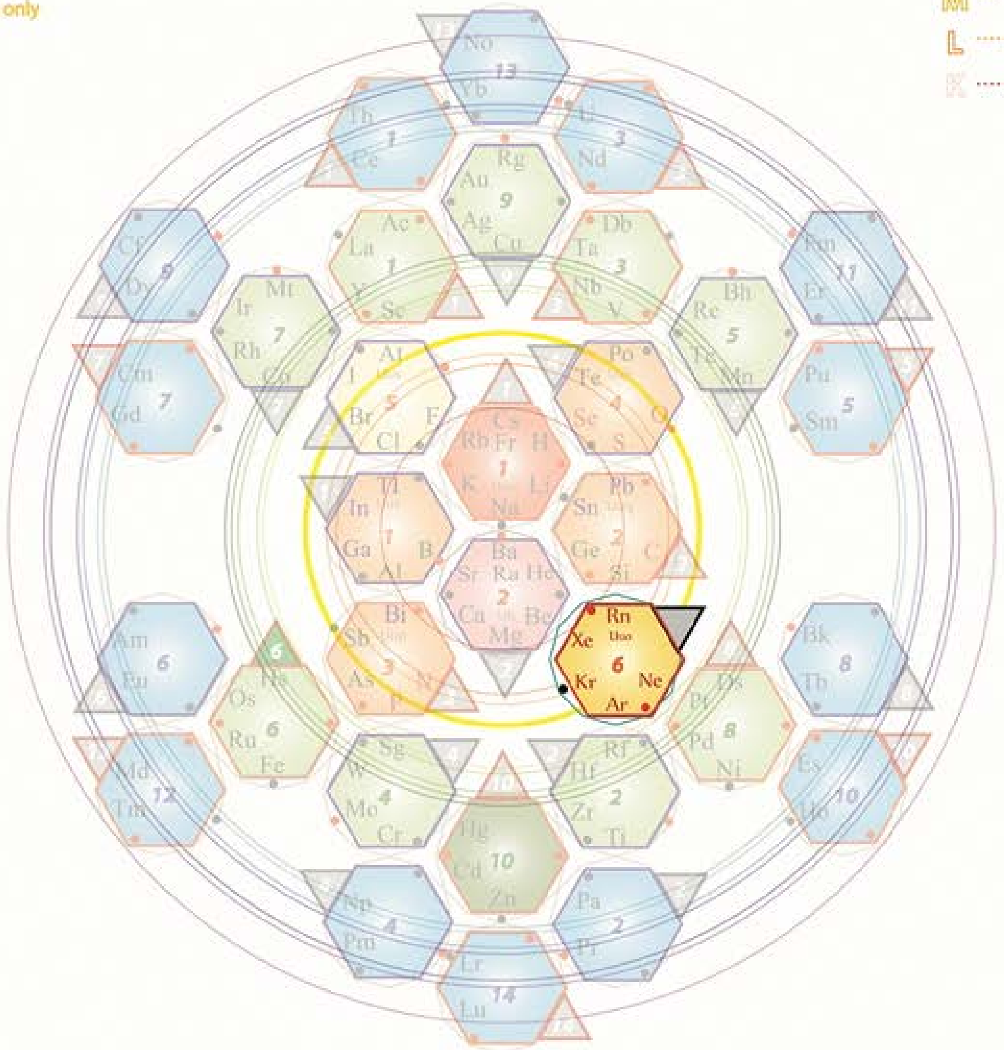
Rn
Uuo
Xe
6
Kr
Ne
Ar

6
Nobel Gases

6
5
7
4
2
3
Quantum level

Neon, argon, krypton, and xenon are obtained from air using the methods of liquefaction of gases and fractional distillation.

Helium is typically separated from natural gas, and radon is usually isolated from the radioactive decay of dissolved radium compounds.

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Transitional Metals

In chemistry, the term transition metal commonly refers to any element in the d-block of the periodic table, including the group 12 elements zinc, cadmium and mercury.

This corresponds to groups 3 to 12 on the periodic table, which are all metals.

More strictly, IUPAC defines a transition metal as "an element whose atom has an incomplete d sub-shell, or which can give rise to cations with an incomplete d sub-shell."

The first definition is simple and has traditionally been used. However, many interesting properties of the transition elements as a group are the result of their partly filled d subshells.

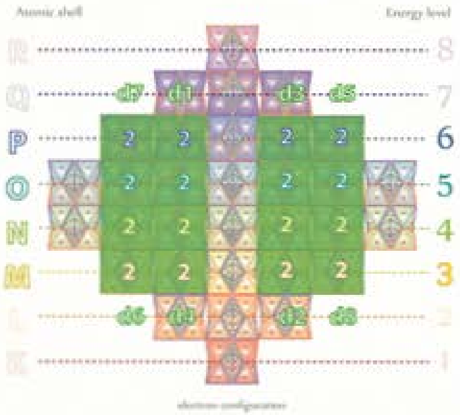
Atomic shell
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
d7
d1
d3
d5
d6
d4
d2
d8
2
electron configuration

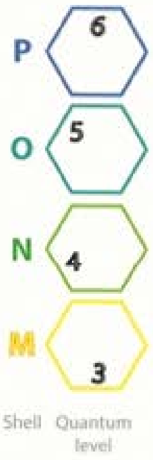
P
6
O
5
N
4
M
3
Shell
Quantum level

d
1-8
Transition Metal

4 d-Orbitals

n3-6

d1-8 sub-orbitals

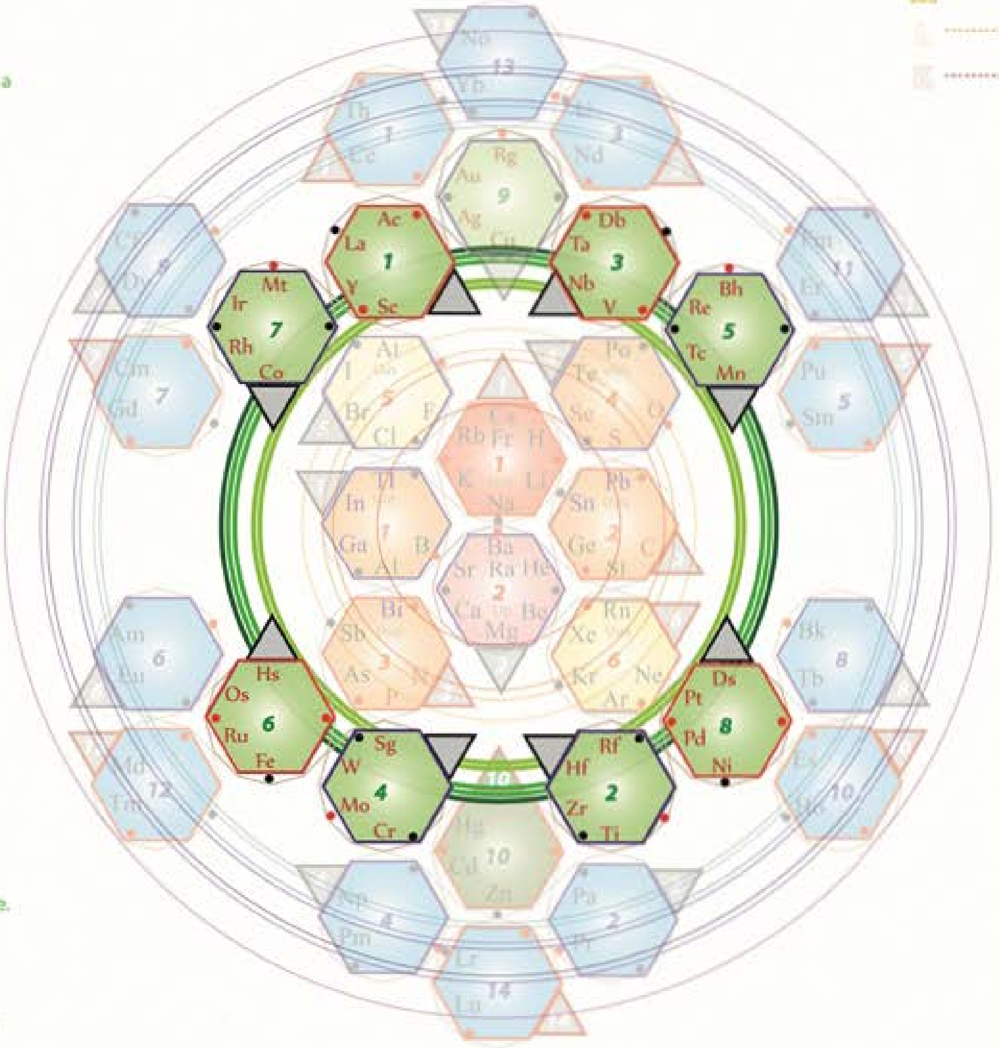
Ac
La
Y
Sc
1
Db
Ta
Nb
V
3
Mt
Ir
Rh
Co
7
Bh
Re
Tc
Mn
5
Hs
Os
Ru
Fe
6
Ds
Pt
Pd
Ni
8
Sg
W
Mo
Cr
4
Rf
Hf
Zr
Ti
2
Rg
Au
Ag
Cu
9
Hg
Cd
Zn
10
No
Yb
13
Lr
Lu
14

32 Transition Metals

6
5
4
3
Quantum level

The name transition comes from their position in the periodic table. In each of the four periods in which they occur, these elements represent the successive addition of electrons to the d atomic orbitals of the atoms.

In this way, the transition metals represent the transition between group 2 elements and group 13 elements.

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Post-Transition Metals

In chemistry, the term post-transition metal is used to describe the category of metallic elements to the right of the transition elements on the periodic table.

There are two IUPAC definitions of "transition element" that have been in apparent conflict with one another since September 2007.

According to the first definition, transition metals are elements in group 3 through group 11.
In this case, post-transition metals include all of group 12—zinc, cadmium, mercury, and ununbium

According to the second definition, transition elements either have an incomplete d-subshell or have the ability to form an incomplete d-subshell.

Post Transitional metals are normally defined as completed d orbitals

Tetryonics suggests it may be appropriate to include all the d5 orbital elements in this grouping

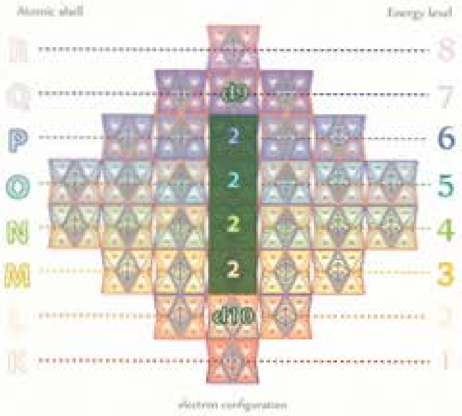
Atomic shell
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
d9
2
2
2
2
d10
electron configuration

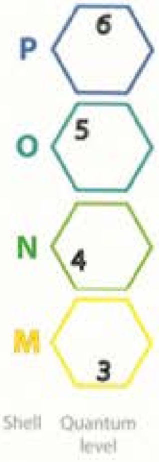
P
6
O
5
N
4
M
3
Shell
Quantum level

d
9-10
Post Transition Metal

d5 Orbital

n3-6

d9-10 sub-orbitals

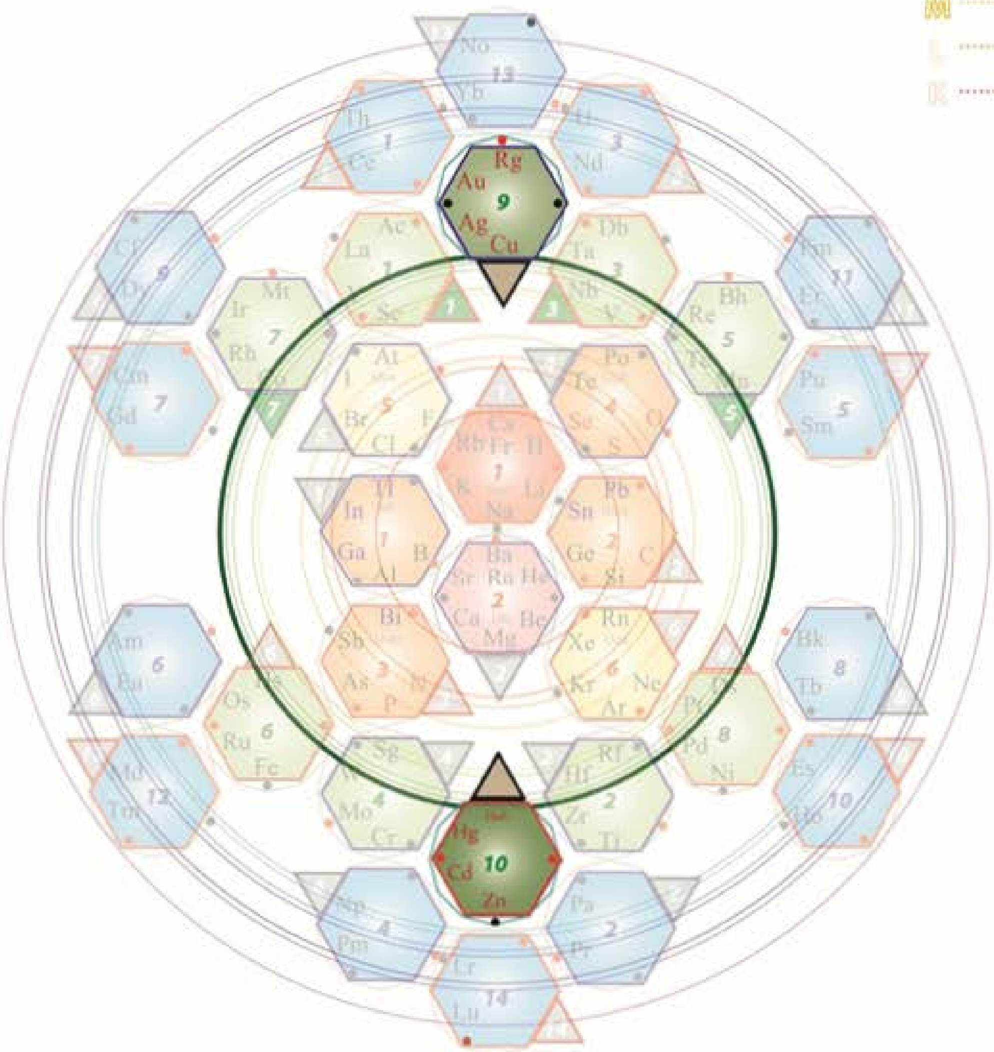
Rg
Au
9
Ag
Cu
Hg
Cd
10
Zn
No
Yb
13
Th
Ce
1
U
Nd
3
Ac
La
Db
Ta
Nb
V
Cf
Dy
9
Mt
Ir
Rh
7
Bh
Re
5
Fm
Er
11
Cm
Gd
7
Pu
Sm
5
Am
Eu
6
Os
Ru
Fe
6
Bk
Tb
8
Pt
Pd
Ni
8
Md
Tm
12
Es
Ho
10
Sg
Mo
Cr
4
Rf
Hf
Zr
Ti
2
Np
Pm
4
Pa
Pr
2
Lr
Lu
14
Fr
Rb
K
Na
1
Ra
Sr
Ca
Mg
Be
He
2
At
I
Br
Cl
F
5
Po
Te
Se
S
O
4
Tl
In
Ga
Al
B
1
Pb
Sn
Ge
Si
C
2
Bi
Sb
As
P
N
3
Rn
Xe
Kr
Ar
Ne
6

8
Post-transitional Metals

In 2007, mercury(IV) fluoride was synthesized.[2][3] This compound contains a mercury atom with an incomplete d-subshell, and ununbium is predicted to have the capacity to form a similar electronic configuration.

In this case, post-transition metals include only zinc and cadmium within group 12.

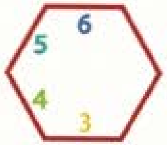

Quantum level

Lanthanoids

All lanthanoids are f-block elements, corresponding to the filling of the 4f electron shell

The lanthanoid series (Ln) is named after Lanthanum.

The trivial name "rare earths" is sometimes used to describe all the lanthanoids together with scandium and yttrium.

These elements are in fact fairly abundant in nature, although rare as compared to the "common" earths such as lime or magnesia. Cerium is the 26th most abundant element in the Earth's crust, neodymium is more abundant than gold and even thulium (the least common naturally-occurring lanthanoid) is more abundant than iodine.

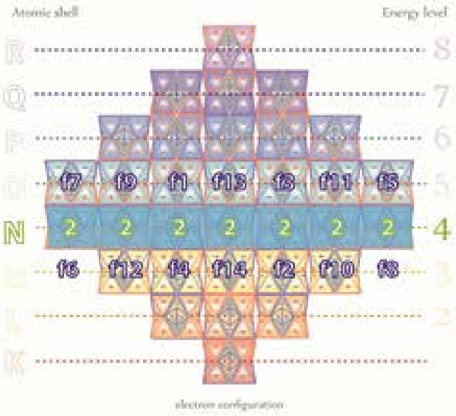
Atomic shell
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
f7
f9
f1
f13
f3
f11
f5
2
2
2
2
2
2
2
f6
f12
f4
f14
f2
f10
f8
electron configuration

f
1-14
Lanthanoid

N
4
Shell
Quantum level

7 f-Orbitals

n4

f1-14 sub-orbitals

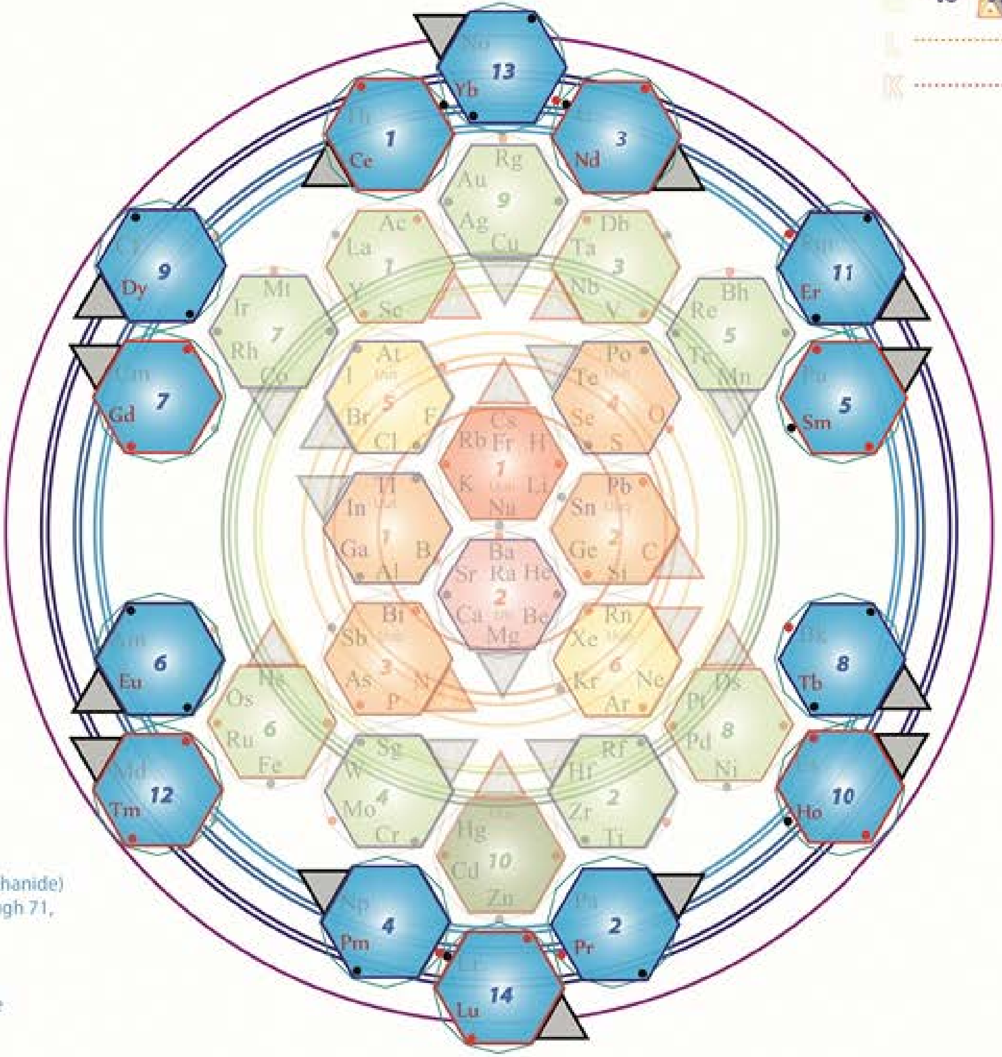
13
Yb
1
Ce
3
Nd
9
Dy
11
Er
7
Gd
5
Sm
6
Eu
8
Tb
12
Tm
10
Ho
4
Pm
2
Pr
14
Lu
Rg
Au
Ag
Cu
Ac
La
Y
Sc
Db
Ta
Nb
V
Mt
Ir
Rh
Co
Bh
Re
Tc
Mn
At
I
Br
Cl
F
Po
Te
Se
S
O
Cs
Rb
Fr
H
K
Li
Na
Tl
In
Ga
Al
B
Pb
Sn
Ge
Si
C
Ba
Sr
Ra
He
Ca
Be
Mg
Bi
Sb
As
P
N
Rn
Xe
Kr
Ne
Ar
Hs
Os
Ru
Fe
Ds
Pt
Pd
Ni
Sg
W
Mo
Cr
Rf
Hf
Zr
Ti
Hg
Cd
Zn

14 Lanthanoids

The term "rare earths" arises from the minerals from which they were isolated, which were uncommon oxide-type minerals.

According to the IUPAC terminology, the lanthanoid (previously lanthanide) series comprises the fifteen elements with atomic numbers 57 through 71, from Lanthanum to Lutetium.

The use of this name is deprecated by IUPAC, as they are neither rare in abundance nor "earths" (an obsolete term for water-insoluble strongly basic oxides of electropositive metals incapable of being smelted into metal using late 18th century technology).

4
Quantum level

Actinoids

According to IUPAC nomenclature, the actinoid (previously actinide) series encompasses the 15 chemical elements that lie between actinium and lawrencium included on the periodic table, with atomic numbers 89 - 103.

The actinoid series derives its name from the first element in the series, actinium, and ultimately from the Greek ακτις (aktis), "ray," reflecting the elements' radioactivity.

The actinoids display less similarity in their chemical properties than the lanthanoid series (Ln), exhibiting a wider range of oxidation states, which initially led to confusion as to whether actinium, thorium, and uranium should be considered d-block elements. All actinoids are radioactive.

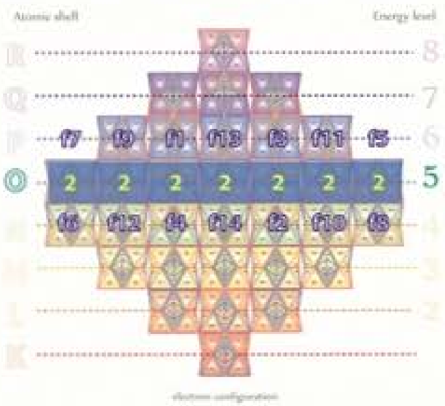
Atomic shell
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
f7
f9
f1
f13
f3
f11
f5
2
2
2
2
2
2
2
f6
f12
f4
f14
f2
f10
f8
electron configuration

f 1-14 Actinoid

O 5

Shell Quantum level

7 f-Orbitals

n5

f1-14 sub-orbitals

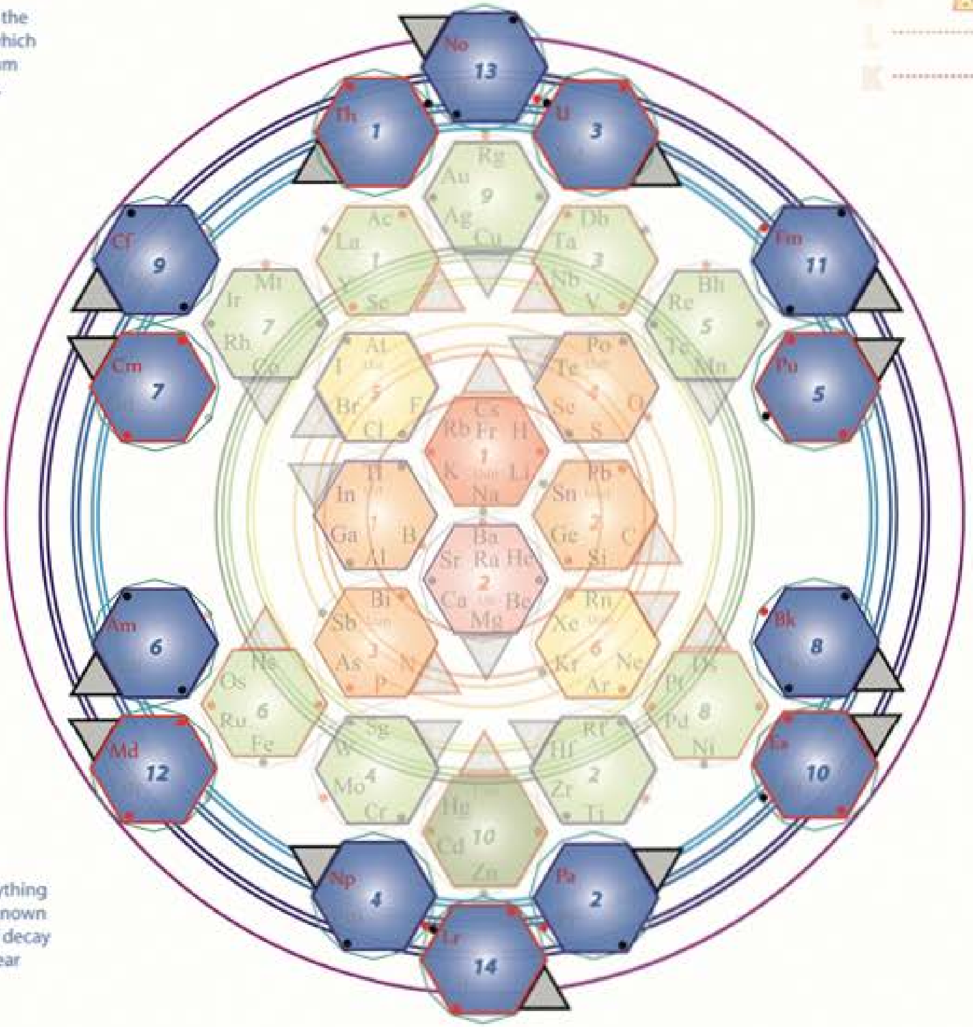
No 13
Th 1
U 3
Cf 9
Fm 11
Cm 7
Pu 5
Am 6
Bk 8
Md 12
Es 10
Np 4
Pa 2
Lr 14
Rg Au Ag Cu 9
Ac La Y Sc
Db Ta Nb V 3
Mt Ir Rh Co 7
Bh Re Tc Mn 5
At I Br Cl F 5
Po Te Se S O 4
Cs Rb Fr H K Li Na 1
Tl In Ga Al B 1
Pb Sn Ge Si C 2
Ba Sr Ra He Ca Be Mg 2
Bi Sb As N P 3
Rn Xe Kr Ne Ar 6
Hs Os Ru Fe 6
Ds Pt Pd Ni 8
Sg W Mo Cr 4
Rf Hf Zr Ti 2
Hg Cd Zn 10

14 Actinoids

5

Quantum level

Only thorium and uranium occur naturally in the earth's crust in anything more than trace quantities. Neptunium and plutonium have been known to show up naturally in trace amounts in uranium ores as a result of decay or bombardment. The remaining actinoids were discovered in nuclear fallout, or were synthesized in particle colliders.

The latter half of the series possess exceedingly short half-lives.

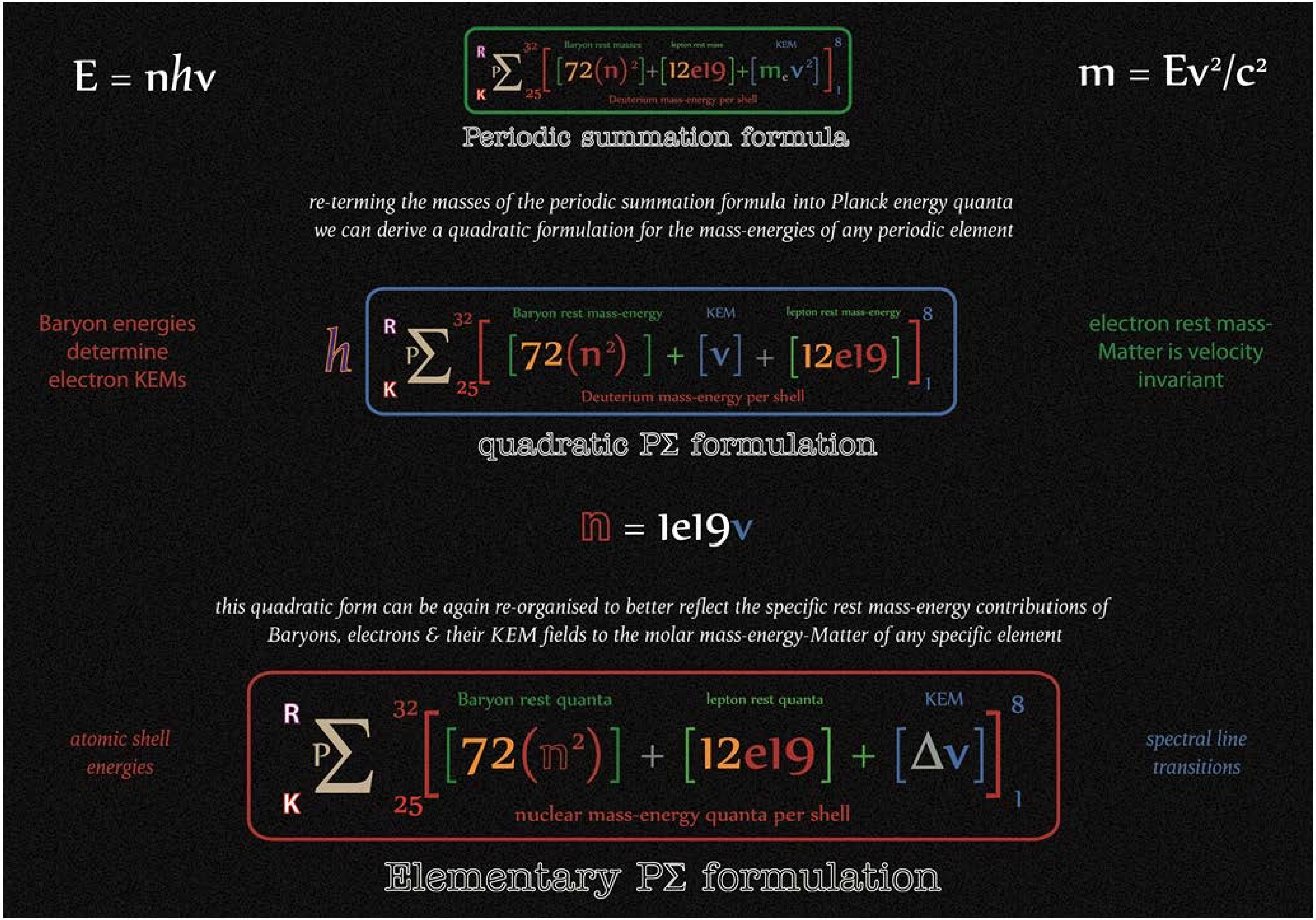

$$E = nhv$$

$$m = Ev^2/c^2$$

$${}^{R}_{K}\,{}^{}_{P}\!\sum_{25}^{32}\left[\overset{\text{Baryon rest masses}}{[72(n)^2]}+\overset{\text{lepton rest mass}}{[12e19]}+\overset{\text{KEM}}{[m_e v^2]}\right]_1^8$$

Deuterium mass-energy per shell

Periodic summation formula

re-terming the masses of the periodic summation formula into Planck energy quanta we can derive a quadratic formulation for the mass-energies of any periodic element

Baryon energies determine electron KEMs

$$h\;{}^{R}_{K}\,{}^{}_{P}\!\sum_{25}^{32}\left[\overset{\text{Baryon rest mass-energy}}{[72(n^2)]}+\overset{\text{KEM}}{[v]}+\overset{\text{lepton rest mass-energy}}{[12e19]}\right]_1^8$$

Deuterium mass-energy per shell

electron rest mass-Matter is velocity invariant

quadratic PΣ formulation

$$n = 1e19v$$

this quadratic form can be again re-organised to better reflect the specific rest mass-energy contributions of Baryons, electrons & their KEM fields to the molar mass-energy-Matter of any specific element

atomic shell energies

$${}^{R}_{K}\,{}^{}_{P}\!\sum_{25}^{32}\left[\overset{\text{Baryon rest quanta}}{[72(n^2)]}+\overset{\text{lepton rest quanta}}{[12e19]}+\overset{\text{KEM}}{[\Delta v]}\right]_1^8$$

nuclear mass-energy quanta per shell

spectral line transitions

Elementary PΣ formulation

Tetryonics 52.13 - Periodic element summation formula

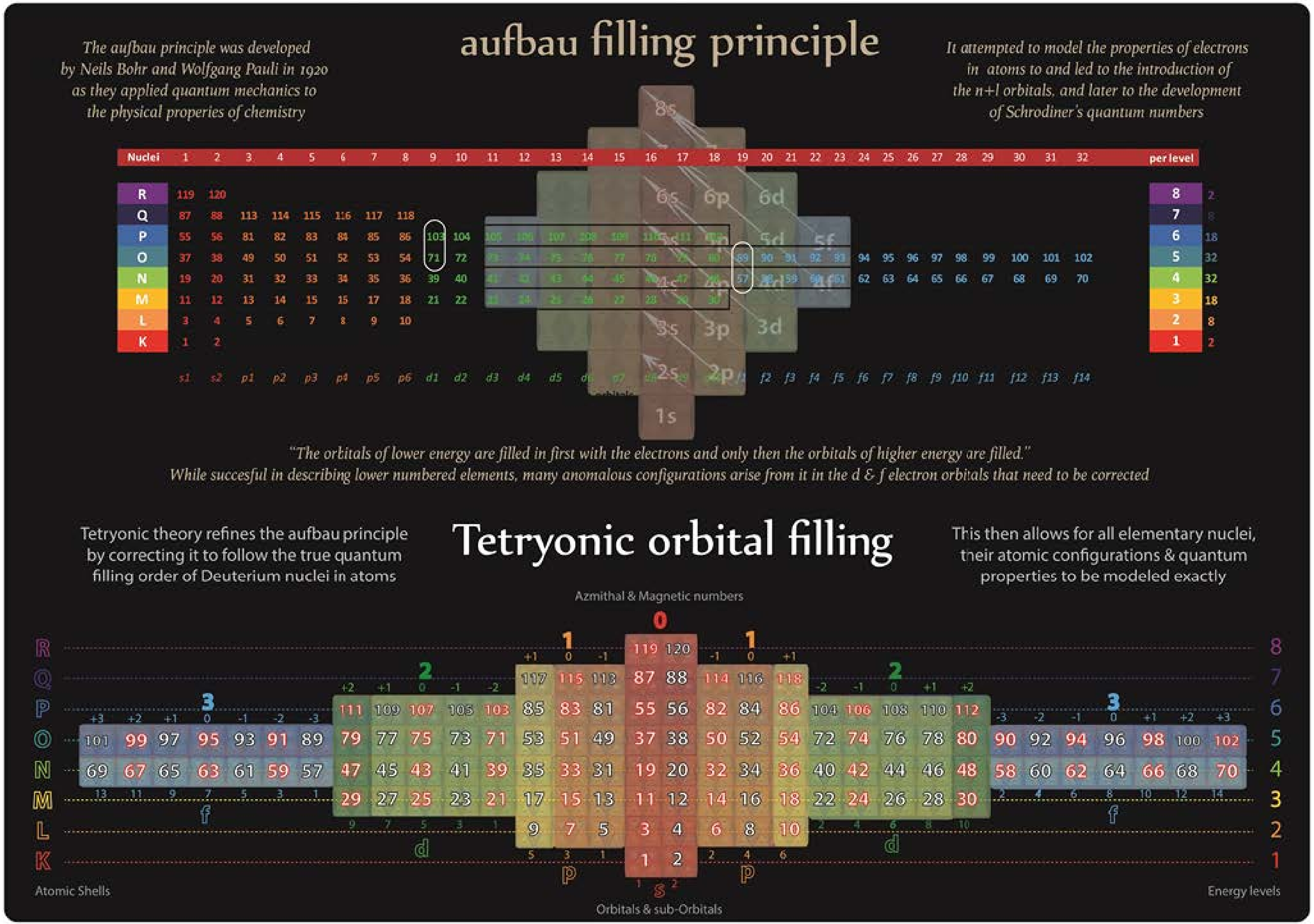

aufbau filling principle

The aufbau principle was developed by Neils Bohr and Wolfgang Pauli in 1920 as they applied quantum mechanics to the physical properies of chemistry

It attempted to model the properties of electrons in atoms to and led to the introduction of the n+l orbitals, and later to the development of Schrodiner's quantum numbers

Nuclei	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	per level	
R	119	120																															8	2
Q	87	88	113	114	115	116	117	118																									7	8
P	55	56	81	82	83	84	85	86	103	104	105	106	107	108	109	110	111	112															6	18
O	37	38	49	50	51	52	53	54	71	72	73	74	75	76	77	78	79	80	89	90	91	92	93	94	95	96	97	98	99	100	101	102	5	32
N	19	20	31	32	33	34	35	36	39	40	41	42	43	44	45	46	47	48	57	58	59	60	61	62	63	64	65	66	67	68	69	70	4	32
M	11	12	13	14	15	15	17	18	21	22	23	24	25	26	27	28	29	30															3	18
L	3	4	5	6	7	8	9	10																									2	8
K	1	2																															1	2
	s1	*s2*	*p1*	*p2*	*p3*	*p4*	*p5*	*p6*	*d1*	*d2*	*d3*	*d4*	*d5*	*d6*	*d7*	*d8*	*d9*	*d10*	*f1*	*f2*	*f3*	*f4*	*f5*	*f6*	*f7*	*f8*	*f9*	*f10*	*f11*	*f12*	*f13*	*f14*		

"The orbitals of lower energy are filled in first with the electrons and only then the orbitals of higher energy are filled."
While succesful in describing lower numbered elements, many anomalous configurations arise from it in the d & f electron orbitals that need to be corrected

Tetryonic orbital filling

Tetryonic theory refines the aufbau principle by correcting it to follow the true quantum filling order of Deuterium nuclei in atoms

This then allows for all elementary nuclei, their atomic configurations & quantum properties to be modeled exactly

Azmithal & Magnetic numbers

	+3	+2	+1	0	-1	-2	-3	+2	+1	0	-1	-2	+1	0	-1			-1	0	+1	-2	-1	0	+1	+2	-3	-2	-1	0	+1	+2	+3	
R																119	120																8
Q													117	115	113	87	88	114	116	118													7
P								111	109	107	105	103	85	83	81	55	56	82	84	86	104	106	108	110	112								6
O	101	99	97	95	93	91	89	79	77	75	73	71	53	51	49	37	38	50	52	54	72	74	76	78	80	90	92	94	96	98	100	102	5
N	69	67	65	63	61	59	57	47	45	43	41	39	35	33	31	19	20	32	34	36	40	42	44	46	48	58	60	62	64	66	68	70	4
M								29	27	25	23	21	17	15	13	11	12	14	16	18	22	24	26	28	30								3
L													9	7	5	3	4	6	8	10													2
K																1	2																1

Atomic Shells

Orbitals & sub-Orbitals

Energy levels

Tetryonics 52.14 - Tetryonic aufbau orbital filling

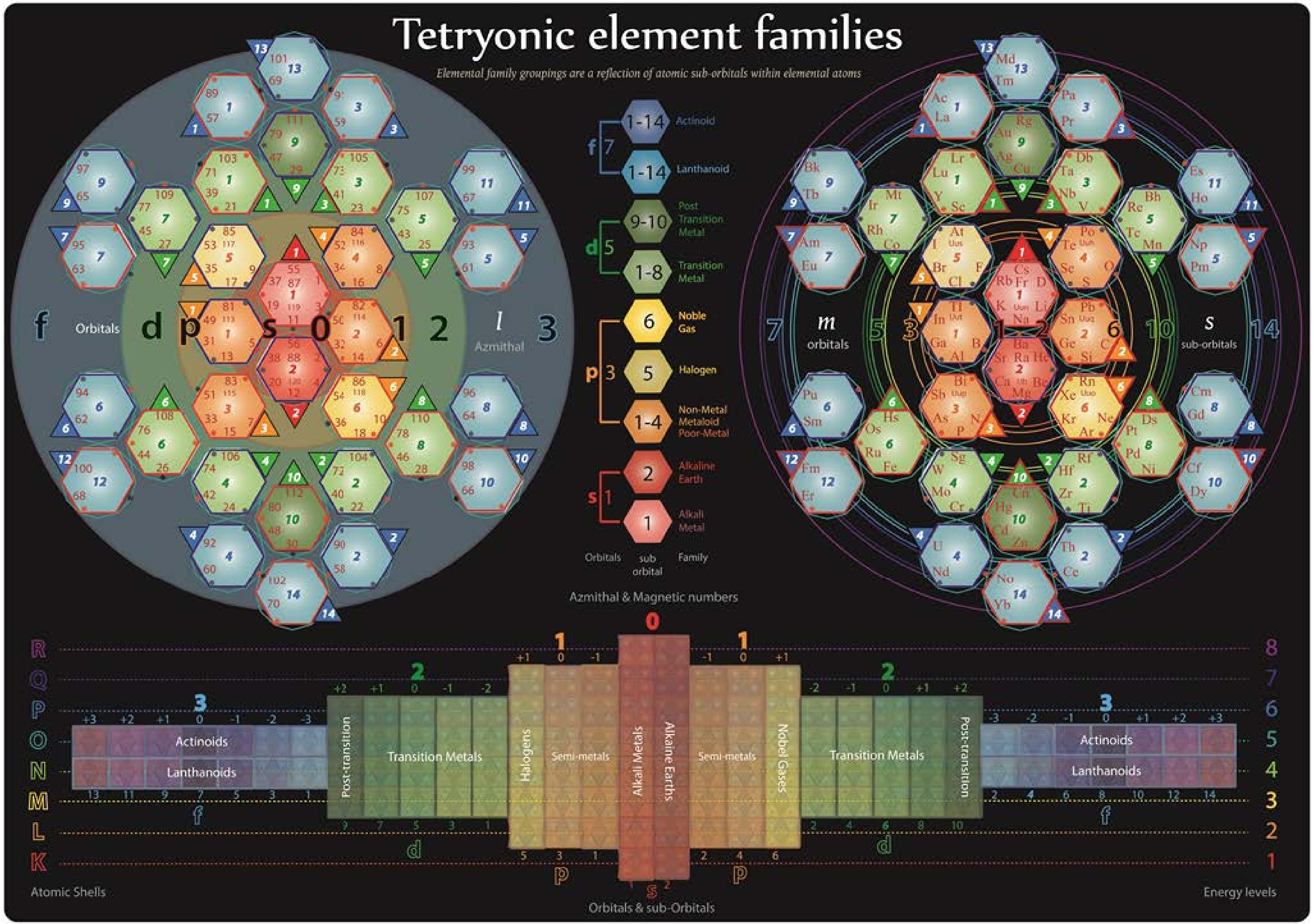

Tetryonic element families

Elemental family groupings are a reflection of atomic sub-orbitals within elemental atoms

f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metaloid Poor-Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Orbitals
sub orbital
Family
f Orbitals d p s 0 1 2 l Azmithal 3
7 m orbitals 5 3 1 2 6 10 s sub-orbitals 14
Azmithal & Magnetic numbers
R Q P O N M L K
Atomic Shells
8 7 6 5 4 3 2 1
Energy levels
3 2 1 0 1 2 3
Actinoids
Lanthanoids
Post-transition
Transition Metals
Halogens
Semi-metals
Alkali Metals
Alkaine Earths
Semi-metals
Nobel Gases
Transition Metals
Post-transition
Actinoids
Lanthanoids
f d p s p d f
Orbitals & sub-Orbitals

Tetryonics 52.15 - Tetryonic elemental families

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elemental family geometry

electron configuration

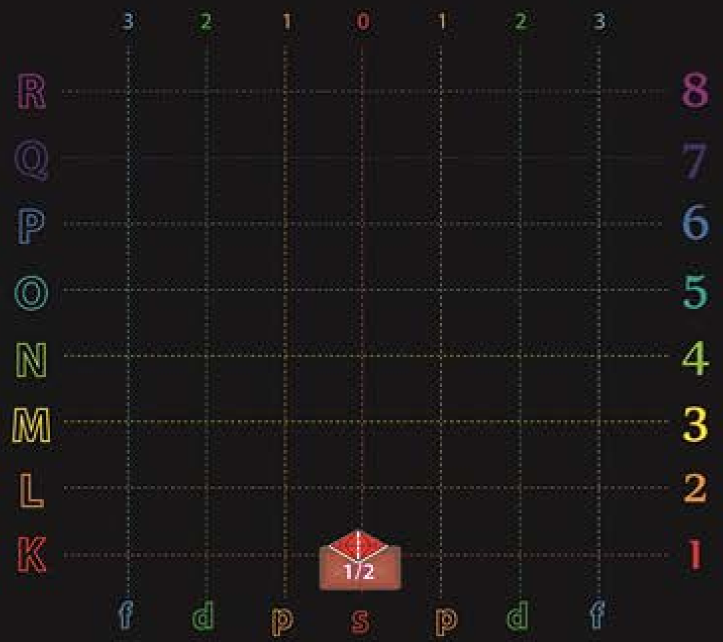
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1/2
f
d
p
s
p
d
f

Hydrogen is NOT a periodic table element

Hydrogen

Baryonic energy levels determine photo-electron KEM field energies

$${}_{K}^{P}\sum_{25}\left[\overset{\text{Baryon rest quanta}}{[72(n^{2})]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]}\right]_{1}^{8}$$

nuclear mass-energy quanta per shell

Free Radical element

accelerating photo-electrons produce spectral lines

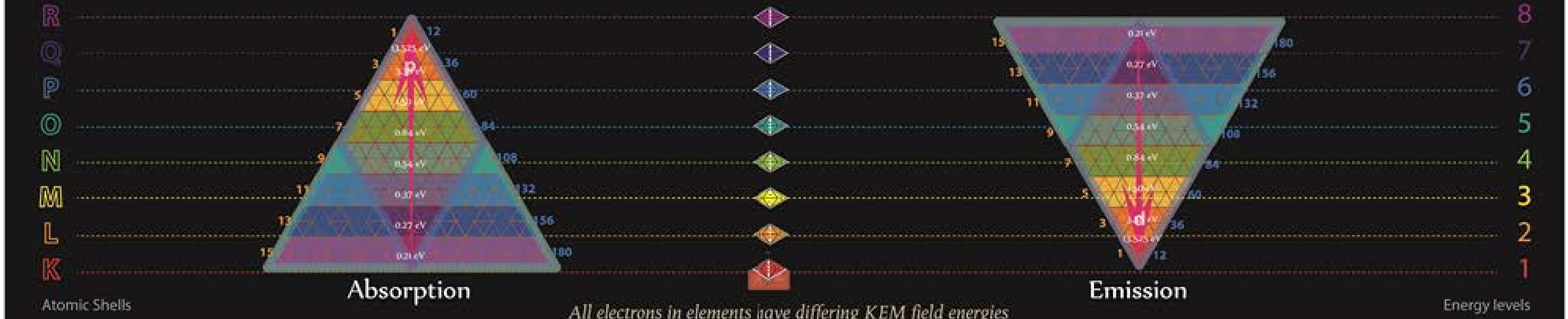
R
Q
P
O
N
M
L
K
1
3
5
7
9
11
13
15
12
36
60
84
108
132
156
180
13.525 eV
3.4 eV
p
0.84 eV
0.54 eV
0.37 eV
0.27 eV
0.21 eV
Absorption
0.21 eV
0.27 eV
0.37 eV
0.54 eV
0.84 eV
3.4 eV
d
13.525 eV
Emission
8
7
6
5
4
3
2
1
Atomic Shells
Energy levels

All electrons in elements have differing KEM field energies

Tetryonics 53.00 - Hydrogen atomic config

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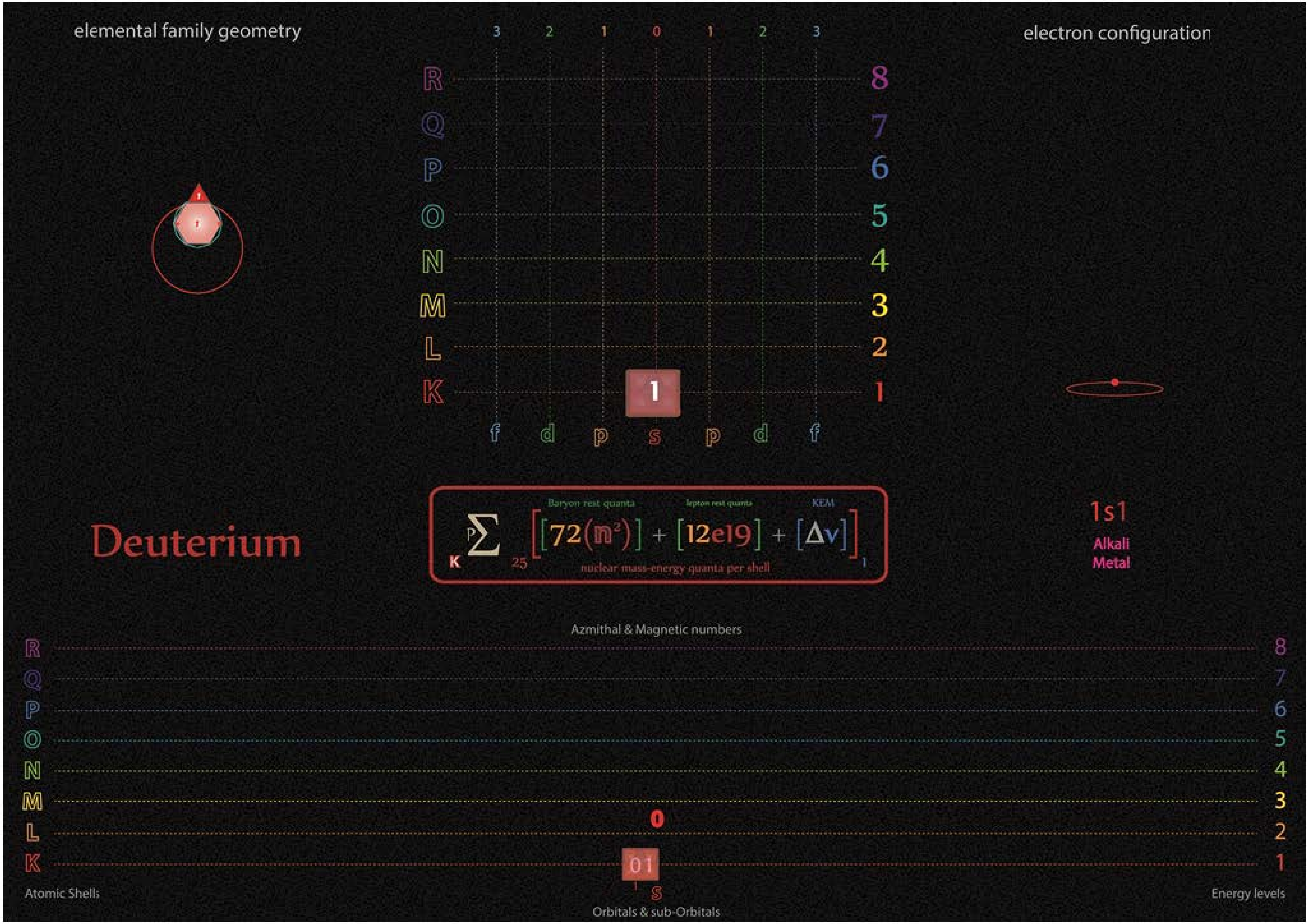
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
1
f d p s p d f
Deuterium
Baryon rest quanta
lepton rest quanta
KEM
$_{K}\sum^{P}{}_{25}\left[[72(m^2)] + [12e19] + [\Delta v]\right]_1$
nuclear mass-energy quanta per shell
1s1
Alkali
Metal
Azmithal & Magnetic numbers
0
01
1
s
Atomic Shells
Orbitals & sub-Orbitals
Energy levels

Tetryonics 53.01 - Deuterium atomic config

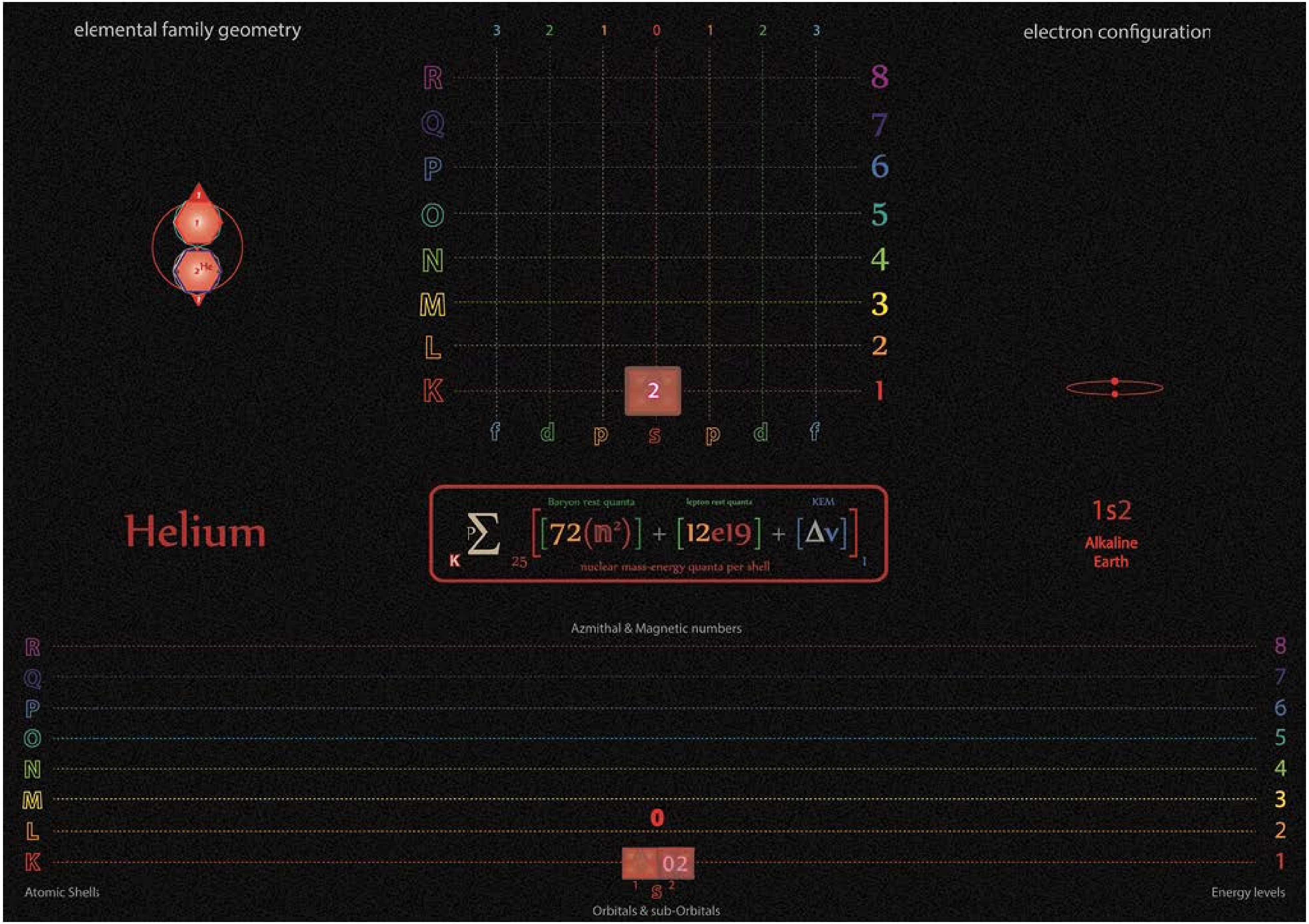
elemental family geometry
3 2 1 0 1 2 3
electron configuration
R Q P O N M L K
8 7 6 5 4 3 2 1
2
f d p s p d f
1
2He
Helium
Baryon rest quanta
lepton rest quanta
KEM
K P Σ 25 [[72(m²)] + [12e19] + [Δv]] 1
nuclear mass-energy quanta per shell
1s2
Alkaline Earth
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
02
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.02 - Helium atomic config

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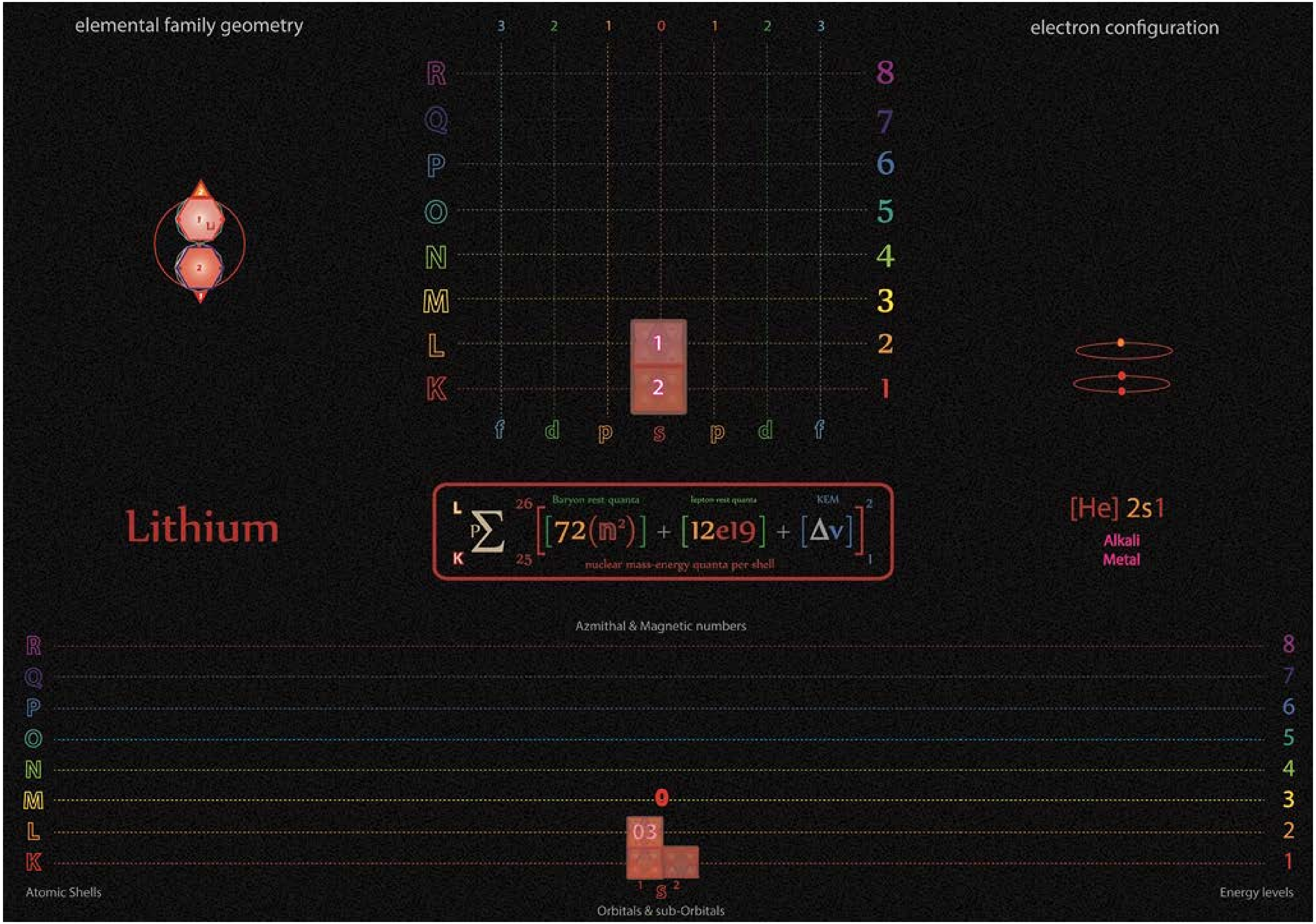
elemental family geometry
3 2 1 0 1 2 3
electron configuration
R Q P O N M L K
8 7 6 5 4 3 2 1
1
2
f d p s p d f
Lithium
L
K
P
26
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
2
1
nuclear mass-energy quanta per shell
[He] 2s1
Alkali
Metal
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
03
1 s 2
Atomic Shells
Orbitals & sub-Orbitals
Energy levels

Tetryonics 53.03 - Lithium atomic config

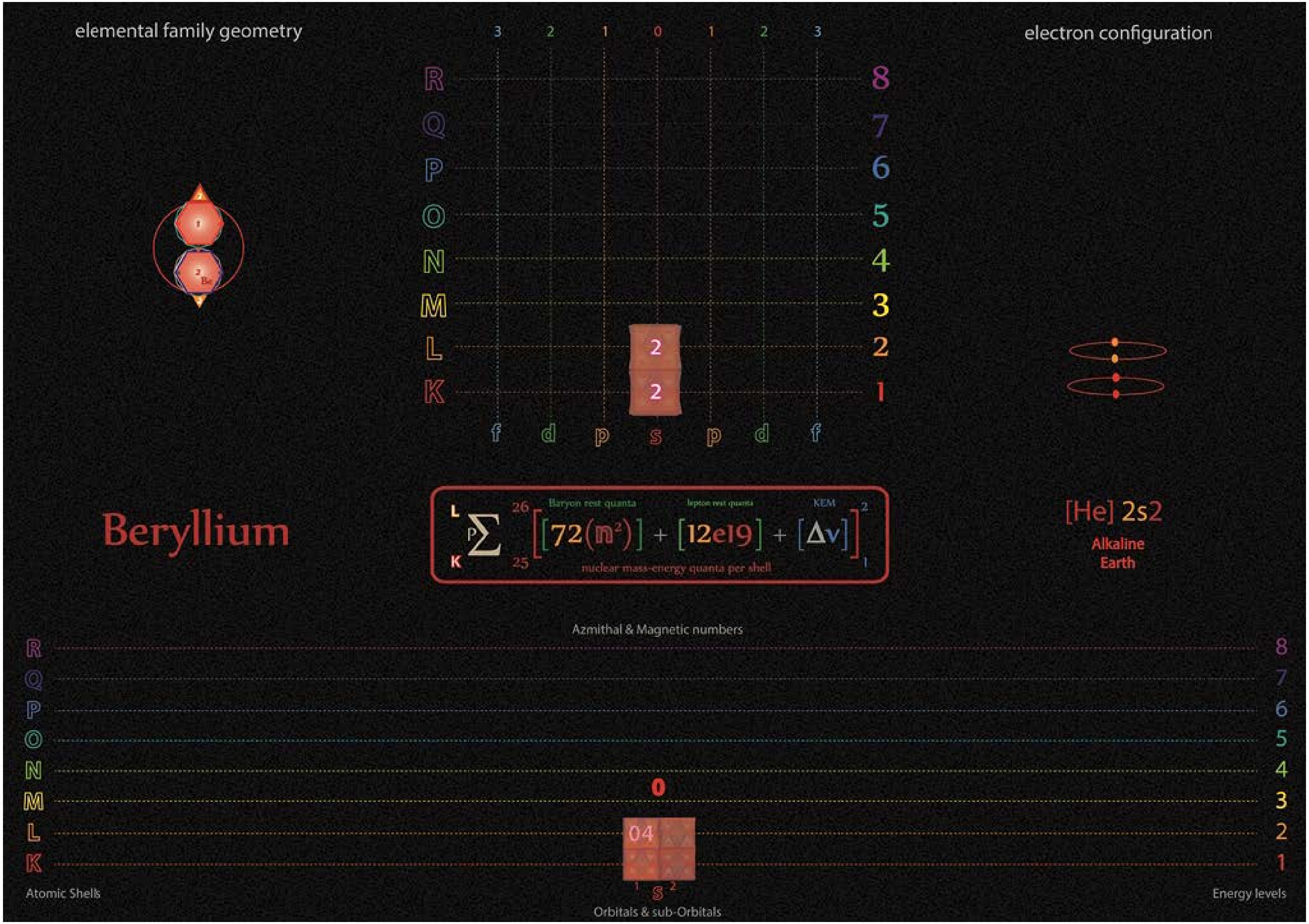

elemental family geometry

electron configuration

Beryllium

$$ {}_{K}^{L}{}^{P}\sum_{25}^{26} \left[\overset{\text{Baryon rest quanta}}{[72(n^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]} \right]_{1}^{2} $$

nuclear mass-energy quanta per shell

[He] 2s2

Alkaline Earth

3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
2
f d p s p d f
2
1
2
Be
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
04
1 s 2
Atomic Shells
Orbitals & sub-Orbitals
Energy levels

Tetryonics 53.04 - Beryllium atomic config

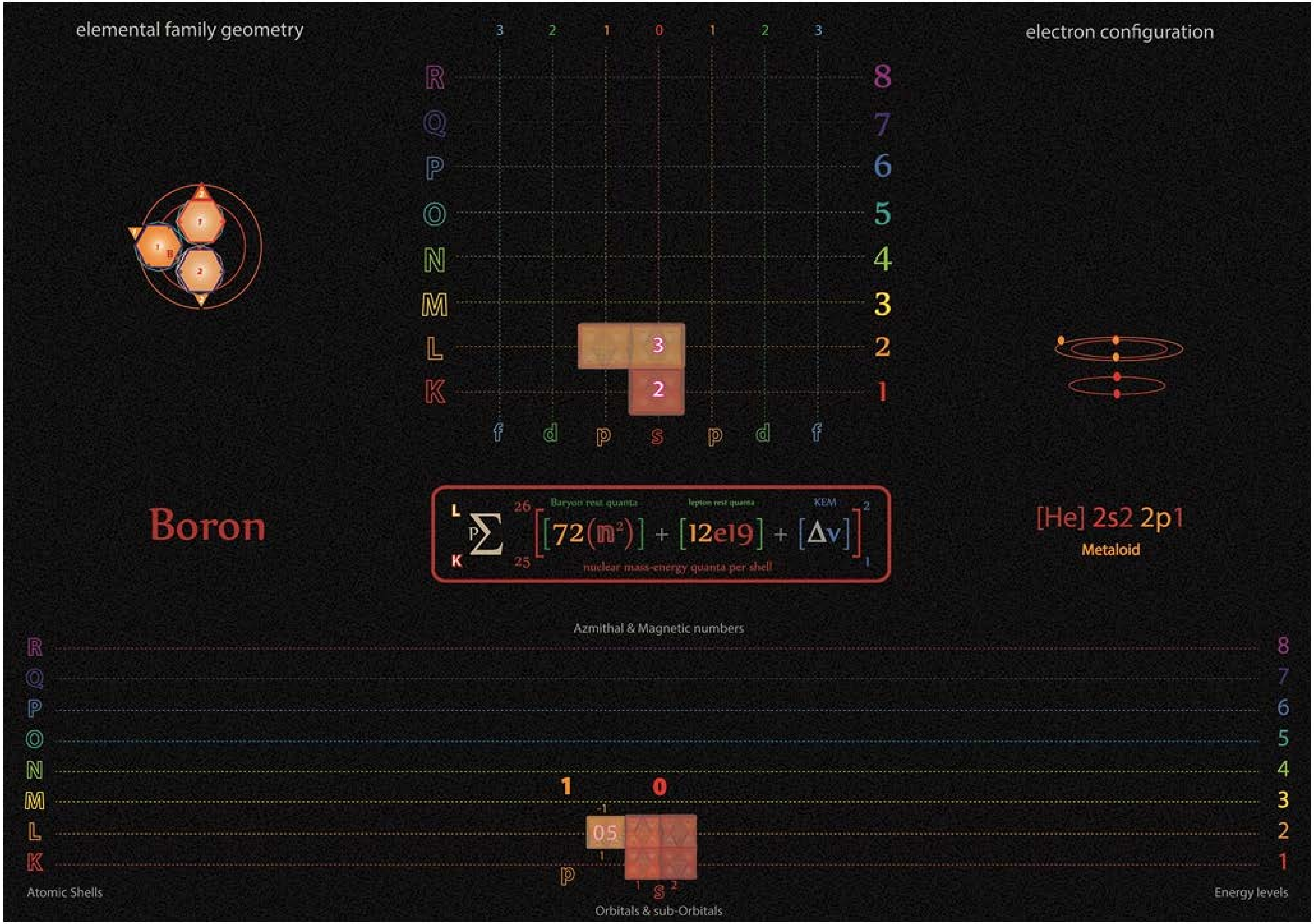
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
3
2
f d p s p d f
Boron
L
K
P
26
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
2
1
nuclear mass-energy quanta per shell
[He] 2s2 2p1
Metaloid
Azmithal & Magnetic numbers
1 0
-1
05
1
p
1 s 2
Atomic Shells
Orbitals & sub-Orbitals
Energy levels

Tetryonics 53.05 - Boron atomic config

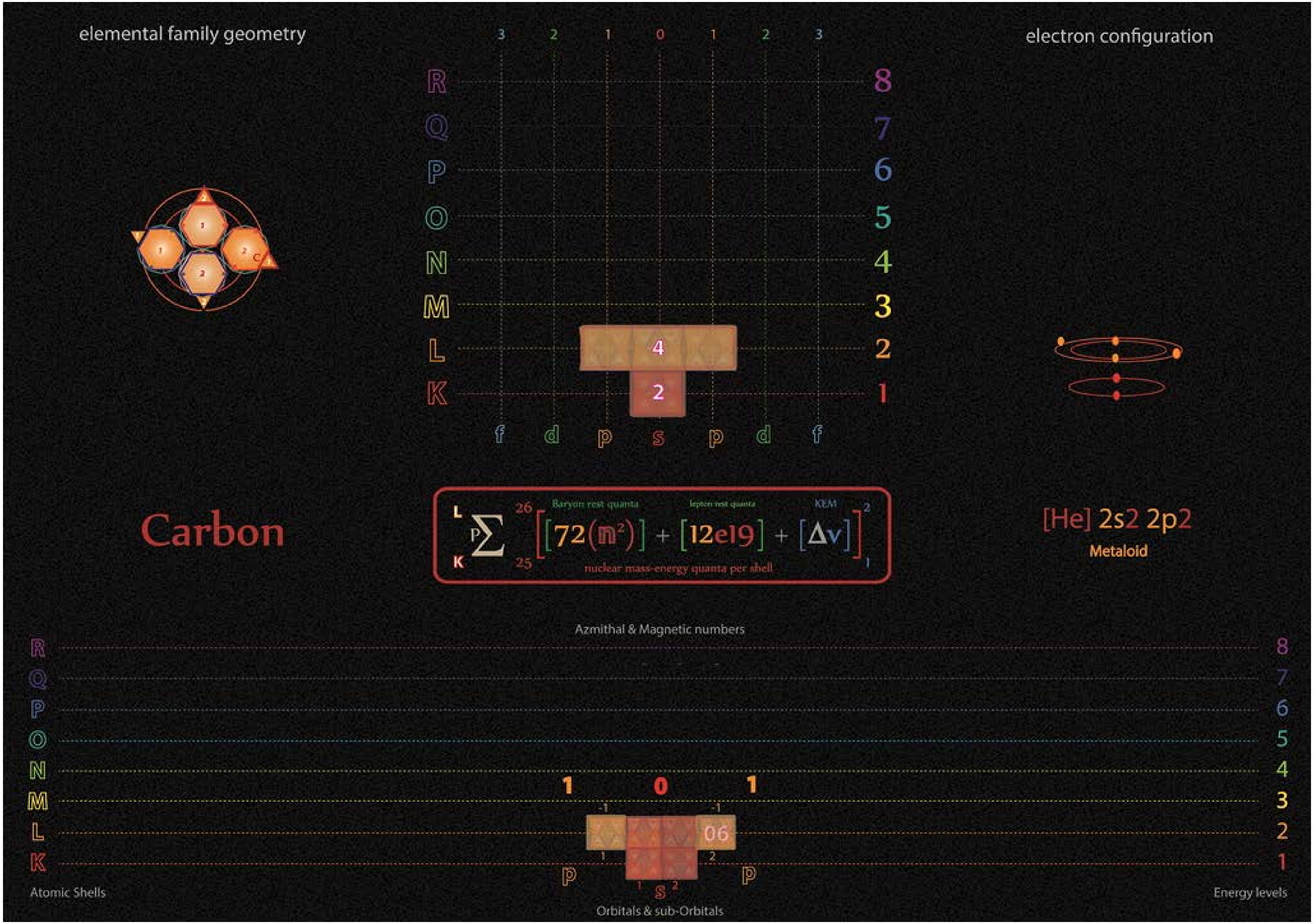
elemental family geometry
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
4
2
f d p s p d f
electron configuration
1
2
C
Carbon
Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell
[He] 2s2 2p2
Metaloid
Azmithal & Magnetic numbers
1 0 1
-1 -1
06
1 2
p s p
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

$$\sum_{K}^{L} {}_{P}\sum_{25}^{26}\left[\left[72(\mathbb{m}^2)\right] + \left[12e19\right] + \left[\Delta v\right]\right]_1^2$$

Tetryonics 53.06 - Carbon atomic config

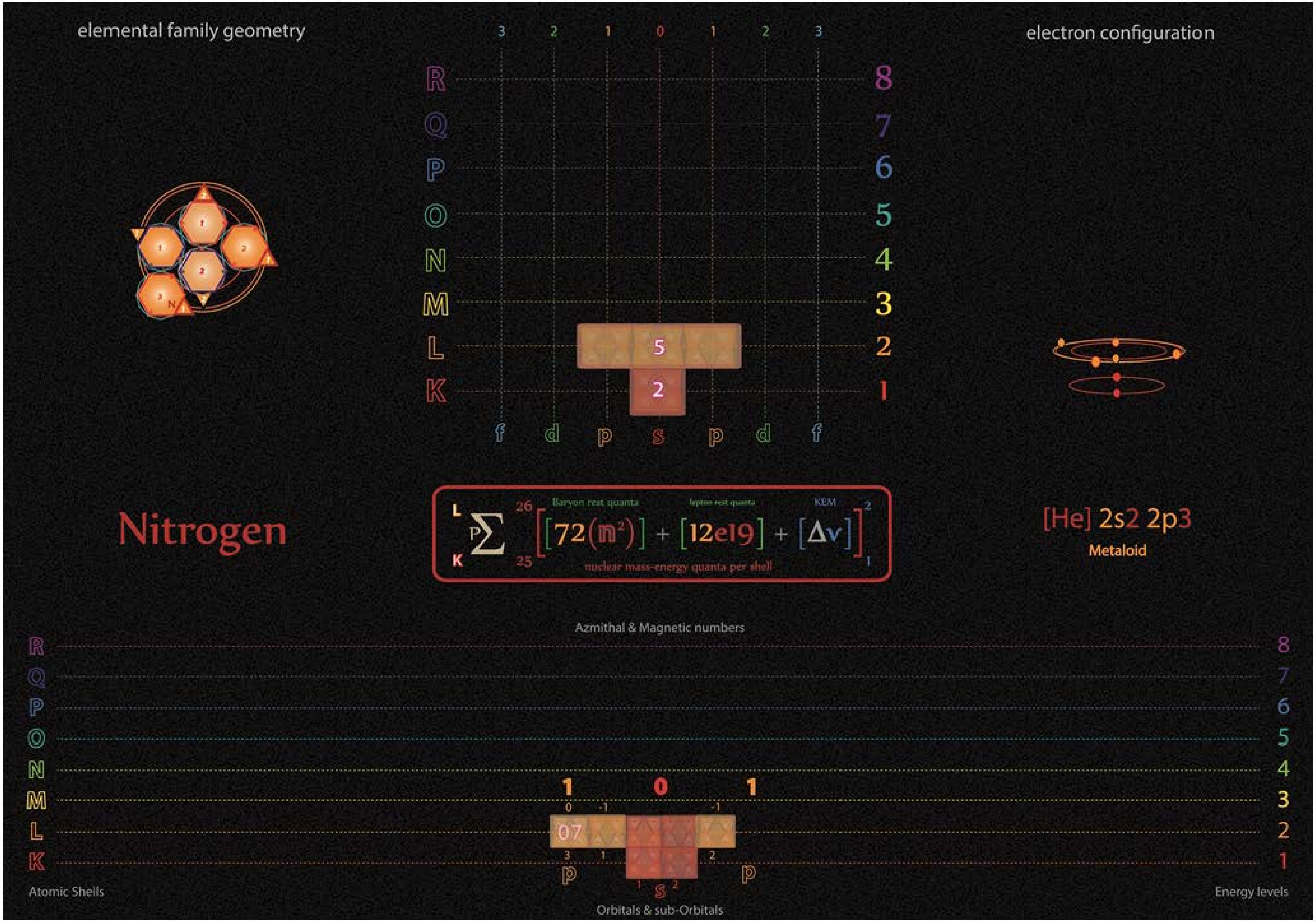

elemental family geometry

electron configuration

3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
5
2
f
d
p
s
p
d
f
1
2
1
1
2
2
3
N

Nitrogen

$$\sum_{K}^{L} {}_{P} \left[[72(\mathfrak{m}^2)] + [12e19] + [\Delta v] \right]_{1}^{2}$$

26
25
Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell

[He] 2s2 2p3

Metaloid

Azmithal & Magnetic numbers

R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1
0
1
0
-1
-1
07
3
1
2
p
p
1
s
2

Atomic Shells

Orbitals & sub-Orbitals

Energy levels

Tetryonics 53.07 - Nitrogen atomic config

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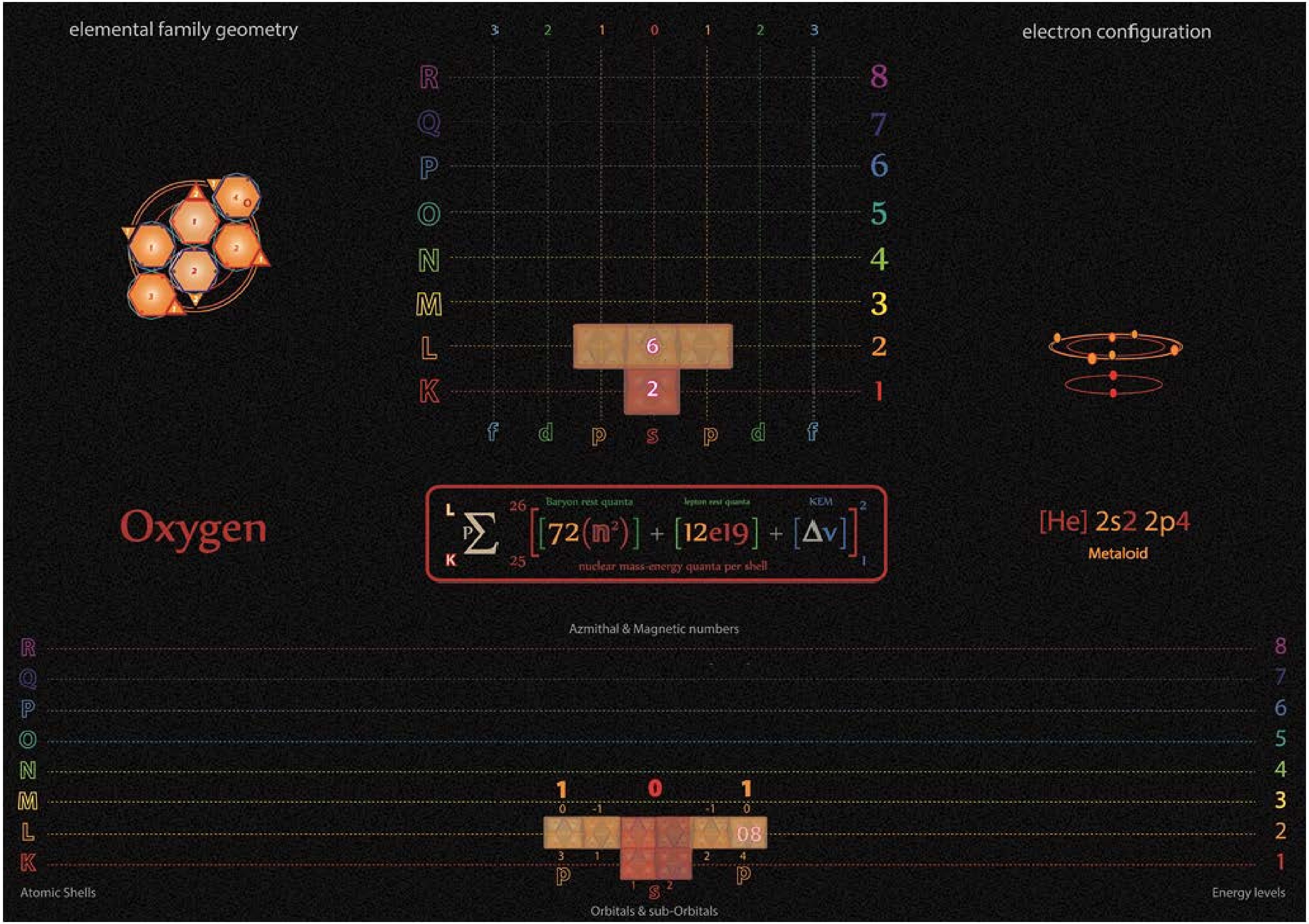
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
6
2
f d p s p d f
Azmithal & Magnetic numbers
1 0 1
0 -1 -1 0
08
3 1 2 4
p s p
1 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Oxygen

$$\sum_{K}^{L} {}_{P}\,{}^{26}_{25}\left[\overset{\text{Baryon rest quanta}}{[72(n^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]} \right]^{2}_{1}$$

nuclear mass-energy quanta per shell

[He] 2s2 2p4

Metaloid

Tetryonics 53.08 - Oxygen atomic config

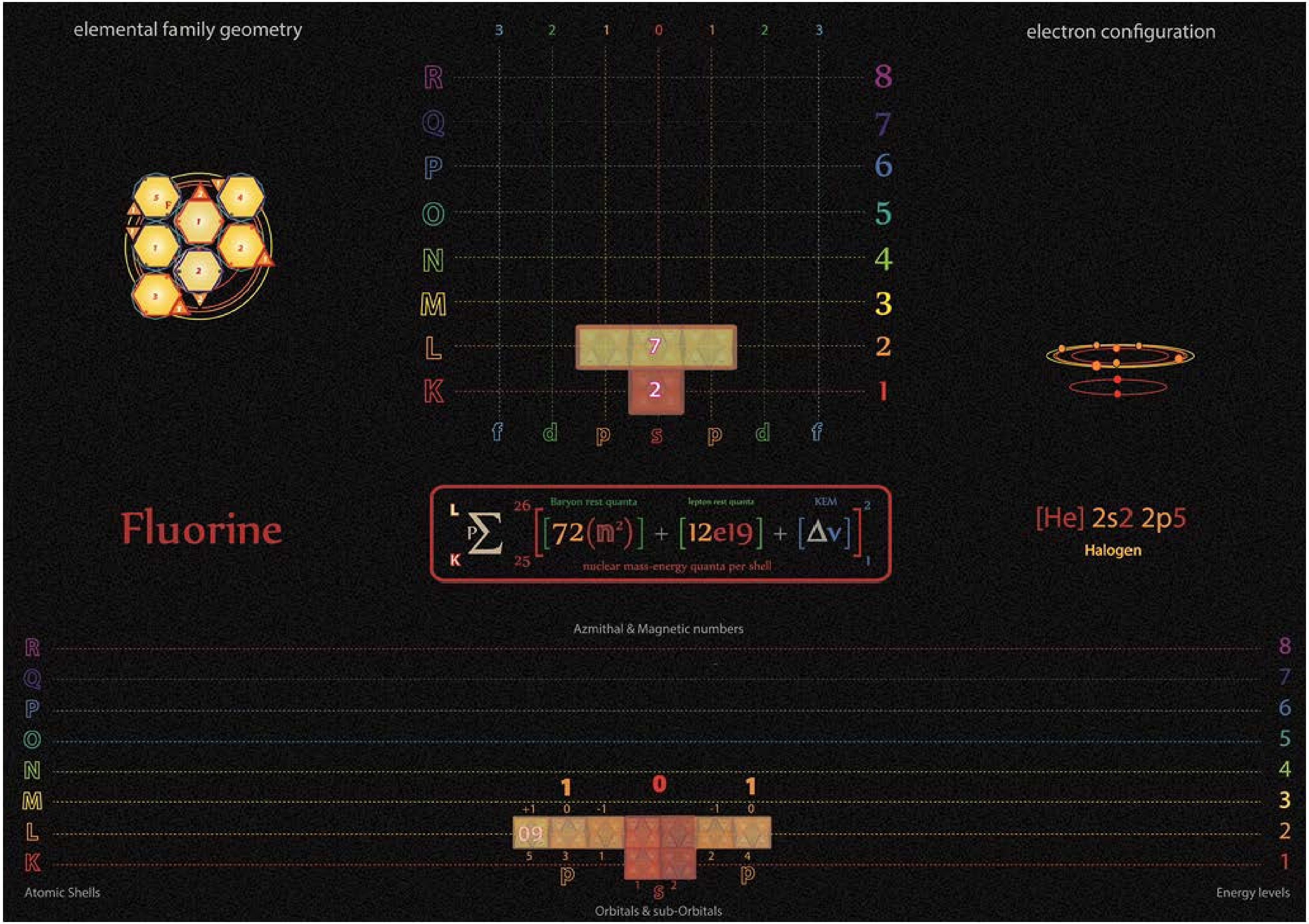
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
7
2
f d p s p d f
5 F 4 1 1 2 2 3
Azmithal & Magnetic numbers
1 0 1
+1 0 -1 -1 0
09
5 3 1 2 4
p s p
1 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Fluorine

$$\sum_{K}^{L} P \left[[72(\mathrm{m}^2)] + [12e19] + [\Delta v] \right]_{1}^{2}$$

26 25 Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[He] 2s2 2p5

Halogen

Tetryonics 53.09 - Fluorine atomic config

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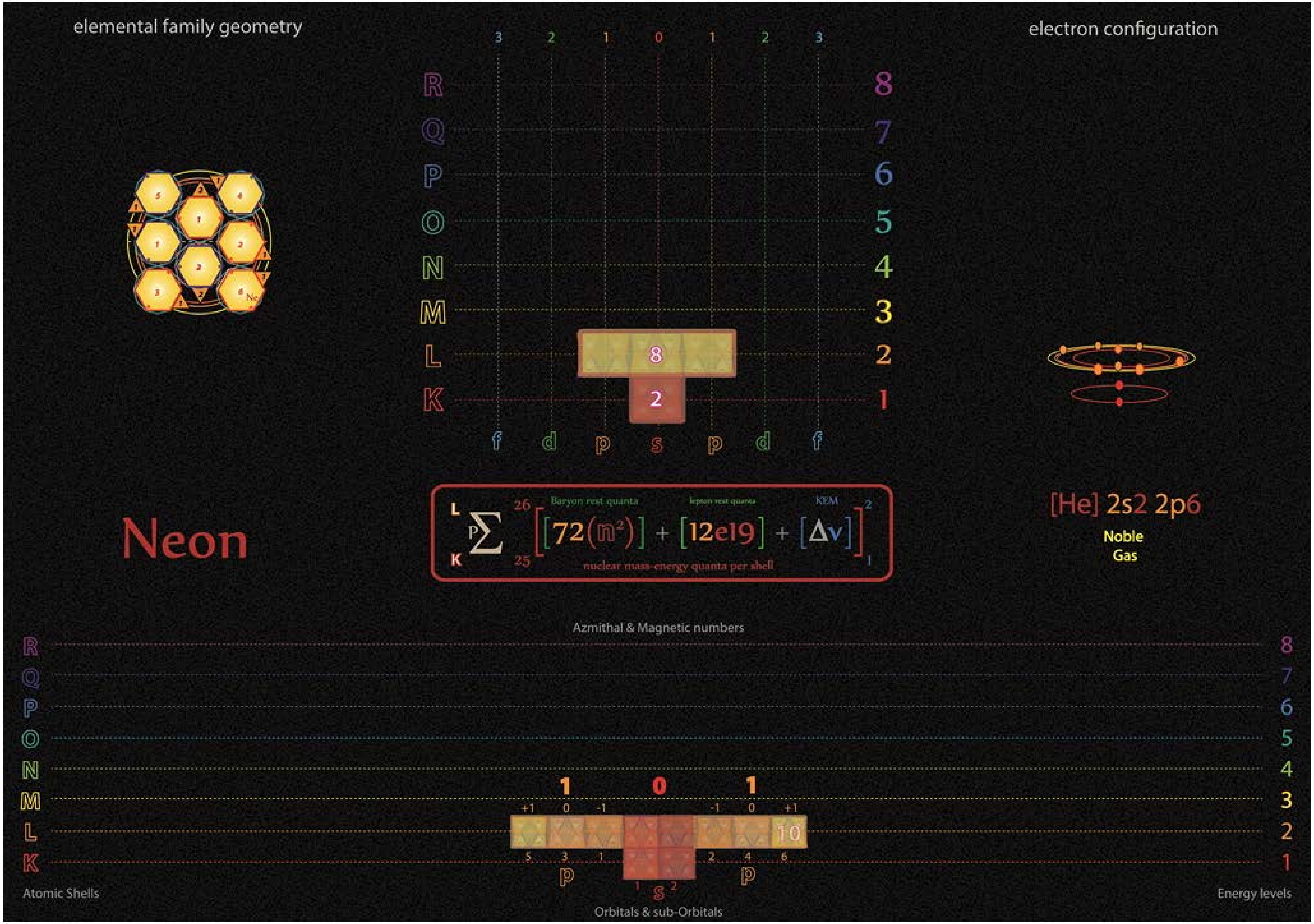
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
8
2
f d p s p d f
Neon
[He] 2s2 2p6
Noble Gas
L
K
P
26
25
Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell
Azmithal & Magnetic numbers
1 0 1
+1 0 -1 -1 0 +1
10
5 3 1 2 4 6
p p
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

$${}_{K}^{L}\,{}^{P}\sum_{25}^{26}\Big[\,[72(n^2)] + [12e19] + [\Delta v]\,\Big]_1^2$$

Tetryonics 53.10 - Neon atomic config

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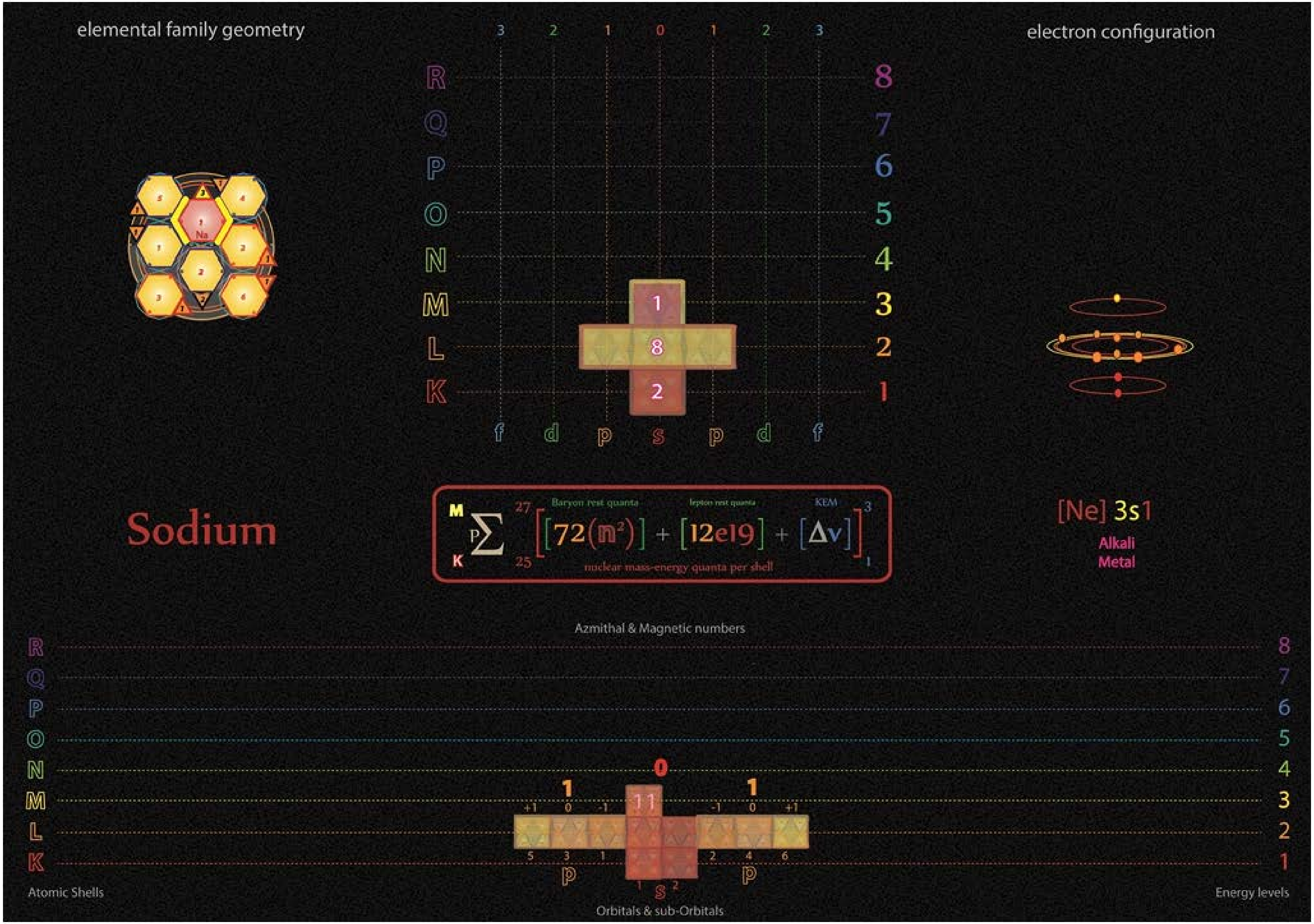

elemental family geometry

electron configuration

Sodium

$$\sideset{_{K}^{M}}{_{25}^{27}}\sum_{p}\left[\,[72(n^2)] + [12e19] + [\Delta v]\,\right]_1^3$$

Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[Ne] 3s1

Alkali Metal

Na
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
1
8
2
f d p s p d f
Azmithal & Magnetic numbers
0
1
1
+1 0 -1
1 1
-1 0 +1
5 3 1
2 4 6
p
1 s 2
p
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.11 - Sodium atomic config

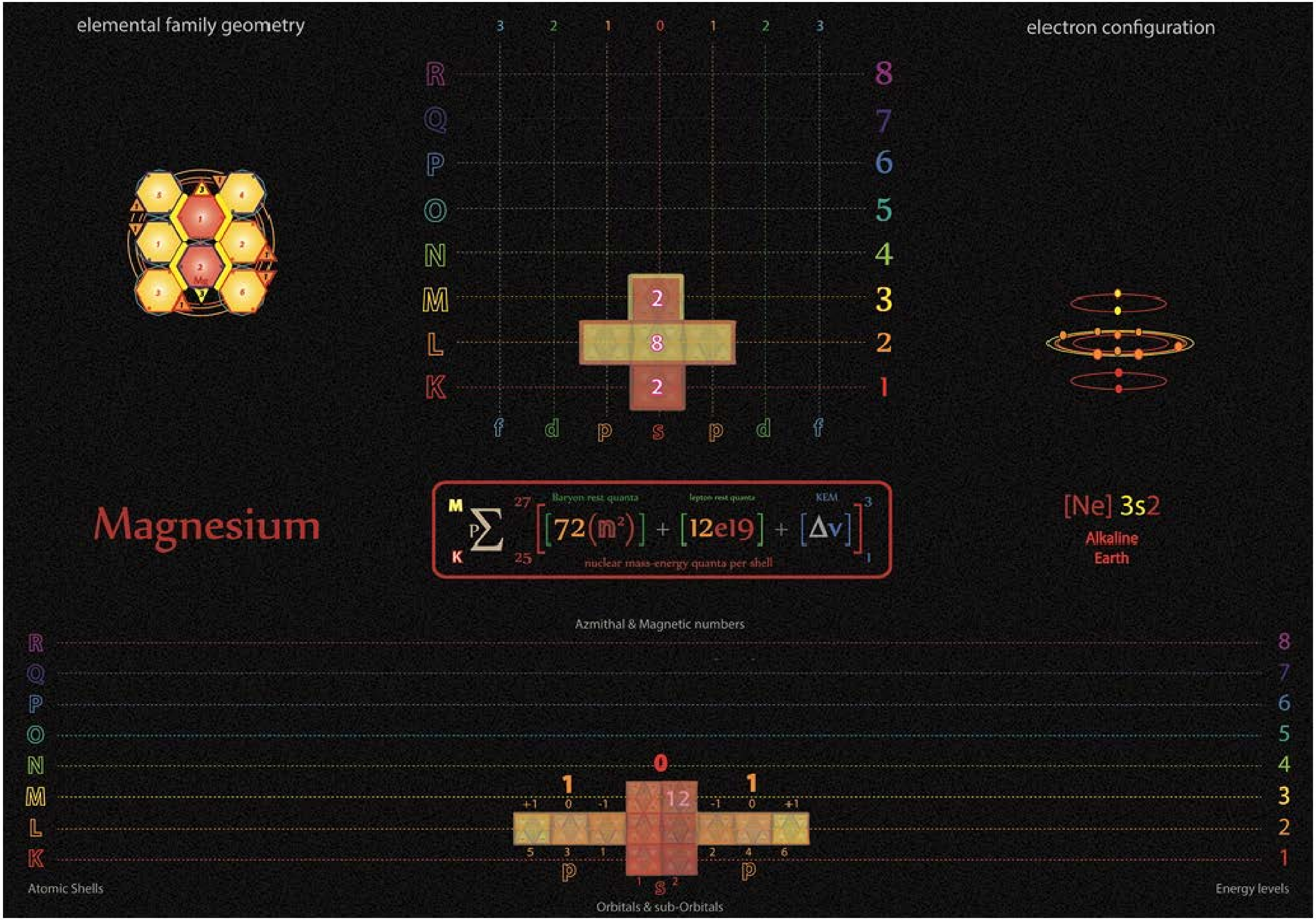
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
2
f d p s p d f
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
1 1
+1 0 -1 12 -1 0 +1
5 3 1 2 4 6
p s p
1 2
Atomic Shells
Orbitals & sub-Orbitals
Energy levels

Magnesium

$$\sum_{K}^{M} p \sum_{25}^{27} \left[\overset{\text{Baryon rest quanta}}{\left[72(\mathrm{m}^2)\right]} + \overset{\text{lepton rest quanta}}{\left[12e19\right]} + \overset{\text{KEM}}{\left[\Delta v\right]} \right]_{1}^{3}$$

nuclear mass-energy quanta per shell

[Ne] 3s2

Alkaline
Earth

Tetryonics 53.12 - Magnesium atomic config

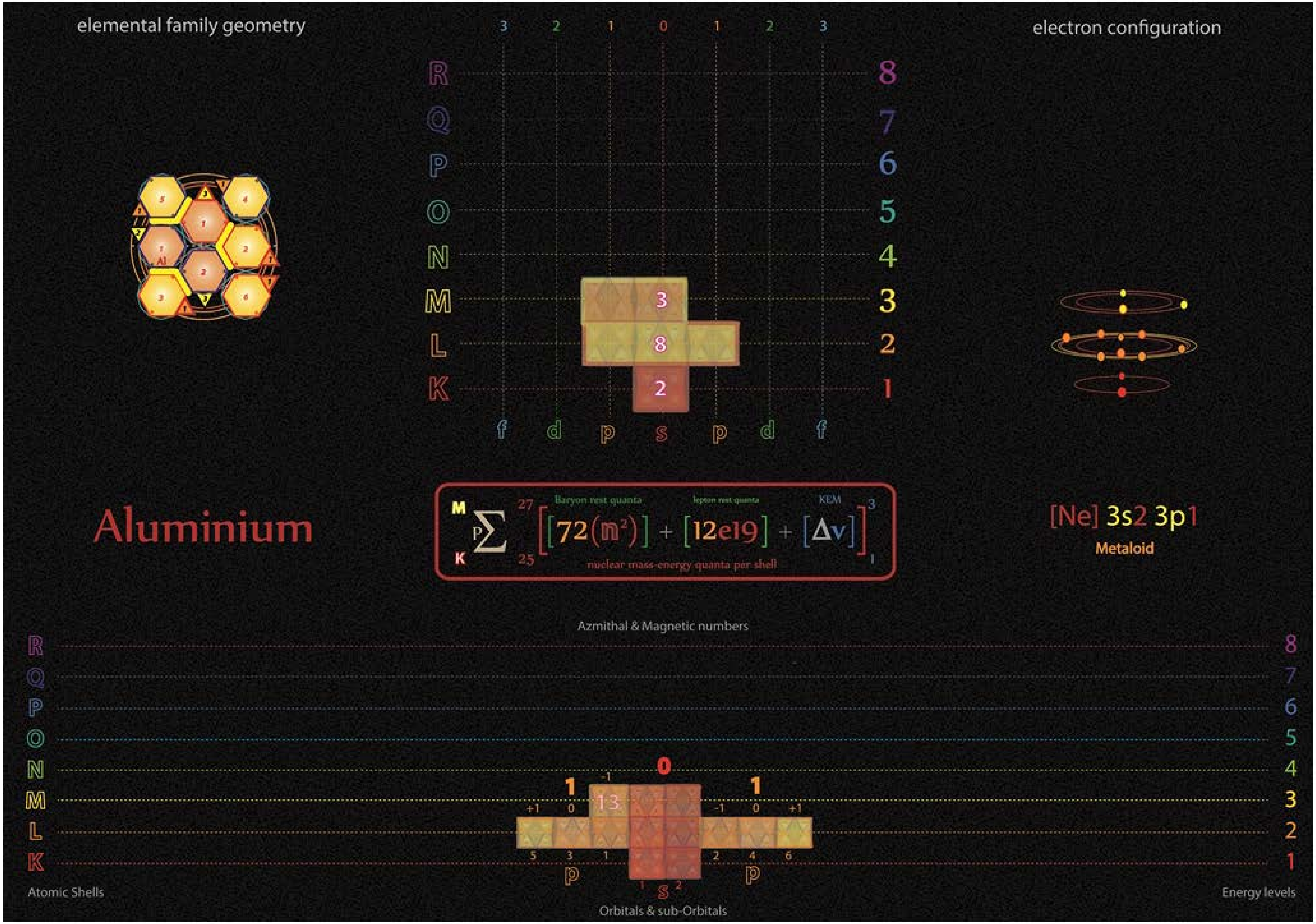

elemental family geometry

electron configuration

Aluminium

$$ {}_{K}^{M}{}_{p}\sum_{25}^{27}\left[\left[72(\mathfrak{m}^2)\right]+\left[12e19\right]+\left[\Delta v\right]\right]_{1}^{3} $$

Baryon rest quanta

lepton rest quanta

KEM

nuclear mass-energy quanta per shell

[Ne] 3s2 3p1

Metaloid

Azmithal & Magnetic numbers

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
3
8
2
f d p s p d f
Al
1 2 3 4 5 6
0
1
1
-1
13
+1 0 -1 0 +1
5 3 1 2 4 6
p
p
1 s 2

Tetryonics 53.13 - Aluminium atomic config

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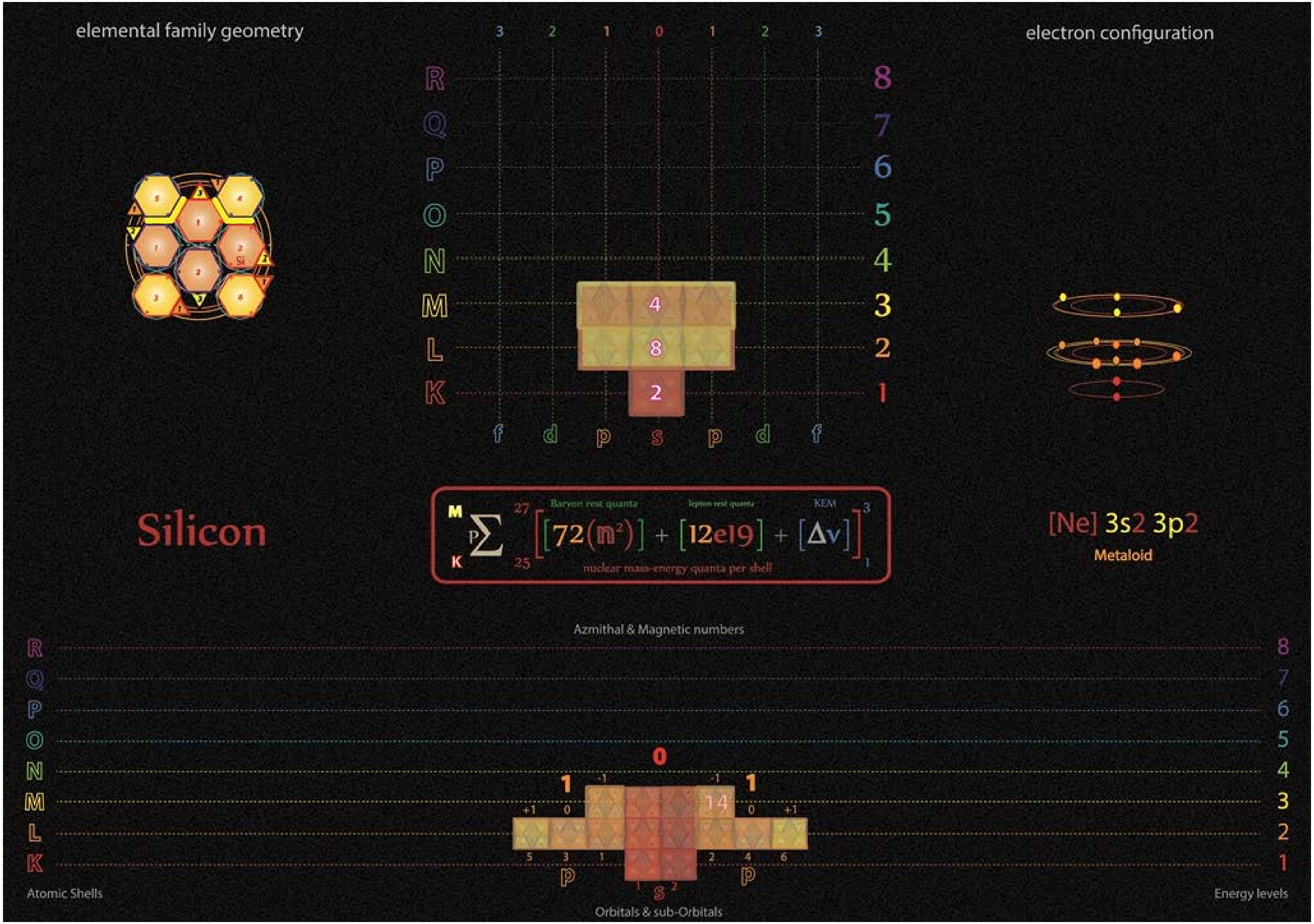
elemental family geometry
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
4
8
2
f d p s p d f
electron configuration
Silicon
M
K
P
27
25
Baryon rest quanta
lepton rest quanta
KEM
3
1
[72(m²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
[Ne] 3s2 3p2
Metaloid
Azmithal & Magnetic numbers
0
1
1
-1
-1
+1
0
14
0
+1
5
3
1
2
4
6
p
p
1
s
2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.14 - Silicon atomic config

elemental family geometry

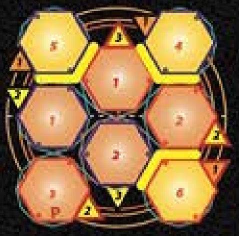
5
3
4
1
1
2
2
3
6
P

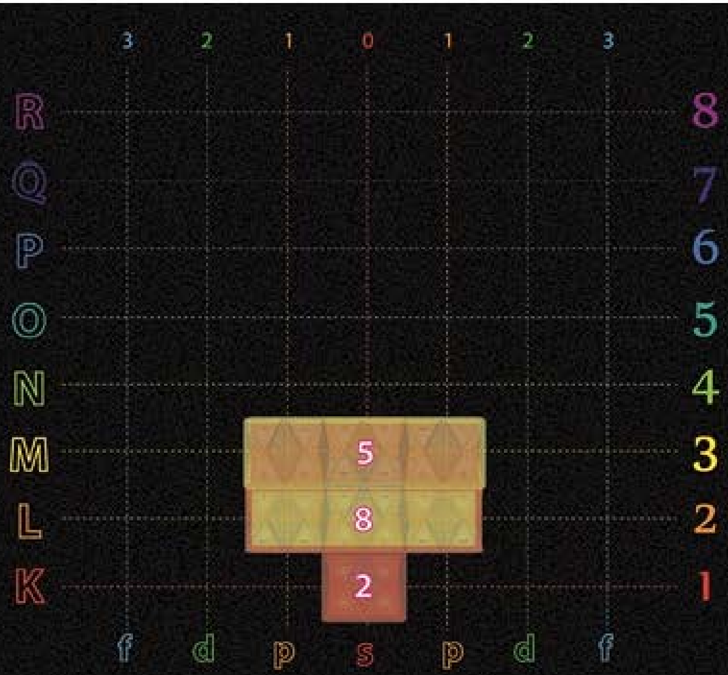
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
5
8
2
f
d
p
s
p
d
f

electron configuration

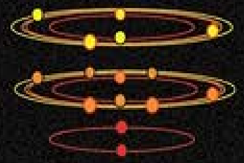

Phosphorus

$$\sum_{K}^{M} {}_{P}\left[\overset{\text{Baryon rest quanta}}{[72(\mathrm{m}^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]} \right]_{1}^{3}$$

27

25

nuclear mass-energy quanta per shell

[Ne] 3s2 3p3

Metaloid

Azmithal & Magnetic numbers

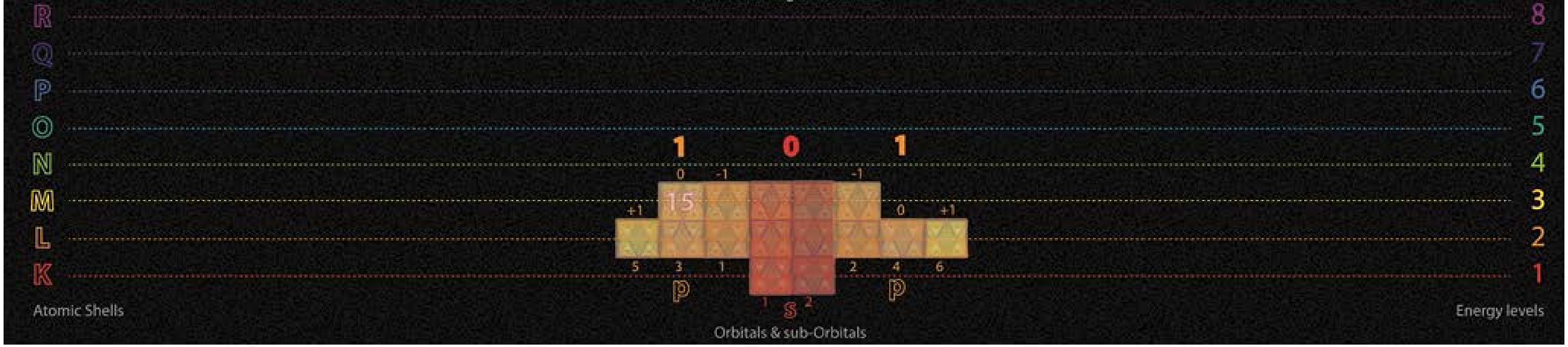
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1
0
1
0
-1
-1
+1
15
0
+1
5
3
1
2
4
6
p
p
1
s
2
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.15 - Phosphorus atomic config

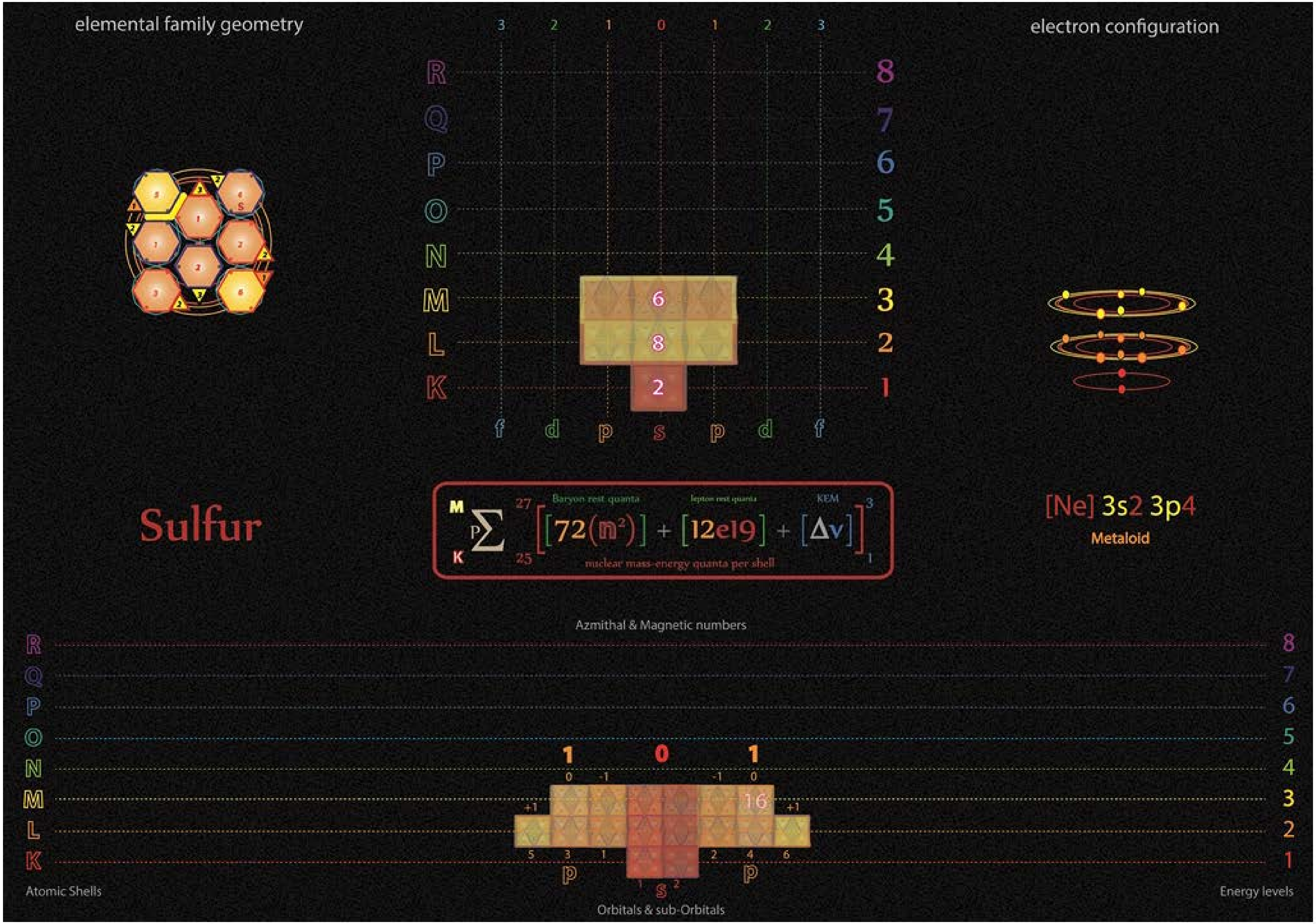
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
6
8
2
f d p s p d f
Sulfur
M
K
P
27
25
Baryon rest quanta
lepton rest quanta
KEM
[[72(m²)] + [12e19] + [Δv]]
3
1
nuclear mass-energy quanta per shell
[Ne] 3s2 3p4
Metaloid
Azmithal & Magnetic numbers
1 0 1
0 -1 -1 0
+1 +1
16
5 3 1 2 4 6
p s p
1 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.16 - Sulfur atomic config

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elemental family geometry

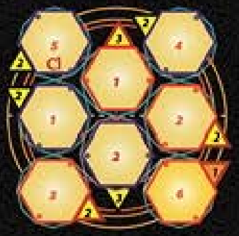

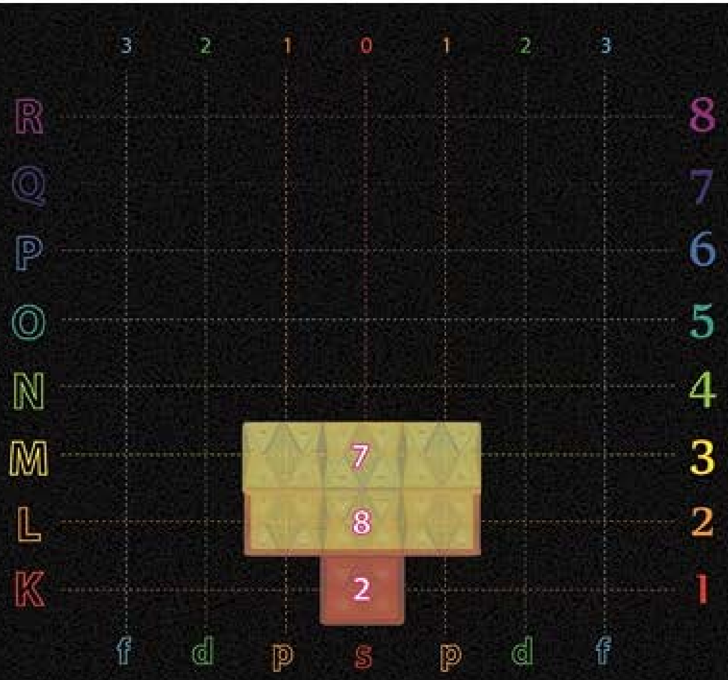
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
7
8
2
f
d
p
s
p
d
f

electron configuration

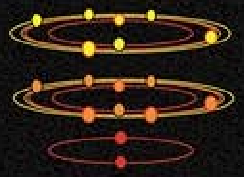

Chlorine

$$\sum_{K}^{M} P \sum_{25}^{27} \left[\overset{\text{Baryon rest quanta}}{[72(n^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]} \right]_{1}^{3}$$

nuclear mass-energy quanta per shell

[Ne] 3s2 3p5

Halogen

Azmithal & Magnetic numbers

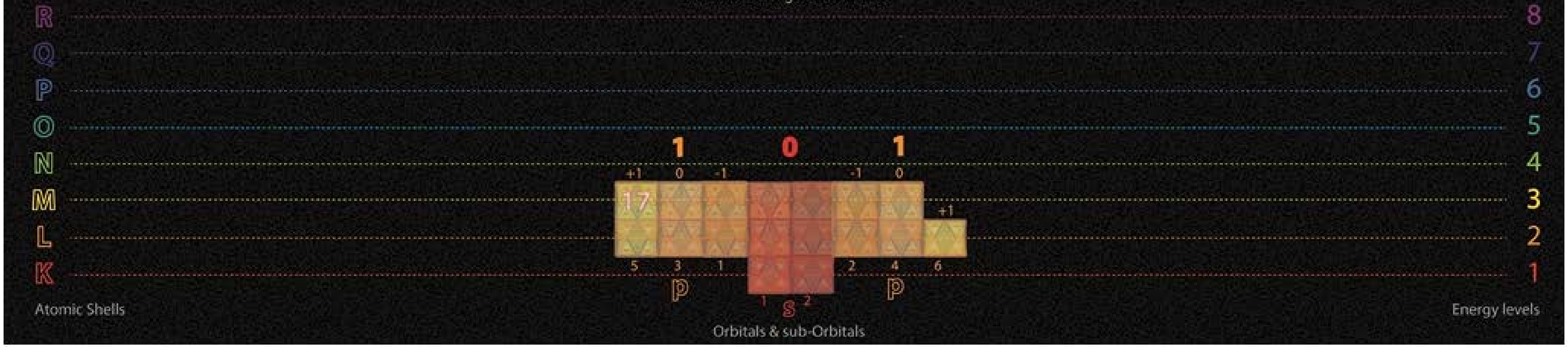
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1
0
1
+1
0
-1
-1
0
+1
17
5
3
1
2
4
6
p
s
1
2
p
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.17 - Chlorine atomic config

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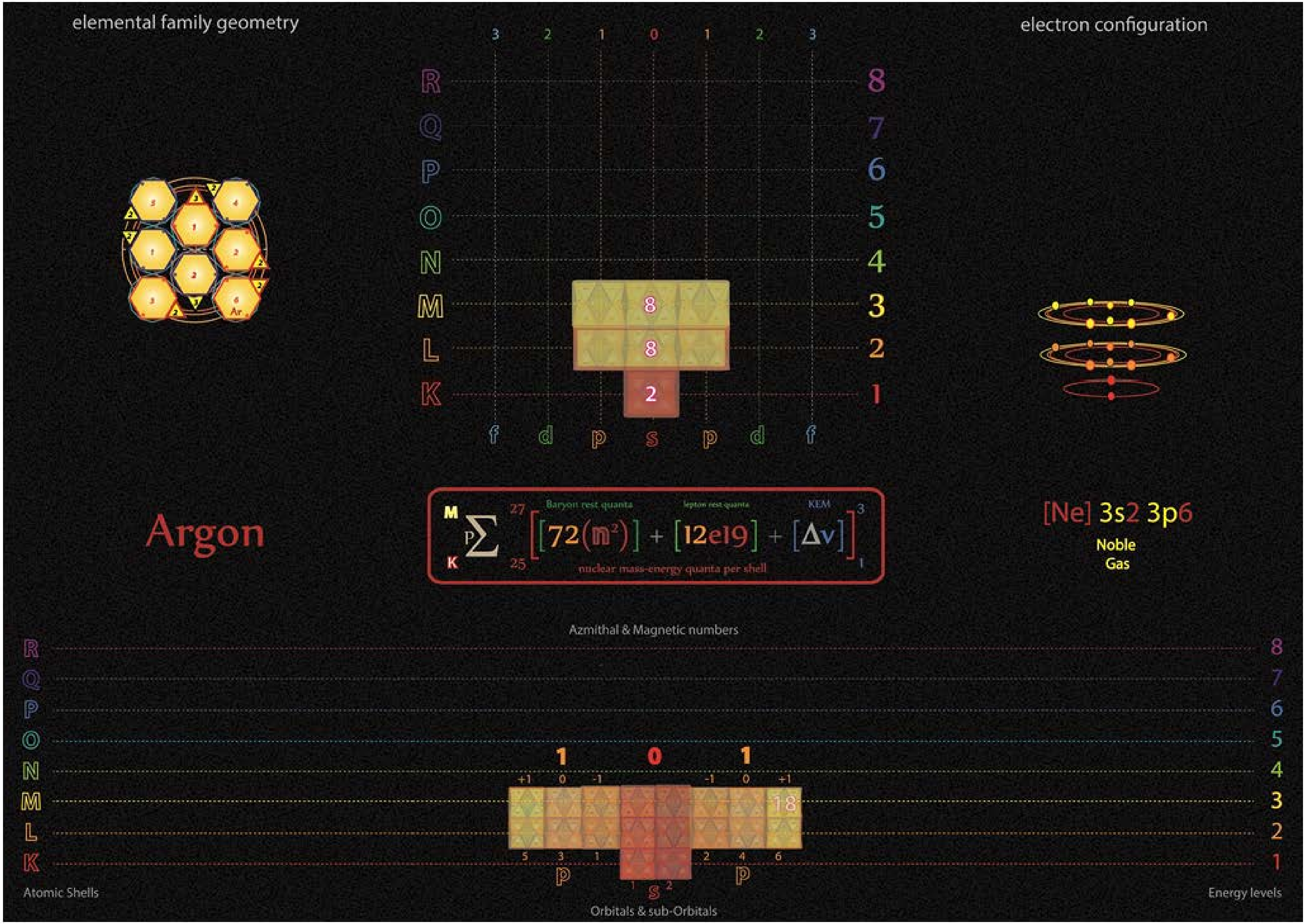
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
8
8
2
f d p s p d f
Ar
Argon
M
K
27
25
Baryon rest quanta
lepton rest quanta
KEM
p∑ [72(m²)] + [12e19] + [Δv]
3
1
nuclear mass-energy quanta per shell
[Ne] 3s2 3p6
Noble Gas
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
1 0 1
+1 0 -1 -1 0 +1
18
5 3 1 2 4 6
p p
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.18 - Argon atomic config

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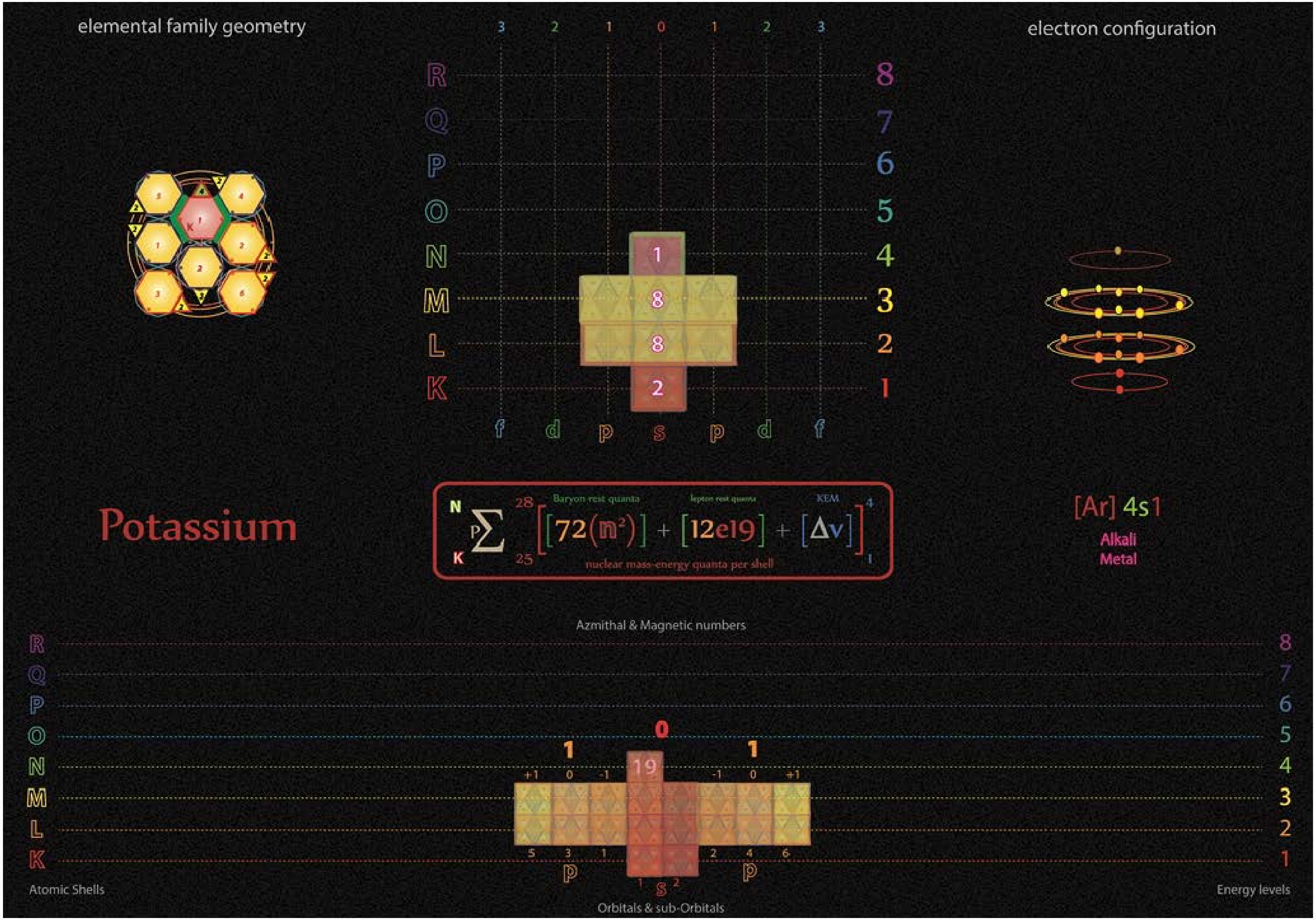
elemental family geometry
3 2 1 0 1 2 3
electron configuration
R Q P O N M L K
8 7 6 5 4 3 2 1
1
8
8
2
f d p s p d f
Potassium
N
K
P
28
25
Baryon rest quanta
lepton rest quanta
KEM
[72(n²)] + [12e19] + [Δv]
4
1
nuclear mass-energy quanta per shell
[Ar] 4s1
Alkali
Metal
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
1
1
19
+1 0 -1
-1 0 +1
5 3 1
2 4 6
p
p
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.19 - Potassium atomic config

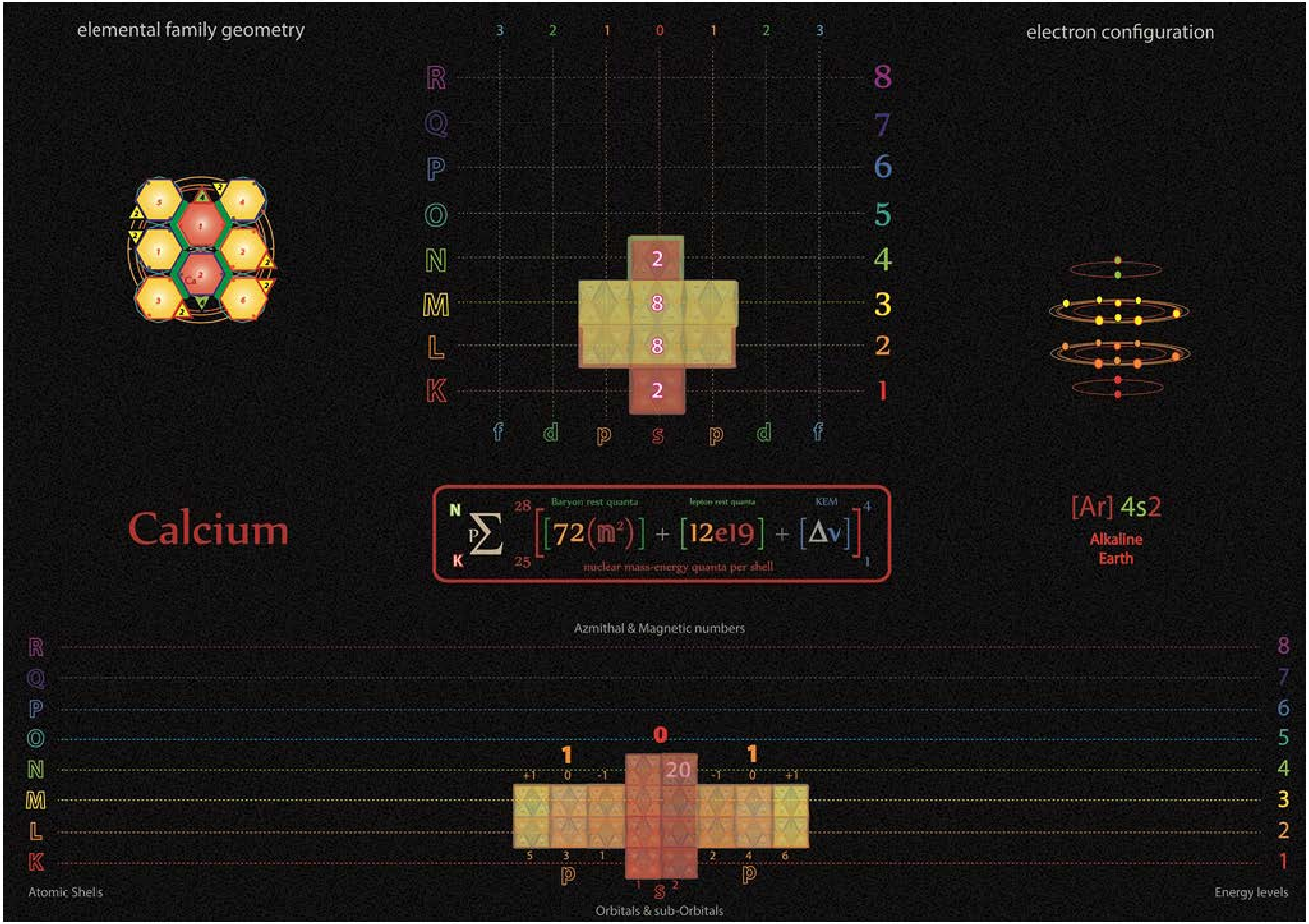
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
8
2
f d p s p d f
Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell
Azmithal & Magnetic numbers
0
1
1
20
+1 0 -1 -1 0 +1
5 3 1 2 4 6
p s p
1 2
Atomic Shels
Orbitals & sub-Orbitals
Energy levels

Calcium

$$\sum_{K}^{N} P \; {}_{25}^{28}\left[[72(\mathfrak{m}^2)] + [12e19] + [\Delta v]\right]_{1}^{4}$$

[Ar] 4s2

Alkaline Earth

Tetryonics 53.20 - Calcium atomic config

elemental family geometry

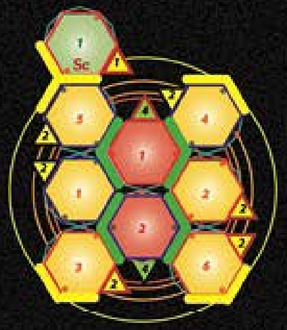

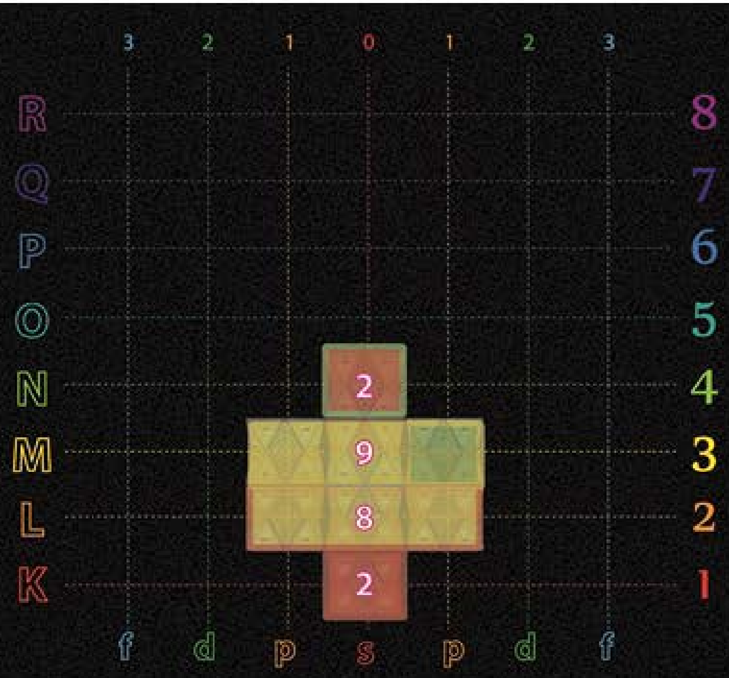
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
9
8
2
f
d
p
s
p
d
f

electron configuration

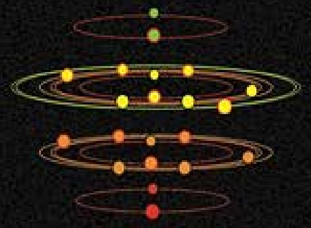

Scandium

$$\sum_{K}^{N} {}_{p}\sum_{25}^{28} \left[\underbrace{72(m^2)}_{\text{Baryon rest quanta}} \right] + \left[\underbrace{12e19}_{\text{lepton rest quanta}} \right] + \left[\underbrace{\Delta v}_{\text{KEM}} \right]_{1}^{4}$$

nuclear mass-energy quanta per shell

[Ar] 3d1 4s2

Transition Metal

Azmithal & Magnetic numbers

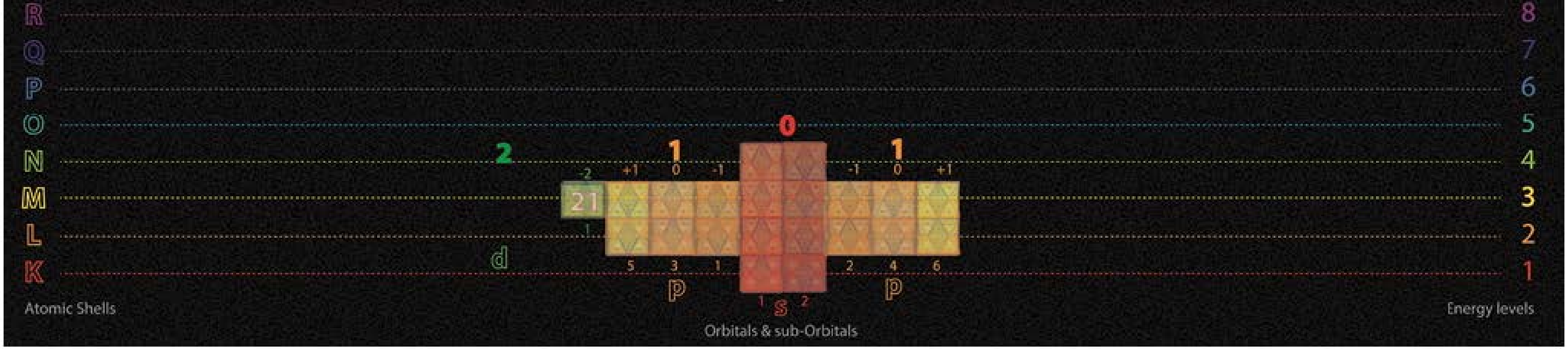
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
1
0
1
-2
+1
0
-1
-1
0
+1
21
1
d
5
3
1
2
4
6
p
p
1
s
2
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.21 - Scandium atomic config

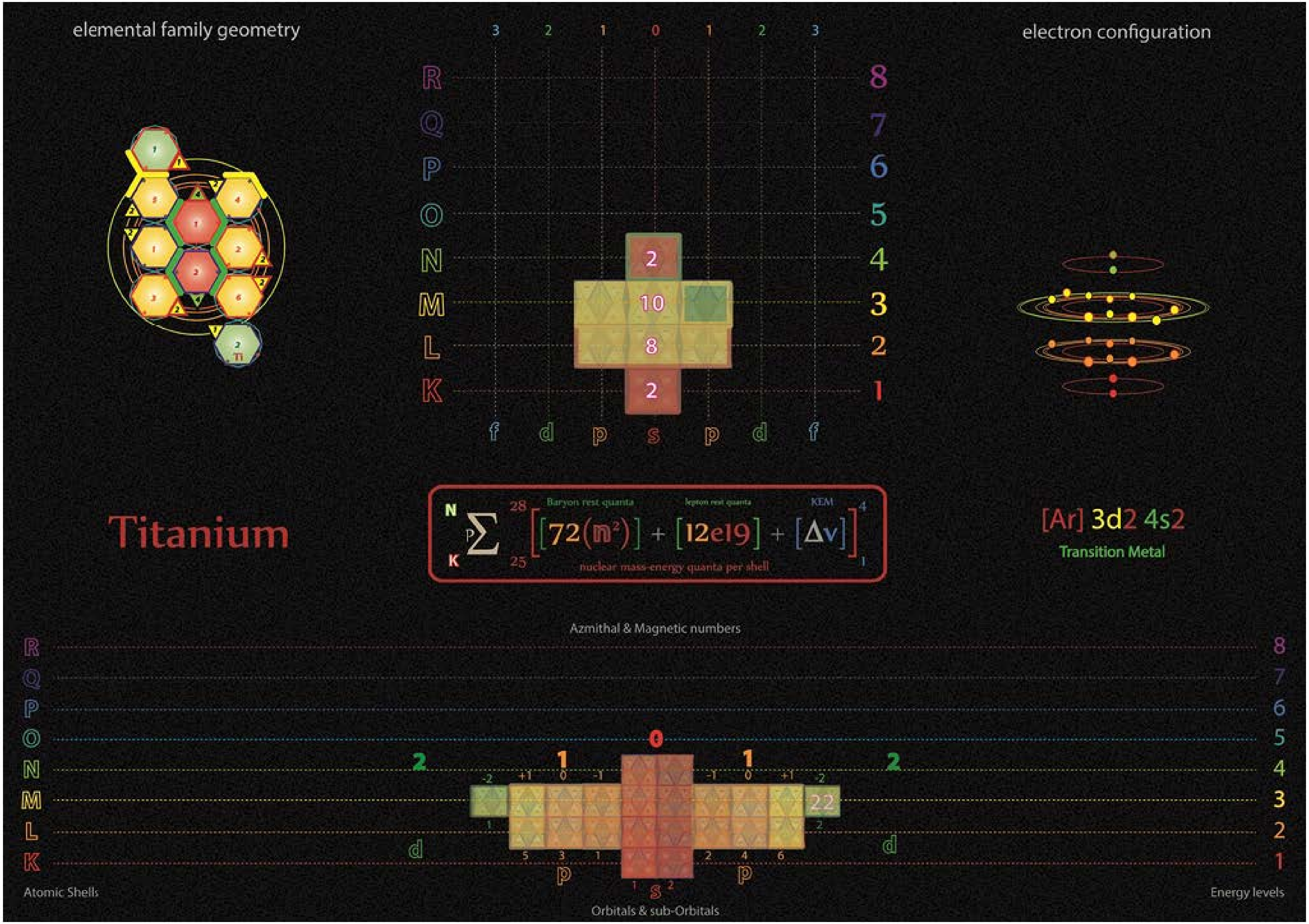

elemental family geometry

electron configuration

Titanium

$$\overset{N}{\underset{K}{{}_{p}\sum}}\ {}^{28}_{25}\left[\overset{\text{Baryon rest quanta}}{[72(m^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]}\right]^{4}_{1}$$

nuclear mass-energy quanta per shell

[Ar] 3d2 4s2

Transition Metal

Azmithal & Magnetic numbers

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
10
8
2
f d p s p d f
Ti
0
2 1 1 2
-2 +1 0 -1 -1 0 +1 -2
22
1 2
5 3 1 2 4 6
d p s p d
1 2

Tetryonics 53.22 - Titanium atomic config

elemental family geometry

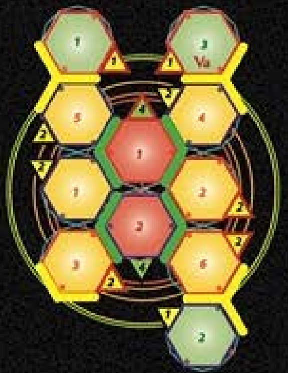
1
3
Va
5
4
1
1
2
2
3
6
2

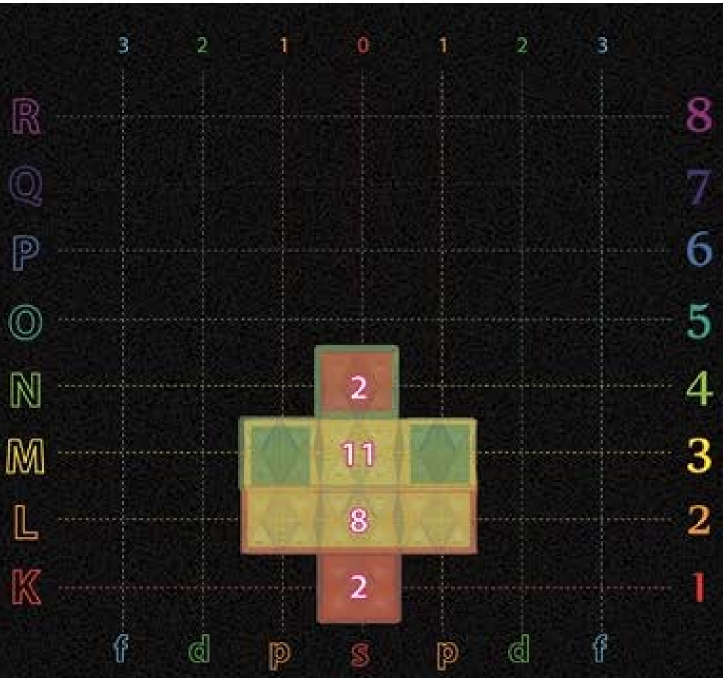
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
11
8
2
f
d
p
s
p
d
f

electron configuration

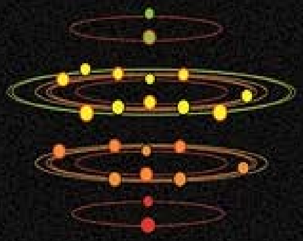

Vanadium

$$\sum_{K}^{N} P \left[[72(m^2)] + [12e19] + [\Delta v] \right]_{25\;1}^{28\;4}$$

Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[Ar] 3d3 4s2

Transition Metal

Azmithal & Magnetic numbers

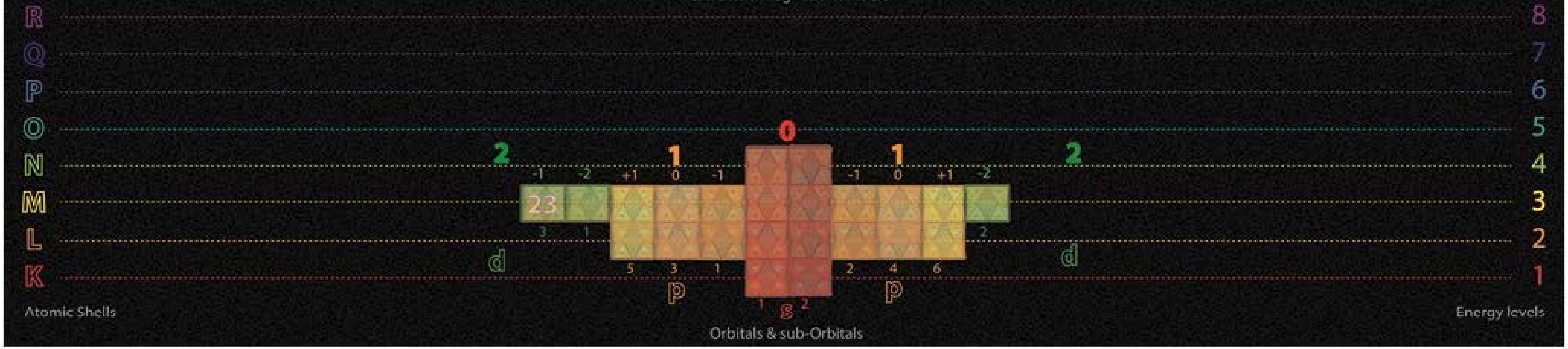
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
1
0
1
2
-1
-2
+1
0
-1
-1
0
+1
-2
23
3
1
5
3
1
2
4
6
2
d
p
s
p
d
1
2
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.23 - Vanadium atomic config

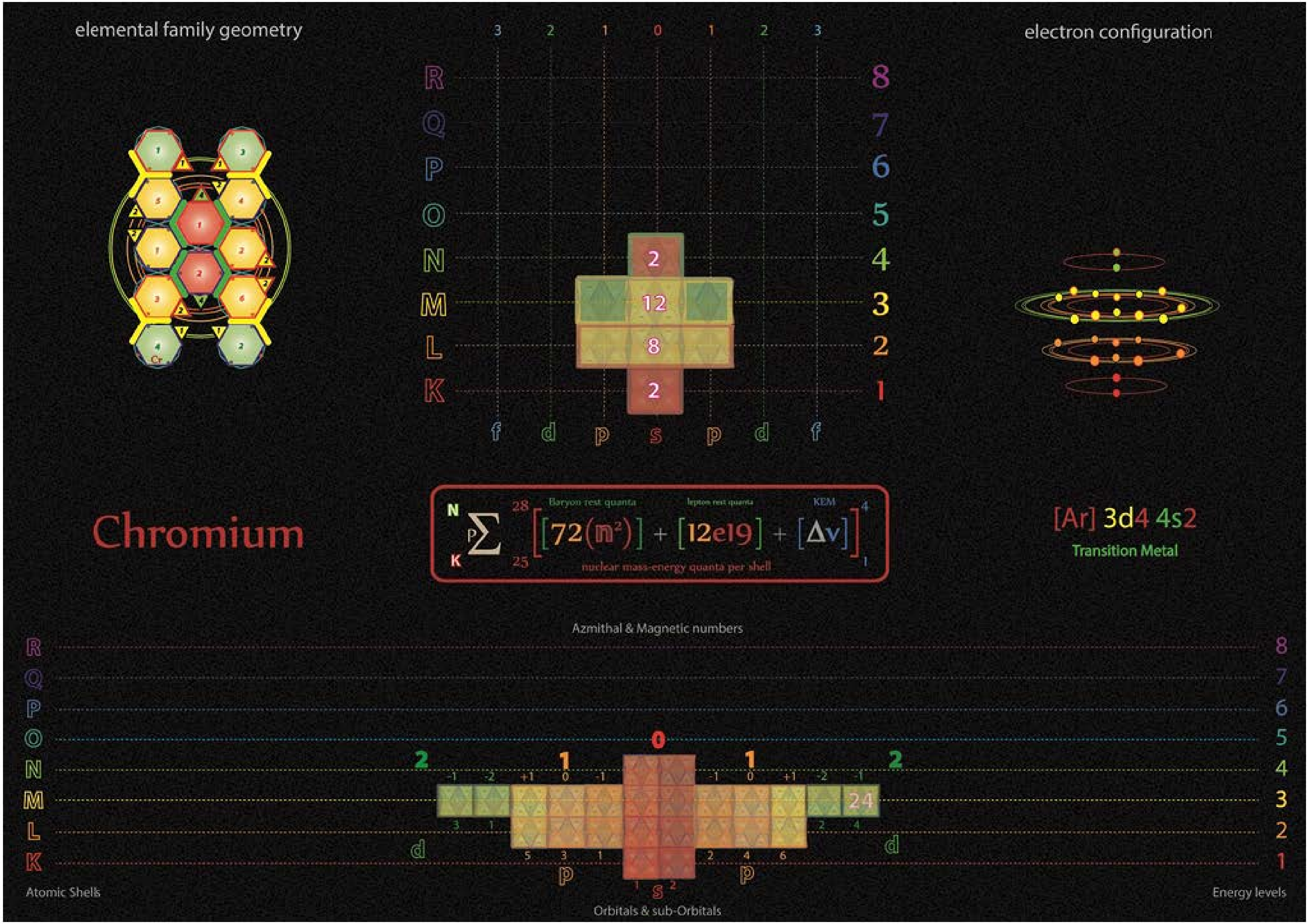
elemental family geometry
Cr
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
12
8
2
f d p s p d f
electron configuration
Chromium
N
K
P
28
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
4
1
nuclear mass-energy quanta per shell
[Ar] 3d4 4s2
Transition Metal
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
2 1 0 1 2
-1 -2 +1 0 -1 -1 0 +1 -2 -1
24
3 1 2 4
5 3 1 2 4 6
d p s p d
1 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.24 - Chromium atomic config

elemental family geometry

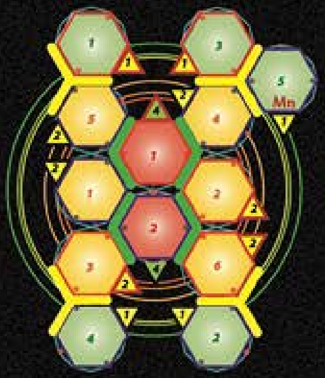
1
3
5
Mn
5
4
1
2
1
3
6
4
2

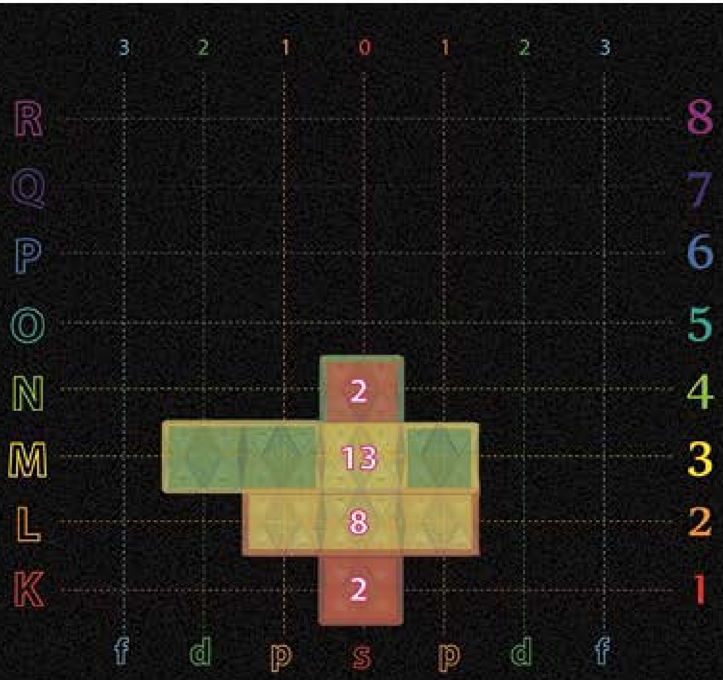
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
13
8
2
f
d
p
s
p
d
f

electron configuration

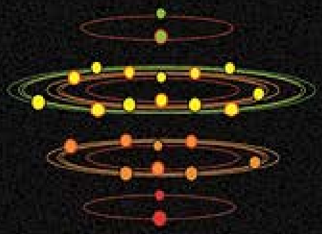

Manganese

$$ {}_{K}^{N}\sum_{P} {}^{28}_{25}\left[\overset{\text{Baryon rest quanta}}{[72(m^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]} \right]^{4}_{1} $$

nuclear mass-energy quanta per shell

[Ar] 3d5 4s2

Transition Metal

Azmithal & Magnetic numbers

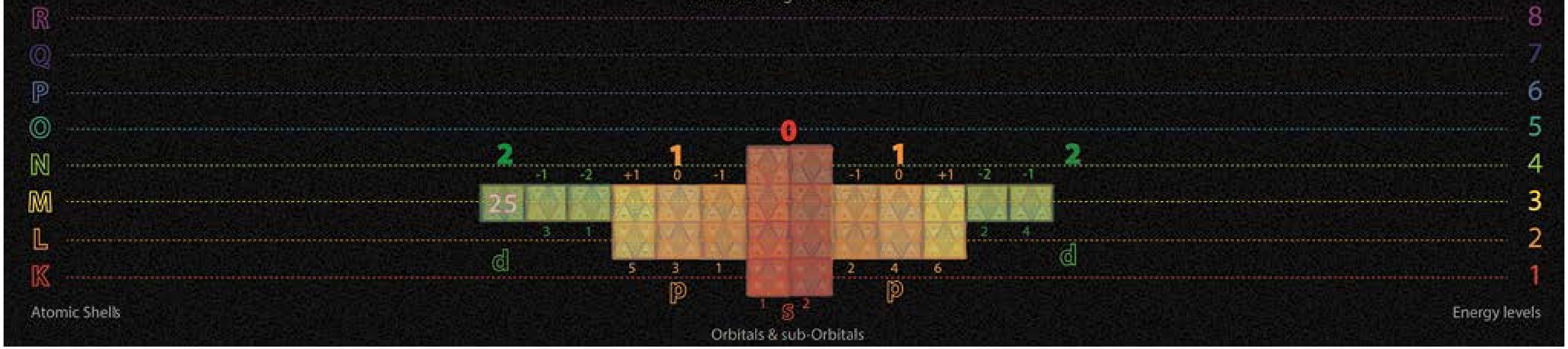
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
1
0
1
2
-1
-2
+1
0
-1
-1
0
+1
-2
-1
25
3
1
2
4
d
d
5
3
1
2
4
6
p
p
1
s
2
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.25 - Manganese atomic config

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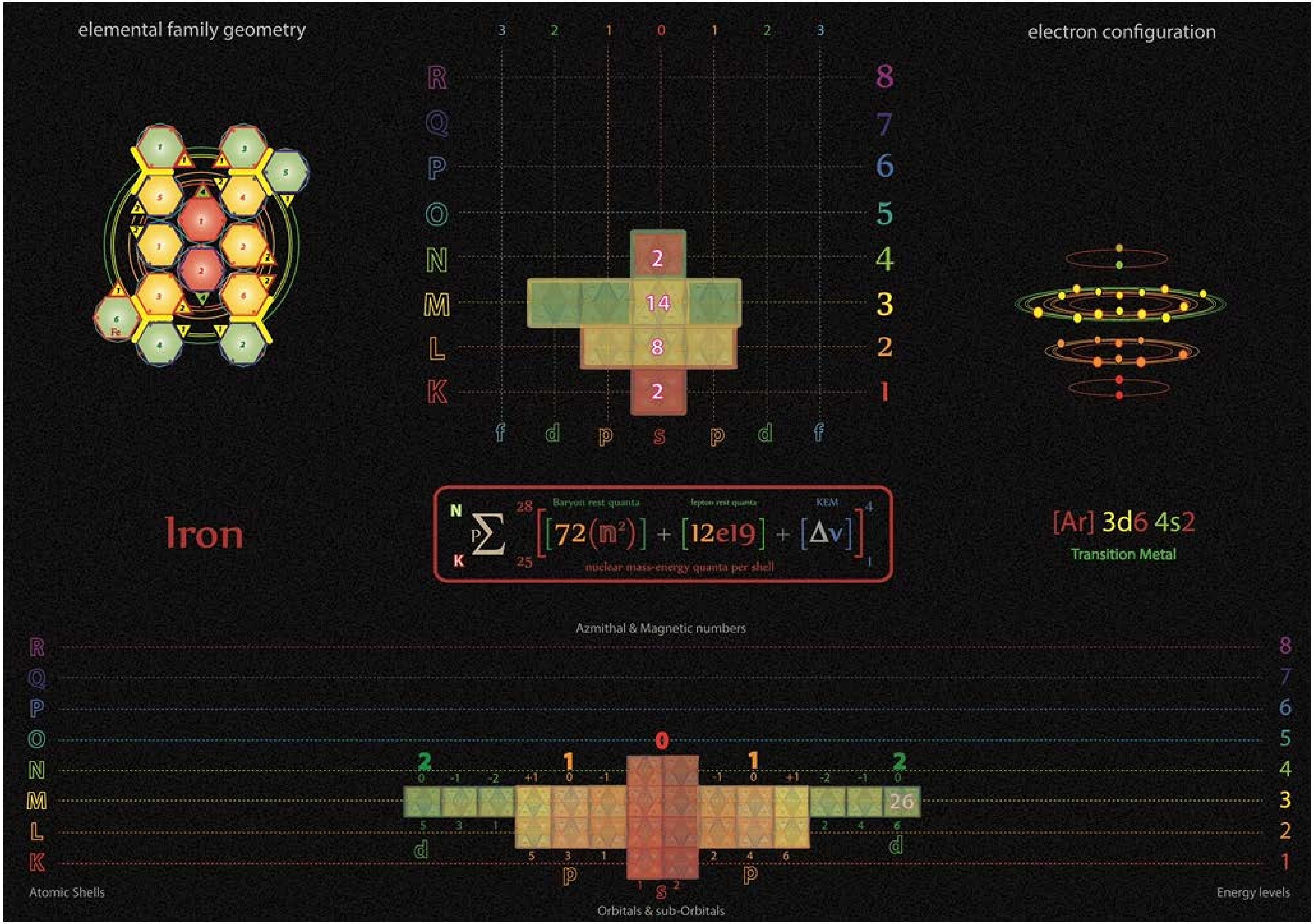
elemental family geometry
Fe
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
14
8
2
f d p s p d f
electron configuration
Iron
N
K
P
28
25
Baryon rest quanta
lepton rest quanta
KEM
[72(n²)] + [12e19] + [Δv]
4
1
nuclear mass-energy quanta per shell
[Ar] 3d6 4s2
Transition Metal
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
2 1 0 1 2
0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0
26
5 3 1 2 4 6
d d
5 3 1 2 4 6
p p
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.26 - Iron atomic config

elemental family geometry

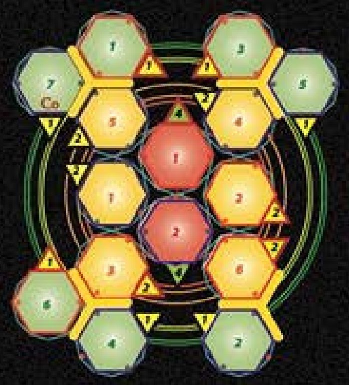
Co
1
3
7
5
5
4
1
1
2
2
3
6
6
4
2

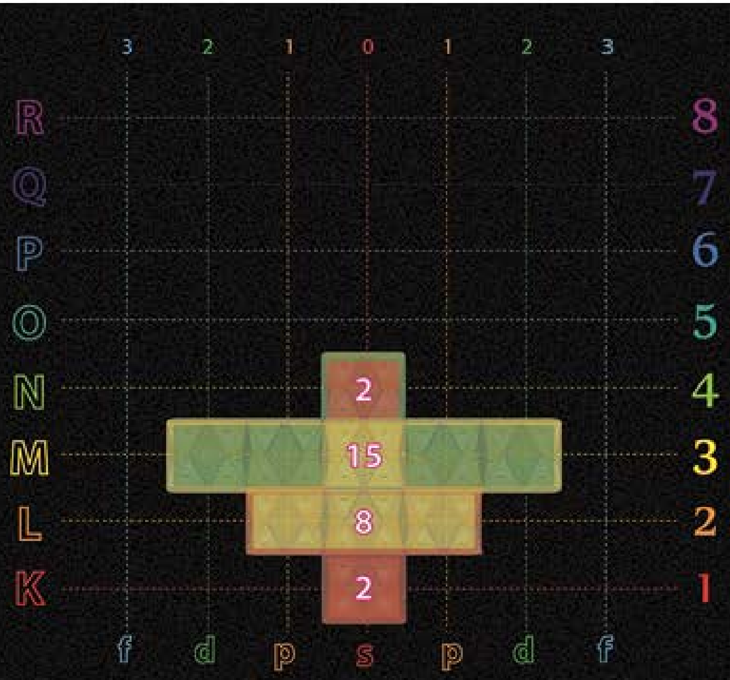
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
15
8
2
f
d
p
s
p
d
f

electron configuration

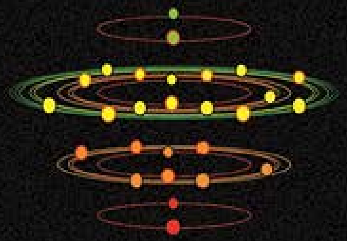

Cobalt

$$\sum_{K}^{N} \mathrm{P} \; {}^{28}_{25}\left[72(\mathrm{m}^2)\right] + \left[12e19\right] + \left[\Delta v\right]^{4}_{1}$$

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Ar] 3d7 4s2

Transition Metal

Azmithal & Magnetic numbers

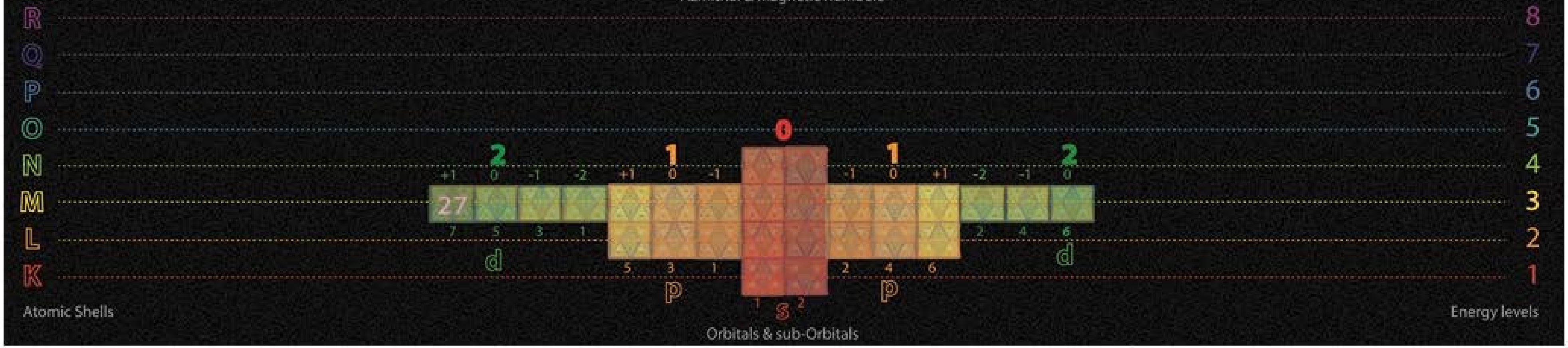
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
2
1
1
2
+1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0
27
7 5 3 1
2 4 6
d
d
5 3 1
2 4 6
p
p
1 s 2

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.27 - Cobalt atomic config

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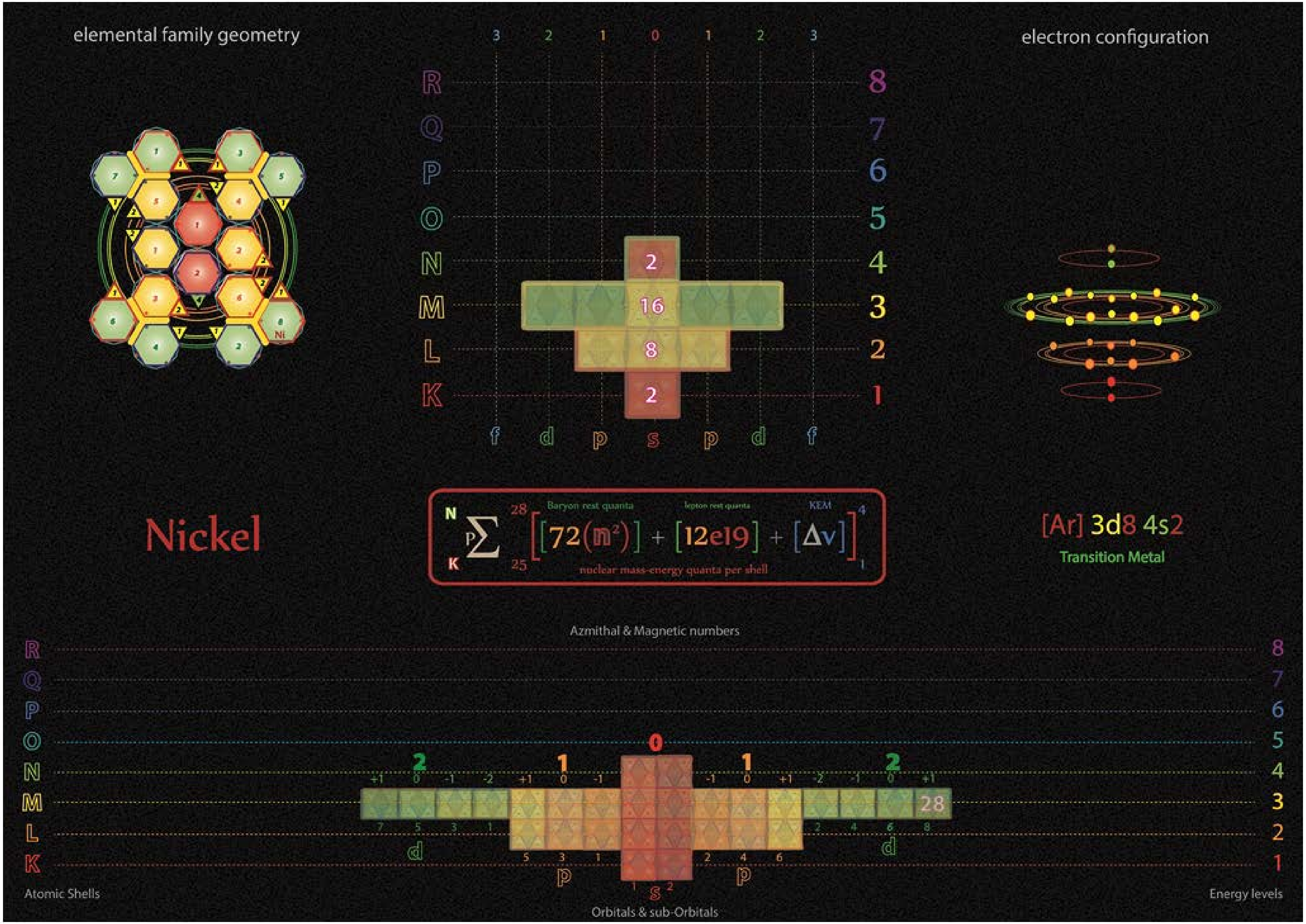

elemental family geometry

electron configuration

Nickel

$$\overset{N}{\underset{K}{}}\;{}_{P}\sum_{25}^{28}\left[\overset{\text{Baryon rest quanta}}{[72(m^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]}\right]_{1}^{4}$$

nuclear mass-energy quanta per shell

[Ar] 3d8 4s2

Transition Metal

Azmithal & Magnetic numbers

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
16
8
2
f d p s p d f
Ni
2 1 0 1 2
+1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1
28
7 5 3 1 2 4 6 8
5 3 1 2 4 6
d p s p d
1 2

Tetryonics 53.28 - Nickel atomic config

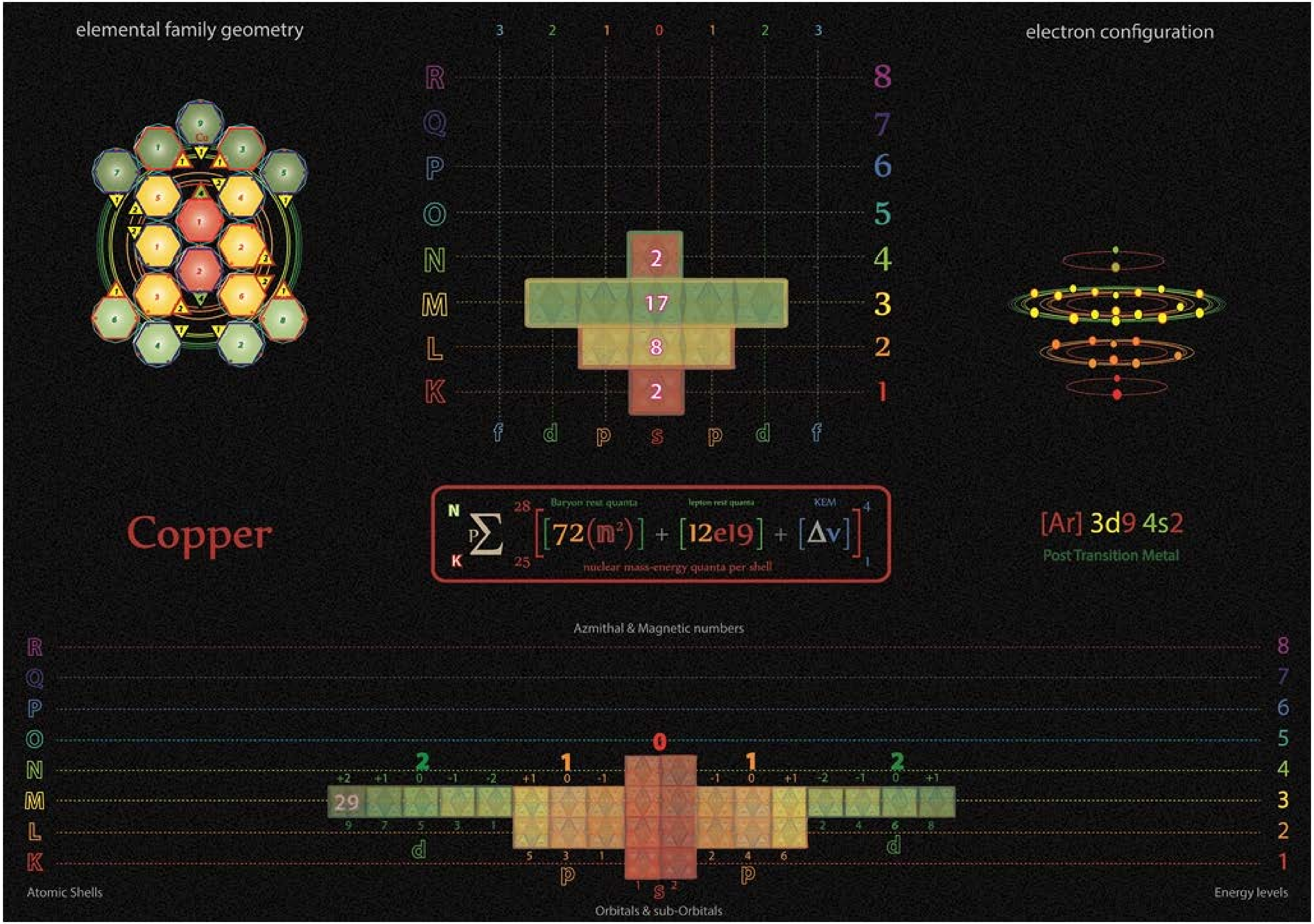
elemental family geometry
Cu
electron configuration
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
2
17
8
2
Copper
N
K
P∑
28
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
4
1
nuclear mass-energy quanta per shell
[Ar] 3d9 4s2
Post Transition Metal
Azmithal & Magnetic numbers
2 1 0 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1
29
9 7 5 3 1
2 4 6 8
5 3 1
2 4 6
d p s p d
1 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.29 - Copper atomic config

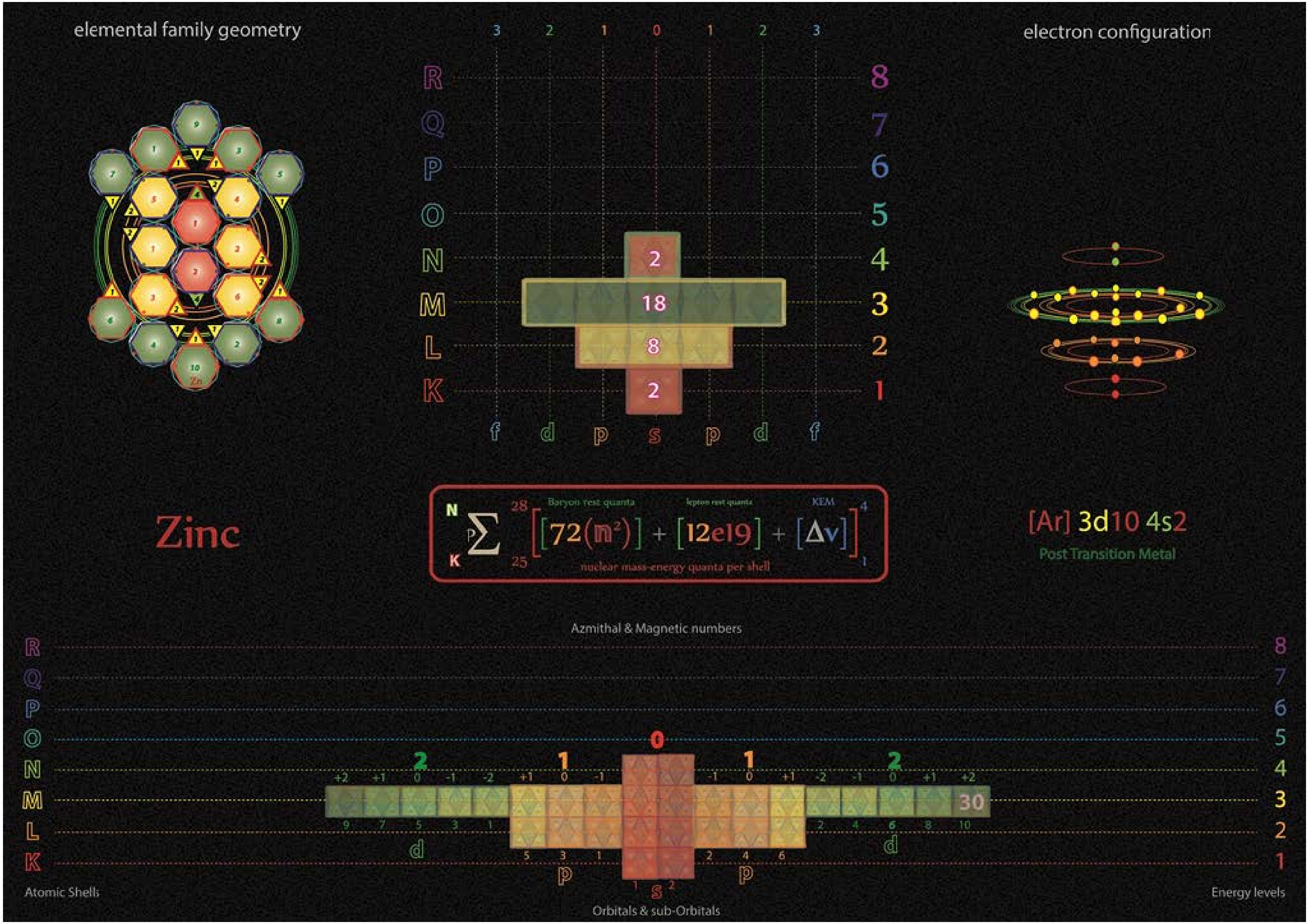
elemental family geometry
electron configuration
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
18
8
2
f
d
p
s
p
d
f
Zinc
N
K
28
25
p
Baryon rest quanta
lepton rest quanta
KEM
4
1
nuclear mass-energy quanta per shell
[Ar] 3d10 4s2
Post Transition Metal
Azmithal & Magnetic numbers
0
1
1
2
2
+2
+1
0
-1
-2
+1
0
-1
-1
0
+1
-2
-1
0
+1
+2
30
9
7
5
3
1
5
3
1
2
4
6
2
4
6
8
10
d
p
s
p
d
1
2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

$$ {}_{K}^{N}\,{}_{p}\sum_{25}^{28}\left[\,[72(\mathrm{m}^2)] + [12e19] + [\Delta v]\,\right]_{1}^{4} $$

Tetryonics 53.30 - Zinc atomic config

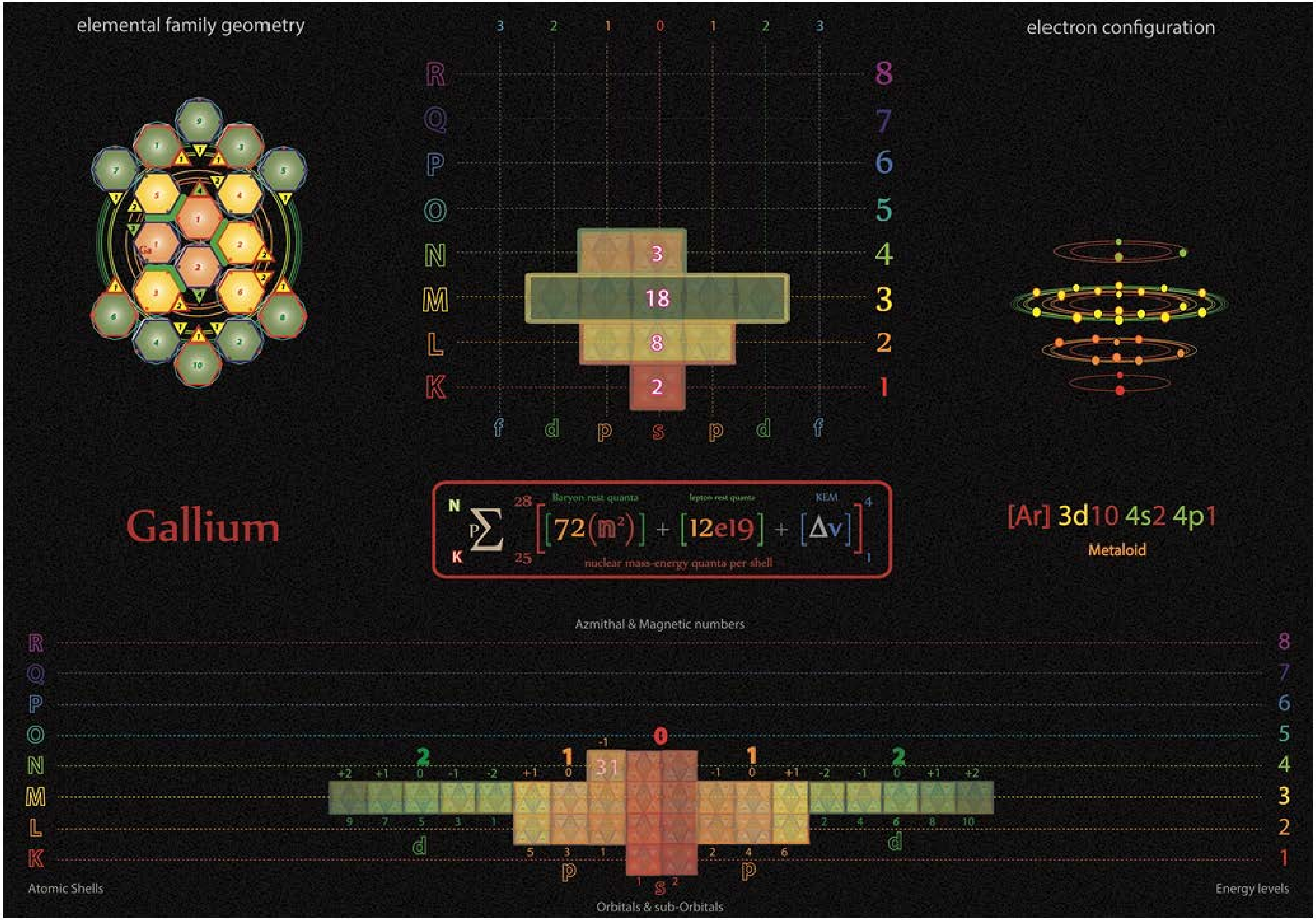
elemental family geometry
Ga
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
3
18
8
2
f d p s p d f
electron configuration
Gallium
N
K
P
28
25
Baryon rest quanta
lepton rest quanta
KEM
4
1
[72(m²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
[Ar] 3d10 4s2 4p1
Metaloid
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
2 1 0 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
31
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
Atomic Shells
Orbitals & sub-Orbitals
Energy levels

Tetryonics 53.31 - Gallium atomic config

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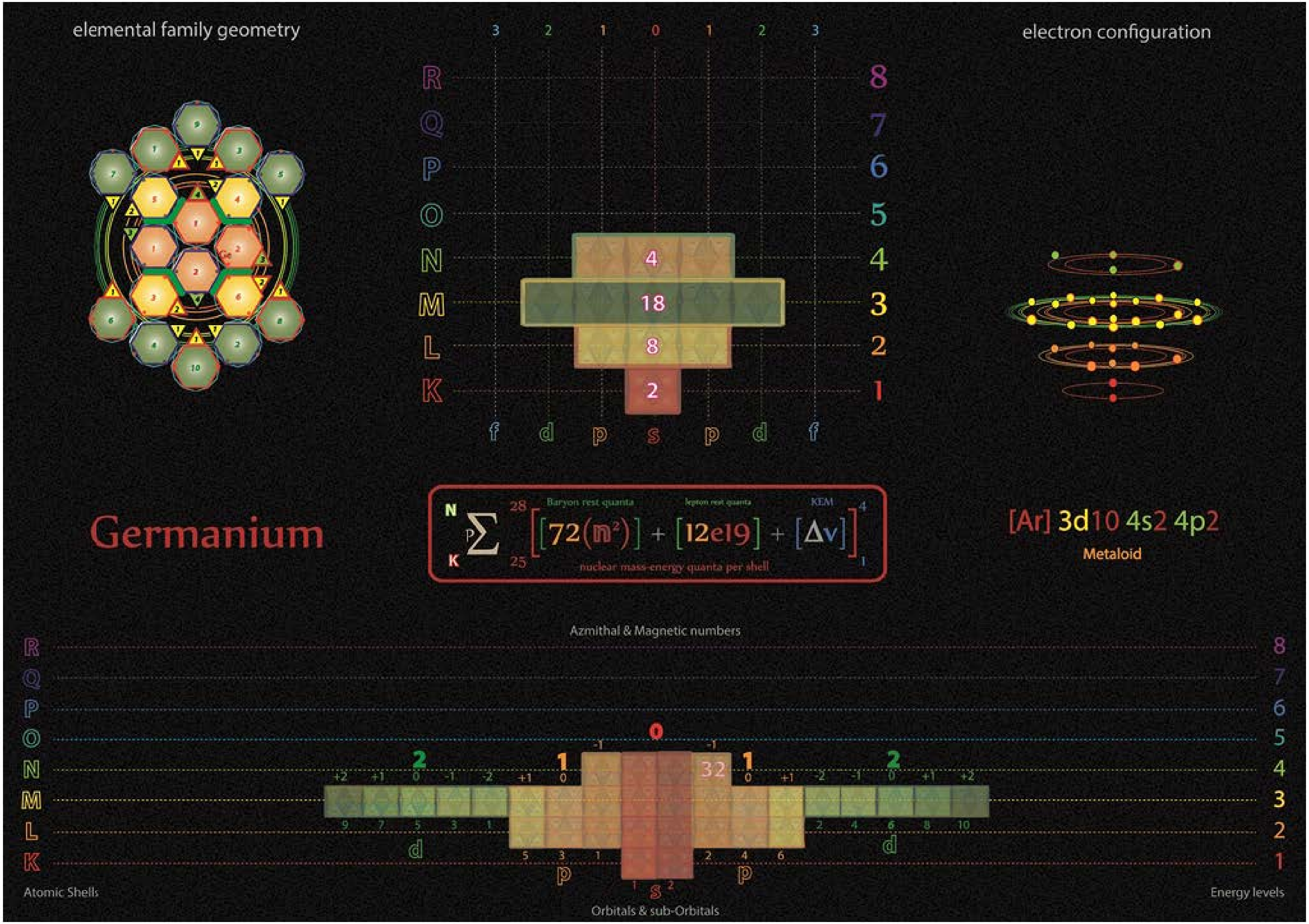
elemental family geometry
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
4
18
8
2
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
2 1 1 2
-1 -1
32
+2 +1 0 -1 -2 +1 0 -2 -1 0 +1 +2
9 7 5 3 1 2 4 6 8 10
d
5 3 1 2 4 6
p p
1 s 2
d
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Germanium

Baryon rest quanta · lepton rest quanta · KEM

$$\sideset{_{K}^{N}}{}{}{}_{p}\sum_{25}^{28}\left[[72(n^{2})]+[12e19]+[\Delta v]\right]_{1}^{4}$$

nuclear mass-energy quanta per shell

[Ar] 3d10 4s2 4p2

Metaloid

Tetryonics 53.32 - Germanium atomic config

elemental family geometry

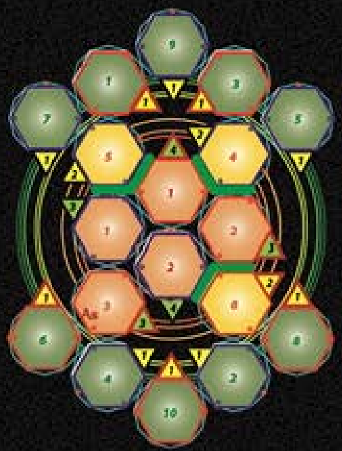
9
1
3
7
5
5
4
1
1
2
2
3
6
6
8
4
2
10

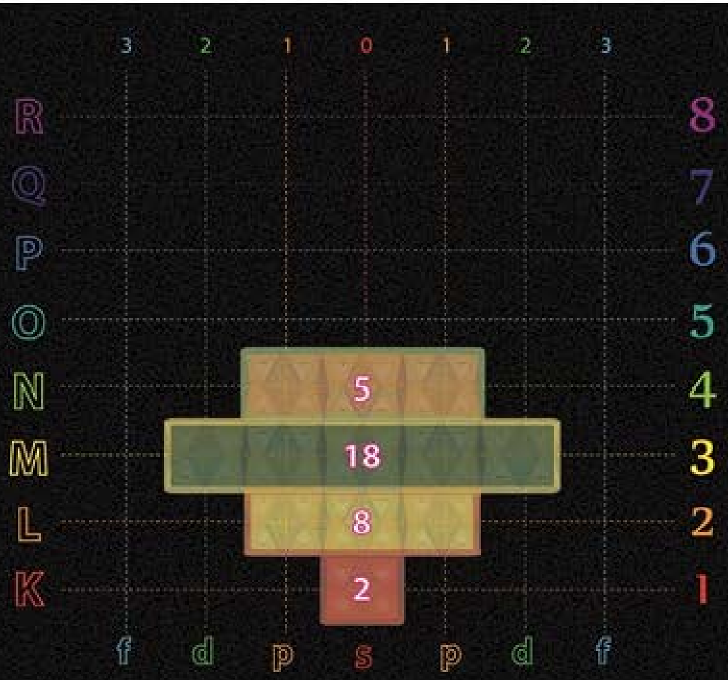
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
5
18
8
2
f
d
p
s
p
d
f

electron configuration

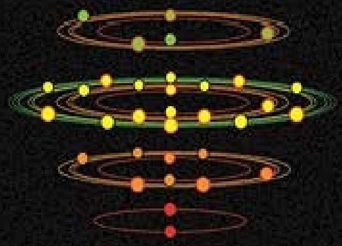

Arsenic

$$\sum_{K}^{N} P \sum_{25}^{28} \left[[72(n^2)] + [12e19] + [\Delta v] \right]_{1}^{4}$$

Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[Ar] 3d10 4s2 4p3

Metaloid

Azmithal & Magnetic numbers

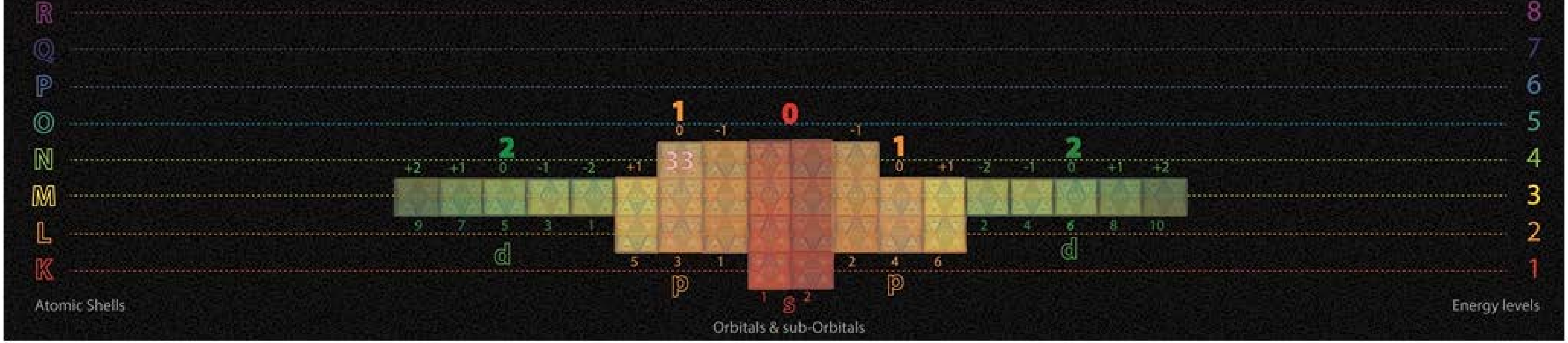
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
+2
+1
0
-1
-2
1
0
-1
+1
33
0
-1
1
0
+1
2
-2
-1
0
+1
+2
9
7
5
3
1
5
3
1
1
2
2
4
6
2
4
6
8
10
d
p
s
p
d

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.33 - Arsenic atomic config

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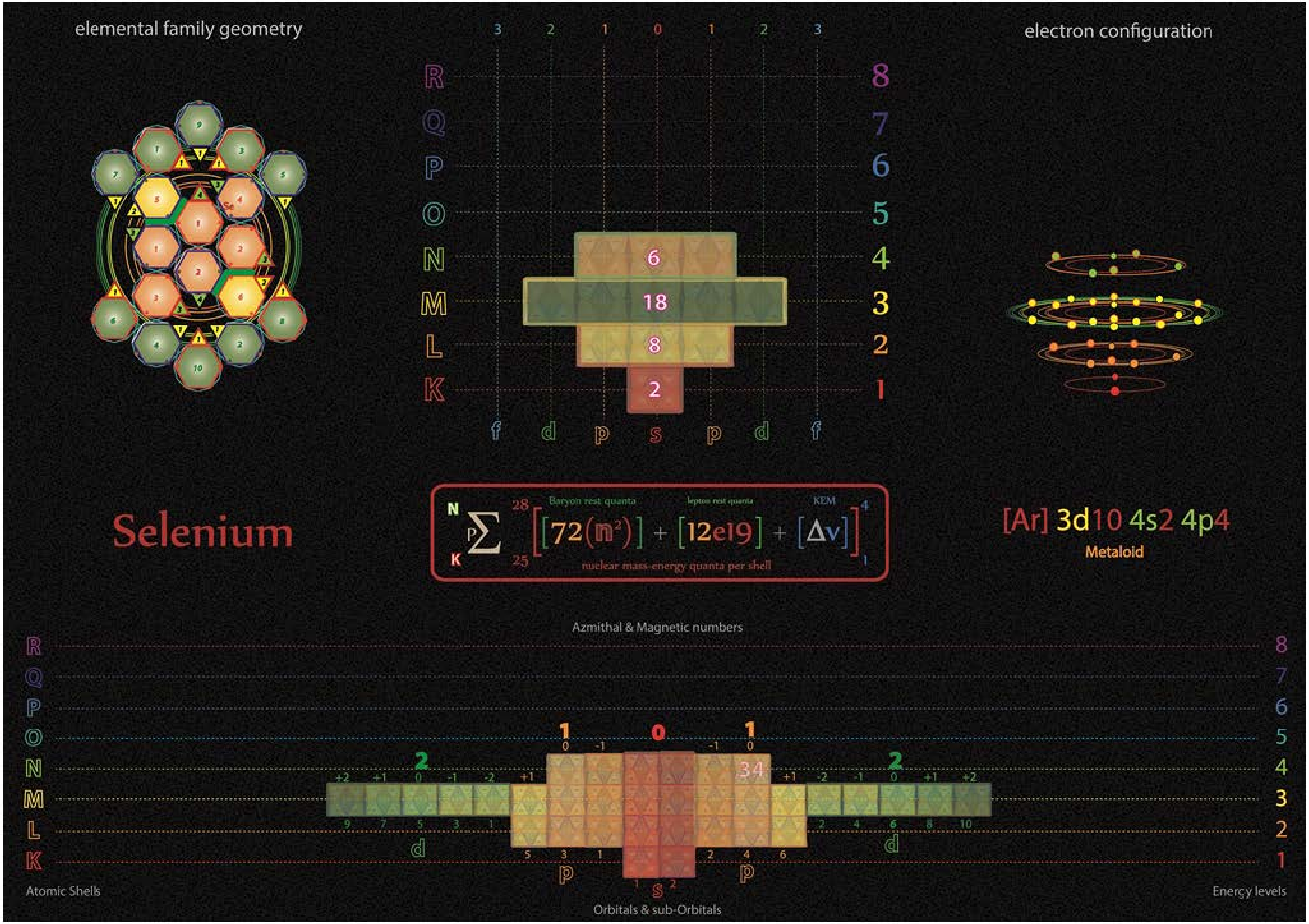
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
6
18
8
2
f d p s p d f
Selenium
N
K
p
28
25
Baryon rest quanta
lepton rest quanta
KEM
[[72(m²)] + [12e19] + [Δv]]
4
1
nuclear mass-energy quanta per shell
[Ar] 3d10 4s2 4p4
Metaloid
Azmithal & Magnetic numbers
2 1 0 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
34
9 7 5 3 1 5 3 1 1 2 2 4 6 2 4 6 8 10
d p s p d
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.34 - Selenium atomic config

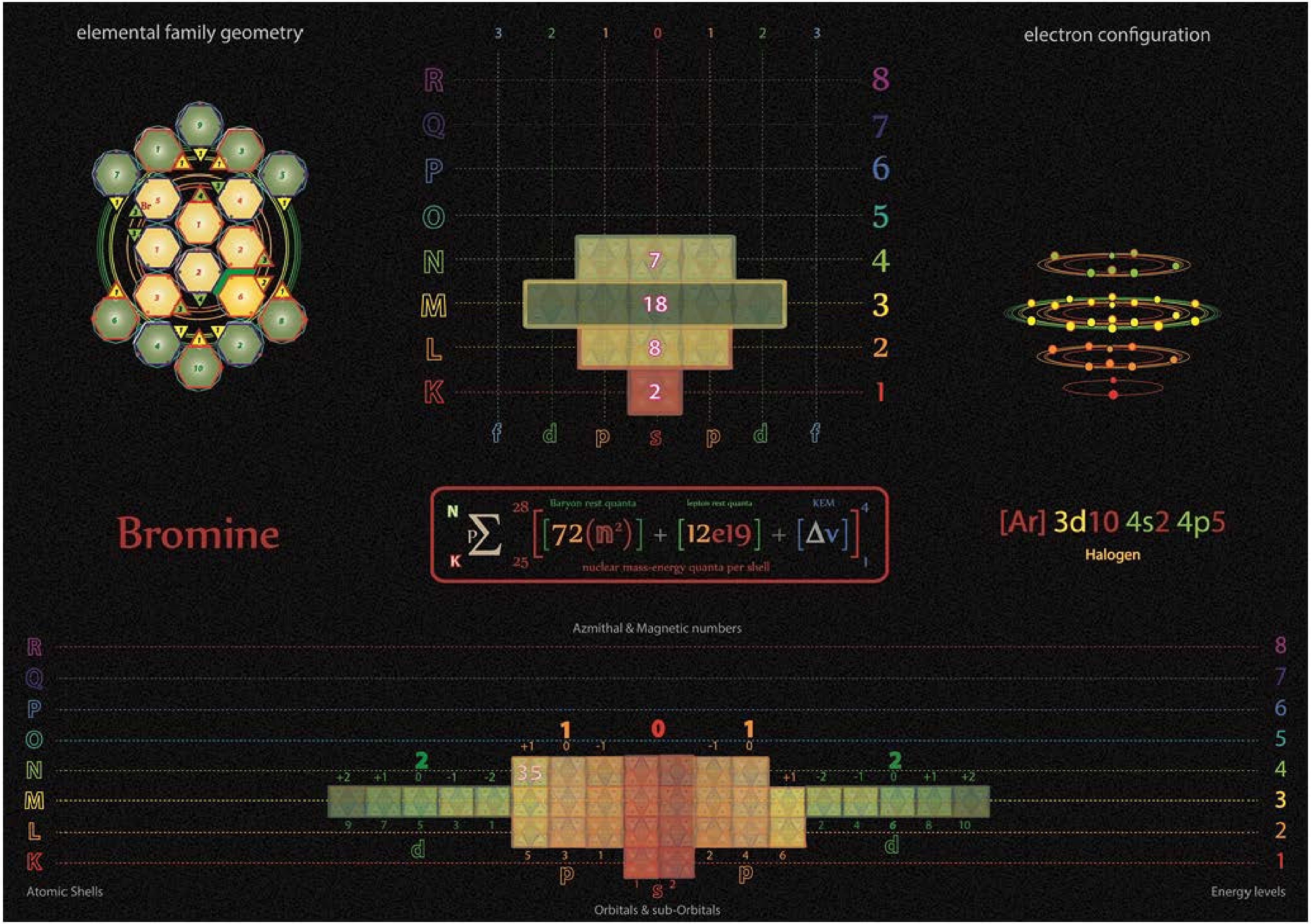
elemental family geometry
Br
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
7
18
8
2
f d p s p d f
electron configuration
Bromine
N
K
P
28
25
Baryon rest quanta
lepton rest quanta
KEM
$\sum_{K}^{N} {}_{P}\left[[72(\mathrm{m}^2)] + [12e19] + [\Delta v] \right]_1^4$
nuclear mass-energy quanta per shell
[Ar] 3d10 4s2 4p5
Halogen
Azmithal & Magnetic numbers
2 1 0 1 2
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
35
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
d p s p d
1 2
Atomic Shells
Orbitals & sub-Orbitals
Energy levels

Tetryonics 53.35 - Bromine atomic config

elemental family geometry

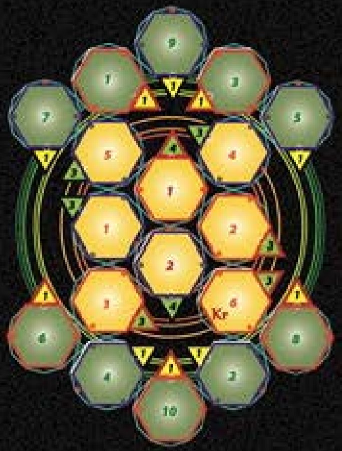

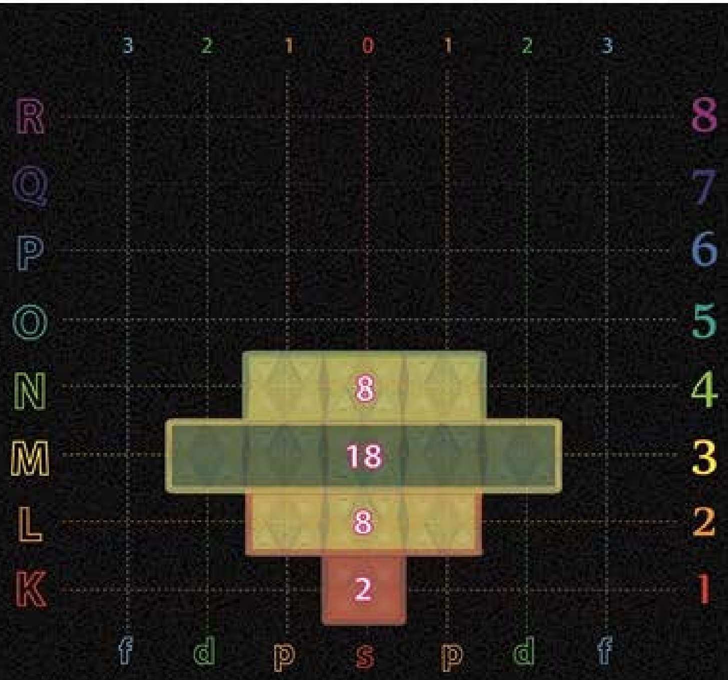
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
8
18
8
2
f d p s p d f

electron configuration

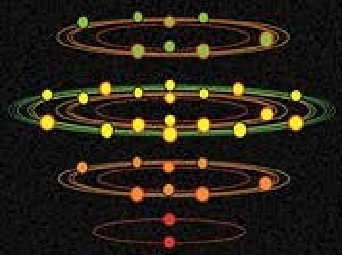

Krypton

$$\sum_{K}^{N} {}_{P}\!\sum_{25}^{28} \left[\underset{\text{Baryon rest quanta}}{[72(m^2)]} + \underset{\text{lepton rest quanta}}{[12e19]} + \underset{\text{KEM}}{[\Delta v]} \right]_1^4$$

nuclear mass-energy quanta per shell

[Ar] 3d10 4s2 4p6

Noble
Gas

Azmithal & Magnetic numbers

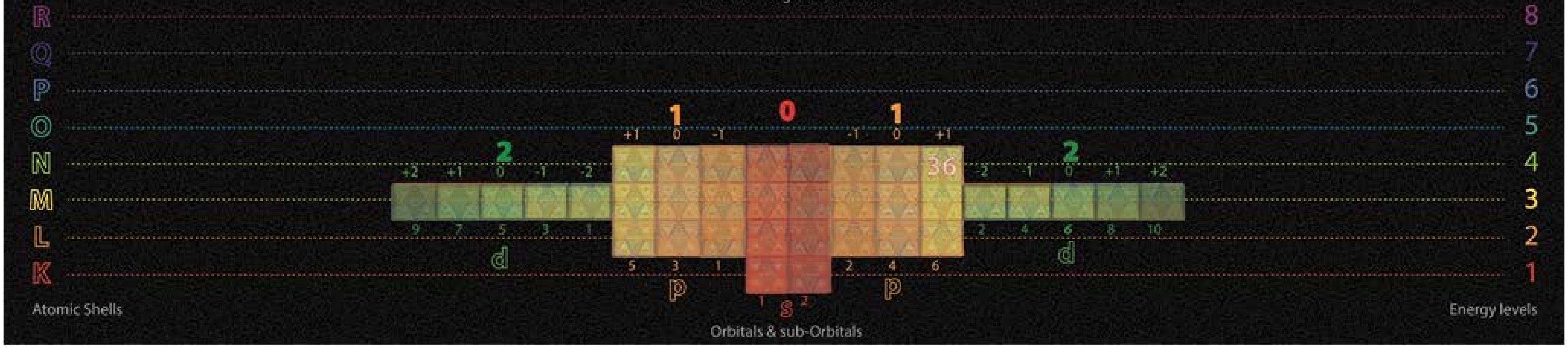
R Q P O N M L K
8 7 6 5 4 3 2 1
2 1 0 1 2
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
36
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
d p s p d

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.36 - Krypton atomic config

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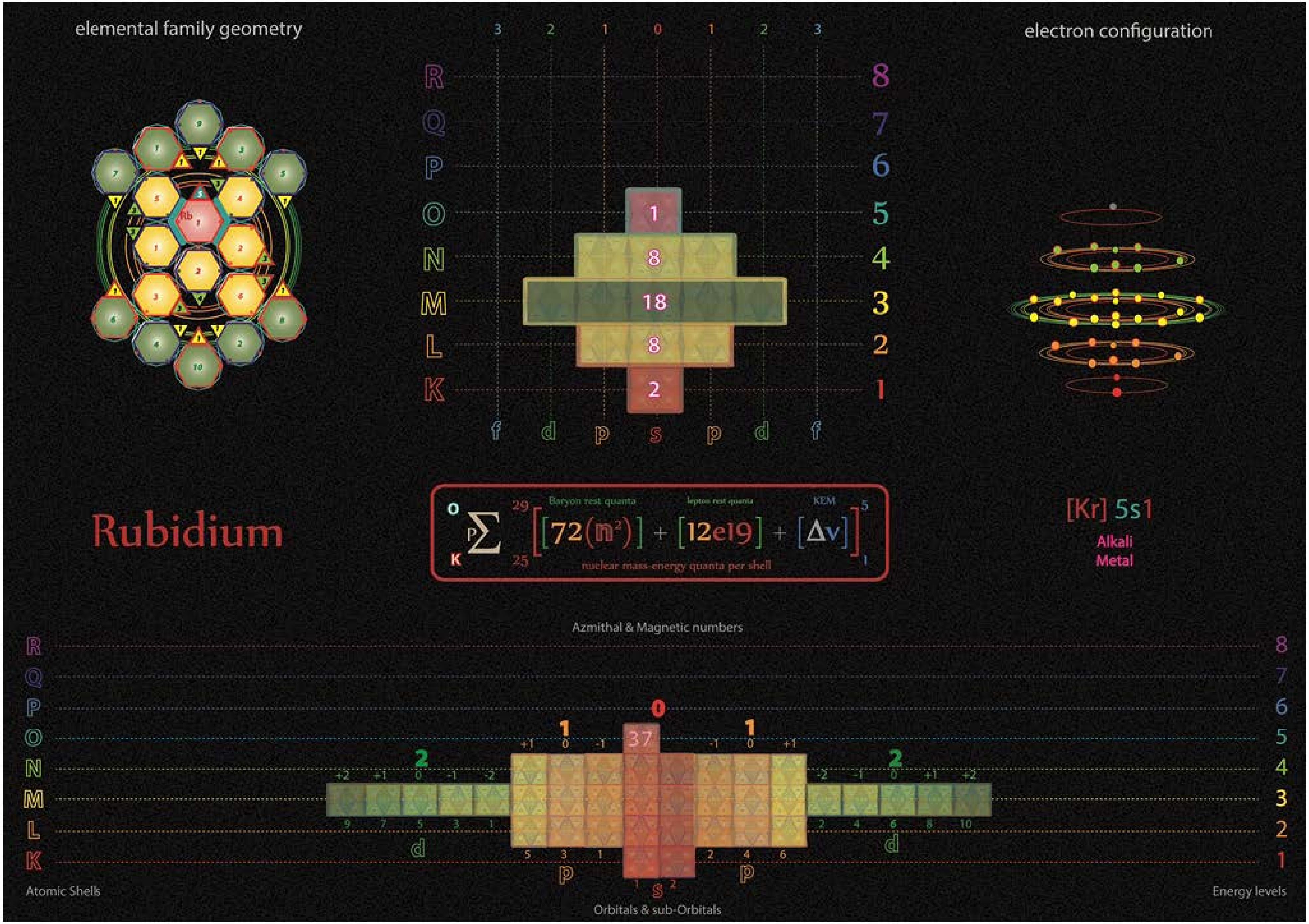
elemental family geometry
Rb
electron configuration
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
1
8
18
8
2
Rubidium
O
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(n²)] + [12e19] + [Δv]
5
1
nuclear mass-energy quanta per shell
[Kr] 5s1
Alkali
Metal
Azmithal & Magnetic numbers
0
1 1
2 2
37
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
d p s p d
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.37 - Rubidium atomic config

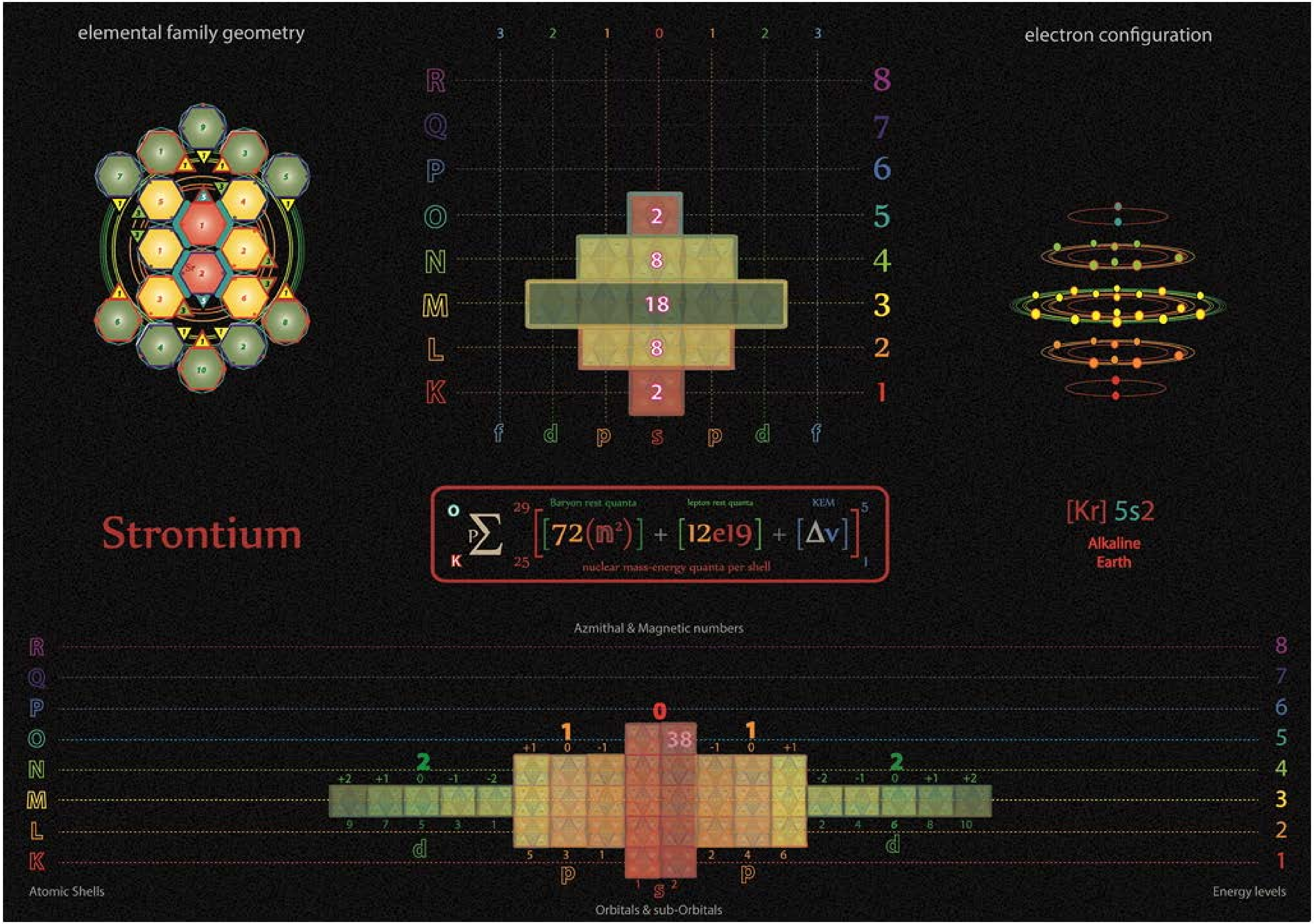
elemental family geometry
3 2 1 0 1 2 3
electron configuration
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
18
8
2
f d p s p d f
Strontium
O
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
5
1
nuclear mass-energy quanta per shell
[Kr] 5s2
Alkaline Earth
Azmithal & Magnetic numbers
0
1
1
2
2
38
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
d p s p d
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

$$_{K}^{O}{}^{P}\sum_{25}^{29}\left[[72(\mathfrak{m}^2)] + [12e19] + [\Delta v]\right]_1^5$$

Tetryonics 53.38 - Strontium atomic config

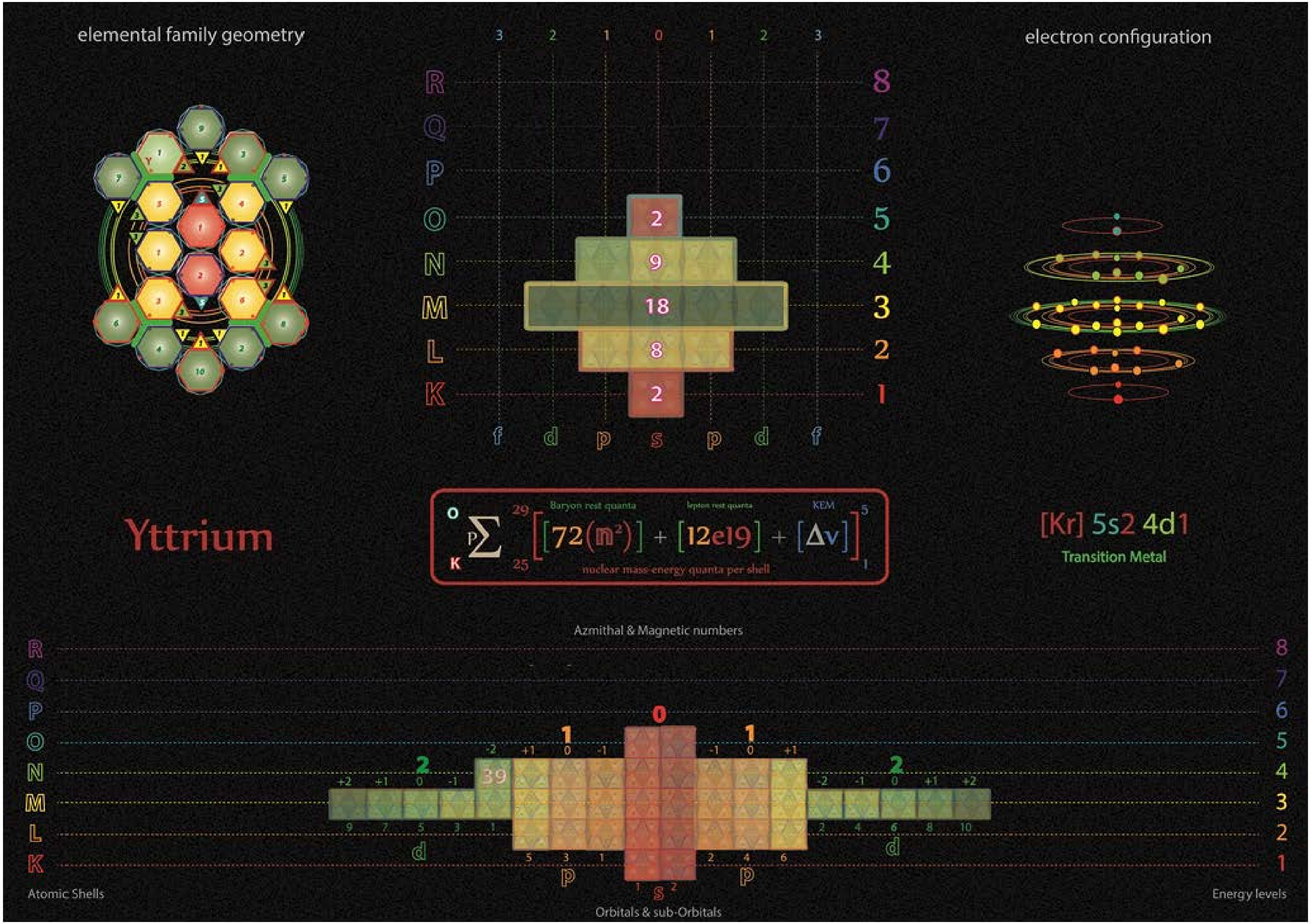
elemental family geometry
3 2 1 0 1 2 3
electron configuration
R Q P O N M L K
8 7 6 5 4 3 2 1
2
9
18
8
2
f d p s p d f
Yttrium
O
K
p
29
25
Baryon rest quanta
lepton rest quanta
KEM
5
1
[72(n²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
[Kr] 5s2 4d1
Transition Metal
Azmithal & Magnetic numbers
0
1
1
2
2
-2 +1 0 -1
-1 0 +1
+2 +1 0 -1
-2 -1 0 +1 +2
39
9 7 5 3 1
2 4 6 8 10
d
d
5 3 1
2 4 6
p
p
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.39 - Yttrium atomic config

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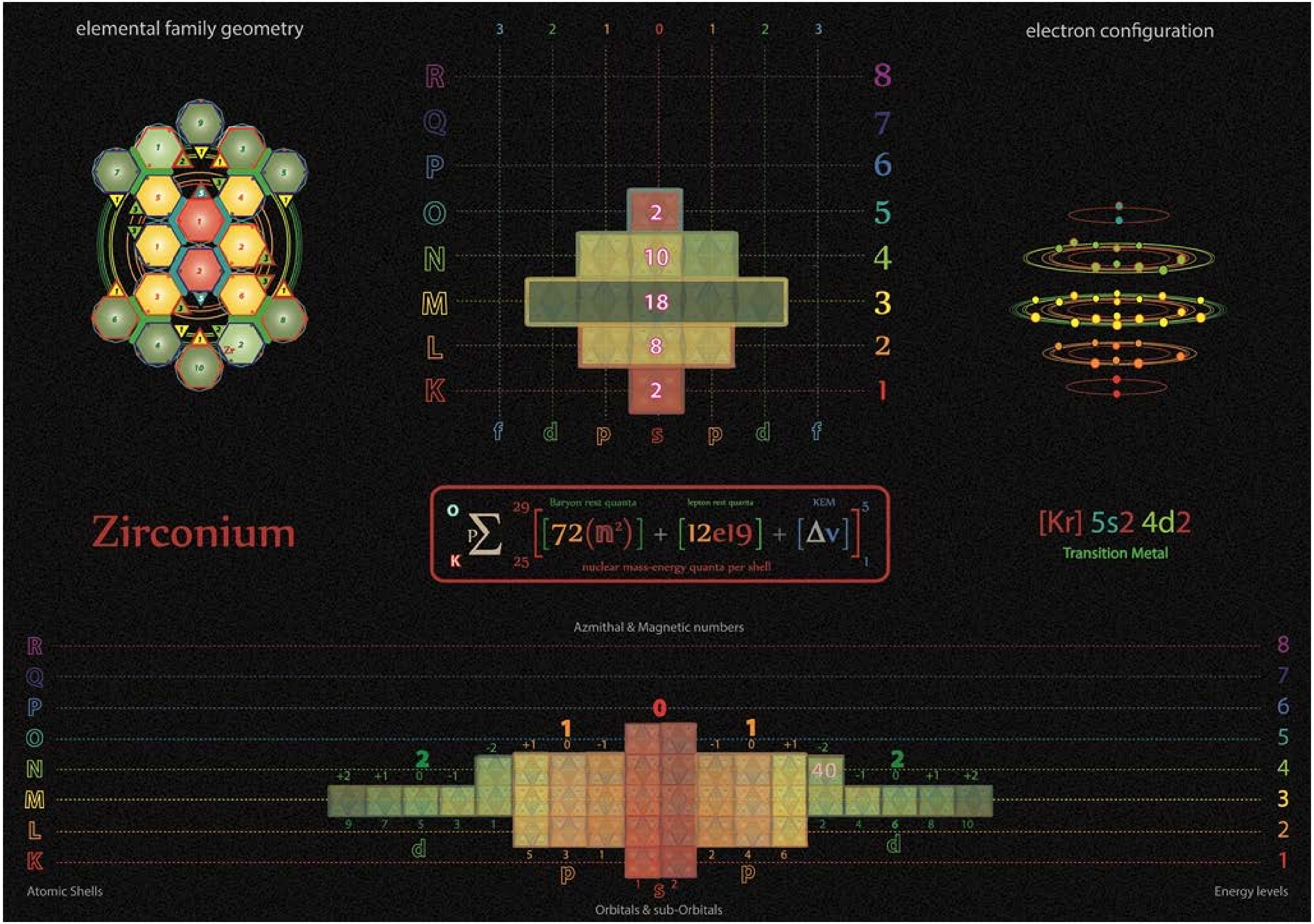
elemental family geometry
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
10
18
8
2
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
0
1 1
2 2
-2 +1 0 -1 -1 0 +1 -2
+2 +1 0 -1 -1 0 +1 +2
40
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Zirconium

$$\sum_{K}^{O} {}_{P}\left[{}^{29}_{25}\left[72(\mathrm{n}^2)\right] + \left[12e19\right] + \left[\Delta v\right]\right]^{5}_{1}$$

Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[Kr] 5s2 4d2

Transition Metal

Tetryonics 53.40 - Zirconium atomic config

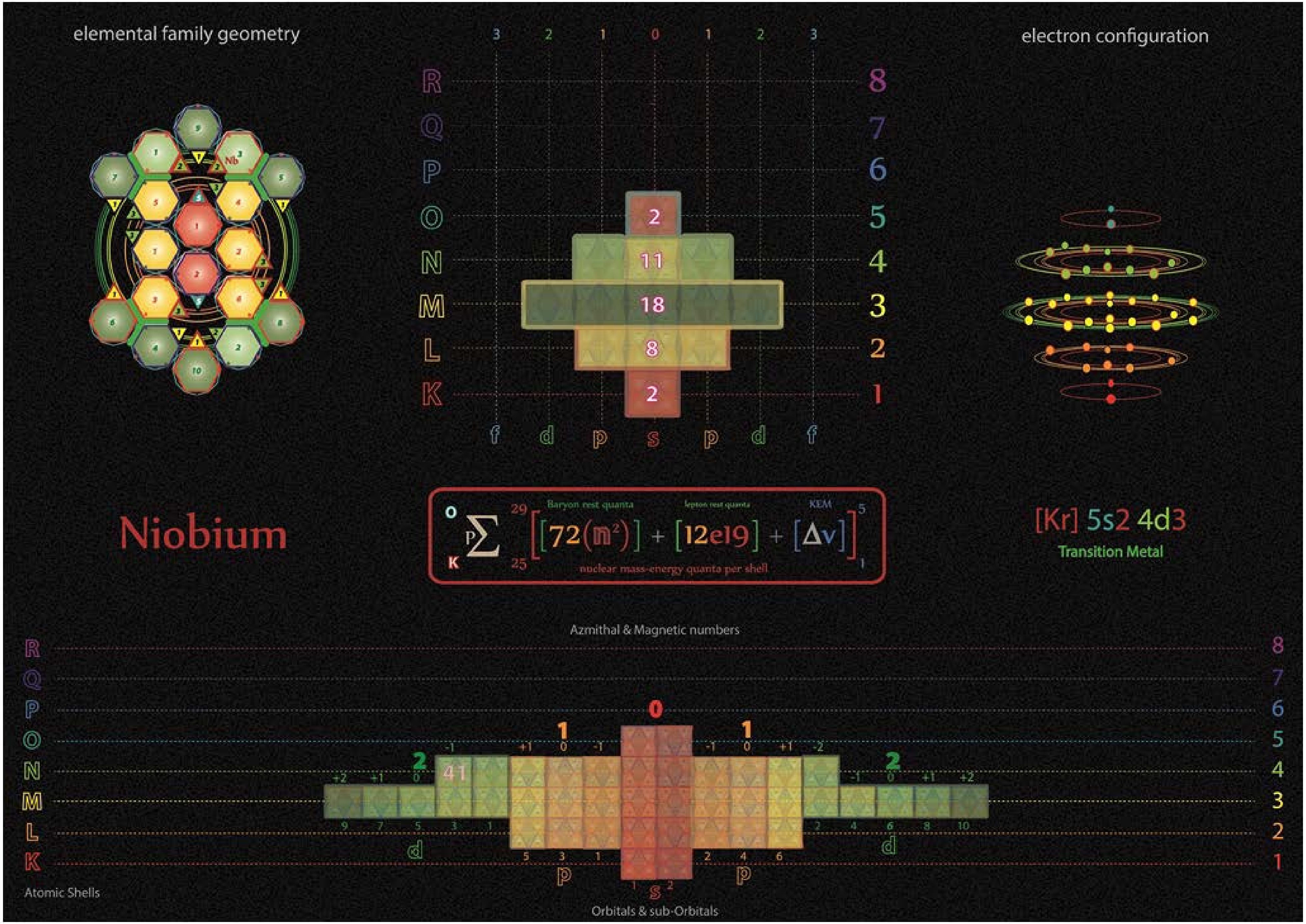
elemental family geometry
Nb
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
11
18
8
2
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
0
1
1
2
2
41
+2 +1 0 -1 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
9 7 5 3 1 5 3 1 2 4 6 2 4 6 8 10
d p s p d
1 2
Atomic Shells
Orbitals & sub-Orbitals

Niobium

$$\sum_{K}^{O}{}_{P}\sum_{25}^{29}\Big[[72(m^2)] + [12e19] + [\Delta v]\Big]_{1}^{5}$$

Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[Kr] 5s2 4d3

Transition Metal

Tetryonics 53.41 - Niobium atomic config

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elemental family geometry

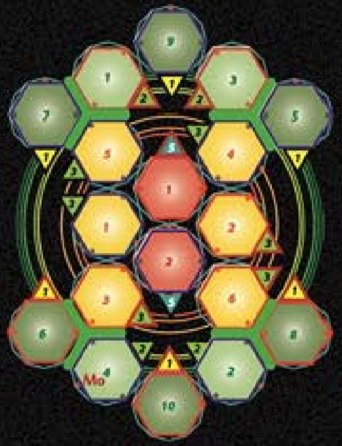

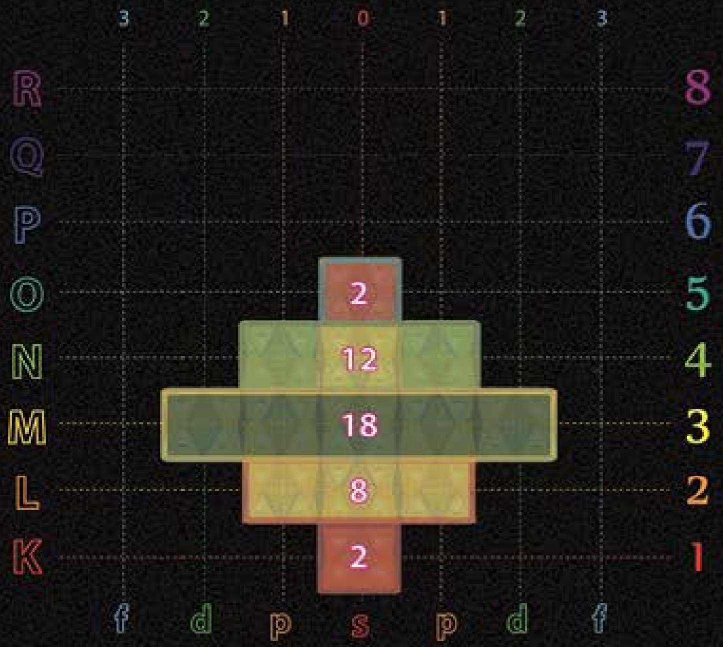
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
12
18
8
2
f d p s p d f

electron configuration

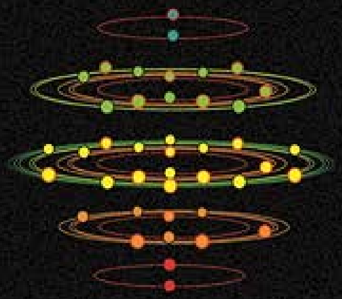

Molybdenum

$$ {}^{O}_{K}{}_{P}\sum {}^{29}_{25}\left[[72(n^{2})] + [12e19] + [\Delta v] \right]^{5}_{1} $$

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Kr] 5s2 4d4

Transition Metal

Azmithal & Magnetic numbers

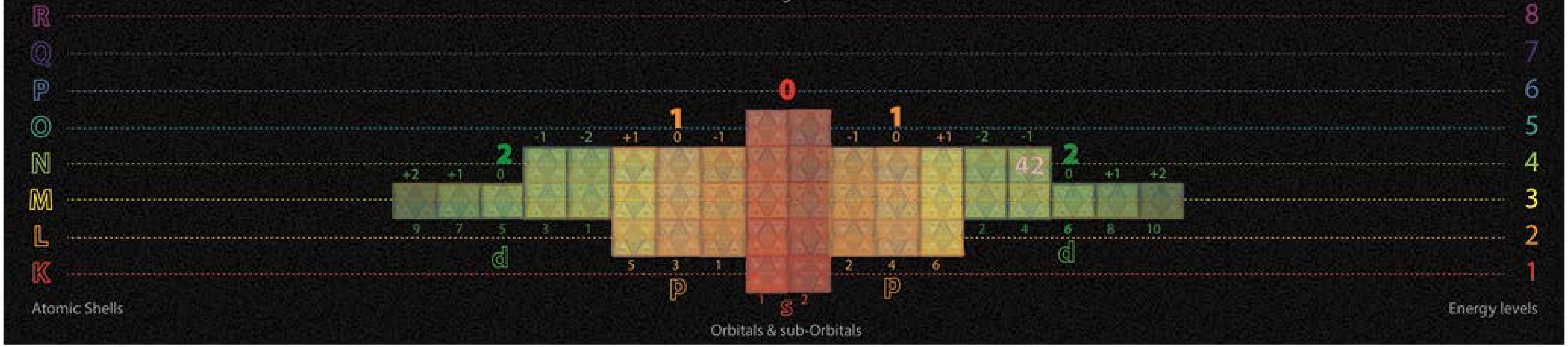
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
2
-1 -2 +1 0 -1 -1 0 +1 -2 -1
+2 +1 0 0 +1 +2
42
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.42 - Molybdenum atomic config

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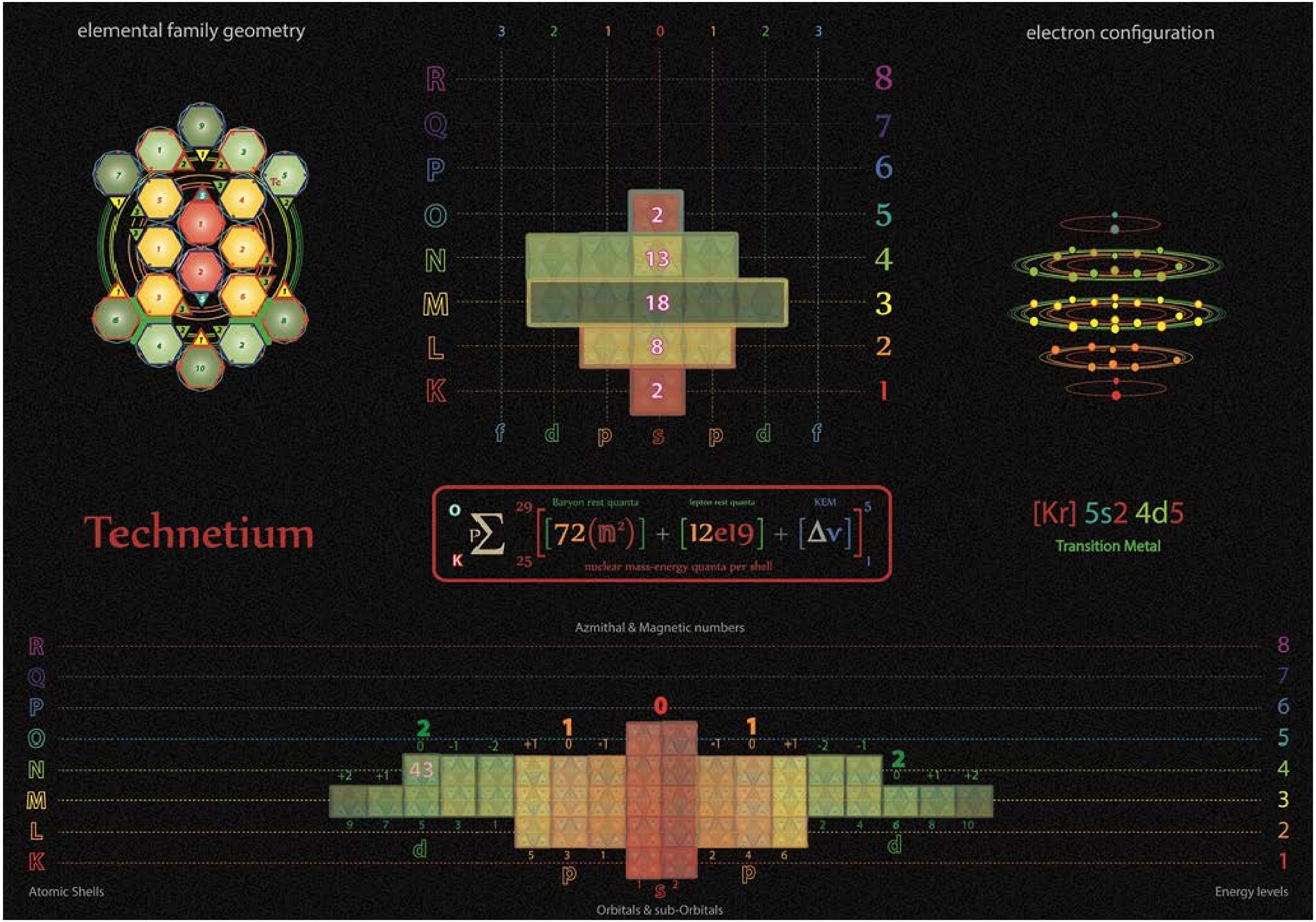

elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2 13 18 8 2
f d p s p d f
Azmithal & Magnetic numbers
2 1 0 1 2
0 -1 -2 +1 0 -1 -1 0 +1 -2 -1
+2 +1 43 0 +1 +2
9 7 5 3 1 2 4 6 8 10
5 3 1 2 4 6
1 s 2
d p p d
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Technetium

$$\sum_{K}^{O} p \; {}_{25}^{29}\left[[72(m^2)] + [12e19] + [\Delta v] \right]_{1}^{5}$$

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Kr] 5s2 4d5

Transition Metal

Tetryonics 53.43 - Technetium atomic config

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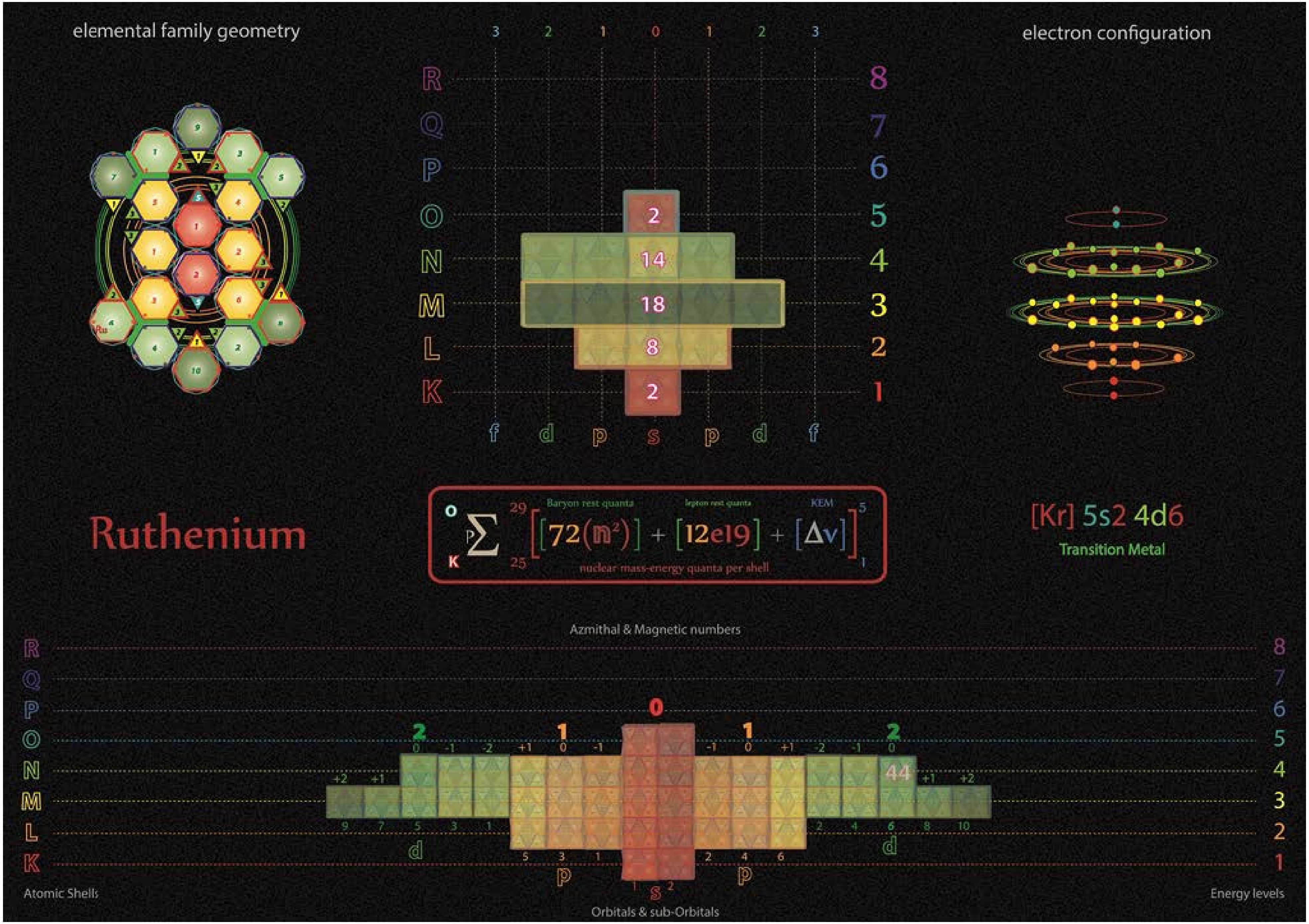
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
14
18
8
2
f d p s p d f
Ruthenium
O
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
$\sum [72(m^2)] + [12e19] + [\Delta v]$
5
1
nuclear mass-energy quanta per shell
[Kr] 5s2 4d6
Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0
+2 +1 +1 +2
44
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.44 - Ruthenium atomic config

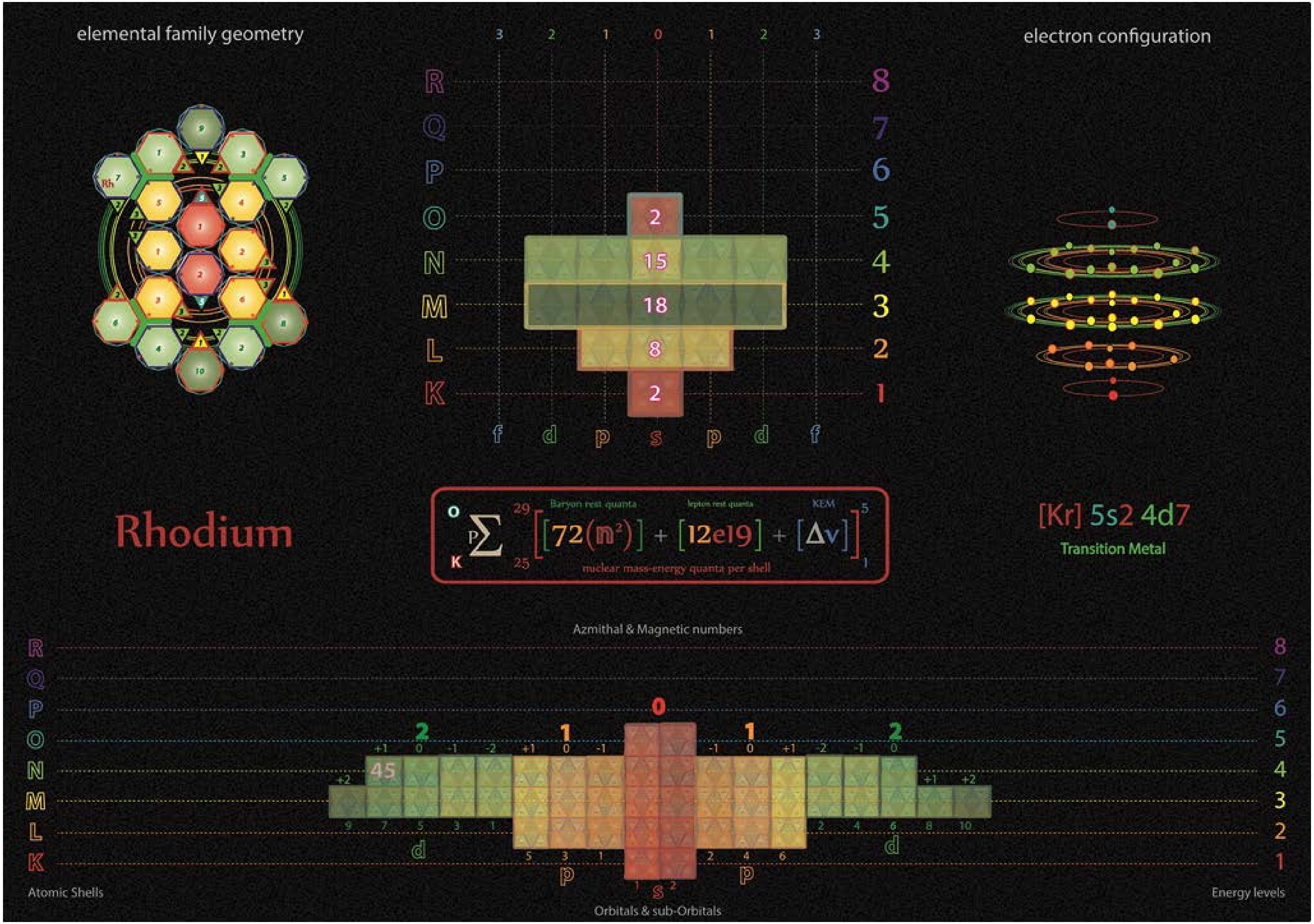
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
15
18
8
2
f d p s p d f
Rh
Rhodium
O
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
5
1
nuclear mass-energy quanta per shell
[Kr] 5s2 4d7
Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
+1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0
+2 +1 +2
45
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.45 - Rhodium atomic config

elemental family geometry

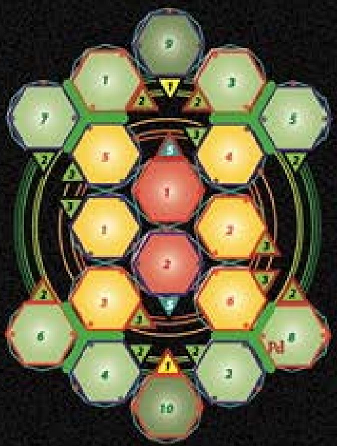
9
1
3
7
5
5
4
1
2
3
6
6
4
2
10
Pd

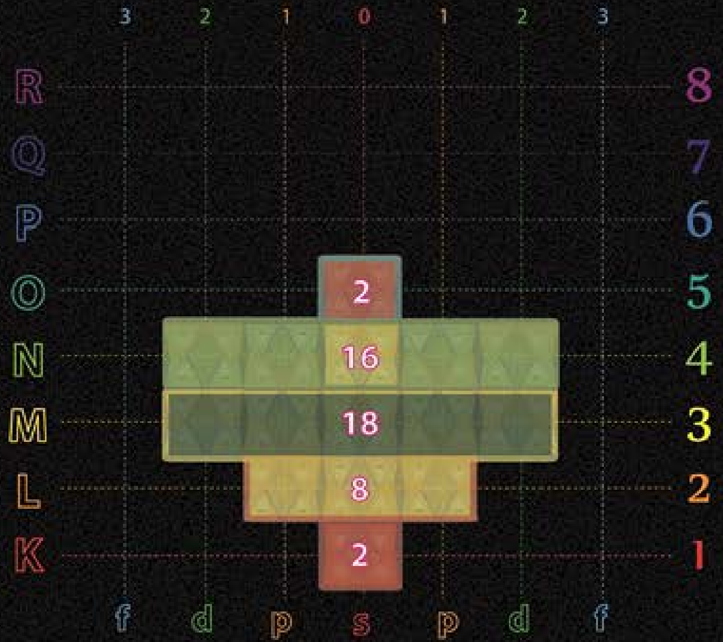
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
16
18
8
2
f
d
p
s
p
d
f

electron configuration

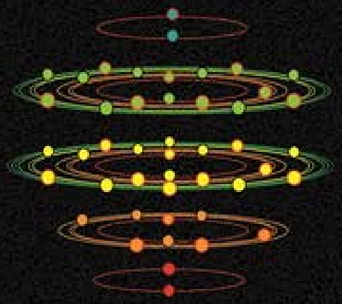

Palladium

$$\sum_{K}^{O}{}_{p}\,{}_{25}^{29}\Big[[72(m^2)] + [12e19] + [\Delta v]\Big]_{1}^{5}$$

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Kr] 5s2 4d8

Transition Metal

Azmithal & Magnetic numbers

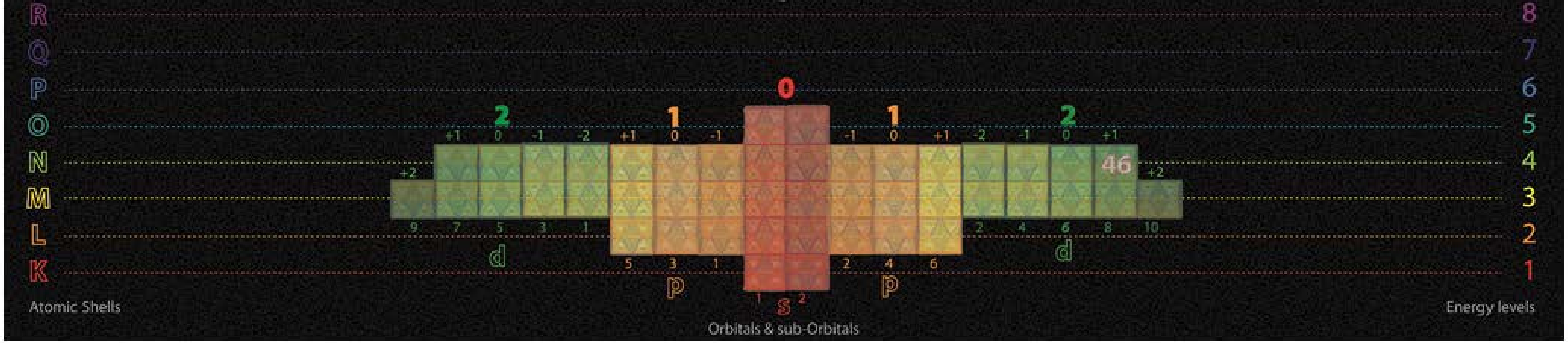
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
2
1
1
2
+1
0
-1
-2
+1
0
-1
-1
0
+1
-2
-1
0
+1
+2
+2
46
9
7
5
3
1
2
4
6
8
10
d
d
5
3
1
2
4
6
p
p
1
s
2

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.46 - Palladium atomic config

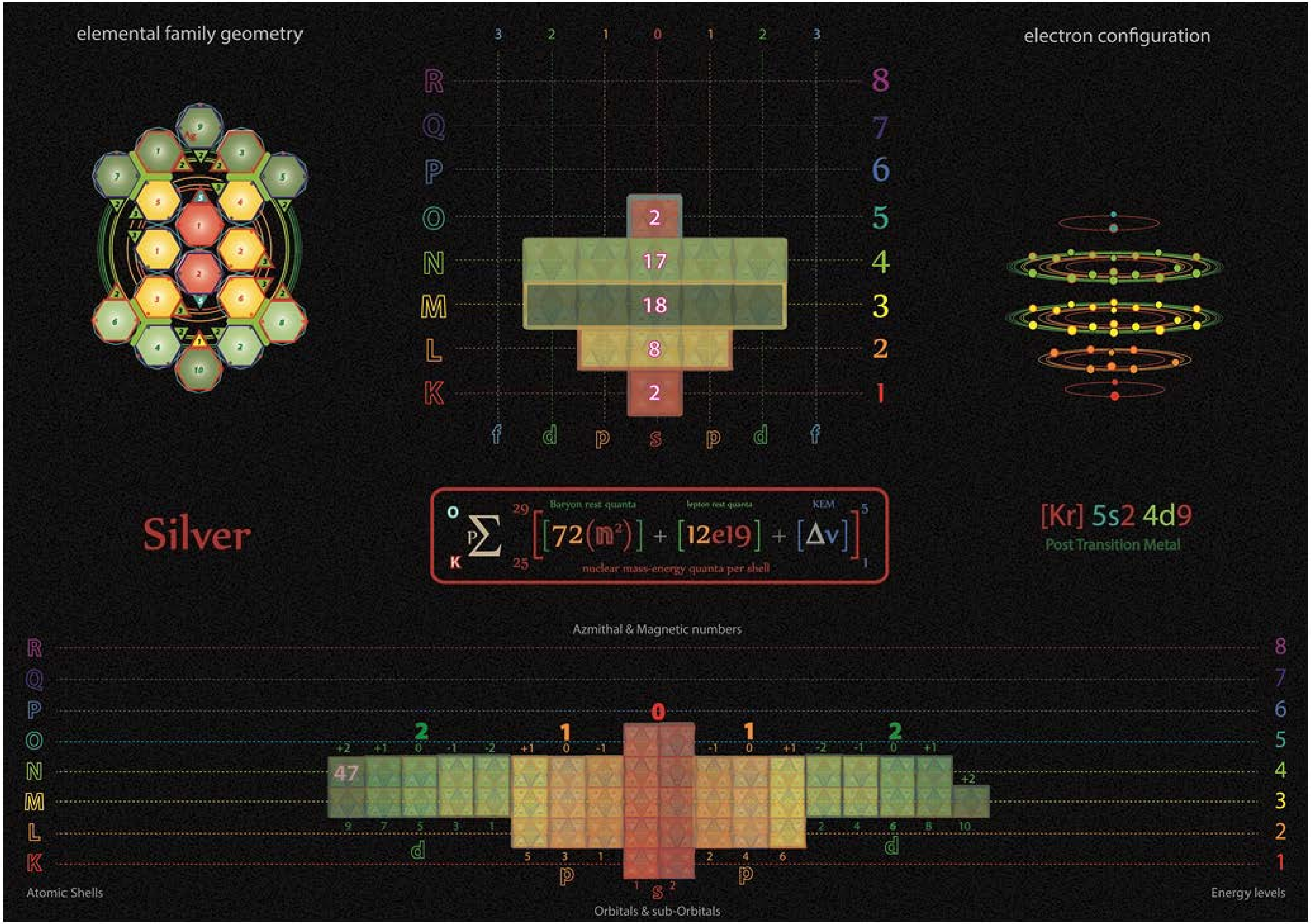

elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
17
18
8
2
f d p s p d f
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
2 1 0 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
47
9 7 5 3 1 5 3 1 1 2 2 4 6 2 4 6 8 10
d p s p d
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Silver

$$ {}^{O}_{K}\,{}^{P}\!\sum_{25}^{29}\left[\,[72(m^2)] + [12e19] + [\Delta v]\,\right]_{1}^{5} $$

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Kr] 5s2 4d9

Post Transition Metal

Tetryonics 53.47 - Silver atomic config

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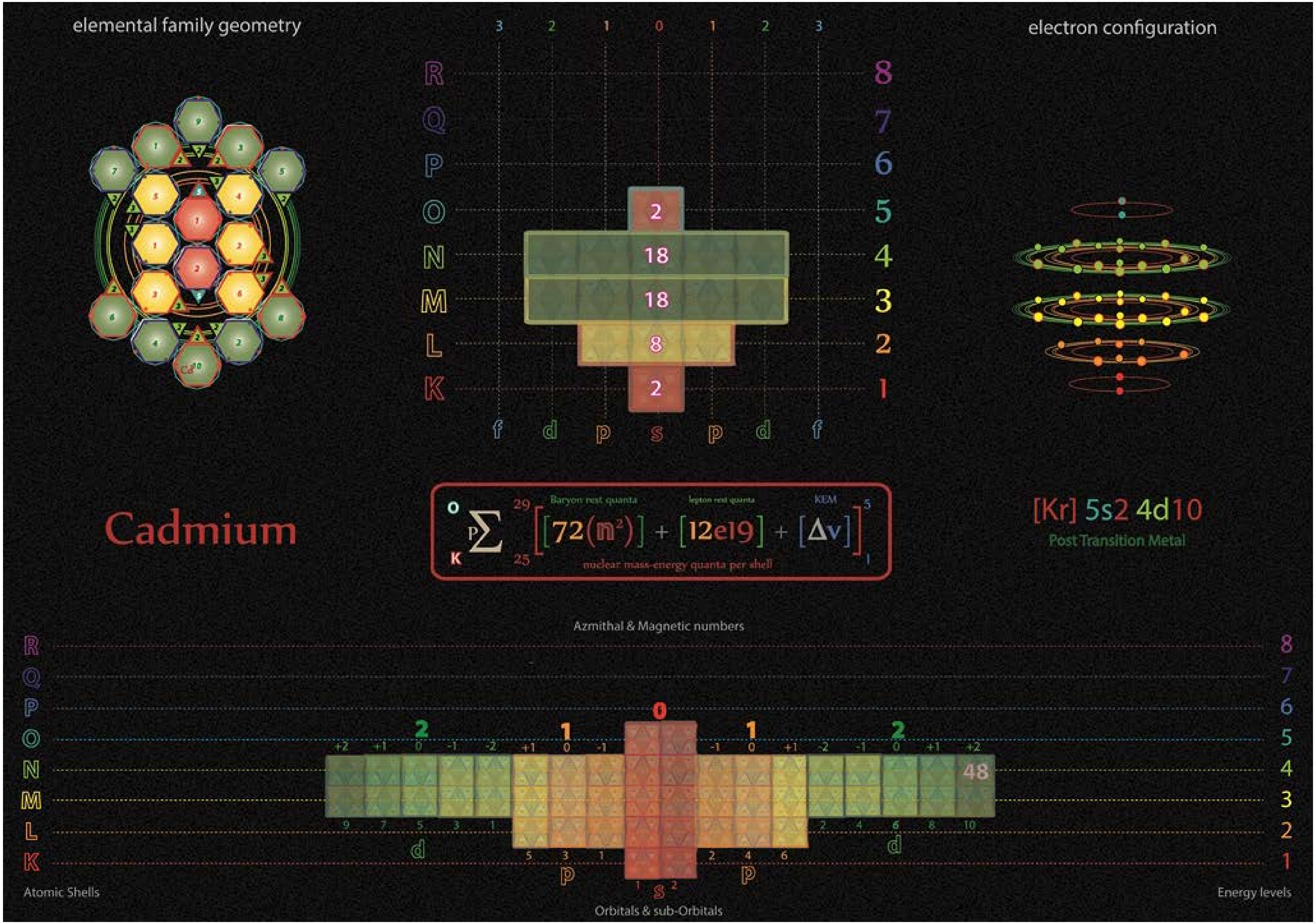
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
18
18
8
2
f d p s p d f
Cd 10
0
2 1 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
48
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2

elemental family geometry

electron configuration

Cadmium

$$\sideset{_{\mathrm{K}}^{\mathrm{O}}}{}{\sum}_{\mathrm{P}} \; {}^{29}_{25}\left[\overset{\text{Baryon rest quanta}}{[72(\mathrm{n}^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]}\right]^{5}_{1}$$

nuclear mass-energy quanta per shell

[Kr] 5s2 4d10

Post Transition Metal

Azmithal & Magnetic numbers

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.48 - Cadmium atomic config

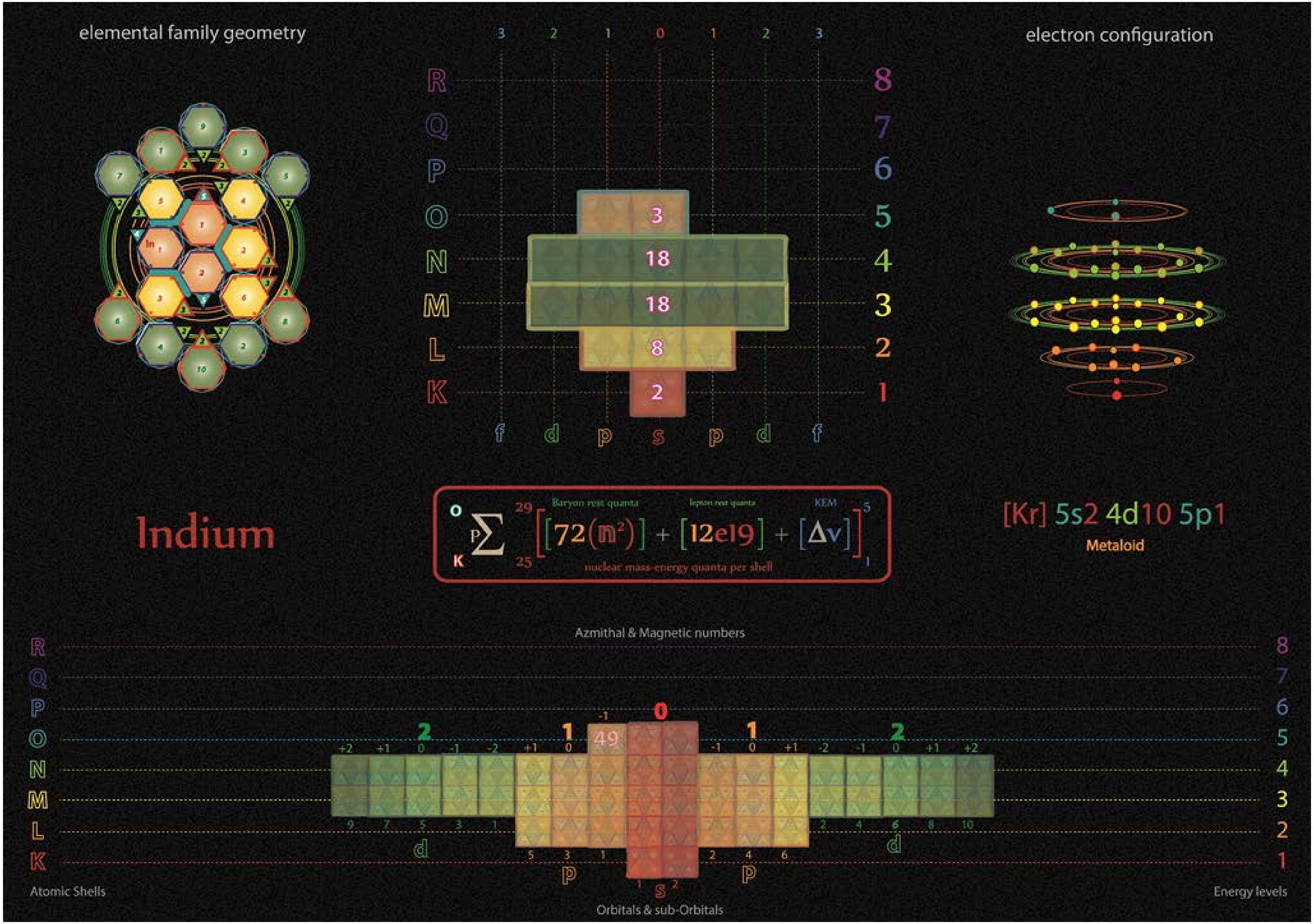
elemental family geometry
electron configuration
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3
18
18
8
2
f
d
p
s
p
d
f
In

Indium

$$^{O}_{K}\,P\sum_{25}^{29}\Big[[72(m^2)] + [12e19] + [\Delta v]\Big]_{1}^{5}$$

Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell

[Kr] 5s2 4d10 5p1

Metaloid

Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
1
0
1
2
-1
49
+2
+1
0
-1
-2
+1
0
-1
0
+1
-2
-1
0
+1
+2
9
7
5
3
1
2
4
6
8
10
d
d
5
3
1
2
4
6
p
p
1
s
2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.49 - Indium atomic config

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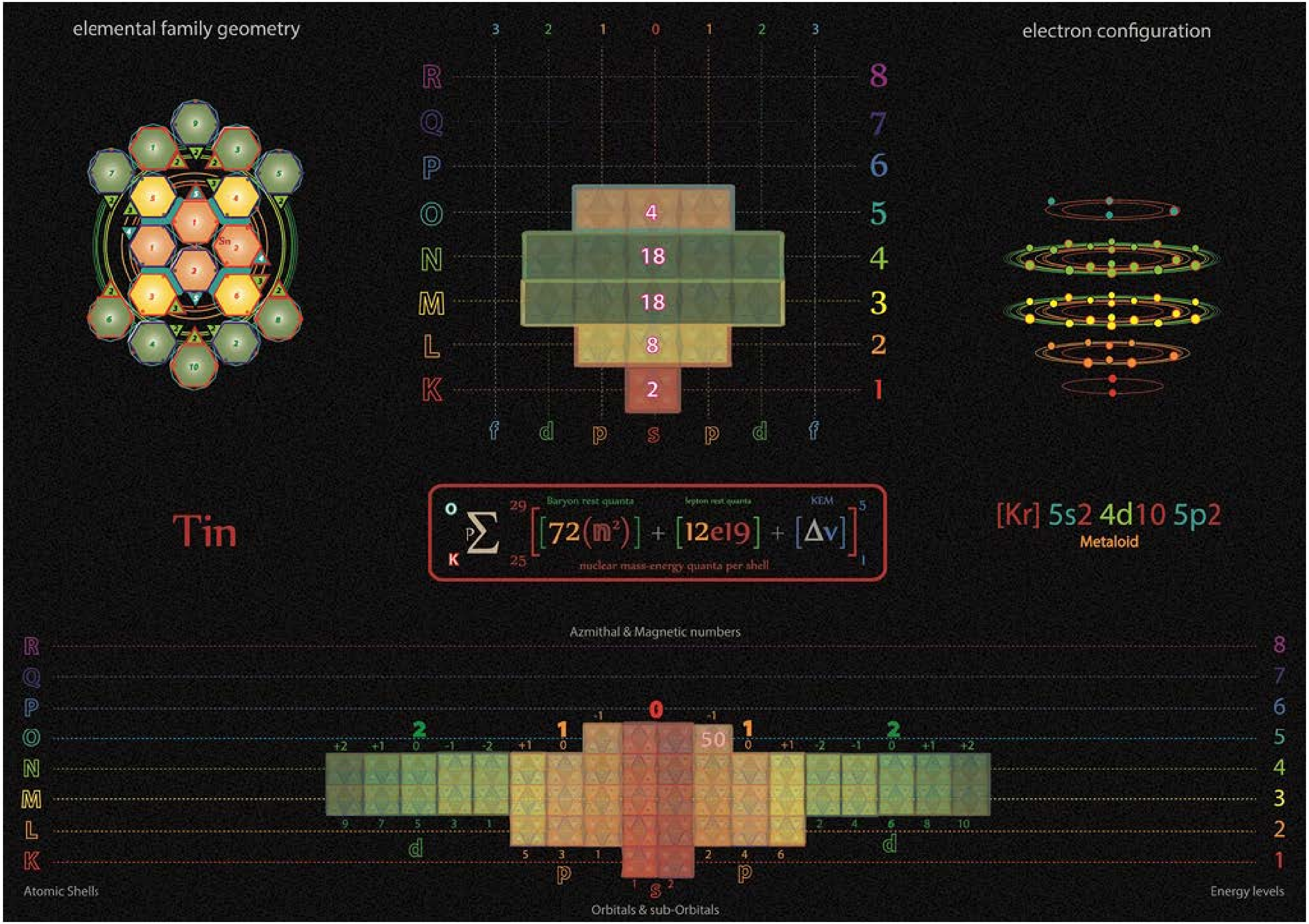
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
4
18
18
8
2
f d p s p d f
Sn
Tin
O
K
p
29
25
Baryon rest quanta
lepton rest quanta
KEM
5
1
[72(m²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
[Kr] 5s2 4d10 5p2
Metaloid
Azmithal & Magnetic numbers
2 1 0 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
50
9 7 5 3 1 5 3 1 2 4 6 2 4 6 8 10
d p s p d
1 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.50 - Tin atomic config

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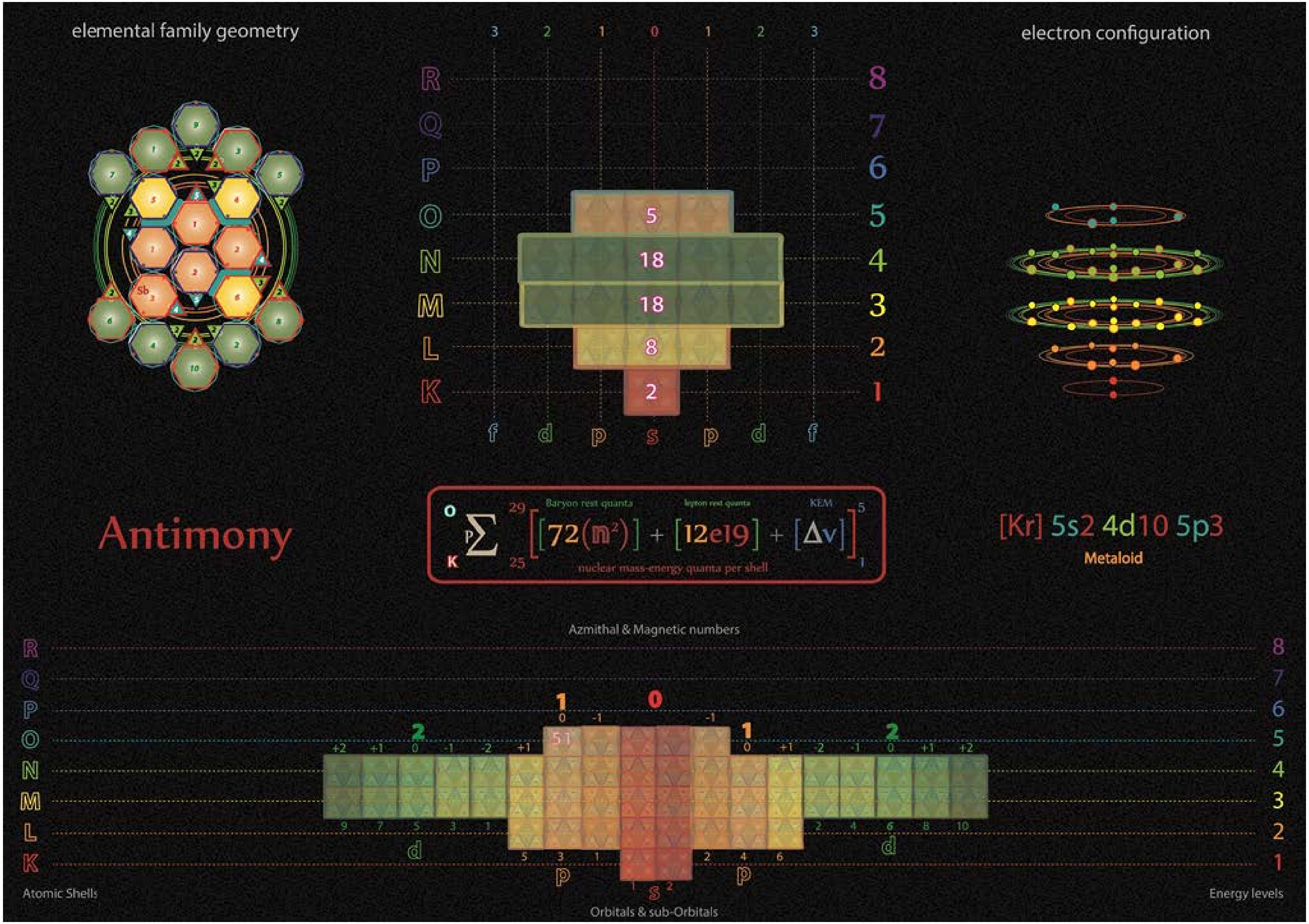
elemental family geometry
electron configuration
Antimony
Sb
[Kr] 5s2 4d10 5p3
Metaloid
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
5
18
18
8
2
f d p s p d f
Baryon rest quanta
lepton rest quanta
KEM
O
K
P
29
25
5
1
[72(m²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
Azmithal & Magnetic numbers
Atomic Shells
Energy levels
Orbitals & sub-Orbitals
2 1 0 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
51
9 7 5 3 1 5 3 1 1 2 2 4 6 2 4 6 8 10
d p s p d

Tetryonics 53.51 - Antimony atomic config

elemental family geometry

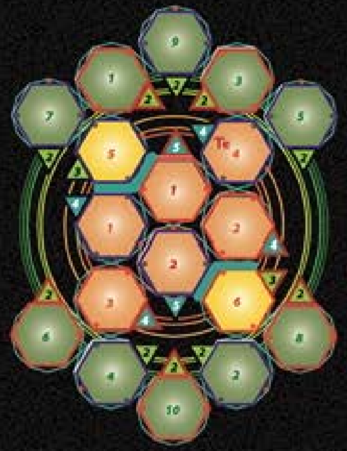

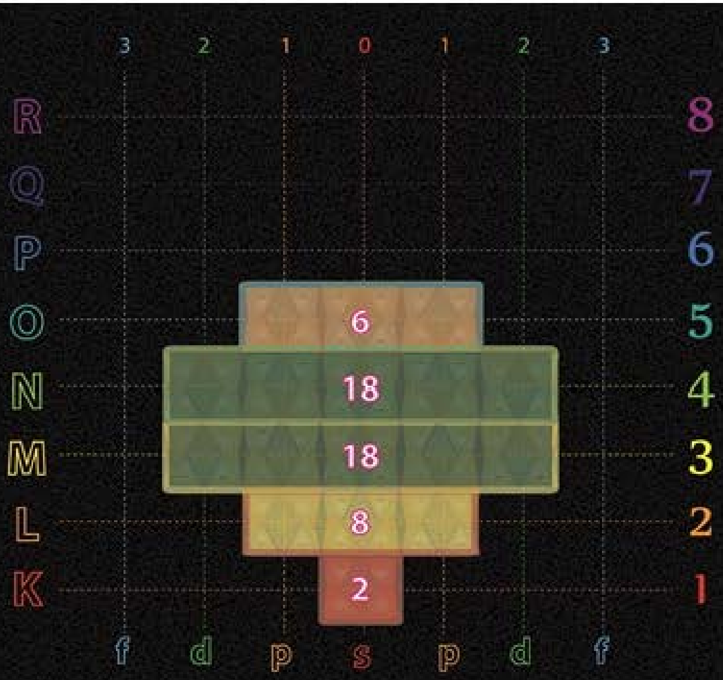
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
6
18
18
8
2
f
d
p
s
p
d
f

electron configuration

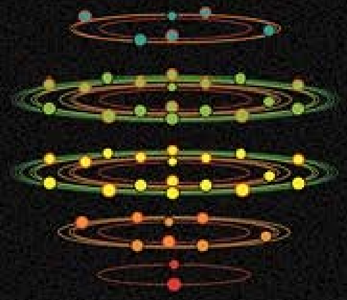

Tellurium

$${}^{O}_{K}\sum P \sum_{25}^{29} \left[[72(n^2)] + [12e19] + [\Delta v] \right]_{1}^{5}$$

Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[Kr] 5s2 4d10 5p4

Metaloid

Azmithal & Magnetic numbers

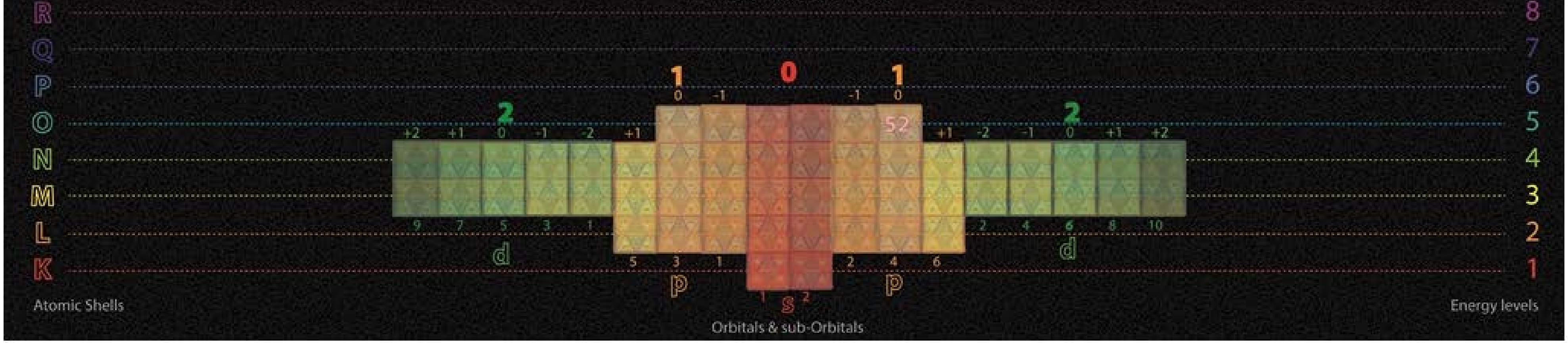
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
1
0
1
2
+2
+1
0
-1
-2
+1
0
-1
-1
0
52
+1
-2
-1
0
+1
+2
9
7
5
3
1
2
4
6
8
10
d
5
3
1
2
4
6
p
p
1
s
2
d

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.52 - Tellurium atomic config

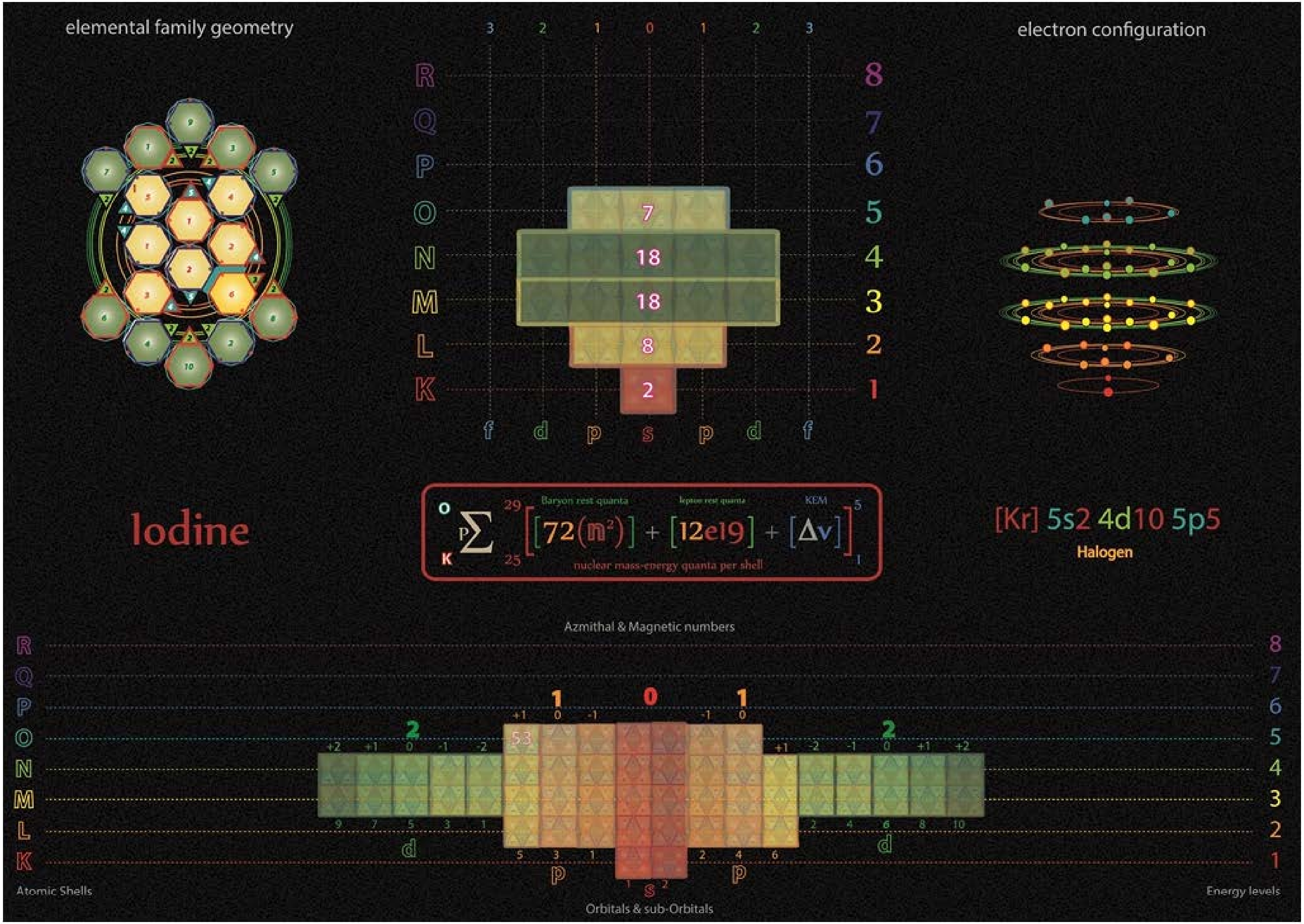
elemental family geometry
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
7
18
18
8
2
f d p s p d f
electron configuration
Iodine
O
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(n²)] + [12e19] + [Δv]
5
1
nuclear mass-energy quanta per shell
[Kr] 5s2 4d10 5p5
Halogen
Azmithal & Magnetic numbers
2 1 0 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
53
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 2
s
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.53 - Iodine atomic config

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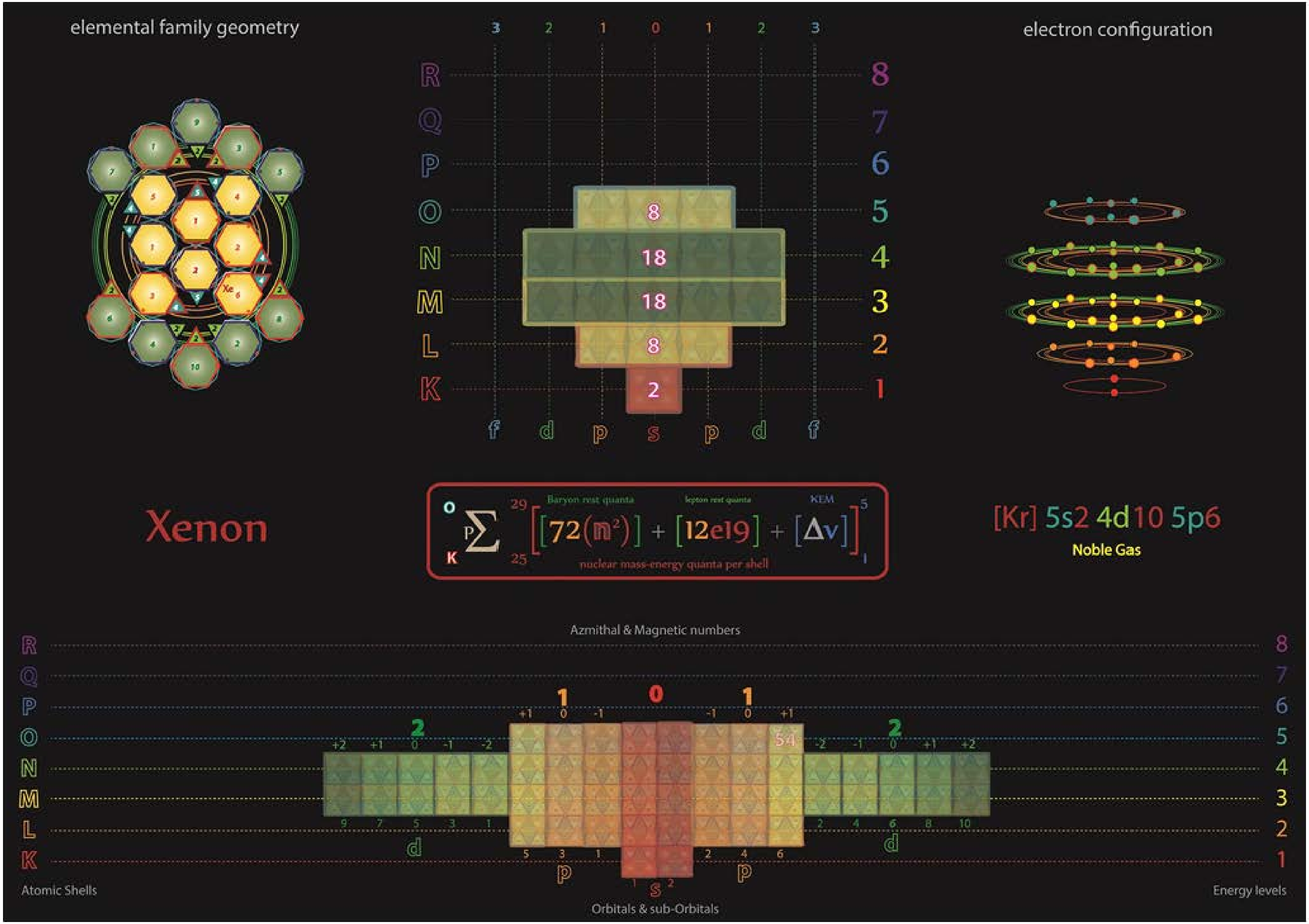
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
8
18
18
8
2
f d p s p d f
Xenon
O
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
5
1
nuclear mass-energy quanta per shell
[Kr] 5s2 4d10 5p6
Noble Gas
Azmithal & Magnetic numbers
1 0 1
2 2
+1 0 -1 -1 0 +1
+2 +1 0 -1 -2 -2 -1 0 +1 +2
54
9 7 5 3 1 2 4 6 8 10
5 3 1 2 4 6
d p s p d
1 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.54 - Xenon atomic config

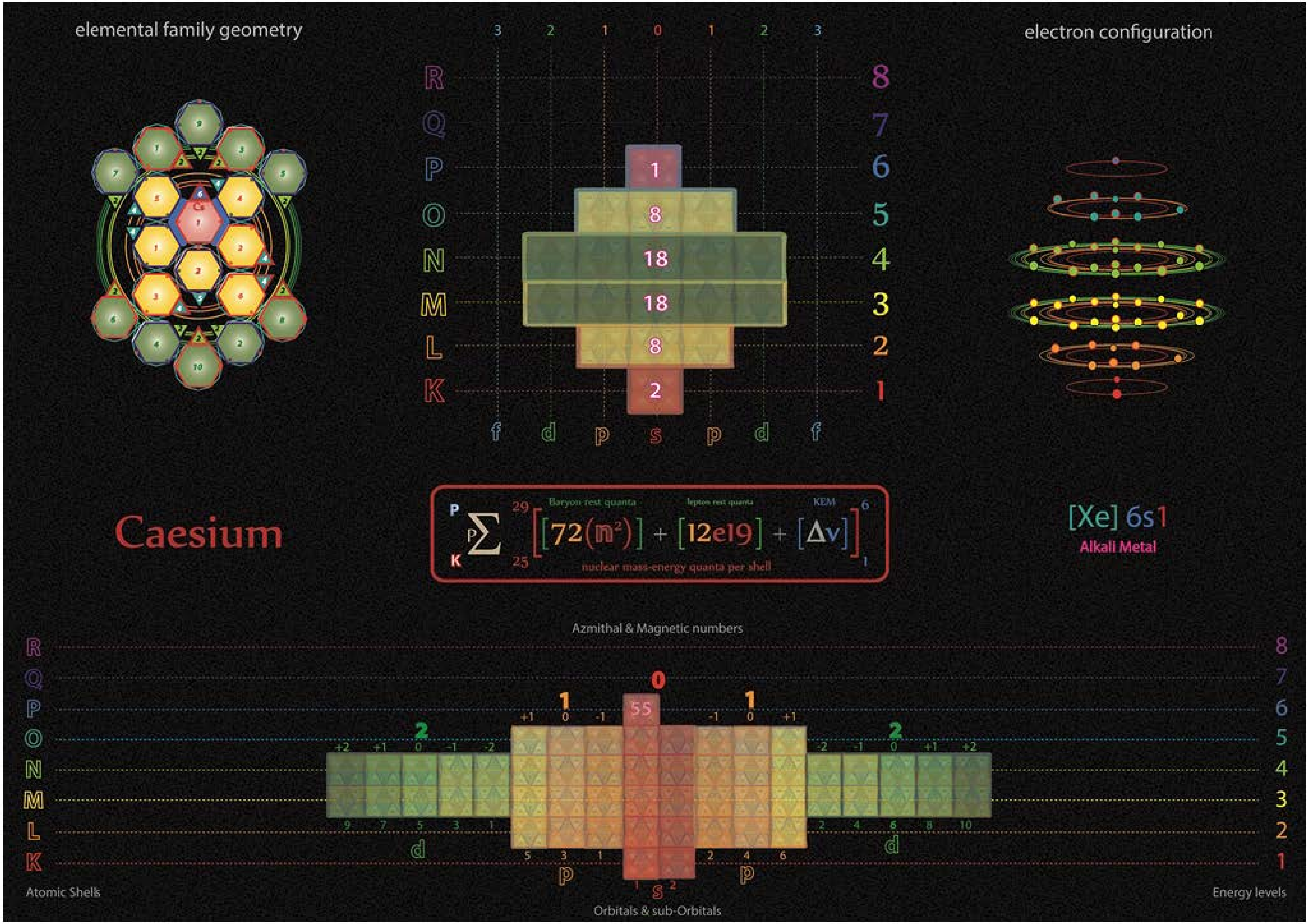
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
1
8
18
18
8
2
f d p s p d f
Caesium
[Xe] 6s1
Alkali Metal
Azmithal & Magnetic numbers
0
1
1
2
2
55
+1 0 -1
-1 0 +1
+2 +1 0 -1 -2
-2 -1 0 +1 +2
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
d
p
s
1 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

$$\sum_{K}^{P} {}_{P}\!\!\sum_{25}^{29}\left[\left[72(n^2)\right] + \left[12e19\right] + \left[\Delta v\right]\right]_{1}^{6}$$

Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell

Tetryonics 53.55 - Caesium atomic config

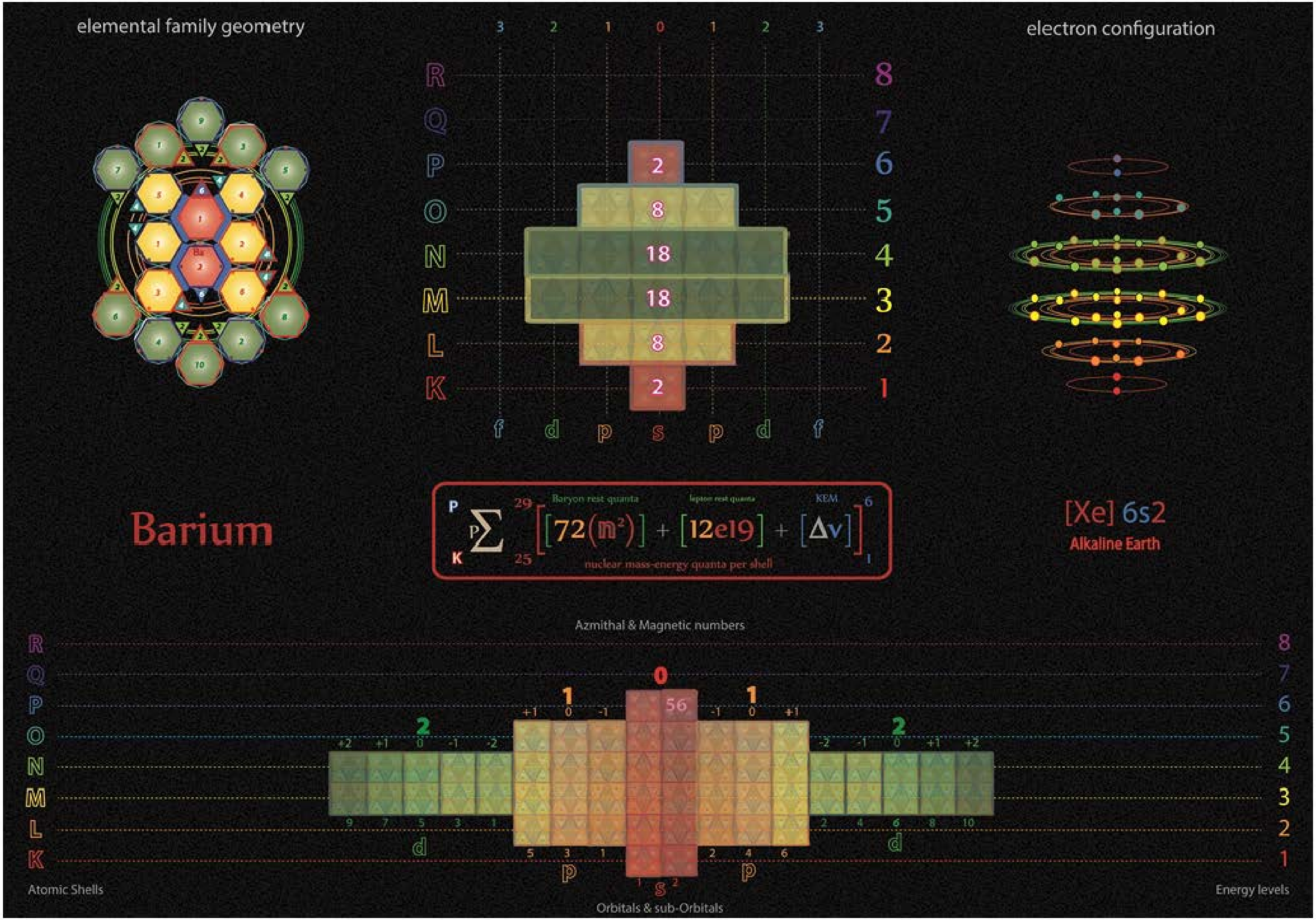
elemental family geometry
Ba
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
18
18
8
2
f d p s p d f
electron configuration
Barium
P
K
$\sum_{K}^{P} {}_{p}\sum_{25}^{29}\left[[72(\mathfrak{m}^2)] + [12e19] + [\Delta v]\right]_{1}^{6}$
Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell
[Xe] 6s2
Alkaline Earth
Azmithal & Magnetic numbers
0
56
1 1
+1 0 -1 -1 0 +1
2 2
+2 +1 0 -1 -2 -2 -1 0 +1 +2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.56 - Barium atomic config

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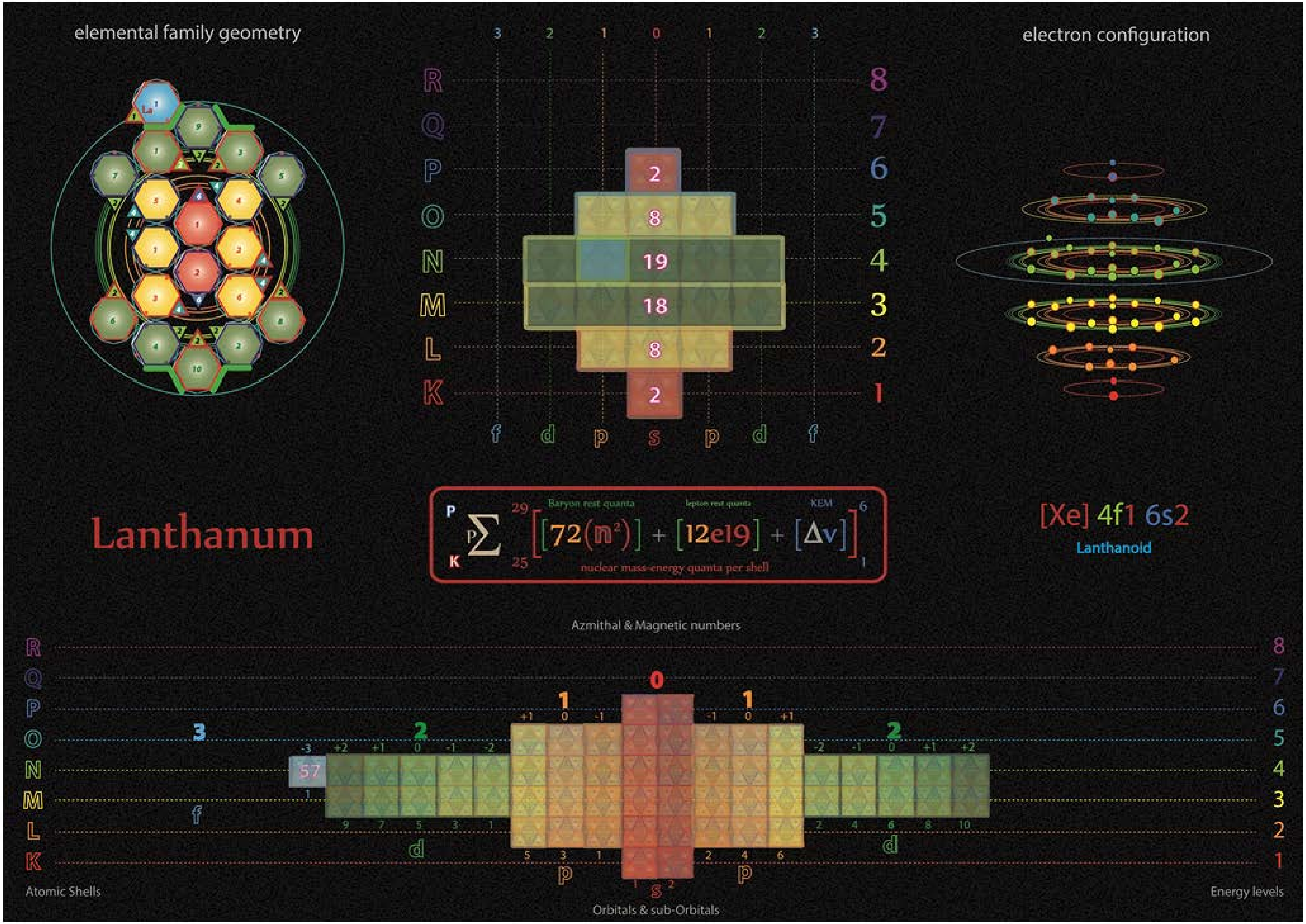
elemental family geometry
La
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
19
18
8
2
f d p s p d f
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
3
2
1
0
1
2
57
f
d
p
s
p
d
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Lanthanum

$$ {}_{K}^{P} \mathrm{p}\sum_{25}^{29}\left[[72(\mathrm{n}^2)] + [12e19] + [\Delta v]\right]_{1}^{6} $$

Baryon rest quanta

lepton rest quanta

KEM

nuclear mass-energy quanta per shell

[Xe] 4f1 6s2

Lanthanoid

Tetryonics 53.57 - Lanthanum atomic config

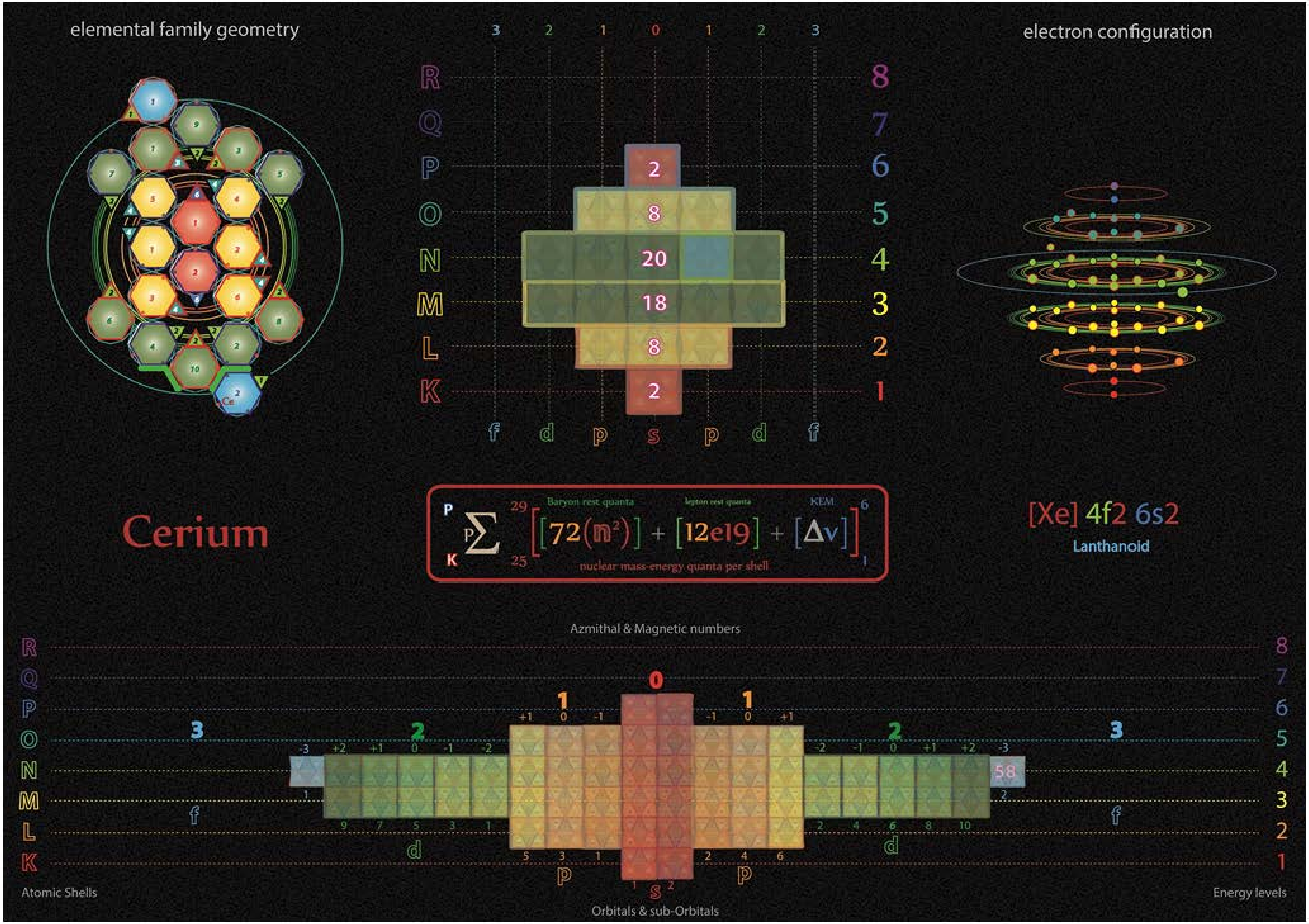
elemental family geometry
Ce
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
20
18
8
2
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
-3 +2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2 -3
58
1 2
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Cerium

$$\underset{K}{\overset{P}{}}\ {}_{P}\sum_{25}^{29}\left[\overset{\text{Baryon rest quanta}}{[72(n^2)]}+\overset{\text{lepton rest quanta}}{[12e19]}+\overset{\text{KEM}}{[\Delta v]}\right]_{1}^{6}$$

nuclear mass-energy quanta per shell

[Xe] 4f2 6s2

Lanthanoid

Tetryonics 53.58 - Cerium atomic config

elemental family geometry

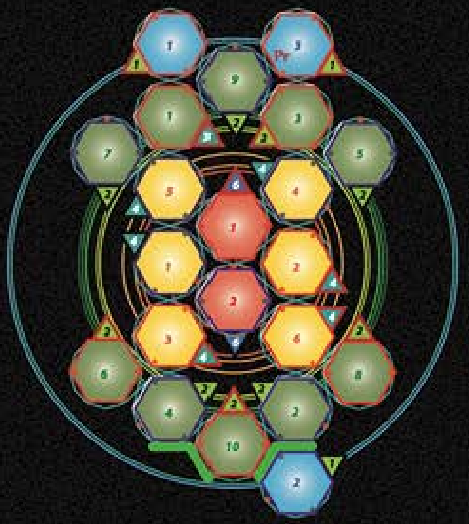

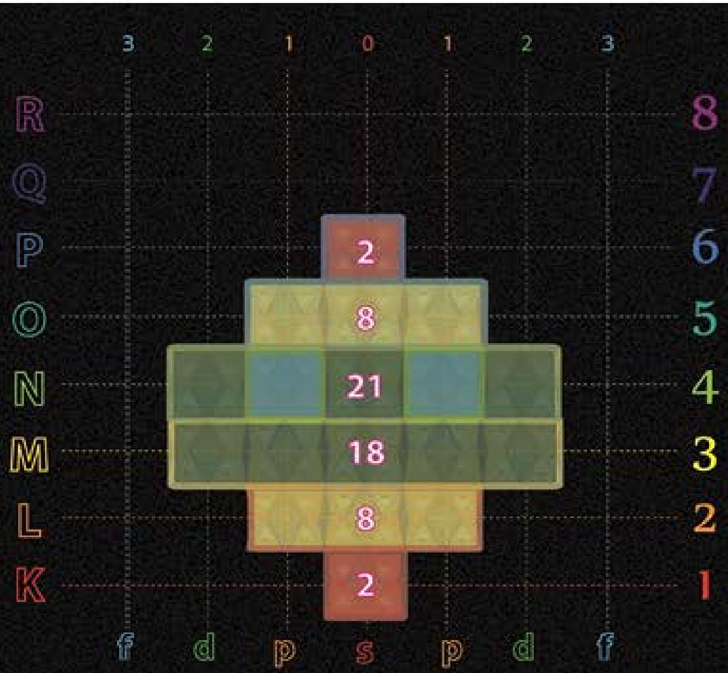
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
2
8
21
18
8
2
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

electron configuration

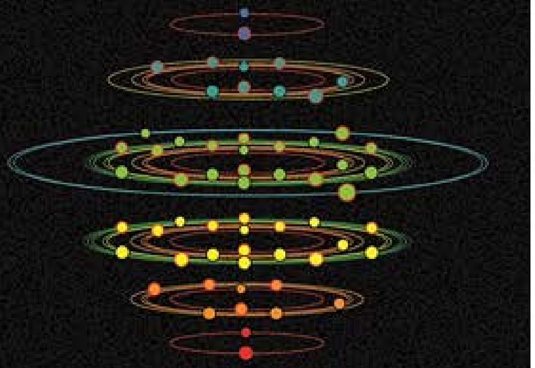

Praseodymium

Baryon rest quanta — lepton rest quanta — KEM

$$\sum_{K}^{P} {}_{25}^{29}\left[72(\mathrm{m}^2)\right] + \left[12e19\right] + \left[\Delta v\right]_{1}^{6}$$

nuclear mass-energy quanta per shell

[Xe] 4f3 6s2

Lanthanoid

Azmithal & Magnetic numbers

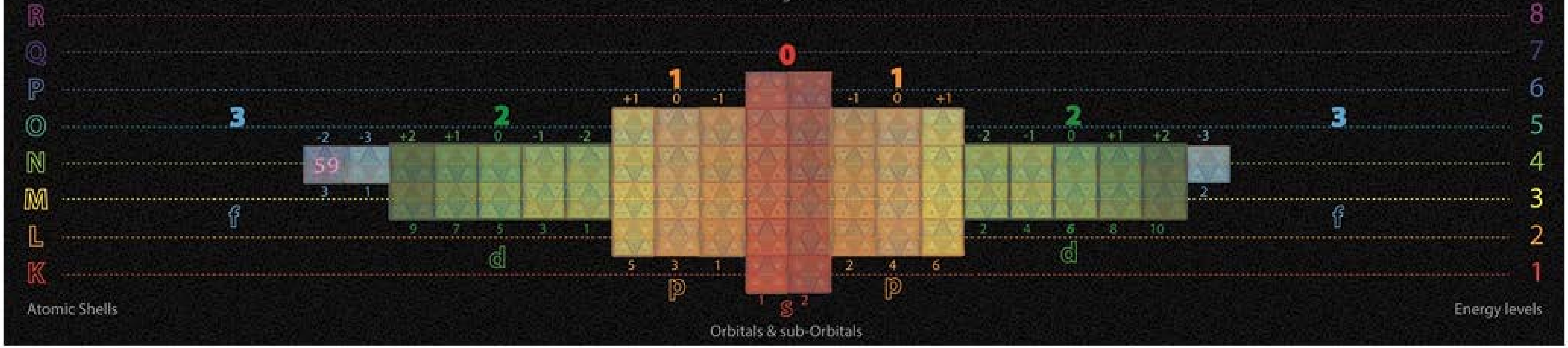
R
Q
P
O
N
M
L
K
0
1
1
2
2
3
3
+1
0
-1
-1
0
+1
-2
-3
+2
+1
0
-1
-2
-2
-1
0
+1
+2
-3
59
3
1
2
9
7
5
3
1
2
4
6
8
10
5
3
1
2
4
6
1
2
f
d
p
s
p
d
f
8
7
6
5
4
3
2
1
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.59 - Praseodymium atomic config

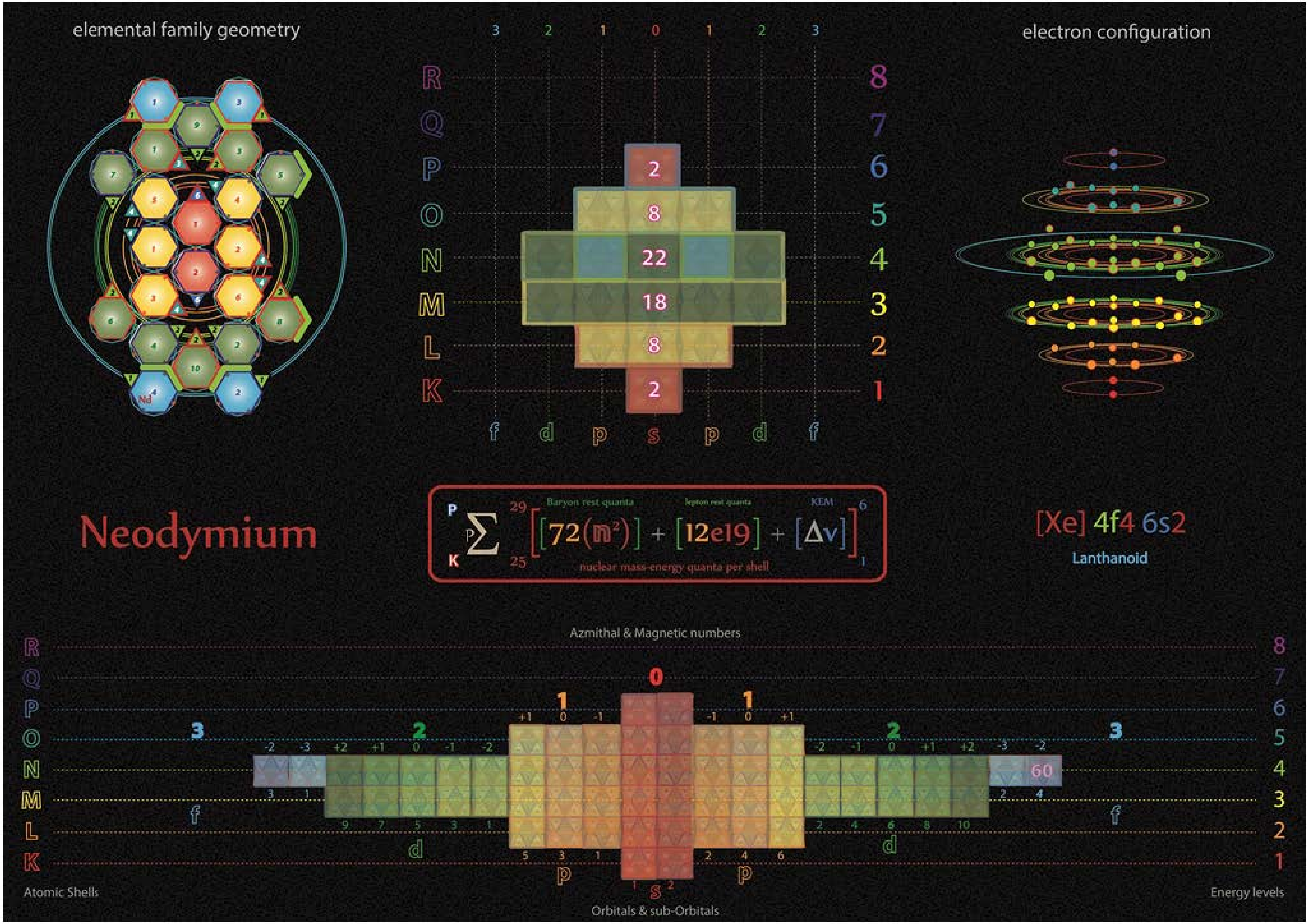
elemental family geometry
Nd
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
22
18
8
2
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
0
1 1
3 2 2 3
+1 0 -1 -1 0 +1
-2 -3 +2 +1 0 -1 -2 -2 -1 0 +1 +2 -3 -2
60
3 1 2 4
9 7 5 3 1 2 4 6 8 10
5 3 1 2 4 6
f d p s p d f
1 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Neodymium

$$ {}^{P}_{K}\,{}_{p}\sum_{25}^{29}\left[\underset{\text{Baryon rest quanta}}{[72(m^2)]}+\underset{\text{lepton rest quanta}}{[12e19]}+\underset{\text{KEM}}{[\Delta v]}\right]_{1}^{6} $$

nuclear mass-energy quanta per shell

[Xe] 4f4 6s2

Lanthanoid

Tetryonics 53.60 - Neodymium atomic config

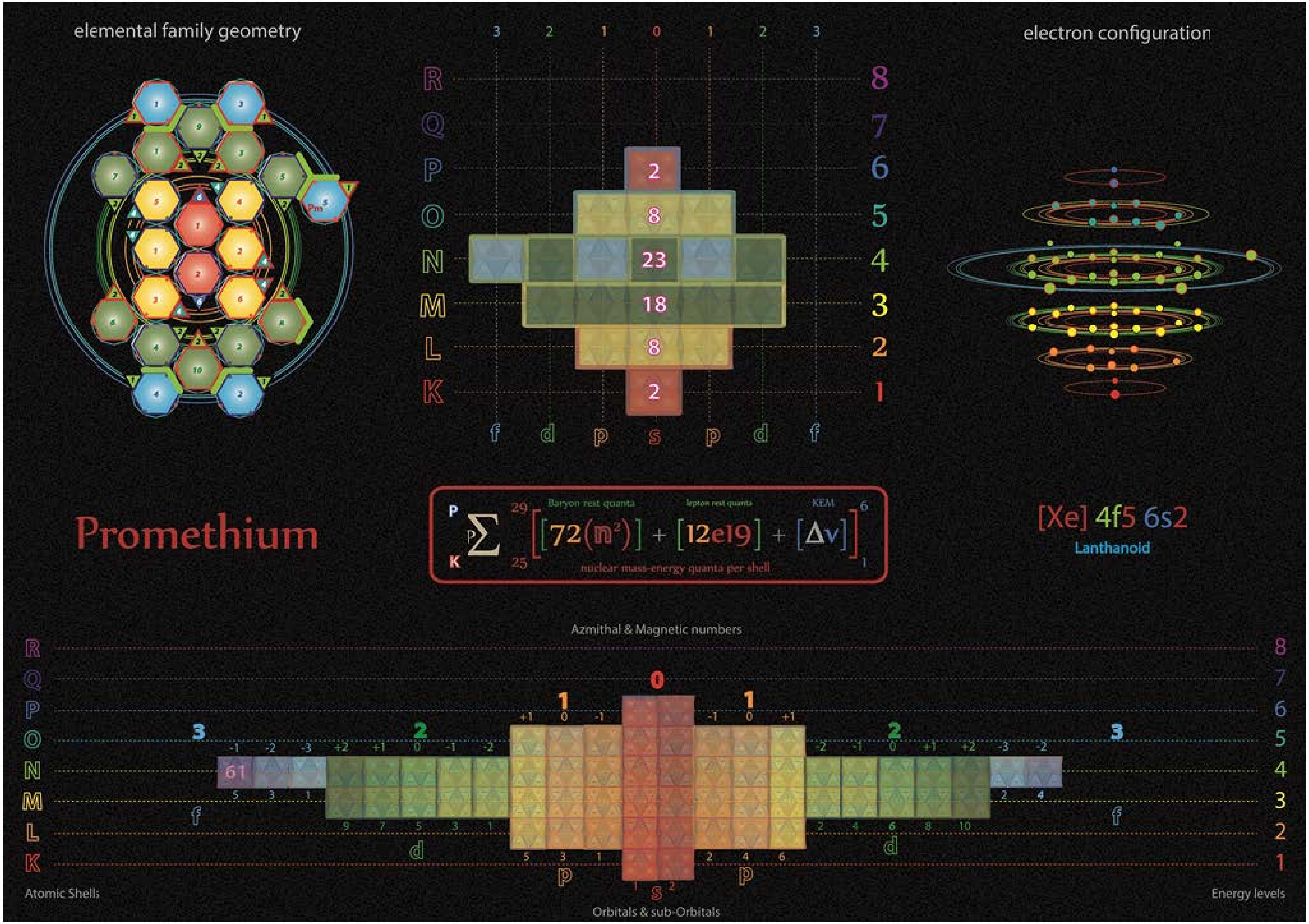
elemental family geometry
Pm
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
8
23
18
8
2
f
d
p
s
p
d
f
electron configuration
Azmithal & Magnetic numbers
Atomic Shells
Energy levels
Orbitals & sub-Orbitals
61

Promethium

$$\sum_{K}^{P} {}^{29}_{25}\left[72(m^2)\right]+\left[12e19\right]+\left[\Delta v\right]^{6}_{1}$$

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Xe] 4f5 6s2

Lanthanoid

Tetryonics 53.61 - Promethium atomic config

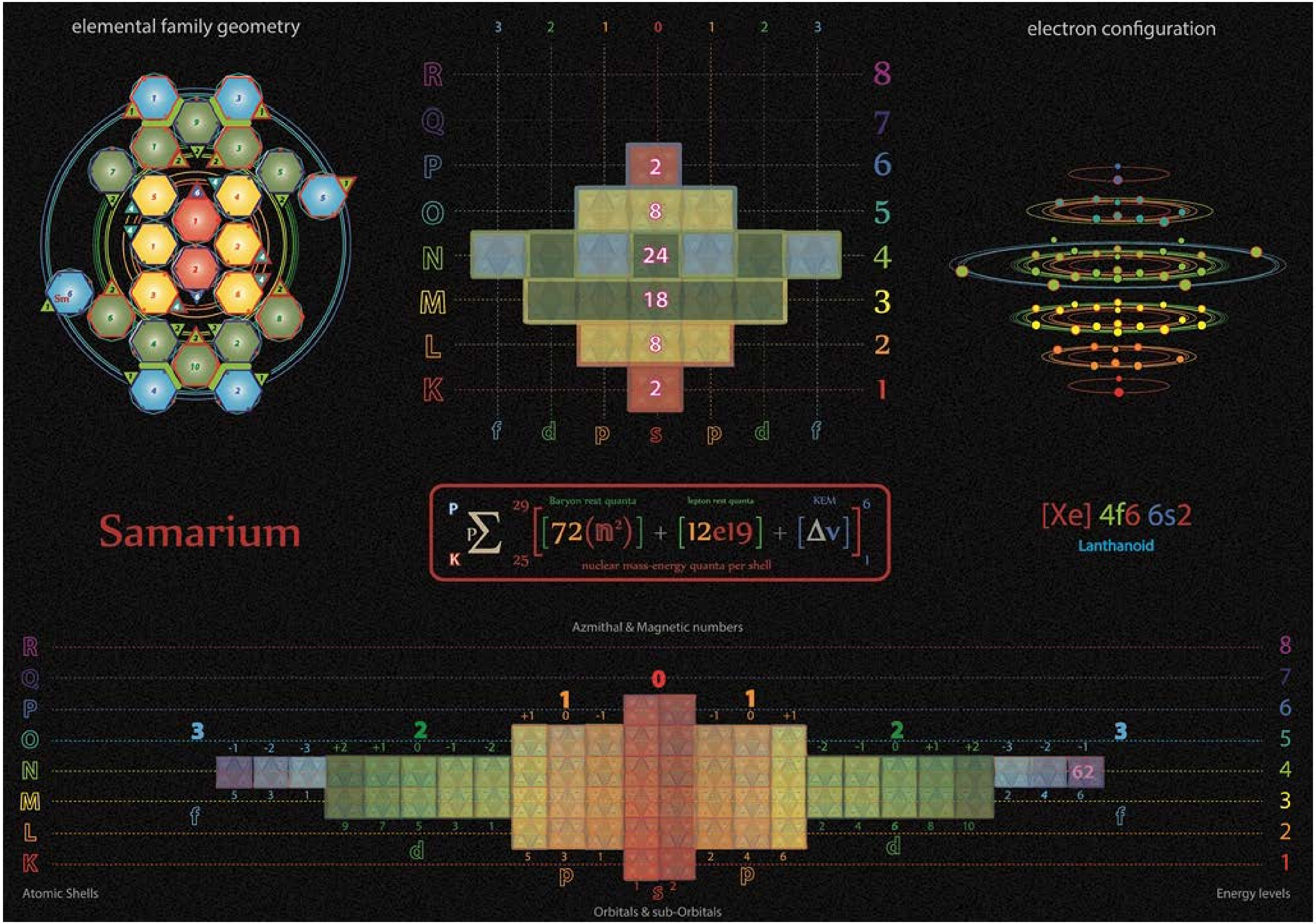
elemental family geometry
Sm
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
24
18
8
2
f d p s p d f
Samarium
P
K
29
25
6
1
Baryon rest quanta
lepton rest quanta
KEM
P∑ [72(m²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
[Xe] 4f6 6s2
Lanthanoid
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+1 0 -1 -1 0 +1
-1 -2 -3 +2 +1 0 -1 -2 -2 -1 0 +1 +2 -3 -2 -1
62
5 3 1 2 4 6
9 7 5 3 1 2 4 6 8 10
5 3 1 2 4 6
1 2
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.62 - Samarium atomic config

elemental family geometry

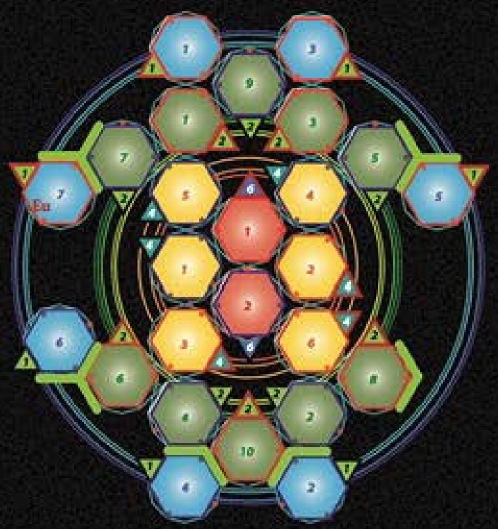

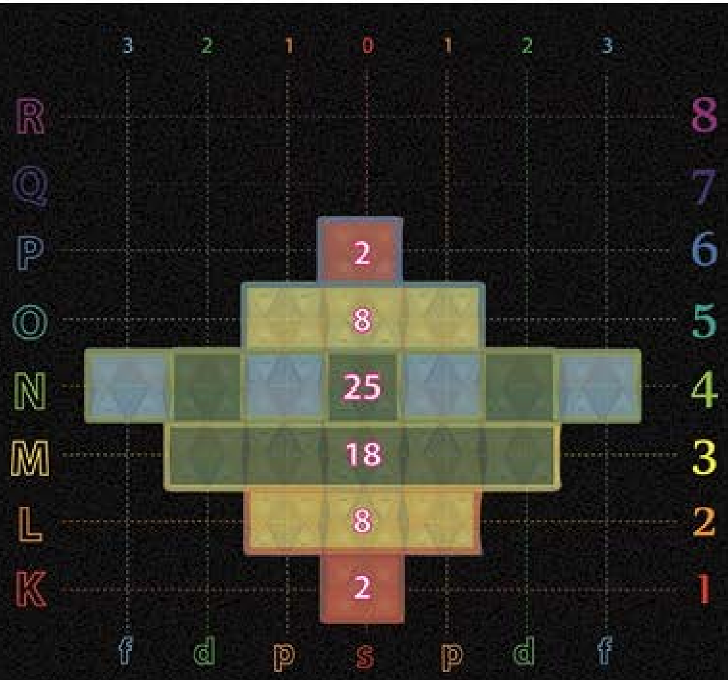
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
25
18
8
2
f d p s p d f

electron configuration

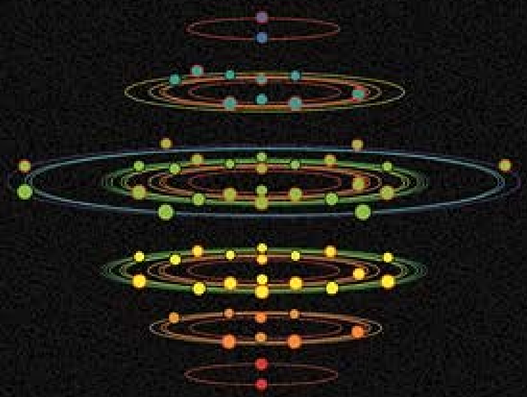

Europium

Baryon rest quanta — lepton rest quanta — KEM

$$\sum_{K}^{P} {}_{25}^{29}\left[\,[72(\text{m}^2)] + [12e19] + [\Delta v]\,\right]_{1}^{6}$$

nuclear mass-energy quanta per shell

[Xe] 4f7 6s2

Lanthanoid

Azmithal & Magnetic numbers

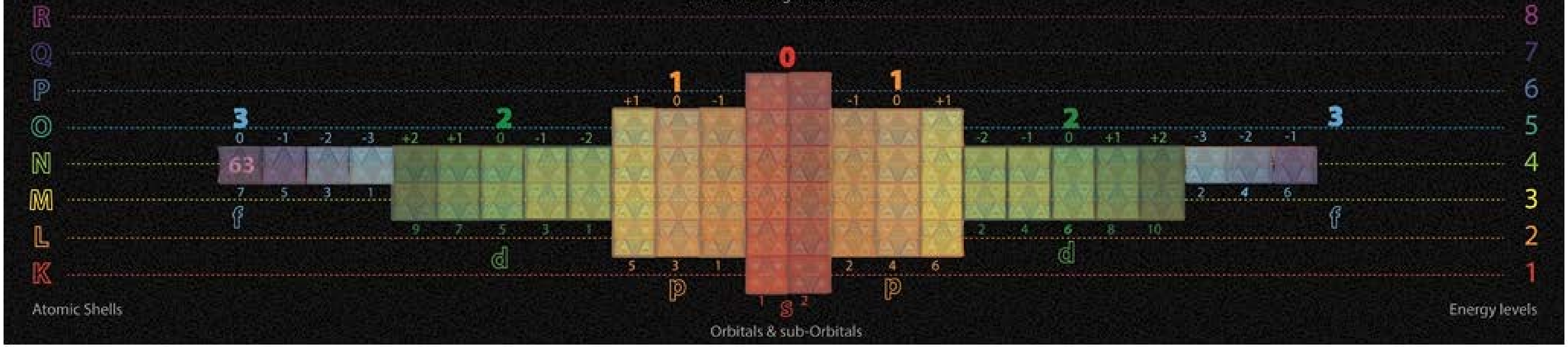
R Q P O N M L K
8 7 6 5 4 3 2 1
0
1 1
+1 0 -1 -1 0 +1
2 2
+2 +1 0 -1 -2 -2 -1 0 +1 +2
3 3
0 -1 -2 -3 -3 -2 -1
63
7 5 3 1 2 4 6
f f
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

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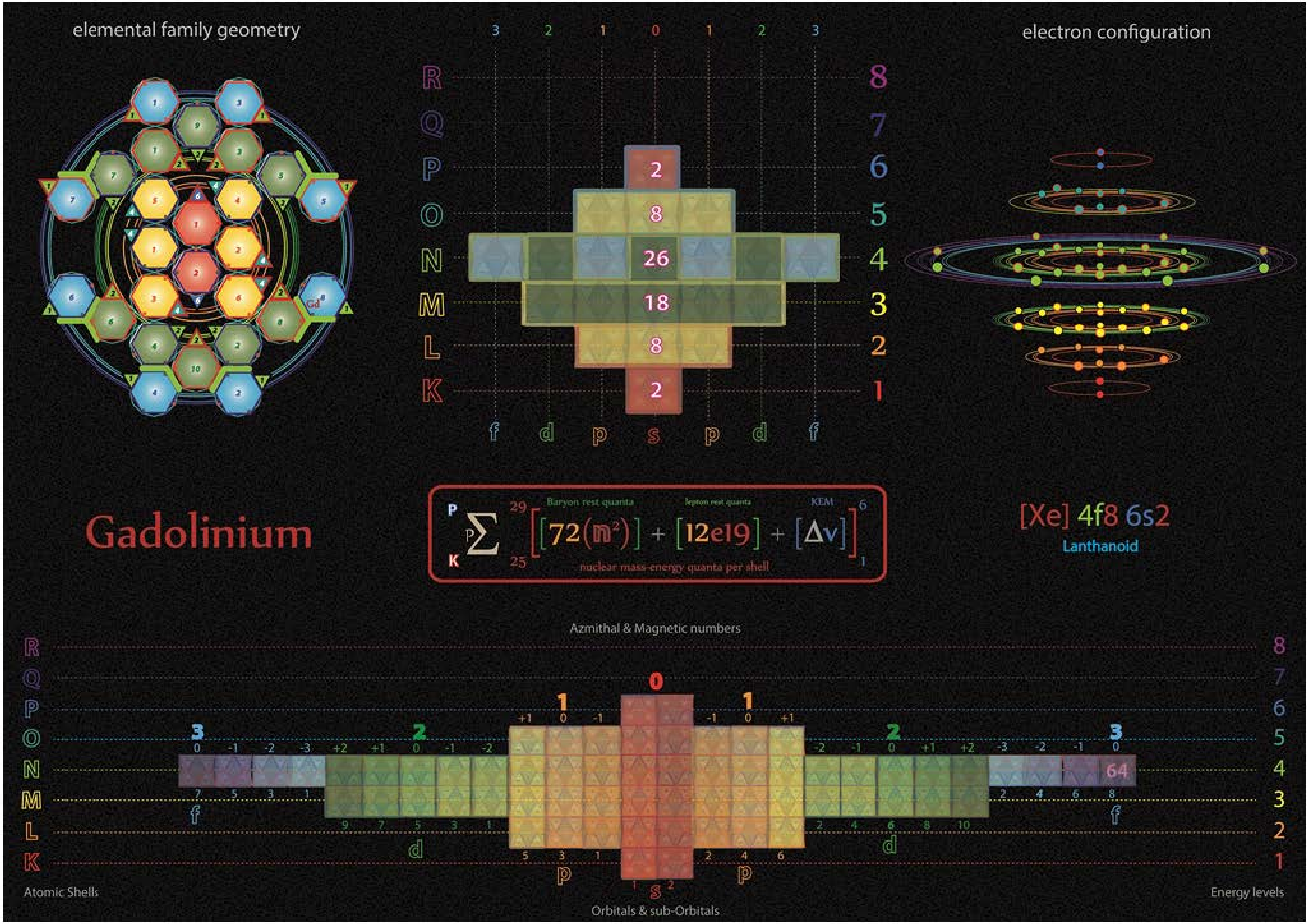
elemental family geometry
electron configuration
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
2
8
26
18
8
2
f d p s p d f
Azmithal & Magnetic numbers
0
1
-1 0 +1
2
-2 -1 0 +1 +2
3
-3 -2 -1 0
64
f
d
p
s
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Gadolinium

$$\sum_{K}^{P} \, {}^{29}_{25}\left[[72(m^2)] + [12e19] + [\Delta v] \right]^{6}_{1}$$

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Xe] 4f8 6s2

Lanthanoid

Tetryonics 53.64 - Gadolinium atomic config

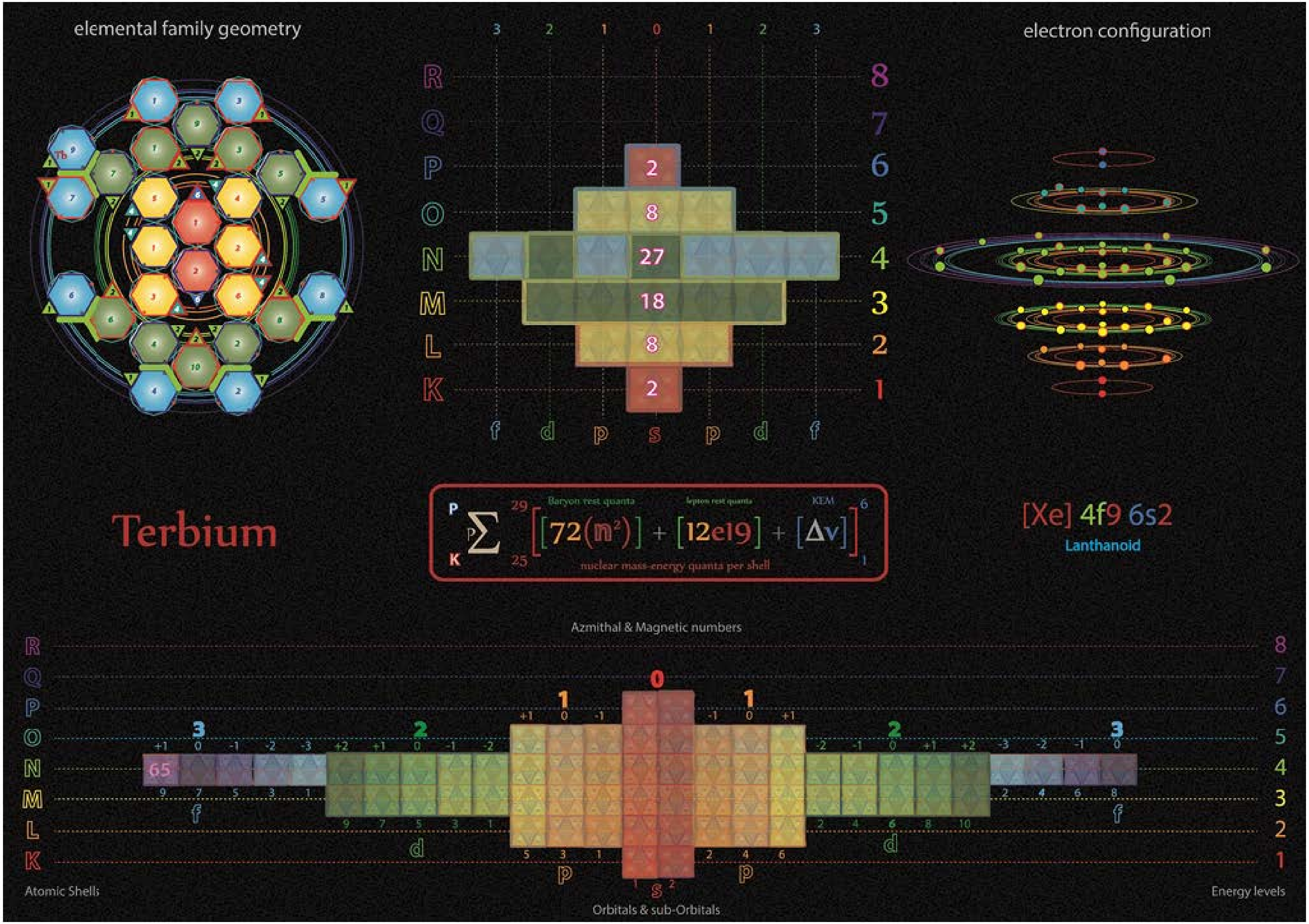
elemental family geometry
Tb
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
27
18
8
2
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
0
1
1
+1 0 -1
-1 0 +1
2
2
3
3
65
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Terbium

$$\sum_{K}^{P} {}_{p}\sum_{25}^{29} \left[\overset{\text{Baryon rest quanta}}{[72(m^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]} \right]_{1}^{6}$$

nuclear mass-energy quanta per shell

[Xe] 4f9 6s2

Lanthanoid

Tetryonics 53.65 - Terbium atomic config

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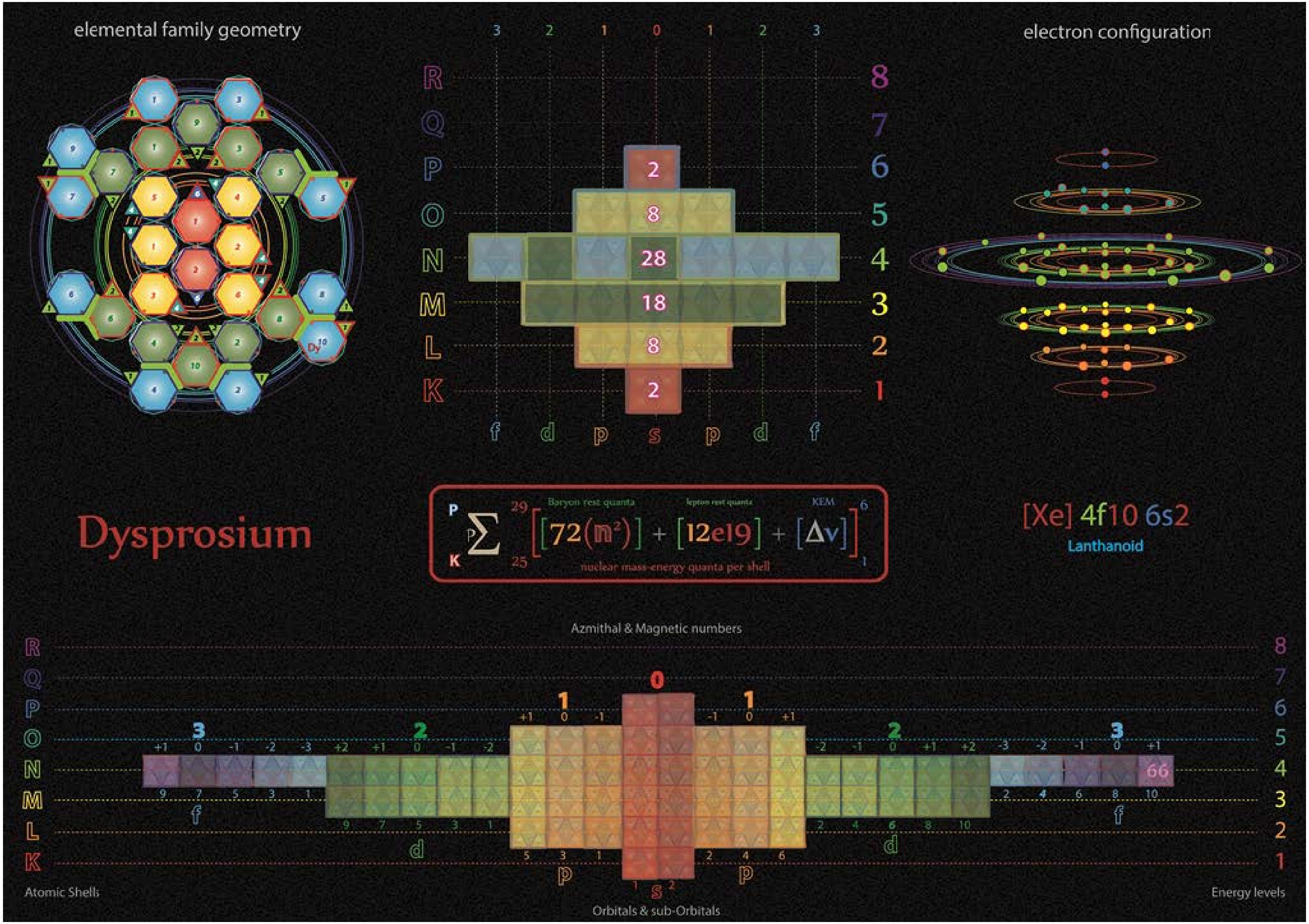
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
28
18
8
2
f d p s p d f
Dy 10
Dysprosium
P
K
29
25
Baryon rest quanta
lepton rest quanta
KEM
$\sum_{K}^{P} {}_{25}^{29}\left[[72(m^2)] + [12e19] + [\Delta v] \right]_1^6$
nuclear mass-energy quanta per shell
[Xe] 4f10 6s2
Lanthanoid
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+1 0 -1 -2 -3 +2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2 -3 -2 -1 0 +1
66
9 7 5 3 1 2 4 6 8 10
9 7 5 3 1 2 4 6 8 10
5 3 1 2 4 6
1 2
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.66 - Dysprosium atomic config

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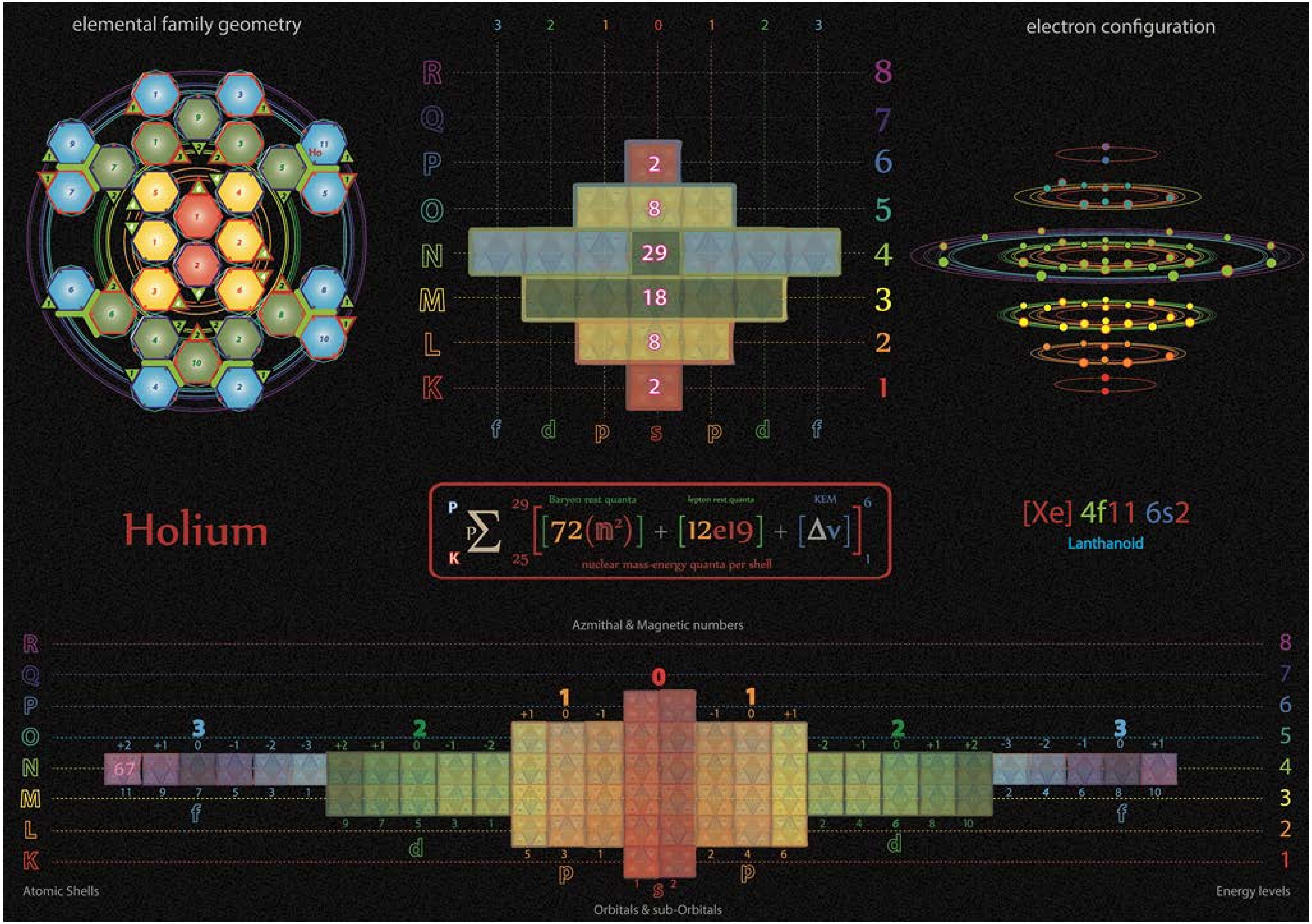
elemental family geometry
electron configuration
Ho
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
2
8
29
18
8
2
Holium
Baryon rest quanta
lepton rest quanta
KEM
P
K
29
25
6
1
[72(m²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
[Xe] 4f11 6s2
Lanthanoid
Azmithal & Magnetic numbers
67
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.67 - Holium atomic config

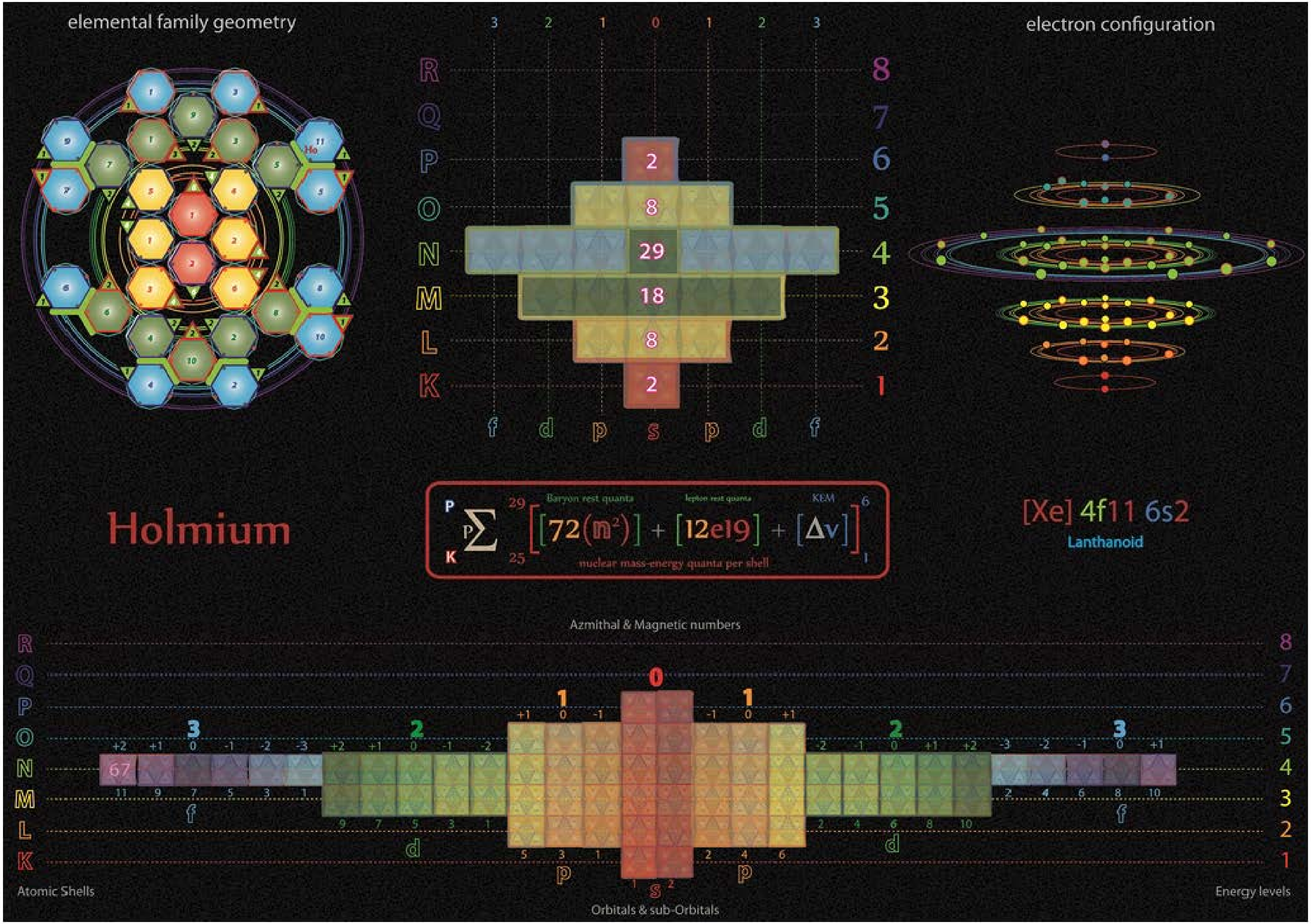
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
29
18
8
2
f d p s p d f
Holmium
P K
29 25
Baryon rest quanta
lepton rest quanta
KEM
[[72(m²)] + [12e19] + [Δv]]
nuclear mass-energy quanta per shell
[Xe] 4f11 6s2
Lanthanoid
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
67
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.67 - Holmium atomic config

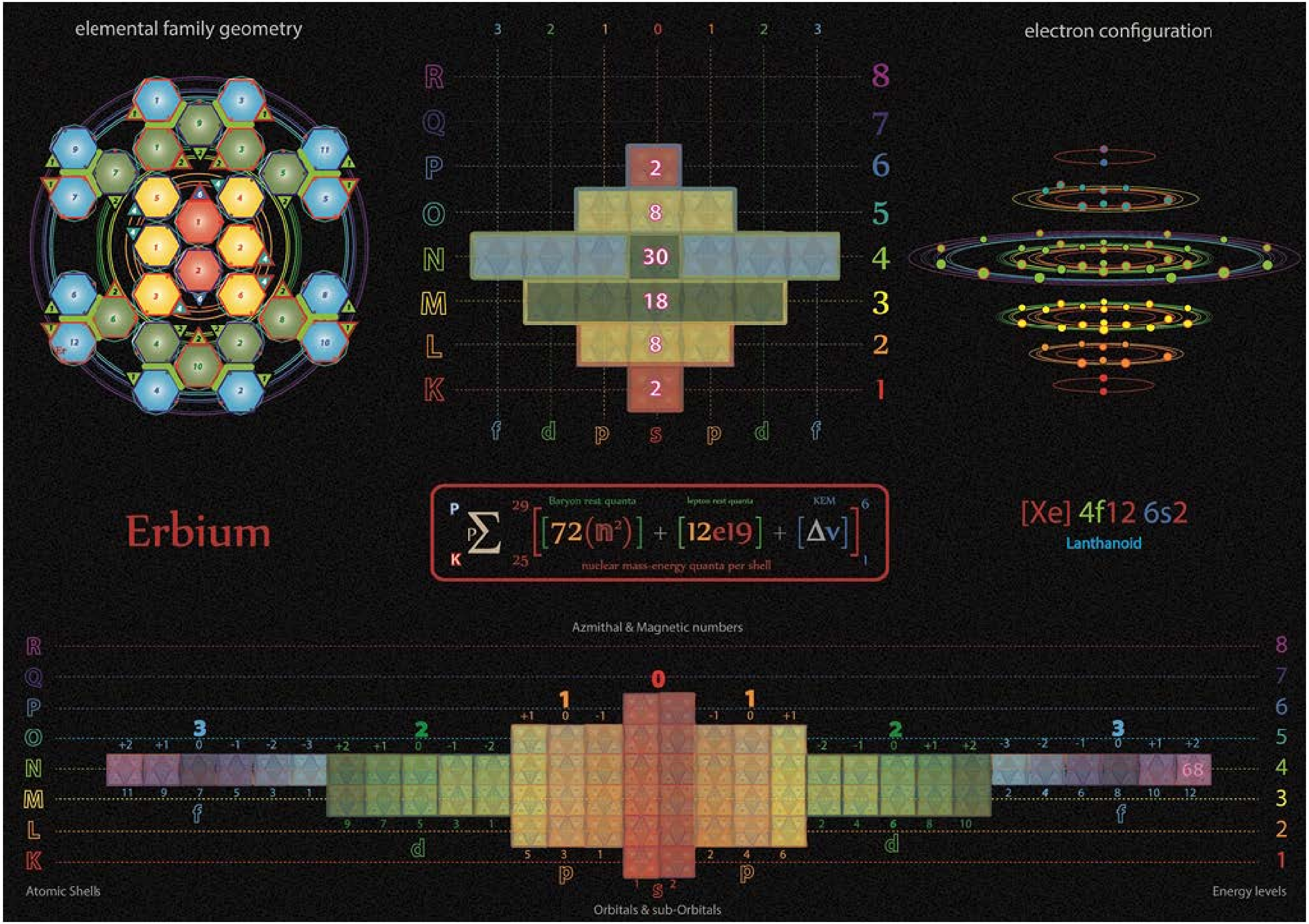
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
30
18
8
2
f d p s p d f
Erbium
P
K
$\sum_{p}$ 29 25
Baryon rest quanta
lepton rest quanta
KEM
$\left[[72(n^2)] + [12e19] + [\Delta v] \right]_1^6$
nuclear mass-energy quanta per shell
[Xe] 4f12 6s2
Lanthanoid
Azmithal & Magnetic numbers
3 2 1 0 1 2 3
+2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2
68
11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.68 - Erbium atomic config

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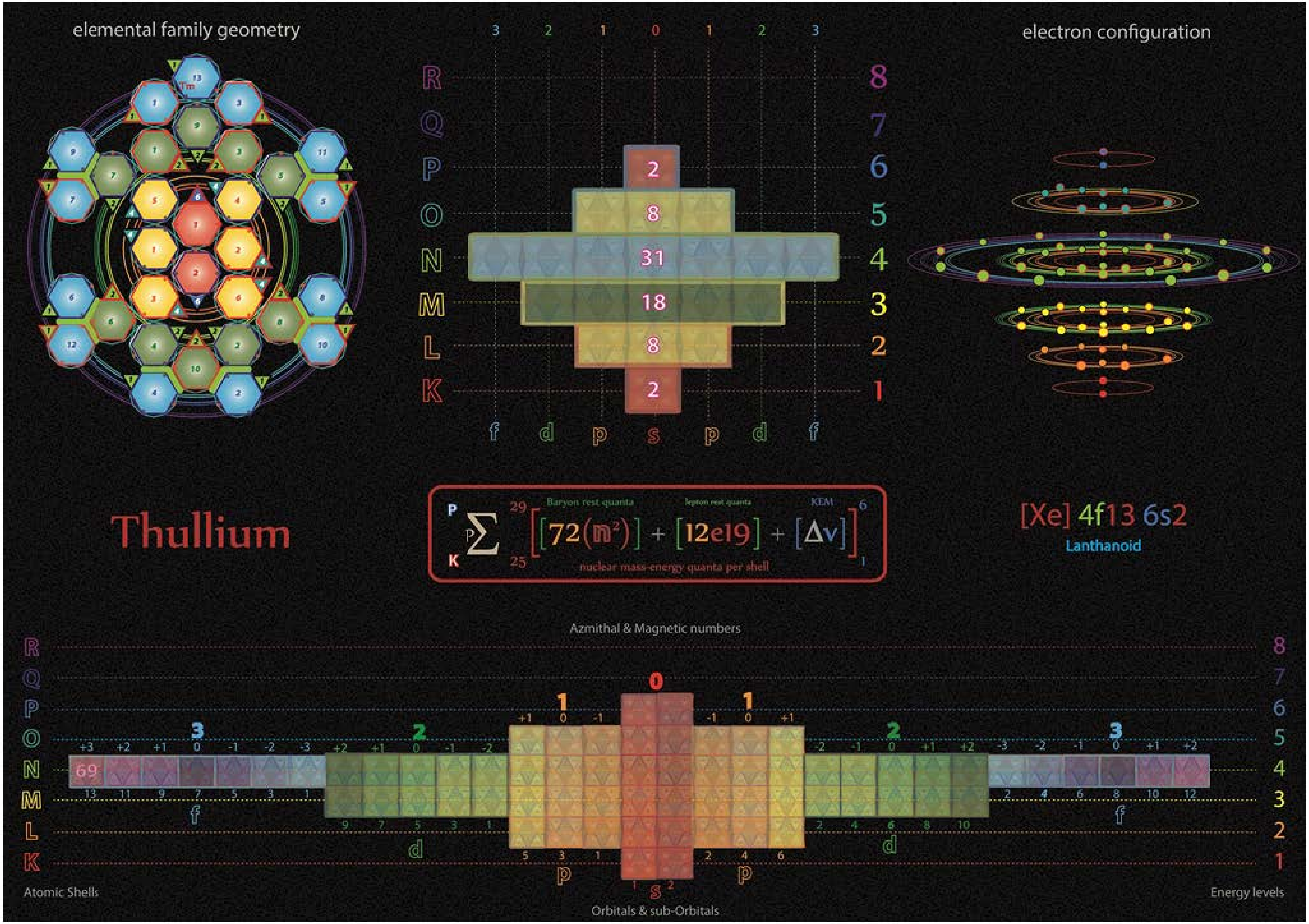
elemental family geometry
Tm
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
31
18
8
2
f d p s p d f
Thullium
P
K
Σ
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
6
1
nuclear mass-energy quanta per shell
[Xe] 4f13 6s2
Lanthanoid
Azmithal & Magnetic numbers
69
3 2 1 0 1 2 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 s 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.69 - Thulium atomic config

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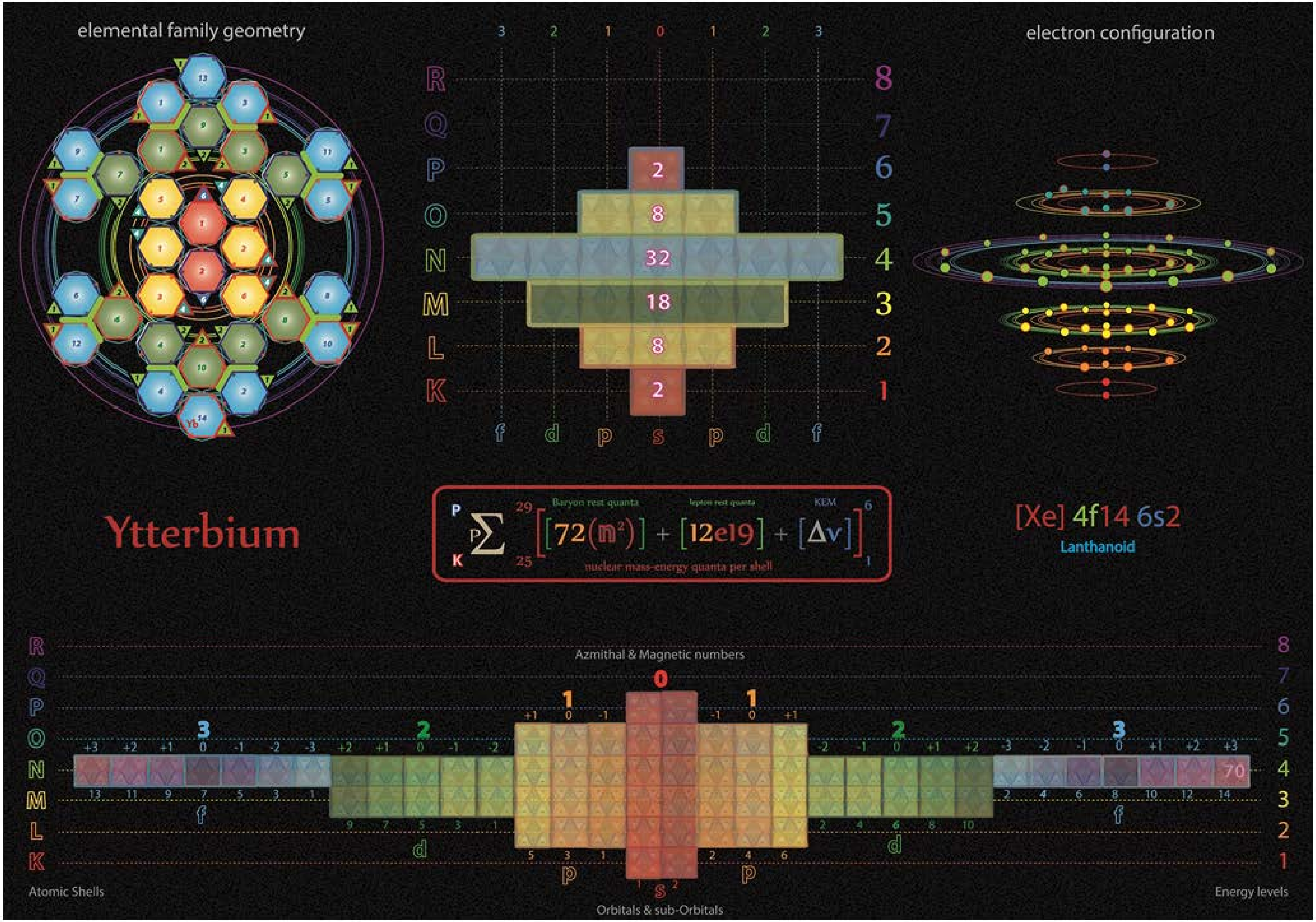
elemental family geometry
Yb
electron configuration
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
2
8
32
18
8
2
f d p s p d f
Ytterbium
P
K
29
25
Baryon rest quanta
lepton rest quanta
KEM
6
1
$\sum [72(m^2)] + [12e19] + [\Delta v]$
nuclear mass-energy quanta per shell
[Xe] 4f14 6s2
Lanthanoid
Azmithal & Magnetic numbers
0
1
2
3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
70
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 s 2
f
d
p
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.70 - Ytterbium atomic config

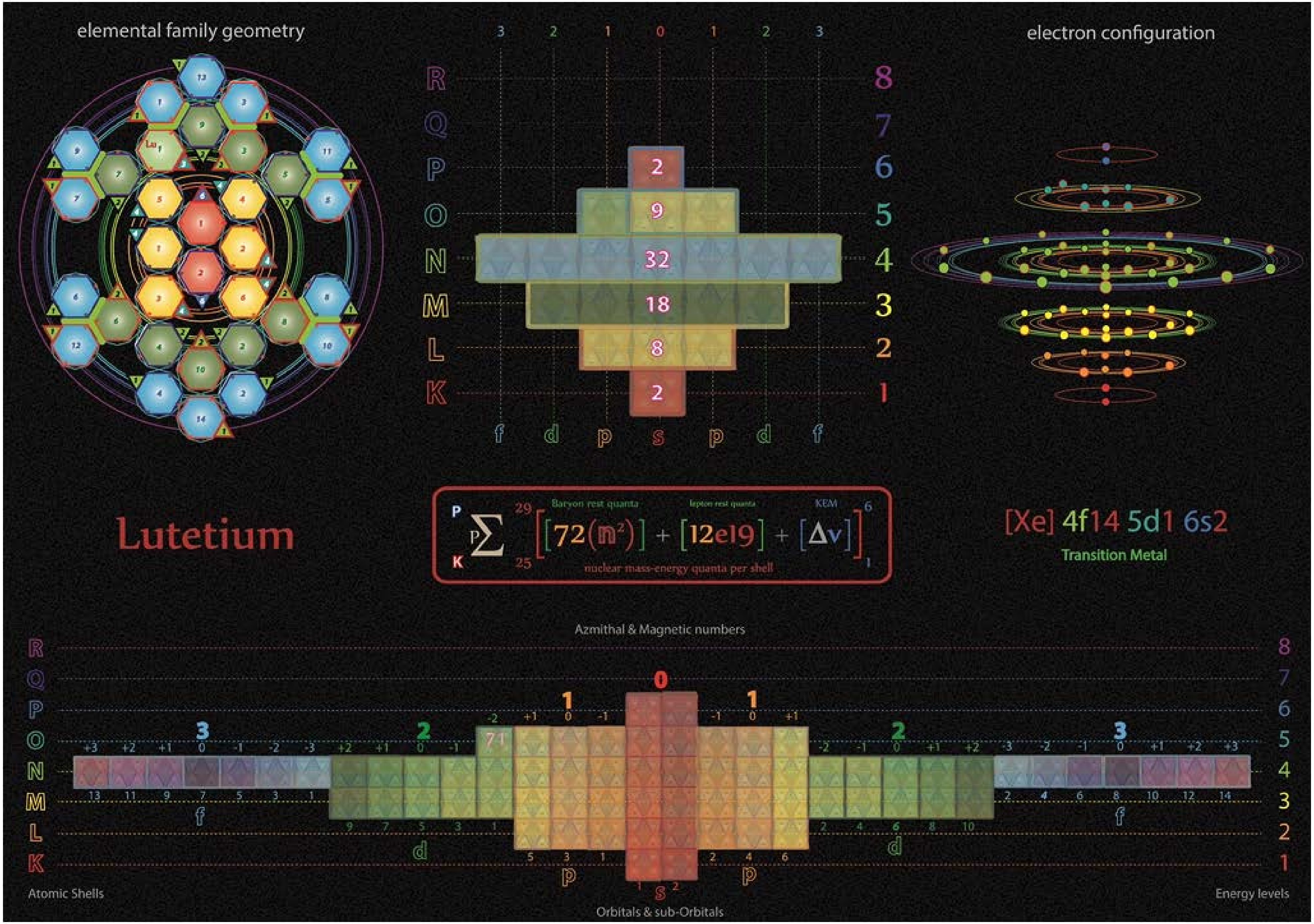
elemental family geometry
Lu
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
2
9
32
18
8
2
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
electron configuration
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
71
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f
d
p
s
p
d
f
Atomic Shells
Orbitals & sub-Orbitals
Energy levels

Lutetium

Baryon rest quanta — lepton rest quanta — KEM

$${}^{P}_{K}\sum_{25}^{29}\left[[72(m^2)] + [12e19] + [\Delta v]\right]^{6}_{1}$$

nuclear mass-energy quanta per shell

[Xe] 4f14 5d1 6s2

Transition Metal

Tetryonics 53.71 - Lutetium atomic config

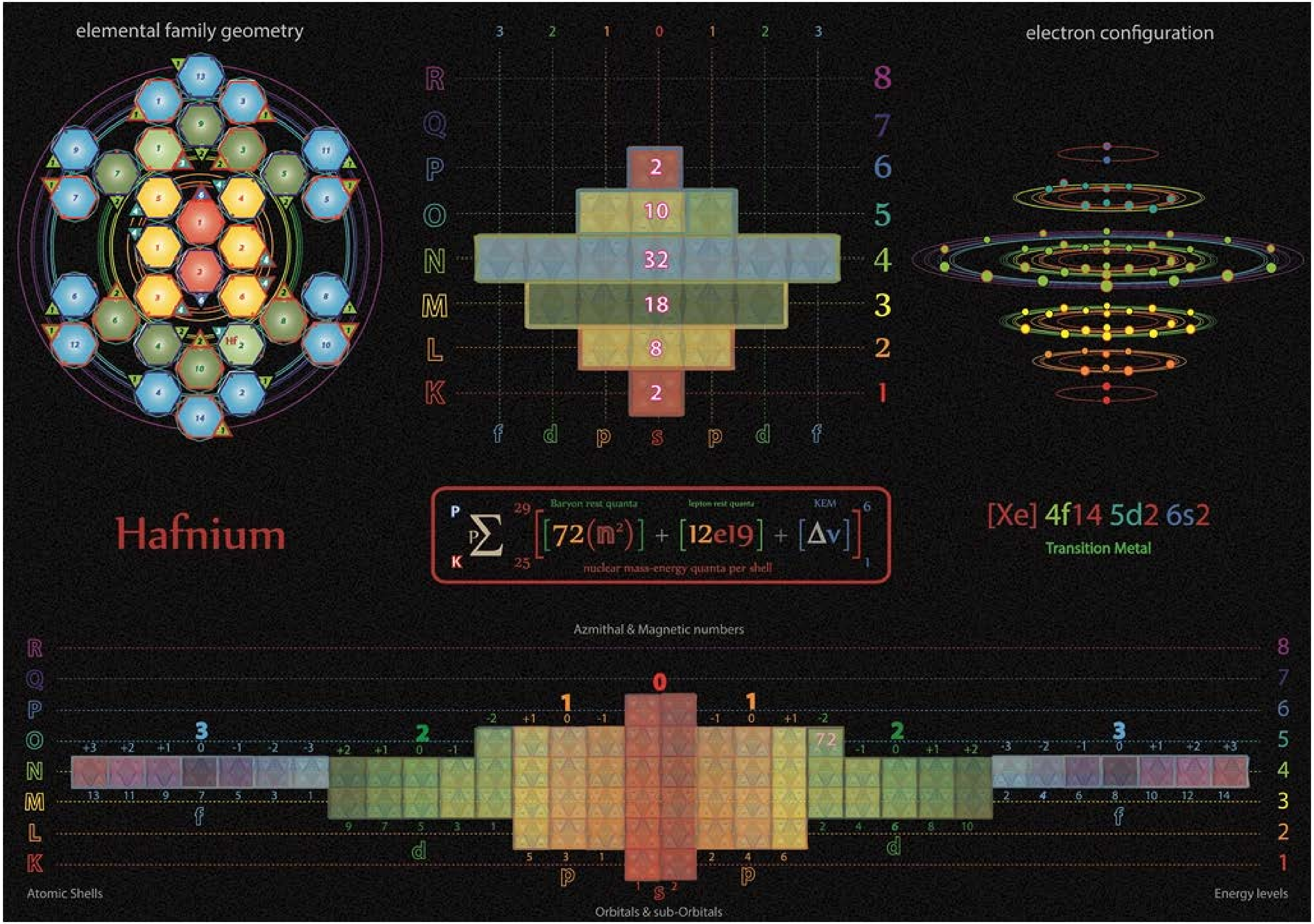
elemental family geometry
Hf
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
10
32
18
8
2
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1
-2 +1 0 -1
-1 0 +1 -2
72
-1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Hafnium

$$\sum_{K}^{P} {}_{P}\left[\left[72(m^2)\right] + \left[12e19\right] + \left[\Delta v\right]\right]_{1}^{6}$$

29 25

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Xe] 4f14 5d2 6s2

Transition Metal

Tetryonics 53.72 - Hafnium atomic config

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elemental family geometry

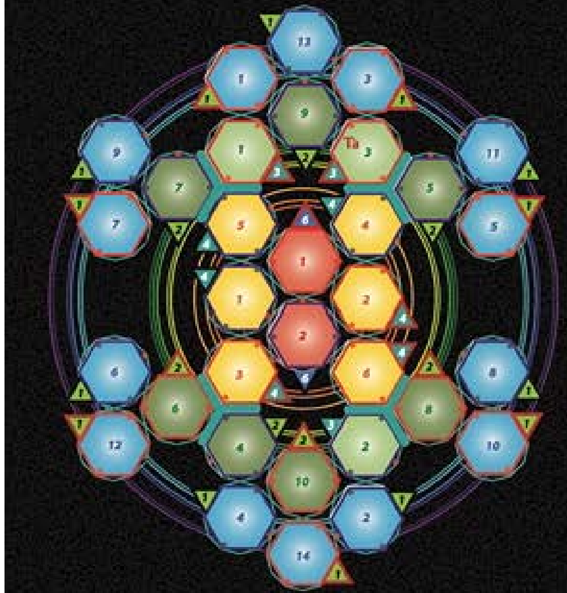

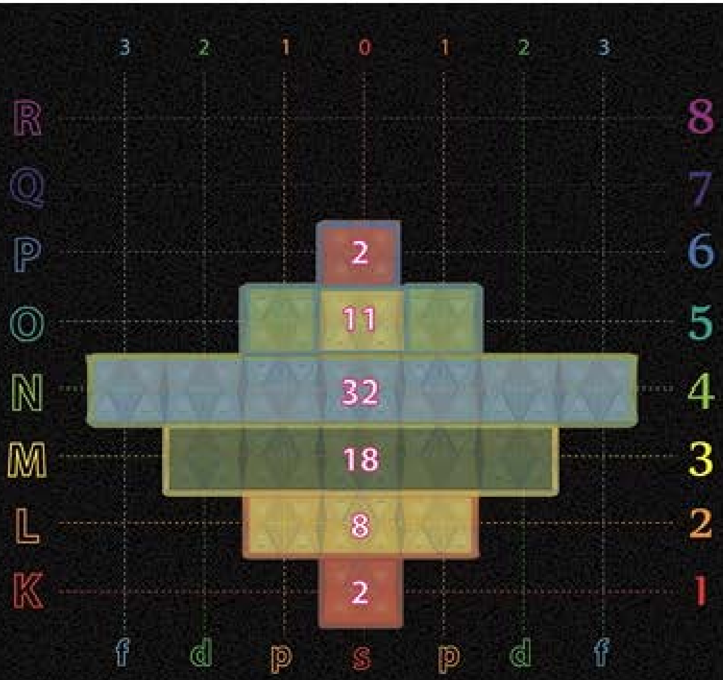
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
2
11
32
18
8
2
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

electron configuration

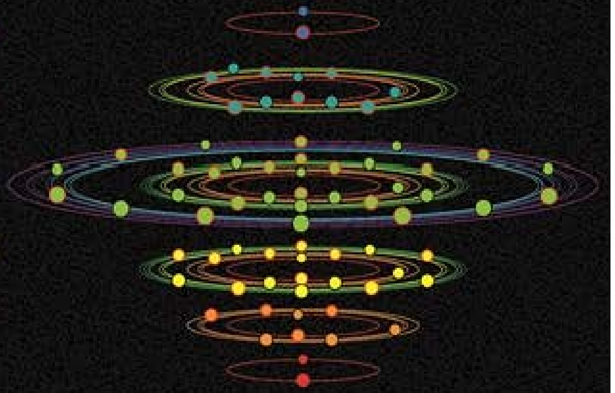

Tantalum

$$\sum_{K}^{P} {}_{P}\!\sum_{25}^{29}\left[\underbrace{\overbrace{[72(n^2)]}^{\text{Baryon rest quanta}} + \overbrace{[12e19]}^{\text{lepton rest quanta}} + \overbrace{[\Delta v]}^{\text{KEM}}}_{\text{nuclear mass-energy quanta per shell}}\right]_{1}^{6}$$

[Xe] 4f14 5d3 6s2

Transition Metal

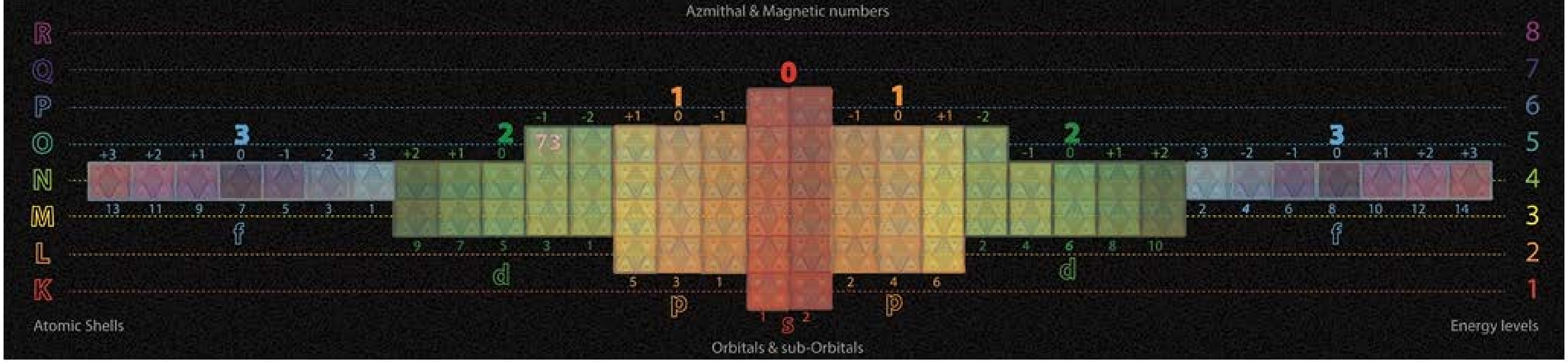
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
2
3
3
73
f
d
p
s
p
d
f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.73 - Tantalum atomic config

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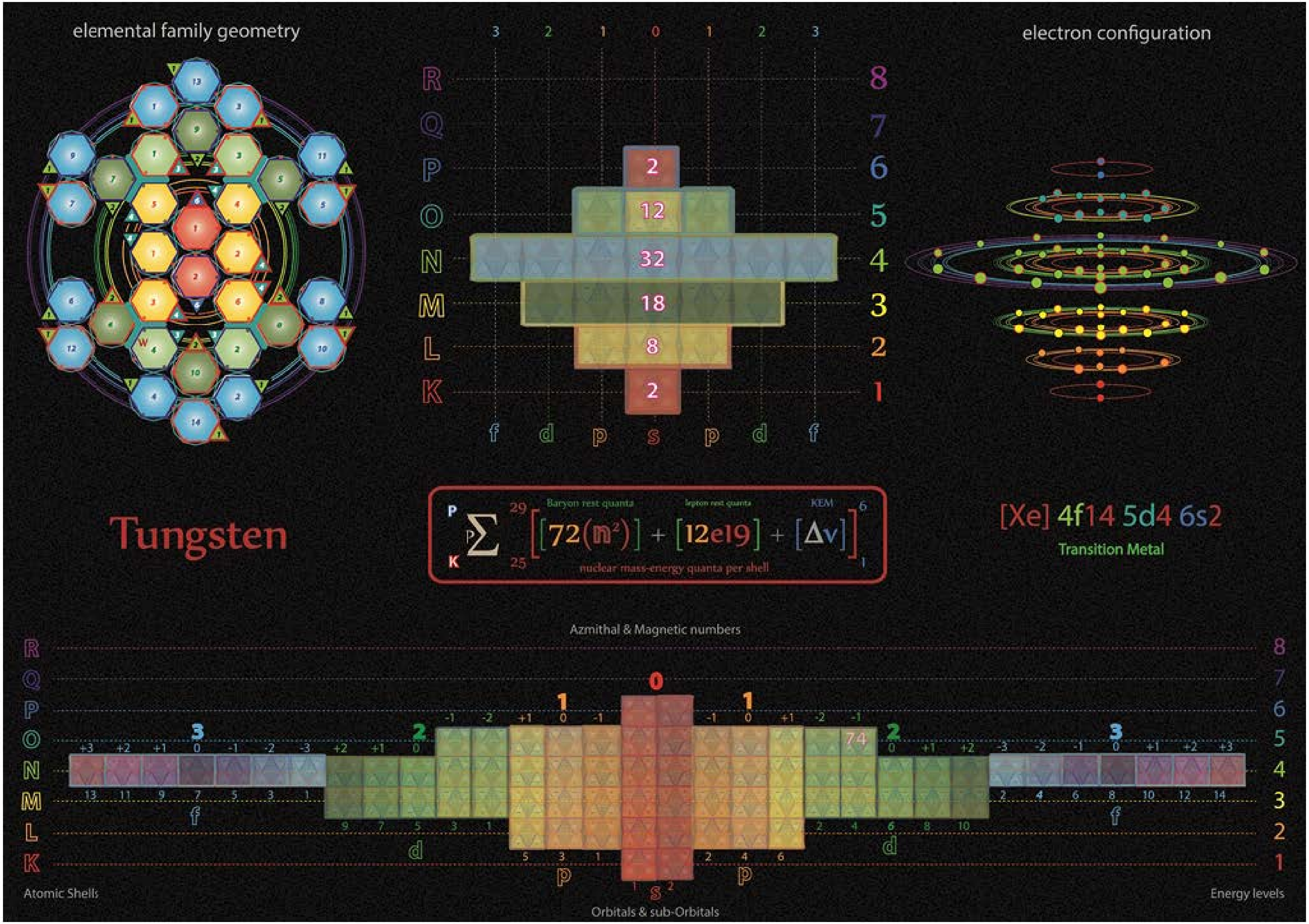
elemental family geometry
Tungsten
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
2
12
32
18
8
2
f d p s p d f
electron configuration
[Xe] 4f14 5d4 6s2
Transition Metal
P ∑ K 29 25 [72(m²)] + [12e19] + [Δv] 6 1
Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell
Azmithal & Magnetic numbers
74
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.74 - Tungsten atomic config

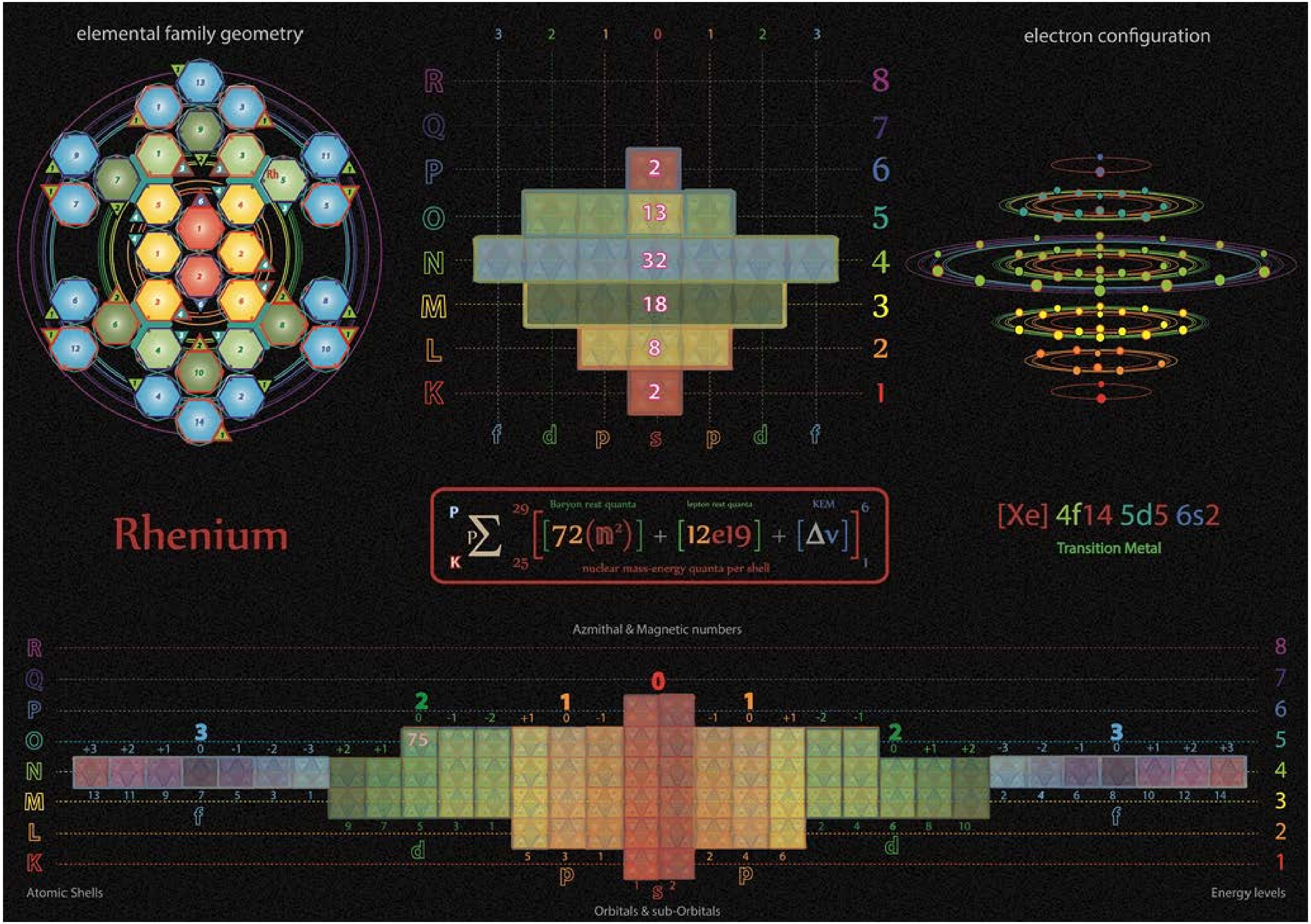
elemental family geometry
electron configuration
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
2
13
32
18
8
2
f d p s p d f
Rhenium
Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell
[Xe] 4f14 5d5 6s2
Transition Metal
Azmithal & Magnetic numbers
Atomic Shells
Energy levels
Orbitals & sub-Orbitals
75

$$_{K}^{P}\,{}_{P}\sum_{25}^{29}\left[\,[72(m^2)] + [12e19] + [\Delta v]\,\right]_{1}^{6}$$

Tetryonics 53.75 - Rhenium atomic config

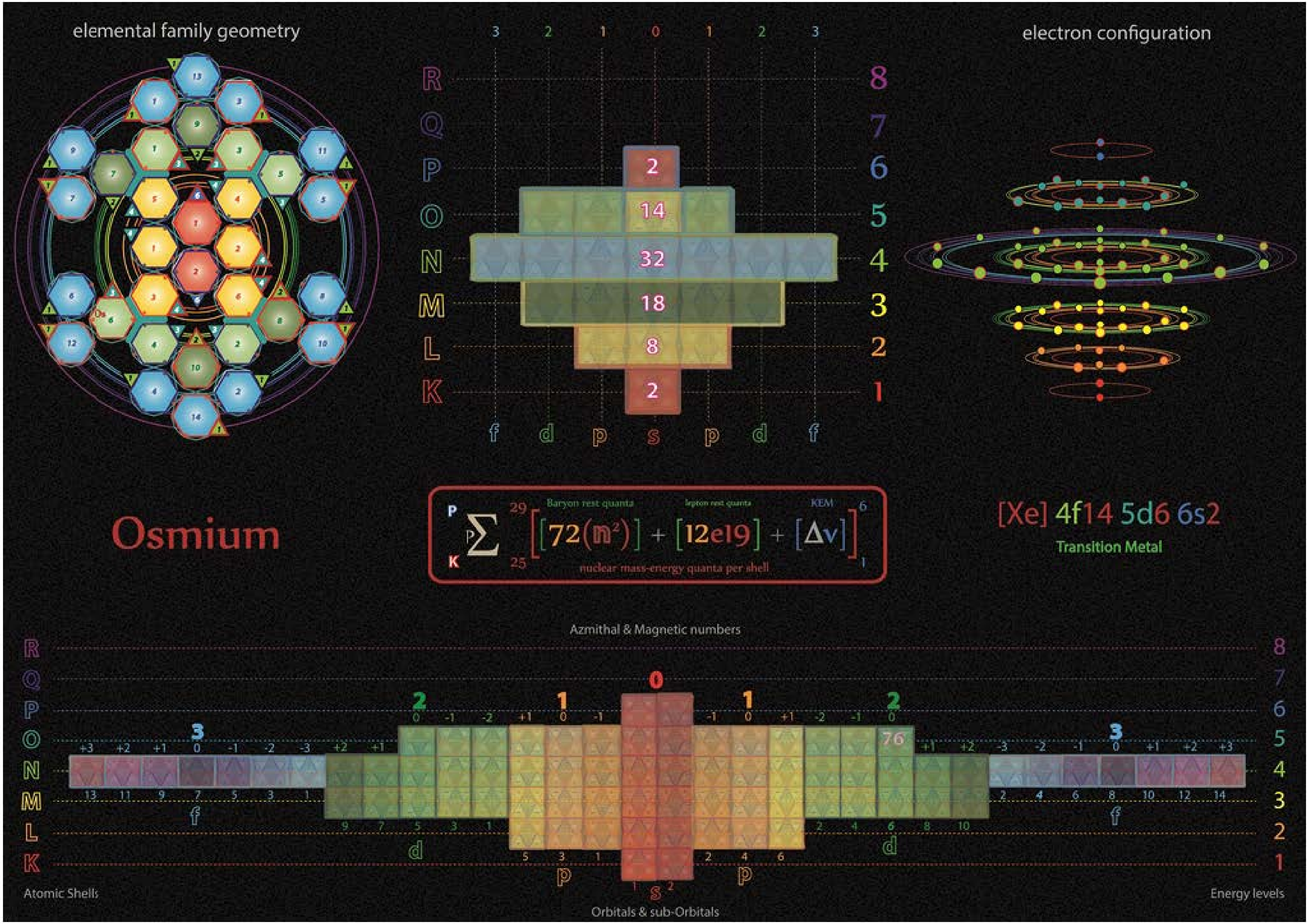
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
14
32
18
8
2
f d p s p d f
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
76
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Osmium

$$\sum_{K}^{P} {}_{p}\sum_{25}^{29}\left[\underset{\text{Baryon rest quanta}}{[72(n^2)]} + \underset{\text{lepton rest quanta}}{[12e19]} + \underset{\text{KEM}}{[\Delta v]}\right]_{1}^{6}$$

nuclear mass-energy quanta per shell

[Xe] 4f14 5d6 6s2

Transition Metal

Tetryonics 53.76 - Osmium atomic config

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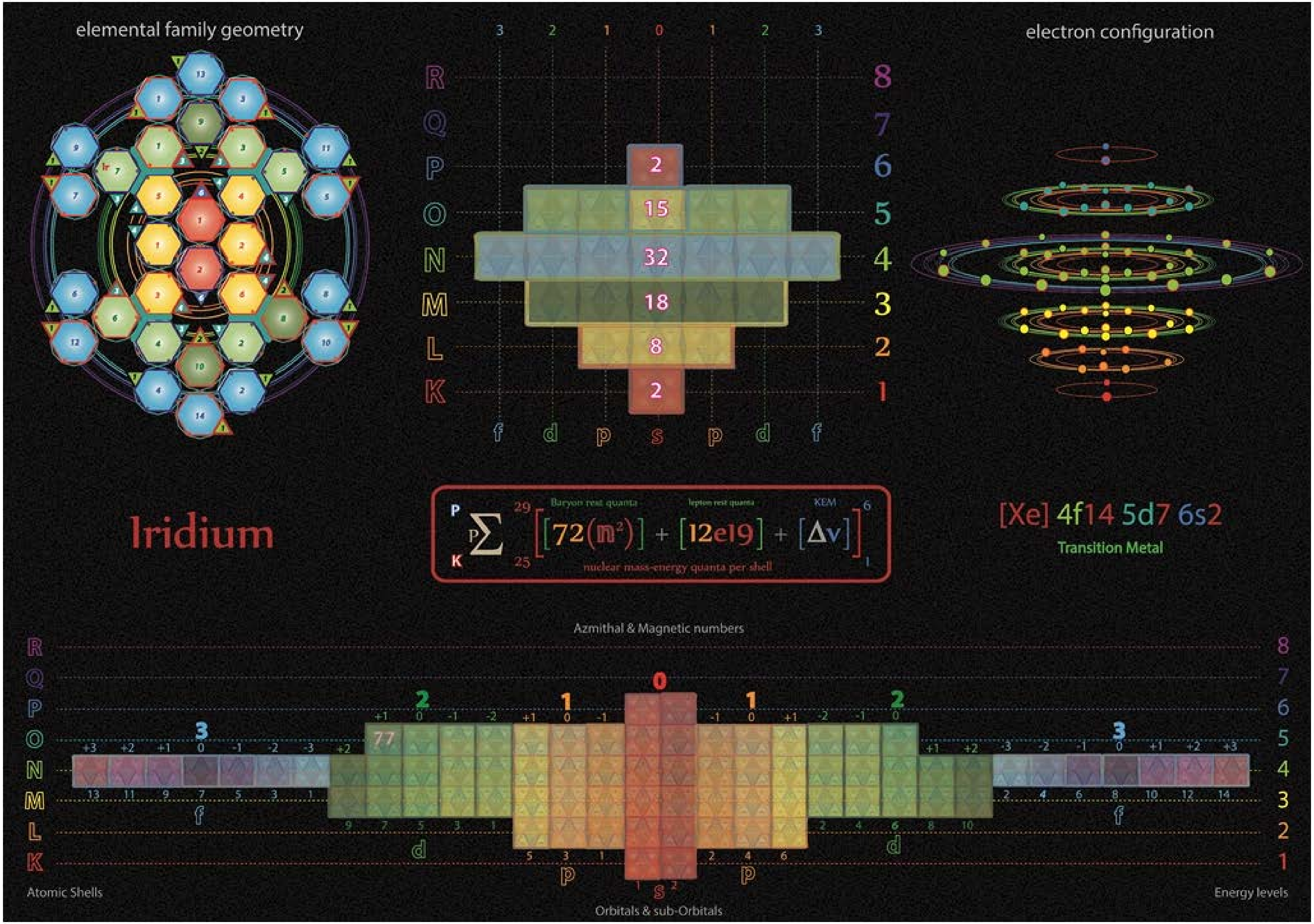
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
15
32
18
8
2
f d p s p d f
Iridium
P
K
29
25
Baryon rest quanta
lepton rest quanta
KEM
6
1
$_{P}\sum_{25}^{29}\left[\left[72(\mathrm{m}^2)\right]+\left[12e19\right]+\left[\Delta v\right]\right]_{1}^{6}$
nuclear mass-energy quanta per shell
[Xe] 4f14 5d7 6s2
Transition Metal
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
77
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 s 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.77 - Iridium atomic config

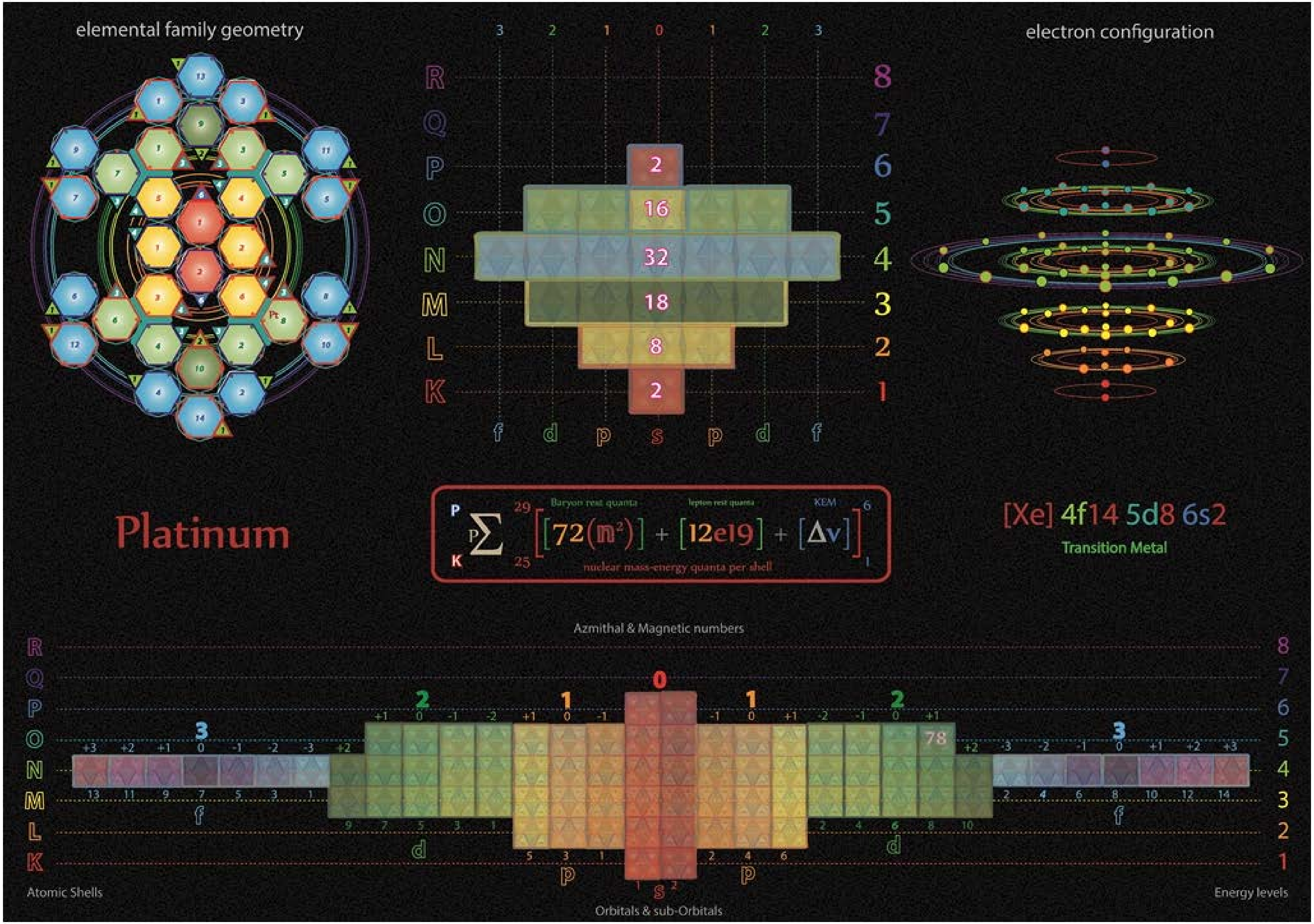
elemental family geometry
Pt
Platinum
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
2
16
32
18
8
2
8
7
6
5
4
3
2
1
f d p s p d f
electron configuration
[Xe] 4f14 5d8 6s2
Transition Metal
Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell
Azmithal & Magnetic numbers
0
1
2
3
78
d
p
s
f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

$$\sum_{K}^{P} {}_{P}\sum_{25}^{29}\left[\left[72(\mathrm{m}^2)\right]+\left[12e19\right]+\left[\Delta v\right]\right]_{1}^{6}$$

Tetryonics 53.78 - Platinum atomic config

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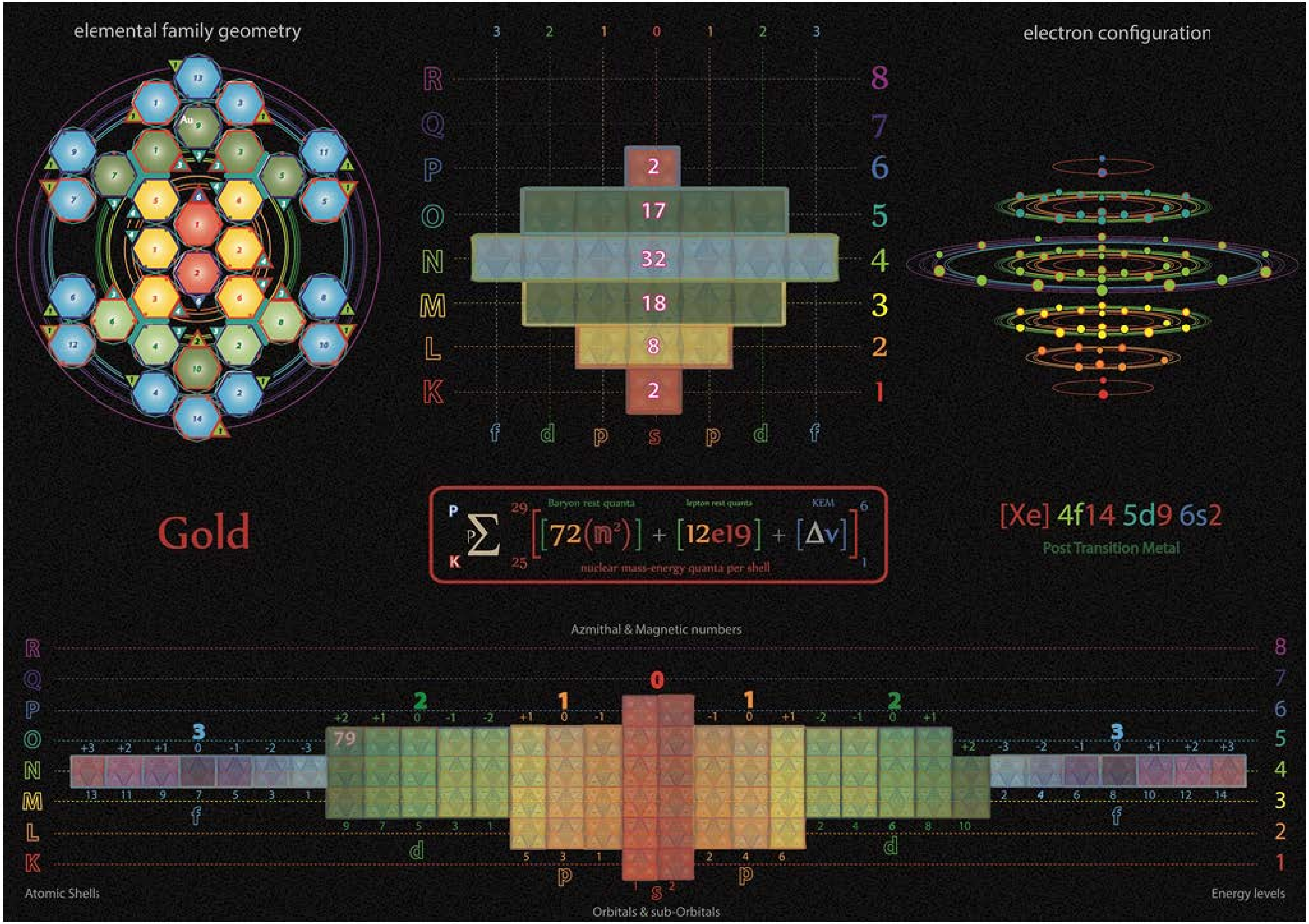
elemental family geometry
Au
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
17
32
18
8
2
f d p s p d f
Azmithal & Magnetic numbers
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
0
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
79
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Gold

$$\sum_{K}^{P} {}_{25}^{29}\left[72(n^2)\right] + \left[12e19\right] + \left[\Delta v\right]_{1}^{6}$$

Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[Xe] 4f14 5d9 6s2

Post Transition Metal

Tetryonics 53.79 - Gold atomic config

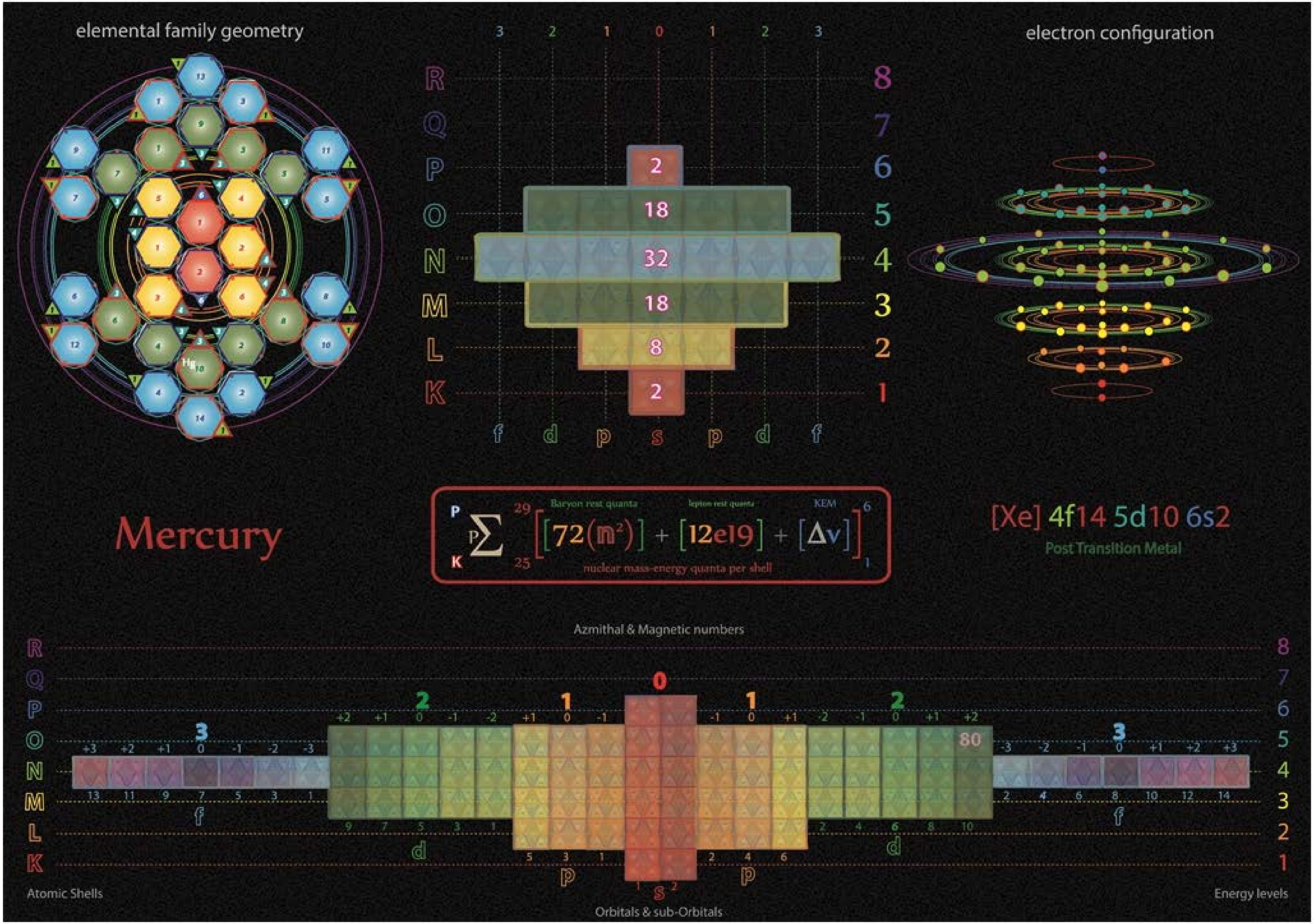
elemental family geometry
Hg
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
18
32
18
8
2
f d p s p d f
electron configuration
Mercury
P
K
29
25
Baryon rest quanta
lepton rest quanta
KEM
6
1
$\sum_{K}^{P} \left[[72(m^2)] + [12e19] + [\Delta v] \right]$
nuclear mass-energy quanta per shell
[Xe] 4f14 5d10 6s2
Post Transition Metal
Azmithal & Magnetic numbers
0
1
2
3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
80
13 11 9 7 5 3 1
f
9 7 5 3 1
d
5 3 1
p
1 s 2
2 4 6
p
2 4 6 8 10
d
2 4 6 8 10 12 14
f
Atomic Shells
Orbitals & sub-Orbitals
Energy levels

Tetryonics 53.80 - Mercury atomic config

elemental family geometry

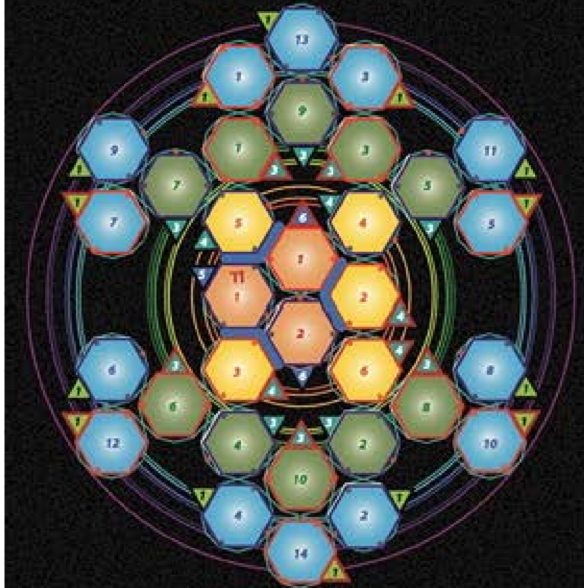
Tl
13
9
11
7
5
1
3
2
6
4
8
12
10
14

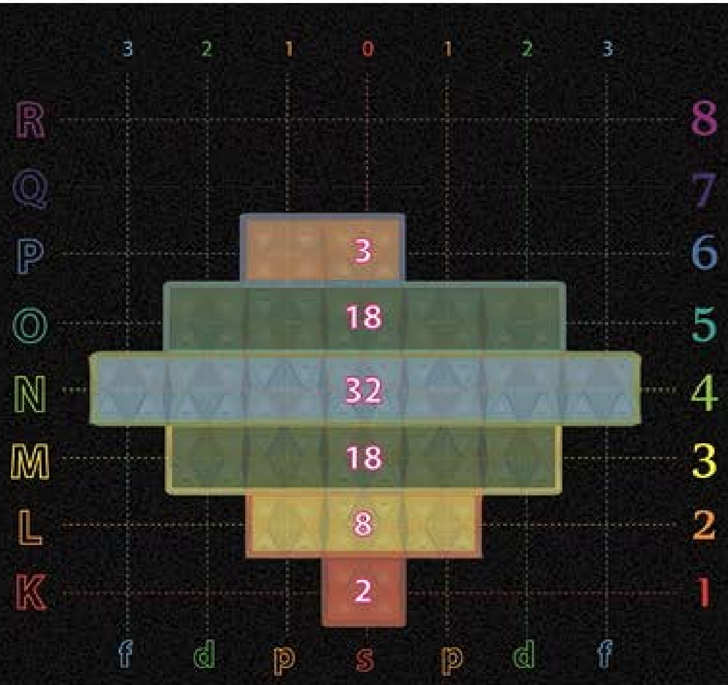
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
3
18
32
18
8
2
8
7
6
5
4
3
2
1
f d p s p d f

electron configuration

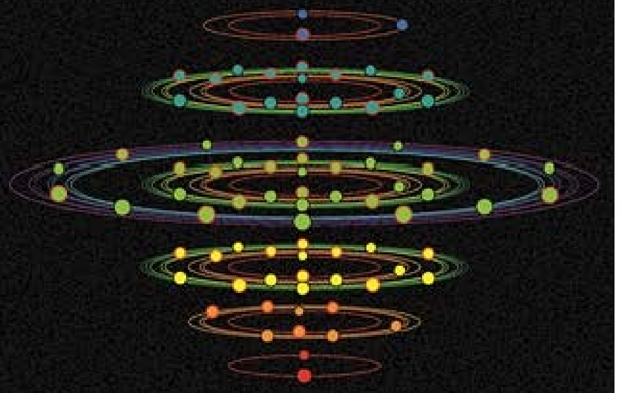

Thallium

$$\sum_{K}^{P}{}_{p}\sum_{25}^{29}\left[\overset{\text{Baryon rest quanta}}{\left[72(n^2)\right]} + \overset{\text{lepton rest quanta}}{\left[12e19\right]} + \overset{\text{KEM}}{\left[\Delta v\right]}\right]_{1}^{6}$$

nuclear mass-energy quanta per shell

[Xe] 4f14 5d10 6s2 6p1

Metaloid

Azmithal & Magnetic numbers

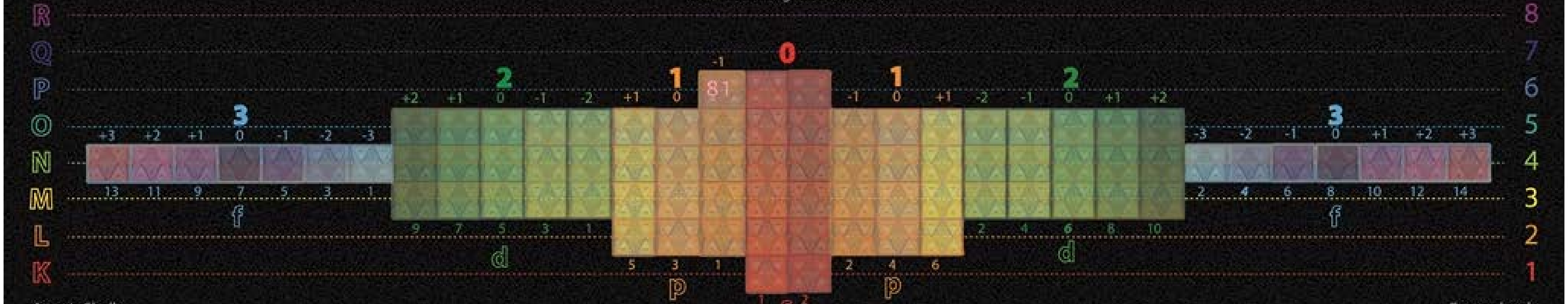
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3
+3 +2 +1 0 -1 -2 -3
13 11 9 7 5 3 1
f
2
+2 +1 0 -1 -2
9 7 5 3 1
d
1
+1 0 -1
5 3 1
p
0
81
1 s 2
1
-1 0 +1
2 4 6
p
2
-2 -1 0 +1 +2
2 4 6 8 10
d
3
-3 -2 -1 0 +1 +2 +3
2 4 6 8 10 12 14
f

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.81 - Thallium atomic config

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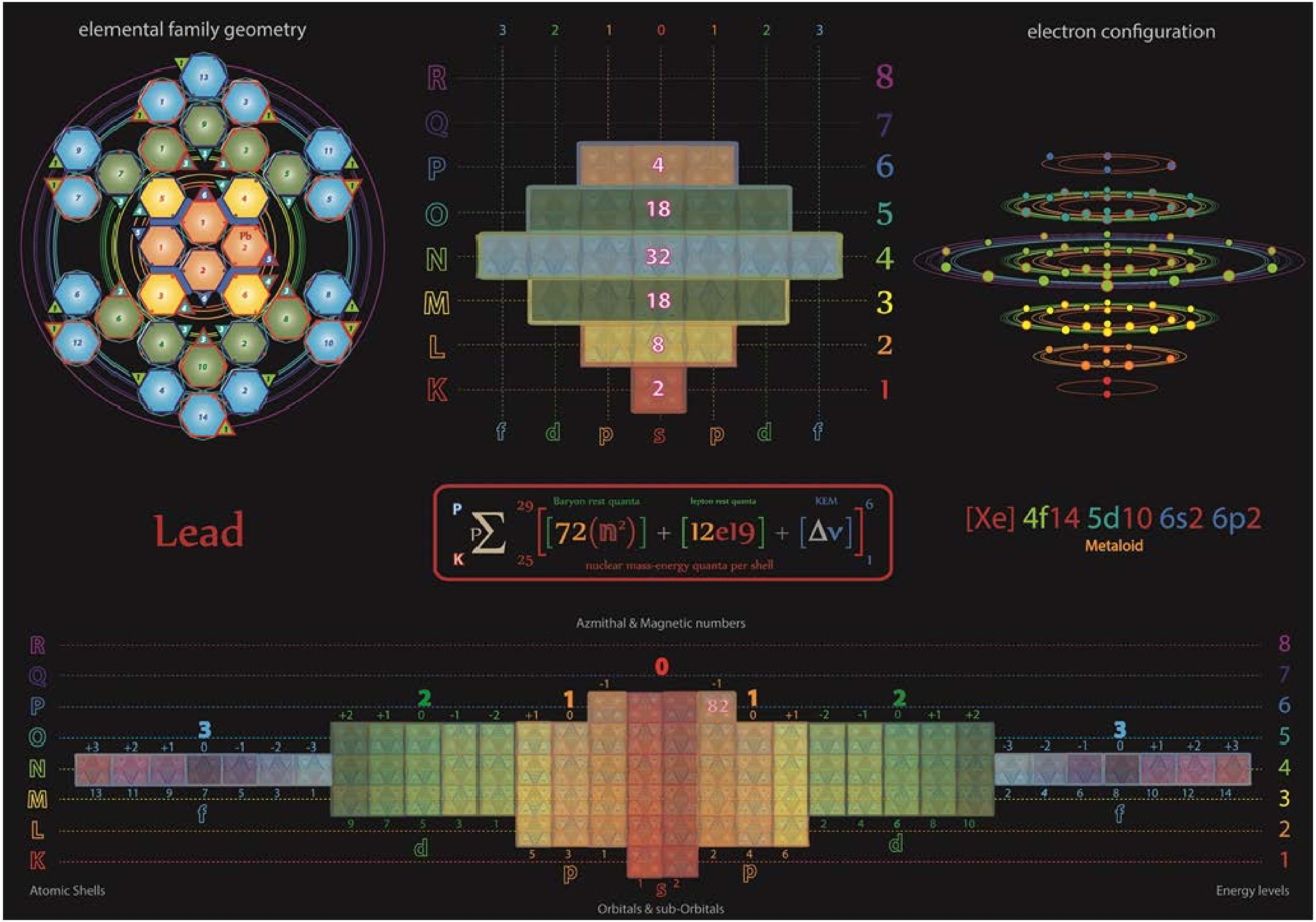
elemental family geometry
Pb
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
4
18
32
18
8
2
f d p s p d f
electron configuration
Lead
P
K
P
Σ
29
25
Baryon rest quanta
[72(m²)]
+
lepton rest quanta
[12e19]
+
KEM
[Δv]
6
1
nuclear mass-energy quanta per shell
[Xe] 4f14 5d10 6s2 6p2
Metaloid
Azmithal & Magnetic numbers
0
82
3 2 1 1 2 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 +1
-3 -2 -1 0 +1 +2 +3
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.82 - Lead atomic config

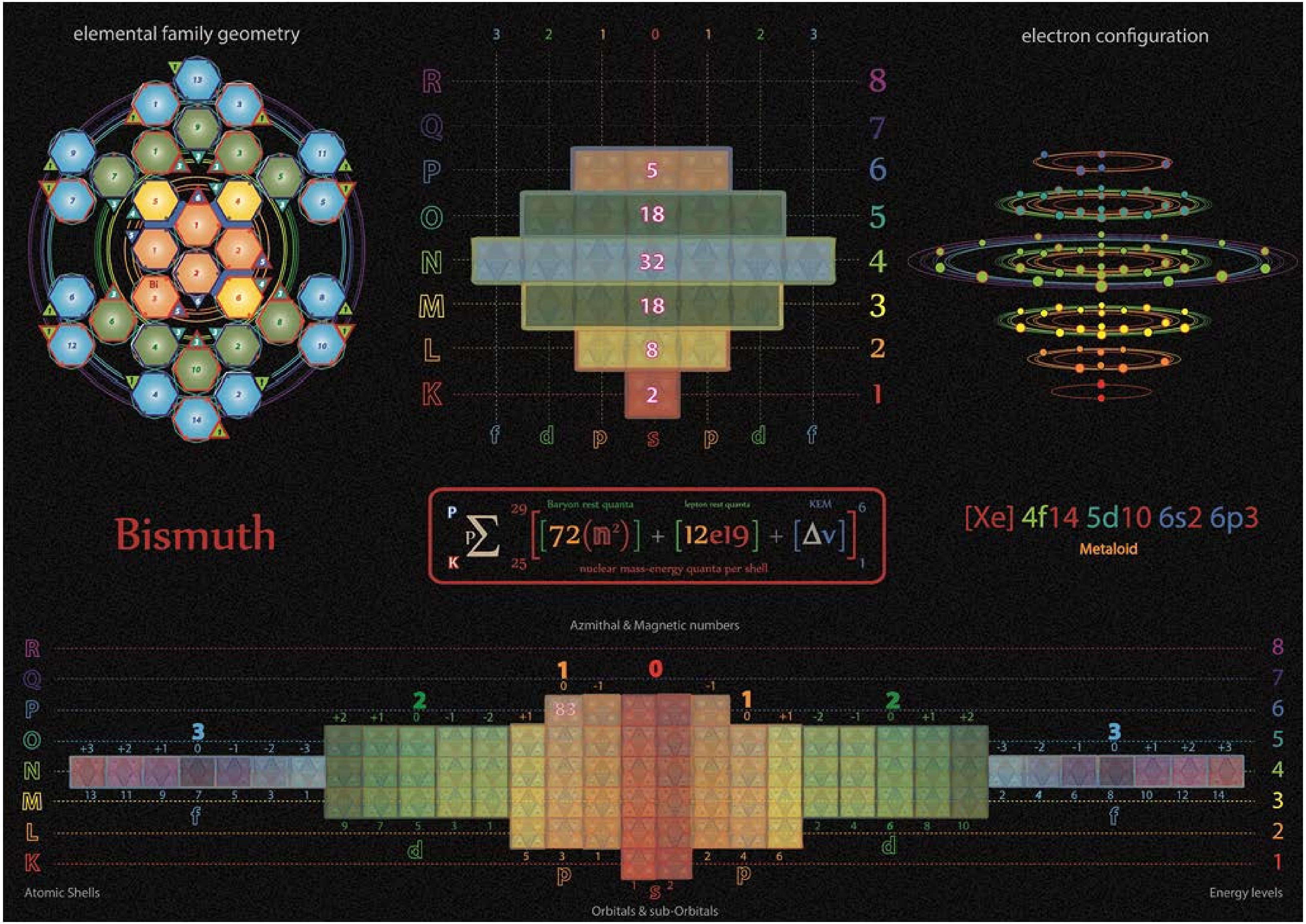
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
5
18
32
18
8
2
f d p s p d f
Bismuth
P
K
29
25
6
1
Baryon rest quanta
lepton rest quanta
KEM
$\sum [72(m^2)] + [12e19] + [\Delta v]$
nuclear mass-energy quanta per shell
[Xe] 4f14 5d10 6s2 6p3
Metaloid
Azmithal & Magnetic numbers
83
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.83 - Bismuth atomic config

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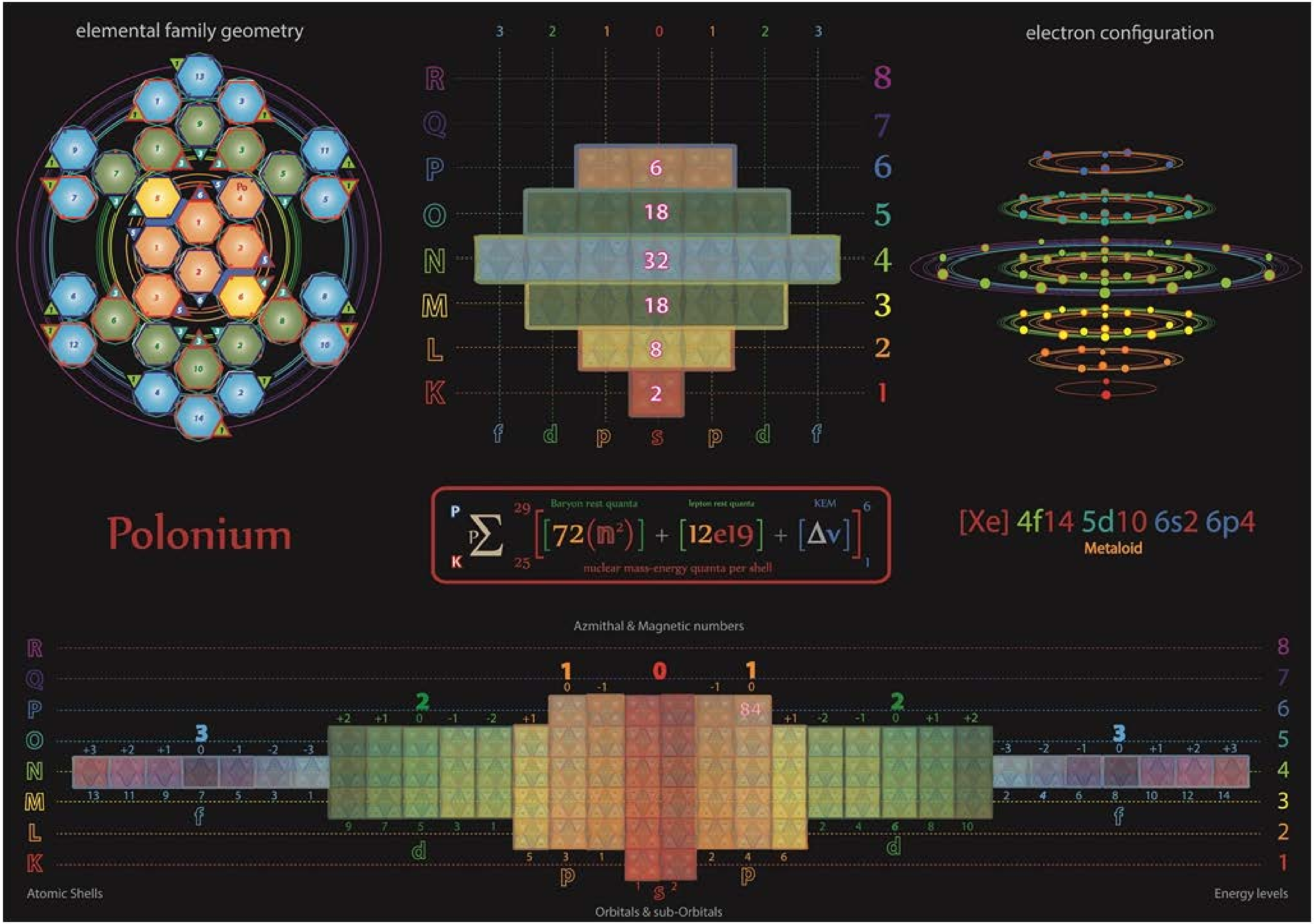
elemental family geometry
electron configuration
Polonium
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
[Xe] 4f14 5d10 6s2 6p4
Metaloid
R Q P O N M L K
8 7 6 5 4 3 2 1
6 18 32 18 8 2
f d p s p d f
Azmithal & Magnetic numbers
84
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.84 - Polonium atomic config

elemental family geometry

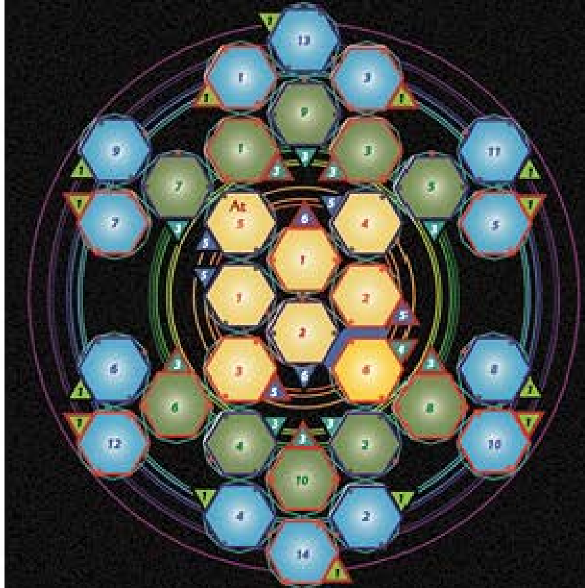
At
1
2
3
4
5
6
7
8
9
10
11
12
13
14

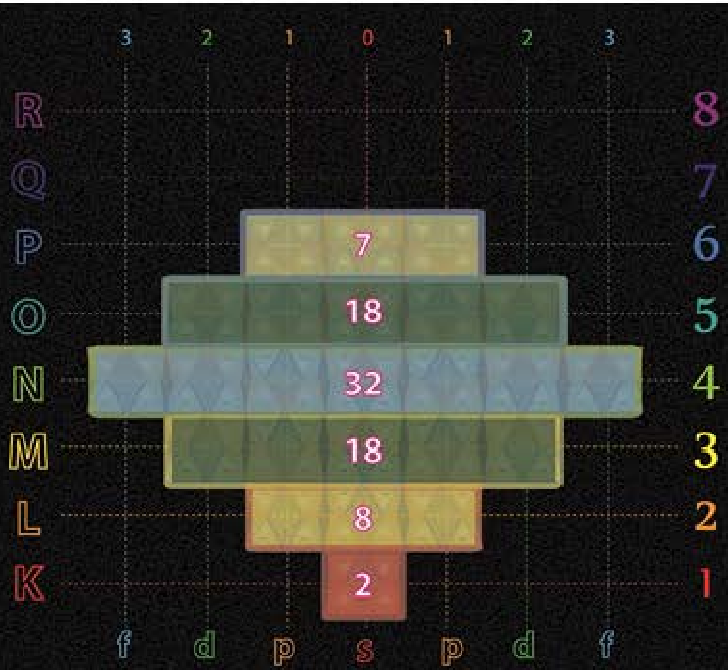
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
7
18
32
18
8
2
8
7
6
5
4
3
2
1
f d p s p d f

electron configuration

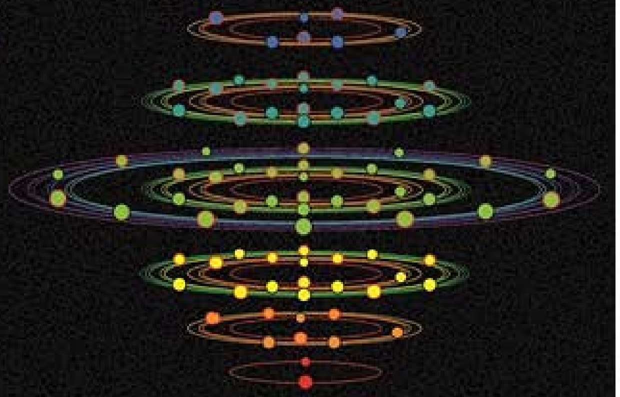

Astatine

$$ {}^{P}_{K}\;{}_{P}\sum^{29}_{25}\left[\overset{\text{Baryon rest quanta}}{\left[72(\mathrm{m}^{2})\right]}+\overset{\text{lepton rest quanta}}{\left[12e19\right]}+\overset{\text{KEM}}{\left[\Delta v\right]}\right]^{6}_{1} $$

nuclear mass-energy quanta per shell

[Xe] 4f14 5d10 6s2 6p5

Halogen

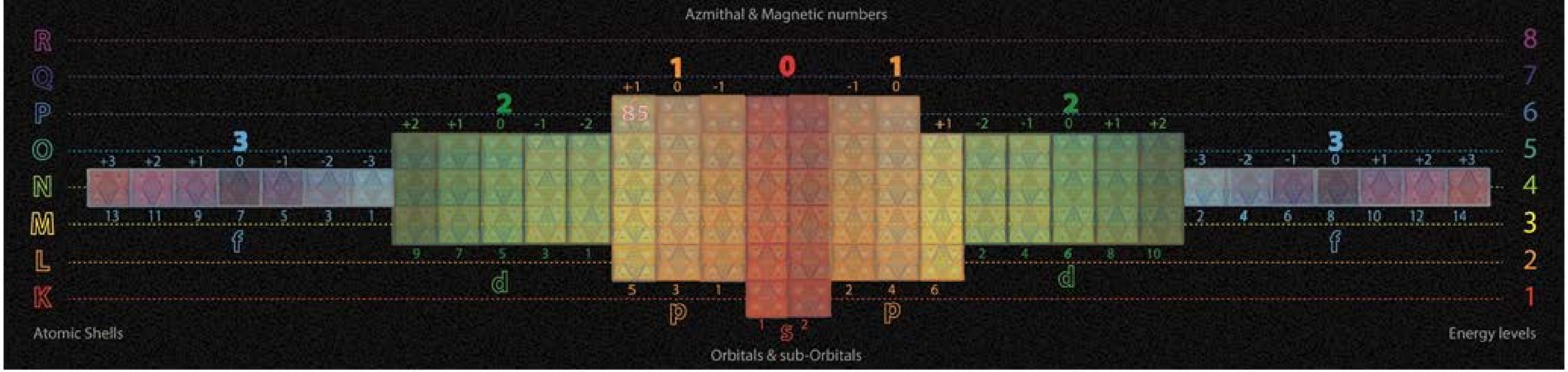
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3
+3 +2 +1 0 -1 -2 -3
13 11 9 7 5 3 1
f
2
+2 +1 0 -1 -2
9 7 5 3 1
d
1
+1 0 -1
85
5 3 1
p
0
1 s 2
1
-1 0 +1
2 4 6
p
2
-2 -1 0 +1 +2
2 4 6 8 10
d
3
-3 -2 -1 0 +1 +2 +3
2 4 6 8 10 12 14
f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.85 - Astatine atomic config

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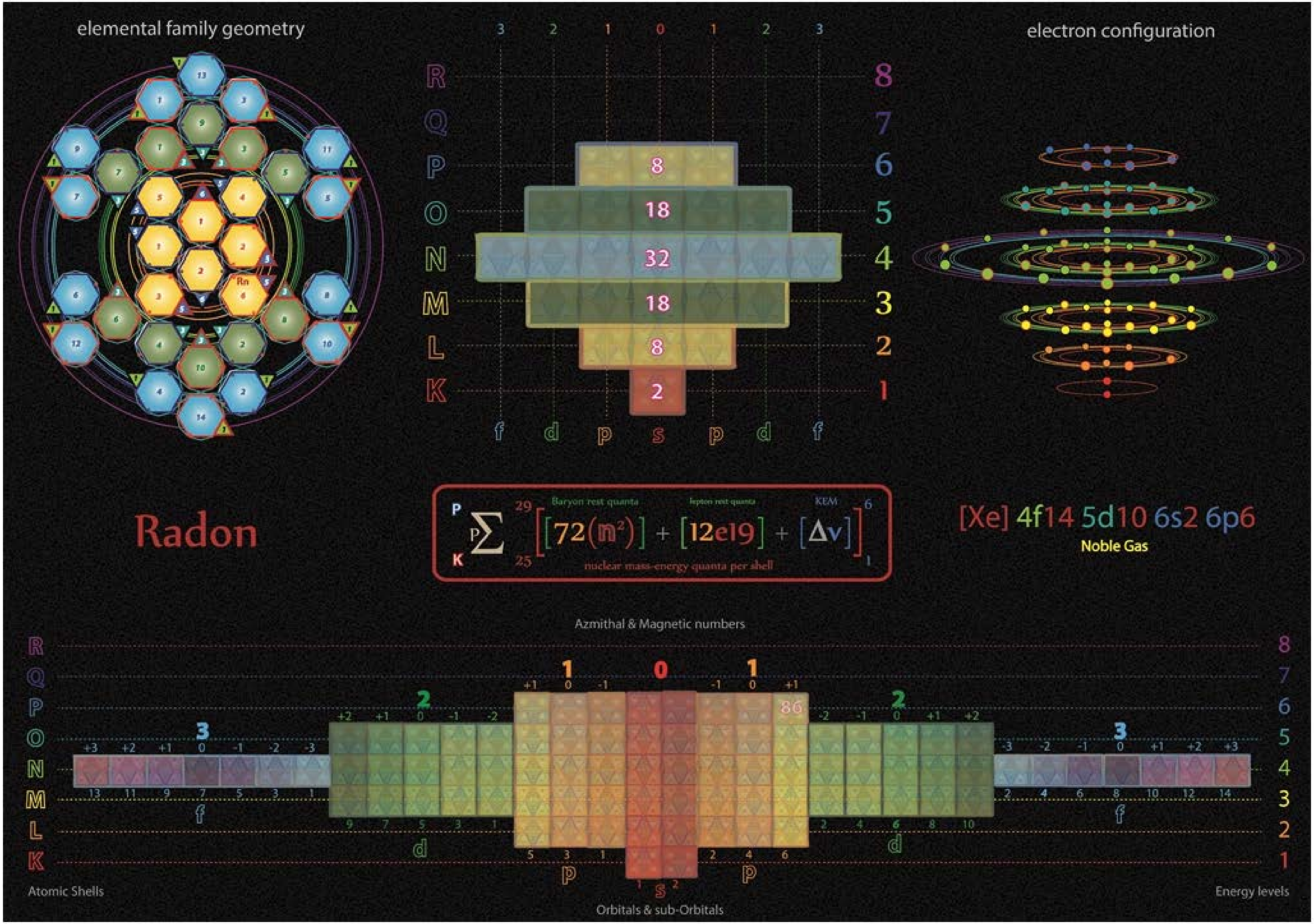
elemental family geometry
electron configuration
Radon
[Xe] 4f14 5d10 6s2 6p6
Noble Gas
P K ∑ 29 25 [[72(m²)] + [12e19] + [Δv]] 6 1
Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell
R Q P O N M L K
8 7 6 5 4 3 2 1
2 8 18 32 18 8
f d p s p d f
Azmithal & Magnetic numbers
86
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.86 - Radon atomic config

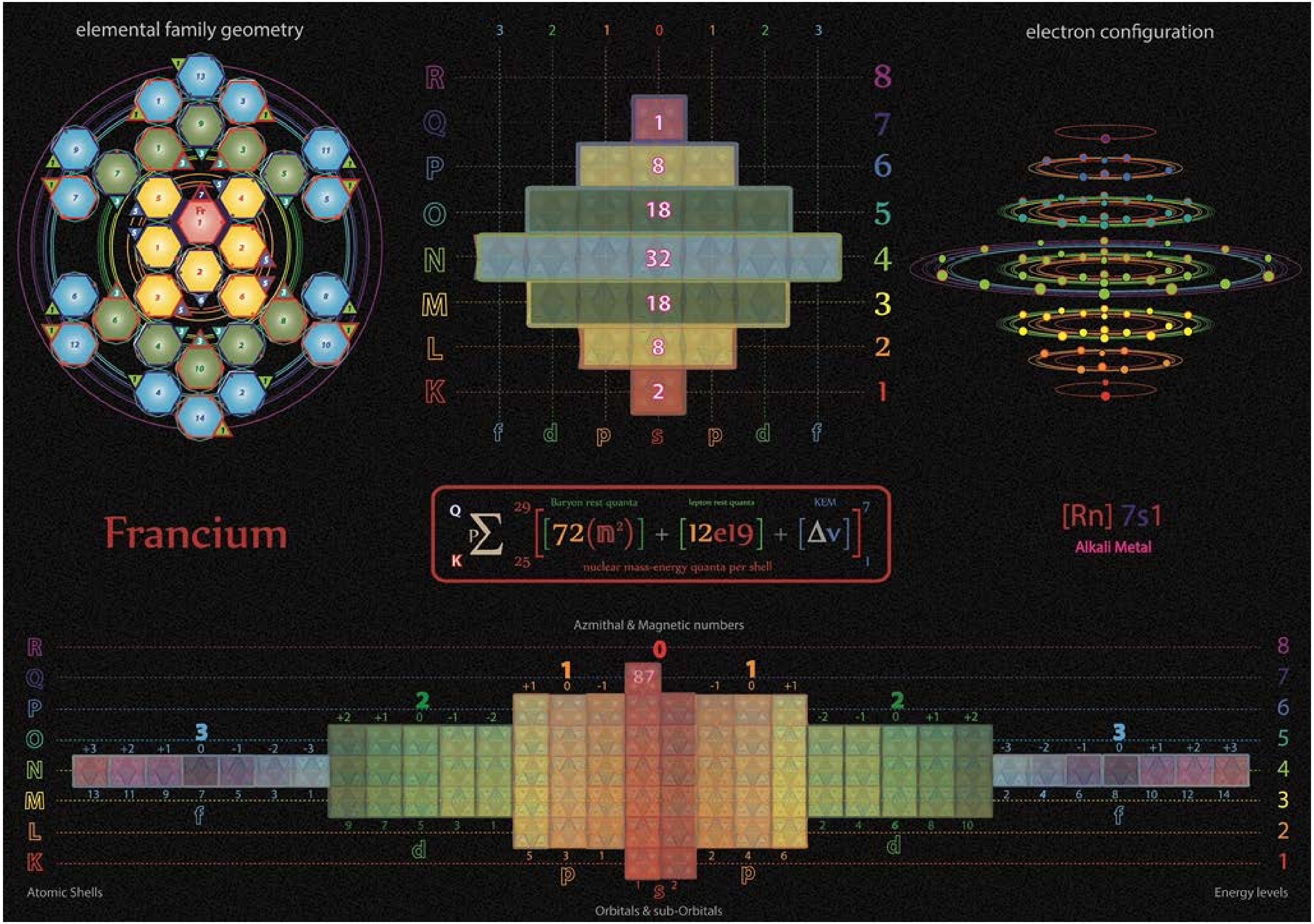
elemental family geometry
electron configuration
Francium
[Rn] 7s1
Alkali Metal
Q
P
K
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
7
1
nuclear mass-energy quanta per shell
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
1
8
18
32
18
8
2
Azmithal & Magnetic numbers
0
1
2
3
87
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 s 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.87 - Francium atomic config

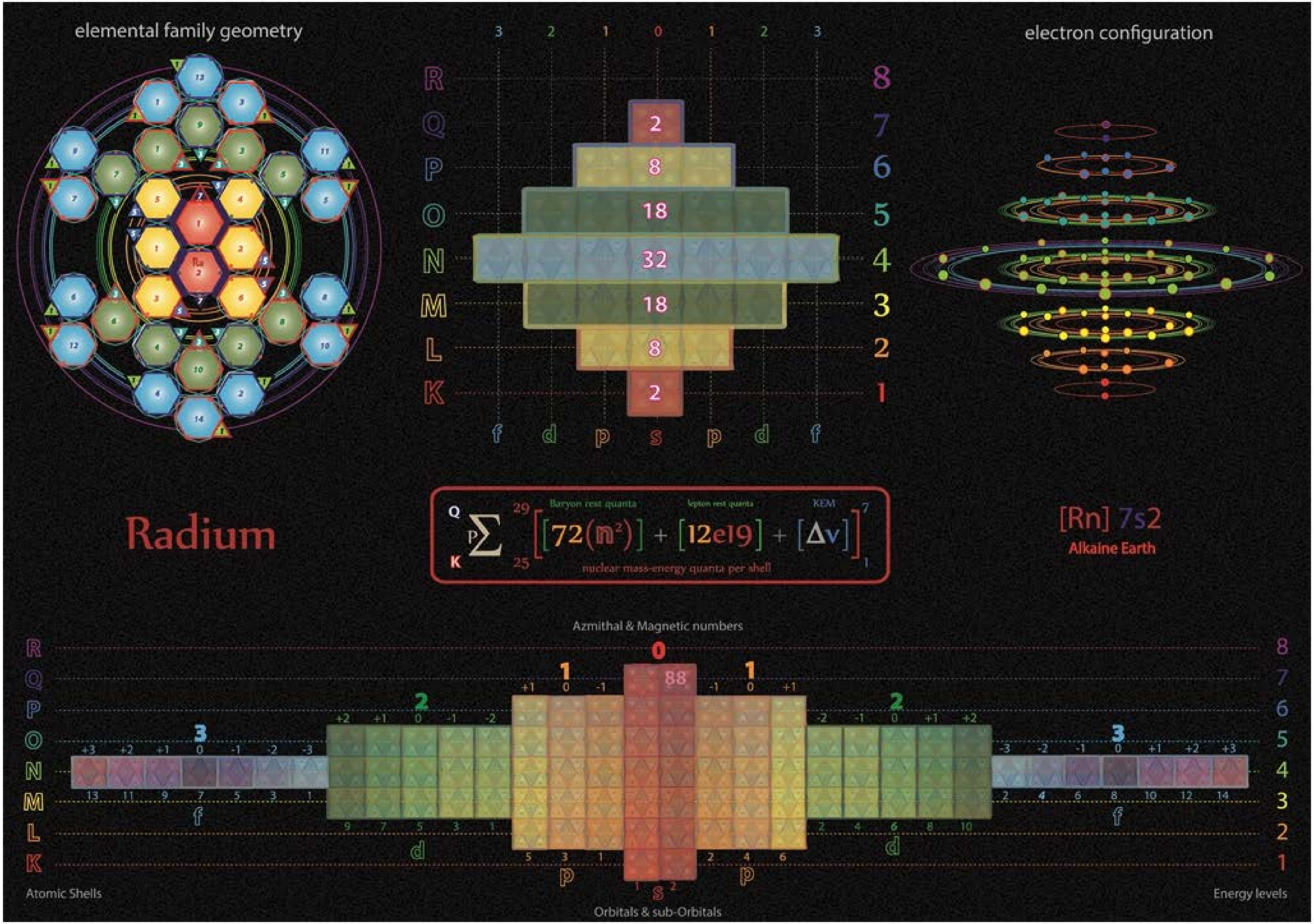
elemental family geometry
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
18
32
18
8
2
f d p s p d f
electron configuration
Radium
[Rn] 7s2
Alkaine Earth
Azmithal & Magnetic numbers
0
88
1
2
3
+3 +2 +1 0 -1 -2 -3
13 11 9 7 5 3 1
f
+2 +1 0 -1 -2
9 7 5 3 1
d
+1 0 -1
5 3 1
p
1 s 2
-1 0 +1
2 4 6
p
-2 -1 0 +1 +2
2 4 6 8 10
d
-3 -2 -1 0 +1 +2 +3
2 4 6 8 10 12 14
f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

$$\sum_{K}^{Q} {}_{P} \, {}_{25}^{29}\left[\underset{\text{}}{\overset{\text{Baryon rest quanta}}{[72(n^2)]}} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]} \right]_{1}^{7}$$

nuclear mass-energy quanta per shell

Tetryonics 53.88 - Radium atomic config

elemental family geometry

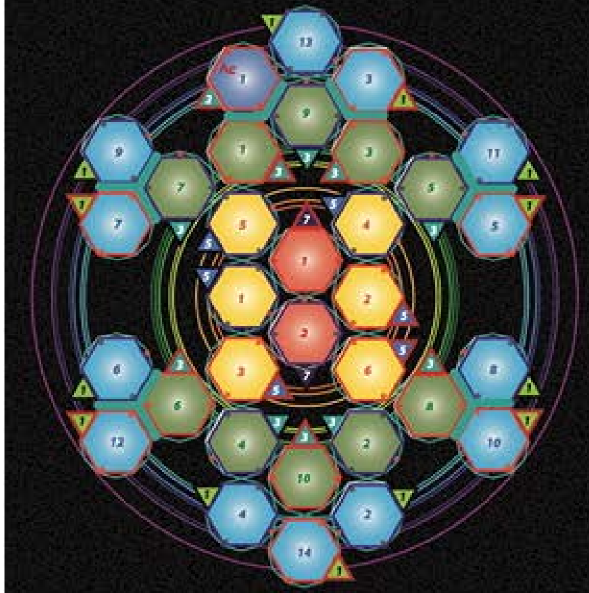

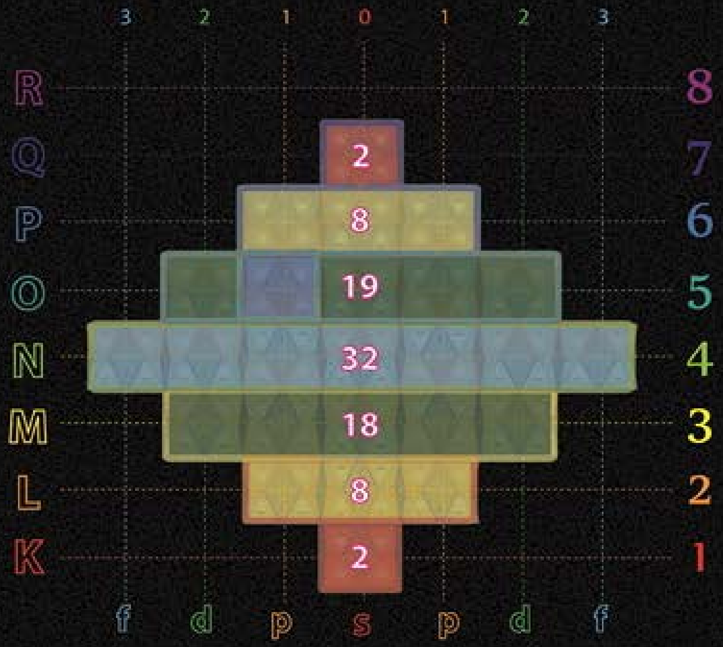
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
2
8
19
32
18
8
2
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

electron configuration

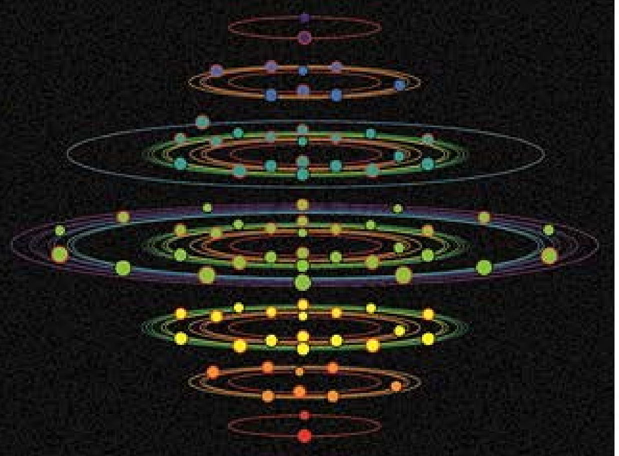

Actinium

$$\sum_{K}^{Q} P \; {}^{29}_{25}\left[[72(m^2)] + [12e19] + [\Delta v] \right]^{7}_{1}$$

Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[Rn] 5f1 7s2

Actinoid

Azmithal & Magnetic numbers

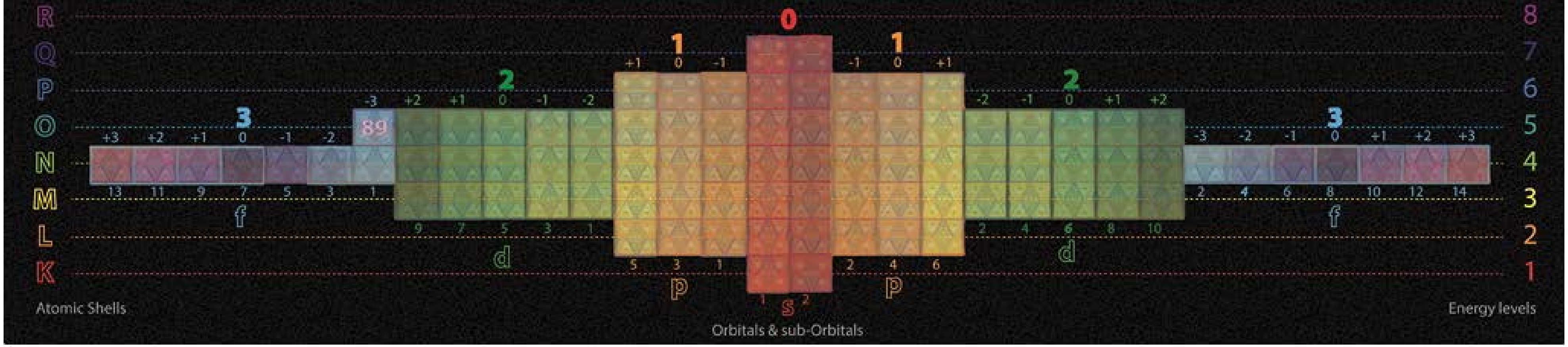
0
1
1
2
2
3
3
+1
0
-1
-1
0
+1
-3
+2
+1
0
-1
-2
-2
-1
0
+1
+2
+3
+2
+1
0
-1
-2
-3
-2
-1
0
+1
+2
+3
89
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
13
11
9
7
5
3
1
2
4
6
8
10
12
14
f
f
9
7
5
3
1
2
4
6
8
10
d
d
5
3
1
2
4
6
p
p
1
s
2
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.89 - Actinium atomic config

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elemental family geometry

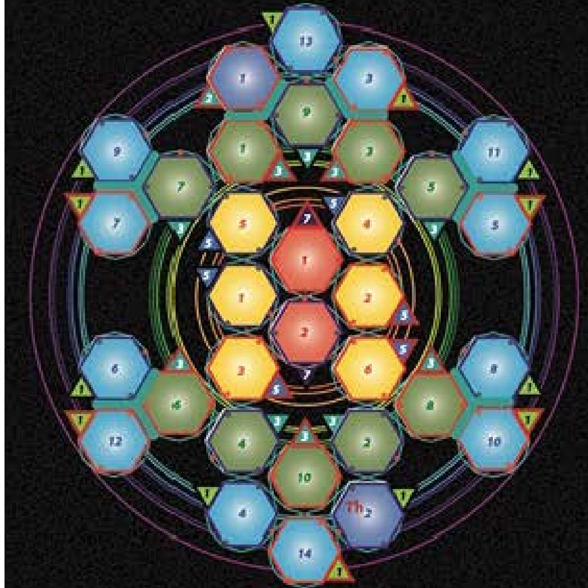
13
1
3
9
11
7
5
1
1
2
2
10
12
6
8
14
th
2

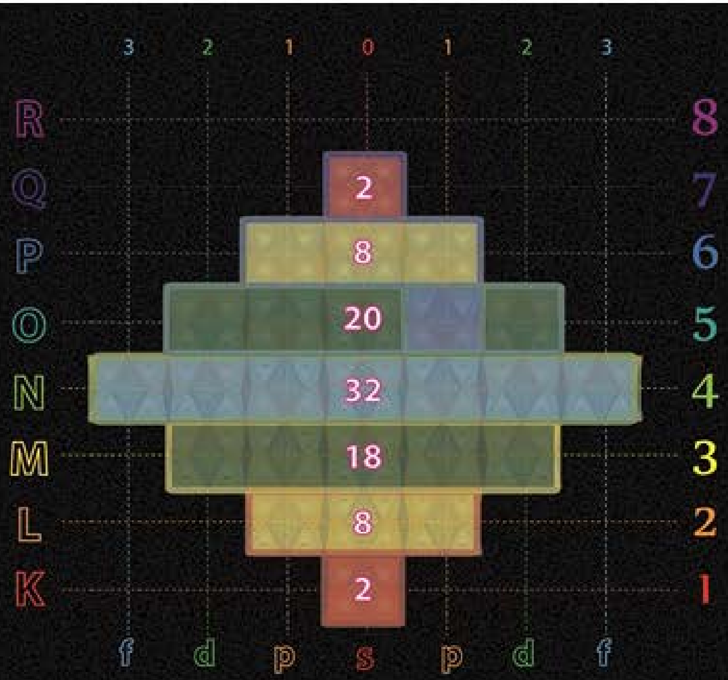
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
8
20
32
18
8
2
f
d
p
s
p
d
f

electron configuration

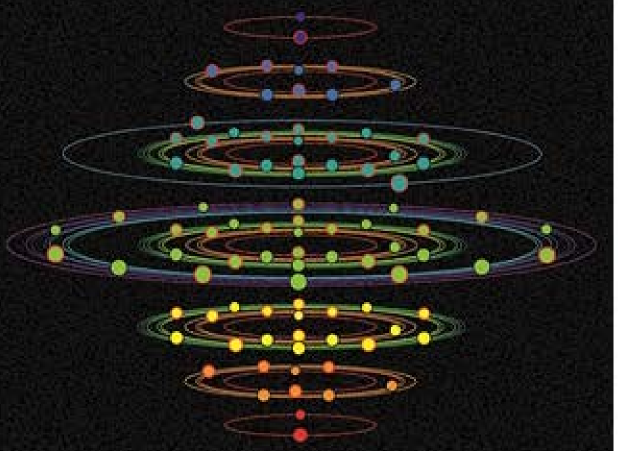

Thorium

$$
{}_{K}^{Q}{}_{P}\sum_{25}^{29}\left[\overset{\text{Baryon rest quanta}}{[72(m^2)]}+\overset{\text{lepton rest quanta}}{[12e19]}+\overset{\text{KEM}}{[\Delta v]}\right]_{1}^{7}
$$

nuclear mass-energy quanta per shell

[Rn] 5f2 7s2

Actinoid

Azmithal & Magnetic numbers

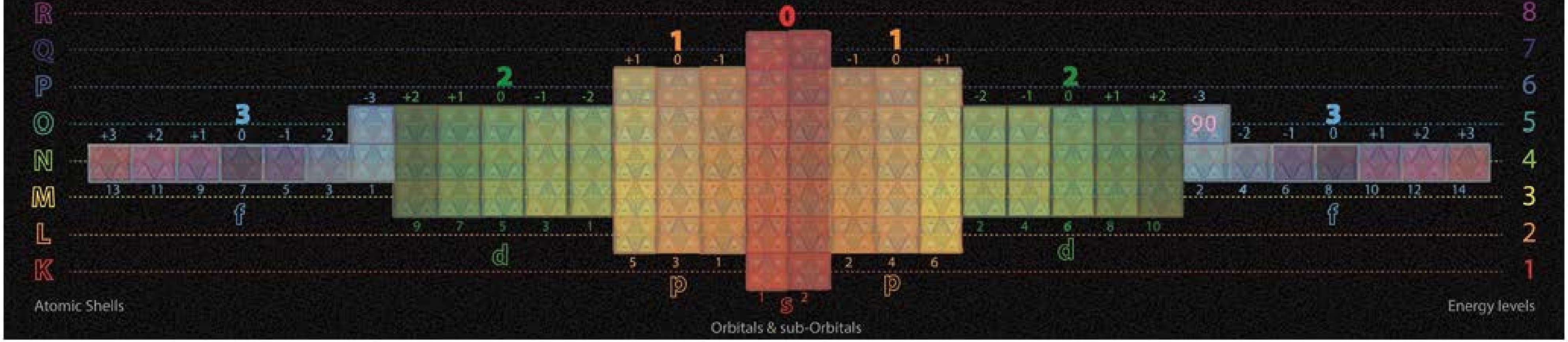
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
2
3
3
+1
0
-1
-1
0
+1
-3
+2
+1
0
-1
-2
-2
-1
0
+1
+2
-3
+3
+2
+1
0
-1
-2
90
-2
-1
0
+1
+2
+3
13
11
9
7
5
3
1
2
4
6
8
10
12
14
9
7
5
3
1
2
4
6
8
10
5
3
1
2
4
6
1
2
f
d
p
s
p
d
f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.90 - Thorium atomic config

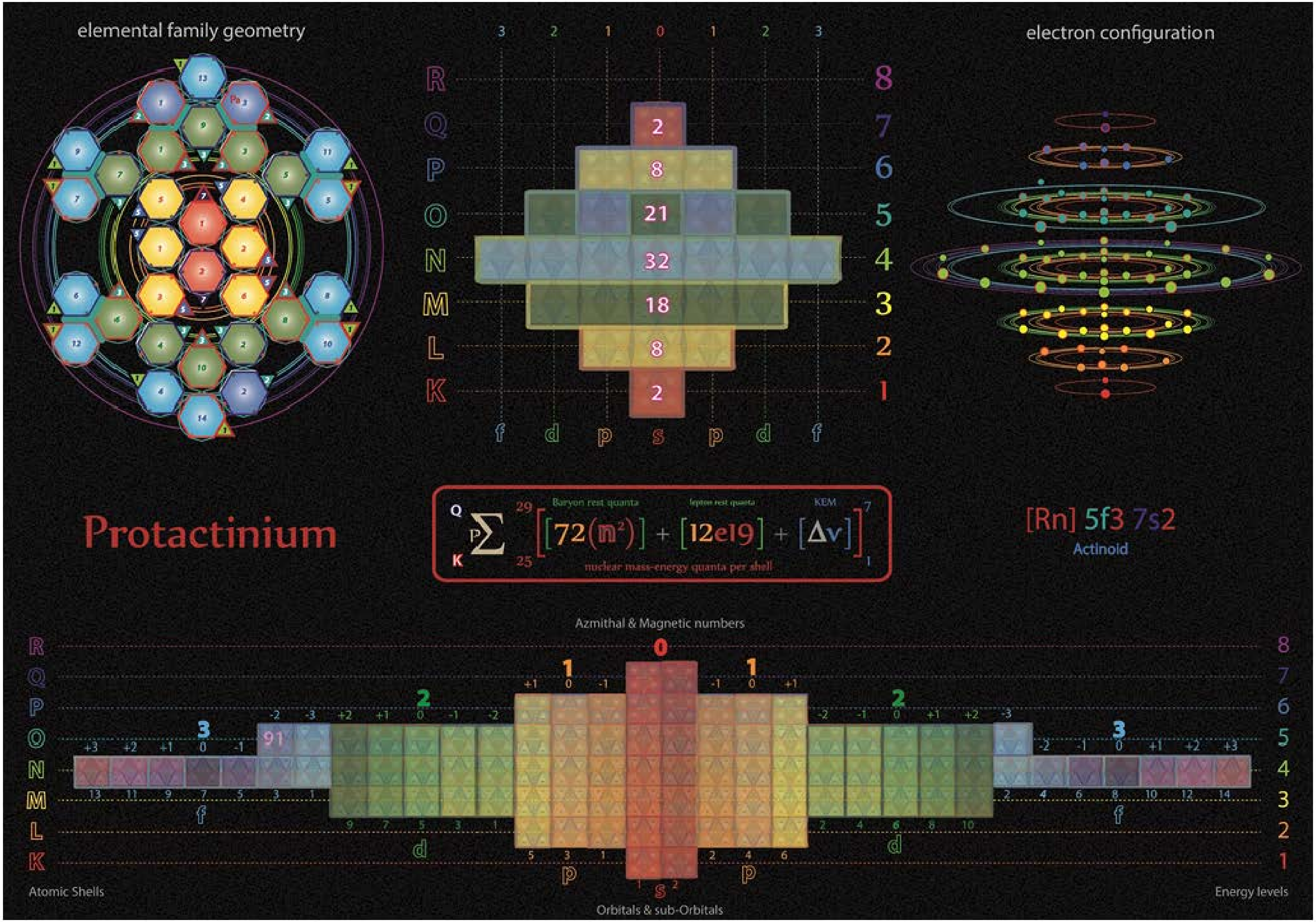
elemental family geometry
Pa 3
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
2
8
21
32
18
8
2
8
7
6
5
4
3
2
1
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+1 0 -1 -1 0 +1
-2 -3 +2 +1 0 -1 -2 -2 -1 0 +1 +2 -3
+3 +2 +1 0 -1 -2 -1 0 +1 +2 +3
91
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1 2 4 6
1 s 2
f d p p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Protactinium

Baryon rest quanta — lepton rest quanta — KEM

$$\sum_{K}^{Q} {}_{p} \; {}^{29}_{25}\left[[72(m^2)] + [12e19] + [\Delta v] \right]^{7}_{1}$$

nuclear mass-energy quanta per shell

[Rn] 5f3 7s2

Actinoid

Tetryonics 53.91 - Protactinium atomic config

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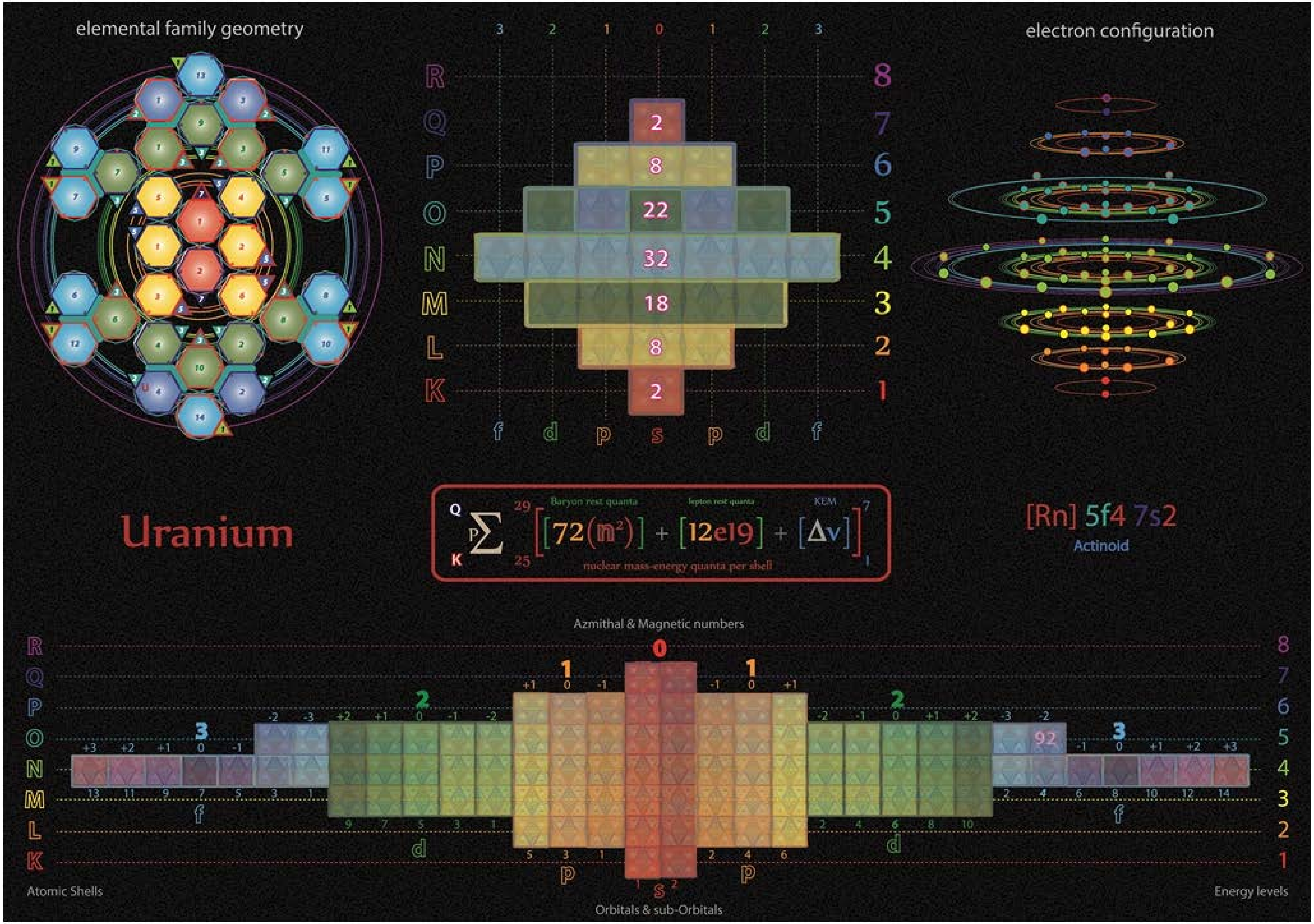
elemental family geometry
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2 8 22 32 18 8 2
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+1 0 -1
-1 0 +1
-2 -3 +2 +1 0 -1 -2
-2 -1 0 +1 +2 -3 -2
+3 +2 +1 0 -1
-1 0 +1 +2 +3
92
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Uranium

$$\sum_{K}^{Q} {}^{P} \, {}_{25}^{29}\left[\,[72(m^2)] + [12e19] + [\Delta v]\,\right]_{1}^{7}$$

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Rn] 5f4 7s2

Actinoid

Tetryonics 53.92 - Uranium atomic config

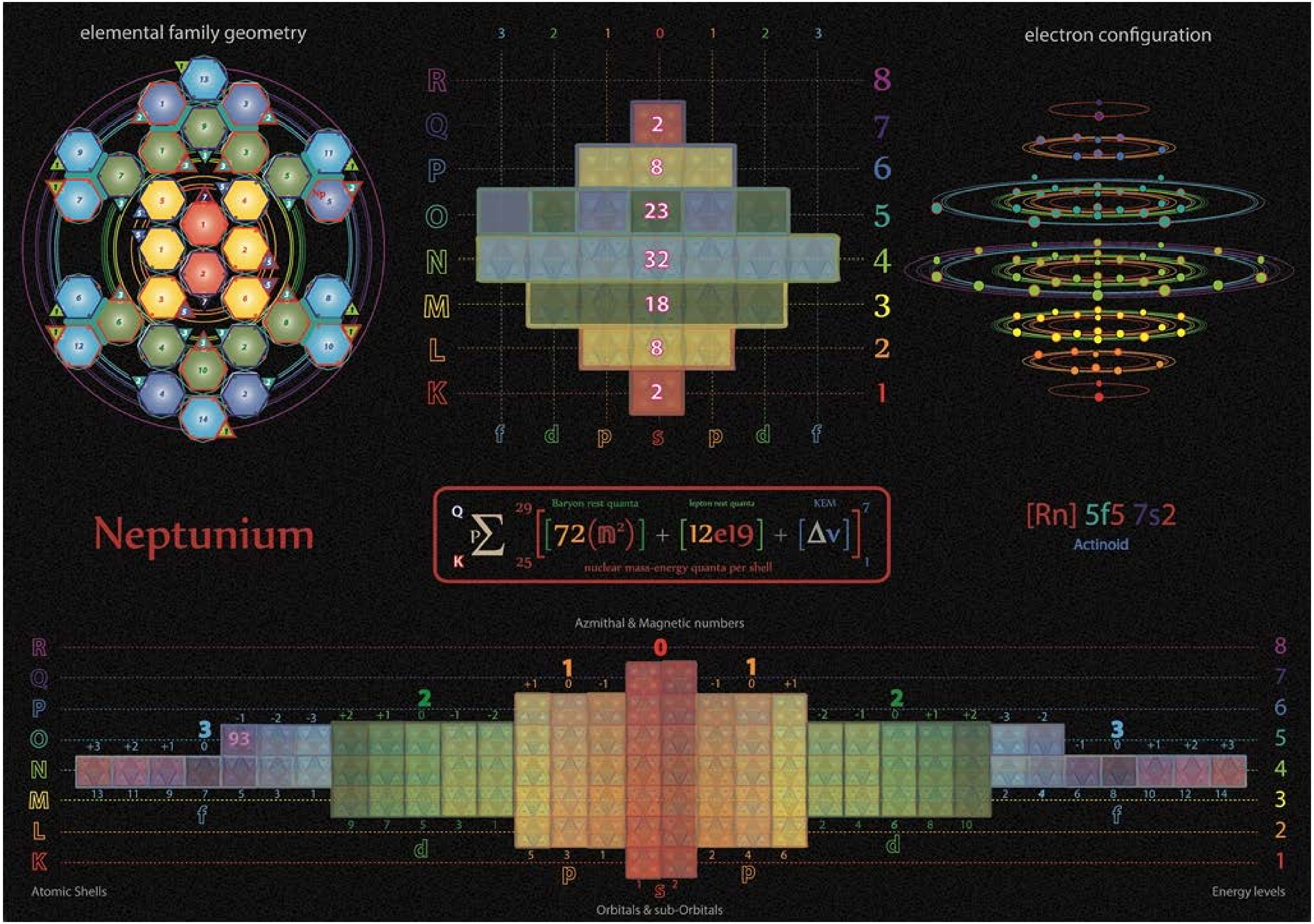
elemental family geometry
Np
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
23
32
18
8
2
f d p s p d f
Neptunium
Q
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
7
1
nuclear mass-energy quanta per shell
[Rn] 5f5 7s2
Actinoid
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
93
Atomic Shells
Energy levels
Orbitals & sub-Orbitals
f d p s p d f

Tetryonics 53.93 - Neptunium atomic config

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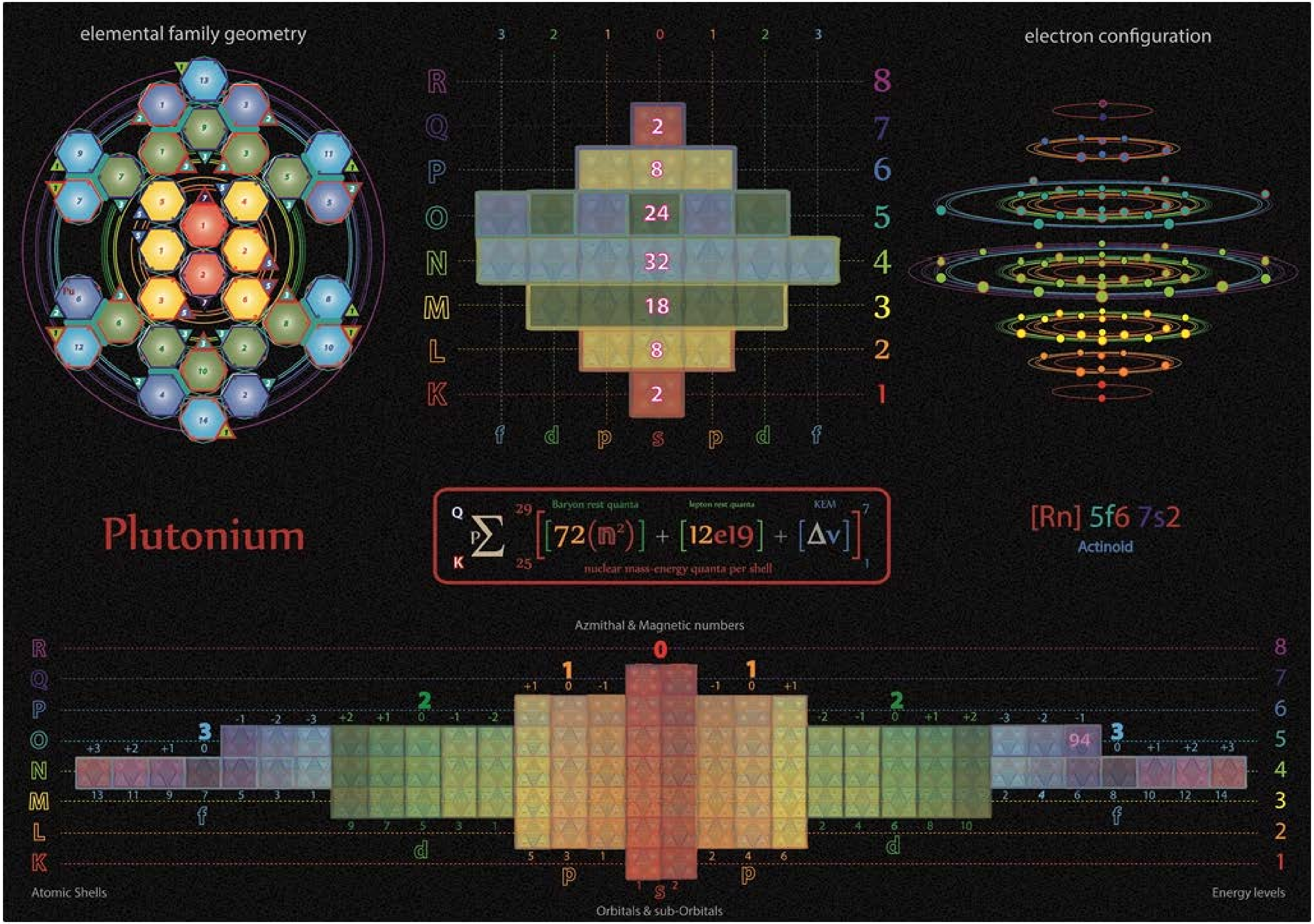
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
24
32
18
8
2
f d p s p d f
Plutonium
Q
K
p∑ 29 25
Baryon rest quanta
lepton rest quanta
KEM
[72(n²)] + [12e19] + [Δv] 7 1
nuclear mass-energy quanta per shell
[Rn] 5f6 7s2
Actinoid
Azmithal & Magnetic numbers
0
1
2
3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
94
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 s 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.94 - Plutonium atomic config

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elemental family geometry

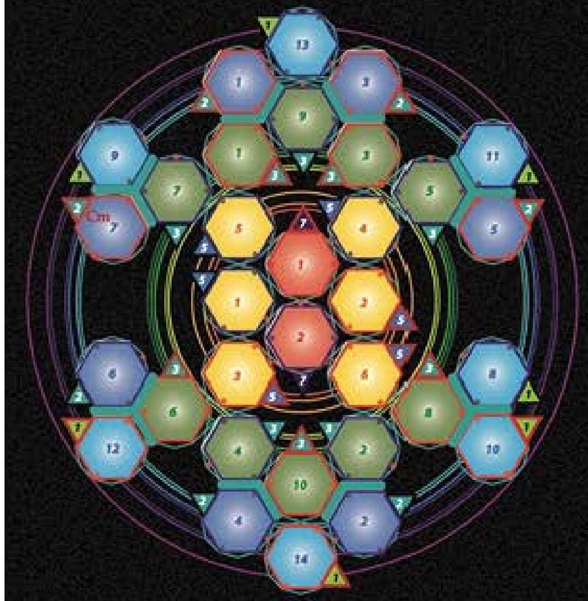

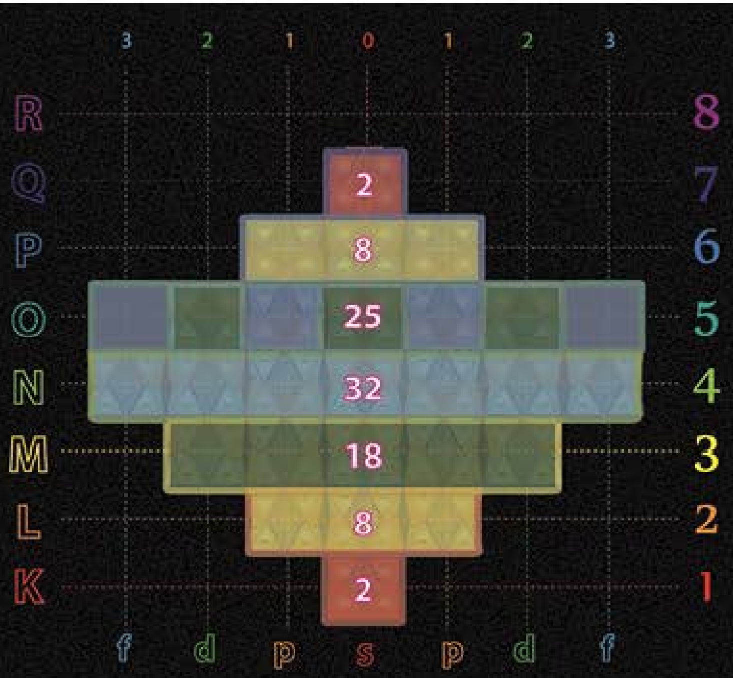
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
25
32
18
8
2
f d p s p d f

electron configuration

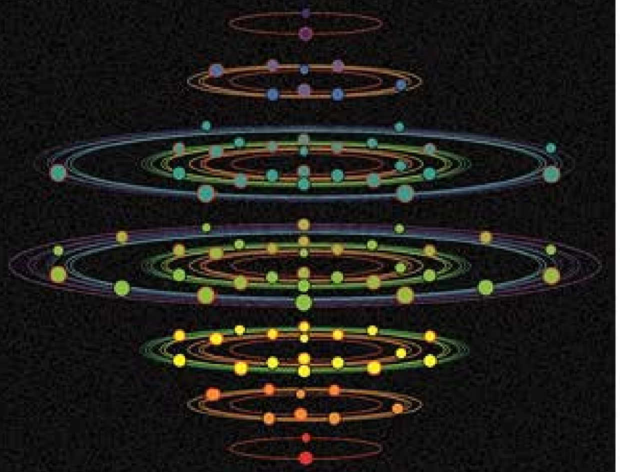

Americium

$$\sum_{K}^{Q} {}_{P}\!\sum_{25}^{29}\left[[72(\mathrm{m}^2)] + [12e19] + [\Delta v]\right]_{1}^{7}$$

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Rn] 5f7 7s2

Actinoid

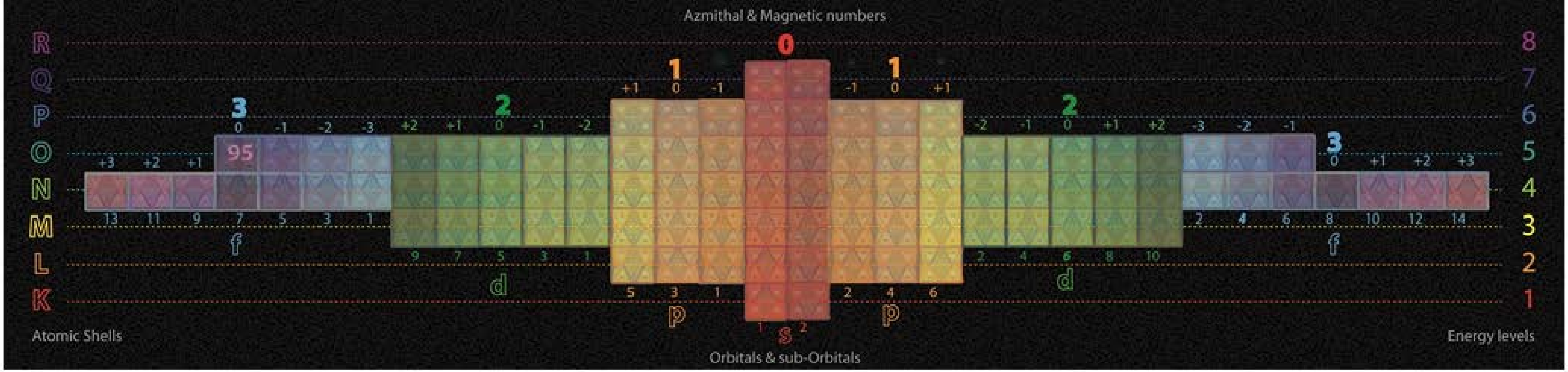
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
95
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.95 - Americium atomic config

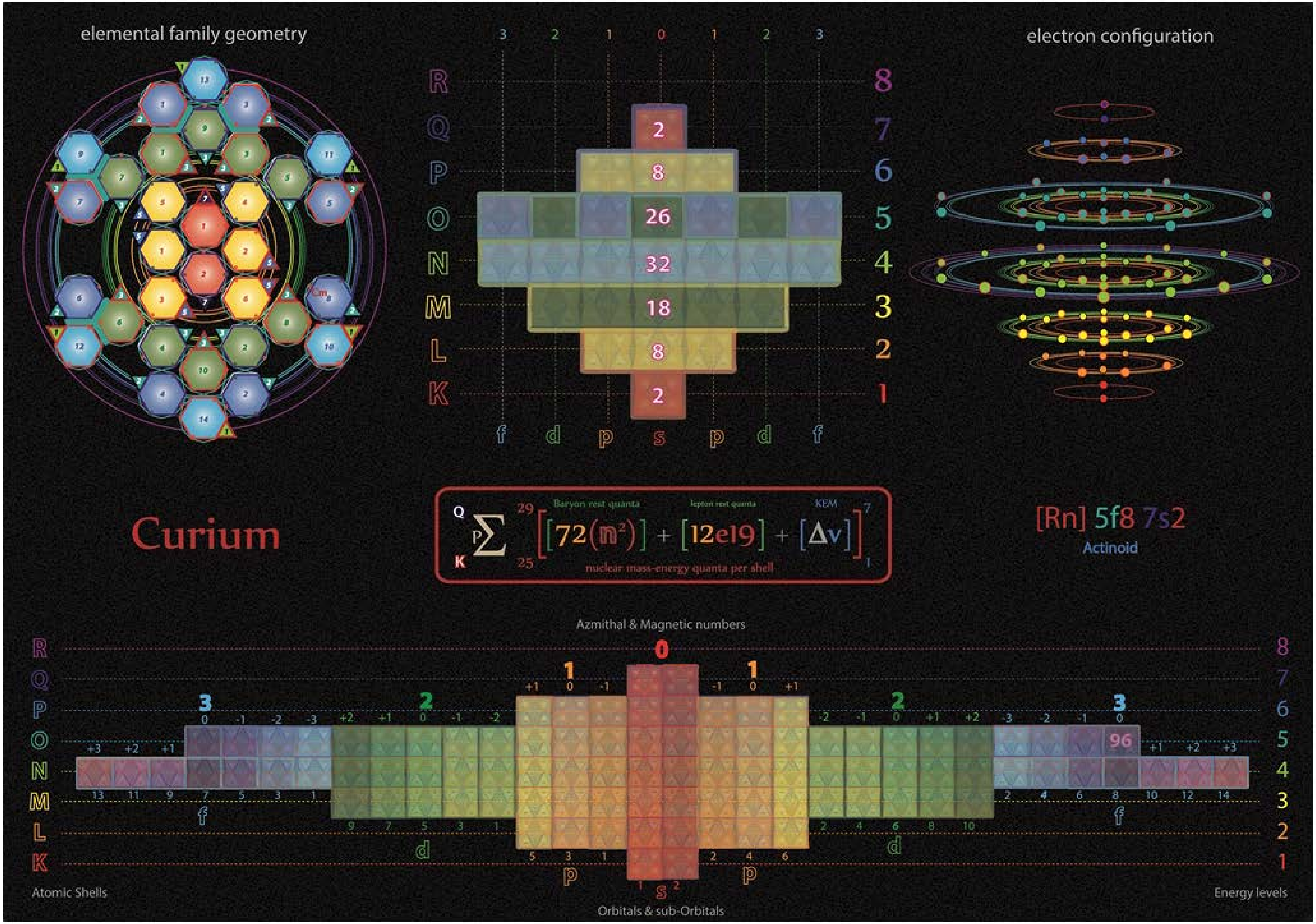
elemental family geometry
electron configuration
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
2
8
26
32
18
8
2
f d p s p d f
Curium
Q
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
7
1
[72(m²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
[Rn] 5f8 7s2
Actinoid
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
96
f
d
p
s
p
d
f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

$$\sum_{K}^{Q} P \, {}_{25}^{29}\left[[72(m^2)] + [12e19] + [\Delta v] \right]_{1}^{7}$$

Tetryonics 53.96 - Curium atomic config

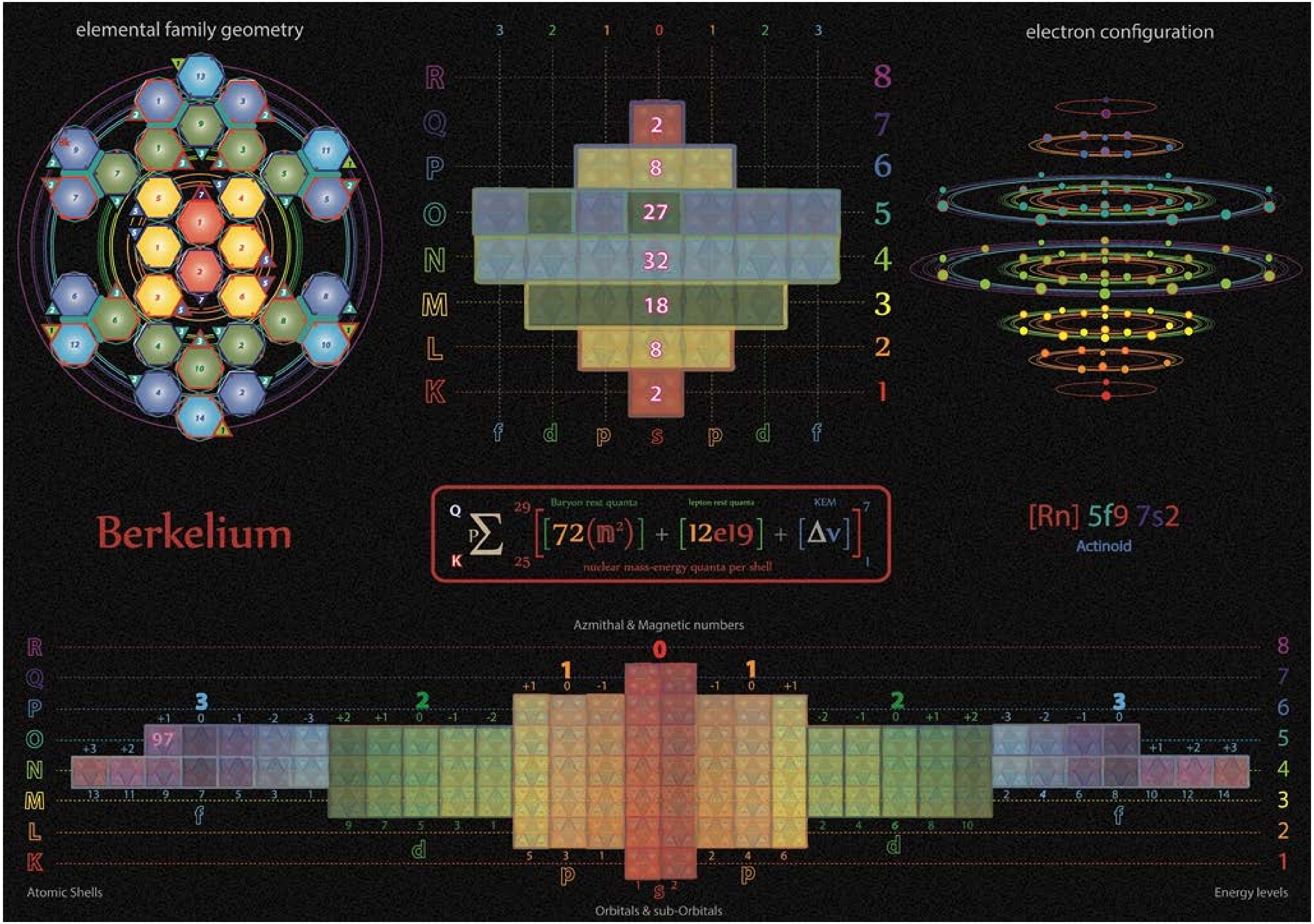
elemental family geometry
electron configuration
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
8
27
32
18
8
2
f
d
p
s
p
d
f
Berkelium
Q
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
[Rn] 5f9 7s2
Actinoid
Azmithal & Magnetic numbers
97
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.97 - Berkelium atomic config

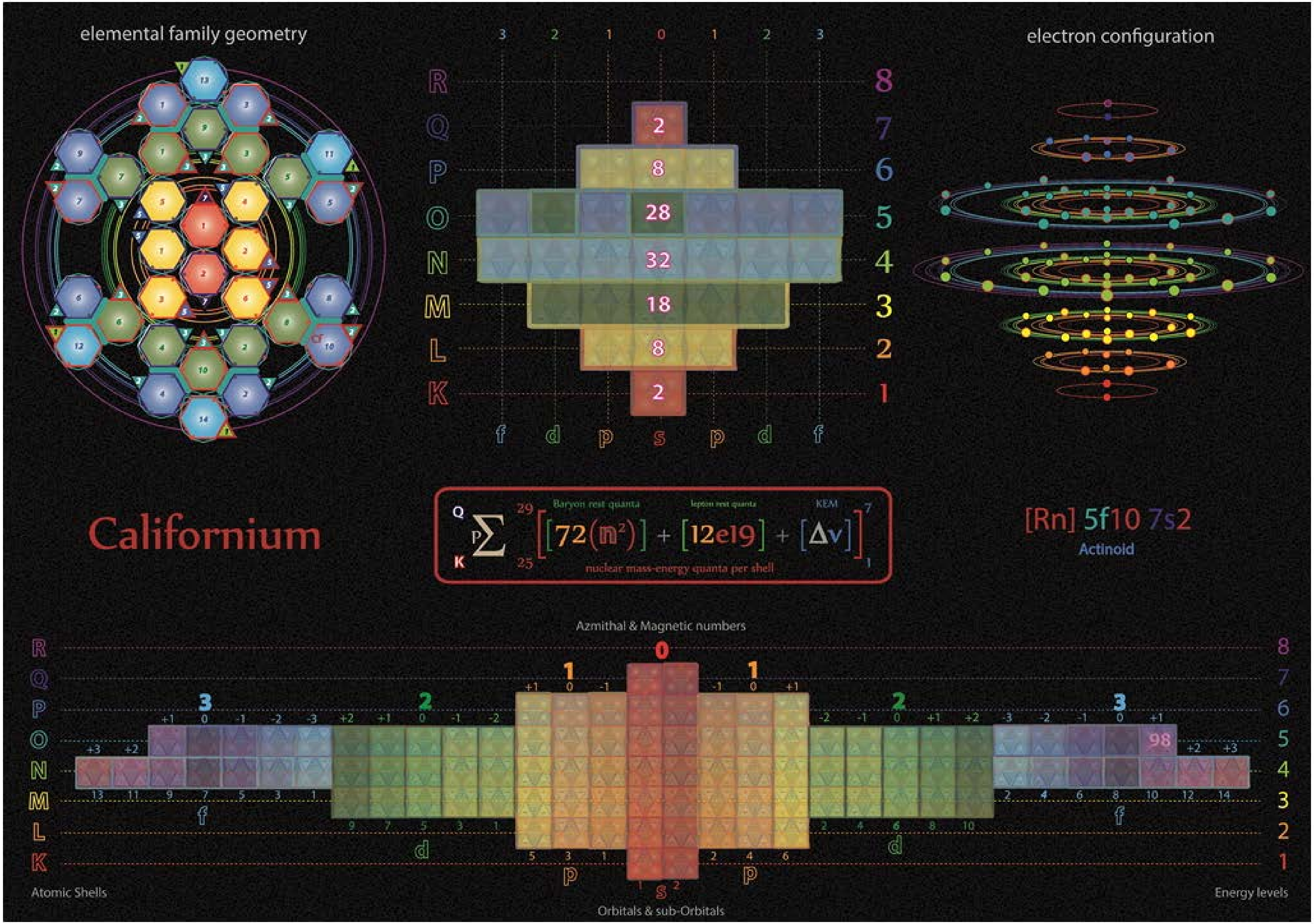
elemental family geometry
3 2 1 0 1 2 3
R Q P O N M L K
2
8
28
32
18
8
2
8 7 6 5 4 3 2 1
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
0
1 1
+1 0 -1
-1 0 +1
2 2
3 3
+2 +1 0 -1 -2
-2 -1 0 +1 +2
+1 0 -1 -2 -3
-3 -2 -1 0 +1
+3 +2
98 +2 +3
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 s 2
f d p p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Californium

$$\sum_{K}^{Q} P\sum_{25}^{29}\left[\left[72(n^2)\right]+\left[12e19\right]+\left[\Delta v\right]\right]_{1}^{7}$$

Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[Rn] 5f10 7s2

Actinoid

Tetryonics 53.98 - Californium atomic config

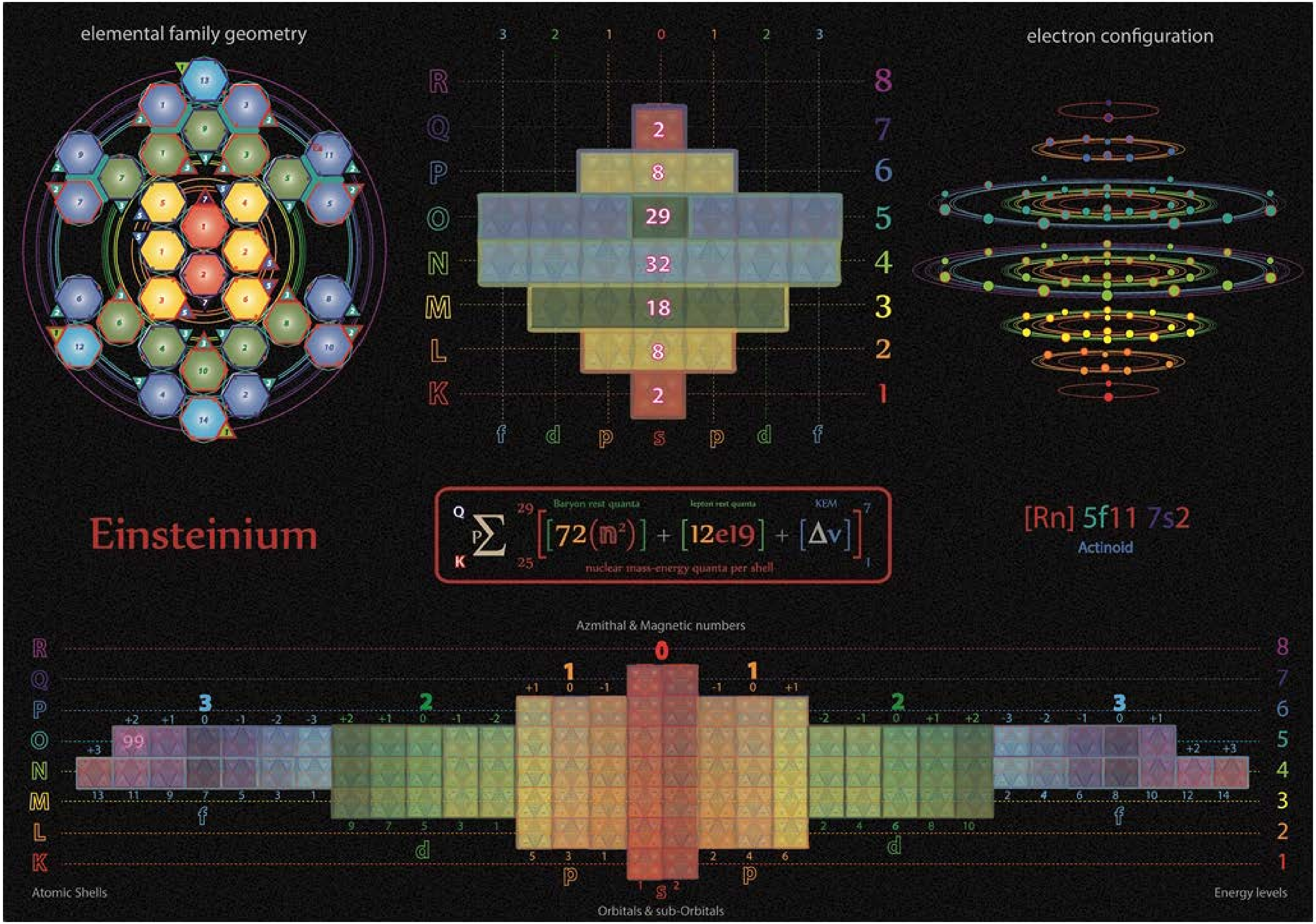
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
29
32
18
8
2
f d p s p d f
Einsteinium
Q
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
7
1
nuclear mass-energy quanta per shell
[Rn] 5f11 7s2
Actinoid
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+1 0 -1
-1 0 +1
+2 +1 0 -1 -2
-2 -1 0 +1 +2
+3 +2 +1 0 -1 -2 -3
-3 -2 -1 0 +1 +2 +3
99
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.99 - Einsteinium atomic config

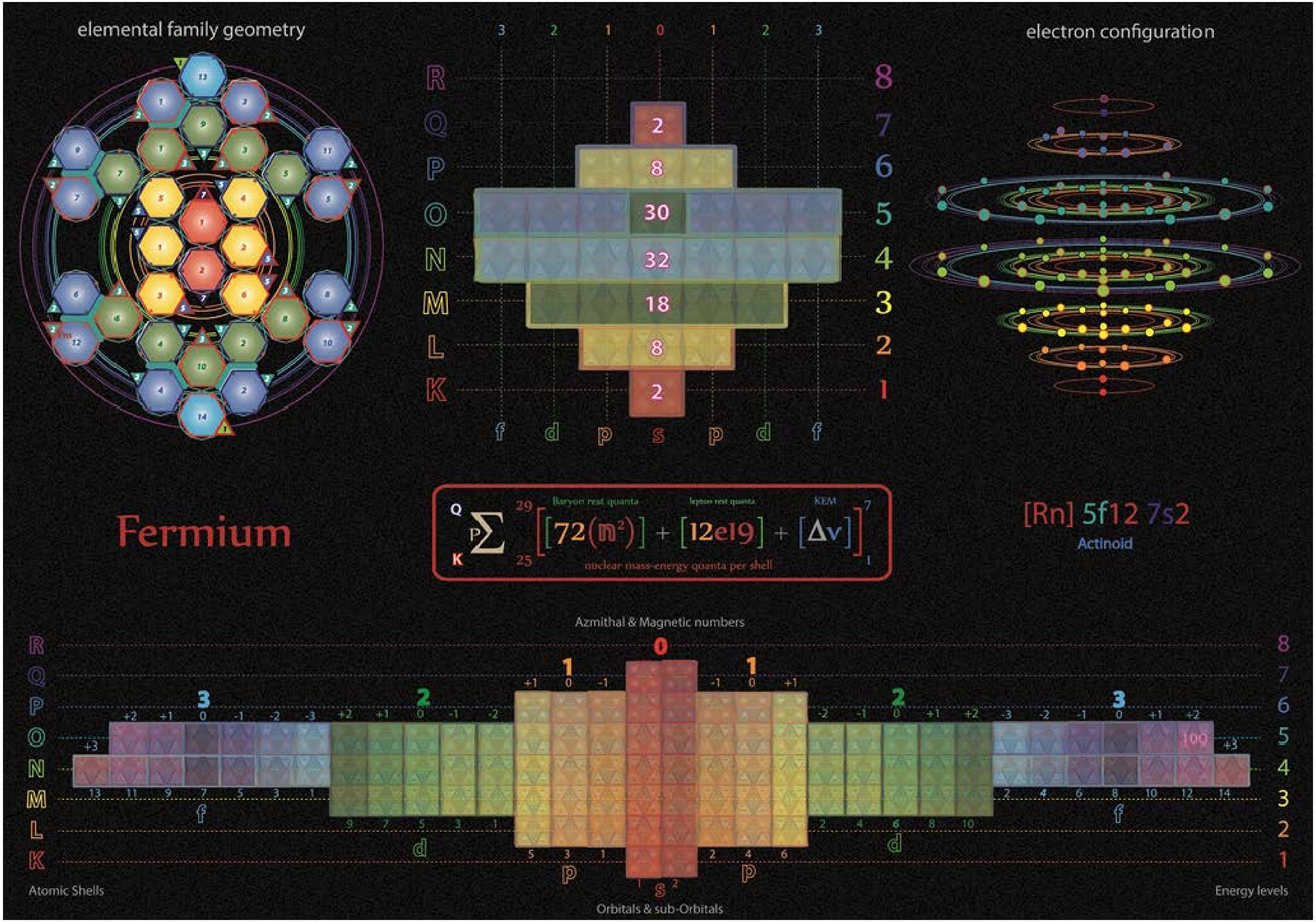
elemental family geometry
electron configuration
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
2
8
30
32
18
8
2
f d p s p d f
Fermium
Q
P
K
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
7
1
nuclear mass-energy quanta per shell
[Rn] 5f12 7s2
Actinoid
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
100
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 s 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.100 - Fermium atomic config

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elemental family geometry

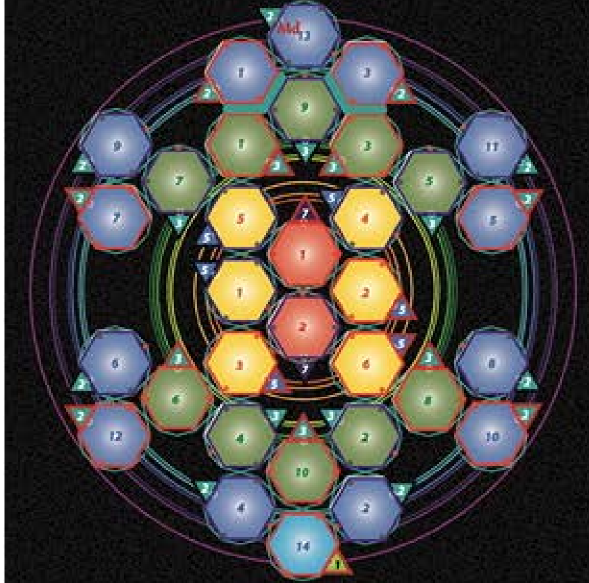

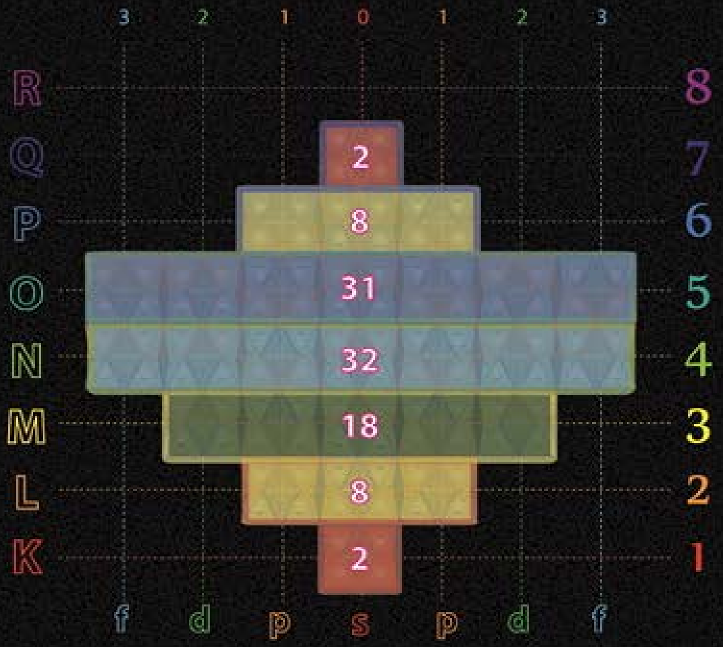
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
31
32
18
8
2
f d p s p d f

electron configuration

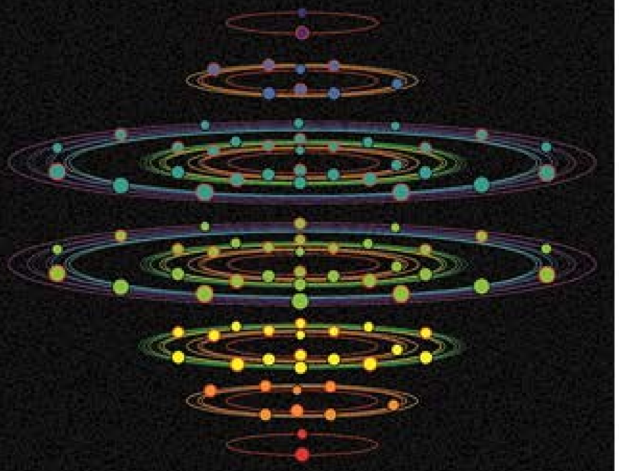

Mendelevium

$$\sum_{K}^{Q} P \; {}^{29}_{25}\Big[\,[72(m^2)] + [12e19] + [\Delta v]\,\Big]^{7}_{1}$$

Baryon rest quanta — lepton rest quanta — KEM

nuclear mass-energy quanta per shell

[Rn] 5f13 7s2

Actinoid

Azmithal & Magnetic numbers

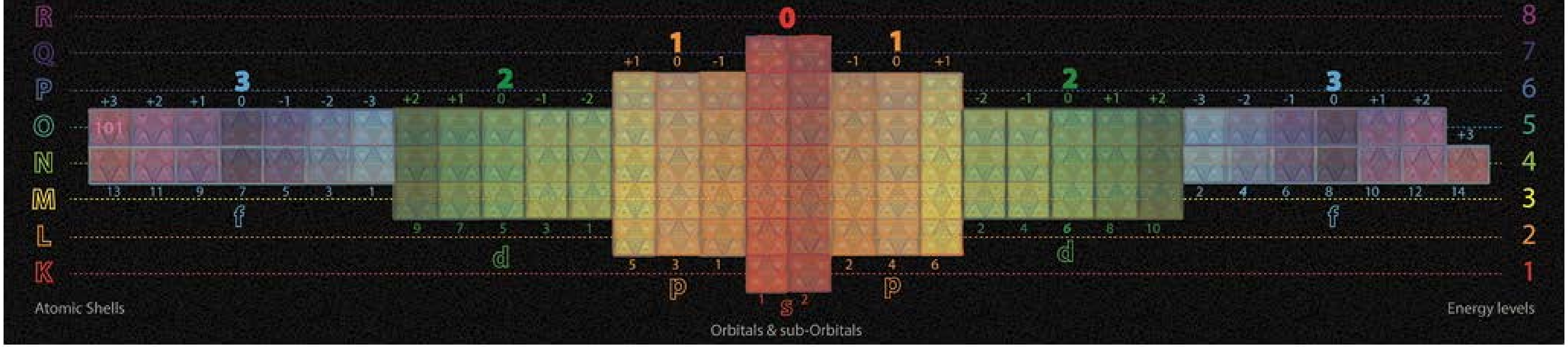
R Q P O N M L K
8 7 6 5 4 3 2 1
0
1 1
2 2
3 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
101
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p s p d f
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.101 - Mendelevium atomic config

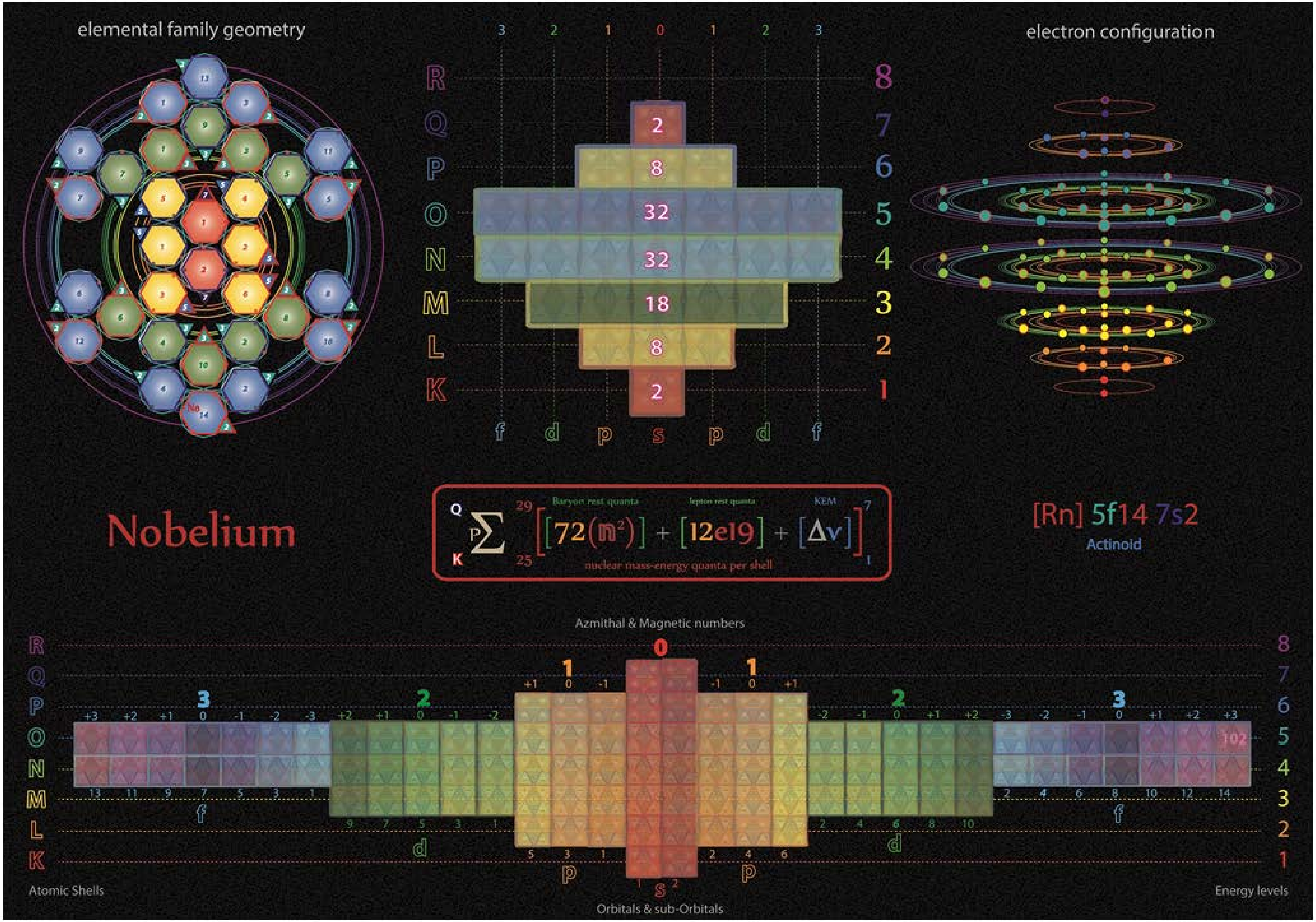
elemental family geometry
Nobelium
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2 8 32 32 18 8 2
f d p s p d f
electron configuration
Q
K
P
25
29
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
1
7
nuclear mass-energy quanta per shell
[Rn] 5f14 7s2
Actinoid
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
102
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 s 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.102 - Nobelium atomic config

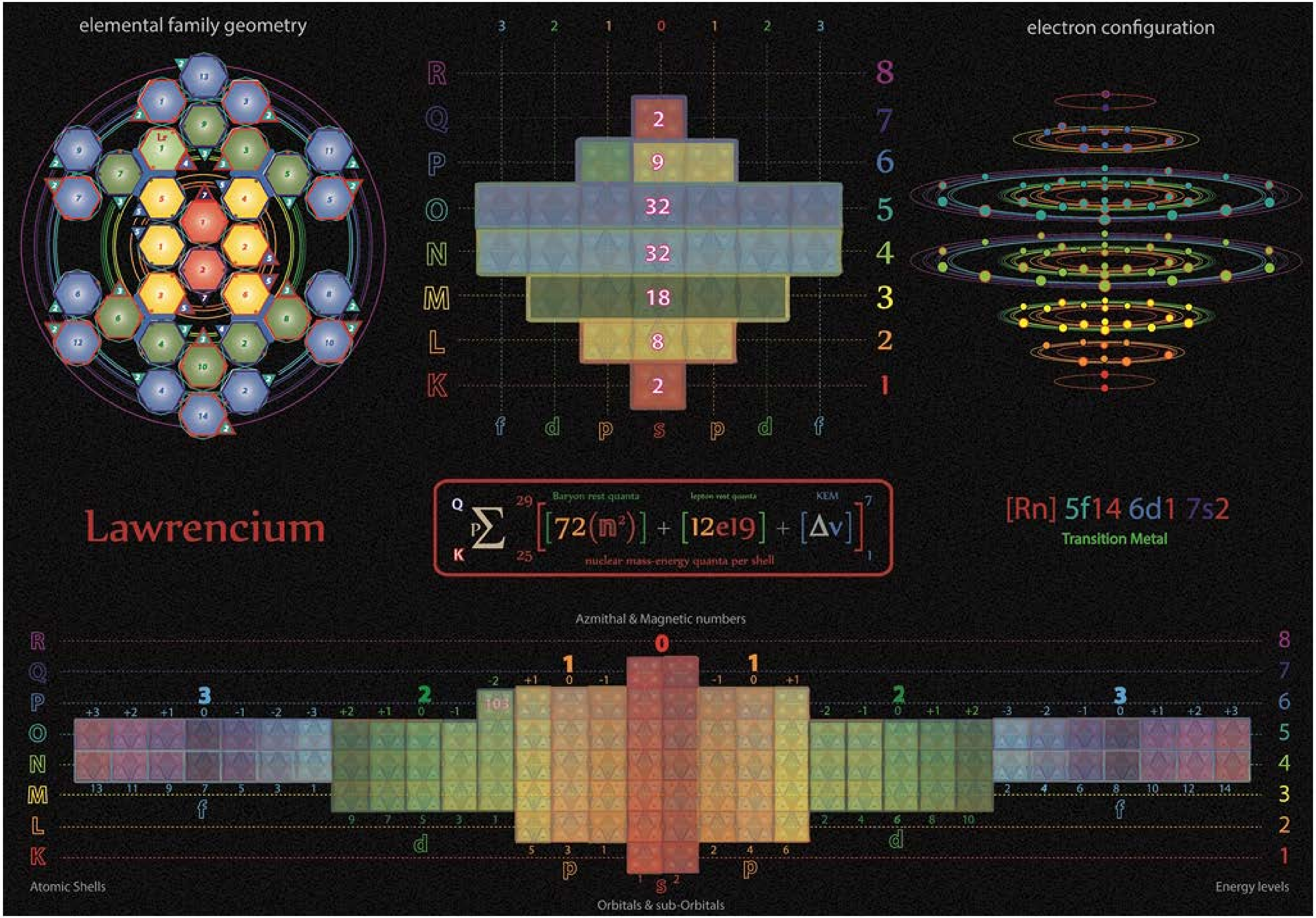
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
9
32
32
18
8
2
f d p s p d f
Lawrencium
[Rn] 5f14 6d1 7s2
Transition Metal
Azmithal & Magnetic numbers
Atomic Shells
Energy levels
Orbitals & sub-Orbitals
103

$$\sideset{_{P}}{}\sum_{K}^{Q}{}_{25}^{29}\left[\left[72(n^2)\right]+\left[12e19\right]+\left[\Delta v\right]\right]_{1}^{7}$$

Baryon rest quanta
lepton rest quanta
KEM
nuclear mass-energy quanta per shell

Tetryonics 53.103 - Lawrencium atomic config

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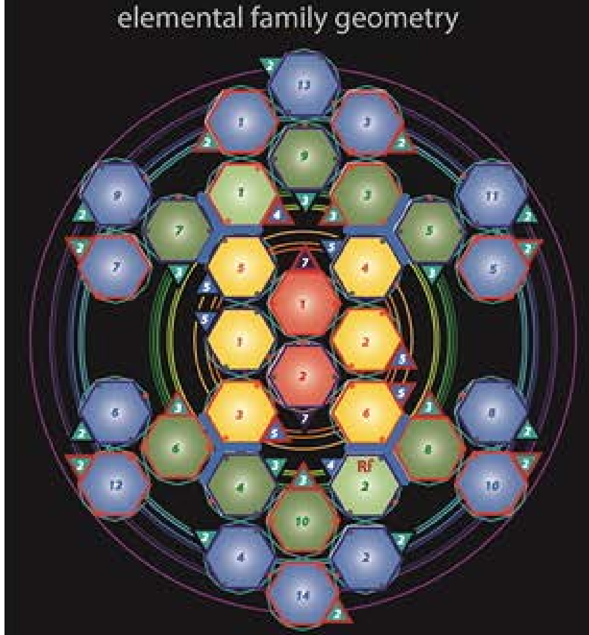
elemental family geometry

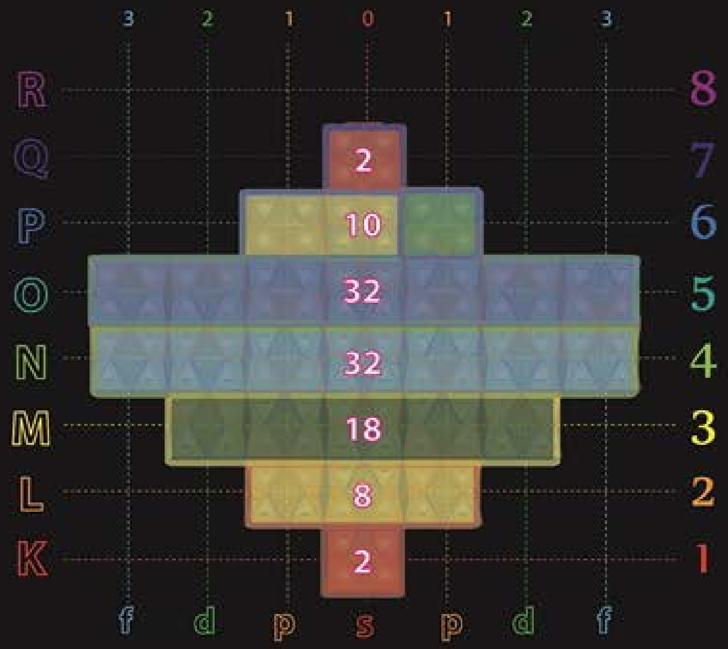
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
10
32
32
18
8
2
f
d
p
s
p
d
f

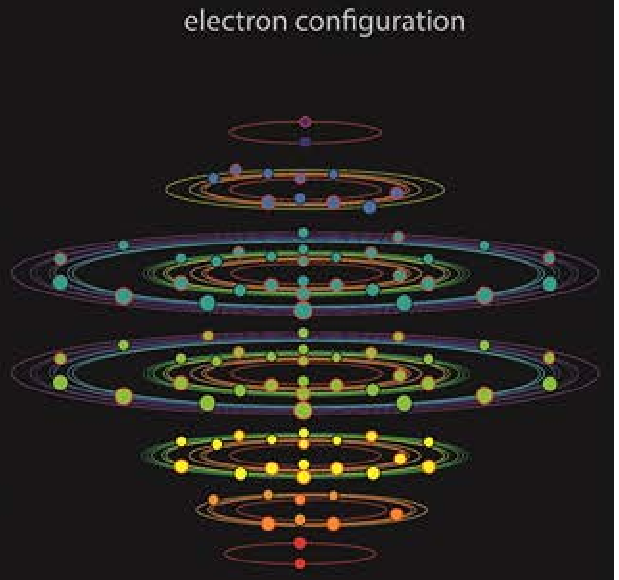
electron configuration

Rutherfordium

$$\sum_{K}^{Q} {}_{P}\,{}^{29}_{25}\left[\overset{\text{Baryon rest quanta}}{[72(m^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]}\right]^{7}_{1}$$

nuclear mass-energy quanta per shell

[Rn] 5f14 6d2 7s2

Transition Metal

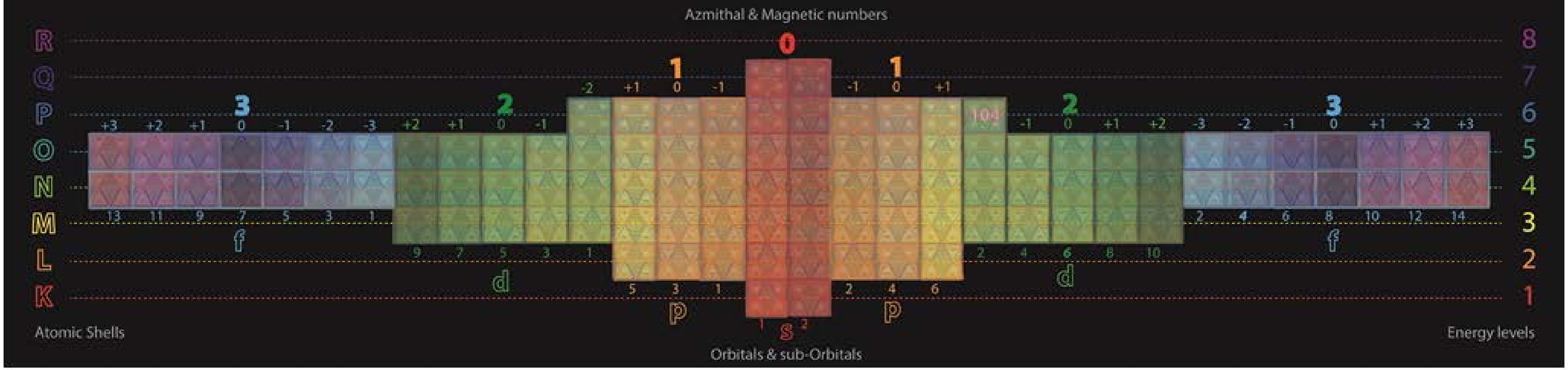
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
2
3
3
104
f
d
p
s
p
d
f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.104 - Rutherfordium atomic config

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elemental family geometry

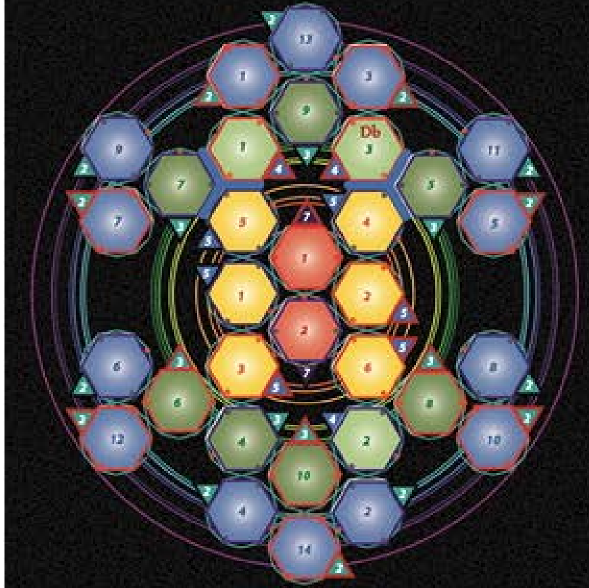
Db
1
2
3
4
5
6
7
8
9
10
11
12
13
14

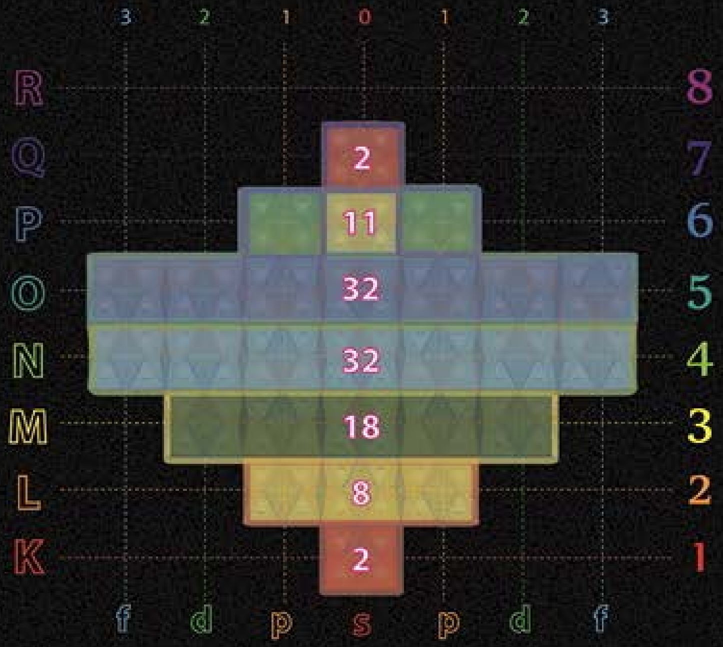
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
11
32
32
18
8
2
f d p s p d f

electron configuration

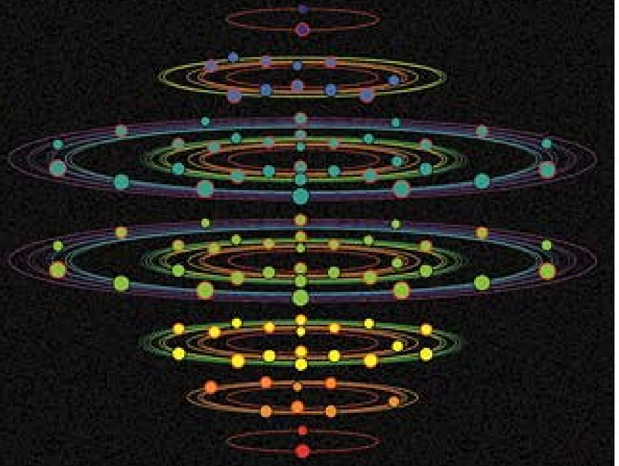

Dubnium

$$ {}_{K}^{Q}\,{}_{P}\!\sum_{25}^{29} \left[\overset{\text{Baryon rest quanta}}{\left[72\left(\mathrm{m}^2\right)\right]} + \overset{\text{lepton rest quanta}}{\left[12e19\right]} + \overset{\text{KEM}}{\left[\Delta v\right]} \right]_{1}^{7} $$

nuclear mass-energy quanta per shell

[Rn] 5f14 6d3 7s2

Transition Metal

Azmithal & Magnetic numbers

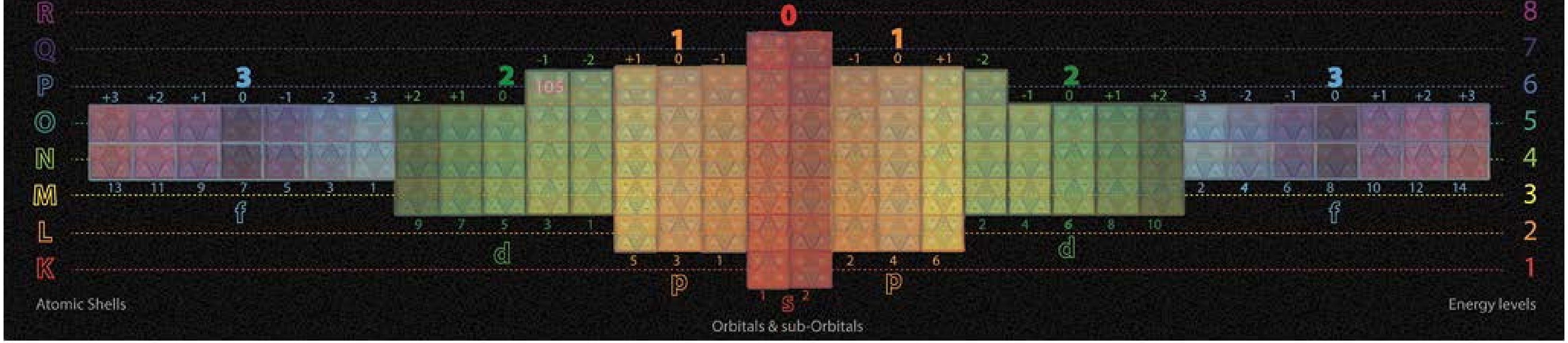
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
2
3
3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
-1 0 +1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
105
13 11 9 7 5 3 1
f
9 7 5 3 1
d
5 3 1
p
1 s 2
2 4 6
p
2 4 6 8 10
d
2 4 6 8 10 12 14
f
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.105 - Dubnium atomic config

elemental family geometry

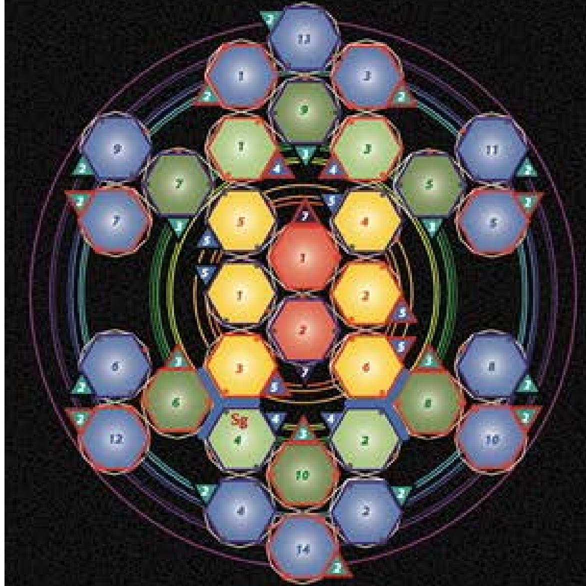

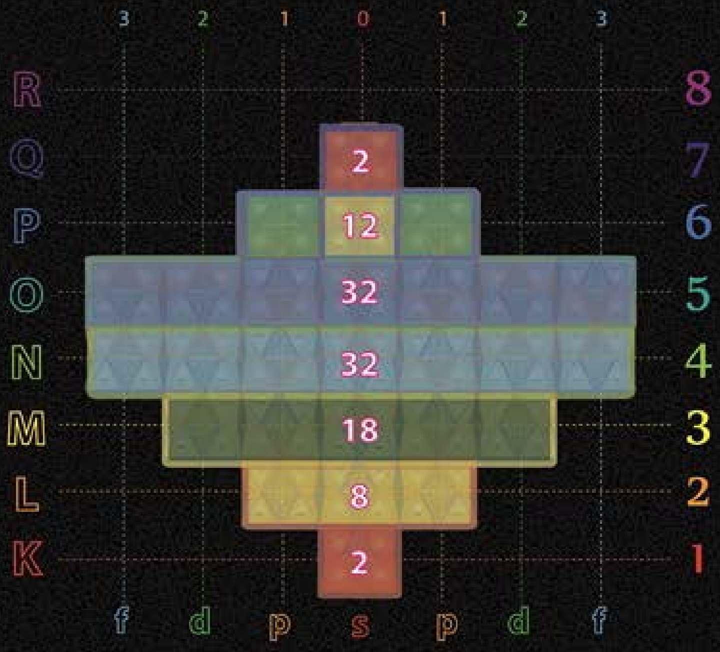
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
2
12
32
32
18
8
2
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

electron configuration

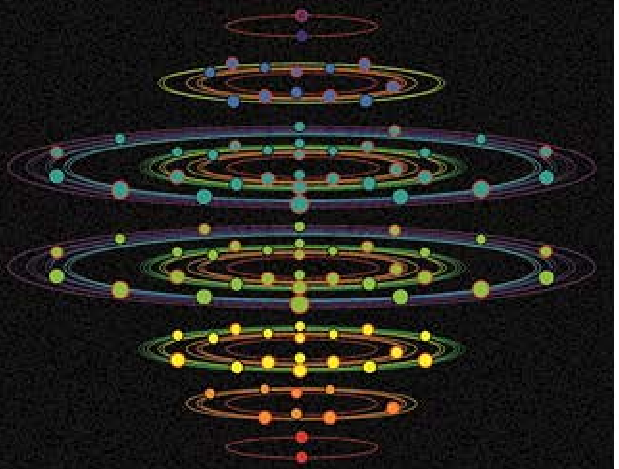

Seaborgium

$$\overset{Q}{\underset{K}{P}}\sum_{25}^{29}\left[\overset{\text{Baryon rest quanta}}{72(n^2)}\right]+\left[\overset{\text{lepton rest quanta}}{12e19}\right]+\left[\overset{\text{KEM}}{\Delta v}\right]_{1}^{7}$$

nuclear mass-energy quanta per shell

[Rn] 5f14 6d4 7s2

Transition Metal

Azmithal & Magnetic numbers

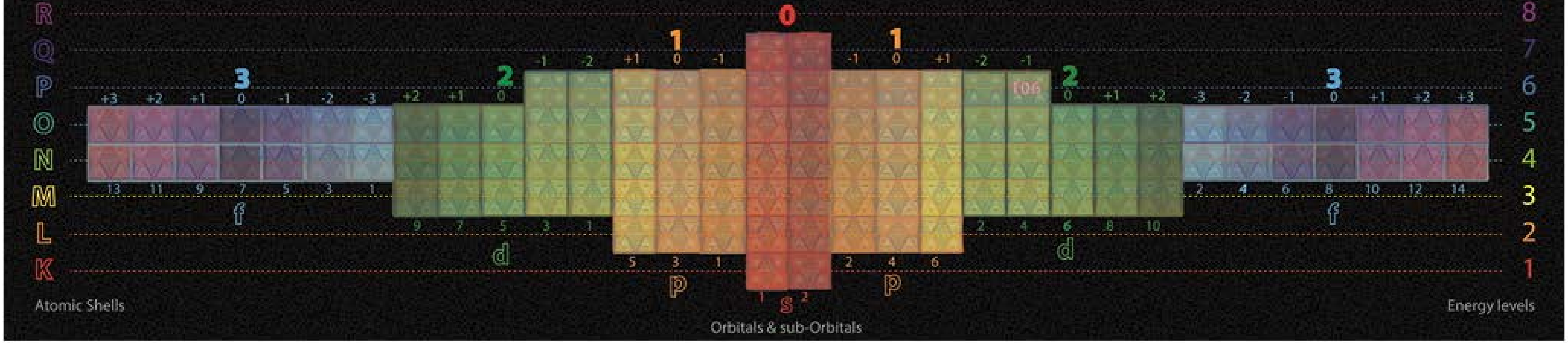
R
Q
P
O
N
M
L
K
0
1
1
2
2
3
3
+3
+2
+1
0
-1
-2
-3
+2
+1
0
-1
-2
+1
0
-1
-1
0
+1
-2
-1
0
+1
+2
-3
-2
-1
0
+1
+2
+3
106
13
11
9
7
5
3
1
f
9
7
5
3
1
d
5
3
1
p
1
s
2
2
4
6
p
2
4
6
8
10
d
2
4
6
8
10
12
14
f
8
7
6
5
4
3
2
1

Atomic Shells

Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.106 - Seaborgium atomic config

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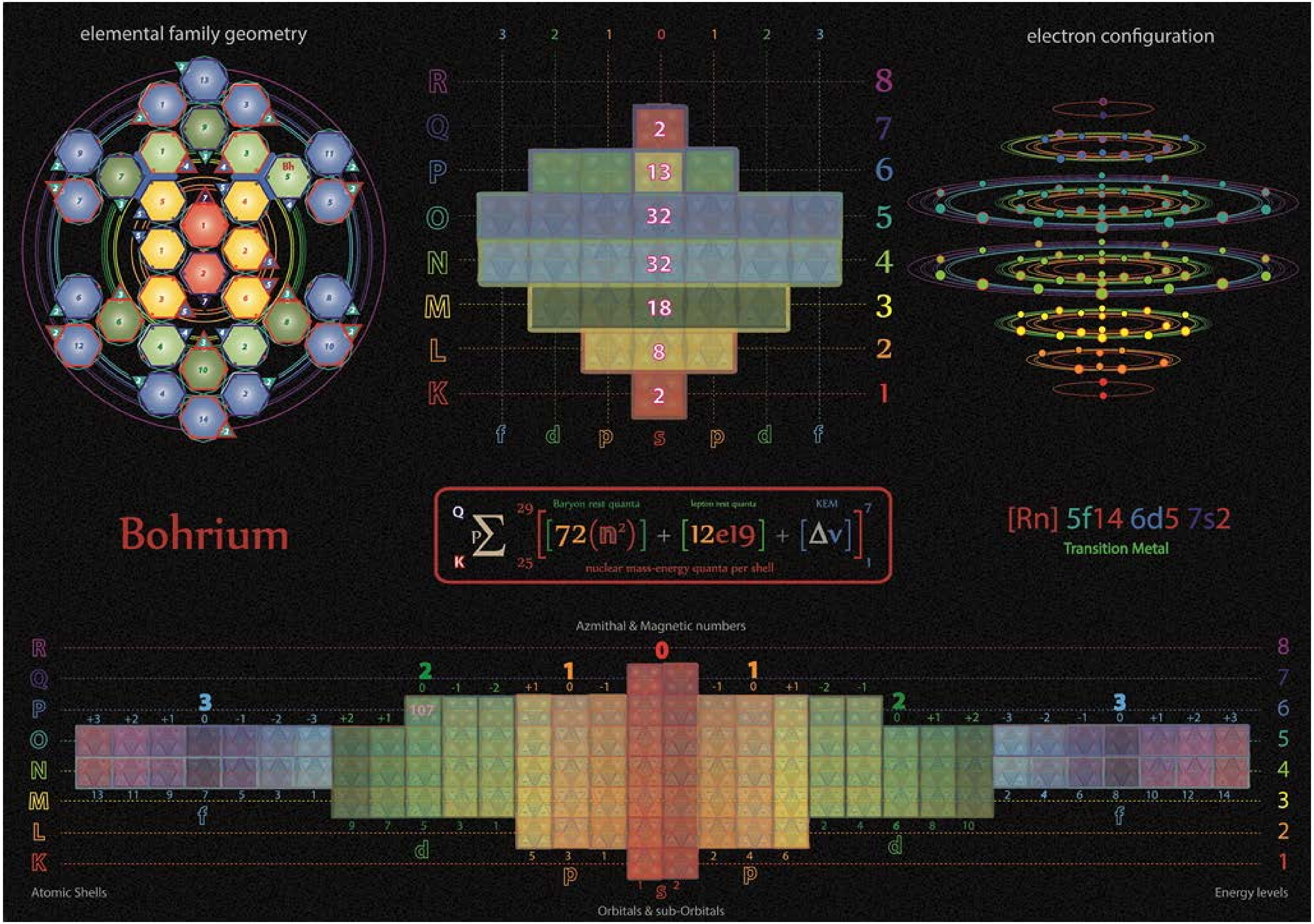
elemental family geometry
Bh
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
13
32
32
18
8
2
f
d
p
s
p
d
f
electron configuration
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
107
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Bohrium

$$\sum_{K}^{Q} P \left[\left[72(n^2)\right]_{25}^{29} + \left[12e19\right] + \left[\Delta v\right] \right]_{1}^{7}$$

Baryon rest quanta   lepton rest quanta   KEM

nuclear mass-energy quanta per shell

[Rn] 5f14 6d5 7s2

Transition Metal

Tetryonics 53.107 - Bohrium atomic config

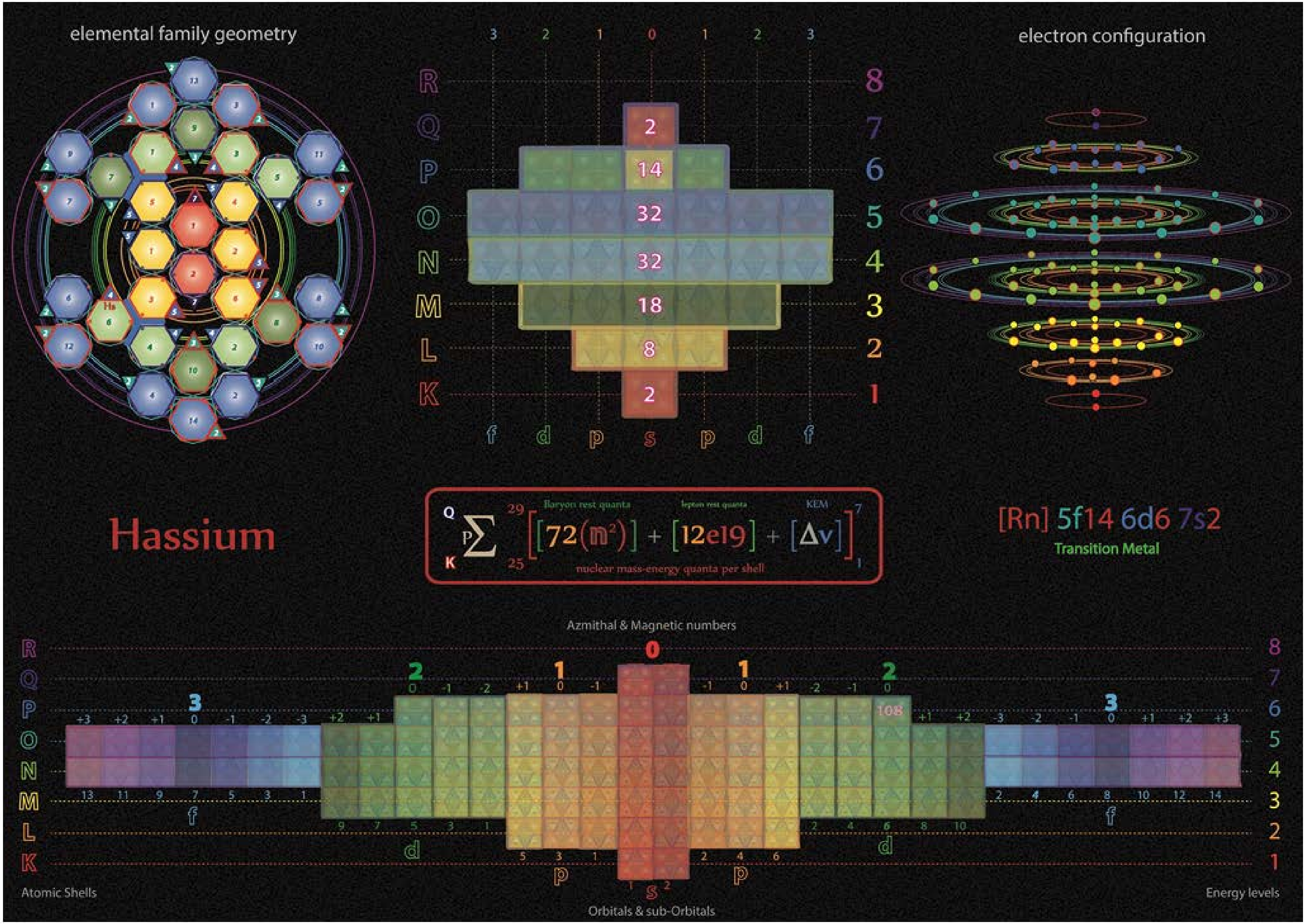
elemental family geometry
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
14
32
32
18
8
2
f d p s p d f
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
108
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 s 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Hassium

$$ {}_{K}^{Q}\,{}^{P}\sum_{25}^{29}\left[\underset{\text{nuclear mass-energy quanta per shell}}{\overset{\text{Baryon rest quanta}}{\left[72\left(n^{2}\right)\right]} + \overset{\text{lepton rest quanta}}{\left[12e19\right]} + \overset{\text{KEM}}{\left[\Delta v\right]}}\right]_{1}^{7} $$

[Rn] 5f14 6d6 7s2

Transition Metal

Tetryonics 53.108 - Hassium atomic config

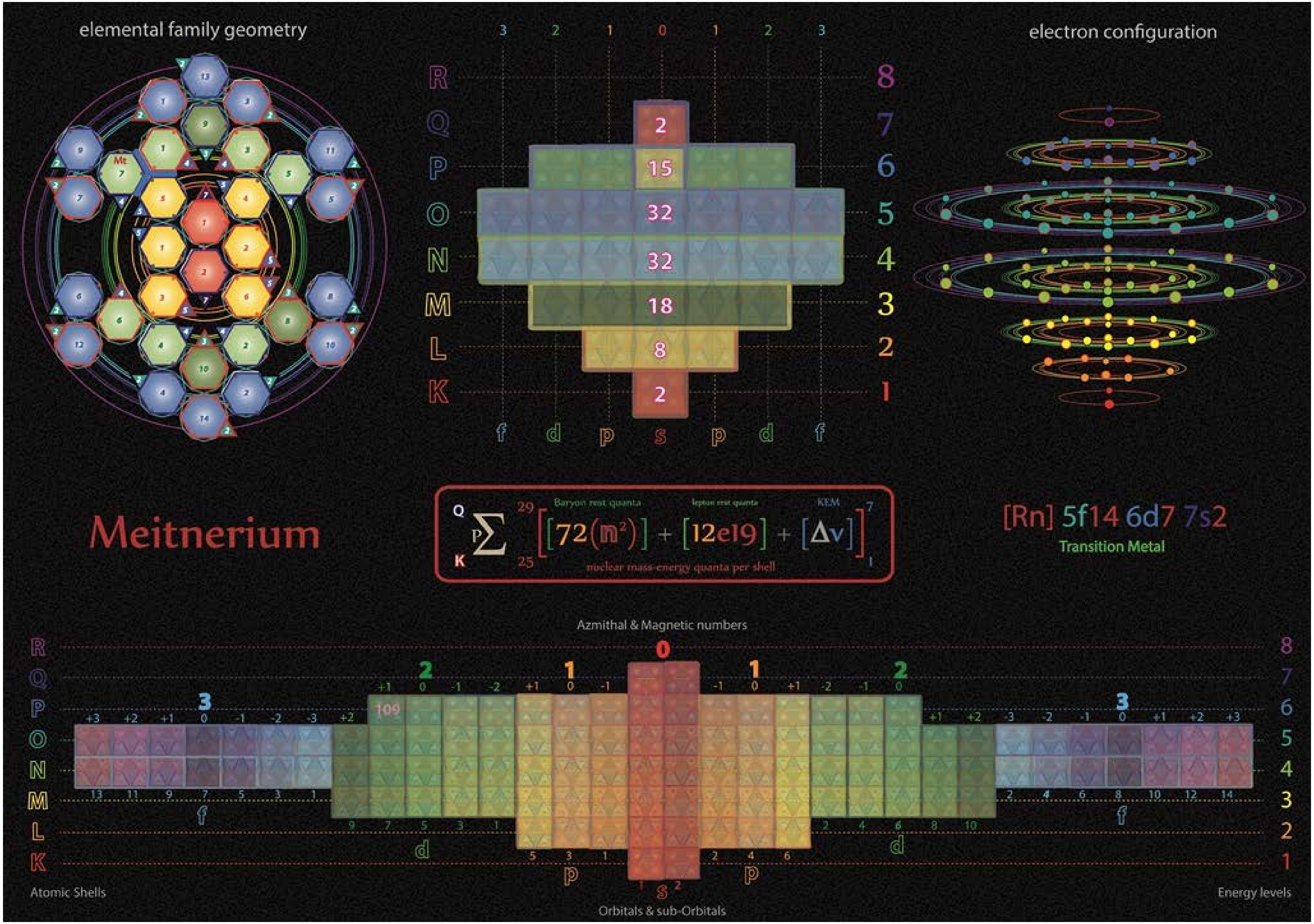
elemental family geometry
Mt
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
15
32
32
18
8
2
f d p s p d f
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
109
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Meitnerium

$$\sum_{K}^{Q} P \; {}^{29}_{25}\Big[\underbrace{\overset{\text{Baryon rest quanta}}{[72(n^2)]}}_{} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]}\Big]^{7}_{1}$$

nuclear mass-energy quanta per shell

[Rn] 5f14 6d7 7s2

Transition Metal

Tetryonics 53.109 - Meitnerium atomic config

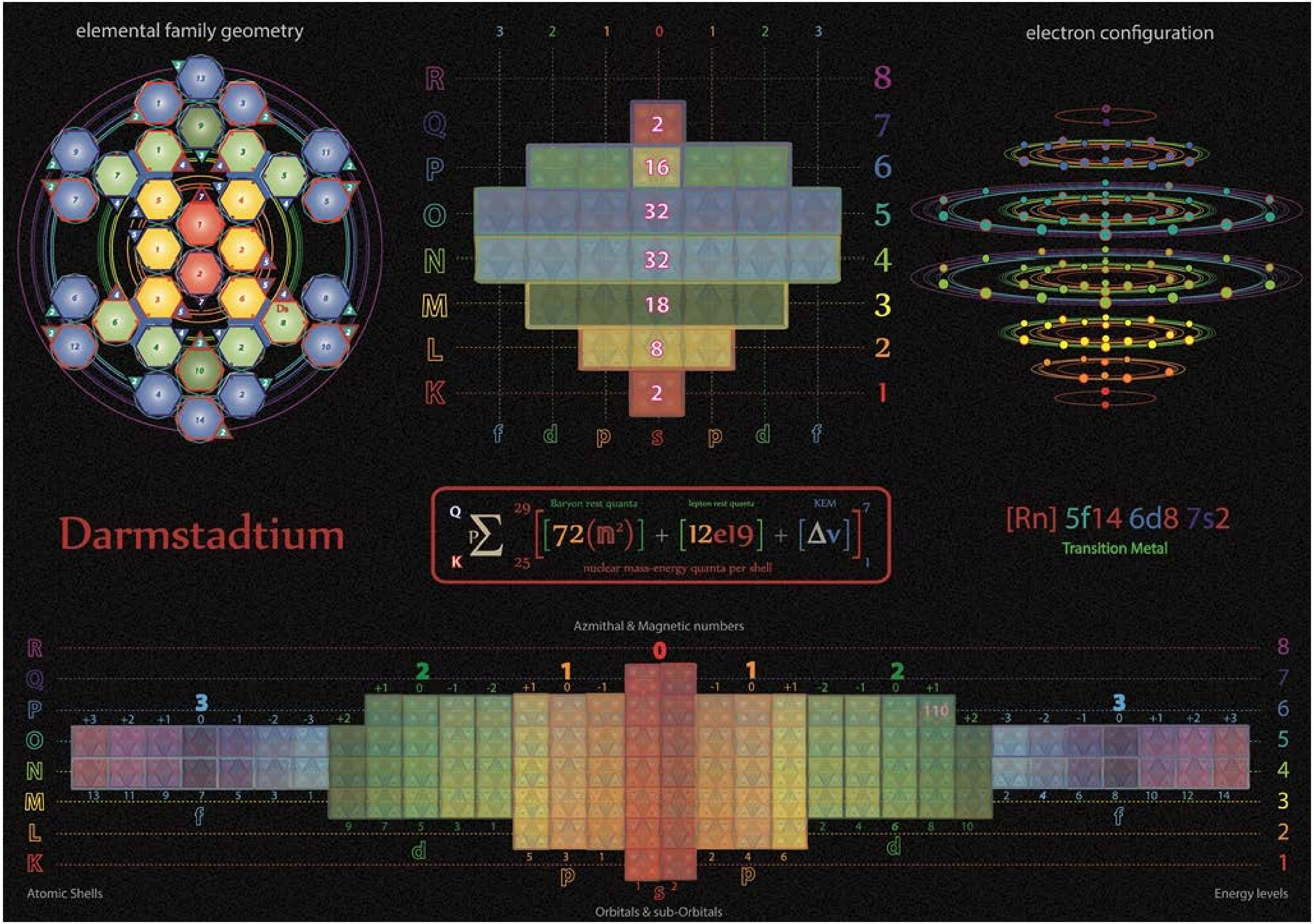
elemental family geometry
electron configuration
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
2
16
32
32
18
8
2
f d p s p d f
Darmstadtium
Q
P
K
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
7
1
nuclear mass-energy quanta per shell
[Rn] 5f14 6d8 7s2
Transition Metal
Azmithal & Magnetic numbers
0
1
2
3
110
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.110 - Darmstadtium atomic config

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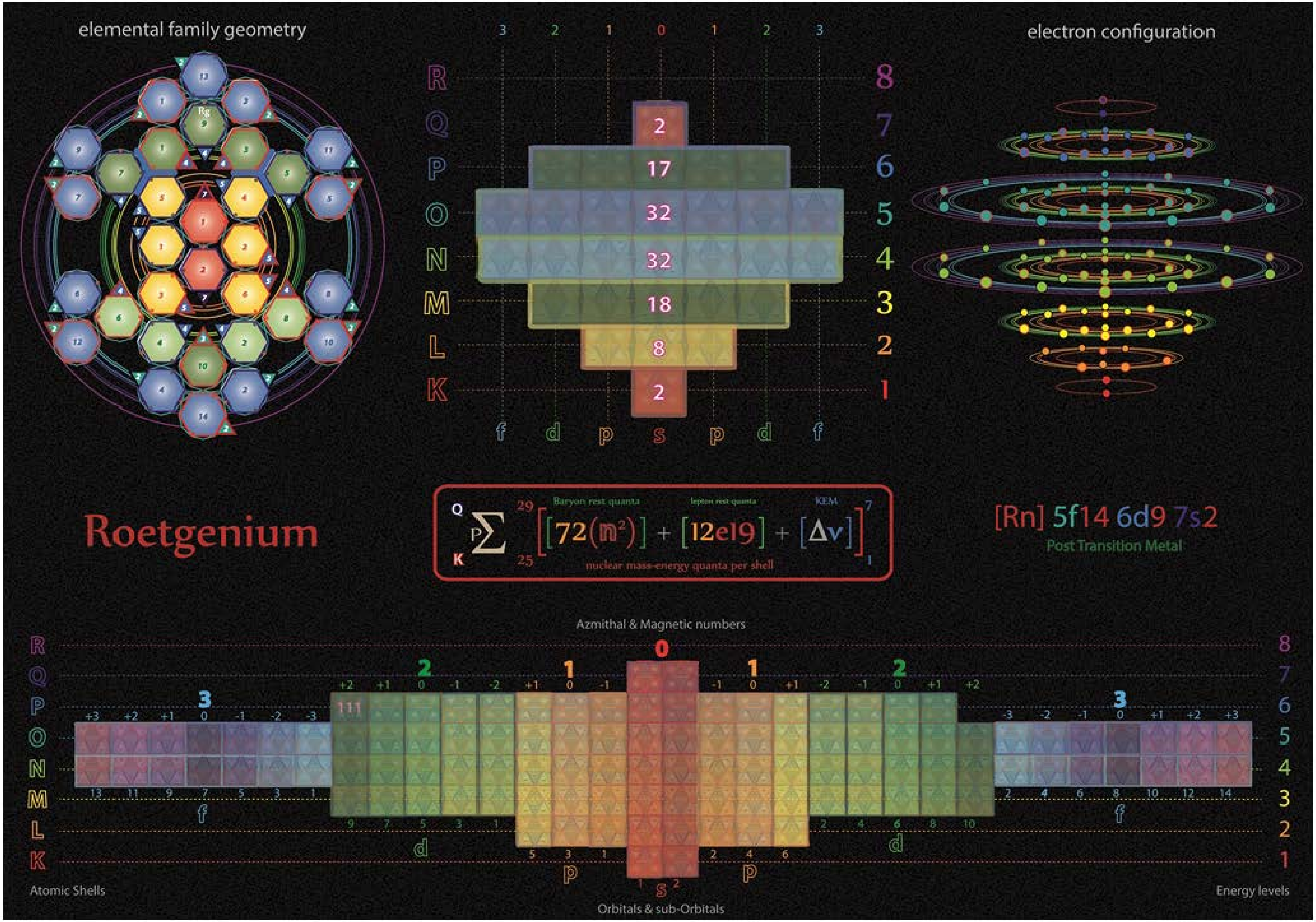
elemental family geometry
electron configuration
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
2
17
32
32
18
8
2
f d p s p d f
Roetgenium
Q
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
7
1
nuclear mass-energy quanta per shell
[Rn] 5f14 6d9 7s2
Post Transition Metal
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
111
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 s 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.111 - Roetgenium atomic config

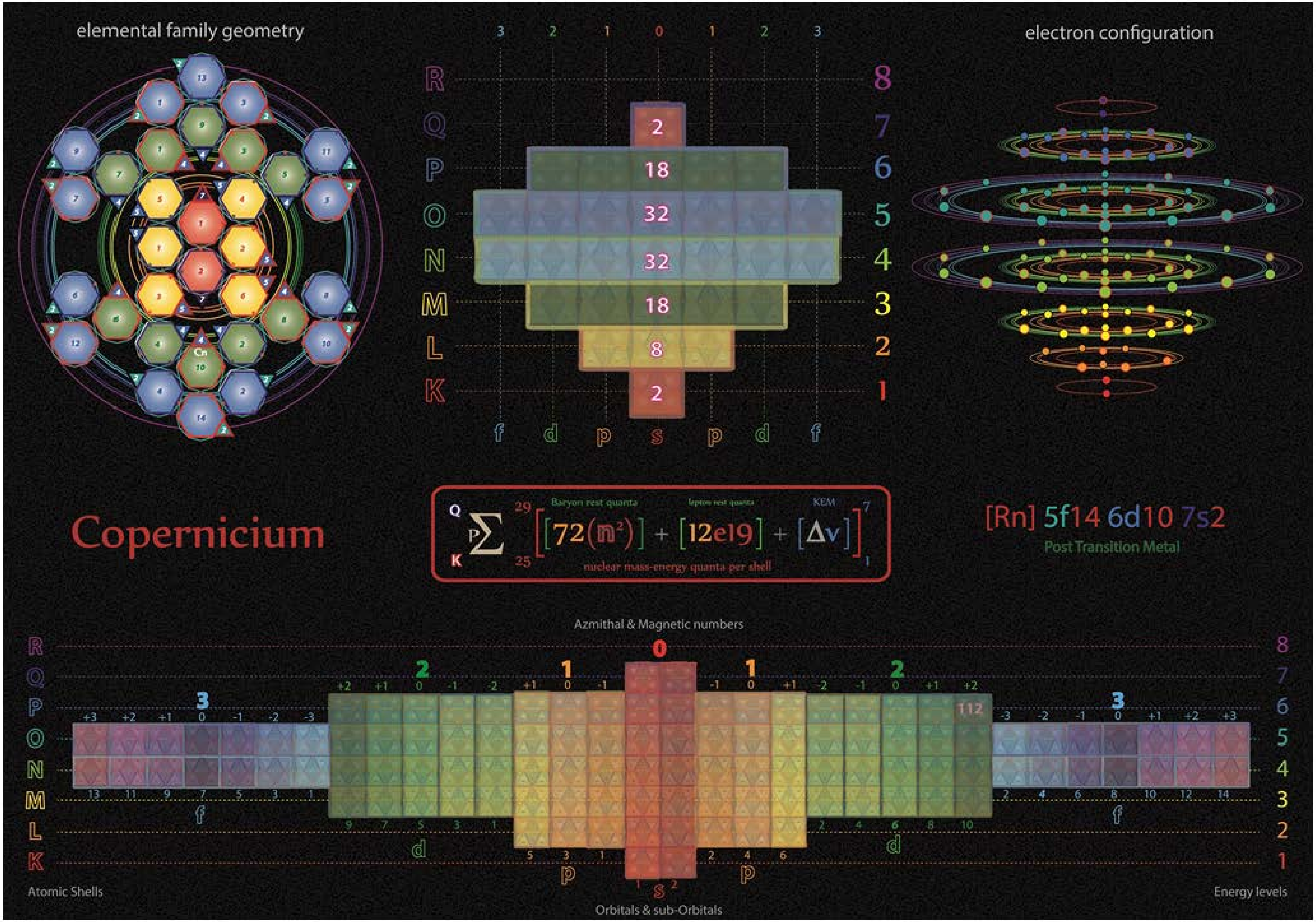

Copernicium

$$\sum_{K}^{Q} P \left[\left[72(n^2)\right] + \left[12e19\right] + \left[\Delta v\right] \right]_{25}^{29} {}_{1}^{7}$$

Baryon rest quanta, lepton rest quanta, KEM

nuclear mass-energy quanta per shell

[Rn] 5f14 6d10 7s2

Post Transition Metal

elemental family geometry
Cn
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
2
18
32
32
18
8
2
f d p s p d f
Azmithal & Magnetic numbers
0
1
2
3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
112
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.112 - Copernicium atomic config

elemental family geometry

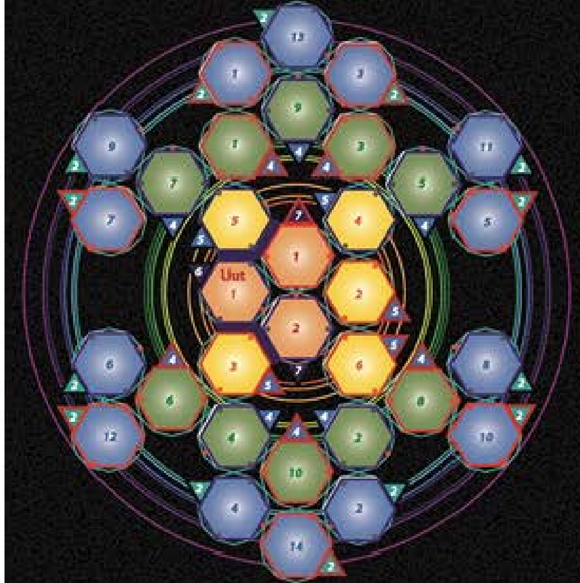

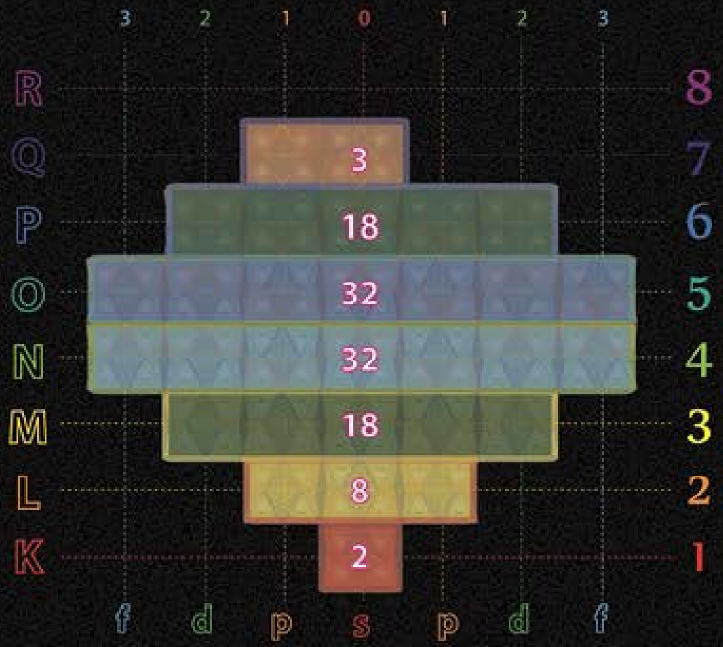
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
3
18
32
32
18
8
2
8
7
6
5
4
3
2
1
f d p s p d f

electron configuration

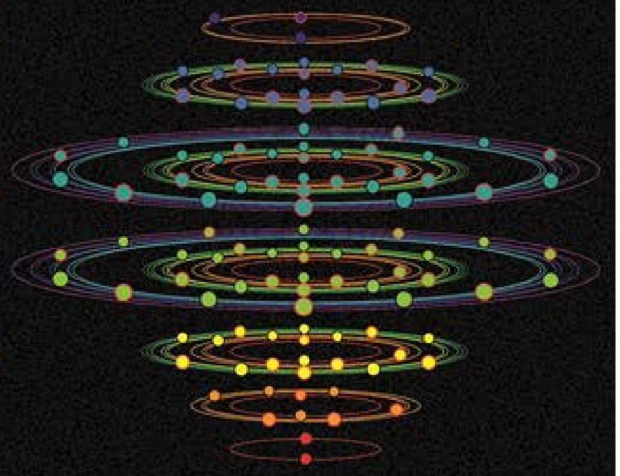

Ununtrium

$$\sum_{K}^{Q} P \left[\overset{\text{Baryon rest quanta}}{[72(m^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]} \right]_{25}^{29}{}_{1}^{7}$$

nuclear mass-energy quanta per shell

[Rn] 5f14 6d10 7s2 7p1

Metaloid

Azmithal & Magnetic numbers

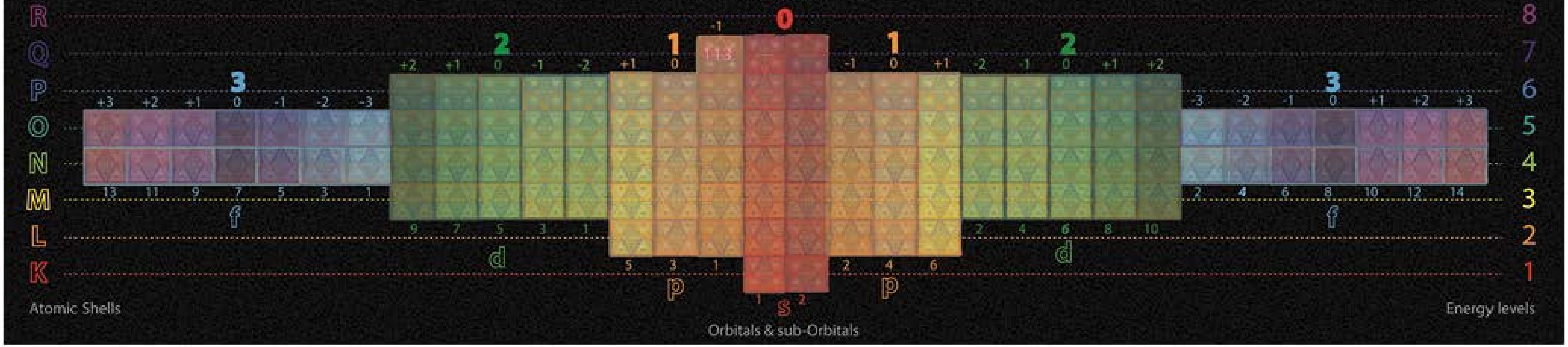
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
-1
113
1
1
2
2
3
3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f
d
p
s
p
d
f
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

Tetryonics 53.113 - Ununtrium atomic config

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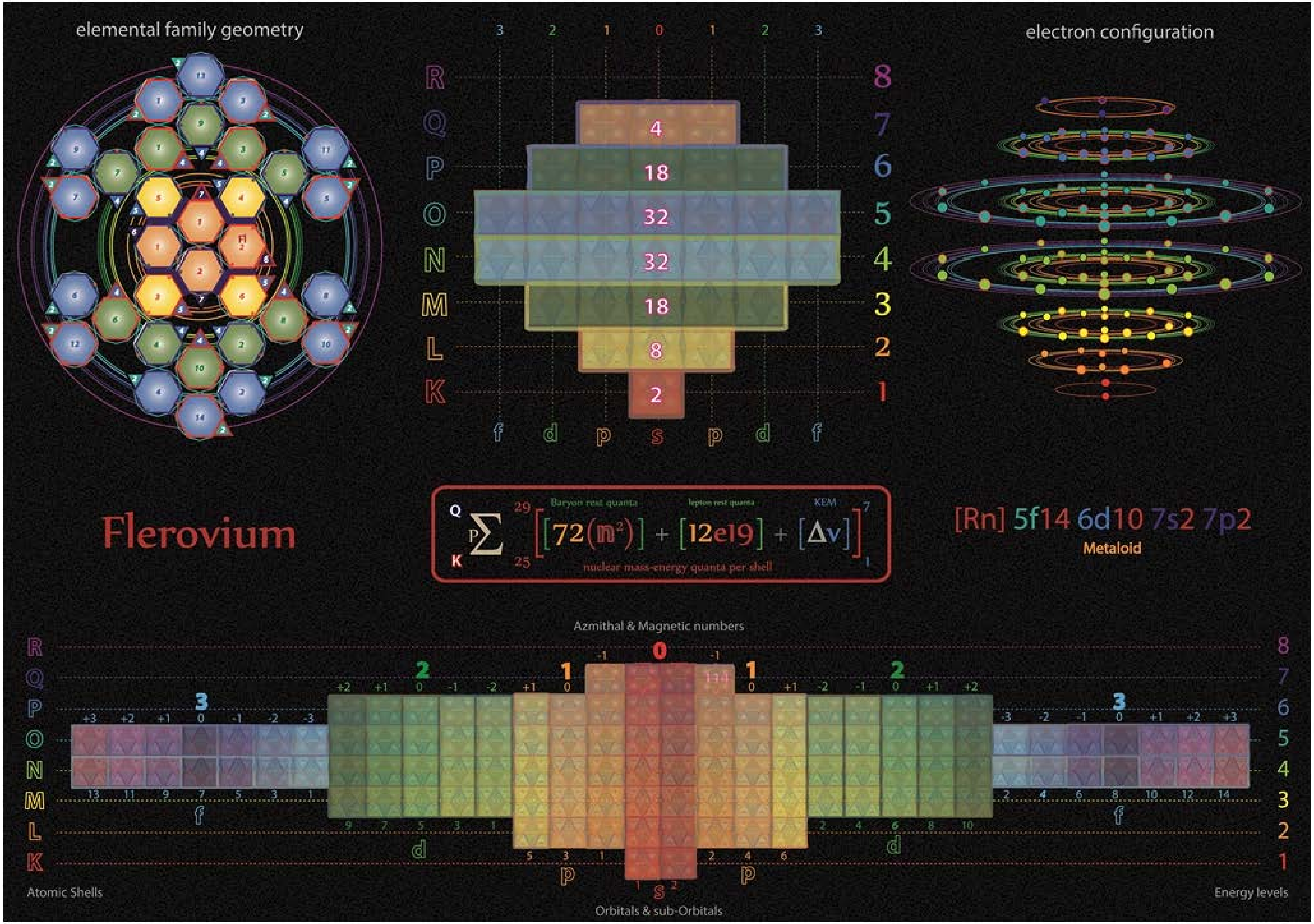
elemental family geometry
Fl
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
4
18
32
32
18
8
2
f d p s p d f
electron configuration
Azmithal & Magnetic numbers
3 2 1 0 1 2 3
114
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Flerovium

$$\sum_{K}^{Q} P \;{}^{29}_{25}\left[\overset{\text{Baryon rest quanta}}{[72(m^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]}\right]^{7}_{1}$$

nuclear mass-energy quanta per shell

[Rn] 5f14 6d10 7s2 7p2

Metaloid

Tetryonics 53.114 - Flerovium atomic config

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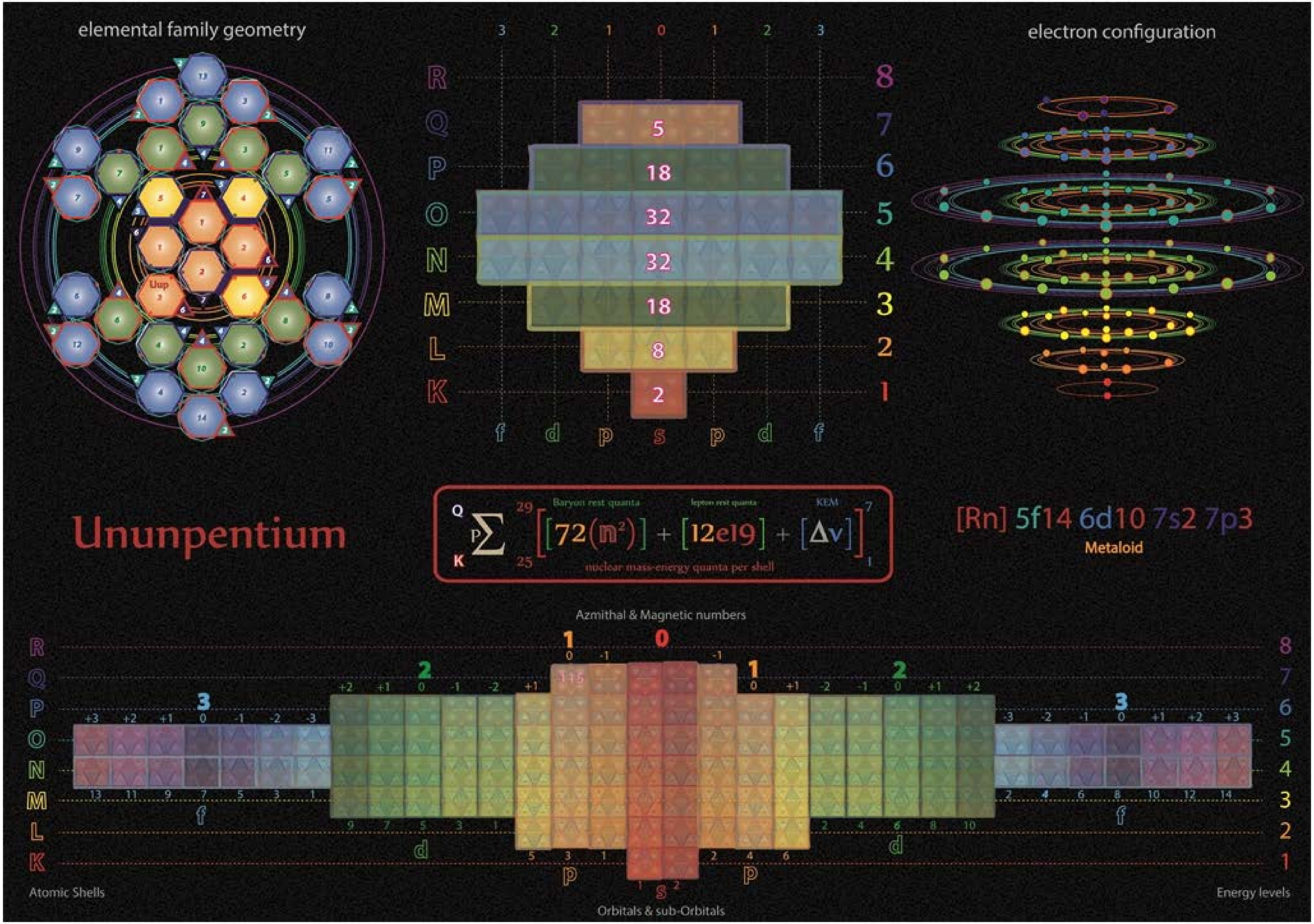
elemental family geometry
Uup
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
5
18
32
32
18
8
2
8
7
6
5
4
3
2
1
f d p s p d f
electron configuration
Ununpentium
Q
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
7
1
[72(n²)] + [12e19] + [Δv]
nuclear mass-energy quanta per shell
[Rn] 5f14 6d10 7s2 7p3
Metaloid
Azmithal & Magnetic numbers
3
2
1
0
1
2
3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
115
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f
d
p
s
p
d
f
Atomic Shells
Orbitals & sub-Orbitals
Energy levels

Tetryonics 53.115 - Ununpentium atomic config

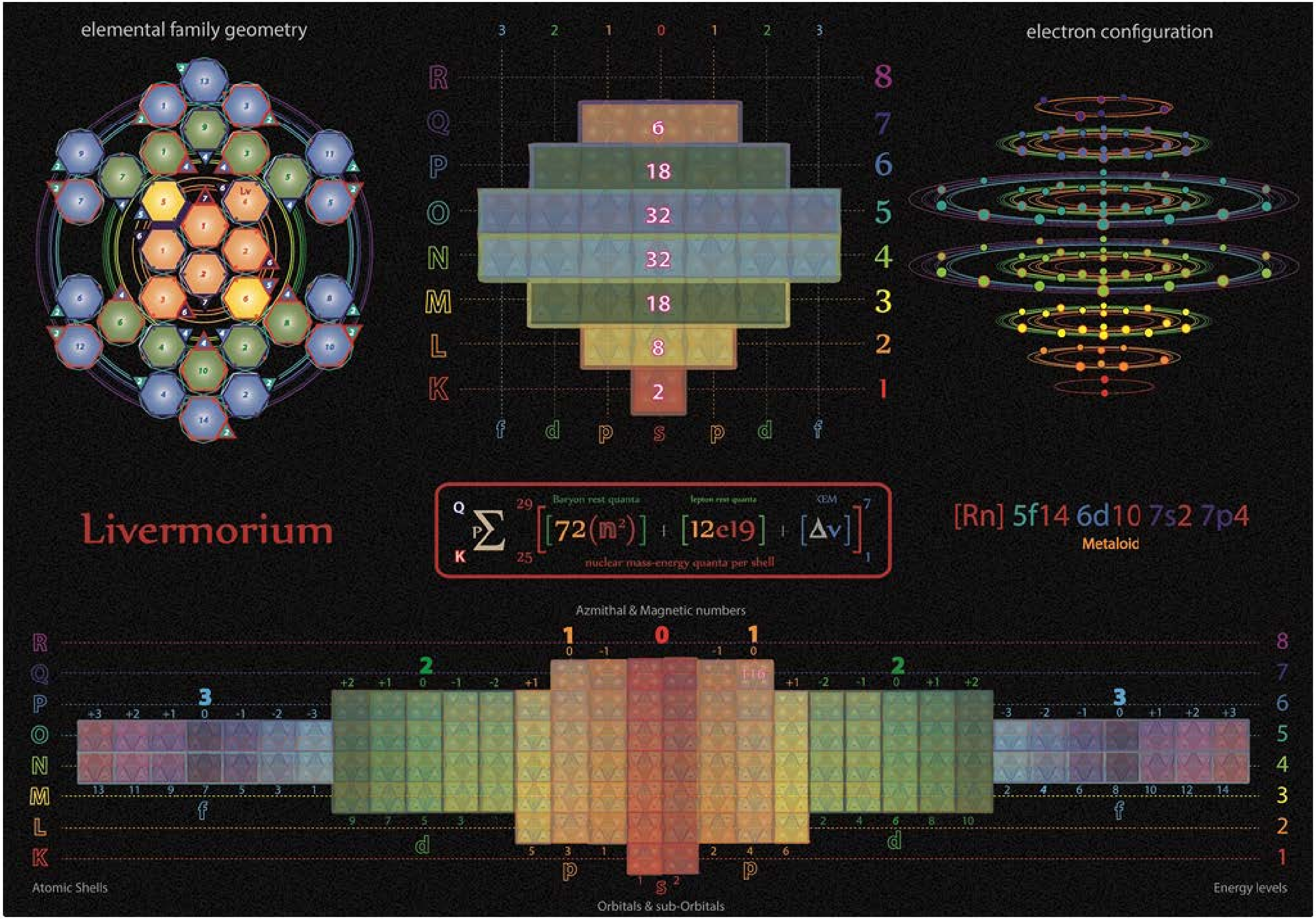
elemental family geometry
Lv
electron configuration
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
6
18
32
32
18
8
2
f d p s p d f
Livermorium
Q
K
P
29
25
Baryon rest quanta
lepton rest quanta
KEM
[72(m²)] + [12e19] + [Δv]
7
1
nuclear mass-energy quanta per shell
[Rn] 5f14 6d10 7s2 7p4
Metaloid
Azmithal & Magnetic numbers
1 0 1
2 2
3 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
0 -1 -1 0
+1 -1 0 +1
-3 -2 -1 0 +1 +2 +3
116
13 11 9 7 5 3 1
9 7 5 3
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.116 - Livermorium atomic config

elemental family geometry

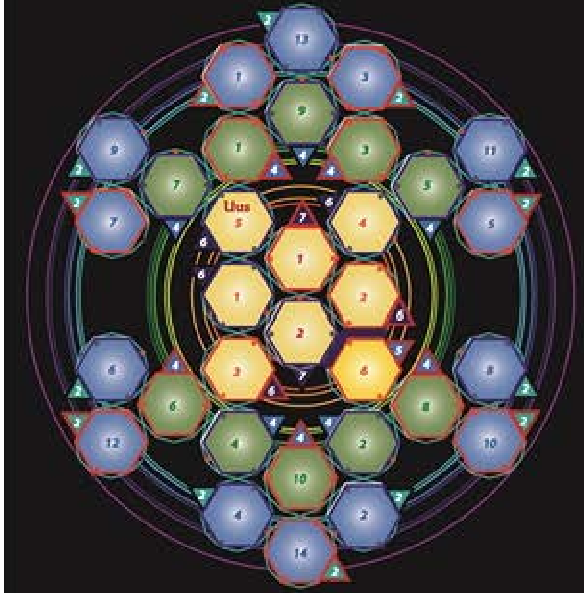

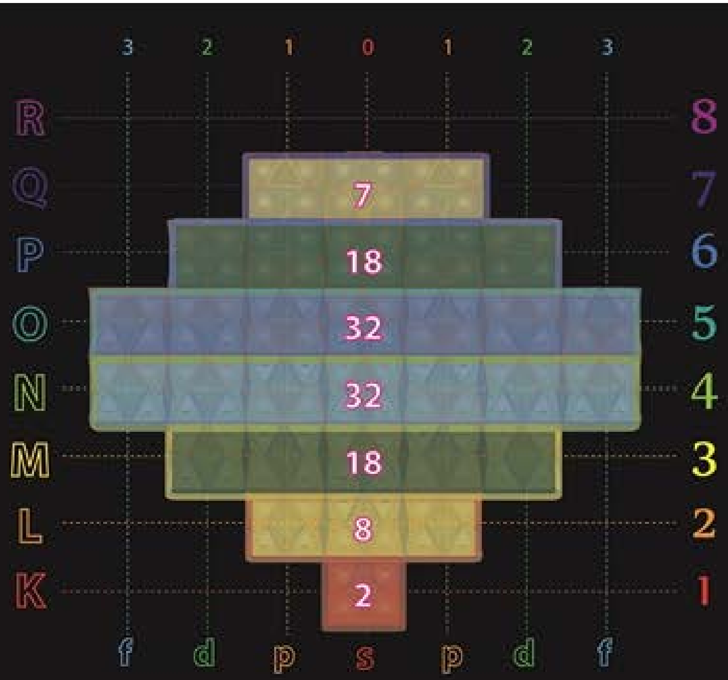
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
7
18
32
32
18
8
2
f d p s p d f

electron configuration

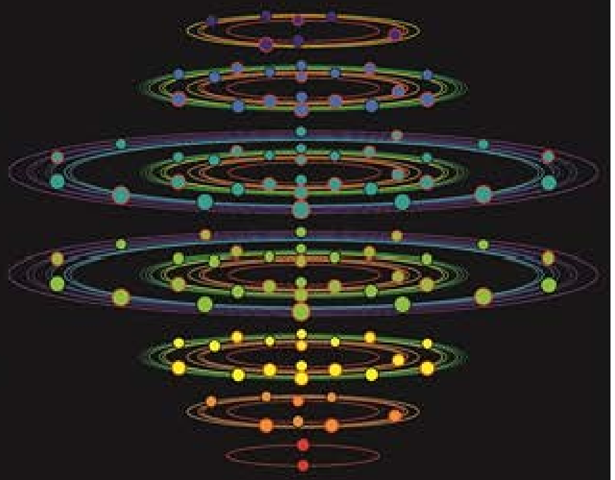

Unbinilium

$$\sum_{K}^{Q}{}_{P}\;{}^{29}_{25}\left[\overset{\text{Baryon rest quanta}}{\left[72(\mathfrak{m}^2)\right]}+\overset{\text{lepton rest quanta}}{\left[12e19\right]}+\overset{\text{KEM}}{\left[\Delta v\right]}\right]_1^7$$

nuclear mass-energy quanta per shell

[Rn] 5f14 6d10 7s2 7p5

Halogen

Azmithal & Magnetic numbers

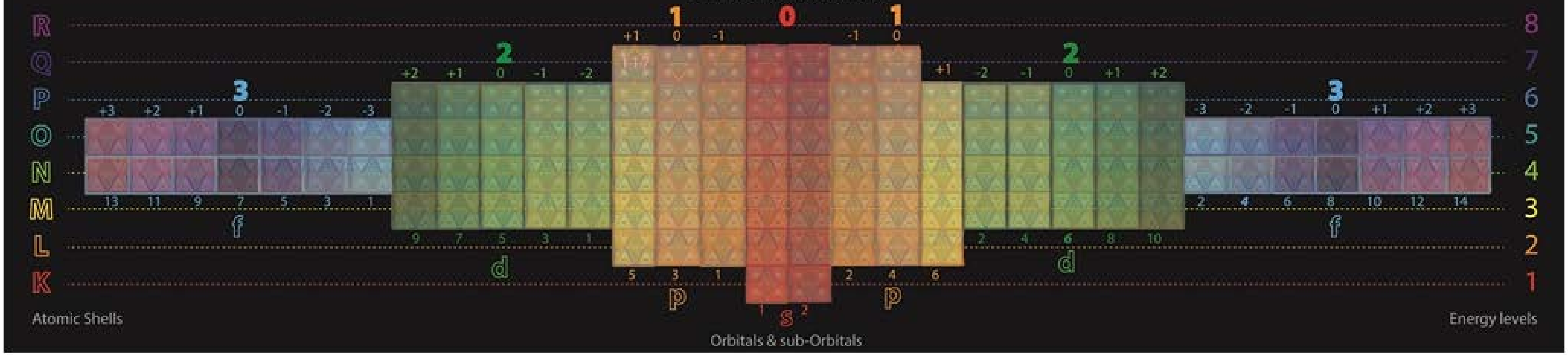
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
-1 0 +1
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 s 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f d p s p d f
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

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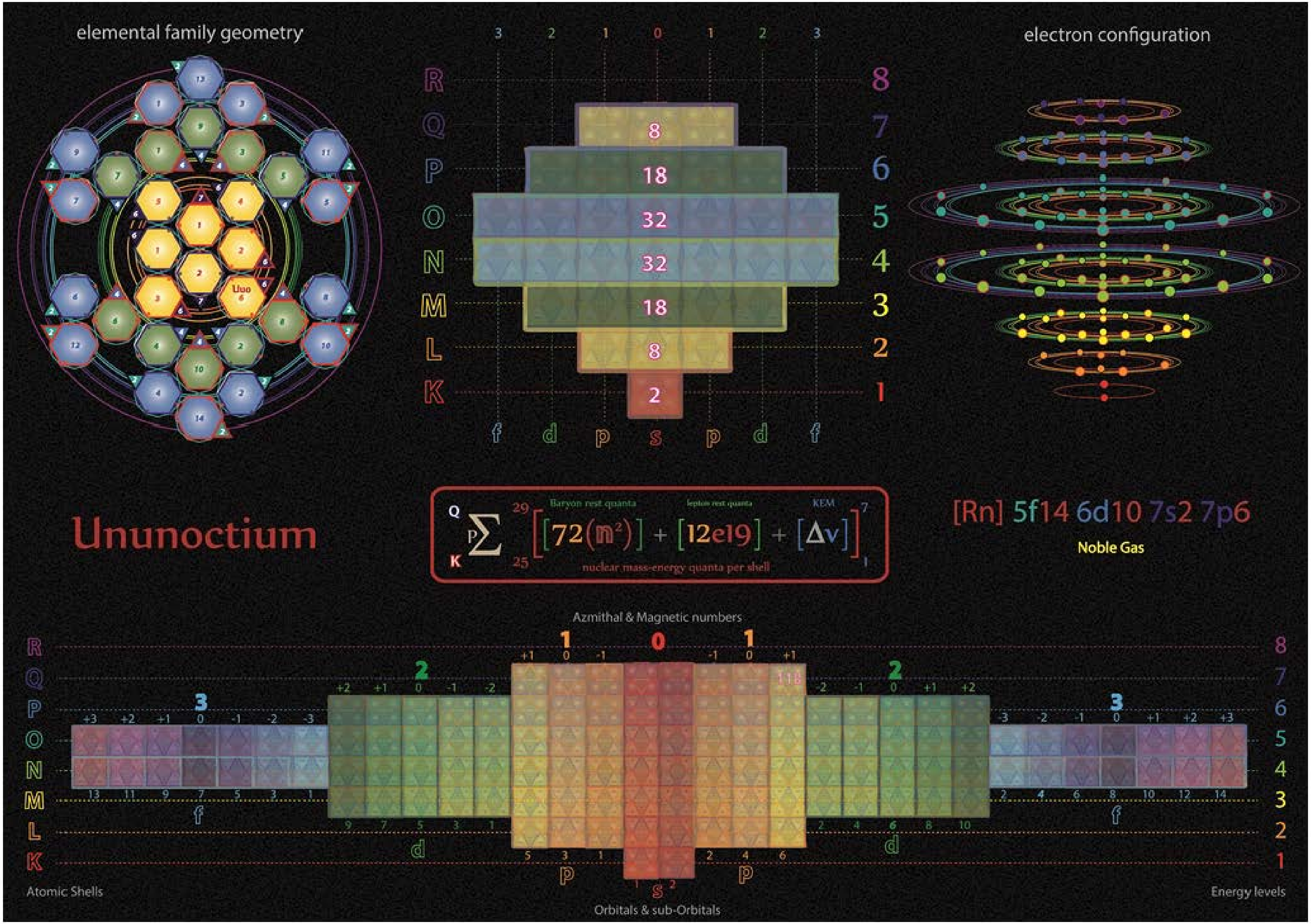
elemental family geometry
electron configuration
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
8
18
32
32
18
8
2
f d p s p d f
Uuo
Azmithal & Magnetic numbers
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Ununoctium

$$\sum_{K}^{Q} P \; {}_{25}^{29}\left[[72(m^2)] + [12e19] + [\Delta v] \right]_{1}^{7}$$

Baryon rest quanta · lepton rest quanta · KEM

nuclear mass-energy quanta per shell

[Rn] 5f14 6d10 7s2 7p6

Noble Gas

Tetryonics 53.118 - Ununoctium atomic config

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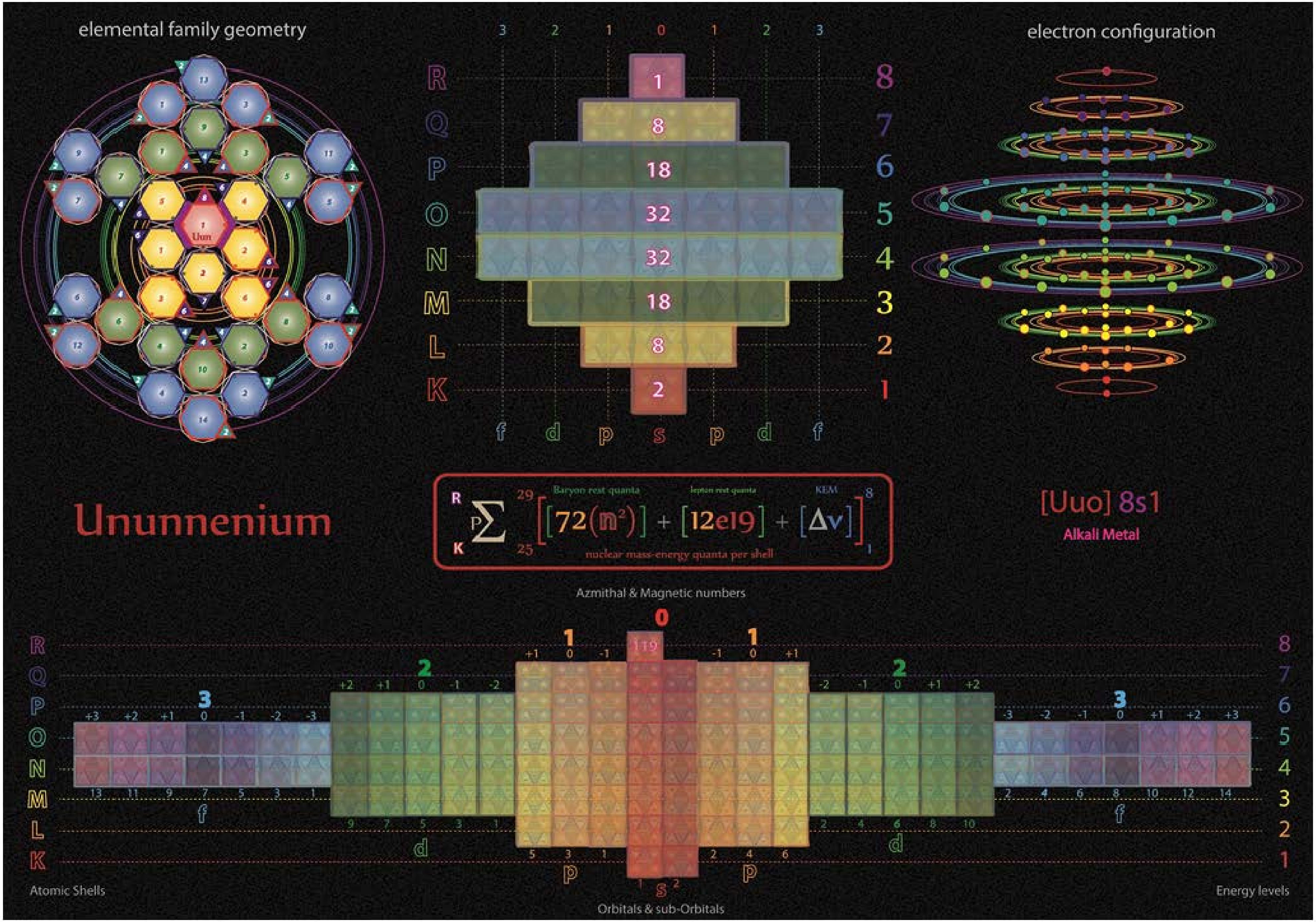
elemental family geometry
Uun
electron configuration
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
1
8
18
32
32
18
8
2
f d p s p d f
Ununnenium
R
K
P∑
29
25
Baryon rest quanta
lepton rest quanta
KEM
[[72(m²)] + [12e19] + [Δv]]
8
1
nuclear mass-energy quanta per shell
[Uuo] 8s1
Alkali Metal
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+1 0 -1
-1 0 +1
+2 +1 0 -1 -2
-2 -1 0 +1 +2
+3 +2 +1 0 -1 -2 -3
-3 -2 -1 0 +1 +2 +3
119
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
f d p s p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 53.119 - Ununnenium atomic config

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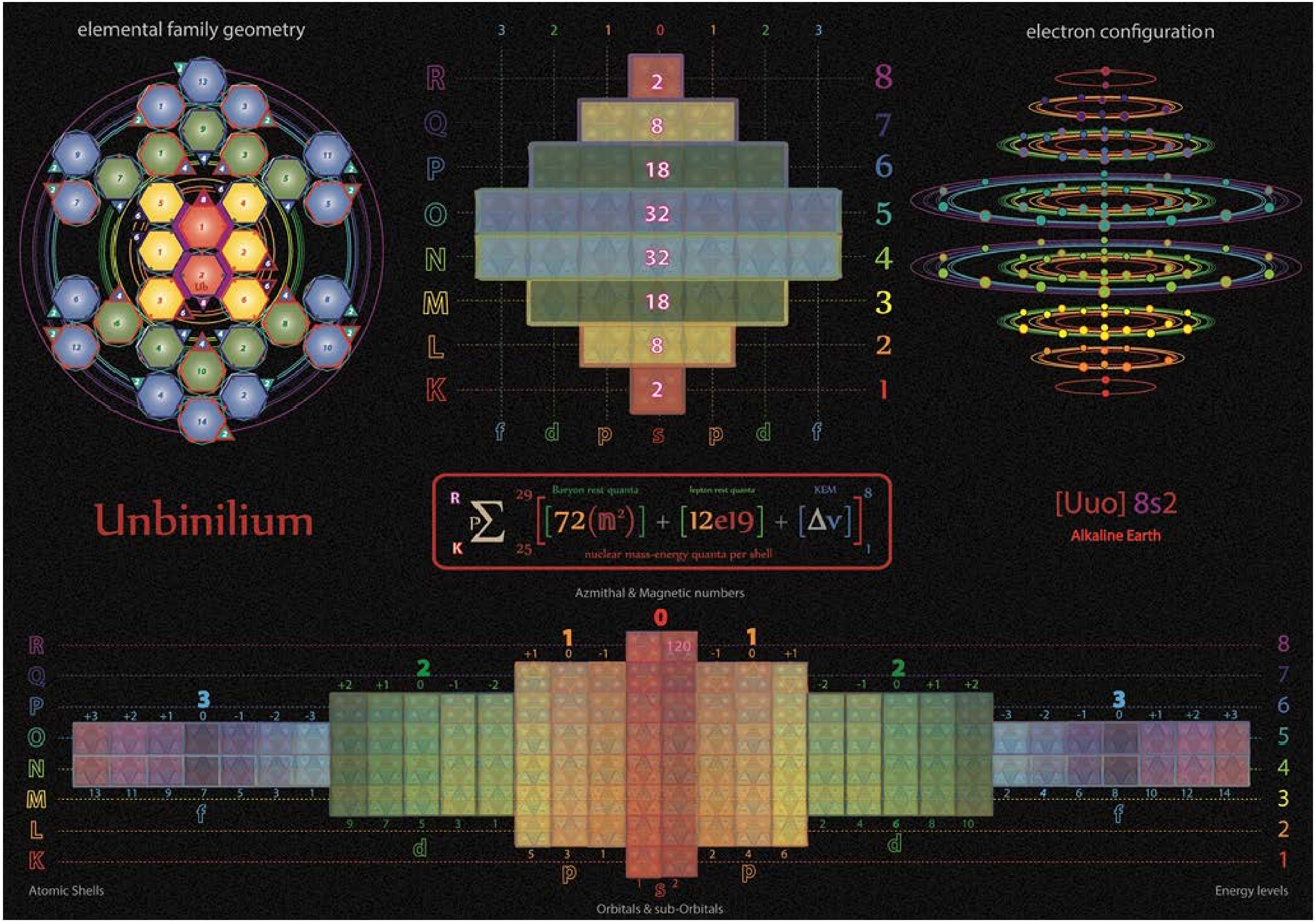
elemental family geometry
electron configuration
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
2
8
18
32
32
18
8
2
f d p s p d f
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
120
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Unbinilium

$$\sum_{K}^{R} {}_{P}\sum_{25}^{29} \left[\overset{\text{Baryon rest quanta}}{[72(m^2)]} + \overset{\text{lepton rest quanta}}{[12e19]} + \overset{\text{KEM}}{[\Delta v]} \right]_{1}^{8}$$

nuclear mass-energy quanta per shell

[Uuo] 8s2

Alkaline Earth

Tetryonics 53.120 - Unbinilium atomic config

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Chemical element bonding

All Deuterium nuclei pack in hexagonal patterns
to form larger atoms & molecules

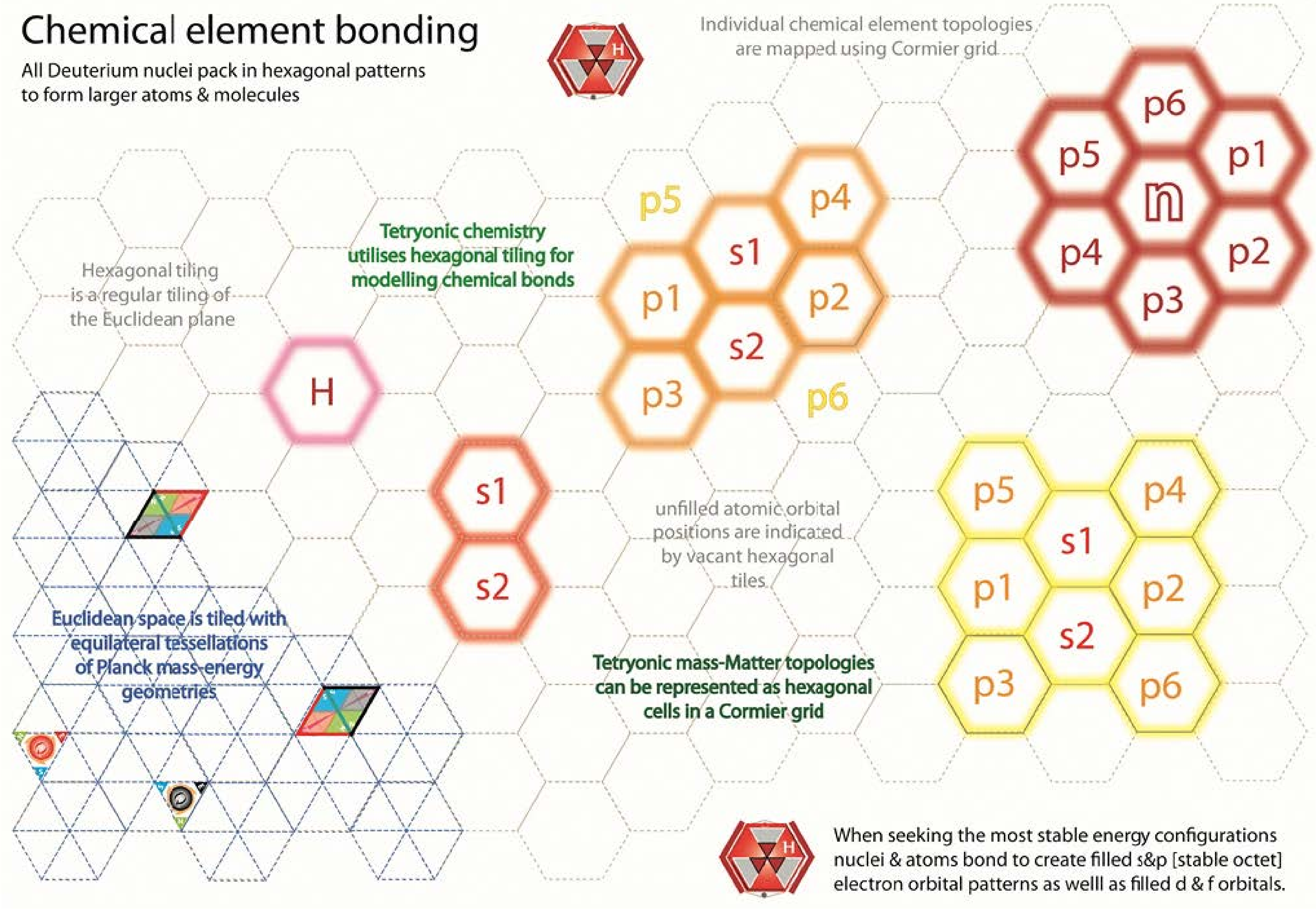

Individual chemical element topologies
are mapped using Cormier grid

Hexagonal tiling
is a regular tiling of
the Euclidean plane

**Tetryonic chemistry
utilises hexagonal tiling for
modelling chemical bonds**

unfilled atomic orbital
positions are indicated
by vacant hexagonal
tiles

**Euclidean space is tiled with
equilateral tessellations
of Planck mass-energy
geometries**

**Tetryonic mass-Matter topologies
can be represented as hexagonal
cells in a Cormier grid**

When seeking the most stable energy configurations
nuclei & atoms bond to create filled s&p [stable octet]
electron orbital patterns as welll as filled d & f orbitals.

Tetryonics 54.01 - Chemical element bonding

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Periodic Table Atomic configurations

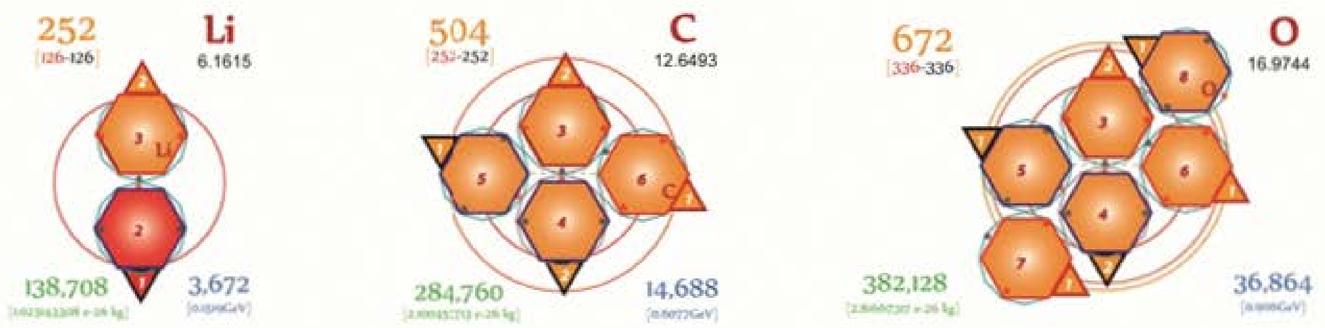
252
[126-126]
Li
6.1615
Li
138,708
3,672
504
[252-252]
C
12.6493
C
284,760
14,688
672
[336-336]
O
16.9744
O
382,128
36,864

Allotropes are different structural forms of the same element and can exhibit quite different physical properties and chemical behaviours

Allotropes

The Periodic Table, although useful in identifying Elements via their atomic and quantum numbers, does not reflect all the charged topologes that Deuterium nuclei can form as they combine.

Various atomic configurations with the same Tetryonic charge, but differing in their final mass-Matter topologies and properties can be formed - they are the Allotropes

Some of the more plentiful chemical elements form this way

Lithium

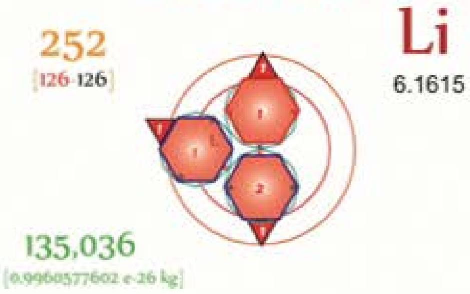
252
[126-126]
Li
6.1615
135,036
[0.99605777602 e-26 kg]

Oxygen

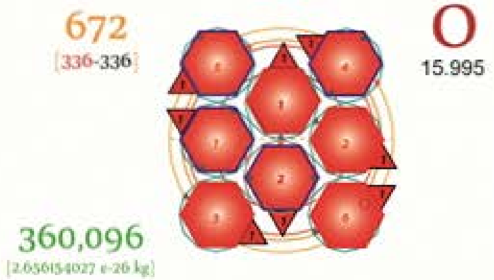
672
[336-336]
O
15.995
360,096
[2.656154027 e-26 kg]

Carbon

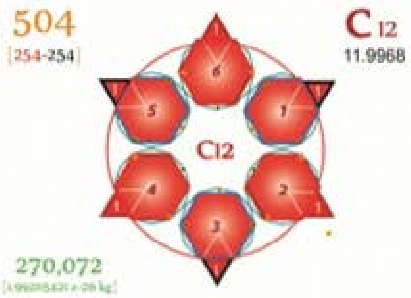
504
[254-254]
C12
11.9968
C12
270,072

6 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1

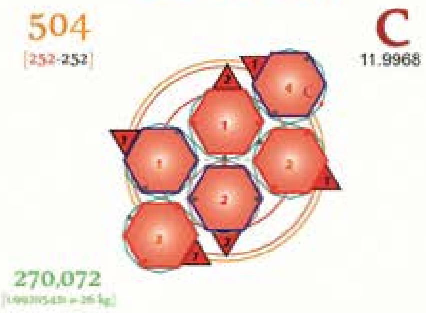
504
[252-252]
C
11.9968
270,072

6 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1

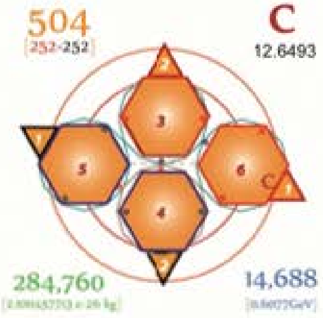
504
[252-252]
C
12.6493
C
284,760
14,688

6 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-2

Allotropes are elements created from the same number of Deuterium nuclei as periodic elements but possess a differing mass-Matter topology

Q

same component charge

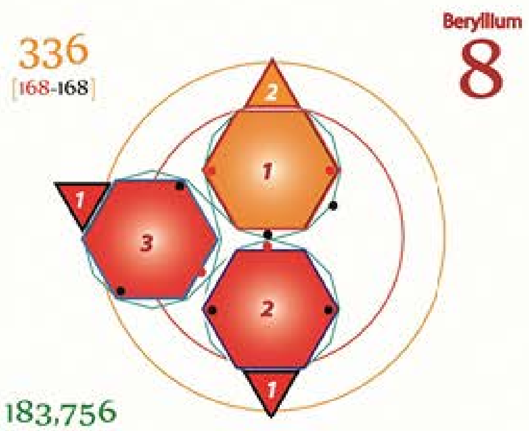
336
[168-168]
Beryllium
8
2
1
1
3
2
1
183,756

different Matter geometries

M

The varying material geometries allows what is the same chemical element to possess vastly different bonding points and chemical attributes

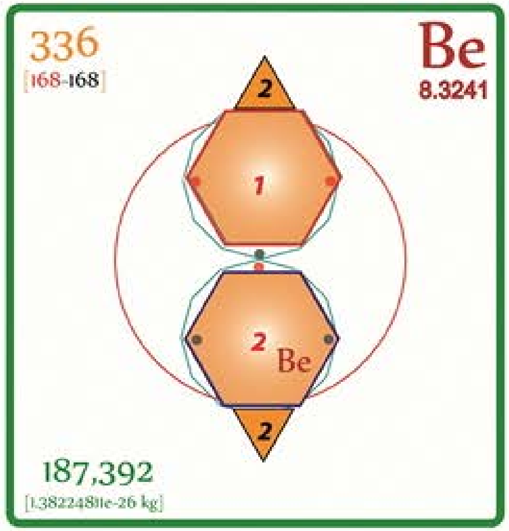
336
[168-168]
Be
8.3241
2
1
2
Be
2
187,392
[1.38224811e-26 kg]

Allotropic geometries

[charge vs Matter]

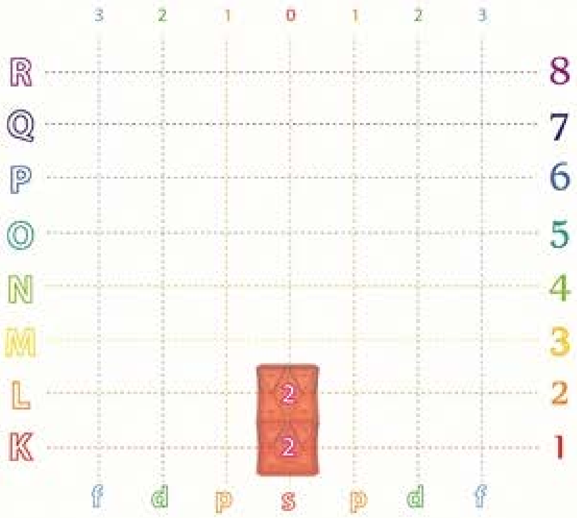
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
2
f
d
p
s
p
d
f

Some element allotropes have different Matter topologies that persist in different phases

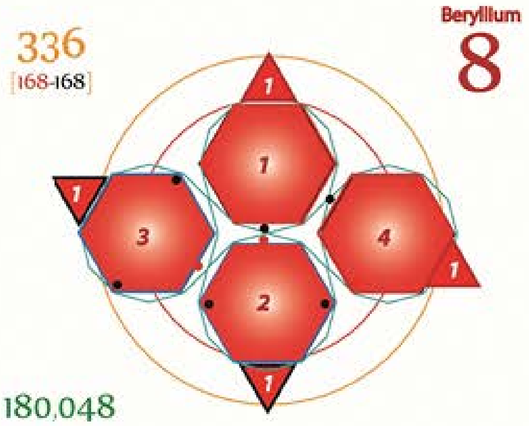
336
[168-168]
Beryllium
8
1
1
1
3
4
1
2
1
180,048

Allotropes vs. Isotopes

Isotopes are elementary atoms with the same number of nuclei, but with differing energy levels, resulting in different mass-energies

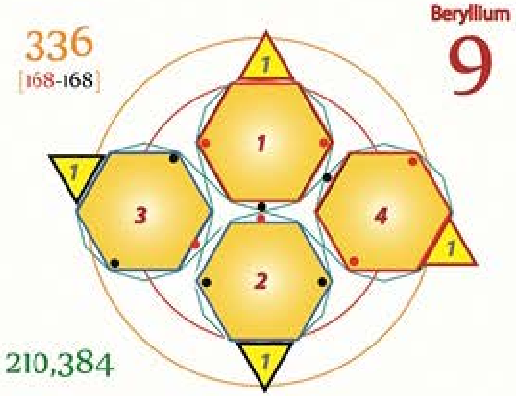
336
[168-168]
Beryllium
9
1
1
1
3
4
1
2
1
210,384

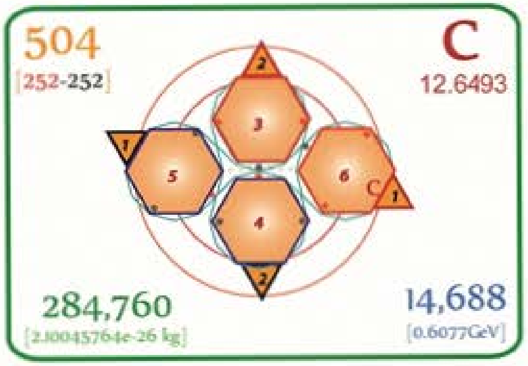
504
[252-252]
C
12.6493
2
1
3
5
6
4
C
1
2
284,760
[2.100457764e-26 kg]
14,688
[0.6077GeV]

Carbon Allotropes

Carbon is capable of forming many allotropes due to its valency.

Well known forms of carbon include:

Carbon
Diamond
Graphite
Graphene
Amorphous carbon
Buckminsterfullerenes
Carbon nanotubes
Glassy carbon
atomic & diatomic carbon

Tetryonic theory affords us the ability to model the charged mass-energy geometries & 3D Matter topologies of each element along with its bonding points

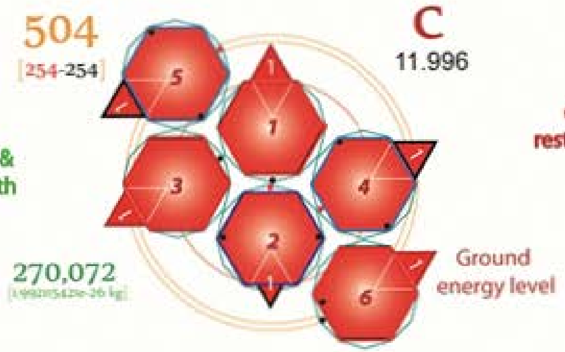
504
[254-254]
C
11.996
5
1
3
4
2
6
270,072
Ground energy level

It also allows for the calculation of the molar rest mass-energy geometry of any Matter topology

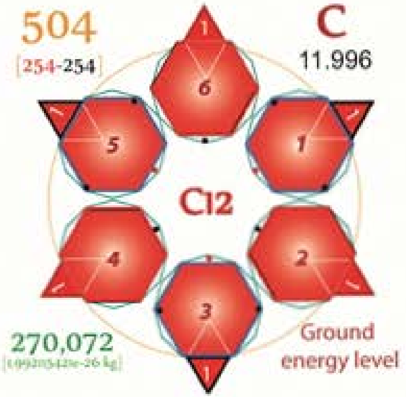
504
[254-254]
C
11.996
6
5
1
C12
4
2
3
270,072
Ground energy level

Graphene has a unique p orbital arrangement of its electrons

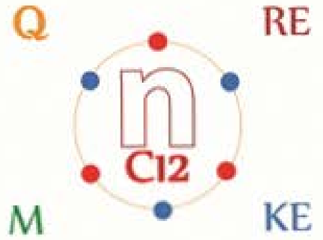
Q
RE
n
C12
M
KE

Electron Configuration

[n] p6

Shell			Molar meM	Nuclei per shell
R	8	446,976	19.855	6
Q	7	418,680	18.598	6
P	6	391,392	17.385	6
O	5	365,112	16.218	6
N	4	339,840	15.095	6
M	3	315,576	14.018	6
L	2	292,320	12.985	6
K	1	270,072	11.996	6

energy level

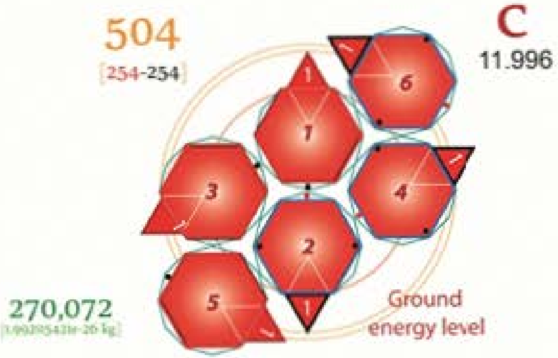
504
[254-254]
C
11.996
6
1
3
4
2
5
1
270,072
Ground energy level

Carbon-14, a radioactive isotope of carbon with a half-life of 5,730 years, is used to find the age of formerly living things through a process known as radiocarbon dating.

In 1961 the international unions of physicists and chemists agreed to use the mass of the isotope carbon-12 as the basis for atomic weight.

There are nearly ten million known carbon compounds and an entire branch of chemistry, known as organic chemistry, is devoted to their study.

Graphene

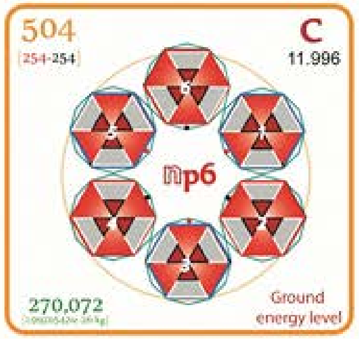

Graphene is also an allotrope of carbon.

Its structure is one-atom-thick planar sheets of sp2-bonded carbon atoms that are densely packed in a honeycomb crystal lattice

Graphite

The mineral graphite is an allotrope of carbon.

Unlike periodic table carbon [diamond], graphite is an electrical conductor, a semi-metal.

And Graphite is the most stable form of carbon under standard conditions.

Graphite has a layered, planar structure. In each layer, the carbon atoms are arranged in a hexagonal lattice

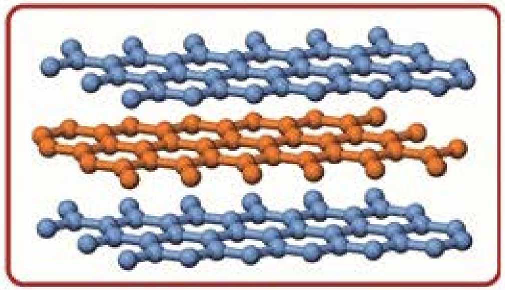

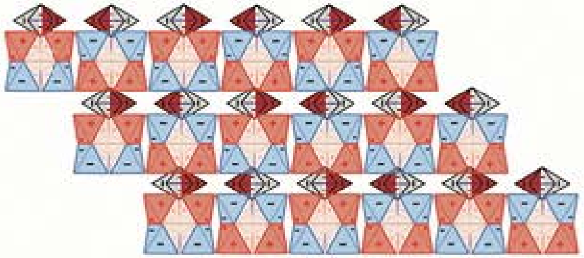

Graphite electrons can act as atomic bearings between the planar sheets of graphene

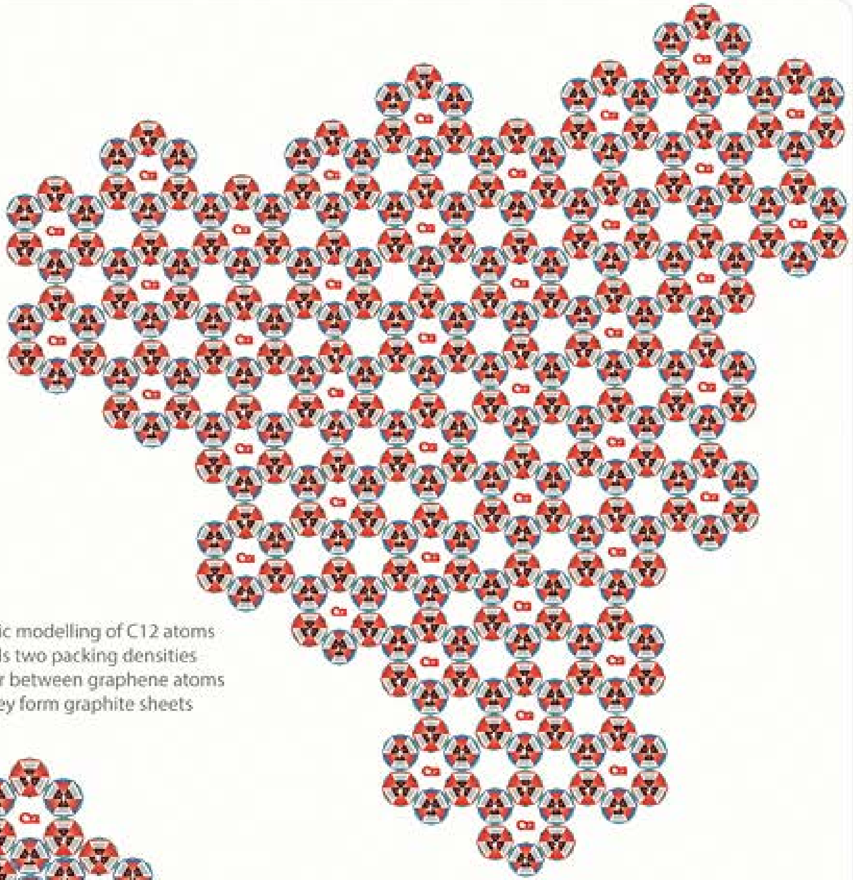

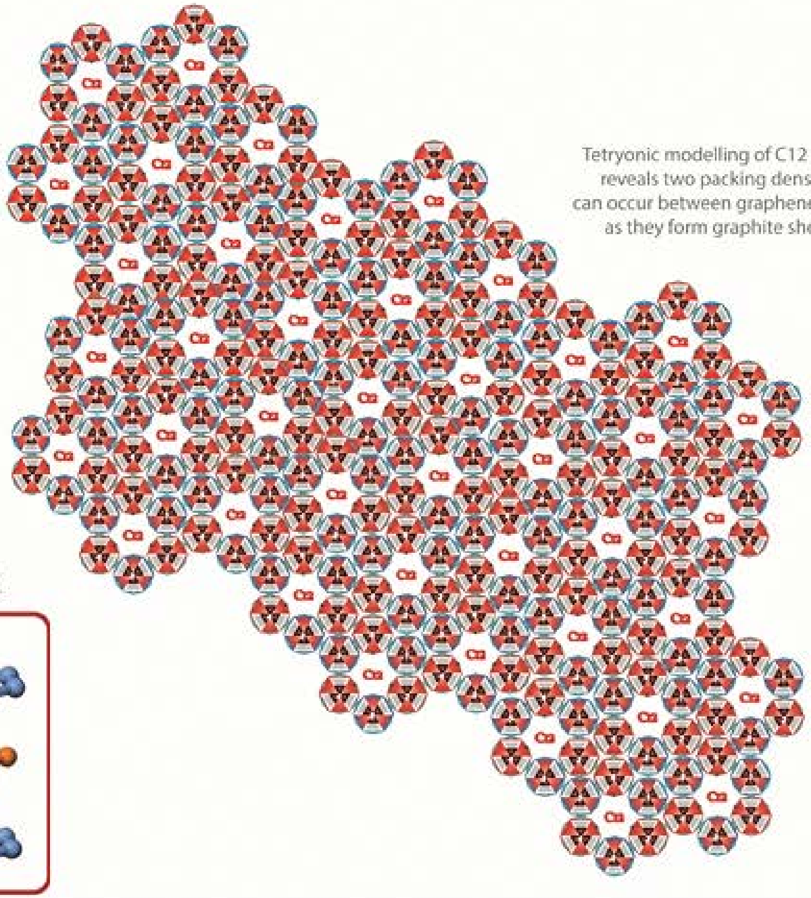

Tetryonic modelling of C12 atoms reveals two packing densities can occur between graphene atoms as they form graphite sheets

Unlike periodic carbon where electrons are tightly bound, graphite is highly conductive, with electrical energy being propagated via the electrons & their KEM fields

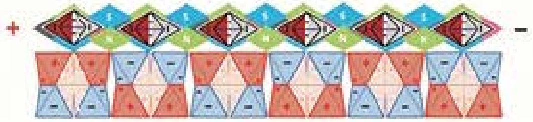

Graphene electrons are loosley bound to the top of the Deuterium nuclei

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Carbon Nanotubes

Carbon nanotubes (CNTs) are allotropes of carbon
with a cylindrical nanostructure.

Large molecules consisting only of carbon, known as buckminsterfullerenes, or buckyballs, have recently been discovered and are currently the subject of much scientific interest.

A single buckyball consists of 60 or 70 carbon atoms (C60 or C70) linked together in a structure that looks like a soccer ball.

They can trap other atoms within their framework, appear to be capable of withstanding great pressures and have magnetic and superconductive properties.

C36

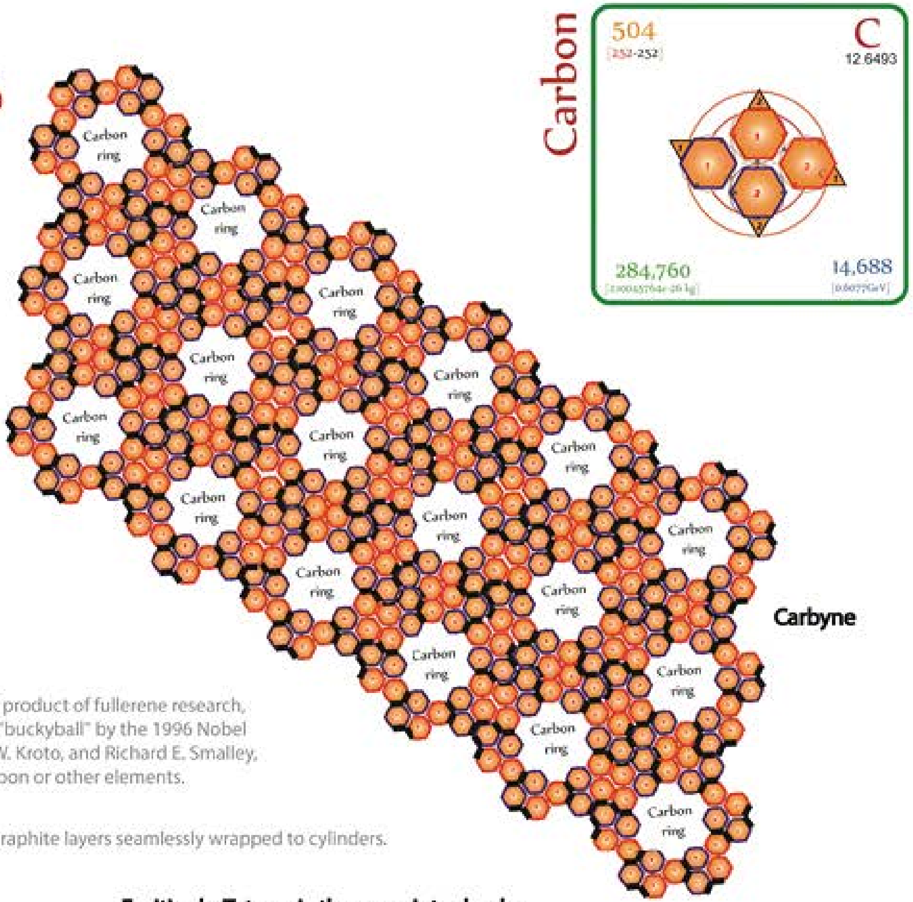

They can be thought of as a sheet of graphite
(a hexagonal lattice of carbon) rolled into a cylinder.

C12

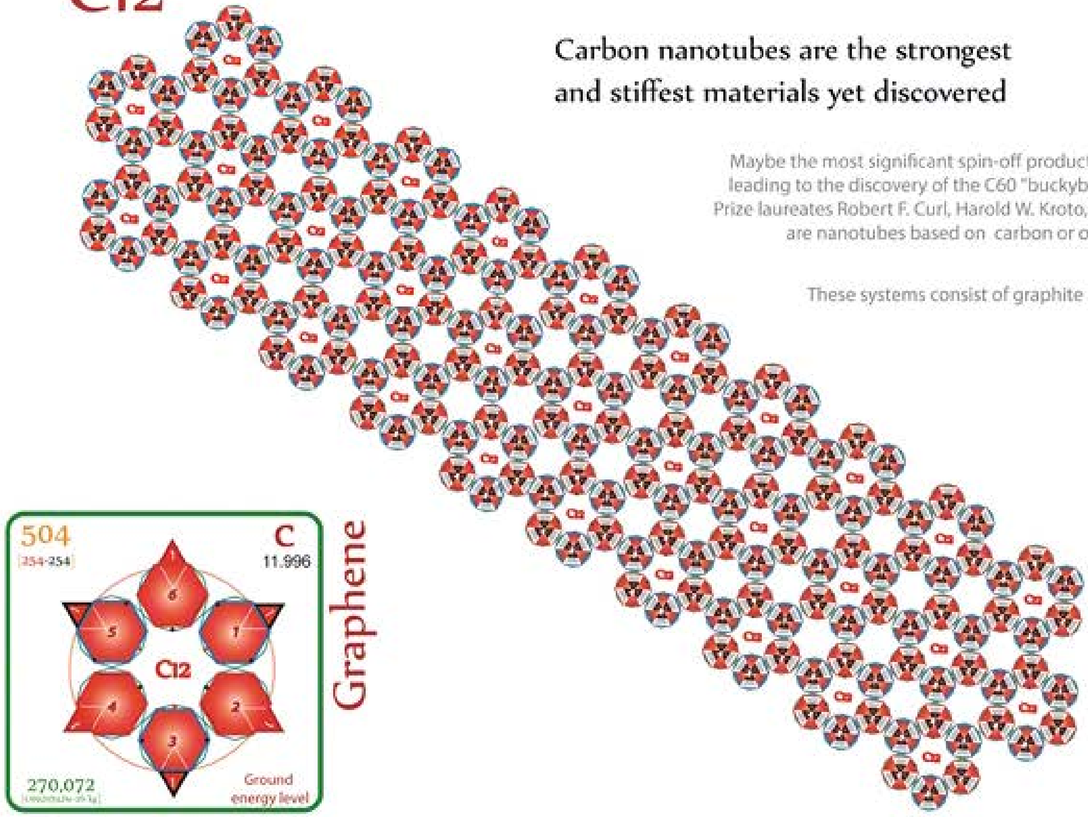

Carbon nanotubes are the strongest and stiffest materials yet discovered

Maybe the most significant spin-off product of fullerene research, leading to the discovery of the C60 "buckyball" by the 1996 Nobel Prize laureates Robert F. Curl, Harold W. Kroto, and Richard E. Smalley, are nanotubes based on carbon or other elements.

These systems consist of graphite layers seamlessly wrapped to cylinders.

Excitingly, Tetryonic theory points clearly to the possibility that organo-carbon nanotubes can be created.

Where C36 periodic carbon could be used insetad of conventional C12 graphene atoms

Carbyne

C60

Nanotubes are members of the fullerene structural family, which also includes the spherical buckyballs, and the ends of a nanotube may be capped with a hemisphere of the buckyball structure.

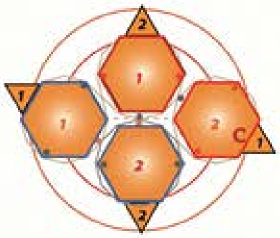

Periodic [C6] Carbon

Diamonds are renowned as a material with superlative physical qualities, most of which originate from the strong fascia bonds between its atoms.

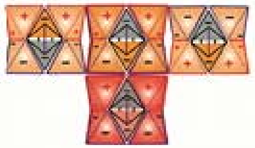

Diamonds

are a metastable allotrope of carbon, where the carbon atoms are arranged in cubic crystal structure called a diamond lattice.

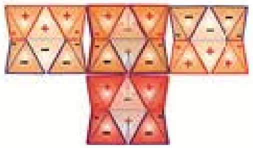

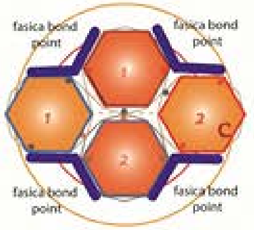

Ionised [C6] Carbon

Most natural diamonds are formed at high temperature and pressure at depths of 140 to 190 kilometers in the Earth's mantle [resulting in the loss of electrons form bound positions, making them poor conductors compared to grahphene atoms].

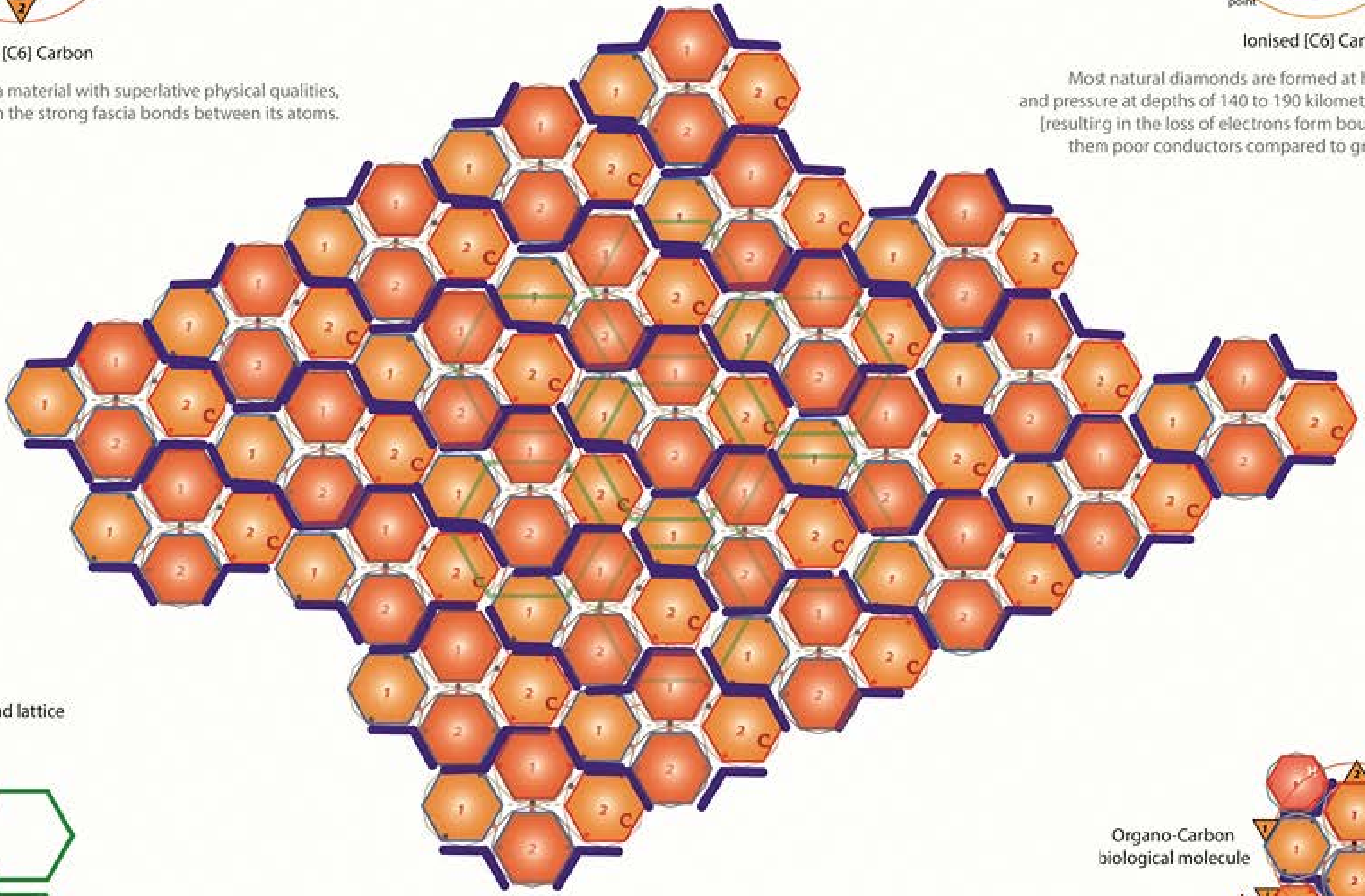

filled n[C7] Carbon diamond lattice

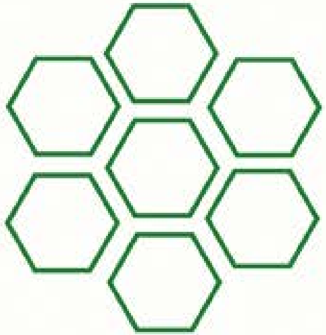

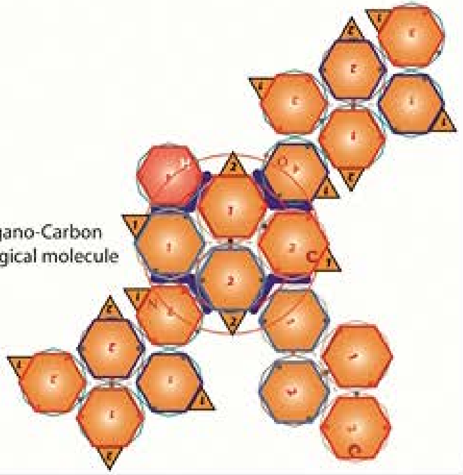

Organo-Carbon
biological molecule

The chemical bonds that hold the carbon atoms in diamonds together are stronger than those in graphite.

In diamonds, the bonds form an inflexible three-dimensional lattice, whereas in graphite, the atoms are tightly bonded into sheets, which can slide easily over one another, making the overall structure weaker

Oxygen Allotropes

There are several known allotropes of oxygen.
The most familiar is molecular oxygen (O2), present at significant levels in Earth's atmosphere and also known as dioxygen or triplet oxygen.
Another is the highly reactive ozone (O3).

Others include:
Atomic oxygen (O1, a free radical)
Singlet oxygen (O2), either of two metastable states of molecular oxygen
Tetraoxygen (O4), another metastable form
Solid oxygen, existing in six variously colored phases, of which one is O8 and another one metallic

Atomic Oxygen also forms bonds easily with Hydrogen to create Hydroxy compounds

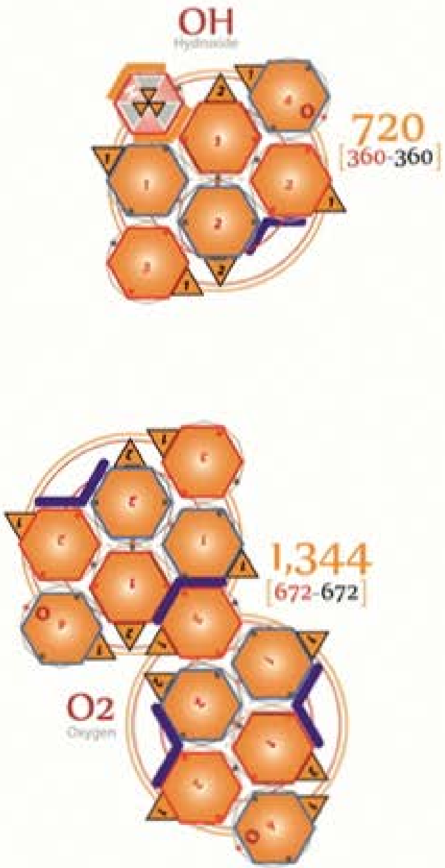
OH
Hydroxide
720
[360-360]
1,344
[672-672]
O2
Oxygen

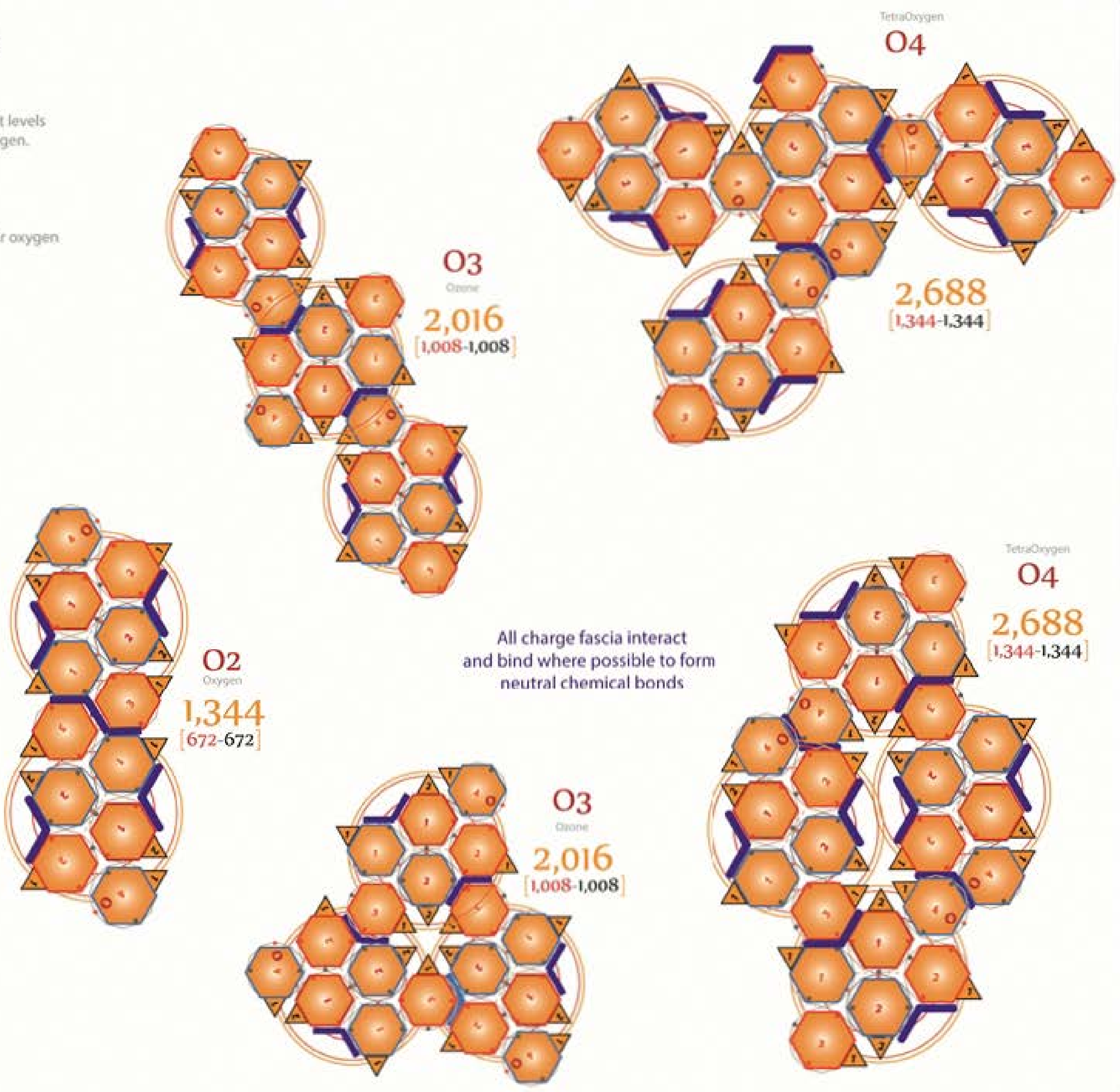
TetraOxygen
O4
2,688
[1,344-1,344]
O3
Ozone
2,016
[1,008-1,008]
O2
Oxygen
1,344
[672-672]
TetraOxygen
O4
2,688
[1,344-1,344]
O3
Ozone
2,016
[1,008-1,008]

All charge fascia interact
and bind where possible to form
neutral chemical bonds

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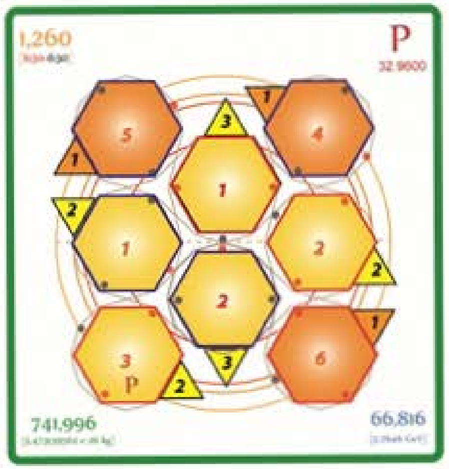
1,260
P
32.9600
741,996
66,816

Phosphor Allotropes

Elemental phosphorus can exist in several allotropes; the most common of which are white and red solids.

Solid violet and black allotropes are also known.

Gaseous phosphorus exists as diphosphorus and atomic phosphorus.

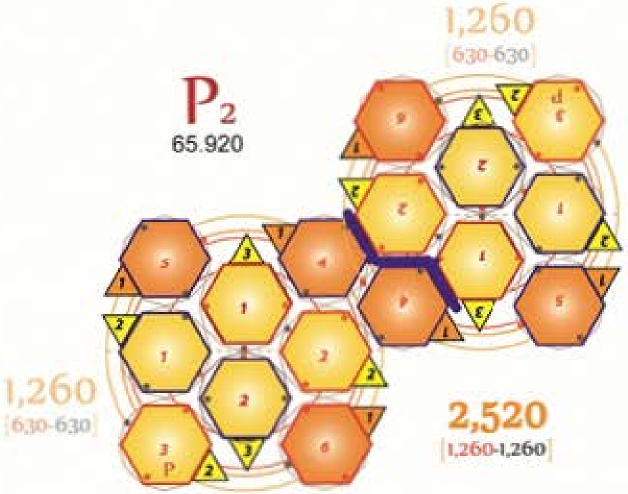
P_2
65.920
1,260
[630-630]
1,260
[630-630]
2,520
[1,260-1,260]

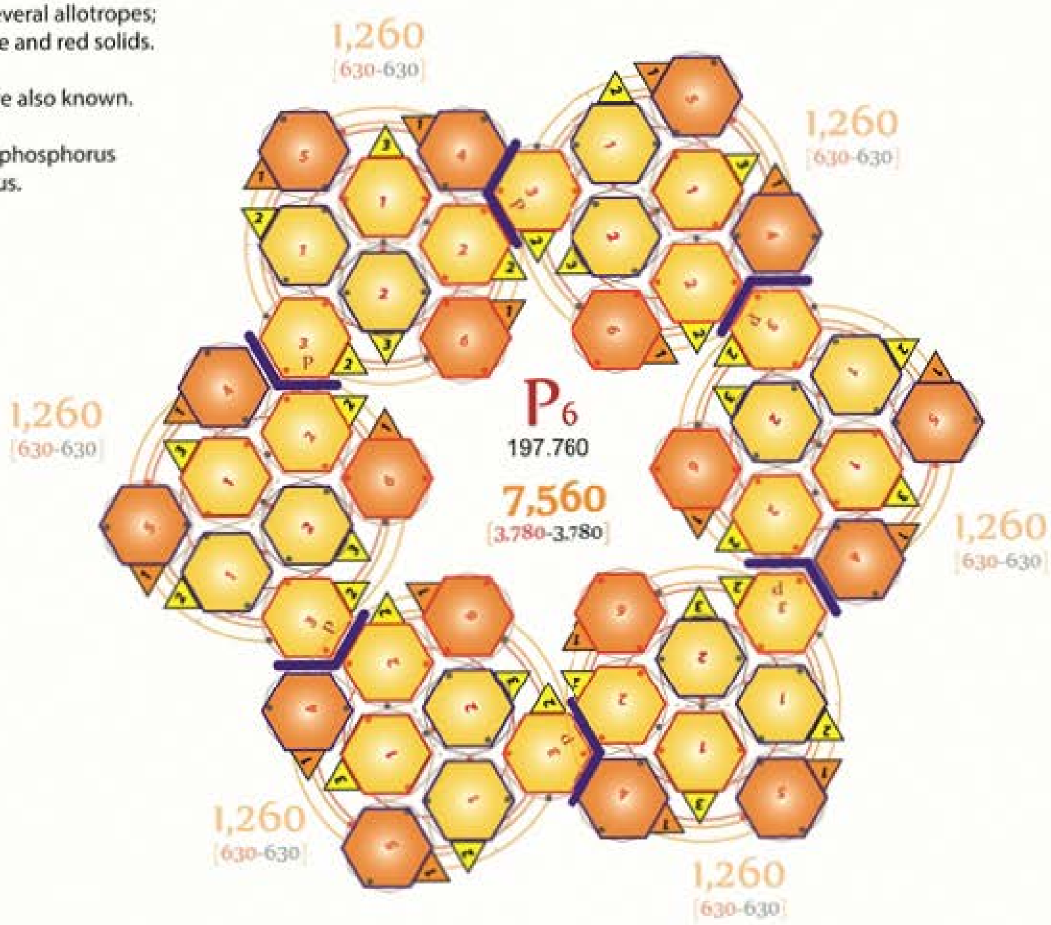
P_6
197.760
7,560
[3,780-3,780]
1,260
[630-630]
1,260
[630-630]
1,260
[630-630]
1,260
[630-630]
1,260
[630-630]
1,260
[630-630]

The diphosphorus allotrope (P2) can be obtained normally only under extreme conditions (for example, from P4 at 1100 kelvin).

Nevertheless, some advancements were obtained in generating the diatomic molecule in homogenous solution, under normal conditions with the use by some transition metal complexes (based on for example tungsten and niobium).

Black phosphorus is the thermodynamically stable form of phosphorus at room temperature and pressure. It is obtained by heating white phosphorus under high pressures (12,000 atmospheres).

In appearance, properties and structure it is very like graphite, being black and flaky, a conductor of electricity, and having puckered sheets of linked atoms

Sulfur Allotropes

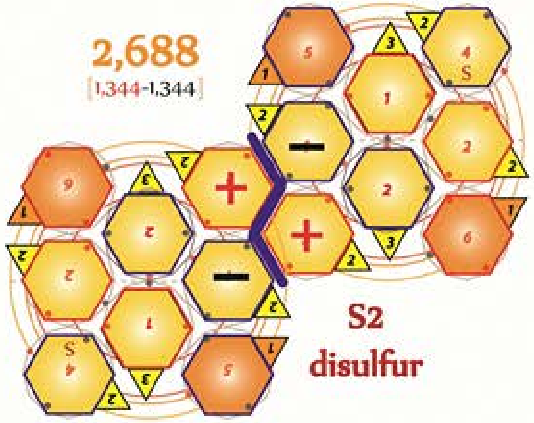
2,688

[1,344-1,344]

S2

disulfur

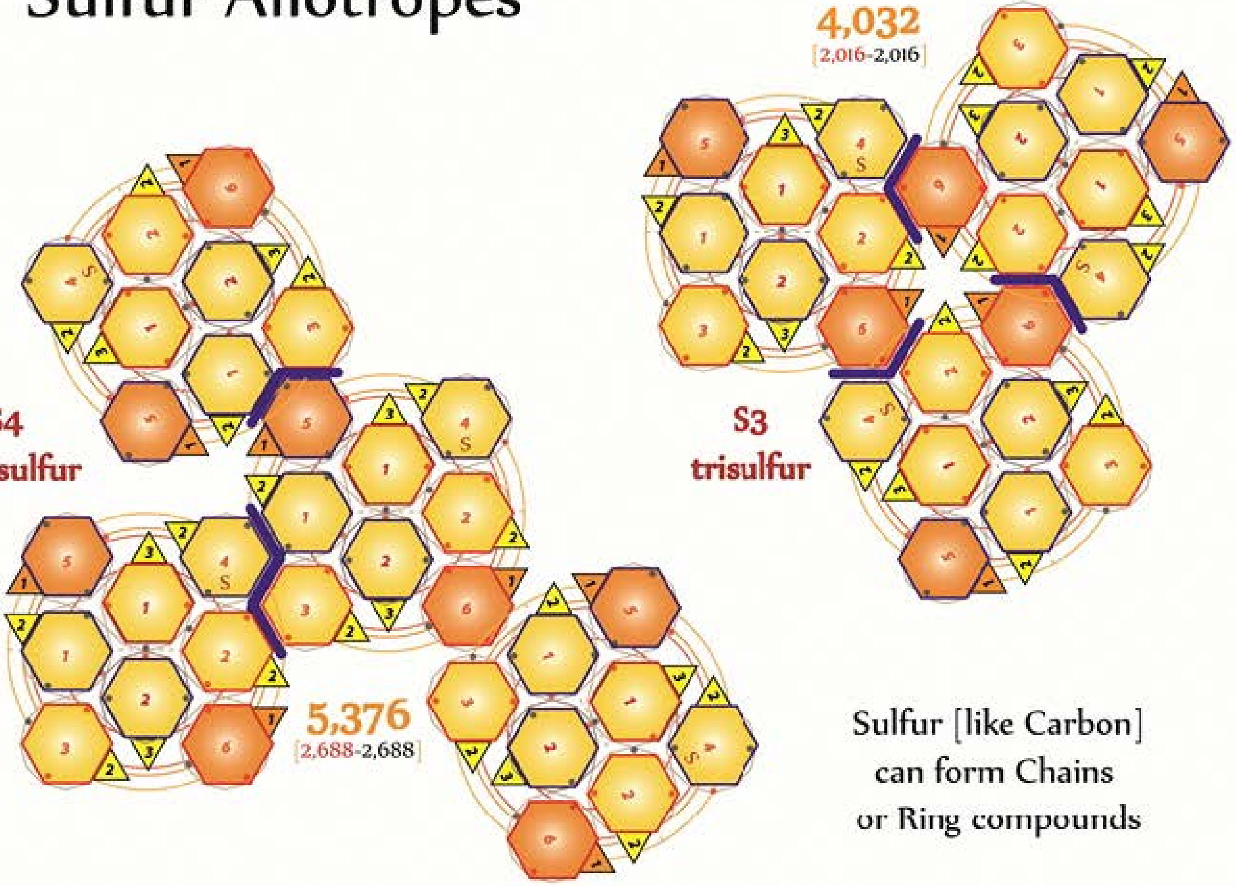
S4

tetrasulfur

5,376

[2,688-2,688]

4,032

[2,016-2,016]

S3

trisulfur

Sulfur [like Carbon]
can form Chains
or Ring compounds

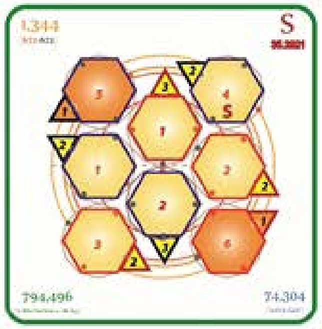

Charged fascia interactions
between differing elements
result in the familiar
chemical bonds

There are a large number of allotropes of sulfur.
In this respect, sulfur is second only to carbon.

cyclo-hexasulfur

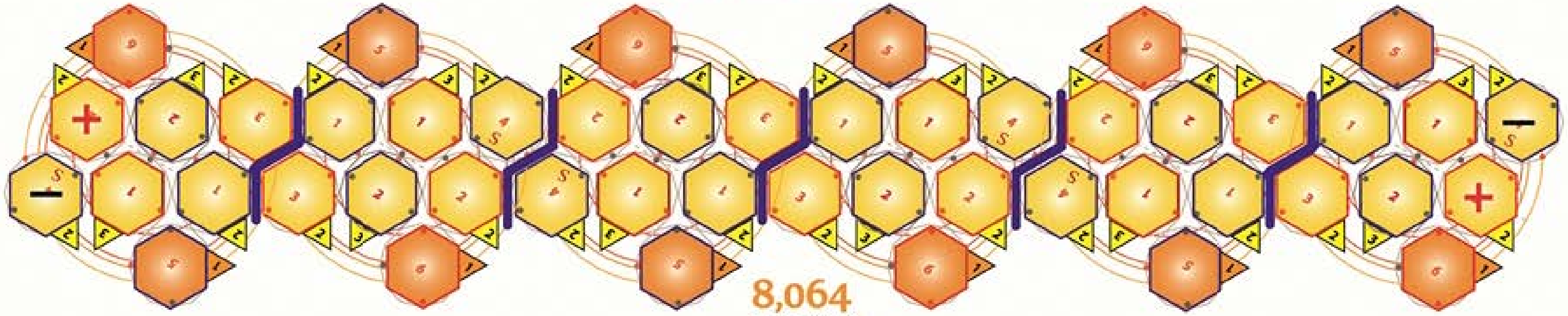

8,064

[4,032-4,032]

Isotopes

In addition to forming varying allotropic elements

Atoms can also absorb energy directly and create numerous elemental isotopes as a result of their differing nuclear energy levels

Deuterium nuclei with bound photo-electrons form quantum-scale synchronous converters

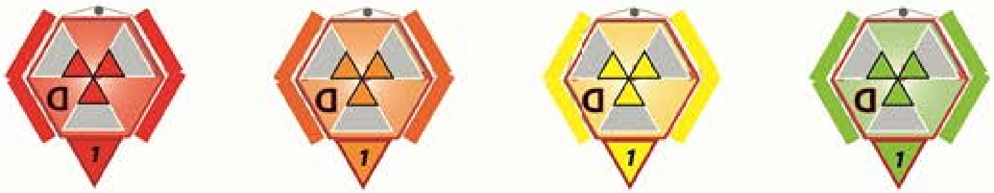

n
R
8
Q
7
P
6
O
5
N
4
M
3
L
2
K
1
Shell
Level

0	Hydrogen	22,512	24,384	26,352	28,416	30,576	32,832	35,184	37,632
Element		1	2	3	4	5	6	7	8
1	Deuterium	45,012	48,720	52,596	56,640	60,852	65,232	69,780	74,496
2	Helium	90,024	97,440	105,192	113,280	121,704	130,464	139,560	148,992
3	Lithium	135,036	146,160	157,788	169,920	182,556	195,696	209,340	223,488
4	Berylium	180,048	194,880	210,384	226,560	243,408	260,928	279,120	297,984
5	Boron	225,060	243,600	262,980	283,200	304,260	326,160	348,900	372,480
6	Carbon	270,072	292,320	315,576	339,840	365,112	391,392	418,680	446,976
7	Nitrogen	315,084	341,040	368,172	396,480	425,964	456,624	488,460	521,472
8	Oxygen	360,096	389,760	420,768	453,120	486,816	521,856	558,240	595,968
9	Fluorine	405,108	438,480	473,364	509,760	547,668	587,088	628,020	670,464
10	Neon	450,120	487,200	525,960	566,400	608,520	652,320	697,800	744,960
11	Sodium	495,132	535,920	578,556	623,040	669,372	717,552	767,580	819,456
12	Magnesium	540,144	584,640	631,152	679,680	730,224	782,784	837,360	893,952
13	Aluminium	585,156	633,360	683,748	736,320	791,076	848,016	907,140	968,448
14	Silicon	630,168	682,080	736,344	792,960	851,928	913,248	976,920	1,042,944
15	Phosphorus	675,180	730,800	788,940	849,600	912,780	978,480	1,046,700	1,117,440
16	Sulfur	720,192	779,520	841,536	906,240	973,632	1,043,712	1,116,480	1,191,936
17	Chlorine	765,204	828,240	894,132	962,880	1,034,484	1,108,944	1,186,260	1,266,432
18	Argon	810,216	876,960	946,728	1,019,520	1,095,336	1,174,176	1,256,040	1,340,928
19	Potassium	855,228	925,680	999,324	1,076,160	1,156,188	1,239,408	1,325,820	1,415,424
20	Calcium	900,240	974,400	1,051,920	1,132,800	1,217,040	1,304,640	1,395,600	1,489,920

Level
R
8
Q
7
P
6
O
5
N
4
M
3
L
2
K
1
Shell

It is the increased nucleonic energy levels that creates isotopes (not extra Neutrons within an atomic nucleus)

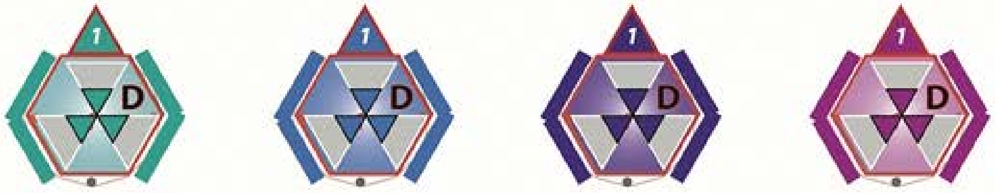

The energy level of Baryons determines the KEM energies of photo-electrons bound to them

Most isotopes are considered
to be radioactive as a result of
the nuclei seeking to release excess
energy in the form of photons of energy
or particles with high kinetic energies

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Carbon Isotopes

It is widely held in the scientific community that: Carbon-14, 14C, or radiocarbon, is a radioactive isotope of carbon with a nucleus containing 6 protons and 8 neutrons.

It is in fact a nucleus comprised of 6 deuterium nuclei [with 6 Protons, 6 Neutrons & 6 electrons]

The mistaken belief in 'extra' neutrons being present in the nucleus stems from the fact that electrons and protons combine in equal numbers in the atomic nucleus and historically attributing the mass in excess of this as being the result of the mass contribution of 'extra' neutrons

Tetryonics finally corrects this erroneous assumption

Carbon 12-14

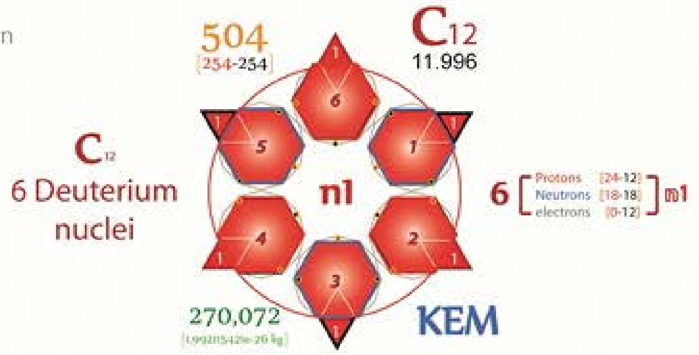
504
[254-254]
C12
11.996
C12
6 Deuterium
nuclei
6
5
1
n1
4
2
3
6 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1
270,072
[1.99215426e-26 kg]
KEM

There are NO extra neutrons (in excess of the element's Z#) in the nuclei of atomic isotopes.

The measured 'excess mass' is the direct result of the raised quantum levels of the Deuterium nuclei that comprise each atomic element

And is compreletely accounted for in Tetryonic theory by calculating for the total rest mass-energies in each elementary Matter topology.

The 'extra' mass historically attrtibuted to neutron numbers above that of the elemental number are now reflected as stored kinetic 'chemical' energies as they always were.

ALL elements & isotopes have equal numbers of Protons, electrons & Neutrons

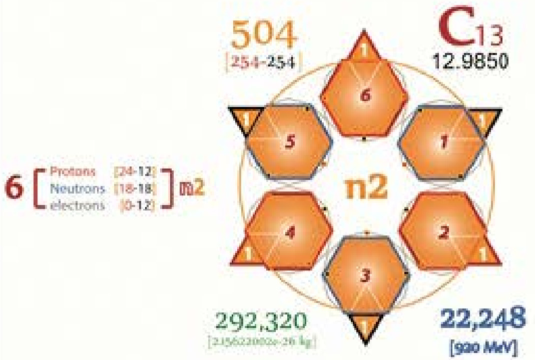
504
[254-254]
C13
12.9850
6
5
1
n2
4
2
3
6 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n2
292,320
[2.15622002e-26 kg]
22,248
[920 MeV]

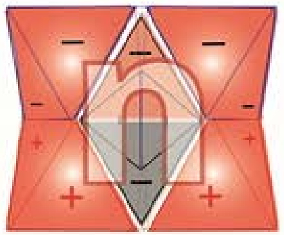

Quantum levels of atomic nuclei contribute to the molar mass [Isotopes are higher energy nuclei]

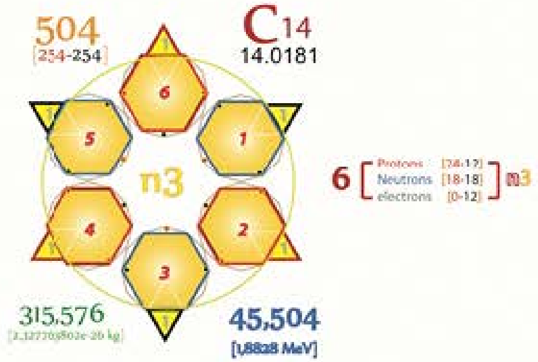
504
[254-254]
C14
14.0181
6
5
1
n3
4
2
3
6 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n3
315,576
[2.32770...e-26 kg]
45,504
[1,8828 MeV]

		n1	n2	n3	n4	n5	n6	n7	n8
	C12	270,072	292,320	315,576	339,840	365,112	391,392	418,680	446,976
KEM diff		0	22,248	45,504	69,768	95,040	121,320	148,608	176,904
neutron #			.98	2.0	3.1	4.2	5.4	6.6	7.8

This applies equally to all atomic nuclei

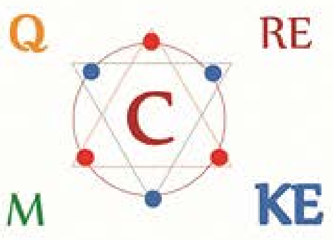

Electron Configuration
[n] p1

Atoms store mass-energies
in their standing wave Matter topologies
and release it via radioactive decay paths

**It is increased kinetic energy level
geometries that create nuclear isotopes
(not extra Neutrons within a nucleus)**

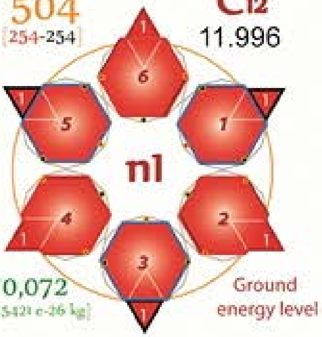

504
[254-254]
C12
11.996
270,072
[1.99211542 e-26 kg]
Ground
energy level

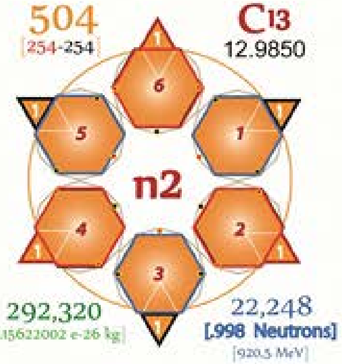

504
[254-254]
C13
12.9850
292,320
[2.15622002 e-26 kg]
22,248
[.998 Neutrons]
[920.5 MeV]

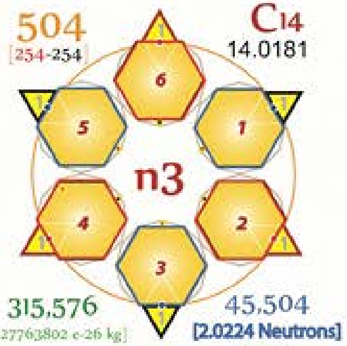

504
[254-254]
C14
14.0181
315,576
[2.327763802 e-26 kg]
45,504
[2.0224 Neutrons]
[1.882 GeV]

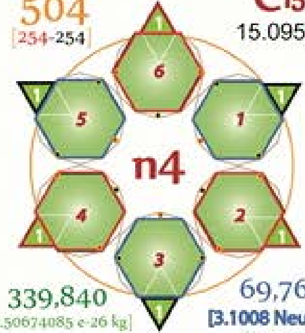

504
[254-254]
C15
15.0959
339,840
[2.50674085 e-26 kg]
69,768
[3.1008 Neutrons]
[2.886 GeV]

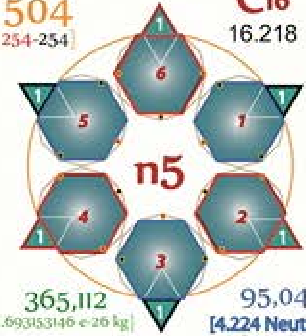

504
[254-254]
C16
16.218
365,112
[2.693153146 e-26 kg]
95,040
[4.224 Neutrons]
[3.925 GeV]

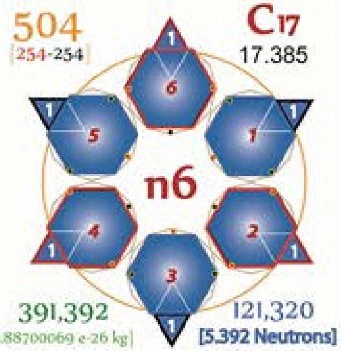

504
[254-254]
C17
17.385
391,392
[2.88700069 e-26 kg]
121,320
[5.392 Neutrons]
[5.019 GeV]

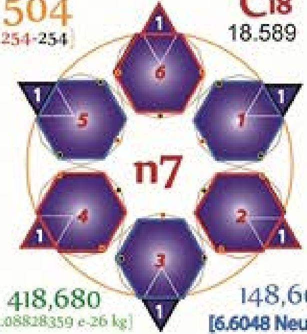

504
[254-254]
C18
18.589
418,680
[3.08828359 e-26 kg]
148,608
[6.6048 Neutrons]
[6.145 GeV]

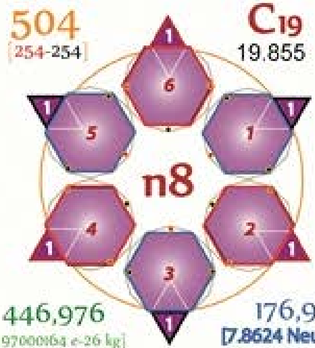

504
[254-254]
C19
19.855
446,976
[23.297000164 e-26 kg]
176,904
[7.8624 Neutrons]
[7.319 GeV]

Shell			Molar meM	Nuclei per shell
R	8	446,976	19.855	6
Q	7	418,680	18.598	6
P	6	391,392	17.385	6
O	5	365,112	16.218	6
N	4	339,840	15.095	6
M	3	315,576	14.018	6
L	2	292,320	12.985	6
K	1	270,072	11.996	6

energy
level

22,500
[1 Neutron]

n

[930.97 MeV]

Kinetic mass-energy geometries
stored in 3D Matter topologies
is released as Chemical energies

Deuterium nuclei with bound photo-electrons fom quantum-scale synchronous converters

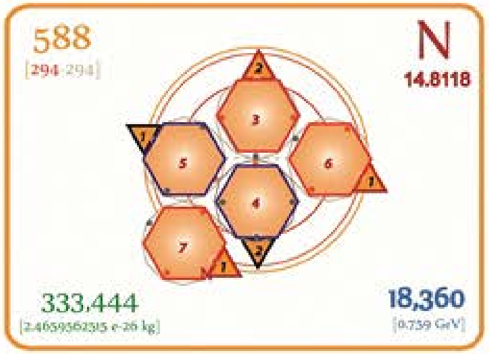
588
[294-294]
N
14.8118
3
2
5
1
6
1
4
2
7
1
333,444
[2.4659562315 e-26 kg]
18,360
[0.759 GeV]

It is increased Nucleonic energy levels that creates Isotopes
(not extra Neutrons within any elementary Nucleus)

Nitrogen gas

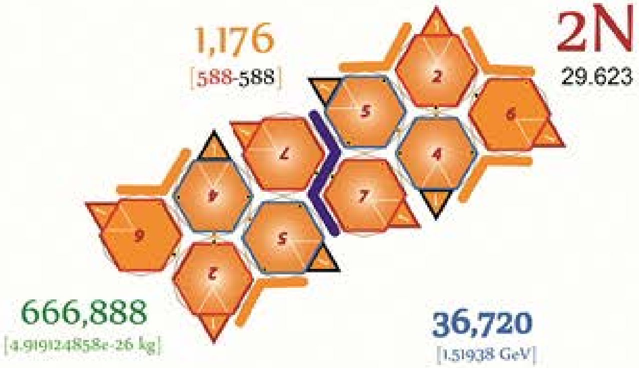
1,176
[588-588]
2N
29.623
2
5
6
4
7
4
7
9
5
2
666,888
[4.919124858e-26 kg]
36,720
[1.51938 GeV]

Nitrogen Allotropes & Isotopes

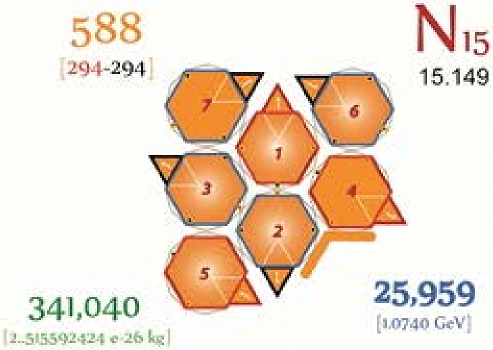
588
[294-294]
N15
15.149
7
6
1
3
4
2
5
341,040
[2..515592424 e-26 kg]
25,959
[1.0740 GeV]

Isotopes are created by increasing the number of Planck mass-energies stored in the standing-wave geometries of chemical elements

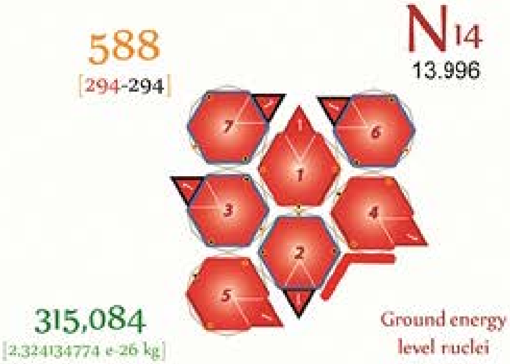
588
[294-294]
N14
13.996
7
6
1
3
4
2
5
315,084
[2.324134774 e-26 kg]
Ground energy
level nuclei

The charged mass-energy geometries of differing allotropic topologies create various chemical bond points

Shell			Molar meM	Nuclei per shell
R	8	521,472	23.164	7
Q	7	488,460	21.697	7
P	6	456,624	20.283	7
O	5	425,964	18.921	7
N	4	396,480	17.612	7
M	3	368,172	16.354	7
L	2	341,040	15.149	7
K	1	315,084	13.996	7
				7

energy level

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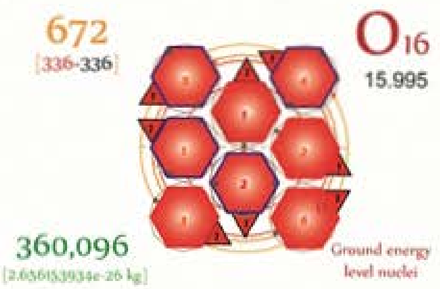
672
[336-336]
O_{16}
15.995
360,096
[2.6561539334e-26 kg]
Ground energy level nuclei

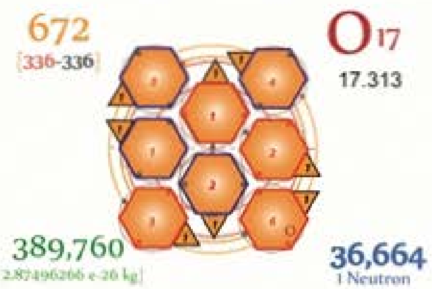
672
[336-336]
O_{17}
17.313
389,760
[2.87496266 e-26 kg]
36,664
1 Neutron

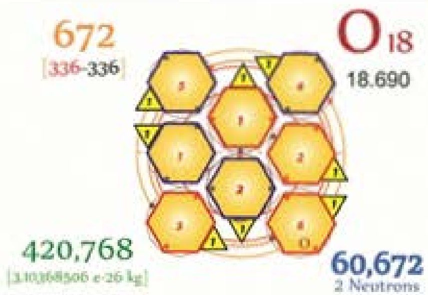
672
[336-336]
O_{18}
18.690
420,768
[3.10368506 e-26 kg]
60,672
2 Neutrons

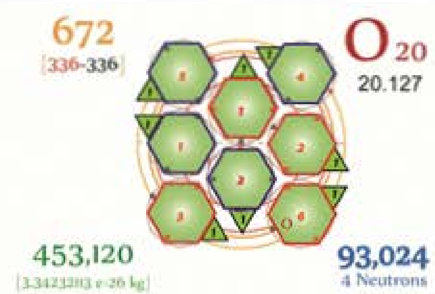
672
[336-336]
O_{20}
20.127
453,120
[3.3423213 e-26 kg]
93,024
4 Neutrons

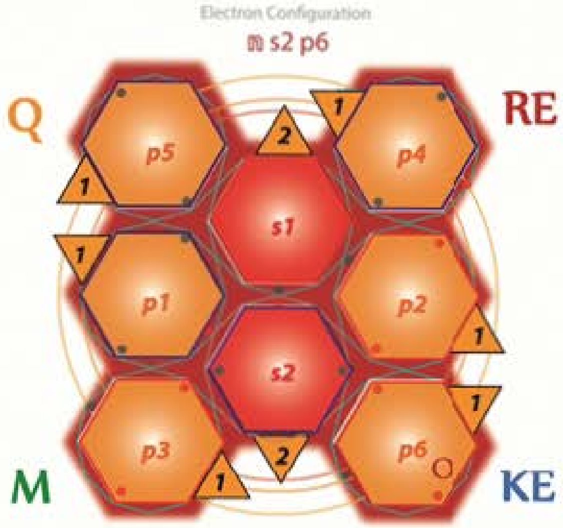
Electron Configuration
m s2 p6
Q
RE
M
KE
p5
p4
s1
p1
p2
s2
p3
p6
1
2
1
1
1
1
2
1

This oxygen allotrope's nuclei arrangement is very stable and inert like Neon [due to its filled sp electron orbitals]

Oxygen Allotropes & Isotopes

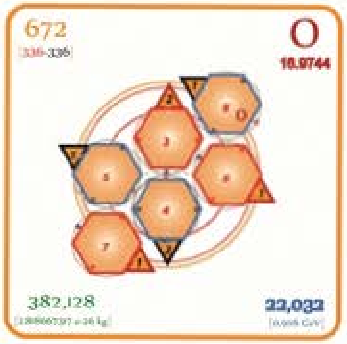
672
[336-336]
O
18.9744
382,128
22,032

There exists an allotrope of Oxygen formed when 8 nuclei combine in a single level SP orbital arrangement

Shell			Molar meM	Nuclei per shell
R	8	595,968	26.473	8
Q	7	558,240	24.797	8
P	6	521,856	23.181	8
O	5	486,816	20.825	8
N	4	453,120	20.127	8
M	3	420,768	18.690	8
L	2	389,760	17.313	8
K	1	360,096	15.995	8

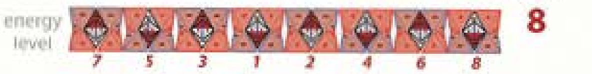
energy level
7
5
3
1
2
4
6
8
8

It is increased Nucleonic energy levels that creates Isotopes (not extra Neutrons within a Nucleus)

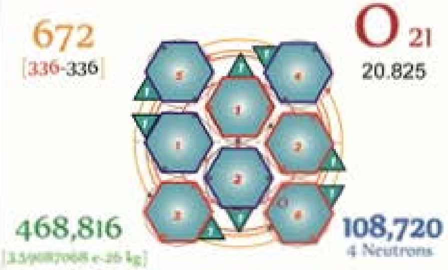
672
[336-336]
O_{21}
20.825
468,816
[3.59087068 e-26 kg]
108,720
4 Neutrons

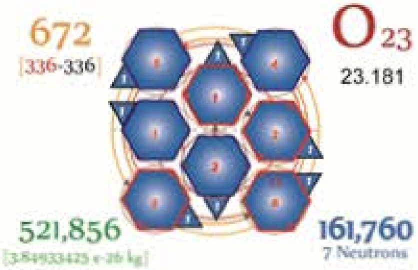
672
[336-336]
O_{23}
23.181
521,856
[3.84933425 e-26 kg]
161,760
7 Neutrons

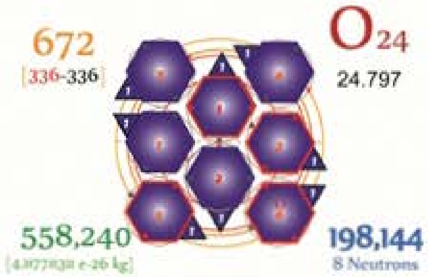
672
[336-336]
O_{24}
24.797
558,240
[4.1177031 e-26 kg]
198,144
8 Neutrons

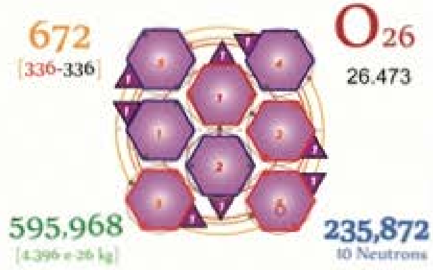
672
[336-336]
O_{26}
26.473
595,968
[4.396 e-26 kg]
235,872
10 Neutrons

Tetryonics 54.15 - Oxygen isotopes

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Bose–Einstein condensates exist at the low energy extremes

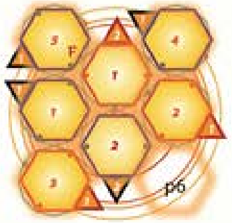

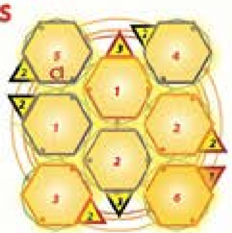

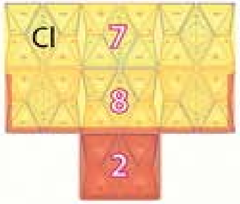

Gaseous

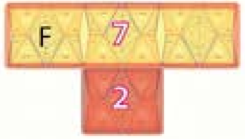

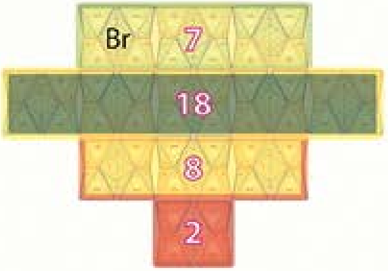

Liquid

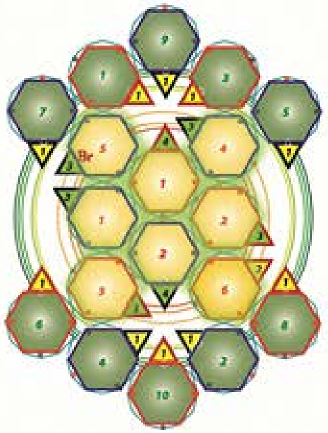

The Natural states of Matter

(room temperature)

Elements appear in their natural phase at room temperature as a gas, liquid, solid or synthetic

As energy is added or removed from any element's charged Matter topology or their baryonic KEM field geometry their phase states & Brownian motion changes

The halogen element family provides a great example of all 4 states of Matter at room temperature

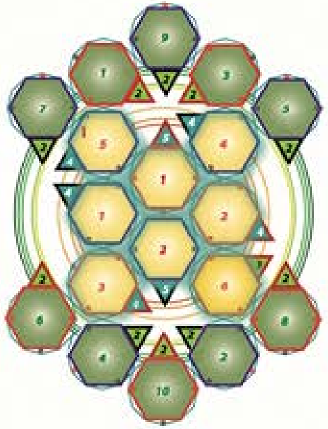

Solid

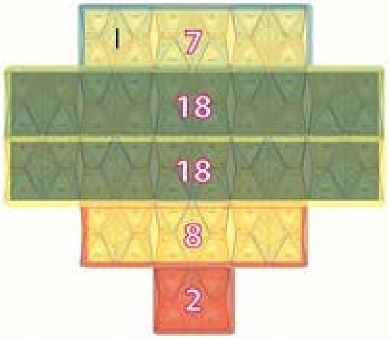

Radioactive

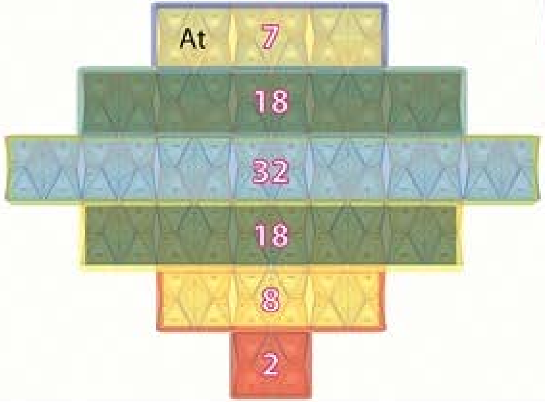

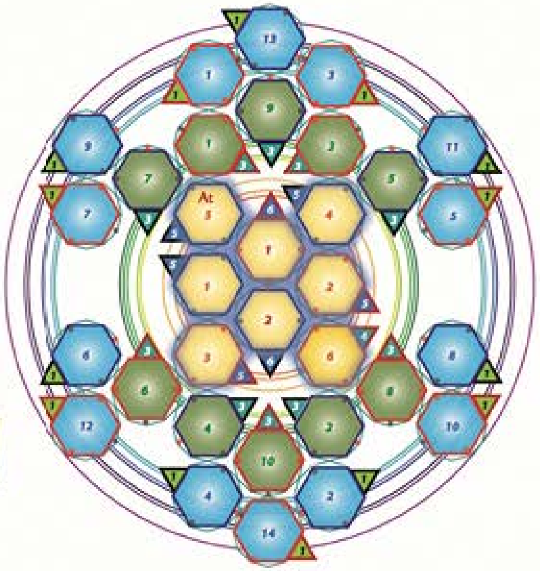

At the high energy extremes exist the Plasma states of Matter

Chemical bonds

A chemical bond is an attraction between atoms that allows the formation of chemical substances that contain two or more atoms.

Particle charge & Inter-fascia electric interaction provides the foundation of chemical bonds

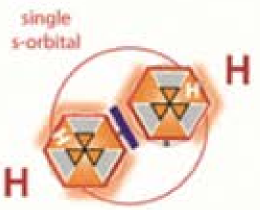
single
s-orbital
H
H

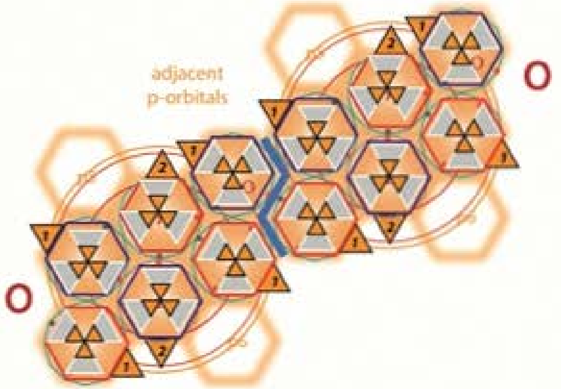
adjacent
p-orbitals
O
O

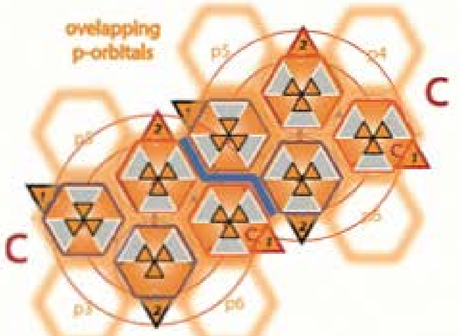
ovelapping
p-orbitals
C
C
p5
p4
p3
p6

It is usually taught that based on electron sharing principles a single bond contains 2 paired electrons, a double bond has 4 electrons and a triple bond has 6 shared electrons

filled electron shells
[weak KEM'ical bonds]

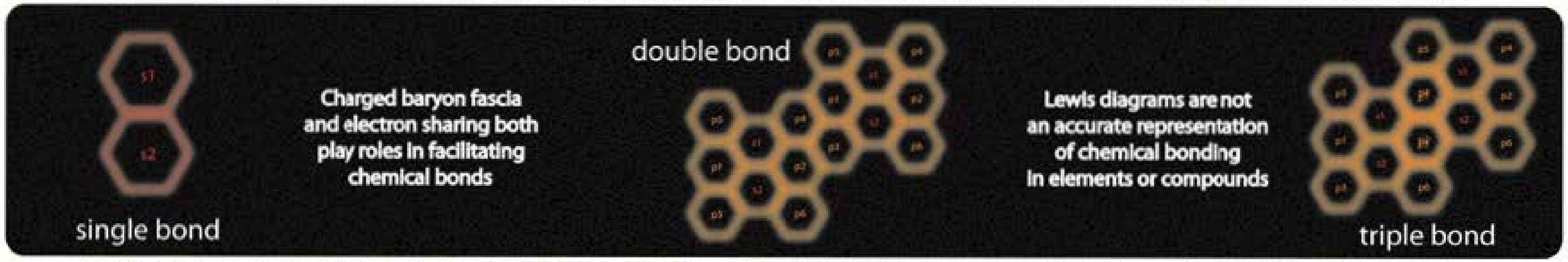
single bond
double bond
triple bond

Charged baryon fascia and electron sharing both play roles in facilitating chemical bonds

Lewis diagrams are not an accurate representation of chemical bonding in elements or compounds

unfilled electron shells
[stronger KEM'ical bonds]

Tetryonic geometry provides an advanced quantum topology for all atoms and compounds that is superior to the older Lewis diagrams and even molecular orbital theory, facilitating a clear understanding of the quantum geometry of each element, its nuclear bonds and electron sharing in all compound chemical structures; along with the core & valence electron configurations & interactive electric charge fascia bonding positions for each compound created.

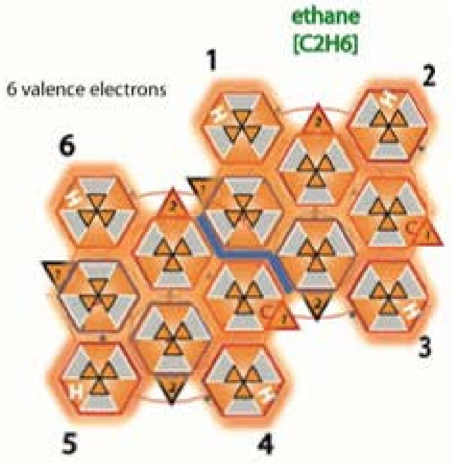
ethane
[C2H6]
6 valence electrons
1
2
6
3
5
4

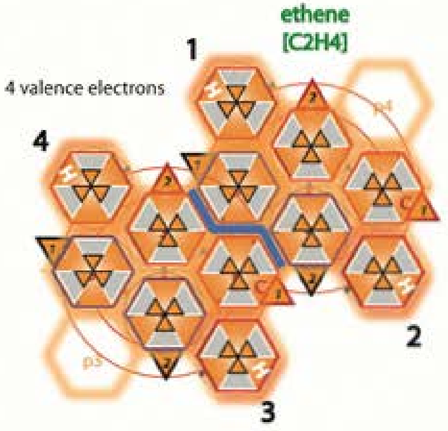
ethene
[C2H4]
4 valence electrons
1
4
2
3

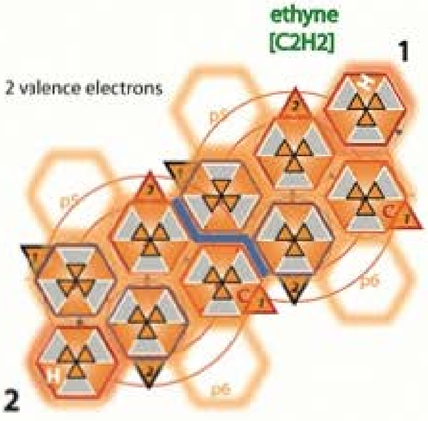
ethyne
[C2H2]
2 valence electrons
1
2

Valance electrons also play an important role in determining the strength of chemical bonds

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Van der Waals Forces

Van der Waals forces include attractions between atoms, molecules, and surfaces. They differ from covalent and ionic bonding in that they are caused by correlations in the fluctuating polarizations of nearby particles

All charges seek equilibrium

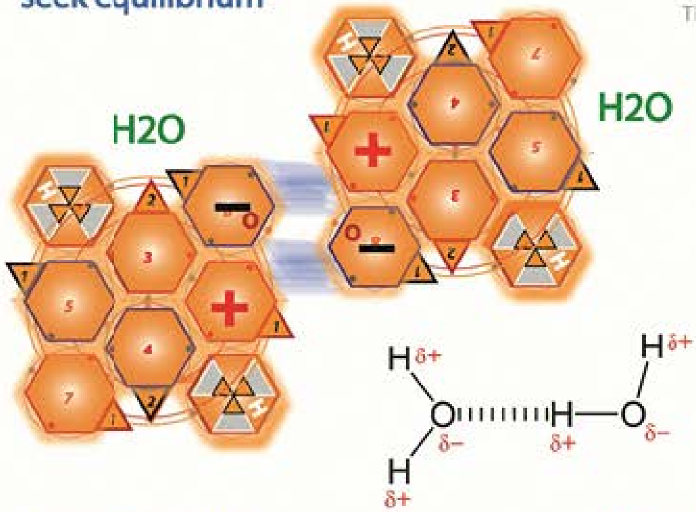

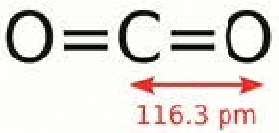

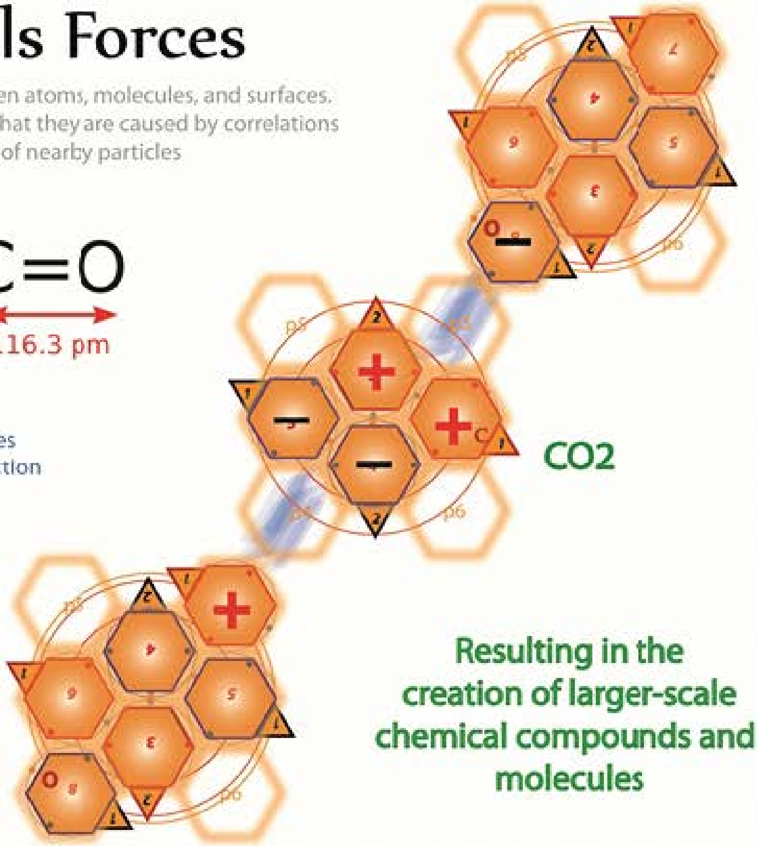

Van der Walls and London forces are the geometric fields of interaction between charged Matter topologies

The Forces of interaction can be attractive or repulsive

Residual interactive bonding force between the charged fascia of atoms

Resulting in the creation of larger-scale chemical compounds and molecules

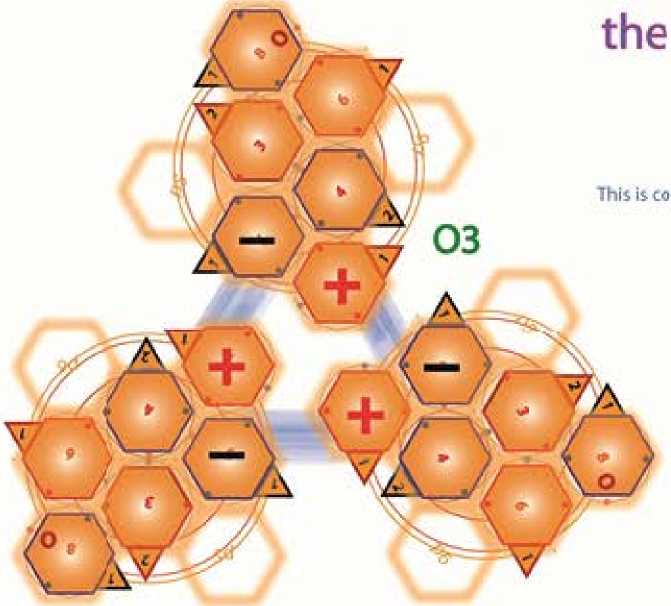

This is considered to be the only attractive intermolecular force present between neutral atoms (e.g., a noble gas configurations and charge neutral atomic topologies).

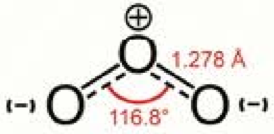

Without London forces, there would be no attractive force between noble gas atoms, and they wouldn't exist in liquid form.

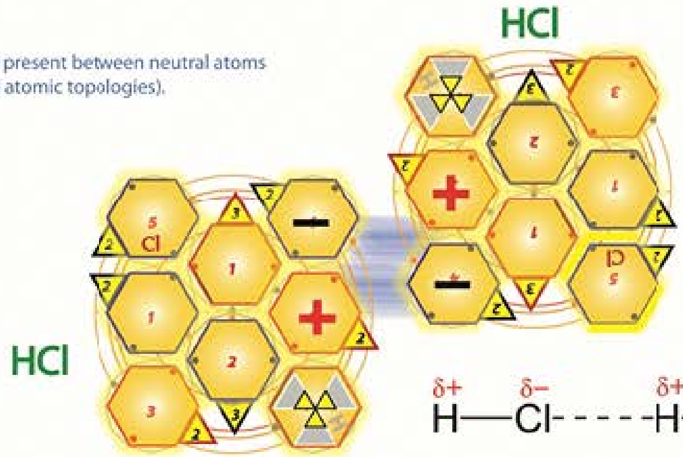

δ+ δ− δ+ δ−
H—Cl- - - -H—Cl

Lewis Structures

The Lewis structure was named after Gilbert N. Lewis,
who introduced it in his 1916 article
The Atom and the Molecule.

BeCl2

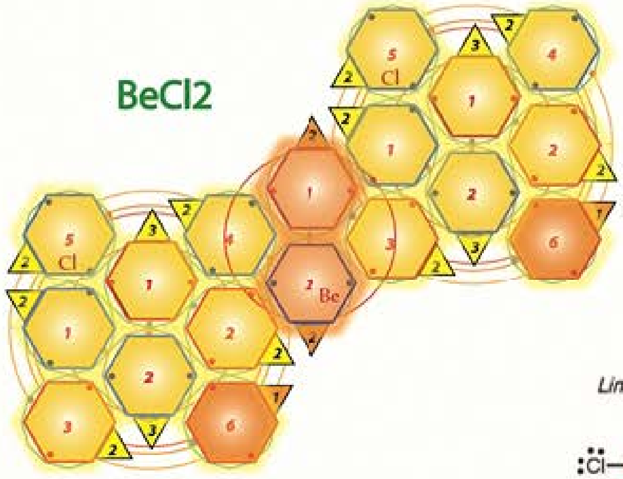

HF

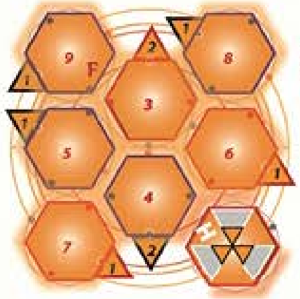

Lewis structures, also called Lewis-dot diagrams,
are diagrams that show the bonding between the atoms of any molecule,
and the lone pairs of electrons that may exist in the molecule.

Line drawings can be used to depict molecular geometry:

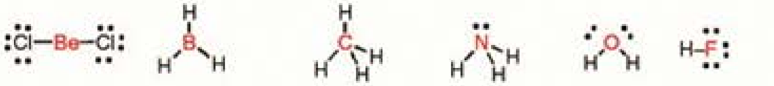

Beryllium dichloride $BeCl_2$	Borane BH_3	Methane CH_4	Ammonia NH_3	Water H_2O	Hydrofluoric acid HF
linear	*trigonal planar*	*tetrahedral*	*trigonal pyrimidal*	*bent*	*linear*

Also applies to molecules with multiple bonding:

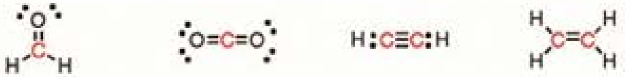

methanal (formaldehyde)	Carbon dioxide	ethyne (acetylene)	ethane (ethylene)
trigonal planar	*linear*	*linear*	*both carbons are trigonal planar*

Hydrogen is a
'free radical' atom
whose energy can be
changed to facilitate
chemical bonding
between elements

Tetryonic geometry uses the
charged geometry of the
element fascia themselves

to show the bonds and
charge interactions between
differing elements as they
form larger compounds

as well as the actual final
quantum topology of
compound elements
and molecules

They are similar to electron dot diagrams in that the valence electrons in lone pairs are represented as dots,
but they also contain lines to represent shared pairs in a chemical bond (single, double, triple, etc.).

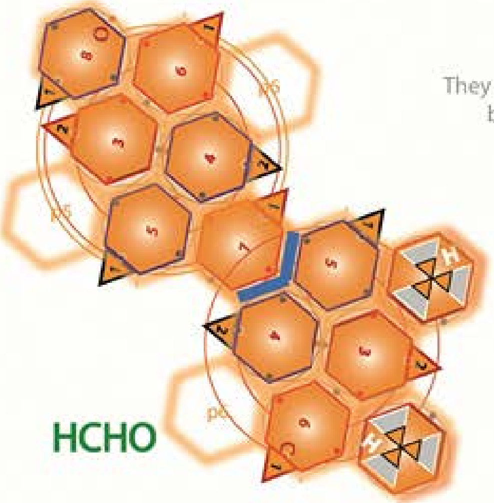

HCHO

single
fascia bond

double
fascia bonds

triple
fascia bond

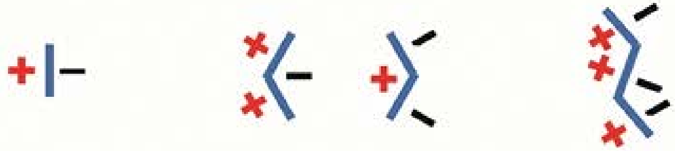

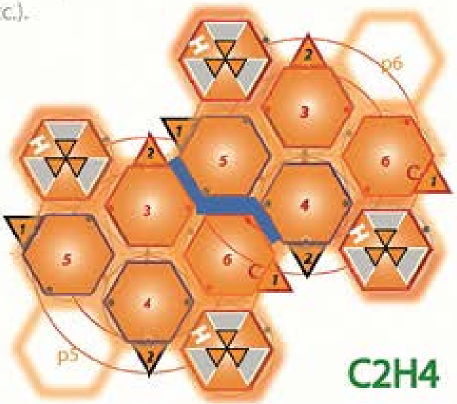

C2H4

it is the electric field fascia of baryons that facilitates chemical bonds

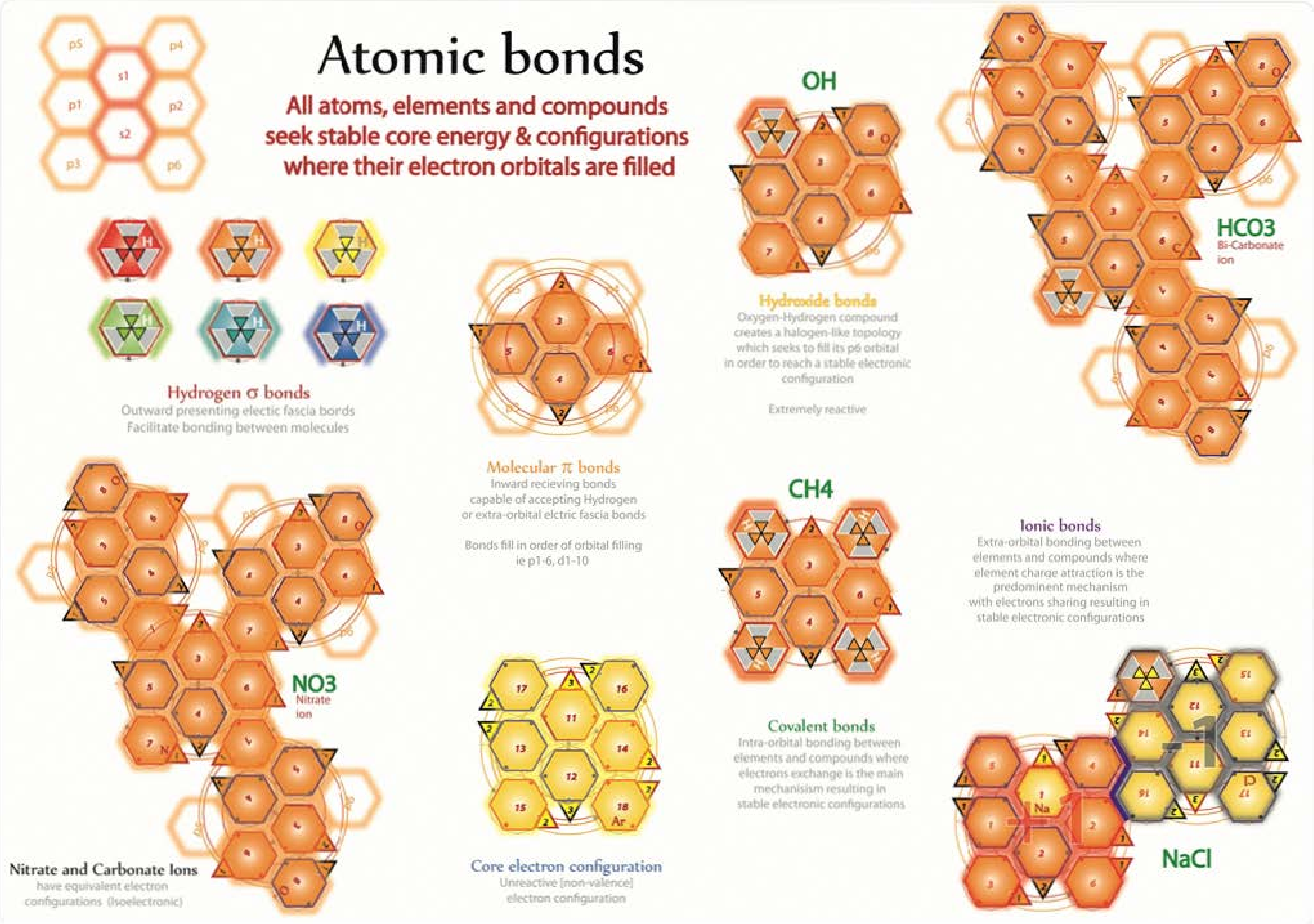

Atomic bonds

All atoms, elements and compounds seek stable core energy & configurations where their electron orbitals are filled

Hydrogen σ bonds
Outward presenting electic fascia bords
Facilitate bonding between molecules

Molecular π bonds
Inward recieving bonds
capable of accepting Hydrogen
or extra-orbital elctric fascia bonds

Bonds fill in order of orbital filling
ie p1-6, d1-10

Hydroxide bonds
Oxygen-Hydrogen compound
creates a halogen-like topology
which seeks to fill its p6 orbital
in order to reach a stable electronic
configuration

Extremely reactive

Ionic bonds
Extra-orbital bonding between
elements and compounds where
element charge attraction is the
predominent mechanism
with electrons sharing resulting in
stable electronic configurations

Covalent bonds
Intra-orbital bonding between
elements and compounds where
electrons exchange is the main
mechanisium resulting in
stable electronic configurations

Nitrate and Carbonate Ions
have equivalent electron
configurations (Isoelectronic)

Core electron configuration
Unreactive [non-valence]
electron configuration

Tetryonics 55.05 - Atomic facsia Bonds

Atomic bonds

All atoms, elements and compounds seek stable core electron configurations where their electron orbitals are filled

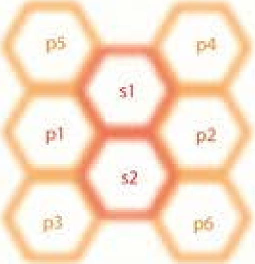

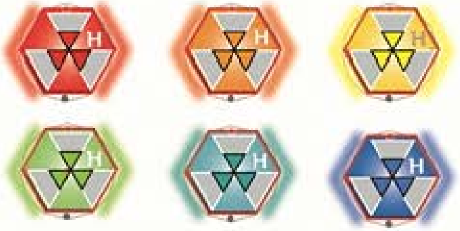

Hydrogen Bonds

Outward presenting electic fascia bonds
Facilitate bonding between molecules

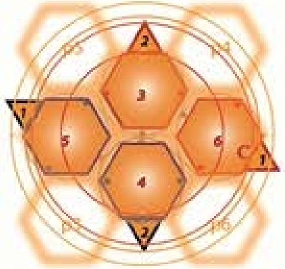

Molecular bonds

Inward recieving bonds
capable of accepting Hydrogen
or extra-orbital elctric fascia bonds

Bonds fill in order of orbital filling
ie p1-6, d1-10

OH

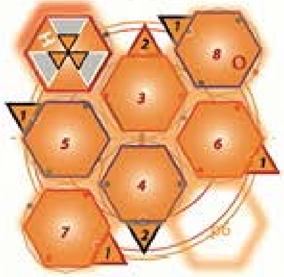

Hydroxide bonds

Oxygen-Hydrogen compound
creates a halogen-like geometry
which seeks to fill its p6 orbital
in order to reach a stable electronic
configuration

Extremely reactive

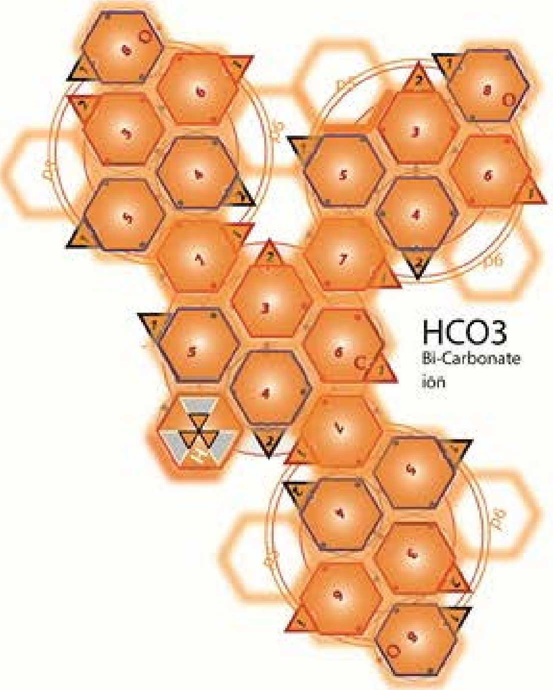

HCO3
Bi-Carbonate
ion

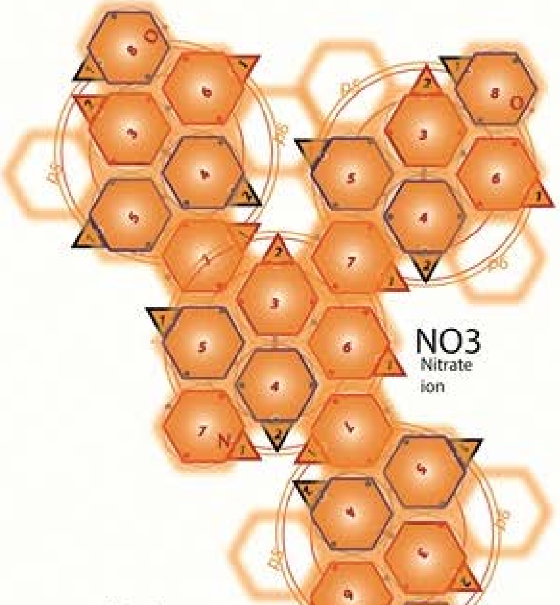

NO3
Nitrate
ion

Nitrate and Carbonate Ions

have equivalent electron
configurations (Isoelectronic)

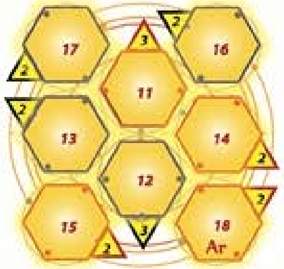

Core electron configuration

Unreactive [non-valence]
electron configuration

CH4

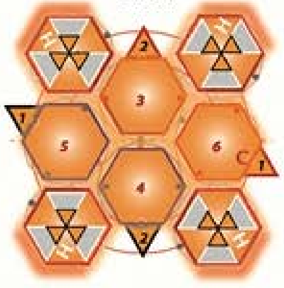

Covalent bonds

Intra-orbital bonding between
elements and compounds where
electrons exchange is the main
mechanisism resulting in
stable electronic configurations

Ionic bonds

Extra-orbital bonding between
elements and compounds where
element charge attraction is the
predominent mechanism
with electrons sharing resulting in
stable electronic configurations

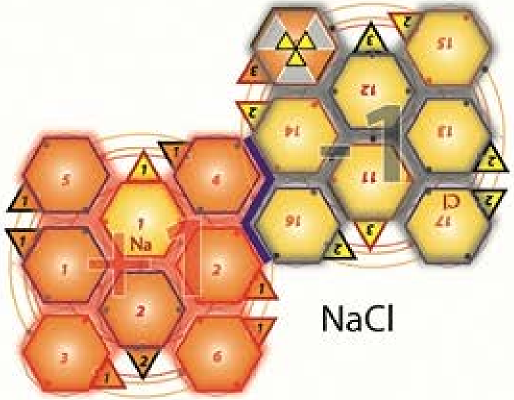

NaCl

CORE ELECTRON configurations

			[He]
L	1s2	2s2 2p6	[Ne]
M	1s2 2s2 2p6	3s2 3p6	[Ar]
N	1s2 2s2 2p6 3s2 3p6 3d10	4s2 4p6	[Kr]
O	1s2 2s2 2p6 3s2 3p6 3d10 4s2 4p6 4d10	5s2 5p6	[Xe]
P	1s2 2s2 2p6 3s2 3p6 3d10 4s2 4p6 4d10 4f14 5s2 5p6 5d10	6s2 6p6	[Rn]
Q	1s2 2s2 2p6 3s2 3p6 3d10 4s2 4p6 4d10 4f14 5s2 5p6 5d10 5f14 6s2 6p6 6d10	7s2 7p6	[Uuo]

The term "core electrons" or "noble gas core" refers to the electrons within the atom which have the same electron configuration as the nearest noble gas of lower atomic number and contain filled s&p orbitals

'Nobel Gas' configuration
full s,p orbitals

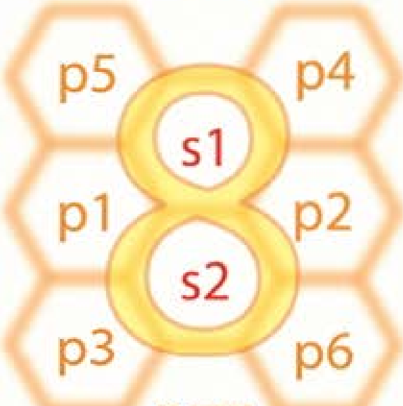
p5
p4
s1
p1
p2
s2
p3
p6

'core electron' configurations are present in energy levels L [2] - [7] Q

electrons not in filled or complete atomic orbitals are valence electrons

"OCTET"
No valance

Using core electron notation greatly reduces complexity of the electron configuration notations of larger elements in the periodic table

[Ub] 1s2 2s2 2p6 3s2 3p6 3d10 4s2 4p6 5s2 4d10 5p6 4f14 5d10 6s2 6p6 5f14 6d10 7s2 7p6 8s2
120

2 8 18 32 32 18 8 2

They are the electrons in the inner part of the atom that are not valence electrons and therefore do not participate in bonding

[Uuo] 8s2
118

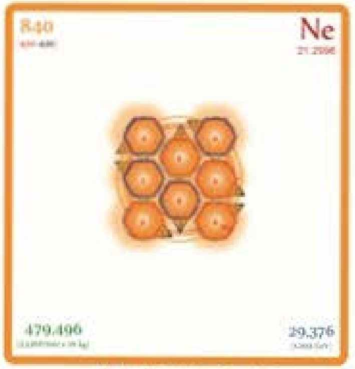
840
Ne
479,496
29,376

[He] 2s2 2p6
2

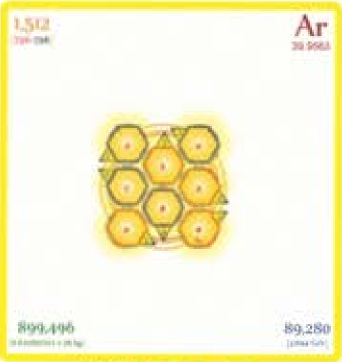
1,512
Ar
899,496
89,280

[Ne] 3s2 3p6
10

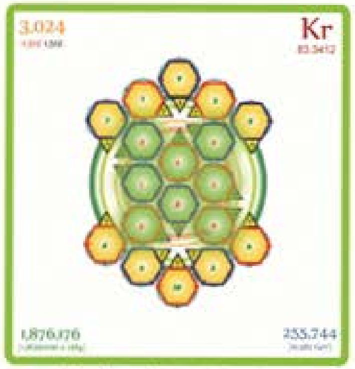
3,024
Kr
1,876,176
255,744

[Ar] 3d10 4s2 4p6
18

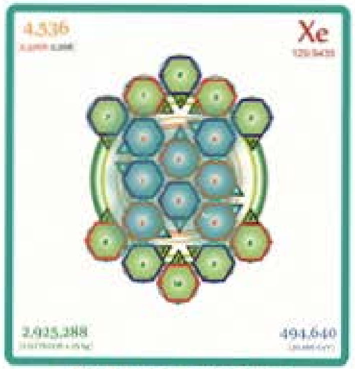
4,536
Xe
2,925,288
494,640

[Kr] 4d10 5s2 5p6
36

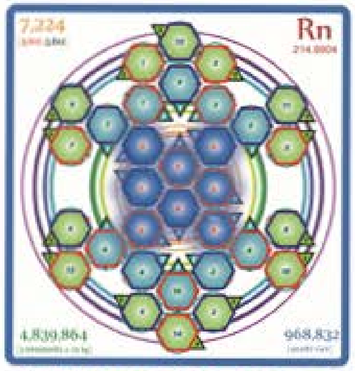
7,224
Rn
4,839,864
968,832

[Xe] 4f14 5d10 6s2 6p6
54

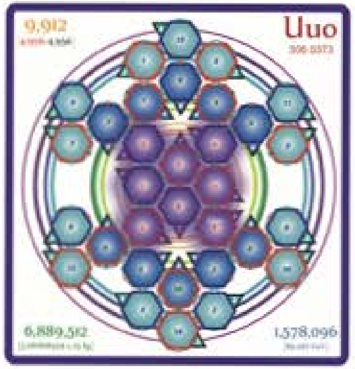
9,912
Uuo
6,889,512
1,578,096

[Rn] 5f14 6d10 7s2 7p6
86

Core electron configurations

Core electrons are the electrons in an atom that are not valence electrons and therefore do not participate in bonding.

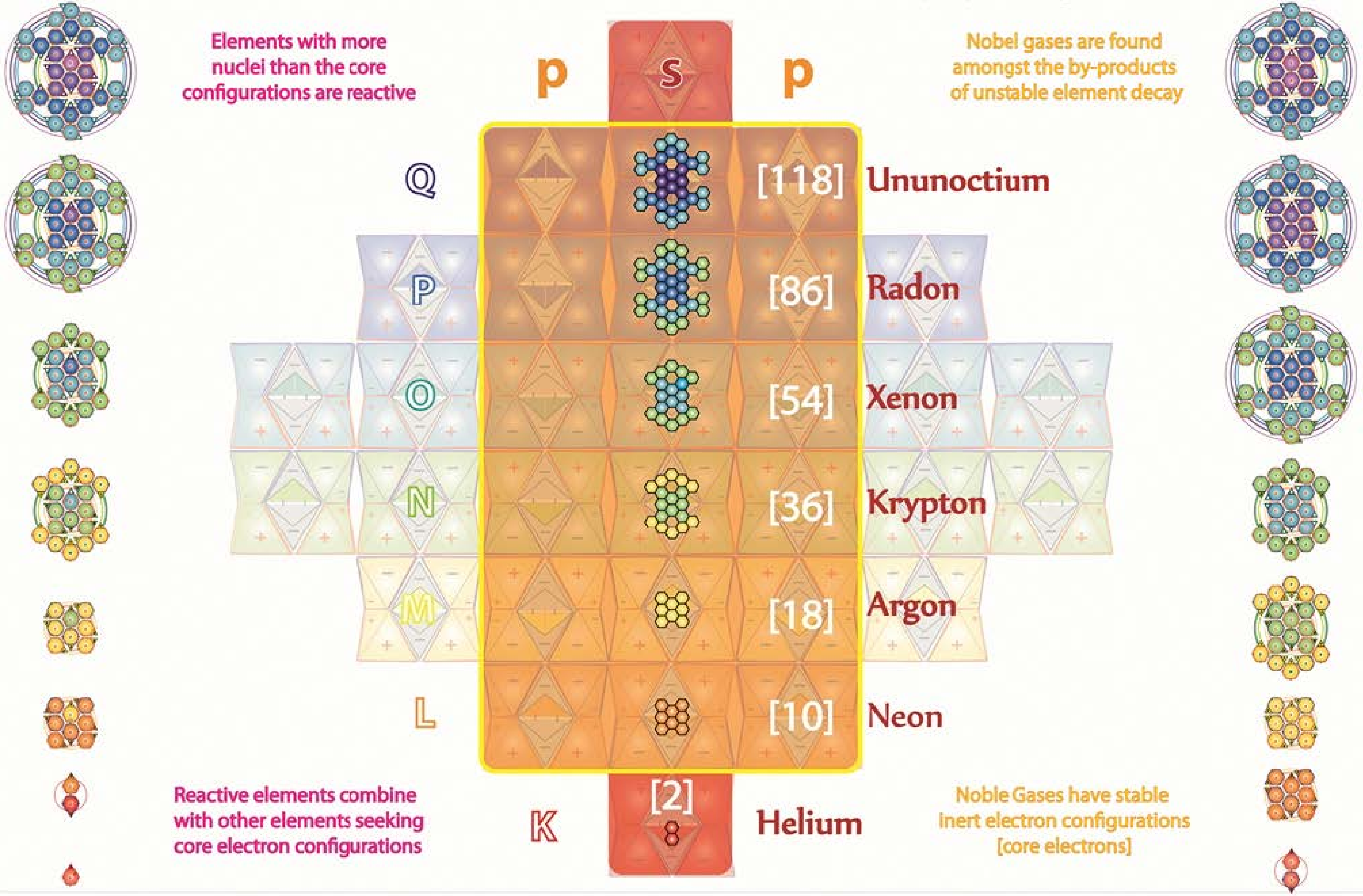

Reactive

Inert

Elements with more nuclei than the core configurations are reactive

Nobel gases are found amongst the by-products of unstable element decay

Reactive elements combine with other elements seeking core electron configurations

Noble Gases have stable inert electron configurations [core electrons]

p
s
p
Q
[118]
Ununoctium
P
[86]
Radon
O
[54]
Xenon
N
[36]
Krypton
M
[18]
Argon
L
[10]
Neon
K
[2]
Helium

Helium is a unique noble gas in that it only has filled s-orbitals

suggesting that it be more appropriate to designate it as an alkaline earth gas

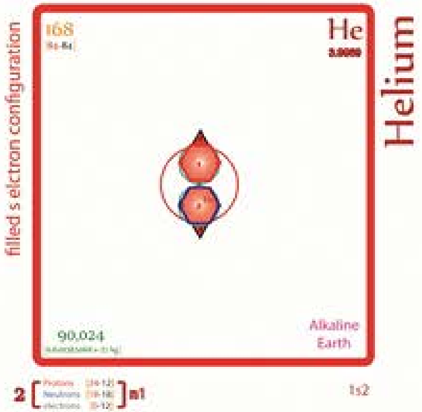
filled s elctron configuration
168
He
Helium
90,024
Alkaline Earth
2
Protons
Neutrons
electrons
1s2

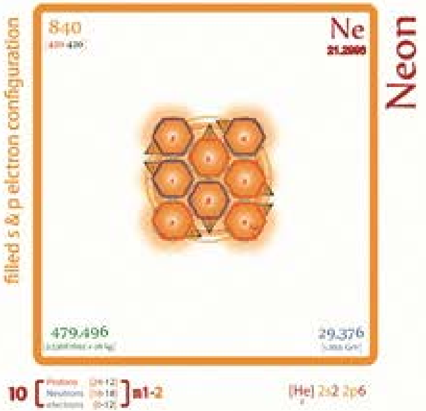
filled s & p elctron configuration
840
Ne
Neon
479,496
29,376
10
Protons
Neutrons
electrons
m1-2
[He] 2s2 2p6

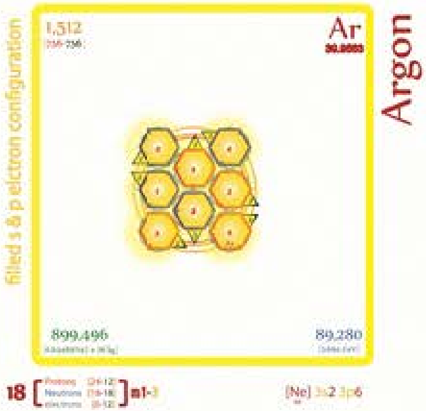
filled s & p elctron configuration
1,512
Ar
Argon
899,496
89,280
18
Protons
Neutrons
electrons
m1-3
[Ne] 3s2 3p6

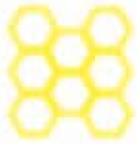

Nobel gases all have inert core sp electron configurations

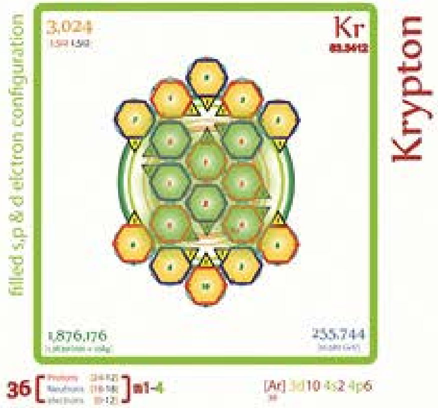
filled s,p & d elctron configuration
3,024
Kr
Krypton
1,876,176
255,744
36
Protons
Neutrons
electrons
m1-4
[Ar] 3d10 4s2 4p6

The Nobel Gases

are nuclei whose electron orbitals are completely filled
(and consequently have no valence electrons for bonding)

2			[He]
10	1s2	2s2 2p6	[Ne]
18	1s2 2s2 2p6	3s2 3p6	[Ar]
36	1s2 2s2 2p6 3s2 3p6 3d10	4s2 4p6	[Kr]
54	1s2 2s2 2p6 3s2 3p6 3d10 4s2 4p6 4d10	5s2 5p6	[Xe]
86	1s2 2s2 2p6 3s2 3p6 3d10 4s2 4p6 4d10 4f14 5s2 5p6 5d10	6s2 6p6	[Rn]
118	1s2 2s2 2p6 3s2 3p6 3d10 4s2 4p6 4d10 4f14 5s2 5p6 5d10 5f14 6s2 6p6 6d10	7s2 7p6	[Uuo]

All nobel gases have filled electron orbitals creating inert, chemically un-reactive elements

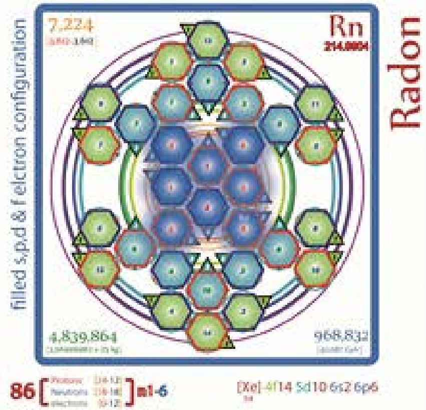
filled s,p,d & f elctron configuration
7,224
Rn
Radon
4,839,864
968,832
86
Protons
Neutrons
electrons
m1-6
[Xe] 4f14 5d10 6s2 6p6

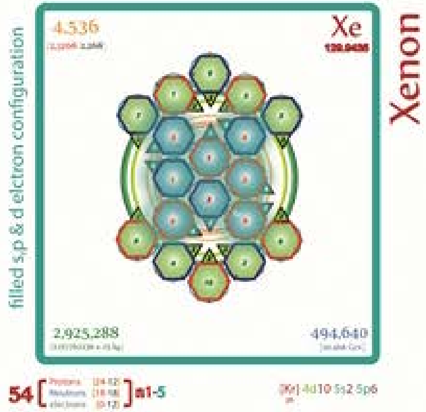
filled s,p & d elctron configuration
4,536
Xe
Xenon
2,925,288
494,640
54
Protons
Neutrons
electrons
m1-5
[Kr] 4d10 5s2 5p6

The noble gases are a group of chemical elements with very similar properties: under standard conditions, they are all odorless, colorless, monatomic gases, with a very low chemical reactivity.

Whilst some of the nobel gases are often termed core electron configurations the large elements also have filled d & f orbitals in them

The six noble gases that occur naturally are Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe), and the radioactive noble gases are Radon (Rn) and Ununioctium (Uuo).

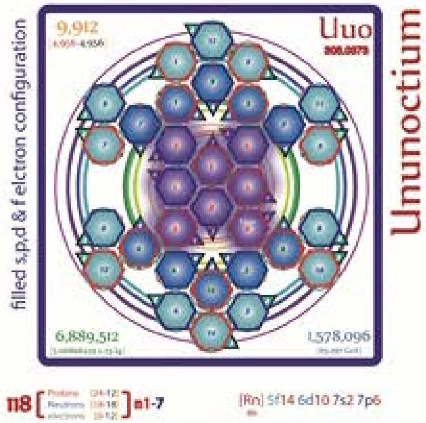
filled s,p,d & f elctron configuration
9,912
Uuo
Ununoctium
6,889,512
1,578,096
118
Protons
Neutrons
electrons
m1-7
[Rn] 5f14 6d10 7s2 7p6

Molecular Bonds

Hydrogen bonds

A weak, primarily electrostatic, bond between a hydrogen atom bound to a highly electronegative element in a given molecule and a second highly electronegative atom in another molecule

Diatomic bonds are fascia interactions between molecules with the same nuclei number [O2, F2, I2, Cl2]

Sigma bonds

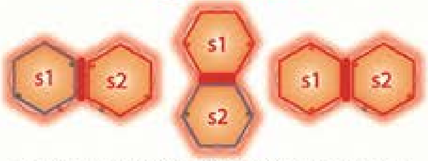
s1
s2
s1
s2
s1
s2

The residual EM force between opposite charge fascia in nuclei holds individual nuclei together in turn resulting in larger molecules and compounds

Pi bonds

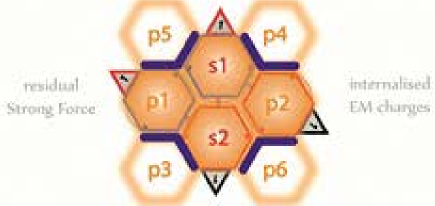
p5
p4
s1
residual Strong Force
p1
p2
internalised EM charges
s2
p3
p6

Molecular bonds

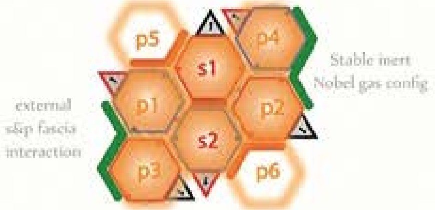
p5
p4
s1
Stable inert Nobel gas config
external s&p fascia interaction
p1
p2
s2
p3
p6

A molecular bond is an attractive force between nuclei that allows two or more elements or atoms to combine into a singular, complex compound structure

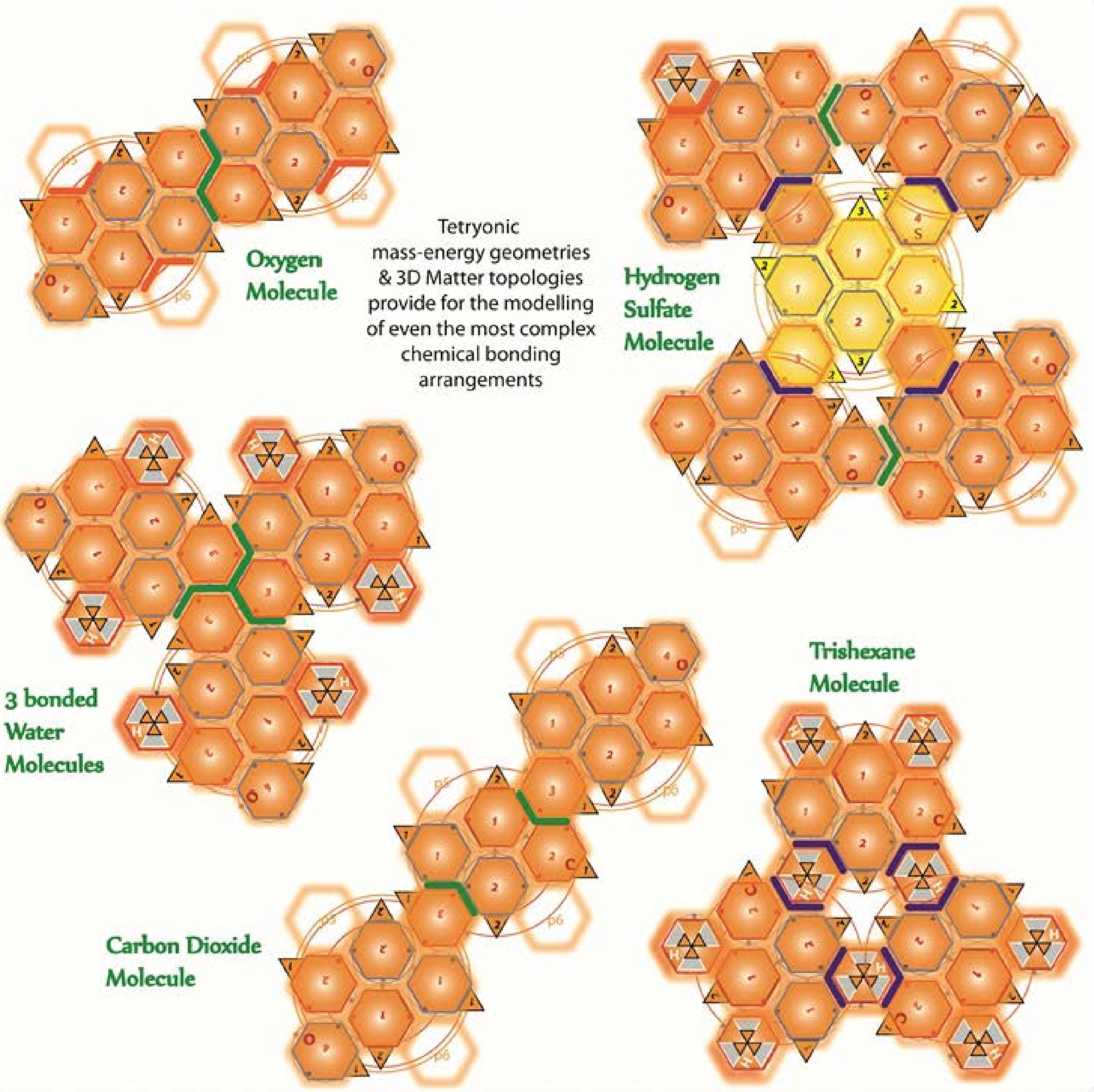

Oxygen Molecule

Tetryonic mass-energy geometries & 3D Matter topologies provide for the modelling of even the most complex chemical bonding arrangements

Hydrogen Sulfate Molecule

3 bonded Water Molecules

Carbon Dioxide Molecule

Trishexane Molecule

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Covalent bonds are chemical links between two atoms in which electrons are shared between them.

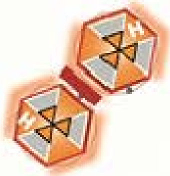

Sigma bonds are covalent bonds formed by direct overlapping of two adjacent atom's outermost orbitals.

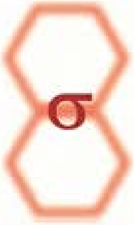

Note: sigma bonds can be formed by the bonding of either s-orbitals [or two adjacent p-orbitals]

Lewis electron dot diagrams fail to illustrate reality in that molecules exist as 3D objects and not as a two dimensional systems as shown by them.

Tetryonic geometry & topologies provide a polar view of 3D atomic nuclei that can be viewed as an exact representation of what a molecule & its bonds would look like when viewed from above.

Sigma & Pi covalent bonds

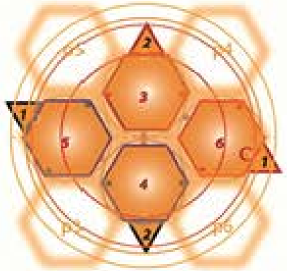

A pi bond is a covalent bond formed between two neighboring atom's unbonded p-orbitals.

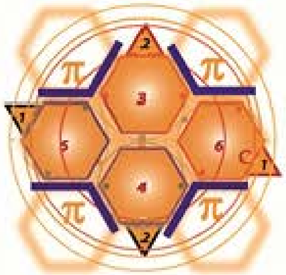

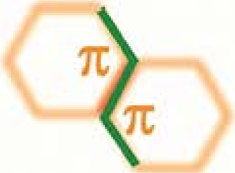

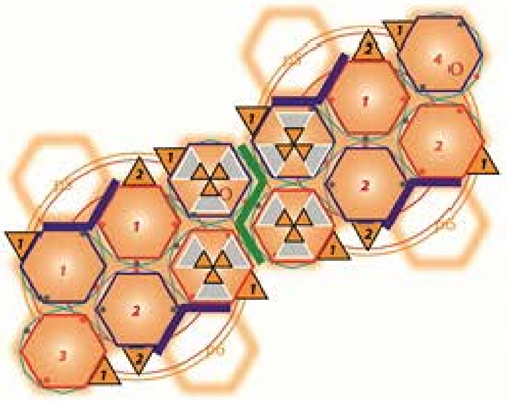

Double and triple bonds between atoms are usually made up of a single sigma bond and one or two pi bonds

π—σ—π

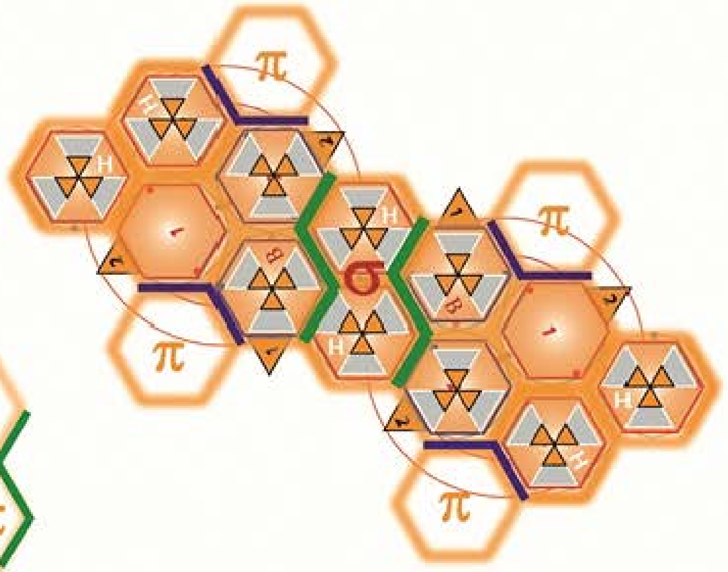

The single electrons from each atom's p orbital combine to form an electron pair creating the sigma bond.

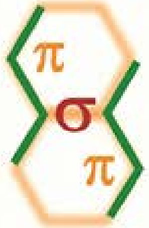

Alkali Metals

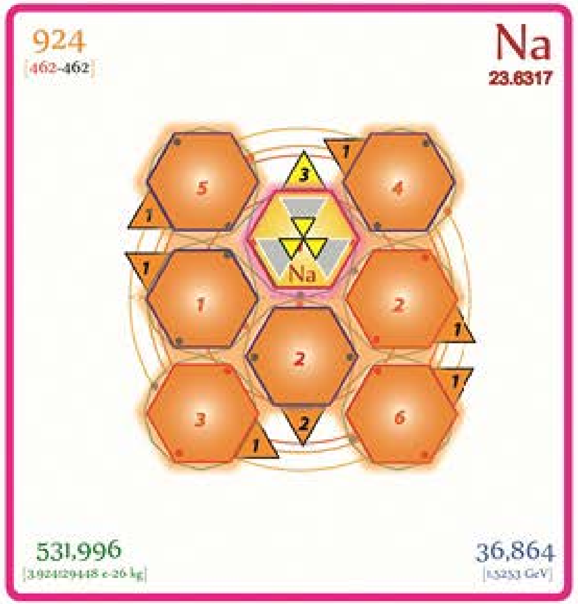
924
[462-462]
Na
23.6317
5
4
3
1
1
1
2
2
1
1
3
2
1
6
531,996
[3.924129448 e-26 kg]
36,864
[1.5253 GeV]

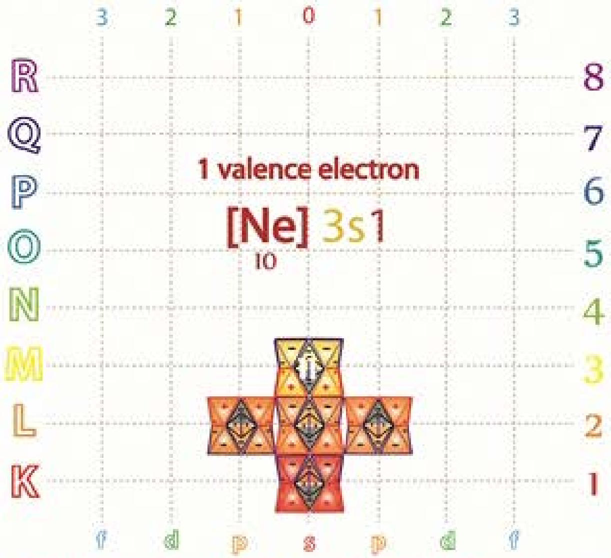
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1 valence electron
[Ne] 3s1
10
f
d
p
s
p
d
f

Atoms with more electrons than a closed shell are also highly reactive,
as the extra valence electrons are easily removed from that orbital
(to form a positive ion)

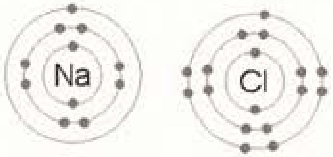

Valence electrons

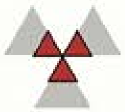

are the highest energy electrons in an atom forming the outermost electrons of an atom, and are important in determining how the atom reacts chemically with other atoms

Historically, the number of valence electrons was reflected by the element's group number in the Mendeleev table and formed the basis of elemental families

Tetryonic topologies now replace the older, incorrect models of valence electron configurations with the full 3D modelling of all atoms, elements & compounds

[zz] are core electron configurations

providing a superior visual means of accurately determining the energies and position of any electron in chemical compounds and determining the valence numbers

Halogens

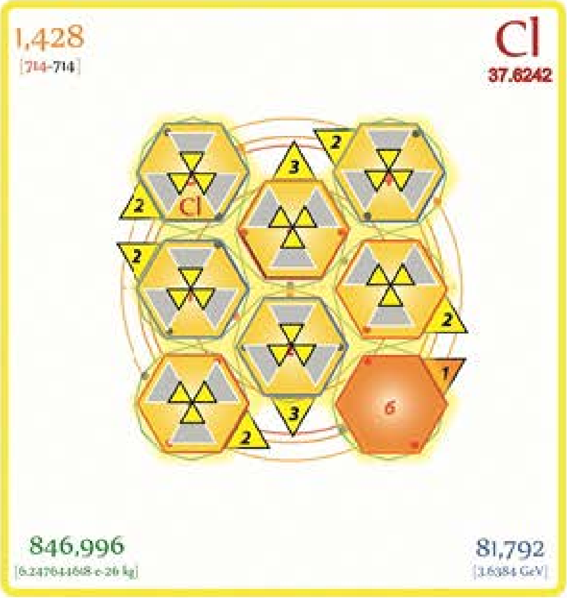
1,428
[714-714]
Cl
37.6242
2
3
2
Cl
2
2
1
6
3
2
846,996
[6.247644668 e-26 kg]
81,792
[3.6384 GeV]

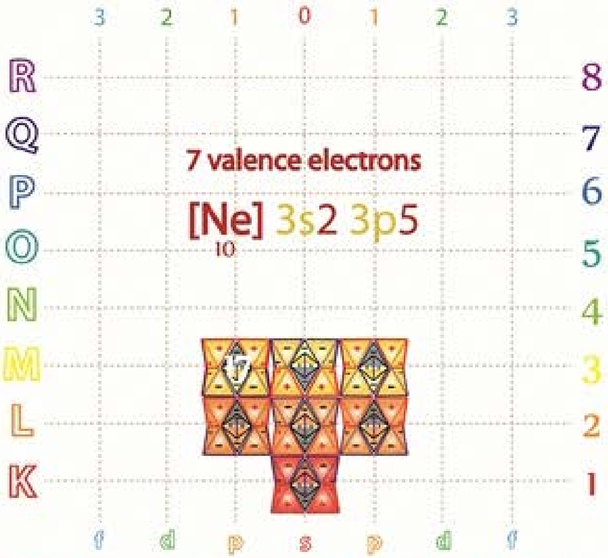
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
7 valence electrons
[Ne] 3s2 3p5
10
f
d
p
s
p
d
f

Atoms one or two valence electrons short of a closed shell are highly reactive,
due to their tendency to seek to gain the missing valence electrons
(thereby forming a negative ion)

Hydro-Chloric acid

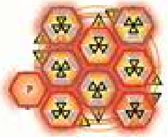

HCl

HNO_3

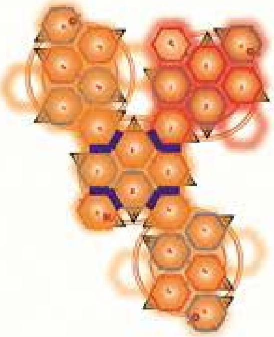

Nitric acid

Carbonic acid

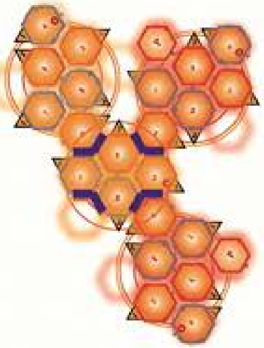

H_2CO_3

H_2SO_4

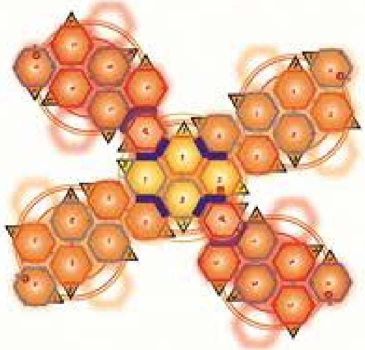

Sulfuric acid

Common Acids

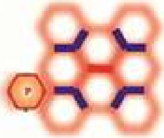

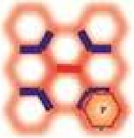

The Arrhenius definition defines acids as substances which increase the concentration of hydrogen ions (H^+), or more accurately, hydronium ions (H_3O^+), when dissolved in water.

The Brønsted-Lowry definition is the most widely used definition where acid-base reactions are assumed to involve the transfer of a proton (H^+) from an acid to a base.

A Lewis acid is a substance that can accept a pair of electrons to form a covalent bond.

$HC_2H_3O_2$

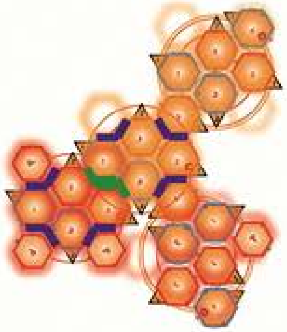

Acetic acid

Phosphoric acid

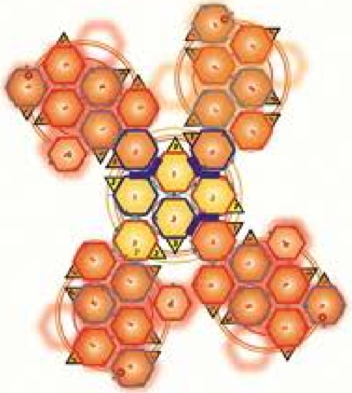

H_3PO_4

$H_2C_2O_4$

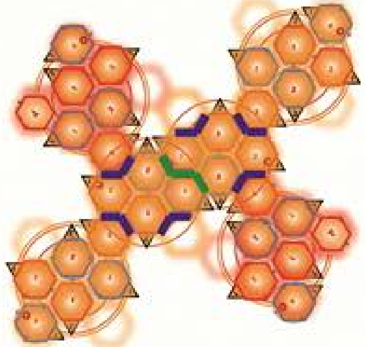

Oxalic acid

Citric acid

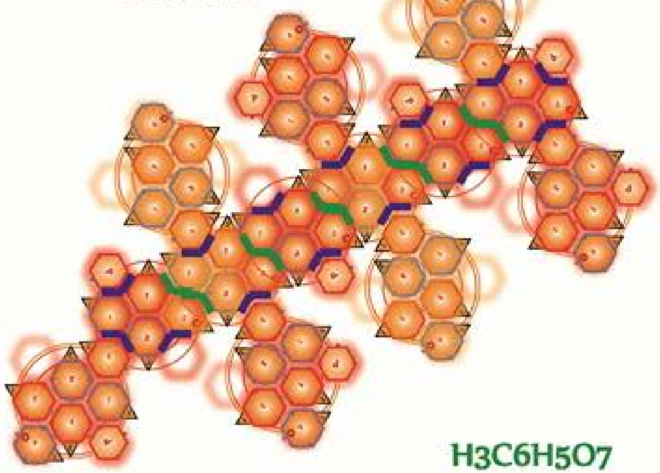

$H_3C_6H_5O_7$

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Chemical reactions

Valence Bonds & Molecular orbitals

A chemical reaction is a process that leads to the transformation of one set of chemical substances to another.

Valence bond theory focuses on how the atomic orbitals of the dissociated atoms combine in molecular formations to give rise to individual chemical bonds.

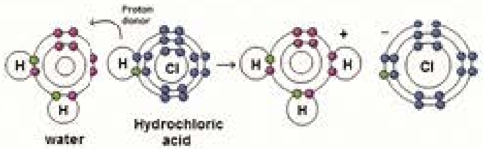

water

Hydrochloric acid

In contrast, molecular orbital theory has orbitals that are designed to cover the whole molecule but is mathematically more complex in application

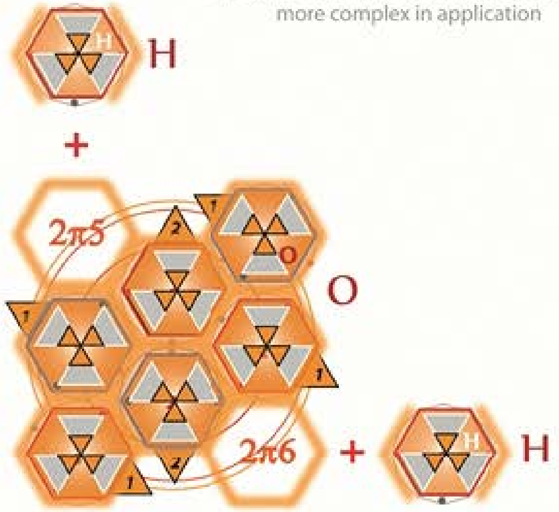

Hydrogen Chloride gas

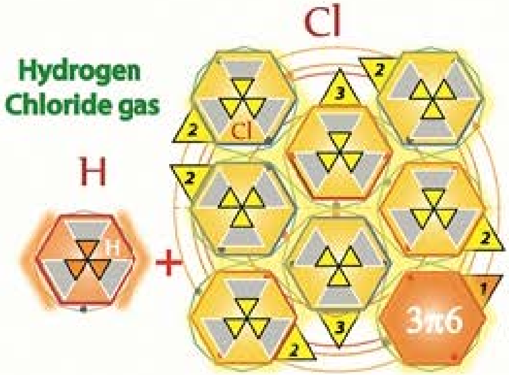

7 valence electrons
1 [n3] valence bond available
(8 electron stable configuration)

In order to form Hydro-chloric acid [HCl aq] and bond with similar water [H2O] molecules, the n2 Hydrogen atom's energy must be raised so it can migrate to the [3π6] orbital and bond

[n2] Hydrogen atom cannot bond in the [3π6] valence position so in HCl gas it forms a [n2] di-atomic bond instead and its electron migrates to the [π6] orbital

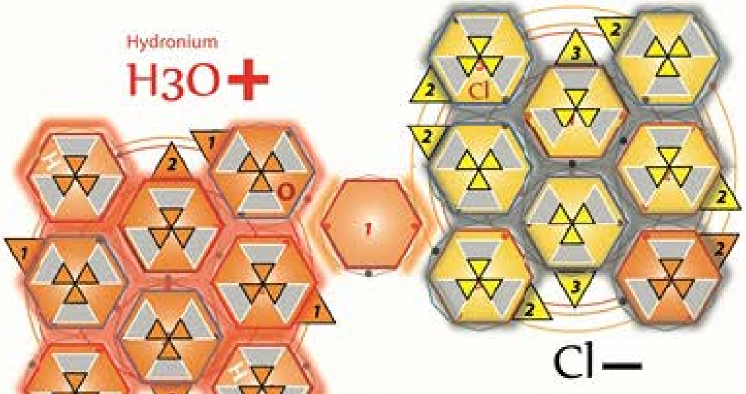

Aqueous Hydro-Chloric acid solution

Tetryonic theory replaces both VB & MO theories by modelling the physical quantum charge topologies and rest mass-energy geometry of all elements and compounds

6 valence electrons
2 [n2] valence bonds available
(8 electron stable configuration)

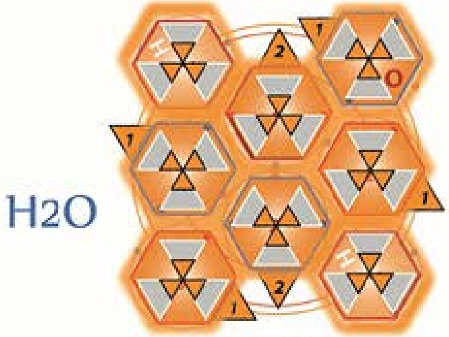

water

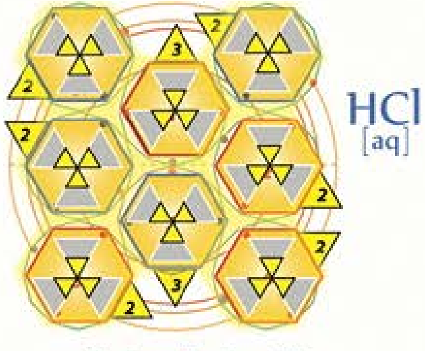

Hydrochloric acid

Valence configurations seek to create stable filled obital configurations

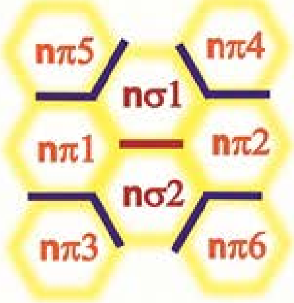

Building on exisiting electron configuration nomenclature tetryonic theory provides a new bonding schema for elements and complex compounds alike that is fully reflective of the physical quantum charge interactions

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Ionic Bonding

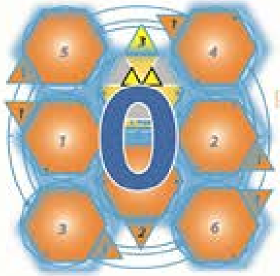
0
5
4
1
2
3
6
960
[480-480]

Alkaline Metal

Sodium atom gives up an electron in order to create a stable [Ne] nobel gas configuration

Sodium atom develops into a nett POSITIVE charge ion

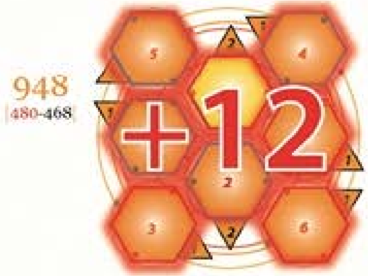
948
[480-468]
+12
5
4
1
2
3
6

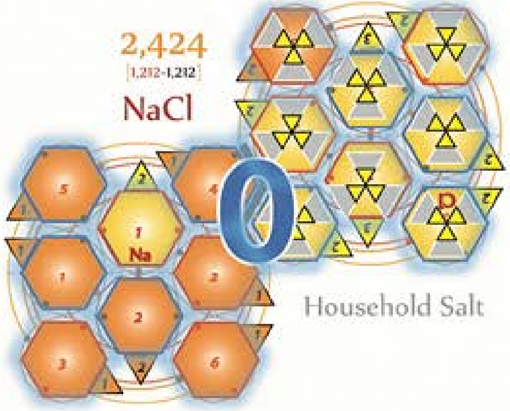
2,424
[1,212-1,212]
NaCl
0
Na
Household Salt

Resultant salt [NaCl] molecule has a NEUTRAL charge with the n3 electron migrating to fill the 3p6 orbital

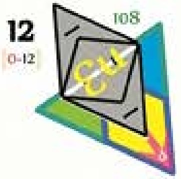
12
[0-12]
108
Cu

Chlorine atom seeks an electron to order to create a stable [Ar] nobel gas configuration

Halogen

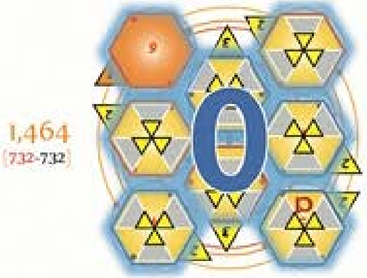
1,464
[732-732]
0

OPPOSITES ATTRACT

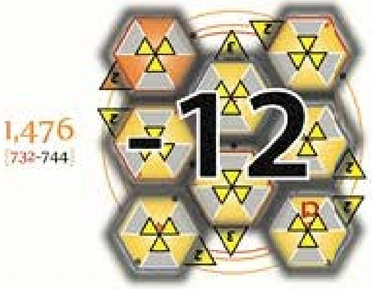
1,476
[732-744]
-12

Chlorine atom develops into a nett NEGATIVE charge ion

All atoms and molecules seek equilibrium via stable electron configurations

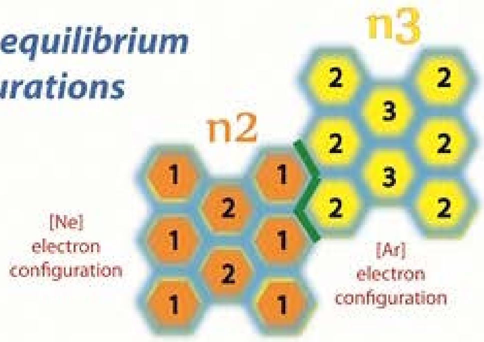
n3
n2
1
2
3
[Ne] electron configuration
[Ar] electron configuration

In short, it is a bond formed by the attraction between two oppositely charged ions.

An ionic bond (or electrovalent bond) is a type of chemical bond that can often form between metal and non-metal ions (or polyatomic ions such as ammonium) through electrostatic attraction.

The metal donates one or more electrons, forming a positively charged ion or cation with a stable electron configuration.
These electrons then enter the non metal, causing it to form a negatively charged ion or anion which also has a stable electron configuration.
The electrostatic attraction between the oppositely charged ions causes them to come together and form a bond.

Valence electron rules

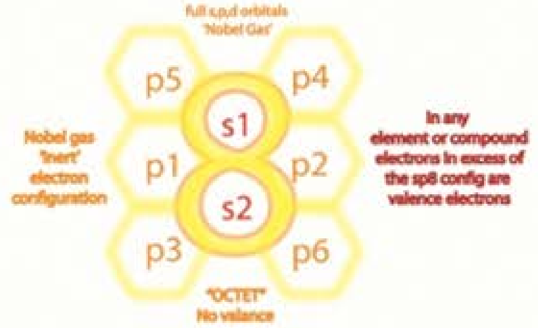
Full s,p,d orbitals
'Nobel Gas'
p5
p4
s1
p1
p2
s2
p3
p6
Nobel gas
'inert'
electron
configuration
In any
element or compound
electrons in excess of
the sp8 config are
valence electrons
"OCTET"
No valance

sp8 - core electron orbital grouping

Tetryonic quantum charge topologies
provide the complete picture

Valence electrons are the highest quantum level electrons in
elemental or compound atom nuclei in excess of the core
sp8 'noble gas' electron configuration

They are located in the outer most shells (ie K-Q or Quantum 1-7)
making them easily ionised from the elemental nuclei

s 1-2 (electron orbital pair)
p 1-2, 3-4, 5-6 (electron orbital pairs)
d 1-2, 3-4, 5-6, 7-8, 9-10 (electron orbital pairs)
f 1-2, 3-4, 5-6, 7-8, 9-10, 11-12, 13-14 (electron orbital pairs)

Valance electron congigurations always include 's' orbital electrons
due to their higher quantum levels

Developed from Lewis diagrams
is usually only useful for elements Z<20

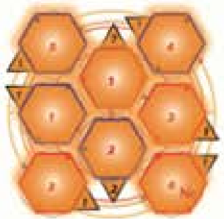

Neon
[He] 2s2, 2p6

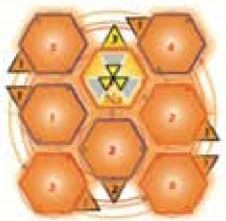

Sodium
[Ne] 3s1
Valence - 1

Fluorine
[He] 2s2, 2p5
Valence - 7

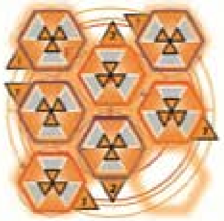

Scandium
[Ar] 3d1, 4s2
Valence - 3

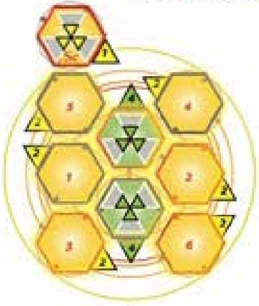

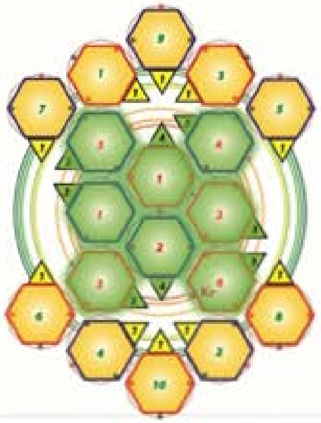

Krypton
[Ar] 4s2, 4p6

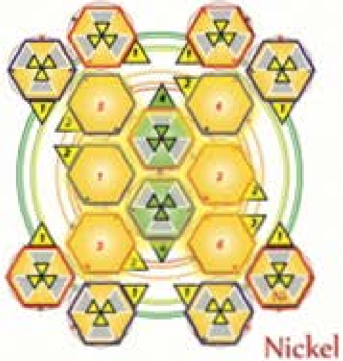

Nickel
[Ar] 3d8, 4s2
Valence - 10

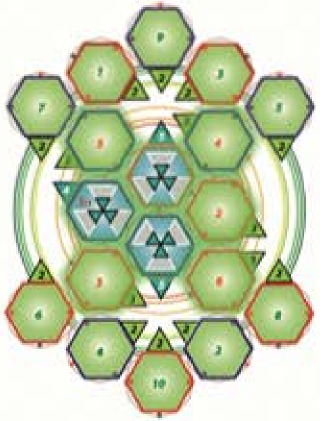

Indium
[Kr] 4d10, 5s2, 5p1
Valence - 3

Gold
[Xe] 4f14, 5d9, 6s2
Valence - 11

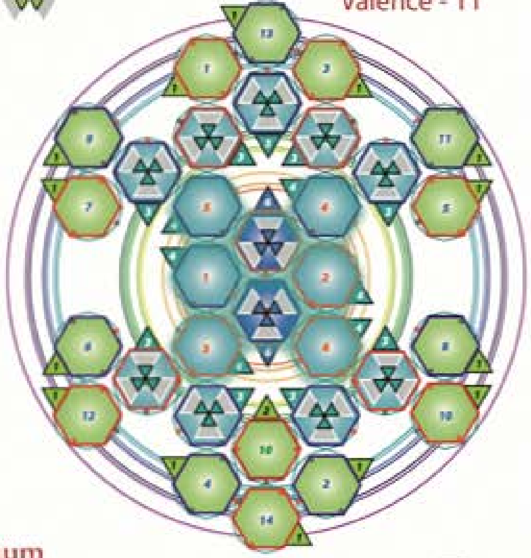

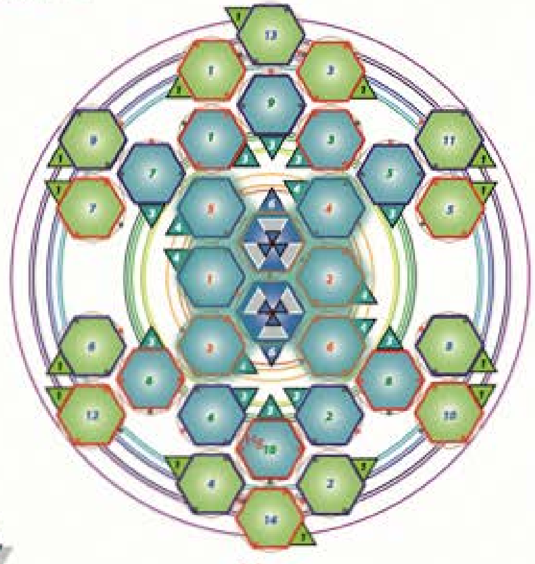

Mercury
[Xe] 4f14, 5d10, 6s2

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Filled electron orbitals

Once 8 valence electrons are reached a stable valence cofiguration is created

Once sub-orbit 8 (P7-8) is reached sequential valence numbering switches to paired valence numbering (as per orbital energies)

Valence numbers can be calculated by adding the 2 highest energy orbitals together (and subtracting 8 - if the total is higher than 8)

The octet rule is a simple chemical rule of thumb that states that atoms tend to combine in such a way that they each have eight electrons in their valence shells, giving them the same electronic configuration as a noble gas.

The rule is applicable to the main-group elements, especially carbon, nitrogen, oxygen, and the halogens, but also to metals such as sodium or magnesium. In simple terms, molecules or ions tend to be most stable when the outermost electron shells of their constituent atoms contain eight electrons.

In short, an element's valence shell is full and most stable when it contains eight electrons, corresponding to an s2p6 election configuration.

CORE ELECTRONS

This stability is the reason that the noble gases are so unreactive, for example neon with electron configuration 1s2 2s2 2p6. (Helium is an exception as explained).

Note that a "full shell" means that there are the eight electrons in the valence shell when the next shell starts filling, even though higher subshells (d, f, etc.) have not been filled.

There can be at most eight valence electrons in a ground-state atom because p subshells are always followed by the s subshell of the next shell.

OCTET RULE

This means that once there are 8 valence electrons (when the p subshell is filled), the next additional electron goes into the next shell, which then becomes the valence shell.

A consequence of the octet rule is that atoms generally react by gaining, losing, or sharing electrons in order to achieve a complete octet of valence electrons. Reaction of atoms occurs primarily in two ways: ionically and covalently.

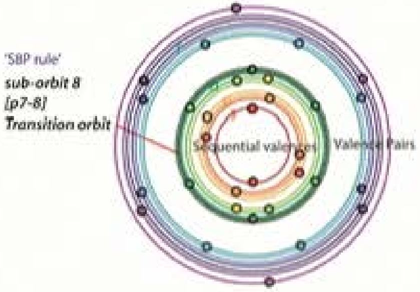
'SBP rule'
sub-orbit 8
[p7-8]
Transition orbit
Sequential valences
Valence Pairs

Once 8 valence electrons are reached the sub-orbits are stable and form a stable, non-reactive valence configuration.

Additionally, valence numbers proceed sequentially (1,2,3,4,5,6,7) up to sub-orbit 8 (P7-8) at which point all sub-orbit valences number in valence pairs (1-2, 3-4, 5-6, 7-8, 9-10, 11-2, 13-14)

The siginificance is that sub-orbit 8 is the middle sub-orbit (of 16 total sub-orbits possible)

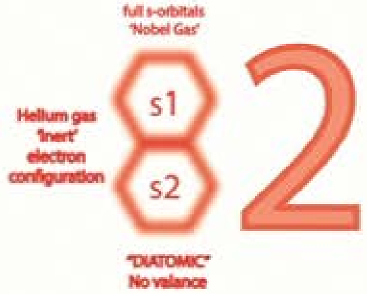
full s-orbitals
'Nobel Gas'
Helium gas
'Inert'
electron
configuration
s1
s2
2
"DIATOMIC"
No valance

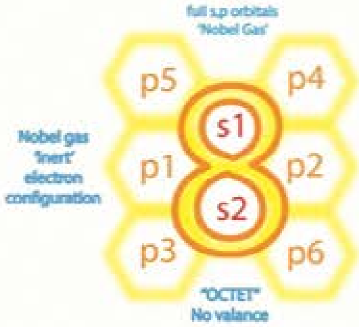
full s,p orbitals
'Nobel Gas'
Nobel gas
'Inert'
electron
configuration
p5
p4
s1
p1
8
p2
s2
p3
p6
"OCTET"
No valance

free
radical
atom
reactive
Hydrogen
bond
Hydrogen bond

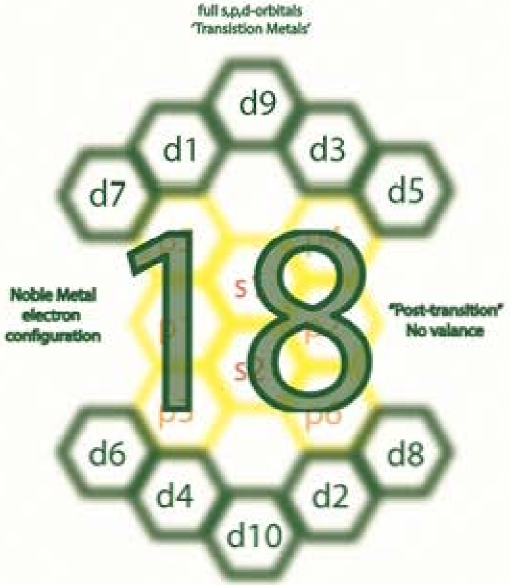
full s,p,d-orbitals
'Transistion Metals'
d9
d1
d3
d7
d5
Noble Metal
electron
configuration
18
s1
s2
"Post-transition"
No valance
d6
d8
d4
d2
d10

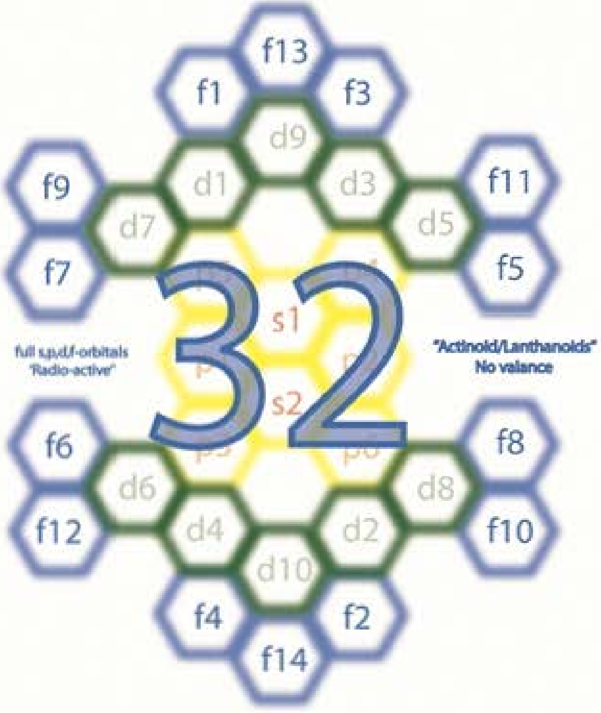
f13
f1
f3
d9
f9
d1
d3
f11
d7
d5
f7
f5
32
s1
s2
full s,p,d,f-orbitals
'Radio-active'
"Actinoid/Lanthanoids"
No valance
f6
f8
d6
d8
f12
d4
d2
f10
d10
f4
f2
f14

ACID

Hydrochloric acid is a clear, colourless solution of hydrogen chloride in water, it is a highly corrosive, strong mineral acid

Aqueous Hydro-Chloric acid solution

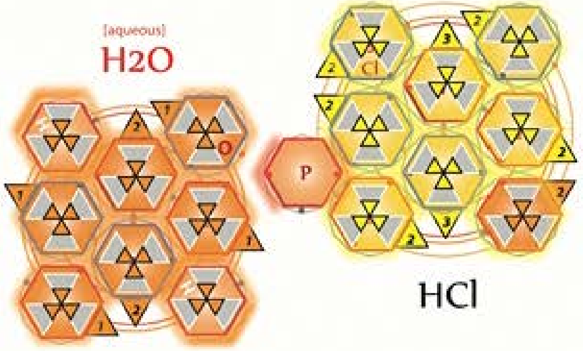
[aqueous]
H2O
P
Cl
HCl

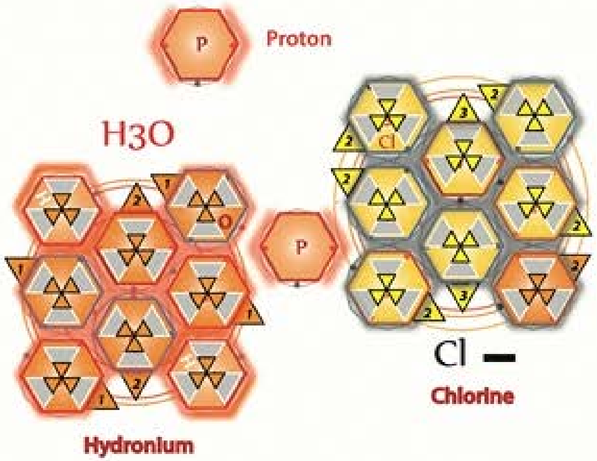
P
Proton
H3O
P
Cl −
Chlorine
Hydronium

The H(+) cation of the acid combines with the OH(-) anion of the base to form water.

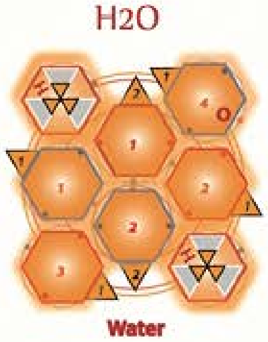

combining the free Protons & electrons

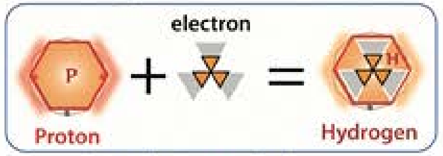
electron
P
+
=
Proton
Hydrogen

neutralises the ions and releases energy

+

all charges seek equilibrium

When an acid and a base are placed together, they react to neutralize the acid and base properties, producing a salt.

$HCl(aq) + NaOH(aq) \dashrightarrow NaCl(aq) + H_2O(l)$

⇒

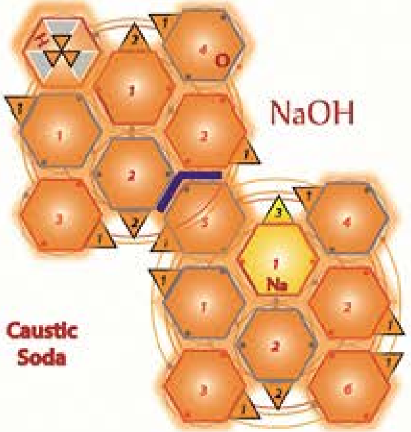
NaOH
Na
Caustic Soda

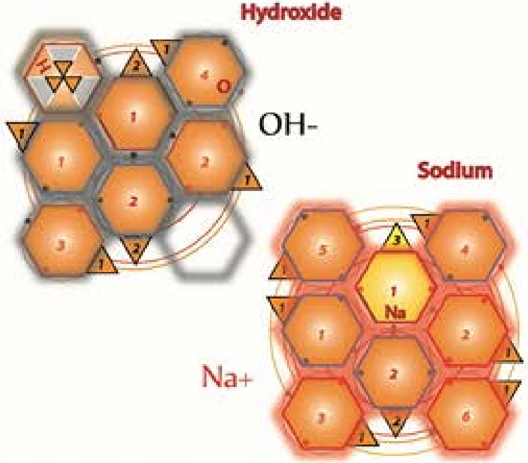
Hydroxide
OH-
Sodium
Na
Na+

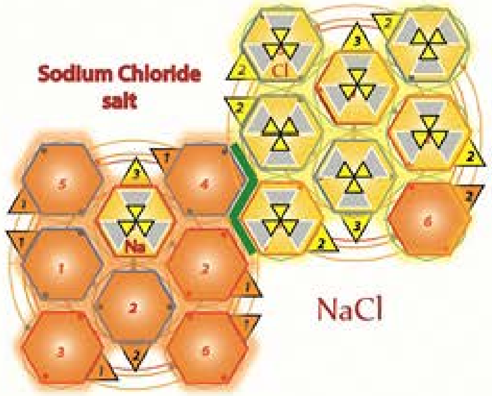
Sodium Chloride salt
Cl
Na
NaCl

The compound formed by the cation of the base and the anion of the acid is called a salt.

BASE

Sodium hydroxide, also known as caustic soda, or lye, has the molecular formula NaOH and is a highly caustic metallic base and alkali salt.

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Geometric Molecular Topology

Molecules are most often held together with covalent bonds involving single, double, and/or triple bonds,
where a "bond" is a pair of electrons shared between elements as they seek equilibrium
(another method of bonding is ionic bonding and involves a positive cation and a negative anion).

Hydrogen

A Hydrogen bond is a chemical bond in which a hydrogen atom of one molecule is attracted to an electronegative atom, especially nitrogen, oxygen, or flourine atoms, usually of another molecule

The hydrogen bond is often described as an electrostatic dipole-dipole interaction.

However, it also has some features of covalent bonding: it is directional and strong, acting over interatomic distances shorter than that of van der Waals radii

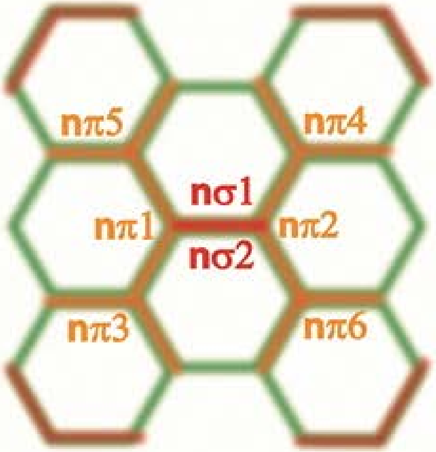

Oxygen

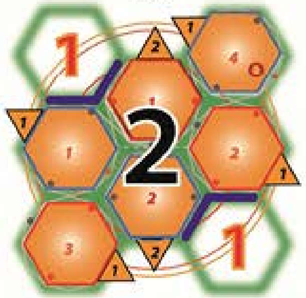

The oxidation state of oxygen is −2 in almost all known compounds

Oxides of Oxygen & oxygen molecules are found throughout the range of Organic & inorganic compounds

All molecules seek KEM'ical charge and energy equilibrium

Geometric Molecular Topology is the overall arrangement of the atoms in a molecule, where the bonded atoms in a molecule are responsible for determining the final molecular topology of a chemical system of bonded elements.

As the numbers of atoms in molecules increases, the quantum molecular topology of a system grows increasingly complex and can only be modelled accurately using Tetryonic charged geometries

by bonding together and forming larger complex molecules

Common nitrogen functional groups include: amines, amides, nitro groups, imines, and enamines.

Compounds of Carbon form the 'backbones' of Organic & inorganic compounds

Molecular Octets

The concept of the Expanded Octet occurs in any system that has an atom with more than four electron pairs attached to it.

Most commonly, atoms will expand their octets to contain a total of five or six electron pairs, in total. In theory, it is possible to expand beyond those number.

The large amounts of negative charge concentrated in small volumes of space prevent those larger expanded octets from forming.

When an atom expands its octet, it does so by making use of empty d-orbitals that are available in the valence level of the atom doing the expanding.

The atom that expands its octet in a structure will usually be located in the center of the structure and the system will not use any multiple bonds in attaching atoms to the central atom.

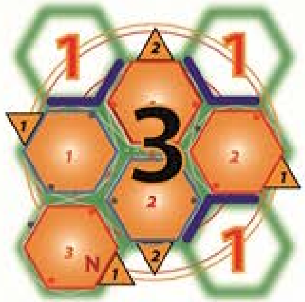

Nitrogen

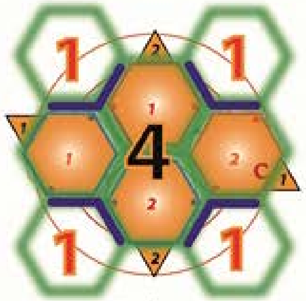

Carbon

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48
[24-24]

Hydrogen bonds

H

96
[48-48]

1 Proton
1 electron

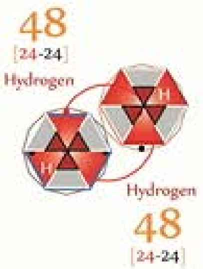
48
[24-24]
Hydrogen
H
H
Hydrogen
48
[24-24]

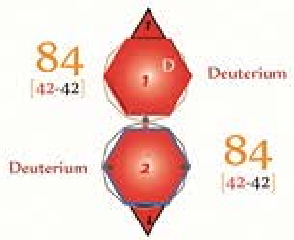
84
[42-42]
D
1
Deuterium
Deuterium
2
84
[42-42]

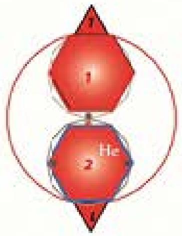

168
[84-84]

2 Protons
2 Neutrons
2 electrons

Hydrogen is a 'free radical' atom

H2 has a smaller s-orbital [lower energy level] compared to Helium

Deuterium is the building block of elements

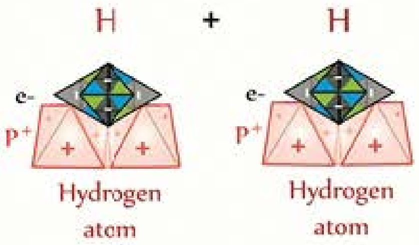
H
+
H
e-
P+
+
+
Hydrogen
atom
e-
P+
+
+
Hydrogen
atom

Hydrogen atoms → form Covalent bonds

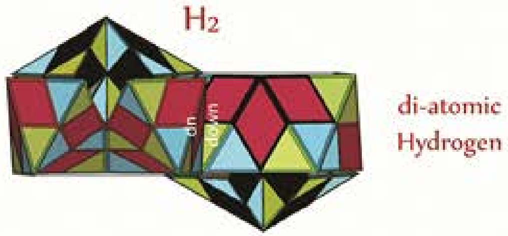
H2
up
down
di-atomic
Hydrogen

Hydrogen, bound mostly to carbon and nitrogen, is part of almost every molecule in your body: DNA, proteins, sugars, fats.
Hydrogen bonds - which form between atoms that "share" a hydrogen atom, is one of the most important interactions that makes biological molecules behave as they do.

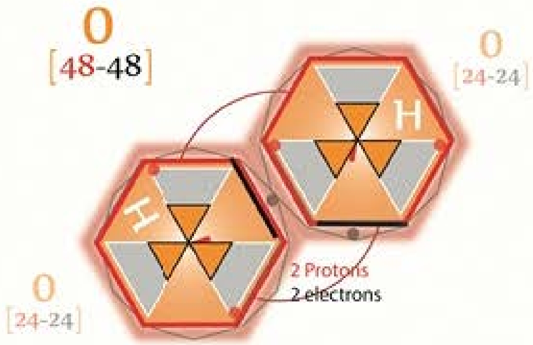
0
[48-48]
0
[24-24]
H
H
0
[24-24]
2 Protons
2 electrons

Hydrogen bonds are sigma bonds

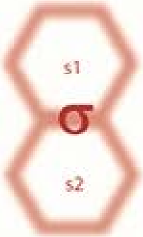

note: n2 energy level Hydrogen is illustrative only
[Hydrogen bonds can be of any energy level]

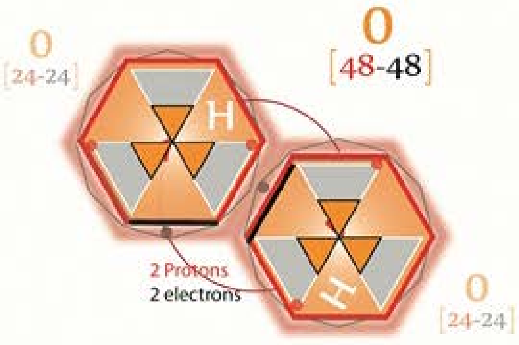
0
[24-24]
0
[48-48]
H
H
2 Protons
2 electrons
0
[24-24]

The charged fascia of Baryonic quarks facilitates chemical [hydrogen] bonding in molecules

Carbon Compounds

504

[252-252]

Carbon can bond in four places, and it can bond to itself so it's easy to make lots of different molecules.

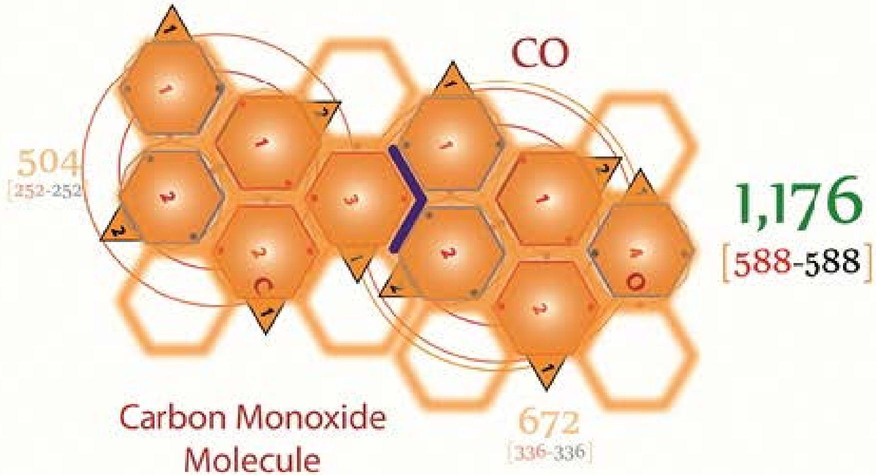
CO
504
[252-252]
1,176
[588-588]
672
[336-336]
C
O

Carbon Monoxide Molecule

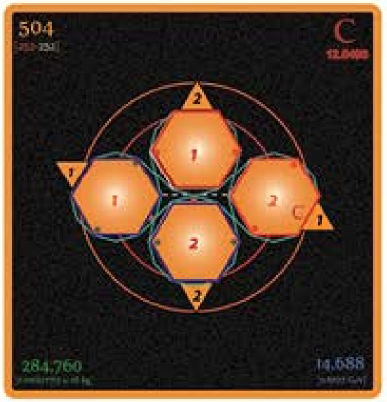
504
C
284,760
14,688

[He]$_2$ 2s2 2p2

Many carbon compounds are essential for life as we know it.
Some of the most common carbon compounds are: carbon dioxide (CO2), carbon monoxide (CO), carbon disulfide (CS2), chloroform (CHCl3), carbon tetrachloride (CCl4), methane (CH4), ethylene (C2H4), acetylene (C2H2), benzene (C6H6), ethyl alcohol (C2H5OH) and acetic acid (CH3COOH) to name just a few.

Acetylene Molecule

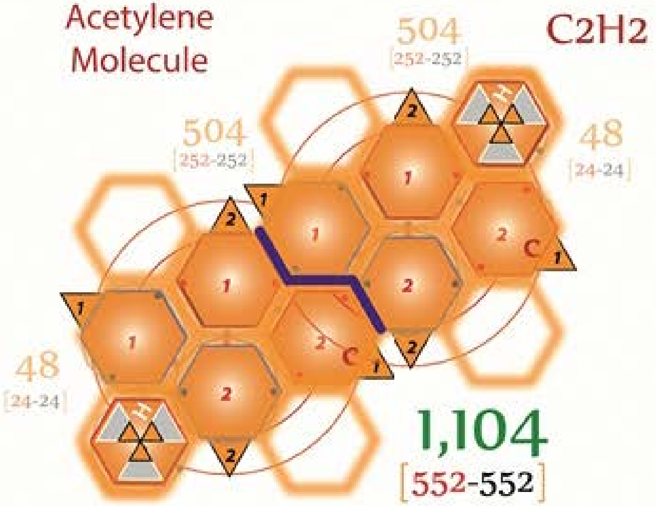
504
[252-252]
C2H2
504
[252-252]
48
[24-24]
48
[24-24]
1,104
[552-552]
C
H

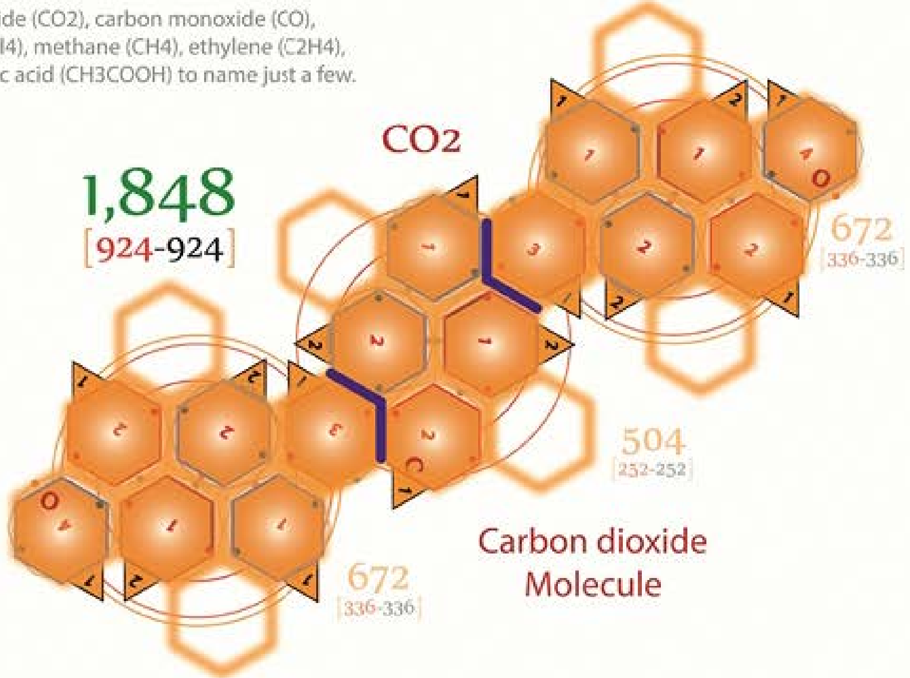
CO2
1,848
[924-924]
672
[336-336]
504
[252-252]
672
[336-336]
C
O

Carbon dioxide Molecule

C

There are nearly ten million known carbon compounds and an entire branch of chemistry, known as organic chemistry, is devoted to their study.

Nitrogen Compounds

588
[294-294]

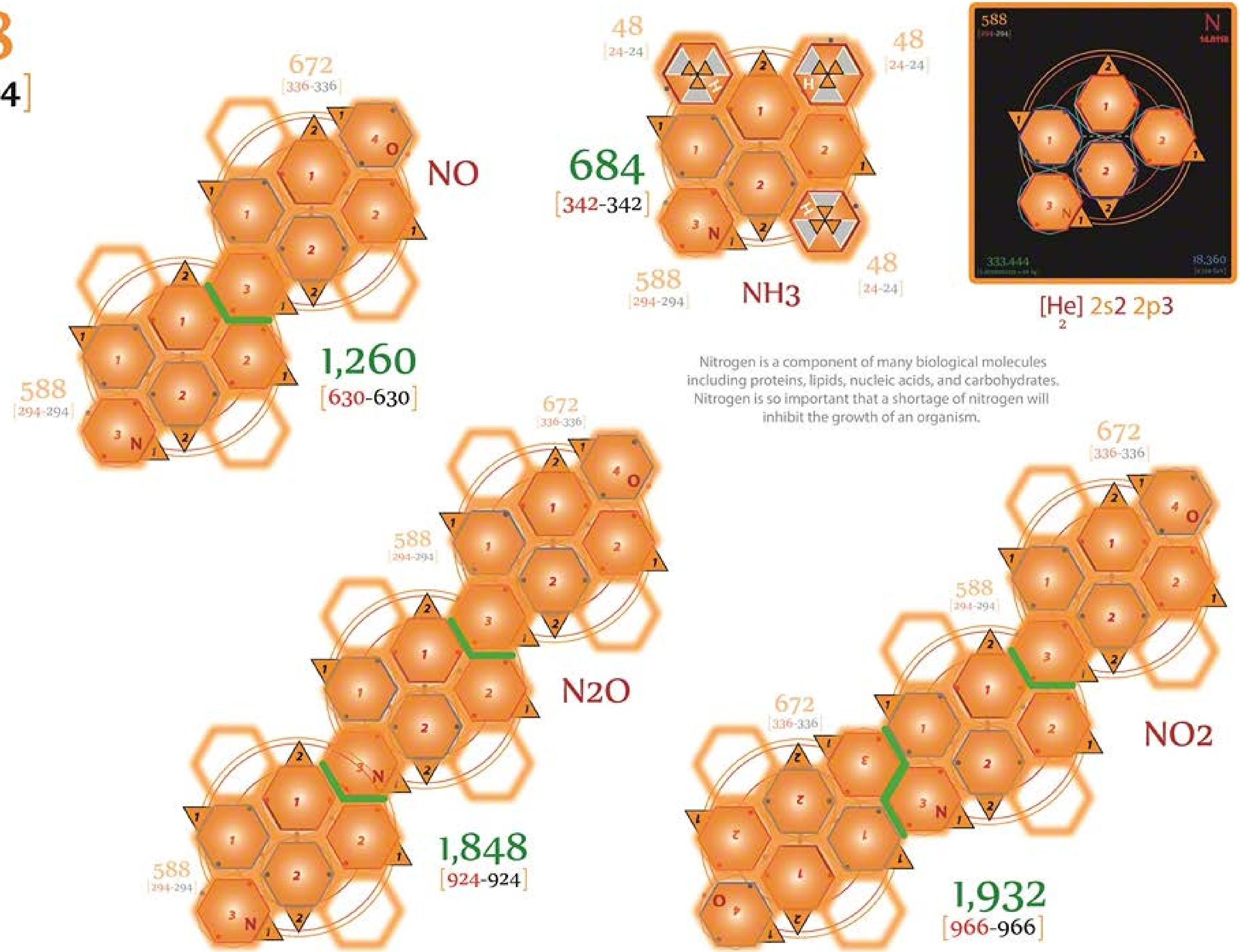
672
[336-336]
NO
588
[294-294]
1,260
[630-630]
48
[24-24]
48
[24-24]
684
[342-342]
588
[294-294]
NH3
48
[24-24]
588
N
333.444
18,360
[He] 2s2 2p3
672
[336-336]
588
[294-294]
N2O
588
[294-294]
1,848
[924-924]
672
[336-336]
588
[294-294]
672
[336-336]
NO2
1,932
[966-966]
H
N
O

Nitrogen is a component of many biological molecules including proteins, lipids, nucleic acids, and carbohydrates. Nitrogen is so important that a shortage of nitrogen will inhibit the growth of an organism.

N

Oxygen Compounds

672

[336-336]

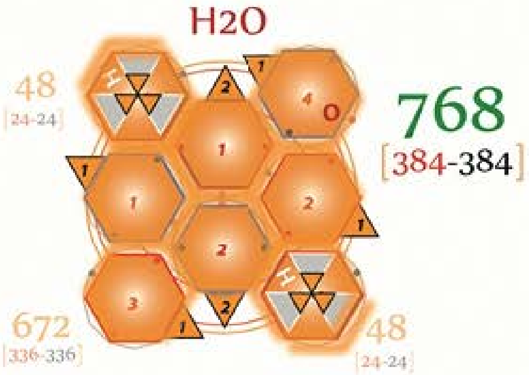
H2O
48
[24-24]
768
[384-384]
672
[336-336]
48
[24-24]

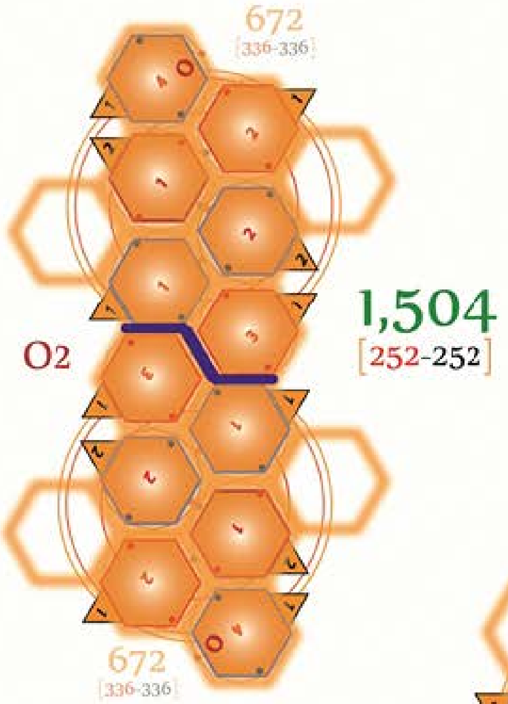
672
[336-336]
O2
1,504
[252-252]
672
[336-336]

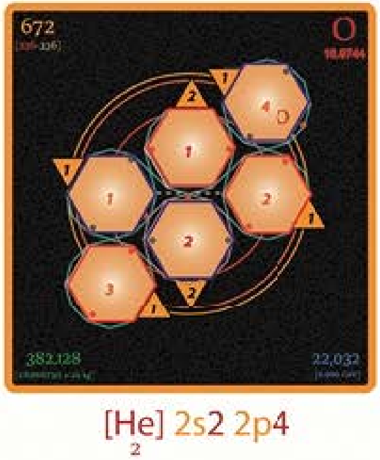
672
O
382,128
22,032
[He] 2s2 2p4
2

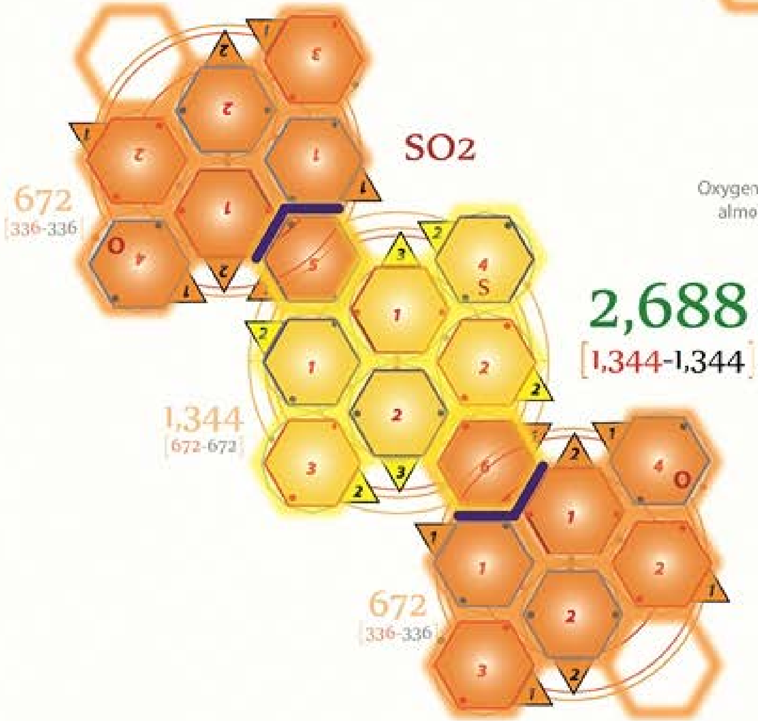
SO2
672
[336-336]
2,688
[1,344-1,344]
1,344
[672-672]
672
[336-336]

Oxygen forms oxide compounds with almost all of the known elements

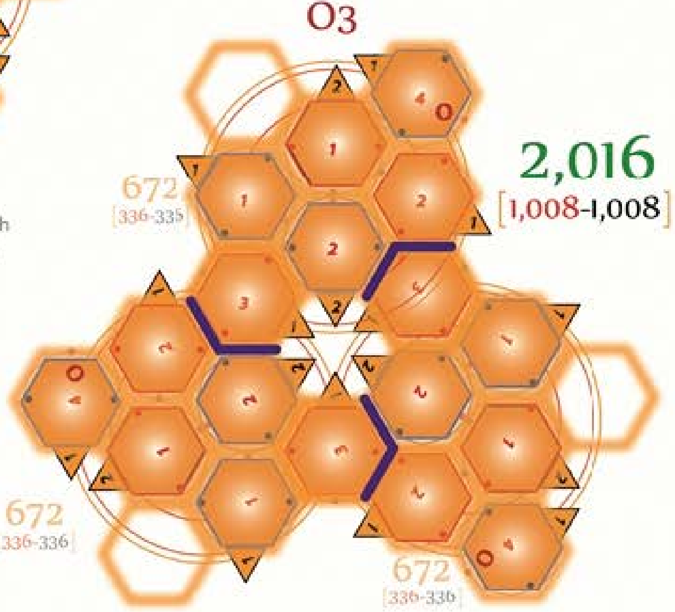
O3
672
[336-335]
2,016
[1,008-1,008]
672
[336-336]
672
[336-336]

As soon as the oxygen enters your blood, a passing protein molecule called hemoglobin picks it up. Each molecule of hemoglobin can transport four molecules of oxygen to almost anywhere in the body.

The hemoglobin transport the oxygen to your cells where another protein, called cytochrome C oxidase makes two molecules of water out of every molecules of oxygen delivered to it

O

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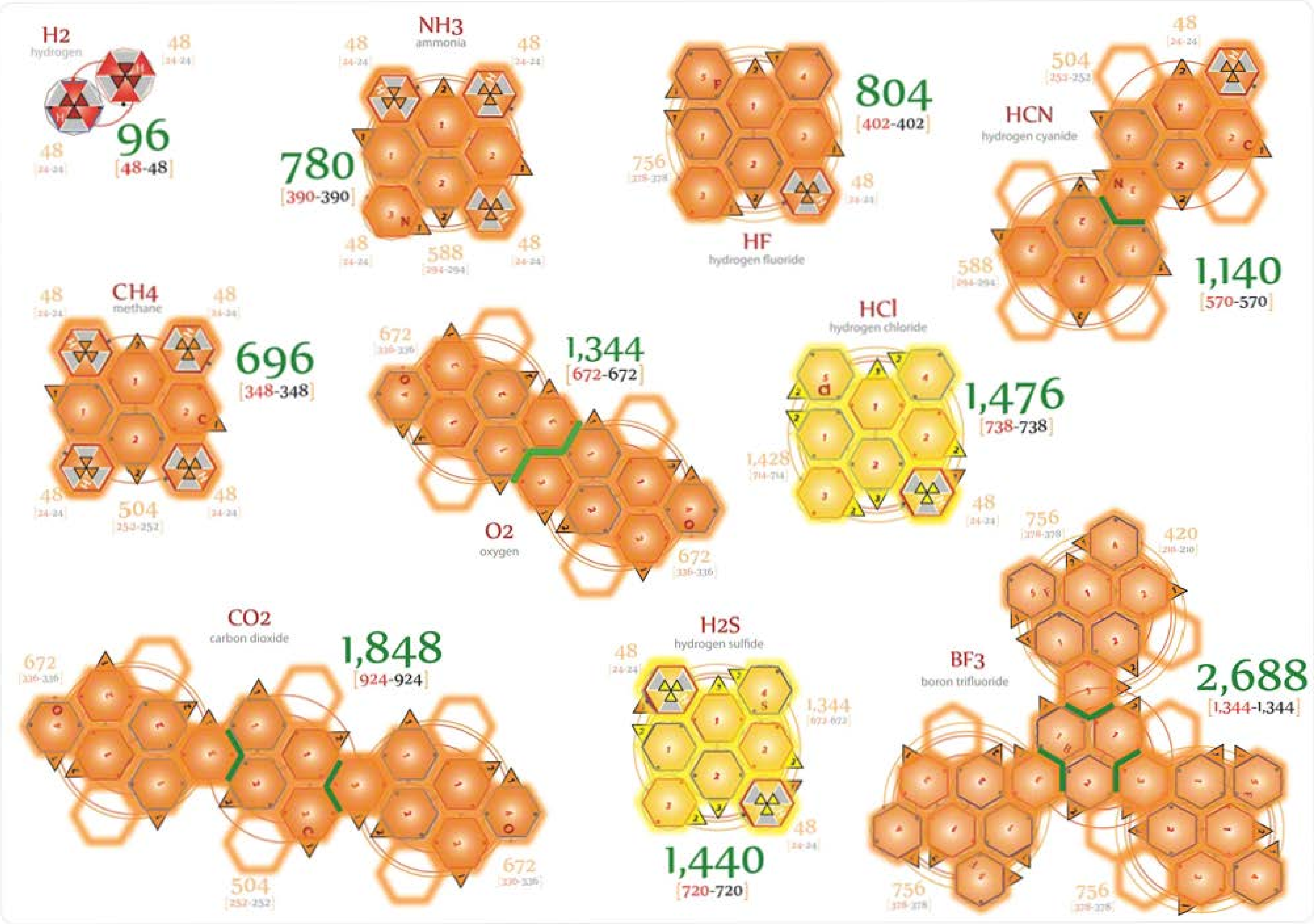
H2
hydrogen
96
[48-48]
48
[24-24]
48
[24-24]
NH3
ammonia
780
[390-390]
48
[24-24]
48
[24-24]
48
[24-24]
48
[24-24]
588
[294-294]
804
[402-402]
756
[378-378]
48
[24-24]
HF
hydrogen fluoride
HCN
hydrogen cyanide
504
[252-252]
48
[24-24]
588
[294-294]
1,140
[570-570]
CH4
methane
696
[348-348]
48
[24-24]
48
[24-24]
48
[24-24]
48
[24-24]
504
[252-252]
1,344
[672-672]
672
[336-336]
672
[336-336]
O2
oxygen
HCl
hydrogen chloride
1,476
[738-738]
1,428
[714-714]
48
[24-24]
CO2
carbon dioxide
1,848
[924-924]
672
[336-336]
504
[252-252]
672
[336-336]
H2S
hydrogen sulfide
48
[24-24]
1,344
[672-672]
48
[24-24]
1,440
[720-720]
BF3
boron trifluoride
2,688
[1,344-1,344]
756
[378-378]
420
[210-210]
756
[378-378]
756
[378-378]

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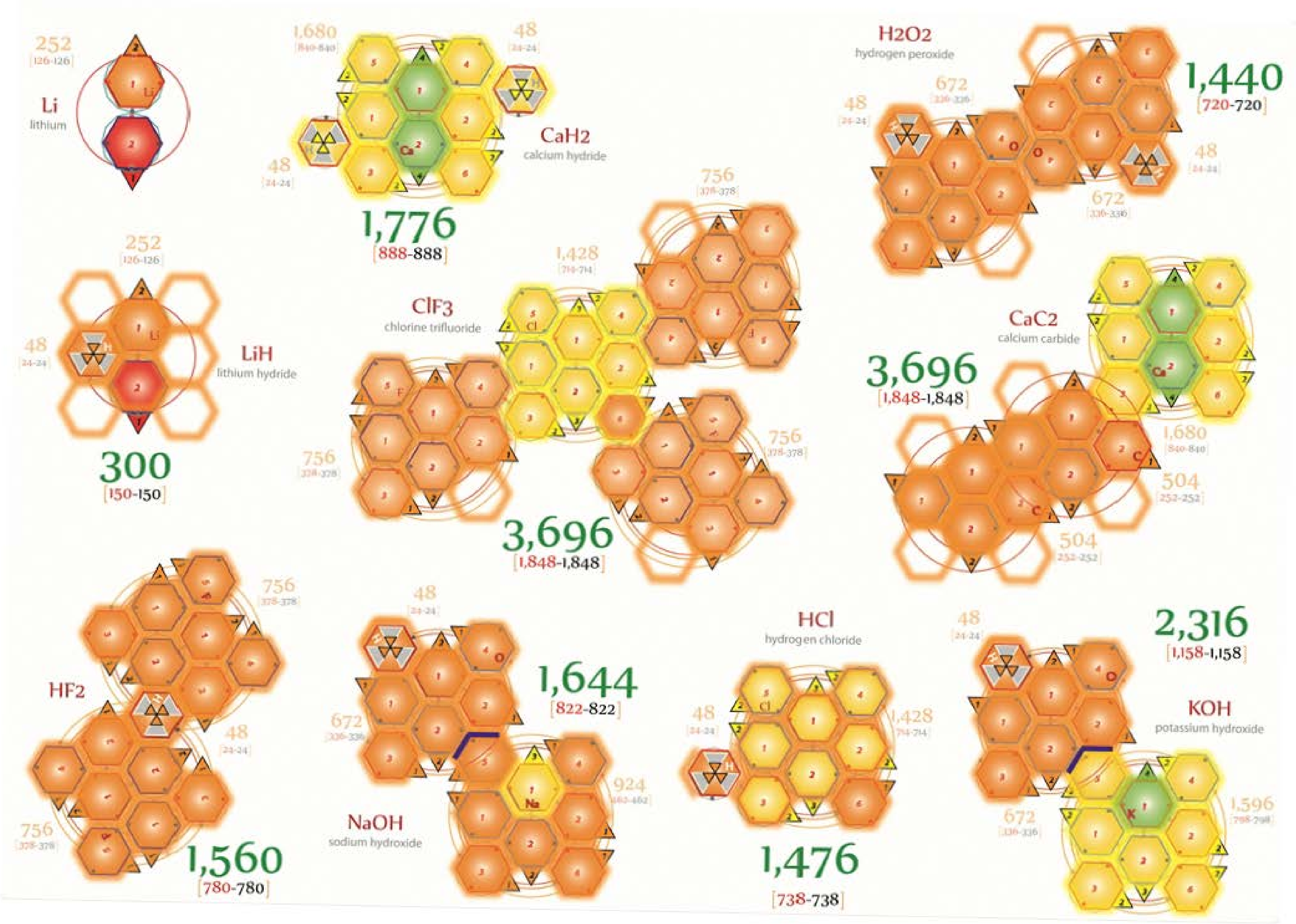
252
[126-126]
Li
lithium
1,680
[840-840]
48
[24-24]
48
[24-24]
CaH2
calcium hydride
1,776
[888-888]
H2O2
hydrogen peroxide
672
[336-336]
48
[24-24]
1,440
[720-720]
48
[24-24]
672
[336-336]
252
[126-126]
48
[24-24]
LiH
lithium hydride
300
[150-150]
ClF3
chlorine trifluoride
1,428
[714-714]
756
[378-378]
756
[378-378]
756
[378-378]
3,696
[1,848-1,848]
CaC2
calcium carbide
3,696
[1,848-1,848]
1,680
[840-840]
504
[252-252]
504
[252-252]
756
[378-378]
HF2
48
[24-24]
756
[378-378]
1,560
[780-780]
48
[24-24]
672
[336-336]
1,644
[822-822]
924
[462-462]
NaOH
sodium hydroxide
HCl
hydrogen chloride
48
[24-24]
1,428
[714-714]
1,476
[738-738]
48
[24-24]
2,316
[1,158-1,158]
KOH
potassium hydroxide
672
[336-336]
1,596
[798-798]

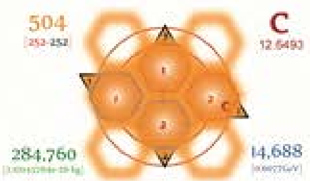
504
C
12.6493
284,760
14,688

Chemistry

is a branch of physical science, concerning the study of the composition, properties and behavior of Matter

Compounds containing bonds between carbon and a metal are called organometallic compounds.

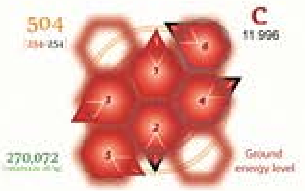
504
C
11.996
270,072
Ground energy level

Inorganic compounds are produced by non-living natural processes or in the laboratory.

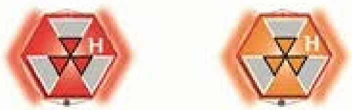

Inorganic compounds can form salts.

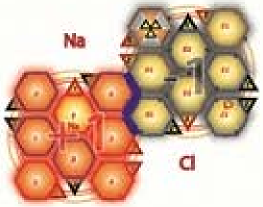

Inorganic compounds contain metal atoms.

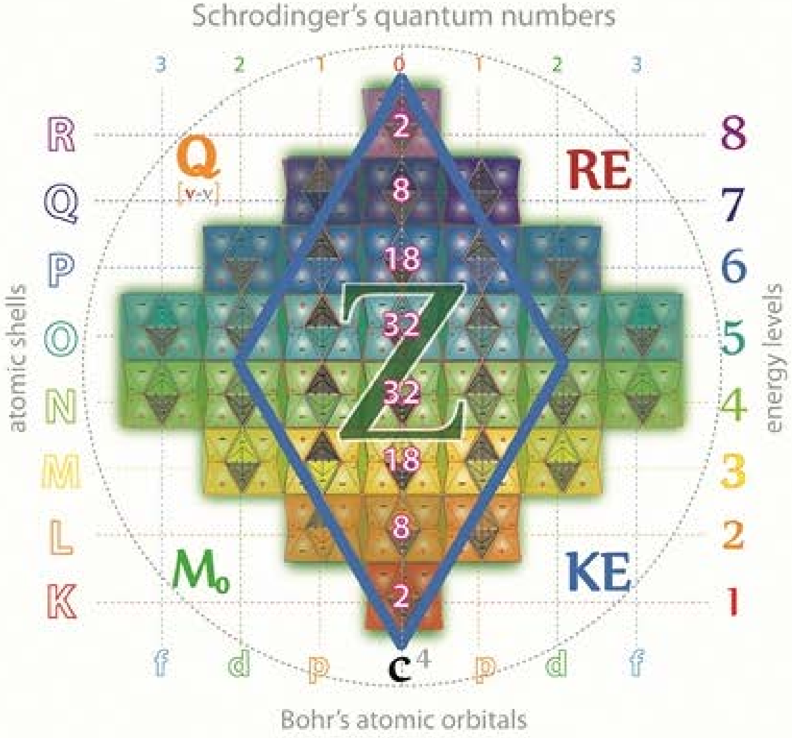
Schrodinger's quantum numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
atomic shells
8
7
6
5
4
3
2
1
energy levels
Q
[v-v]
RE
M_0
KE
2
8
18
32
Z
32
18
8
2
f
d
p
c^4
p
d
f
Bohr's atomic orbitals

Organic compounds are produced by living things.

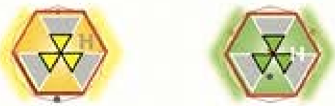

Organic compounds can't form salts.

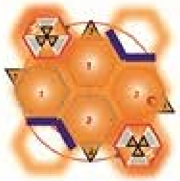

Organic compounds contain carbon-hydrogen bonds.

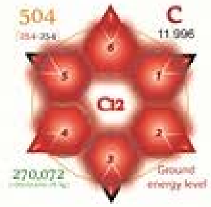
504
C
11.996
C12
1
2
3
4
5
6
270,072
Ground energy level

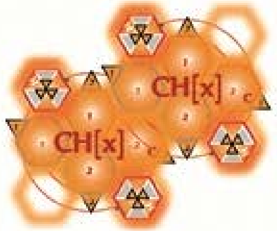

Tetryonic theory unifies and expands upon the currently disjointed physical and chemical theories through the application of 2D equilateral charged mass-energy geometries in 3D standing-wave mass-Matter topologies

Inorganic

Typically the difference is defined as being whether or not a substance contains carbon or carbon-hydrogen bonds

Organic

A chemical compound is a collection of elements bonded together in a way that the resultant ions, atoms or molecules form a 3D material geometric structure. Tetryonic chemical geometries, along with its firm definition and distinction between EM mass & Matter provide a clear visual path for the differentiation between both branckes of modern chemistry - as well as the source of animation in living Matter

Functional Groups

A functional group is a reactive portion of a molecule.

carbonyl group

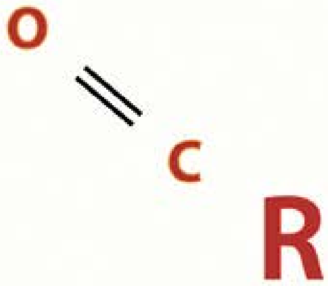

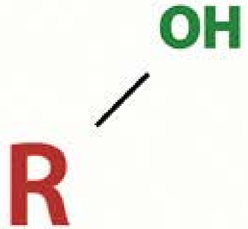

hydroxyl group

Organic molecules containing a hydroxyl group are known as alcohols.

carboxyl group

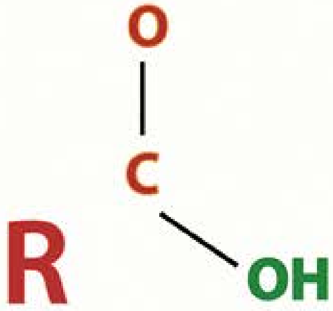

The combinations of functional groups with hydrocarbons produce a vast number of compounds.

Carbon monoxide

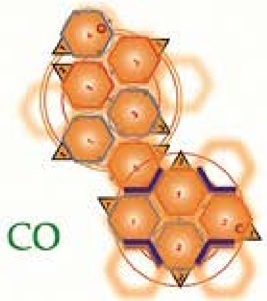

carbonyl group is composed of a carbon atom double-bonded to an oxygen atom

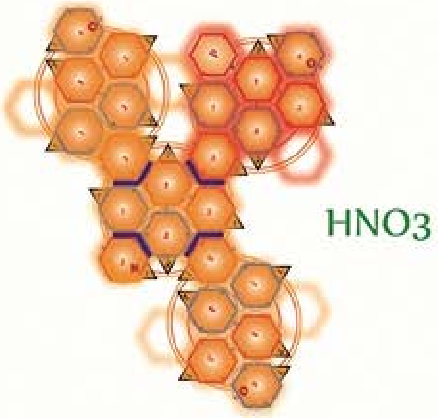

Nitric acid

Carbonic acid

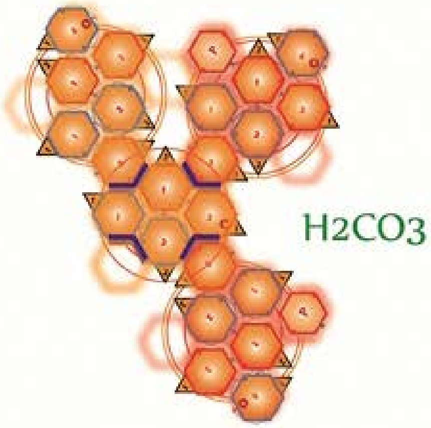

The carboxyl group is present in amino acids and carboxylic acids.

Derivatives of Hydrocarbons

An almost unlimited number of carbon compounds can be formed by the addition of a functional group to a hydrocarbon

Esters

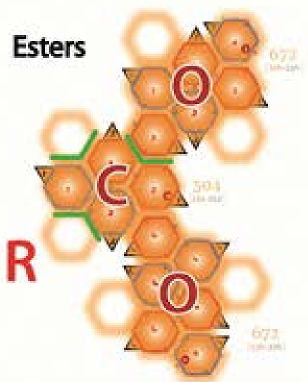

Most esters have pleasant odors.
Esters are responsible for the fragrances of
many flowers & the tastes of ripened fruits.

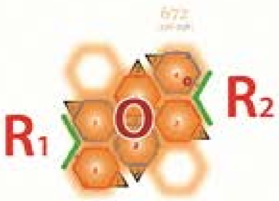

Ethers

The best known ether is diethyl ether.
It is a volatile, highly flammable liquid
that was used as an anesthetic in the past.

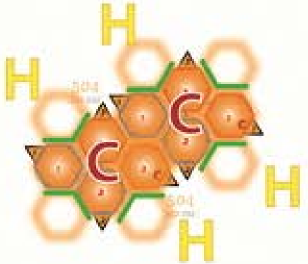

Alkyl Halides - haloalkanes

Common alkyl halides include medical anesthetics,
chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs)
and hydrofluorocarbons (HFCs).

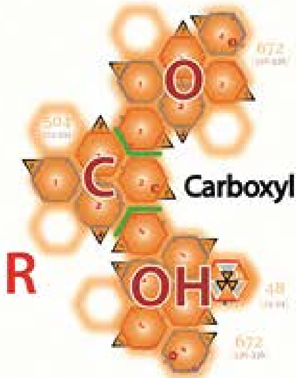

Carboxylic Acids

The simplest of the carboxylic acids is formic acid
and is a constituent of bee stings and the bites of
other insects including mosquitos.

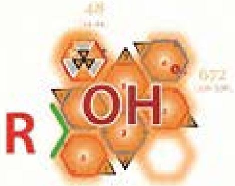

Alcohols

Alcohols are organic compounds containing a
hydroxyl group, [OH], substituted for a hydrogen atom.
Ethanol is the alcohol in alcoholic beverages and
it is also widely used as a solvent.

H
hydro

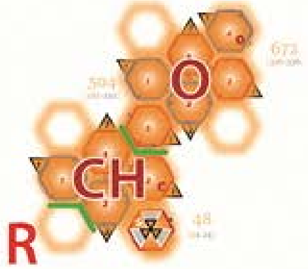

Aldehydes

An aldehyde is a compound containing a
carbonyl group with at least one hydrogen attached to it.
With a Hydrogen in place of the R group it forms Formaldehyde

C
carbons

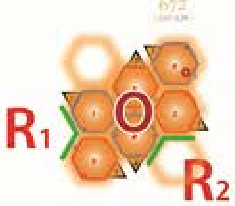

Ketones

Acetone is the simplest of the ketones.
Acetone is a commonly used solvent and is
the active ingredient in nail polish remover
and some paint thinners.

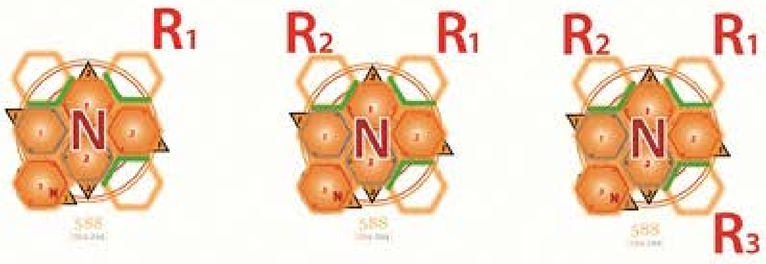

Amines

Amines are organic compounds that contain nitrogen,
they are basic compounds with strong odors,
often described as "fishy"

"R's" stand for carbon substituents or hydrogen atoms.

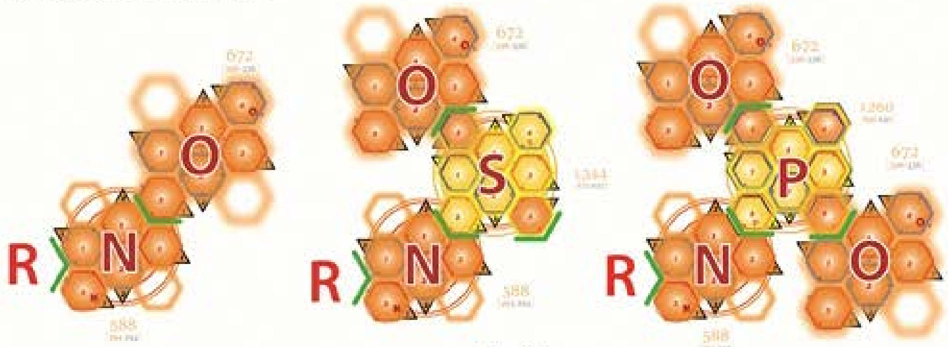

Amides

Amides are nitrogen-containing organic compounds
and are formed when amino acids react to form proteins.

Hydrocarbons

In organic chemistry, a methylene group is any part of a molecule that consists of two hydrogen atoms bound to a carbon atom, which is connected to the remainder of the molecule

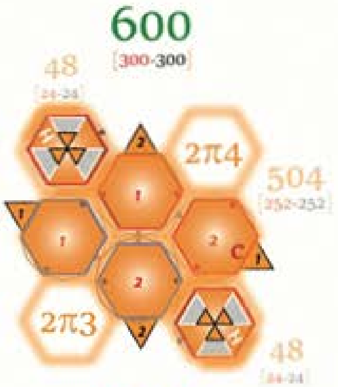
600
[300-300]
48
[24-24]
2π4
504
[252-252]
2π3
48
[24-24]

CH2

Methylene

The methylene group should be distinguished from the free methylene radical, also called carbene, whose molecule is a methylene group all by itself.

H2C

Carbene

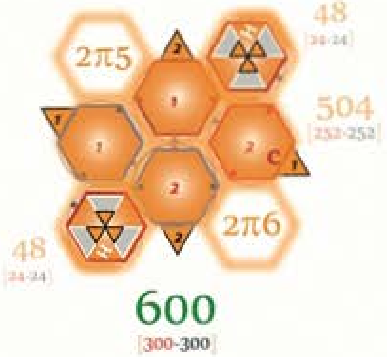
2π5
48
[24-24]
504
[252-252]
2π6
48
[24-24]
600
[300-300]

CH4

Methane

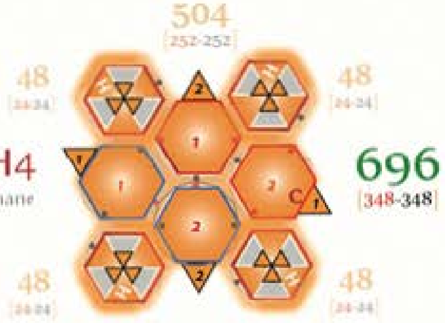
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[24-24]

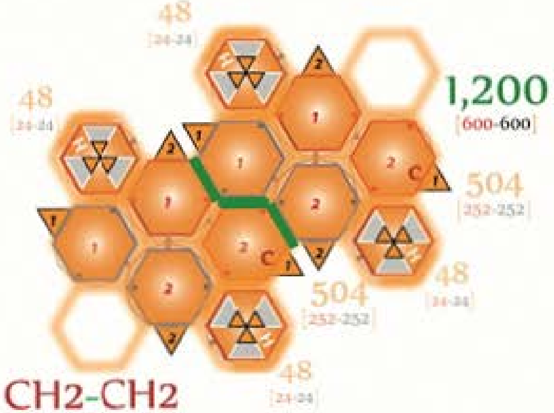
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48
[24-24]
1,200
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504
[252-252]
48
[24-24]
504
[252-252]
48
[24-24]

CH2-CH2

Ethylene

CH3-CH3

Ethane

C2H6

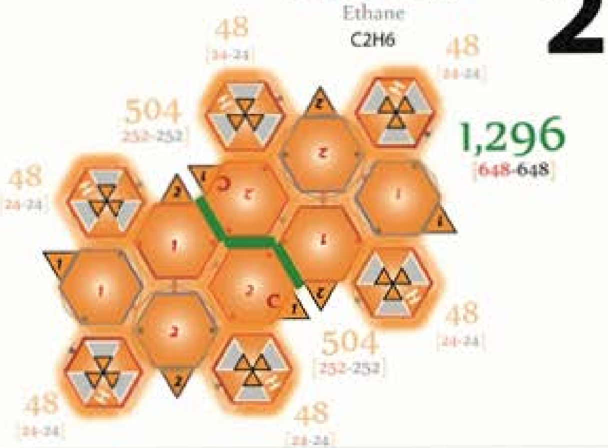
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[24-24]
48
[24-24]
504
[252-252]
1,296
[648-648]
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[24-24]
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[24-24]
504
[252-252]
48
[24-24]
48
[24-24]

2

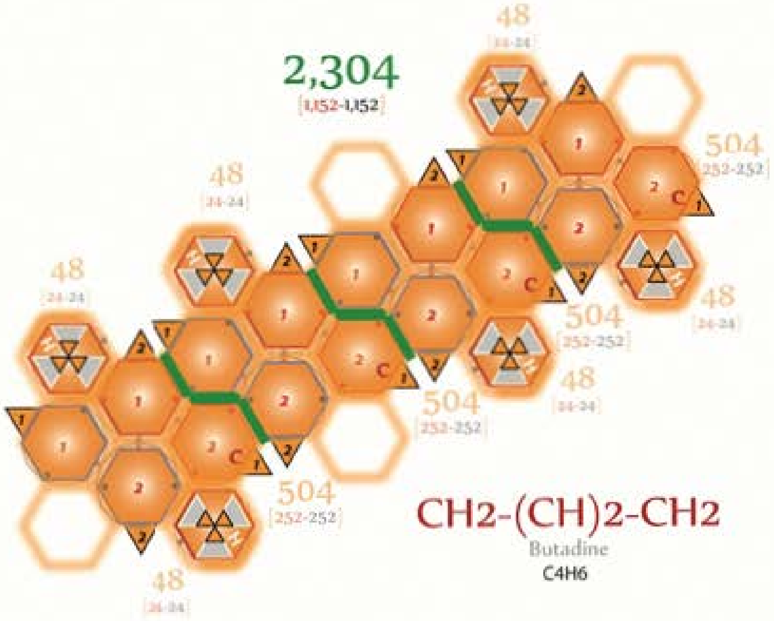
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2,304
[1,152-1,152]
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[252-252]
48
[24-24]
48
[24-24]
504
[252-252]
48
[24-24]
504
[252-252]
48
[24-24]
504
[252-252]
48
[24-24]

CH2-(CH)2-CH2

Butadine

C4H6

CH3-(CH2)-CH3

Propane

C3H8

3

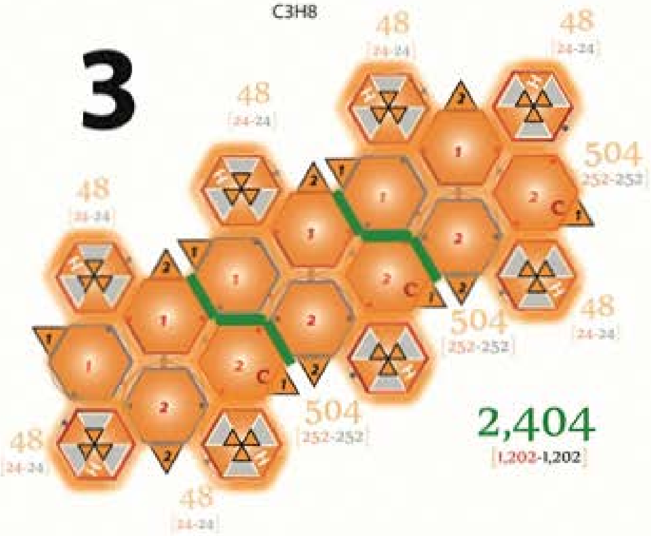
48
[24-24]
48
[24-24]
48
[24-24]
504
[252-252]
48
[24-24]
504
[252-252]
48
[24-24]
504
[252-252]
2,404
[1,202-1,202]
48
[24-24]
48
[24-24]

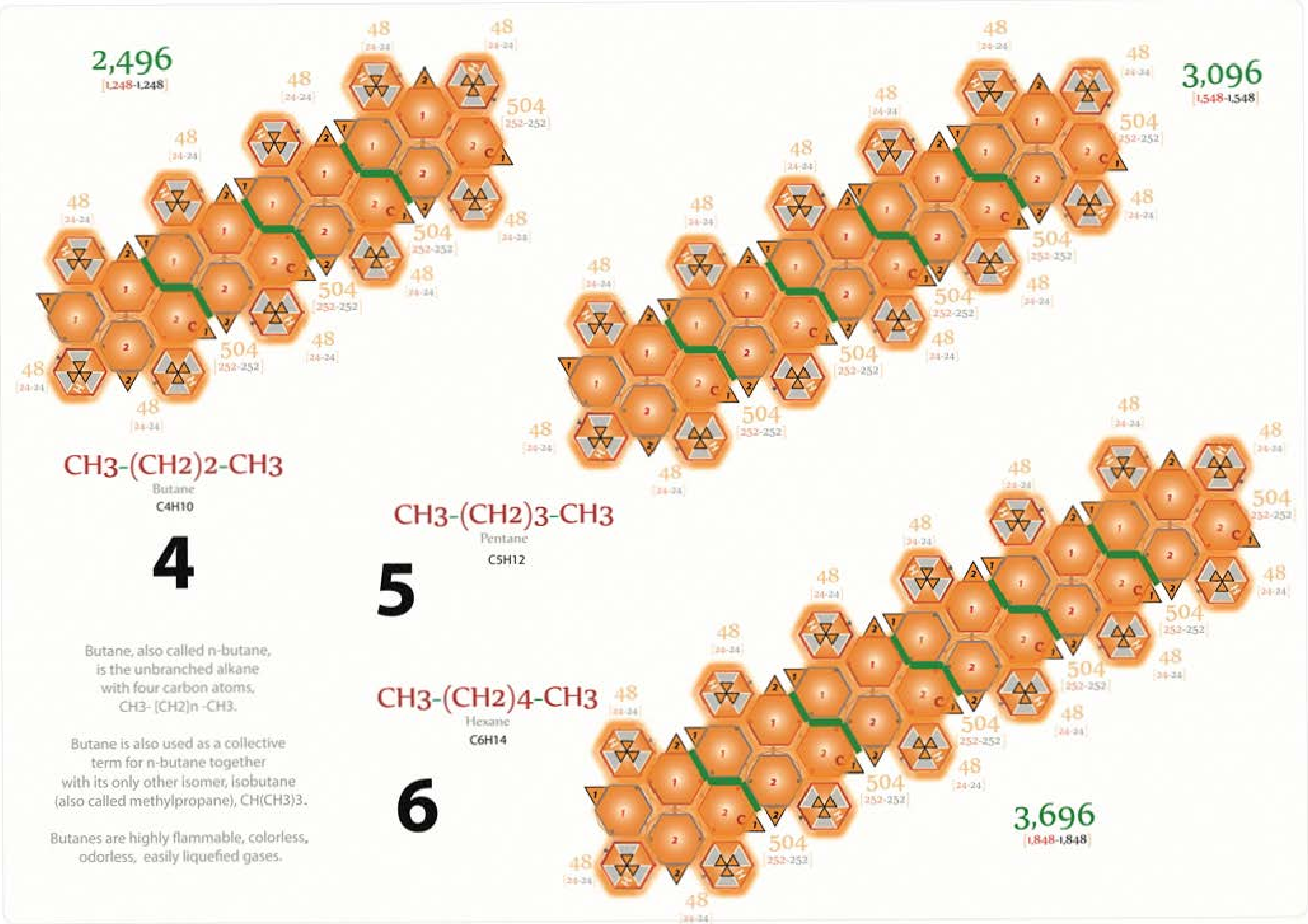
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[1,248-1,248]
3,096
[1,548-1,548]
3,696
[1,848-1,848]
48
[24-24]
504
[252-252]
1
2
C

CH3-(CH2)2-CH3

Butane

C4H10

4

CH3-(CH2)3-CH3

Pentane

C5H12

5

CH3-(CH2)4-CH3

Hexane

C6H14

6

Butane, also called n-butane,
is the unbranched alkane
with four carbon atoms,
CH3- [CH2]n -CH3.

Butane is also used as a collective
term for n-butane together
with its only other isomer, isobutane
(also called methylpropane), CH(CH3)3.

Butanes are highly flammable, colorless,
odorless, easily liquefied gases.

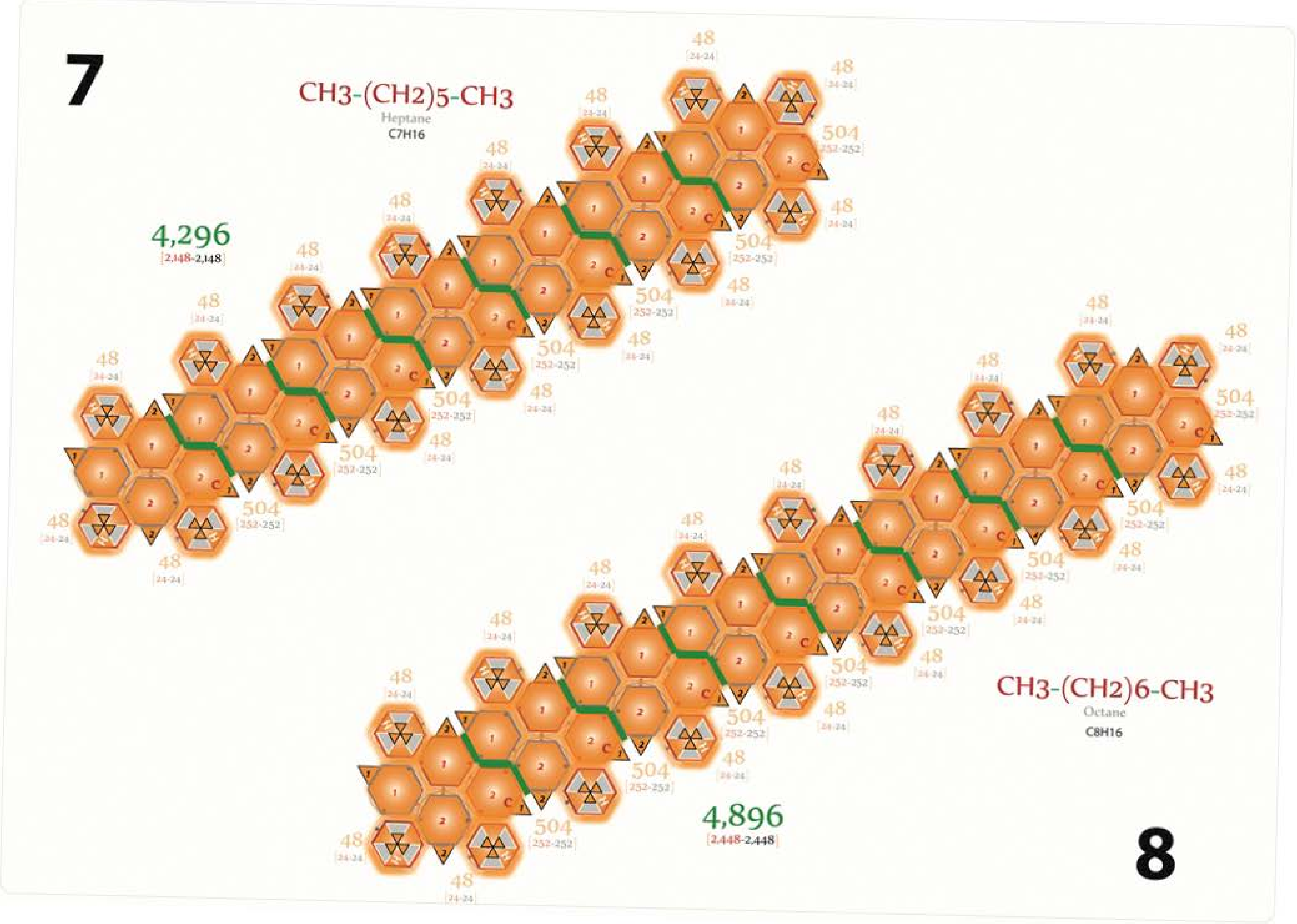
7
CH3-(CH2)5-CH3
Heptane
C7H16
4,296
[2,148-2,148]
48
[24-24]
504
[252-252]
CH3-(CH2)6-CH3
Octane
C8H16
4,896
[2,448-2,448]
8

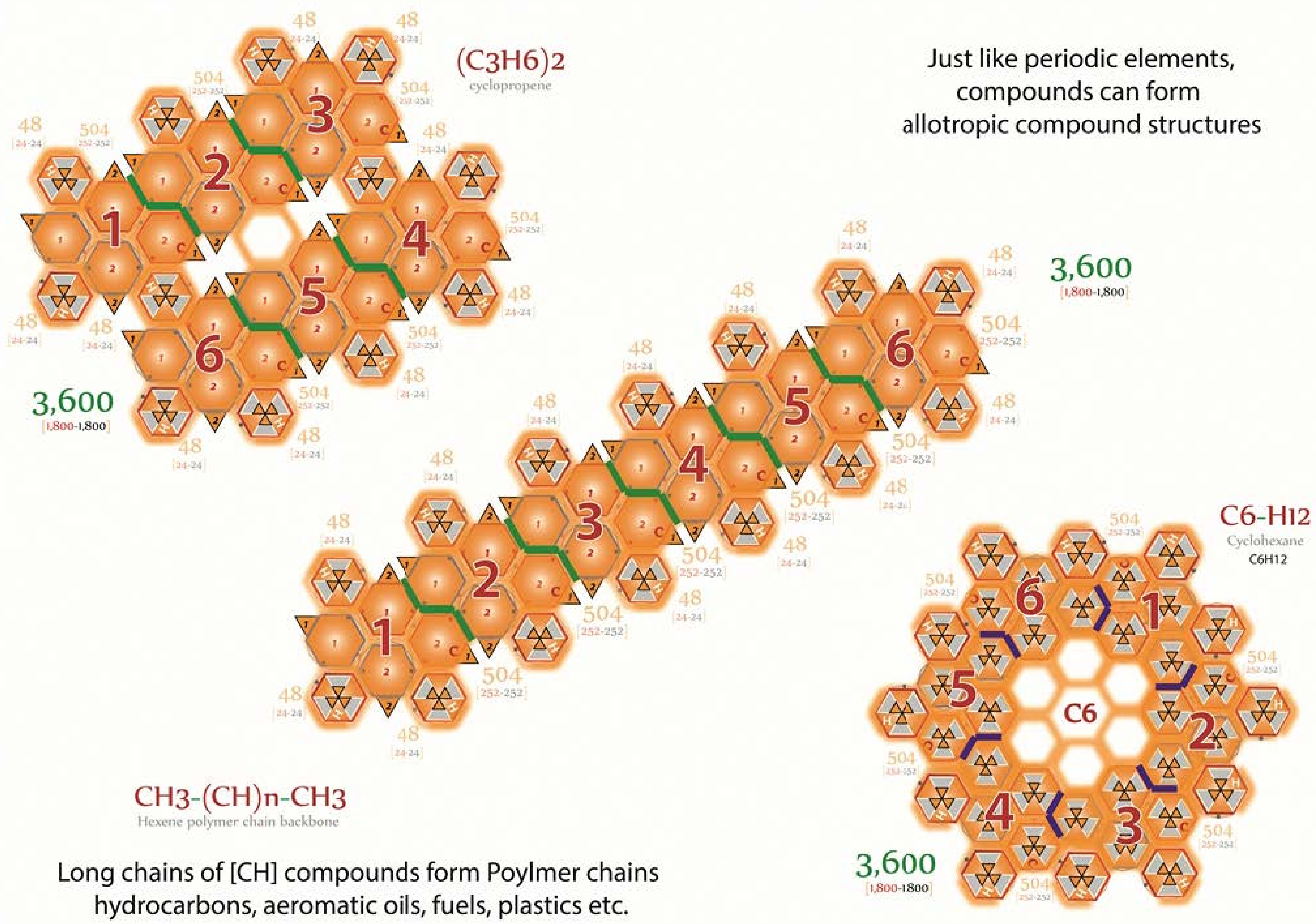
(C3H6)2
cyclopropene
3,600
[1,800-1,800]
48
[24-24]
504
[252-252]
1
2
3
4
5
6
CH3-(CH)n-CH3
Hexene polymer chain backbone
3,600
[1,800-1,800]
C6-H12
Cyclohexane
C6H12
C6
3,600
[1,800-1800]

Just like periodic elements,
compounds can form
allotropic compound structures

Long chains of [CH] compounds form Poylmer chains
hydrocarbons, aeromatic oils, fuels, plastics etc.

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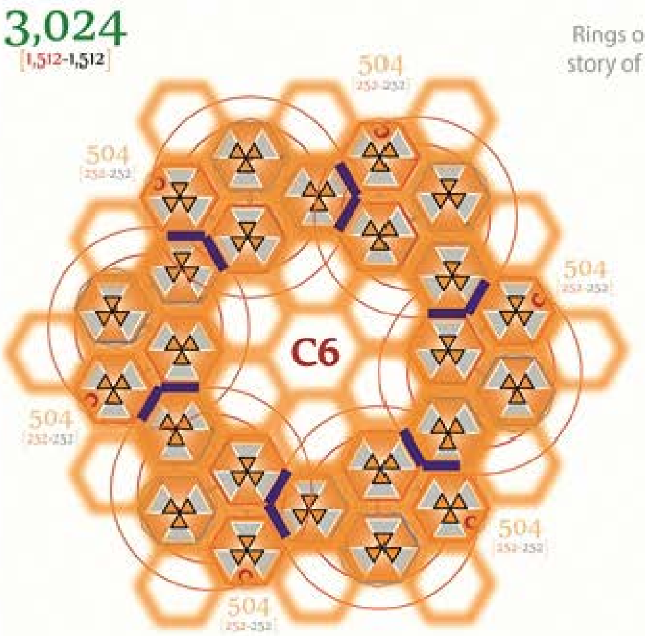
3,024
[1,512-1,512]
504
[252-252]
504
[252-252]
504
[252-252]
C6
504
[252-252]
504
[252-252]
504
[252-252]

Carbon ring

Rings of atoms are also common in organic structures. You may have heard the famous story of Auguste Kekulé first realizing that benzene has a ring structure when he dreamt of snakes biting their own tails.

Friedrich August Kekul

(7 September 1829 - 13 July 1896)

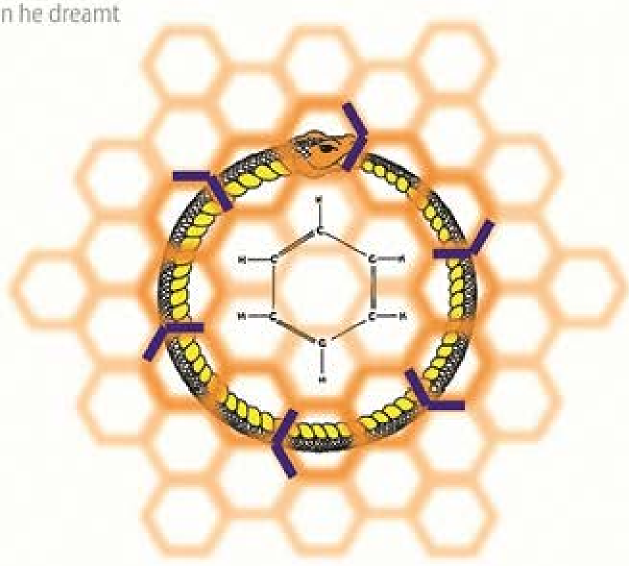

Organic Chemistry

In 1865, August Kekulé presented a paper at the Académie des Sciences in Paris suggesting a cyclic structure for benzene, the inspiration for which he ascribed to a dream. However, was Kekulé the first to suggest that benzene was cyclic. Some credit an Austrian schoolteacher, Josef Loschmidt with the first depiction of cyclic benzene structures.

In 1861, 4 years before Kekulé's dream, Loschmidt published a book in which he represented benzene as a set of rings. It is not certain whether Loschmidt or Kekulé—or even a Scot named Archibald Couper—got it right first

Some non-benzene-based compounds called heteroarenes, which follow Hückel's rule, are also aromatic compounds. In these compounds, at least one carbon atom is replaced by one of the heteroatoms oxygen, nitrogen, or sulfur.

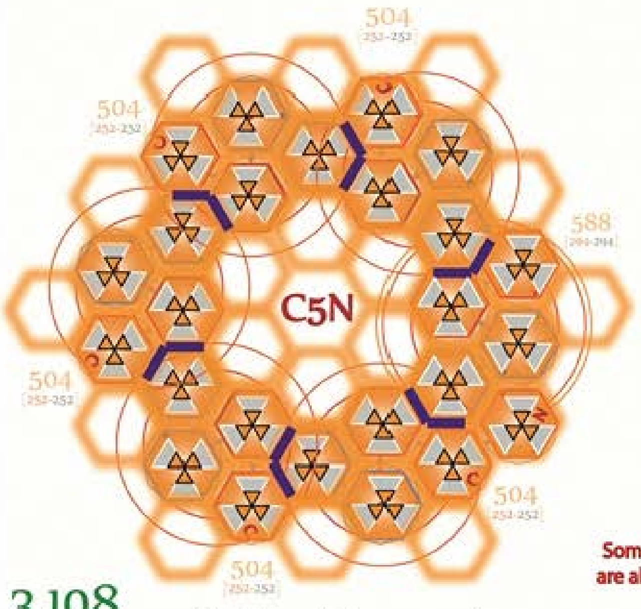
504
[252-252]
504
[252-252]
588
[294-294]
C5N
504
[252-252]
504
[252-252]
504
[252-252]
3,108
[1,554-1,554]

Carbon-Nitrogen ring

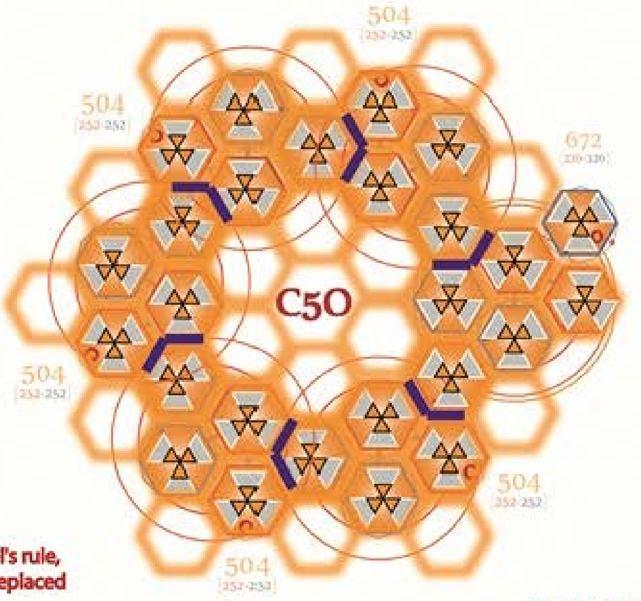
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[252-252]
504
[252-252]
672
[336-336]
C5O
504
[252-252]
504
[252-252]
504
[252-252]
3,192
[1,596-1,596]

Carbon-Oxygen ring

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Benzene molecules

Benzene, or benzol, is an organic chemical compound and a known carcinogen with the molecular formula C6H6.

It is sometimes abbreviated Ph–H.
Benzene is a colorless and highly flammable liquid with a sweet smell and a relatively high melting point.

Because it is a known carcinogen, its use as an additive in gasoline is now limited, but it is an important industrial solvent and precursor in the production of drugs, plastics, synthetic rubber, and dyes. Benzene is a natural constituent of crude oil, and may be synthesized from other compounds present in petroleum.

Benzene is an aromatic hydrocarbon and the second [n]-annulene ([6]-annulene), a cyclic hydrocarbon with a continuous pi bond.

Cyclic hydrocarbon compounds
are often referred to as
Aromatic compounds
due to their sweet smell

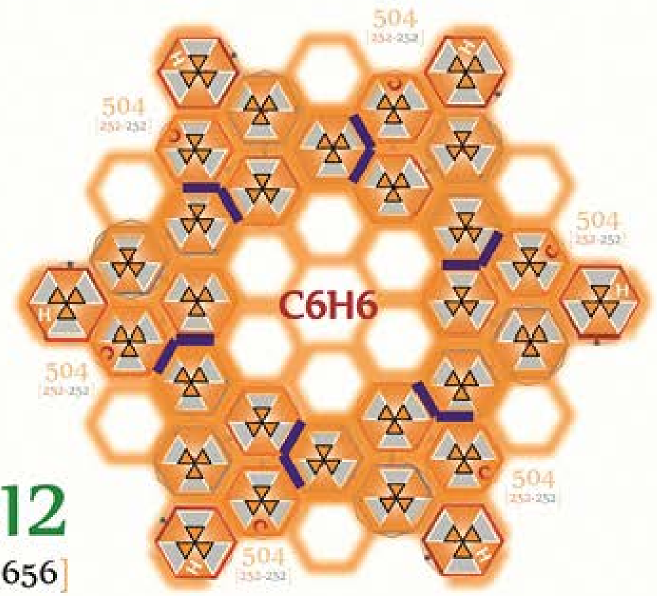
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
C6H6

3,312
[1,656-1,656]

(CH)6

Benzene ring
C6H6

A aromatic hydrocarbon is formed
when CH compounds form a
cyclic molecule

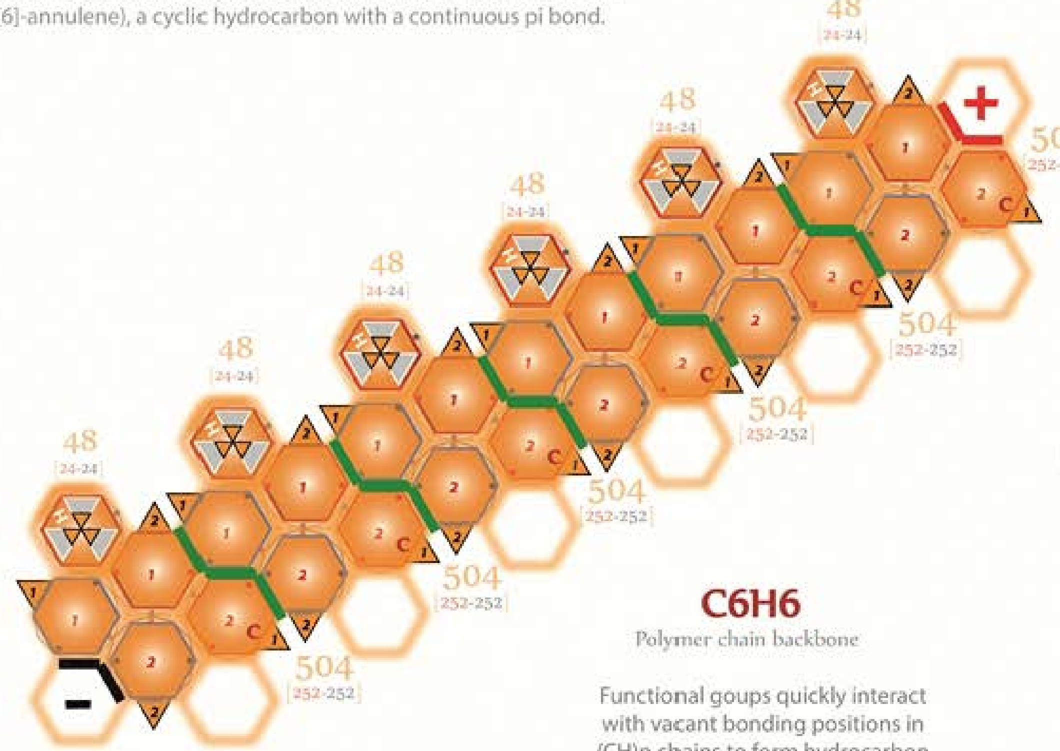
48
[24-24]
48
[24-24]
48
[24-24]
48
[24-24]
48
[24-24]
48
[24-24]
+
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
–

C6H6

Polymer chain backbone

Functional goups quickly interact with vacant bonding positions in (CH)n chains to form hydrocarbon compounds

Many important additional chemical compounds are derived from benzene by replacing one or more of its hydrogen atoms with another functional group.

Examples of simple benzene derivatives are phenol, toluene, and aniline, abbreviated PhOH, PhMe, and PhNH2, respectively

Linear (CH)n chains are rarely found in nature
as the Positive and Negative tail ends of
Hydrocarbon chain interact and bond
to form cyclic compounds.

Carbon-Nitrogen Chains

CN

Carbon-Nitrogen
chain backbone

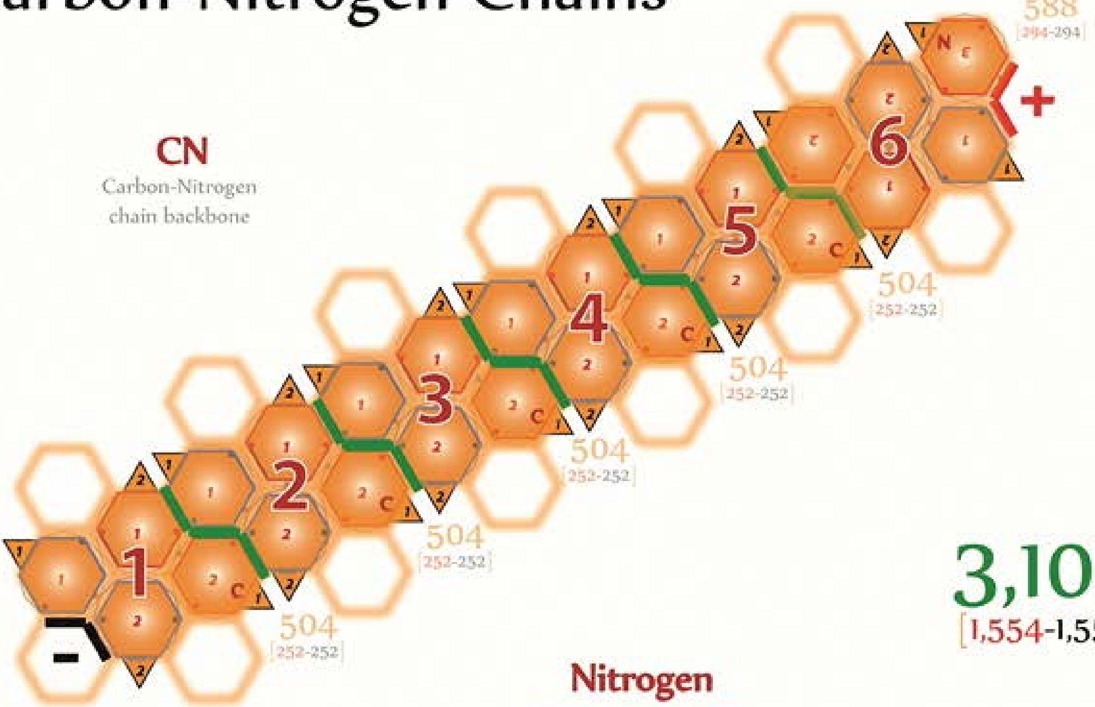
588
[294-294]
N
+
6
5
4
3
2
1
C
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
-

Carbon

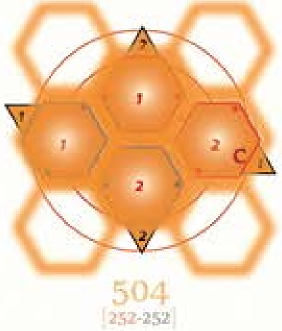
1
1
2
2
C
504
[252-252]

Hydrogen

48
[24-24]
H
48
[24-24]
H

3,108

[1,554-1,554]

Nitrogen

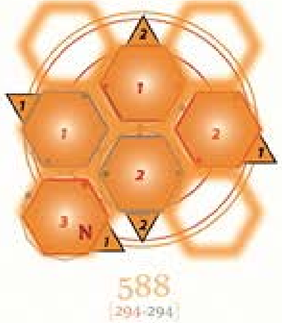
1
1
2
2
3
N
588
[294-294]

37 Protons

37 electrons

37 Neutrons

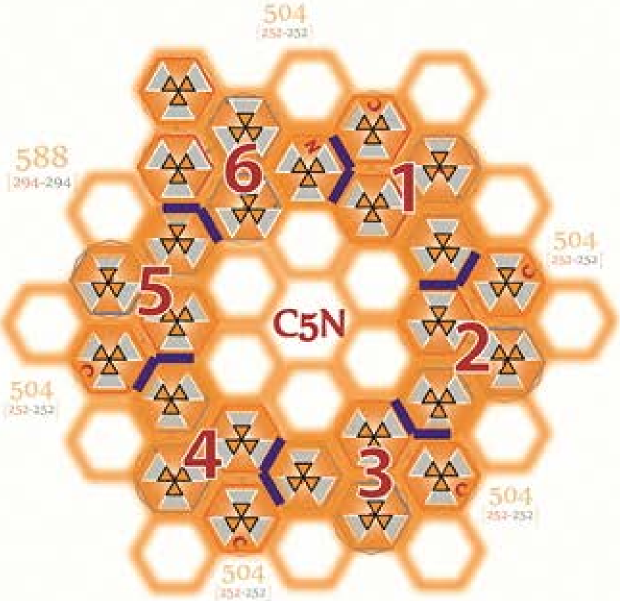
504
[252-252]
588
[294-294]
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
6
1
5
C5N
2
4
3

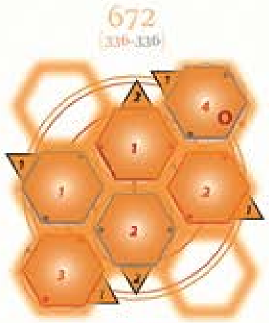
672
[336-336]
4
O
1
1
2
2
3

Oxygen

Carbon-Oxygen Chains

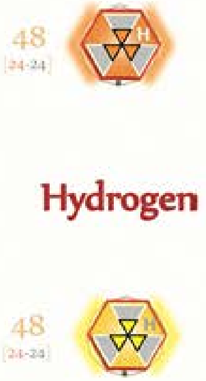
48
[24-24]
H
Hydrogen
48
[24-24]
H

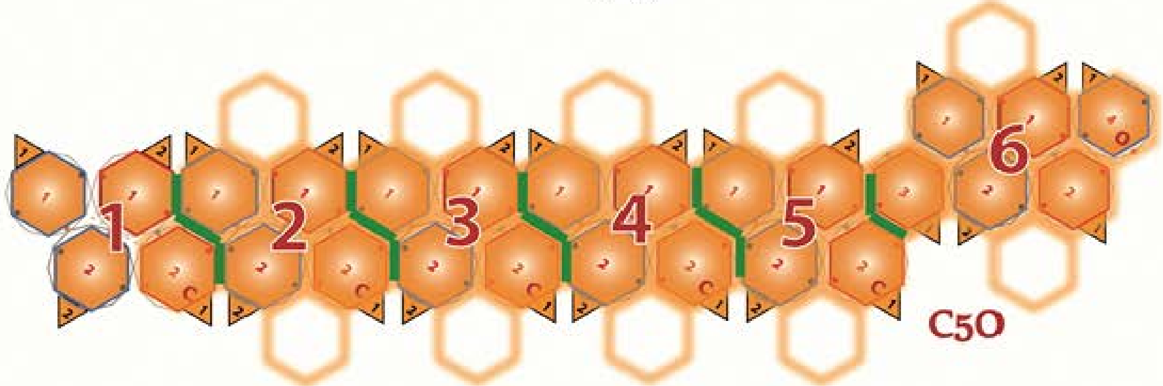
1
2
3
4
5
6
C
O
C5O

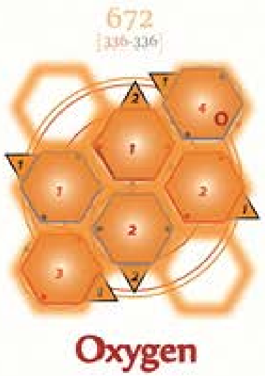
672
[336-336]
O
Oxygen

Heterocyclic Rings

Tetrahydropyran is the organic compound consisting of a saturated six-membered ring containing five carbon atoms and one oxygen atom.

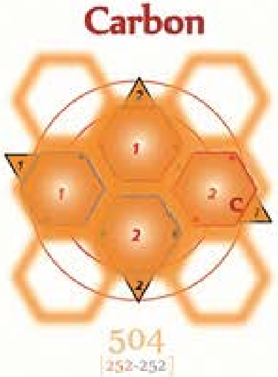
Carbon
C
504
[252-252]

3,192
[1,596-1,596]

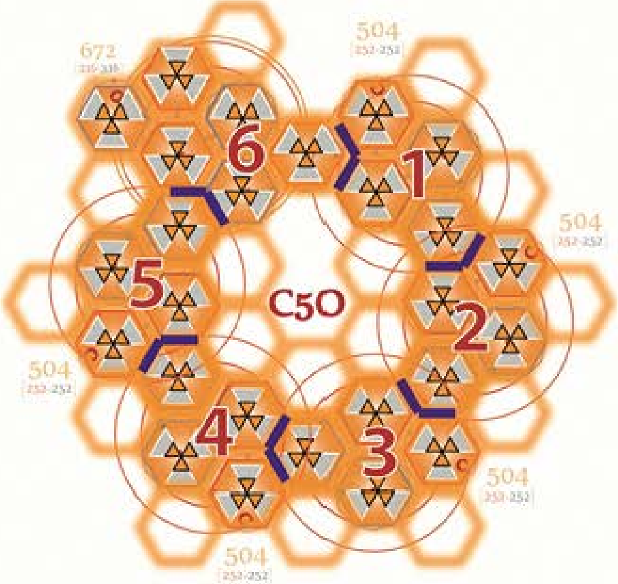
672
[336-336]
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
504
[252-252]
6
1
2
3
4
5
C5O

38 Protons
38 electrons
38 Neutrons

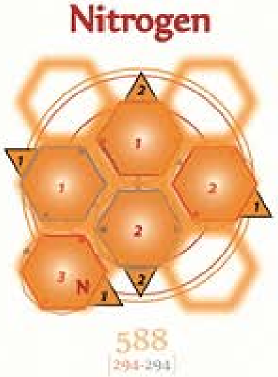
Nitrogen
N
588
[294-294]

C6H2(NO2)3CH3

Trinitrotoluene

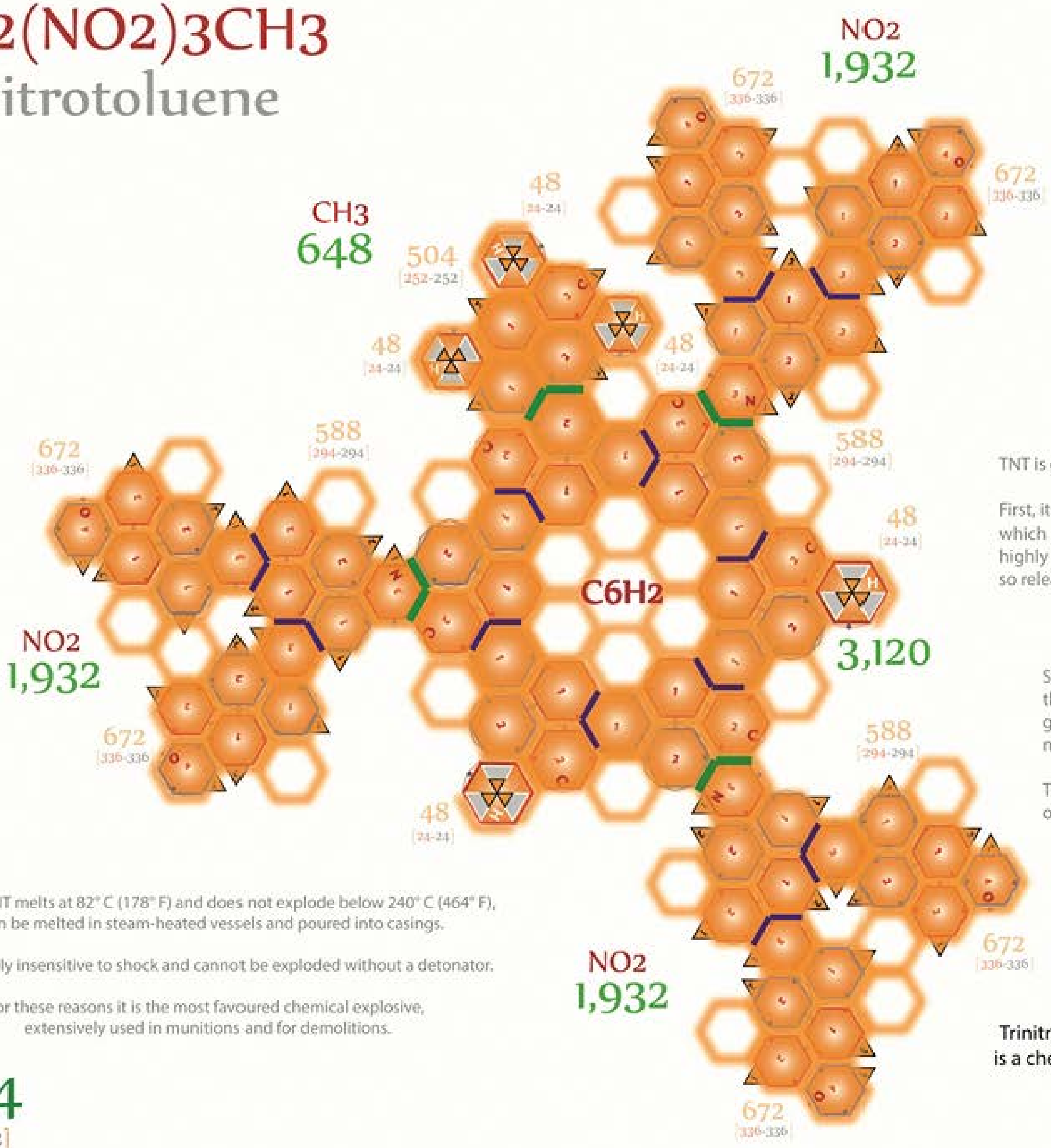
CH3
648
504
[252-252]
48
[24-24]
48
[24-24]
48
[24-24]
NO2
1,932
672
[336-336]
672
[336-336]
588
[294-294]
588
[294-294]
672
[336-336]
NO2
1,932
672
[336-336]
C6H2
48
[24-24]
3,120
48
[24-24]
588
[294-294]
672
[336-336]
NO2
1,932
672
[336-336]

2,4,6-trinitrotoluene is better known by its initials, TNT.
It is an important explosive, since it can very quickly change from a solid into hot expanding gases.

TNT is explosive for two reasons;

First, it contains the elements carbon, oxygen and nitrogen, which means that when the material burns it produces highly stable substances (CO, CO2 and N2) with strong bonds, so releasing a great deal of energy.

Secondly, TNT is chemically unstable - the nitro groups are so closely packed that they experience a great deal of strain and hindrance to movement from their neighbouring groups.

Thus it doesn't take much of an initiating force to break some of the strained bonds, and the molecule then flies apart.

Because TNT melts at 82° C (178° F) and does not explode below 240° C (464° F), it can be melted in steam-heated vessels and poured into casings.

It is relatively insensitive to shock and cannot be exploded without a detonator.

For these reasons it is the most favoured chemical explosive, extensively used in munitions and for demolitions.

Trinitrotoluene, or more specifically, 2,4,6-trinitrotoluene, is a chemical compound with the formula C6H2(NO2)3CH3

9,564
[4,782-4,782]

(C6)4-H10

Pyrene

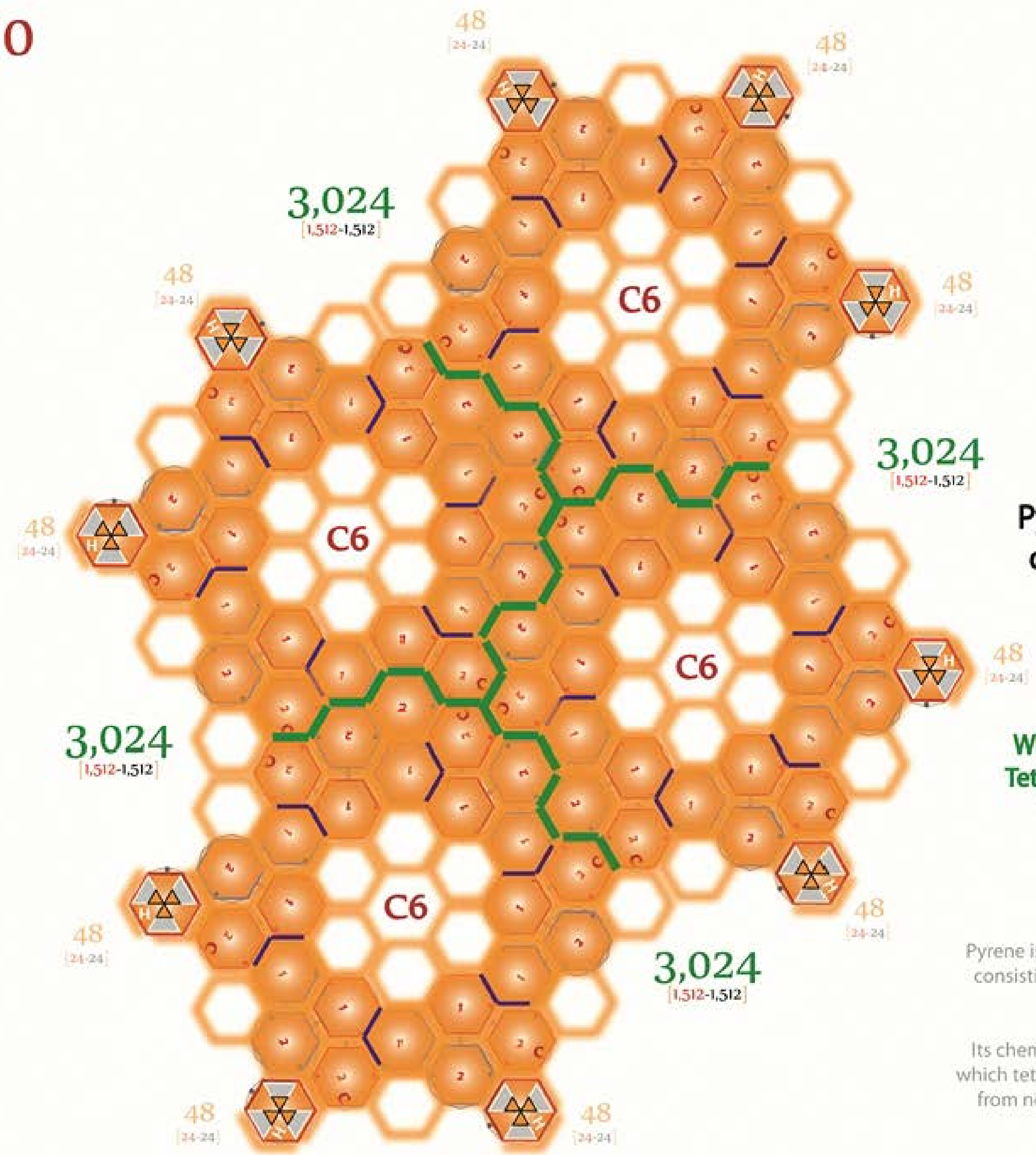
48
[24-24]
48
[24-24]
3,024
[1,512-1,512]
48
[24-24]
C6
48
[24-24]
3,024
[1,512-1,512]
48
[24-24]
C6
48
[24-24]
C6
3,024
[1,512-1,512]
48
[24-24]
C6
48
[24-24]
3,024
[1,512-1,512]
48
[24-24]
48
[24-24]
H

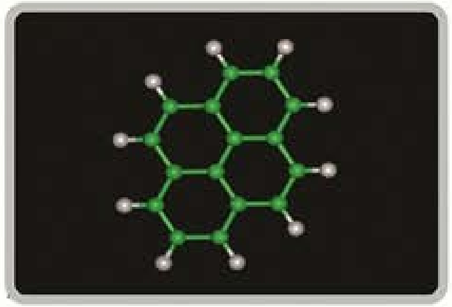

Pyrene highlights the failings of Lewis diagram structures

Which can be rectified using charged Tetryonic geometric Matter topologies for all elements and compound interactions & modelling

Pyrene is a polycyclic aromatic hydrocarbon (PAH) consisting of four fused benzene rings, resulting in a flat aromatic system.

Its chemcial formula as is often stated as $C_{16}H_{10}$, which tetryonic geometry shows is an error resulting from not using equilateral quantum geometries in chemical topology modelling.

Four cyclic carbon rings cannot be formed with only 16 C-atoms

12,576

[6,288-6,288]

Ammonium Nitrate

3,384

NH4NO3,

Ammonium nitrate is composed of two polyatomic ions:
1) Ammonium Ion (NH4+)
2) Nitrate Ion (NO3-)

The bond between these ions is an ionic bond meaning the ammonium ion transfers an electron to the nitrate ion.

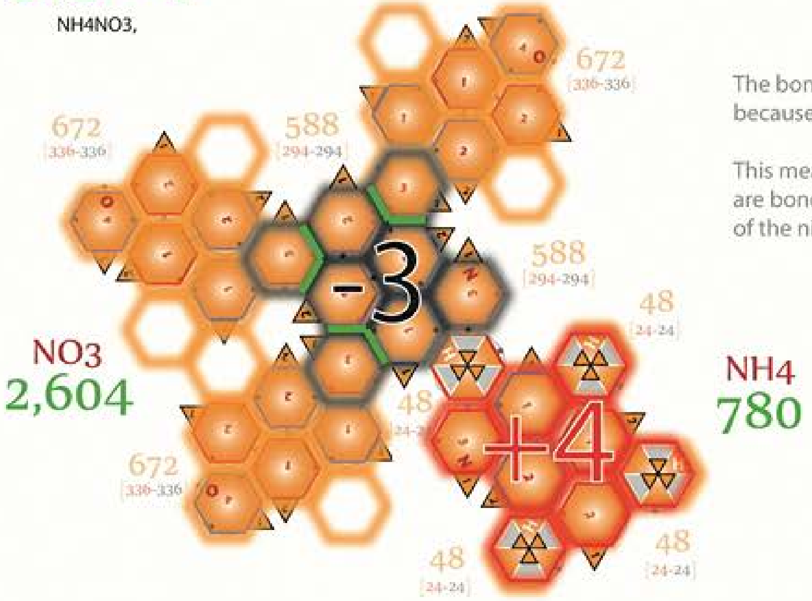
672
[336-336]
588
[294-294]
672
[336-336]
588
[294-294]
-3
48
[24-24]
NO3
2,604
48
[24-24]
+4
NH4
780
672
[336-336]
48
[24-24]
48
[24-24]

The bonds in a polyatomic atomic ion are covalent because they take place between gases.

This means that the hydrogens of the ammonium ion are bonded to the nitrogen covalently and that the oxygens of the nitrate are bonded to the nitrogen covalently

Ammonium nitrate decomposes into the gases nitrous oxide and water vapor when heated (non-explosive reaction); however, ammonium nitrate can be induced to decompose explosively by detonation.

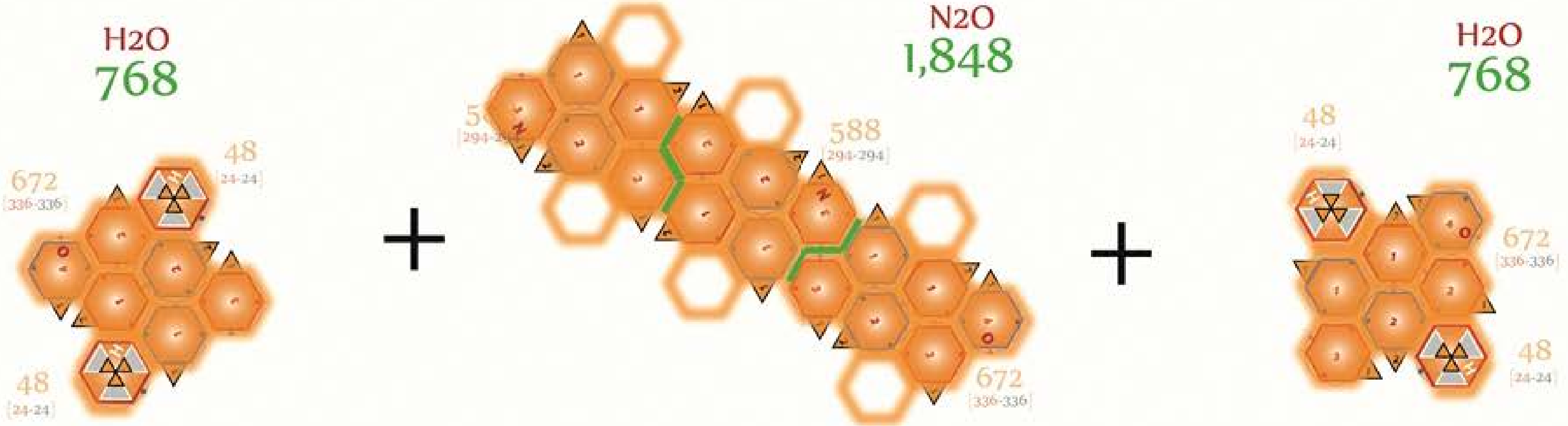
H2O
768
672
[336-336]
48
[24-24]
48
[24-24]
+
N2O
1,848
588
[294-294]
672
[336-336]
+
H2O
768
48
[24-24]
672
[336-336]
48
[24-24]

Carbohydrates

A carbohydrate is an organic compound that consists only of carbon, hydrogen, and oxygen (with a hydrogen:oxygen ratio of 2:1) in other words, with the empirical formula $C_m(H_2O)_n$

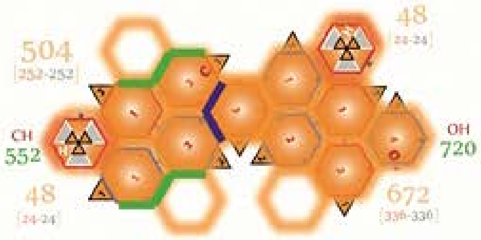
504
[252-252]
48
[24-24]
CH
552
48
[24-24]
OH
720
672
[336-336]

Monosaccharides

Oligosaccharides

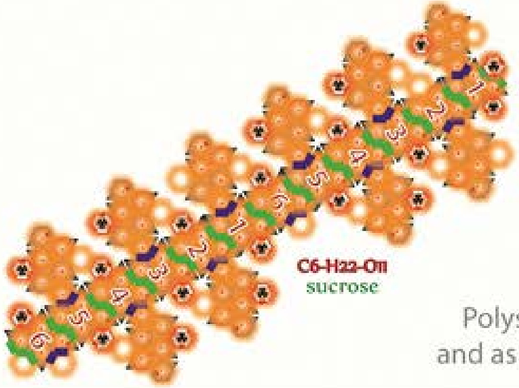
C6-H22-O11
sucrose
1
2
3
4
5
6

Ribose

Gluclose

Lactose

$$\boxed{C_m(H_2O)_n}$$

Fructose

Sucrose

Deoxyribose

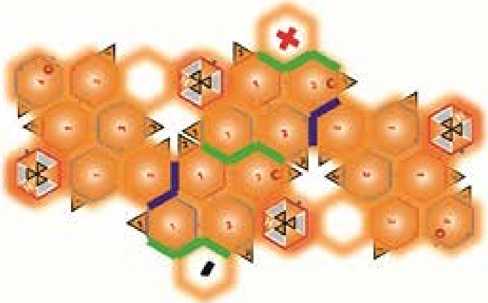

Disaccharides

Polysaccharides

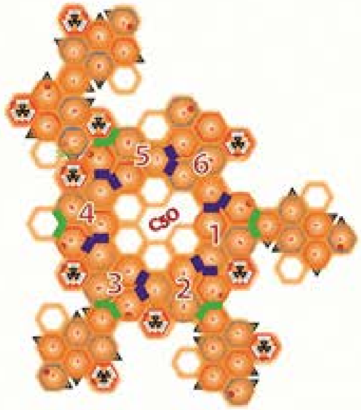

Carbohydrates perform numerous roles in living organisms. Polysaccharides serve for the storage of energy (e.g., starch and glycogen), and as structural components (e.g., cellulose in plants and chitin in arthropods)

Monosaccharides

Monosaccharides are the simplest carbohydrates in that they cannot be hydrolyzed to smaller carbohydrates

The Carbon nuclei in Monosaccharides join together to form chains of biologically important carbohydrates

1,272

[636-636]

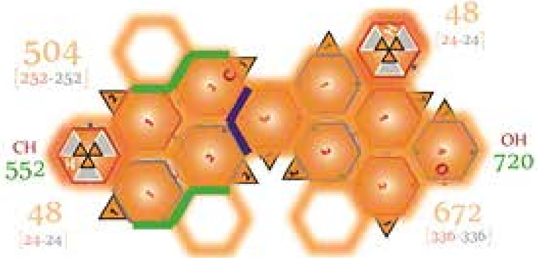
504
[252-252]
48
[24-24]
CH
552
OH
720
48
[24-24]
672
[336-336]

C(H2O)

The general chemical formula of an unmodified monosaccharide is (C•H2O) n, literally a "carbon hydrate."

CH 552

CH-OH

OH 720

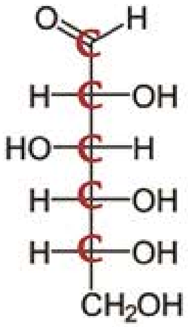
O
H
H—C—OH
HO—C—H
H—C—OH
H—C—OH
CH₂OH

D-Glucose

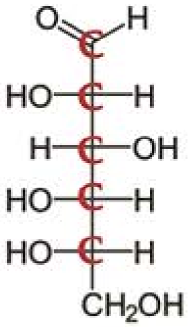
O
H
HO—C—H
H—C—OH
HO—C—H
HO—C—H
CH₂OH

L-Glucose

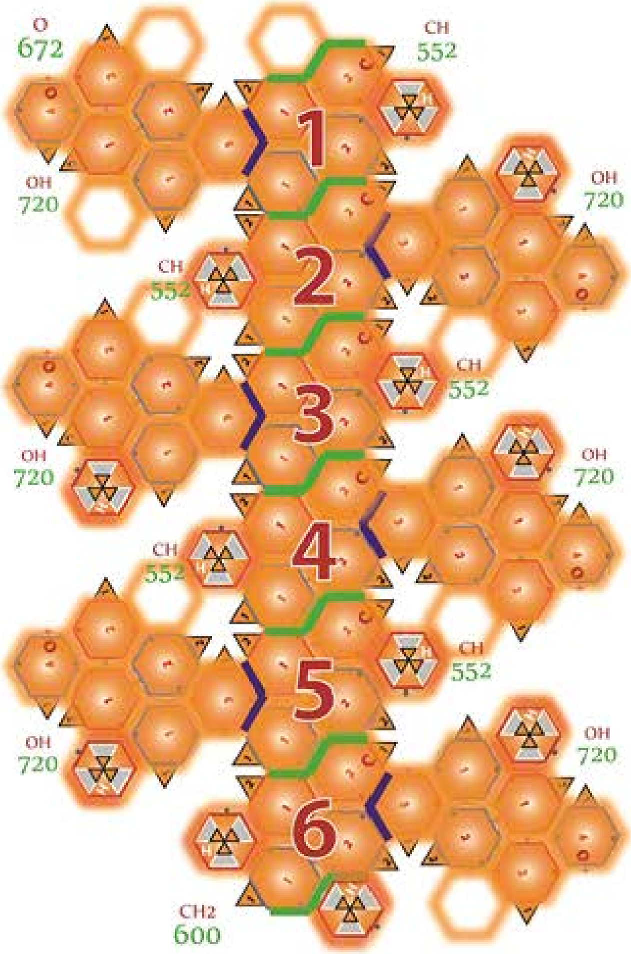
O
672
CH
552
OH
720
1
OH
720
2
CH
552
3
CH
552
OH
720
OH
720
4
CH
552
5
CH
552
OH
720
OH
720
6
CH2
600

C(H2O)6

D-glucose

C6-H12-O6

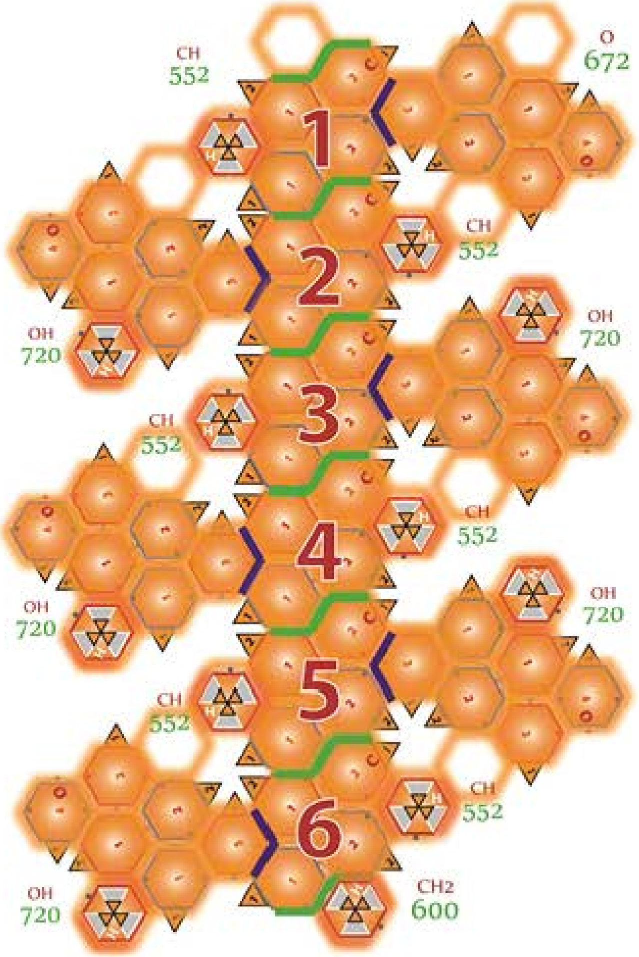
CH
552
O
672
1
CH
552
2
OH
720
OH
720
3
CH
552
CH
552
4
OH
720
OH
720
5
CH
552
CH
552
6
OH
720
CH2
600

C(H2O)6

L-glucose

C6-H12-O6

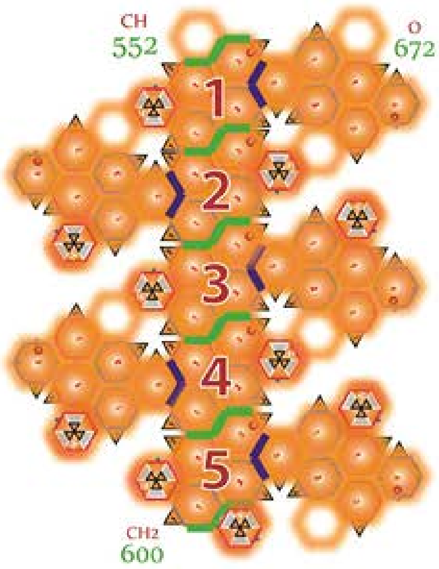
CH
552
O
672
1
2
3
4
5
CH2
600

C(H2O)5
ribose
C5-H10-O5

C(H2O)n

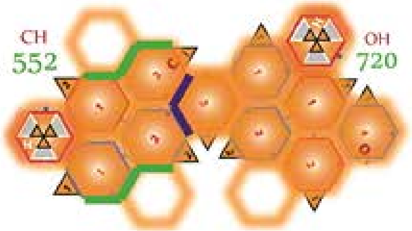
CH
552
OH
720

C(H2O)6
fructose
C6-H12-O6

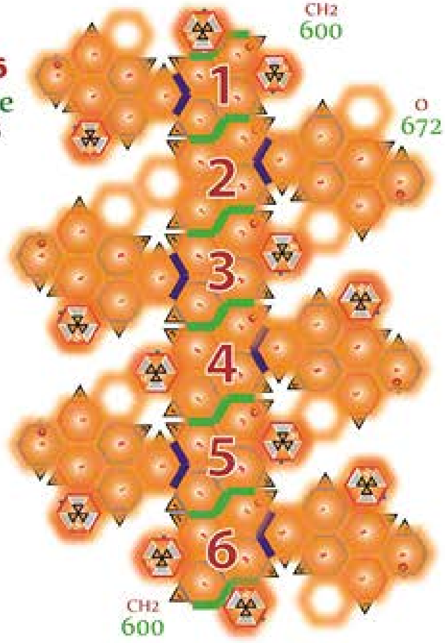
CH2
600
O
672
1
2
3
4
5
6
CH2
600

Major Monosaccharides

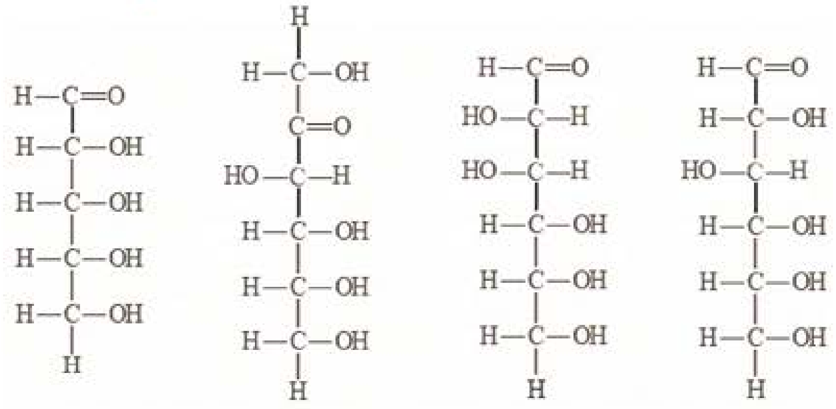

ribose fructose mannose glucose

D D & L sugars are chiral, mirror images of one another and have the same name. **L**

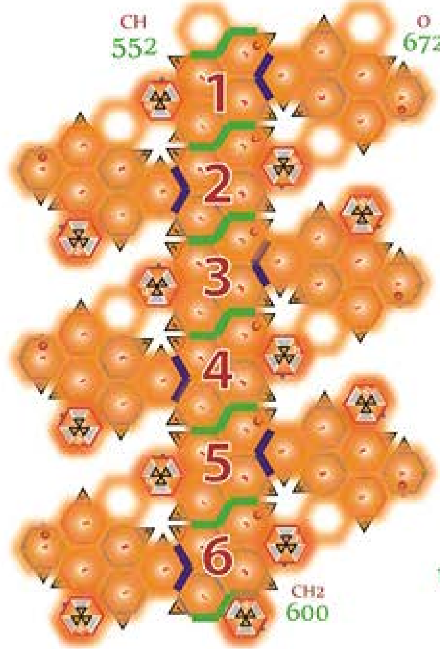
CH
552
O
672
1
2
3
4
5
6
CH2
600

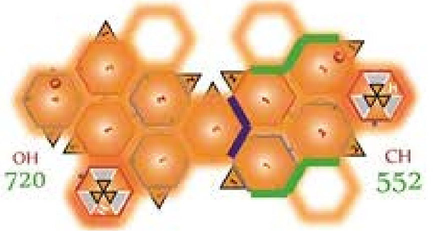
OH
720
CH
552

C(H2O)6
mannose
C6-H12-O6

C(H2O)6
glucose
C6-H12-O6

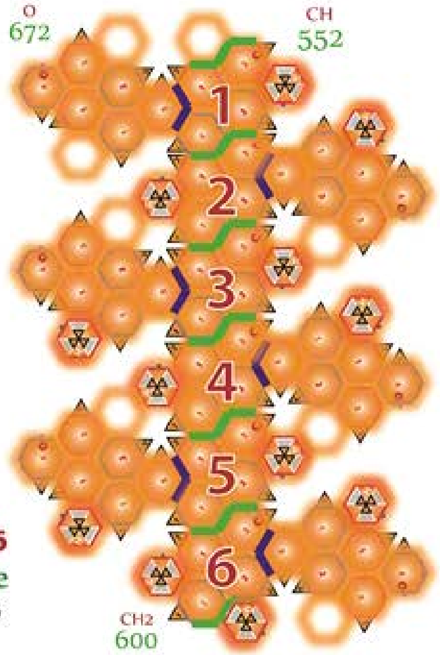
O
672
CH
552
1
2
3
4
5
6
CH2
600

A monosaccharide often switches from the acyclic (open-chain) form to a cyclic form, through a nucleophilic addition reaction between the carbonyl group and one of the hydroxyls of the same molecule.

cyclic monosaccharides

For many monosaccharides (including glucose), the cyclic forms predominate, and therefore the same name commonly is used for forms of isomers.

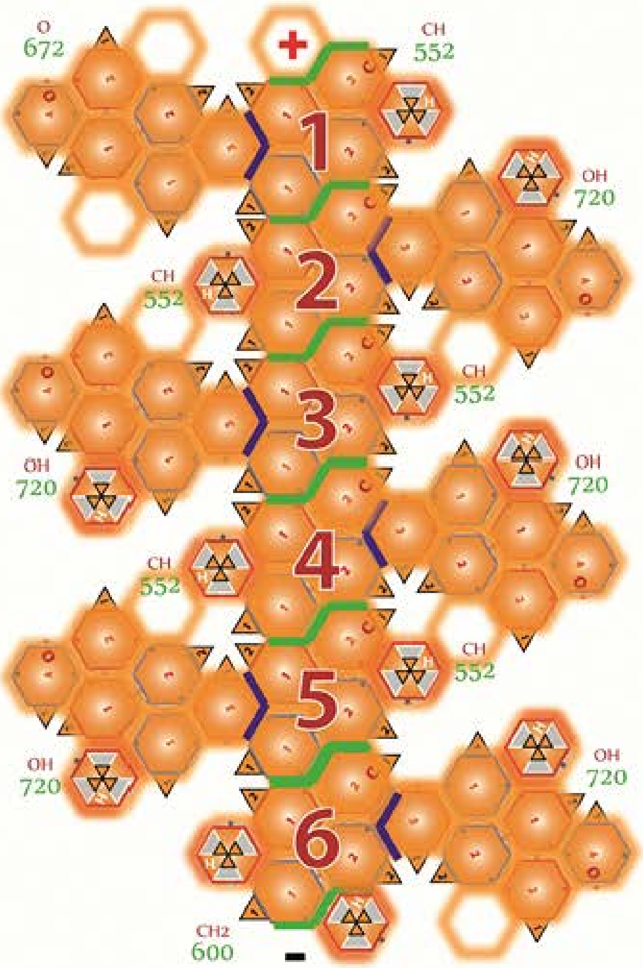
O
672
+
CH
552
1
OH
720
2
CH
552
3
CH
552
OH
720
OH
720
4
CH
552
5
CH
552
OH
720
OH
720
6
CH2
600
-

C(H2O)6
glucose
C6-H12-O6

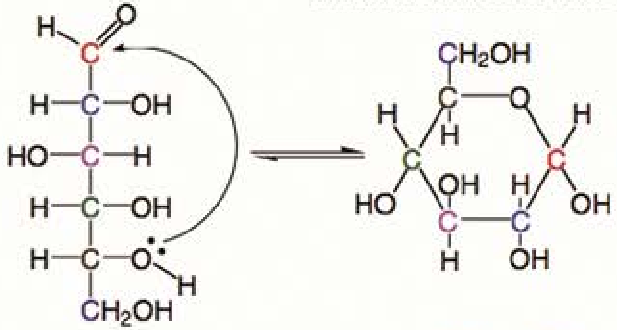
H
C
O
H
C
OH
HO
C
H
H
C
OH
H
C
O
H
CH₂OH
CH₂OH
C
O
H
H
C
H
C
HO
OH
H
C
OH
C
C
H
OH

C(H2O)6
glucopyranose
C6-H12-O6

cyclic Oxygen-Carbon ring

Allotropic cyclic [Carbon-Oxygen] forms of polycarbohydrates can also be formed via other element bonding processes

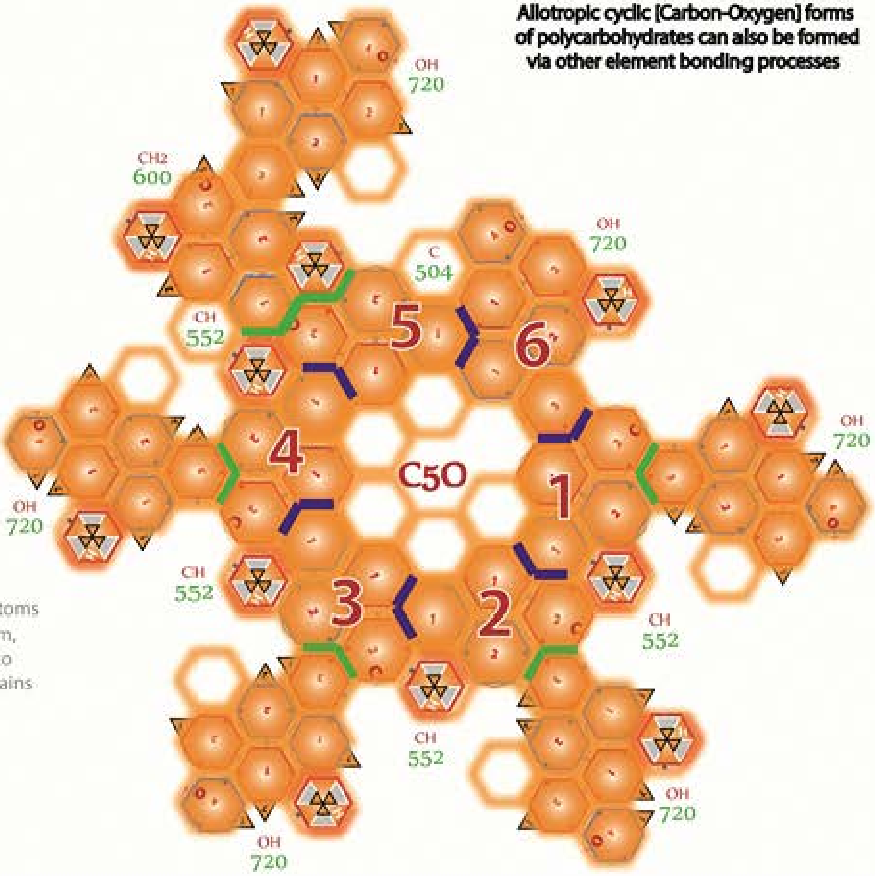
OH
720
CH2
600
OH
720
C
504
CH
552
5
6
4
C50
1
OH
720
OH
720
CH
552
3
2
CH
552
CH
552
OH
720
OH
720

C6-H12-O6

7,632

[3,816-3,816]

The reaction creates a ring of carbon atoms closed by one bridging oxygen atom, which in turn can be easily broken to restore the linear monosaccharide chains

linear saccharide chain

The Carbon nuclei in Monosaccharides chains can join together to form cyclic [Carbon-Oxygen] rings or polycarbohydrates through condensation

acyclic monosaccharides

Condensed Disaccharides

Condensed Disaccharides are formed when two monosaccharides are joined together and a molecule of water is removed

For example, milk sugar (lactose) is made from glucose and galactose
whereas cane sugar (sucrose) is made from glucose and fructose

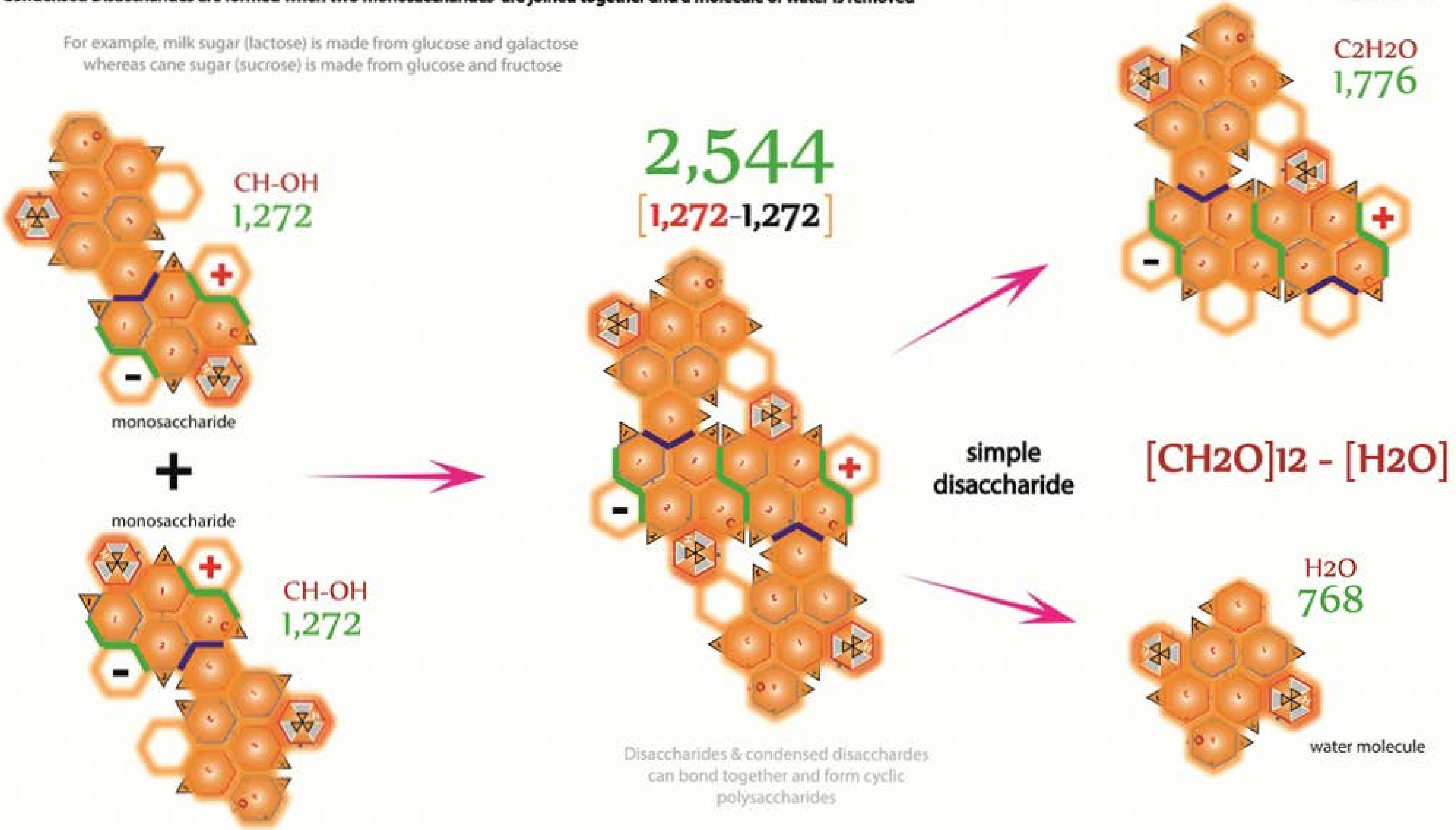

CH-OH
1,272
monosaccharide
+
monosaccharide
CH-OH
1,272

2,544
[1,272-1,272]

simple
disaccharide

condensed
disaccharide
C_2H_2O
1,776

$[CH_2O]_{12} - [H_2O]$

H_2O
768
water molecule

Disaccharides & condensed disaccharides
can bond together and form cyclic
polysaccharides

The reverse of this reaction, the formation of two monosaccharides from one disaccharide, is called a hydrolysis reaction and requires one water molecule to supply the H and OH to the sugars formed.

Sucrose is used in many plants for transporting food reserves, often from the leaves to other parts of the plant.
Lactose is the sugar found in the milk of mammals and maltose is the first product of starch digestion
and is further broken down to glucose before absorption in the human gut.

14,496

[7,248-7,248]

Disaccharides

Disaccharides are one of the four basic categories of carbohydrates,
(the others are monosaccharides, oligosaccharides, and polysaccharides)

Monosaccharides, such as glucose, are the monomers out of which disaccharides are constructed.

C12-(H2O)11

Disaccharides & condensed disaccharides can bond together and form cyclic polysaccharides

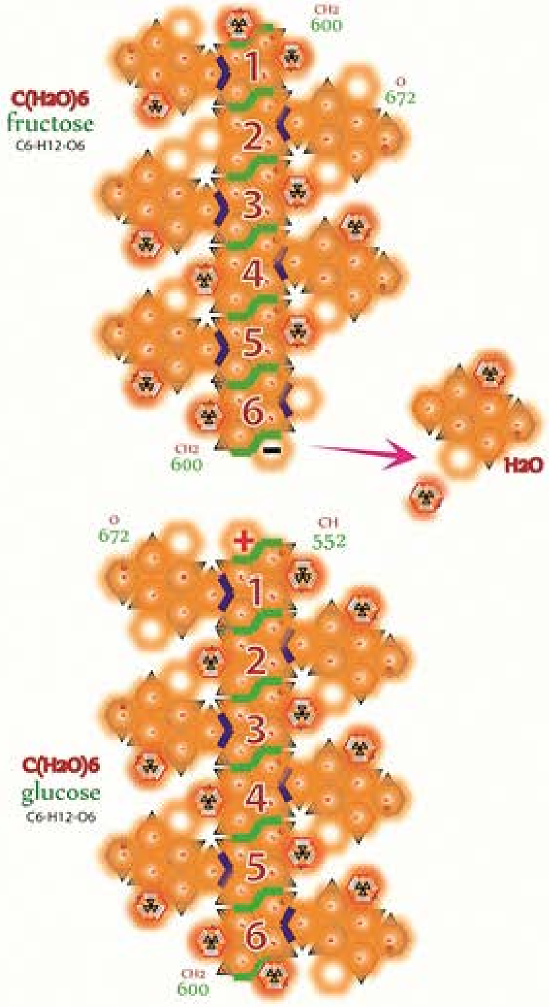
C(H2O)6
fructose
C6-H12-O6
CH2
600
O
672
1
2
3
4
5
6
CH2
600
−
H2O
O
672
+
CH
552
1
2
3
4
5
6
C(H2O)6
glucose
C6-H12-O6
CH2
600

sucrose
C12-H22-O11

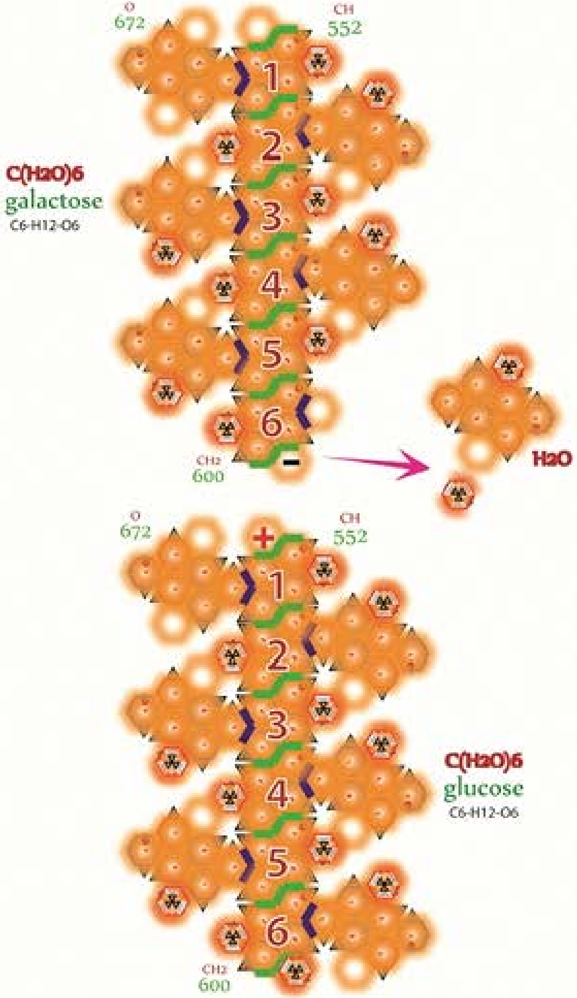
O
672
CH
552
C(H2O)6
galactose
C6-H12-O6
1
2
3
4
5
6
CH2
600
−
H2O
O
672
+
CH
552
1
2
3
4
5
6
C(H2O)6
glucose
C6-H12-O6
CH2
600

lactose
C12-H22-O11

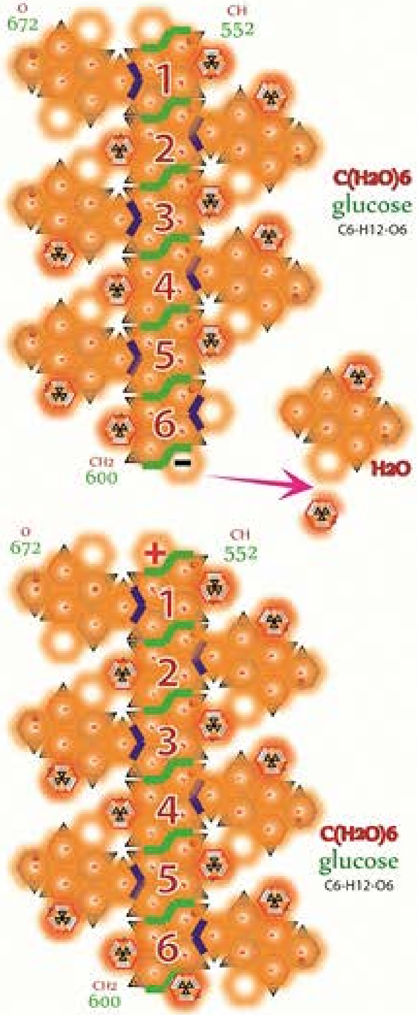
O
672
CH
552
1
2
3
4
5
6
C(H2O)6
glucose
C6-H12-O6
CH2
600
−
H2O
O
672
+
CH
552
1
2
3
4
5
6
C(H2O)6
glucose
C6-H12-O6
CH2
600

maltose
C12-H22-O11

The general chemical formula for carbohydrates, C(H2O),
gives the relative proportions of carbon, hydrogen, and oxygen in a monosaccharide
(the proportion of these atoms are 1:2:1)-(H2O)

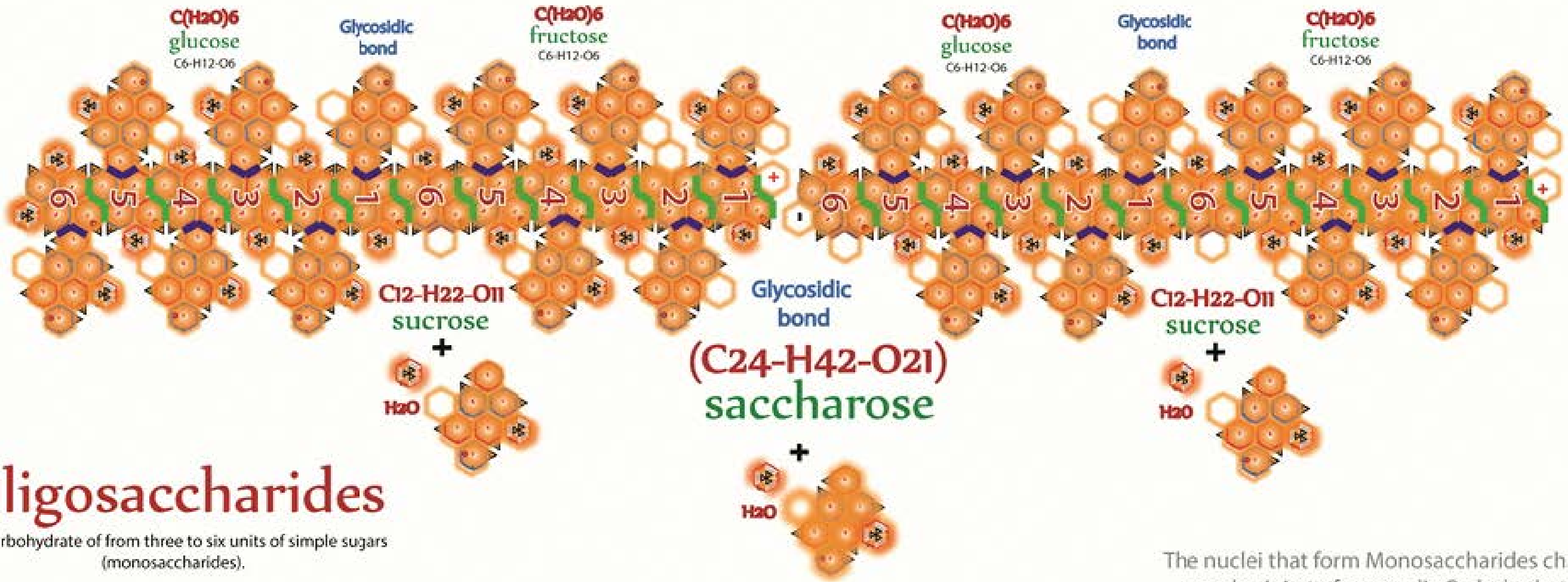
C(H2O)6
glucose
C6-H12-O6
Glycosidic
bond
C(H2O)6
fructose
C6-H12-O6
C(H2O)6
glucose
C6-H12-O6
Glycosidic
bond
C(H2O)6
fructose
C6-H12-O6
6 5 4 3 2 1 6 5 4 3 2 1
6 5 4 3 2 1 6 5 4 3 2 1
C12-H22-O11
sucrose
+
H2O
Glycosidic
bond
(C24-H42-O21)
saccharose
+
H2O
C12-H22-O11
sucrose
+
H2O

Oligosaccharides

any carbohydrate of from three to six units of simple sugars (monosaccharides).

The nuclei that form Monosaccharides chains can also join to form cyclic Carbohydrates [Polysaccharides]

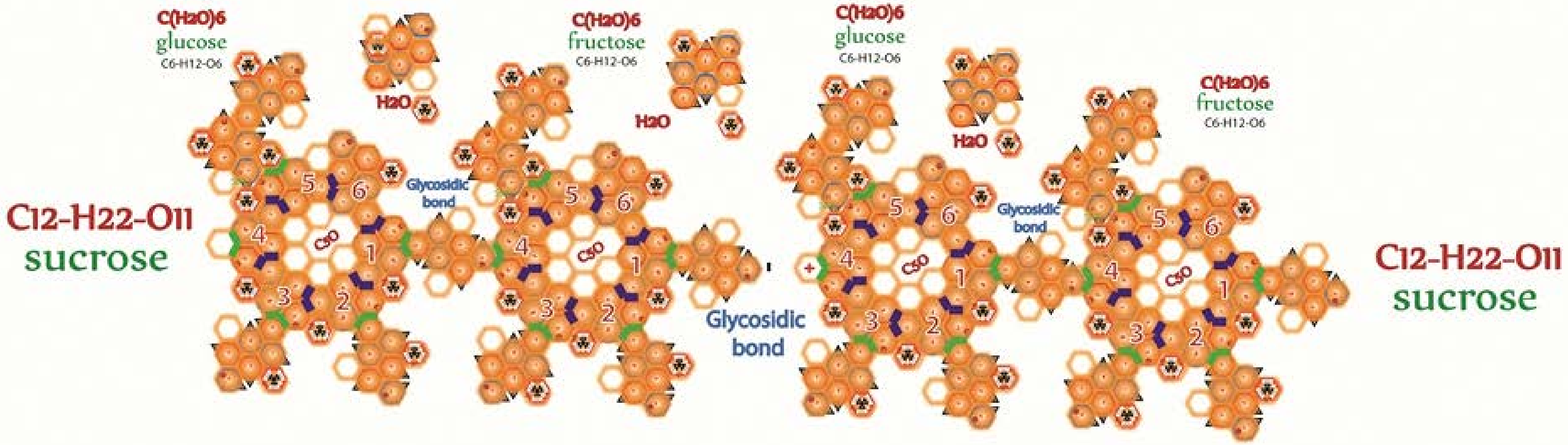
C(H2O)6
glucose
C6-H12-O6
H2O
C(H2O)6
fructose
C6-H12-O6
H2O
C(H2O)6
glucose
C6-H12-O6
H2O
C(H2O)6
fructose
C6-H12-O6
C12-H22-O11
sucrose
5 6 4 C6O 1 3 2
Glycosidic
bond
5 6 4 C6O 1 3 2
Glycosidic
bond
5 6 4 C6O 1 3 2
Glycosidic
bond
5 6 4 C6O 1 3 2
C12-H22-O11
sucrose

An oligosaccharide is a saccharide polymer containing a small number (typically two to ten) component sugars (monosaccharides). Oligosaccharides can have many functions; for example, they are commonly found on the plasma membrane of animal cells where they can play a role in cell–cell recognition.

Starch or amylum is a carbohydrate consisting of a large number of glucose units joined by glycosidic bonds. This polysaccharide is produced by most green plants as an energy store.

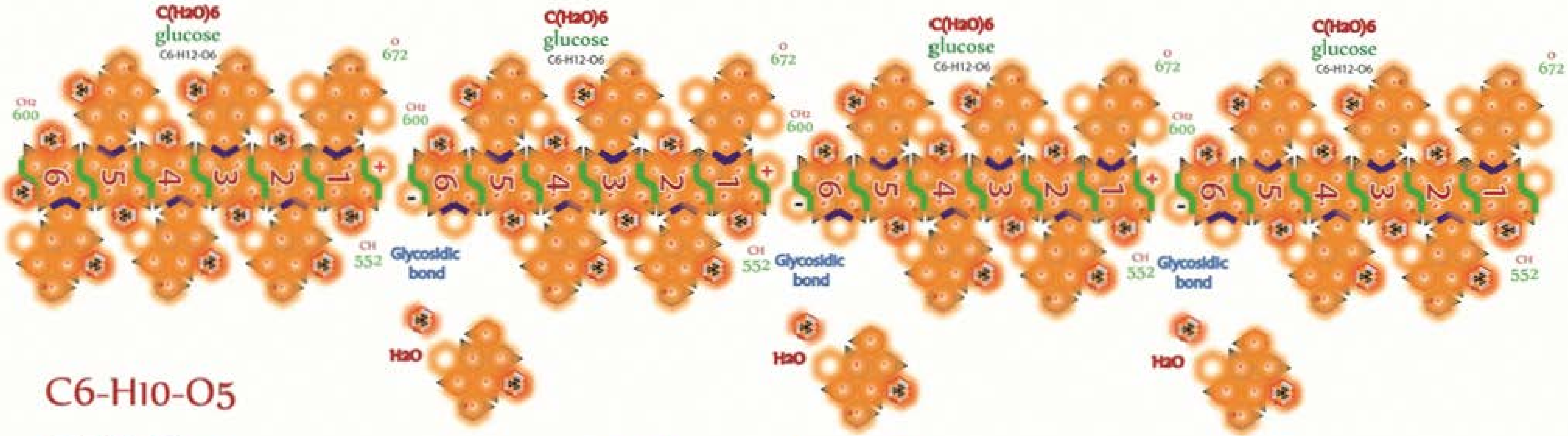
C(H2O)6
glucose
C6-H12-O6
O
672
CH2
600
CH
552
Glycosidic bond
H2O
6
5
4
3
2
1
+
-

C6-H10-O5

6,864 n

[3,432-3,432]

Polysaccharides

Polysaccharides have a general formula of Cx(H2O)y where x is usually a large number between 200 and 2500.

The repeating units in a Polysaccharide polymer backbone are often six-carbon monosaccharides, their general formula can be represented as (C6-H10-O5)n

$C_x[H2O]_y$

Polysaccharides are generally comprised of chains of cyclic monosaccharides

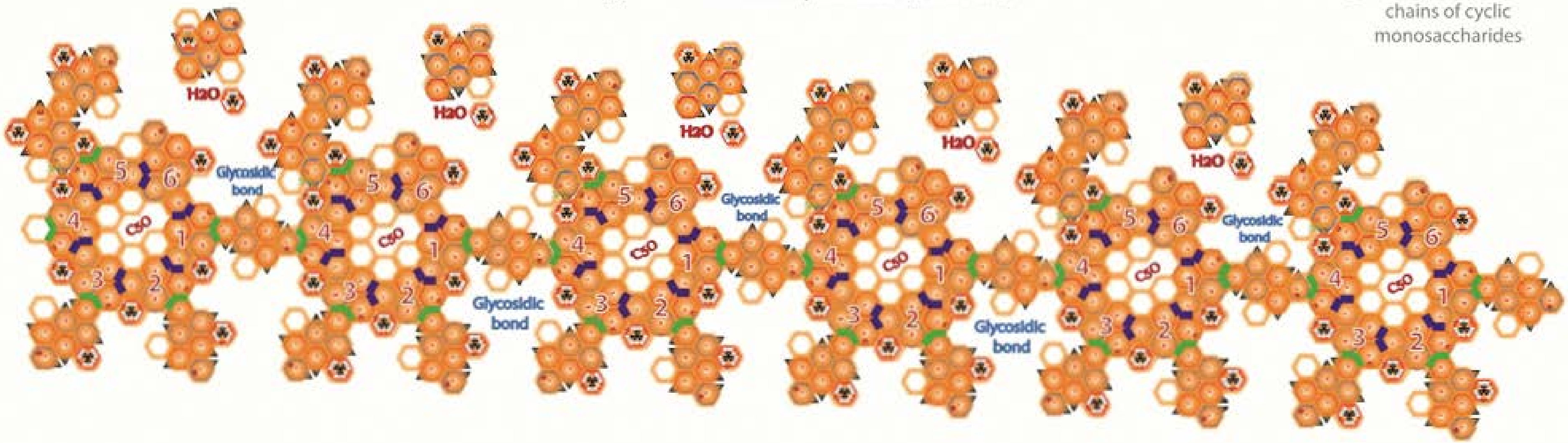
H2O
Glycosidic bond
C5O
1
2
3
4
5
6

Cellulose is an organic compound with the formula (C6H10O5)n, a polysaccharide consisting of a linear chain of several hundred to over ten thousand linked D-glucose sugars.

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Amines

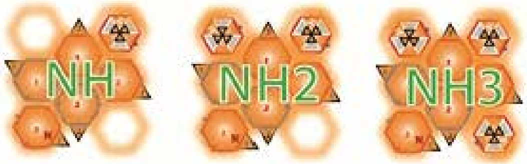

Amines are organic compounds that contain Nitrogen

$NH_2\text{-}[HC\text{-}R]\text{-}COOH$ + $NH_2\text{-}[HC\text{-}R]\text{-}COOH$

As both the amine and carboxylic acid groups of amino acids can react to form amide bonds, one amino acid molecule can react with another and become joined through an amide linkage. This polymerization of amino acids is what creates proteins.

$OH + NH_2$ -----> $NH + H_2O$

This yields a peptide bond and a molecule of water
via a condensation reaction

Carboxylic Acids

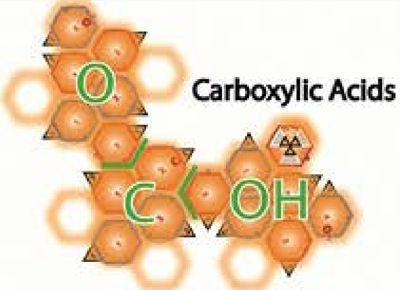

The general formula of a carboxylic acid is R-COOH

Amino Acids

Amino acids are biologically important organic compounds made from amine and carboxylic acid functional groups, along with a side-chain specific to each amino acid

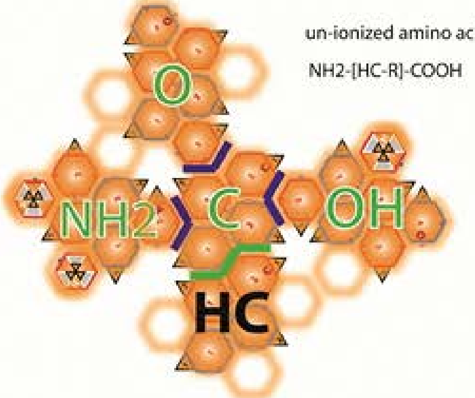

un-ionized amino acid

$NH_2\text{-}[HC\text{-}R]\text{-}COOH$

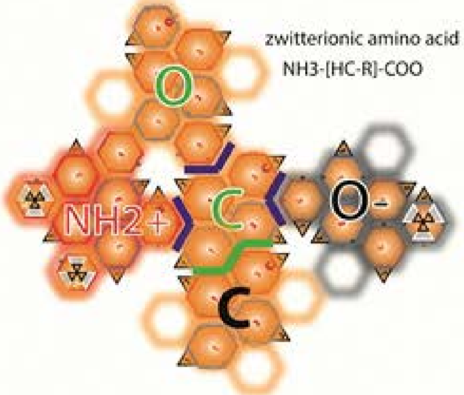

zwitterionic amino acid

$NH_3\text{-}[HC\text{-}R]\text{-}COO$

The α-carbon.

The α-amino acids in peptides and proteins consist of a carboxylic acid (-COOH) and an amino (-NH2) functional group attached to the same tetrahedral carbon atom

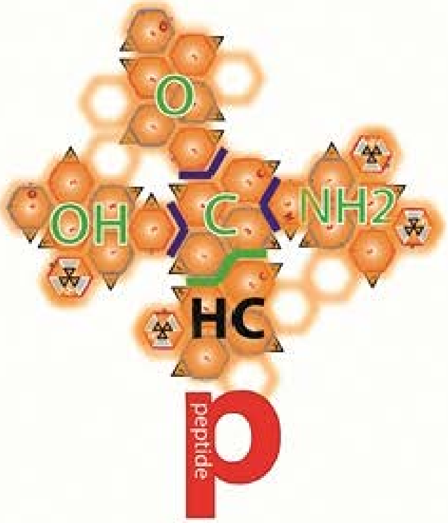

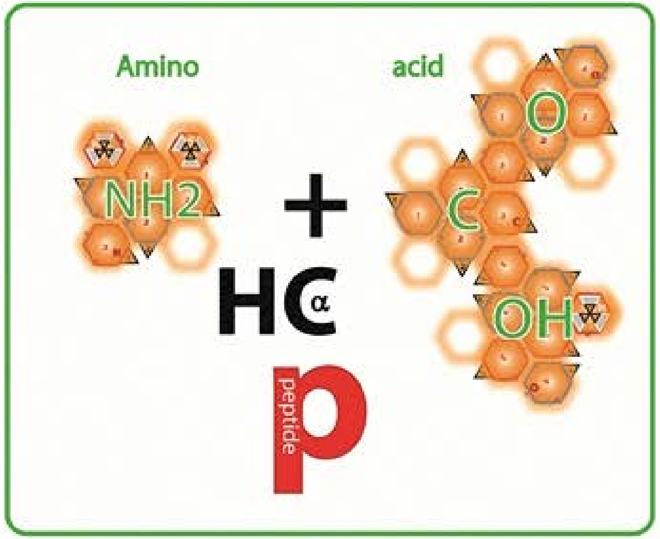

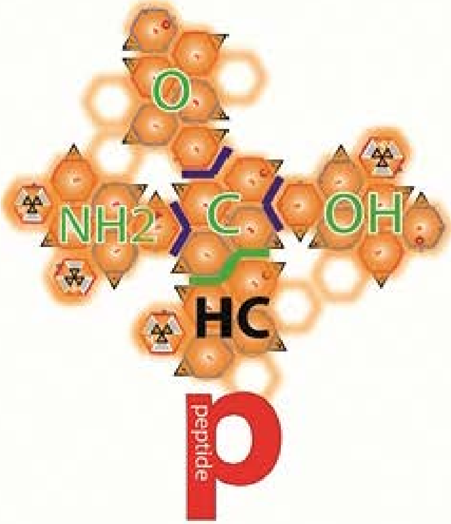

The peptide group attached to the alpha carbon distinguishes one amino acid from another (Tetryonic theory defines these compound side-chains of atoms as peptides [p])

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Peptide side chains

Amino acids are the structural units (monomers) that join together
to form short polymer chains called peptides;
or longer chains called either polypeptides or proteins

AAA
AAG
AAC
AAU
AGA
AGG
AGC
AGU
ACA
ACG
ACC
ACU
AUA
AUG
AUC
AUU

A
C5-H5-N5
Adenine

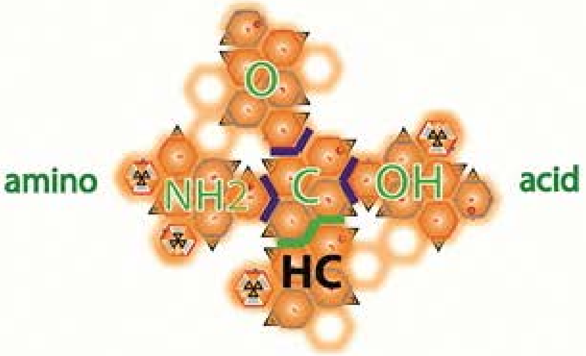

CAA
CAG
CAC
CAU
CGA
CGG
CGC
CGU
CCA
CCG
CCC
CCU
CUA
CUG
CUC
CUU

C
C4-H5-N3-O
Cytosine

3,180
Gly
C2H5NO2

3,780
Ala
C3H7NO2

4,452
Ser
C3H7NO3

4,884
Pro
C5H9NO2

4,980
Val
C5H11NO2

5,052
Thr
C4H9NO3

5,124
Cys
C3H7NO2S

5,580
Lle
C6H13NO2

5,580
Leu
C6H13NO2

5,592
Asn
C4H8N2O3

5,628
Asp
C4H7NO4

p
peptide side chain

*current chemical theory
hypothesizes that all
peptides and proteins
are the result of codon
triplet side chains
on amino acids*

*Tetryonic theory reveals
serious flaws in this line
of thought*

6,192
Gln
C5H10N2O3

6,216
Lys
C6H14N2O2

6,228
Glu
C5H9NO4

6,324
Met
C5H11NO2S

6,564
His
C6H9N3O2

6,996
Phe
C9H11NO2

7,392
Arg
C6H14N4O2

7,668
Tyr
C9H11NO3

8,640
Trp
C11H12N2O2

GAA
GAG
GAC
GAU
GGA
GGG
GGC
GGU
GCA
GCG
GCC
GCU
GUA
GUG
GUC
GUU

G
C5-H5-N5-O
Guanine

UAA
UAG
UAC
UAU
UGA
UGG
UGC
UGU
UCA
UCG
UCC
UCU
UUA
UUG
UUC
UUU

U
C4-H4-N2-O2
Uracil

Tetryonics 59.10 - Peptide side chains.jpg

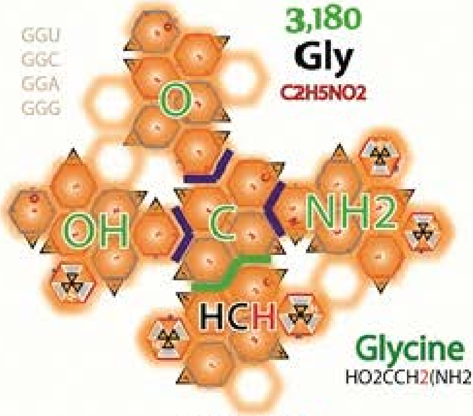
O
OH
C
NH2
HCH

GGU
GGC
GGA
GGG

3,180

Gly

$C_2H_5NO_2$

Glycine

$HO_2CCH_2(NH_2)$

HCH

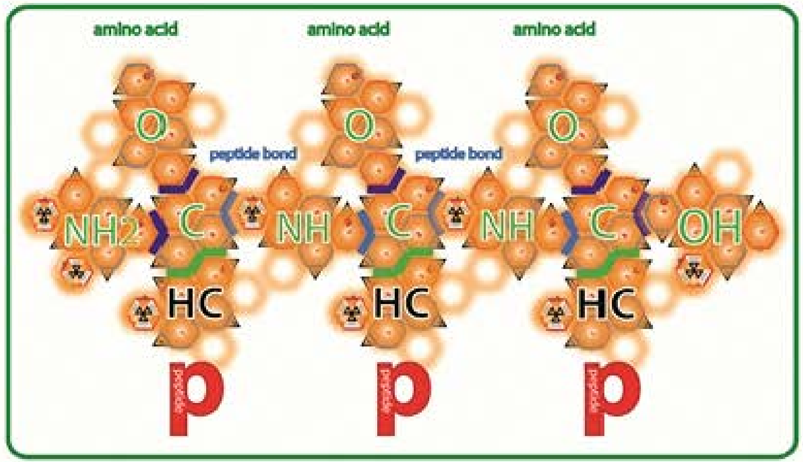
amino acid
amino acid
amino acid
O
O
O
peptide bond
peptide bond
NH2
C
NH
C
NH
C
OH
HC
HC
HC
p
p
p
peptide
peptide
peptide

poly-peptide chains

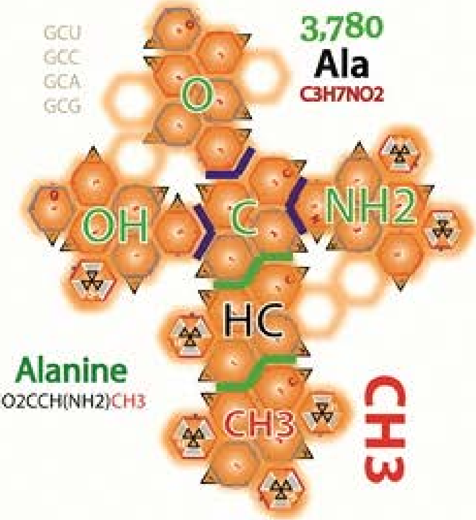
O
OH
C
NH2
HC
CH3
CH3

GCU
GCC
GCA
GCG

3,780

Ala

$C_3H_7NO_2$

Alanine

$HO_2CCH(NH_2)CH_3$

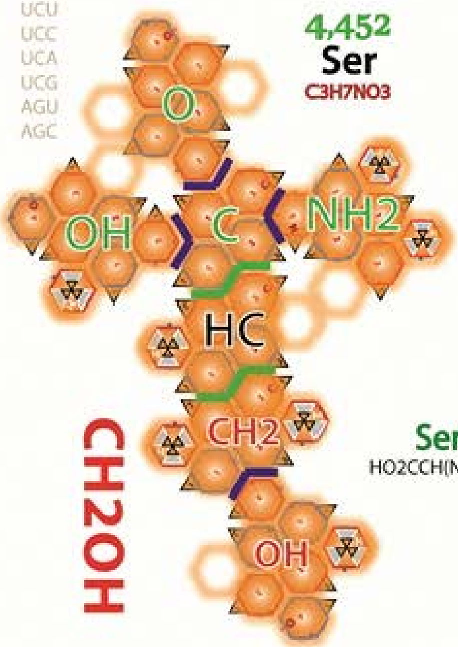
O
OH
C
NH2
HC
CH2
OH
CH2OH

UCU
UCC
UCA
UCG
AGU
AGC

4,452

Ser

$C_3H_7NO_3$

Serine

$HO_2CCH(NH_2)CH_2OH$

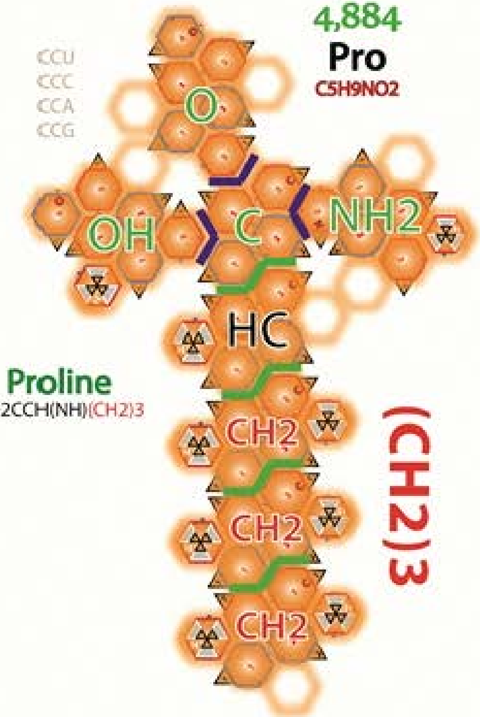
O
OH
C
NH2
HC
CH2
CH2
CH2
(CH2)3

CCU
CCC
CCA
CCG

4,884

Pro

$C_5H_9NO_2$

Proline

$HO_2CCH(NH)(CH_2)_3$

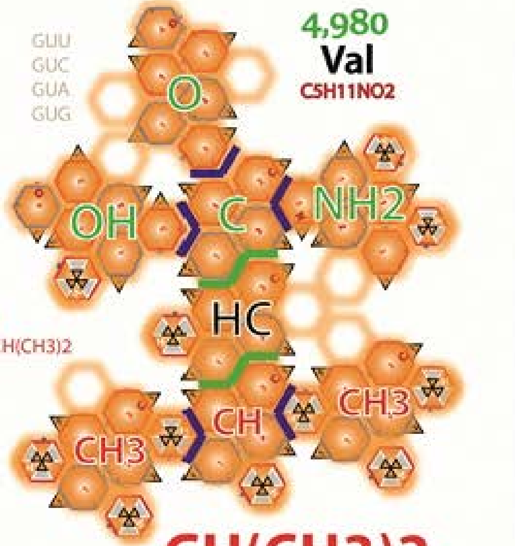
O
OH
C
NH2
HC
CH3
CH
CH3

GUU
GUC
GUA
GUG

4,980

Val

$C_5H_{11}NO_2$

Valine

$HO_2CCH(NH_2)CH(CH_3)_2$

CH(CH3)2

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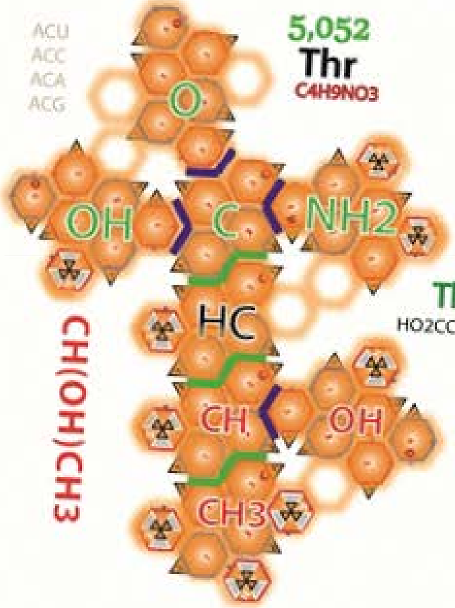
ACU
ACC
ACA
ACG
O
OH
C
NH2
HC
CH
OH
CH3

5,052
Thr
C4H9NO3

Threonine
HO2CCH(NH2)CH(OH)CH3

CH(OH)CH3

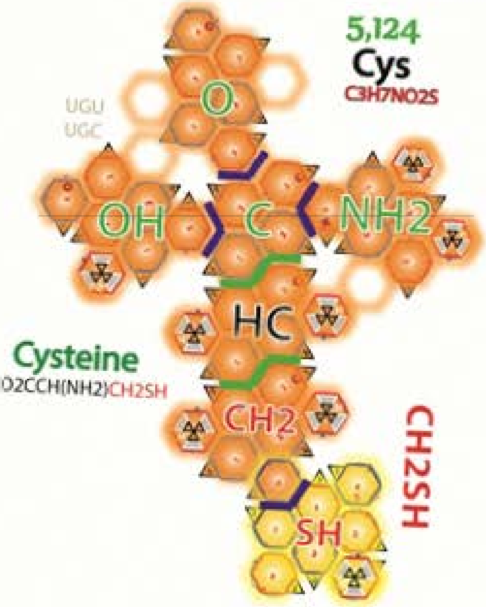
UGU
UGC
O
OH
C
NH2
HC
CH2
SH

5,124
Cys
C3H7NO2S

Cysteine
HO2CCH(NH2)CH2SH

CH2SH

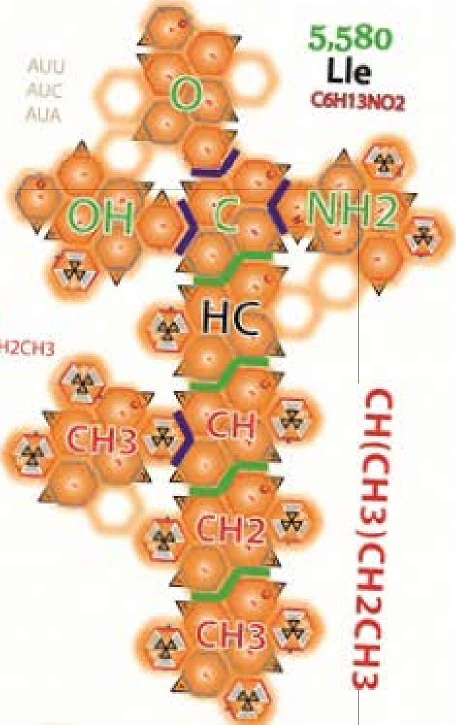
AUU
AUC
AUA
O
OH
C
NH2
HC
CH3
CH
CH2
CH3

5,580
Ile
C6H13NO2

Isoleucine
HO2CCH(NH2)CH(CH3)CH2CH3

CH(CH3)CH2CH3

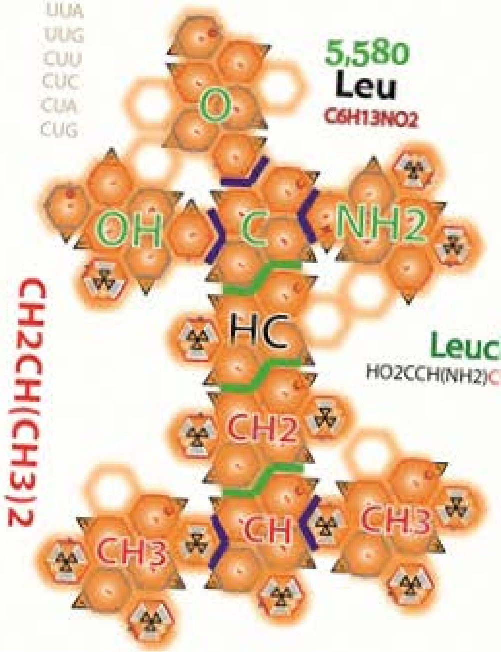
UUA
UUG
CUU
CUC
CUA
CUG
O
OH
C
NH2
HC
CH2
CH3
CH
CH3

5,580
Leu
C6H13NO2

Leucine
HO2CCH(NH2)CH2CH(CH3)2

CH2CH(CH3)2

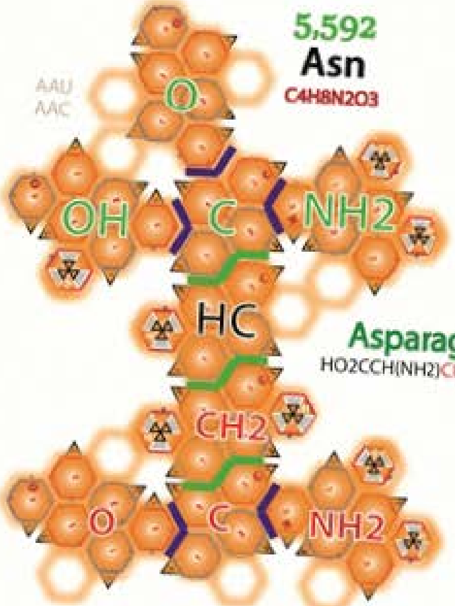
AAU
AAC
O
OH
C
NH2
HC
CH2
O
C
NH2

5,592
Asn
C4H8N2O3

Asparagine
HO2CCH(NH2)CH2CO(NH2)

CH2CO(NH2)

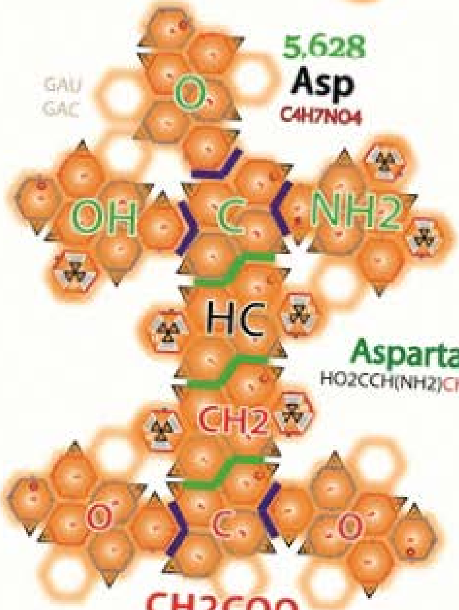
GAU
GAC
O
OH
C
NH2
HC
CH2
O
C
O

5,628
Asp
C4H7NO4

Aspartate
HO2CCH(NH2)CH2COO

CH2COO

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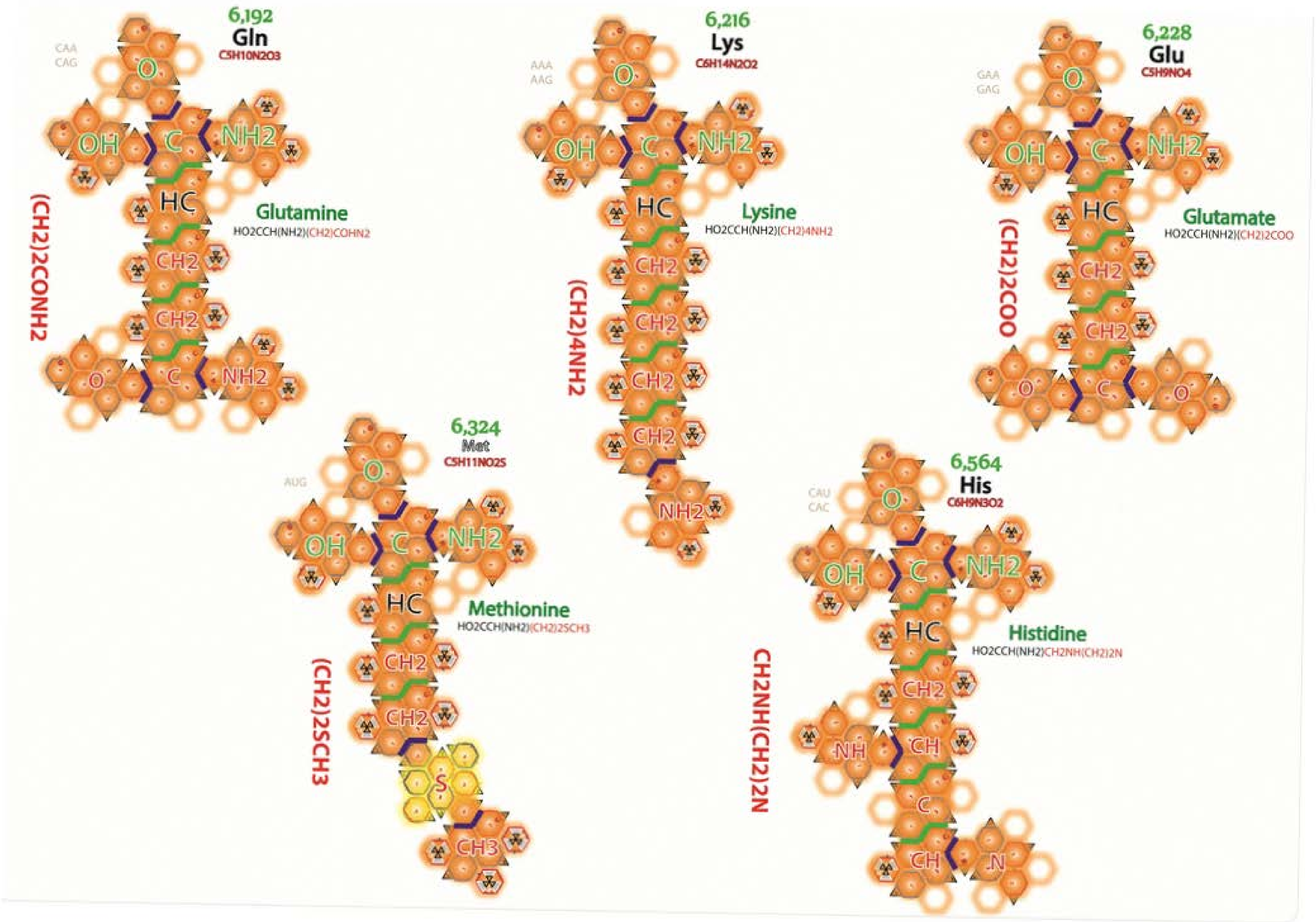
6,192
Gln
C5H10N2O3
CAA
CAG
O
OH
C
NH2
HC
CH2
CH2
O
C
NH2
Glutamine
HO2CCH(NH2)(CH2)COHN2
(CH2)2CONH2
6,216
Lys
C6H14N2O2
AAA
AAG
O
OH
C
NH2
HC
CH2
CH2
CH2
CH2
NH2
Lysine
HO2CCH(NH2)(CH2)4NH2
(CH2)4NH2
6,228
Glu
C5H9NO4
GAA
GAG
O
OH
C
NH2
HC
CH2
CH2
O
C
O
Glutamate
HO2CCH(NH2)(CH2)2COO
(CH2)2COO
6,324
Met
C5H11NO2S
AUG
O
OH
C
NH2
HC
CH2
CH2
S
CH3
Methionine
HO2CCH(NH2)(CH2)2SCH3
(CH2)2SCH3
6,564
His
C6H9N3O2
CAU
CAC
O
OH
C
NH2
HC
CH2
NH
CH
C
CH
N
Histidine
HO2CCH(NH2)CH2NH(CH2)2N
CH2NH(CH2)2N

Tetryonics 59.13 - Peptides [3]

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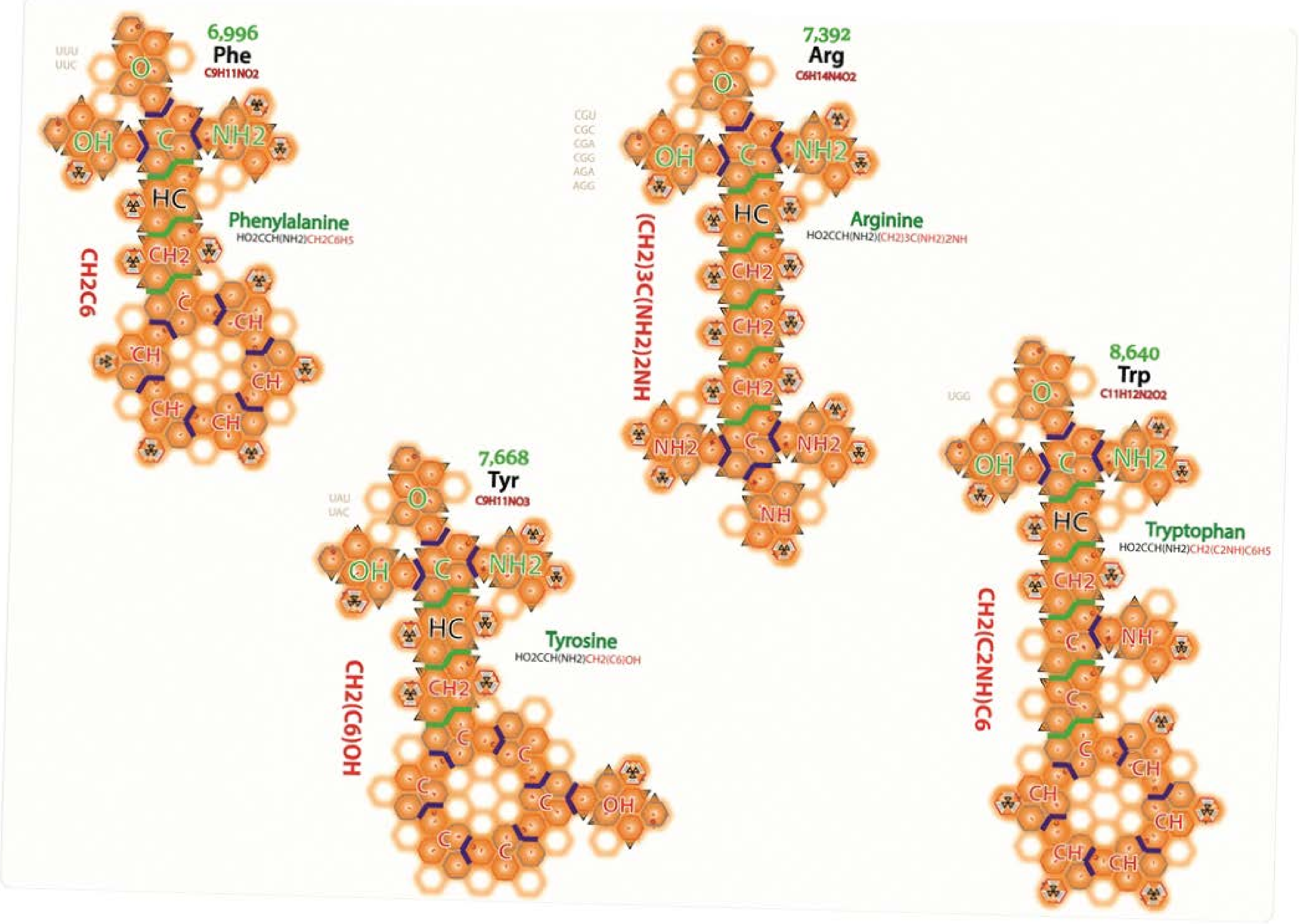
UUU
UUC
6,996
Phe
C9H11NO2
O
OH
C
NH2
HC
Phenylalanine
HO2CCH(NH2)CH2C6H5
CH2
CH2C6
C
CH
CH
CH
CH
CH
CGU
CGC
CGA
CGG
AGA
AGG
7,392
Arg
C6H14N4O2
O
OH
C
NH2
HC
Arginine
HO2CCH(NH2)(CH2)3C(NH2)2NH
(CH2)3C(NH2)2NH
CH2
CH2
CH2
NH2
C
NH2
NH
UAU
UAC
7,668
Tyr
C9H11NO3
O
OH
C
NH2
HC
Tyrosine
HO2CCH(NH2)CH2(C6)OH
CH2(C6)OH
CH2
C
C
C
C
OH
C
C
UGG
8,640
Trp
C11H12N2O2
O
OH
C
NH2
HC
Tryptophan
HO2CCH(NH2)CH2(C2NH)C6H5
CH2(C2NH)C6
CH2
C
NH
C
C
CH
CH
CH
CH
CH

Peptide Bonds

The four-atom functional group
-CONH- is called a peptide link.

Polypeptide chains of amino acids
arre held together by peptide bonds

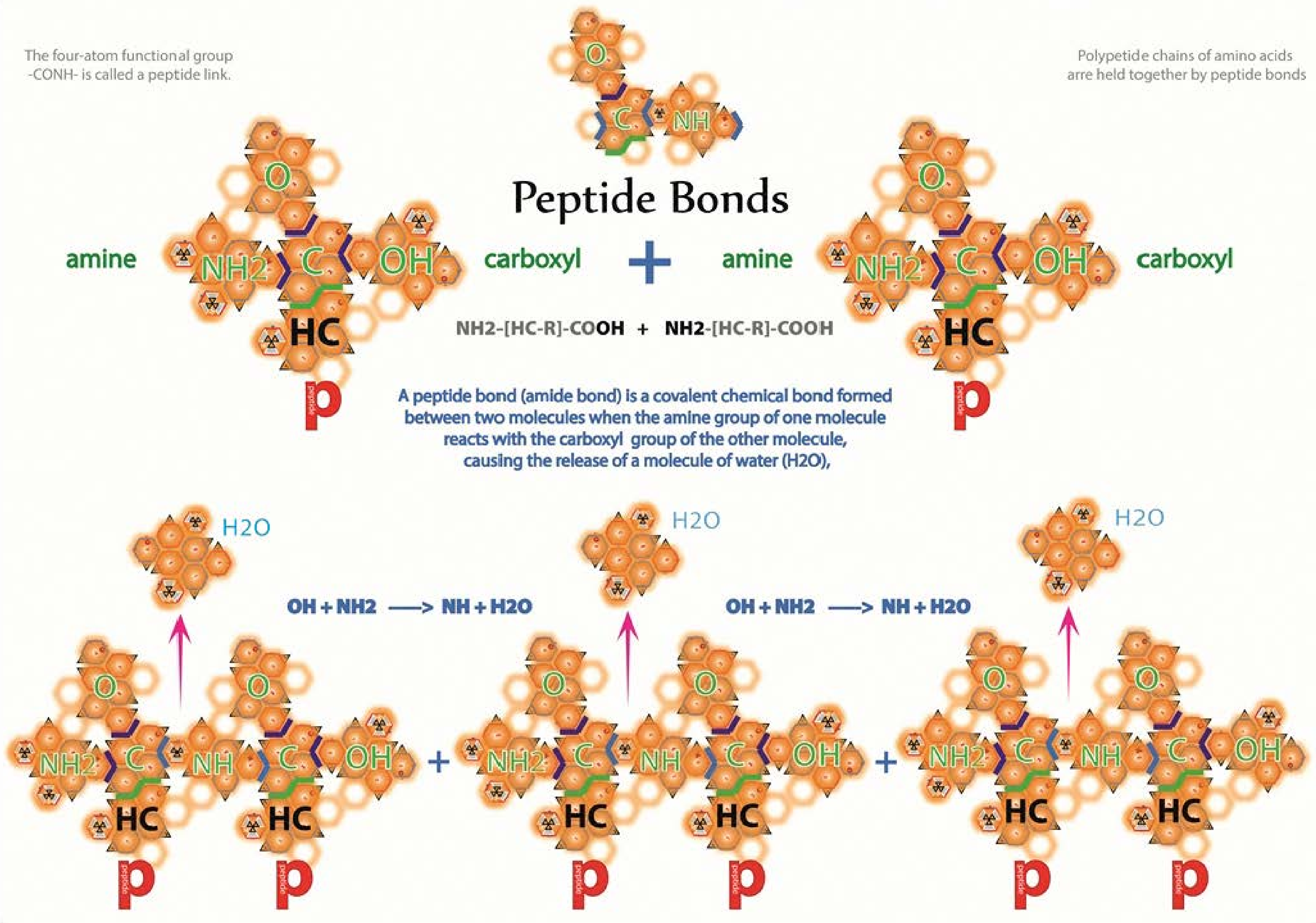
O
C
NH
amine
NH2
C
OH
O
HC
carboxyl
+
amine
NH2
C
OH
O
HC
carboxyl
p
peptide
p
peptide
H2O
H2O
H2O
NH2
C
NH
C
OH
+
NH2
C
NH
C
OH
+
NH2
C
NH
C
OH
HC
HC
HC
HC
HC
HC
O
O
O
O
O
O
p
p
p
p
p
p

NH2-[HC-R]-COOH + NH2-[HC-R]-COOH

A peptide bond (amide bond) is a covalent chemical bond formed
between two molecules when the amine group of one molecule
reacts with the carboxyl group of the other molecule,
causing the release of a molecule of water (H2O),

OH + NH2 ——> NH + H2O

OH + NH2 ——> NH + H2O

Tetryonics 59.15 - Peptide bonds

amino terminus

The beginning of a polypeptide protein molecule has a free amino group.

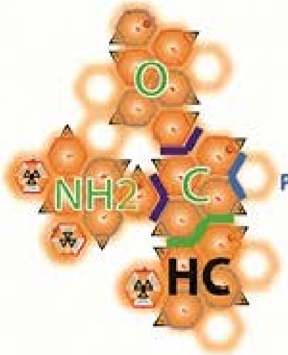

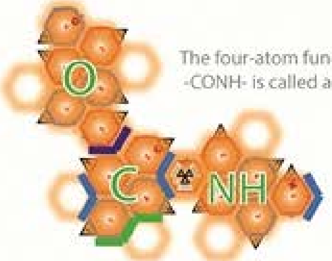

The four-atom functional group -CONH- is called a peptide link.

carboxy terminus

The end of a polypeptide protein molecule has a free carboxyl group.

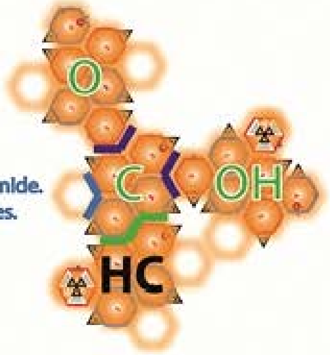

Proteins [poly-peptides] are formed by joining the -CO2H [carboxyl] end of one amino acid with the -NH2 [amine] end of another to form an amide. The -CONH- bond between amino acids is known as a peptide bond because relatively short polymers of amino acids are known as peptides.

polypeptide chains

Proteins are formed when amino acids are covalently linked together.

DNA and RNA have a deoxyribose and ribose sugar backbone, respectively, whereas PNA's backbone is composed of repeating (2-aminoethyl)-glycine units linked by peptide bonds.

Proteins (polypeptides) are chains of amino acids held together by peptide bonds which form the backbone stringers of PNA, RNA & DNA.

Proteins

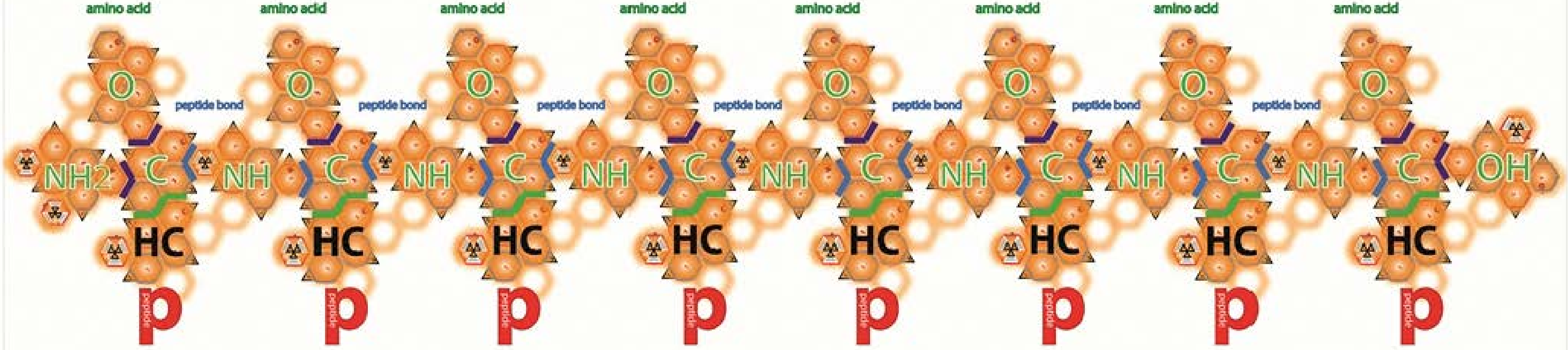
amino acid
amino acid
amino acid
amino acid
amino acid
amino acid
amino acid
amino acid
peptide bond
peptide bond
peptide bond
peptide bond
peptide bond
peptide bond
peptide bond
NH2
OH
O
C
NH
HC
p
peptide

There are 20 different nucleotide side chains present in biological molecules.

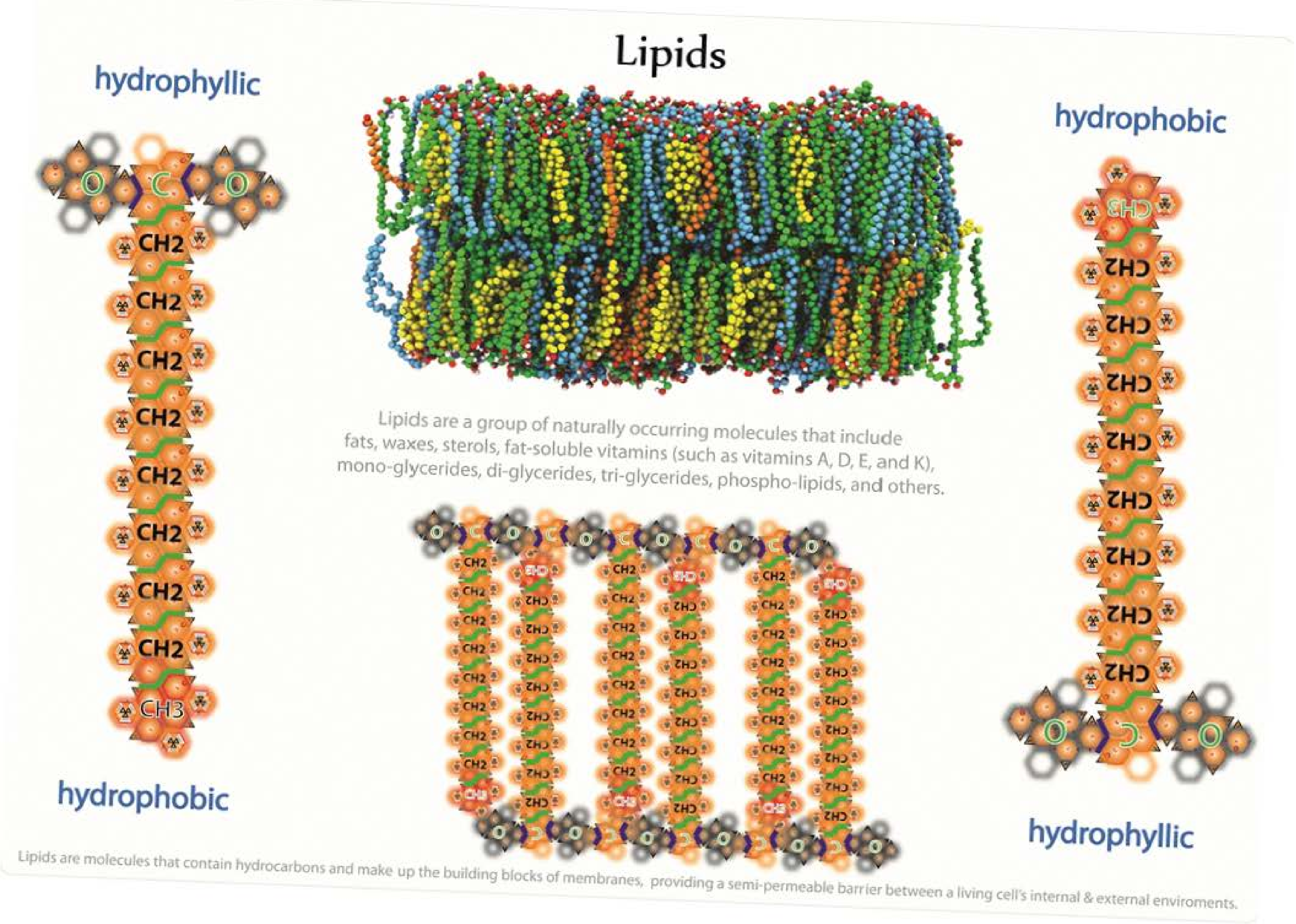

Lipids

Lipids are a group of naturally occurring molecules that include fats, waxes, sterols, fat-soluble vitamins (such as vitamins A, D, E, and K), mono-glycerides, di-glycerides, tri-glycerides, phospho-lipids, and others.

hydrophyllic
O
C
O
CH2
CH2
CH2
CH2
CH2
CH2
CH2
CH2
CH3
hydrophobic
hydrophobic
CH3
CH2
CH2
CH2
CH2
CH2
CH2
CH2
CH2
O
C
O
hydrophyllic

Lipids are molecules that contain hydrocarbons and make up the building blocks of membranes, providing a semi-permeable barrier between a living cell's internal & external enviroments.

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Acetylcholine

is an organic molecule that acts as a neurotransmitter in many organisms, including humans. It is an ester of acetic acid and choline

Ach

C7H16NO2

CH3COO(CH2)2N+(CH3)3

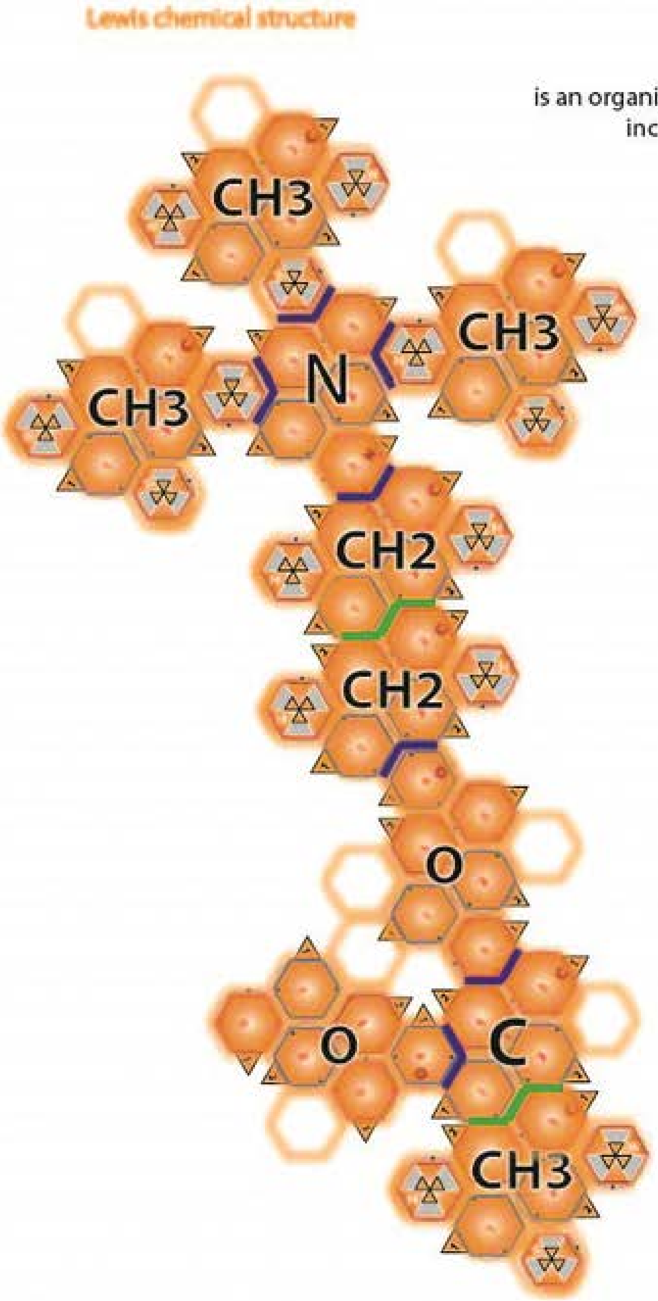
Lewis chemical structure
CH3
CH3
N
CH3
CH2
CH2
O
O
C
CH3

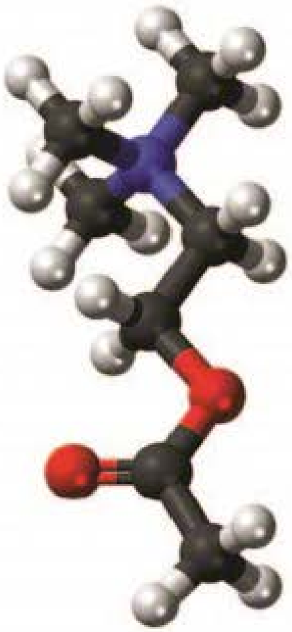

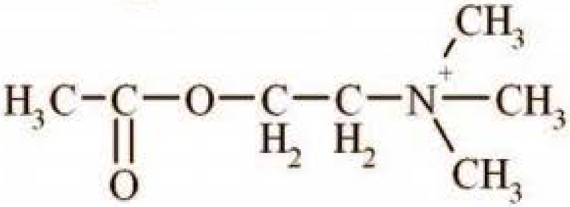

$$\mathrm{H_3C-\underset{\underset{\textstyle O}{\|}}{C}-O-\underset{H_2}{C}-\underset{H_2}{C}-\underset{\diagdown\ CH_3}{\overset{\diagup\ CH_3}{\overset{+}{N}}}-CH_3}$$

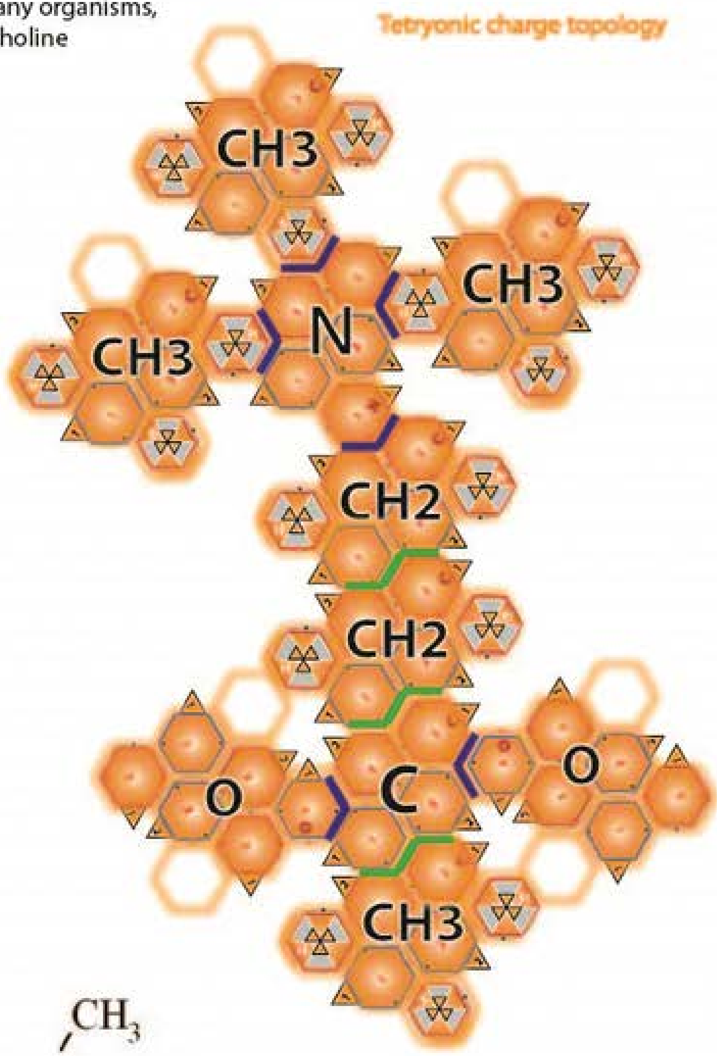
Tetryonic charge topology
CH3
CH3
N
CH3
CH2
CH2
O
C
O
CH3

6,228

Tetryonics 59.18 - Acetylcholine [Ach]

Ribose

6,360

[3,180-3,180]

C5-H10-O5

Carbohydrate compounds can form acyclic sugars

Carbohydrate compounds can also form cyclic sugars

Ribose is an organic compound with the formula C5H10O5; specifically, a monosaccharide (simple sugar) with linear form H–(C=O)–(CHOH)4–H

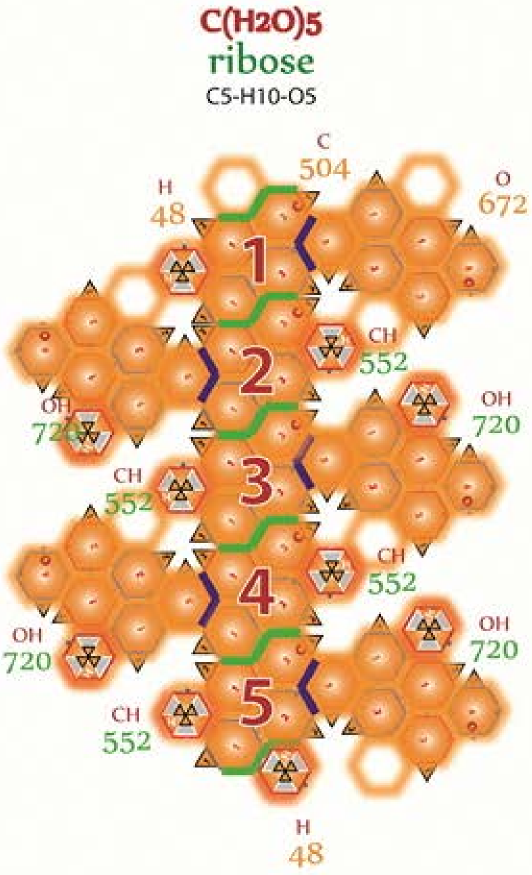
C(H2O)5
ribose
C5-H10-O5
C
504
H
48
O
672
1
2
3
4
5
CH
552
OH
720
CH
552
OH
720
CH
552
OH
720
OH
720
CH
552
H
48

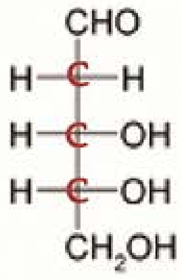
CHO
H C H
H C OH
H C OH
CH2OH

H-(CO)-(CHOH)4-H

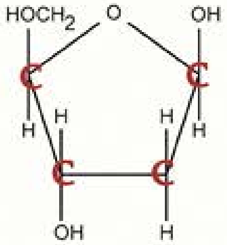
HOCH2
O
OH
C
C
H
H
H
H
C
C
OH
H

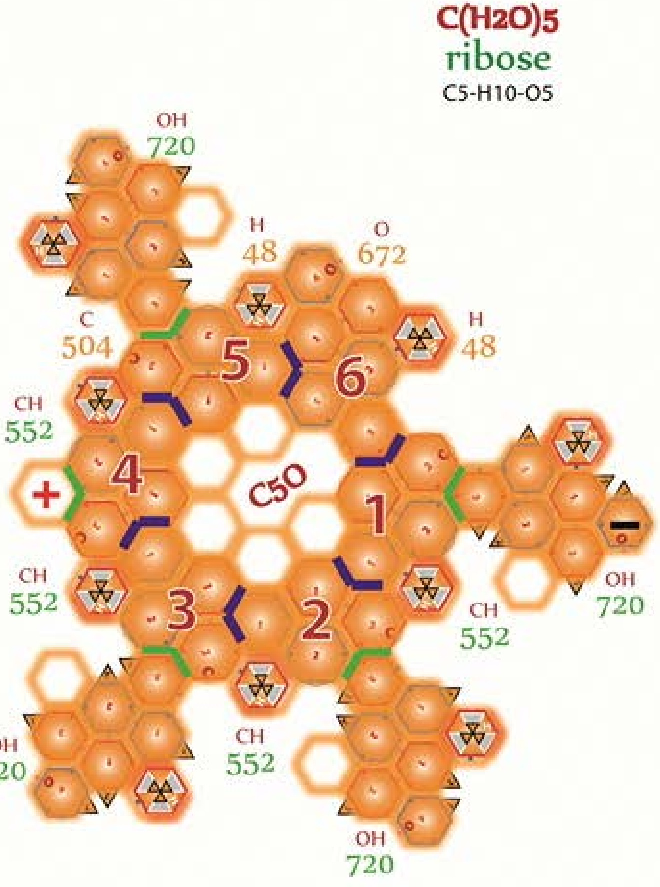
C(H2O)5
ribose
C5-H10-O5
OH
720
H
48
O
672
C
504
H
48
CH
552
5
6
4
C5O
1
+
−
CH
552
3
2
OH
720
CH
552
OH
720
CH
552
OH
720

Ribose forms part of the backbone of RNA.
It is related to deoxyribose, which is found in DNA.

Ribose is present within every living cell of the body and is used to manufacture ATP (the energy currency of the cell) from scratch. Whilst the body can manufacture its own ribose from glucose, this requires energy and is a very slow process.

As its name indicates it is a deoxygenated sugar,
meaning that it is derived from the sugar
ribose by loss of an oxygen atom

Deoxyribose

5,688

[2,844-2,844]

As a component of DNA, 2-deoxyribose derivatives have an important role in biology

The DNA (deoxyribonucleic acid) molecule, which is the main repository of genetic information in life, consists of a long chain of deoxyribose-containing units called nucleotides, linked via phosphate groups

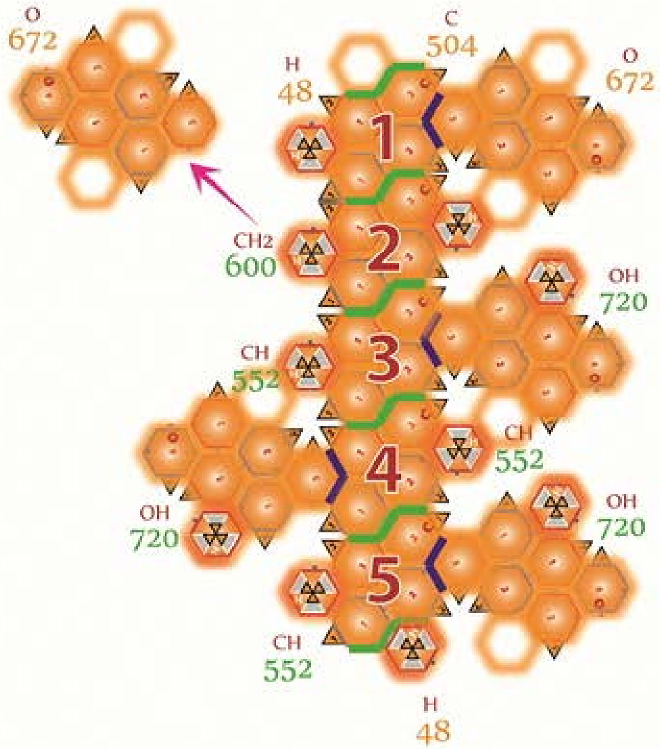
O
672
H
48
C
504
O
672
1
2
CH2
600
OH
720
CH
552
3
CH
552
4
OH
720
OH
720
5
CH
552
H
48

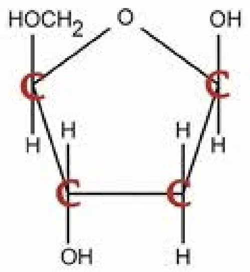
HOCH2
O
OH
C
C
H
H
H
H
C
C
OH
H

Deoxyribose, more, precisely 2-deoxyribose, is a monosaccharide

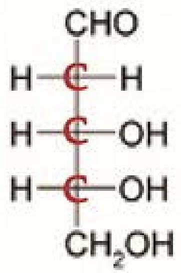

$$\begin{array}{c} CHO \\ H-C-H \\ H-C-OH \\ H-C-OH \\ CH_2OH \end{array}$$

C5-H10-O4
deoxyribose

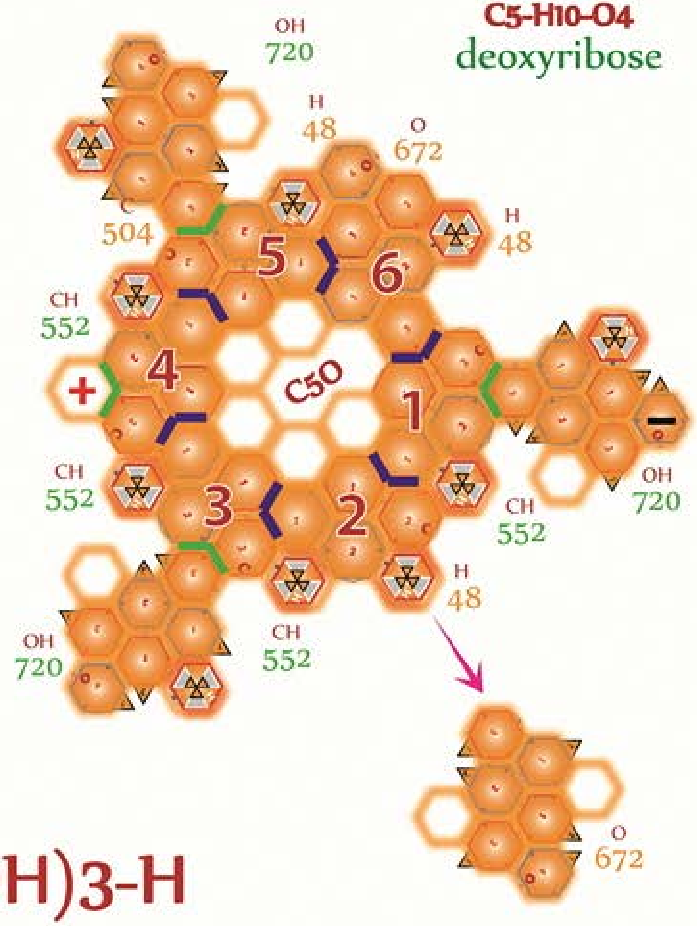
OH
720
H
48
O
672
C
504
H
48
5
6
CH
552
4
+
C5O
1
−
CH
552
3
2
OH
720
CH
552
H
48
OH
720
CH
552
O
672

C5-H10-O4
deoxyribose

H-(CO)-(CH2)-(CHOH)3-H

Hermann Emil Fischer won the Nobel Prize in Chemistry (1902) for his work in determining the structure of the D-aldohexoses.

However, the linear, free-aldehyde structures that Fischer proposed represent a very minor percentage of the forms that hexose sugars adopt in solution. It was Edmund Hirst and Clifford Purves, in the research group of Walter Haworth, who conclusively determined that the hexose sugars preferentially form a pyranose, or six-membered, ring. Haworth drew the ring as a flat hexagon with groups above and below the plane of the ring – the Haworth projection

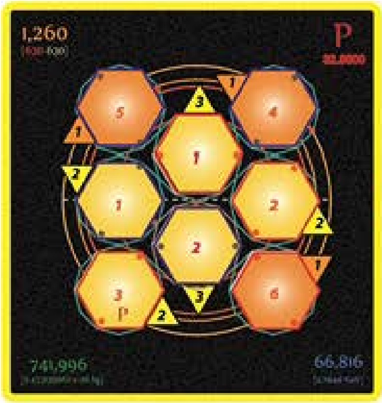
1,260
P
1
2
3
4
5
6
741,996
66,816

Phosporus

3,996

[1,998-1,998]

HPO4

phosphate

group

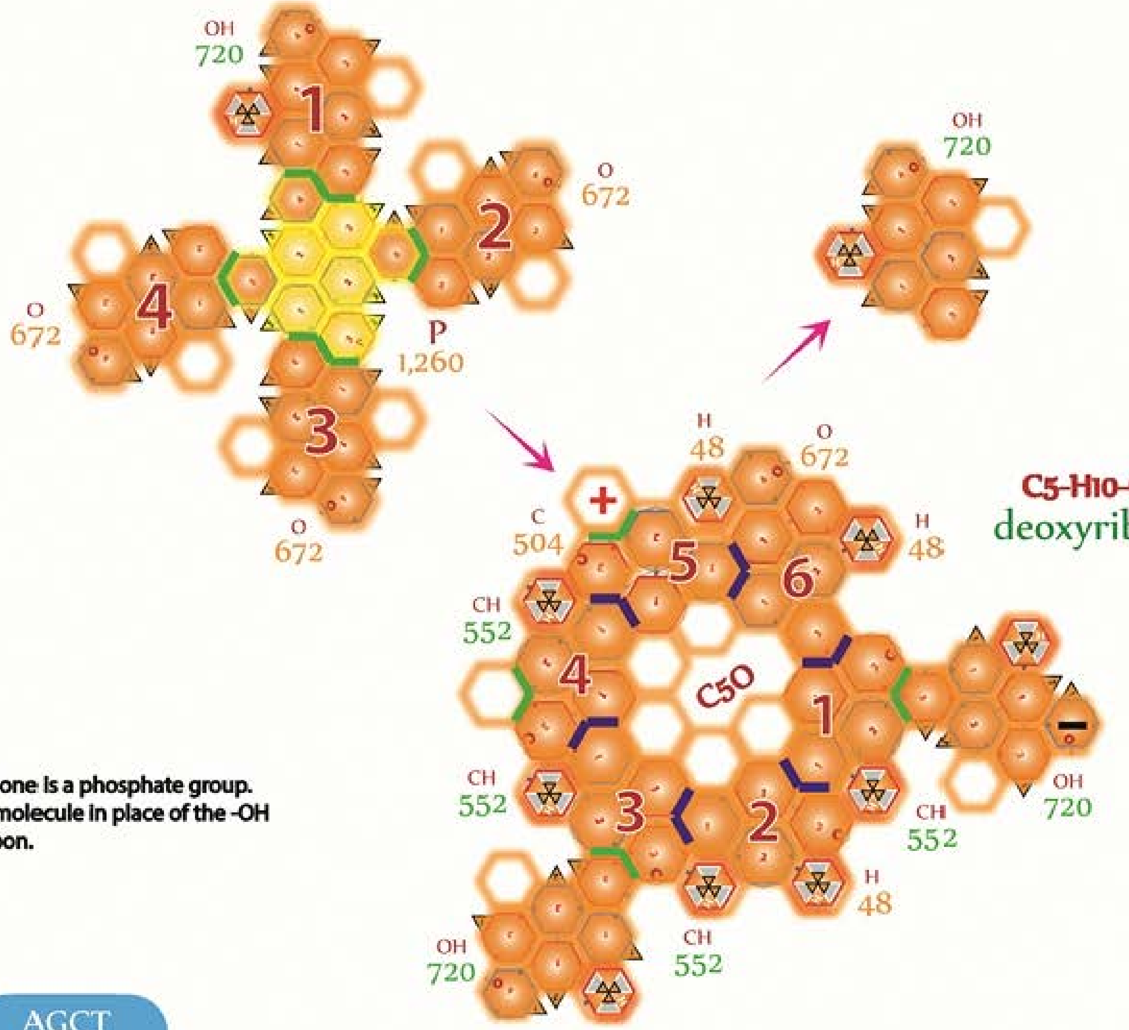
OH
720
1
O
672
2
P
1,260
4
O
672
3
O
672
OH
720
H
48
O
672
H
48
C
504
+
5
6
CH
552
4
C5O
1
−
CH
552
3
2
OH
720
CH
552
H
48
OH
720
CH
552

C5-H10-O4

deoxyribose

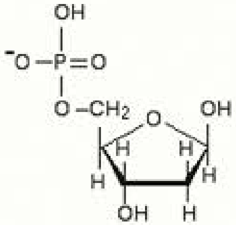
OH
-O
P
O
O
CH2
O
OH
H
H
H
H
OH
H

**The other repeating part of the DNA backbone is a phosphate group.
A phosphate group is attached to the sugar molecule in place of the -OH
group on the 5' carbon.**

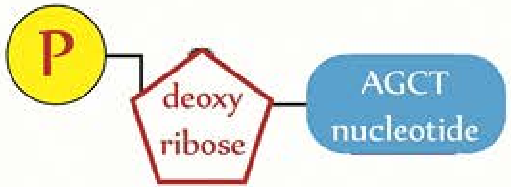
P
deoxy
ribose
AGCT
nucleotide

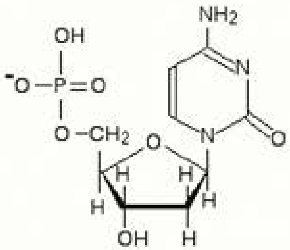
NH2
N
O
N
OH
-O
P
O
O
CH2
O
H
H
H
H
OH
H

5,688

[2,844-2,844]

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Radioactive Decay

The Atom releases excess energies in various forms as it seeks a lower energy, state of equilibria with its surrounding EM energy environment

Energy in all its forms seeks equilibirium

Photons, Heat, Vibration & Kinetics can all raise the energy levels of atomic nuclei

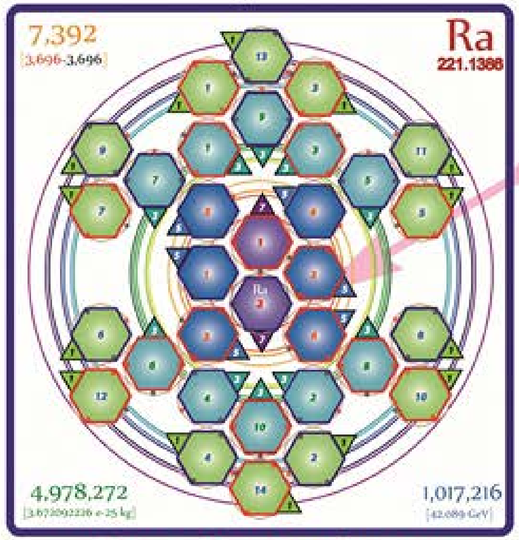
7,392
[3,696-3,696]
Ra
221.1388
4,978,272
1,017,216

stable core electron configurations

The spectral line emissions of photons from bound electrons in addition to Alpha, Beta and Gamma Particle emissions from nuclei can release KEM energies over long time spans

E

scalar equilateral

mass-ENERGY-Matter

geometries

topologies

mc^2

Mc^4

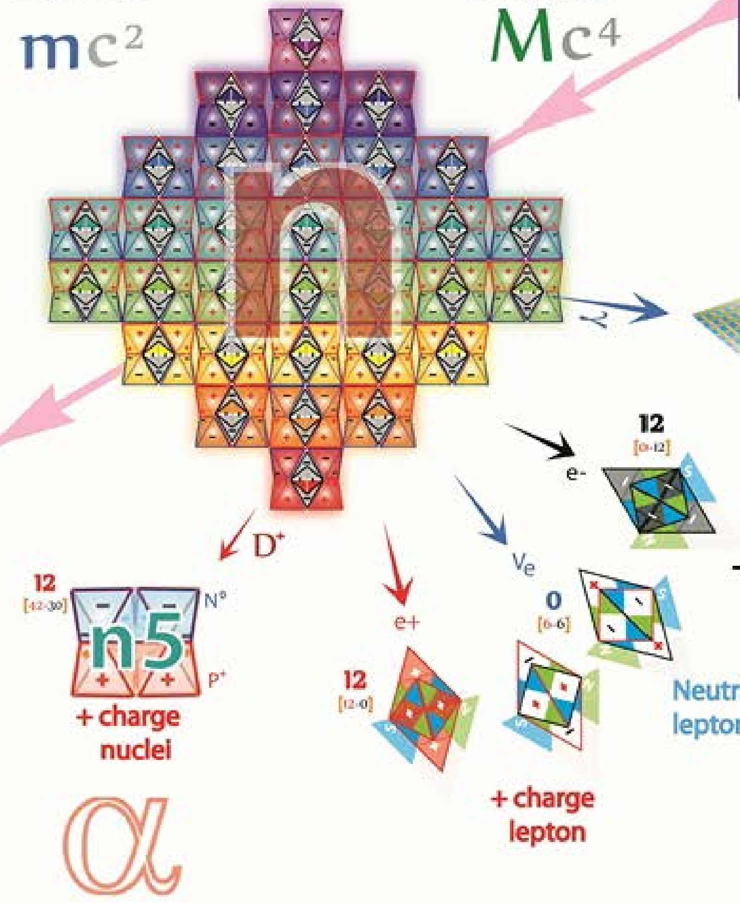
n
D⁺
12
[42-30]
N°
P⁺
n5
e+
12
[12-0]
Ve
0
[6-6]
e-
12
[0-12]
α

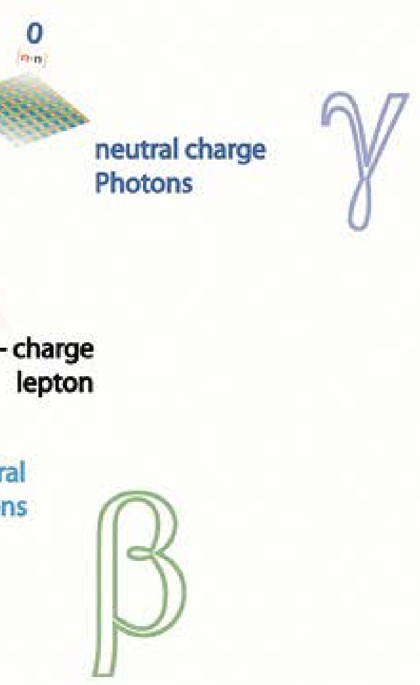

neutral charge Photons

- charge lepton

Neutral leptons

+ charge nuclei

+ charge lepton

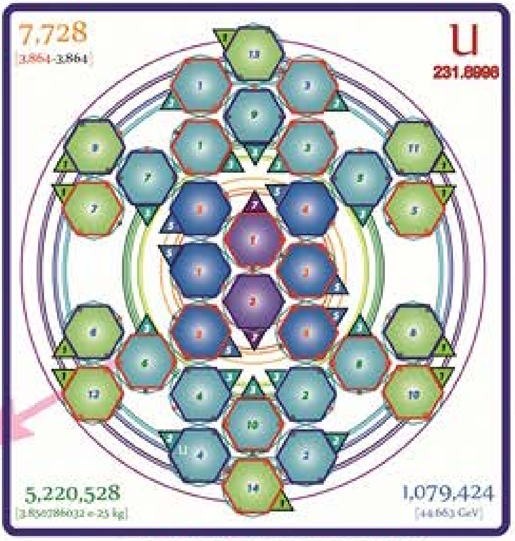
7,728
[3,864-3,864]
U
231.8998
5,220,528
1,079,424

unstable high energy nuclei

Radio-Carbon isotope dating

Radiocarbon dating (sometimes simply known as carbon dating) is a radiometric dating method that uses the naturally occurring radioisotope carbon-14 (14C) to estimate the age of carbon-bearing materials up to about 58,000 to 62,000 years

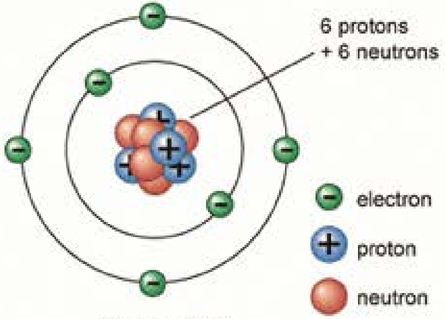
6 protons
+ 6 neutrons
electron
proton
neutron

Carbon atom

Standing-wave KE not 'excess' Neutrons

It is the stored Kinetic Energies [KE] that increase the mass of Carbon12 to create its isotopes, historically these mass-energies have been mistakenly thought to be extra Neutrons in the nuclei

C14 half-life
5730 ± 40

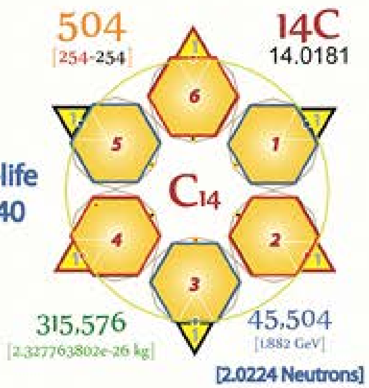
504
[254-254]
14C
14.0181
6
5
1
C14
4
2
3
315,576
[2.327763802e-26 kg]
45,504
[1.882 GeV]
[2.0224 Neutrons]

Carbon-14, 14C, or radiocarbon, is a radioactive isotope of carbon with a nucleus containing 6 protons, 6 neutrons and 6 electrons with an excess energy content of 1.88 GeV

[6 Deuterium nuclei]

ALL elemental Carbon atoms have an atomic configuration of 6 protons, 6 neutrons and 6 electrons

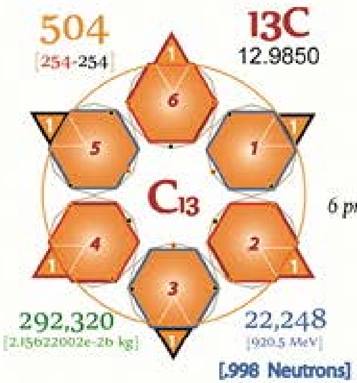
504
[254-254]
13C
12.9850
6
5
1
C13
4
2
3
292,320
[2.15622002e-26 kg]
22,248
[920.5 MeV]
[.998 Neutrons]

Carbon-13, 13C, is a weakly radioactive isotope of carbon with a nucleus containing 6 protons, 6 neutrons and 6 electrons with an excess energy content of 920 MeV

Radio-Carbon dating can be used to determine the age of carbonaceous materials up to about 60,000 years old

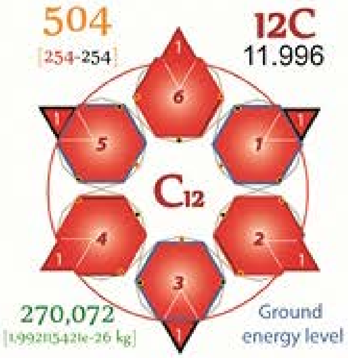
504
[254-254]
12C
11.996
6
5
1
C12
4
2
3
270,072
[1.99211542le-26 kg]
Ground
energy level

Tetryonic theory corrects historical errors of atomic geometries and nuclear energies

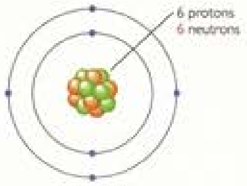
6 protons
6 neutrons

Carbon-12
(6P + 6N)
Atomic weight = 12

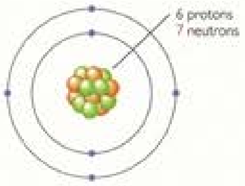
6 protons
7 neutrons

Carbon-13
(6P + 7N)
Atomic weight = 13

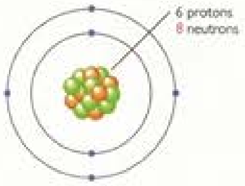
6 protons
8 neutrons

Carbon-14
(6P + 8N)
Atomic weight = 14

Isotopic mass-charge quotient determines an element's properties

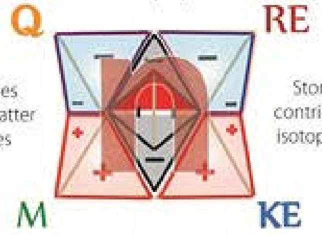

Net Charges create 3D Matter topologies

Stored KE contributes to isotopic mass

The stored KE [chemical] mass-energies of the Carbon 12+ isotopes comes from various radiological [and biological] processes and its steady, predictable release through the quantum mechanics of the synchronous convertors that make up Carbon nuclei make it useful in dating objects based on their decay rates

Radioactive Isotopes

Where the elementary nuclei's Deuteron energy levels are raised from their ground levels radioactive isotopes are created

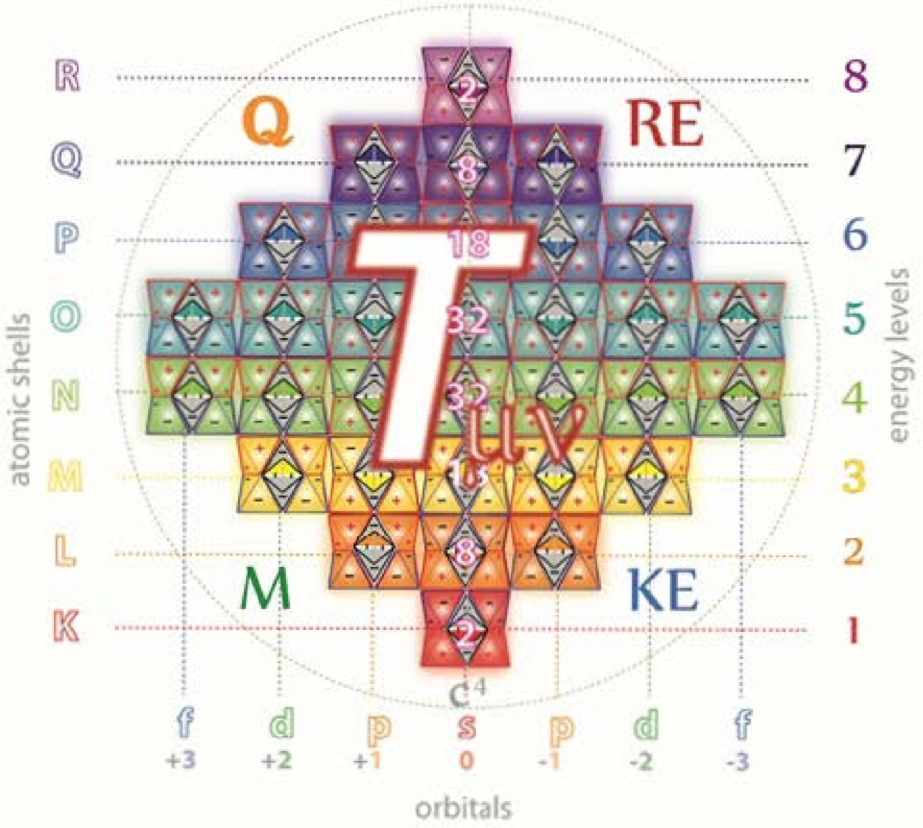

Each periodic element is comprised of an EQUAL number of Protons, Neutrons & electrons that form each element's unique 2D mass-energy geometries & 3D Matter topology and contribute to its observed properties

The $\frac{mass}{c^2}$ ~ $\frac{energy}{c^4}$ content of Matter

Einstein's relativistic stress energy tensor models mass-energy-Matter as a nebulous energy-momenta density-pressure gradient

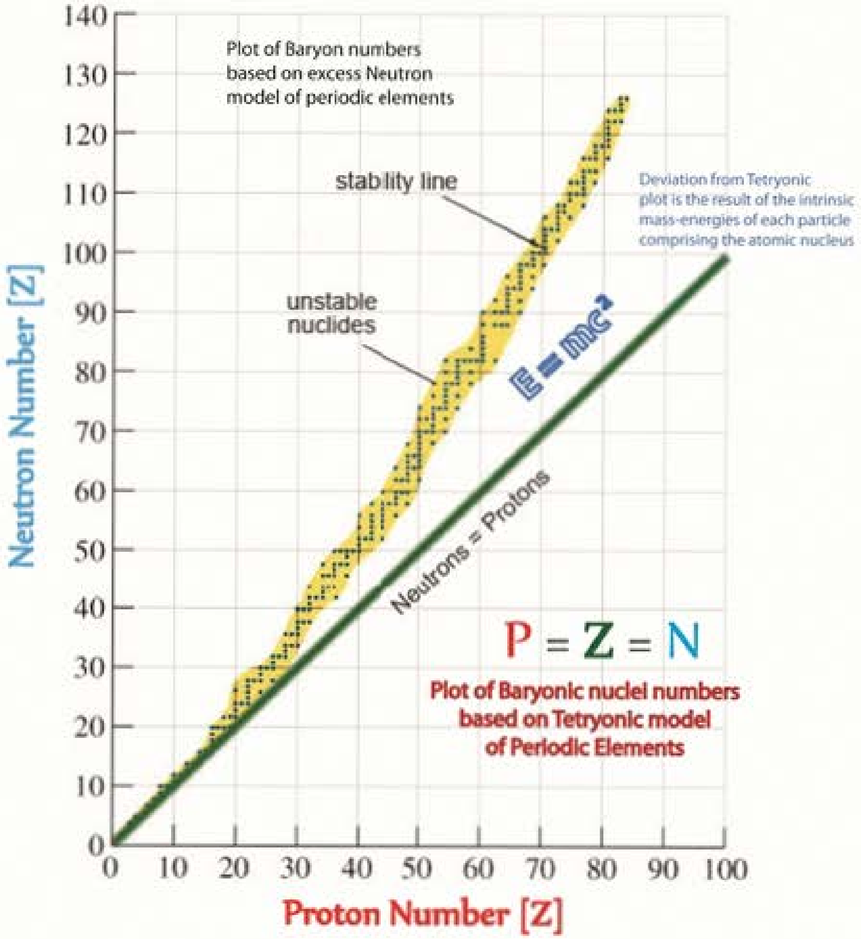

Plot of Baryon numbers based on excess Neutron model of periodic elements

Deviation from Tetryonic plot is the result of the intrinsic mass-energies of each particle comprising the atomic nucleus

Plot of Baryonic nuclei numbers based on Tetryonic model of Periodic Elements

Tetryonic theory redefines the relativistic stress energy tensor [$T_{\mu\nu}$] into a geometric measure of the charged 2D electromagnetic mass-energies & 3D Matter topologies within any spatial co-ordinate system

Nuclear Decay processes

is the set of processes by which an unstable atomic nucleus emits subatomic particles

Charge & mass-energy momenta are conservative physical properties

Radioactivity was discovered in 1896 by the French scientist Henri Becquerel, while working on phosphorescent materials. These materials glow in the dark after exposure to light, and he suspected that the glow produced in cathode ray tubes by X-rays might be associated with phosphorescence

Charged Matter equivalence

Neutrogen $\underset{[6\text{-}6]}{\nu e} + \underset{[18\text{-}18]}{N^0} \overset{[24\text{-}24]}{\sim} \underset{[24\text{-}12]}{P^+} + \underset{[0\text{-}12]}{e^-}$ **Hydrogen**

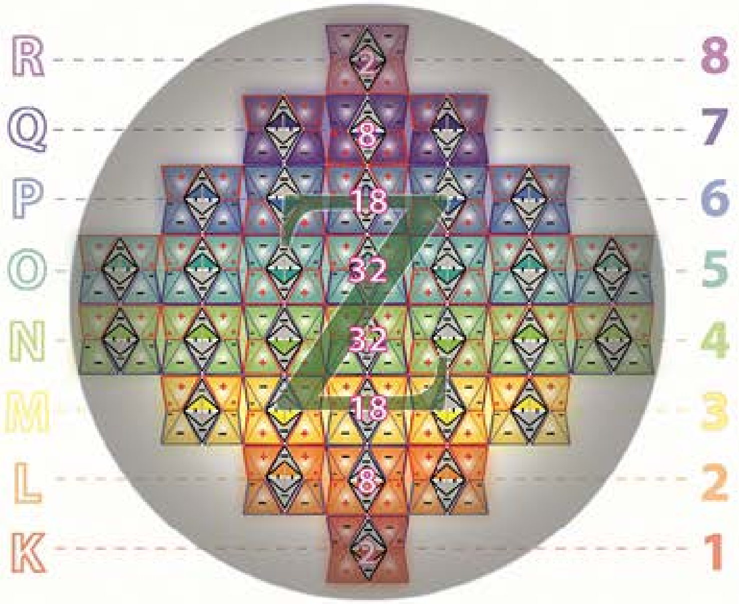

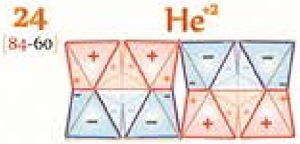

alpha-particles

$$\underset{[42\text{-}30]}{D^+} + \underset{[42\text{-}30]}{D^+} \longrightarrow \underset{[84\text{-}60]}{He^{+2}}$$

alpha particle production

E

Energy can be released from atomic nuclei through various processes

alpha-particles
beta-particles
gamma rays
spectral lines
heat & motion

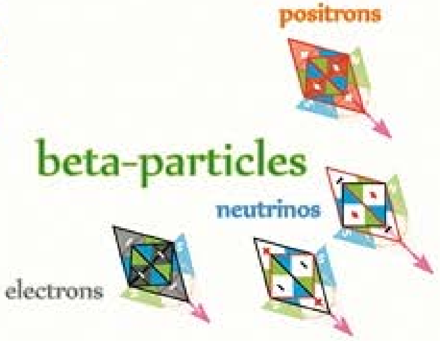

beta-particles

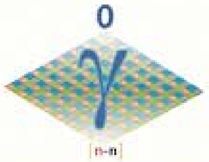

gamma rays

$$\underset{[v\text{-}v]}{KE} \longrightarrow \underset{[n\text{-}n]}{\gamma}$$

gamma ray production

m *All nuclear decay particles are determined by Tetryonic charge topologies* M

Charge Matter particle creation follows chemical equilibrium formulae

$$\underset{[18\text{-}18]}{N^0} \longrightarrow \underset{[12\text{-}0]}{e^+} + \underset{[6\text{-}6]}{\nu e} + \underset{[0\text{-}12]}{e^-}$$

Neutron decay processes

$$\underset{[18\text{-}18]}{N^0} \longrightarrow \underset{[6\text{-}6]}{\nu e} + \underset{[6\text{-}6]}{\nu e} + \underset{[6\text{-}6]}{\nu e}$$

3D Matter topologies are not conservative

Alpha radiation

(Deuteron emissions)

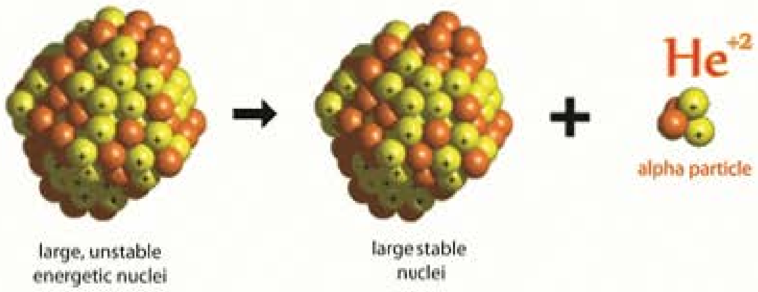
large, unstable
energetic nuclei
large stable
nuclei
He^{+2}
alpha particle

Alpha particles are released during alpha decay processes in ultra-heavy nuclei like uranium, thorium, actinium, and radium

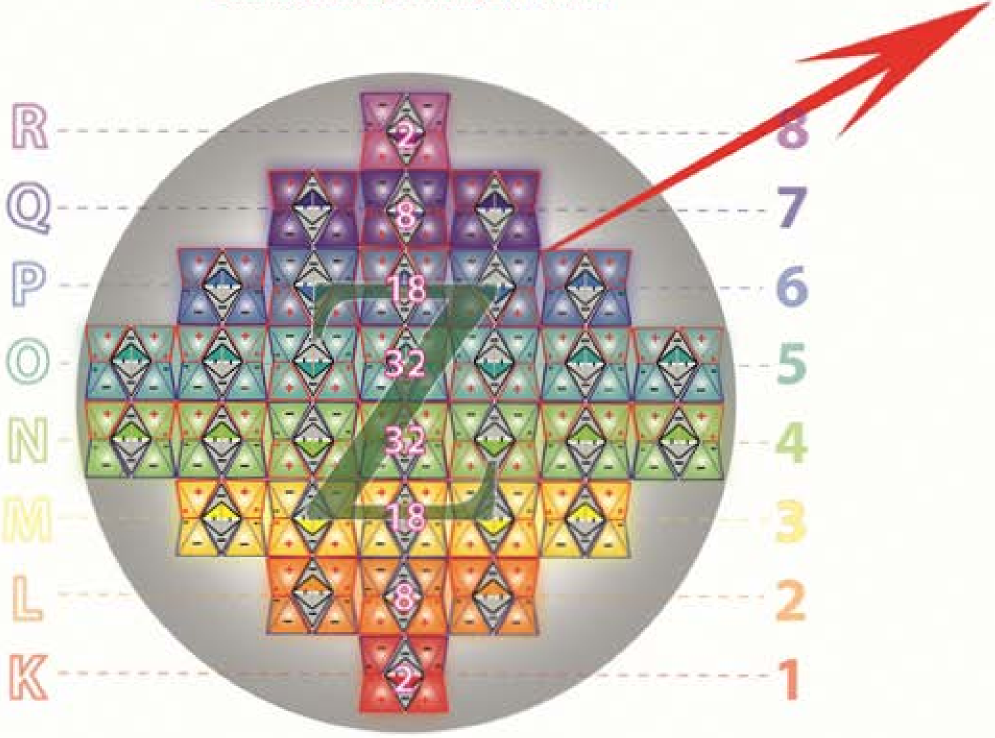
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
8
18
32
32
18
8
2
Z

Beta radiation - Negative charge sets (Nuclei)
Gamma radiation - Neutral Charge sets (Photons)

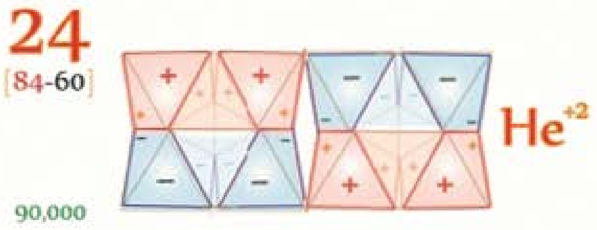
24
[84-60]
90,000
He^{+2}

Helium nuclei creation

D^{+} [42-30] D^{+} [42-30]
+
[0-12] e^{-} [0-12] e^{-}
→ He^{0} [84-84]

charged
alpha nuclei bond
&
capture electrons
to form neutral
Helium

alpha particles

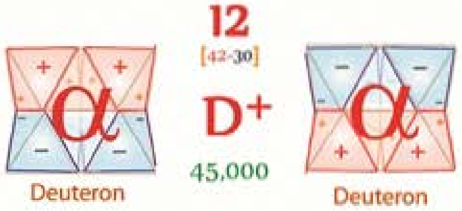
Deuteron
12
[42-30]
D^{+}
45,000
Deuteron

The radioactive isotope Americium 241 emits alpha particles which are used in smoke detectors.

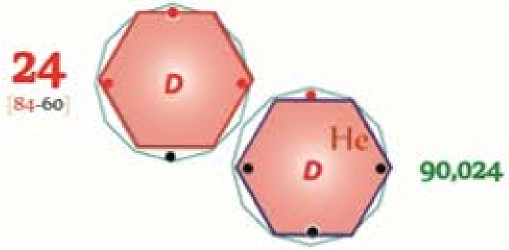
24
[84-60]
D
He
D
90,024

Due to their larger masses compared to beta and gamma particles, alpha particles can be easily stopped by a piece of paper or human skin.

Beta particle decay

$$\underset{[18\text{-}18]}{N^0} \rightarrow \underset{[12\text{-}0]}{e^+} + \underset{[6\text{-}6]}{\nu e} + \underset{[0\text{-}12]}{e^-}$$

Neutron decay paths

$$\underset{[18\text{-}18]}{N^0} \rightarrow \underset{[6\text{-}6]}{\nu e} + \underset{[6\text{-}6]}{\nu e} + \underset{[6\text{-}6]}{\nu e}$$

(the emission of leptons from atomic nuclei)

Beta decay

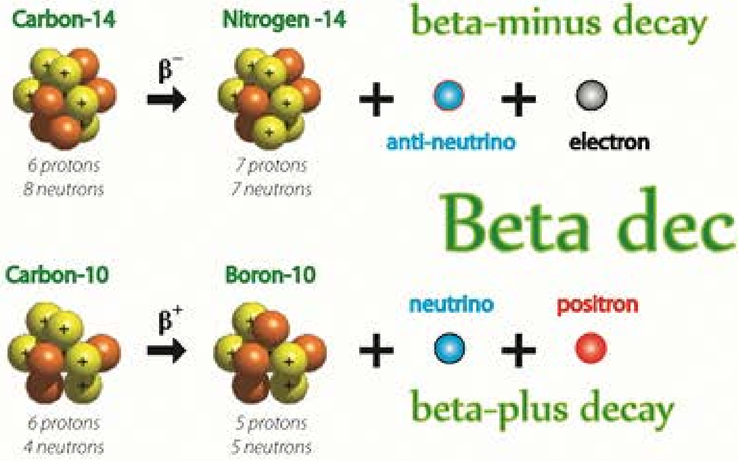
Carbon-14
Nitrogen -14
beta-minus decay
β⁻
6 protons
8 neutrons
7 protons
7 neutrons
anti-neutrino
electron
Carbon-10
Boron-10
β⁺
neutrino
positron
6 protons
4 neutrons
5 protons
5 neutrons
beta-plus decay

Charge is a conserved physical property of all material objects

$$\underset{[18\text{-}18]}{N^0} + \underset{[6\text{-}6]}{\nu e} \xrightarrow{[24\text{-}24]} \underset{[24\text{-}12]}{P^+} + \underset{[0\text{-}12]}{e^-}$$

Neutron decay is not a spontaneous process

All beta decay processes are the result of neutrino interaction with Neutrons

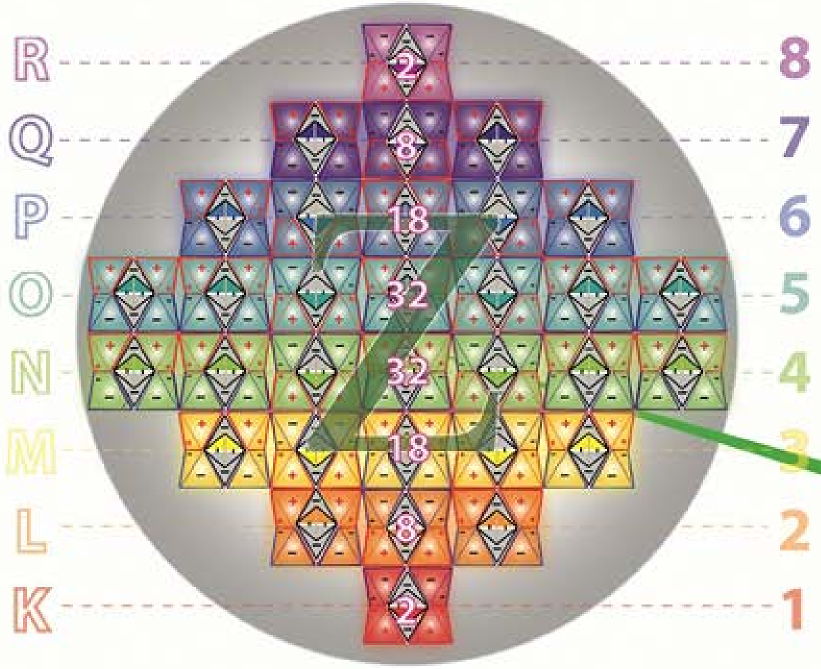
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
8
18
32
32
18
8
2
Z

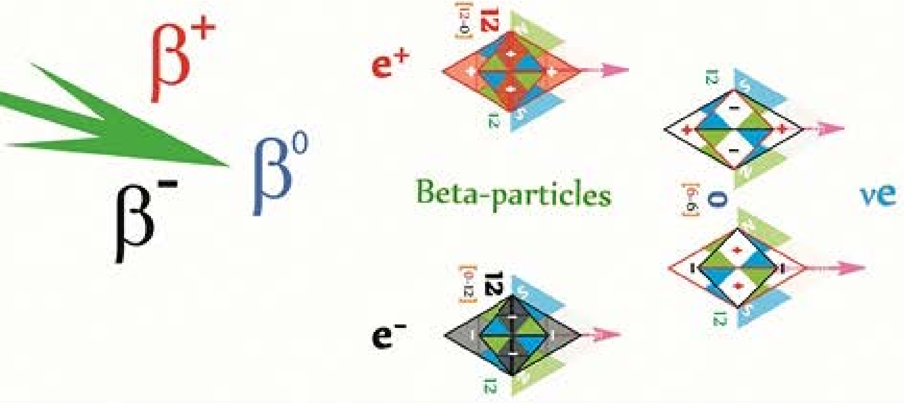
β⁺
β⁰
β⁻
e⁺
[12-0]
12
Beta-particles
[6-6]
0
νe
12
e⁻
[0-12]
12

Alpha radiation - Positive charge particles (Nuclei)
Gamma radiation - Neutral charge quanta (Photons)

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Gamma Radiation

(high energy photon emission)

Natural sources of gamma rays on Earth include gamma decay from naturally occurring radioisotopes, and secondary radiation from atmospheric interactions with cosmic ray particles.

$\lambda[f]$ *All ejected gamma ray photons are neutral energy quanta sets [photons / EM waves]* $[f]\lambda$

Gamma rays typically have frequencies above 10 exahertz (or >10^19 Hz), and therefore generally have energies above 100 keV and wavelengths less than 10 picometers (less than the diameter of an atom)

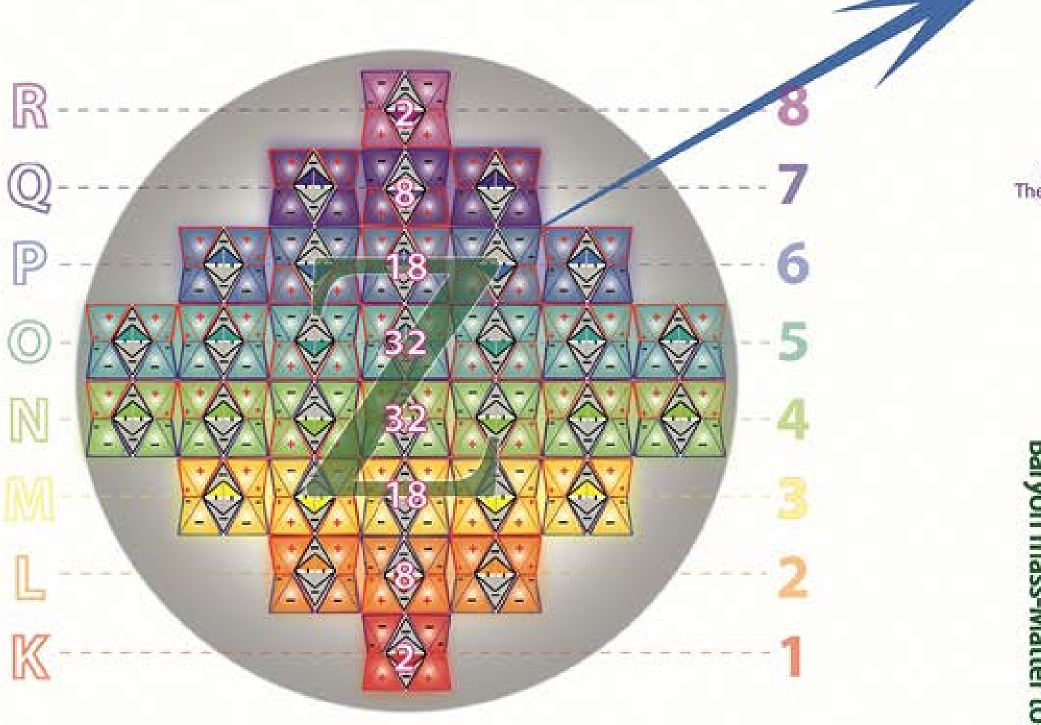

Alpha radiation - Positive charge particles (nuclei)
Beta radiation - Negative charge particles (leptons)

gamma rays

Gamma decay produces rays with energies of only a few hundred keV, and almost always less than 10MeV

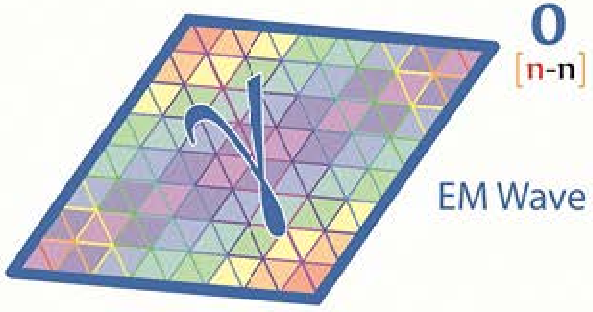

EM Field　Planck quanta

$$2\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

Photons　ElectroMagnetic　mass　velocity

Gamma rays are a form of ionizing radiation, and they have very good penetrating power. They result from the release of atomic energies and will cause biological damage to living tissue.

$$2hv = E = hf$$

Care must always be taken to distingush between charged Planck quanta [v] and photons [f]

gamma ray bursts

Baryon mass-Matter topology

$$N^0_{[18\text{-}18]} \rightarrow [2.25\ e23]_{[v\text{-}v]}$$

$$E = 2mc^2 = hf$$

930 MeV　930 MeV

gamma ray mass-energy geometry

are the result of the stored KEM mass-energies of Matter topologies being released as mass-energy momenta geometries

neutrino-Neutron Interactions

Neutrogen

$\nu e + N^0 \overset{[24\text{-}24]}{\sim} P^+ + e^-$

[6-6] [18-18] [24-12] [0-12]

Charged Matter equivalence

Hydrogen

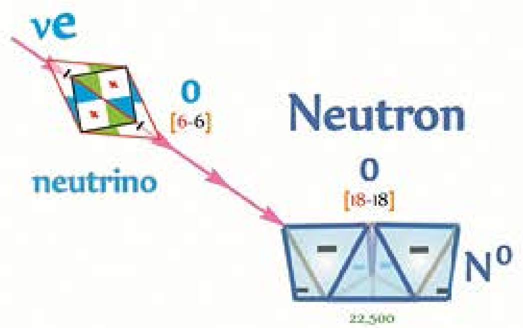
νe
0
[6-6]
neutrino
Neutron
0
[18-18]
N⁰
22,500

neutrino capture

Neutron decay is not the spontaneous process hypothesied by modern nuclear physicists

The observed decay products are the result of solar neutrinos interacting with Neutrons (both within nuclei and free)

the neutrinos also have an equally likely probability of interacting with Protons in the nuclei

[24-24]

A Neutronium atom has an identical mass-charge quotient to that of Hydrogen

[24-24]

Neutronium decay processes

A Neutron/neutrino interaction can decay into 4 differing particle sets

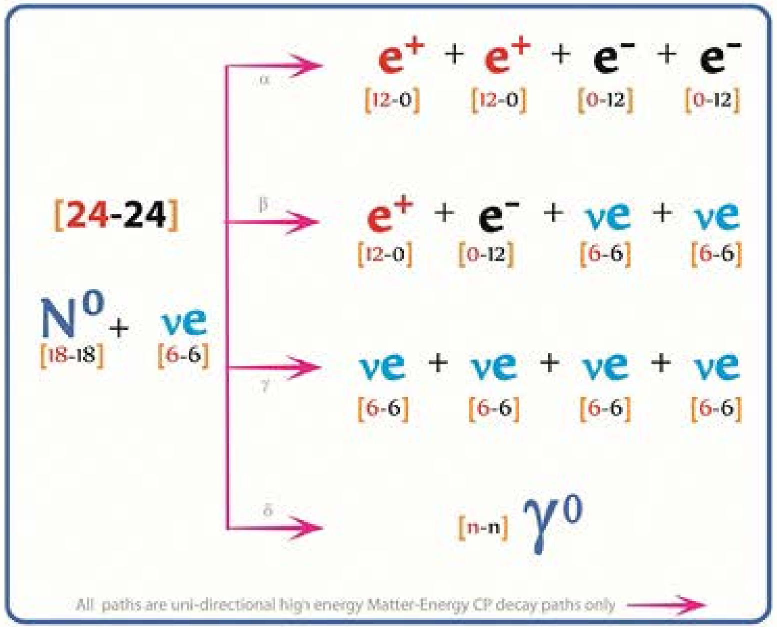
[24-24]
N⁰ + νe
[18-18] [6-6]
α
β
γ
δ

$e^+ + e^+ + e^- + e^-$
[12-0] [12-0] [0-12] [0-12]

$e^+ + e^- + \nu e + \nu e$
[12-0] [0-12] [6-6] [6-6]

$\nu e + \nu e + \nu e + \nu e$
[6-6] [6-6] [6-6] [6-6]

[n-n] γ^0

All paths are uni-directional high energy Matter-Energy CP decay paths only

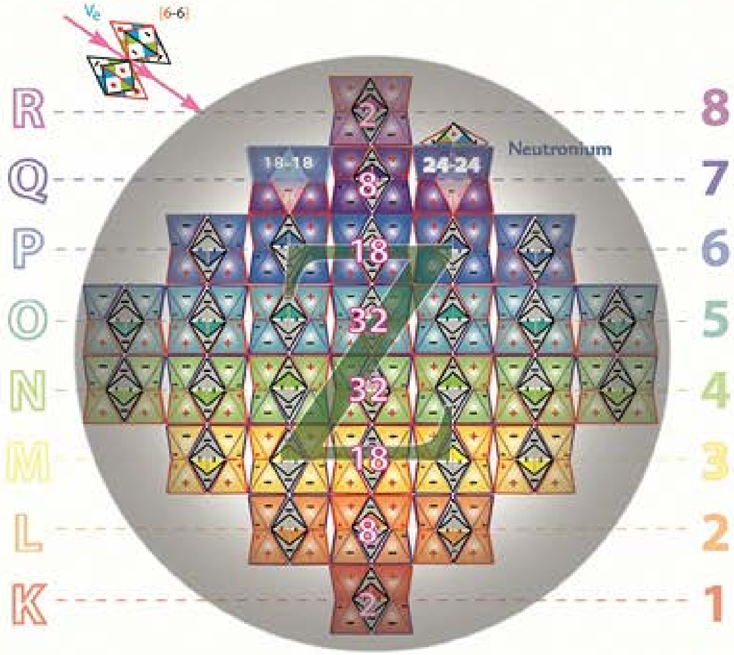
Ve
[6-6]
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
18-18
24-24
Neutronium
2
8
18
32
32
18
8
2
Z

Excluding their nett Charge,
Neutrons have neutral particle geometries [18-18]
identical to that of a Proton [24-12]

$N^0 \neq P^+ + e^-$

[18-18] [24-12] [0-12]

[24-24]

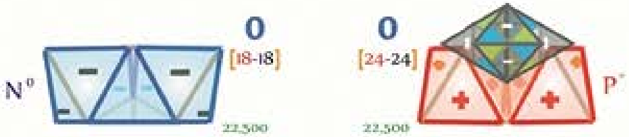
N⁰
0
[18-18]
22,500
0
[24-24]
P⁺
22,500

Spontaneous Neutron decay into Proton-electron-neutrinos is not possible without the interaction of Muonic neutrinos (see Tetryonic Charge numbers)

A Neutron is NOT a Proton that has absorbed an electron

neutrino-Proton Interactions

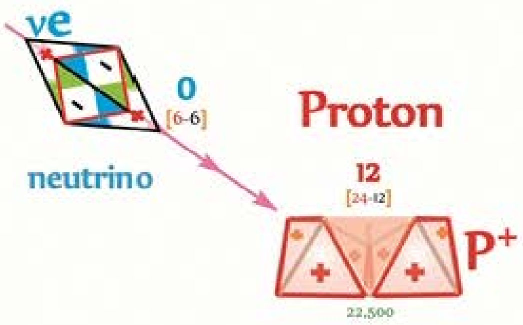

neutrino capture

Neutron decay is not the spontaneous process hypothesied by modern nuclear physicists

The observed decay products are the result of solar neutrinos interacting with Neutrons (both within nuclei and free)

the neutrinos also have an equally likely probability of interacting with Neutrons in the nuclei

[30-18]

A Proton-neutrino atom would have an identical charge quotient to that of a Proton

[24-12]

Although very weakly interacting, neutrinos can still be attracted to and bind to Protons via their negative charge fascia

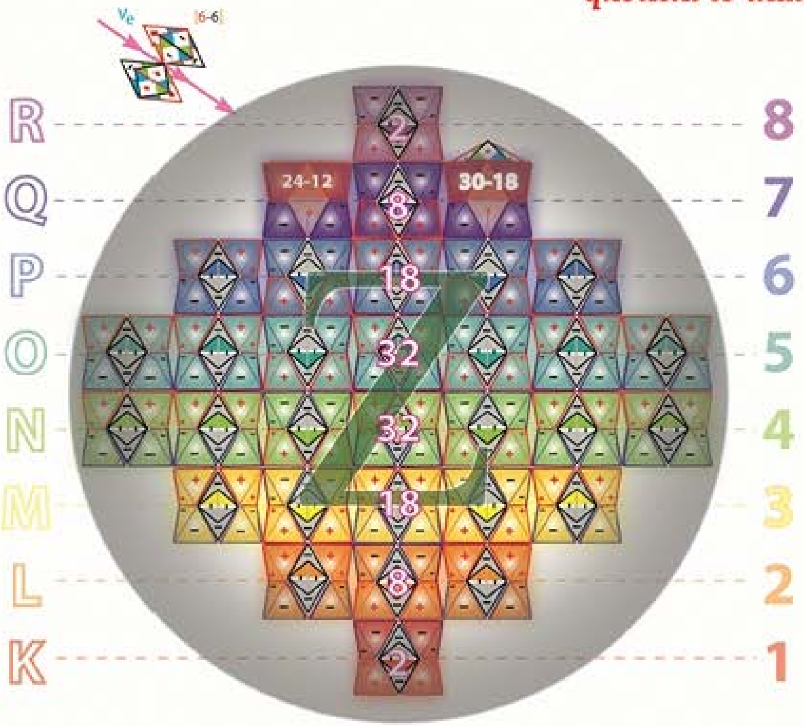

Proton decay paths

A Proton/Neutrino interaction can decay into 4 differing particle sets

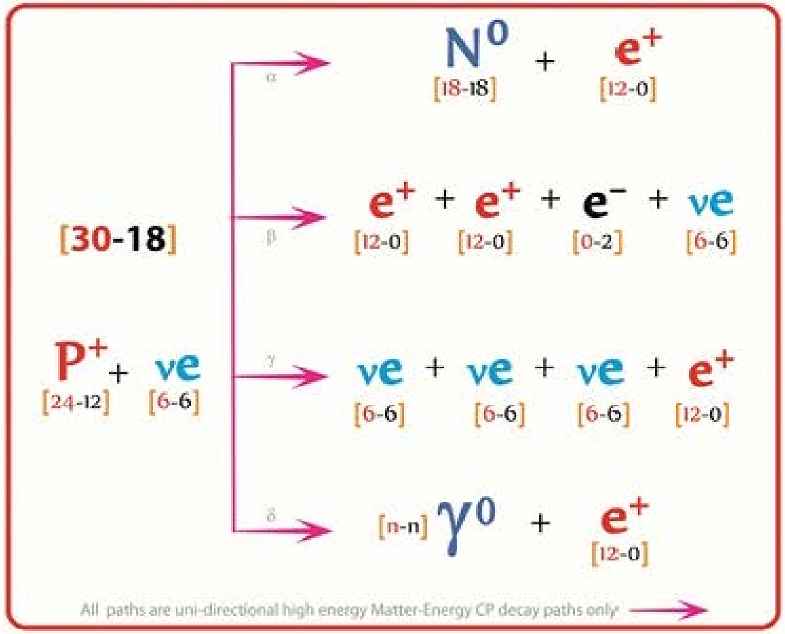

[30-18]

P^+ [24-12] + ve [6-6]

N^0 [18-18] + e^+ [12-0]

e^+ [12-0] + e^+ [12-0] + e^- [0-2] + ve [6-6]

ve [6-6] + ve [6-6] + ve [6-6] + e^+ [12-0]

[n-n] γ^0 + e^+ [12-0]

All paths are uni-directional high energy Matter-Energy CP decay paths only

If they exist, Proton-neutrino particle couplings would function in a manner identical to that of Proton-electron couplings and could be detected by the anomalous spin measurements that would result

A Proton has a Positive charge geometry [24-12] equivalent to that of a Neutral Neutron [18-18]

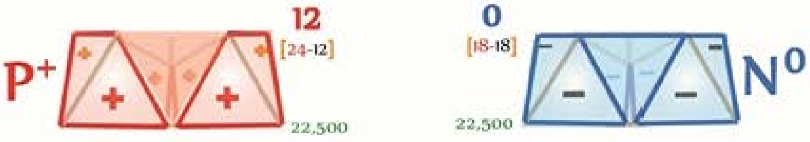

A Proton is topologically identical to a Neutron (differing only in the net charge created)

Quantum Batteries

Atomic nuclei can be easily scaled to non-quantum sizes to offer clean, safe and portable long term Energy storage devices that can store energy indefinitely and release it on demand anywhere in the World

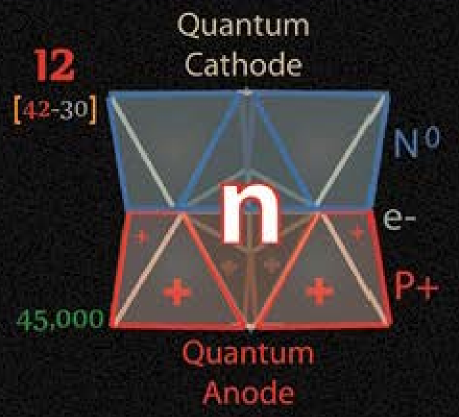
Quantum
Cathode
12
[42-30]
N^0
n
e-
P+
45,000
Quantum
Anode

The quantum battery is unique in that in addition to storing energy indefinitely, when an electron binds to the Deuteron nuclei it has the ability to release specific energies [photons] by way of its quantum-scale synchronous converter topologies

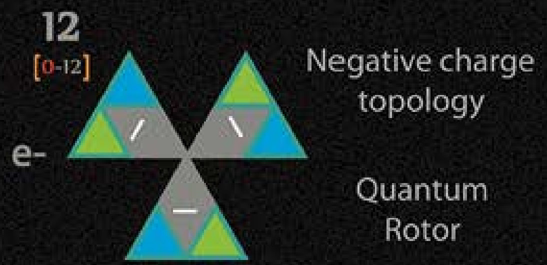
12
[0-12]
e-
Negative charge
topology
Quantum
Rotor

12 loop quantum inductive rotor

(Atomic Nuclei)

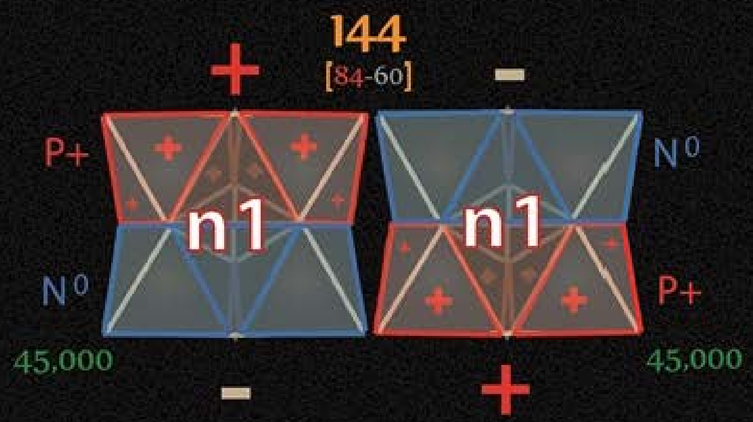
144
[84-60]
+
-
P+
n1
n1
N^0
N^0
P+
45,000
45,000
-
+

anti-Parallel Configuration

+ E90
03-2013
Energizer

Synchronous quantum converter topologies can be connected in parallel or series to meet varying power requirements anywhere in the World and provides for the safe storage of nuclear energy as mass

Series Configuration

+ E90
03-2013
Energizer

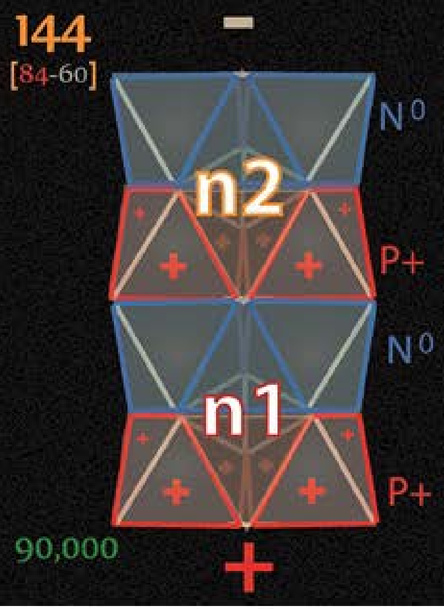
144
[84-60]
-
N^0
n2
P+
N^0
n1
P+
90,000
+

Quantum synchronous Converters

Energy can be stored in macro-scaled quantum converters as mass

The electron has a charged Tetryonic
Matter topology that is electrically
equivalent to a 6 loop inductive rotor

Energy

Planck quanta

$$\frac{12\pi}{c^4}\left[\left[m\Omega v^2\right]\right]_{n1}^{n8}$$

mass velocity

momenta

Quantum
Cathode

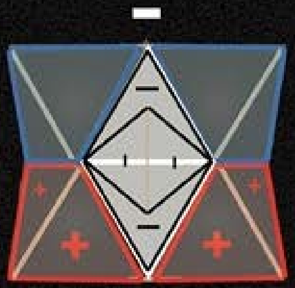

Quantum
Anode

Matter is radiant EM energy
in a standing-waveform

Energy

Nuclei

Planck quanta

$$\frac{72\pi}{c^4}\left[\left[m\Omega v^2\right]\right]_{n25}^{n32}$$

mass velocity

momenta

Building on the charged topology of Deuterium nuclei,
scaled electromechanical quantum converters can be manufactured
to provide efficient electrical mass-energy storage & distribution devices

Energy

Deuterons

Planck quanta

$$\frac{84\pi}{c^4}{}_{n25}^{n32}\left[\left[m\Omega v^2\right]\right]_{n1}^{n8}$$

mass velocity

momenta

These devices can be transported any where demand requires them worldwide with their energies stored in the form of mass

Negating the need for centralised power stations and distribution lines extending vast distances to provide power to remote communities

A quantum synchronous converter
can store and release 3 forms of energy

Angular Momentum (motional energy)
square root linear momentum

Radiant Energy (emission/absorption)
of photon/boson mass-energy geometries

EM mass-Matter (stored masses in Matter topologies)
radiant EM mass-energies stored in standing wave Matter topologies

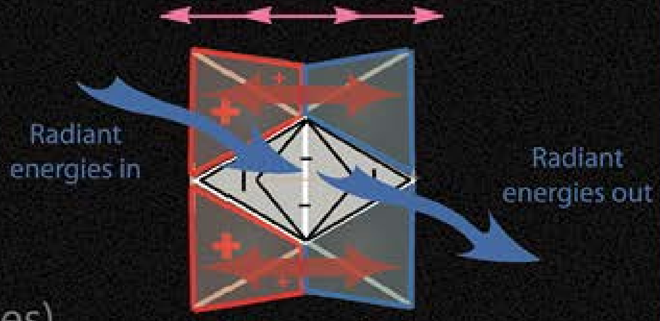

Leptons rotate within the
Baryonic EM fields of the Nucleus

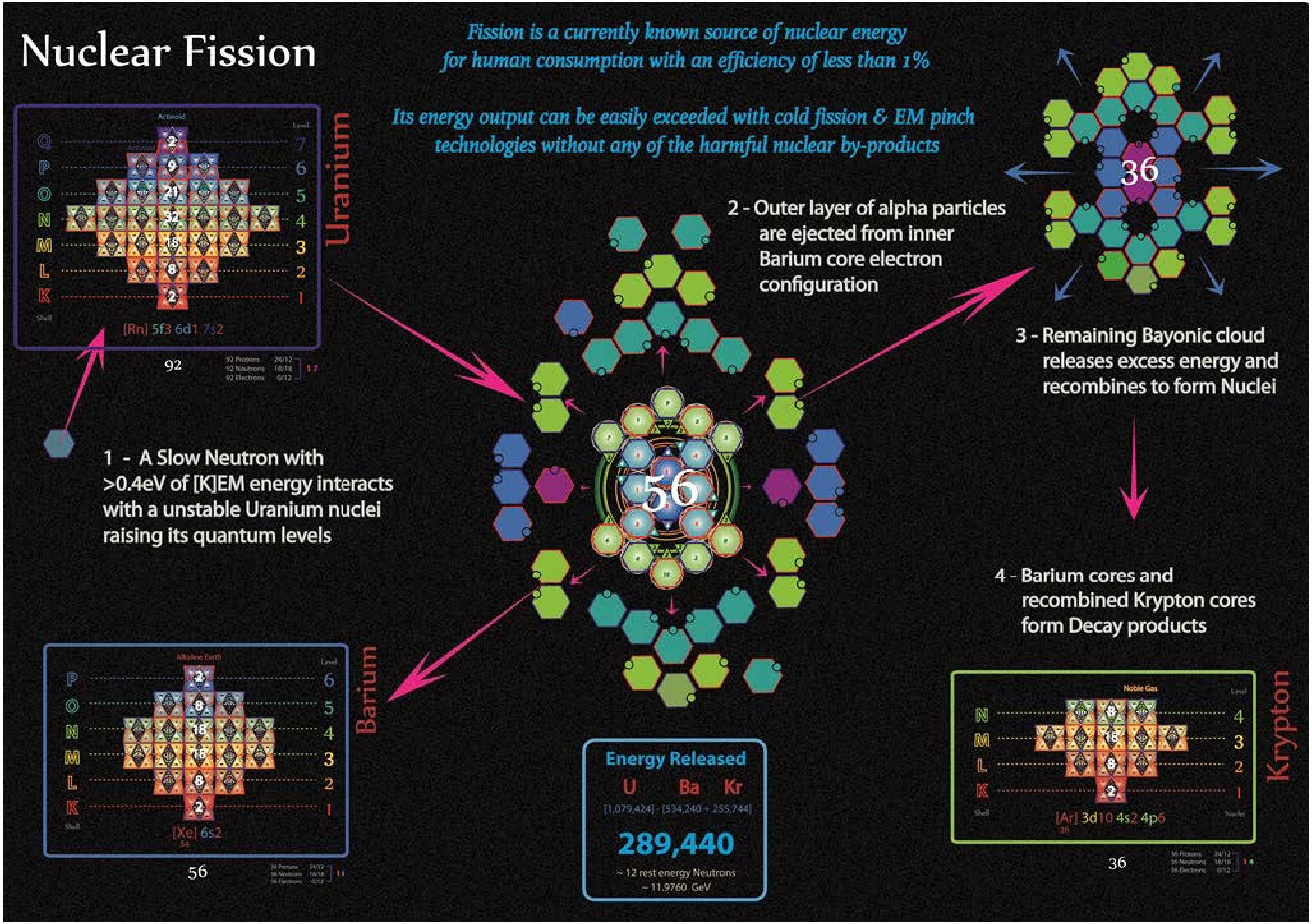

Nuclear Fission

Fission is a currently known source of nuclear energy for human consumption with an efficiency of less than 1%

Its energy output can be easily exceeded with cold fission & EM pinch technologies without any of the harmful nuclear by-products

1 - A Slow Neutron with >0.4eV of [K]EM energy interacts with a unstable Uranium nuclei raising its quantum levels

2 - Outer layer of alpha particles are ejected from inner Barium core electron configuration

3 - Remaining Bayonic cloud releases excess energy and recombines to form Nuclei

4 - Barium cores and recombined Krypton cores form Decay products

Energy Released

U Ba Kr

[1,079,424] - [534,240 + 255,744]

289,440

~ 12 rest energy Neutrons
~ 11.9760 GeV

Uranium
Actinoid
Level
Q
P
O
N
M
L
K
Shell
7
6
5
4
3
2
1
2
9
21
32
18
8
2
[Rn] 5f3 6d1 7s2
92
92 Protons 24/12
92 Neutrons 18/18
92 Electrons 0/12
1 7
56
36
Barium
Alkaline Earth
Level
P
O
N
M
L
K
Shell
6
5
4
3
2
1
2
8
18
18
8
2
[Xe] 6s2
54
56
Krypton
Noble Gas
Level
N
M
L
K
Shell
4
3
2
1
8
18
8
2
[Ar] 3d10 4s2 4p6
36

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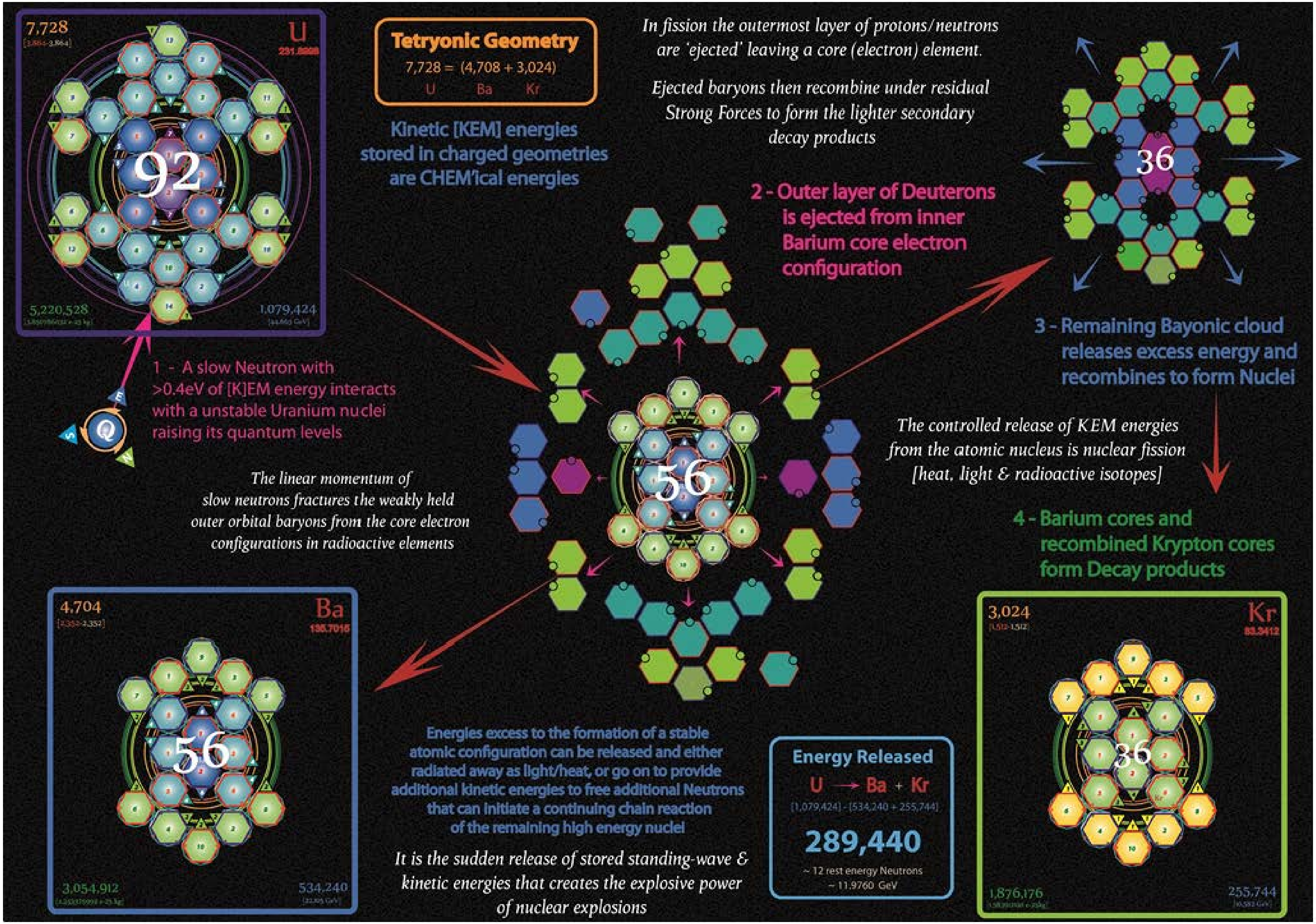

Tetryonic Geometry

7,728 = (4,708 + 3,024)
U Ba Kr

Kinetic [KEM] energies stored in charged geometries are CHEM'ical energies

1 - A slow Neutron with >0.4eV of [K]EM energy interacts with a unstable Uranium nuclei raising its quantum levels

The linear momentum of slow neutrons fractures the weakly held outer orbital baryons from the core electron configurations in radioactive elements

In fission the outermost layer of protons/neutrons are 'ejected' leaving a core (electron) element.

Ejected baryons then recombine under residual Strong Forces to form the lighter secondary decay products

2 - Outer layer of Deuterons is ejected from inner Barium core electron configuration

3 - Remaining Bayonic cloud releases excess energy and recombines to form Nuclei

The controlled release of KEM energies from the atomic nucleus is nuclear fission [heat, light & radioactive isotopes]

4 - Barium cores and recombined Krypton cores form Decay products

Energies excess to the formation of a stable atomic configuration can be released and either radiated away as light/heat, or go on to provide additional kinetic energies to free additional Neutrons that can initiate a continuing chain reaction of the remaining high energy nuclei

It is the sudden release of stored standing-wave & kinetic energies that creates the explosive power of nuclear explosions

Energy Released

U → Ba + Kr

[1,079,424] - [534,240 + 255,744]

289,440

~ 12 rest energy Neutrons
~ 11.9760 GeV

Tetryonics 60.13 - Nuclear Fission process

Sonoluminescence

Sonoluminescence is the first hint at the energies that can be released from Tetryonic collapse and involves the emission of short bursts of light from imploding bubbles in a liquid when excited by sound.

It is a key step on the road to realising technologies that can provide Humanity with clean, safe, efficient Energy production through the conversion of Matter into various forms of EM radiation

The production of light as a result of the passing of sound waves through a liquid medium.

The sound waves cause the formation of bubbles that emit bright flashes of light when they collapse.

Sonoluminesence is the result of energy releases from the collapse of standing-wave Matter topologies within Fluids

Finding an efficient means of inducing and managing a controlled reaction where 3D Matter topologies are converted into 2D radiant energy is a key step on the path to creating a future energy source of all Humanity

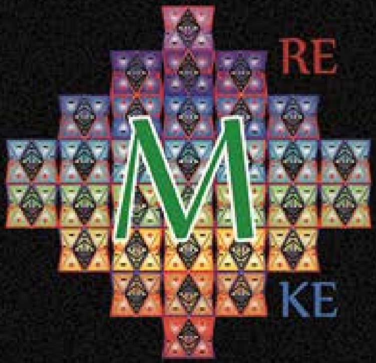

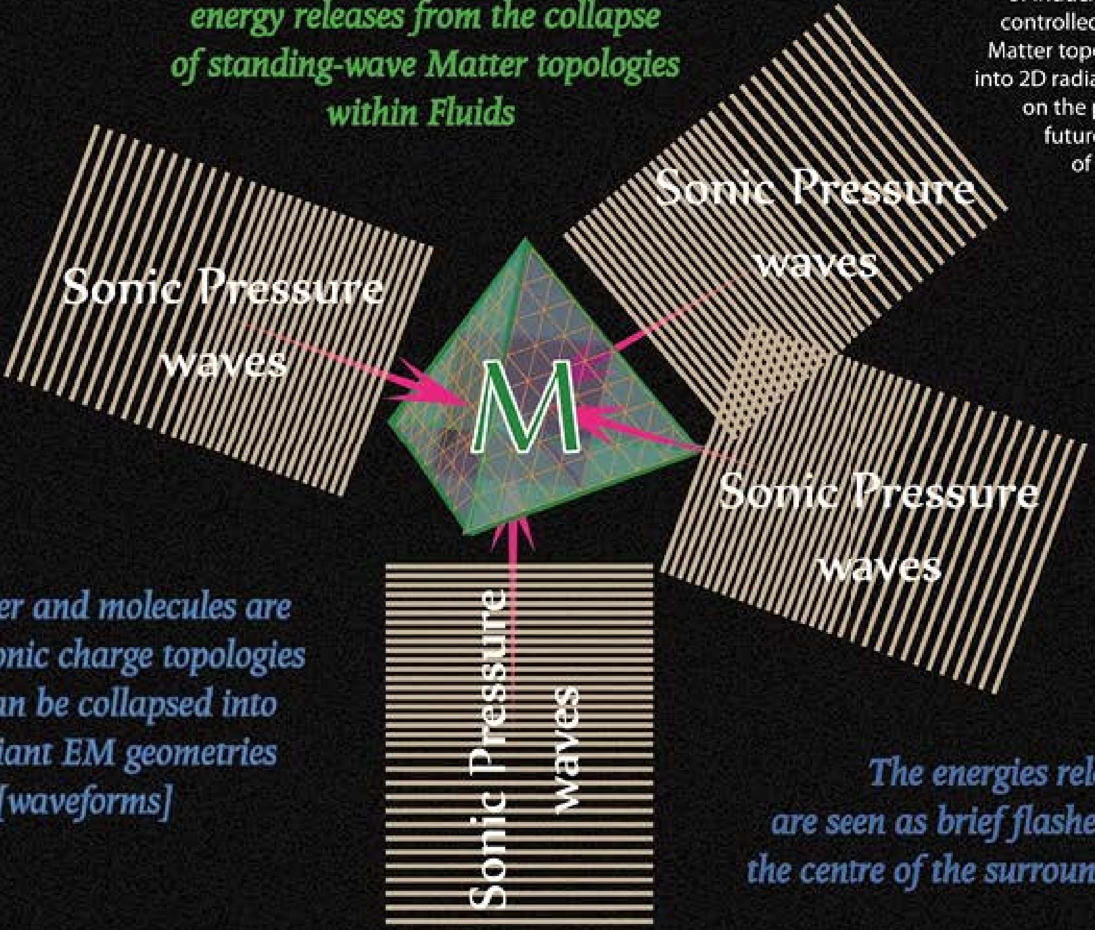

The gauge transformation of Matter into EM radiation is the most efficient form of energy release available to us

All Matter and molecules are 3D Tetryonic charge topologies which can be collapsed into 2D radiant EM geometries [waveforms]

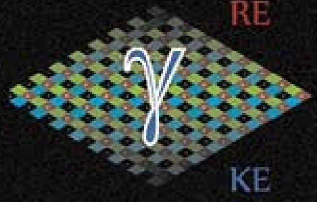

The energies released are seen as brief flashes of light at the centre of the surrounding medium

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Cold Fission

Stanley Pons Martin Fleischmann

(23 August 1943) (29 March 1927 – 3 August 2012)

'Nuclear fusion of the type postulated
would be inconsistent with current understanding
and, if verified, would require theory to
be extended in an unexpected way'

*Palladium's rest molar mass is 108.7867
with a stored Kinetic energy content of
15.699 Gev [16 neutron equivalence]*

3,864
[1,932-21,932]

Pd
108.7857

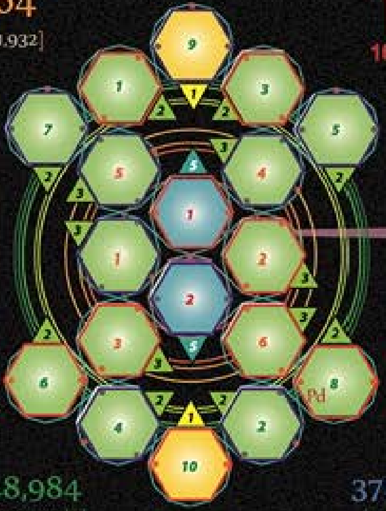

2,448,984
[1.806429039 e-25 kg]

378,432
[15.699 GeV]

Palladium

[Kr] 4d8 5s2
36

Transition
Metal

46 Protons 24-12
46 Neutrons 18-18
46 Electrons 0-12
1 5

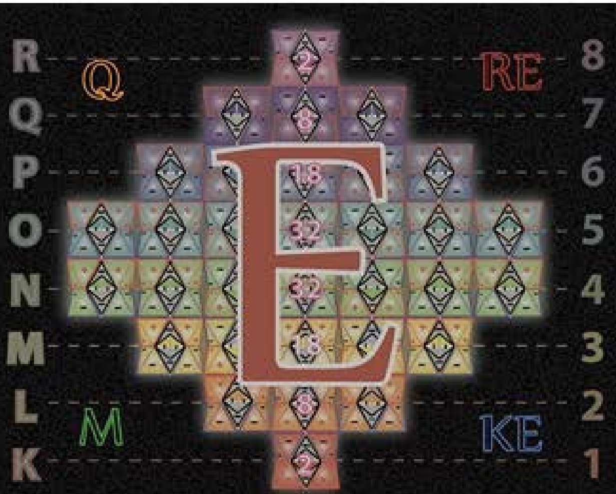

The reported excess energy released is often refused as being impossible
as it woud require the release of massive neutron radiation bath.

Expelling the non-core atomic nuclei
results in a release of stored KEM energies
as the deuterium nuclei seek to reach
a ground energy level state

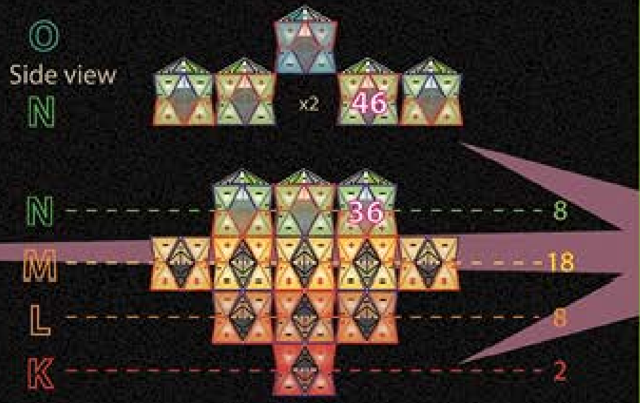

2 x n5
10 Deuterons
8 x n4

{ 122,688
[5.076 GeV] }

*Energy
equivalent to
5+ Neutrons*

NO excess Neutrons are ever released
~ only stored KEM energies and alpha particles

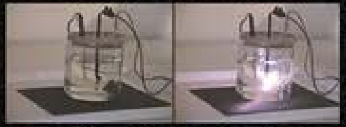

*Atomic nuclei can easily release
the reported energies without Neutron
particle emissions when an accurate
model of the atomic nuclei is used*

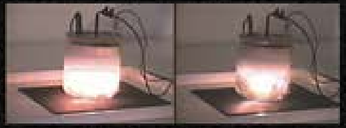

'Fusion' is a fictious nuclear process
'cold fusion' is in fact a form of nuclear fission

*Krypton's rest molar mass is 83.3412
with a stored Kinetic energy content of
10.582 Gev [11 neutron equivalence]*

3,024
[1,512-1,512]

Kr
83.3412

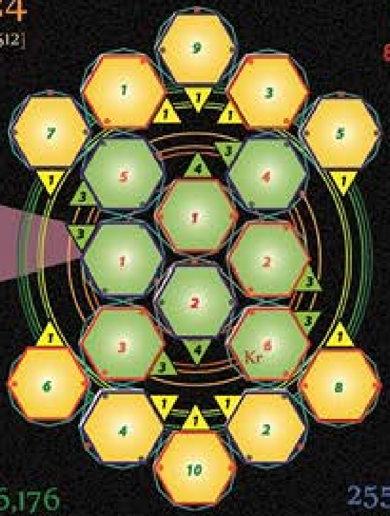

1,876,176
[1.383912190 e-25kg]

255,744
[10.582 GeV]

Krypton

[Ar] 3d10 4s2 4p6
36

Noble
Gas

36 Protons 24-12
36 Neutrons 18-18
36 Electrons 0-12
1 4

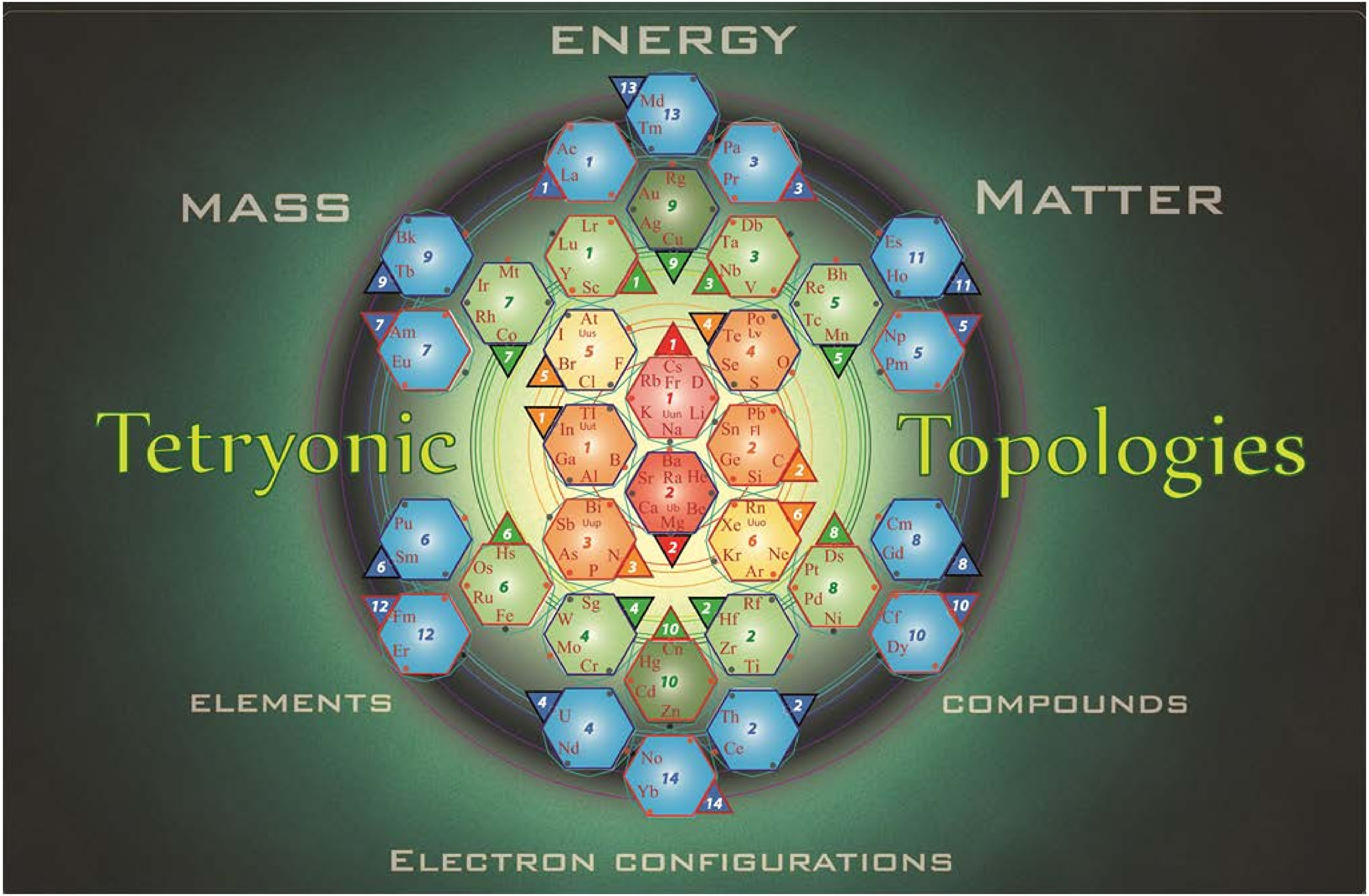
ENERGY
MASS
MATTER
Tetryonic
Topologies
ELEMENTS
COMPOUNDS
ELECTRON CONFIGURATIONS
Md Tm 13
Ac La 1
Pa Pr 3
Rg Au Ag Cu 9
Lr Lu Y Sc 1
Db Ta Nb V 3
Bk Tb 9
Es Ho 11
Mt Ir Rh Co 7
Bh Re Tc Mn 5
Am Eu 7
Np Pm 5
At I Uus Br Cl F 5
Po Te Lv Se S O 4
Cs Rb Fr D K Uun Li Na 1
Tl In Uut Ga Al B 1
Pb Sn Fl Ge Si C 2
Ba Sr Ra He Ca Ub Be Mg 2
Bi Sb Uup As P N 3
Rn Xe Uuo Kr Ar Ne 6
Pu Sm 6
Cm Gd 8
Hs Os Ru Fe 6
Ds Pt Pd Ni 8
Fm Er 12
Cf Dy 10
Sg W Mo Cr 4
Cn Hg Cd Zn 10
Rf Hf Zr Ti 2
U Nd 4
Th Ce 2
No Yb 14

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Tetryonic Chemistry

The charged topology of periodic and compound Matter

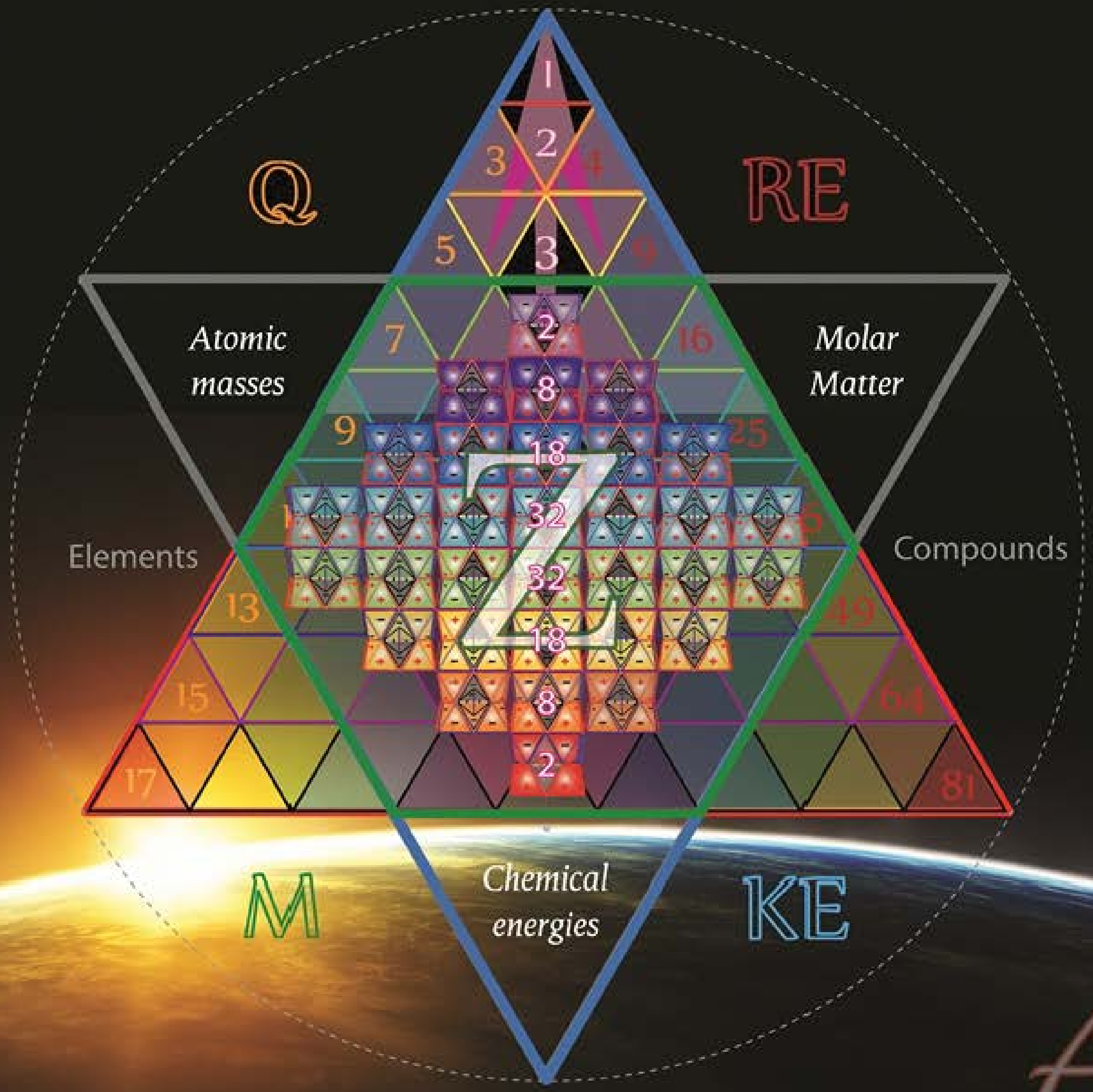
Q
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Atomic masses
Molar Matter
Elements
Compounds
M
KE
Chemical energies
Z
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5
9
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7
16
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25
18
32
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13
49
18
15
8
64
17
2
81

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Abraham

TETRYONICS

The charged interactions of universal Gravitation

Q
RE
Radiant masses
Standing-wave Matter
Gravitational GEM fields
Interactive KEM fields
M
KE
Vacuum Energies
ε
G
μ
1
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4
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6
7
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49
25

Foundational Quantum Cosmology

Abraham

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Laws of Force

$F = ma$

Sir Issac Newton

(25 December 1642 – 20 March 1727)

$w = mg$

Gravity

Newton's Principia formulated the laws of motion and of universal gravitation

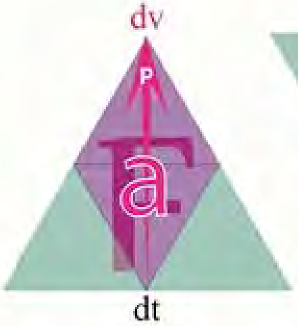

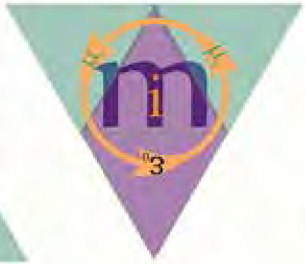

changing Magnetic lines of Force

Michael Faraday

(22 September 1791 – 25 August 1867)

create changing Electric fields of Force

Faraday discovered the principles of electromagnetic induction, diamagnetism, and the laws of electromagnetism.

Electro-Magnetism

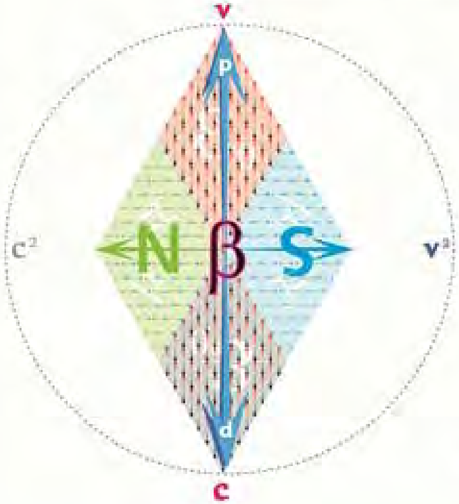

$$\oint \vec{E}\cdot d\vec{A} = \frac{q}{\varepsilon_0}$$

Gauss

Light is an electromagnetic wave

Faraday

$$\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

James Clerk Maxwell

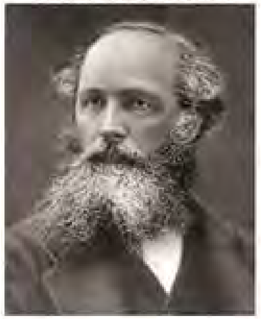

(13 June 1831 – 5 November 1879)

$$\oint \vec{B}\cdot d\vec{A} = 0$$

Gauss

The separate works of Gauss, Ampere & Faraday were unified to create an electromagnetic wave field theory

Ampere

$$\oint \vec{B}\cdot d\vec{s} = \mu_0 i + \frac{1}{c^2}\frac{\partial}{\partial t}\int \vec{E}\cdot d\vec{A}$$

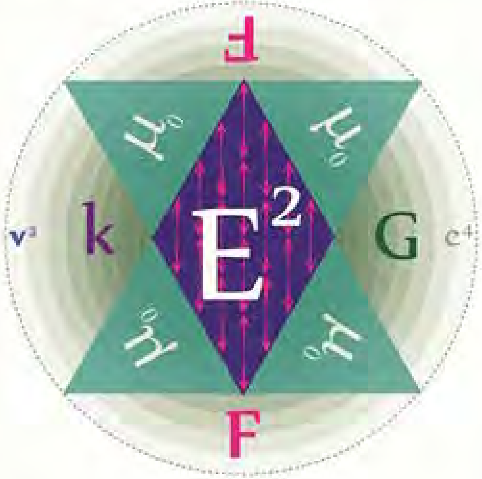

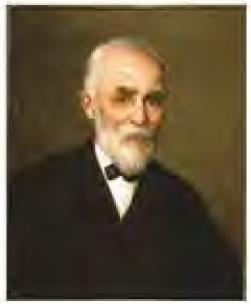

Lorentz Contraction

Lorentz proposed that moving bodies contract in the direction of motion (Lorentz–Fitzgerald contraction)

Hendrik Lorentz

(18 July 1853 – 4 February 1928)

Lorentz Transformations

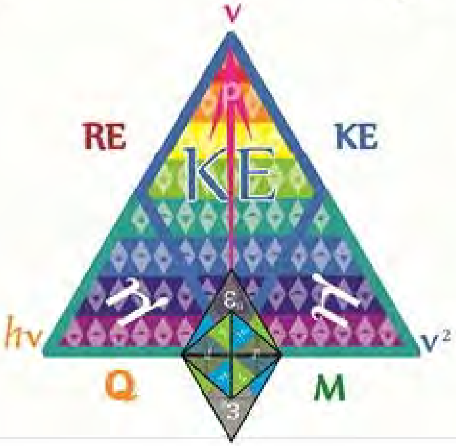

Special Relativity

attempted to explain the constant speed of Light using relative motion & Lorentz contractions

Albert Einstein

(14 March 1879 – 18 April 1955)

&

later attempted to explain gravity as a curvature of spacetime caused by Matter

General Relativity

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Early physics of Motion

In the 4th century BC, the Greek philosopher Aristotle believed that there is no effect or motion without a cause

In Book VII of his De Architectura, the Roman engineer and architect Vitruvius contends that gravity is not dependent on a substance's "weight" but rather on its "nature".

The cause of the downward motion of heavy bodies, such as the element earth, was related to their nature, which caused them to move

In the 7th Century the Indian mathematician Brahmagupta stated "Bodies fall towards the earth as it is in the nature of the earth to attract bodies, just as it is in the nature of water to flow."

Greek philosopher Aristotle

(384 BC - 322 BC)

Aristotle defined space to be the boundary geometry of a body

[x,y,z]

geometry, toplogy

Aristotle defined time to be a measure of movement

the past Δ the future

'Nature abhors a vacuum'

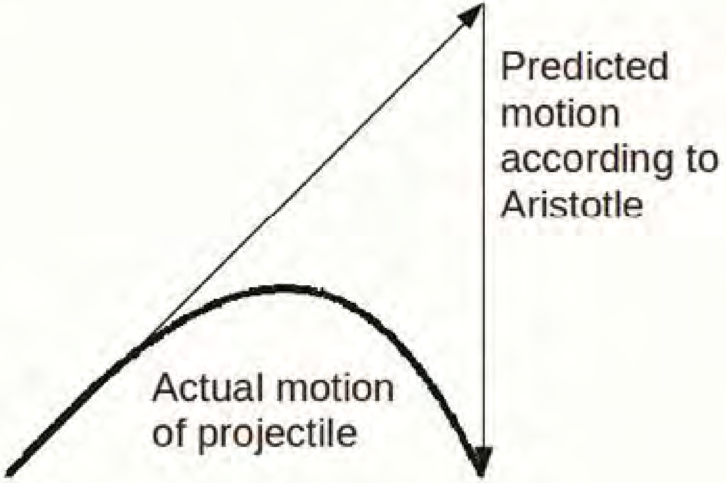
Predicted motion according to Aristotle
Actual motion of projectile

Heavier things fall faster, with speed being proportional to weight.

The speed with which a body falls is inversely proportional to the density of the medium it is falling through.

Indian Mathematician Brahmagupta

(597–668 AD)

Brahmagupta dedicated a substantial portion of his work to geometry

height
base

Brahmagupta is considered the first to formulate the concept of zero

negative numbers 0 positive numbers

Brahmagupta introduced new algebric methods for solving quadratic equations

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Galileo Galilei

(15 February 1564 – 8 January 1642)

Galilean Gravity

Galileo claimed to have a Universal Law of Gravitation
covering both terrestrial gravity and the motion of planets
which he was afraid to discuss.

But this looks more an inspired aspiration than a reality,
as he seems not to have considered gravitational force as
decreasing with distance from its source.

He did however, definitively show that objects experience a uniform
acceleration in a gravitational field (irrespective of their masses)
which was central to Newton's later Universal Law of Gravitation

The Motion of Falling Bodies

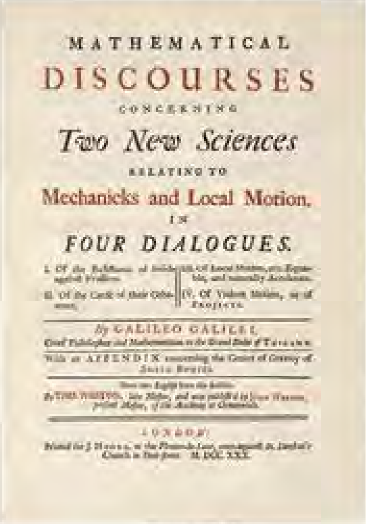

MATHEMATICAL
DISCOURSES
CONCERNING
Two New Sciences
RELATING TO
Mechanicks and Local Motion,
IN
FOUR DIALOGUES.

By GALILEO GALILEI,

LONDON:

(ca. 1590)

*Galileo dismissed as a "useless fiction" the idea, held by his
contemporary Johannes Kepler, that the moon caused the tides.*

*Galileo also refused to accept Kepler's elliptical orbits of the planets,
considering the circle the "perfect" shape for planetary orbits.*

Galileo was the first to counter Aristotle's earlier idea's of motion by teaching that
All objects experience a uniform acceleration in a Gravitational field
(irrespective of their different mass-Matter contents)

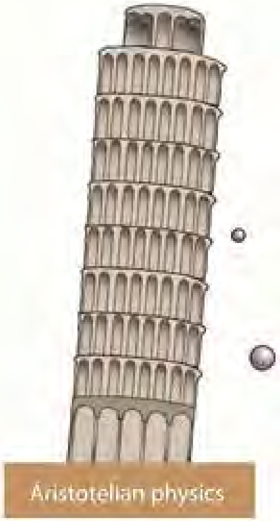

In De motu Galileo proposed that in free fall bodies dropped with a characteristic uniform speed determined not by their weight but by their specific gravity.

He put this theory to the test by dropping bodies from heights and found that his experiments did not confirm his theory.

It is quoted in 'Galileo's Daughter' that the lighter body (i.e. that of the lower specific gravity) will move ahead of the heavier body at the start of the fall, and that the heavier body then overtakes it and arrives at the bottom slightly earlier.

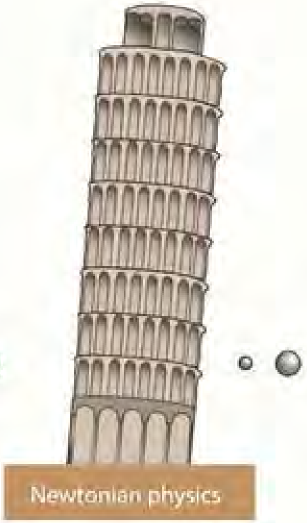

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Sir Issac Newton

(25 December 1642 – 20 March 1727)

In the late 17th century, Robert Hooke's suggested
'that there is a gravitational force which depends on the inverse square of the distance'

Newtonian Gravitation

Newton's monograph Philosophiæ Naturalis Principia Mathematica, published in 1687, lays the foundations for most of classical mechanics. In this work, Newton described Universal gravitation and the three laws of motion, which dominated the scientific view of the physical universe for the next three centuries.

Newton showed that the motions of objects on Earth and of celestial bodies are governed by the same set of natural laws, by demonstrating the consistency between Kepler's laws of planetary motion and his theory of gravitation, thus removing the last doubts about heliocentrism and advancing the Scientific Revolution.

The Principia is generally considered to be one of the most important scientific books ever written.

Principia Mathematica

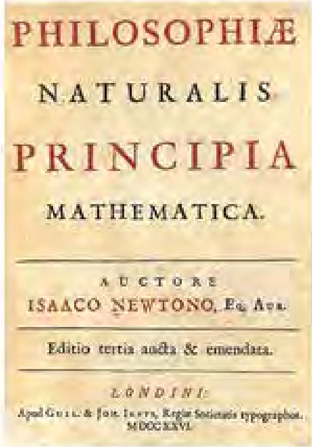

PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

AUCTORE
ISAACO NEWTONO, Eq. Aur.

Editio tertia aucta & emendata.

LONDINI:
Apud Guil. & Joh. Innys, Regiæ Societatis typographos.
MDCCXXVI.

first edition (1686/1687)

First Law of Motion

$$\sum \mathbf{F} = 0 \Rightarrow \frac{d\mathbf{v}}{dt} = 0$$

Bodies at rest - remain at rest
unless acted upon by an outside Force

Second Law of Motion

$$\sum \mathbf{F} = \frac{\mathrm{d}\mathbf{p}}{\mathrm{d}t} = m\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t} + \mathbf{v}\frac{\mathrm{d}m}{\mathrm{d}t}$$

The nett force on a particle is equal to the time
rate of change of its linear momentum [p]

Third Law of Motion

$$\sum \mathbf{F}_{a,b} = -\sum \mathbf{F}_{b,a}$$

For every action there is
an equal and opposite reaction

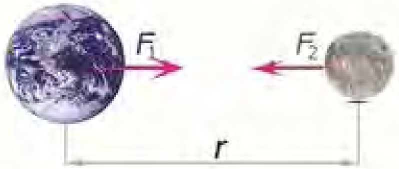

Newton's Law of universal Gravitation

"I deduced that the forces which keep the planets in their orbs must [be] reciprocally as the squares of their distances from the centers about which they revolve: and thereby compared the force requisite to keep the Moon in her Orb with the force of gravity at the surface of the Earth; and found them answer pretty nearly"

$$F = -G\,\frac{M_1 m_2}{r^2}$$

"hitherto I have not been able to discover the cause of those properties of gravity from the phenomena, and I frame no hypothesis"

According to Bošković's simple dynamistic atomism, Matter is not only endowed with forces (dynamic system), but it is composed of forces (dynamistic system). Forces flow out of the atom and permeate empty space.

This idea led to the concept of the field, much later formulated by M. Faraday (1844), who together with J.C. Maxwell introduced the idea of fields of force into science.

Boskovic is famous for his atomic theory and made many important contributions to astronomy, including the first geometric procedure for determining the equator of a rotating planet from three observations of a surface feature and for computing the orbit of a planet from three observations of its position.

In 1753 he also discovered the absence of atmosphere on the Moon.

Rudjer Boskovic

(18 May 1711 – 13 February 1787)

k

Boskovic proposed that attractive Gravitational fields could be explained as diminshed interactive EM fields that result in a nett converent force at great distances

G

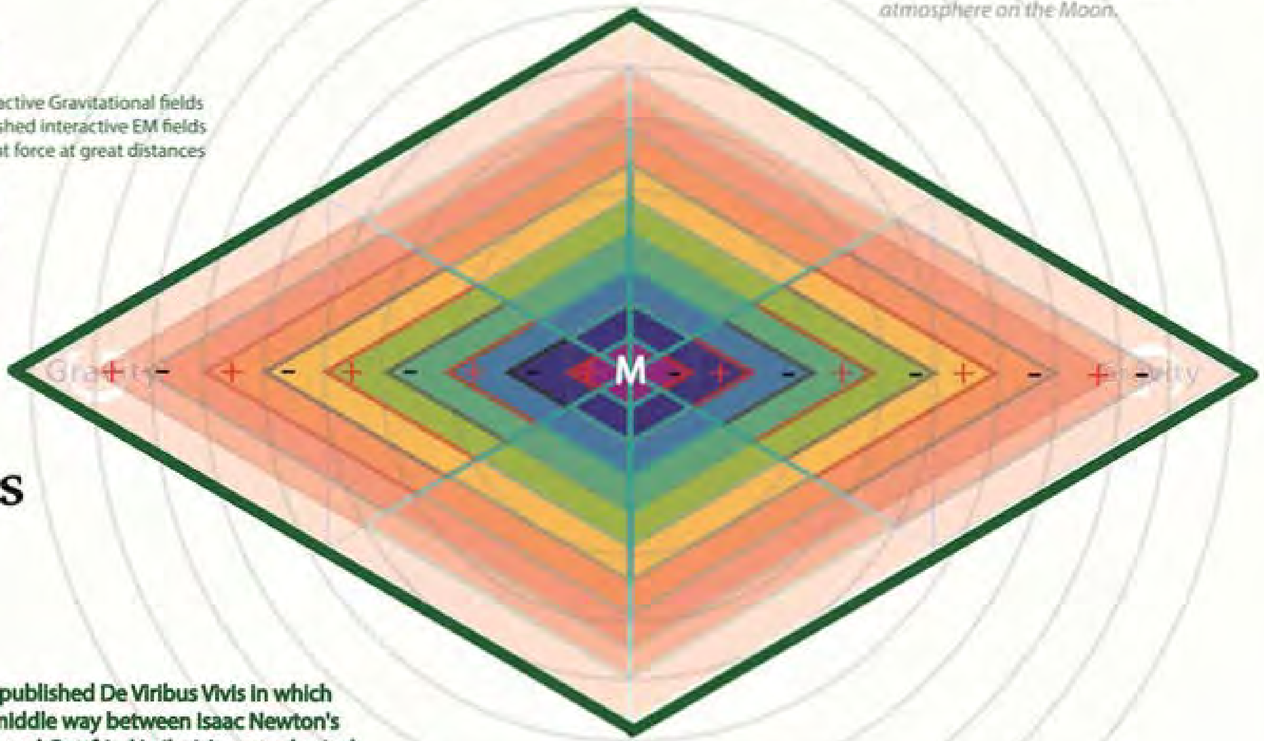

Diminished EM waves

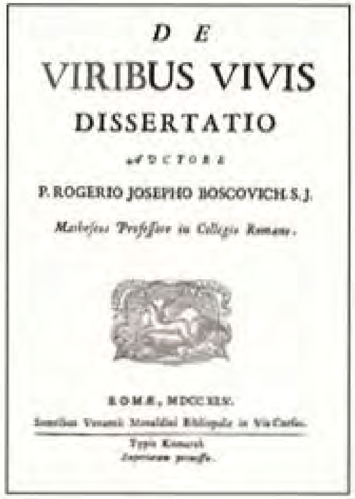

D E

VIRIBUS VIVIS

DISSERTATIO

AUCTORE

P. ROGERIO JOSEPHO BOSCOVICH S.J.

Matheseos Professore in Collegio Romano.

ROMÆ, MDCCXLV.

In 1745 Bošković published De Viribus Vivis in which he tried to find a middle way between Isaac Newton's gravitational theory and Gottfried Leibniz's metaphysical theory of monad-points

The force is repulsive when this curve lies above the line AC and attractive when it lies below it.

At very large distances (at and beyond V), it is attractive and approaches Newton's inverse-square law of force produced by gravity

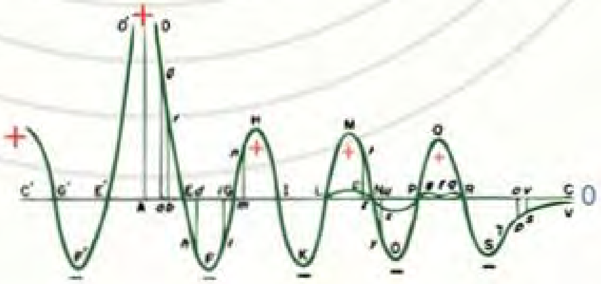

nett attractive force at large distances

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Gaussian Gravity

Gauss's law for gravity bears the same mathematical relation to Newton's law that Gauss's law for electricity bears to Coulomb's law.

G

Gauss's law for gravity is mathematically similar in form to Gauss's law for electrostatics.

k

the striking mathematical similarity in the formulation of electrostatics and gravitation has puzzled science for centuries

$$F_{elec}\ k \propto \frac{Q_1 Q_2}{r^2}$$

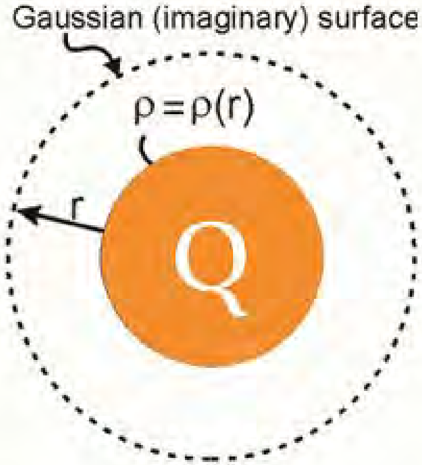

$$\oint \vec{E} \cdot d\vec{A} = \frac{q}{\varepsilon_0} = 4\pi kq$$

The electric flux through any closed surface is proportional to the enclosed electric charge.

$$\nabla \cdot E = \frac{\rho}{\varepsilon_0} = 4\pi k\rho$$

Carl Friedrich Gauss

(30 April 1777 – 23 February 1855)

Gauss's law for gravity, also known as Gauss's flux theorem for gravity, is a law of physics which is essentially equivalent to Newton's law of universal gravitation.

Although Gauss's law for gravity is physically equivalent to Newton's law, there are many situations where Gauss' law for gravity offers a more convenient and simple way to do a calculation than Newton's law.

note: 4π spherical topologies are equivalent to 4π tetrahedral topologies
[see Euler characteristics & Gauss-Bonnet topology theorem]

$$F_{grav}\ G \propto \frac{M_1 m_2}{r^2}$$

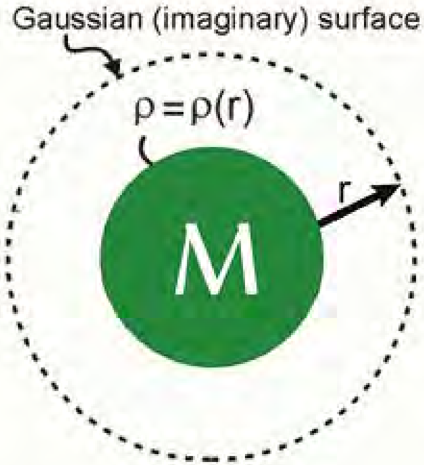

$$\oint_{\partial V} \mathbf{g} \cdot d\mathbf{A} = -4\pi GM$$

The gravitational flux through any closed surface is proportional to the enclosed Matter

$$\nabla \cdot \mathbf{g} = -4\pi G\rho$$

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Poisson's Gravity fields

Charges are the sources and sinks of EM fields

Matter is the source of Gravitational fields

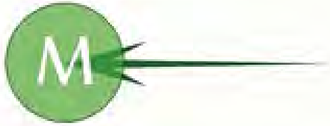

Poisson recognised that charges are the sources and sinks of electrostatic fields:
positive charges emanate electric field lines, and the field lines terminate at negative charges.

Similarly, in Newton's gravitation masses are the sources of the gravity field
so that field lines terminate at objects that have mass.

Poisson formalised Gauss' Law for electric fields (using the more general divergence theorem)

$$\iint \vec{E}\cdot d\vec{S} = \frac{q_e}{\epsilon_0} \Rightarrow \vec{\nabla}\cdot\vec{E} = \frac{\rho_e}{\epsilon_0}$$

and then applied the same formulation to spherical Matter for gravitation

$$\iint \vec{g}\cdot d\vec{S} = -4\pi G_c m \Rightarrow \vec{\nabla}\cdot\vec{g} = -4\pi G_c \rho_m$$

Simeon Poisson

(21 June 1781 – 25 April 1840)

All EM field interactions are the result of superpositioned EM fields (comprising of convergent AND divergent energy momenta) whose quanta create differing field strengths,
The inverse square forces of gravity can be modelled using the same field geometry thus illustrating the reason for the geometric & mathematical similarity between Newton's & Coulomb's constants

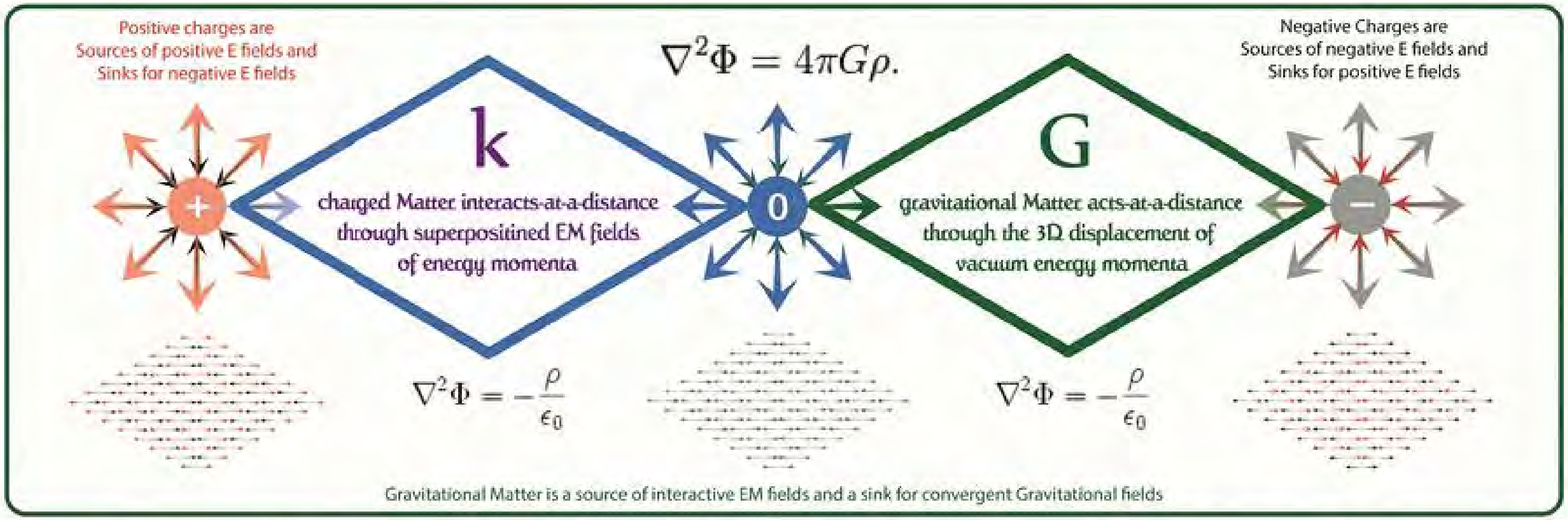

Positive charges are
Sources of positive E fields and
Sinks for negative E fields

$$\nabla^2\Phi = 4\pi G\rho.$$

Negative Charges are
Sources of negative E fields and
Sinks for positive E fields

k

charged Matter interacts-at-a-distance
through superpositined EM fields
of energy momenta

G

gravitational Matter acts-at-a-distance
through the 3D displacement of
vacuum energy momenta

$$\nabla^2\Phi = -\frac{\rho}{\epsilon_0}$$

$$\nabla^2\Phi = -\frac{\rho}{\epsilon_0}$$

Gravitational Matter is a source of interactive EM fields and a sink for convergent Gravitational fields

Tetryonic QM & QED clearly shows that both the sink and source fields are the result of bidirectional energy momenta

Poison's field equations shows that weak KEM field geometries can be used to model the convergent forces of Gravitational fields

Gravito-Electro-Magnetism

inverse squared law

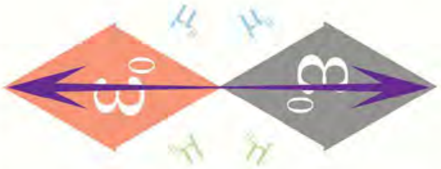

nett divergent
Electric field forces

$1/r^2$

$$\oint \vec{E} \cdot d\vec{A} = \frac{q}{\varepsilon_0}$$

k

$$\oint \vec{B} \cdot d\vec{A} = 0$$

Maxwell's 1864 achievements concerning electromagnetism have been called the "second great unification in physics", following on from the first one realised by Isaac Newton.

inverse cubed law

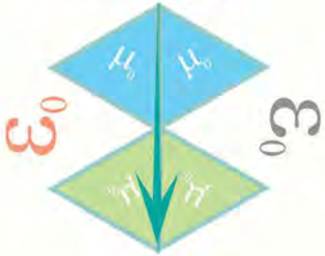

vector
Magnetic forces

$1/r^3$

Maxwell's equations

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \frac{1}{\epsilon_0 c^2}\mathbf{J} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}$$

James Clerk Maxwell

(13 June 1831 – 5 November 1879)

Any opinion as to the form in which the energy of gravitation exists in space is of great importance, and whoever can make his opinion probable will have, made an enormous stride in physical speculation.

The apparent universality of gravitation, and the equality of its effects on matter of all kinds are most remarkable facts, hitherto without exception; but they are purely experimental facts, liable to be corrected by a single observed exception.

We cannot conceive of Matter with negative inertia or mass; but we see no way of accounting for the proportionality of gravitation to mass by any legitimate method of demonstration

GEM equations

$$\nabla \cdot \mathbf{E}_g = -4\pi G \rho_g$$

$$\nabla \cdot \mathbf{B}_g = 0$$

$$\nabla \times \mathbf{E}_g = -\frac{\partial \mathbf{B}_g}{\partial t}$$

$$\nabla \times \mathbf{B}_g = 4\left(-\frac{4\pi G}{c^2}\mathbf{J}_g + \frac{1}{c^2}\frac{\partial \mathbf{E}_g}{\partial t}\right)$$

$1/r^2$

strictly convergent vector force

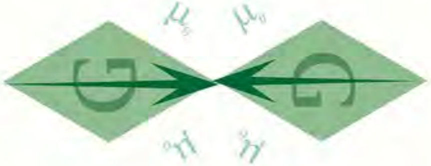

Maxwell proposed a set of equations based on his EM field laws that created a Gravito-Electro-Magnetic field reflective of the similarities between Newton's & Coulomb's Laws

$$\nabla \times \mathbf{E}_g = -\frac{\partial \mathbf{B}_g}{\partial t}$$

G

$$\nabla \cdot \mathbf{B}_g = 0$$

giving rise to spectulation about the existence of 'gravitons'
a theorised Gravitational 'charge' carrier

$1/r^3$

gravitomagnetic dipole

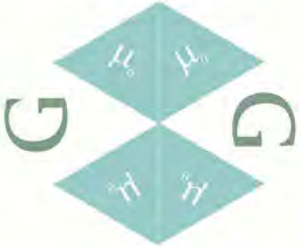

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General Relativity

The General Theory of Relativity
In 1915, Einstein extended SR and proposed a new theory of gravitation to account for accelerating bodies

Einstein said that when he "was sitting in a chair in the patent office at Bern when all of a sudden a thought occurred to me: 'If a person falls freely he will not feel his own weight.' I was startled. This simple thought ... impelled me toward a theory of gravitation. ..."

$$G_{ab} = 8\pi G\, T_{\mu\nu}$$

$$R_{\mu\nu} - \tfrac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

The EFE is a tensor equation relating a set of symmetric 4 x 4 tensors.

the scalar curvature

Newton's gravitational constant

Ricci curvature tensor

$$R_{\mu\nu} - \tfrac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

the stress-energy tensor

the metric tensor

the speed of light in vacuum

Each tensor has 10 independent components

Spacetime

Matter

$$G_{\mu\nu} + g_{\mu\nu}\Lambda = 8\pi T_{\mu\nu}$$

the cosmological constant

Albert Einstein

(14 March 1879 – 18 April 1955)

$$G_{ab} = \kappa\, T_{\mu\nu}$$

curved spacetime

mass-energy tensor

where

$$\kappa = -\frac{8\pi G}{c^4}$$

General Relativity describes gravity as a warping of space itself, not as a force.
Einstein pictured space as a three-dimensional version of a thin rubber sheet

Einstein's General Theory of Relativity, which was published in 1916 had as its foundation that the laws of nature in an accelerating frame are equivalent to the laws of a gravitational field.

This is known as the Equivalence Principle.

GEM fields & Gravity

Sir Issac Newton

(25 December 1642 – 20 March 1727)

Gravity is one of the four fundamental interactions of nature,
along with electromagnetism and the nuclear strong and weak forces

[for centuries scientific enquiry has been aimed squarely at discerning a physical mechanism for gravitation]

$$\overset{\text{Matter}}{\frac{4n\pi}{c^4}}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

Tetryonics reveals Gravity to be the result of the displacement of vacuum energies by mass-Matter topologies which is accurately modelled using GEM field geometry

Albert Einstein

(14 March 1879 – 18 April 1955)

$$F = -G\frac{\overset{\text{masses}}{M_1 m_2}}{r^2}$$

$$G_{ab} = \frac{8\pi G}{c^4}\overset{\text{energies}}{T_{\mu\nu}}$$

Gravity is responsible for keeping the Earth and the other planets in their orbits around the Sun;
for keeping the Moon in its orbit around the Earth; for the formation of tides; for natural convection,
by which fluid flow occurs under the influence of a density gradient and gravity;
for heating the interiors of forming stars and planets to very high temperatures;
and for various other phenomena observed on Earth.

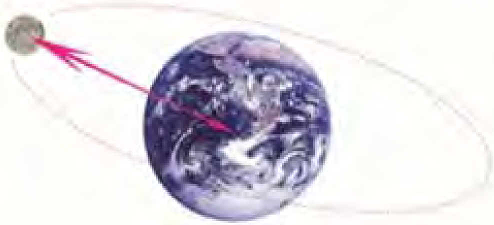

instantaneous
action-at-a-distance

Gravity is a natural phenomenon by which physical bodies attract each other with a force proportional to their mass Matter content.

Gravity is most familiar as the agent that gives weight to objects with mass and causes them to fall to the ground when dropped.

Gravity causes dispersed Matter to coalesce, and coalesced Matter to remain intact, to the creation of the SUN, the Earth, and to source of energy in the stars that light our universe.

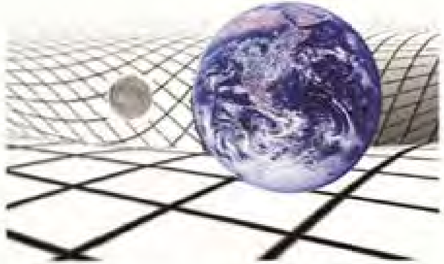

motion in
curved spacetime

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Separating Space & Time

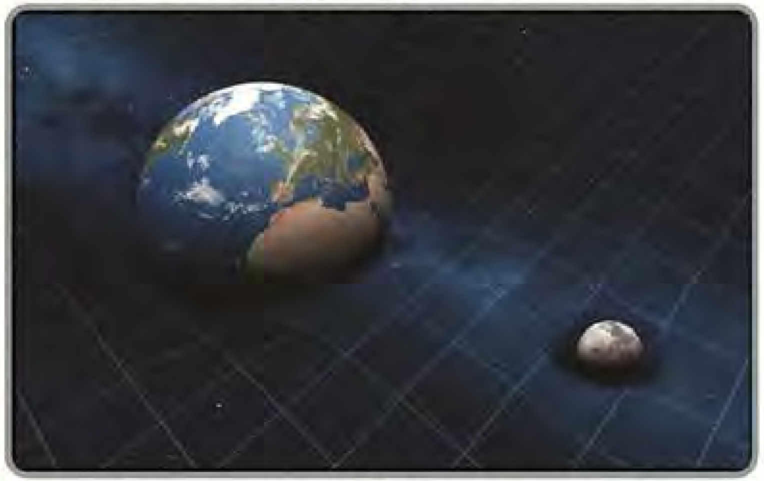

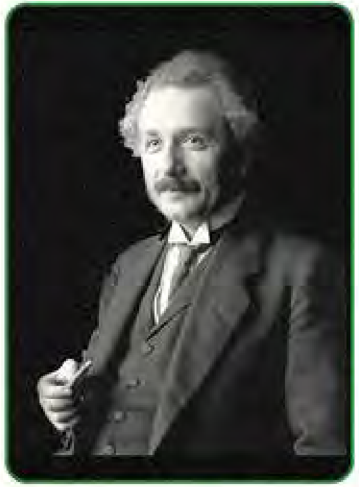

(in the search for Gravity)

Instantaneous
'action-at-a-distance'

Relativistic
spacetime 'curvature'

DOES

The Earth pull on the moon and
the moon pull proportionally back on the Earth

OR

Does the Earth curve spacetime in its vicinity
with the moon following the geodesic path created

Tetryonic theory through its clear definitions of charged mass-ENERGY-Matter provides the long-sought answer to Gravitation

Empty Space

is defined in Tetryonic & relativistic theory
by the speed of light

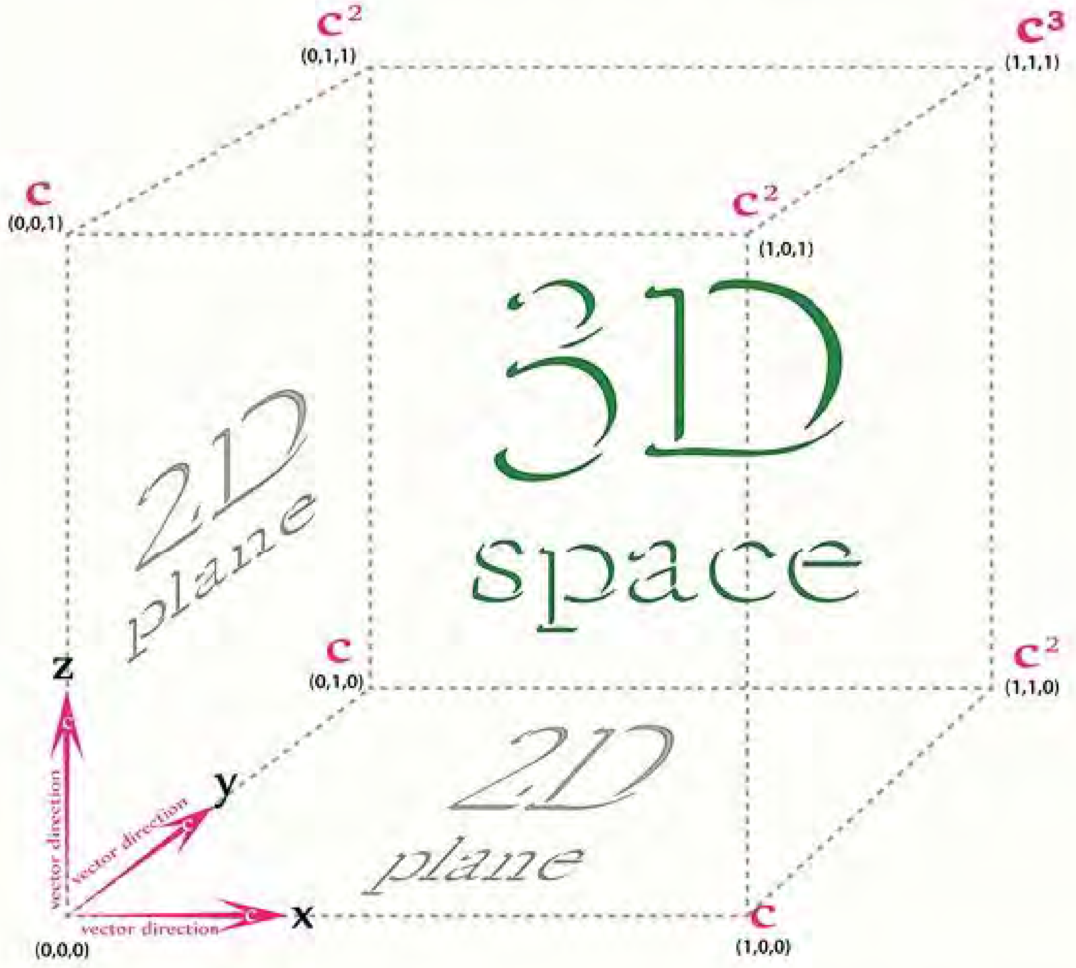
c²
(0,1,1)
c³
(1,1,1)
c
(0,0,1)
c²
(1,0,1)
3D
space
2D
plane
z
c
(0,1,0)
c²
(1,1,0)
y
vector direction
vector direction
c
2D
plane
x
vector direction
(0,0,0)
c
(1,0,0)

Energy

content of free space is Zero

A Spatial region is defined
by a co-ordinate system so as to
measure the physics and motion
of mass-ENERGY-Matter
within its confines

mass

is Energy content per unit of time

EM mass-energies can
be found in (and move through)
empty Space in various forms:
radiant energies, Matter etc

Matter

is Energy content per unit of time squared

Space can be any regular geometry
[Cubic, Spherical or polyhedral]
limited by the spatial co-ordinates
used to define the region or volume

Empty Space is defined as a geometric volume devoid of any form of Energy

Spacetime co-ordinates

The linear force vectors of divergent Energy
can form various co-ordinate systems
based on their vector directions
per unit of time

Charge radiates unilaterally
in the direction of its
vector linear momentum

Vector forces

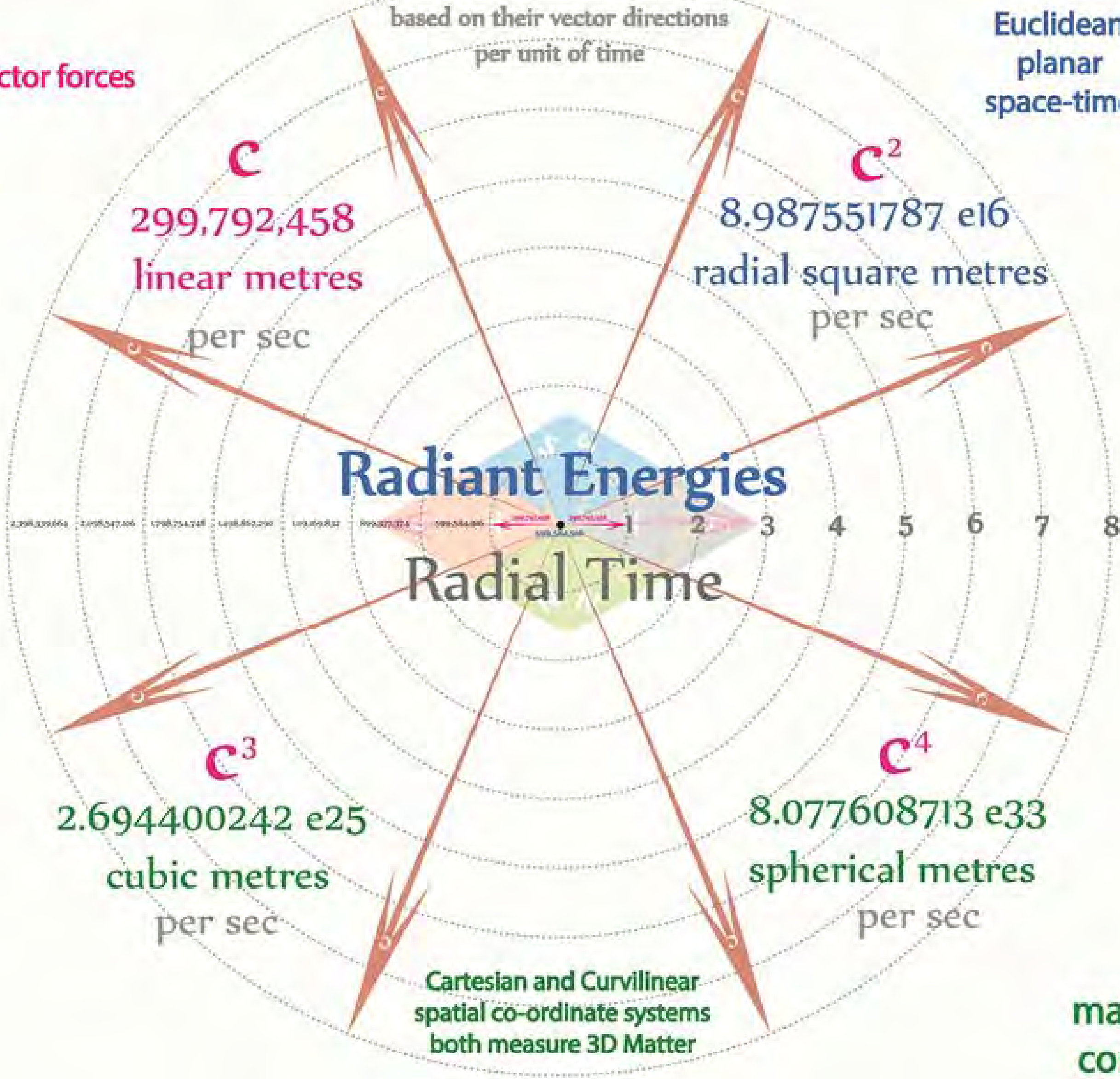
Radiant Energies
Radial Time
2,398,339,664
2,098,547,206
1,798,754,748
1,498,962,290
1,199,169,832
899,377,374
599,584,916
1
2
3
4
5
6
7
8

c
299,792,458
linear metres
per sec

c²
8.987551787 e16
radial square metres
per sec

c³
2.694400242 e25
cubic metres
per sec

c⁴
8.077608713 e33
spherical metres
per sec

Cartesian and Curvilinear
spatial co-ordinate systems
both measure 3D Matter

Euclidean
planar
space-time

EM Light radiates bi-laterally
in the 2 directions of its
linear momentum vectors

Time in Physics is a measure
of how long it takes for light to
travel 299,792,458 metres
from its source in a vacuum

$$\frac{\text{metre}}{299{,}792{,}458\ \text{sec}}$$

A metre in Physics is
the distance light travels in
1/ 299,792,458 of a second
from its source

$$\frac{299{,}792{,}458\ \text{m}}{\text{second}}$$

Energy entropy
of a system

mass-energy-Matter
content of a system

Spatial co-ordinate geometries

based on the vector speed of light
form distinct spatial co-ordinate systems
for the measurement of physics

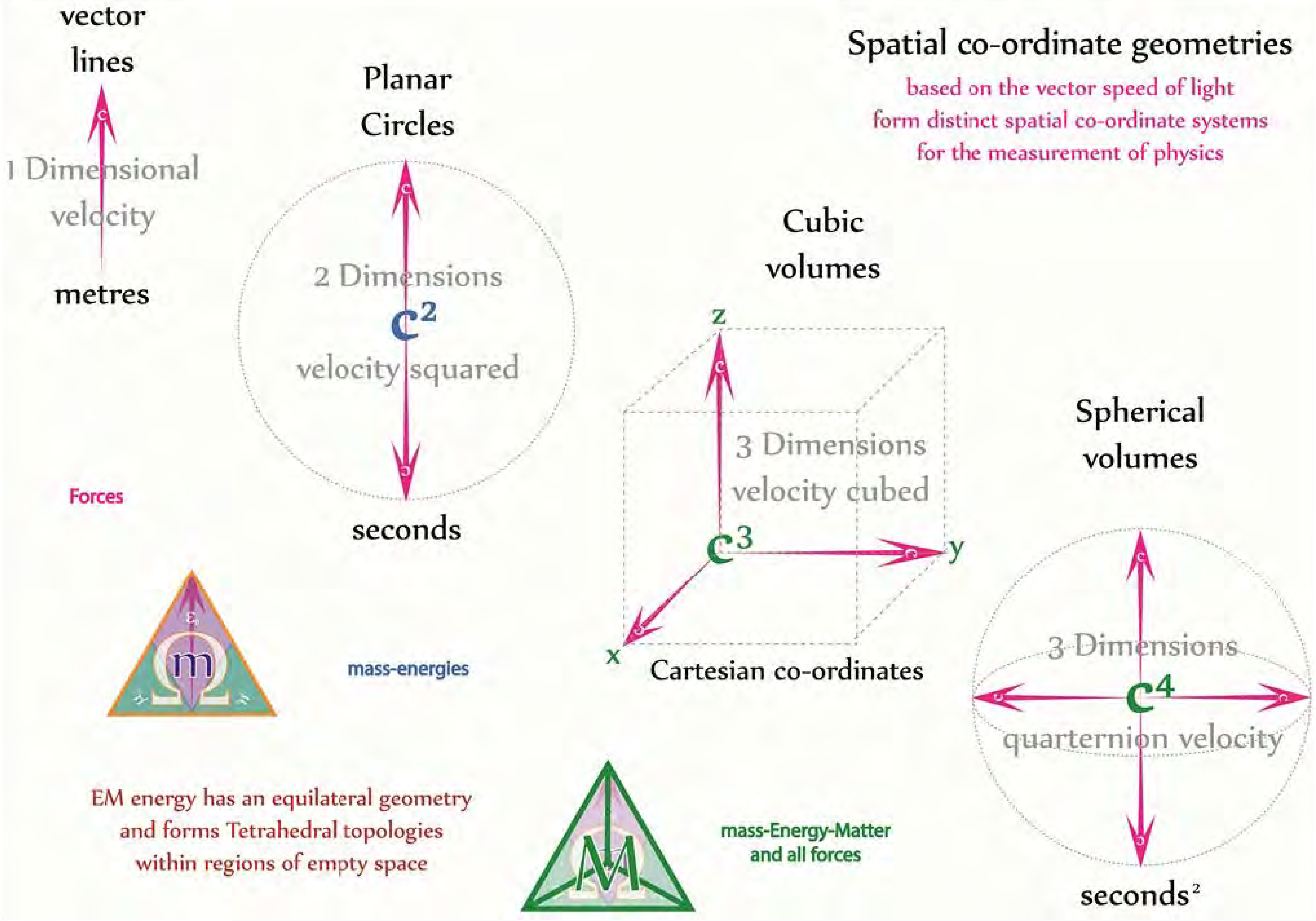

vector lines

1 Dimensional velocity

metres

Planar Circles

2 Dimensions

c^2

velocity squared

seconds

Cubic volumes

3 Dimensions

velocity cubed

c^3

Cartesian co-ordinates

Spherical volumes

3 Dimensions

c^4

quarternion velocity

seconds²

Forces

mass-energies

EM energy has an equilateral geometry
and forms Tetrahedral topologies
within regions of empty space

mass-Energy-Matter
and all forces

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Spatial co-ordinate systems

Cubic

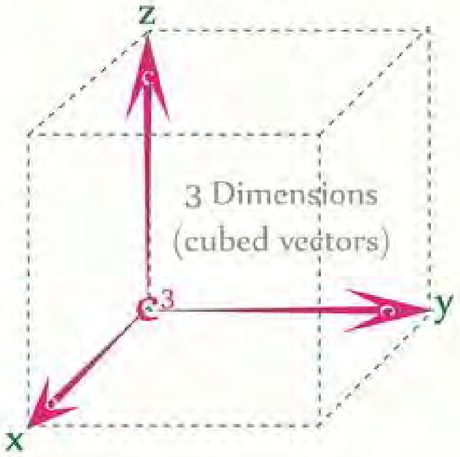

Spacetime (or space-time, or space time) is any mathematical model that combines space and time into a single continuum.

Spacetime is usually interpreted with space as being three-dimensional and time playing the role of a fourth dimension that is different from the spatial dimensions.

Tetryonic theory redefines as time to be a measure of the changing quantised angular momenta of Planck scale Charges In any spatial plane or volume

By combining space and time into a single manifold, we can significantly simply a large number of physical theories, and re-formulate them in a more uniform way to explain the mechanics of the Universe at all scales

Tetryonics maps radial spacetime co-ordinates through the vector momentum of Energy

Spherical

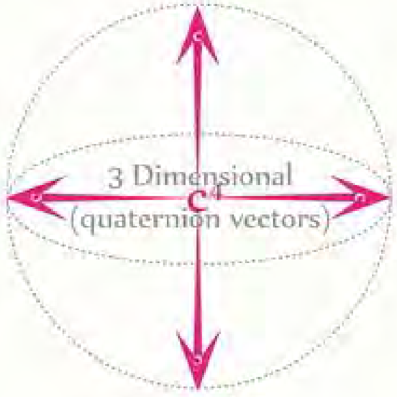

seconds²

Cartesian Space-Time

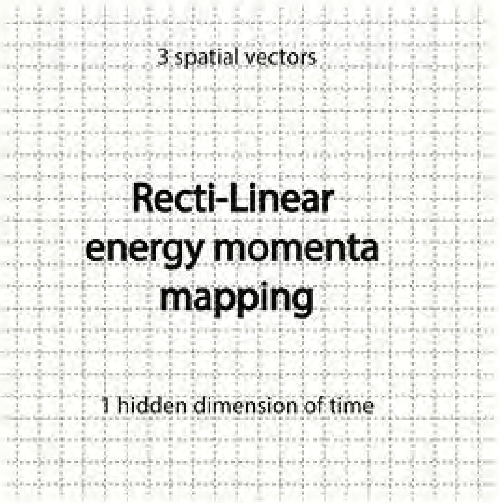

3 spatial vectors

Recti-Linear energy momenta mapping

1 hidden dimension of time

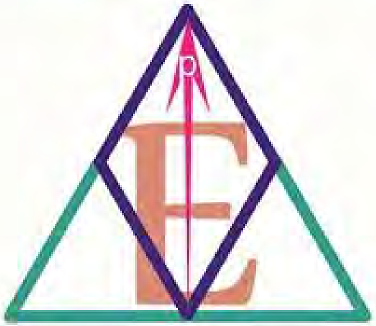

The quantised angular momenta of mass-Energy and Matter are triangular geometries

The current methodologies for mapping energy densities onto Euclidean, Cartesian and Reimannian co-ordinates are inaccurate reflections of the charged mass-ENERGY-Matter geometries, introducing a mathematical complexity to a otherwise simple foundational equilateral geometry

Tetryonic Space-Time

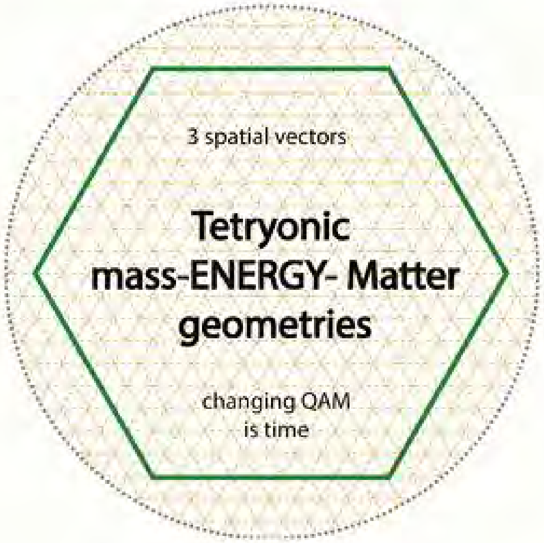

3 spatial vectors

Tetryonic mass-ENERGY- Matter geometries

changing QAM is time

By mapping equilateral mass-energies & Matter into radial spatial co-ordinates Tetryonic theory is able to reveal the hidden 4th dimension of time

Space & time separated

All equilateral mass-energies & tetrahedral Matter can be mapped with planar spatial geometries within spherical space-time co-ordinates

Space is the region of measurement defined by the vector propagation of light
time is a measure of the changing QAM within any spatial region

Tπ standing-waves

c^4 spatial regions contain mass-Matter

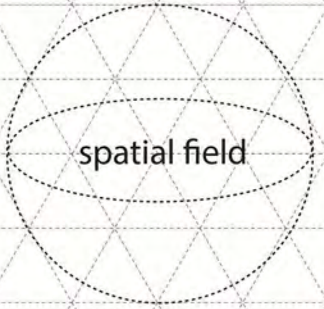

spatial field

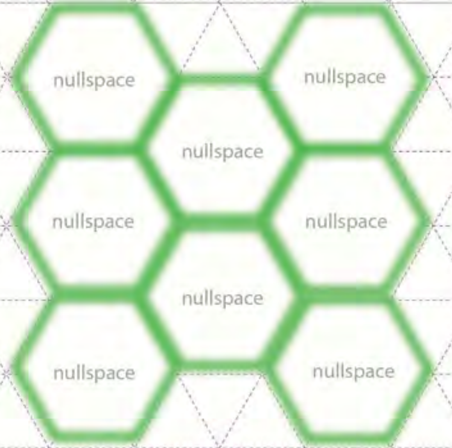
nullspace
nullspace
nullspace
nullspace
nullspace
nullspace
nullspace
nullspace

compounds

c^2 spatial regions contain mass-energies

nπ radiant geometries

weak irradiated mass-energies permeate 'empty' space
[vacuum energies]

γ

photons

ε
ε
3
ε
3
ε
3
ε
3
3

Baryons

Elements

3D Matter

topologies

Molecules

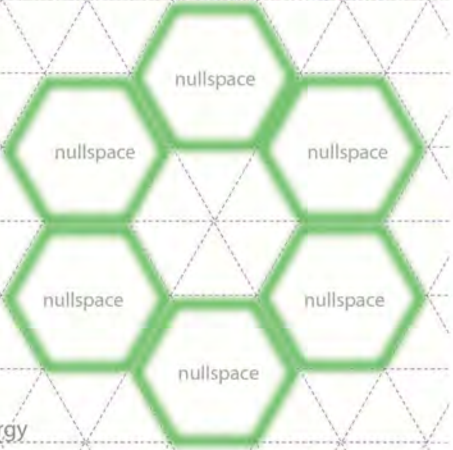
nullspace
nullspace
nullspace
nullspace
nullspace
nullspace

W+

2D mass-energy

geometries

+q

charges

bosons

photons

γ

-q

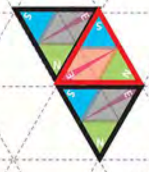

W-

'nullspace' is a spatial region devoid of all forms of energy
[found only within tetrahedral Matter topologies]

2D Euclidean spatial geometry

All 2D mass-energy momenta map onto **FLAT** Euclidian co-ordinates

[x,y] ΔΩ

(2D space & time)

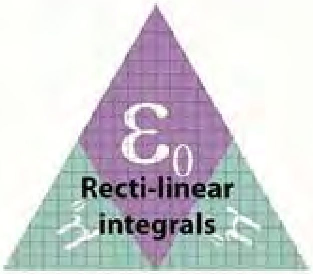
ε_0
Recti-linear
integrals

Cartesian spatial co-ordinates

fail to accurately map
equilateral energy momenta

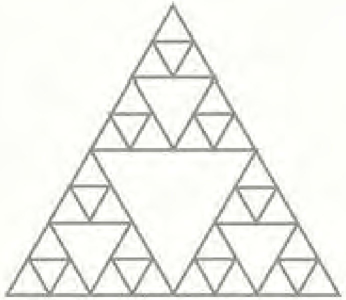

Minkowski spacetime

is a close approximation of
Tetryonic energy momenta

ε_0
Equilateral
integrals

Tetryonic space-time

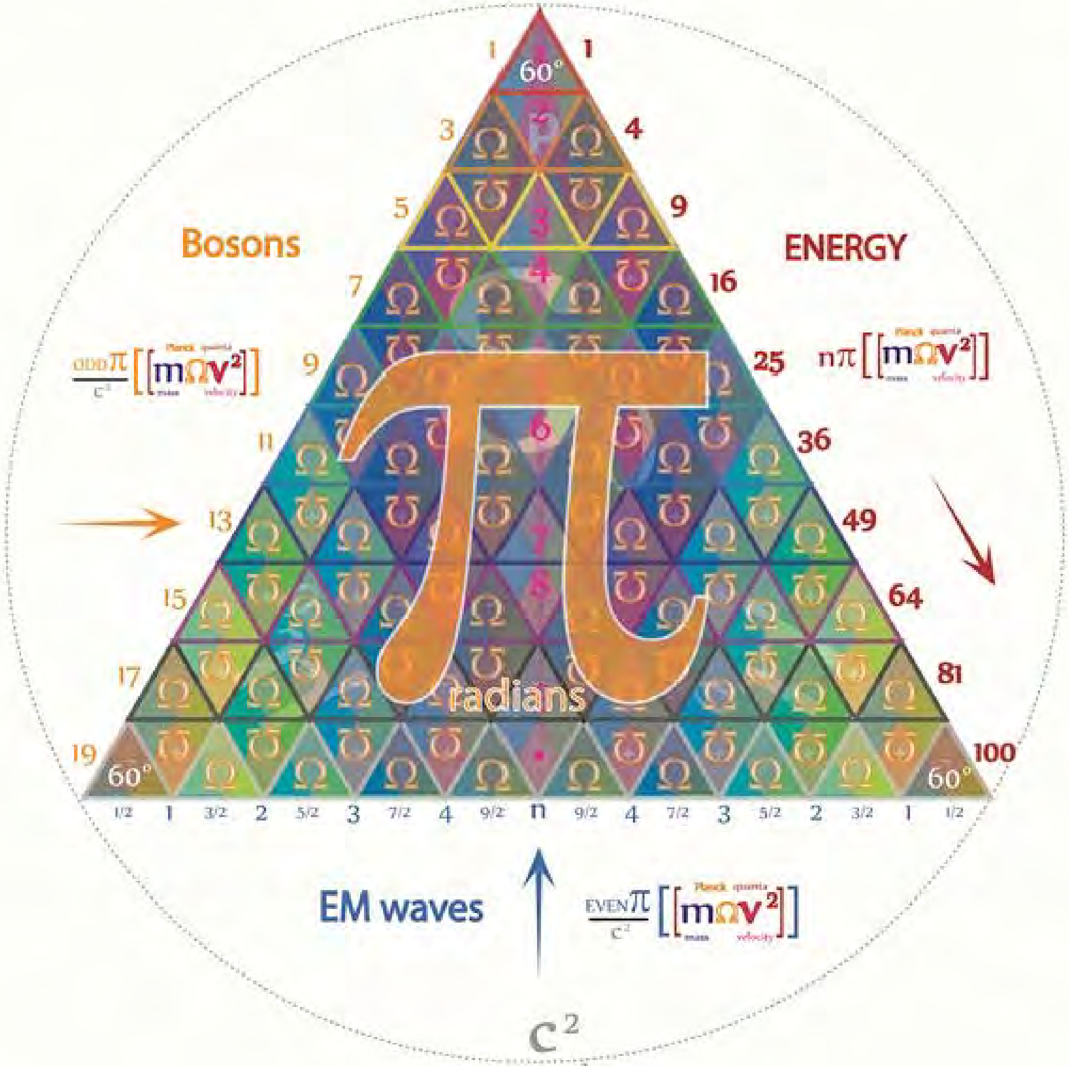
60°
1
1
3
4
5
9
7
16
9
25
11
36
13
49
15
64
17
81
19
100
60°
60°
Bosons
ENERGY
$\frac{ODD\pi}{c^2}[[m\Omega v^2]]$
$n\pi[[m\Omega v^2]]$
Planck quanta
mass velocity
π
radians
1/2 1 3/2 2 5/2 3 7/2 4 9/2 n 9/2 4 7/2 3 5/2 2 3/2 1 1/2
EM waves
$\frac{EVEN\pi}{c^2}[[m\Omega v^2]]$
c^2
seconds

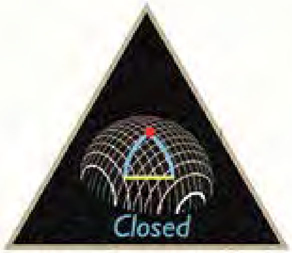

negative curvative
angles add up to > 180 °

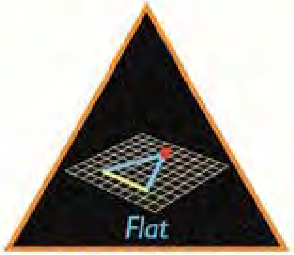

flat Euclidean
angles = 180 °

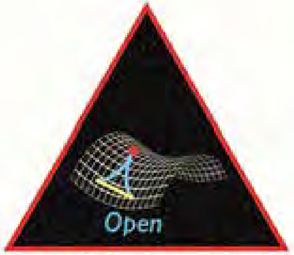

positive curvature
angles add up to < 180 °

Light cones space & time

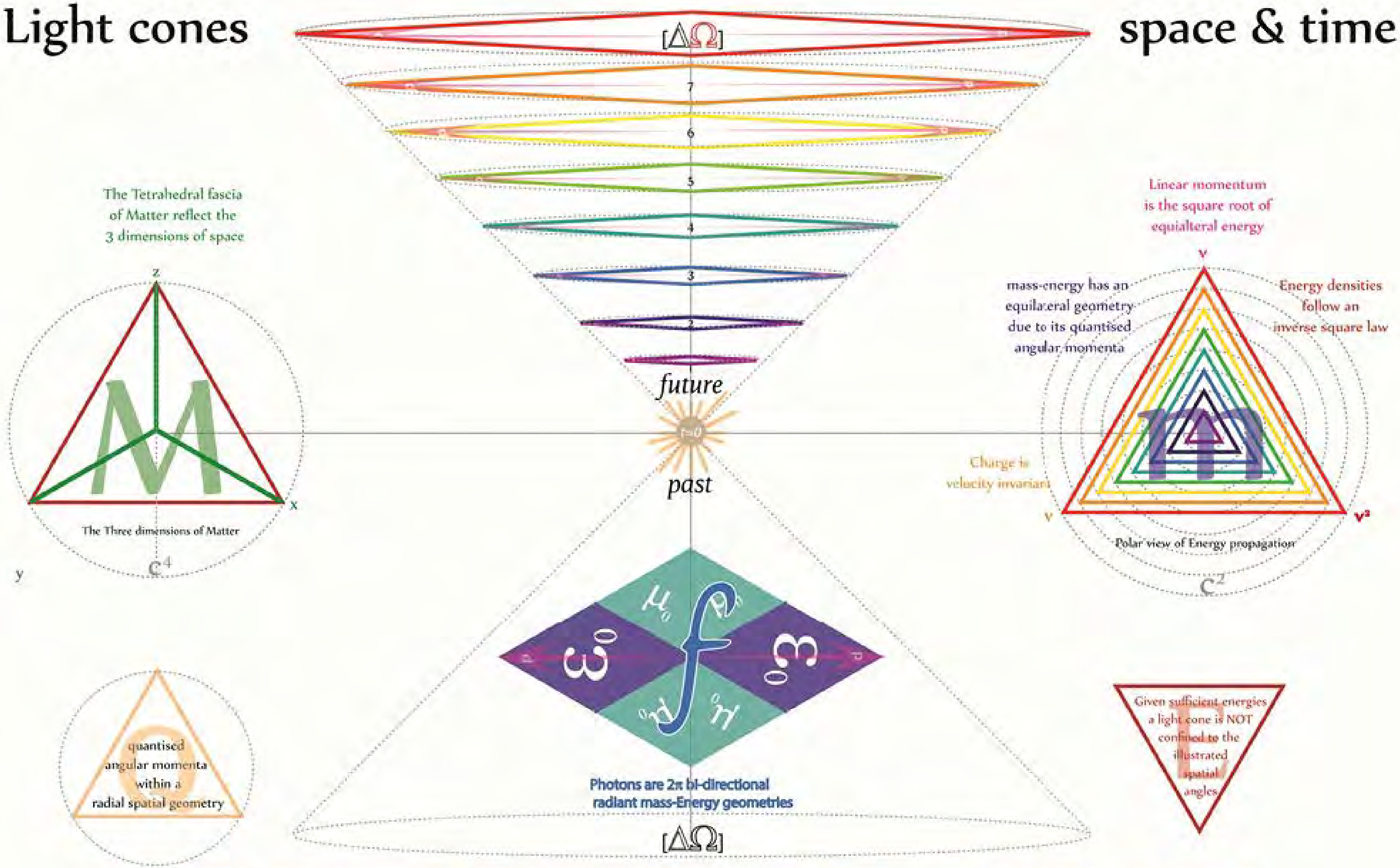

The Tetrahedral fascia of Matter reflect the 3 dimensions of space

The Three dimensions of Matter

quantised angular momenta within a radial spatial geometry

Photons are 2π bi-directional radiant mass-Energy geometries

Linear momentum is the square root of equialteral energy

mass-energy has an equilateral geometry due to its quantised angular momenta

Energy densities follow an inverse square law

Charge is velocity invariant

Polar view of Energy propagation

Given sufficient energies a light cone is NOT confined to the illustrated spatial angles

time is the measurement of the changing quantised angular momenta in any spatial region

A light cone is the path that a flash of light, emanating from a single event
(localized to a single point in space and a single moment in time) and traveling in all directions,
would take through space & time.

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Charge, energy momenta & time

measurements of the changing quantised angular momenta of scalar energy is the basis of measuring time

$$\Omega$$

$$\boxed{.0012}$$

$$\frac{m^2}{s}$$

quantised angular momentum

$$\beta = \left[\frac{v}{c}\right]$$

Linear Lorentz factor

metres

$$\frac{m^2}{s} \cdot \frac{s}{m}$$

$$\boxed{\frac{\Omega}{v}}$$

$$\lambda$$

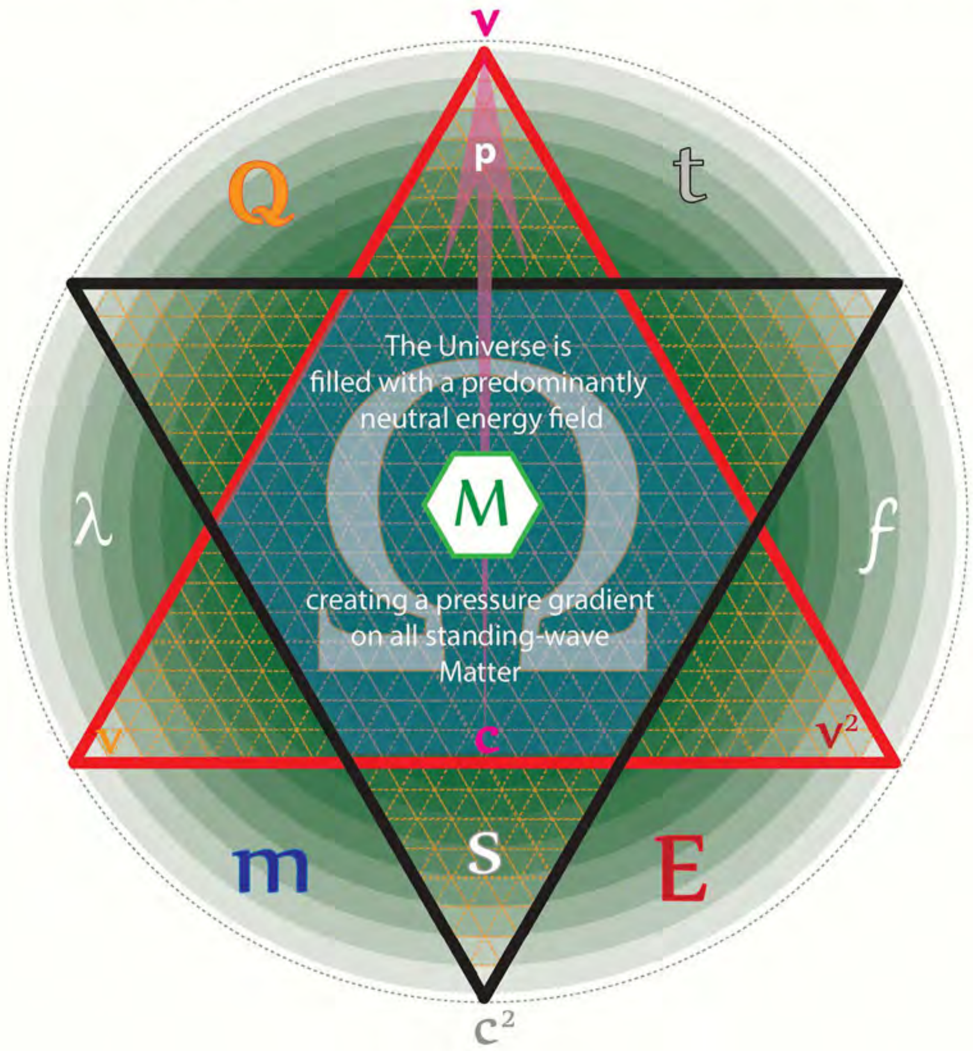

The Universe is filled with a predominantly neutral energy field

creating a pressure gradient on all standing-wave Matter

$$q$$

$$\boxed{\frac{\Omega}{c^2}}$$

$$\frac{m^2}{s} \cdot \frac{s^2}{m^2}$$

seconds

$$\left[\frac{v^2}{c^2}\right] = \beta^2$$

Scalar Lorentz factor

per second

$$\frac{m^2}{s^2} \cdot \frac{s}{m^2}$$

$$\boxed{\frac{v^2}{\Omega}}$$

$$f$$

Velocity of Light

$$c = \left[\underbrace{\overset{\lambda}{\left[\frac{\Omega}{c}\right]}}_{\text{Wavelength}} \cdot \underbrace{\overset{f}{\left[\frac{c^2}{\Omega}\right]}}_{\text{Frequency}}\right]$$

$\vec{p}$

Spatial co-ordinate systems are defined by the vectors of their linear energy momentum

Space
[x,y,z]

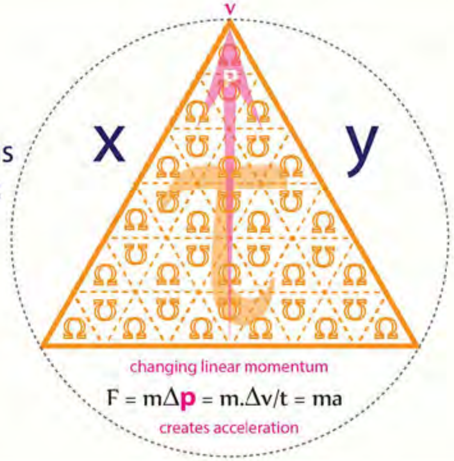

changing linear momentum

$F = m\Delta \mathbf{p} = m.\Delta v/t = ma$

creates acceleration

$\Delta\Omega$

Time is a measure of the changing quantised angular momenta in any defined region of space

Time
[seconds]

Spacetime Fields

are spatial geometries that contain changing Quantised Angular energy-Momenta [Planck quanta]

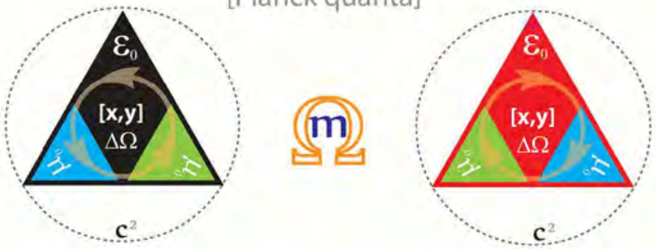
ε_0
[x,y]
ΔΩ
c^2
m
ε_0
[x,y]
ΔΩ
c^2

Charge is the nett distribution of Planck quanta mass.[Quantised Angular Momenta] within any spatial co-ordintate system

EM masses are 2D planar energy waveforms

2D mass-energy quanta have linear & angular momenta

Matter has a 3D volumetric energy waveform

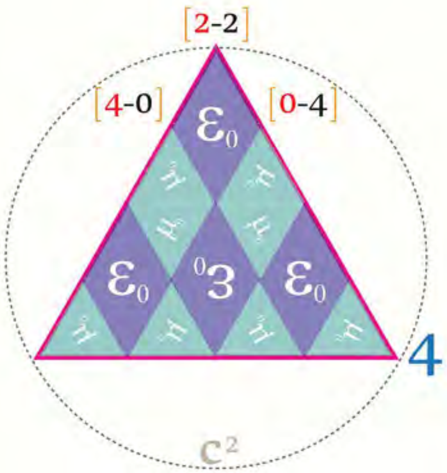
[2-2]
[4-0]
[0-4]
ε_0
ε_0
$^0 3$
ε_0
4
c^2

mass   Planck quanta

$$\frac{n\pi}{c^2}[[m\Omega v^2]]$$

mass   velocity

Tetryonic geometry restores symmetry to Einstein's mass-energy equivalence and reveals a mass-ENERGY-Matter equivalance

radiant mass-energies can form standing-wave Matter

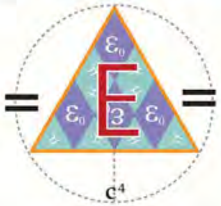
ε_0
E
ε_0
3
ε_0
c^4

$$\frac{m}{c^2} = E = M$$

standing-wave Matter can release radiant mass-energies

where space and time are separated

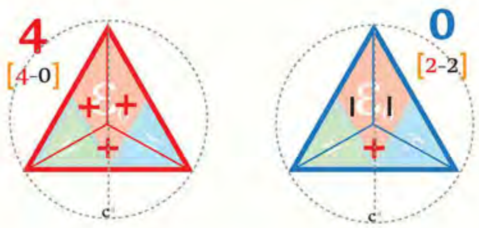

Matter   Planck quanta

$$\frac{T\pi}{c^4}[[m\Omega v^2]]$$

mass   velocity

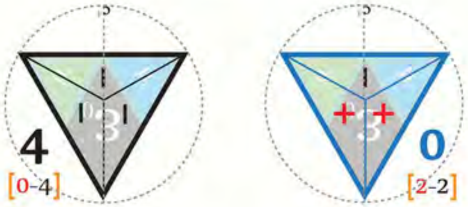
c
|
| |
3
4
[0-4]
c
|
+ +
3
0
[2-2]

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The 4th dimension of Time

is charge, the angular momenta associated with any planar mass-energy

Accelerate

$\vec{\mathbf{p}}$

increasing a systems's linear momentum

$F = m\Delta\mathbf{p} = m.\Delta v/t = ma$

creates acceleration

Decelerate

$\overleftarrow{\mathbf{p}}$

decreasing a systems's linear momentum

$F = m\Delta\mathbf{p} = m.\Delta v/t = ma$

creates decceleration

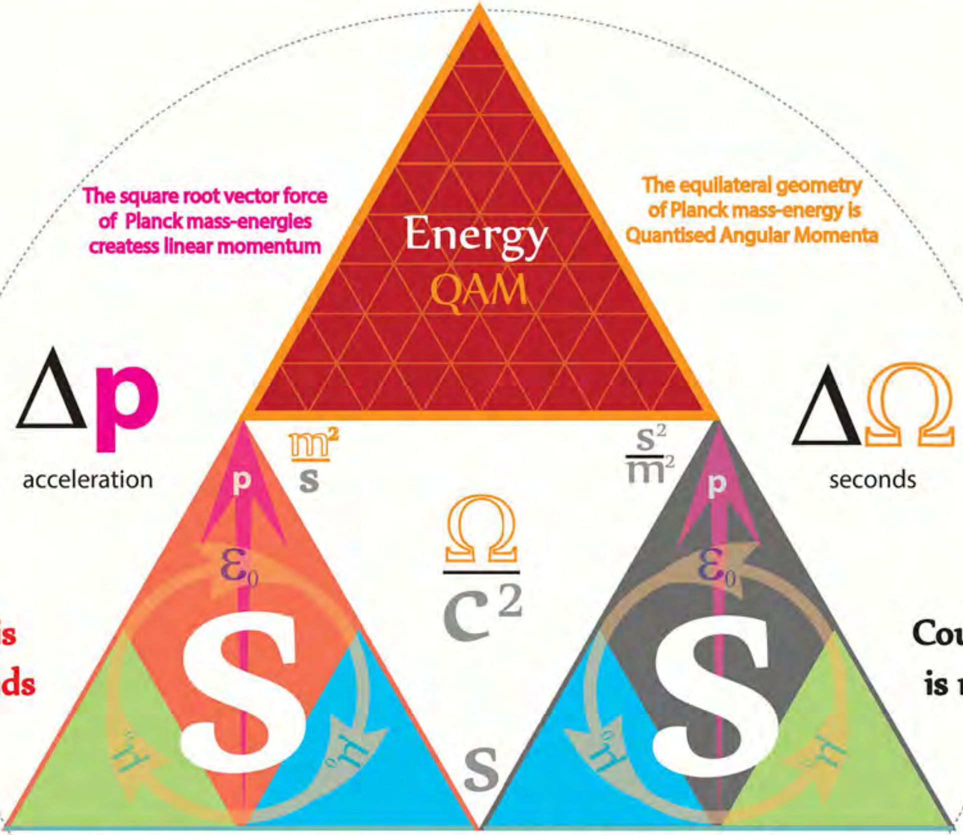

The square root vector force of Planck mass-energies createss linear momentum

The equilateral geometry of Planck mass-energy is Quantised Angular Momenta

$\Delta\mathbf{p}$

acceleration

$\Delta\Omega$

seconds

Clockwise charge is positive mass-seconds

Counter-clockwise charge is negative mass-seconds

Positive charge

Negative charge

the two 'arrows' of time in physics are a mathematical mis-interpretation of charge

Positive and Negative charges on opposite sides of Planck energy quanta,
the direct result of the equilateral geometry of all energy momenta
has been historically mis-represented in mathematics as
being two directional arrows of time

$\Delta\Omega$

Positive Time

Time is a measure of the changing angular momenta-energy (Planck geometry) of any given spatial region

$\Delta\Omega$

Negative Time

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CHARGE

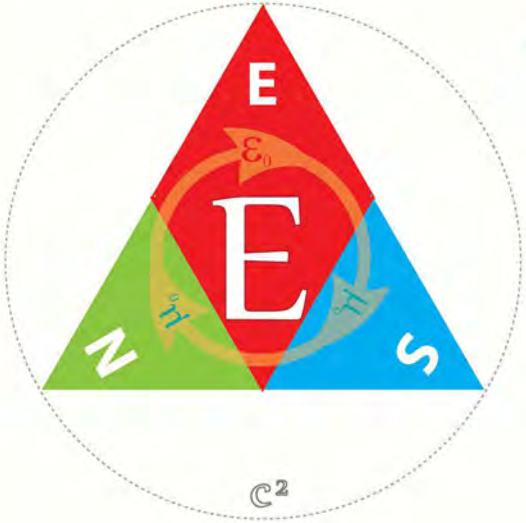
E
ε_0
E
μ_0
μ_0
N
S
c^2

all ideal inductive loops
resist changes to their
Energy levels

INERTIAL mass

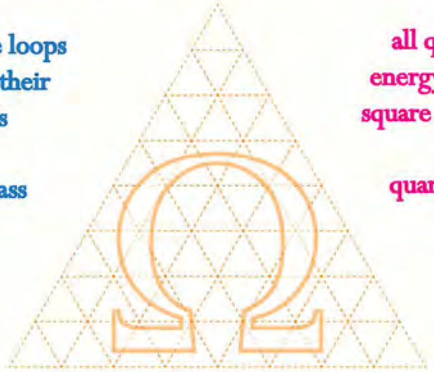

All quantised angular momentum
is an equilateral geometry

all quantised Planck
energy momenta posses
square root vector Forces

quantum of WORK

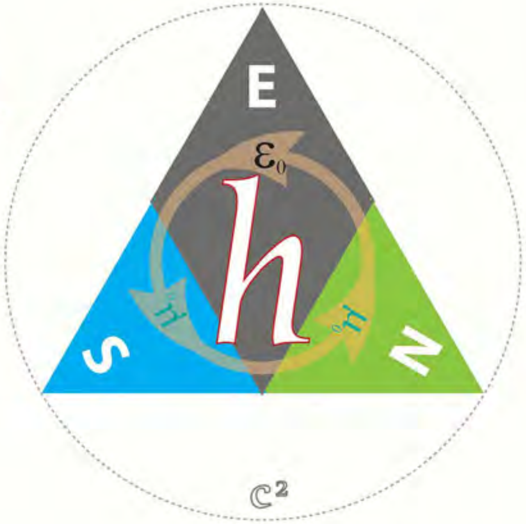
E
ε_0
h
μ_0
μ_0
S
N
c^2

vector velocity results from
linear momentum - the square root
of all scalar energies

$$\mathrm{kg}\left[\frac{m^2}{s^2}\ \frac{s^2}{m^2}\right]$$

Scalar energy
per unit time

mass

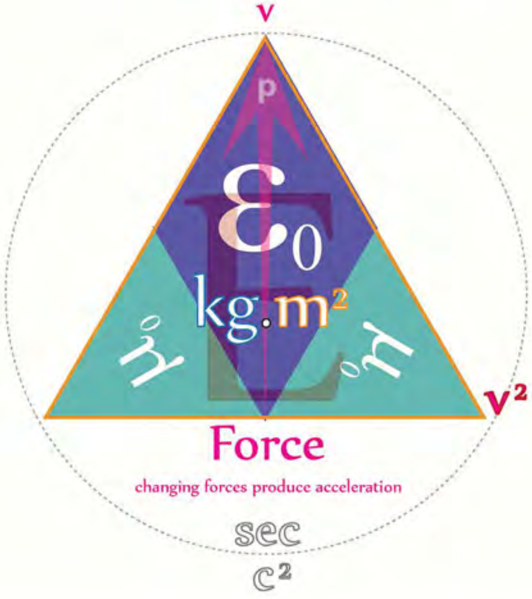
v
p
ε_0
kg.m²
E
μ_0
μ_0
v²
sec
c^2

Force

changing forces produce acceleration

$$\mathrm{kg}\left[\frac{m^2}{s}\ \frac{s^2}{m^2}\right]$$

Planck quanta
per unit time

mass.seconds

Tetryonics 62.12 - Charge is mass.time

Charge is the equilateral geometry of Energy that gives form to all mass & Matter

Positive charged mass-energy

1

[1-0]

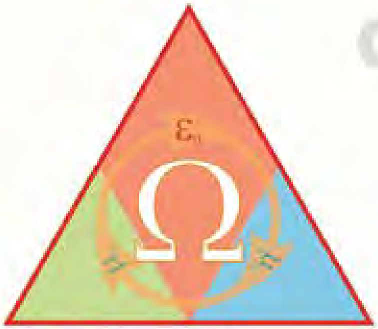

Clockwise inductive energy flux

charge

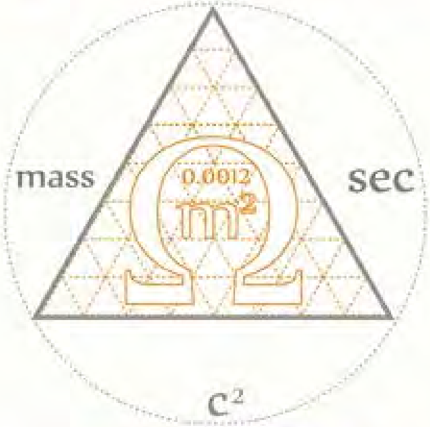

time

Negative charged mass-energy

1

[0-1]

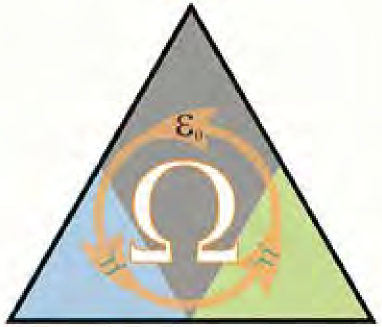

Counter clockwise energy flux

mass.seconds in physics is expressed as Coulombs [charge]

ε_0
m
Ω

t

$$\frac{\Delta\Omega}{c^2}$$

$$\frac{m^2}{s}\,\frac{s^2}{m^2}$$

$$s$$

seconds

t

ε_0
m
Ω

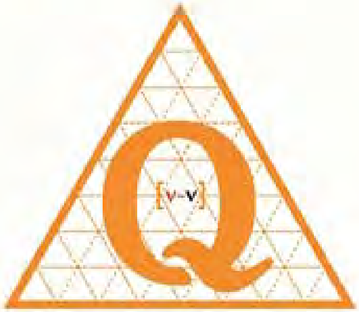

ElectroMagnetic Charge is a quantum property resulting from the equilateral QAM geometry of mass-energy

1.33518 e-20 s

Changes to nett quantised angular momenta [charged mass-energies] within any spatial co-ordinate system forms the basis of time

Two ElectroMagnetic charges are possible & both are created through the tesselation of EM energy momenta in ideal inductive loops

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The Quantum Arrow of Time

In physics is a measurement of changes to quantised angular momenta

Thermodynamic arrow of time

The Entropy of a system always increases

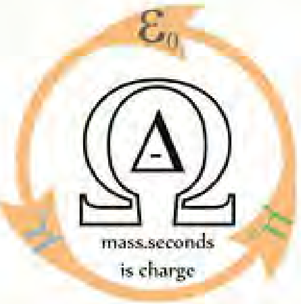

ε_0
mass.seconds
is charge

Radiative arrow of time

EM mass-energies rative outward from a point source

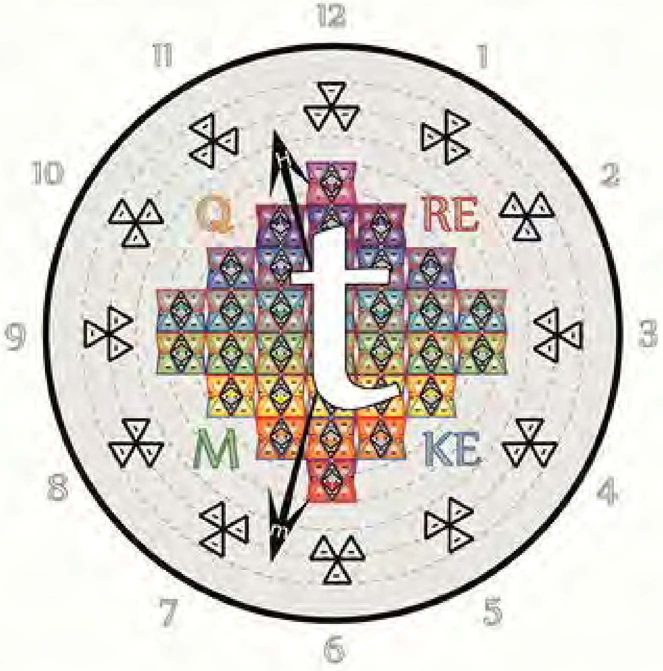

12
1
2
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4
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6
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8
9
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11
Q
RE
M
KE
t

Cosmological arrow of time

The Universe is evolving from a big bang to ?

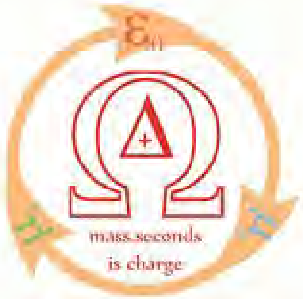

ε_0
mass.seconds
is charge

Causal arrow of time

A cause always precedes its effect

Tetryonic theory maps QAM as equilateral Planck geometries & reveals ΔQAM to be time
Time and the spatial dimensions it creates are mapped with radial & spherical co-ordinates

$\Delta m\Omega$

Decceleration

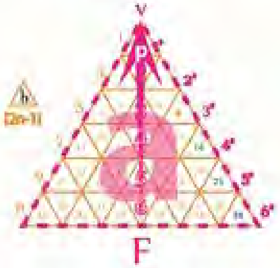

The Arrow of Time

is our perception of changing quantum-scale angular momenta

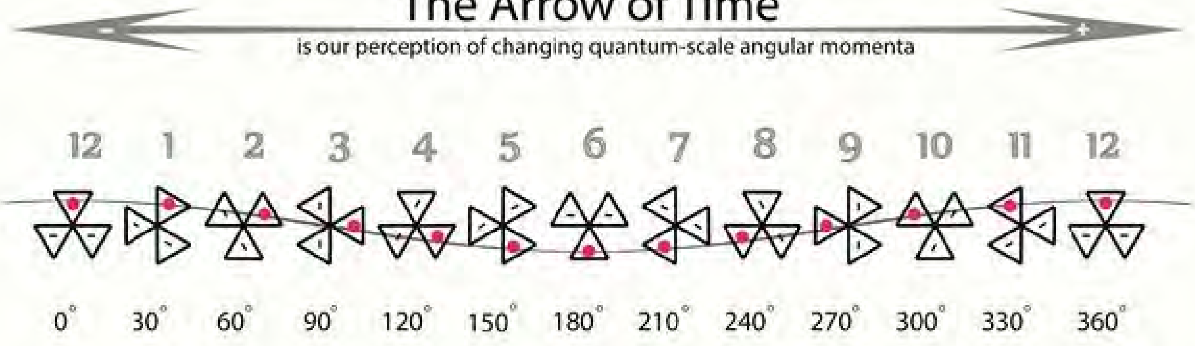

-
+
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5
6
7
8
9
10
11
12
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°

$\Delta m\Omega$

Acceleration

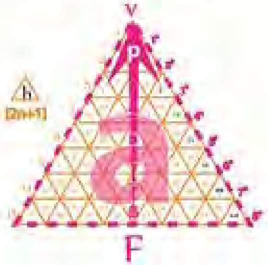

Time dilation

An accurate clock at rest with respect to one observer may be measured to tick at a different rate when compared to a second observer's own equally accurate clocks.
This effect arises neither from technical aspects of the clocks nor from the fact that signals need time to propagate, but from the nature of spacetime itself.

**The changing quantised angular momenta of
all mass-energy-Matter densities in any spatial region
all impact on our measurement of time [ΔΩ]**

*increasing the mass of Matter
increases the stress energy tensor
[mass-energy gradient]*

Stronger G fields

GR

Vacuum energy-Matter
pressure gradients

Weaker G fields

*gravity is proportional to
the material displacement volume of mass-Matter
in a given spatial region of vacuum energy*

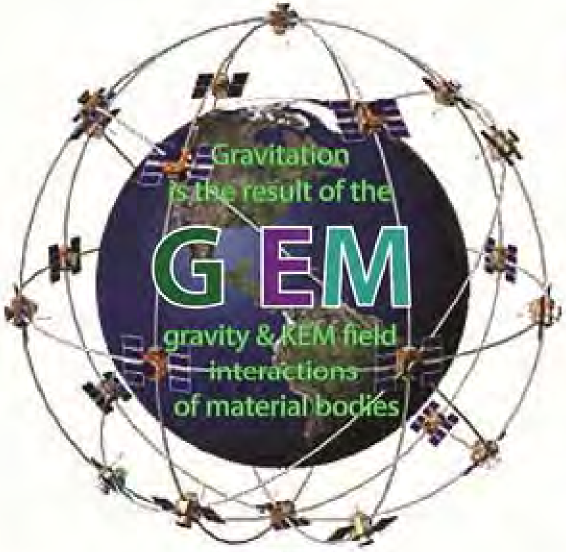

*tests of GR using
photons are erroneous
tests of SR*

*accelerating material objects
increases the Planck quanta
[mass.QAM] in their KEM fields*

Stronger KEM fields

SR

Kinetic EM energies
of motion

Weaker KEM fields

*decelerating material objects
decreases the Planck quanta
[mass.QAM] in their KEM fields*

Any attempt to accurately model the full effections of Gravitation must include
a complete definition and differentiation of all mass-energy & Matter
along with the vacuum energy pressure gradient created by them

In the theory of relativity, time dilation is an actual difference of elapsed time between two events as measured by observers either moving relative to each other or differently situated from gravitational masses.

Entropy in physical systems

is the result of changes to the net organisation of quantised angular momenta as it seeks equilibrium

Second law of thermodynamics

An isolated physical system, if not already in its own internal state of thermodynamic equilibrium, spontaneously evolves towards it.
In an isolated physical system, there is a tendency towards spatial homogeneity.

The Boltzmann equation was developed to describe the dynamics of an ideal gas

$$\frac{\partial f}{\partial t} + v\frac{\partial f}{\partial x} + \frac{F}{m}\frac{\partial f}{\partial v} = \frac{\partial f}{\partial t}$$

Ludwig Eduard Boltzmann

(February 20, 1844 – September 5, 1906)

$$S = k\cdot[\log(W)]$$

Boltzmann entropy formula

Tetryonic theory utilises the equilateral geometry of ideal quantum inductors to model EM energies

mass-energy radiator

normal statisitcal distribution of energies

Energy in all its forms seeks equilibrium

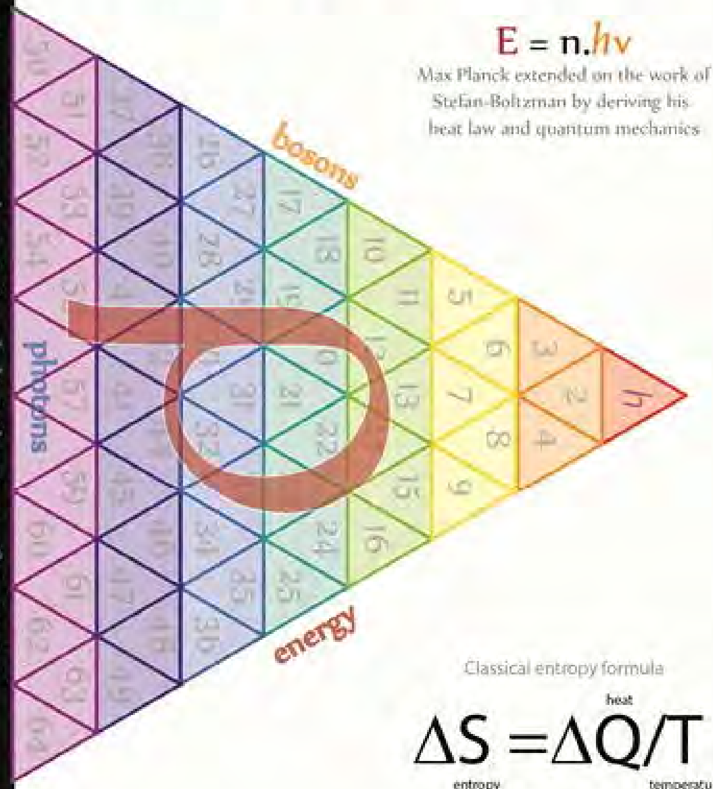

$E = n.hv$

Max Planck extended on the work of Stefan-Boltzman by deriving his heat law and quantum mechanics

Classical entropy formula

$$\underset{\text{entropy}}{\Delta S} = \Delta \overset{\text{heat}}{Q} / \underset{\text{temperature}}{T}$$

Energy always moves from higher energy organised systems to a lower dis-organised system

lower energy blackbody

A black body is an idealized physical body that absorbs all incident electromagnetic radiation

Jacob David Bekenstein

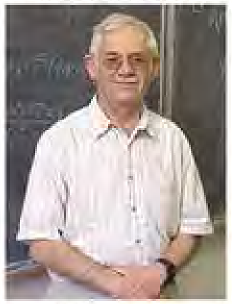

(born May 1, 1947)

Bekenstein-Hawking entropy formula

$$S = \frac{\pi A k c^3}{2hG}$$

still uses 3D [c³] classical cartesian co-ordinates

Stephen William Hawking

(born 8 January 1942)

Tetryonic theory unites classical and quantum mechanics with relativity through equilateral QAM

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The Aether

Aether theories in physics propose the existence of a medium, the aether a space-filling substance or field, thought to be necessary as a transmission medium for the propagation of electromagnetic waves.

bosons, photons and Matter are simply geometric concentrations of EM energy in regions of Space

Spacetime is the QAM geometry of any measured spatial [LT] region

Vast radiant energy fields exist throughout all of Space save inside Matter topologies

Matter geometries form perfect quantum Faraday cages excluding all energies thus creating nullspaces

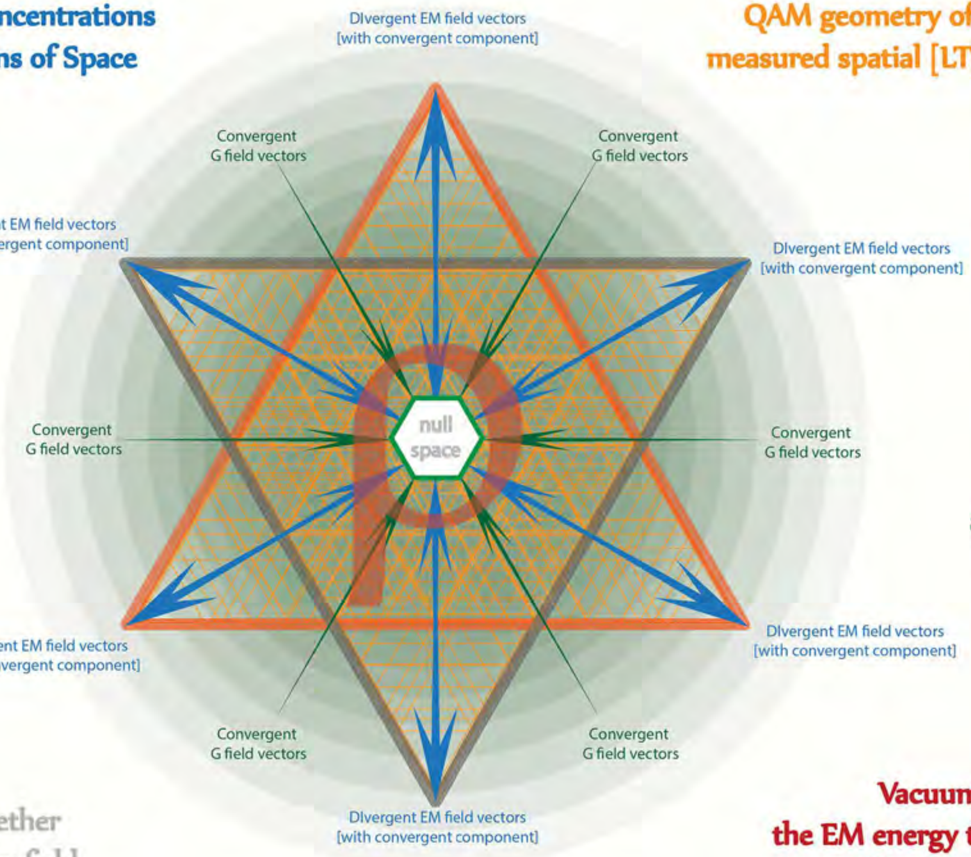
Divergent EM field vectors [with convergent component]
Convergent G field vectors
Convergent G field vectors
Divergent EM field vectors [with convergent component]
Divergent EM field vectors [with convergent component]
Convergent G field vectors
null space
Convergent G field vectors
Divergent EM field vectors [with convergent component]
Divergent EM field vectors [with convergent component]
Convergent G field vectors
Convergent G field vectors
Divergent EM field vectors [with convergent component]

The low level EM fields permeating the space between Matter forms a background vacuum energy density

The vacuum energy field acts upon the internal 'null space' volumes of all Matter creating a gravitational pressure gradient

Historically refered to as the Aether (or the Ether) this vacuum energy field has been the source of much contention

Vacuum Energy is the EM energy that permeates and fills any spatial region

Photons do not require the aether to propagate however the aether is permeated with 'weak' superpositioned EM fields

The Luminiferous Aether

$$\frac{\rho}{m^2}$$

Photons are radiant 2D mass-energy geometries

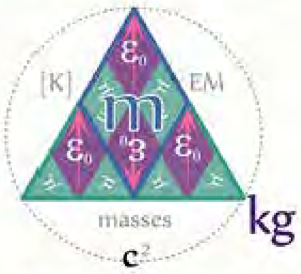

Vacuum energies are very long wavelength photons

Hendrik Lorentz created an electron/aether theory, in which he introduced a strict separation between Matter and the aether

In the late 19th century, luminiferous aether or ether, meaning light-bearing aether, was proposed as a medium for the propagation of light.

Newton's Opticks (1704) postulated an "Aethereal Medium" transmitting vibrations faster than light, by which light, is put into "Fits of easy Reflexion and easy Transmission"

Maxwell proposed a mechanical sea of molecular vortices to explain the transfer of ElectroMagnetic energies

Einstein wrote that one can actually speak about a "new aether", but one may not speak of motion in relation to that aether

In Tetryonics all EM radiation & Matter are revealed to be concentrations of geometric Energies seeking equilibrium in regions of Spacetime

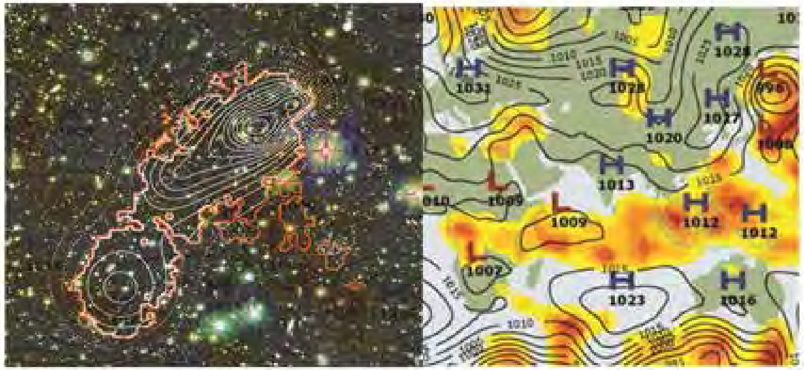

The aether does NOT facilitate the transmission of Energies throughout the Universe, it is the result of radiated [K]EM energies

Vacuum energies can be likened to the mean atmospheric pressure, with 2D mass-energies being HIGHER pressure 'gusts'

and

the nullspaces within 3D Matter creating a LOW pressure gradient [providing a driving mechanism akin to to that of Storms, Cyclones or Tornados]

$$\frac{\rho}{m^3}$$

All Matter are 3D mass-energy topologies containing nullspaces

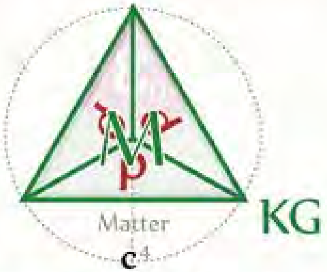

Planets, Stars and Galaxies contain high densities of mass-energies

Michaelson and Morley sought to detect the Relative motion between the Earth and aether by measuring the speed of light

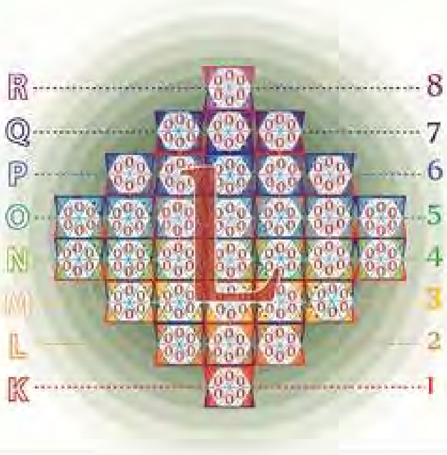

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Vacuum Energy

Vacuum energy is an underlying background mass-energy that exists
in free space even when the space is devoid of matter

**The Universe is Electric in nature
and all Matter in it interacts via
Gravito-Electro-magnetic [GEM] fields**

Tetryonics shows that all Matter is quantised and
these charged mass-energy quanta produce EM fields
of varying strengths in turn radiating out from
the source Matter into Space to
form GEM fields

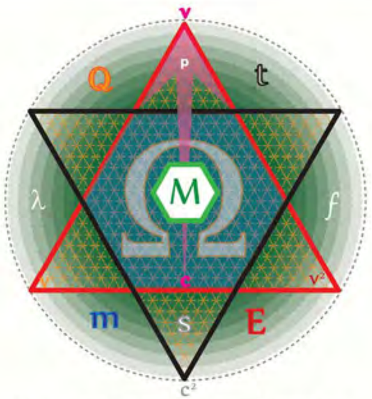

VE is not a 'quantum foam' as
popularly depicted, it is a
triangular Euclidean geometry
of neutral mass-energies

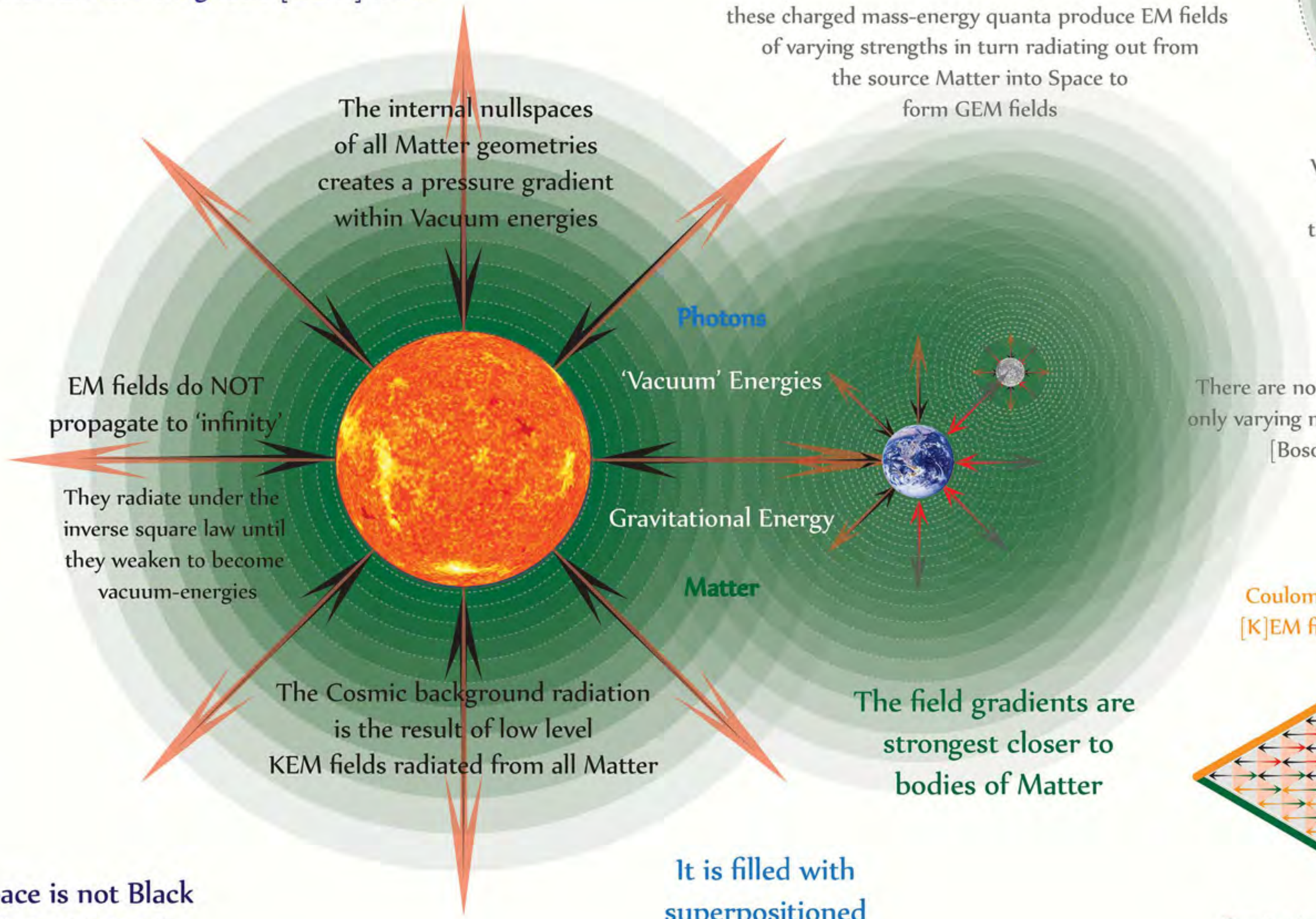

The internal nullspaces
of all Matter geometries
creates a pressure gradient
within Vacuum energies

EM fields do NOT
propagate to 'infinity'

They radiate under the
inverse square law until
they weaken to become
vacuum-energies

The Cosmic background radiation
is the result of low level
KEM fields radiated from all Matter

There are no 'virtual particles' in free space
only varying mass-Energy density geometries
[Bosons, Photons & Matter]

The field gradients are
strongest closer to
bodies of Matter

Coulombic fields are DIVERGENT
[K]EM fields with interactive forces

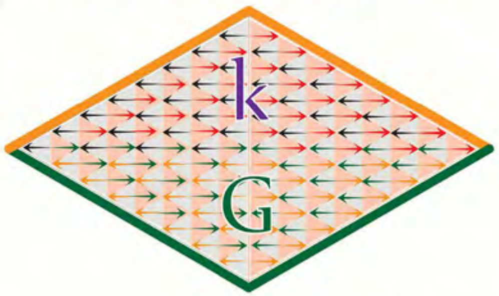

Gravitational fields are CONVERGENT
Gravity is always attractive

**Space is not Black
[it is INDIGO]**

It is filled with
superpositioned
EM fields

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The Higgs Field

is another name for the Aether
(or vacuum energy field) that fills
free Space, its interaction with
inductive Tetryonic topologies
creates the inertial properties
observed in mass-Matter

Peter Higgs

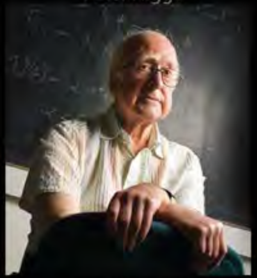

(born 29 May 1929)

All Higgs vacuum fields
are equilateral mass-Energy-momenta
fields

The 'Higgs Boson' is
just a W boson by
another name

Free Space

is any spatial region
free of EM energy quanta
(nullspace within Tetryons)

Vacuum Energy

is the lowest denisty [longest wavelength]
electromagnetic mass-energy that
having diverged from Matter
radiates outwards to fill space
& create a pressure gradient

'Virtual particles'
do NOT exist

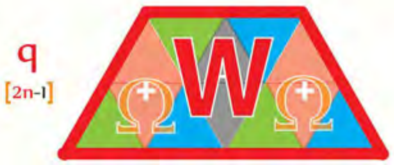

All Bosons have ODDn planar electromagnetic charge geometries

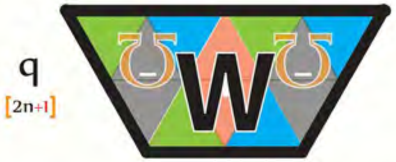

Inductive resistance to changes of the energy content of charged fascia through vacuum energy fields creates inertial mass

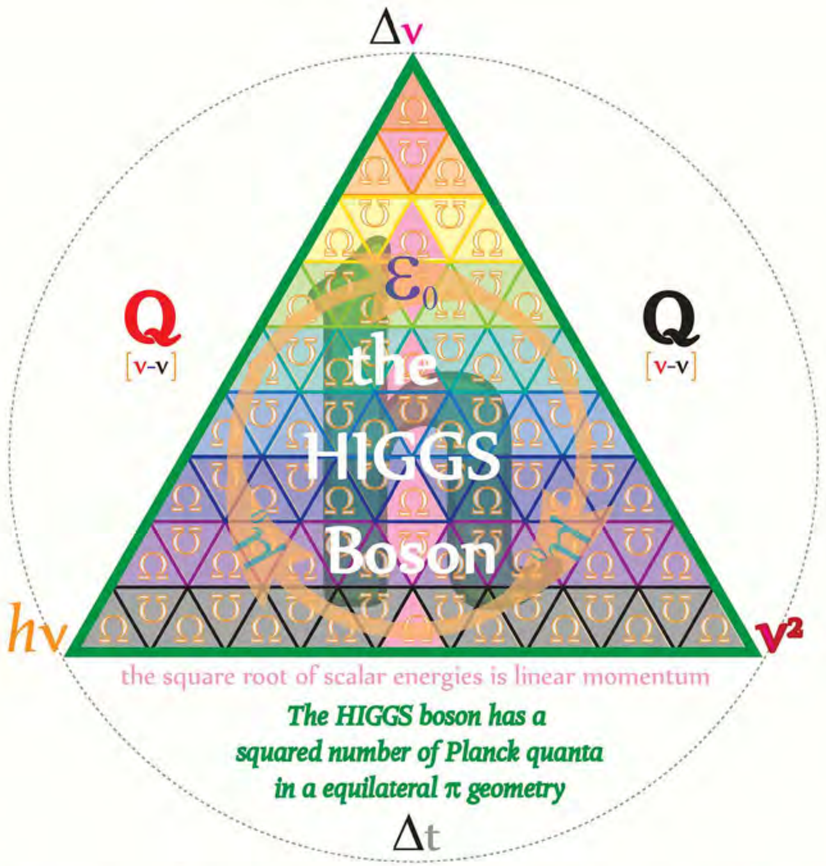

the square root of scalar energies is linear momentum

The HIGGS boson has a squared number of Planck quanta in a equilateral π geometry

TETRYONS

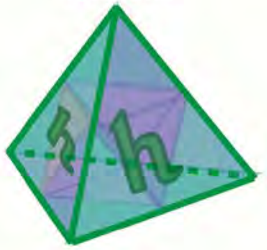

All Matter has 4n enclosed tetrahedral charge topologies

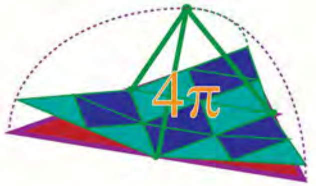

mass Planck quanta

$$\frac{n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

Electromagnetic mass
is a measure of the Energy
content of a 2D geometry
per unit of Time

Matter Planck quanta

$$\frac{T\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

3D material Matter is a
EM standing-wave topology
whose mass is a measure of its
geometric Energy content

The HIGGS boson is an alternative name for the 2D charged mass-energy fascia of all Matter
[whose inductive QAM quanta create the physical property of inertial mass]

m

mass-energy is a 2D geometric property of 3D Matter

$$F = ma$$

inertial mass is a measure of a body's resistance to changes in acceleration due to external forces

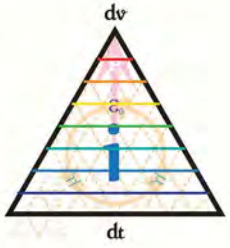

M

Matter is the 3D topology created by mass-energies

Charged Planck quanta form the geometry of of all mass-ENERGY-Matter
[each charge fascia contains equilateral mass-energy momenta]

The energy momenta density of standing wave Matter

determines its inertial mass

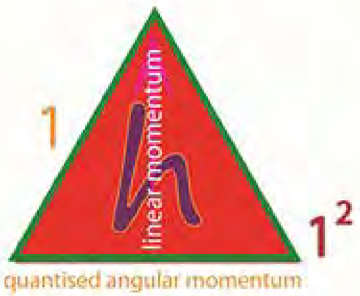
1
h
linear momentum
1²
quantised angular momentum

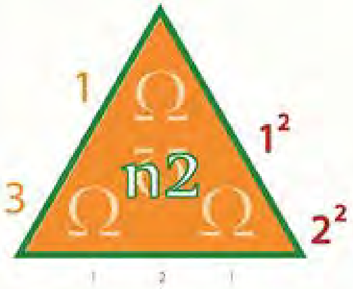
1
3
n2
1²
2²
1 2 1

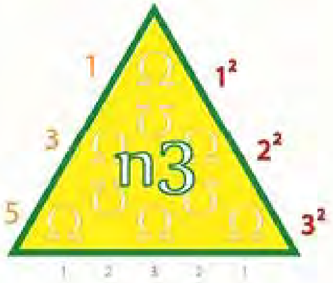
1
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n3
1²
2²
3²
1 2 3 2 1

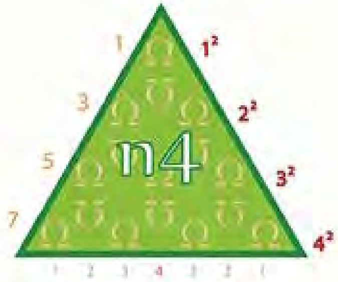
1
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7
n4
1²
2²
3²
4²
1 2 3 4 3 2 1

m

mass

kg

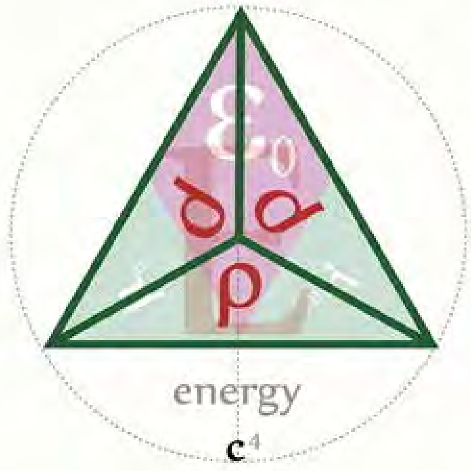
ε₀
d
d
ρ
energy
c⁴

M

Matter

KG

Spatial topology

$$\overset{\text{Matter}}{\frac{4n\pi}{c^4}}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

EM mass-energies

de Broglie Wavelengths

$$\frac{\rho}{c^2}$$

mass

m

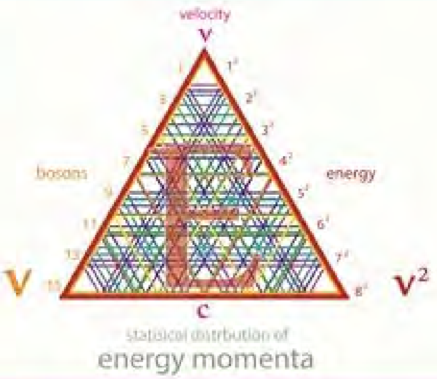
velocity
v
1 3 5 7 9 11 13 15
1² 2² 3² 4² 5² 6² 7² 8²
bosons
energy
v
v²
c
statistical distribution of
energy momenta

$$\frac{\rho}{c^4}$$

Matter

M

Compton Frequencies

The mass-energy content of Matter is contained entirely within its charged fascia topology

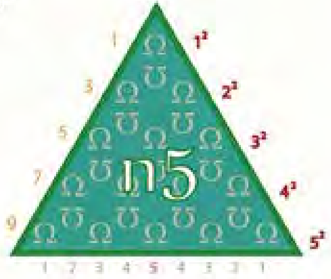
1
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4²
5²
1 2 3 4 5 4 3 2 1

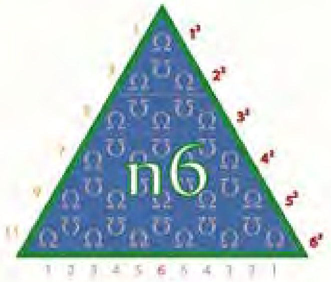
1
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4²
5²
6²
1 2 3 4 5 6 5 4 3 2 1

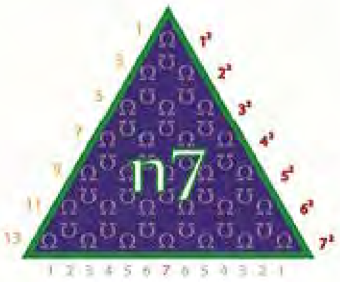
1
3
5
7
9
11
13
n7
1²
2²
3²
4²
5²
6²
7²
1 2 3 4 5 6 7 6 5 4 3 2 1

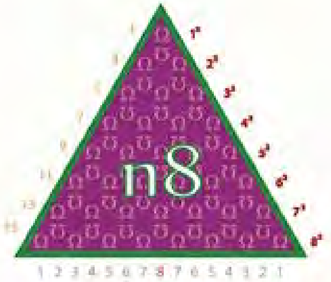
1
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7
9
11
13
15
n8
1²
2²
3²
4²
5²
6²
7²
8²
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1

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3D Nullspaces

Planck mass-energy quanta clothe
only the topologies of Matter

**3D EM fields with volume
are measurements of
Energy per unit Time squared
[Matter]**

$$T\pi$$

**Nullspace is proportional to the
internal volumes of Tetryons**

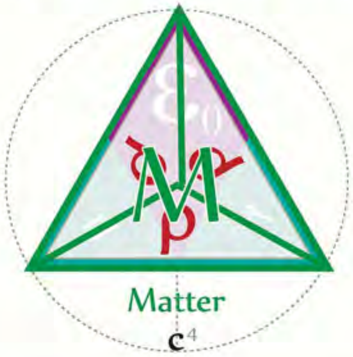

**2D planar EM fields
are measurements of
Energy per unit Time
[EM mass]**

$$[m\Omega v^2]$$

**The mass-energy densities [fascia] of
Matter do NOT influence nullspaces**

**Inside the Tetrahedral topologies
of all Matter exists the only true vacuum**

**Any radiant energy trying to enter
the interior volume of a Tetryon
will be absorbed into the fascia,
increasing its Tetryonic mass
(or increasing its KEM field energy)**

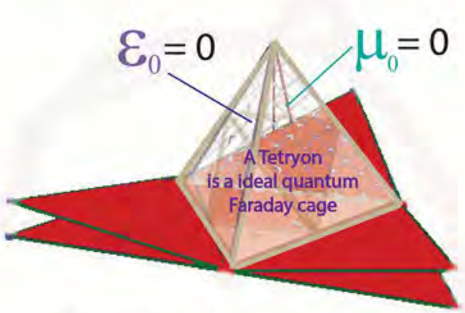

A volume devoid of any possible energy quanta
[ie The True vacuum]

**The interior volume of Tetryons has the
lowest energy density/pressure possible
and is accumulative as Matter forms
increasingly complex states, creating
regions of low energy density within
the nuclei of all Matter**

*Outer space is considered a high-quality vacuum,
with the equivalent of just a few hydrogen atoms
per cubic meter on average. However even it is
permeated with superpositioned EM fields
of vacuum mass-energies*

$$\frac{\rho_0}{T}$$

*A true vacuum is a spatial volume
that is completely devoid of EM mass-energies,
such that its energy density/pressure is much lower
than of the surrounding energy density/pressure
[a nullspace]*

[x,y] ΔΩ

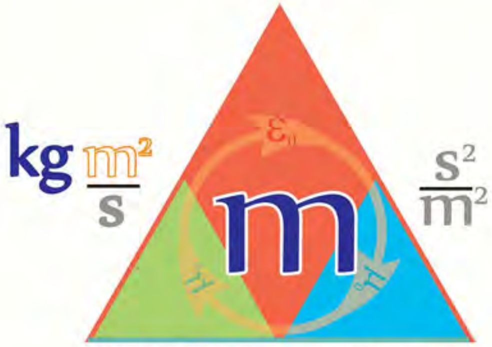

Positive charges in 2D space
are classically modelled as
clockwise energy fluxs

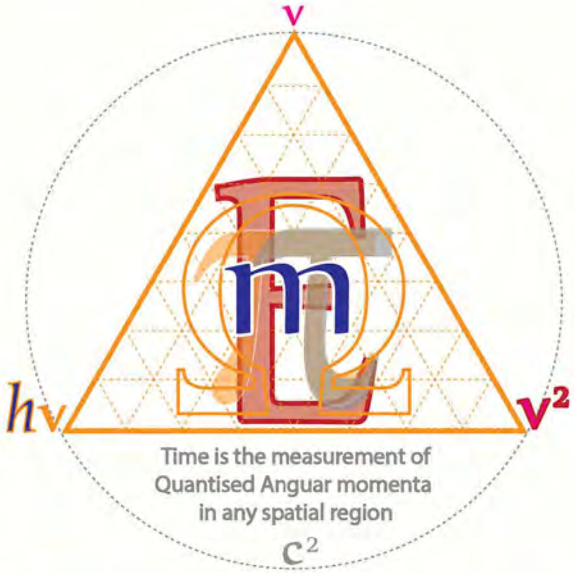

Time is the measurement of
Quantised Anguar momenta
in any spatial region

[x,y] ΔΩ

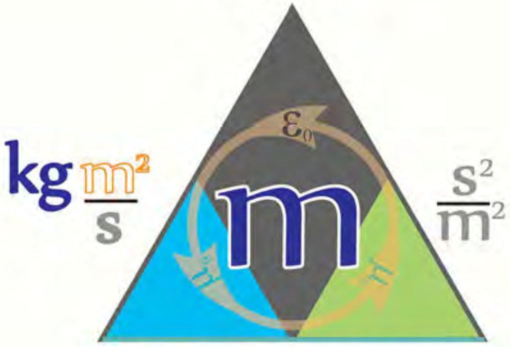

Negative charges in 2D space
are classically modelled as
anti-clockwise energy fluxs

mass Planck quanta

$$\frac{n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

m

mass

Charged Planck mass-energies provide the scaffolding of 3D Matter

[x,y,z] ΔΩ

3D Space and Time

M

Matter

Matter Planck quanta

$$\frac{T\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

2D
mass geometries
are a property of
3D Matter

2 Dimensional mass-energies

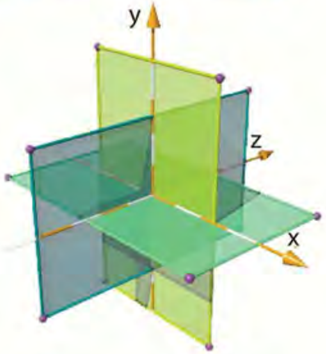

3 Dimensions of Space

kg

radiant
2D mass-energy momenta

EM Field Planck quanta

$$T\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

impedance mass velocity

creates 3D standing-wave
Matter

KG

2D charged fascia

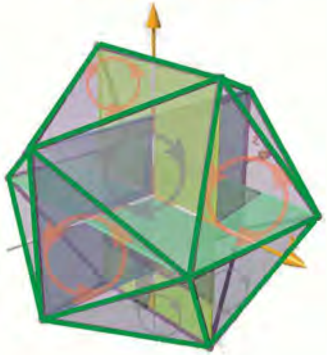

3D Space + Time

3D
Matter topology
is not a property of
2D mass-energy

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The impedance of any spatial region

is determined by its scalar energy content

Positive Matter

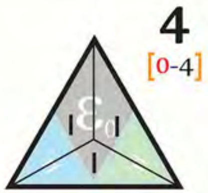

Negative Matter

$$\frac{m}{hv^2}$$

$$\frac{mc^2}{v^2}$$

$$\frac{mc^2}{h}$$

$$\frac{v^2}{c^2}$$

1.112650056 e-17

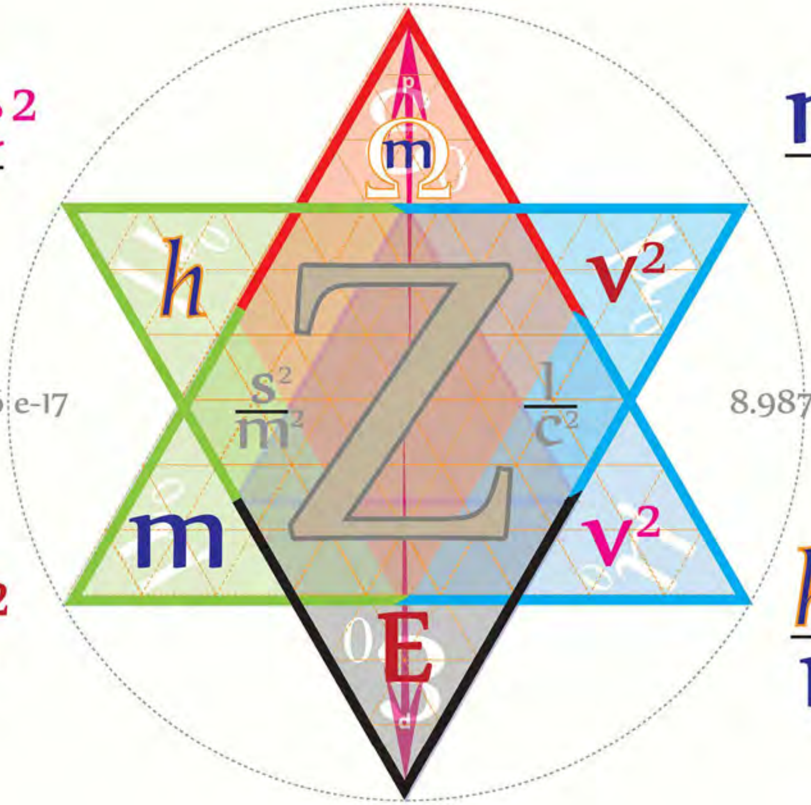

8.987551787 $e16^{-1}$

$$\frac{h}{m}$$

$$\frac{hv^2}{c^2}$$

$$\frac{hv^2}{m}$$

111.265 ohms

Neutral Matter

The impedance of any medium determines
the velocity of propagation for mass-energy momenta through it

Neutral Matter

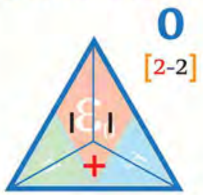

EM mass vs. Matter

Often a source of confusion,
Tetryonics provides a rigorous
definition of both EM mass & Matter

6.022141579 e23
[Avagadros number]

**1 ton of Carbon & 1 ton of Lead
have the same mass-energies**

**But they have differing Matter topologies
that create a differing energy densities
for any spational region of measurement**

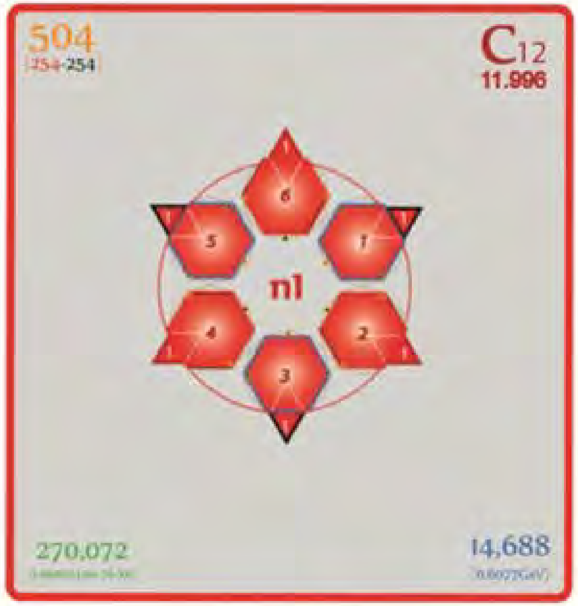
504
254-254
C12
11.996
6
5
1
n1
4
2
3
270,072
14,688

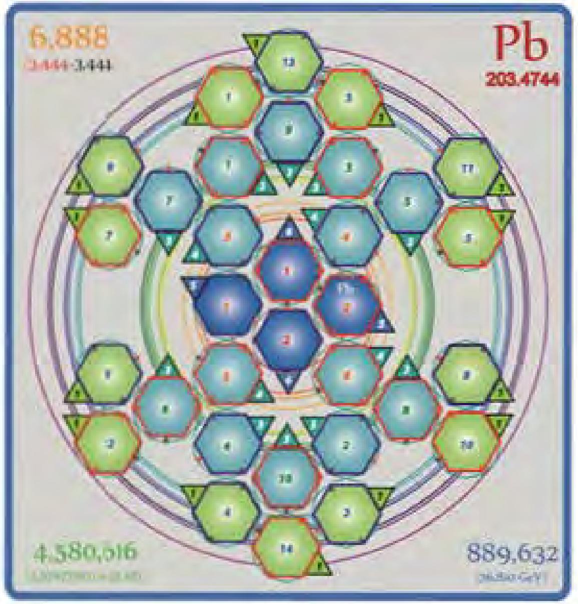
6,888
3444-3444
Pb
203.4744
4,580,516
889,632

**1 mole of Carbon atoms
[11.996 grams]**

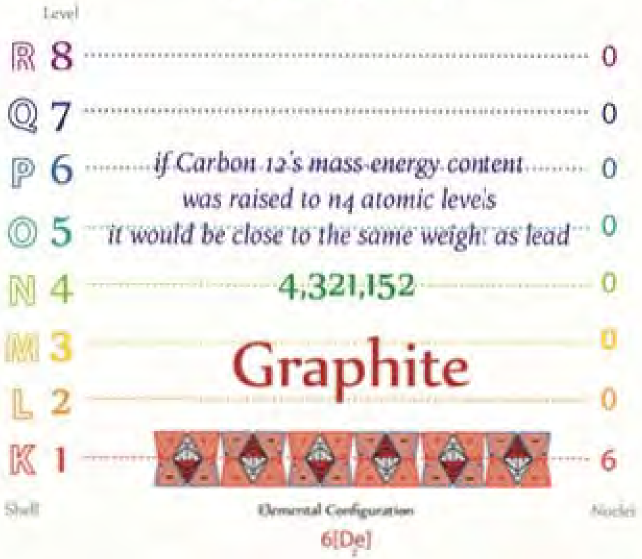
Level
R 8
Q 7
P 6
O 5
N 4
M 3
L 2
K 1
0
0
0
0
0
0
0
6
4,321,152
Graphite
Shell
Elemental Configuration
Nuclei
6[De]

*if Carbon 12's mass-energy content
was raised to n4 atomic levels
it would be close to the same weight as lead*

*In terms of charged Matter topology
Carbon12 displaces 1/14th the volume of Lead*

504
Carbon12 atom
270,072

1 : 17

4,580,616
Lead atom
6,888

*In terms of mass-ENERGY-Matter densities
Lead is 17 times denser than Carbon
as a result of the mass quanta per charge fascia*

**1 mole of Lead
[203.4744 grams]**

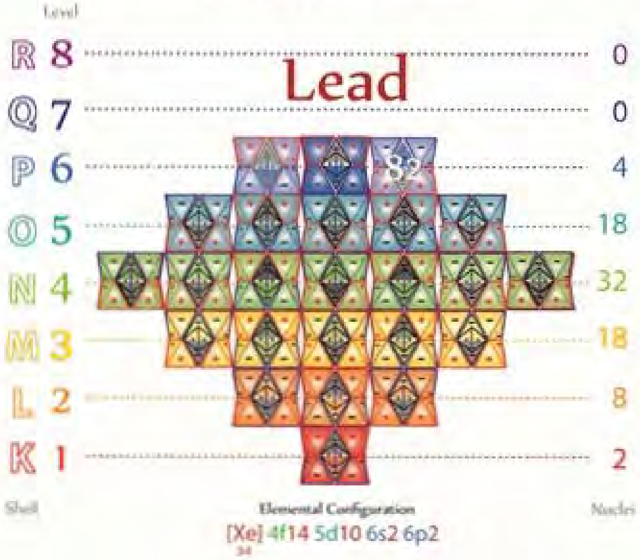
Level
R 8
Q 7
P 6
O 5
N 4
M 3
L 2
K 1
0
0
4
18
32
18
8
2
Lead
82
Shell
Elemental Configuration
Nuclei
[Xe] 4f14 5d10 6s2 6p2

EM mass-energy geometries

are 2D Euclidean EM fields posessing energy momenta

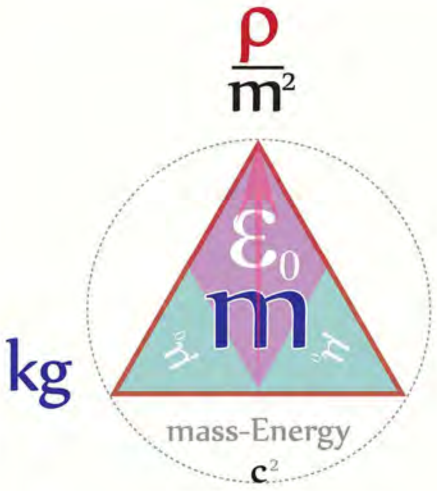

Charge
$$\frac{1\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Bosons
$$\frac{\text{ODD}\,\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Photons
$$\frac{2\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

EM waves
$$\frac{\text{EVEN}\,\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

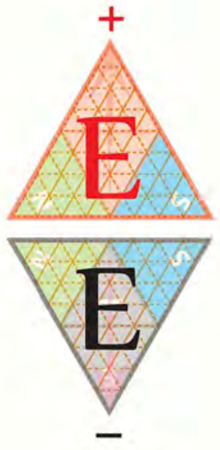

mass
$$\frac{n\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

m

ENERGY

$$n\pi\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

M

Matter
$$\frac{T\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Equilateral mass-energy geometries & Matter Topologies are measured in radial spatial-time co-ordinate systems

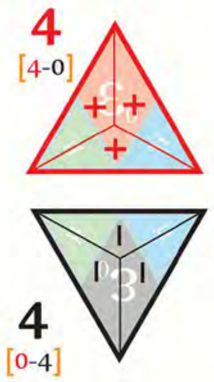

Tetryons
$$\frac{4\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Fermions
$$\frac{12\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Baryons
$$\frac{36\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Deuterons
$$\frac{84\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

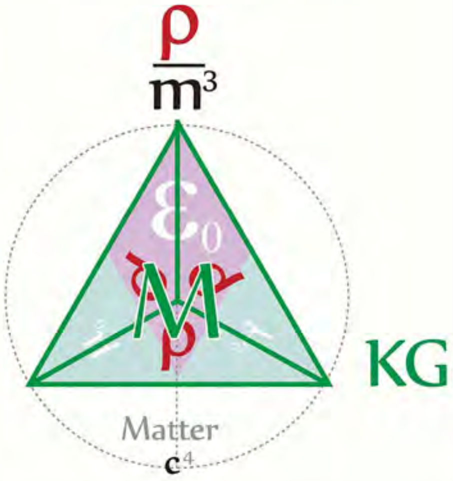

Matter Topologies

are 3D standing-wave [4nπ] mass-energy geometries

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mass-energy-Matter quanta

are all defined by charged geometries & topologies

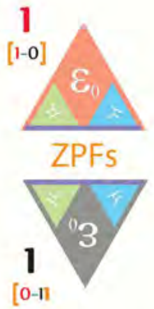
1
[1-0]
ε0
ZPFs
03
1
[0-1]

Bosons (v)

Bosons

$$\frac{\mathrm{ODD}\,\pi}{c^2}\left[\left[m\,\Omega\,v^2\right]\right]$$

Planck quanta

mass velocity

charges

1π	ZPF	v
ODD π	boson	v

Inductive charges

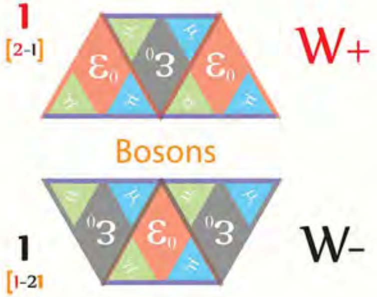
1
[2-1]
ε0
03
ε0
W+
Bosons
1
[1-2]
03
ε0
03
W-

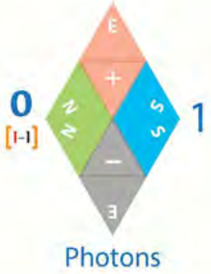
E
+
0
[1-1]
N
N
S
S
1
-
E
Photons

Photons(f)

EM waves

$$\frac{\mathrm{EVEN}\,\pi}{c^2}\left[\left[m\,\Omega\,v^2\right]\right]$$

Planck quanta

mass velocity

mass-energies

2π	photon	$2v^2$
EVEN π	EM wave	$2v^2$

EM waves

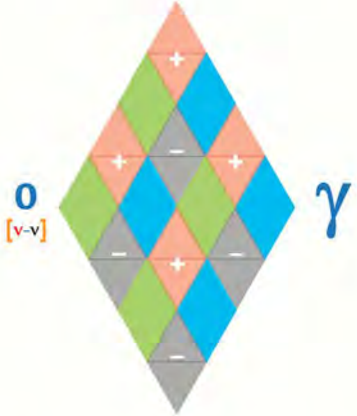

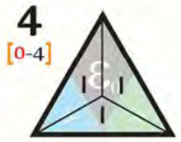

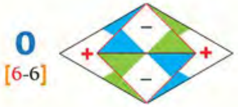

Tetryons (n)

Matter

$$\frac{4n\pi}{c^4}\left[\left[m\,\Omega\,v^2\right]\right]$$

Planck quanta

mass velocity

mass-Matter

4π	tetryon	n
12π	lepton	n
24π	meson	n
36π	Baryon	n

Matter particles

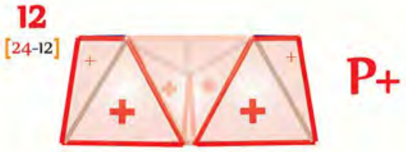

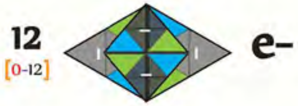

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Differentiating mass & Matter

geometries topologies

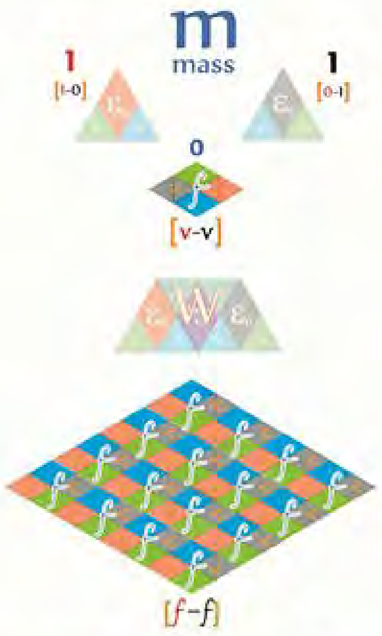

All modern physical theories including relativity fail to define and differentiate between mass & Matter

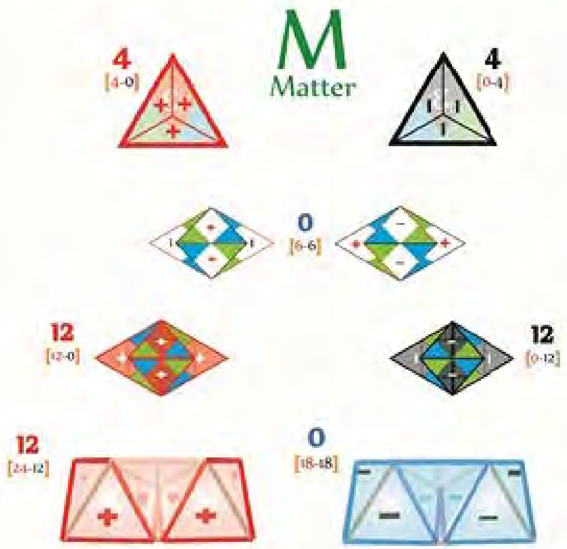

kg

geometry

Charged Planck quanta
7.376238634 e-51 kg

Photons
1.475247727 e-50 kg

EM waves
5.900990907 e-50 kg

nπ
mass

radiant mass-energies

Equilateral energy momenta

Tπ
Matter

standing-wave Matter

KG

Topology

Neutrino
8.851486361 e-50 kg

Lepton
8.851486361 e-31 kg

Baryon
1.6596536693 e-27 kg

Increasing a particle's speed increases its Kinetic EM mass-energies (rest Matter's EM mass-energy content is velocity invariant)

Charge

$$\frac{1\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Photons

$$\frac{2\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Bosons

$$\frac{\text{ODD}\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

EM waves

$$\frac{\text{EVEN}\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

All Matter has EM mass-energies not all EM mass-energies form Matter

Tetryons

$$\frac{4\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Fermions

$$\frac{12\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Baryons

$$\frac{36\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Deuterons

$$\frac{84\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

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$$E = mv^2$$

E

Energy

$$kg\,\frac{m^2}{s^2}$$

6.629432351 e-34 J

Planck quanta

$$E = n\pi\left[\left[m\Omega v^2\right]\right]$$

Energy

mass velocity

ENERGY

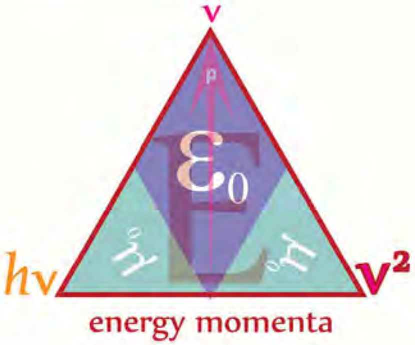
v
p
ε_0
μ_0
μ_0
hv
v^2
energy momenta

the proagation velocity of energy is determined by the impedance of any spatial region

$$E=hv^2$$

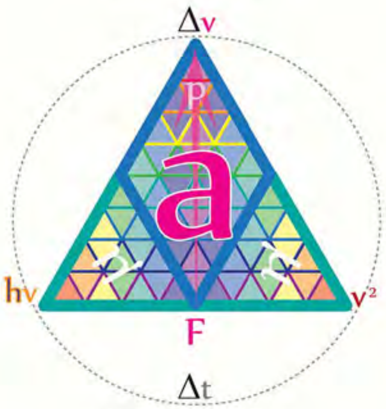
Δv
p
a
hv
v²
F
Δt

$$F=ma$$

the scalar impedance of space

$$\frac{s^2}{m^2}$$

$$\varepsilon_0 \times \mu_0$$

Electric permittivity & Magnetic permeability

$$1.11265\text{ e-}17\ \frac{s^2}{m^2}$$

$$\frac{1}{c^2}$$

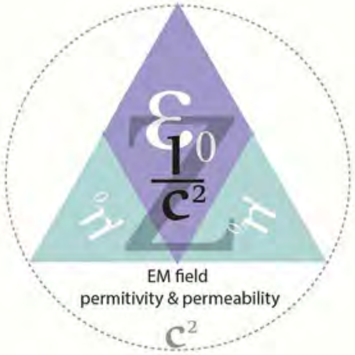
ε_0
$\frac{1}{c^2}$
μ_0
μ_0
EM field
permitivity & permeability
c^2

the Forces created by energy momenta in any spatial region are related through the scalar constant of mass

EM mass

$$m = \frac{E}{c^2}$$

m

mass

kg

field impedance

Planck quanta

$$n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

mass

ElectroMagnetic

mass velocity

7.376238376 e-51 kg

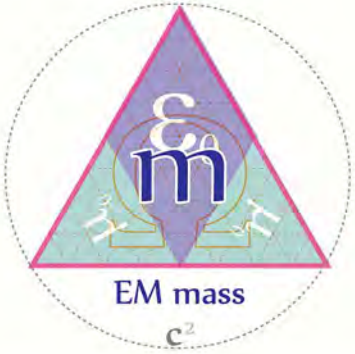
ε_0
m
μ_0
μ_0
EM mass
c^2

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The energy-momenta of Matter

$$\mathbf{p} = mv$$

Linear correction factor

$$\beta = \left[\frac{v}{c}\right]$$

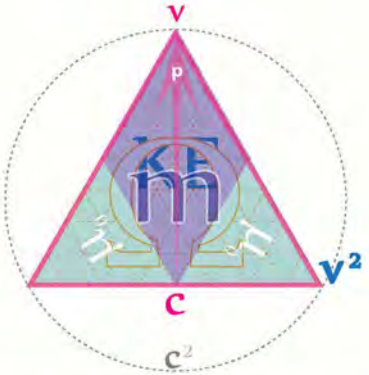

The Energy comprising all KEM fields is proportional to the particle's velocity

$$\beta^2 = \left[\frac{v^2}{c^2}\right]$$

Scalar correction factor

$$\mathbf{p}^2 = E = mv^2$$

$$\mathbf{p} = T\pi\left[\left[m\overset{\text{Energy}}{\underset{\text{momenta}}{\Omega}}v\right]\right]$$

As the velocity of a particle increases so does its KEM field's mass-energy momentum

$$mv = \mathbf{p} = hv$$

$$\text{kg}\,\frac{\text{m}}{\text{s}}$$

$$\sqrt{6.629432351\text{ e-}34\text{ J}}$$

$$4n\pi\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v}\right]$$

2.5476847 e-17 kg m/s

The linear momentum of mass-energies in standing-wave rest Matter topologies propagates at c

$$\mathbf{p}_M = 4\pi[mv]$$

The rest mass of a particle with NO motion is the total EM mass-energy of the particle

Its linear four-momentum is the square root of its scalar energies

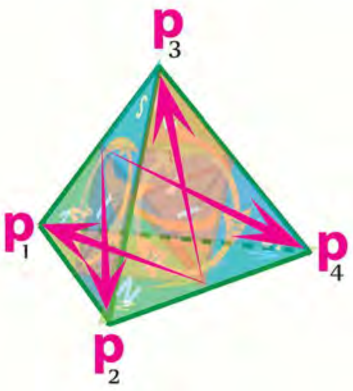

rest mass-Matter

In standing-wave Matter, where there is NO external forces acting on the particle, all internal momenta act in opposition and add to ZERO

all fascia

$$\vec{\mathbf{p}}_0 = \sum \vec{\mathbf{p}}$$

Gravitational mass-Matter quanta

gravity pulls on things proportional to their mass-Matter content

$$F = -G \frac{M_1 M_2}{r^2}$$

Radiant mass-energy geometries

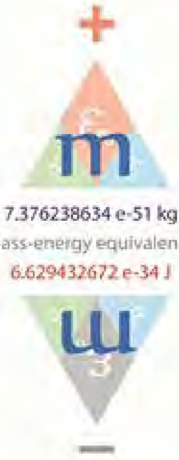
+
m
7.376238634 e-51 kg
mass-energy equivalence
6.629432672 e-34 J
ω
−

All 3D Tetryonic topologies create displacement Matter volumes that in turn generate KEM fields as a result of the motion of their charge fascia

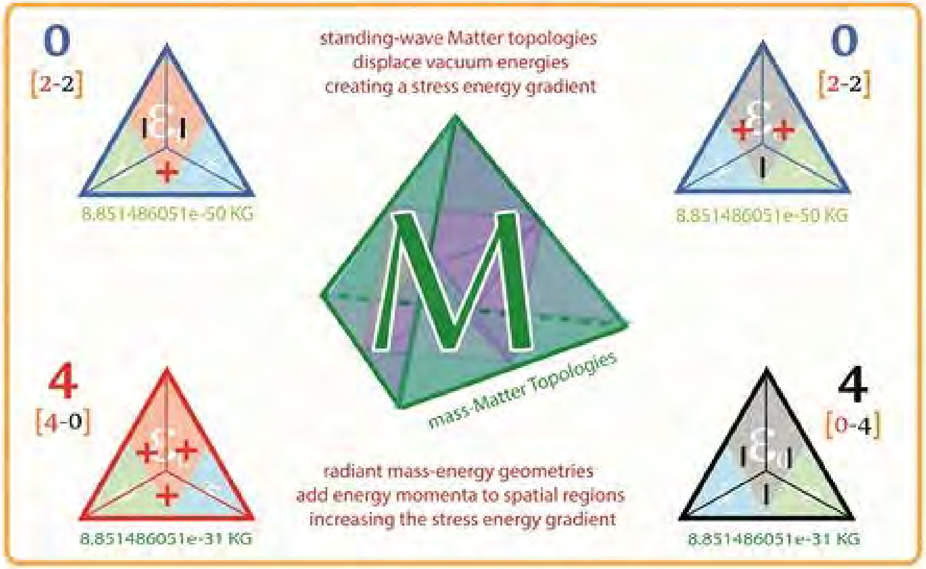
0
[2-2]
8.851486051e-50 KG
0
[2-2]
8.851486051e-50 KG
M
mass-Matter Topologies
4
[4-0]
8.851486051e-31 KG
4
[0-4]
8.851486051e-31 KG

standing-wave Matter topologies displace vacuum energies creating a stress energy gradient

radiant mass-energy geometries add energy momenta to spatial regions increasing the stress energy gradient

Gravitation attraction is a strictly UNI-DIRECTIONAL CONVERGENT FORCE

Standing-wave Matter Topologies

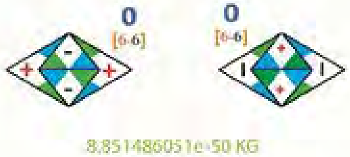
0
[6-6]
0
[6-6]
8.851486051e-50 KG

Matter particles can have the same Tetryonic topologies but possess a differing charged mass-energy momenta content

8.851486051e-31 KG

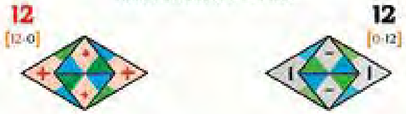
12
[12-0]
12
[0-12]

Gravitational Attraction can be modelled as a dipole attraction of opposite charged mass fascia of Matter topologies through its differing energy field interactions

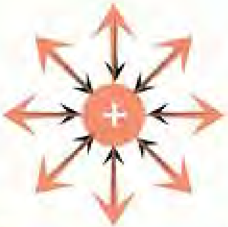

$$k = 8.99\text{e}9 \, \frac{N\,m^2}{C^2}$$

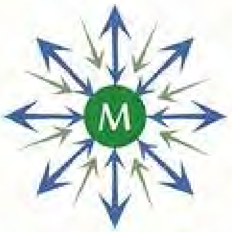

$$G = 6.67\text{e-}11 \, \frac{N\,m^2}{KG^2}$$

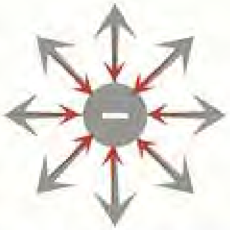

KEM field energy momenta produce a BI-DIRECTIONAL INTERACTION FIELD

Gravitation attraction is 20 orders of magnitude weaker

KEM field energy momenta produce a BI-DIRECTIONAL INTERACTION FIELD

Stress energy gradients

Energy's highest density form is 3D Matter [comprised of planar 2D EM mass-energies]
whilst its lowest pressure form is the vacuum energies created by radiated mass-energies filling space

ENERGY in all its forms seeks equilibrium

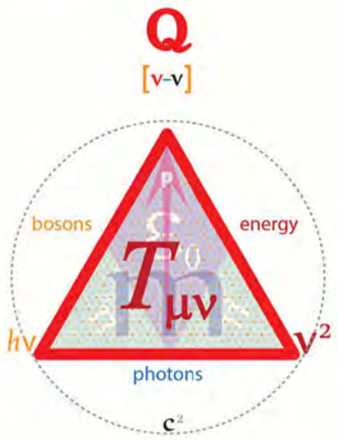

Where Newton's Law of Gravitation is modelled on geometric means

$$F = k\frac{Q_1 Q_2}{r^2}$$

Inverse Square Law

$$F = -G\frac{M_1 m_2}{r^2}$$

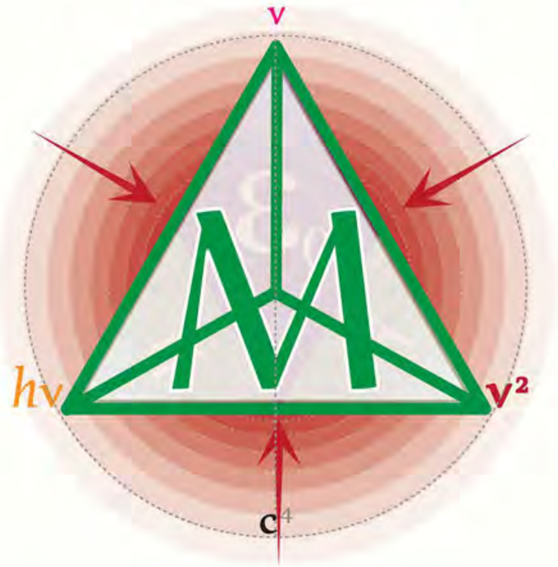

Like any pressure gradient, ENERGY always flows from areas of highest density to regions of low density seeking to reduce 'pressure' differentials and reach a state of equilibrium.

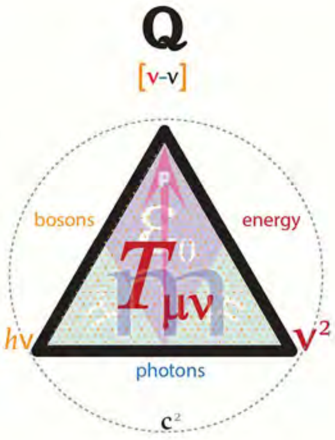

Einstein's General Relativity is modelled on energy pressure

$$PV = nRT$$

Matter tells Spacetime how to bend
Spacetime tells Mater how to move

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$$

mass-Matter topologies create stress energy differentials in the vacuum energies of space

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Gravitational Matter & weight

is a measure of the amount of mass-energy in Matter

The gravitational mass of a body determined by its response to the force of gravity

mass-Matter

Matter

Planck quanta

$$\frac{4n\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

The gravitational acceleration of a body in any gravity field is uniform and proportional to its mass-Matter

$$w = F = M.g$$

48

[24-24]

charge topology

N_A

Avagadro

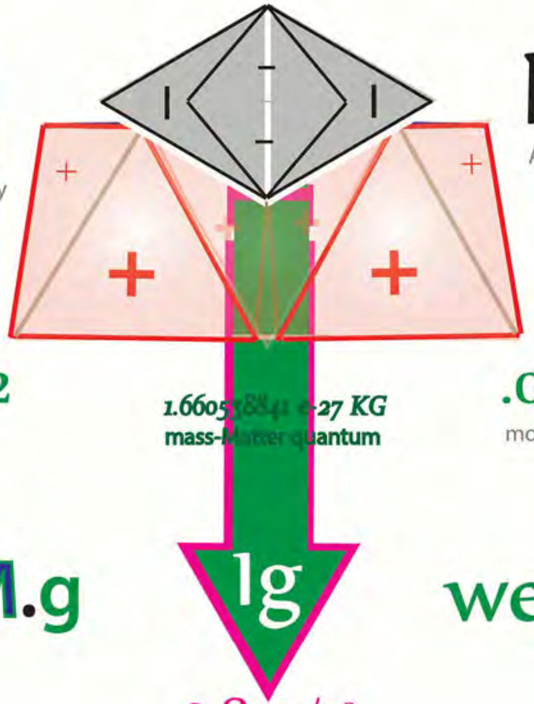

electrons

Planck quanta

$$\frac{12\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

mass-energy-Matter

8.8514586361 e-31 KG

Baryons

Planck quanta

$$\frac{36\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

mass-energy-Matter

1.659653693 e-27 KG

22,512

mass-Matter

1.660538841 e-27 KG

mass-Matter quantum

.001 KG

molar mass

$$w=M.g$$

weight

9.8 m/s²

$$F=Ma_g$$

$= [.001] \times [9.8]$

$= .0098$ N

KG

g

Force

$$\frac{\left[kg\,\frac{m}{s^2}\right]}{KG}$$

Zero Point Fields

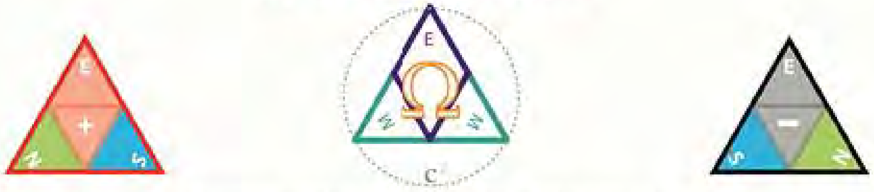

ZPF quanta charges are the opposite sides of the same 'quantum coin'

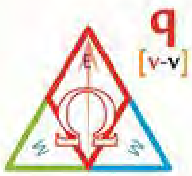

ZPF quanta have unidirectional
energy momenta orientations

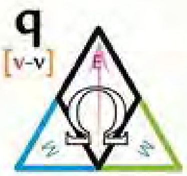

KEM fields

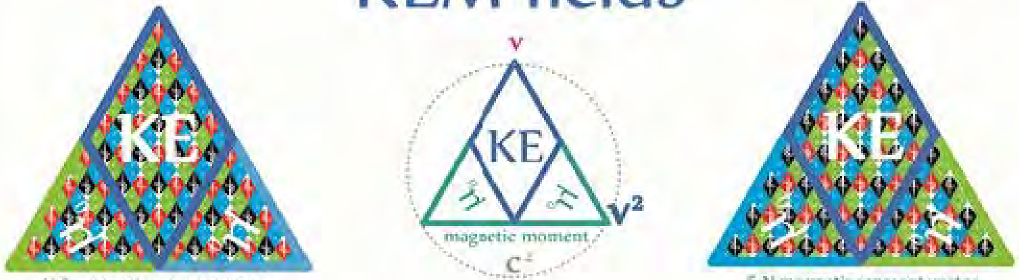

N-S magnetic moment vector

S-N magnetic moment vector

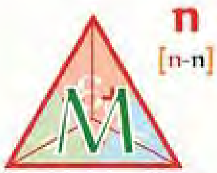

standing-wave mass-Matter

As the velocity of Matter increases
its relativistic mass-Energy quanta increase
as a result of the associated momentum,
kinetic energy and magnetic moment

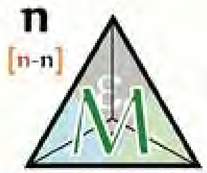

standing-wave mass-Matter

in addition to their standing-wave topologies
mass-Matter also posesses

radiant mass-energies

Gravity & EM fields

All energy fields are velocity dependent
and combine to form vectorial K-EM fields

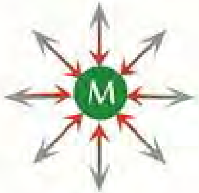

All charged Matter posseses
bi-directional interactive
radiant EM fields

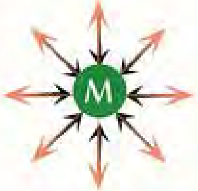

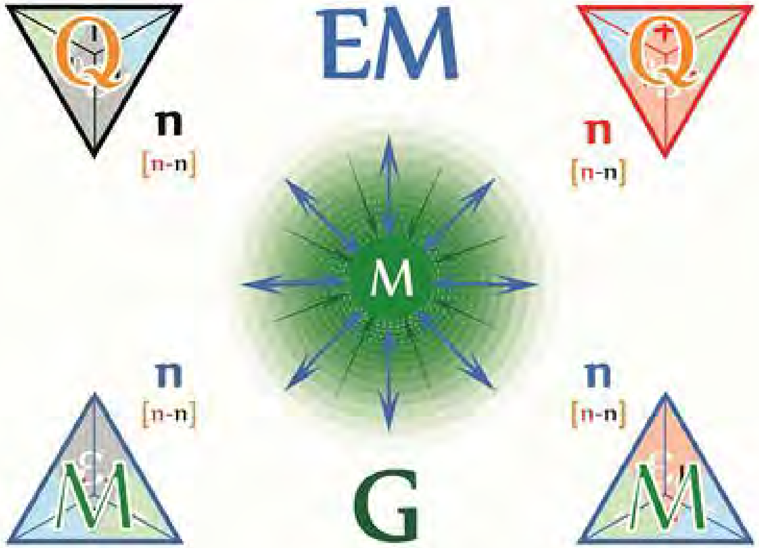

charged Matter topologies create
uni-directional convergent
energy gradiants

All mass-Matter is velocity invariant
and creates convergent G fields

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Matterless EM mass-energies

Photons are often termed as 'mass-less' particles in physics which is a complete mis-nomer.
Leading to many erroneous supersitions on the true nature and physics of light and gravity

$$\frac{E}{c^2} = \underset{\text{mass geometry}}{m}$$

$$\underset{\text{Matter topology}}{M} = \frac{E}{c^4}$$

mass is a measure of planar Energy per second

mass-less infers no energy momenta

Photons are weightless radiant EM energies not massless particles

photons possess 2D planar radiant EM mass-energy momenta

A Particle has a charged Matter topology

Matter is a closed tetrahedral standing-wave energy possessing volume

photons & EM waves have no 3D Matter topology, they are Matter-less geometries

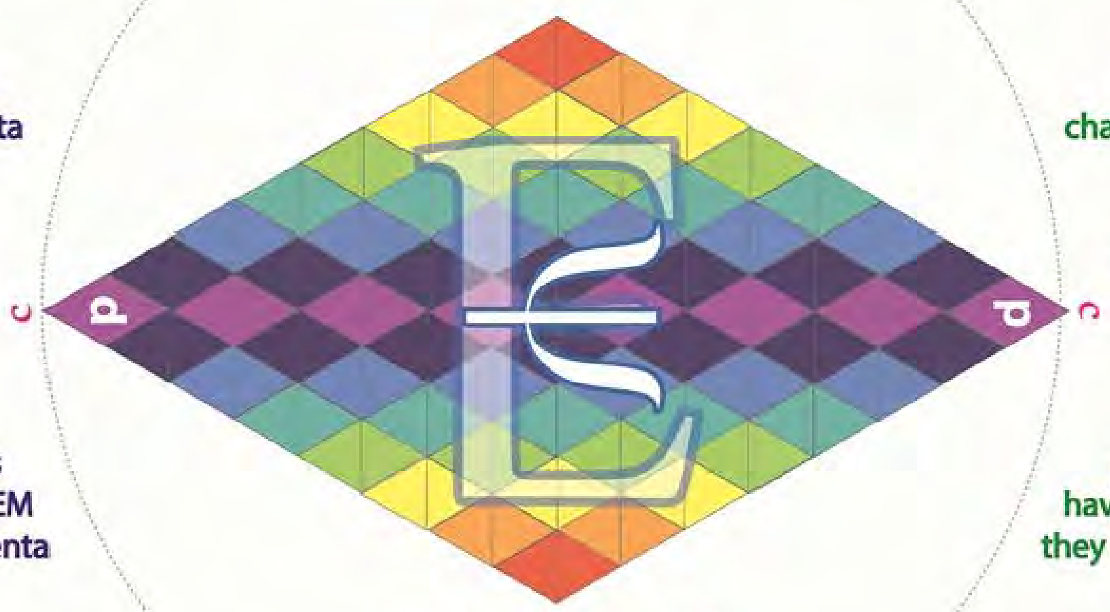

$$\frac{\overset{\text{ENERGY}}{n\pi}\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]}{\underset{\text{second}}{c^2}}$$

$$\frac{\overset{\text{mass}}{n\pi}}{c^2}\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

The definition and distinction between mass & Matter
is a major failing of modern physics, corrected for by Tetryonic theory

$$\frac{\overset{\text{Matter}}{T\pi}}{c^4}\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

EM fields, vacuum energies and gravity

all result from radiant equilateral mass-energy momenta
and standing-wave Matter in radial space

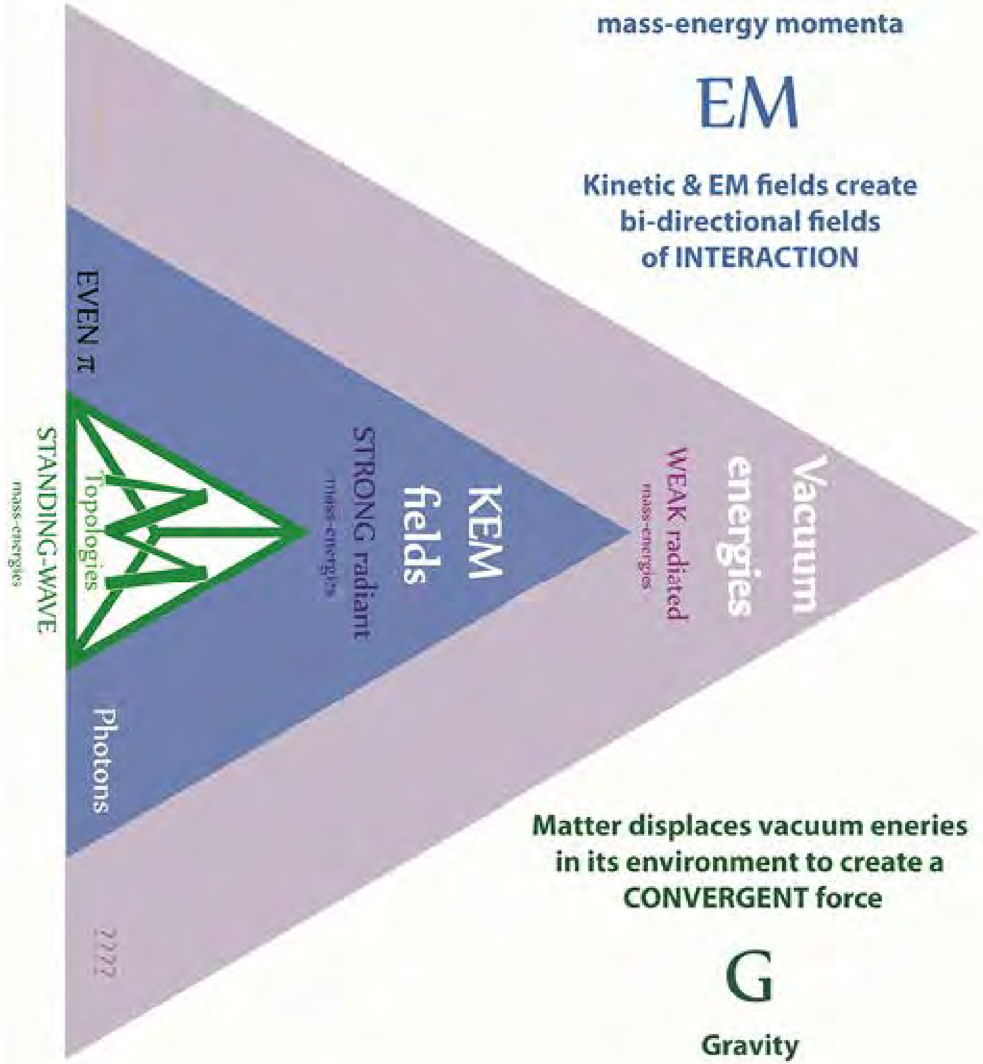
EVEN π
STANDING-WAVE
mass-energies
Topologies
Photons
????
STRONG radiant
mass-energies
KEM
fields
WEAK radiated
mass-energies
Vacuum
energies

mass-energy momenta

EM

**Kinetic & EM fields create
bi-directional fields
of INTERACTION**

**Matter displaces vacuum eneries
in its environment to create a
CONVERGENT force**

G

Gravity

**All GEM fields
have equilateral
quantum geometries**

$$F = k\frac{Q_1 Q_2}{r^2}$$

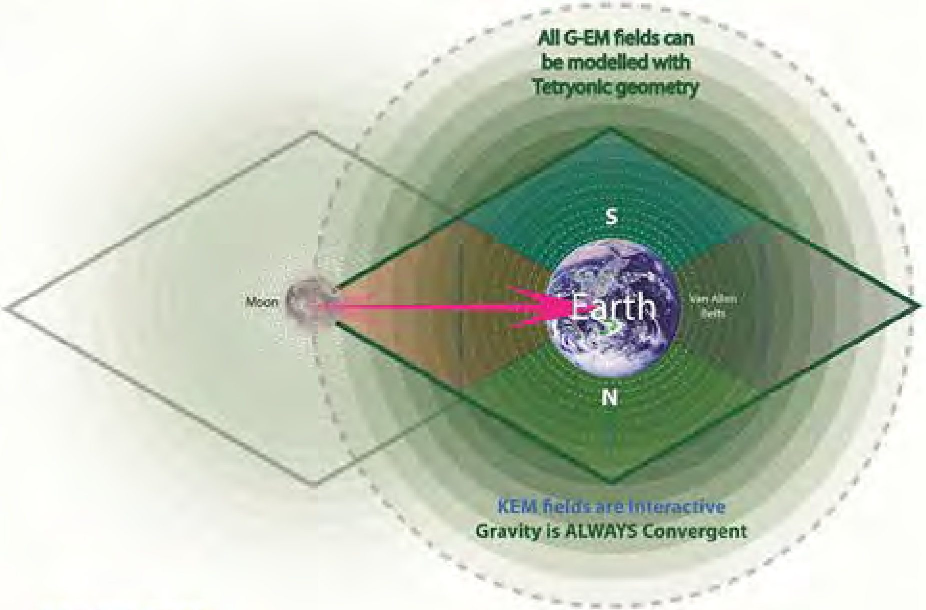
S
N
Moon
Earth
Van Allen
Belts

**All G-EM fields can
be modelled with
Tetryonic geometry**

**KEM fields are Interactive
Gravity is ALWAYS Convergent**

*the proportional attraction of
material bodies towards each other
can be easily modeled with Tetryonic fields*

$$F = -G\frac{M_1 m_2}{r^2}$$

geometric mean

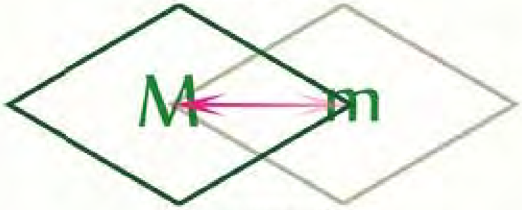

inverse square law

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Charges vs. Gravity

both can be modelled as interactive or attractive geometric forces

Charged particles are comprised of non-neutralised Planck quanta

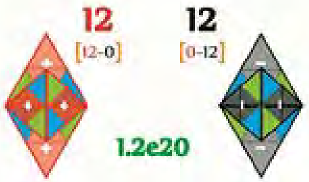
12
[12-0]
12
[0-12]
1.2e20

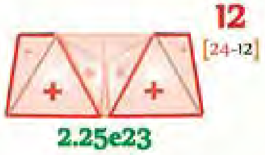
12
[24-12]
2.25e23

$$F = k\frac{Q_1 Q_2}{r^2}$$

Charges produce bi-lateral interactive forces

mass

Matter

Nuclei

Elements

$$F = -G\frac{M_1 M_2}{r^2}$$

Gravity is a convergent attractive force

Neutral Matter is comprised of neutralised Planck quanta

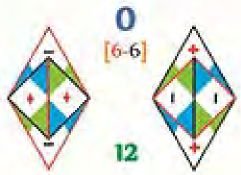

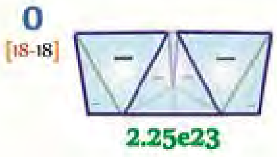
0
[18-18]
2.25e23

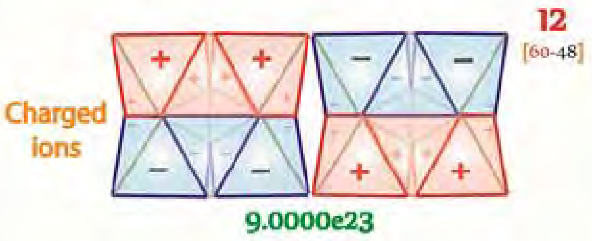
12
[60-48]
Charged ions
9.0000e23

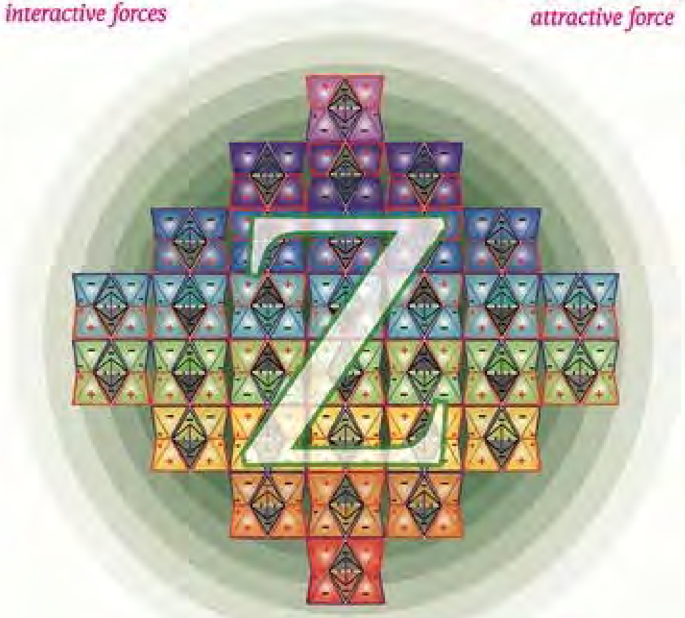

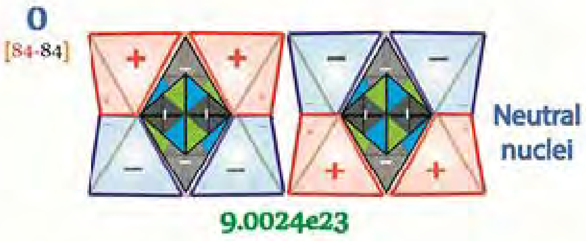
0
[84-84]
Neutral nuclei
9.0024e23

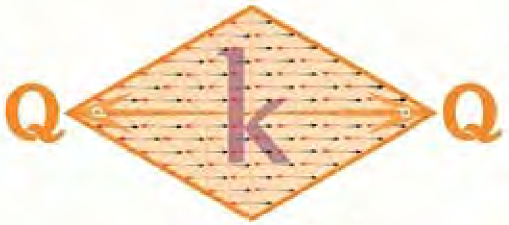

$8.99 \times 10^{9}\ \frac{N\,m^2}{kg^2}$

Opposites Attract
Similars Repel

Interactive mass-energies & **Gravitational mass-Matter**

both produce inverse squared forces

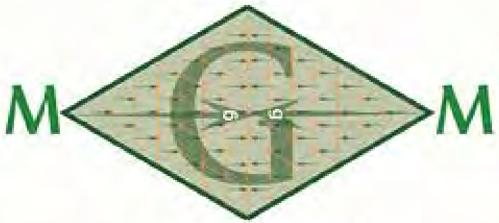

$7.49 \times 10^{-11}\ \frac{N\,m^2}{KG^2}$

Gravitational Matter
is always Attractive

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$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

GravitoElectroMagnetism, (abbreviated GEM), refers to a set of formal analogies between Maxwell's field equations and an approximation, valid under certain conditions, of the Einstein field equations for General Relativity.

$$\nabla \cdot \mathbf{B} = 0$$

$$\mathbf{F} = q\left(\frac{-1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{\mathbf{r}}\right) = q\mathbf{E}$$

$$F = k\,\frac{Q_1 Q_2}{r^2}$$

$$k = 8.99 \times 10^{9}\,\frac{\mathrm{N\,m}^2}{\mathrm{C}^2}$$

nett Charge is a DIVERGENT field

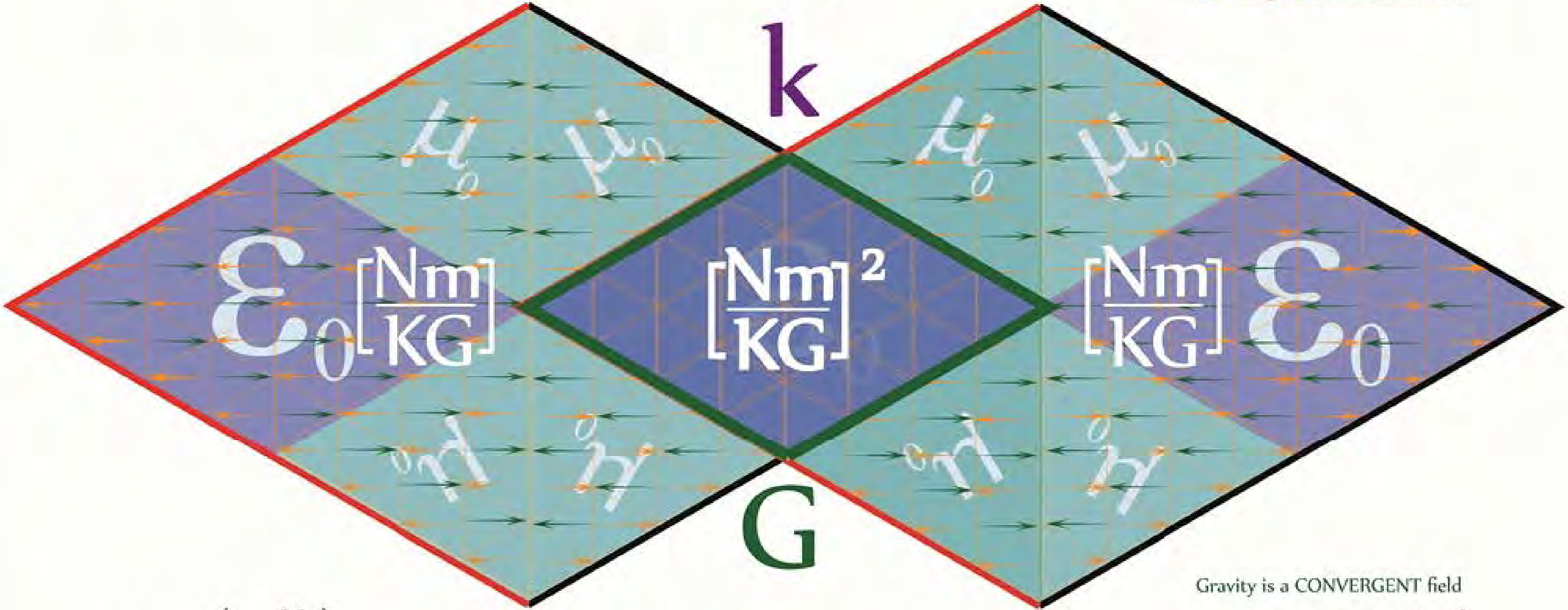
k
μ_0
μ_0
μ_0
μ_0
$\varepsilon_0 \left[\frac{\mathrm{Nm}}{\mathrm{KG}}\right]$
$\left[\frac{\mathrm{Nm}}{\mathrm{KG}}\right]^2$
$\left[\frac{\mathrm{Nm}}{\mathrm{KG}}\right] \varepsilon_0$
μ_0
μ_0
μ_0
μ_0
G

Gravity is a CONVERGENT field

$$\mathbf{F} = m\left(-G\frac{M}{r^2}\hat{\mathbf{r}}\right) = m\mathbf{g}.$$

$$F = -G\,\frac{M_1 M_2}{r^2}$$

$$G = 6.67 \times 10^{-11}\,\frac{\mathrm{N\,m}^2}{\mathrm{kg}^2}$$

$$\nabla \times \mathbf{E}_g = -\frac{\partial \mathbf{B}_g}{\partial t}$$

GEM fields are an accurate way of modelling Gravitational attraction between massive bodies using weak KEM field vectors

$$\nabla \cdot \mathbf{B}_g = 0$$

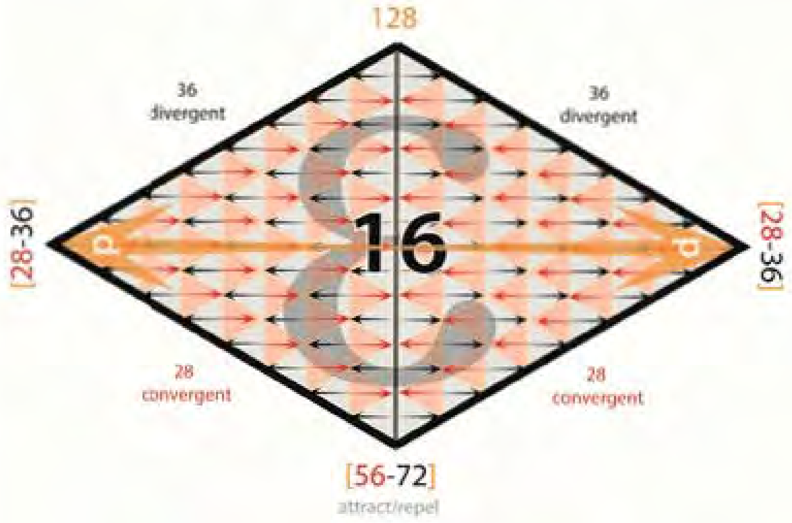
128
36
divergent
36
divergent
[28-36]
p
16
p
[28-36]
28
convergent
28
convergent
[56-72]
attract/repel

Electrostatic fields

Charges attract or repel dependent on polarity
Neutral Matter is largely unaffected (equally repel & attract)

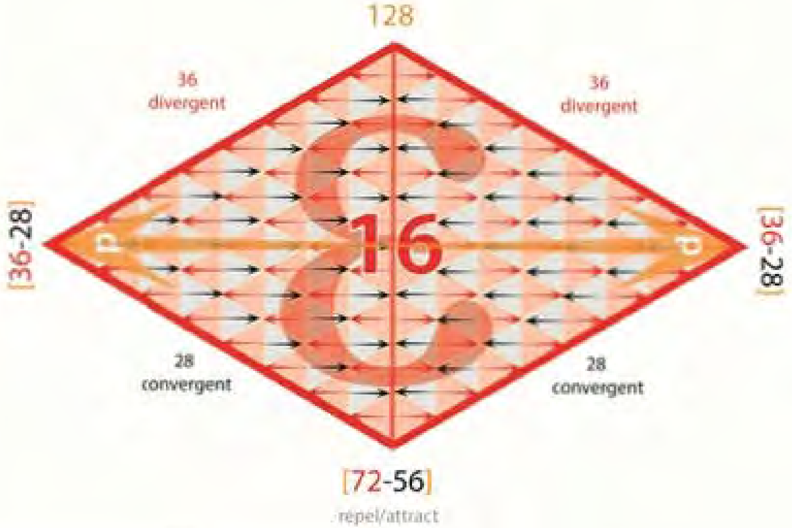
128
36
divergent
36
divergent
[36-28]
p
16
p
[36-28]
28
convergent
28
convergent
[72-56]
repel/attract

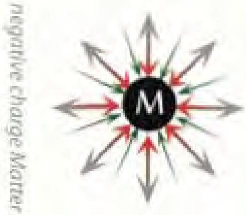
negative charge Matter
M

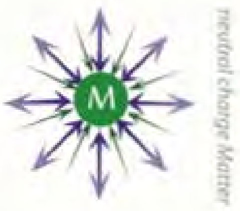
neutral charge Matter
M

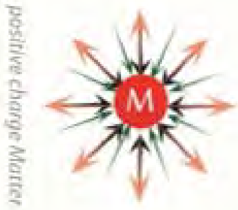
positive charge Matter
M

Gravitational fields can be modelled as weak convergent EM fields

Charged Matter INTERACTS electrically

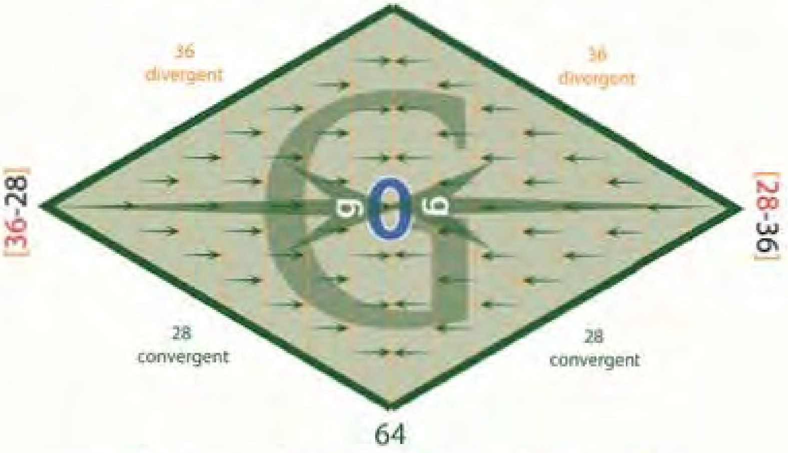
36
divergent
36
divergent
[36-28]
G
g
0
g
[28-36]
28
convergent
28
convergent
64

All Matter ATTRACTS gravitationally

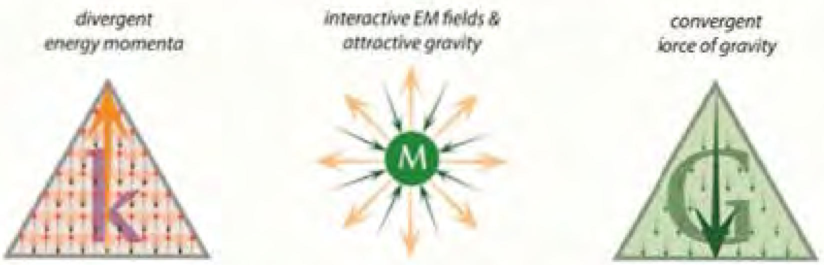
divergent
energy momenta
k
interactive EM fields &
attractive gravity
M
convergent
force of gravity
G

Nett KEM field interaction is divergent from source
Gravitational attraction is the convergent mean force between two sources

Gravitational & Electric constants

are scaling constant relating Gravitational gradients to superpositioned EM fields

[1665]

Newton was the first to apply the Inverse Square law to Gravity

but was unaware of ElectroMagnetic forces

GEM

Gravito ElectroMagnetism

[1769]

Coulomb applied the Inverse Square Law to Charge Interactions

and obtained the value for the Electric Constant

Newton's convergent Gravity & Couolomb's Charge interaction both follow inverse squared laws (geometric means)

Attractive Gravity has the negative vector of nett Charge Interaction

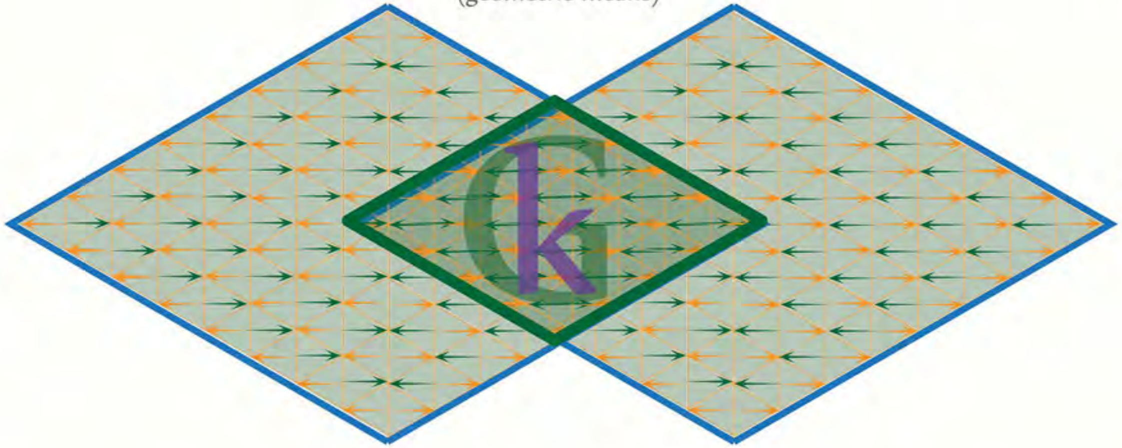

Interactive EM fields are 20 orders of magnitude stronger than Gravity

'Graviton'
Gravitational 'charge' carrier

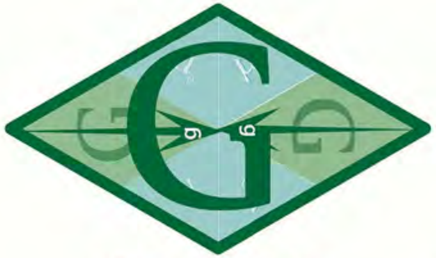

Convergent force vectors

superpositioned EM fields can be used to model the strength and direction of the weaker Graviational force vectors at any point in the fields as they are both inverse squared forces

Producing the ongoing speculation of the existence of a gravitational charge carrier

(an erroneous assumption that stems from using mathematics alone, without a solid understanding of geometric mass-energies & Matter topologies)

Photon
Electric charge carrier

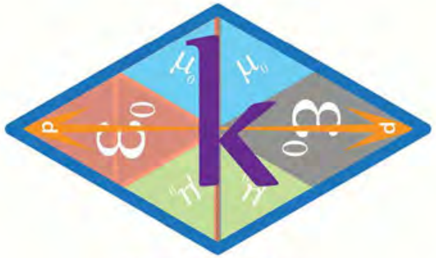

Divergent force vectors

Newton's attractive Gravity & Coulomb's Charge interaction
both follow inverse square laws

Instantaneous
action-at-a-distance

The Force of Gravity

Absolute
Space & Time
(x,y,z) (t)

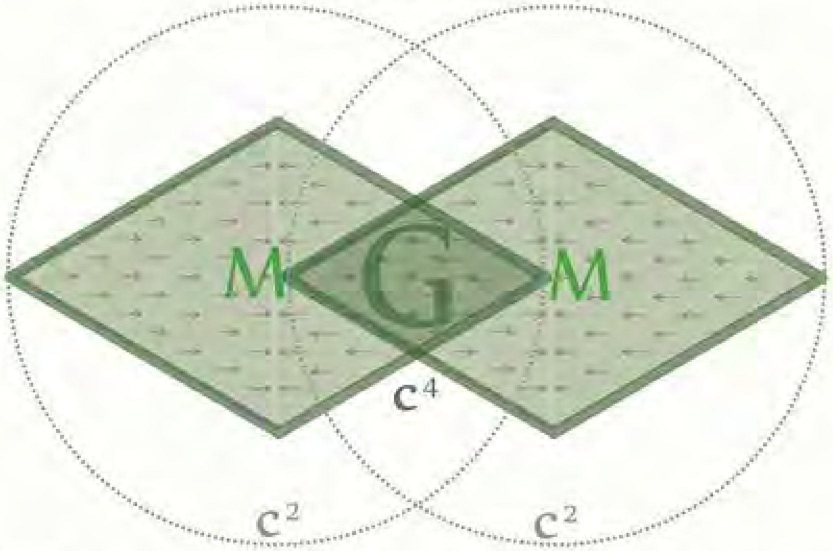

Gravitational action
limited to c

mass-ENERGY-Matter

Curved relativistic
Spacetime
(x,y,z,t)

Modelling Gravity with EM field geometries

while superpositioned EM fields can be used to model the strength and vector direction
of weaker Gravitational fields at any point in time within the field geometry
they DO NOT reflect the actual physicality of the fields involved

$$R_{00} = 4\pi\rho$$

The speed of Gravity is not limited to c
as changes to the energy density-pressure
gradient are immediately translated through
the aether from one object to the other

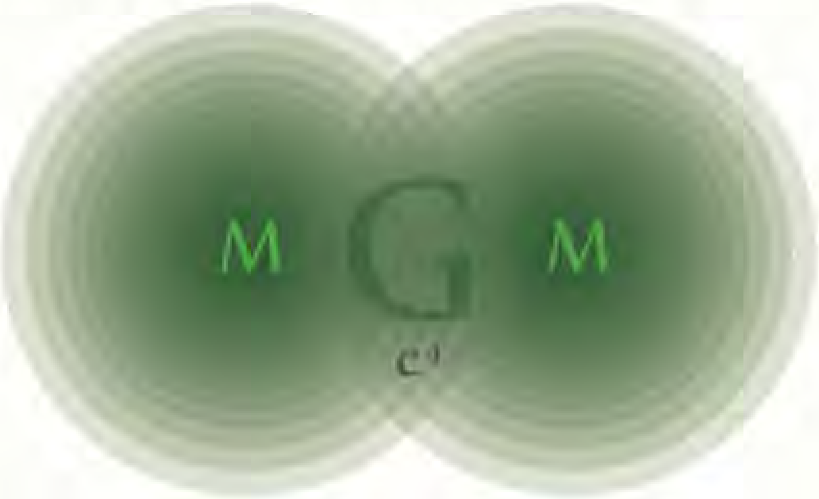

$$R_{\mu\nu} - \tfrac{1}{2}R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Gravity is a the pressure gradient created
by the displacement of vacuum energies
though the presence of 3D mass-Matter
topologies in any region of space

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Fields of Interaction

All topological Matter in motion creates a interactive Kinetic EM field
in addition to its inherent convergent Gravitational field

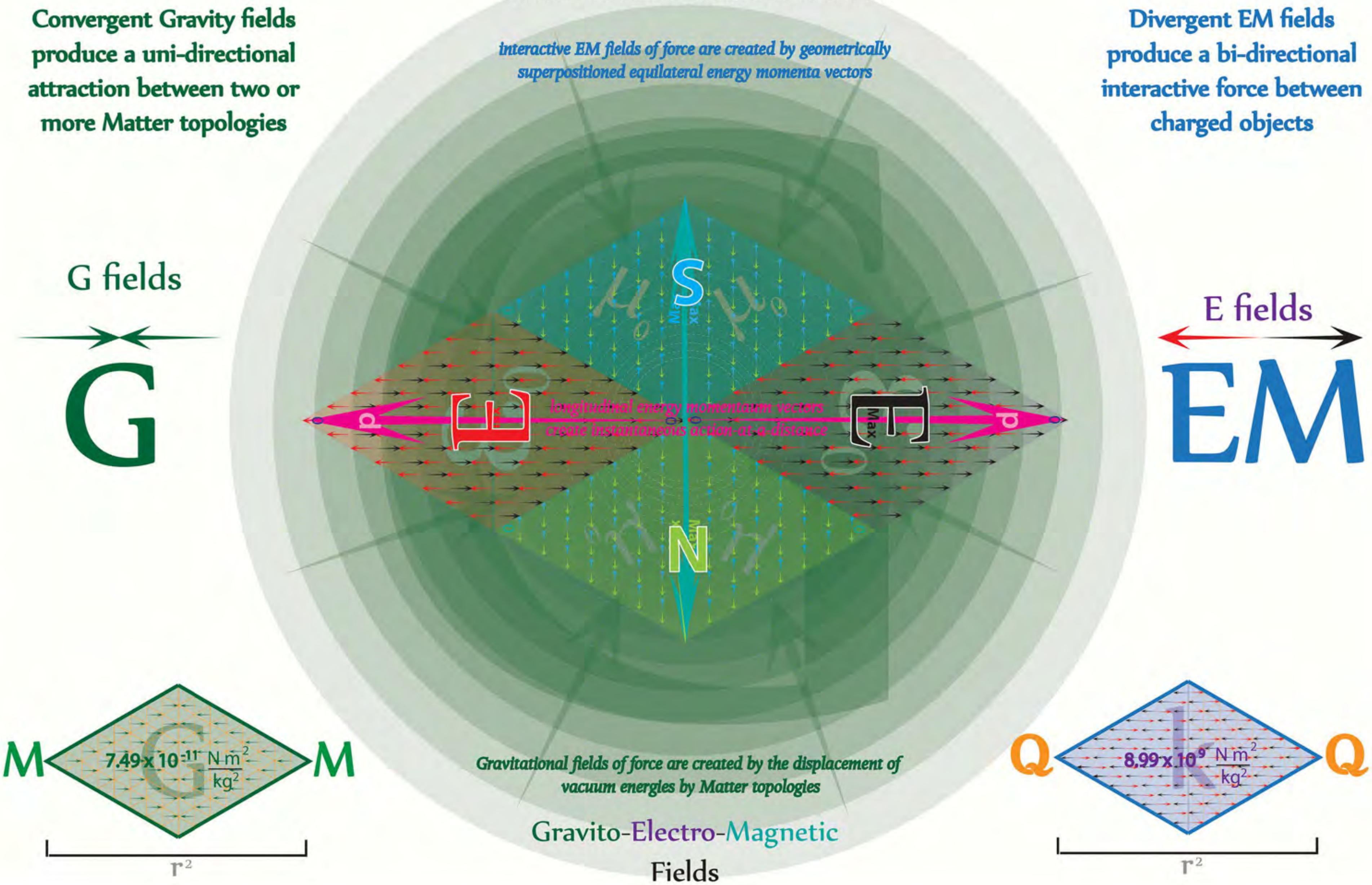

Convergent Gravity fields produce a uni-directional attraction between two or more Matter topologies

interactive EM fields of force are created by geometrically superpositioned equilateral energy momenta vectors

Divergent EM fields produce a bi-directional interactive force between charged objects

longitudinal energy momentum vectors create instantaneous action-at-a-distance

Gravitational fields of force are created by the displacement of vacuum energies by Matter topologies

Gravito-Electro-Magnetic
Fields

G fields
G
E fields
EM
S
N
E
E
Max
Max
p
p
μ_0
ε_0
M
M
G
$7.49 \times 10^{-11} \frac{N\,m^2}{kg^2}$
r^2
Q
Q
k
$8.99 \times 10^{9} \frac{N\,m^2}{kg^2}$
r^2

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GEM gradients

The gravitational field of Material objects is the result of zero energy nullspace volumes encompassed by all Matter which in turn creates a displacement energy pressure differential gradient with the surrounding Vacuum Energies

Gravitational attraction can be modelled as a CONVERGENT EM FIELD created by the nullspace differential of Matter

All Matter in motion creates an eternally dynamic system of Gravitational fields and radiative ElectroMagnetic Energies

EM radiation is a bidirectional DIVERGENT-CONVERGENT FIELD resulting from quanta imbalances

radiative EM fields are created by all Matter as it seeks equilibrium with its environment, the impedance of space creates a propagation velocity equal to the speed of light

convergent Gravitational fields

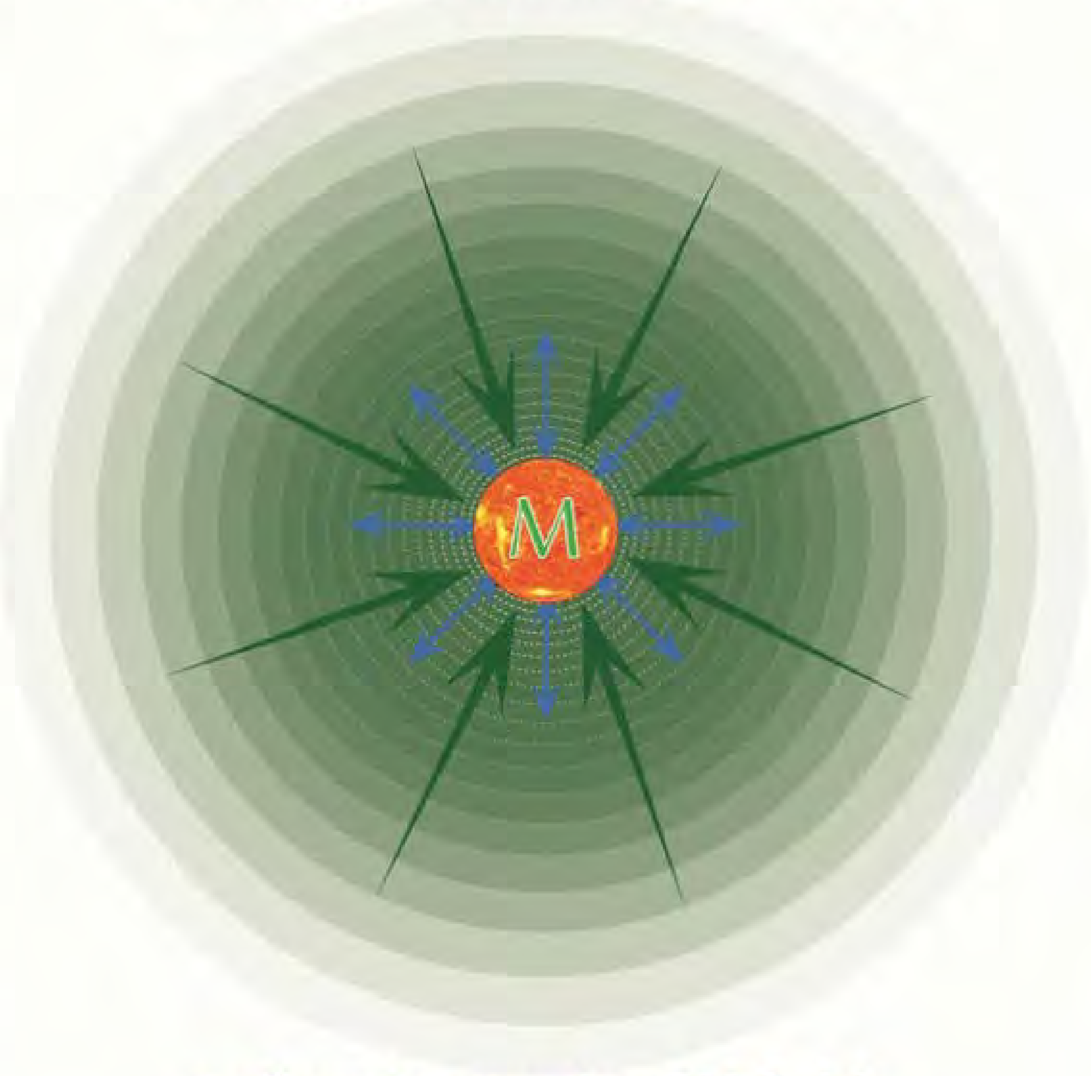

radiant interactive EM fields

Gravity and ElectroMagnetic fields

Newtonian Gravity

Gravity & Electro-Magnetic field strengths all converge to zero at the centre of the sphere

General Relativity

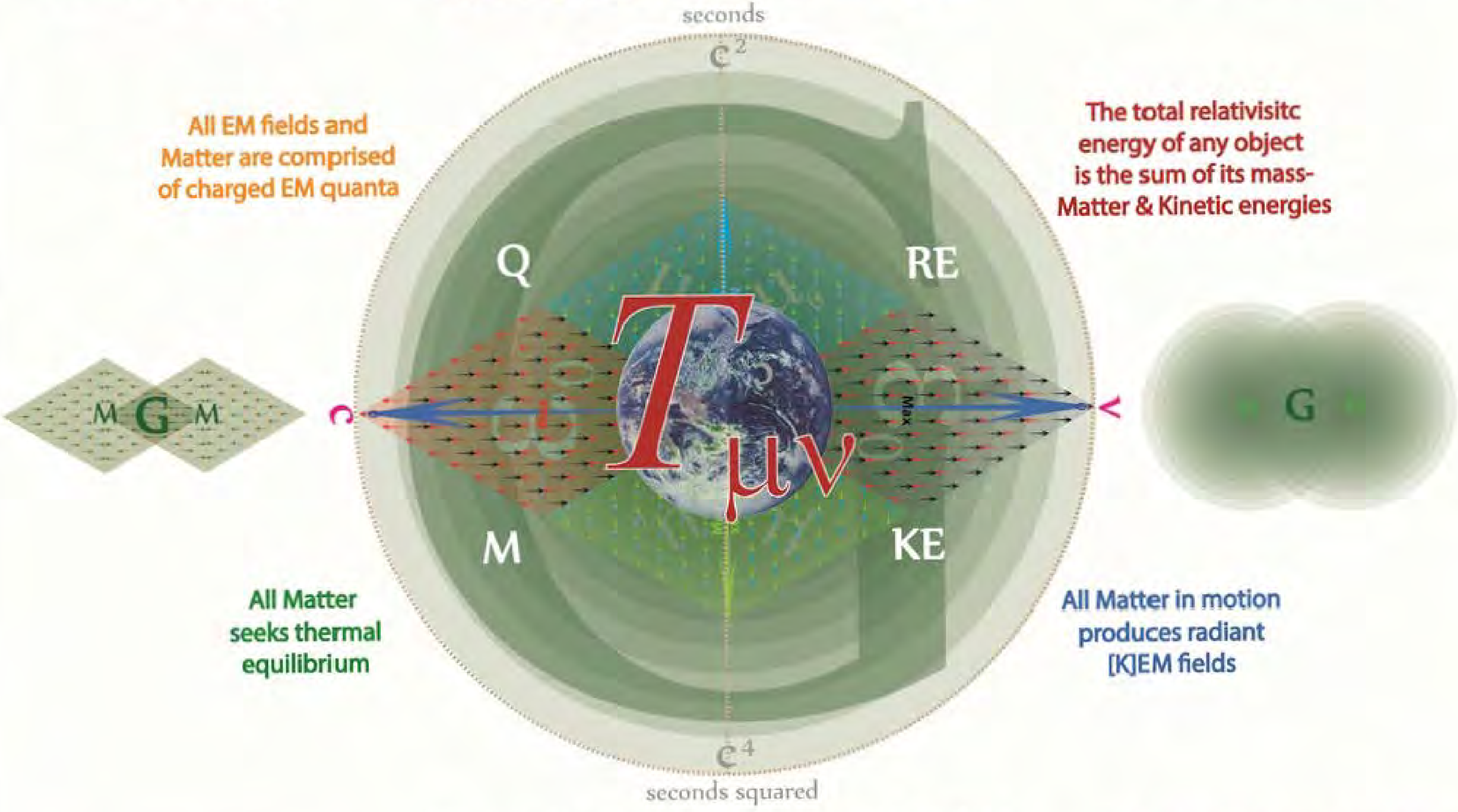

All EM fields and Matter are comprised of charged EM quanta

The total relativisitc energy of any object is the sum of its mass-Matter & Kinetic energies

All Matter seeks thermal equilibrium

All Matter in motion produces radiant [K]EM fields

Charges are Interactive

Gravimetric fields can be modelled as weak EM fields [space-time curvatures] created by Matter

Gravity is always attractive

Electric vs Gravitational Fields

C

KG

interactive electrostatic fields

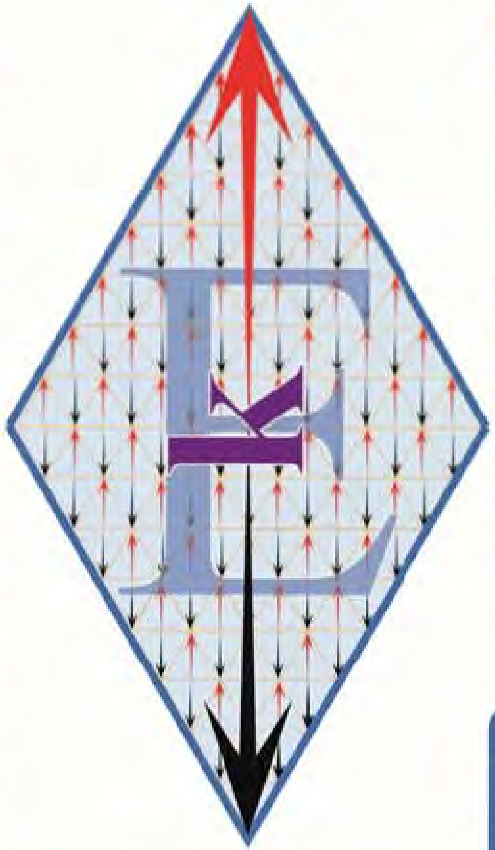

In fields of charge the nett divergent field encloses the convergent field

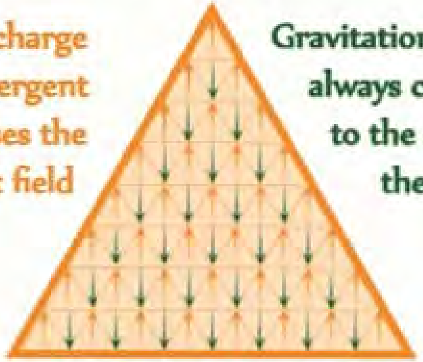

Gravitational fields are always convergent to the source of the field

nett Divergent Field

strictly Convergent Field

SR *Using Special relativity as the basis for the development of a General theory of Relativity to model Gravity is problematic* **GR**

[as SR models EM interactions]

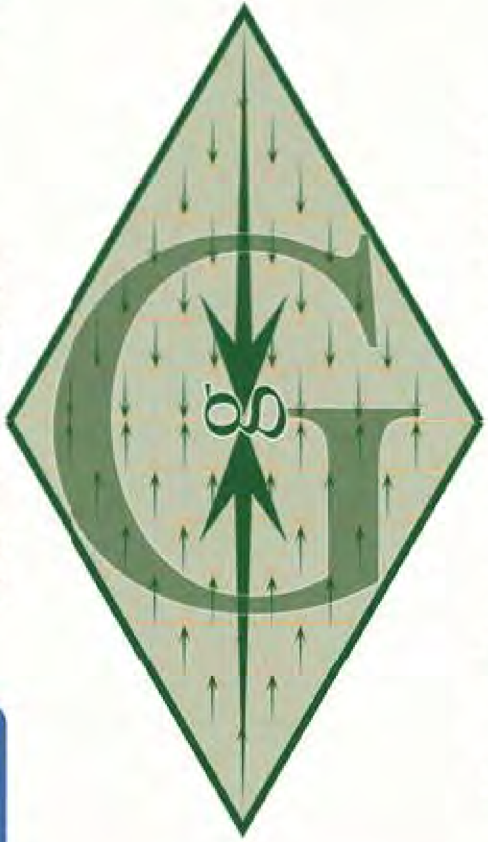

attractive gravitational fields

Field	Units	Equation
Gravity	$\vec{g} = \frac{\text{newtons}}{\text{kilogram}} \left(\frac{N}{kg}\right)$	$\vec{F} = m\vec{g}$
Electricity	$\vec{E} = \frac{\text{newtons}}{\text{coulomb}} \left(\frac{N}{c}\right)$	$\vec{F} = q\vec{E}$

Electrical interaction is the result of the nett EM geometry of [K]EM fields

Gravitational attraction is the result of the displacement topology of Matter

Q

The similarities between Electro-Magnetic and Gravitational fields can be shown by modelling their effects through EM field geometries

M

Tetryonics 66.01 - Electric vs. Gravitational fields

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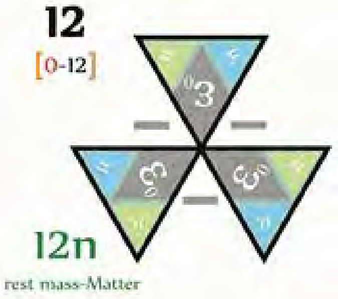

Electric fields and Gravitation

Electrostatic forces are much greater than Gravitational forces (by about 10^20 times).
The force of gravity is attractive for all Matter, whereas electrostatic forces are repulsive for like charged Matter,
There are no negative [repulsive] gravitational charges, while there are both positive and negative electric charges.

Electrostatic forces are interactive
while Gravitational forces are always attractive

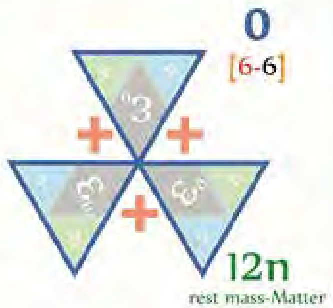

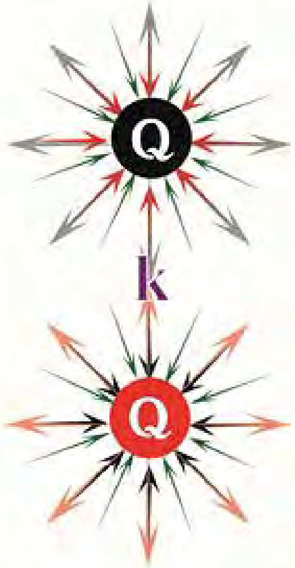

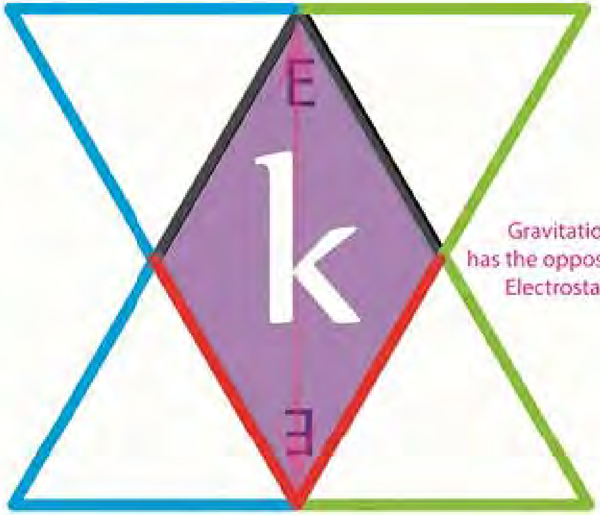

Gravitational attraction
has the opposite force vector of
Electrostatic interaction

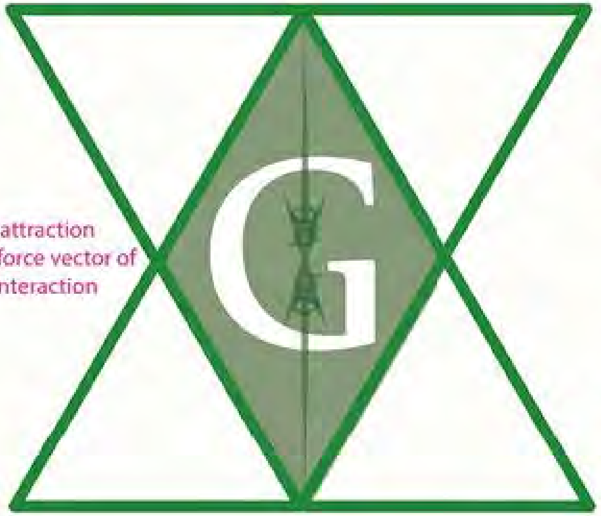

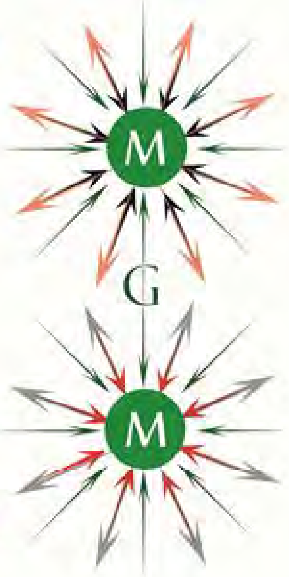

All ElectroMagnetic field quanta are subject to
Lorentz wavelength-frequency corrections due to velocity

Gravitational Matter topologies are NOT affected by
Lorentz corrections due to their velocity of motion

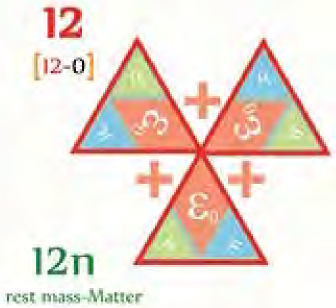

There are similarities between the Electric field and the Gravity field of Matter,
(so sometimes Matter is refered to as "gravitational charge")

Both act in a vacuum and are central and conservative.
Both obey an inverse-square law (both are inversely proportional to square of r).
Both field types propagate at the finite speed of c, the speed of light.
Electric charges and EM mass-energies are conservative

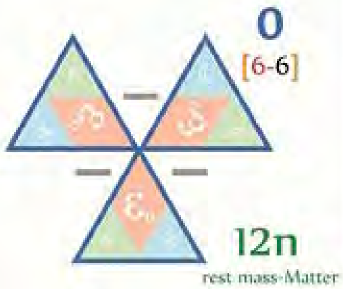

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Charge vs Gravitation

Coulombic interaction is proportional to Charge
(energy geometry imbalances)

[empirically determined value]
8.987551787e9 N

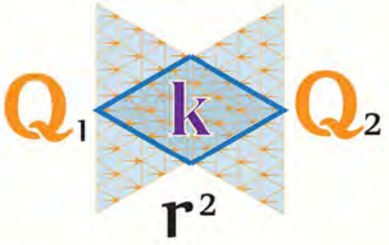

"The magnitude of the electrostatic force between two charges is directly proportional to the product of the magnitudes of each charge and inversely proportional to the square of the distance between the charges."

Charge interaction can be modelled as a DIVERGENT EM FIELD

We have two fundamental laws stating that the forces between two particles are directly proportional to the product of their charges/masses and inversely proportional to the square of the distance between them

Gravitational attraction can be modelled as a CONVERGENT EM FIELD

"The magnitude of the gravitational force between two masses is directly proportional to the product of the magnitudes of each mass and inversely proportional to the square of the distance between the charges."

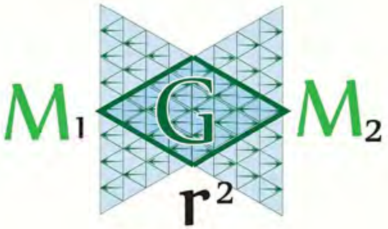

6.67428e-11 N
[empirically determined value]

$$F = k\,\frac{Q_1 Q_2}{r^2}$$

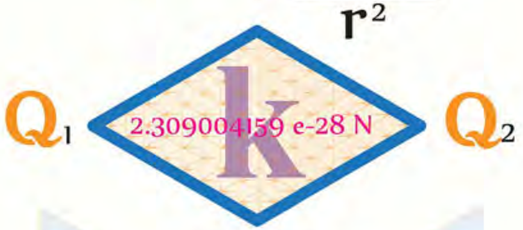

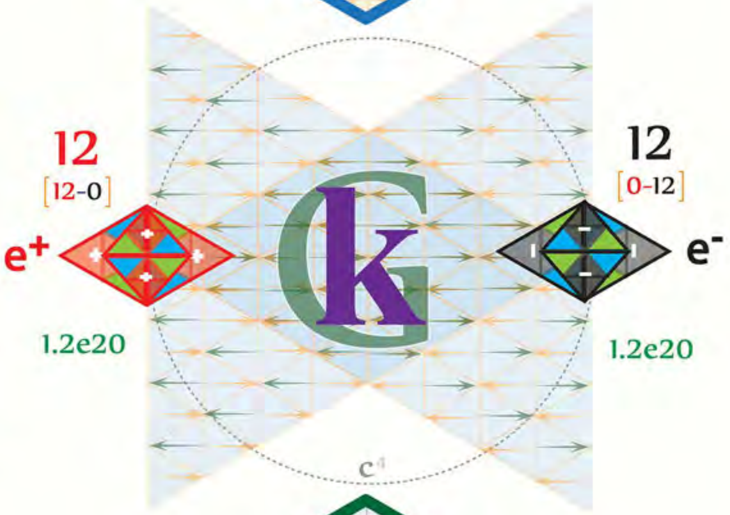

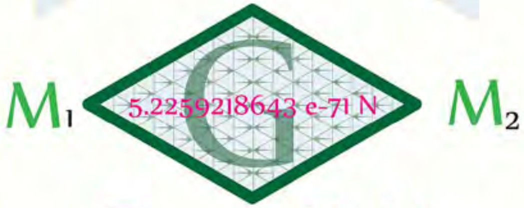

$$F = -G\,\frac{M_1 M_2}{r^2}$$

Gravitational attraction is proportional to Matter
(total rest EM mass-energy content)

*It can now be clearly demonstrated that **Newtonian Gravity** can be modelled as a weak convergent Electro-Magnetic Force*

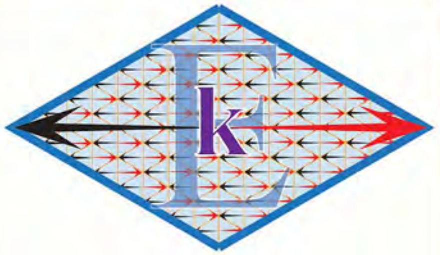

$$\frac{k \quad 8.9875 \ \ e9 \ \ N}{G \quad 6.67384\ e\text{-}11\ \ N} = 1.346\ e20$$

The field strength differential is reflective of the Compton frequency of electron
[1.20 e20 quanta]

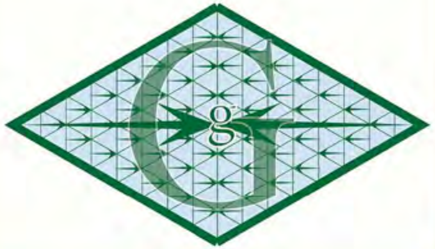

Einstein's general relativity offers a different model of Gravitational attraction however

Gravito-Electro-Magnetic interaction

$$F \propto \frac{Q_1 Q_2}{r^2}$$

The ElectroMagnetic [Coulombic] field strength is proportional to an object's relativistic charge

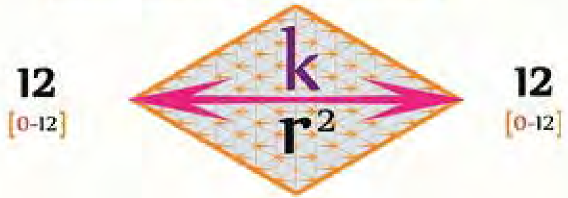

$$F = k\,\frac{Q_1 Q_2}{r^2}$$

Charge interactions can be modelled as a superpositional
DIVERGENT FORCE

equilateral mass-energy momenta quanta create the interactive fields of Force between material bodies of Matter

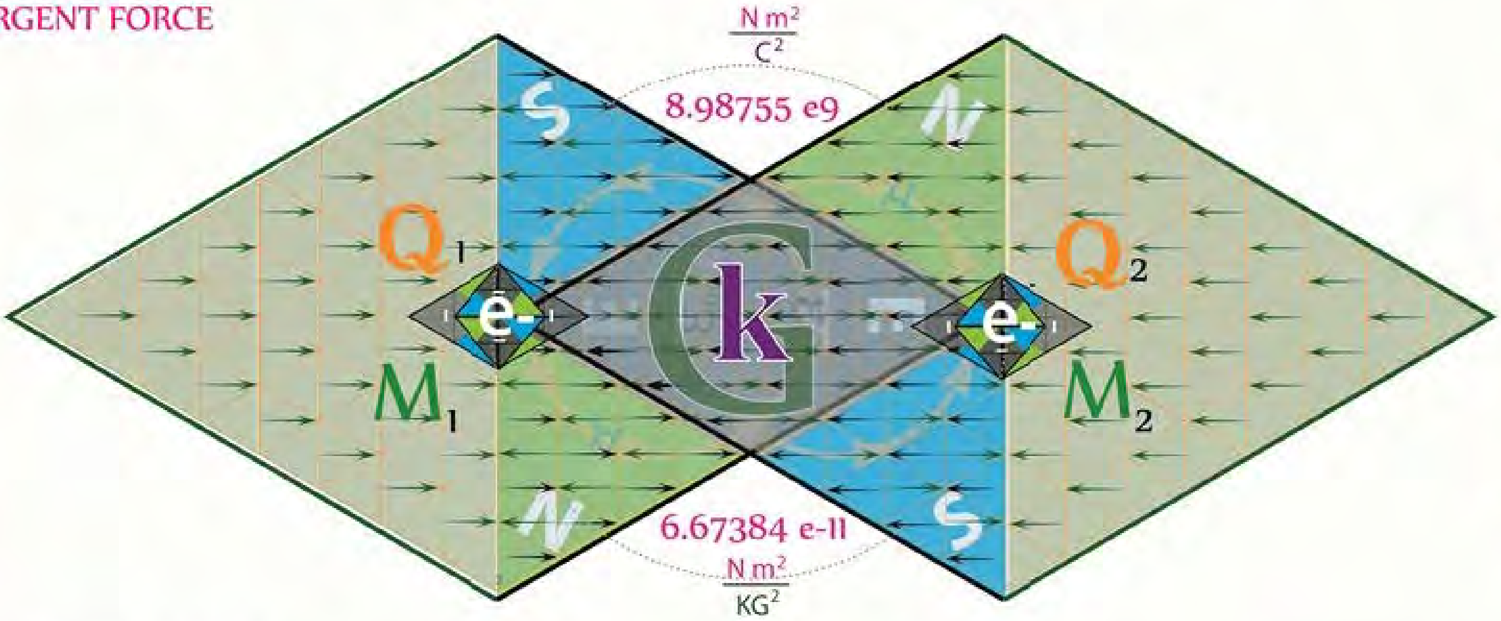

The attractive strength of Gravity is 20 orders of magnitude weaker than the strength of Electrostatic interaction

Gravitational attraction can be modelled as a superpositional
CONVERGENT FORCE

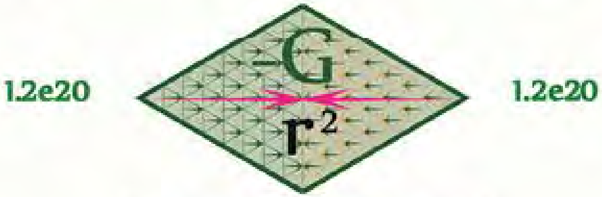

Gravitational field strenth is proportional to the rest Matter topology (and can be modelled with weak coulombic fields)

$$F = -G\,\frac{M_1 m_2}{r^2}$$

$$F \propto \frac{M_1 m_2}{r^2}$$

Charged Matter Gravitational interactions

Electrostatic force fields dominate Gravitational fields
and can be modelled via their superpositioned
energy momenta force fields

Following the field symmetries
provided by Tetryonic geometry
we can now model all fields

$$F = k\frac{Q_1 Q_2}{r^2}$$

Electromagnetic interactions
as well as the convergent
Gravitational atraction

2.30900415 e-28 Newtons

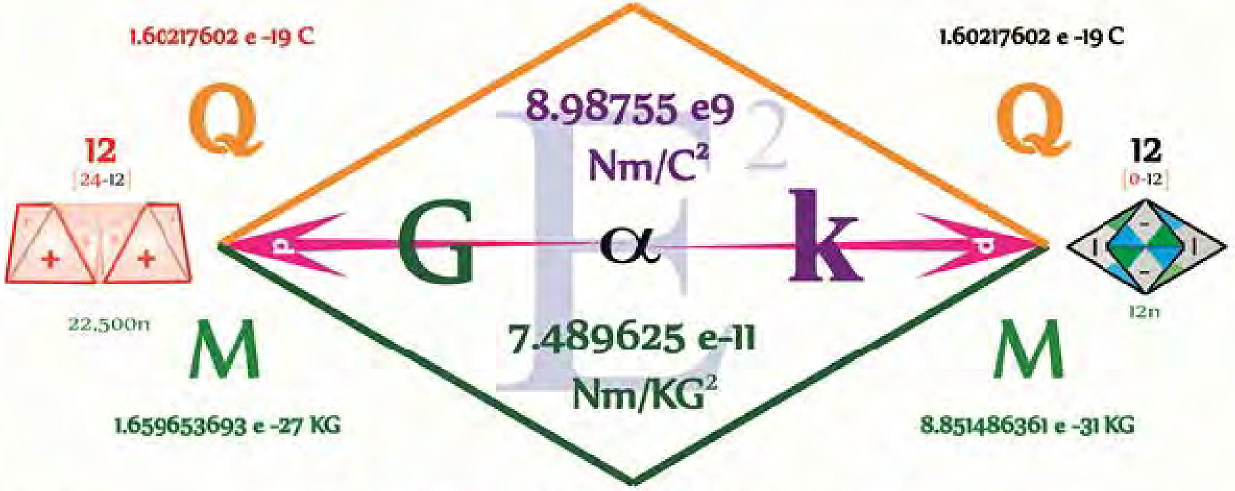
1.60217602 e -19 C
Q
12
[24-12]
+
+
22,500n
M
1.659653693 e -27 KG
8.98755 e9
Nm/C²
E
2
G
α
k
p
p
7.489625 e-11
Nm/KG²
1.60217602 e -19 C
Q
12
[0-12]
12n
M
8.851486361 e -31 KG

Proton
Matter-charge
9.6577107 e7 C/kg

electron
Matter-charge
1.810820762 e11 C/kg

1.10025594 e-67 Newtons

Reflecting all of the
geometric force interactions in terms of
EM mass-ENERGY & Matter

$$F = -G\frac{M_1 m_2}{r^2}$$

Allowing an accurate value
of the graviationl constant
to be derived

Gravity [like electrostatic] fields
can be modelled as superpositioned
Energy momenta force fields

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The Gravitational Constant

The gravitational constant is a difficult physical constant to measure to high accuracy,
in fact it was not measured until over seventy years after Newton's death by
Henry Cavendish with his torsion beam experiment, performed in 1798

G

The gravitational constant is denoted by letter G,
it is an empirical physical constant involved in the calculation
of the gravitational force between two material bodies.

It usually appears in Sir Isaac Newton's law of universal gravity,
and in Albert Einstein's theory of general relativity.

Henry Cavendish

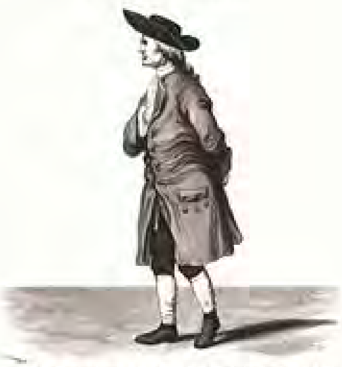

(10 October 1731 – 24 February 1810)

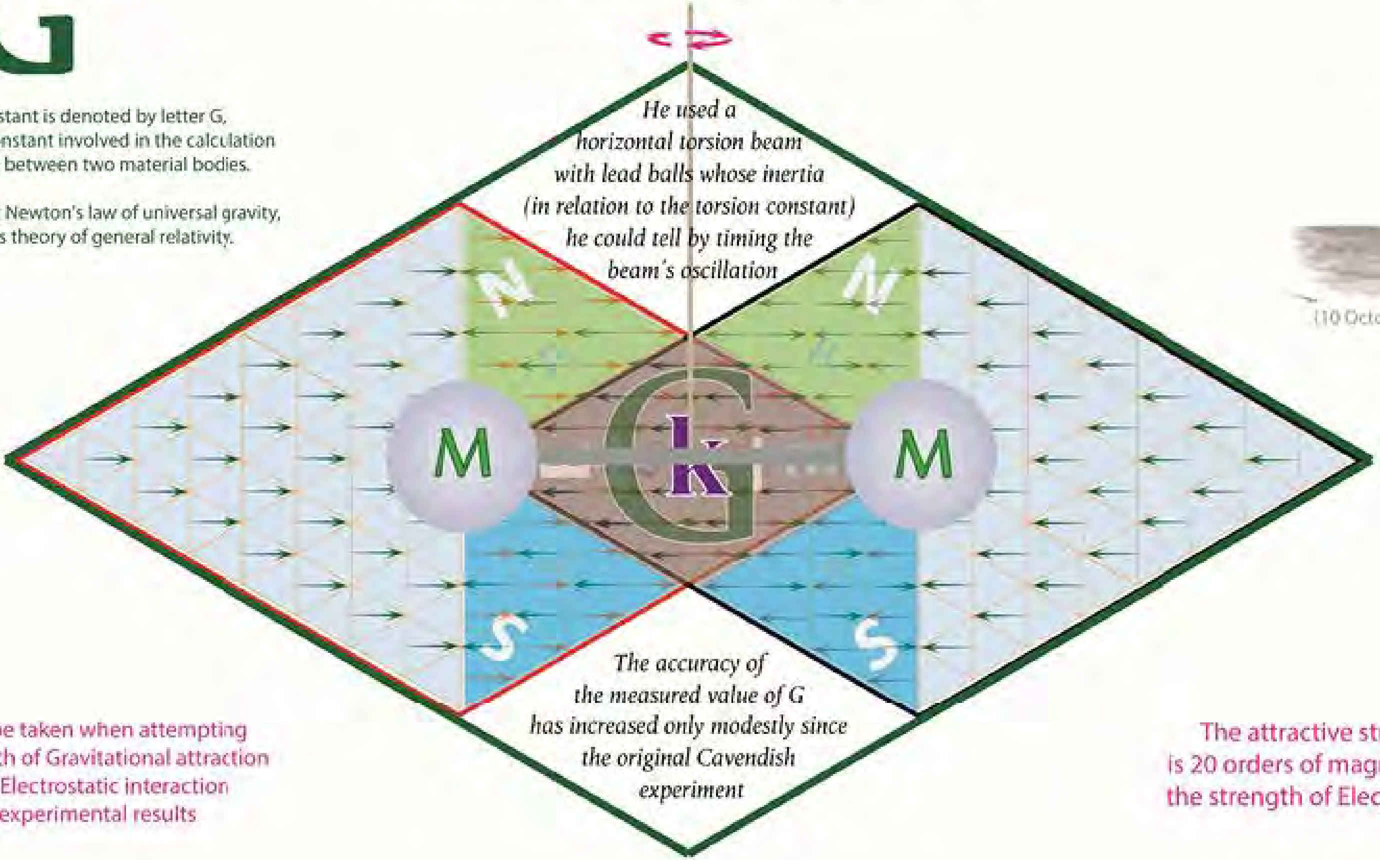

He used a horizontal torsion beam with lead balls whose inertia (in relation to the torsion constant) he could tell by timing the beam's oscillation

The accuracy of the measured value of G has increased only modestly since the original Cavendish experiment

Extreme care must be taken when attempting
to measure the strength of Gravitational attraction
to ensure that NO Electrostatic interaction
influences the experimental results

The attractive strength of Gravity
is 20 orders of magnitude weaker than
the strength of Electrostatic interaction

8.98755 e9 N

It is also known as the universal gravitational constant,
Newton's constant, and colloquially as Big G.

6.67384 e-11 N

$$F = k\,\frac{Q_1 Q_2}{r^2}$$

g

It should not be confused with "little g" (g),
which is the local gravitational field
(equivalent to the free-fall acceleration),
especially that at the Earth's surface.

G

$$F = -G\,\frac{M_1 m_2}{r^2}$$

Gravity has no established relation to other fundamental forces, so it does not appear possible to calculate it indirectly from other constants that can be measured more accurately, as is done in some other areas of physics

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Fundamental field strengths

are the result of equilateral energy momenta geometries

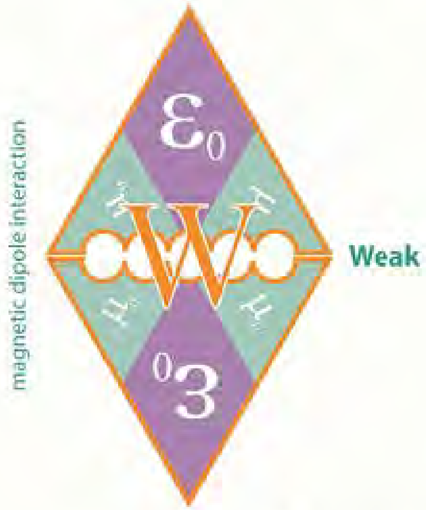
magnetic dipole interaction
ε0
W
03
Weak

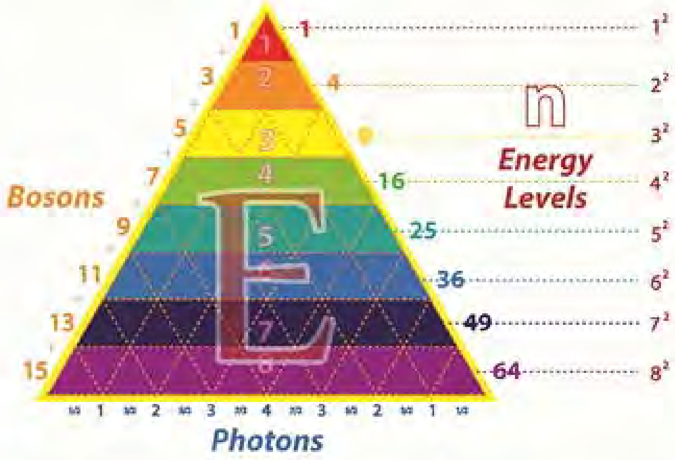
Bosons
1
3
5
7
9
11
13
15
1
4
16
25
36
49
64
1^2
2^2
3^2
4^2
5^2
6^2
7^2
8^2
n
Energy Levels
E
1 2 3 4 3 2 1
Photons

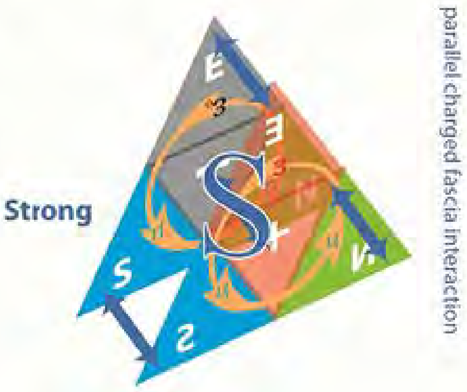
Strong
S
parallel charged fascia interaction

Force	Approximate Relative Strength	Range
Strong Nuclear	10^{38}	10^{-15}
ElectroMagnetic	10^{36}	Infinite
Weak	10^{2}	10^{-18}
Gravitational	1	infinite

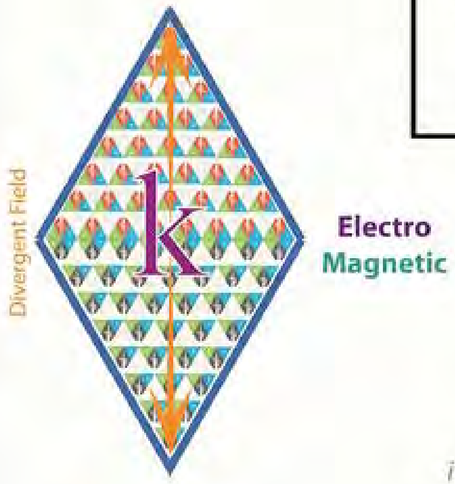
Divergent Field
k
Electro Magnetic

All the field strengths of the fundamental interactions are a direct result of the interactions of their Tetryonic mass-energy goemetries and Tetryonic Matter topologies

m E M

geometries density topologies

(whilst Gravity can be modelled as a weak convergent Coulombic attraction its actual physics are the result of vacuum energy displacement by Matter topologies)

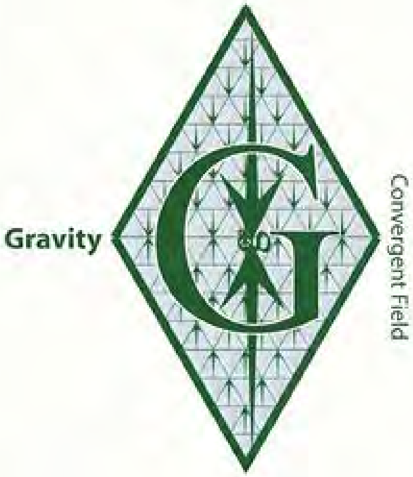
Gravity
G
Convergent Field

The Strength of the Gravitational Constant

Coulomb's Constant

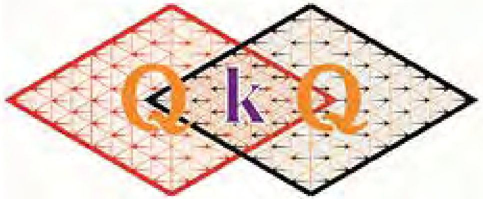

[24-12]

Proton nett charge

1.60217646 e -19 C

equal (but opposite) nett Charges

[0-12]

Electron nett charge

1.60217646 e -19 C

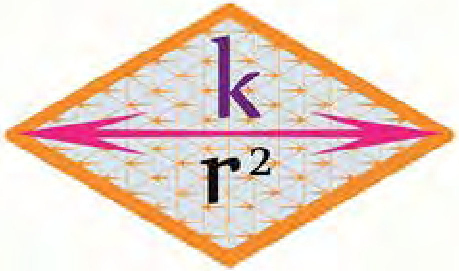

8.987551787e9 N

CHARGED mass-energy geometries interact

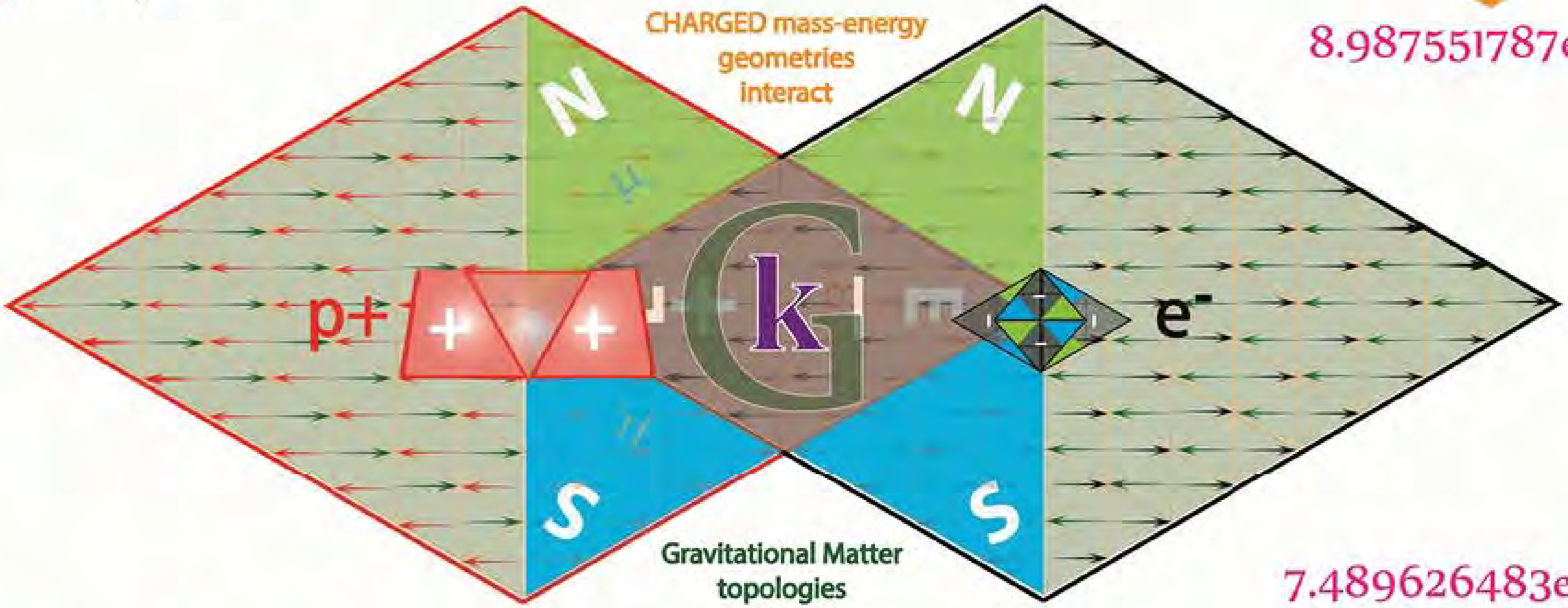

Gravitational Matter topologies attract

7.489626483e-11 N

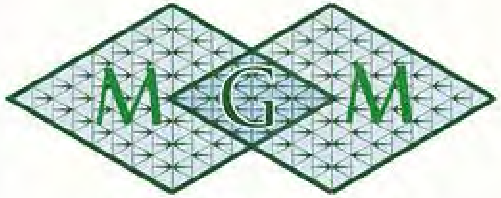

Newton's Constant

1.659653693 e -27 KG

Proton rest mass-Matter

[1.5e23-7.5e22]

1875

8.851486361 e -31 KG

electron rest mass-Matter

[1.2e20]

Although it provides a coherent and accurate model of all the motive forces & interactions present the modelling of Gravity with EM fields does not account for the source, strength & unilateral direction of Gravitational fields

Tetryonic Matter interaction and Gravitation

Electrostatic convergence can serve as a model for Gravitational attraction

All Matter is comprised of EM mass-Energies

All gravitational systems are comprised of Matter & KEM fields

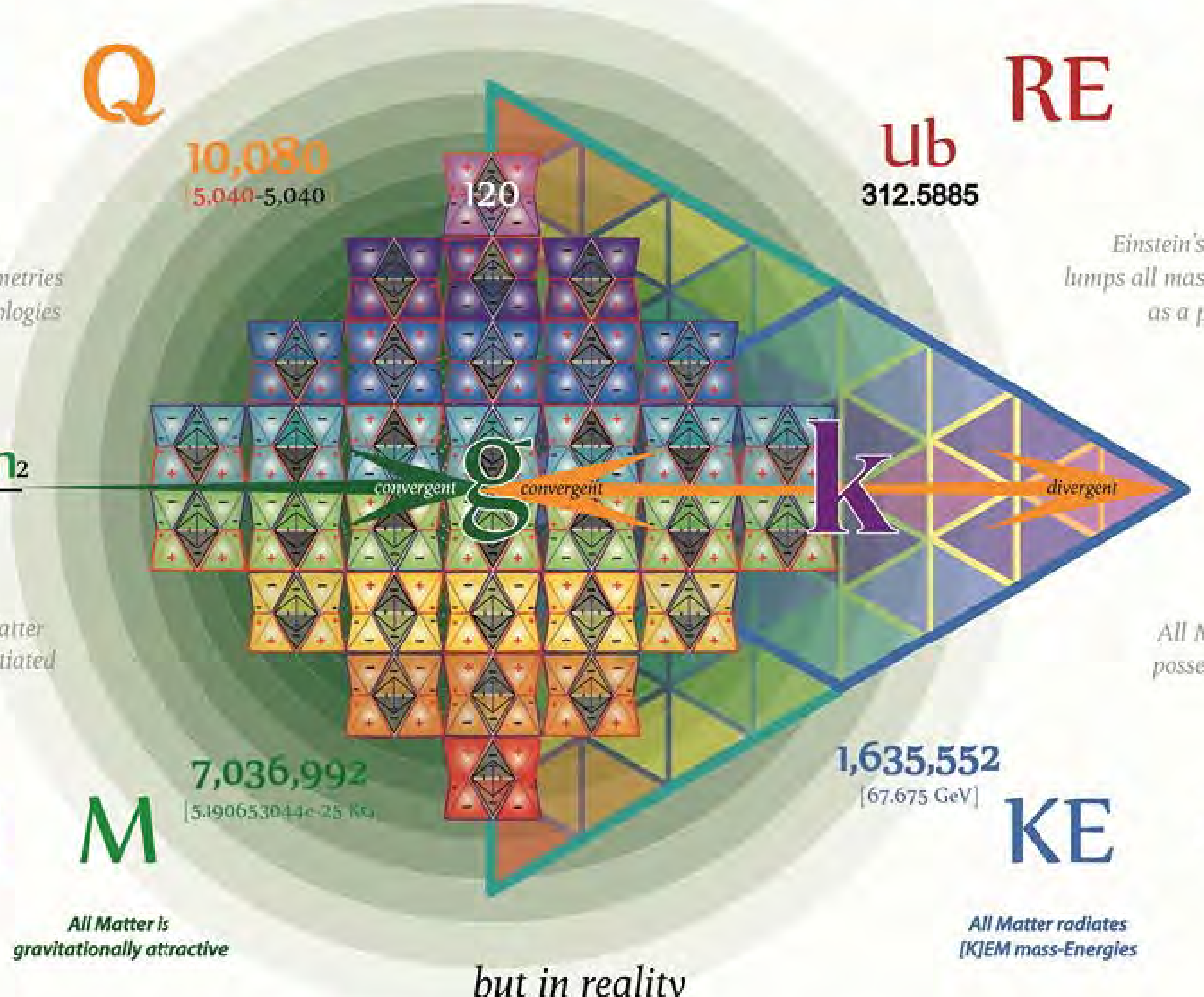

Charged mass-energy geometries form Matter topologies

Einstein's stress-energy tensor lumps all mass-Energy-matter together as a pressure gradient

$$F = -G\frac{M_1 m_2}{r^2}$$

$$F = k\frac{Q_1 Q_2}{r^2}$$

EM mass & Matter must be differentiated

All Matter in motion posseses [K]EM fields

Matter

$$\frac{4n\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

EM waves

$$\frac{\text{EVEN}\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

All Matter is gravitationally attractive

All Matter radiates [K]EM mass-Energies

but in reality

Gravitational attraction results from the displacement of vacuum energies by Matter topologies

[The effects of stronger [K]EM fields can be excluded from the long distance attractive [gravitational] motion of material bodies to each other]

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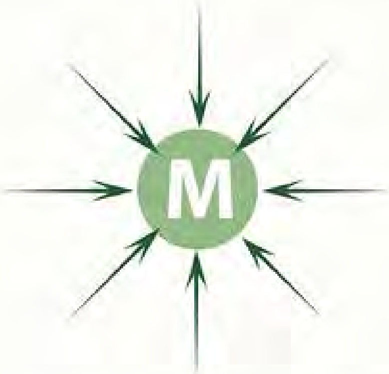

Modelling the force of Gravity

It is in many ways very similar to Coulomb's law of Interaction
between charged particles developed by Coulomb
(after Newton's Gravitation)

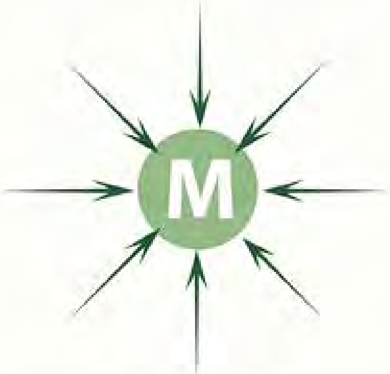

Gravity can be modelled as weak convergent EM field

For many people, it is easiest to picture gravity
as a kind of special invisible force,
emanating from ALL the Matter in the universe.
Newton's law of Gravity leads one to sees
it this way and it is probably the view
most of us were given when we learned
about gravity in elementary school.

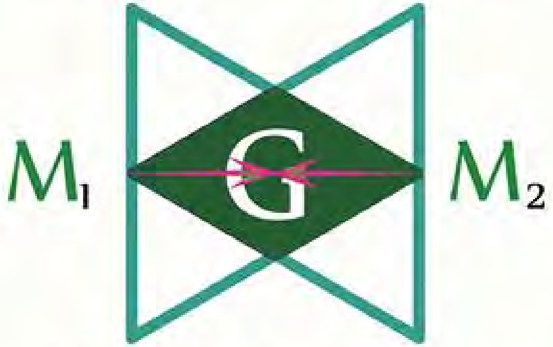

However, there is another way
to model Gravity's effects.
It stems from Albert Einstein's
General theory of Relativity,
a theory that describes gravitation
as being the result of the curvature of
spacetime as a result of energy gradiant

Gravity can also be modelled as convergent pressure gradients

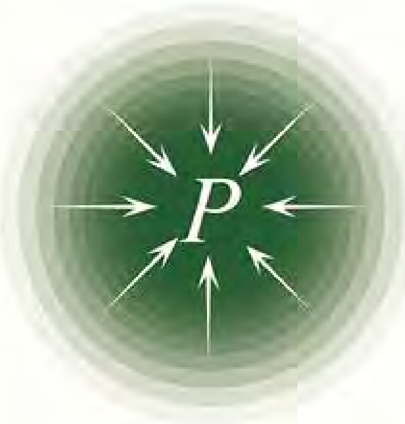

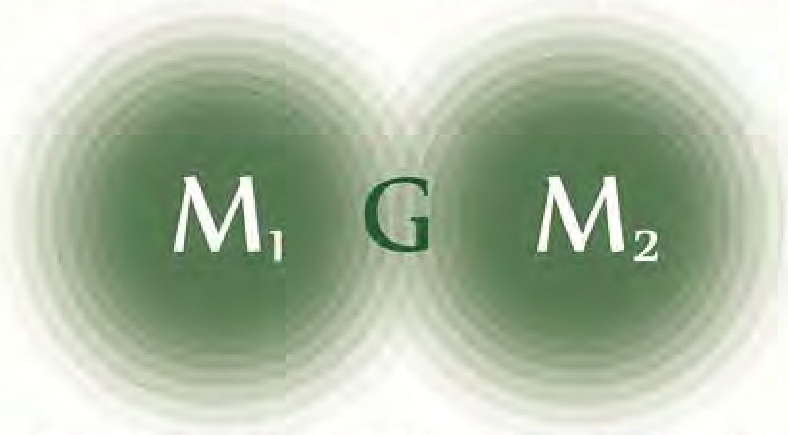

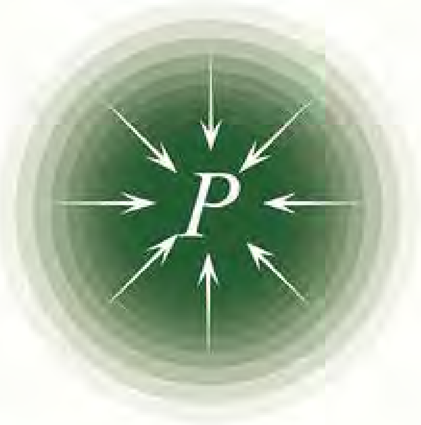

To understand what gravity really is you must have a clear understanding of the distinctions between radiant EM mass and standing-wave Matter and the various quantum interactions they produce.

Tetryonics provides a clear geometric definition and distinction between 2D radiant mass-energy geometries and 3D Matter topologies along with a new unified model of the mechanics of Universal Gravitation at all scales

radiant mass-energy geometries

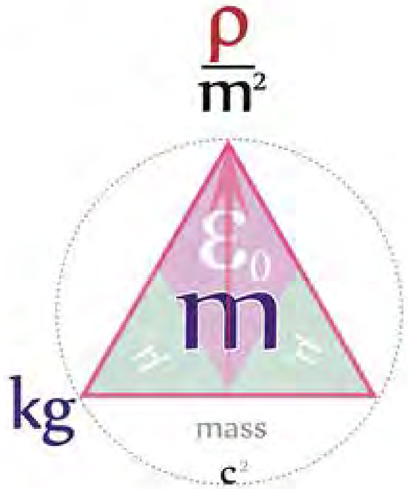

'Action-at-a-Distance'

mass-energies

$$\frac{n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

Planck quanta

mass velocity

[K]EM mass-Energies with QAM create interactive divergent [and convergent] charge geometries

Newtonian Gravity

Toplogical mass is Matter

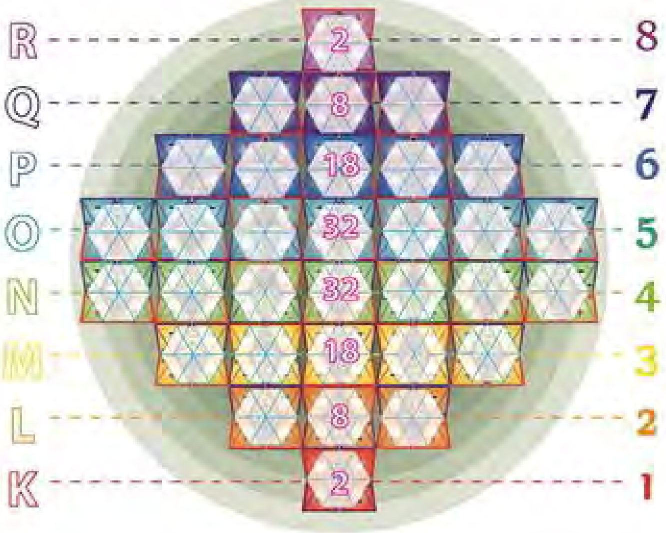

All Matter contains nullspaces and produces motional KEM fields

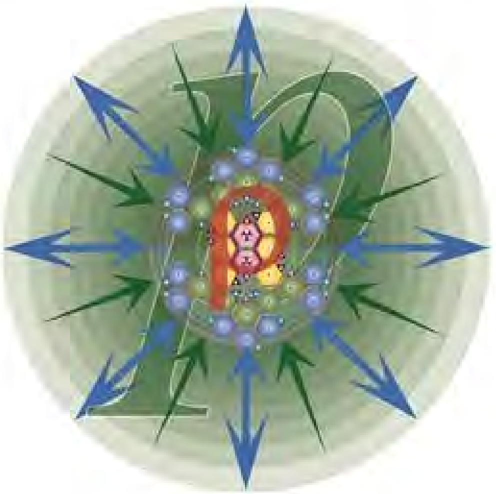

standing-wave Matter toplogies

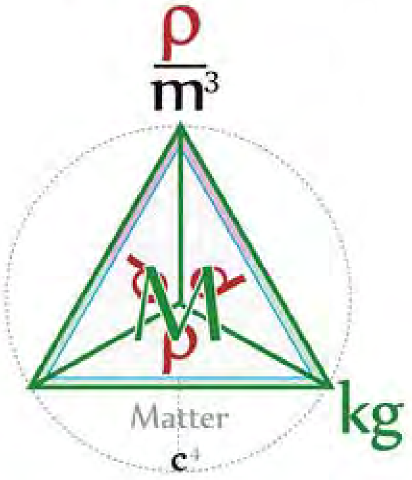

'Folded Space-Time'

Matter

$$\frac{4n\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

Planck quanta

mass velocity

Tetryonic Matter creates low pressure nullspace resulting in convergent Energy pressure gradients

General Relativity

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Instantaneous action-at-a-distance

Tetryonic QED theory shows that where the linear energy momentum of longitudinal waves align and act in a co-linear direction they can facilitate near instantanous action-at-a-distance

$$\sum \mathbf{F} = 0 \Rightarrow \frac{d\mathbf{v}}{dt} = 0$$

Free particles move with constant vector-velocity
(that is, with zero acceleration, unless acted upon by an outside force).

The Earth orbits the SUN where it is now about a common centre of gravity

'Action-at-a-Distance' and 'Instantaneous' forces were introduced into Physics within Newton's notion of absolute space and time

If the SUN were to vanish the Earth would cease traveling in its current elipical orbit immediately

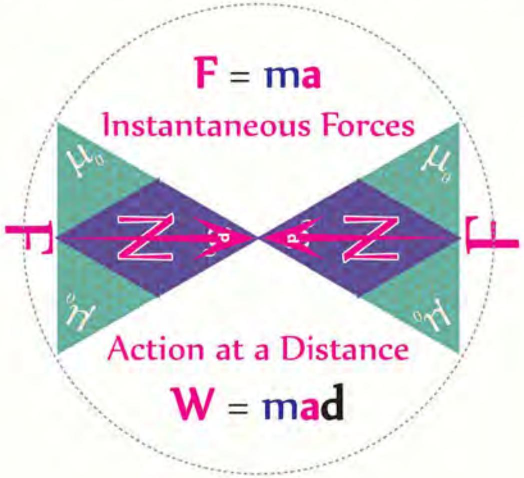
F = ma
Instantaneous Forces
μ_0
μ_0
F
N
p
p
N
F
μ_0
μ_0
Action at a Distance
W = mad

$$\sum \mathbf{F} = \frac{d\mathbf{p}}{dt} = m\frac{d\mathbf{v}}{dt} + \mathbf{v}\frac{dm}{dt}$$

The vector-force on a particle equals the product of its mass by its vector acceleration

$$\mathbf{F} = m\mathbf{a} = \frac{\Delta \mathbf{p}}{\Delta t} = \Delta\left[\frac{m\mathbf{v}}{t}\right]$$

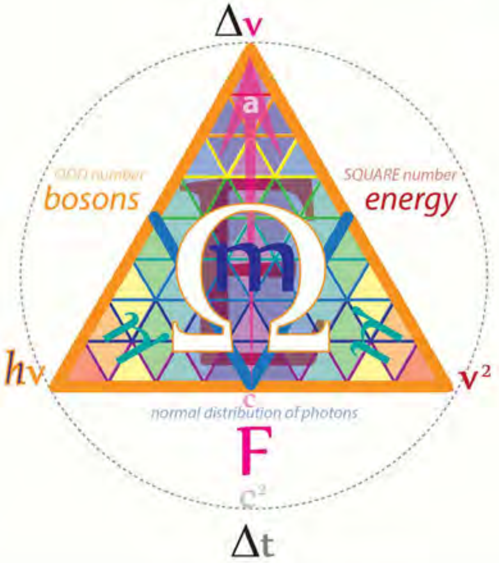
Δv
a
ODD number
bosons
SQUARE number
energy
m
Ω
$h\nu$
v^2
c
normal distribution of photons
F
c^2
Δt

The speed of gravity is limited to c

Einstein's GR theory replaces Newton's force of gravity and absolute space & time with a relativistic spacetime gradient curved by mass-energies

If the SUN were to vanish the Earth would continue traveling in its current orbit for 8⅓ minutes

The forces of action and reaction are equal and opposite;
(if a particle A exerts a force f on a particle B, then B exerts a force –f on A)

$$\sum \mathbf{F}_{a,b} = -\sum \mathbf{F}_{b,a}$$

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Newton's Gravitational Constant

$$F = -G\frac{M_1 m_2}{r^2}$$

According to Newton's law of universal gravitation,

the attractive force (F) between the centres of two bodies of mass-Matter, is proportional to the product of their Matter (M1 and m2), and inversely proportional to the square of the distance (r) between them

Long distance force

spacetime curvature

Newton's Gravitional Force models a motive force for gravitational acceleration

M
Centre of Gravity
Newton's
Gravitational
Constant
m

Einstein's General relativity has no motive force for gravitational accelerations

6.67384 e-11

$$\left[\frac{N\,m}{kg}\right].\left[\frac{N\,m}{kg}\right]$$

The gravitational force between two interacting bodies of Matter is

$$4\pi G\rho \qquad \left[\frac{N\,m^2}{kg^2}\right] = \left[kg\frac{m}{s^2}\frac{m^2}{kg^2}\right] = \left[\frac{m^3}{kg\,s^2}\right] \qquad 8\pi G\rho$$

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Action-at-a-Distance

All Matter
creates KEM fields of
energy momenta

All Matter
creates a displacement
of vacuum energies

radiant mass-energies
INTERACT

standing-wave Matter
ATTRACTS

Once established longitudinal EM fields between Matter form an 'inelastic rod' of energy momenta that can facilitate an instantaneous 'Action-at-a-Distance'

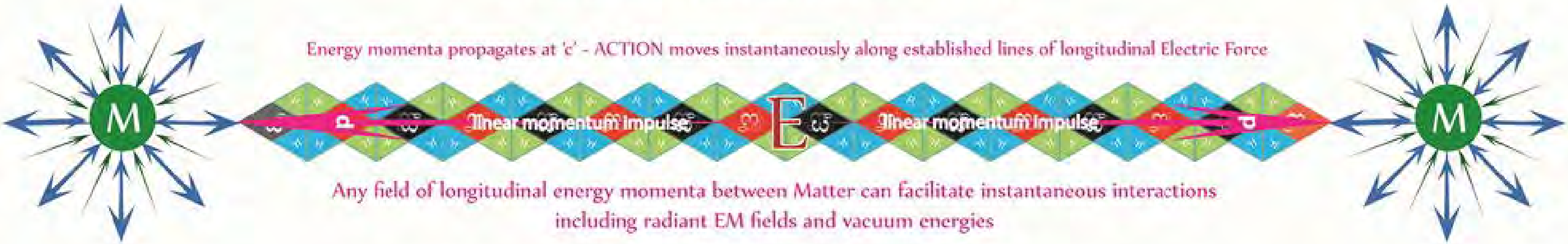

Energy momenta propagates at 'c' - ACTION moves instantaneously along established lines of longitudinal Electric Force

Any field of longitudinal energy momenta between Matter can facilitate instantaneous interactions
including radiant EM fields and vacuum energies

Gravity is known as a Universal force of attraction
between two objects that is proportional to their mass-Matter content

Newton's theory of gravity offered no prospect of identifying any mediator of gravitational interaction.
His theory assumed that gravity acts instantaneously, regardless of distance.

Energy momenta
creates universal
motive forces

According to Albert Einstein's theory of special relativity, instantaneous action-at-a-distance was seen to violate the relativistic upper limit on speed of propagation of information.

If one of the interacting objects were to suddenly be displaced from its position, the other object would feel its influence instantaneously, meaning information had somehow been transmitted faster than the speed of light.

Gravity fields
create a universal
attractive field

Gravitational Constant

The gravitational constant denoted by letter G, is an empirical physical constant involved in the calculation(s) of gravitational force between two bodies.
It appears in Sir Isaac Newton's law of universal gravitation, and in Albert Einstein's theory of general relativity.
It is also known as the universal gravitational constant, Newton's constant, and colloquially as Big G.

It should not be confused with "little g", which is the local gravitational field (equivalent to the free-fall acceleration), at the Earth's surface

Gravitational Forces can be modelled

$6.67\ e\text{-}11\ \left[\frac{Nm}{kg}\right]^2$

linear Newton metres

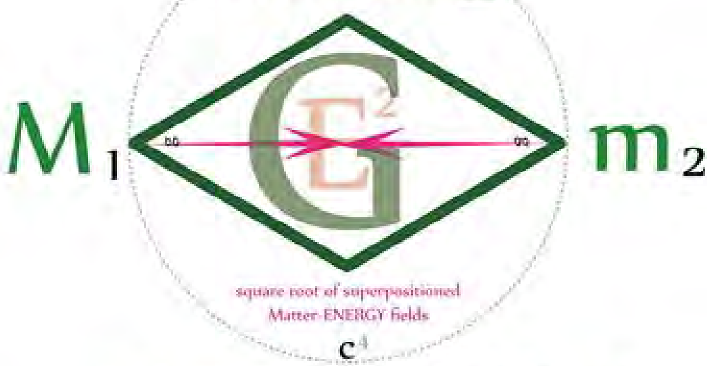

$6.67\ e\text{-}11\ \left[\frac{E}{kg}\right]^2$

scalar Energy momentum

as the geometric MEAN of superpositioned fields of gravitational energy

$$F = -G\,\frac{M_1\, m_2}{r^2}$$

The gravitational force between
two neutral interacting bodies is

N.m = Joules

$$\left[\frac{Nm}{kg}\right]\cdot\left[\frac{Nm}{kg}\right]$$

$[N.m/kg]^2 \sim [E/kg]^2$

Gravitational acceleration

Gravitational acceleration can be viewed as a reflection of the change in an object's momentum over time

$$\sum \mathbf{F} = \frac{\mathrm{d}\mathbf{p}}{\mathrm{d}t} = m\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t} + \mathbf{v}\frac{\mathrm{d}m}{\mathrm{d}t}$$

$$\frac{\left[\frac{\mathrm{m}}{\mathrm{s}}\right]}{\mathrm{s}}$$

$$\vec{g} = \frac{\vec{F}_g}{m} = -G\frac{mM}{mr^2}\hat{r} = -\frac{GM}{r^2}\hat{r}$$

expressed vectorially the force is always ATTRACTIVE to the larger masss and acts in opposition to the KEM field's divergent momenta

F=ma

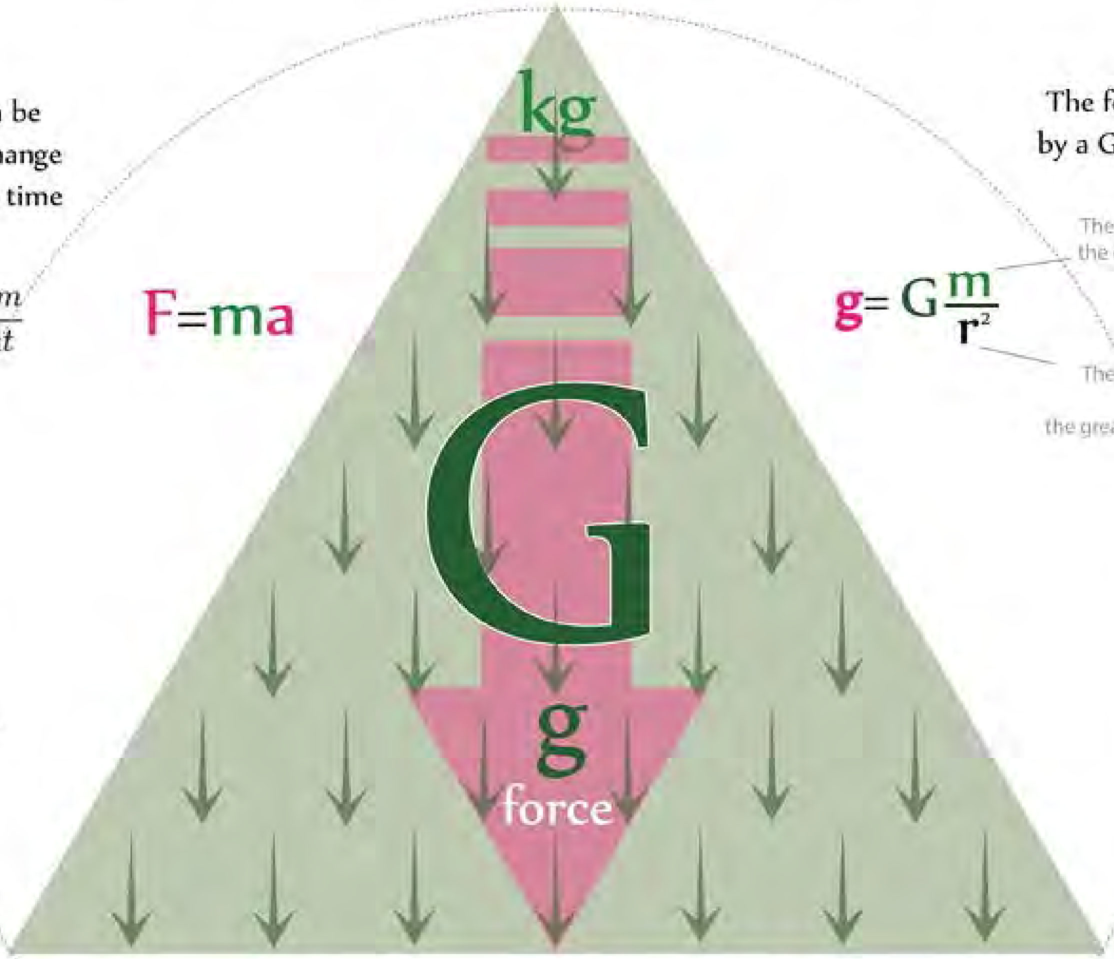

The force on a body acted upon by a Gravitational field is given by

$$\mathrm{g} = \mathrm{G}\frac{\mathrm{m}}{\mathbf{r}^2}$$

The greater the mass of a gravitating object the greater the acceleration due to the mass

The closer a body is to a the source of a Gravitational field the greater the acceleration due to the field

$$\left[\frac{\mathrm{N}}{\mathrm{kg}}\right] = \left[\frac{\mathrm{m}}{\mathrm{s}^2}\right] = \frac{\left[\mathrm{kg}\,\frac{\mathrm{m}}{\mathrm{s}^2}\right]}{\mathrm{kg}}$$

gravitational acceleration can be modelled as the convergent vector component of superpositioned EM fields

$$\left[\frac{\mathrm{Nm}}{\mathrm{kg}}\right]^2$$

The gravitational force between TWO neutral interacting bodies is

$$\left[\frac{\mathrm{Nm}}{\mathrm{kg}}\right]\cdot\left[\frac{\mathrm{Nm}}{\mathrm{kg}}\right]$$

Modelling Gravitational fields

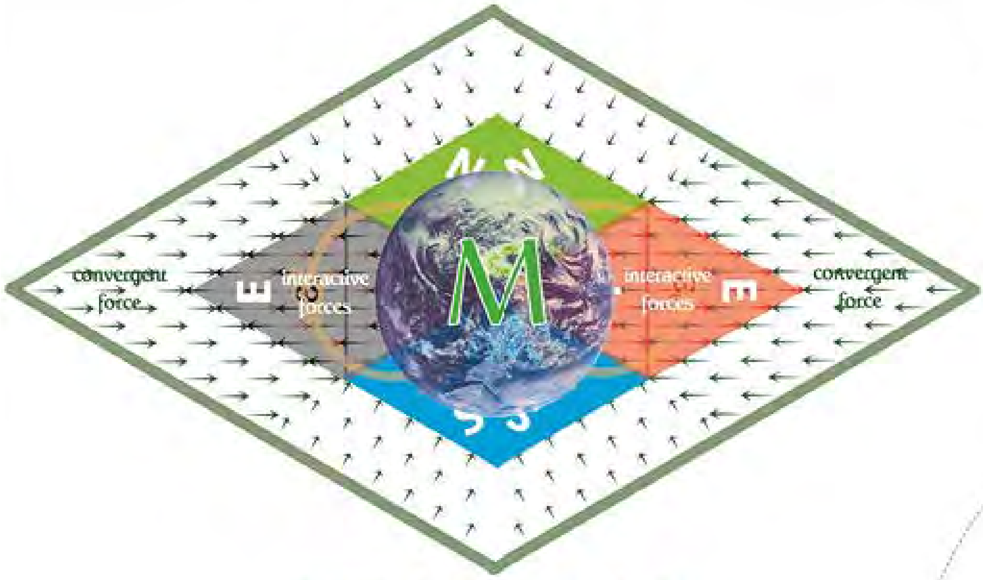
N
convergent force
E
interactive forces
M
interactive forces
E
convergent force
S

The [K]EM fields of planetary bodies are the result of their mass-Matter density and motion in space

Gravity can be modelled as weak convergent force created by and acting between the mass-Matter in planetary bodies

Matter topologies
displace vacuum energies
creating Gravity

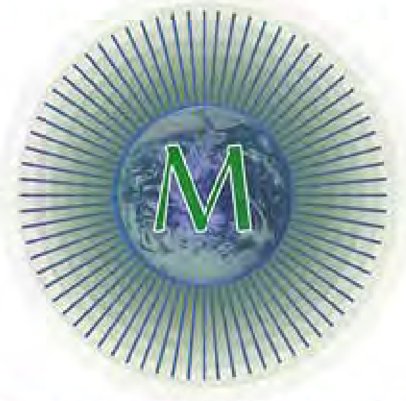

Weak KEM fields
can accurately model
Gravitational fields

Gravitational fields are the result of the displacement of vacuum energies by Matter topologies and the interactive energy momenta of their radiant KEM fields

$$F = k\,\frac{Q_1 Q_2}{r^2}$$

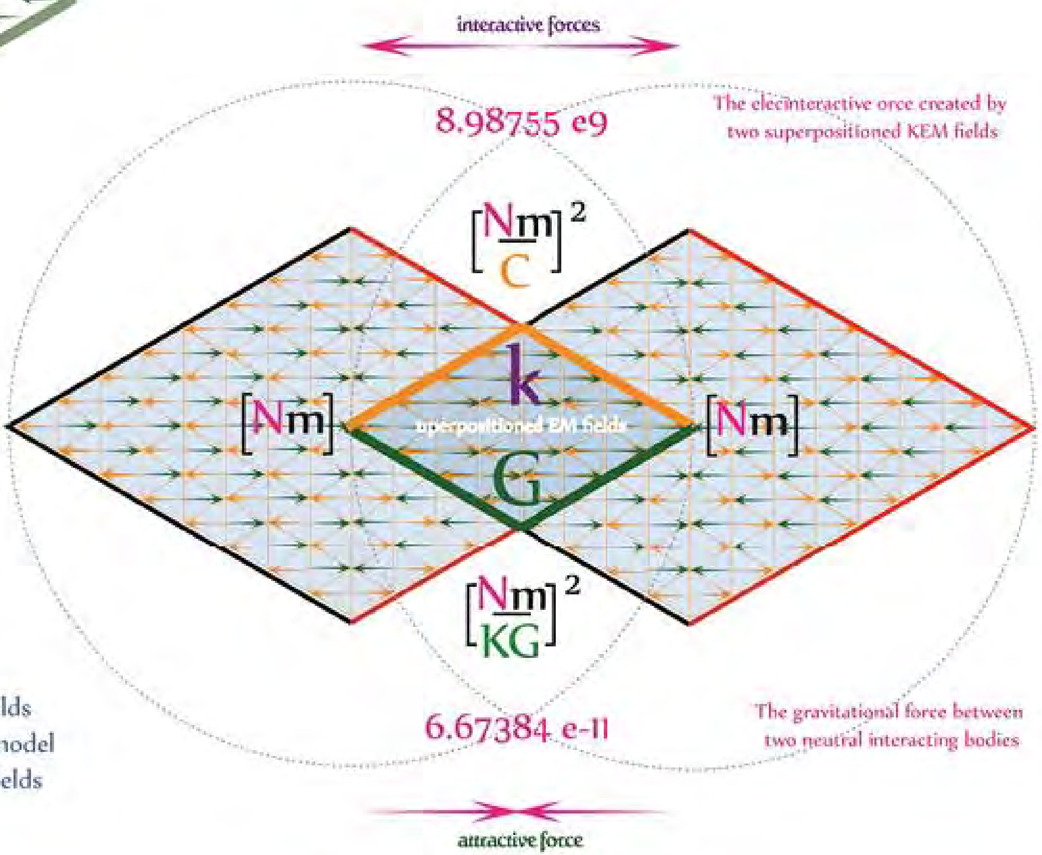
interactive forces
8.98755 e9
The elecinteractive orce created by two superpositioned KEM fields
$\left[\frac{Nm}{C}\right]^2$
[Nm]
k
superpositioned EM fields
G
[Nm]
$\left[\frac{Nm}{KG}\right]^2$
6.67384 e-11
The gravitational force between two neutral interacting bodies
attractive force

$$F = -G\,\frac{M_1 M_2}{r^2}$$

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Centres of Gravity

are determined by
the distribution of the combined
gravitational mass-Matter in a system

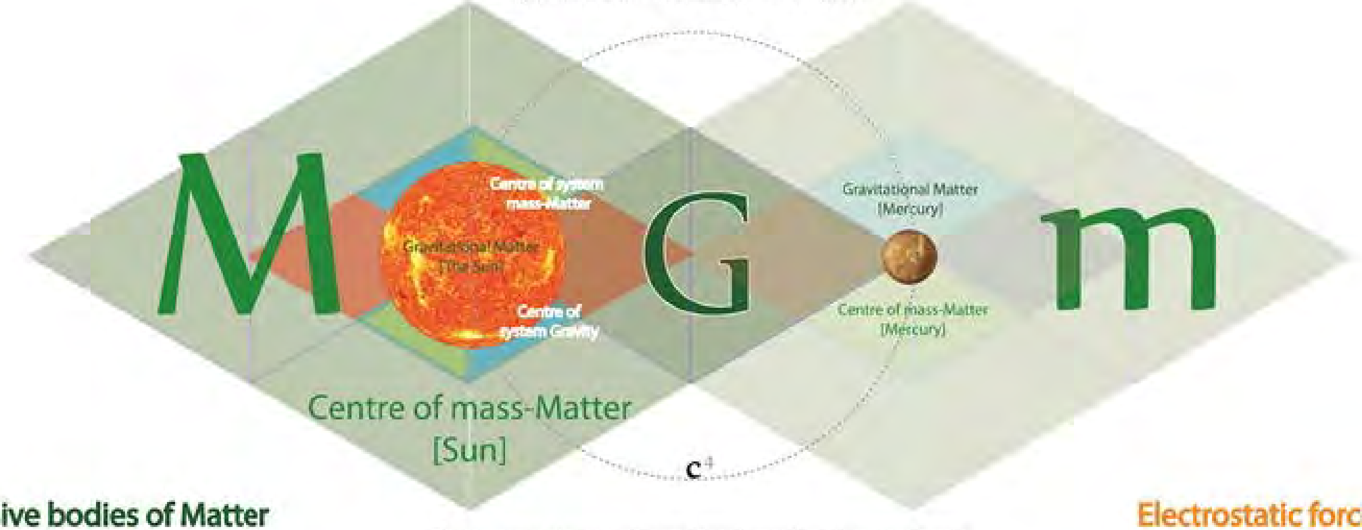
M
Centre of system
mass-Matter
Gravitational Matter
[The Sun]
Centre of
system Gravity
G
Gravitational Matter
(Mercury)
Centre of mass-Matter
(Mercury)
m
Centre of mass-Matter
[Sun]
c^4

**Any two massive bodies of Matter
(be they Stars or Neutrinos)
will orbit about their
'Centre of Gravity'**

The term center of mass is often used interchangeably with center of gravity, but they are physically different concepts. They happen to coincide in a uniform gravitational field, but where gravity is not uniform, center of gravity refers to the mean location of the gravitational force acting on a body.

**Electrostatic forces are many orders
of magnitude greater than gravity
& dominate nuclear interactions
at the quantum scale**

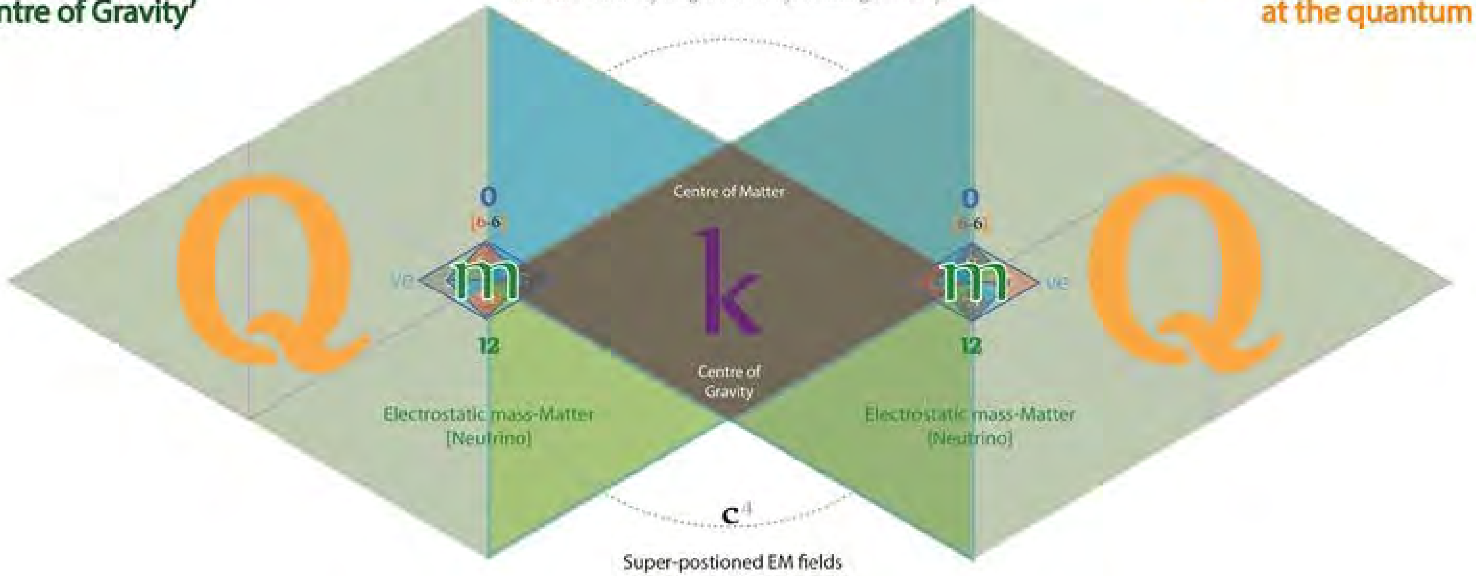
Q
0
[6-6]
ve
m
12
Centre of Matter
k
Centre of
Gravity
0
(6-6)
m
ve
12
Q
Electrostatic mass-Matter
[Neutrino]
Electrostatic mass-Matter
(Neutrino)
c^4

Super-postioned EM fields
have c^4 geometries [c^2 x c^2]

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There are two quite distinct types of mass in Newton's theory of mechanics and gravitation.

(i) inertial mass, which occurs as the ratio between force and acceleration in Newton's second law
and thus measures a particle's resistance to acceleration, and

(ii) Gravitational mass, which may be regarded as the gravitational analog of electric charge,
and which occurs in Newton's Gravitational equation

$$F=ma$$

Inertial mass
is a measure of the total
energy momenta geometries
of Matter topologies

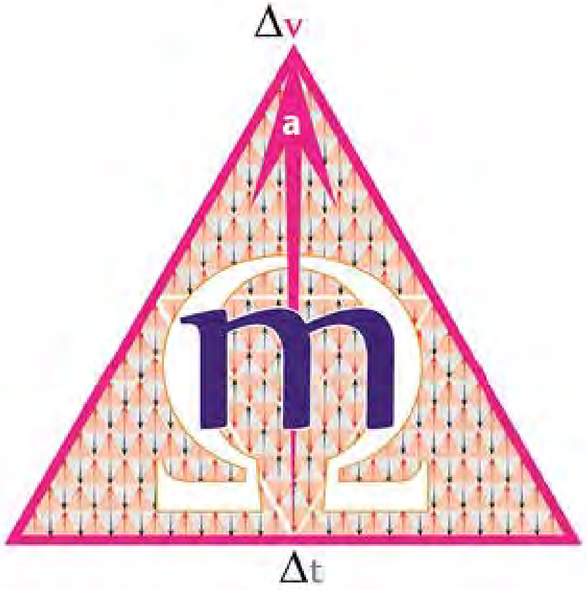

Inertial mass

results from constituent quanta
acting against (or with) any
Force applied to a mass

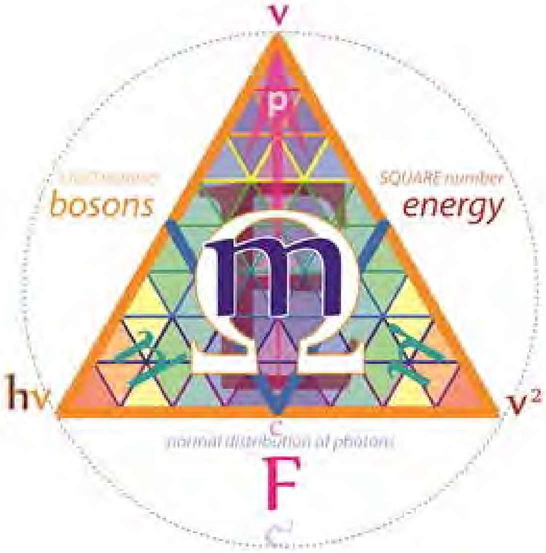

Often stated as the 'Principle of Equivalence'
on which General relativity is founded ,
it can be summarised as follows:

$$a = \frac{m}{m}\,g$$

*"Inertial mass and Gravitational mass
are equivalent"*

***whilst mass-energies contribute equally
to inertial & gravitational mass
it is Matter topologies that creates Gravity***

$$F_g = -G\,\frac{m}{r^2}$$

All Gravitational Matter
has EM mass geometries in
its Matter topology

'Gravitational' mass

is seen as being the constituent quanta
of opposite charge polarity
attracting another particle's quanta

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$$M + KE$$

gravitational mass-Matter

fields of force

Discerning between the competing laws of Gravity

At the heart of resolving the true nature of Gravity is the formal definitions of mass-Energy-Matter and the interplay between the various field interactions they produce and possess

$$= RE$$

relativisitic mass-energy densities

Newton's view of gravity

Sir Isaac Newton described gravity as a force that attracts things possessing Matter

Sir Issac Newton

(25 December 1642 – 20 March 1727)

$$F = -G \frac{M_1 m_2}{r^2}$$

Newton taught that masses attract each other with a force inversly proportional to the distance between the masses.

Newton's idea was that planets are held in their orbits around the Sun by a force proprtional to the mass of the Sun and the planets, and that force is always pointing inwards (i.e. planets get pulled in the direction of the Sun, and the Sun gets pulled in the directions of the planets).

Newton said that a person standing on the Earth is being held to the Earth by a force due to the mass of the Earth and the mass of the person, and that force is always pointing inwards (i.e. a person gets pulled in the direction toward the center of the Earth, and the Earth gets pulled in the direction of that person).

Newton's and Einstein's view of gravity differ markedly

Einstein, on the other hand, taught that all things with mass (including the Sun, Earth, and the rest of the planets) create a energy density gradient that causes spacetime to curve and that this curvature is an alteration the geometry of spacetime.

The curvature casues Matter to move toward the center of the largest nearby mass. The closer to this mass the larger the degree of curvature in the local spacetime.

Additionally, Einstein taught that if there are no external forces acting upon an object (even those without any mass such as photons) then that object will simply follow its natural path (geodesic) through the altered geometry of the local spacetime - regardless of the degree of curvature of that local spacetime. This implies that if an object is somehow kept from following its natural path (geodesic) then a net force does exist and is measurable on that object.

Einstein's view of gravity

Albert Einstein described gravity as a 3D curvature of spacetime caused by Matter

Albert Einstein

(14 March 1879 – 18 April 1955)

Gravity is an instantaneous 'Action-at-a-Distance' mediated by a means unknown

Ricci curvature

scalar curvature

Gravitational constant

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

stress-energy tensor

spatial geometry

Matter and energy tell spacetime how to curve. Spacetime tells matter how to move

There is no doubt that both Sr Isaac Newton & Albert Einstein were both brilliant, their theories describing Universal Gravitation have remained at the fore for hundreds of years now.

However, a more accurate model of the Universal Gravitation is now at hand and its true nature is revealed via the Tetryonic geometry of EM mass-Energy-Matter and its associated field interactions.
Tetryonic Gravitation demonstrates the validity of both approaches and reveals the true geometry behind the field interplays that result in the familiar force of Gravity

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The two models of Gravitation

Newtonian gravitation models the observed large-scale convergent force between all material bodies

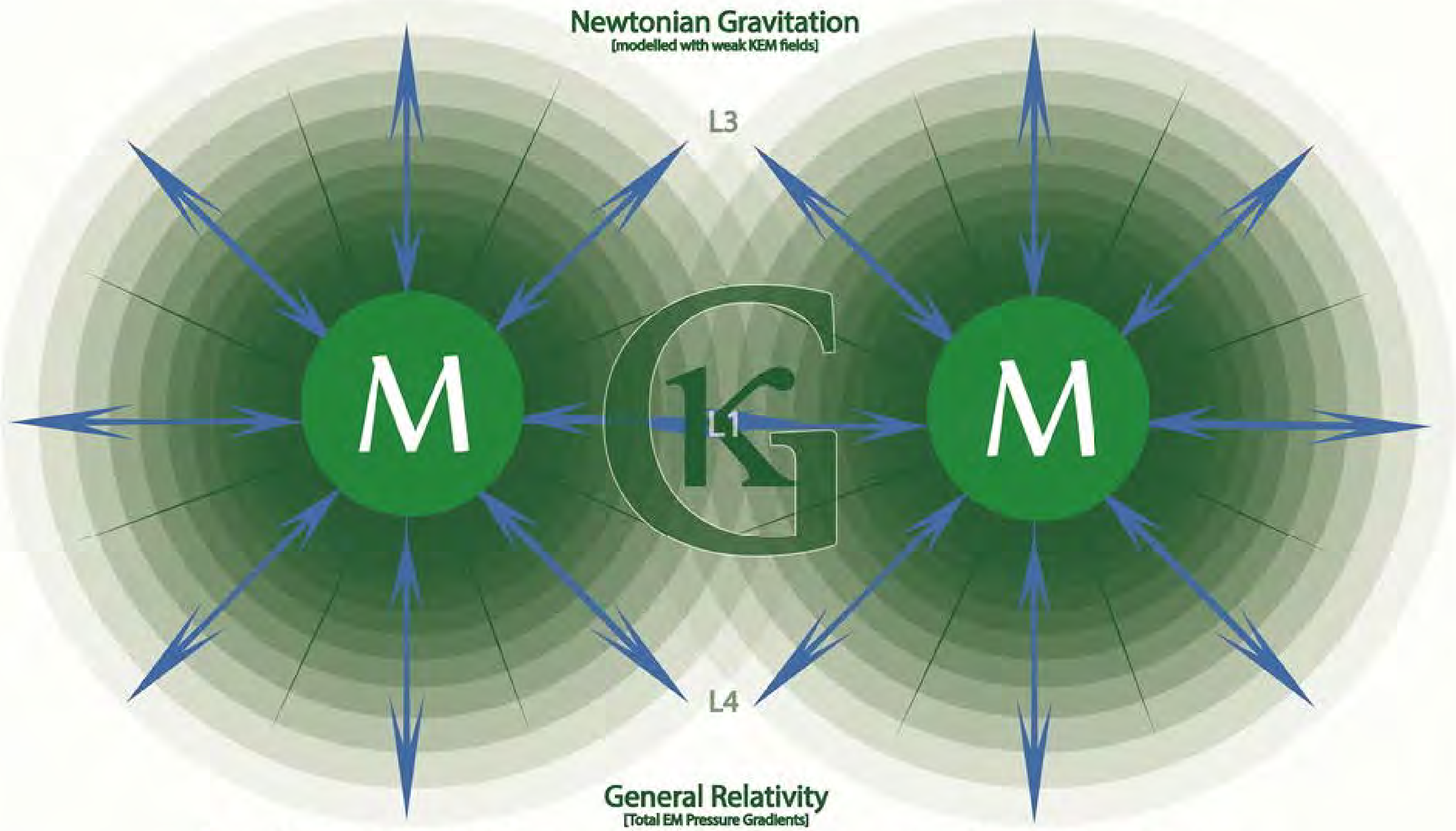
Newtonian Gravitation
[modelled with weak KEM fields]
L3
M
G
K
L1
M
L4
General Relativity
[Total EM Pressure Gradients]

General Relativity models the convergent pressure gradiant created by all forms of energy

While both models are very successful they both fail to reveal the quantum-scale geometries and topologies that give rise to universal gravitation

Theories of gravitation

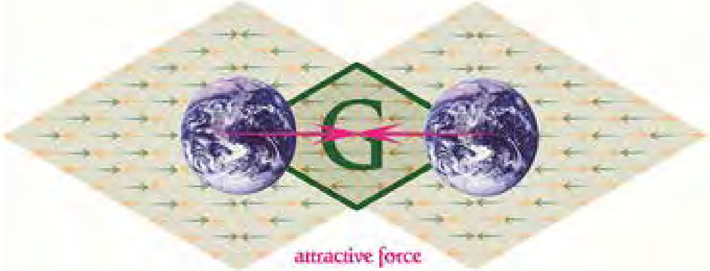
G
attractive force

Newton viewed Gravitation as
an attractive FORCE of Matter
(inverse square field strength)

for the mechanics of gravitation
"I feign no Hypothesis"

"Gravity is the result of
curved spacetime"

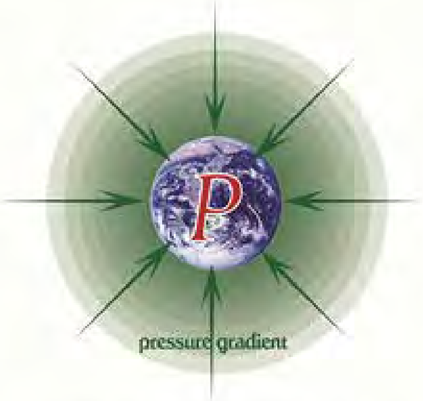
P
pressure gradient

Einstein viewed it as the
curvature of 4D spacetime
(PRESSURE gradient)

$$F = -G\frac{M_1 M_2}{r^2}$$

$$G_{ab} = \kappa T_{\mu\nu}$$

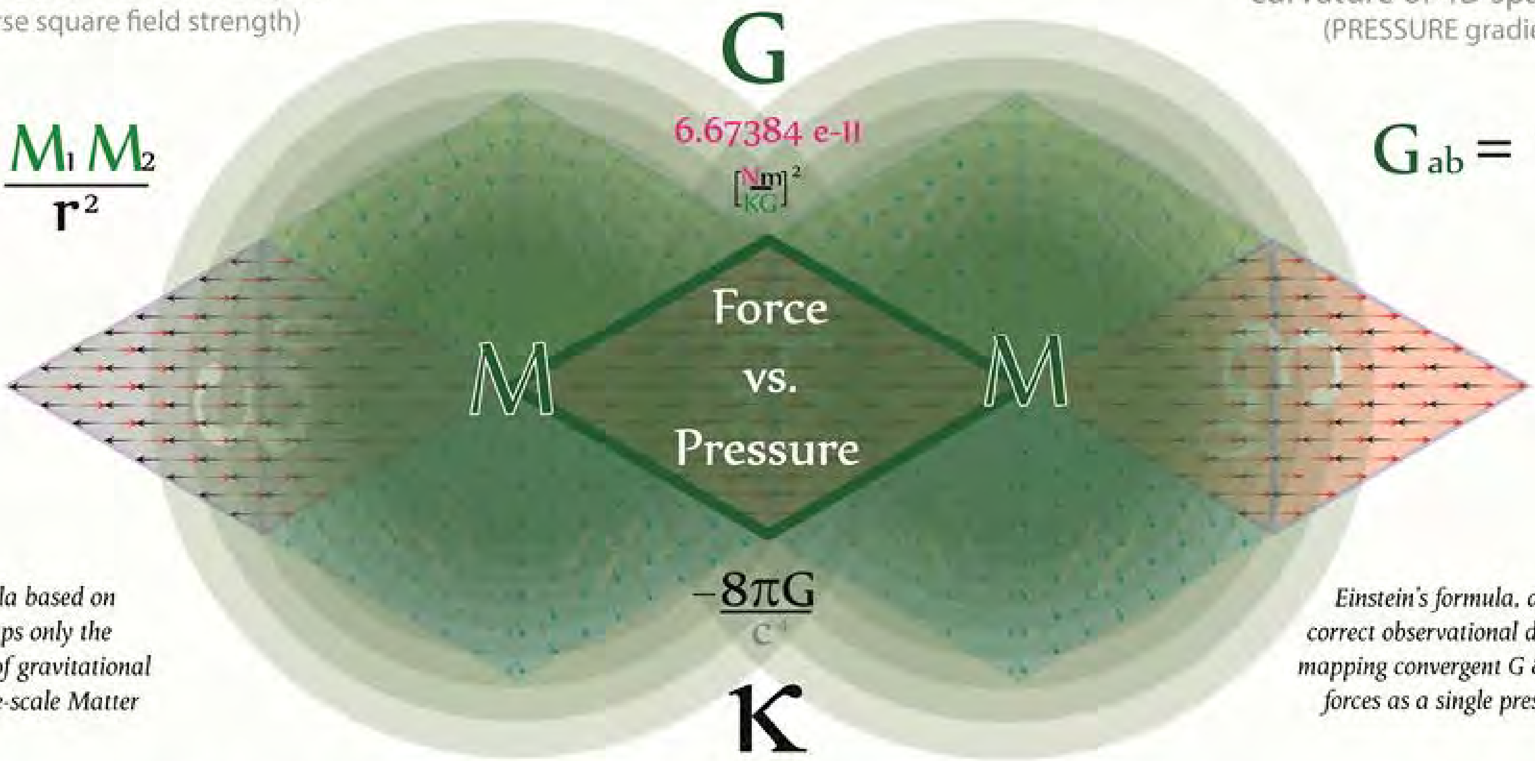
G
6.67384 e-11
$\left[\frac{Nm}{KG}\right]^2$
Force
vs.
Pressure
M
M
$-\frac{8\pi G}{c^4}$
κ

Newton's formula based on observations maps only the observed nett force of gravitational attraction on large-scale Matter

Einstein's formula, attempted to correct observational discrepancies by mapping convergent G & divergent EM forces as a single pressure gradient

Both Newton and Einstein failed to define and distingush between mass-energy geometries & Matter topologies

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Newton's G vs Einstein GR

Both Newton and Einstein developed their gravitational models
from the observed motions of celestial bodies without any distinction
between mass and Matter or the quantum forces at work

Gravitational Matter

Newton maps Matter's gravitational attraction
[excluding any perturbations caused by [K]EM fields]

All mass-energies

Einstein's GR maps Newton's G & SR effects
[mass-energy momenta [K]EM interactions]

Φ

F

$\nabla^2\Phi$

ρ

$g_{\mu\nu}$

$\Gamma^{\sigma}_{\mu\nu}$

$R_{\mu\nu}$

$T_{\mu\nu}$

Increasing accuracy in the measurements of the motions
of spacecraft interacting with planetary bodies [using EM waves]
has resulted in the need for refinement of both theories

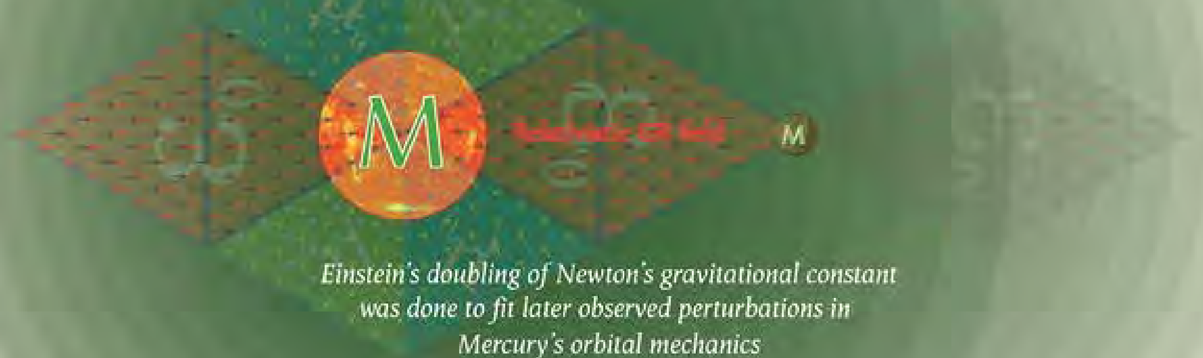

Einstein's doubling of Newton's gravitational constant
was done to fit later observed perturbations in
Mercury's orbital mechanics

Newtonian G field

Any valid tests of the purely gravitational fields of Matter
must exclude KEM fields and not use EM masses to test it

$$[\text{Newton}] = \frac{4\pi GMm}{r^2}$$

$$\nabla^2\Phi = 4\pi G\rho$$

Poisson

$$[\text{Einstein}] = \frac{8\pi GT_{\mu\nu}}{c^4}$$

Pressure gradients and GR

Tensor mathematics is utilised in General relativity to model mass-energy geometries and energy pressure gradients as curved spacetime

$$F = -G\frac{M_1}{r^2}$$

Newton's Gravitational fields are modelled on the observed motions of large-scale Matter attraction

$$G_{ab} = \kappa T_{\mu\nu}$$

Einstein's GR gradients corrects Newtonian gravity by modelling all forms of EM mass-Energy momenta

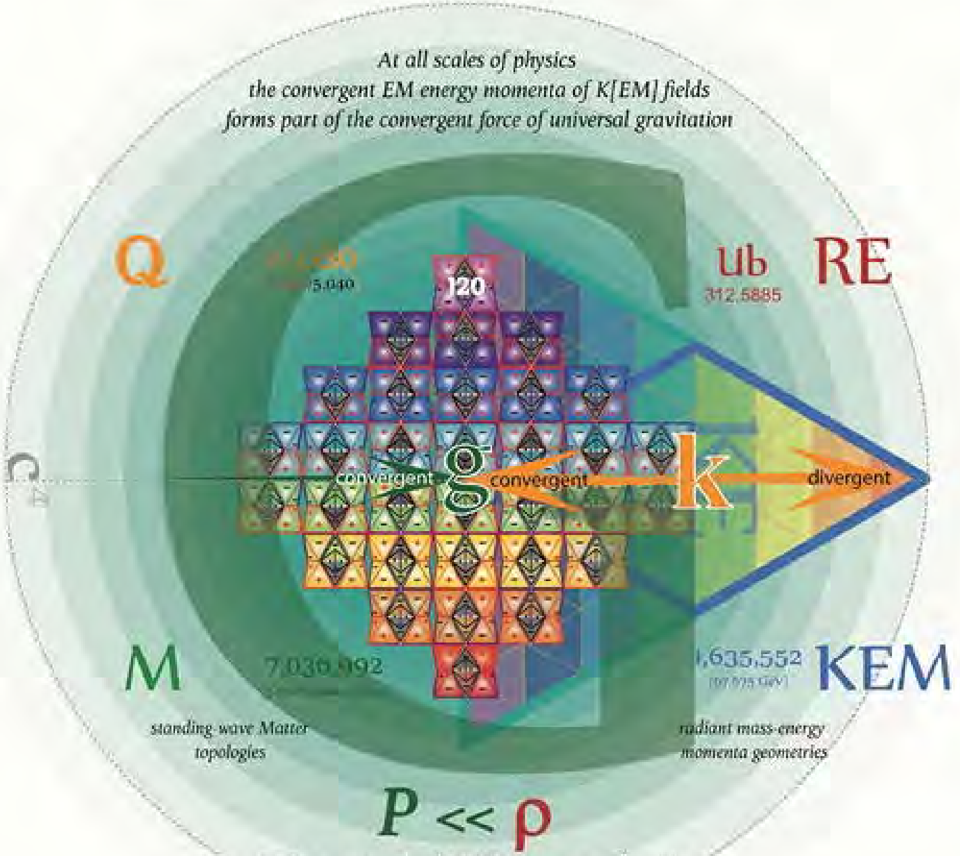
Q
5,040
120
Ub
312.5885
RE
convergent
g
convergent
k
divergent
M
7,030,992
,635,552
KEM
standing-wave Matter topologies
radiant mass-energy momenta geometries

At all scales of physics the convergent EM energy momenta of K[EM] fields forms part of the convergent force of universal gravitation

$$P \ll \rho$$

At the quantum level KEM mass-energy densities overwhelm the vacuum pressure gradients created by Matter topologies

Newtonian G field

$$4\pi$$

Einstein's G field

$$8\pi$$

G

K

Vector Force between Matter

Pressure gradient per unit Volume

$$n\pi\rho = \underset{\text{geometries}}{n\pi}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right] = T_{\mu\nu}$$

representive of ALL the mass-energy momenta of any spatial volume

Stress energy-pressure gradiants

are the result of Tetryonic charge geometries & topologies

$$\frac{\overset{\text{mass}}{n\pi}}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Radiant mass-energies have planar energy geometries

nπ	Energy quanta
EVENπ	photons
ODDπ	bosons
4π	tetryons
12π	quarks
12π	leptons
24π	mesons
36π	Baryons

All Matter topologies are tetrahedral standing-wave mass-energy geometries

$$\frac{\overset{\text{Matter}}{T\pi}}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

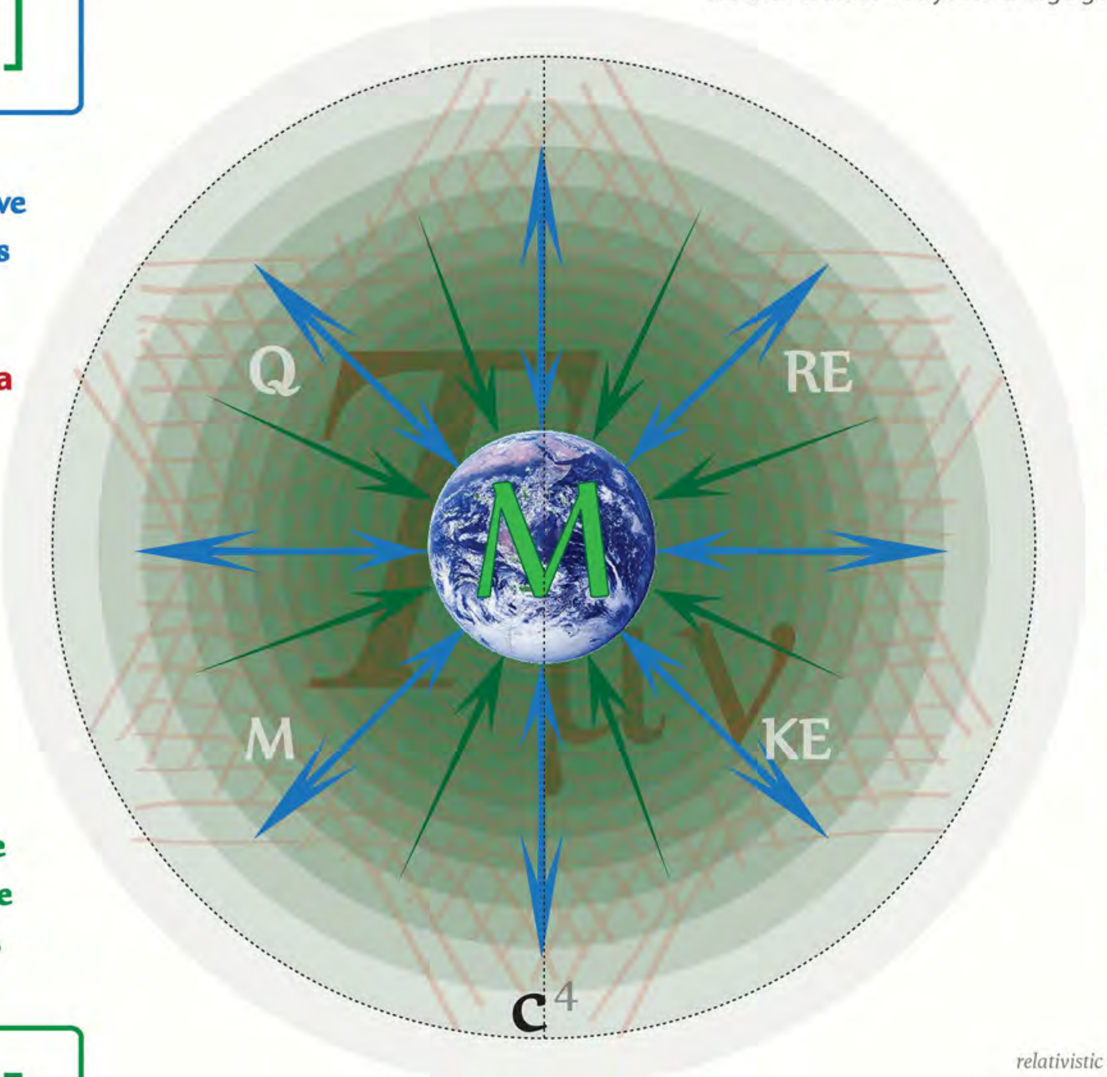

On the non-quantum scale all Matter topologies can be generalised and mathematically modelled as SPHERICAL 4π mass-energy topologies

radiated [K]EM fields
have interactive energy momenta
[convergent & divergent]

fields of Force

KEM

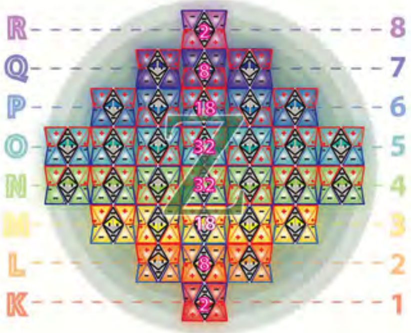

M

standing-wave topologies

displace vacuum energies
creating convergent Gravity

$$\underset{\text{stress energies}}{\overset{\text{relativistic mass-energies}}{RE}} = \underset{\text{topologies}}{\overset{\text{standing-wave Matter}}{M}} + \underset{\text{geometries}}{\overset{\text{radiant mass-energies}}{KEM}}$$

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Stress Energy tensor

In the Einstein field equations [EFE] of general relativity, the stress-energy tensor is the source of gravitational mass just as Matter is the source of such a field in Newtonian gravity

$$T_{\mu\nu}$$

In Einstein's general relativity, the symmetric stress-energy tensor acts as the source of spacetime curvature

mass *ENERGY* *Matter*

m E M

geometries *momenta* *topologies*

Matter

Planck quanta

$$\frac{4n\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

The Tetryonic unified field equation models all mass-ENERGY geometries & Matter topologies

A recognised problem in General Relativity is that the stress tensor models all forms of mass-energy-Matter in the form of a generalised stress energy pressure gradient but fails to differentiate between either mass or Matter and their resulting interactions within the fields

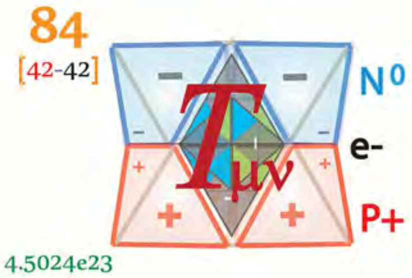

Planck quanta

$$n\pi\left[m\Omega v^2\right]$$

mass velocity

radiant mass-energies create interactive fields of force

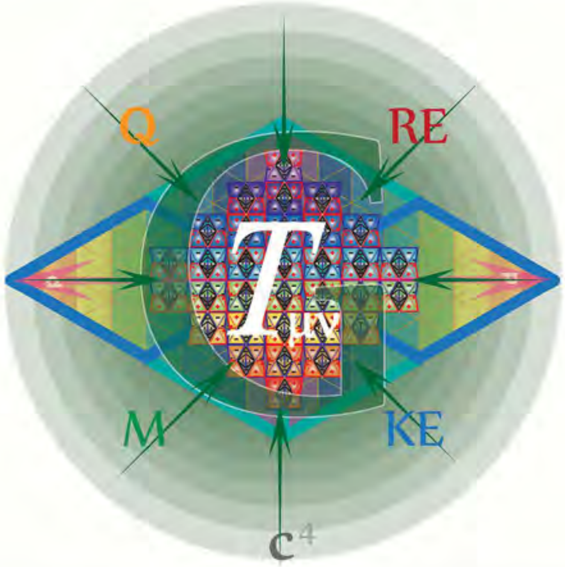

$$T\pi[\rho]$$

standing-wave Matter creates vacuum energy pressure gradients

Gravimetric topologies

Charges create radiant mass-energy geometries & standing-wave Matter topologies

kg

2D mass geometries

EM mass is not Matter

mass Planck quanta mass velocity

$$\frac{n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

Charged energy geometries are the basis for 2D mass

Photons have mass-energy momenta geometries but no Matter topology

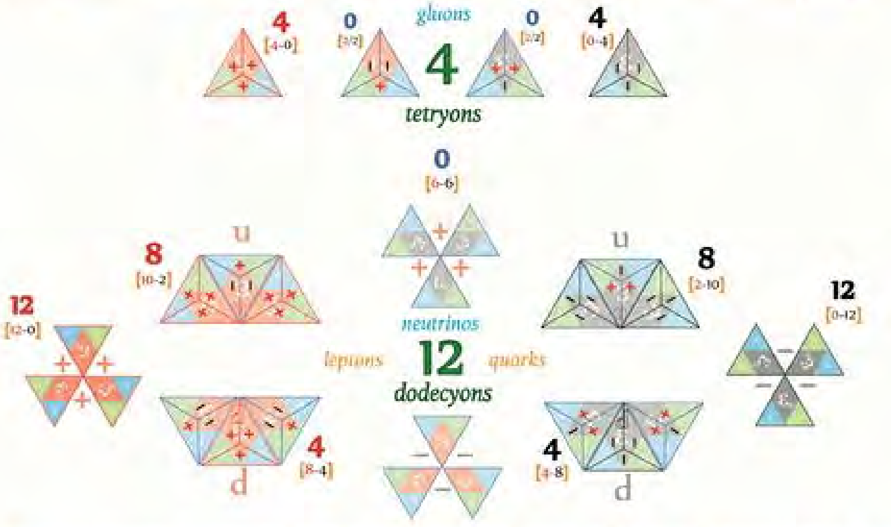
4
[4-0]
0
[2-2]
gluons
4
0
[2-2]
4
[0-4]
tetryons
0
[6-6]
8
[10-2]
u
12
[12-0]
u
8
[2-10]
12
[0-12]
neutrinos
leptons
12
quarks
dodecyons
4
[8-4]
d
4
[4-8]
d

2D mass-energy geometries form surface integral areas of charged Matter topologies

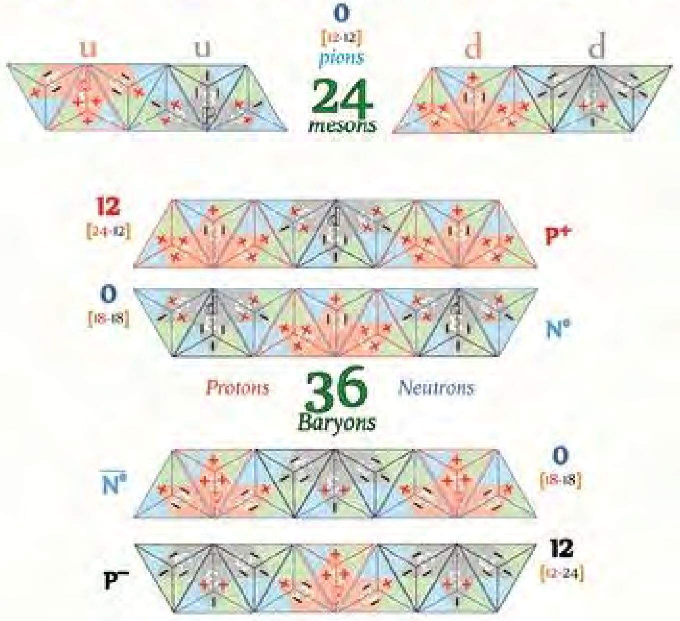
0
[12-12]
u
u
pions
d
d
24
mesons
12
[24-12]
P⁺
0
[18-18]
N°
Protons
36
Neutrons
Baryons
N̄°
0
[18-18]
P⁻
12
[12-24]

KG

3D Matter topologies

Matter has mass energies

Matter Planck quanta mass velocity

$$\frac{T\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

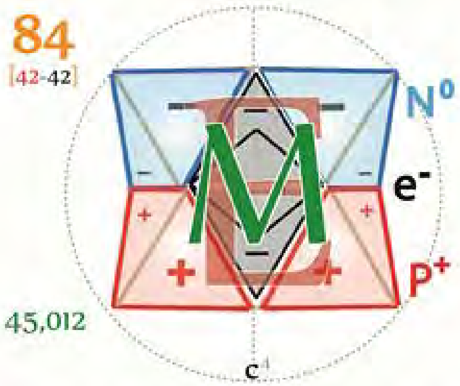
84
[42-42]
N⁰
e⁻
P⁺
45,012
c⁴

Charged mass-energy topologies are the basis for 3D Matter

Its topology forms a quantum Faraday cage [with a charged surface integral of mass-energies]

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Interactive mass-energies vs. gravitational Matter

energy in all its forms seeks equilibrium

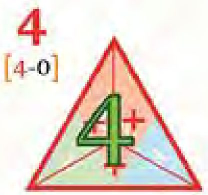

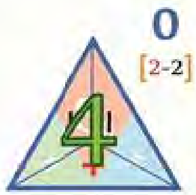

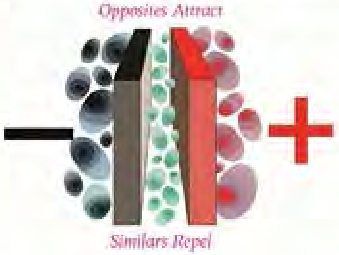

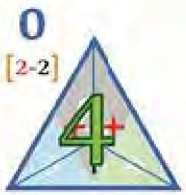

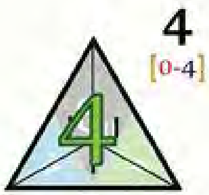

radiant mass-energy geometries

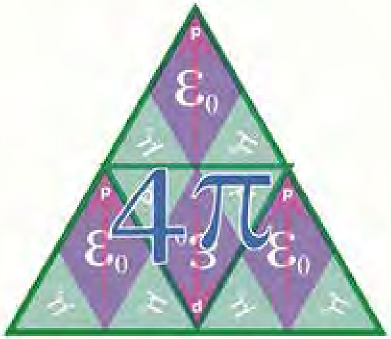

$$\overset{\text{mass}}{\frac{n\pi}{c^2}}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

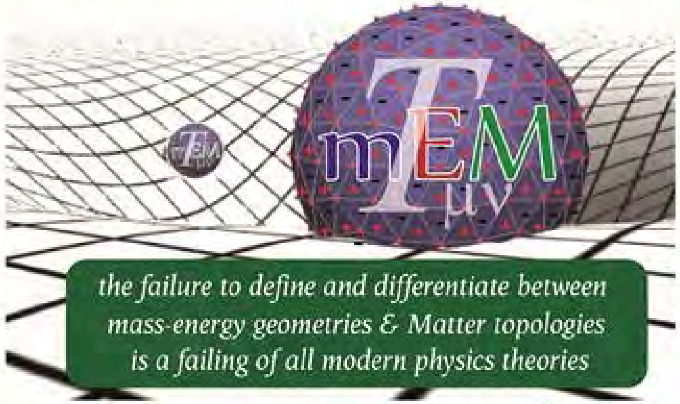

the failure to define and differentiate between
mass-energy geometries & Matter topologies
is a failing of all modern physics theories

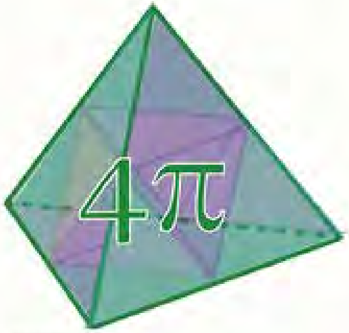

$$\overset{\text{Matter}}{\frac{T\pi}{c^4}}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

standing-wave Matter topologies

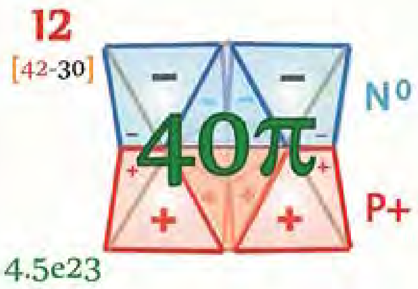

Charged Planck quanta of mass-energy momenta that form topologies
displace the vacuum energies surrounding them in turn creating
a mass-energy-Matter pressure gradient

Compton frequency of rest Matter is what creates inertial mass,
its Gravitational Matter results from its charged topology

The integral inductive EM mass-energy momenta in Matter fascia
create the physical property of inertial mass

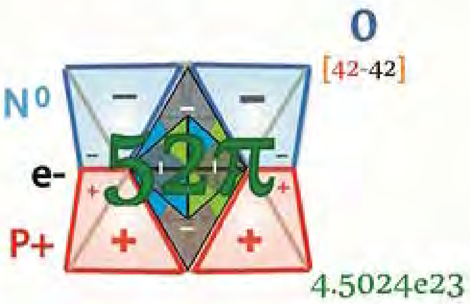

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$$F_z = \Delta P . \Delta A$$

Pressure is the force per unit area
applied in a direction perpendicular to the surface of an object

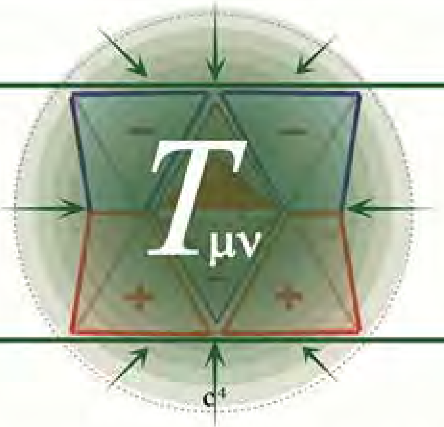

The theory of general relativity uses a stress-energy tensor to reflect to the pressure differentials created by Energy in ALL its forms (making no distinction between EM masses & Matter)

In Tetryonics the stress energy tensor is expanded, through geometric terms, to differentiate between radiant mass-energy interactions and Matter topologies in radial spatial co-ordinate systems defined by the speed of light

Radiant EM masses

mass

$$\frac{n\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Photons are often referred to as 'massless particles' are better defined as Matterless EM mass-energy momenta

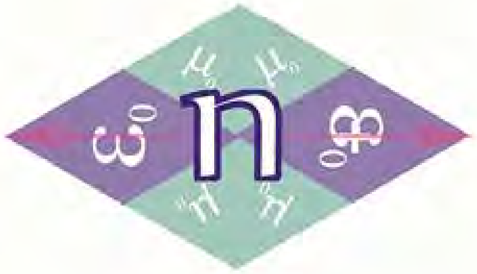

Photons

$$\frac{2\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

interactive mass-energy momenta geometries

Energy Pressure gradients

The vacuum energy pressure gradient created by the charged topology of Matter is distinct from its intrinsic & radiative mass-energy geometries

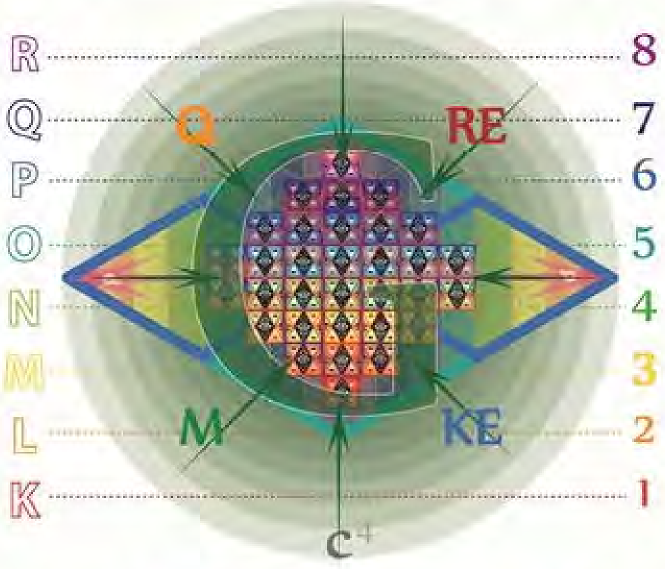

Any theory of gravitation that attempts to model it on any scale must account for energy in all its forms

Standing-wave Matter

Matter

$$\frac{T\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Tetryons, the quantum building blocks of Matter have EM mass-energy topologies that create a vaccum pressure gradient

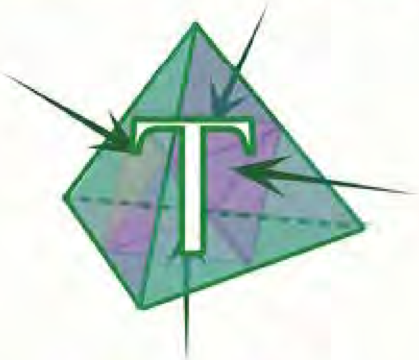

Tetryons

$$\frac{4\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

gravitational Matter topologies

Convergent mass-energies & Gravitational Matter

m

$$\overset{\text{Spacetime curvature}}{R_{\mu\nu} - \tfrac{1}{2}Rg_{\mu\nu}} = \frac{8\pi G}{c^4}\,\overset{\text{Stress-Energy Tensor}}{T_{\mu\nu}}$$

M

The concept of mass in general relativity (GR) is more complex than the concept of mass in special relativity. In fact, general relativity does not offer a single definition for the term mass, but offers several different definitions which are applicable under different circumstances.

Komar mass **Bondi mass** **ADM mass**

Under some circumstances, the mass or Matter components of a system may not even be defined

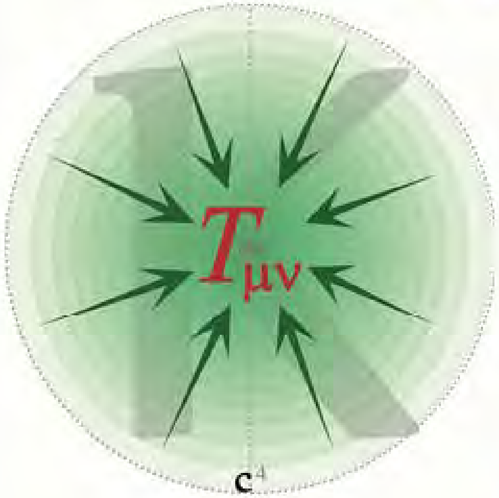

Einstein Field equation

$$\overset{\text{Spacetime curvature}}{R_{\mu\nu} - \tfrac{1}{2}Rg_{\mu\nu}} = \underset{\text{constant}}{\overset{\text{gravitation}}{K}}\;\underset{\text{per spatial volume}}{\overset{\text{total mass-energy-Matter}}{\frac{n\pi}{c^4}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega\,\underset{\text{velocity}}{v^2}}\right]\right]}}$$

Tetryonic geometries & topologies

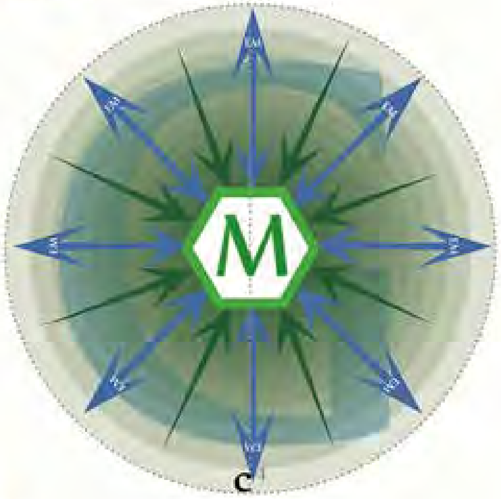

In contrast Tetryonic field equations explicitly differentiate all EM mass-energies and Matter via their charged geometries along with their contributions to the total energy density of any spatial region

GR models the convergent force of gravitation as a convergent energy density pressure gradient created by mass-energies

$$\underset{\text{mass-Matter}}{\overset{\text{gravitational}}{M}} + \underset{\text{mass-energies}}{\overset{\text{interactive}}{kEM}} = \underset{\text{energies}}{\overset{\text{stress}}{U}}$$

Tetryonics models gravitation as the result of mass-energy interactions AND Matter topology displacement of vacuum energies

Interactive EM force fields are subject to Lorentz velocity corrections

Faraday

$$\mathcal{E} = -\frac{d\Phi_B}{dt},$$

$$|\mathcal{E}| = N\left|\frac{d\Phi_B}{dt}\right|$$

$$\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{E}\cdot d\vec{A} = \frac{q}{\varepsilon_0}$$

$$\oint \vec{B}\cdot d\vec{A} = 0$$

$$\oint \vec{B}\cdot d\vec{s} = \mu_0 i + \frac{1}{c^2}\frac{\partial}{\partial t}\int \vec{E}\cdot d\vec{A}$$

Maxwell

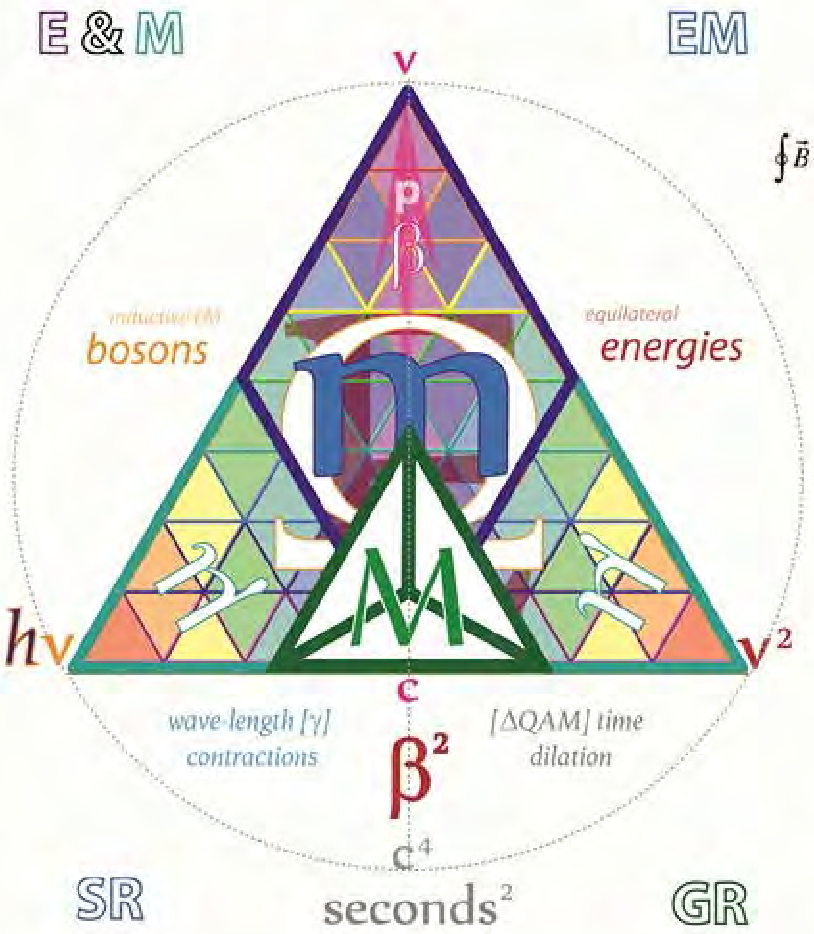
E & M
EM
v
p
β
inductive EM
bosons
equilateral
energies
m
γ
M
γ
hv
v²
c
wave-length [γ]
contractions
[ΔQAM] time
dilation
β²
c⁴
SR
seconds²
GR

Special Relativity was developed from the foundation of Lorentz corrections to EM fields

General Relativity was developed from Special Relativity and incorporates EM field interactions

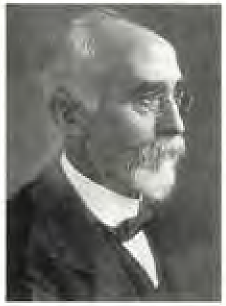

Lorentz

$$L = L'\sqrt{1-\frac{v^2}{c^2}}$$

$$t' = \frac{t}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$G_{\mu\nu} = 8\pi G T_{\mu\nu}$$

$$E=\frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

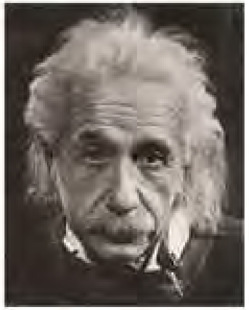

Einstein

Standing-wave Matter topologies are Lorentz invariant

the failure to differentiate between mass & Matter has lead to major misconceptions in physics

Tensor Rankings

Rank 0

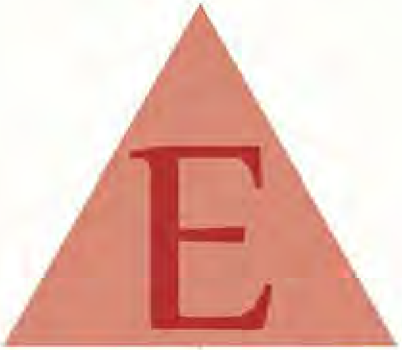

scalars

A tensor may consist of a single number, in which case it is referred to as a tensor of order zero, or simply a scalar

An example of a scalar would be the EM mass-energy of a particle or field

A second example of a scalar field would be the value of the gravitational potential energy as a function of position

Rank 3

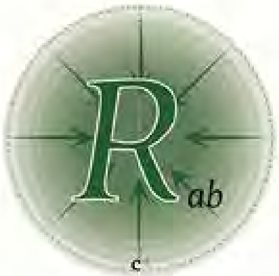

curved spacetime

Rank 4 Tensors as used in Einstein's General Theory of Relativity, describe the curvature of spacetime [the so-called Riemann curvature tensor].

Rank 1

The next most complicated tensor is the tensor of order one, otherwise known as a vector.

vectors

A vector can be defined as a direction between two points, its strength may vary continuously from point-to-point, thereby defining a vector field

Next above a vector are tensors of order 2, which are often referred to as matrices.

Tetryonic Matrices

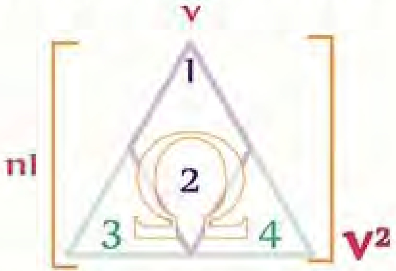

EM fields can be represented by Tetryonic Matrices [Tensors] identical to current square Tensor Matrices with the only difference being the change in the geometry of the matrix to better reflect the true geometry of EM fields

This better facilitates the easy recognition of Electric & Magnetic scalar fields and their associated energy-momenta vectors

Rank 2

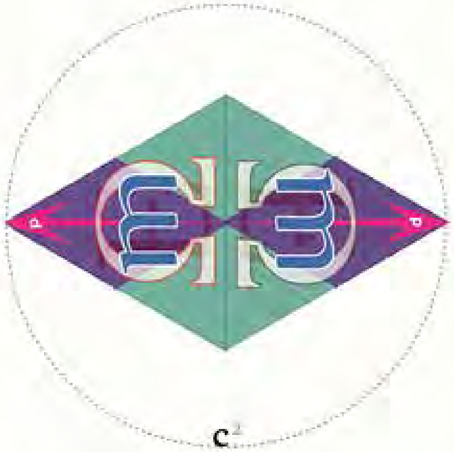

mass-energy momenta

A tensor of rank 2 is defined as a system that has a magnitude and two associated vector directions within the fields that it describes

Rank 4

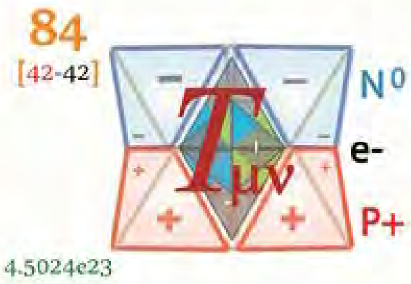

mass-Matter topology

the total mass-energies of Matter & fields thatcontribute to creating gravity.

ElectroMagnetic field tensor

The electromagnetic tensor or electromagnetic field tensor (sometimes called the field strength tensor, Faraday tensor or Maxwell bivector) is a mathematical object that describes the electromagnetic field of a physical system in Maxwell's theory of electromagnetism

Energy

$$2\pi\left[\frac{1}{c^2}\cdot\left[m\Omega v^2\right]\right]$$

Photons momenta

Photons

Planck quanta

$$\frac{2\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

Visualising EM waves and photons in terms of their Tetryonic geometry the scalar relationships between Electric and Magnetic fields becomes readily apparent.

ε_0
γ
μ_0

$$F^{\mu\nu} = -F^{\nu\mu}$$

photons are their own anti-particles

ε_0
γ
μ_0

A EM field tensor has six degrees of freedom, representing the three components of each of the electric and magnetic fields

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

Speed of Light

$$\varepsilon_0\mu_0 = \frac{1}{c^2}$$

EM Fields

EM wave factors such as Lorentz's velocity corrections arise naturally from the geometry providing a clear and concise illustration of the relationships between EM mass-energies, Charge, Electric & Magnetic fields and the speed of Light

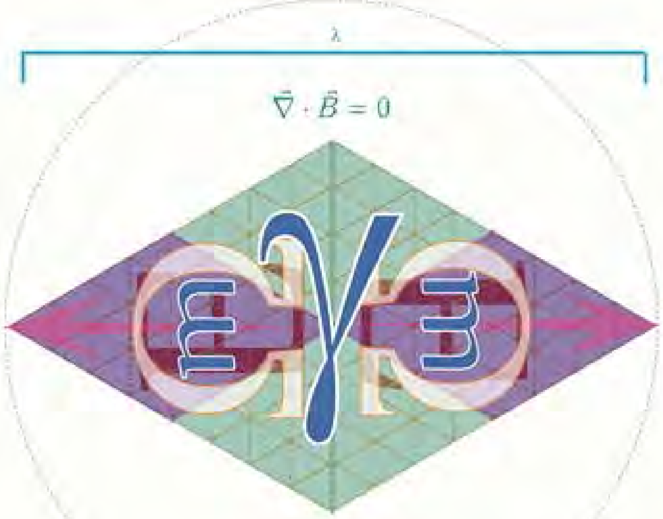

$$\vec{\nabla}\cdot\vec{E} = \frac{\rho}{\epsilon_0}$$

$$\vec{\nabla}\cdot\vec{E} = \frac{\rho}{\epsilon_0}$$

$$\frac{\partial\vec{B}}{\partial t} + \vec{\nabla}\times\vec{E} = 0$$

the change of the magnetic field with respect to time plus the curl of the electric field is equal to zero

$$\vec{\nabla}\times\vec{B} - \frac{1}{c^2}\frac{\partial\vec{E}}{\partial t} = \mu_0\vec{J}$$

The curl of the magnetic field vector minus the change of the electric field with respect to time, is equal to the field's current density

Wavelength contraction

$$L = L'\sqrt{1-\frac{v^2}{c^2}}$$

$$\beta^2 = \left[\frac{v^2}{c^2}\right]$$

Scalar correction factor

Linear correction factor

$$\beta = \left[\frac{v}{c}\right]$$

speed of Light

$$c = \left[\left[\frac{c^2}{\Omega}\right]\cdot\left[\frac{\Omega}{c}\right]\right]$$

velocity of propagation

f Frequency

λ Wavelength

$$p = \frac{h}{\lambda} = \frac{E}{c}$$

Linear Momentum

$$\det(F) = \frac{1}{c^2}\left(\vec{B}\cdot\vec{E}\right)^2$$

the electromagnetic tensor may also be written in terms of the 4-vector potential

3D space time

$[\Delta x, \Delta y, \Delta z] \quad \Delta\tau$

In Tetryonics, the relativistic Four vector reflects the changing quantised angular momenta [time] of EM mass-energies & Matter in 3D space

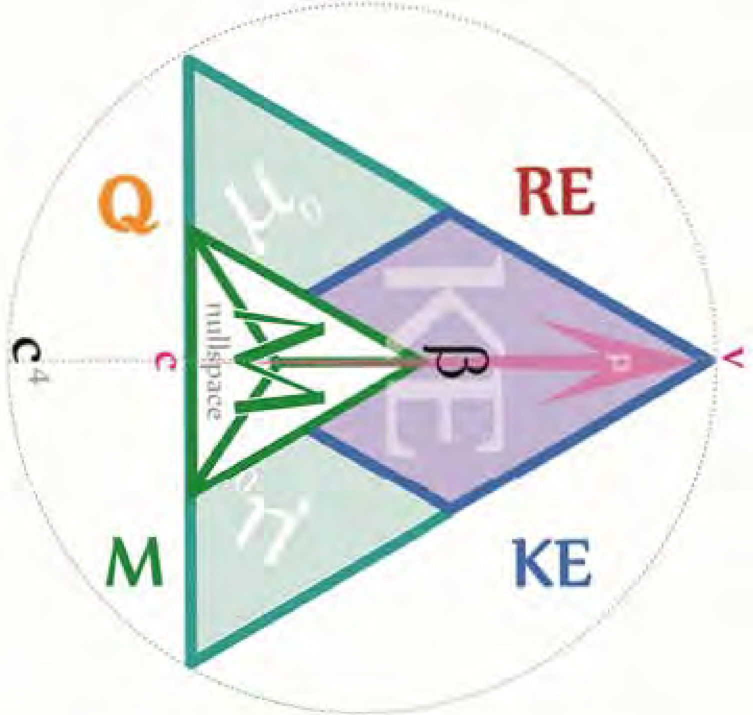

$$M_0 + KE = E$$

Standing-wave four-vector

Lorentz corrected mass-energies

Stress energy momenta tensor

Relativistic Four-vectors

Charged Matter interacts at-a-distance through super-positioned energy momenta fields from which our force constants are derived

The electromagnetic four-potential is a potential from which electromagnetic field can be derived. It combines both the electric scalar potential and the magnetic vector potential into a single space-time four-vector

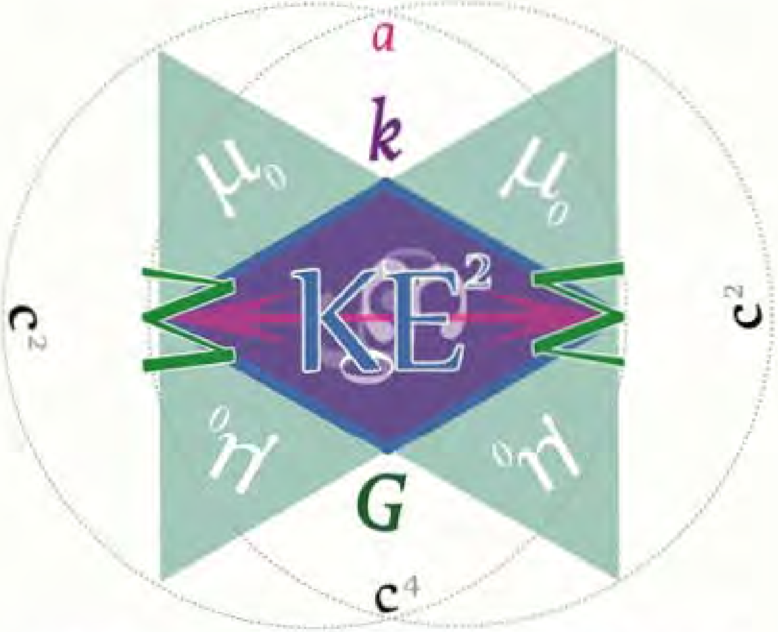

Inverse sqaured Gravity can be mathematically modeled using the same geometry explaining the similar formulations for charge interaction & gravitation

$$m^2v^4 = KE^2 = p^2v^2$$

EM mass radiant energies momenta

Four-vectors are reflective of the total EM mass-energy momenta of superpositioned [K]EM fields where the KE is the interactive force component

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Special and General relativity

General relativity was developed by Einstein in an attempt to describe the acceleration forces experienced by graviational Matter (on the foundation of special relativity) which in turn was an extension of Lorentz corrections of EM waves developed to account for the fixed speed of light and established Newtonian mechanics

SR

Special Relativity

(describes inertial frames of reference
in flat Euclidean spacetime)

mass-energy

mass

$$\frac{n\pi}{c^2}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\Omega\,\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

geometries

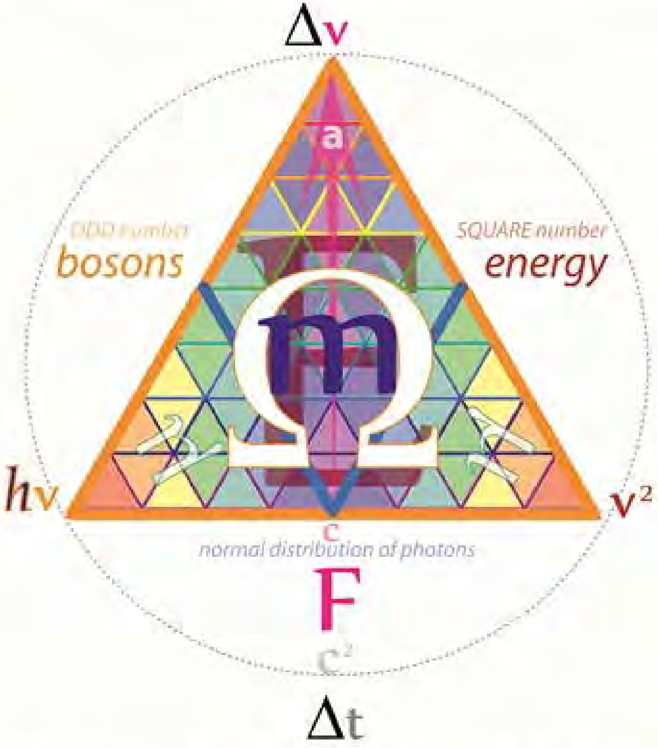

GR

General Relativity

(describes accelerating frames of reference
in curved Riemannian spacetime)

Matter

Matter

$$\frac{4n\pi}{c^4}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\Omega\,\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

topologies

2D

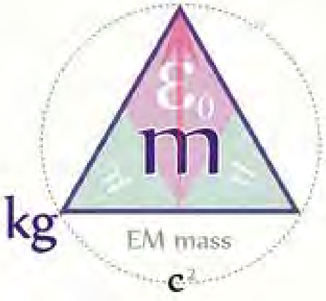

all physical theories to date have failed to explain the mechanics of gravitation at all scales of energy and distance

$$\frac{\rho}{m^2}$$

6.629432351 e-34 J

ENERGY

$$n\pi\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\Omega\,\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

7.376238376 e-51 kg

$$\frac{\rho}{m^3}$$

3D

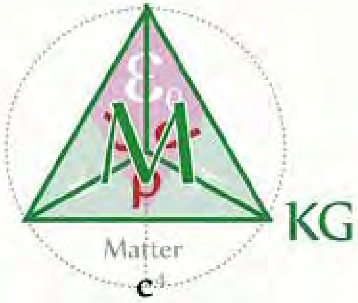

The Weak Equivalence Principle

$m_g . a = m_i . g$

Newton

The uniqueness of free fall states than any two test bodies must fall with the same acceleration in a given external gravitational field

$m_g = m_i \sum_A \eta^A \frac{E^A}{c^2}$

Einstein

The uniqueness of free fall trajectories allows one to regard spacetime as filled being with curved energy gradients

$F = ma$

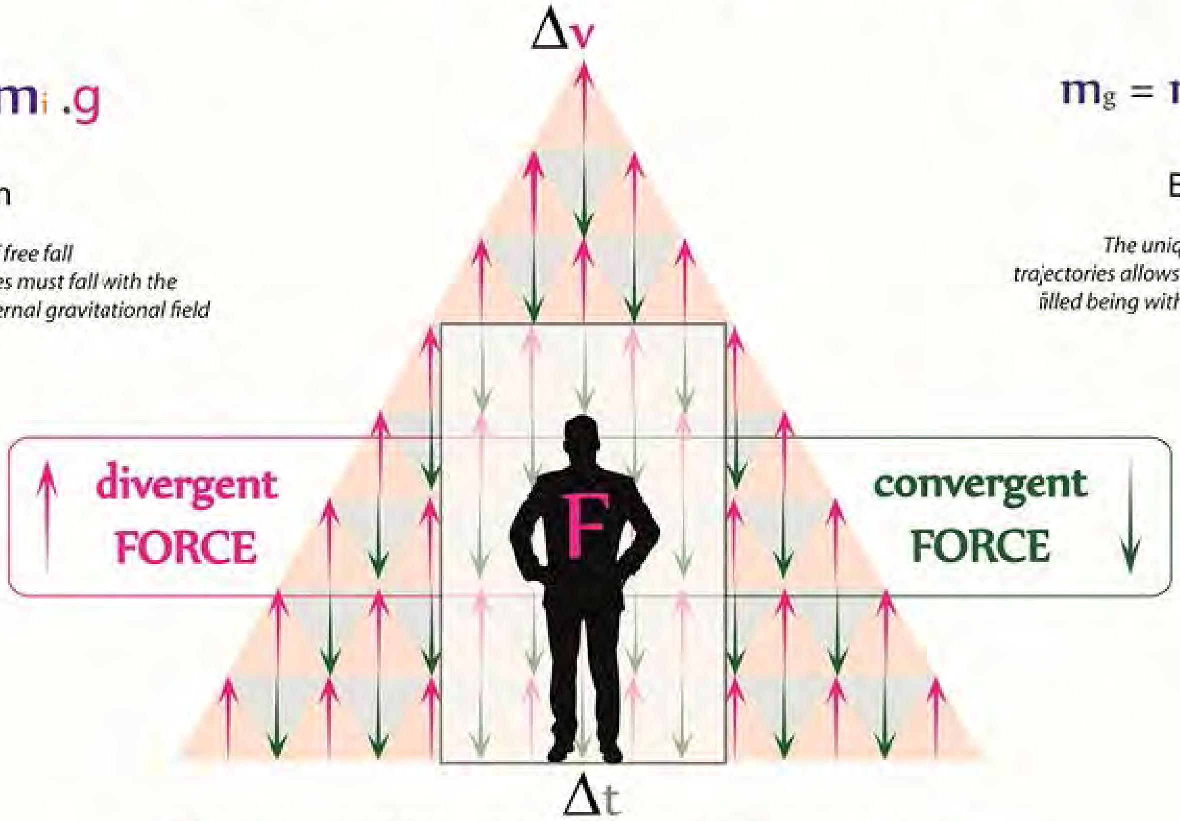

$F = mg$

F_i

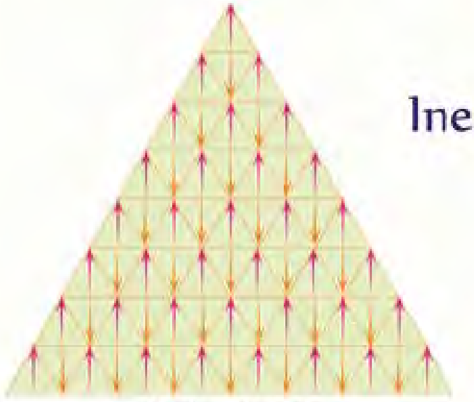

acceleration vs inertial mass

'There is no way of distinguishing between the effects on an observer of a uniform gravitational field and that of constant acceleration'

Inertial and Gravitational masses are equivalent

Of particular note is the fact that the relativistic formulation of the weak equivalence principle hints at the fact that mass-energies in all their forms must be accounted for and correctly modeled for an accurate picture of the mechanics of gravitation on all-scales to be developed

F_g

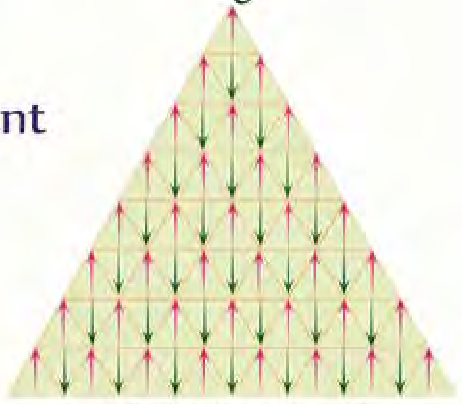

acceleration vs gravitational mass

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Einstein's Gravitational Constant

Newton gave a law for the behavior of objects that experienced gravitational forces:
$F = ma$, where $F = -m\nabla\phi$ for a given gravitational field ϕ

And along with Gauss & Poisson also gave a law determining how φ is generated:
$\nabla^2\phi = 4\pi G\rho$.

Einstein subsiquently re-expressed Newtonian Gravitation as a curvation of spacetime brought about by the presence of all mass-Energies

$$G_{ab} = \kappa T_{\mu\nu}$$

General Relativity

spactime curvature

Gravitational constant

stress energies

$$G_{ab} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

speed of light

Einstein viewed gravitation as the result of a curvature of spacetime created by a mass-energy-pressure gradiant

EM

2D euclidean mass-energy-momenta

Rank 2 tensors

convergent & divergent forces

$$m = \frac{\rho}{c^2}$$

$$G_{ab} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

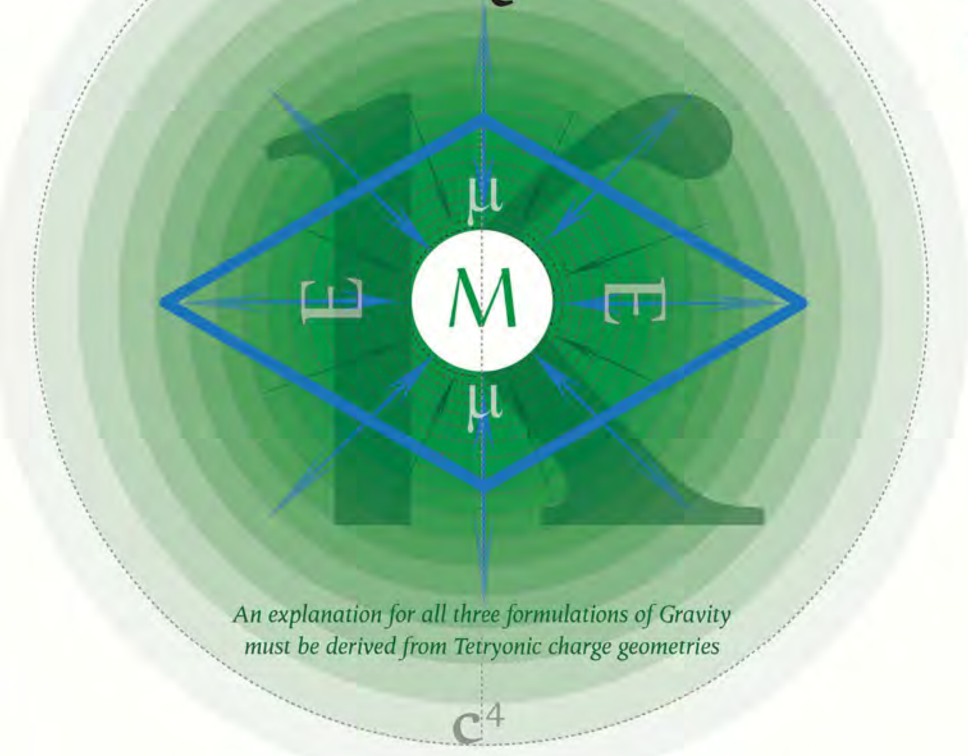

An explanation for all three formulations of Gravity must be derived from Tetryonic charge geometries

$$n\pi[mEM]$$

Tetryonic charged geometries

Gravitational Matter topologies

Interactive mass-energy geometries

$$T\pi\left[\frac{\rho}{c^4}\right] + n\pi\left[\frac{\rho}{c^2}\right]^2$$

3D spatial region

2D spatial fields

Tetryonics differentiates between Matter & interactive mass-energies via their charged geometries and topologies

M

3D mass-Matter topologies

Rank 4 tensors

convergent pressure gradient

$$M = \frac{\rho}{c^4}$$

By modeling all mass-energy geometries and Matter topologies as a stress energy tensor General Relativity fails to differentiate between the interactive Forces of mass-energy momenta and gravitational Matter

mass-energy-Matter spatial interactions

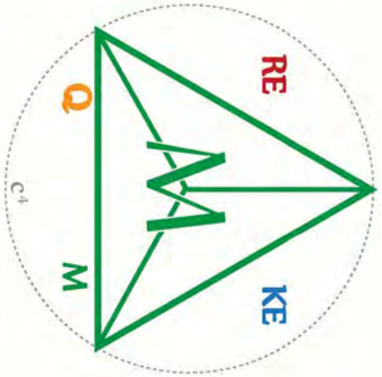

No two Fermions [3D Matter topologies]
can occupy the same physical space
at the same time - Pauli exclusion

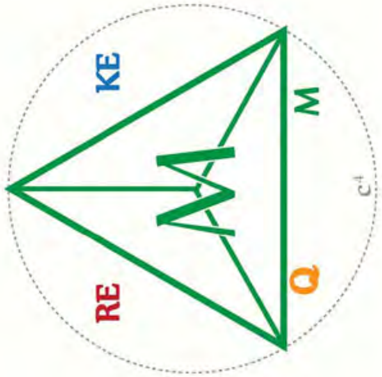

c^4

is a volumetric measure
of the amount of space
taken up by Matter

Fermions

Planck quanta

$$\frac{4n\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

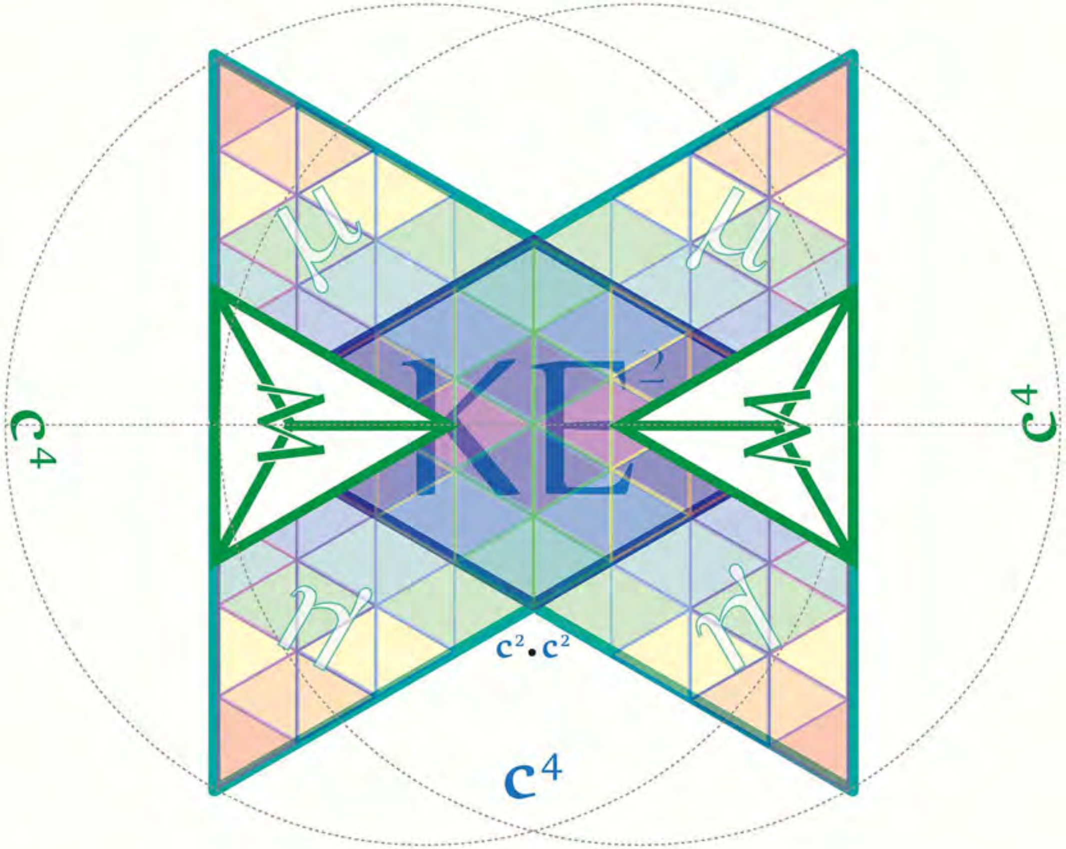
μ
μ
μ
μ
KE^2
M
M
c^4
c^4
$c^2 \cdot c^2$
c^4

c^4

is also a spatial measure
of two superpositioned
interactive KEM fields

Force interaction

Planck quanta

$$\frac{2\pi}{c^2}\cdot\frac{2\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

v
RE
Ω
μ
KE
ρ
v
c^2
m
μ
KE
v^2

All separated particles
interact with each other via 2D fields of Force
(superpositioned [K]EM fields)

v^2
KE
m
μ
v
ρ
KE
c^2
μ
RE
Ω
v

$$\frac{F}{m^2}$$

c^2

SR

Special relativity applies
Lorentz velocity corrections to
radiant mass-energy momenta

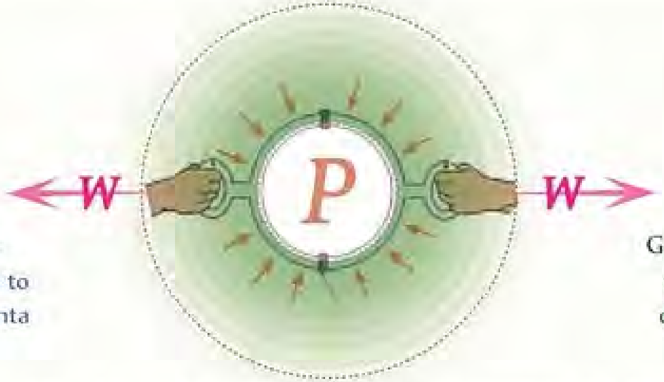

GR

General relativity applies SR
to total energy momenta
density-pressure gradients

$$\frac{E}{m^3}$$

c^4

Otto von Guericke, (1602-1686), a German physicist, performed a famous experiment: the "Magdeburg Hemispheres".

When two halves of a large, hollow metal ball had all the air removed from the volume they created when joined, two teams of horses couldn't pull them apart, because the pressure of the Earth's atmosphere (external to the volume created) exerted a very large force on the ball as it sought to equalise the pressure gradient created.

Nullspace energy pressure gradients

mass-energy geometries

$$P = \frac{\text{Force}}{\text{Area}} = \frac{F}{A} \Rightarrow \frac{F.d}{A.d} \Leftarrow \frac{W}{V} = \frac{\text{Energy}}{\text{Volume}} = U$$

mass-Matter topologies

The scalar mass-energies of all Matter topologies are all contained in their charged fascia

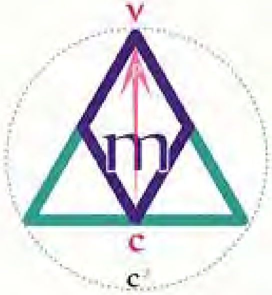

$$n\pi\left[\frac{\rho}{c^2}\right]$$

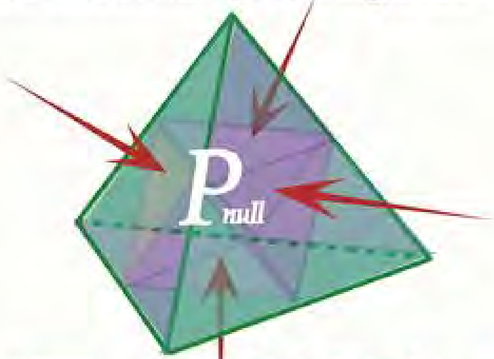

$$T\pi\left[\frac{\rho}{c^4}\right]$$

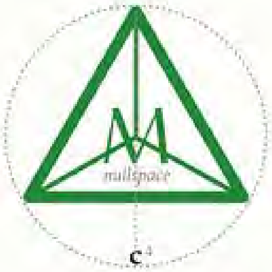

A Faraday cage is a metallic enclosure that prevents the entry or escape of an electromagnetic field (EM field)

All Matter topologies are ideal Faraday cages, quantum standing-waves of EM mass-energies that in turn create regions of nullspace

An ideal quantum Faraday cage consists of an unbroken, perfectly conducting shell. (a Matter topology of scalar mass-energies)

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Total stress energies & Matter

The stress energy tensor can be regarded only as a provisional means of representing all of the interactive mass-energies & gravitational Matter in any physical system.

$$T_{\mu\nu}$$

GR's Stress Energy Tensor does NOT differentiate between EM mass & Matter

Einstein

It is only in present circumstances that we find we have insufficient knowledge of the electromagnetic field of concentrated charges that compels us, provisionally, to leave, undetermined in present theory, the true form of this tensor...

The right hand side the EFE is a formal condensation of all things whose comprehension in the sense of a field theory is still problematic.

Not for a moment... did I doubt that this formulation was merely a makeshift in order to give the general principle of relativity a preliminary closed form expression.

For it was essentially no more than a theory of the gravitational field, which was isolated somewhat artificially from a total field of as yet unknown structure.

Abraham

mass

$$\frac{n\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

ENERGY

$$n\pi\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Matter

$$\frac{T\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Q

changing quantised angular momenta creates charge~Time

3D MATTER topologies displace vacuum energies creating Gravity

Vacuum energies are formed from weak radiated mass-energies

M

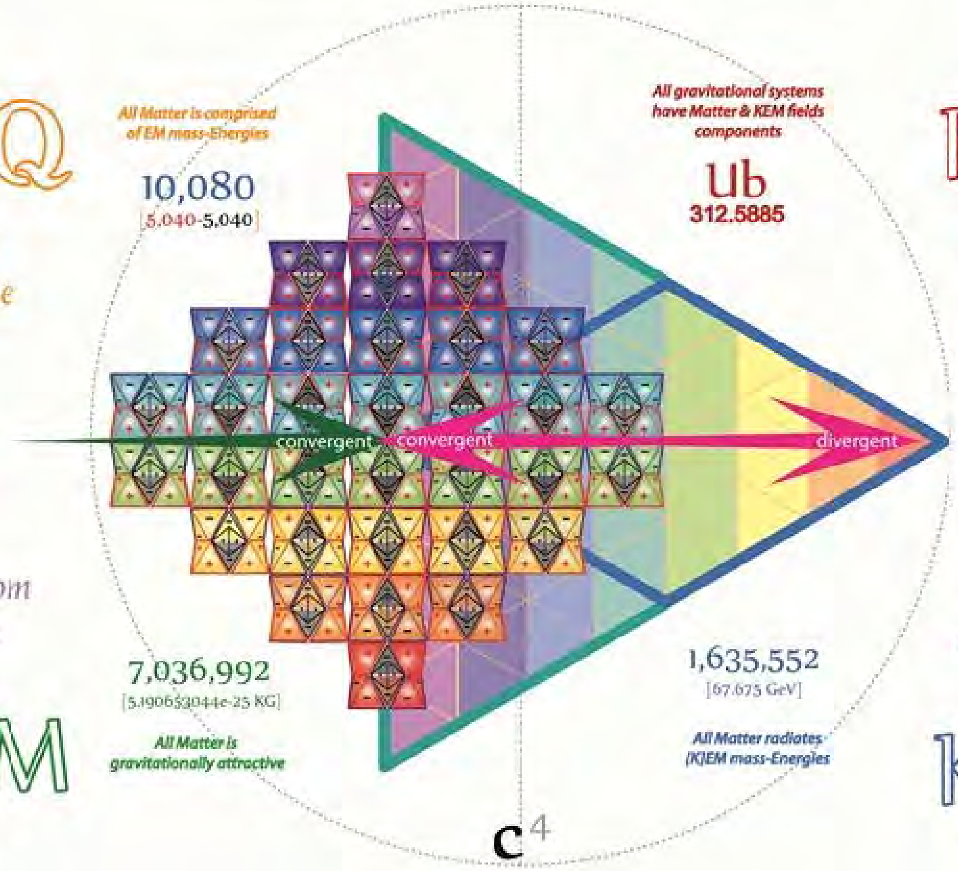
All Matter is comprised of EM mass-Energies
10,080
[5,040-5,040]
All gravitational systems have Matter & KEM fields components
Ub
312.5885
convergent
convergent
divergent
7,036,992
[5.1906532044e-25 KG]
All Matter is gravitationally attractive
1,635,552
[67.675 GeV]
All Matter radiates (K)EM mass-Energies
c^4

RE

changing linear momentum creates forces of Acceleration

radiant 2D planar mass-ENERGIES create interactive forces

KEM field energy momenta create fields of interactive Force

KE

Tetryonics 69.10 - Total stress energies & Matter

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Einstein's Field Equation

"Spacetime tells Matter how to move; *Matter tells spacetime how to curve"*
John Archibald Wheeler

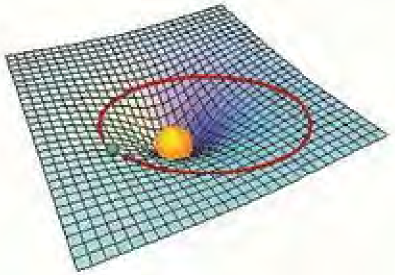

$$R_{ab} - \tfrac{1}{2}R\,g_{ab} = \frac{8\pi G}{c^4}\,T_{\mu\nu}$$

The solutions of the Einstein field equations are metrics of spacetime

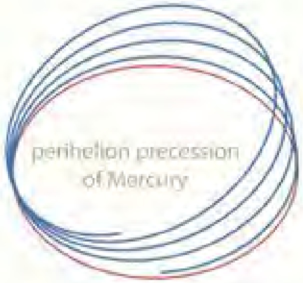

General Relativity was developed to account for the observed perihilion precession of Mercury's orbit around the SUN
[only noticable through detailed observations after Newton developed his law of universal gravitation]

Newtonian G field

4π

the scalar curvature
the cosmological constant
Newton's gravitational constant

Ricci curvature tensor $R_{ab} - \tfrac{1}{2}g_{ab}\,R + \Lambda g_{ab} = \dfrac{8\pi G}{c^4}\,T_{\mu\nu}$ the stress-energy tensor

the metric tensor

the spatial region of mass-energy-Matter being measured
as determined by the speed of Energy in vacuum

The EFE is a tensor equation relating a set of symmetric 4 x 4 tensors. Each tensor has 10 independent components

Einstein's G field

8π

The EFE (based on SR principles) reduces to Newton's law of gravitation where the radiant mass-energy fields are weak and velocities are much less than the speed of light
[highlighting the inability of GR to distingush between radiant mass-energy geometries & the standing-wave Matter topologies comprising the total energies within the stress Energy tensor]

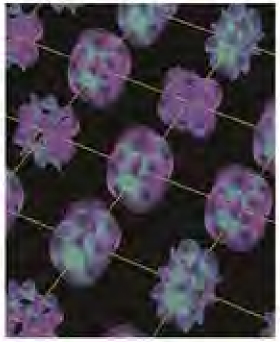

Curved Spacetime
Einstein's
gravitational constant

$$G_{ab} + \Lambda g_{ab} = \kappa\,T_{\mu\nu}$$

the cosmological constant
mass-ENERGY-Matter

Despite the successes of General Relativity, the problems of quantum gravity and spacetime singularities remain open problems in its formulation of curved spacetime geometries

ZPF

All Energies are quantised

Quantum theory

m

Gravitation is Universal

Newtonian Mechanics

M

Gravity results from curved spacetime

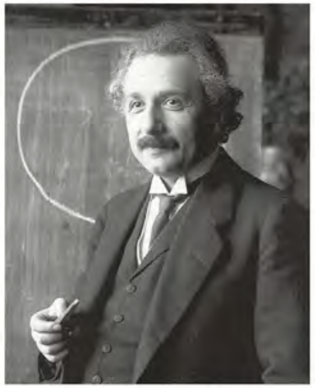

Relativity theory

VE

Quantum gravity is the effort in theoretical physics to create a theory that includes both general relativity and the standard model of particle physics. Currently, these two theories describe different scales of nature and attempts to explore the scale where they overlap yield results that don't quite make sense, like the force of gravity (or curvature of spacetime) becoming infinite.

Euclidean quantum gravity

Scalar theories

Modified Newtonian dynamics (MOND)

Einstein-Cartan Bimetric theories

Tensor-vector-scalar

DGP model

Geometrodynamics

Loop Quantum Gravity

Lovelock theory

Kaluza-Klein theory

Induced gravity

Canonical Quantum Gravity

Jackiw-Teitelboim gravity

Quantum gravity

Gravity as it is currently understood cannot be reconciled with the laws of quantum mechanics.

String theory

Liouville gravity

Causal Set theory

Brans-Dicke

Massive gravity

Composite gravity

Teleparallelism

Scalar-tensor-vector

Causal dynamical triangulation

Conformal gravity

Gauge theory gravity

Nonsymmetric gravitation

2+1D topological gravity

Gauss-Bonnet gravity

f(R) gravity

Supergravity

Unified theory

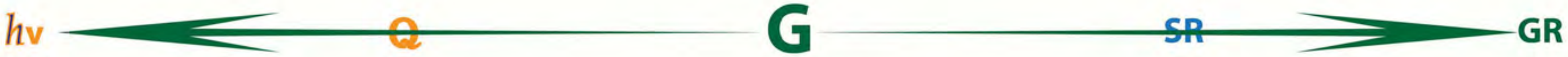

1899
Planck's law

1785
Couolomb's law

1686
Newton's law of Gravitation

1905
Special relativity

1915
General relativity

Without the aid of Tetryonic's charged geometries
Gravitational & EM fields point to mathematical singularities

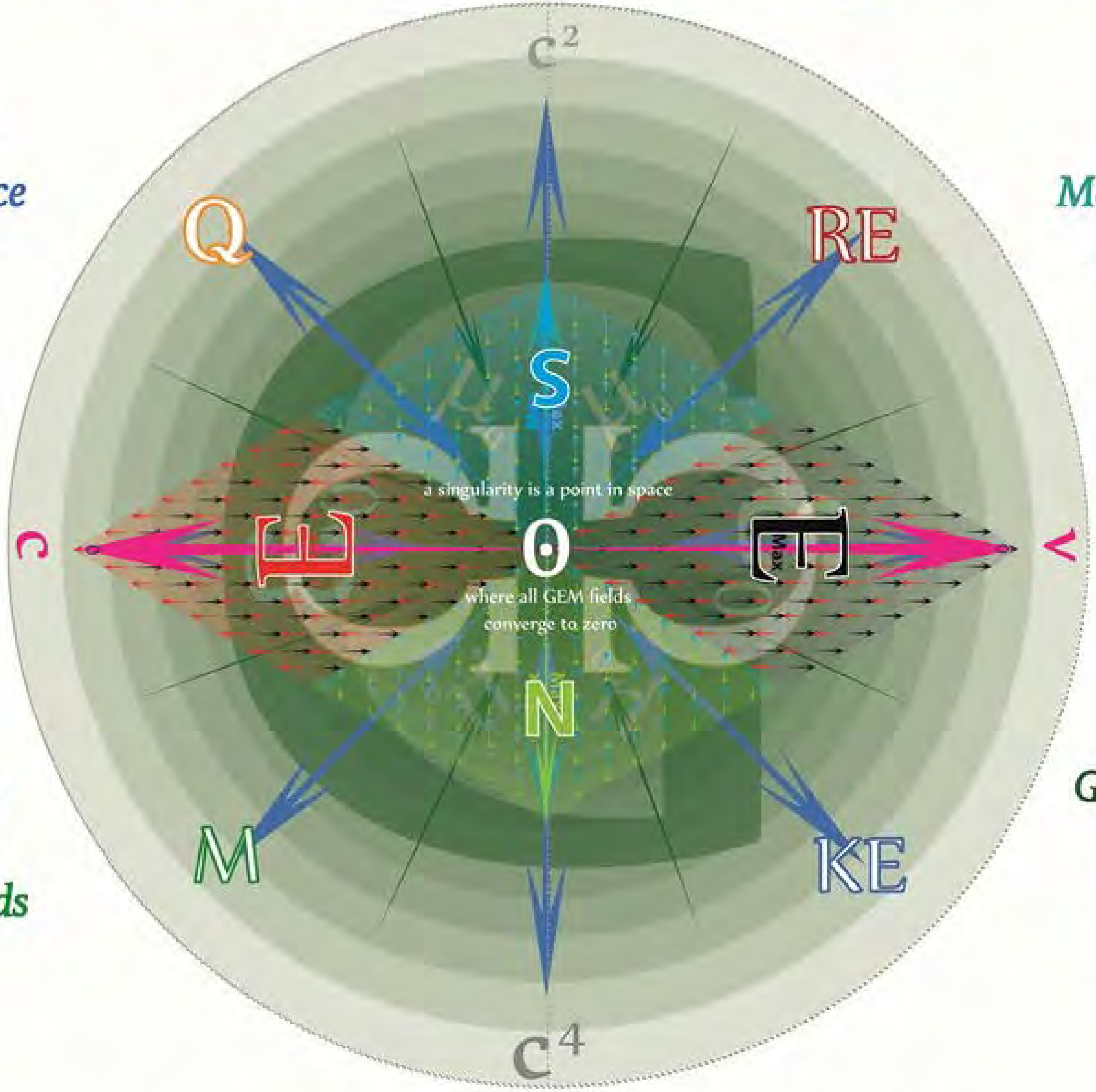
c²
Q
RE
S
a singularity is a point in space
c
E
0
E Max
v
where all GEM fields
converge to zero
N
M
KE
c⁴

Inverse squared
Electric fields produce
INTERACTIVE
fields of force

Inverse squared
Magnetic fields produce
PURTURBATIVE
fields of force

There are NO
Black Holes

There are NO
point Particles

Matter produces
CONVERGENT
inverse squared fields
of Gravity

Gravitation is the nett
convergent force
produced by all
G-E-M fields

GravitoElectroMagnetic fields

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Matter topologies and gravity

the positive spatial displacements created by tetrahedral standing-wave mass-energies displace vacuum energies found in those regions to create a energy density pressure gradient

A convergent Gravity field is the result of the higher density-pressure vacuum energies in any spatial region seeking to equalise the lower pressure regions of nullspace within Matter topologies

Matter has a
Tetrahedral mass-energy
quantum topology
[non-Spherical]

M

The mass-energies
of Matter topologies
are stored in the integral
surface area geometries
of their charged fascia

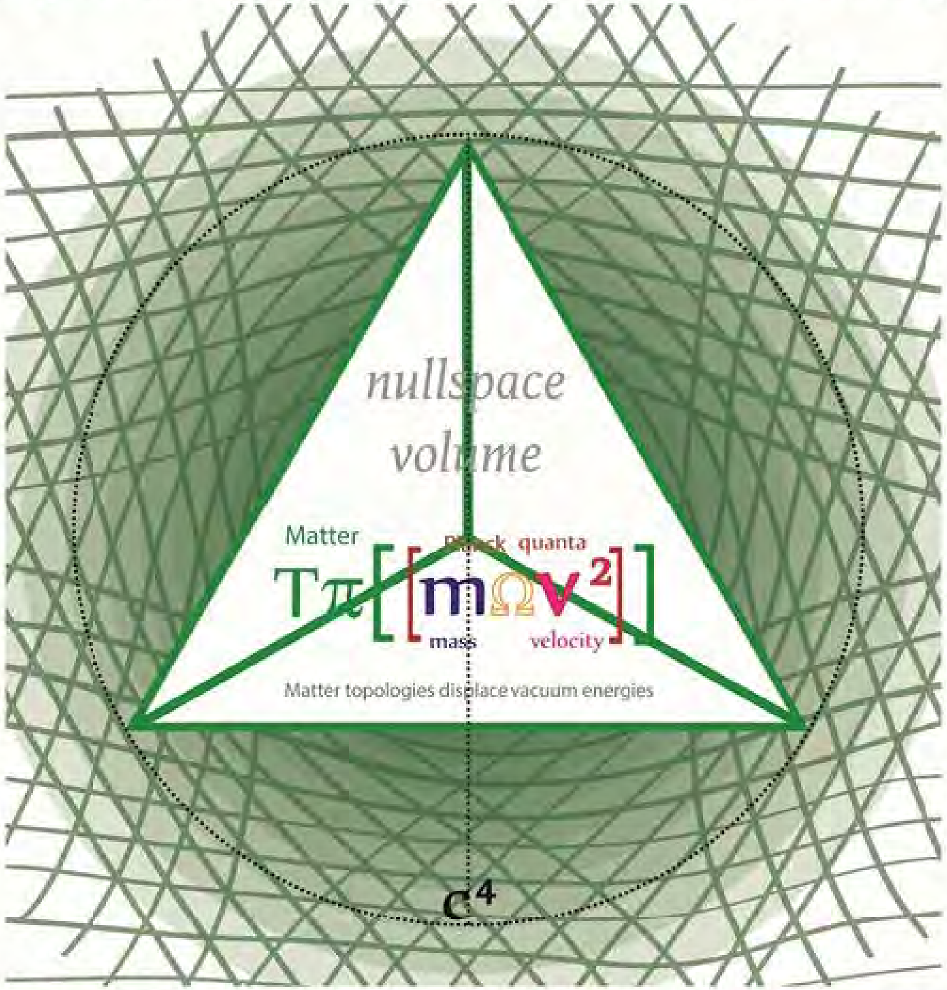

Gravity itself is
the result of vacuum
energy pressure gradients
not Coloumbic fields

G

Gravitation is the
result of the convergent
gravity AND interactive
[k]EM fields that all quantum
Matter topologies create

The resultant density-pressure gradients created by the displacement of vacuum energies by Matter topologies can be modelled using equilateral EM field geometries and a reduced Coloumb constant

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Spatial displacement of GEM energies by Matter topologies

The positive 4nπ displacement of vacuum eneriges by Matter topologies creates

Spatial energy density-pressure

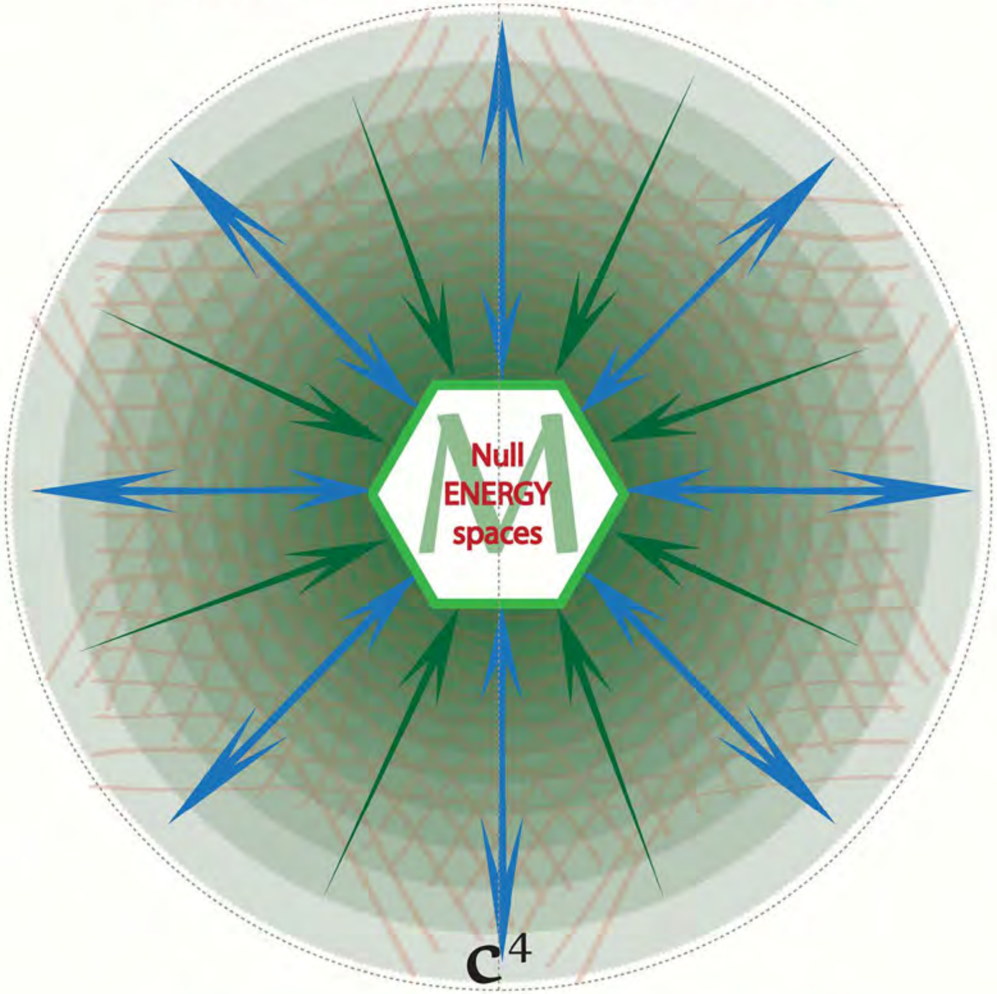

Convergent Gravitational fields

$$F = -G\frac{M_1 m_2}{r^2}$$

Planets orbit
around the SUN

Newtonian fields models the resultant attraction as gravity

EM fields accelerate
charged Matter

$$F = k\frac{Q_1 Q_2}{r^2}$$

$$G_{ab} = 8\pi G T_{\mu\nu}$$

All EM mass & Matter
create stress energies

Einstein models the GEM energy densities as curved spacetime

Orbital precessions
must be accounted for

Newton		Einstein
4π	vs.	8π
G		G+SR

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Newtonian Gravity

model the observed, long range attraction between two bodies of Matter
[exclusive of the close range electromagnetic interactions of each body]

A gravity field is produced by the charged topology of mass-Matter as it displaces vacuum energies and creates intrisic nullspace energy differentials

The strength of a Gravity field produced by Matter is proportional to the total EM mass-energy geometry/topology of any body and its convergent force can be modelled with equilateral Tetryonic geometries

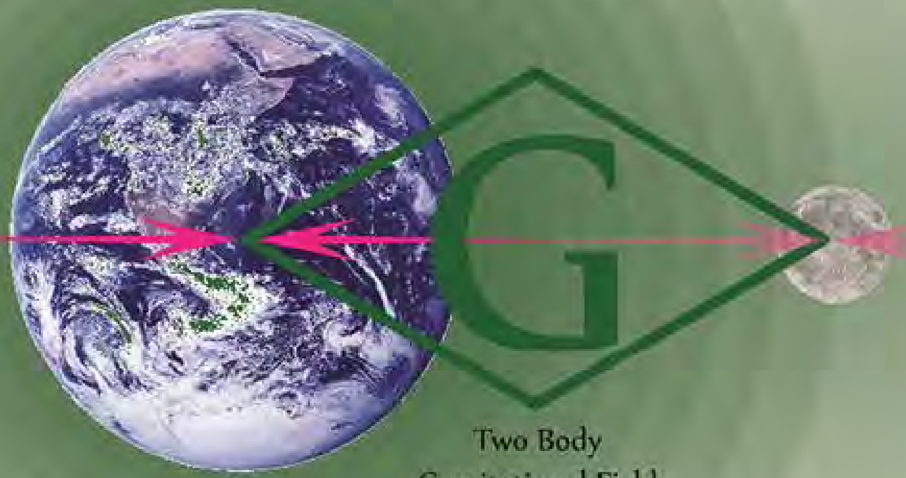

Single Body
Gravitational Field

$$F = -G\frac{M_1}{r^2}$$

Single Body
Gravitational Field

$$F = -G\frac{m_2}{r^2}$$

Two Body
Gravitational Field

$$F = -G\frac{M_1 m_2}{r^2}$$

However, unless it is at absolute zero all Matter topologies produce interactive EM fields that contribute to gravitational forces as evidenced with the perihelion of Mercury where later observations revealed inaccuracies in Newton's formulation for the motion of material bodies subject to convergent G forces & interactive EM fields

Gravitational energies as a geometric mean

the geometric mean of two numbers is the square root of their product

EM standing waves
[Matter] can be
created and destroyed

EM mass-energies
can be neither
created or destroyed

Sir Issac Newton was the first to realise that gravity could be modelled as an inverse square Force

$$F = -G\frac{M_1 m_2}{r^2}$$

M

E

The Force of Gravity
can be accurately modelled

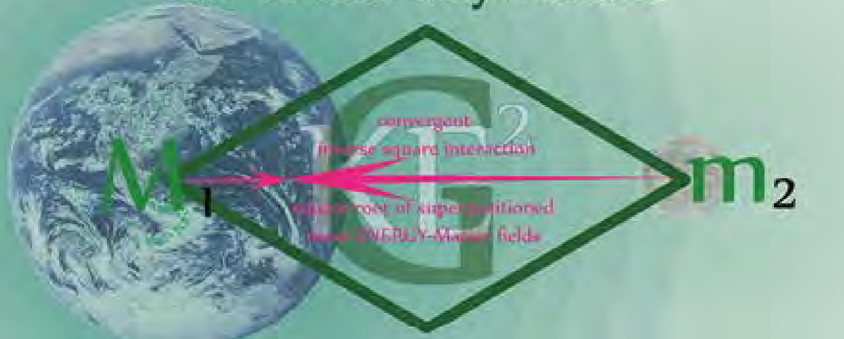
M_1
convergent
inverse square interaction
square root of superpositioned
mass ENERGY-Matter fields
G^2
m_2

as the convergent geometric MEAN of interactive
superpositioned E-fields that represent the total
mass-energies of the gravitational Matter

Gravitational field of mass-Matter only

$$F_G = 4\pi G\rho$$

[ignoring EM interactions]

Gravitational energy of Matter in motion

$$G_{ab} = 8\pi G T_{\mu\nu}$$

[including KEM field interactions]

$$F_G = \frac{M_1 . m_2}{r^2}$$

$$F_G = \sqrt{M_1 . m_2}$$

Gravity is the result of spatial energy density differentials created by the internal null-space volumes of Matter.
Energy (in all its forms) will seek to fill areas of lower pressure in search of universal equilbrium

Newton modelled the
attractive forces between
objects of Matter

Matter topologies are non-conservative and as they are destroyed
the low pressure nullspace gradient [convergent gravitational Force] they created
is replaced with conservative forms of radiative EM energy [interactive vacuum energies-photons]

GR models the
energy density created
by mass-Matter

Gravitational Tidal Forces

The tidal force is a secondary effect of the force of gravity resulting from the geometry of massive bodies attracting each other.

Its geometric effects allow acceleration fields to be distingushed from pure graviation fields

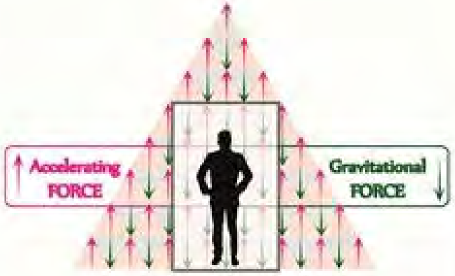

Over a small area on the surface of a Gravitating body, gravitational attaction is often modelled as a uniform field acting downwards across the whole area.

The Gravity of a material body of mass-Matter has historically been defined as a strictly attracitve force between bodies

$$F = -G\frac{M_1 m_2}{r^2}$$

Tetryonics reveals Gravitation to be the nett result of 3 distinct interactions:
Convergent G-fields
Interactive E-fields and
Perturbative M-fields

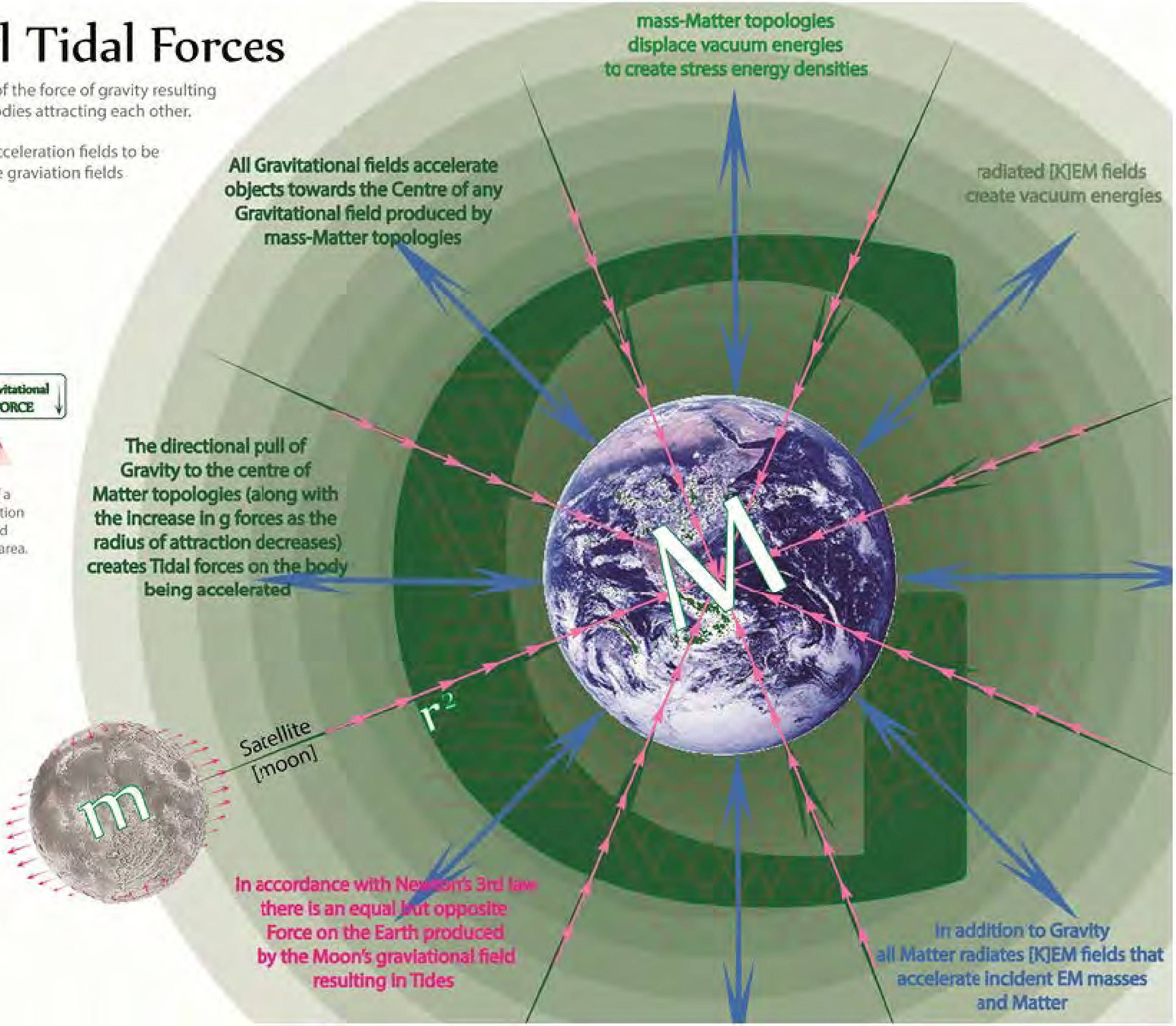

mass-Matter topologies displace vacuum energies to create stress energy densities

All Gravitational fields accelerate objects towards the Centre of any Gravitational field produced by mass-Matter topologies

radiated [K]EM fields create vacuum energies

The directional pull of Gravity to the centre of Matter topologies (along with the increase in g forces as the radius of attraction decreases) creates Tidal forces on the body being accelerated

In accordance with Newton's 3rd law there is an equal but opposite Force on the Earth produced by the Moon's gravlational field resulting in Tides

In addition to Gravity all Matter radiates [K]EM fields that accelerate incident EM masses and Matter

Tetryonic Gravitation

is the result of the combined interactions
of radiant EM geometries & Matter topologies
in any spatial region of measurement

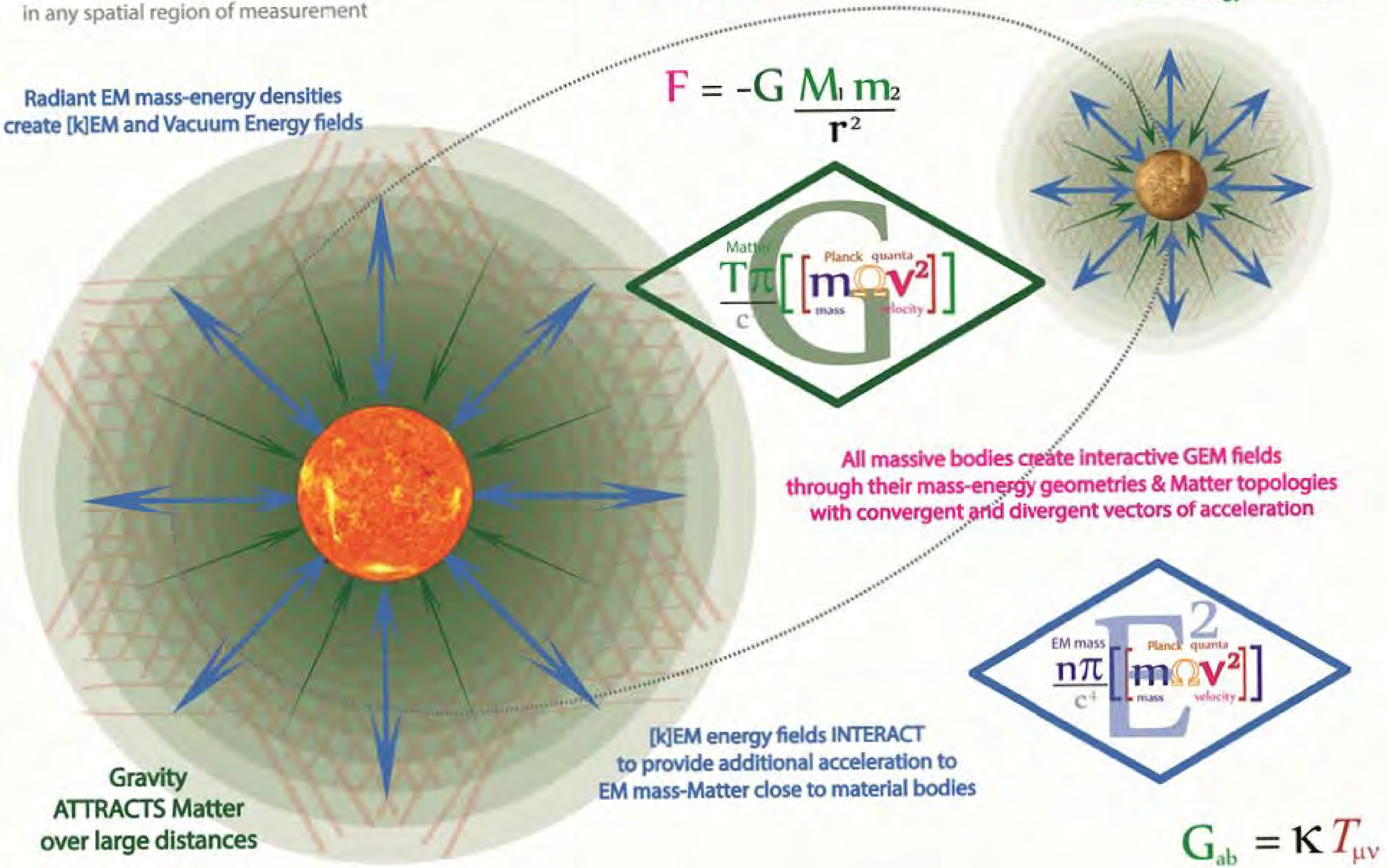
Matter
$\frac{T\pi}{c}\left[\left[m\Omega v^2\right]\right]$
Planck quanta
mass
velocity
G
EM mass
$\frac{n\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$
Planck quanta
mass
velocity
E^2

[k]EM fields & Vacuum energy gradients
create energy momenta pressure differentials
that accelerate Matter

3D mass-Matter topologies
create nullspace
vacuum energy differentials

Radiant EM mass-energy densities
create [k]EM and Vacuum Energy fields

$$F = -G\frac{M_1 m_2}{r^2}$$

All massive bodies create interactive GEM fields
through their mass-energy geometries & Matter topologies
with convergent and divergent vectors of acceleration

[k]EM energy fields INTERACT
to provide additional acceleration to
EM mass-Matter close to material bodies

Gravity
ATTRACTS Matter
over large distances

$$G_{ab} = \kappa T_{\mu\nu}$$

EM masses & Gravitational Matter

$$\frac{\rho}{m^2}$$

The core problem preventing the unification of Classical gravitation with QM & Relativity theory
is the imprecise formulation, definition and differentiation between mass & Matter

$$\frac{\rho}{m^3}$$

v
ε_0
m
Ω
c
c^2
kg

$$E = mc^2$$

radiant mass-energy geometry

$$F = ma$$

mass is a conserved quantity
Matter is not a conserved quantity

$$F = -G\,\frac{M_1\,m_2}{r^2}$$

inertial mass
active gravitational mass
passive gravitational mass

$$G_{ab} = \kappa\,T_{\mu\nu}$$

Even GR offers no clear distinction

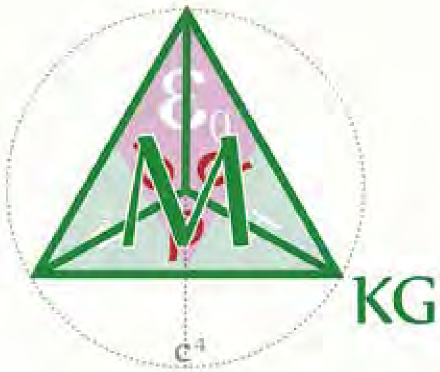

$$E = Mc^4$$

standing-wave Matter topology

General relativity has been heralded as a highly successful model of gravitation and cosmology, which has so far passed every unambiguous observational and experimental test.

Even so, there are strong indications the theory is incomplete

Without a clear, concise understanding and accurate models of the relationship between mass & Matter [and their interactions] a Unified Field theory is impossible

$$\overset{\text{mass}}{\frac{n\pi}{c^2}}\left[\overset{\text{Energy}}{\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]}\right]$$

mass is a geometric measure of a field's planar energy momenta content per unit Time

2D masses

bosons photons

$$mc^2 = E = Mc^4$$

Note: in both cases the amount of Energy described is identical
It is the changing spatial co-ordinate systems used to measure Energy in all it forms
that allows for the differentiation between mass-energy geometries & Matter-energy topologies

$$\overset{\text{Matter}}{\frac{T\pi}{c^4}}\left[\overset{\text{Energy}}{\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]}\right]$$

Matter is a topological measure of an object's planar mass-energy content per unit of Time

3D Matter

Fermions, Baryons

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mass-ENERGY-Matter equivalence

Einstein's mass-energy equivalence can be further refined and differentiated through charge geometries
[in turn creating a symetric mass-ENERGY-Matter equivalence formulation]

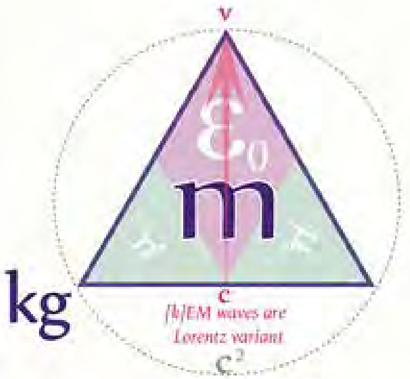
v
ε_0
m
μ_0
μ_0
kg
c
[k]EM waves are
Lorentz variant
c^2

mass

The mass-energies of EM waveforms is contained within its charged geometry

$$E = mc^2$$

EM mass-energy is a property of Matter

standing-wave

topologies

$$m = \frac{E}{c^2}$$

radiant EM mass geometry

$$\frac{m}{c^2} = M$$

standing-wave Matter topology

$$\frac{E}{c^4} = M$$

radiant

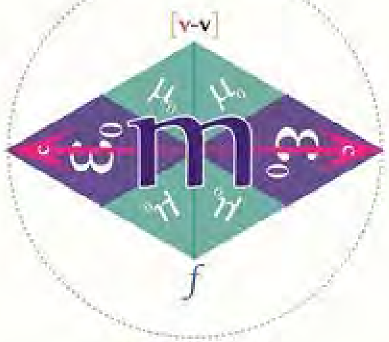
[v-v]
μ_0
μ_0
ε_0
ε_0
m
c
c
μ_0
μ_0
f

geometries

Matter is NOT a property of EM mass-energy

$$E = Mc^4$$

The mass-energies of Matter is contained entirely within its charged fascia topology

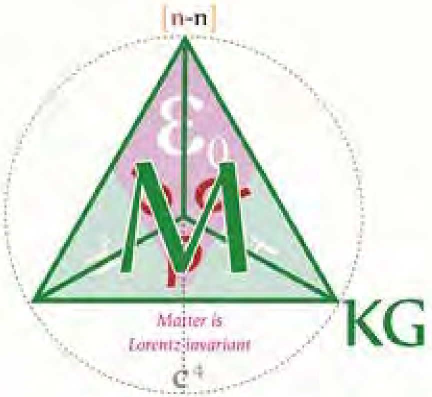
[n-n]
ε_0
M
KG
Matter is
Lorentz invariant
c^4

Matter

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Tetryonic unified GEM fields

Equilateral Tetryonic geometry/topology provides a unified quantum field equation to model all Gravito-Electro-Magnetic mass-ENERGY-Matter interactions

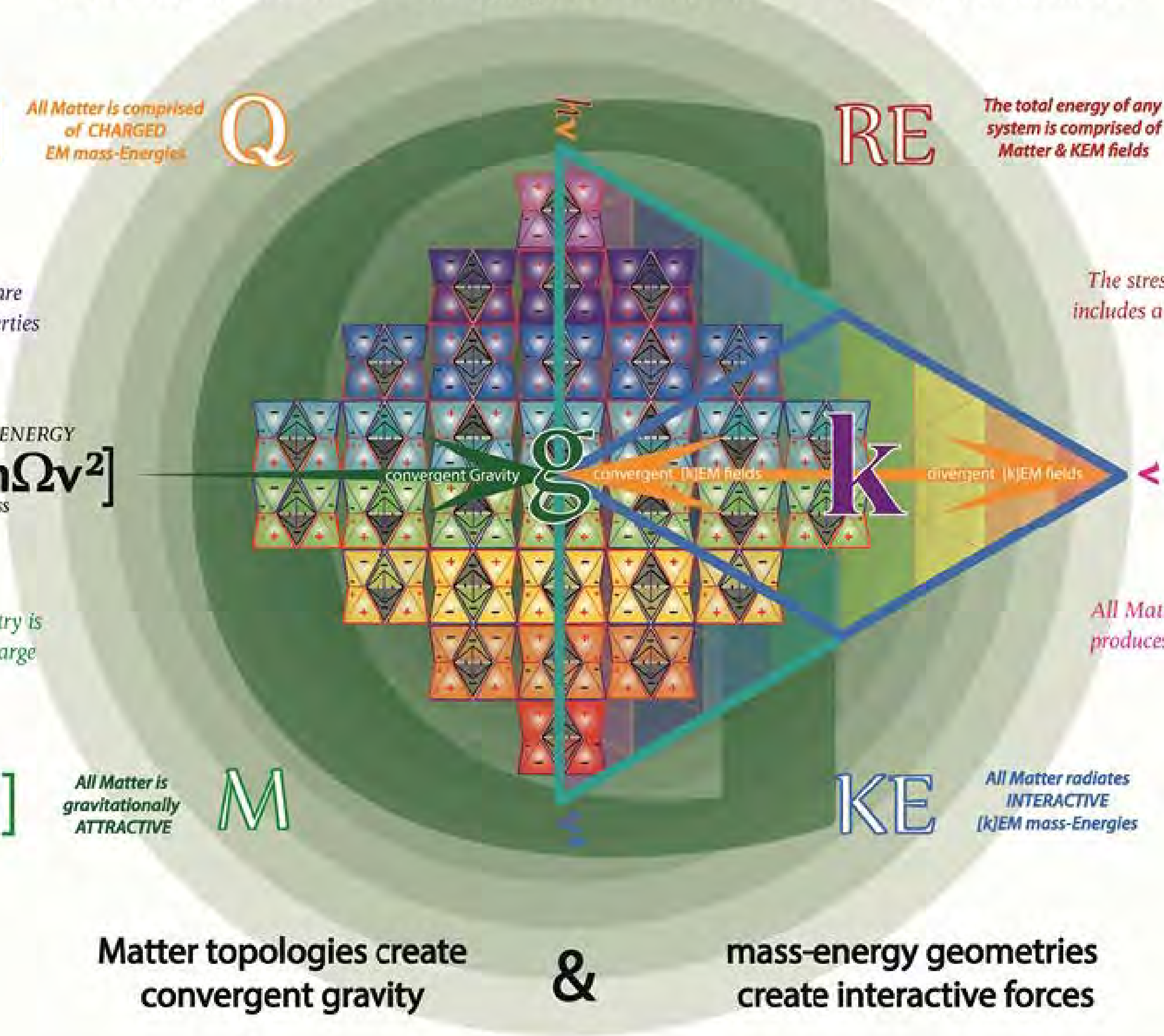

Bosons

$$\frac{ODD\pi}{c^2}\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\Omega\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]$$

All Matter is comprised of CHARGED EM mass-Energies

Q

RE

The total energy of any system is comprised of Matter & KEM fields

ENERGY

$$n\pi\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\Omega\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]$$

mass & Matter are distinct EM properties

The stress-Energy tensor includes all forms of energy

ENERGY

$$\underset{\text{Matter}}{T\pi}\left[\underset{\text{mass}}{m}\Omega v^2\right]$$

Equilateral energy momenta are geometrically related to the square of velocity

3D Matter geometry is determined by charge

All Matter in motion produces a [k]EM field

Matter

$$\frac{T\pi}{c^4}\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\Omega\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]$$

All Matter is gravitationally ATTRACTIVE

M

KE

All Matter radiates INTERACTIVE [k]EM mass-Energies

EM waves

$$\frac{EVEN\pi}{c^2}\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\Omega\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]$$

Matter topologies create convergent gravity & mass-energy geometries create interactive forces

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Quantum Gravity

At present, one of the deepest problems of modern theoretical physics is the unification of General Relativity, which describes gravitation, and applies to large-scale structures (stars, planets, galaxies), with Quantum Mechanics, which describes the other three fundamental forces acting on the atomic scale

M

Newtonian Gravitation models observed motions of large-scale MATTER

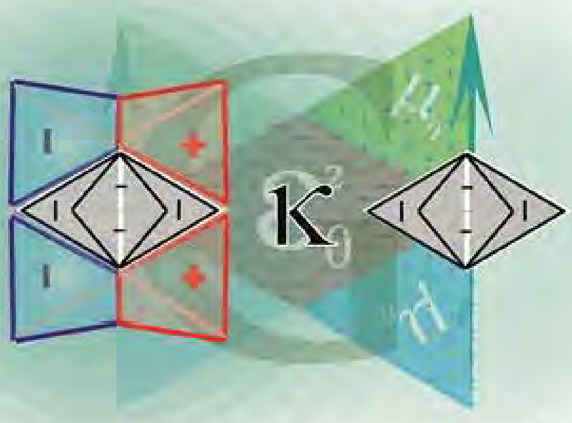

$T_{\mu\nu}$

Einstein's GR models interactions of all mass-energy-Matter

G

The large scale Cosmos is ruled by GRAVITY

There are major points of tension between Quantum mechanics and General relativity.

Firstly, classical general relativity breaks down at singularities, and Quantum mechanics becomes inconsistent with general relativity in the neighborhood of singularities

Secondly, it is not clear how to determine the gravitational field of a particle, since under the Heisenberg uncertainty principle of Quantum mechanics its location and velocity at any instant of Time cannot be known with certainty.

Thirdly, there is the Problem of Time in Quantum gravity. Time has a different meanings in Quantum mechanics and General relativity and hence there are subtle issues to resolve when trying to formulate a theory which combines the two.

k

The Quantum world is ruled by ELECTROMAGNETISM

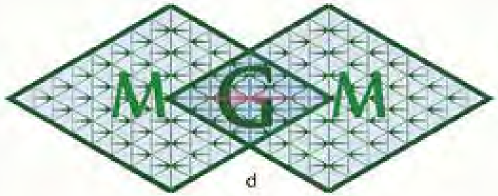

Gravitational attraction is a convergent Force between Matter

Newton

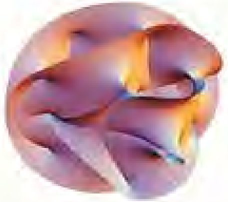

Gravitation results from energy density-pressure gradients

Einstein

Attempts to generalize ordinary quantum field theories, used in elementary particle physics to describe the fundamental interaction of gravity have to date led to serious problems.

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Gravitons

Gravitons are not required in Tetryonic theory as gravitational attraction is a convergent force created by the EM energy differential produced by 3D Matter topologies in a vacuum energy field

All standing-wave Matter geometries create Gravity

G

CONVERGENT
Gravitation

Gravitons are the hypothetical carriers of the attractive Gravitational FORCE

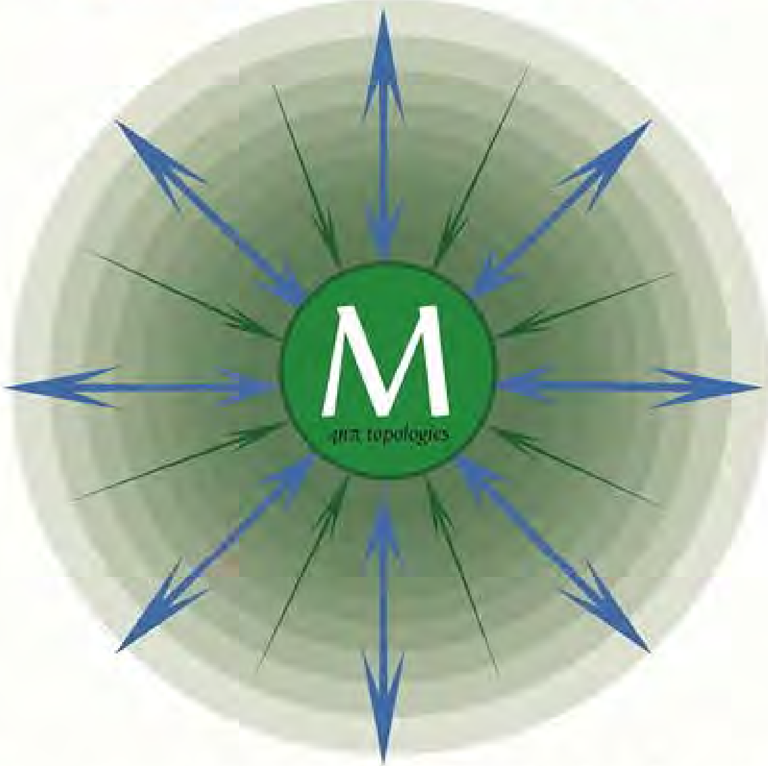

Radiant EM fields are produced by all Matter in motion

EM

DIVERGENT
ElectroMagnetism

Photons are the carriers of the interactive ElectroMagnetic FORCE

Gravitons were proposed as the gravitational equivalent of the Photon in ElectroMagnetic theory but have never been detected

4πG

8πG

They were postulated because of the great success of quantum field theory (in particular, the Standard Model) at modeling the behavior of all other known forces of nature as being mediated by elementary particles: electromagnetism by the photon, the strong interaction by the gluons, and the weak interaction by the W and Z bosons.

The hypothesis was that the gravitational interaction is likewise mediated by a – yet undiscovered – elementary particle, dubbed the graviton. In the classical limit the theory would allow Newton's law of gravitation in the weak-field limit to conform with Einstein's field equations of General relativity

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Laplacian field interactions

energy density

electric permittivity

impedance of a medium

$$Z = \frac{\rho}{c^2} = \varepsilon_0 \mu_0$$

field geometry

magnetic permeability

The planar two-dimensional Laplacian is given by

$$\Delta = \nabla^2 = \nabla \quad \nabla = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$$

This fundamental differential operator of Applied Mathematics was introduced by Laplace
in his 1782 study of the force of gravitational attraction exerted by spheroids
and was named after him by Maxwell in his 1873 treatise on electromagnetism.

energy density

Einstein's constant

$$G_P = K \frac{\rho}{c^4}$$

energy density pressure gradient

spatial volume

The net divergence of Positive charge fields is due to the anti-symmetry of their component Planck quanta

The net divergence of Negative charge fields is due to the anti-symmetry of their component Planck quanta

$$E = \frac{\rho}{c^2 \mu_0}$$

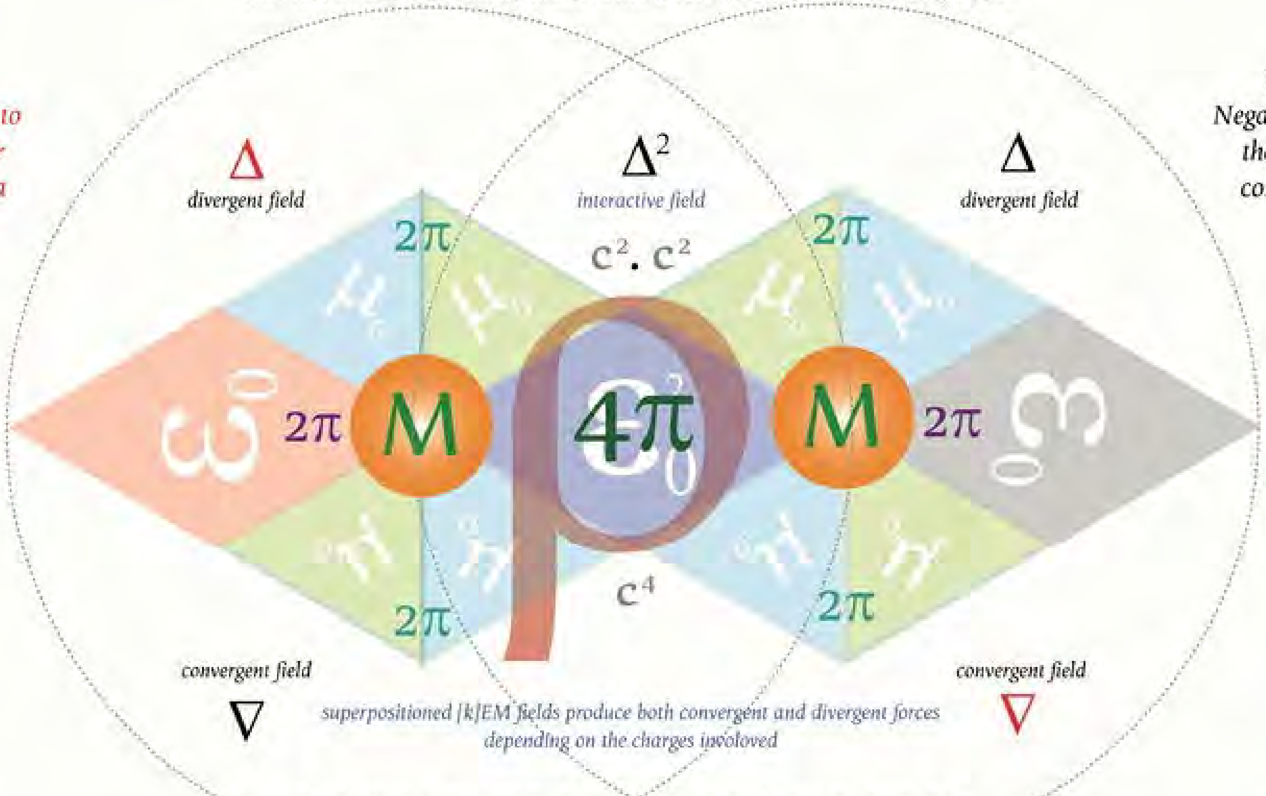
Δ
divergent field
Δ^2
interactive field
Δ
divergent field
2π
$c^2 . c^2$
2π
μ_0
μ_0
μ_0
μ_0
ε_0
2π
M
4π
ε_0
M
2π
ε_0
μ_0
μ_0
μ_0
μ_0
2π
c^4
2π
convergent field
∇
convergent field
∇

superpositioned [k]EM fields produce both convergent and divergent forces depending on the charges involoved

$$B = \frac{\rho}{c^2 \varepsilon_0}$$

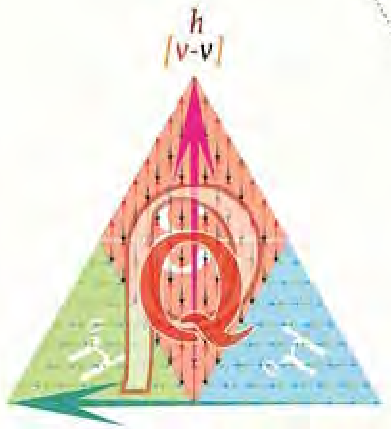
h
[v-v]
Q
μ_0
μ_0

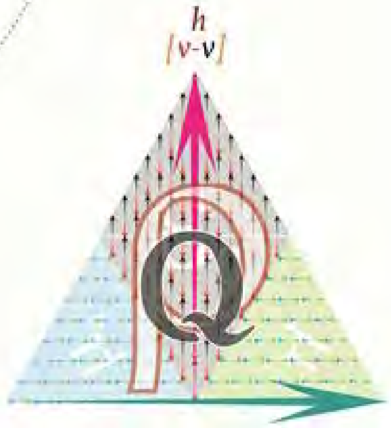
h
[v-v]
Q
μ_0
μ_0

The Laplacian of any scalar field is interpreted as being the limit of the
net outward flux per unit enclosed area of this field through a closed contour
surrounding the point of evaluation

$$\Delta \phi = \lim_{A \to 0} \frac{1}{A} \oint_{\partial D} \frac{\partial \phi}{\partial \nu}\, dl, \quad A = \text{area}(D)$$

co-ordinate-free representation of the Laplacian

Newton's Gravitational Constant
has been shown to be a greatly
reduced version of Coulomb's
Electric interaction Constant

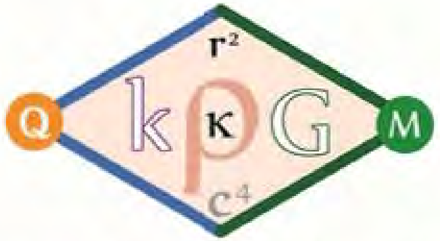
Q
k
ρ
κ
G
M
r²
c⁴

Newtonian Gravitation models
the observed convergent force of
GEM interactions that results in
the motion of large-scale Matter

Any compete Unified field equation for
Gravitation must take into account both
the Nullspace gravitation resulting from
Matter topologies as well as the Coulombic
2D interaction fields that result from charge
and the motion of Matter through the aether

Combined Interactive & Gravitational Forces

mass-energy-Matter

$$G_{\rho} = \kappa\,\frac{\rho}{c^{4}}$$

spatial volume

Coulomb's Law

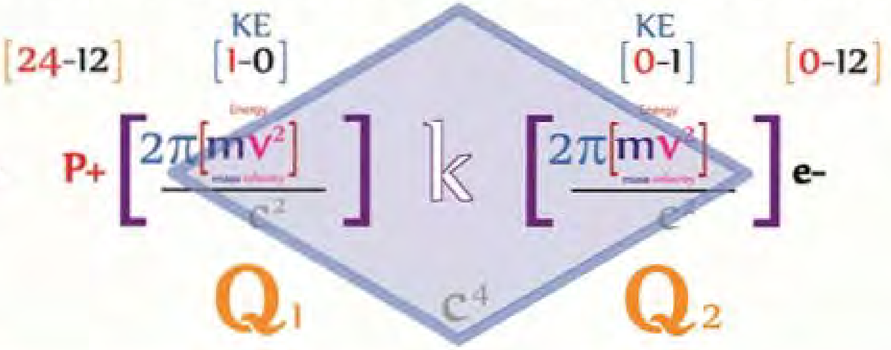
[24-12]
KE
[1-0]
KE
[0-1]
[0-12]
Energy
mass velocity
Energy
mass velocity
Q₁
Q₂
c⁴

$$P_{+}\left[\frac{2\pi\,[mv^{2}]}{c^{2}}\right] k \left[\frac{2\pi\,[mv^{2}]}{c^{2}}\right] e^{-}$$

Coulombic
[k]EM fields

Divergent [Interaction]
radiative EM Fields

[k]EM interactive superpositioned EM fields of Force [k]EM

$$P_{+}\left[\frac{T\pi}{c^{4}}\overset{\text{Energy}}{\underset{\text{mass}}{[m]}} + \left[\underset{\text{mass}}{n\pi}\,\frac{\overset{\text{Lorentz}}{\underset{\text{correction}}{[mv^{2}]}}}{c^{2}}\;\underset{\text{Einstein's constant}}{\kappa}\;\underset{\text{mass}}{n\pi}\,\frac{\overset{\text{Lorentz}}{\underset{\text{correction}}{[mv^{2}]}}}{c^{2}}\right] + \frac{T\pi}{c^{4}}\overset{\text{Energy}}{\underset{\text{mass}}{[m]}}\right] e^{-}$$

Matter *convergent gravitational field of Force* *Matter*

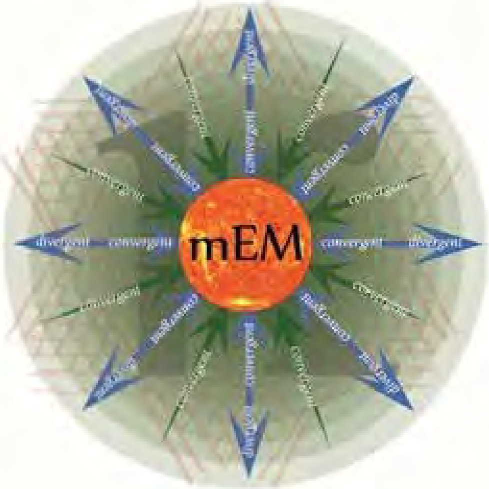
mEM
divergent
convergent
divergent
convergent
convergent
divergent

Newton's Law

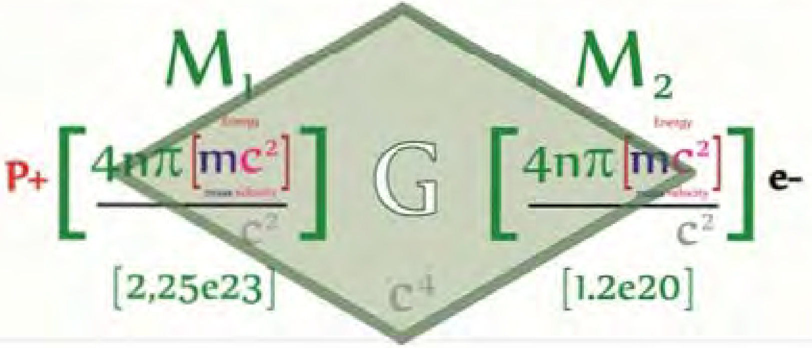
M₁
M₂
Energy
mass velocity
Energy
mass velocity
[2,25e23]
[1.2e20]
c⁴

$$P_{+}\left[\frac{4n\pi\,[mc^{2}]}{c^{2}}\right] G \left[\frac{4n\pi\,[mc^{2}]}{c^{2}}\right] e^{-}$$

Gravitational
Matter

Convergent [Attractive]
Gravity Field

The observed net convergent force between
objects of mass-Matter are the result of
convergent G & interactive EM fields

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vacuum impedance $Z = \frac{1}{c^2} = \varepsilon_0 \mu_0$ electric permittivity, magnetic permeability

mass-energy density

$G_\rho = \kappa \frac{\rho}{c^4}$

spatial region

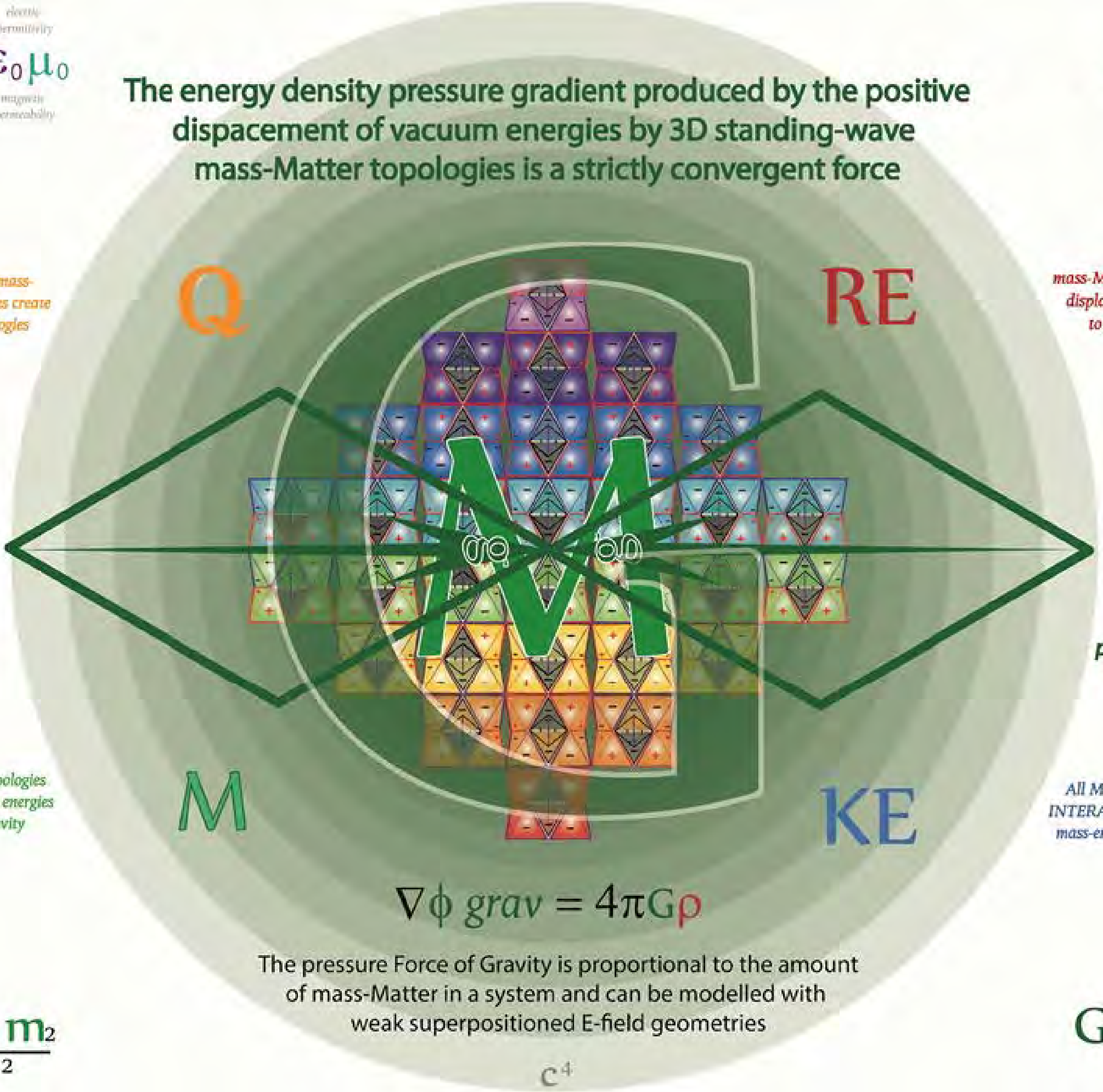

The energy density pressure gradient produced by the positive dispacement of vacuum energies by 3D standing-wave mass-Matter topologies is a strictly convergent force

$P = \frac{kT}{V}$

mass-Matter-Vacuum energy displacements contributes to STRESS energies

CHARGED mass-energy geometries create Matter topologies

M

All Matter is gravitationally ATTRACTIVE

m

Gravity fields produce a convergent inverse square force

mass-Matter topologies displace vacuum energies to create gravity

All Matter radiates INTERACTIVE [k]EM mass-energy momenta

$$\nabla \phi \; grav = 4\pi G \rho$$

The pressure Force of Gravity is proportional to the amount of mass-Matter in a system and can be modelled with weak superpositioned E-field geometries

c^4

$$F = -G \frac{M_1 m_2}{r^2}$$

$$G = \frac{8\pi G \, T_{\mu\nu}}{c^4}$$

Tetryonics 71.05 - Newton's Gravity Fields

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Inverse squared interactive E-fields

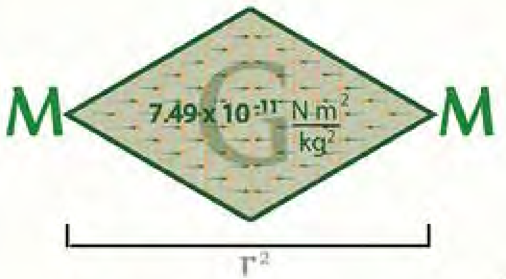
M
$7.49 \times 10^{-11} \frac{N\,m^2}{kg^2}$
G
M
r^2

wherever mass-energies create standing-wave topologies they also create Gravity

Although present, the Gravitational Attraction between quantum scale Matter particles is vastly overwhelmed by the Coulombic Interaction field resulting from the nett Charge Imbalances of Matter and its fields of motion

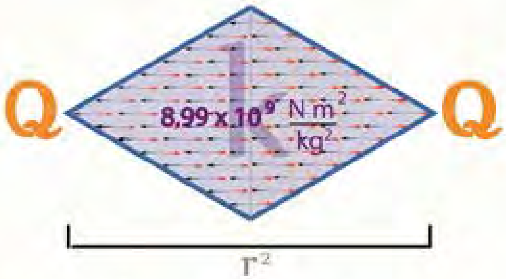
Q
$8.99 \times 10^{9} \frac{N\,m^2}{kg^2}$
k
Q
r^2

wherever there exists mass-energy imbalances energy will seek equilibirum via radiant EM fields

Protons have Stronger G fields than electrons but weaker [k]EM fields

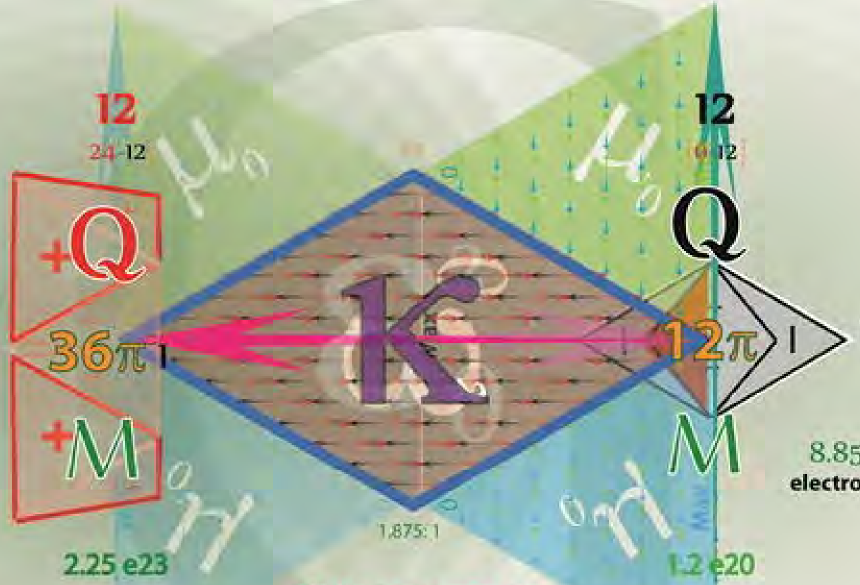
12
24-12
μ_0
+Q
P+
36π
+M
ε_0
2.25 e23
K
1.875: 1
12
0 12
μ_0
Q
12π
e-
M
ε_0
1.2 e20

electrons have Weaker G fields than Protons but stronger [k]EM fields

1.6596×10^{-27} KG
proton mass-Matter

8.8514×10^{-31} KG
electron mass-Matter

All Matter in motion create inverse squared forces due to their divergent [K]EM fields

M

Matter 36π topology * mass-energy 25n² geometry

KEM

superpositioned kEM fields create forces of attraction & repulsion

Gravity creates a strictly convergent force of attraction

G

c^4

Matter 12π topology * mass-energy 1n² geometry

[k]EM

mass-Matter topologies displace vacuum energies to form convergent gravity

Equilateral [k]EM mass-energies contribute to the total stress energies of any region

vacuum impedance

electric permittivity $\varepsilon_0 = \frac{1}{c^2 \mu_0}$ magnetic permeability

$\varepsilon_0 = 8.8541878176\,e^{-12}$ F/m

Vacuum Permittivity

The Electric fields produced by Matter produce interactive nett divergent forces

Opposites ATTRACT
Similars REPEL

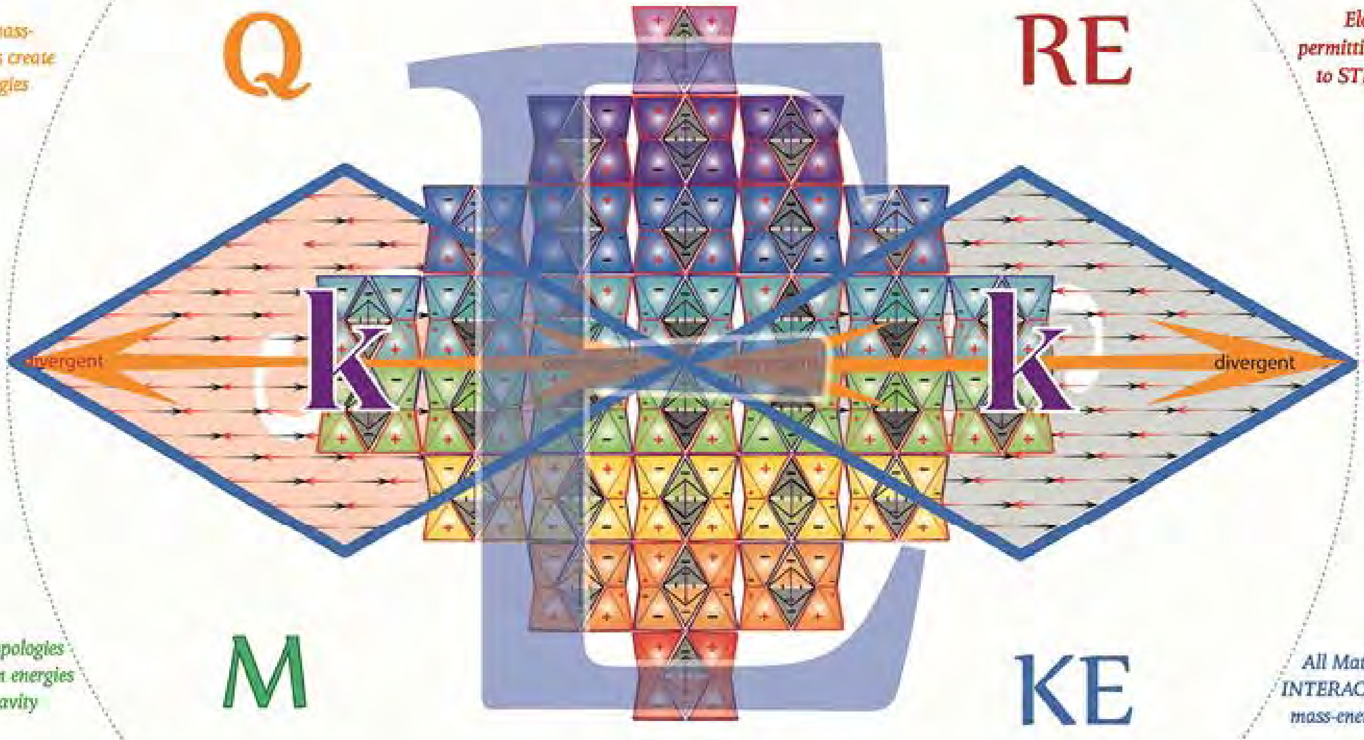

CHARGED mass-energy geometries create Matter topologies

$P = \frac{kT}{V}$

Electric field permittivity contributes to STRESS energies

All Electric fields are nett divergent charge geometries >

< Electric fields follow the inverse square law

mass-Matter topologies displace vacuum energies to create gravity

All Matter radiates INTERACTIVE [k]EM mass-energy momenta

Equal opposing E-field energy-momenta create electrostatic fields around Matter [that produce Lorentz forces]

electric permittivity

vacuum impedance $Z = \frac{1}{c^2} = \varepsilon_0 \mu_0$

magnetic permeability

c^2

electric permittivity of a spatial region

$$4\pi \frac{1}{c^2 \mu_0} \left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}} \overset{\text{quanta}}{\Omega} \underset{\text{velocity}}{v^2} \right] \right]$$

Perturbative M-forces

ElectroMagnetism is a velocity dependent vector interaction that dominates the Gravitational attraction of Matter

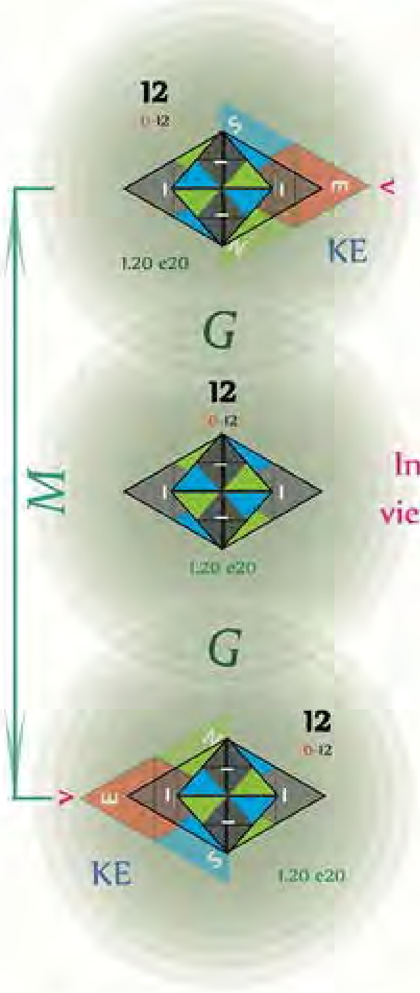

Inertial viewpoint

EM

Maxwells ElectroMagnetism

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \times \mathbf{B} = \frac{1}{\epsilon_0 c^2}\mathbf{J} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}$$

[k]EM fields have electric and magnetic field components

The Tetryonic GEM model reveals the interplay of Convergent [Gravity], interactive [E-fields] & perturbative [M-field] forces

Gravitational Matter is ALWAYS attractive vectorial ElectroMagnetic fields are interactive

Gravity can be modelled with pseudo-electric and pseudo-magnetic field components

GravitoElectroMagnetism

$$\nabla \cdot \mathbf{E}_g = -4\pi G \rho_g$$

$$\nabla \cdot \mathbf{B}_g = 0$$

$$\nabla \times \mathbf{E}_g = -\frac{\partial \mathbf{B}_g}{\partial t}$$

$$\nabla \times \mathbf{B}_g = -\frac{4\pi G}{c^2}\mathbf{J}_g + \frac{1}{c^2}\frac{\partial \mathbf{E}_g}{\partial t}$$

G

Inertial viewpoint

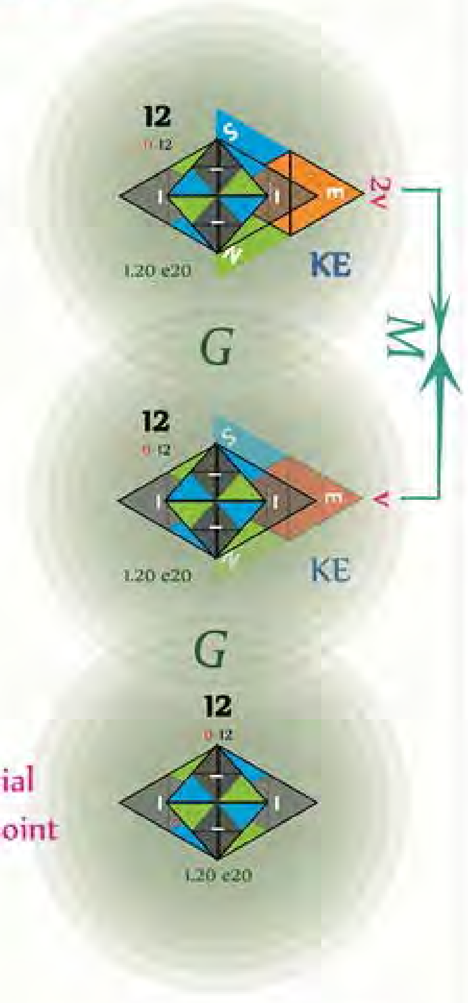

The sign of the effect is different (attraction in one case, repulsion in another), but this is just because in electromagnetism the sign of the electric part of the acceleration is opposite that of gravity; electric charges of the same type repel each other, while in gravity two massive objects attract.

Apart from this sign, there is such a close analogy to magnetism that this velocity-dependent gravitational effect is often termed Gravito-magnetism

The Gravitational forces on the central particle are always equal irrespective of the inertial viewpoints

The ElectroMagnetic forces resulting from inertial motion in a different frame of reference produces different KINETIC [EM] forces

Tetryonics 71.08 - Perturbative M-Force

vacuum impedance

magnetic permeability $\mu_0 = \frac{1}{c^2 \varepsilon_0}$ *electric permittivity*

The Magnetic fields of Matter produce perturbative interactions

$\mu_0 = 1.2566370614\ e^{-12}$ N/A^2

Vacuum Permeability

$P = \frac{kT}{V}$

Magnetic field permeability contributes to STRESS energies

CHARGED mass-energy geometries create Matter topologies

Q

RE

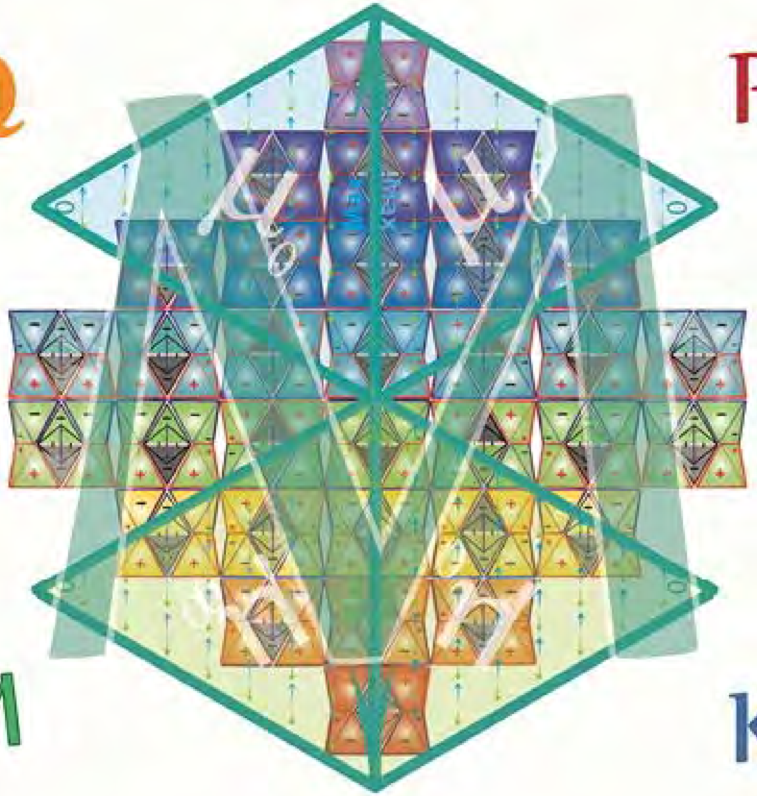

Magnetic dipoles follow the inverse cubed law

Magnetic fields follow the inverse square law

M

KE

mass-Matter topologies displace vacuum energies to create gravity

All Matter radiates INTERACTIVE [k]EM mass-energy momenta

Matter posesses a secondary magnetic moment that is subject to Lorentz forces

vacuum impedance $Z = \frac{1}{c^2} = \varepsilon_0 \mu_0$ *electric permittivity* *magnetic permeability*

c^2

magnetic permeability of a spatial region

$4\pi \frac{1}{c^2 \varepsilon_0} \left[\left[m \Omega v^2 \right] \right]$

Planck quanta

mass velocity

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Gravitational & EM fields

Any unified Field equation that attempts to accurately model celestial scale gravitational attraction must also take into account KEM field interactions between the bodies resulting from their respective motions

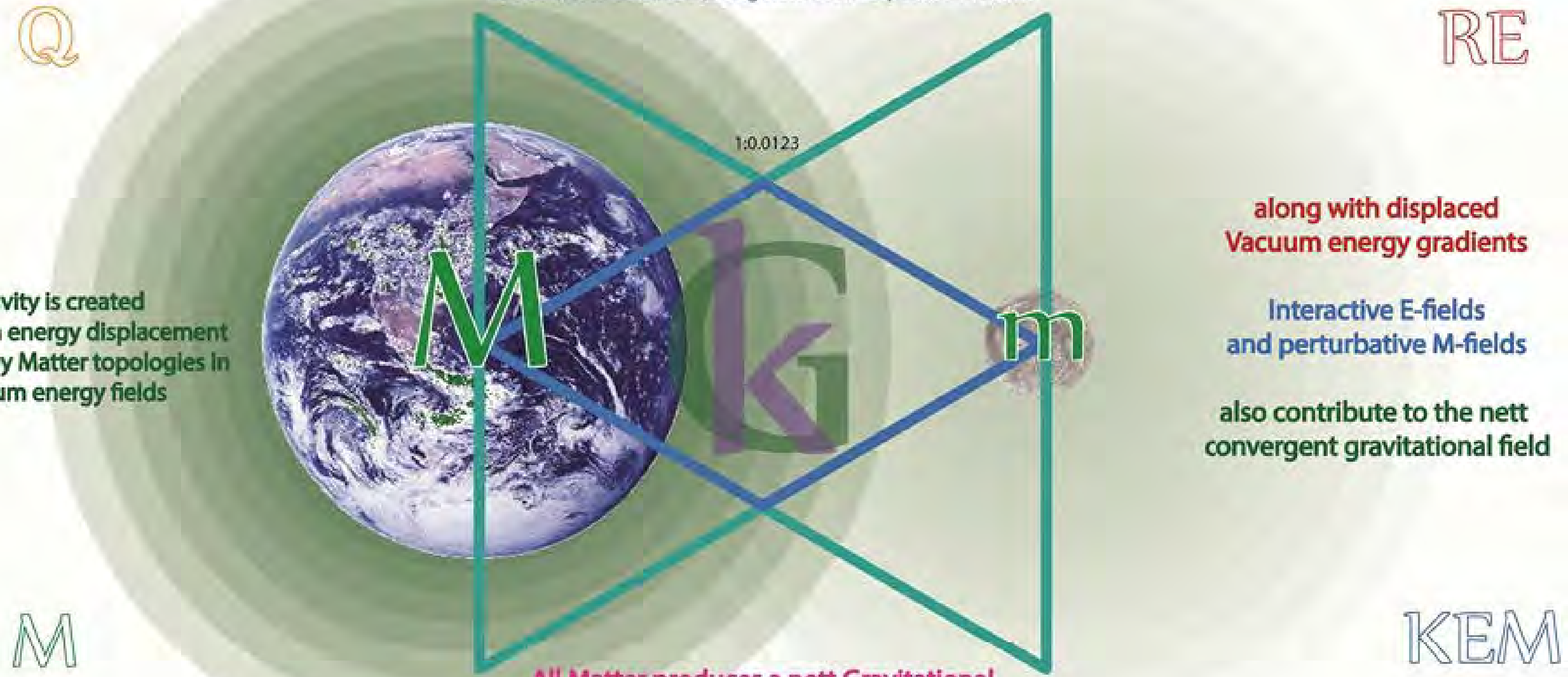

Gravity is created by vacuum energy displacement produced by Matter topologies in vacuum energy fields

along with displaced Vacuum energy gradients

Interactive E-fields and perturbative M-fields

also contribute to the nett convergent gravitational field

All Matter produces a nett Gravitational [convergent] force as a direct result of its mass-Matter topologies & KEM mass-energies

mass-Matter
5.9736×10^{24} KG

mass-Matter
7.3477×10^{22} KG

interactive KEM field mass-energy momenta

$$\text{Earth}\;\left[\frac{\overset{\text{Matter}}{4n\pi}}{c^4}\overset{\text{Energy}}{\underset{\text{mass}}{[\rho]}}+\left[2n\pi\frac{\overset{\text{EM mass}}{[\rho]}}{c^2}\;\;K\;\;2n\pi\frac{\overset{\text{EM mass}}{[\rho]}}{c^2}\right]+\frac{\overset{\text{Matter}}{4n\pi}}{c^4}\overset{\text{Energy}}{\underset{\text{mass}}{[\rho]}}\right]\;\text{moon}$$

2.8673e26 π
displacement topology

3.526e24 π
displacement topology

$$r^2$$

Gravitational gradients can be modelled as weak KEM fields

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Independently and almost simultaneously in1964 three groups of physicists proposed the proposed the Higgs mechanism thorugh which the inertial mass properties of Matter are created:
François Englert and Robert Brout; by Peter Higgs (inspired by ideas of Philip Anderson); and by Gerald Guralnik, C. R. Hagen, and Tom Kibble.

CERN
Higgs search update

The Higgs mechanism was incorporated into modern particle physics

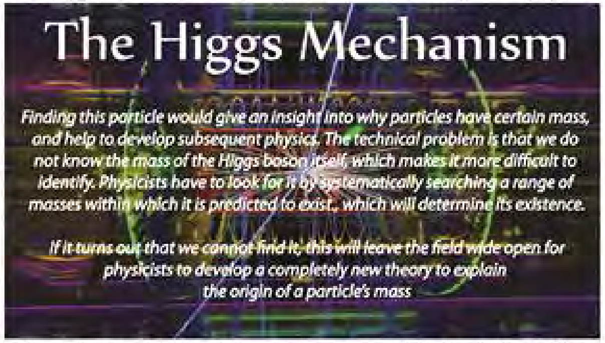

The Higgs Mechanism

Finding this particle would give an insight into why particles have certain mass, and help to develop subsequent physics. The technical problem is that we do not know the mass of the Higgs boson itself, which makes it more difficult to identify. Physicists have to look for it by systematically searching a range of masses within which it is predicted to exist, which will determine its existence.

If it turns out that we cannot find it, this will leave the field wide open for physicists to develop a completely new theory to explain the origin of a particle's mass

by Steven Weinberg and Abdus Salam, and is an essential part of the standard model.

As the Universe cooled and the temperature fell below a critical value, an invisible force field called the 'Higgs field' was formed together with the associated 'Higgs boson'

The Higgs mechanism is a process by which vector bosons can obtain mass

M

TETRYONS / FERMIONS / BARYONS
3D tetrahedral standing-waves
[4nπ EM mass-Matter topologies]
interact with the vacuum energy aether

Matter

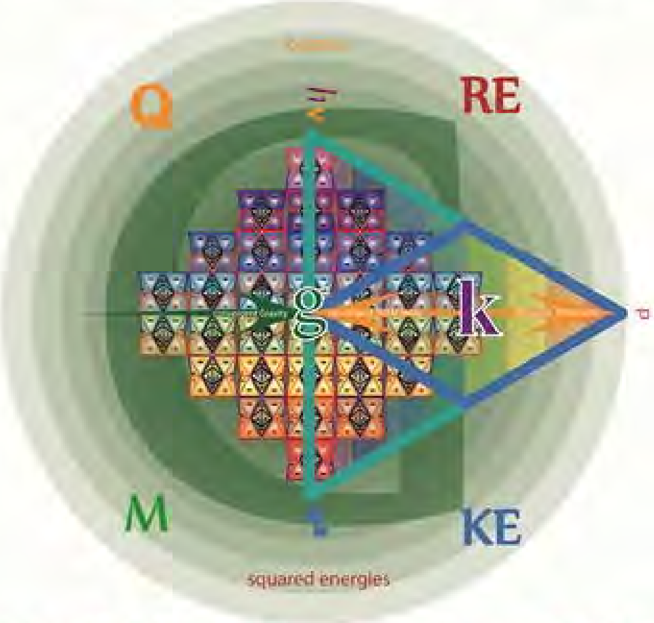

m

BOSONS / PHOTONS
2D planar matterless fields
[nπ EM mass-energy geometries]
'slice' through the vacuum energy aether

EM masses

Tetryonics is a full relativistic unified theory of electromagnetic mass-ENERGY & Matter and motion in which the classical properties of inerital mass and quantum mechanical quantised energy momenta are explained as being direct result of the geometric properties of inductive equilateral energies moving through external electromagnetic fields

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Applying the Unified Field Equation

for ElectroMagnetic masses & Matter interactions

All Matter has a
4π standing-wave
mass-energy topology

Matter topologies

$$G_{ab} = 8\pi G T_{\mu\nu}$$

The net gravitational force is the geometric mean of all EM mass-ENERGY-Matter interactions

All kEM waves have
4π superpositioned
mass-energy geometries

mass-ENERGY geometries

$$-G\frac{M_1 m_2}{r^2} = F$$

$$F = k\frac{Q_1 Q_2}{r^2}$$

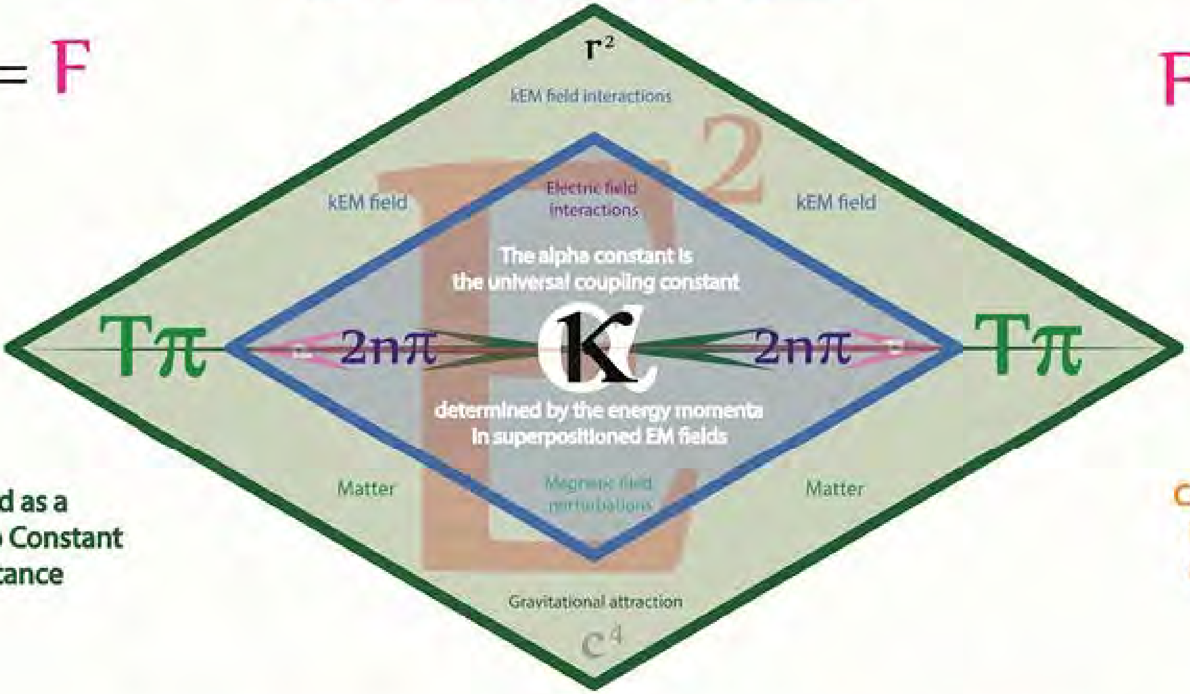
r^2
kEM field interactions
kEM field
Electric field interactions
kEM field
The alpha constant is the universal coupling constant
$T\pi$
$2n\pi$
α
$2n\pi$
$T\pi$
determined by the energy momenta in superpositioned EM fields
Matter
Magnetic field perturbations
Matter
Gravitational attraction
c^4
E^2

G

k

Gravity can be modelled as a reduced negative Coloumb Constant acting over a large distance

Coloumb's Constant is a large interactive Electric constant acting over a short distance

Tetryons - 4π
Leptons - 12π
Quarks - 12π
Mesons - 24π
Baryons - 36π

Charges - 1π

Photons -2π

EM Fields - 2nπ

Ignoring interactive [k]EM field interactions reduces GR [k] to Newtonian [G]

$$G_{ab} = 4\pi G T_{\mu\nu}$$

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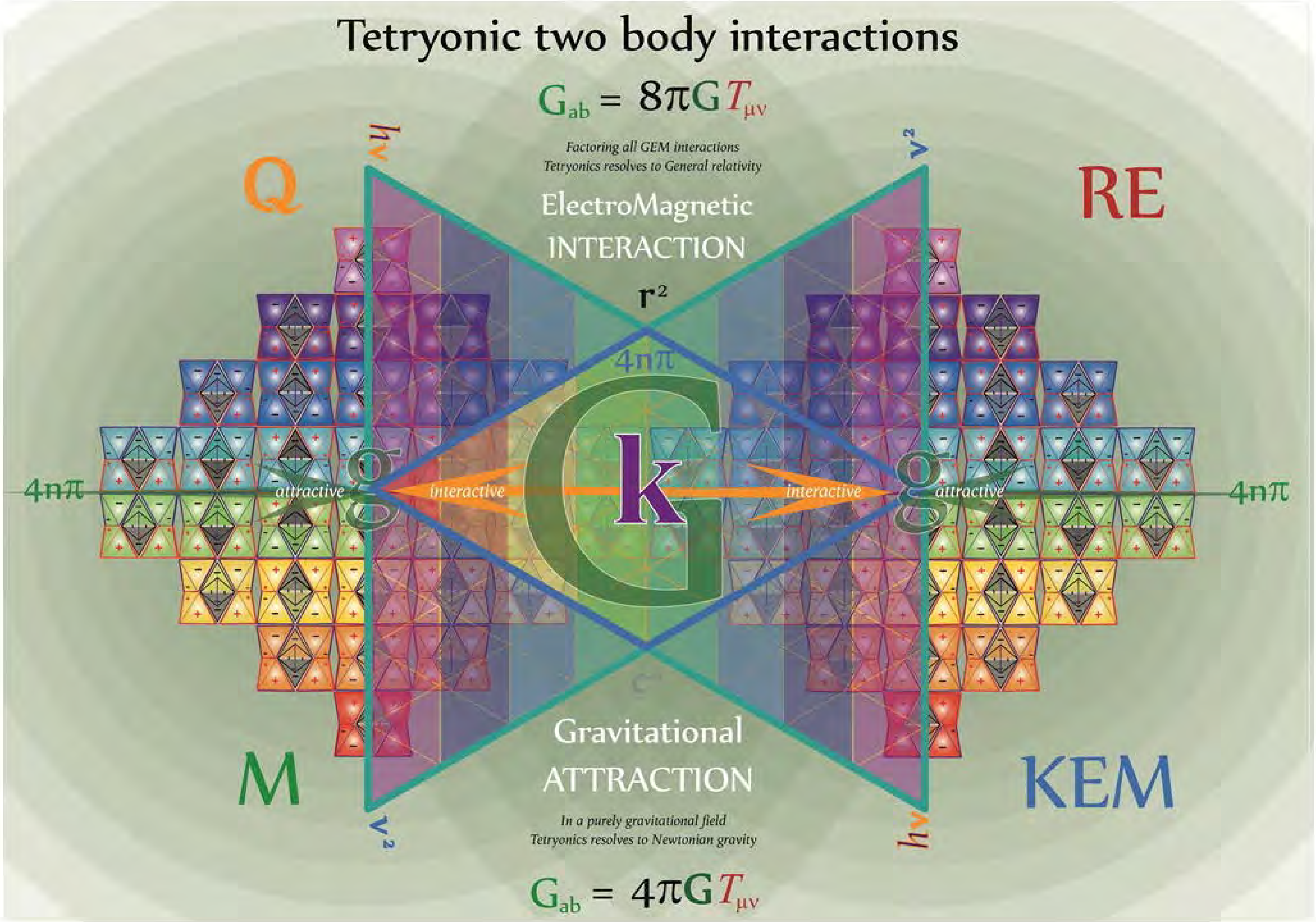

Tetryonic two body interactions

$$G_{ab} = 8\pi G T_{\mu\nu}$$

Factoring all GEM interactions
Tetryonics resolves to General relativity

ElectroMagnetic
INTERACTION

Gravitational
ATTRACTION

In a purely gravitational field
Tetryonics resolves to Newtonian gravity

$$G_{ab} = 4\pi G T_{\mu\nu}$$

Q
RE
M
KEM
hv
v²
v²
hv
r²
4nπ
4nπ
4nπ
attractive
interactive
interactive
attractive
g
g
G
k
c²

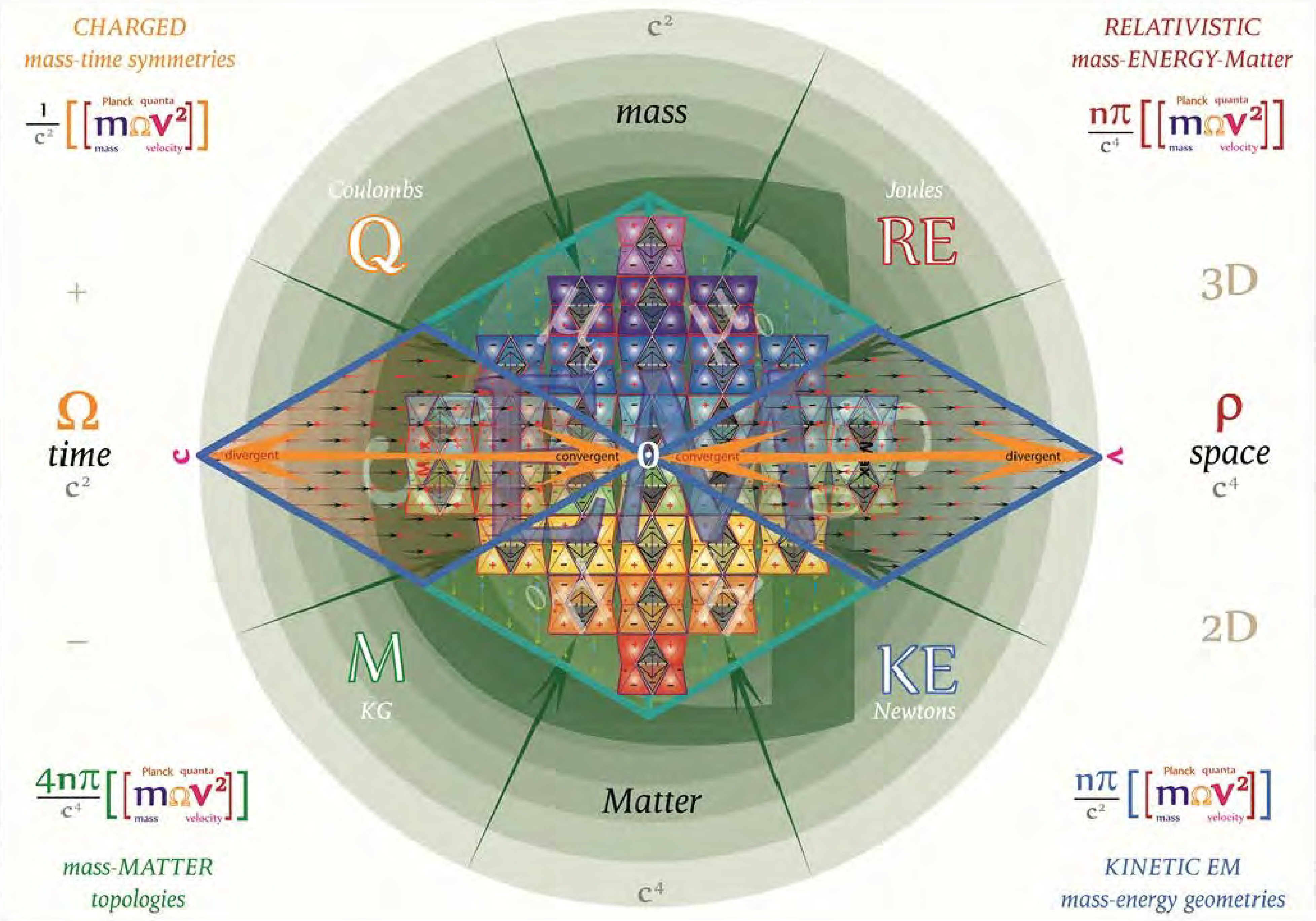

CHARGED
mass-time symmetries

$$\frac{1}{c^2}\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

RELATIVISTIC
mass-ENERGY-Matter

$$\frac{n\pi}{c^4}\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

+

Ω
time
c^2

—

3D

ρ
space
c^4

2D

$$\frac{4n\pi}{c^4}\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

mass-MATTER
topologies

$$\frac{n\pi}{c^2}\left[\left[\underset{\text{mass}}{\overset{\text{Planck}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

KINETIC EM
mass-energy geometries

c^2
mass
Coulombs
Q
Joules
RE
c
divergent
convergent
0
convergent
divergent
v
M
KG
KE
Newtons
Matter
c^4

Tetryonics 71.14 - Quantum GEM space-time fields

Our EM SUN

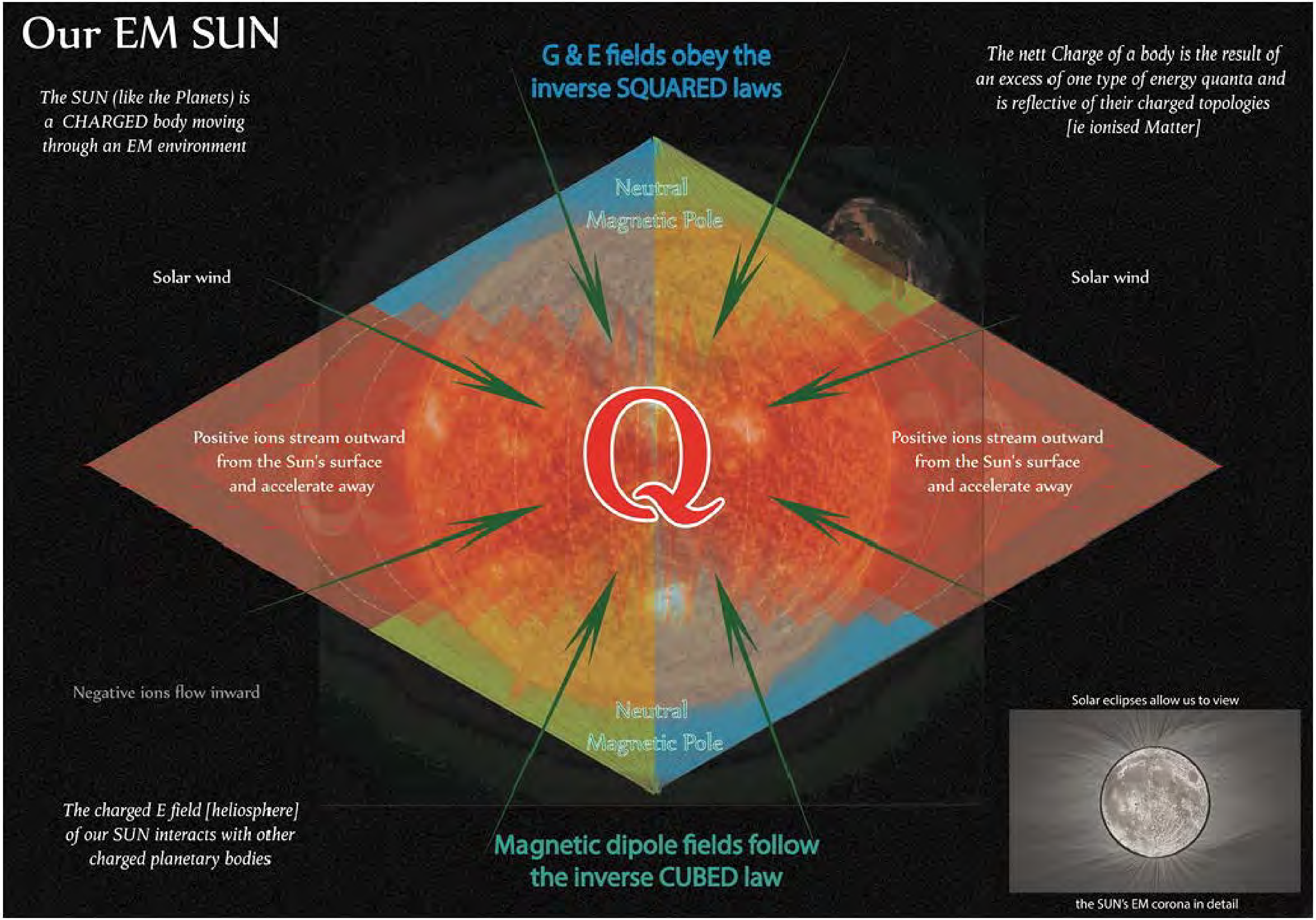

The SUN (like the Planets) is a CHARGED body moving through an EM environment

G & E fields obey the inverse SQUARED laws

The nett Charge of a body is the result of an excess of one type of energy quanta and is reflective of their charged topologies [ie ionised Matter]

Solar wind
Solar wind
Neutral Magnetic Pole
Positive ions stream outward from the Sun's surface and accelerate away
Q
Positive ions stream outward from the Sun's surface and accelerate away
Negative ions flow inward
Neutral Magnetic Pole

The charged E field [heliosphere] of our SUN interacts with other charged planetary bodies

Magnetic dipole fields follow the inverse CUBED law

Solar eclipses allow us to view the SUN's EM corona in detail

Solar Dynamics

The SUN is a ElectroMagnetohydrodynamo

Prominences

Flares, Prominences and CMEs are the result of Electro-Magnetic geometries

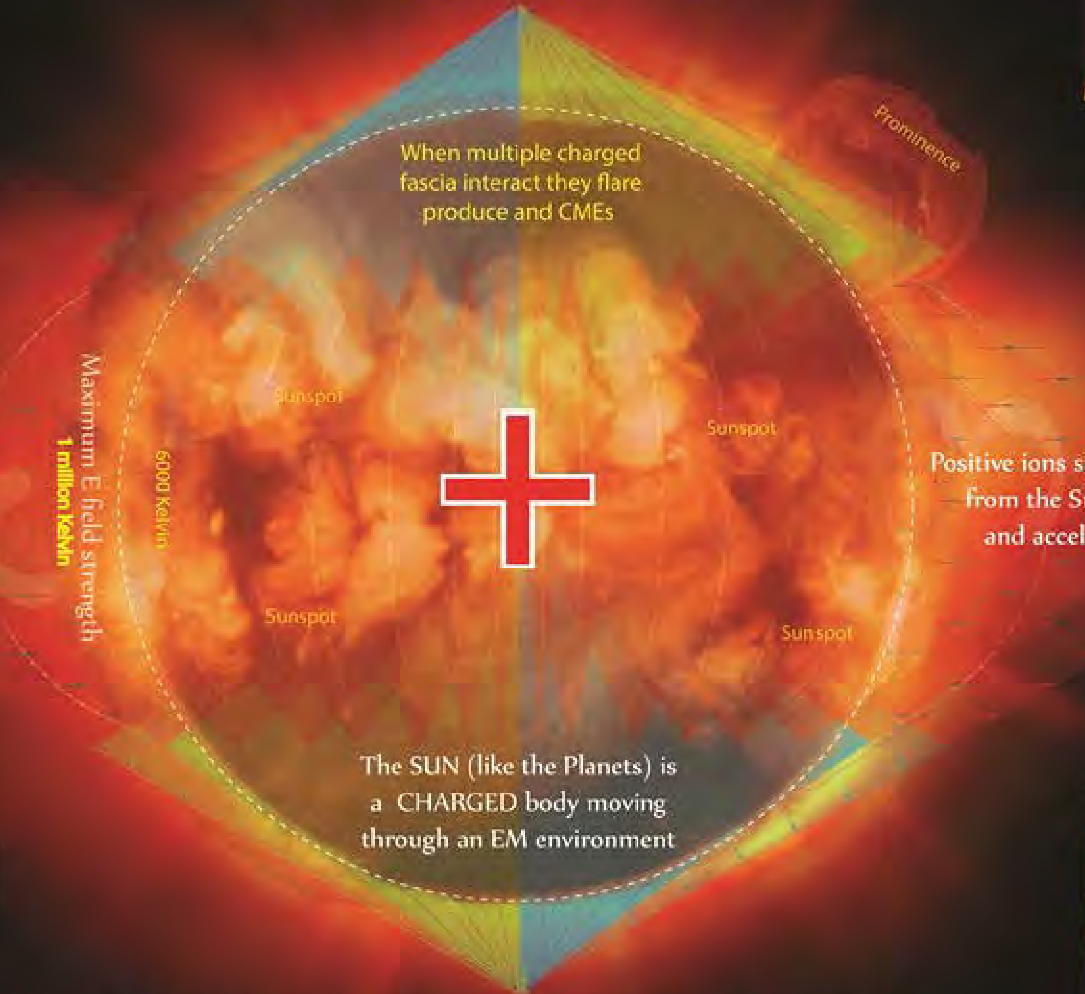

When multiple charged fascia interact they flare produce and CMEs

The SUN (like the Planets) is a CHARGED body moving through an EM environment

Sunspot
Sunspot

Tetryonic charge geometries explain Solar EM field dynamics

Positive ions stream outward from the Sun's surface and accelerate away

Where Solar EM loops breakdown or interact flares result

Solar Flares

The breaking of large inductive EM loops creates CMEs [Coronal Matter Ejections]

CMEs

The Earth is located at an average distance of about 150 million kilometers [1AU] from the Sun
It takes sunlight travelling at the speed of Light [c] about 8.3 minutes to cross this distance and reach the Earth.

BUT due to the nature of Longitudinal waves emitted by the SUN mechanical momenta impulses [action-at-a-distance] can be transfered from the SUN to the planets nearly instantanteously providing the mechanism for Newton's instataneous pull of Gravity on planetary bodies

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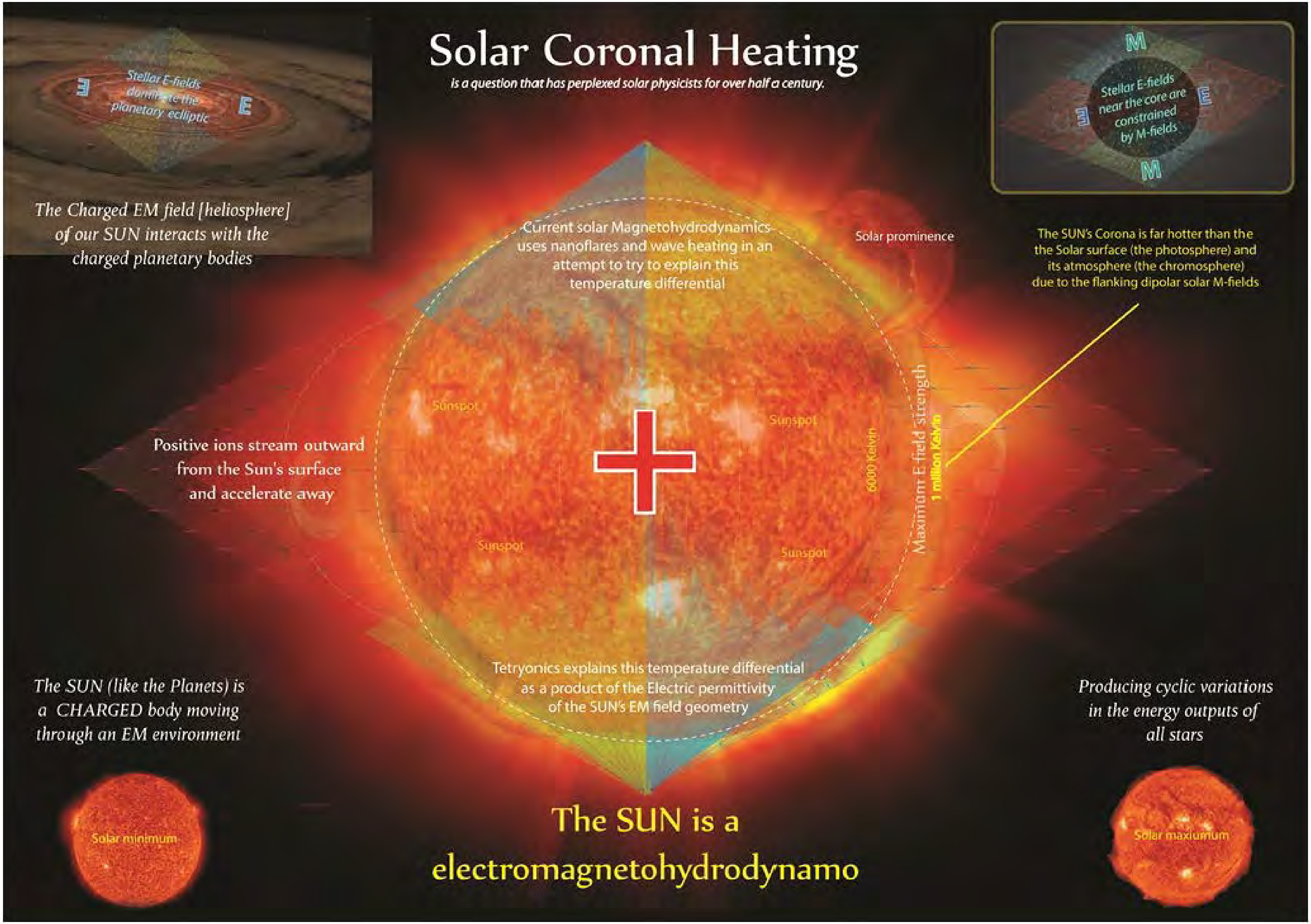
Stellar E-fields dominate the planetary ecliptic
E
E
Stellar E-fields near the core are constrained by M-fields
M
M
E
E
Solar prominence
Sunspot
Sunspot
Sunspot
Sunspot
6000 Kelvin
Maximum E-field strength
1 million Kelvin
Solar minimum
Solar maxiumum

Solar Coronal Heating

is a question that has perplexed solar physicists for over half a century.

The Charged EM field [heliosphere] of our SUN interacts with the charged planetary bodies

Current solar Magnetohydrodynamics uses nanoflares and wave heating in an attempt to try to explain this temperature differential

The SUN's Corona is far hotter than the the Solar surface (the photosphere) and its atmosphere (the chromosphere) due to the flanking dipolar solar M-fields

Positive ions stream outward from the Sun's surface and accelerate away

Tetryonics explains this temperature differential as a product of the Electric permittivity of the SUN's EM field geometry

The SUN (like the Planets) is a CHARGED body moving through an EM environment

Producing cyclic variations in the energy outputs of all stars

The SUN is a electromagnetohydrodynamo

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Solar cycles

On an 11 year cycle, the shape of the corona oscillates from a wide crown about the Sun's equator to a completely closed envelope surrounding the Sun

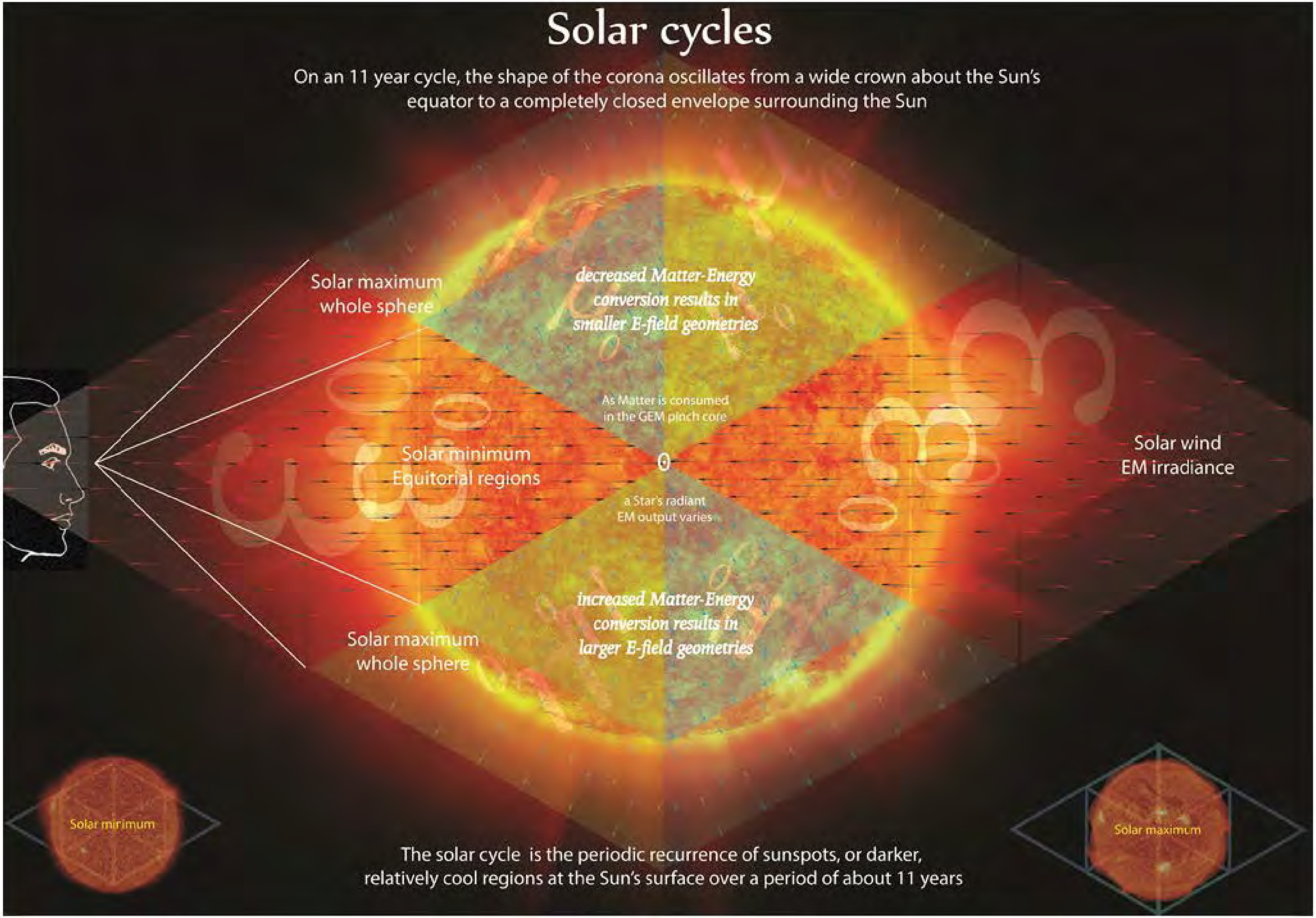

Solar maximum
whole sphere

decreased Matter-Energy
conversion results in
smaller E-field geometries

As Matter is consumed
in the GEM pinch core

Solar minimum
Equitorial regions

0

Solar wind
EM irradiance

a Star's radiant
EM output varies

increased Matter-Energy
conversion results in
larger E-field geometries

Solar maximum
whole sphere

Solar minimum

Solar maximum

The solar cycle is the periodic recurrence of sunspots, or darker, relatively cool regions at the Sun's surface over a period of about 11 years

Tetryonics 72.04 - Solar cycles

Sunspot cycles

This is a question that has perplexed solar physicists for over half a century.

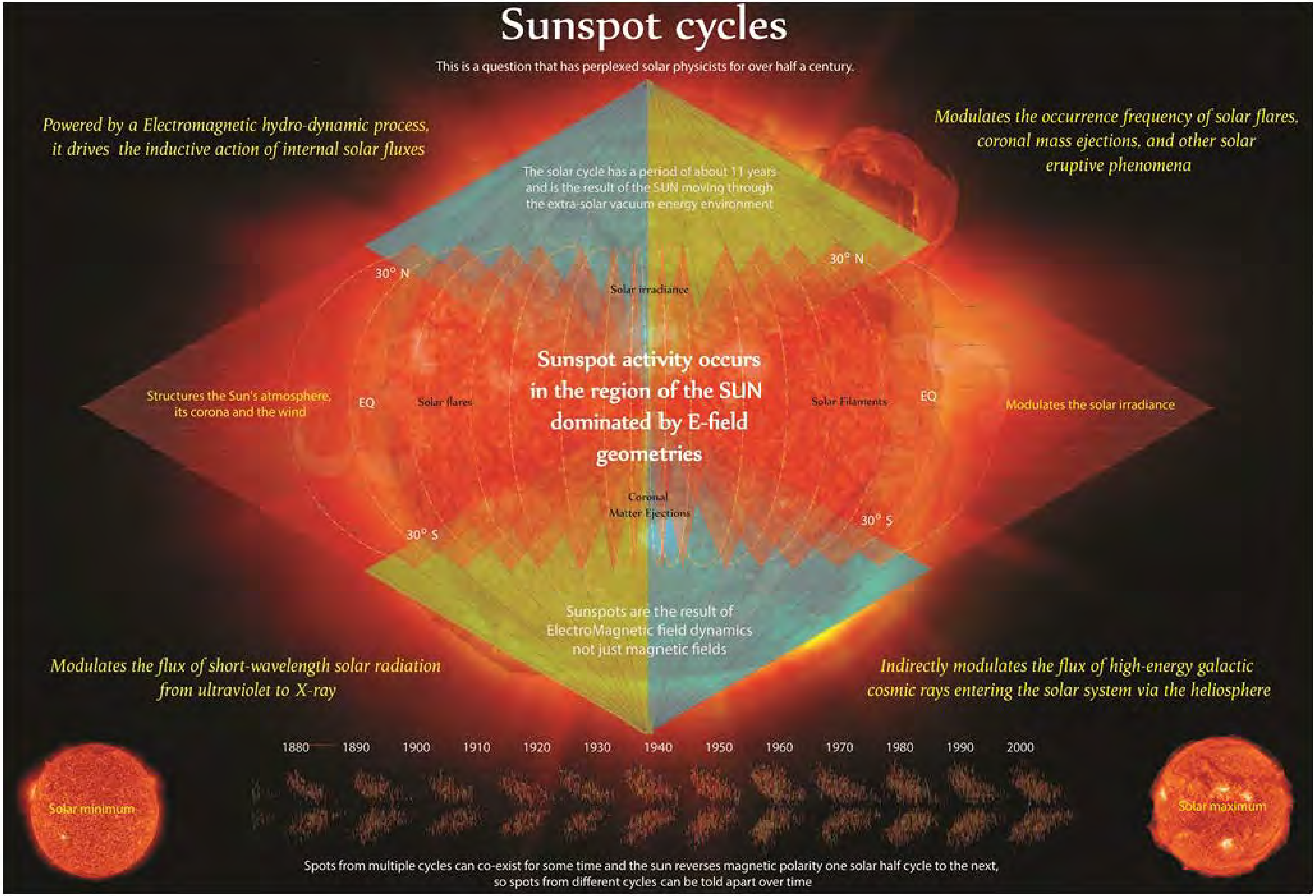

Powered by a Electromagnetic hydro-dynamic process, it drives the inductive action of internal solar fluxes

Modulates the occurrence frequency of solar flares, coronal mass ejections, and other solar eruptive phenomena

The solar cycle has a period of about 11 years and is the result of the SUN moving through the extra-solar vacuum energy environment

Structures the Sun's atmosphere, its corona and the wind

Sunspot activity occurs in the region of the SUN dominated by E-field geometries

Modulates the solar irradiance

Sunspots are the result of ElectroMagnetic field dynamics not just magnetic fields

Modulates the flux of short-wavelength solar radiation from ultraviolet to X-ray

Indirectly modulates the flux of high-energy galactic cosmic rays entering the solar system via the heliosphere

30° N
30° N
Solar irradiance
EQ
Solar flares
Solar Filaments
EQ
Coronal Matter Ejections
30° S
30° S
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Solar minimum
Solar maximum

Spots from multiple cycles can co-exist for some time and the sun reverses magnetic polarity one solar half cycle to the next, so spots from different cycles can be told apart over time

Tetryonics 72.05 - Sunspot cycles

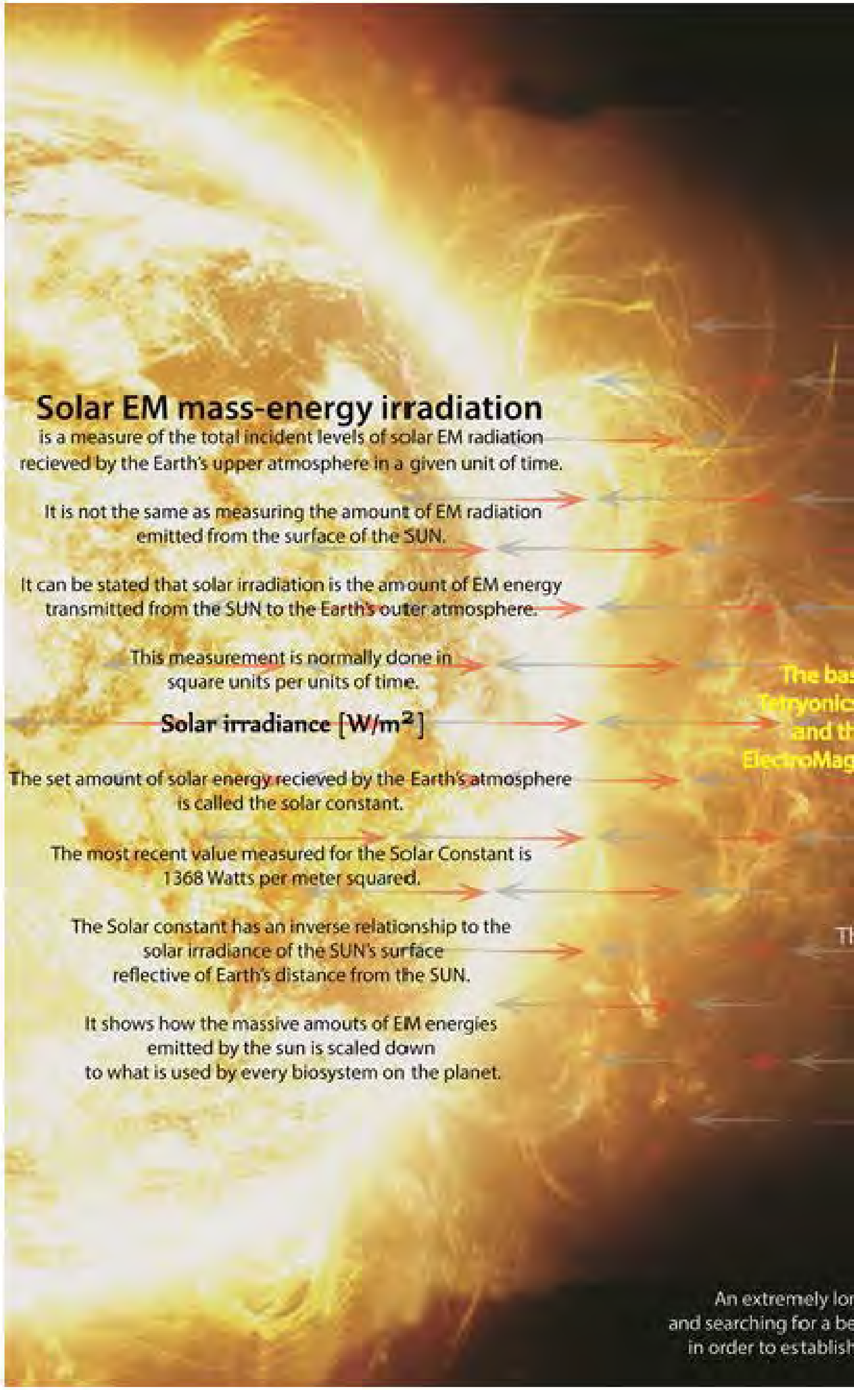

Solar irradiance

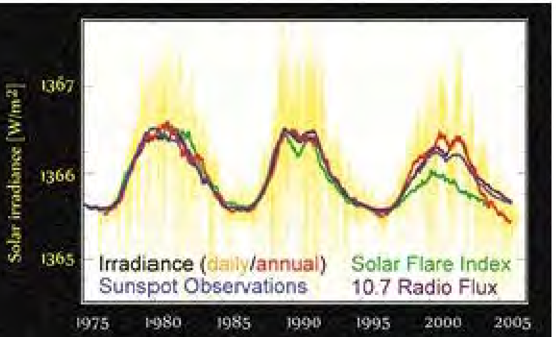

The SUN is an ElectroMagnetic pinch reactor

The total solar irradiance (TSI) is
the amount of solar radiative energy
incident on the Earth's upper atmosphere

Solar EM mass-energy irradiation

is a measure of the total incident levels of solar EM radiation
recieved by the Earth's upper atmosphere in a given unit of time.

It is not the same as measuring the amount of EM radiation
emitted from the surface of the SUN.

It can be stated that solar irradiation is the amount of EM energy
transmitted from the SUN to the Earth's outer atmosphere.

This measurement is normally done in
square units per units of time.

Solar irradiance [W/m^2]

The set amount of solar energy recieved by the Earth's atmosphere
is called the solar constant.

The most recent value measured for the Solar Constant is
1368 Watts per meter squared.

The Solar constant has an inverse relationship to the
solar irradiance of the SUN's surface
reflective of Earth's distance from the SUN.

It shows how the massive amouts of EM energies
emitted by the sun is scaled down
to what is used by every biosystem on the planet.

The Sun emits longitudinal EM radiation across
most of the electromagnetic spectrum.

**The basic causes of the solar variability and solar cycles are still under debate,
Tetryonics dictates a EM mechanism for the energies produced at the core of Stars
and that the variability of the stellar outputs may be due to changes in the
ElectroMagnetic environment that Stars [and their planetary systems] move through**

The spectrum of the Sun's solar radiation is close to that of a
black body with a temperature of about 5,800 K.

Changes in the SUN's EM output
can have a direct effect on the
weather and electrical activity
of the Earth and other planets

Solar irradiation produces Carbon 14

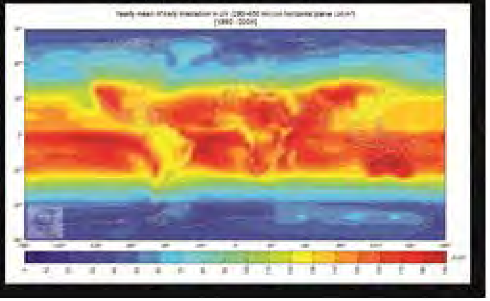

An extremely long stretch of low activity in recent years has left scientists baffled
and searching for a better model of the SUN's interal processes and how to forcast its output
in order to establish a better link between the solar cycle and global climate flucuations

Stellar refraction of EM waves

Any test of General Relativity using photons (or EM waves) will only measure SR interactions
[ie Gravitational red-shifting is a SR effect on EM masses not graviational Matter]

G

The motion of Matter is affected by gravitational attraction and EM interactions

Photons are NOT 'bent' by Gravitational fields they are refracted by propagation velocity changes resulting from their EM interactions with the solar corona

$$\alpha[\text{einstein}] = \frac{8\pi GM}{c^2}$$

EM

The motion of EM masses is affected by EM interactions and creates refraction

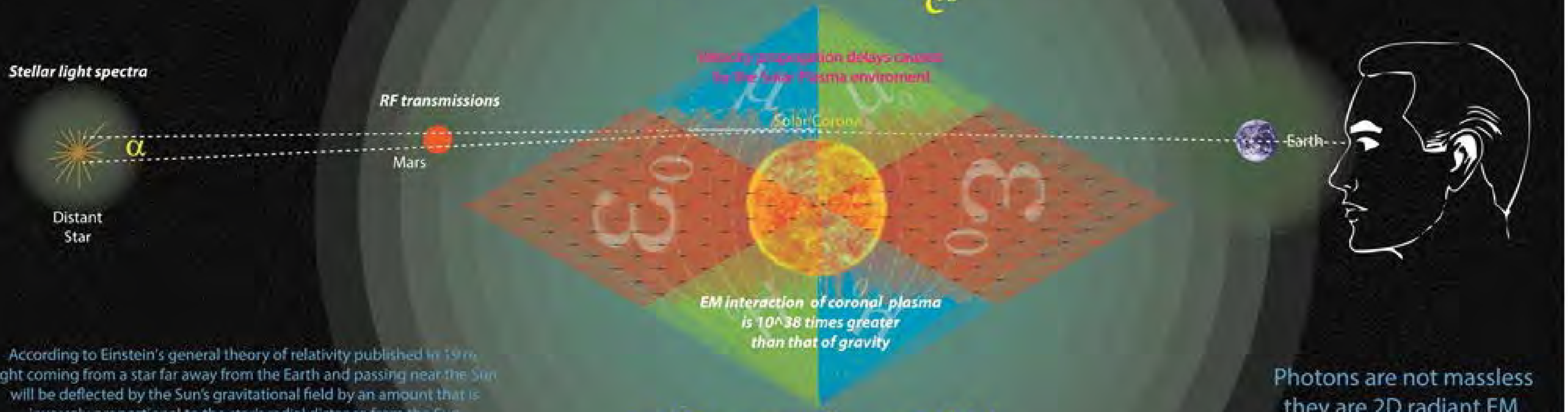
Stellar light spectra
α
Distant Star
RF transmissions
Mars
Velocity propagation delays caused by the Solar Plasma environment
μ
ω
Solar Corona
ε
Earth
EM interaction of coronal plasma is 10^38 times greater than that of gravity

According to Einstein's general theory of relativity published in 1916 light coming from a star far away from the Earth and passing near the Sun will be deflected by the Sun's gravitational field by an amount that is inversely proportional to the star's radial distance from the Sun

1.745" at the Sun's limb
(this is the result of EM refraction NOT Matter gravitation)

$$\alpha[\text{newton}] = \frac{4\pi GM}{r}$$

Photons are not massless they are 2D radiant EM mass-energy momenta geometries

r

The additional 'bending' of light rays as they pass by a Gravitational body as predicited in Einstein's general relativity is caused by refractive EM interactions not by the force of gravity

4π 4π

c^2

Gravitation in General relativity is Newton's Gravity with SR corrections

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The Solar Heliosphere

The planetary obits, often hypothesised as being created by the SUN's accreation disk during its formation and 'spun up' to their current orbital momenta can now be visualised as having been formed by the SUN's constant interactive Gravito-Electro-Magnetic fields

The eight planets (plus Pluto and all those other dwarf planets) orbit within a very small volume of the heliosphere (the volume of space dominated by the E field influence of the Sun)

Comets go around the Sun in a highly elliptical orbits.

They can spend hundreds and thousands of years out in the depths of the solar system before they return to the Sun at their perihelion

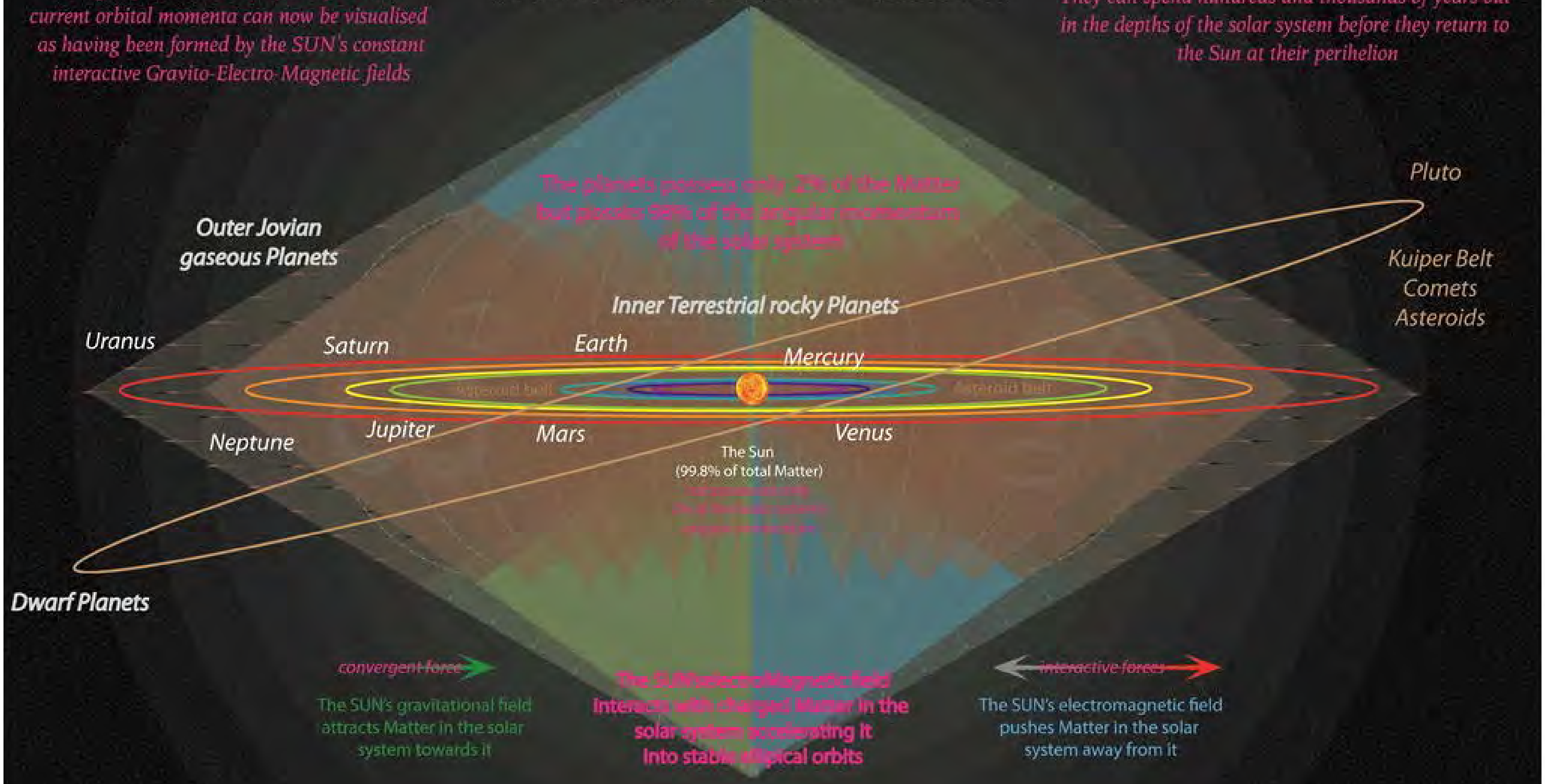
Pluto
Outer Jovian gaseous Planets
Kuiper Belt
Comets
Asteroids
Inner Terrestrial rocky Planets
Uranus
Saturn
Earth
Mercury
asteroid belt
Neptune
Jupiter
Mars
Venus
Dwarf Planets
convergent force
interactive forces

The planets possess only 2% of the Matter but posses 98% of the angular momentum of the solar system

The Sun
(99.8% of total Matter)

The SUN's gravitational field attracts Matter in the solar system towards it

The SUN's electroMagnetic field Interacts with charged Matter in the solar system accelerating it Into stable elliptical orbits

The SUN's electromagnetic field pushes Matter in the solar system away from it

The SUN is the Solar system's dominant charged electromagnetic mass-Matter body

Planetary Orbits are NOT to scale

Planetary solar Orbits, though technically ellipses, are nearly circular

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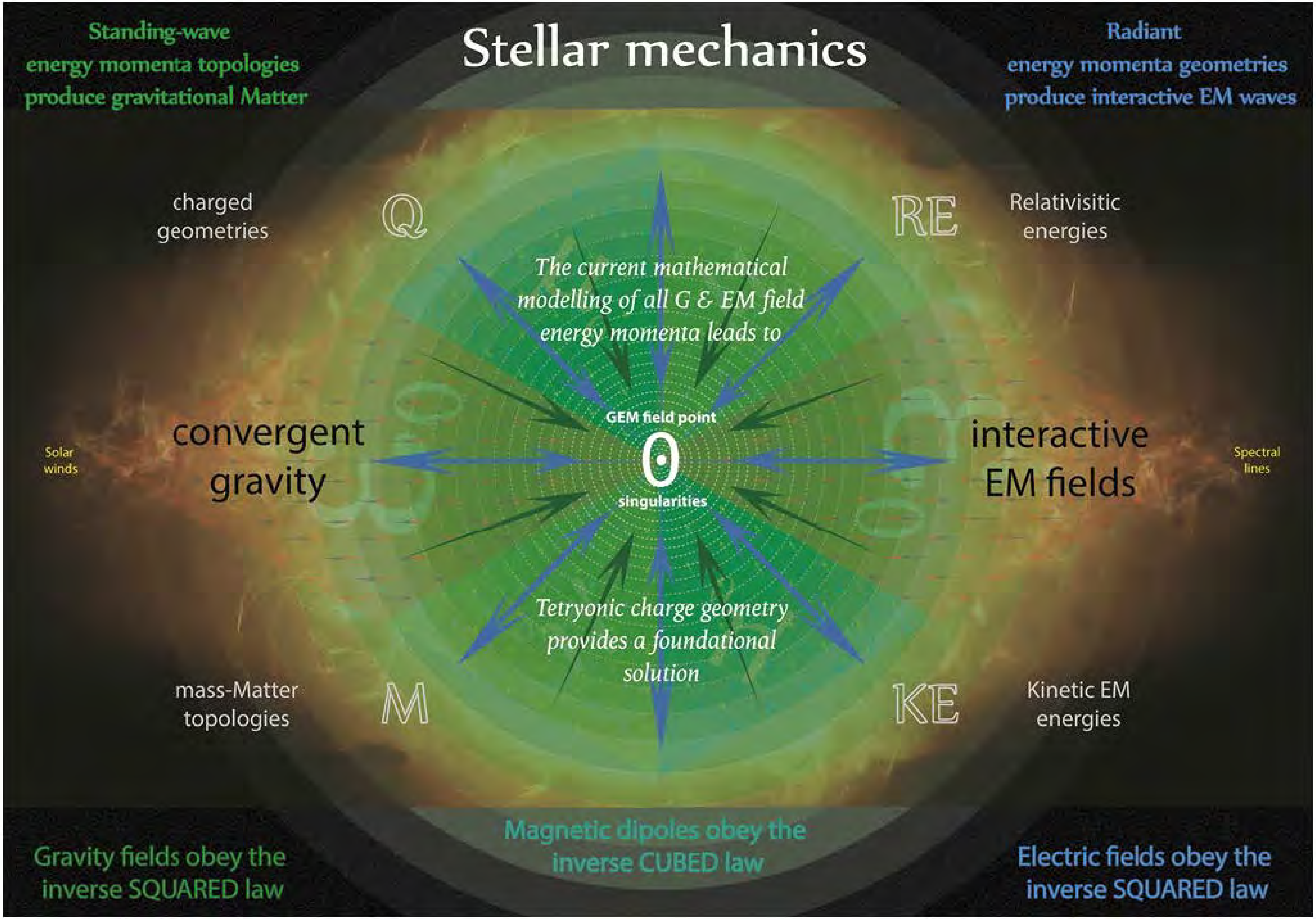

Stellar mechanics

Standing-wave
energy momenta topologies
produce gravitational Matter

Radiant
energy momenta geometries
produce interactive EM waves

charged
geometries

Q

RE

Relativisitic
energies

The current mathematical modelling of all G & EM field energy momenta leads to

GEM field point

0

singularities

Solar
winds

convergent
gravity

interactive
EM fields

Spectral
lines

Tetryonic charge geometry provides a foundational solution

mass-Matter
topologies

M

KE

Kinetic EM
energies

Gravity fields obey the
inverse SQUARED law

Magnetic dipoles obey the
inverse CUBED law

Electric fields obey the
inverse SQUARED law

Tetryonics 73.01 - Stellar mechanics

Anti-Matter Stars

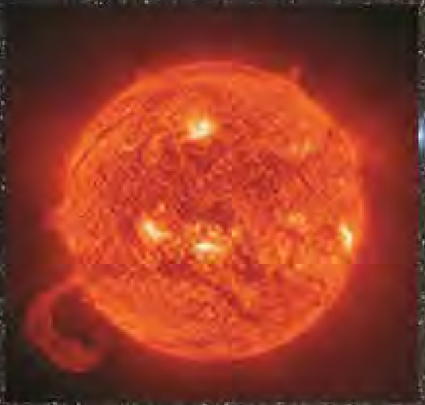

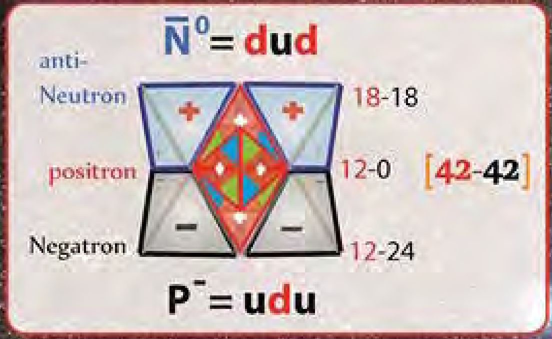
$\bar{N}^0$ = dud
anti-Neutron
18-18
positron
12-0
[42-42]
Negatron
12-24
P^- = udu

anti-Matter stars have
the opposite charge topology
to Matter stars

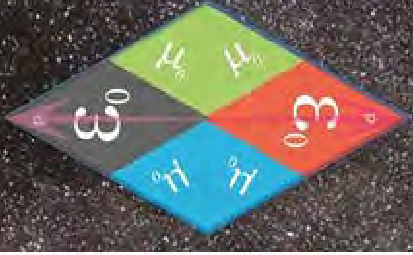
μ_0
μ_0
ε_0
ε_0
μ_0
μ_0

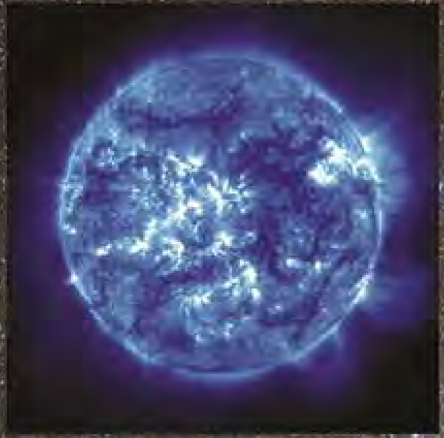

Neutron Stars

Colours used are illustrative of Matter types only

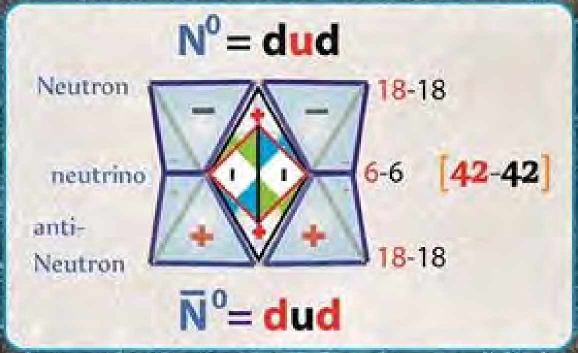
N^0 = dud
Neutron
18-18
neutrino
6-6
[42-42]
anti-Neutron
18-18
$\bar{N}^0$ = dud

All stars types emit Neutral Photons

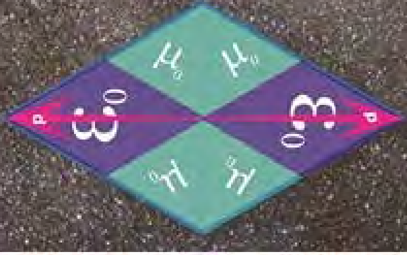
μ_0
μ_0
ε_0
ε_0
μ_0
μ_0

Matter Stars

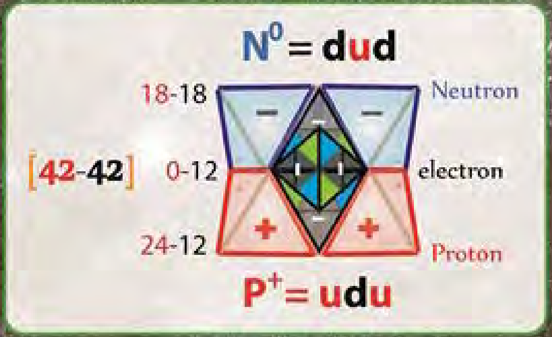
N^0 = dud
18-18
Neutron
[42-42]
0-12
electron
24-12
Proton
P^+ = udu

Matter stars have
the opposite charge topology
to anti-Matter stars

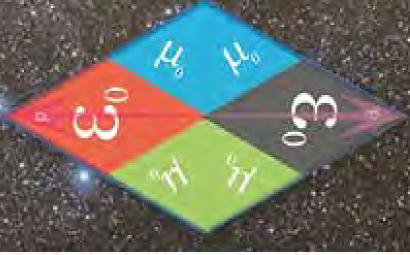
μ_0
μ_0
ε_0
ε_0
μ_0
μ_0

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Star classifications

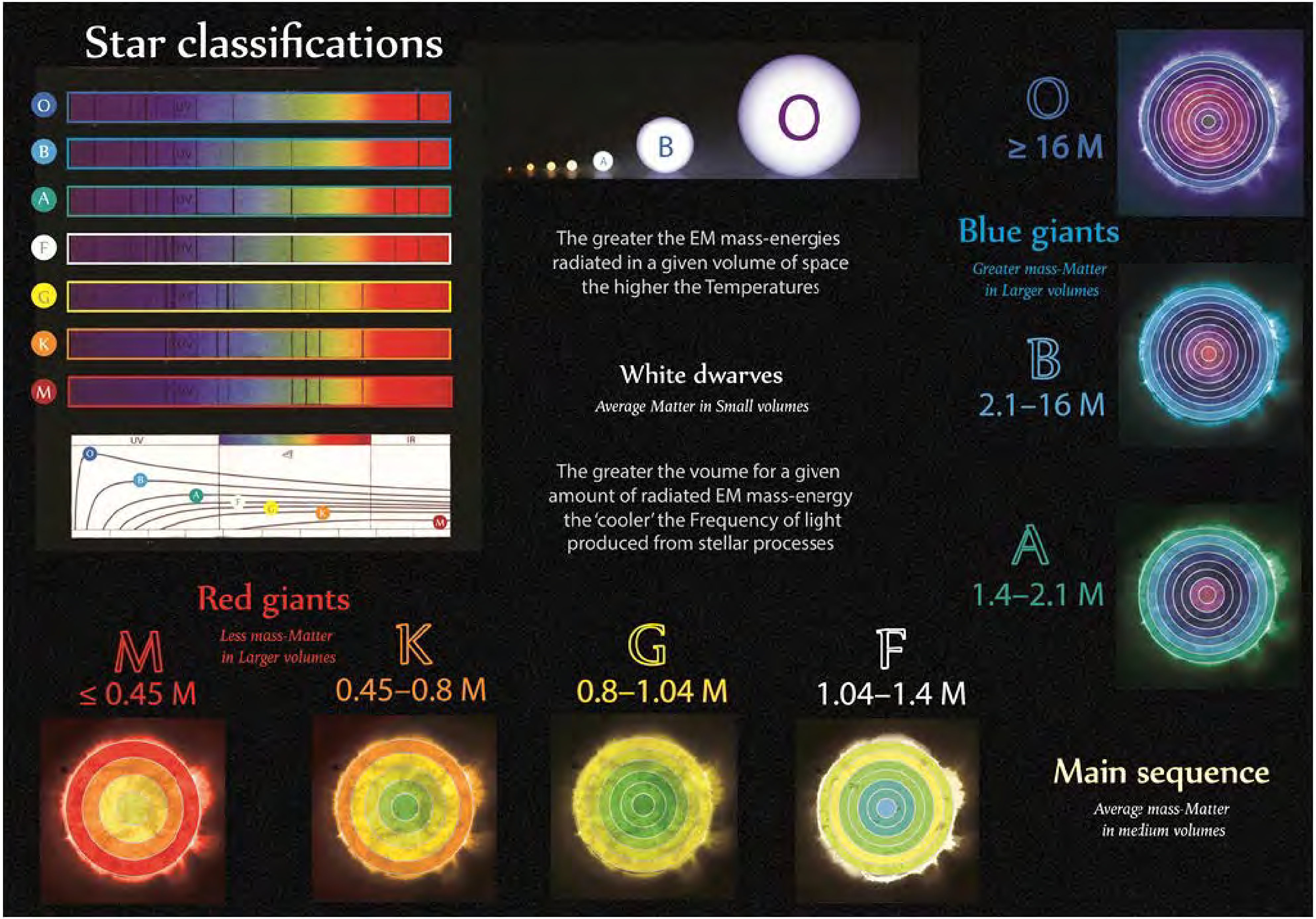

The greater the EM mass-energies radiated in a given volume of space the higher the Temperatures

White dwarves

Average Matter in Small volumes

The greater the voume for a given amount of radiated EM mass-energy the 'cooler' the Frequency of light produced from stellar processes

O
≥ 16 M

Blue giants

Greater mass-Matter in Larger volumes

B
2.1–16 M

A
1.4–2.1 M

Red giants

Less mass-Matter in Larger volumes

M
≤ 0.45 M

K
0.45–0.8 M

G
0.8–1.04 M

F
1.04–1.4 M

Main sequence

Average mass-Matter in medium volumes

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Nucleosynthesis

The goal of nucleosynthesis is to understand the vastly differing abundances of the chemical elements and their several isotopes as being a result of natural history

Nucleosynthesis is the process of creating new atomic nuclei from pre-existing nucleons (protons and neutrons)

All Stars have a dominant spectral colour and emit a multitude of spectral lines

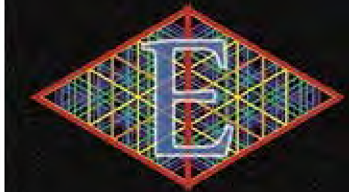

All Stars emit various colour spectra that combine to form spectral lines reflective of the star's energy output

The CNO cycle describing element creation inside Stars is erroneous ....

All spectral lines can be produced by the excitation of stellar nuclei by photons released by GEM pinch Matter-Energy conversion

Nucleosynthesis problems such as the abundances of observed elements & low mass element synthesis remain open problems for the current theory

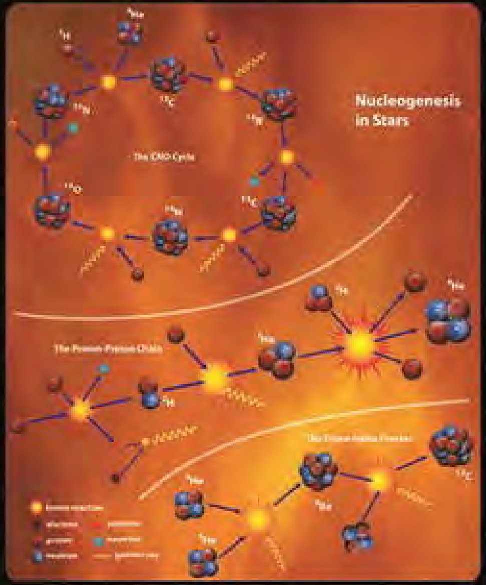

Elements in the Sun

Element	% of total atoms	% of total mass
Hydrogen	91.2	71.0
Helium	8.7	27.1
Oxygen	0.078	0.97
Carbon	0.043	0.40
Nitrogen	0.0088	0.096
Silicon	0.0045	0.099
Magnesium	0.0038	0.076
Neon	0.0035	0.058
Iron	0.030	0.014
Sulfur	0.015	0.040

In 1920, Arthur Eddington was the first to suggest that stars obtained their energy from nuclear fusion of hydrogen to form helium.

The P-P Chain describing the FUSION of elements to release energy is erroneous ....

All Matter-Energy conversion inside Stars is the result of ElectroMagnetic Pinches

Despite intense efforts to create suitable conditions, FUSION as described in nuclear theory, remains an ellusive source of Energy

The CNO cycle and P-P reactions are incorrect theorical models, developed to explain the SUN's GEM pinch dynamics and broad spectral line emissions

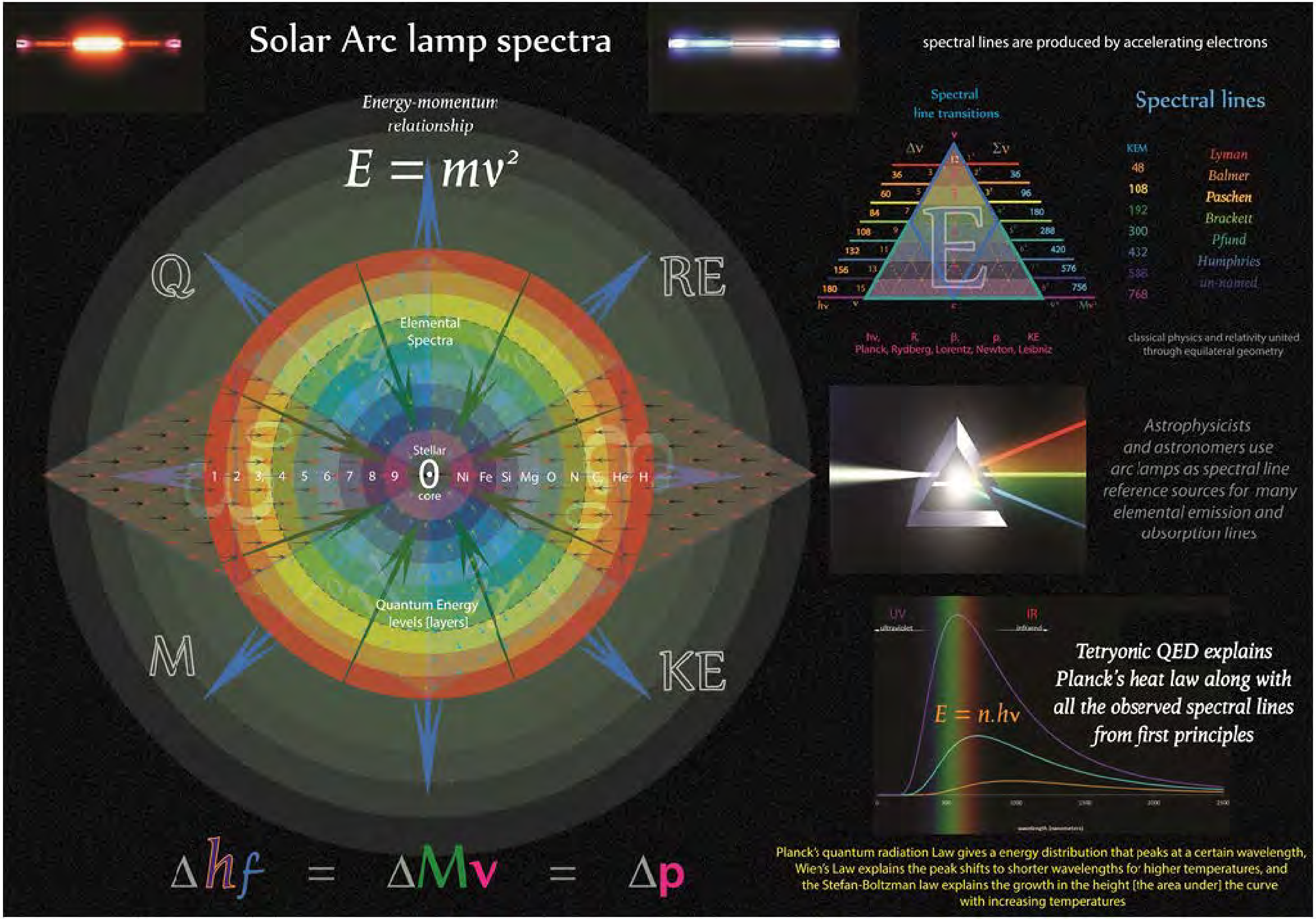

Solar Arc lamp spectra

spectral lines are produced by accelerating electrons

Energy-momentum relationship

$$E = mv^2$$

Q
RE
M
KE
Elemental Spectra
Stellar
0
core
1 2 3 4 5 6 7 8 9
Ni Fe Si Mg O N C He H
Quantum Energy levels [layers]

$$\Delta hf = \Delta Mv = \Delta p$$

Spectral line transitions

v
Δv
Σv
12
36 3 3' 36
60 5 5' 96
84 7 7' 180
108 9 9' 288
132 11 11' 420
156 13 13' 576
180 15 15' 756
hν v c v² Mv²
E

hν, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

Spectral lines

KEM	
48	*Lyman*
108	*Balmer*
192	*Paschen*
300	*Brackett*
432	*Pfund*
588	*Humphries*
768	*un-named*

classical physics and relativity united through equilateral geometry

Astrophysicists and astronomers use arc lamps as spectral line reference sources for many elemental emission and absorption lines

UV
ultraviolet
IR
infrared
E = n.hν
0
500
1000
1500
2000
2500
wavelength (nanometers)

Tetryonic QED explains Planck's heat law along with all the observed spectral lines from first principles

Planck's quantum radiation Law gives a energy distribution that peaks at a certain wavelength, Wien's Law explains the peak shifts to shorter wavelengths for higher temperatures, and the Stefan-Boltzman law explains the growth in the height (the area under) the curve with increasing temperatures

Stellar spectral lines

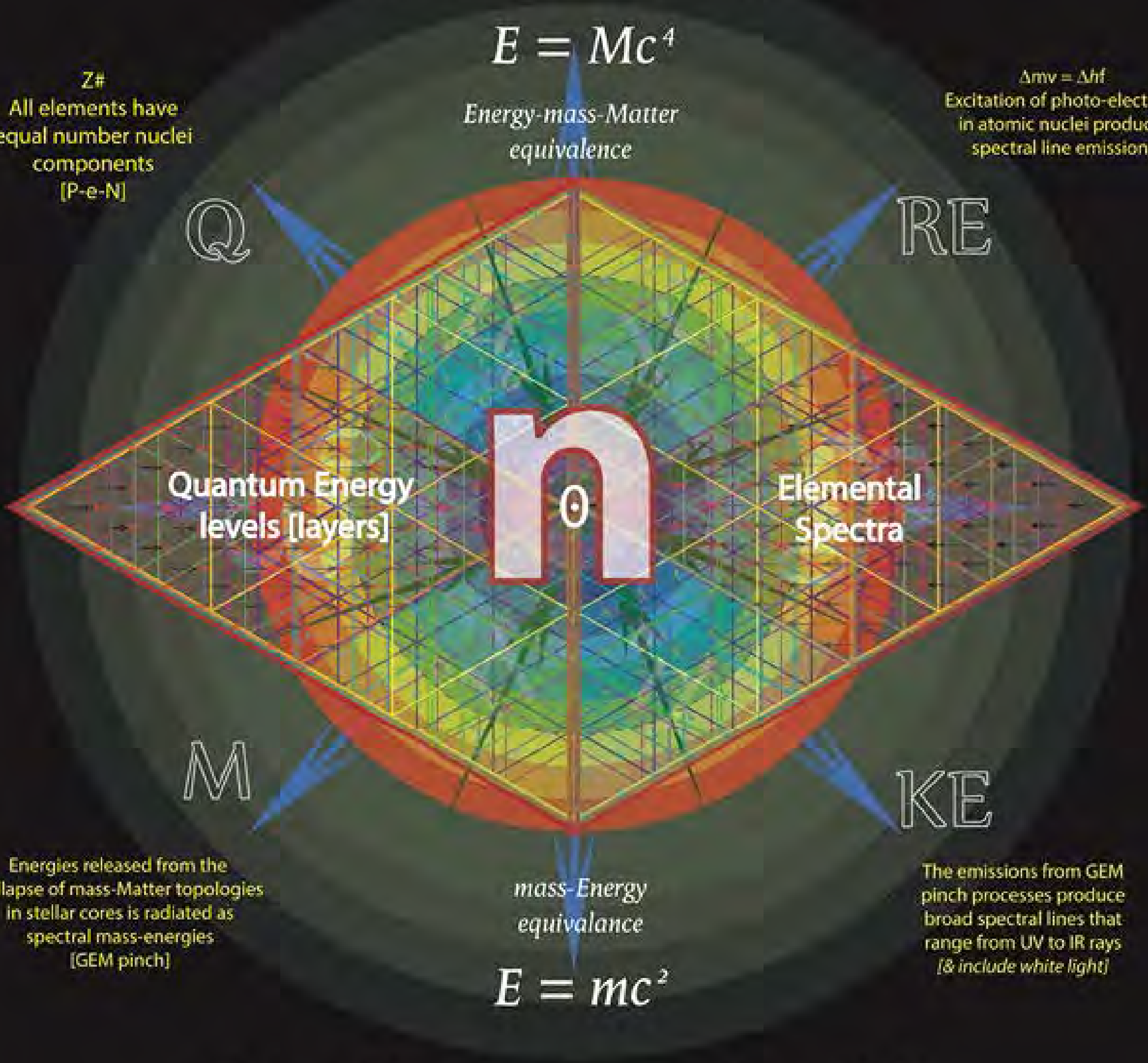
Q
RE
M
KE
Quantum Energy levels [layers]
Elemental Spectra
n
0

$$E = Mc^4$$

Energy-mass-Matter equivalence

Z#
All elements have equal number nuclei components
[P-e-N]

$\Delta mv = \Delta hf$
Excitation of photo-electrons in atomic nuclei produces spectral line emissions

Energies released from the collapse of mass-Matter topologies in stellar cores is radiated as spectral mass-energies
[GEM pinch]

mass-Energy equivalance

$$E = mc^2$$

The emissions from GEM pinch processes produce broad spectral lines that range from UV to IR rays
[& include white light]

The spectral lines of all elements can be mimicked by Deuterium nuclei with rasied energy levels undergoing energy transitions

Tetryonic Electrodynamics

Δhv
Quantum differentials

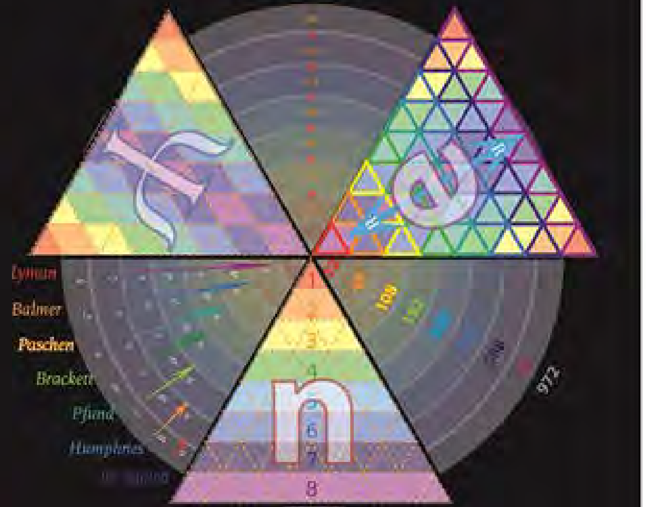
h
n
Lyman
Balmer
Paschen
Brackett
Pfund
Humphreys
1
2
3
4
5
6
7
8
972

$$hf = \Delta Mv = \Delta p$$

spectral lines are produced by accelerating electrons

As energy is 'released' by the collapse of mass-Matter topologies in the stellar core they radiate outward raising the nuclear energies of the surrounding Matter which in turn radiate spectral series photons

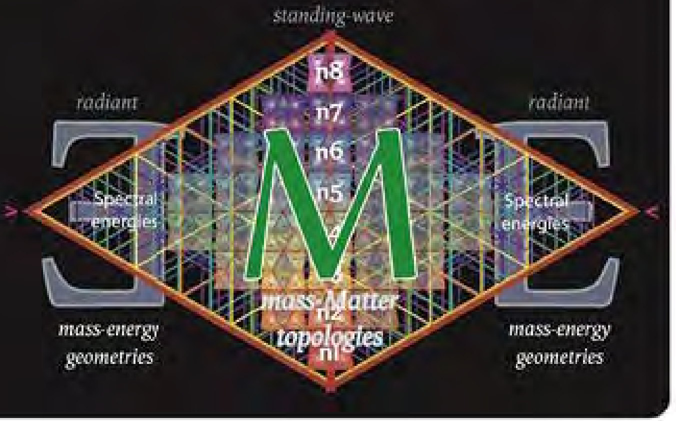
standing-wave
radiant
radiant
n8
n7
n6
n5
n2
n1
M
Spectral energies
Spectral energies
mass-Matter topologies
mass-energy geometries
mass-energy geometries

Joseph von Fraunhofer

(6 March 1787 – 7 June 1826)

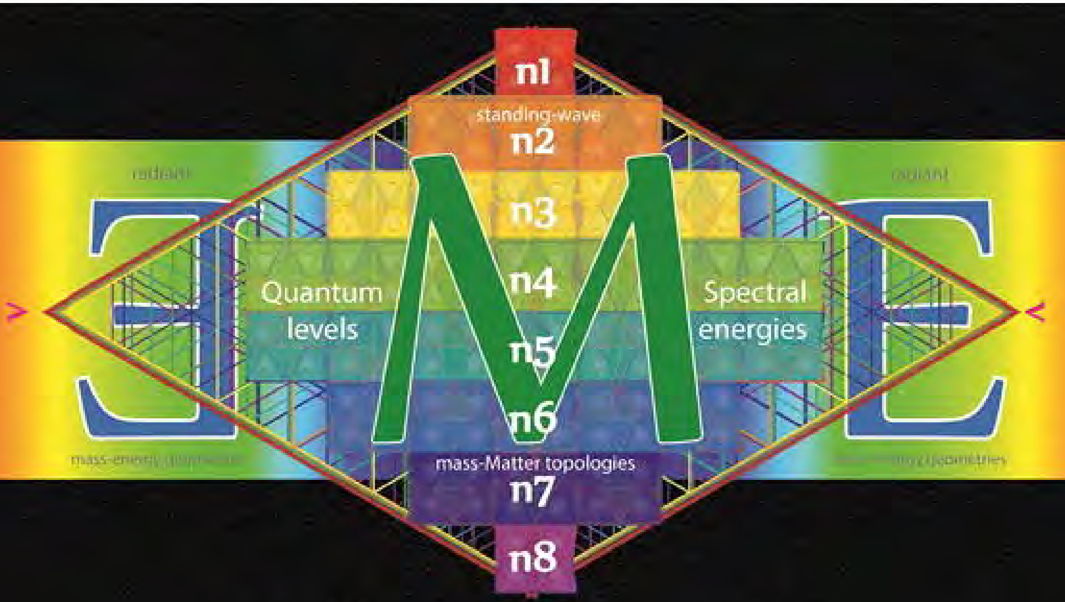
n1
standing-wave
n2
n3
n4
n5
n6
mass-Matter topologies
n7
n8
radiant
radiant
Quantum levels
Spectral energies
mass-energy geometries
mass-energy geometries
M
E
E
>
<

Annie Jump Cannon

(December 11, 1863 – April 13, 1941)

SPECTRAL SERIES

Lyman
Balmer
Paschen
Brackett
Pfund
Humphries

ATOMIC SHELLS

K
L
M
N
O
P

Stellar spectroscopy

Astronomical spectroscopy is the technique of spectroscopy used in astronomy.
The object of study is the spectrum of electromagnetic radiation, including visible light,
which radiates from stars and other celestial objects.

Spectral absorption lines are often referred to as Fraunhofer lines

QUANTUM LEVELS

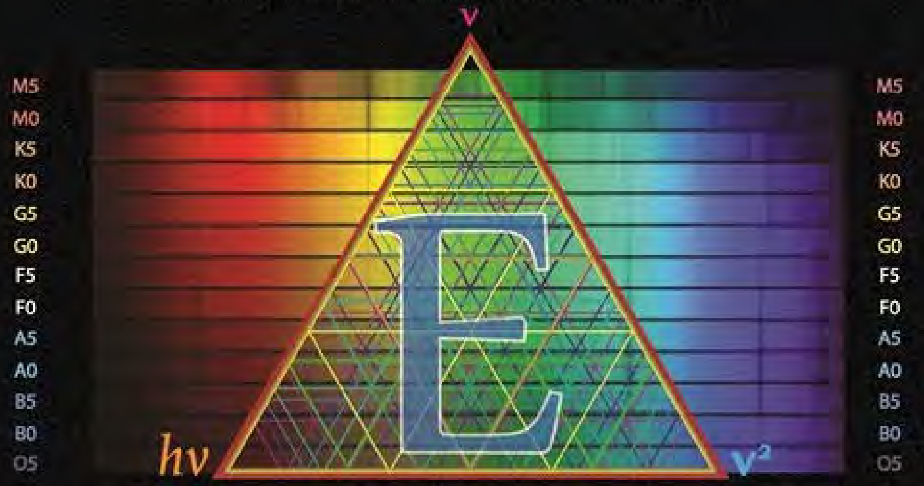
v
M5
M0
K5
K0
G5
G0
F5
F0
A5
A0
B5
B0
O5
M5
M0
K5
K0
G5
G0
F5
F0
A5
A0
B5
B0
O5
E
hv
v²

In 1901 Annie Cannon improved upon the 1897 work of Harvard associate Antonia Maury to produce the Harvard spectral class

STELLAR CLASSIFICATIONS

Spectroscopy can be used to derive many properties of distant stars and galaxies, such as their chemical composition, and motion through Doppler shift measurements.

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mass-ENERGY-Matter

Energy from the SUN

EM energies released by the collapse of standing-wave Matter topologies in the SUN radiate through space as mass-energy momenta and interact with Matter

All atoms are comprised of Deuterium nuclei

Radiant electromagnetic waves propagate

at the speed of light in a vacuum [c] taking 8.3 minutes to reach Earth

$$E = hf$$

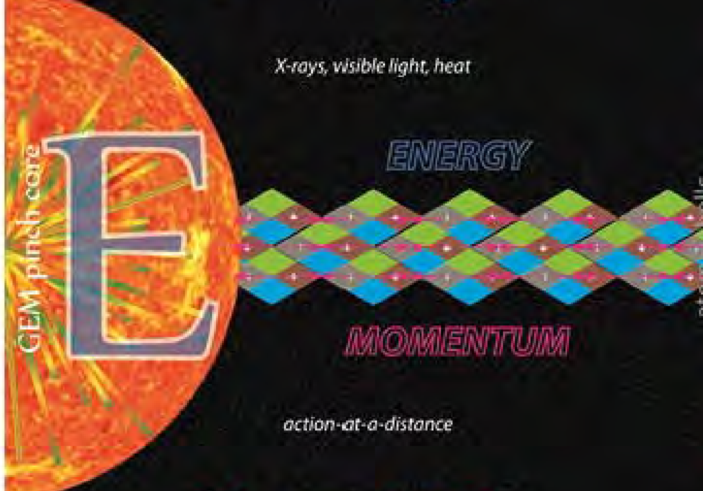
X-rays, visible light, heat
GEM pinch core
E
ENERGY
MOMENTUM
action-at-a-distance

$$p = mc$$

Square root linear momenta present in all longitudinal EM waveforms from rigid rods

and once established propagate impulses of momenta near-instantaneously along the longitudinal waves arriving 8.3 minutes before visible light

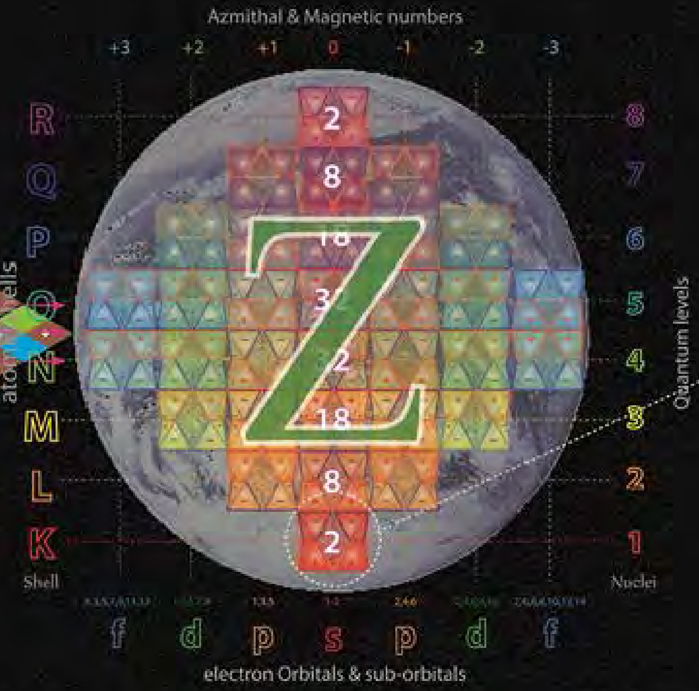
Azmithal & Magnetic numbers
+3
+2
+1
0
-1
-2
-3
R
Q
P
O
N
M
L
K
Shell
atomic shells
2
8
18
32
32
18
8
2
Z
8
7
6
5
4
3
2
1
Quantum levels
Nuclei
f
d
p
s
p
d
f
electron Orbitals & sub-orbitals

The Earth receives a broad spectrum of energies from the SUN [with visible light falling into the Balmer spectral series]

$$hf = \underset{366.859\text{ nm}}{kEM} = \frac{hcR}{n^2}$$

By inductively coupling to the raised quantum KEM fields of the bound electrons their energies can be extracted and utilised

Deuterium nuclei are quantum synchronous convertors of electromagnetic energies

$$kEM = Mv^2$$

As energy momenta is recieved the energy levels of the Baryons increases in turn affecting and raising the KEM field energies of bound electrons

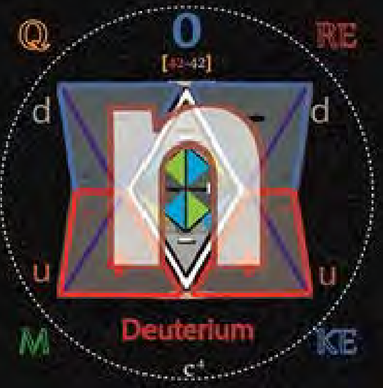
Q
O
RE
d
d
n
u
u
M
Deuterium
c²
KE

spectral lines, atomic transitions, photo-electric effect

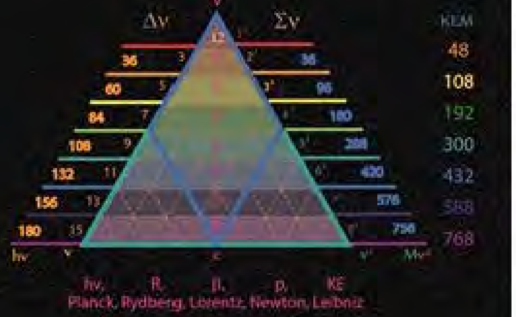
v
Δv
Σv
KEM
36
60
84
108
132
156
180
3
5
7
9
11
13
15
36
96
180
288
420
576
756
48
108
192
300
432
588
768
hv
v
c
v²
Mv²
hv, R, μ, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

changing spectral emissions $\Delta hf = \Delta Mv = \Delta p$ accelerate photo-electrons

Stellar Energies

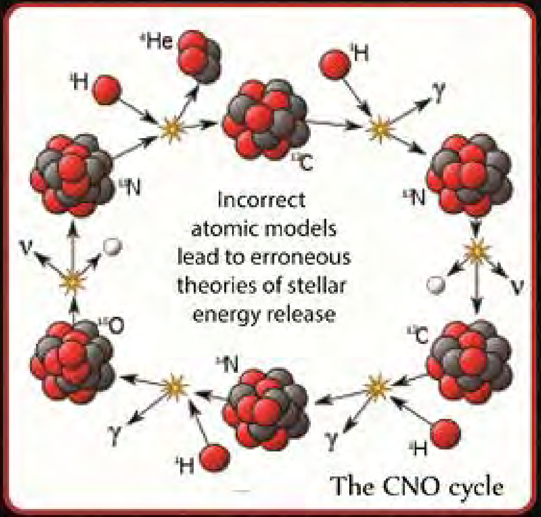
⁴He
¹H
¹H
γ
¹²C
¹⁵N
¹³N
ν
ν
¹⁵O
¹³C
¹⁴N
γ
γ
¹H
¹H
Incorrect atomic models lead to erroneous theories of stellar energy release
The CNO cycle

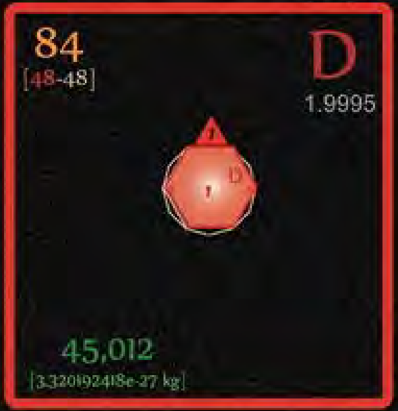
84
[48-48]
D
1.9995
45,012
[3.320192418e-27 kg]

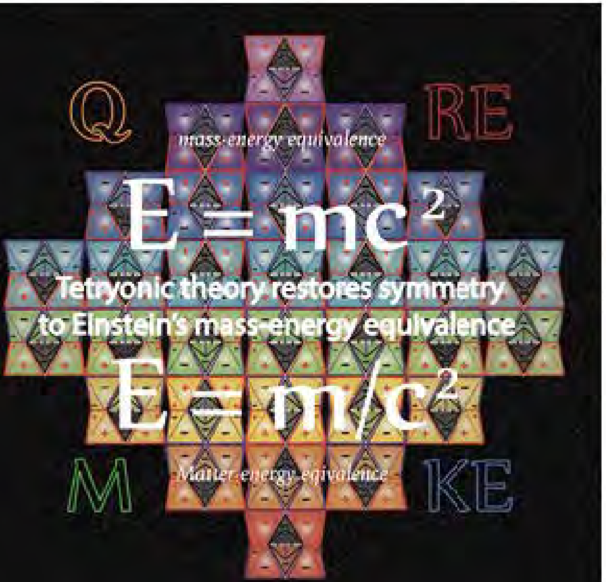
Q
RE
mass-energy equivalence
E = mc²
Tetryonic theory restores symmetry to Einstein's mass-energy equivalence
E = m/c²
M
KE
Matter-energy equivalence

ENERGY

$$mc^2 = E = Mc^4$$

mass Matter

mass-ENERGY-Matter equivalence shows that a tiny amount of mass-Matter can be converted into a tremendous amount of radiant EM mass-energy

The energy released hypothesised by 'Fusion' is 1/200th that of the Tetryonic collapse of Matter into radiant EM mass-energies

All mass-ENERGY-Matter topologies are modelled in Tetryonic theory and Baryon decay is instigated by neutrinos

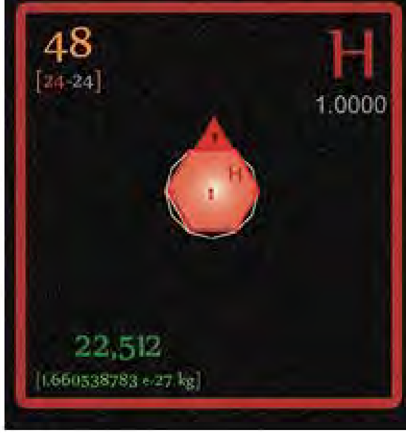
48
[24-24]
H
1.0000
22,512
[1.660538783 e-27 kg]

Neutrons are NOT Protons with an absorbed electron inside their charge topology

High pressure tunneling through the Coulomb barrier does NOT occur

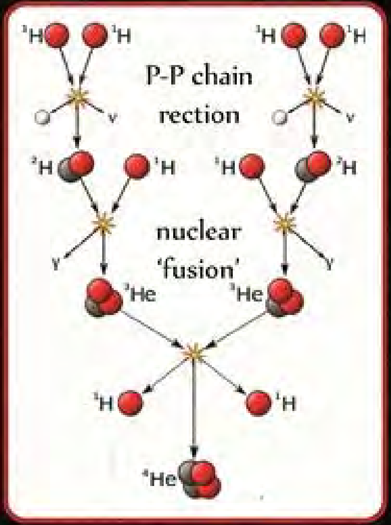
¹H
¹H
¹H
¹H
P-P chain rection
ν
ν
²H
¹H
¹H
²H
nuclear 'fusion'
γ
γ
³He
³He
¹H
¹H
⁴He

The P-P fusion chain of Hydrogen->Helium is completely erroneous

The neutrino production of Proton-Proton chain reactions is 1/3 of what is detected

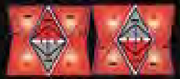

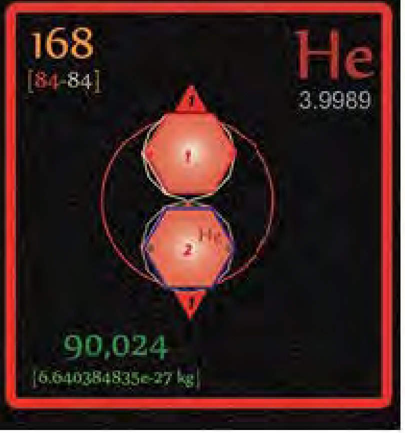
168
[84-84]
He
3.9989
90,024
[6.640384835e-27 kg]

The SUN's energy comes from Tetryonic Matter collapse NOT the fusion of atomic nuclei

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Stellar Nuclear Fusion

is the process of fusing of light atomic nuclei in order to facilitate energy releases

'COLD fusion'

can be realised through the fragmenting of large atomic nuclei thus releasing stored nuclear [K]EM waveform energies

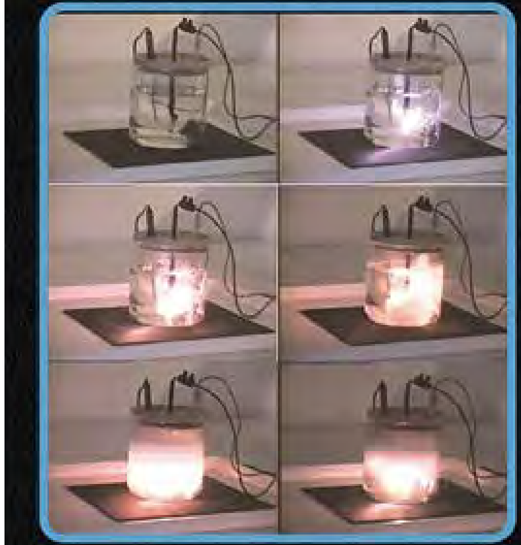

The much-maligned 'COLD fusion' of Palladium is in fact a form of atomic fission that releases the stored chemical [kEM] energies of atomic nuclei and is 12-13% efficient

Long sought after, but never realised, Fusion energies remain an ellusive source of clean limitless energy.

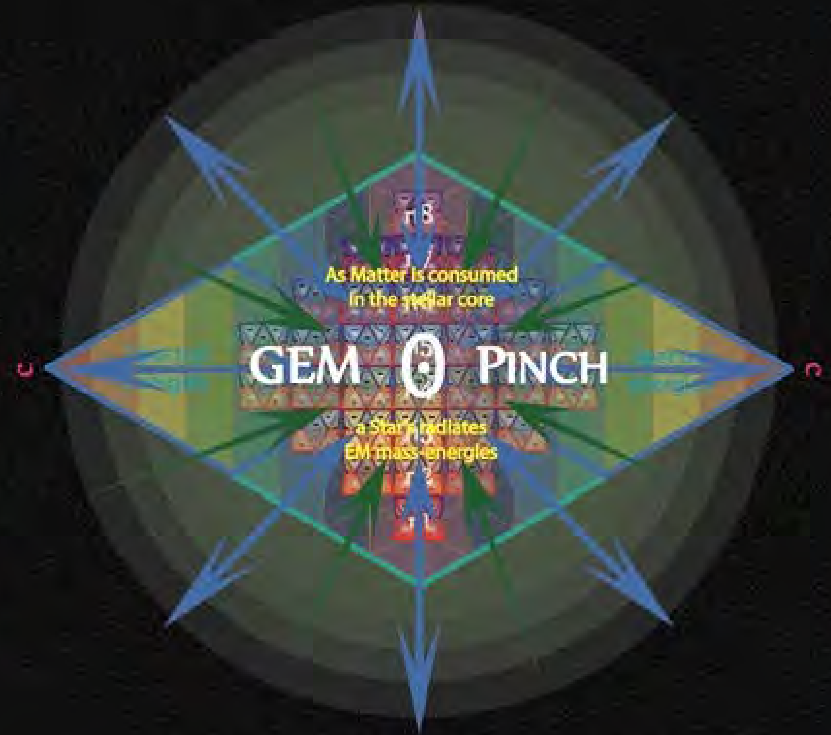
As Matter is consumed in the stellar core
c
GEM
PINCH
c
a Star radiates EM mass-energies

Tetryonics reveals the true mechanics behind the cold 'fusion' observed by Drs. Pons & Fleischmann and corrects the model of stellar processes to reveal new energy sources for the future

'HOT fusion'

is a fallacy, Stars release energy by collapsing standing-wave Matter into radiant EM mass-energy geometries in electromagnetic pinches

The hypothesised 'HOT fusion' of elements in stars is the Tetryonic conversion of mass-Matter within the star into radiant mass-energies requiring an electromagnetic pinch reaction but is 100% efficient

Tetryonics 73.10 - Fission, Fusion & EM pinches

Where Fusion went Wrong

The conversion of standing-wave Matter into radiant mass-energy constitutes a sustainable, virtually unlimited environmentally compatible long-term source of energy that can meet all of Humanity's needs.

The toriodal design of Tokamak reactors does not allow for the formation of plasma pinches at their cores

Tokamak design

Among a small number of approaches, the concept of toroidal magnetic confinement of fusion plasmas has achieved the most impressive scientific and technical progress towards energy release by thermonuclear burn of deuterium-tritium fuels.

The plasma consists of charged nuclei and electrons, which move in tight spirals around the lines of force of strong magnetic fields.

Of the two designs only inertial confinement offered the best chance of creating the conditions required to effectively collapse Matter topologies in order to release the EM energies it contains.

However a far superior approach would be the electromagnetic pinching of Matter (as present in all stellar cores)

The basic problems in attaining useful nuclear fusion conditions are

(1) to heat the gas to these very high temperatures and

(2) to confine a sufficient quantity of the reacting nuclei for a long enough time to permit the release of more energy than is needed to heat and confine the gas.

A subsequent major problem is the capture of this energy and its conversion to electrical energy for work

Inertial confinement fusion produces brief shockwaves, excessive heating and no sustained EM field

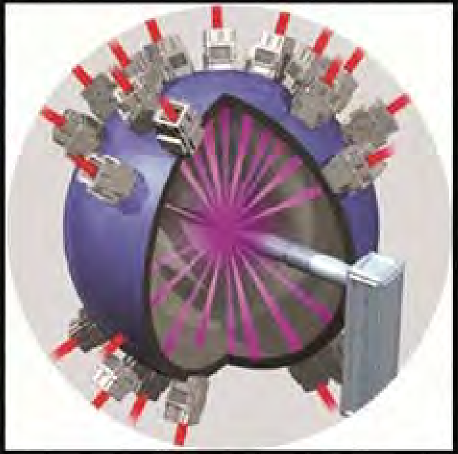

Inertial confinement

In inertia confinement the fuel—tritium or deuterium is contained within a tiny glass sphere that is then bombarded on several sides by a pulsed laser or heavy ion beam.

This causes an implosion of the glass sphere, setting off a thermonuclear reaction that ignites the fuel but offer no self-regualation and relase of radiant mass-energies.

E_{in}

In any useful fusion device, the energy output must exceed the energy required to confine and heat the plasma

E_{out}

ElectroMagnetic Pinch technology

can serve as the gateway to realising new forms of clean, safe, efficient Energy production through the conversion of any Matter into various forms of EM radiation utilising electromagnetic pinch geometries developed from Tetryonic theory

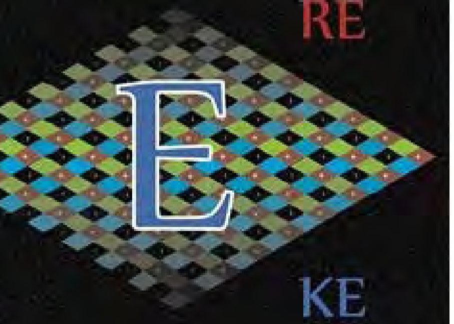

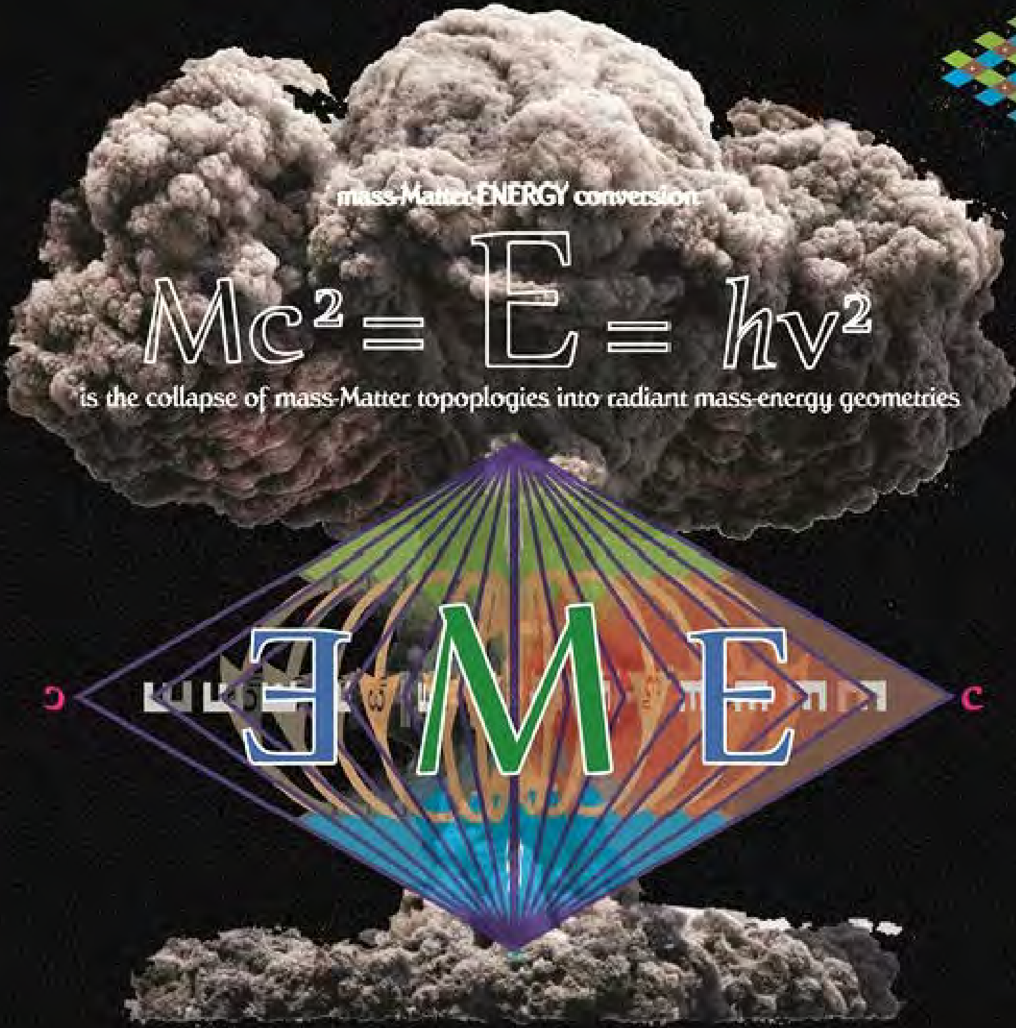

mass-Matter ENERGY conversion

$$Mc^2 = E = hv^2$$

is the collapse of mass-Matter topoplogies into radiant mass-energy geometries

Charged Matter topologies are standing wave EM mass-energies

Radiant mass-energies form kEM wave geometries

An electromagnetic pulse (sometimes abbreviated EMP) is a burst of electromagnetic radiation that results from an explosion (usually from the detonation of a nuclear weapon) and/or a suddenly fluctuating magnetic field. The resulting rapidly changing electric fields or magnetic fields may couple with electrical/electronic systems to produce damaging current and voltage surges.

Stellar GEM Pinches

The century old theoretical mechanism of FUSION
from which the SUN generates its broad radiative EM energies
must be replaced with Gravito-Electro-Magnetic pinches

M

Gravity fields obey the
inverse SQUARE law

Polar Magnetic fields obey the inverse SQUARED law
Magnetic dipoles obey the inverse CUBED law

E

Electric fields obey the
inverse SQUARE law

3D
standing-wave
topologies

$$E = Mc^4$$

Energy-mass-Matter
equivalence

mass-Matter
creates Gravity

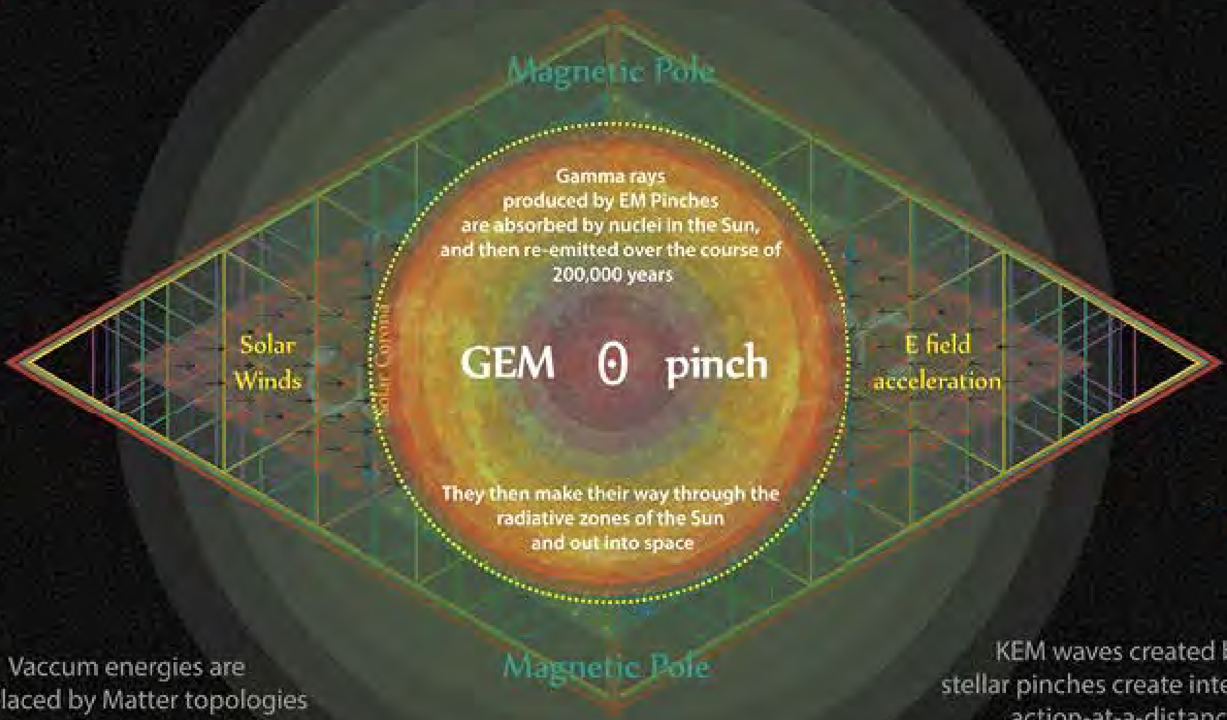

Magnetic Pole
Gamma rays
produced by EM Pinches
are absorbed by nuclei in the Sun,
and then re-emitted over the course of
200,000 years
Solar Winds
Solar Corona
GEM θ pinch
E field acceleration
They then make their way through the
radiative zones of the Sun
and out into space
Magnetic Pole

2D
radiant
geometries

$$E = mc^2$$

mass-Energy
equivalance

mass-energies
create kEM fields

Vaccum energies are
displaced by Matter topologies
to form convergent gravity

KEM waves created by
stellar pinches create interactive
action-at-a-distance

The conversion of Matter to Energy
in stellar GEM pinches is
100% efficient

The Fusion of elements
is NOT the energy
source of Stars

mass-Matter-ENERGY conversion

Stars emit broad spectra
LONGITUDINAL
electromagnetic waves

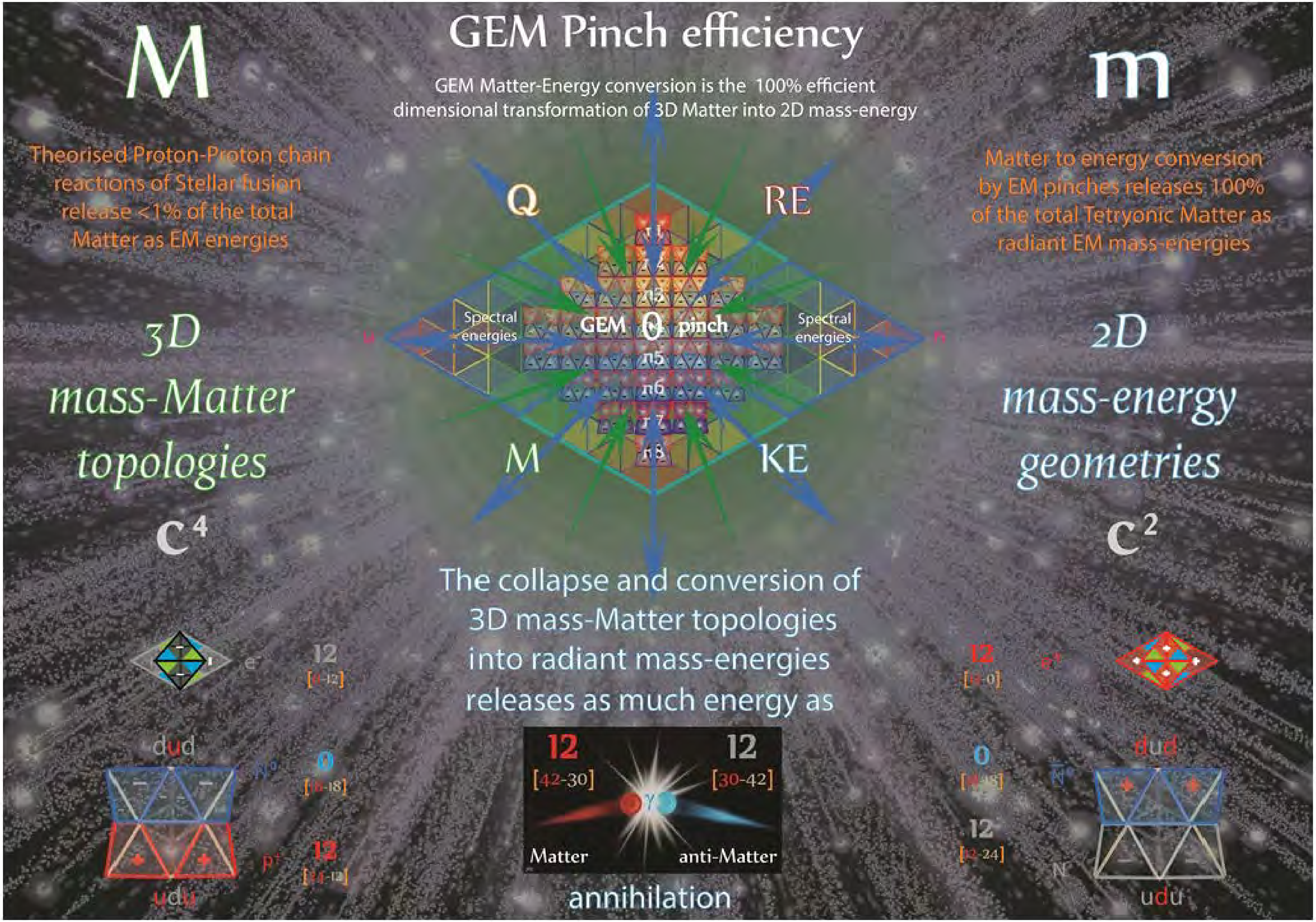

GEM Pinch efficiency

GEM Matter-Energy conversion is the 100% efficient dimensional transformation of 3D Matter into 2D mass-energy

M

Theorised Proton-Proton chain reactions of Stellar fusion release <1% of the total Matter as EM energies

3D mass-Matter topologies

c^4

m

Matter to energy conversion by EM pinches releases 100% of the total Tetryonic Matter as radiant EM mass-energies

2D mass-energy geometries

c^2

The collapse and conversion of 3D mass-Matter topologies into radiant mass-energies releases as much energy as annihilation

Q
RE
M
KE
n1
n2
n3
n4
n5
n6
n7
n8
Spectral energies
GEM 0 pinch
Spectral energies
e⁻
12
[0-12]
dud
N⁰
0
[18-18]
p⁺
12
[24-12]
udu
12
[42-30]
12
[30-42]
γ
Matter
anti-Matter
12
[12-0]
e⁺
dud
N̄⁰
0
[18-18]
12
[12-24]
N
udu

Tetryonics 73.14 - Matter-Energy collapse

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EM Pinch reactors

The technology required to create clean, limitless energy and meet all of humanity's future energy requirements has existed since the 1900's.

The basic steps to build a EM Pinch reactor are

(1) design and build a EM pinch field into which a fuel pellet can be injected

(2) the fuel can be any form of Matter that exhibits both Electric & Magnetic dipoles to facilitate the automatic positioning of the material fuel into the pinch core [the EM fields interact untill they equalise]

(3) enclose the EM Pinch core in a containment casing that can both capture and absorb the radiant EM energies produced by the collapse of Matter at the core and convert these energies into electricity

Th efficiency of the containment vessel along with energy storage and distribution can all be improved through the use of various Tetryonic field geometries to capture and re-circulate all EM energies produced

There are no moving parts to wear out or require extensive maintenance regimes

Upon any loss of Power to the system the EM pinch will be unsustainable and shutdown automatically preventing any possibility of runaway reactions

Photons

$$\frac{2\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

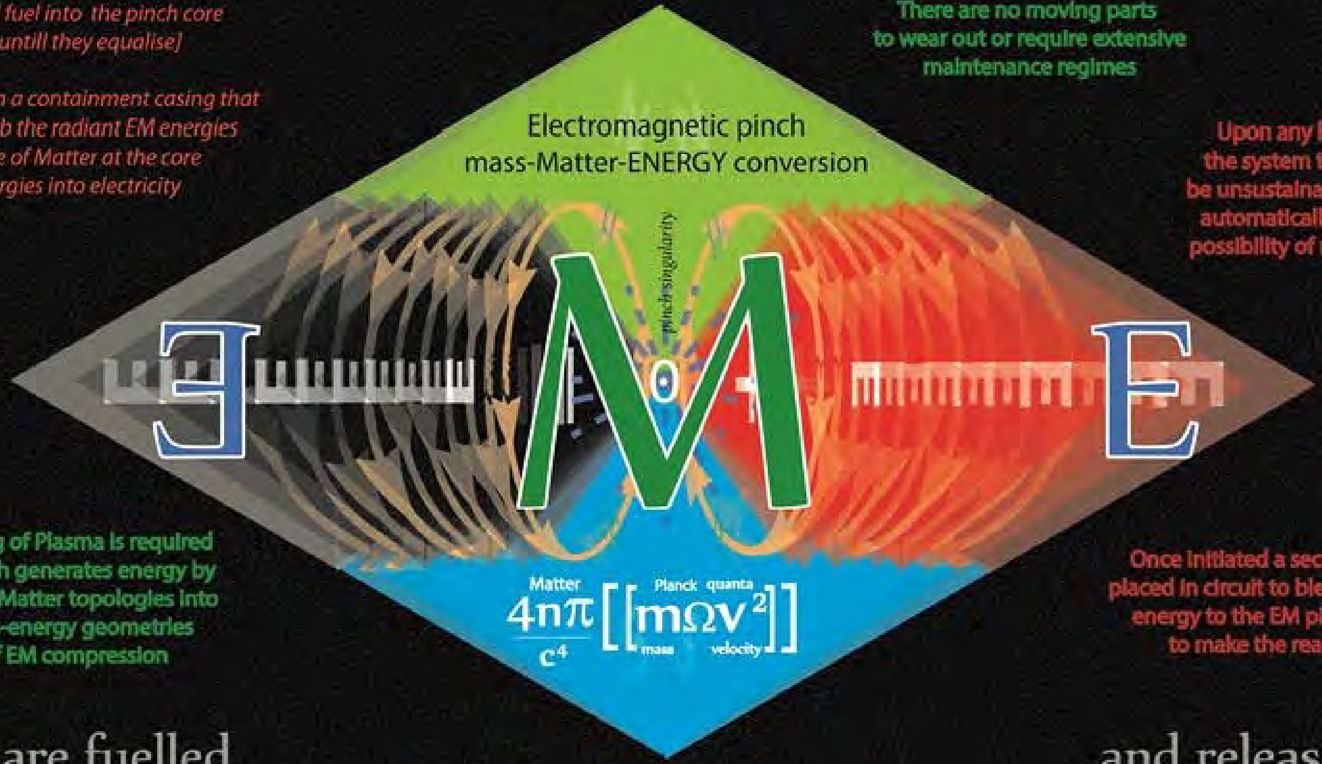
Electromagnetic pinch
mass-Matter-ENERGY conversion
pinch singularity
E
M
0
E
Matter
$\frac{4n\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$

EM waves

$$\frac{2n\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

No preheating of Plasma is required as the EM pinch generates energy by collapsing' 3D Matter topologies into 2D EM mass-energy geometries by way of EM compression

Once initiated a secondary 'circuit' could be placed in circuit to bleed off and return suficient energy to the EM pinch field circuit in order to make the reaction self-sustaining

EM pinches are fuelled

by any form of Matter

The electromagnetic pinching of Matter (as utilised in Nature in all stellar cores) produces only EM radiation [light & heat] as a by-product - there are no harmful wastes - as the Matter is converted with 100% efficiency

and release mass-energy

as radiative KEM fields

Tetryonics 73.15 - The EM Pinch reactor

EM Pinch reactor containment vessel

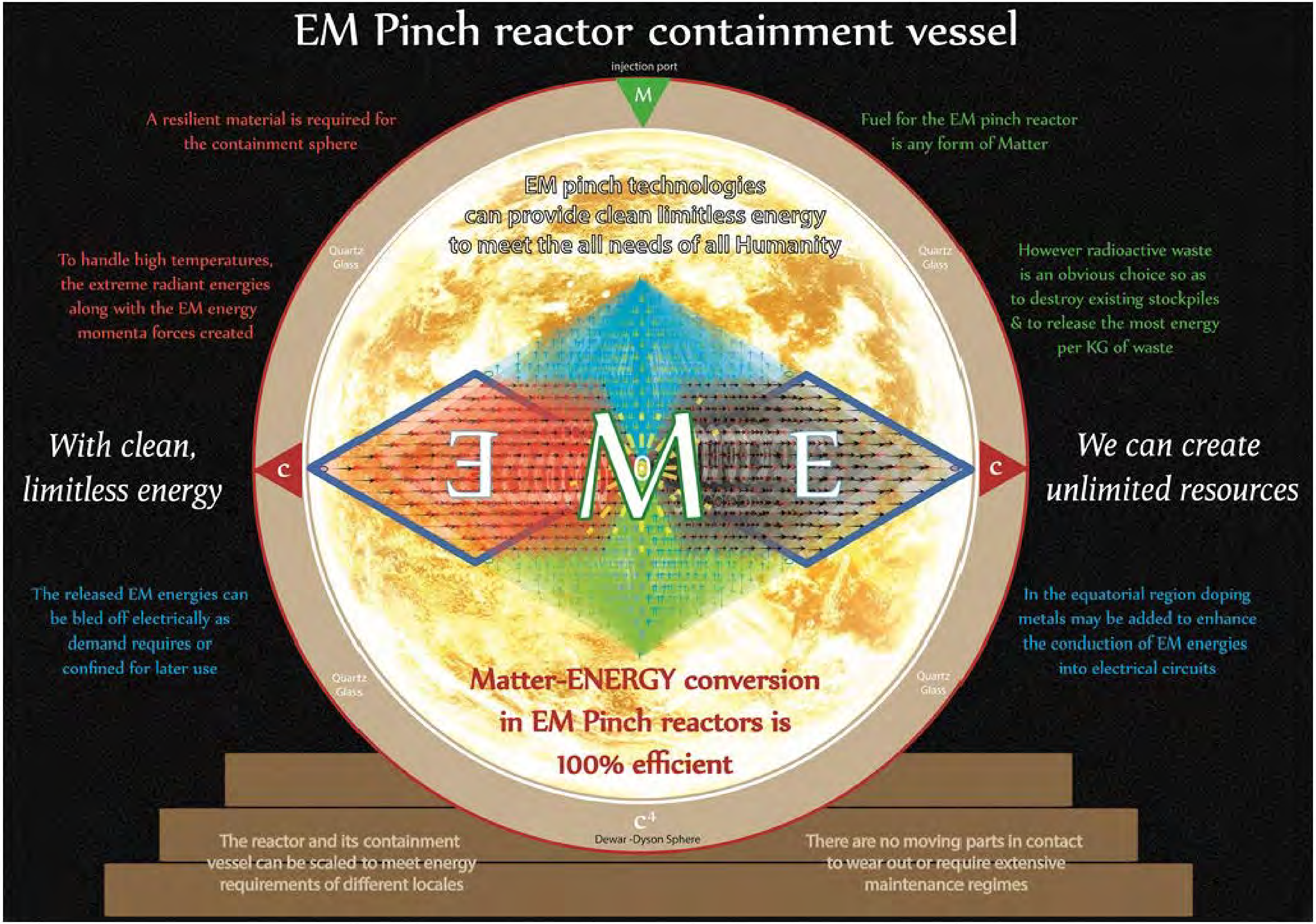

A resilient material is required for the containment sphere

Fuel for the EM pinch reactor is any form of Matter

EM pinch technologies can provide clean limitless energy to meet the all needs of all Humanity

To handle high temperatures, the extreme radiant energies along with the EM energy momenta forces created

However radioactive waste is an obvious choice so as to destroy existing stockpiles & to release the most energy per KG of waste

With clean, limitless energy

We can create unlimited resources

The released EM energies can be bled off electrically as demand requires or confined for later use

In the equatorial region doping metals may be added to enhance the conduction of EM energies into electrical circuits

Matter-ENERGY conversion in EM Pinch reactors is 100% efficient

The reactor and its containment vessel can be scaled to meet energy requirements of different locales

There are no moving parts in contact to wear out or require extensive maintenance regimes

Tetryonics 73.16 - EM Pinch reactor containment

The Earth has finite resources and an ever increasing human population puts pressure on its ability to supply resources to meet our needs

Unlimited material Resources

Tetryonics offers a solution to human problems that have plagued civilization from its beginnings leading to wars, disease and famines

With clean, limitless energy sources

Unlimited resources can be created

mass-energy geometries
cannot be created or destroyed

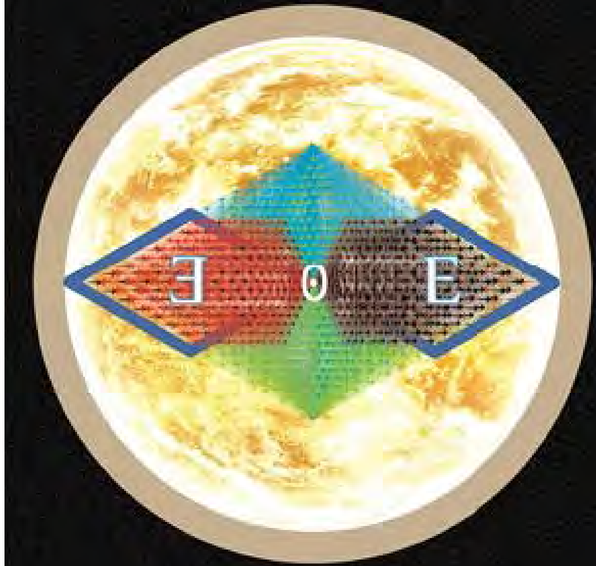

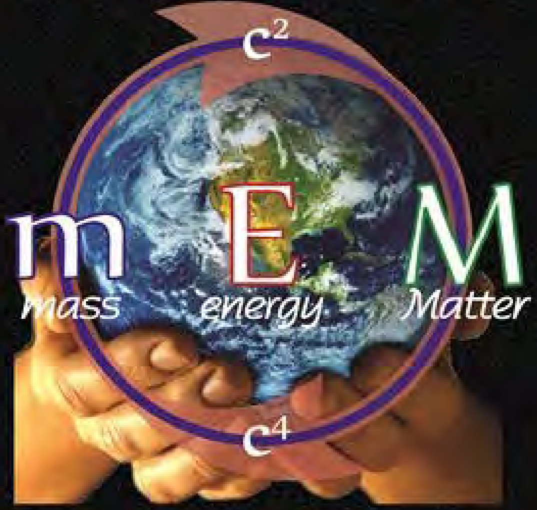

mass-Matter topologies
can be created and destroyed

Resources

Health

With this new understanding of the charged mass-energy geometries of Matter excess energies generated from the destruction of Matter topologies can be reformed into any desired element or compound, and all harmful waste can be removed from our environment

Food

Water

Tetryonics 73.17 - Unlimited resources

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Classical Gravity models the observed motion of Planetary bodies

[without explaining its motivating force]

Denser, rocky planets are strongly attracted to the SUN

Newtonian Gravity

G

Denser, rocky planets orbit closer to the SUN where radiant EM energies are stronger

Light measurement	AU	KM travelled
1 light-second	0.0020	299,792.458
1 light-minute	0.1202	17.98 million
1 light-hour	7.2143	1.08 billion
1 light-day	173.14	25.9 billion
1 light-week	1212.0	181.3 billion
1 light-month	5194.3	777.06 billion
1 light-year	9.46 trillion	5.89 trillion

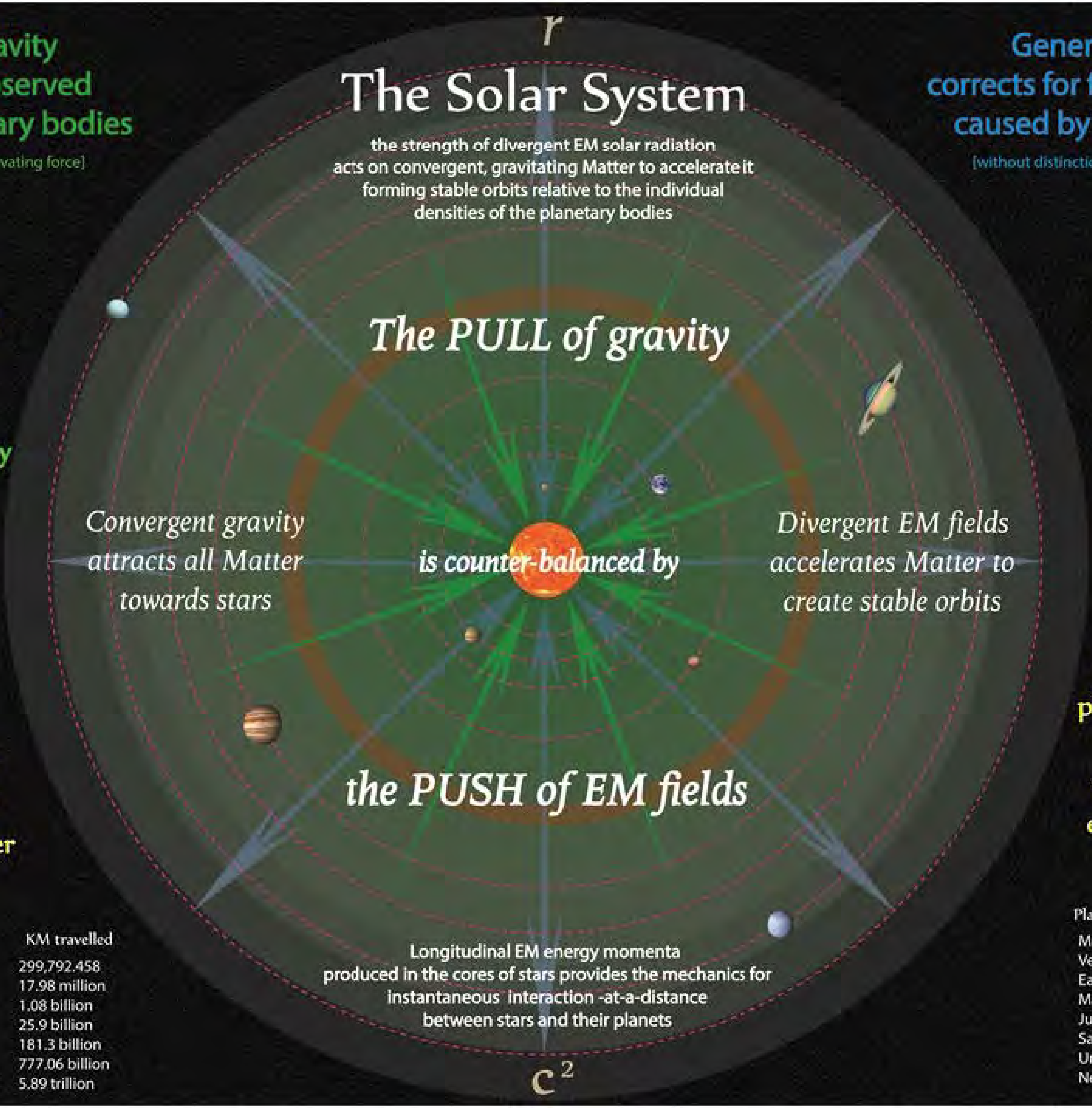

The Solar System

the strength of divergent EM solar radiation acts on convergent, gravitating Matter to accelerate it forming stable orbits relative to the individual densities of the planetary bodies

The PULL of gravity

Convergent gravity attracts all Matter towards stars

is counter-balanced by

Divergent EM fields accelerates Matter to create stable orbits

the PUSH of EM fields

Longitudinal EM energy momenta produced in the cores of stars provides the mechanics for instantaneous interaction -at-a-distance between stars and their planets

General Relativity corrects for fine purturbations caused by EM interactions

[without distinction between its various forms]

Lighter, gaseous planets are less strongly attracted to the SUN

Special Relativity

EM

Lighter, gaseous planets orbit further from the SUN where radiant EM energies are weaker

Planet	Distance from Sun
Mercury	192 light-seconds
Venus	361 light-seconds
Earth	500 light-seconds
Mars	762 light-seconds
Jupiter	2,598 light-seconds
Saturn	4,752 light-seconds
Uranus	9,576 light-seconds
Nepture	14,976 light-seconds

Tetryonics 74.01 - The Solar System

Kepler's Laws

Kepler's three laws of planetary motion can be described as follows:

The path of the planets about the sun is elliptical in shape,
with the center of the sun being located at one focus.
(The Law of Ellipses)

An imaginary line drawn from the center of the sun to the center of
the planet will sweep out equal areas in equal intervals of time.
(The Law of Equal Areas)

The ratio of the squares of the periods of any two planets is equal to
the ratio of the cubes of their average distances from the sun.
(The Law of Harmonies)

$$T^2 = k\ a^3$$

The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

Gravity attracts Matter towards stars

The divergent energy momenta of kEM fields create an acceleration FORCE on material bodies

The orbit of every planet is an ellipse
with the Sun at one of the two foci.

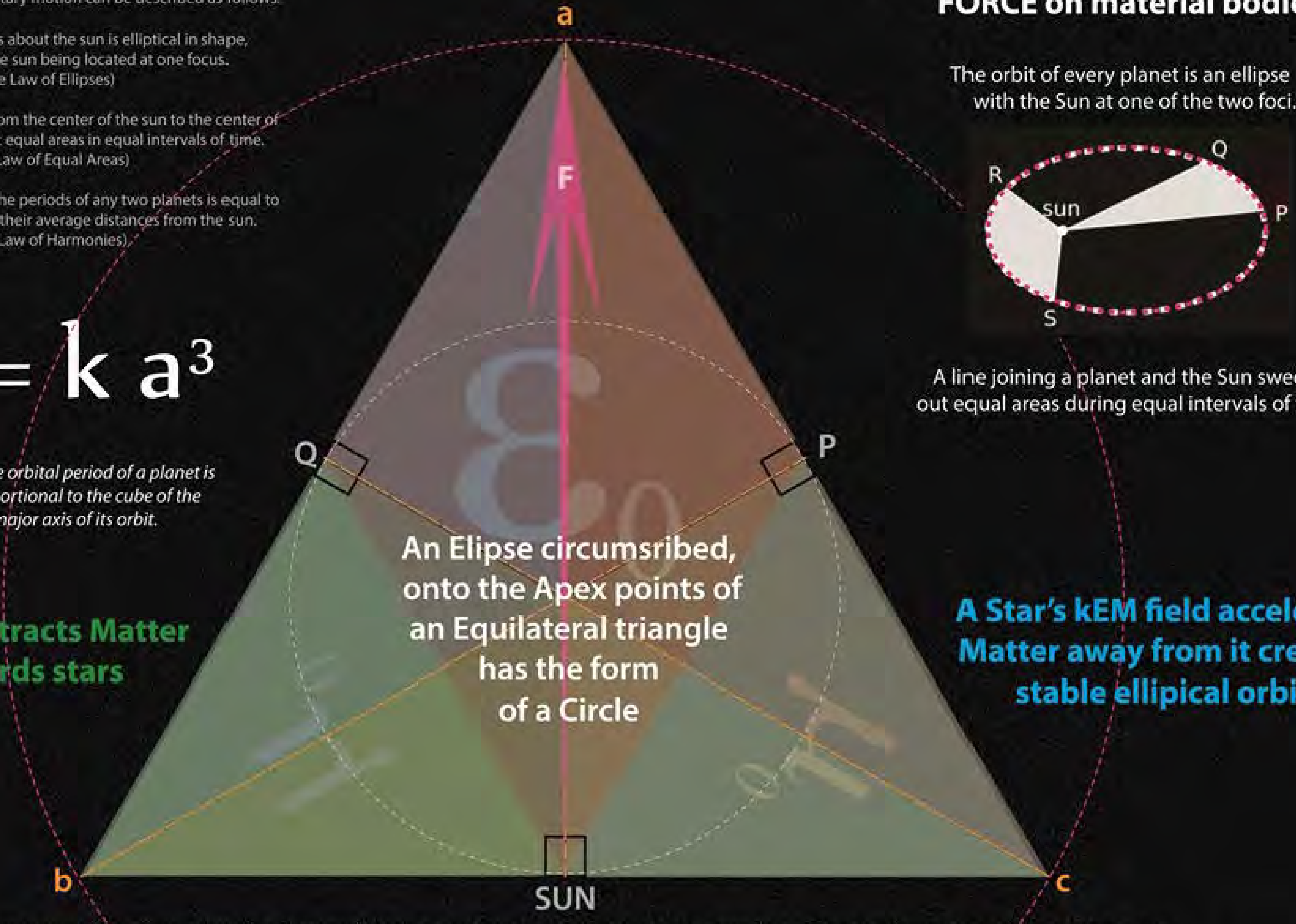

A line joining a planet and the Sun sweeps
out equal areas during equal intervals of time.

A Star's kEM field accelerates Matter away from it creating stable ellipical orbits

An Elipse circumsribed,
onto the Apex points of
an Equilateral triangle
has the form
of a Circle

With an equilateral triangle, draw lines from the center of the circle to each vertex and each midpoint, creating six right triangles, as shown with six different colored triangles.
Each right triangle has a radius of the circle for one leg, and half of a side of the original triangle for another.
Any two right triangles sharing one of the radial lines must therefore be congruent, and that implies that the hypotenuses of the triangles are all equal.
This in turn shows that the six right triangles are all congruent, and so the large triangle they combine to form is equilateral

The Major celestial bodies

All planetary orbits are the result of a balance between gravitation Matter and interactive kEM fields

The sun is a rotating charged mass-Matter object, and it creates a solar system-wide kEM field.

The solar mass is large enough to produce a EM field with lines of Force reaching the orbit of Pluto.

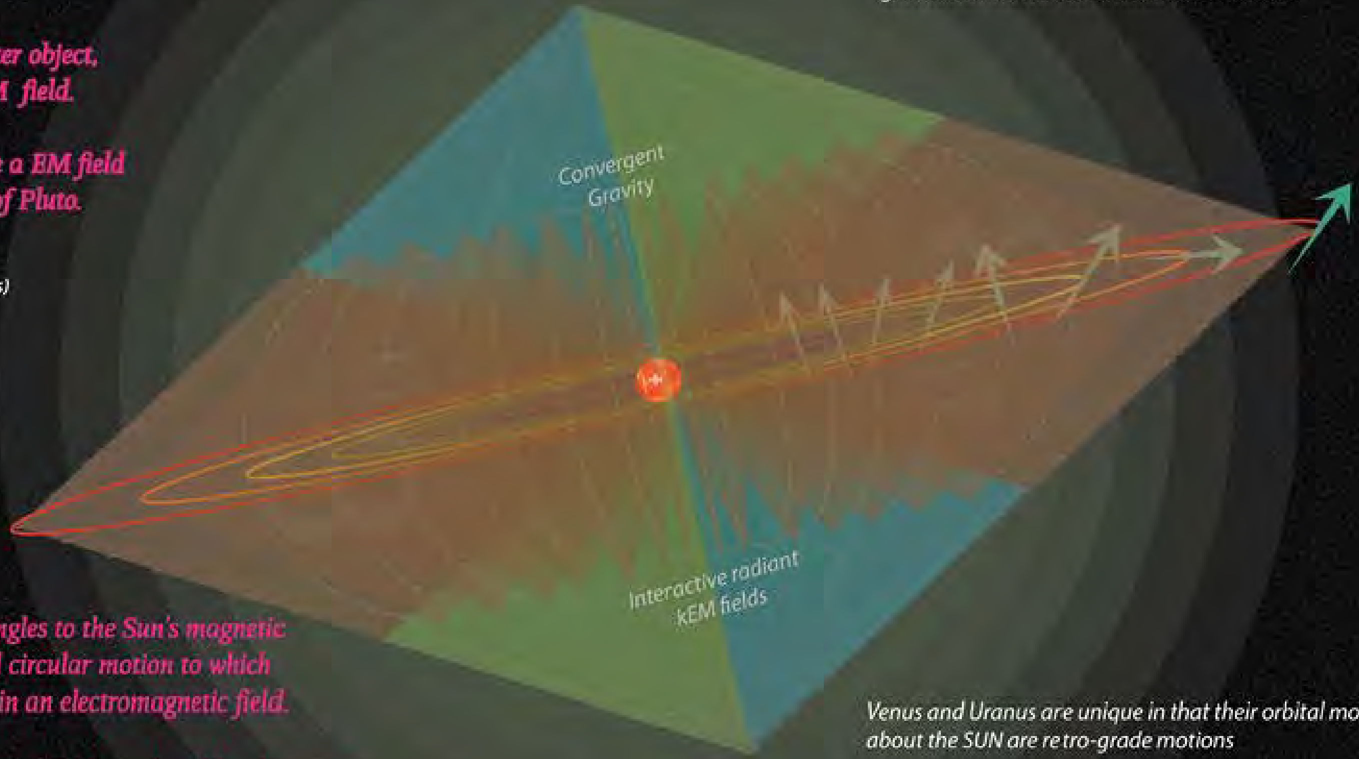

Planet	*Object Axial tilt (°)*	*Axial tilt (radians)*
Mercury	~0.01	0.00
Venus	177.4	3.10
Earth	23.44	0.41
Moon	1.5424	0.03
Mars	25.19	0.44
Jupiter	3.13	0.06
Saturn	26.73	0.47
Uranus	97.77	1.71
Neptune	28.32	0.49
Pluto	119.61	2.09

The charged planets move at right angles to the Sun's magnetic lines of force and describe the usual circular motion to which moving charged bodies are subject to in an electromagnetic field.

Venus and Uranus are unique in that their orbital motions about the SUN are retro-grade motions

Satellites, in turn, revolve in the smaller magnetic fields produced by the rotation of the planets. Mercury and Venus have no satellites as they produce extremely weak electromagnetic fields in addition to their Gravitational fields.

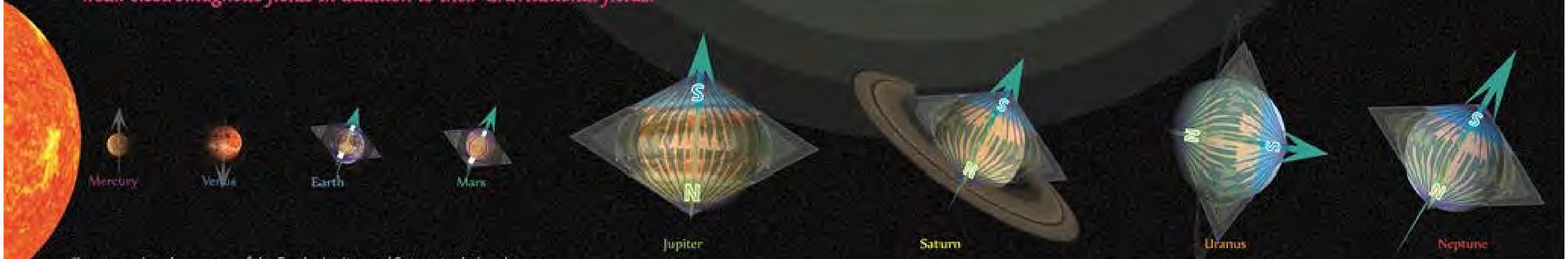

"In comparing the masses of the Earth, Jupiter and Saturn to their volumes, one remarks that the densities of these planets are, to some degree, inverse to their mean distances from the Sun. This rule is not true for Venus and Uranus"

Urbain Le Verrier

Solar orbit Inclinations

Inclination to Sun's equator (°)

Rocky Planets	
Mercury	3.38
Venus	3.86
Earth	7.15
Mars	5.65
Gas giants	
Jupiter	6.09
Saturn	5.51
Uranus	6.48
Neptune	6.43

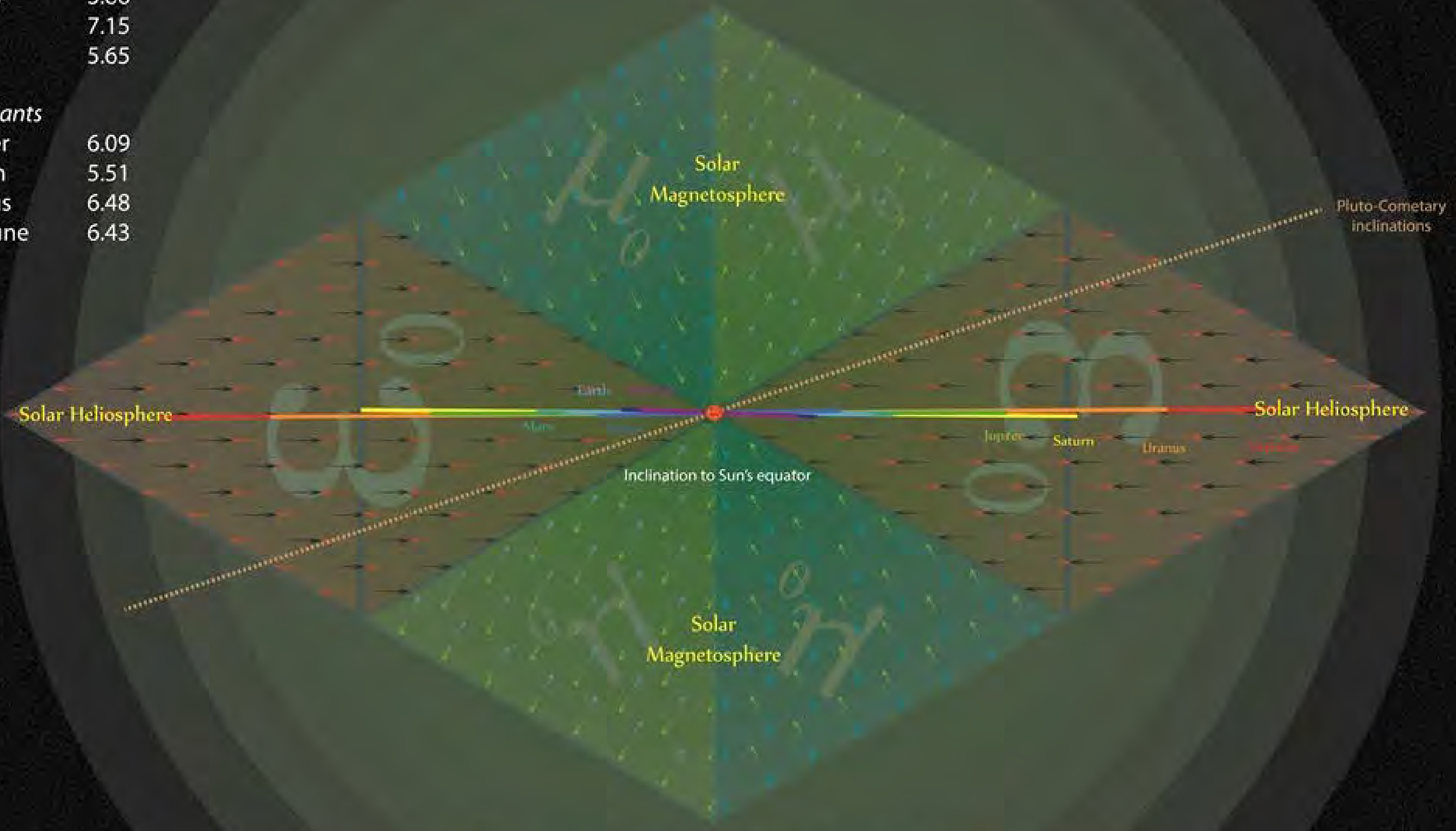
Solar Magnetosphere
μ_0
Pluto-Cometary inclinations
ε_0
Solar Heliosphere
Earth
Mars
Solar Heliosphere
Jupiter
Saturn
Uranus
Neptune
Inclination to Sun's equator
ε_0
Solar Magnetosphere
μ_0

Orbital inclination is one of the six orbital parameters describing the shape and orientation of a celestial orbit.

It is the angular distance of the orbital plane from the plane of reference (usually the primary's equator or the ecliptic), normally stated in degrees.

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Gravity is a strictly convergent Force

GR = G + EM

Einstein Newton Lorentz

General Relativity models
Newtonian Gravity with SR
interactions

The Lagrange Points

are the five positions in an orbital configuration where a small object affected only by gravity can be stationary relative to two larger material bodies of mass-Matter

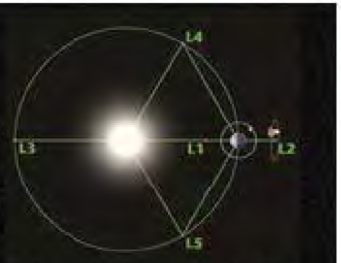

GEM forces between two bodies
can be modelled with super-positioned
equilateral energy geometries

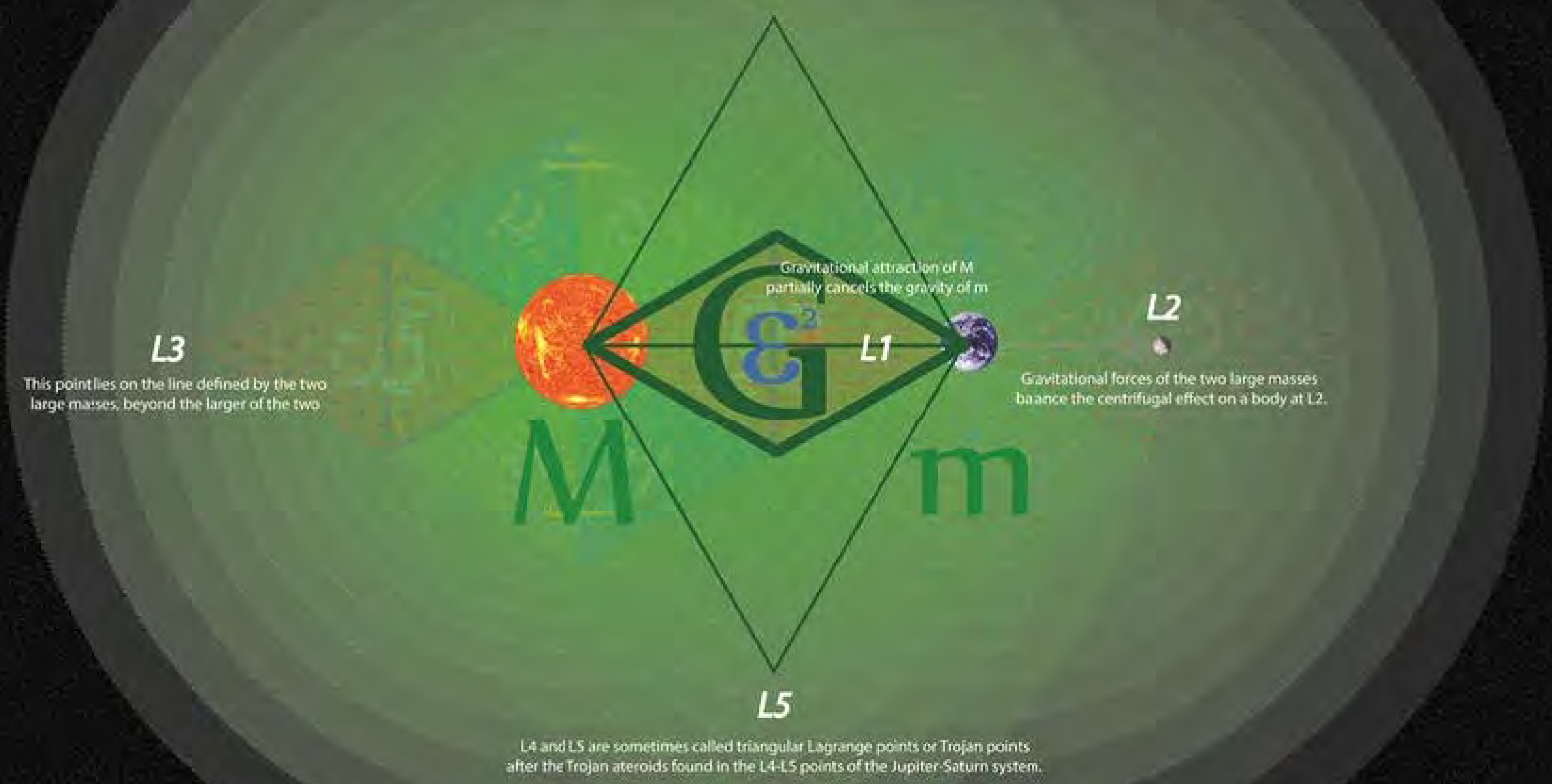

Gravitational forces from the two massive bodies are in the same ratio as the material masses of the two bodies

Gravitational attraction of M partially cancels the gravity of m

This point lies on the line defined by the two large masses, beyond the larger of the two

Gravitational forces of the two large masses baance the centrifugal effect on a body at L2.

L4 and L5 are sometimes called triangular Lagrange points or Trojan points after the Trojan ateroids found in the L4-L5 points of the Jupiter-Saturn system.

Newtonian Gravitation [illegible] the
observed attractive force
between Matter

The Lagrange points mark positions where
the combined gravitational pull of the two
large masses provides precisely the right
centripetal force required to rotate with them

Lagrange found his points of stabilty
by subtracting the gravitational potential
energy from the object's kinetic energy.

Tetryonics 74.05 - Lagrangian Points

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Earth-Moon Gravito-Electro-Magnetic fields

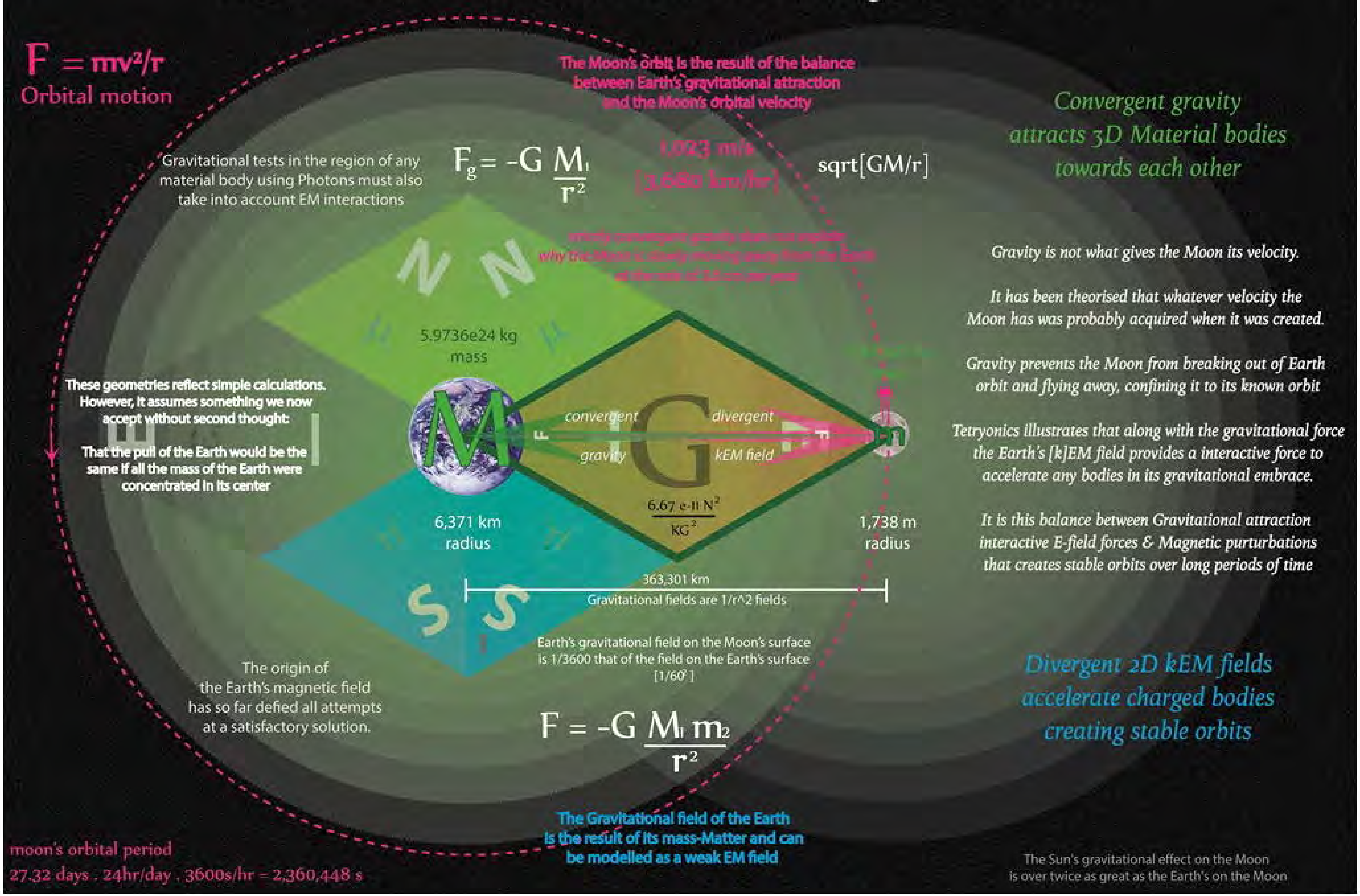

$F = mv^2/r$
Orbital motion

The Moon's orbit is the result of the balance
between Earth's gravitational attraction
and the Moon's orbital velocity

1,023 m/s
[3,680 km/hr]

sqrt[GM/r]

strictly convergent gravity does not explain
why the Moon is slowly moving away from the Earth
at the rate of 3.8 cm per year

Gravitational tests in the region of any material body using Photons must also take into account EM interactions

$F_g = -G \frac{M_1}{r^2}$

These geometries reflect simple calculations. However, it assumes something we now accept without second thought:

That the pull of the Earth would be the same if all the mass of the Earth were concentrated in its center

The origin of the Earth's magnetic field has so far defied all attempts at a satisfactory solution.

Earth's gravitational field on the Moon's surface is 1/3600 that of the field on the Earth's surface [$1/60^2$]

$F = -G \frac{M_1 m_2}{r^2}$

The Gravitational field of the Earth is the result of its mass-Matter and can be modelled as a weak EM field

moon's orbital period
27.32 days . 24hr/day . 3600s/hr = 2,360,448 s

Convergent gravity attracts 3D Material bodies towards each other

Gravity is not what gives the Moon its velocity.

It has been theorised that whatever velocity the Moon has was probably acquired when it was created.

Gravity prevents the Moon from breaking out of Earth orbit and flying away, confining it to its known orbit

Tetryonics illustrates that along with the gravitational force the Earth's [k]EM field provides a interactive force to accelerate any bodies in its gravitational embrace.

It is this balance between Gravitational attraction interactive E-field forces & Magnetic perturbations that creates stable orbits over long periods of time

Divergent 2D kEM fields accelerate charged bodies creating stable orbits

The Sun's gravitational effect on the Moon is over twice as great as the Earth's on the Moon

Tetryonics 74.06 - Earth-Moon EM interaction field

The Earth's ElectroMagnetic field

Earth's magnetic field (also known as the geomagnetic field) is the magnetic field
that extends from the Earth's inner core to where it meets the solar wind,

It is the magnetic dipole field
tilted at an angle of 11 degrees
with respect to the rotational axis

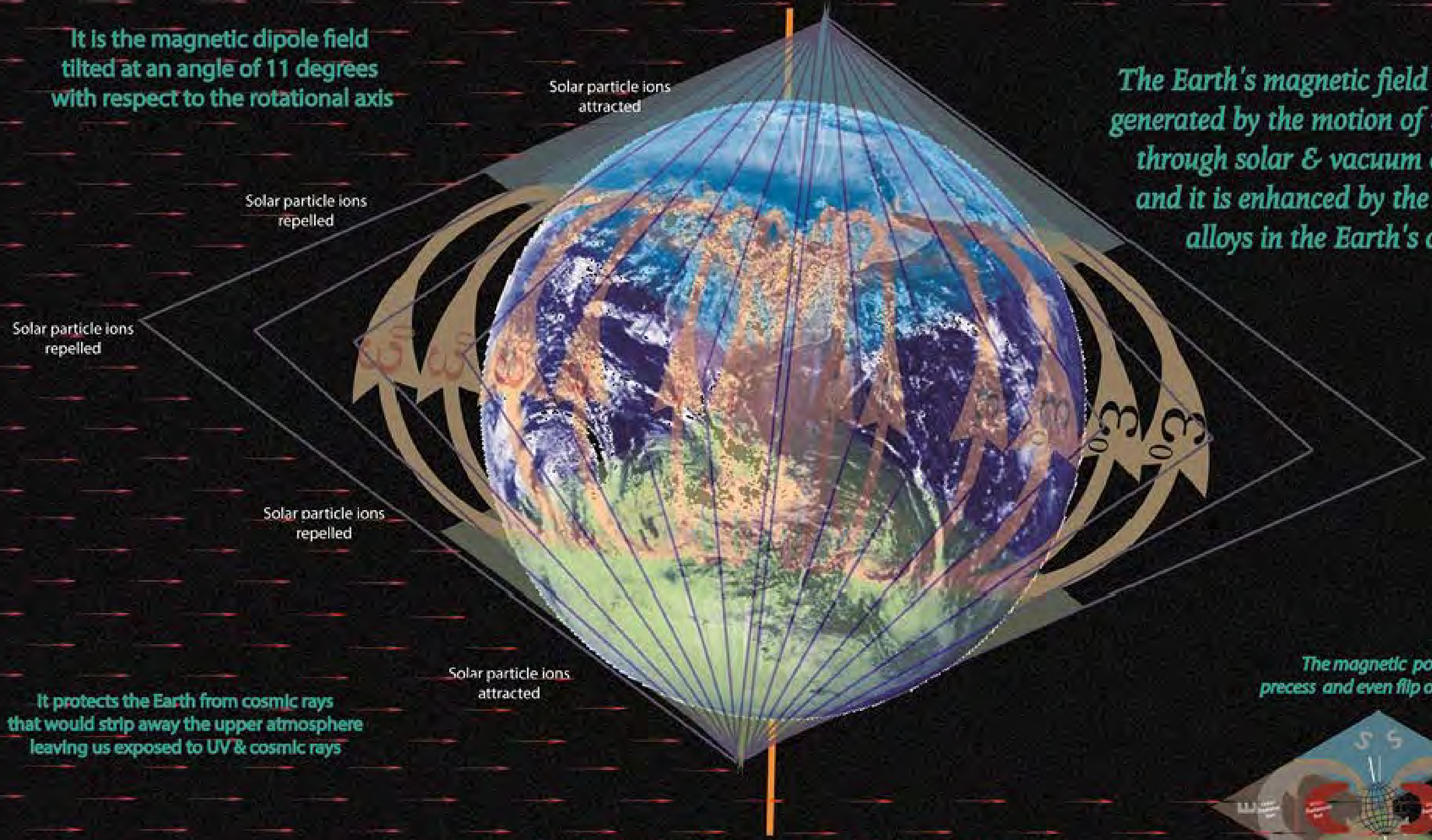
Solar particle ions
attracted
Solar particle ions
repelled
Solar particle ions
repelled
Solar particle ions
repelled
Solar particle ions
attracted

*The Earth's magnetic field is really
generated by the motion of the Earth
through solar & vacuum energies
and it is enhanced by the molten
alloys in the Earth's core*

It protects the Earth from cosmic rays
that would strip away the upper atmosphere
leaving us exposed to UV & cosmic rays

*The magnetic poles
precess and even flip over time*

At random intervals (several hundred thousand years) the Earth's field reverses
(the north and south geomagnetic poles change places with each other)

Tetryonics 74.07 - The Earth's Magnetic field

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The Earth's molten core

The Earth has an outer silicate solid crust, a highly viscous mantle, a liquid outer core that is much less viscous than the mantle, and a solid inner core. Scientific understanding of Earth's internal structure is based on observations of topography and bathymetry.

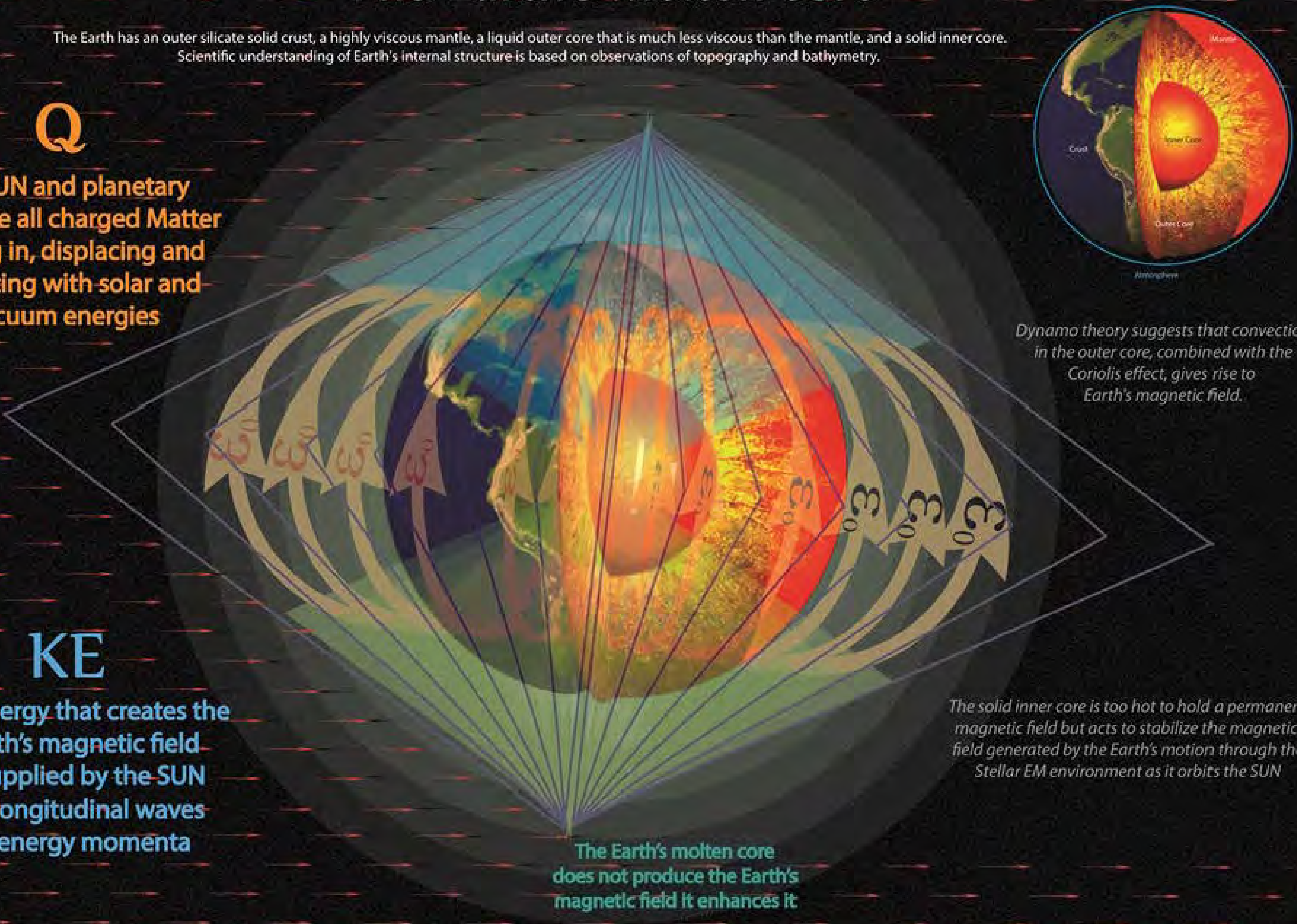

Q

The SUN and planetary bodies are all charged Matter moving in, displacing and interacting with solar and vacuum energies

Dynamo theory suggests that convection in the outer core, combined with the Coriolis effect, gives rise to Earth's magnetic field.

KE

The energy that creates the Earth's magnetic field is supplied by the SUN via longitudinal waves of energy momenta

The solid inner core is too hot to hold a permanent magnetic field but acts to stabilize the magnetic field generated by the Earth's motion through the Stellar EM environment as it orbits the SUN

The Earth's molten core does not produce the Earth's magnetic field it enhances it

The force exerted by Earth's gravity can be used to calculate its mass, and by estimating the volume of the planet, its average density can be calculated.

Astronomers can also calculate Earth's mass from its orbit and effects on nearby planetary bodies.

Terrestrial Aurora

result from the interaction of the Earth's magnetic field and the energetic solar wind,
which provides energised ions and photons to the polar regions of Planets

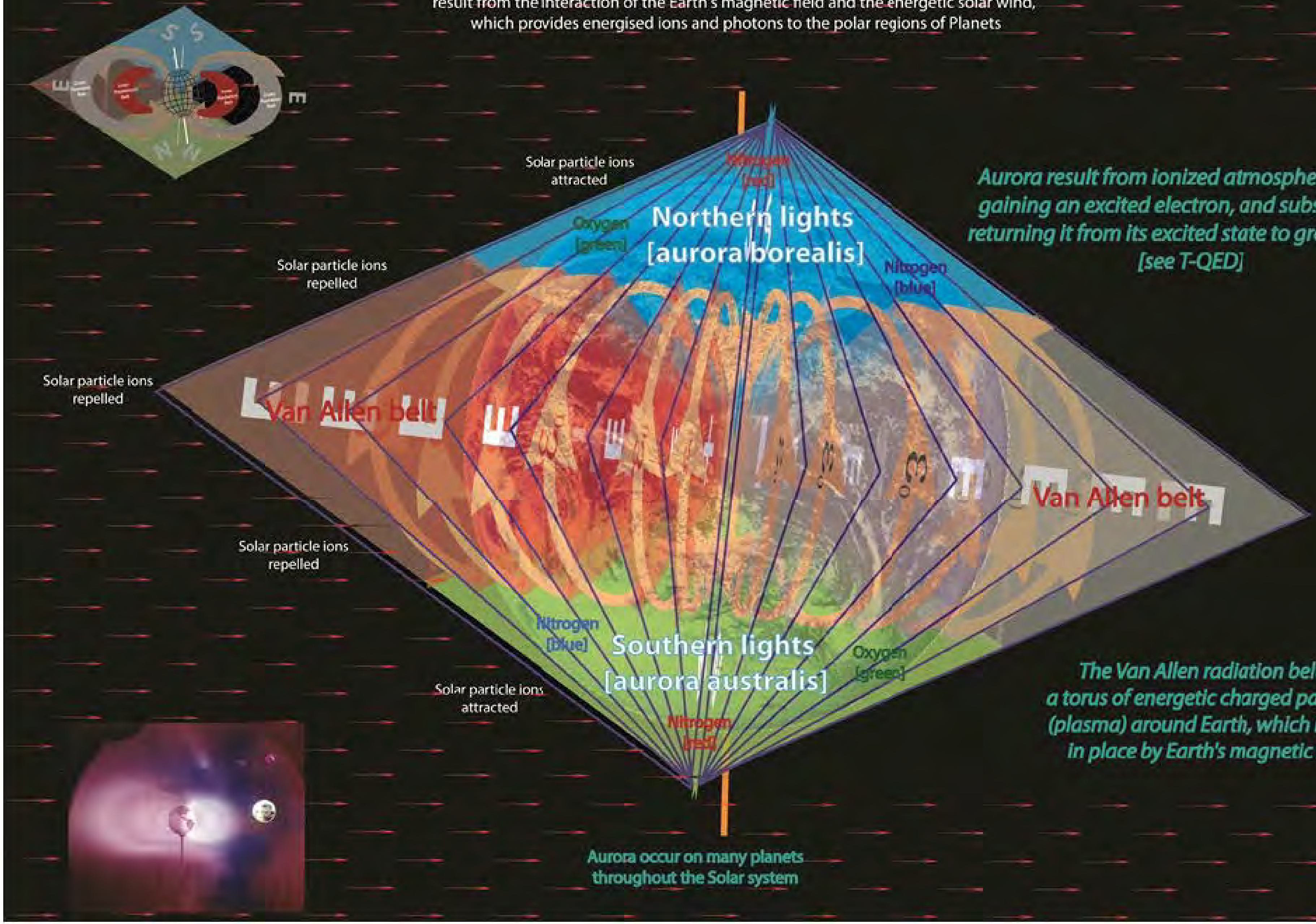
S
S
E
E
N
N
Solar particle ions attracted
Nitrogen [red]
Oxygen [green]
Northern lights [aurora borealis]
Nitrogen [blue]
Solar particle ions repelled
Solar particle ions repelled
Van Allen belt
Van Allen belt
Solar particle ions repelled
Nitrogen [blue]
Southern lights [aurora australis]
Oxygen [green]
Solar particle ions attracted
Nitrogen [red]

Aurora result from ionized atmospheric atoms gaining an excited electron, and subsequently returning it from its excited state to ground state [see T-QED]

The Van Allen radiation belt is a torus of energetic charged particles (plasma) around Earth, which is held in place by Earth's magnetic field

Aurora occur on many planets throughout the Solar system

Absolute Rest Frames

Absolute Rest is intrinsically linked to the concepts of absolute time and space originally introduced by Sir Isaac Newton in the Philosophiæ Naturalis Principia Mathematica, which provided a theoretical foundation that facilitated Newtonian mechanics.

According to Newton, absolute time and space respectively are independent aspects of objective reality.

Rest in physics refers to an object being stationary relative to a particular frame of reference or another object

In Tetryonics an Inertial Rest frame can be determined by the absence of a Kinetic EM field & its Magnetic moment

The concepts of space and time were separate in physical theory prior to the advent of special relativity theory, which connected the two and showed both to be dependent upon the observer's inertial state of motion relative to other inertial frames.

In Einstein's theories, the ideas of absolute time and space were superseded by the notion of spacetime in special relativity, and by dynamically curved spacetime in general relativity.

$$p^2 = E = mv^2$$

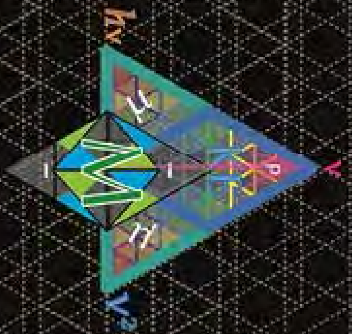

$$\frac{p^2}{2} = KE = \tfrac{1}{2}Mv^2$$

In some of his later paper (especially in 1920 and 1924), Einstein gave a new definition of the aether by identifying it with "properties of space", and this aether can be called absolute, as long as its state cannot be influenced by Matter.

So he argued that Newton's absolute space can be considered as an "absolute aether". Also the four-dimensional spacetime of special relativity (which replaces the absolute space of Newton) would be some sort of "absolute aether", as its states cannot be influenced by Matter.

Tetryonics clearly establishes free space as a 3D volume filled with a interactive vacuum [aether] and EM energies against which any relative motion can be deduced by the presence (or absence) of divergent [K]EM fields produced as a direct result of Matter in motion additionally, 3D mass-Matter topologies displace the aether [vacuum energy field] producing convergent differential energy gradients [gravity fields]

Red-shifted Photonic Energies

Energy is ALWAYS conserved... longer wavelength [red-shifted] photon energies are a reflection of the time specific measurement of photonic energies at a particular distance from the source of the light

Photons are neutral, coupled charge equilateral mass-energy momenta geometries that radiate bilaterally at the speed of light in a vacuum

Photons

$$\frac{2\pi}{c^2}\left[\left[\overset{\text{Planck}}{m}\,\Omega\,\overset{\text{quanta}}{v^2}\right]\right]$$

mass velocity

EM waves

$$\frac{EVEN\pi}{c^2}\left[\left[\overset{\text{Planck}}{m}\,\Omega\,\overset{\text{quanta}}{v^2}\right]\right]$$

mass velocity

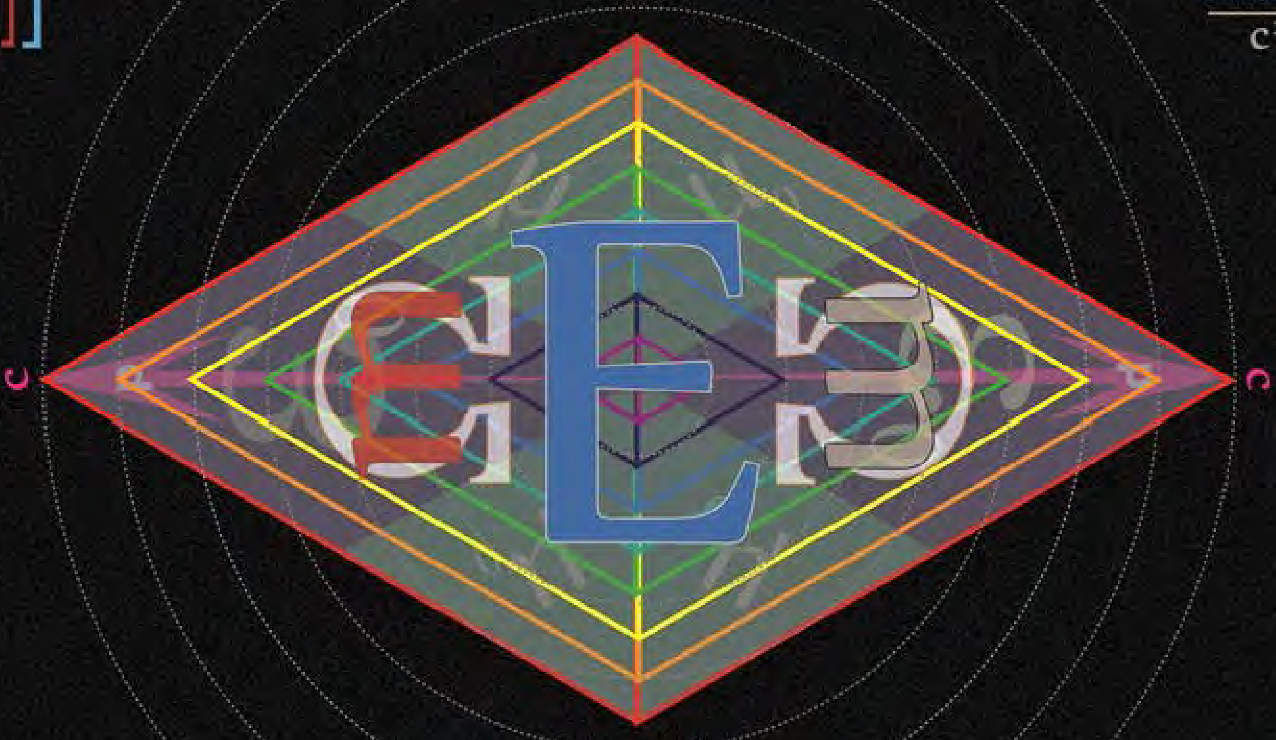

As photons radiate from a point source at 'c'

their EM energies diminsh as per the inverse square law

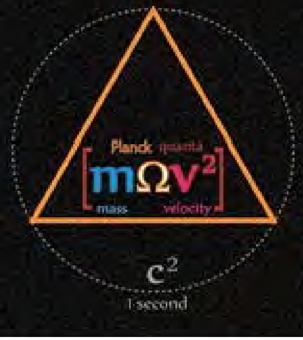

producing the familiar red-shifting of spectral lines

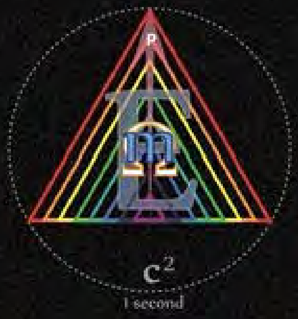

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The red shift of Photons

$d\lambda$ df

According to special relativity, as something approaches the speed of light, the passage of time slows.
A twin moving at the speed of light would not age or change relative to the stationary twin.

General relativity additionally states that the cosmological red shift is the result of a photon traveling through an expanding space time field which causes the photon to loose energy and it's wavelength correspondingly increases.

A photon travels at the speed of light; therefore it will not experience the passage of time, therefore it will not change; yet it does.

The divergent spreading of EM energy over time from a source creates the spacetime aether

The Quantised Angular Momentum and Energy content are directly related through the geometry of Photons

All EM Energy waveforms (save Matter) radiate outward following the inverse square law & reducing their energy content over time

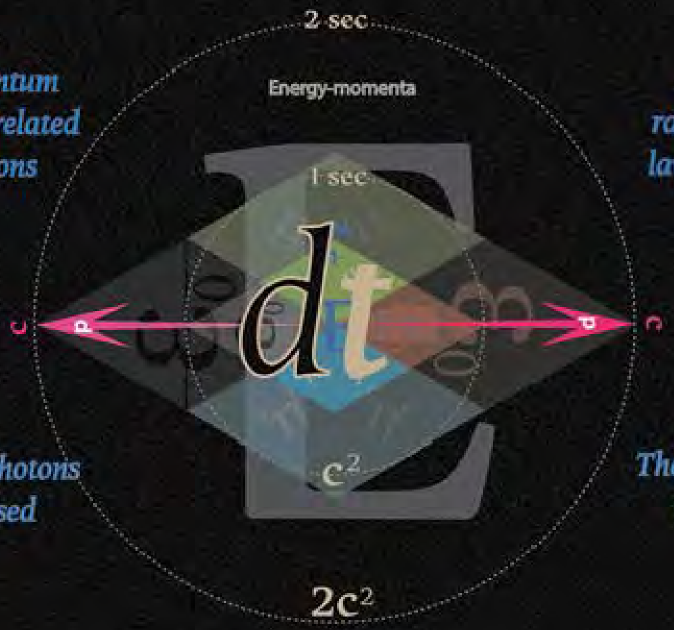

Blue-shifted photon travelling towards observer

Red-shifted photon moving away from observer

The EM mass-energy content of photons reveals photons to be a quantised electromotive field

The wavelength of a photon is related directly to its quantised mass-energy momenta geometry per unit of time

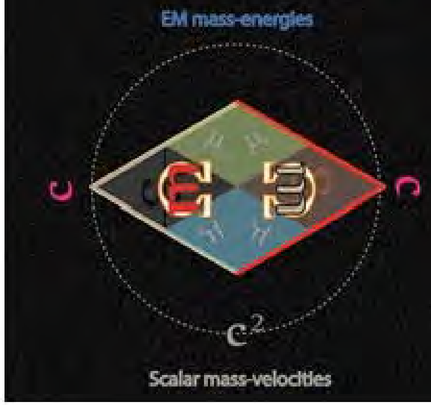

Tetryonic geometry relates photon mass-energy momenta to
the constant velocity of light in a vacuum and its intrinsic quantised angular momenta

$$\frac{mc^2}{c^2} = KE = \frac{hv^2}{c^2}$$

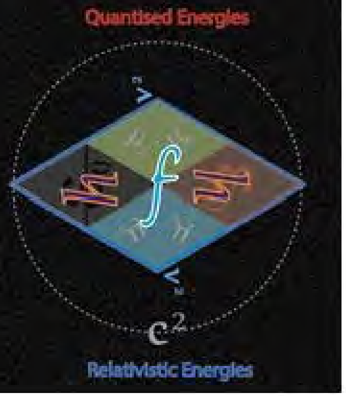

Tetryonics 75.03 - The Red-shift of Photons

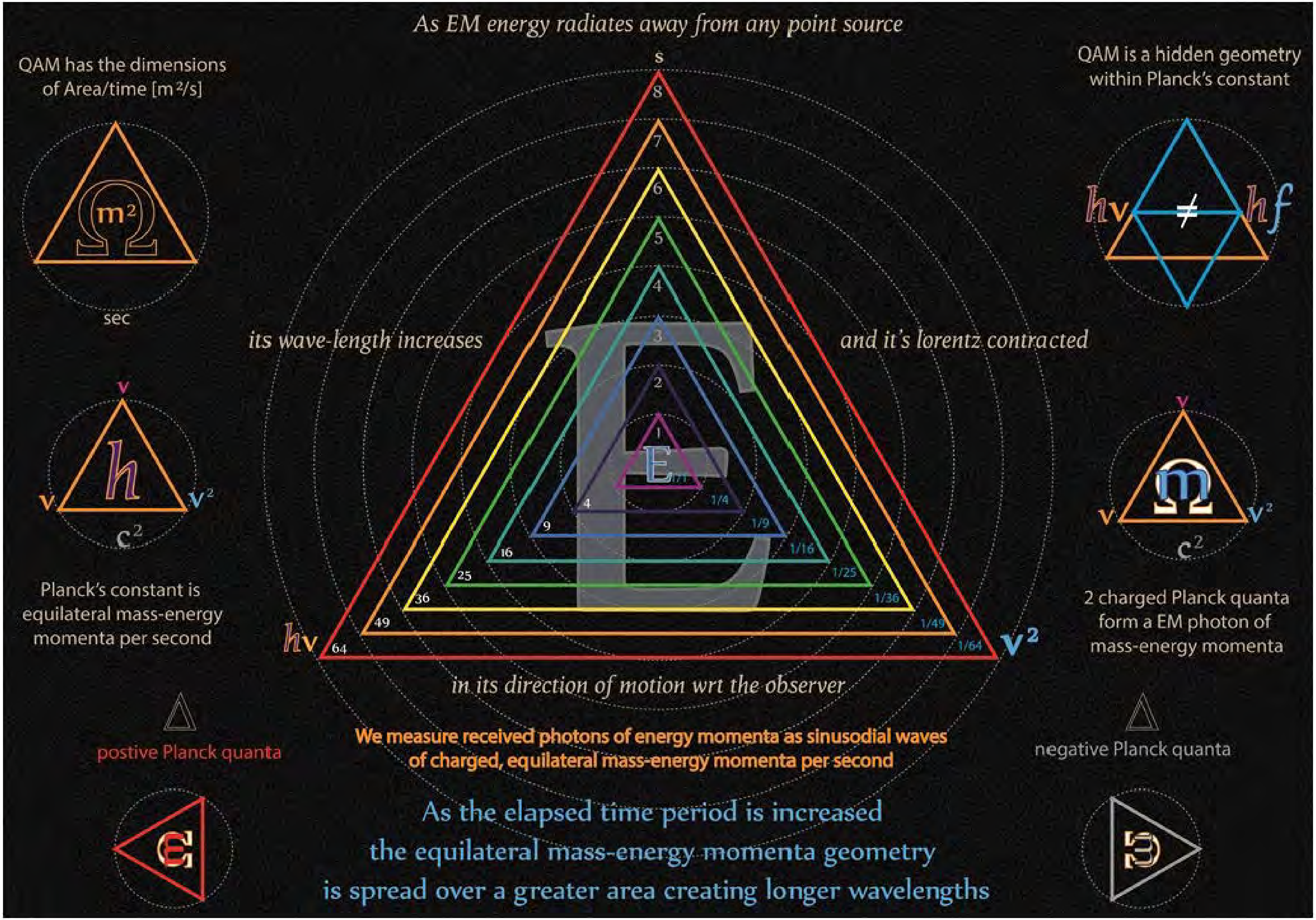

As EM energy radiates away from any point source

QAM has the dimensions of Area/time [m²/s]

QAM is a hidden geometry within Planck's constant

its wave-length increases

and it's lorentz contracted

Planck's constant is equilateral mass-energy momenta per second

2 charged Planck quanta form a EM photon of mass-energy momenta

in its direction of motion wrt the observer

postive Planck quanta

negative Planck quanta

We measure received photons of energy momenta as sinusodial waves of charged, equilateral mass-energy momenta per second

As the elapsed time period is increased
the equilateral mass-energy momenta geometry
is spread over a greater area creating longer wavelengths

Tetryonics 75.04 - Doppler wavelengths

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The Doppler shifting of EM waves

Photons

Planck quanta

$$\frac{2\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

EM waves

Planck quanta

$$\frac{\text{EVEN}\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

General relativity incorrectly holds that the cosmological red shift is the result of a photon traveling through an expanding space time field which causes the photon to loose energy and it's wavelength correspondingly increases

Photonic energies form inifitie energy loops [quantum transformers]

It is the Photon's intrinsic geometry that increases the further it travels from the source due to the inverse square law resulting in less energy (per unit of time) being recieved at increasing distances from the source as the Photon's specific QAM [m²/s] has increased over time

All EM waves are comprised of Photons of specific energies [Light is superpositioned EM waves]

All Photons are quantum harmonic oscillators and create sinusoidal EM waveforms are they radiate and are detected

Radiating geometric EM mass-energies from a source (over Distance-Time) creates the spatial vacuum aether

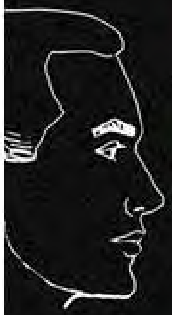

Blue-shifted

observer moves towards source *or* source moves towards observer

Any relative motion between the source & observer that reduces the distance between them produces a Blue-shift in the measured quanta-frequency/ energy of the EM wave

observer moves away from source *or* source moves away from observer

Red-shifted

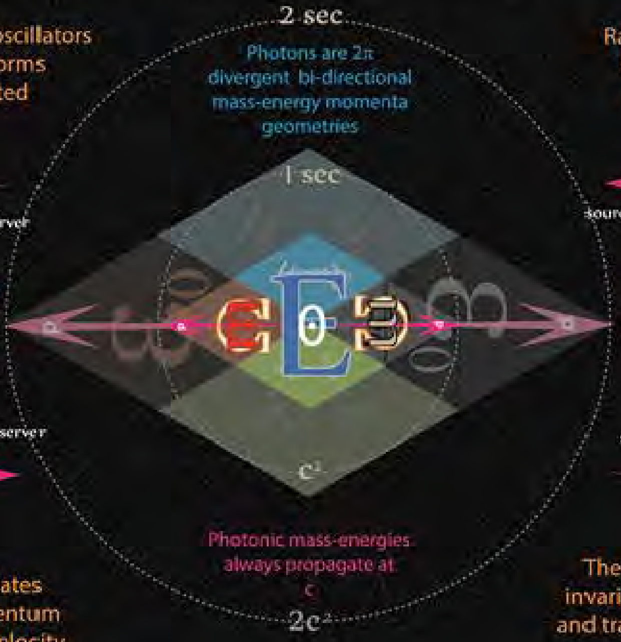

Photons are 2π divergent bi-directional mass-energy momenta geometries

Photonic mass-energies always propagate at c

Red-shifted

source moves away from observer *or* observer moves away from source

Any relative motion between the source and observer that increases the distance bewteen them produces a Red-shift in the measured quanta-frequency/ energy of the EM wave

source moves towards observer *or* observer moves towards source

Blue-shifted

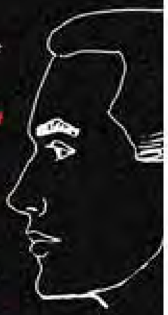

Tetryonics clearly shows and relates Time to quantised angular momentum and Planck energy momenta to velocity

The energy of indiviudal photons is invariant until they interact with Matter and transfer their mass-energy momenta

motion toward the source increases the number of quanta per sec measured

[v+v]

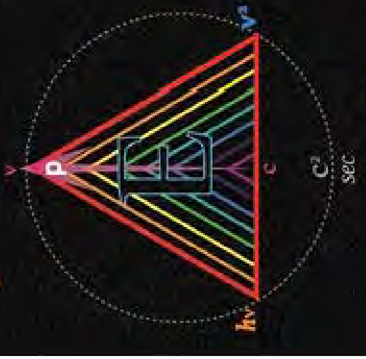

Poor definintions of Energy per unit of Time along with the interchange of quanta and frequency have led to the mistaken concept of photons losing energy

$$mv^2 = E = hv^2$$

Photons DO NOT lose energy as they travel. the group energy [per unit of time] of the EM wave they form spreads out over time as a direct result of the inverse square law

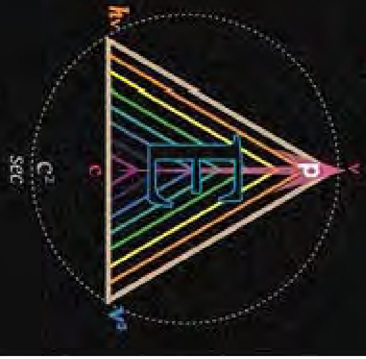

motion away from the source decreases the number of quanta per sec measured

[v-v]

Cosmological doppler-shifting of Light is the direct result of the motion of Matter in the Universe

Gravitational Red-shifting is an EM effect not gravitational

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$d\lambda$

Relativistic Corrections

are applied to only [kinetic]EM mass-energy geometries

$$\frac{Mv^2}{c^2} = KEM = \frac{hv^2}{c^2}$$

dt

Wave-length contraction

linear
Lorentz corrections

$$\beta = \left[\frac{v}{c}\right]$$

SR - measuring rods in differing interial frames have different contracted lengths

GR - lengths measured in curved spacetime are different to straight lines in flat spacetime

$$\frac{\Delta\Omega}{c}$$

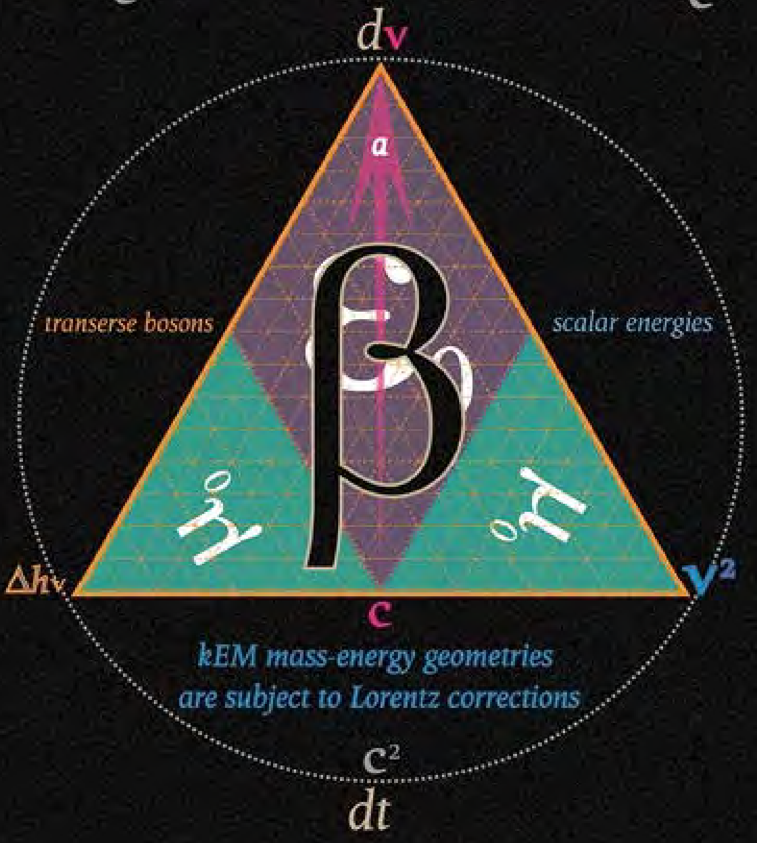

kEM mass-energy geometries
are subject to Lorentz corrections

Time Dilation

scalar
Lorentz corrections

$$\beta^2 = \left[\frac{v^2}{c^2}\right]$$

SR - clocks in differing inertial frames experience time dilation

GR - clocks in differing Gravitational fields experience time dilation

$$\frac{\Delta\Omega}{c^2}$$

scalar energy momenta

Matter

$$\frac{T\pi}{c^4}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\Omega\,\overset{\text{quanta}}{\underset{\text{velocity}}{v}}\right]^2\right]$$

linear momentum

The mass-energies of standing-wave Matter topologies are Lorentz invariant

GPS relativistic corrections

Claims that the Global Positioning System (GPS) provides a valid test of General relativity are erroneous
[GR provides Lorentzian [SR] correcttions under the guise of Gravitational effects]

Photons are mass-energy momenta quanta
[they are Matter-less NOT mass-less]
and are subect to Lorentz Forces and corrections

Newton G + SR = GR *Einstein*
Lorentz

Graviational Matter

M

All Matter topologies
produce
a Gravitational field

Newtonian Gravity
is universal

The gravitational effects
caused by Matter can only
be accurately modelled [or
tested] through the exclusion
of all EM fields interactions

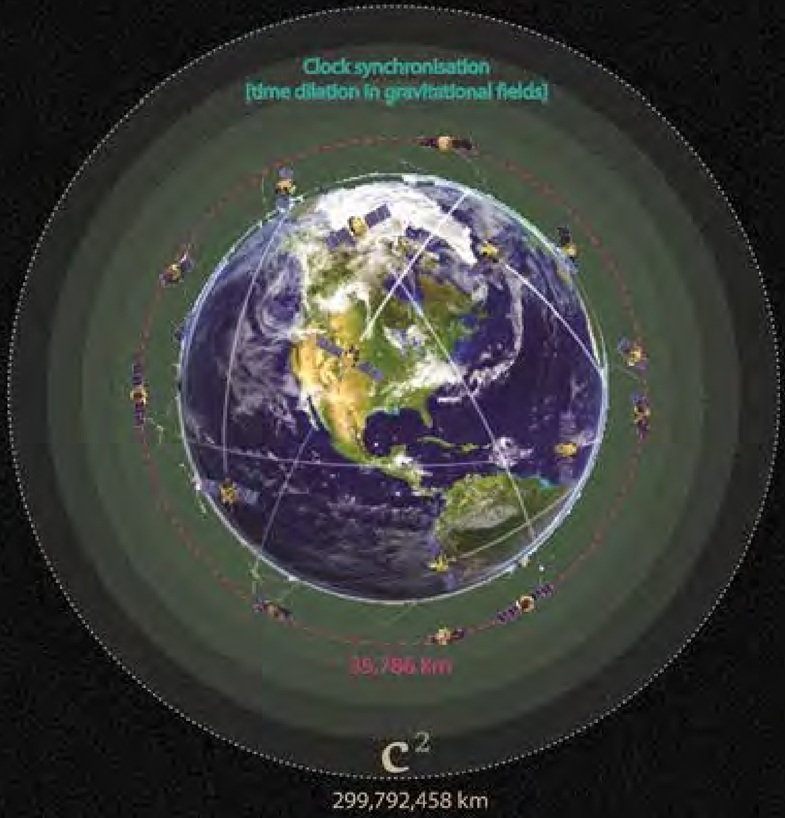

Interactive masses

m

All Matter in motion
produces
interactive mass-energies

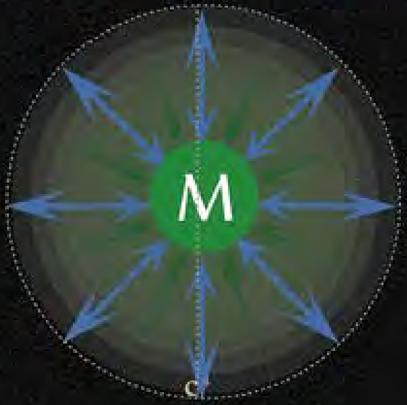

General Relativity
is limted to c

Any test of GR using Photons
as a testing mechanism
by definition is affected by
and subject to Special relativity
[ElectroMagnetic effects]

The 'gravitational' frequency shifting [Red-Blue shifting of EM waves] is in fact an electromagnetic effect

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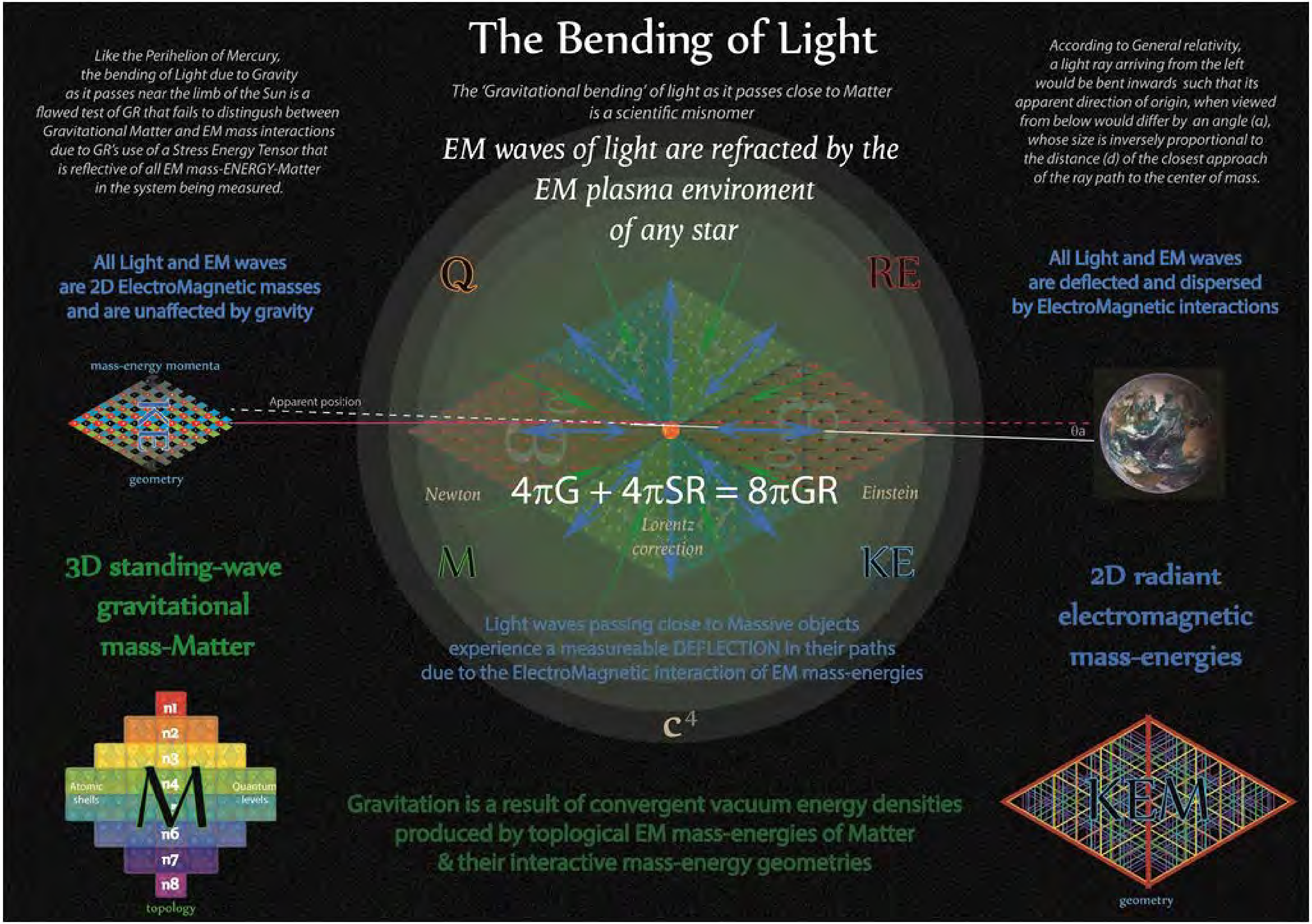

The Bending of Light

Like the Perihelion of Mercury,
the bending of Light due to Gravity
as it passes near the limb of the Sun is a
flawed test of GR that fails to distingush between
Gravitational Matter and EM mass interactions
due to GR's use of a Stress Energy Tensor that
is reflective of all EM mass-ENERGY-Matter
in the system being measured.

The 'Gravitational bending' of light as it passes close to Matter
is a scientific misnomer

*EM waves of light are refracted by the
EM plasma enviroment
of any star*

According to General relativity,
a light ray arriving from the left
would be bent inwards such that its
apparent direction of origin, when viewed
from below would differ by an angle (a),
whose size is inversely proportional to
the distance (d) of the closest approach
of the ray path to the center of mass.

**All Light and EM waves
are 2D ElectroMagnetic masses
and are unaffected by gravity**

**All Light and EM waves
are deflected and dispersed
by ElectroMagnetic interactions**

$$4\pi G + 4\pi SR = 8\pi GR$$

Lorentz
correction

**3D standing-wave
gravitational
mass-Matter**

Light waves passing close to Massive objects
experience a measureable DEFLECTION in their paths
due to the ElectroMagnetic interaction of EM mass-energies

**2D radiant
electromagnetic
mass-energies**

**Gravitation is a result of convergent vacuum energy densities
produced by toplogical EM mass-energies of Matter
& their interactive mass-energy geometries**

Tetryonics 75.08 - The Bending of Light

The Perihelion of Mercury

is the result of EM interactions in addition to gravitational attraction

The perihelion of Mercury's orbit precesses at a measurable rate, but even after accounting for gravitational perturbations caused all other planets in the solar system, Newton's theory (assuming a precise inverse-square relationship for distance) predicts a rate of precession that differs from the measured rate by approximately 43 arcseconds per century.

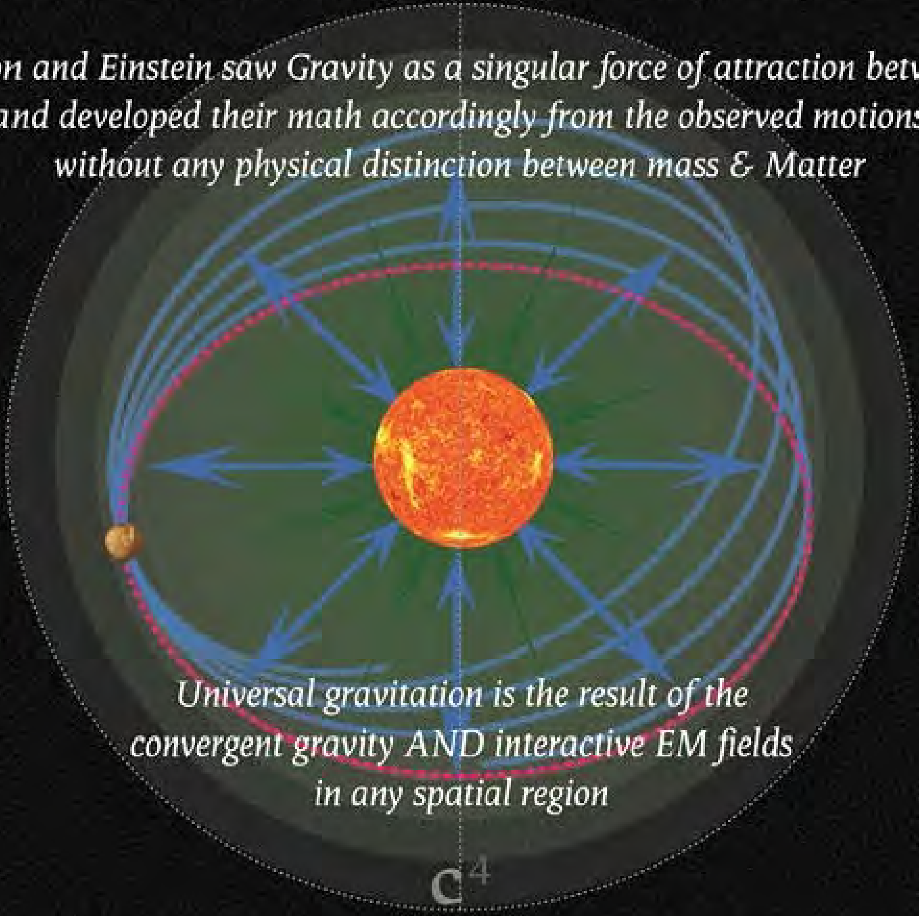

Both Newton and Einstein saw Gravity as a singular force of attraction between objects and developed their math accordingly from the observed motions without any physical distinction between mass & Matter

$4\pi G$

$8\pi G$

Newton modelled only the observed nett attractive force of Matter in the system

Einstein modelled the nett convergent force of all energies without differentiation

$$F = -G\frac{M_1 m_2}{r^2}$$

$$G_{ab} = \kappa T_{ab}$$

Universal gravitation is the result of the convergent gravity AND interactive EM fields in any spatial region

c^4

Newton

G

Einstein

G+EM

Newton Lorentz

General relativity was developed in part to provide an estimate for this rate of precession that better matches observations.

Newton's theory can also be 'incorrectly modified' to explain this perihelion by factoring in the gravitational pull due to other planets or making tiny adjustments to parameters in the gravitational equation to reflect the effect of ElectroMagnetic interactions between the Sun and Mercury.

By modelling the quantum interactions of ALL GEM mass-ENERGIES and their distinct geometries Tetryonic theory explains recently measured discrepancies in both Newtonian & GR formulations of Gravity

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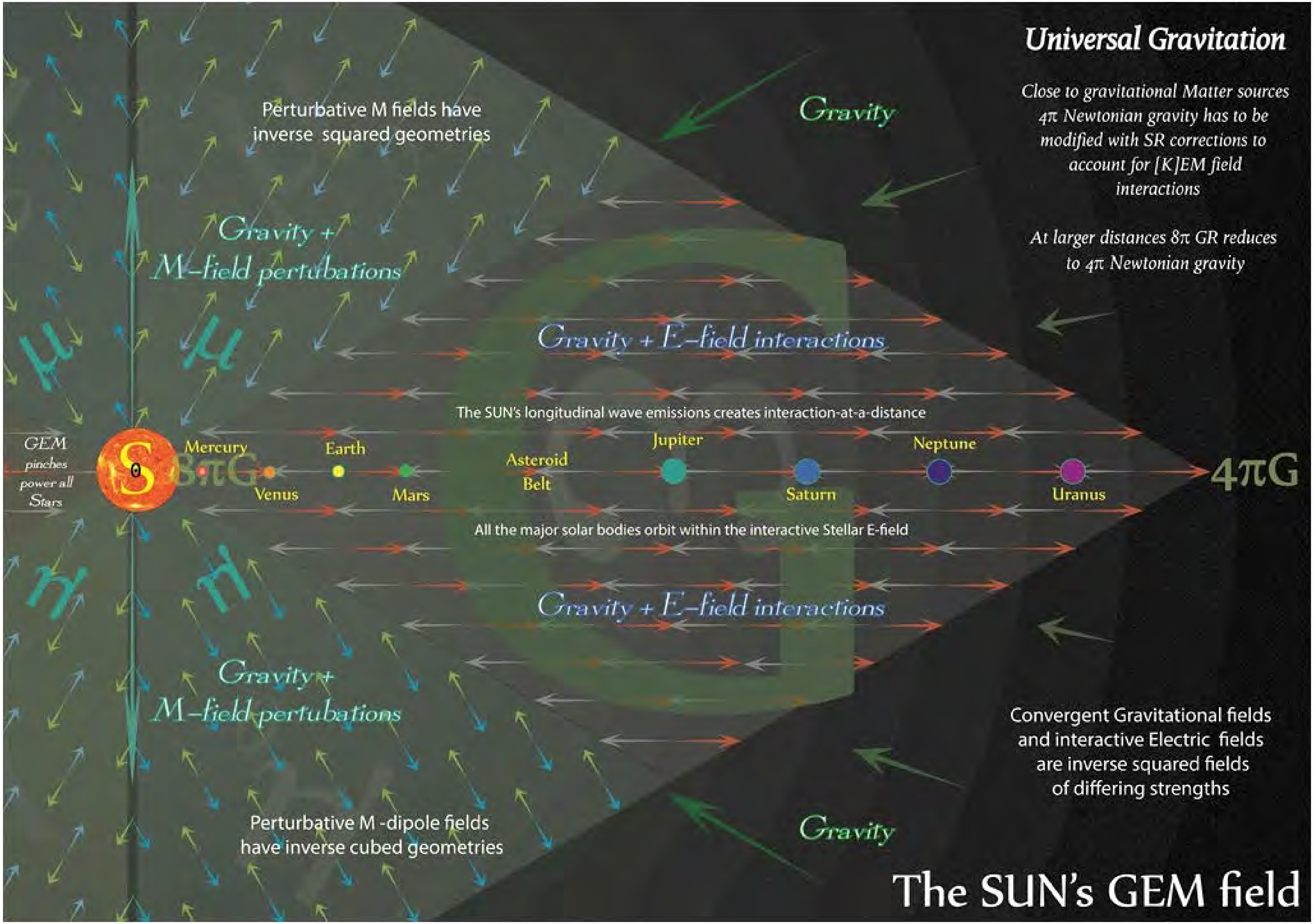
Gravity
Gravity
Gravity + M–field pertubations
Gravity + M–field pertubations
Gravity + E–field interactions
Gravity + E–field interactions
μ
μ
η
η
GEM pinches power all Stars
S
8πG
Mercury
Venus
Earth
Mars
Asteroid Belt
Jupiter
Saturn
Neptune
Uranus
4πG

Universal Gravitation

Close to gravitational Matter sources 4π Newtonian gravity has to be modified with SR corrections to account for [K]EM field interactions

At larger distances 8π GR reduces to 4π Newtonian gravity

Perturbative M fields have inverse squared geometries

The SUN's longitudinal wave emissions creates interaction-at-a-distance

All the major solar bodies orbit within the interactive Stellar E-field

Convergent Gravitational fields and interactive Electric fields are inverse squared fields of differing strengths

Perturbative M -dipole fields have inverse cubed geometries

The SUN's GEM field

Tetryonics 76.01 - The SUN's GEM field

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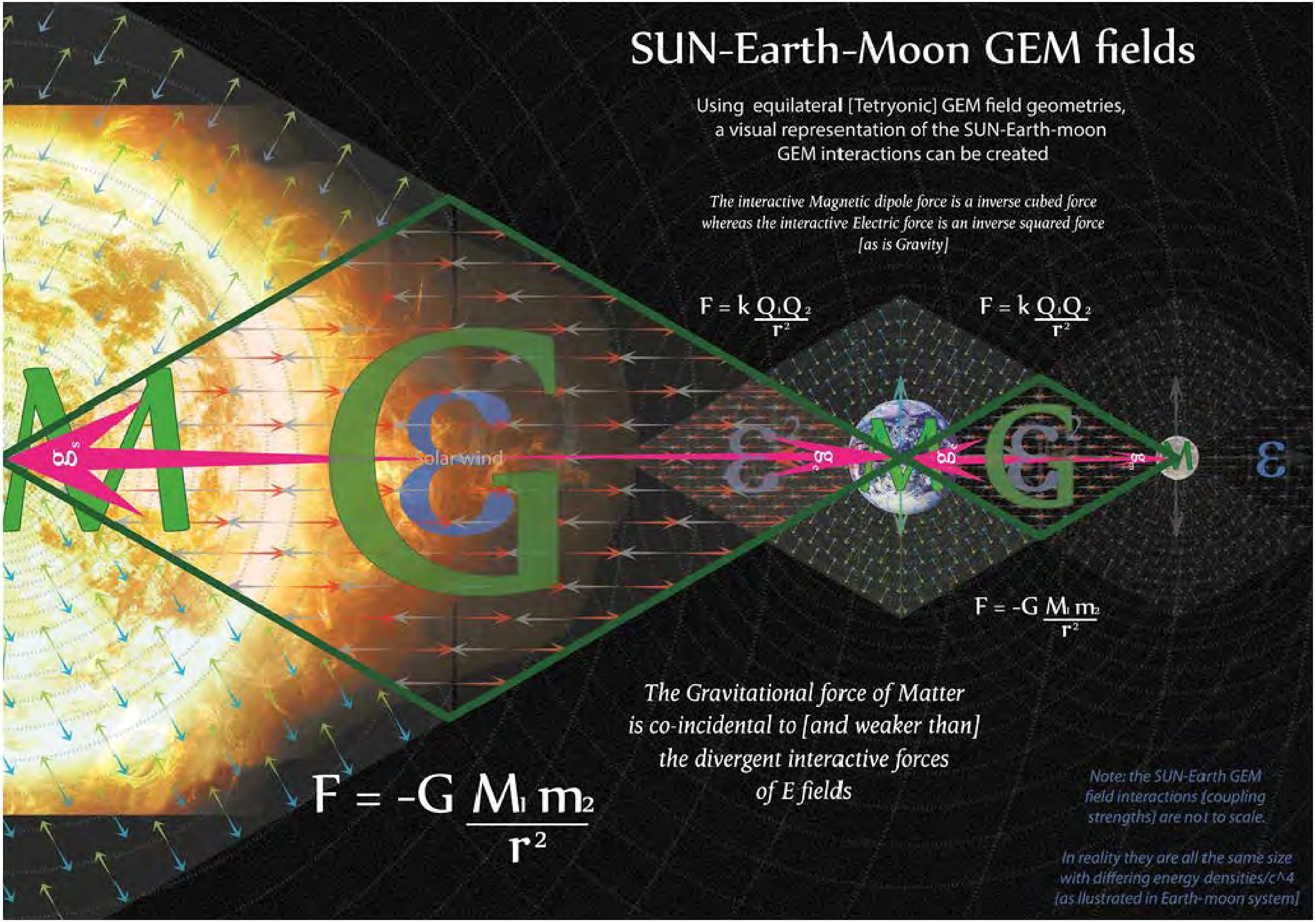

SUN-Earth-Moon GEM fields

Using equilateral [Tetryonic] GEM field geometries,
a visual representation of the SUN-Earth-moon
GEM interactions can be created

The interactive Magnetic dipole force is a inverse cubed force whereas the interactive Electric force is an inverse squared force [as is Gravity]

$F = k\frac{Q_1Q_2}{r^2}$

$F = k\frac{Q_1Q_2}{r^2}$

$F = -G\frac{M_1 m_2}{r^2}$

*The Gravitational force of Matter
is co-incidental to [and weaker than]
the divergent interactive forces
of E fields*

$$F = -G\frac{M_1 m_2}{r^2}$$

Note: the SUN-Earth GEM field interactions [coupling strengths] are not to scale.

In reality they are all the same size with differing energy densities/c^4 [as illustrated in Earth-moon system]

Tetryonics 76.02 - SUN-Earth-moon GEM fields

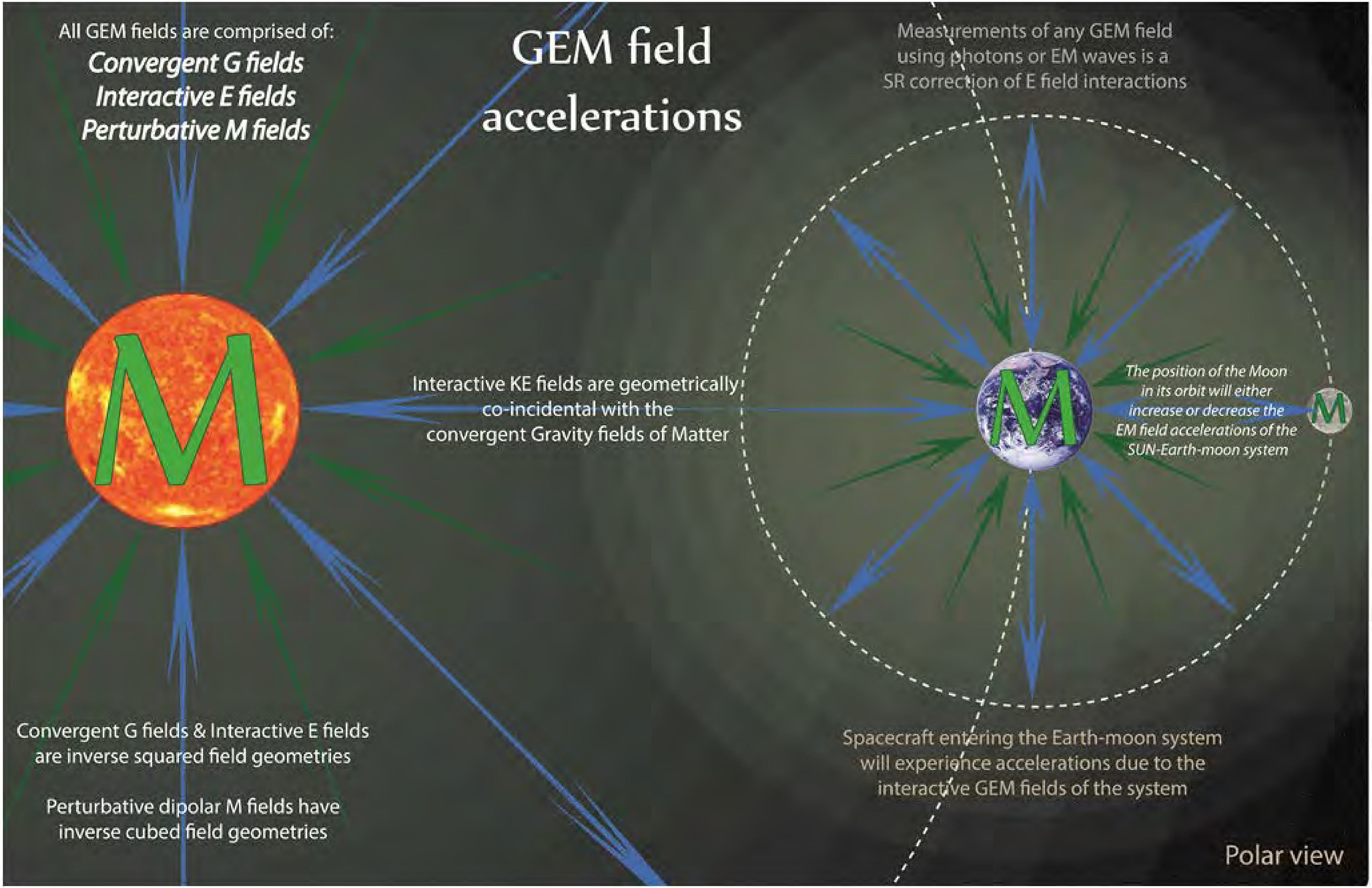

GEM field accelerations

All GEM fields are comprised of:

Convergent G fields
Interactive E fields
Perturbative M fields

Measurements of any GEM field using photons or EM waves is a SR correction of E field interactions

Interactive KE fields are geometrically co-incidental with the convergent Gravity fields of Matter

The position of the Moon in its orbit will either increase or decrease the EM field accelerations of the SUN-Earth-moon system

Convergent G fields & Interactive E fields are inverse squared field geometries

Perturbative dipolar M fields have inverse cubed field geometries

Spacecraft entering the Earth-moon system will experience accelerations due to the interactive GEM fields of the system

Polar view

Tetryonics 76.03 - GEM fields [Polar]

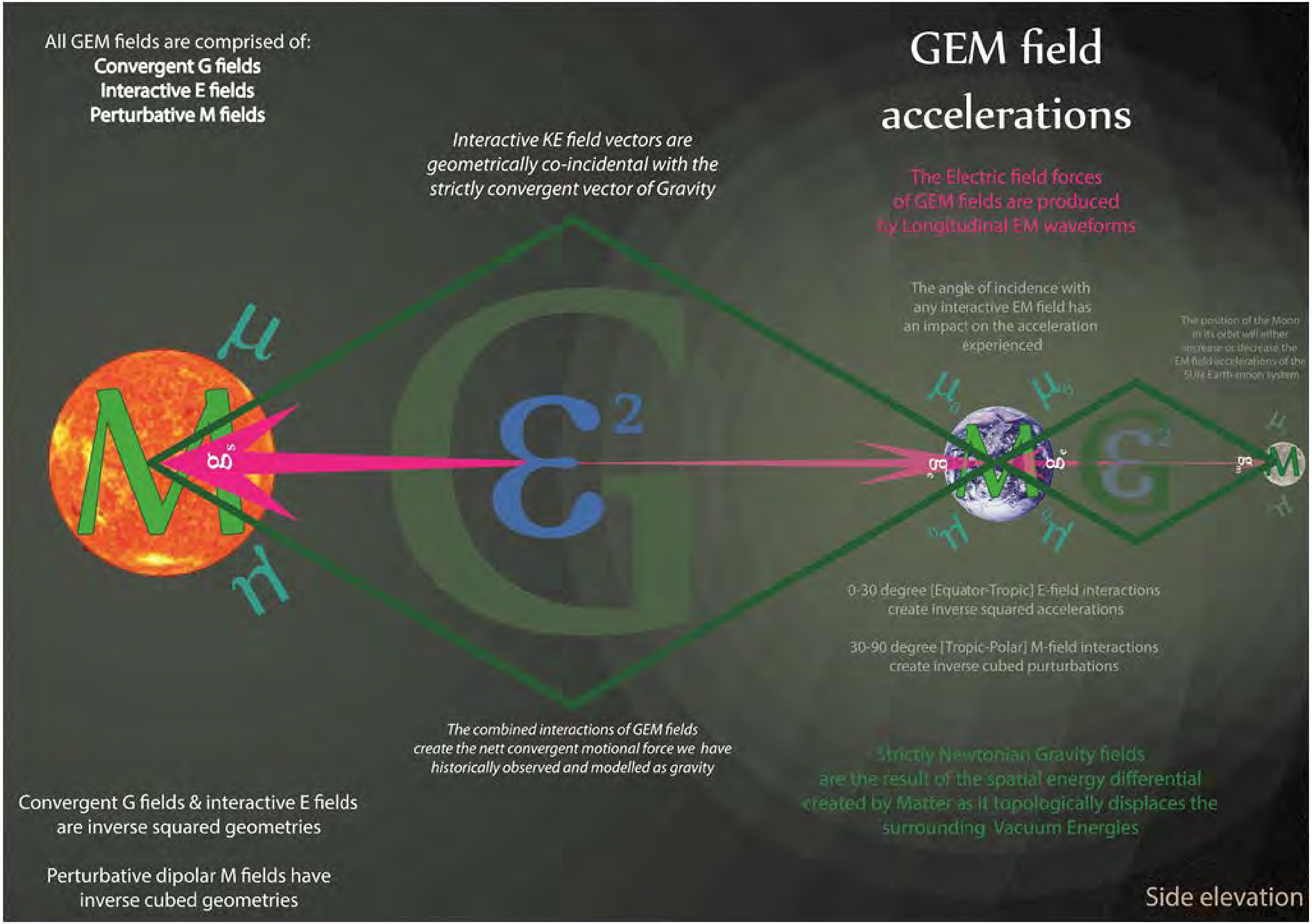

GEM field accelerations

All GEM fields are comprised of:
Convergent G fields
Interactive E fields
Perturbative M fields

Interactive KE field vectors are geometrically co-incidental with the strictly convergent vector of Gravity

The Electric field forces of GEM fields are produced by Longitudinal EM waveforms

The angle of incidence with any interactive EM field has an impact on the acceleration experienced

The position of the Moon in its orbit will either increase or decrease the EM field accelerations of the SUN Earth-moon system

0-30 degree [Equator-Tropic] E-field interactions create inverse squared accelerations

30-90 degree [Tropic-Polar] M-field interactions create inverse cubed purturbations

The combined interactions of GEM fields create the nett convergent motional force we have historically observed and modelled as gravity

Strictly Newtonian Gravity fields are the result of the spatial energy differential created by Matter as it topologically displaces the surrounding Vacuum Energies

Convergent G fields & interactive E fields are inverse squared geometries

Perturbative dipolar M fields have inverse cubed geometries

Side elevation

Tetryonics 76.04 - GEM fields [Side]

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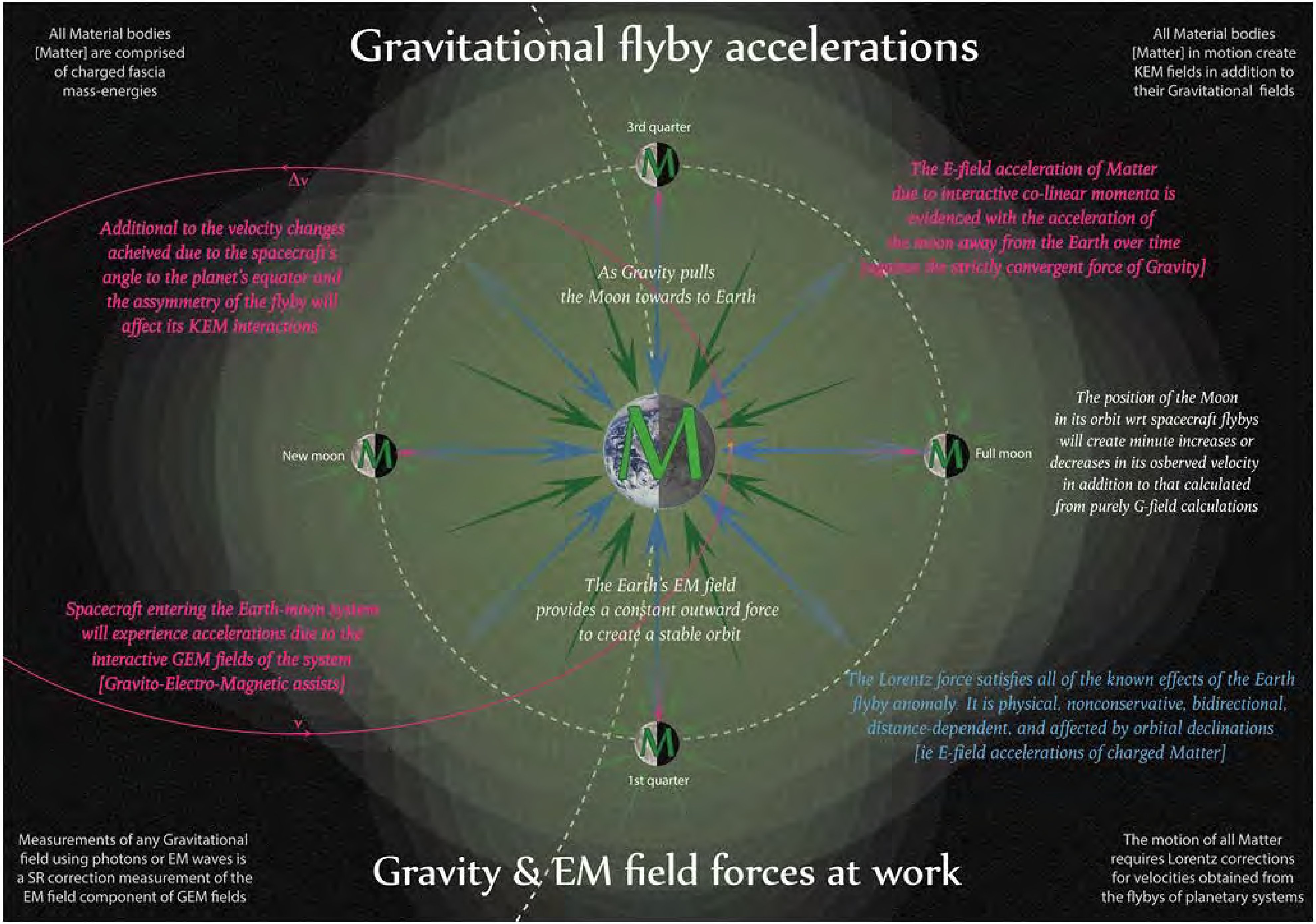

Gravitational flyby accelerations

All Material bodies
[Matter] are comprised
of charged fascia
mass-energies

All Material bodies
[Matter] in motion create
KEM fields in addition to
their Gravitational fields

*Additional to the velocity changes
acheived due to the spacecraft's
angle to the planet's equator and
the assymmetry of the flyby will
affect its KEM interactions*

*The E-field acceleration of Matter
due to interactive co-linear momenta is
evidenced with the acceleration of
the moon away from the Earth over time
[against the strictly convergent force of Gravity]*

*As Gravity pulls
the Moon towards to Earth*

*The position of the Moon
in its orbit wrt spacecraft flybys
will create minute increases or
decreases in its osberved velocity
in addition to that calculated
from purely G-field calculations*

*The Earth's EM field
provides a constant outward force
to create a stable orbit*

*Spacecraft entering the Earth-moon system
will experience accelerations due to the
interactive GEM fields of the system
[Gravito-Electro-Magnetic assists]*

*The Lorentz force satisfies all of the known effects of the Earth
flyby anomaly. It is physical, nonconservative, bidirectional,
distance-dependent, and affected by orbital declinations
[ie E-field accelerations of charged Matter]*

Measurements of any Gravitational
field using photons or EM waves is
a SR correction measurement of the
EM field component of GEM fields

Gravity & EM field forces at work

The motion of all Matter
requires Lorentz corrections
for velocities obtained from
the flybys of planetary systems

Tetryonics 76.05 - Gravitational flyby accelerations

Flyby anomalies

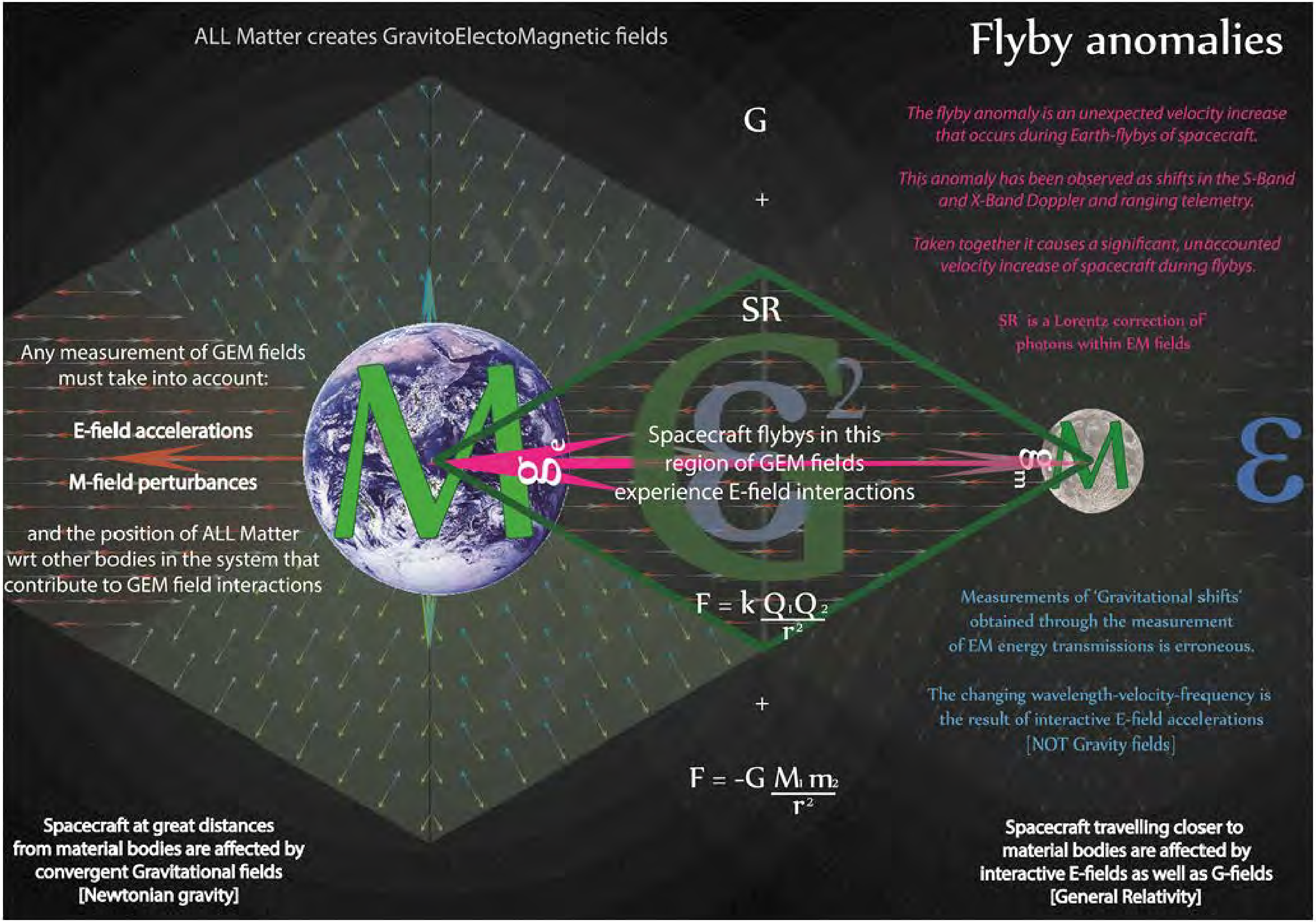

ALL Matter creates GravitoElectoMagnetic fields

The flyby anomaly is an unexpected velocity increase that occurs during Earth-flybys of spacecraft.

This anomaly has been observed as shifts in the S-Band and X-Band Doppler and ranging telemetry.

Taken together it causes a significant, unaccounted velocity increase of spacecraft during flybys.

SR is a Lorentz correction of photons within EM fields

Any measurement of GEM fields must take into account:

E-field accelerations

M-field perturbances

and the position of ALL Matter wrt other bodies in the system that contribute to GEM field interactions

Spacecraft flybys in this region of GEM fields experience E-field interactions

$$F = k\frac{Q_1 Q_2}{r^2}$$

$$F = -G\frac{M_1 m_2}{r^2}$$

Measurements of 'Gravitational shifts' obtained through the measurement of EM energy transmissions is erroneous.

The changing wavelength-velocity-frequency is the result of interactive E-field accelerations [NOT Gravity fields]

Spacecraft at great distances from material bodies are affected by convergent Gravitational fields [Newtonian gravity]

Spacecraft travelling closer to material bodies are affected by interactive E-fields as well as G-fields [General Relativity]

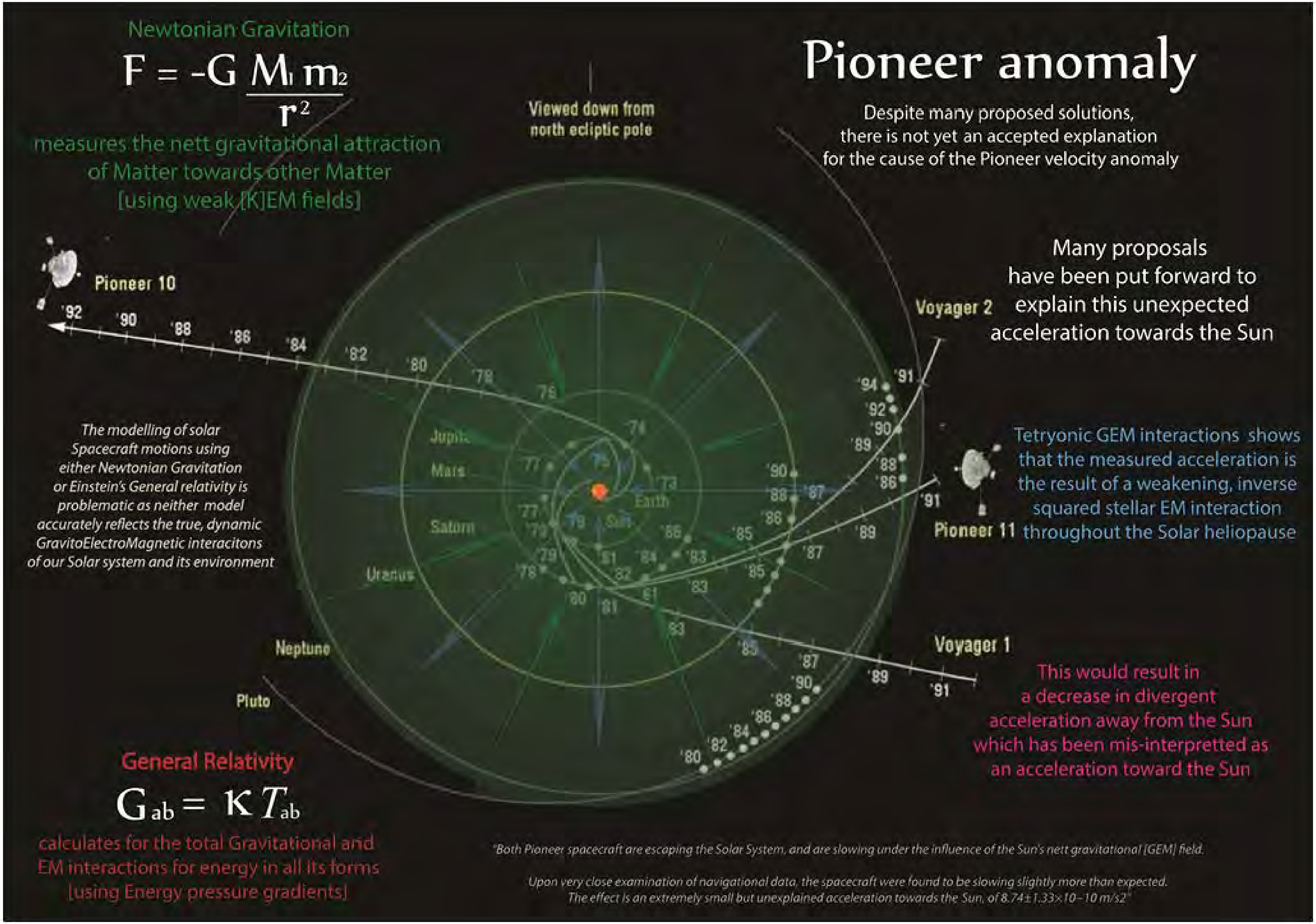

Newtonian Gravitation

$$F = -G\,\frac{M_1 m_2}{r^2}$$

measures the nett gravitational attraction of Matter towards other Matter [using weak [K]EM fields]

Pioneer anomaly

Despite many proposed solutions, there is not yet an accepted explanation for the cause of the Pioneer velocity anomaly

Many proposals have been put forward to explain this unexpected acceleration towards the Sun

The modelling of solar Spacecraft motions using either Newtonian Gravitation or Einstein's General relativity is problematic as neither model accurately reflects the true, dynamic GravitoElectroMagnetic interacitons of our Solar system and its environment

Tetryonic GEM interactions shows that the measured acceleration is the result of a weakening, inverse squared stellar EM interaction throughout the Solar heliopause

This would result in a decrease in divergent acceleration away from the Sun which has been mis-interpretted as an acceleration toward the Sun

General Relativity

$$G_{ab} = \kappa T_{ab}$$

calculates for the total Gravitational and EM interactions for energy in all its forms [using Energy pressure gradients]

"Both Pioneer spacecraft are escaping the Solar System, and are slowing under the influence of the Sun's nett gravitational [GEM] field.

Upon very close examination of navigational data, the spacecraft were found to be slowing slightly more than expected. The effect is an extremely small but unexplained acceleration towards the Sun, of 8.74±1.33×10−10 m/s2"

Viewed down from north ecliptic pole
Pioneer 10
'92
'90
'88
'86
'84
'82
'80
'78
'76
'74
Voyager 2
'91
'94
'92
'90
'89
'88
'86
Pioneer 11
Voyager 1
'89
'91
Jupiter
Mars
Saturn
Uranus
Neptune
Pluto
Earth
Sun
'87
'85
'83
'80
'82
'84

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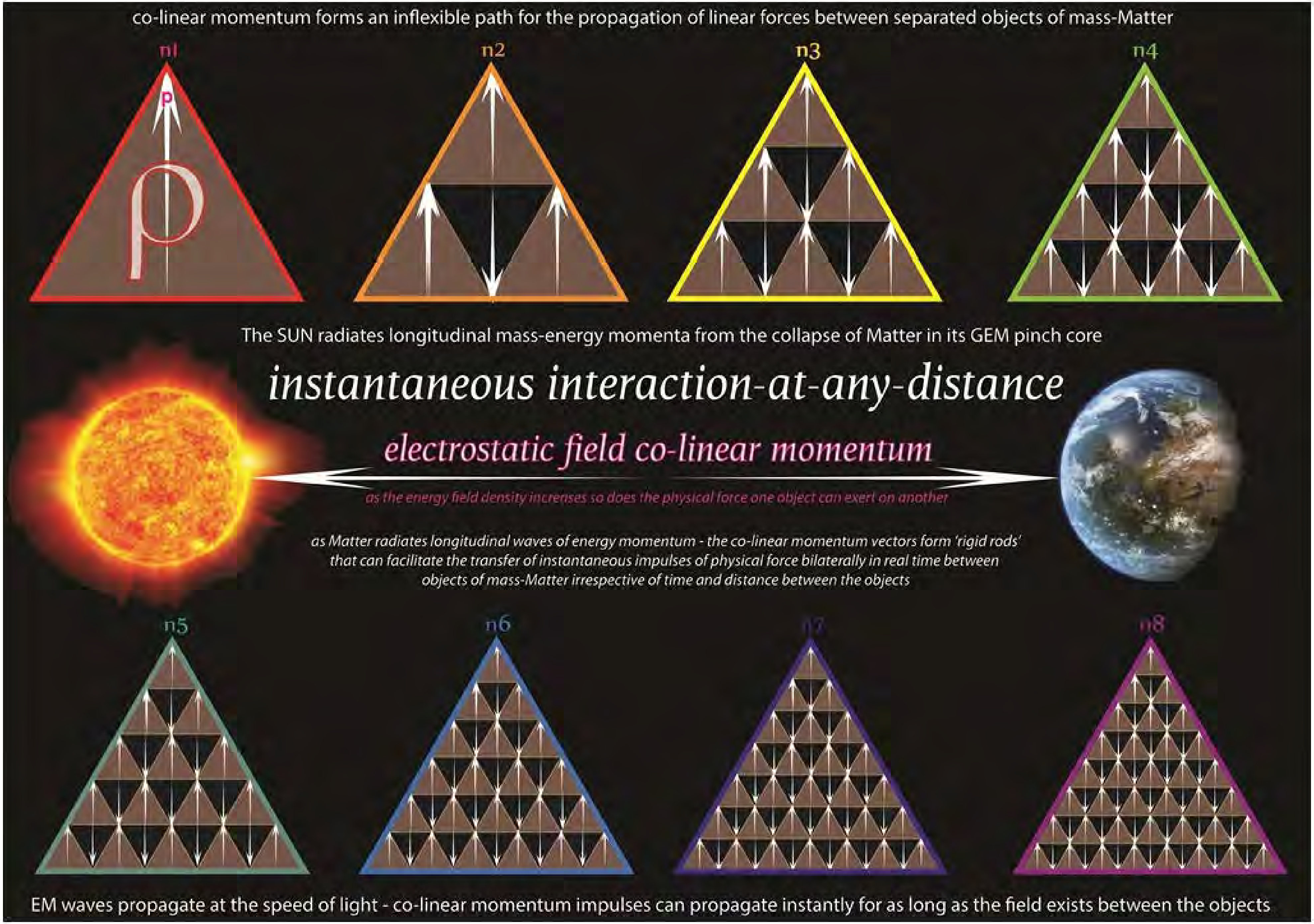

co-linear momentum forms an inflexible path for the propagation of linear forces between separated objects of mass-Matter

The SUN radiates longitudinal mass-energy momenta from the collapse of Matter in its GEM pinch core

instantaneous interaction-at-any-distance

electrostatic field co-linear momentum

as the energy field density increases so does the physical force one object can exert on another

*as Matter radiates longitudinal waves of energy momentum - the co-linear momentum vectors form 'rigid rods'
that can facilitate the transfer of instantaneous impulses of physical force bilaterally in real time between
objects of mass-Matter irrespective of time and distance between the objects*

EM waves propagate at the speed of light - co-linear momentum impulses can propagate instantly for as long as the field exists between the objects

Tetryonics 76.08 - Co-linear momentum [interaction-at-a-distance]

Instantaneous interaction-at-a-distance

One of the major points of disagreement between Newtonian Graviation and General Relativity concerns Einstein's limiting of information and energy momenta propagation to the speed of light whereas the Newtonian physics for Gravitation acts instantly between Matter irrespective of distance and time

partilces interact with others in real time irrespective of distance

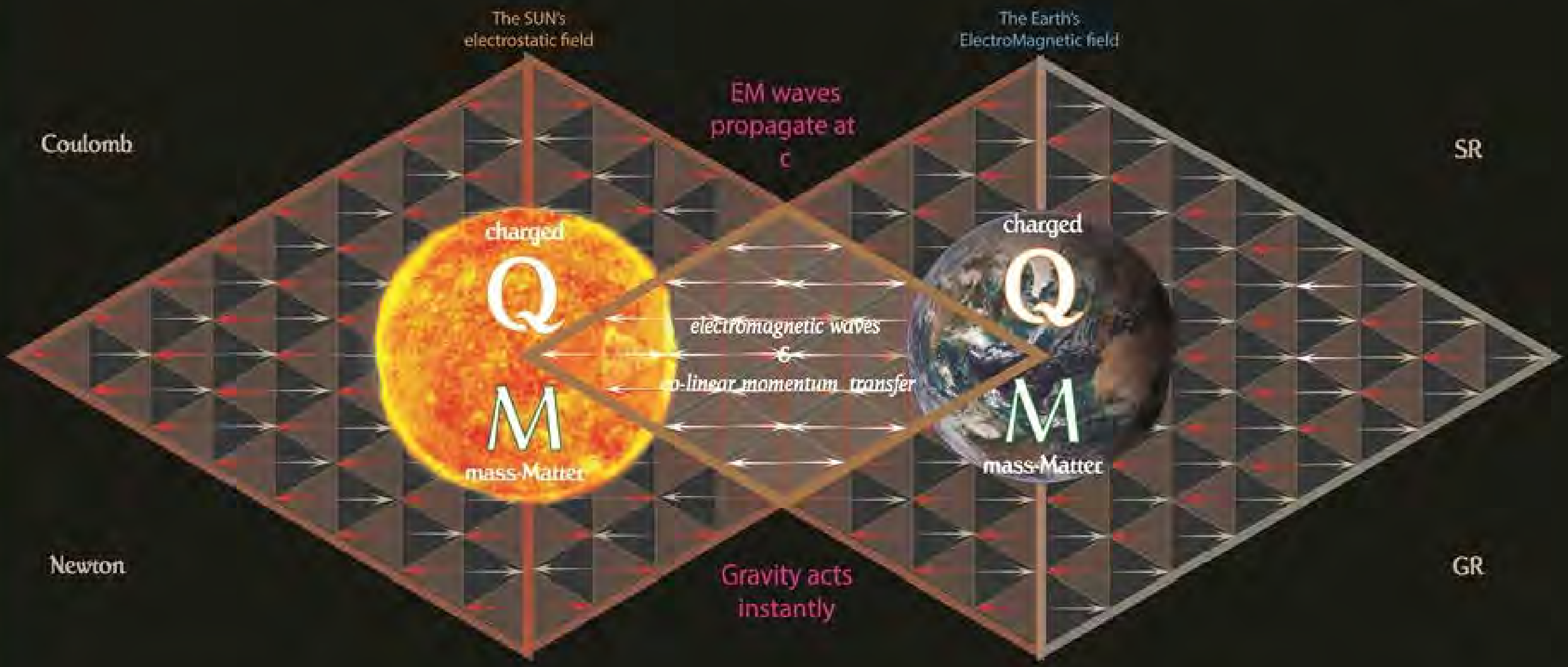
The SUN's electrostatic field
The Earth's ElectroMagnetic field
EM waves propagate at c
Coulomb
SR
charged
Q
M
mass-Matter
electromagnetic waves & co-linear momentum transfer
charged
Q
M
mass-Matter
Newton
GR
Gravity acts instantly

the flow of energy and information is limited to the speed of light

Where electrostatic and/or electromagnetic fields overlap they form fields of interaction between bodies of Matter

the 'quantum rods' of co-linear momentum in their EM fields facilitate 'FTL spooky interaction-at-a-distance' facilitating near instantaneous [real time] impulses of linear momentum to convey physical forces over vast distances without loss for as long as the fields exist between the objects

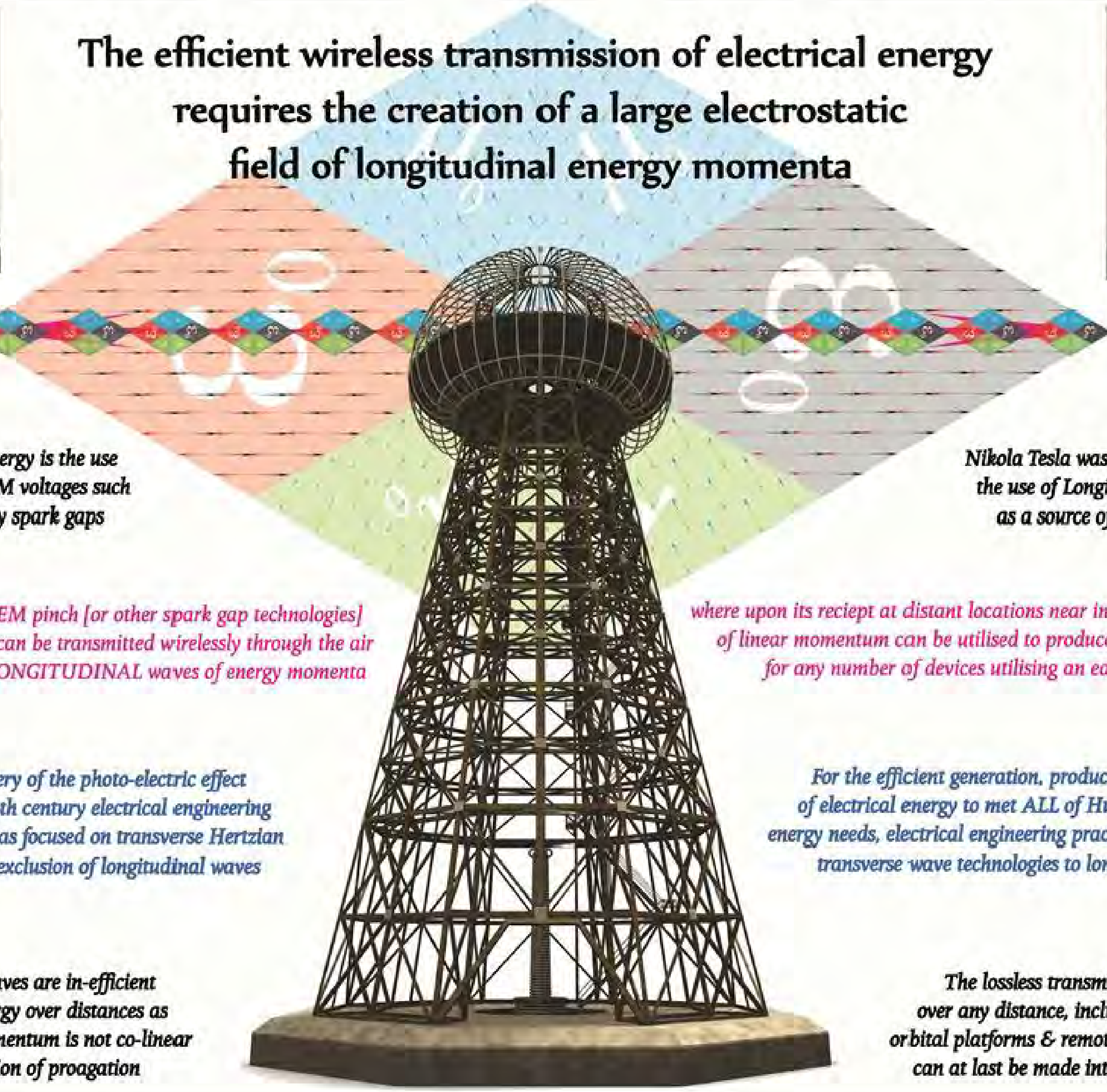

The efficient wireless transmission of electrical energy requires the creation of a large electrostatic field of longitudinal energy momenta

The key to wireless energy is the use
of LONGITUDINAL EM voltages such
as those produced by spark gaps

Nikola Tesla was the first to promote
the use of Longitudinal EM waves
as a source of wireless energy

Once generated by EM pinch [or other spark gap technologies]
real electrical power can be transmitted wirelessly through the air
without loss using LONGITUDINAL waves of energy momenta

where upon its reciept at distant locations near instanteous impulses
of linear momentum can be utilised to produce electrical work
for any number of devices utilising an earth return

Since the discovery of the photo-electric effect
at the turn of the 19th century electrical engineering
and physics theory has focused on transverse Hertzian
waveforms to the exclusion of longitudinal waves

For the efficient generation, production and storage
of electrical energy to met ALL of Humanities growing
energy needs, electrical engineering practices must move from
transverse wave technologies to longitudinal waves

Transverse EM waves are in-efficient
for transmitting energy over distances as
their linear energy momentum is not co-linear
with their direction of proagation

The lossless transmission of power
over any distance, including to and from
orbital platforms & remote locations on Earth,
can at last be made into a physical reality

Super-luminal communications

Creating a near instantaneous real-time communications network

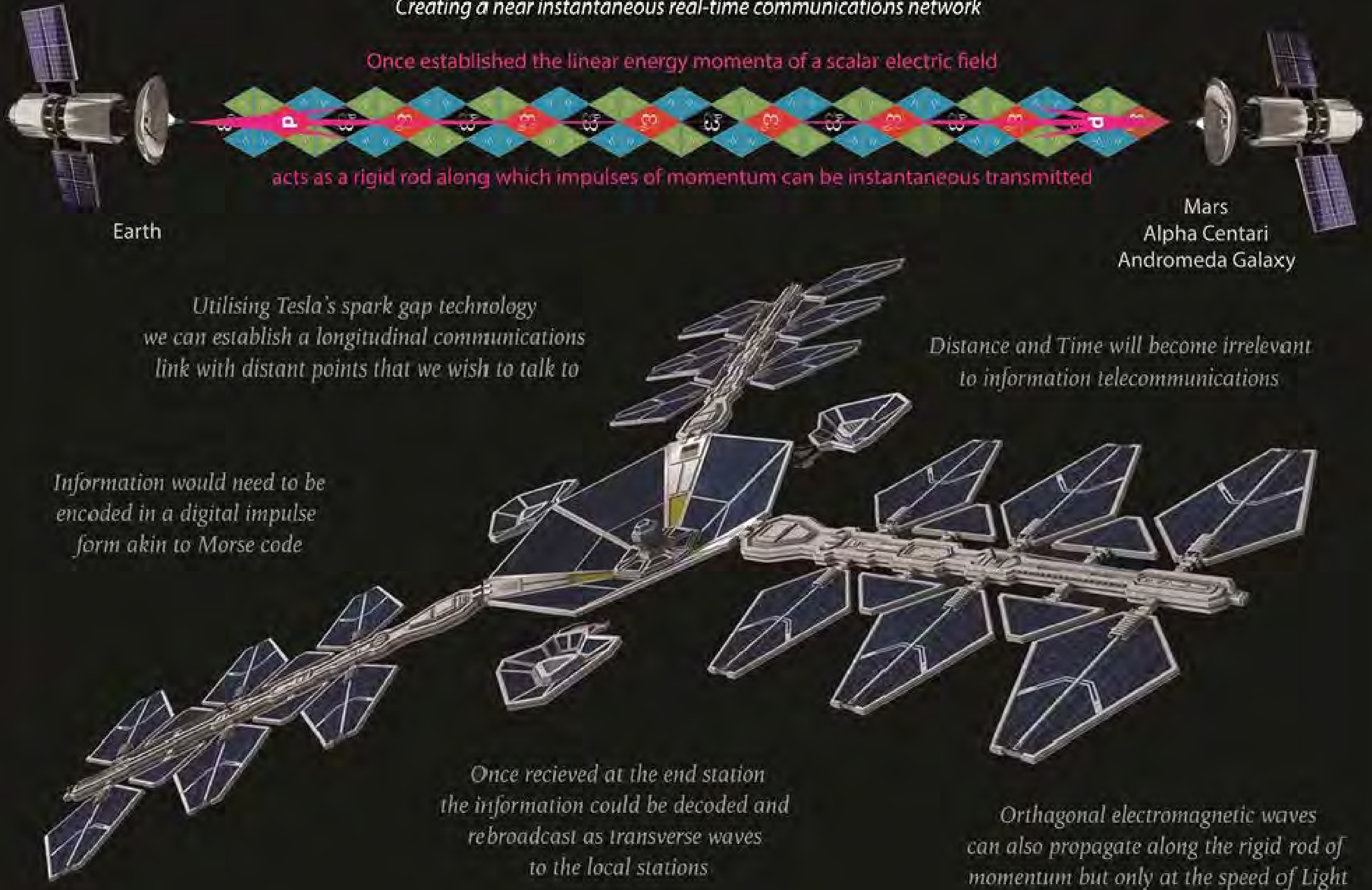

Once established the linear energy momenta of a scalar electric field

acts as a rigid rod along which impulses of momentum can be instantaneous transmitted

Utilising Tesla's spark gap technology we can establish a longitudinal communications link with distant points that we wish to talk to

Distance and Time will become irrelevant to information telecommunications

Information would need to be encoded in a digital impulse form akin to Morse code

Once recieved at the end station the information could be decoded and rebroadcast as transverse waves to the local stations

Orthagonal electromagnetic waves can also propagate along the rigid rod of momentum but only at the speed of Light

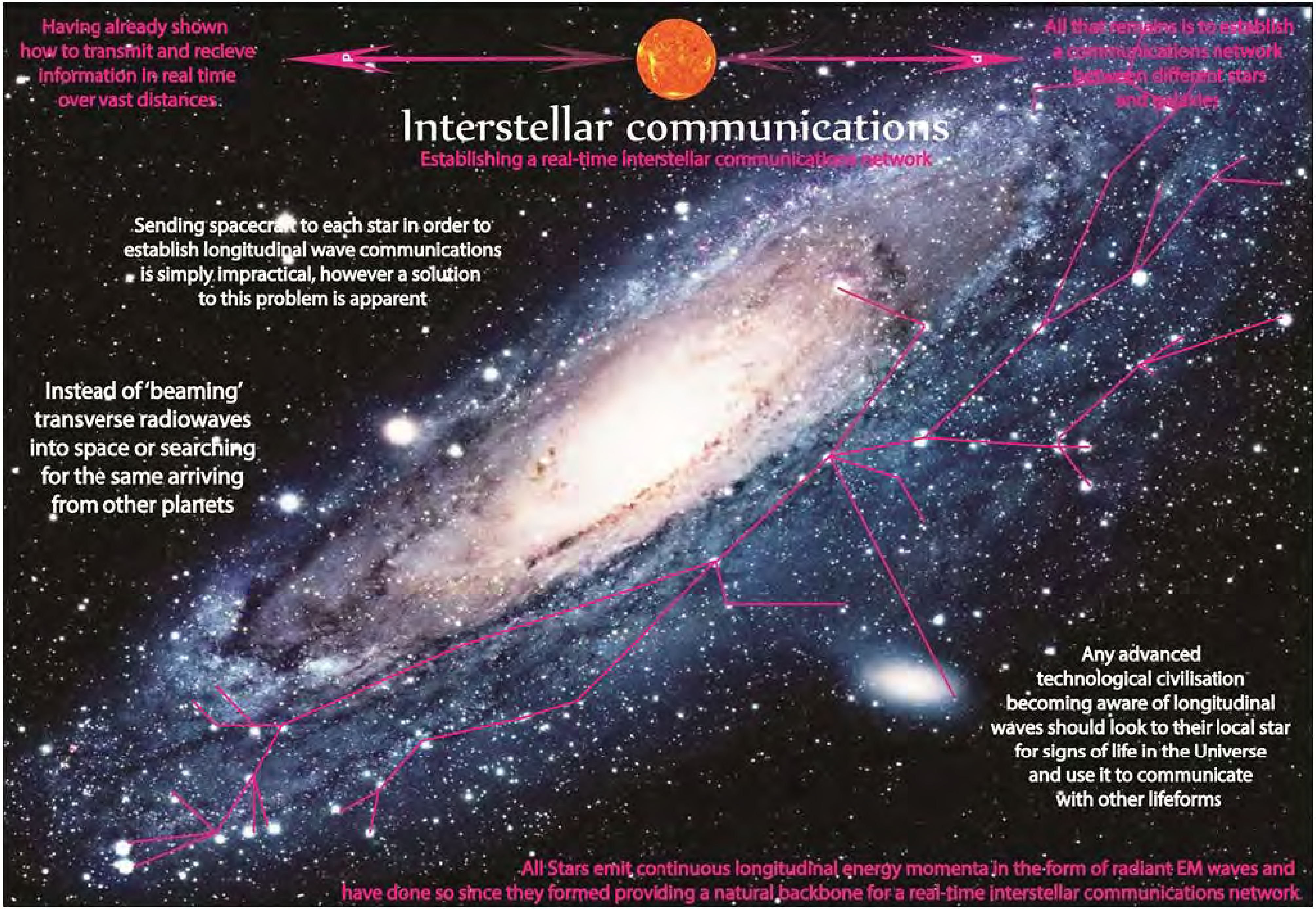

Having already shown how to transmit and recieve information in real time over vast distances

Interstellar communications

Establishing a real-time interstellar communications network

All that remains is to establish a communications network between different stars and galaxies

Sending spacecraft to each star in order to establish longitudinal wave communications is simply impractical, however a solution to this problem is apparent

Instead of 'beaming' transverse radiowaves into space or searching for the same arriving from other planets

Any advanced technological civilisation becoming aware of longitudinal waves should look to their local star for signs of life in the Universe and use it to communicate with other lifeforms

All Stars emit continuous longitudinal energy momenta in the form of radiant EM waves and have done so since they formed providing a natural backbone for a real-time interstellar communications network

Tetryonics 76.12 - Interstellar communication

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Mercurial anomalies

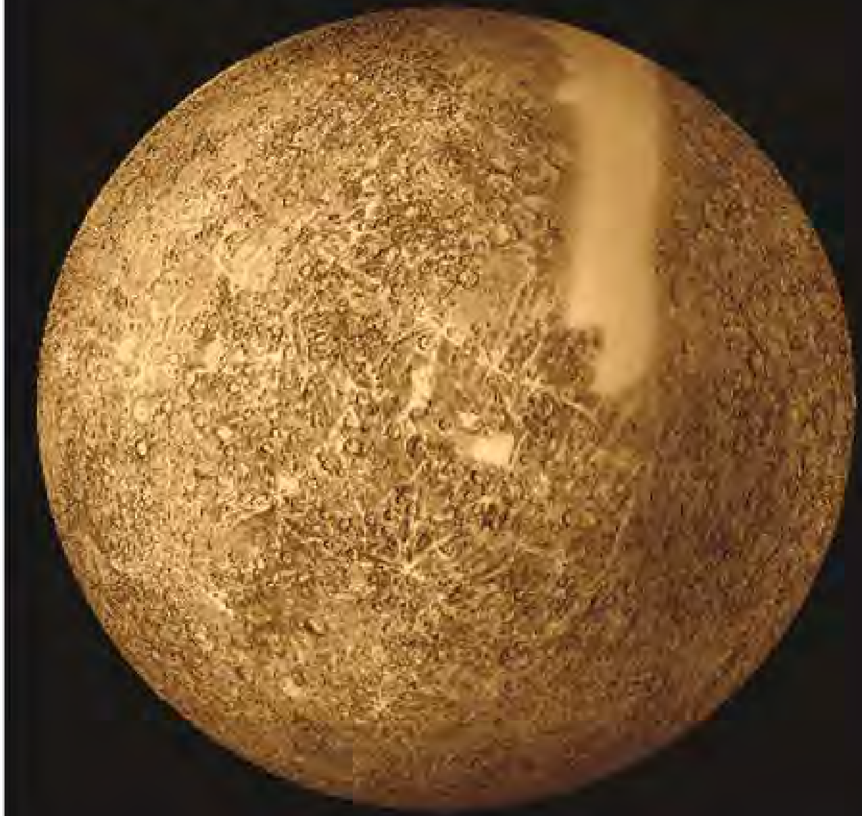

Mercury has a weak magnetic field

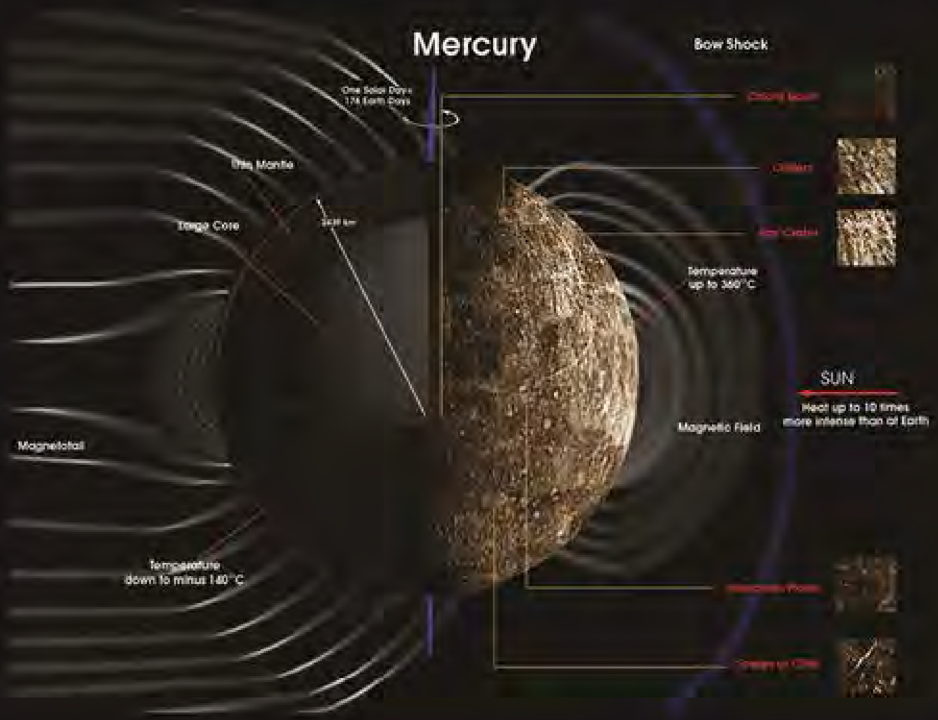
Mercury
Bow Shock
One Solar Day = 176 Earth Days
Thin Mantle
Large Core
Temperature up to 360°C
SUN
Heat up to 10 times more intense than at Earth
Magnetic Field
Magnetotail
Temperature down to minus 140°C

Mercury has heat of its own, not just reflected heat of the Sun;

Mercury has still an atmosphere of Hydrogen, possibly the last vestiges of a more extensive halo and trail (caduceus)

Mercury rotates because it is in its present orbit it is strongly affected by the EM field of the SUN,

Because the ElectroMagnetic forces near the Sun need to be accounted for in the motion of any satellite about a more massive body [ie Satellite-Planet or Planet- Sun], the stronger E & perturbative M forces are responsible for the observed precession of the perihelion of Mercury, and Leverrier's discovery of this precession can be modelled with Einsteins' General relativity through Tetryonic geometries

Laplace showed that should a celestial body attracted by its primary as inverse square of distance be subject to another attraction that changes as the inverse cube of distance, a precession by that body would result.

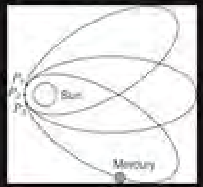
P_1
P_2
P_3
Sun
Mercury

Einstein corrected Newton's gravitational results by calculating for ALL the energies in a system but failed to realise that his 'graviational correction' was in fact a Lorentz correction for EM interactions

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Venusian anomalies

is sometimes referrd to as Earth's "twin" owing to their similar size, gravity, and bulk composition.

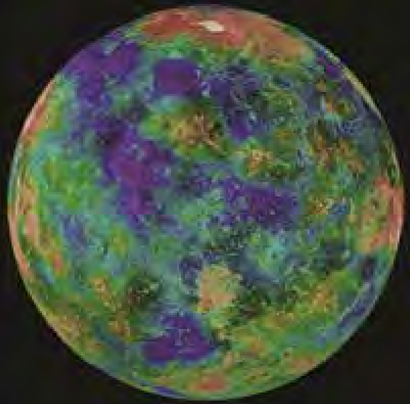

Venus has the densest atmosphere of all the terrestrial planets
in the Solar System, consisting of mostly carbon dioxide.
The atmospheric pressure at the planet's surface is 92 times that of the Earth.

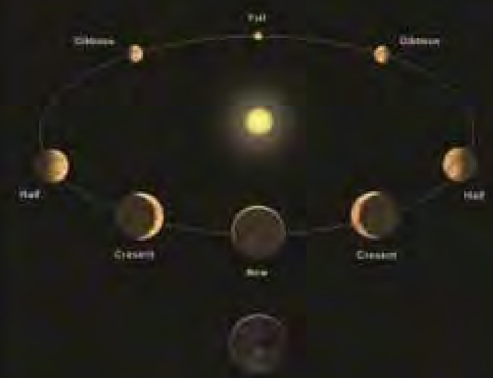

Galileo's discovery that Venus showed phases
(while being never very far from the Sun in our sky)
proved that it orbits the Sun and not the Earth

The Venusian year is about 225 Earth days long.

Venus takes 243 Earth days to rotate on its axis,
which means that days on Venus would be longer
than years. However, because of Venus' curious
retrograde rotation, the time from one sunrise
to the next is only about 117 Earth days

Venus is the hottest world in the solar system.
Although Venus is not the planet closest to the sun,
its dense atmosphere traps heat in a runaway version
of the greenhouse effect that warms up the Earth.

As a result, temperatures on Venus reach 465 degrees C

The lack of an intrinsic magnetic field at Venus was surprising
given it is similar to Earth in size, and was expected also to
contain a dynamo at its core

Venus has no moons or rings

The very top layer of Venus' clouds zip around the planet
every four Earth days, propelled by hurricane-force winds
traveling roughly 224 miles (360 kilometers) per hour.

This super-rotation of the planet's atmosphere, some 60 times faster
than Venus itself rotates, may be one of Venus' biggest mysteries.

Earth-Moon anomalies

The Moon is slowly accelerating away from the Earth

Athough it is attracted gravitationally to the Earth the Moon is moving away from the Earth at about 4cm per year as a result of the Earth's EM field interactions with Matter in its vicinity.

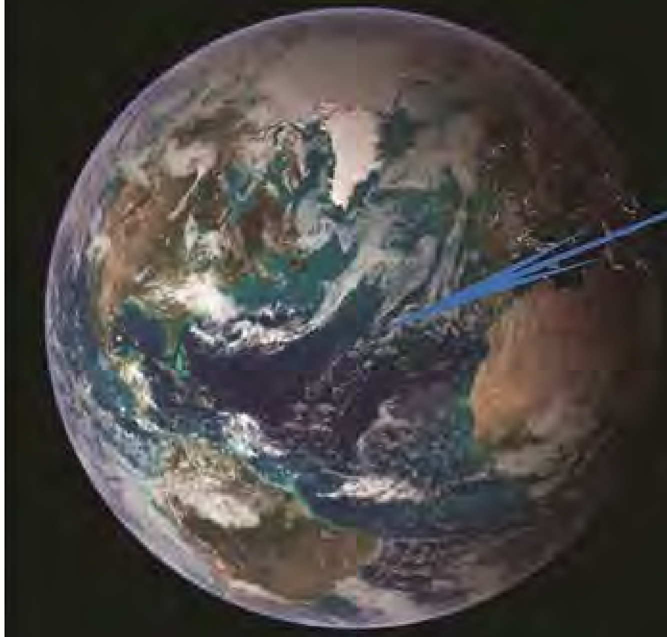

The Earth's EM field accelerates the moon against the pull of gravity stabilising its orbit.

its current field strength forces the moon to slowly accelerate away from the Earth over time

The Moon's Origin

Most scientists think the moon was born from a gargantuan collision, when a young, 30-million-year-old Earth was sideswiped by an embryonic planet the size of Mars some 4.5 billion years ago, with debris from our planet and this impactor eventually coalescing from the ejecta to form our Moon.

The Lunar a lunar day is a month long,
the same as the Moon's orbital period

The Moon only shows one face to the Earth

it is gravitational locked in its orbit with one side always facing the Earth when viewed from the Earthat night. There is no such thing as the "dark side of the moon". The sun shines on all sides

The Moon is 400 times smaller than the SUN
The SUN is 400 times more distant

"There is no astronomical reason why the moon and the sun should fit so well. It is the sheerest of coincidences, and only the Earth among all the planets is blessed in this fashion." ....Isaac Asimov

The Moon looks exactly the same size as the Sun

A striking coincidence that has had astronomers thinking since ancient times is why the Sun and the Moon appear to be the same size during an eclipse. It's known that the Sun's diameter is 400 times that of the Moon, but, then again, the Moon is 400 times further away from the Sun.

This creates the optical illusion that the two are actually the same size, allowing us to observe the Solar corona and its EM field lines

Our moon is the only moon in the solar system that has a stationary, near-perfect circular orbit. Stranger still, the moon's center of mass is about 6000 feet closer to the Earth than its geometric center (which should cause wobbling), but the moon's bulge is on the far side of the moon, away from the Earth. "Something" had to put the moon in orbit with its precise altitude, course, and speed.

Martian anomalies

Phobos

There is no completely satisfactory theory as to how Deimos and Phobos came to be in orbit around Mars

With a dametre of 6 km Deimos
is one of the smallest known moons
in the solar system

Deimos

Although Mars is much smaller than Earth, [approx 1/4 the size]
its surface area is about the same as the land surface area of Earth

Deimos and Phobos are probably asteroids perturbed
by Jupiter into orbits that allowed them to be captured by Mars

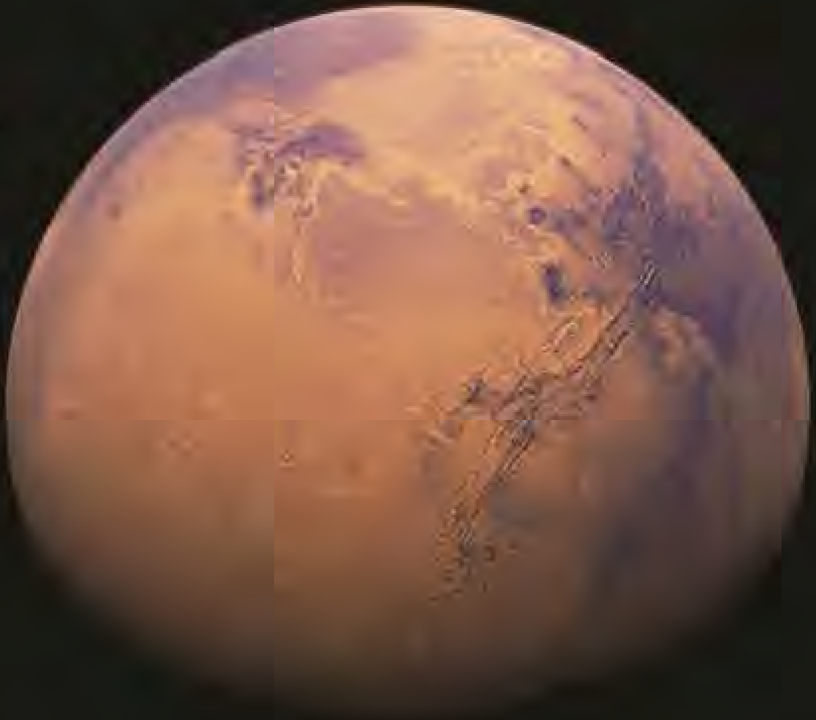

The southern hemisphere of Mars
is predominantly ancient
cratered highlands somewhat
similar to the Moon.

In contrast, the northern hemisphere
consists of plains which are much younger,
lower in elevation and have a much
more complex history.

Mars orbits about
1.5au from the SUN

An abrupt elevation change of several kilometers seems to occur at the boundary

Jupiters' anomalies

Jupiter has an intense and far-reaching magnetic field.
Exactly what drives the magnetic powerhouse and
how deep inside the planet it originates, however, is unknown

Jupiter's diameter is approx
1/10 that of the SUN and
10 times the size of Earth

Jupiter has twelve satellites.

The five inner moons revolve around their planet in orbits only slightly inclined to the planet's equator at distances from about 110,000 miles for the innermost to about 640,000 miles for the outermost.

Jupiter's mass is 2.5 times that of all the other planets in our Solar System combined

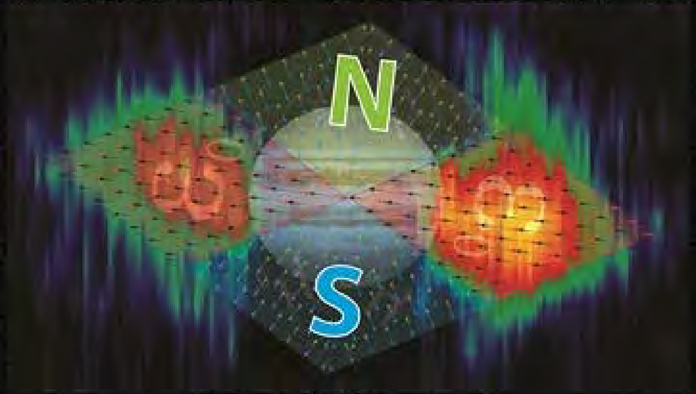

Tetryonic EM geometry
offers answers to many of the dynamic
mysteries of Jupiter and its moons

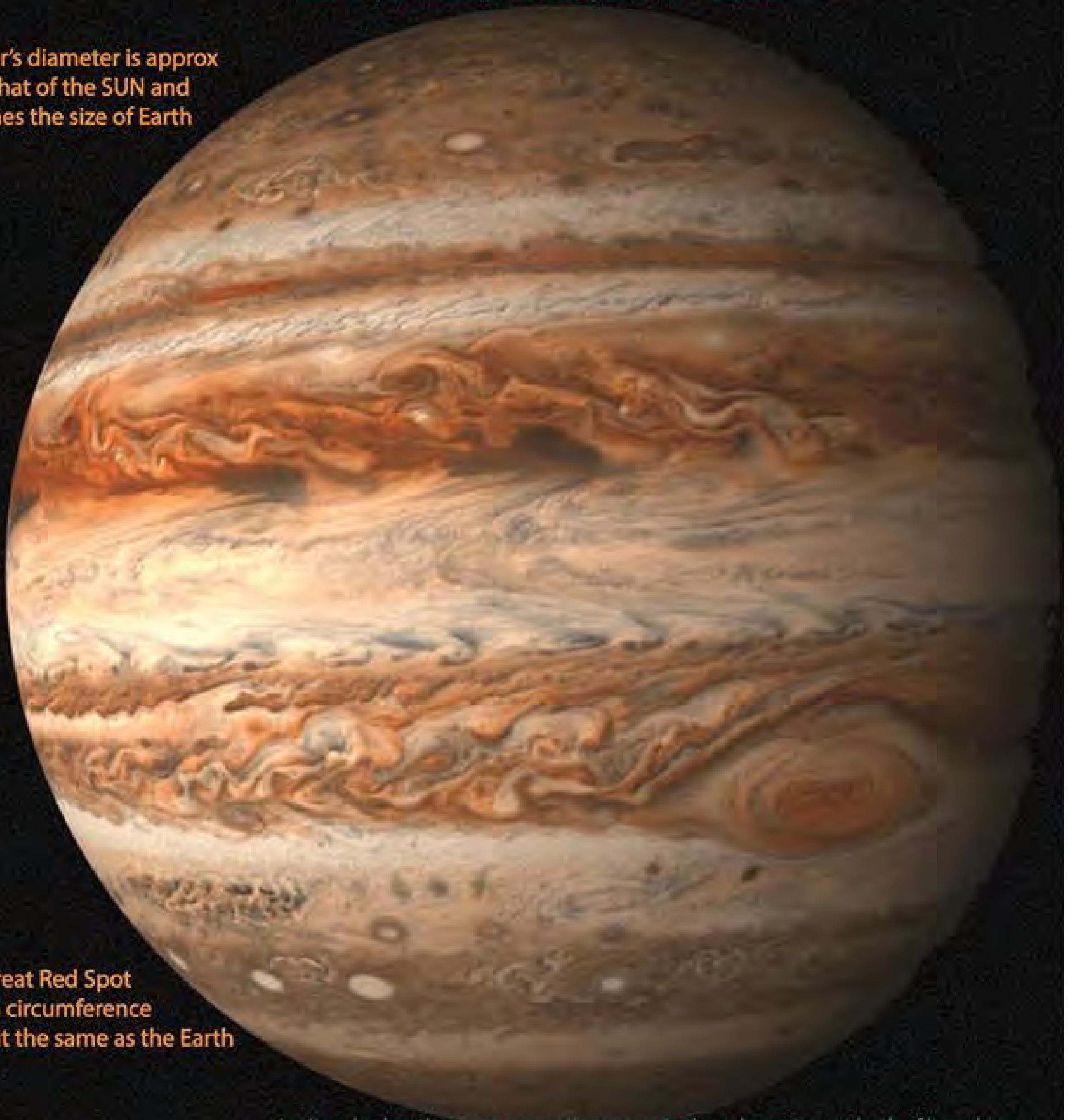

Then there is a group of three moons whose orbits are inclined to the planet's equator by almost 30° at distances of about 7 million miles from Jupiter.

These three moons also revolve around the planet in the predicted direction.

The four outer moons, however, move around the planet in retrograde motion, or opposite to that of the other eight satellites, at distances from about 12 to 13 million miles from the planet

Its Great Red Spot
has a circumference
about the same as the Earth

Jupiter also has the most energetic auroras in the solar system at both of its poles

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Saturnian anomalies

In addition to the planet's giant rings, Saturn has nine major moons and more than 60 known satellites.

The motion of the outermost, Phoebe, is retrograde, moving in a direction opposite to the other eight moons and opposite to that predicted from an evolutionary origin.

Tetryonic theory suggests that this retrograde motion is the result of it being a gravitationally captured body whose motion over time will be slowed, eventually forcing it into the same motion as the others

TITAN
is the only moon that
possesses a thick atmosphere, and
it's the only place beyond Earth to have
stable bodies of liquid Methane on its surface

The rings of Saturn occasionally exhibit ghostly radial spokes that seemingly defy the laws of gravity

The Saturnian rings, like many others, are formed by the electric field of the planet and subject to seasonal fluctuations of the SUN's heliosheric E-field

Tetryonic GEM interactions shows that these features are the result of electric forces additional to gravity

Strange features abound within the rings of Saturn. These include hundreds of "record grooves" or narrow fluctuations in the B ring, the most massive ring.

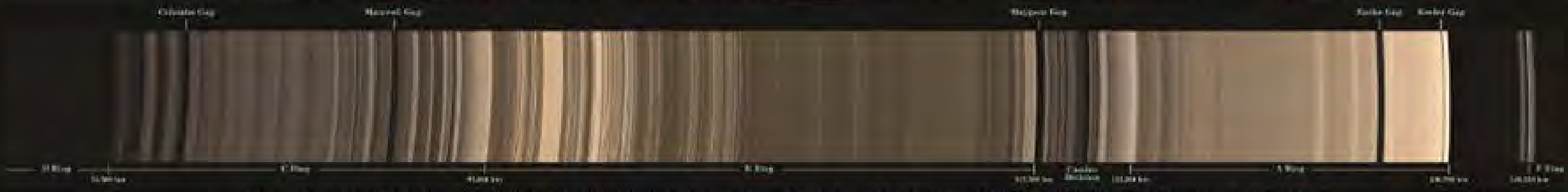

These also include "plateaus" in the C ring, the innermost main ring—broad, dark, sharp-edged features thicker than elsewhere in the ring.

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Neptunes' anomalies

Neptune was the first planet found by mathematical prediction
rather than by empirical observation

Neptune has two satellites.

Nereid, a small moon, moves around Neptune in the predicted direction, but Triton, one of the larger satellites in the solar system with a mass almost twice that of the earth's moon.

Of Neptune's 13 moons, Triton is by far the biggest and the only one massive enough to be spheroidal.

Weirdly, Triton has a "retrograde" orbit, revolving in the opposite direction of the planet and other moons.

Plus, the orbit is at an angle rather than in the plane around the equator like typical satellites

The magnetic field of Neptune, like that of Uranus,
is highly tilted at 47 degrees from the rotation axis and offset
at least 0.55 radii (about 13,500 kilometers or 8,500 miles) from the physical center

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Uranus' anomalies

Uranus is remarkable, even though it rotates around the sun in the same direction as the other planets in an orbit inclined less than a degree (46') from the ecliptic (the plane of the earth's orbit around the sun), the axis of rotation of Uranus is nearly in the plane of its orbit.

Accordingly, the inclination of the equator of Uranus to the plane of its orbit is 98°, and its axial rotation is retrograde.

The five moons or satellites of Uranus move exactly in the equatorial plane of the planet and they revolve in the same direction as the planet rotates.

Their motion, with respect to the remainder of the solar system, is, therefore, also retrograde.

The direction of the axial rotation of Uranus and the motion of its satellites is opposite to that predicted on the basis of an evolutionary origin.

Tetryonic theory dictates that Uranus' peculiar planetary mechanics may be the result of the EM interactions of Uranus itself with its satellites rather than the current evolutionary explanation

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Pluto's anomalies

Pluto is much smaller than any of the official planets
and due to its size and orbital inclination
is now classified as a "dwarf planet"

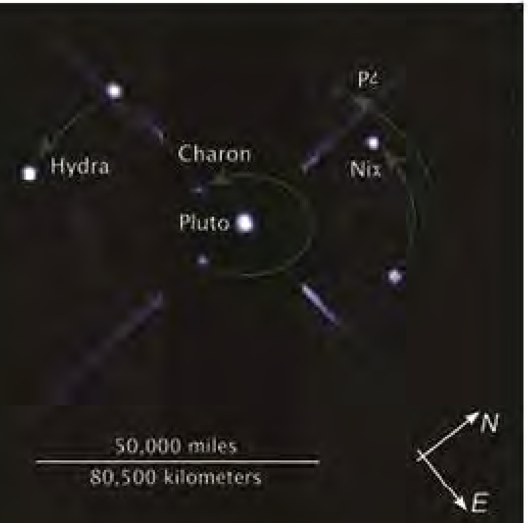
P4
Hydra
Charon
Nix
Pluto
50,000 miles
80,500 kilometers
N
E

Pluto rotates in the opposite direction
to that of most of the other planets

Pluto is locked in a 3:2 resonance with Neptune;
i.e. Pluto's orbital period is exactly 1.5 times longer than Neptune's.
Its orbital inclination is also much higher than the other planets

Pluto's orbit is highly eccentric.
At times it is closer to the Sun than Neptune

Charon is unusual in that it is
the largest moon with respect to its
primary planet in the Solar System
(a distinction once held by Earth's moon)

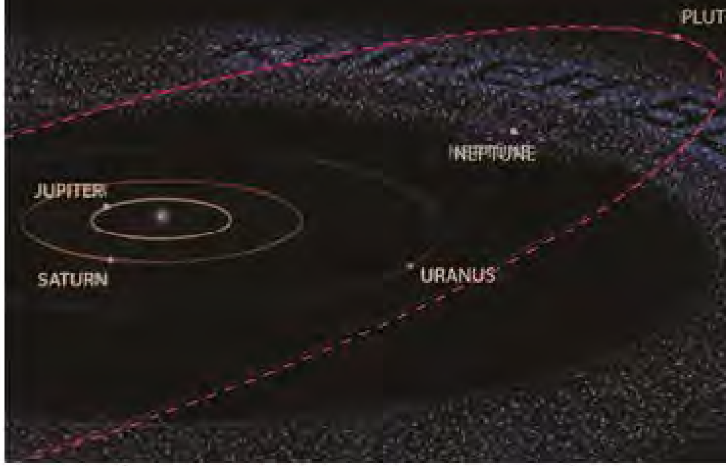
PLUTO
NEPTUNE
JUPITER
SATURN
URANUS

The Pluto–Charon system is noteworthy
for being one of the Solar System's
few binary system

Pluto
Nix
Hydra
Charon

Cometary anomalies

Comets provide some of the clearest evidence of Electromagnetic interactions between the SUN and other planetary bodies

While the solid nucleus of comets is generally less than 50 km across, the coma may be larger than the Sun, and Ion tails have been observed to extend 3-4 astronomical units (5-600 million km)

Cometary discharging may also occur due to any disturbances of its electrical plasma sheath as it passes through regions of varying electric potential.

This seems to have occurred in the recent "totally surprising" outburst of Comet Holmes 17P as it moved away from the Sun's domain.

In 2000 the explosive break up of Comet Linear provoked great amazement as the event occurred well over a hundred million kilometers from the Sun

Other anomalies that can be explained by a CHARGED model of cometary nuclei are: Unexpectedly high temperatures and X-ray emissions from cometary comas

The sharply carved relief of comets [the exact opposite of what is expected under the "dirty snowball" model]

The unexplained ability of a relatively minuscule comet nucleus to hold in place a highly spherical coma, up to millions of miles in diamater, against the force of the solar wind;

Ejection of larger particles and "gravel" that was never anticipated under the idea that comets accreted from primordial clouds of ice, gas, and dust;

A short supply or complete absence of water and other volatiles on comets" nuclei;

The Electric Universe's model of charged solar bodies predicted the occurrence of an electrical flash in advance to the impact of a projectile into the nucleus of Comet Tempel 1 (Deep Impact.)

Comets have two tails:
A Dust tail and
A Ion tail
most recently observed
in comet Hale-Bopp

The Dust tail is the result of reflective ejected Matter following the comet's path throught solar system while the Ion tail is the result of ejected charged particles of Matter and is heavily influenced by the SUN's radiated E fields

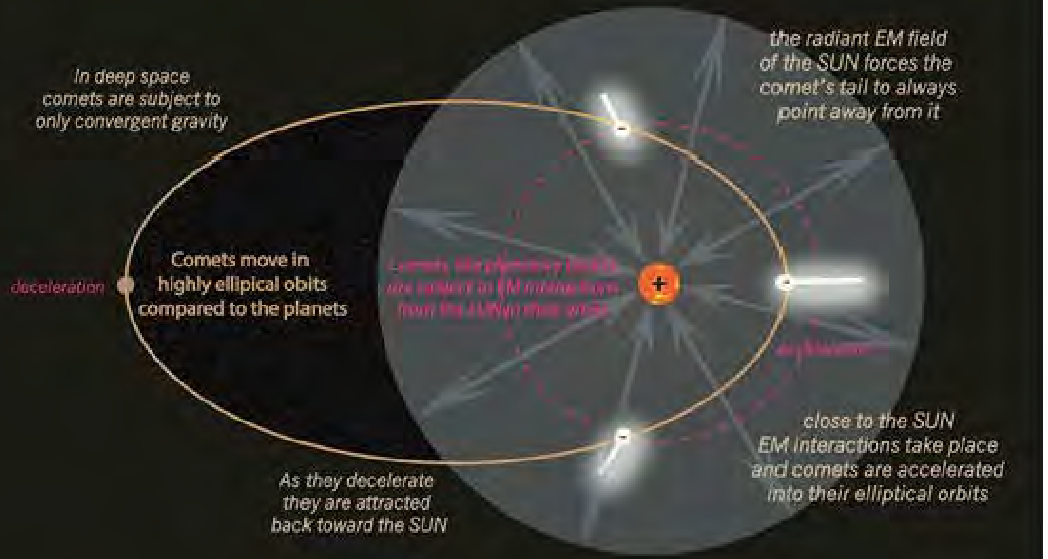

In deep space comets are subject to only convergent gravity

the radiant EM field of the SUN forces the comet's tail to always point away from it

Comets move in highly ellipical obits compared to the planets

close to the SUN EM interactions take place and comets are accelerated into their elliptical orbits

As they decelerate they are attracted back toward the SUN

deceleration
Comets like planetary bodies
are subject to EM interactions
from the SUN in their orbit
+
acceleration

The tails of comets always point away from the Sun, so after a comet has passed the Sun it actually travels tail first

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The Plasma universe

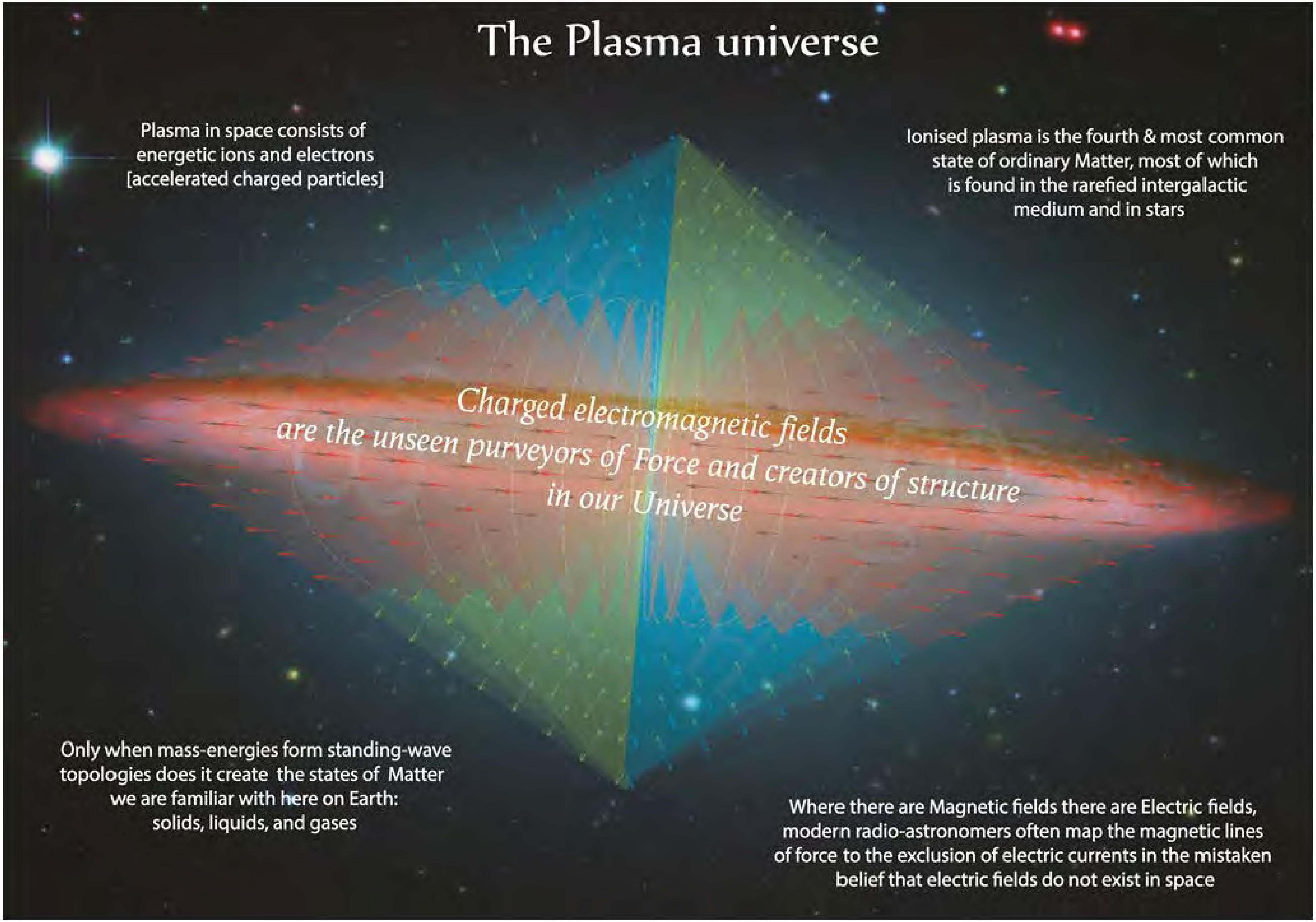

Plasma in space consists of
energetic ions and electrons
[accelerated charged particles]

Ionised plasma is the fourth & most common
state of ordinary Matter, most of which
is found in the rarefied intergalactic
medium and in stars

*Charged electromagnetic fields
are the unseen purveyors of Force and creators of structure
in our Universe*

Only when mass-energies form standing-wave
topologies does it create the states of Matter
we are familiar with here on Earth:
solids, liquids, and gases

Where there are Magnetic fields there are Electric fields,
modern radio-astronomers often map the magnetic lines
of force to the exclusion of electric currents in the mistaken
belief that electric fields do not exist in space

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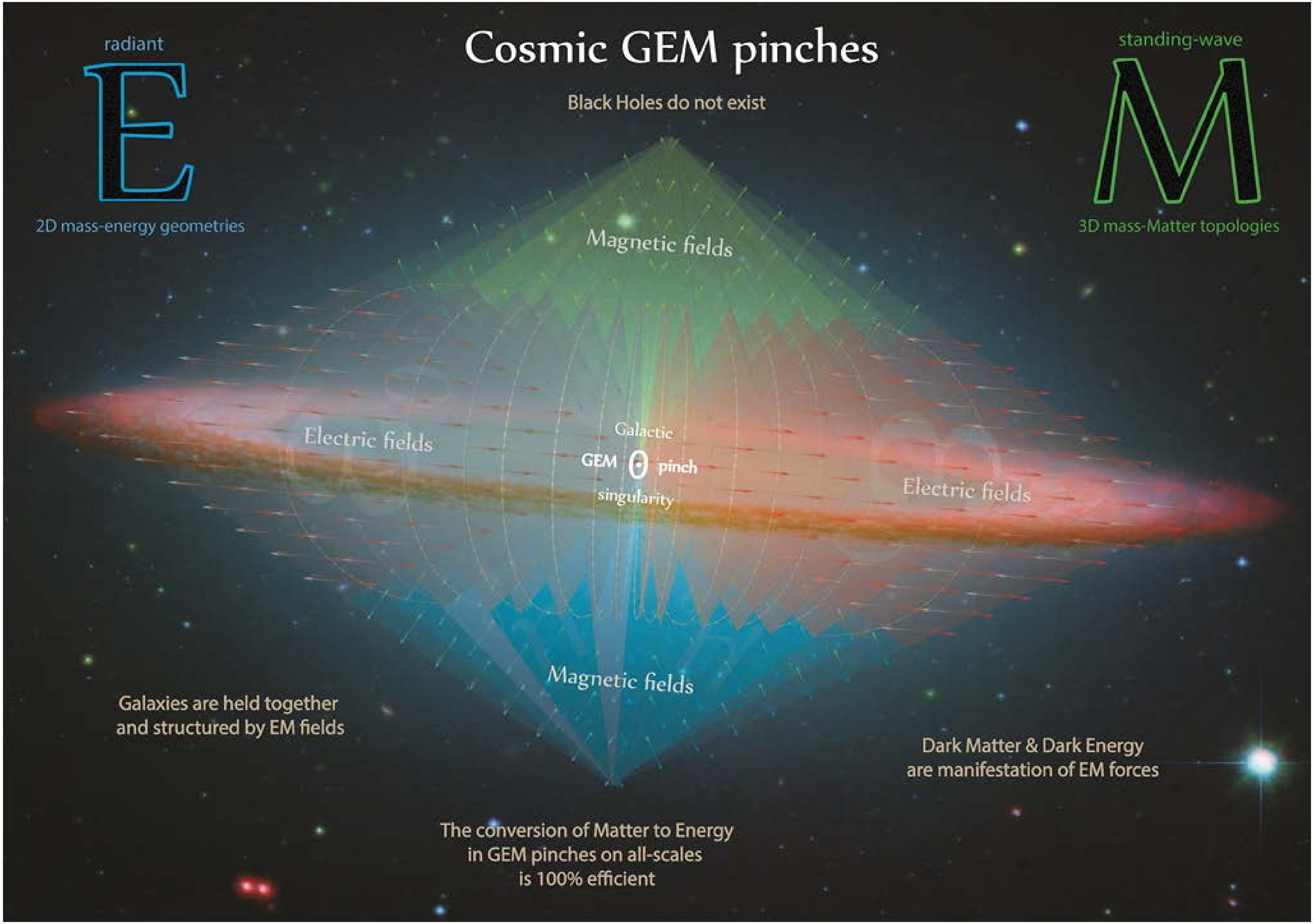

Cosmic GEM pinches

Black Holes do not exist

radiant
E
2D mass-energy geometries
standing-wave
M
3D mass-Matter topologies
Magnetic fields
Electric fields
Galactic
GEM
θ
pinch
singularity
Electric fields
Magnetic fields

Galaxies are held together
and structured by EM fields

Dark Matter & Dark Energy
are manifestation of EM forces

The conversion of Matter to Energy
in GEM pinches on all-scales
is 100% efficient

Tetryonics 78.02 - GEM pinches

PLASMA FIELDS

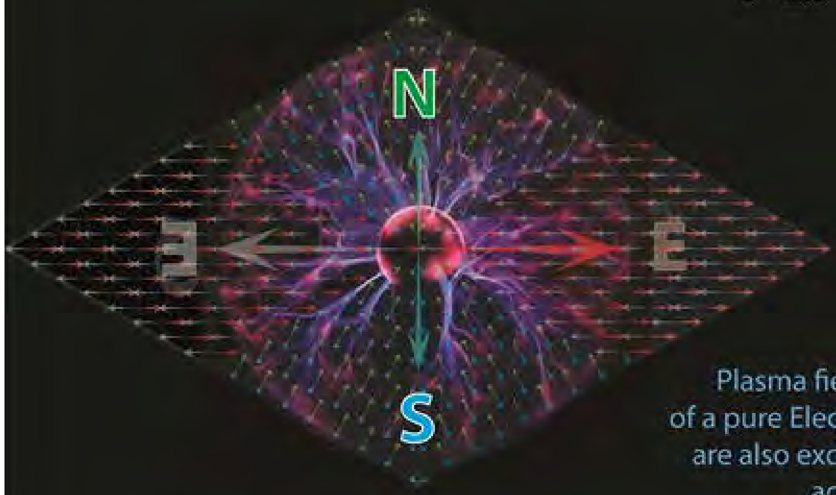

The Cosmos is
electromagnetic
in nature

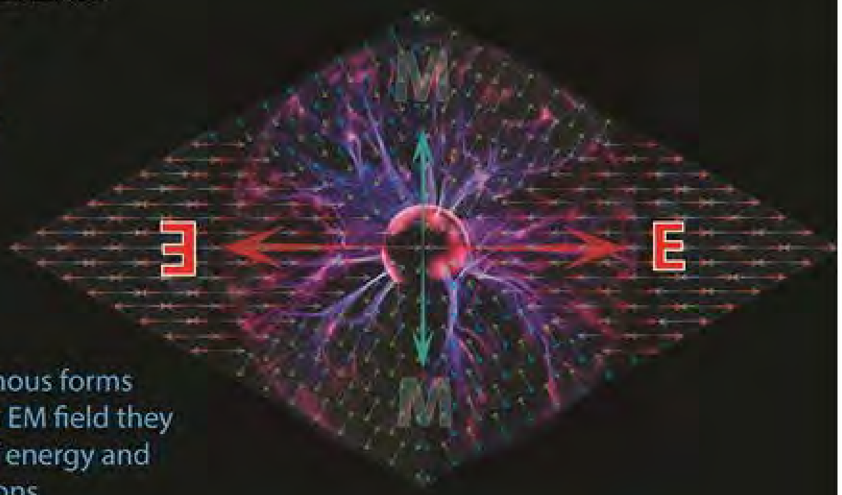

Plasma fields create the most tenous forms of a pure Electrical field, and being a EM field they are also exceptional conductors of energy and accelerators of charged Ions

Magnetised Plasma fields
neutral electric charge EM fields
(with a magnetic magneton)

Charged Plasma fields
charged electrostatic EM fields
(with no magnetic magneton)

Neutron stars

Matter

antiMatter

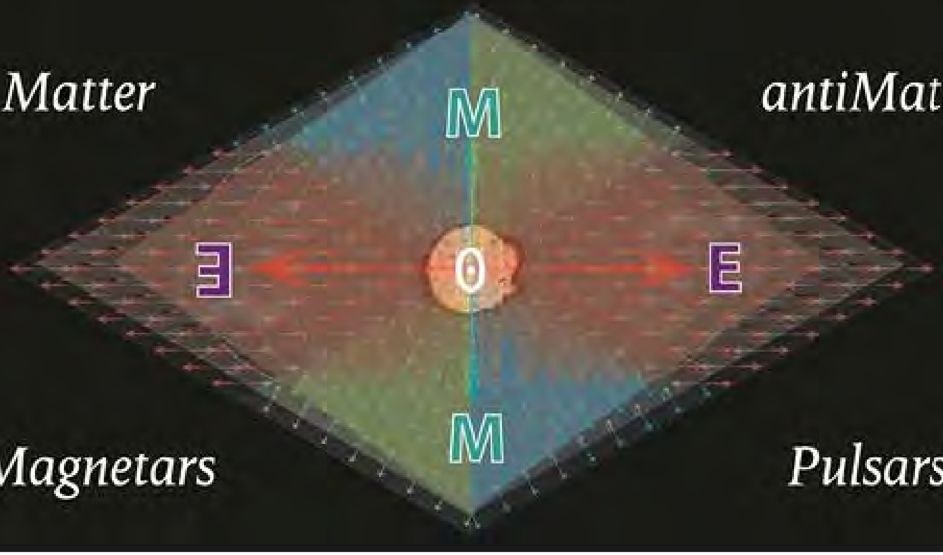

Accretion discs

Gamma rays

Magnetars

Pulsars

Tetryonics 78.03 - Plasma Fields

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Neutron Stars

All Gravitational fields
are comprised of quantum
GEM fields

In current astrophysical theories in order to create a

Neutron star

the central region of the star collapses under gravity.

It collapses so much that protons and electrons combine to form neutrons. and neutrogenic Matter

Hence the name "neutron star".

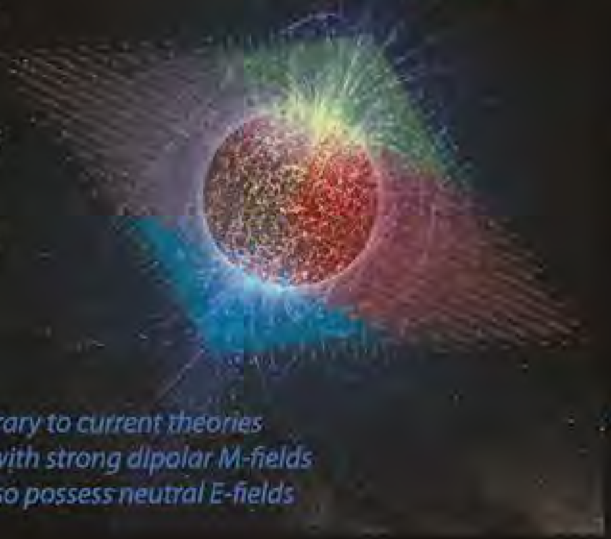

Typical Neutron stars have very strong M-fields

Contrary to current theories
any star with strong dipolar M-fields
must also possess neutral E-fields

"A neutron star is a type of remnant that can result from the gravitational collapse of a massive star during a Type II, Type Ib or Type Ic supernova event.

Such stars are composed almost entirely of neutrogenic Matter, [Neutrons, antiNeutrons and neutrinos] which against current theory act in exactly the same manner as ordinary Matter in producing spectral lines.

"Neutron stars are very hot and are supported against further collapse because of the Pauli exclusion principle.

This principle states that no two neutrons (or any other fermionic particle) can occupy the same place and quantum state simultaneously""

As shown throughout Tetryonic theory
Neutron stars can be formed
comprised completely of 'Neutral Matter'

Neutral Matter is comprised of
Neutron - anti-Neutron - Neutrino
atomic nuclei

Neutral matter atoms function identically to normal matter-antimatter particle topologies and releases energy in the form of photons

The gravitational collapse of any stellar material must overcome the radiant EM energies that it releases

Pulsars are non-neutral stellar objects that have weak M-fields but emit extremely strong E-field radiation as they collapse

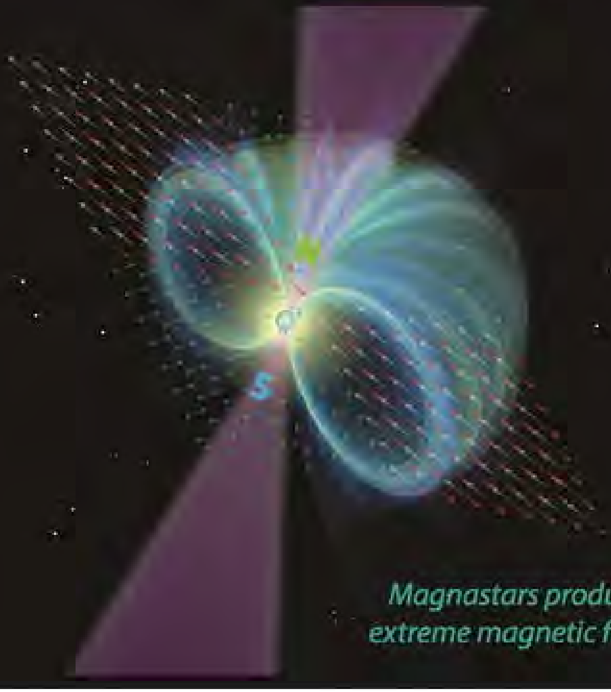

Magnastars produce extreme magnetic fields

Neutral matter in Neutron stars experience the same ElectroMagnetic forces as normal matter and anti-matter stars but have differing charge arrangements

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Neutrons & Neutronium formation neutrinos

Neutronium is a proposed name for a substance composed entirely of Neutrons & neutrinos

Neutron degeneracy

As a star collapses, the Fermi energy of the electrons increases to the point where it is energetically favorable for them to combine with protons to produce neutrons (via inverse beta decay, also termed "neutralization" and electron capture)

This, as shown through Tetryonic geometry, is incorrect

Neutrons are NOT comprised of Protons with electrons fused into them under pressure

Gravitational fields are comprised of convergent gravity and interactive EM fields

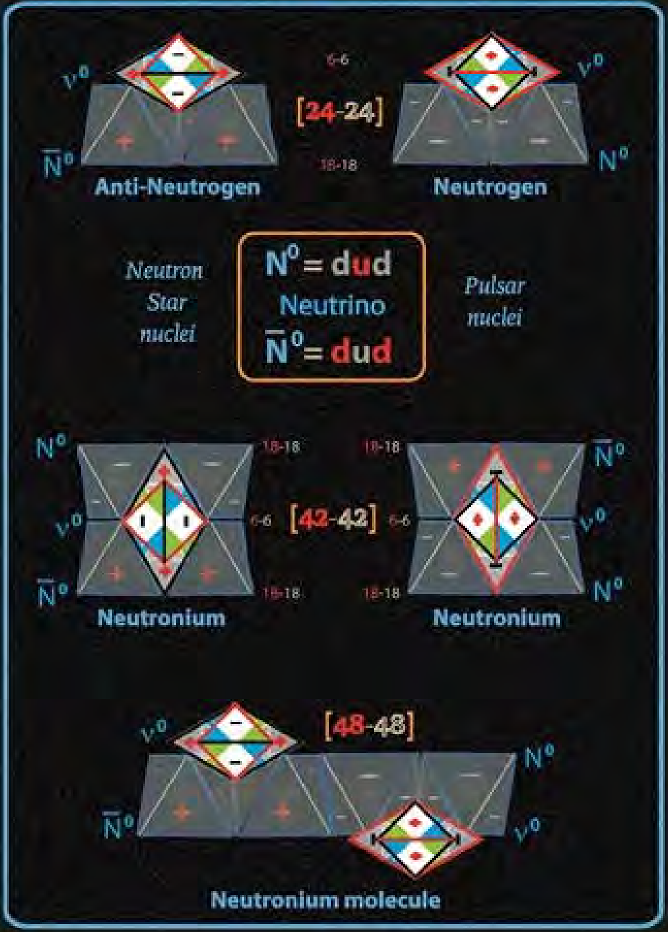
ν^0
$\bar{N}^0$
Anti-Neutrogen
6-6
[24-24]
18-18
ν^0
N^0
Neutrogen
Neutron Star nuclei
N^0 = dud
Neutrino
$\bar{N}^0$ = dud
Pulsar nuclei
N^0
ν^0
$\bar{N}^0$
18-18
6-6
[42-42]
6-6
18-18
18-18
18-18
$\bar{N}^0$
ν^0
N^0
Neutronium
Neutronium
ν^0
[48-48]
N^0
$\bar{N}^0$
ν^0
Neutronium molecule

"The gravitational field at the star's surface is about 2×10^11 times stronger than on Earth.

Such a strong gravitational field acts as a gravitational lens and bends the radiation emitted by the star such that parts of the normally invisible rear surface become visible"

Photons and EM waves are REFACTED by EM fields NOT bent by gravity as currently hypothesized

Neutronium

$$\frac{T\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]$$

The neutral nuclei of neutron stars emit exactly the same light as normal stars do

Neutron stars are made of neutronium nuclei

A neutron star is a type of stellar remnant that can result from the gravitational collapse of a massive star during a Type II, Type Ib or Type Ic supernova event.

Such stars are composed almost entirely of neutrons, which are subatomic particles without electrical charge and with the same mass-Matter as protons. Neutron stars are very hot and are supported against further collapse by quantum degeneracy pressure due to the Pauli exclusion principle.

This principle states that no two neutrons (or any other fermionic particles) can occupy the same place and quantum state simultaneously

N^0 ν^0

Tetryonics 78.05 - Neutronium formation

Equilateral Planck geometries create elementary charge topologies

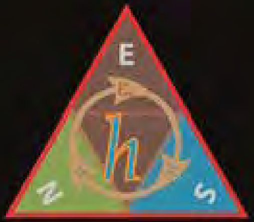

Neutron star types

Neutron stars comprise one of the possible evolutionary end-points for stars,
they are compact stellar objects measuring between 10 and 20 km across
with intense magnetic fields around 10^12 times that of the Earth

Like all forms of Matter, neutron stars are formed from 3 distinct charge flavours of Matter

Matter

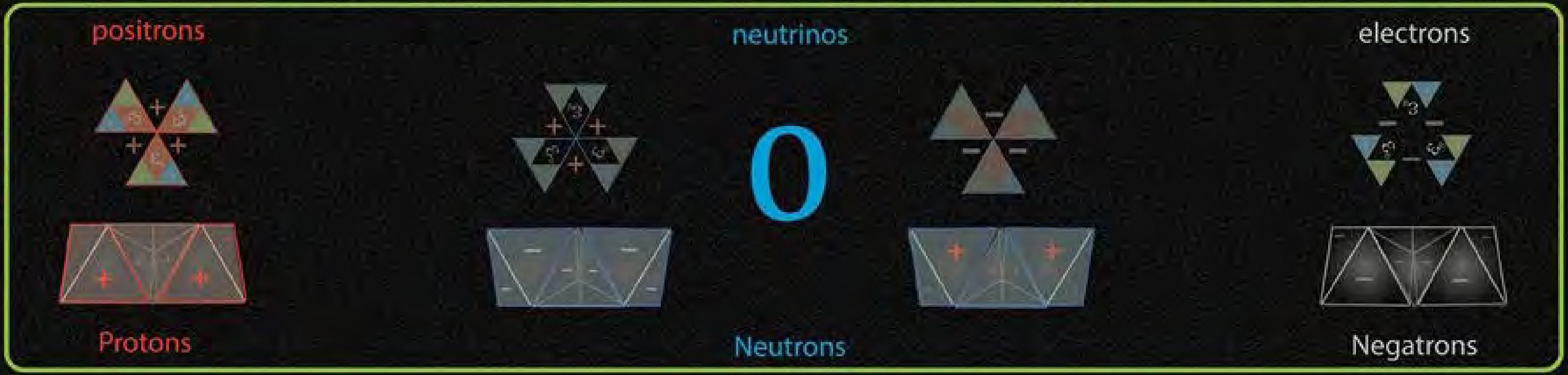
positrons
neutrinos
electrons
0
Protons
Neutrons
Negatrons

anti-Matter

Neutron stars are neutral charge pulsars

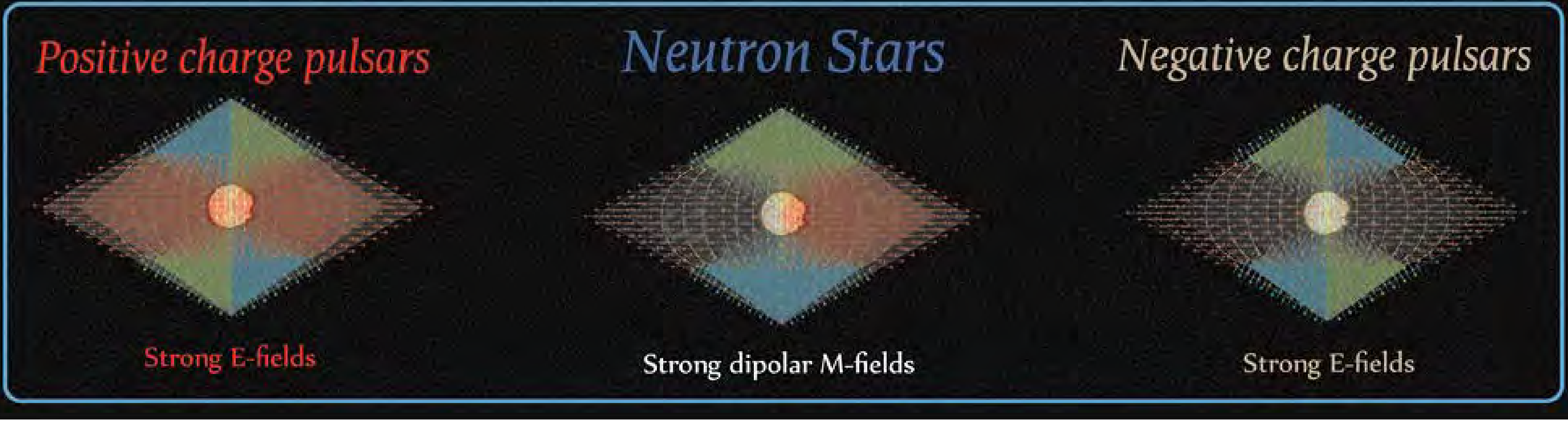
Positive charge pulsars
Neutron Stars
Negative charge pulsars
Strong E-fields
Strong dipolar M-fields
Strong E-fields

Tetryonics 78.06 - Neutron star types

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Pulsars

A pulsar is a rotating neutron star that emits a beam of electromagnetic radiation.

This radiation can only be observed when the beam of emission is pointing towards the Earth,
much the way a lighthouse can only be seen when the light is pointed in the direction of an observer,
and is responsible for the pulsed appearance of emission.

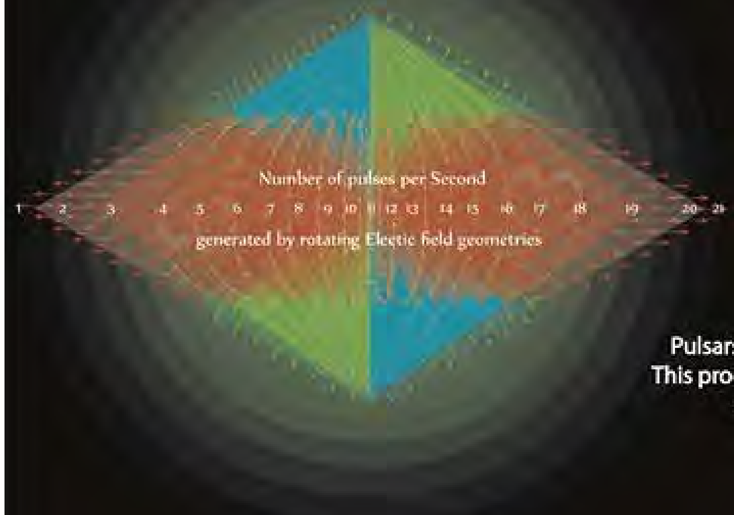
Number of pulses per Second
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
generated by rotating Electic field geometries

Pulsars are electrially charged versions of neutron stars that have weak M-fields in comparision to Neutron stars themselves

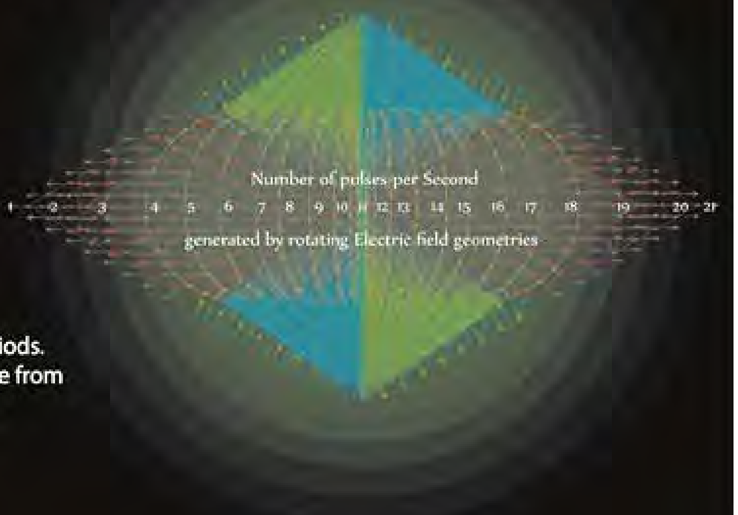
Number of pulses per Second
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
generated by rotating Electic field geometries

Pulsars are very dense, and have short, regular rotational periods.
This produces a very precise interval between pulses that range from
milliseconds to several seconds for individual pulsars

E-field waves accelerate charged particles M-fields do no work

Ampere

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

Electric force *Magnetic field*

Lorentz

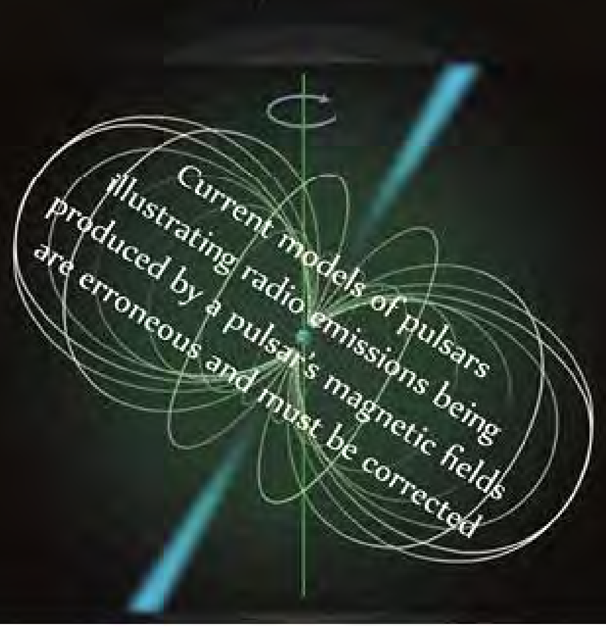

Current models of pulsars illustrating radio emissions being produced by a pulsar's magnetic fields are erroneous and must be corrected

Radio wave astomony detects E-field waves of energy momenta not magnetic waves

Maxwell

Because a magnetic force is always perpendicular to the motion,
the magnetic field can do no work on an isolated charge.

It can only do work indirectly, via the electric field
generated by a changing magnetic field

Faraday

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Pulsars

Are compact Matter bodies with strong GEM fields

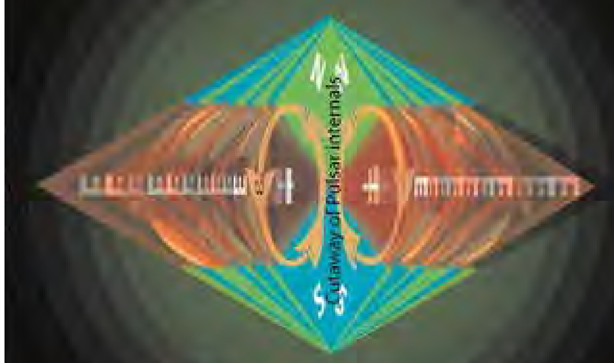

Like all Stellar bodies their GEM fields resolve to a point at their core

The gravitational collapse of Matter produces radiative electromagnetic waves

A millisecond pulsar (MSP) is a pulsar with a rotational period in the range of about 1-10 milliseconds.

Millisecond pulsars have been detected in the radio, X-ray, and gamma ray portions of the electromagnetic spectrum.

The origin of millisecond pulsars is still unknown.

The leading theory is that they begin life as longer period pulsars but are spun up or "recycled" through accretion. For this reason, millisecond pulsars are often called recycled pulsars.

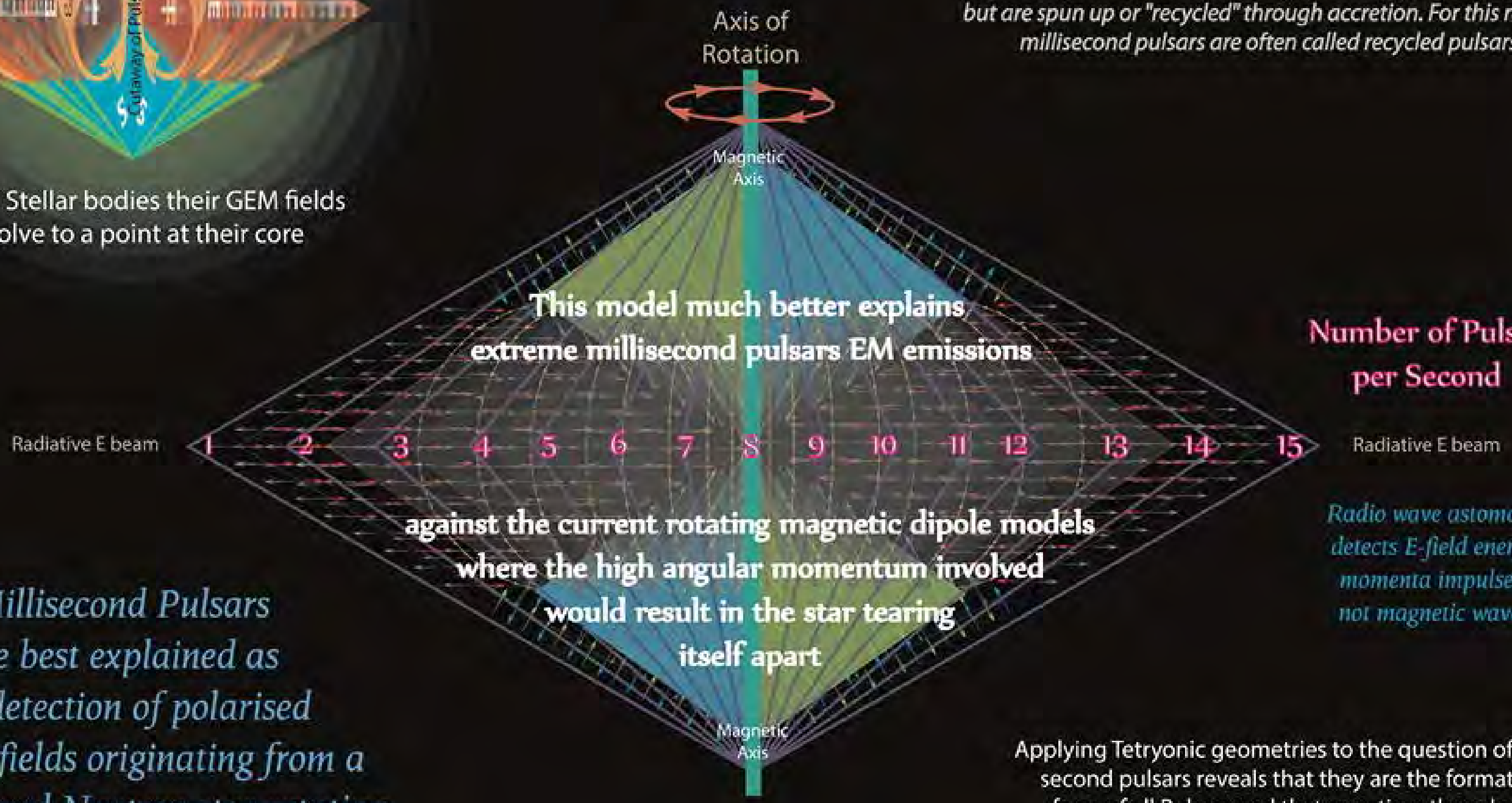

This model much better explains extreme millisecond pulsars EM emissions against the current rotating magnetic dipole models where the high angular momentum involved would result in the star tearing itself apart

Number of Pulses per Second

Radio wave astomony detects E-field energy momenta impulses not magnetic waves

Millisecond Pulsars are best explained as the detection of polarised Electric fields originating from a non-charged Neutron star rotating with high angular momentum

Applying Tetryonic geometries to the question of millisecond pulsars reveals that they are the formative form of all Pulsars and that over time they slow down to become the observed longer period pulsars [obeying the conservation of Angular momentum law]

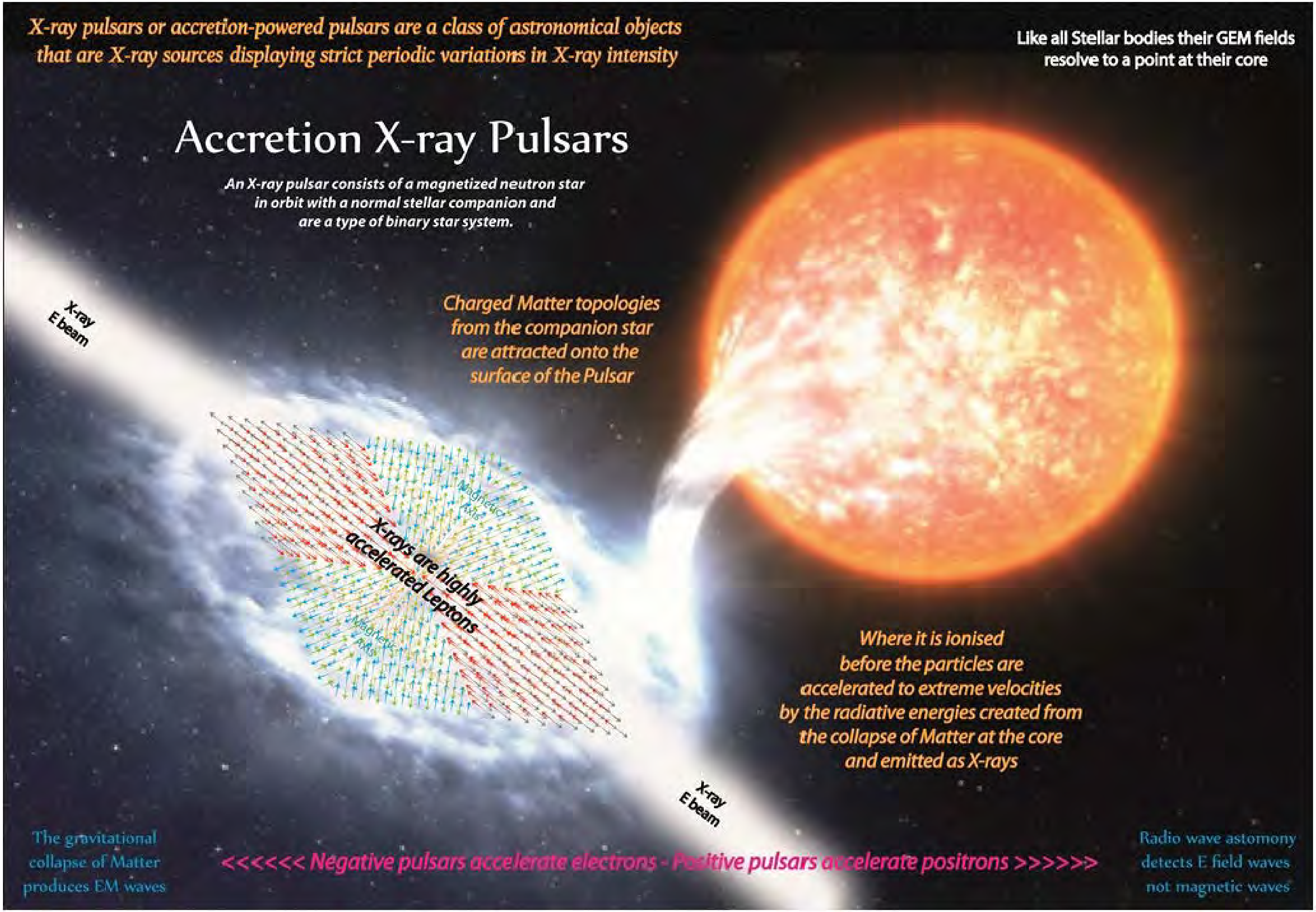

X-ray pulsars or accretion-powered pulsars are a class of astronomical objects that are X-ray sources displaying strict periodic variations in X-ray intensity

Like all Stellar bodies their GEM fields resolve to a point at their core

Accretion X-ray Pulsars

An X-ray pulsar consists of a magnetized neutron star in orbit with a normal stellar companion and are a type of binary star system.

Charged Matter topologies from the companion star are attracted onto the surface of the Pulsar

Where it is ionised before the particles are accelerated to extreme velocities by the radiative energies created from the collapse of Matter at the core and emitted as X-rays

The gravitational collapse of Matter produces EM waves

<<<<<< Negative pulsars accelerate electrons - Positive pulsars accelerate positrons >>>>>>

Radio wave astomony detects E field waves not magnetic waves

Tetryonics 78.09 - Accretion X-ray Pulsars

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Stellar Novae

Novae are cataclysmic stellar phenomena that take place in binary systems consisting of a compact stellar object and a low-mass star.

Novae are cataclysmic nuclear explosions in a white dwarf star.

It is caused by the accretion of hydrogen on to the surface of the star, which ignites and starts a runaway nuclear 'fusion' process

All stellar 'fusion' processes are in fact GEM pinches that convert standing wave Matter into radiant mass-energy

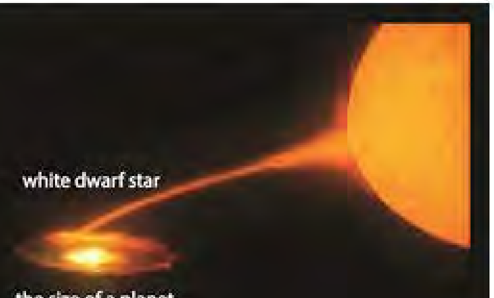

the size of a planet
but with a mass of up to
1.4 times that of the Sun

The stars must be close enough for the intense gravitational field of the white dwarf to tear material away from the outer layers of its companion.

photons of energy momenta form kEM fields that accelerate ions and electrons

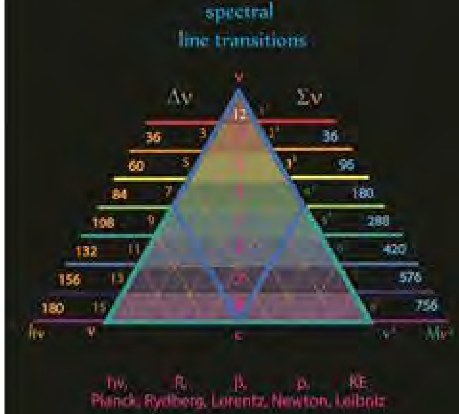

all elemental spectral lines are the result of accelerating photo-electrons

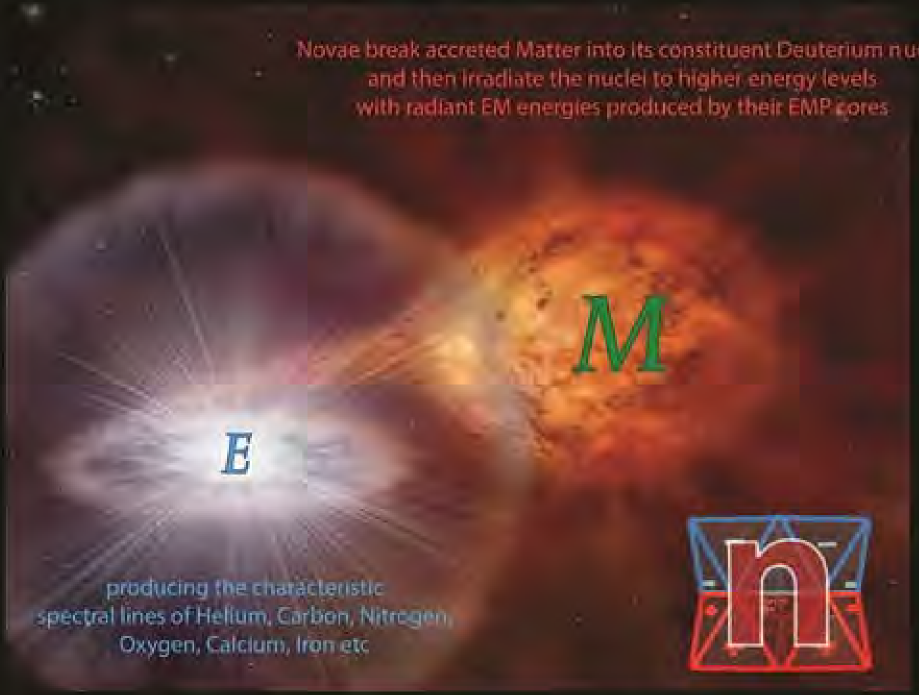

Novae break accreted Matter into its constituent Deuterium nuclei and then irradiate the nuclei to higher energy levels with radiant EM energies produced by their EMP cores

producing the characteristic spectral lines of Helium, Carbon, Nitrogen, Oxygen, Calcium, Iron etc

runaway
Matter-energy conversion
within the supernova

12	*Lyman*
48	*Balmer*
108	*Paschen*
192	*Brackett*
300	*Pfund*
432	*Humphries*
588	*un-named*
768	*ionised leptons*

accelerates ions & photo-electrons producing spectral line emissions and creates gamma ray bursts

An enigma that has puzzled experts for over 50 years is the origin of the irregular, inhomogeneous distribution of nova ejecta

The material transferred by the companion star is often of solar composition (i.e., close to 98% hydrogen and helium by mass).

Elements, in the range between carbon (C) and calcium (Ca) on the periodic table, can account for 30% to 50% of the material ejected during a nova explosion.

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Supernovae explosions

Supernovae are extremely luminous and cause a burst of radiation that often briefly outshines an entire galaxy,

The GEM pinching [collapse of Matter waveforms]
always results in divergent neutral charge
KEM mass-energies

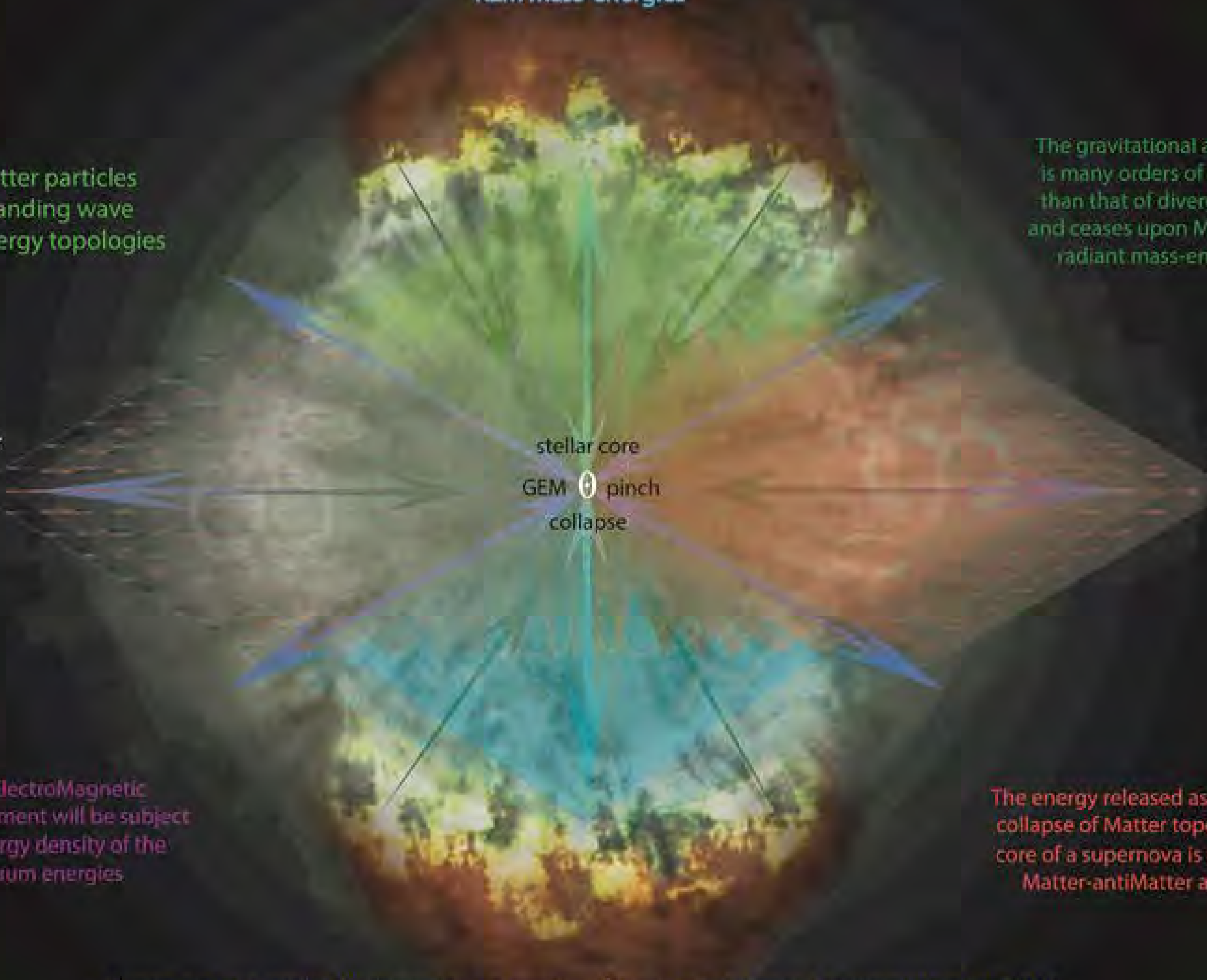

All Matter particles
are standing wave
mass-energy topologies

The gravitational attraction of Matter
is many orders of magnitude weaker
than that of divergent KEM energies
and ceases upon Matter's collapse into
radiant mass-energy geometries

*If the EM pinch at the core of a Star
rapidly increases its efficiency or
loses its abili'ty to confine the
resultant KEM energies the
star will be blasted apart*

*Black holes, hypothesied in physics
as a solution to the math of Einstein's
General relativity since it was was first
formulated in 1915, do NOT exist*

*All their physics are provided for
by GEM pinch field mechanics*

A star moving in a ElectroMagnetic
vacuum energy environment will be subject
to changes in the energy density of the
surrounding vacuum energies

The energy released as a result of the
collapse of Matter topologies in the
core of a supernova is as efficient as
Matter-antiMatter annihilation

Supernovae are created by the sudden disruption of the counter balanced convergent and radiative
mass-ENERGY-Matter output of GEM pinch singularities at the core of compact stellar objects
which results in the sudden release of massive amounts of divergent mass-energy
all at once from the stellar core blasting away the remaining stellar Matter

Tetryonics 79.02 - Supernovae explosions

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Singularities

A gravitational singularity or spacetime singularity is a location where the quantities that are used to measure the gravitational electromagnetic fields become infinite in a way that does not depend on the spatial co-ordinate system

Just as the radiative KEM fields of Matter in motion and charged EM fields gives rise to the modern physics misconceptions of spherical point particles and String theories

Tetryonic theory precludes point particles and black holes through analytic mass-energy geometries & Gaussian Matter topologies that result from equilateral Planck energy momenta interactions

The collapse of 3D Matter releases its standing-wave energies as radiant 2D mass-energies foms the basis for all Stellar energy releases

Current theories based on mathematical modelling of General relativity without accurate quantum mechanical models predicts that at densities greater than those supported by fermion degeneracy, gravity overwhelms all other forces collapsing the 3D material body of a large star to create a singularity and the eventual formation of a black hole.

Equilateral Planck charge geometries are the key to understanding stellar processes

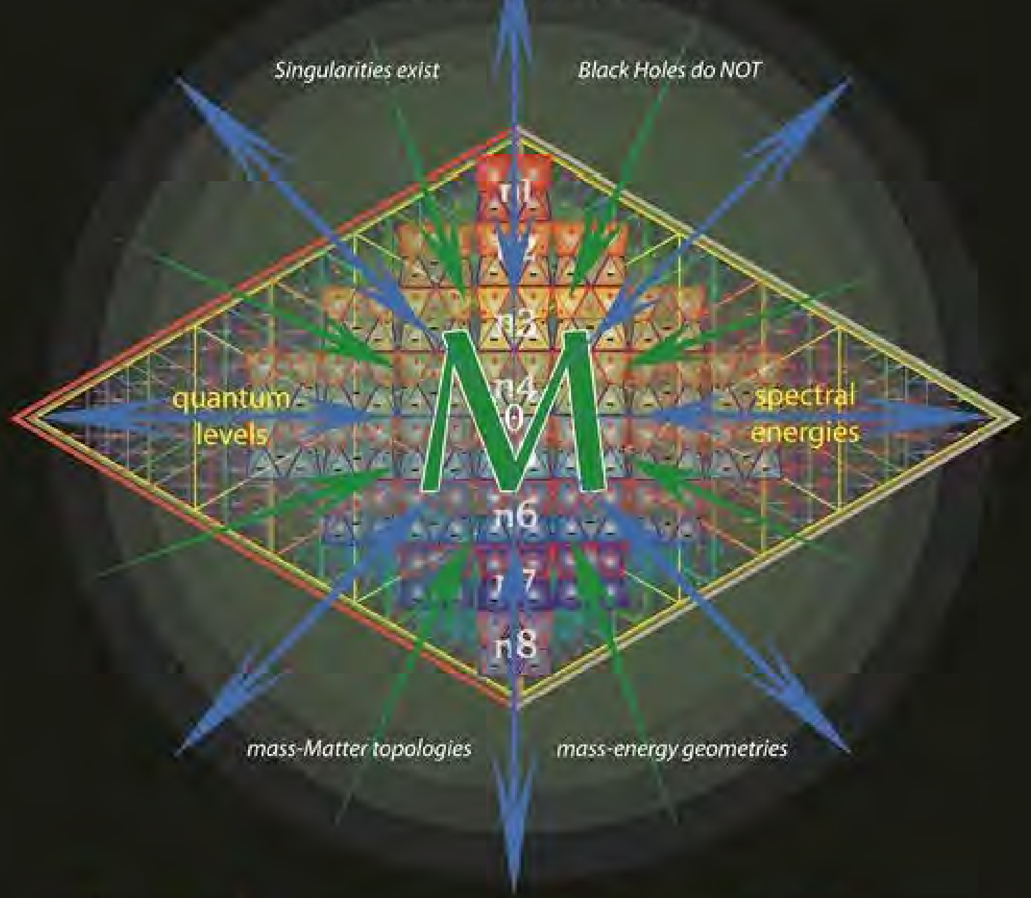

The smallest quanta of 3D Matter is a Tetryon

(any attempt to reduce its 3 spatial dimensions results in its collapse into 2D divergent mass-energy waveforms)

Tracing the GravitoElectroMagnetic fields of Matter back to their origin point can give rise to the misconception of a EM field singularity leading to a black hole

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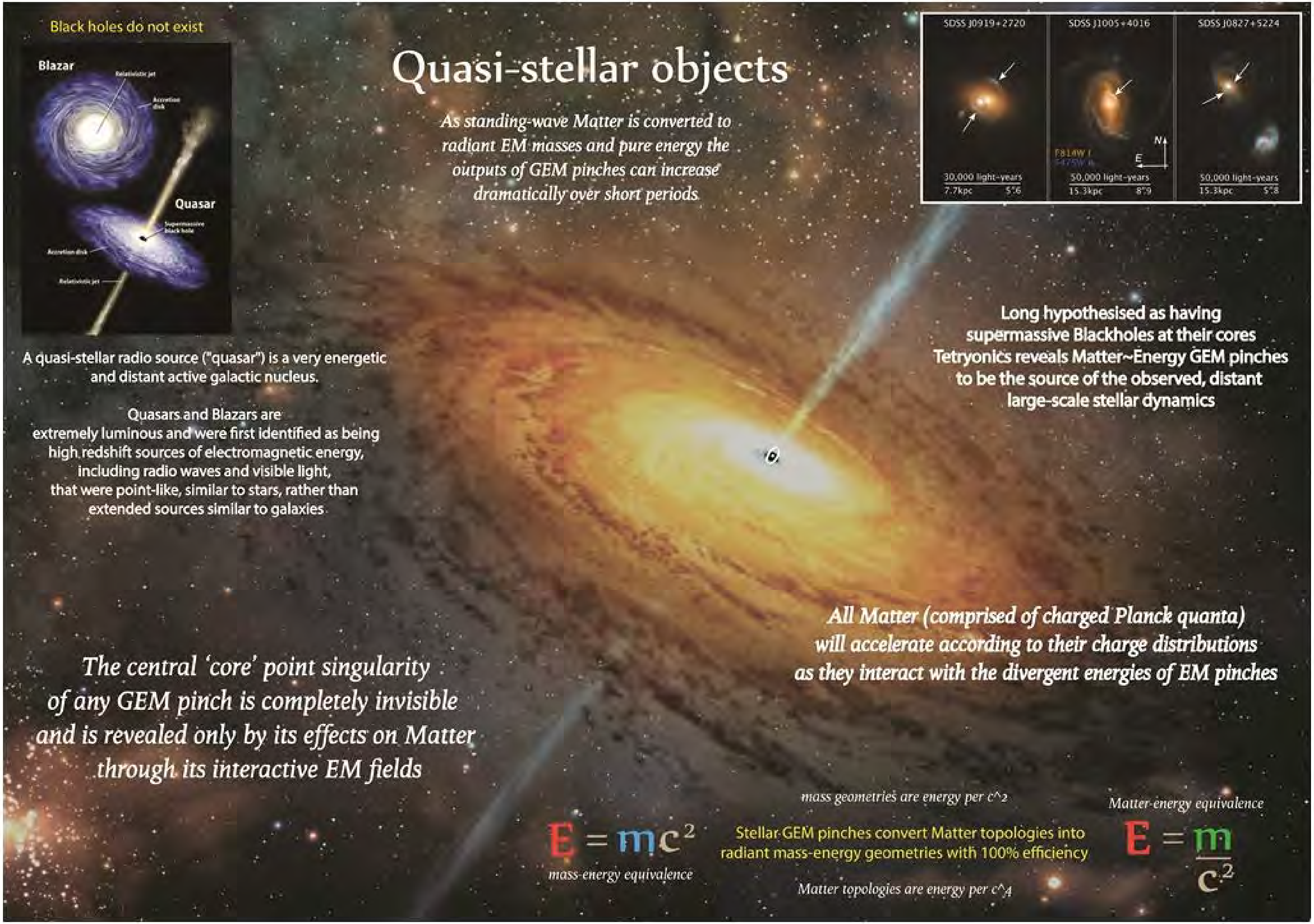
Blazar
Relativistic jet
Accretion disk
Quasar
Supermassive black hole
Accretion disk
Relativistic jet
SDSS J0919+2720
30,000 light-years
7.7kpc
5"6
SDSS J1005+4016
F814W I
F475W B
N
E
50,000 light-years
15.3kpc
8"9
SDSS J0827+5224
50,000 light-years
15.3kpc
5"8

Quasi-stellar objects

As standing-wave Matter is converted to radiant EM masses and pure energy the outputs of GEM pinches can increase dramatically over short periods

Black holes do not exist

A quasi-stellar radio source ("quasar") is a very energetic and distant active galactic nucleus.

Quasars and Blazars are extremely luminous and were first identified as being high redshift sources of electromagnetic energy, including radio waves and visible light, that were point-like, similar to stars, rather than extended sources similar to galaxies

Long hypothesised as having supermassive Blackholes at their cores Tetryonics reveals Matter~Energy GEM pinches to be the source of the observed, distant large-scale stellar dynamics

All Matter (comprised of charged Planck quanta) will accelerate according to their charge distributions as they interact with the divergent energies of EM pinches

The central 'core' point singularity of any GEM pinch is completely invisible and is revealed only by its effects on Matter through its interactive EM fields

$$E = mc^2$$

mass-energy equivalence

mass geometries are energy per c^2

Stellar GEM pinches convert Matter topologies into radiant mass-energy geometries with 100% efficiency

Matter topologies are energy per c^4

Matter-energy equivalence

$$E = \frac{m}{c^2}$$

Active Galaxies

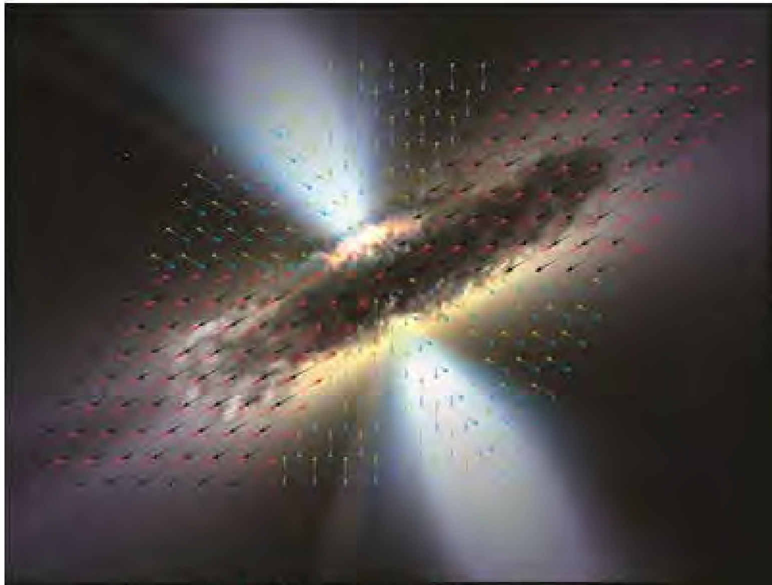

In addition to the E-field acceleration of charged particles GEM pinches can also release energies along their Magnetic axis

An active galactic nucleus (AGN) is a compact region at the centre of a galaxy that has a much higher than normal luminosity over at least some portion, and possibly all, of the electromagnetic spectrum.

The motion of stars about a central point in a galaxy's core is the result of a GEM pinch's radiated interactive forces

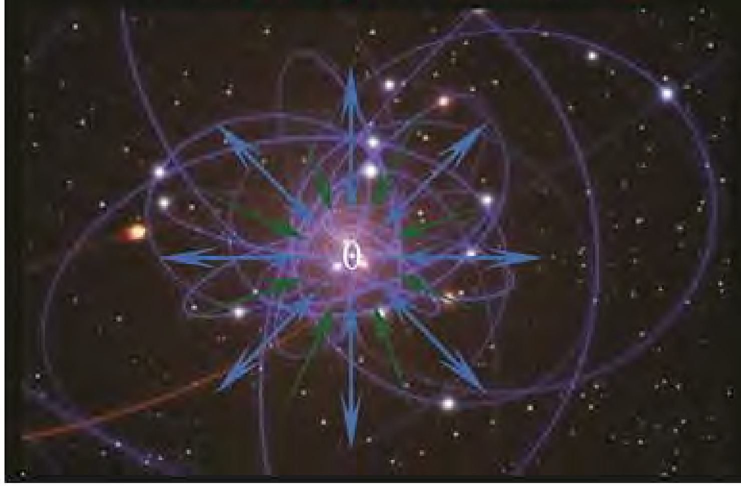

GR uses stress tensors to
model the gravitational effects of ALL
energy in a system in its various forms
without distinction or differentiation
between mass-energy geometries
and Matter topologies

EM PINCHES ARE 100% EFFICIENT CONVERTERS OF MATTER INTO ENERGY

Using Tetryonic geometry the Universe is revealed as being completely dominated by ElectroMagnetic forces, with Gravity aiding at the larger scales to help shape the differing forms of Galaxies that we see

EM PINCHES REDUCE TO SINGULARITIES AT THE FOCUS OF THEIR DIVERGENT FIELDS

Tetryonic geometry reveals
divergent interactive EM masses
&
convegent gravitational Matter
all contribute to the nett force of
Gravitational fields

The current astrophysical models of active galaxies propose supermassive Blackholes as the only mechanism possible to produce the observed large-scale dynamics

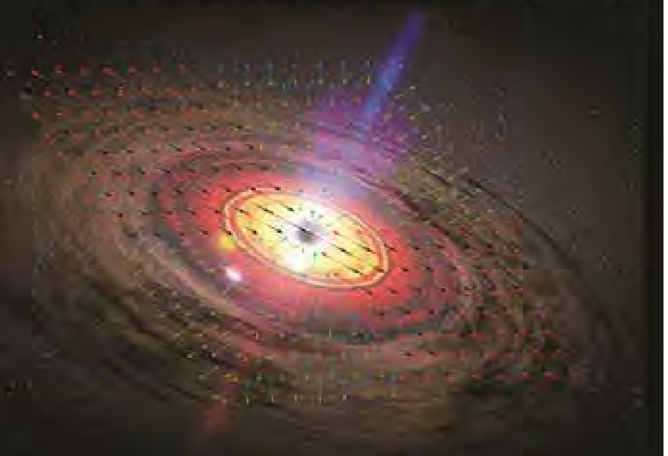

E-fields hold Matter in a disc and M-fields release highly polarised energies

Tetryonics reveals the Galactic EM Pinches are also capable of fitting the observed data and explaining many of the current mysteries surrounding how active galaxies generate their power.

The energies released by the conversion of Matter into energy in GEM pinches is the most energetic process in the Universe

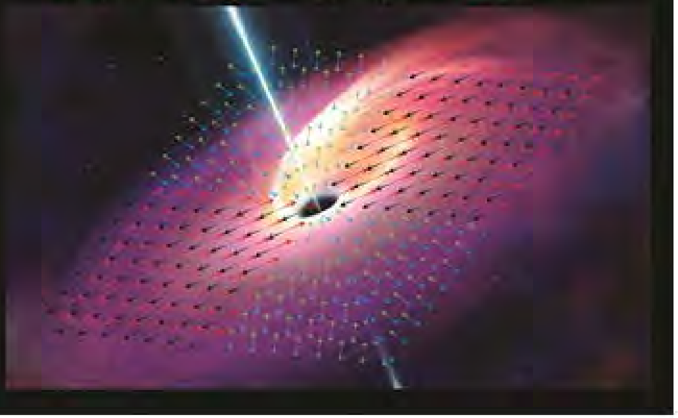

Black holes

[Garbage IN - Garbage OUT]

Computer-based modelling of GR
mathematics without charge geometries
leads to paradoxial & erroneous outcomes

Tetryonics allows for Supermassive Matter to form but does NOT allow for the classically defined Black holes

Matter topology collapse
radiant mass-energies

The centres of Galaxies & Quasars hypothesised as being powered by supermassive blackholes are in fact the foci of ElectroMagnetic pinches

In General relativity, a black hole is a region of space in which the gravitational field is so powerful that nothing, including light, can escape its gravitational pull.

The black hole has a one-way surface, called an event horizon, into which objects can fall, but out of which nothing can come. It is called "black" because it absorbs all the light that hits it, reflecting nothing, just like a perfect blackbody in thermodynamics.

'Standard Model' quantum analysis of black holes shows them to possess a temperature and emit Hawking radiation.

In Standard Model Quantum Mechanics a problem arises in that Charge and Gravity equations break down and produce infinities and other impossible results

Very large non-radiating 'Dark Matter' would be the closest thing possible to the currently theorised black-holes.

However the 3D volume of such an object would be limited to the space taken up by its constituent Tetryonic charge Matter topologies. (ie Tetryons face-to face without Space present between any facsias)

This is similar to the current models of Neutron Stars , WIMPs and MACHOs

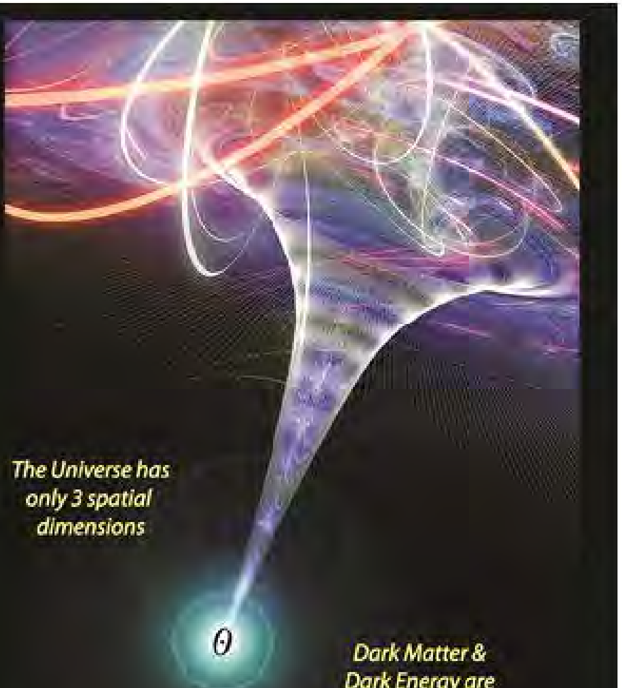

The Universe has
only 3 spatial
dimensions

Dark Matter &
Dark Energy are
EM vector forces

Black holes, Worm holes &
other passable singularities
do NOT exist

The collapse of standing-wave Matter topologies results in the release of divergent radiative mass-energy geometries

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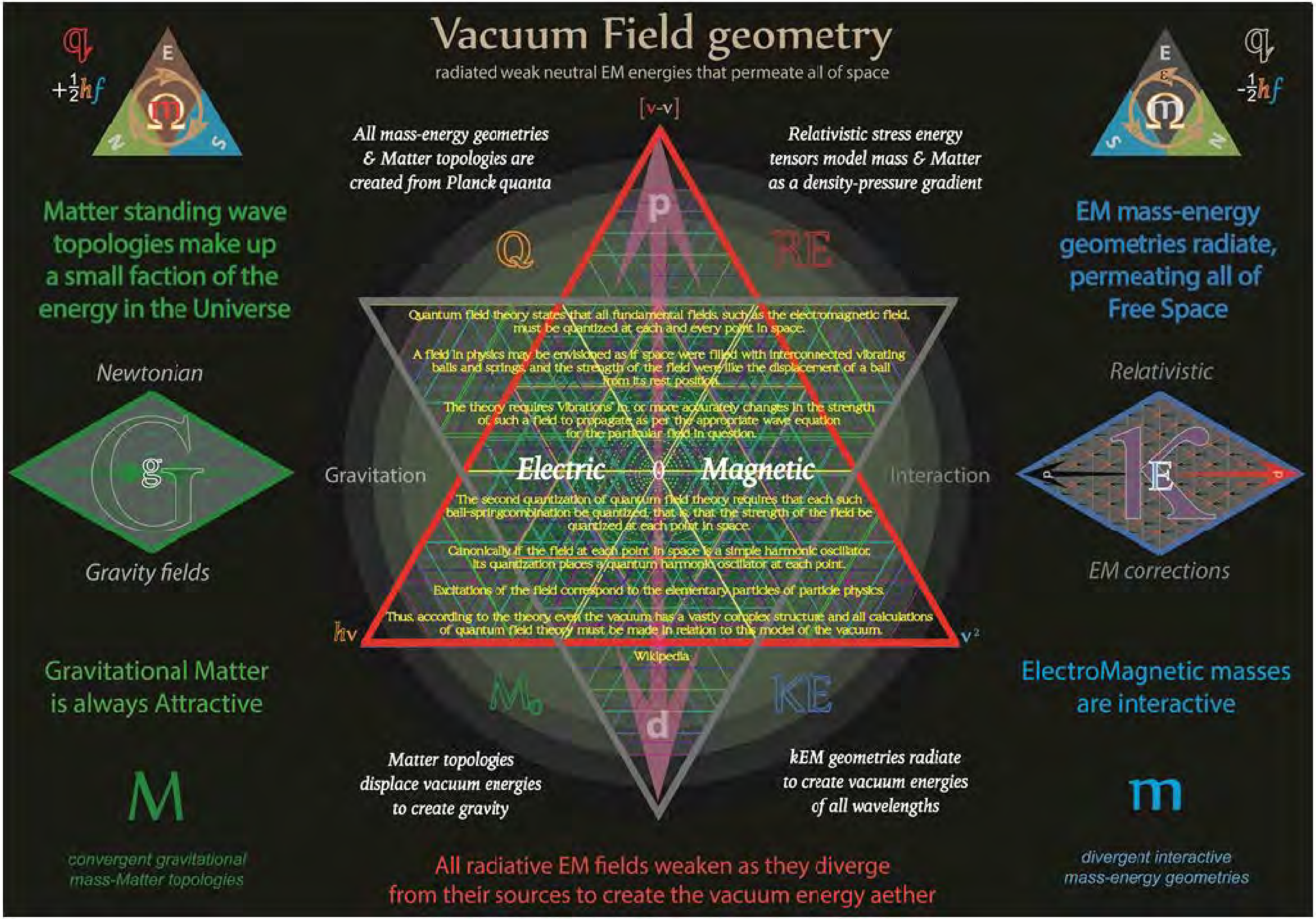

Vacuum Field geometry

radiated weak neutral EM energies that permeate all of space

All mass-energy geometries & Matter topologies are created from Planck quanta

Relativistic stress energy tensors model mass & Matter as a density-pressure gradient

Matter standing wave topologies make up a small faction of the energy in the Universe

EM mass-energy geometries radiate, permeating all of Free Space

Newtonian

Gravity fields

Relativistic

EM corrections

Gravitation

Interaction

Electric **Magnetic**

Quantum field theory states that all fundamental fields, such as the electromagnetic field, must be quantized at each and every point in space.

A field in physics may be envisioned as if space were filled with interconnected vibrating balls and springs, and the strength of the field were like the displacement of a ball from its rest position.

The theory requires 'vibrations' in, or more accurately changes in the strength of such a field to propagate as per the appropriate wave equation for the particular field in question.

The second quantization of quantum field theory requires that each such ball-springcombination be quantized, that is, that the strength of the field be quantized at each point in space.

Canonically, if the field at each point in space is a simple harmonic oscillator, its quantization places a quantum harmonic oscillator at each point.

Excitations of the field correspond to the elementary particles of particle physics.

Thus, according to the theory, even the vacuum has a vastly complex structure and all calculations of quantum field theory must be made in relation to this model of the vacuum.

Wikipedia

Gravitational Matter is always Attractive

ElectroMagnetic masses are interactive

Matter topologies displace vacuum energies to create gravity

kEM geometries radiate to create vacuum energies of all wavelengths

M

convergent gravitational mass-Matter topologies

m

divergent interactive mass-energy geometries

All radiative EM fields weaken as they diverge from their sources to create the vacuum energy aether

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The Big Bang theory

The Big Bang is a considered to be a well-tested scientific theory which is widely accepted within the scientific community because it is the most accurate and comprehensive explanation for the full range of phenomena astronomers observe.

The framework for the Big Bang model relies on Albert Einstein's general relativity and on simplifying assumptions such as homogeneity and isotropy of space.

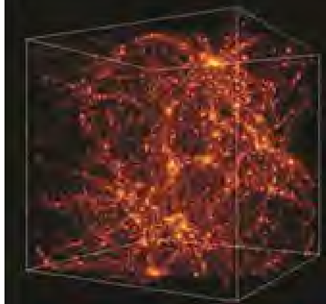

Primodial Atom

According to the Big Bang theory, the Universe was once in an extremely hot and dense state which expanded rapidly

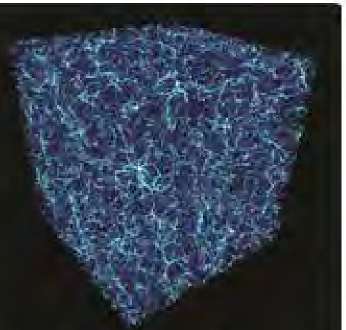

The Big Crunch

If the mass density of the Universe were greater than the critical density, then the Universe would reach a maximum size and then begin to collapse.

It would become denser and hotter again, ending with a state similar to that in which it started

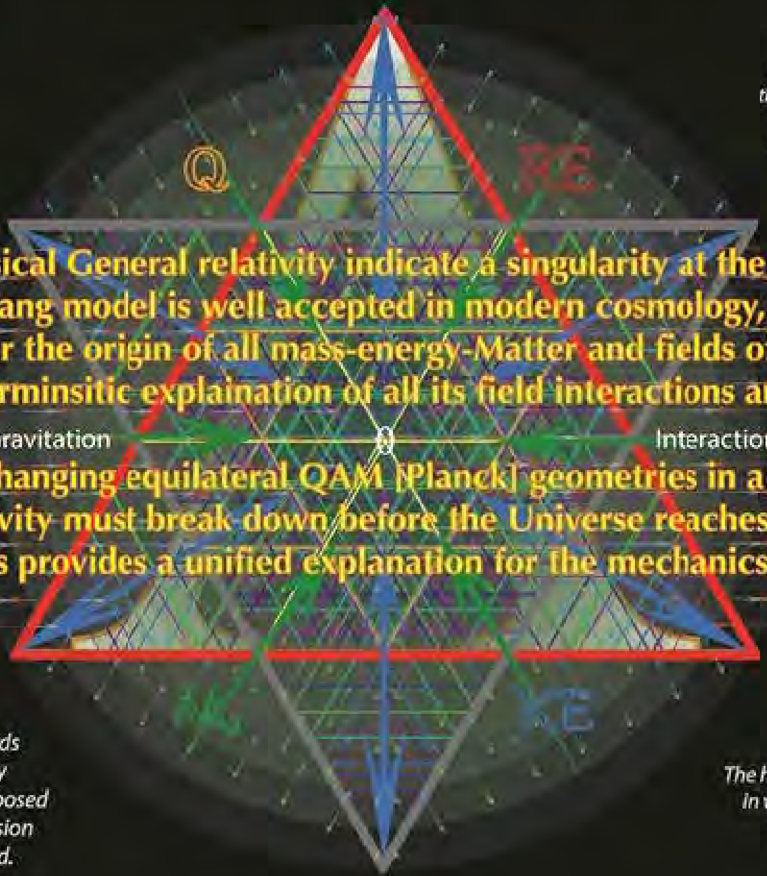

The equations of classical General relativity indicate a singularity at the origin of cosmic time, and while the Big Bang model is well accepted in modern cosmology, Tetryonics provides a clear causal model for the origin of all mass-energy-Matter and fields of force in our Universe, offering a unified, determinsitic explaination of all its field interactions and ultimate energy fate.

Tetryonics relates Time to changing equilateral QAM [Planck] geometries in a dynamic evolving Universe. Moreover, general relativity must break down before the Universe reaches the Planck temperature while Tetryonics provides a unified explanation for the mechanics of the Universe

Big Bang

Extrapolation of the expansion of the Universe backwards in time using general relativity yields an infinite density and temperature at a finite time in the past, which it is proposed underwent a explosive birth and a period of rapid expansion in order to produce the homognetity currently observed.

The Big Chill

The heat death of the universe is a suggested ultimate fate of the universe, in which the universe has diminished to a state of no thermodynamic free energy and therefore can no longer sustain motion or life.

Inflation

The Big Bang theory is the prevailing cosmological model that attempts to explain the early development of the Universe

Energy death

Tetryonics 79.08 - The Big Bang

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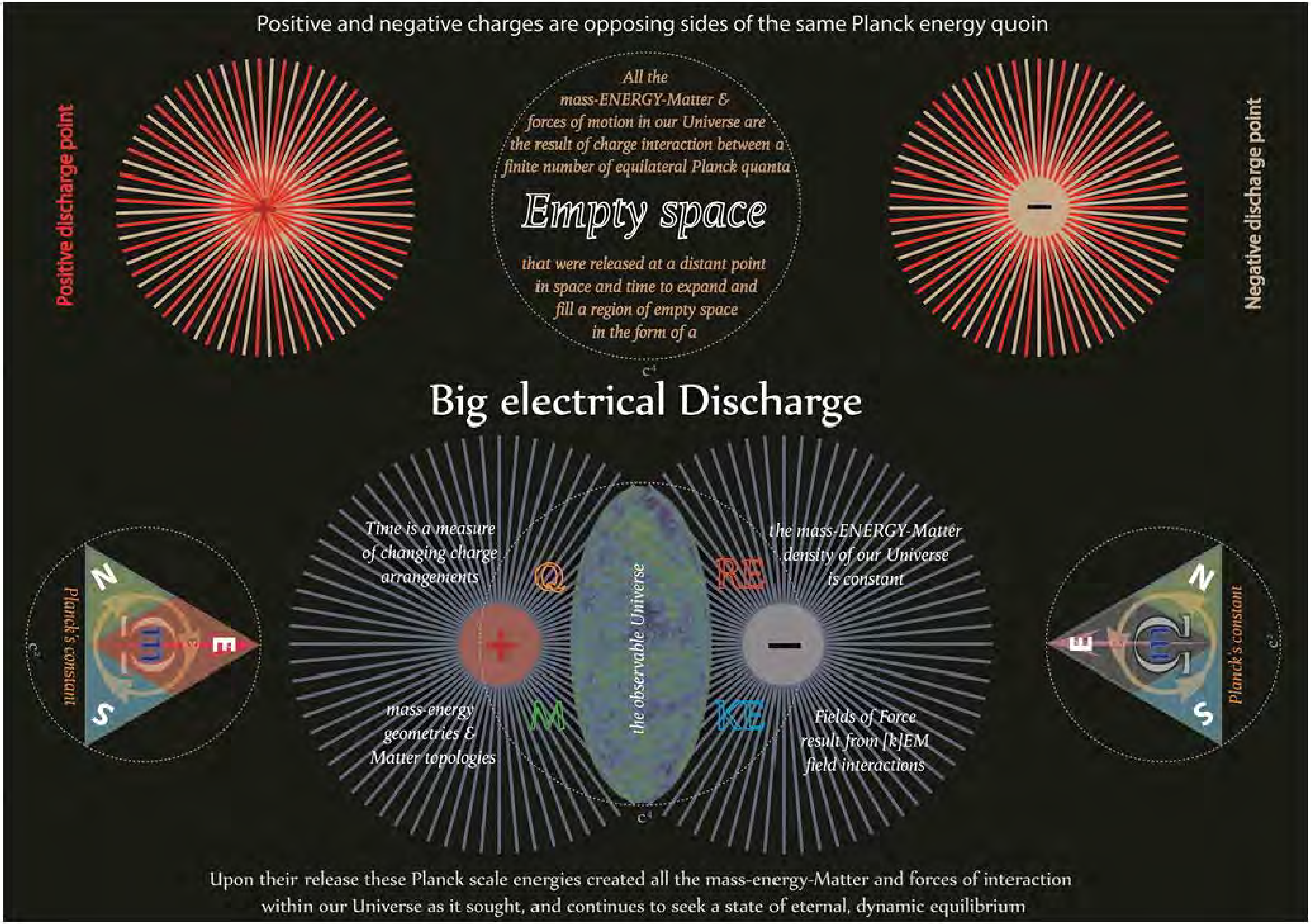

Positive and negative charges are opposing sides of the same Planck energy quoin

All the mass-ENERGY-Matter & forces of motion in our Universe are the result of charge interaction between a finite number of equilateral Planck quanta

Empty space

that were released at a distant point in space and time to expand and fill a region of empty space in the form of a

Big electrical Discharge

Time is a measure of changing charge arrangements

the mass-ENERGY-Matter density of our Universe is constant

mass-energy geometries & Matter topologies

Fields of Force result from [k]EM field interactions

Upon their release these Planck scale energies created all the mass-energy-Matter and forces of interaction within our Universe as it sought, and continues to seek a state of eternal, dynamic equilibrium

Positive discharge point
Negative discharge point
−
c^4
Q
RE
M
KE
+
−
the observable Universe
c^4
N
E
S
Planck's constant
c^2
N
E
S
Planck's constant
c^2

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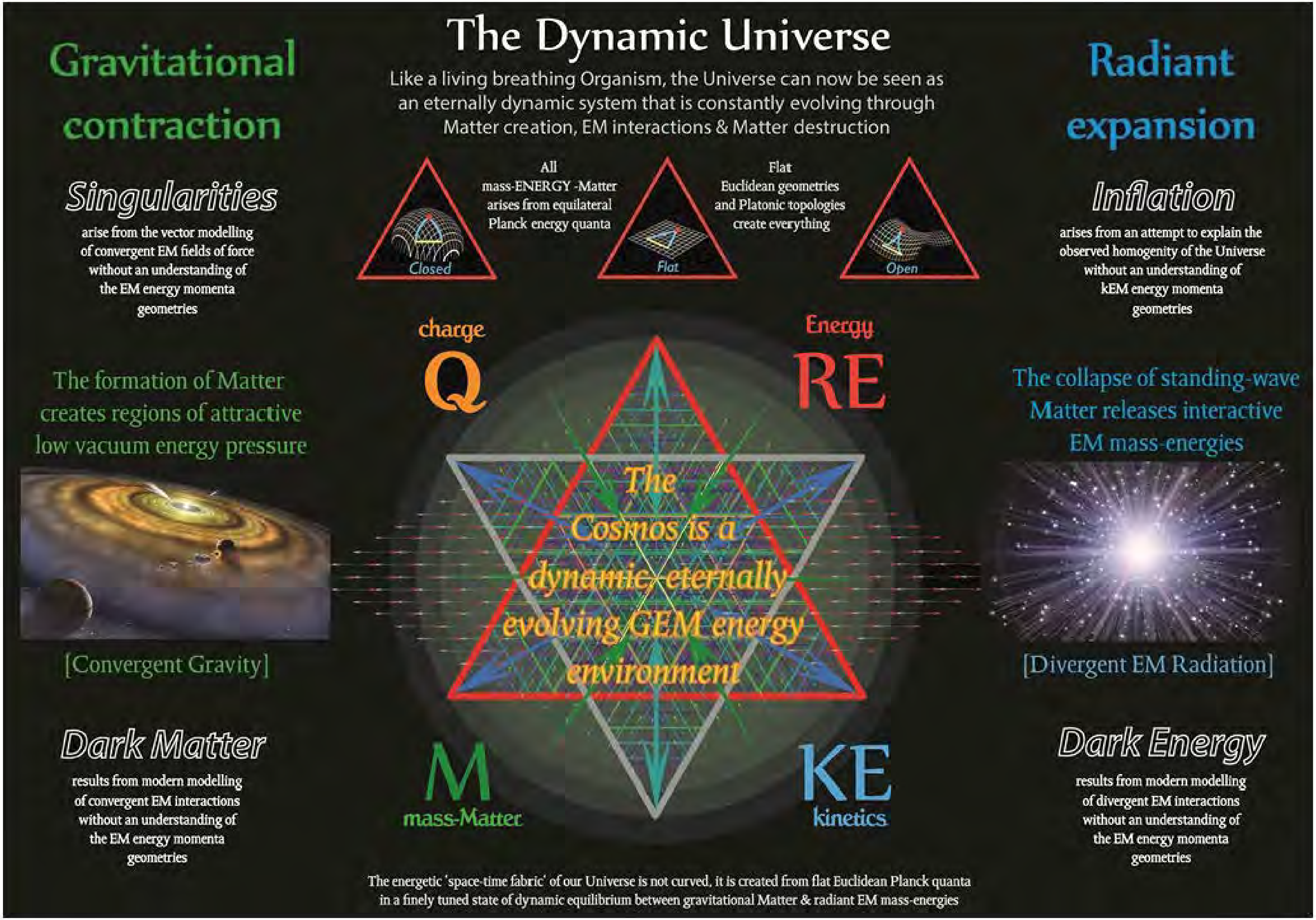

The Dynamic Universe

Like a living breathing Organism, the Universe can now be seen as an eternally dynamic system that is constantly evolving through Matter creation, EM interactions & Matter destruction

Gravitational contraction

Singularities

arise from the vector modelling of convergent EM fields of force without an understanding of the EM energy momenta geometries

The formation of Matter creates regions of attractive low vacuum energy pressure

[Convergent Gravity]

Dark Matter

results from modern modelling of convergent EM interactions without an understanding of the EM energy momenta geometries

All mass-ENERGY -Matter arises from equilateral Planck energy quanta

Flat Euclidean geometries and Platonic topologies create everything

The Cosmos is a dynamic eternally evolving GEM energy environment

Radiant expansion

Inflation

arises from an attempt to explain the observed homogenity of the Universe without an understanding of kEM energy momenta geometries

The collapse of standing-wave Matter releases interactive EM mass-energies

[Divergent EM Radiation]

Dark Energy

results from modern modelling of divergent EM interactions without an understanding of the EM energy momenta geometries

The energetic 'space-time fabric' of our Universe is not curved, it is created from flat Euclidean Planck quanta in a finely tuned state of dynamic equilibrium between gravitational Matter & radiant EM mass-energies

Tetryonics 79.10 - The Dynamic Universe

Galactic GEM interactions

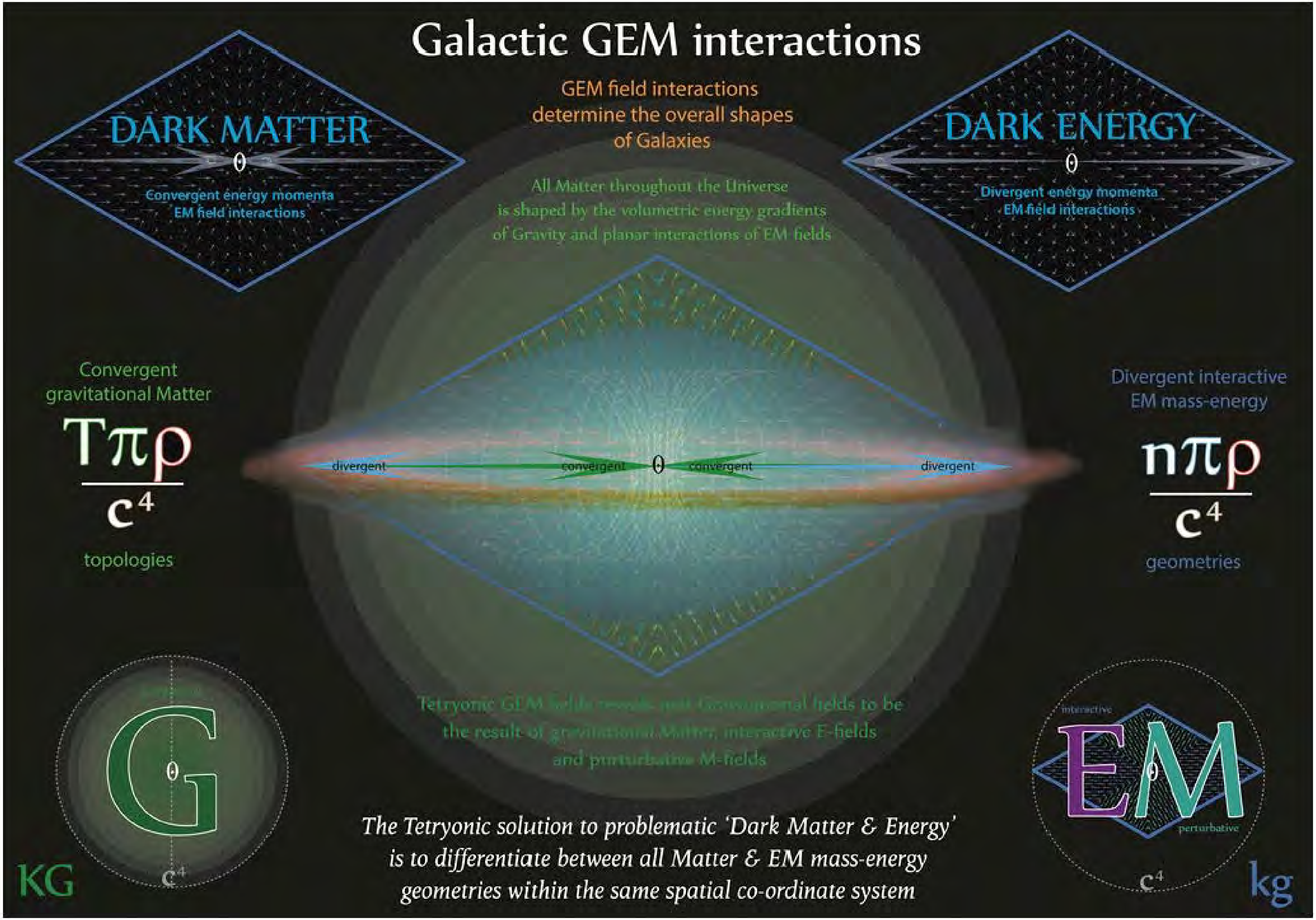

GEM field interactions determine the overall shapes of Galaxies

All Matter throughout the Universe is shaped by the volumetric energy gradients of Gravity and planar interactions of EM fields

DARK MATTER
0
Convergent energy momenta
EM field interactions
DARK ENERGY
0
Divergent energy momenta
EM field interactions
divergent
convergent
0
convergent
divergent
interactive
perturbative
0
KG
kg

Convergent gravitational Matter

$$\frac{T\pi\rho}{c^4}$$

topologies

Divergent interactive EM mass-energy

$$\frac{n\pi\rho}{c^4}$$

geometries

Tetryonic GEM fields reveals all Gravitational fields to be the result of gravitational Matter, interactive E-fields and perturbative M-fields

The Tetryonic solution to problematic 'Dark Matter & Energy' is to differentiate between all Matter & EM mass-energy geometries within the same spatial co-ordinate system

Tetryonics 79.11 - Universal GEM interactions

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The Dark Forces

Gravitational attraction is the result of the nullspace of Matter.
It is many orders of magnitude weaker than ElectroMagnetic forces
(Gravity does not hold the whole galaxy together)

charged energy geometries

energy momenta quanta

$$n\pi\left[\underset{\text{mass}}{m}\Omega\underset{\text{velocity}}{v}\right]^2$$

$$G_{ab}+\Lambda g_{ab}=\frac{8\pi G}{c^4}T_{\mu\nu}$$

Newtonian Gravity
models the motion resulting
from the attractive force
between Matter

General Relativity
models perturbative force
resulting from the total energy
of any system

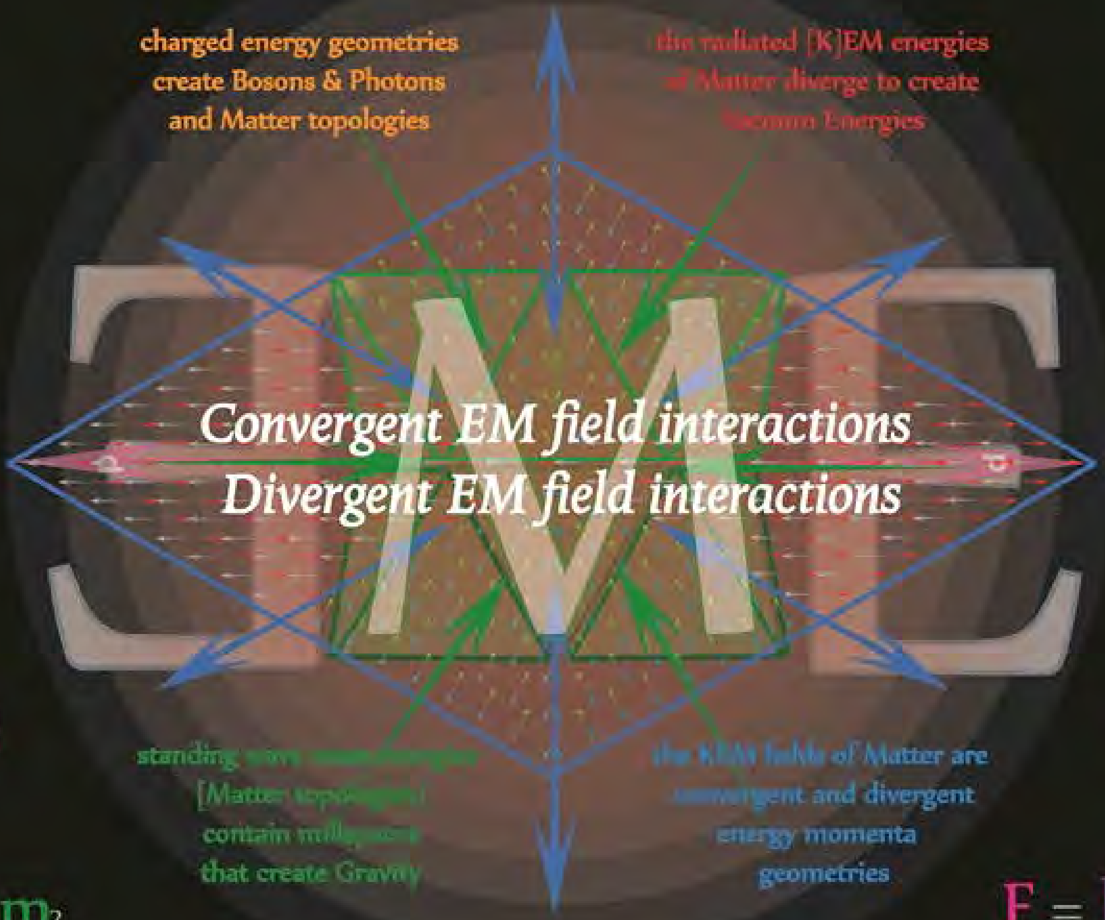

charged energy geometries
create Bosons & Photons
and Matter topologies

the radiated [K]EM energies
of Matter diverge to create
Vacuum Energies

Convergent EM field interactions
Divergent EM field interactions
M

standing wave mass-energies
[Matter topologies]
contain nullspaces
that create Gravity

the KEM fields of Matter are
convergent and divergent
energy momenta
geometries

All [K]EM radiation has
a CONVERGENT component in its
interactive field that increases
when Matter is in motion

DARK MATTER

or when its standing-wave Matter
topology is destroyed

All [K]EM radiation has
a DIVERGENT omponent in its
interactive field that increases
when Matter is in motion

DARK ENERGY

or when its standing-wave Matter
topology is destroyed

$$E\xrightarrow[\text{energy momenta}]{\text{convergent}}M$$

$$M\xrightarrow[\text{energy momenta}]{\text{divergent}}E$$

$$F=-G\frac{M_1m_2}{r^2}$$

$$F=k\frac{Q_1Q_2}{r^2}$$

Gravitational
Matter
is attractive

G

Tetryonics dictates that in order to correct for measured Gravitational accelerations
we must distingush between EM mass and Matter and take into account
all the EM forces as well as that of Gravity produced by Matter

k

ElectroMagnetic
mass-energies
are interactive

Tetryonics 80.01 - The Dark Forces

Vacuum Energies

Vacuum energy is an underlying background energy that exists in space even when it is devoid of Matter (free space) and results from the introduction of the Cosmological constant [Λ] by Albert Einstein as a modification of his original theory of General relativity in order to achieve a static universe.

Dark Matter is a measure of CONVERGENT KEM interactions additional to that of Gravity

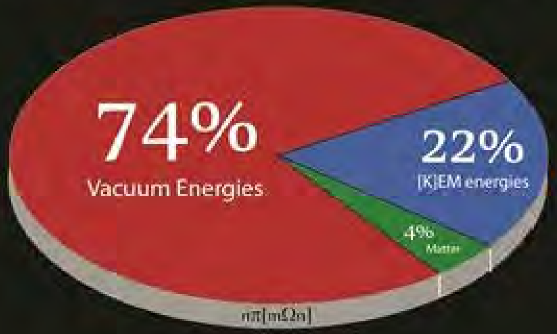

Dark Energy is a measure of DIVERGENT KEM interactions opposing that of Gravity

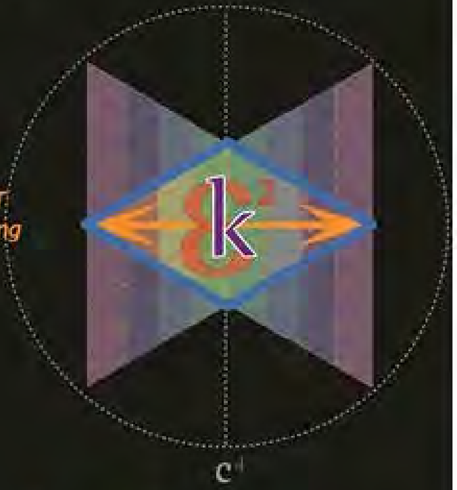

Gravitational Matter is always attractive

He later abandoned this concept after observations of the Hubble redshift indicated that the universe might not be stationary

ElectroMagnetic masses are always interactive

$$G_{ab} + \Lambda g_{ab} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

total system energy

Matter

M

topologies

mass

m

geometries

Unlike Einstein's Special and General theories of Relativity that utilizes a scalar energy density tensor, Tetryonics utilizes analytical geometry & topology to differentiate between EM mass & Matter and model all energy interactions in any spatial region

Gravity results from standing-wave Matter

Gravito-Electro-magnetic interactions

Total energy geometries

quantised energy momenta

$$\mathrm{GEM} = \frac{n\pi[m\Omega v]^2}{c^4}$$

of all EM mass-ENERGY-Matter in the Universe can be defined as

spatial volume of mass-energy-Matter interactions

EM interactions result from superpositioned EM masses

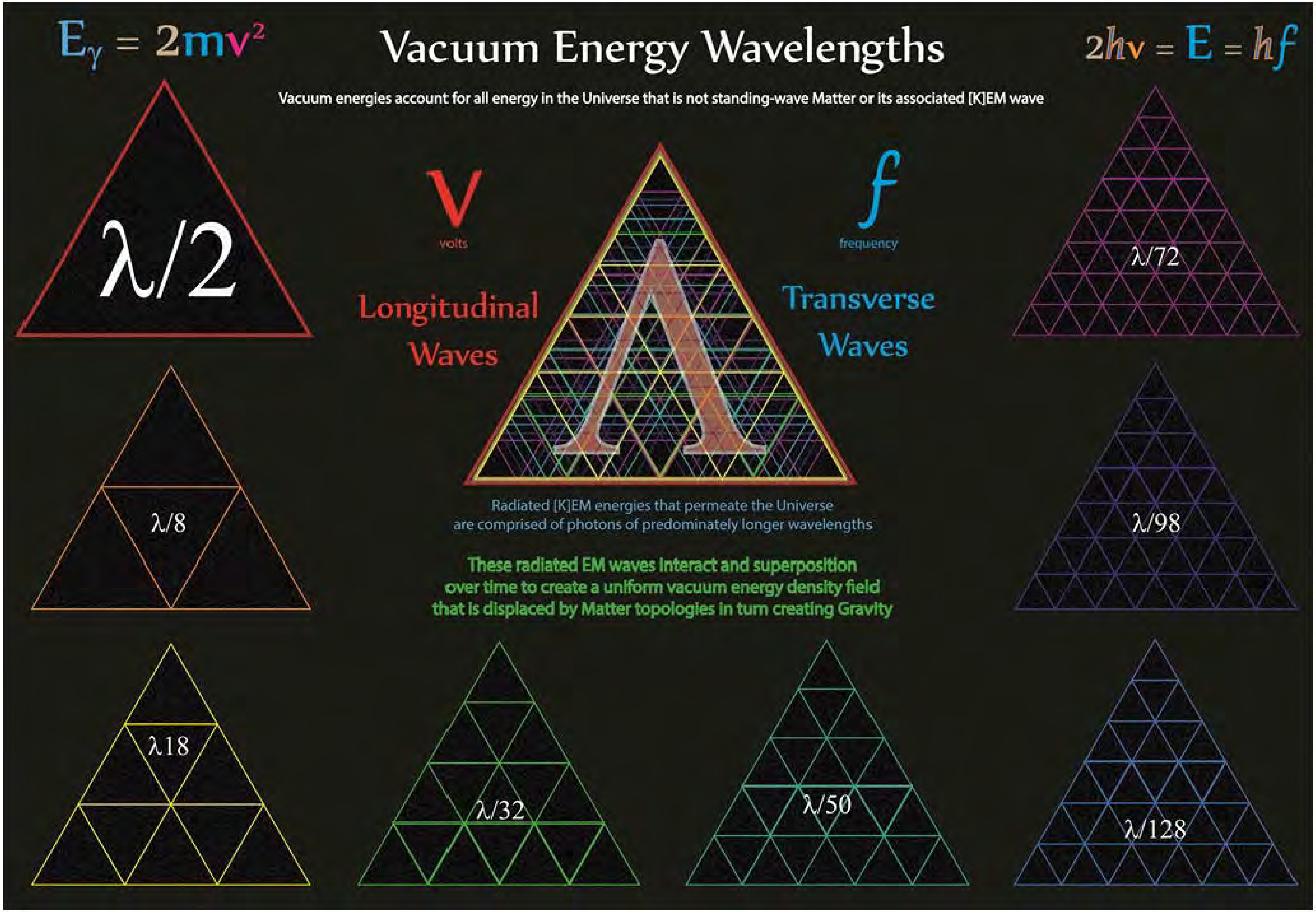

$E_\gamma = 2mv^2$

Vacuum Energy Wavelengths

$2hv = E = hf$

Vacuum energies account for all energy in the Universe that is not standing-wave Matter or its associated [K]EM wave

λ/2
V
volts
Longitudinal Waves
f
frequency
Transverse Waves
λ/72
λ/8
λ/98
λ18
λ/32
λ/50
λ/128

Radiated [K]EM energies that permeate the Universe
are comprised of photons of predominately longer wavelengths

**These radiated EM waves interact and superposition
over time to create a uniform vacuum energy density field
that is displaced by Matter topologies in turn creating Gravity**

Tetryonics 80.03 - Vacuum Energy Wavelengths

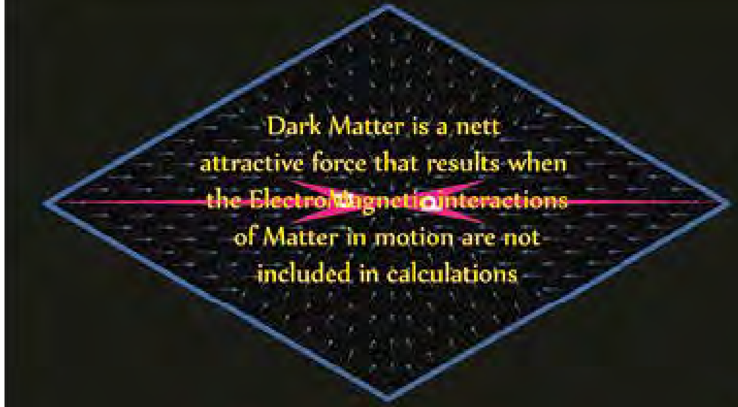

Dark Matter is a nett
attractive force that results when
the ElectroMagnetic interactions
of Matter in motion are not
included in calculations

In addition to Gravity the [K]EM waves
of all Matter in motion possess a
convergent component which in turn
creates a unidirectional 'force'

The convergent EM force component
can be modelled as being the result of
an 'invisible' form of Matter or
additional gravitational force

DARK MATTER

Convergent EM field vector momenta

All Matter emits
divergent EM radiation photons
comprised of bidirectional
vector momenta

Matter produces Gravity
EM waves are interactive

Dark Matter is matter that neither emits nor scatters light
or other electromagnetic radiation, and so cannot be
directly detected via optical or radio astronomy.

Gravity is the result of the
displacement of vacuum energies
by 3D Matter topologies

*All [K]EM radiation has
a convergent component in its
interactive field that increases
when Matter is in motion or
created in the form of EM
standing-wave topologies*

DARK MATTER

*As Matter is destroyed and energy is released
the attractive force of Gravity decreases
but the convergent acceleration
due to Dark Matter
increases*

Dark Matter

Dark matter is estimated to constitute
84% of the Matter in the universe and
23% of the total mass-energies

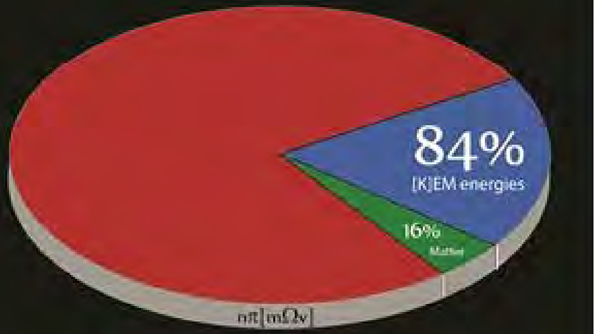

Dark Matter created by KEM field convergence
contributes to the total energies
of the cyclic Universe

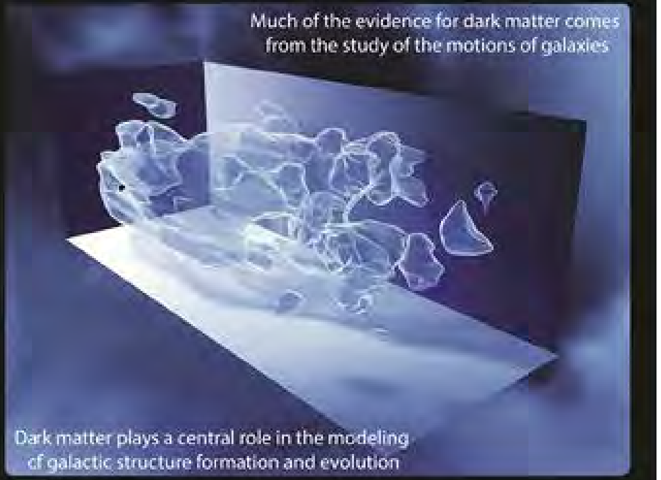

Much of the evidence for dark matter comes
from the study of the motions of galaxies

Dark matter plays a central role in the modeling
of galactic structure formation and evolution

Dark Matter's existence is inferred from its gravitational effects
on visible Matter and the convergent lensing of background radiation

Galaxy Rotations

In 1986, Nobel laureate Hannes Alfven
postulated at an electrical model
for the solar system

The rotation curve of a galaxy (also called a velocity curve)
can be represented by a graph that plots the orbital speed (in km/s) of the stars or gas
in the galaxy on the y-axis against the distance from the center of the galaxy on the x-axis

The dynamic modelling
of large scale Matter must take
into account all forces present

Based on Newtonian mechanics and assuming, as was originally thought, that most of the Matter of the galaxy had to be in the galactic bulge near the center, Matter (such as stars and gas) in the disk portion of a spiral should orbit the center of the galaxy similar to the way in which planets in the solar system orbit the sun, i.e. where the average orbital speed of an object any distance away from the majority of the Matter would decrease inversely with the square root of the radius of the orbit

G

Gravitational
Matter
is attractive

Newtonian gravity
models convergent
Gravity only

$$F = -G \frac{M_1}{r^2}$$

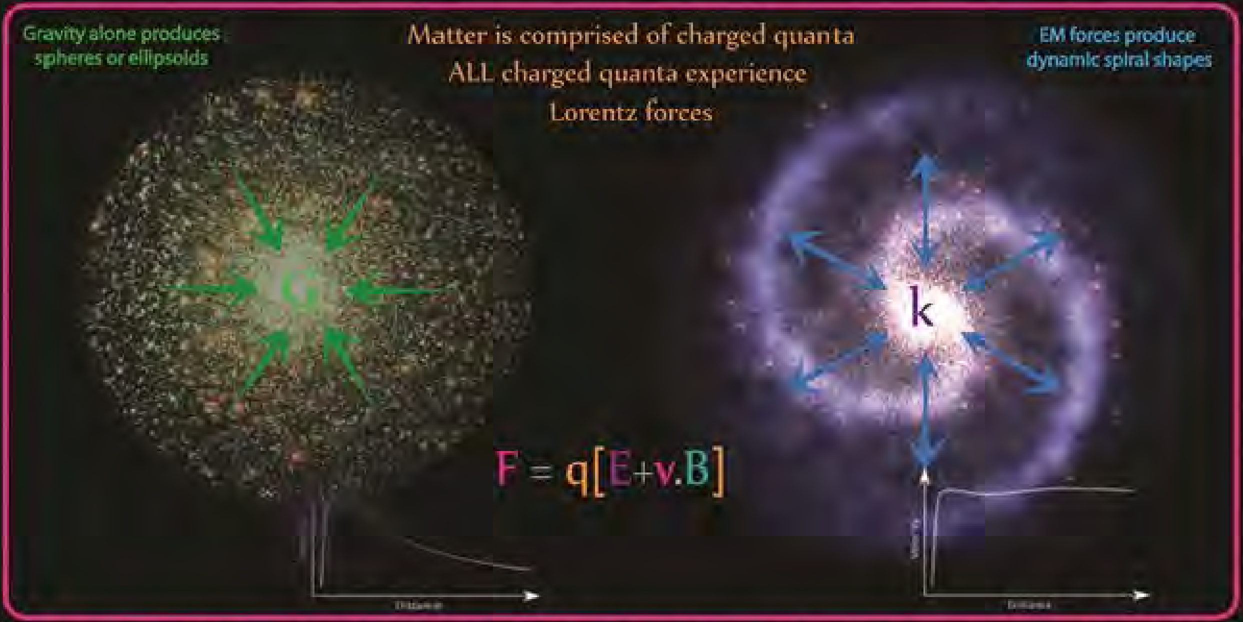

Gravity alone produces
spheres or ellipsoids

Matter is comprised of charged quanta
ALL charged quanta experience
Lorentz forces

EM forces produce
dynamic spiral shapes

$$F = q[E+v.B]$$

The curves of the rotational velocities of stars within Galaxies do not decrease in the expected inverse square root relationship but are "flat", i.e. outside of the central bulge their speed is nearly constant from the centre out ot the edge of the galaxy [identical to the forces produced by homopolar motors]

SR

ElectroMagnetic
mass-Energy
is interactive

General relativity
models interactive
GEM energies

$$F = k \frac{Q_1}{r^2}$$

*Tetryonics dictates that we must take into account EM forces as well as Gravity
in order to account for any perturbations that convergent Gravitation alone cannot account for*

Observations have shown there is not sufficient visible Matter in the Universe to account for the apparent strength of gravitational forces within and between galaxies leading to the hypothesis that up to 90% of the Matter in the Universe is

Dark Matter

Gravity alone does not hold the whole galaxy together
It is many orders of magnitude weaker than ElectroMagnetic forces

Gravitational attraction is the nett convergent force resulting from three distinct quantum forces

To account for the redshift-magnitude relation of type Ia supernovae General relativity requires that much of the energy in the Universe consists of a component with large negative pressure, this negative-gravity has been dubbed

Dark Energy

Dark Energy

Dark energy is a hypothetical form of energy that permeates all of space and tends to increase the rate of expansion of the universe.

EM mass-energies are conservative

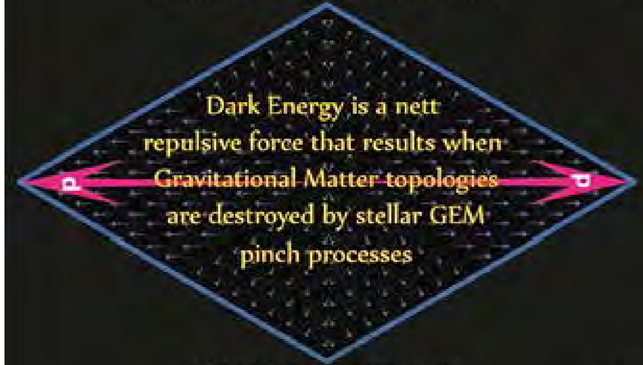
Dark Energy is a nett
repulsive force that results when
Gravitational Matter topologies
are destroyed by stellar GEM
pinch processes

Matter is not conservative

*All [K]EM radiation has
a divergent component in its
interactive field that increases
when Matter is in motion*

DARK ENERGY

*or its standing-wave topology
is destroyed*

*As Matter is destroyed and energy is released
the attractive force of Gravity decreases
and the divergent acceleration
due to Dark Energy
increases*

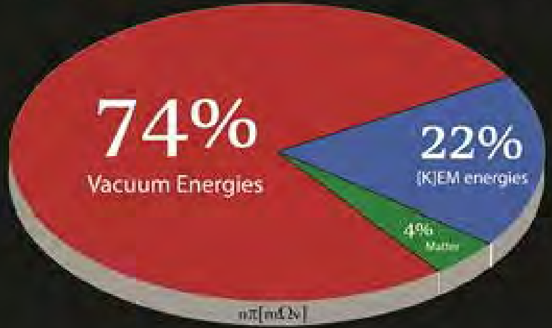

Independent from its actual nature, dark energy would need to have a strong negative pressure (repulsive force or divergent energy opposite that of gravitational attraction) in order to explain the observed acceleration in the expansion rate of the universe.

The [K]EM fields of Matter
are comprised of
DARK ENERGY
Divergent EM field interactions
KEM fields contributes to the total energies
of the cyclic Universe

Dark Energy is the divergent scalar field created by [K]EM field energies

2D [K]EM fields
create interactive forces
between Matter

The cosmological constant is physically equivalent to vacuum energy

DARK MATTER
Convergent EM field interactions

A major outstanding problem is that most quantum field theories predict a huge energy value for the quantum vacuum, more than 100 orders of magnitude too large.

This would need to be cancelled almost, but not exactly, by an equally large term of the opposite sign.

DARK ENERGY
Divergent EM field interactions

In fact a negative pressure does not influence the gravitational interaction between Matter [which remains attractive] but rather alters the overall evolution of the universe at the cosmological scale, typically resulting in the localised accelerating expansion of the universe despite the attraction between Matter present throughout the Universe.

Tetryonics 80.06 - Dark Energy

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Energy-momenta geometry

The super-positioned EM fields of free space is comprised of Planck energy momenta

A major outstanding problem is that most quantum field theories predict a huge cosmological constant from the energy of the quantum vacuum, more than 100 orders of magnitude too large.

If the Higgs field does exist, another field with an unknown negative energy is needed to reduce the total energy in the vacuum to a slightly positive value to correspond with the current accelerated rate of expansion

Summing over all possible Energy quanta at all points in space gives a large but NOT infinite quantity of energy-momenta

Due to the equilateral asymmetry of all the energy momenta quanta in charged electromagnetic fields

Dark Energy is Divergent Vacuum Energy momenta in free Space

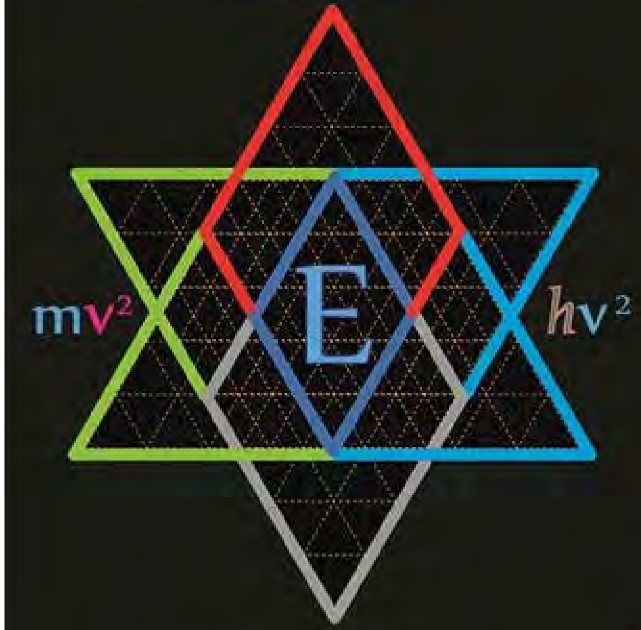

Convergent Vacuum Energy momenta in free Space is Dark Matter

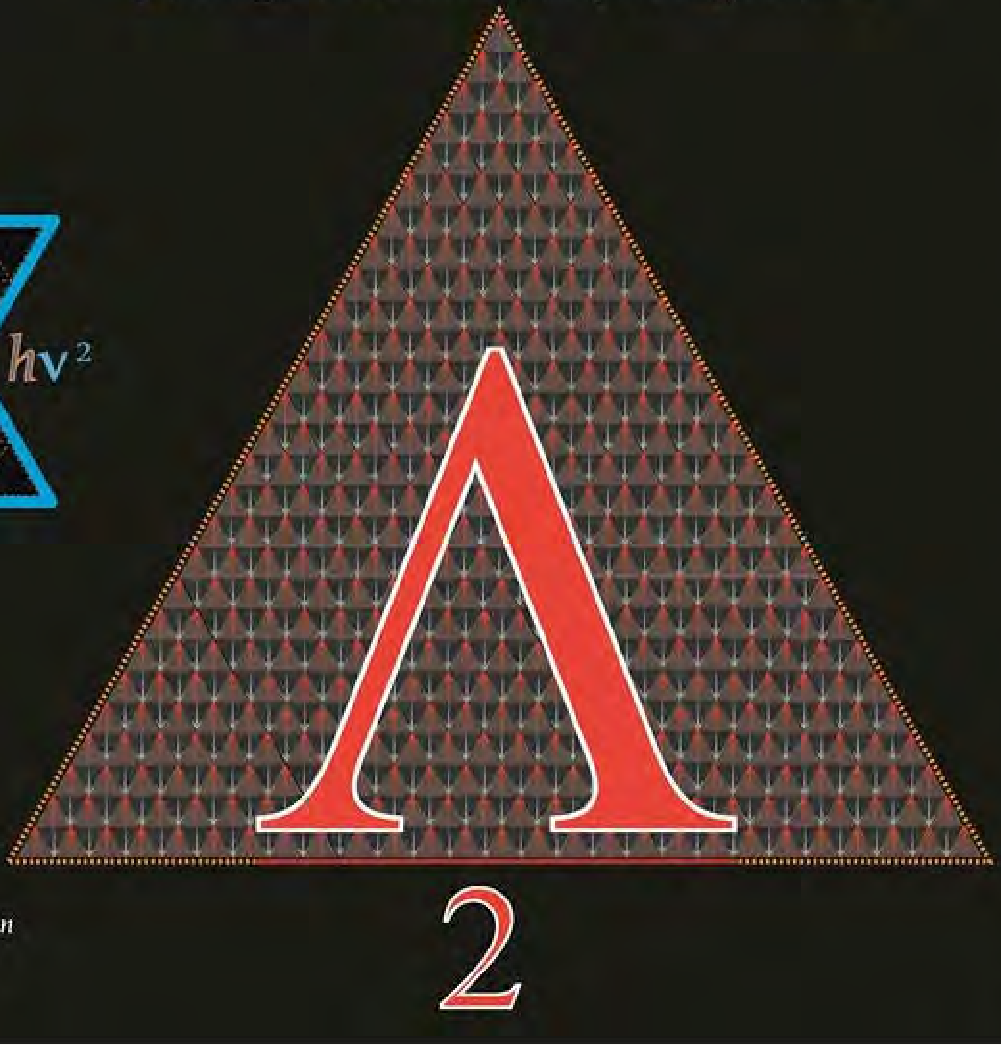

E Field Coulombic forces

convergent momenta ↓

divergent momenta ↑

Vacuum charge momentum

1	1		1
2	3		0.666667
3	5		0.6
4	7		0.571429
5	9		0.555556
6	11		0.545455
7	13		0.538462
8	15		0.533333
9	17		0.529412
10	19		0.526316
11	21		0.52381
12	23		0.521739
13	25		0.52
14	27		0.518519
15	29		0.517241
16	31		0.516129
17	33		0.515152
18	35		0.514286
19	37		0.513514
20	39		0.512821
21	41		0.512195
22	43		0.511628
23	45		0.511111
24	47		0.510638
25	49		0.510204
26	51		0.509804
27	53		0.509434
28	55		0.509091
29	57		0.508772
30	59		0.508475

The total Vacuum Energy in any spatial region contains fields of Planck energy-momenta seeking an equalised, homgenous state

Divergent energy momenta always dominates over Convergent energy momenta

Tetryonics 80.07 - Vacuum Energy-momenta

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Charged electrostatic fields

E Field Coulombic forces

convergent momenta **divergent momenta**

Charge interaction

DIVERGENT CHARGE FIELDS
are external Energy momenta

momenta

CONVERGENT CHARGE FIELDS
are internal Energy momenta

Energy-momenta forces

Forward velocity **downward Thrust**

Momenta acceleration

1	1		1
2	3		0.666667
3	5		0.6
4	7		0.571429
5	9		0.555556
6	11		0.545455
7	13		0.538462
8	15		0.533333
9	17		0.529412
10	19		0.526316
11	21		0.52381
12	23		0.521739
13	25		0.52
14	27		0.518519
15	29		0.517241
16	31		0.516129
17	33		0.515152
18	35		0.514286
19	37		0.513514
20	39		0.512821
21	41		0.512195
22	43		0.511628
23	45		0.511111
24	47		0.510638
25	49		0.510204
26	51		0.509804
27	53		0.509434
28	55		0.509091
29	57		0.508772
30	59		0.508475

Electrostatic fields can provide a source of thrust

The greater the EM charge field strength the greater the divergent force

a source of cost effective space launches

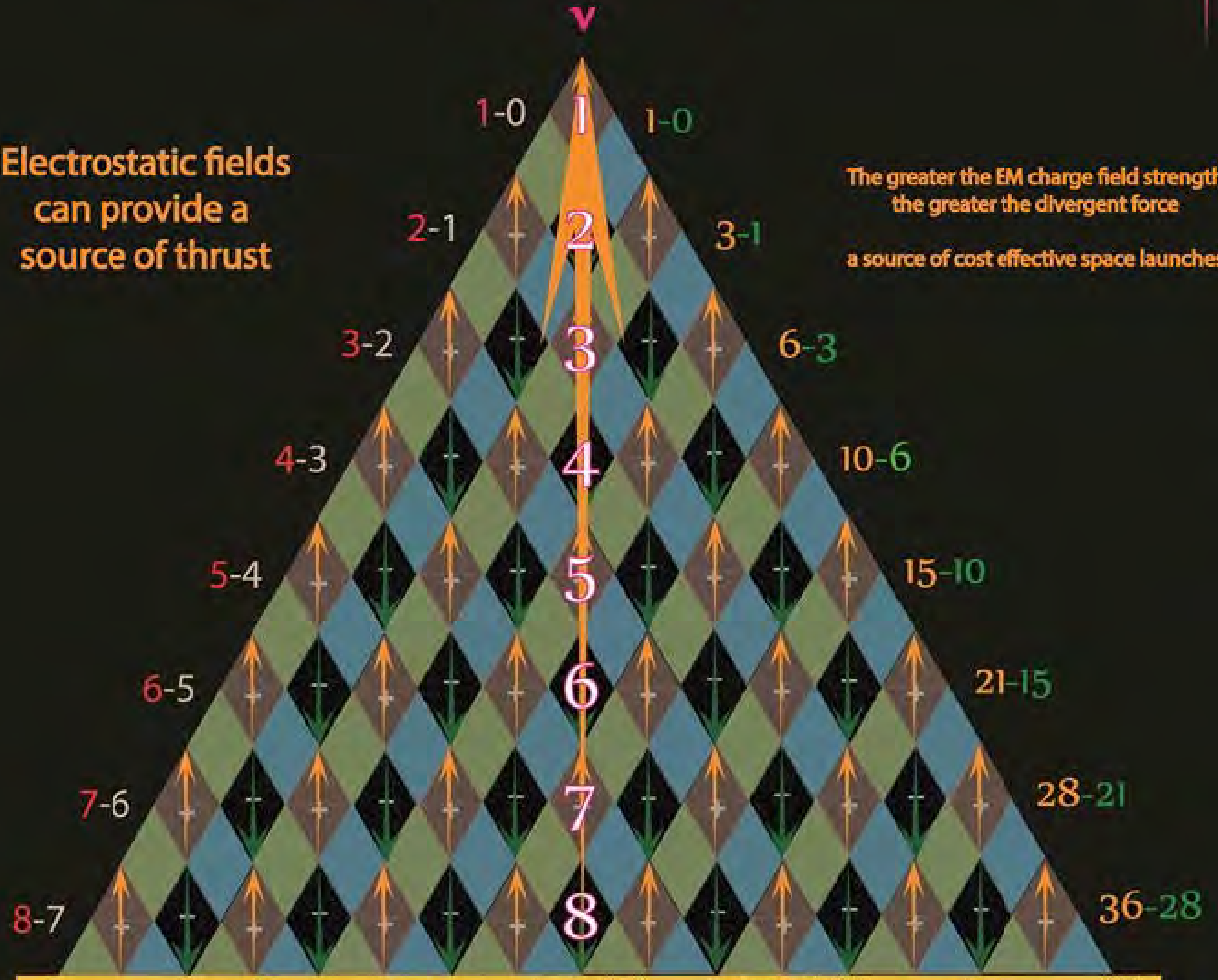

1 0
3 .25
2 .333
1,666 .375
1.5 .4
1.4 .4166
1.333 .4375
1,2857 .4375

7/15

#		Pos	Neg		Charge		Pos %	Neg %		Pos Split	Neg Split		Power		SQRT
1000		1000	999		1		0.50025	0.49975		500500	499500		1000000		1000

Launch Pad

Momentum splits are reversed for Negative charges

Electric Charge divergence is always superior to Charge convergence

Momentum trends to 50/50 split (but never reaches it)

Launch Pad

Tetryonics 80.08 - Electro-Gravitic Charge lauches

Electrostatic lifters

Electrostatic levitation is the process of using an electric field to levitate a charged object and counteract the effects of gravity

Tetryonic geometries and Coulombic forces offers an alternative means of propulsion for space lauches and frictionless transports

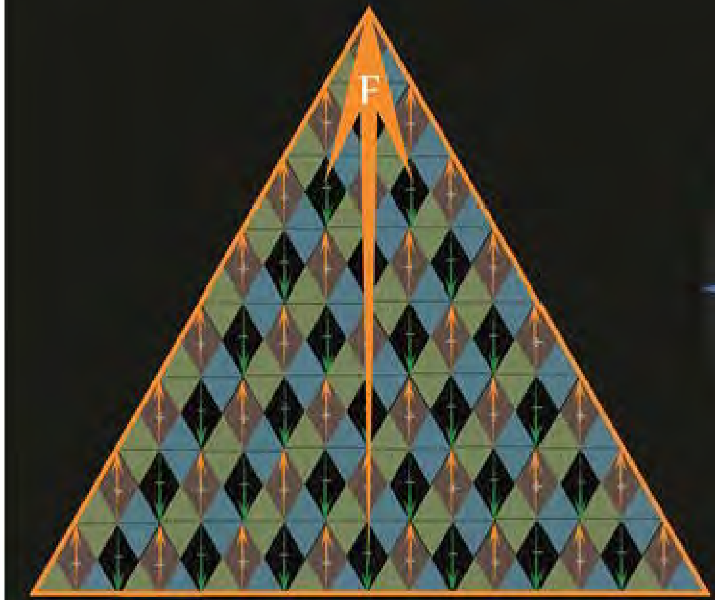

Charged voltage fields contain nett divergent energy momenta [Planck quanta] that can do work over distances

Electrostatic charges are always divergent from their sources

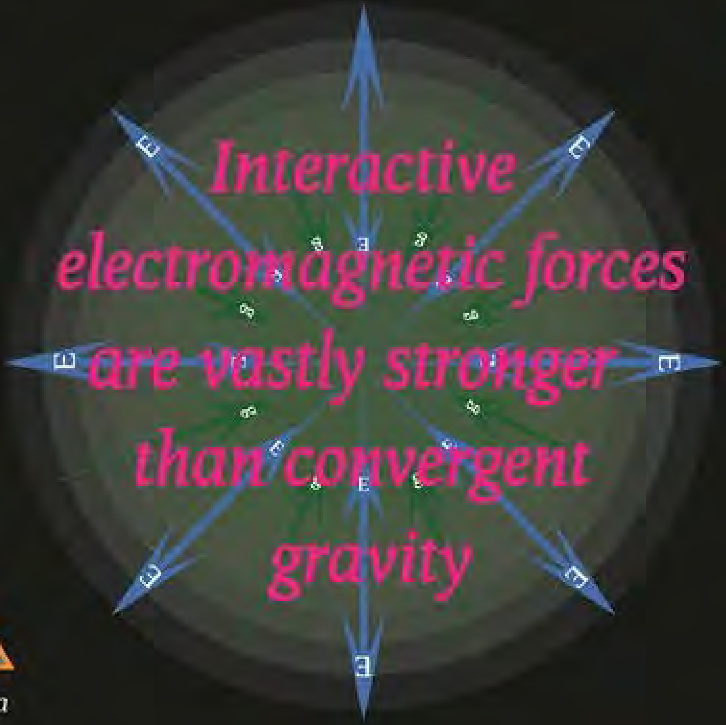

Interactive electromagnetic forces are vastly stronger than convergent gravity

Static electricity is the result of electrostatic charges

Electrostatic charges are comprised of divergent energy momenta

Electrostatic levitation

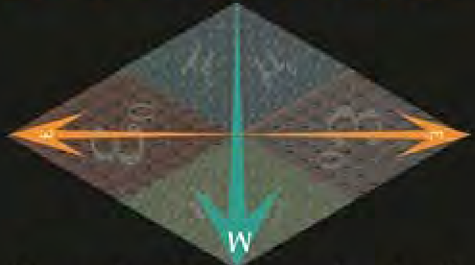

forces should not be confused with

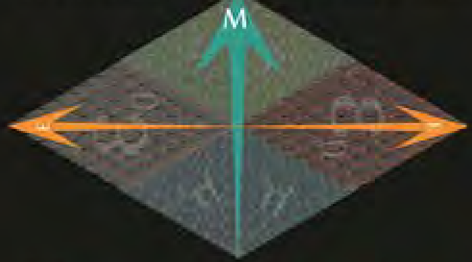

Magnetic levitation

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The Light speed barrier

BOSONS/PHOTONS
2D Planar massless particles
[EM mass-Energies]
'slice' throught the
vacuum energy aether

**The 'speed of Light'
is the limiting speed of
transverse EM accelerations
[it is not THE limit]**

TETRYONS/BARYONS
3D Tetrahedral EM Matter
[4nπ EM mass-Energies]
interact at various angles with the
vacuum energy aether

$$E = Mv^2$$

CHARGED
particle or massive body

REST MATTER
remains invariant
(but accelerates)

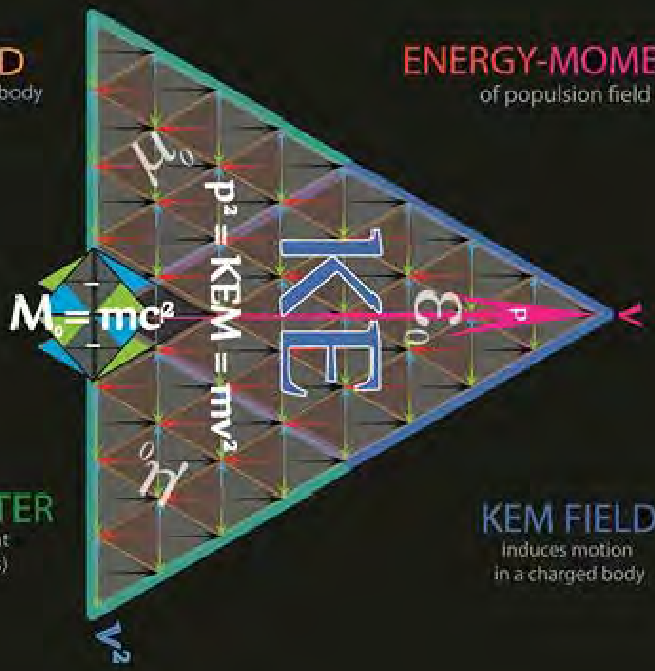

ENERGY-MOMENTA
of populsion field

KEM FIELD
induces motion
in a charged body

**The Compton frequency of quanta
in any EM field is directly proportional
to the field's velocity of propagation**

$$KE = \frac{1}{2}Mv^2$$

MOTION VECTOR
direction of propulsion
of a charged body

**Tetryonic geometry clearly shows that here is NO limit to the
energy content that can be released into any spatial region,
negating the long held belief of a Light speed barrier**

V

According to special relativity, c is the maximum speed at which all EM mass-Energy and information in the universe can travel.
It is predicted by General relativity to be the absolute velocity of all 'massless particles' and associated fields
- Including ElectroMagnetic radiation such as Light in a vacuum.

Such particles and waves travel at c regardless of the motion of the source or the inertial frame of reference of the observer.
In the theory of relativity, c interrelates space and time, and appears in the famous equation of mass–energy equivalence E = mc2.

C

The speed at which light waves propagate in vacuum
is independent both of the motion of the wave source
and of the inertial frame of reference of the observer

$$E = n\pi\left[\left[\overset{\text{Planck quanta}}{\underset{\text{mass}}{m}\Omega\underset{\text{velocity}}{v^2}}\right]\right]$$

The speed of light in vacuum, usually denoted by c,
is a physical constant important in many areas of physics
and is determined by the impedance of the medium

Tetryonics 80.10 - The Light Speed Barrier

Inflation

While the detailed particle physics mechanisms responsible for inflation are not known, the basic picture makes a number of predictions that have been confirmed by observation.

Inflation is thus now considered part of the standard hot Big Bang cosmology

$$\underset{\text{momentum}}{\overset{\text{ENERGY}}{n\pi}}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v}\right]^2\right]$$

v
p
KE
c
hv
v²
Γ
c²

All mass-energy propagates
at a velocity directly related to
the impedance of the medium

Tetryonics now provides a detailed physical model of ALL ponderable Matter and its kinetics through the charged geometry of mass-ENERGY-Matter

The energy in any spatial region
possesses a related mass-velocity
[linear momentum] component

The observable Universe could have originated from a region of pure energy in it's past.

This point would have contained all the Energy that ultimately formed all the mass-Matter of the Universe and Forces that we now observe and measure in two 2D planar fields

GIVEN SUFFICIENT ENERGIES ANY REGION OF SPACE-TIME
WILL UNDERGO SUPERLUMINAL EXPANSION [INFLATION]

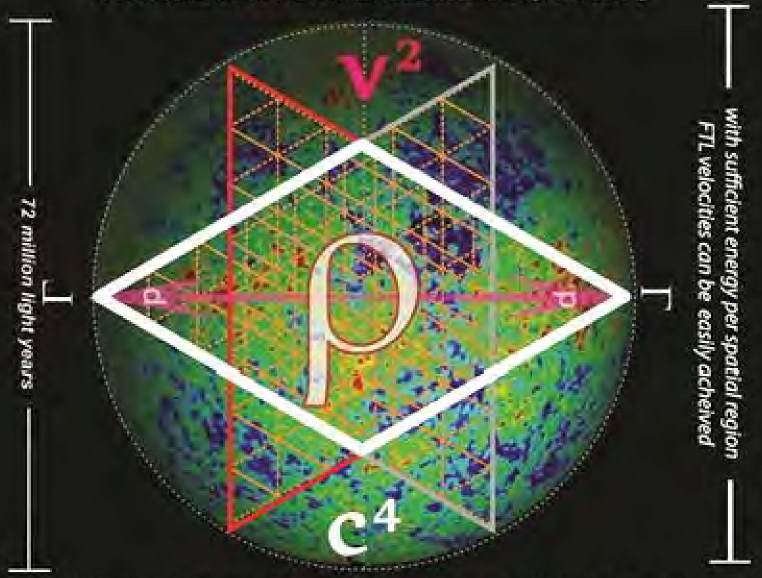
v²
ρ
p
p
c⁴
72 million light years
with sufficient energy per spatial region
FTL velocities can be easily achieved

UNTIL IT REACHES A CRITICAL ENERGY DENSITY THAT RESULTS IN
THE OSBERVED SPEED OF LIGHT THAT WE NOW MEASURE

"And God said,
Let there be light:
and there was light"

The planar EM Energies released at that point would have resulted in faster-than-light divergence from that point as dictated by the geometric energy-momenta velocity relationship

$$\frac{\overset{\text{mass}}{n\pi}}{c^2}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v}^2\right]\right]$$

It prescribes a dynamical EM Universe evolving over time
into a state of equilibrium between gravitational mass-Matter topologies
and radiant, interactive mass-energy momenta geometries

$$\frac{\overset{\text{Matter}}{T\pi}}{c^4}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v}^2\right]\right]$$

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Superluminal velocities

REQUIRED VELOCITY

$$\beta = \left[\frac{v}{c}\right]$$

Linear correction factor

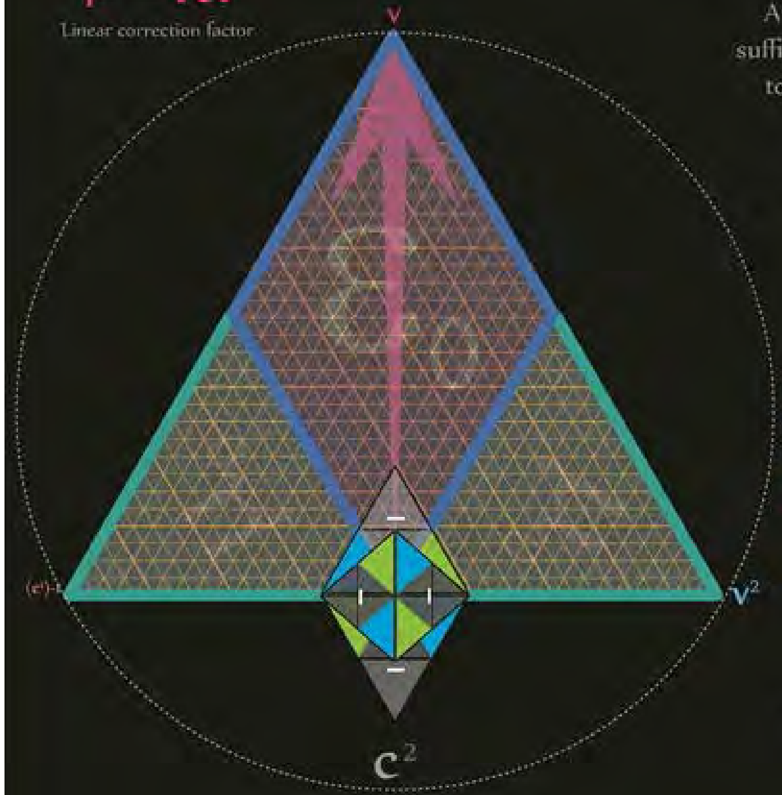

Any velocity is obtainable by Matter providing sufficient energy is released in very short durations to a region of space containing a charged body

$$\Sigma F = \frac{\Delta p}{dt} = m.\frac{dv}{dt}$$

W bosons

$[hv]-$

decelerate

E

W bosons

$+[hv]$

accelerate

Every quantum energy level change requires a related change in the number of quanta compared to the previous energy level (ad infinitum)

Note: Inertial considerations still apply
Instanteous release of energy to acheive superluminal velocities is not advised

The speed of light is a limiting velocity for accelerations due to transverse wave electromagnetic energies

Providing the KEM geometry contains enough energy per c^2 geometry the long held belief of 'the speed of light' being an ultimate speed barrier is shown to be invalid

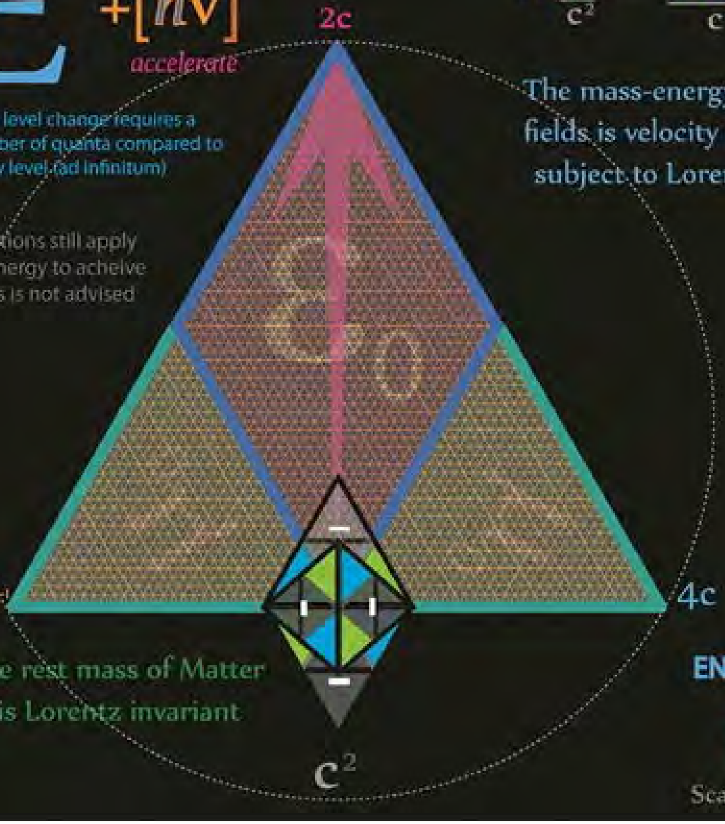

The rest mass of Matter is Lorentz invariant

KEM fields contain energy-momenta

$$p^2 = KEM = mv^2$$

Any mass-energy field moving at superluminal velocities is still subject to Lorentz contractions

Any Matter held within, and moving along with, a superluminal EM field remains Lorentz invariant

$$\frac{mv^2}{c^2} = \frac{KEM}{c^2} = \frac{hv^2}{c^2}$$

The mass-energy of Kinetic EM fields is velocity dependent and subject to Lorentz corrections

ENERGY REQUIRED

$$\beta^2 = \left[\frac{v^2}{c^2}\right]$$

Scalar correction factor

Faster than Light Travel

It has been well established by Tetryonic geometry that the speed of light 'c' is not a insurmountable barrier as long expounded by Relativity theory

The natural speed of Light is easily surpassed given the right technologies (and sources of energy)

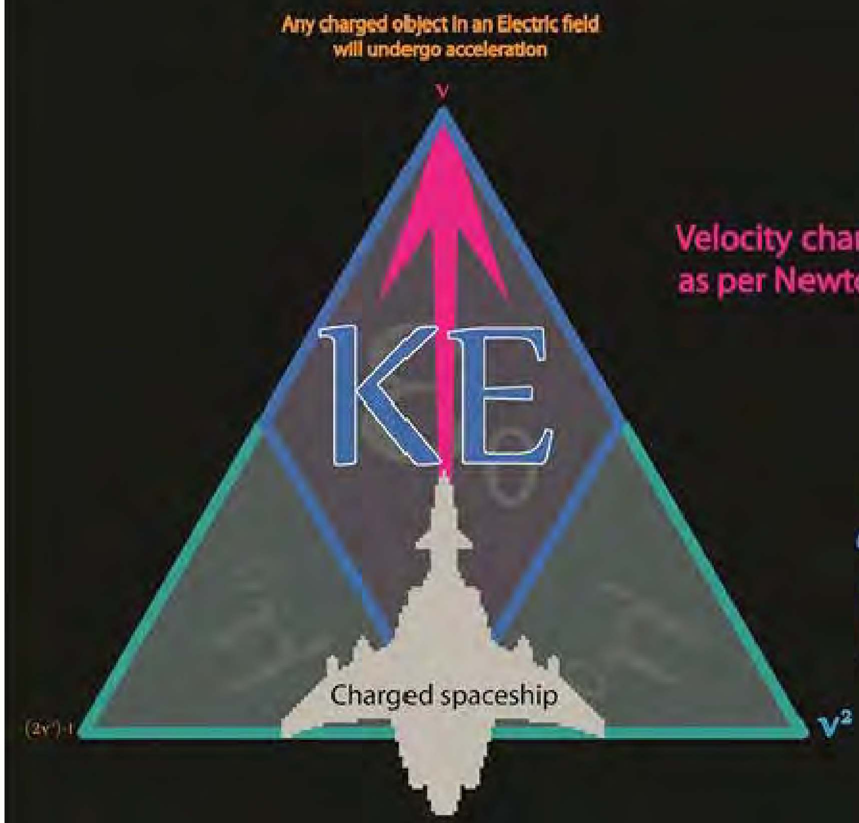
Any charged object in an Electric field will undergo acceleration
v
KE
Charged spaceship
$(2v^2)$-1
v^2

Velocity changes are additive as per Newtonian mechanics

The energy requirements to accelerate Matter to increasing velocities are exponental and follow equilateral geometries

As the Spaceship's Velocity increases the wavelength of Kinetic Energies decreases and the Compton Frequency increases

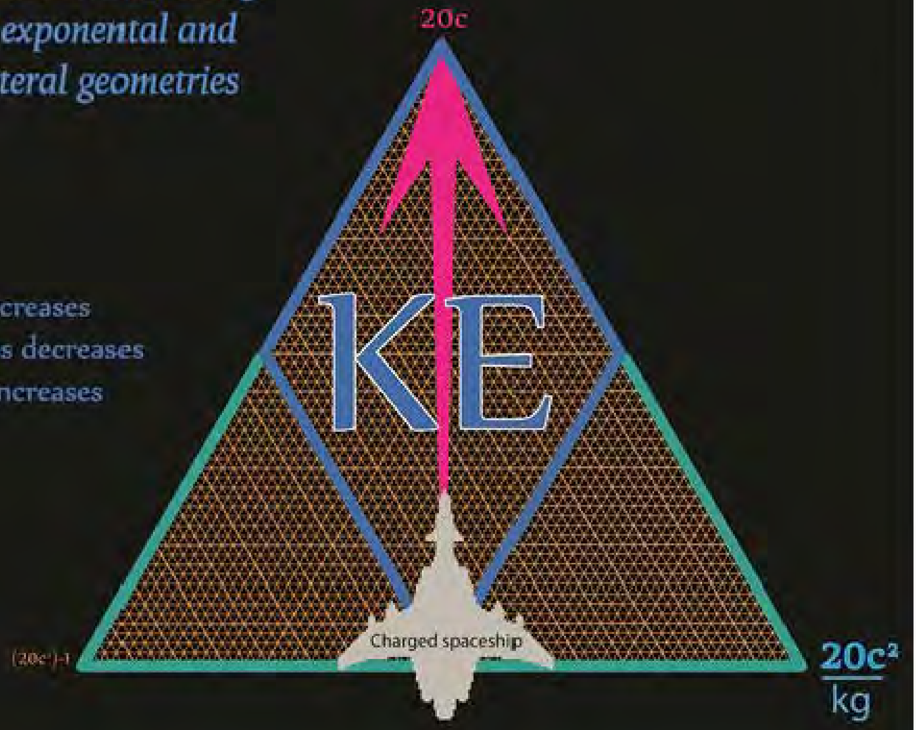
20c
KE
Charged spaceship
$(20c^2)$-1
$\frac{20c^2}{kg}$

Warp Speed Scotty

Proposed explanation for GAMMA RAY BURSTS (GRB)

Any massive body using KEM fields as a motive force for faster-than-Light travel would produce an extremely bright release of Gamma rays at their point of acceleration (as only 1/2 of the photonic energy would be used to accelerate the craft in any one direction). additionally anybody noticing the burst of required Energy would not find a 'source' for the Gamma ray burst when they looked as the craft would have accelerated away from that point in free space

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The finely tuned Universe

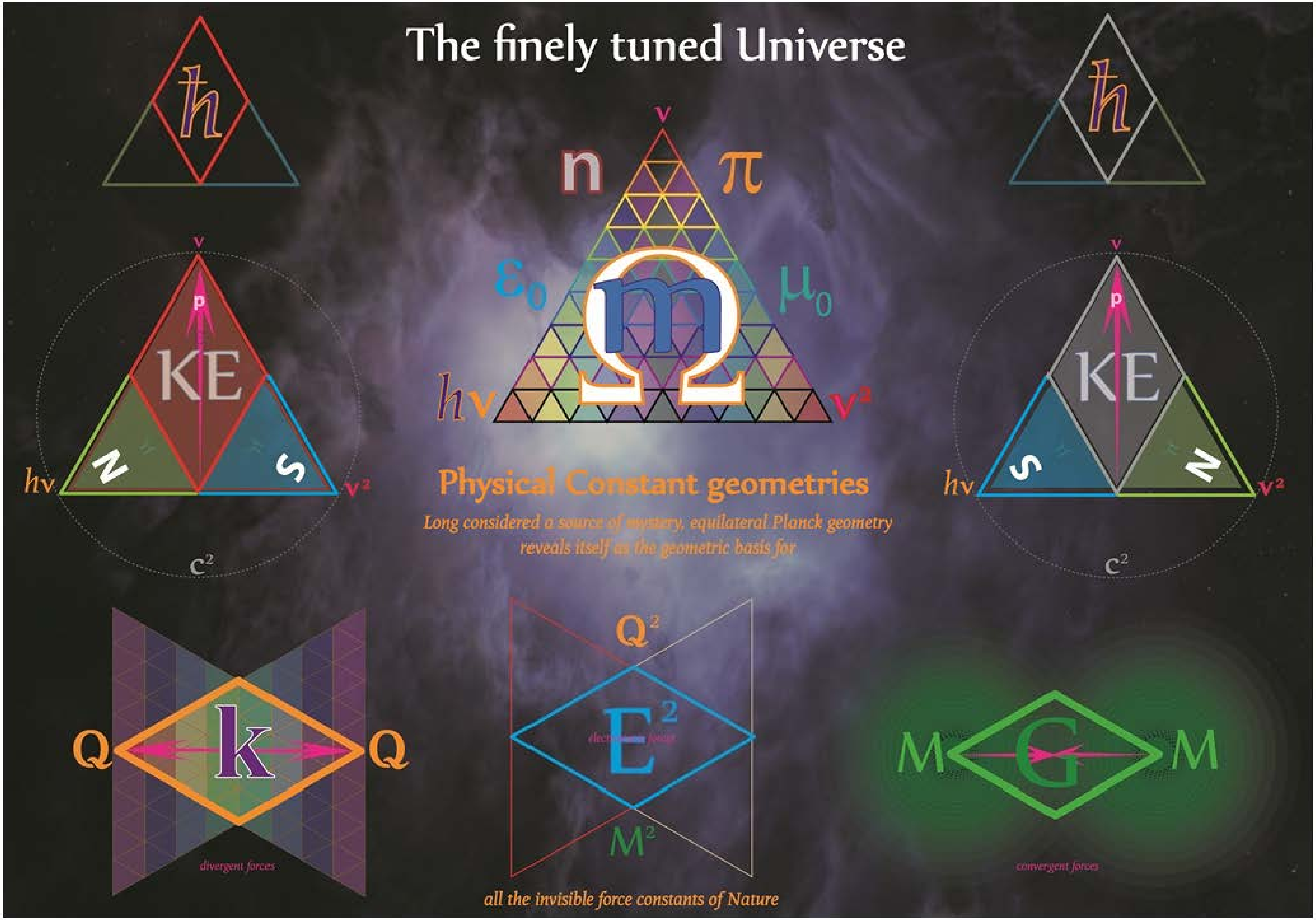
ħ
v
n
π
ε₀
m
Ω
μ₀
hv
v²
p
KE
N
S
hv
v²
c²
ħ
v
p
KE
S
N
hv
v²
c²
Q
k
Q
divergent forces
Q²
E²
M²
M
G
M
convergent forces

Physical Constant geometries

Long considered a source of mystery, equilateral Planck geometry reveals itself as the geometric basis for

all the invisible force constants of Nature

Conservation symmetry

A conservation law states that some quantity X
(describing any physical system)
remains constant throughout its motion

$$\frac{\Delta x}{dt} = 0$$

Rotation symmetry gives
conservation of angular momentum

conservation of
angular momenta

$$\left[\frac{\Omega}{c^2}\right]$$

QAM / second

conservation of
linear momentum

Noether's Symmetry

The action of a physical system
is the integral over time
of a Lagrangian function

The invariance of physical systems
with respect to spatial translation
(the laws of physics do not
vary with locations in space)

Amalie Emmy Noether

(23 March 1882 – 14 April 1935)

Time translation symmetry
gives conservation of energy

conservation of
energy

v
ε_0
E
μ_0
μ_0
v^2

6.629432672 e-34 J
Planck quanta

$$\left[m\Omega v^2\right]$$

mass velocity
7.376238634 e-51 kg

mass-ENERGY quanta

conservation of
mass

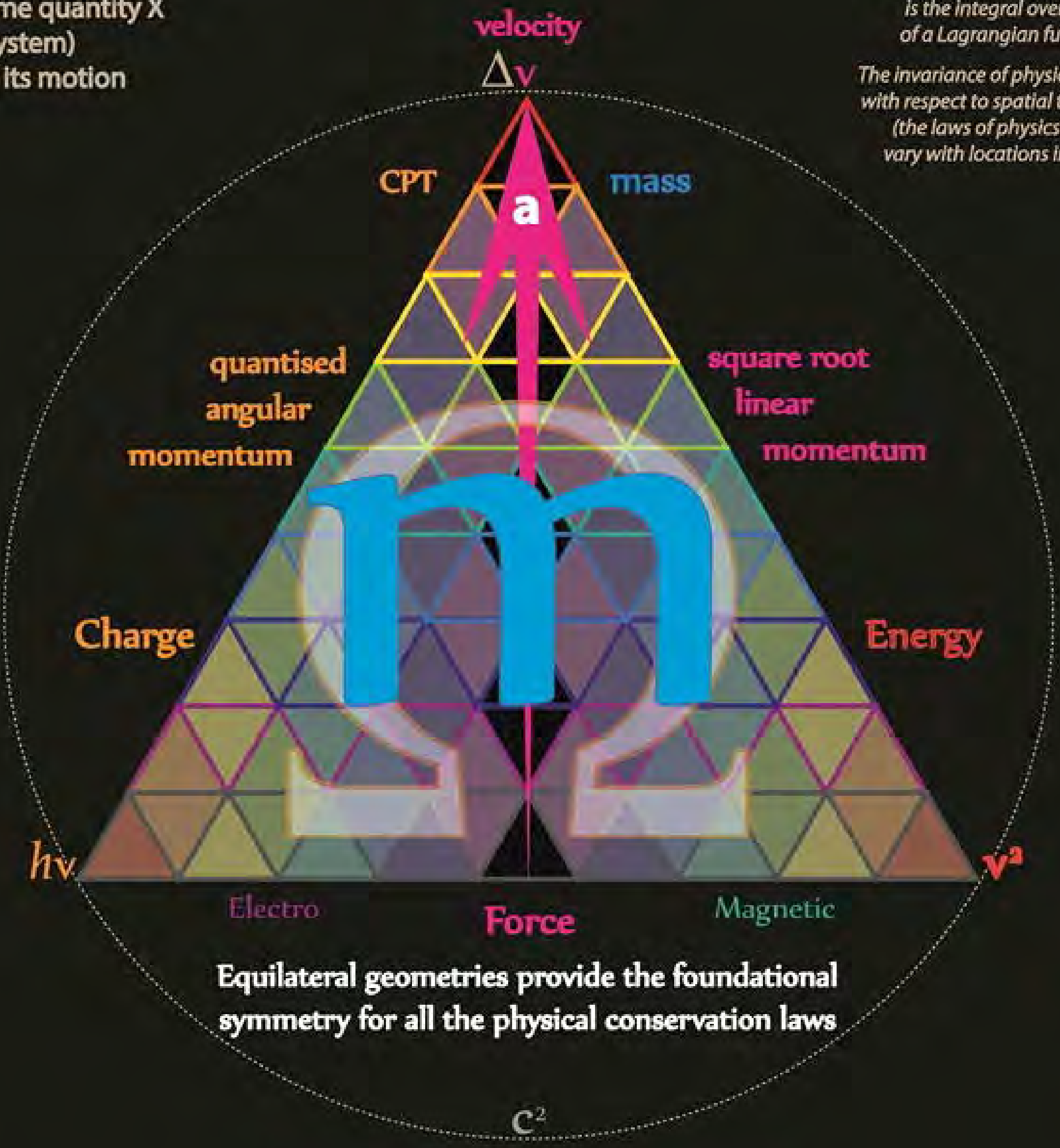
velocity
Δv
CPT
mass
a
quantised
angular
momentum
square root
linear
momentum
m
Ω
Charge
Energy
hv
v^2
Electro
Force
Magnetic
c^2

Equilateral geometries provide the foundational symmetry for all the physical conservation laws

Matter topologies are not conservative

Tetryonics 80.15 - Conservation symmetry

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Virtual Particles

In physics, a virtual particle is a particle that exists for a limited time and space.
The energy and momentum of a virtual particle are uncertain according to the uncertainty principle.
The degree of uncertainty of each is inversely proportional to
time duration (for energy) or to position span (for momentum).

In Tetryonics the Uncertainty principle has been negated with deterministic, re-normalisable charged mass-ENERGY geometries & Matter topologies

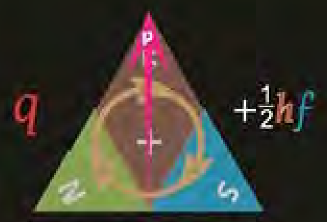
q
$+\frac{1}{2}hf$
P
+
N
S

Positive Zero Point Field
energy momenta

Longitudinal waves facilitate
action-at-a-distance

Convergent Gravitation
is attractive

Material Gravitation

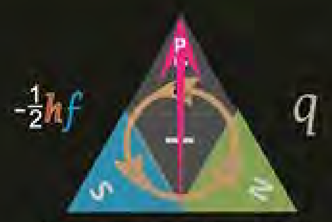
$-\frac{1}{2}hf$
q
P
-
S
N

Negative Zero Point Field
energy momenta

Energy propagates at the
speed of light

Divergent Coulomb forces
are interactive

EM Interactions

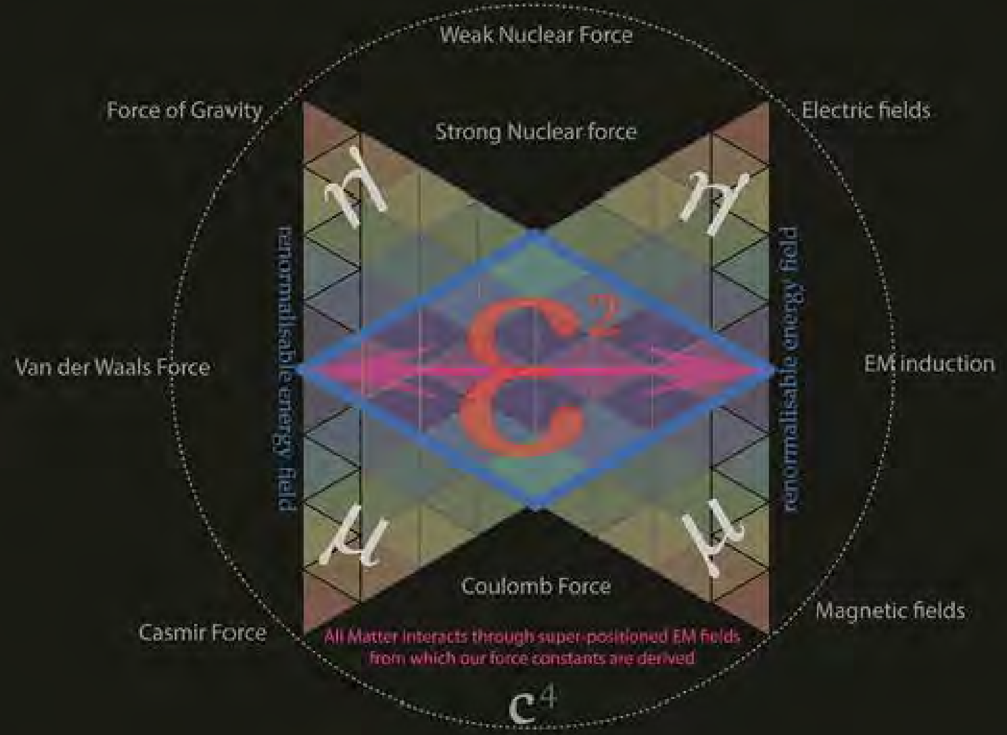
Weak Nuclear Force
Force of Gravity
Electric fields
Strong Nuclear force
η
η
renormalisable energy field
renormalisable energy field
Van der Waals Force
EM induction
ε²
μ
μ
Coulomb Force
Casmir Force
Magnetic fields
c⁴

All Matter interacts through super-positioned EM fields
from which our force constants are derived

M

Charged Matter topologies
in vacuum energy fields
create Gravity

Vacuum field Energies

$$m^2c^4 = E^2 = p^2c^2$$

EM mass   momenta

m

Superpositioned EM fields
create interactive
EM forces

virtual Particles are not a required part of tetryonic theory

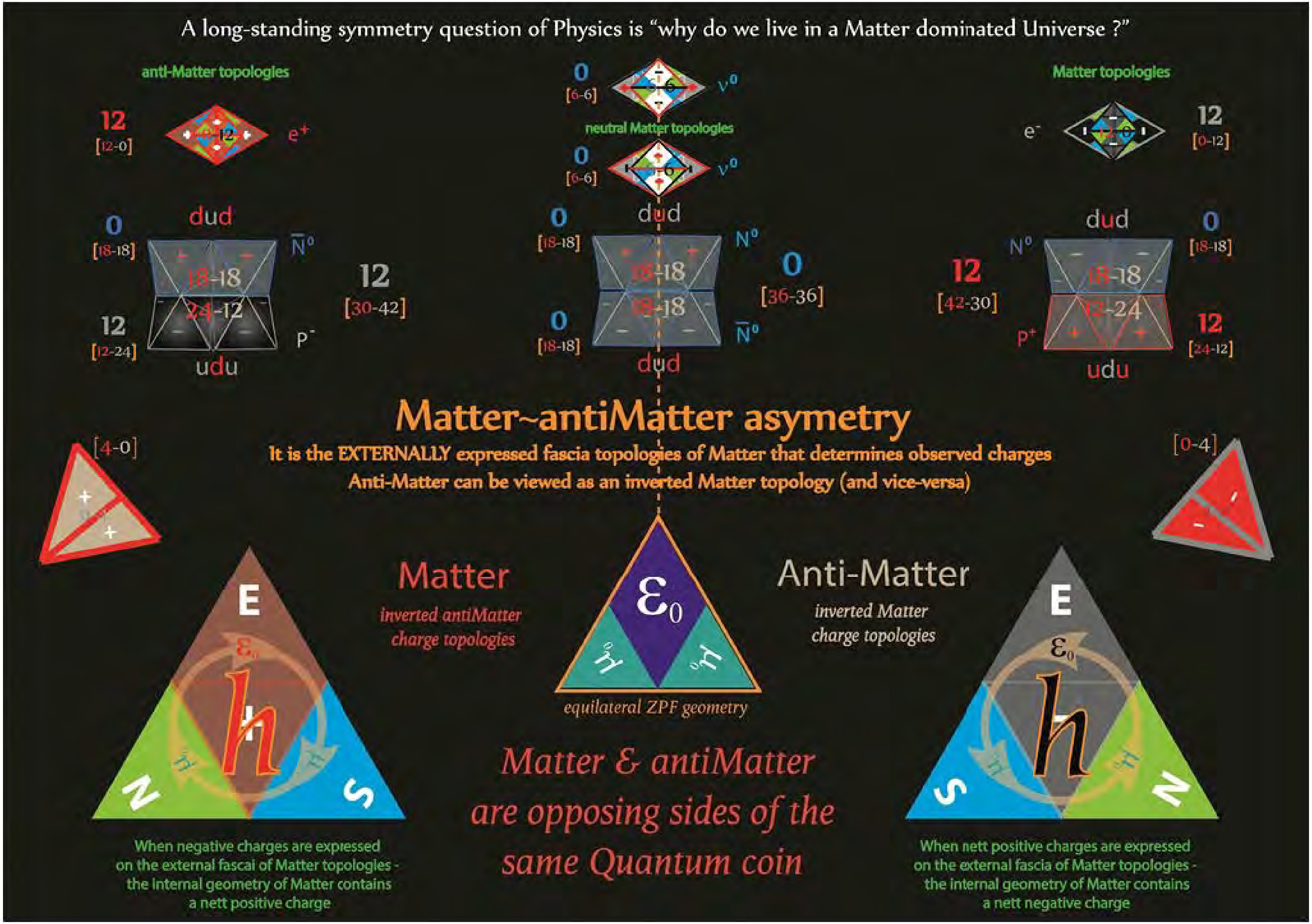
anti-Matter topologies
12
[12-0]
e^+
0
[6-6]
ν^0
neutral Matter topologies
0
[6-6]
ν^0
Matter topologies
e^-
12
[0-12]
0
[18-18]
dud
$\bar{N}^0$
18-18
24-12
12
[12-24]
P^-
udu
12
[30-42]
0
[18-18]
dud
N^0
18-18
18-18
0
[18-18]
$\bar{N}^0$
dud
0
[36-36]
12
[42-30]
N^0
dud
18-18
12-24
0
[18-18]
P^+
udu
12
[24-12]
[4-0]
[0-4]
E
ε_0
h
N
S
ε_0
μ_0
μ_0
E
ε_0
h
S
N

A long-standing symmetry question of Physics is “why do we live in a Matter dominated Universe ?”

Matter~antiMatter asymetry

It is the EXTERNALLY expressed fascia topologies of Matter that determines observed charges

Anti-Matter can be viewed as an inverted Matter topology (and vice-versa)

Matter

inverted antiMatter charge topologies

Anti-Matter

inverted Matter charge topologies

equilateral ZPF geometry

Matter & antiMatter are opposing sides of the same Quantum coin

When negative charges are expressed on the external fascai of Matter topologies - the internal geometry of Matter contains a nett positive charge

When nett positive charges are expressed on the external fascia of Matter topologies - the internal geometry of Matter contains a nett negative charge

Tetryonics 80.17 - Charged fascia chirality

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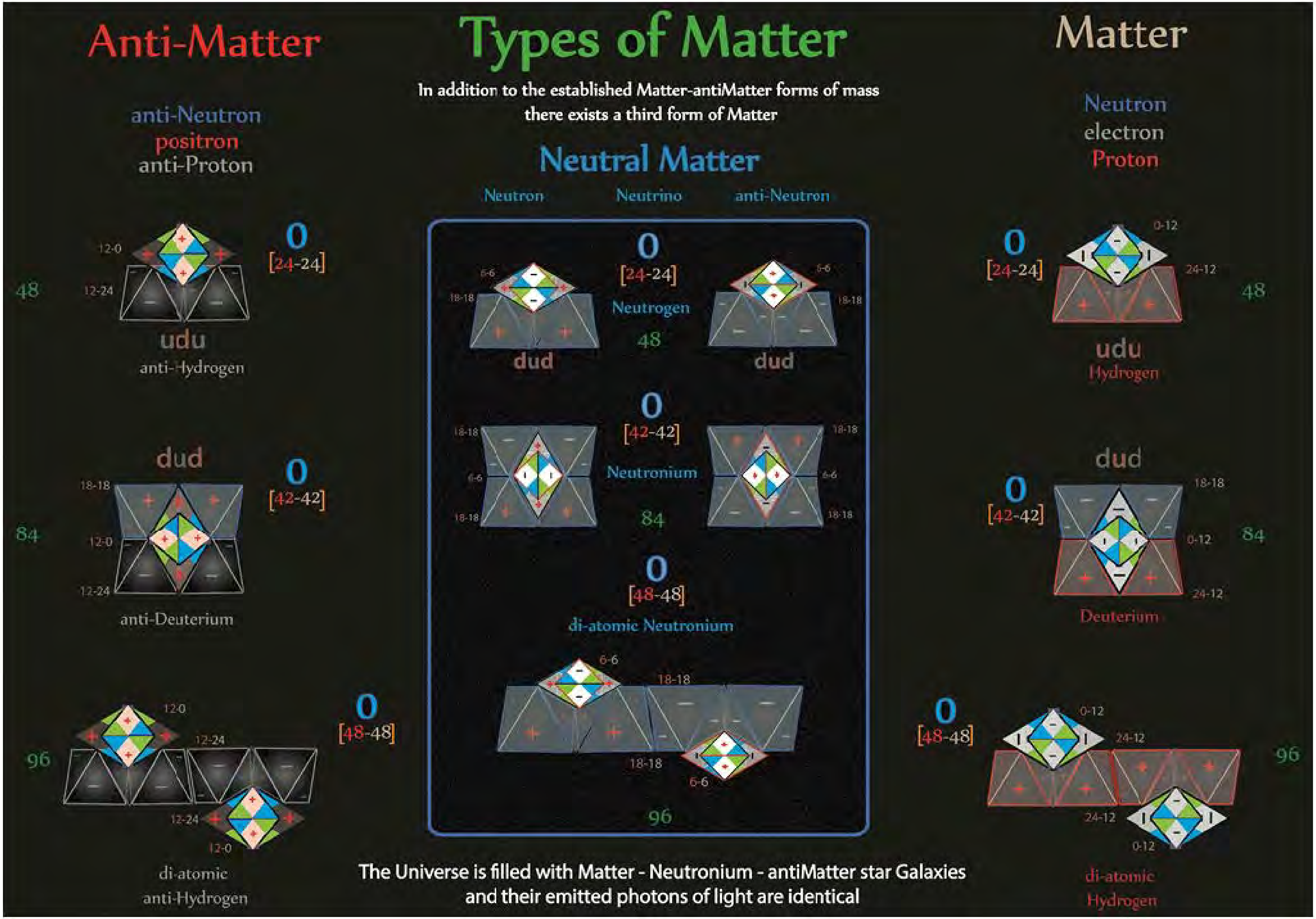

Types of Matter

In addition to the established Matter-antiMatter forms of mass
there exists a third form of Matter

Neutral Matter

Anti-Matter
anti-Neutron
positron
anti-Proton
Matter
Neutron
electron
Proton
Neutron
Neutrino
anti-Neutron
12-0
12-24
48
0
[24-24]
udu
anti-Hydrogen
dud
18-18
12-0
12-24
84
0
[42-42]
anti-Deuterium
12-0
12-24
96
12-24
12-0
0
[48-48]
di-atomic
anti-Hydrogen
0
[24-24]
6-6
18-18
Neutrogen
48
dud
dud
0
[42-42]
18-18
6-6
18-18
Neutronium
84
0
[48-48]
di-atomic Neutronium
6-6
18-18
18-18
6-6
96
0
[24-24]
0-12
24-12
48
udu
Hydrogen
dud
0
[42-42]
18-18
0-12
24-12
84
Deuterium
0
[48-48]
0-12
24-12
24-12
0-12
96
di-atomic
Hydrogen

The Universe is filled with Matter - Neutronium - antiMatter star Galaxies
and their emitted photons of light are identical

Tetryonics 80.18 - Types of Matter

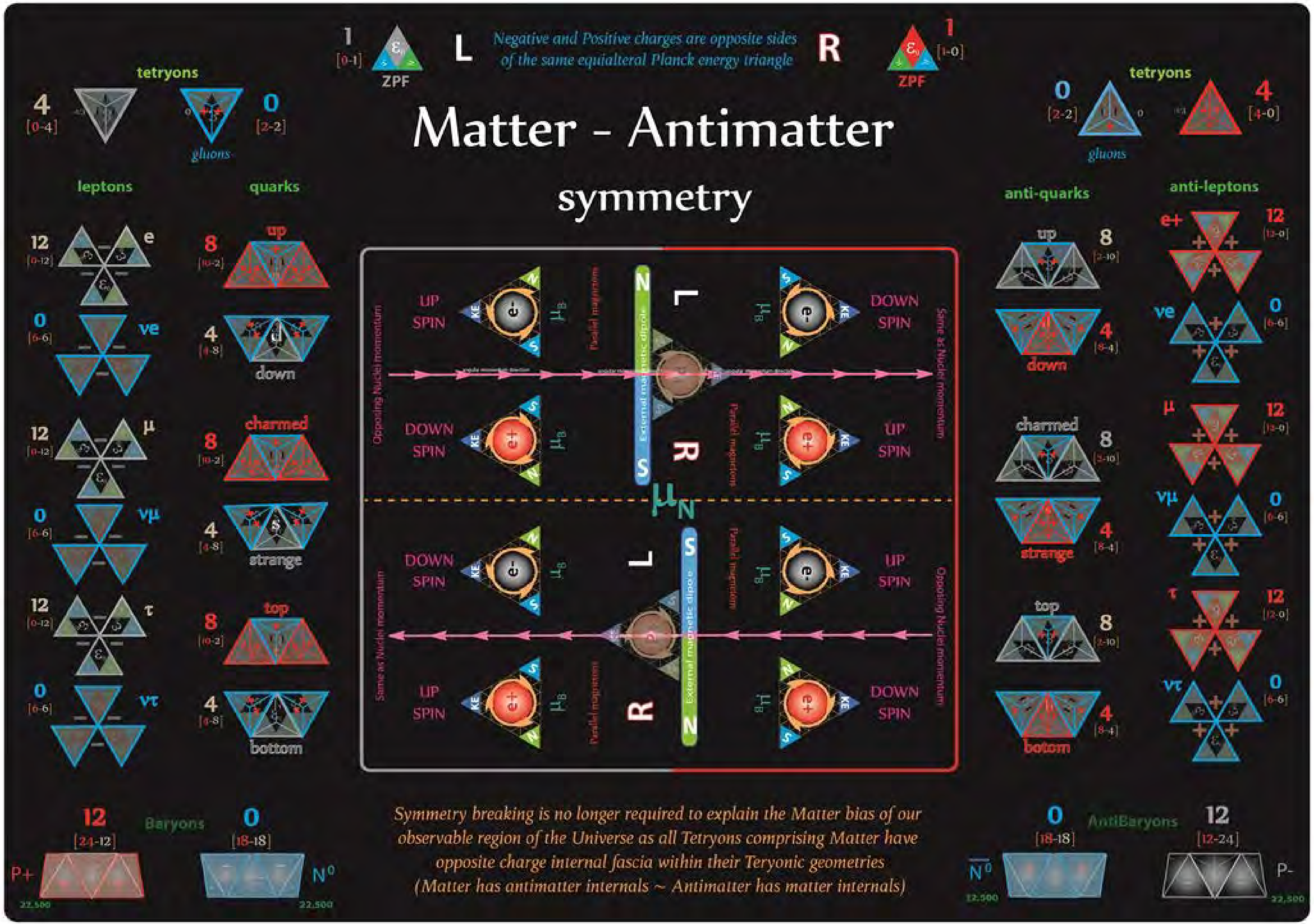

Matter - Antimatter

symmetry

Negative and Positive charges are opposite sides of the same equialteral Planck energy triangle

Symmetry breaking is no longer required to explain the Matter bias of our observable region of the Universe as all Tetryons comprising Matter have opposite charge internal fascia within their Teryonic geometries (Matter has antimatter internals ~ Antimatter has matter internals)

1
[0-1]
ZPF
L
R
1
[1-0]
ZPF
tetryons
4
[0-4]
0
[2-2]
gluons
tetryons
0
[2-2]
gluons
4
[4-0]
leptons
quarks
anti-quarks
anti-leptons
12
[0-12]
e
0
[6-6]
ve
12
[0-12]
μ
0
[6-6]
νμ
12
[0-12]
τ
0
[6-6]
ντ
8
[10-2]
up
4
[4-8]
down
8
[10-2]
charmed
4
[4-8]
strange
8
[10-2]
top
4
[4-8]
bottom
up
8
[2-10]
down
4
[8-4]
charmed
8
[2-10]
strange
4
[8-4]
top
8
[2-10]
botom
4
[8-4]
e+
12
[12-0]
ve
0
[6-6]
μ
12
[12-0]
νμ
0
[6-6]
τ
12
[12-0]
ντ
0
[6-6]
UP SPIN
DOWN SPIN
DOWN SPIN
UP SPIN
DOWN SPIN
UP SPIN
UP SPIN
DOWN SPIN
e-
e+
KE
N
S
μB
Parallel magnetons
External magnetic dipole
Opposing Nuclei momentum
Same as Nuclei momentum
L
R
L
R
N
S
S
N
μN
12
[24-12]
P+
Baryons
0
[18-18]
N0
22,500
22,500
0
[18-18]
N̄0
AntiBaryons
12
[12-24]
P-
22,500
22,500

Tetryonics 80.19 - Matter - Antimatter symmetry

Anti-Matter

Baryon asymmetry

Matter

The Big Bang should have produced equal amounts of Matter and antiMatter, as such, there should have been total cancellation of both.

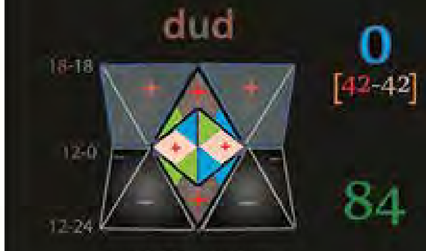

anti-Deuterium

It is not yet understood why the Universe has more matter than antimatter.
It is generally assumed that when the Universe was young and very hot,
it was in equilibrium and contained equal numbers of baryons and antibaryons.

Protons should have cancelled with antiprotons, electrons with antielectrons (positrons),
neutrons with antineutrons, and so on for all elementary particles.
This would have resulted in a sea of photons in the universe with no matter.

However, observations suggest that the Universe, including its most distant parts,
is made almost entirely of normal matter.

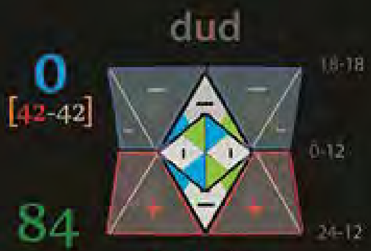

Deuterium

anti-Neutron
positron
anti-Proton

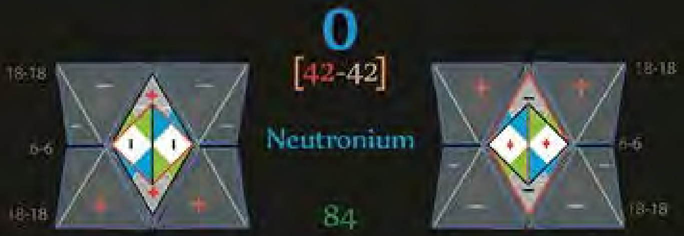

Neutron
electron
Proton

antiMatter dominated Galaxy

Neutral Matter

Neutron Neutrino anti-Neutron

Matter dominated Galaxy

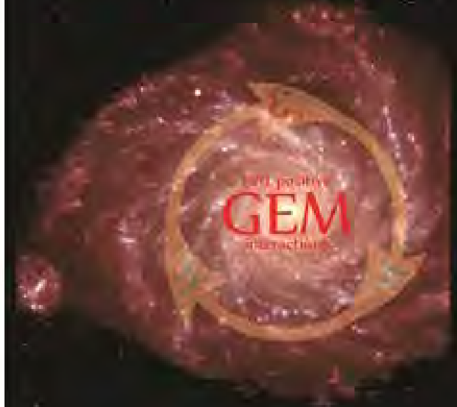

Tetryonics dictates that the Universe is filled with Matter - Neutronium - Antimatter star Galaxies and their emitted light photons are identical

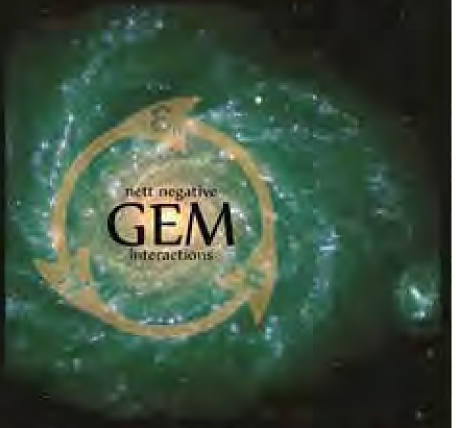

Tetryonics also demonstrates that the charge topologies of each Matter type prevalent in the formation of each Galaxy determines the overall resultant EM field geometries that shapes their large-scale evolution

Clockwise rotation

It is hypothesised that the rotation direction of galaxies is also influenced by how each galaxy was formed
in particular the predominance of Matter over antiMatter interactions and
the electrodynamic fields of each Galaxy's GEM pinch core

Counter-clockwise rotation

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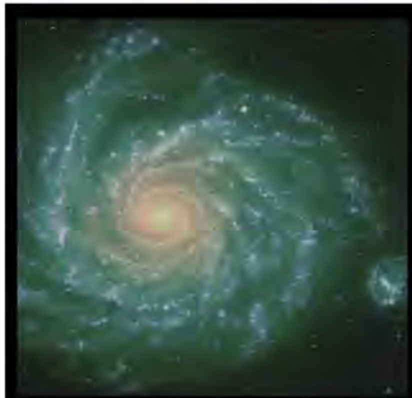

Opposites attract - Similars repel
even on the galactic-scale

Galactic Matter distributions

Tetryonics dictates that the Universe is filled with 3 forms of
Matter - Neutronium - Antimatter stars and Galaxies
their light is identical and cannot be used to distingush them

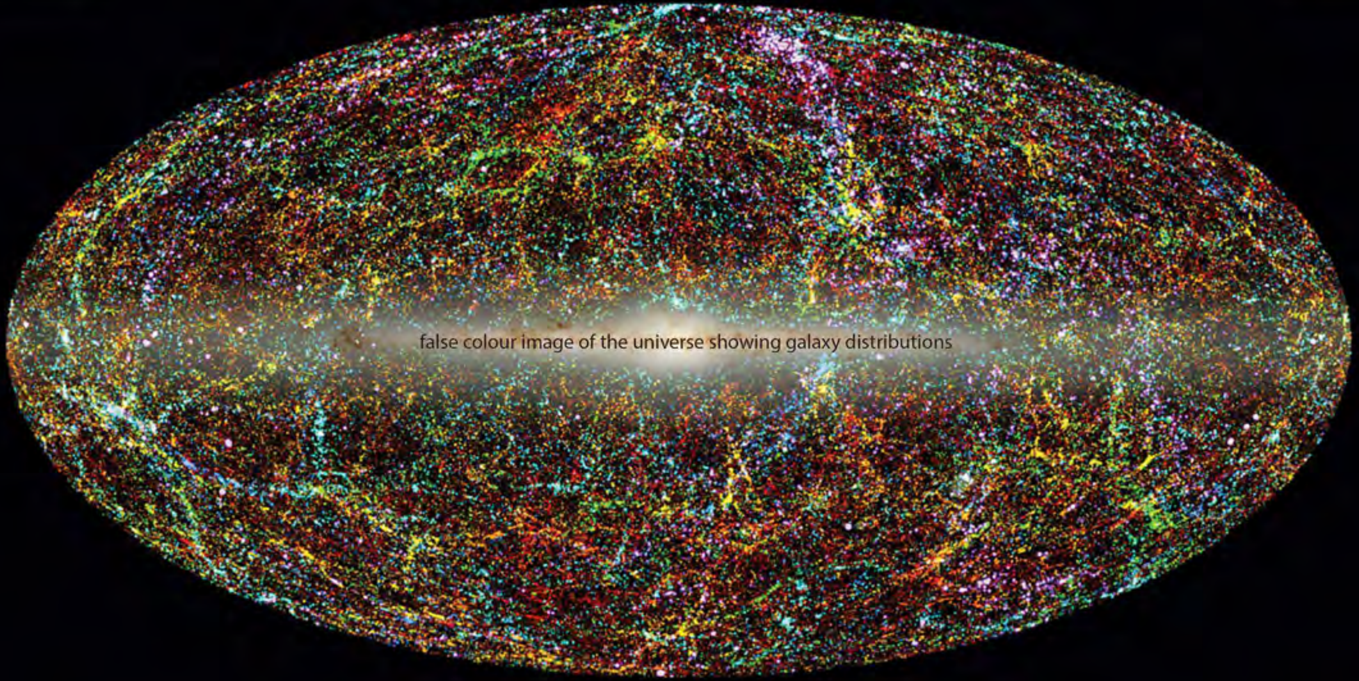

false colour image of the universe showing galaxy distributions

Matter

Neutron
Electron
Proton

Neutronium

Neutron
Neutrino
anti-Neutron

Neutronium is found predominantly in Neutron stars and Pulsars
spread throughout Matter and antiMatter galaxies
however it is conceivable that neutral galaxies may exist

Anti-Matter

anti-Neutron
Positron
anti-Proton

Tetryonics 80.21 - Galactic Matter distribution

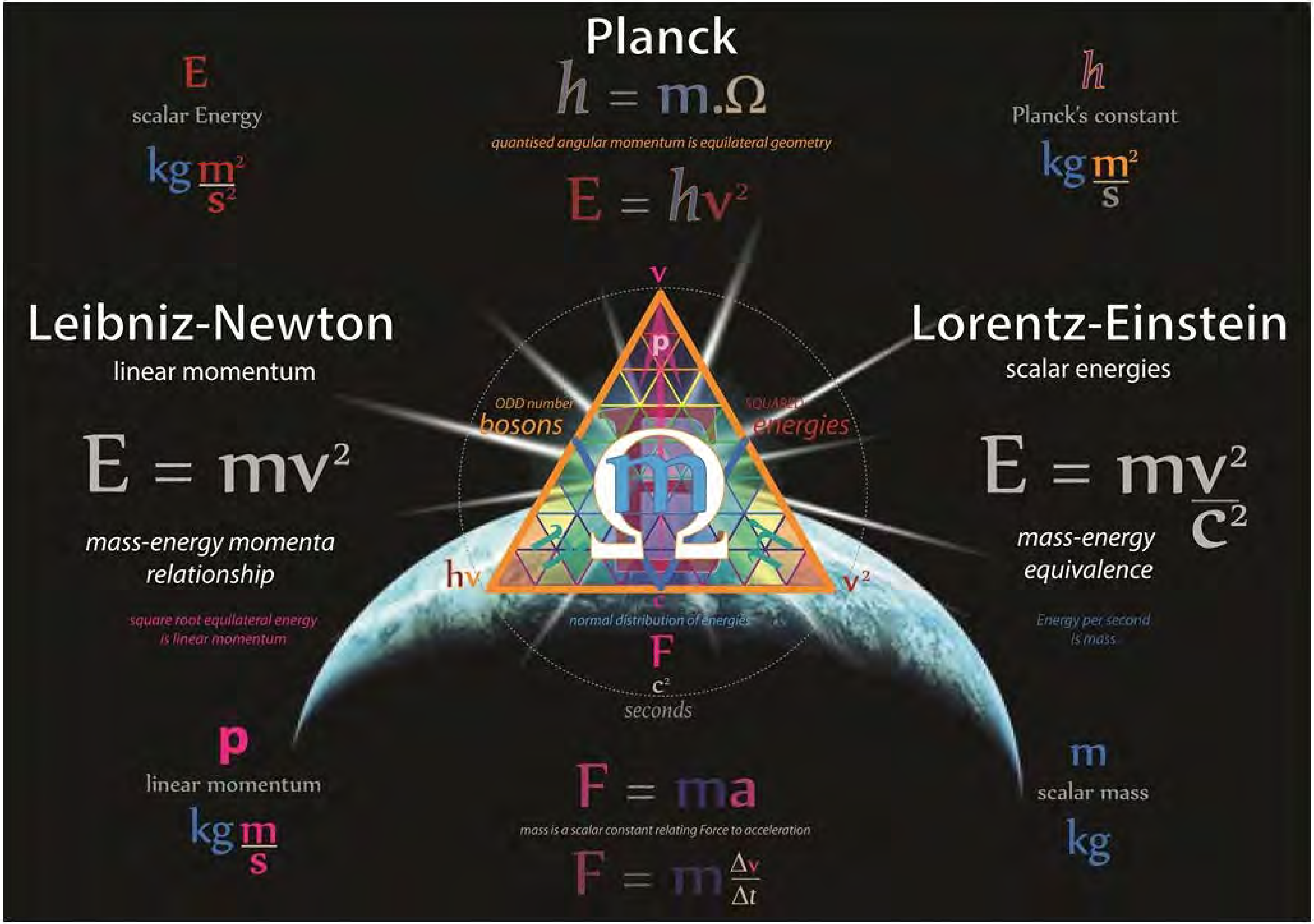

Planck

$$h = m.\Omega$$

quantised angular momentum is equilateral geometry

$$E = hv^2$$

E

scalar Energy

$$kg\,\frac{m^2}{s^2}$$

h

Planck's constant

$$kg\,\frac{m^2}{s}$$

v
p
ODD number
bosons
SQUARED
energies
m
Ω
hv
v²
c
normal distribution of energies
F
c²
seconds

Leibniz-Newton

linear momentum

$$E = mv^2$$

mass-energy momenta relationship

square root equilateral energy is linear momentum

Lorentz-Einstein

scalar energies

$$E = \frac{mv^2}{c^2}$$

mass-energy equivalence

Energy per second is mass

p

linear momentum

$$kg\,\frac{m}{s}$$

$$F = ma$$

mass is a scalar constant relating Force to acceleration

$$F = m\frac{\Delta v}{\Delta t}$$

m

scalar mass

kg

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Tetryonic Theory

The charged geometry of ElectroMagnetic mass-ENERGY
& Matter in motion

Charged geometries

Bosons

$$\frac{\text{ODD}\,\pi}{c^2}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

Total Relativistic Energies

ENERGY

$$n\pi\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

Q

[v-v]

RE

Quantum Mechanics

Chemistry

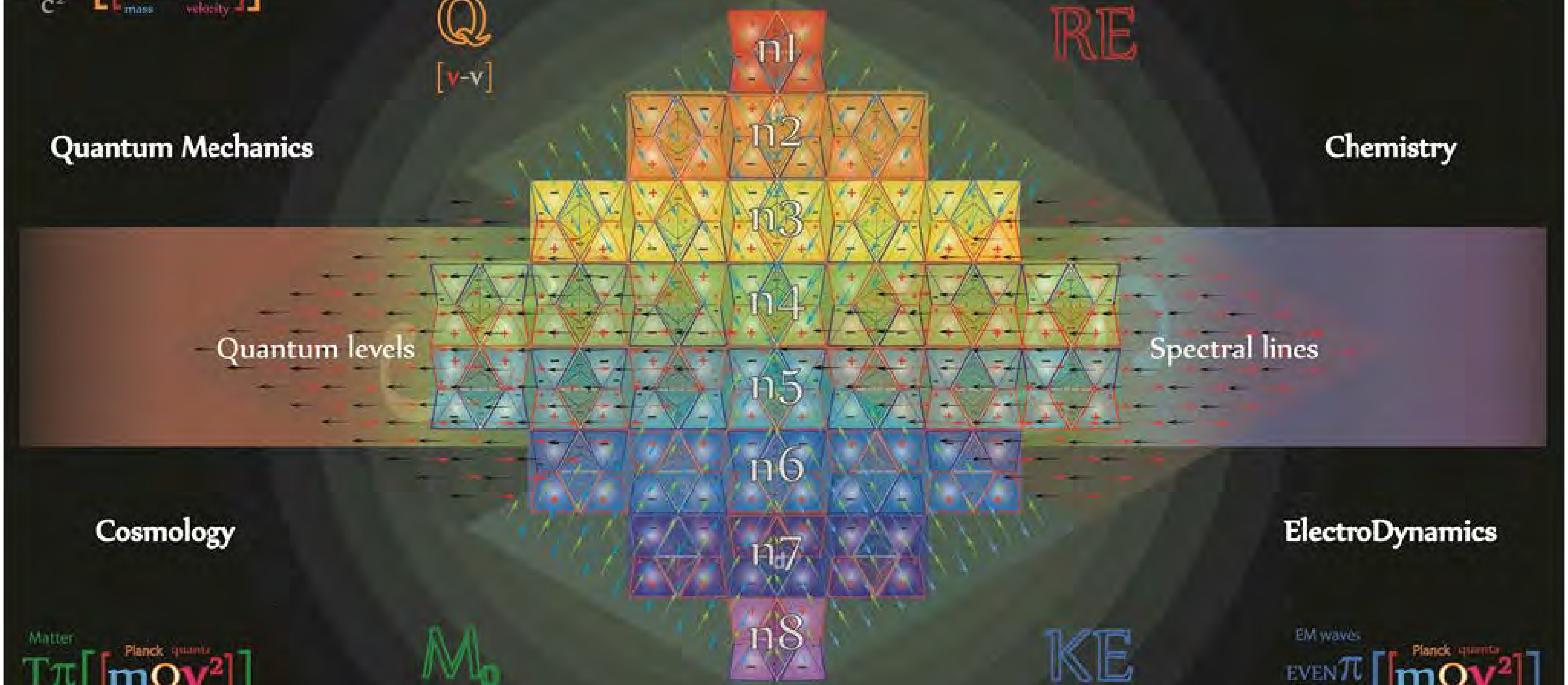

Cosmology

ElectroDynamics

M_0

KE

Matter

$$\frac{T\pi}{c^4}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

EM waves

$$\frac{\text{EVEN}\,\pi}{c^2}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

mass/Matter topologies

Unifying QM, QED, Chemistry and Cosmology
through charged equilateral Planck mass-energy momenta

Kinetic Energies of motion

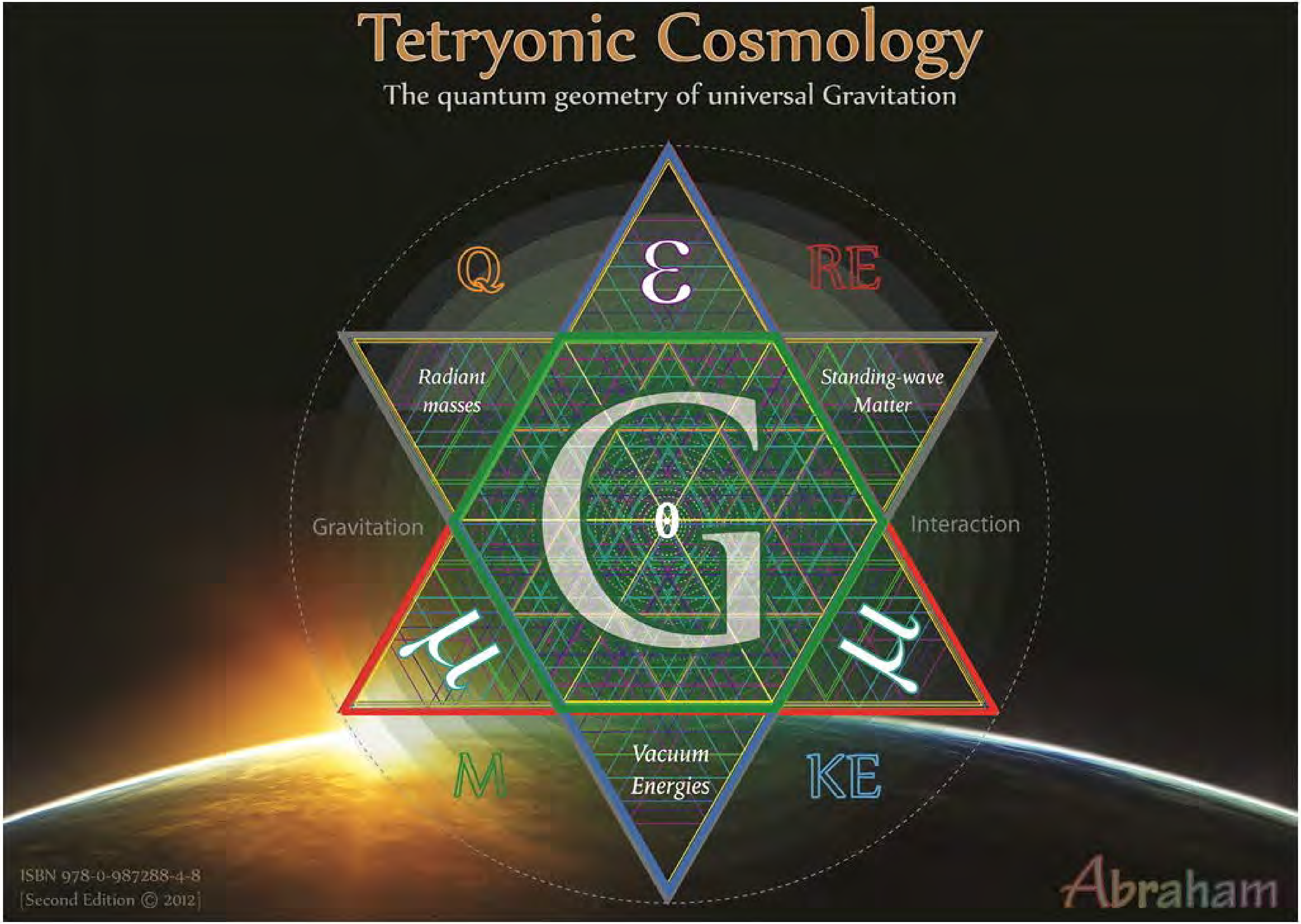

Tetryonic Cosmology

The quantum geometry of universal Gravitation

Q
ε
RE
Radiant
masses
Standing-wave
Matter
G
0
Gravitation
Interaction
μ
γ
M
Vacuum
Energies
KE
Abraham

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Tetryonics 80.24 - Quantum Cosmology

TETRYONICS

The equilateral geometry underpinning the mathematics of Physics

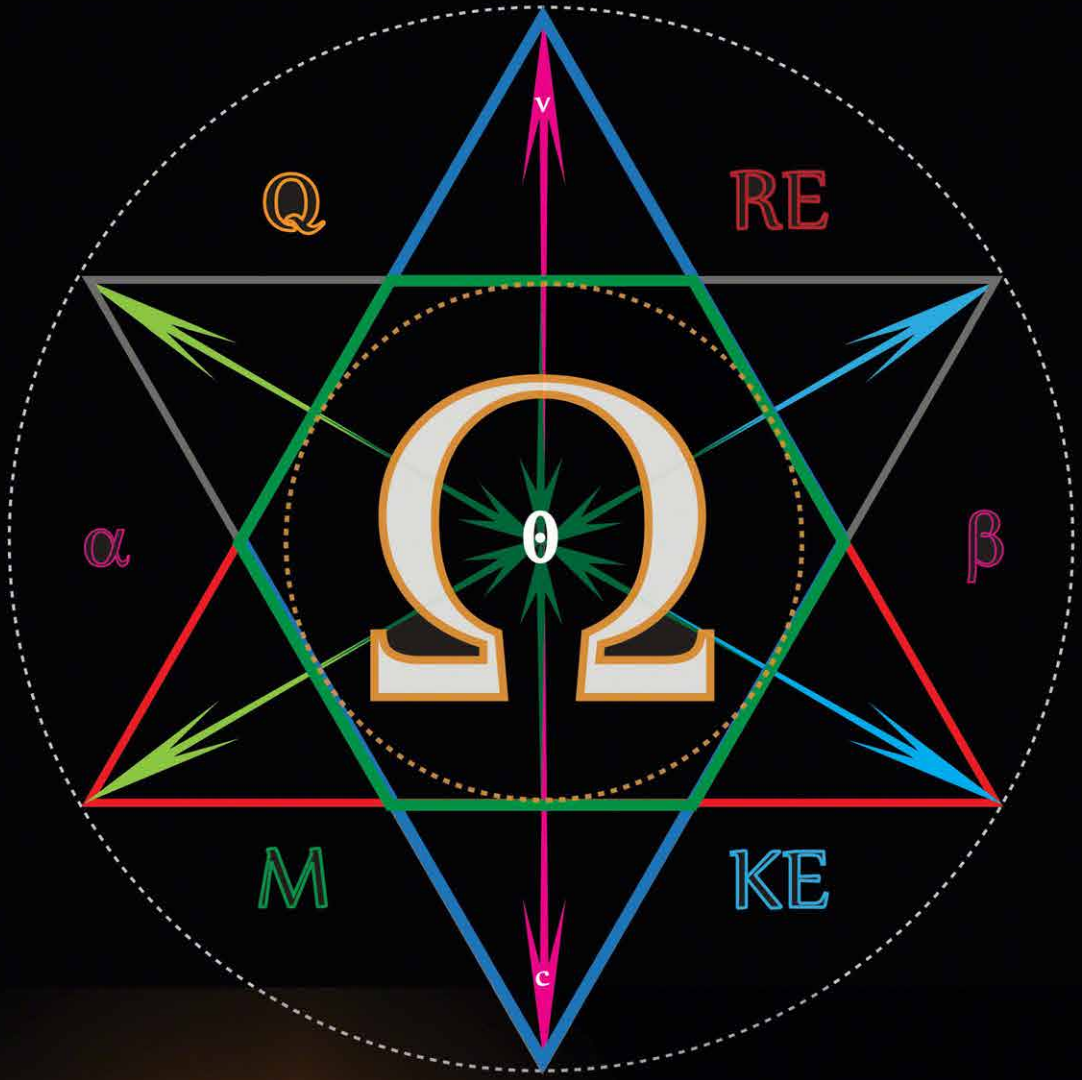

Foundational physics Mathematics

Abraham

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Geometry and the Theory of Everything

Plato

(c.428-348 BC)

DIFFERENT TYPE OF GEOMETRIES

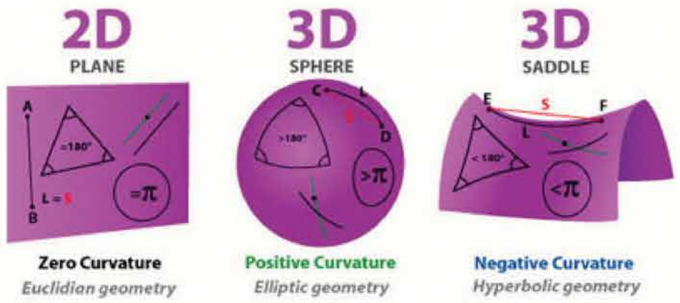

Zero Curvature *Euclidian geometry*

Positive Curvature *Elliptic geometry*

Negative Curvature *Hyperbolic geometry*

(studied by Omar Khayyam, Girolamo Saccheri, Bernhard Riemann, ...)

Euclid

(c.330-275 BC, fl. c.300 BC)

The Socratic tradition was not particularly congenial to mathematics, as may be gathered from Socrates' inability to convince himself that 1 plus 1 equals 2, but it seems that his student Plato gained an appreciation for mathematics after a series of conversations with his friend Archytas in 388 BC.

One of the things that most caught Plato's imagination was the existence and uniqueness of what are now called the five "Platonic solids".

It's uncertain who first described all five of these shapes - it may have been the early Pythagoreans - but some sources (including Euclid) indicate that Theaetetus (another friend of Plato's) wrote the first complete account of the five regular solids.

Presumably this formed the basis of the constructions of the Platonic solids that constitute the concluding Book XIII of Euclid's Elements.

In any case, Plato was mightily impressed by these five definite shapes that constitute the only perfectly symmetrical arrangements of a set of (non-planar) points in space, and late in life he expounded a complete "theory of everything", in the treatise called Timaeus, based explicitly on these five solids.

Interestingly, almost 2000 years later, Johannes Kepler was similarly fascinated by these five shapes, and developed his own cosmology from them

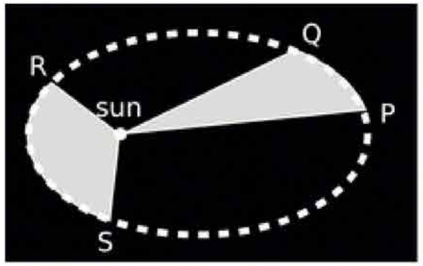

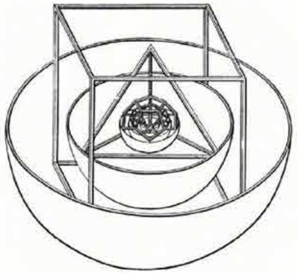

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Tetractys

The Greek Tetractys is a
triangular figure consisting of ten points
arranged in four rows:

one, two, three, and four points in each row,
which is the geometrical representation of the
fourth triangular number.

As a mystical symbol, it was very important to
the secret worship of the Pythagoreans.

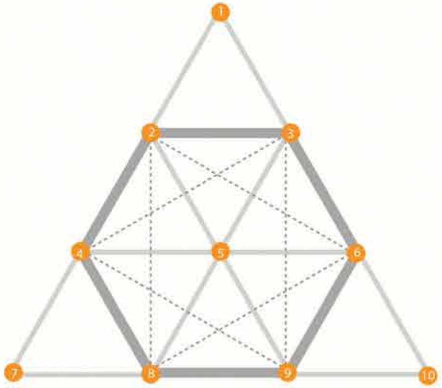

Sacred numbers

A

The Tetractys historically symbolized the four elements
[Earth, Air, Fire, and Water]
and the relationship between Humanity
and the cosmos created by GOD

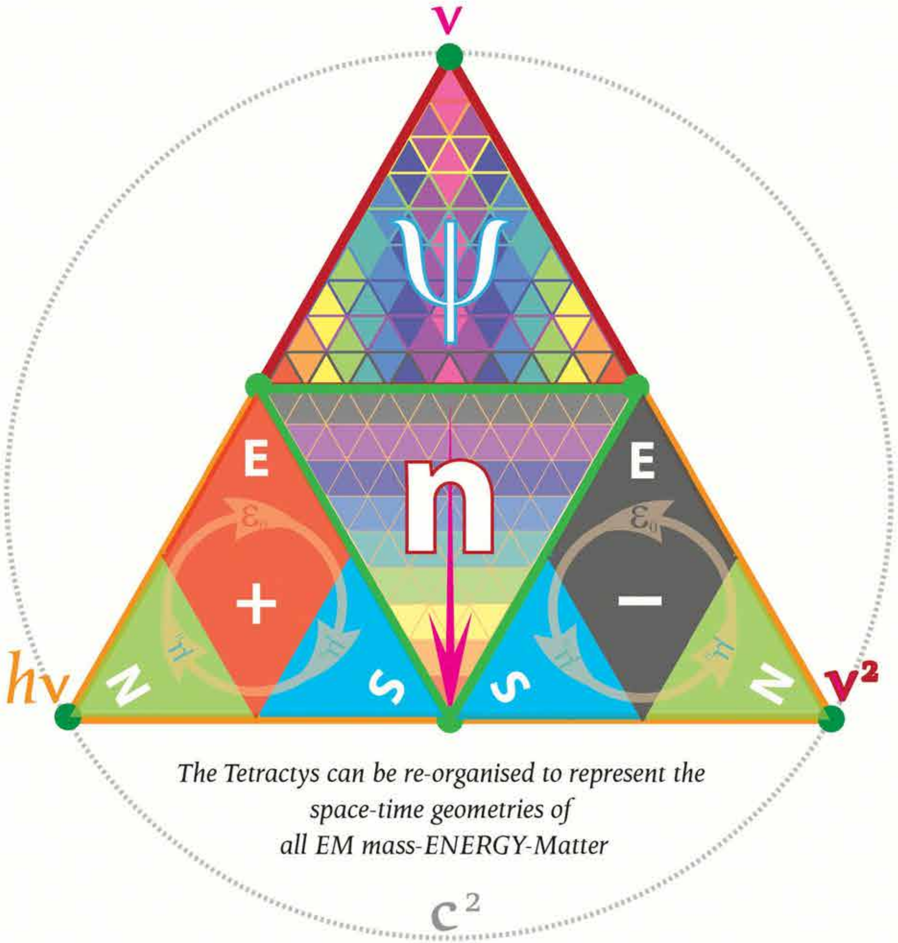

The Tetractys can be re-organised to represent the
space-time geometries of
all EM mass-ENERGY-Matter

The single triangle in the first row represents zero-dimensions (a point)
A vector direction in one-dimension can be represented as a line between any two points
The second row represents a Boson (two-dimensions in a plane defined by a rhombus of three triangles)
The whole figure folded represents three-dimensions (a tetrahedron defined by four apex points)
Photons of ElectroMagnetic mass-Energy quanta are represented by two opposing triangles

The tetrad was the name given to
the number four -
in Pythagorean philosophy
there were four seasons
and four elements,
and the number was also associated
with planetary motions and music

As a mystical symbol, it was very important to
the secret worship of the Pythagoreans.

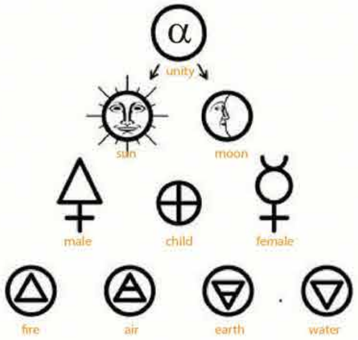

The Cosmos

Ω

The Greek Zodiac

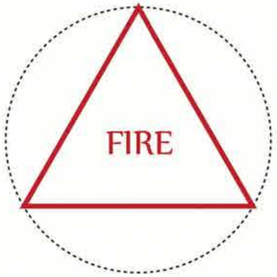

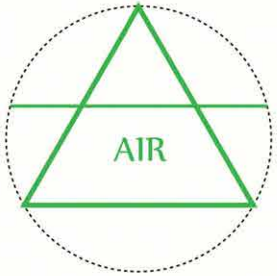

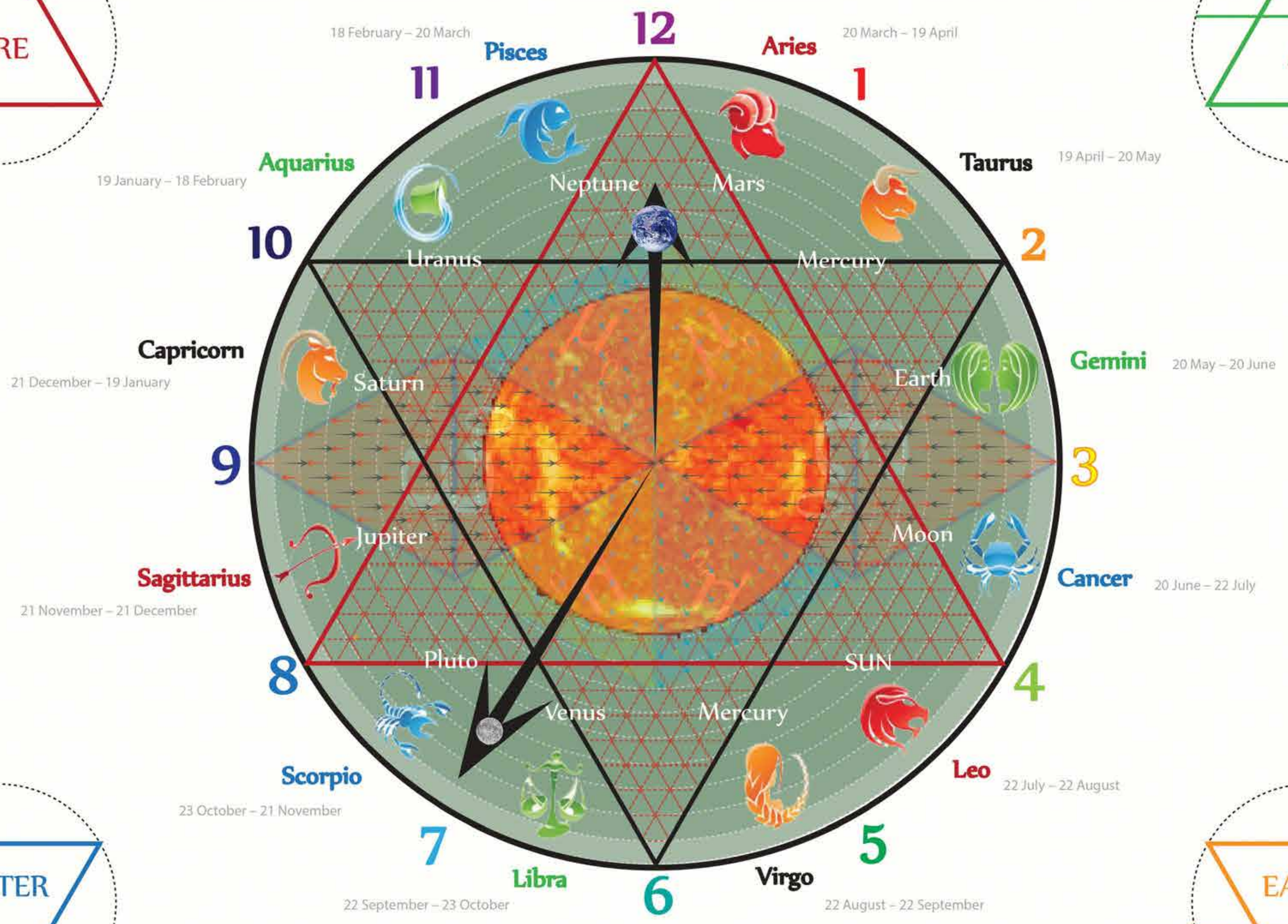
12
Aries
1
20 March – 19 April
Taurus
19 April – 20 May
2
Gemini
20 May – 20 June
3
Cancer
20 June – 22 July
4
Leo
22 July – 22 August
5
Virgo
22 August – 22 September
6
Libra
22 September – 23 October
7
Scorpio
23 October – 21 November
8
Sagittarius
21 November – 21 December
9
Capricorn
21 December – 19 January
10
Aquarius
19 January – 18 February
11
Pisces
18 February – 20 March
Neptune
Mars
Uranus
Mercury
Saturn
Earth
Jupiter
Moon
Pluto
SUN
Venus
Mercury

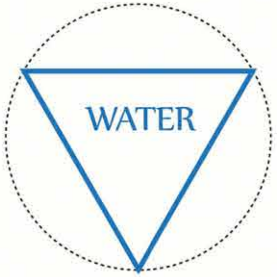

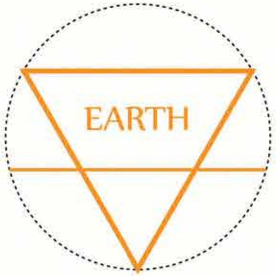

The Greek Elements

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Equilateral Triangles

An equilateral triangle is a triangle in which all three sides are equal

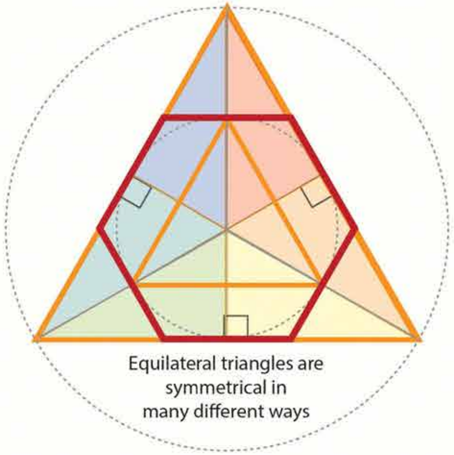

Equilateral triangles are
symmetrical in
many different ways

It is unique in that it is the only polygon
that can be tiled [or divided] and produce
only identical geometries and squares numbers

The equilateral triangle
is eminently suited for
the construction of fractals

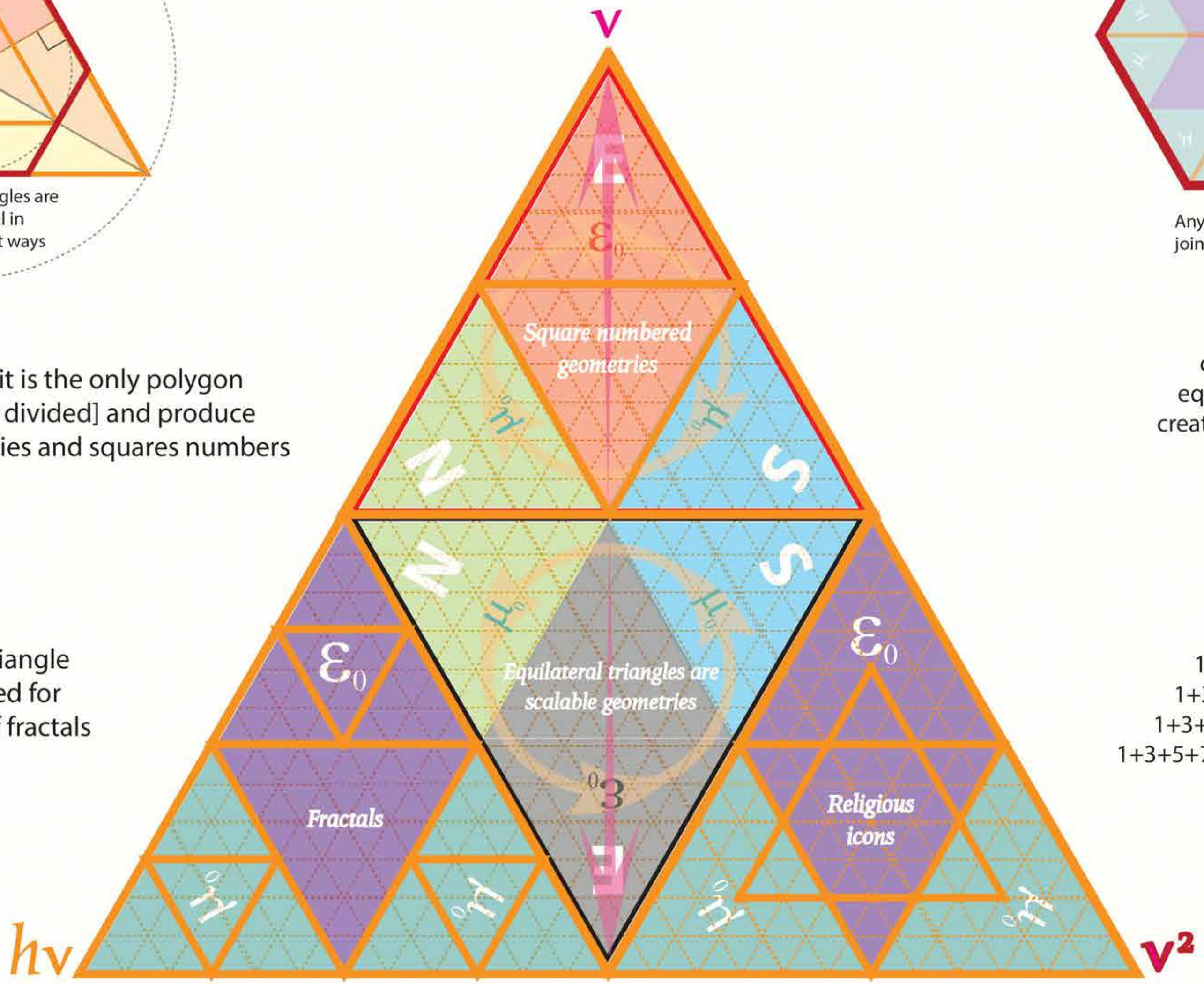
v
ε_0
Square numbered geometries
μ_0
N
S
Equilateral triangles are scalable geometries
Fractals
Religious icons
$h\nu$
v^2

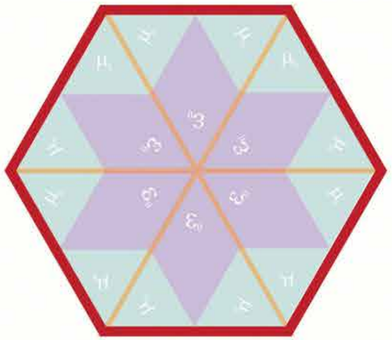
μ_0
ε_0

Any six equilateral triangles
joined can make a hexagon.

The
tesselation of
odd numbered
equilateral triangles
creates square numbers

That is,

1
1+3 = 4
1+3+5 = 9
1+3+5+7 = 16
1+3+5+7+9 = 25
1+3+5+7+9+11 = 36
1+3+5+7+9+11+13 = 49
1+3+5+7+7+9+11+13+15 = 64
etc

An equilateral triangle is simply a specific case of a regular polygon with 3 sides

The Pythagorean Theorem

Though attributed to Pythagoras, it is not certain that he was the first person to prove it.

The first clear proof came from Euclid, and it is possible the concept was known
1000 years before Pythoragas by the Babylonians

$$a^2 + b^2 = c^2$$

The square of the hypotenuse of a triangle is equal to the sum of the squares of its sides.

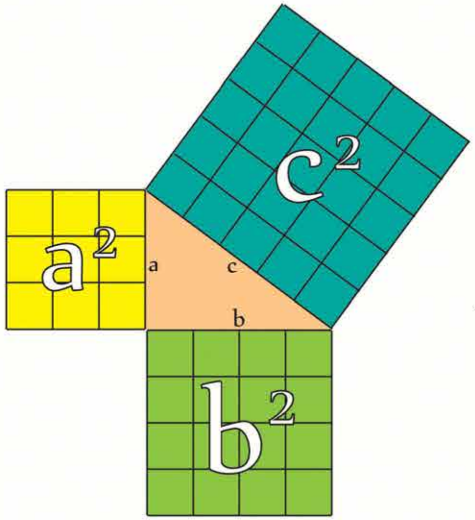

*In any right triangle,
the area of the square whose side is the hypotenuse
(the side opposite the right angle) is equal to
the sum of the areas of the squares
whose sides are the two legs
(the two sides that meet at a right angle)*

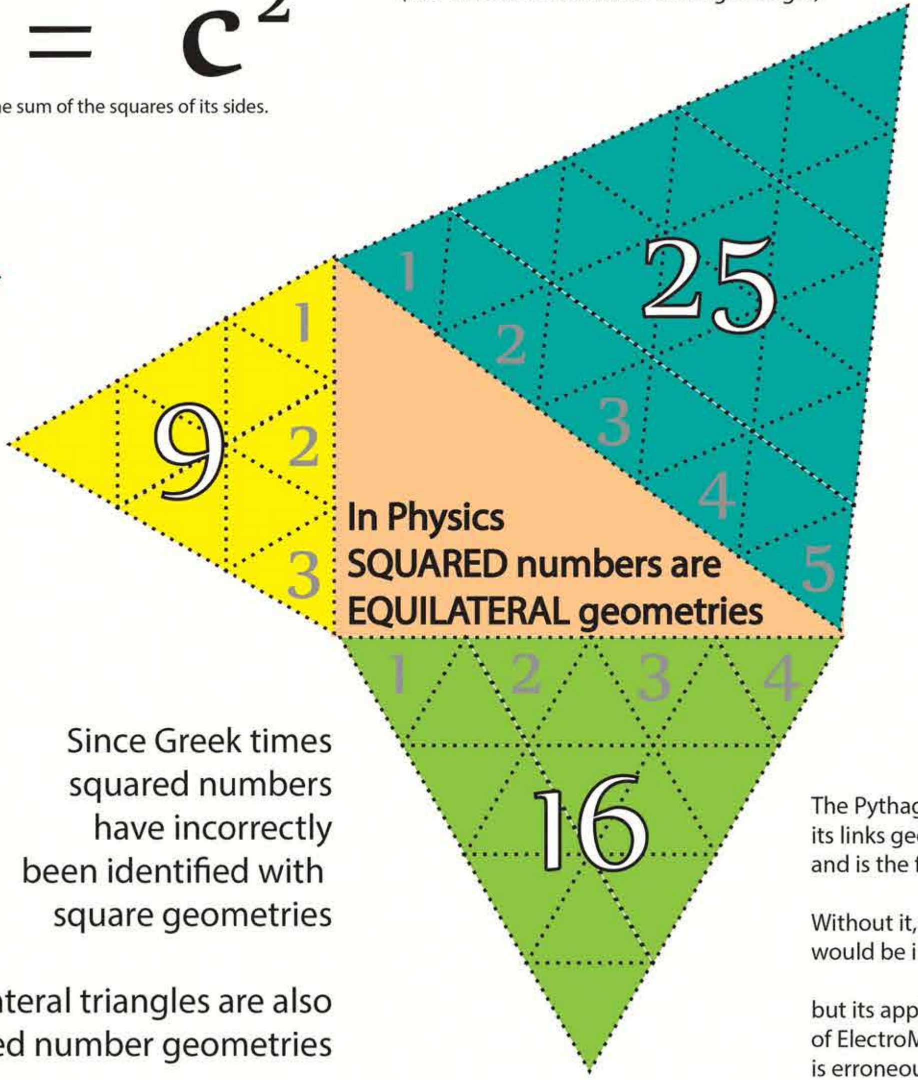
1
2
3
9
1
2
3
4
5
25
In Physics
SQUARED numbers are
EQUILATERAL geometries
1
2
3
4
16

Pythagoras of Samos

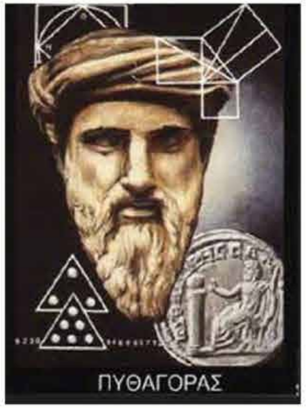

about (570 – 495 BC)

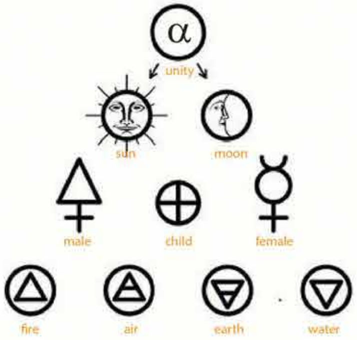
α
unity
sun
moon
male
child
female
fire
air
earth
water

Pythagorean Tetractys

Since Greek times
squared numbers
have incorrectly
been identified with
square geometries

Equilateral triangles are also
squared number geometries

The Pythagorean equation is at the core of much of geometry,
its links geometry with algebra,
and is the foundation of trigonometry.

Without it, accurate surveying, mapmaking, and navigation
would be impossible,

but its application to the energy-momenta geometries
of ElectroMagnetic fields and Matter in motion in Physics
is erroneous and must be corrected for science to advance

Hexagons

A regular hexagon can be subdivided into six equilateral triangles

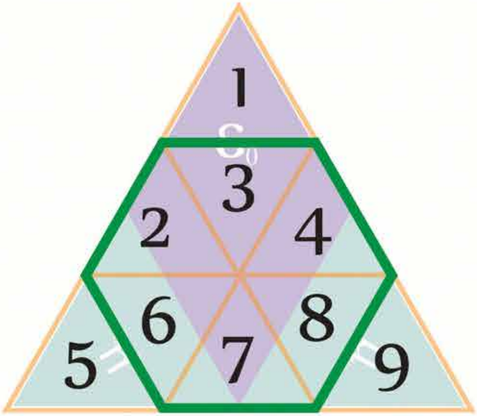

Energy geometries

Atomic nuclei geometries

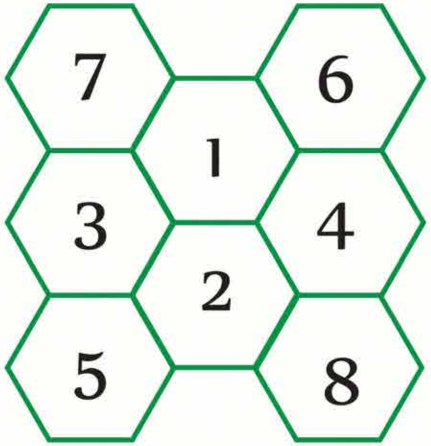

Hexagons can be tiled or tessellated in a regular pattern on a flat two-dimensional plane

Hexagons are the only regular polygon that can be subdivided into another regular polygon

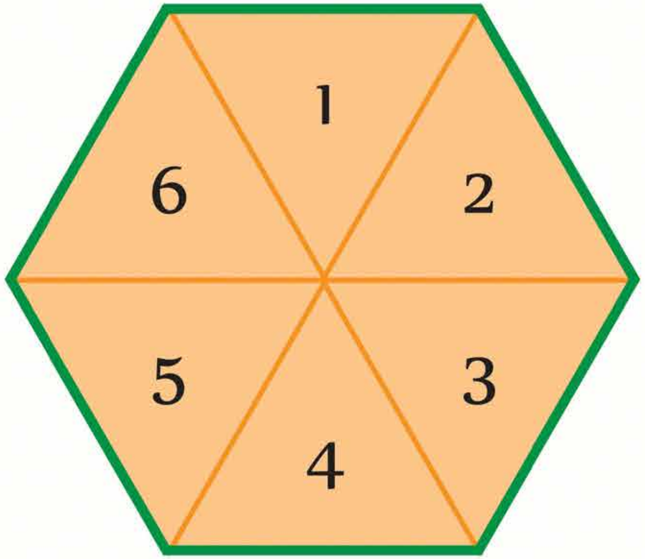

Hexagons are the unique regular polygon such that the distance between the center and each vertex is equal to the length of each side

Six is a highly composite number,
the second-smallest composite number,
and the first perfect number.

That is, 1*2*3=1+2+3=6

An interesting relationship between circular and hexagonal geometry is that hexagonal patterns often appear spontaneously when natural forces are trying to approximate circles

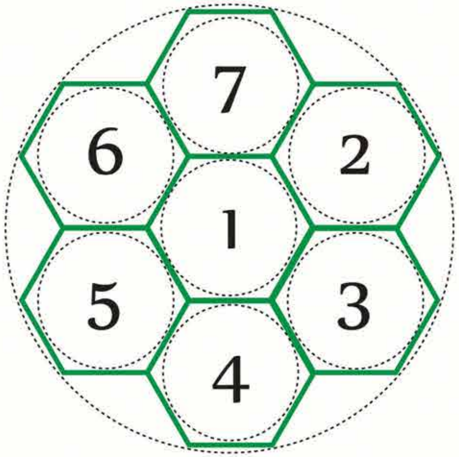

Hexagonal tessellation is topologically identical to the close packing of circles on a plane

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Platonic Solids

The Pythagoreans knew that there were only five regular convex solids,
the tetrahedon, cube, octahedron, icosohedron and dodecahedron
and each one could be accurately circumscribed by a sphere.

FIRE

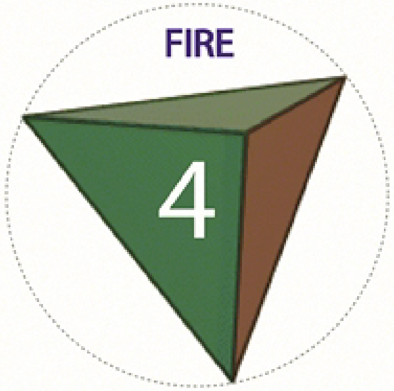

4 triangles meet to form
a Tetrahedron

EARTH

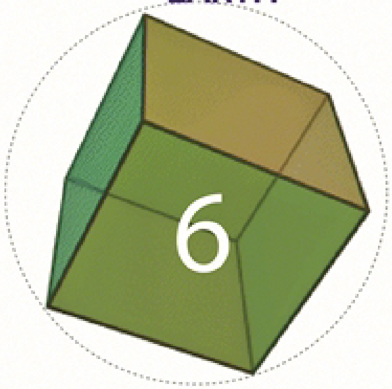

6 squares meet to form
a Cube

AIR

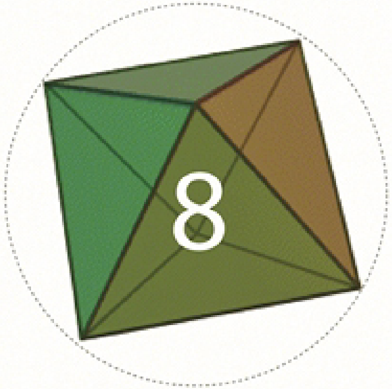

8 triangles meet to form
a Octahedron

tetryons **4**

regular deltahedrons

leptons **12**

8 *quarks*

regular deltahedrons

20 *Baryons*

$$F - E + V = 2$$

faces edges vertexs

12 pentagons meet to form
a Dodecahedron

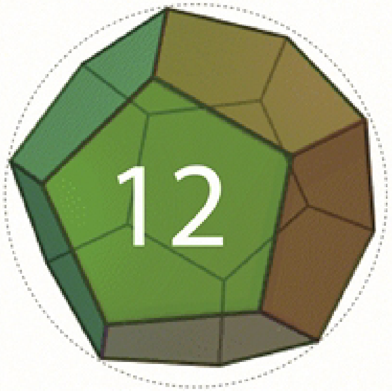

THE HEAVENS

Plato

(c.428-348 BC)

The philosopher Plato concluded that they must be the fundamental building blocks
– the atoms – of nature, and assigned to them what he believed to be
the essential elements of the universe.

20 triangles meet to form
a Icosahedron

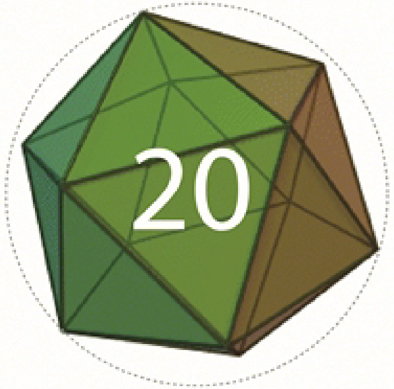

WATER

Tetryonic Solids

Despite their unique topologies Tetryonic solids are not unlike Platonic solids save that their toplogies are comprised entirely from complex hitherto undescribed **$4n\pi$ equilateral Planck mass-energy momenta geometries** that also match the Euler numbers of Platonic solids

+ tetryon

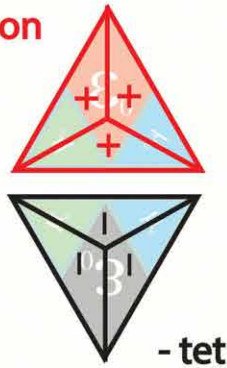

4 faces
6 edges
4 vertices

2

- tetryon

up quark

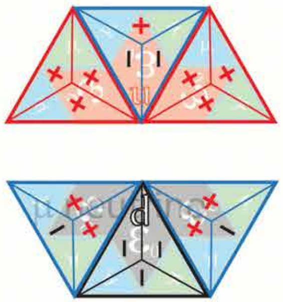

2

8 faces
12 edges
6 vertices

down quark

mass geometries		Matter topologies
4π	*tetryons*	4π
	regular deltahedrons	
12π	*leptons*	12π

Matter topologies		mass geometries
8π	*quarks*	12π
	regular deltahedrons	
20π	*Baryons*	36π

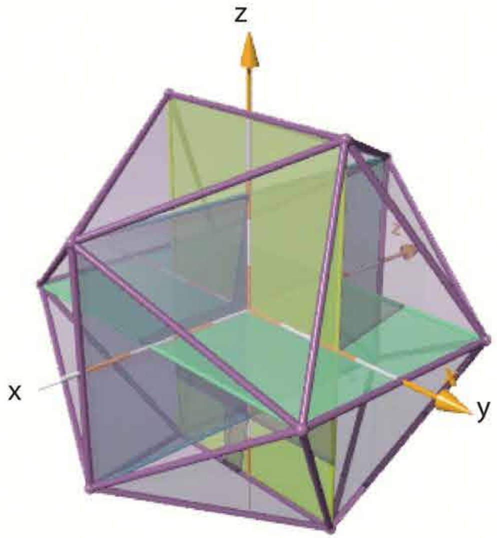

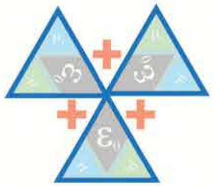

neutrino

12 faces
18 edges
8 vertices

2

electron

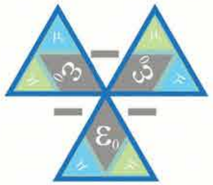

Their equilateral topologies are best described as regular topologic-deltahedrons:

tetra-delta-hedrals	**tetryons**	4π external charge fascia
octa-delta-hedrals	**quarks**	8π external charge fascia
dodeca-delta-hedrals	**leptons**	12π external charge fascia
icoso-delta-hedrals	**Baryons**	20π external charge fascia

note:
Charged mass-energy fascia geometries and edges become "hidden" upon the meshing of delta-hedra to form Matter topologies

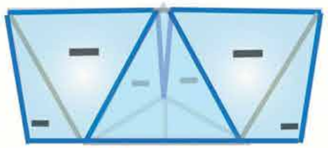

Neutron

2

20 faces
30 edges
12 vertices

Proton

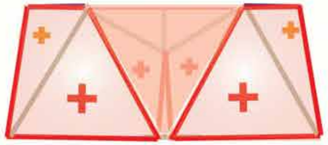

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Euclidean geometry

Euclid

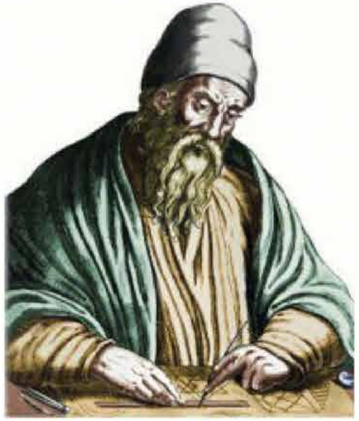

(c.330-275 BC, fl. c.300 BC)

Arguably the most influential Mathematics book ever written is Euclid's 'The Elements'

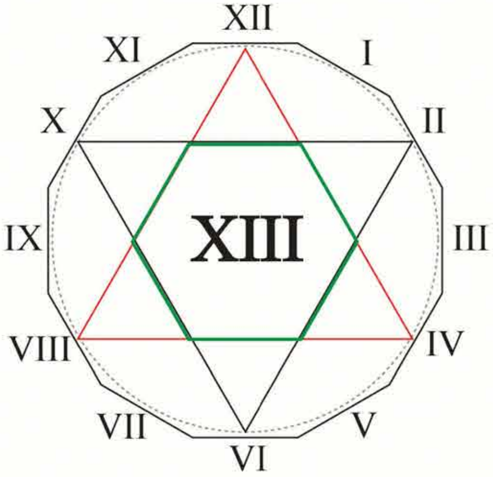

In all, it contains 465 theorems and proofs, described in a clear, logical and elegant style, and using only a compass and a straight edge.

The Elements - Book 1 - Definition 20

Of the trilateral figures, an equilateral triangle is that which has its three EQUAL sides

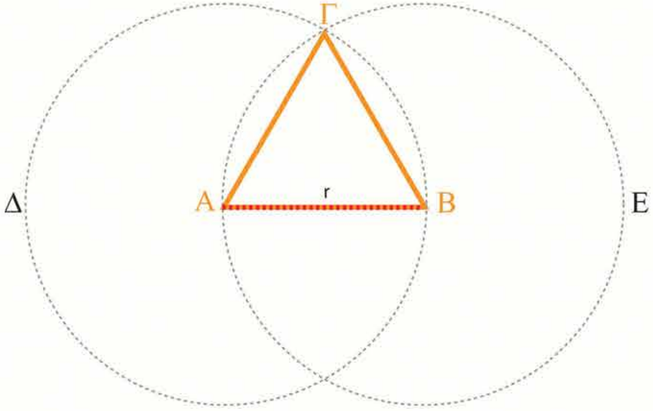

Euclid's Elements - Book 1 - Proposition 1
Method of constructing an Equialteral triangle

Euclid's five general axioms were:

Things which are equal to the same thing are equal to each other.

If equals are added to equals, the wholes (sums) are equal.

If equals are subtracted from equals, the remainders (differences) are equal.

Things that coincide with one another are equal to one another.

The whole is greater than the part

Archimedes

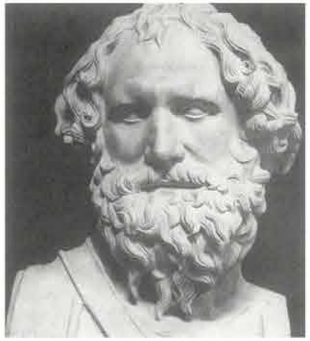

c. (287 BC – c. 212 BC)

As its definition relates to the circle,
π is found in many formulae in trigonometry and geometry,
especially those concerning circles, ellipses, or spheres.

It is also found in formulae from other branches of science,
such as cosmology, number theory, statistics, fractals,
thermodynamics, mechanics, and electromagnetism

Incorrect identification of Pi [c/d] as opposed to Pi radians
in Physics has led to the inappropriate association
of spherical particles to the physical sciences
whereas equilateral triangles & tetrahedra
form its true geometry

The number π is a mathematical constant that is
the ratio of a circle's circumference to its diameter.

Pi

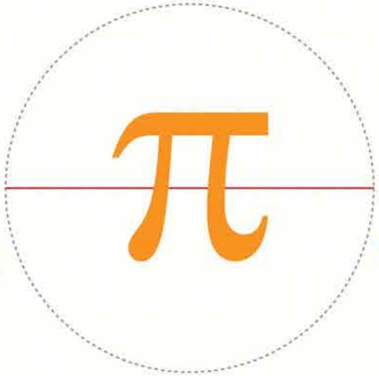

$\pi = c/d$

π is an irrational number
its decimal representation
never ends and never repeats.

The ratio C/d is constant,
regardless of the circle's size

3.141592654.......

Proof of the fact that C=2πr and how Archimedes proved it

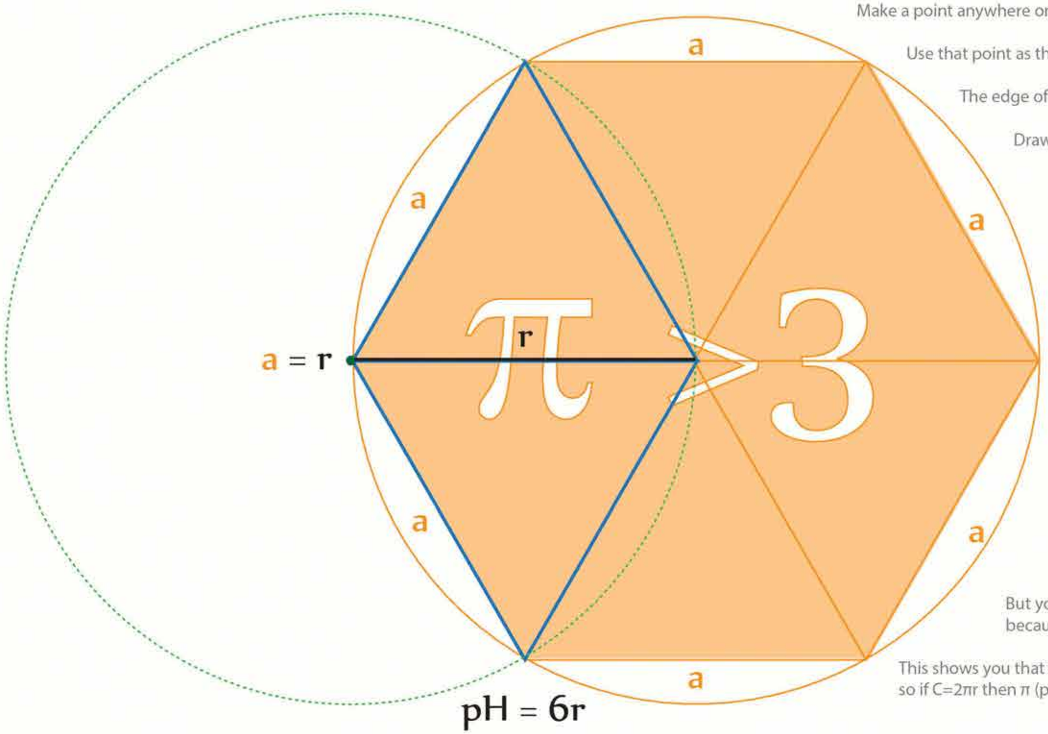

Draw any circle.

Make a point anywhere on the circumference of the [green] circle.

Use that point as the center of a second [blue] circle with the same radius as the green circle.

The edge of the blue circle should touch the center of the green circle.

Draw the line segment connecting the centers of the two circles.

That forms the radius of both of the circles.

Now draw the line connecting the center of the blue circle to where it crosses the green circle
on both sides, and complete the triangles.

You should have two equilateral triangles whose sides are equal to the radius of the green circle

Now extend all of the radius lines so they become diameter lines,
all the way across the circle, and finish drawing all of the triangles to connect them.

You've got six equilateral triangles now, that make an orange hexagon.

So the perimeter of your hexagon is the same as six times the radius of your circle.

But your circumference is a little bigger than the perimeter of your hexagon,
because the shortest distance between two points is always a straight line.

This shows you that the circumference of the blue circle has to be more than 6r,
so if C=2πr then π (pi) has to be a little bigger than 3, which it is.

The more sides we draw on our polygon, the closer we will get to the real value of pi (3.14159 etc.).
Using a polygon with 96 sides, Archimedes was able to calculate that π was a little bigger than 3.1408

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The Golden Ratio

Two quantities are in the golden ratio (φ) if the ratio of the sum of the quantities to the larger quantity is equal to the ratio of the larger quantity to the smaller one.

The figure to the right illustrates the geometric relationship

[1.61803]

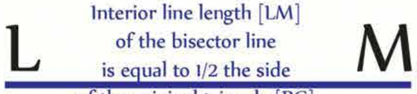

Interior line length [LM] of the bisector line is equal to 1/2 the side of the original triangle [BC] [AB] or [CA]

Φ

Golden ratio phi

$$\hbar = \frac{h}{2\pi}$$

Tetryonic geometry reveals the maximum E-field amplitude of the reduced Planck constant to be an example of the Golden ratio in physics

velocity vectors

The height of the triangle [ALM] produced by the bisecting line is 1/2 the height of the height of [ABC]

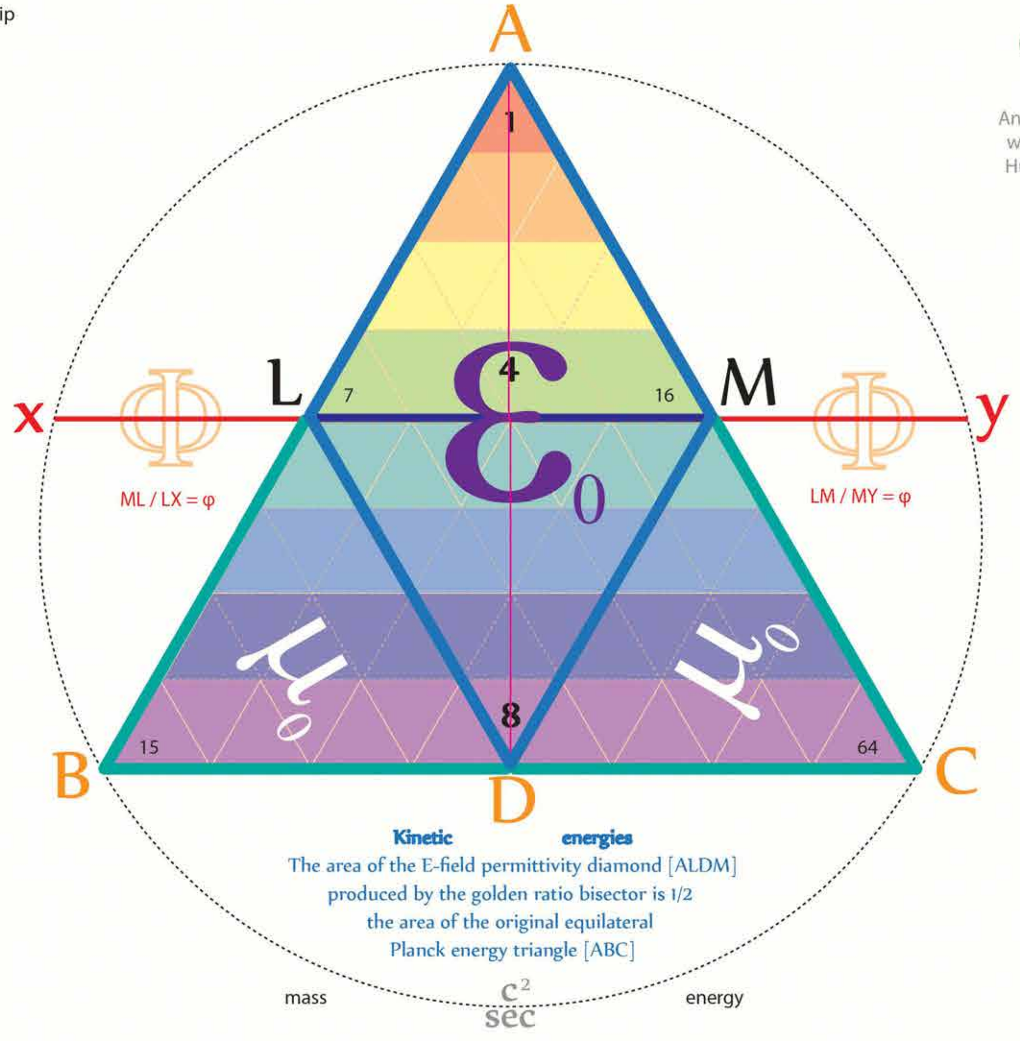

Kinetic **energies**

The area of the E-field permittivity diamond [ALDM] produced by the golden ratio bisector is 1/2 the area of the original equilateral Planck energy triangle [ABC]

Planck's constant [h]

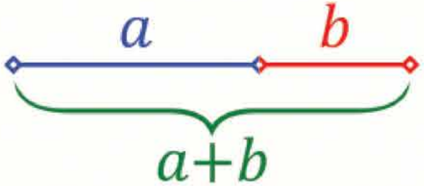

a+b is to a as a is to b

An intriguing showing of φ in an equilateral triangle was observed by George Odom, a resident of the Hudson River Psychiatric Center, in the early 1980s

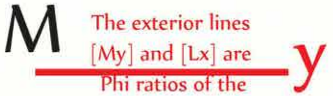

The exterior lines [My] and [Lx] are Phi ratios of the interior line [LM]

Let L and M be the midpoints of the sides AB and AC of an equilateral triangle ABC

By measurement and the Intersecting Chords Theorem

$$MX \cdot MY = AM \cdot MC.$$

which is of the form

$$(a + b) \cdot b = a \cdot a.$$

Denoting a/b = x, we see that

$$1 + x = x^2,$$

George Odom

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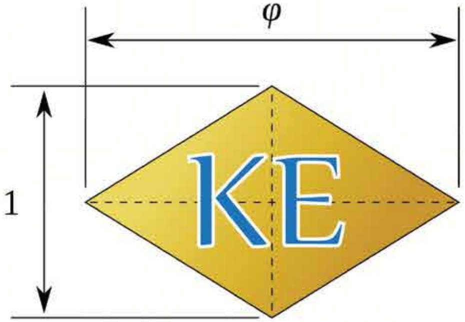

The Golden Rhombus

Applying the golden ratio (φ) to quantum scale electrodynamic geometry we can quickly determine that the linear momentum and magnetic moment vectors of photons & EM waves can also be expressed as a golden ratio

vector velocities
vs
magnetic vector

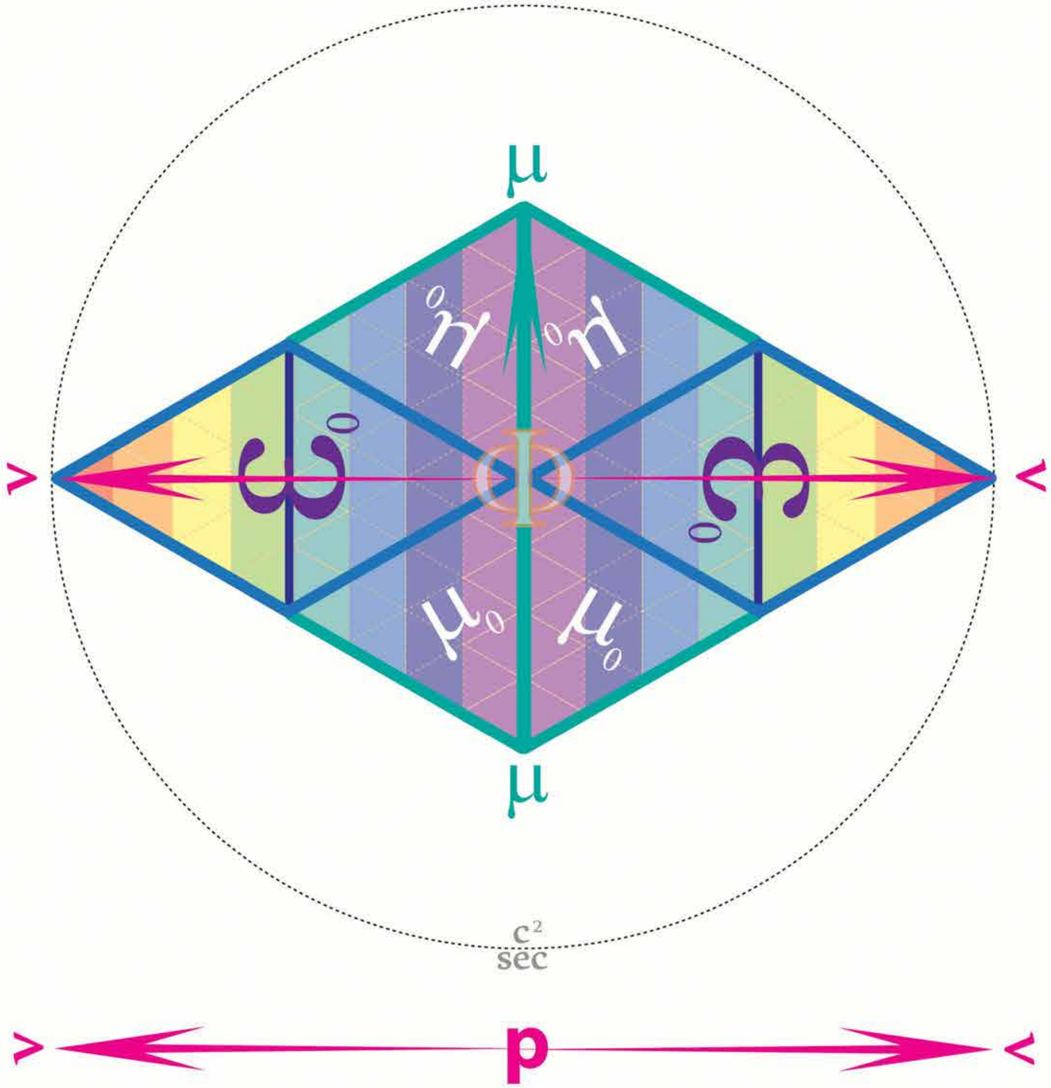

Φ

Golden ratio phi

[1.61803]

magnetic Force
vs
electric Force

photons
of
EM energy

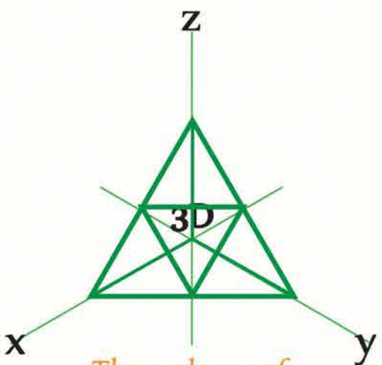

The 3 planes of Cartesian co-ordinates

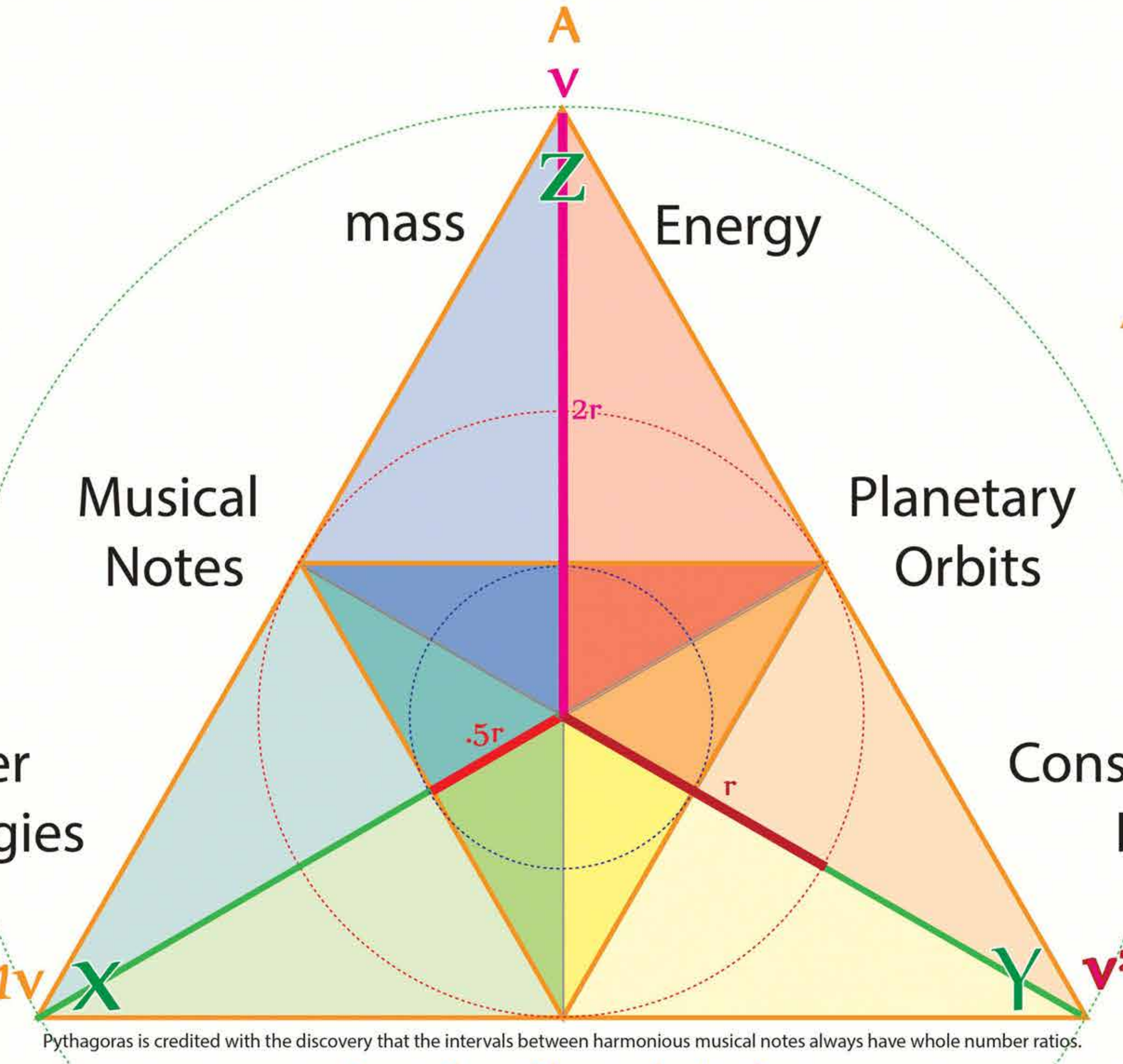
A
v
Z
mass
Energy
2r
Musical Notes
Planetary Orbits
.5r
r
Matter topologies
Conservation Laws
hv
X
Y
v²
B
C

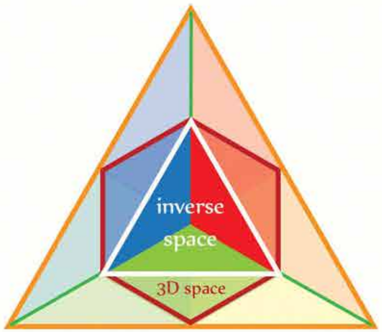
inverse space
3D space

An equilateral [square] triangle divided into 12 equal semitones

Pythagoras is credited with the discovery that the intervals between harmonious musical notes always have whole number ratios.

An equilateral [square] triangle
divided into 6 equal semitones
and 6 equal quarter tones

With an Equilateral triangle, draw lines from the center of the circle to each vertex and each midpoint, creating six right triangles, as shown with six different colored triangles.
Each right triangle has a radius of the circle for one leg, and half of a side of the original triangle for another.
Any two right triangles sharing one of the radial lines must therefore be congruent, and that implies that the hypotenuses of the triangles are all equal.
This in turn shows that the six right triangles are all congruent, and so the large triangle they combine to form is equilateral

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Equilateral Fifths

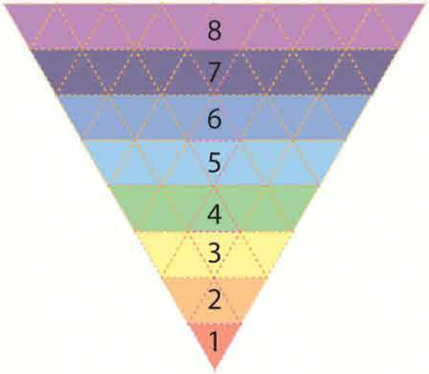

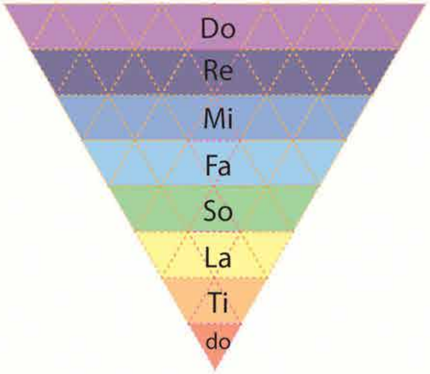
Do
Re
Mi
Fa
So
La
Ti
do

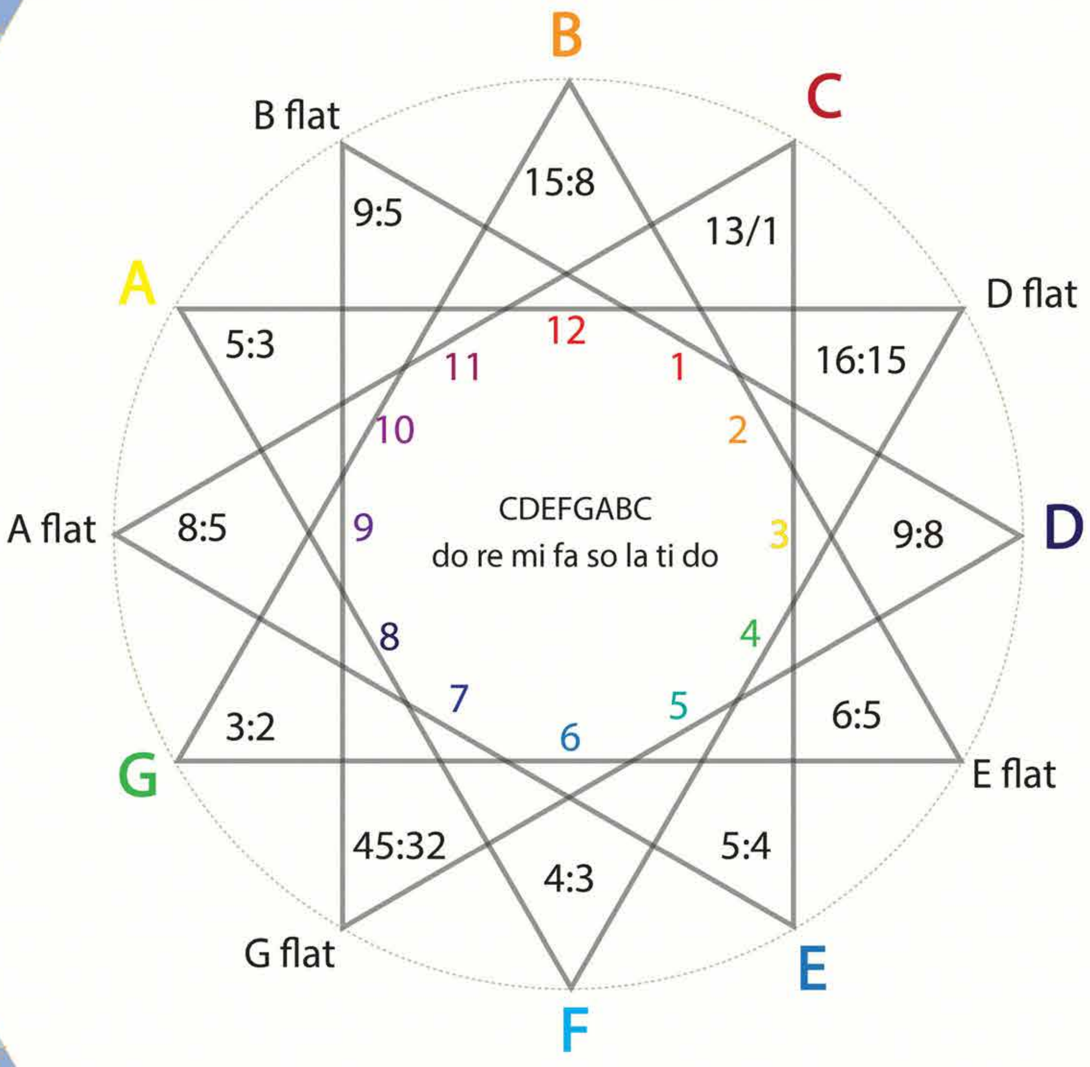
B
C
D flat
D
E flat
E
F
G flat
G
A flat
A
B flat
15:8
13/1
16:15
9:8
6:5
5:4
4:3
45:32
3:2
8:5
5:3
9:5
12
1
2
3
4
5
6
7
8
9
10
11
CDEFGABC
do re mi fa so la ti do

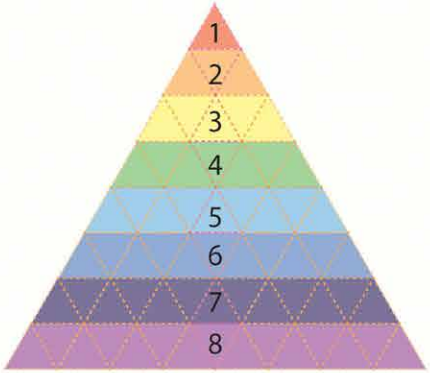

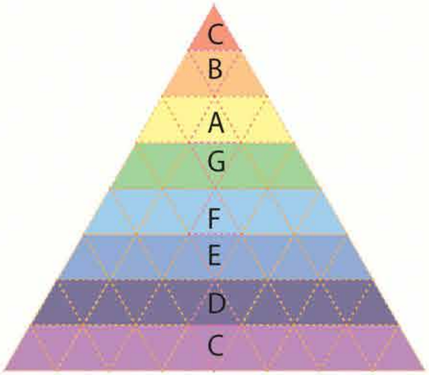

Musical Notes

2D radiated mass-energies

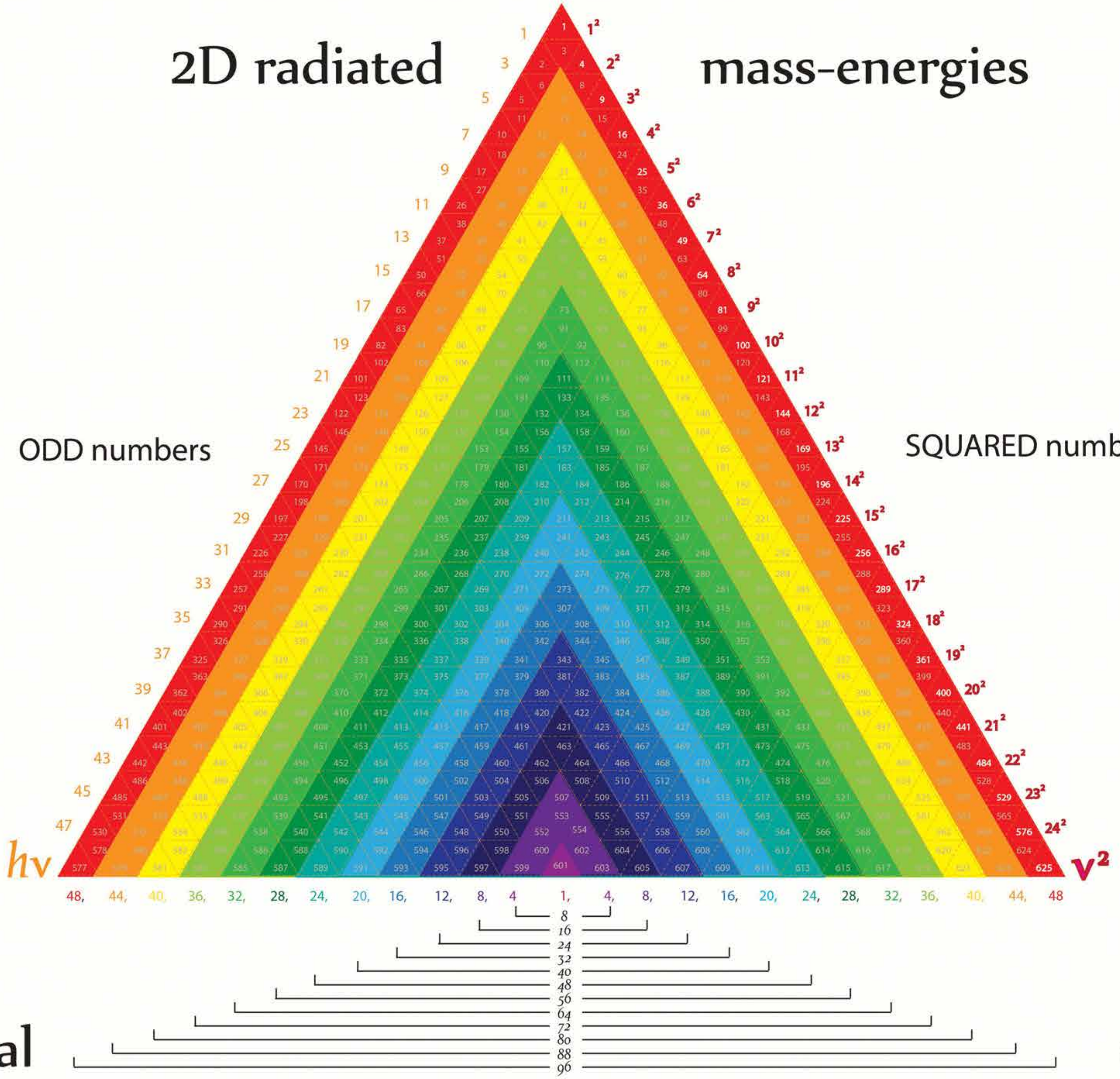
ODD numbers
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
hν
SQUARED numbers
1²
2²
3²
4²
5²
6²
7²
8²
9²
10²
11²
12²
13²
14²
15²
16²
17²
18²
19²
20²
21²
22²
23²
24²
v²
48, 44, 40, 36, 32, 28, 24, 20, 16, 12, 8, 4
1,
4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48
8
16
24
32
40
48
56
64
72
80
88
96

Equilateral Octaves

Ternary Diagrams

Viviani's Theorem implies that lines parallel to the sides of an equilateral triangle provide (homogeneous/barycentric/areal/trilinear) coordinates for ternary diagrams for representing three quantities A,B,C whose sum is a constant (which can be normalized to unity).

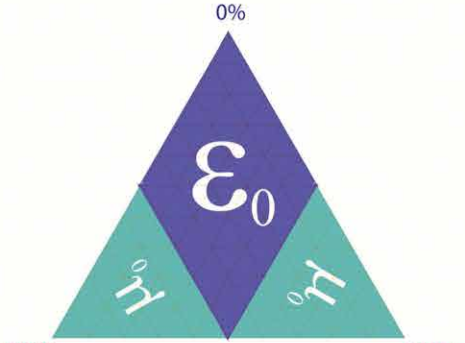
0%
ε_0
μ_0
μ_0
100%
100%

Ternary diagrams should NOT be used to model EM field strengths

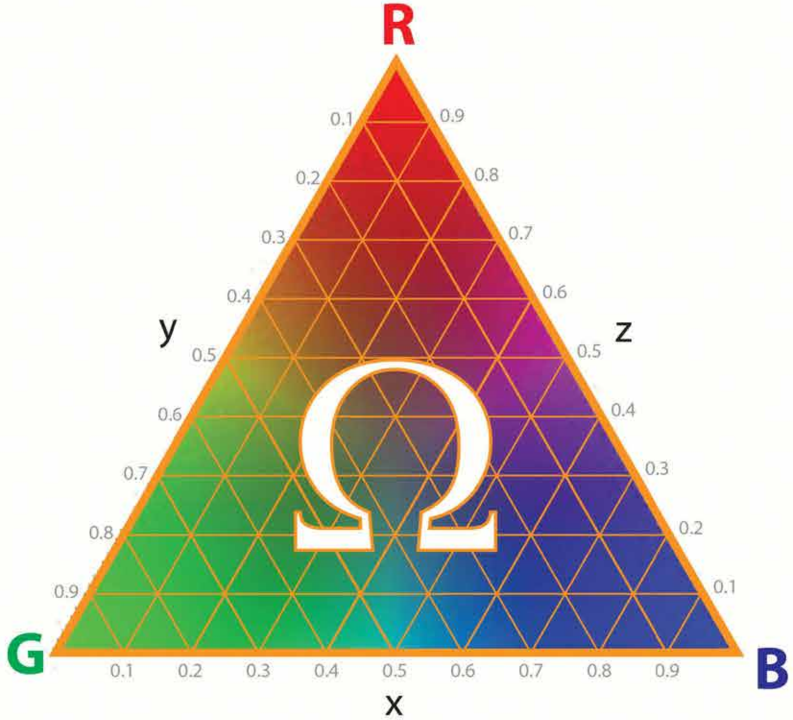
R
G
B
y
z
x
Ω
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

In a ternary plot, of EM energy the Electric field [E] and the Magnetic dipole [N-S] must renormalise to 1

A ternary diagram is simply a triangular coordinate system in which the 3 edges correspond to the axes.

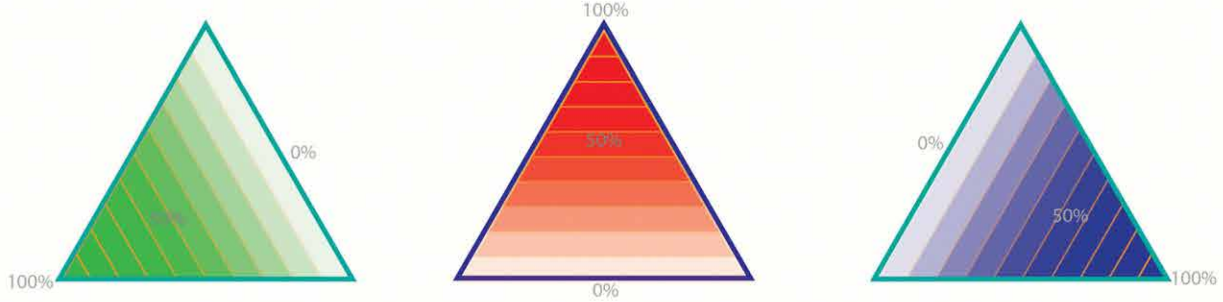
0%
50%
100%
100%
50%
0%
0%
50%
100%

Trilinear charts are commonly used for finding the result of mixing three components (such as gases, chemical compounds, soil, color, etc.) that add to 100% of a quantity.

Whilst the Pythagorean Theorem boasts a slightly greater economy of terms than the Eutrigon Theorem (Wayne Roberts 2003), the latter contains an important area not included in the former:

the area enclosed or swept out by the three points of the triangle in question

$$ab = a^2 + b^2 - c^2$$

the area of any eutrigon is equal to the combined areas of the equilateral triangles on legs 'a' and 'b', minus the area of the equilateral triangle on its hypotenuse 'c'.

The Pythagorean theorem

$$a^2 + b^2 = c^2$$

The square of the hypotenuse of a triangle is equal to the sum of the squares of its sides.

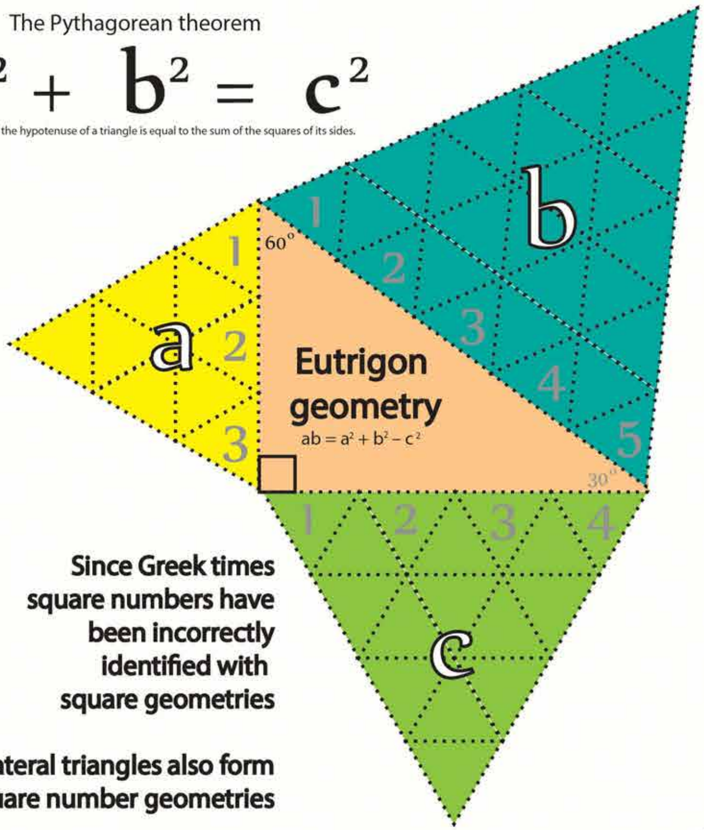

Since Greek times square numbers have been incorrectly identified with square geometries

Equilateral triangles also form square number geometries

Eutrigons

are an important new class of triangle (mathematically defined by Wayne Roberts), as the analogue of the right-triangle in orthogonal (Cartesian) coordinate geometry

Kepler's Second Law of planetary motion

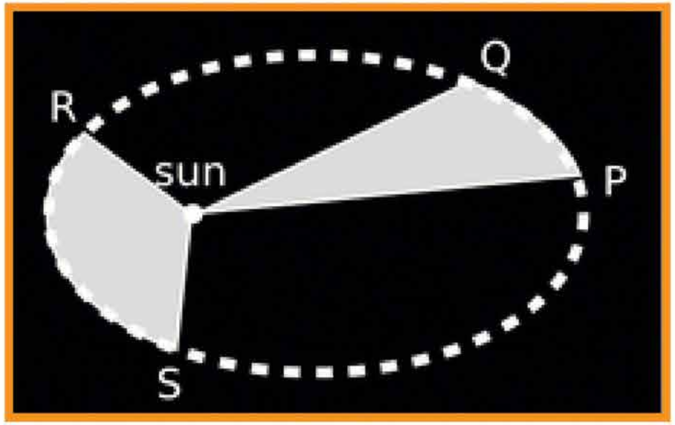

The orbit of every planet is an ellipse with the Sun at one of the two foci.

A line joining a planet and the Sun sweeps out equal areas during equal intervals of time.

The algebraic form of the Eutrigon Theorem, (like the algebraic form of Pythagoras' Theorem), is proven to be special case of the Cosine Rule...

Tetryonic theory reveals the equilateral [square] energy geometry that reveals the 'harmonics at play' in physical laws such as the second law of Kepler, and in many other phenomena in physics, chemistry, cosmology, biochemistry and number theory thus providing the foundation for the mathematics of quantum mechanics

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Number theory

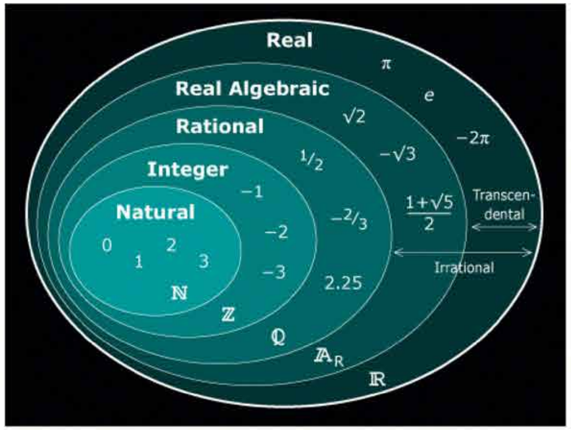
Real
π
Real Algebraic
e
√2
−2π
Rational
1/2
−√3
Integer
−1
Natural
1+√5 / 2
Transcen-dental
0
1
2
3
−2
−2/3
Irrational
−3
2.25
ℕ
ℤ
ℚ
𝔸_R
ℝ

The Pythagoreans also established the foundations of number theory, with their investigations of triangular, square and also perfect numbers (numbers that are the sum of their divisors).

They discovered several new properties of square numbers, such as that the square of a number n is equal to the sum of the first n odd numbers (e.g. 1 + 3 + 5 + 7 = 16).

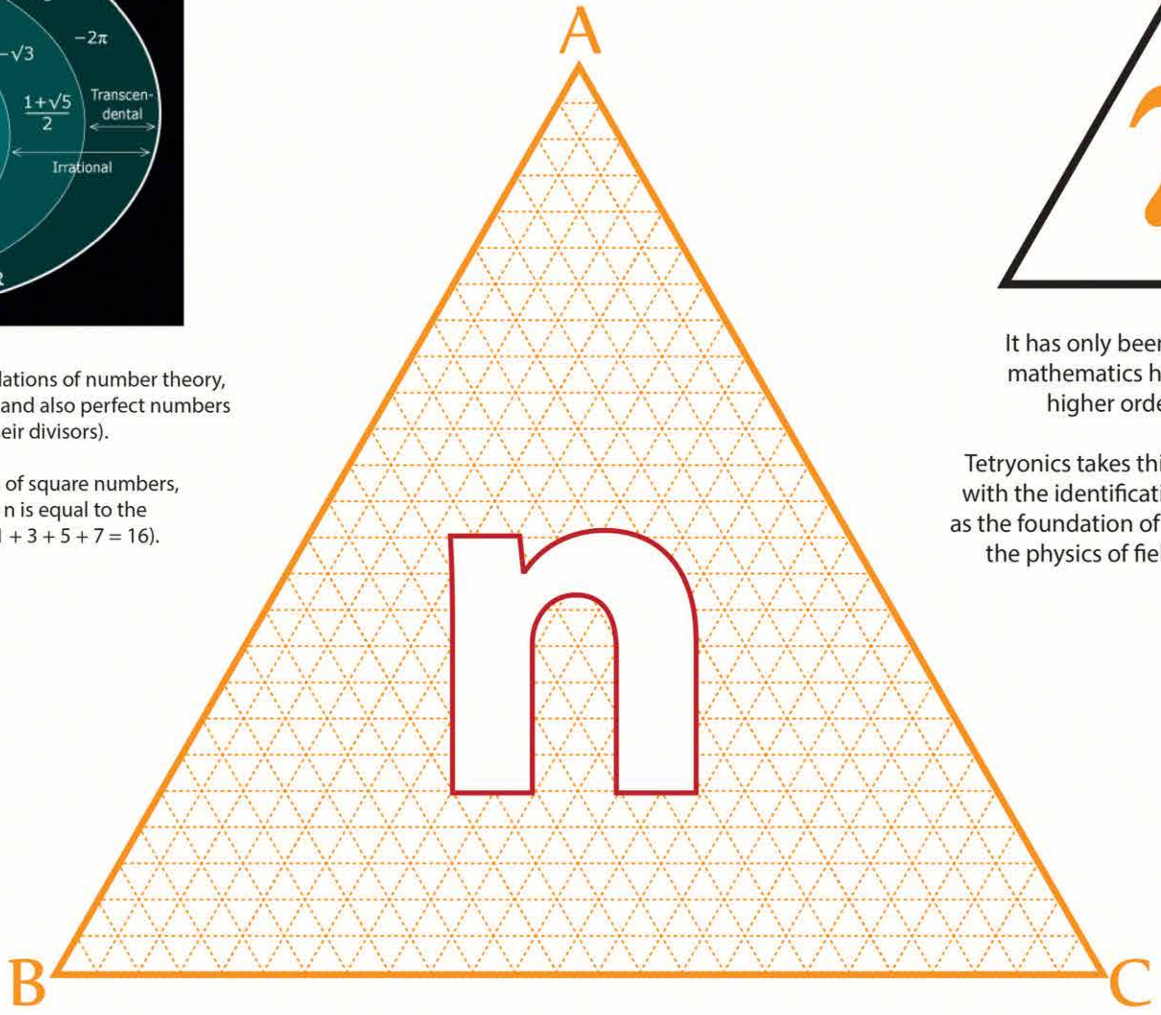

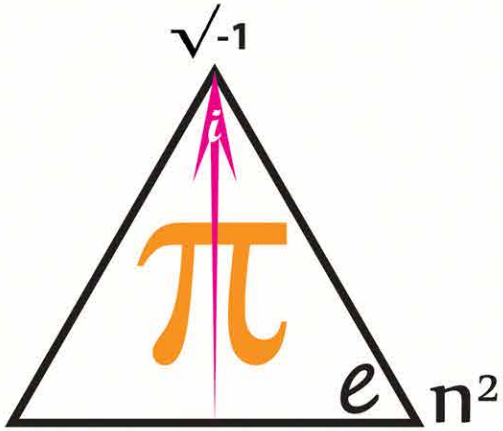

It has only been in recent centuries that mathematics has begun to explore the higher order irrational numbers

Tetryonics takes this investigation to new levels with the identification of equilateral geometries as the foundation of transcendental numbers and the physics of fields and particles in motion

What mathematics has failed to appreciate is the significance application of equilateral geometries to the 'square' numbers of physics and science in general

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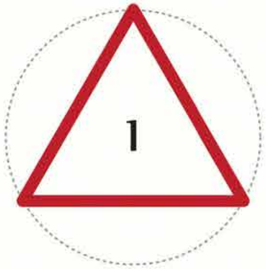

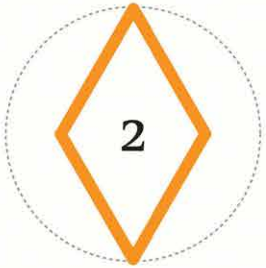

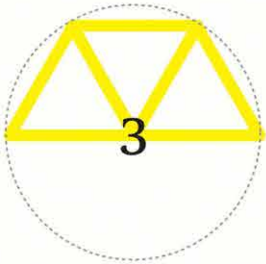

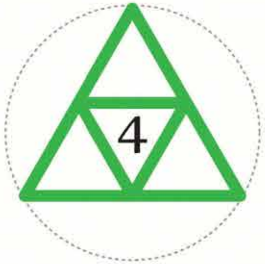

TETRYONICS

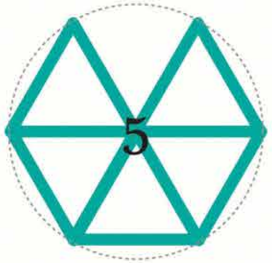

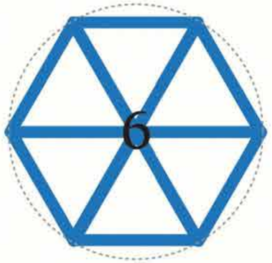

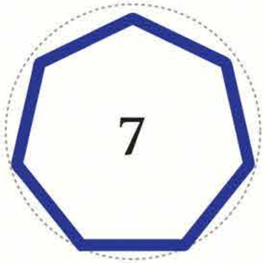

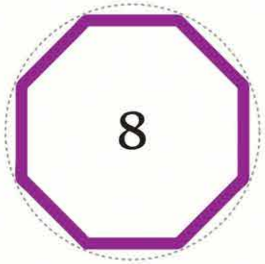

COUNTING POLYGONS

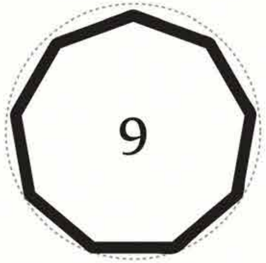

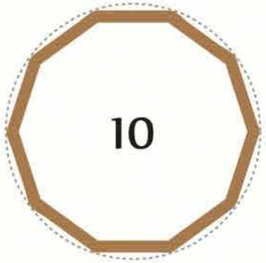

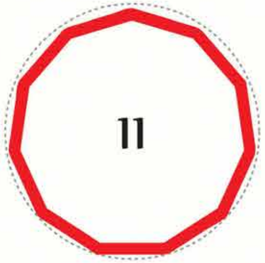

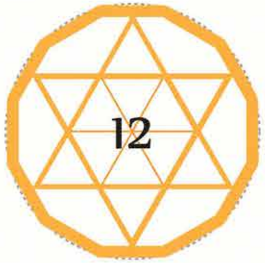

SQUARED energies in quantum mechanics are EQUILATERAL geometries

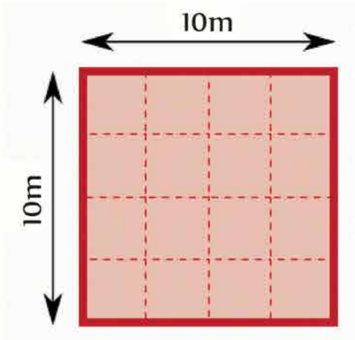

Square

area = s^2 = [100]

Circles

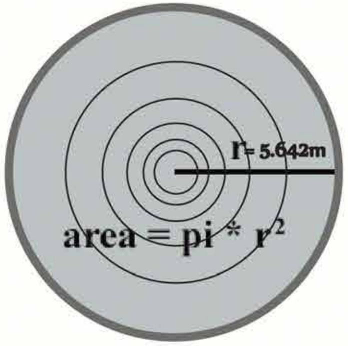
r= 5.642m
area = pi * r²

= pi *$[5.642]^2$
= 100

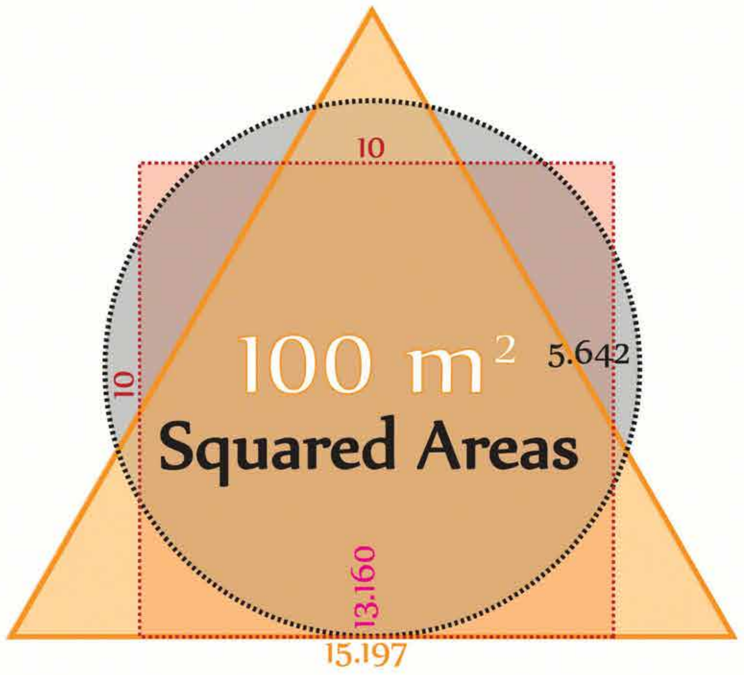
10
10
100 m²
5.642
Squared Areas
13.160
15.197

can be created by a number of planar geometries

For a long time it has been assumed by scientists (and mathematicians) that circular [and squared] geometries are the geometric foundation of all physics, leading to a serioulsy flawed model of particles and forces in quantum mechanics

Tetryonic theory now reveals that quantised equilateral angular momenta creates the foundational geometry of all the mass-Energy-Matter & forces of physics

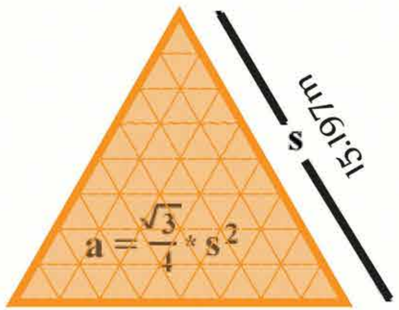
$a = \frac{\sqrt{3}}{4} * s^2$
s
15.197m

Equilateral

area = $(\frac{1}{2}*b)*h$

Triangles

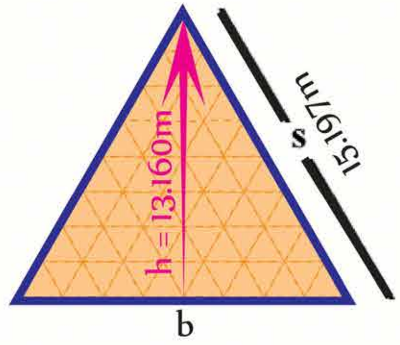
h = 13.160m
s
15.197m
b

b h
[.5x15.197] x 13.160
= 100

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0.987654321

SQUARE ROOTS

80/81

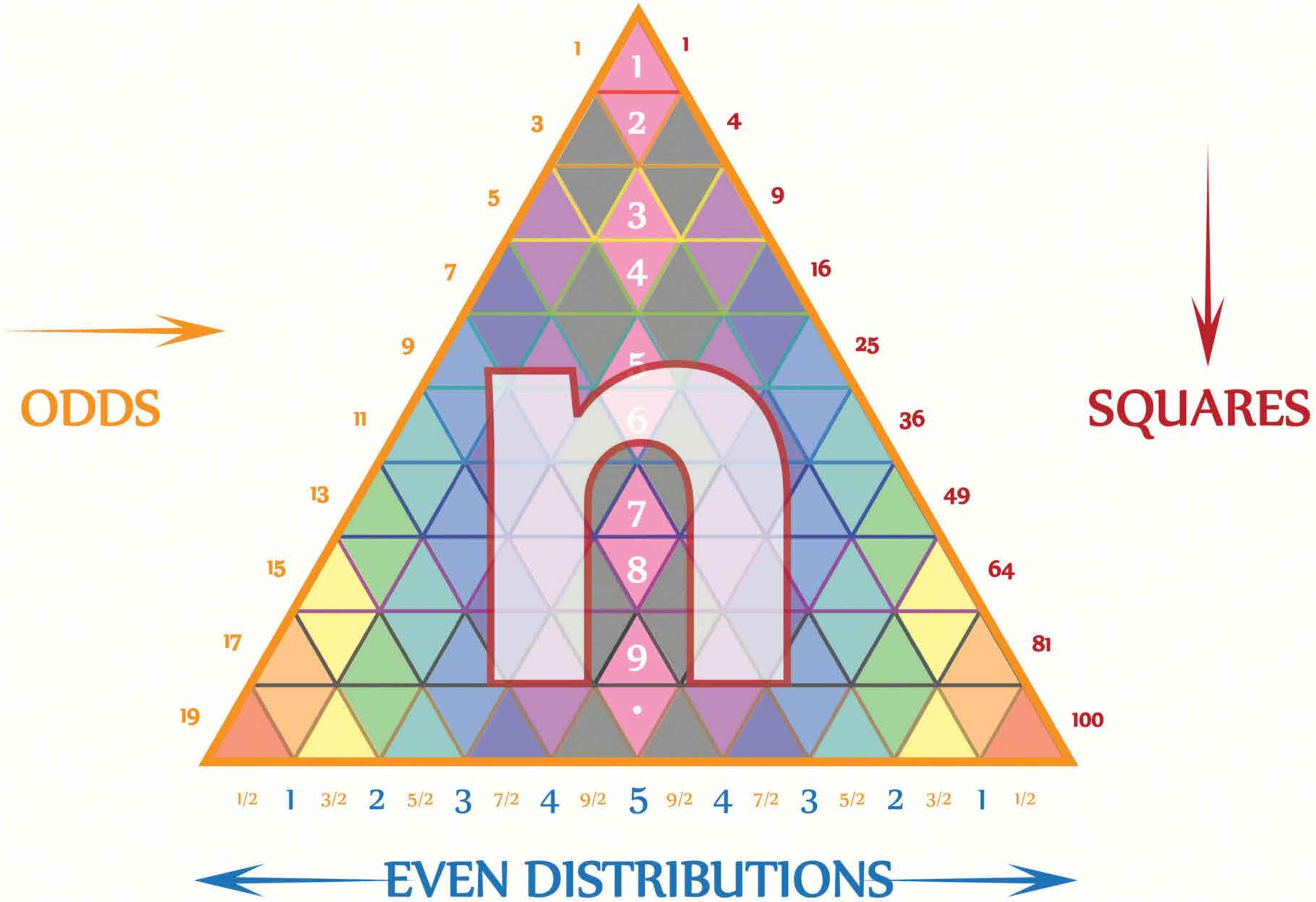
1
2
3
4
5
6
7
8
9
•
1
3
5
7
9
11
13
15
17
19
1
4
9
16
25
36
49
64
81
100
ODDS
SQUARES
1/2
1
3/2
2
5/2
3
7/2
4
9/2
5
9/2
4
7/2
3
5/2
2
3/2
1
1/2
EVEN DISTRIBUTIONS

Integers

The integers (from the Latin integer), literally "untouched", hence "whole"
in Tetryonics it is the basis for the Planck charge quantum

2n-1

[[n] + [n-1]]

Triangular numbered geometries are NOT equialteral geometries

0, 1, 3, 6, 10, 15, 21, 28, 36, 45, 55, ...

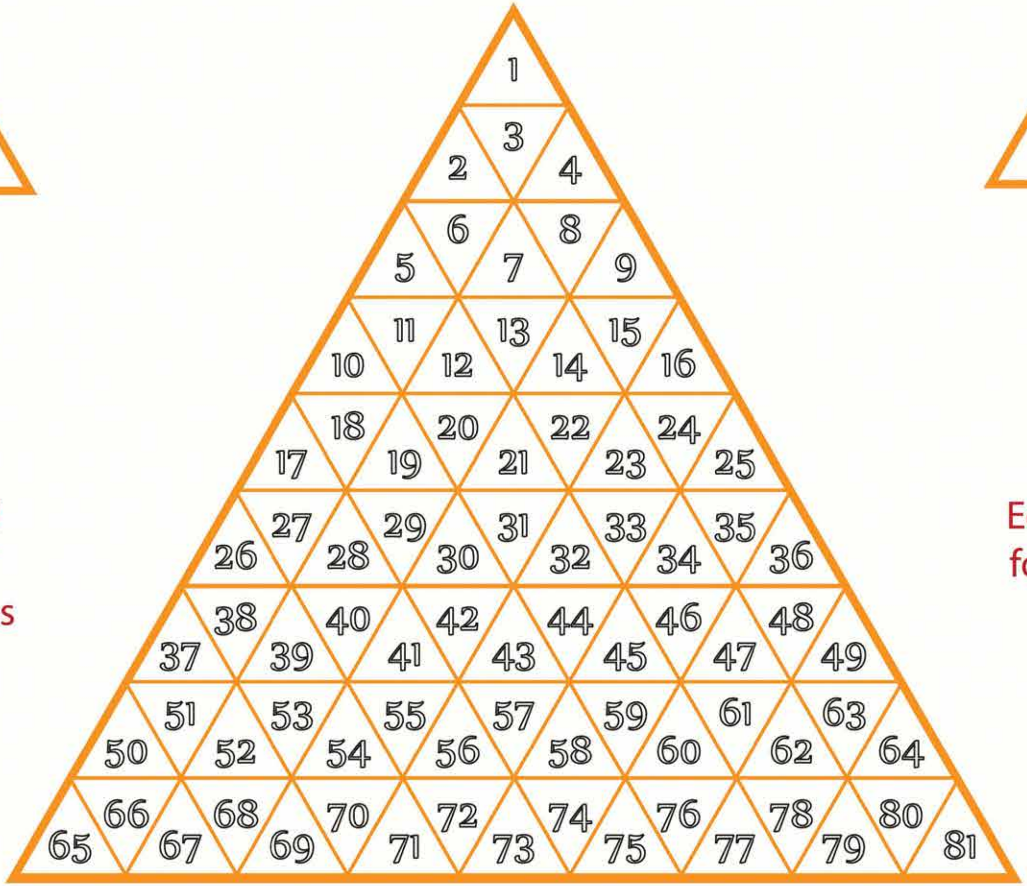
1
2 3 4
5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 43 44 45 46 47 48 49
50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81

1 2 3 4 5 6 7 8 9 8 7 6 5 4 3 2 1

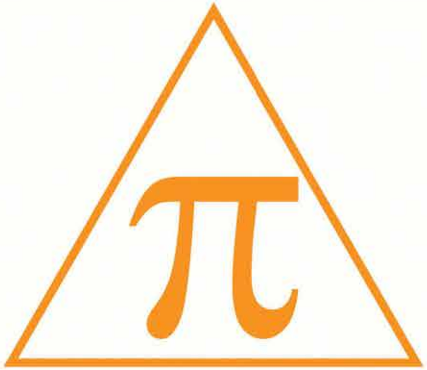

$$\sum_{1}^{n}[2n-1]$$

Equilateral geometries form **SQUARE** number geometries

1, 4, 9, 16, 25, 49, 64, 81, 100, 121, 144, ...

Equilateral energy quanta form a normal longitudinal distribution

Viewed as a subset of the real numbers, they are numbers that can be written without a fractional or decimal component

ε_0
π
μ_0
μ_0

Bosons are a transverse measure of scalar energy momenta

ODD numbers

An odd number is an integer which is not a multiple of two.

E
E
μ_0
μ_0
n
3
ε_0
ε_0
+
−
N
S
S
N

Quantum

Bosons have ODD number quanta

Quantum Levels

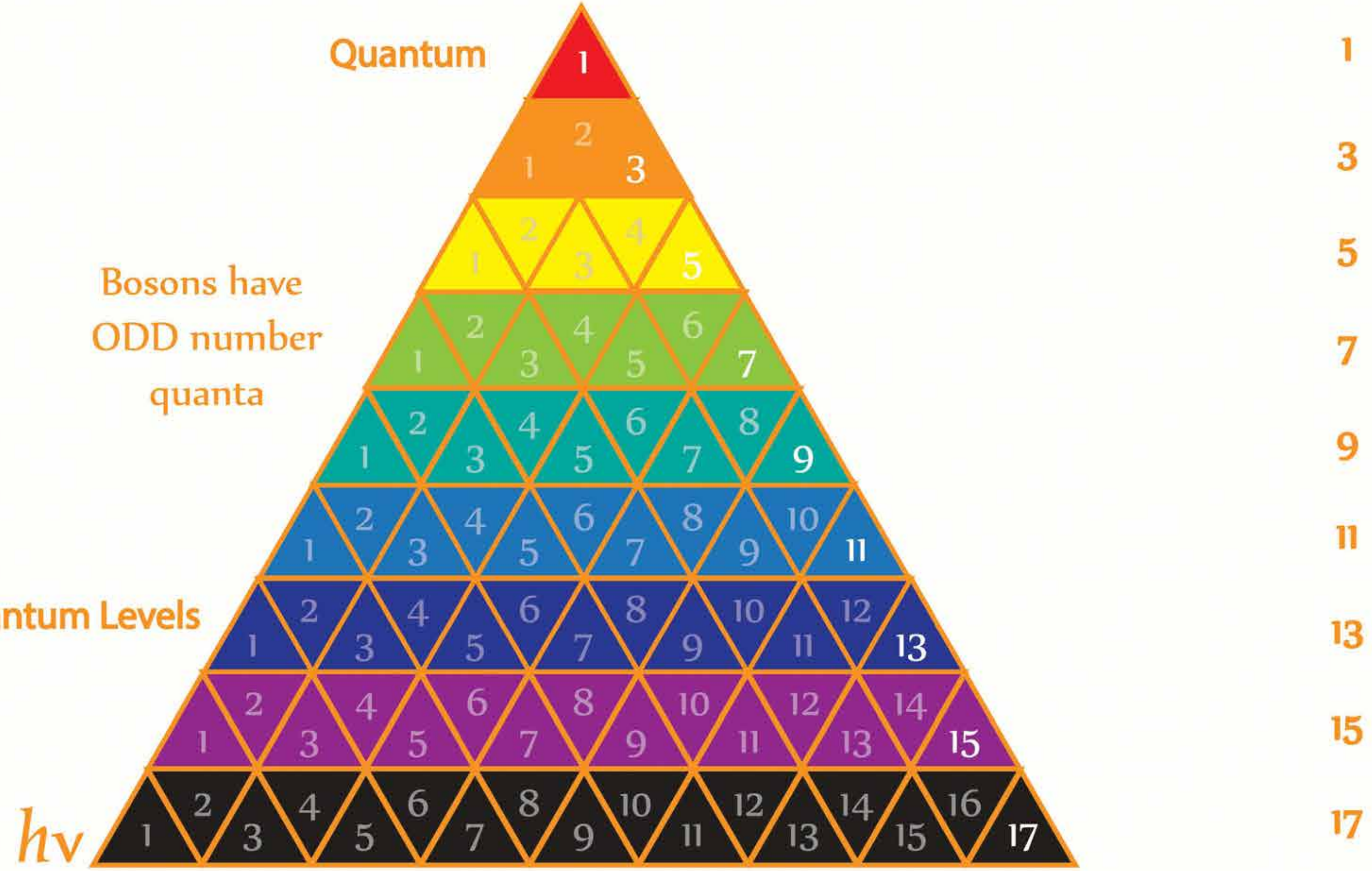
1
1 2 3
1 2 3 4 5
1 2 3 4 5 6 7
1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9 10 11
1 2 3 4 5 6 7 8 9 10 11 12 13
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
hv
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
1
3
5
7
9
11
13
15
17

An odd number, when divided by two, will result in a fraction

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Tau radians

Around the whole outside of a circle,
there are about 6.283 radians - or, Tau radians

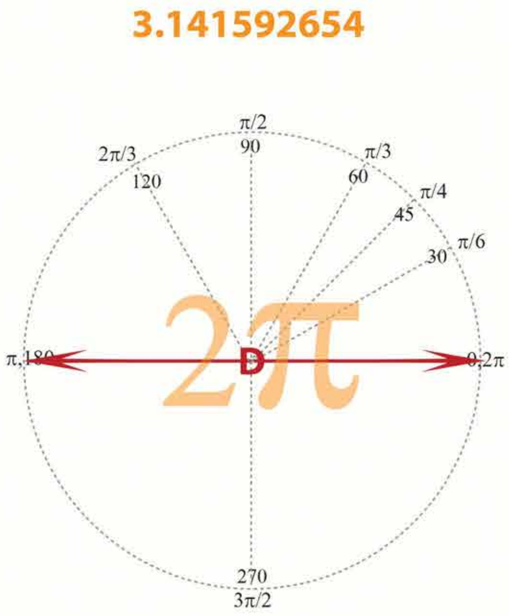
3.141592654
π/2
90
2π/3
120
π/3
60
π/4
45
π/6
30
π,180
0,2π
2π
D
270
3π/2

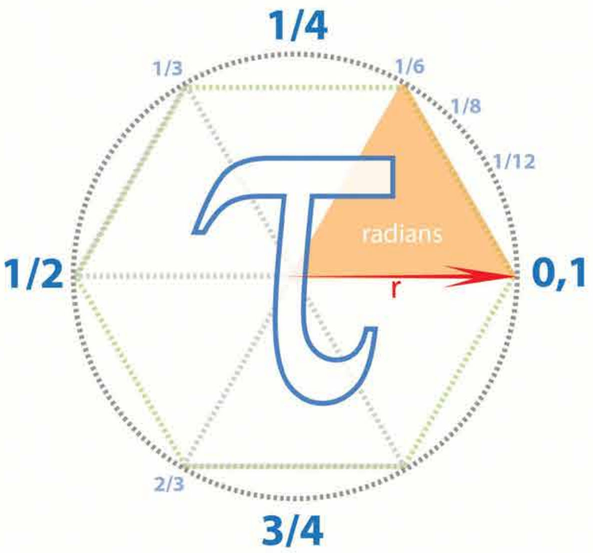
1/4
1/3
1/6
1/8
1/12
1/2
0,1
τ
radians
r
2/3
3/4

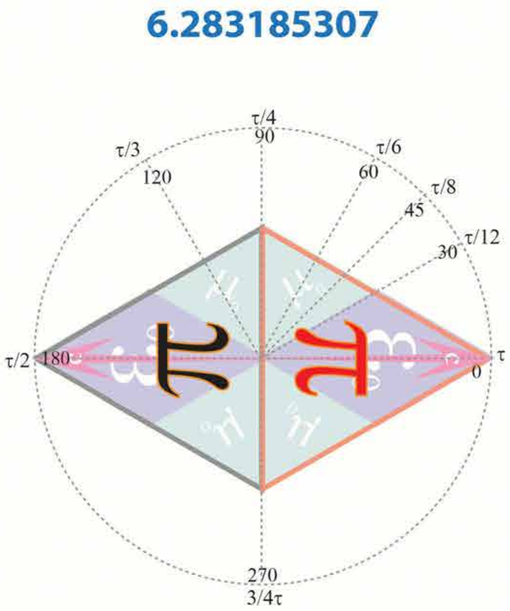
6.283185307
τ/4
90
τ/3
120
τ/6
60
τ/8
45
τ/12
30
τ/2
180
τ
0
π
270
3/4τ

τ is a more 'natural' radian system for geometric physics than π
Tau = 2π = 360 degree rotation about a point

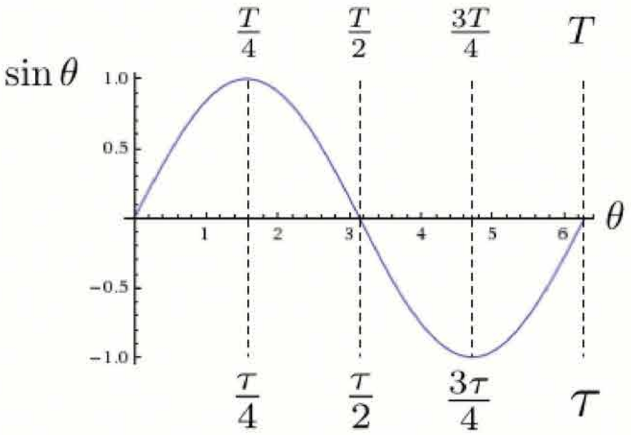

π
historically defined as the
ratio of a circle's circumference to its DIAMETER
should be redefined in physics to

τ
the ratio of its circumference to its RADIUS

in doing so many of the π/2 terms common to physics
will re automatically rationalised and will better reflect
the Tetryonic geometry of mass-ENERGY-Matter in motion

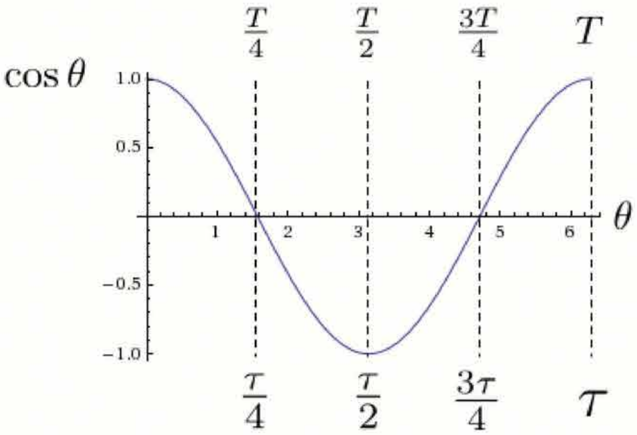

Photons are a longitudinal measure of scalar energy momenta

E
ε0
+
2
N
N
S
S
−
μ0
E

Photons are
EVEN number
quantums

EVEN numbers

An integer that is not an odd number is an even number

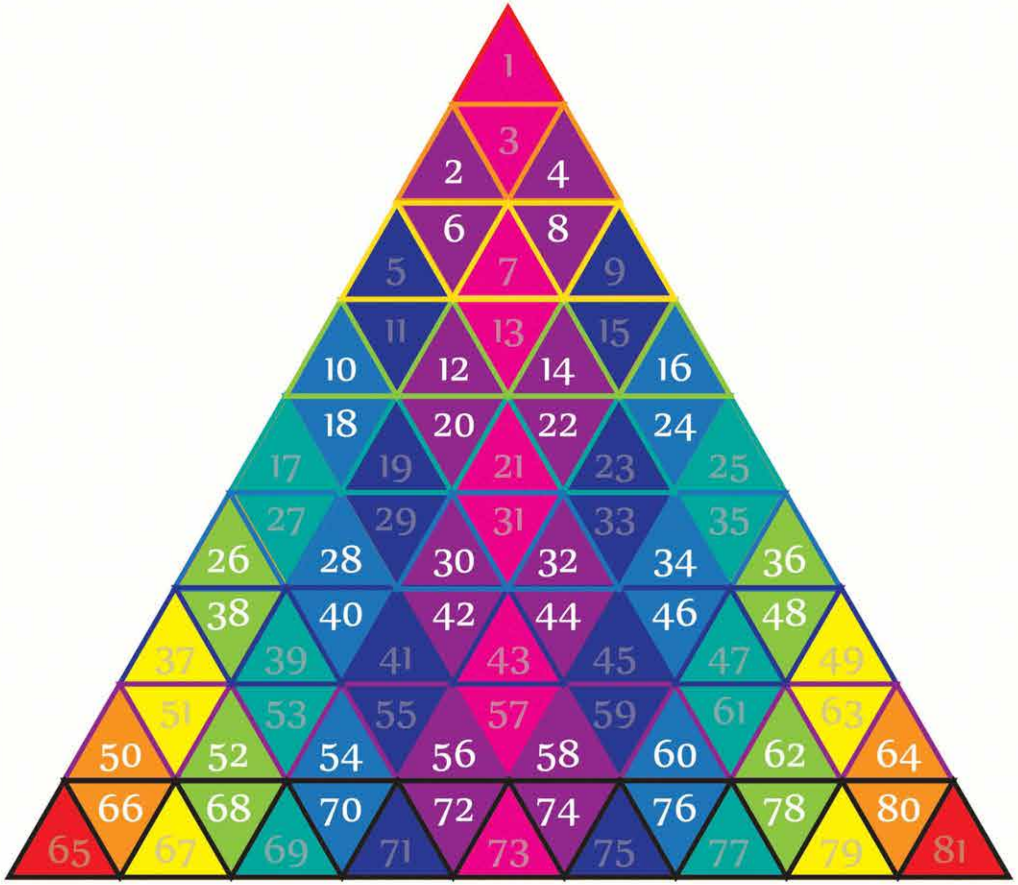
1
2 3 4
5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 43 44 45 46 47 48 49
50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81

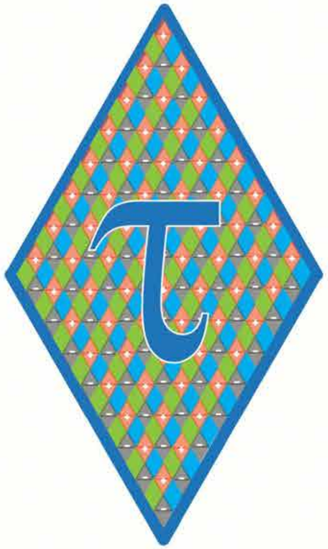

EM waves are
comprised of EVEN
numbered quanta

If an even number is divided by two, the result is another whole number

1/2 **1** 3/2 **2** 5/2 **3** 7/2 **4** 9/2 **4** 7/2 **3** 5/2 **2** 3/2 **1** 1/2

If an odd number is divided by two, the result is a fractional number

Triangular numbers

Historically, a triangular number counts quanta that can pack together to form an equilateral triangle

1, 3, 6, 10, 15, 21, 28, 36, 45, 55, ...

this form of geometric counting of same charges over-complicated the simpler physical reality

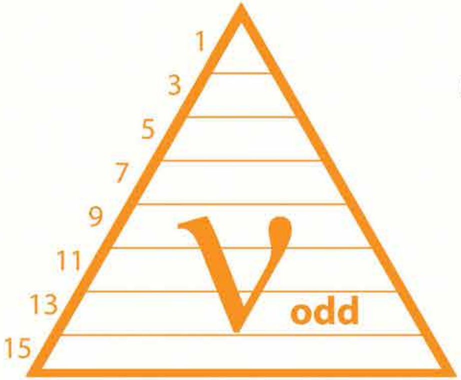
1
3
5
7
9
11
13
15
ν
odd

$$2\nu-1$$

$$[\nu] + [\nu-1]$$

Equilateral chords or quantum levels are ODD numbers

1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21,....

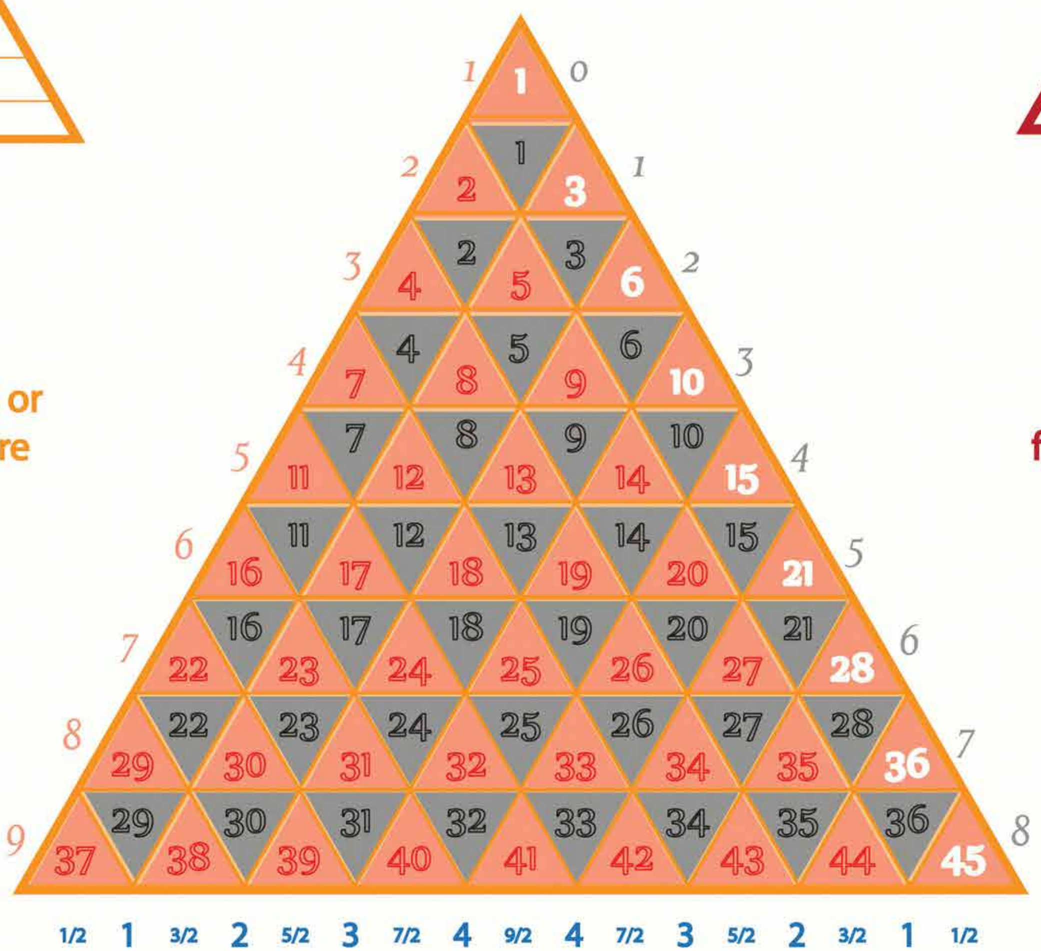
1 1 0
2 2 1 3 1
3 4 2 5 3 6 2
4 7 4 8 5 9 6 10 3
5 11 7 12 8 13 9 14 10 15 4
6 16 11 17 12 18 13 19 14 20 15 21 5
7 22 16 23 17 24 18 25 19 26 20 27 21 28 6
8 29 22 30 23 31 24 32 25 33 26 34 27 35 28 36 7
9 37 29 38 30 39 31 40 32 41 33 42 34 43 35 44 36 45 8
1/2 1 3/2 2 5/2 3 7/2 4 9/2 4 7/2 3 5/2 2 3/2 1 1/2

Triangular energy quanta form normal distributions

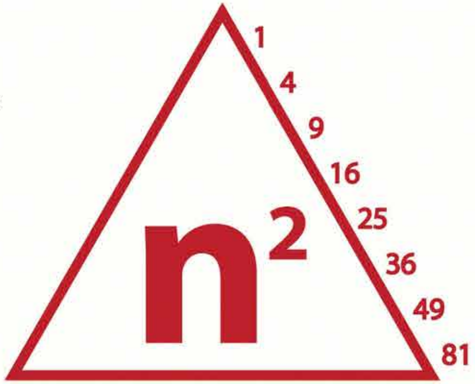
n²
1
4
9
16
25
36
49
81

$$\sum_{1}^{n} [2n-1]$$

Equilateral geometries form SQUARE numbered geometries

1, 4, 9, 16, 25, 49, 64, 81, 100, 121, 144, ...

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Squared numbers

A square number, sometimes also called a perfect square,
is the result of an integer multiplied by itself

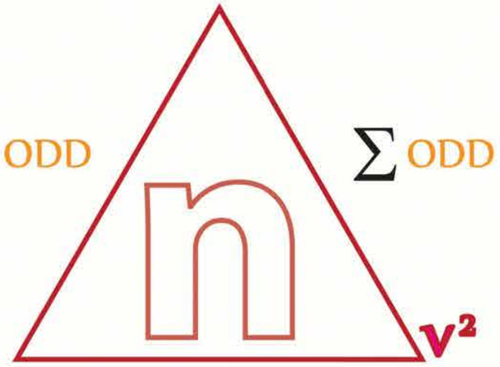

ODD
n
$\sum$ ODD
v^2

1
+
3
+
5
+
7
+
9
+
11
+
13
+
15
+
17

Square numbers result from
the summing of consecutive
ODD numbers

ODDS

2n-1

[[n] + [n-1]]

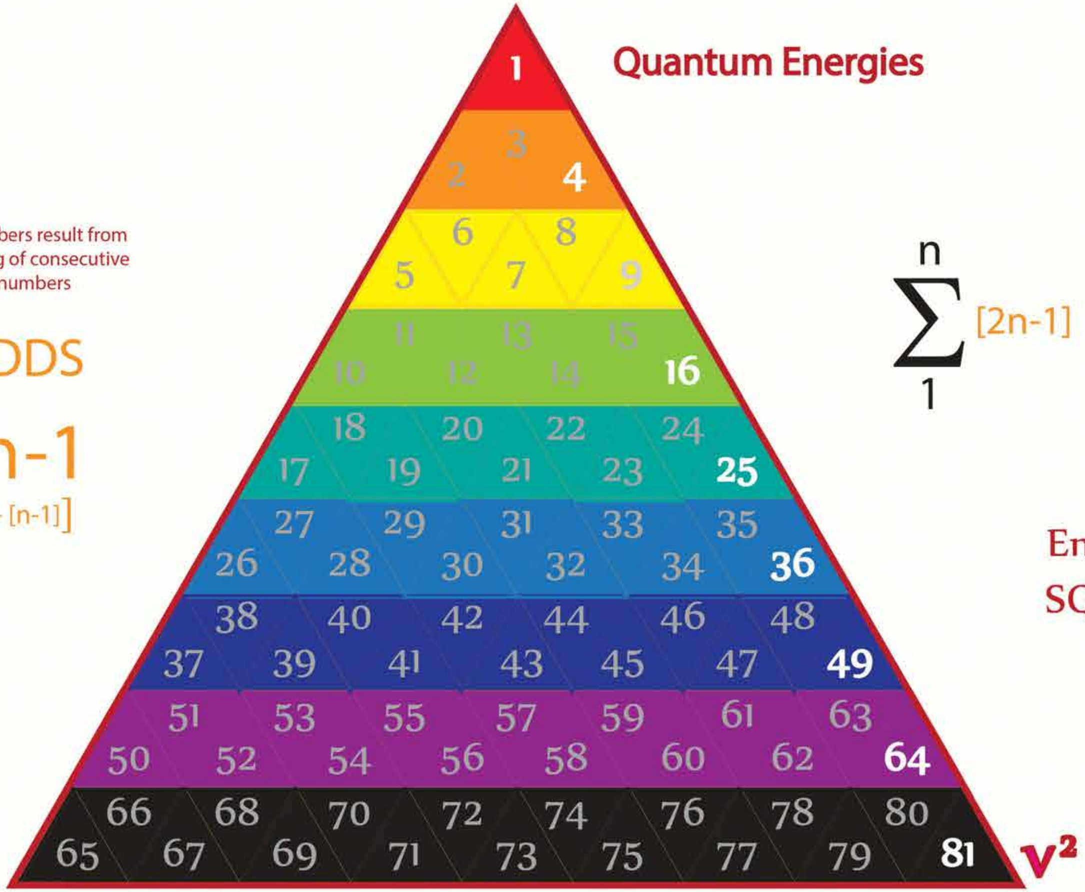

1
2 3 4
5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 43 44 45 46 47 48 49
50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81
v^2

Quantum Energies

$$\sum_{1}^{n} [2n-1]$$

Energy levels have
SQUARE number
quanta

Compton Frequency

In Tetryonics Square numbers produce equilateral geometries

Square roots

A square root of a number is a number that, when it is multiplied by itself (squared) , gives the first number again.

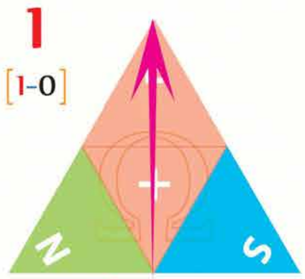

Root of positive one

-*i* and +*i*

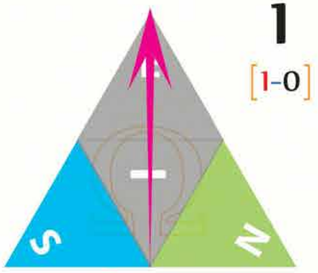

Root of negative one

Square roots of negative numbers have a basis in physical reality

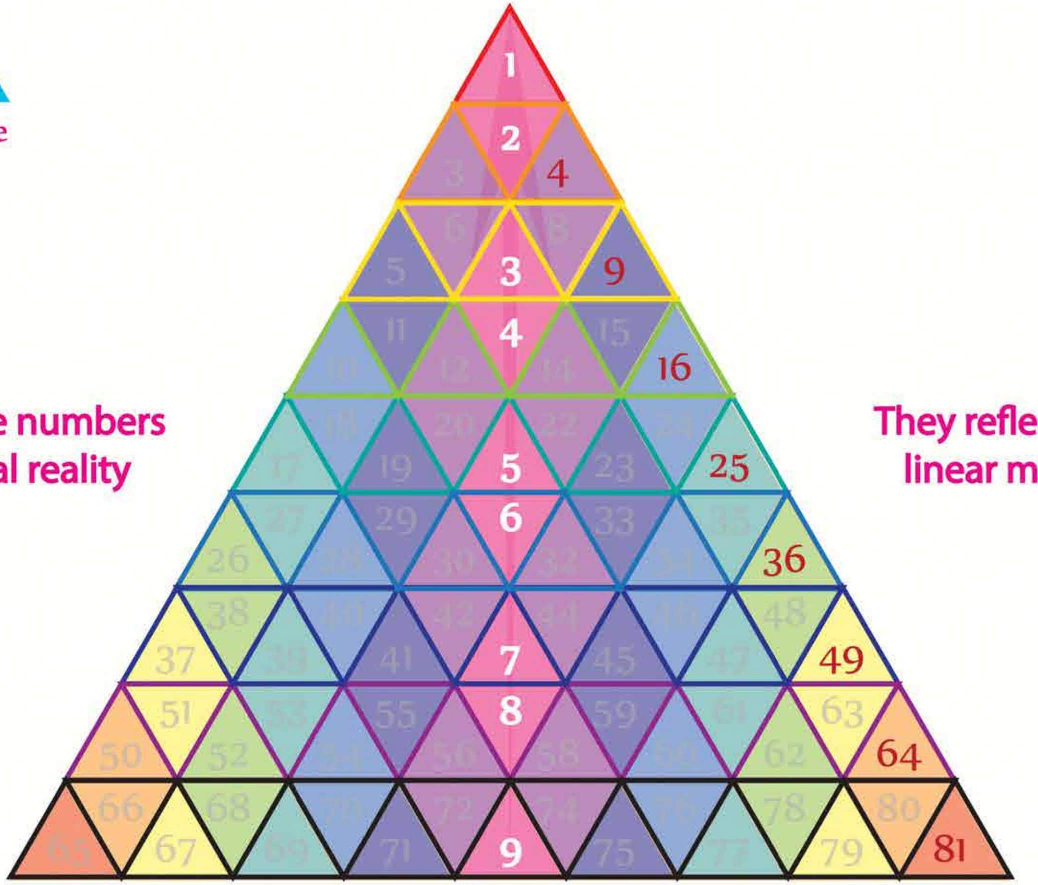

They reflect the real non-negative linear momentum of a system

A whole number with a square root that is also a whole number is called a perfect square in Tetryonic theory they are actually equilateral geometries

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Real Numbers

In mathematics, a real number is a value that represents a quantity along a continuous line. The real numbers include all the rational numbers,

Quantum levels

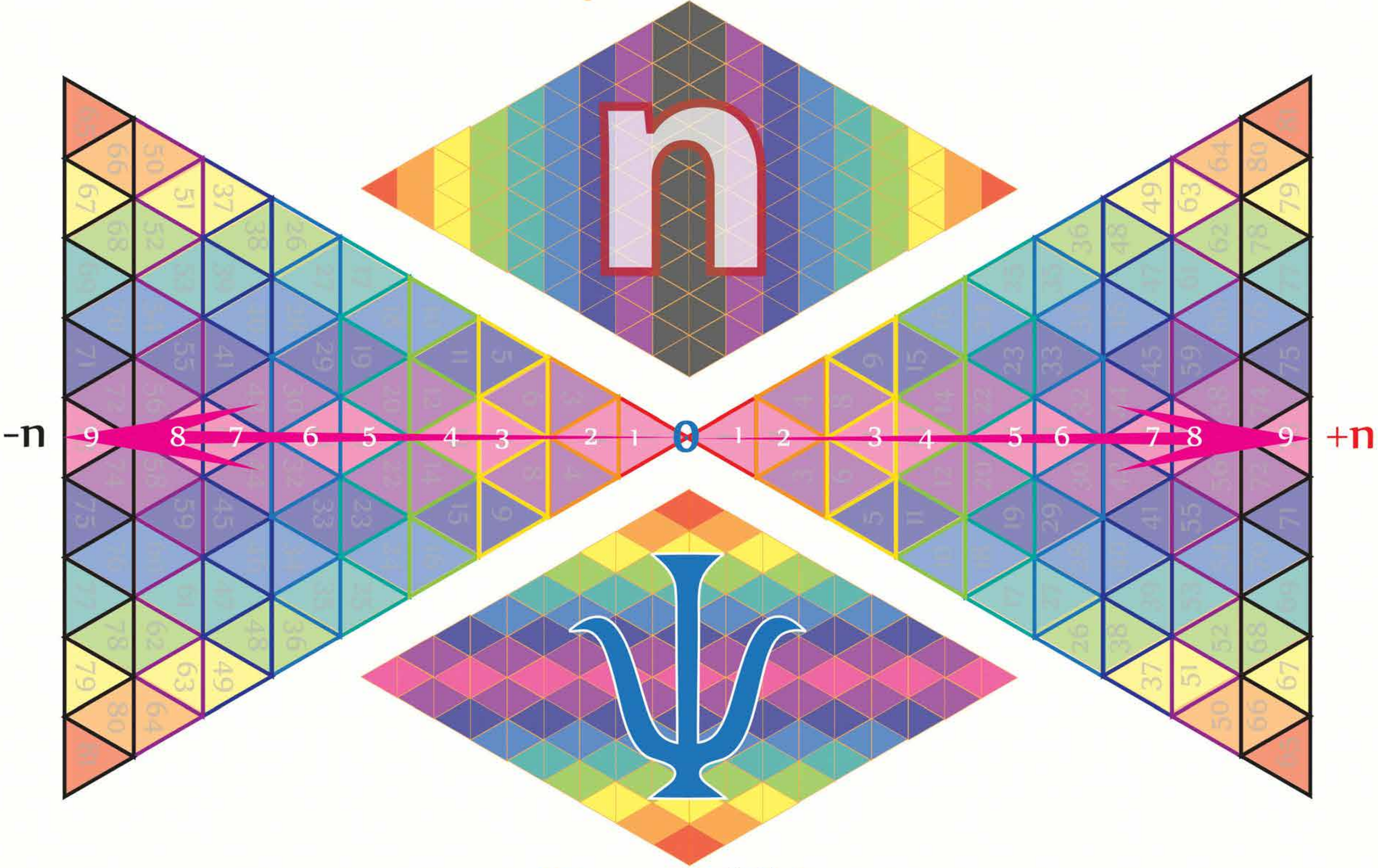

Wave probabilities

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ONE to ∞^2

Quantum levels →

ODD numbers

[2n-1]

1, 3, 5, 7, 9......

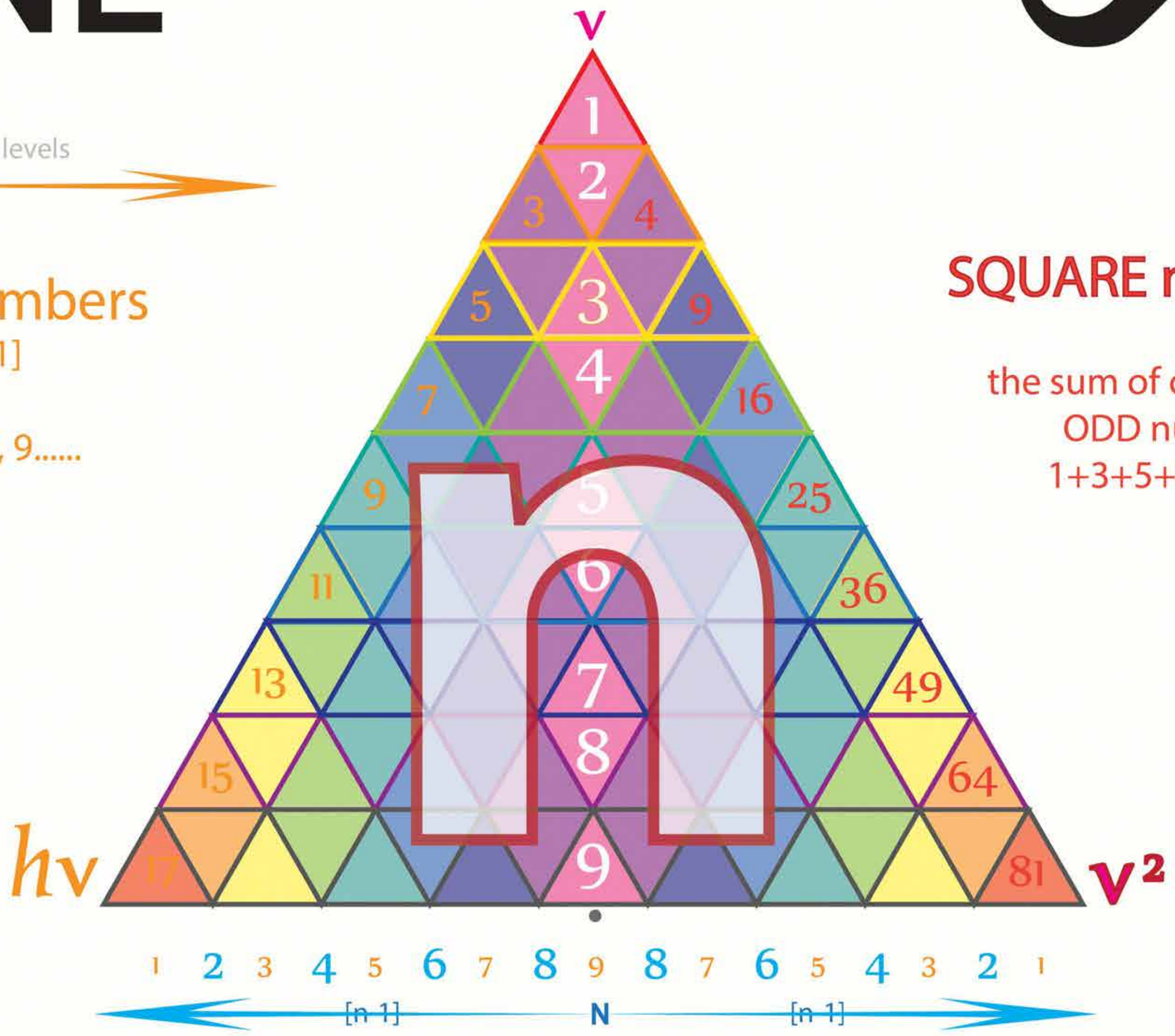
v
1
2
3
4
3
5
9
4
7
16
5
9
25
6
11
36
7
13
49
8
15
64
9
17
81
n
hv
v²
1 2 3 4 5 6 7 8 9 8 7 6 5 4 3 2 1
[n-1]
N
[n-1]

SQUARE numbers

the sum of consecutive ODD numbers

1+3+5+7+9+......

Scalar Energies

Linear energy momentum

NORMAL DISTRIBUTION

Tetryonics 82.13 - One to Infinity squared

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Basic Properties of nested scribed Equilateral Triangles

Given an equilateral triangle of side s

altitude

$\sqrt{3/2}\,S$

$3S$

perimeter

$\sqrt{3/4}\,S^2$

area

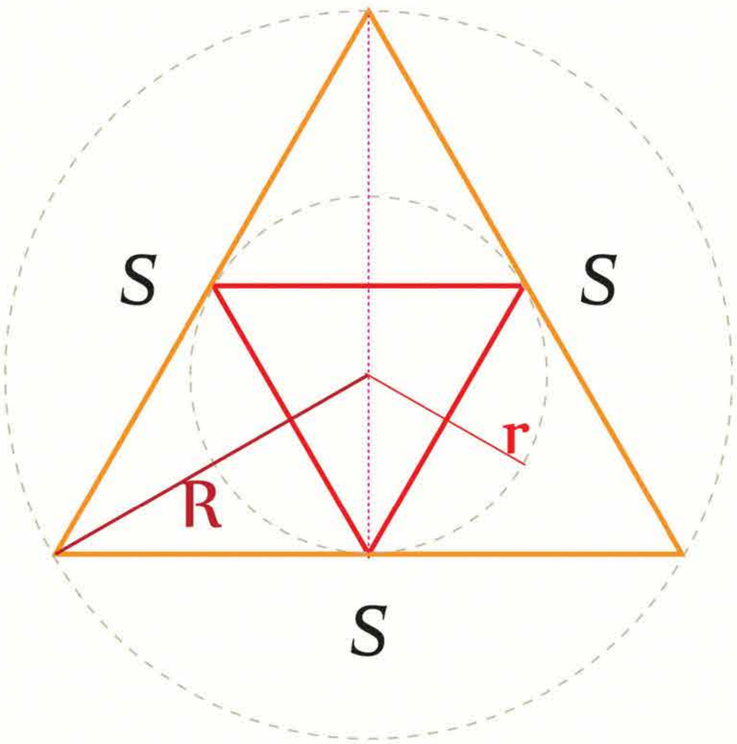

$\sqrt{3/6}\,S$

in-radius

$\sqrt{\pi/12}\,S^2$

in-circle area

circum-radius

$\sqrt{3/3}\,S$

circum-circle area

$\sqrt{\pi/3}\,S^2$

Tetryonic [equilateral] geometry

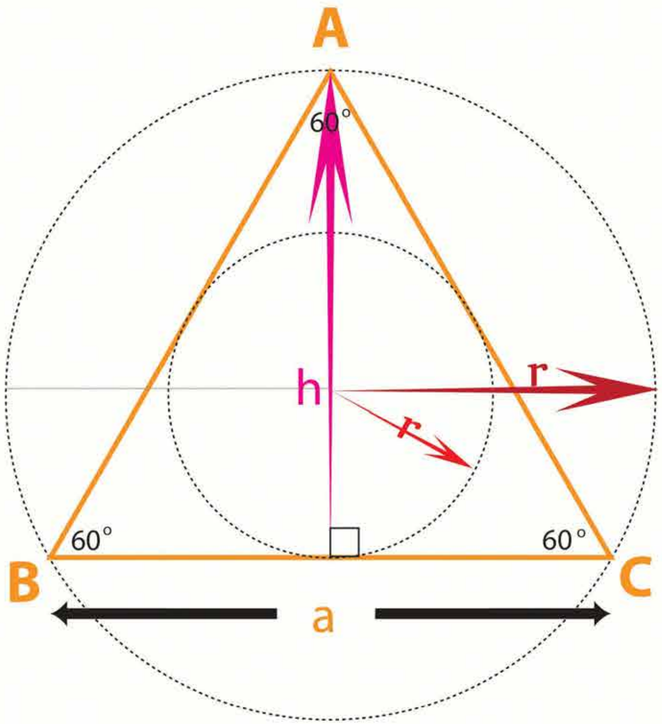

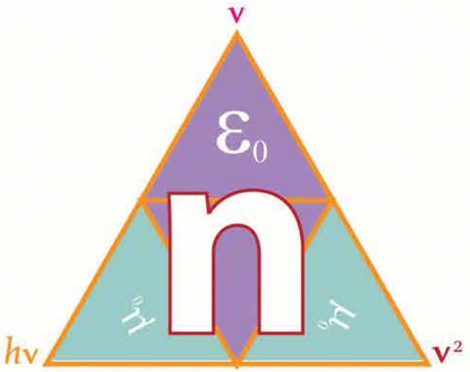

The equilateral triangle exhibits 'square symmetry'
it can always be divided into n^2 [number]
of smaller self-similar parts

**All triangles are
flat euclidean
π radian
geometries
[180°]**

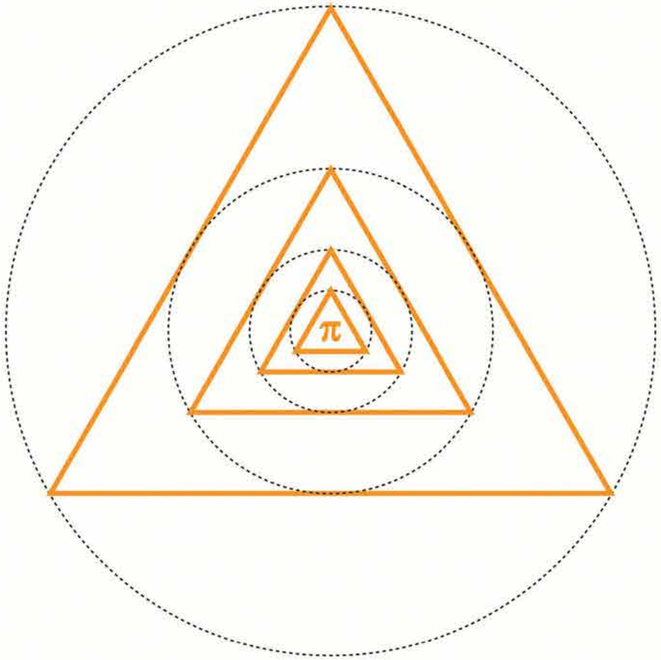

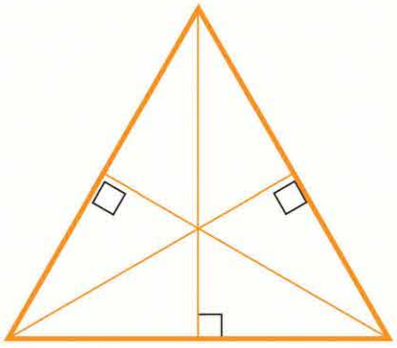

An equilateral triangle is the most symmetrical triangle,
having 3 lines of reflection and rotational symmetry of order 3 about its center

CHARGE

Scribed equilateral geometries

reflect space-time's geometric relationship with charged mass-energy

Energy

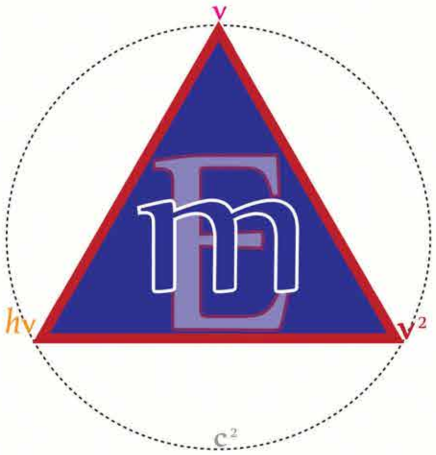

Energy per spatial unit

mass

$$m = \frac{E}{c^2}$$

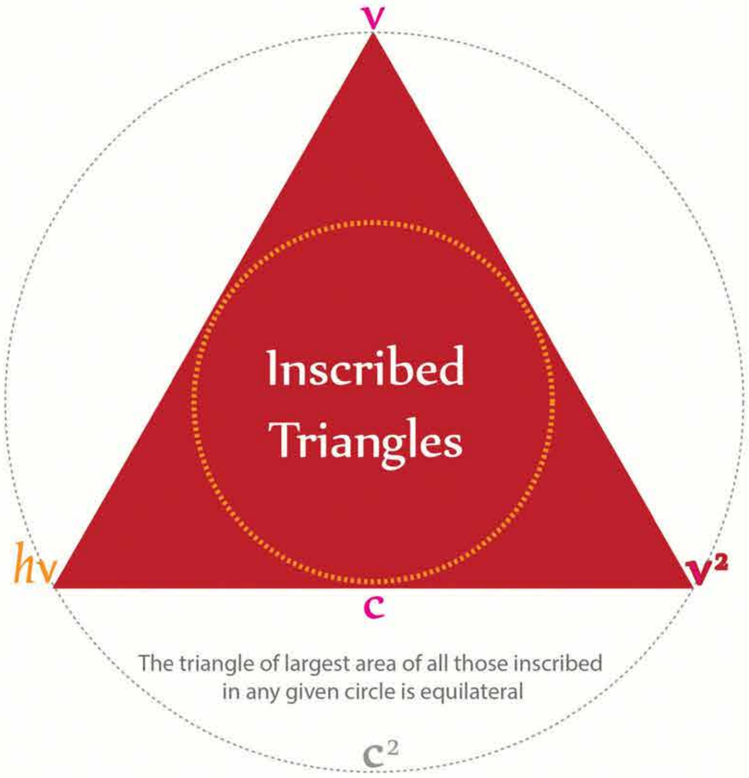
v
Inscribed Triangles
hv
v²
c
c²

The triangle of largest area of all those inscribed in any given circle is equilateral

QAM

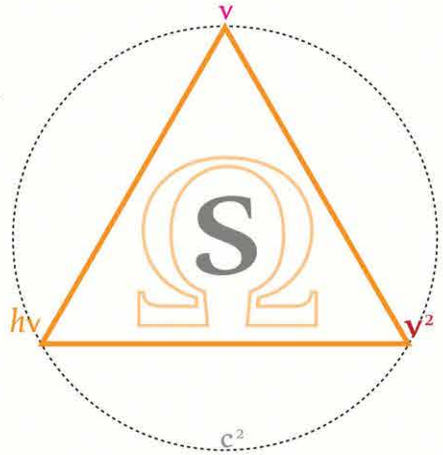

QAM per spatial unit

seconds

$$\frac{\Omega}{c^2} = s$$

Circumscribed Triangles

reflect Energy's relationship with Time

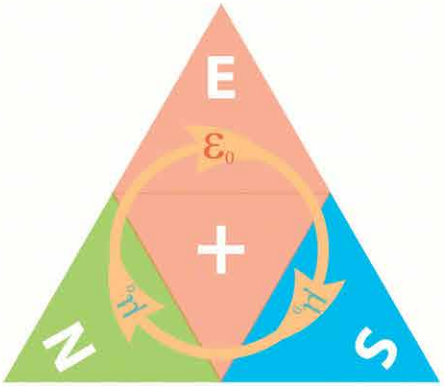
E
ε_0
+
μ_0
μ_0
N
S

Positive Planck Charge

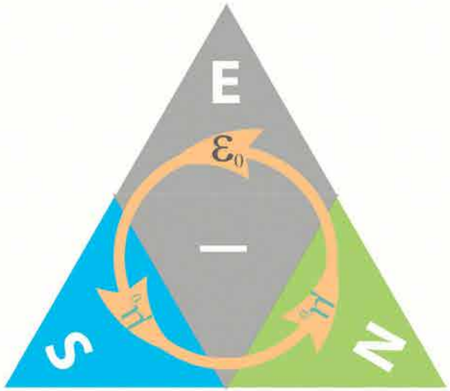
E
ε_0
–
μ_0
μ_0
S
N

Negative Planck Charge

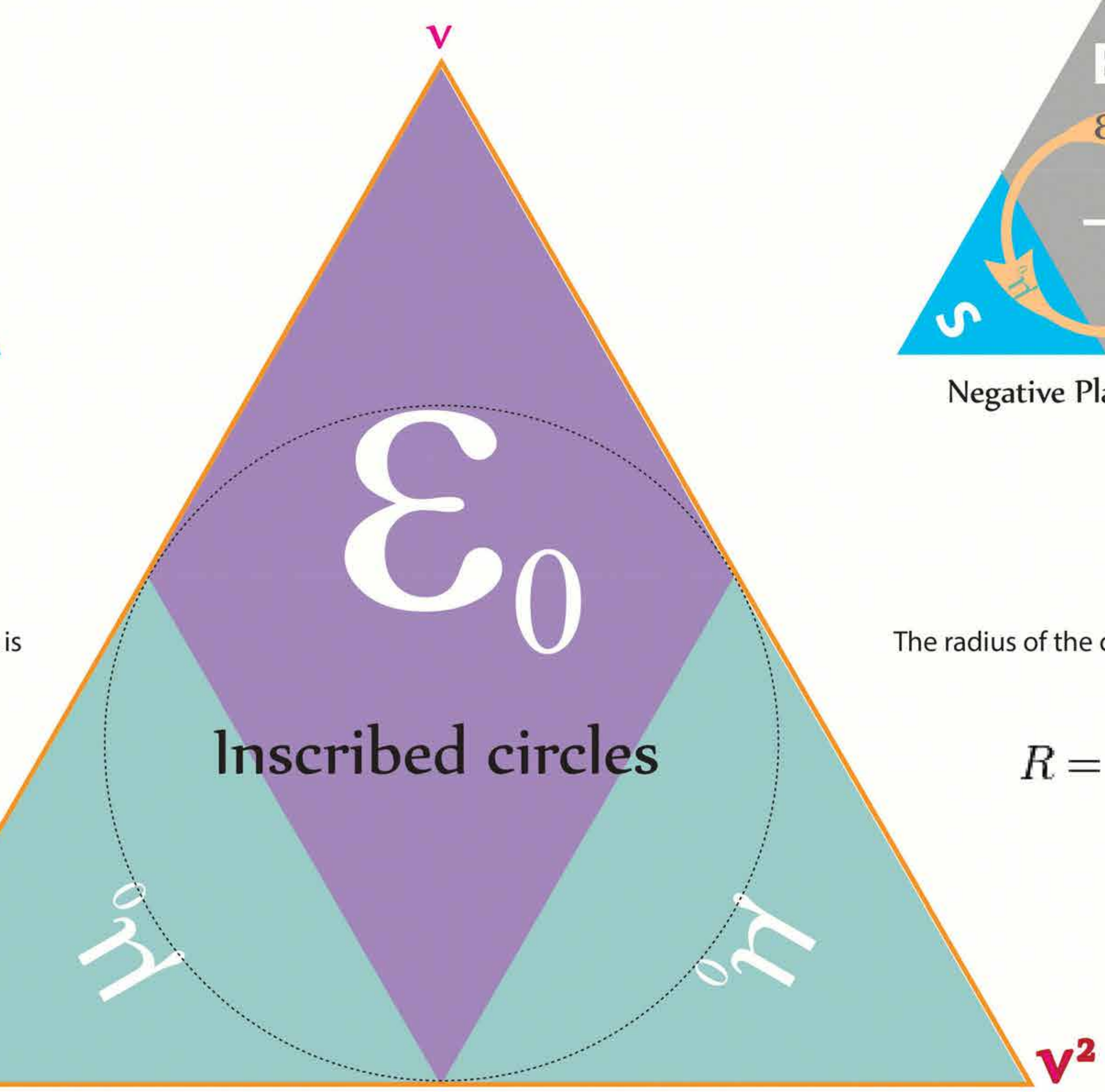
v
ε_0
Inscribed circles
μ_0
μ_0
hv
v^2

The perimiter of an equilateral triangle is

$$p = 3a$$

The radius of the circumscribed circle is

$$R = \frac{\sqrt{3}}{3}a$$

The equilateral triangle has the smallest area of all those circumscribed around a given circle

Circumscribed circles

By Euler's inequality, the equilateral triangle has the smallest ratio R/r of the circumradius to the inradius of any triangle: specifically, R/r = 2

The ratio of the area to the square of the perimeter of an equilateral triangle

$$\frac{1}{12\sqrt{3}}$$

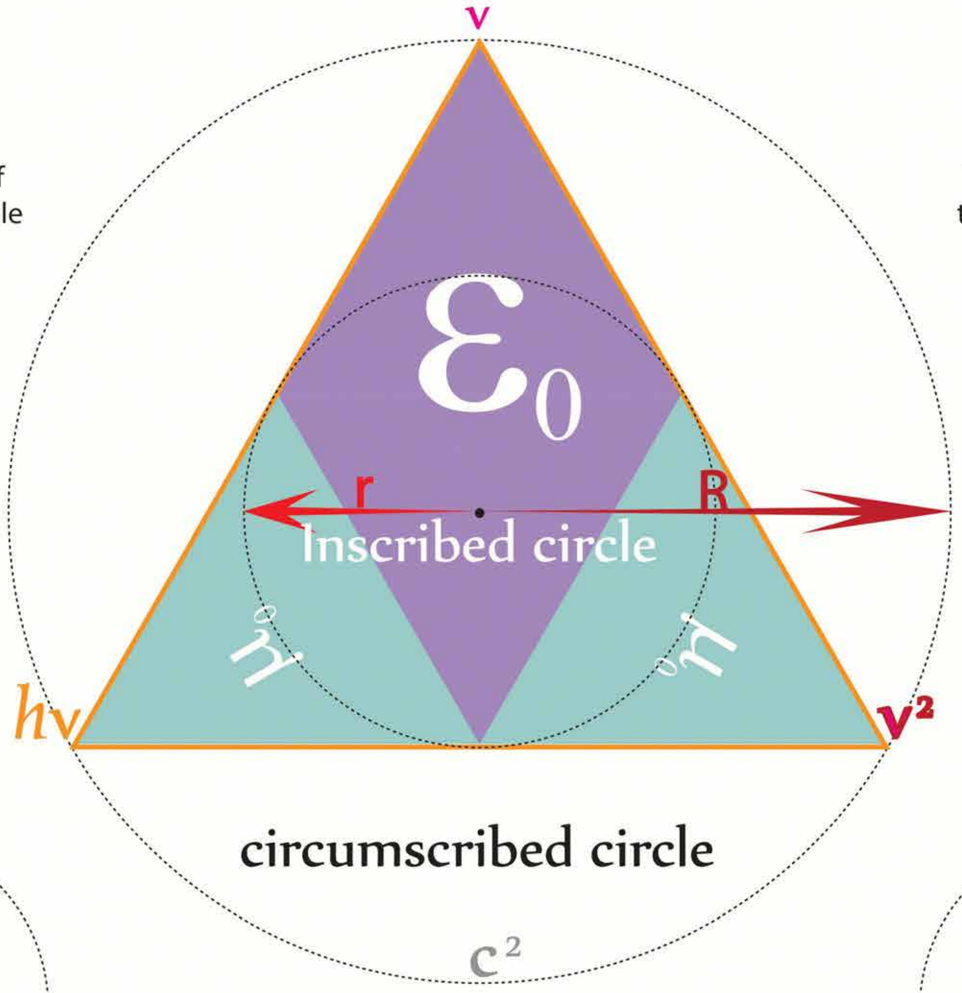
v
ε_0
r
R
Inscribed circle
μ_0
μ_0
hv
v²
circumscribed circle
c^2

The ratio of the area of the incircle to the area of an equilateral triangle

$$\frac{\pi}{3\sqrt{3}}$$

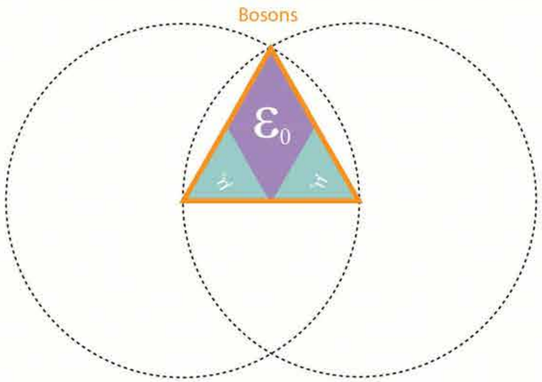
Bosons
ε_0
μ_0
μ_0

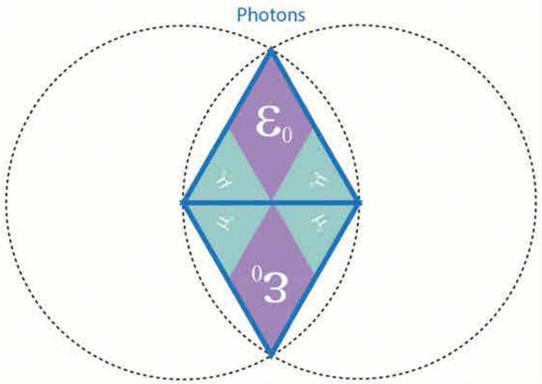
Photons
ε_0
μ_0
μ_0
μ_0
μ_0
ε_0

Equilateral triangles and Tetrahedrons will scale at exactly the same proportion as Circles and Spheres scribing them

Charged mass-ENERGIES

Charge is the result of quantised angular momenta
[the inscribed circular flux of energy in equilateral geometries]

Time is a measure of changing quantised angular momenta
[the circumscribed spatial co-ordinate of equilateral energy geometries]

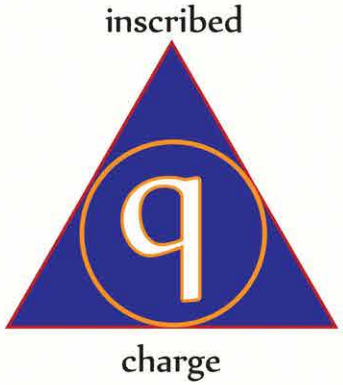

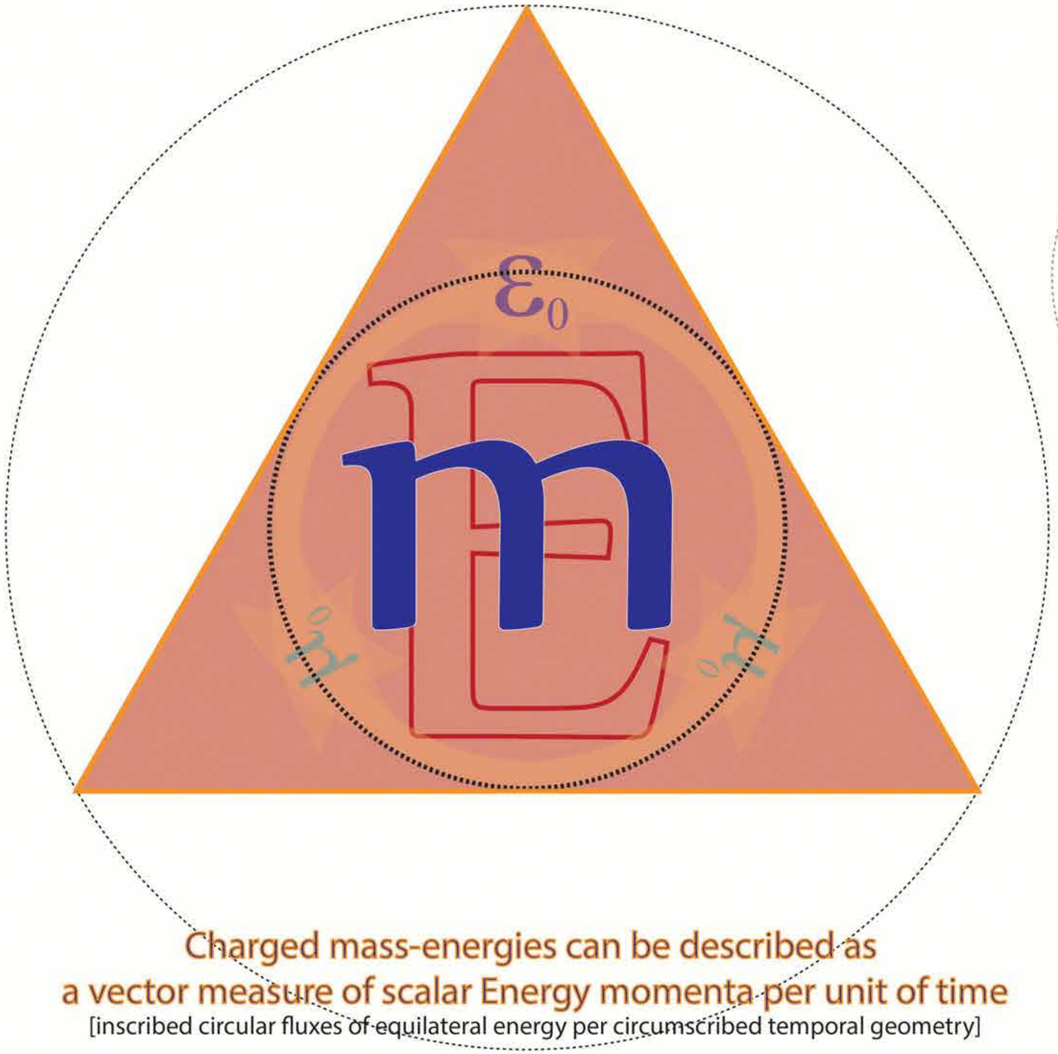

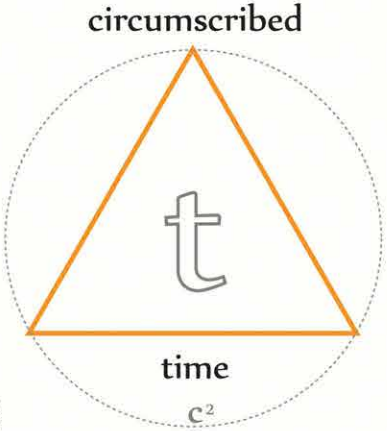

It is the equilateral geometry of energy not a classical vector rotation that creates QAM

Scalar EM mass is a measure of equilateral Planck energy per spatial co-ordinate system

m

Charged mass-energies can be described as
a vector measure of scalar Energy momenta per unit of time
[inscribed circular fluxes of equilateral energy per circumscribed temporal geometry]

E

Trigometric functions

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

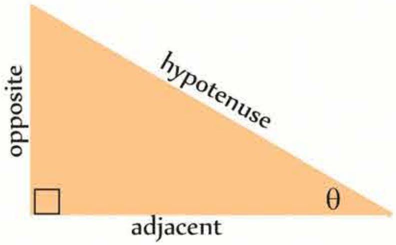
opposite
hypotenuse
θ
adjacent

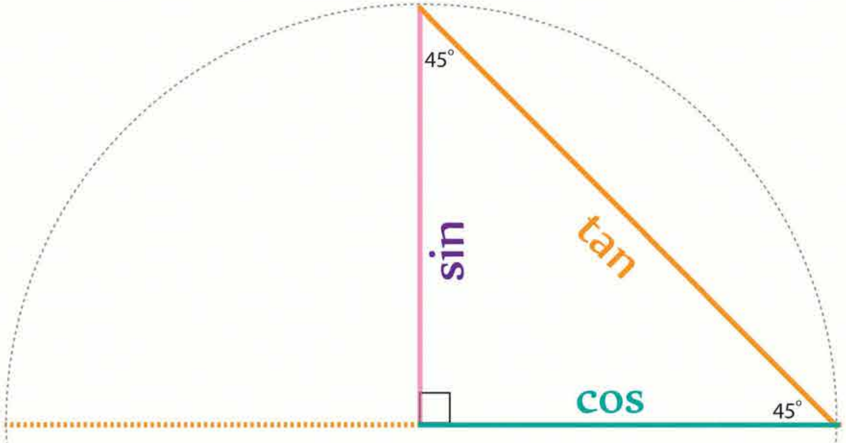
45°
sin
tan
cos
45°

The most familiar trigonometric functions are the sine, cosine, and tangent.

In the context of the standard unit circle with radius 1,
where a triangle is formed by a ray originating at the origin and
making some angle with the x-axis,

the SINE of the angle gives the length of the y-component (rise) of the triangle,
the COSINE gives the length of the x-component (run), and
the TANGENT function gives the slope
(y-component divided by the x-component)

Standard trigometric functions must be carefully applied to
measurements of equilateral Planck mass-energy geometries
in scribed circular space-time co-ordinate systems

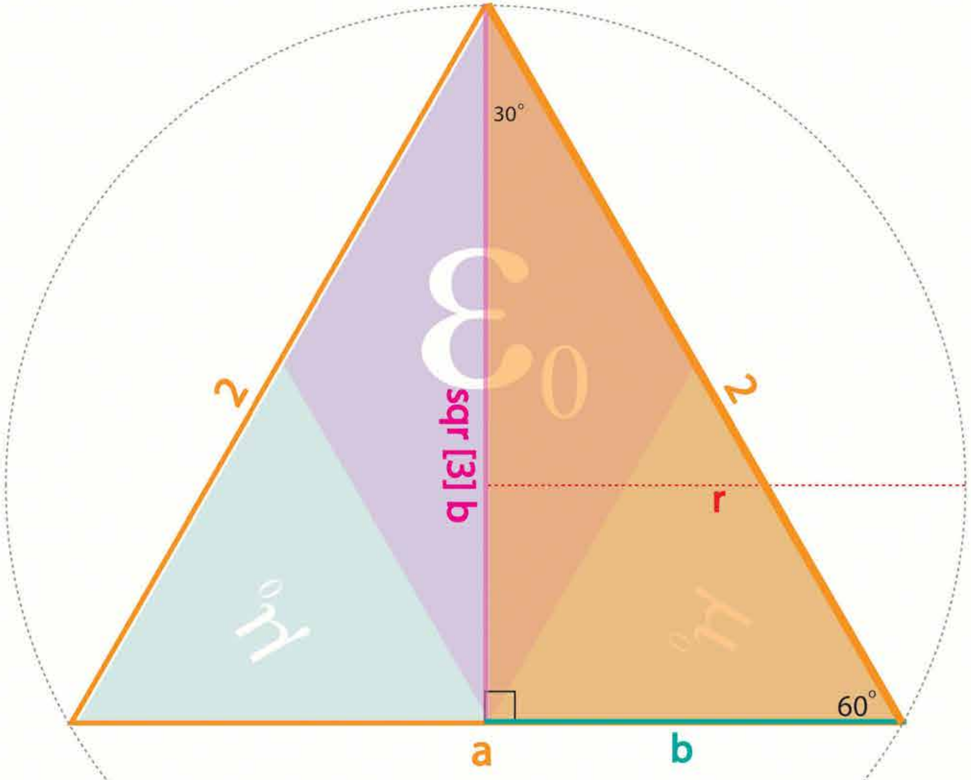
30°
ε0
2
2
sqr [3] b
r
μ0
μ0
60°
a
b

In most cases it is in fact easier to
ignore the trigonomteric functions and math
and simpy draw their related equilateral geometries

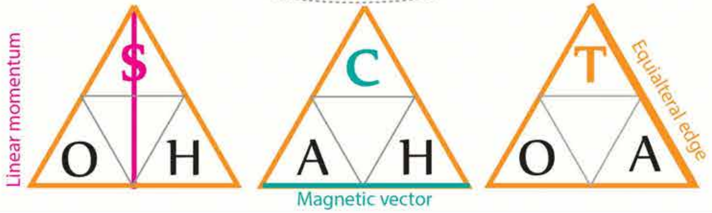
Linear momentum
S
O
H
C
A
H
Magnetic vector
T
O
A
Equilateral edge

The roots of scribed equilateral triangles

Scalar equilateral energies map directly onto circular space-time co-ordinates
through their square root linear momentum

r

The ratio of the
circumscribed circle of
an equilateral triangle
to its inscribed circle
is 2:1

d

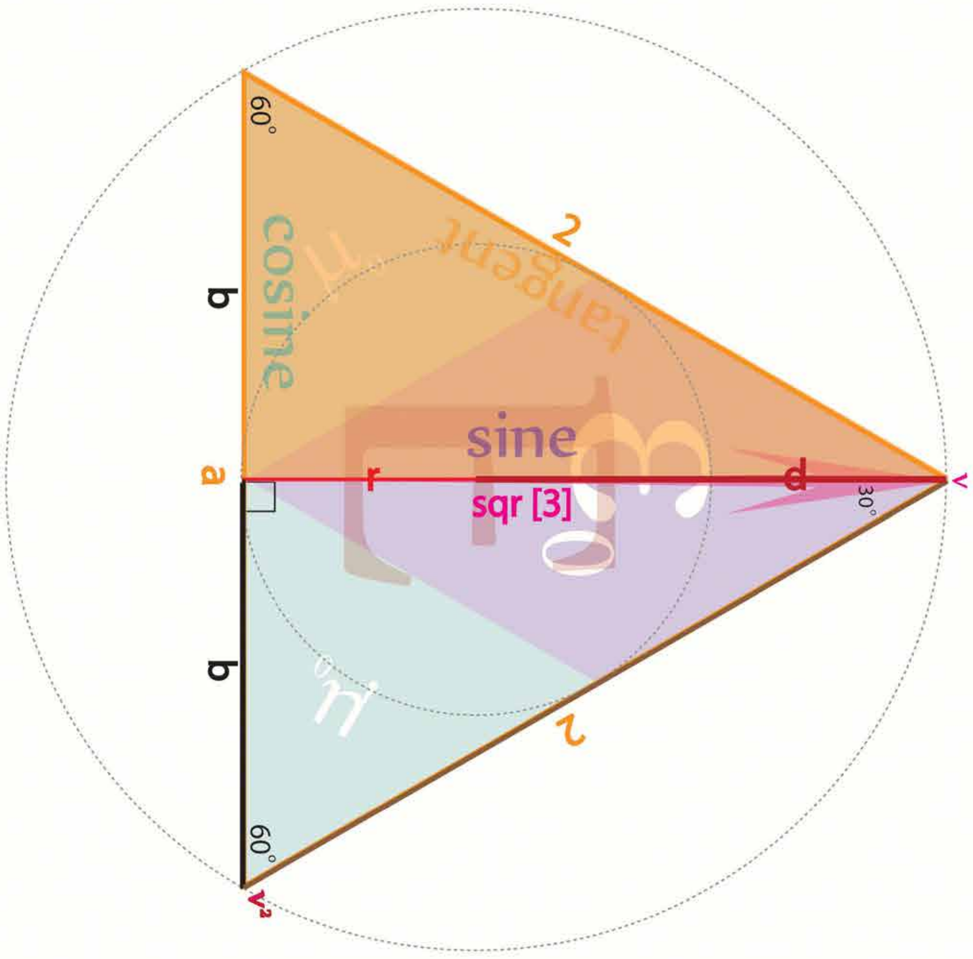
60°
2
tangent
cosine
b
sine
a
r
d
sqr [3]
v
30°
b
2
60°
v²

0.866 r

The ratio of the
side of an equilateral triangle
to the radius of
its incribed circle
is sqr [3]/2

a

The ratio of the
side of an equilateral triangle
to the radius of
its circumscribed circle
is sqr [3]

1.732 d

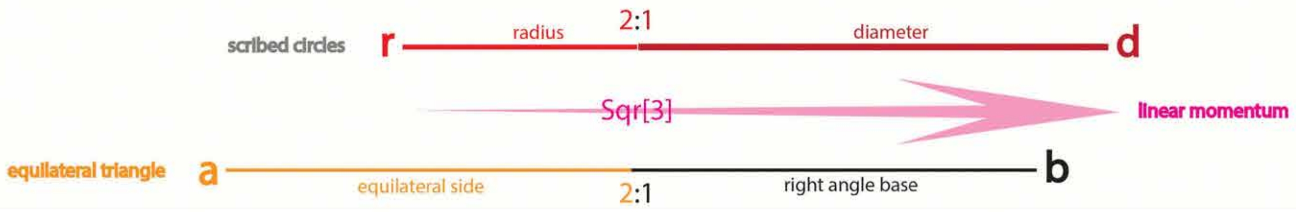
scribed circles
r
radius
2:1
diameter
d
Sqr[3]
linear momentum
equilateral triangle
a
equilateral side
2:1
right angle base
b

Equilateral triangles and scribed circles

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{1}{\sqrt{1-\beta^2}} = \frac{dt}{d\tau}$$

$$\gamma(\beta) = 1 + \frac{1}{2}\beta^2 + \frac{3}{8}\beta^4 + \frac{5}{16}\beta^6 + \frac{35}{128}\beta^8 + \ldots$$

$$L = L'\sqrt{1 - \frac{v^2}{c^2}}$$

$$E_k = \frac{mc^2}{\sqrt{1-(v/c)^2}} - mc^2$$

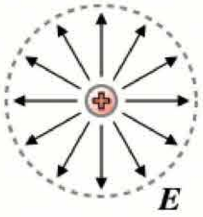

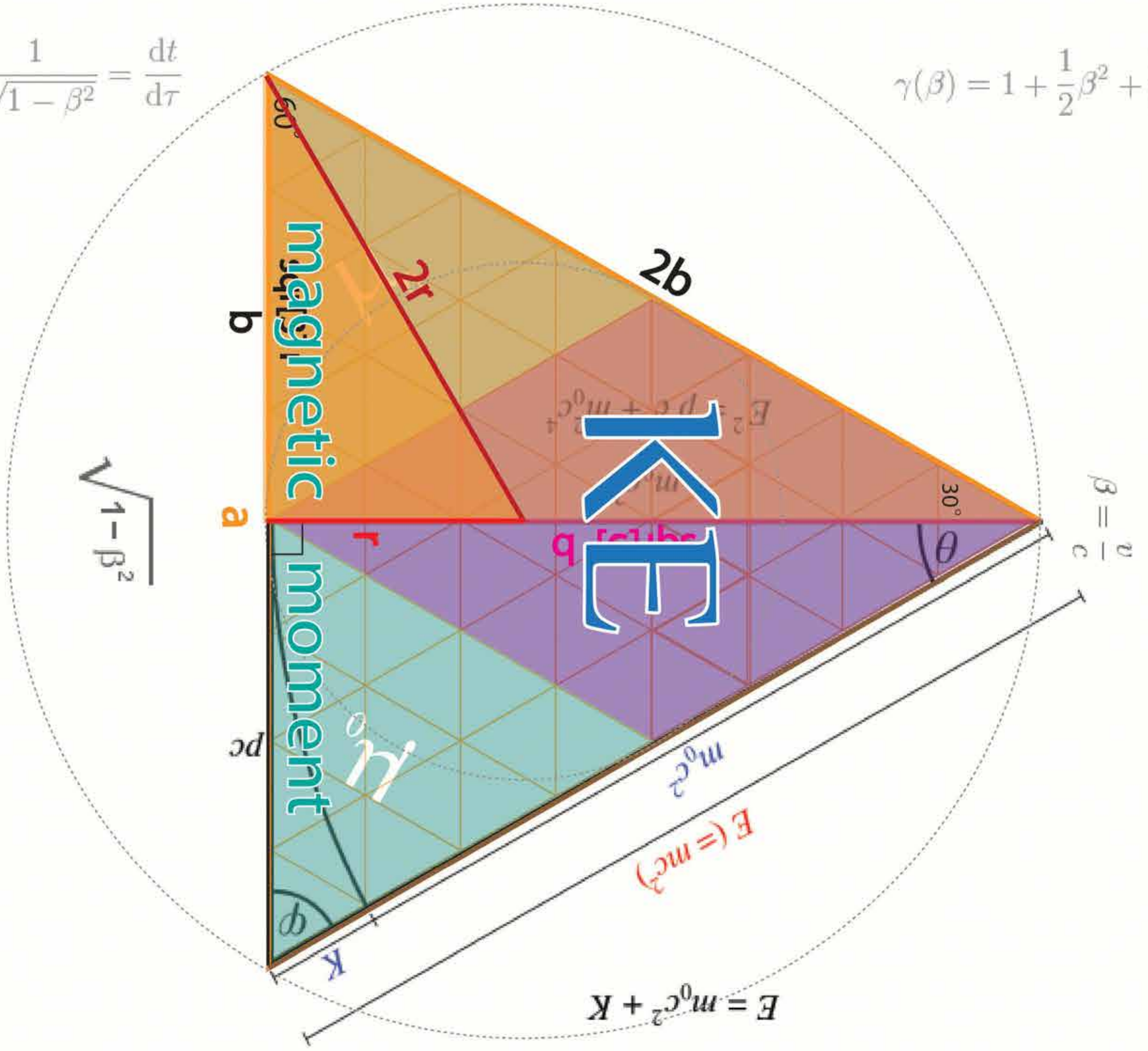
60°
2r
2b
b
magnetic
moment
a
r
q
KE
30°
θ
φ
pc
μ
μ₀
m_0c^2
$E\ (= mc^2)$
K
$E = m_0c^2 + K$
$\sqrt{1-\beta^2}$
$\beta = \frac{v}{c}$

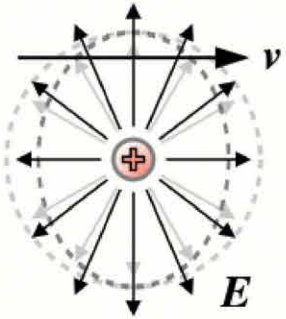

$$mc^2\left\{\frac{1}{\sqrt{1-v^2/c^2}} - 1\right\}$$

$$p = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}} = \gamma m_0 v$$

$$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\sqrt{1 - \left(\frac{v}{c}\right)^2}$$

All the relativistic relationships historically attributed to circularised energies and modelled through the use of the math of right angled triangles are in fact the result of equilateral, scalar geometries

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Finite sequences and series have defined first and last terms,

$$\sum a_n = a_0 + a_1 + a_2$$

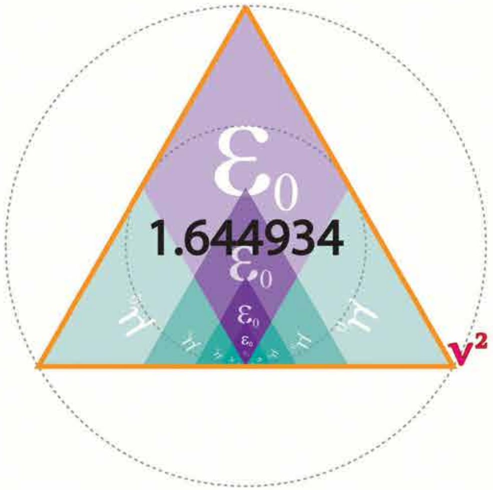

$$\sum_{n=1}^{\infty} \frac{1}{n^2} = \lim_{n\to+\infty} \left(\frac{1}{1^2} + \frac{1}{2^2} + \cdots + \frac{1}{n^2} \right).$$

whereas infinite sequences and series continue indefinitely

The Basel problem is a famous problem in mathematical analysis with relevance to number theory, first posed by Pietro Mengoli in 1644 and solved by Leonhard Euler in 1735.

$$\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \frac{1}{4^2} + \frac{1}{5^2} + \ldots = \frac{\pi^2}{6}$$

Tetryonics now provides a geometric solution to visualising and solving the Basel problem

$$\zeta(2) = 1 + \frac{1}{2^2} + \frac{1}{3^2} + \cdots = \frac{\pi^2}{6} \approx 1.645;$$

Tetryonic Infinite Series

is a infinite sequence of square numbers,
the result of adding all those terms together
[or their geometric inverse]

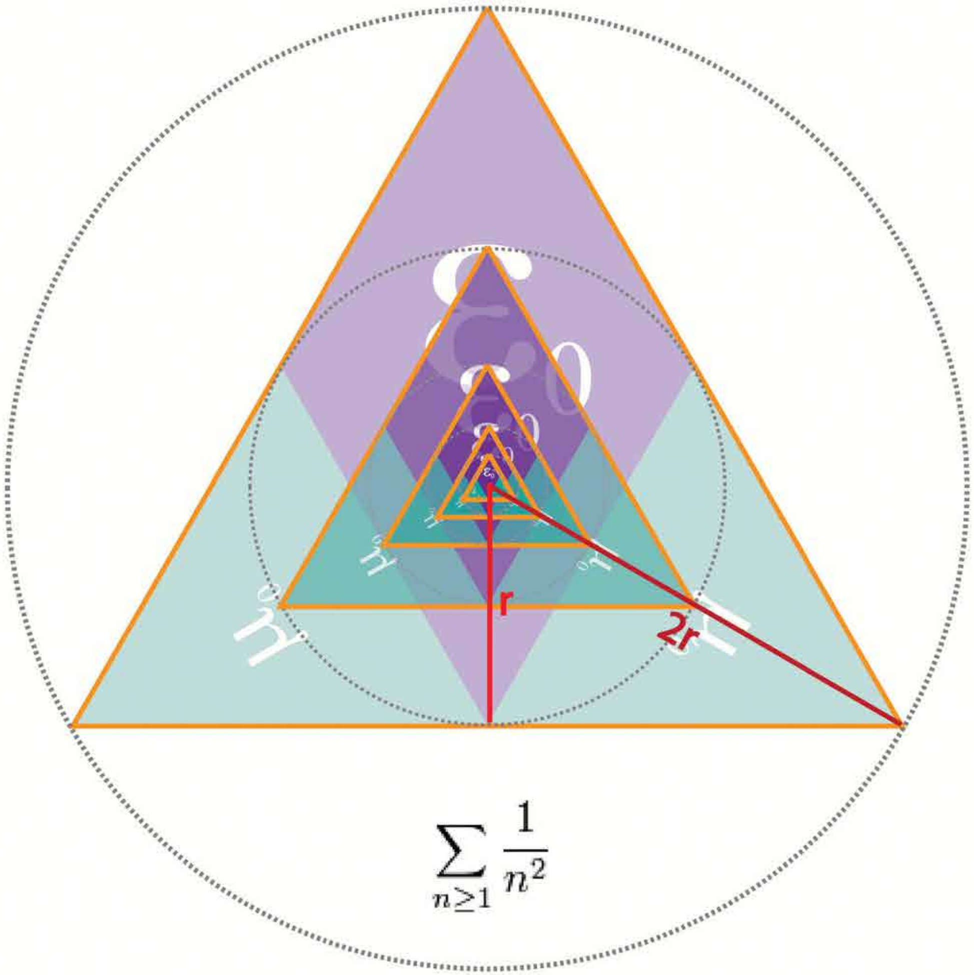

$$\sum_{n\geq 1} \frac{1}{n^2}$$

The entire sum of the series is equal to
twice the size of the radius of the largest inscribed circle
which is equal to the largest circle circumscribing the triangular series.

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Inverting the Circle

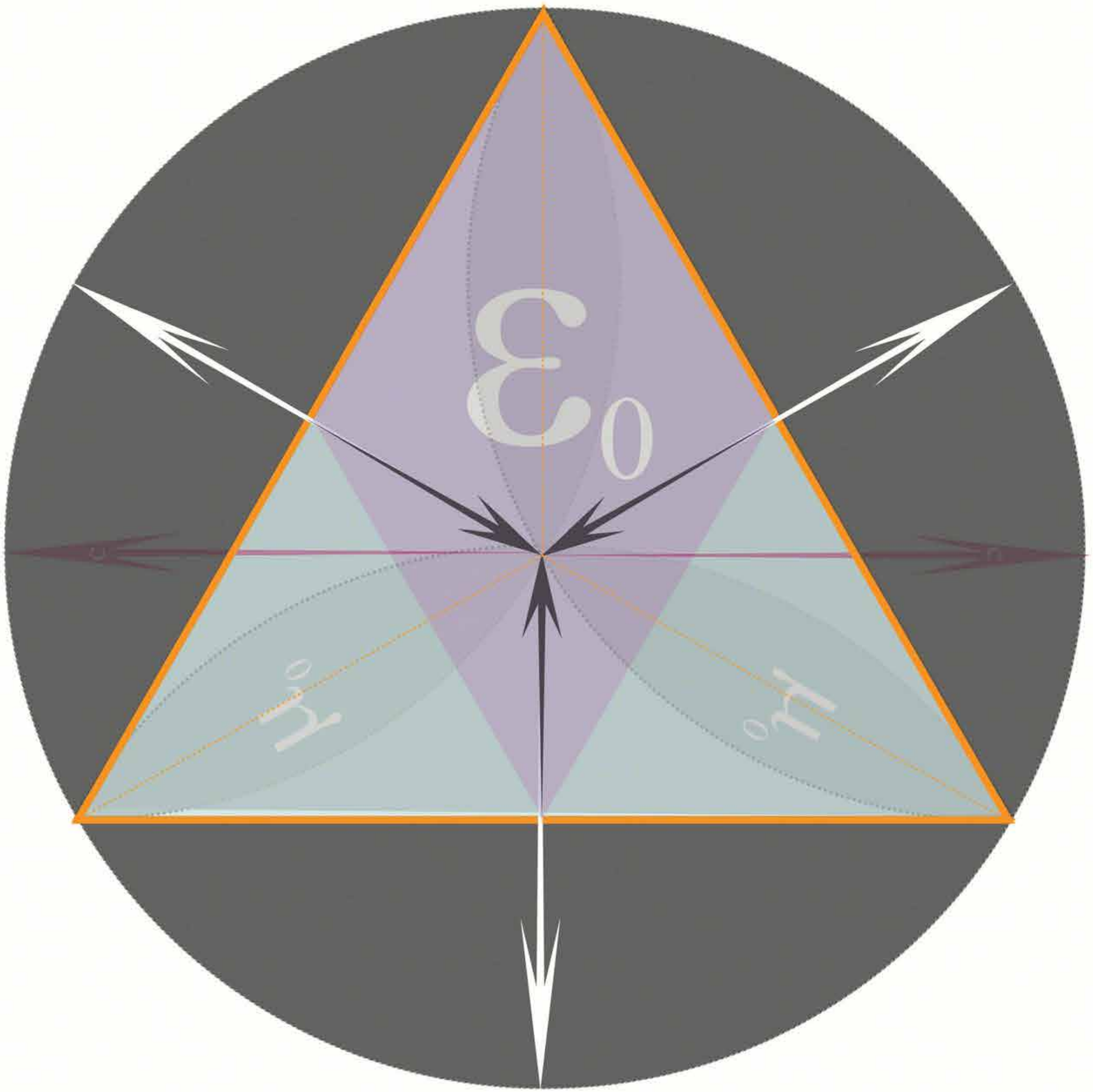

Electric
Permittivity

ε_0

Magnetic
Permeability

μ_0

c^2

$\frac{1}{c^2}$

2D spatial
co-ordinates

ElectroMagnetic
fields

Tetryonics 83.11 - Inverting the Circle

Irrational numbers

an irrational number cannot be represented as a simple fraction.
Irrational numbers are those real numbers that cannot be represented as terminating or repeating decimals

sin(x)=-square root of (3)/2

0.866025403.......

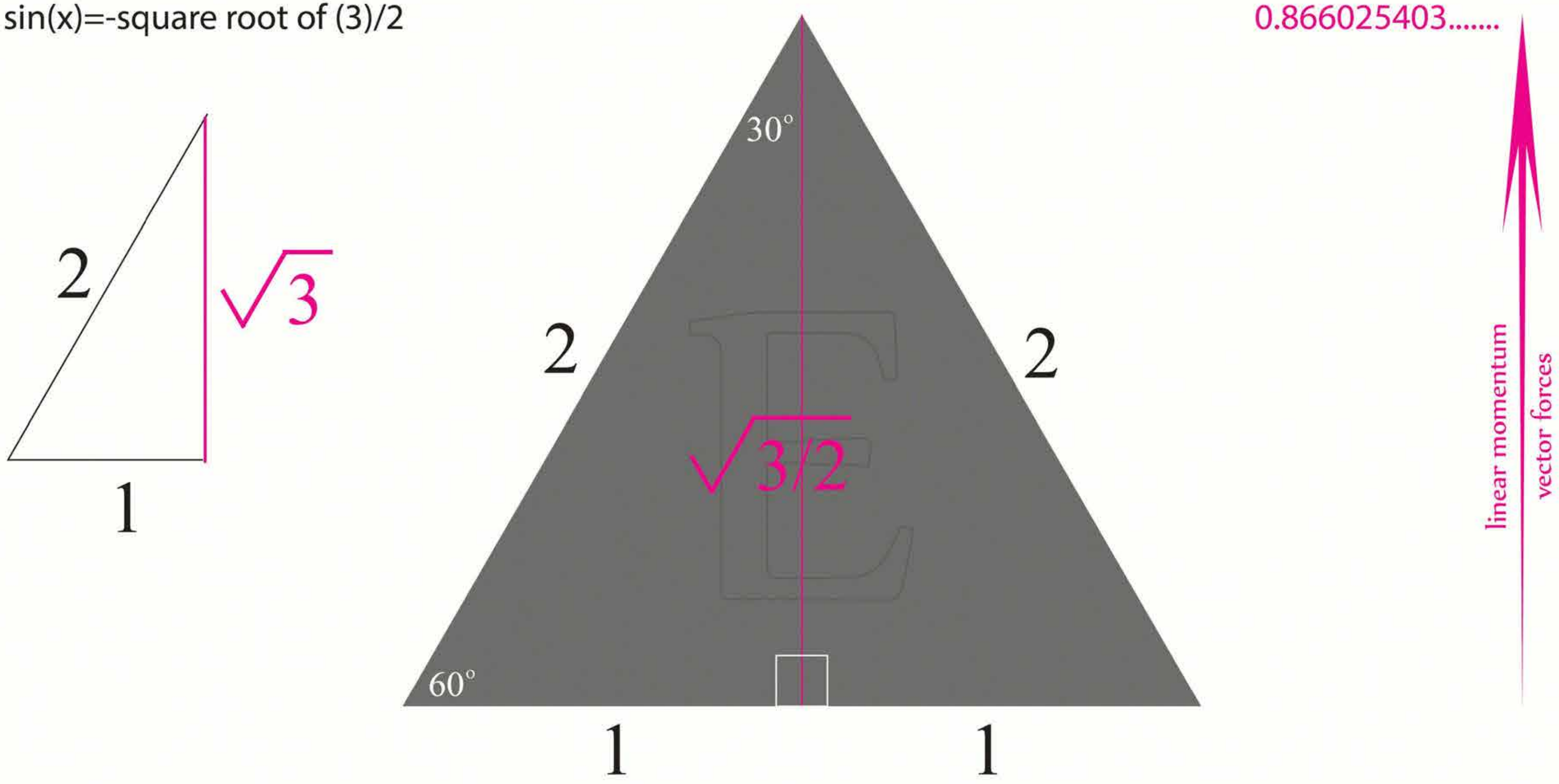
2
$\sqrt{3}$
1
30°
2
2
$\sqrt{3/2}$
60°
1
1
linear momentum
vector forces

Pythagφras’ theoreom
and irratiφnal numbers expressed in terms of right-angled triangles in Physics
offer a ‘half truth’ regarding the equilateral geometry of Energy

Leibniz

Newton

Newton focused his work on linear momentum which he developed into his famous laws of motion

Leibniz introduced the concept of vis viva (living force) which attempted to quantify life force

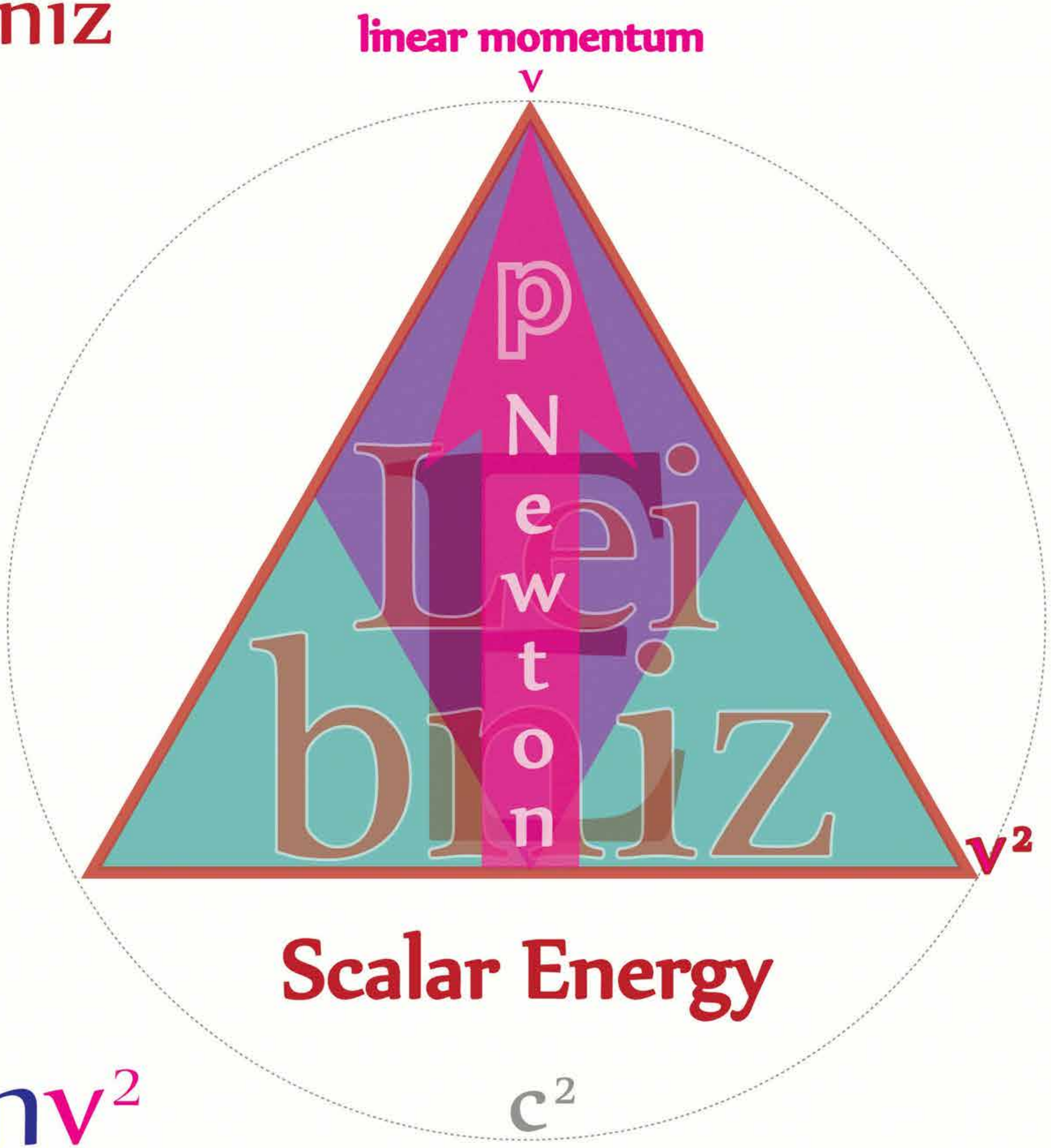

Newton and Leibniz disagreed about what the world is made of and how its physics shaped our scientific concepts of force, energy, and momentum

Tetryonics reveals the physical relationships they both described mathematically as geometric properties of equilateral Planck energy momenta

$E=mv^2$

$p=mv$

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Geometric Square Roots

In geometrical terms, the square root function maps the area of a square to its side length.

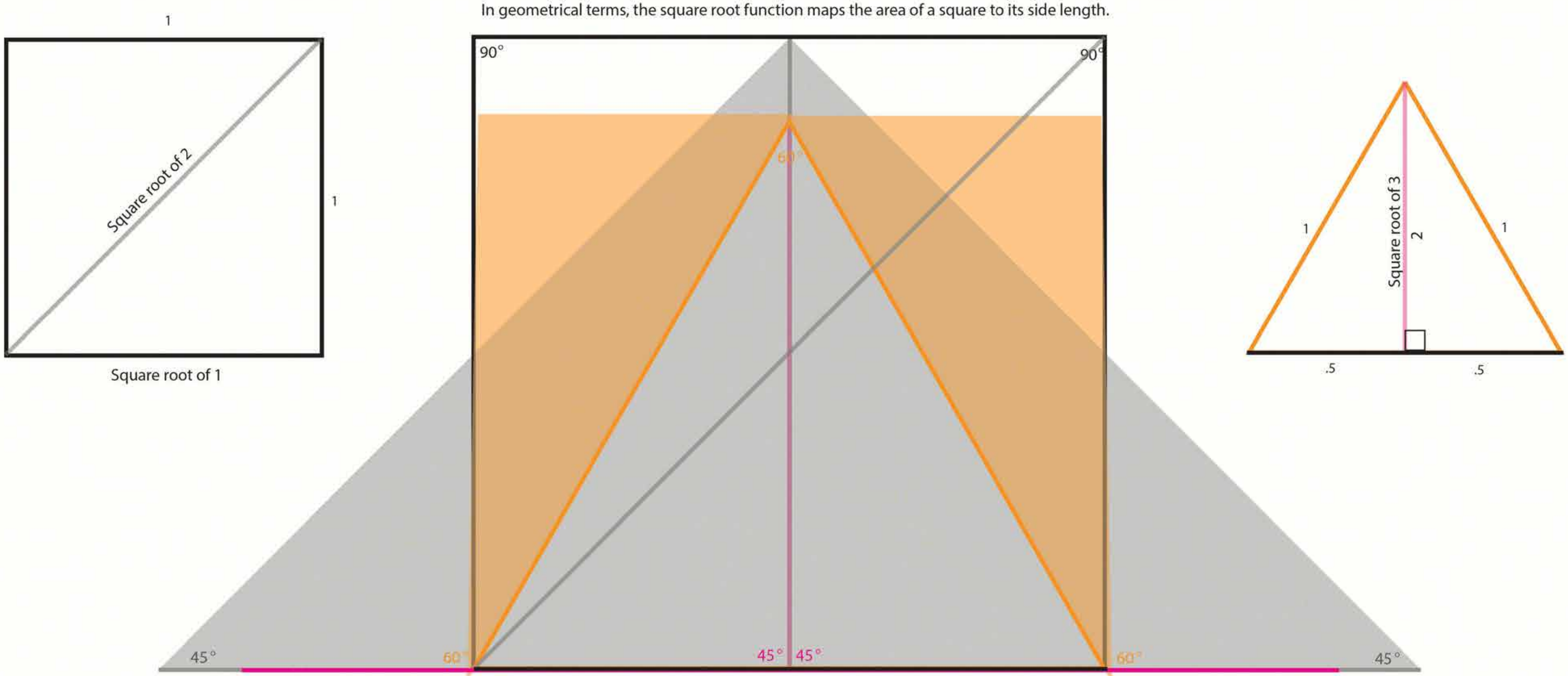

"In mathematics, as in any scientific research, we find two tendencies present. On the one hand, the tendency toward abstraction seeks to crystallize the logical relations inherent in the maze of material that is being studied, and to correlate the material in a systematic and orderly manner. On the other hand, the tendency toward intuitive understanding fosters a more immediate grasp of the objects one studies, a live rapport with them, so to speak, which stresses the concrete meaning of their relations"

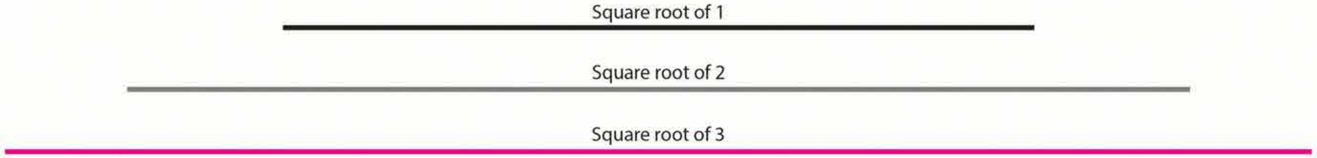

"As to geometry, in particular, the abstract tendency has here led to the magnificent systematic theories of Algebraic Geometry, of Riemannian Geometry, and of Topology; these theories make extensive use of abstract reasoning and symbolic calculation in the sense of algebra.

Notwithstanding this, it is still as true today as it ever was that intuitive understanding plays a major role in geometry. And such concrete intuition is of great value not only for the research worker, but also for anyone who wishes to study and appreciate the results of research in geometry"

David Hilbert [Geometry and the Imagination]

Square Roots in Physics

In mathematics, a square root of a number a is a number [n] such that [n]2 = x,
or, in other words, a number [n] whose square (the result of multiplying the number by itself, or [n × n]) is x.

Modern calculators use the
Square Root Algorithm
to calculate the value

It is an approximate numerical value

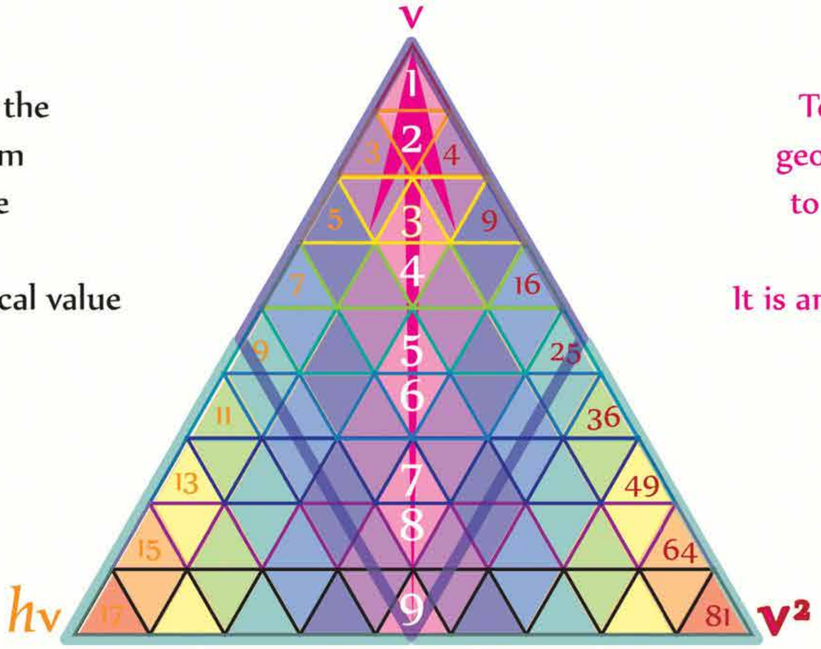

Tetryonics uses the
geometric Square Root
to calculate the value

It is an exact geometric value

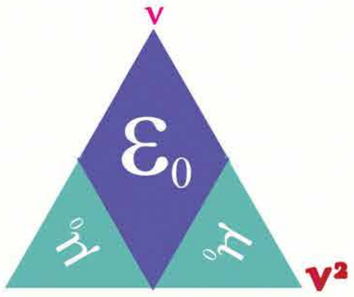

$$E = mv^2$$

In classical geometry,
the square root function maps the
area of a square to its side length.

$$p = \sqrt{E}$$

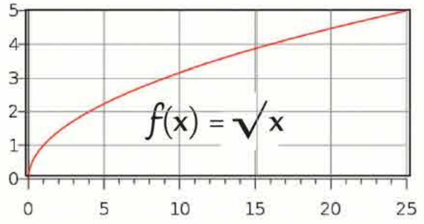

Geometry can easily map irrational numbers

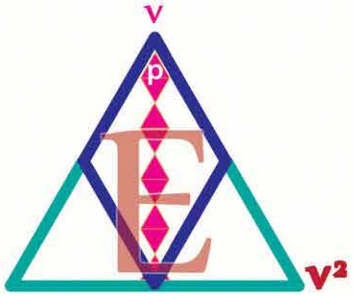

$$p^2 = E$$

In physics,
the square root function maps
ENERGY [E] to momentum [mv]

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The Square roots of n

Historically, any number raised to the power of 2 has been modeled using a polygon--the square
That's why we call raising a number to the second power "squaring the number."

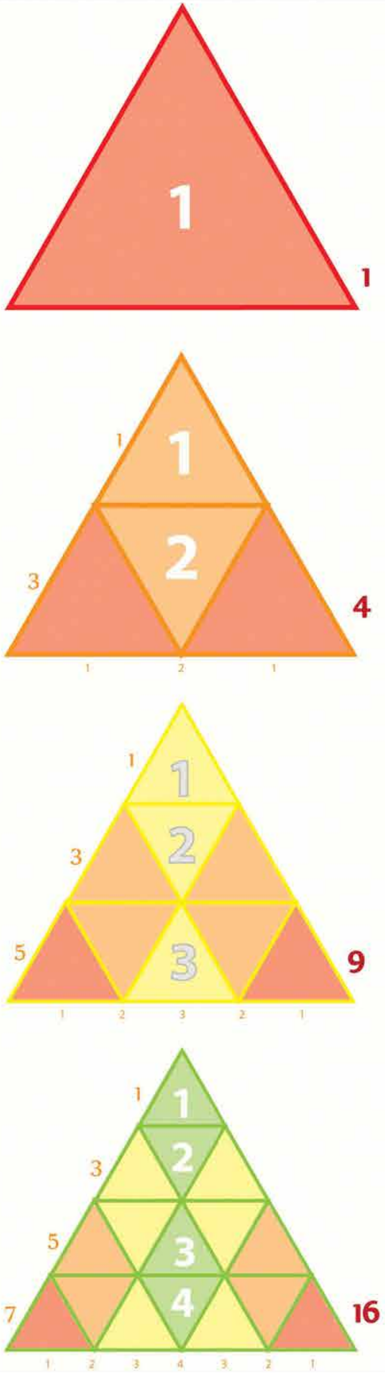

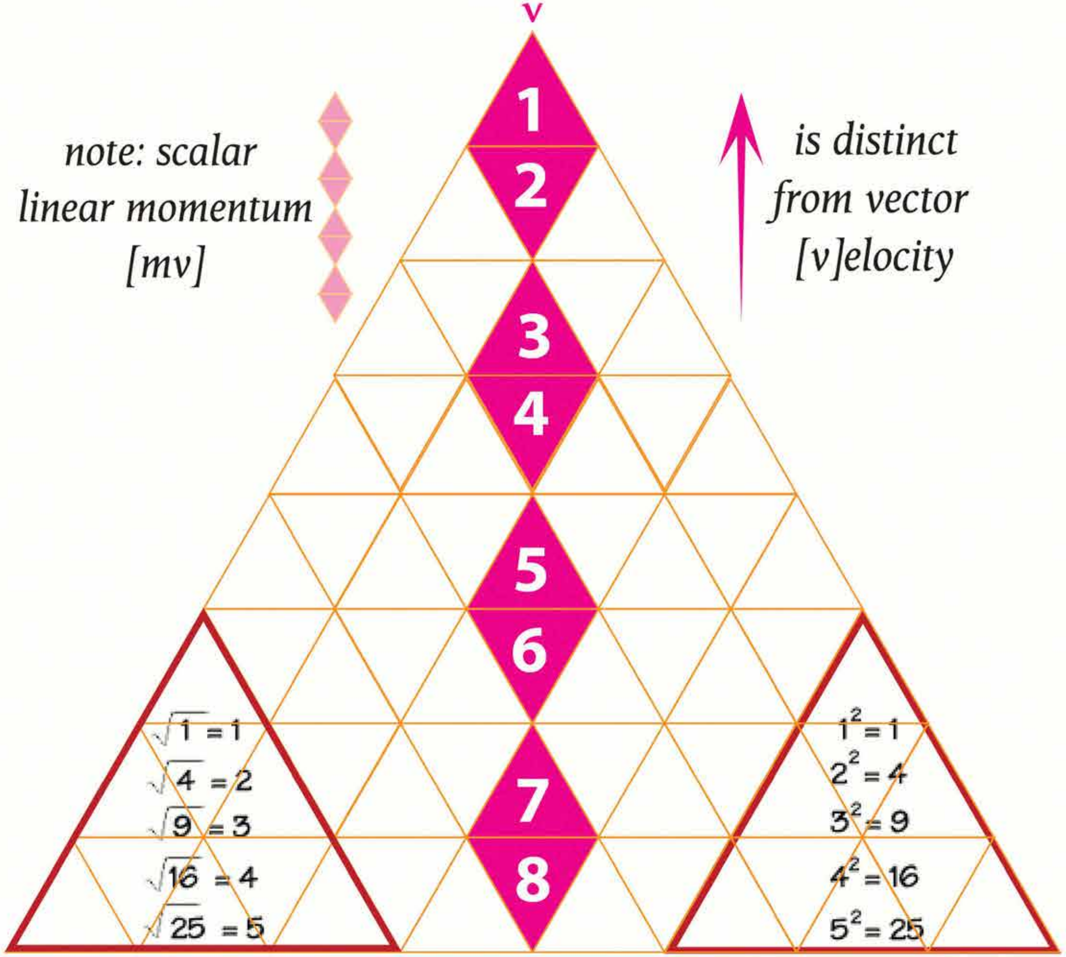

note: scalar linear momentum [mv]

is distinct from vector [v]elocity

$\sqrt{1}=1$
$\sqrt{4}=2$
$\sqrt{9}=3$
$\sqrt{16}=4$
$\sqrt{25}=5$

$1^2=1$
$2^2=4$
$3^2=9$
$4^2=16$
$5^2=25$

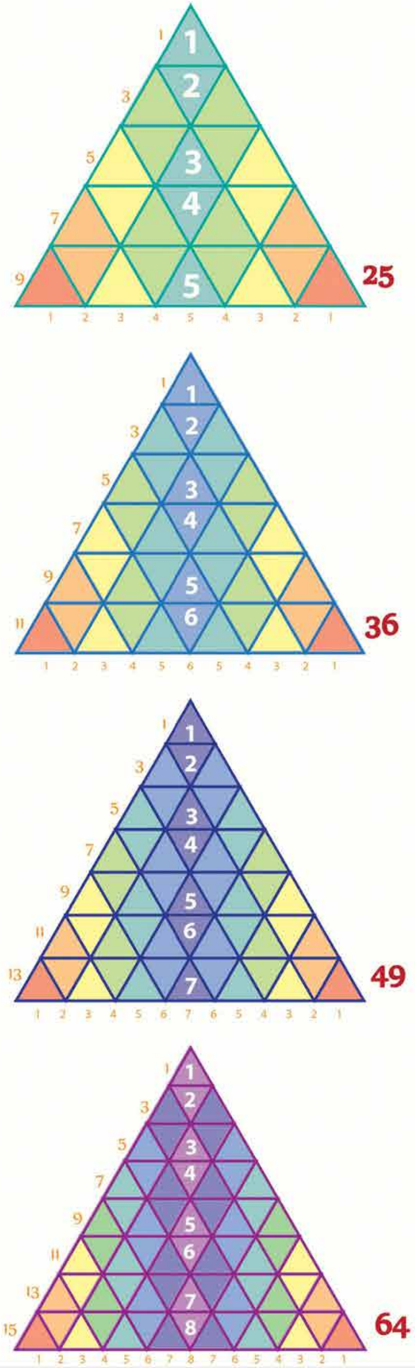

[In physics square numbers are in fact equilateral geometries]

The perfect squares are squares of whole numbers.
Here are the first eight perfect squares

The Square root of Negative 1

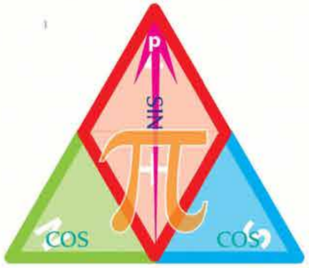

Positive fields are out of phase with Negative fields

Magnetic fields are out of phase with Electric fields

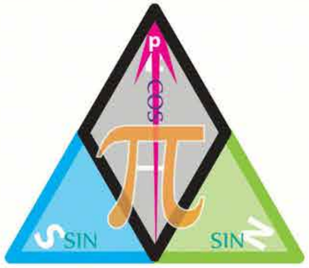

Euler's Formula

Euler's formula is often considered to be the basis of the complex number system.
In deriving this formula, Euler established a relationship between the trigonometric functions, sine and cosine, and e raised to a power

$$e^{ix} = \cos(x) + i\sin(x)$$

a mathematical description of EM-Energy waveforms

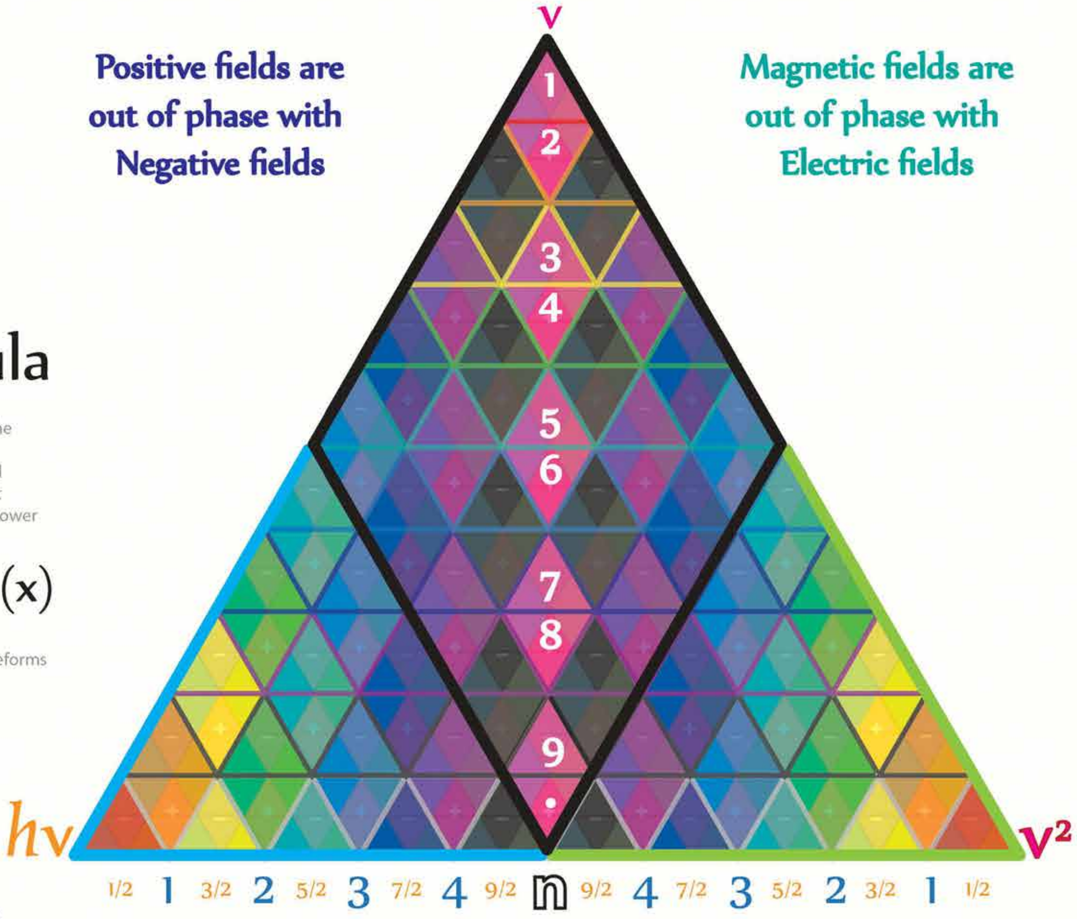

Leonhard Euler

(15 April 1707 – 18 September 1783)

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \ldots$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \ldots$$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \frac{x^5}{5!} + \ldots$$

$$\sin x + \cos x = 1 + x - \frac{x^2}{2!} - \frac{x^3}{3!} + \frac{x^4}{4!} + \frac{x^5}{5!} + \ldots$$

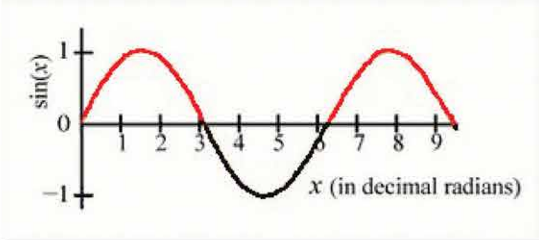

$$e^{i\pi} = -1$$

$$e^{i\pi} + 1 = 0$$

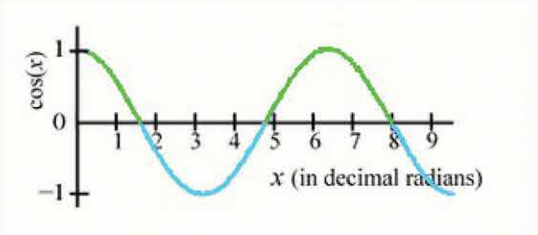

Geometric means

The geometric mean of two numbers, is the square root of their product

geometric square root
of positive one

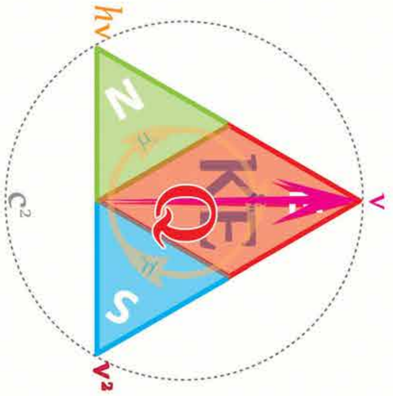

$$F = k\frac{Q_1 Q_2}{r^2}$$

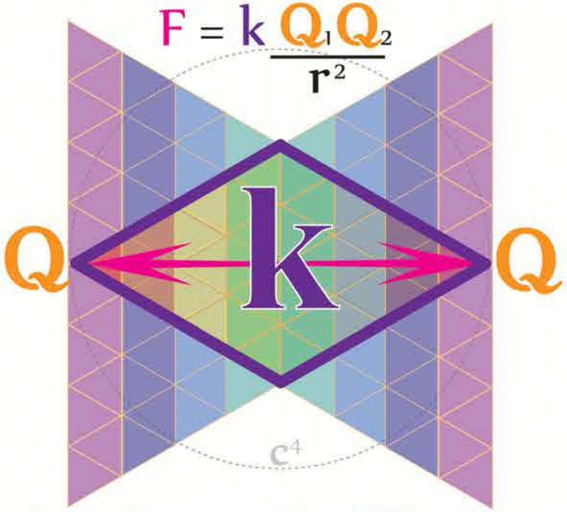

geometric square root
of negative one

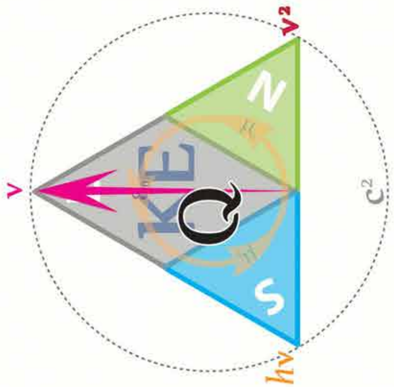

In physics, the geometric mean of two superpositioned fields produces a vector square root Force

It is generally stated that
the geometric mean applies
only to positive numbers.

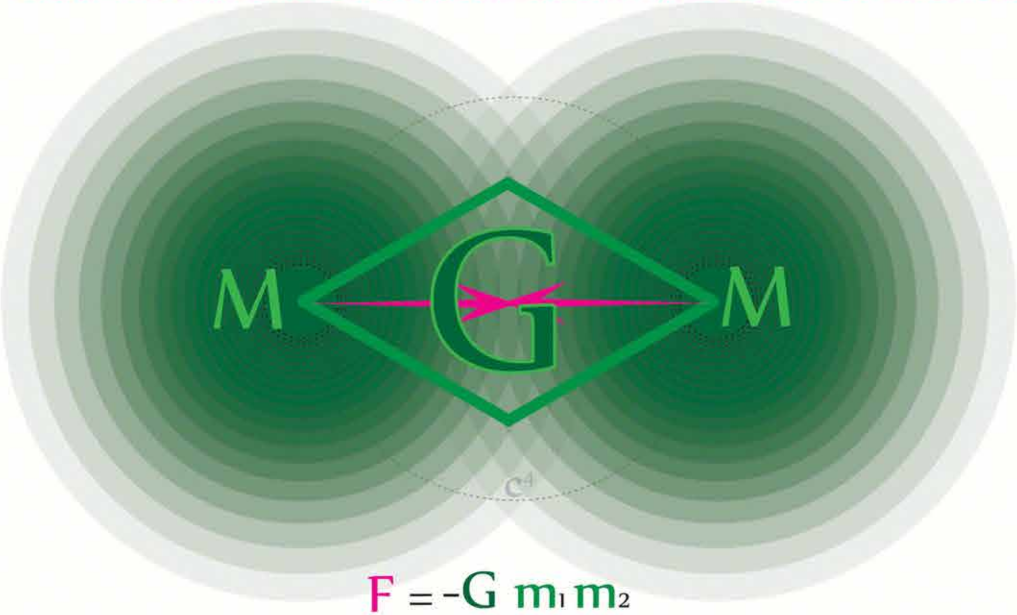

$$F = -G\frac{m_1 m_2}{r^2}$$

In Tetryonic geometry
the geometric mean applies
to positive & negative fields.

Superpositioning

When two or more waves traverse the same space,
the net amplitude at each point is the
sum of the amplitudes of the individual waves.

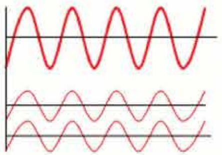

constructive interference

In phase

Additive

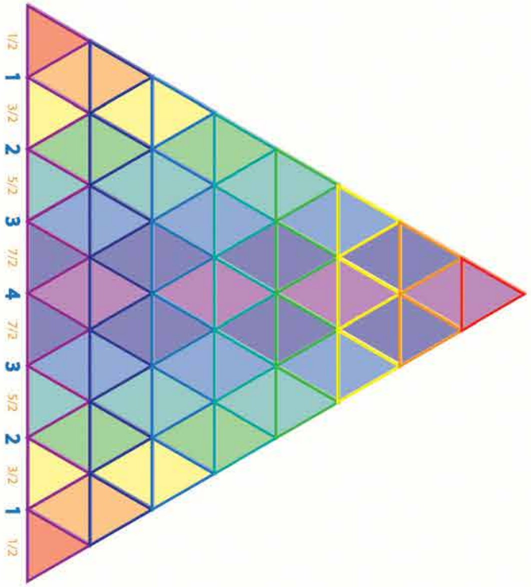
1/2
1
3/2
2
5/2
3
7/2
4
7/2
3
5/2
2
3/2
1
1/2

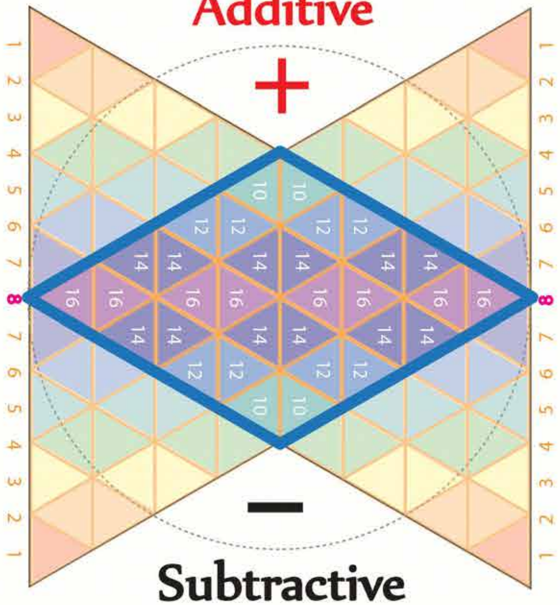
+
1
2
3
4
5
6
7
8
7
6
5
4
3
2
1
10
12
14
16
−

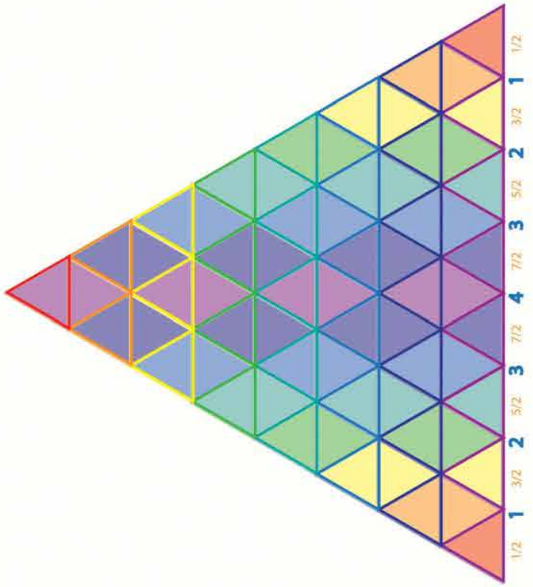
1/2
1
3/2
2
5/2
3
7/2
4
7/2
3
5/2
2
3/2
1
1/2

Subtractive

Out of phase

destructive interference

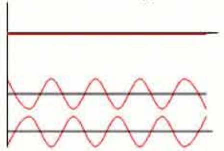

When two or more waves traverse the same space,
if the summed variation has a smaller amplitude
than the constiuent component variations.

The lines of Force

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Tetryonic Multiplication table

A multiplication table is a mathematical grid used to define a multiplication operation and its results

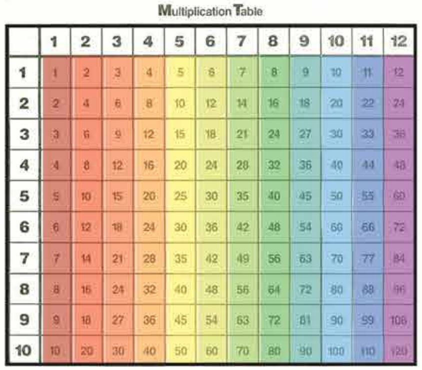

Multiplication Table

	1	2	3	4	5	6	7	8	9	10	11	12
1	1	2	3	4	5	6	7	8	9	10	11	12
2	2	4	6	8	10	12	14	16	18	20	22	24
3	3	6	9	12	15	18	21	24	27	30	33	36
4	4	8	12	16	20	24	28	32	36	40	44	48
5	5	10	15	20	25	30	35	40	45	50	55	60
6	6	12	18	24	30	36	42	48	54	60	66	72
7	7	14	21	28	35	42	49	56	63	70	77	84
8	8	16	24	32	40	48	56	64	72	80	88	96
9	9	18	27	36	45	54	63	72	81	90	99	108
10	10	20	30	40	50	60	70	80	90	100	110	120

Historically Multiplication tables
have been based on Square geometries

In Tetryonics multiplication tables can
also be based on EQUILATERAL geometries

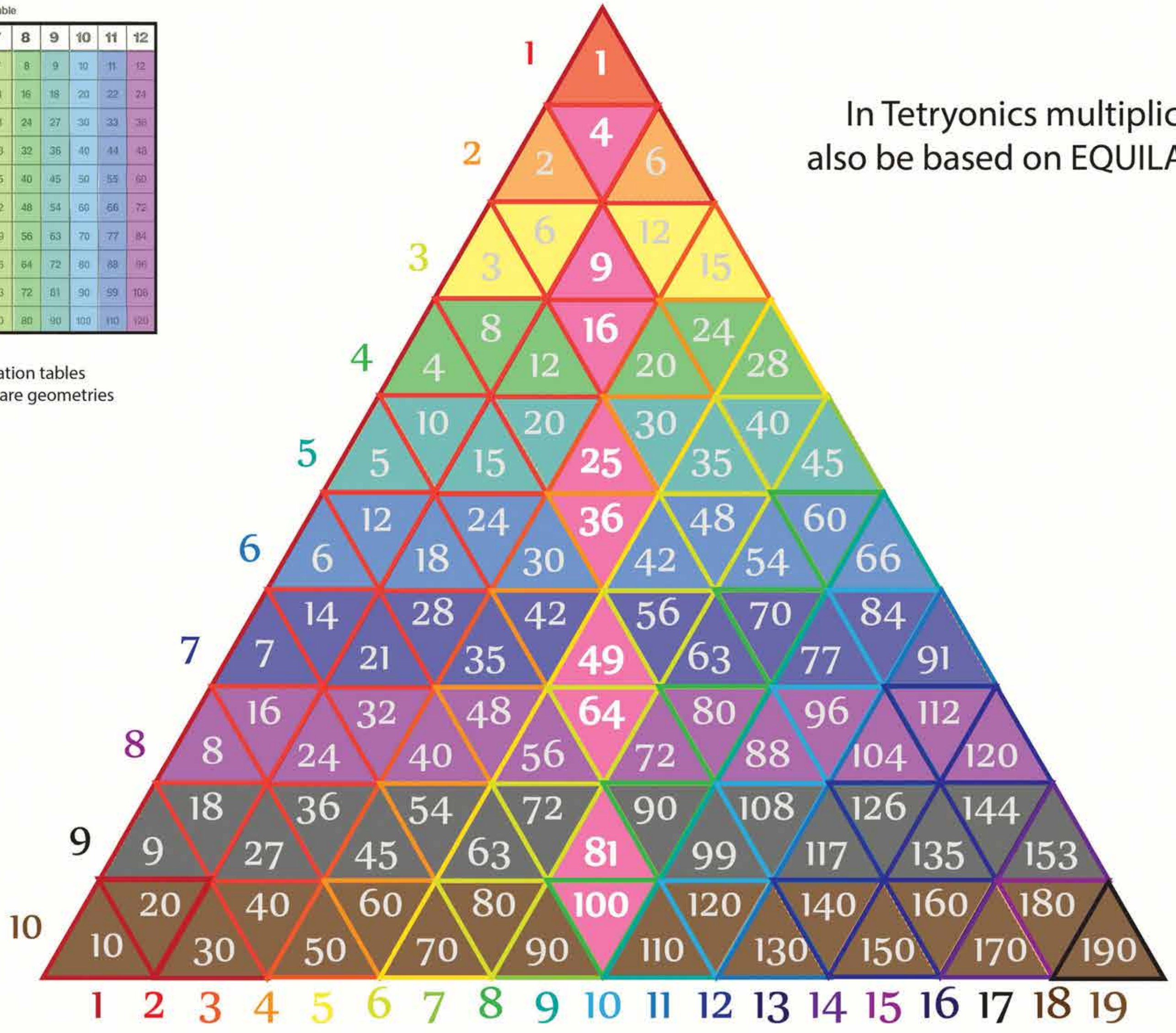
1
1
2
4
2 6
3
6 12
3 9 15
4
8 16 24
4 12 20 28
5
10 20 30 40
5 15 25 35 45
6
12 24 36 48 60
6 18 30 42 54 66
7
14 28 42 56 70 84
7 21 35 49 63 77 91
8
16 32 48 64 80 96 112
8 24 40 56 72 88 104 120
9
18 36 54 72 90 108 126 144
9 27 45 63 81 99 117 135 153
10
20 40 60 80 100 120 140 160 180
10 30 50 70 90 110 130 150 170 190
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

The integer multiplicitors are colour coded

Rhombic Multiplication Tables

1	2	3	4	5	6	7	8	9	10
2	**4**	6	8	10	12	14	16	18	20
3	6	**9**	12	15	18	21	24	27	30
4	8	12	**16**	20	24	28	32	36	40
5	10	15	20	**25**	30	35	40	45	50
6	12	18	24	30	**36**	42	48	54	60
7	14	21	28	35	42	**49**	56	63	70
8	16	24	32	40	48	56	**64**	72	80
9	18	27	36	45	54	63	72	**81**	90
10	20	30	40	50	60	70	80	90	**100**

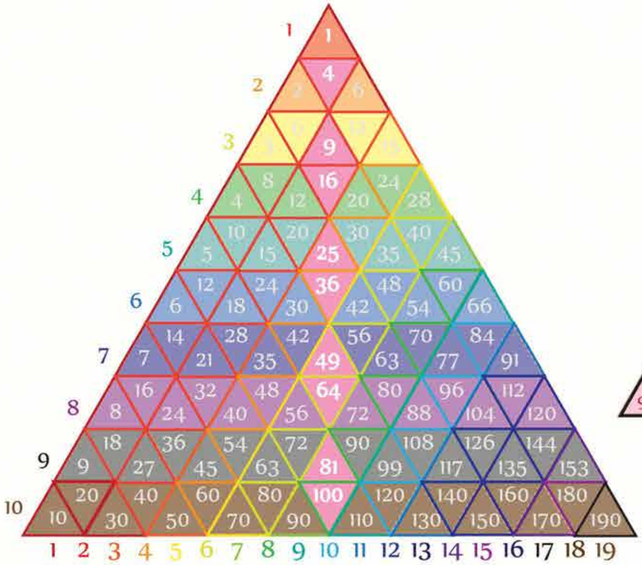

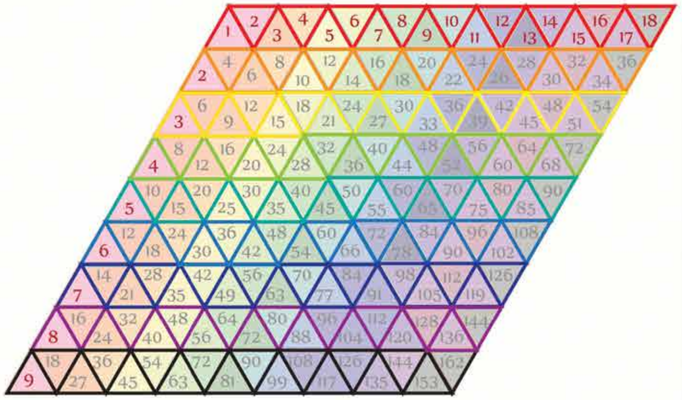

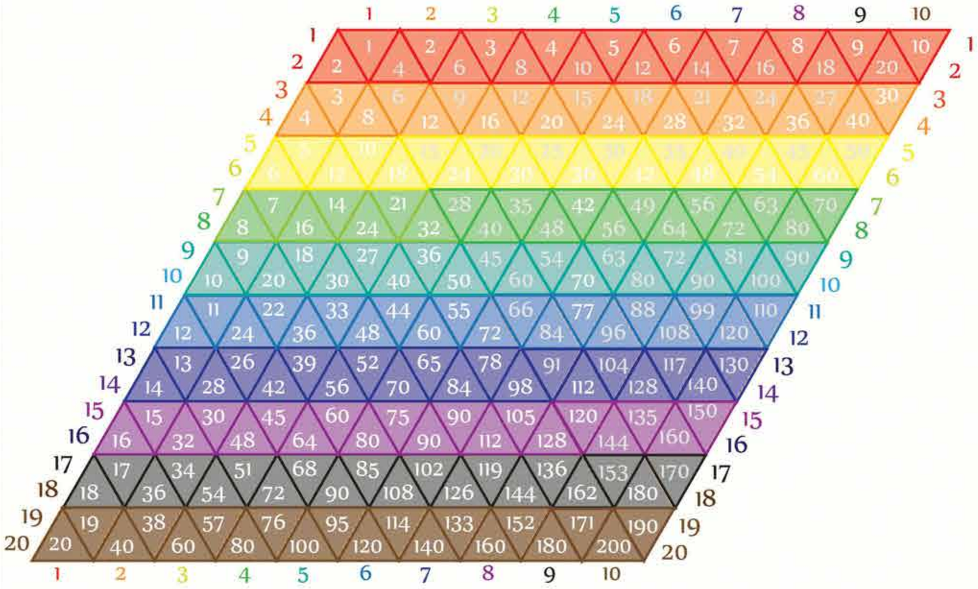

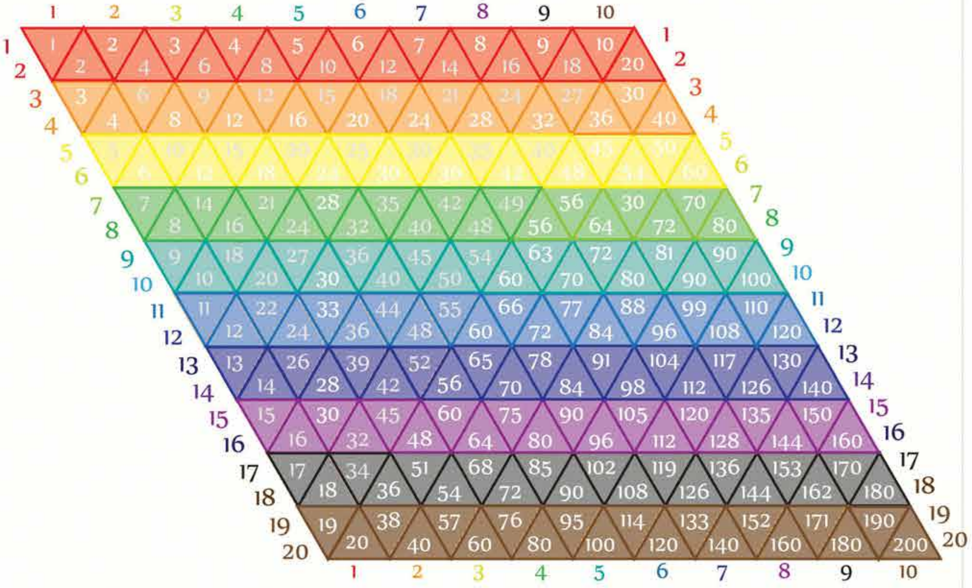

Tetryonics 85.03 - Rhombic multiplication tables

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Photonic Root Tables

Tetryonic multiplication table can take a number of geometric forms

Square root median

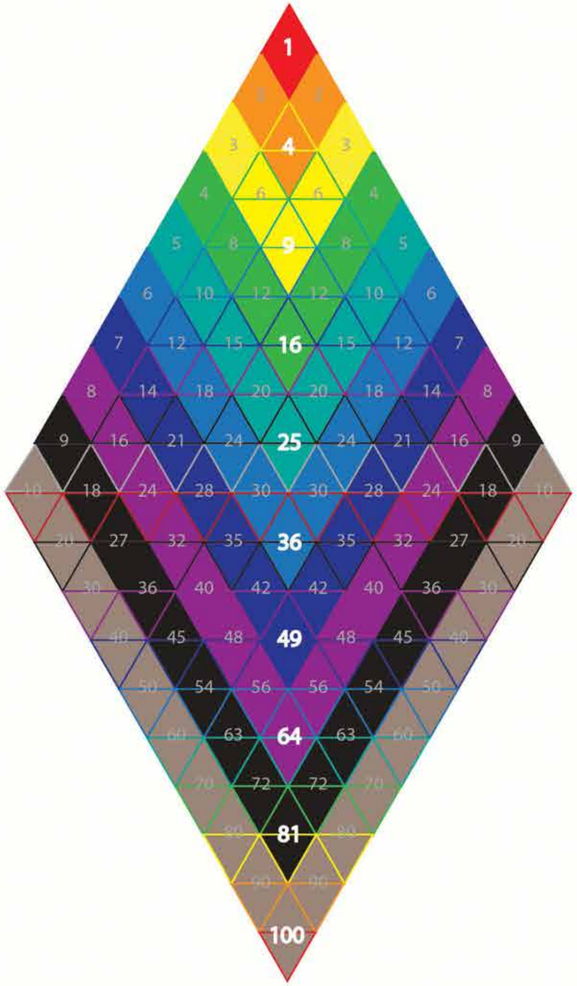
1
4
9
16
25
36
49
64
81
100

Table read diagonally

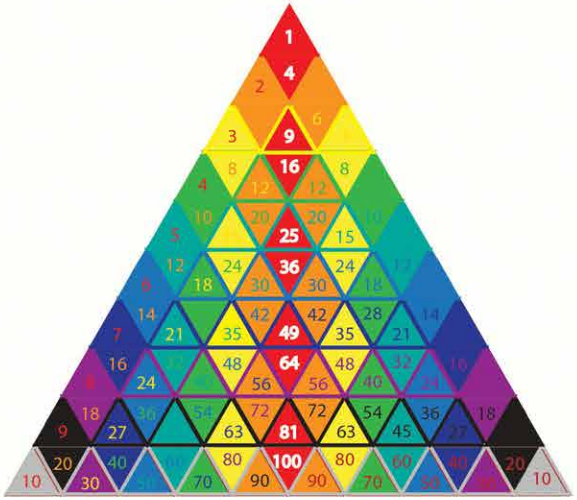
1
4
9
16
25
36
49
64
81
100

1	2	3	4	5	6	7	8	9	10
2	**4**	6	8	10	12	14	16	18	20
3	6	**9**	12	15	18	21	24	27	30
4	8	12	**16**	20	24	28	32	36	40
5	10	15	20	**25**	30	35	40	45	50
6	12	18	24	30	**36**	42	48	54	60
7	14	21	28	35	42	**49**	56	63	70
8	16	24	32	40	48	56	**64**	72	80
9	18	27	36	45	54	63	72	**81**	90
10	20	30	40	50	60	70	80	90	**100**

Integer median

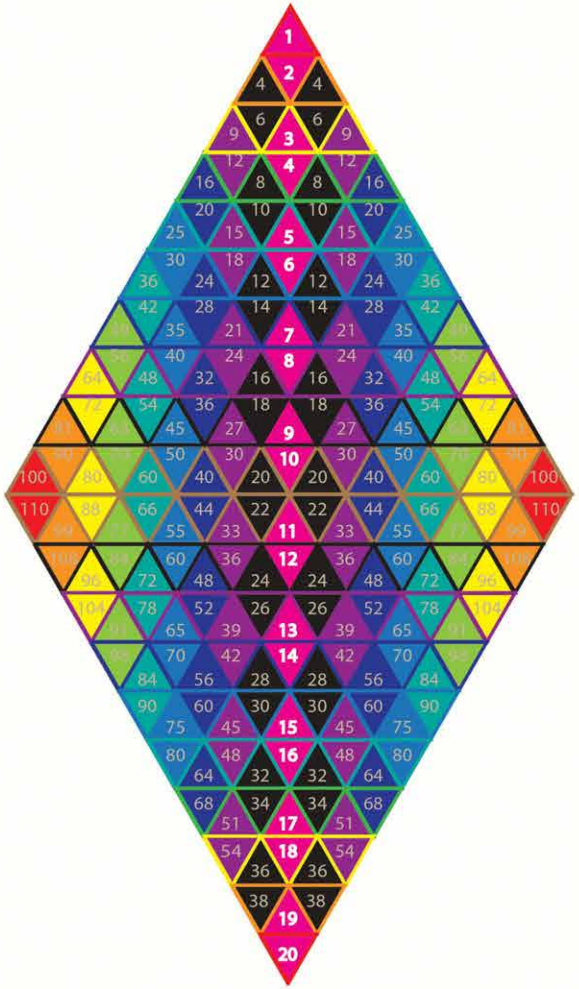
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Table read from centre
to outside edge then down

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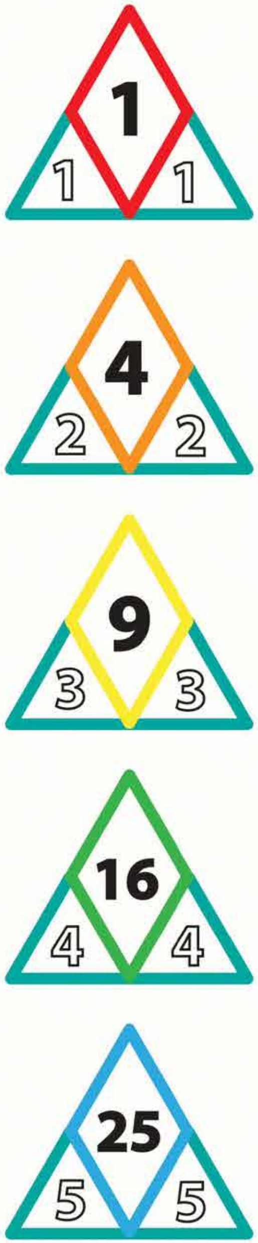
1
1 1
4
2 2
9
3 3
16
4 4
25
5 5

Divide [division] tables

Minus [subtraction] tables

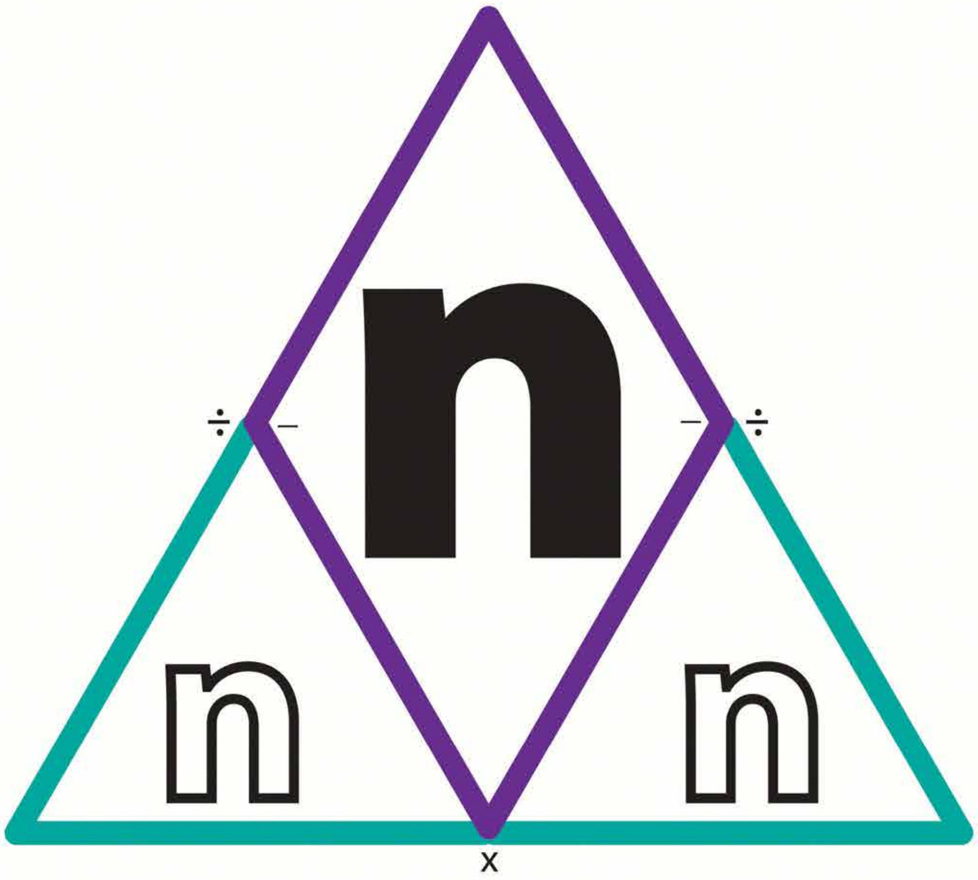

Times [multiplication] tables

Plus [addition] tables

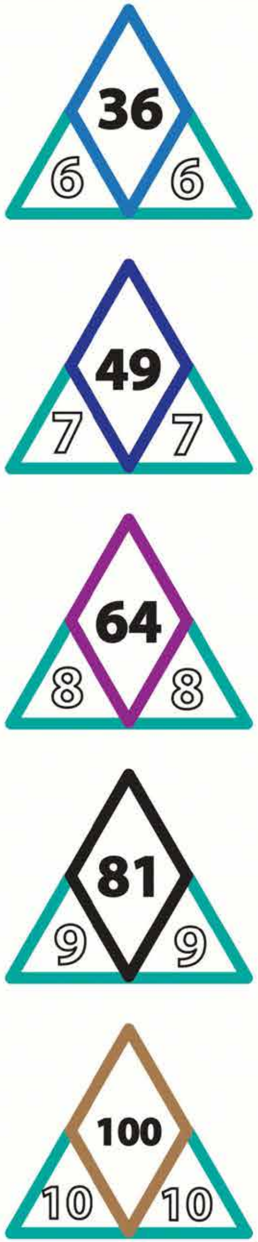
36
6 6
49
7 7
64
8 8
81
9 9
100
10 10

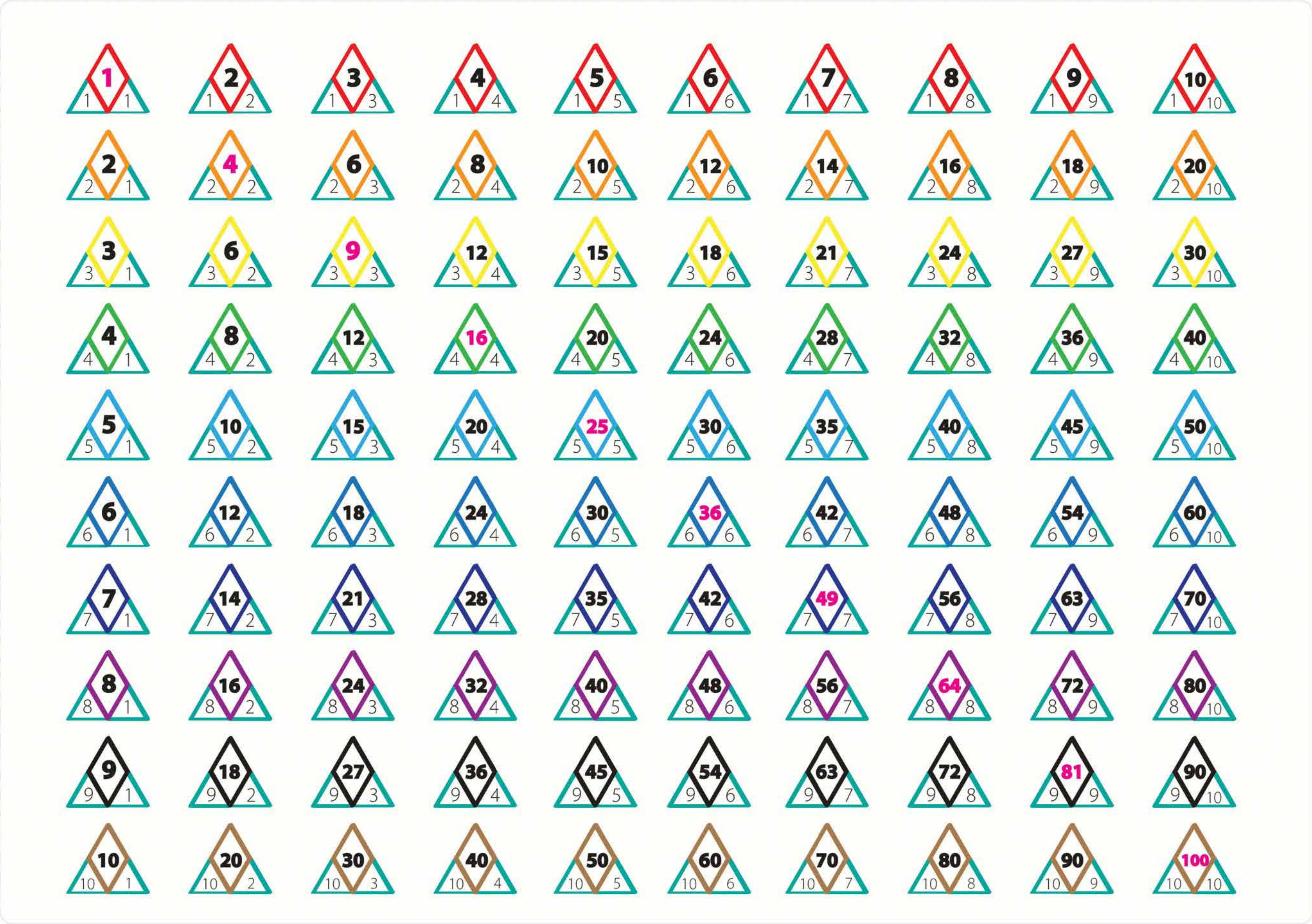

1 1 1	2 1 2	3 1 3	4 1 4	5 1 5	6 1 6	7 1 7	8 1 8	9 1 9	10 1 10
2 2 1	4 2 2	6 2 3	8 2 4	10 2 5	12 2 6	14 2 7	16 2 8	18 2 9	20 2 10
3 3 1	6 3 2	9 3 3	12 3 4	15 3 5	18 3 6	21 3 7	24 3 8	27 3 9	30 3 10
4 4 1	8 4 2	12 4 3	16 4 4	20 4 5	24 4 6	28 4 7	32 4 8	36 4 9	40 4 10
5 5 1	10 5 2	15 5 3	20 5 4	25 5 5	30 5 6	35 5 7	40 5 8	45 5 9	50 5 10
6 6 1	12 6 2	18 6 3	24 6 4	30 6 5	36 6 6	42 6 7	48 6 8	54 6 9	60 6 10
7 7 1	14 7 2	21 7 3	28 7 4	35 7 5	42 7 6	49 7 7	56 7 8	63 7 9	70 7 10
8 8 1	16 8 2	24 8 3	32 8 4	40 8 5	48 8 6	56 8 7	64 8 8	72 8 9	80 8 10
9 9 1	18 9 2	27 9 3	36 9 4	45 9 5	54 9 6	63 9 7	72 9 8	81 9 9	90 9 10
10 10 1	20 10 2	30 10 3	40 10 4	50 10 5	60 10 6	70 10 7	80 10 8	90 10 9	100 10 10

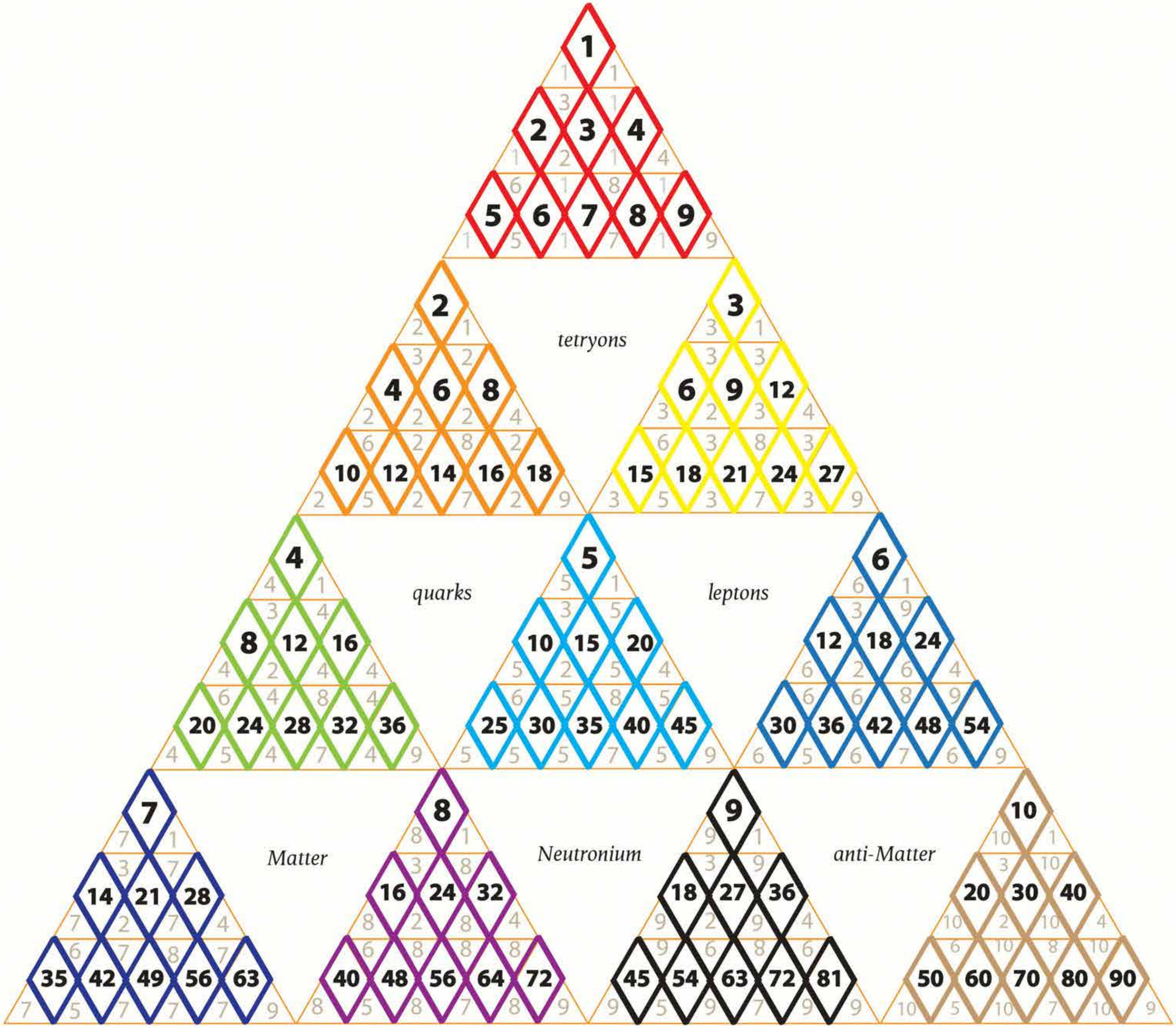

1
2 3 4
5 6 7 8 9
2
4 6 8
10 12 14 16 18
tetryons
3
6 9 12
15 18 21 24 27
4
8 12 16
20 24 28 32 36
quarks
5
10 15 20
25 30 35 40 45
leptons
6
12 18 24
30 36 42 48 54
7
14 21 28
35 42 49 56 63
Matter
8
16 24 32
40 48 56 64 72
Neutronium
9
18 27 36
45 54 63 72 81
anti-Matter
10
20 30 40
50 60 70 80 90

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Irrational Numbers

An irrational number is defined to be any number that is the part of the real number system that cannot be written as a complete ratio of two integers

One well known irrational number is π

Irrational numbers can be easily represented geometrically

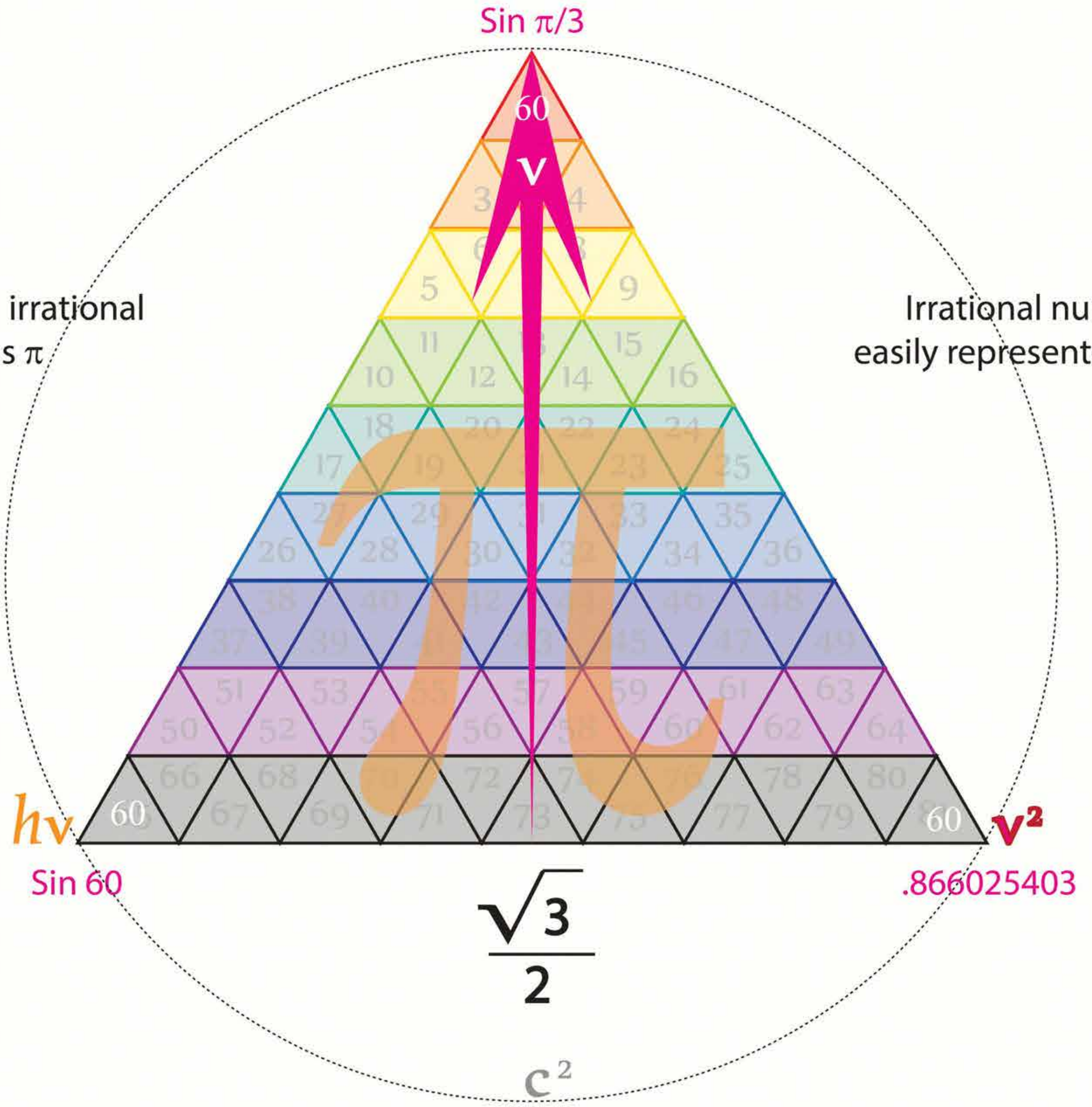
Sin π/3
60
v
hv
60
60
v²
Sin 60
.866025403
$\frac{\sqrt{3}}{2}$
c²

Exponentials & Logarithms

e and the Natural Log are inverse functions of each other:

e^x is the amount of continuous GROWTH after a certain amount of time.
Natural Log (ln) is the amount of TIME of continuous growth to reach a certain level

1	0
10	1
100	2
1,000	3

$10{,}000 = 10^4$

e

How much growth after x units of time
(and 100% continuous growth)

$$e^x = \lim_{n\to\infty}(1 + x/n)^n,$$

GROWTH

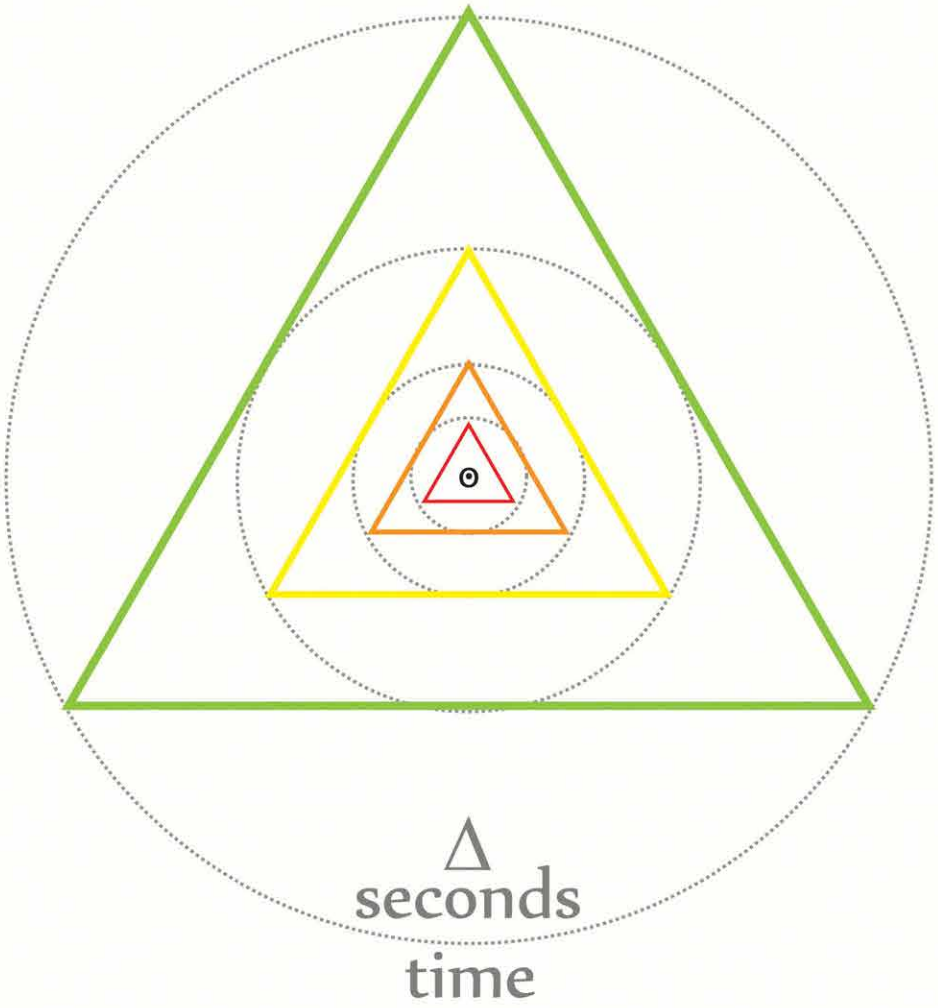

$\log(10{,}000) = 4$

ln

ln(x) lets us plug in continuous growth
and get the time it would take.

$$\ln(x) = \lim_{n\to\infty} n(x^{1/n} - 1).$$

PERIOD

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Exponential growth

GEOMETRIC

$$\text{growth} = e = \lim_{n\to\infty}\left(1+\frac{r}{n}\right)^t$$

GROWTH

3.141592654

e represents the idea that all continually growing systems
are scaled versions of a common rate

2.718281828

π

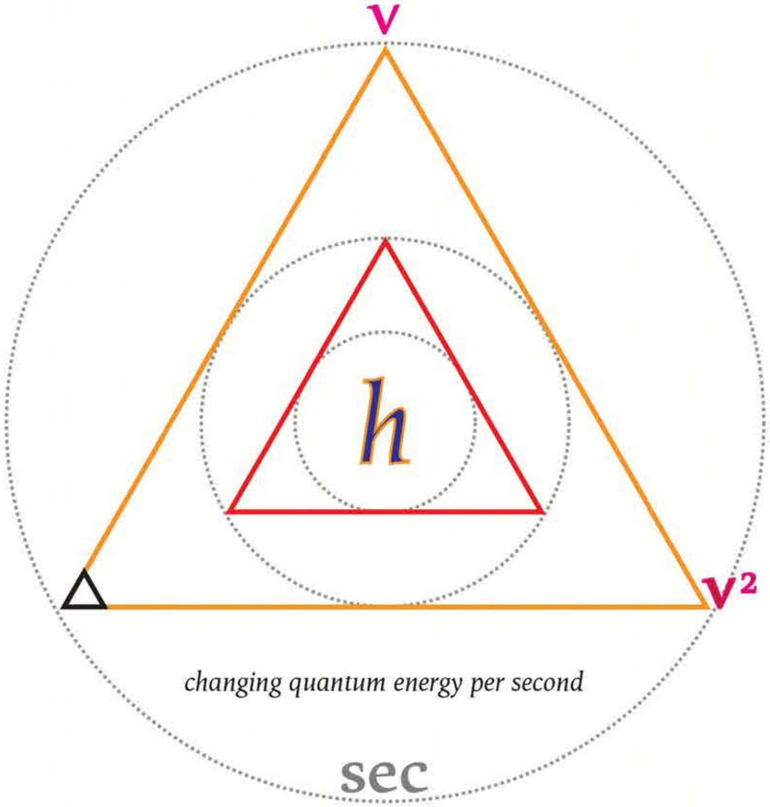

e

Pi is the ratio between
circumference and diameter
shared by all circles.

It is a fundamental ratio inherent in all circles
and therefore impacts any calculation of
circumference, area, volume, and surface areas

Pi radians are equally important and show
all quantised equilateral energy geometries
are related to their scribed circles

e is the base rate of growth
shared by all continually growing processes.

e lets you take a simple growth rate
(where all the change happens all at once
at the end of a period of time - ie quantised growth)

e shows up whenever systems grow
exponentially and continuously.....
radioactive decay, interest calculations
and populations

tetryons

EM fields

quarks

**e can be applied to the equilateral energy geometries of physical systems
only where the rate of increase is a integer factor of a squared number**

leptons

Baryons

Nuclear Energy levels

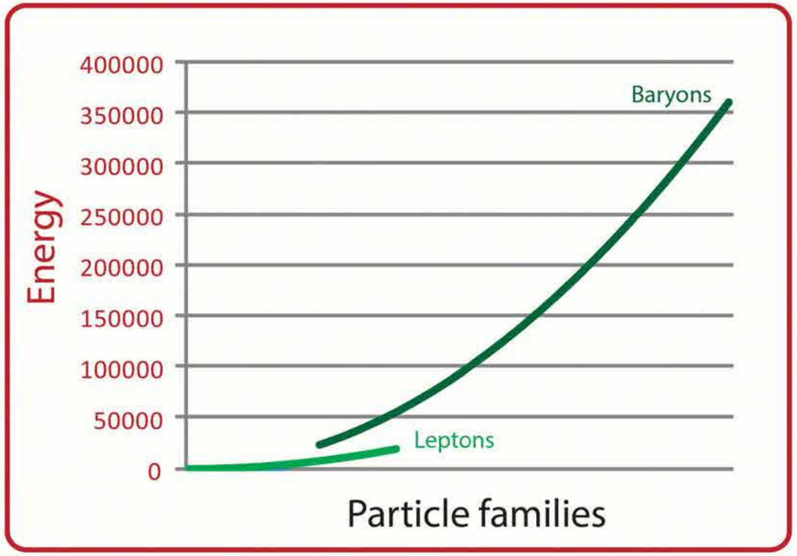

Exponential energy levels

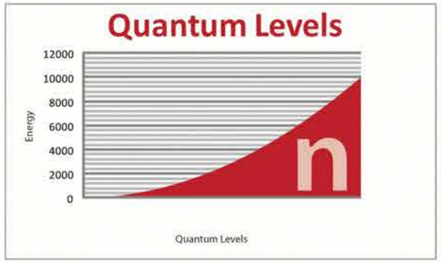

Radioactive decays follow exponential curves determined by the Tetryonic topology of the sub-atomic particle families

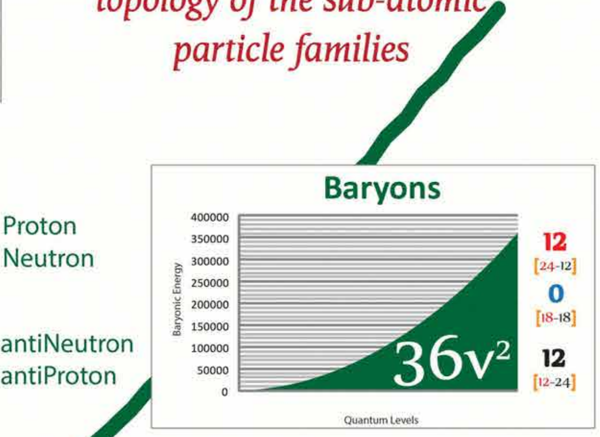

Proton
Neutron

antiNeutron
antiProton

The emission and absorption of bosons and Photons within sub-atomic nuclei

Increase and decrease in integer amounts according to the charged Tetryonic topologies of the particles involved

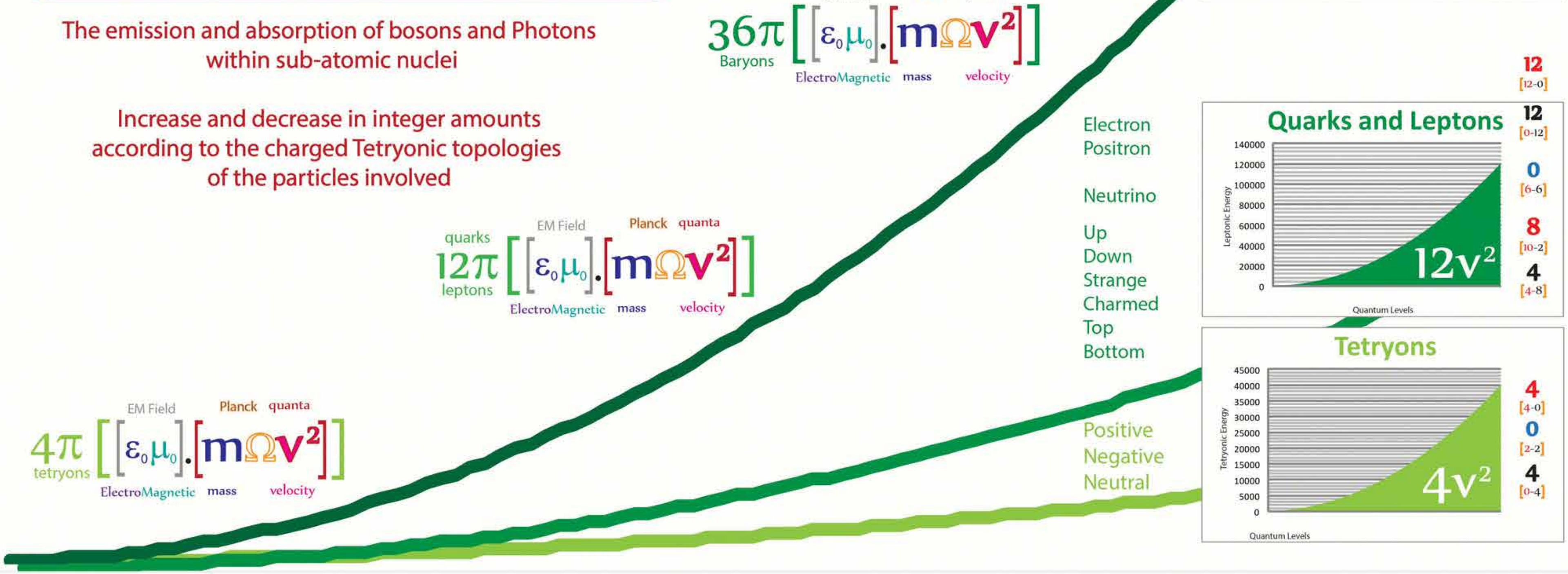

EM Field, Planck quanta

$$36\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Baryons — ElectroMagnetic, mass, velocity

EM Field, Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

quarks, leptons — ElectroMagnetic, mass, velocity

EM Field, Planck quanta

$$4\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

tetryons — ElectroMagnetic, mass, velocity

Electron
Positron

Neutrino

Up
Down
Strange
Charmed
Top
Bottom

Positive
Negative
Neutral

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Series addition & the Riemann Zeta Function

The second series addition of the Reimann Zeta function is where x=2: (pi^2)/6=1+1/2^2+1/3^2+1/4^2+...
(the sum of the reciprocals of the squares)

$$\zeta(s) = \sum_{n} \frac{1}{n^s}$$

$$\zeta(2) = \frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \frac{1}{4^2} + \cdots = \frac{\pi^2}{6}$$

$$f(n) = 1/n^2$$

$$\sum_{n=1}^{\infty} \frac{1}{n^x}$$

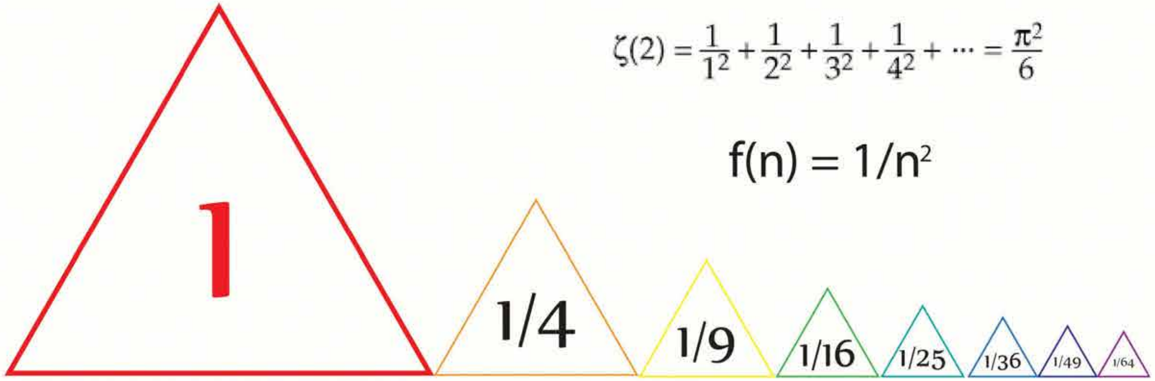

In mathematics, the Riemann zeta function, is a prominent function of great significance in number theory. It is a named after German mathematician Bernhard Riemann.
It is so important because of its relation to the distribution of prime numbers. It also has applications in other areas such as physics, probability theory, and applied statistics

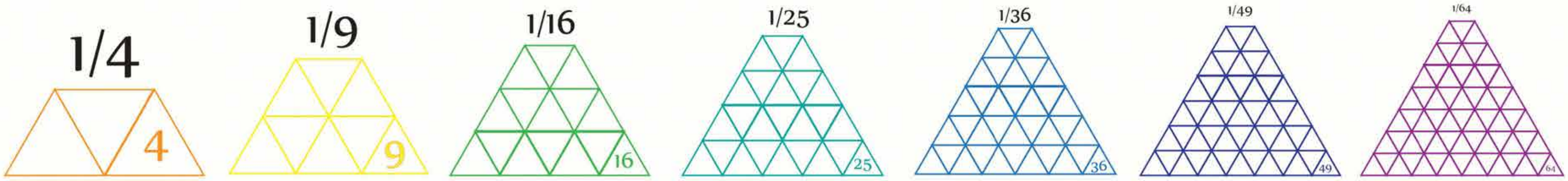

The mystery of prime numbers
Question: which natural numbers are prime? how are they distributed among natural numbers?

Primes are basic building blocks for natural numbers:

- any natural number is a product of prime numbers
- a prime number is only divisible by itself and by 1:
  (it cannot be further simplified)

We don't know how to predict where the prime numbers are:

“Prime numbers grow like weeds among the natural numbers, seeming to obey no other law than that of chance but also exhibit stunning regularity" (Don Zagier, number theorist)

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Adding the odd numbers in order produces the square numbers

Apart from 2, all primes are odd numbers;
the difference between two consecutive squares being odd,
every prime can be expressed as the difference between two squares

SPECTRAL LINES

Primes can be modelled as Bosons
[ODD number energy momenta geometries]

[2n-1]

KEM ENERGIES

Primes can be expressed as Bosons
[the difference of two squared energies]

$n^2 - [n-1]^2$

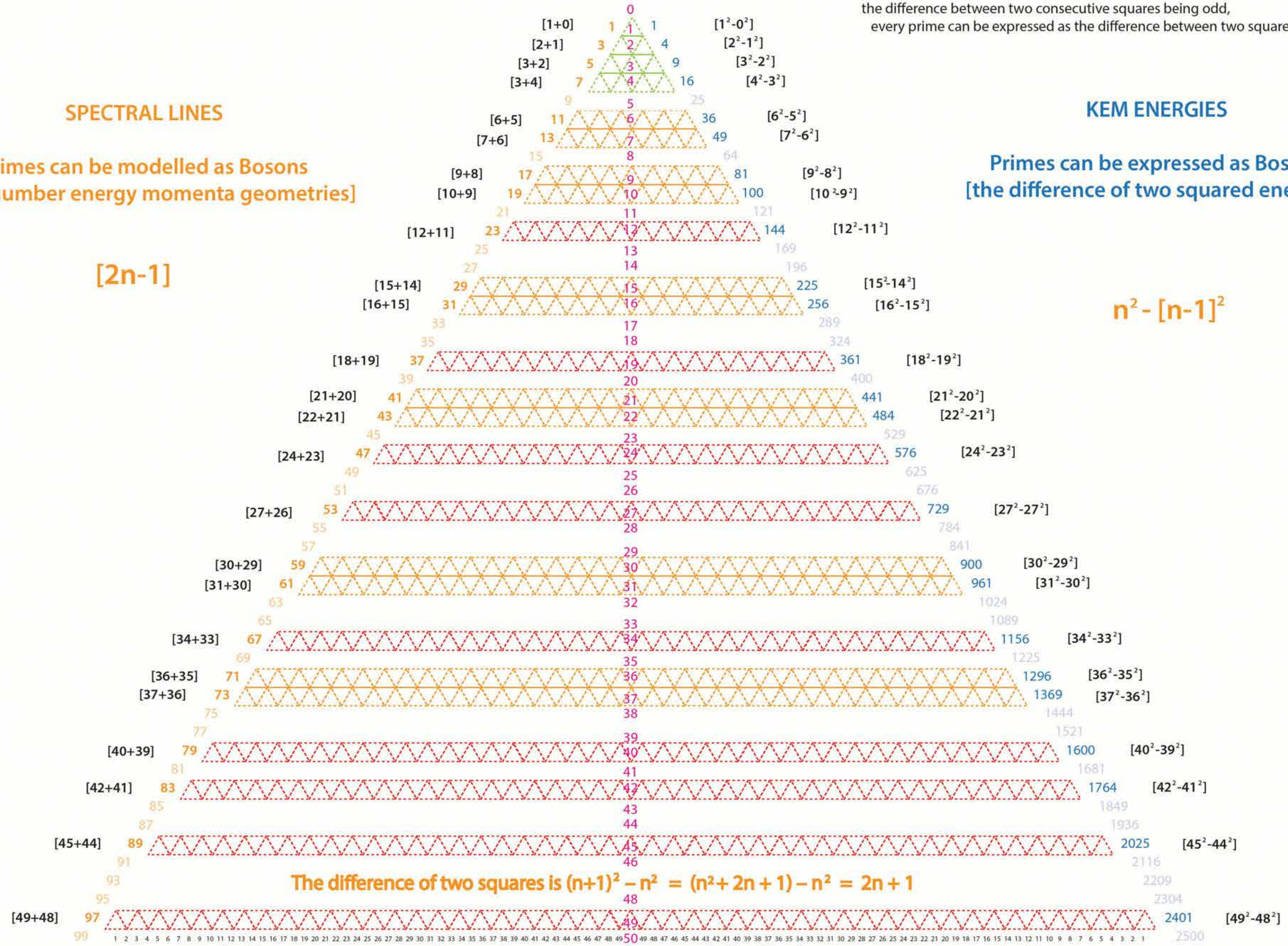
0
[1+0] 1 1 1 $[1^2-0^2]$
[2+1] 3 2 4 $[2^2-1^2]$
[3+2] 5 3 9 $[3^2-2^2]$
[3+4] 7 4 16 $[4^2-3^2]$
9 5 25
[6+5] 11 6 36 $[6^2-5^2]$
[7+6] 13 7 49 $[7^2-6^2]$
15 8 64
[9+8] 17 9 81 $[9^2-8^2]$
[10+9] 19 10 100 $[10^2-9^2]$
21 11 121
[12+11] 23 12 144 $[12^2-11^2]$
25 13 169
27 14 196
[15+14] 29 15 225 $[15^2-14^2]$
[16+15] 31 16 256 $[16^2-15^2]$
33 17 289
35 18 324
[18+19] 37 19 361 $[18^2-19^2]$
39 20 400
[21+20] 41 21 441 $[21^2-20^2]$
[22+21] 43 22 484 $[22^2-21^2]$
45 23 529
[24+23] 47 24 576 $[24^2-23^2]$
49 25 625
51 26 676
[27+26] 53 27 729 $[27^2-27^2]$
55 28 784
57 29 841
[30+29] 59 30 900 $[30^2-29^2]$
[31+30] 61 31 961 $[31^2-30^2]$
63 32 1024
65 33 1089
[34+33] 67 34 1156 $[34^2-33^2]$
69 35 1225
[36+35] 71 36 1296 $[36^2-35^2]$
[37+36] 73 37 1369 $[37^2-36^2]$
75 38 1444
77 39 1521
[40+39] 79 40 1600 $[40^2-39^2]$
81 41 1681
[42+41] 83 42 1764 $[42^2-41^2]$
85 43 1849
87 44 1936
[45+44] 89 45 2025 $[45^2-44^2]$
91 46 2116
93 2209
95 48 2304
[49+48] 97 49 2401 $[49^2-48^2]$
99 50 2500

The difference of two squares is $(n+1)^2 - n^2 = (n^2 + 2n + 1) - n^2 = 2n + 1$

[n-1] **all energy quanta create normal distributions** [n-1]

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Prime number Distributions

A twin prime is a prime number that differs from another prime number by two, for example the twin prime pair (41, 43). Sometimes the term twin prime is used for a pair of twin primes; an alternative name for this is prime twin or prime pair.

Twin primes appear despite the general tendency of gaps between adjacent primes to become larger as the numbers themselves get larger due to the prime number theorem (the "average gap" between primes less than n is log(n)).

$$p_2 - p_1 = 2$$

Every twin prime pair except (3, 5) is of the form (6n – 1, 6n + 1) for some natural number n, and with the exception of n = 1, n must end in 0, 2, 3, 5, 7, or 8

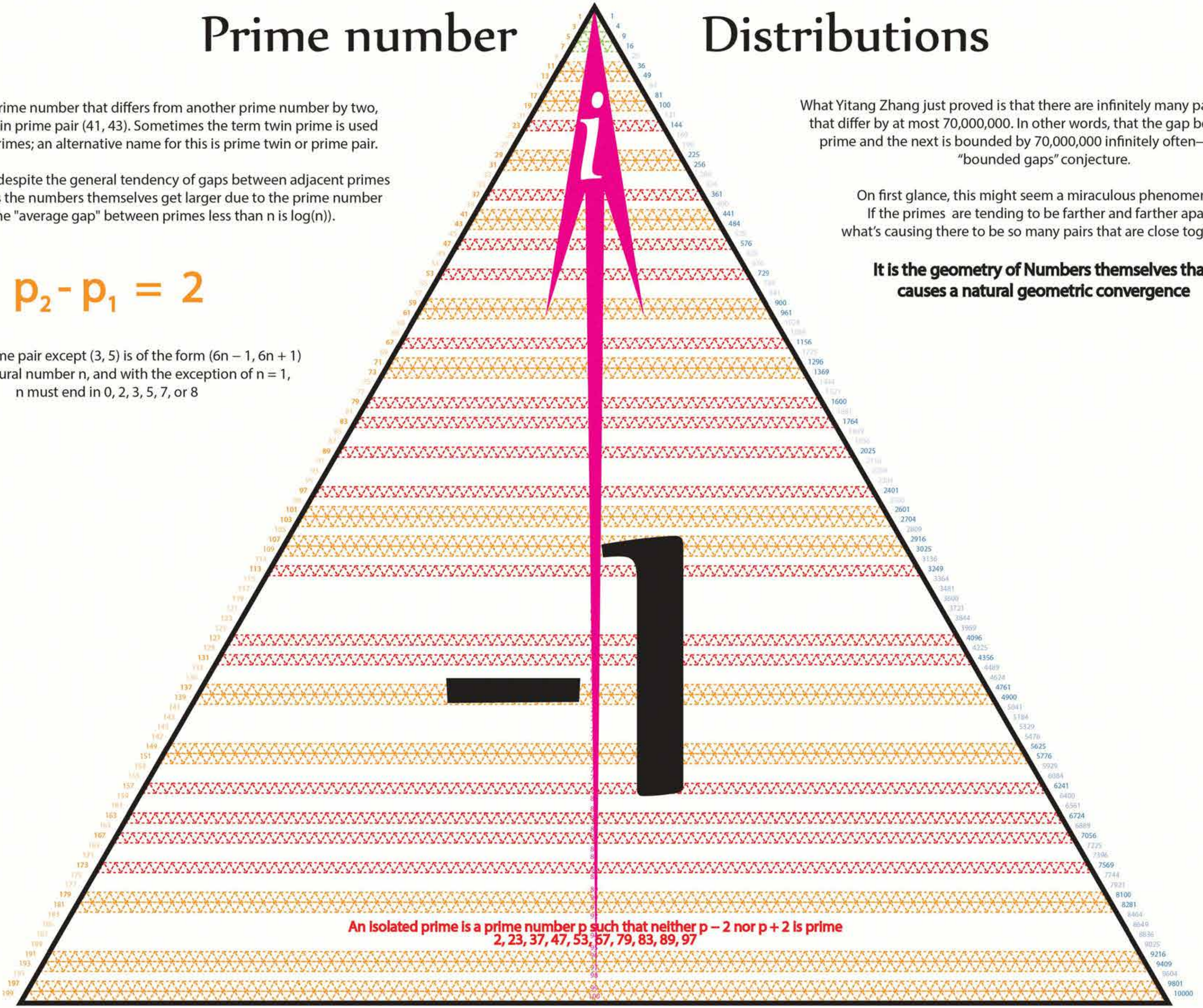

An isolated prime is a prime number p such that neither p – 2 nor p + 2 is prime
2, 23, 37, 47, 53, 67, 79, 83, 89, 97

What Yitang Zhang just proved is that there are infinitely many pairs of primes that differ by at most 70,000,000. In other words, that the gap between one prime and the next is bounded by 70,000,000 infinitely often—thus, the "bounded gaps" conjecture.

On first glance, this might seem a miraculous phenomenon.
If the primes are tending to be farther and farther apart,
what's causing there to be so many pairs that are close together?

It is the geometry of Numbers themselves that causes a natural geometric convergence

The Digital roots of Prime numbers

The digital root (also repeated digital sum) of a number is the (single digit) value obtained by an iterative process of summing digits, on each iteration using the result from the previous iteration to compute a digit sum.

The process continues until a single-digit number is reached.

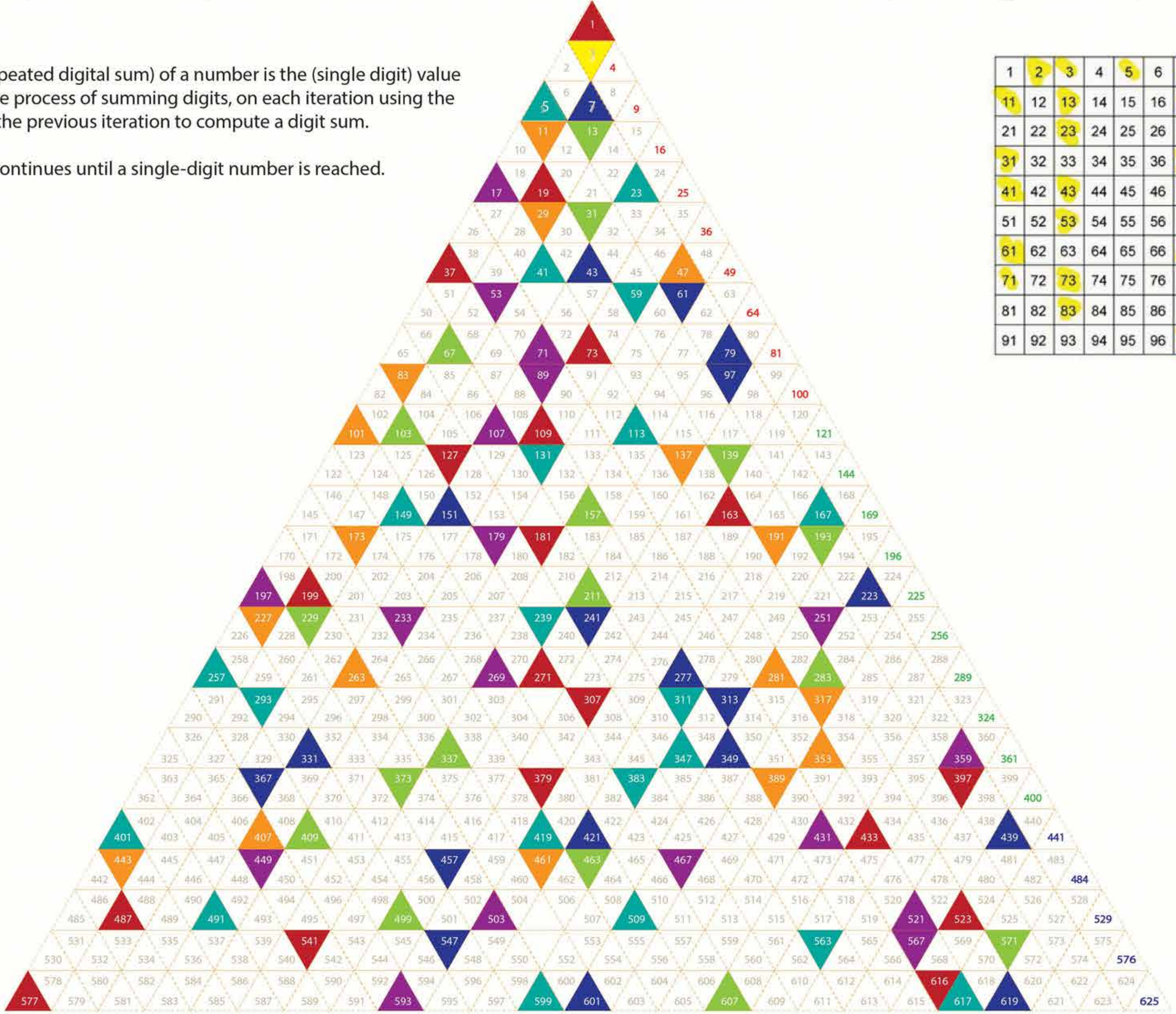

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

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Archimedes is given credit for the first calculus.

Archimedes infinite series

Today's calculus was published by Newton.

1 + 3/4 + 3/16 + 3/64 + 3/256 + 3/1024 + ...

1 + .75 + .1875 + .046875 + .01171875 + ...

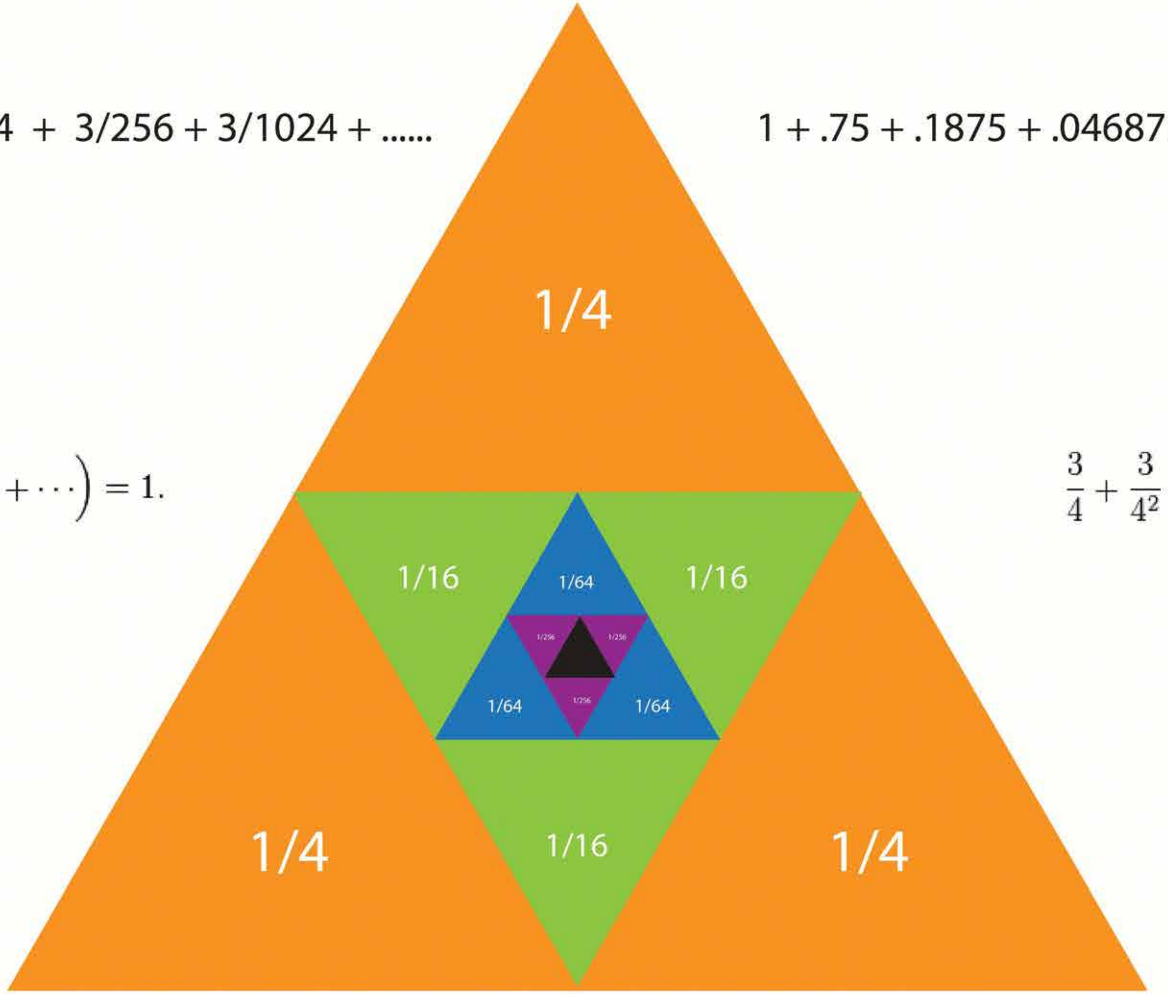
1/4
1/16
1/64
1/16
1/256
1/256
1/64
1/256
1/64
1/4
1/16
1/4

$$3\left(\frac{1}{4}+\frac{1}{4^2}+\frac{1}{4^3}+\frac{1}{4^4}+\cdots\right)=1.$$

$$\frac{3}{4}+\frac{3}{4^2}+\frac{3}{4^3}+\frac{3}{4^4}+\cdots=1.$$

Nested convergent infinite series

Summing a convergent infinite series

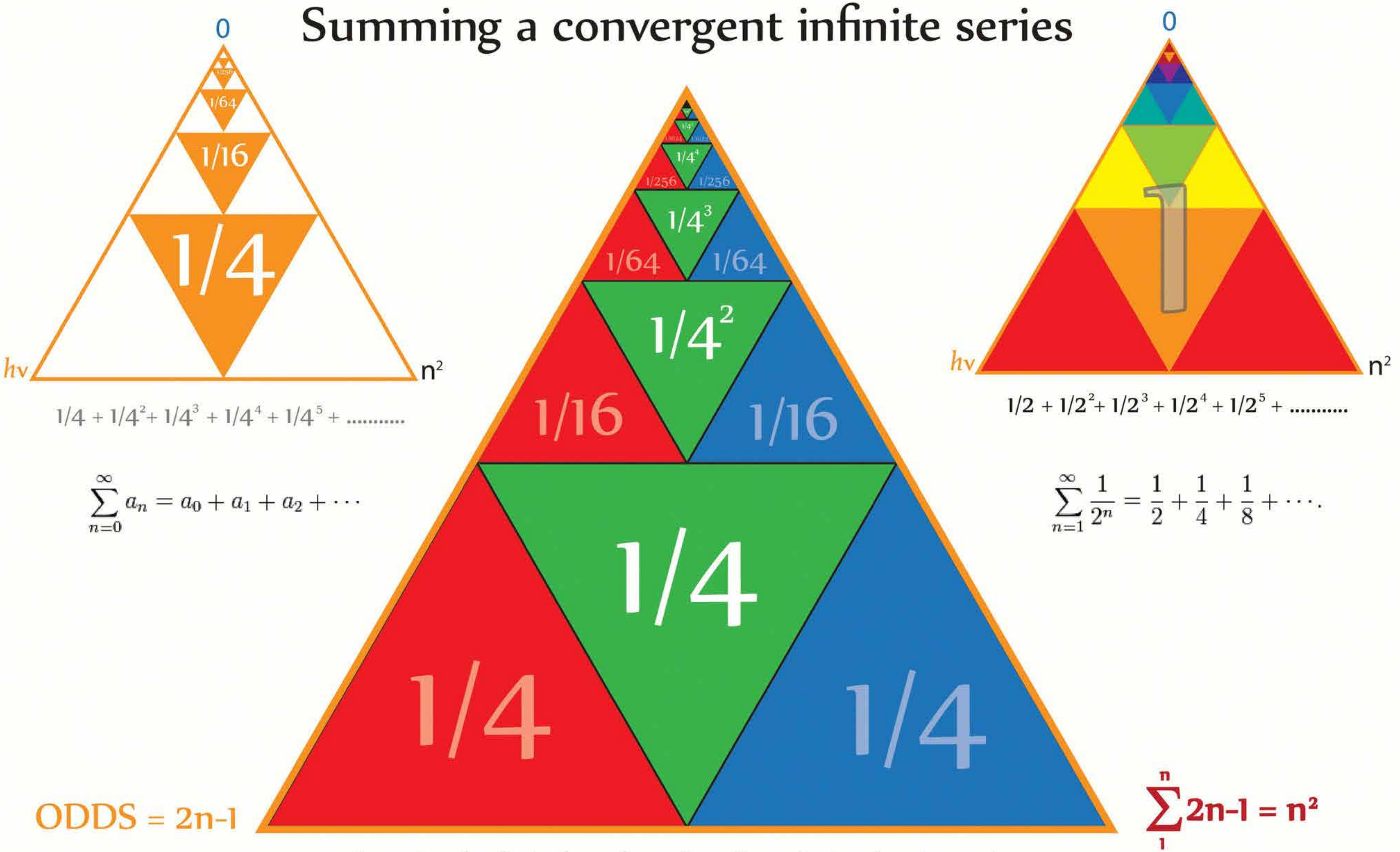
0
1/256
1/64
1/16
1/4
hv
n²
1/4⁵
1/1024
1/4⁴
1/256
1/4³
1/64
1/4²
1/16
1/4
0
1
hv
n²

$1/4 + 1/4^2 + 1/4^3 + 1/4^4 + 1/4^5 + \ldots\ldots\ldots\ldots$

$$\sum_{n=0}^{\infty} a_n = a_0 + a_1 + a_2 + \cdots$$

$1/2 + 1/2^2 + 1/2^3 + 1/2^4 + 1/2^5 + \ldots\ldots\ldots\ldots$

$$\sum_{n=1}^{\infty} \frac{1}{2^n} = \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \cdots.$$

ODDS = 2n-1

$$\sum_{1}^{n} 2n-1 = n^2$$

Summing the dissimilar coloured equilateral triangles gives unity

1/3 1/3 1/3

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1/3 1/3 1/3

Summing the dissimilar coloured equilateral triangles gives unity

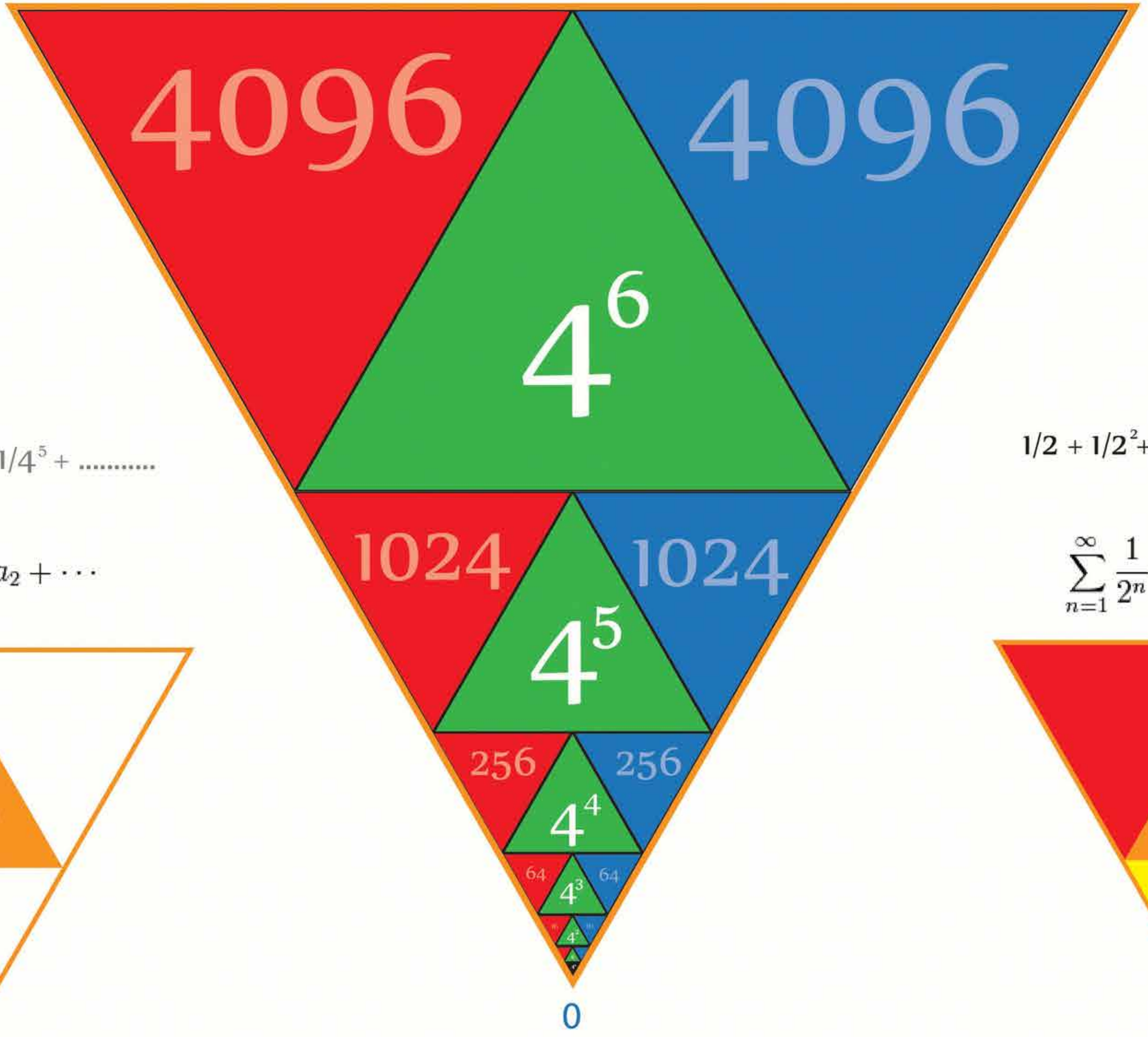
4096
4096
4^6
1024
1024
4^5
256
256
4^4
64
64
4^3
0

$1/4 + 1/4^2 + 1/4^3 + 1/4^4 + 1/4^5 + ...$

$$\sum_{n=0}^{\infty} a_n = a_0 + a_1 + a_2 + \cdots$$

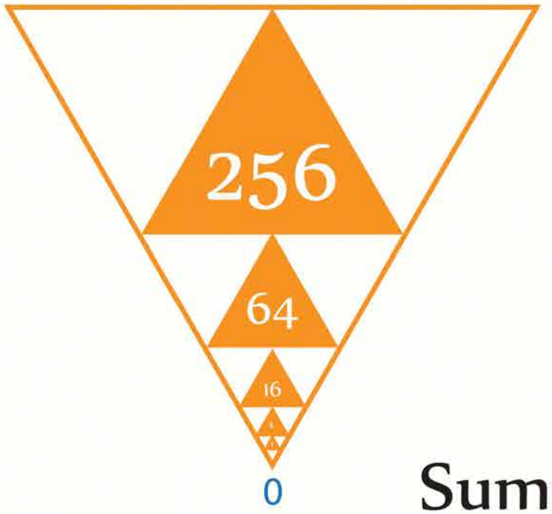

$1/2 + 1/2^2 + 1/2^3 + 1/2^4 + 1/2^5 + ...$

$$\sum_{n=1}^{\infty} \frac{1}{2^n} = \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \cdots.$$

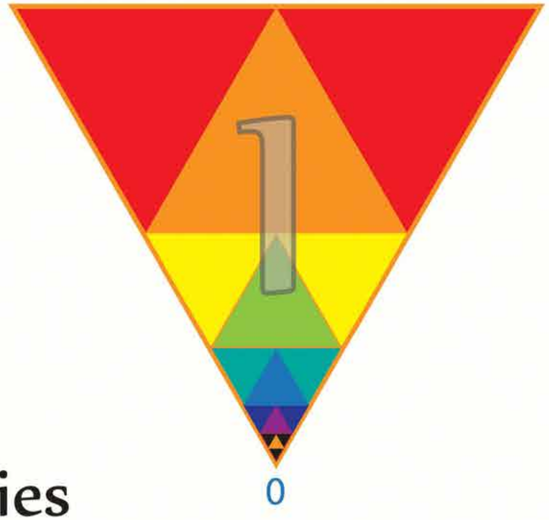

Summing a divergent infinite series

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Pietro Mengoli

(1626 – June 7, 1686)

The Basel Problem

The Basel problem is a famous problem in mathematical analysis with relevance to number theory, first posed by Pietro Mengoli in 1644 and solved by Leonhard Euler in 1735.

Leonhard Euler

(15 April 1707 – 18 Sept 1783)

$$\zeta(2)=\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\frac{1}{4^2}+\cdots=\frac{\pi^2}{6} \approx 1.644934$$

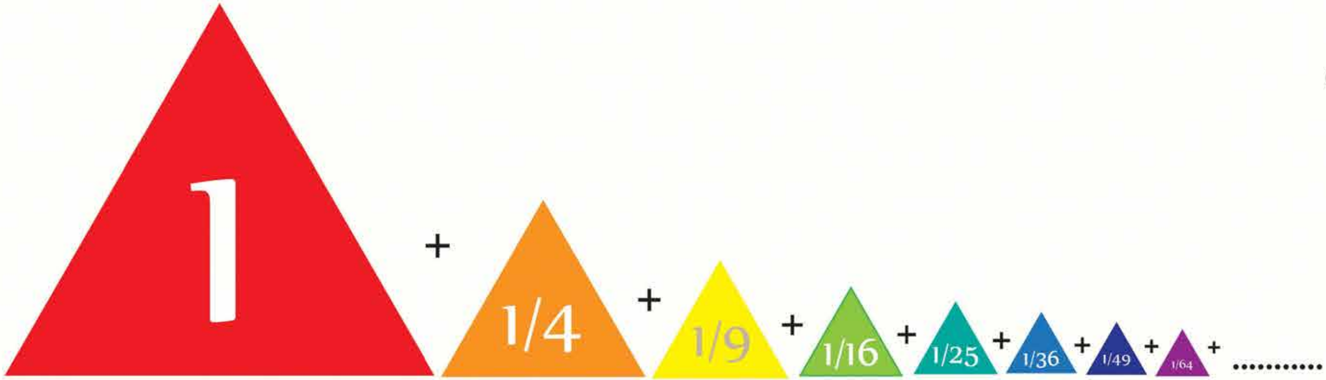

The Basel problem asks for the precise summation of the reciprocals of the squares of the natural numbers, i.e. the precise sum of the infinite series

$$f(n) = 1/n^2$$

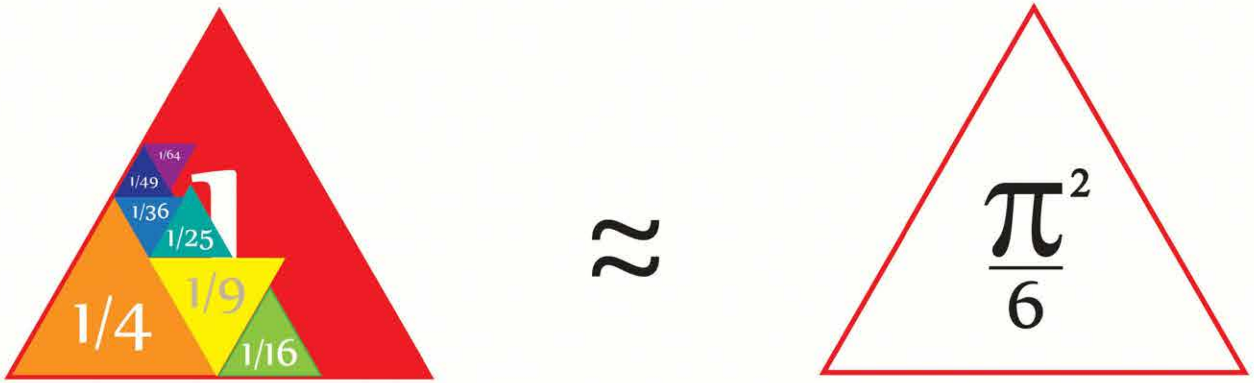

Integrals of mass-energy

is a means of finding scalar areas using summation and limits.

The summation of equilateral energy momenta quanta
with respect to their linear vector components

Integration is a micro adding of ***CONTINUOUS*** quantities.

$$\int_{n}^{\infty} f(x)$$

Integration is a special case of summation.

Integration is defined as the limit of a summation
as the number of elements approches infinity while
a part of their respective value approaches zero.

Summation is the finite sum of multiple, fixed values.

$$\sum_{n}^{\infty} x$$

Summation is a macro adding of ***DISCRETE*** quantities.

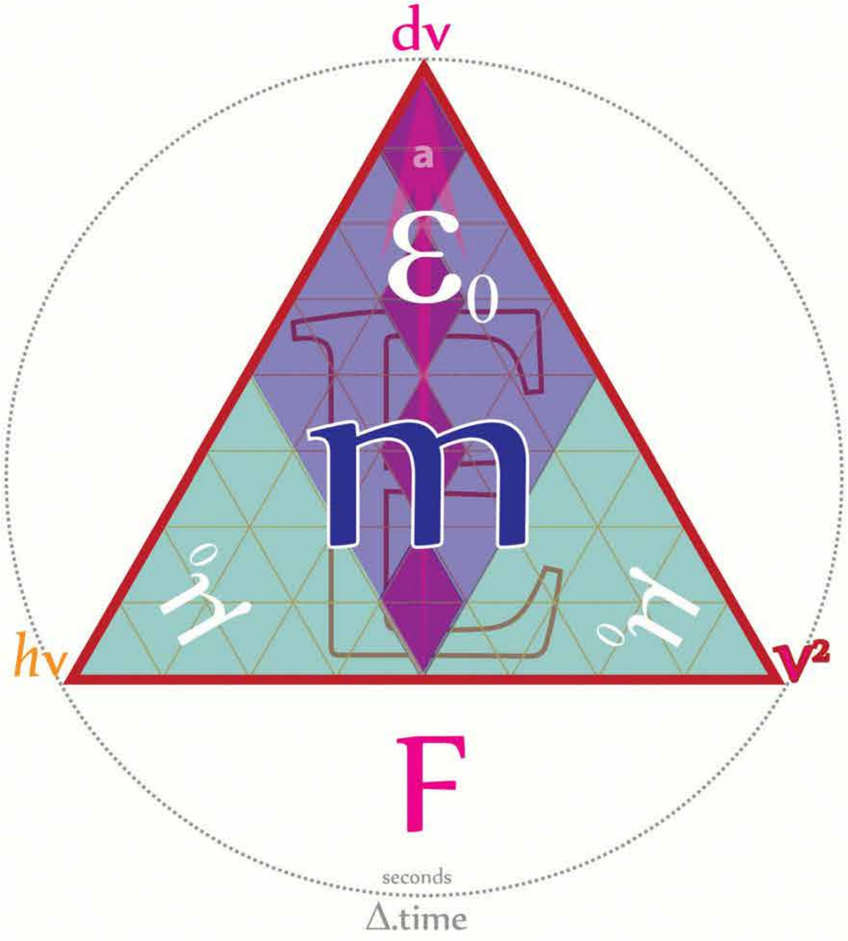

Integrating the energy quanta contained within equilateral charge geometry
gives the variable Force required to acheive changes in motion
[Energy, work, acceleration]

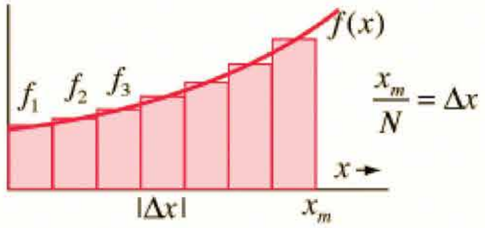

The Integral of the continuous area under the curve
is the summation of an infinte number of disctrete
rectangular measurements made to a specified limit

An integration isn't a simple summation,
but the limit of a sequence of summations

All Planck energies are discrete
equilateral geometries

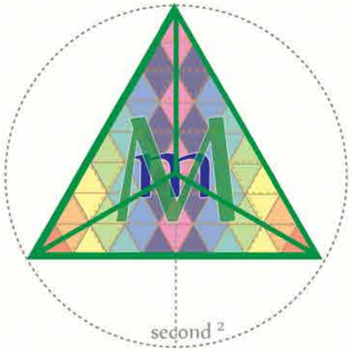

mass is the surface integral of
EM energy geometries
per unit of time

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"The calculus of infinitesimals"

The fundamental theorem of calculus
simply states that the sum of infinitesimal changes in a quantity over time
adds up to the net change in the quantity.

Scalar Energy

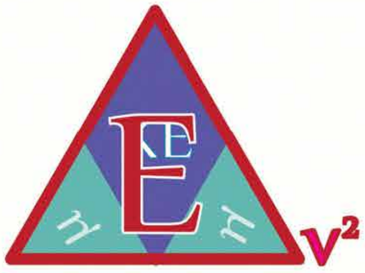

$E = mv^2$

Leibniz's vis viva
(Latin for living force)
is mv2,

[2 x kinetic energy]

vector Force

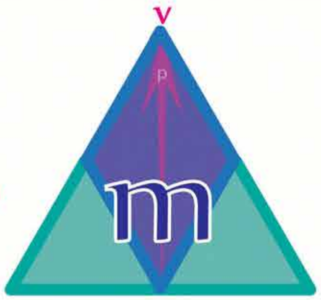

$F = m[dv/dt]$

Much of Newton's work
centred around momentum
and changes to it

[mass.velocity]

Gottfried Wilhelm von Leibniz

(July 1, 1646 – November 14, 1716)

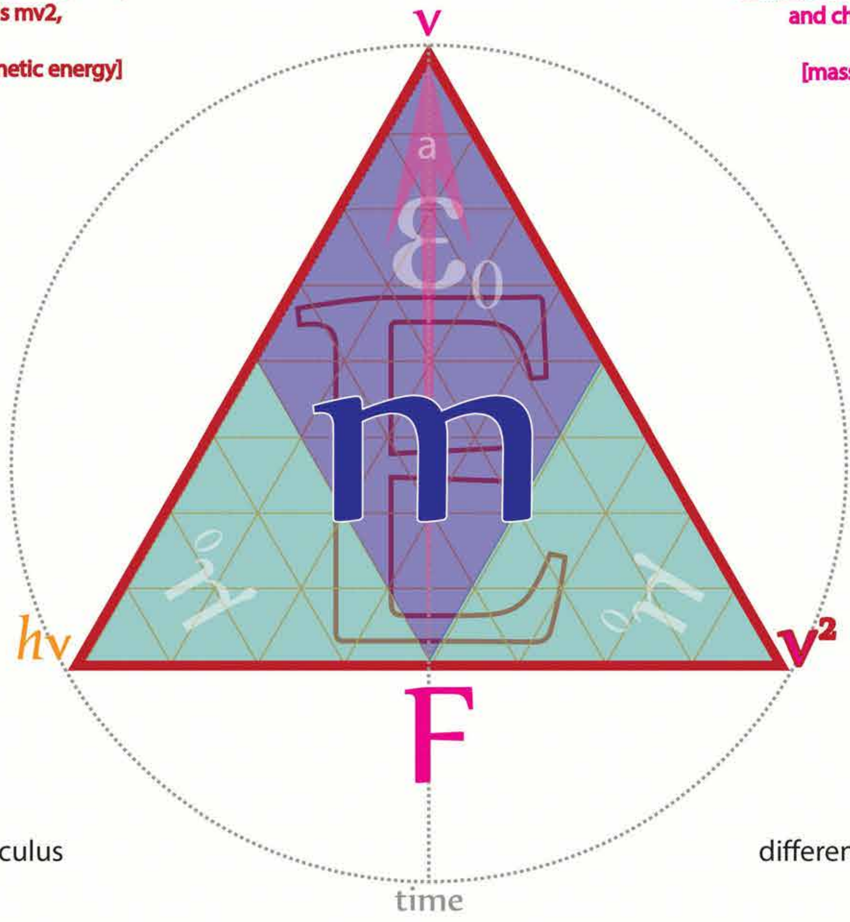

Sir Isaac Newton

(1643-1727)

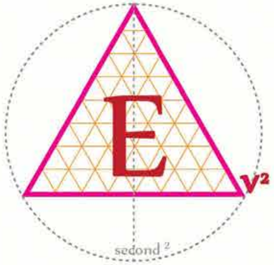

integral calculus

differential calculus

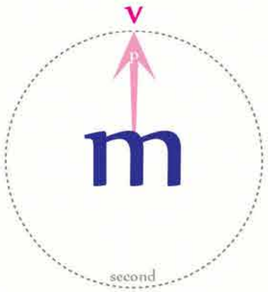

The founders of calculus thought
of the integral as an infinite sum of
rectangles of infinitesimal width

The fundamental theorem of calculus is a theorem that links
the concept of the integral with the derivative of a function.

In calculus, a branch of mathematics,
the derivative is a measure of how
a function changes as its input changes

Leibniz

scalar energies

linear momentum is the square root vector force
of the scalar energy required to do a set amount of work

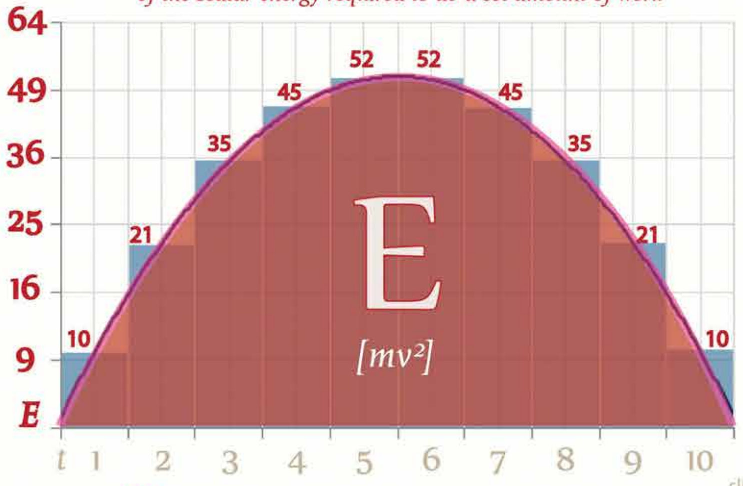

Energy momentum geometries

$$E = p^2$$

Energy momentum

$$kg\left[\frac{m}{s}\right]^2$$

print out this page

then cut out the 10
Planck energy momenta triangles
shown

Newton

linear momentum

$$d[mv]/dt = dp/dt = ma$$

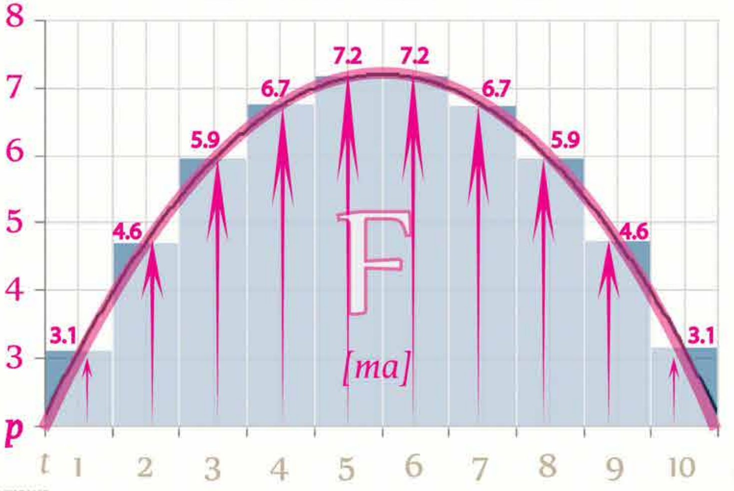

slice fine lines along the pink linear momentum arrows
with a razor blade or similar as highlighted
under the Newtonian acceleration curve

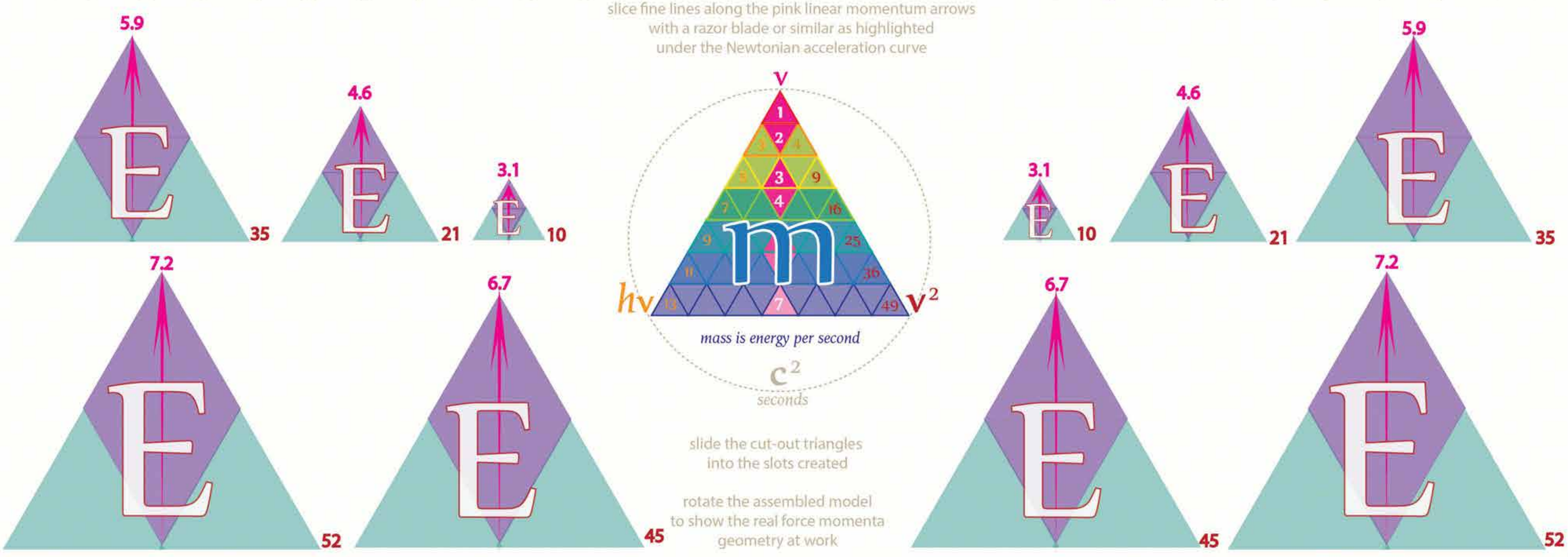
5.9
E
35
4.6
E
21
3.1
E
10
7.2
E
52
6.7
E
45
v
1
2
3
4
3
9
4
16
m
7
hv
v²
mass is energy per second
c²
seconds
3.1
E
10
4.6
E
21
5.9
E
35
6.7
E
45
7.2
E
52

slide the cut-out triangles
into the slots created

rotate the assembled model
to show the real force momenta
geometry at work

linear momentum is the square root vector force
of the scalar energy required to do a set amount of work

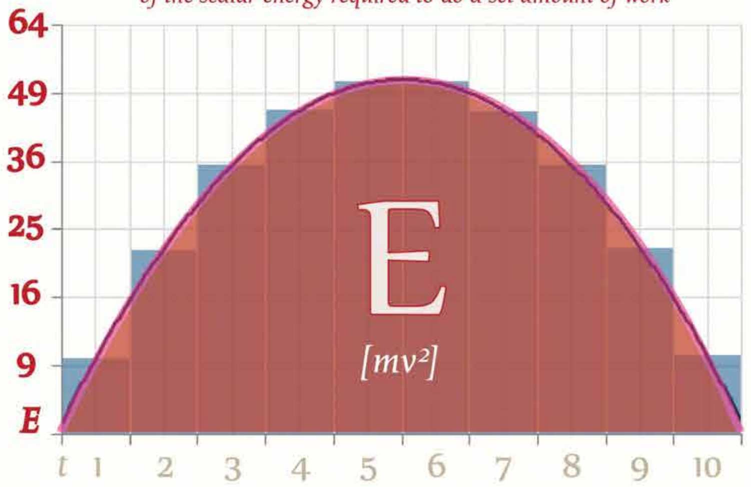

p

linear momentum

$\text{kg}\,\frac{\text{m}}{\text{s}}$

print out this page

$d[mv]/dt = dp/dt = ma$

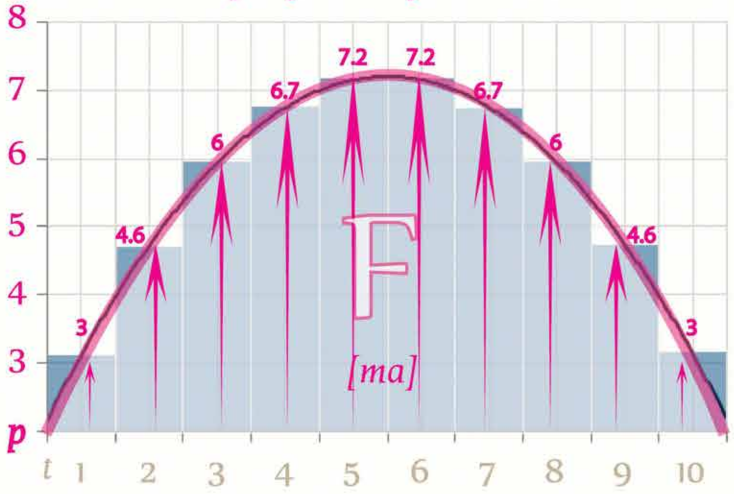

Leibniz

scalar energies

$$E = mv^2$$

mass-energy momenta relationship

square root equilateral energy is linear momentum

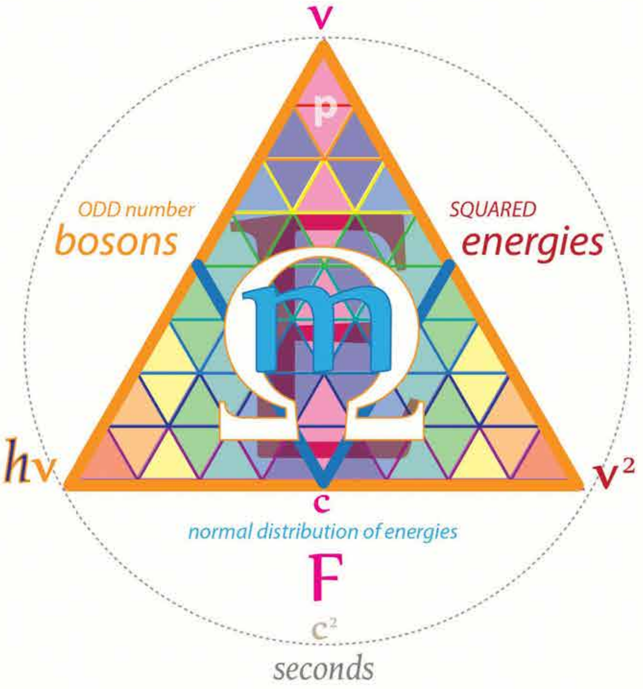
v
p
ODD number
bosons
SQUARED
energies
m
Ω
E
hv
v²
c
normal distribution of energies
F
c²
seconds

Planck quanta and their vector linear momentum
lie at 90 degrees to the angle use in the graphs of motion in calculus

Newton

linear momentum

$$F = ma$$

mass is a scalar constant relating Force to acceleration

$$F = m\frac{\Delta v}{\Delta t}$$

Differentiation

Differentiation is concerned with things like speeds and accelerations, slopes and curves etc.
These are Rates of Change, they are things that are defined locally.

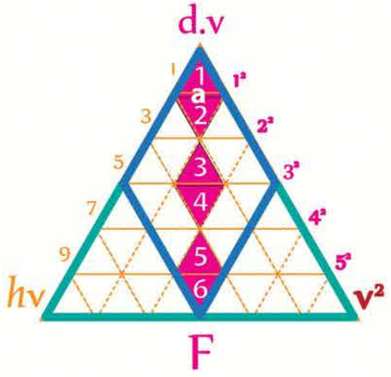
d.v
1
a
2
1²
3
2²
3
4
3²
5
4²
5
6
5²
7
9
hv
v²
F

An increase in a force opposing an object's vector velocity results in

DECCELERATION

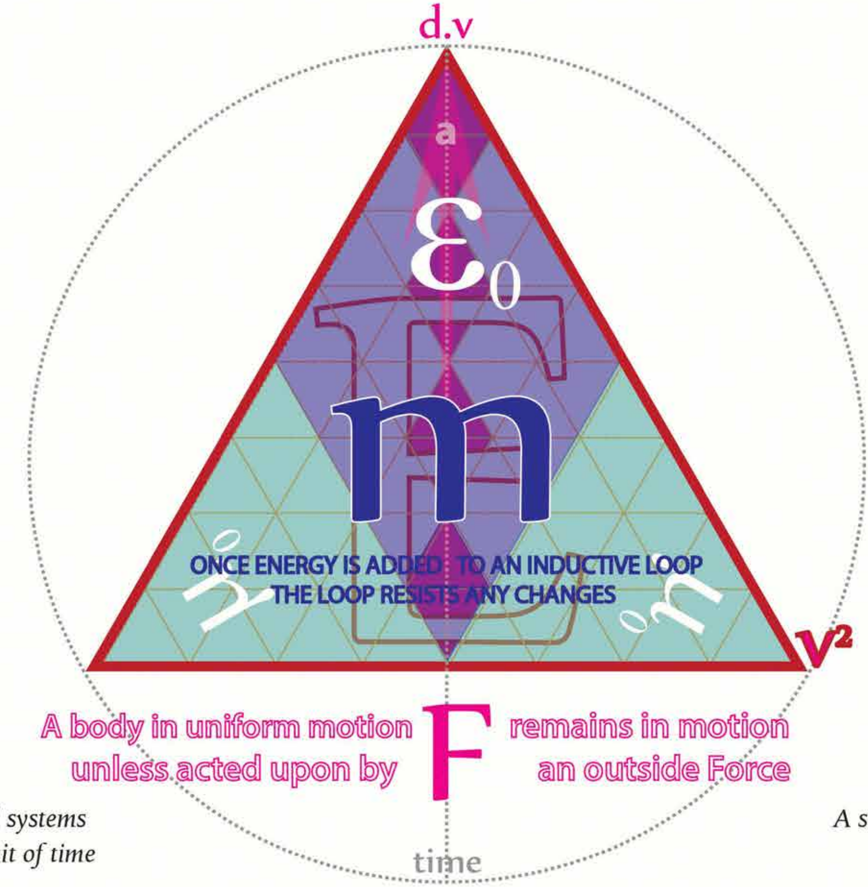
d.v
a
ε_0
m
ONCE ENERGY IS ADDED TO AN INDUCTIVE LOOP
THE LOOP RESISTS ANY CHANGES
v²
F
time

A body in uniform motion remains in motion unless acted upon by an outside Force

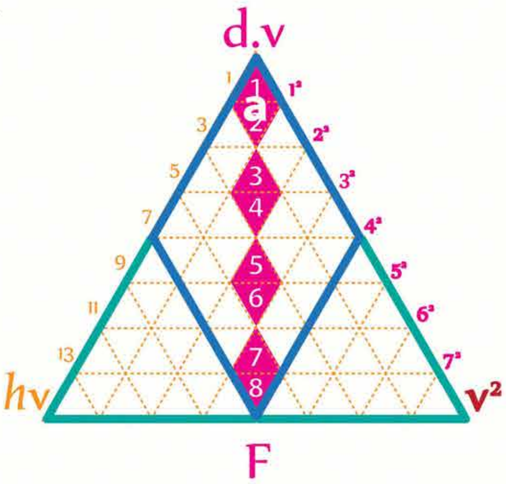
d.v
1
a
2
1²
3
2²
3
4
3²
5
4²
5
6
5²
7
6²
9
11
7
8
7²
13
hv
v²
F

An increase in a force in line with an object's vector velocity results in

ACCELERATION

A linear measure of Forces acting on physical systems resulting in changes to distance covered per unit of time

A scalar measure of Forces acting on physical systems resulting in changes to their rate of motion

$$v = \frac{\Delta d}{\Delta t}$$

$$= m/s$$

$$F = ma$$

In physics, the derivative of the displacement of a moving body with respect to time is the velocity of the body, and the derivative of velocity with respect to time is acceleration.

$$\sum \mathbf{F} = \frac{\mathrm{d}\mathbf{p}}{\mathrm{d}t} = m\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t} + \mathbf{v}\frac{\mathrm{d}m}{\mathrm{d}t}$$

Newton's second law of motion states that the derivative of the momentum of a body equals the force applied to the body.

$$a = \frac{\Delta v}{\Delta t}$$

$$= m/s^2$$

Visualising the geometric half-truths of relativistic physics

The source of all the physical relationships of mass-energy momenta and the constants in Physics is the Equilateral Triangle (and all texts must be corrected)

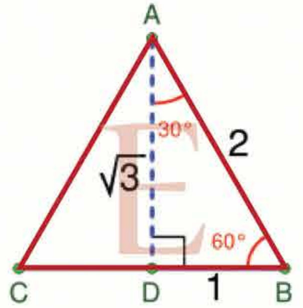

Energy geometries within Physics including Special Relativity with its Lorentz corrections have historically been incorrectly illustrated through the geometry of right angled triangles

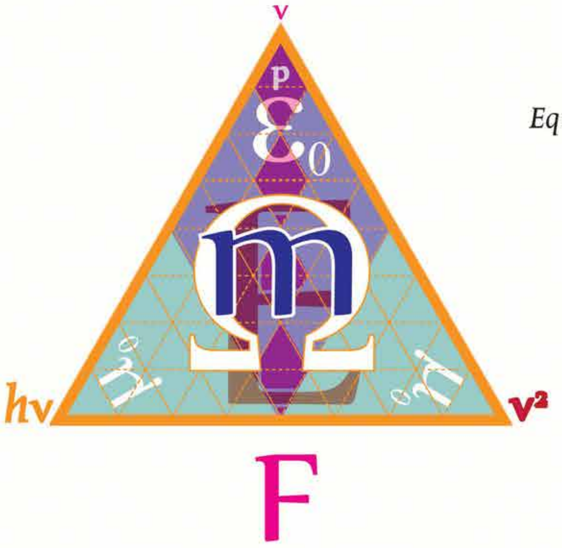

$$\sum \mathbf{F} = \frac{d\mathbf{P}}{dt} = m\frac{d\mathbf{v}}{dt} = m\mathbf{a}$$

$$\mathbf{F} = m\mathbf{a}\,.$$

Physics is geometry,
one cannot be separated from the other

Equilateral geomtries lead to a intuitive understandings of Physics, Chemistry, Electrodynamics and Gravitation along with all the other apsects of Nature.

$$mv^2 = E = hv^2$$

ENERGY

6.629432673 e-34 J

Planck quanta
$$\left[m\Omega v^2\right]$$
mass velocity

7.376238634 e-51 kg

momentum

$$p^2 = mv^2$$

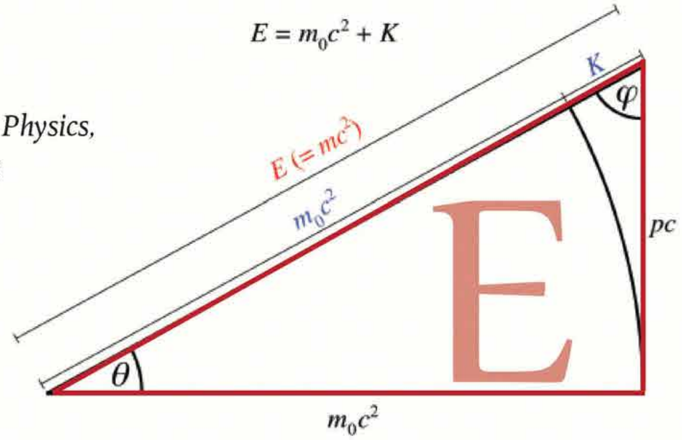

$$E^2 = p^2c^2 + m_0^2c^4$$

Generalizing, we see that the square of the total energy, mass, or distance in spacetime is the sum of the components squared.

We can see an origin of distance in spacetime relating to velocity in pc in which Energy is subject to Lorentz corrections [v/c]

$$E = pc.$$

Additionally, EM mass can be directly related tot the Energy content of a body by the velocity of Energy

$$E = mc^2$$

Velocity

In physics, velocity is the measurement of the rate and direction of change in the position of an object.

It is a vector physical quantity; both magnitude and direction are required to define it.

The scalar absolute value (magnitude) of velocity is speed, a quantity that is measured in metres per second (m/s or ms–1) when using the SI (metric) system.

$$\frac{m}{s}$$

Speed is the scalar value of the
Distance traveled per unit of TIme

$$\bar{\mathbf{v}} = \frac{\Delta \mathbf{x}}{\Delta t}.$$

Velocity is the vector value of the
Distance traveled per unit of Time

$$\frac{\vec{m}}{s}$$

Velocity squared is the scalar value of the
Distance traveled per unit of Time squared
(Energy of a given spatial volume)

$$\frac{m^2}{s^2}$$

v Velocity $\frac{m}{s}$

sec

is a 2D
radial Space-time
MEASUREMENT

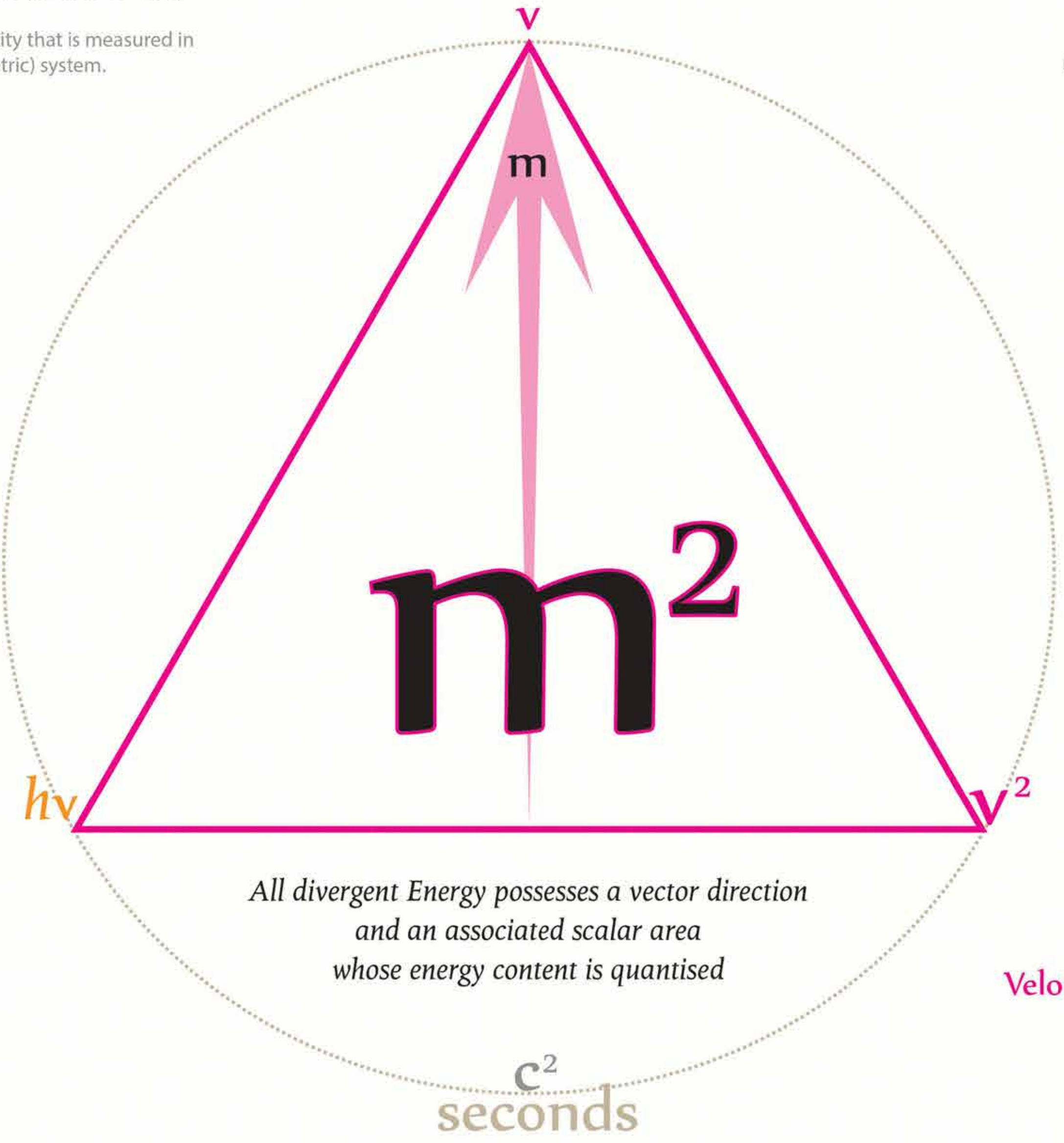

*All divergent Energy possesses a vector direction
and an associated scalar area
whose energy content is quantised*

Velocity squared

$$\frac{m^2}{s^2}$$

is a 3D
Spherical Space-time
MEASUREMENT

a Acceleration $\frac{m}{s^2}$

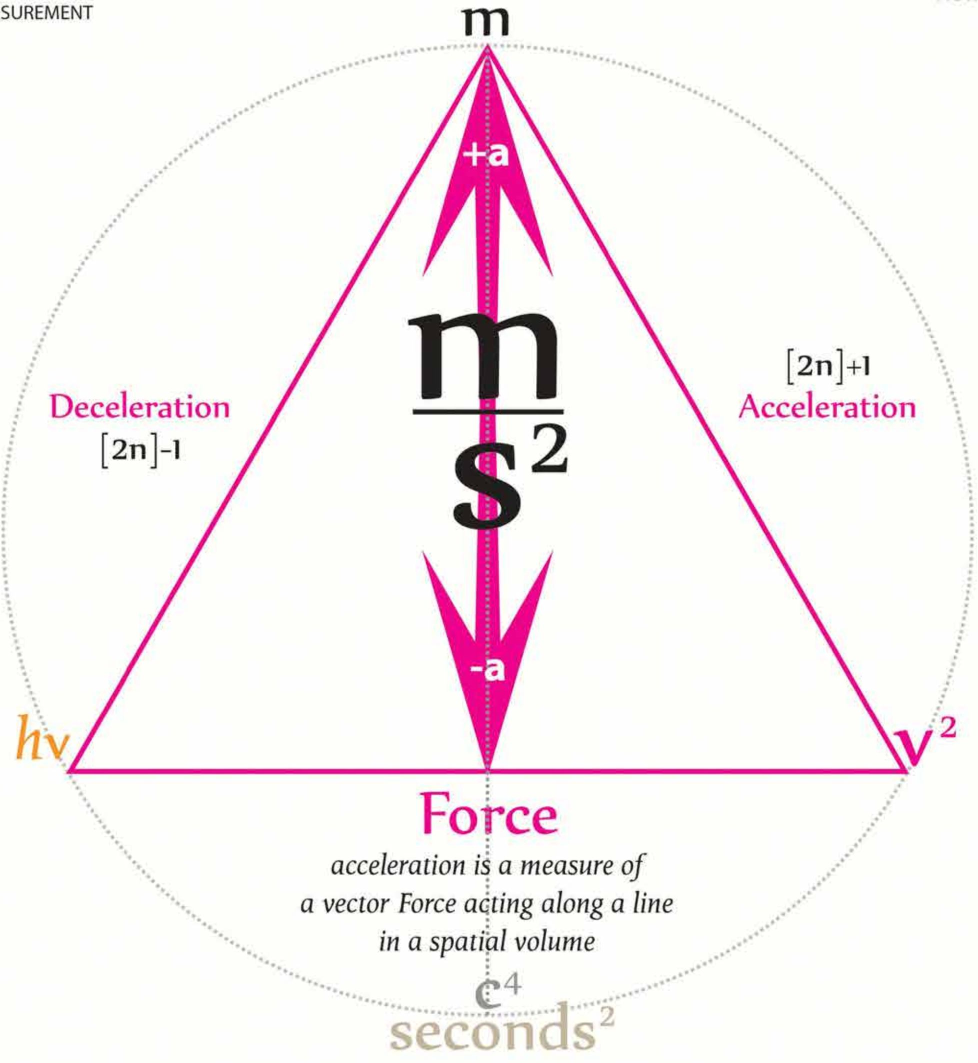

Force

acceleration is a measure of
a vector Force acting along a line
in a spatial volume

Acceleration

In physics, acceleration is the rate of change of velocity over time [dt]

In one dimension, acceleration is the rate at which something speeds up or slows down.

However, since velocity is a vector, acceleration describes the rate of change of both the magnitude and the direction of velocity.

Acceleration has the dimensions [Length]/[Time Squared]
In SI units, acceleration is measured in meters per second squared (m/s^2).

$$a = \frac{\Delta y}{\Delta x} = \frac{\Delta v}{\Delta t}.$$

In classical mechanics, for a body with constant mass,
the acceleration of the body is proportional to the net force acting on it
(Newton's second law)

$$F=ma \longrightarrow a=F/m$$

Force

$$kg\,\frac{m}{s^2}$$

Additionally, for a mass with constant velocity,
(ie in an inertial frame)
the energy of motion is expressed as its momentum
(acceleration causes changes in Energy-momentum)

$$p = kg\,\frac{m}{s}$$

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Momentum

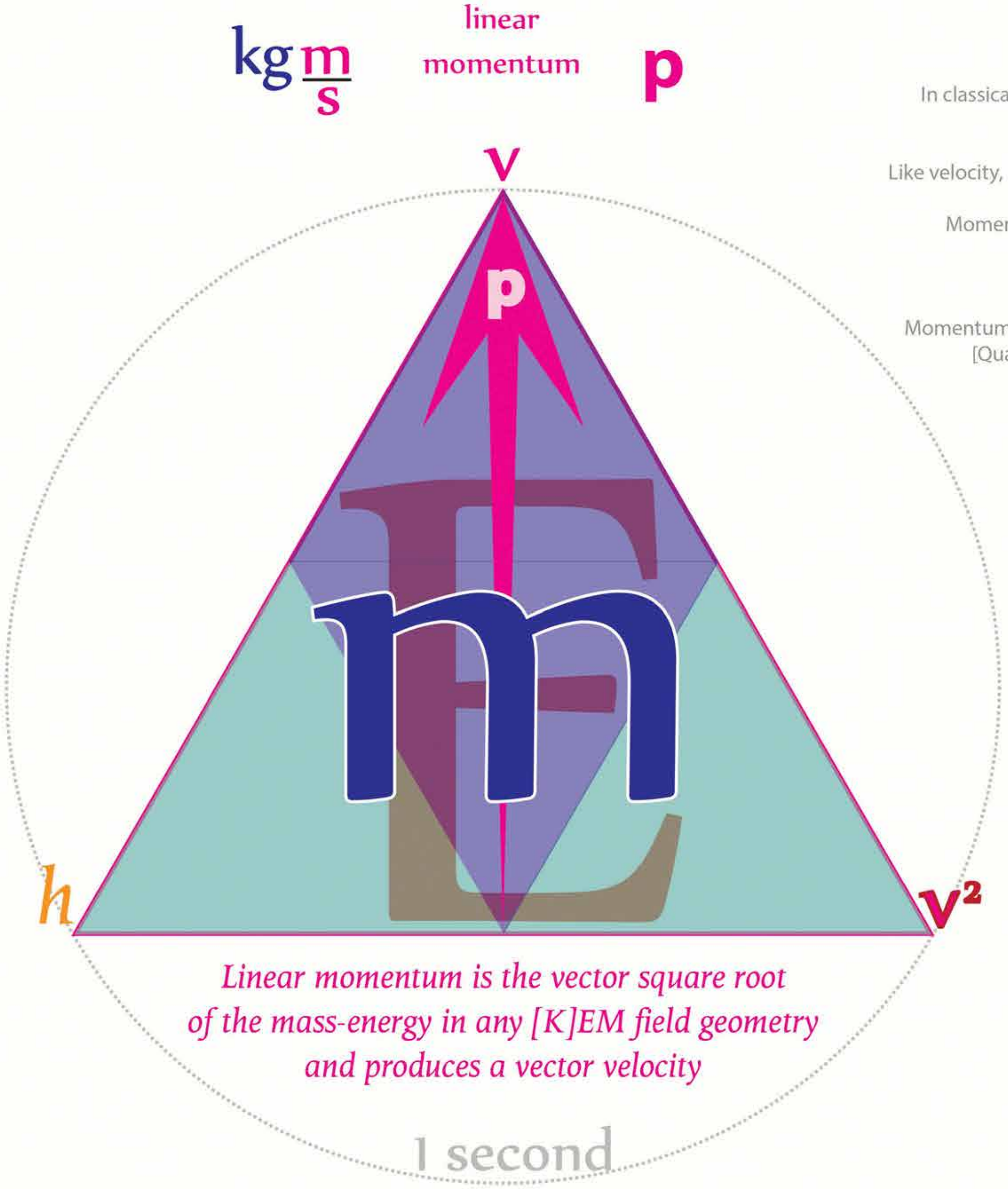

Linear momentum is the vector square root of the mass-energy in any [K]EM field geometry and produces a vector velocity

In classical mechanics, momentum (pl. momenta; SI unit kg·m/s, or, equivalently, N·s) is the product of the mass and velocity of an object (p).

Like velocity, momentum is a vector quantity, possessing a direction as well as a magnitude.

Momentum is a conserved quantity (law of conservation of linear momentum), meaning that if a closed system is not affected by external forces, its total momentum cannot change.

Momentum should be referred to in its specific forms to distinguish it in its various forms [Quantised Angular, Linear, Rotational and quantum/nuclear momentum]

$$\boxed{p = \frac{hv^2}{v} = mv}$$

Although originally expressed in Newton's Second Law, the conservation of momentum also holds in special relativity and, with appropriate definitions, a (generalized) momentum conservation law holds in electrodynamics, quantum mechanics, quantum field theory, and general relativity.

In relativistic mechanics, non-relativistic momentum is further multiplied by the Lorentz factor.

$$p^2 = E = mv^2$$

Energy can be expressed as the square of linear momentum

$$kg\frac{m^2}{s^2}$$

equilateral Planck energy momenta

$m\Omega v^2$

Energy-momentum relationship

The total number of equilateral Planck quanta [quantised mass-energy momenta] is directly related to the square of its linear momentum [mass-velocity]

Quantum Mechanics

$$h = \frac{E}{v^2}$$

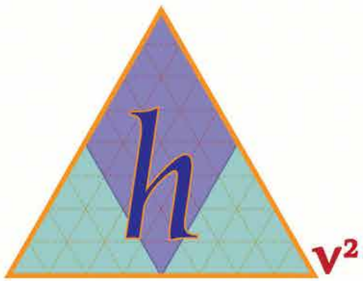

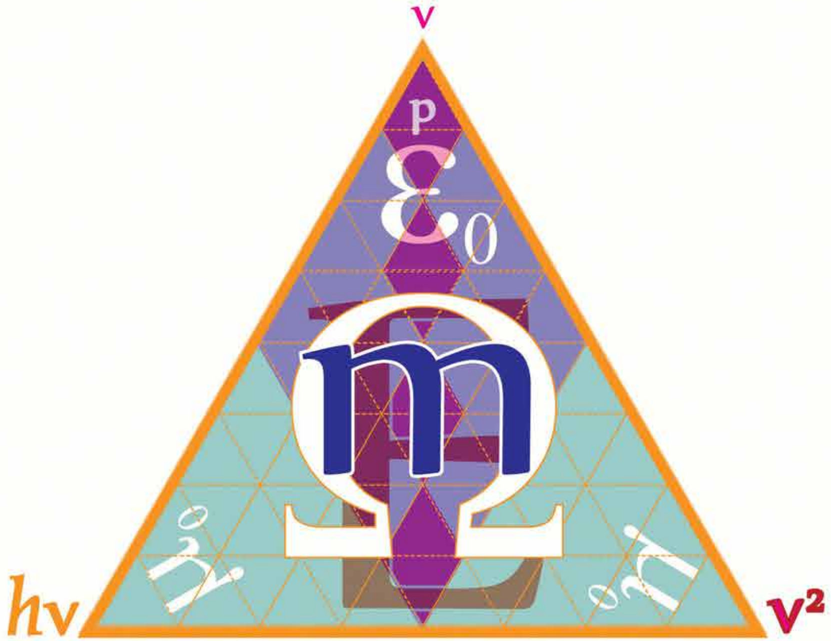

Newtonian physics

$$m = \frac{E}{v^2}$$

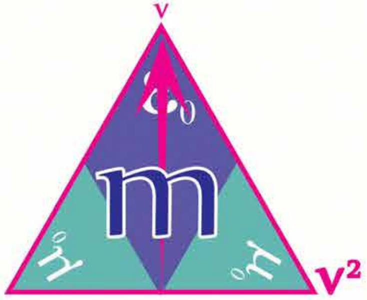

Quantised energy equilateral momenta

$$hv^2$$

Quantised Energy momenta is related to Scalar mass energy momenta through the equilateral geometry of Planck's constant

Scalar energy linear momentum

$$pv$$

$$m\Omega v^2 = E = mv^2$$

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Inertial resistance to Force

Inertia is the resistance of any physical object
to a change in its state of motion.

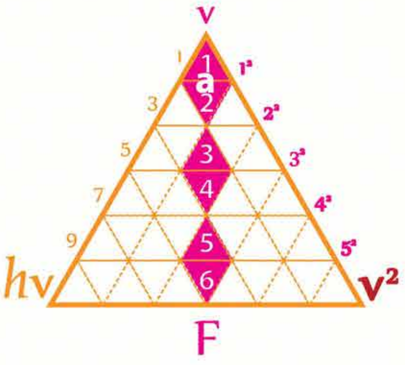
v
a
1
2
3
4
5
6
1
3
5
7
9
1²
2²
3²
4²
5²
hv
v²
F

Changes to mass-velocity
require a corresponding
change to boson quanta

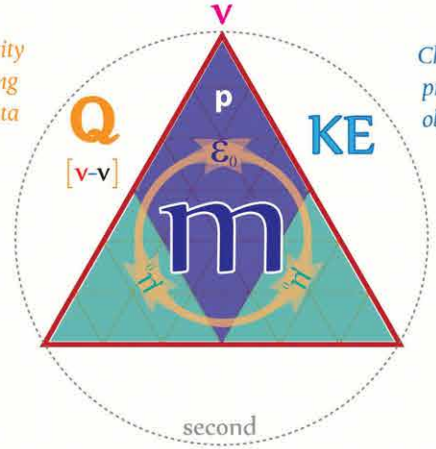
v
Q
[v-v]
p
KE
ε₀
m
second

Changes to mass-velocity
produces a change in an
object's Kinetic Energies

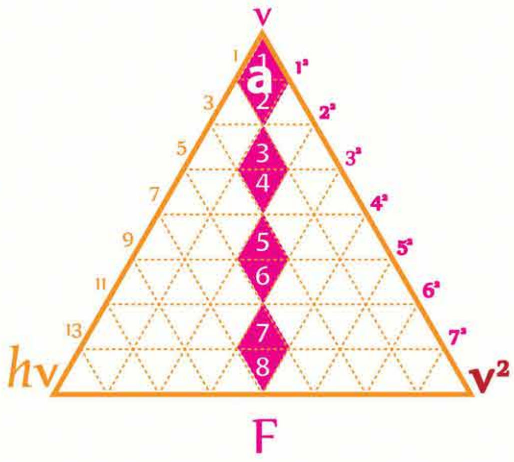
v
a
1
2
3
4
5
6
7
8
1
3
5
7
9
11
13
1²
2²
3²
4²
5²
6²
7²
hv
v²
F

$$E = mc^2$$

The total intrinsic momenta of all energy waveforms is the sum of their constituent Quantised Angular momenta (mass-energy momenta)

$$M_0 = m/c^2$$

Any change in motion results in changes to
the Charge geometries creating in turn proportional
changes to KEM mass and momenta components

$$F = ma$$

**The 'inductive resistance' of Charge quanta fields to
changes in their mass-energy momenta content
is what we term Inertia**

$$KEM = Mv^2$$

Matter in motion
has Kinetic Energies
in addition to invariant
rest mass-Energy

KE = RE - rest Matter

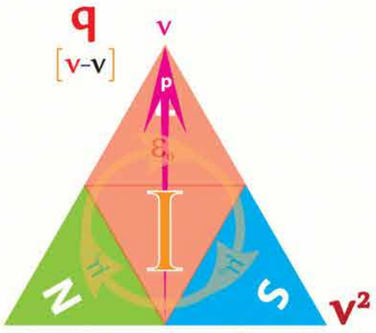
q
[v-v]
v
p
ε₀
I
N
S
v²

quantised moment of inertia

**Any change to an object's velocity results in a corresponding
change to its mass-Energy momenta which is reflected by its inertia**

$$p^2 = E = mv^2$$

Inertial mass can be related to Charge through inductive Planck quanta

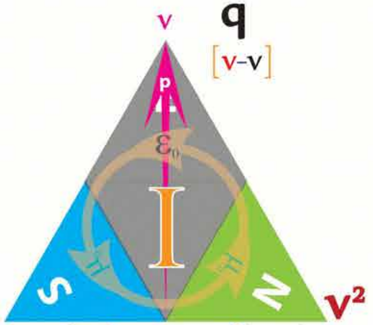
v
q
[v-v]
p
ε₀
I
S
N
v²

quantised moment of inertia

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Quantised Angular momentum

As it is a physical [equilateral] geometry QAM is conservative in any system where there are no external Forces and serves as the foundational geometric source for all the conservation laws of physics

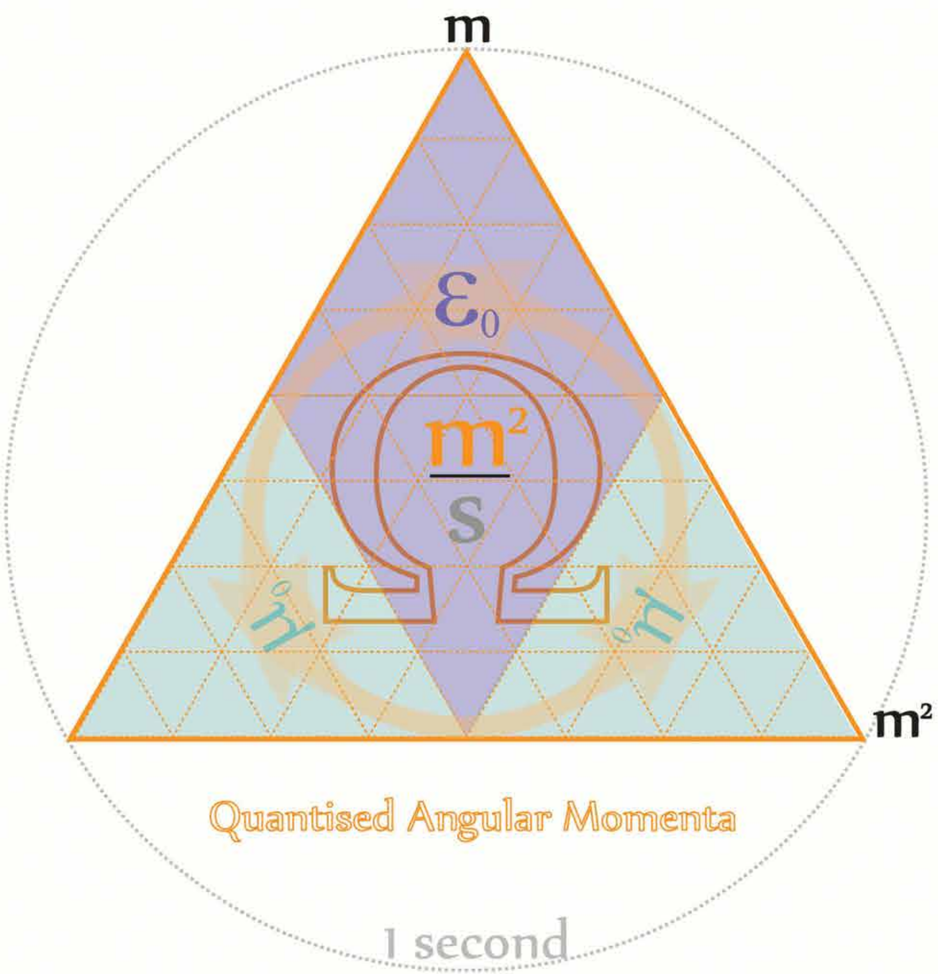

Angular momentum is sometimes described as the rotational analog of linear momentum, in Tetryonics it is revealed to be the equilateral geometry of quantised mass-energy momenta within any defined space-time co-ordinate system

A major re-definition of quantised angular momentum in physics is revealed

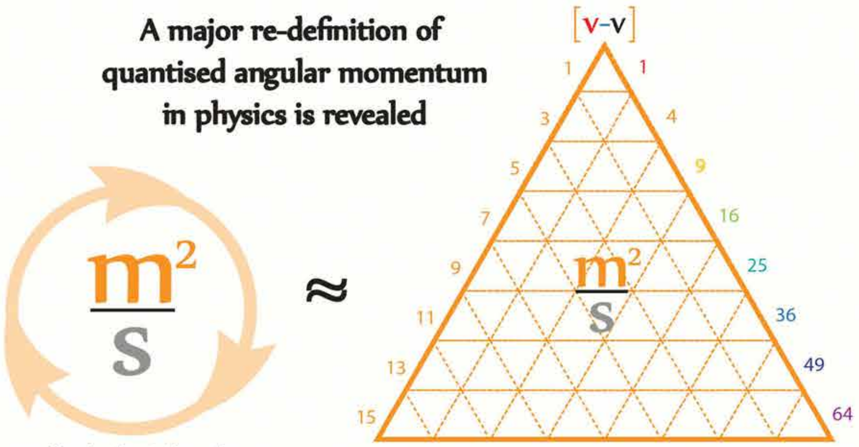

classical rotational angular momentum

Quantised Angular momentum

In quantum mechanics, angular momentum is quantised – that is, it cannot vary continuously, but only in ODD number "quantum steps" between the allowed SQUARE nuclear Energy levels

In physics, angular momentum, moment of momentum, or rotational momentum is a conserved vector quantity that can be used to describe the overall state of a physical system.

When applied to specific mass-Energy-Matter systems QAM reveals the true quantum geometry and nature of Energy in our universe

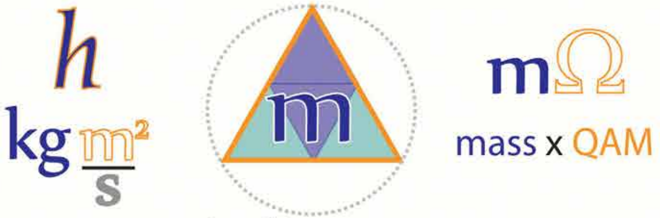

Planck's Constant

Normally viewed as an expression of rotational momentum Quantised Angular Momentum [QAM] is in fact a result of the equilateral geometric quantization of mass-energy

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Charged geometries

All charge geometries are nett divergent

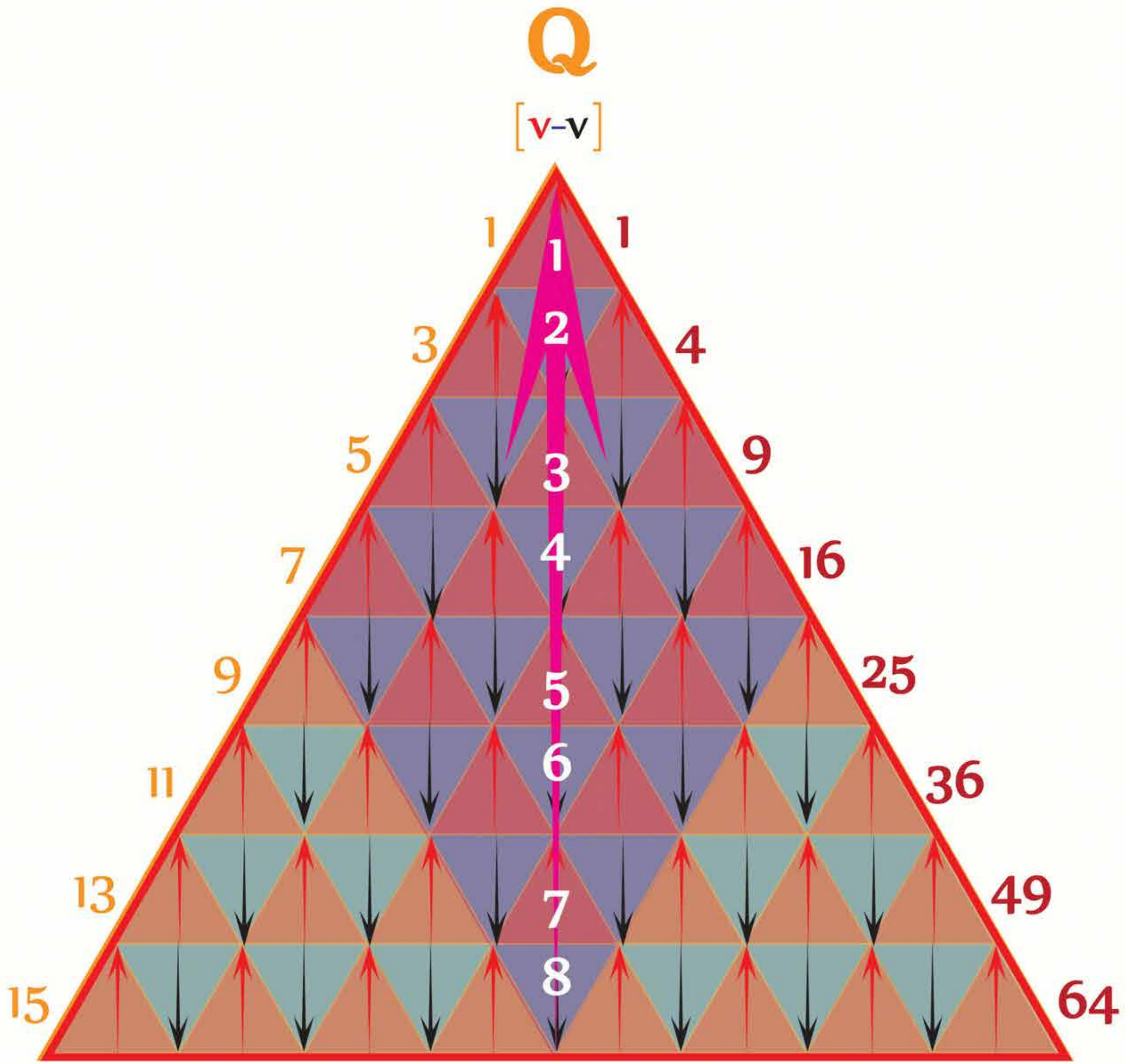
Q
[v-v]
1
1
3
4
5
9
7
16
9
25
11
36
13
49
15
64
1
2
3
4
5
6
7
8

Divergent energy momenta	Convergent energy momenta
1	0
3	1
6	3
10	6
15	10
21	15
28	21
36	28

All charge geometries are comprised of finite equilateral energy momenta quanta

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Renormalisation

Renormalization was first developed in quantum electrodynamics (QED) to make sense of infinite integrals in perturbation theory.
The problem of infinities first arose in the classical electrodynamics of point particles in the19th and
later in the calculation of Gravitational fields in General Relativity in the early 20th century.

In QED Infinities must be cancelled

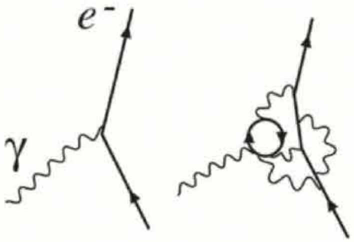

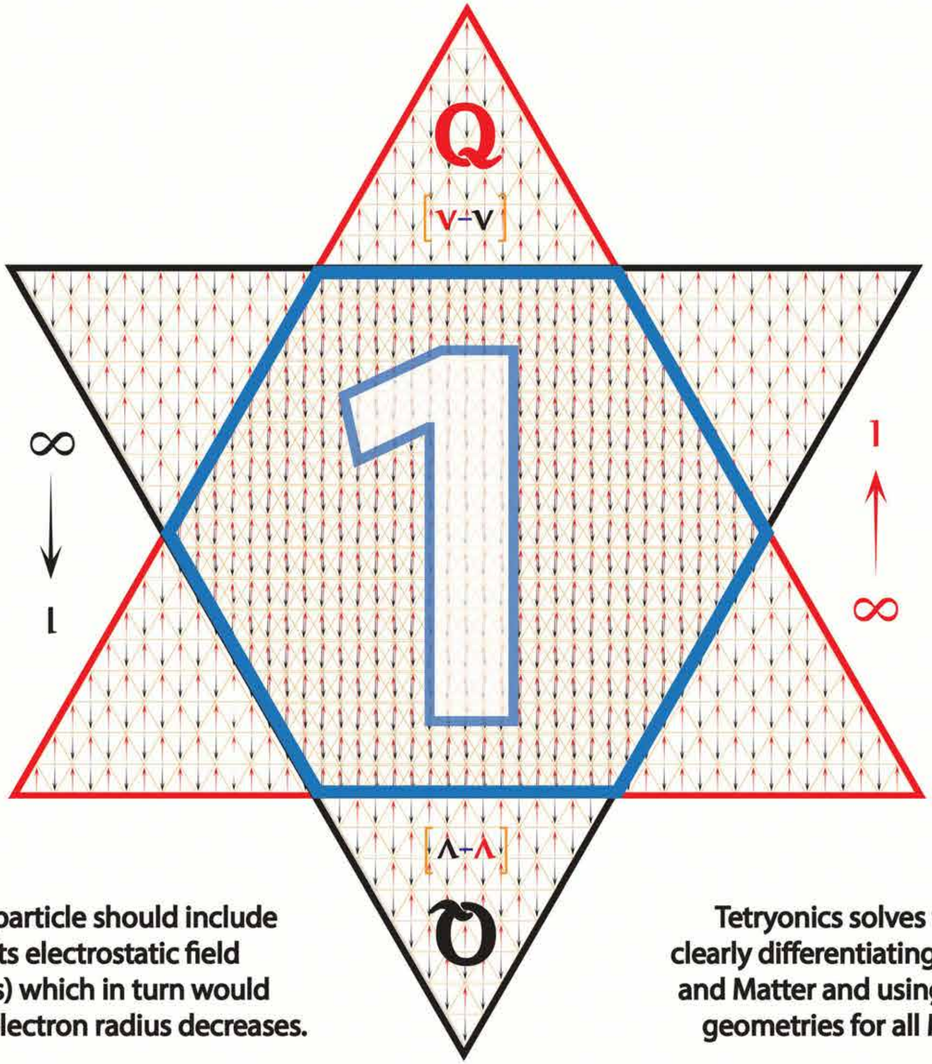

In Tetryonics Infinities do not exist

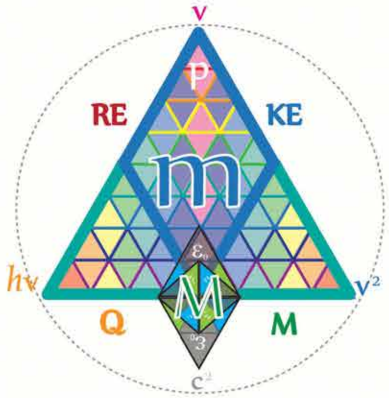

The mass of a charged particle should include the mass-energy in its electrostatic field (Electromagnetic mass) which in turn would approach infinity as the electron radius decreases.

Tetryonics solves the problem by clearly differentiating between EM mass and Matter and using finite equilateral geometries for all Matter in motion

Initially viewed as a suspicious provisional procedure by some of its originators, renormalization was eventually embraced as an important and self-consistent tool in several fields of physics and mathematics.

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2D space [c^2]

The adjective Cartesian refers to the French mathematician and philosopher René Descartes who developed the coordinate system in 1637

Since then many other coordinate systems have been developed such as the polar coordinates for the plane, and the spherical and cylindrical coordinates for three-dimensional space.

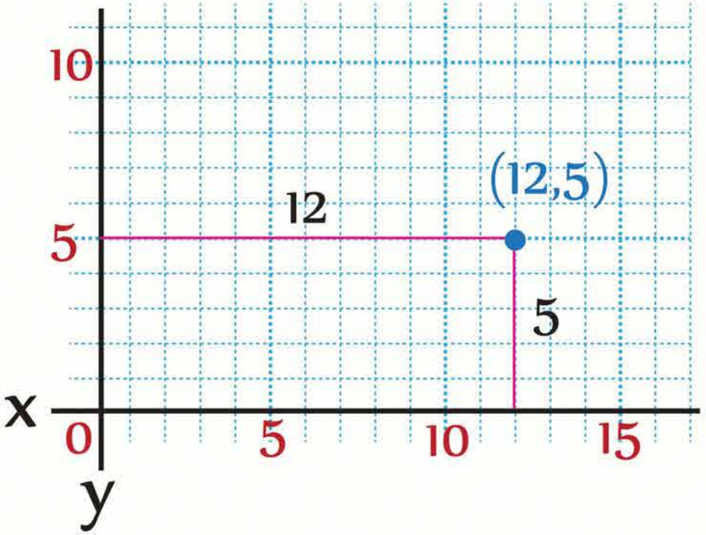

Cartesian coordinates are the foundation of analytic geometry, and provide enlightening geometric interpretations for many other branches of mathematics, such as linear algebra, complex analysis, differential geometry, multivariate calculus, group theory, and more

Mapping 3D spaces using Recti-linear co-ordinates

Cartesian coordinates can be defined as the positions of the perpendicular projections of a point onto the two or more axes, expressed as signed distances from the origin.

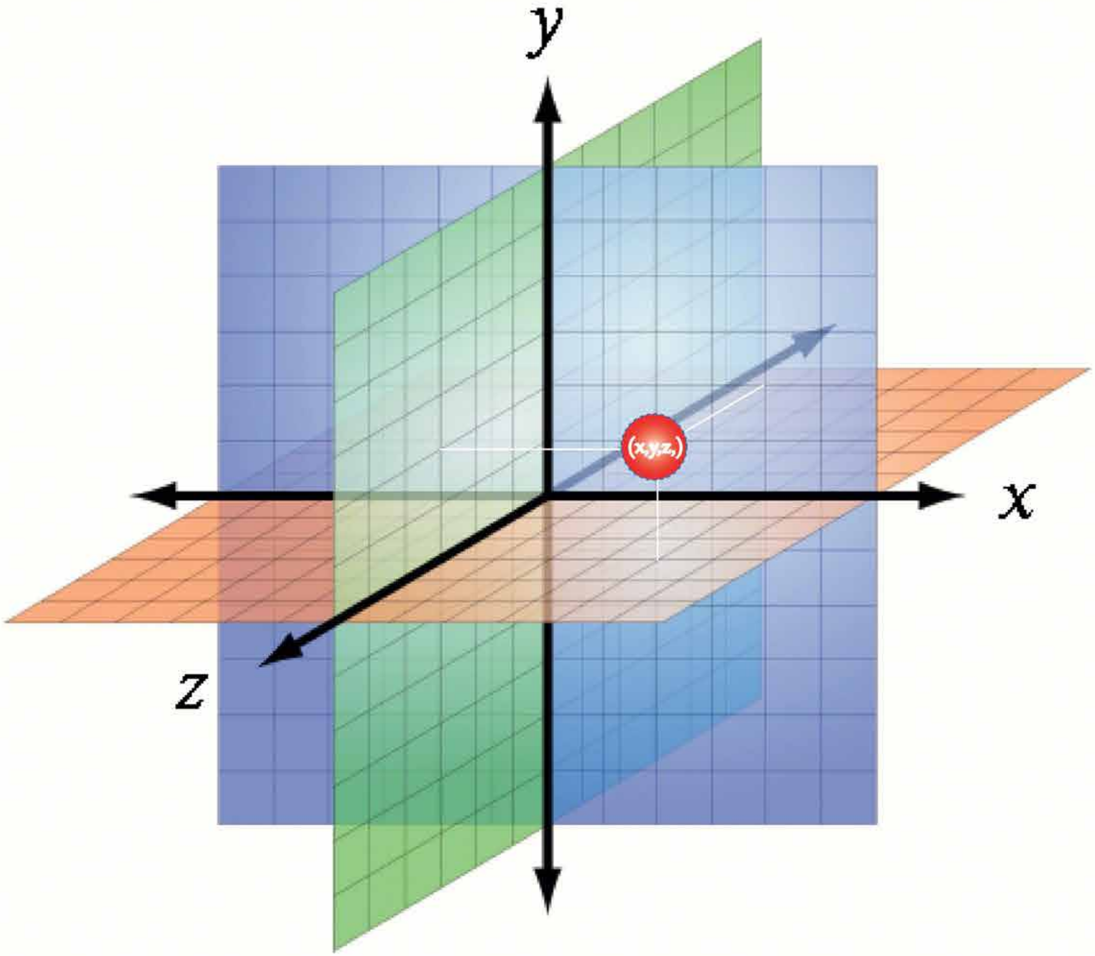

3D Cartesian co-ordinate [c^3] systems are distinct from spherical co-ordinate [c^4] systems

Polar co-ordinates

In mathematics, the polar coordinate system is a two-dimensional co-ordinate system in which each point on a plane is determined by a distance from a fixed point and an angle from a fixed direction.

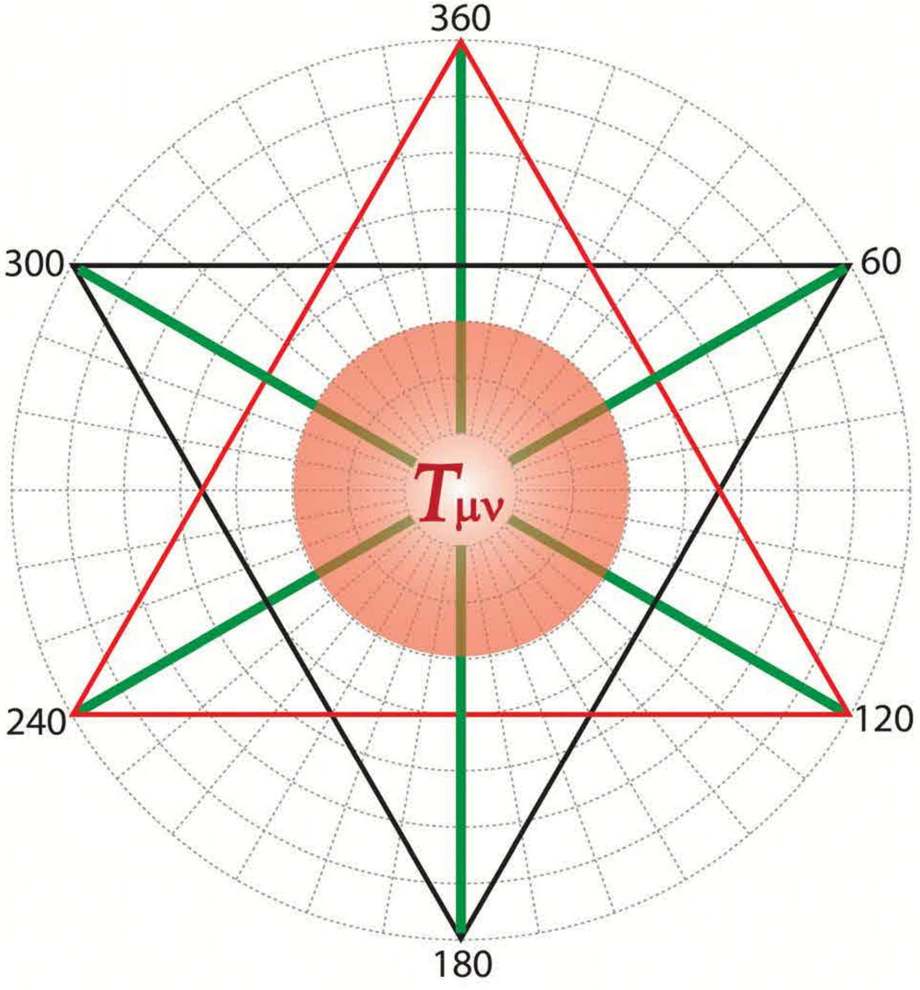

In geometry, curvilinear coordinates are a coordinate system for Euclidean space in which the co-ordinate lines may be curved.

Action Dynamics

Curvilinear co-ordinates may be derived from a set of rectilinear Cartesian coordinates by using a locally invertible transformation that maps one point to another in both systems

Metric Tensors

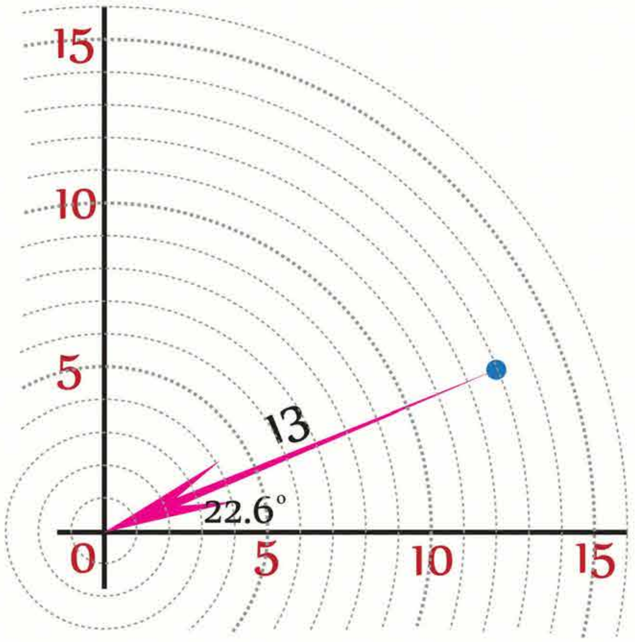

Gravitational acceleration

Polar or curvilinear co-ordinate systems are used extensively by Einstein in his theory of General Relavtivity

Reimannian curved space-time

Co-ordinate transformations

There are many different possible coordinate systems for describing geometrical figures and they can all be related to one another.

Such relations are described by coordinate transformations which give formulas for the coordinates in one system in terms of the coordinates in another system

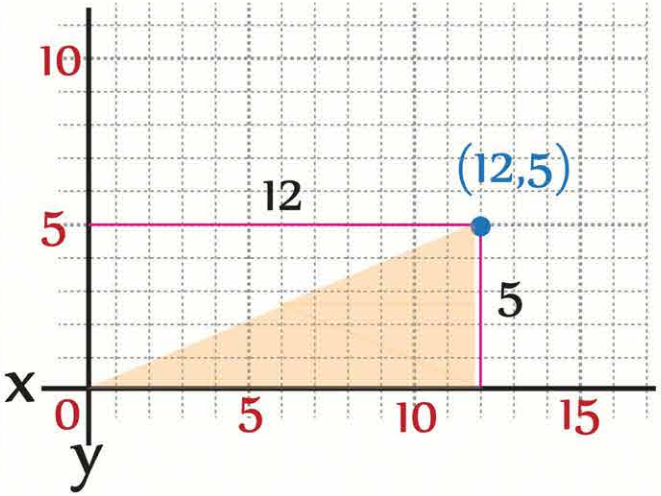

Converting between
Polar and Cartesian
coordinates

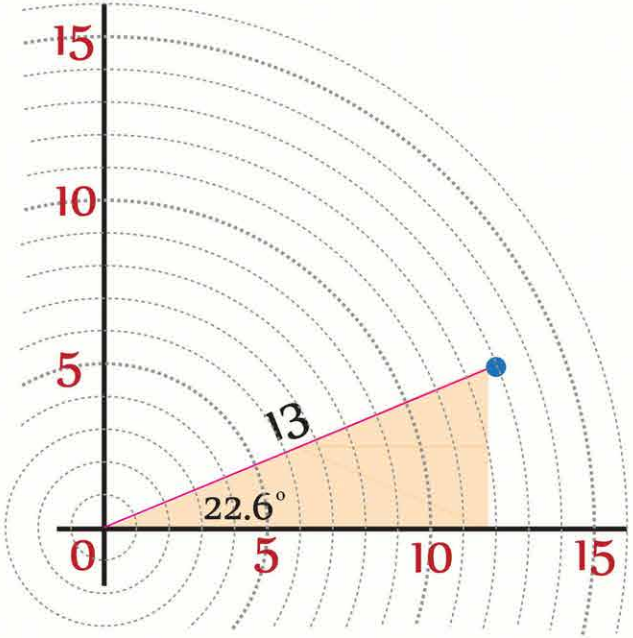

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$= \tan^{-1}(5/12)$$

$$= 22.619$$

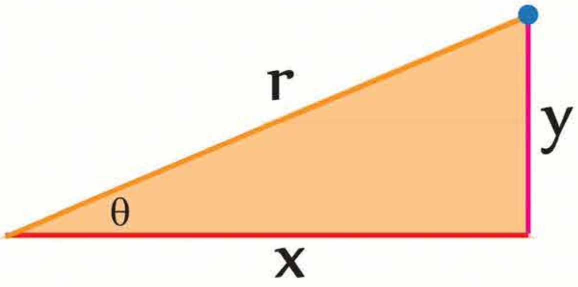

$$r^2 = 12^2 + 5^2$$

$$= \sqrt{169}$$

$$= 13$$

solving for the triangle
using trigometric functions

Spatial co-ordinates systems

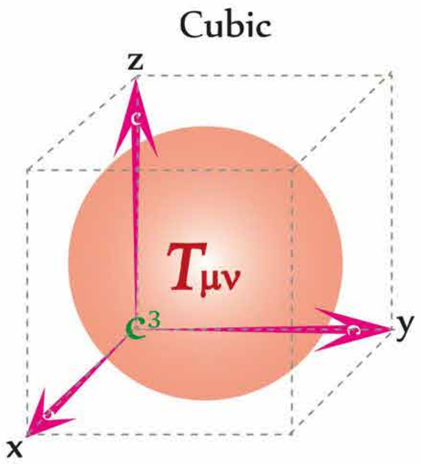
Cubic
z
y
x
Tμν
c³
c
c
c

Spacetime is any mathematical co-ordinate system or model that combines space and time into a single continuum.

Spacetime is usually interpreted with space as being three-dimensional with time playing the role of a fourth dimension that is different from the spatial dimensions.

From a Euclidean space perspective, the universe has three spatial dimensions and one dimension of time [reflected by quantised angular momentum].

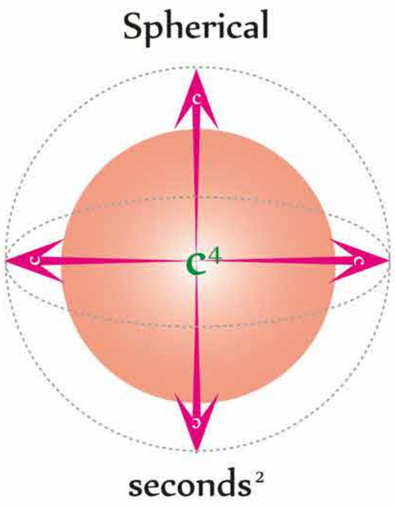
Spherical
c⁴
c
c
c
c
seconds²

Tetryonics maps spatial co-ordinates through the momenta vectors of equilateral Energy

Cartesian Space-Time

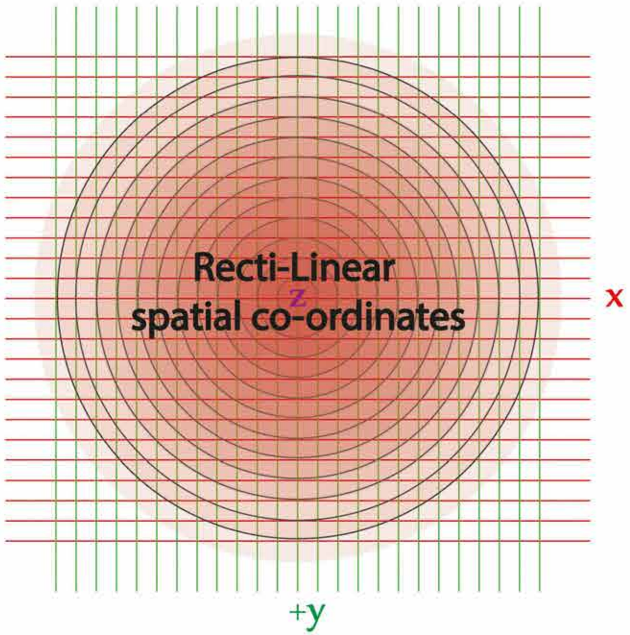
Recti-Linear
spatial co-ordinates
z
x
+y

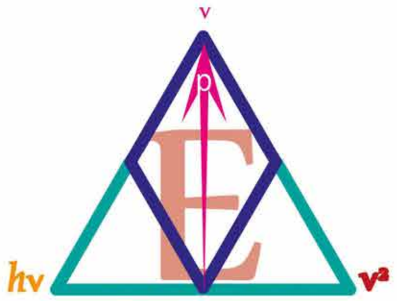

EM mass-ENERGY momenta are equilateral geometries

Tetryonic Space-Time

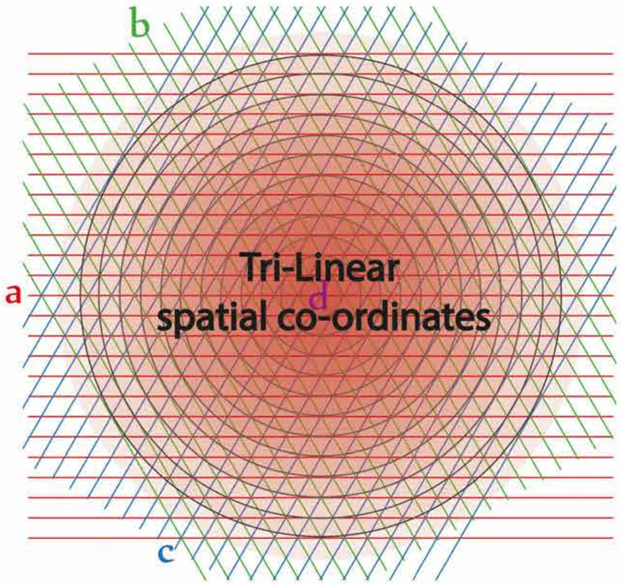
b
a
c
d
Tri-Linear
spatial co-ordinates

Mapping equilateral Energy geometries onto recti or curvi-linear spatial co-ordinate systems introduces mathematical complexity to a otherwise simplistic geometry for all EM mass-Energy-Matter interactions

In physics spatial co-ordinates to date have been based on Cartesian co-ordinates when in fact Energy momenta follow a Tri-Linear co-ordinate geometry

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vectors

1 Dimensional velocity

Euclidean

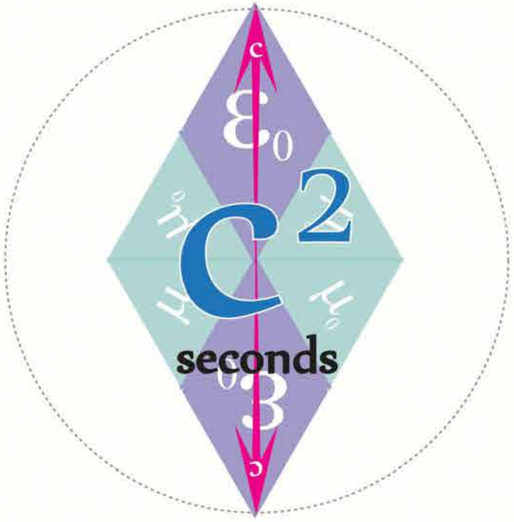
c
ε_0
c^2
μ_0
seconds
c

2 Dimensions velocity squared

$m = \frac{E}{c^2}$

mass-energy equivalence

mass-Matter

$\frac{m}{c^2} = M$

equivalence

$T_{\mu\nu}$

energy-Matter equivalence

$M = \frac{E}{c^4}$

GR fails differentiate betweem EM mass-ENERGY-Matter unlike Tetryonic theory

Cartesian co-ordinates

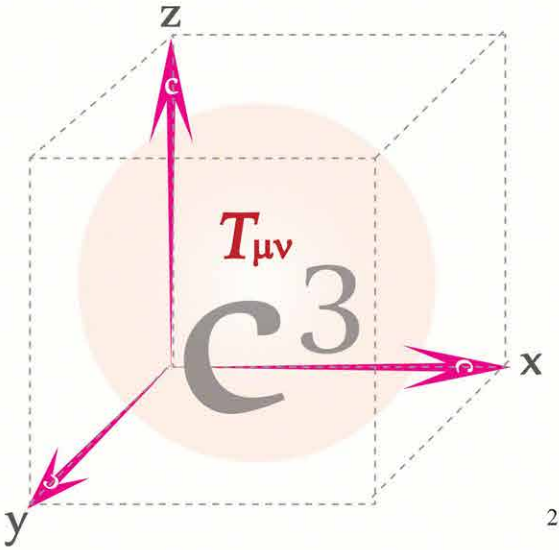
z
c
$T_{\mu\nu}$
c^3
c
x
c
y

3 Dimensions velocity cubed

Spherical

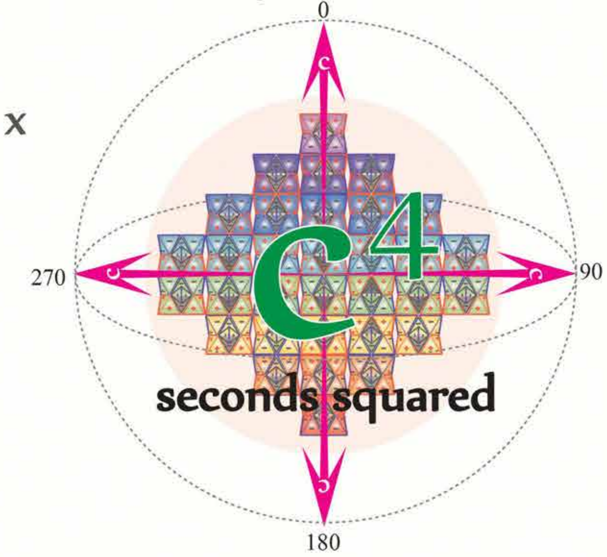
0
c
270
c
c^4
c
90
seconds squared
c
180

3 Dimensions quadrature velocity

Space-time co-ordinates

The propagation of Energy momenta forms distinct spatial co-ordinate systems

Where angles are typically measured in degrees (°) or radians (rad), where 360° = 2π rad = τ radians.

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Tetryonic co-ordinate systems

Energy per second

m

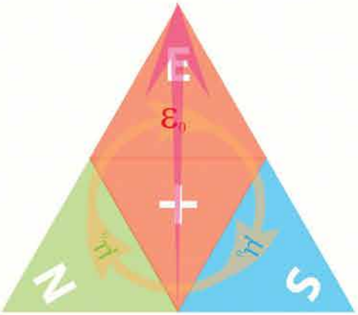
E
ε_0
+
N
S
μ_0
μ_0

2D mass-energy geometries

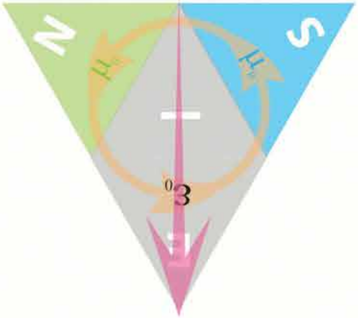
N
S
μ_0
μ_0
-
ε_0

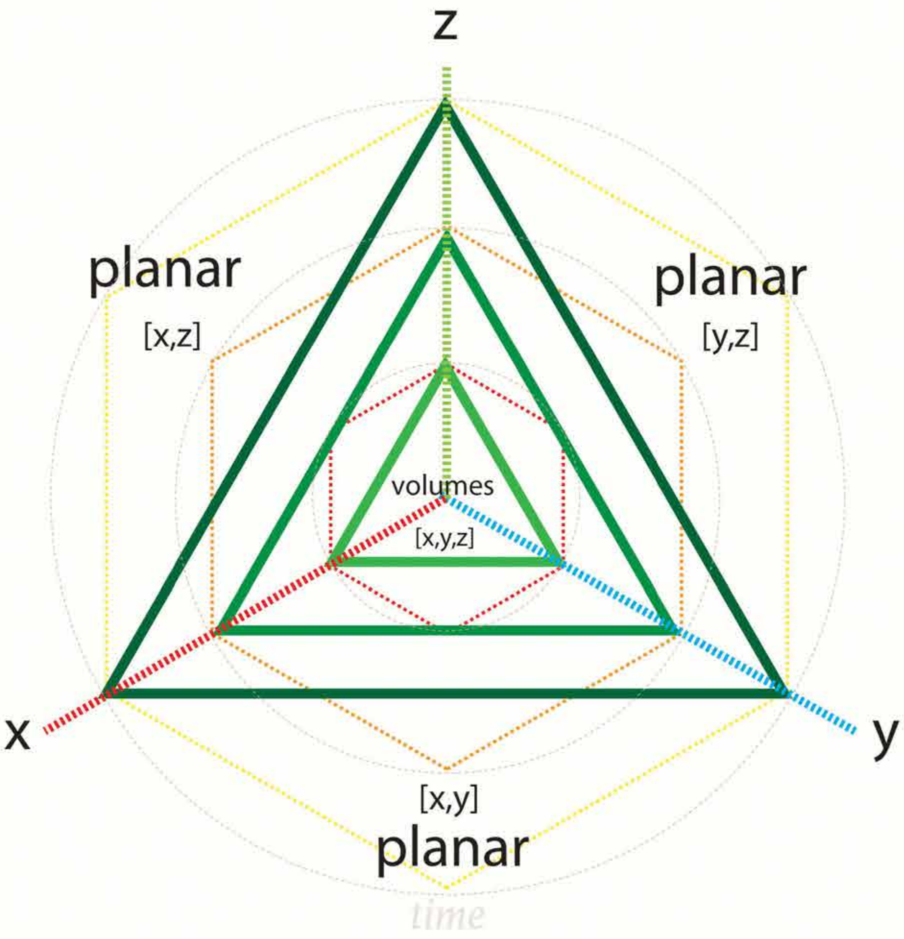
z
planar
[x,z]
planar
[y,z]
volumes
[x,y,z]
x
y
[x,y]
planar
time

Planar mass-energy geometries have no z-components

Differentiation between 2D mass-energy & 3D Matter is key to extending our understanding of physics

Matter topologies have z-components

Energy per second squared

M

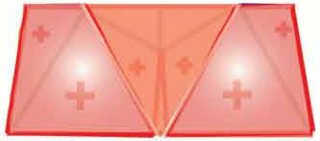

Proton

3D Matter topologies

Neutron

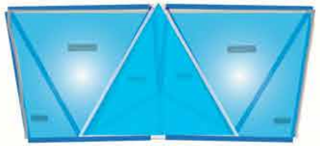

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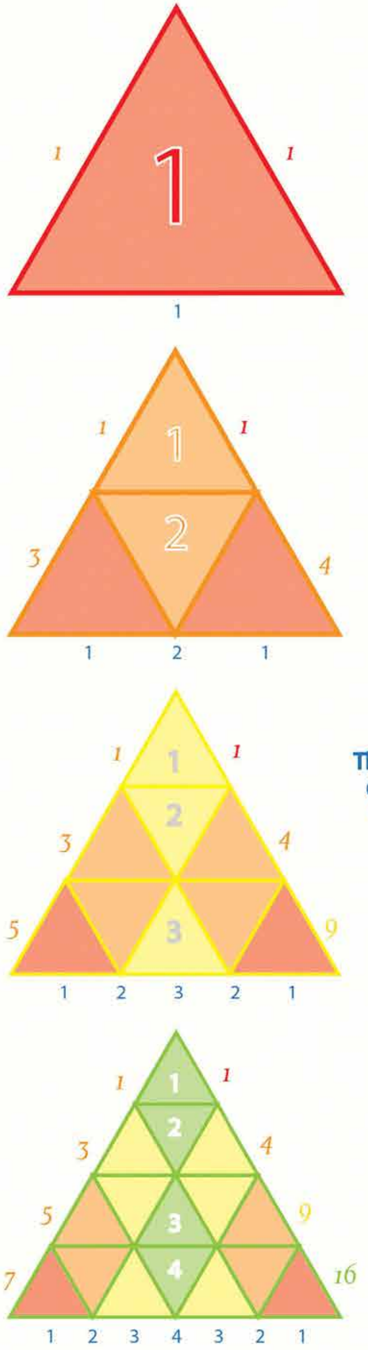
1
1 1
1
1
2
1 1
3 4
1 2 1
1
2
3
1 1
3 4
5 9
1 2 3 2 1
1
2
3
4
1 1
3 4
5 9
7 16
1 2 3 4 3 2 1

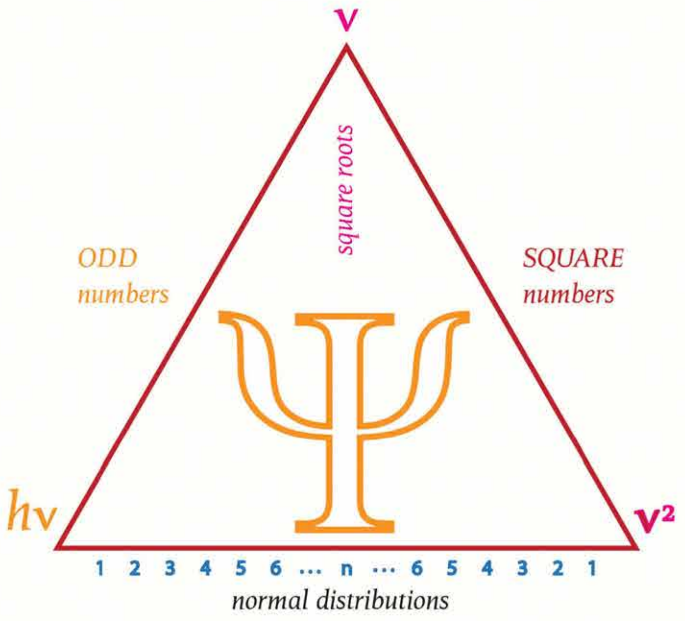
v
square roots
ODD numbers
SQUARE numbers
Ψ
hv
v²
1 2 3 4 5 6 … n … 6 5 4 3 2 1
normal distributions

Quantum probability distributions

The equilateral geometry and distribution of quantised Energy momenta provides the basis for all statistical probabilities in Quantum mechanics, thermodynamic & information entropy - including a solution to Heisenberg's Uncertainty Principle thus paving the way forward for a new understanding, and manipulation of physical phenomena at the quantum level

1
1 2 1
1 2 3 2 1
1 2 3 4 3 2 1
1 2 3 4 5 4 3 2 1
1 2 3 4 5 6 5 4 3 2 1
1 2 3 4 5 6 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1

Normal distributions are extremely important in statistics, and are often used in the natural and social sciences for real-valued random variables whose distributions are not known

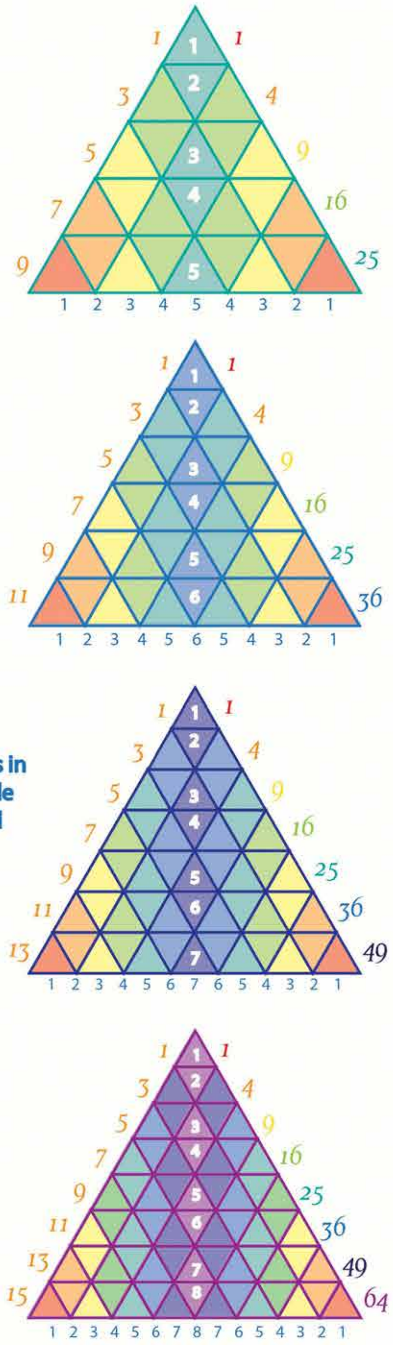
1 1
1 2 3 4 5
3 4
5 9
7 16
9 25
1 2 3 4 5 4 3 2 1
1 1
1 2 3 4 5 6
3 4
5 9
7 16
9 25
11 36
1 2 3 4 5 6 5 4 3 2 1
1 1
1 2 3 4 5 6 7
3 4
5 9
7 16
9 25
11 36
13 49
1 2 3 4 5 6 7 6 5 4 3 2 1
1 1
1 2 3 4 5 6 7 8
3 4
5 9
7 16
9 25
11 36
13 49
15 64
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1

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Quantum Probability Distributions

The normal distribution is a probability distribution.
It is also called Gaussian distribution because it was discovered by Carl Friedrich Gauss.

x/n^2

Probabilities are the square of the Amplitude

n

$\Sigma\ x/n^2$

All probabilities are re-normalisable and sum to Unity

1

square root momenta

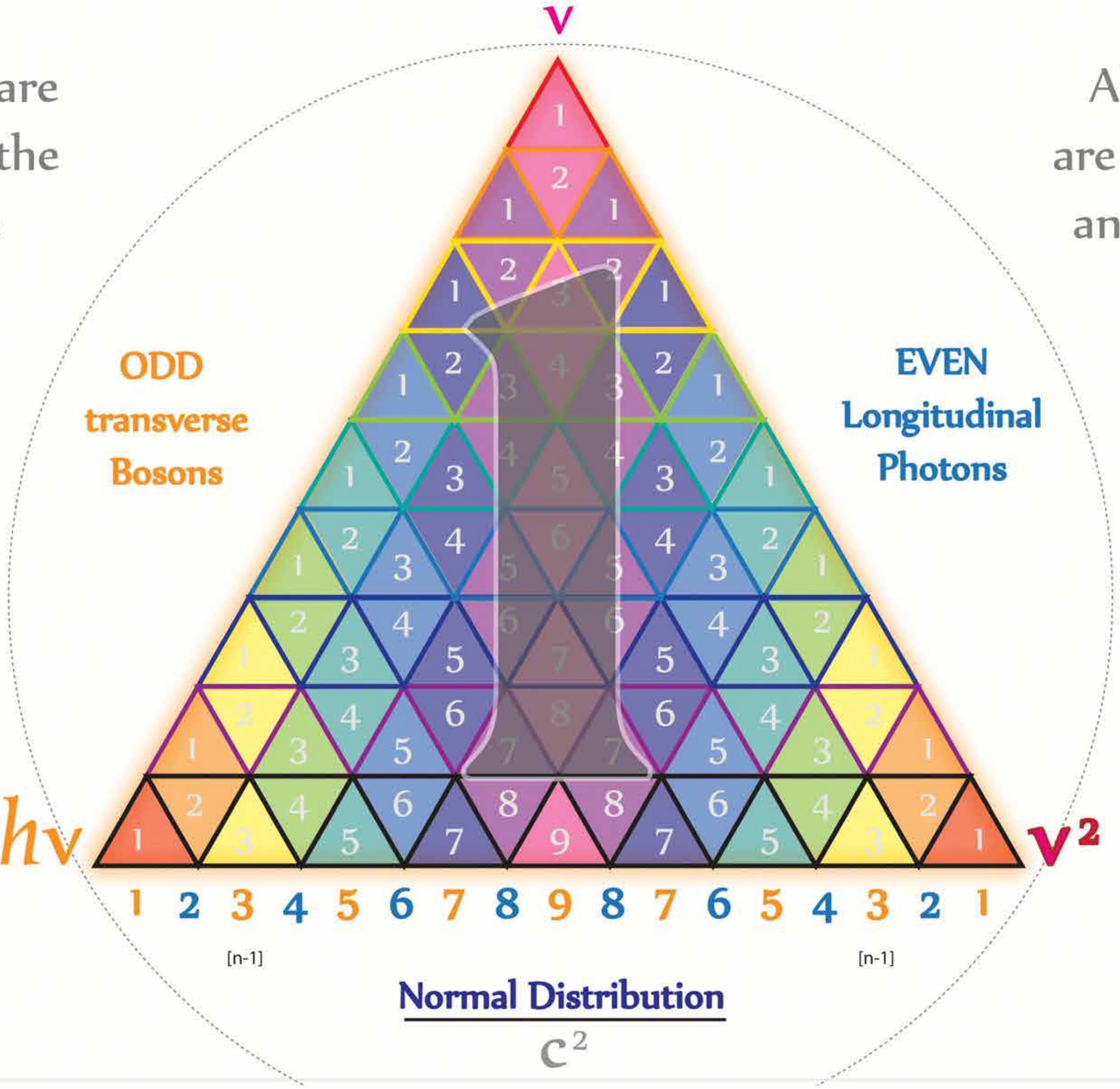

ODD transverse Bosons

EVEN Longitudinal Photons

Planck quanta

hv

v^2

Square energies

Normal Distribution

c^2

Quanta Distributions

Quantum Levels

transverse bosons

$2h\nu = E = hf$

Quantum Probabilities

longitudinal photons

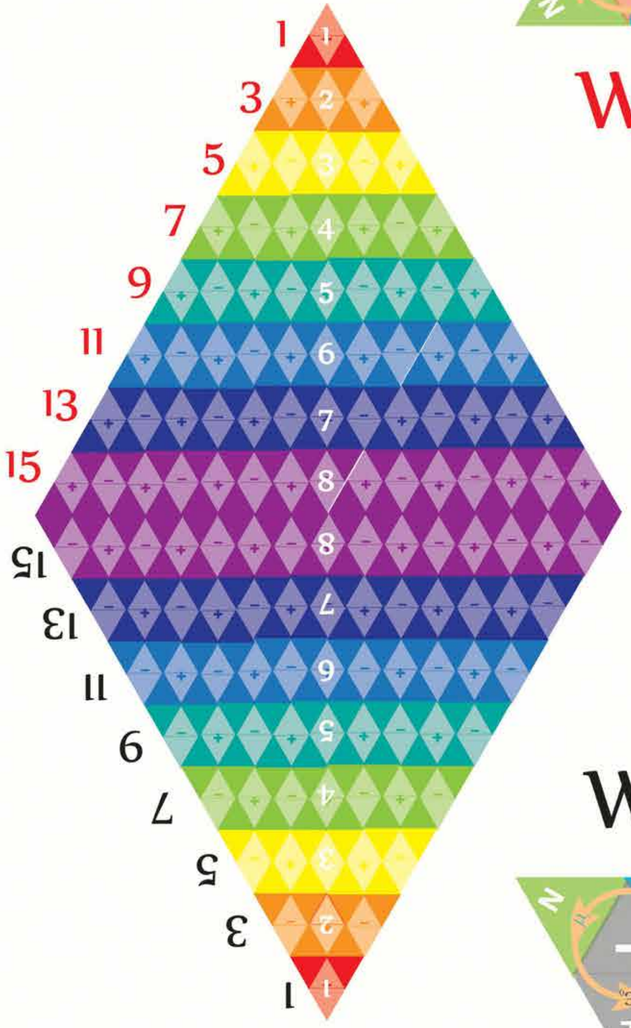
1
3
5
7
9
11
13
15
15
13
11
9
7
5
3
1
1
2
3
4
5
6
7
8
8
7
6
5
4
3
2
1

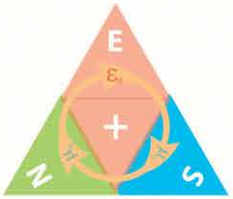

W+

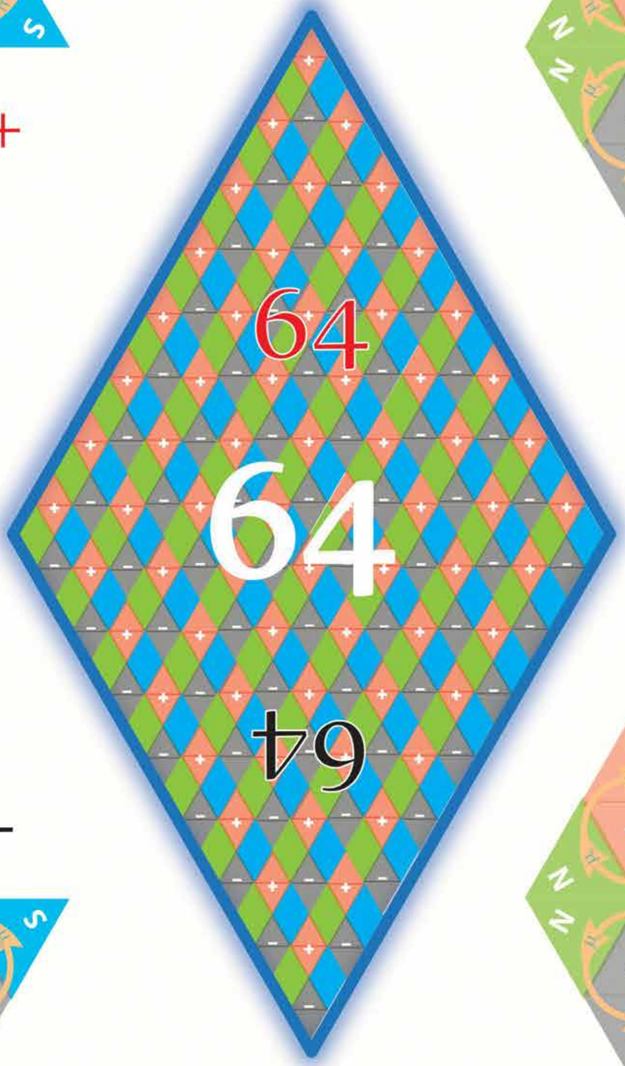

W-

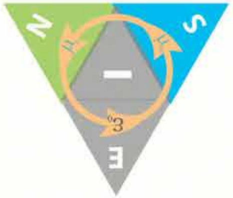

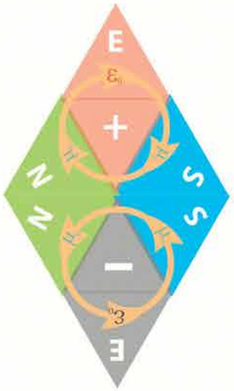

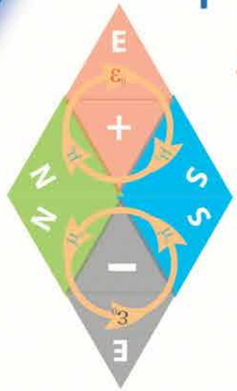

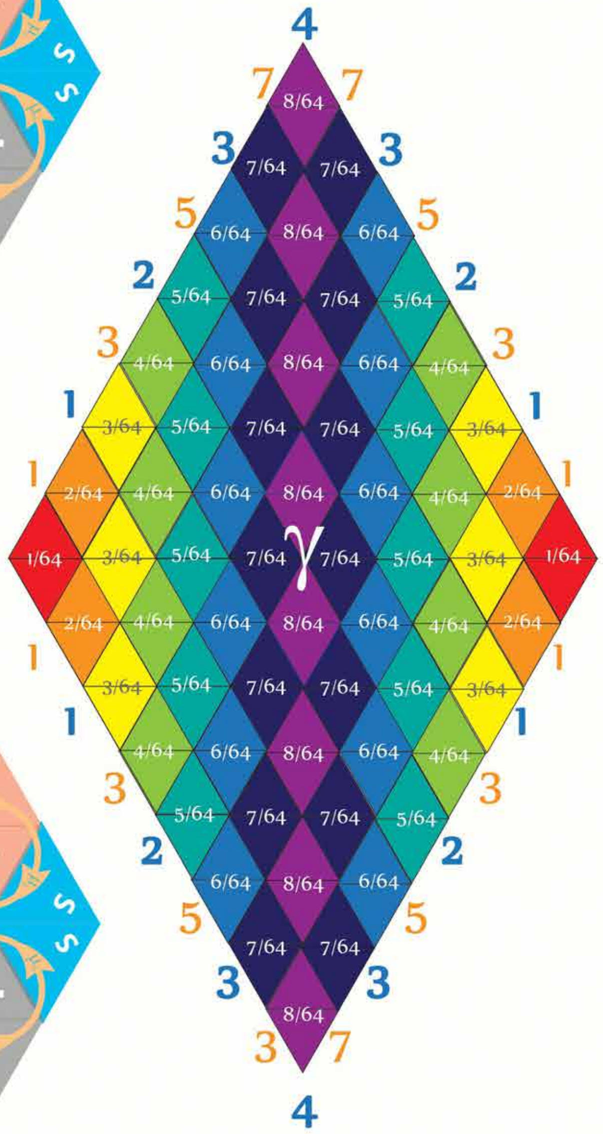
4
7 7
8/64
3 3
7/64 7/64
5 5
6/64 8/64 6/64
2 2
5/64 7/64 7/64 5/64
3 3
4/64 6/64 8/64 6/64 4/64
1 1
3/64 5/64 7/64 7/64 5/64 3/64
1 1
2/64 4/64 6/64 8/64 6/64 4/64 2/64
1/64 3/64 5/64 7/64 γ 7/64 5/64 3/64 1/64
2/64 4/64 6/64 8/64 6/64 4/64 2/64
1 1
3/64 5/64 7/64 7/64 5/64 3/64
1 1
4/64 6/64 8/64 6/64 4/64
3 3
5/64 7/64 7/64 5/64
2 2
6/64 8/64 6/64
5 5
7/64 7/64
3 3
8/64
3 7
4

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Wavefunctions

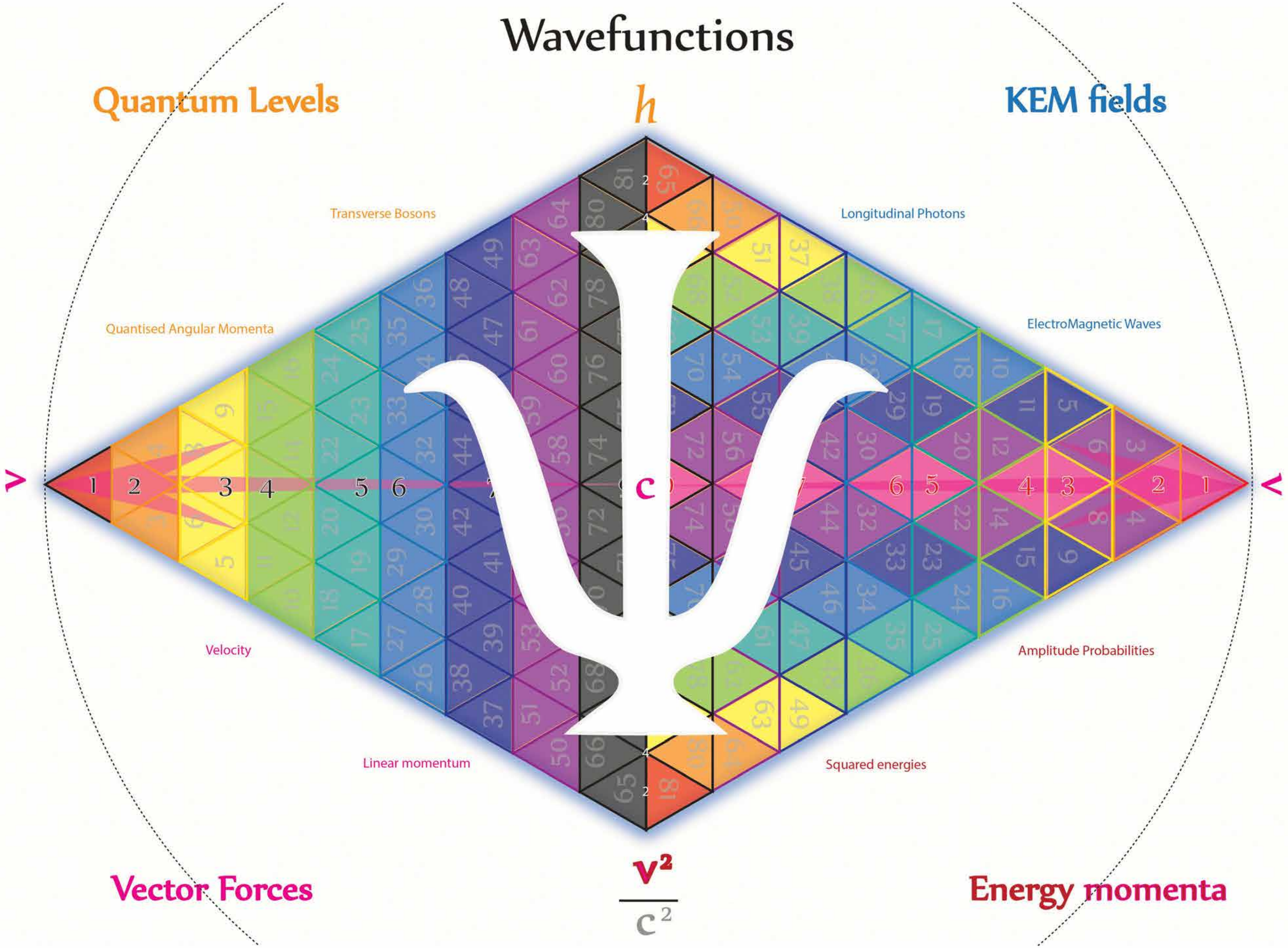
Quantum Levels
h
KEM fields
Transverse Bosons
Longitudinal Photons
Quantised Angular Momenta
ElectroMagnetic Waves
v
1 2 3 4 5 6 7
c
7 6 5 4 3 2 1
v
Velocity
Amplitude Probabilities
Linear momentum
Squared energies
Vector Forces
$\frac{v^2}{c^2}$
Energy momenta

EM waveforms

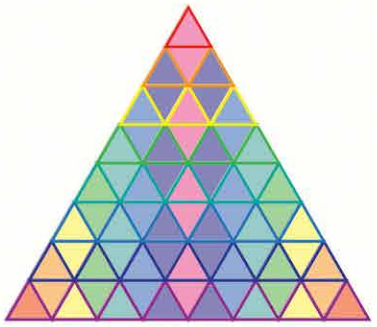

All EM waveforms can be measured by either their Transverse EM masses [Bosons] or their Longitudinal EM masses [Photons]

PHOTONS

EM waves Planck quanta

$\frac{\text{EVEN}\,\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$

mass velocity

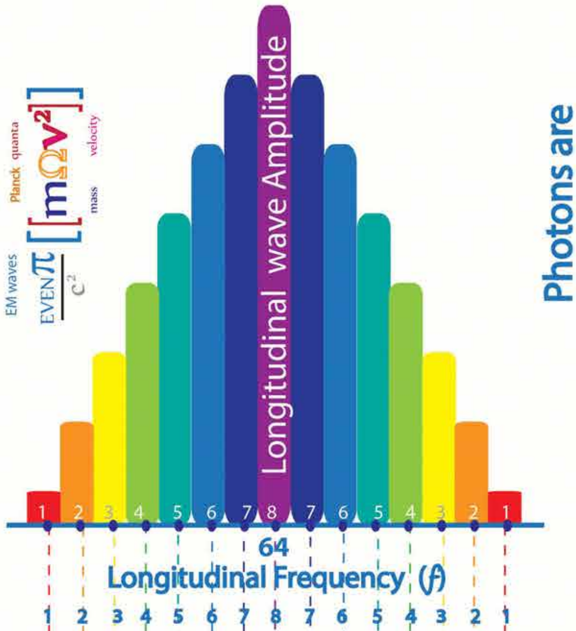
Longitudinal wave Amplitude
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
64
Longitudinal Frequency (f)

Photons are longitudinal quanta

vs.

BOSONS

Bosons Planck quanta

$\frac{\text{ODD}\,\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$

mass velocity

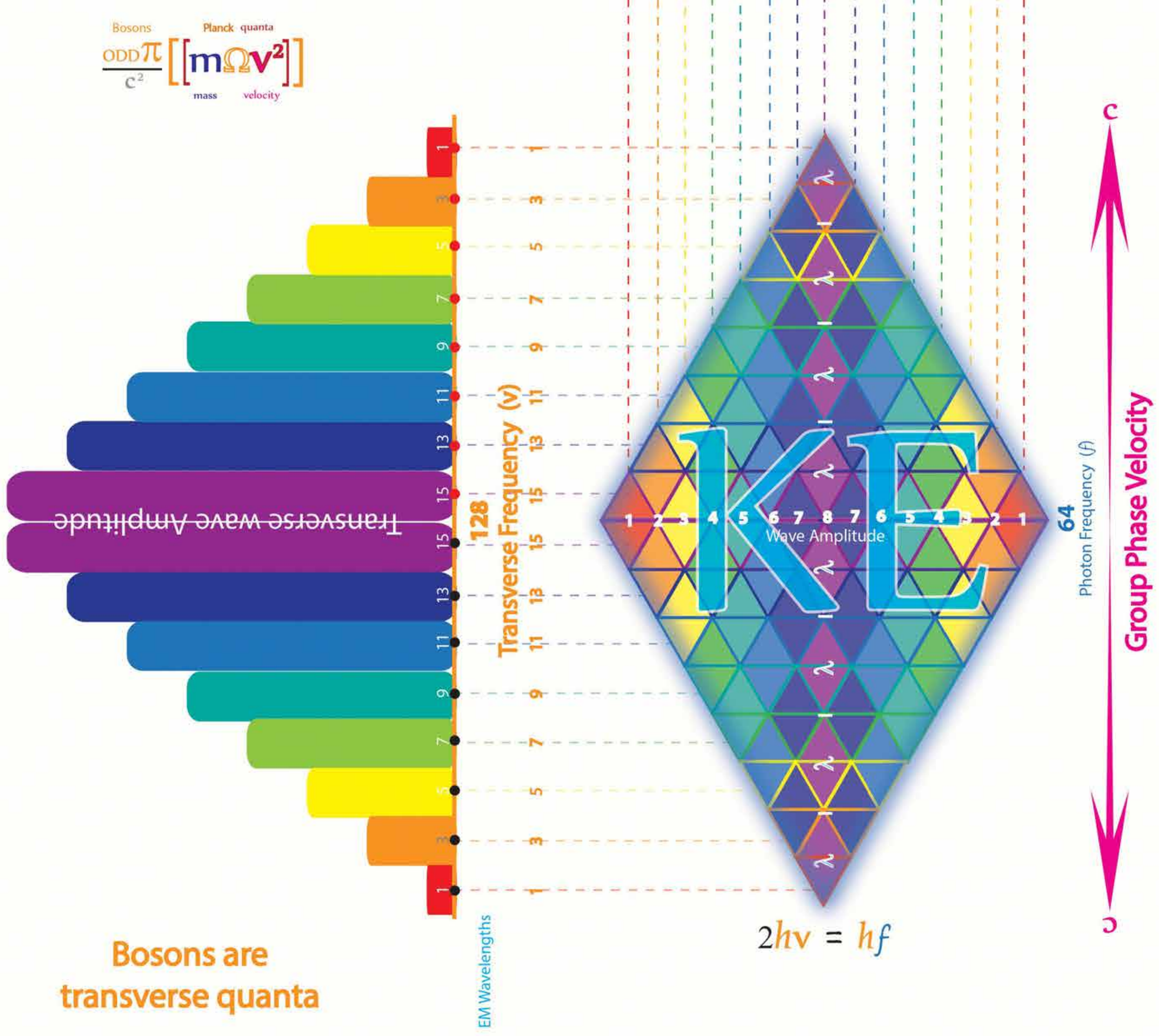
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
Transverse wave Amplitude
1 3 5 7 9 11 13 15 15 13 11 9 7 5 3 1
128
Transverse Frequency (v)
EM Wavelengths
KE
Wave Amplitude
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
64
Photon Frequency (f)
c
Group Phase Velocity
c
2hv = hf

Bosons are transverse quanta

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Quantum Energy distributions

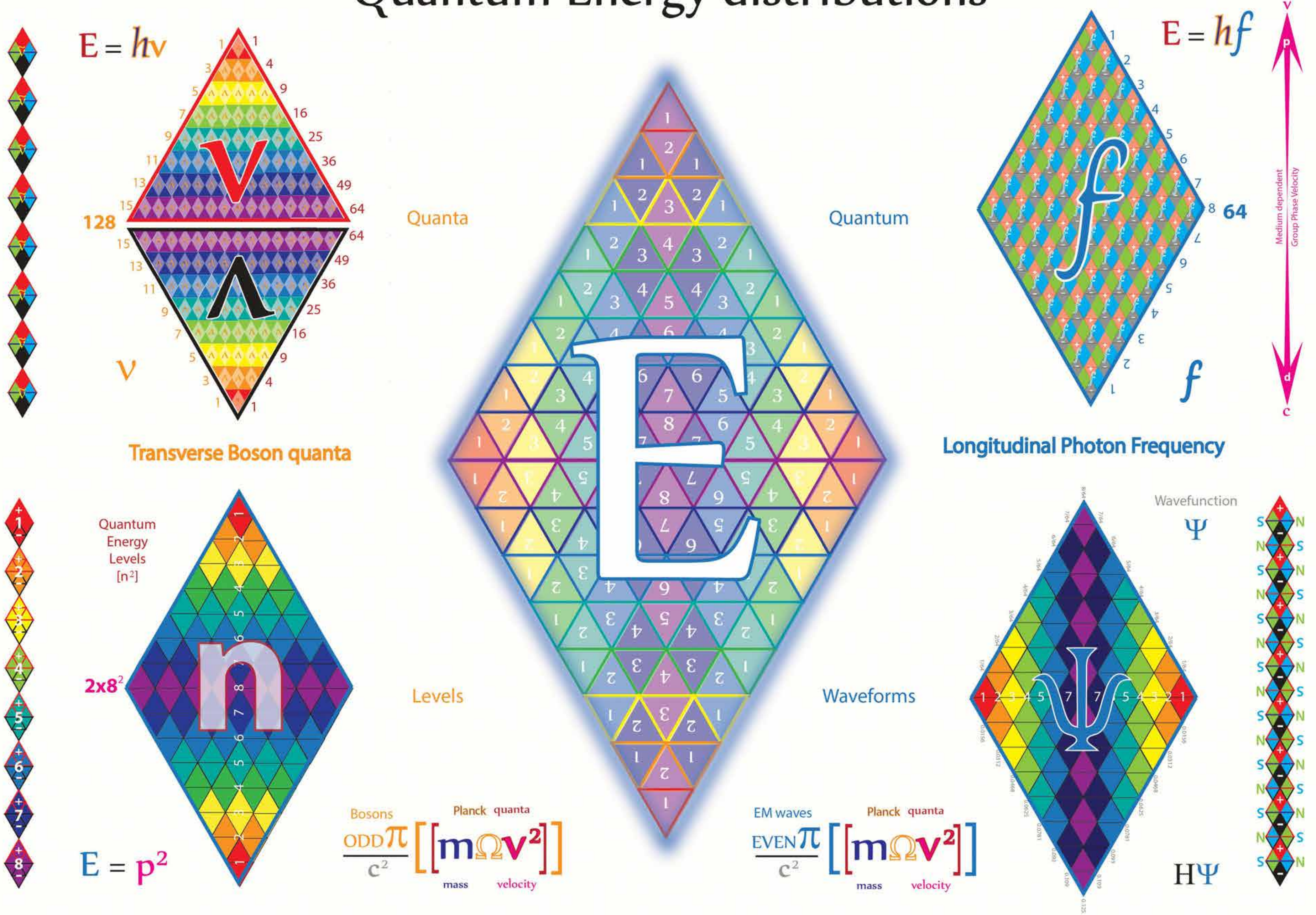

$E = h\nu$

Quanta

Transverse Boson quanta

$E = hf$

Quantum

Longitudinal Photon Frequency

Medium dependent

Group Phase Velocity

Quantum Energy Levels $[n^2]$

Levels

$E = p^2$

Bosons

$\frac{\text{ODD}\,\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$

Planck quanta

mass velocity

Wavefunction

Ψ

Waveforms

EM waves

$\frac{\text{EVEN}\,\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$

Planck quanta

mass velocity

$H\Psi$

Normal Distributions

The Gaussian distribution sometimes informally called the bell curve.

Pierre de Fermat

Pierre de Fermat is given credit
for early developments that led to
infinitesimal calculus.

$$\frac{1}{\sqrt{2\pi\sigma^2}}\, e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

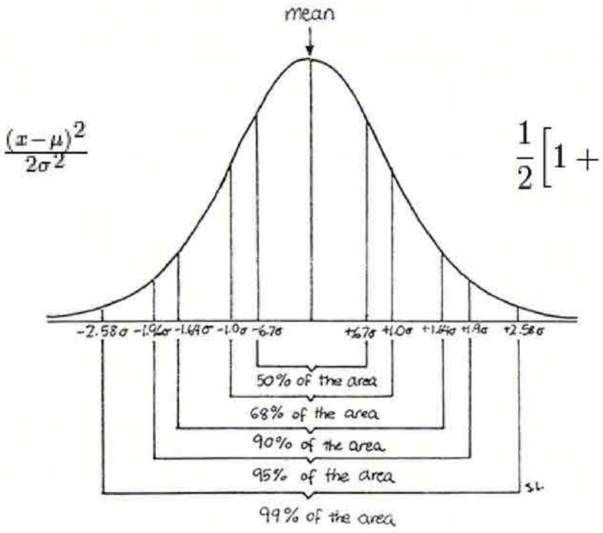

$$\frac{1}{2}\left[1+\operatorname{erf}\left(\frac{x-\mu}{\sqrt{2\sigma^2}}\right)\right]$$

Leonhard Euler

Leonhard Euler developed a formula
which links complex exponentiation
with trigonometric functions

all ODD numbers are

$$a^2 - b^2 = [a-b].[a+b]$$

the difference of two squares

**A bell shaped curve defines the standard normal distribution,
in which the probability of observing a point is greatest near the average,
and declines rapidly as one moves away from the mean.**

$$e^{i\pi} = -1$$

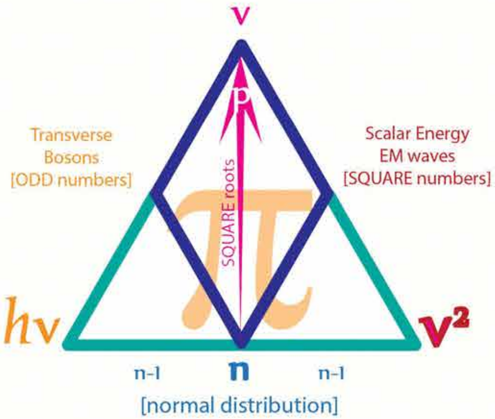
v
p
SQUARE roots
Transverse
Bosons
[ODD numbers]
Scalar Energy
EM waves
[SQUARE numbers]
hv
v²
n-1
n
n-1
[normal distribution]

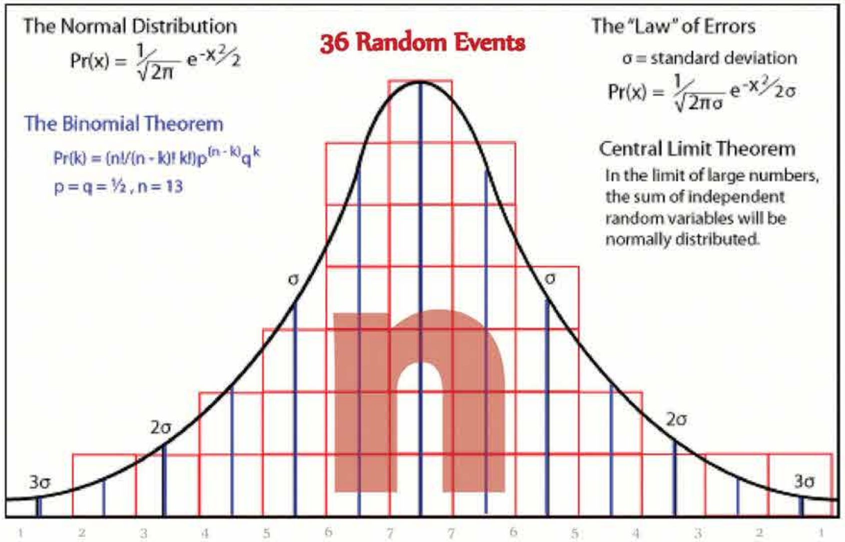

The Normal Distribution

$$Pr(x) = \frac{1}{\sqrt{2\pi}}\, e^{-x^2/2}$$

36 Random Events

The Binomial Theorem

$$Pr(k) = (n!/(n-k)!\,k!)p^{(n-k)}q^{k}$$

$$p = q = ½,\ n = 13$$

The "Law" of Errors

σ = standard deviation

$$Pr(x) = \frac{1}{\sqrt{2\pi\sigma}}\, e^{-x^2/2\sigma}$$

Central Limit Theorem

In the limit of large numbers, the sum of independent random variables will be normally distributed.

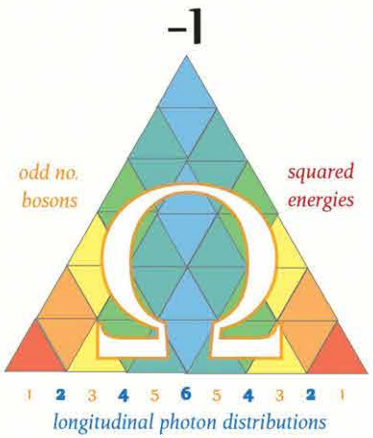
-1
odd no.
bosons
squared
energies
Ω
1
2
3
4
5
6
5
4
3
2
1
longitudinal photon distributions

In probability theory, the normal (or Gaussian) distribution is a continuous probability distribution that has a bell-shaped probability density function, known as the Gaussian function

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Fundamental theorem of Energy momenta

A nth level scalar energy momenta waveform has exactly n linear momentum in unit circle co-ordinate systems
(with Longitudinal and Transverse equilateral Planck waveforms being orthogonal to each other)

scalar energies

E

mv^2

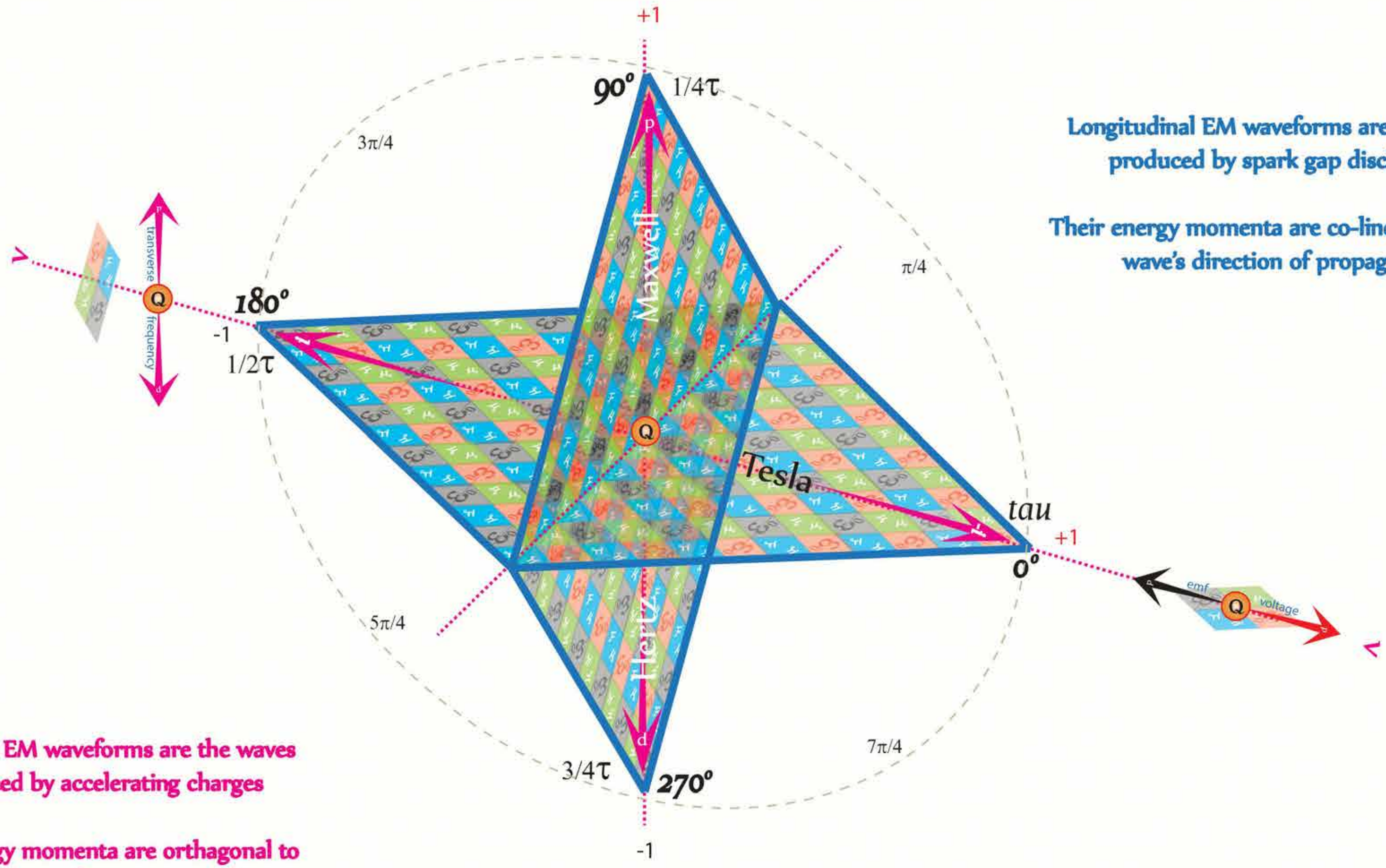
+1
90°
1/4τ
3π/4
π/4
Maxwell
transverse
frequency
Q
180°
-1
1/2τ
Q
Tesla
tau
+1
0°
emf
voltage
Q
5π/4
Hertz
7π/4
3/4τ
270°
-1

Longitudinal EM waveforms are the waves produced by spark gap discharges

Their energy momenta are co-linear with the wave's direction of propagation

p

mv

linear momentum

Transverse EM waveforms are the waves produced by accelerating charges

Their energy momenta are orthogonal to the direction of wave propagation

[Mathematics] *i or j* *[Electrical theory]*

square root of negative one

Velocity and Time dependent EM fields

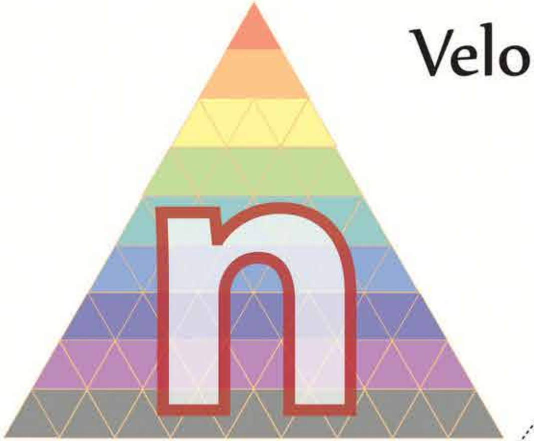

Quantum levels

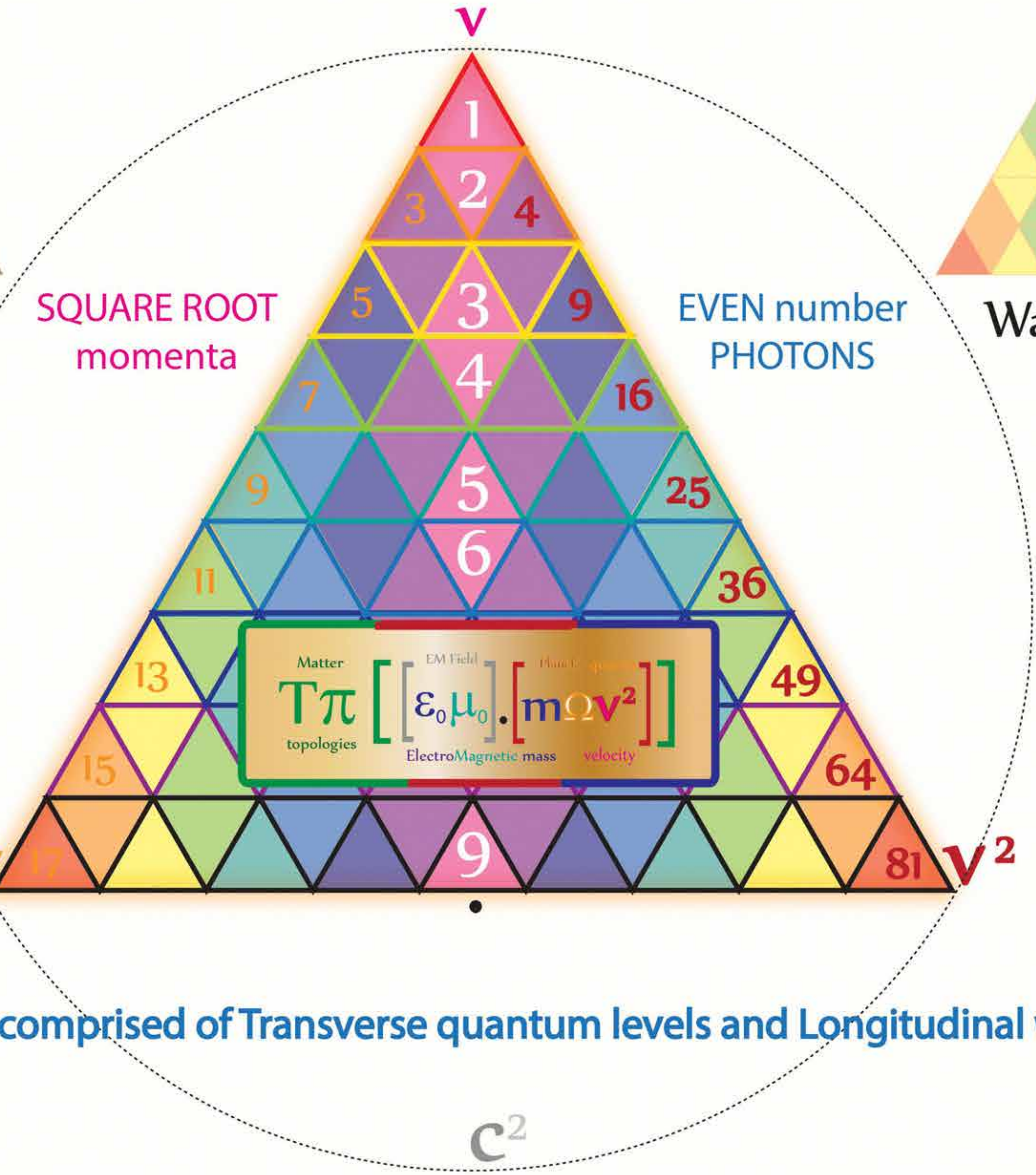
v
1
3
2
4
5
3
9
7
4
16
9
5
25
6
11
36
13
49
15
64
hv
17
9
81
v²
Matter
Tπ
topologies
EM Field
$[[\varepsilon_0\mu_0].[m\Omega v^2]]$
ElectroMagnetic mass
velocity
c²

SQUARE ROOT
momenta

EVEN number
PHOTONS

ODD number
BOSONS

SQUARE number
ENERGIES

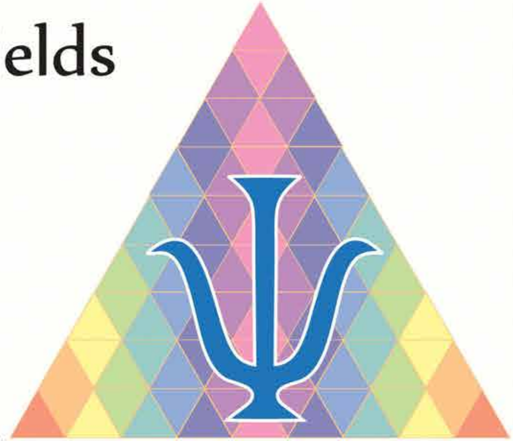

Wave probabilities

All EM geometries are comprised of Transverse quantum levels and Longitudinal wave probabilities

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Matrices

Matrices are a key tool in linear algebra.
One use of matrices is to represent linear transformations,
which are higher-dimensional analogs of linear functions
of the form f(x) = cx, where c is a constant; matrix multiplication
corresponds to composition of linear transformations.

Further developing equilateral Matrices and tensor mathematics to
reflect the 2D geometry of EM , KEM and GEM quantum fields,
along with the geometric quantisation of mass-energiy momenta
and their energy distributions allows for field interactions
to be accurately visualised and modelled

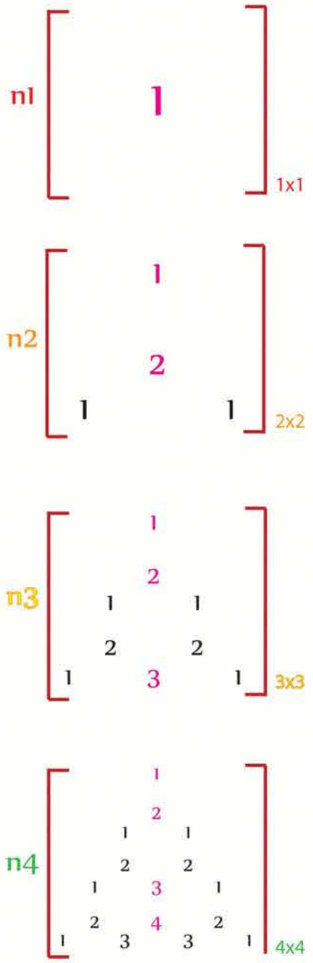
n1
1
1x1
n2
1
2
1 1
2x2
n3
1
2
1 1
2 2
1 3 1
3x3
n4
1
2
1 1
2 2
1 3 1
2 4 2
1 3 3 1
4x4

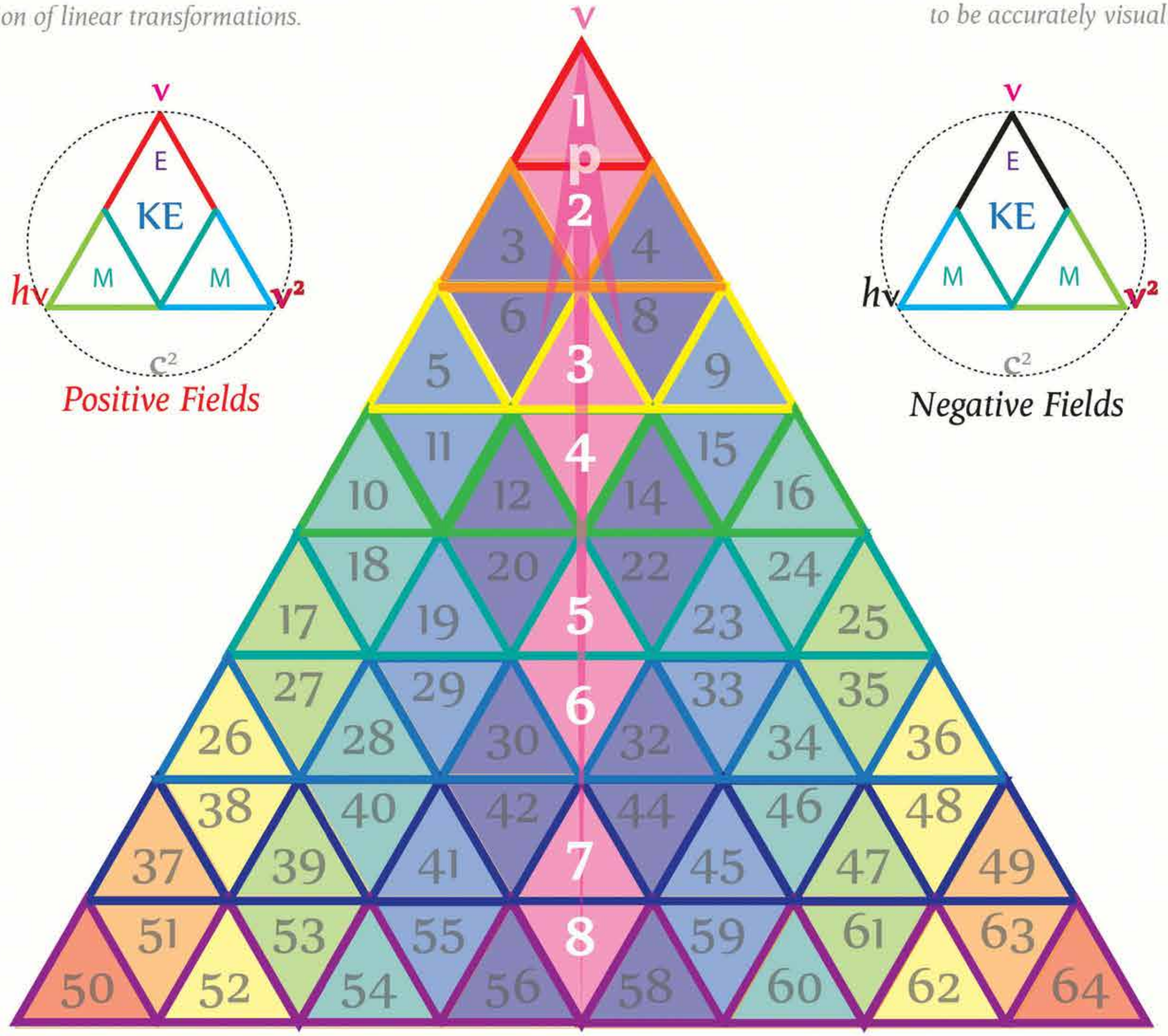
v
E
KE
M
M
hv
v²
c²

Positive Fields

v
p
1
2
3
4
5
6
7
8
3 4
5 6 8 9
10 11 12 14 15 16
17 18 19 20 22 23 24 25
26 27 28 29 30 32 33 34 35 36
37 38 39 40 41 42 44 45 46 47 48 49
50 51 52 53 54 55 56 58 59 60 61 62 63 64

v
E
KE
M
M
hv
v²
c²

Negative Fields

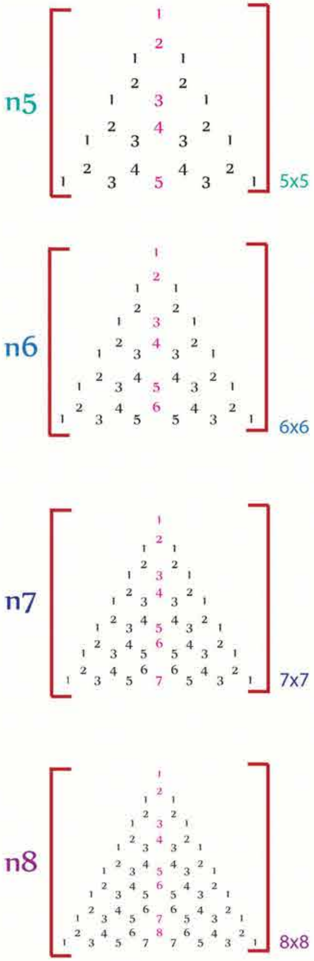
n5
5x5
n6
6x6
n7
7x7
n8
8x8

Tensors are geometric entities introduced into mathematics and physics to extend the notion of scalars, geometric vectors, and matrices to increasingly higher orders.

Modifying Square matrices to reflect the equialteral geometries of Tetryonic fields allows for the accurate geometric modelling of all Scalar & Vector fields along with their varied intrinsic quantum energies and physical properties

Energy momenta Tensors

momenta
(a property of Energy)
is converative

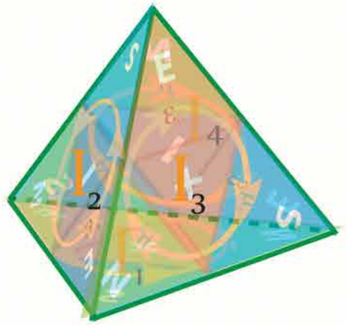

Matter
(a geometric property)
is NOT conservative

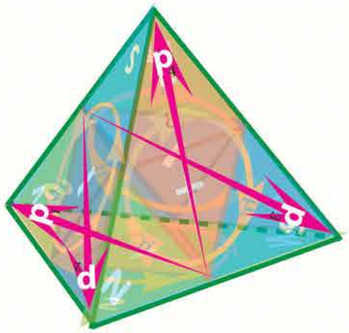

$$p_M \longrightarrow (E, p1, p2, p3, p4).$$

All standing-wave Matter topologies can be modelled using its Tetryonic charge energy momenta Tensors

with an additional Kinetic EM energy-momenta tensor required for Matter in motion

$$p_{KEM} \longrightarrow (E, p5).$$

2D+1 [SR] mass-energy momenta can be folded into 3D+1 [GR] Matter
that can be modelled using 4 Energy-momenta tensors

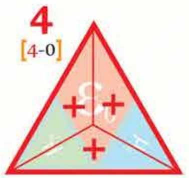

Positive standing-wave Matter

$$E = \sum_{\text{all fascia}} E$$

Energy of a massive particle is the total of all Planck quanta (compton frequency) in a 3D geometry

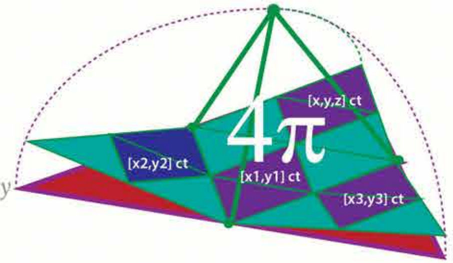

$$\vec{p} = \sum_{\text{all fascia}} \vec{p}$$

Total Momentum is the total of all quanta linear Momenta in a 3D particle

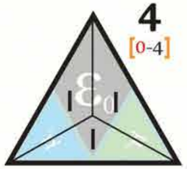

Negative standing-wave Matter

Relativistic Matter in motion

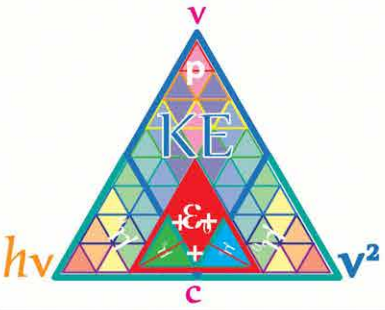

$$I = \sum_{\text{all fascia}} I$$

Inertial mass is the total of all inertia in a 3D particle

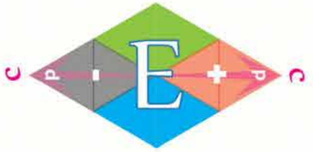

Photons have null energy-momentum tensors

Note that both 2D mass-energies [Special Relativity] and 3D Matter [General Relativity] have distinct Energy momenta

It is the 3D Tetrahedral topologies that provides a definative basis for Matter

Relativistic Matter in motion

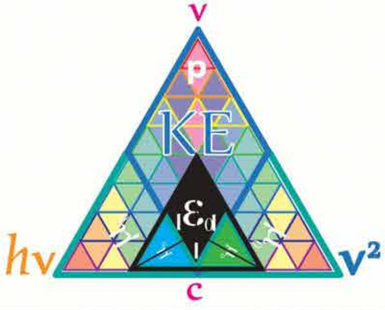

Tetryonic Energy momenta tensors should not be confused with Four vector tensors which map energy-momenta vectors in 3D spatial[cartesian] co-ordinate systems

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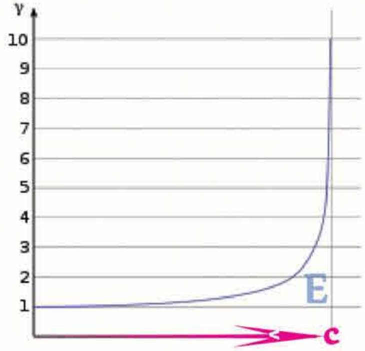

Relativistic Lorentz correction factor

The Lorentz factor or Lorentz term is an expression which appears in several equations in special relativity
It is often incorrectly graphed [as pictured to the right] as an increasing function of velocity approaching but never reaching c

'c' is the maximum velocity acheivable through the electrical acceleration of particles
is NOT the maximum velocity possible for Matter in motion

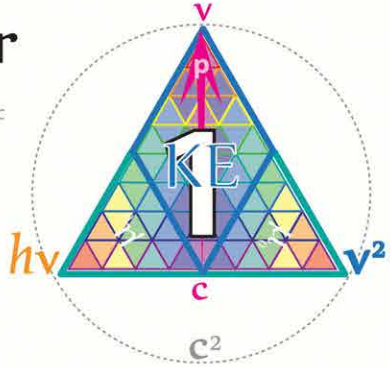

Linear correction factor

$$\beta = \left[\frac{v}{c}\right]$$

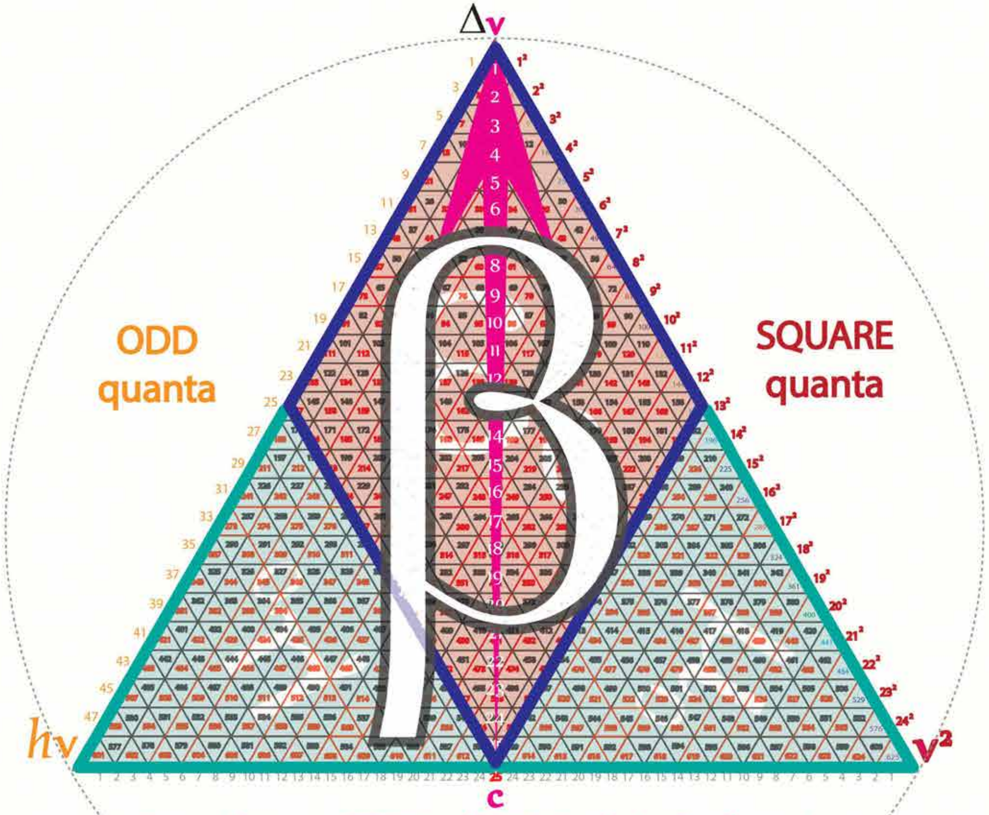

Scalar correction factor

$$\beta^2 = \left[\frac{v^2}{c^2}\right]$$

Lorentz factors are LINEAR and SCALAR velocity related corrections
to the relativistic mass-energy momenta content of any
physical system accelerated by EM Forces

$$\Delta\frac{\gamma}{c^2}$$

Wavelength contraction

Time Dilation

$$\Delta\frac{\Omega}{c^2}$$

$$\frac{\Gamma}{c^2}$$

Lorentz corrections

$$\Delta\frac{mv}{c^2}$$

Relativistic momentum

Relativistic mass-energy

$$\Delta\frac{hv}{c^2}$$

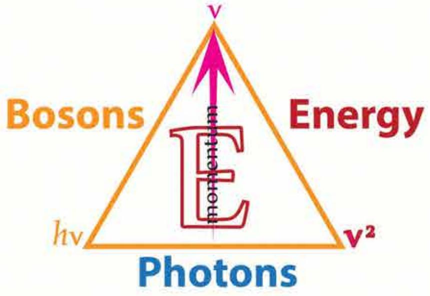
v
Bosons
Energy
momentum
E
hv
v²
Photons

form the basis for all charged energy geometries and their associated quanta distributions

Equilateral energies

Any measurements of mass without a Space-Time co-ordinate system are measurements of Energy

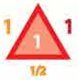

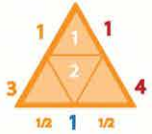
1
1
1
2
3
4
1/2 1 1/2

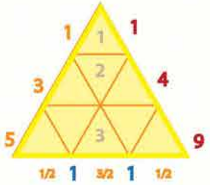
1
1
1
2
3
3
4
5
9
1/2 1 3/2 1 1/2

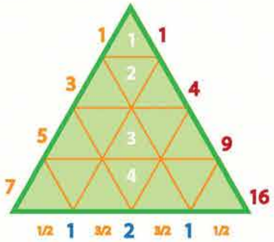
1 3 5 7
1 4 9 16
1 2 3 4
1/2 1 3/2 2 3/2 1 1/2

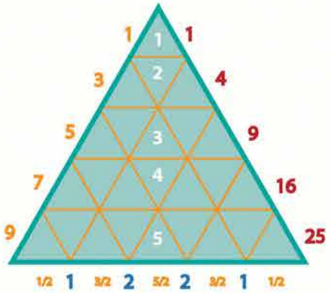
1 3 5 7 9
1 4 9 16 25
1 2 3 4 5
1/2 1 3/2 2 5/2 2 3/2 1 1/2

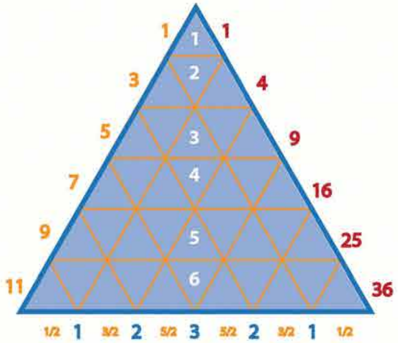
1 3 5 7 9 11
1 4 9 16 25 36
1 2 3 4 5 6
1/2 1 3/2 2 5/2 3 5/2 2 3/2 1 1/2

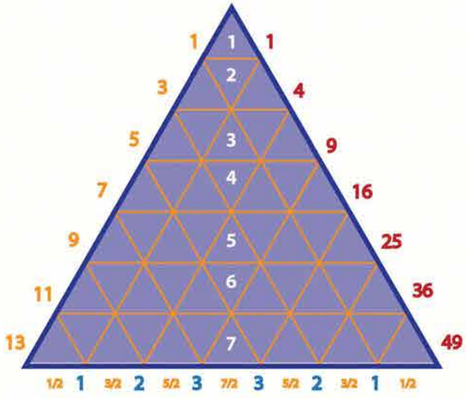
1 3 5 7 9 11 13
1 4 9 16 25 36 49
1 2 3 4 5 6 7
1/2 1 3/2 2 5/2 3 7/2 3 5/2 2 3/2 1 1/2

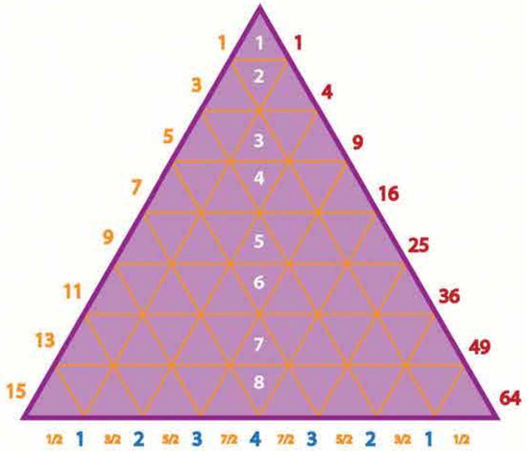
1 3 5 7 9 11 13 15
1 4 9 16 25 36 49 64
1 2 3 4 5 6 7 8
1/2 1 3/2 2 5/2 3 7/2 4 7/2 3 5/2 2 3/2 1 1/2

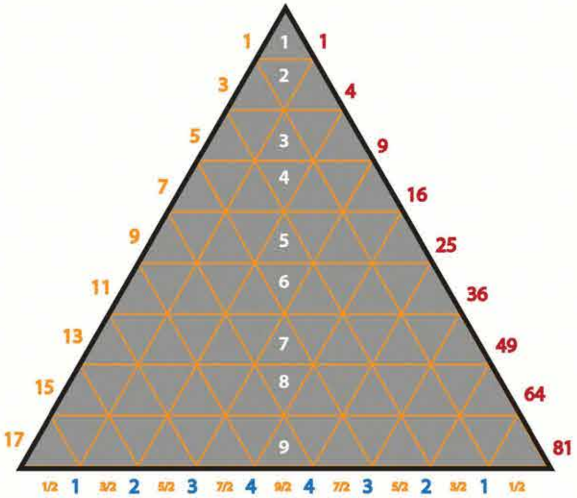
1 3 5 7 9 11 13 15 17
1 4 9 16 25 36 49 64 81
1 2 3 4 5 6 7 8 9
1/2 1 3/2 2 5/2 3 7/2 4 9/2 4 7/2 3 5/2 2 3/2 1 1/2

Electromagnetic mass

2D mass-energy is the surface integral of 3D Matter

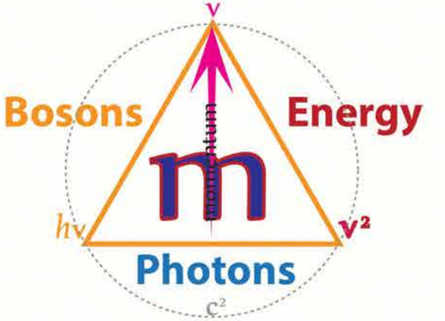
v
Bosons
Energy
m
hv
v²
Photons
c²

Time specific measurements of equilateral ENERGY momenta geometries forms the basis for EM mass

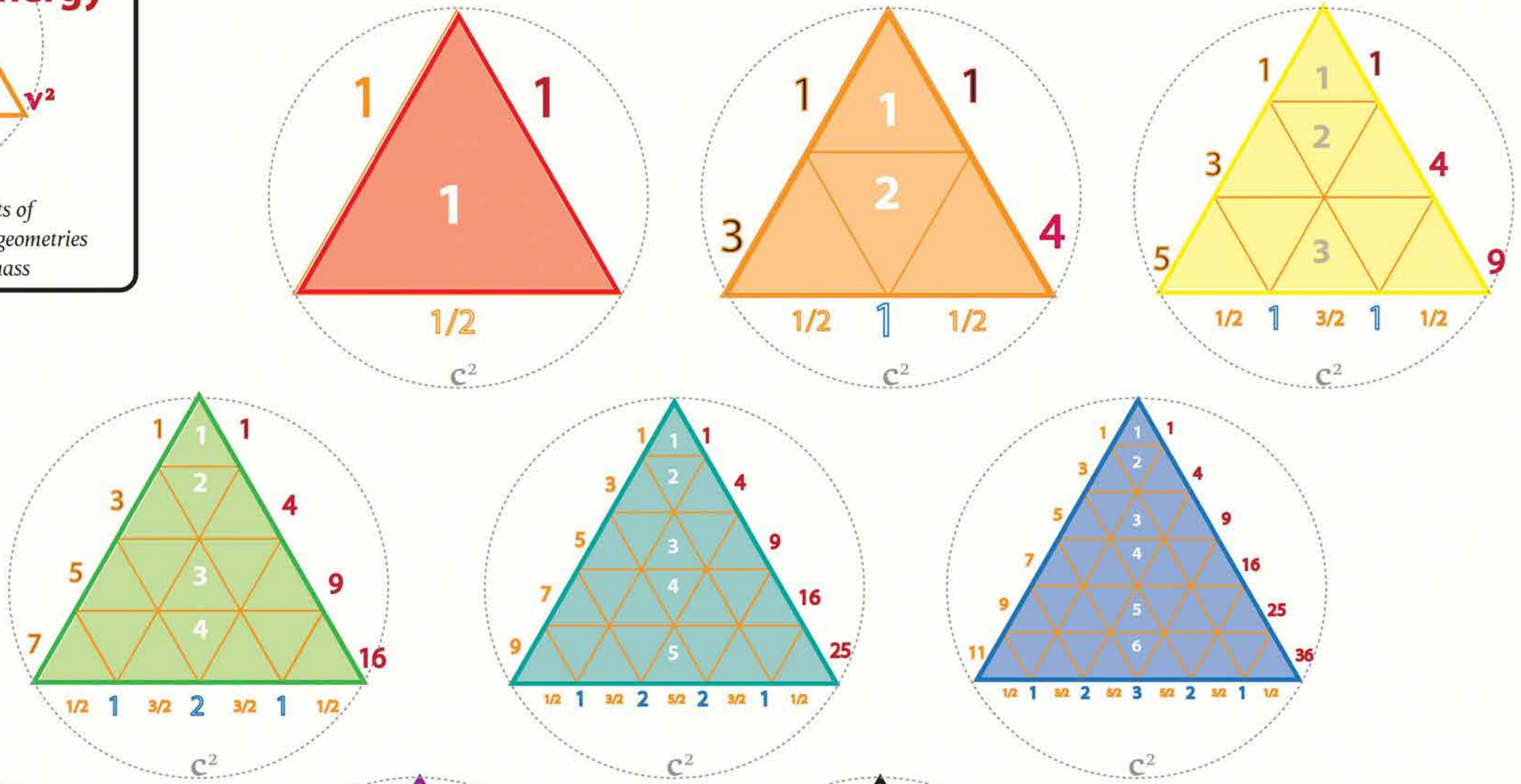
1
1
1
1/2
c²
1
1
1
2
3
4
1/2 1 1/2
c²
1
1
1
2
3
3
4
5
9
1/2 1 3/2 1 1/2
c²
1 3 5 7
1 4 9 16
1 2 3 4
1/2 1 3/2 2 3/2 1 1/2
c²
1 3 5 7 9
1 4 9 16 25
1 2 3 4 5
1/2 1 3/2 2 5/2 2 3/2 1 1/2
c²
1 3 5 7 9 11
1 4 9 16 25 36
1 2 3 4 5 6
1/2 1 3/2 2 5/2 3 5/2 2 3/2 1 1/2
c²

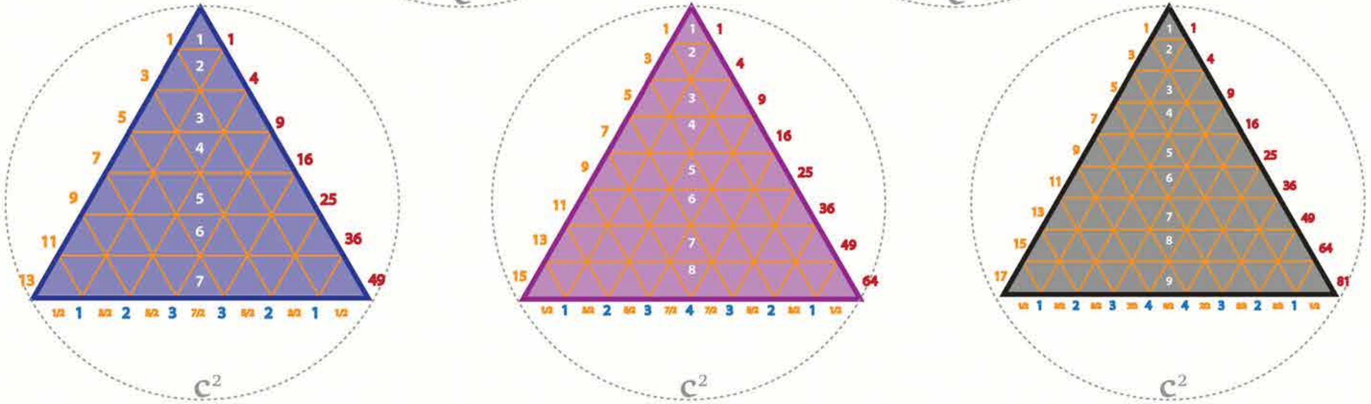
1 3 5 7 9 11 13
1 4 9 16 25 36 49
1 2 3 4 5 6 7
1/2 1 3/2 2 5/2 3 7/2 3 5/2 2 3/2 1 1/2
c²
1 3 5 7 9 11 13 15
1 4 9 16 25 36 49 64
1 2 3 4 5 6 7 8
1/2 1 3/2 2 5/2 3 7/2 4 7/2 3 5/2 2 3/2 1 1/2
c²
1 3 5 7 9 11 13 15 17
1 4 9 16 25 36 49 64 81
1 2 3 4 5 6 7 8 9
c²

mass-less particles is a physical misnomer

All measurements of energy in spatial co-ordinate systems are measurements of mass

Matter-less is the appropriate terminology

Standing-wave Matter

Matter is a higher order 3D topology created by standing wave mass-energies

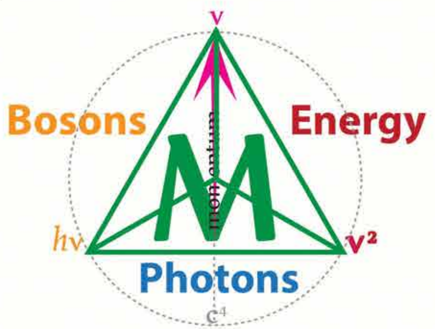
v
Bosons
Energy
M
momentum
hv
v²
Photons
c⁴

The equilateral mass-ENERGY content of 4nπ Tetrahedral standing-wave topologies forms the basis of Matter

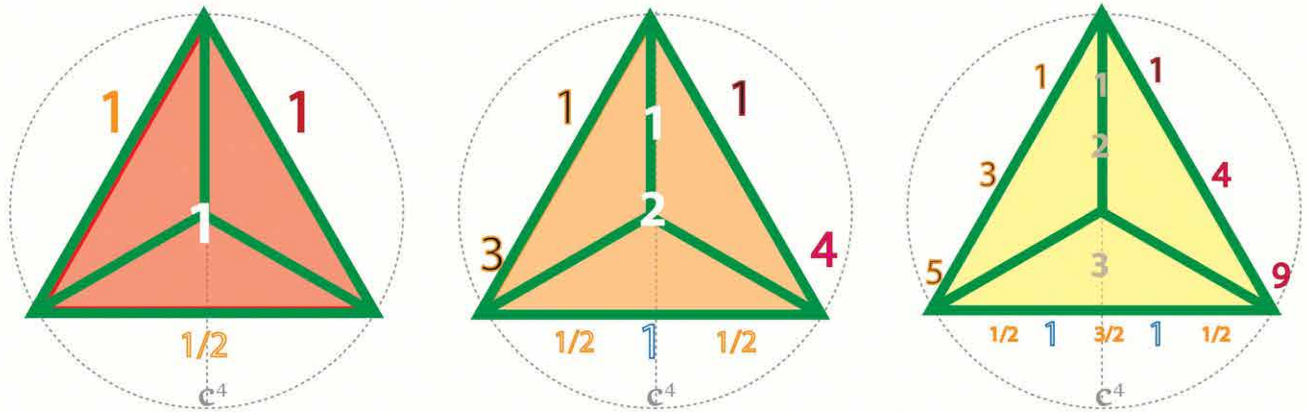
1 1 1
1/2
c⁴
1 1 1 2 3 4
1/2 1 1/2
c⁴
1 1 1 2 3 4 5 9 3
1/2 1 3/2 1 1/2
c⁴

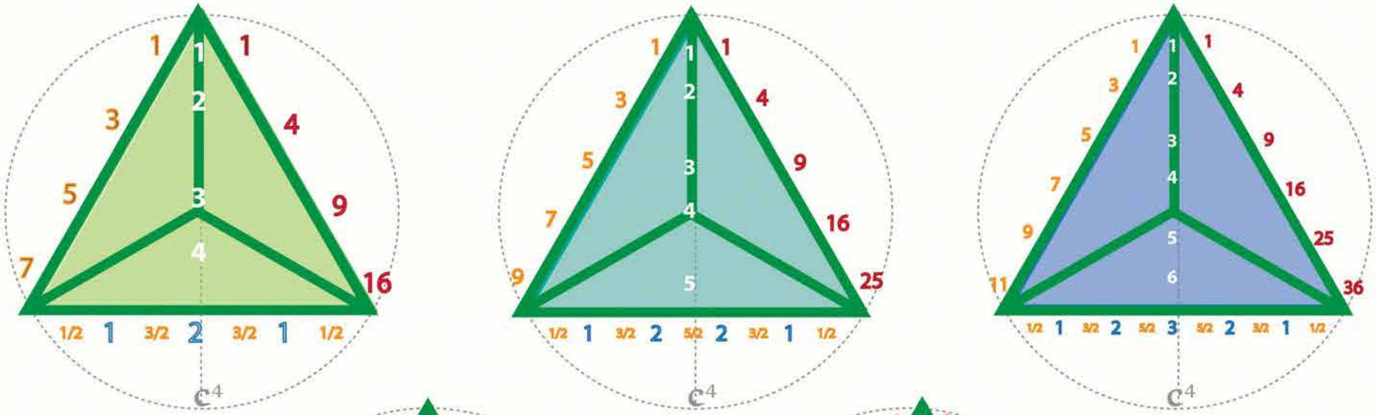
1 3 5 7
1 4 9 16
1 2 3 4
1/2 1 3/2 2 3/2 1 1/2
c⁴
1 3 5 7 9
1 4 9 16 25
1 2 3 4 5
1/2 1 3/2 2 5/2 2 3/2 1 1/2
c⁴
1 3 5 7 9 11
1 4 9 16 25 36
1 2 3 4 5 6
1/2 1 3/2 2 5/2 3 5/2 2 3/2 1 1/2
c⁴

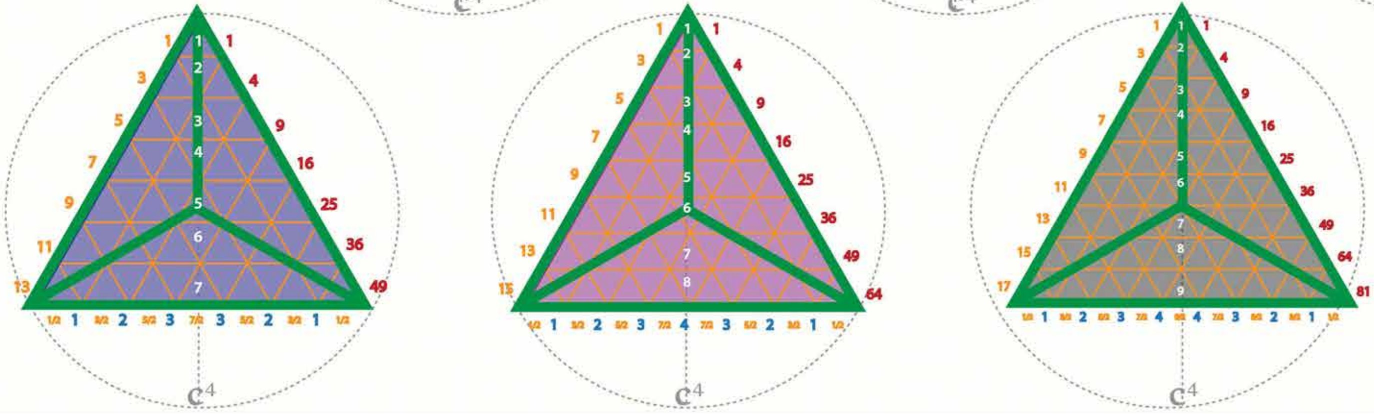
1 3 5 7 9 11 13
1 4 9 16 25 36 49
1 2 3 4 5 6 7
1/2 1 3/2 2 5/2 3 7/2 3 5/2 2 3/2 1 1/2
c⁴
1 3 5 7 9 11 13 15
1 4 9 16 25 36 49 64
1 2 3 4 5 6 7 8
1/2 1 3/2 2 5/2 3 7/2 4 7/2 3 5/2 2 3/2 1 1/2
c⁴
1 3 5 7 9 11 13 15 17
1 4 9 16 25 36 49 64 81
1 2 3 4 5 6 7 8 9
1/2 1 3/2 2 5/2 3 7/2 4 9/2 4 7/2 3 5/2 2 3/2 1 1/2
c⁴

Only mass-ENERGIES contained in the tetryonic fascia of standing-wave topologies contribute to weight

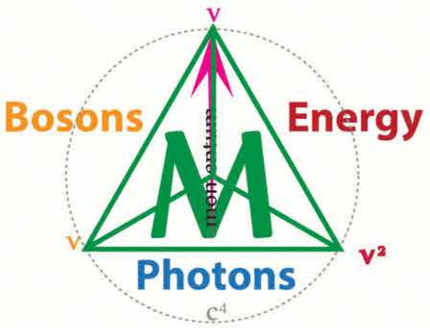
v
Bosons
Energy
momentum
M
v
v²
Photons
c4

The mass-ENERGY content of
4nπ Tetrahedral standing-wave topologies
forms the basis of all periodic elements

Periodic element nuclei

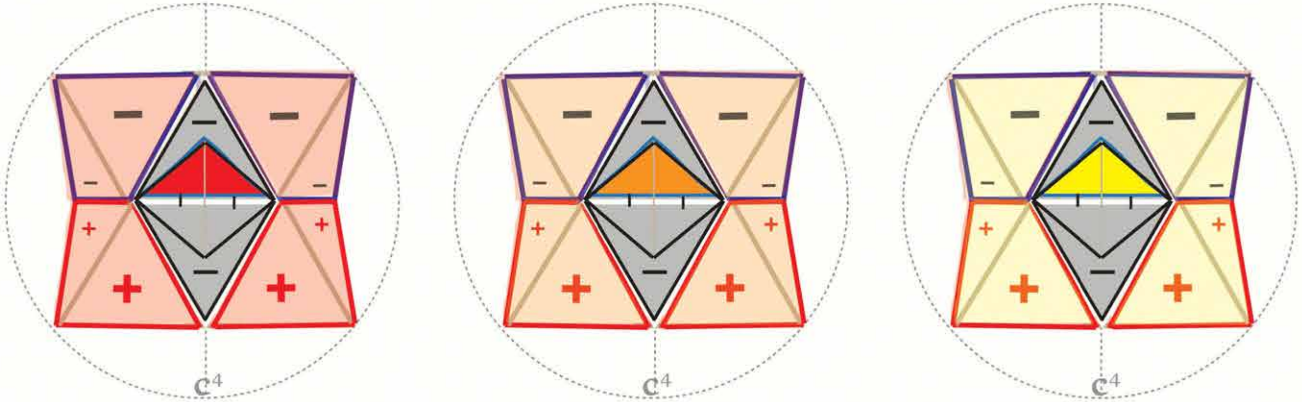

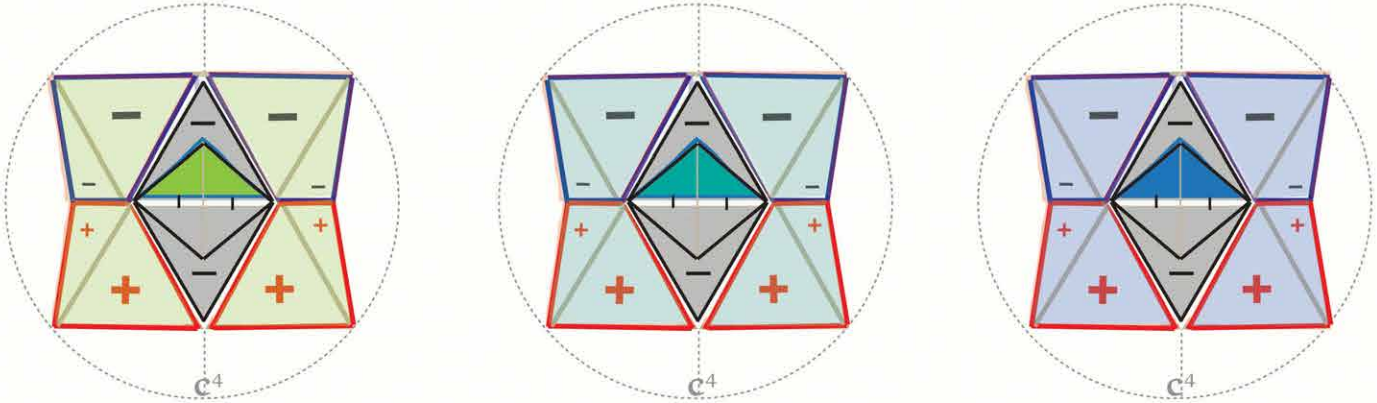

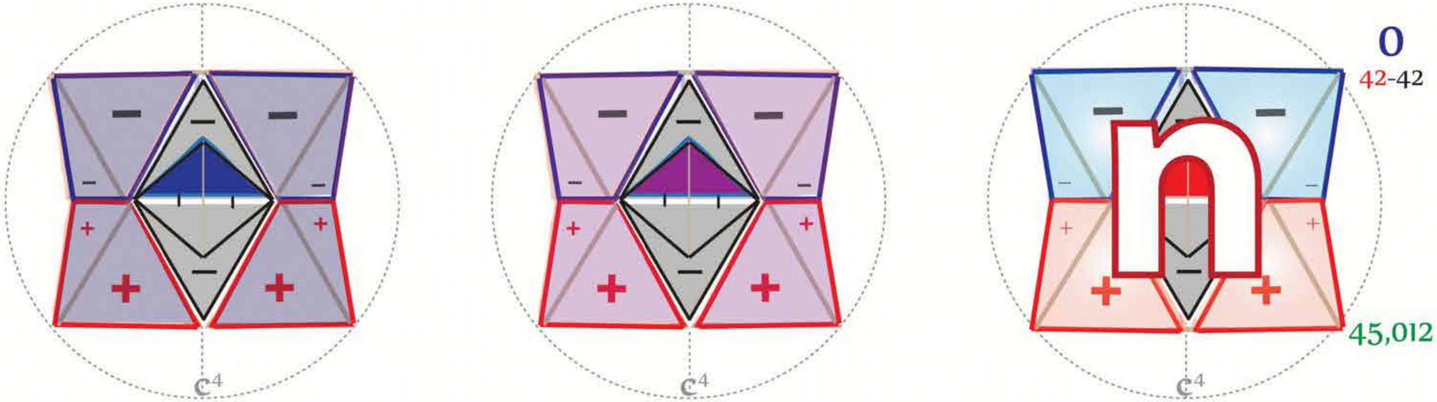
c4
c4
n
0
42-42
45,012
c4

ALL
periodic elements are
comprised of
n level deuterium
nuclei

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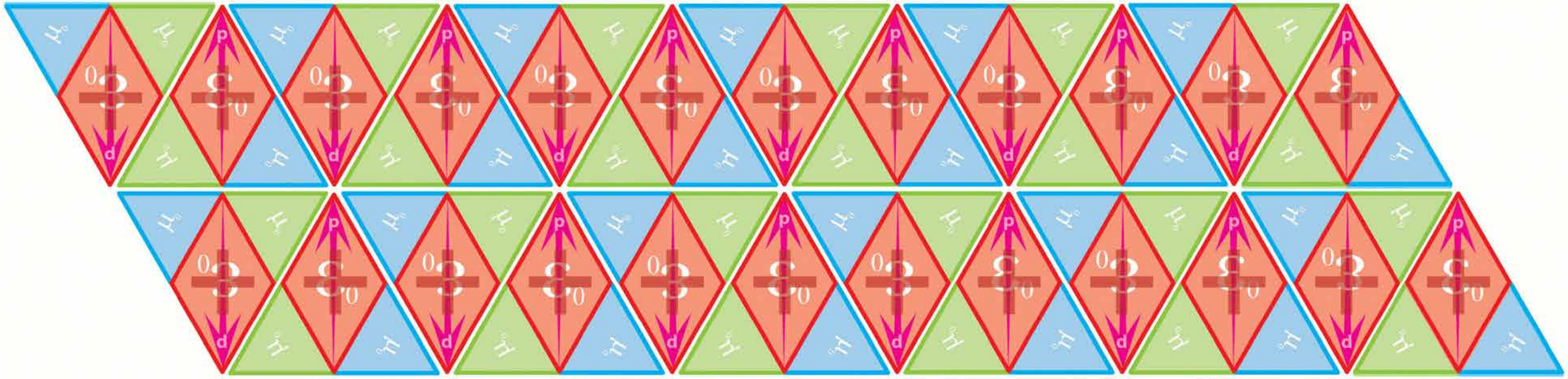
p
d
μ_0
ε_0

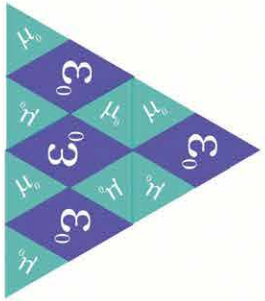
μ_0
ε_0

2D radiant EM mass-Energies

n1 - Charged Tetryon Templates

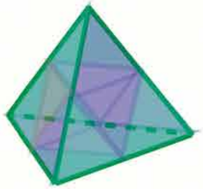

3D standing-wave Matter

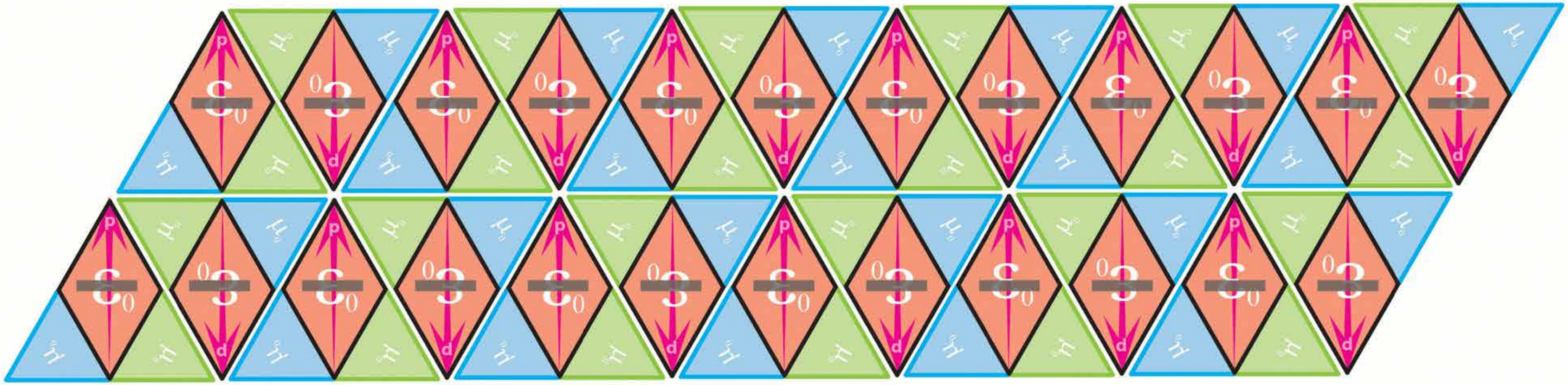
p
d
μ_0
ε_0

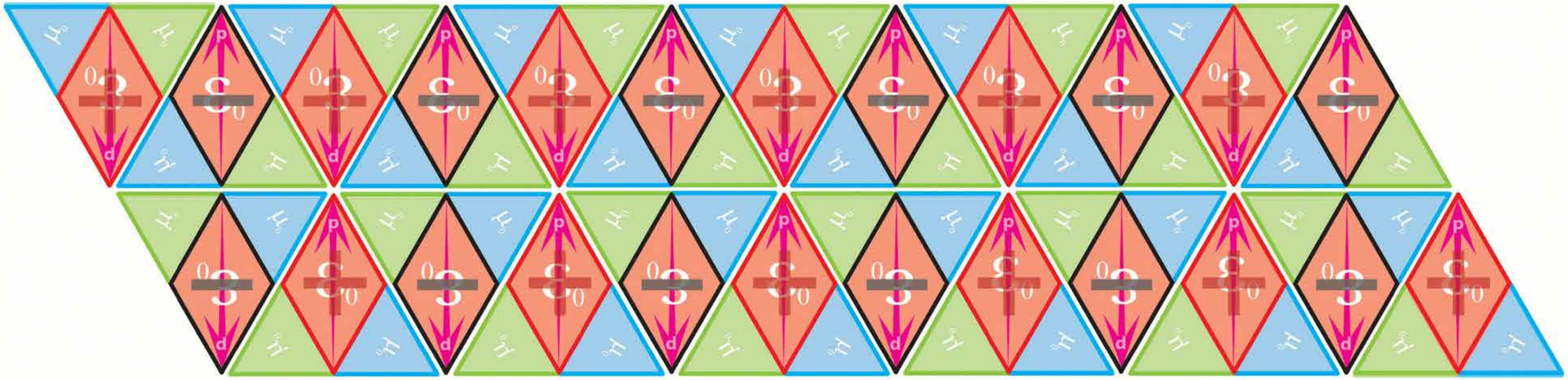
μ_0
ε_0
p
d

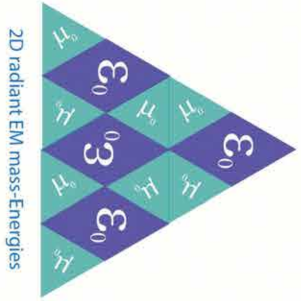
2D radiant EM mass-Energies
μ_0
ε_0

n1 - Neutral Tetryon Templates

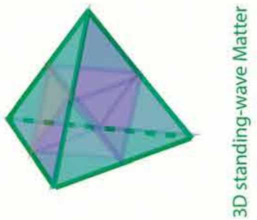
3D standing-wave Matter

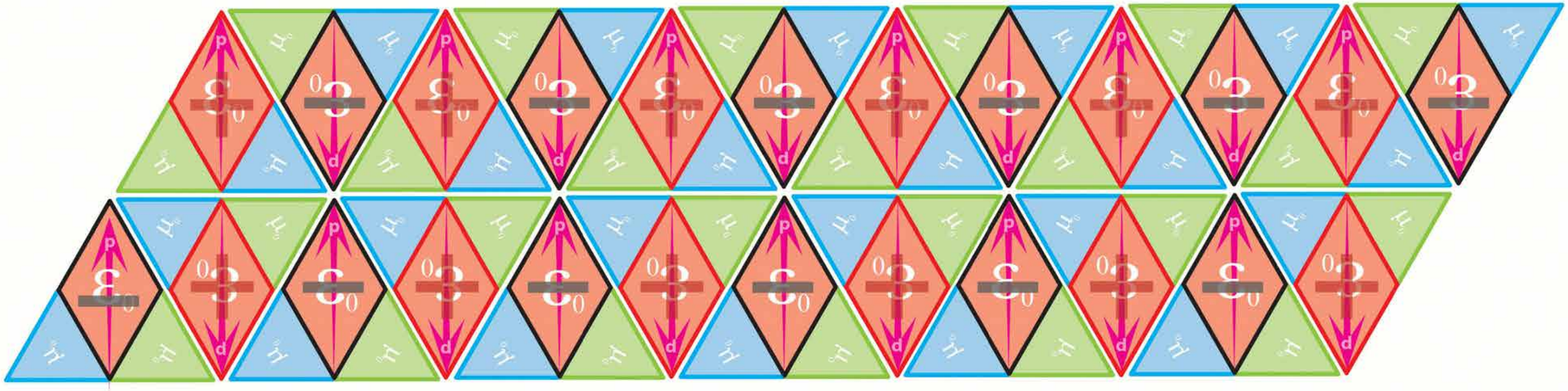
μ_0
ε_0
p
d

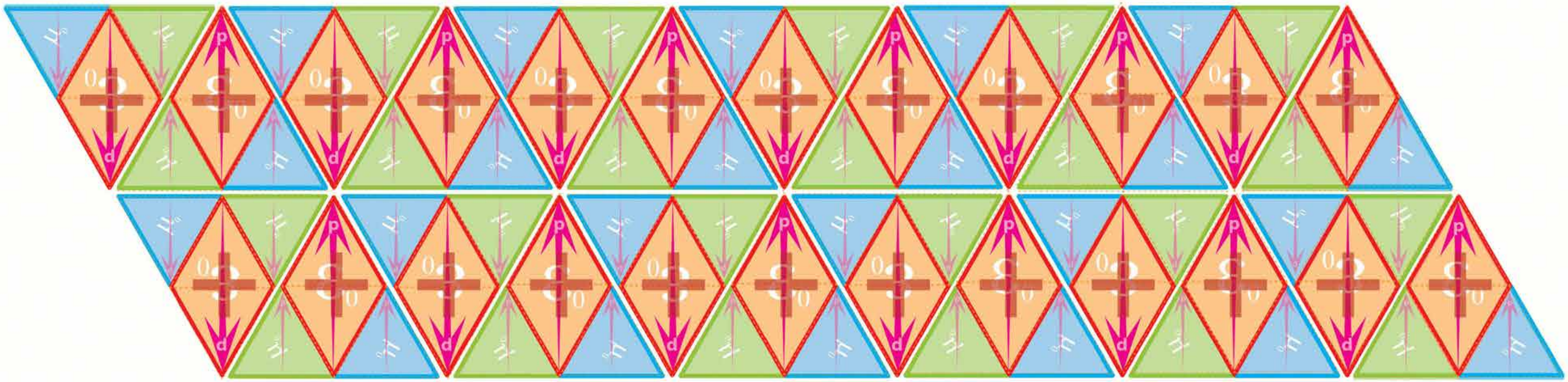

2D radiant EM mass-Energies
μ0
ε0

n2 - Charged Tetryon Templates

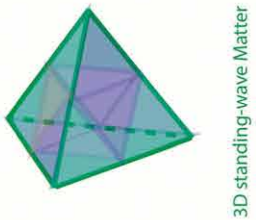
3D standing-wave Matter

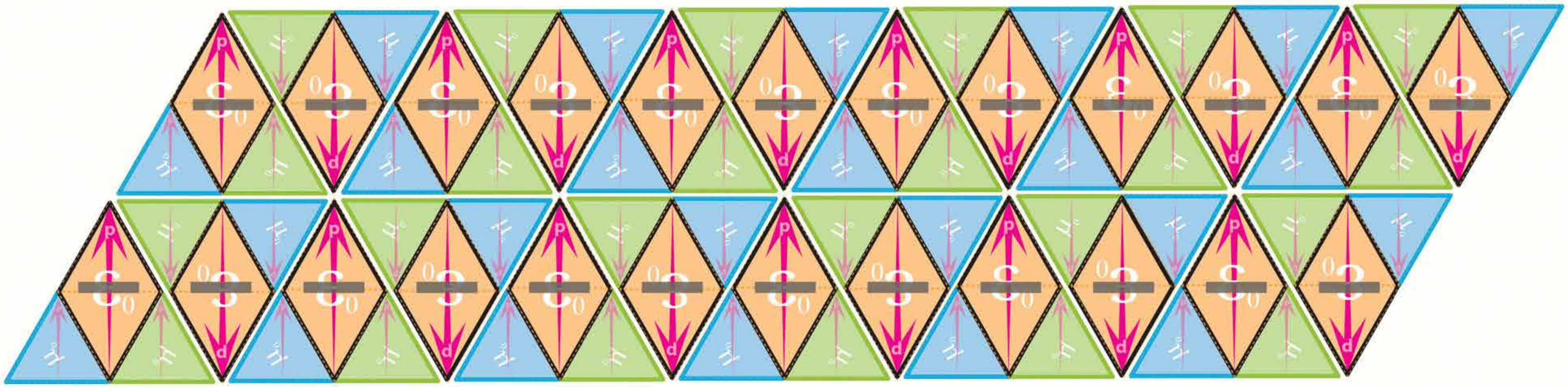

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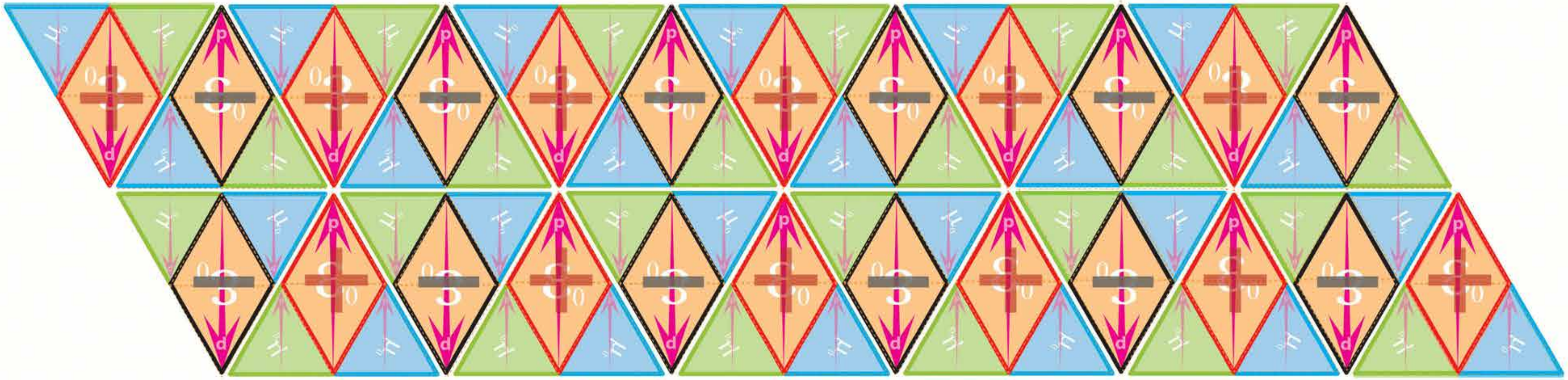

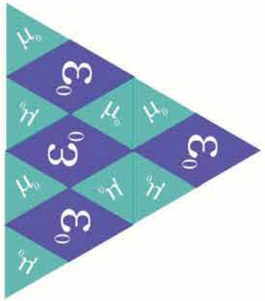

2D radiant EM mass-Energies

n2 - Neutral Tetryon Templates

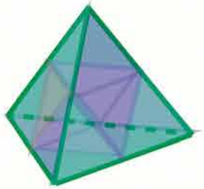

3D standing-wave Matter

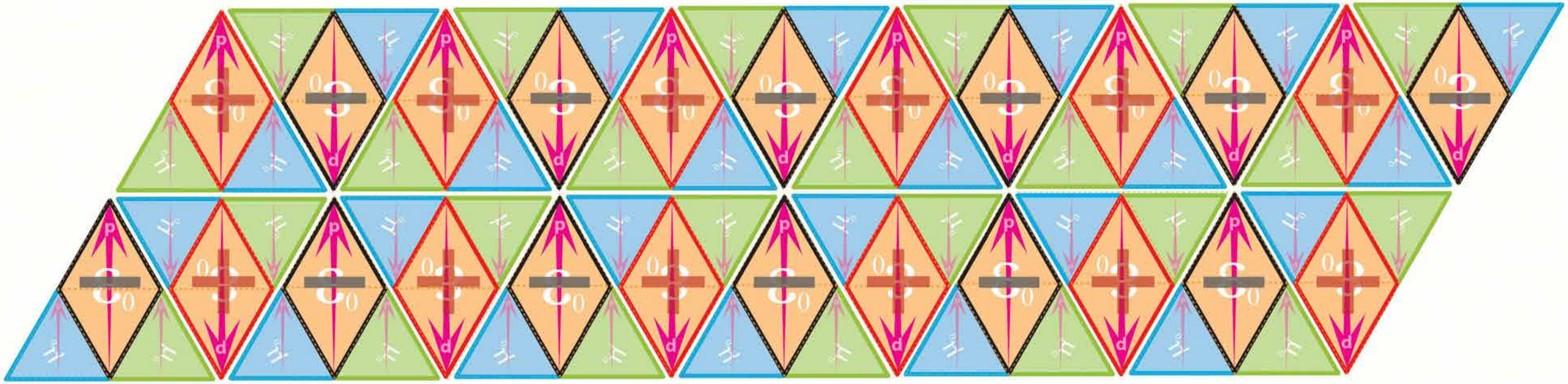

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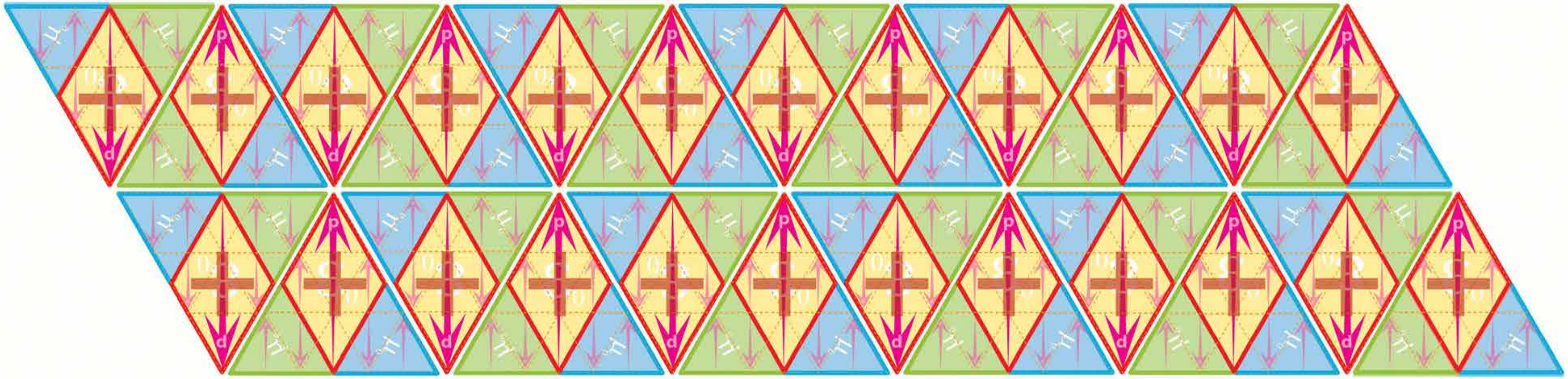

μ_0
ε_0
p
d

2D radiant EM mass-Energies
μ_0
ε_0

n3 - Charged Tetryon Templates

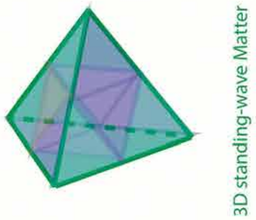

3D standing-wave Matter

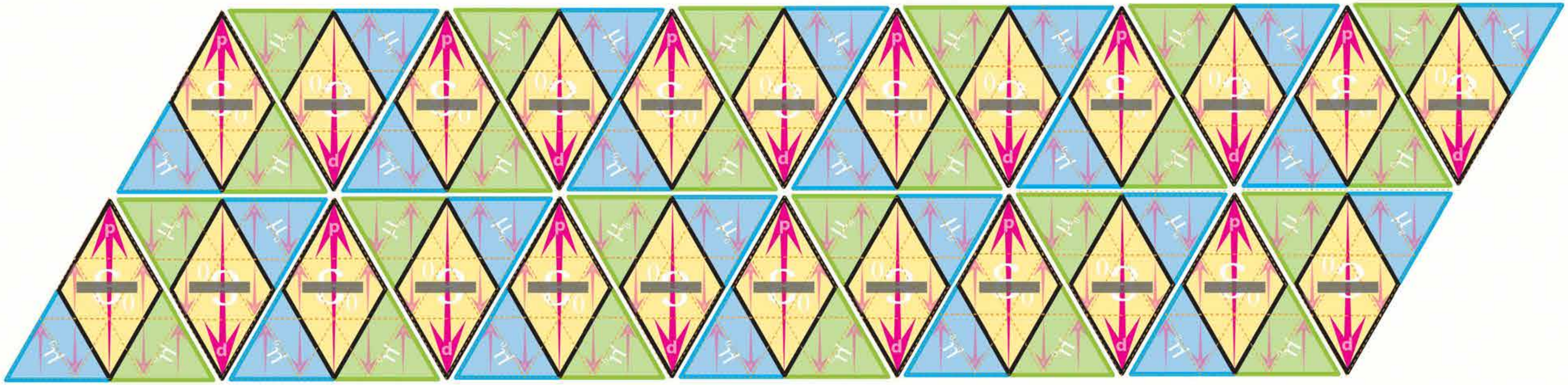

μ_0
ε_0
p
d

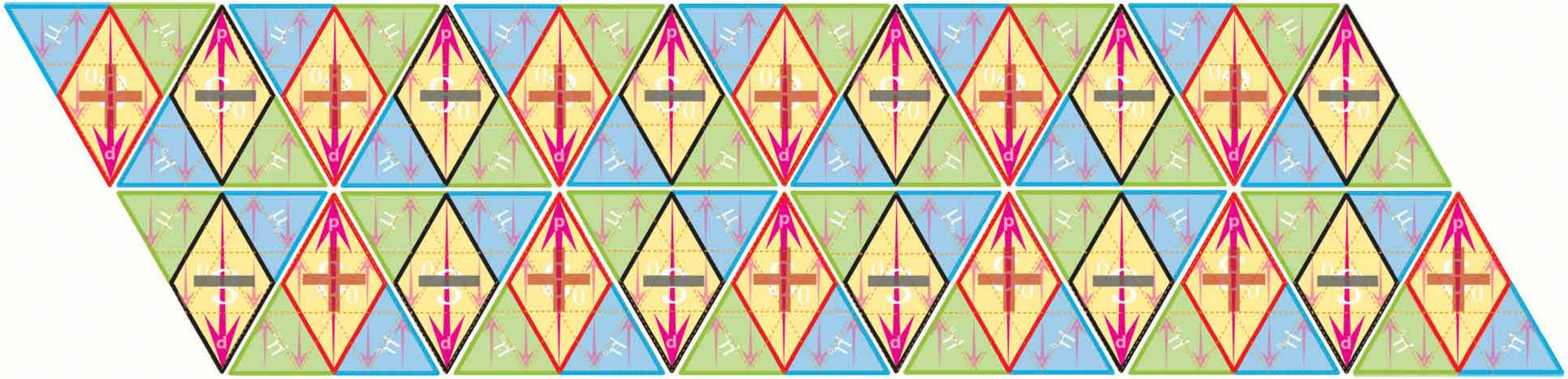

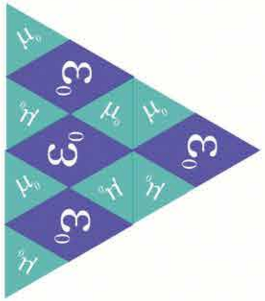

2D radiant EM mass-Energies

n3 - Neutral Tetryon Templates

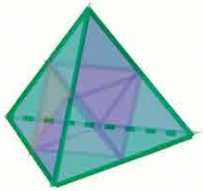

3D standing-wave Matter

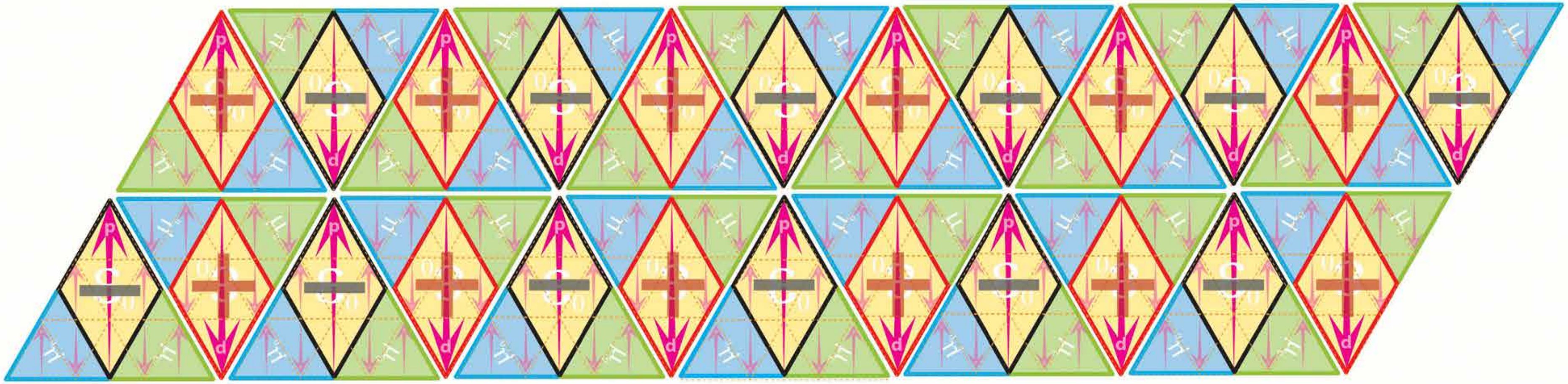

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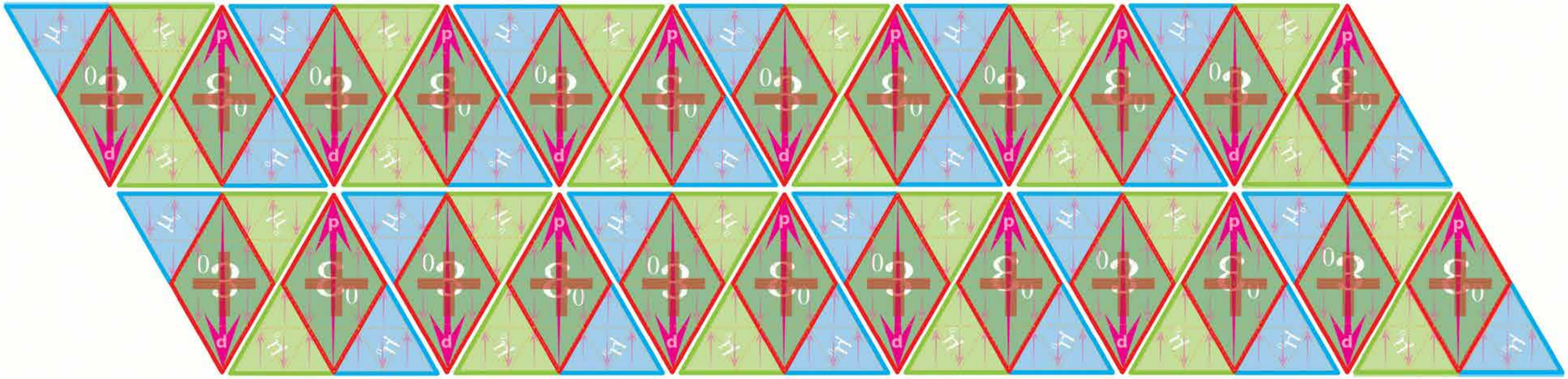

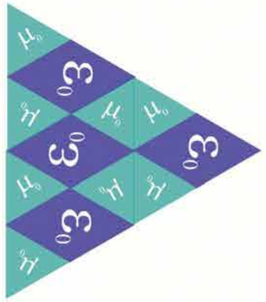
2D radiant EM mass-Energies
μ_0
ε_0

n4 - Charged Tetryon Templates

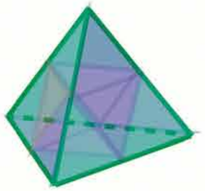
3D standing-wave Matter

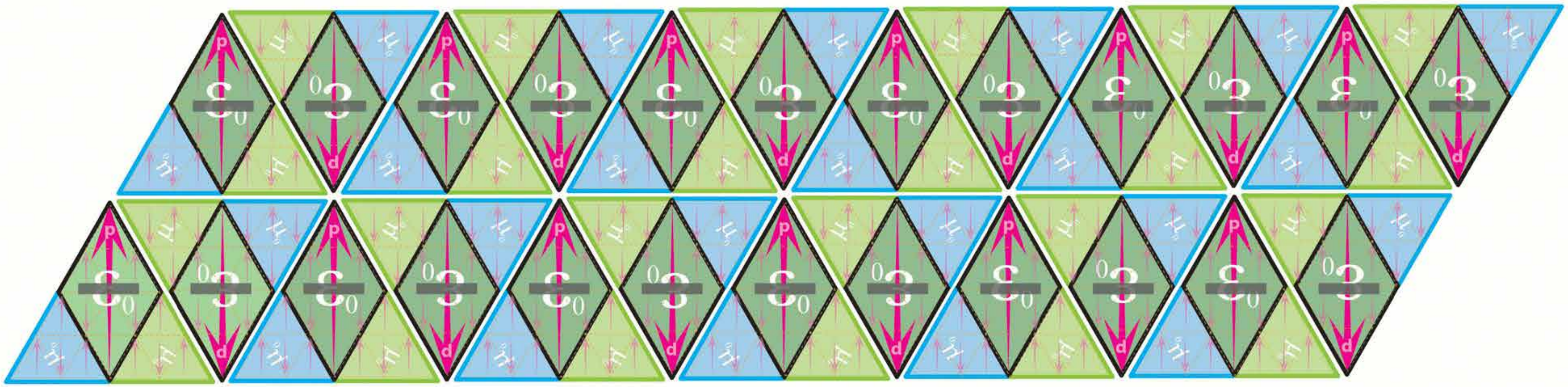

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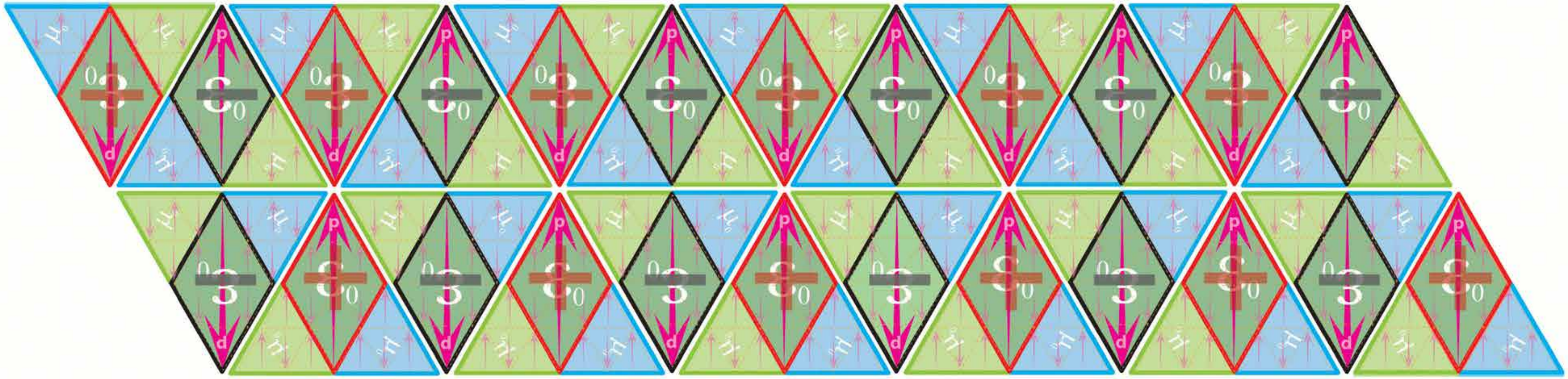
p
d
μ_0
ε_0

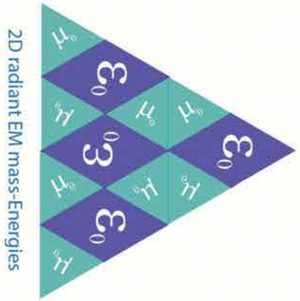
2D radiant EM mass-Energies
μ_0
ε_0

n4 - Neutral Tetryon Templates

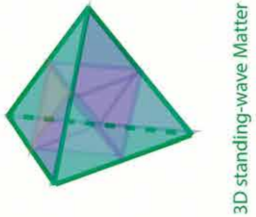
3D standing-wave Matter

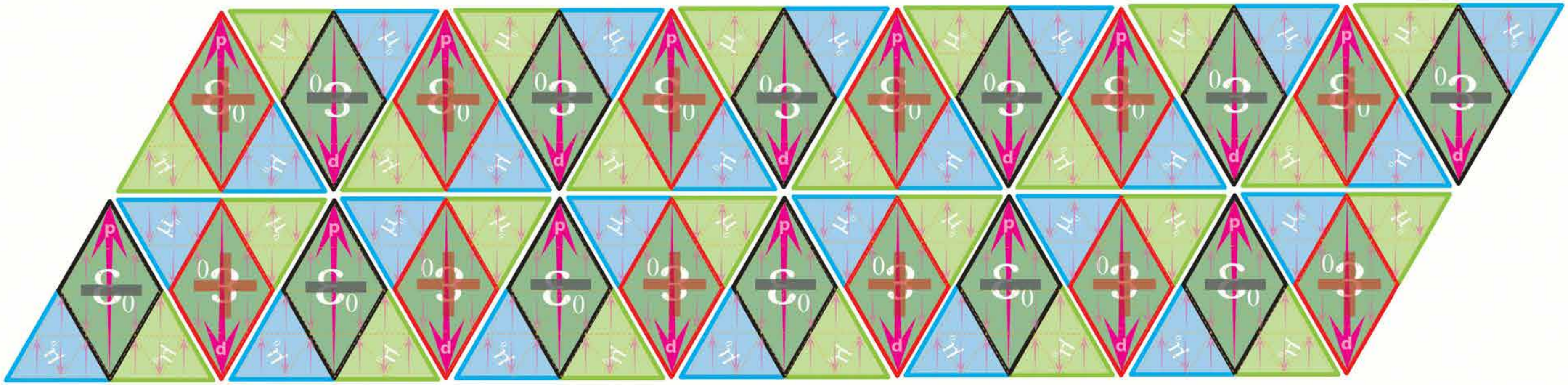
p
d
μ_0
ε_0

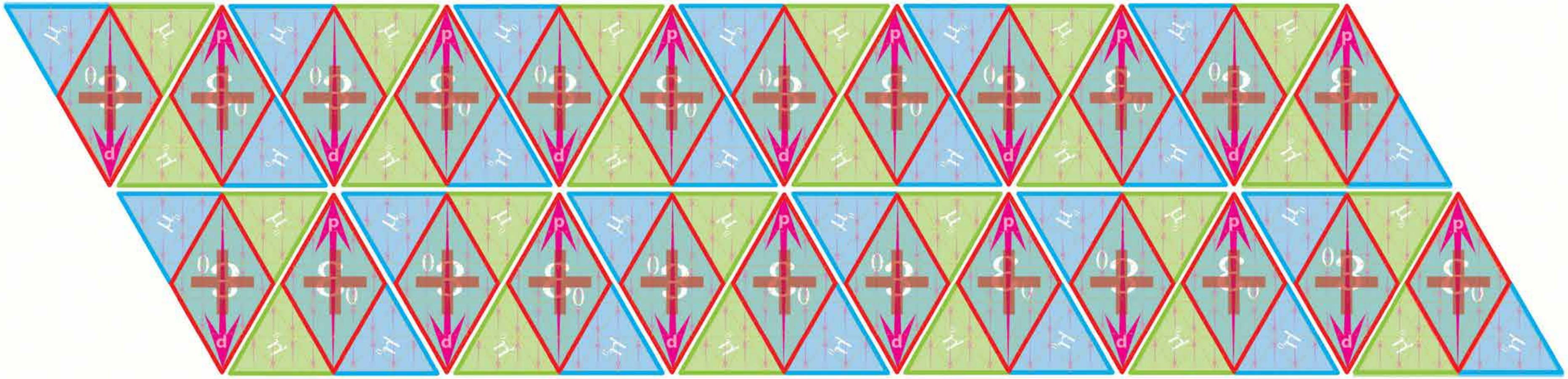

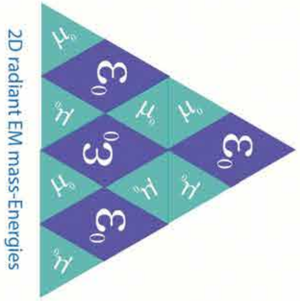
2D radiant EM mass-Energies

n5 - Charged Tetryon Templates

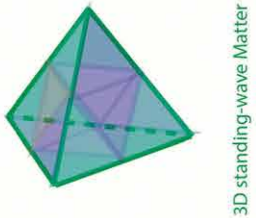
3D standing-wave Matter

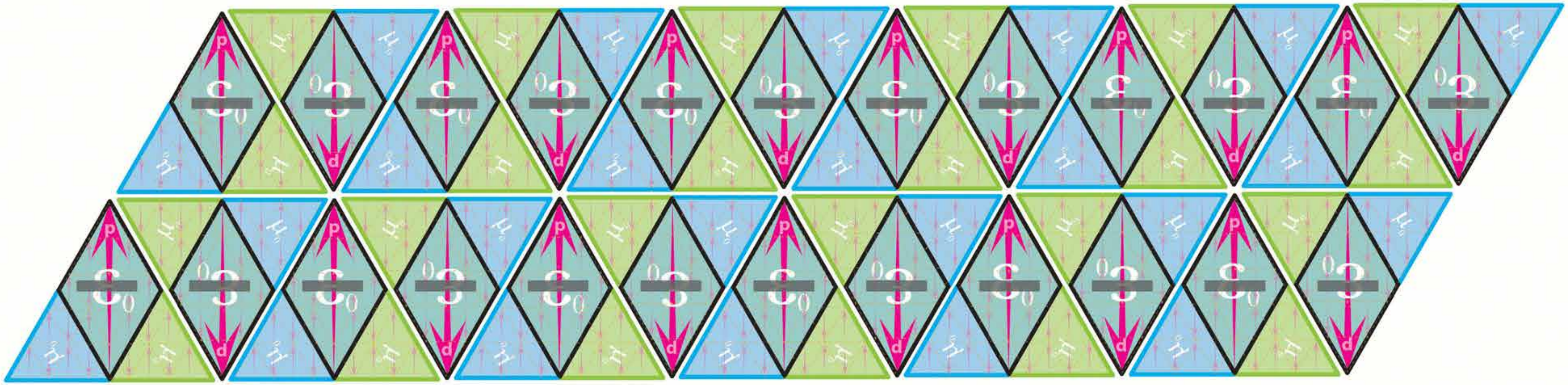

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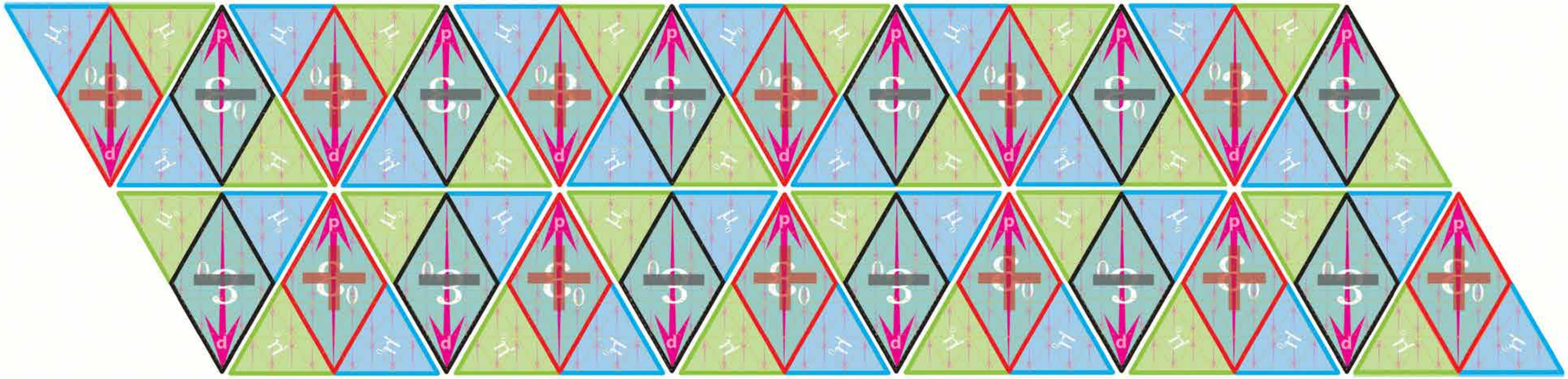
p
d
μ_0
ε_0

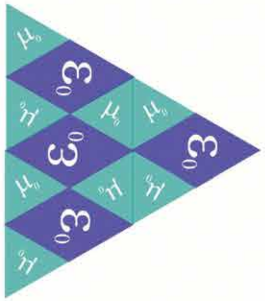
μ_0
ε_0

2D radiant EM mass-Energies

n5 - Neutral Tetryon Templates

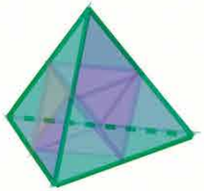

3D standing-wave Matter

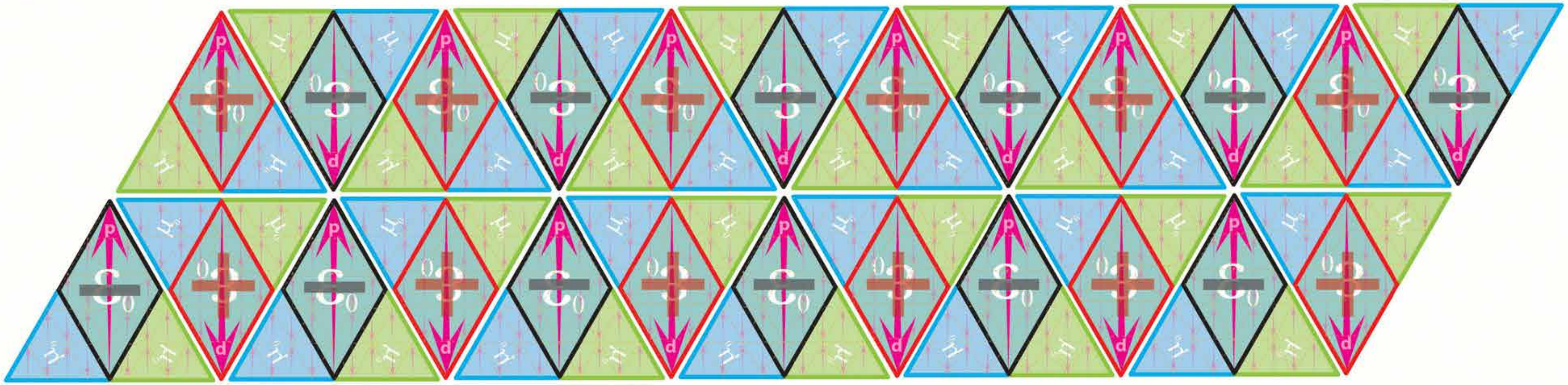
p
d
μ_0
ε_0

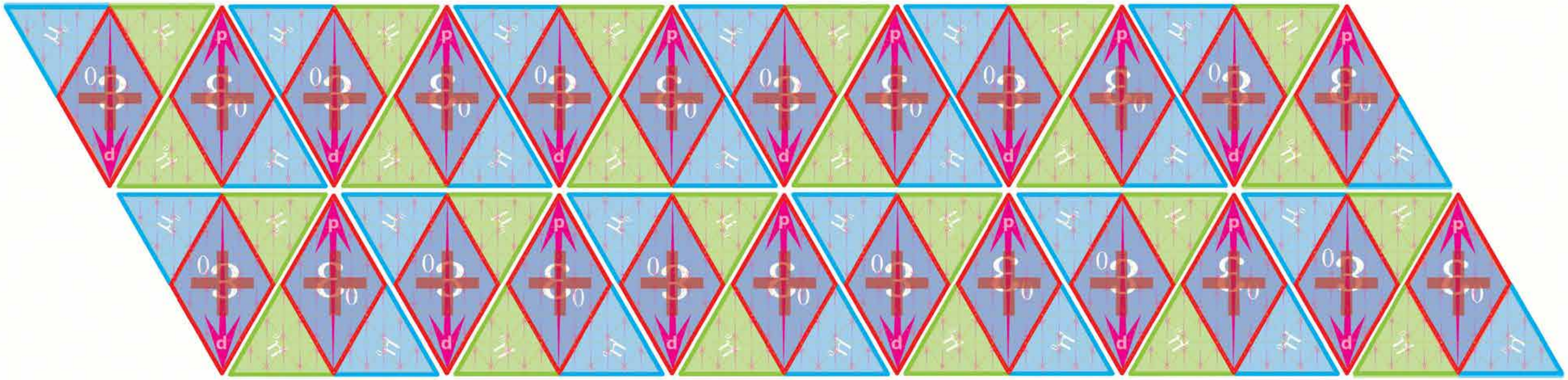

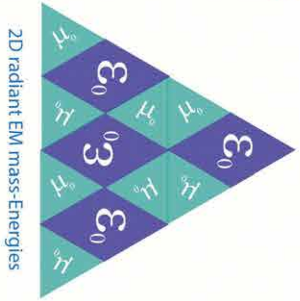

2D radiant EM mass-Energies

n6 - Charged Tetryon Templates

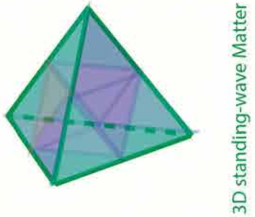

3D standing-wave Matter

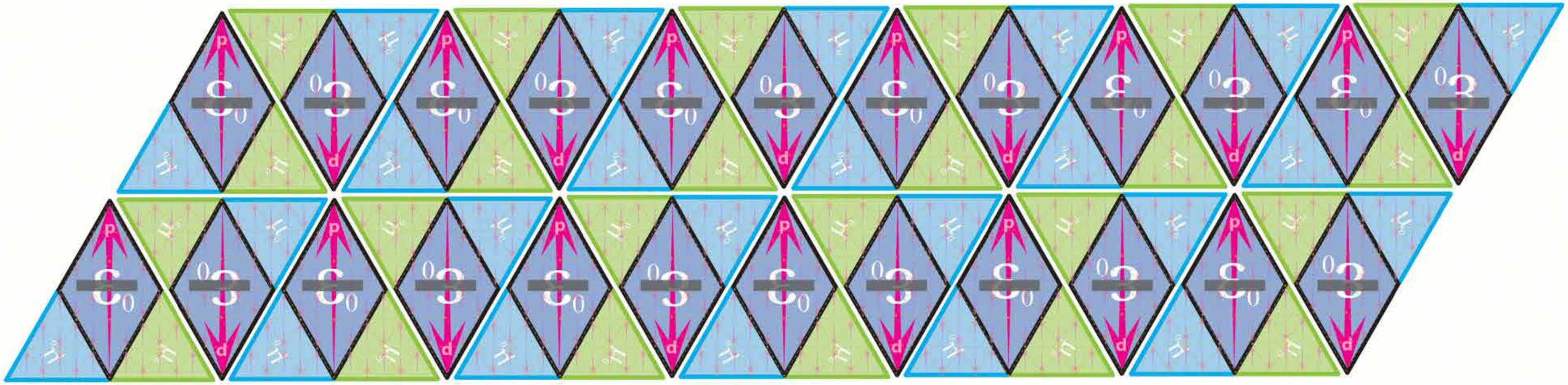

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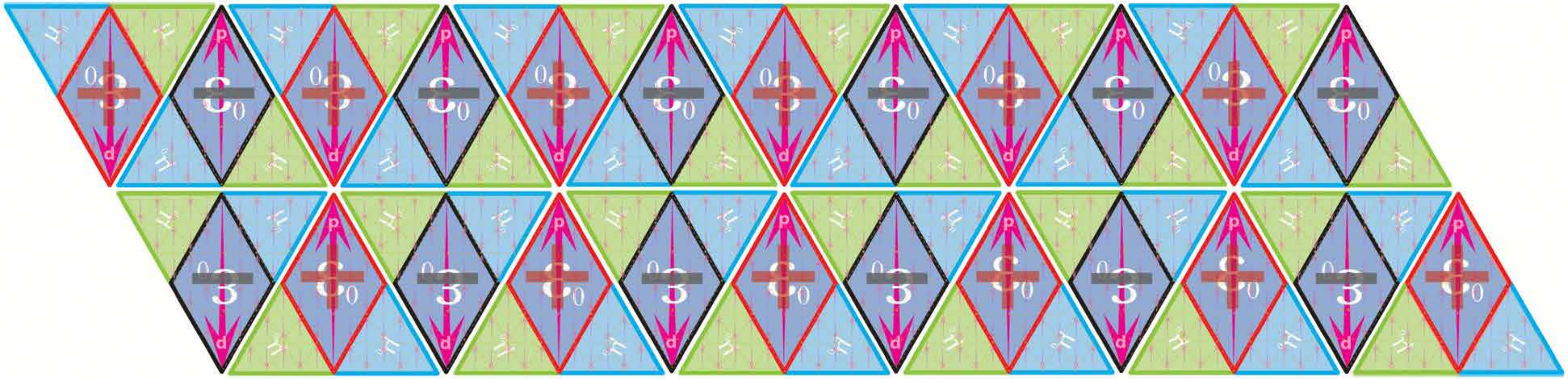
p
d
ε_0
μ_0

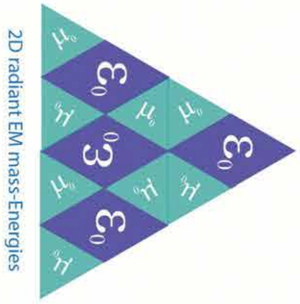
2D radiant EM mass-Energies
ε_0
μ_0

n6 - Neutral Tetryon Templates

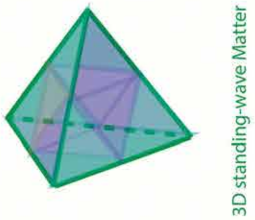
3D standing-wave Matter

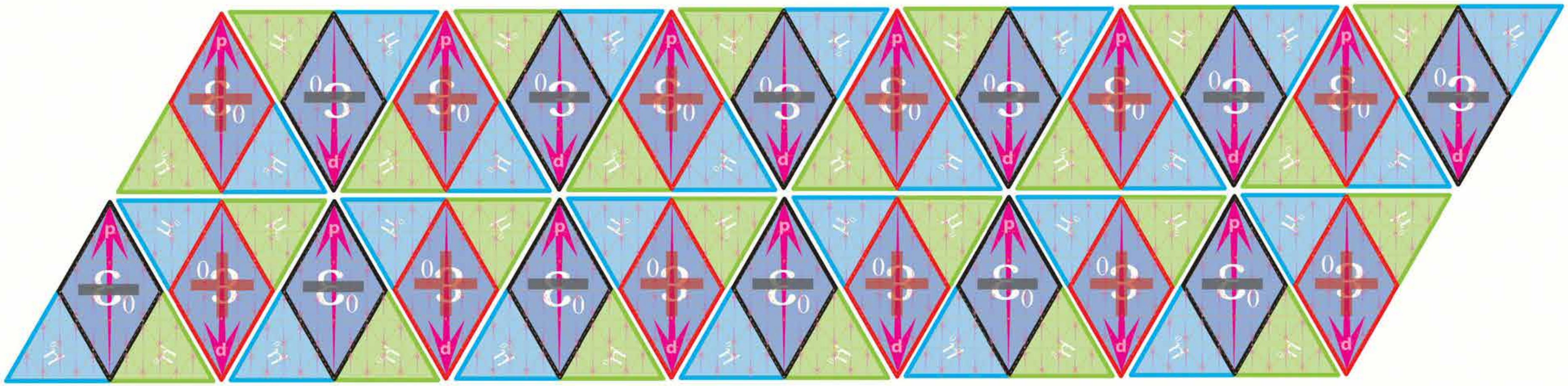
p
d
ε_0
μ_0

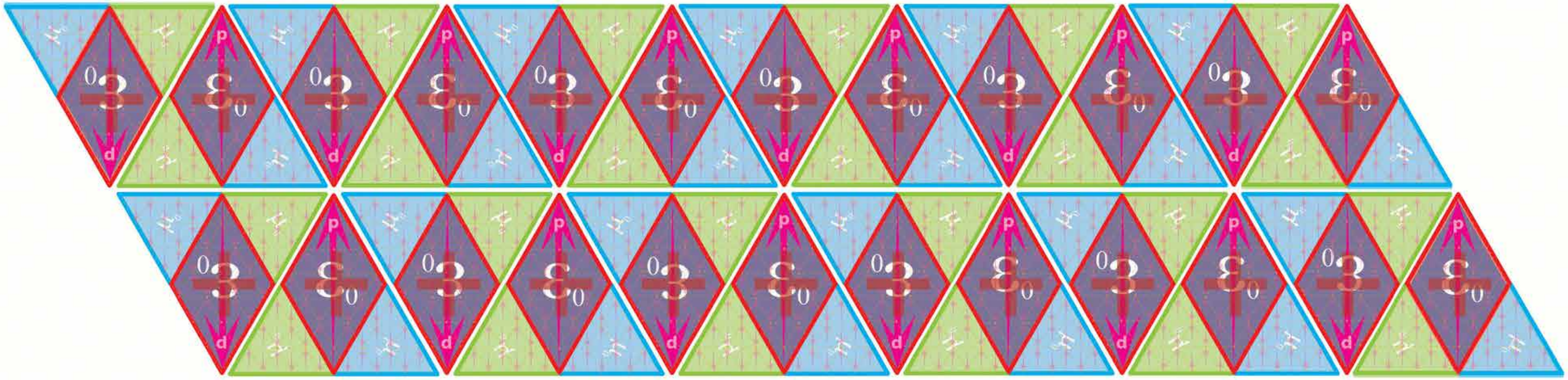

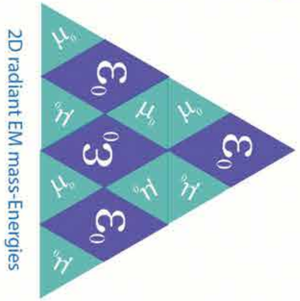
2D radiant EM mass-Energies

n7 - Charged Tetryon Templates

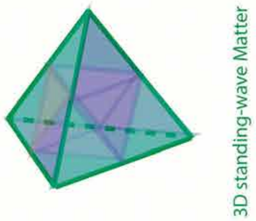
3D standing-wave Matter

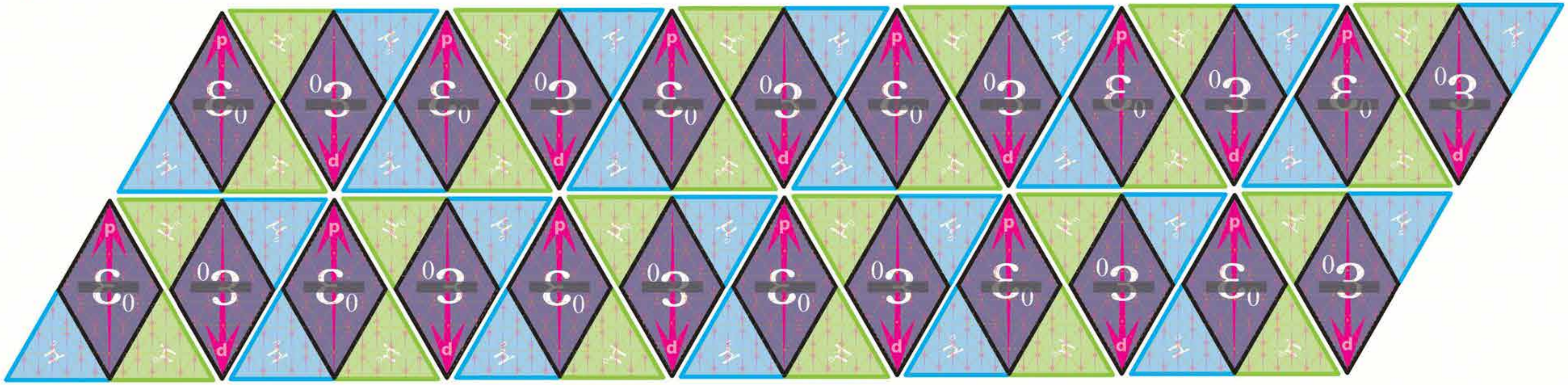

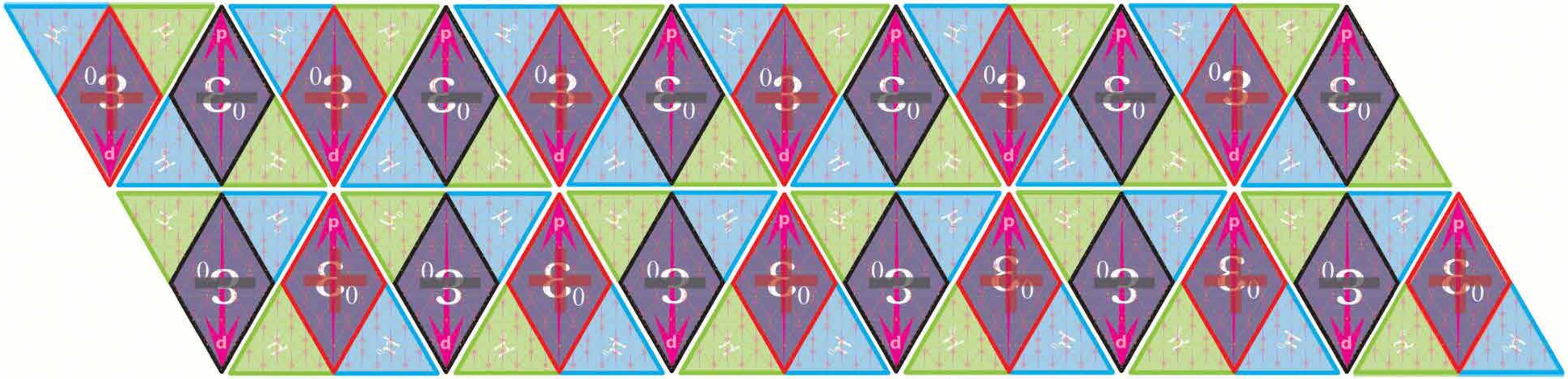

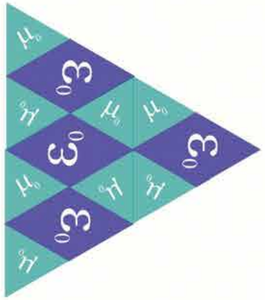

2D radiant EM mass-Energies

n7 - Neutral Tetryon Templates

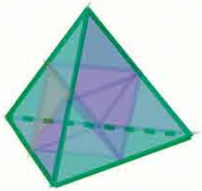

3D standing-wave Matter

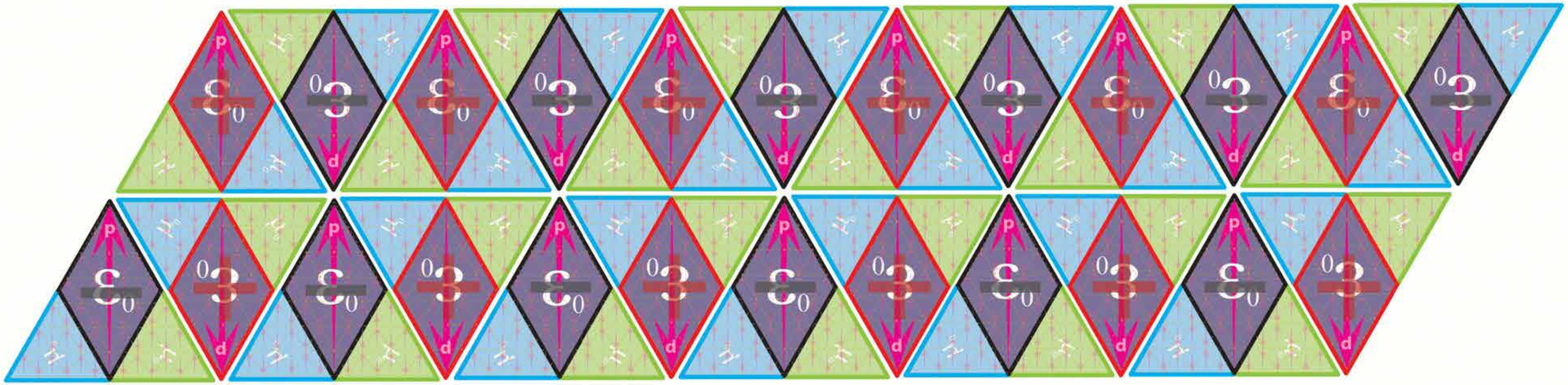

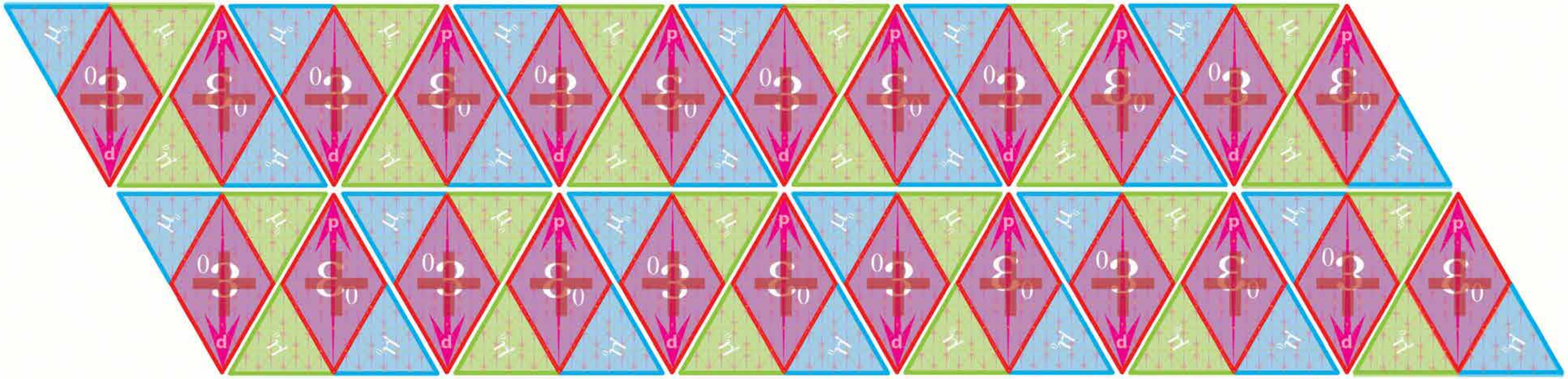
p
d
μ_0
ε_0

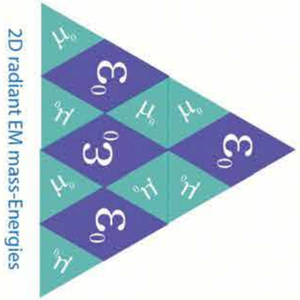
2D radiant EM mass-Energies
μ_0
ε_0

n8 - Charged Tetryon Templates

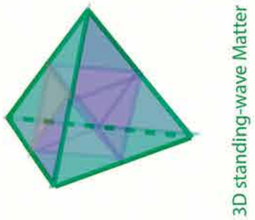
3D standing-wave Matter

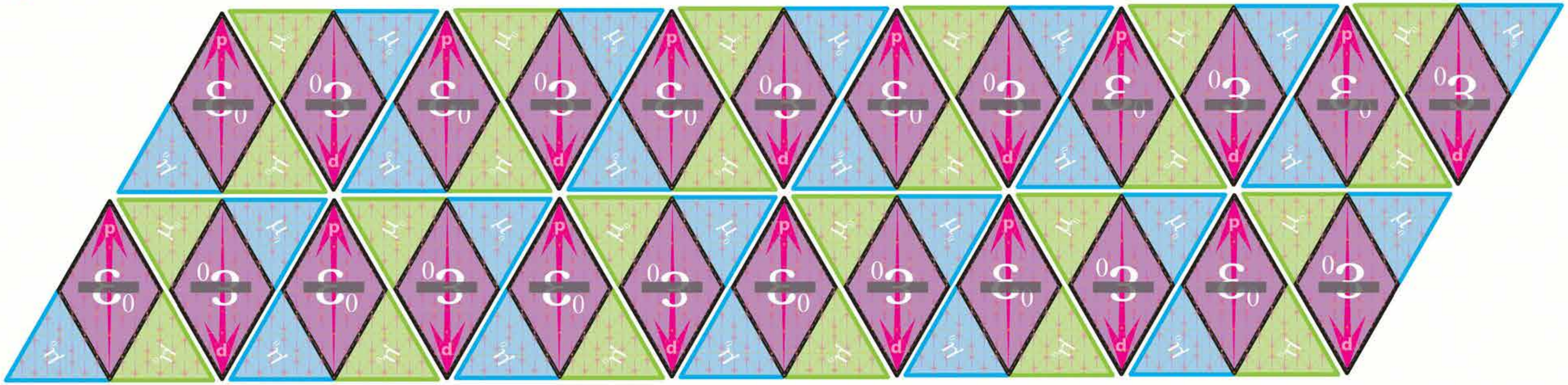
p
d
μ_0
ε_0

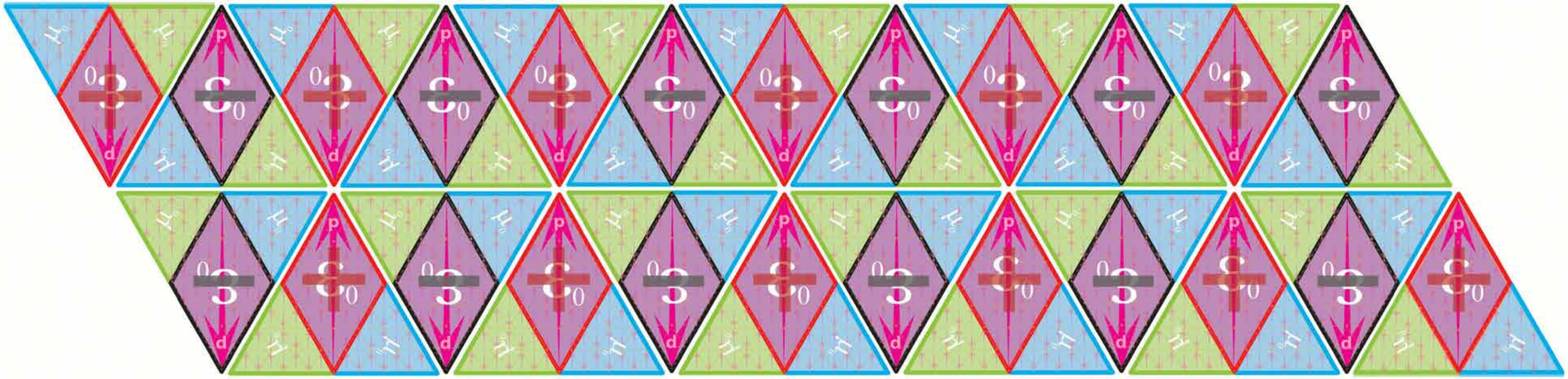
p
d
ε_0
μ_0

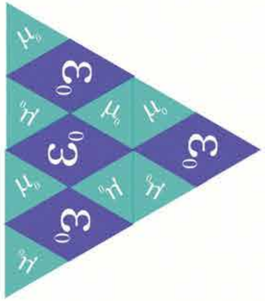
ε_0
μ_0

2D radiant EM mass-Energies

n8 - Neutral Tetryon Templates

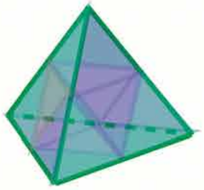

3D standing-wave Matter

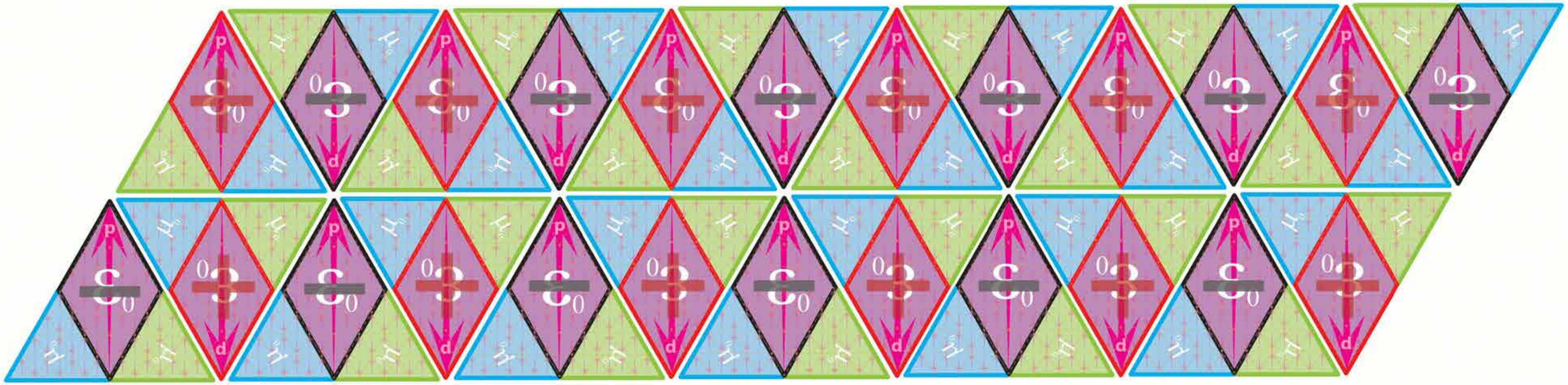
p
d
ε_0
μ_0

Periodic element geometries

An electron shell may be thought of as an orbit followed by electrons around an atom's nucleus. The closest shell to the nucleus is called the "1 shell" (also called "K shell"), followed by the "2 shell" (or "L shell"), then the "3 shell" (or "M shell"), and so on further and further from the nucleus. The shell letters K, L, M, ... are alphabetical

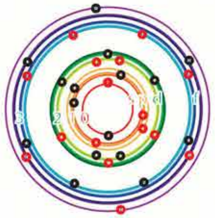

Each shell consists of one or more subshells, and each subshell consists of one or more atomic orbitals.

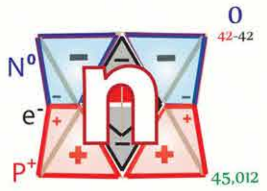
0
42-42
N⁰
n
e⁻
P⁺
45,012

Each shell can contain only an integer number of whole deuterium nuclei [Proton, Neutron & electron]

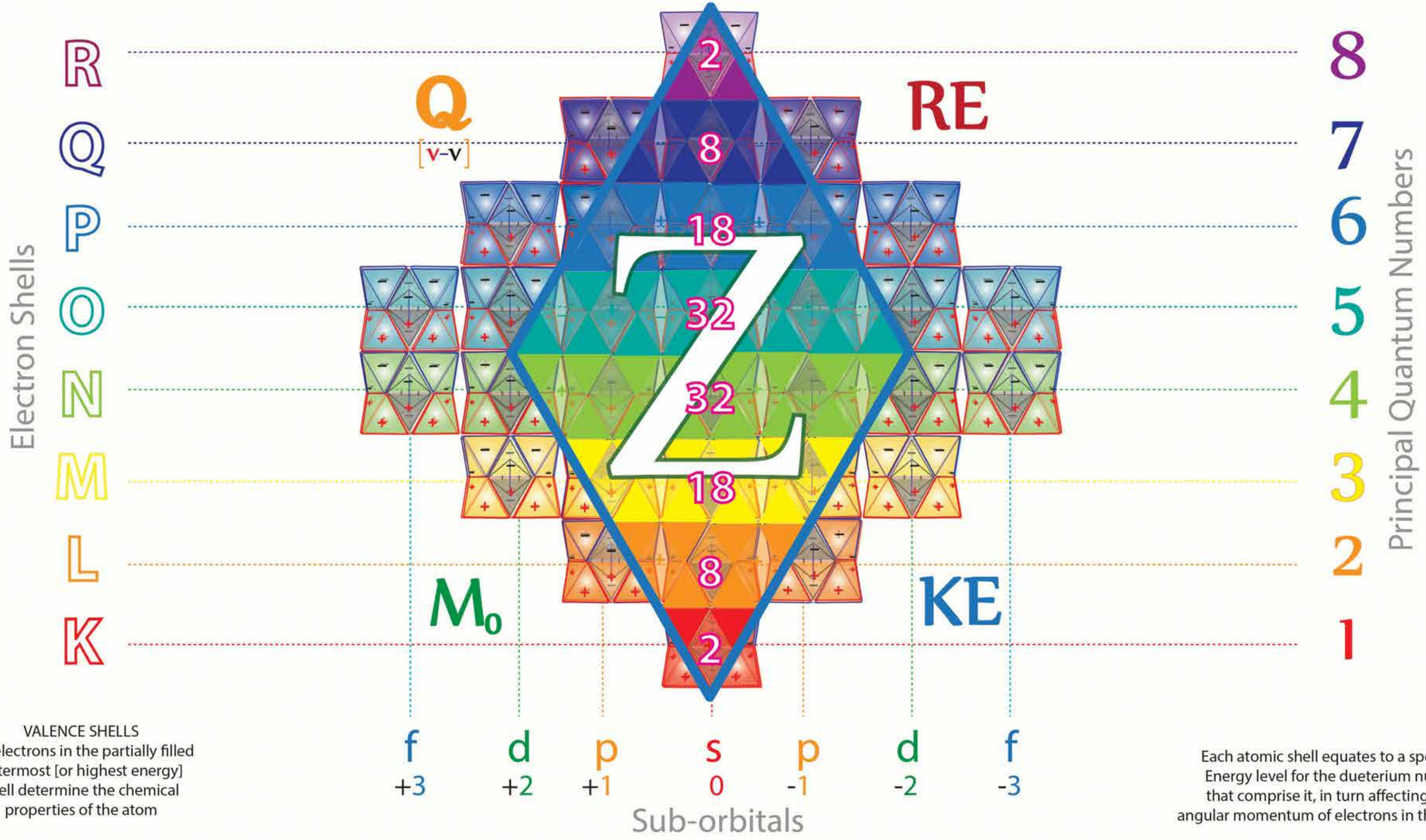
Electron Shells
R
Q
P
O
N
M
L
K
Q
[v-v]
RE
Z
2
8
18
32
32
18
8
2
M0
KE
8
7
6
5
4
3
2
1
Principal Quantum Numbers
f
+3
d
+2
p
+1
s
0
p
-1
d
-2
f
-3
Sub-orbitals

VALENCE SHELLS
The electrons in the partially filled outermost [or highest energy] shell determine the chemical properties of the atom

Each atomic shell equates to a specific Energy level for the dueterium nuclei that comprise it, in turn affecting the angular momentum of electrons in that shell

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Periodic Harmonic motions

$$x = A\cos(\omega t + \varphi)$$

Circular motion

Much of the math in of modern physics
is predicated on the assumption that
π [where it appears] is related to
the properties of a circle

$$F = -kx$$

Linear motion

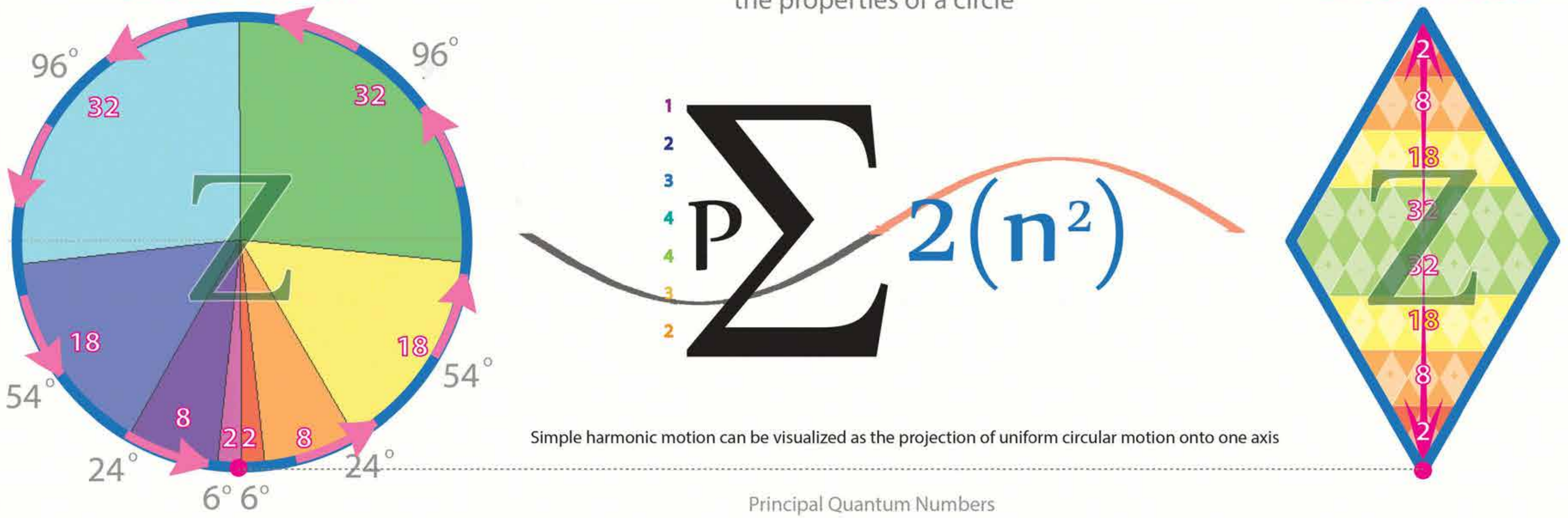
96°
32
96°
32
Z
18
18
54°
54°
8
2 2
8
24°
24°
6° 6°
1
2
3
4
4
3
2
2
8
18
32
32
18
8
2
Z

$$P\sum 2(n^2)$$

Simple harmonic motion can be visualized as the projection of uniform circular motion onto one axis

circular harmonic motion

**Circular motions describe
the motion of a body
with a changing velocity vector
[the result of an acceleration force].**

Principal Quantum Numbers

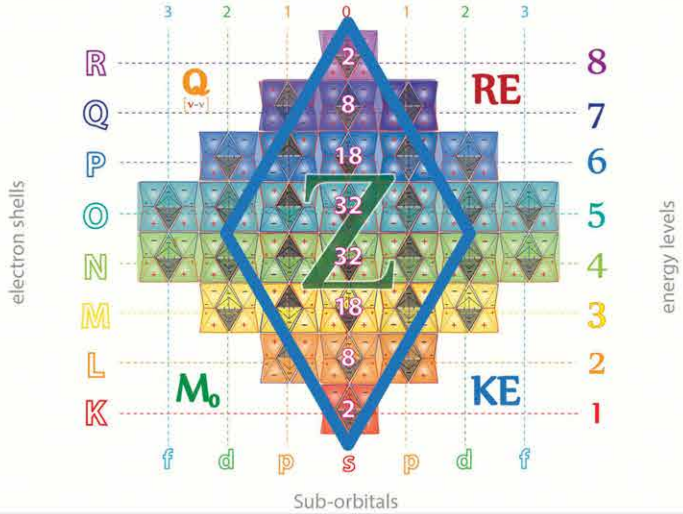
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
Q
[v-v]
RE
2
8
18
32
32
18
8
2
Z
M_0
KE
8
7
6
5
4
3
2
1
electron shells
energy levels
f d p s p d f
Sub-orbitals

simple harmonic motion

**Nuclei per shell in elements follows
a 'periodic summation rule'
that is reflective of
photonic energies**

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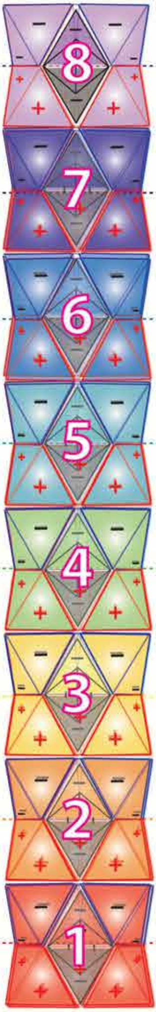

Baryon mass-energies n		E *The quantum level mass-energies of Baryons determines the kinetic energies of electrons* 1n - 1 e19v		electron KEM field hv²
73,728	n32	8	v8	3.268969693 e15
69,192	n31	7	v7	2.502804921 e15
64,800	n30	6	v6	1.838795452 e15
60,552	n29	5	v5	1.276941286 e15
56,448	n28	4	v4	8.172424232 e14
52,488	n27	3	v3	4.596988631 e14
48,672	n26	2	v2	2.043106058 e14
45,000	n25	1	v1	5.107765145 e13
Compton frequencies 930 MeV		1.2 e20 electron rest Matter is velocity invariant 496 keV		**spectral frequencies** 13.6 eV

Atomic nuclei mass-energies

Each element's weight [mass-Matter in a gravitational field] is the result of the total quanta comprising that element

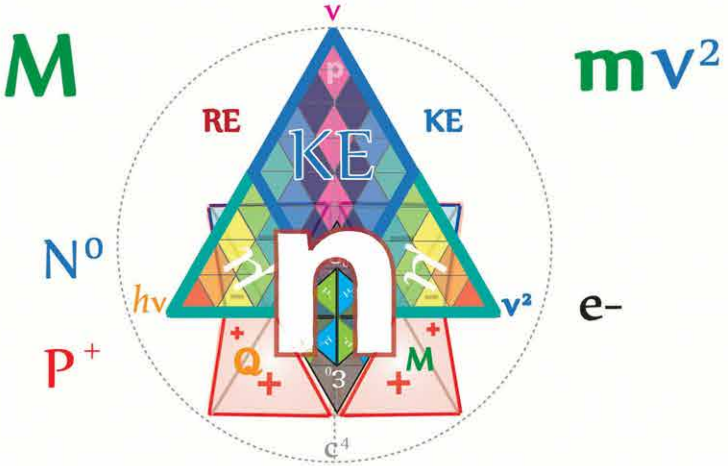

The nuclei forming each atomic shell have specific mass-energy quanta

Baryon rest masses lepton rest mass KEM

$$\overset{8}{\underset{1}{n}}\left[[72(n)^{2}]+[12e19]+[m_{e}v^{2}]\right]$$

Deuterium mass-energy per shell

Despite having differing mass-energies each Deuterium nuclei has the same velocity invariant Matter geometry [84π]

spin orbital coupling in synchronous quantum convertors

Electrons act as quantum scale rotating armatures in atomic nuclei and can only have specific energies reflective of the electron orbital energy level of the Baryons in which they are found

They acheive these energy levels by absorbing or emitting photons to acheive the specific angular momentum required

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Baryons

930.947 MeV +

KEM fields

13.525 ev +

electrons

496.519 keV

Mapping Planck mass-energy contributions to elementary Matter and isotopes

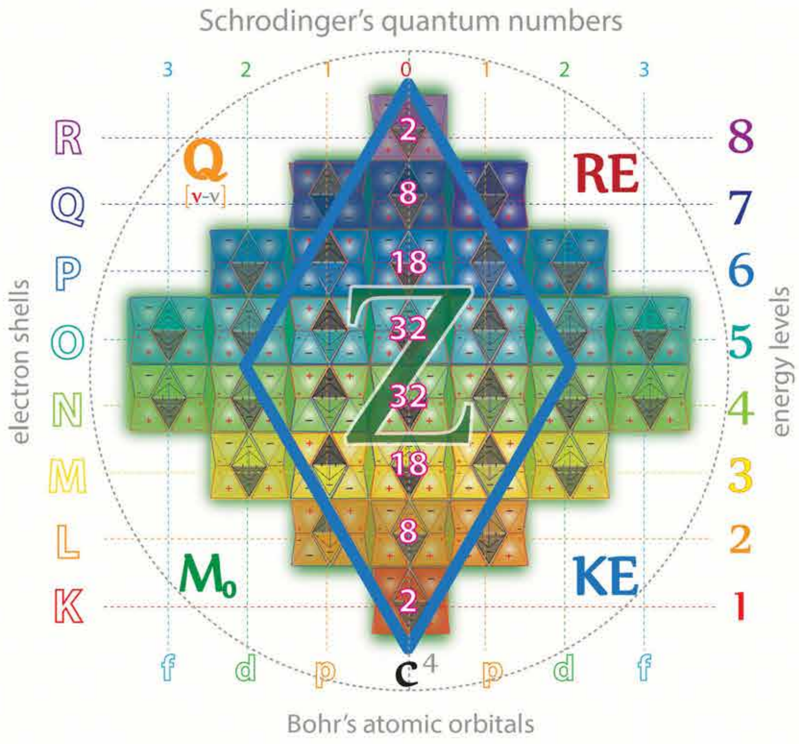
Schrodinger's quantum numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
[v-v]
RE
2
8
18
Z
32
32
18
8
2
M₀
KE
8
7
6
5
4
3
2
1
energy levels
f
d
p
c⁴
p
d
f
Bohr's atomic orbitals

$$E = hv^2$$

$$n^2 + v^2 + e = Z$$

general form quatratic equation

$$ax^2 + bx + c = Z$$

$$E = nhv$$

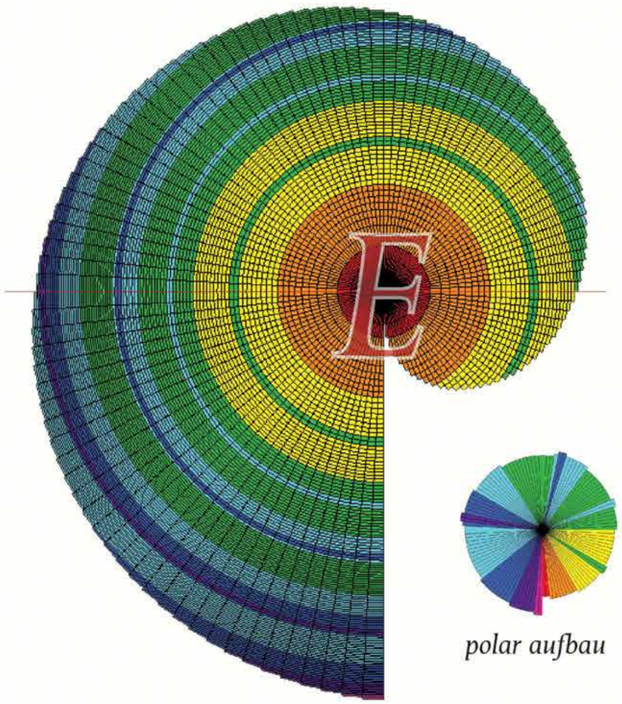
E
polar aufbau

polar energy spirals courtesy of Rene Cormier

Identifying electron rest Matter topologies as velocity invariant we can re-arrange the component Planck mass-energy geometry formulation of periodic elements to

$h[$ **72[v²]** Deuteron rest mass + **v** Spectral lines + **1.20 e20 v** electron rest mass $]$

reveal a quadratic formulation for all Z numbers

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$$\sum_{K}^{R}$$

nuclei per shell

STEP ONE

Periodic summation follows the atomic shell electron config

$${}^{P}\sum_{K}^{R} Z$$

Periodic Summation

Periodic summation is a notation developed for Tetryonic theory to model the geometric series addtion of Z[n²] energy level Deuterium nuclei that form the periodic elements

$$\sum_{1}^{120} Z$$

element number

STEP TWO

Periodic elements build up following the aufbau sequence

1 R
2
3
4
4
3
2
1 K

$${}^{P}\sum_{K}^{R} 2(x^2) =$$

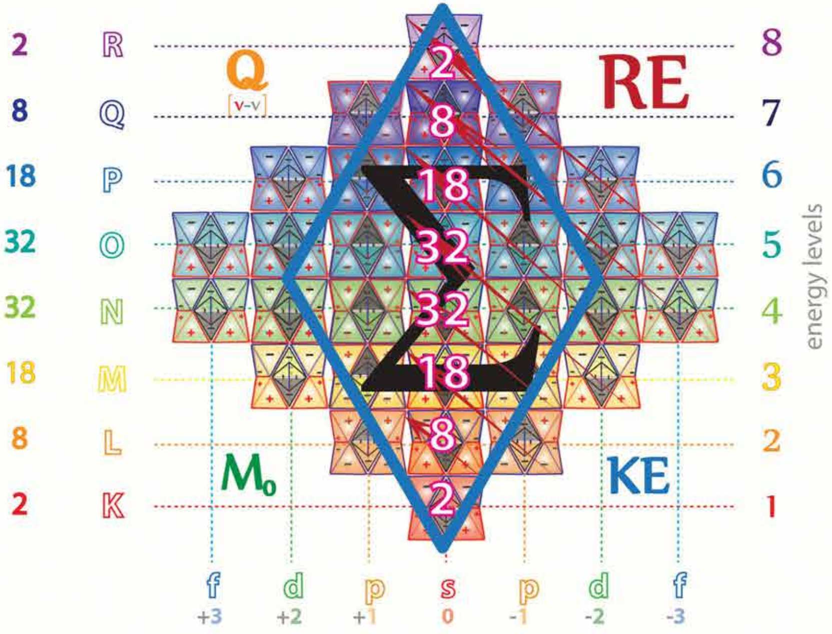

Each atomic shell can hold only a fixed number of deuterium nuclei

${}^{P}\sum R = 2$	2 nuclei [74.496 ea]	120	Unbinilium
	+		
${}^{P}\sum Q = 8$	8 nuclei [69,780 ea]	118	Ununoctium
	+		
${}^{P}\sum P = 18$	18 nuclei [65,232 ea]	110	Darmstadtium
	+		
${}^{P}\sum O = 32$	32 nuclei [60,852 ea]	92	Uranium
	+		
${}^{P}\sum N = 32$	32 nuclei [56,640 ea]	60	Neodymuim
	+		
${}^{P}\sum M = 18$	18 nuclei [52,596 ea]	28	Argon
	+		
${}^{P}\sum L = 8$	8 nuclei [48,720 ea]	10	Neon
	+		
${}^{P}\sum K = 2$	2 nuclei [45,012 ea]	2	Helium
		0	Hydrogen

THe LHS of the notation determine the number of nuclei in each atomic shell, from the periodic mass-energy levels for atoms, and the RHS follows the aufbau building principle to determine the rest mass-Matter of any specific element

Aufbau

Each periodic element is made of Z [n² energy] deuterium nuclei

$$Z\#\left[\begin{array}{ll} z\ \text{Protons} & [24\text{-}12] \\ z\ \text{Neutrons} & [18\text{-}18] \\ z\ \text{electrons} & [0\text{-}12] \end{array}\right] n1\text{-}8$$

Planck mass-energies form the surface integral of rest Matter topologies for each periodic element

Proton - Neutron Curve

The graph below is a plot of neutron number against proton number.
It is used as rule to determine which nuclei are stable or unstable.

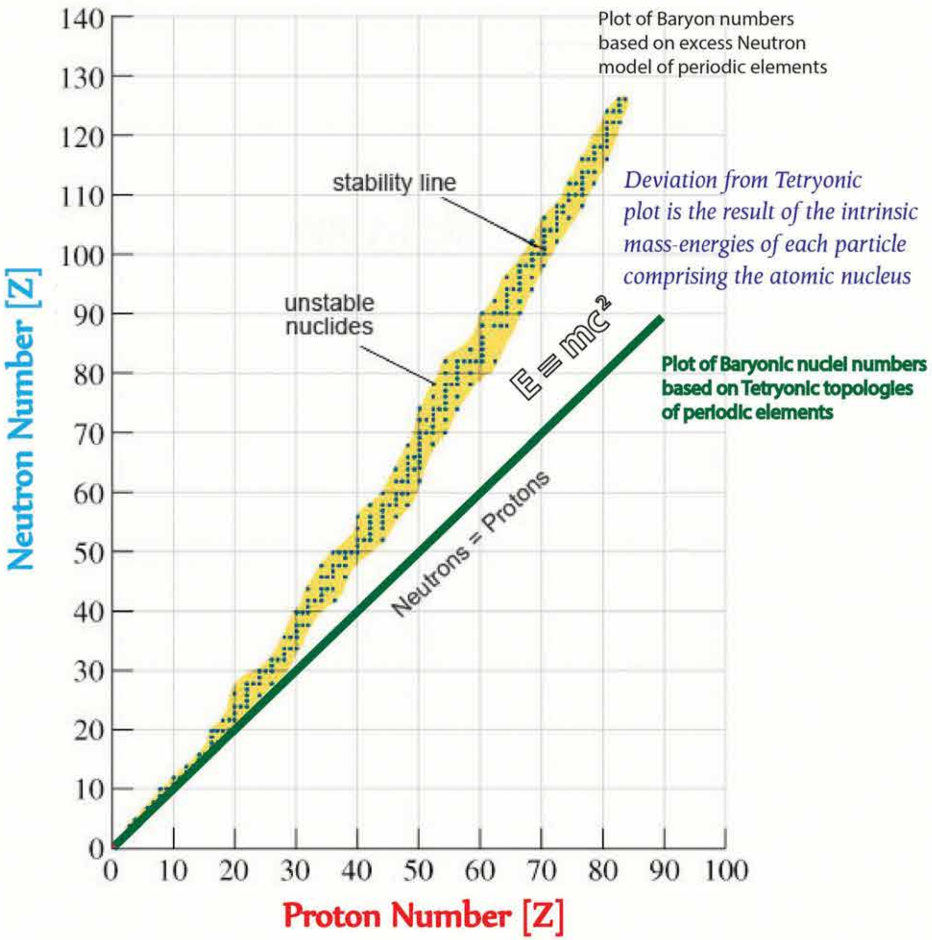

Plot of Baryon numbers based on excess Neutron model of periodic elements

Deviation from Tetryonic plot is the result of the intrinsic mass-energies of each particle comprising the atomic nucleus

Plot of Baryonic nuclei numbers based on Tetryonic topologies of periodic elements

Historically, Proton-electron numbers are viewed as being equivalent in neutral elementary matter with the excess molar mass measured being the result of 'excess or extra' Neutrons in the atom

Atomic Nuclei Numbers

All periodic elements have an EQUAL number of Protons, Neutrons & Electrons with their molar mass-Matter being determined by their quantum level mass-energies

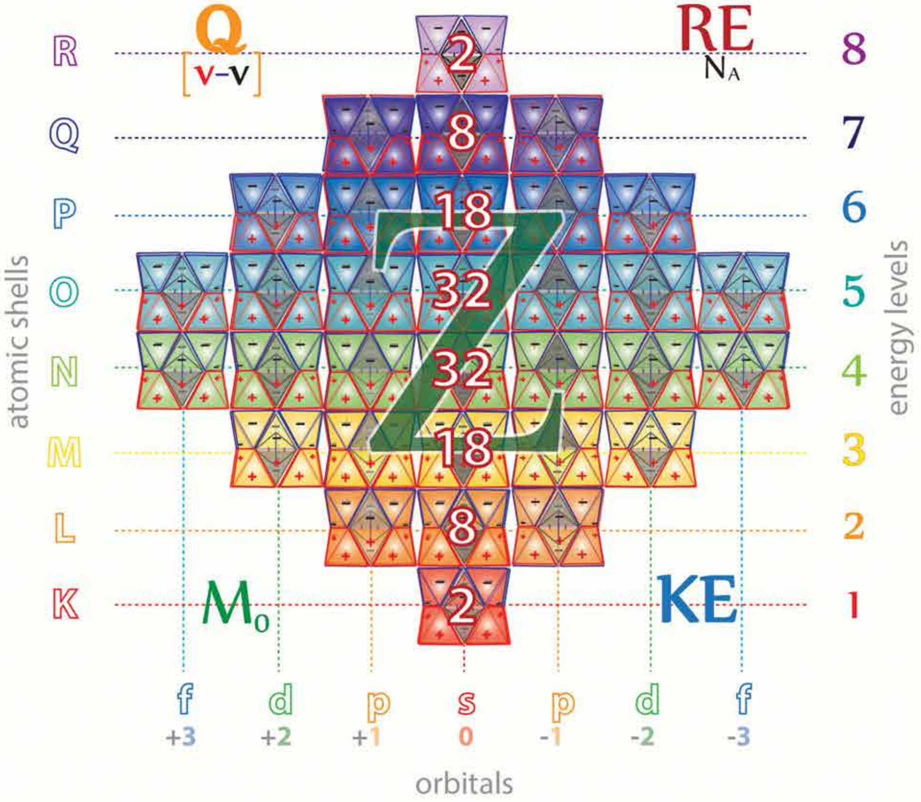

Tetryonic modelling of the charged mass-ENERGY-Matter topologies of elementary atoms and the nuclei that comprise them, reveals a DIRECT LINEAR relationship for the number of Protons-electrons-Neutrons in all periodic elements and nuclear isotopes

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Planck mass-energy contributions to elementary Matter and isotopes

The mass-energy content of Deuterium nuclei creates the molar mass of elements
[not extra neutrons in excess of the elemental number]

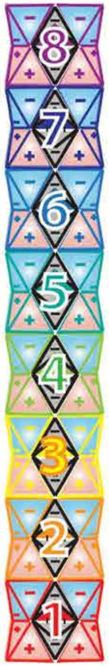

Deuteron	electron eV	KEM	Z
32 3,050.6 MeV	8	En = -13.52 eV	291,166
31 2,5862.9 MeV	7	En = -10.35 eV	285,065
30 2,6811 MeV	6	En = -7.60 eV	262,158
29 2,505.4 MeV	5	En = -5.28 eV	213,887
28 2,335.6 MeV	4	En = -3.38 eV	133,697
27 2,171.8 MeV	3	En = -1.90 eV	58,940
26 2,013.9 MeV	2	En = -0.84 eV	19,840
25 1,861.9 MeV	1	En = -0.21 eV	3,725
n	496.519 keV Quantum levels	v²	

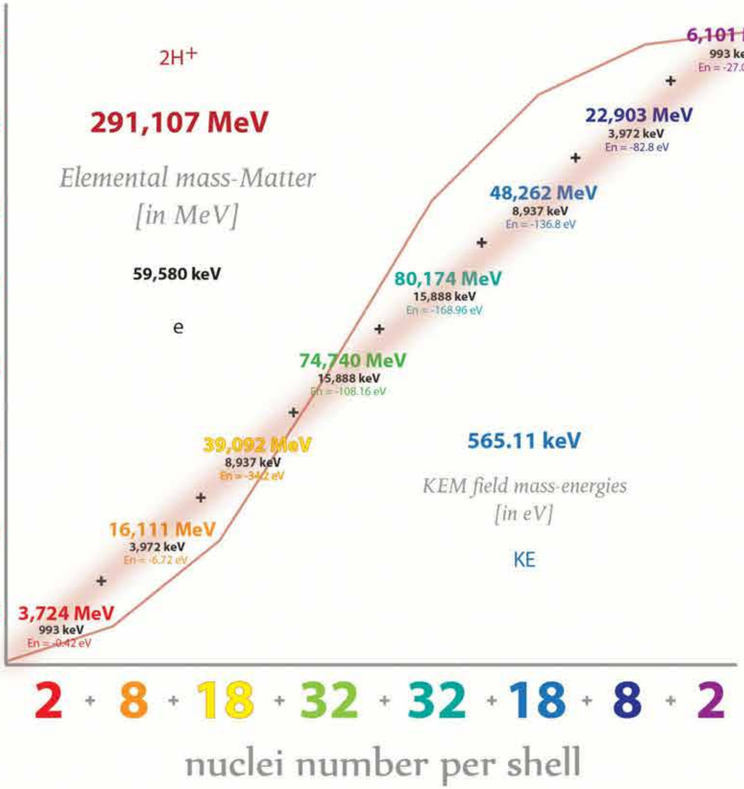

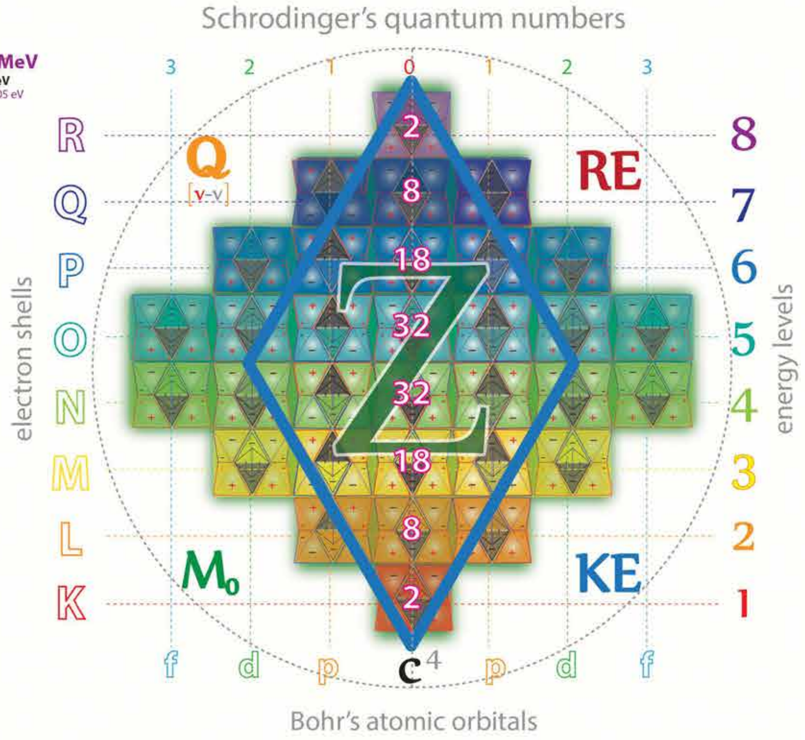
Schrodinger's quantum numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
[v-v]
RE
2
8
18
32
32
18
8
2
Z
M0
KE
8
7
6
5
4
3
2
1
energy levels
f
d
p
c4
p
d
f
Bohr's atomic orbitals

n1
Elementary nuclei

are comprised of equal numbers of
Protons, Neutrons & electrons
with varying energy levels

Baryons		electrons		KEM fields
930.947 MeV	+	496.519 keV	+	13.525 ev

The mass-energy content of Matter topologies is velocity invariant

The mass-energy content of Baryons determines the KEM field of electrons

All elements are comprised of n level Duetrium nuclei

Baryons **KEM fields** **electrons**

$$Z\,[[72n^2] + [12v^2] + [1.2e20]]$$

1,861,949 MeV **13.525 eV** **496,519 keV**

The atomic shell energy levels of Deuterium nuclei in elements

Deuteron **electron eV** **KEM**

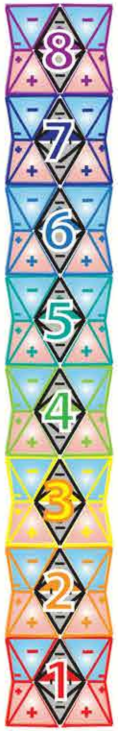

Deuteron		KEM
32	3,050.6 MeV	En = -13.52 eV
31	2,5862.9 MeV	En = -10.35 eV
30	2,6811 MeV	En = -7.60 eV
29	2,505.4 MeV	En = -5.28 eV
28	2,335.6 MeV	En = -3.38 eV
27	2,171.8 MeV	En = -1.90 eV
26	2,013.9 MeV	En = -0.84 eV
25	1,861.9 MeV	En = -0.21 eV

496.519 keV

n v^2

Determines the spectral line [KEM field energies] of electrons bound to them

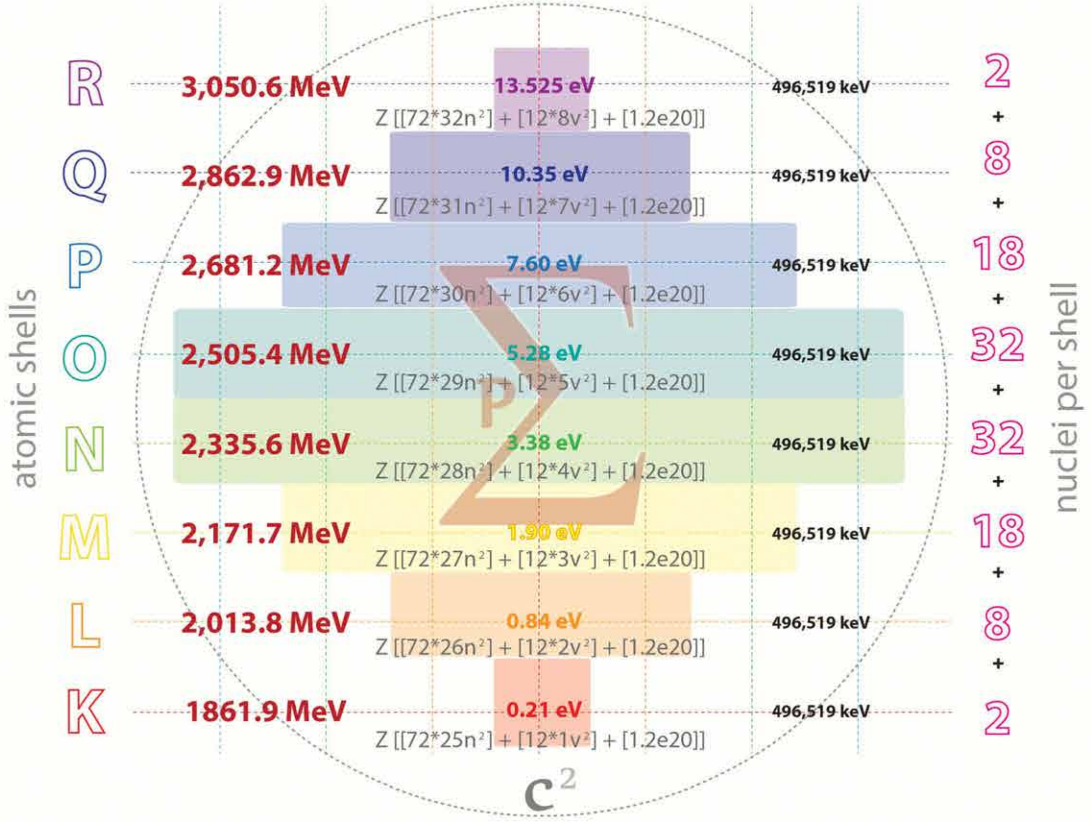

atomic shells					nuclei per shell
R	3,050.6 MeV	13.525 eV	$Z\,[[72*32n^2] + [12*8v^2] + [1.2e20]]$	496,519 keV	2
					+
Q	2,862.9 MeV	10.35 eV	$Z\,[[72*31n^2] + [12*7v^2] + [1.2e20]]$	496,519 keV	8
					+
P	2,681.2 MeV	7.60 eV	$Z\,[[72*30n^2] + [12*6v^2] + [1.2e20]]$	496,519 keV	18
					+
O	2,505.4 MeV	5.28 eV	$Z\,[[72*29n^2] + [12*5v^2] + [1.2e20]]$	496,519 keV	32
					+
N	2,335.6 MeV	3.38 eV	$Z\,[[72*28n^2] + [12*4v^2] + [1.2e20]]$	496,519 keV	32
					+
M	2,171.7 MeV	1.90 eV	$Z\,[[72*27n^2] + [12*3v^2] + [1.2e20]]$	496,519 keV	18
					+
L	2,013.8 MeV	0.84 eV	$Z\,[[72*26n^2] + [12*2v^2] + [1.2e20]]$	496,519 keV	8
					+
K	1861.9 MeV	0.21 eV	$Z\,[[72*25n^2] + [12*1v^2] + [1.2e20]]$	496,519 keV	2

$2H^+$ **Z** γ

$[72n^2]$ $[M_e v^2]$

Elemental mass-Matter [in MeV]

6,101 MeV
993 keV
En = -27.05 eV
+
22,903 MeV
3,972 keV
En = -82.8 eV
+
48,262 MeV
8,937 keV
En = -316.8 eV
+
80,174 MeV
15,888 keV
En = -168.96 eV
+
74,740 MeV
15,888 keV
En = -108.16 eV
+
39,092 MeV
8,937 keV
En = -34.2 eV
+
16,111 MeV
3,972 keV
En = -6.72 eV
+
3,724 MeV
993 keV
En = -0.42 eV

[1.2e20]]

e

the rest mass-Matter of bound photo-electrons is velocity invariant

The relativistic rest mass-energy-Matter of all periodic elements

is the sum of the mass-energies of all atomic nuclei and spectral lines that comprise its mass-Matter topology as measured in any spatial co-ordinate system per unit of time

Ionisation energies

Fractional quantum differentials

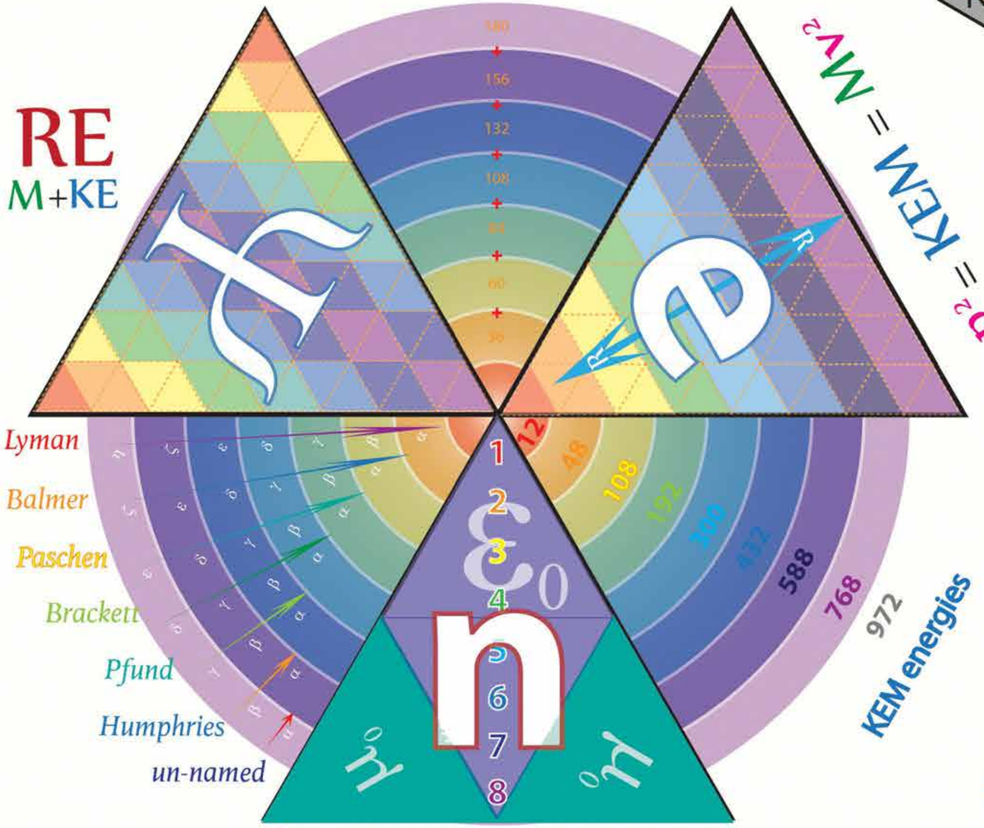
RE
M+KE
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
p² = KEM = Mv²
KEM energies
12
48
108
192
300
432
588
768
972
ε0
n
1
2
3
4
5
6
7
8
R

$$hf = \Delta Mv = \Delta p$$

spectral lines are produced by accelerating electrons

c^2 Note: this is an Illustrative schema for modelling KEM field energies
All KEM fields possess the same physical spatial geometry
in radial-time defined spatial co-ordinate systems c^4

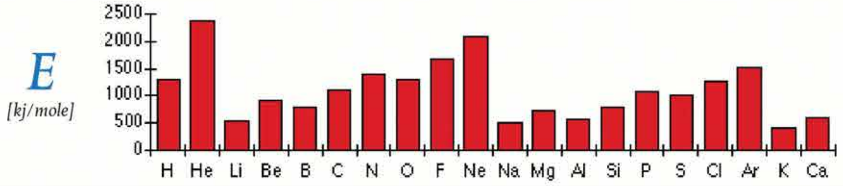

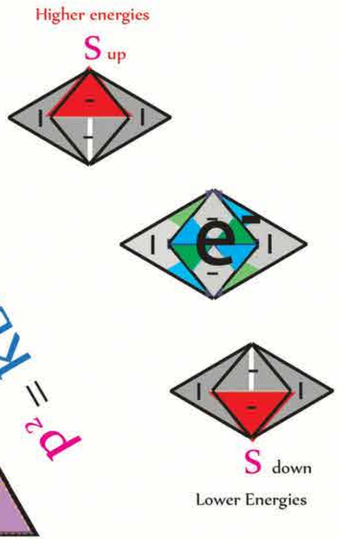
Higher energies
S up
e⁻
S down
Lower Energies

Photo-electrons absorb/emit spectral energies

$$E = eV = \frac{1}{4\pi\epsilon_0}\frac{ne^2}{a}$$

photo-electronic energy momenta

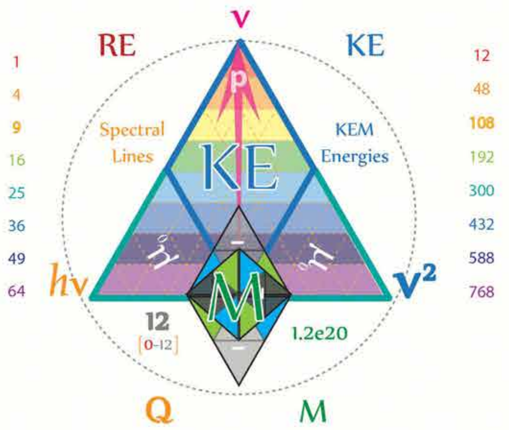
RE
KE
v
p
Spectral Lines
KEM Energies
KE
hv
v²
M
12
[0-12]
1.2e20
Q
M
1
4
9
16
25
36
49
64
12
48
108
192
300
432
588
768

Mapping photo-electron transition energies to Tetryonic energy momenta geometries reveals many key facts about the ionisation energies of nuclei

$$E = -\frac{Z^2}{n^2}\frac{ke^2}{2a_0} = -\frac{13.6Z^2}{n^2}eV$$

The differing fractional KEM field energy momenta of electrons that results from their transitions to specific energy nuclei in elements results in differing QAM quanta and produces spectral lines and fine line splitting

Spectral line transitions

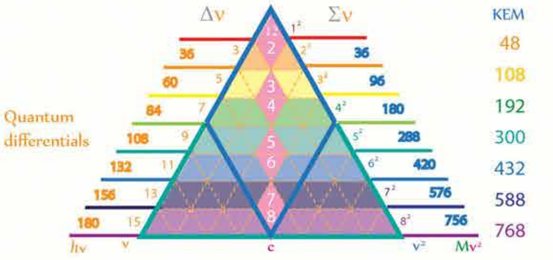
Δv
Σv
Quantum differentials
KEM
48
108
192
300
432
588
768
36
60
84
108
132
156
180
36
96
180
288
420
576
756
hv
v
c
v²
Mv²

hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

uniting classical physics and relativity
through equilateral geometry

Element numbers

Nuclei per shell in elements follow
a 'periodic summation rule'
that is reflective of
photonic energies

$$\begin{matrix}1\ \mathbb{R}\\2\\3\\4\\4\\3\\2\\1\ \mathbb{K}\end{matrix}\ {}^{P}\sum 2\left(x^{2}\right) = \begin{matrix}2\\+\\8\\+\\18\\+\\32\\+\\32\\+\\18\\+\\8\\+\\2\end{matrix}$$

Z

120 Unbinilium 119 Ununennium	n8
118 Ununoctium 87 Francium	n7
112 Copernicium 55 Caesium	n6
102 Nobelium 37 Rubidium	n5
70 Ytterbuim 19 Potassium	n4
30 Zinc 11 Sodium	n3
10 Neon 3 Lithium	n2
2 Helium 1 Deuterium	n1
Hydrogen 0	

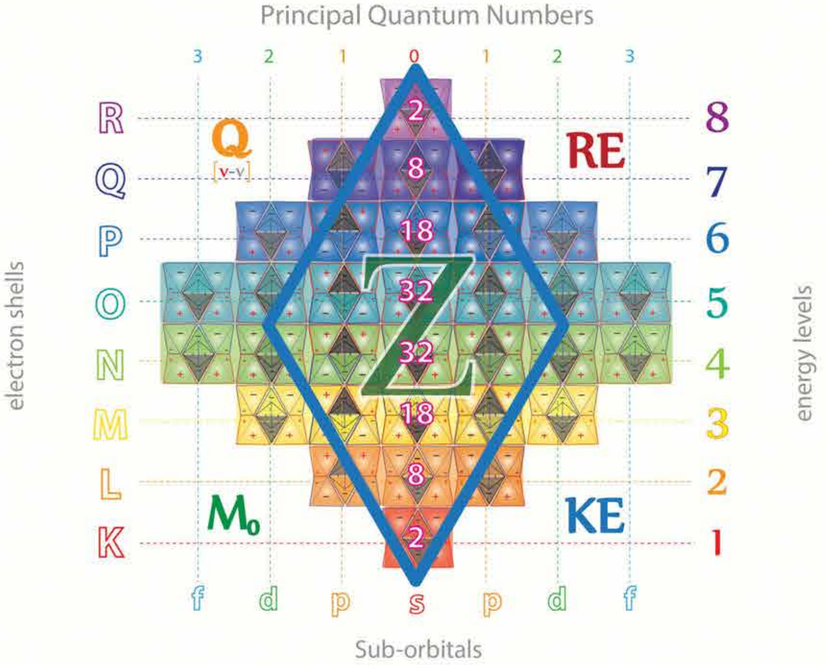

Periodic mass-ENERGY-Matter

Following periodic summation rules for shell filling
n[1-8] quantum energy deuterium nuclei
combine to form elementary Matter

$$ {}^{\mathbb{R}}_{\mathbb{K}}\,{}^{P}\sum_{25}^{32}\Bigg[\underbrace{\overset{\text{Baryon rest masses}}{\left[72(n)^{2}\right]}+\overset{\text{lepton rest mass}}{\left[12e19\right]}+\overset{\text{KEM}}{\left[m_{e}v^{2}\right]}}_{\text{Deuterium mass-energy per shell}}\Bigg]_{1}^{8} $$

The measured weight of Matter in gravitational fields is the result of
planar mass-energies in tetryonic standing-wave geometries

The periodicity of all the elements,
along with their exact molar rest mass-energies and
quantum wavefunctions can be described with Tetryonic geometries

Ionisation energies

γ

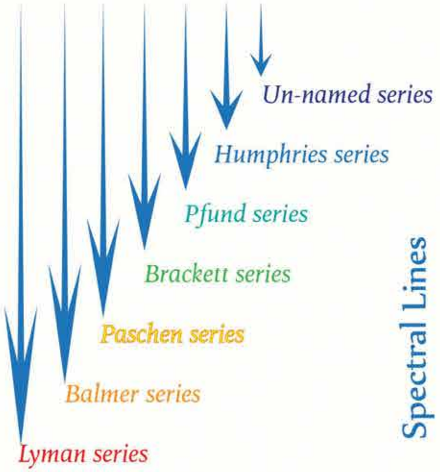

Un-named series
Humphries series
Pfund series
Brackett series
Paschen series
Balmer series
Lyman series

Spectral Lines

$$\boxed{Mv^{2} = \text{KEM} = hcR_{H}}$$

Photon emission/absorption

Spectral line differentials

$$\Delta hv = \Delta Mv = \Delta p$$

changes to energy momenta

accelerate photo-electrons

$$\frac{1}{\lambda} = \frac{R_H}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Ryberg's formula is
a mathematical description
of Tetryonic energy geometry

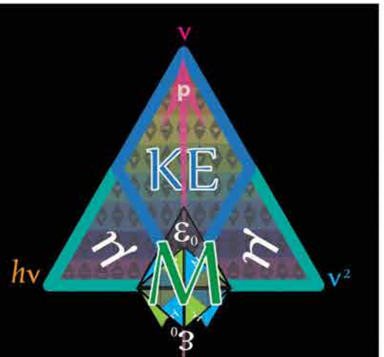
v
p
KE
ε0
M
hv
v²
3

& produces spectral lines

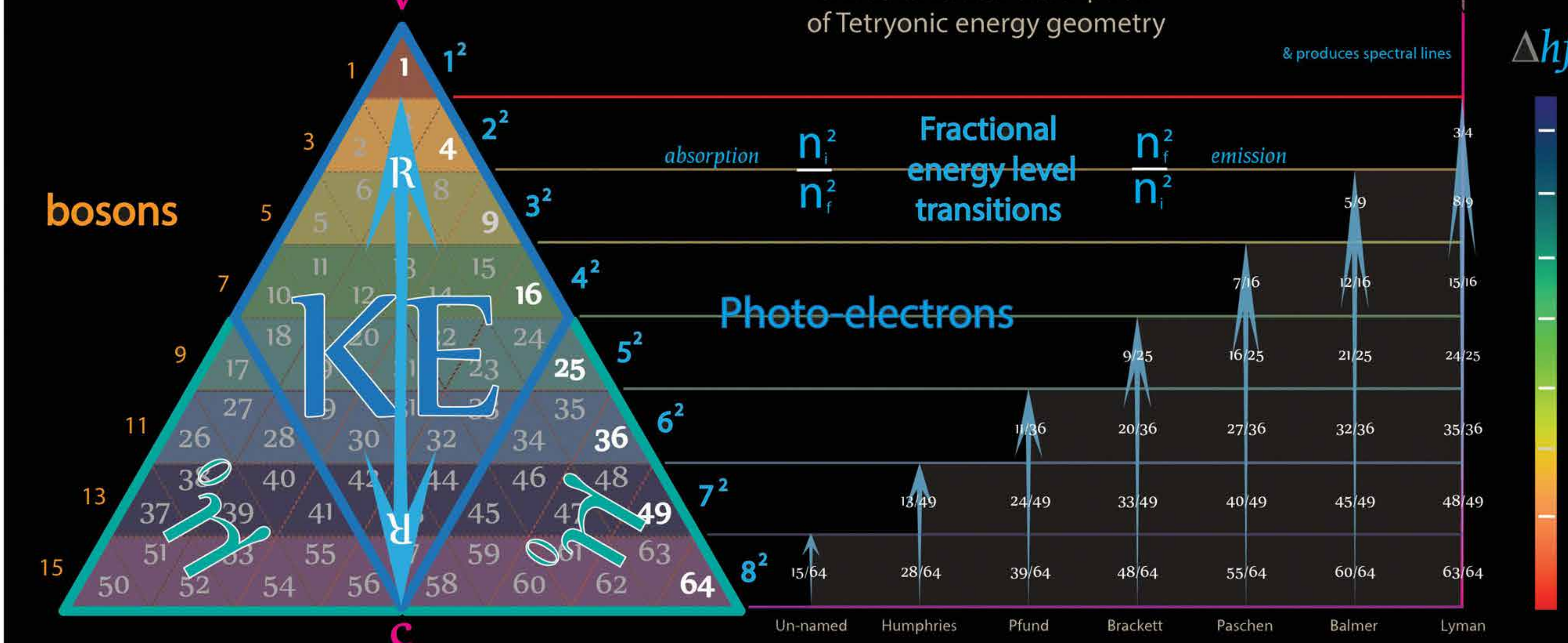
v
c
bosons
KE
R
1
3
5
7
9
11
13
15
1²
2²
3²
4²
5²
6²
7²
8²
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
Δhf
3/4
5/9
8/9
7/16
12/16
15/16
9/25
16/25
21/25
24/25
11/36
20/36
27/36
32/36
35/36
13/49
24/49
33/49
40/49
45/49
48/49
15/64
28/64
39/64
48/64
55/64
60/64
63/64
Un-named
Humphries
Pfund
Brackett
Paschen
Balmer
Lyman

absorption $\frac{n_i^2}{n_f^2}$

Fractional energy level transitions

$\frac{n_f^2}{n_i^2}$ emission

Photo-electrons

Ryberg's constant reflects the changing
energy momentum of a transitioning electron

$$Mv^2 = KEM = hcR$$

*All of the transitions of photo-electrons
bound to Hydrogen atoms can now be
revealed in the fractional geometry
of KEM field energies*

KEM field energies

Fermat's method of Factoring

also known as 'the difference of two squares' is used to factorise large numbers

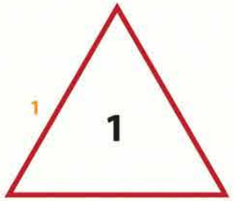

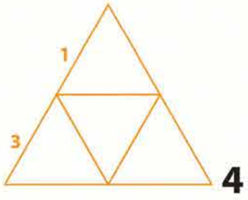

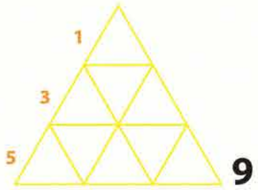

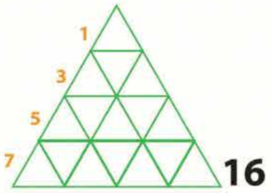

$[x-y].[x+y]$

$x^2 - y^2$

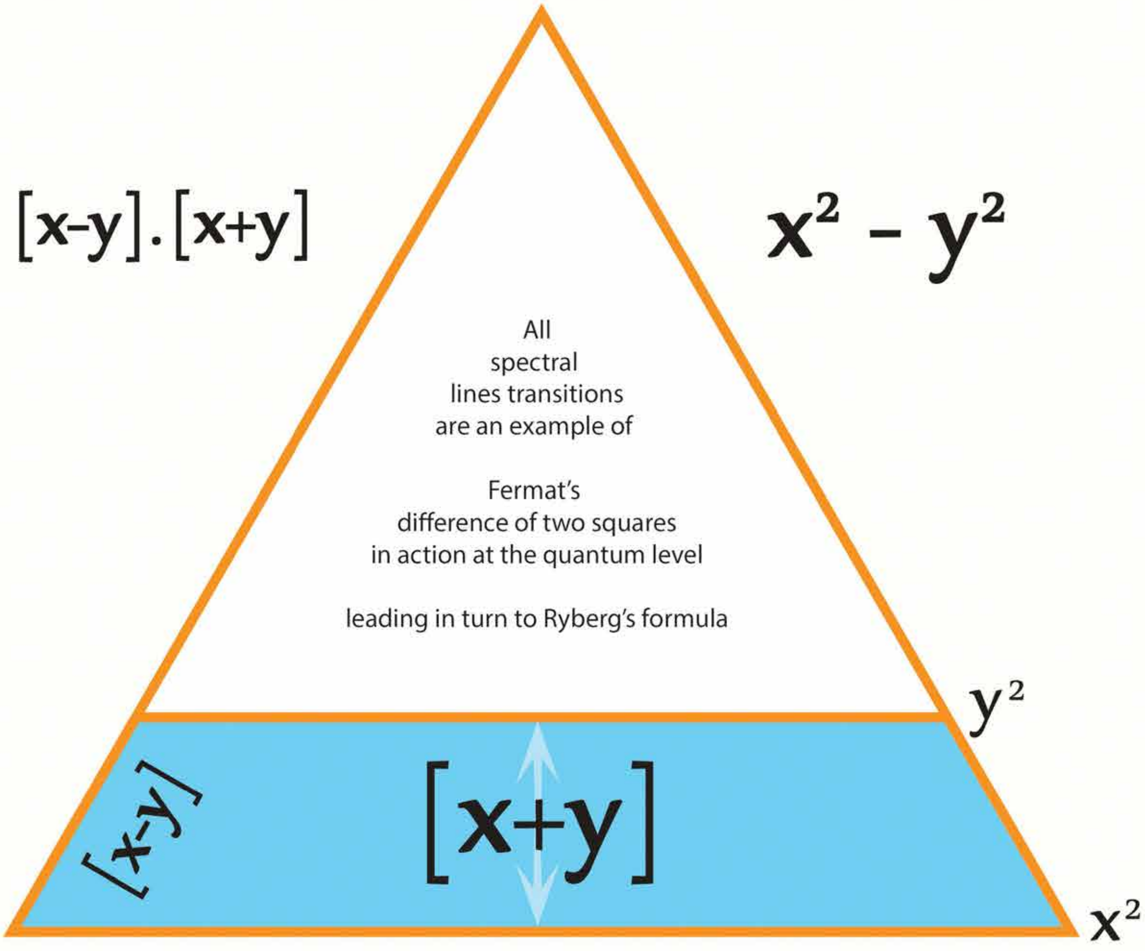

All
spectral
lines transitions
are an example of

Fermat's
difference of two squares
in action at the quantum level

leading in turn to Ryberg's formula

Fermat knew that every odd number could be written as the difference of two squares or as revealed geometrically through Tetryonic theory's equilateral geometry, every 'SQUARE' number is the sequential sum of ODD numbers

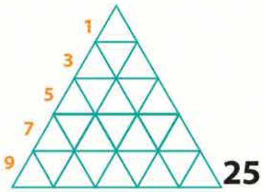

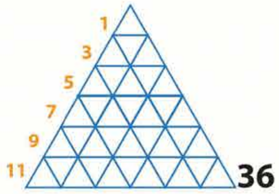

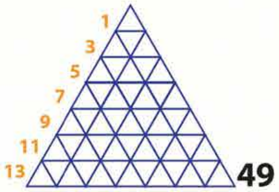
1
3
5
7
9
11
13
49

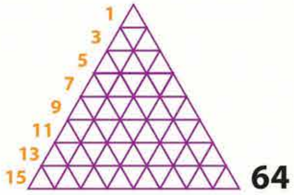
1
3
5
7
9
11
13
15
64

Fractions

A fraction is a number that shows how many equal parts there are

In quantum mechanics fractions appear in quantum steps
as a result of the equilateral geometry of Planck energy momenta

3/4

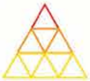

24/25

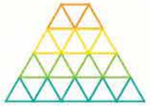

40/49

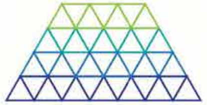

48/64

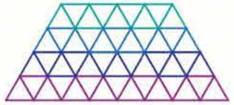

80/81

.987654321

$$\frac{1}{\lambda} = R\left(\frac{1}{1} - \frac{1}{81}\right)$$

.987654321

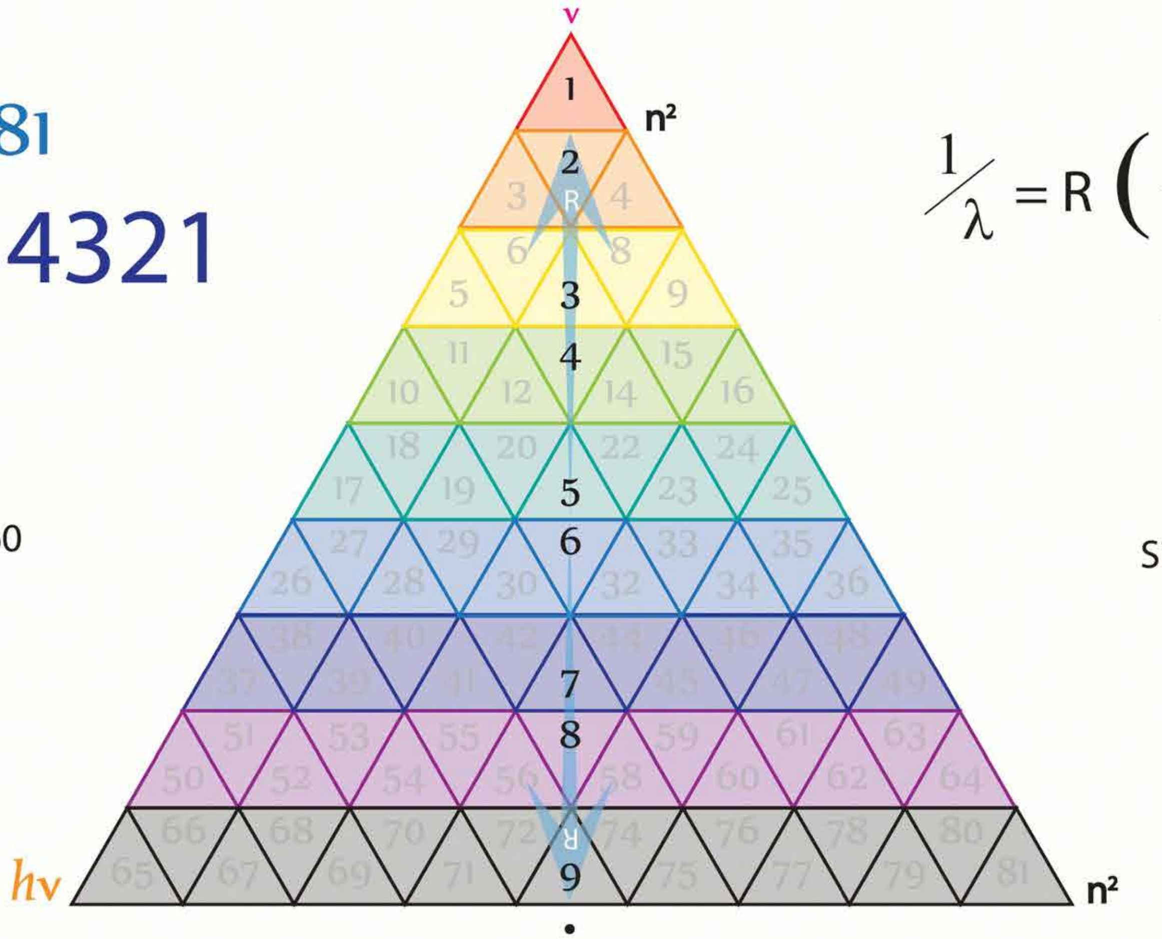
v
n²
1
2
R
3 4
6 8
5 3 9
11 4 15
10 12 14 16
18 20 22 24
17 19 5 23 25
6
27 29 33 35
26 28 30 32 34 36
38 40 42 44 46 48
37 39 41 7 45 47 49
8
51 53 55 59 61 63
50 52 54 56 58 60 62 64
66 68 70 72 74 76 78 80
R
65 67 69 71 9 75 77 79 81
hv
n²

Cos 60

.5

1/2

Sin 60

.866025403

$\sqrt{3}/2$

Tetryonic geometry explains the fractional mathematics of Rydberg's formula

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Lyman spectral transitions

Δhv = KEM = hcR

Planck 13.525 eV Rydberg

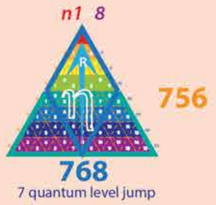

768

7 quantum level jump

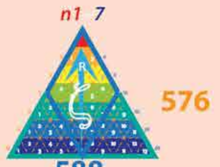

588

6 quantum level jump

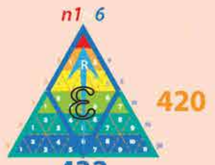

432

5 quantum level jump

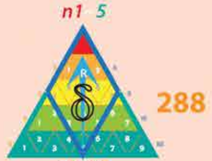

300

4 quantum level jump

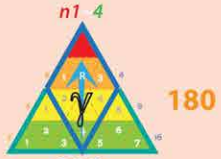

192

3 quantum level jump

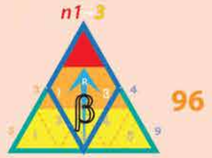

108

2 quantum level jump

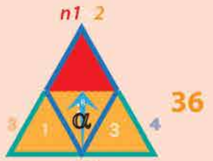

48

1 quantum level jump

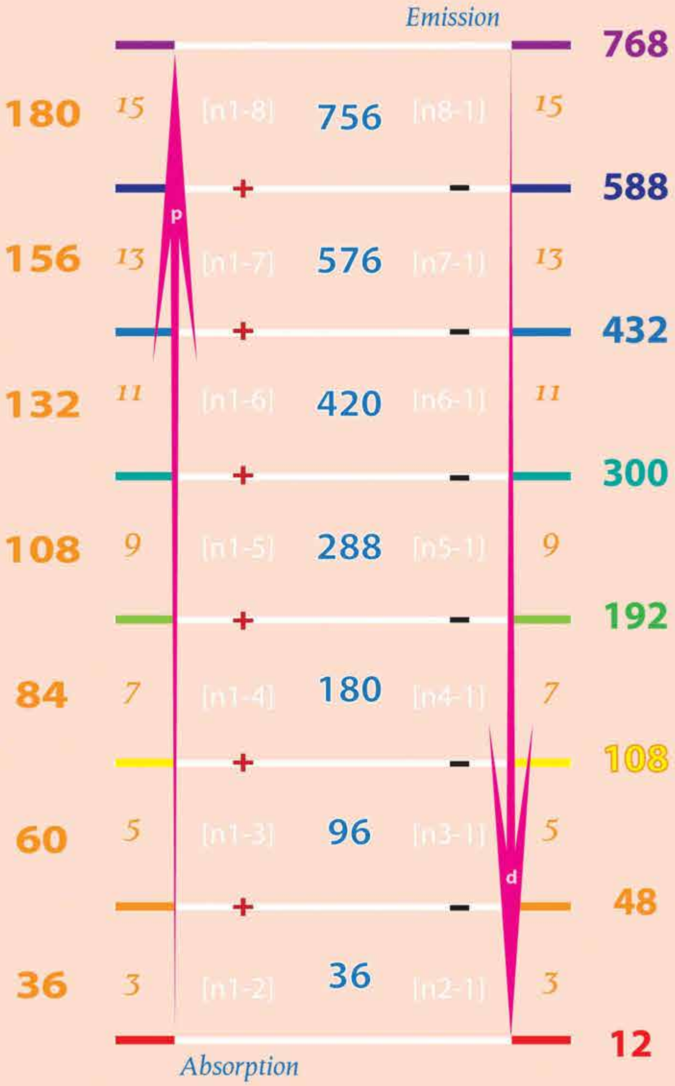
Emission
768
180
15
[n1-8]
756
[n8-1]
15
p
+
–
588
156
13
[n1-7]
576
[n7-1]
13
+
–
432
132
11
[n1-6]
420
[n6-1]
11
+
–
300
108
9
[n1-5]
288
[n5-1]
9
+
–
192
84
7
[n1-4]
180
[n4-1]
7
+
–
108
60
5
[n1-3]
96
[n3-1]
5
d
+
–
48
36
3
[n1-2]
36
[n2-1]
3
12
Absorption

63/64

.9843

λ	93.17075598	nm
$\tilde{v}$	10,732,981.5	m-1
f	3.217666905 x 10^{15}	Hz
E	13.31395504	eV
Ω	27.93188995	m^2/s

$R\left(\frac{1}{1}-\frac{1}{64}\right)$

.984375

48/49

.9795

λ	93.62569132	nm
$\tilde{v}$	10,680,829.01	m-1
f	3.202031983 x 10^{15}	Hz
E	13.24926138	eV
Ω	28.06827613	m^2/s

$R\left(\frac{1}{1}-\frac{1}{49}\right)$

.9795

35/36

.9722

λ	94.33539043	nm
$\tilde{v}$	10,600,475.55	m-1
f	3.177942622 x 10^{15}	Hz
E	13.14958523	eV
Ω	28.28103857	m^2/s

$R\left(\frac{1}{1}-\frac{1}{36}\right)$

.9722

24/25

.9600

λ	95.53641971	nm
$\tilde{v}$	10,467,212.43	m-1
f	3.137991343 x 10^{15}	Hz
E	12.98427616	eV
Ω	28.64109809	m^2/s

$R\left(\frac{1}{1}-\frac{1}{25}\right)$

.96

15/16

.9375

λ	97.82929378	nm
$\tilde{v}$	10,221,5587.14	m-1
f	3.064444671 x 10^{15}	Hz
E	12.67995718	eV
Ω	29.32848445	m^2/s

$R\left(\frac{1}{1}-\frac{1}{16}\right)$

.9375

8/9

.8888

λ	103.1793333	nm
$\tilde{v}$	9,691,863.362	m-1
f	2.90554754 x 10^{15}	Hz
E	12.02247792	eV
Ω	30.93238594	m^2/s

$R\left(\frac{1}{1}-\frac{1}{9}\right)$

.888

3/4

.7500

λ	122.2866172	nm
$\tilde{v}$	8,177,509.712	m-1
f	2.451555737 x 10^{15}	Hz
E	10.14396575	eV
Ω	36.66060556	m^2/s

$R\left(\frac{1}{1}-\frac{1}{4}\right)$

.75

ΔMv^2

Tetryonics 96.04 - Lyman transitions

Balmer spectral transitions

$$\Delta h\nu = \text{KEM} = hcR$$

Planck — 3.381 eV — Rydberg

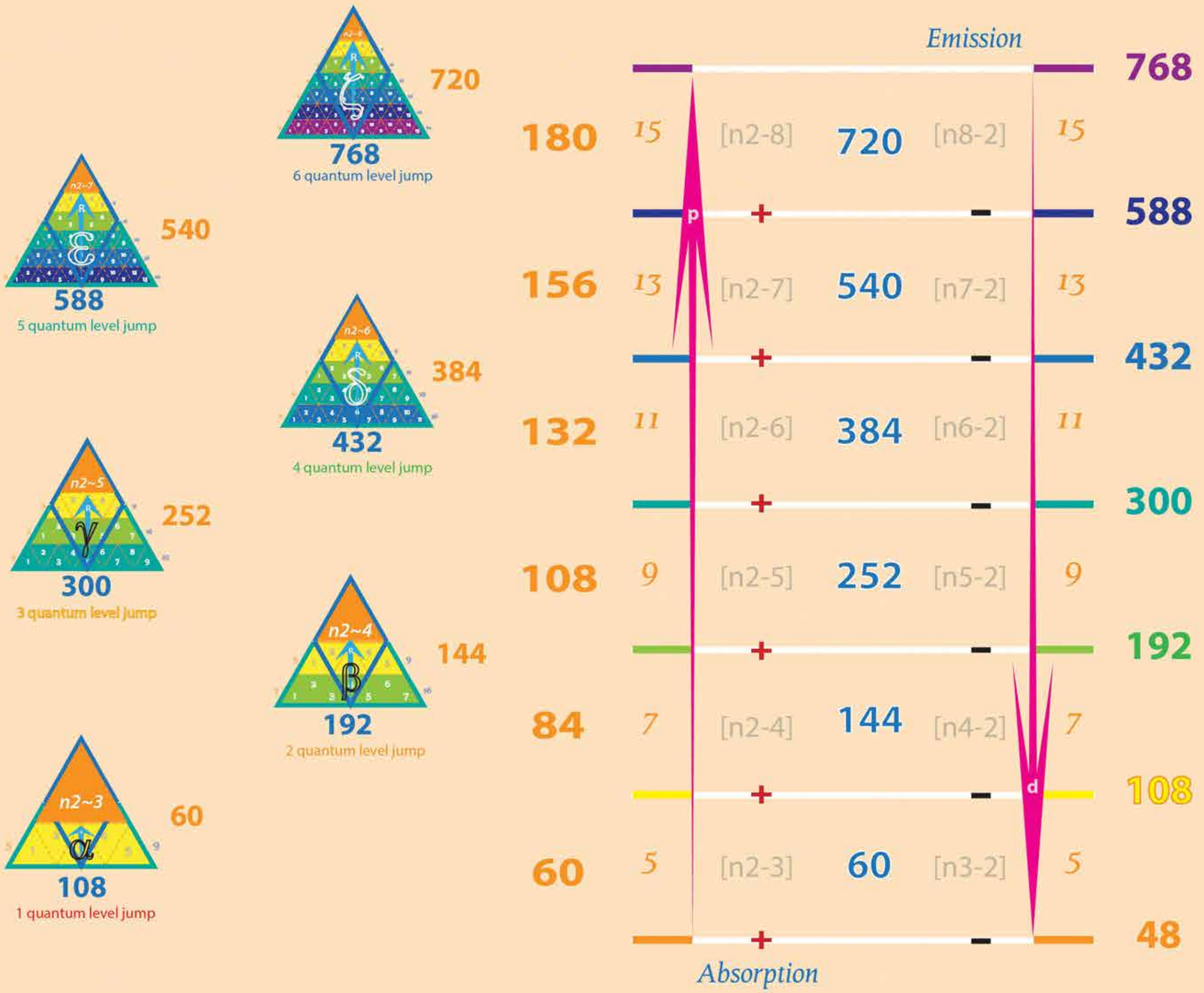
n2~8
768
6 quantum level jump
720
n2~7
588
5 quantum level jump
540
n2~6
432
4 quantum level jump
384
n2~5
300
3 quantum level jump
252
n2~4
192
2 quantum level jump
144
n2~3
108
1 quantum level jump
60
Emission
768
180
15
[n2-8]
720
[n8-2]
15
p
+
−
588
156
13
[n2-7]
540
[n7-2]
13
+
−
432
132
11
[n2-6]
384
[n6-2]
11
+
−
300
108
9
[n2-5]
252
[n5-2]
9
+
−
192
84
7
[n2-4]
144
[n4-2]
7
d
+
−
108
60
5
[n2-3]
60
[n3-2]
5
+
−
48
Absorption

		λ (nm)	$\tilde{\nu}$ (m-1)	f (Hz)	E (eV)	Ω (m²/s)	
60/64	.2343	391.3171751	2,555,471.1785	$7.661111677 \times 10^{14}$	3.169989296	103.1079531	$R\left(\frac{1}{4}-\frac{1}{64}\right)$ .2343
45/49	.2295	399.4696163	2,5033,319.299	$7.50476246 \times 10^{14}$	3.105295637	101.0037092	$R\left(\frac{1}{4}-\frac{1}{49}\right)$ .2295
32/36	.2222	412.7173331	2,422,965.84	$7.26386885 \times 10^{14}$	3.00561948	97.76161483	$R\left(\frac{1}{4}-\frac{1}{36}\right)$ .2222
21/25	.2100	436.7379187	2,289,702.719	$6.864356063 \times 10^{14}$	2.840310409	92.38472601	$R\left(\frac{1}{4}-\frac{1}{25}\right)$ .21
12/16	.1875	489.1464689	2,044,377.428	$6.128889342 \times 10^{14}$	2.535991437	82.48636251	$R\left(\frac{1}{4}-\frac{1}{16}\right)$ .1875
5/9	.138	660.347733	1,514,353.65	$4.539918031 \times 10^{14}$	1.878512175	61.10100927	$R\left(\frac{1}{4}-\frac{1}{9}\right)$ .138

$\Delta M v^2$

Paschen spectral transitions

$$\Delta h\nu \;=\; \text{KEM} \;=\; hcR$$

Planck 1.502 eV Rydberg

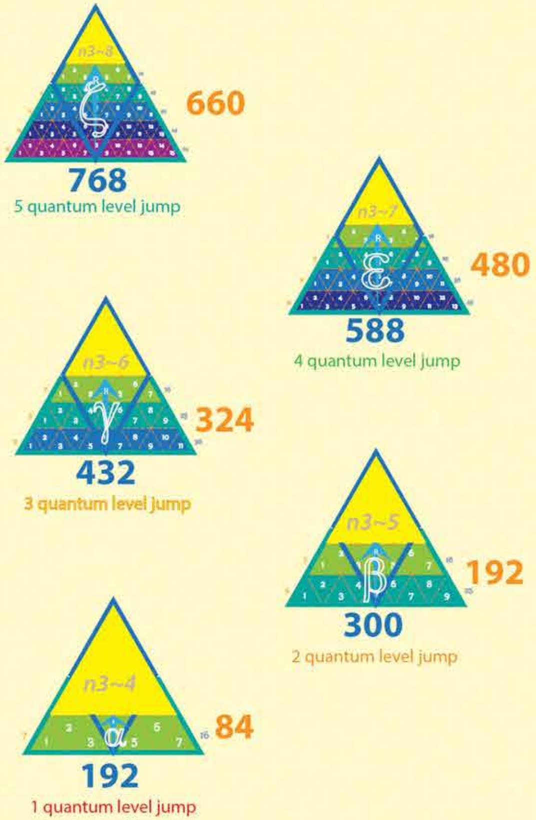
n3~8
660
768
5 quantum level jump
n3~7
480
588
4 quantum level jump
n3~6
324
432
3 quantum level jump
n3~5
192
300
2 quantum level jump
n3~4
84
192
1 quantum level jump

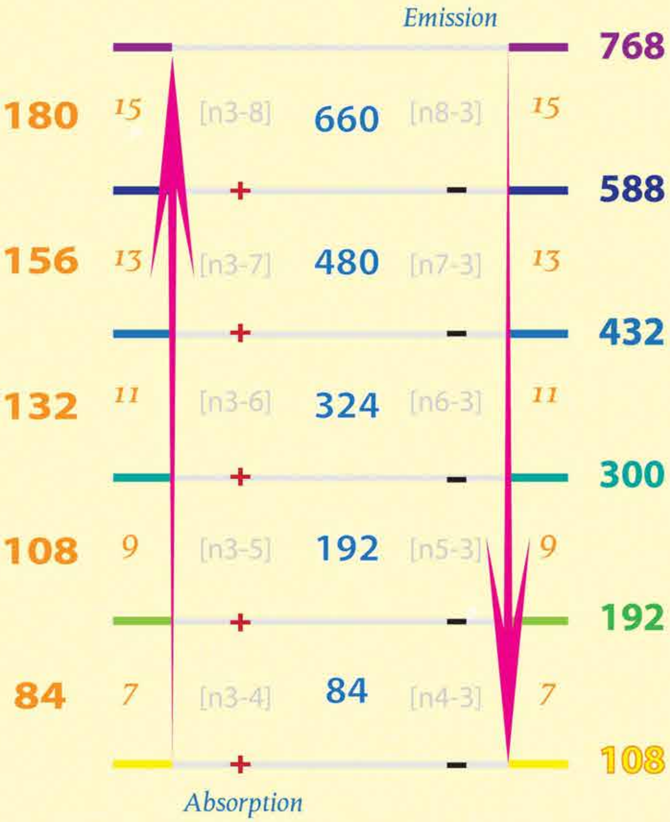
Emission
768
180
15
[n3-8]
660
[n8-3]
15
+
−
588
156
13
[n3-7]
480
[n7-3]
13
+
−
432
132
11
[n3-6]
324
[n6-3]
11
+
−
300
108
9
[n3-5]
192
[n5-3]
9
+
−
192
84
7
[n3-4]
84
[n4-3]
7
+
−
108
Absorption

55/64
.0954

λ	960.5057935	nm
$\tilde{\nu}$	1,041,118.135	m-1
f	$3.121193646 \times 10^{14}$	Hz
E	**1.29147712**	**eV**
Ω	287.9523928	m^2/s

$R\left(\frac{1}{9}-\frac{1}{64}\right)$
.09548

40/49
.0907

λ	1,011.157466	nm
$\tilde{\nu}$	988,965.6492	m-1
f	$2.9464844428 \times 10^{14}$	Hz
E	**1.226783461**	**eV**
Ω	303.1373822	m^2/s

$R\left(\frac{1}{9}-\frac{1}{49}\right)$
.0907

27/36
.8033

λ	1,100.579555	nm
$\tilde{\nu}$	908,612.1902	m-1
f	$2.723950819 \times 10^{14}$	Hz
E	**1.127107305**	**eV**
Ω	329.94545	m^2/s

$R\left(\frac{1}{9}-\frac{1}{36}\right)$
.0833

16/25
.0711

λ	1,289.741666	nm
$\tilde{\nu}$	775,349.069	m-1
f	$2.324438032 \times 10^{14}$	Hz
E	**0.961798233**	**eV**
Ω	386.6548243	m^2/s

$R\left(\frac{1}{9}-\frac{1}{25}\right)$
.0711

7/16
.0486

λ	1,886.707809	nm
$\tilde{\nu}$	530,023.7776	m-1
f	$1.588971311 \times 10^{14}$	Hz
E	**0.657479261**	**eV**
Ω	565.6207715	m^2/s

$R\left(\frac{1}{9}-\frac{1}{16}\right)$
.0486

ΔMv^2

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Brackett spectral transitions

$$\Delta h\nu \;=\; \mathrm{KEM} \;=\; hcR$$

Planck

0.8451 eV

Rydberg

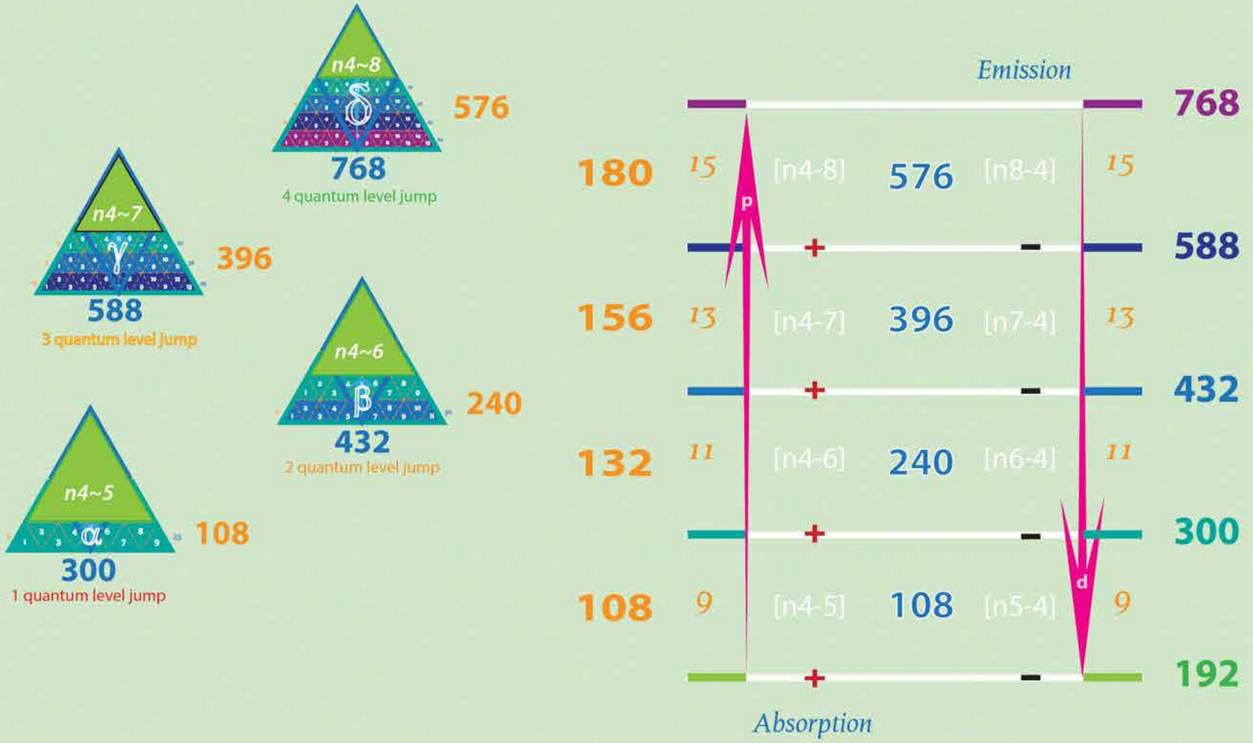
n4~8
δ
576
768
4 quantum level jump
n4~7
γ
396
588
3 quantum level jump
n4~6
β
240
432
2 quantum level jump
n4~5
α
108
300
1 quantum level jump
Emission
768
180
15
[n4-8]
576
[n8-4]
15
p
+
−
588
156
13
[n4-7]
396
[n7-4]
13
+
−
432
132
11
[n4-6]
240
[n6-4]
11
+
−
300
108
9
[n4-5]
108
[n5-4]
9
d
+
−
192
Absorption

48/64

.0468

λ	1,956.585876	nm
ṽ	511,094.357	m-1
f	$1.532222335 \times 10^{14}$	Hz
E	0.634001085	eV
Ω	586.569689	m²/s

$R\left(\frac{1}{16}-\frac{1}{64}\right)$

.0468

33/49

.04209

λ	2,178.92518	nm
ṽ	458,941.8716	m-1
f	$1.375873118 \times 10^{14}$	Hz
E	0.569307096	eV
Ω	653.2253354	m²/s

$R\left(\frac{1}{16}-\frac{1}{49}\right)$

.04209

20/36

.0347

λ	2,641.390932	nm
ṽ	378,588.4126	m-1
f	$1.134979508 \times 10^{14}$	Hz
E	0.469630433	eV
Ω	791.8690801	m²/s

$R\left(\frac{1}{16}-\frac{1}{36}\right)$

.0347

9/25

.0225

λ	4,076.220574	nm
ṽ	245,325.2914	m-1
f	$7.35466721 \times 10^{13}$	Hz
E	0.30432052	eV
Ω	1,222.020185	m²/s

$R\left(\frac{1}{16}-\frac{1}{25}\right)$

.0225

$\Delta M v^2$

Pfund spectral transitions

$$\Delta h\nu \;=\; \mathrm{KEM} \;=\; hcR$$

Planck 0.541 eV Rydberg

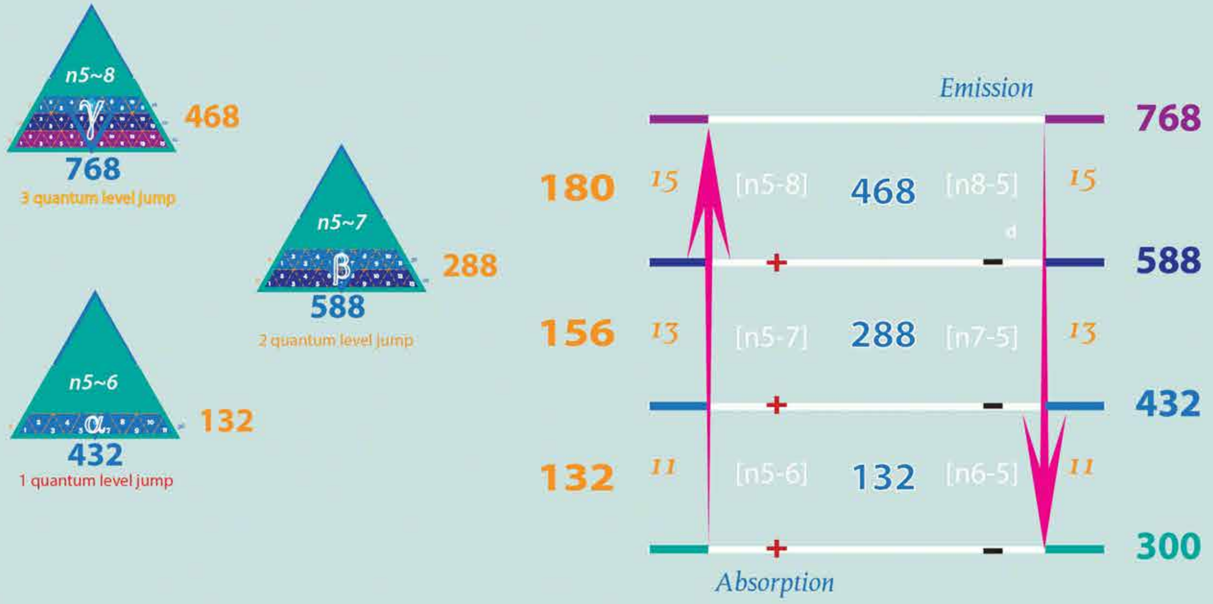
n5~8
γ
468
768
3 quantum level jump
n5~7
β
288
588
2 quantum level jump
n5~6
α
132
432
1 quantum level jump
Emission
768
180
15
[n5-8]
468
[n8-5]
15
+
−
588
156
13
[n5-7]
288
[n7-5]
13
+
−
432
132
11
[n5-6]
132
[n6-5]
11
+
−
300
Absorption

39/64

.0243

λ	3,762.665146	nm
$\tilde{\nu}$	265,769.0656	m-1
f	$7.967556145 \times 10^{13}$	Hz
E	**0.329678886**	**eV**
Ω	1,128.018633	m^2/s

$R\left(\frac{1}{25}-\frac{1}{64}\right)$

.0243

24/49

.0195

λ	4,681.284566	nm
$\tilde{\nu}$	213,616.5802	m-1
f	$6.404063965 \times 10^{13}$	Hz
E	**0.264985227**	**eV**
Ω	1,403.413807	m^2/s

$R\left(\frac{1}{25}-\frac{1}{49}\right)$

.01959

11/36

.0122

λ	7,503.951512	nm
$\tilde{\nu}$	133,263.1212	m-1
f	$3.995127867 \times 10^{13}$	Hz
E	**0.165309071**	**eV**
Ω	2,249.628068	m^2/s

$R\left(\frac{1}{25}-\frac{1}{36}\right)$

.0122

$\Delta M v^2$

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Humphreys spectral transitions

$$\Delta h\nu = \text{KEM} = hcR$$

Planck 0.375 eV Rydberg

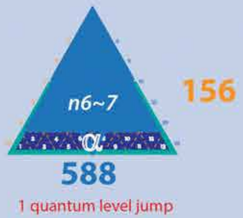
n6~7
156
α
588
1 quantum level jump

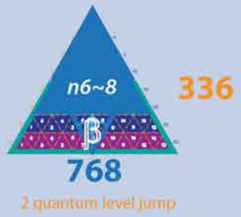
n6~8
336
β
768
2 quantum level jump

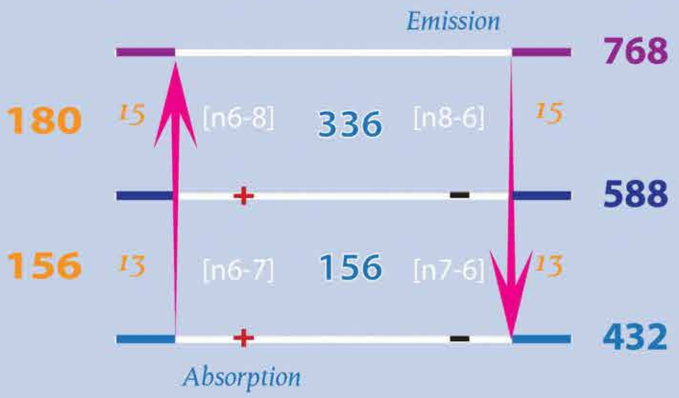
Emission
768
180
15
[n6-8]
336
[n8-6]
15
+
-
588
156
13
[n6-7]
156
[n7-6]
13
+
-
432
Absorption

28/64

.01215

λ	7,546.831235	nm
$\tilde{\nu}$	132,505.9444	m-1
f	$3.972428277 \times 10^{13}$	Hz
E	**0.164369815**	**eV**
Ω	1,128.018633	m^2/s

$$R\left(\frac{1}{36} - \frac{1}{64}\right)$$

.01215

13/49

.00733

λ	12,445.01497	nm
$\tilde{\nu}$	80,353.459	m-1
f	$2.4089936098 \times 10^{13}$	Hz
E	**0.099676156**	**eV**
Ω	1,403.413807	m^2/s

$$R\left(\frac{1}{36} - \frac{1}{49}\right)$$

.0073

$$\Delta M v^2$$

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Un-named spectral transition

$\Delta h\nu$ = KEM = hcR

Planck — 0.276 eV — Rydberg

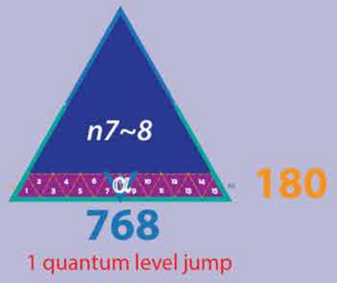
n7~8
α
180
768
1 quantum level jump

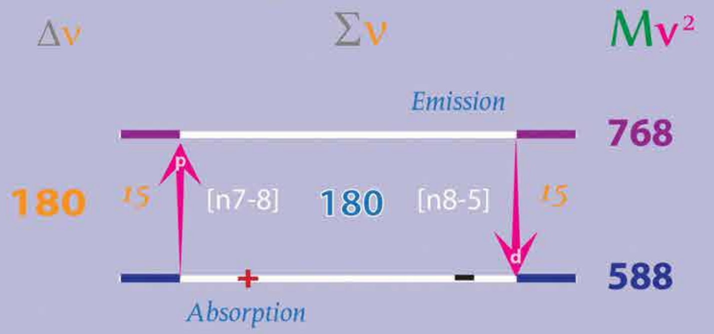
Δν
Σν
Mv²
Emission
768
180
15
p
[n7-8]
180
[n8-5]
15
d
+
−
588
Absorption

15/64

.0047

λ	19,174.54158	nm
$\tilde{\nu}$	52,152.48541	m-1
ƒ	1.563492179 x 10^{13}	Hz
E	0.064693658	eV
Ω	5,748.382952	m²/s

$R\left(\frac{1}{49}-\frac{1}{64}\right)$

.0047

$\Delta M\nu^2$

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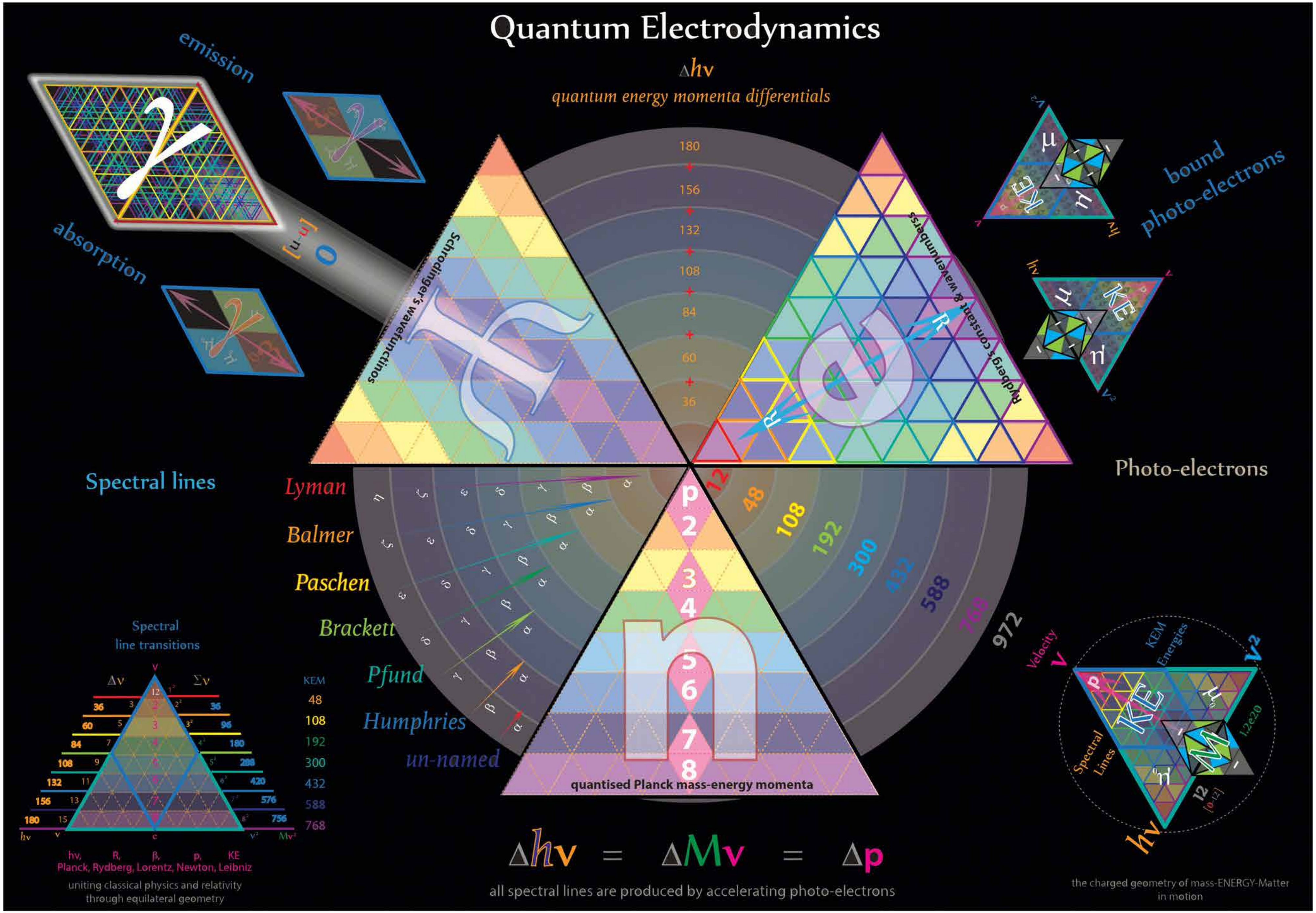

Quantum Electrodynamics

$\Delta h\nu$

quantum energy momenta differentials

emission
absorption
[n-n]
0
Schrodinger's wavefunctions
ψ
180
156
132
108
84
60
36
Rydberg's constant & wavenumbers
R
R
bound photo-electrons
μ
KE
ν
ν²
hν
Photo-electrons
Spectral lines
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
α
β
γ
δ
ε
ζ
η
p
2
3
4
5
6
7
8
n
12
48
108
192
300
432
588
768
972
quantised Planck mass-energy momenta
Velocity
v
KEM Energies
v²
1.2e20
Spectral Lines
M
12
[φ 12]
hν
Spectral line transitions
Δν
Σν
v
12
1²
2
2²
3
3²
4
4²
5
5²
6
6²
7
7²
8
8²
36
60
84
108
132
156
180
3
5
7
9
11
13
15
36
96
180
288
420
576
756
KEM
48
108
192
300
432
588
768
hν
v
c
v²
Mv²
hν, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

uniting classical physics and relativity
through equilateral geometry

$$\Delta h\nu = \Delta M\nu = \Delta p$$

all spectral lines are produced by accelerating photo-electrons

the charged geometry of mass-ENERGY-Matter
in motion

Tetryonics 96.11 - Atomic spectral series transitions

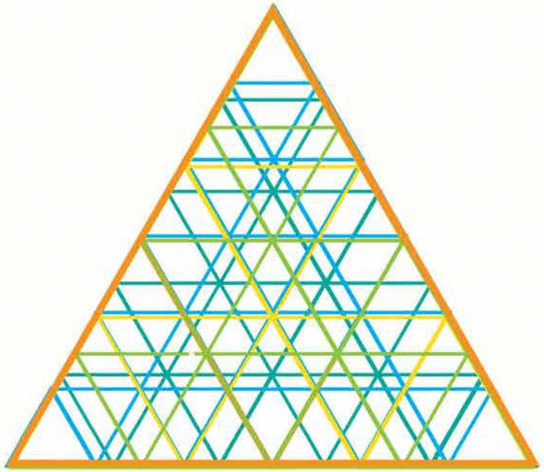

Fractionals and fractals

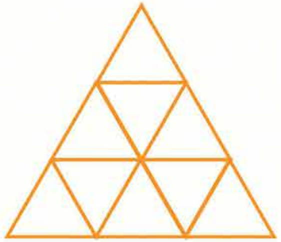

ninths

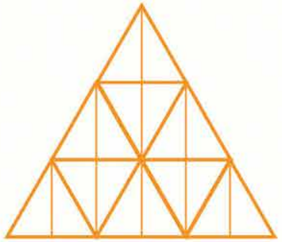

eigteenths

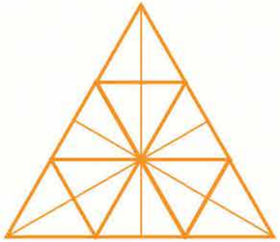

Eighteenths

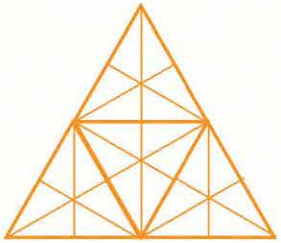

Twenty-fourths

White light
[EM radiation]
is comprised of many
superpositioned
frequencies

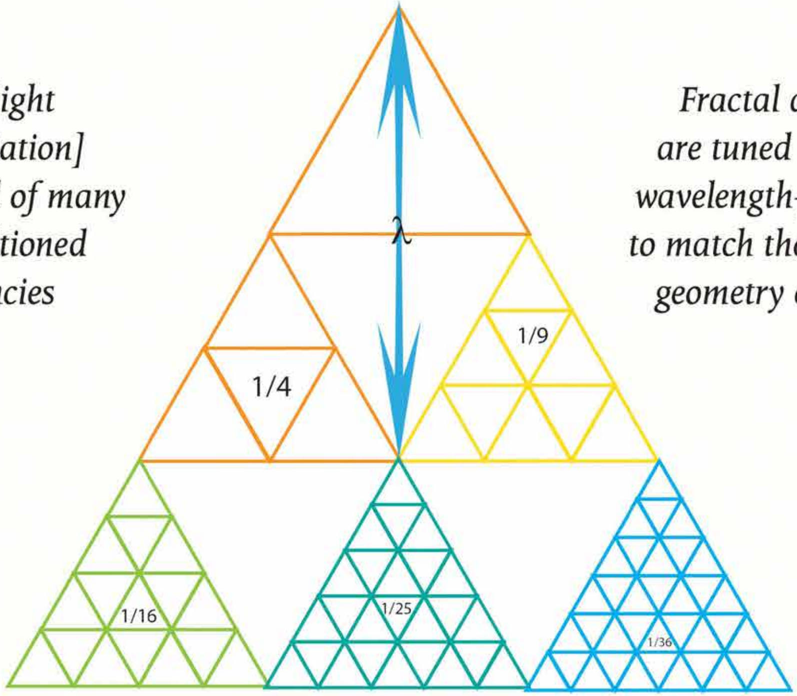

Fractal antennas
are tuned to specific
wavelength-frequencies
to match the equilateral
geometry of photons

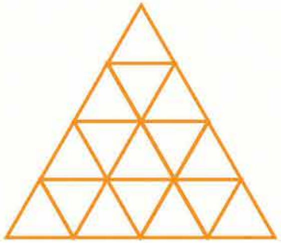

Sizteenths

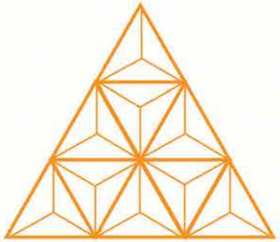

Twenty-sevenths

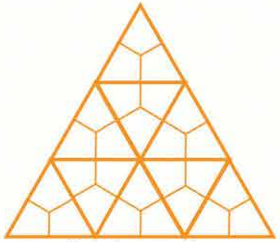

Twenty-sevenths

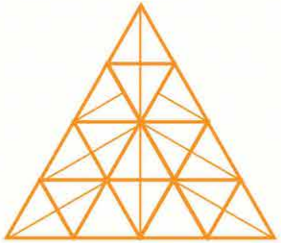

Thirty-seconds

Tetryonics 97.01 - Fractionals and fractals

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Polygons and Angles

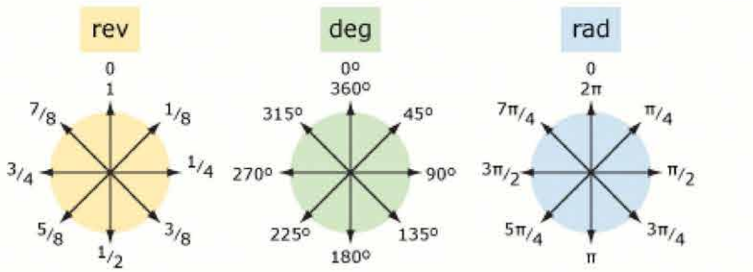
rev
0
1
1/8
1/4
3/8
1/2
5/8
3/4
7/8
deg
0°
360°
45°
90°
135°
180°
225°
270°
315°
rad
0
2π
π/4
π/2
3π/4
π
5π/4
3π/2
7π/4

polygon exterior and interior angles

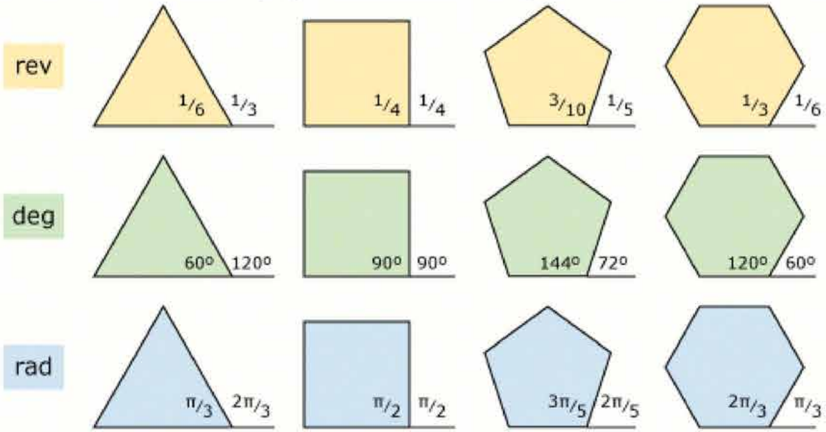
rev
1/6
1/3
1/4
1/4
3/10
1/5
1/3
1/6
deg
60°
120°
90°
90°
144°
72°
120°
60°
rad
π/3
2π/3
π/2
π/2
3π/5
2π/5
2π/3
π/3

dividing the circle

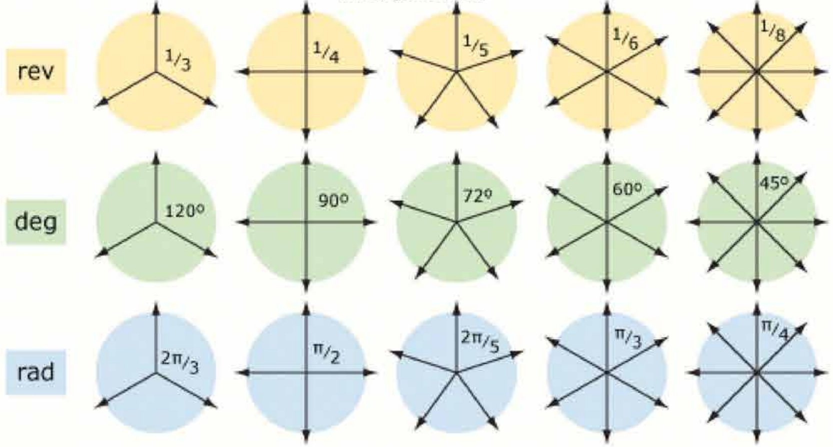
rev
1/3
1/4
1/5
1/6
1/8
deg
120°
90°
72°
60°
45°
rad
2π/3
π/2
2π/5
π/3
π/4

supplementary angles

complementary angles

triangles

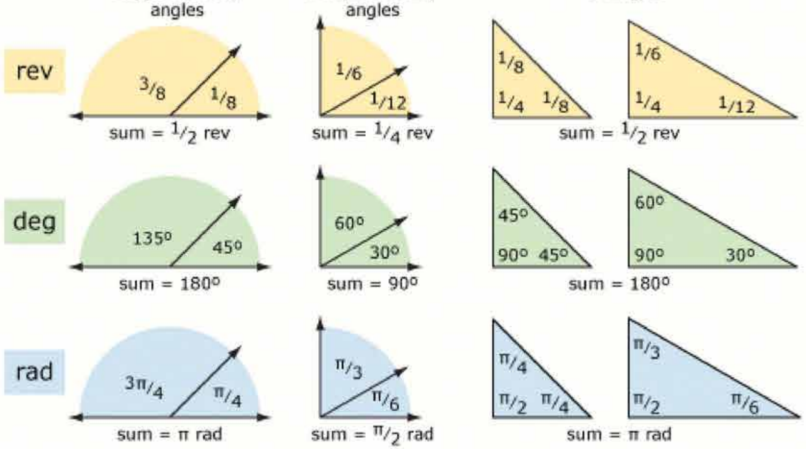
rev
3/8
1/8
sum = 1/2 rev
1/6
1/12
sum = 1/4 rev
1/8
1/4
1/8
1/6
1/4
1/12
sum = 1/2 rev
deg
135°
45°
sum = 180°
60°
30°
sum = 90°
45°
90°
45°
60°
90°
30°
sum = 180°
rad
3π/4
π/4
sum = π rad
π/3
π/6
sum = π/2 rad
π/4
π/2
π/4
π/3
π/2
π/6
sum = π rad

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Pi vs Tau

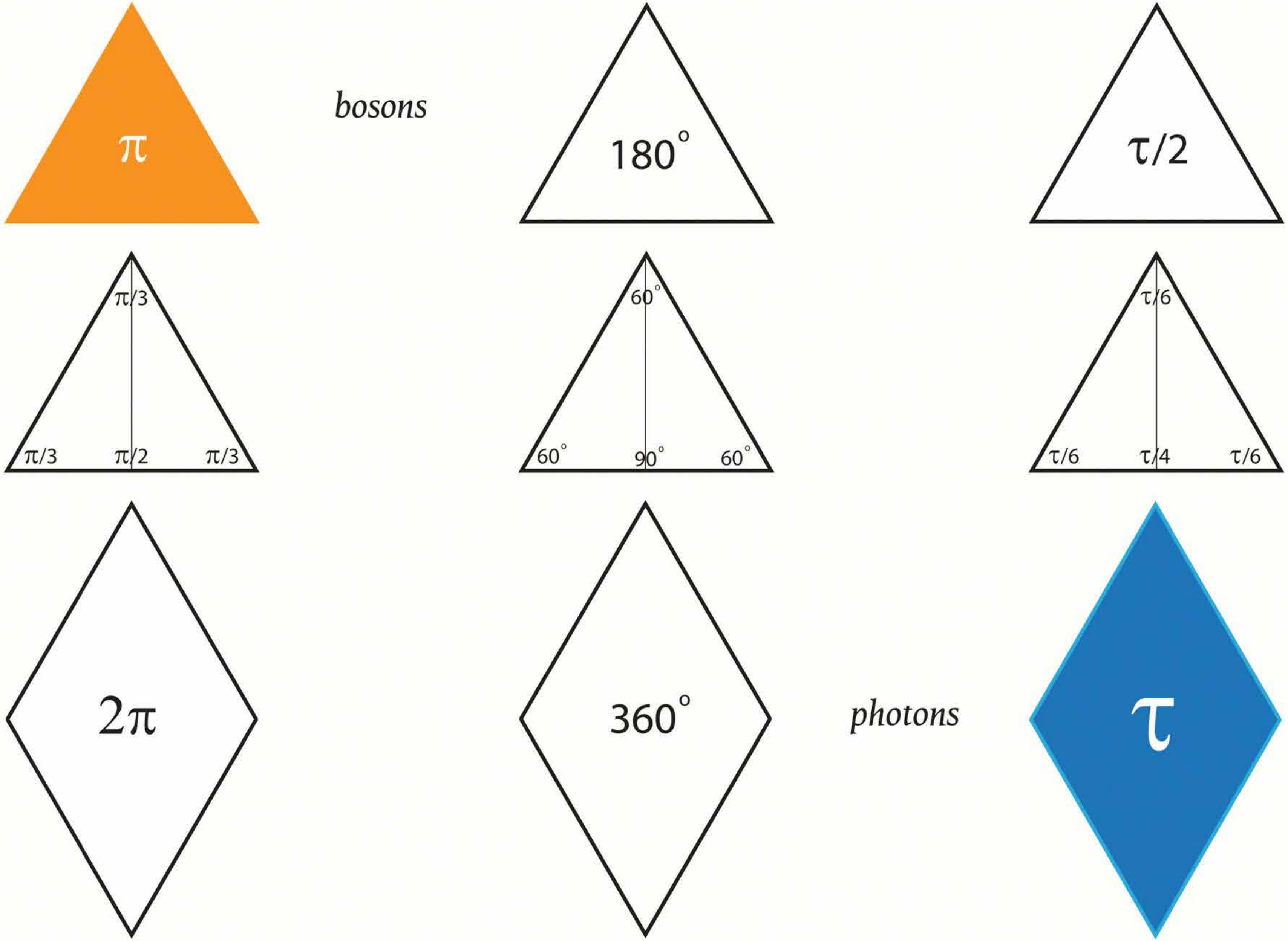
π
bosons
180°
τ/2
π/3
π/3
π/2
π/3
60°
60°
90°
60°
τ/6
τ/6
τ/4
τ/6
2π
360°
photons
τ

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Triangular dissection of an equilateral triangle

is a way of dividing up a original triangle into smaller equilateral triangles,
such that none of the smaller triangles overlap

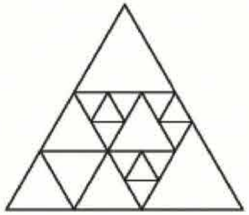

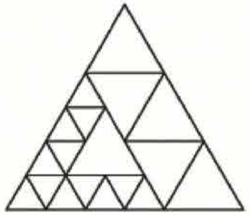

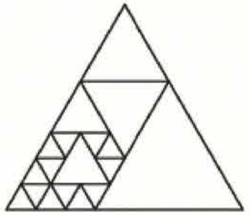

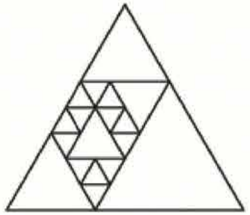

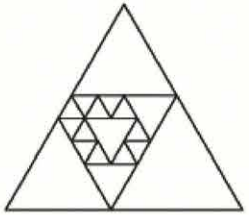

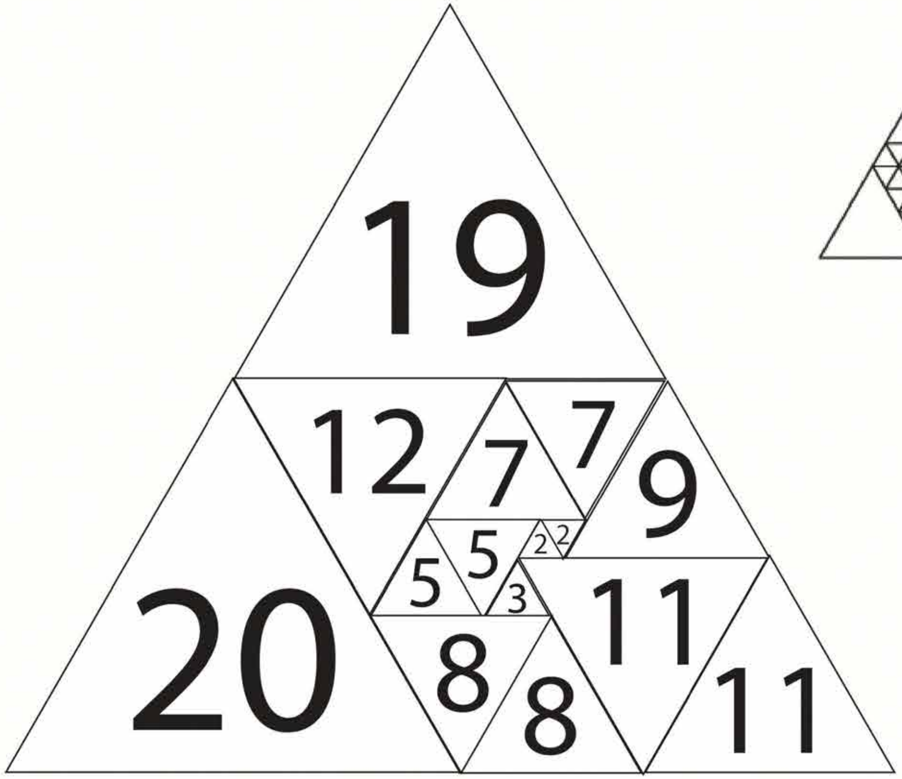

lowest order perfect equilateral triangle dissected by equilateral triangles

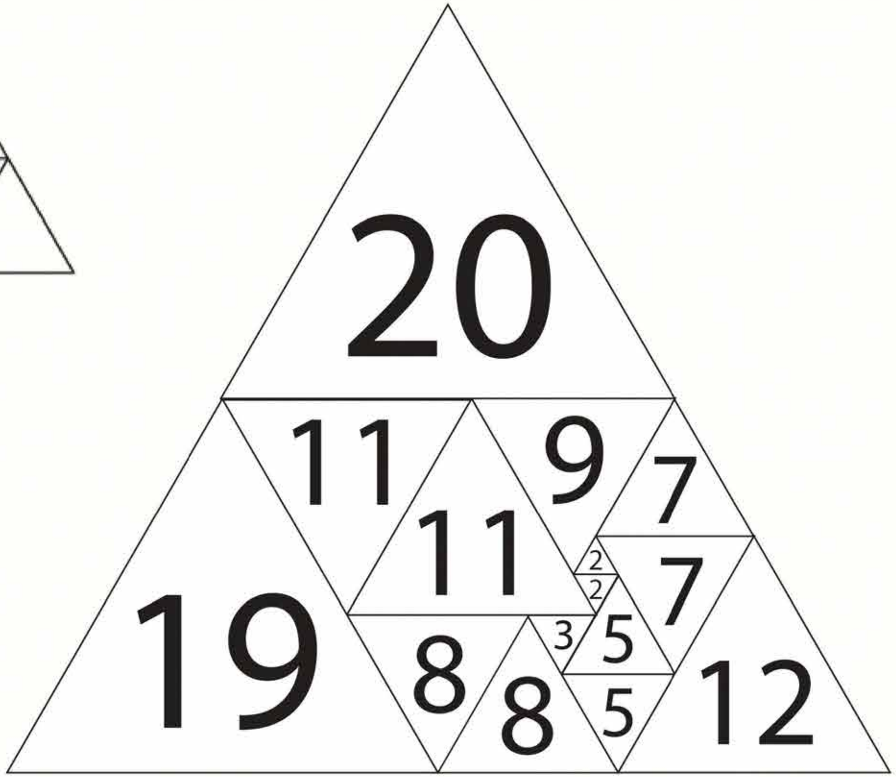

lowest order perfect dissected equilateral triangle, an isomer of the first

Golden mean Spirals

Golden Mean Spiral – This spiral is derived via the golden rectangle, a unique rectangle which has the golden ratio.
This form is found everywhere in nature: the Nautilus Shell, the face of a Sunflower, fingerprints, our DNA, and the shape of the Milky Way

Golden spiral

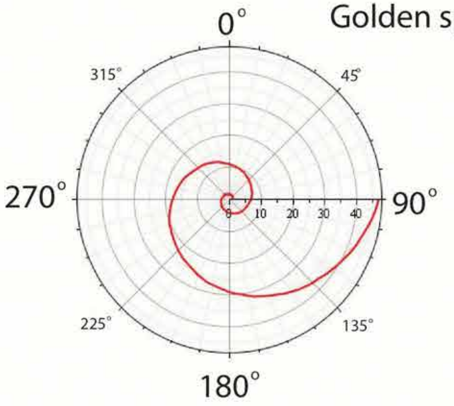

0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, …

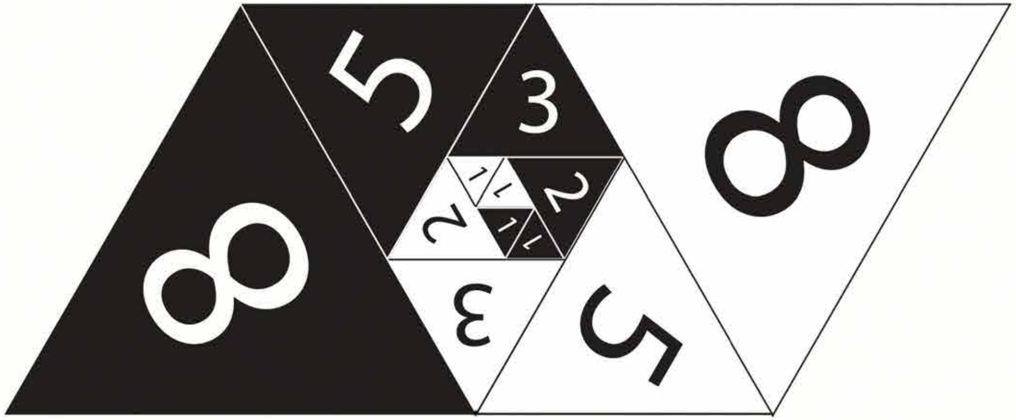

Golden spirals

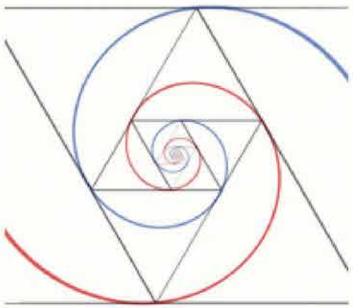

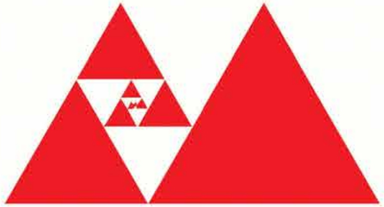

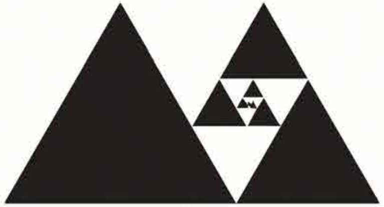

Continued fractions and the Fibonacci sequence

The convergence of the continued fractions

$$1 + \frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\frac{1}{1+}\,\cdots$$

are:

$$\frac{2}{1},\ \frac{3}{2},\ \frac{5}{3},\ \frac{8}{5},\ \frac{13}{8},\ \frac{21}{13},\ \frac{34}{21},\ \frac{55}{34},\ \frac{89}{55},\ \frac{144}{89},\ \frac{233}{144},\ \frac{377}{233},\ \frac{610}{377},$$

The Golden Ratio (Golden Mean, Golden Section)
is defined mathematically as:

$$\varphi = \frac{1+\sqrt{5}}{2} = 1.6180339887\ldots.$$

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Koch fractal Curve

Niels Fabian Helge von Koch (January 25, 1870 – March 11, 1924) was a Swedish mathematician who gave his name to one of the earliest fractal curves ever known

He described the Koch curve, or Koch snowflakes as it popularly known, in a 1904 paper entitled "On a continuous curve without tangents constructible from elementary geometry"

Von Koch wrote several papers on number theory . One of his results was a 1901 theorem proving that the Riemann hypothesis is equivalent to a strengthened form of the prime number theorem.

Three Koch curves form the snowflake.

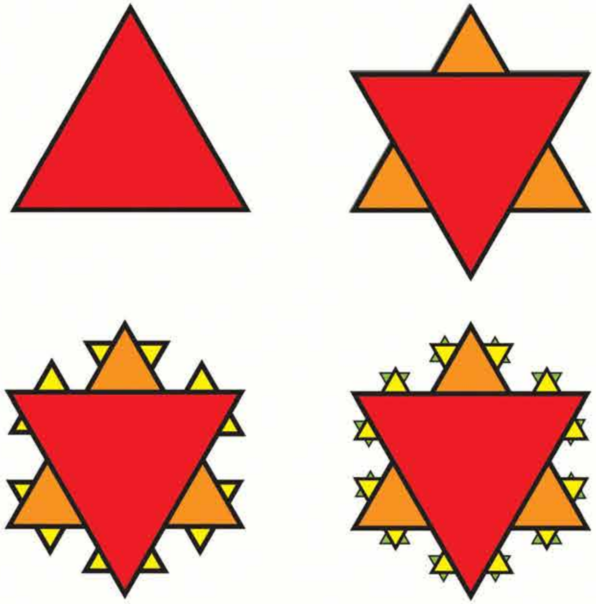

The Koch snowflake (or Koch star) is a mathematical curve and one of the earliest fractal curves to have been described.

Actually Koch described what is now known as the Koch curve, which is the same as the now popular snowflake, except it starts with a line segment instead of an equilateral triangle.

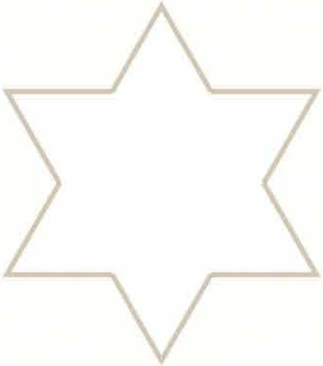

$$a = \frac{1}{2} + \frac{i}{\sqrt{12}}$$

The Koch curve is a special case of the Cesaro curve where:

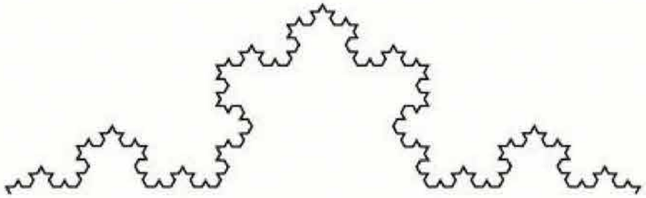

which is in turn a special case of the de Rham curve.

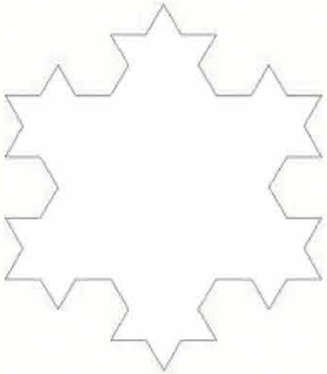

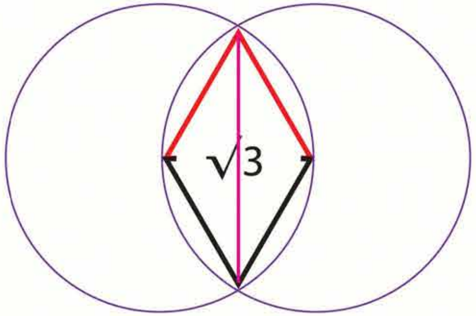

vesica piscis

$$\frac{1351}{780} > \sqrt{3} > \frac{265}{153}\,.$$

Koch snowflake

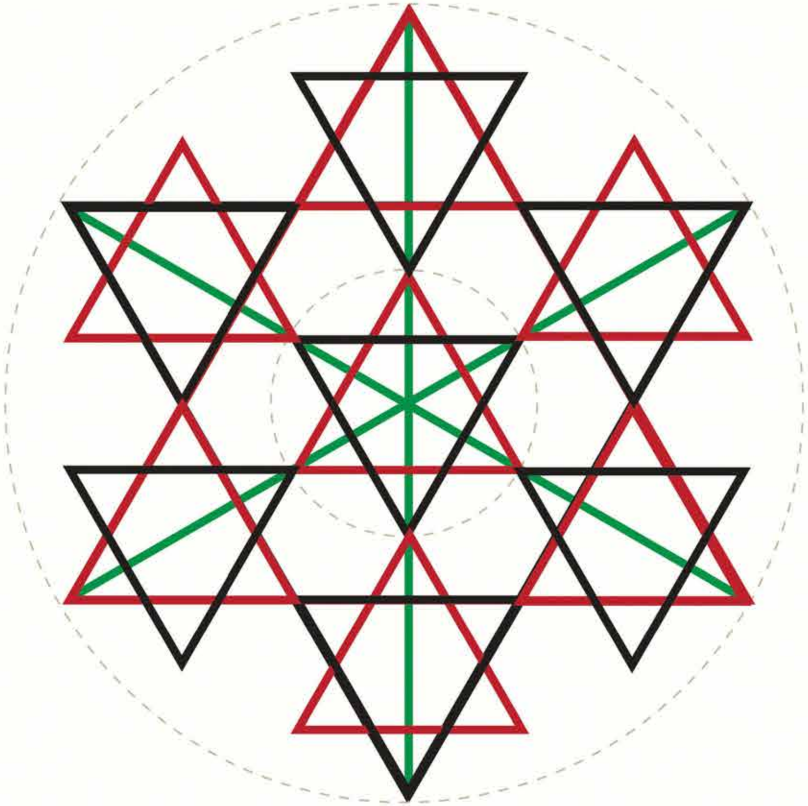

space-time

star tetrahedron

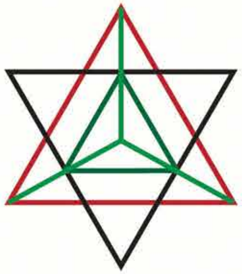

Flower of Life

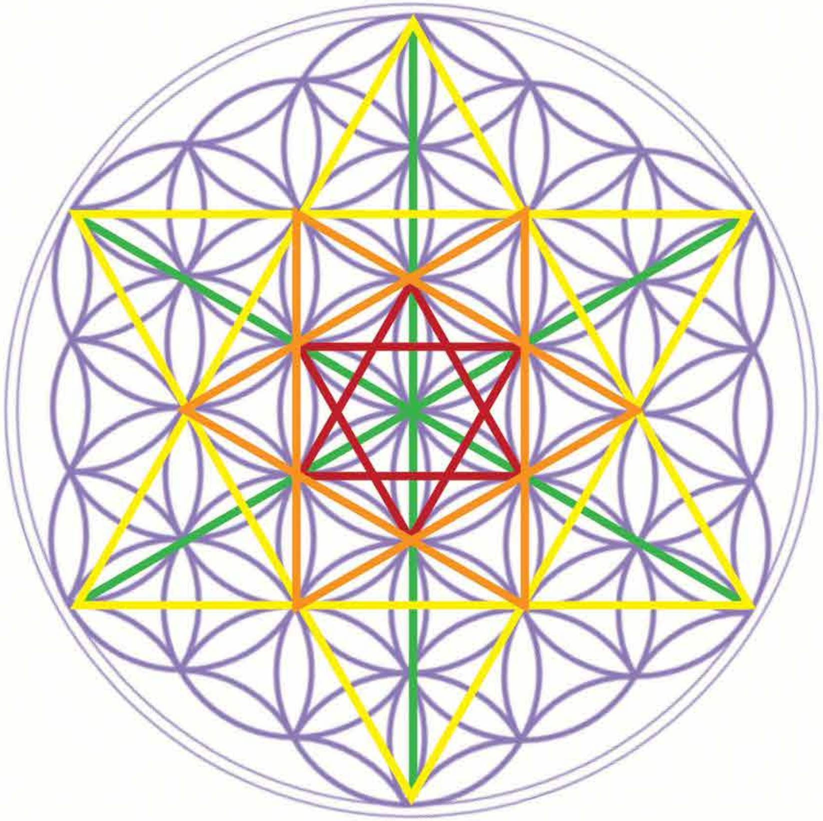

The Flower of Life is a name for a geometrical figure composed of multiple evenly-spaced, overlapping circles.

Unit circles - SINE WAVES - Photons

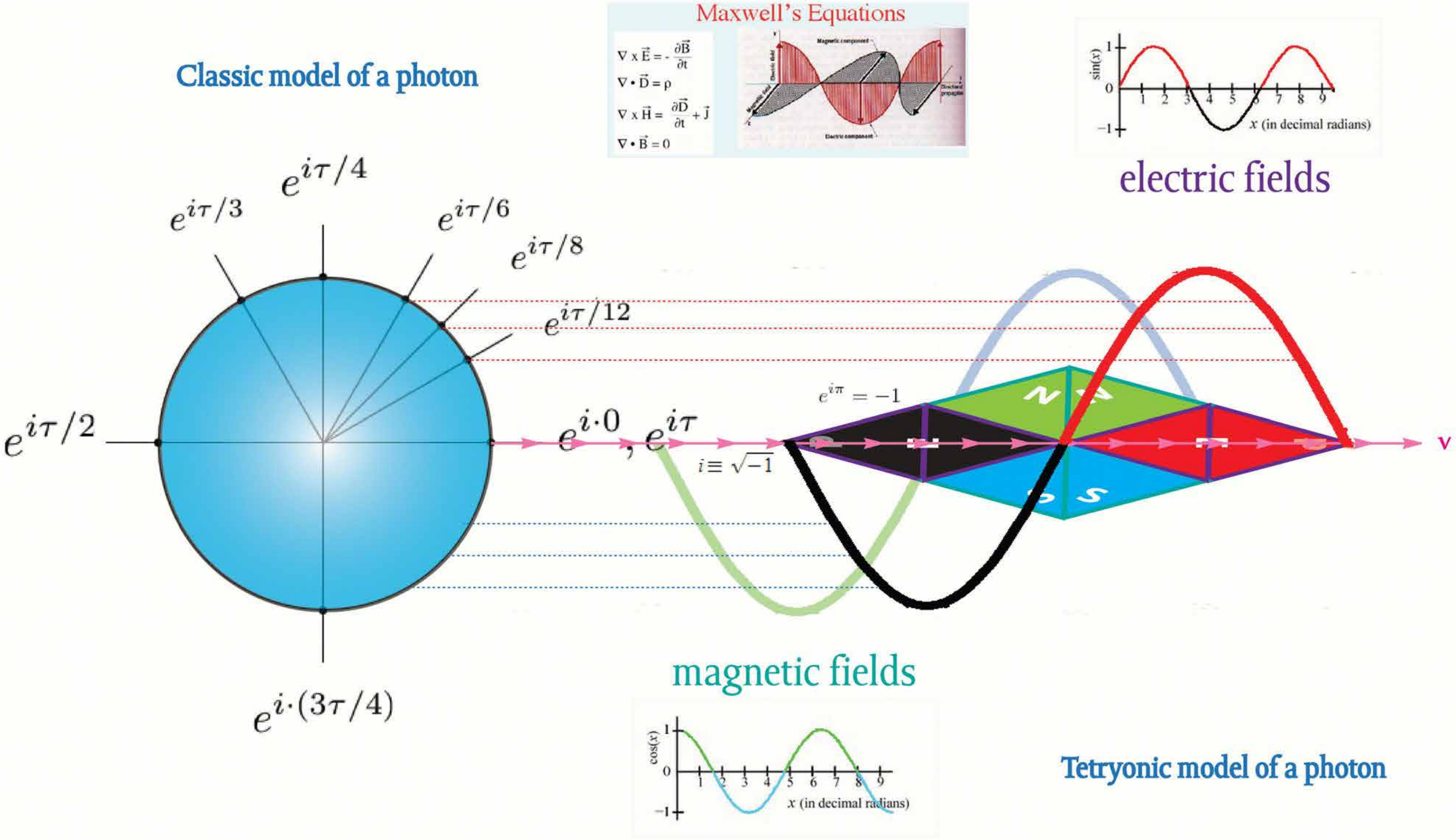

Classic model of a photon

Maxwell's Equations

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{D} = \rho$$

$$\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} + \vec{J}$$

$$\nabla \cdot \vec{B} = 0$$

electric fields

magnetic fields

Tetryonic model of a photon

Magnetic component
Electric component
$e^{i\tau/4}$
$e^{i\tau/3}$
$e^{i\tau/6}$
$e^{i\tau/8}$
$e^{i\tau/12}$
$e^{i\tau/2}$
$e^{i\cdot 0}, e^{i\tau}$
$e^{i\pi} = -1$
$i \equiv \sqrt{-1}$
N
N
S
S
v
$e^{i\cdot(3\tau/4)}$
sin(x)
cos(x)
1
0
−1
1 2 3 4 5 6 7 8 9
x (in decimal radians)

Magnetic waveforms are 90 degrees out of phase with Electric waveforms

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Boson distributions in monochromatic EM waves

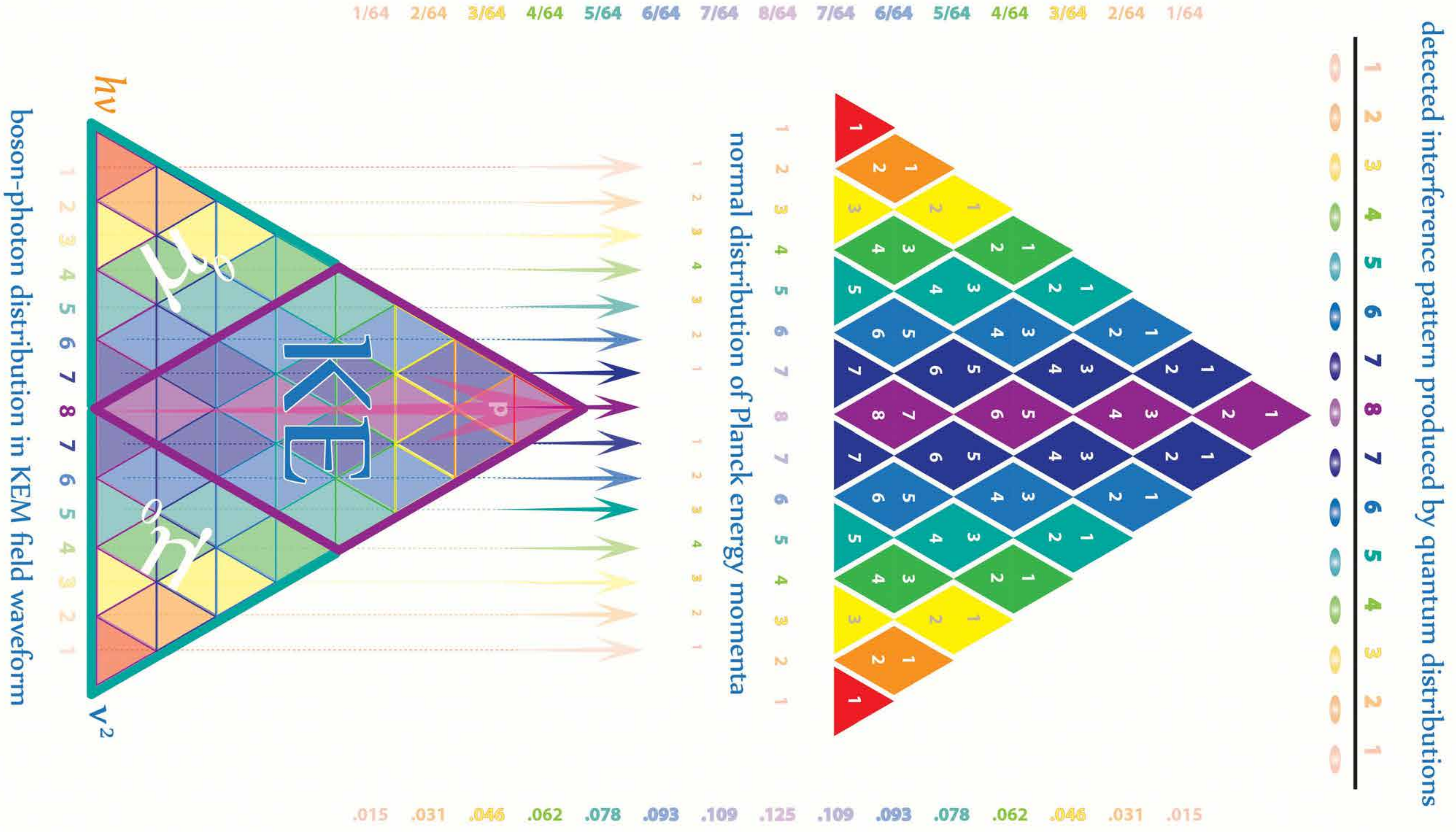
1/64 2/64 3/64 4/64 5/64 6/64 7/64 8/64 7/64 6/64 5/64 4/64 3/64 2/64 1/64
hν
v²
μ₀
ε₀
KE
p
boson-photon distribution in KEM field waveform
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
normal distribution of Planck energy momenta
detected interference pattern produced by quantum distributions
.015 .031 .046 .062 .078 .093 .109 .125 .109 .093 .078 .062 .046 .031 .015

Probability distributions of monochromatic EM waves

Tetryonics 98.02 - Boson distributions in monochromatic EM waves

Wave interference patterns

The double-slit experiment, sometimes called Young's experiment, is a demonstration that matter and energy can display characteristics of both waves and particles, and demonstrates the fundamentally probabilistic nature of quantum mechanical phenomena and Establishes the quantum interference principle known as wave–particle duality.

Matter particles are stopped by the barrier but the [K]EM wave passes through both slits and is diffracted by them producing weaker EM waves that then superposition with each other to produce interference patterns

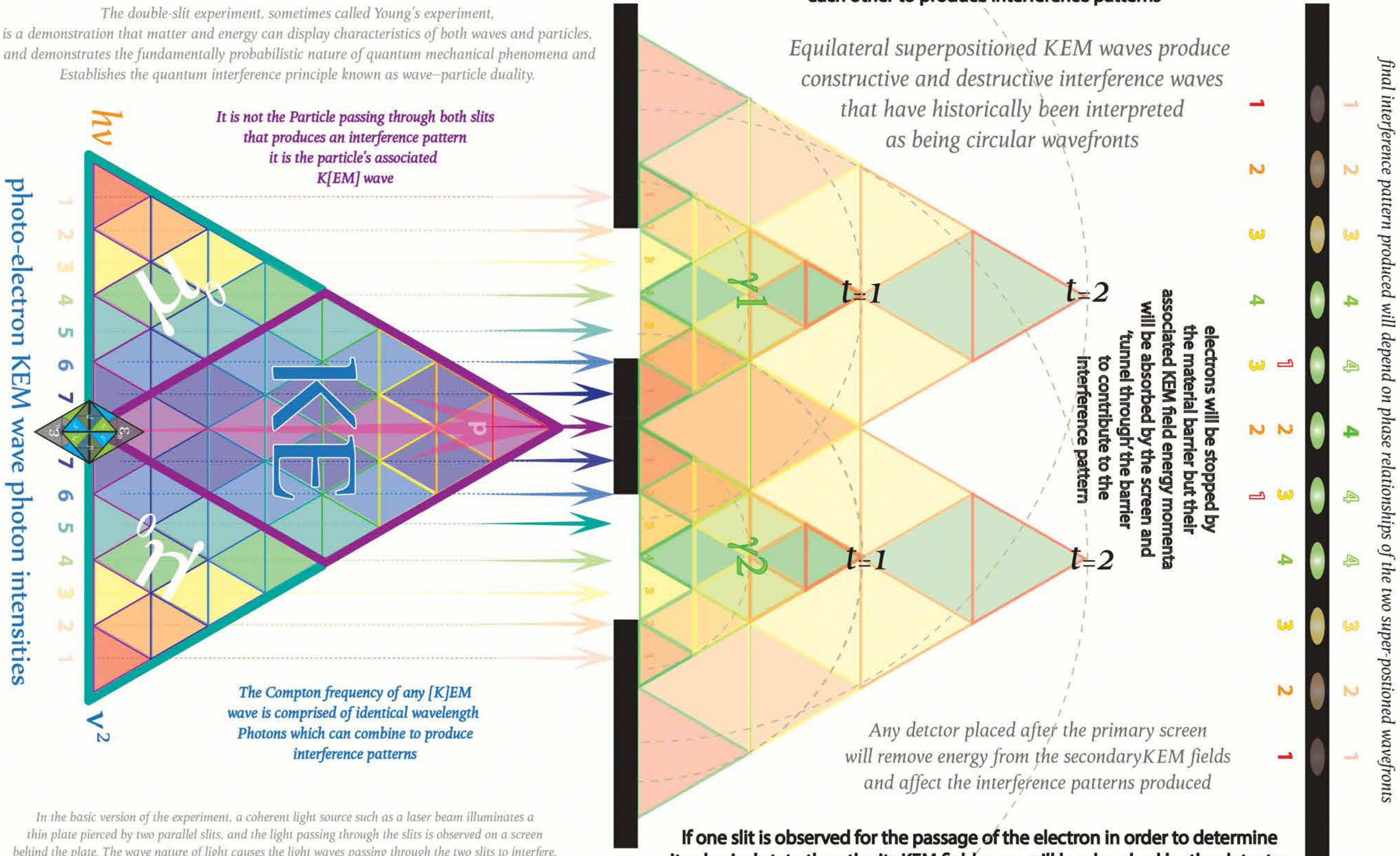

It is not the Particle passing through both slits that produces an interference pattern it is the particle's associated K[EM] wave

photo-electron KEM wave photon intensities

Equilateral superpositioned KEM waves produce constructive and destructive interference waves that have historically been interpreted as being circular wavefronts

electrons will be stopped by the material barrier but their associated KEM field energy momenta will be absorbed by the screen and 'tunnel through' the barrier to contribute to the interference pattern

final interference pattern produced will depend on phase relationships of the two super-postioned wavefronts

The Compton frequency of any [K]EM wave is comprised of identical wavelength Photons which can combine to produce interference patterns

Any detctor placed after the primary screen will remove energy from the secondaryKEM fields and affect the interference patterns produced

In the basic version of the experiment, a coherent light source such as a laser beam illuminates a thin plate pierced by two parallel slits, and the light passing through the slits is observed on a screen behind the plate. The wave nature of light causes the light waves passing through the two slits to interfere, producing bright and dark bands on the screen — a result that would not be expected if light consisted strictly of particles. However, on the screen, the light is always found to be absorbed as though it were composed of discrete particles or photons.

If one slit is observed for the passage of the electron in order to determine its physical state then the its KEM field wave will be absorbed by the detector resulting in only one wave remaining, enforcing a classical particle outcome

Quantum computing via EM wave super-positioning

BY superpositioning two beams
of EM radiation the resultant 'colours'
will perform quantum level computations
that can be read via the resultant
interference patterns produced

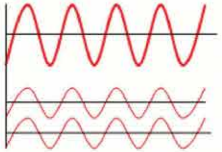

In phase

constructive interference

additive in-phase EM waves

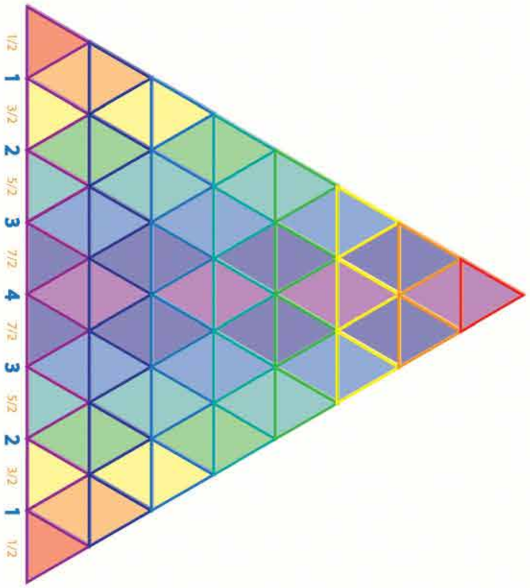
1/2
1
3/2
2
5/2
3
7/2
4
7/2
3
5/2
2
3/2
1
1/2

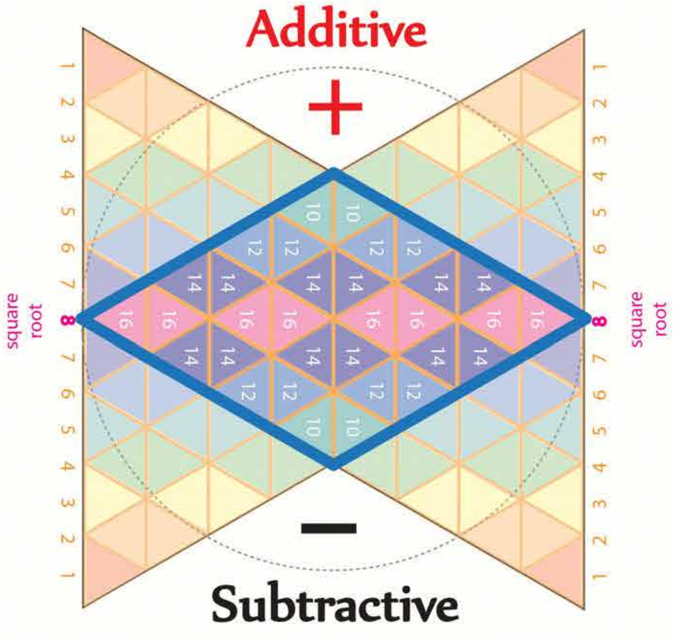
Additive
+
1
2
3
4
5
6
7
8
7
6
5
4
3
2
1
square root
10
12
14
16
−
Subtractive

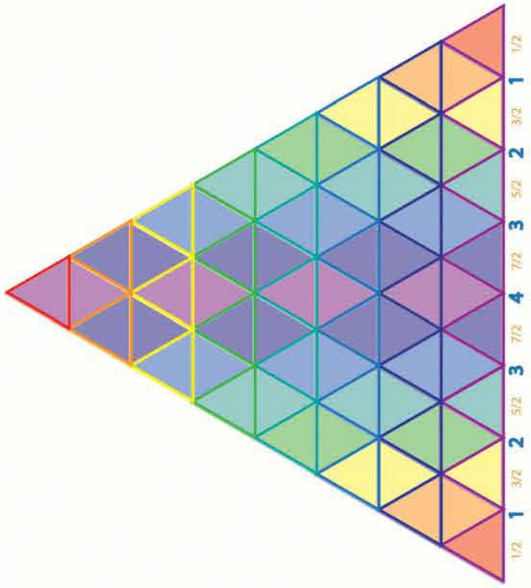
1/2
1
3/2
2
5/2
3
7/2
4
7/2
3
5/2
2
3/2
1
1/2

Out of phase

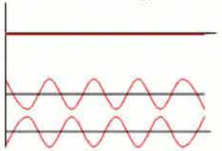

destructive interference

subtractive out-of-phase EM waves

Various basic operations, such as
ADDITION, SUBTRACTION and
SQUARE ROOTS etc
are all easily computed using
EM wave super-positioning

The lines of Force

By utilising the statiscal distribution of equilateral Planck energy momenta quanta in EM waves
Tetryonic theory provides a practical geometric solution to quantum computing problems

P vs. NP

The set of all decision problems for which an algorithm exists which can be carried out by a deterministic Turing machine in **polynomial** *time*

the set of all decision problems for which an algorithm exists which can be carried out by a **non-deterministic** *Turing machine in* **polynomial** *time*

An algorithm of time complexity $O(n)$ is one which increases in time linearly as the "size of the problem" (whatever n stands for) increases.

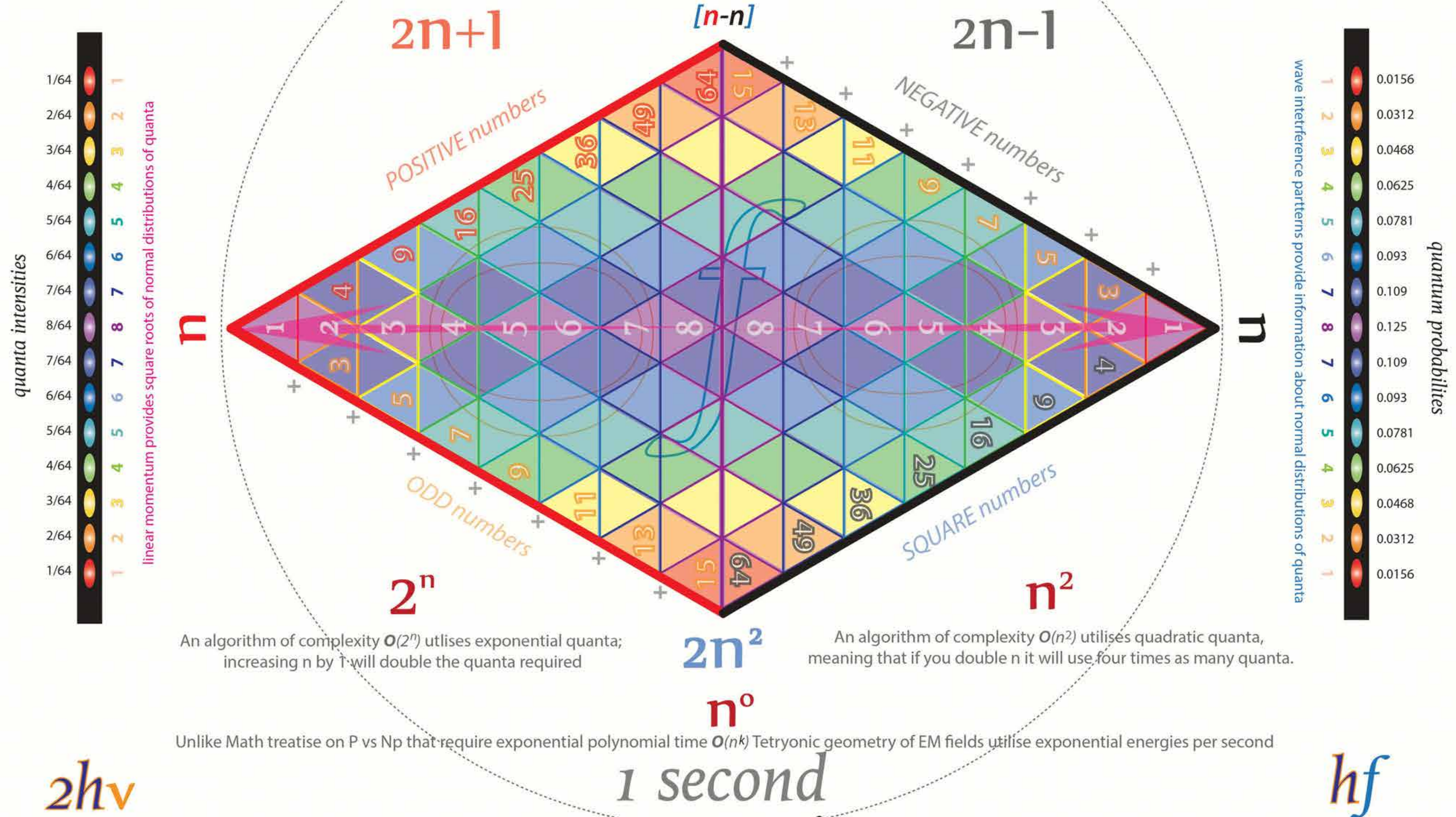
q
bosons
E
photons
2n+1
[n-n]
2n-1
POSITIVE numbers
NEGATIVE numbers
ODD numbers
SQUARE numbers
1 4 9 16 25 36 49 64
3 5 7 9 11 13 15
1 2 3 4 5 6 7 8 8 7 6 5 4 3 2 1
15 13 11 9 7 5 3
4 9 16 25 36 49 64
f
n
n
quanta intensities
1/64
2/64
3/64
4/64
5/64
6/64
7/64
8/64
7/64
6/64
5/64
4/64
3/64
2/64
1/64
linear momentum provides square roots of normal distributions of quanta
wave interference parterns provide information about normal distributions of quanta
quantum probabilites
0.0156
0.0312
0.0468
0.0625
0.0781
0.093
0.109
0.125
0.109
0.093
0.0781
0.0625
0.0468
0.0312
0.0156
2^n
n^2
$2n^2$
n^o
1 second
2hv
hf

An algorithm of complexity $O(2^n)$ utlises exponential quanta; increasing n by 1 will double the quanta required

An algorithm of complexity $O(n^2)$ utilises quadratic quanta, meaning that if you double n it will use four times as many quanta.

Unlike Math treatise on P vs Np that require exponential polynomial time $O(n^k)$ Tetryonic geometry of EM fields utilise exponential energies per second

By relating p to the number of equilateral wave fields in any EM wave very large $[pn^2]$ data sets can be modelled and processed every second

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Quantum Cryptography

If the numerical sequences were applied to amplitude modulation
their non-repeating numerical sequences would appear
to be purely random noise

**Using Tetryonic geometry
advanced non-repeating cyphers
of any complexity
can be easily developed**

The level of encryption can
be easily increased (without limit)
by increasing the dimensions
of the cypher geometry

eg: number of quanta
2D vs 3D geometries

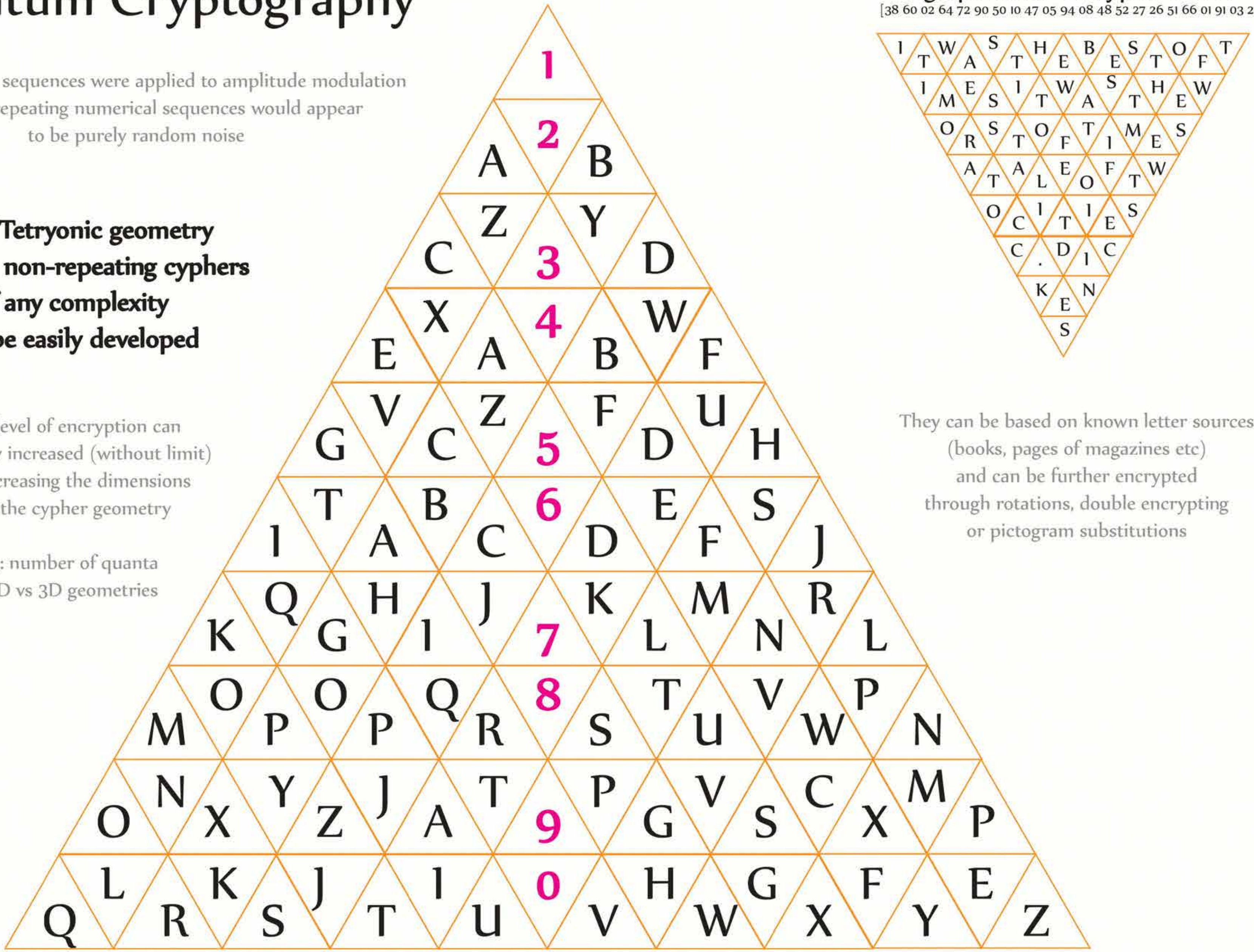
1
A 2 B
C Z 3 Y D
E X A 4 B W F
G V C Z 5 F D U H
I T A B C 6 D E F S J
K Q G H I J 7 K L M N R L
M O P O P Q R 8 S T U V W P N
O N X Y Z J A T 9 P G V S C X M P
Q L R K S J T I U 0 V H W G X F Y E Z

eg: quantum encryption 1024

[38 60 02 64 72 90 50 10 47 05 94 08 48 52 27 26 51 66 01 91 03 20]

I T W A S T H E B E S T O F T
I M E S I T W A S T H E W
O R S T O F T I M E S
A T A L E O F T W
O C I T I E S
C . D I C
K E N
S

They can be based on known letter sources
(books, pages of magazines etc)
and can be further encrypted
through rotations, double encrypting
or pictogram substitutions

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Quantum Computing

The Proton/Neutron geometries of atomic nuclei can be built at the quantum scale
to create an atomic nuclei that can operate as a Opto-memory-transistive computing element,
many elements can then be combined in lattices to create super computers no larger than bacterium

Spin UP

Energy can be gated through individual nuclei
using the centre Baryon as the base transistor element,
in turn effecting the energies of bound photo-electrons

Spin DOWN

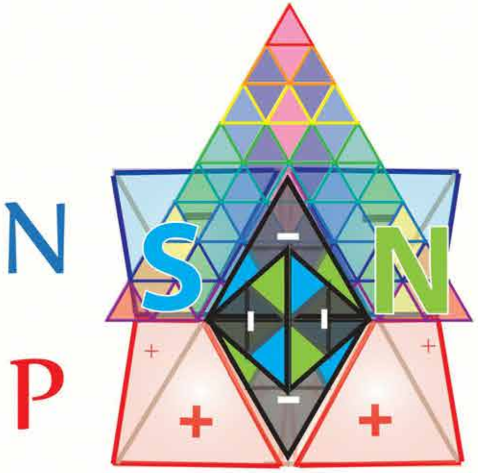

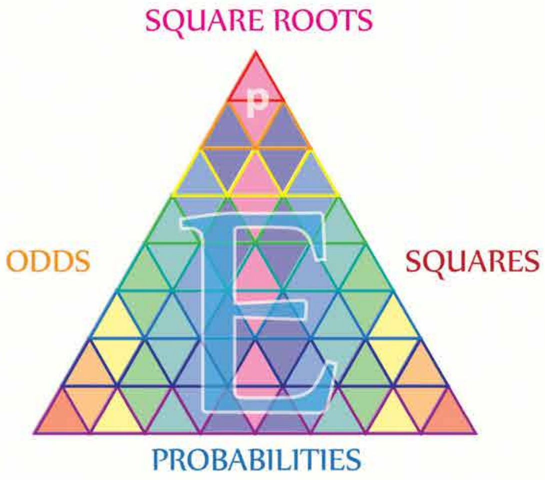

Q-bits

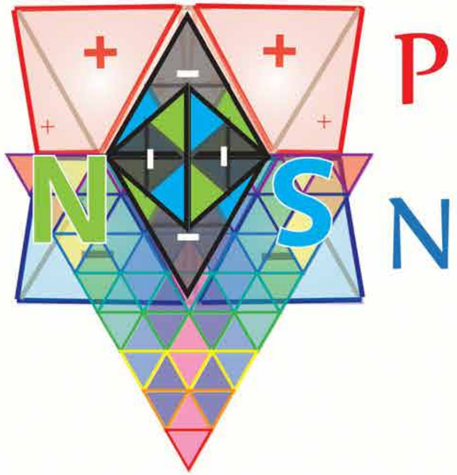

1

photo-electronic transitions can be used to directly recieve
or emit memory states through the absorption and emission
of spectral photons of specific energy momenta

0

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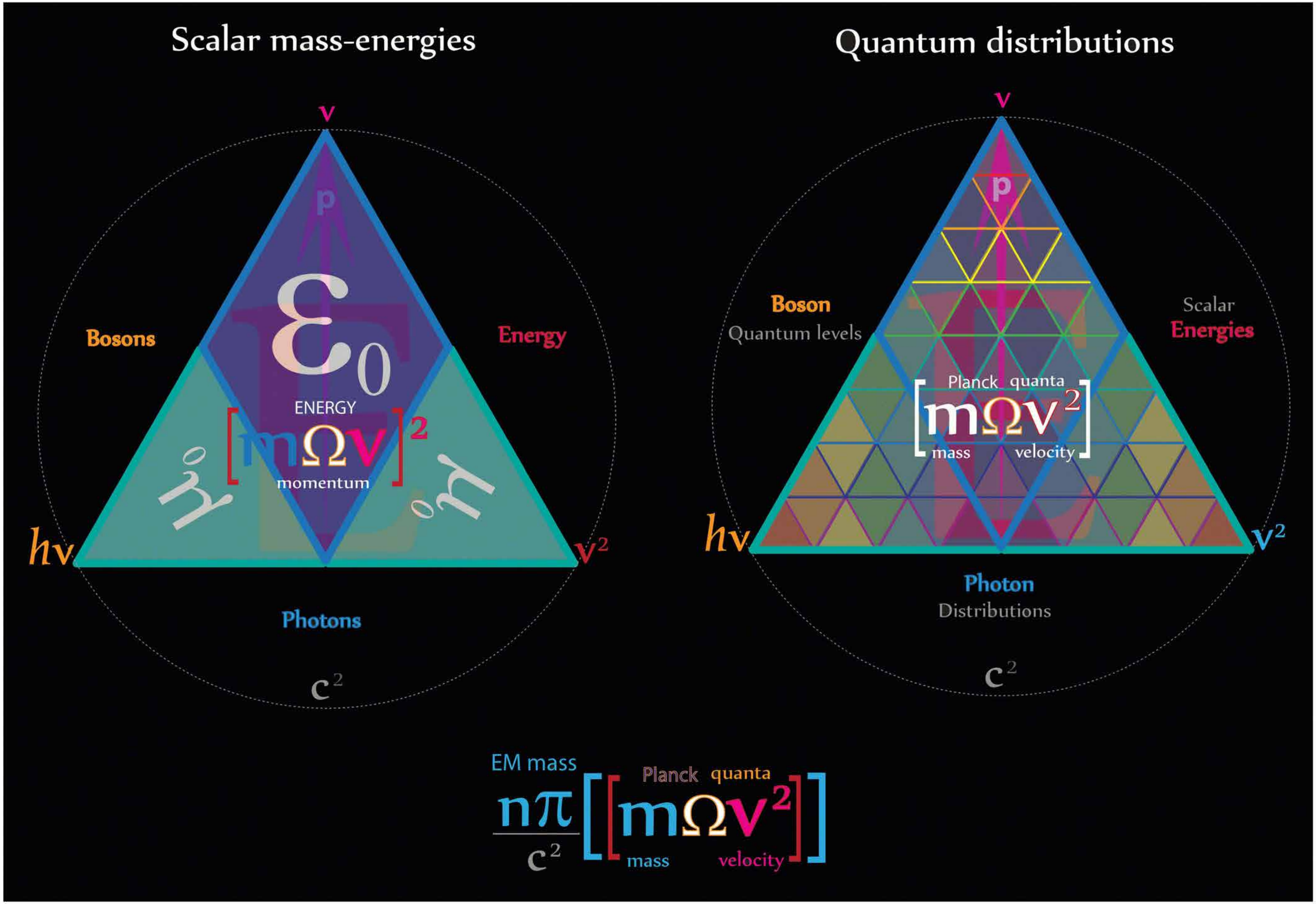
Scalar mass-energies
v
p
ε_0
ENERGY
$[m\Omega v]^2$
momentum
Bosons
Energy
hv
v²
Photons
c²
Quantum distributions
v
p
Boson
Quantum levels
Scalar
Energies
Planck quanta
$[m\Omega v^2]$
mass
velocity
hv
v²
Photon
Distributions
c²
EM mass
Planck quanta
$\frac{n\pi}{c^2}[[m\Omega v^2]]$
mass
velocity

Tetryonics 99.01 - mass-Energy geometry

2D mass

EM mass

$$\frac{n\pi}{c^2}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

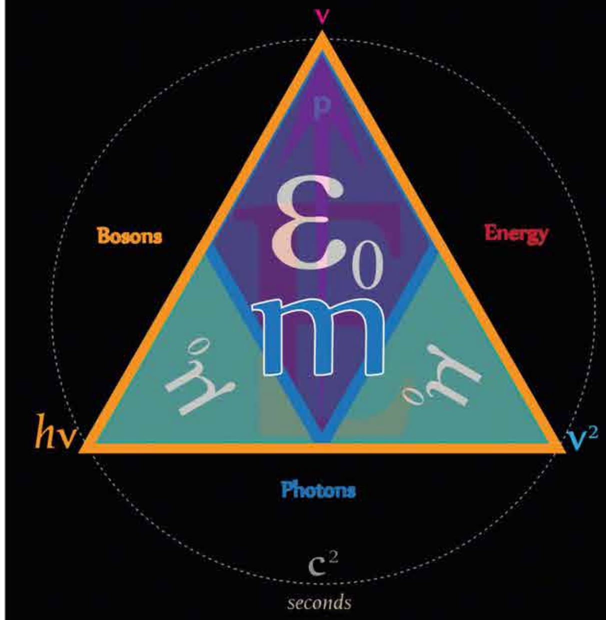
v
p
ε_0
m
Bosons
Energy
hv
v^2
Photons
c^2
seconds

Measure of planar energies
in a nπ radiant wave
geometry
[per second]

mass quantum

7.376238634 e-51 kg

ENERGY

ENERGY

$$n\pi\left[\left[\underset{\text{momenta}}{m\Omega v^2}\right]\right]$$

Equilateral energy momenta
has a mass equivalence
per unit of Time

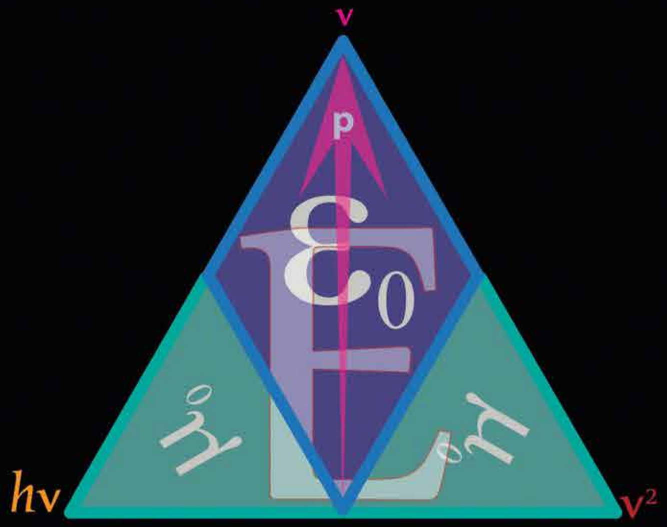
v
p
ε_0
E
hv
v^2

c^2 is the radial geometry
created by radiant energy
in 1 second

Planck Constant

6.629432672 e-34 J.s

3D Matter

Matter

$$\frac{T\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Measure of mass-energy
in a 4nπ standing wave
topology
[per second squared]

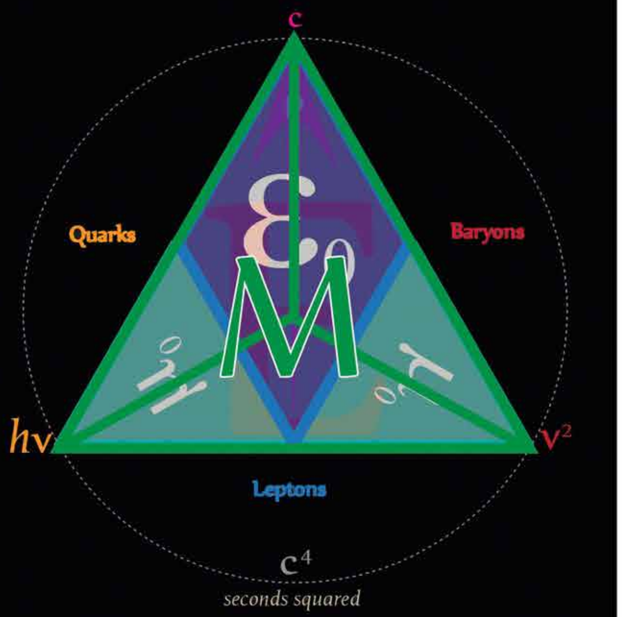
c
ε_0
M
Quarks
Baryons
hv
v^2
Leptons
c^4
seconds squared

Matter quantum

2.9504955454 e-50 kg

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Planck's constant - the quantum of Action

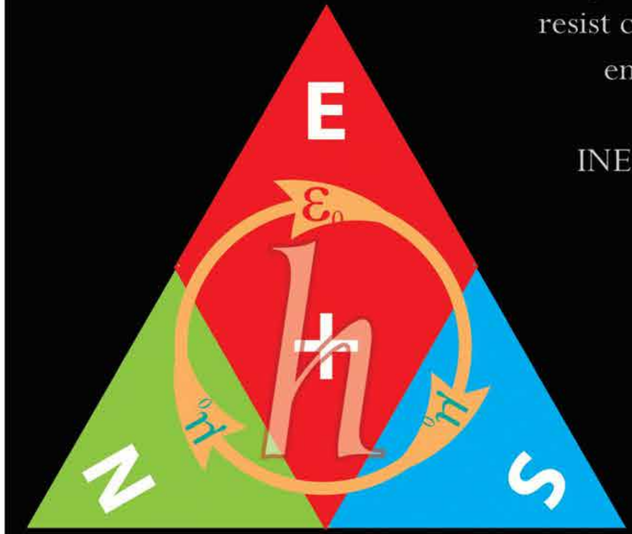
E
ε_0
$\hbar$
μ_0
μ_0
N
S

all ideal quantum inductive loops
resist changes to their
energy levels

INERTIAL mass

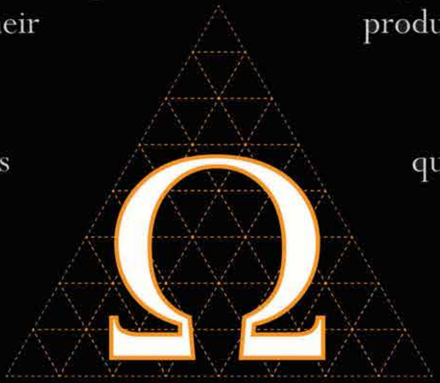

all equilateral energy momenta
produce square root vector
Forces

quantum of WORK

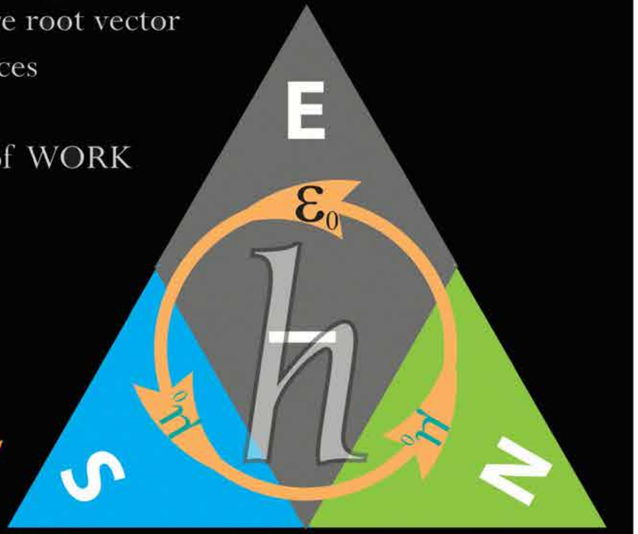
E
ε_0
$\hbar$
μ_0
μ_0
S
N

Quantised angular momentum is equilateral geometry

The two sides of Planck's Constant

The square root of all Energy is linear momentum

Equilateral
energy quanta
per second

mass

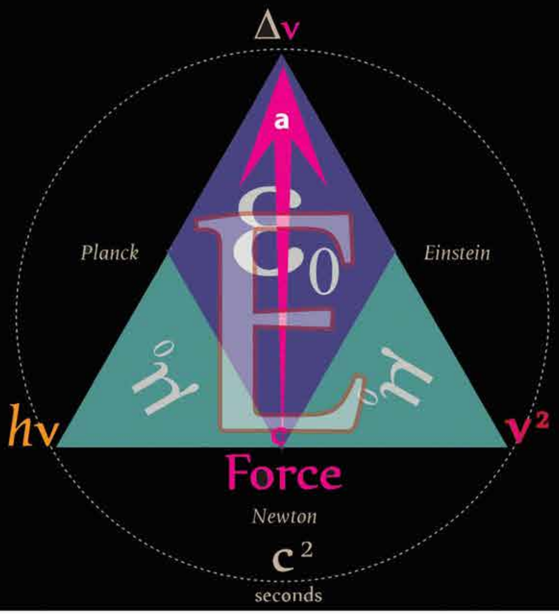
Δv
a
ε_0
E
Planck
Einstein
μ_0
μ_0
hv
v^2
Force
Newton
c^2
seconds

Quantised
angular momenta
per second

time

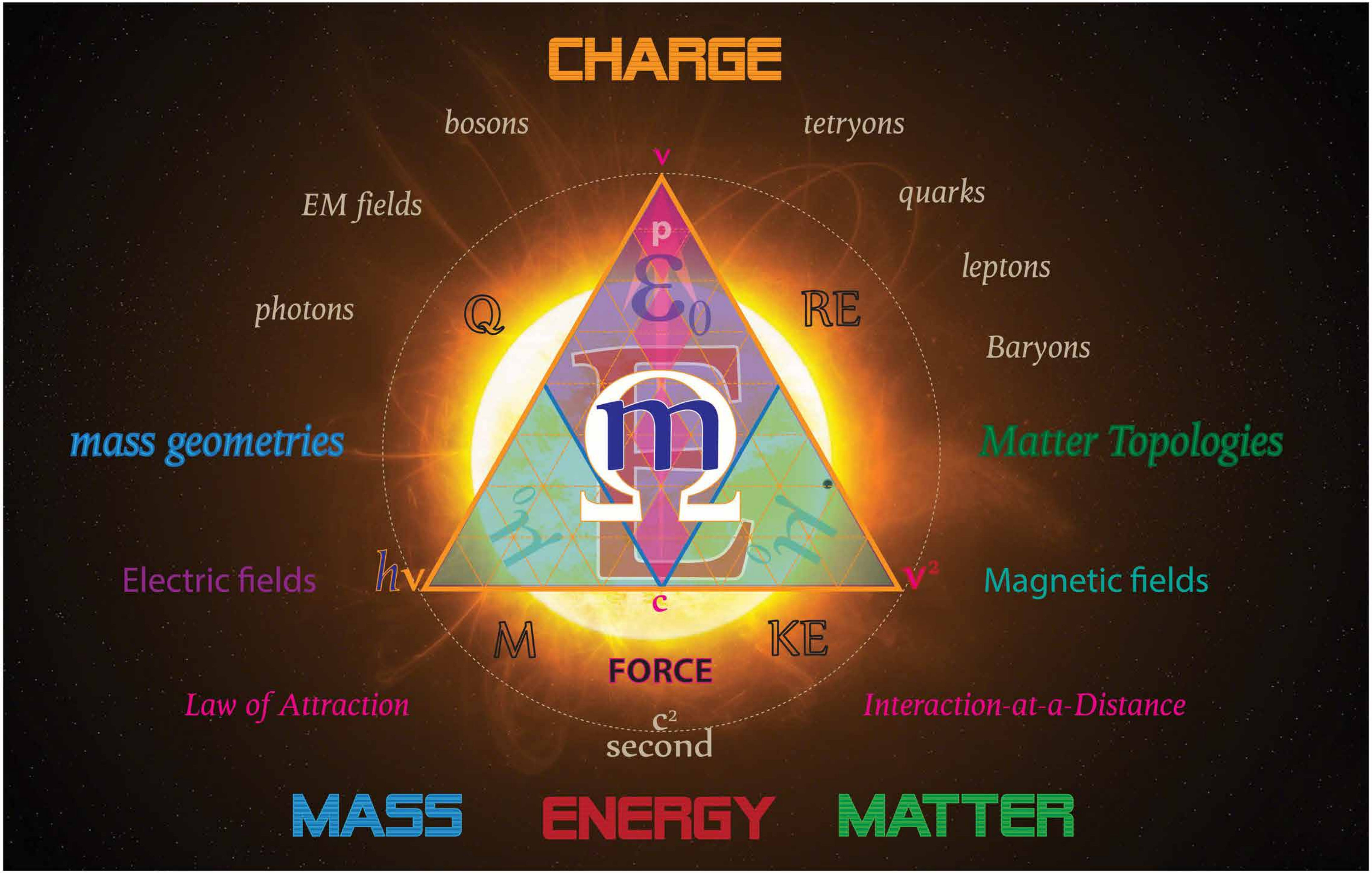

CHARGE

bosons

tetryons

EM fields

quarks

leptons

photons

Baryons

mass geometries

Matter Topologies

Electric fields

Magnetic fields

FORCE

Law of Attraction

Interaction-at-a-Distance

c^2

second

MASS ENERGY MATTER

Tetryonics 99.04 - Charged Planck mass-ENERGY-Matter

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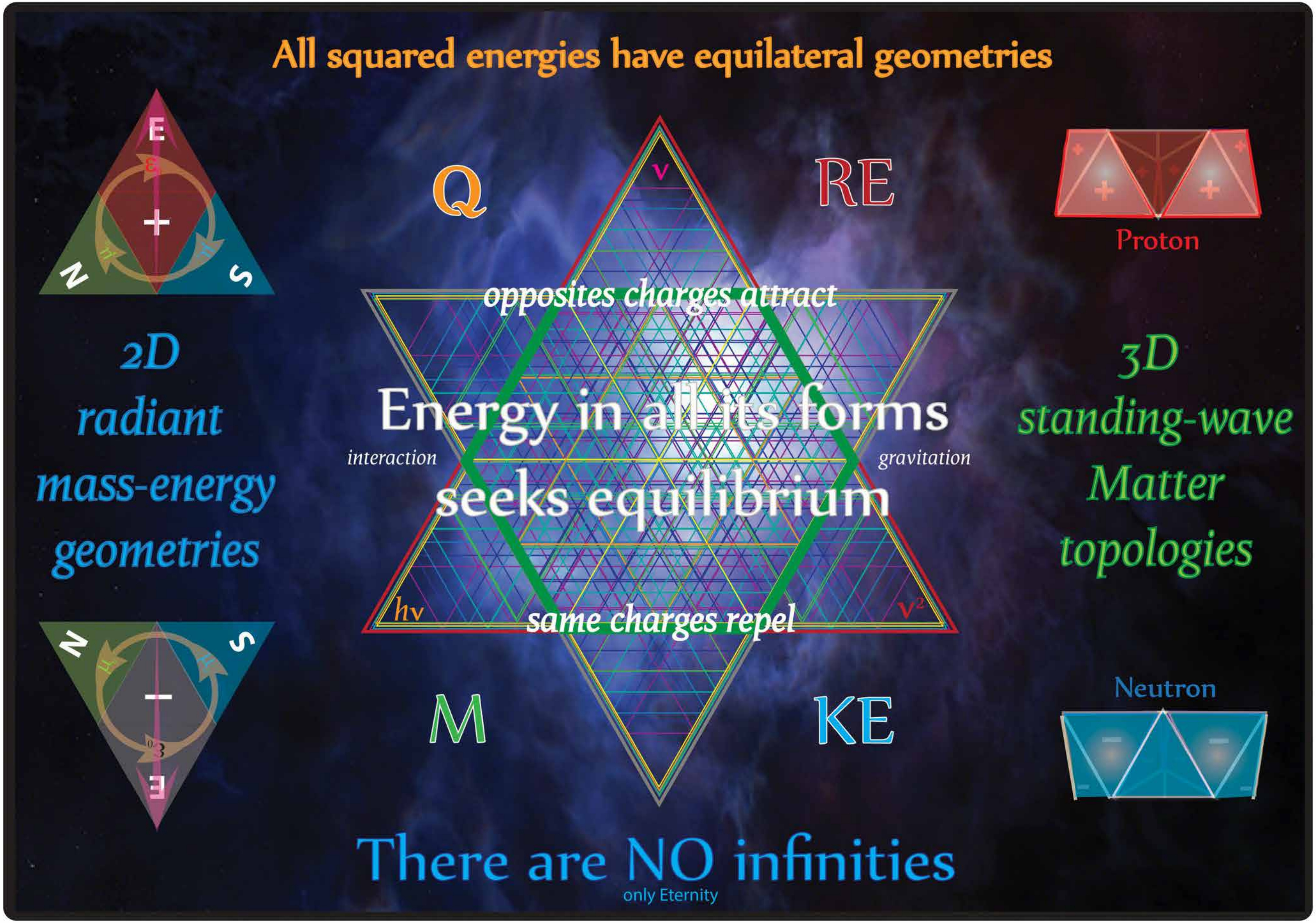

All squared energies have equilateral geometries

2D radiant mass-energy geometries

3D standing-wave Matter topologies

Energy in all its forms seeks equilibrium

opposites charges attract

same charges repel

There are NO infinities

only Eternity

E
+
N
S
N
S
–
E
Q
RE
M
KE
ν
hν
ν²
interaction
gravitation
Proton
Neutron

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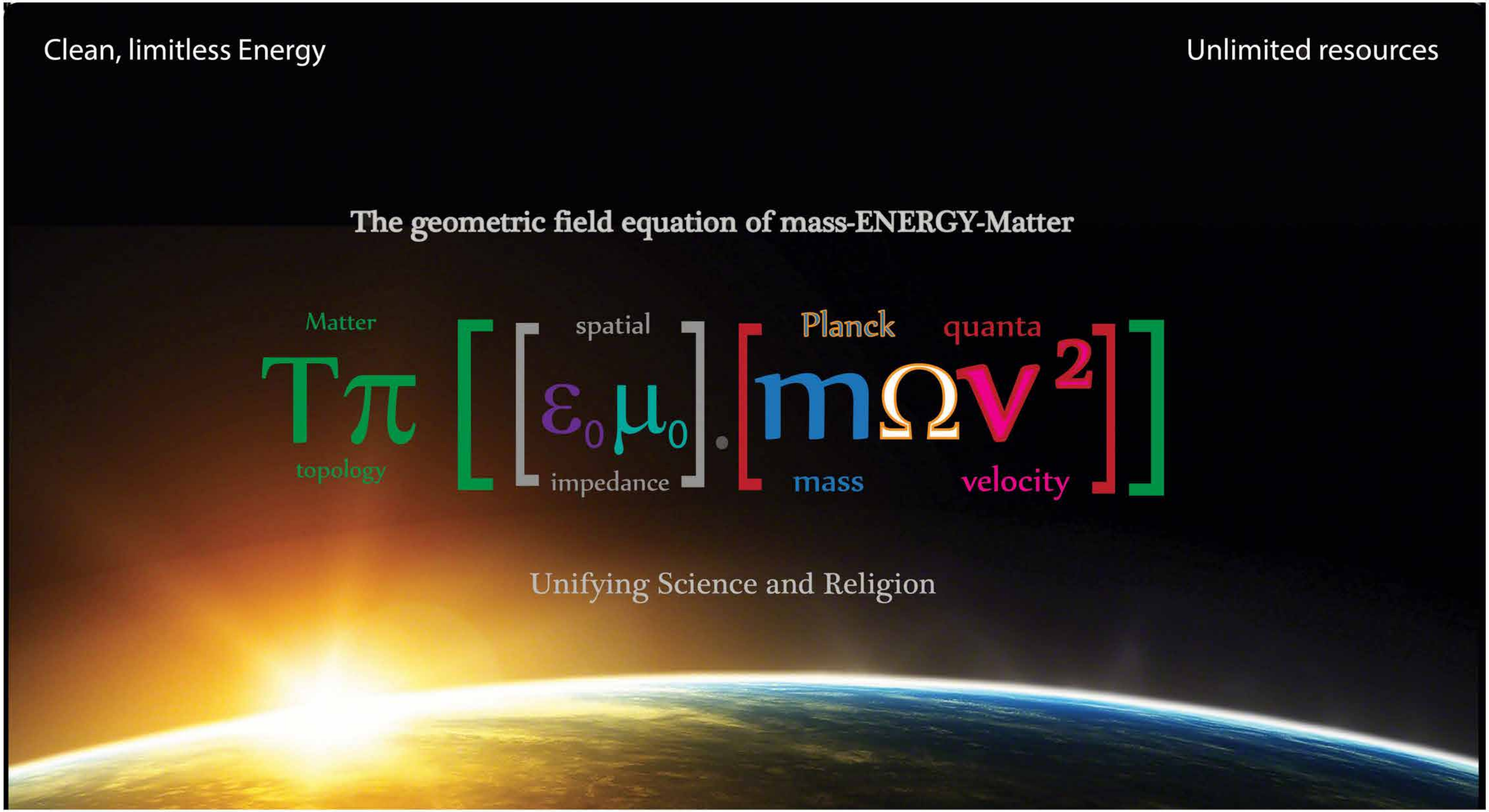

Clean, limitless Energy

Unlimited resources

The geometric field equation of mass-ENERGY-Matter

Matter

topology

spatial

impedance

Planck

quanta

mass

velocity

$$T\pi\left[\left[\varepsilon_0\mu_0\right]\cdot\left[m\Omega v^2\right]\right]$$

Unifying Science and Religion

Tetryonic Theory

All EM mass, energy momenta & Matter can be measured and geometrised with respect to equilateral Quantised Angular Momenta

charged Planck quanta

Bosons

$$\frac{\text{ODD}\,\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

Planck quanta mass velocity

Total Relativistic energies

ENERGY

$$n\pi\left[\left[m\Omega v^2\right]\right]$$

Planck quanta mass velocity

Quantum Mechanics

Quantum Cosmology

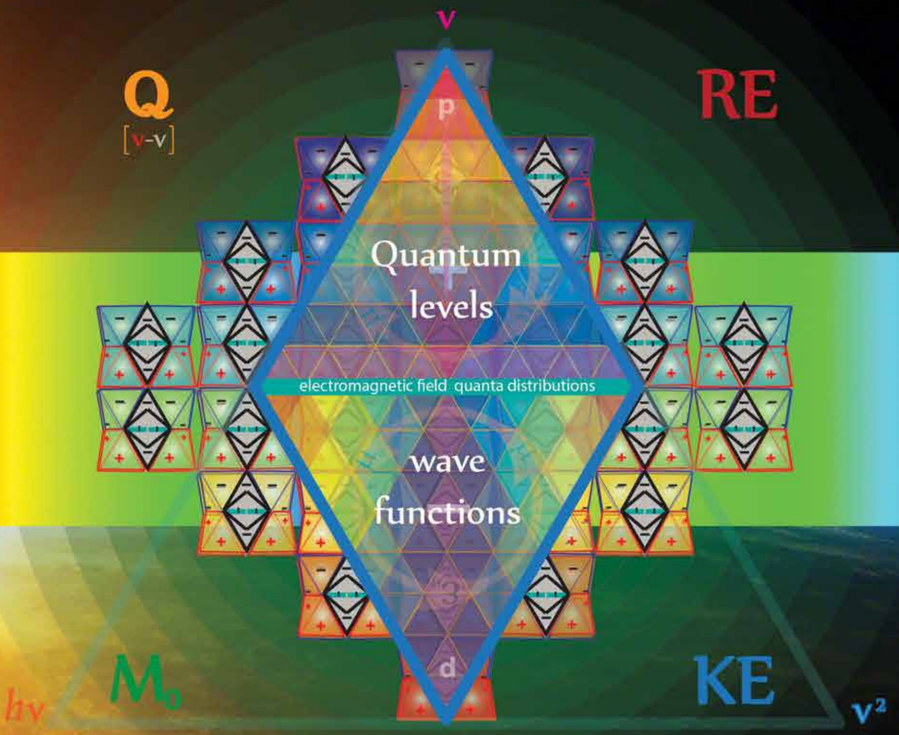

standing-wave mass-Matter

radiant EM mass-energies

Quantum Chemistry

Electrodynamics

Matter

$$\frac{T\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

Planck quanta mass velocity

EM waves

$$\frac{\text{EVEN}\,\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

Planck quanta mass velocity

3D standing-wave mass/Matter topologies

2D radiant mass-energy geometries

The application of equilateral QAM geometries covers all of the Physical disciplines

Tetryonic Geometrics

The equilateral geometry underpinning the mathematics of Physics

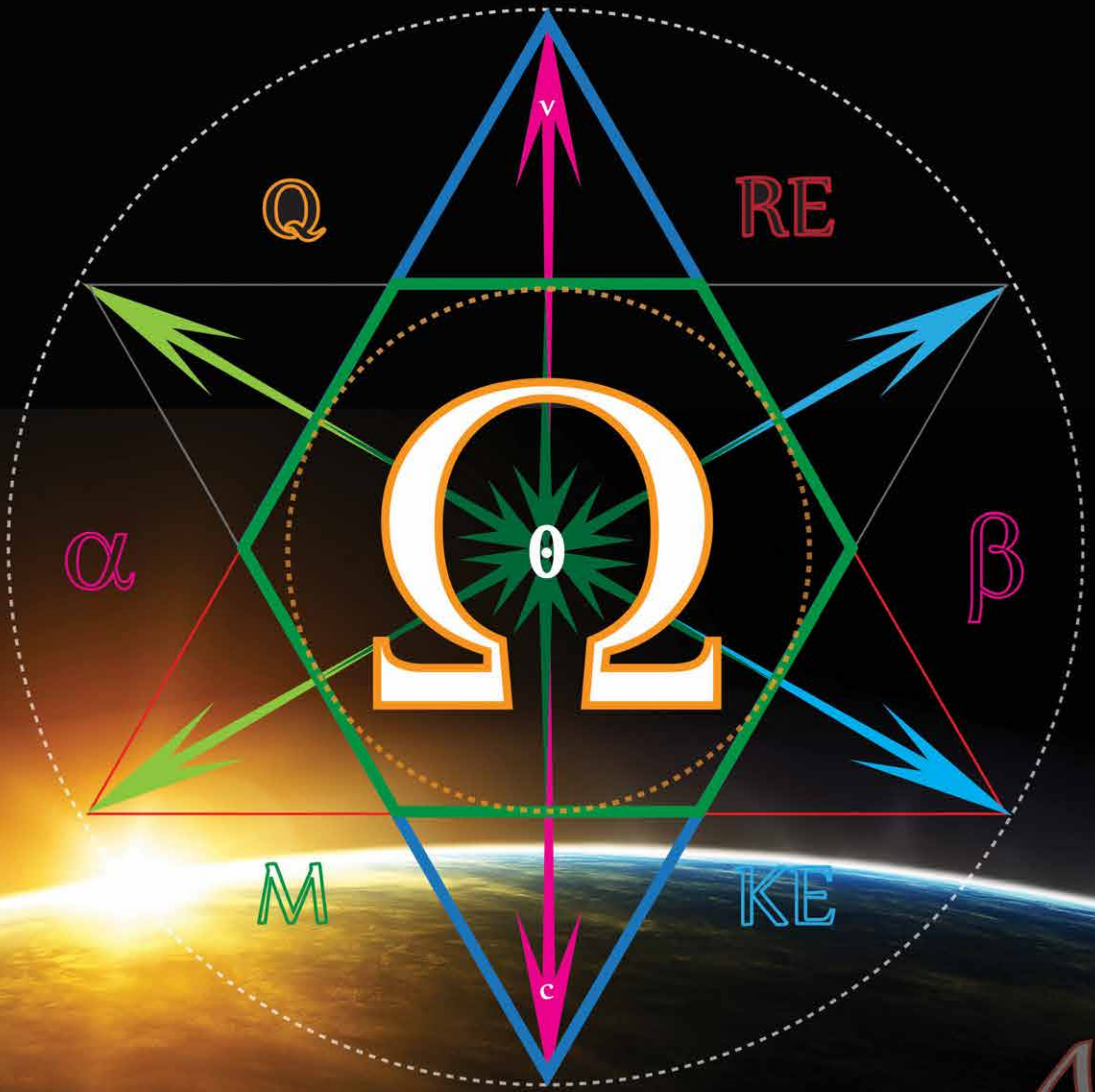

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TETRYONICS

The equilateral geometry underpinning the mathematics of Physics

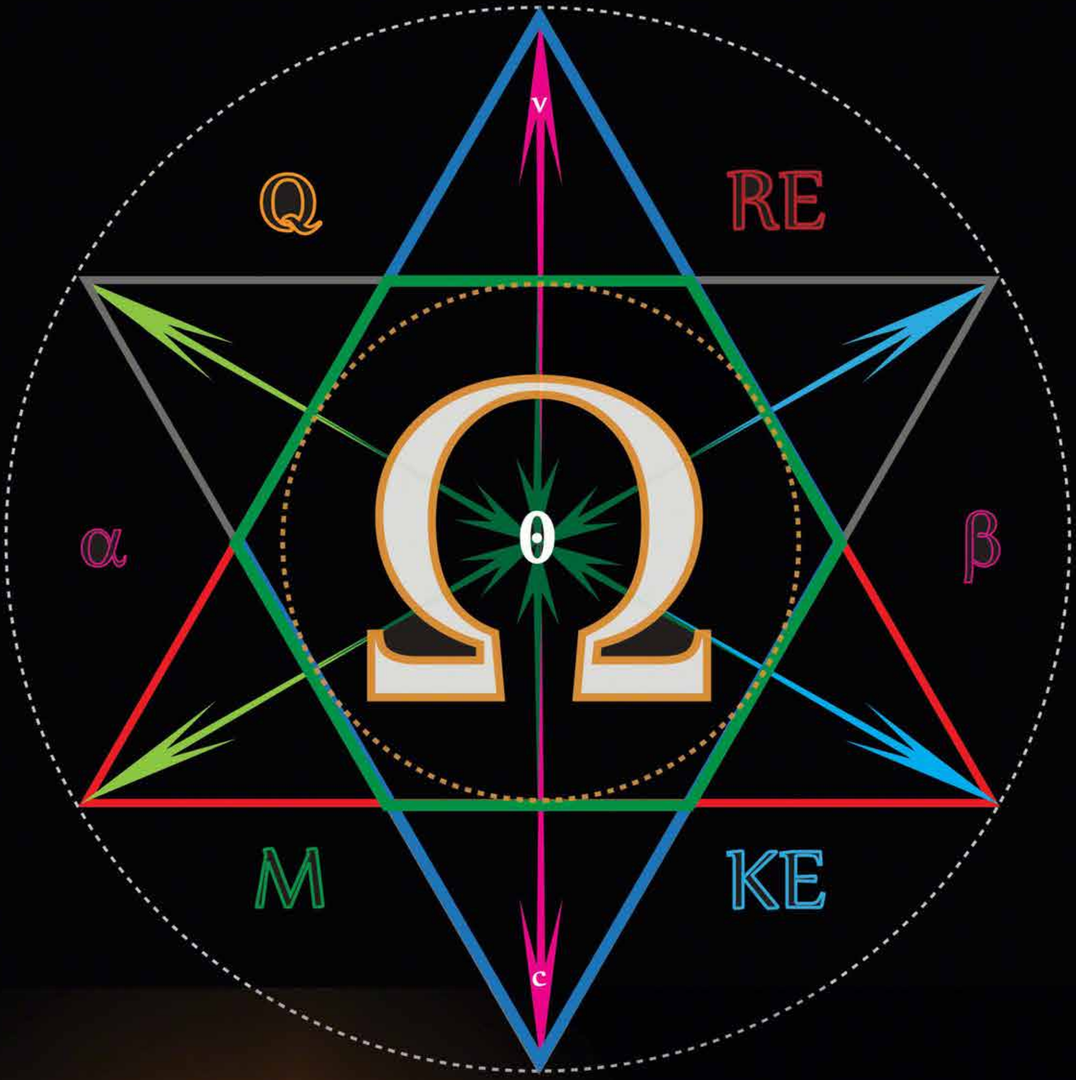

Foundational physics Mathematics

Abraham

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Geometry and the Theory of Everything

Plato

(c.428-348 BC)

DIFFERENT TYPE OF GEOMETRIES

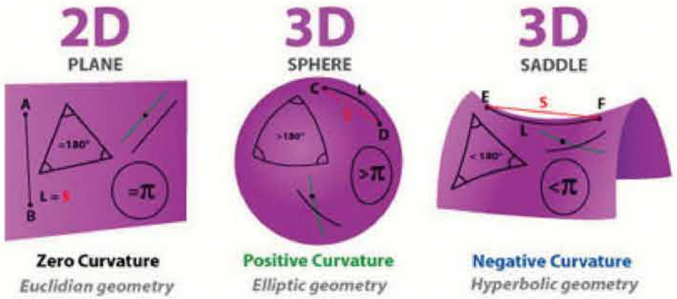

Zero Curvature *Euclidian geometry*

Positive Curvature *Elliptic geometry*

Negative Curvature *Hyperbolic geometry*

(studied by Omar Khayyam, Girolamo Saccheri, Bernhard Riemann, ...)

Euclid

(c.330-275 BC, fl. c.300 BC)

The Socratic tradition was not particularly congenial to mathematics, as may be gathered from Socrates' inability to convince himself that 1 plus 1 equals 2, but it seems that his student Plato gained an appreciation for mathematics after a series of conversations with his friend Archytas in 388 BC.

One of the things that most caught Plato's imagination was the existence and uniqueness of what are now called the five "Platonic solids".

It's uncertain who first described all five of these shapes - it may have been the early Pythagoreans - but some sources (including Euclid) indicate that Theaetetus (another friend of Plato's) wrote the first complete account of the five regular solids.

Presumably this formed the basis of the constructions of the Platonic solids that constitute the concluding Book XIII of Euclid's Elements.

In any case, Plato was mightily impressed by these five definite shapes that constitute the only perfectly symmetrical arrangements of a set of (non-planar) points in space, and late in life he expounded a complete "theory of everything", in the treatise called Timaeus, based explicitly on these five solids.

Interestingly, almost 2000 years later, Johannes Kepler was similarly fascinated by these five shapes, and developed his own cosmology from them

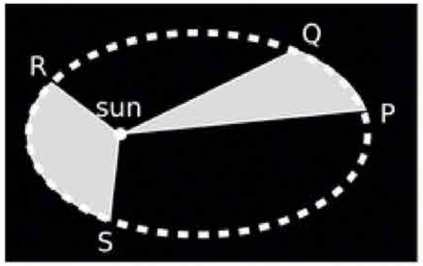

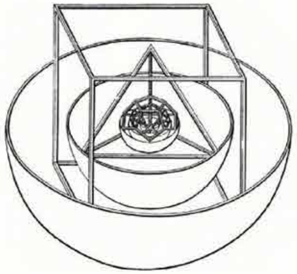

Tetractys

The Greek Tetractys is a
triangular figure consisting of ten points
arranged in four rows:

one, two, three, and four points in each row,
which is the geometrical representation of the
fourth triangular number.

As a mystical symbol, it was very important to
the secret worship of the Pythagoreans.

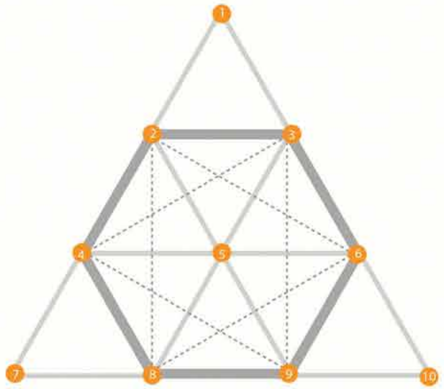

Sacred numbers

A

The Tetractys historically symbolized the four elements
[Earth, Air, Fire, and Water]
and the relationship between Humanity
and the cosmos created by GOD

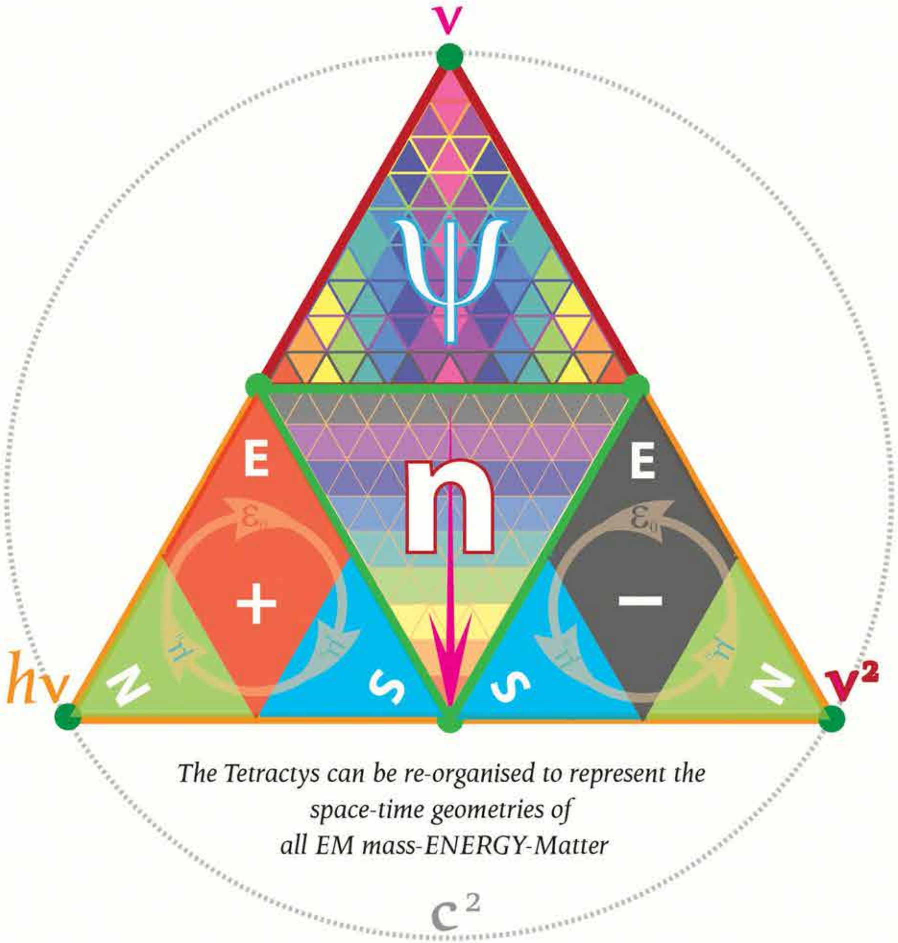

*The Tetractys can be re-organised to represent the
space-time geometries of
all EM mass-ENERGY-Matter*

The tetrad was the name given to
the number four -
in Pythagorean philosophy
there were four seasons
and four elements,
and the number was also associated
with planetary motions and music

As a mystical symbol, it was very important to
the secret worship of the Pythagoreans.

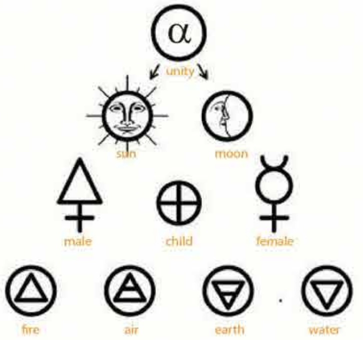

The Cosmos

Ω

The single triangle in the first row represents zero-dimensions (a point)

A vector direction in one-dimension can be represented as a line between any two points

The second row represents a Boson (two-dimensions in a plane defined by a rhombus of three triangles)

The whole figure folded represents three-dimensions (a tetrahedron defined by four apex points)

Photons of ElectroMagnetic mass-Energy quanta are represented by two opposing triangles

The Greek Zodiac

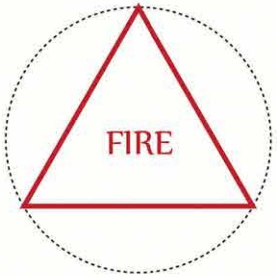

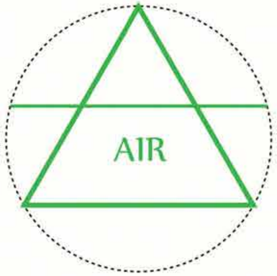

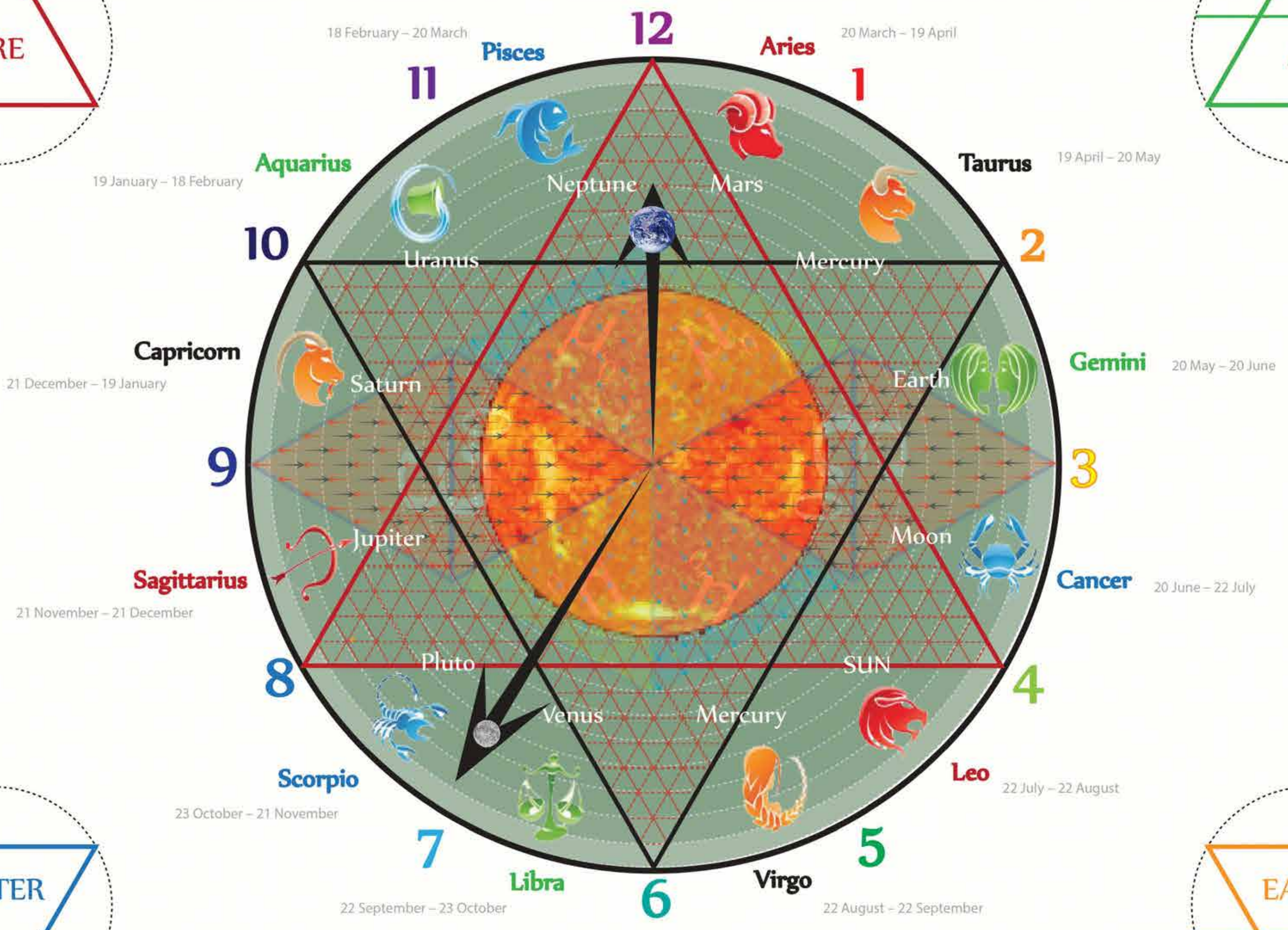
12
Aries
20 March – 19 April
1
Taurus
19 April – 20 May
2
Gemini
20 May – 20 June
3
Cancer
20 June – 22 July
4
Leo
22 July – 22 August
5
Virgo
22 August – 22 September
6
Libra
22 September – 23 October
7
Scorpio
23 October – 21 November
8
Sagittarius
21 November – 21 December
9
Capricorn
21 December – 19 January
10
Aquarius
19 January – 18 February
11
Pisces
18 February – 20 March
Neptune
Mars
Uranus
Mercury
Saturn
Earth
Jupiter
Moon
Pluto
SUN
Venus
Mercury

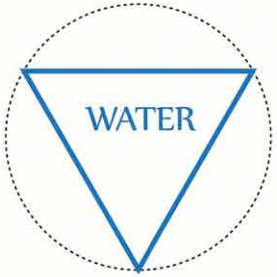

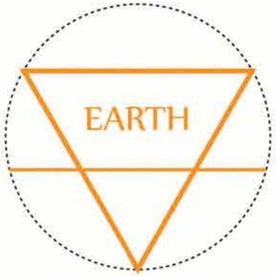

The Greek Elements

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Equilateral Triangles

An equilateral triangle is a triangle in which all three sides are equal

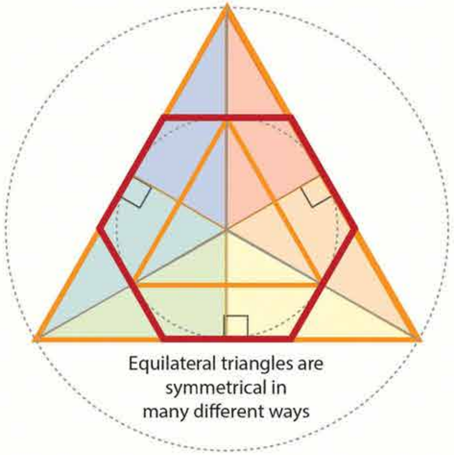

Equilateral triangles are symmetrical in many different ways

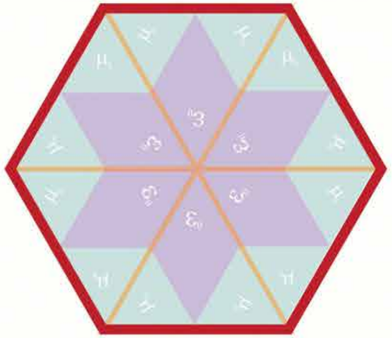

Any six equilateral triangles joined can make a hexagon.

It is unique in that it is the only polygon
that can be tiled [or divided] and produce
only identical geometries and squares numbers

The equilateral triangle
is eminently suited for
the construction of fractals

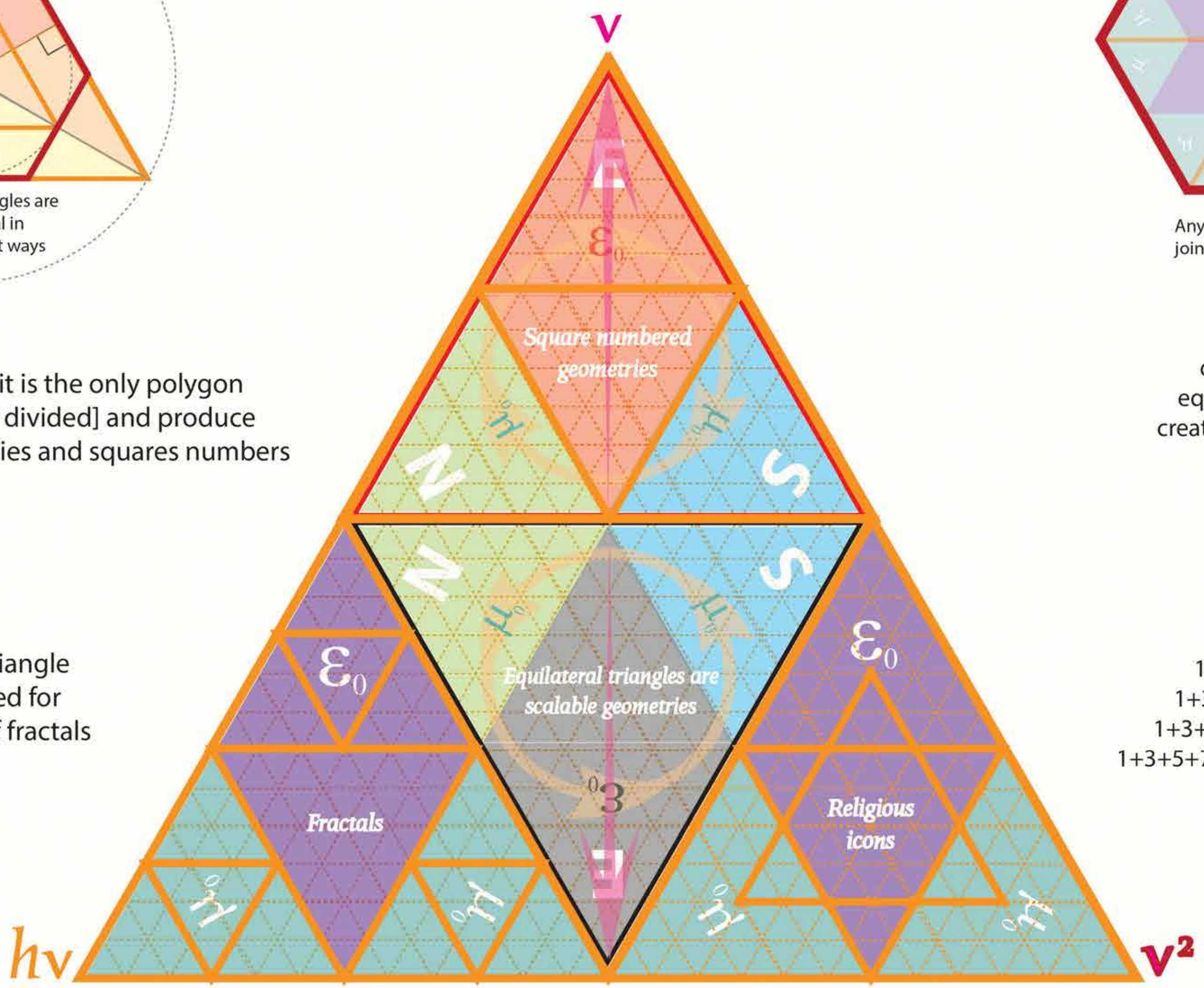
v
ε0
Square numbered geometries
μ0
N
S
Equilateral triangles are scalable geometries
ε0
Fractals
Religious icons
hv
v²

The
tesselation of
odd numbered
equilateral triangles
creates square numbers

That is,

1
1+3 = 4
1+3+5 = 9
1+3+5+7 = 16
1+3+5+7+9 = 25
1+3+5+7+9+11 = 36
1+3+5+7+9+11+13 = 49
1+3+5+7+7+9+11+13+15 = 64
etc

An equilateral triangle is simply a specific case of a regular polygon with 3 sides

The Pythagorean Theorem

Though attributed to Pythagoras, it is not certain that he was the first person to prove it.

The first clear proof came from Euclid, and it is possible the concept was known
1000 years before Pythoragas by the Babylonians

$$a^2 + b^2 = c^2$$

The square of the hypotenuse of a triangle is equal to the sum of the squares of its sides.

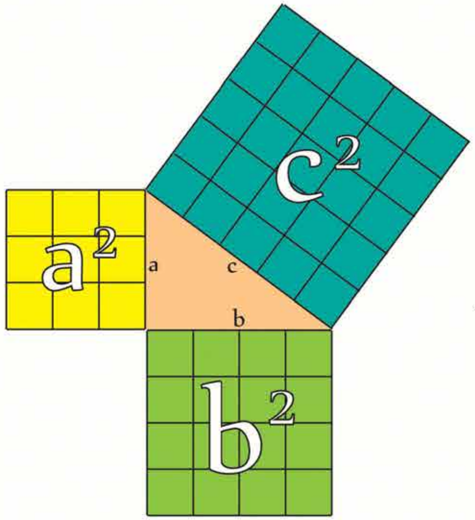

In any right triangle,
the area of the square whose side is the hypotenuse
(the side opposite the right angle) is equal to
the sum of the areas of the squares
whose sides are the two legs
(the two sides that meet at a right angle)

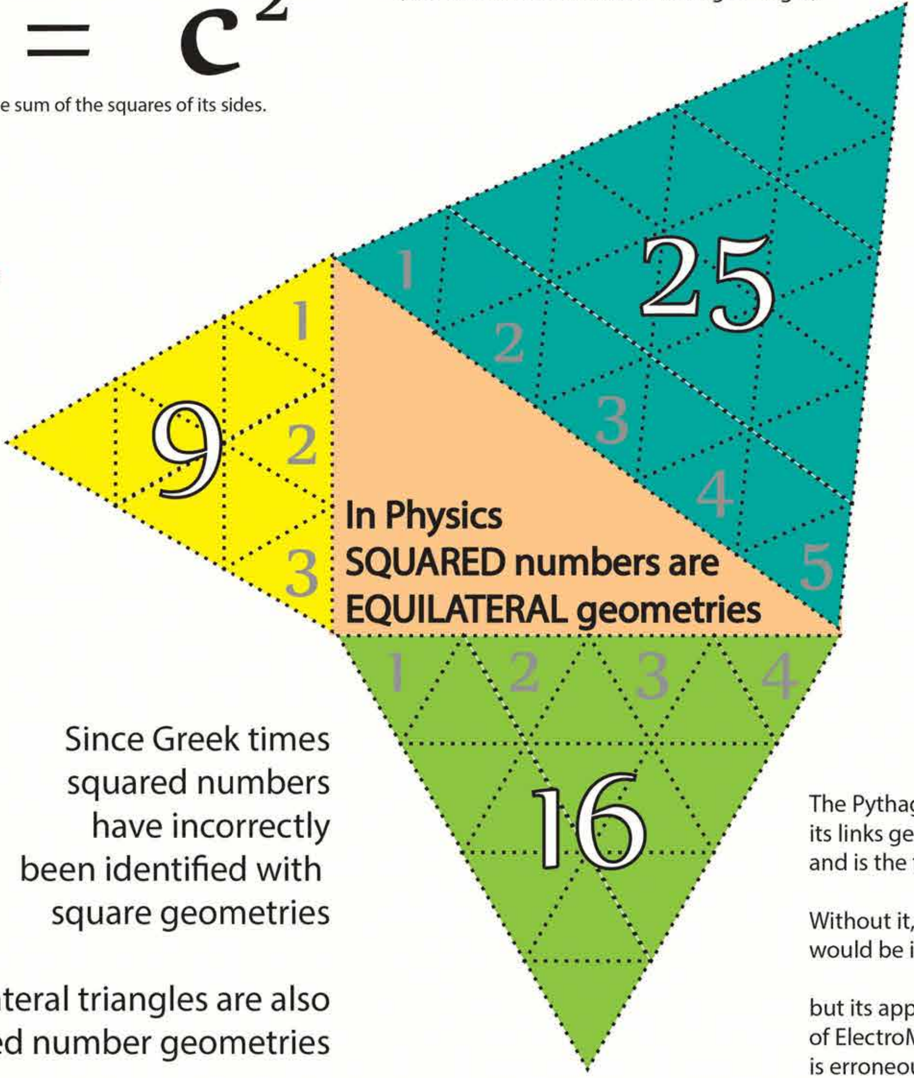

In Physics
SQUARED numbers are
EQUILATERAL geometries

Pythagoras of Samos

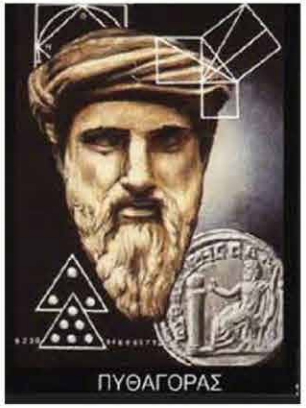

about (570 – 495 BC)

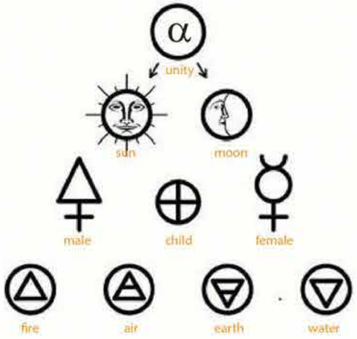

Pythagorean Tetractys

Since Greek times
squared numbers
have incorrectly
been identified with
square geometries

Equilateral triangles are also
squared number geometries

The Pythagorean equation is at the core of much of geometry,
its links geometry with algebra,
and is the foundation of trigonometry.

Without it, accurate surveying, mapmaking, and navigation
would be impossible,

but its application to the energy-momenta geometries
of ElectroMagnetic fields and Matter in motion in Physics
is erroneous and must be corrected for science to advance

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Hexagons

A regular hexagon can be subdivided into six equilateral triangles

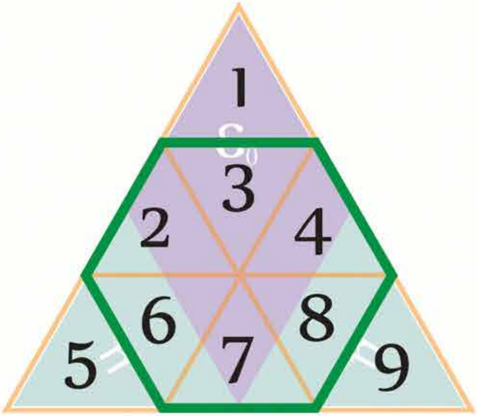

Energy geometries

Hexagons are the only regular polygon that can be subdivided into another regular polygon

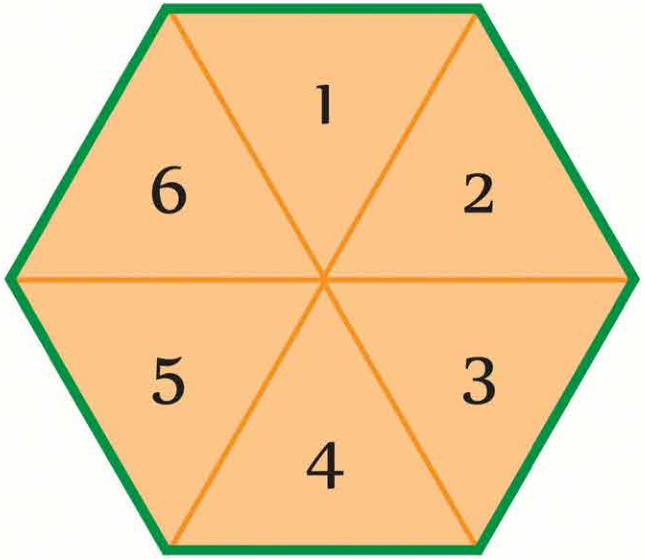

Hexagons are the unique regular polygon such that the distance between the center and each vertex is equal to the length of each side

An interesting relationship between circular and hexagonal geometry is that hexagonal patterns often appear spontaneously when natural forces are trying to approximate circles

Atomic nuclei geometries

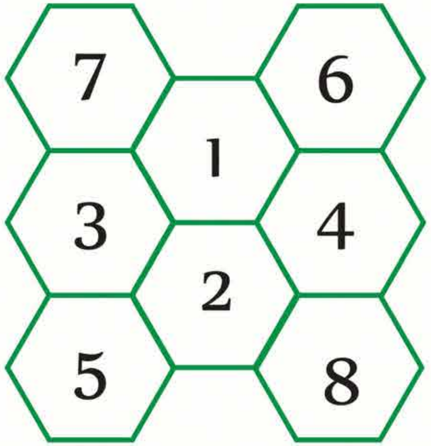

Hexagons can be tiled or tessellated in a regular pattern on a flat two-dimensional plane

Six is a highly composite number,
the second-smallest composite number,
and the first perfect number.

That is, 1*2*3=1+2+3=6

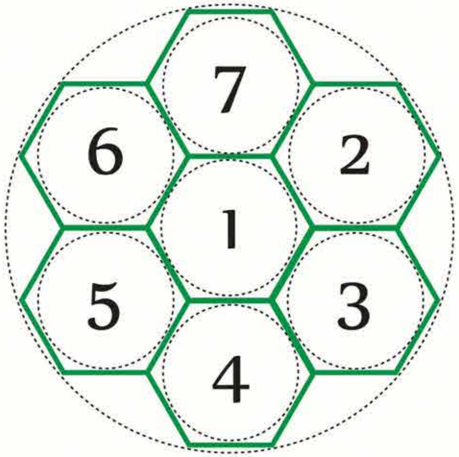

Hexagonal tessellation is topologically identical to the close packing of circles on a plane

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Platonic Solids

The Pythagoreans knew that there were only five regular convex solids, the tetrahedon, cube, octahedron, icosohedron and dodecahedron and each one could be accurately circumscribed by a sphere.

FIRE

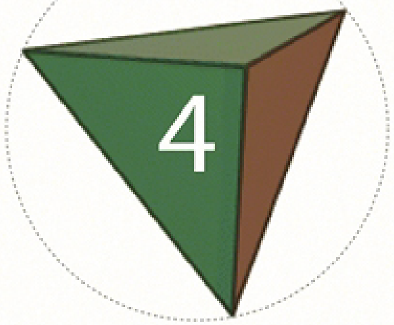

4 triangles meet to form
a Tetrahedron

EARTH

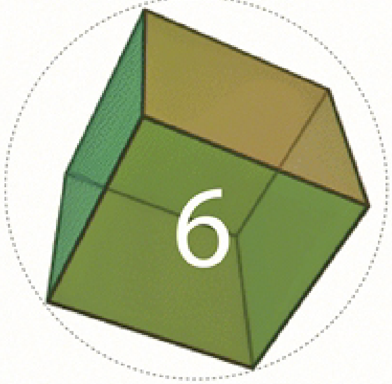

6 squares meet to form
a Cube

AIR

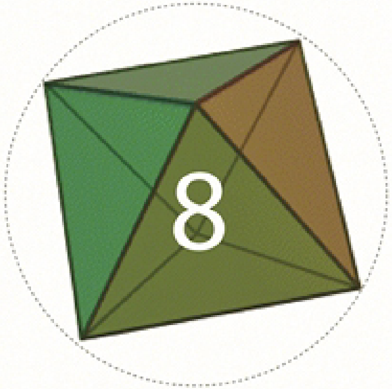

8 triangles meet to form
a Octahedron

tetryons **4**

regular deltahedrons

leptons **12**

$$F - E + V = 2$$

faces edges vertexs

8 ***quarks***

regular deltahedrons

20 ***Baryons***

12 pentagons meet to form
a Dodecahedron

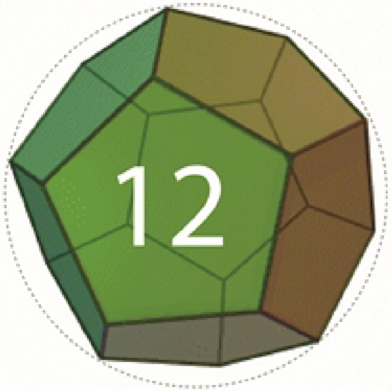

THE HEAVENS

Plato

(c.428-348 BC)

The philosopher Plato concluded that they must be the fundamental building blocks – the atoms – of nature, and assigned to them what he believed to be the essential elements of the universe.

20 triangles meet to form
a Icosahedron

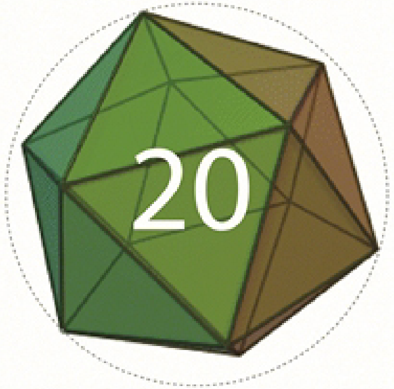

WATER

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Tetryonic Solids

Despite their unique topologies Tetryonic solids are not unlike Platonic solids save that their toplogies are comprised entirely from complex hitherto undescribed **4nπ equilateral Planck mass-energy momenta geometries** that also match the Euler numbers of Platonic solids

+ tetryon

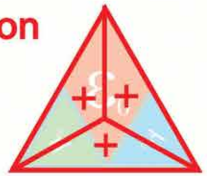

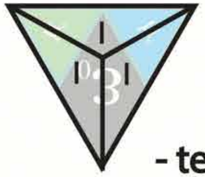

- tetryon

4 faces
6 edges
4 vertices

2

up quark

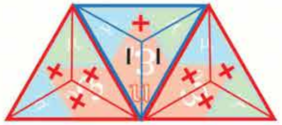

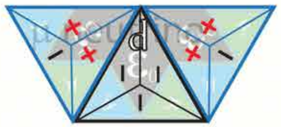

down quark

2

8 faces
12 edges
6 vertices

mass geometries

4π *tetryons* **4π**

regular deltahedrons

12π *leptons* **12π**

Matter topologies

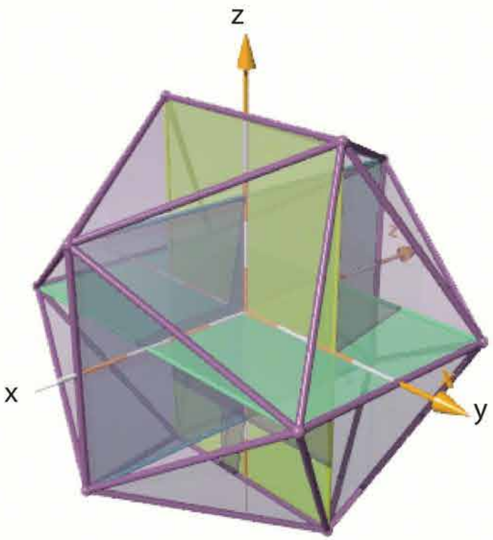

Matter topologies

8π *quarks* **12π**

regular deltahedrons

20π *Baryons* **36π**

mass geometries

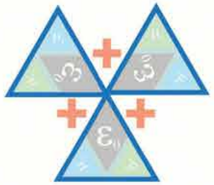

neutrino

electron

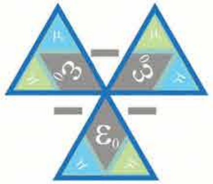

12 faces
18 edges
8 vertices

2

Their equilateral topologies are best described as regular topologic-deltahedrons:

tetra-delta-hedrals	**tetryons**	4π external charge fascia
octa-delta-hedrals	**quarks**	8π external charge fascia
dodeca-delta-hedrals	**leptons**	12π external charge fascia
icoso-delta-hedrals	**Baryons**	20π external charge fascia

note:
Charged mass-energy fascia geometries and edges become "hidden" upon the meshing of delta-hedra to form Matter topologies

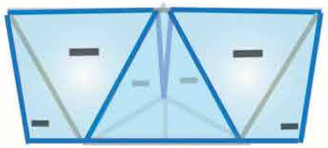

Neutron

2

Proton

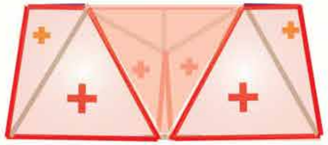

20 faces
30 edges
12 vertices

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Euclidean geometry

Euclid

(c.330-275 BC, fl. c.300 BC)

Arguably the most influential Mathematics book ever written is Euclid's 'The Elements'

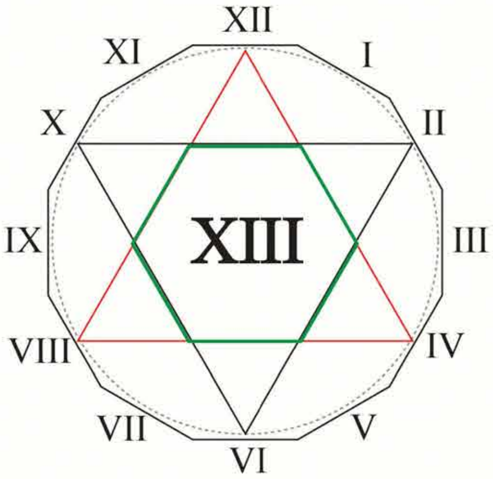

In all, it contains 465 theorems and proofs, described in a clear, logical and elegant style, and using only a compass and a straight edge.

The Elements - Book 1 - Definition 20

Of the trilateral figures, an equilateral triangle is that which has its three EQUAL sides

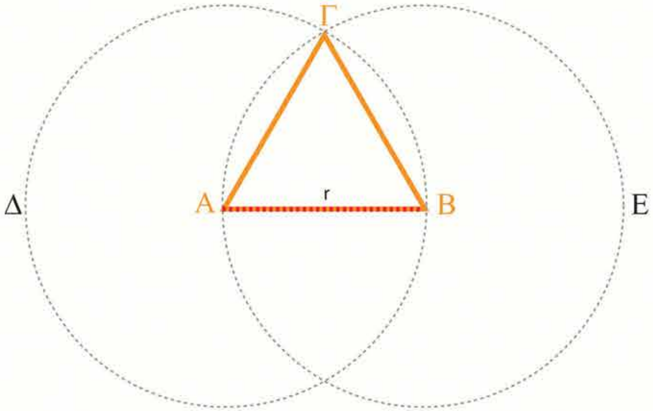

Euclid's Elements - Book 1 - Proposition 1
Method of constructing an Equialteral triangle

Euclid's five general axioms were:

Things which are equal to the same thing are equal to each other.

If equals are added to equals, the wholes (sums) are equal.

If equals are subtracted from equals, the remainders (differences) are equal.

Things that coincide with one another are equal to one another.

The whole is greater than the part

Archimedes

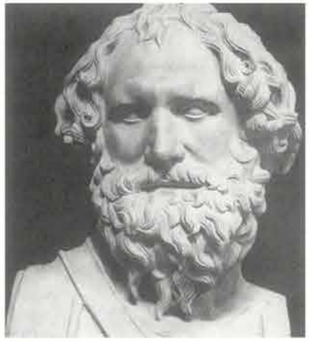

c. (287 BC – c. 212 BC)

As its definition relates to the circle,
π is found in many formulae in trigonometry and geometry,
especially those concerning circles, ellipses, or spheres.

It is also found in formulae from other branches of science,
such as cosmology, number theory, statistics, fractals,
thermodynamics, mechanics, and electromagnetism

Incorrect identification of Pi [c/d] as opposed to Pi radians
in Physics has led to the inappropriate association
of spherical particles to the physical sciences
whereas equilateral triangles & tetrahedra
form its true geometry

The number π is a mathematical constant that is
the ratio of a circle's circumference to its diameter.

Pi

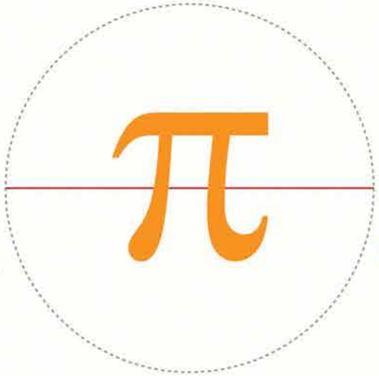

$\pi = c/d$

π is an irrational number
its decimal representation
never ends and never repeats.

The ratio C/d is constant,
regardless of the circle's size

3.141592654........

Proof of the fact that C=2πr and how Archimedes proved it

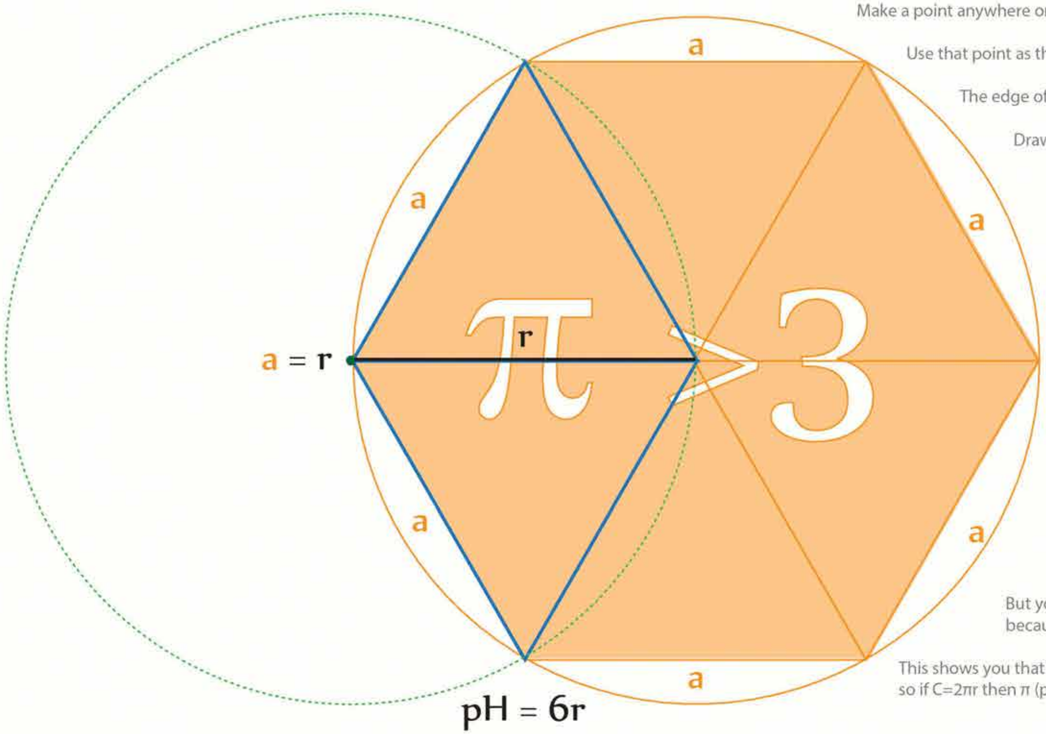

Draw any circle.

Make a point anywhere on the circumference of the [green] circle.

Use that point as the center of a second [blue] circle with the same radius as the green circle.

The edge of the blue circle should touch the center of the green circle.

Draw the line segment connecting the centers of the two circles.

That forms the radius of both of the circles.

Now draw the line connecting the center of the blue circle to where it crosses the green circle
on both sides, and complete the triangles.

You should have two equilateral triangles whose sides are equal to the radius of the green circle

Now extend all of the radius lines so they become diameter lines,
all the way across the circle, and finish drawing all of the triangles to connect them.

You've got six equilateral triangles now, that make an orange hexagon.

So the perimeter of your hexagon is the same as six times the radius of your circle.

But your circumference is a little bigger than the perimeter of your hexagon,
because the shortest distance between two points is always a straight line.

This shows you that the circumference of the blue circle has to be more than 6r,
so if C=2πr then π (pi) has to be a little bigger than 3, which it is.

The more sides we draw on our polygon, the closer we will get to the real value of pi (3.14159 etc.).
Using a polygon with 96 sides, Archimedes was able to calculate that π was a little bigger than 3.1408

The Golden Ratio

Two quantities are in the golden ratio (φ) if the ratio of the sum of the quantities to the larger quantity is equal to the ratio of the larger quantity to the smaller one.

The figure to the right illustrates the geometric relationship

[1.61803]

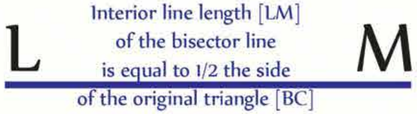

Interior line length [LM] of the bisector line is equal to 1/2 the side of the original triangle [BC] [AB] or [CA]

Φ

Golden ratio phi

$$\hbar = \frac{h}{2\pi}$$

Tetryonic geometry reveals the maximum E-field amplitude of the reduced Planck constant to be an example of the Golden ratio in physics

velocity vectors

The height of the triangle [ALM] produced by the bisecting line is 1/2 the height of the height of [ABC]

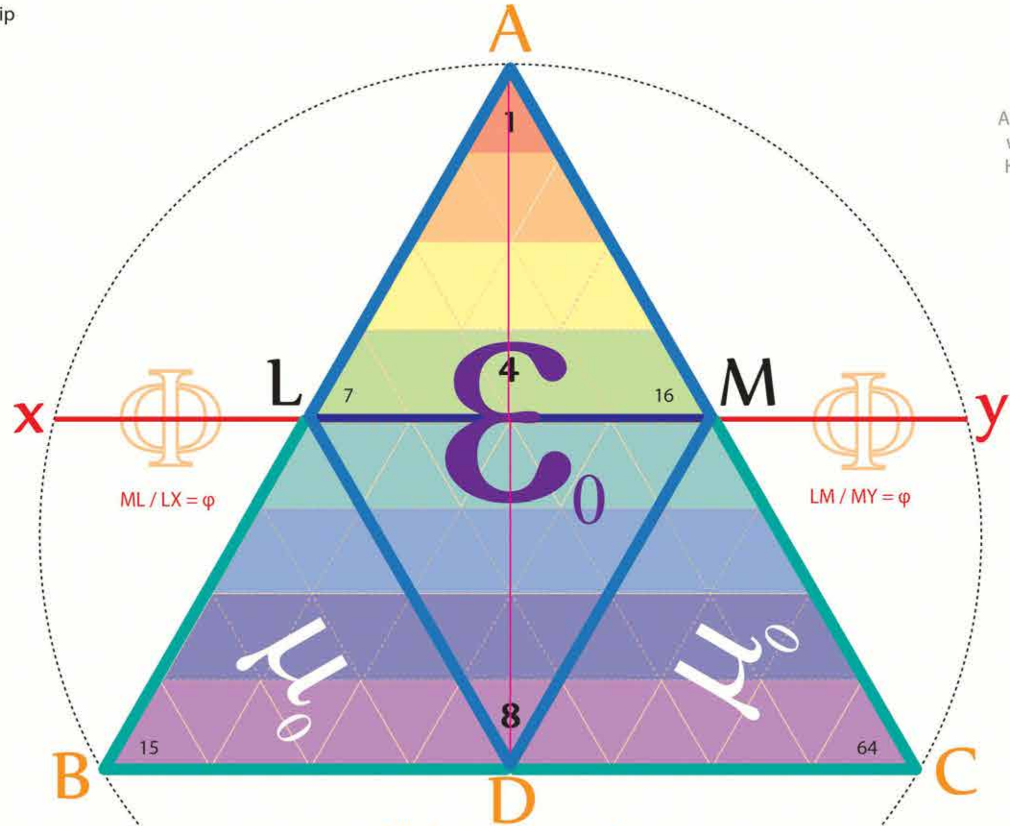

Kinetic energies

The area of the E-field permittivity diamond [ALDM] produced by the golden ratio bisector is 1/2 the area of the original equilateral Planck energy triangle [ABC]

mass $\frac{c^2}{sec}$ energy

Planck's constant [h]

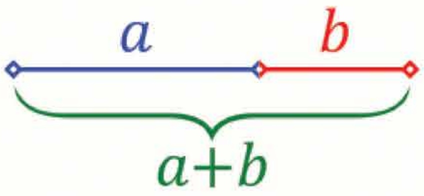

a+*b* is to *a* as *a* is to *b*

An intriguing showing of φ in an equilateral triangle was observed by George Odom, a resident of the Hudson River Psychiatric Center, in the early 1980s

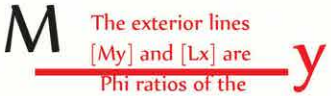

The exterior lines [My] and [Lx] are Phi ratios of the interior line [LM]

Let L and M be the midpoints of the sides AB and AC of an equilateral triangle ABC

By measurement and the Intersecting Chords Theorem

MX·MY = AM·MC.

which is of the form

(a + b)·b = a·a.

Denoting a/b = x, we see that

$1 + x = x^2$,

George Odom

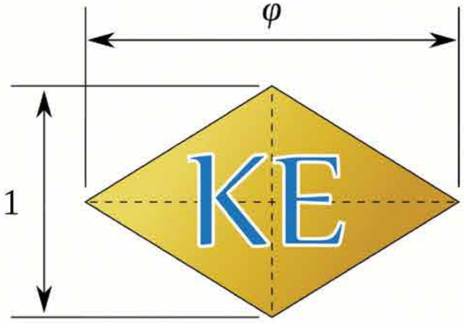

The Golden Rhombus

Applying the golden ratio (φ) to quantum scale electrodynamic geometry we can quickly determine that the linear momentum and magnetic moment vectors of photons & EM waves can also be expressed as a golden ratio

vector velocities
vs
magnetic vector

Φ
Golden ratio phi
[1.61803]

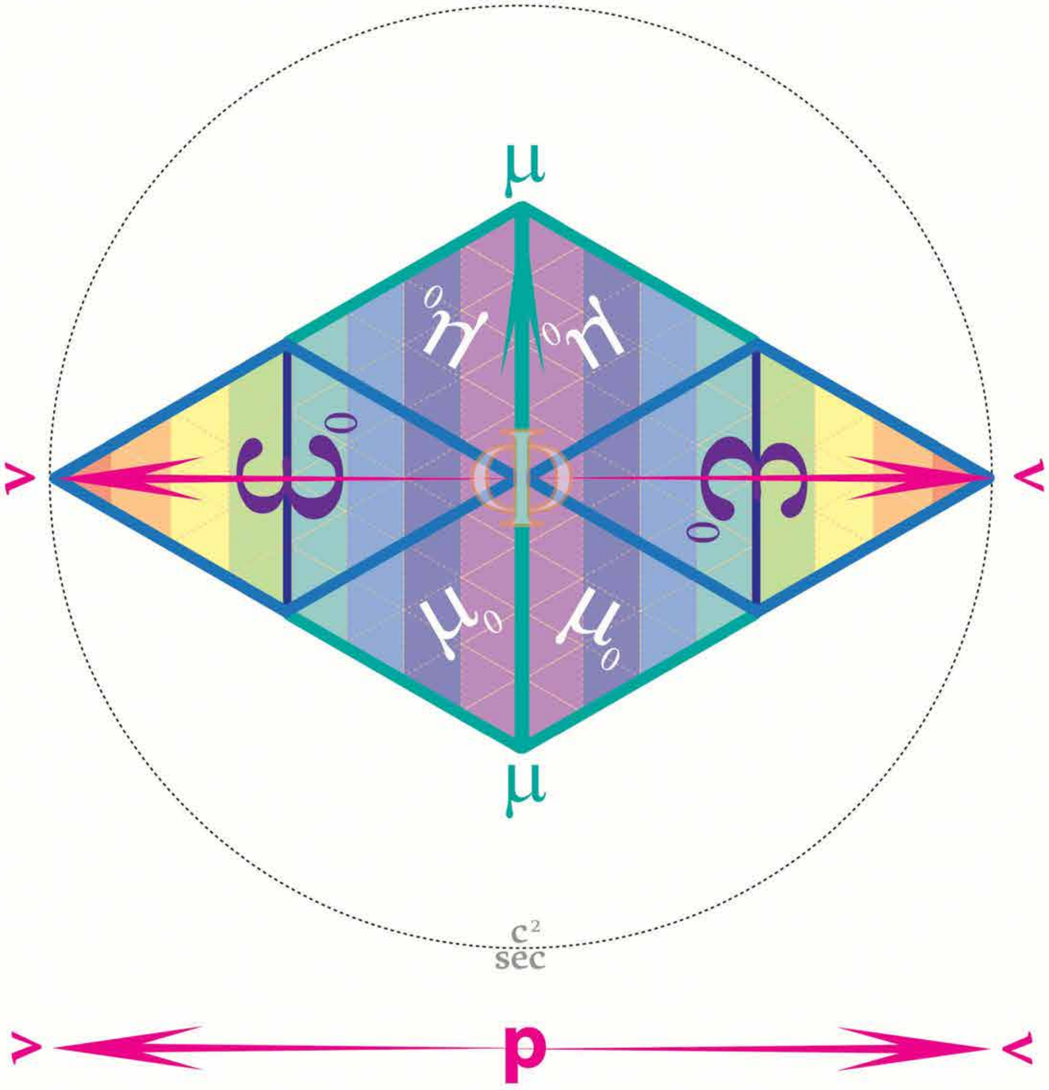
μ
μ_0
μ_0
ε_0
Φ
ε_0
μ_0
μ_0
μ
$\frac{c^2}{sec}$
p

magnetic Force
vs
electric Force

photons
of
EM energy

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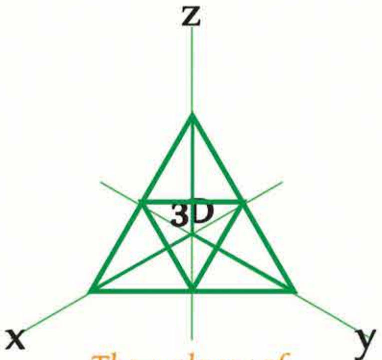

The 3 planes of Cartesian co-ordinates

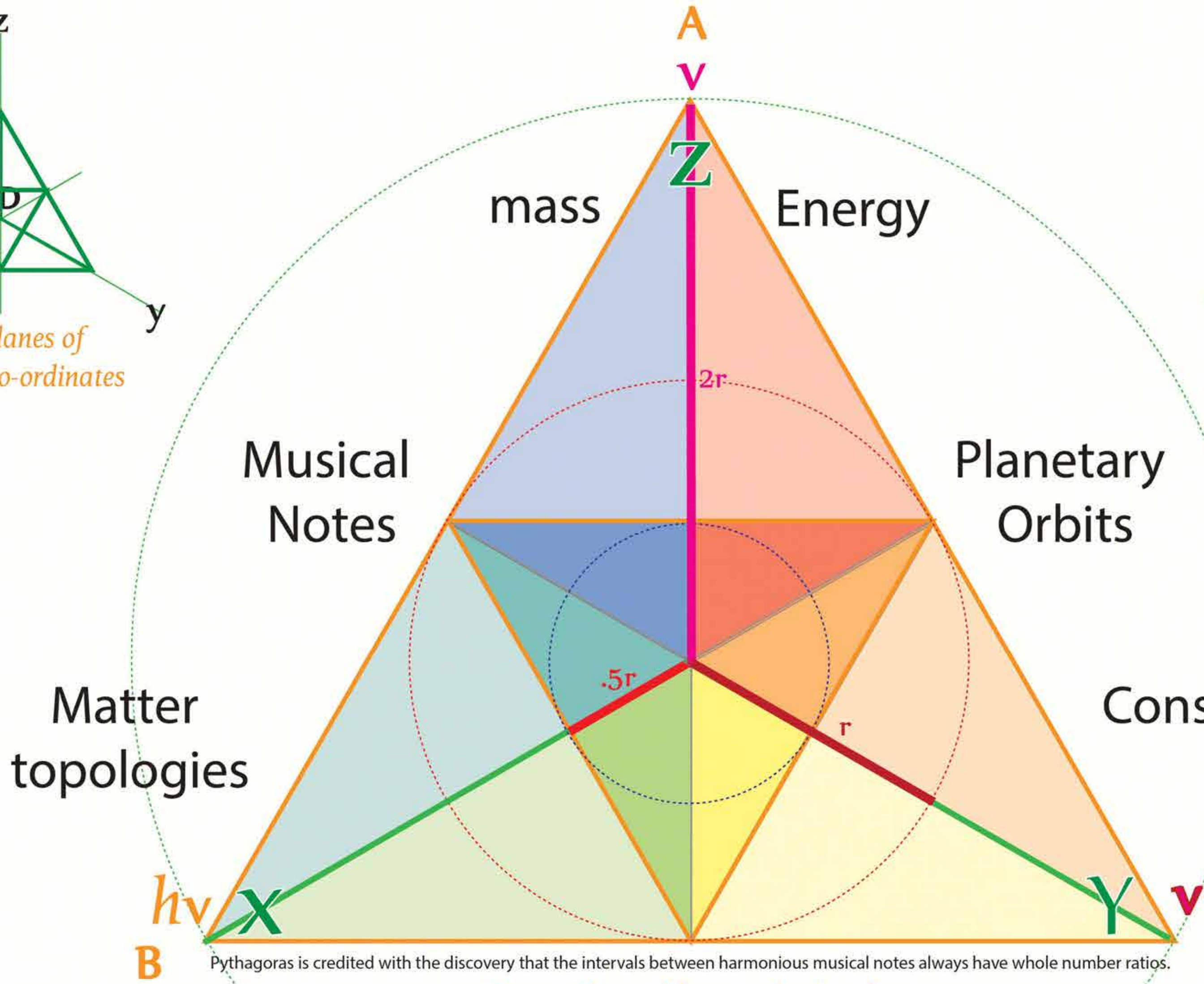
A
v
Z
mass
Energy
2r
Musical Notes
Planetary Orbits
.5r
r
Matter topologies
Conservation Laws
hv
X
Y
v^2
B
C

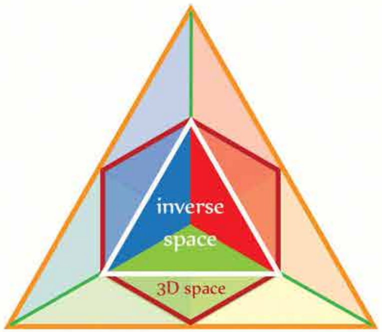
inverse space
3D space

An equilateral [square] triangle divided into 12 equal semitones

Pythagoras is credited with the discovery that the intervals between harmonious musical notes always have whole number ratios.

An equilateral [square] triangle
divided into 6 equal semitones
and 6 equal quarter tones

With an Equilateral triangle, draw lines from the center of the circle to each vertex and each midpoint, creating six right triangles, as shown with six different colored triangles.
Each right triangle has a radius of the circle for one leg, and half of a side of the original triangle for another.
Any two right triangles sharing one of the radial lines must therefore be congruent, and that implies that the hypotenuses of the triangles are all equal.
This in turn shows that the six right triangles are all congruent, and so the large triangle they combine to form is equilateral

Equilateral Fifths

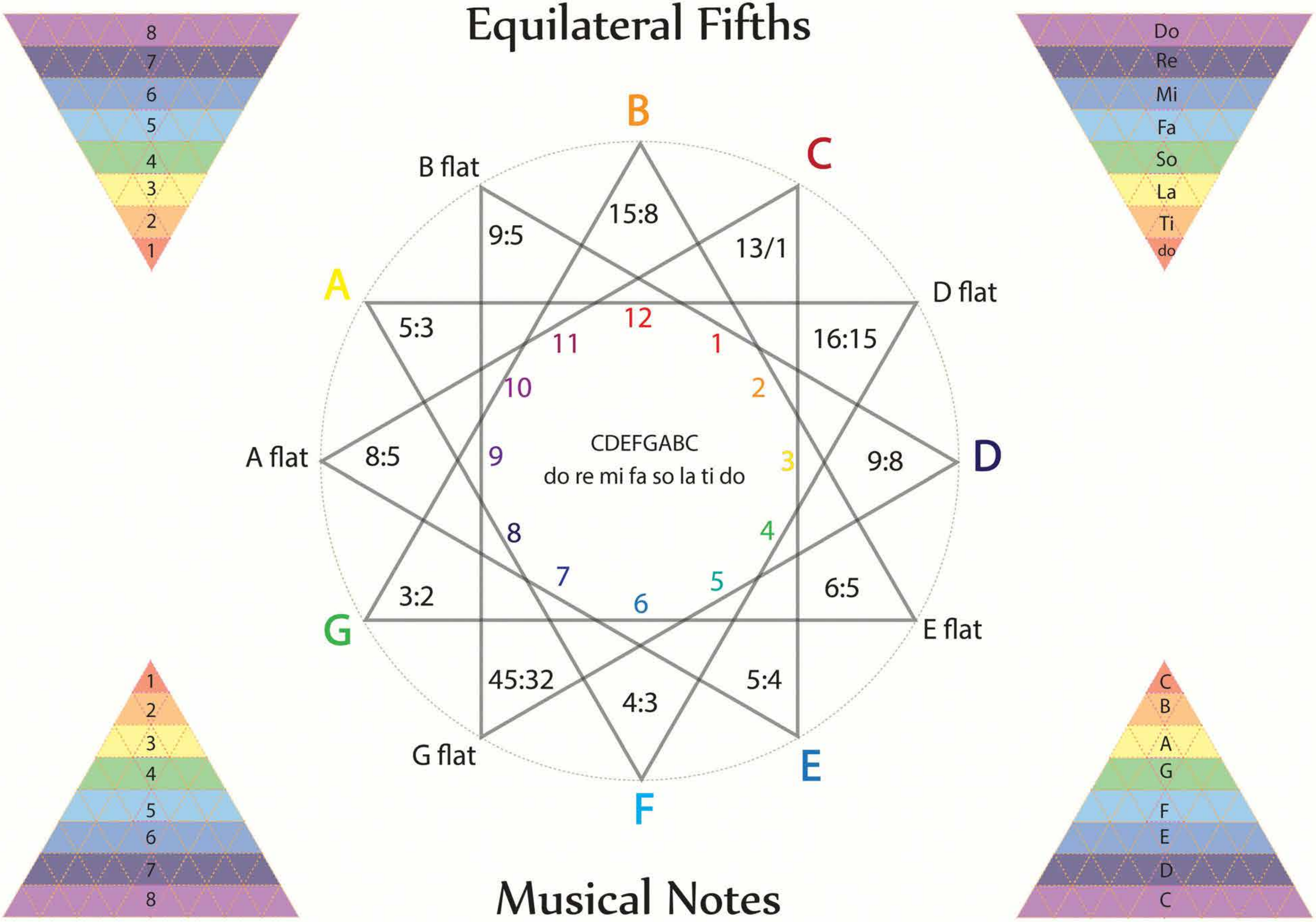
8
7
6
5
4
3
2
1
Do
Re
Mi
Fa
So
La
Ti
do
B
B flat
C
15:8
9:5
13/1
A
D flat
5:3
12
11
1
16:15
10
2
A flat
8:5
9
CDEFGABC
do re mi fa so la ti do
3
9:8
D
8
4
7
5
6
3:2
6:5
G
E flat
45:32
4:3
5:4
G flat
E
F
1
2
3
4
5
6
7
8
C
B
A
G
F
E
D
C

Musical Notes

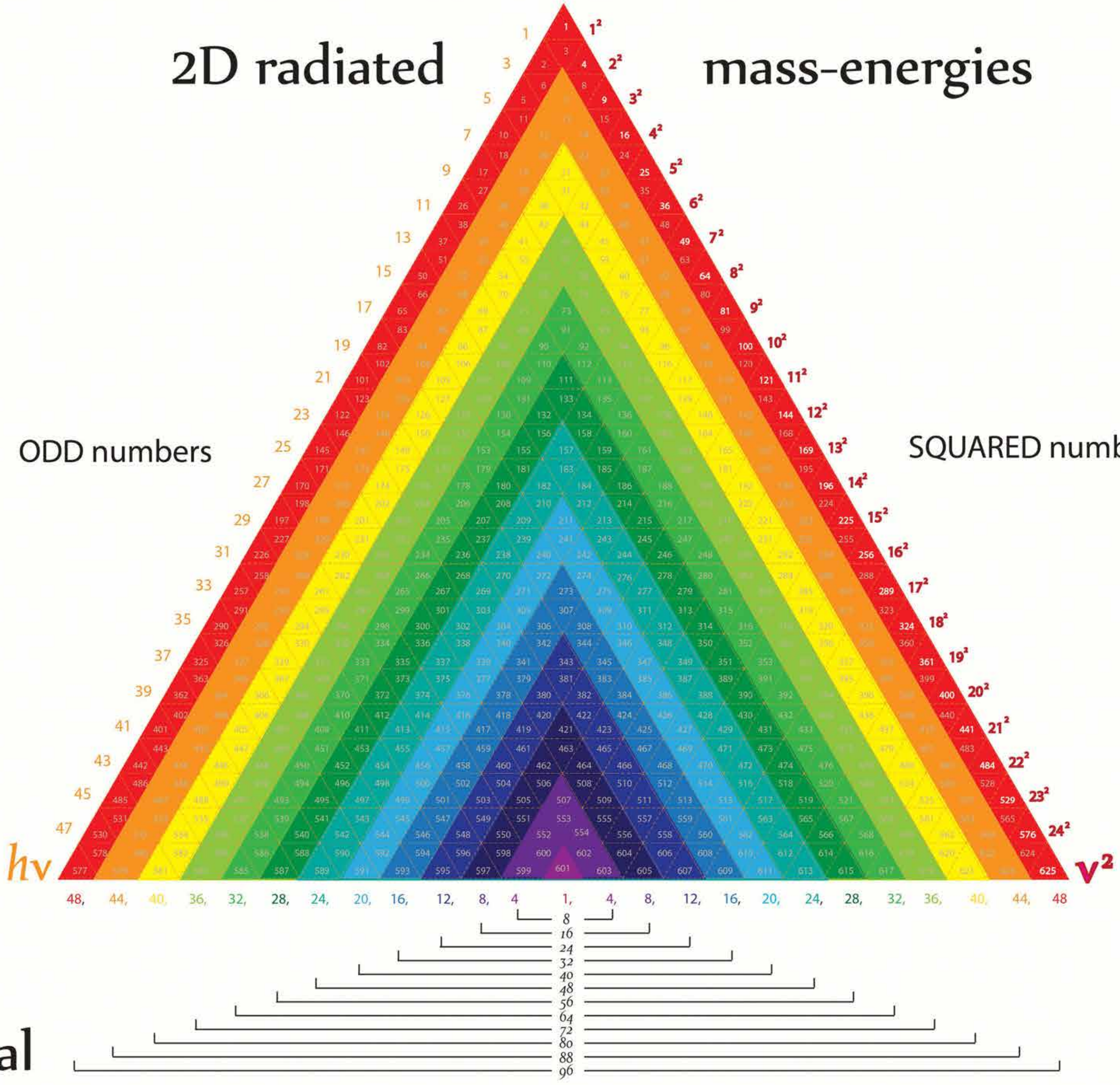

2D radiated mass-energies

ODD numbers

SQUARED numbers

Equilateral Octaves

1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
1^2
2^2
3^2
4^2
5^2
6^2
7^2
8^2
9^2
10^2
11^2
12^2
13^2
14^2
15^2
16^2
17^2
18^2
19^2
20^2
21^2
22^2
23^2
24^2
hv
v^2
48, 44, 40, 36, 32, 28, 24, 20, 16, 12, 8, 4
1, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48
8
16
24
32
40
48
56
64
72
80
88
96

Ternary Diagrams

Viviani's Theorem implies that lines parallel to the sides of an equilateral triangle provide (homogeneous/barycentric/areal/trilinear) coordinates for ternary diagrams for representing three quantities A,B,C whose sum is a constant (which can be normalized to unity).

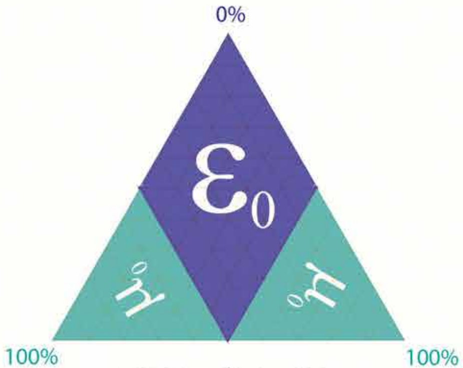

Ternary diagrams should NOT be used to model EM field strengths

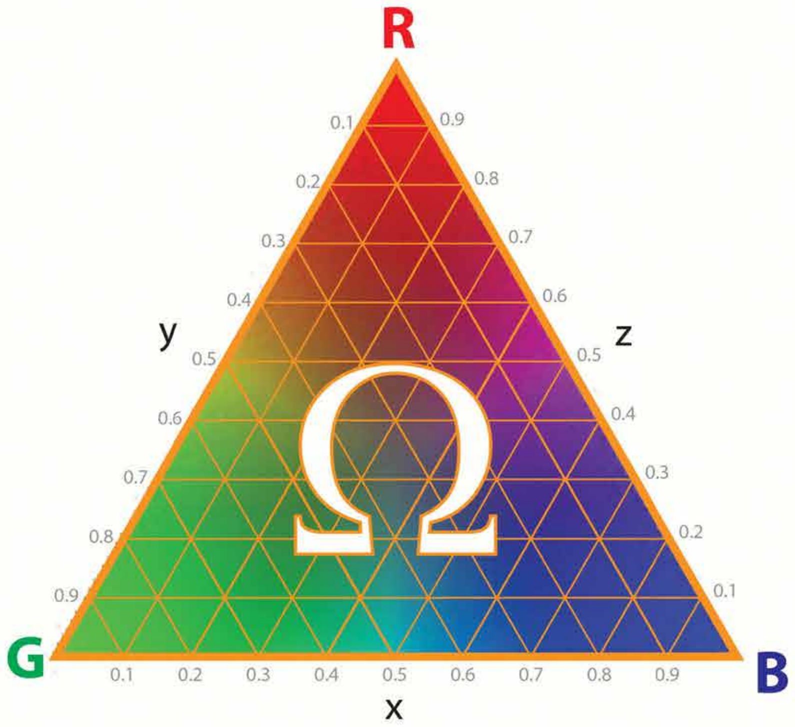

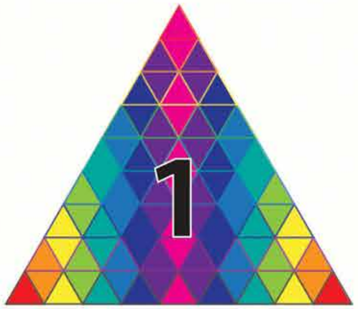

In a ternary plot, of EM energy
the Electric field [E] and the
Magnetic dipole [N-S]
must renormalise
to 1

A ternary diagram is simply a triangular coordinate system in which the 3 edges correspond to the axes.

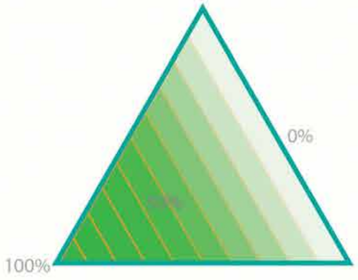

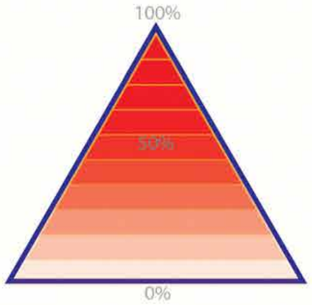

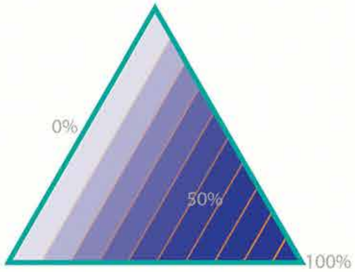

Trilinear charts are commonly used for finding the result of mixing three components (such as gases, chemical compounds, soil, color, etc.) that add to 100% of a quantity.

Whilst the Pythagorean Theorem boasts a slightly greater economy of terms than the Eutrigon Theorem (Wayne Roberts 2003), the latter contains an important area not included in the former:

the area enclosed or swept out by the three points of the triangle in question

$$ab = a^2 + b^2 - c^2$$

the area of any eutrigon is equal to the combined areas of the equilateral triangles on legs 'a' and 'b', minus the area of the equilateral triangle on its hypotenuse 'c'.

The Pythagorean theorem

$$a^2 + b^2 = c^2$$

The square of the hypotenuse of a triangle is equal to the sum of the squares of its sides.

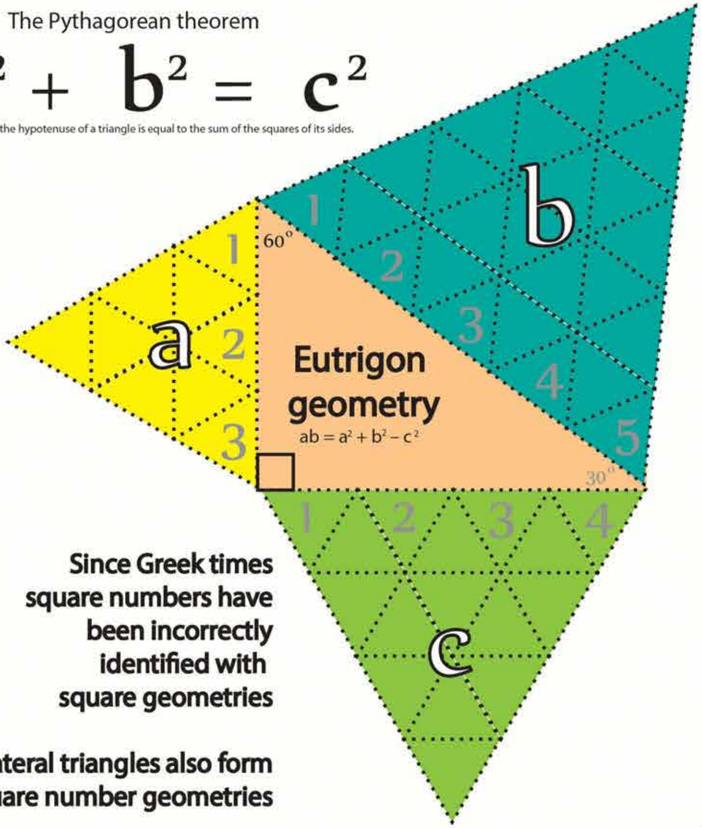

Since Greek times square numbers have been incorrectly identified with square geometries

Equilateral triangles also form square number geometries

Eutrigons

are an important new class of triangle (mathematically defined by Wayne Roberts), as the analogue of the right-triangle in orthogonal (Cartesian) coordinate geometry

Kepler's Second Law of planetary motion

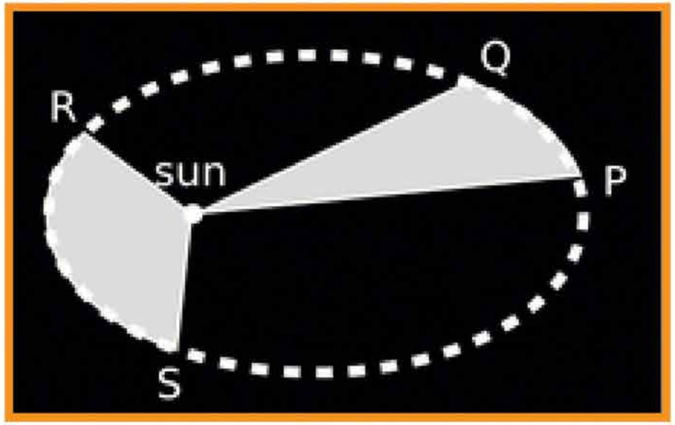

The orbit of every planet is an ellipse with the Sun at one of the two foci.

A line joining a planet and the Sun sweeps out equal areas during equal intervals of time.

The algebraic form of the Eutrigon Theorem, (like the algebraic form of Pythagoras' Theorem), is proven to be special case of the Cosine Rule...

Tetryonic theory reveals the equilateral [square] energy geometry that reveals the 'harmonics at play' in physical laws such as the second law of Kepler, and in many other phenomena in physics, chemistry, cosmology, biochemistry and number theory thus providing the foundation for the mathematics of quantum mechanics

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Number theory

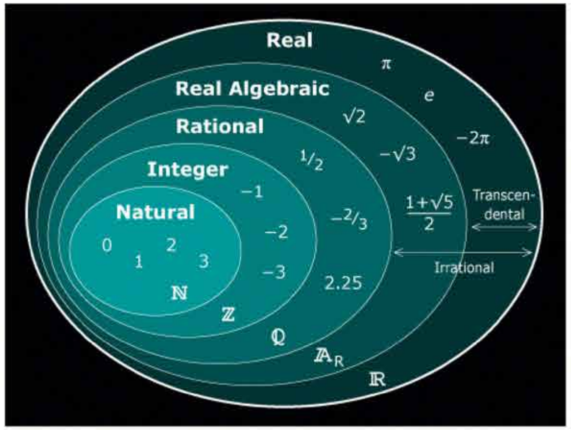
Real
Real Algebraic
Rational
Integer
Natural
0
1
2
3
ℕ
−1
−2
−3
ℤ
1/2
−2/3
2.25
ℚ
√2
−√3
$\frac{1+\sqrt{5}}{2}$
𝔸R
π
e
−2π
Transcen-dental
Irrational
ℝ

The Pythagoreans also established the foundations of number theory, with their investigations of triangular, square and also perfect numbers (numbers that are the sum of their divisors).

They discovered several new properties of square numbers, such as that the square of a number n is equal to the sum of the first n odd numbers (e.g. 1 + 3 + 5 + 7 = 16).

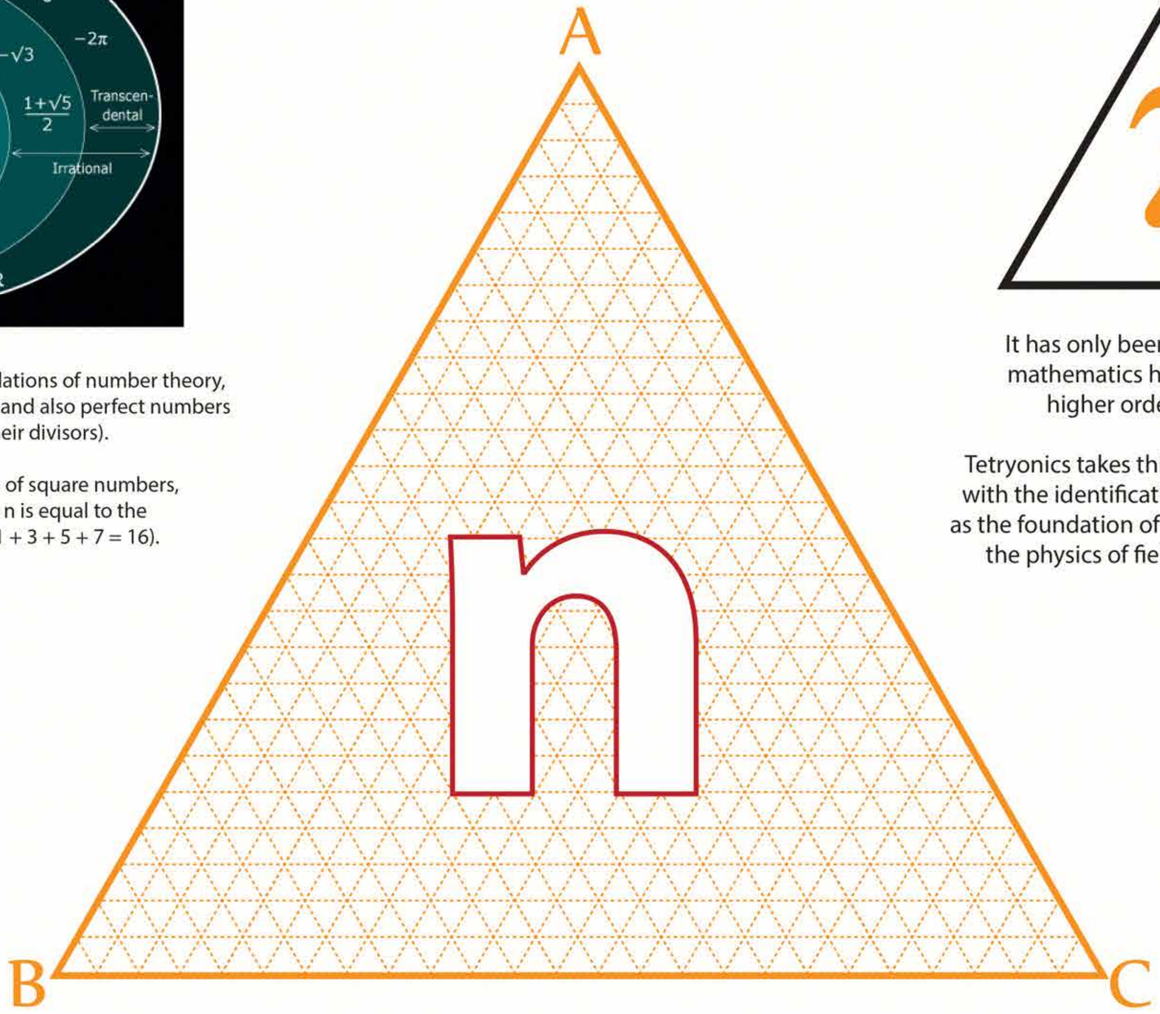

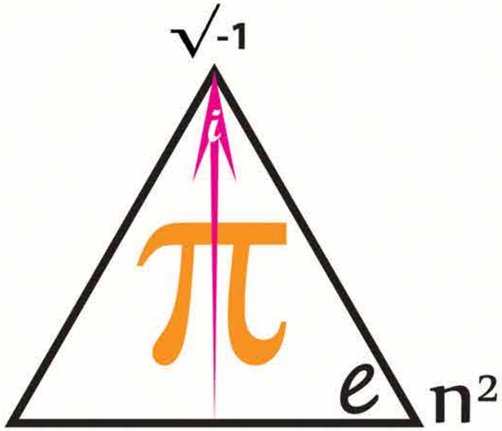

It has only been in recent centuries that mathematics has begun to explore the higher order irrational numbers

Tetryonics takes this investigation to new levels with the identification of equilateral geometries as the foundation of transcendental numbers and the physics of fields and particles in motion

What mathematics has failed to appreciate is the significance application of equilateral geometries to the 'square' numbers of physics and science in general

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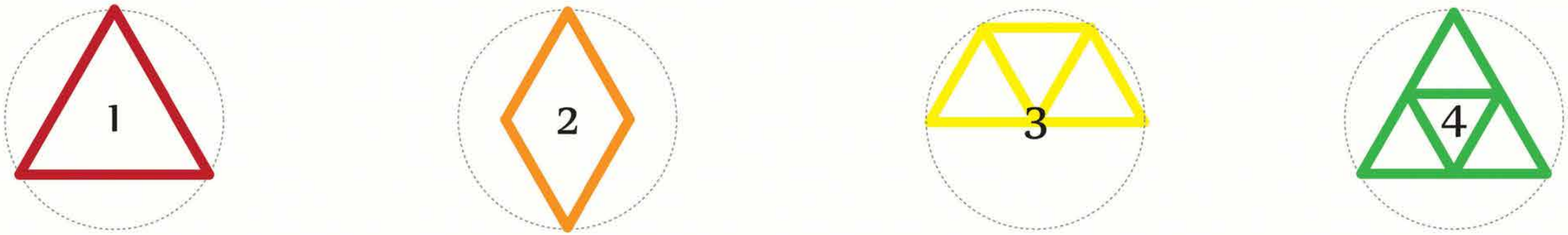

TETRYONICS

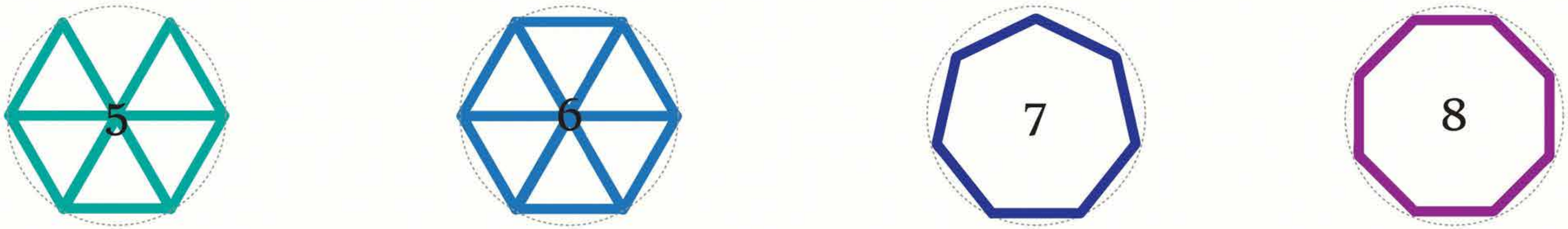

COUNTING POLYGONS

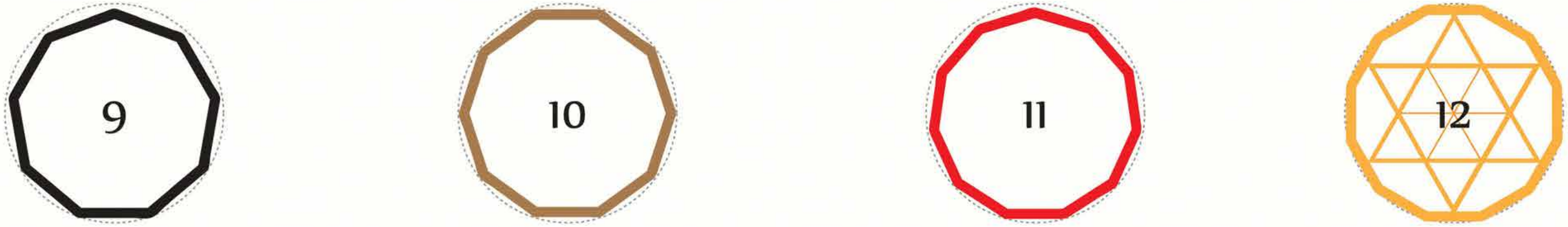

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SQUARED energies in quantum mechanics are EQUILATERAL geometries

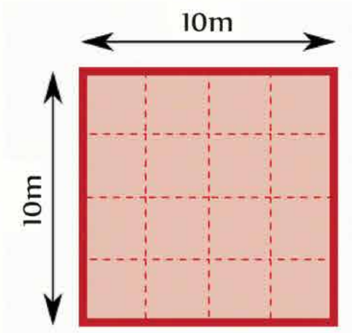

Square

$\text{area} = s^2 = [100]$

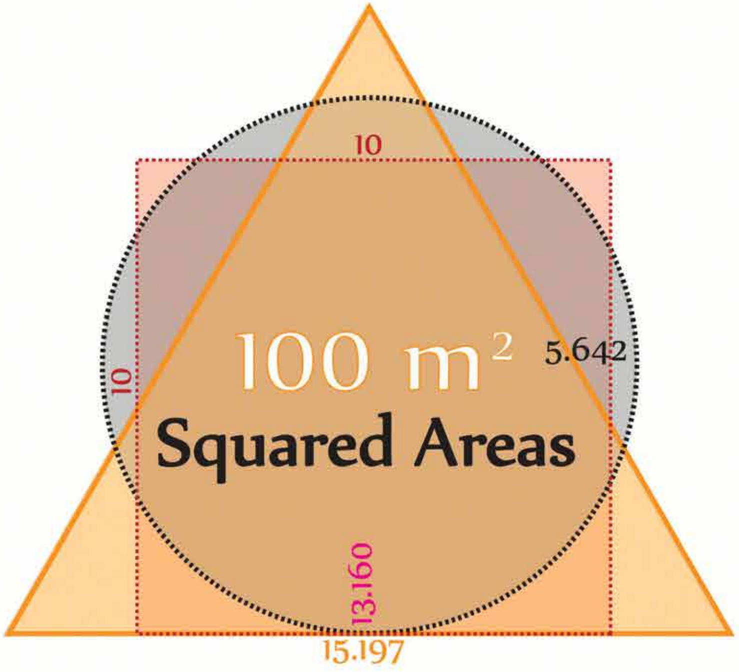
10
10
5.642
100 m²
Squared Areas
13.160
15.197

can be created by a number of planar geometries

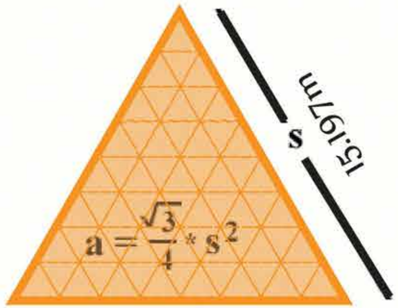
15.197m
s
$a = \frac{\sqrt{3}}{4} * s^2$

Equilateral

$\text{area} = (\frac{1}{2} * b) * h$

Circles

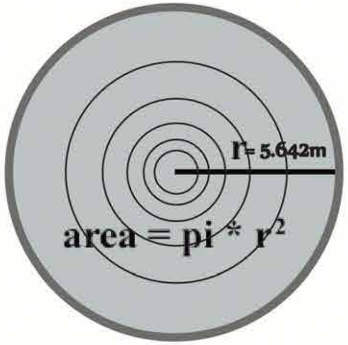
r= 5.642m
area = pi * r²

$= pi * [5.642]^2$
$= 100$

For a long time it has been assumed by scientists (and mathematicians) that circular [and squared] geometries are the geometric foundation of all physics, leading to a serioulsy flawed model of particles and forces in quantum mechanics

Tetryonic theory now reveals that quantised equilateral angular momenta creates the foundational geometry of all the mass-Energy-Matter & forces of physics

Triangles

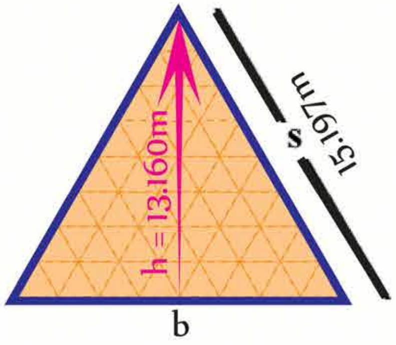
h = 13.160m
s
15.197m
b

$\overset{b}{[.5 \times 15.197]} \times \overset{h}{13.160}$
$= 100$

0.987654321

SQUARE ROOTS

80/81

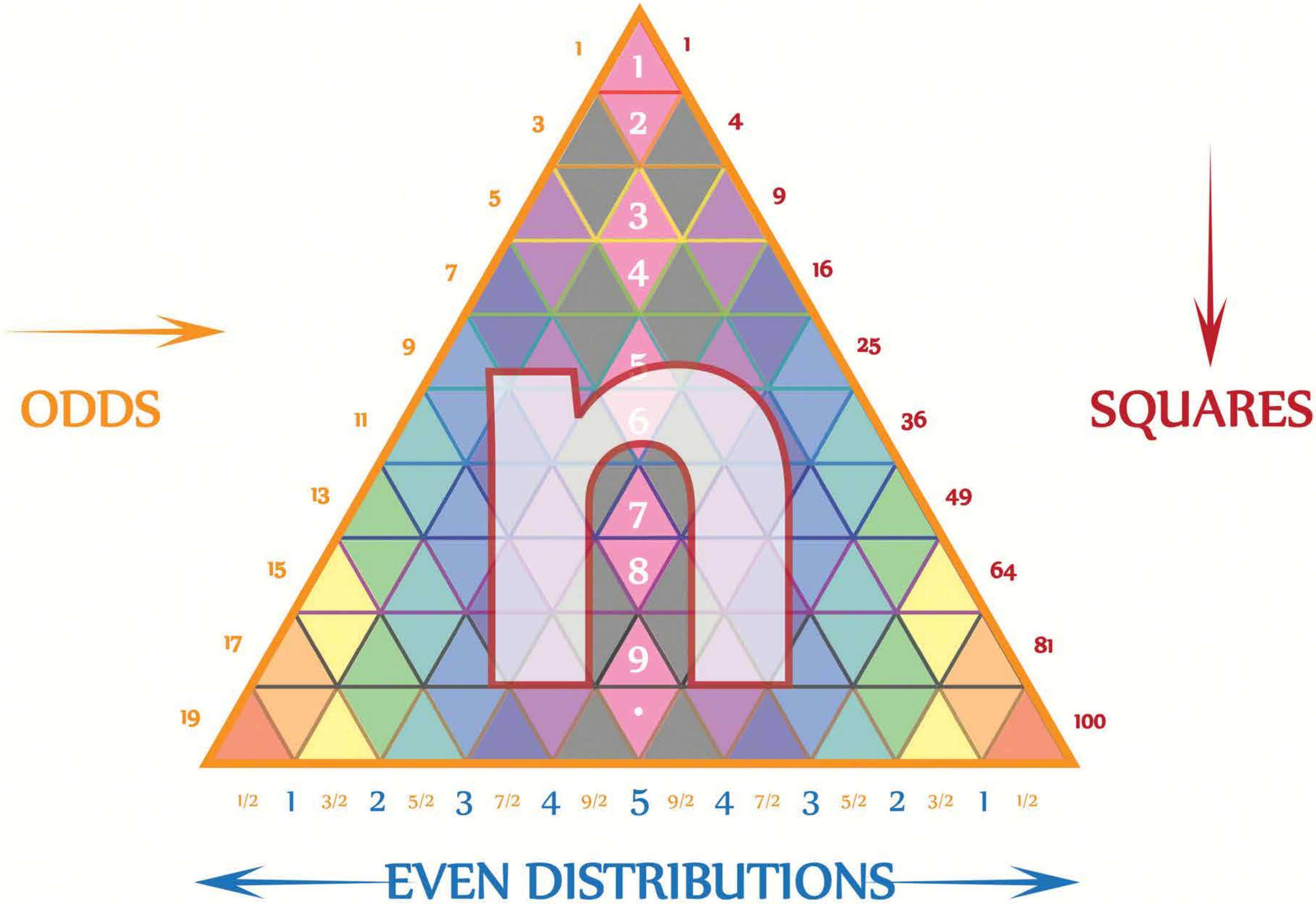
1
2
3
4
5
6
7
8
9
•
n
1
3
5
7
9
11
13
15
17
19
1
4
9
16
25
36
49
64
81
100
1/2
1
3/2
2
5/2
3
7/2
4
9/2
5
9/2
4
7/2
3
5/2
2
3/2
1
1/2

ODDS

SQUARES

EVEN DISTRIBUTIONS

Integers

The integers (from the Latin integer), literally "untouched", hence "whole"
in Tetryonics it is the basis for the Planck charge quantum

$$2n-1$$

$$[[n] + [n-1]]$$

Triangular numbered geometries are NOT equialteral geometries

0, 1, 3, 6, 10, 15, 21, 28, 36, 45, 55, ...

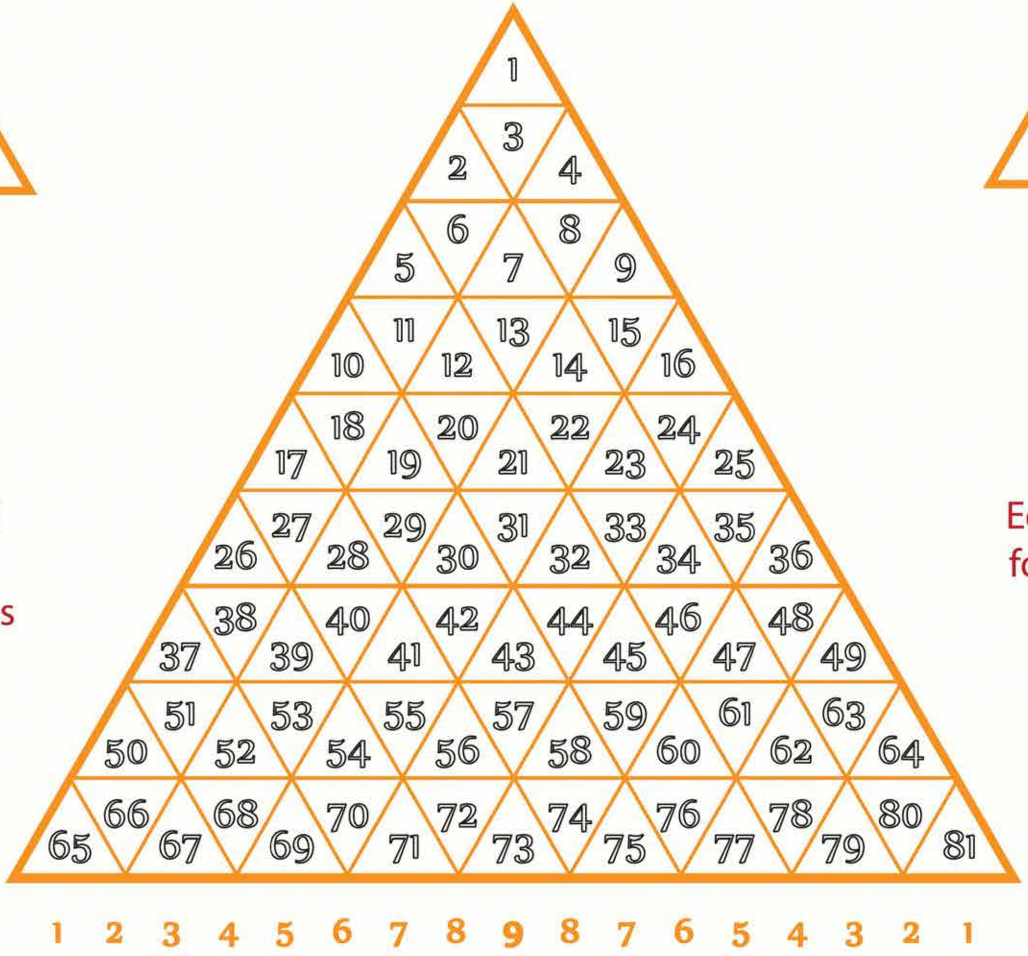
1
2 3 4
5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 43 44 45 46 47 48 49
50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81
1 2 3 4 5 6 7 8 9 8 7 6 5 4 3 2 1

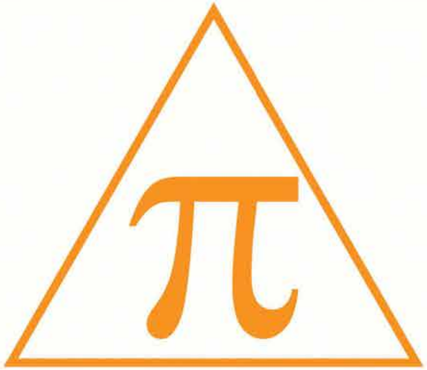

$$\sum_{1}^{n} [2n-1]$$

Equilateral geometries form **SQUARE** number geometries

1, 4, 9, 16, 25, 49, 64, 81, 100, 121, 144, ...

Equilateral energy quanta form a normal longitudinal distribution

Viewed as a subset of the real numbers, they are numbers that can be written without a fractional or decimal component

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ε_0
π
μ_0
μ_0

Bosons are a transverse measure of scalar energy momenta

ODD numbers

An odd number is an integer which is not a multiple of two.

E
μ_0
n
3
μ_0
E
ε_0
ε_0
+
−
N
S
S
N

Quantum

Bosons have ODD number quanta

Quantum Levels

hν

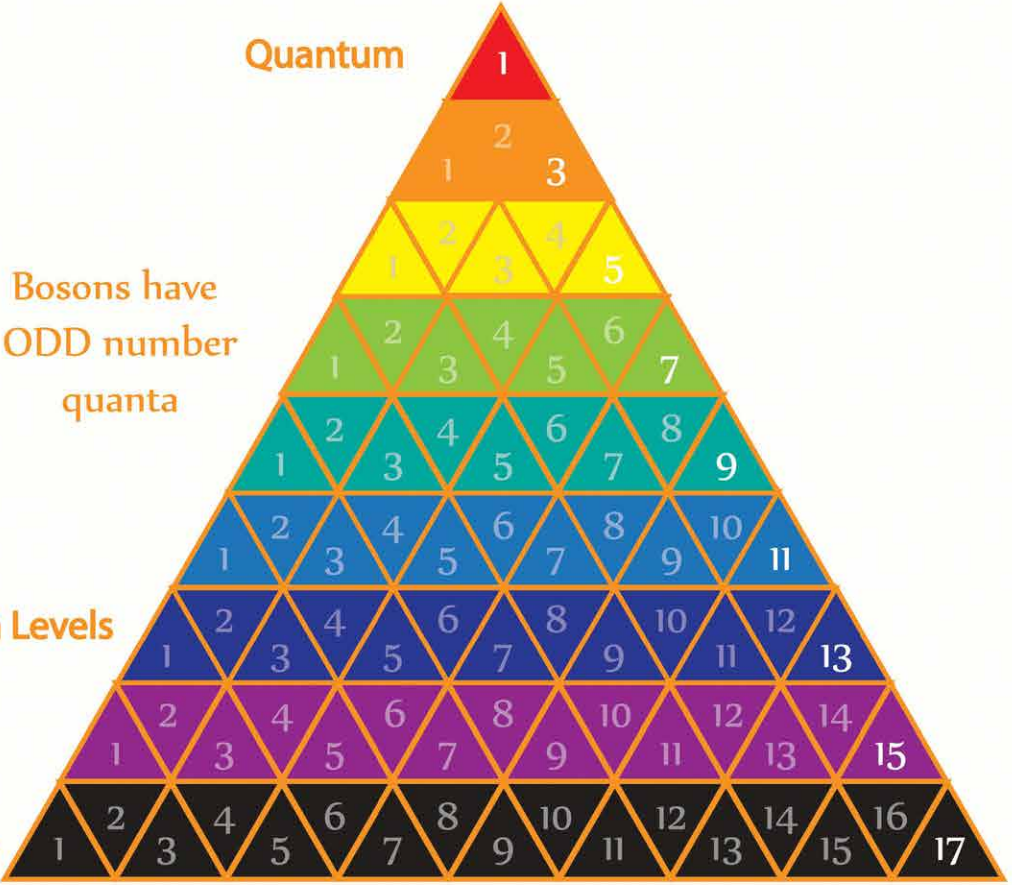
1
1 2 3
1 2 3 4 5
1 2 3 4 5 6 7
1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9 10 11
1 2 3 4 5 6 7 8 9 10 11 12 13
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

1
3
5
7
9
11
13
15
17

An odd number, when divided by two, will result in a fraction

Tau radians

Around the whole outside of a circle,
there are about 6.283 radians - or, Tau radians

3.141592654

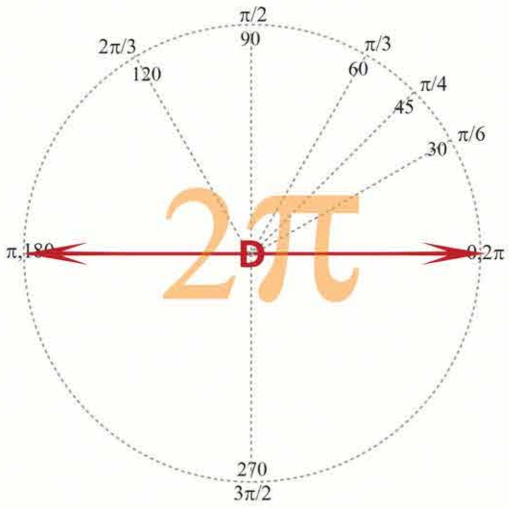
π/2
90
2π/3
120
π/3
60
π/4
45
π/6
30
π,180
0,2π
2π
D
270
3π/2

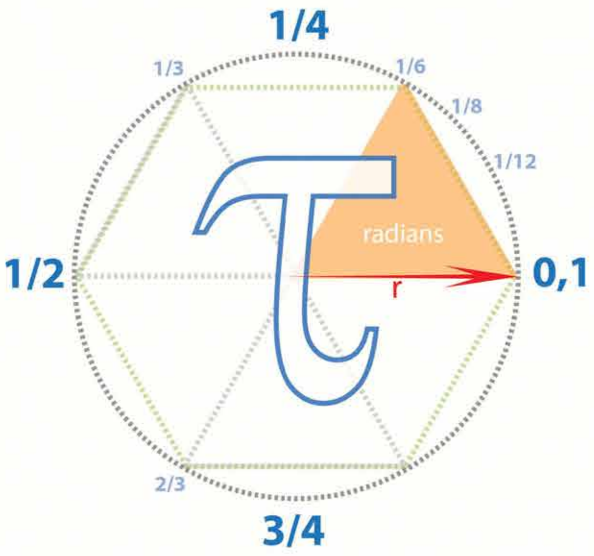
1/4
1/3
1/6
1/8
1/12
1/2
0,1
τ
radians
r
2/3
3/4

6.283185307

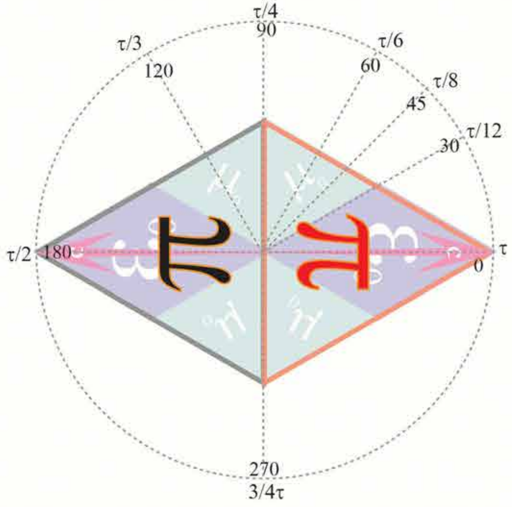
τ/4
90
τ/3
120
τ/6
60
τ/8
45
τ/12
30
τ/2
180
τ
0
π
π
270
3/4τ

τ is a more 'natural' radian system for geometric physics than π
Tau = 2π = 360 degree rotation about a point

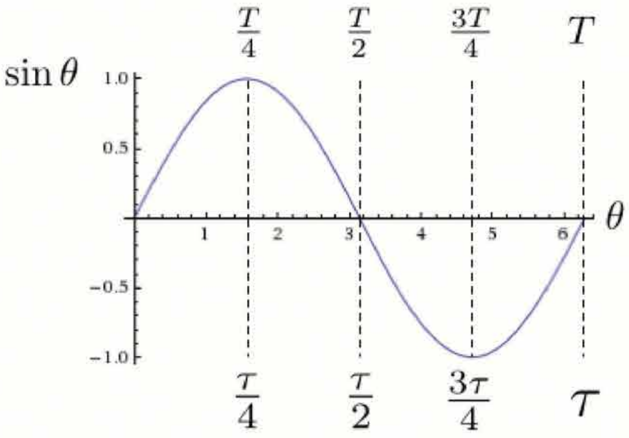

π
historically defined as the
ratio of a circle's circumference to its DIAMETER
should be redefined in physics to

τ
the ratio of its circumference to its RADIUS

in doing so many of the π/2 terms common to physics
will re automatically rationalised and will better reflect
the Tetryonic geometry of mass-ENERGY-Matter in motion

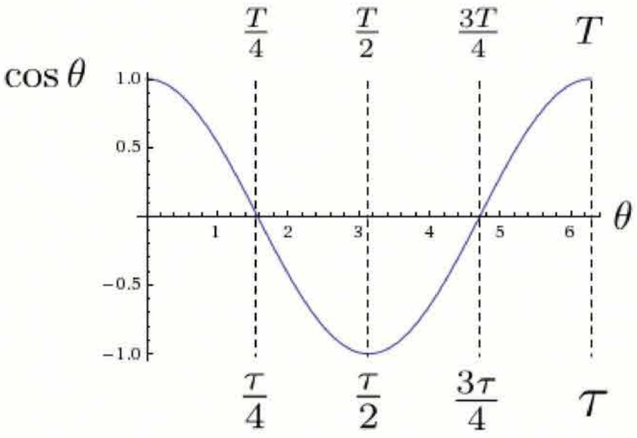

Photons are a longitudinal measure of scalar energy momenta

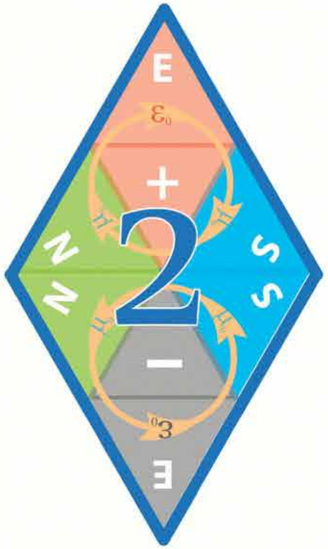
E
ε_0
+
2
N
N
S
S
−
μ_0
E

Photons are
EVEN number
quantums

EVEN numbers

An integer that is not an odd number is an even number

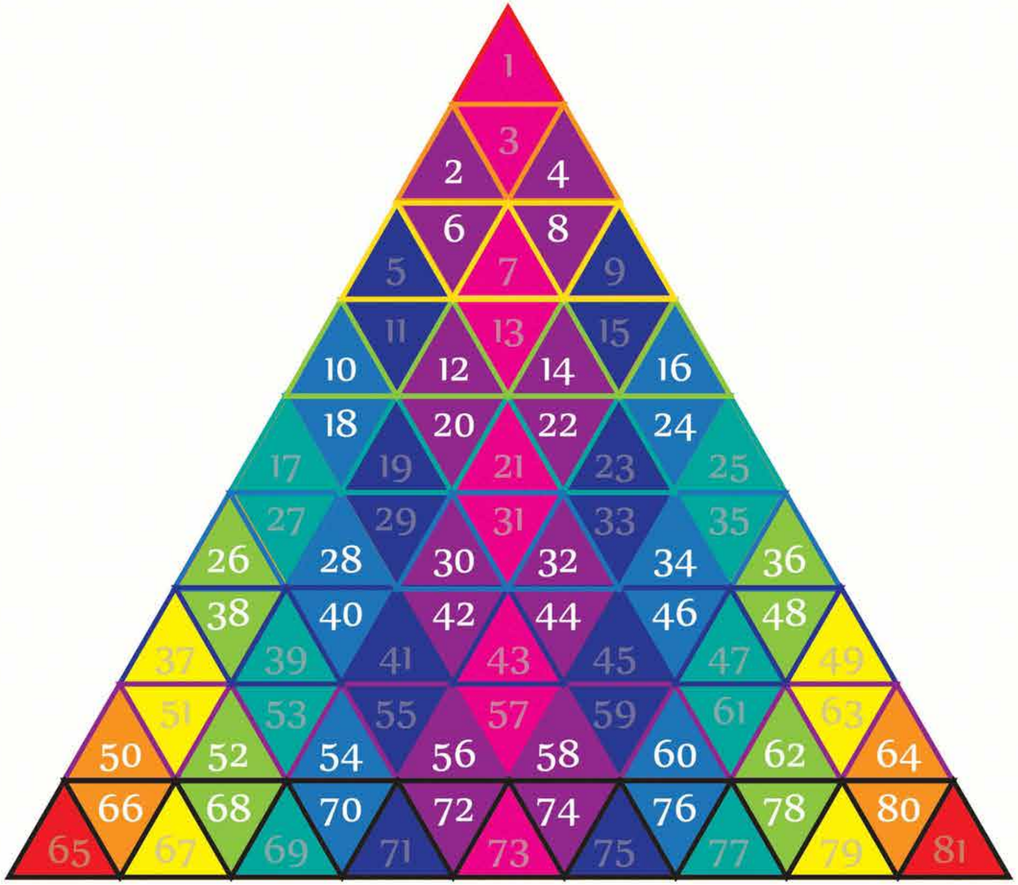
1
2 3 4
5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 43 44 45 46 47 48 49
50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81

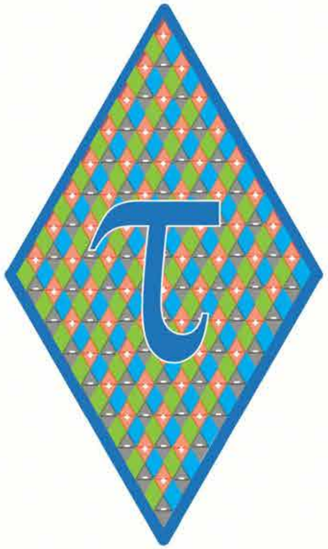

EM waves are
comprised of EVEN
numbered quanta

If an even number is divided by two, the result is another whole number

1/2 **1** 3/2 **2** 5/2 **3** 7/2 **4** 9/2 **4** 7/2 **3** 5/2 **2** 3/2 **1** 1/2

If an odd number is divided by two, the result is a fractional number

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Triangular numbers

Historically, a triangular number counts quanta that can pack together to form an equilateral triangle

1, 3, 6, 10, 15, 21, 28, 36, 45, 55, ...

this form of geometric counting of same charges over-complicated the simpler physical reality

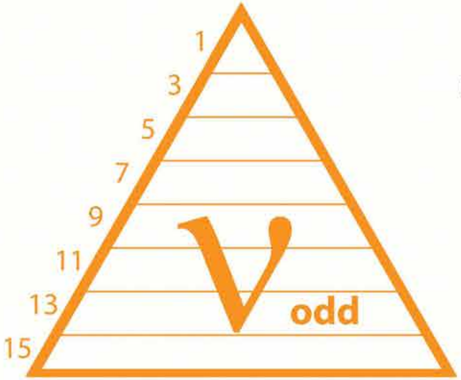
1
3
5
7
9
11
13
15
ν
odd

$$2\nu - 1$$

$$[\nu] + [\nu - 1]$$

Equilateral chords or quantum levels are ODD numbers

1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21,....

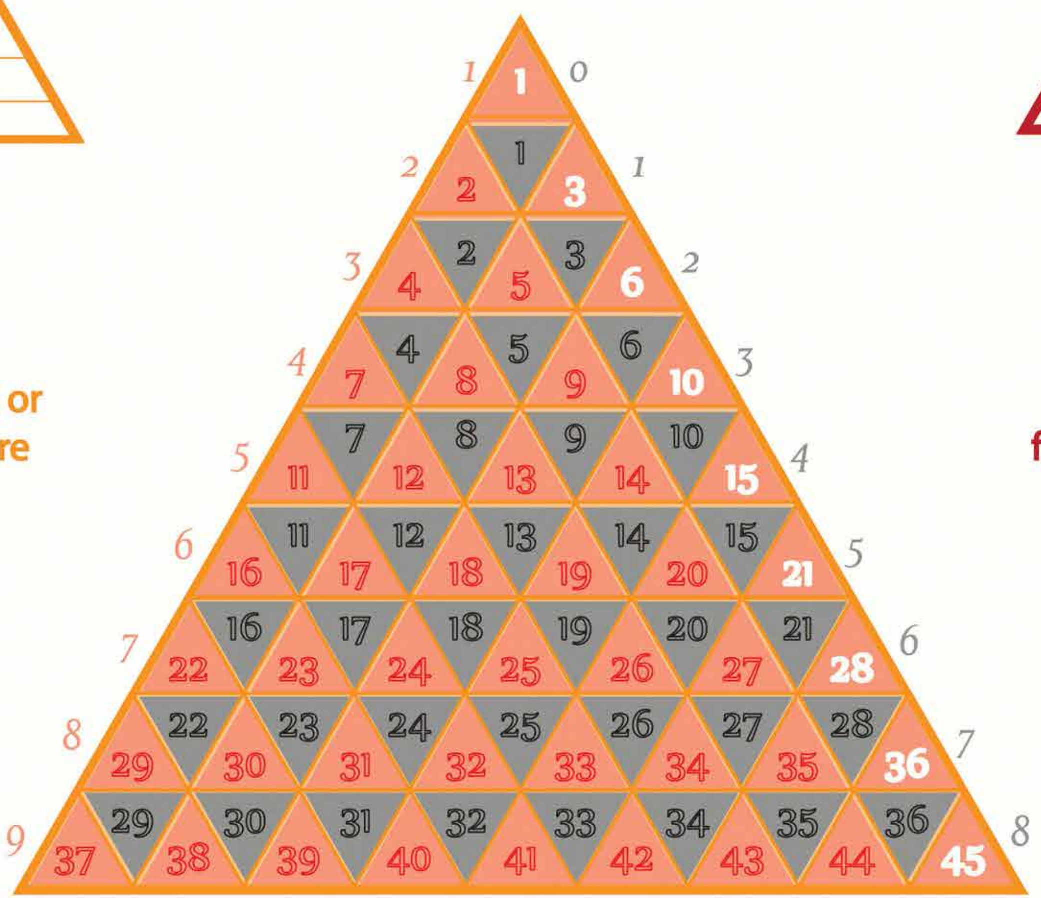
1
0
1
2
1
3
1
2
4
2
5
3
6
2
3
7
4
8
5
9
6
10
3
4
11
7
12
8
13
9
14
10
15
4
5
16
11
17
12
18
13
19
14
20
15
21
5
6
22
16
23
17
24
18
25
19
26
20
27
21
28
6
7
29
22
30
23
31
24
32
25
33
26
34
27
35
28
36
7
8
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
8
9

1/2 1 3/2 2 5/2 3 7/2 4 9/2 4 7/2 3 5/2 2 3/2 1 1/2

Triangular energy quanta form normal distributions

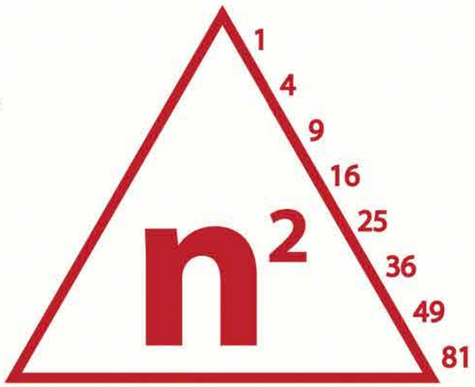
1
4
9
16
25
36
49
81
n²

$$\sum_{1}^{n} [2n-1]$$

Equilateral geometries form SQUARE numbered geometries

1, 4, 9, 16, 25, 49, 64, 81, 100, 121, 144, ...

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Squared numbers

A square number, sometimes also called a perfect square,
is the result of an integer multiplied by itself

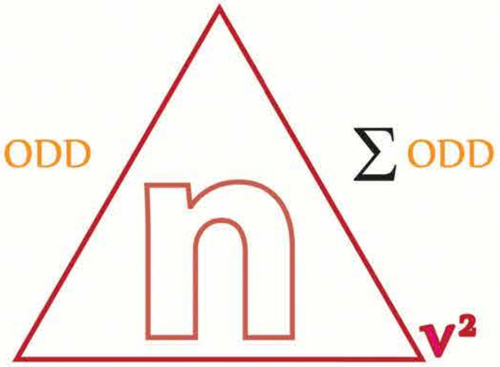
ODD
$\sum$ ODD
n
v^2

1
+
3
+
5
+
7
+
9
+
11
+
13
+
15
+
17

Square numbers result from
the summing of consecutive
ODD numbers

ODDS

$2n-1$

$[[n] + [n-1]]$

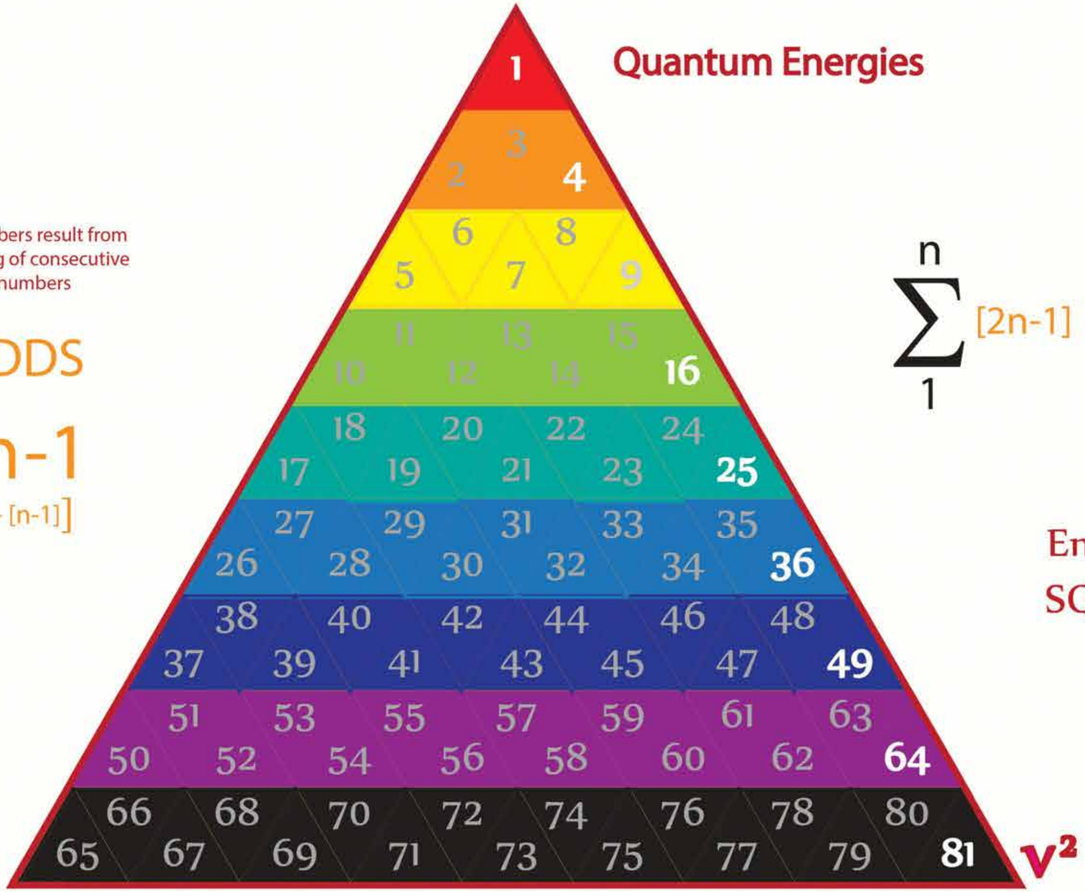
1
2 3 4
5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 43 44 45 46 47 48 49
50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81
v^2

Quantum Energies

$$\sum_{1}^{n} [2n-1]$$

Energy levels have
SQUARE number
quanta

Compton Frequency

In Tetryonics Square numbers produce equilateral geometries

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Square roots

A square root of a number is a number that, when it is multiplied by itself (squared) , gives the first number again.

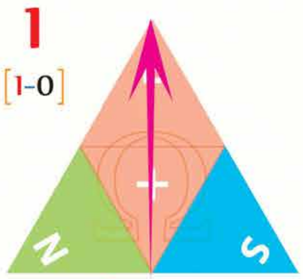

Root of positive one

-*i* and +*i*

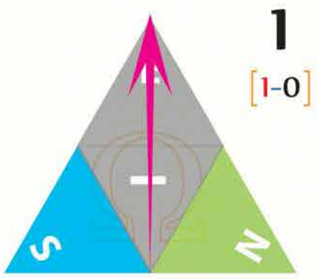

Root of negative one

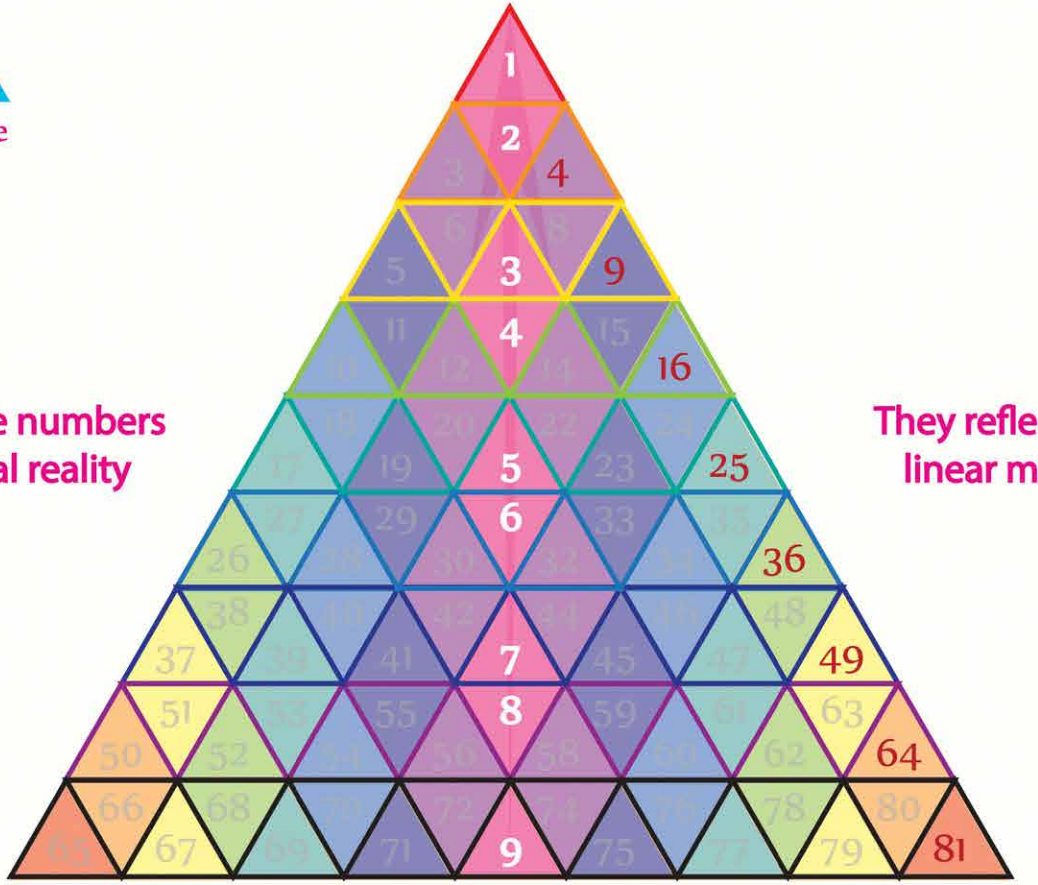
1
2 3 4
5 6 3 8 9
10 11 12 4 14 15 16
17 18 19 20 5 22 23 24 25
26 27 28 29 30 6 32 33 34 35 36
37 38 39 40 41 42 7 44 45 46 47 48 49
50 51 52 53 54 55 56 8 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 9 74 75 76 77 78 79 80 81

Square roots of negative numbers have a basis in physical reality

They reflect the real non-negative linear momentum of a system

A whole number with a square root that is also a whole number is called a perfect square in Tetryonic theory they are actually equilateral geometries

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Real Numbers

In mathematics, a real number is a value that represents a quantity along a continuous line. The real numbers include all the rational numbers,

Quantum levels

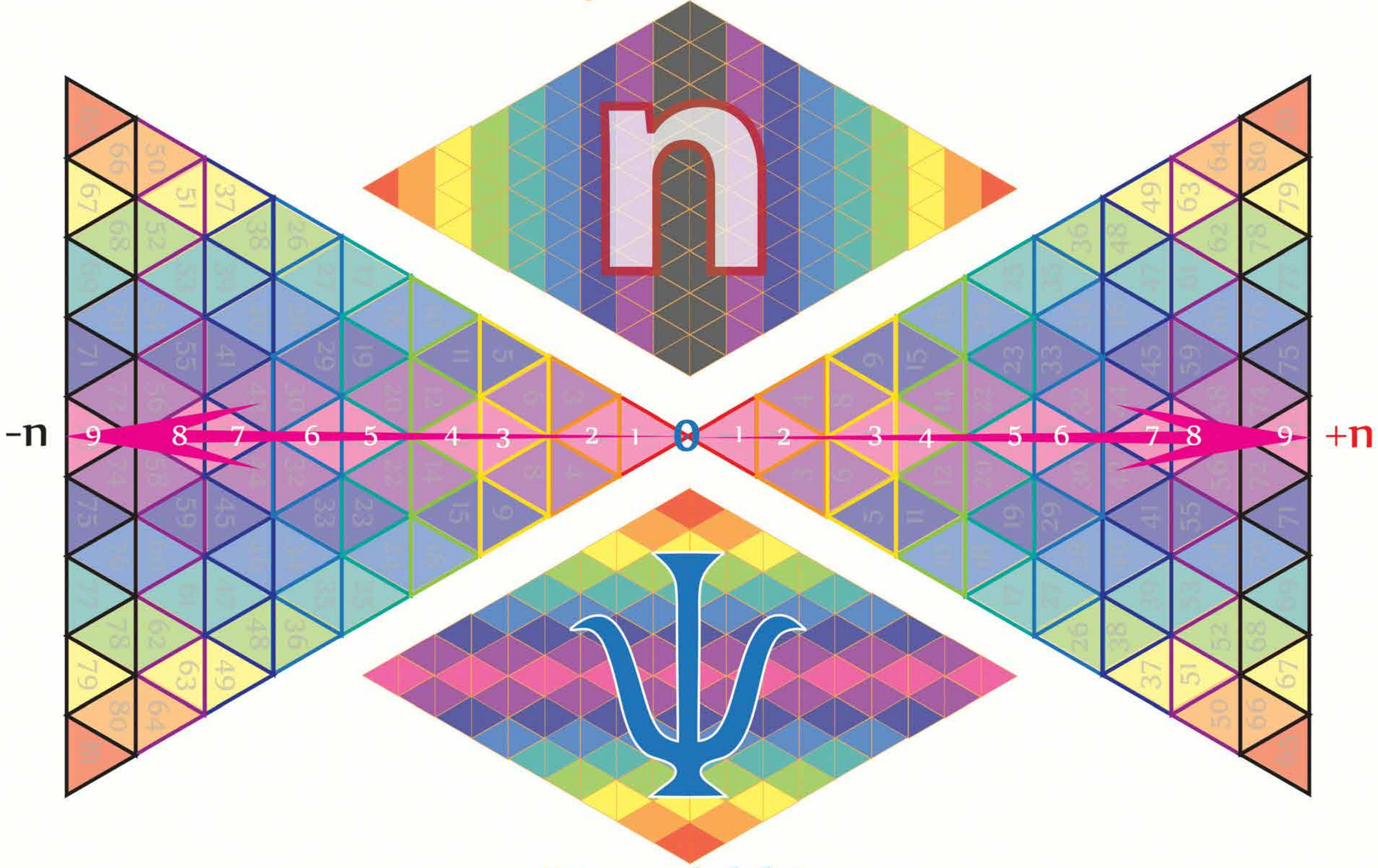

Wave probabilities

ONE to ∞^2

Quantum levels →

ODD numbers

[2n-1]

1, 3, 5, 7, 9......

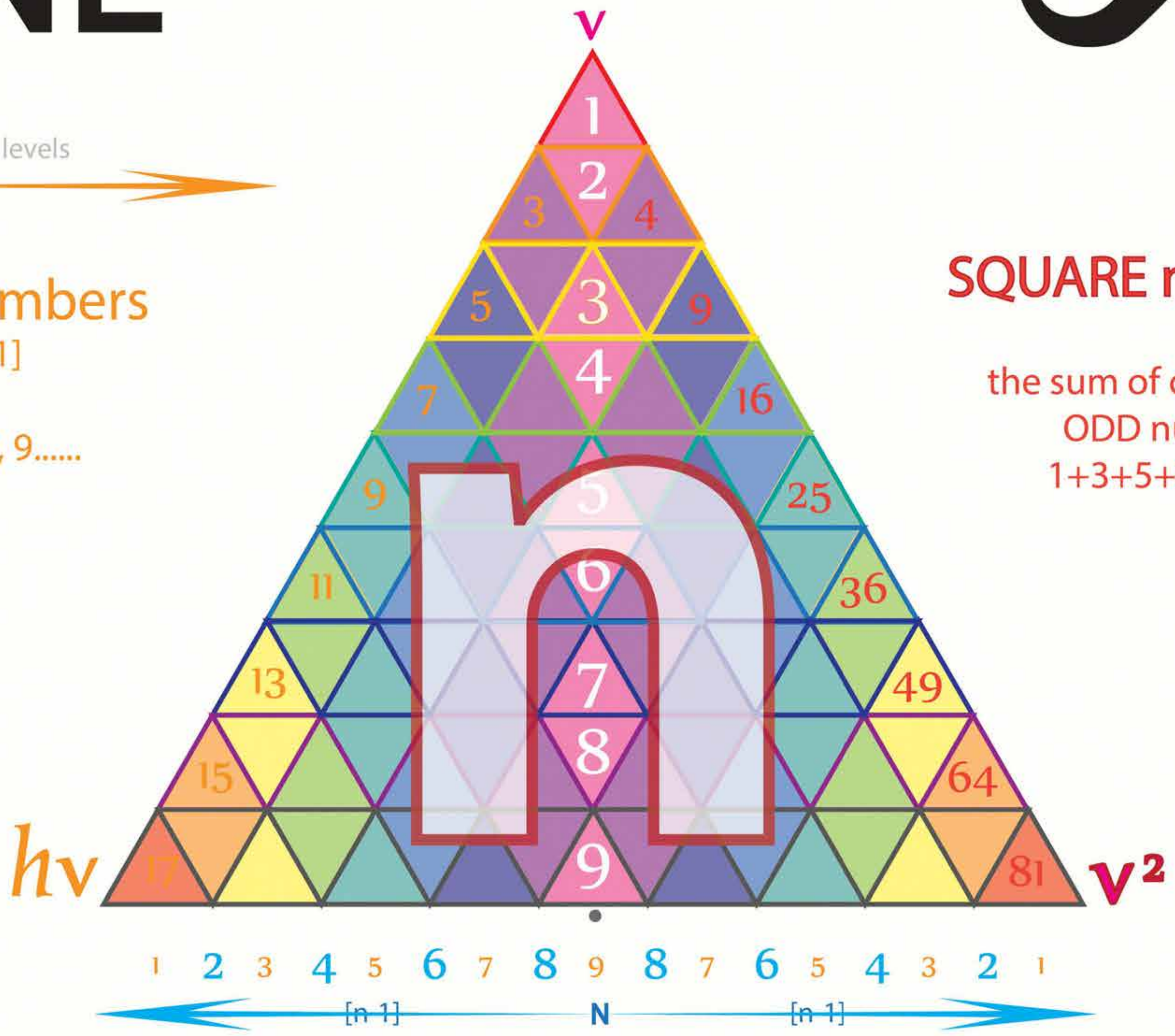
v
1
2
3 4
3
5 9
4
7 16
9 25
5
n
6
11 36
7
13 49
8
15 64
9
17 81
hv
v²
1 2 3 4 5 6 7 8 9 8 7 6 5 4 3 2 1
[n-1] N [n-1]

SQUARE numbers

the sum of consecutive ODD numbers

1+3+5+7+9+......

Scalar Energies ↓

Linear energy momentum

NORMAL DISTRIBUTION

Tetryonics 82.13 - One to Infinity squared

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Basic Properties of nested scribed Equilateral Triangles

Given an equilateral triangle of side s

altitude

$\sqrt{3/2}\,S$

$3S$

perimeter

$\sqrt{3/4}\,S^2$

area

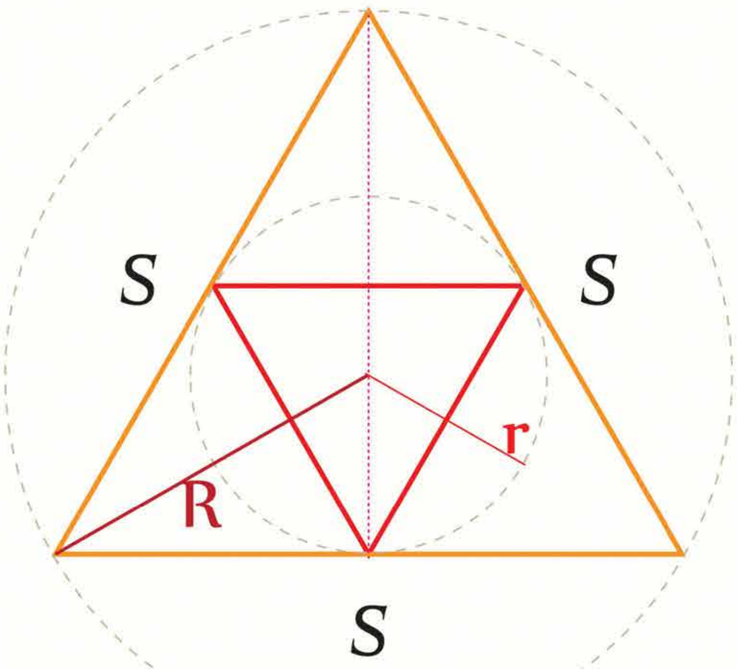

$\sqrt{3/6}\,S$

in-radius

$\sqrt{\pi/12}\,S^2$

in-circle area

circum-radius

$\sqrt{3/3}\,S$

circum-circle area

$\sqrt{\pi/3}\,S^2$

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Tetryonic [equilateral] geometry

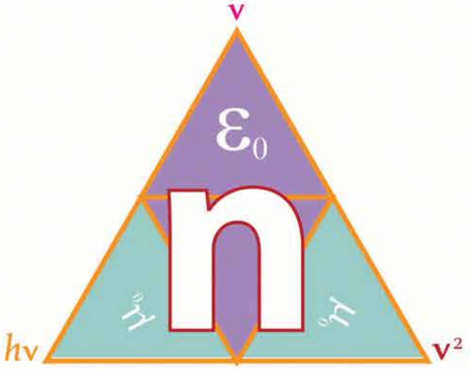

The equilateral triangle exhibits 'square symmetry'
it can always be divided into n^2 [number]
of smaller self-similar parts

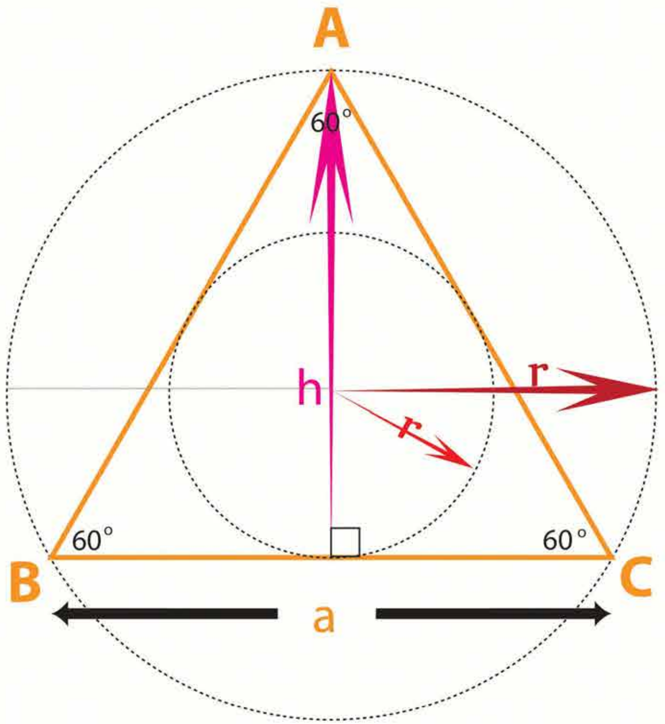

All triangles are
flat euclidean
π radian
geometries
[180°]

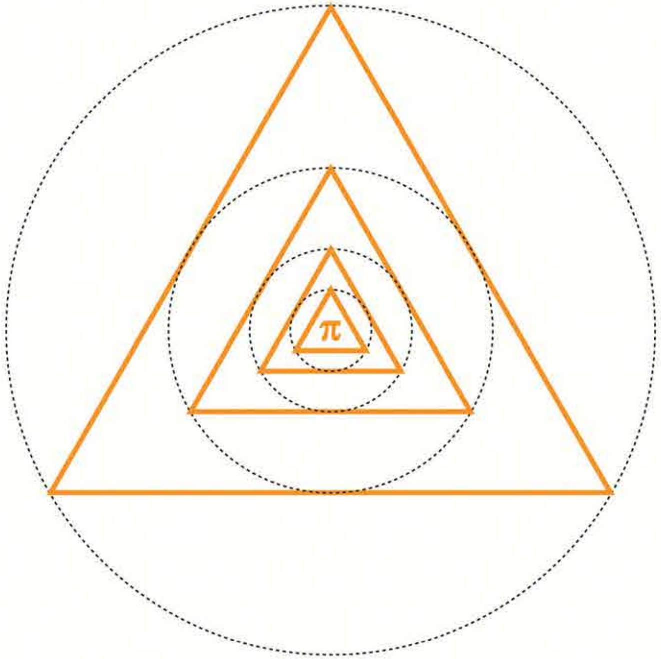

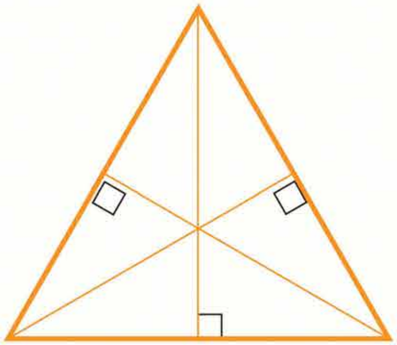

An equilateral triangle is the most symmetrical triangle,
having 3 lines of reflection and rotational symmetry of order 3 about its center

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CHARGE

Scribed equilateral geometries

reflect space-time's geometric relationship with charged mass-energy

Energy

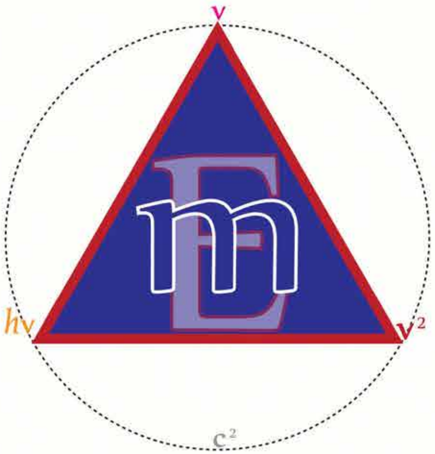

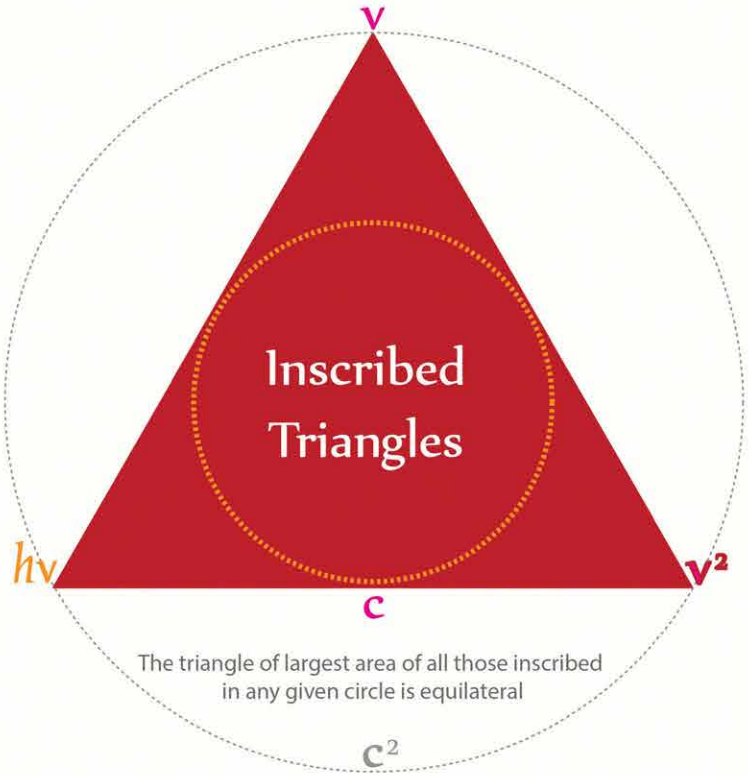
v
Inscribed
Triangles
hv
v²
c
c²

The triangle of largest area of all those inscribed in any given circle is equilateral

QAM

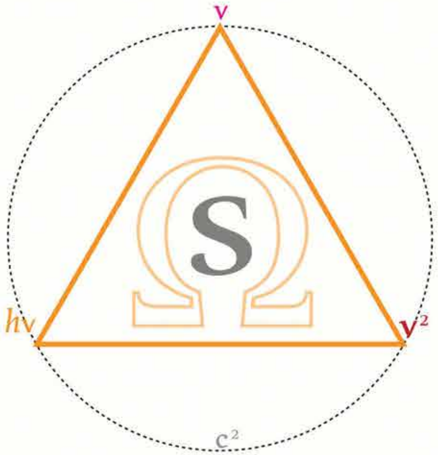

Energy per spatial unit

mass

QAM per spatial unit

seconds

$$m = \frac{E}{c^2}$$

$$\frac{\Omega}{c^2} = s$$

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Circumscribed Triangles

reflect Energy's relationship with Time

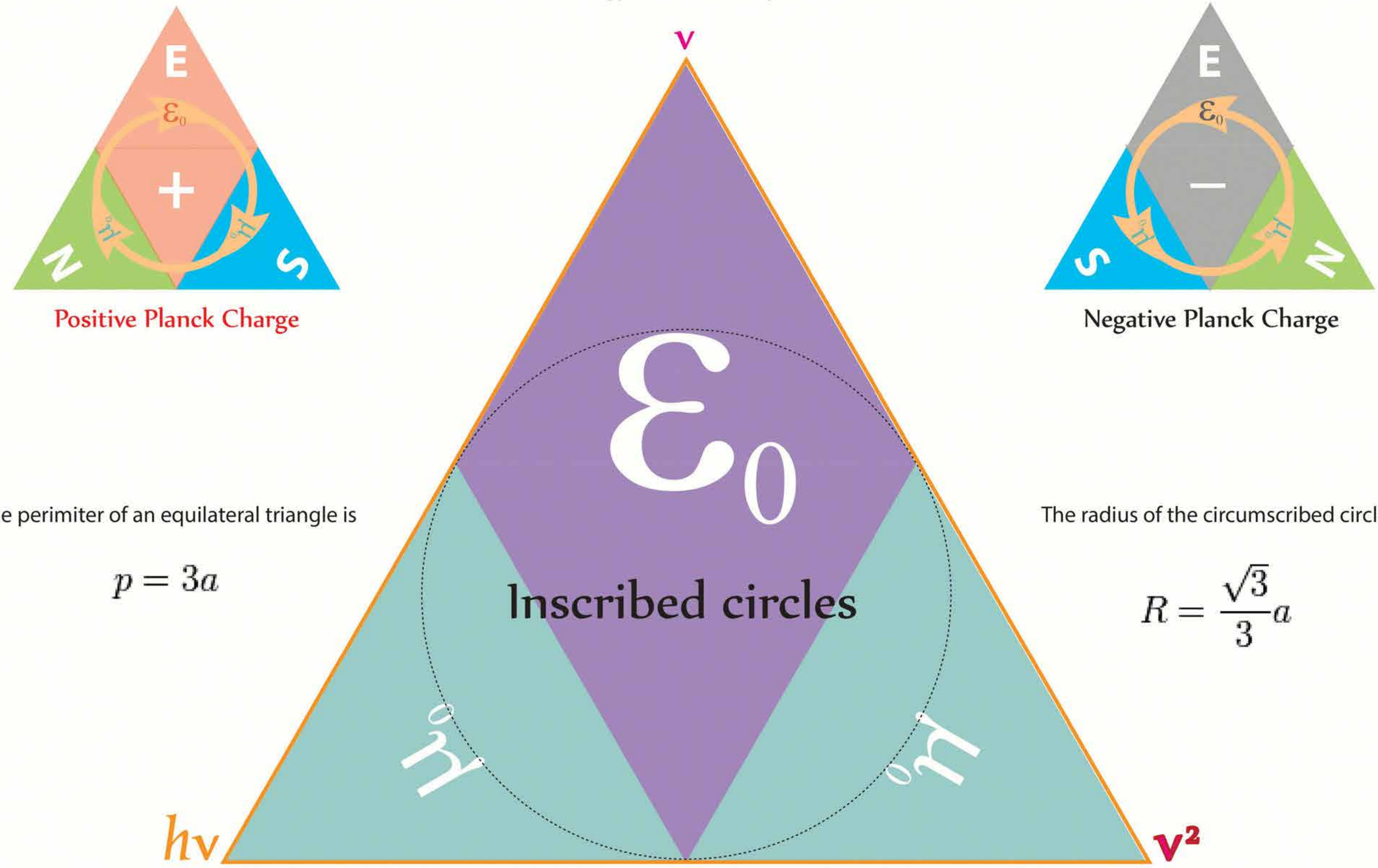
E
ε_0
+
μ_0
μ_0
N
S

Positive Planck Charge

E
ε_0
–
μ_0
μ_0
S
N

Negative Planck Charge

v
ε_0
Inscribed circles
μ_0
μ_0
hv
v²

The perimeter of an equilateral triangle is

$$p = 3a$$

The radius of the circumscribed circle is

$$R = \frac{\sqrt{3}}{3}a$$

The equilateral triangle has the smallest area of all those circumscribed around a given circle

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Circumscribed circles

By Euler's inequality, the equilateral triangle has the smallest ratio R/r of the circumradius to the inradius of any triangle: specifically, R/r = 2

The ratio of the area to the square of the perimeter of an equilateral triangle

$$\frac{1}{12\sqrt{3}}$$

The ratio of the area of the incircle to the area of an equilateral triangle

$$\frac{\pi}{3\sqrt{3}}$$

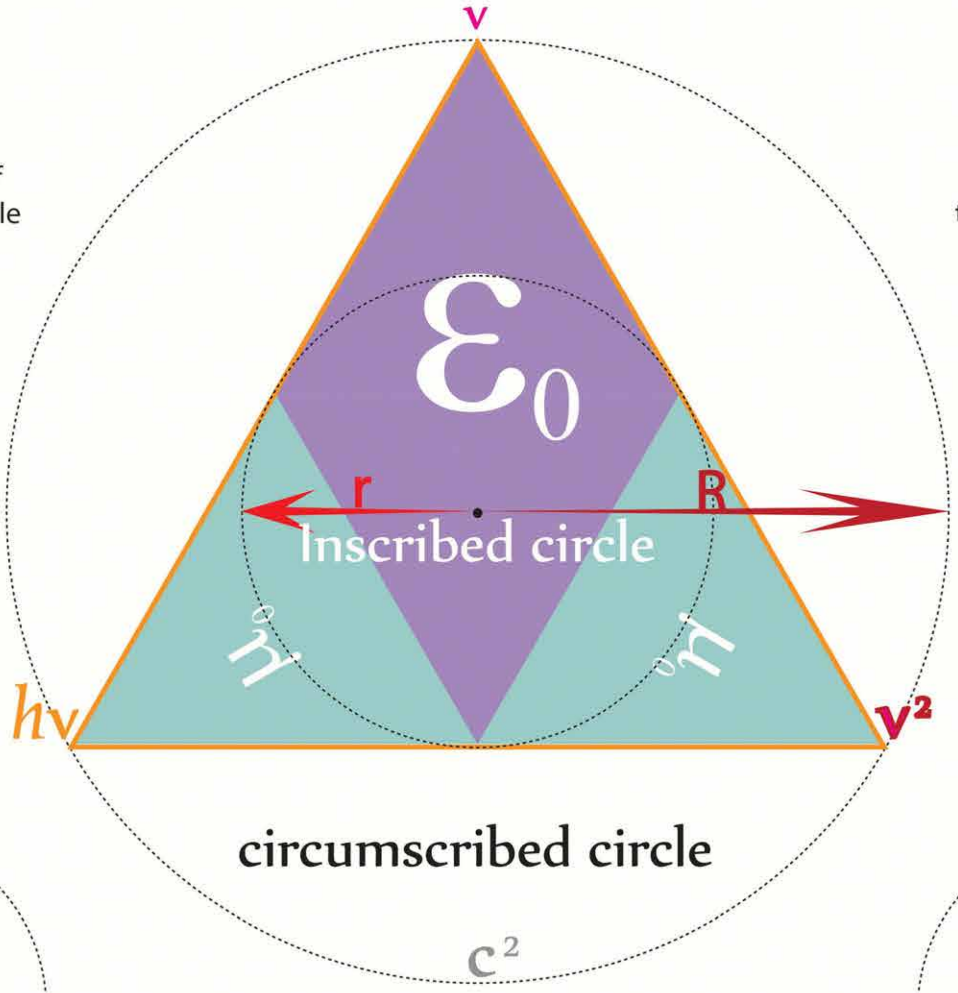
v
ε_0
r
R
Inscribed circle
μ_0
μ_0
hv
v^2
circumscribed circle
c^2

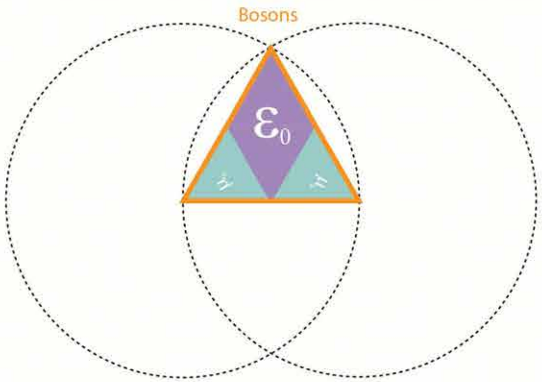
Bosons
ε_0

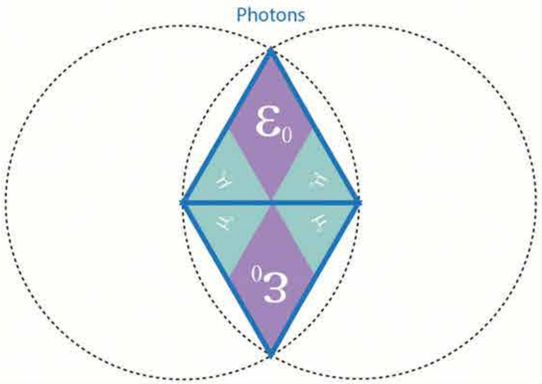
Photons
ε_0

Equilateral triangles and Tetrahedrons will scale at exactly the same proportion as Circles and Spheres scribing them

Charged mass-ENERGIES

Charge is the result of quantised angular momenta
[the inscribed circular flux of energy in equilateral geometries]

Time is a measure of changing quantised angular momenta
[the circumscribed spatial co-ordinate of equilateral energy geometries]

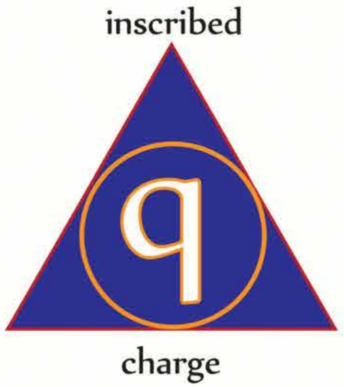

It is the equilateral geometry of energy not a classical vector rotation that creates QAM

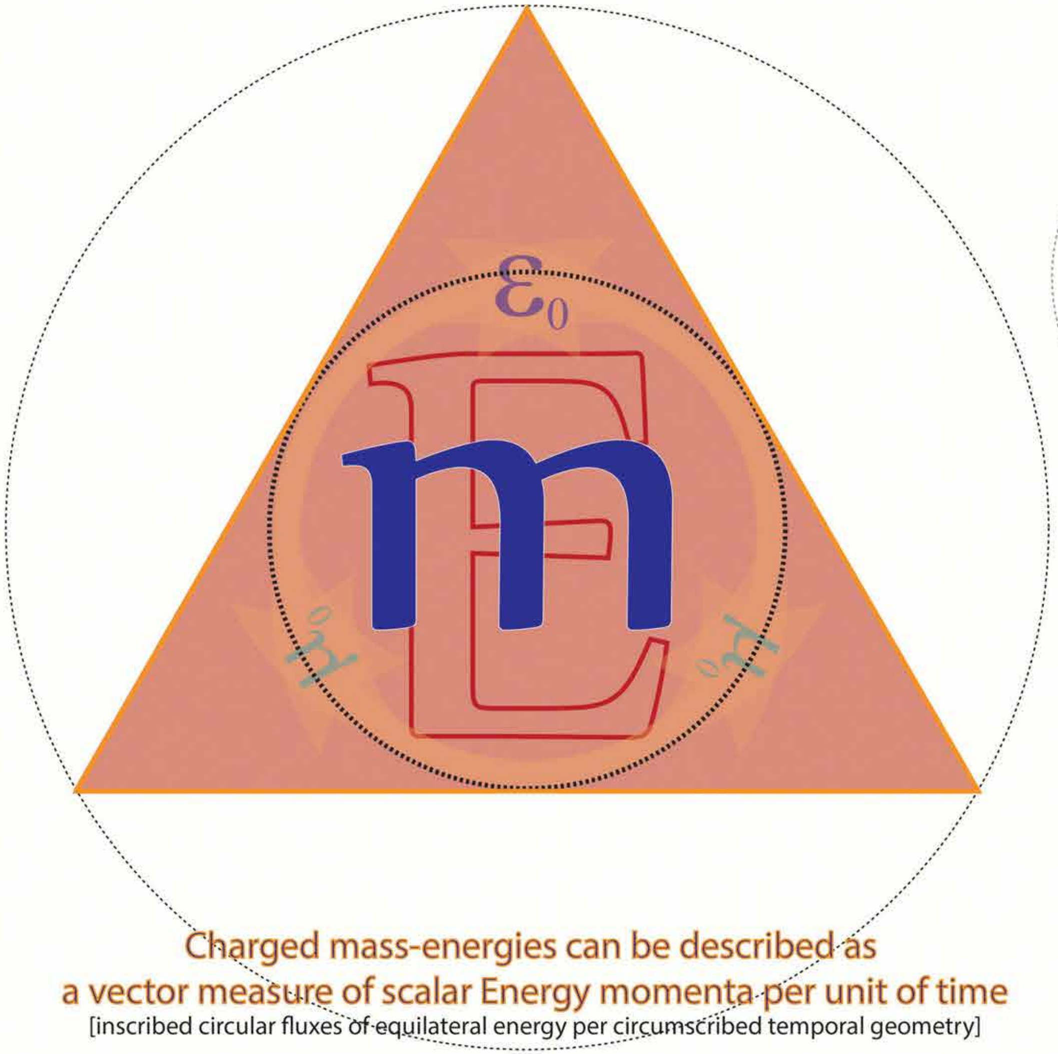

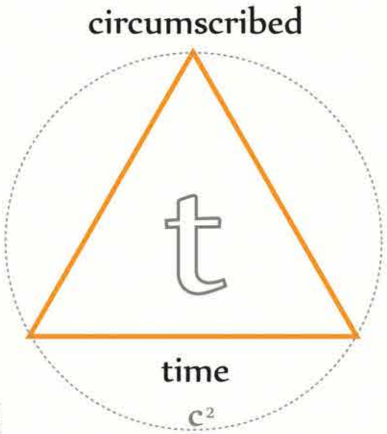

Scalar EM mass is a measure of equilateral Planck energy per spatial co-ordinate system

m

Charged mass-energies can be described as
a vector measure of scalar Energy momenta per unit of time
[inscribed circular fluxes of equilateral energy per circumscribed temporal geometry]

E

Trigometric functions

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

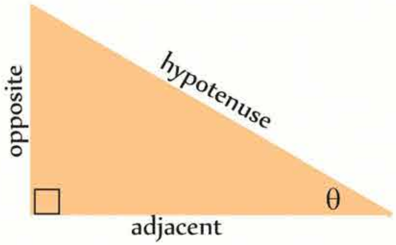
opposite
hypotenuse
θ
adjacent

Standard trigometric functions must be carefully applied to measurements of equilateral Planck mass-energy geometries in scribed circular space-time co-ordinate systems

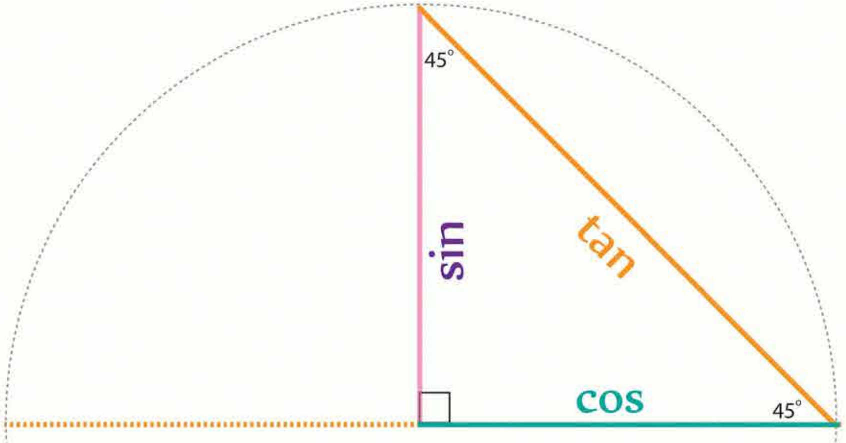
45°
sin
tan
cos
45°

The most familiar trigonometric functions are the sine, cosine, and tangent.

In the context of the standard unit circle with radius 1,
where a triangle is formed by a ray originating at the origin and
making some angle with the x-axis,

the SINE of the angle gives the length of the y-component (rise) of the triangle,
the COSINE gives the length of the x-component (run), and
the TANGENT function gives the slope
(y-component divided by the x-component)

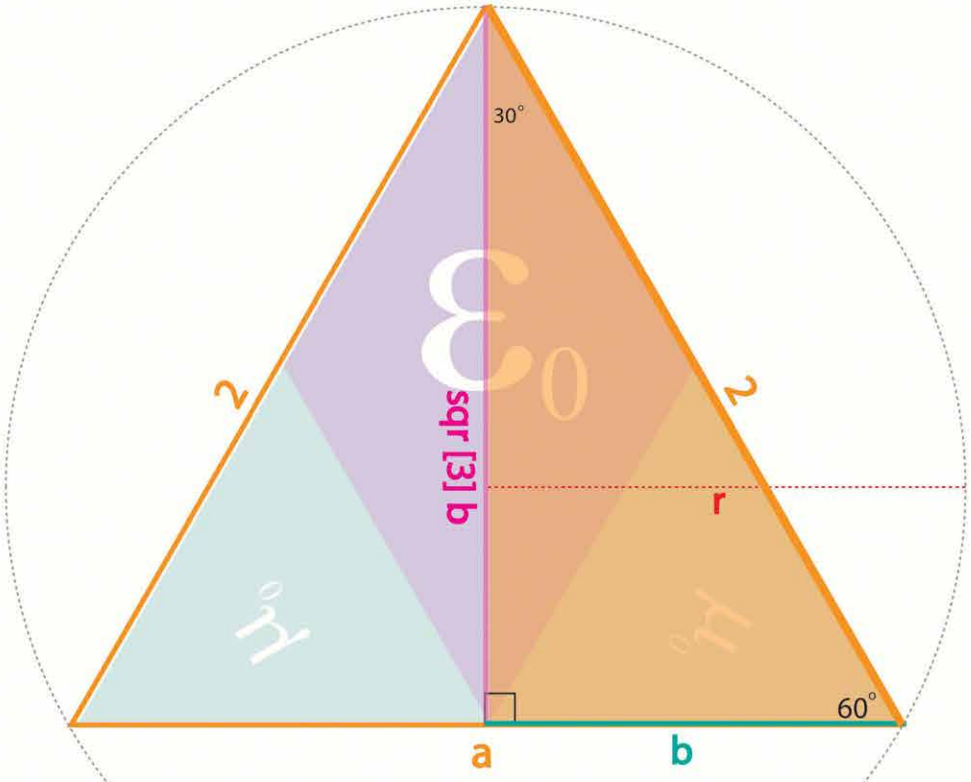
30°
ε0
sqr [3] b
2
2
r
μ0
μ0
60°
a
b

In most cases it is in fact easier to
ignore the trigonomteric functions and math
and simpy draw their related equilateral geometries

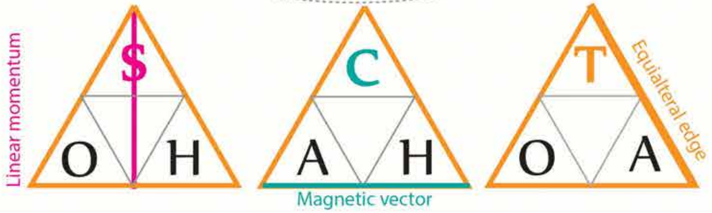
Linear momentum
S
O
H
C
A
H
Magnetic vector
T
O
A
Equilateral edge

The roots of scribed equilateral triangles

Scalar equilateral energies map directly onto circular space-time co-ordinates
through their square root linear momentum

r

The ratio of the
circumscribed circle of
an equilateral triangle
to its inscribed circle
is 2:1

d

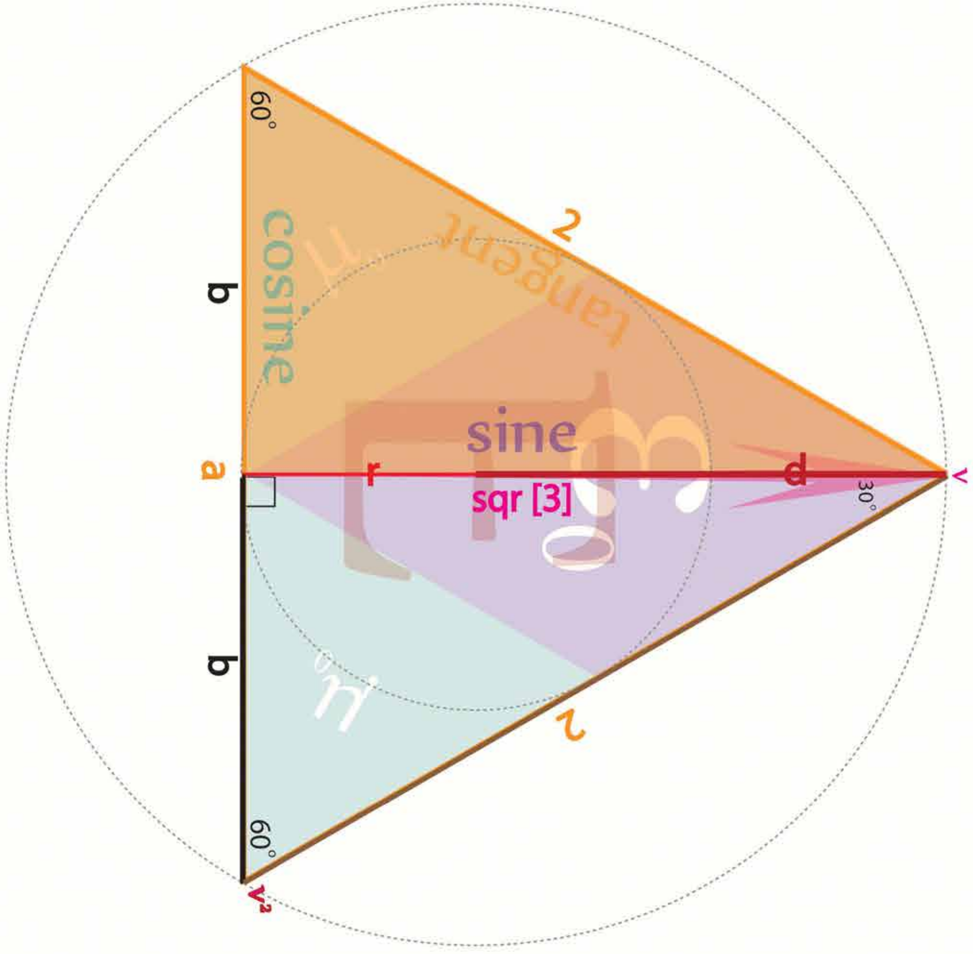
60°
cosine
2
tangent
b
sine
a
r
d
sqr [3]
30°
v
b
2
60°
v²

0.866 r

The ratio of the
side of an equilateral triangle
to the radius of
its incribed circle
is sqr [3]/2

a

The ratio of the
side of an equilateral triangle
to the radius of
its circumscribed circle
is sqr [3]

1.732 d

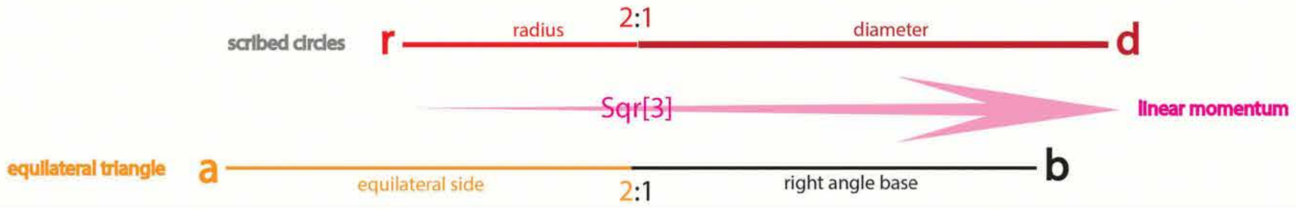
scribed circles
r
radius
2:1
diameter
d
Sqr[3]
linear momentum
equilateral triangle
a
equilateral side
2:1
right angle base
b

Equilateral triangles and scribed circles

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{1}{\sqrt{1-\beta^2}} = \frac{dt}{d\tau}$$

$$\gamma(\beta) = 1 + \frac{1}{2}\beta^2 + \frac{3}{8}\beta^4 + \frac{5}{16}\beta^6 + \frac{35}{128}\beta^8 + \ldots$$

$$L = L'\sqrt{1 - \frac{v^2}{c^2}}$$

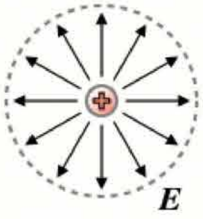

$$mc^2\left\{\frac{1}{\sqrt{1 - v^2/c^2}} - 1\right\}$$

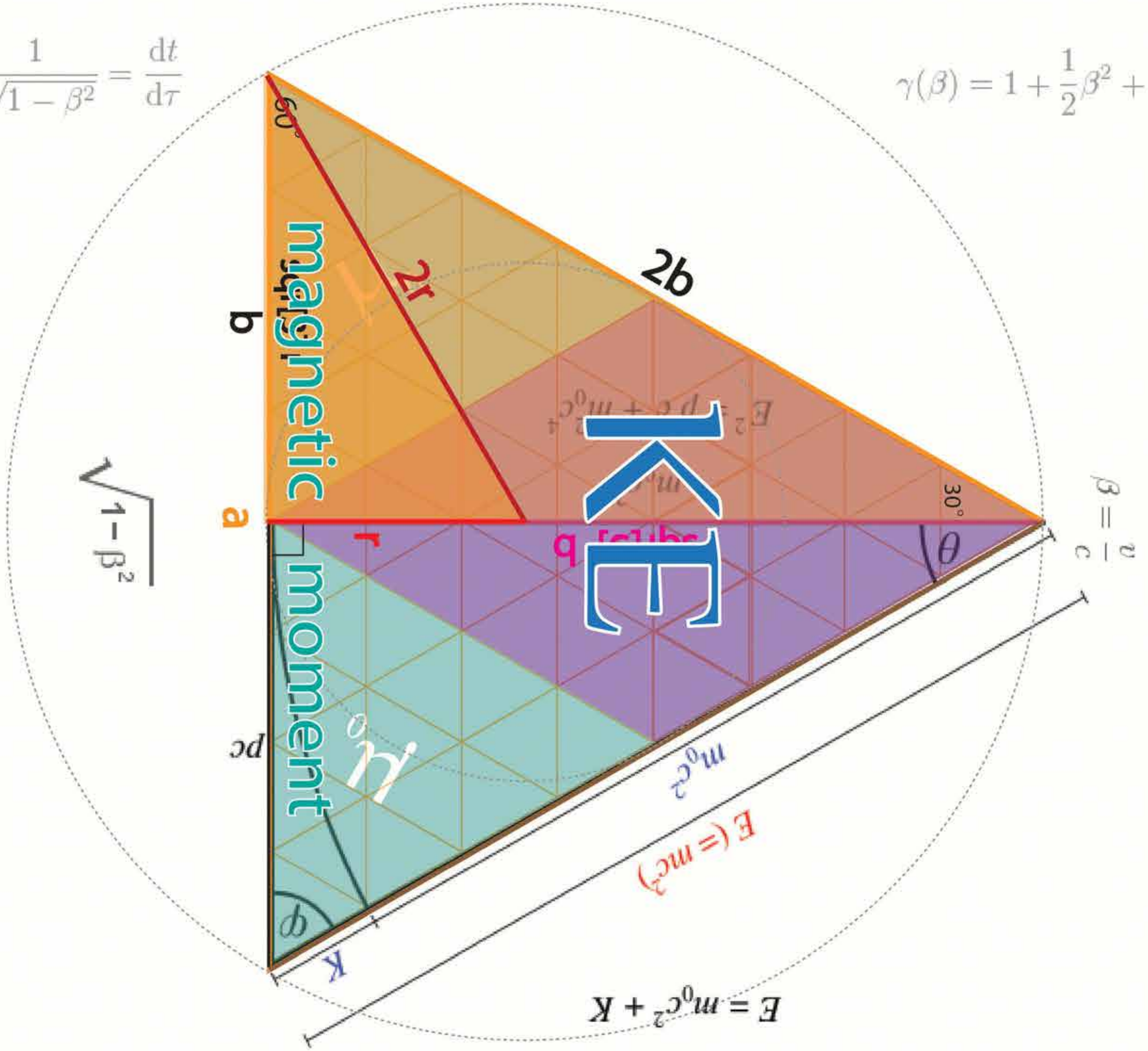
60°
2r
2b
b
magnetic
moment
a
r
q
KE
30°
θ
φ
μ
μ₀
pc
m₀c²
E (= mc²)
K
E² = p²c² + m₀²c⁴
E = m₀c² + K
√1-β²
β = v/c

$$E_k = \frac{mc^2}{\sqrt{1-(v/c)^2}} - mc^2$$

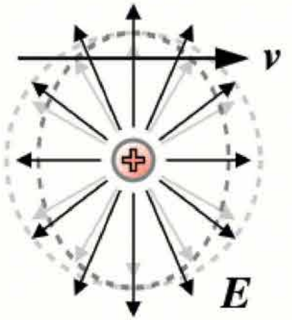

$$p = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}} = \gamma m_0 v$$

$$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

All the relativistic relationships historically attributed to circularised energies and modelled through the use of the math of right angled triangles are in fact the result of equilateral, scalar geometries

$$\sqrt{1 - \left(\frac{v}{c}\right)^2}$$

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Finite sequences and series have defined first and last terms,

$$\sum a_n = a_0 + a_1 + a_2$$

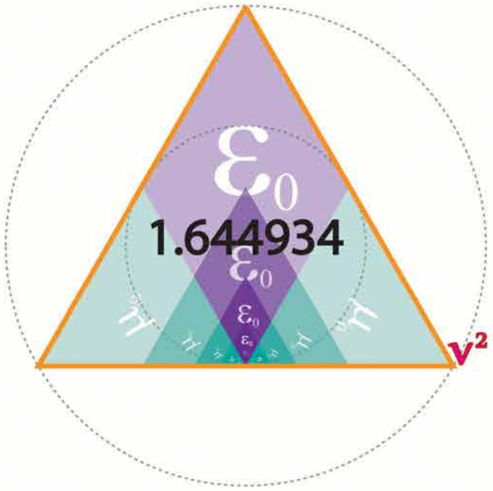

$$\sum_{n=1}^{\infty} \frac{1}{n^2} = \lim_{n\to+\infty} \left(\frac{1}{1^2} + \frac{1}{2^2} + \cdots + \frac{1}{n^2} \right).$$

whereas infinite sequences and series continue indefinitely

The Basel problem is a famous problem in mathematical analysis with relevance to number theory, first posed by Pietro Mengoli in 1644 and solved by Leonhard Euler in 1735.

$$\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \frac{1}{4^2} + \frac{1}{5^2} + \ldots = \frac{\pi^2}{6}$$

Tetryonics now provides a geometric solution to visualising and solving the Basel problem

$$\zeta(2) = 1 + \frac{1}{2^2} + \frac{1}{3^2} + \cdots = \frac{\pi^2}{6} \approx 1.645;$$

Tetryonic Infinite Series

is a infinite sequence of square numbers,
the result of adding all those terms together
[or their geometric inverse]

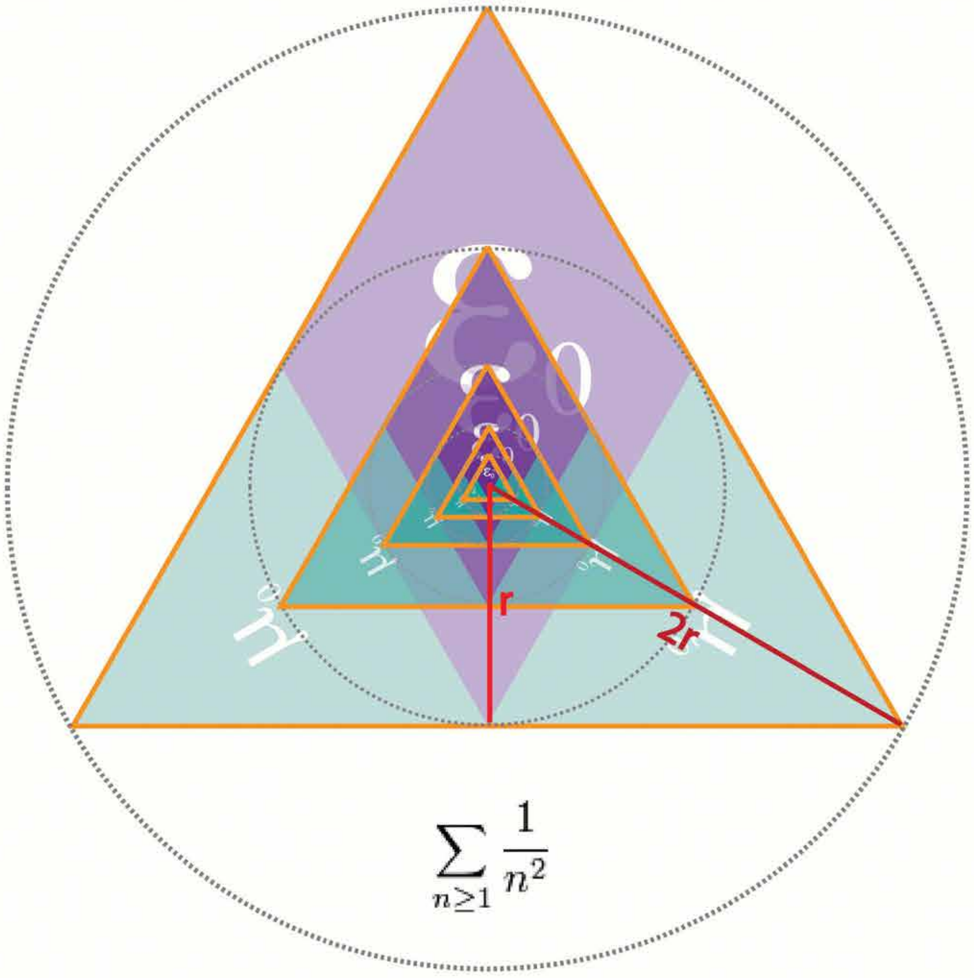

$$\sum_{n\geq 1} \frac{1}{n^2}$$

The entire sum of the series is equal to
twice the size of the radius of the largest inscribed circle
which is equal to the largest circle circumscribing the triangular series.

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Inverting the Circle

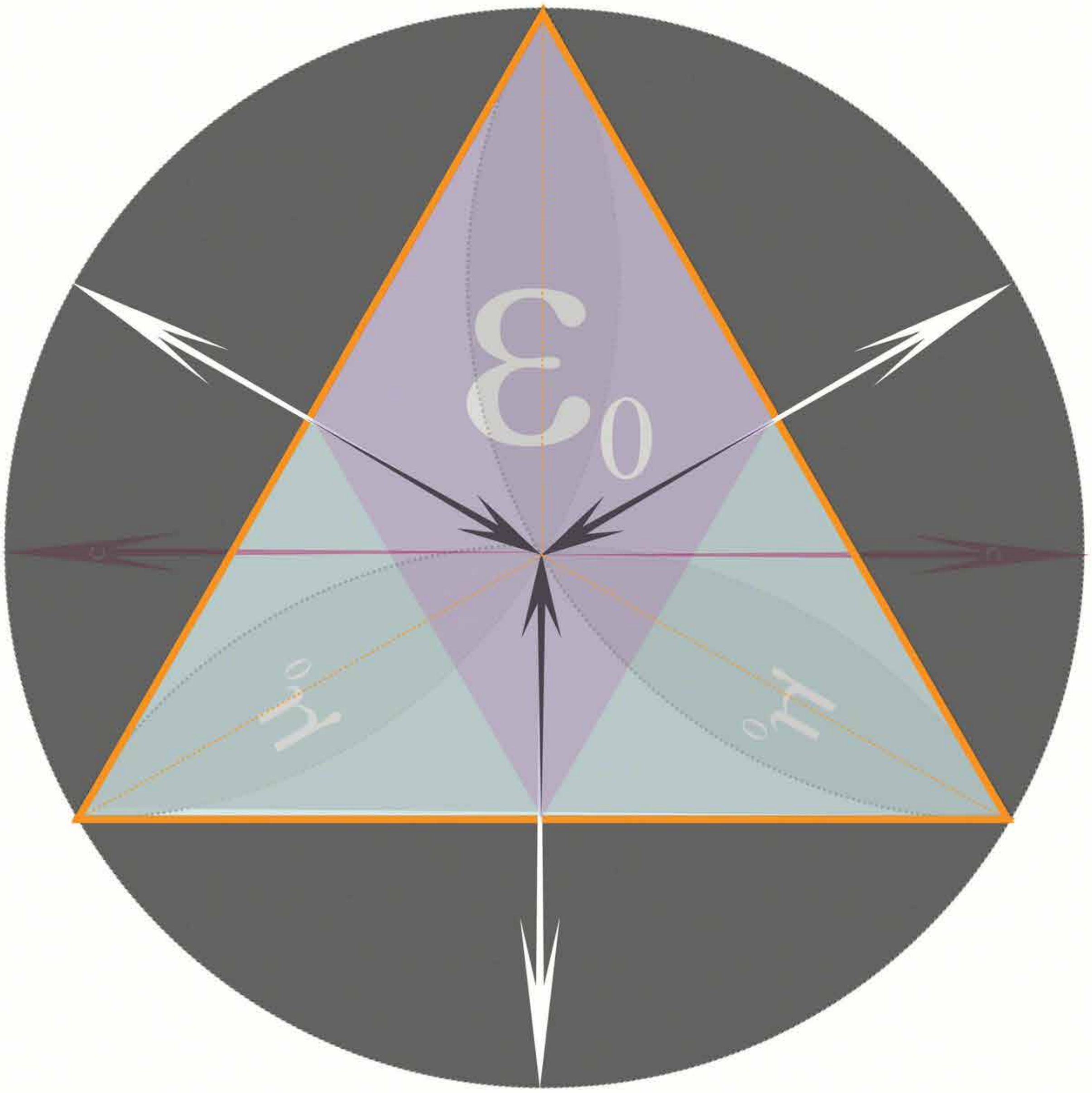

Electric
Permittivity

ε_o

Magnetic
Permeability

μ_o

c^2

2D spatial
co-ordinates

$\frac{1}{c^2}$

ElectroMagnetic
fields

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Irrational numbers

an irrational number cannot be represented as a simple fraction.
Irrational numbers are those real numbers that cannot be represented as terminating or repeating decimals

sin(x)=-square root of (3)/2

0.866025403.......

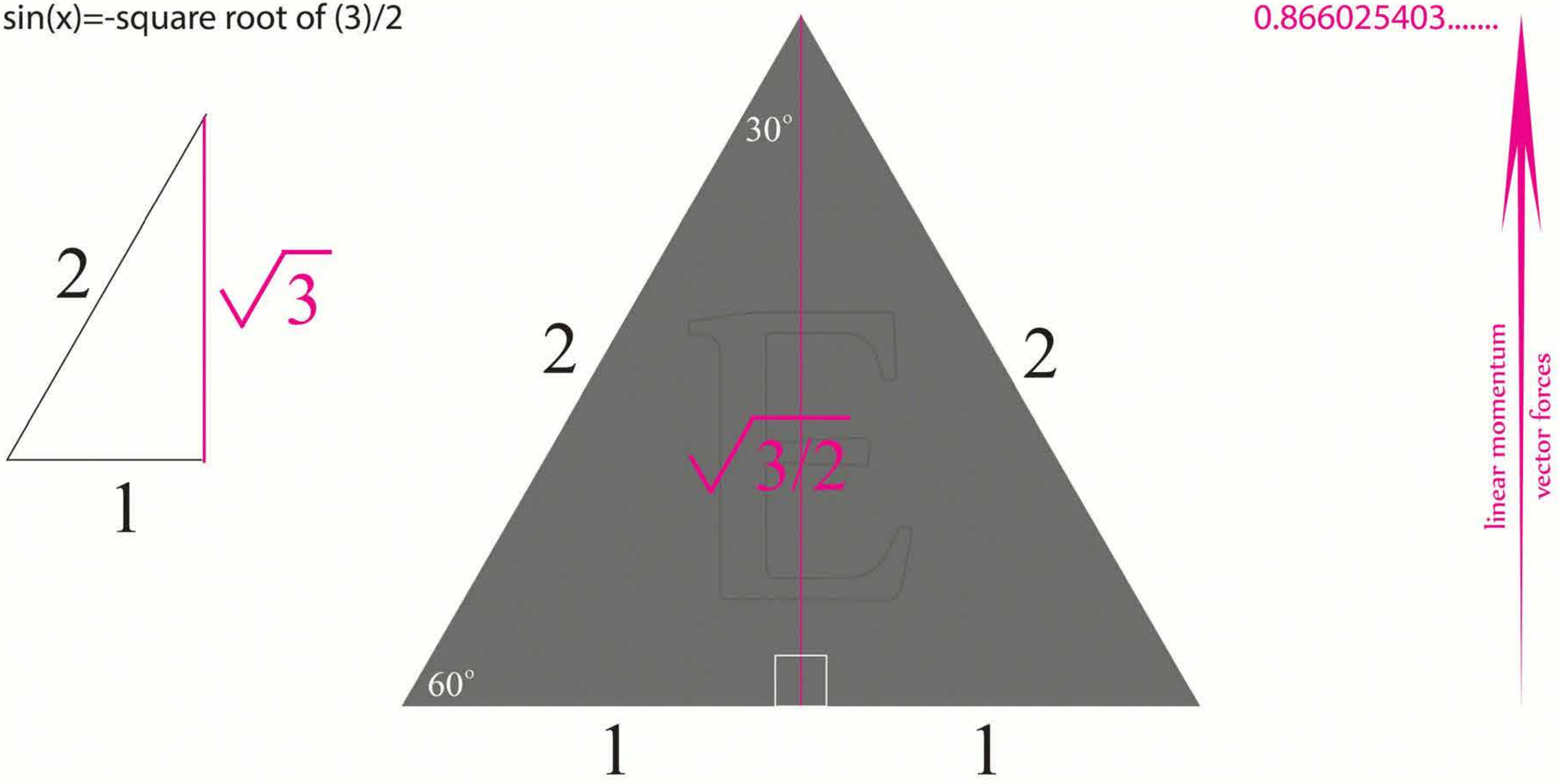
2
$\sqrt{3}$
1
30°
2
2
$\sqrt{3/2}$
60°
1
1
linear momentum
vector forces

Pythagφras' theoreom
and irratiφnal numbers expressed in terms of right-angled triangles in Physics
offer a 'half truth' regarding the equilateral geometry of Energy

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Leibniz

Leibniz introduced the concept of vis viva (living force) which attempted to quantify life force

$E=mv^2$

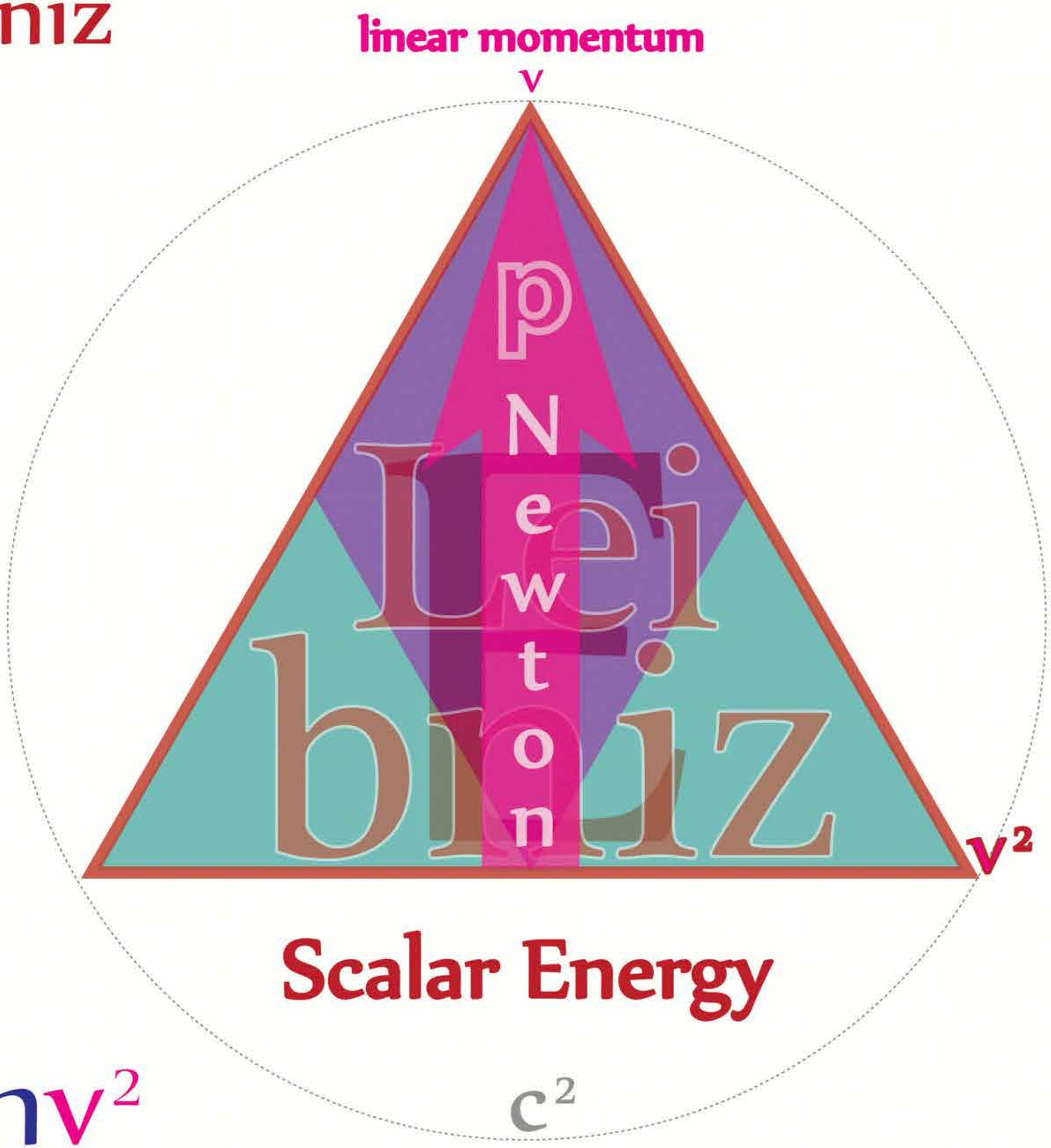

Newton

Newton focused his work on linear momentum which he developed into his famous laws of motion

Newton and Leibniz disagreed about what the world is made of and how its physics shaped our scientific concepts of force, energy, and momentum

Tetryonics reveals the physical relationships they both described mathematically as geometric properties of equilateral Planck energy momenta

$p=mv$

Geometric Square Roots

In geometrical terms, the square root function maps the area of a square to its side length.

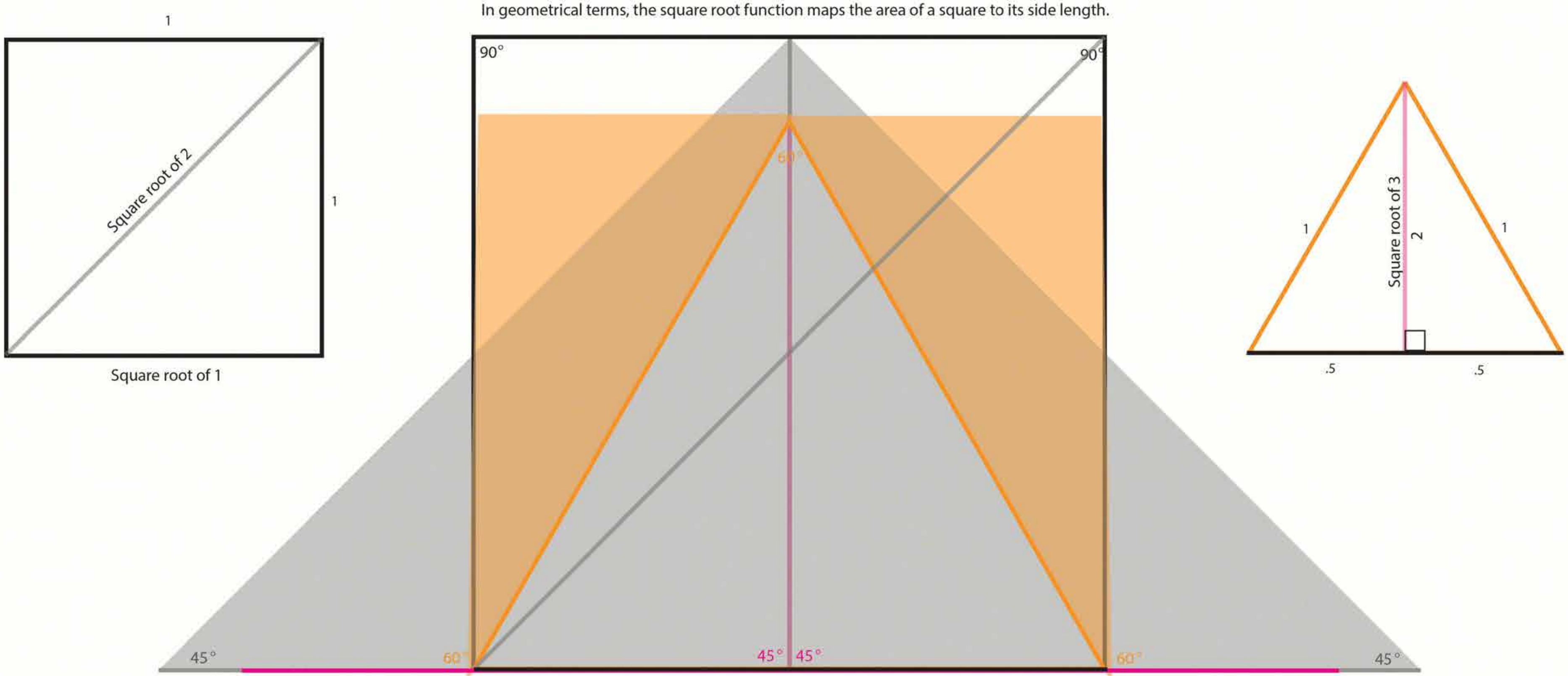

Square root of 1

"In mathematics, as in any scientific research, we find two tendencies present. On the one hand, the tendency toward abstraction seeks to crystallize the logical relations inherent in the maze of material that is being studied, and to correlate the material in a systematic and orderly manner. On the other hand, the tendency toward intuitive understanding fosters a more immediate grasp of the objects one studies, a live rapport with them, so to speak, which stresses the concrete meaning of their relations"

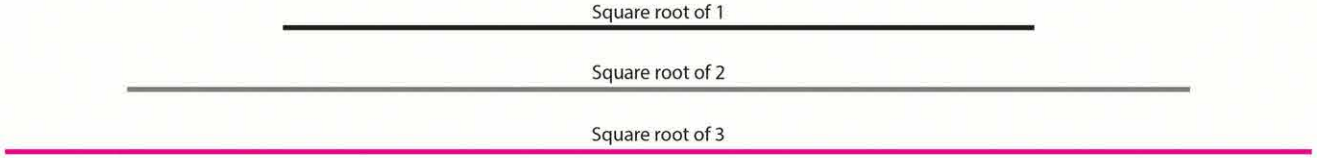

"As to geometry, in particular, the abstract tendency has here led to the magnificent systematic theories of Algebraic Geometry, of Riemannian Geometry, and of Topology; these theories make extensive use of abstract reasoning and symbolic calculation in the sense of algebra.

Notwithstanding this, it is still as true today as it ever was that intuitive understanding plays a major role in geometry. And such concrete intuition is of great value not only for the research worker, but also for anyone who wishes to study and appreciate the results of research in geometry"

David Hilbert [Geometry and the Imagination]

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Square Roots in Physics

In mathematics, a square root of a number a is a number [n] such that [n]2 = x,
or, in other words, a number [n] whose square (the result of multiplying the number by itself, or [n × n]) is x.

Modern calculators use the
Square Root Algorithm
to calculate the value

It is an approximate numerical value

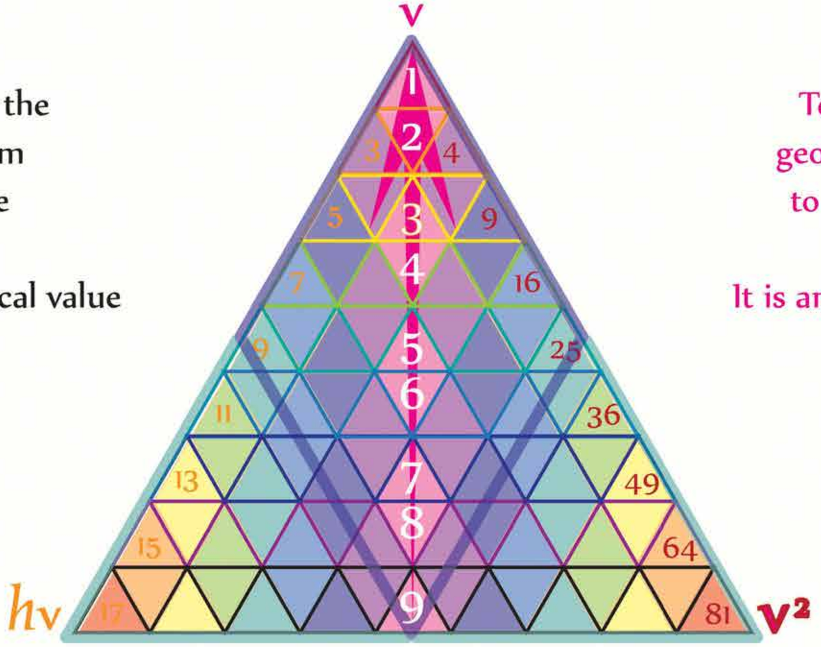

Tetryonics uses the
geometric Square Root
to calculate the value

It is an exact geometric value

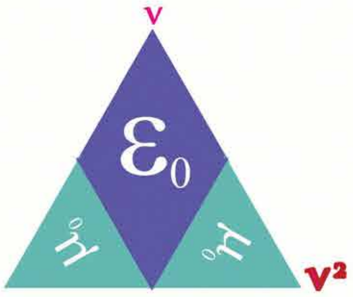

$$E = mv^2$$

In classical geometry,
the square root function maps the
area of a square to its side length.

$$p = \sqrt{E}$$

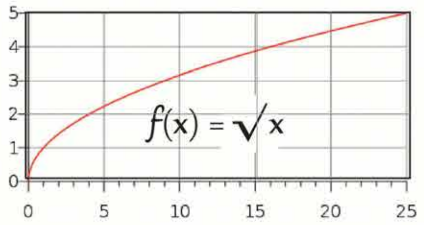

Geometry can easily map irrational numbers

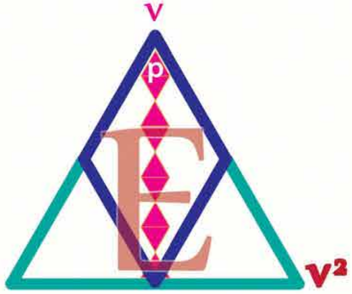

$$p^2 = E$$

In physics,
the square root function maps
ENERGY [E] to momentum [mv]

The Square roots of n

Historically, any number raised to the power of 2 has been modeled using a polygon--the square
That's why we call raising a number to the second power "squaring the number."

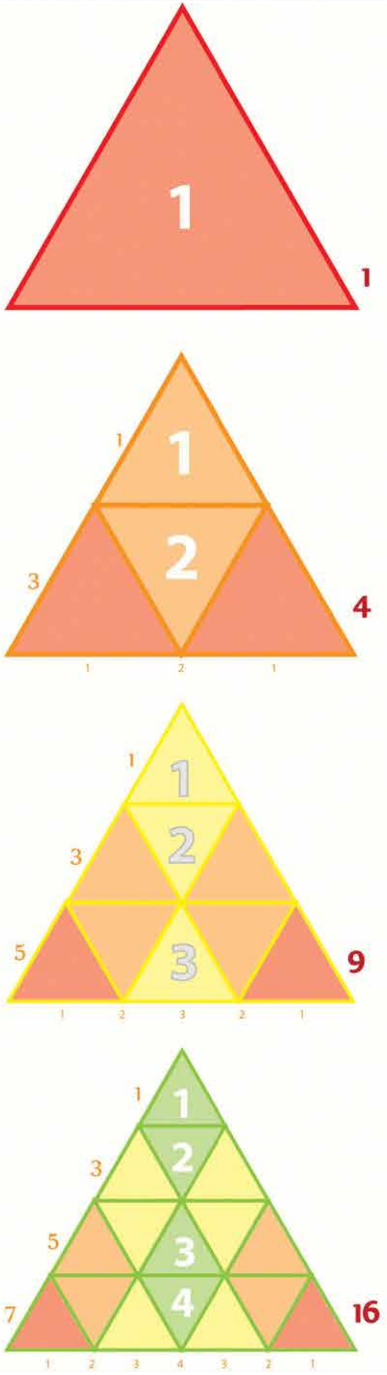
1
1
1
2
4
1
2
3
9
1
2
3
4
16

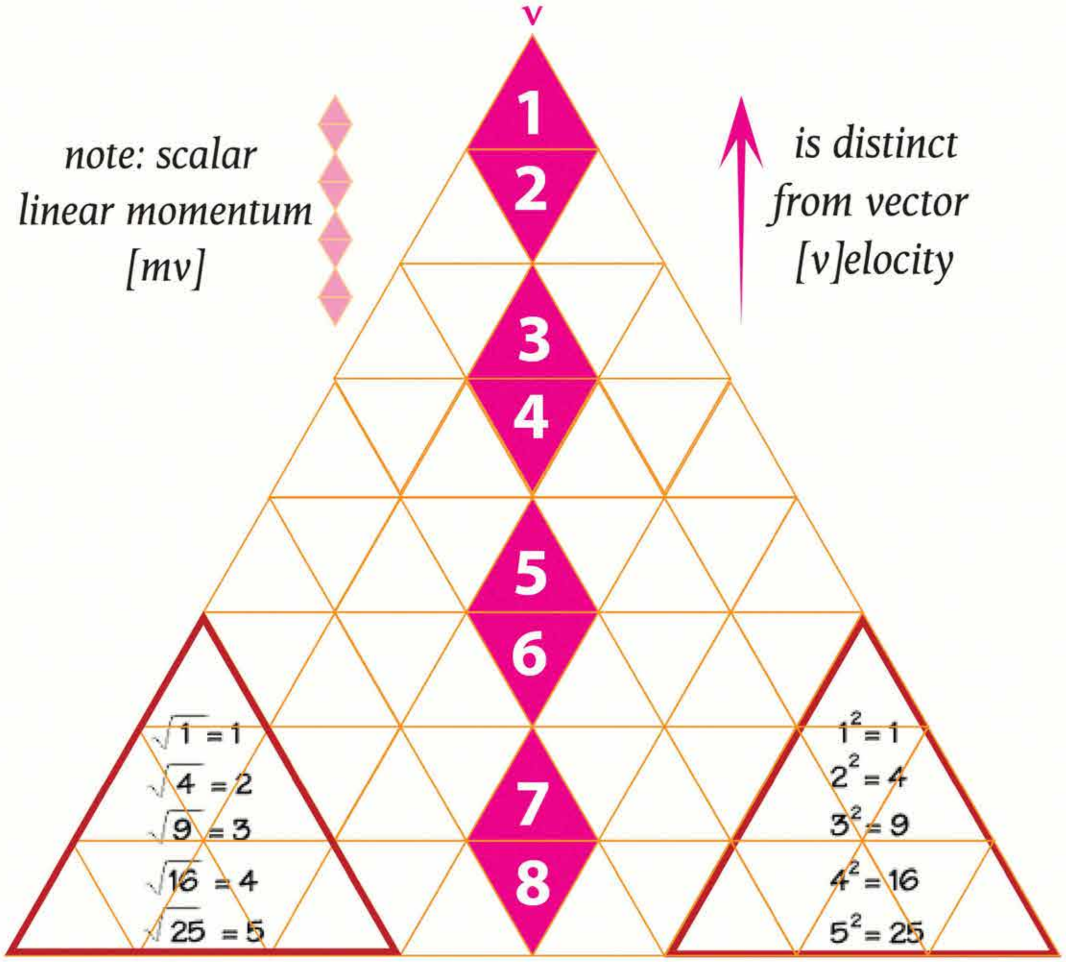
v
1
2
3
4
5
6
7
8
$\sqrt{1} = 1$
$\sqrt{4} = 2$
$\sqrt{9} = 3$
$\sqrt{16} = 4$
$\sqrt{25} = 5$
$1^2 = 1$
$2^2 = 4$
$3^2 = 9$
$4^2 = 16$
$5^2 = 25$

note: scalar linear momentum [mv]

is distinct from vector [v]elocity

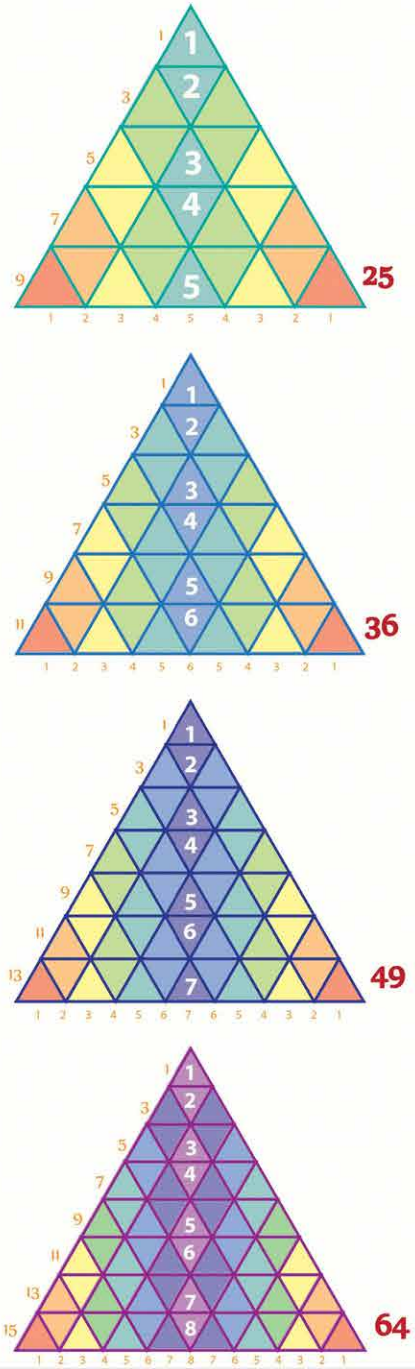
1
2
3
4
5
25
1
2
3
4
5
6
36
1
2
3
4
5
6
7
49
1
2
3
4
5
6
7
8
64

[In physics square numbers are in fact equilateral geometries]
The perfect squares are squares of whole numbers.
Here are the first eight perfect squares

The Square root of Negative 1

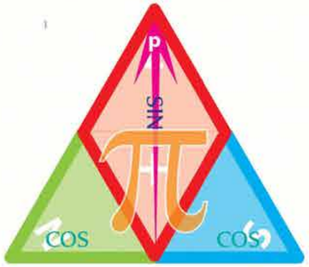

Positive fields are out of phase with Negative fields

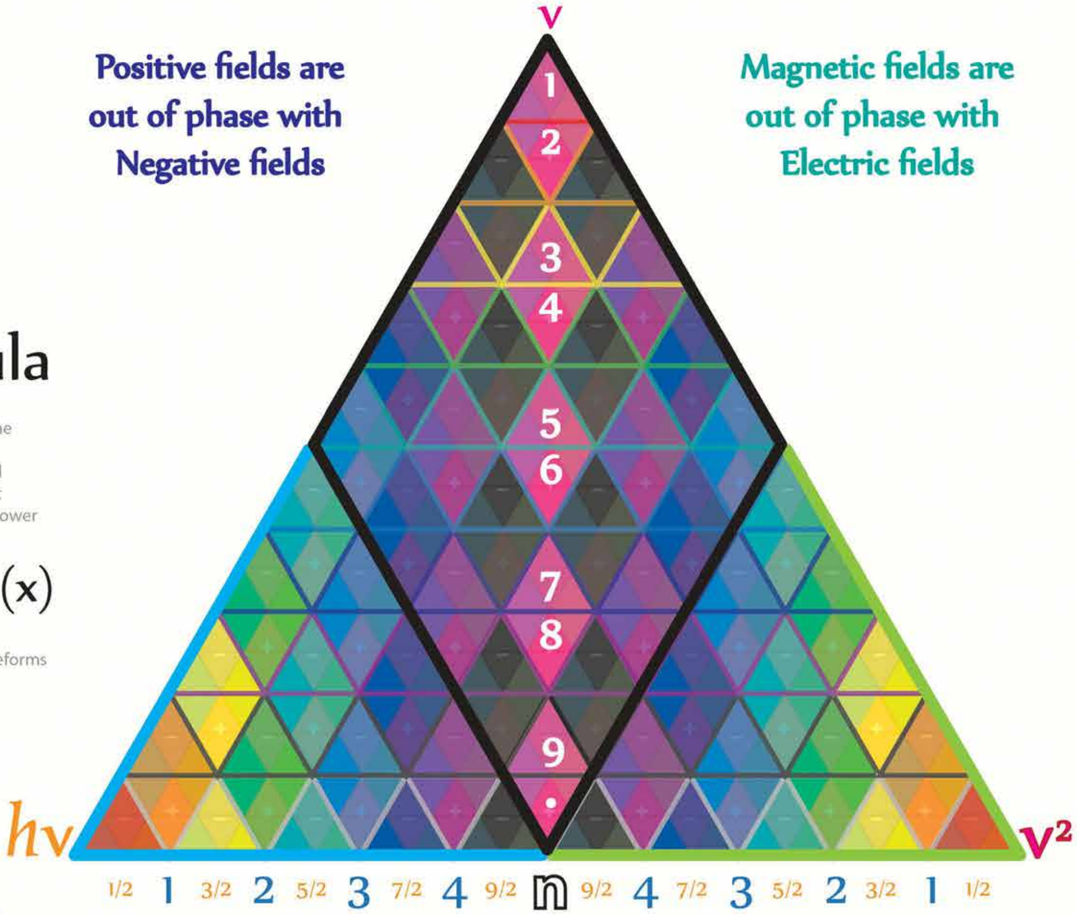

Magnetic fields are out of phase with Electric fields

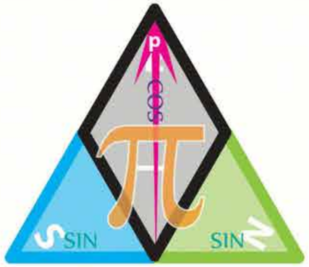

Leonhard Euler

(15 April 1707 – 18 September 1783)

Euler's Formula

Euler's formula is often considered to be the basis of the complex number system.
In deriving this formula, Euler established a relationship between the trigonometric functions, sine and cosine, and e raised to a power

$$e^{ix} = \cos(x) + i\sin(x)$$

a mathematical description of EM-Energy waveforms

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \dots$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \dots$$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \frac{x^5}{5!} + \dots$$

$$\sin x + \cos x = 1 + x - \frac{x^2}{2!} - \frac{x^3}{3!} + \frac{x^4}{4!} + \frac{x^5}{5!} + \dots$$

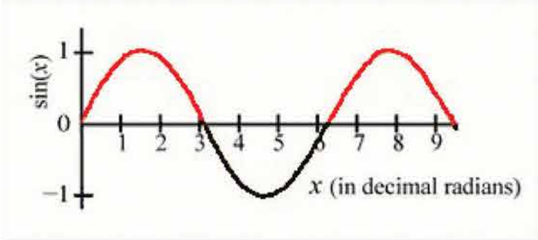

$$e^{i\pi} = -1$$

$$e^{i\pi} + 1 = 0$$

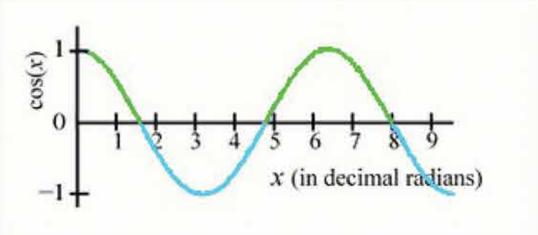

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Geometric means

The geometric mean of two numbers, is the square root of their product

geometric square root
of positive one

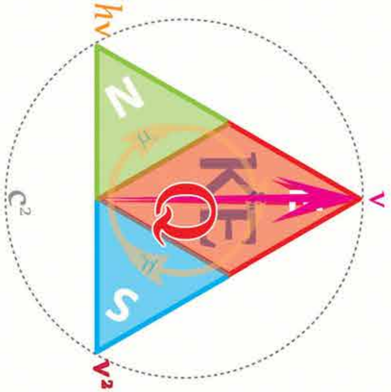

$$F = k\frac{Q_1 Q_2}{r^2}$$

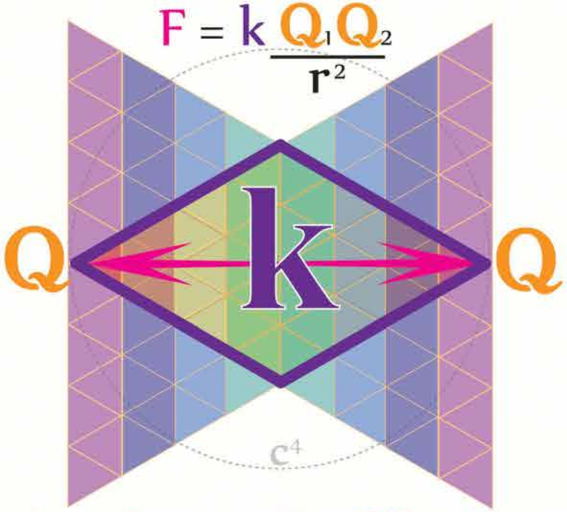

geometric square root
of negative one

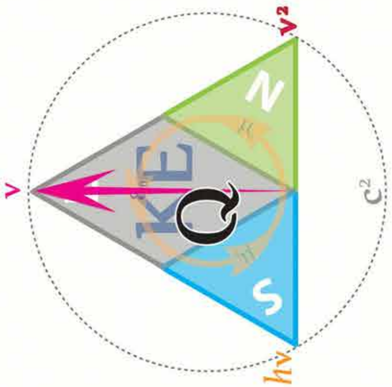

In physics, the geometric mean of two superpositioned fields produces a vector square root Force

It is generally stated that
the geometric mean applies
only to positive numbers.

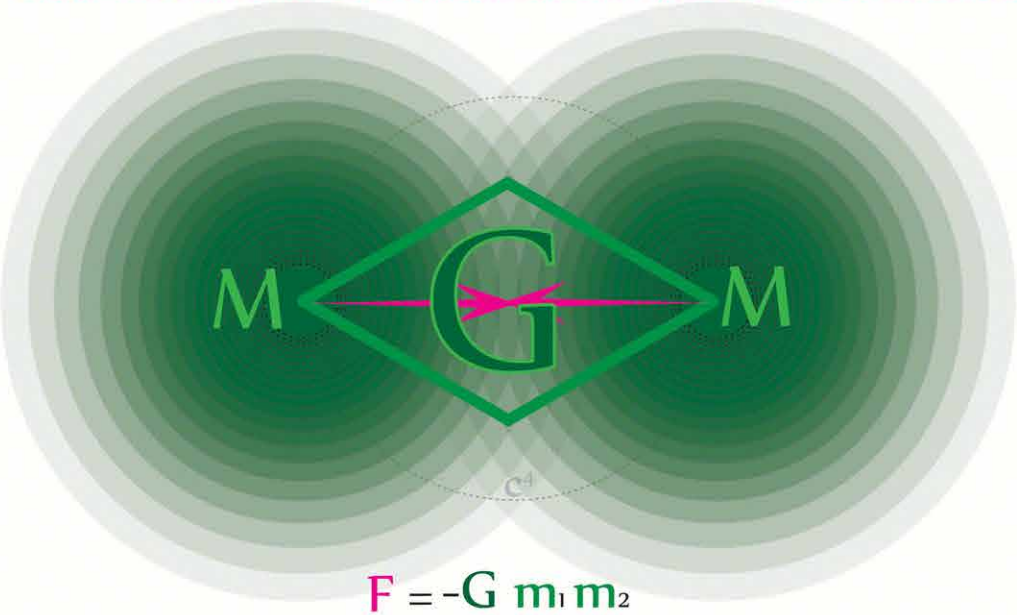

$$F = -G\frac{m_1 m_2}{r^2}$$

In Tetryonic geometry
the geometric mean applies
to positive & negative fields.

Superpositioning

When two or more waves traverse the same space,
the net amplitude at each point is the
sum of the amplitudes of the individual waves.

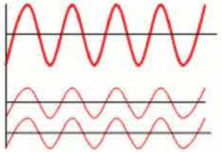

constructive interference

In phase

Additive

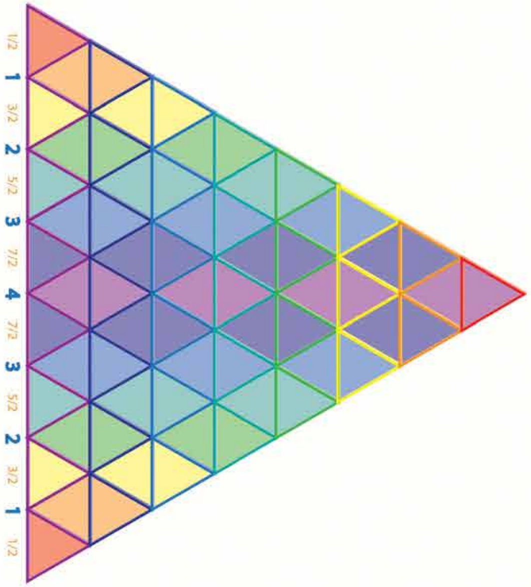
1/2
1
3/2
2
5/2
3
7/2
4
7/2
3
5/2
2
3/2
1
1/2

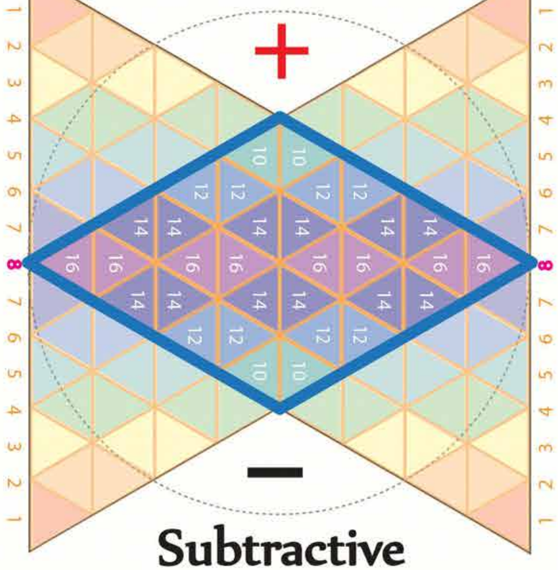
+
1
2
3
4
5
6
7
8
7
6
5
4
3
2
1
10
12
14
16
−

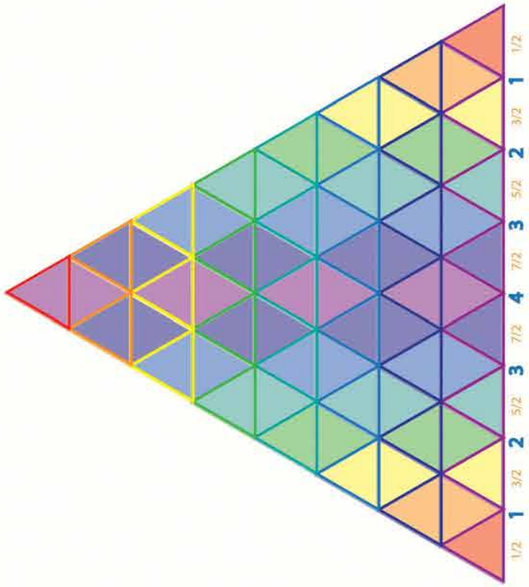
1/2
1
3/2
2
5/2
3
7/2
4
7/2
3
5/2
2
3/2
1
1/2

Subtractive

Out of phase

destructive interference

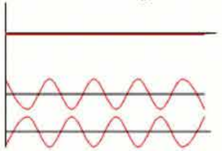

When two or more waves traverse the same space,
if the summed variation has a smaller amplitude
than the constiuent component variations.

The lines of Force

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Tetryonic Multiplication table

A multiplication table is a mathematical grid used to define a multiplication operation and its results

Multiplication Table

	1	2	3	4	5	6	7	8	9	10	11	12
1	1	2	3	4	5	6	7	8	9	10	11	12
2	2	4	6	8	10	12	14	16	18	20	22	24
3	3	6	9	12	15	18	21	24	27	30	33	36
4	4	8	12	16	20	24	28	32	36	40	44	48
5	5	10	15	20	25	30	35	40	45	50	55	60
6	6	12	18	24	30	36	42	48	54	60	66	72
7	7	14	21	28	35	42	49	56	63	70	77	84
8	8	16	24	32	40	48	56	64	72	80	88	96
9	9	18	27	36	45	54	63	72	81	90	99	108
10	10	20	30	40	50	60	70	80	90	100	110	120

Historically Multiplication tables
have been based on Square geometries

In Tetryonics multiplication tables can
also be based on EQUILATERAL geometries

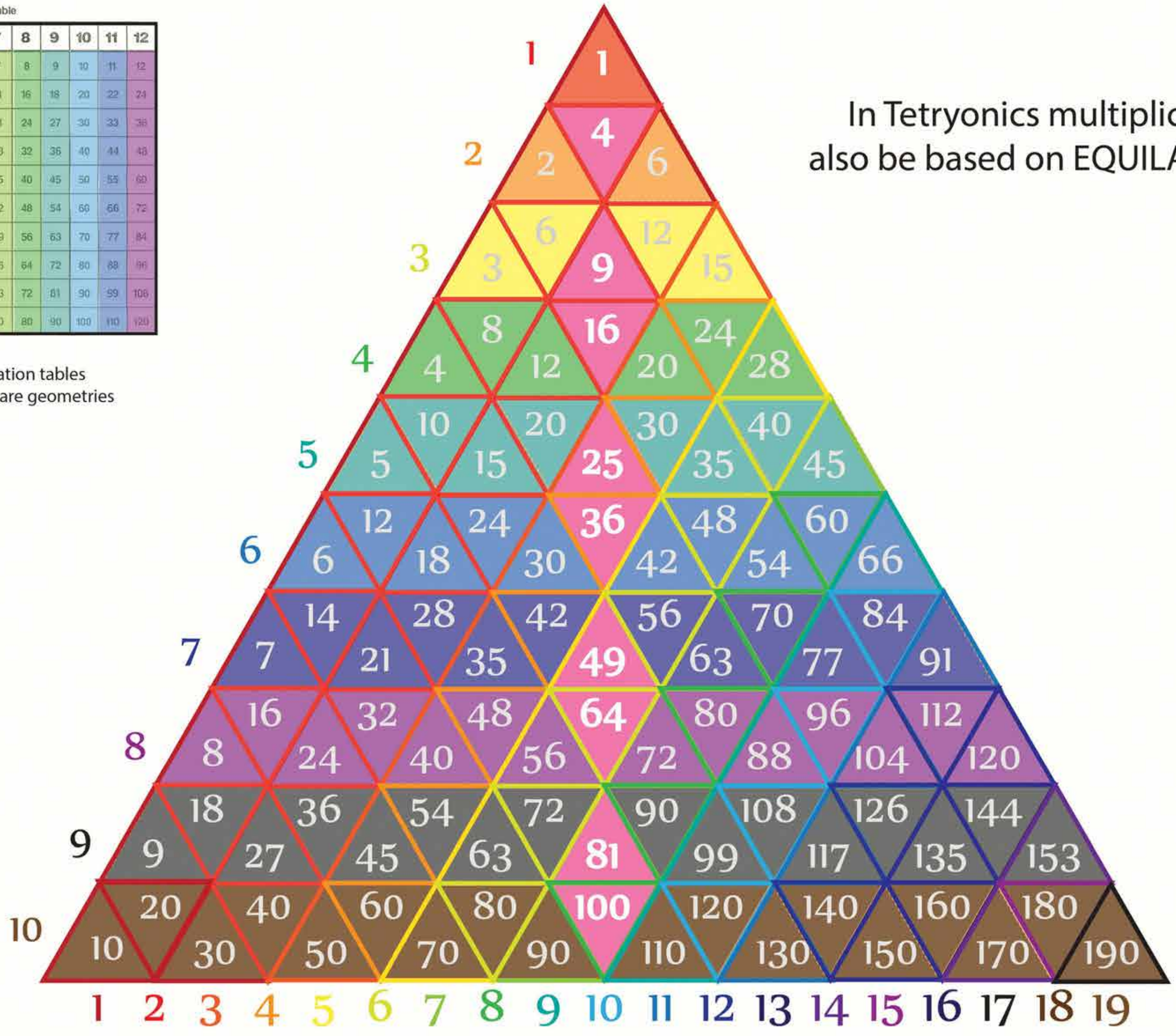

1 | 1
2 | 2 4 6
3 | 3 6 9 12 15
4 | 4 8 12 16 20 24 28
5 | 5 10 15 20 25 30 35 40 45
6 | 6 12 18 24 30 36 42 48 54 60 66
7 | 7 14 21 28 35 42 49 56 63 70 77 84 91
8 | 8 16 24 32 40 48 56 64 72 80 88 96 104 112 120
9 | 9 18 27 36 45 54 63 72 81 90 99 108 117 126 135 144 153
10 | 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

The integer multiplicitors are colour coded

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Rhombic Multiplication Tables

1	2	3	4	5	6	7	8	9	10
2	**4**	6	8	10	12	14	16	18	20
3	6	**9**	12	15	18	21	24	27	30
4	8	12	**16**	20	24	28	32	36	40
5	10	15	20	**25**	30	35	40	45	50
6	12	18	24	30	**36**	42	48	54	60
7	14	21	28	35	42	**49**	56	63	70
8	16	24	32	40	48	56	**64**	72	80
9	18	27	36	45	54	63	72	**81**	90
10	20	30	40	50	60	70	80	90	**100**

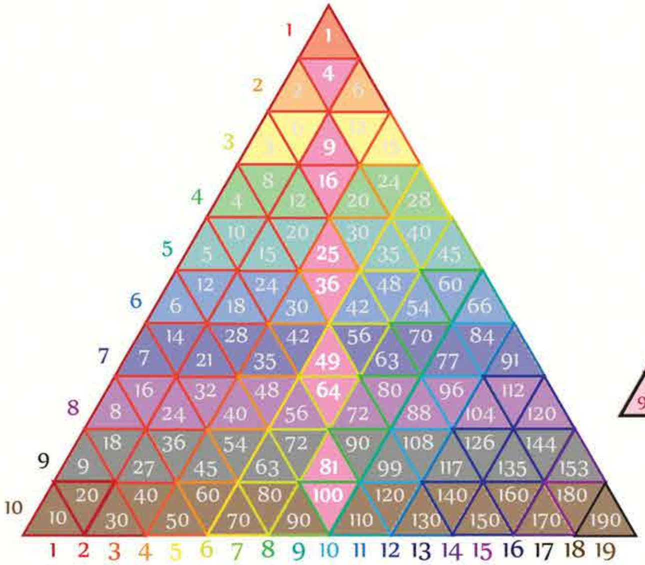

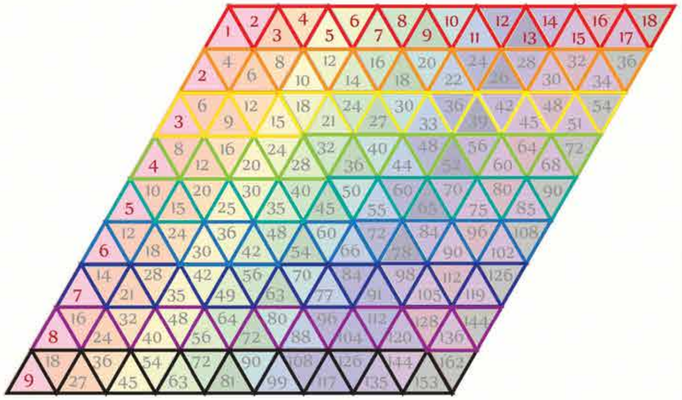

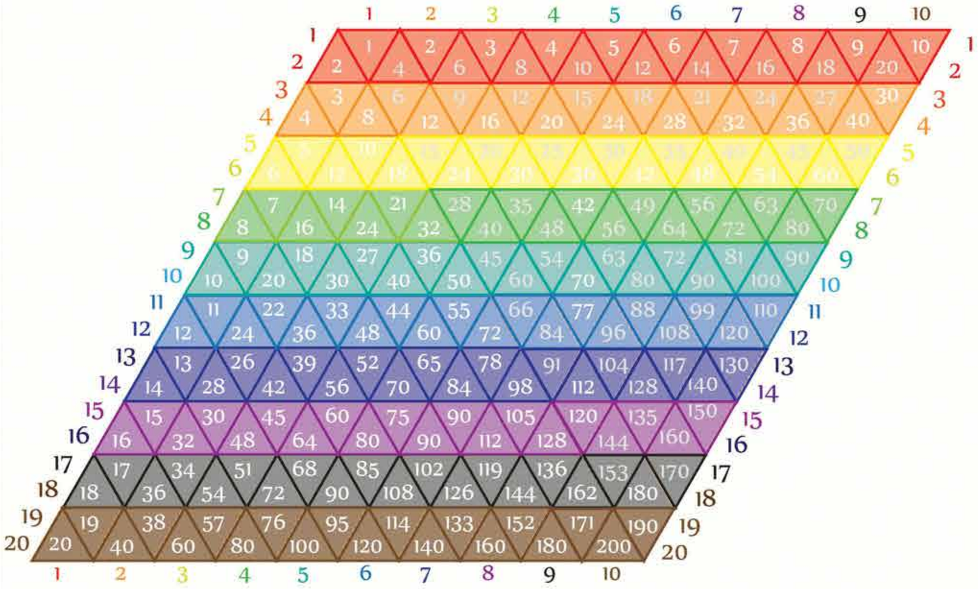

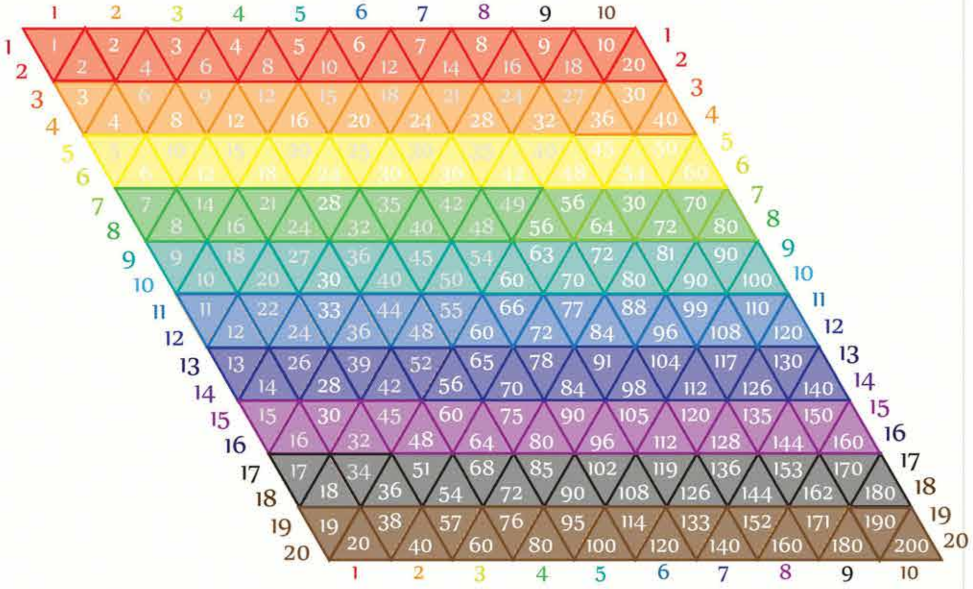

Tetryonics 85.03 - Rhombic multiplication tables

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Photonic Root Tables

Tetryonic multiplication table can take a number of geometric forms

Square root median

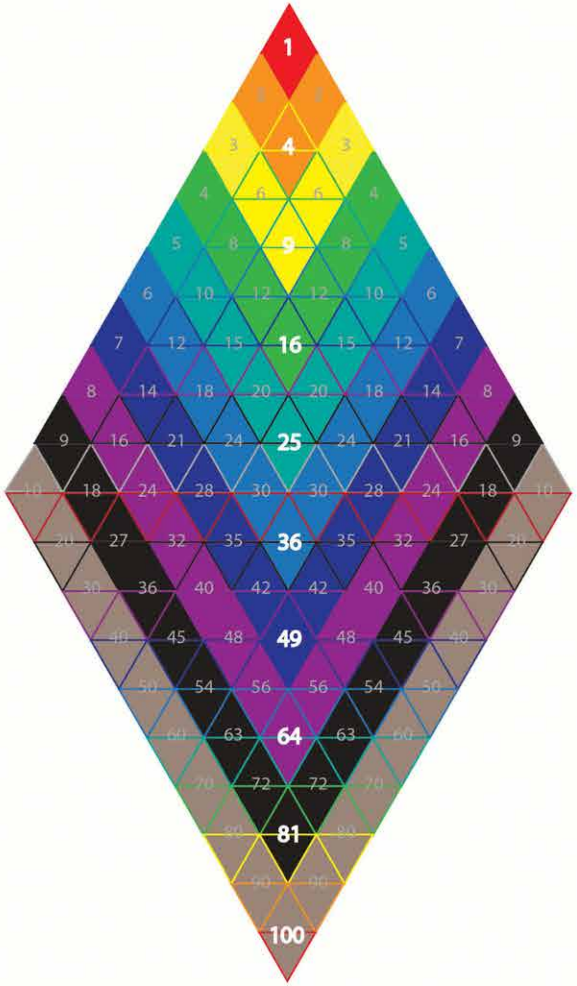
1
4
9
16
25
36
49
64
81
100

Table read diagonally

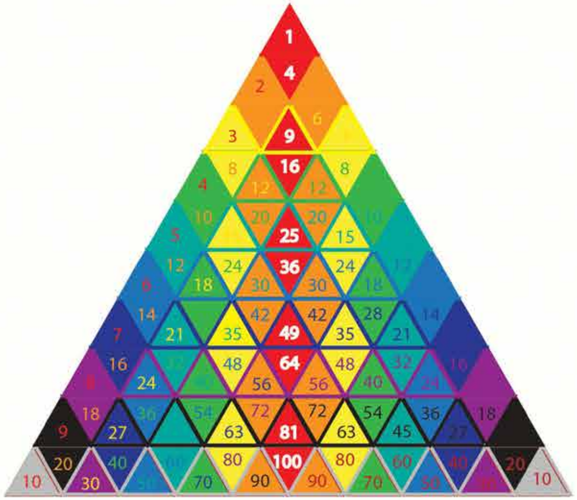
1
4
9
16
25
36
49
64
81
100

1	2	3	4	5	6	7	8	9	10
2	**4**	6	8	10	12	14	16	18	20
3	6	**9**	12	15	18	21	24	27	30
4	8	12	**16**	20	24	28	32	36	40
5	10	15	20	**25**	30	35	40	45	50
6	12	18	24	30	**36**	42	48	54	60
7	14	21	28	35	42	**49**	56	63	70
8	16	24	32	40	48	56	**64**	72	80
9	18	27	36	45	54	63	72	**81**	90
10	20	30	40	50	60	70	80	90	**100**

Integer median

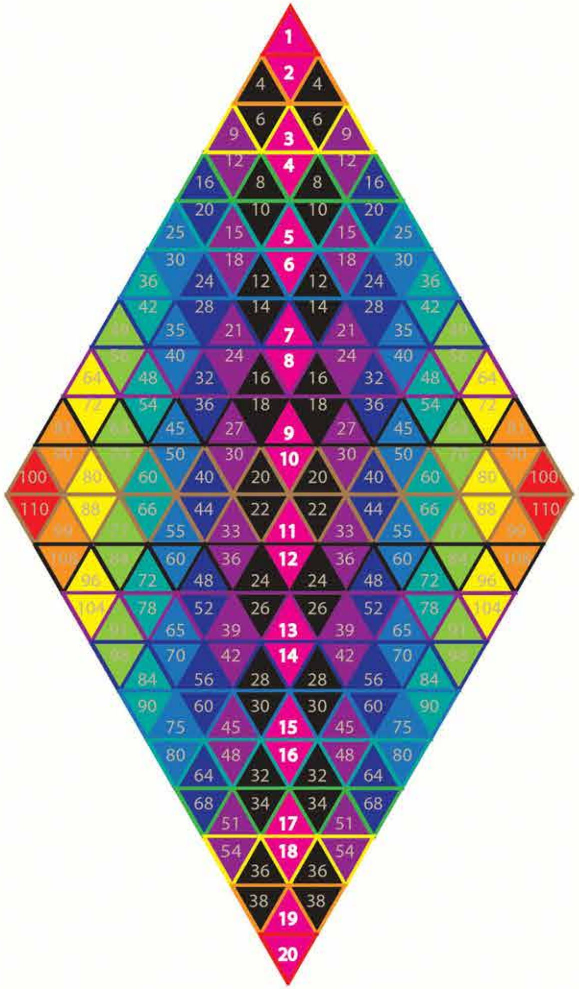
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Table read from centre
to outside edge then down

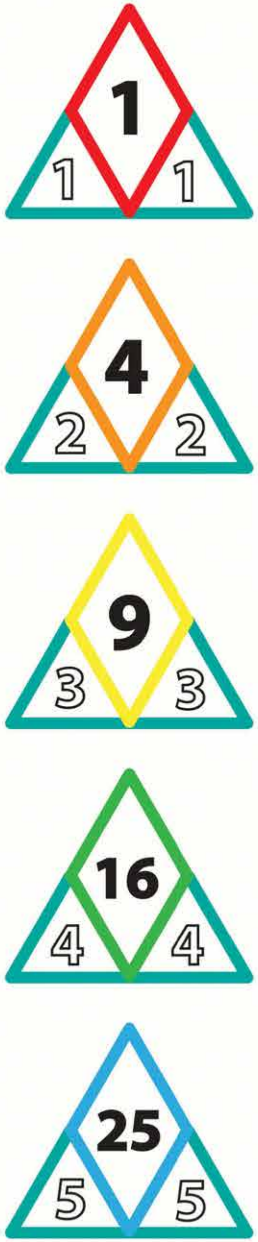
1
1
1
4
2
2
9
3
3
16
4
4
25
5
5

Divide [division] tables

Minus [subtraction] tables

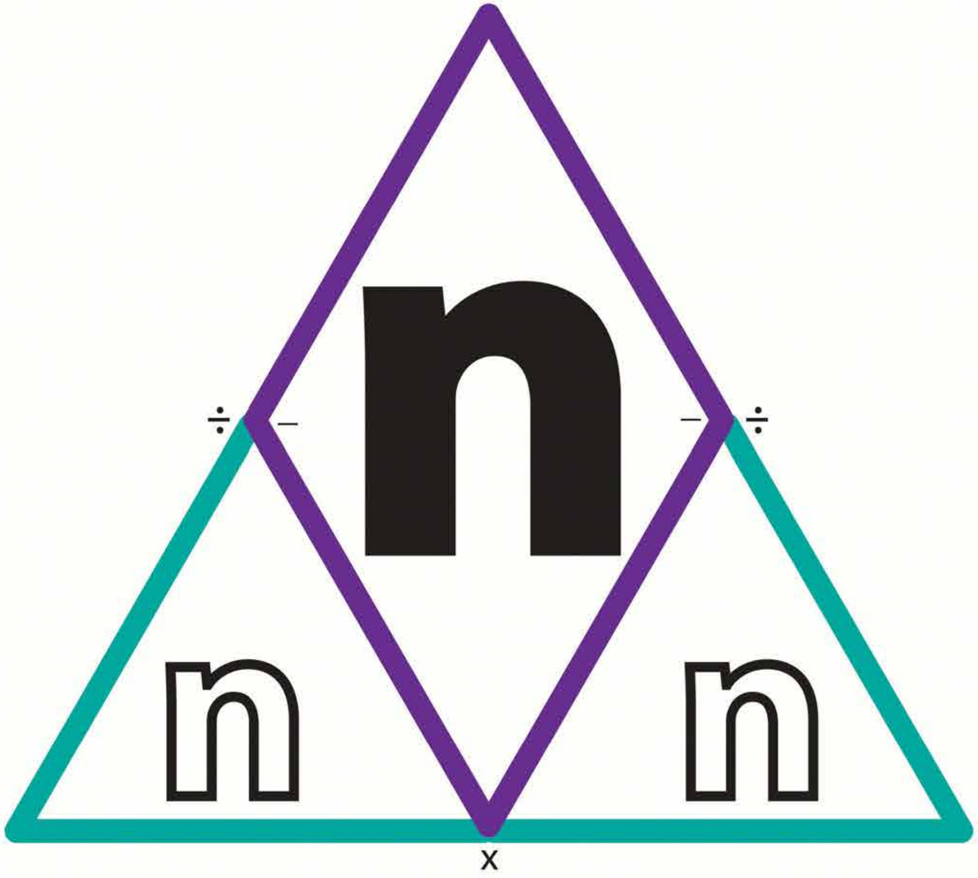

Times [multiplication] tables

Plus [addition] tables

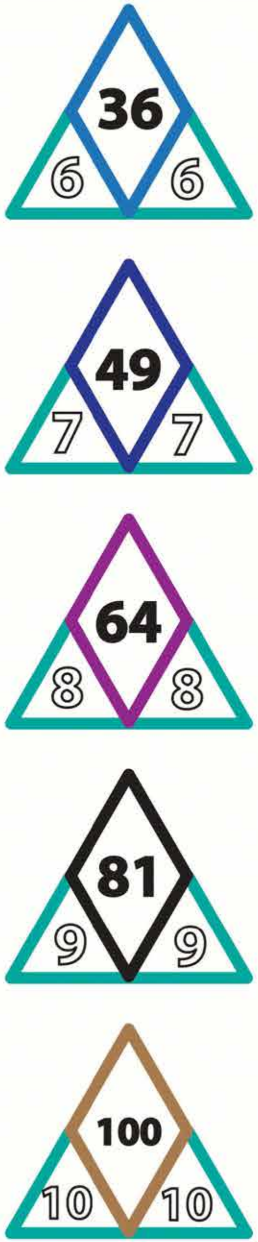
36
6
6
49
7
7
64
8
8
81
9
9
100
10
10

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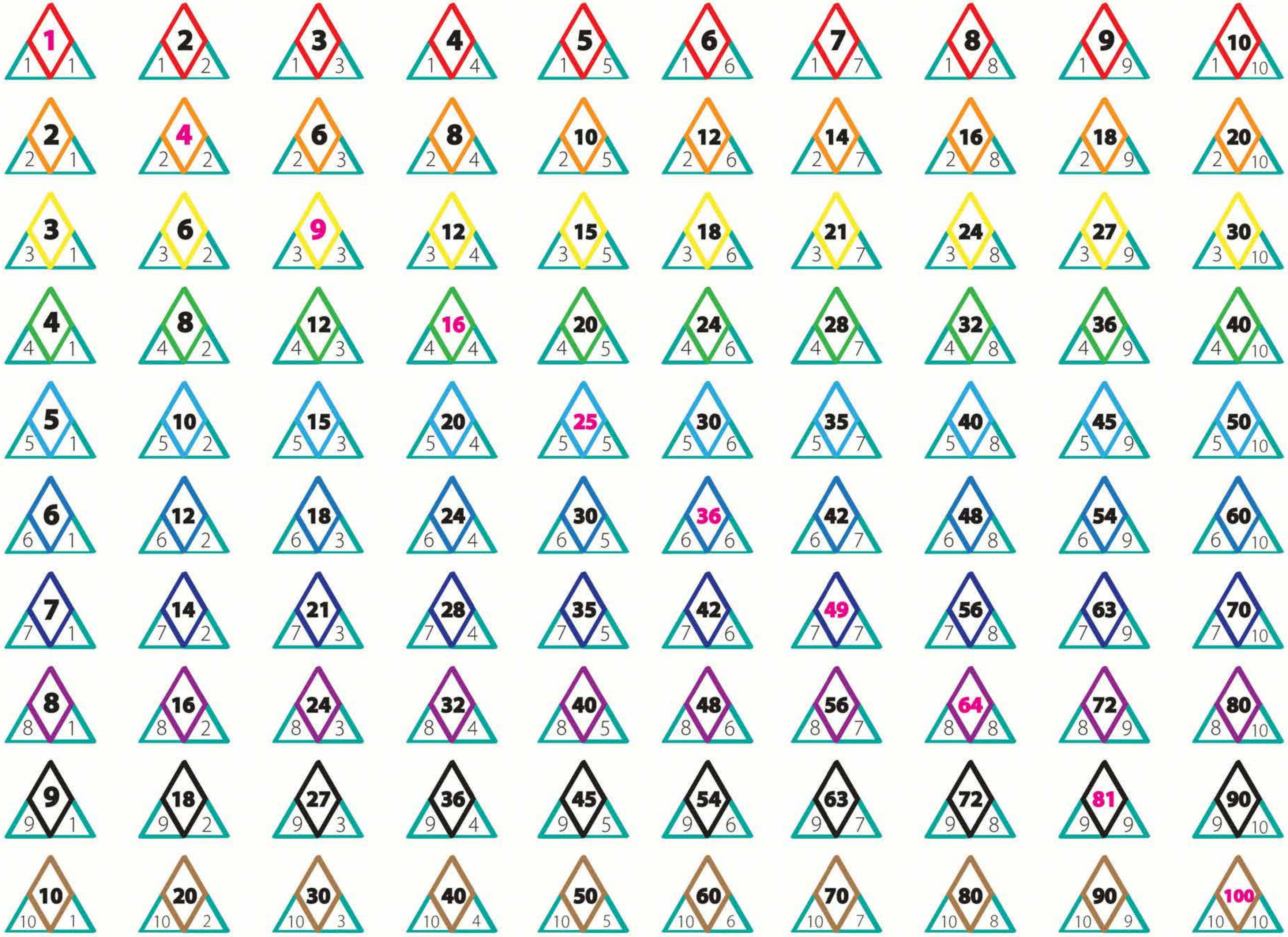

1 1 1	2 1 2	3 1 3	4 1 4	5 1 5	6 1 6	7 1 7	8 1 8	9 1 9	10 1 10
2 2 1	4 2 2	6 2 3	8 2 4	10 2 5	12 2 6	14 2 7	16 2 8	18 2 9	20 2 10
3 3 1	6 3 2	9 3 3	12 3 4	15 3 5	18 3 6	21 3 7	24 3 8	27 3 9	30 3 10
4 4 1	8 4 2	12 4 3	16 4 4	20 4 5	24 4 6	28 4 7	32 4 8	36 4 9	40 4 10
5 5 1	10 5 2	15 5 3	20 5 4	25 5 5	30 5 6	35 5 7	40 5 8	45 5 9	50 5 10
6 6 1	12 6 2	18 6 3	24 6 4	30 6 5	36 6 6	42 6 7	48 6 8	54 6 9	60 6 10
7 7 1	14 7 2	21 7 3	28 7 4	35 7 5	42 7 6	49 7 7	56 7 8	63 7 9	70 7 10
8 8 1	16 8 2	24 8 3	32 8 4	40 8 5	48 8 6	56 8 7	64 8 8	72 8 9	80 8 10
9 9 1	18 9 2	27 9 3	36 9 4	45 9 5	54 9 6	63 9 7	72 9 8	81 9 9	90 9 10
10 10 1	20 10 2	30 10 3	40 10 4	50 10 5	60 10 6	70 10 7	80 10 8	90 10 9	100 10 10

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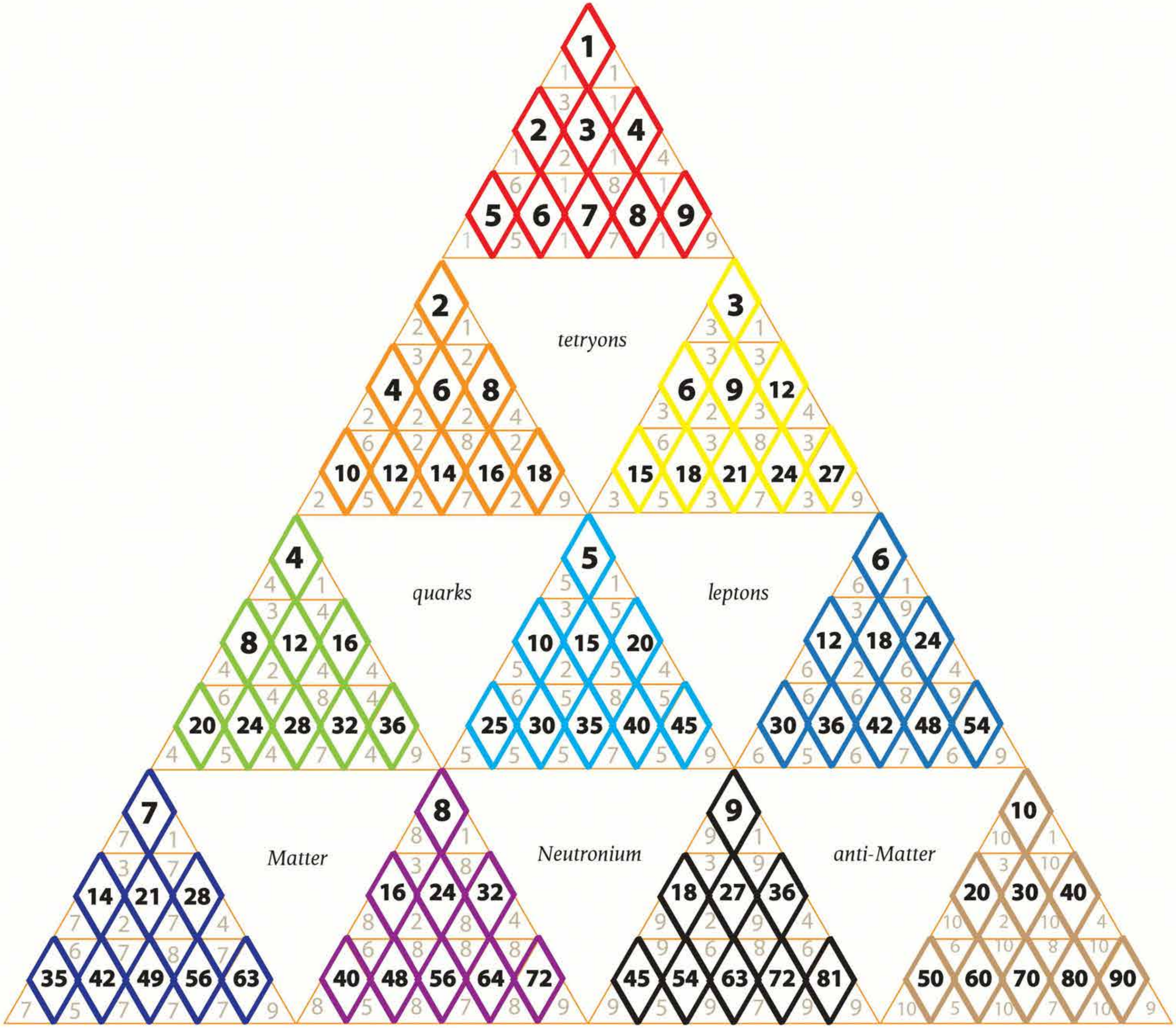
tetryons
quarks
leptons
Matter
Neutronium
anti-Matter
1
2 3 4
5 6 7 8 9
2
4 6 8
10 12 14 16 18
3
6 9 12
15 18 21 24 27
4
8 12 16
20 24 28 32 36
5
10 15 20
25 30 35 40 45
6
12 18 24
30 36 42 48 54
7
14 21 28
35 42 49 56 63
8
16 24 32
40 48 56 64 72
9
18 27 36
45 54 63 72 81
10
20 30 40
50 60 70 80 90

Irrational Numbers

An irrational number is defined to be any number that is the part of the real number system that cannot be written as a complete ratio of two integers

One well known irrational number is π

Irrational numbers can be easily represented geometrically

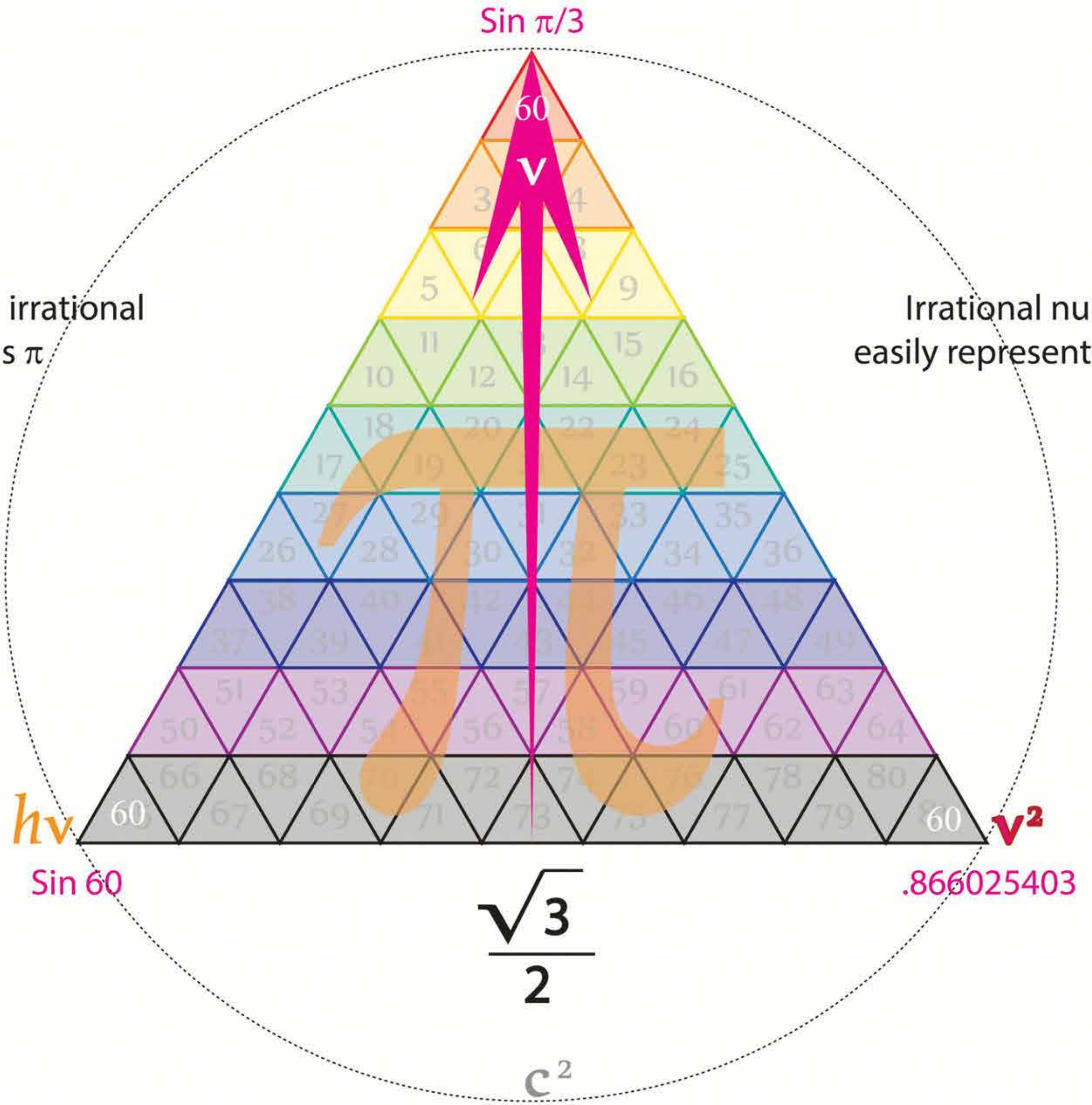
Sin π/3
60
v
π
hv
60
Sin 60
60
v²
.866025403
√3 / 2
c²

Exponentials & Logarithms

e and the Natural Log are inverse functions of each other:

e^x is the amount of continuous GROWTH after a certain amount of time.
Natural Log (ln) is the amount of TIME of continuous growth to reach a certain level

1	0
10	1
100	2
1,000	3

$10{,}000 = 10^4$

$\log(10{,}000) = 4$

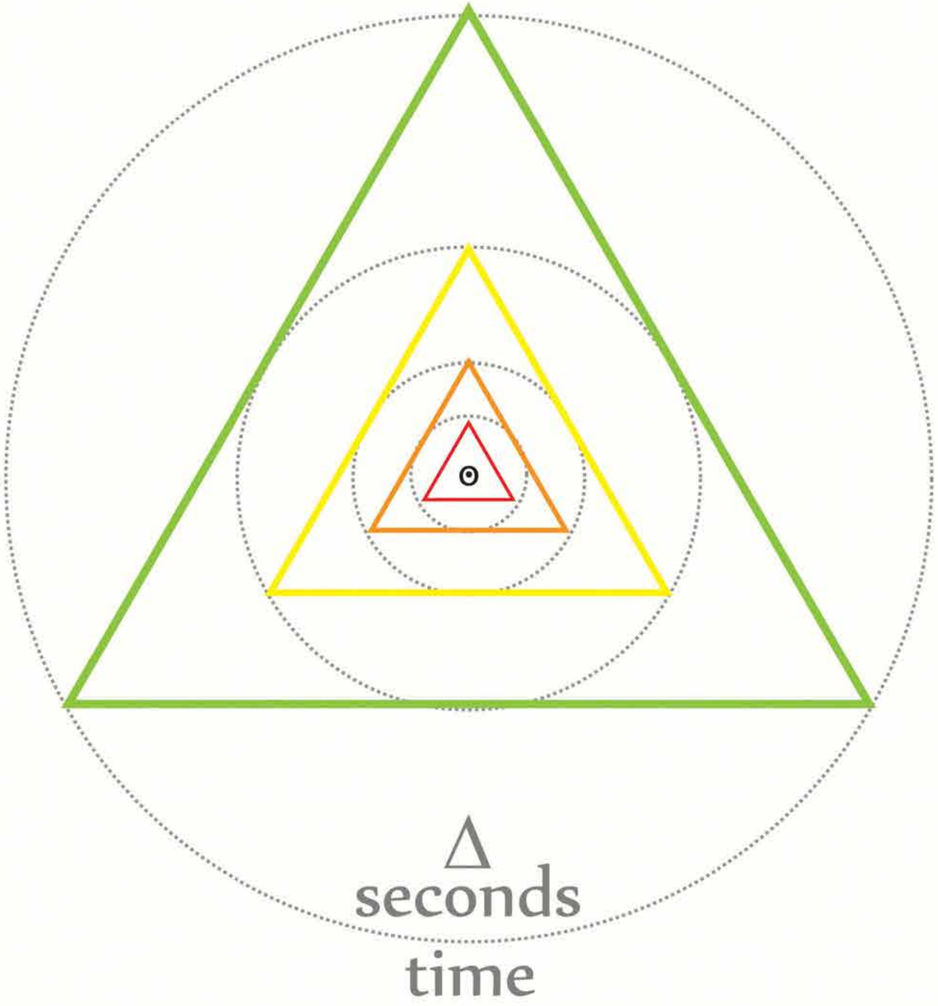

e

How much growth after x units of time
(and 100% continuous growth)

$$e^x = \lim_{n\to\infty}(1+x/n)^n,$$

GROWTH

ln

ln(x) lets us plug in continuous growth
and get the time it would take.

$$\ln(x) = \lim_{n\to\infty} n(x^{1/n}-1).$$

PERIOD

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Exponential growth

$$\text{growth} = e = \lim_{n\to\infty}\left(1+\frac{r}{n}\right)^{t}$$

e represents the idea that all continually growing systems are scaled versions of a common rate

GEOMETRIC

3.141592654

π

Pi is the ratio between circumference and diameter shared by all circles.

It is a fundamental ratio inherent in all circles and therefore impacts any calculation of circumference, area, volume, and surface areas

Pi radians are equally important and show all quantised equilateral energy geometries are related to their scribed circles

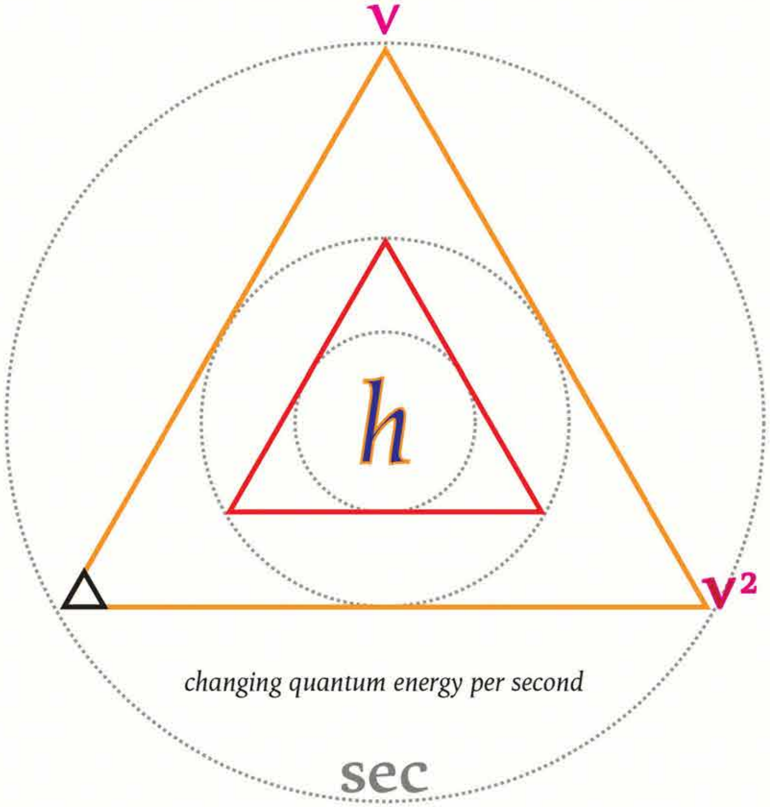

GROWTH

2.718281828

e

e is the base rate of growth shared by all continually growing processes.

e lets you take a simple growth rate (where all the change happens all at once at the end of a period of time - ie quantised growth)

e shows up whenever systems grow exponentially and continuously..... radioactive decay, interest calculations and populations

tetryons

EM fields

quarks

_e_ can be applied to the equilateral energy geometries of physical systems only where the rate of increase is a integer factor of a squared number

leptons

Baryons

Nuclear Energy levels

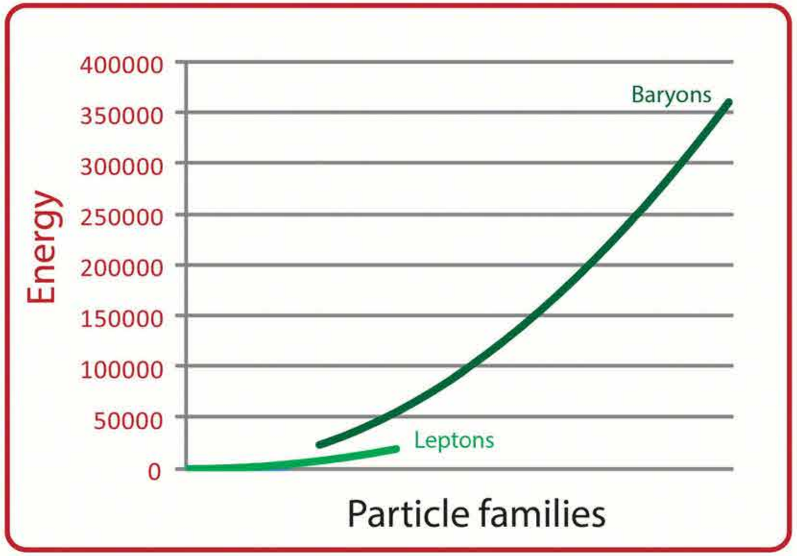

The emission and absorption of bosons and Photons within sub-atomic nuclei

Increase and decrease in integer amounts according to the charged Tetryonic topologies of the particles involved

Exponential energy levels

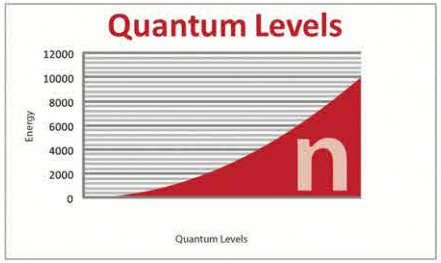

Radioactive decays follow exponential curves determined by the Tetryonic topology of the sub-atomic particle families

Proton
Neutron

antiNeutron
antiProton

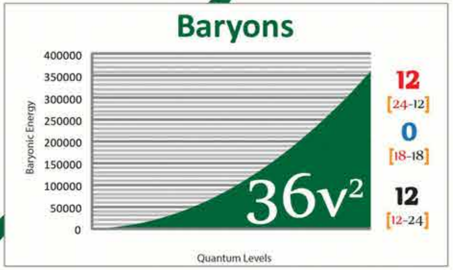

EM Field Planck quanta

$$36\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Baryons ElectroMagnetic mass velocity

Electron
Positron

Neutrino

Up
Down
Strange
Charmed
Top
Bottom

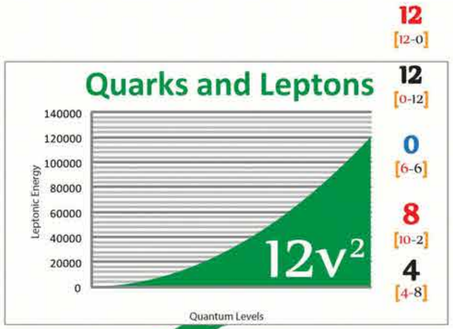

EM Field Planck quanta

quarks

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

leptons ElectroMagnetic mass velocity

Positive
Negative
Neutral

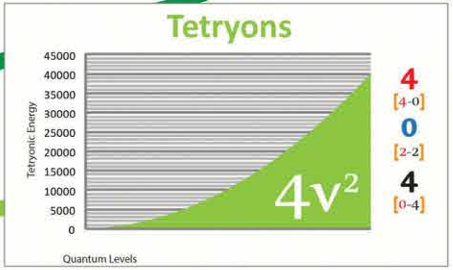

EM Field Planck quanta

$$4\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

tetryons ElectroMagnetic mass velocity

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Series addition & the Riemann Zeta Function

The second series addition of the Reimann Zeta function is where x=2: (pi^2)/6=1+1/2^2+1/3^2+1/4^2+...
(the sum of the reciprocals of the squares)

$$\zeta(s) = \sum_{n} \frac{1}{n^s}$$

$$\zeta(2) = \frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \frac{1}{4^2} + \cdots = \frac{\pi^2}{6}$$

$$f(n) = 1/n^2$$

$$\sum_{n=1}^{\infty} \frac{1}{n^x}$$

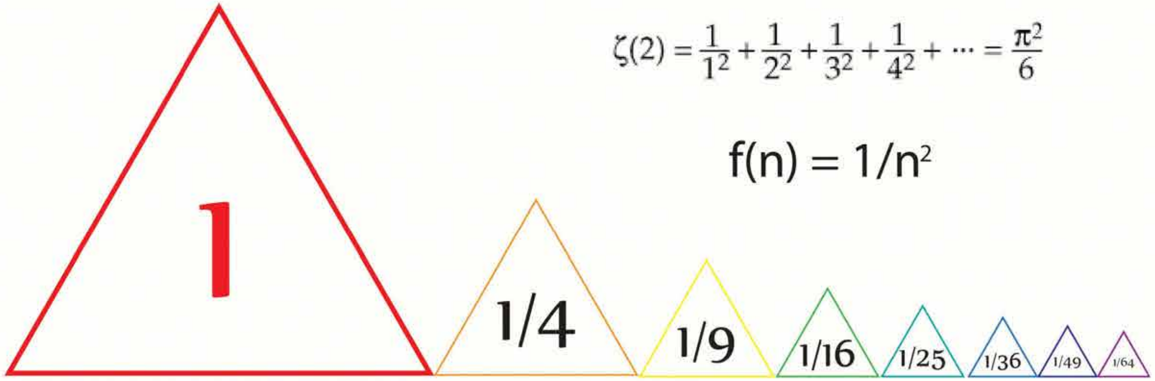

In mathematics, the Riemann zeta function, is a prominent function of great significance in number theory. It is a named after German mathematician Bernhard Riemann. It is so important because of its relation to the distribution of prime numbers. It also has applications in other areas such as physics, probability theory, and applied statistics

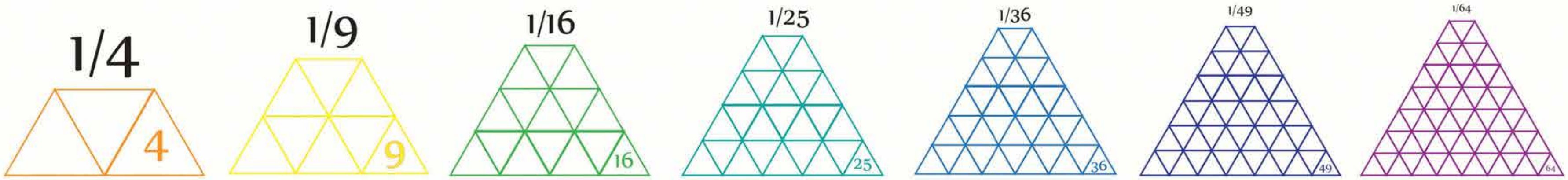

The mystery of prime numbers
Question: which natural numbers are prime? how are they distributed among natural numbers?

Primes are basic building blocks for natural numbers:

- any natural number is a product of prime numbers
- a prime number is only divisible by itself and by 1:
  (it cannot be further simplified)

We don't know how to predict where the prime numbers are:

“Prime numbers grow like weeds among the natural numbers, seeming to obey no other law than that of chance but also exhibit stunning regularity" (Don Zagier, number theorist)

Adding the odd numbers in order produces the square numbers

Apart from 2, all primes are odd numbers;
the difference between two consecutive squares being odd,
every prime can be expressed as the difference between two squares

SPECTRAL LINES

Primes can be modelled as Bosons
[ODD number energy momenta geometries]

[2n-1]

KEM ENERGIES

Primes can be expressed as Bosons
[the difference of two squared energies]

$n^2 - [n-1]^2$

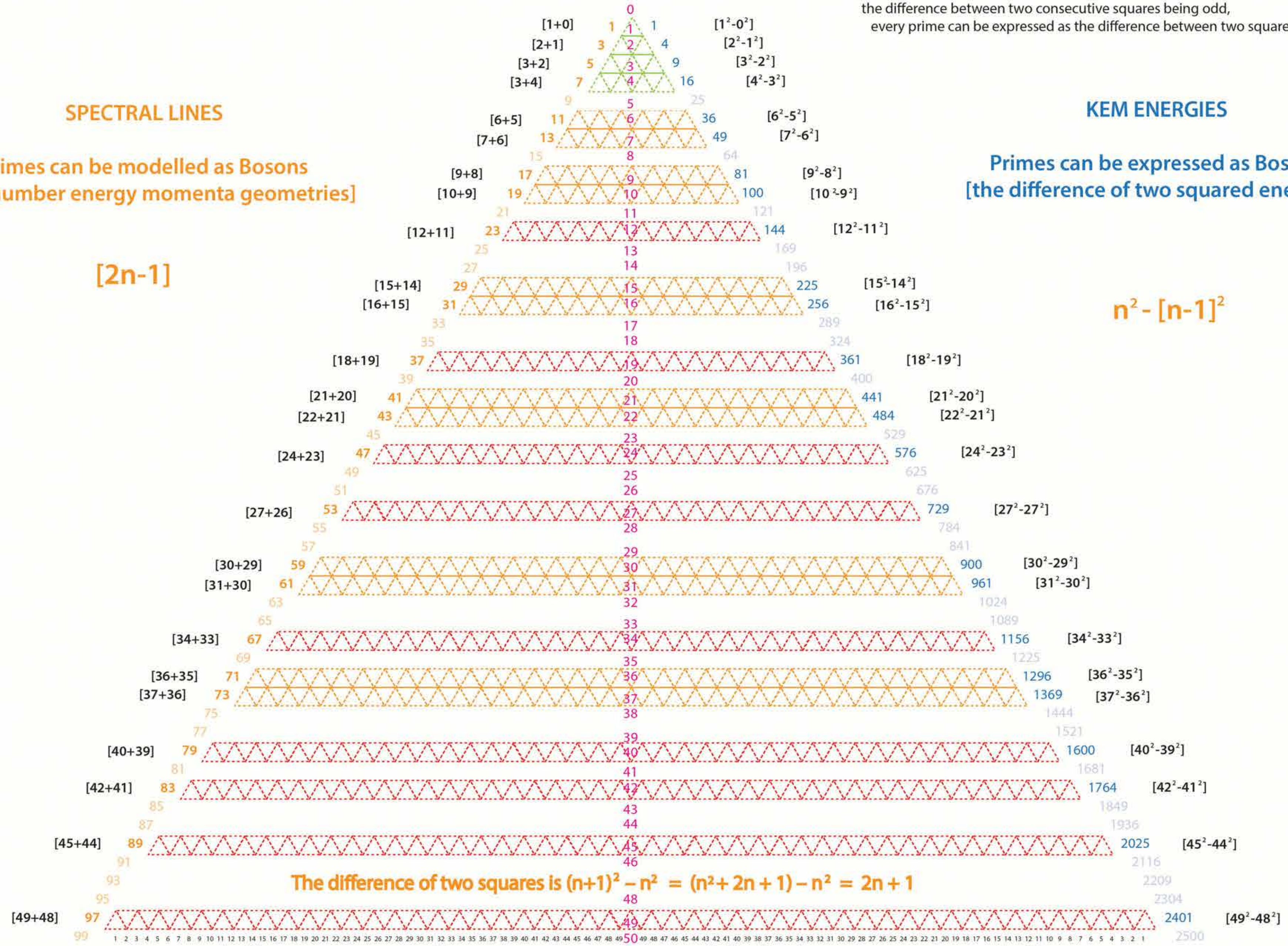
[1+0] 1 1 $[1^2-0^2]$
[2+1] 3 4 $[2^2-1^2]$
[3+2] 5 9 $[3^2-2^2]$
[3+4] 7 16 $[4^2-3^2]$
9 25
[6+5] 11 36 $[6^2-5^2]$
[7+6] 13 49 $[7^2-6^2]$
15 64
[9+8] 17 81 $[9^2-8^2]$
[10+9] 19 100 $[10^2-9^2]$
21 121
[12+11] 23 144 $[12^2-11^2]$
25 169
27 196
[15+14] 29 225 $[15^2-14^2]$
[16+15] 31 256 $[16^2-15^2]$
33 289
35 324
[18+19] 37 361 $[18^2-19^2]$
39 400
[21+20] 41 441 $[21^2-20^2]$
[22+21] 43 484 $[22^2-21^2]$
45 529
[24+23] 47 576 $[24^2-23^2]$
49 625
51 676
[27+26] 53 729 $[27^2-27^2]$
55 784
57 841
[30+29] 59 900 $[30^2-29^2]$
[31+30] 61 961 $[31^2-30^2]$
63 1024
65 1089
[34+33] 67 1156 $[34^2-33^2]$
69 1225
[36+35] 71 1296 $[36^2-35^2]$
[37+36] 73 1369 $[37^2-36^2]$
75 1444
77 1521
[40+39] 79 1600 $[40^2-39^2]$
81 1681
[42+41] 83 1764 $[42^2-41^2]$
85 1849
87 1936
[45+44] 89 2025 $[45^2-44^2]$
91 2116
93 2209
95 2304
[49+48] 97 2401 $[49^2-48^2]$
99 2500
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

The difference of two squares is $(n+1)^2 - n^2 = (n^2 + 2n + 1) - n^2 = 2n + 1$

[n-1] **all energy quanta create normal distributions** **[n-1]**

Prime number Distributions

A twin prime is a prime number that differs from another prime number by two, for example the twin prime pair (41, 43). Sometimes the term twin prime is used for a pair of twin primes; an alternative name for this is prime twin or prime pair.

Twin primes appear despite the general tendency of gaps between adjacent primes to become larger as the numbers themselves get larger due to the prime number theorem (the "average gap" between primes less than n is log(n)).

$$p_2 - p_1 = 2$$

Every twin prime pair except (3, 5) is of the form (6n – 1, 6n + 1) for some natural number n, and with the exception of n = 1, n must end in 0, 2, 3, 5, 7, or 8

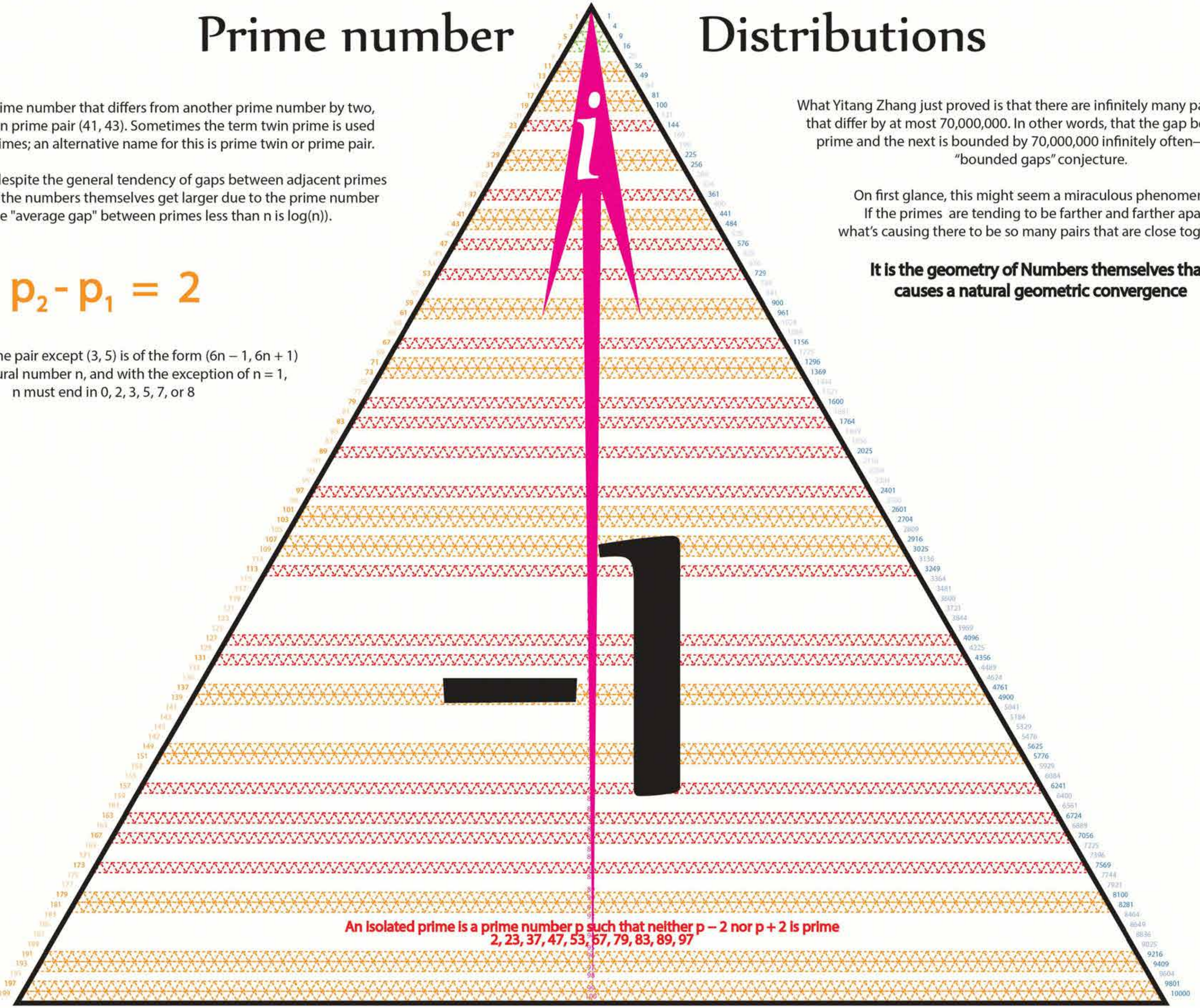

An isolated prime is a prime number p such that neither p – 2 nor p + 2 is prime
2, 23, 37, 47, 53, 67, 79, 83, 89, 97

What Yitang Zhang just proved is that there are infinitely many pairs of primes that differ by at most 70,000,000. In other words, that the gap between one prime and the next is bounded by 70,000,000 infinitely often—thus, the "bounded gaps" conjecture.

On first glance, this might seem a miraculous phenomenon. If the primes are tending to be farther and farther apart, what's causing there to be so many pairs that are close together?

It is the geometry of Numbers themselves that causes a natural geometric convergence

The Digital roots of Prime numbers

The digital root (also repeated digital sum) of a number is the (single digit) value obtained by an iterative process of summing digits, on each iteration using the result from the previous iteration to compute a digit sum.

The process continues until a single-digit number is reached.

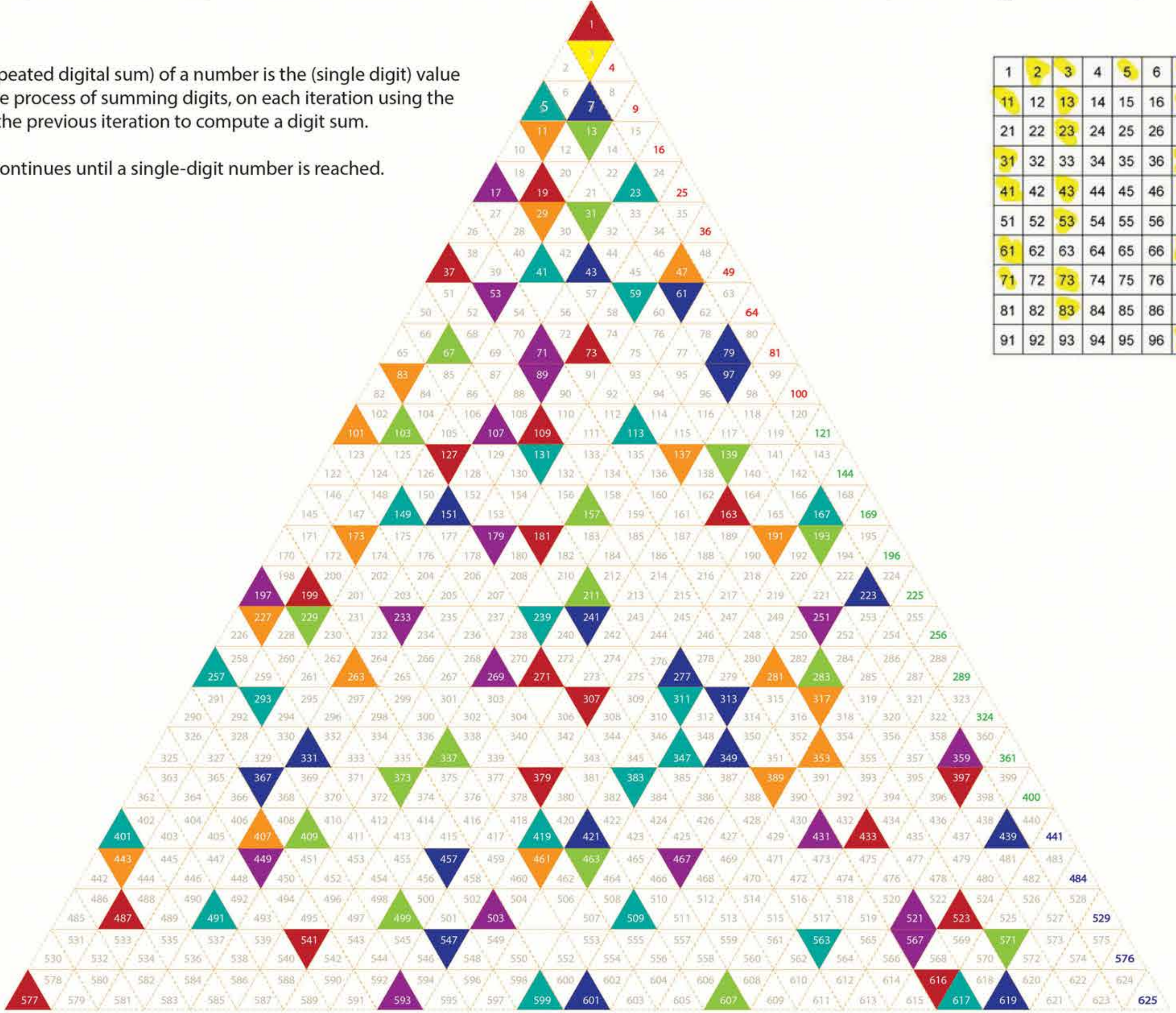
1
2 3 4
5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 43 44 45 46 47 48 49
50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100
101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121
122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144
145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169
170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196
197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225
226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256
257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289
290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324
325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361
362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400
401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441
442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484
485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529
530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576
577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

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Archimedes is given credit for the first calculus.

Archimedes infinite series

Today's calculus was published by Newton.

1 + 3/4 + 3/16 + 3/64 + 3/256 + 3/1024 + ...

1 + .75 + .1875 + .046875 + .01171875 + ...

$$3\left(\frac{1}{4}+\frac{1}{4^2}+\frac{1}{4^3}+\frac{1}{4^4}+\cdots\right)=1.$$

$$\frac{3}{4}+\frac{3}{4^2}+\frac{3}{4^3}+\frac{3}{4^4}+\cdots=1.$$

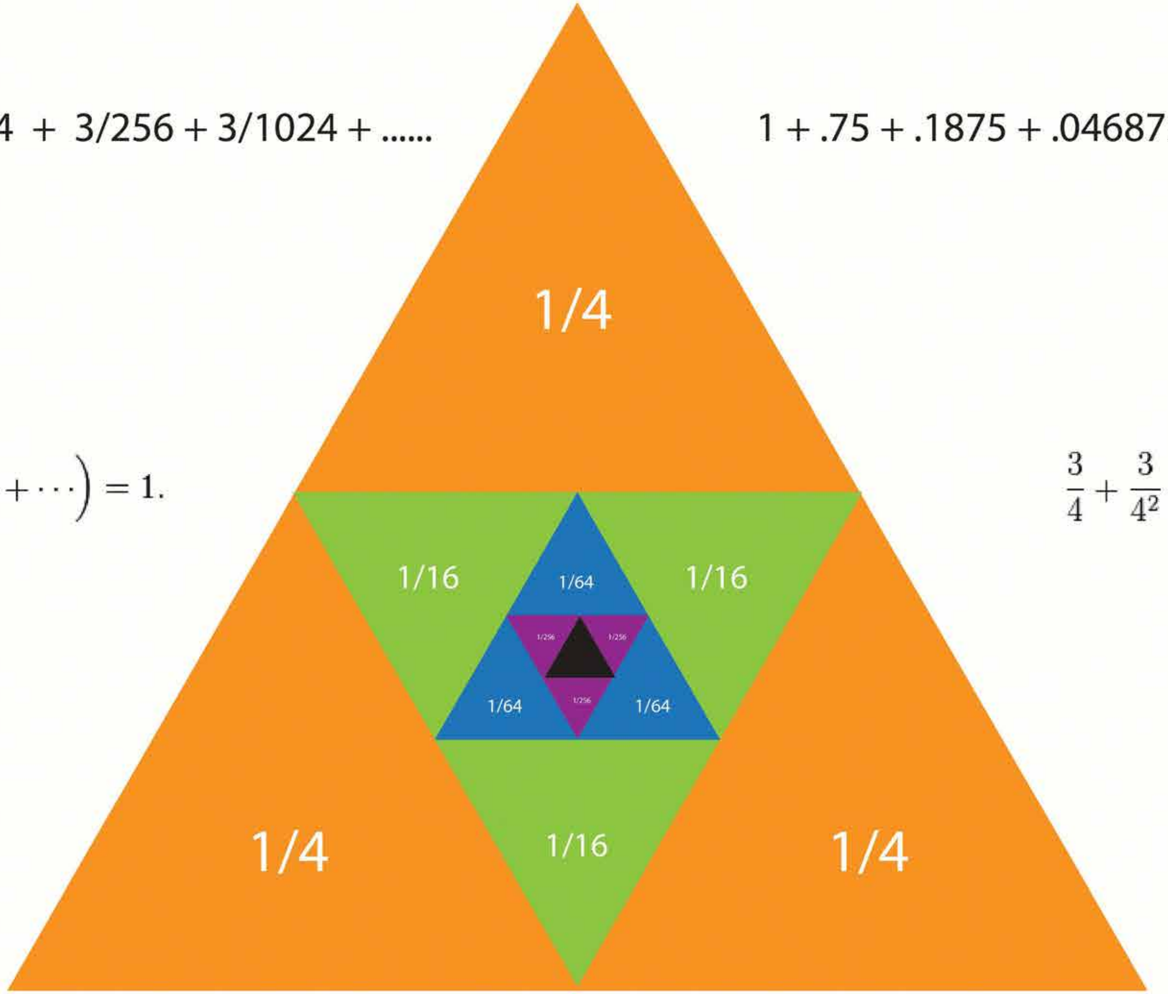
1/4
1/16
1/64
1/16
1/256
1/256
1/64
1/256
1/64
1/4
1/16
1/4

Nested convergent infinite series

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Summing a convergent infinite series

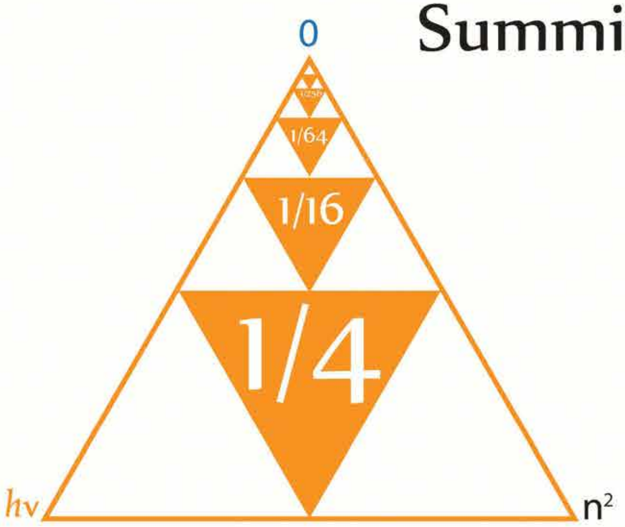
0
1/256
1/64
1/16
1/4
hv
n²

$1/4 + 1/4^2 + 1/4^3 + 1/4^4 + 1/4^5 + \ldots\ldots\ldots$

$$\sum_{n=0}^{\infty} a_n = a_0 + a_1 + a_2 + \cdots$$

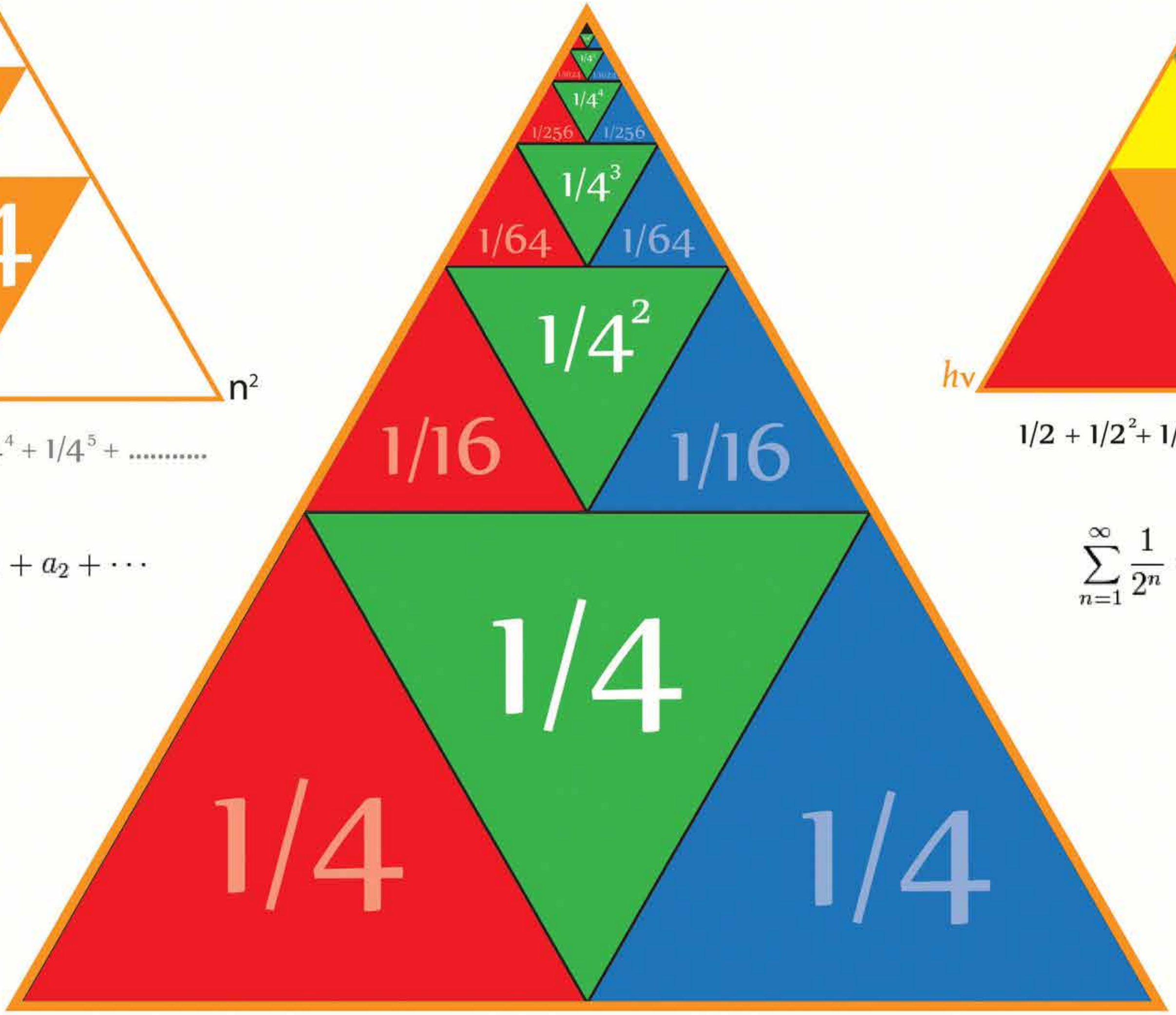
1/4
1/4
1/4
1/4²
1/16
1/16
1/4³
1/64
1/64
1/4⁴
1/256
1/256

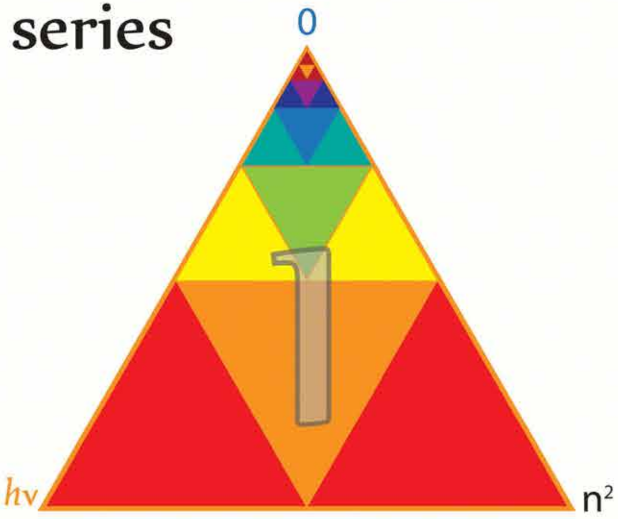

$1/2 + 1/2^2 + 1/2^3 + 1/2^4 + 1/2^5 + \ldots\ldots\ldots$

$$\sum_{n=1}^{\infty} \frac{1}{2^n} = \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \cdots.$$

ODDS = 2n-1

$$\sum_{1}^{n} 2n-1 = n^2$$

Summing the dissimilar coloured equilateral triangles gives unity

1/3 1/3 1/3

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1/3 1/3 1/3

Summing the dissimilar coloured equilateral triangles gives unity

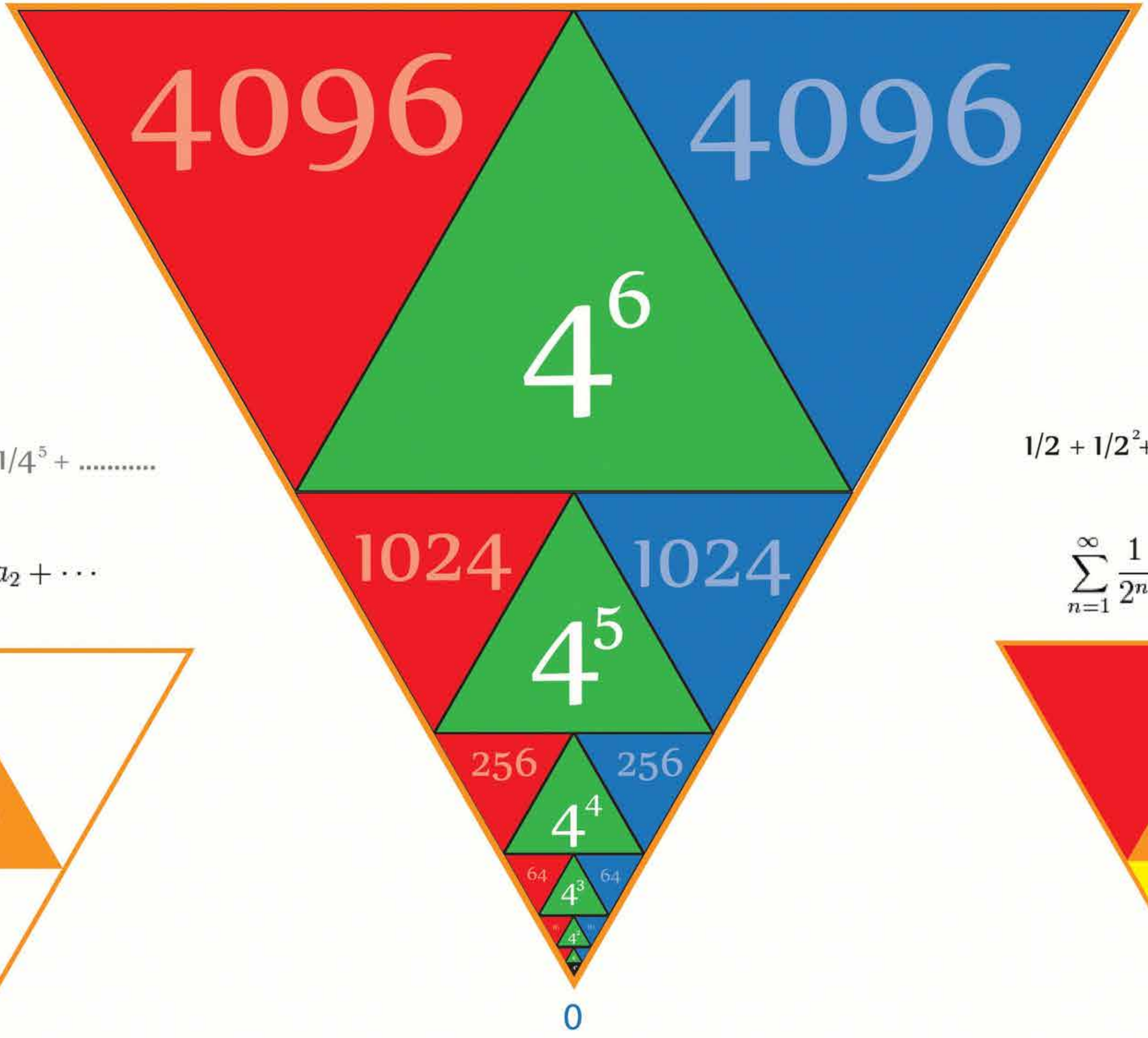
4096
4096
4⁶
1024
1024
4⁵
256
256
4⁴
64
64
4³
0

$1/4 + 1/4^2 + 1/4^3 + 1/4^4 + 1/4^5 + ...$

$$\sum_{n=0}^{\infty} a_n = a_0 + a_1 + a_2 + \cdots$$

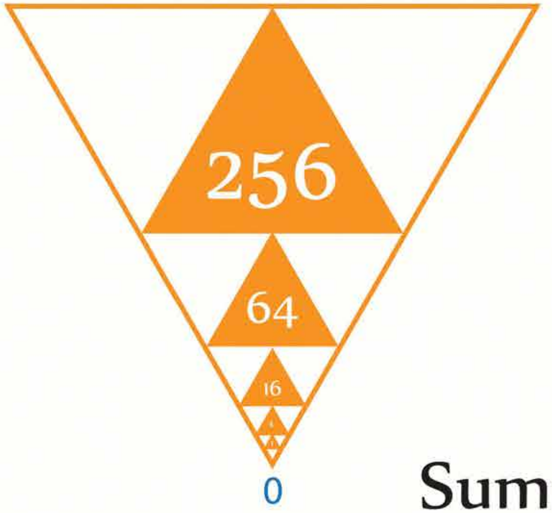

$1/2 + 1/2^2 + 1/2^3 + 1/2^4 + 1/2^5 + ...$

$$\sum_{n=1}^{\infty} \frac{1}{2^n} = \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \cdots.$$

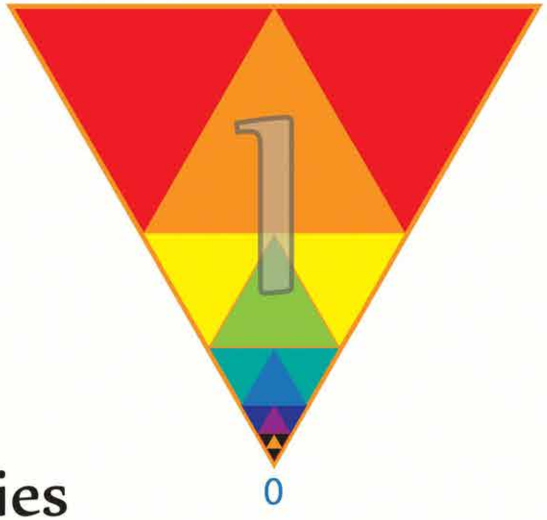

Summing a divergent infinite series

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Pietro Mengoli

(1626 – June 7, 1686)

The Basel Problem

The Basel problem is a famous problem in mathematical analysis with relevance to number theory, first posed by Pietro Mengoli in 1644 and solved by Leonhard Euler in 1735.

$$\zeta(2) = \frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \frac{1}{4^2} + \cdots = \frac{\pi^2}{6} \approx 1.644934$$

Leonhard Euler

(15 April 1707 – 18 Sept 1783)

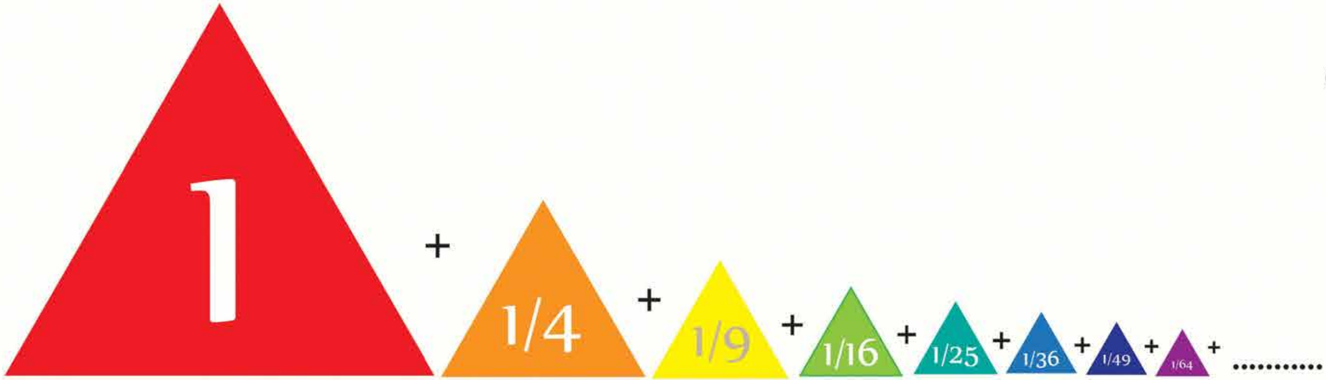

The Basel problem asks for the precise summation of the reciprocals of the squares of the natural numbers, i.e. the precise sum of the infinite series

$$f(n) = 1/n^2$$

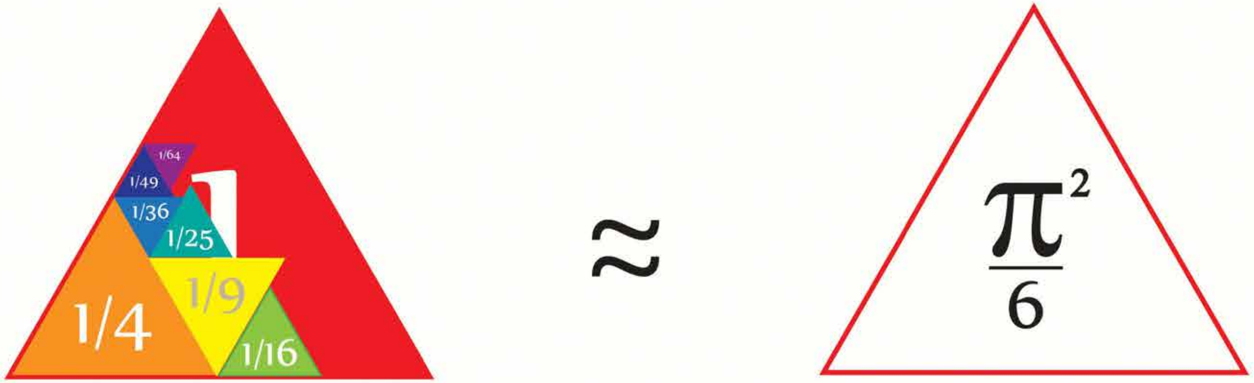

Integrals of mass-energy

is a means of finding scalar areas using summation and limits.

Integration is a micro adding of ***CONTINUOUS*** quantities.

$$\int_{n}^{\infty} f(x)$$

Integration is a special case of summation.

Integration is defined as the limit of a summation as the number of elements approches infinity while a part of their respective value approaches zero.

Summation is the finite sum of multiple, fixed values.

$$\sum_{n}^{\infty} x$$

Summation is a macro adding of ***DISCRETE*** quantities.

The summation of equilateral energy momenta quanta with respect to their linear vector components

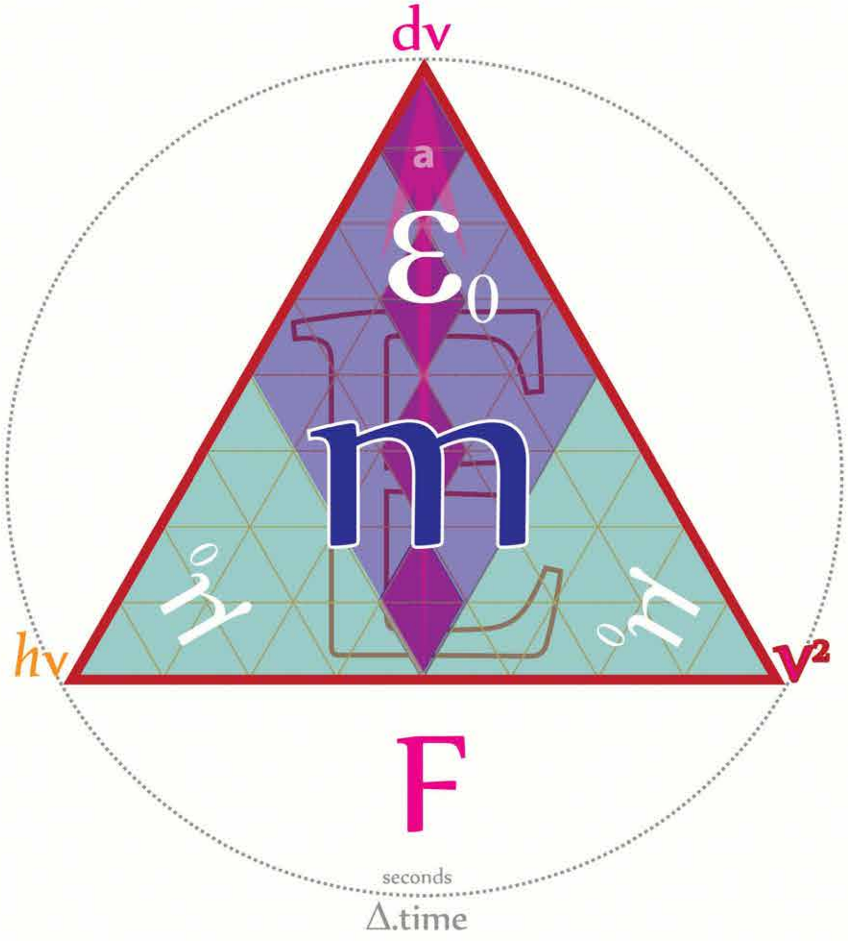

Integrating the energy quanta contained within equilateral charge geometry gives the variable Force required to acheive changes in motion [Energy, work, acceleration]

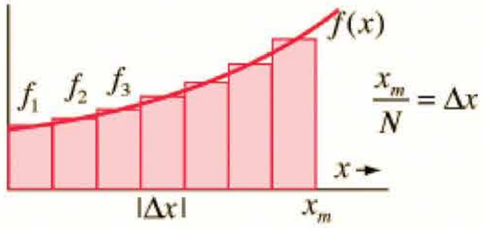

The Integral of the continuous area under the curve is the summation of an infinte number of disctrete rectangular measurements made to a specified limit

An integration isn't a simple summation, but the limit of a sequence of summations

All Planck energies are discrete equilateral geometries

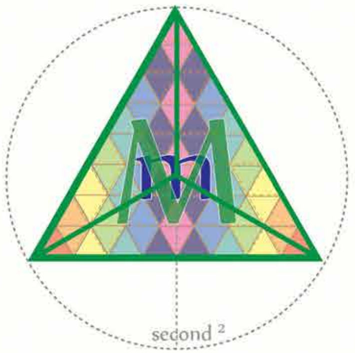

mass is the surface integral of EM energy geometries per unit of time

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"The calculus of infinitesimals"

The fundamental theorem of calculus
simply states that the sum of infinitesimal changes in a quantity over time
adds up to the net change in the quantity.

Scalar Energy

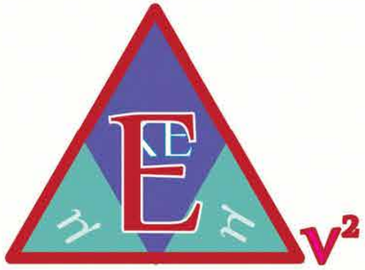

$E = mv^2$

Gottfried Wilhelm von Leibniz

(July 1, 1646 – November 14, 1716)

**Leibniz's vis viva
(Latin for living force)
is mv2,**

[2 x kinetic energy]

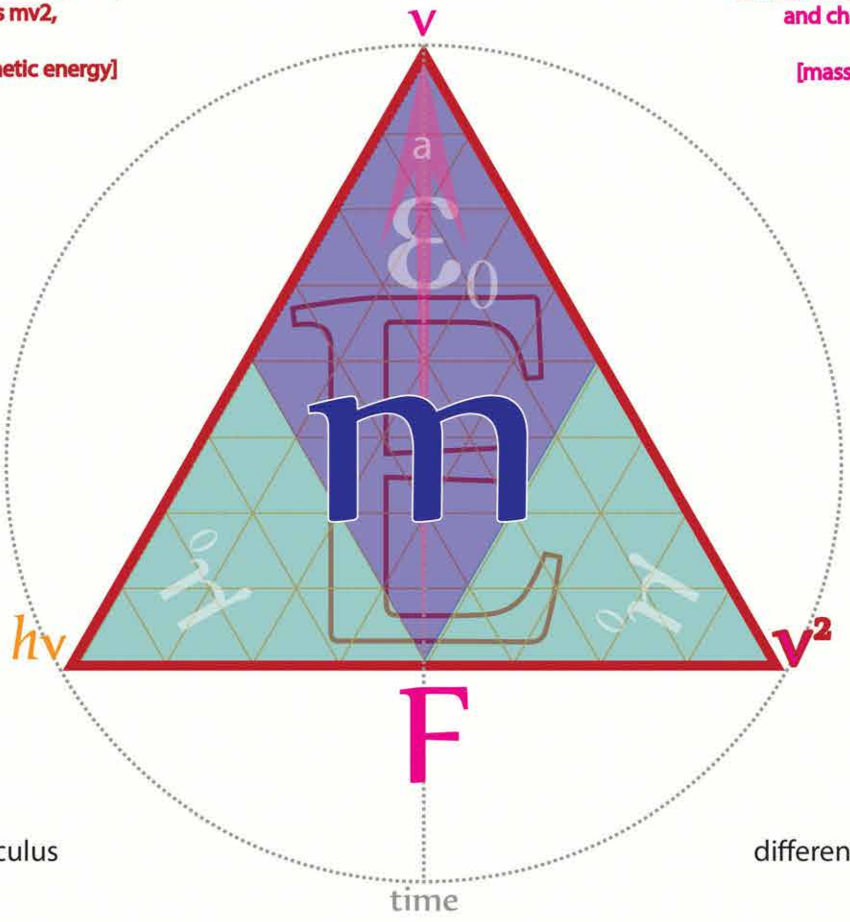

**Much of Newton's work
centred around momentum
and changes to it**

[mass.velocity]

vector Force

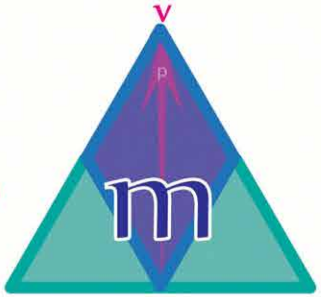

$F = m[dv/dt]$

Sir Isaac Newton

(1643-1727)

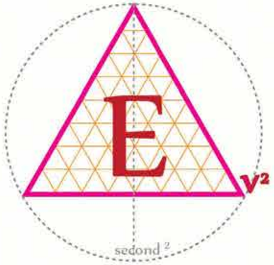

integral calculus

The founders of calculus thought
of the integral as an infinite sum of
rectangles of infinitesimal width

*The fundamental theorem of calculus is a theorem that links
the concept of the integral with the derivative of a function.*

differential calculus

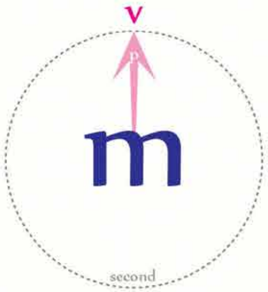

In calculus, a branch of mathematics,
the derivative is a measure of how
a function changes as its input changes

Energy momentum geometries

Leibniz

scalar energies

linear momentum is the square root vector force of the scalar energy required to do a set amount of work

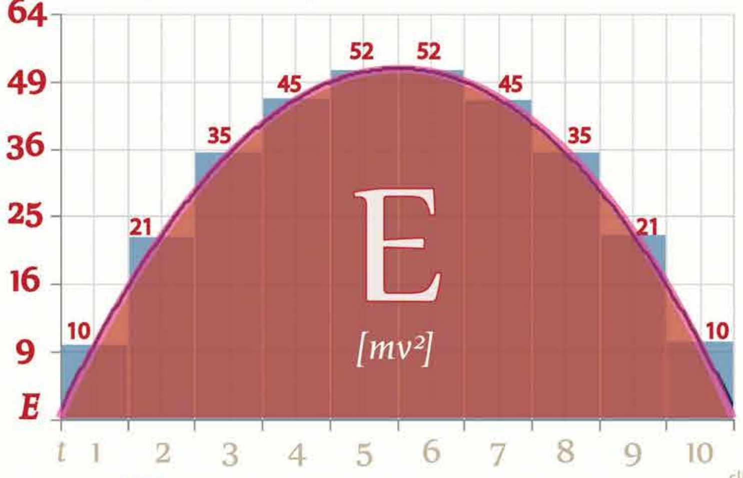

$$E = p^2$$

Energy momentum

$$kg\left[\frac{m}{s}\right]^2$$

print out this page

then cut out the 10 Planck energy momenta triangles shown

Newton

linear momentum

$d[mv]/dt = dp/dt = ma$

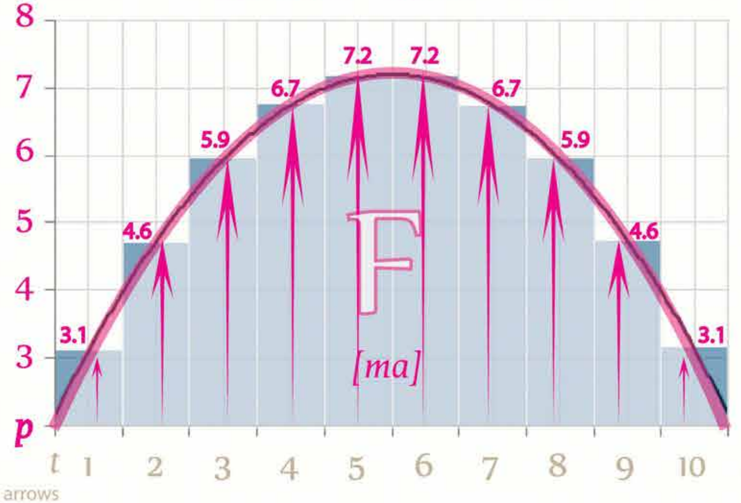

slice fine lines along the pink linear momentum arrows with a razor blade or similar as highlighted under the Newtonian acceleration curve

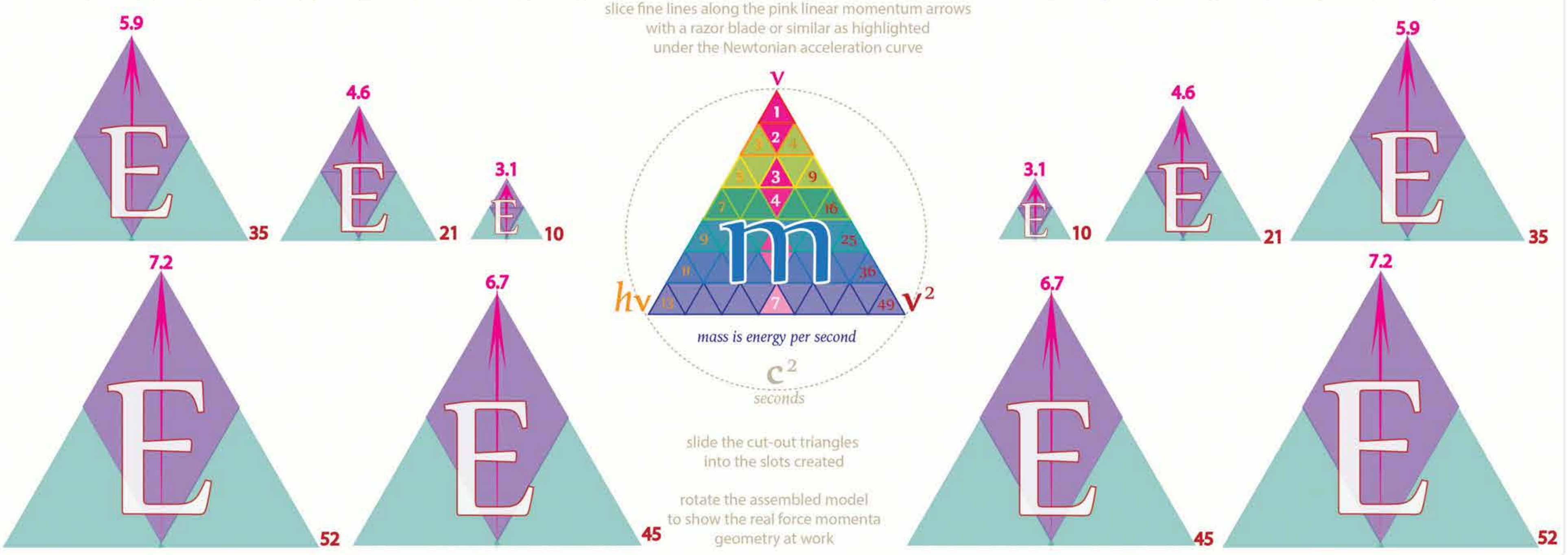
5.9
E
35
4.6
E
21
3.1
E
10
7.2
E
52
6.7
E
45
v
1
2
3
4
9
16
25
36
49
7
m
hv
v²
mass is energy per second
c²
seconds
3.1
E
10
4.6
E
21
5.9
E
35
6.7
E
45
7.2
E
52

slide the cut-out triangles into the slots created

rotate the assembled model to show the real force momenta geometry at work

Tetryonics 87.07 - Physically modeling the geometric forces of acceleration in calculus

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linear momentum is the square root vector force of the scalar energy required to do a set amount of work

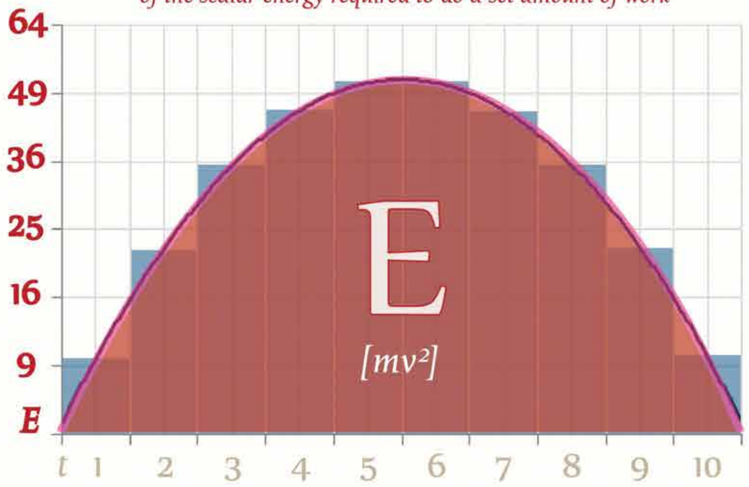

p

linear momentum

$\mathrm{kg}\,\frac{\mathrm{m}}{\mathrm{s}}$

print out this page

$d[mv]/dt = dp/dt = ma$

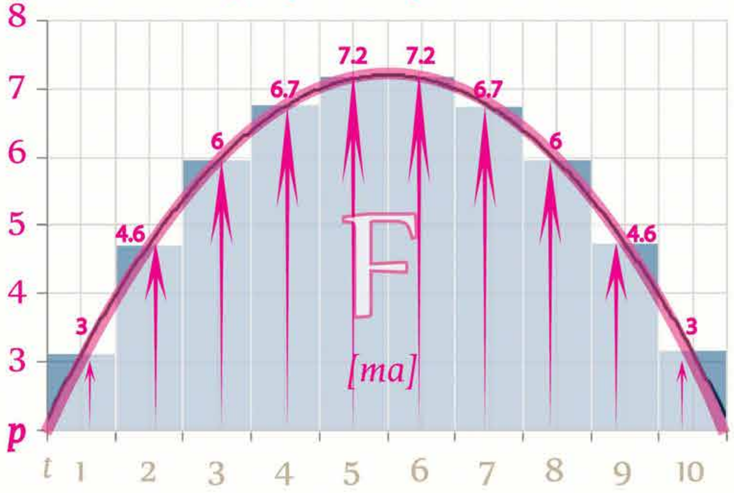

Leibniz

scalar energies

$$E = mv^2$$

mass-energy momenta relationship

square root equilateral energy is linear momentum

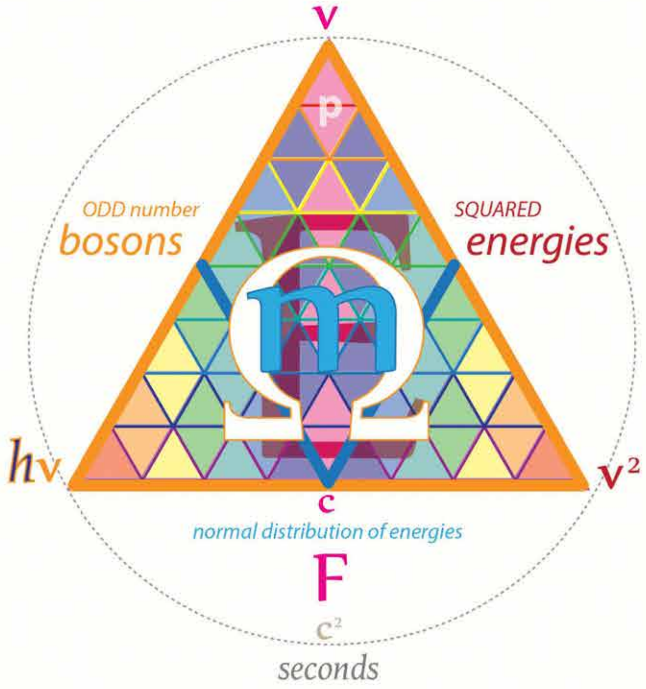
v
p
ODD number
bosons
SQUARED
energies
Ω
m
hv
v²
c
normal distribution of energies
F
c²
seconds

Newton

linear momentum

$$F = ma$$

mass is a scalar constant relating Force to acceleration

$$F = m\frac{\Delta v}{\Delta t}$$

Planck quanta and their vector linear momentum lie at 90 degrees to the angle use in the graphs of motion in calculus

Differentiation

Differentiation is concerned with things like speeds and accelerations, slopes and curves etc.
These are Rates of Change, they are things that are defined locally.

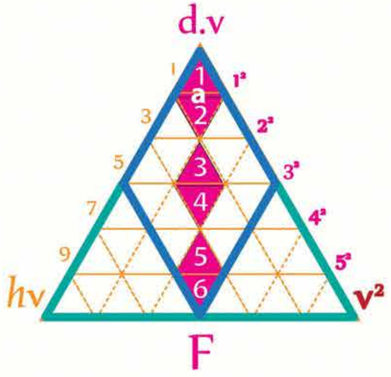
d.v
1
1²
a
2
2²
3
3
3²
5
4
4²
7
5
5²
9
6
hv
v²
F

An increase in a force opposing an object's vector velocity results in *DECCELERATION*

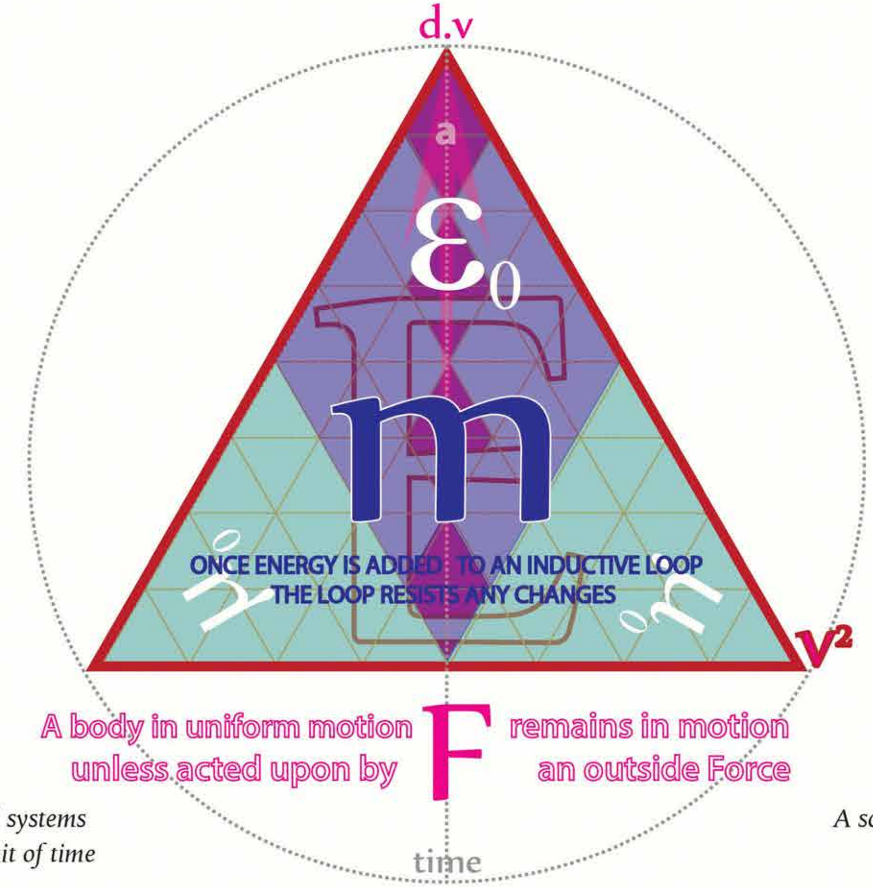
d.v
a
ε_0
E
m
ONCE ENERGY IS ADDED TO AN INDUCTIVE LOOP
THE LOOP RESISTS ANY CHANGES
hv
μ_0
v²
time

A body in uniform motion unless acted upon by **F** remains in motion an outside Force

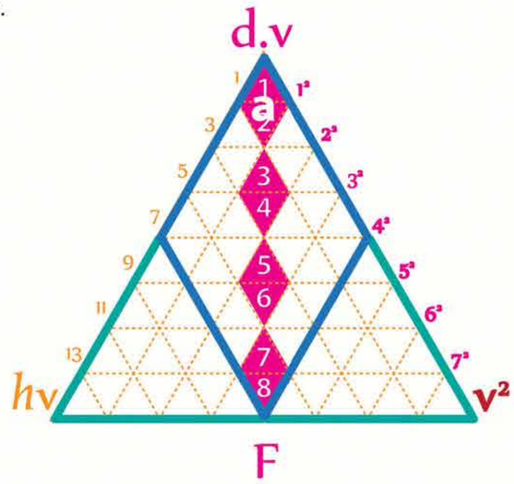
d.v
1
1²
a
2
2²
3
3
3²
5
4
4²
7
5
5²
9
6
6²
11
7
7²
13
8
hv
v²
F

An increase in a force in line with an object's vector velocity results in *ACCELERATION*

A linear measure of Forces acting on physical systems resulting in changes to distance covered per unit of time

A scalar measure of Forces acting on physical systems resulting in changes to their rate of motion

$$v = \frac{\Delta d}{\Delta t}$$

$$= m/s$$

$$F = ma$$

In physics, the derivative of the displacement of a moving body with respect to time is the velocity of the body, and the derivative of velocity with respect to time is acceleration.

$$\sum \mathbf{F} = \frac{d\mathbf{p}}{dt} = m\frac{d\mathbf{v}}{dt} + \mathbf{v}\frac{dm}{dt}$$

Newton's second law of motion states that the derivative of the momentum of a body equals the force applied to the body.

$$a = \frac{\Delta v}{\Delta t}$$

$$= m/s^2$$

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Visualising the geometric half-truths of relativistic physics

The source of all the physical relationships of mass-energy momenta and the constants in Physics is the Equilateral Triangle (and all texts must be corrected)

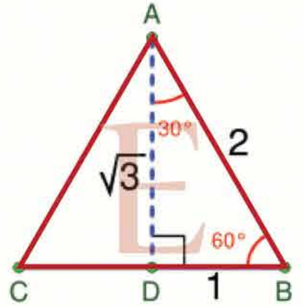

Energy geometries within Physics including Special Relativity with its Lorentz corrections have historically been incorrectly illustrated through the geometry of right angled triangles

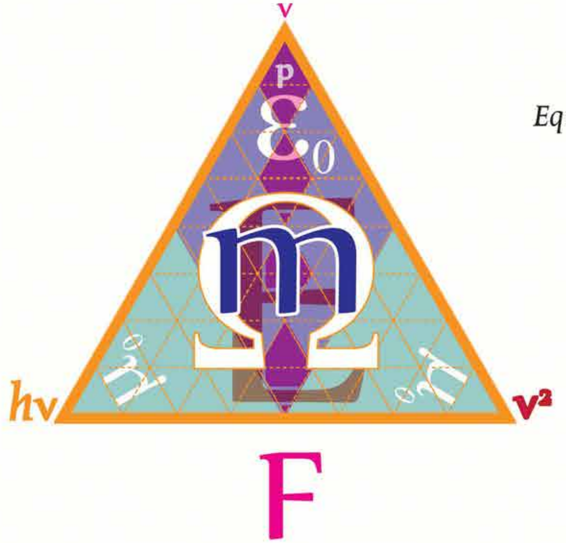

$$\sum \mathbf{F} = \frac{\mathrm{d}\mathbf{P}}{\mathrm{d}t} = m\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t} = m\mathbf{a}$$

$$\mathbf{F} = m\mathbf{a}\,.$$

Physics is geometry,
one cannot be separated from the other

Equilateral geomtries lead to a intuitive understandings of Physics, Chemistry, Electrodynamics and Gravitation along with all the other apsects of Nature.

$$mv^2 = E = hv^2$$

ENERGY

6.629432673 e-34 J

Planck
quanta
mΩv²
mass
velocity

7.376238634 e-51 kg

momentum

$$p^2 = mv^2$$

$$E = m_0c^2 + K$$

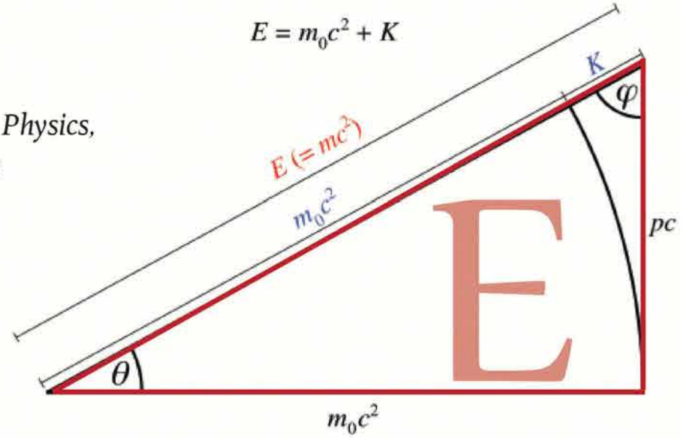

$$E^2 = p^2c^2 + m_0^2c^4$$

Generalizing, we see that the square of the total energy, mass, or distance in spacetime is the sum of the components squared.

We can see an origin of distance in spacetime relating to velocity in pc in which Energy is subject to Lorentz corrections [v/c]

$$E = pc.$$

Additionally, EM mass can be directly related tot the Energy content of a body by the velocity of Energy

$$E = mc^2$$

Velocity

In physics, velocity is the measurement of the rate and direction of change in the position of an object.

It is a vector physical quantity; both magnitude and direction are required to define it.

The scalar absolute value (magnitude) of velocity is speed, a quantity that is measured in metres per second (m/s or ms−1) when using the SI (metric) system.

$$\frac{m}{s}$$

Speed is the scalar value of the
Distance traveled per unit of TIme

$$\bar{\mathbf{v}} = \frac{\Delta \mathbf{x}}{\Delta t}.$$

Velocity is the vector value of the
Distance traveled per unit of Time

$$\frac{\vec{m}}{s}$$

Velocity squared is the scalar value of the
Distance traveled per unit of Time squared
(Energy of a given spatial volume)

$$\frac{m^2}{s^2}$$

v Velocity $\frac{m}{s}$

sec

is a 2D
radial Space-time
MEASUREMENT

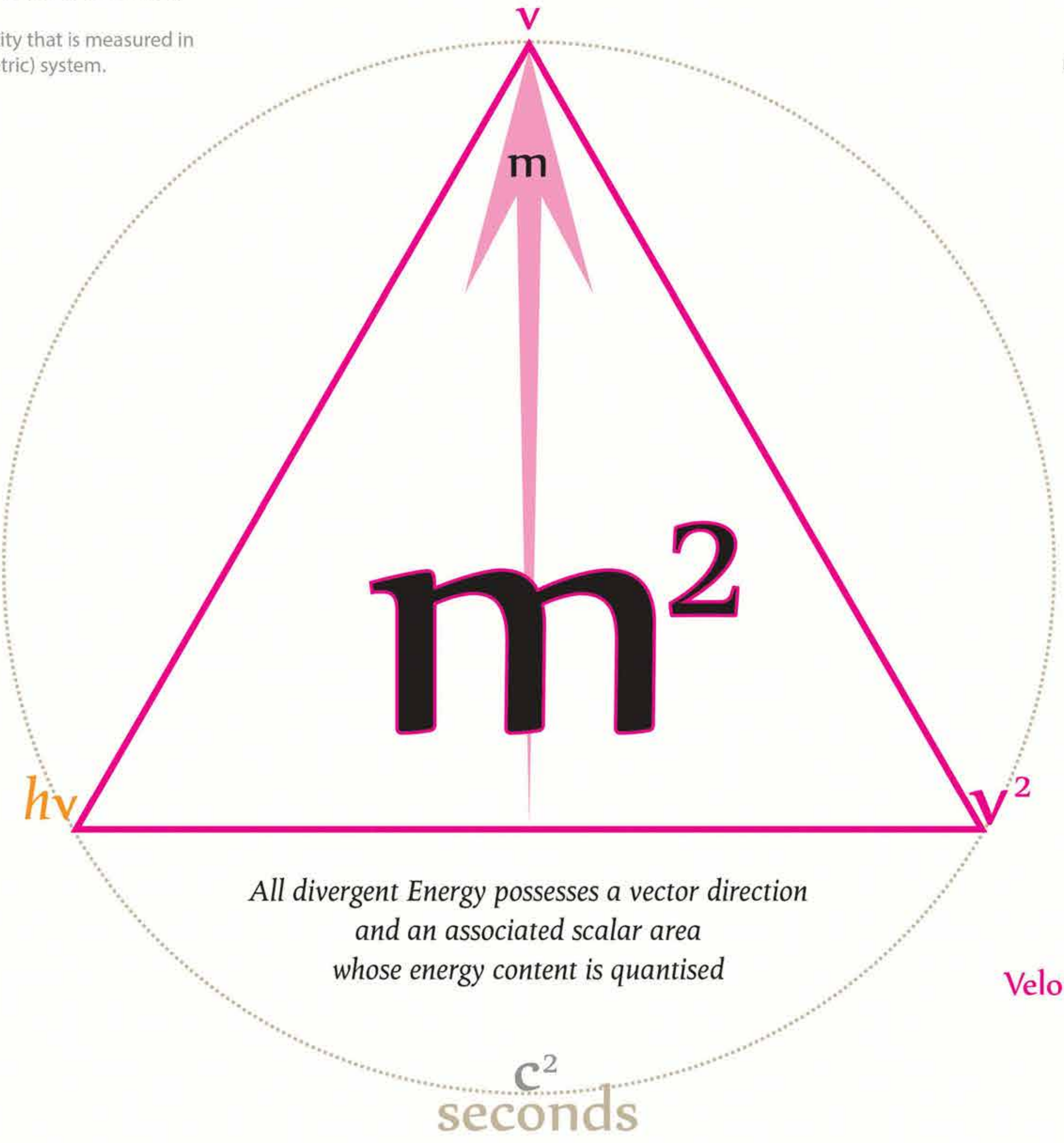

*All divergent Energy possesses a vector direction
and an associated scalar area
whose energy content is quantised*

Velocity squared

$$\frac{m^2}{s^2}$$

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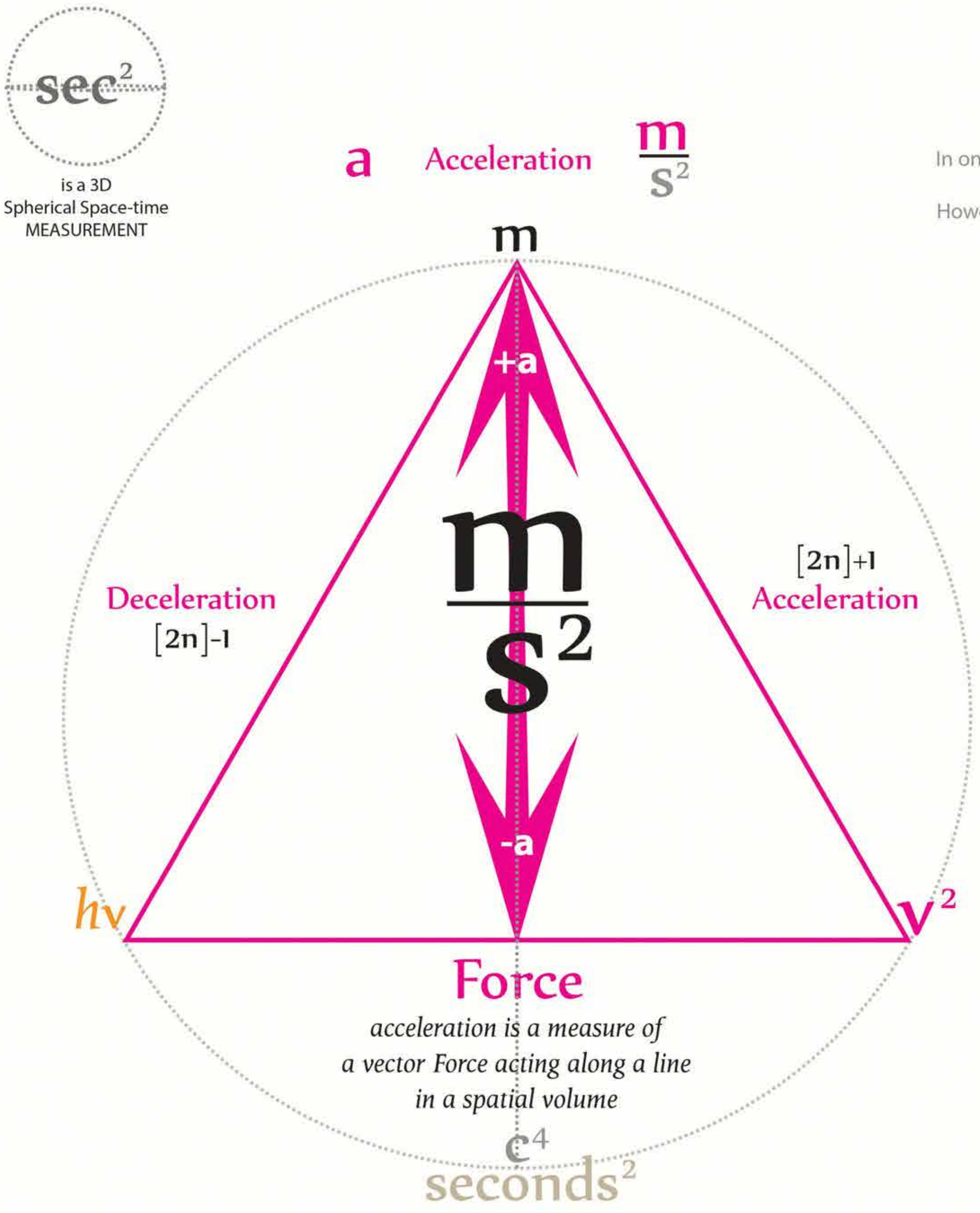
sec^2
is a 3D
Spherical Space-time
MEASUREMENT
a
Acceleration
$\frac{m}{s^2}$
m
+a
$\frac{m}{s^2}$
-a
Deceleration
[2n]-1
[2n]+1
Acceleration
hv
v^2
c^4
$seconds^2$

Force

acceleration is a measure of
a vector Force acting along a line
in a spatial volume

Acceleration

In physics, acceleration is the rate of change of velocity over time [dt]

In one dimension, acceleration is the rate at which something speeds up or slows down.

However, since velocity is a vector, acceleration describes the rate of change of both the magnitude and the direction of velocity.

Acceleration has the dimensions [Length]/[Time Squared]
In SI units, acceleration is measured in meters per second squared (m/s^2).

$$a = \frac{\Delta y}{\Delta x} = \frac{\Delta v}{\Delta t}.$$

In classical mechanics, for a body with constant mass,
the acceleration of the body is proportional to the net force acting on it
(Newton's second law)

$$F=ma \longrightarrow a=F/m$$

Force

$$kg\,\frac{m}{s^2}$$

Additionally, for a mass with constant velocity,
(ie in an inertial frame)
the energy of motion is expressed as its momentum
(acceleration causes changes in Energy-momentum)

$$p = kg\,\frac{m}{s}$$

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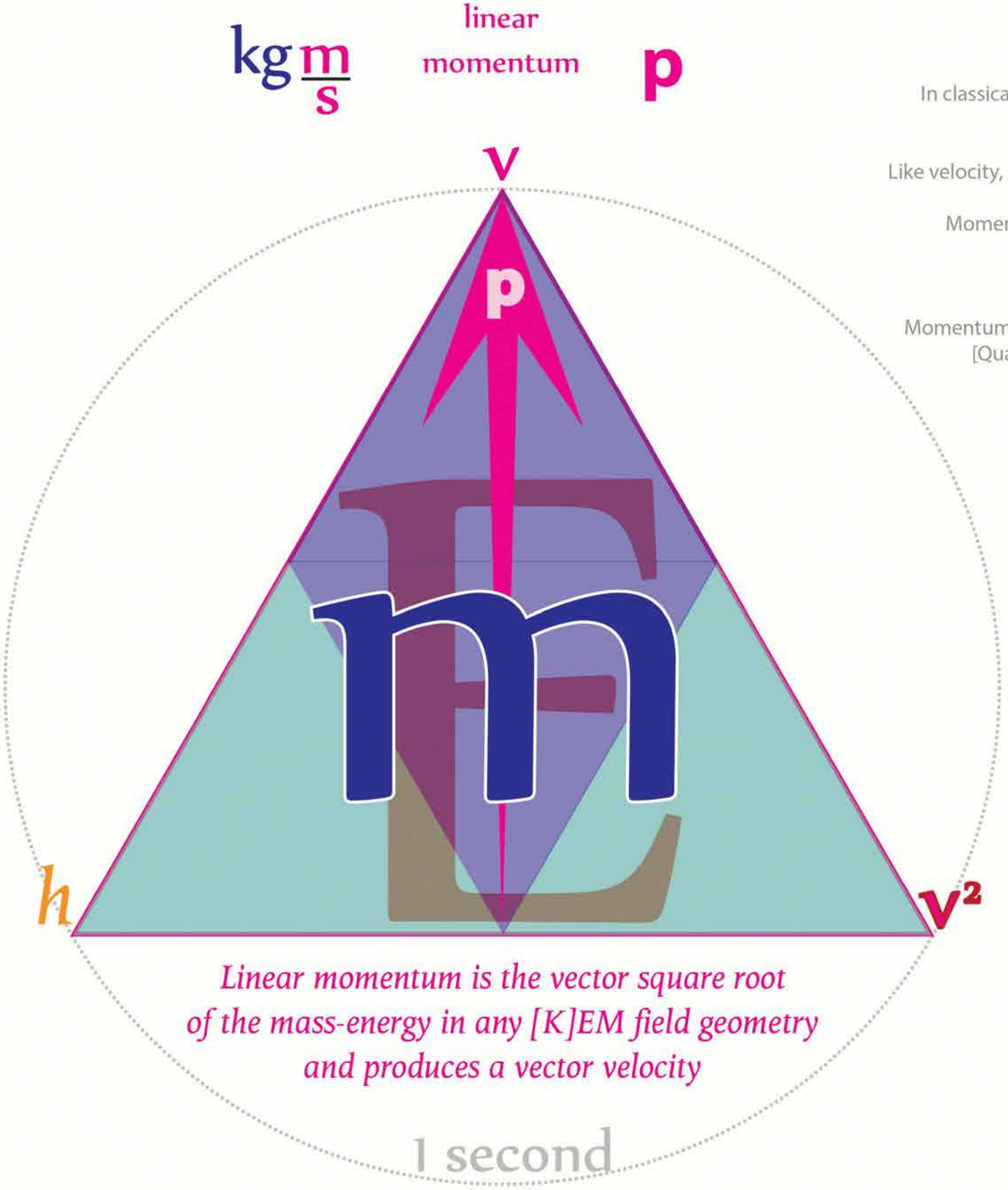

Linear momentum is the vector square root of the mass-energy in any [K]EM field geometry and produces a vector velocity

Momentum

In classical mechanics, momentum (pl. momenta; SI unit kg·m/s, or, equivalently, N·s) is the product of the mass and velocity of an object (p).

Like velocity, momentum is a vector quantity, possessing a direction as well as a magnitude.

Momentum is a conserved quantity (law of conservation of linear momentum), meaning that if a closed system is not affected by external forces, its total momentum cannot change.

Momentum should be referred to in its specific forms to distinguish it in its various forms [Quantised Angular, Linear, Rotational and quantum/nuclear momentum]

$$\boxed{p = \frac{hv^2}{v} = mv}$$

Although originally expressed in Newton's Second Law, the conservation of momentum also holds in special relativity and, with appropriate definitions, a (generalized) momentum conservation law holds in electrodynamics, quantum mechanics, quantum field theory, and general relativity.

In relativistic mechanics, non-relativistic momentum is further multiplied by the Lorentz factor.

$$p^2 = E = mv^2$$

Energy can be expressed as the square of linear momentum

$$kg\frac{m^2}{s^2}$$

equilateral Planck energy momenta

$$m\Omega v^2$$

Energy-momentum relationship

The total number of equilateral Planck quanta [quantised mass-energy momenta]
is directly related to the square of its linear momentum [mass-velocity]

Quantum Mechanics

Newtonian physics

$$h = \frac{E}{v^2}$$

$$m = \frac{E}{v^2}$$

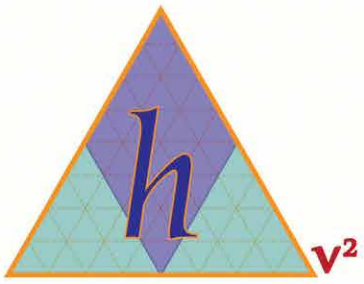

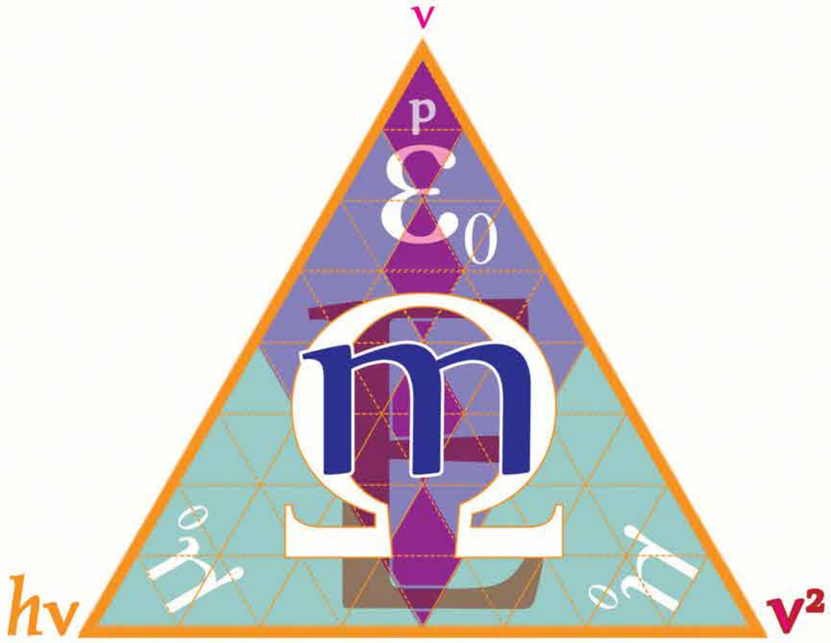

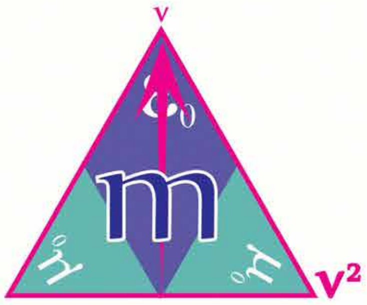

Quantised energy equilateral momenta

hv^2

Quantised Energy momenta is related to
Scalar mass energy momenta through
the equilateral geometry of Planck's constant

Scalar energy linear momentum

pv

$$m\Omega v^2 = E = mv^2$$

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Inertial resistance to Force

Inertia is the resistance of any physical object
to a change in its state of motion.

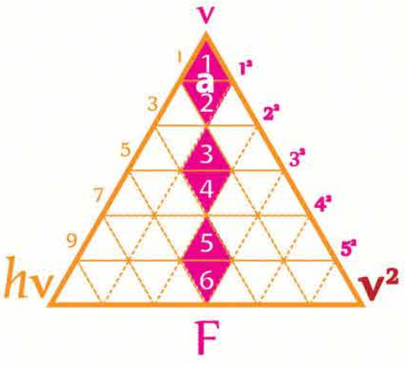
v
1
a
2
1²
3
2²
3
4
5
3²
7
4²
9
5
6
5²
hv
v²
F

Changes to mass-velocity
require a corresponding
change to boson quanta

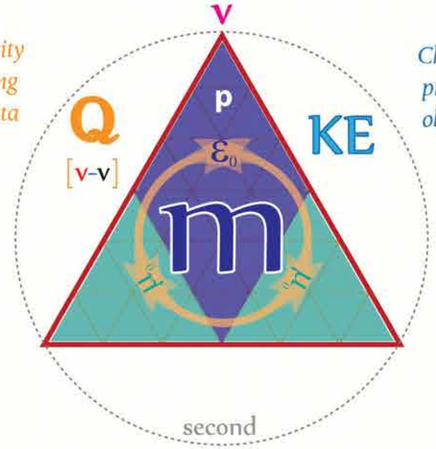
v
p
Q
[v-v]
KE
ε_0
m
second

Changes to mass-velocity
produces a change in an
object's Kinetic Energies

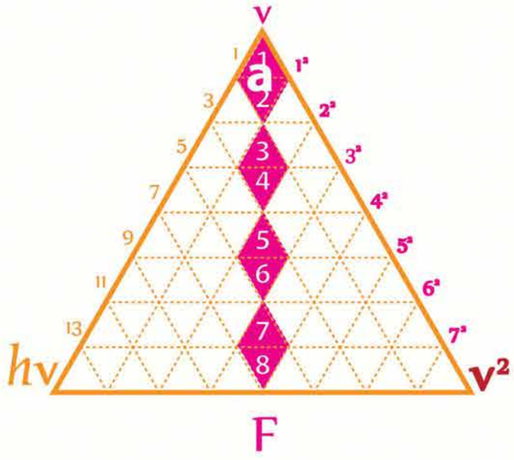
v
1
a
2
1²
3
2²
3
4
5
3²
7
4²
9
5
6
5²
11
6²
13
7
8
7²
hv
v²
F

$$E = mc^2$$

The total intrinsic momenta of all energy waveforms is the sum of their constituent Quantised Angular momenta (mass-energy momenta)

$$M_0 = m/c^2$$

Any change in motion results in changes to
the Charge geometries creating in turn proportional
changes to KEM mass and momenta components

$$F = ma$$

**The 'inductive resistance' of Charge quanta fields to
changes in their mass-energy momenta content
is what we term Inertia**

$$KEM = Mv^2$$

Matter in motion has Kinetic Energies in addition to invariant rest mass-Energy

KE = RE - rest Matter

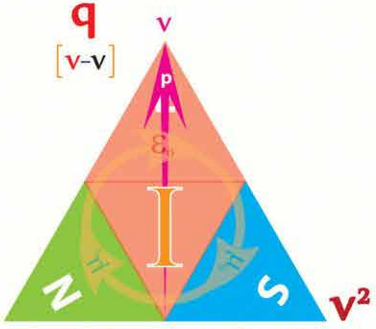
q
[v-v]
v
p
ε_0
I
N
S
v²

quantised moment of inertia

**Any change to an object's velocity results in a corresponding
change to its mass-Energy momenta which is reflected by its inertia**

$$p^2 = E = mv^2$$

Inertial mass can be related to Charge through inductive Planck quanta

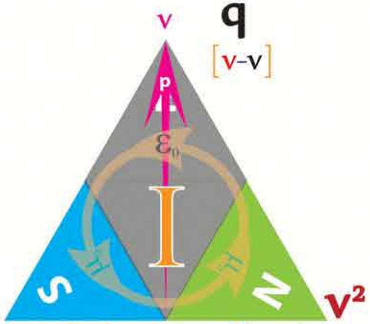
v
q
[v-v]
p
ε_0
I
S
N
v²

quantised moment of inertia

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Quantised Angular momentum

As it is a physical [equilateral] geometry QAM is conservative in any system where there are no external Forces and serves as the foundational geometric source for all the conservation laws of physics

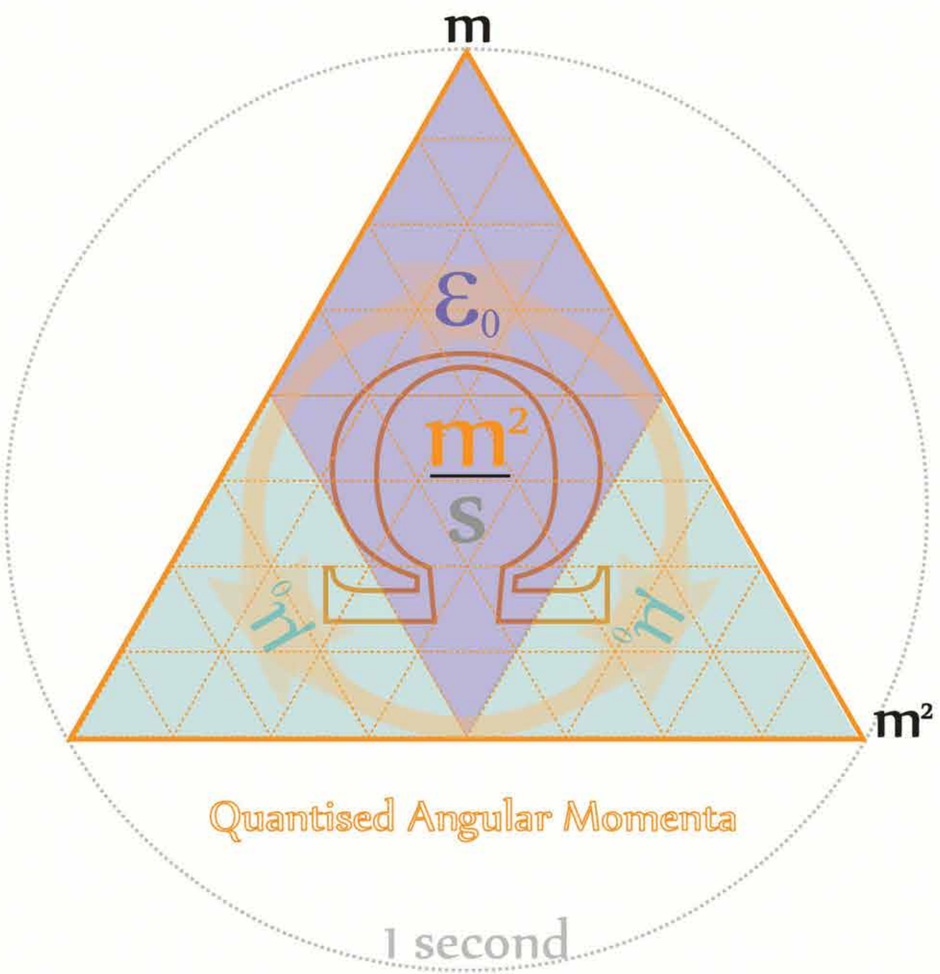
m
ε_0
$\frac{m^2}{s}$
η_0
η_0
m^2
Quantised Angular Momenta
1 second

Angular momentum is sometimes described as the rotational analog of linear momentum, in Tetryonics it is revealed to be the equilateral geometry of quantised mass-energy momenta within any defined space-time co-ordinate system

A major re-definition of quantised angular momentum in physics is revealed

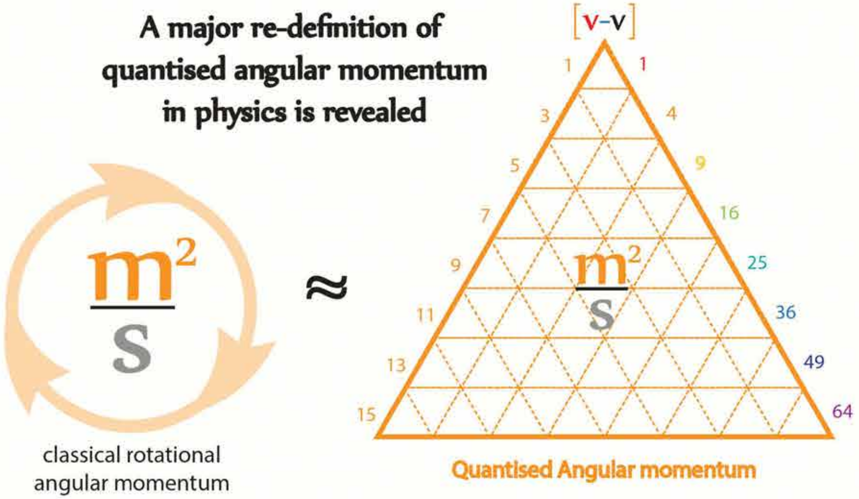
$\frac{m^2}{s}$
classical rotational angular momentum
≈
[v-v]
$\frac{m^2}{s}$
1
3
5
7
9
11
13
15
1
4
9
16
25
36
49
64
Quantised Angular momentum

In quantum mechanics, angular momentum is quantised – that is, it cannot vary continuously, but only in ODD number "quantum steps" between the allowed SQUARE nuclear Energy levels

In physics, angular momentum, moment of momentum, or rotational momentum is a conserved vector quantity that can be used to describe the overall state of a physical system.

When applied to specific mass-Energy-Matter systems QAM reveals the true quantum geometry and nature of Energy in our universe

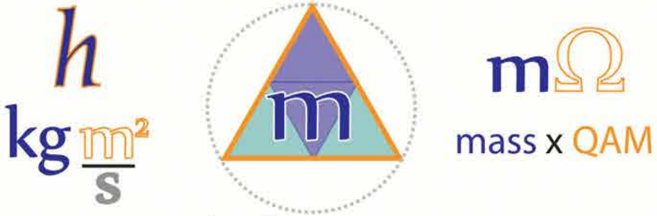
h
kg $\frac{m^2}{s}$
m
mΩ
mass x QAM

Planck's Constant

Normally viewed as an expression of rotational momentum Quantised Angular Momentum [QAM] is in fact a result of the equilateral geometric quantization of mass-energy

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Charged geometries

All charge geometries are nett divergent

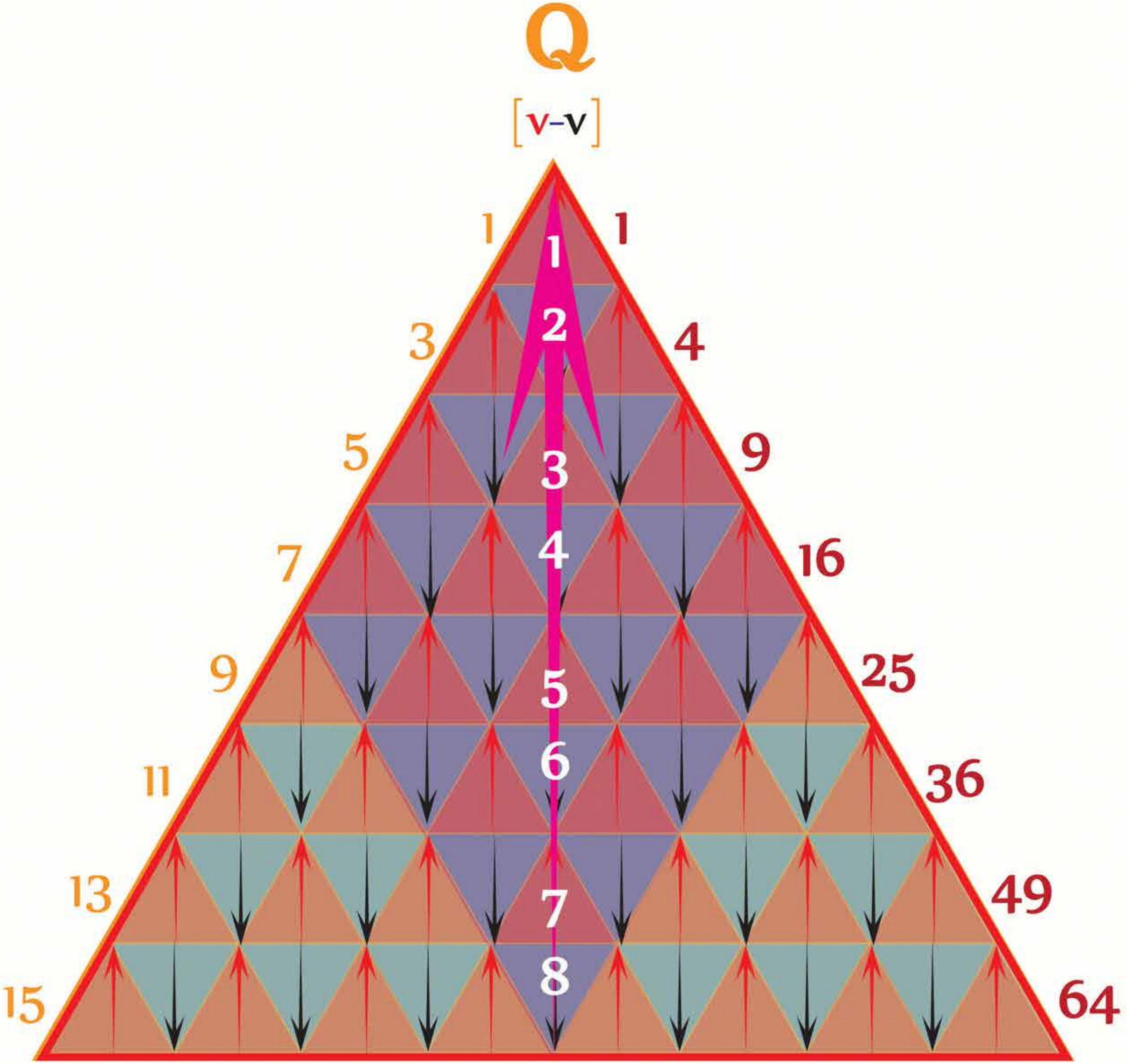
Q
[v-v]
1
1
1
2
3
4
3
5
9
7
16
9
25
11
36
13
49
15
64
1
2
3
4
5
6
7
8

Divergent energy momenta	Convergent energy momenta
1	0
3	1
6	3
10	6
15	10
21	15
28	21
36	28

All charge geometries are comprised of finite equilateral energy momenta quanta

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Renormalisation

Renormalization was first developed in quantum electrodynamics (QED) to make sense of infinite integrals in perturbation theory.
The problem of infinities first arose in the classical electrodynamics of point particles in the19th and
later in the calculation of Gravitational fields in General Relativity in the early 20th century.

In QED
Infinities must be cancelled

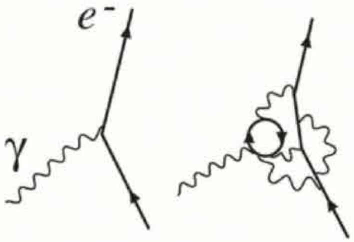

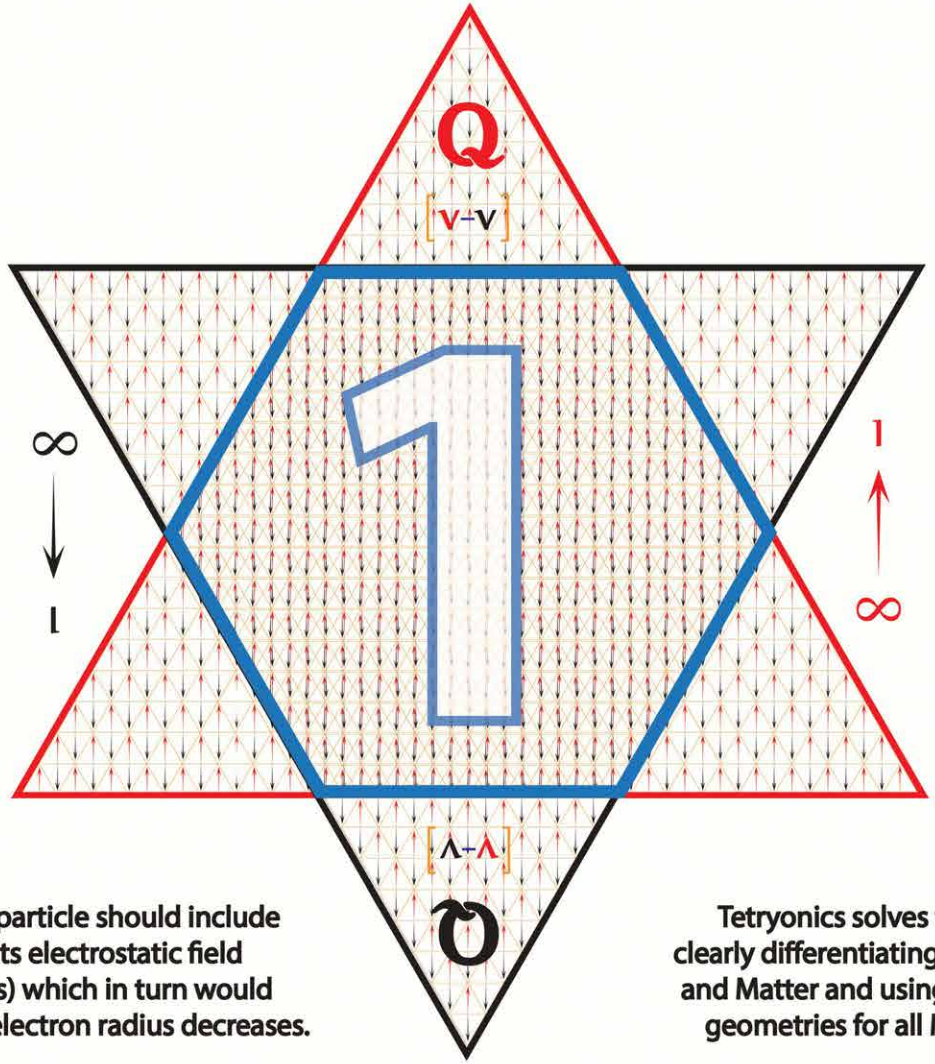

In Tetryonics
Infinities do not exist

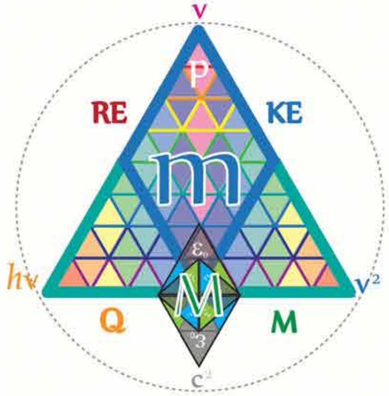

The mass of a charged particle should include the mass-energy in its electrostatic field (Electromagnetic mass) which in turn would approach infinity as the electron radius decreases.

Tetryonics solves the problem by clearly differentiating between EM mass and Matter and using finite equilateral geometries for all Matter in motion

Initially viewed as a suspicious provisional procedure by some of its originators, renormalization was eventually embraced as an important and self-consistent tool in several fields of physics and mathematics.

2D space [c^2]

The adjective Cartesian refers to the French mathematician and philosopher René Descartes who developed the coordinate system in 1637

Since then many other coordinate systems have been developed such as the polar coordinates for the plane, and the spherical and cylindrical coordinates for three-dimensional space.

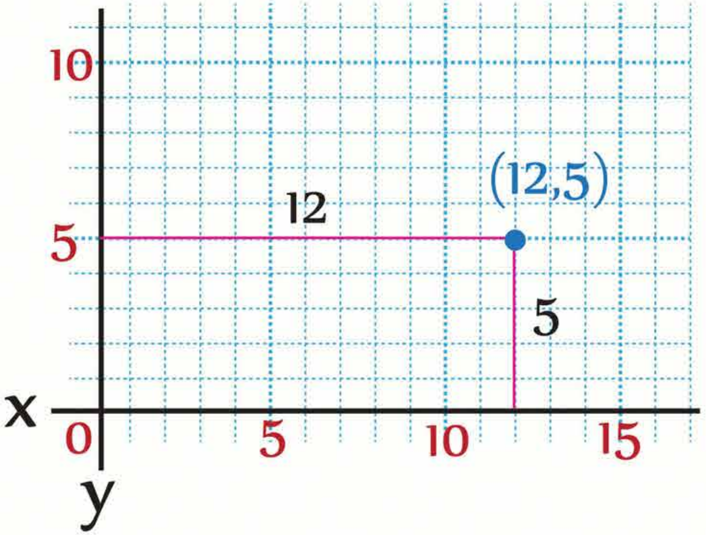

Cartesian coordinates are the foundation of analytic geometry, and provide enlightening geometric interpretations for many other branches of mathematics, such as linear algebra, complex analysis, differential geometry, multivariate calculus, group theory, and more

Mapping 3D spaces using Recti-linear co-ordinates

Cartesian coordinates can be defined as the positions of the perpendicular projections of a point onto the two or more axes, expressed as signed distances from the origin.

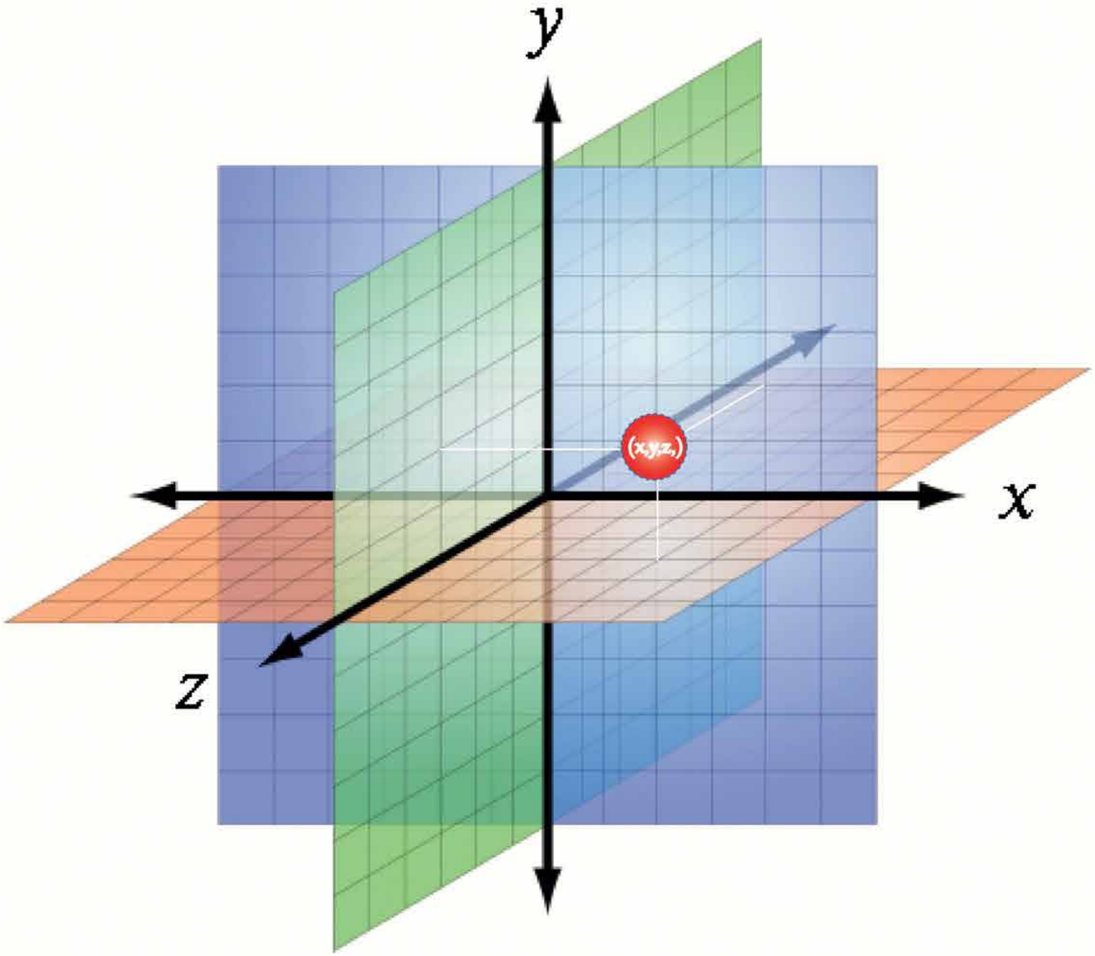

3D Cartesian co-ordinate [c^3] systems are distinct from spherical co-ordinate [c^4] systems

Polar co-ordinates

In mathematics, the polar coordinate system is a two-dimensional co-ordinate system in which each point on a plane is determined by a distance from a fixed point and an angle from a fixed direction.

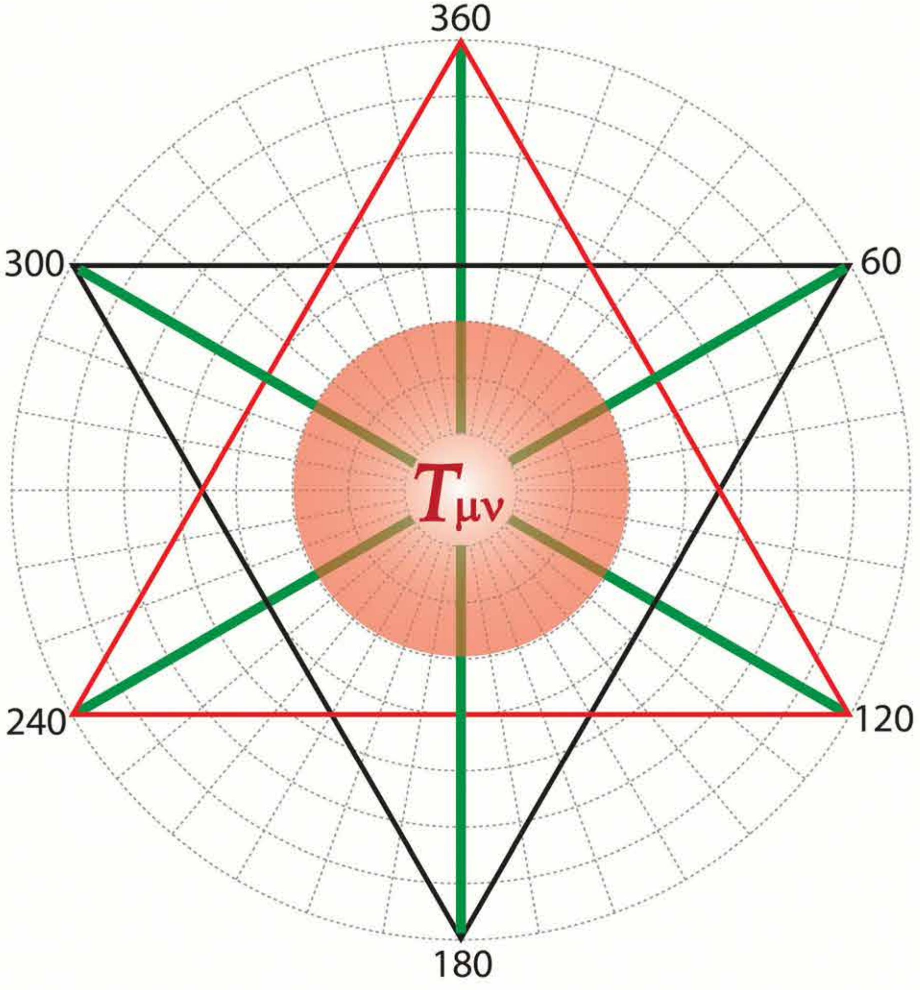

In geometry, curvilinear coordinates are a coordinate system for Euclidean space in which the co-ordinate lines may be curved.

Action Dynamics

Curvilinear co-ordinates may be derived from a set of rectilinear Cartesian coordinates by using a locally invertible transformation that maps one point to another in both systems

Metric Tensors

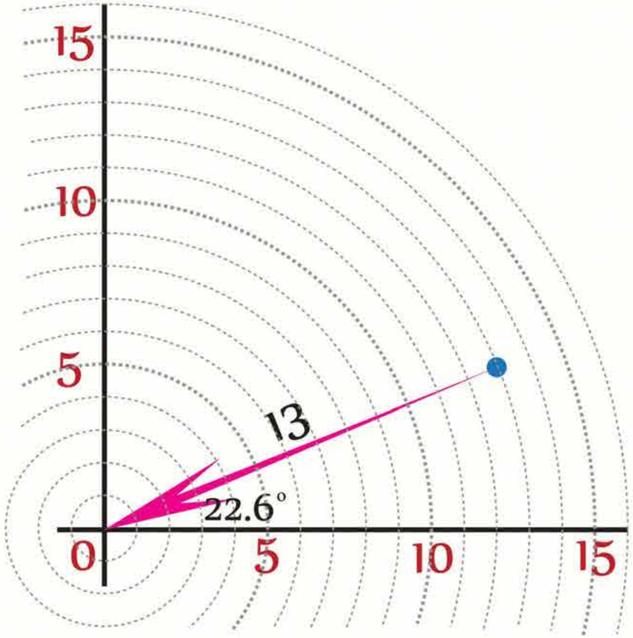

Gravitational acceleration

Polar or curvilinear co-ordinate systems are used extensively by Einstein in his theory of General Relavtivity

Reimannian curved space-time

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Co-ordinate transformations

There are many different possible coordinate systems for describing geometrical figures and they can all be related to one another.

Such relations are described by coordinate transformations which give formulas for the coordinates in one system in terms of the coordinates in another system

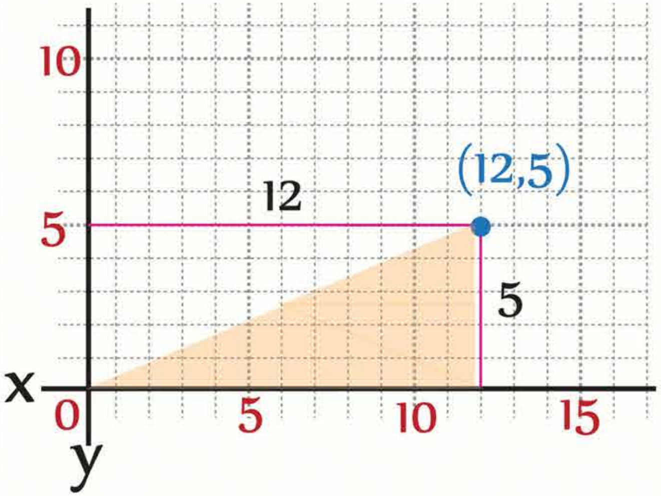

Converting between Polar and Cartesian coordinates

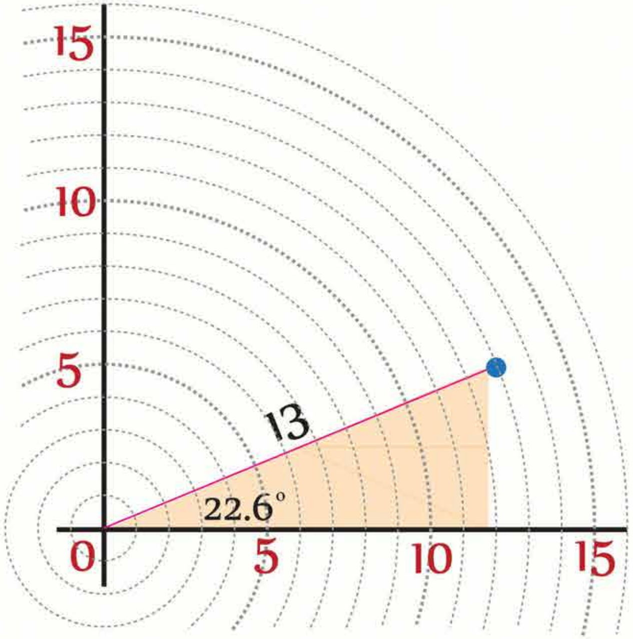

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$= \tan^{-1}(5/12)$$

$$= 22.619$$

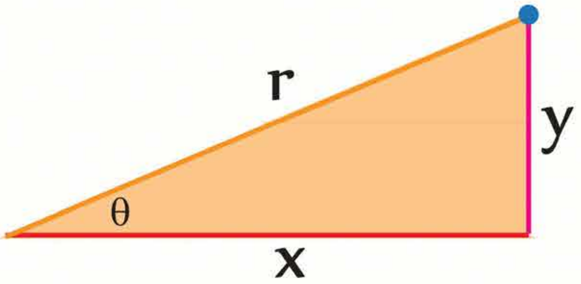

$$r^2 = 12^2 + 5^2$$

$$= \sqrt{169}$$

$$= 13$$

solving for the triangle using trigometric functions

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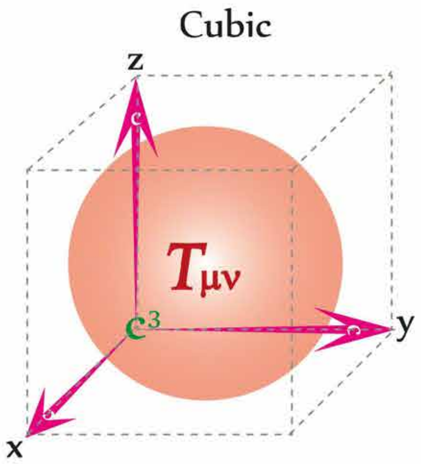
Cubic
z
c
$T_{\mu\nu}$
c^3
c
y
c
x

Spatial co-ordinate systems

Spacetime is any mathematical co-ordinate system or model that combines space and time into a single continuum.

Spacetime is usually interpreted with space as being three-dimensional with time playing the role of a fourth dimension that is different from the spatial dimensions.

From a Euclidean space perspective, the universe has three spatial dimensions and one dimension of time [reflected by quantised angular momentum].

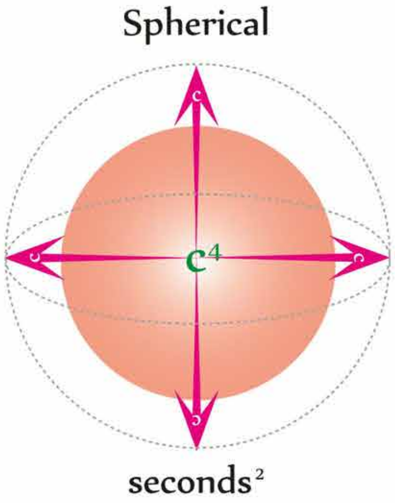
Spherical
c
c
c^4
c
c
seconds²

Tetryonics maps spatial co-ordinates through the momenta vectors of equilateral Energy

Cartesian Space-Time

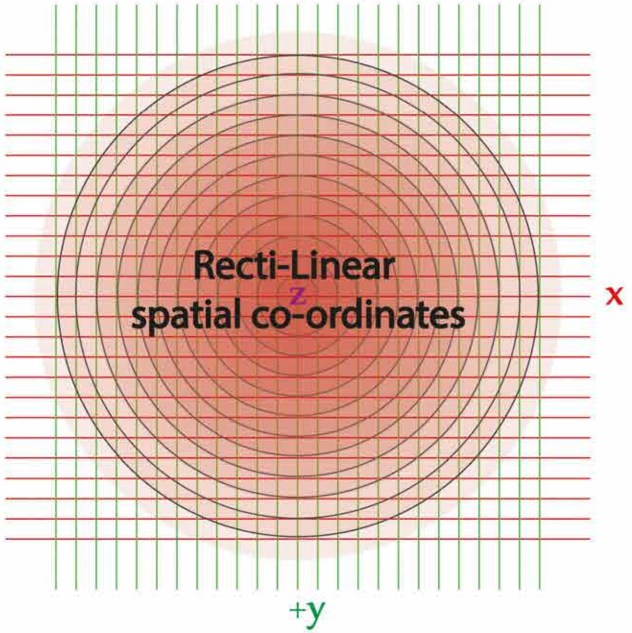
Recti-Linear
spatial co-ordinates
z
x
+y

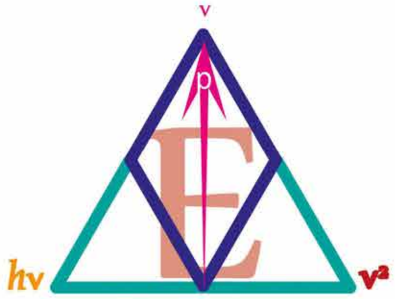

EM mass-ENERGY momenta
are equilateral geometries

Mapping equilateral Energy geometries onto recti or curvi-linear spatial co-ordinate systems introduces mathematical complexity to a otherwise simplistic geometry for all EM mass-Energy-Matter interactions

Tetryonic Space-Time

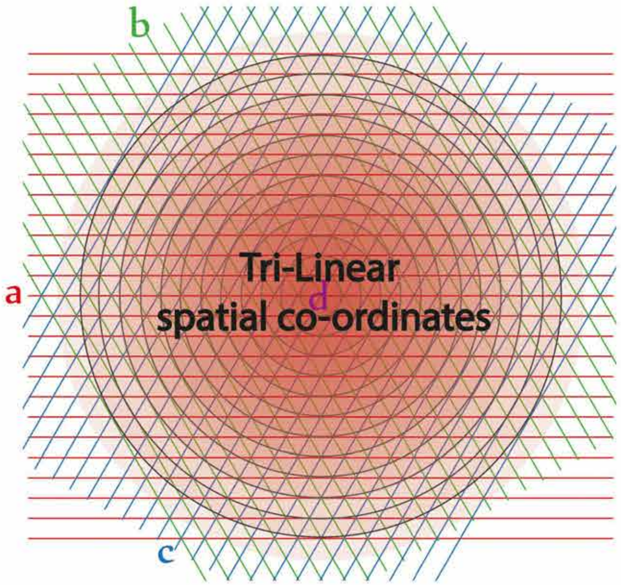
b
a
Tri-Linear
spatial co-ordinates
d
c

In physics spatial co-ordinates to date have been based on Cartesian co-ordinates when in fact Energy momenta follow a Tri-Linear co-ordinate geometry

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vectors

1 Dimensional velocity

Euclidean

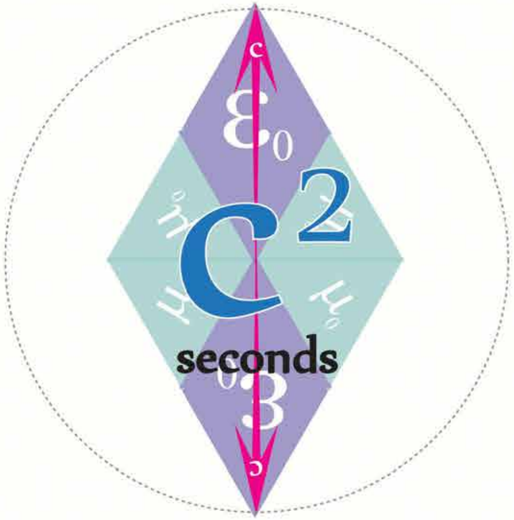
c
ε_0
c^2
μ_0
seconds

2 Dimensions velocity squared

$$m = \frac{E}{c^2}$$

mass-energy equivalence

mass-Matter

$$\frac{m}{c^2} = M$$

equivalence

$$T_{\mu\nu}$$

energy-Matter equivalence

$$M = \frac{E}{c^4}$$

GR fails differentiate betweem
EM mass-ENERGY-Matter
unlike Tetryonic theory

Cartesian co-ordinates

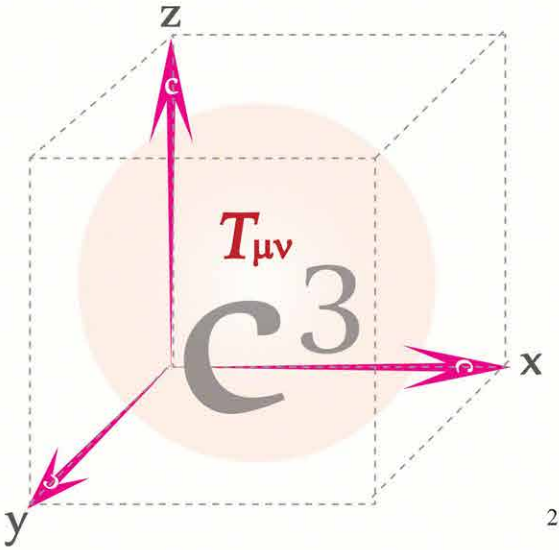
z
x
y
c
$T_{\mu\nu}$
c^3

3 Dimensions velocity cubed

Spherical

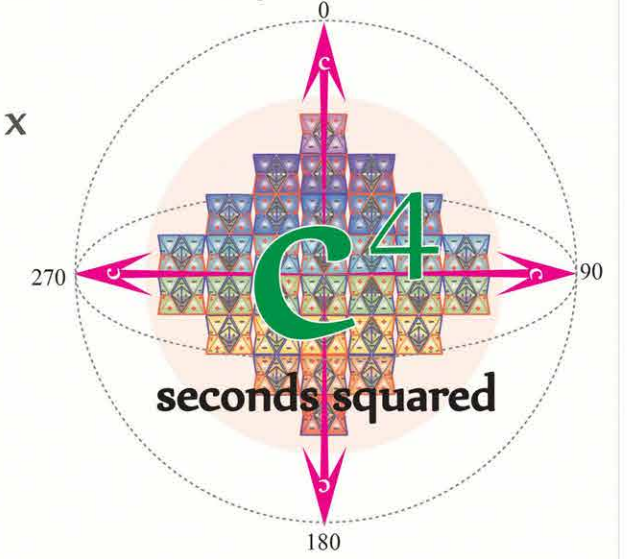
0
90
180
270
c
c^4
seconds squared

3 Dimensions quadrature velocity

Space-time co-ordinates

The propagation of Energy momenta forms distinct spatial co-ordinate systems

Where angles are typically measured in degrees (°) or radians (rad), where 360° = 2π rad = τ radians.

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Tetryonic co-ordinate systems

Energy per second

Energy per second squared

m

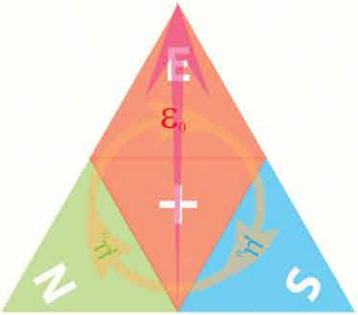

2D mass-energy geometries

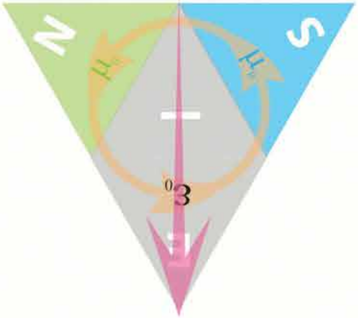

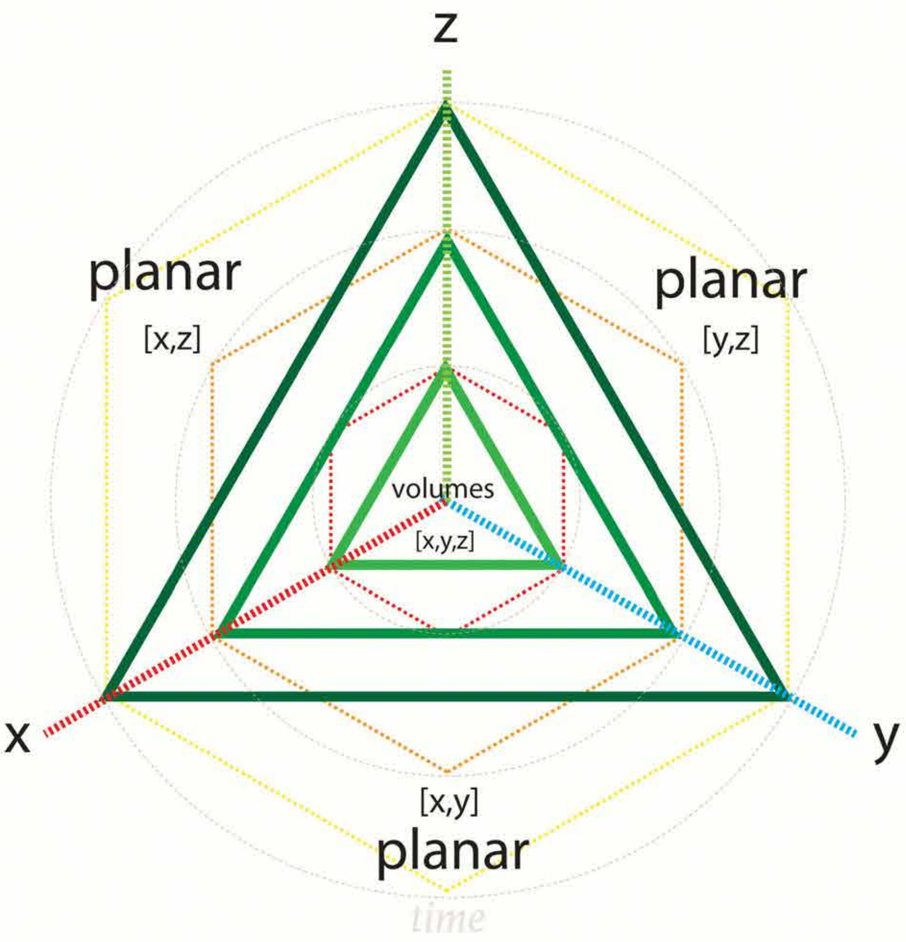
z
planar
[x,z]
planar
[y,z]
volumes
[x,y,z]
x
y
[x,y]
planar
time

M

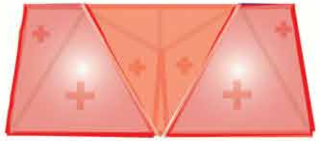

Proton

3D Matter topologies

Neutron

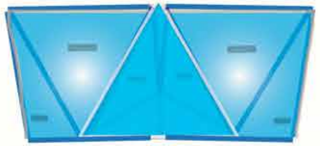

Planar mass-energy geometries have no z-components

Differentiation between 2D mass-energy & 3D Matter is key to extending our understanding of physics

Matter topologies have z-components

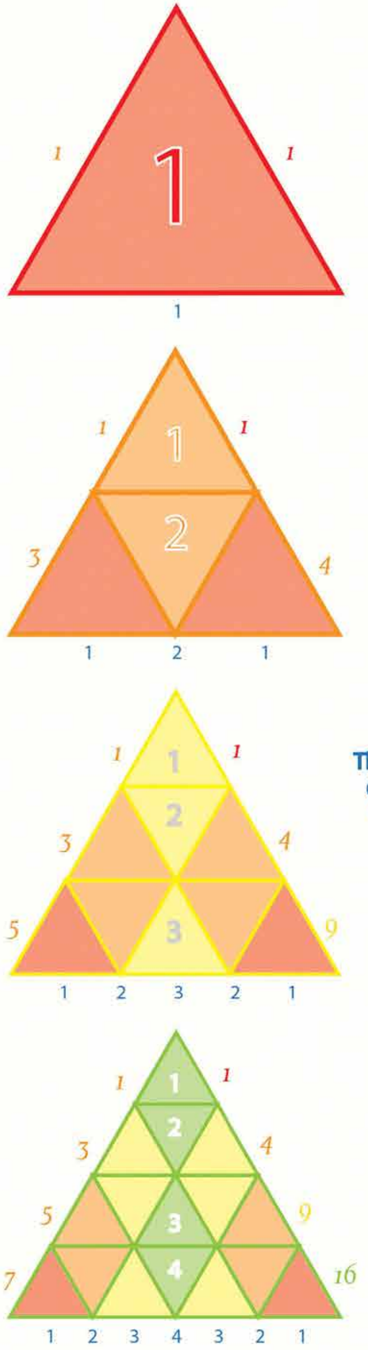
1
1 1
1
1
2
1 1
3 4
1 2 1
1
2
3
1 1
3 4
5 9
1 2 3 2 1
1
2
3
4
1 1
3 4
5 9
7 16
1 2 3 4 3 2 1

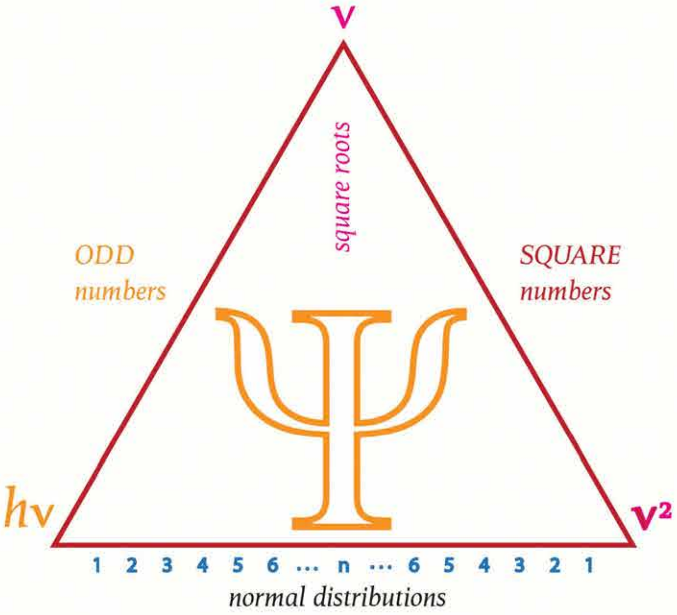
v
square roots
ODD numbers
SQUARE numbers
hv
v²
1 2 3 4 5 6 ... n ... 6 5 4 3 2 1
normal distributions

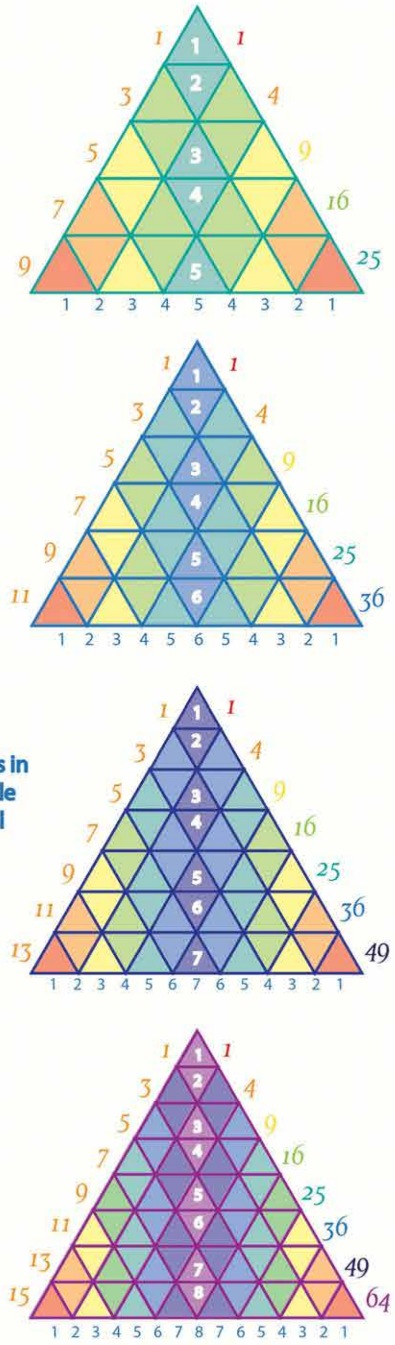
1
2
3
4
5
1 1
3 4
5 9
7 16
9 25
1 2 3 4 5 4 3 2 1
1
2
3
4
5
6
1 1
3 4
5 9
7 16
9 25
11 36
1 2 3 4 5 6 5 4 3 2 1
1
2
3
4
5
6
7
1 1
3 4
5 9
7 16
9 25
11 36
13 49
1 2 3 4 5 6 7 6 5 4 3 2 1
1
2
3
4
5
6
7
8
1 1
3 4
5 9
7 16
9 25
11 36
13 49
15 64
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1

Quantum probability distributions

The equilateral geometry and distribution of quantised Energy momenta provides the basis for all statistical probabilities in Quantum mechanics, thermodynamic & information entropy - including a solution to Heisenberg's Uncertainty Principle thus paving the way forward for a new understanding, and manipulation of physical phenomena at the quantum level

1
1 2 1
1 2 3 2 1
1 2 3 4 3 2 1
1 2 3 4 5 4 3 2 1
1 2 3 4 5 6 5 4 3 2 1
1 2 3 4 5 6 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1

Normal distributions are extremely important in statistics, and are often used in the natural and social sciences for real-valued random variables whose distributions are not known

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Quantum Probability Distributions

The normal distribution is a probability distribution.
It is also called Gaussian distribution because it was discovered by Carl Friedrich Gauss.

x/n^2

Probabilities are
the square of the
Amplitude

n

$\Sigma\ x/n^2$

All probabilities
are re-normalisable
and sum to Unity

1

square root momenta

v

ODD
transverse
Bosons

EVEN
Longitudinal
Photons

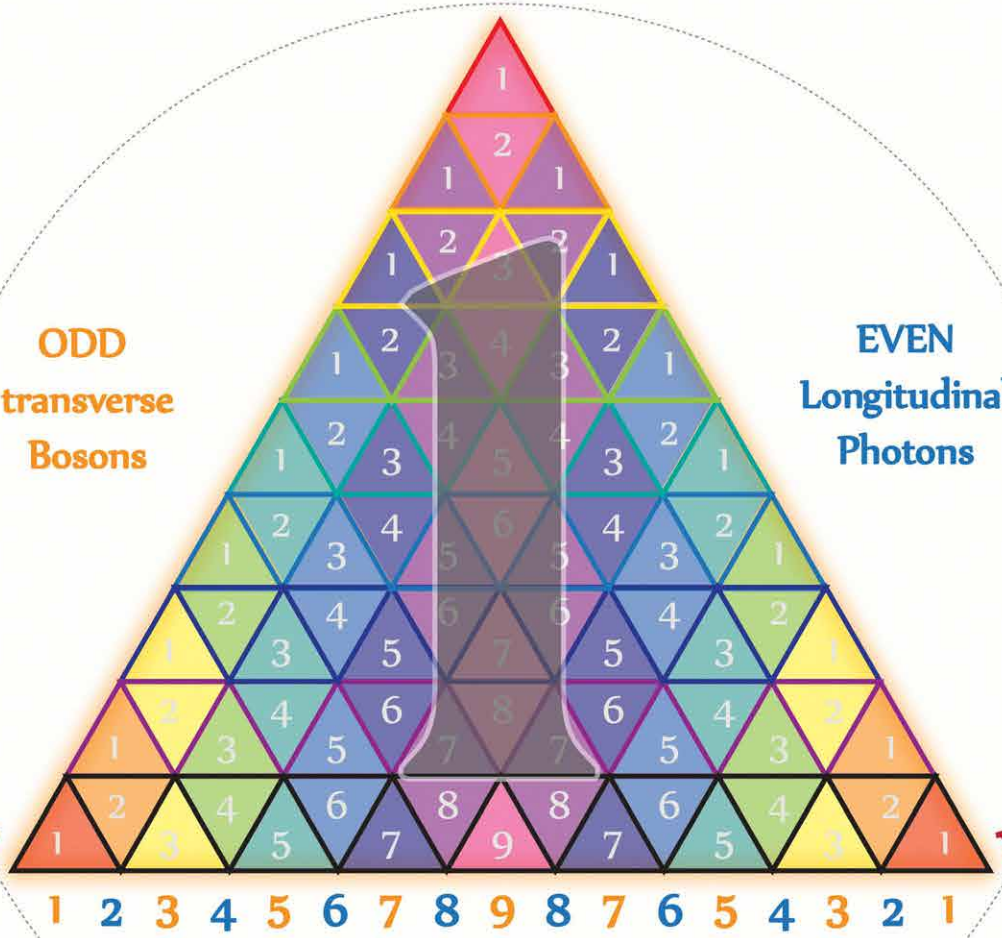
1
1 2 1
1 2 3 2 1
1 2 3 4 3 2 1
1 2 3 4 5 4 3 2 1
1 2 3 4 5 6 5 4 3 2 1
1 2 3 4 5 6 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 9 8 7 6 5 4 3 2 1
1
1 2 3 4 5 6 7 8 9 8 7 6 5 4 3 2 1

Planck
quanta

hv

v^2

Square
energies

[n-1] [n-1]

Normal Distribution

c^2

Quanta Distributions

Quantum Levels

transverse bosons

$2h\nu = E = hf$

Quantum Probabilities

longitudinal photons

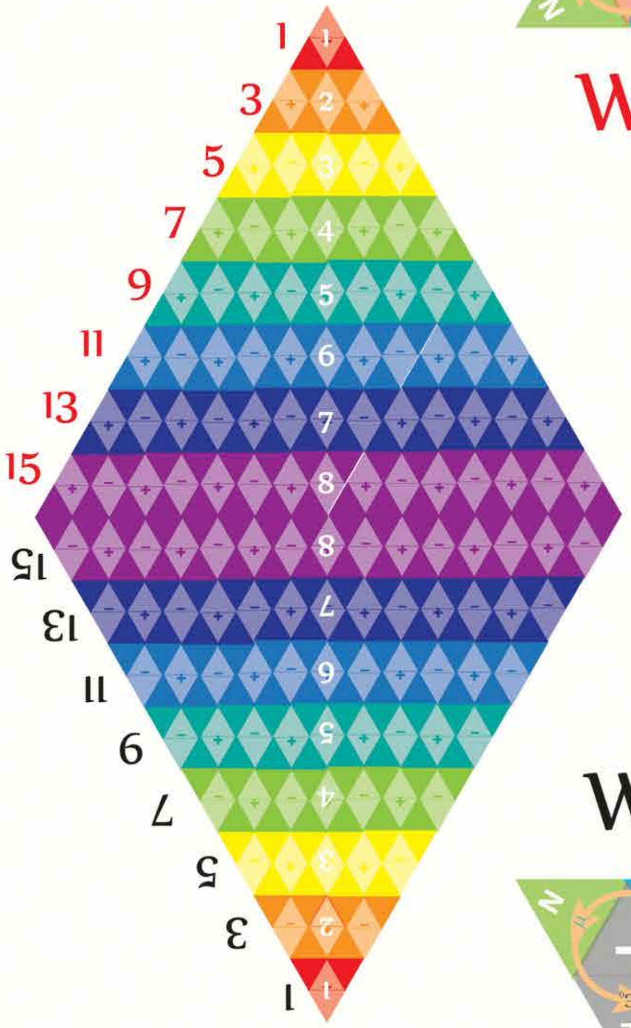
1
3
5
7
9
11
13
15
15
13
11
9
7
5
3
1
1
2
3
4
5
6
7
8
8
7
6
5
4
3
2
1

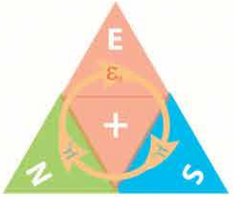

W+

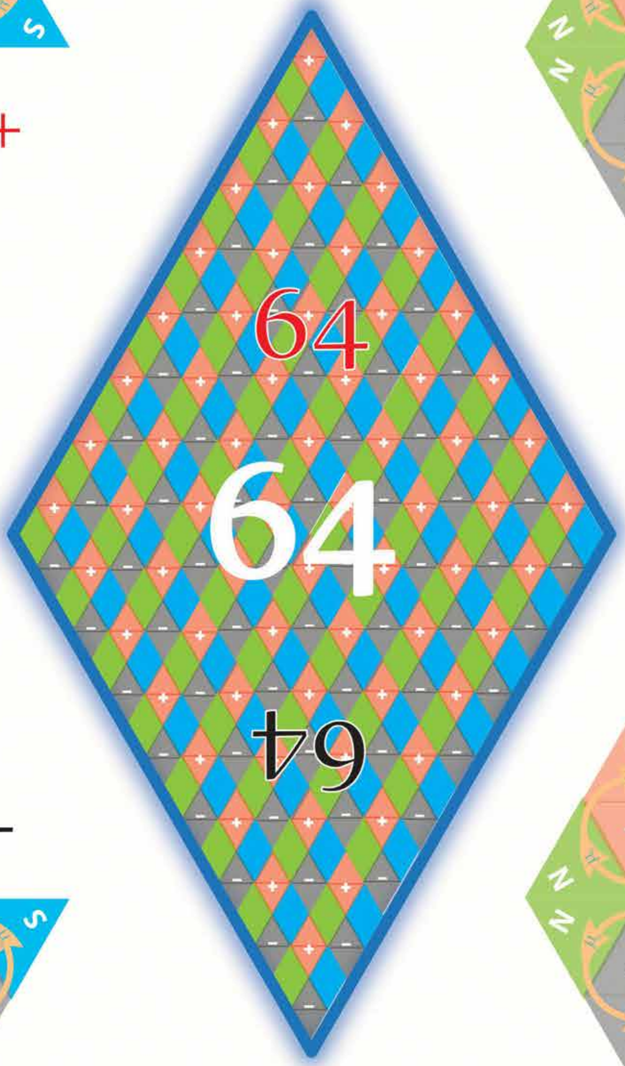

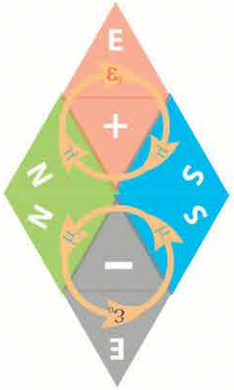
E
ε0
+
N
S
N
S
–
ε0
E

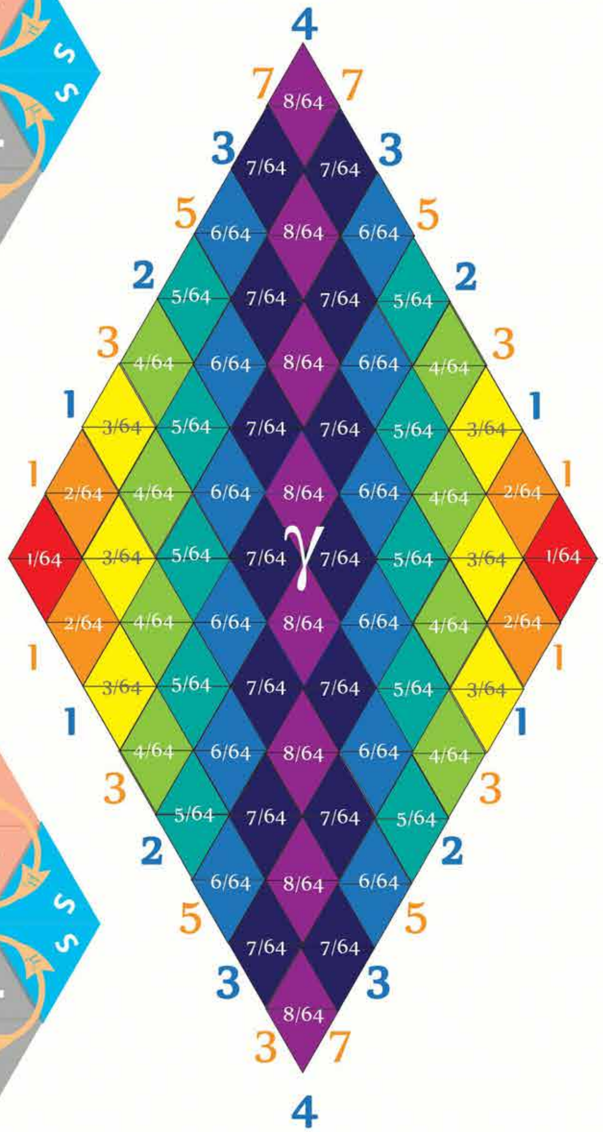
4
7 7
8/64
3 3
7/64 7/64
5 5
6/64 8/64 6/64
2 2
5/64 7/64 7/64 5/64
3 3
4/64 6/64 8/64 6/64 4/64
1 1
3/64 5/64 7/64 7/64 5/64 3/64
1 1
2/64 4/64 6/64 8/64 6/64 4/64 2/64
1/64 3/64 5/64 7/64 γ 7/64 5/64 3/64 1/64
1 1
2/64 4/64 6/64 8/64 6/64 4/64 2/64
1 1
3/64 5/64 7/64 7/64 5/64 3/64
3 3
4/64 6/64 8/64 6/64 4/64
2 2
5/64 7/64 7/64 5/64
5 5
6/64 8/64 6/64
3 3
7/64 7/64
3 7
8/64
4

W-

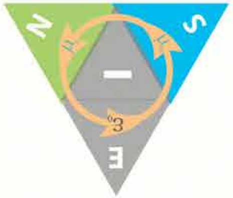

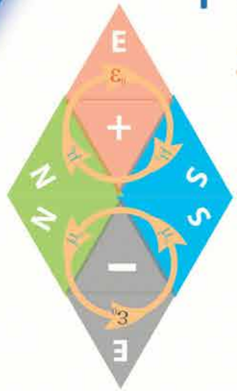
E
ε0
+
N
S
N
S
–
ε0
E

Wavefunctions

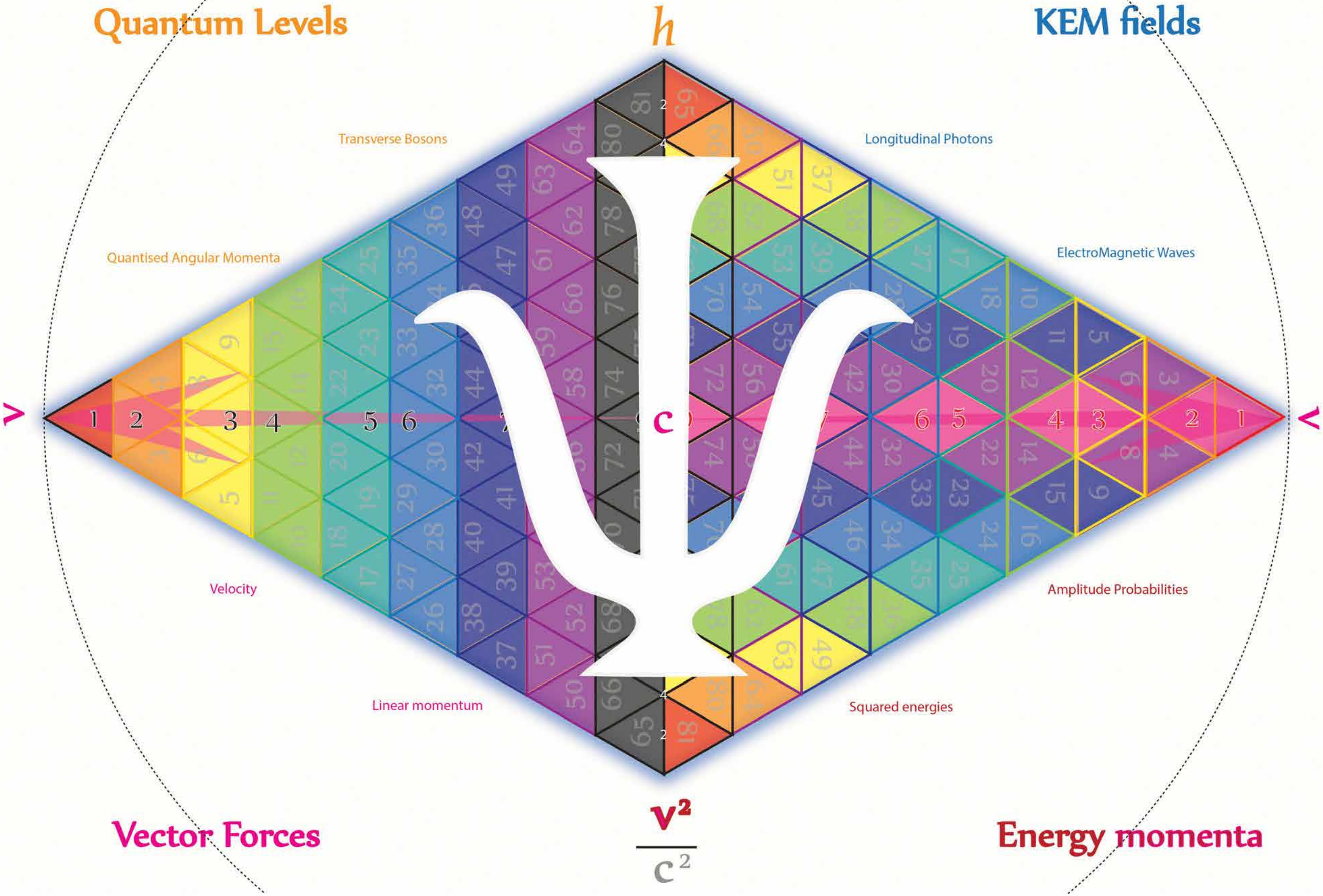
Quantum Levels
h
KEM fields
Transverse Bosons
Longitudinal Photons
Quantised Angular Momenta
ElectroMagnetic Waves
v
1 2 3 4 5 6 7
c
7 6 5 4 3 2 1
v
Velocity
Amplitude Probabilities
Linear momentum
Squared energies
Vector Forces
$\frac{v^2}{c^2}$
Energy momenta

EM waveforms

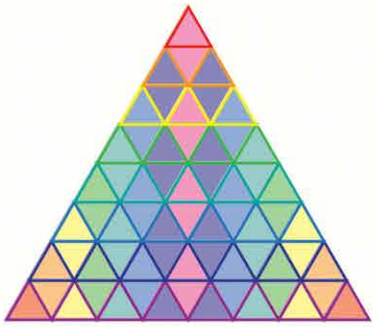

All EM waveforms can be measured
by either their Transverse EM masses [Bosons]
or their Longitudinal EM masses [Photons]

PHOTONS

EM waves

$$\frac{\text{EVEN}\,\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

Planck quanta
mass
velocity

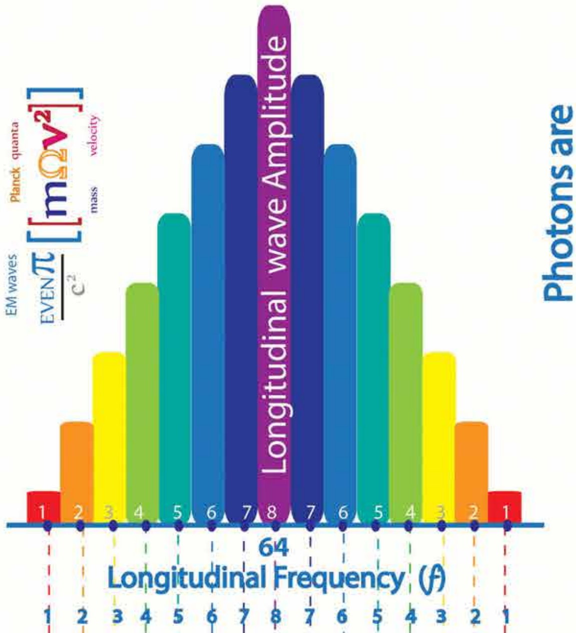
Longitudinal wave Amplitude
1
2
3
4
5
6
7
8
7
6
5
4
3
2
1
64
Longitudinal Frequency (f)

Photons are longitudinal quanta

vs.

BOSONS

Bosons
Planck quanta

$$\frac{\text{ODD}\,\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass
velocity

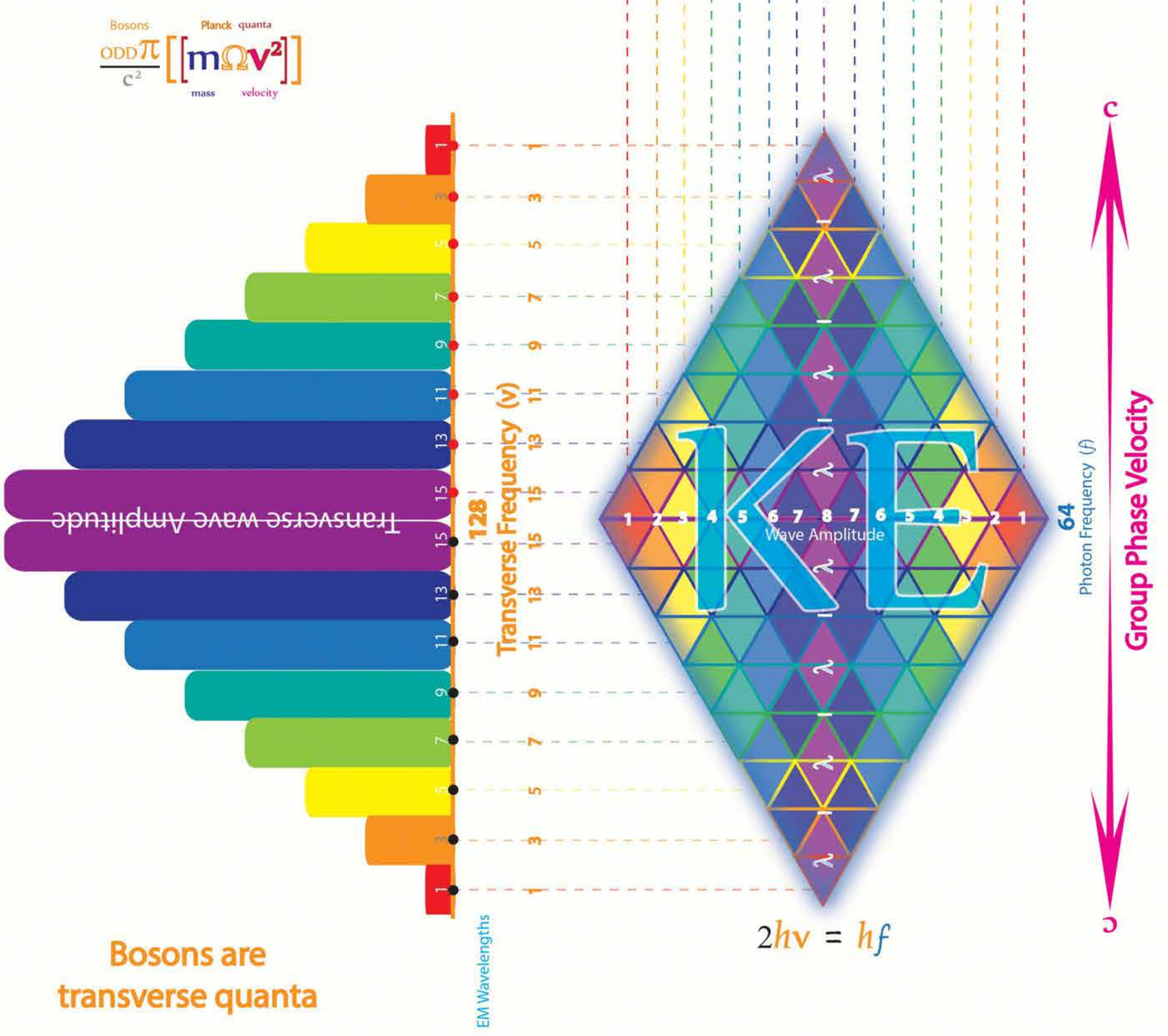
Transverse wave Amplitude
1
3
5
7
9
11
13
15
15
13
11
9
7
5
3
1
128
Transverse Frequency (v)
EM Wavelengths
KE
Wave Amplitude
λ
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
64
Photon Frequency (f)
Group Phase Velocity
c
c

$$2h\nu = hf$$

Bosons are transverse quanta

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Quantum Energy distributions

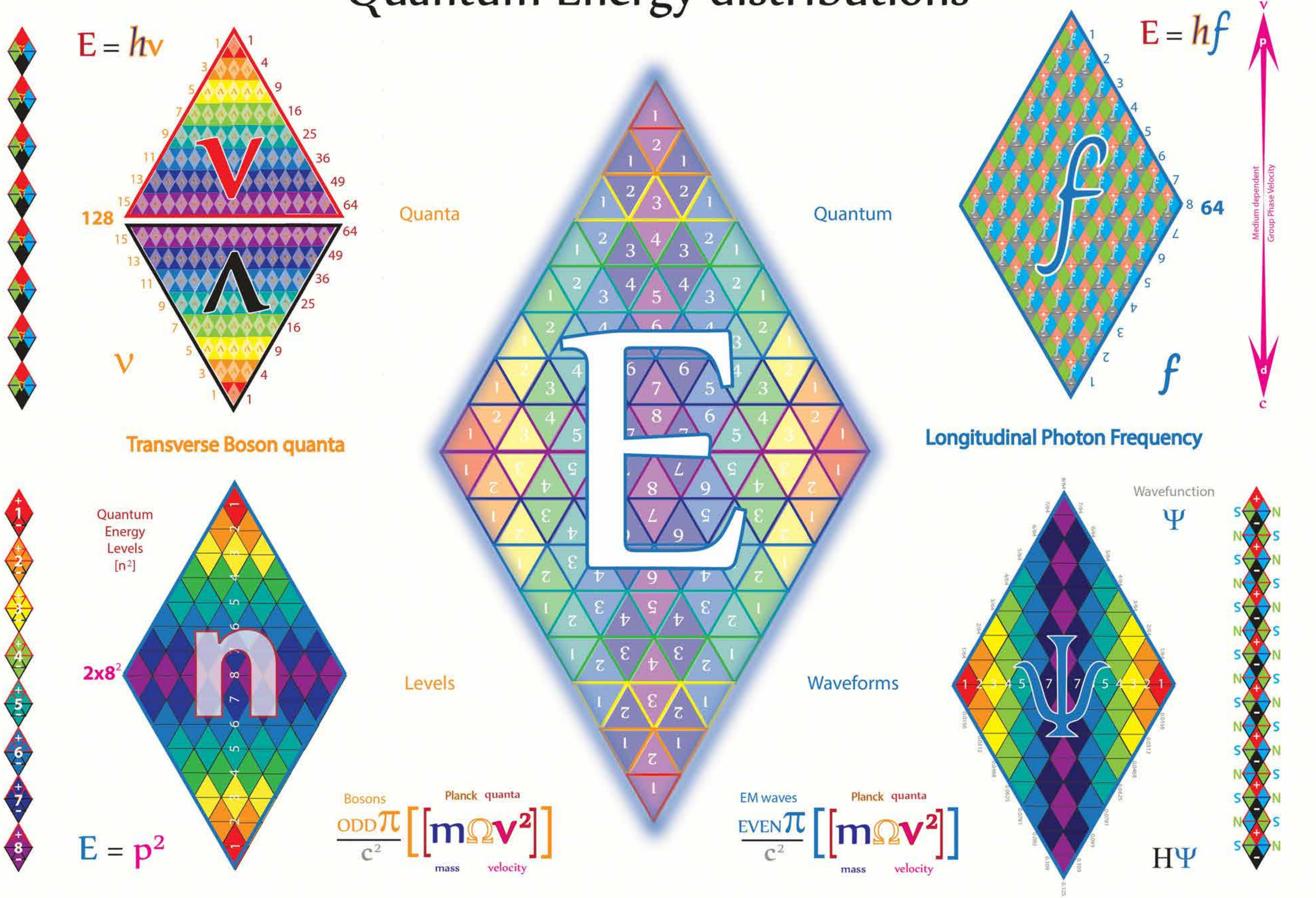

1
3
5
7
9
11
13
15
128
4
9
16
25
36
49
64
ν
Λ
f
1
2
3
4
5
6
7
8
E
n
2x8²
Ψ
1 2 3 4 5 7
7 5 4 3 2 1
S
N
p
d
v
c
Medium dependent
Group Phase Velocity

$E = h\nu$

ν

Quanta

Transverse Boson quanta

$E = hf$

64

f

Quantum

Longitudinal Photon Frequency

Quantum Energy Levels [n²]

Levels

$E = p^2$

Bosons

Planck quanta

$$\frac{\text{ODD}\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

Wavefunction

Ψ

Waveforms

EM waves

Planck quanta

$$\frac{\text{EVEN}\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

$H\Psi$

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Normal Distributions

The Gaussian distribution sometimes informally called the bell curve.

Pierre de Fermat

Pierre de Fermat is given credit for early developments that led to infinitesimal calculus.

$$\frac{1}{\sqrt{2\pi\sigma^2}}\, e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

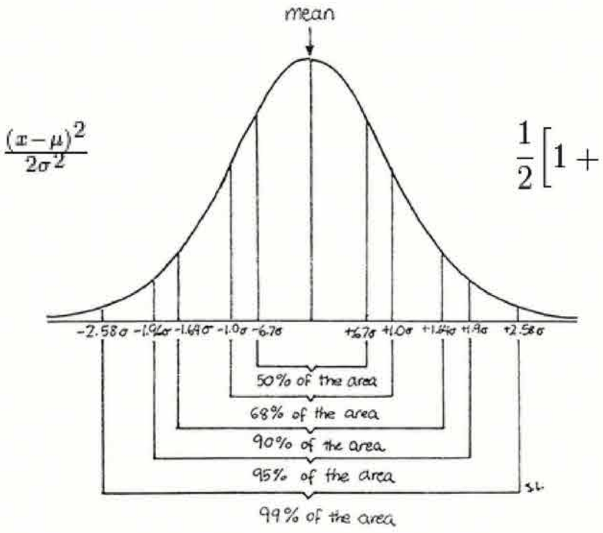
mean
-2.58σ
-1.96σ
-1.69σ
-1.0σ
-.67σ
+.67σ
+1.0σ
+1.69σ
+1.9σ
+2.58σ
50% of the area
68% of the area
90% of the area
95% of the area
99% of the area
S.L.

$$\frac{1}{2}\left[1+\operatorname{erf}\left(\frac{x-\mu}{\sqrt{2\sigma^2}}\right)\right]$$

Leonhard Euler

Leonhard Euler developed a formula which links complex exponentiation with trigonometric functions

A bell shaped curve defines the standard normal distribution, in which the probability of observing a point is greatest near the average, and declines rapidly as one moves away from the mean.

all ODD numbers are

$$a^2 - b^2 = [a-b].[a+b]$$

the difference of two squares

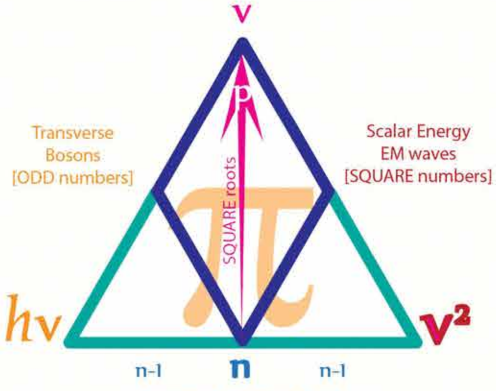
v
p
SQUARE roots
Transverse Bosons [ODD numbers]
Scalar Energy EM waves [SQUARE numbers]
hv
v²
n-1
n
n-1

[normal distribution]

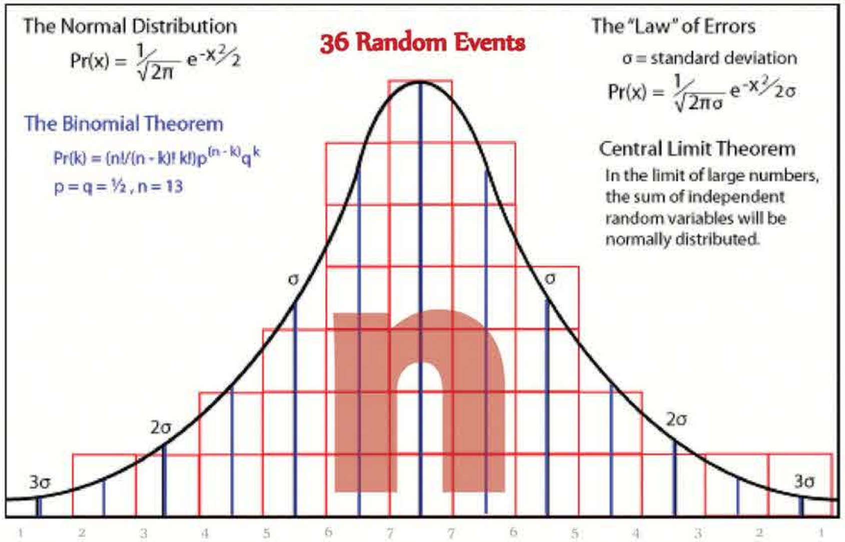

The Normal Distribution

$\Pr(x) = \frac{1}{\sqrt{2\pi}}\, e^{-x^2/2}$

The Binomial Theorem

$\Pr(k) = (n!/(n-k)!\,k!)\,p^{(n-k)}q^k$

$p = q = ½,\ n = 13$

The "Law" of Errors

σ = standard deviation

$\Pr(x) = \frac{1}{\sqrt{2\pi\sigma}}\, e^{-x^2/2\sigma}$

Central Limit Theorem

In the limit of large numbers, the sum of independent random variables will be normally distributed.

$$e^{i\pi} = -1$$

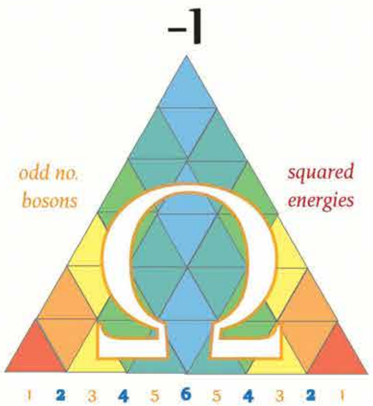
-1
odd no. bosons
squared energies
Ω
1 2 3 4 5 6 5 4 3 2 1

longitudinal photon distributions

In probability theory, the normal (or Gaussian) distribution is a continuous probability distribution that has a bell-shaped probability density function, known as the Gaussian function

Fundamental theorem of Energy momenta

A nth level scalar energy momenta waveform has exactly n linear momentum in unit circle co-ordinate systems
(with Longitudinal and Transverse equilateral Planck waveforms being orthogonal to each other)

scalar energies

E

mv^2

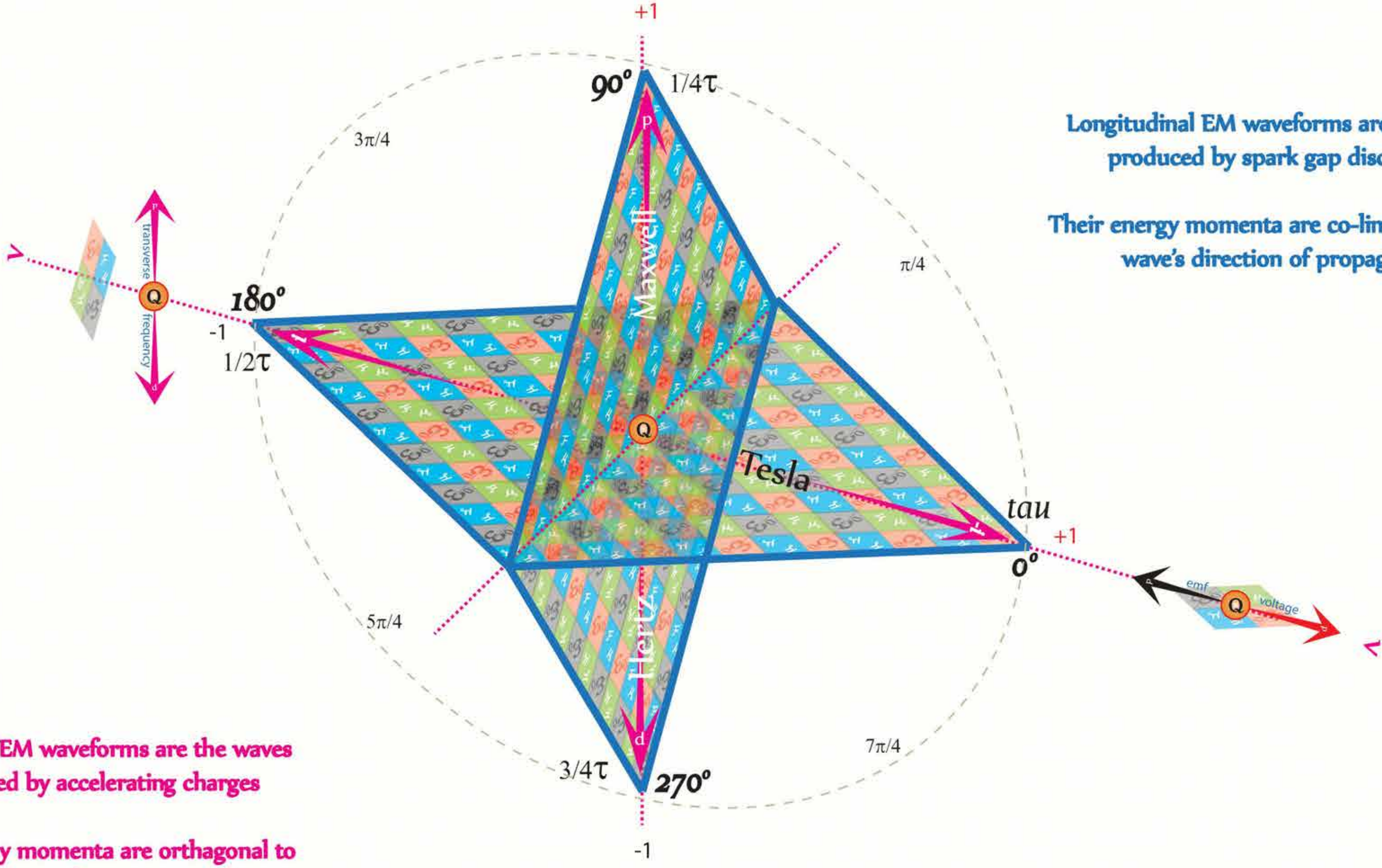
+1
90°
1/4τ
3π/4
π/4
transverse
Q
frequency
180°
-1
1/2τ
Maxwell
Q
Tesla
tau
+1
0°
emf
Q
voltage
5π/4
Hertz
7π/4
3/4τ
270°
-1

Longitudinal EM waveforms are the waves produced by spark gap discharges

Their energy momenta are co-linear with the wave's direction of propagation

Transverse EM waveforms are the waves produced by accelerating charges

Their energy momenta are orthogonal to the direction of wave propagation

p

mv

linear momentum

[Mathematics] *i or j* *[Electrical theory]*

square root of negative one

Velocity and Time dependent EM fields

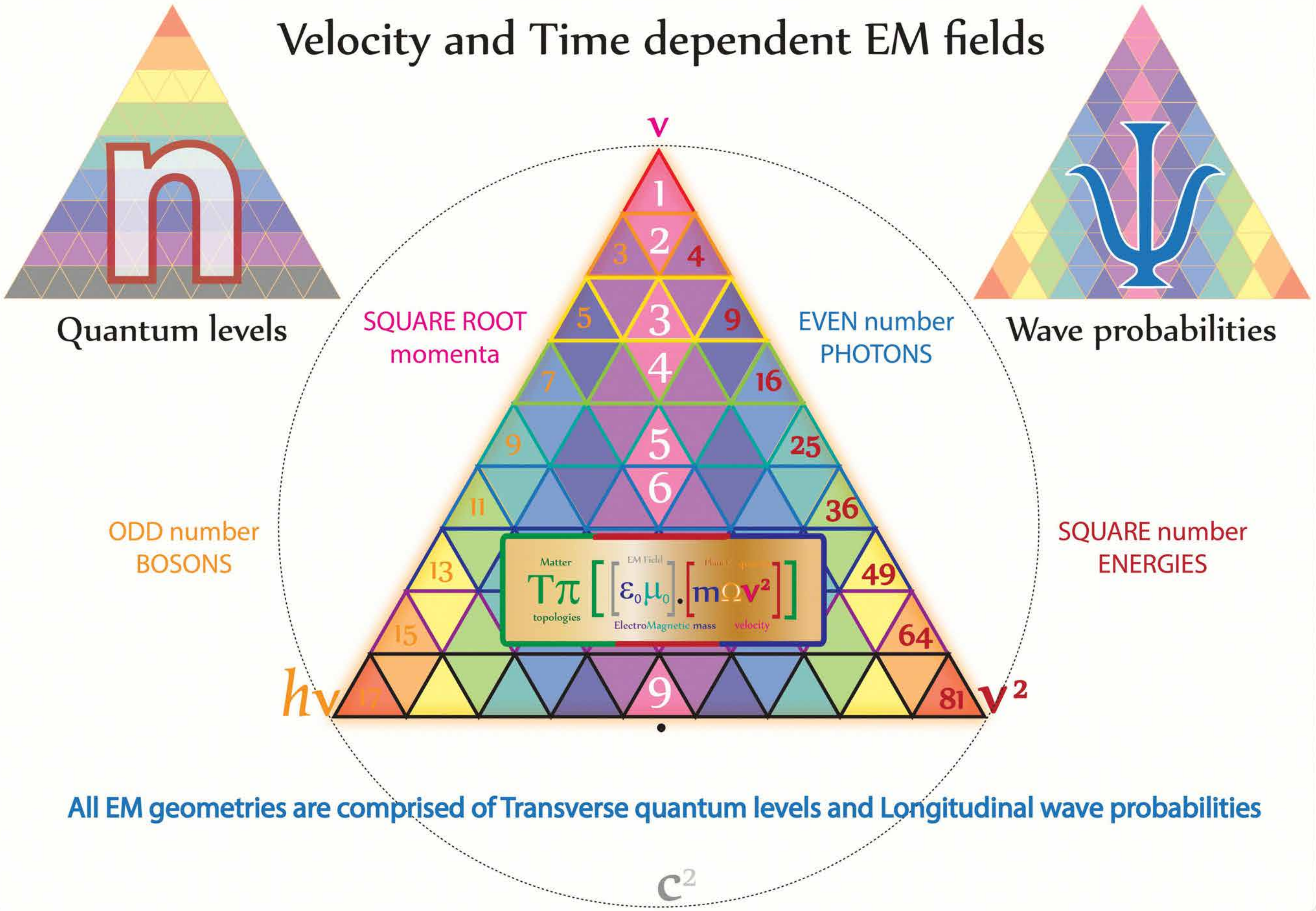
n
Quantum levels
Ψ
Wave probabilities
v
1
2
3
4
3
5
9
4
7
16
5
9
25
6
11
36
13
49
15
64
9
17
81
hv
v²
c²
SQUARE ROOT
momenta
EVEN number
PHOTONS
ODD number
BOSONS
SQUARE number
ENERGIES
Matter
Tπ [[ε₀μ₀].[mΩv²]]
topologies
EM Field
Planck quanta
ElectroMagnetic mass
velocity

All EM geometries are comprised of Transverse quantum levels and Longitudinal wave probabilities

Matrices are a key tool in linear algebra. One use of matrices is to represent linear transformations, which are higher-dimensional analogs of linear functions of the form f(x) = cx, where c is a constant; matrix multiplication corresponds to composition of linear transformations.

Matrices

Further developing equilateral Matrices and tensor mathematics to reflect the 2D geometry of EM , KEM and GEM quantum fields, along with the geometric quantisation of mass-energiy momenta and their energy distributions allows for field interactions to be accurately visualised and modelled

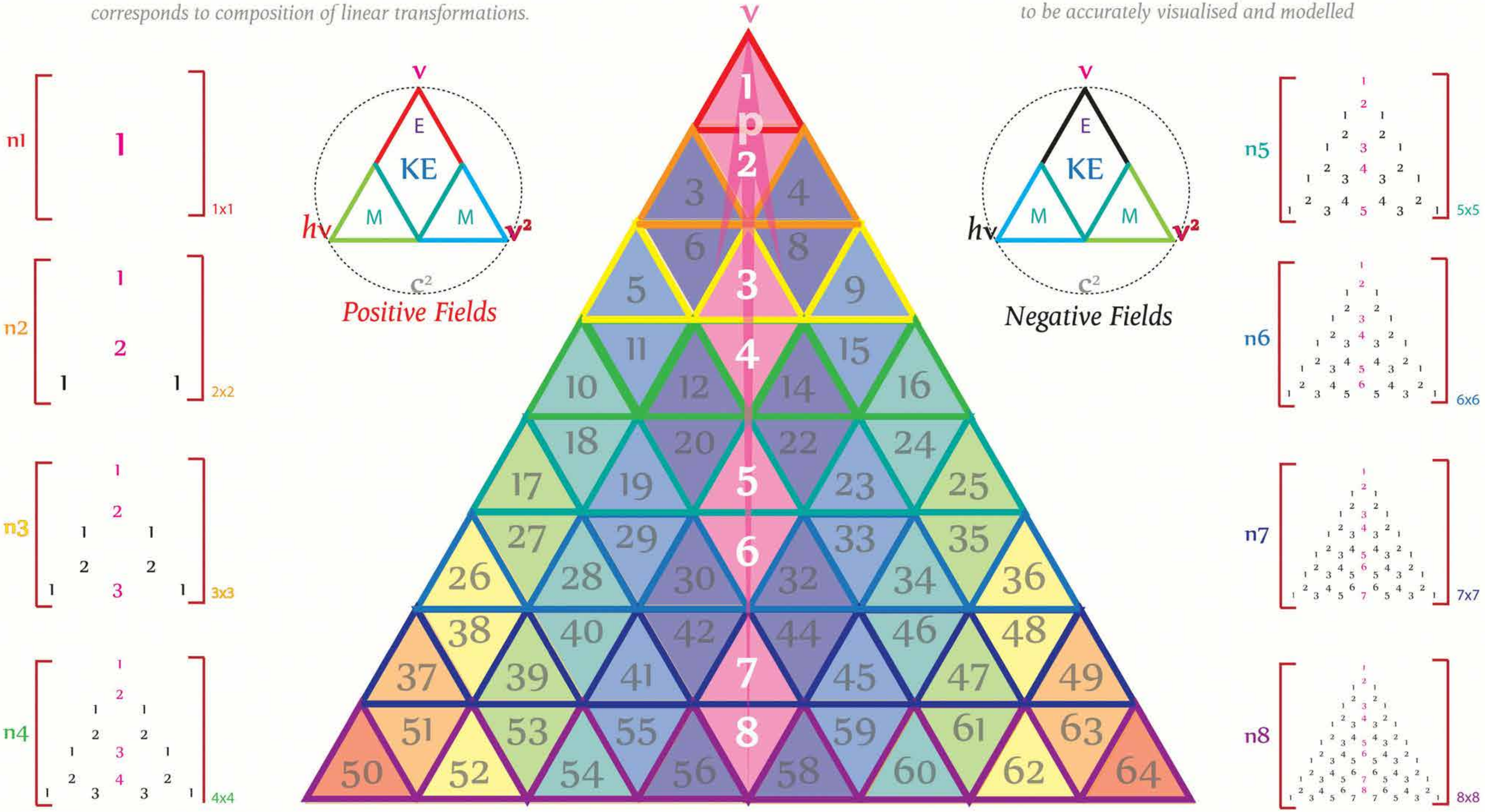
n1
1
1x1
n2
1
2
1 1
2x2
n3
1
2
1 1
2 2
1 3 1
3x3
n4
1
2
1 1
2 2
1 3 1
2 4 2
1 3 3 1
4x4
v
E
KE
M M
hv
v²
c²
Positive Fields
v
1
p
2
3 4
5 6 3 8 9
10 11 4 12 14 15 16
17 18 19 20 5 22 23 24 25
26 27 28 29 30 6 32 33 34 35 36
37 38 39 40 41 42 7 44 45 46 47 48 49
50 51 52 53 54 55 56 8 58 59 60 61 62 63 64
v
E
KE
M M
hv
v²
c²
Negative Fields
n5
5x5
n6
6x6
n7
7x7
n8
8x8

Tensors are geometric entities introduced into mathematics and physics to extend the notion of scalars, geometric vectors, and matrices to increasingly higher orders.

Modifying Square matrices to reflect the equialteral geometries of Tetryonic fields allows for the accurate geometric modelling of all Scalar & Vector fields along with their varied intrinsic quantum energies and physical properties

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Energy momenta Tensors

momenta (a property of Energy) is converative

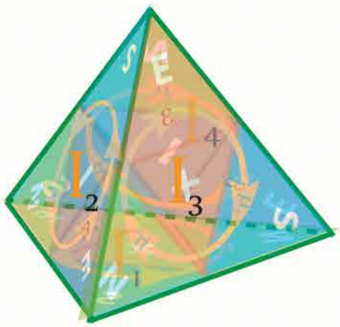

$p_M \longrightarrow (E, p1, p2, p3, p4).$

All standing-wave Matter topologies can be modelled using its Tetryonic charge energy momenta Tensors

with an additional Kinetic EM energy-momenta tensor required for Matter in motion

$p_{KEM} \longrightarrow (E, p5).$

Matter (a geometric property) is NOT conservative

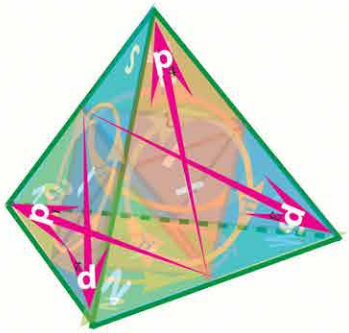

2D+1 [SR] mass-energy momenta can be folded into 3D+1 [GR] Matter that can be modelled using 4 Energy-momenta tensors

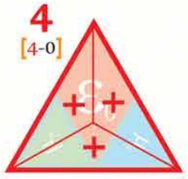

Positive standing-wave Matter

$$E = \sum_{\text{all fascia}} E$$

Energy of a massive particle is the total of all Planck quanta (compton frequency) in a 3D geometry

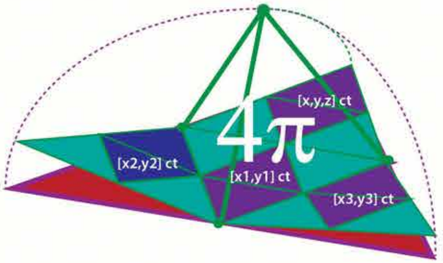

$$\vec{p} = \sum_{\text{all fascia}} \vec{p}$$

Total Momentum is the total of all quanta linear Momenta in a 3D particle

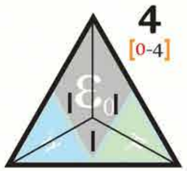

Negative standing-wave Matter

Relativistic Matter in motion

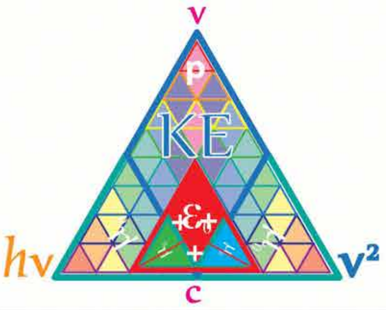

$$I = \sum_{\text{all fascia}} I$$

Inertial mass is the total of all inertia in a 3D particle

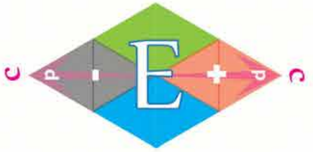

Photons have null energy-momentum tensors

Note that both 2D mass-energies [Special Relativity] and 3D Matter [General Relativity] have distinct Energy momenta

It is the 3D Tetrahedral topologies that provides a definative basis for Matter

Relativistic Matter in motion

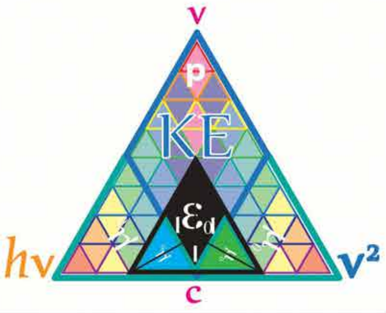

Tetryonic Energy momenta tensors should not be confused with Four vector tensors which map energy-momenta vectors in 3D spatial[cartesian] co-ordinate systems

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Relativistic Lorentz correction factor

The Lorentz factor or Lorentz term is an expression which appears in several equations in special relativity
It is often incorrectly graphed [as pictured to the right] as an increasing function of velocity approaching but never reaching c

**'c' is the maximum velocity acheivable through the electrical acceleration of particles
is NOT the maximum velocity possible for Matter in motion**

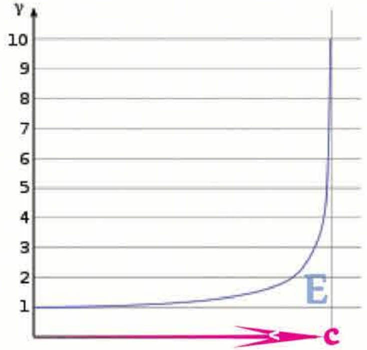

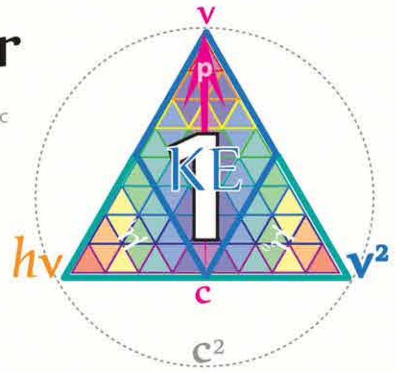

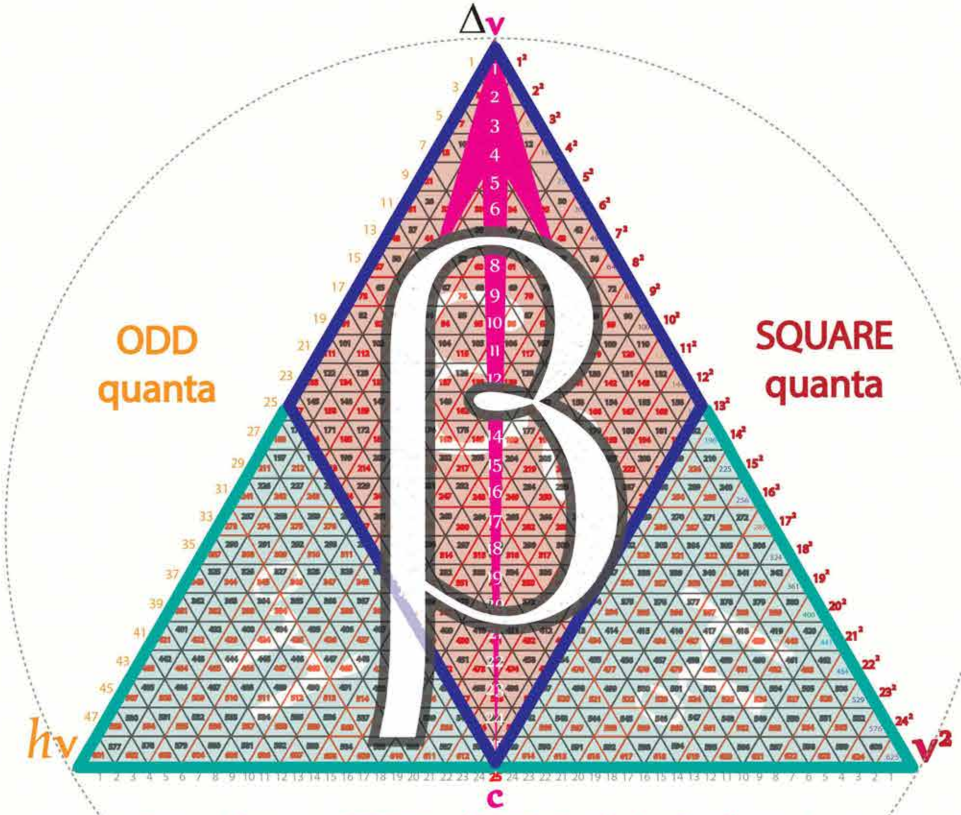

Linear correction factor

$$\beta = \left[\frac{v}{c}\right]$$

Scalar correction factor

$$\beta^2 = \left[\frac{v^2}{c^2}\right]$$

*Lorentz factors are LINEAR and SCALAR velocity related corrections
to the relativistic mass-energy momenta content of any
physical system accelerated by EM Forces*

$\frac{\Delta\gamma}{c^2}$ Wavelength contraction

Time Dilation $\frac{\Delta\Omega}{c^2}$

$\frac{\Delta mv}{c^2}$ Relativistic momentum

$\frac{\Gamma}{c^2}$

Lorentz corrections

Relativistic mass-energy $\frac{\Delta h\nu}{c^2}$

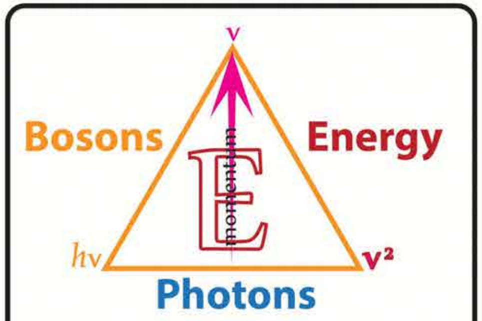
v
Bosons
Energy
E
momentum
hv
v²
Photons

form the basis for all charged energy geometries and their associated quanta distributions

Equilateral energies

Any measurements of mass without a Space-Time co-ordinate system are measurements of Energy

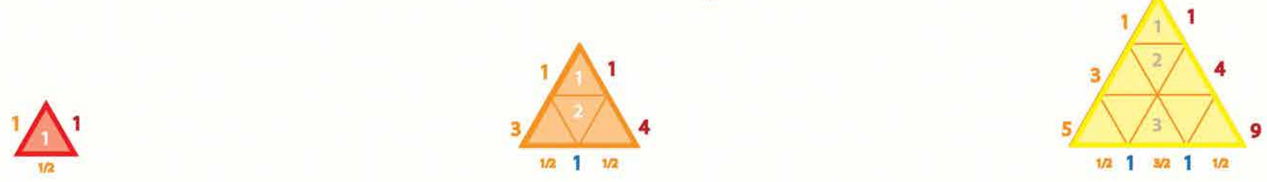
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1/2
1 3 | 1 4 | 1 2
1/2 1 1/2
1 3 5 | 1 4 9 | 1 2 3
1/2 1 3/2 1 1/2

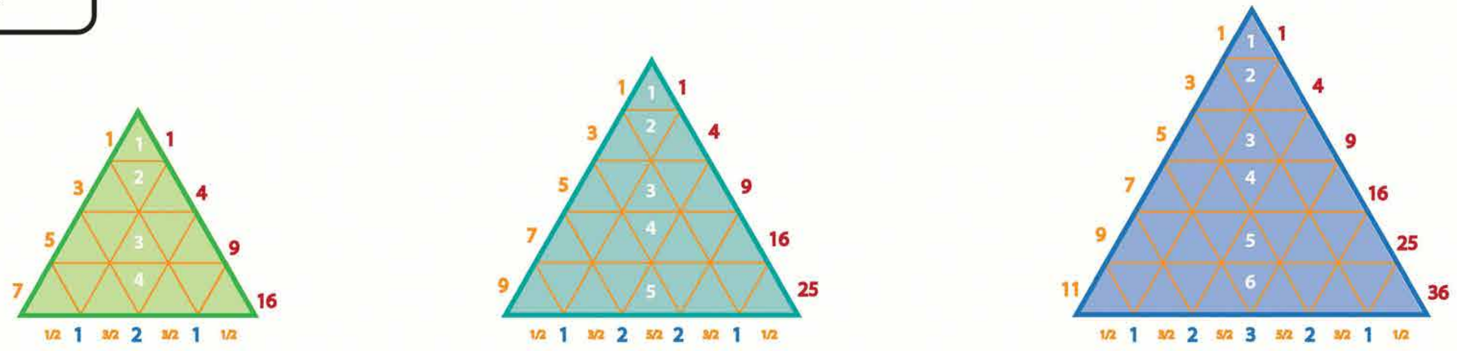
1 3 5 7 | 1 4 9 16 | 1 2 3 4
1/2 1 3/2 2 3/2 1 1/2
1 3 5 7 9 | 1 4 9 16 25 | 1 2 3 4 5
1/2 1 3/2 2 5/2 2 3/2 1 1/2
1 3 5 7 9 11 | 1 4 9 16 25 36 | 1 2 3 4 5 6
1/2 1 3/2 2 5/2 3 5/2 2 3/2 1 1/2

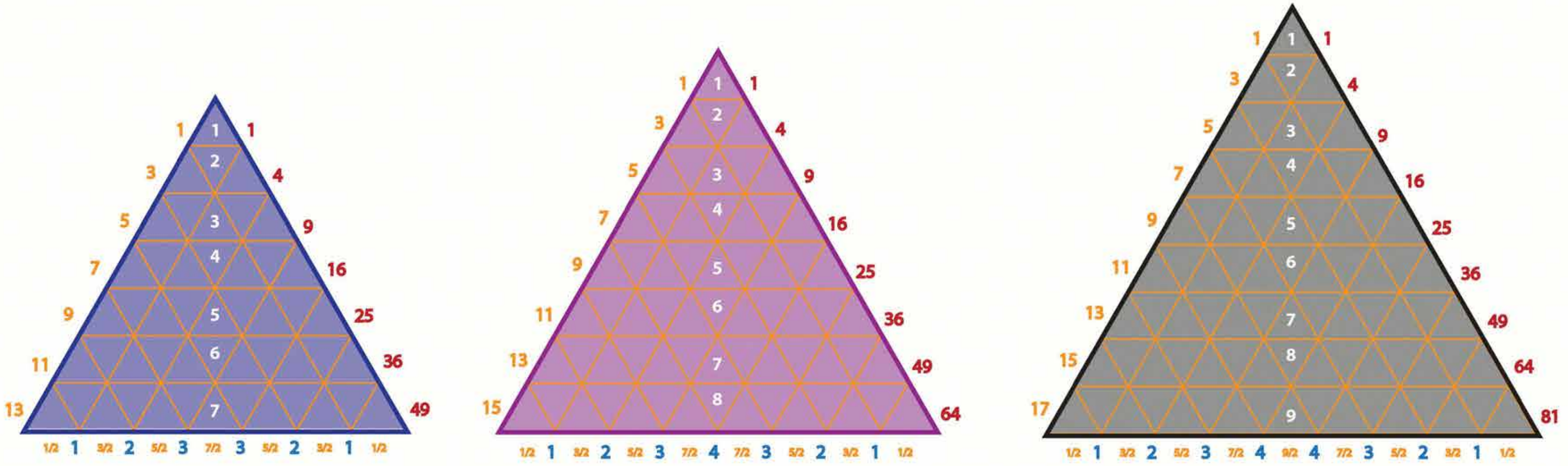
1 3 5 7 9 11 13 | 1 4 9 16 25 36 49 | 1 2 3 4 5 6 7
1/2 1 3/2 2 5/2 3 7/2 3 5/2 2 3/2 1 1/2
1 3 5 7 9 11 13 15 | 1 4 9 16 25 36 49 64 | 1 2 3 4 5 6 7 8
1/2 1 3/2 2 5/2 3 7/2 4 7/2 3 5/2 2 3/2 1 1/2
1 3 5 7 9 11 13 15 17 | 1 4 9 16 25 36 49 64 81 | 1 2 3 4 5 6 7 8 9
1/2 1 3/2 2 5/2 3 7/2 4 9/2 4 7/2 3 5/2 2 3/2 1 1/2

Electromagnetic mass

2D mass-energy is the surface integral of 3D Matter

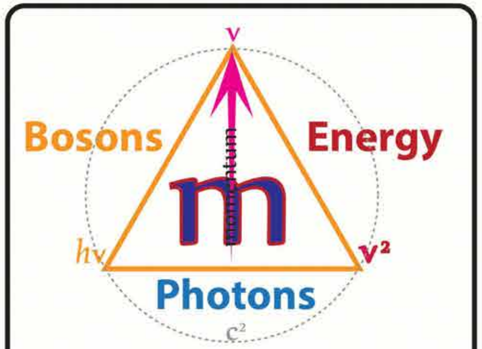
v
Bosons
Energy
m
hv
v²
Photons
c²

Time specific measurements of equilateral ENERGY momenta geometries forms the basis for EM mass

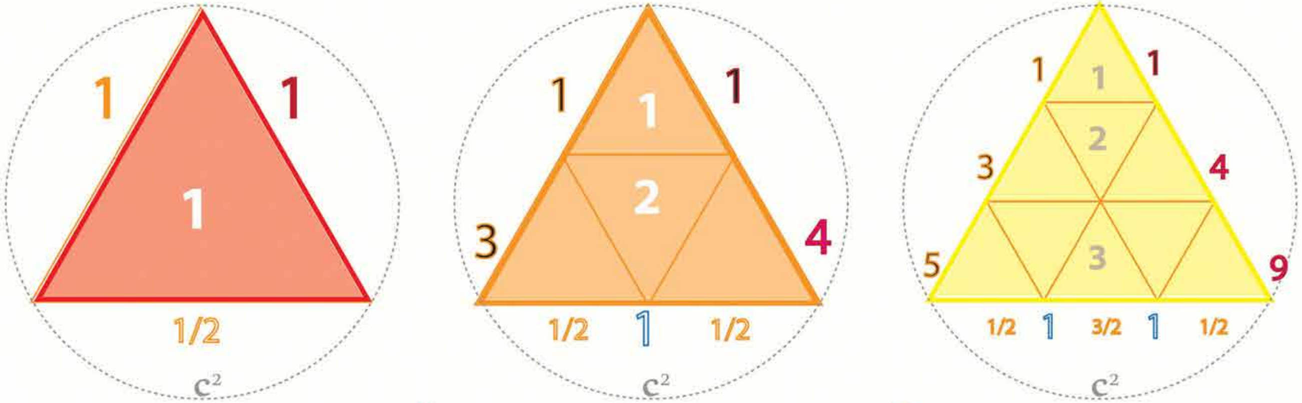
1
1
1
1/2
c²
1
1
1
2
3
4
1/2
1
1/2
c²
1
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1
2
3
4
5
3
9
1/2
1
3/2
1
1/2
c²

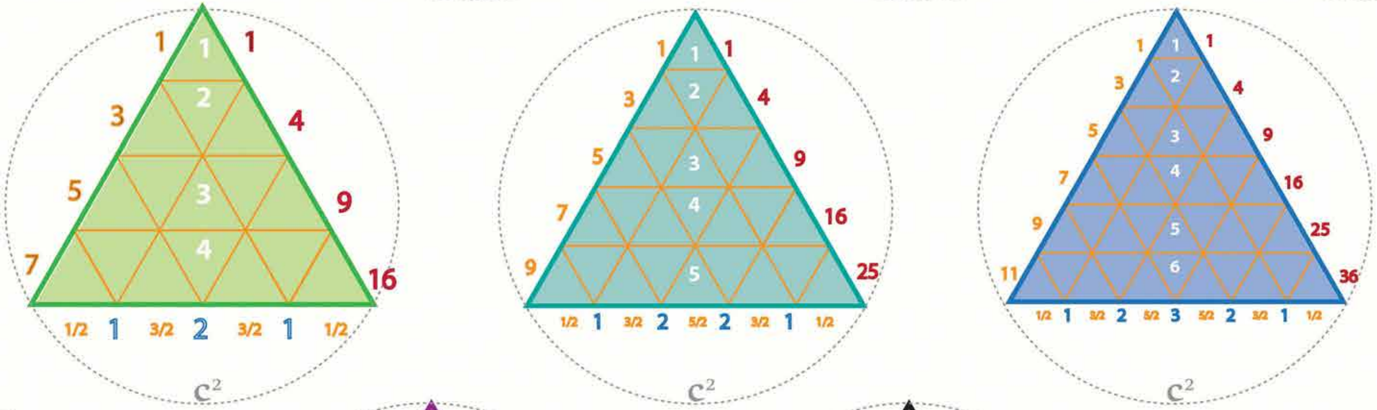
1
3
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9
16
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1/2
1
3/2
2
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1/2
c²
1
3
5
7
9
1
4
9
16
25
1
2
3
4
5
1/2
1
3/2
2
5/2
2
3/2
1
1/2
c²
1
3
5
7
9
11
1
4
9
16
25
36
1
2
3
4
5
6
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1
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2
5/2
3
5/2
2
3/2
1
1/2
c²

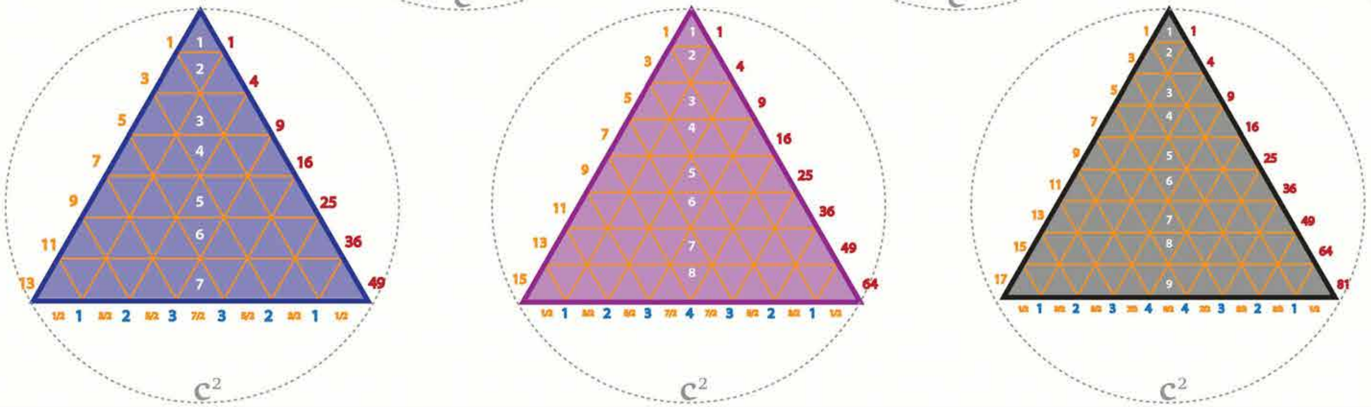
1
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c²
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3
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7
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11
13
15
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4
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36
49
64
1
2
3
4
5
6
7
8
c²
1
3
5
7
9
11
13
15
17
1
4
9
16
25
36
49
64
81
1
2
3
4
5
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7
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9
c²

mass-less particles
is a physical misnomer

All measurements of energy
in spatial co-ordinate systems
are measurements of mass

Matter-less is the appropriate terminology

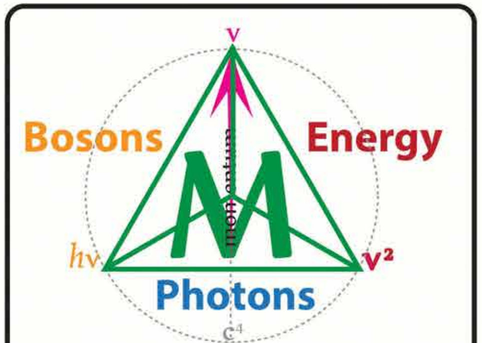
v
Bosons
Energy
M
momentum
hν
v²
Photons
c⁴

The equilateral mass-ENERGY content of 4nπ Tetrahedral standing-wave topologies forms the basis of Matter

Standing-wave Matter

Matter is a higher order 3D topology created by standing wave mass-energies

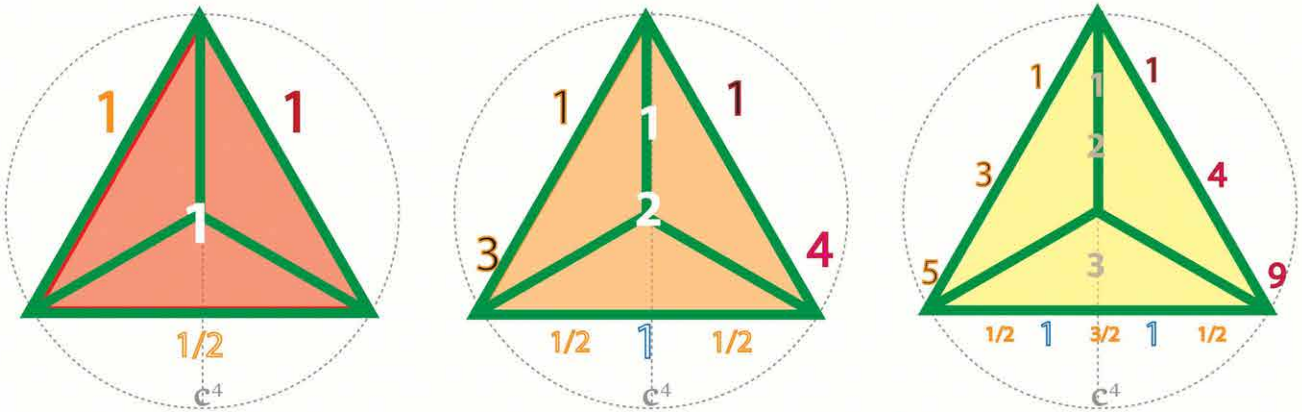
1
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1
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1/2
1
3/2
1
1/2
c⁴

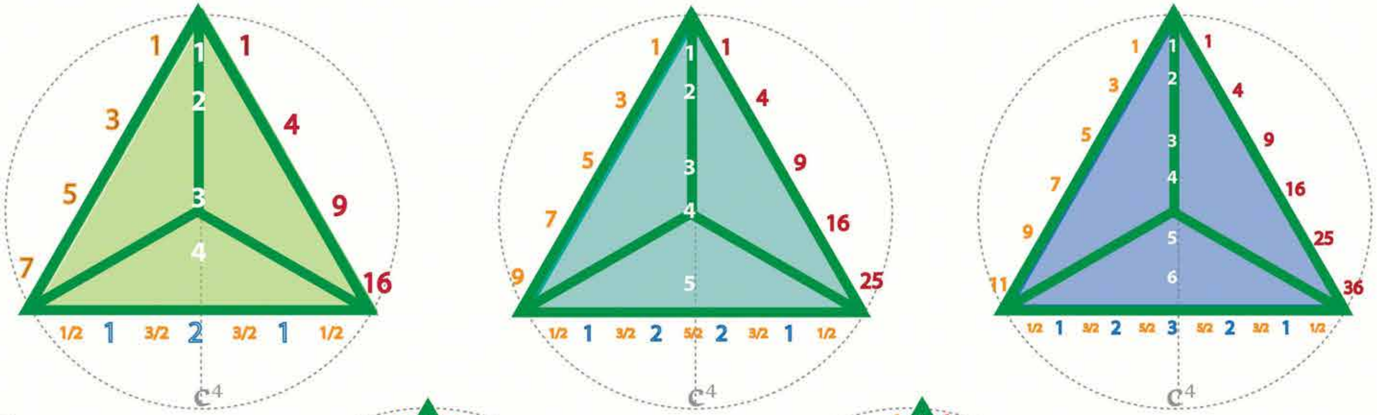
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1/2
c⁴
1
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9
7
16
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1
3/2
2
5/2
2
3/2
1
1/2
c⁴
1
1
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6
3
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7
16
9
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11
36
1/2
1
3/2
2
5/2
3
5/2
2
3/2
1
1/2
c⁴

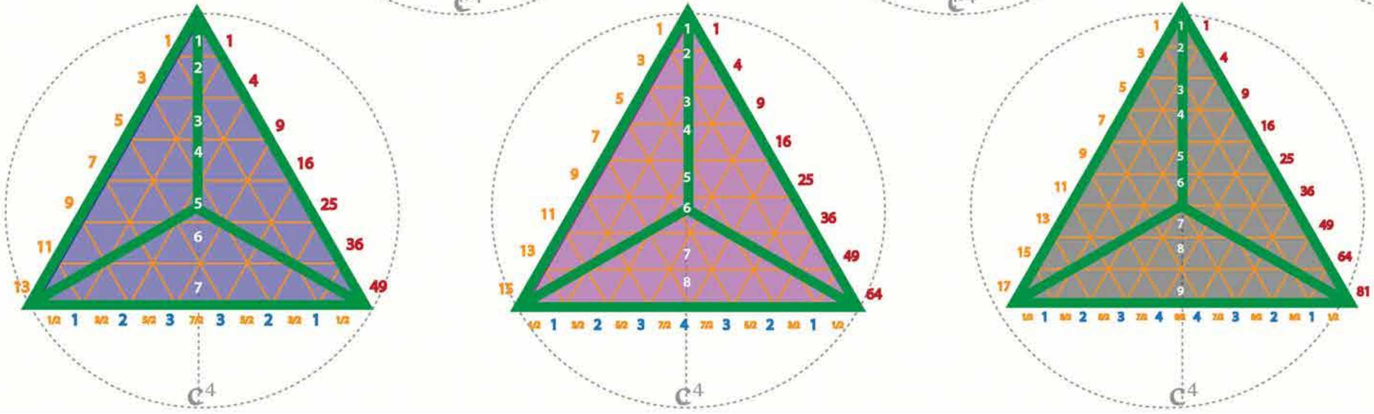
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7/2
3
5/2
2
3/2
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1/2
c⁴
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7/2
4
9/2
4
7/2
3
5/2
2
3/2
1
1/2
c⁴

Only
mass-ENERGIES contained in
the tetryonic fascia of
standing-wave topologies
contribute to weight

Periodic element nuclei

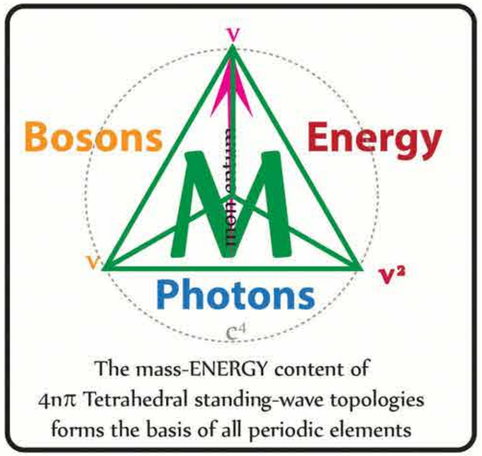
v
Bosons
Energy
momentum
M
v
v²
Photons
c4

The mass-ENERGY content of
4nπ Tetrahedral standing-wave topologies
forms the basis of all periodic elements

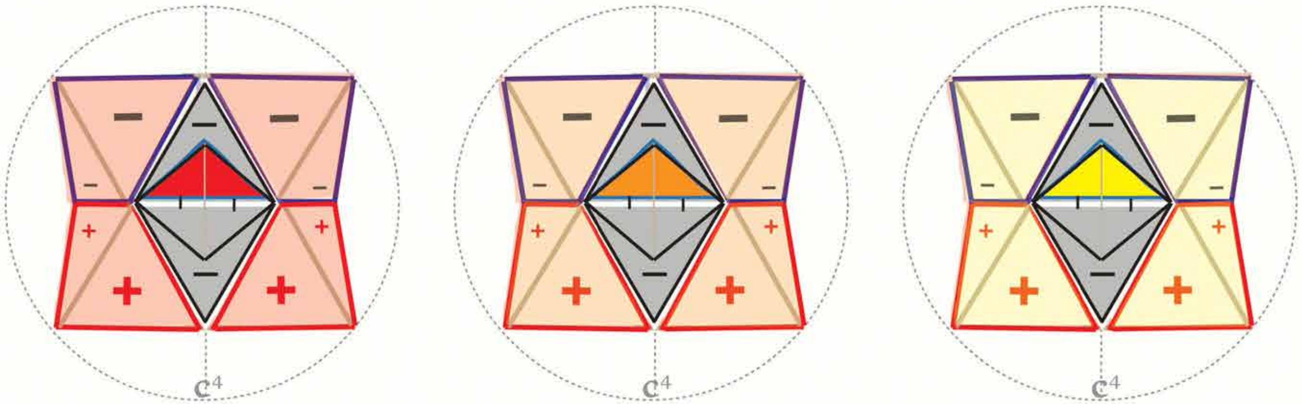
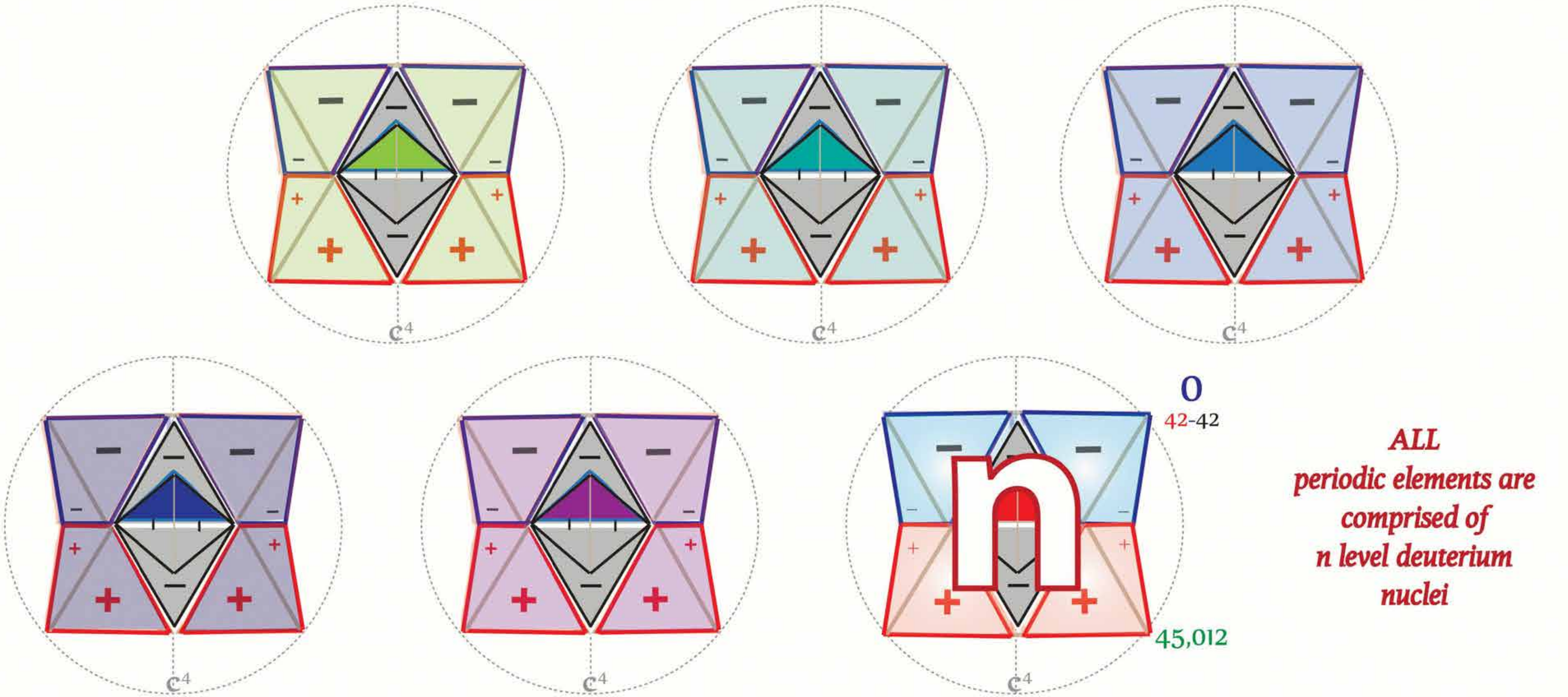
c4
0
42-42
n
45,012

ALL
periodic elements are
comprised of
n level deuterium
nuclei

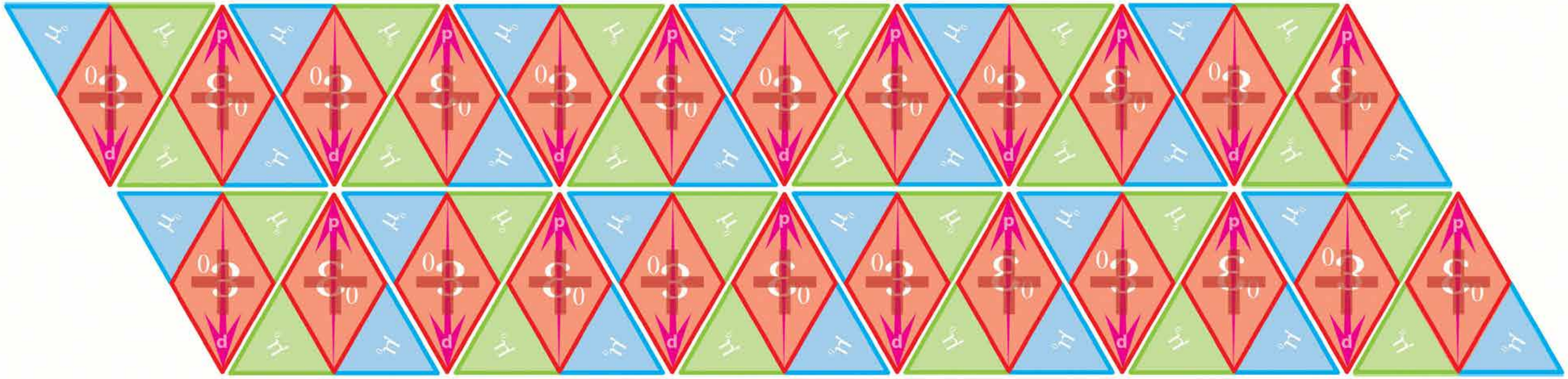

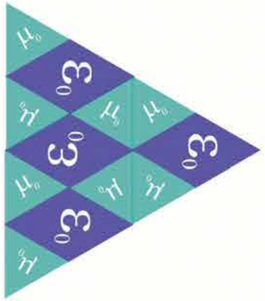

2D radiant EM mass-Energies

n1 - Charged Tetryon Templates

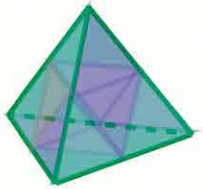

3D standing-wave Matter

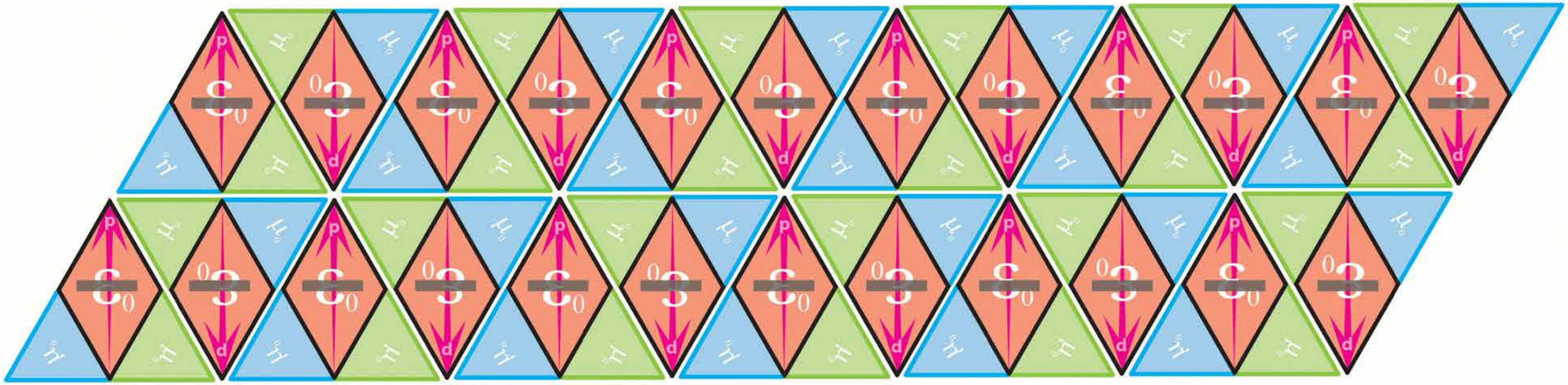

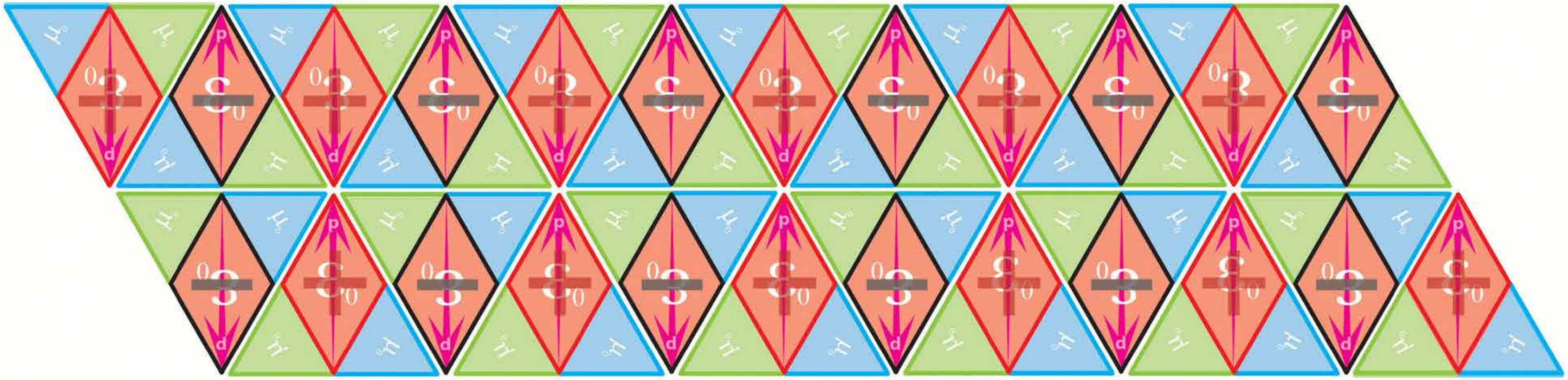

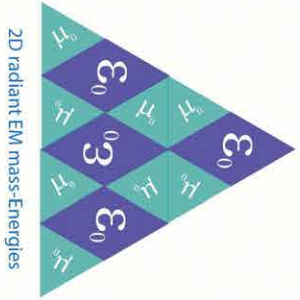

2D radiant EM mass-Energies
ε0
μ0

n1 - Neutral Tetryon Templates

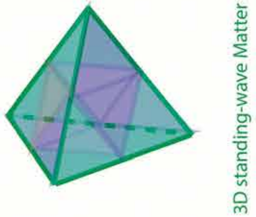

3D standing-wave Matter

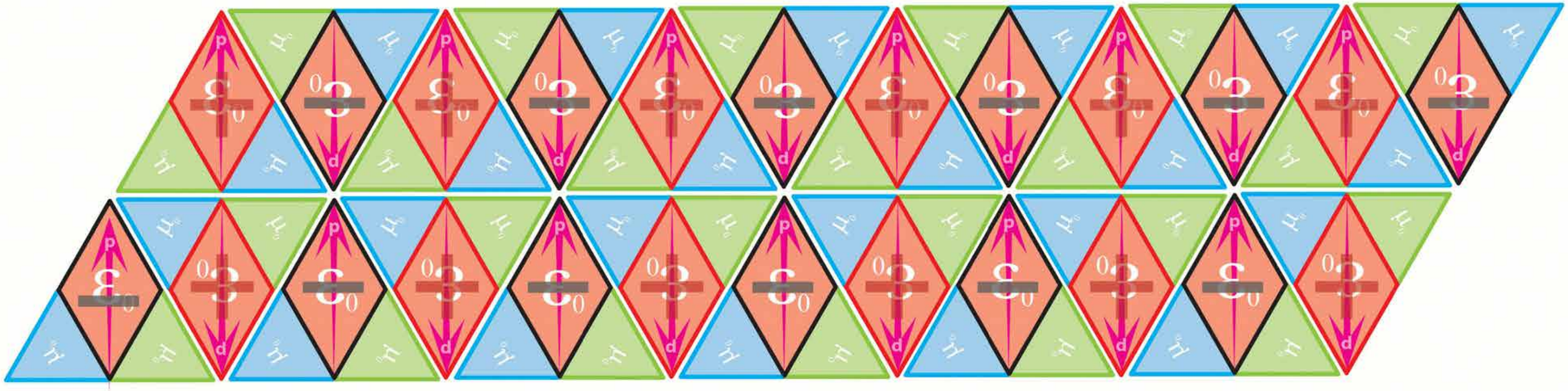

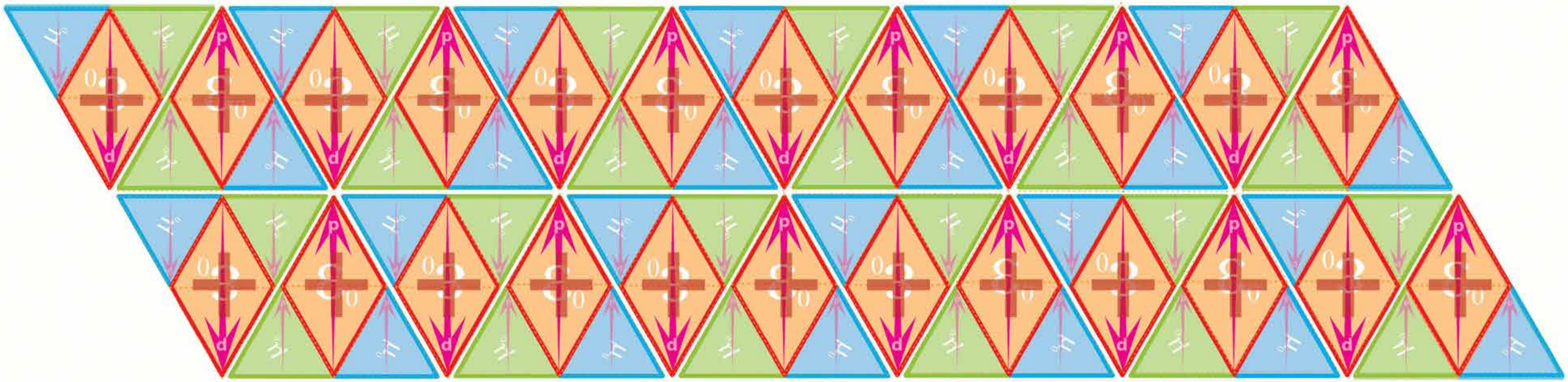

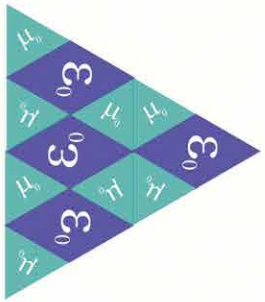

2D radiant EM mass-Energies

n2 - Charged Tetryon Templates

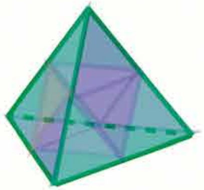

3D standing-wave Matter

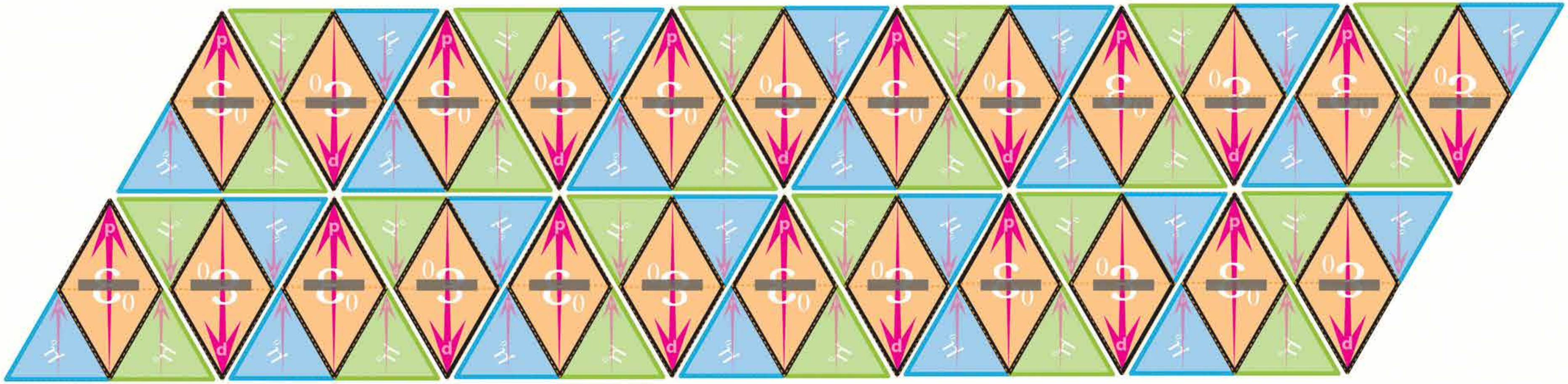

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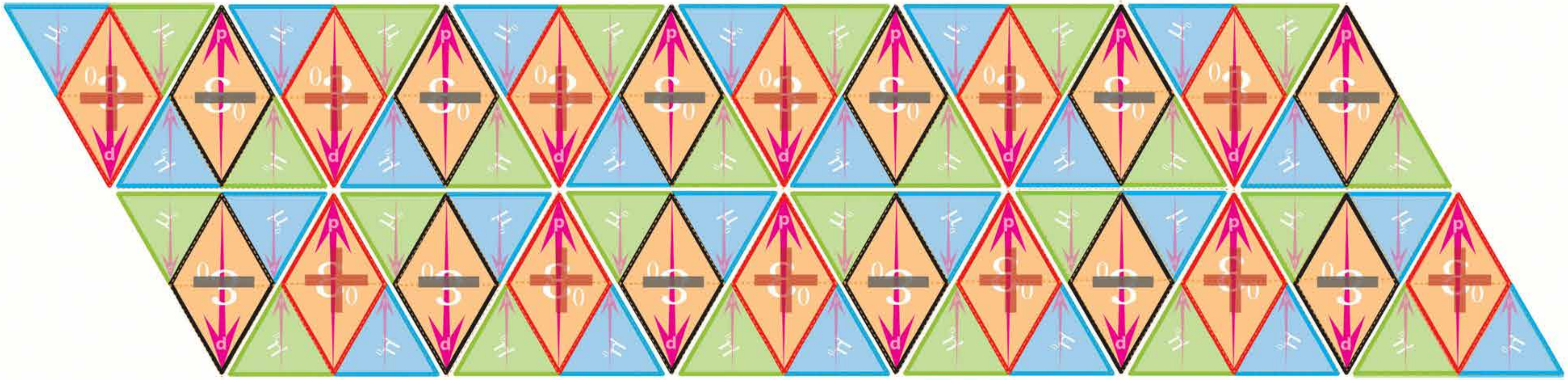

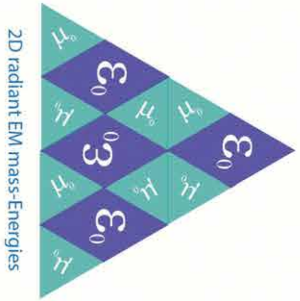
2D radiant EM mass-Energies
ε0
μ0

n2 - Neutral Tetryon Templates

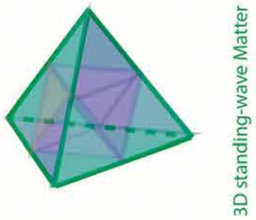
3D standing-wave Matter

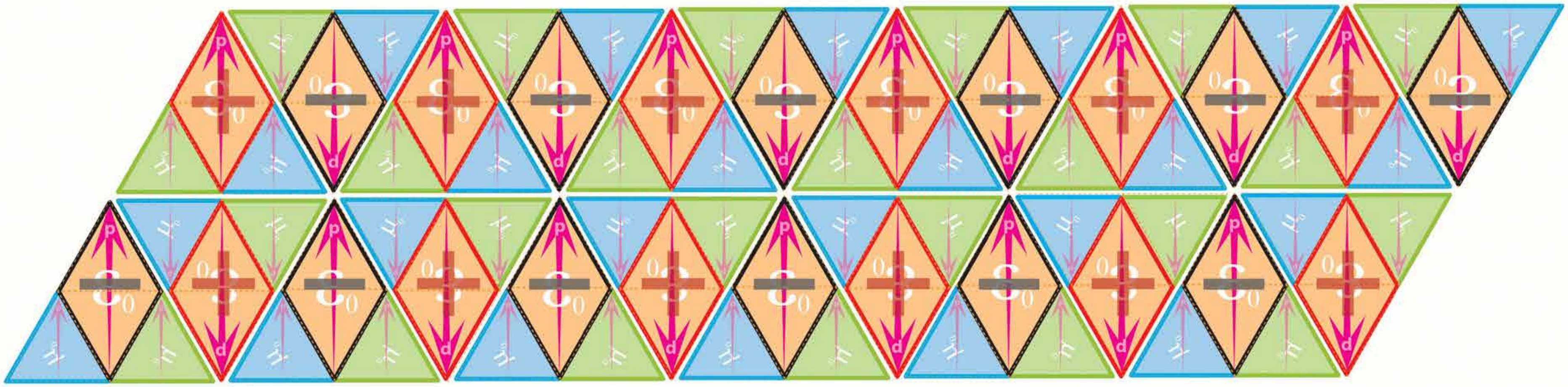

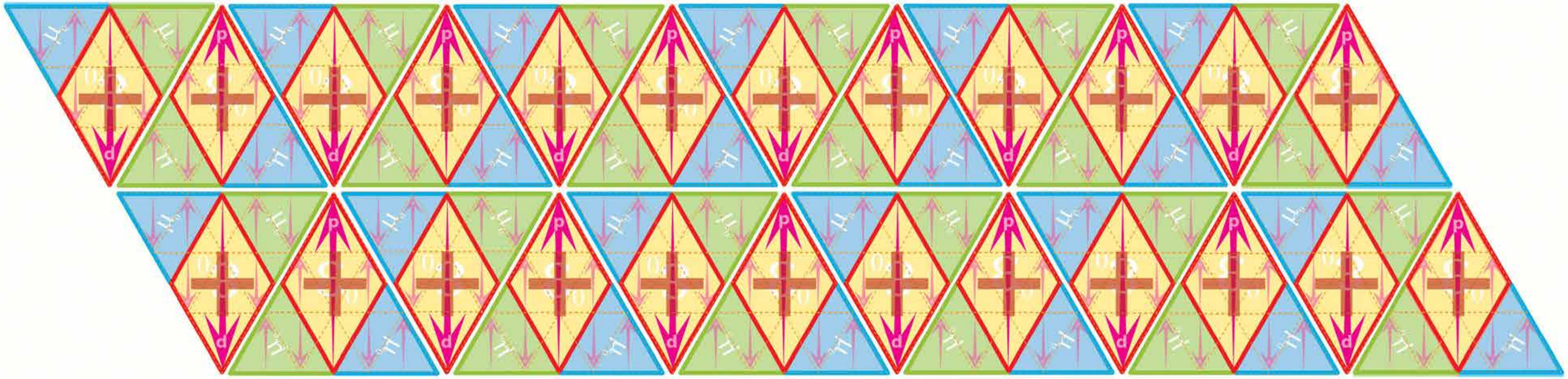
p
d
μ_0
ε_0

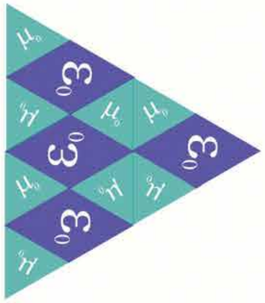

2D radiant EM mass-Energies

n3 - Charged Tetryon Templates

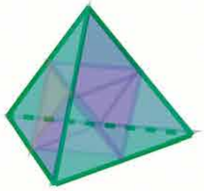

3D standing-wave Matter

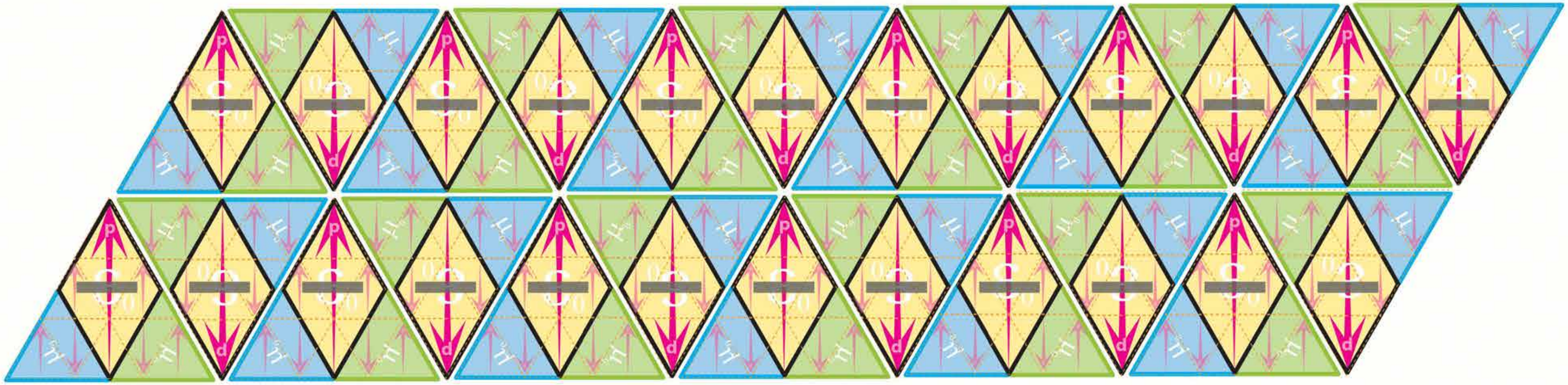
p
d
μ_0
ε_0

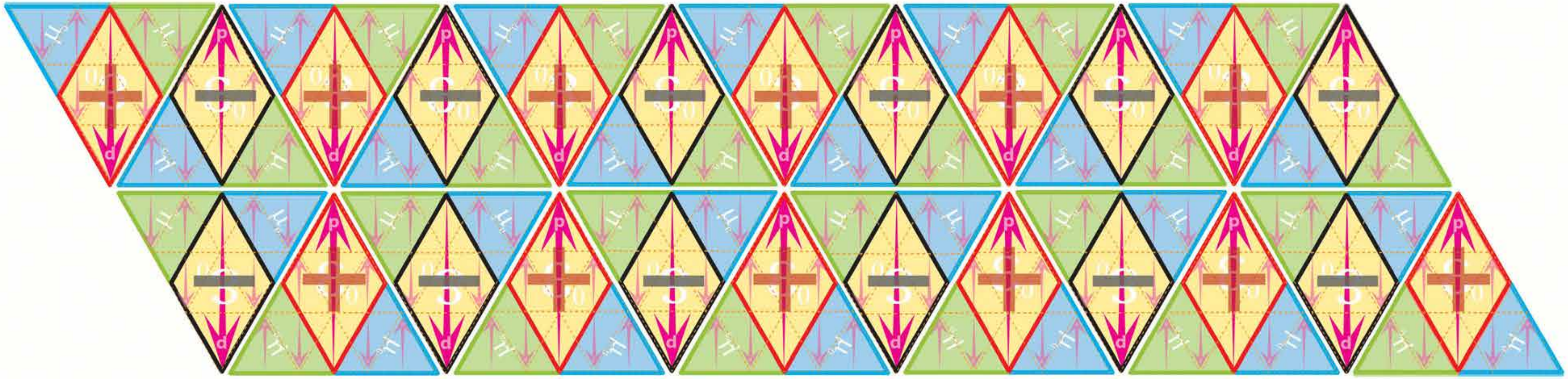

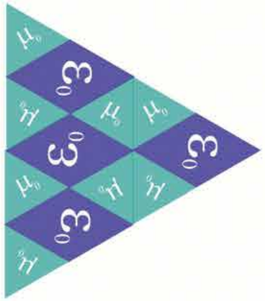
2D radiant EM mass-Energies
ε0
μ0

n3 - Neutral Tetryon Templates

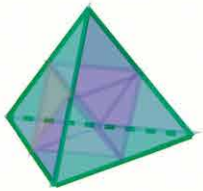
3D standing-wave Matter

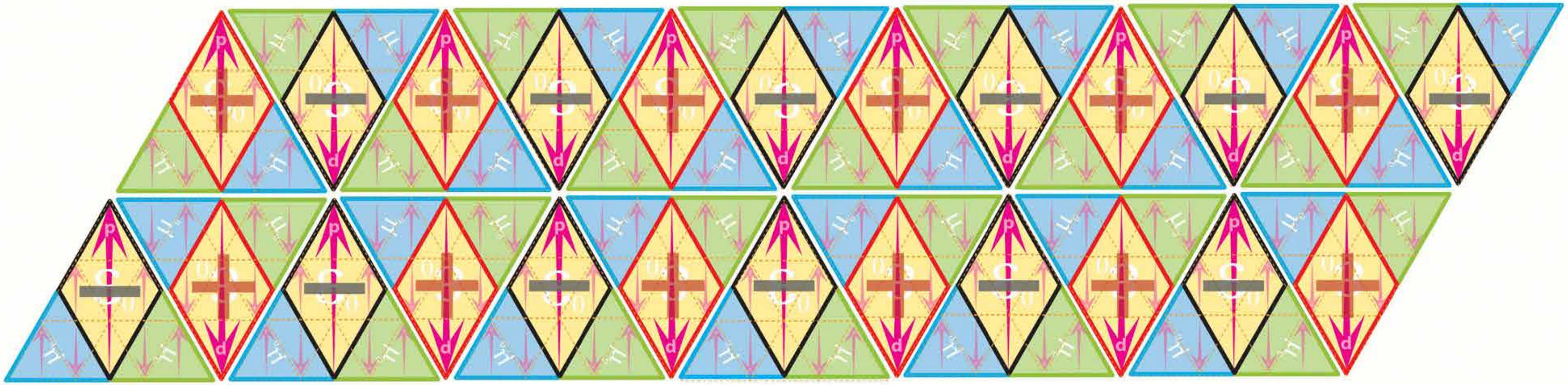

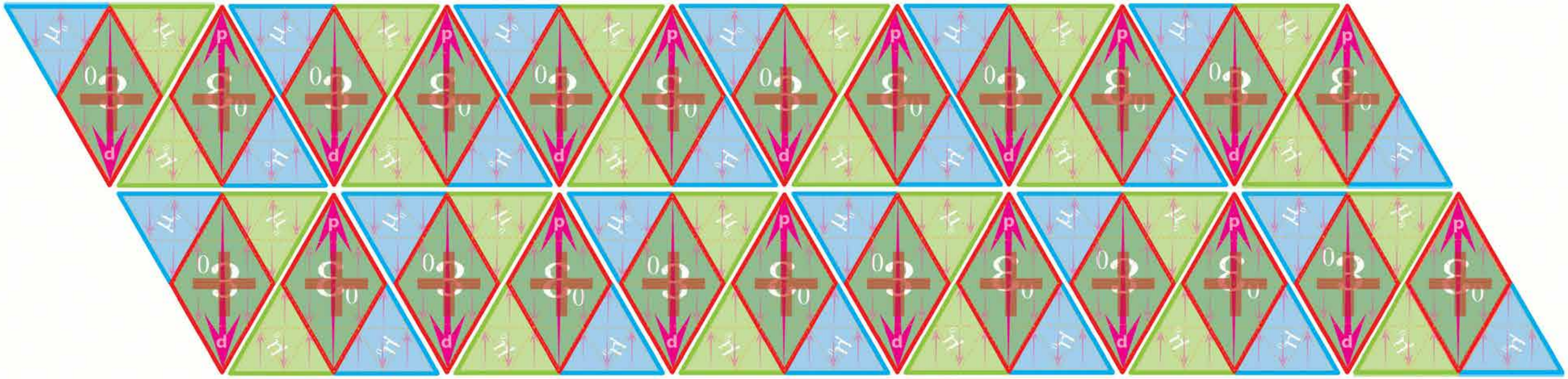

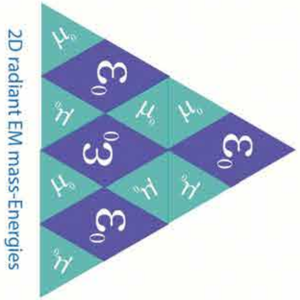

2D radiant EM mass-Energies

n4 - Charged Tetryon Templates

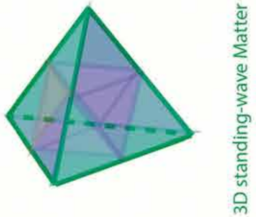

3D standing-wave Matter

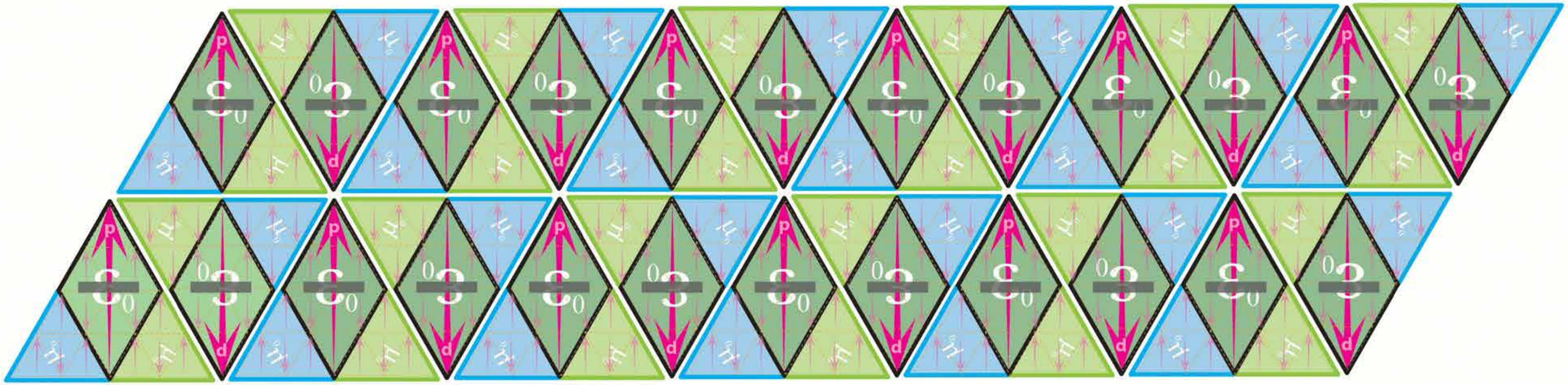

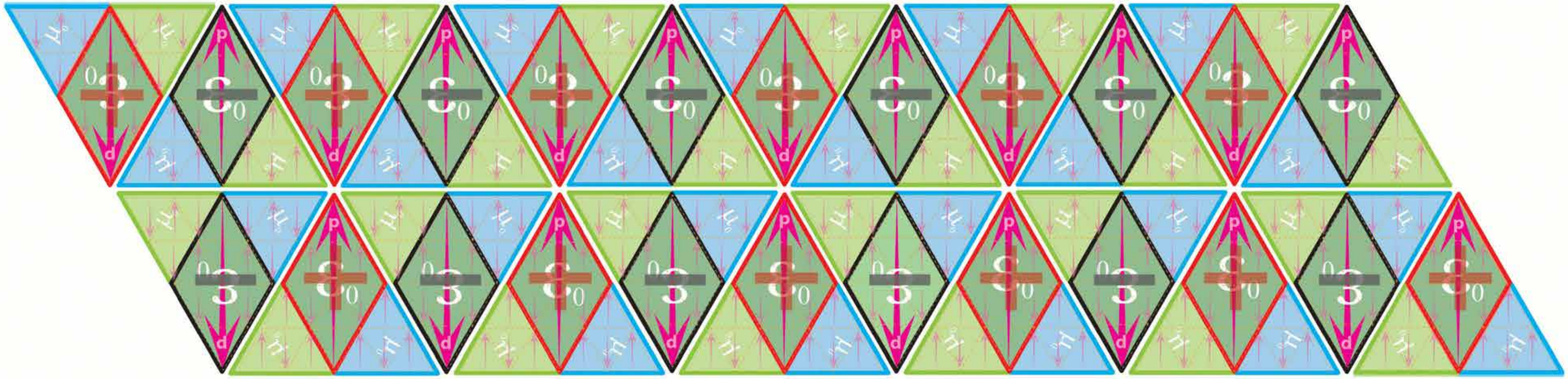
p
d
ε_0
μ_0

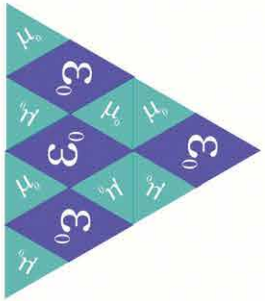
ε_0
μ_0

2D radiant EM mass-Energies

n4 - Neutral Tetryon Templates

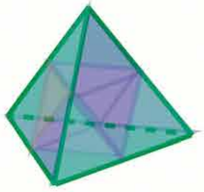

3D standing-wave Matter

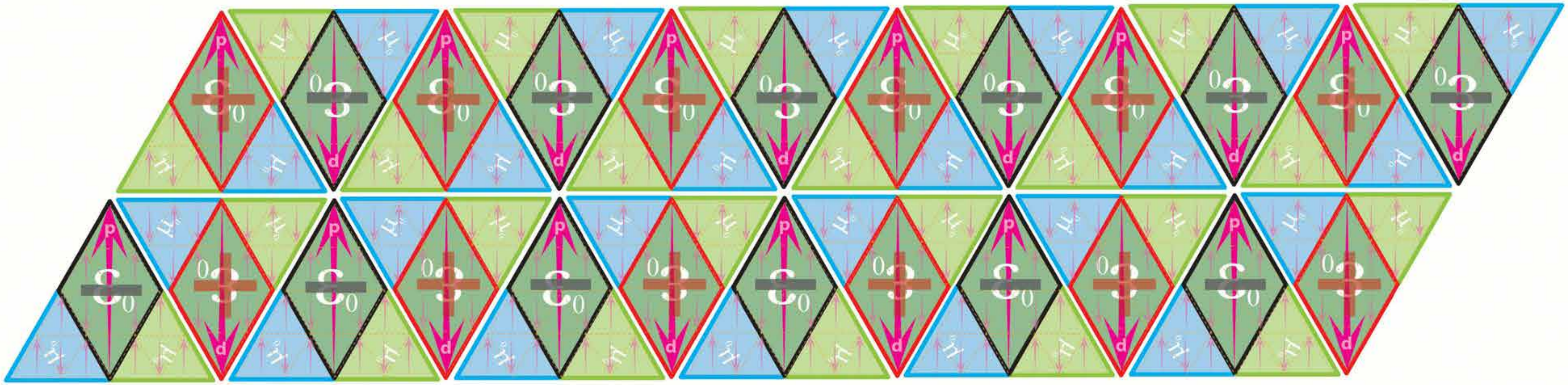
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ε_0
μ_0

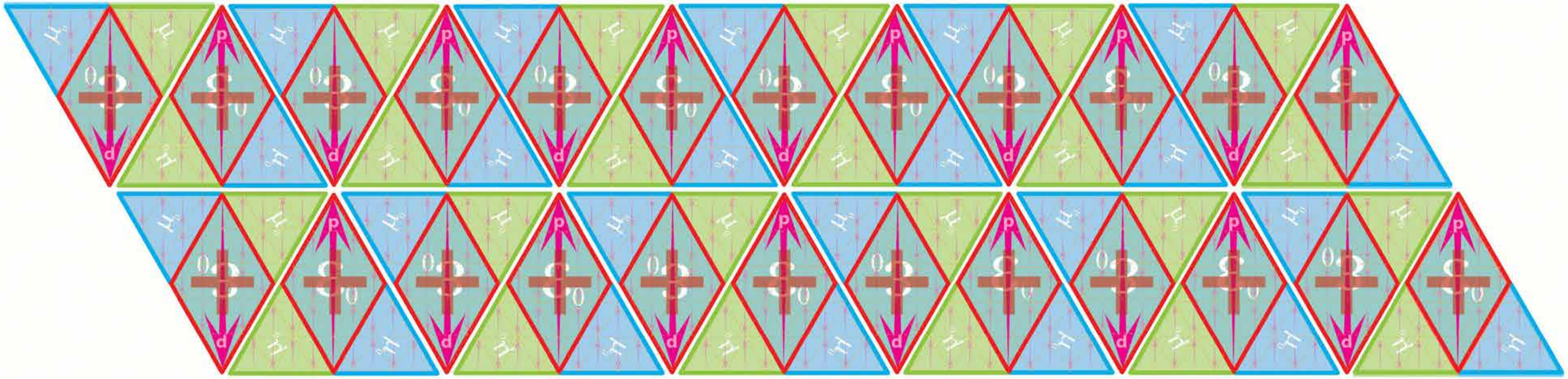

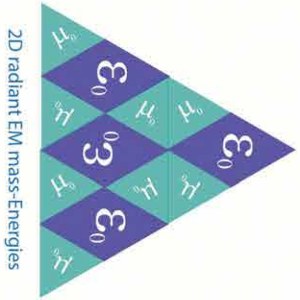
2D radiant EM mass-Energies
μ₀
ε₀

n5 - Charged Tetryon Templates

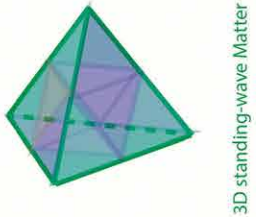
3D standing-wave Matter

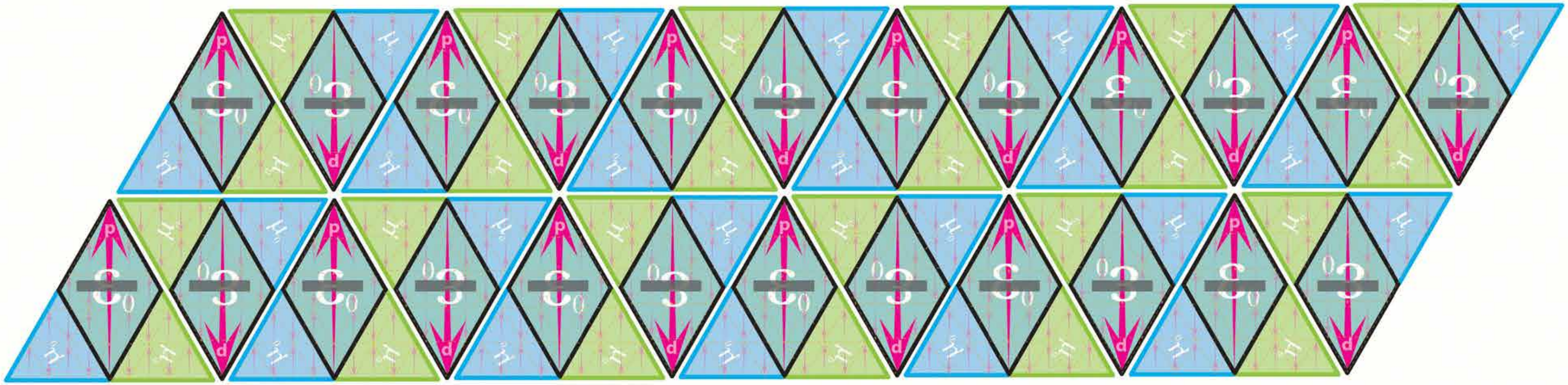

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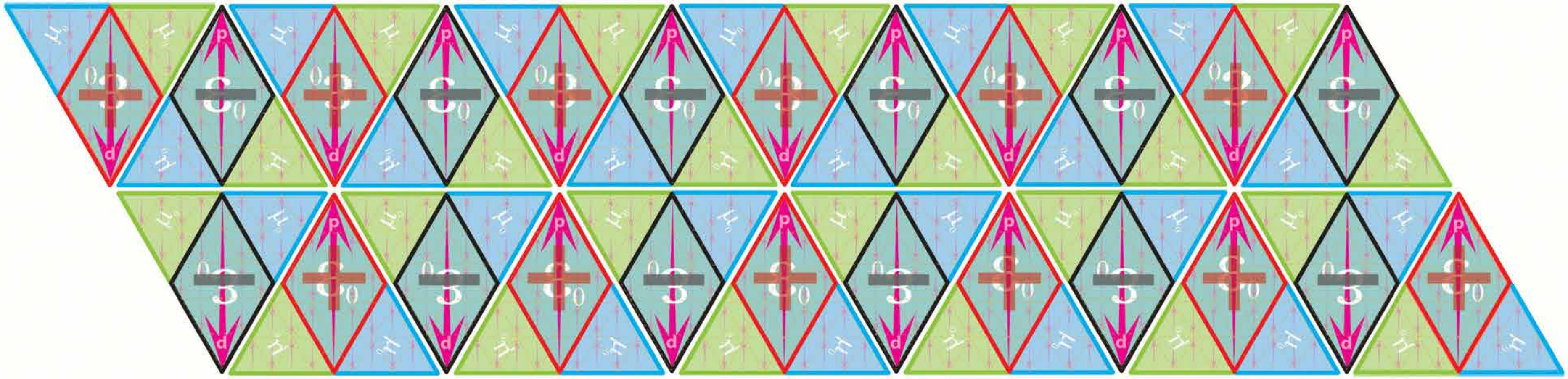
p
d
μ_0
ε_0

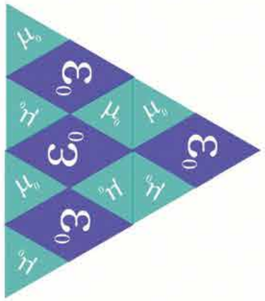
μ_0
ε_0

2D radiant EM mass-Energies

n5 - Neutral Tetryon Templates

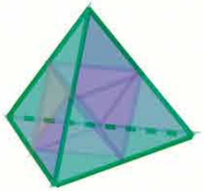

3D standing-wave Matter

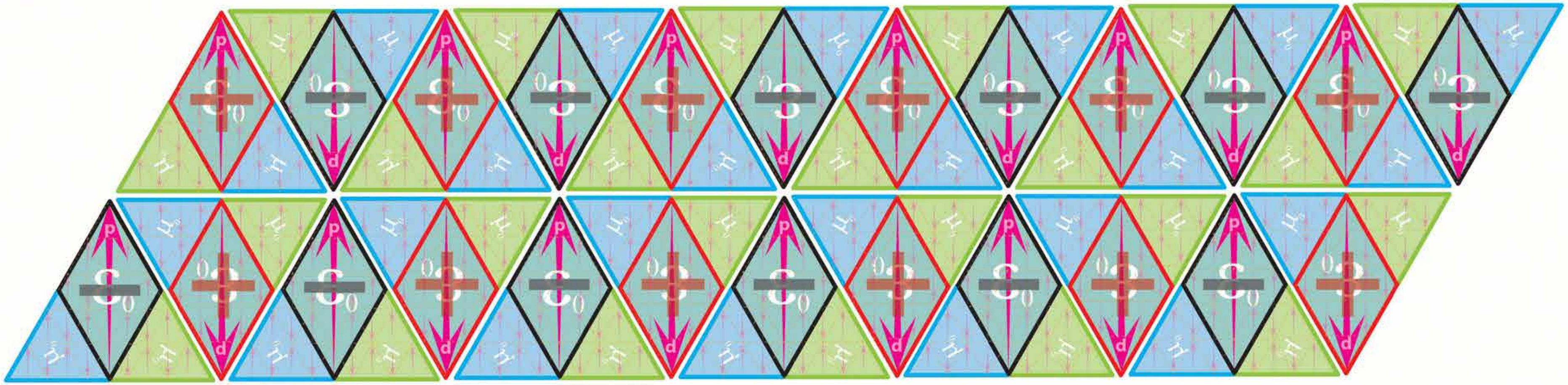
p
d
μ_0
ε_0

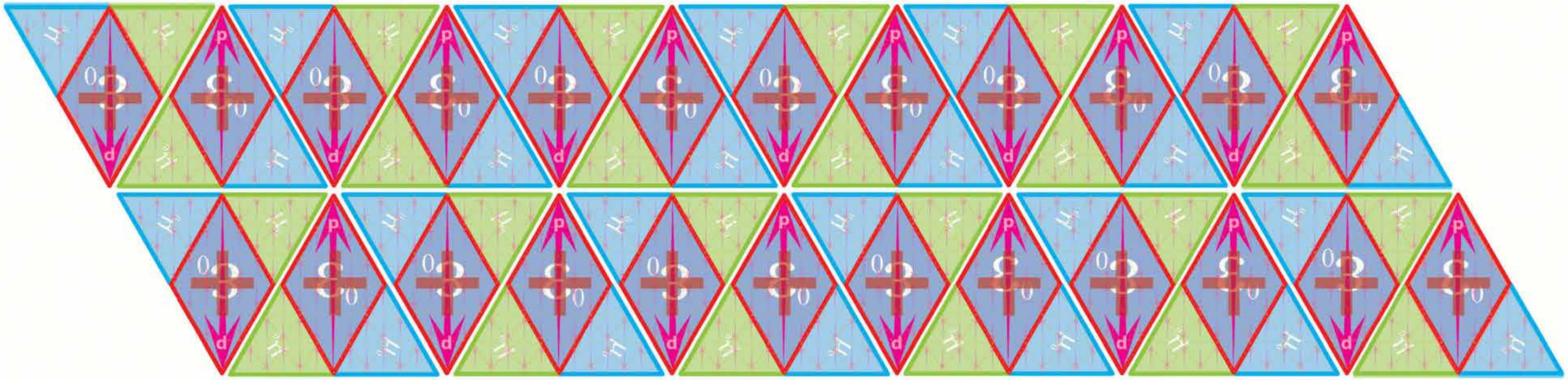

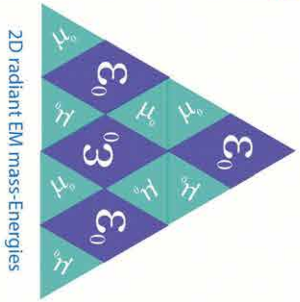
μ0
ε0
2D radiant EM mass-Energies

n6 - Charged Tetryon Templates

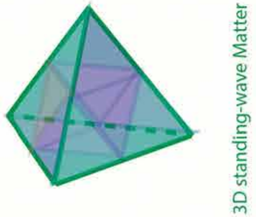
3D standing-wave Matter

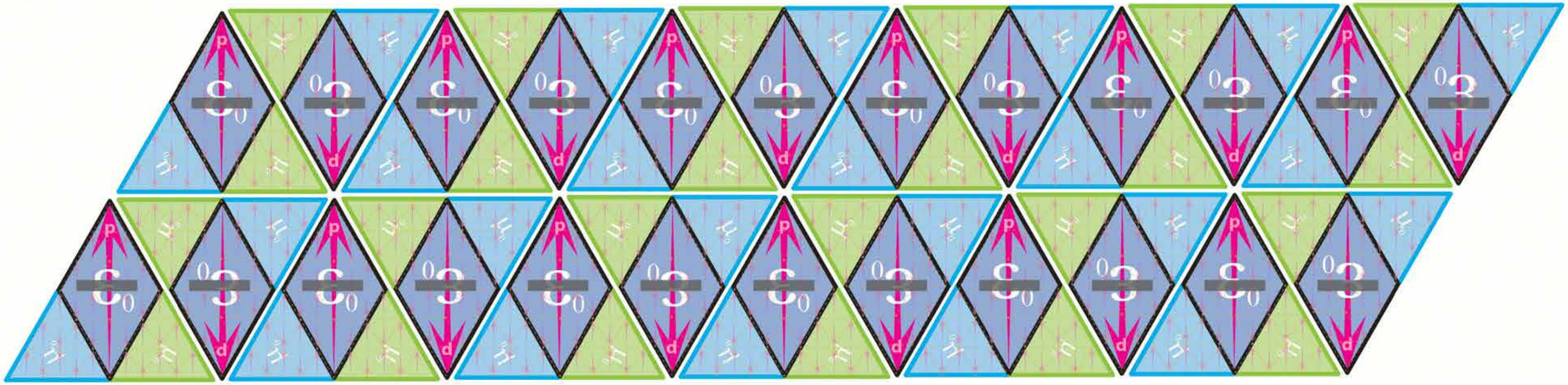

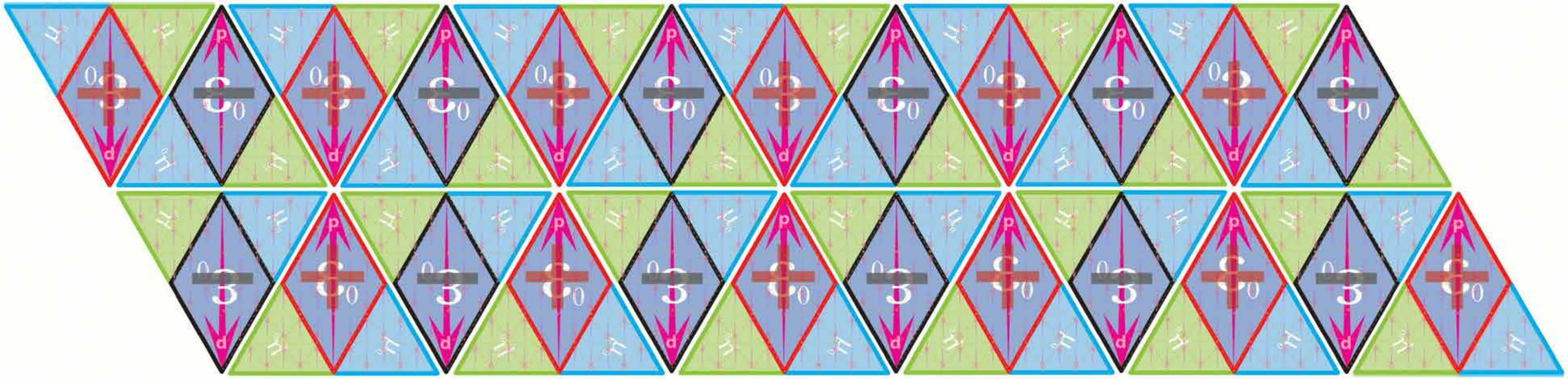

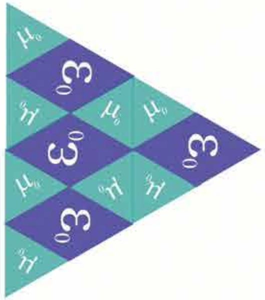

2D radiant EM mass-Energies

n6 - Neutral Tetryon Templates

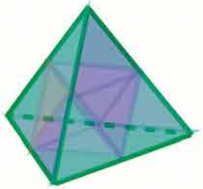

3D standing-wave Matter

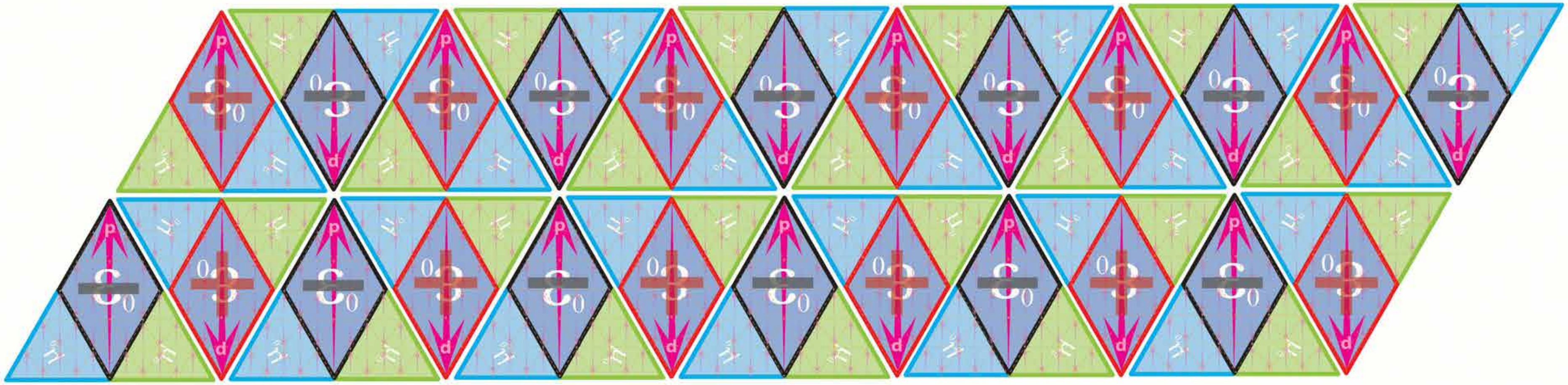

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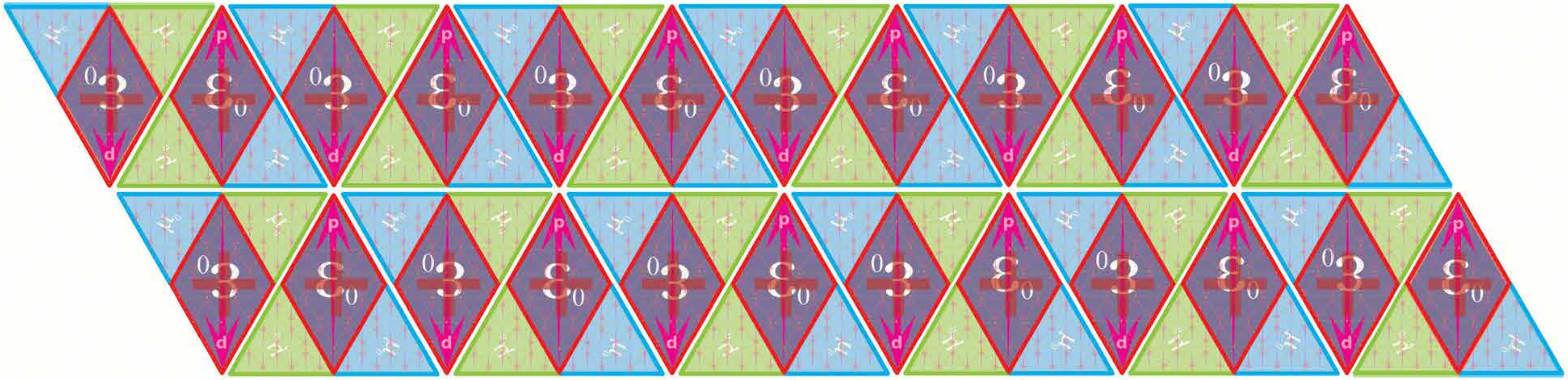
p
d
ε_0
μ_0

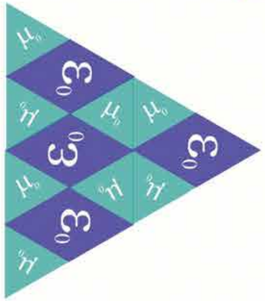
ε_0
μ_0

2D radiant EM mass-Energies

n7 - Charged Tetryon Templates

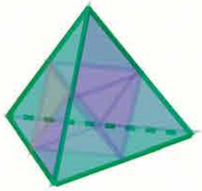

3D standing-wave Matter

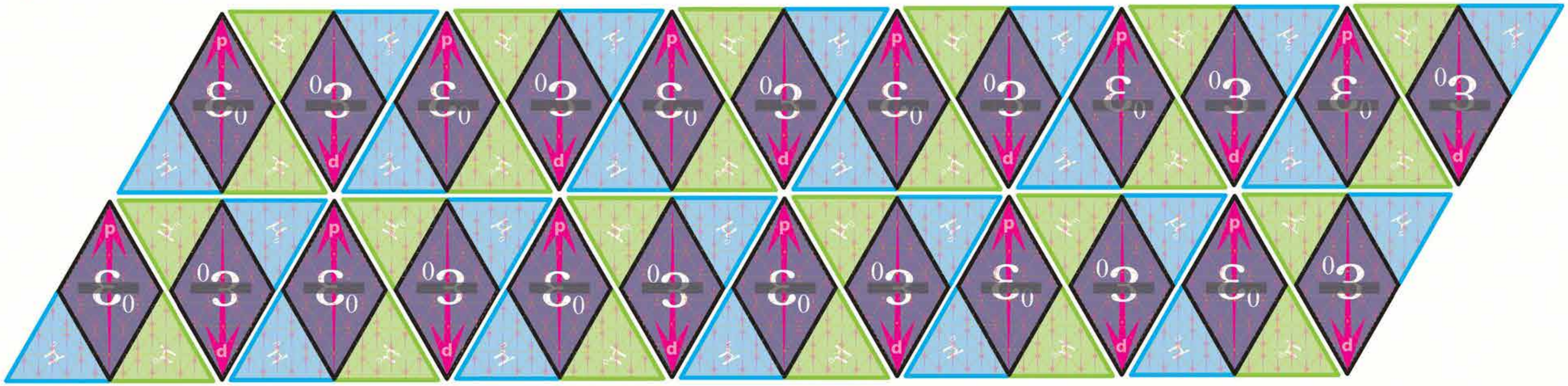
p
d
ε_0
μ_0

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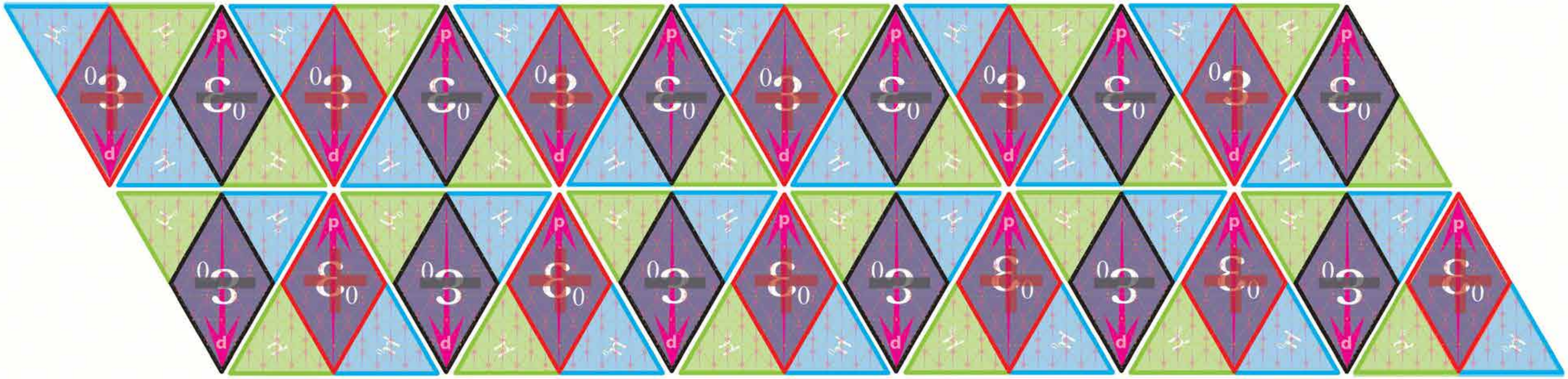
p
d
ε_0
μ_0

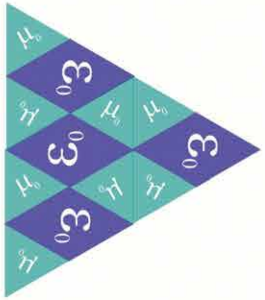
ε_0
μ_0

2D radiant EM mass-Energies

n7 - Neutral Tetryon Templates

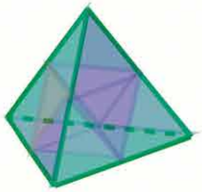

3D standing-wave Matter

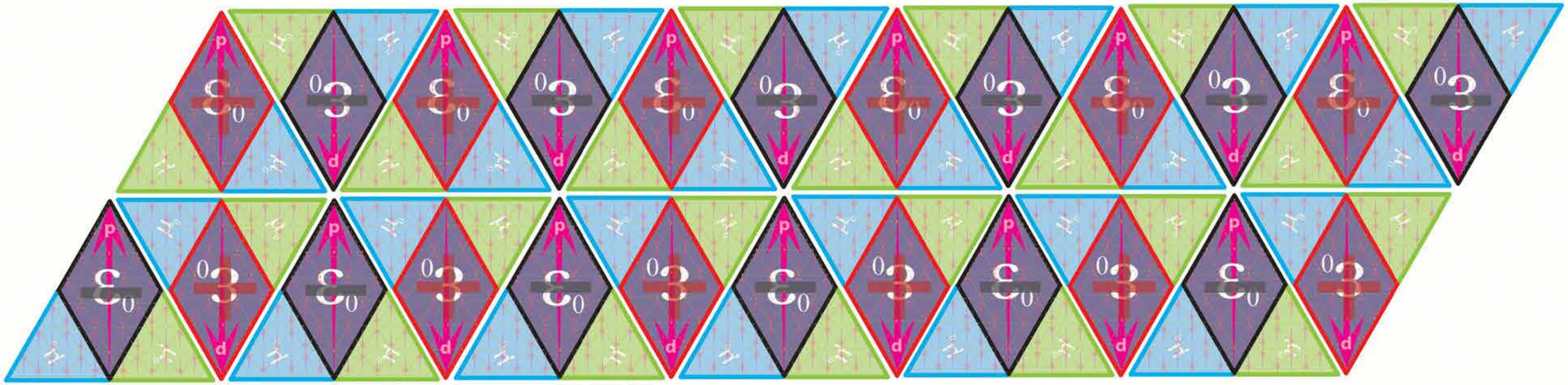
p
d
ε_0
μ_0

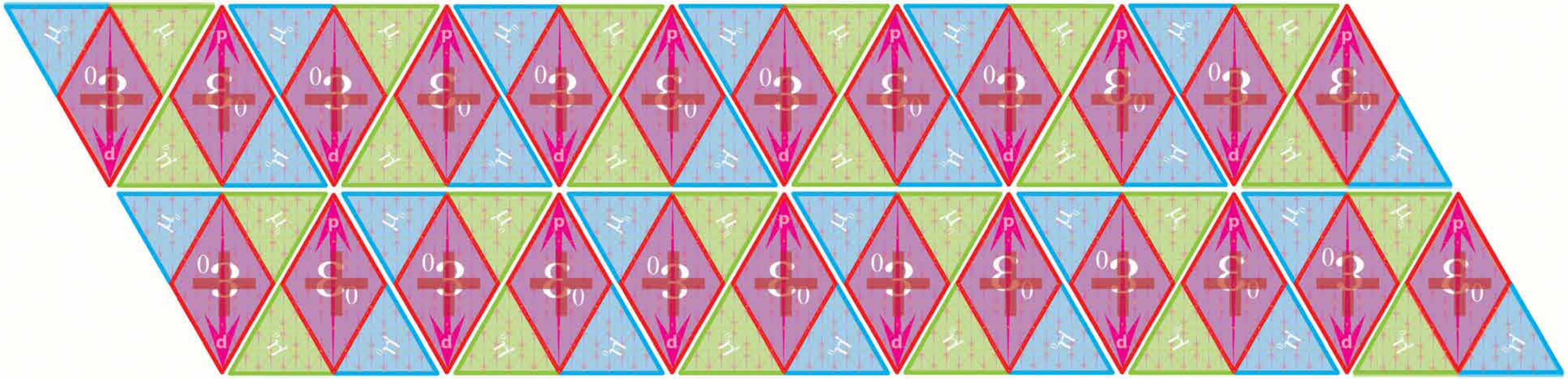
p
d
μ_0
ε_0

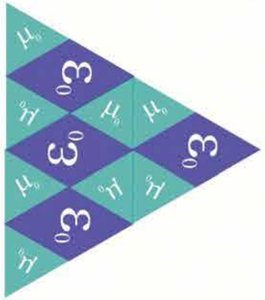
μ_0
ε_0

2D radiant EM mass-Energies

n8 - Charged Tetryon Templates

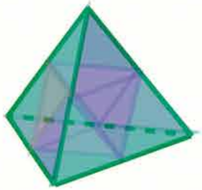

3D standing-wave Matter

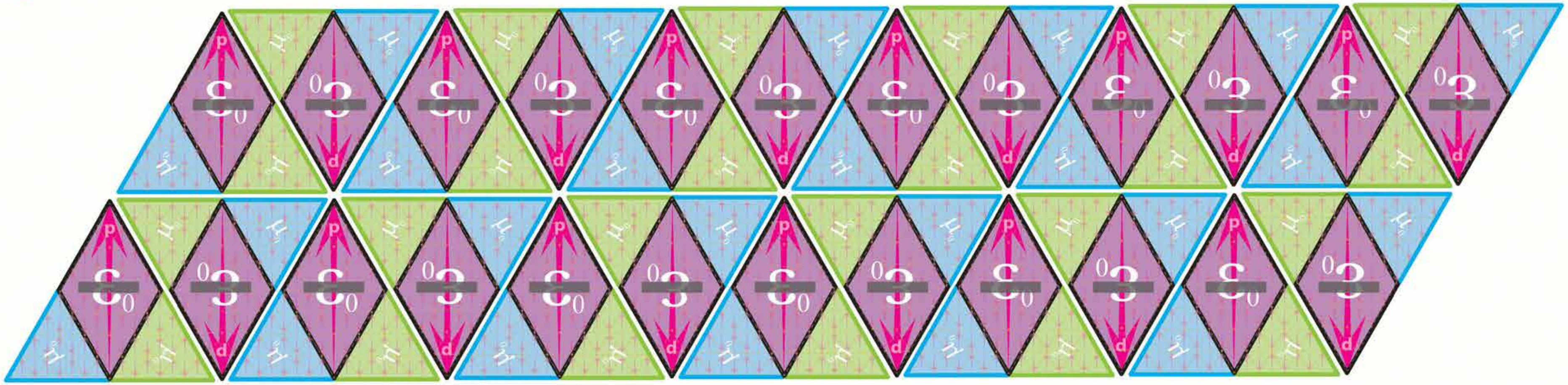
p
d
μ_0
ε_0

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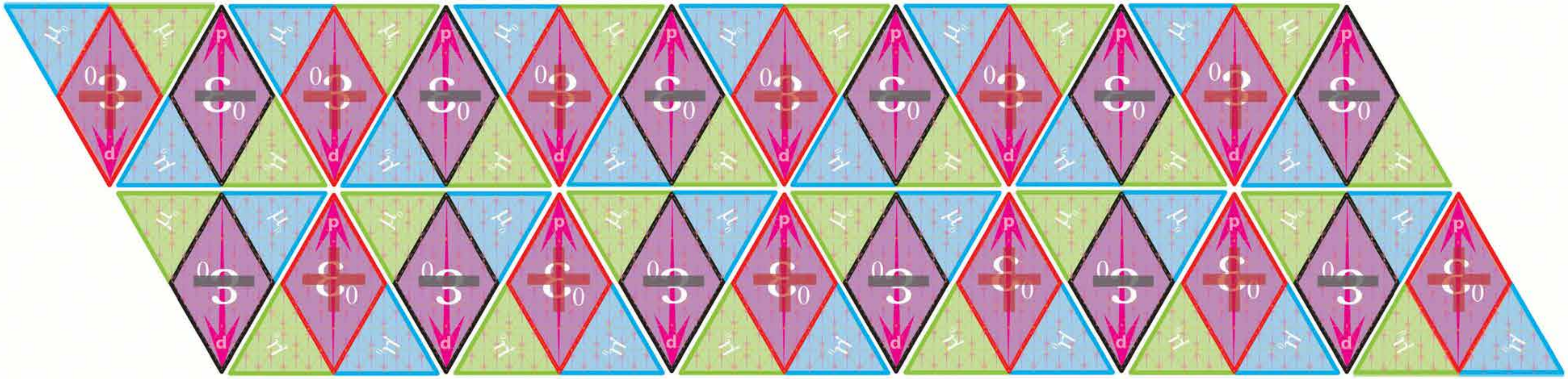

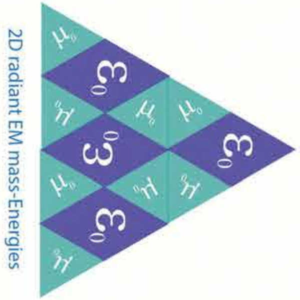
2D radiant EM mass-Energies

n8 - Neutral Tetryon Templates

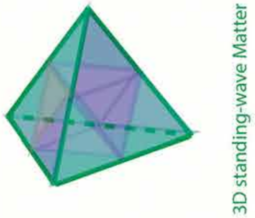
3D standing-wave Matter

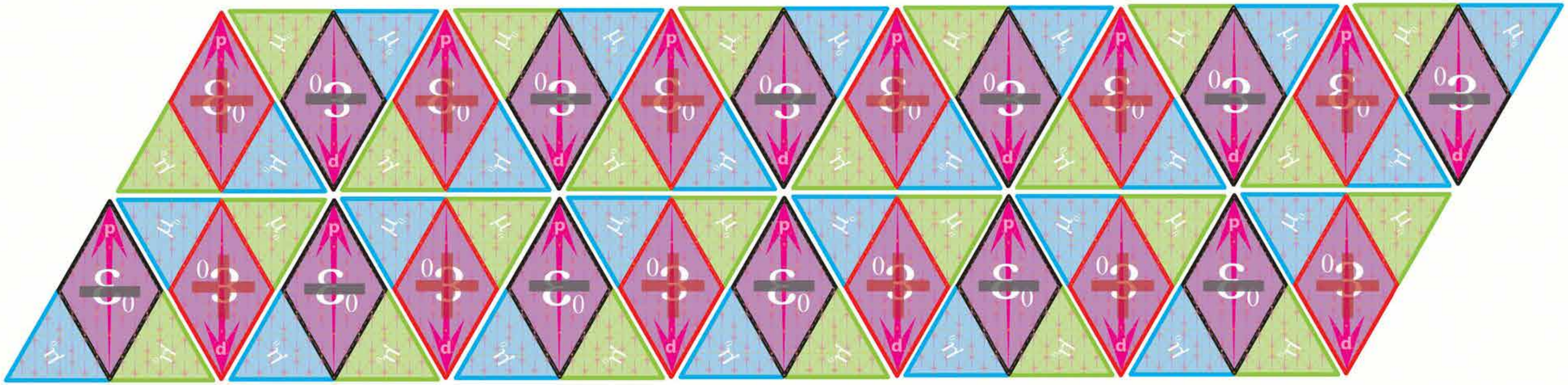

Periodic element geometries

An electron shell may be thought of as an orbit followed by electrons around an atom's nucleus.
The closest shell to the nucleus is called the "1 shell" (also called "K shell"), followed by the
"2 shell" (or "L shell"), then the "3 shell" (or "M shell"), and so on further and further from the nucleus.
The shell letters K, L, M, ... are alphabetical

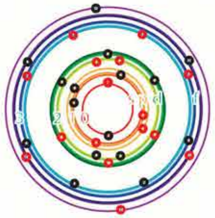

Each shell consists of one or more subshells, and
each subshell consists of one or more atomic orbitals.

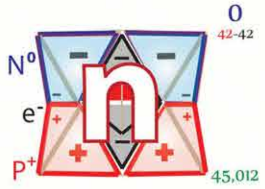
0
42-42
N^0
e^-
n
P^+
45,012

Each shell can contain only an integer
number of whole deuterium nuclei
[Proton, Neutron & electron]

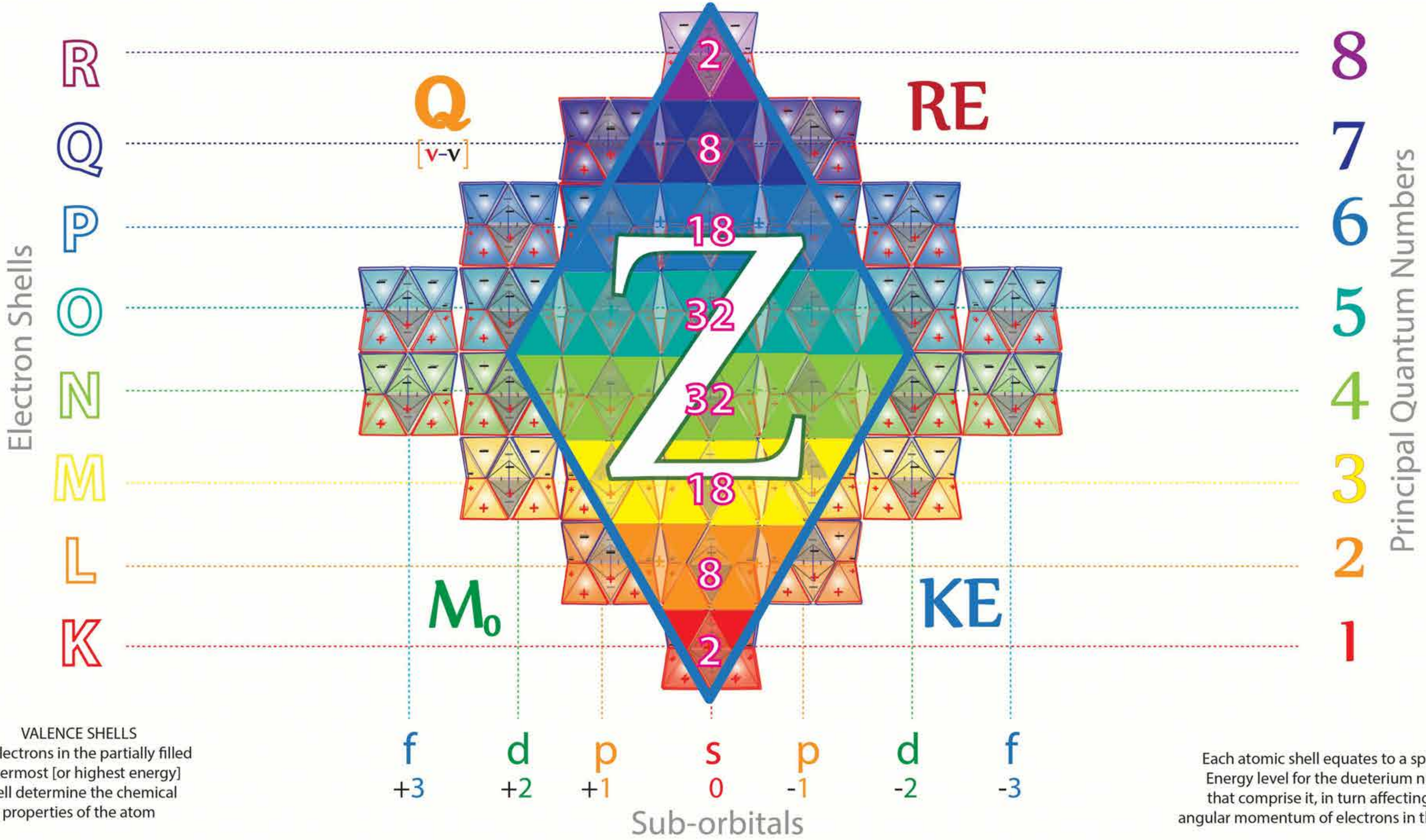
Electron Shells
R
Q
P
O
N
M
L
K
Q
[v-v]
RE
2
8
18
Z
32
32
18
8
2
M_0
KE
8
7
6
5
4
3
2
1
Principal Quantum Numbers
f
+3
d
+2
p
+1
s
0
p
-1
d
-2
f
-3
Sub-orbitals

VALENCE SHELLS
The electrons in the partially filled
outermost [or highest energy]
shell determine the chemical
properties of the atom

Each atomic shell equates to a specific
Energy level for the dueterium nuclei
that comprise it, in turn affecting the
angular momentum of electrons in that shell

Periodic Harmonic motions

$x = A\cos(\omega t + \varphi)$

Circular motion

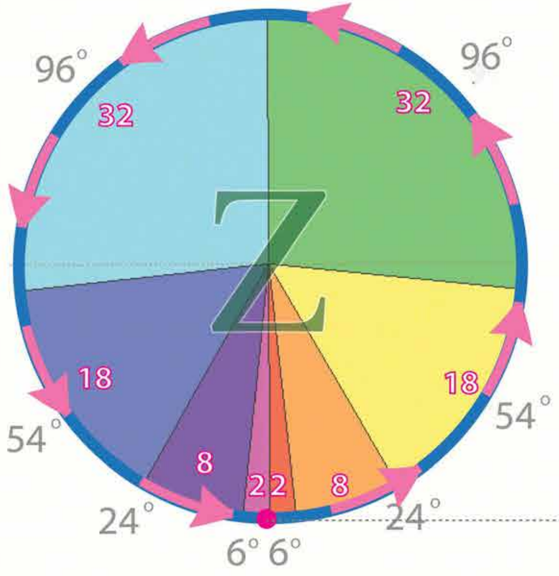
96°
32
96°
32
Z
18
18
54°
54°
8
2 2
8
24°
24°
6° 6°

Much of the math in of modern physics is predicated on the assumption that π [where it appears] is related to the properties of a circle

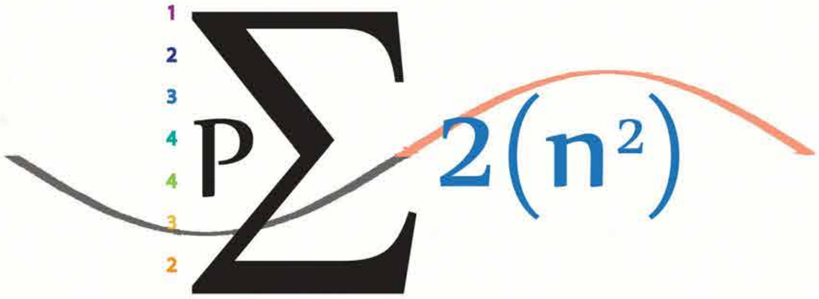

$P\sum 2(n^2)$

$F = -kx$

Linear motion

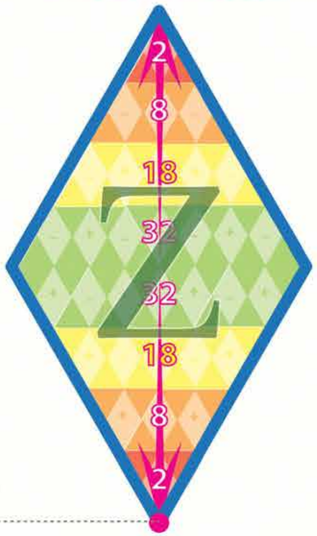
2
8
18
Z
32
32
18
8
2

Simple harmonic motion can be visualized as the projection of uniform circular motion onto one axis

circular harmonic motion

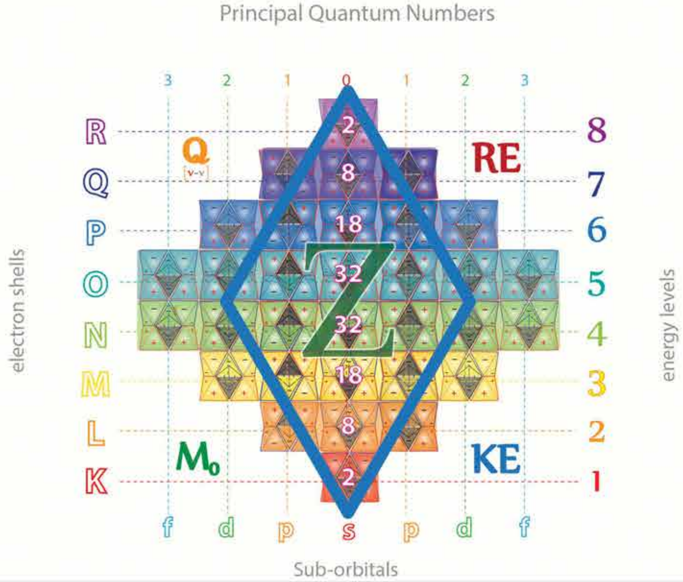
Principal Quantum Numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
[v-v]
RE
2
8
18
Z
32
32
18
8
2
M₀
KE
8
7
6
5
4
3
2
1
electron shells
energy levels
f
d
p
s
p
d
f
Sub-orbitals

simple harmonic motion

Circular motions describe the motion of a body with a changing velocity vector [the result of an acceleration force].

Nuclei per shell in elements follows a 'periodic summation rule' that is reflective of photonic energies

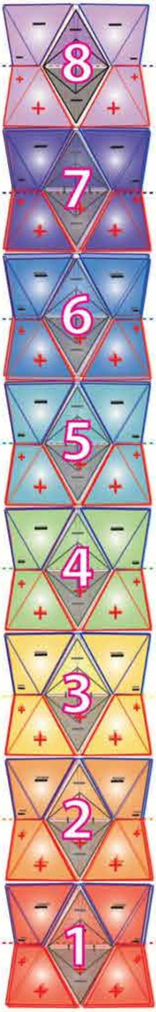

Baryon mass-energies n	E *The quantum level mass-energies of Baryons determines the kinetic energies of electrons* 1n - 1 e19v		electron KEM field hv^2
73,728	n32	v8	3.268969693 e15
69,192	n31	v7	2.502804921 e15
64,800	n30	v6	1.838795452 e15
60,552	n29	v5	1.276941286 e15
56,448	n28	v4	8.172424232 e14
52,488	n27	v3	4.596988631 e14
48,672	n26	v2	2.043106058 e14
45,000	n25	v1	5.107765145 e13
Compton frequencies 930 MeV	1.2 e20 **electron rest Matter is velocity invariant** 496 keV		**spectral frequencies** 13.6 eV

Atomic nuclei mass-energies

Each element's weight [mass-Matter in a gravitational field] is the result of the total quanta comprising that element

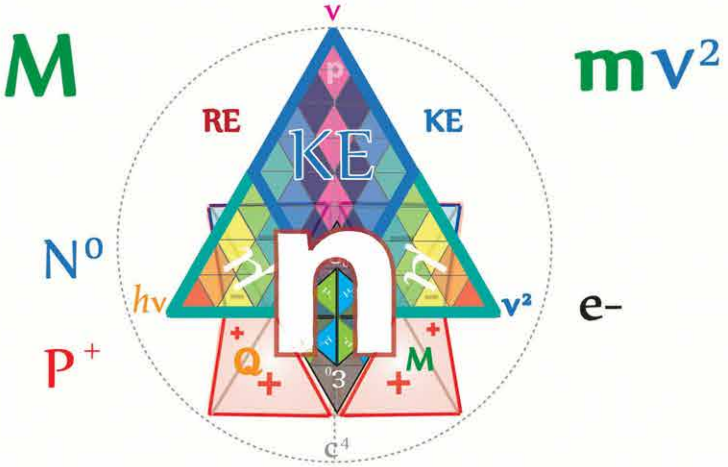

The nuclei forming each atomic shell have specific mass-energy quanta

Baryon rest masses — lepton rest mass — KEM

$$\overset{8}{\underset{1}{n}}\Big[\,[72(n)^2]+[12e19]+[m_e v^2]\,\Big]$$

Deuterium mass-energy per shell

Despite having differing mass-energies each Deuterium nuclei has the same velocity invariant Matter geometry [84π]

spin orbital coupling in synchronous quantum convertors

Electrons act as quantum scale rotating armatures in atomic nuclei and can only have specific energies reflective of the electron orbital energy level of the Baryons in which they are found

They acheive these energy levels by absorbing or emitting photons to acheive the specific angular momentum required

Baryons **930.947 MeV** + **KEM fields** **13.525 ev** + **electrons** **496.519 keV**

Mapping Planck mass-energy contributions to elementary Matter and isotopes

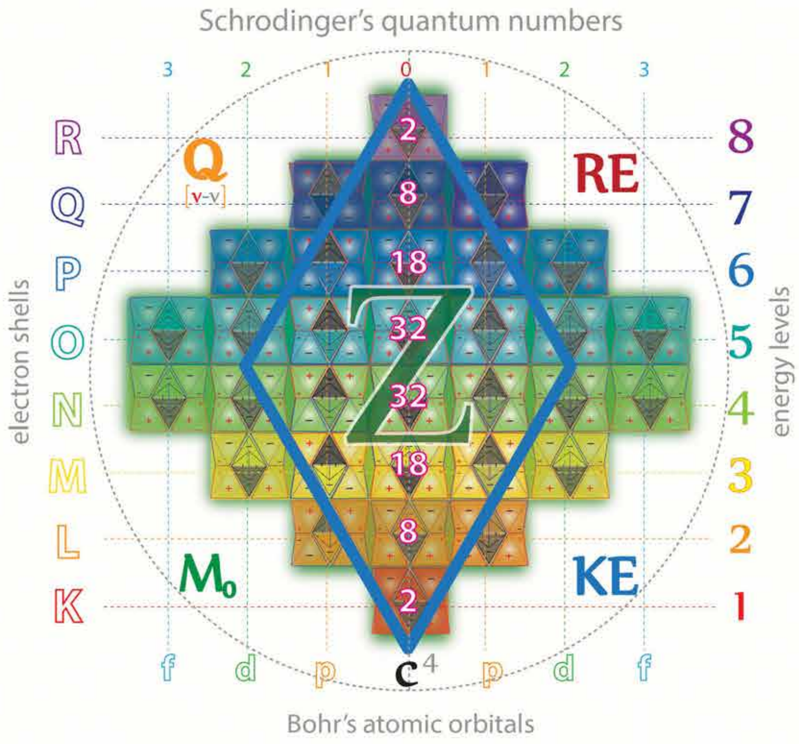
Schrodinger's quantum numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
[v-v]
RE
8
7
6
5
4
3
2
1
energy levels
2
8
18
32
Z
32
18
8
2
M_0
KE
f
d
p
c^4
p
d
f
Bohr's atomic orbitals

$$E = hv^2$$

$$n^2 + v^2 + e = Z$$

general form quatratic equation

$$ax^2 + bx + c = Z$$

$$E = nhv$$

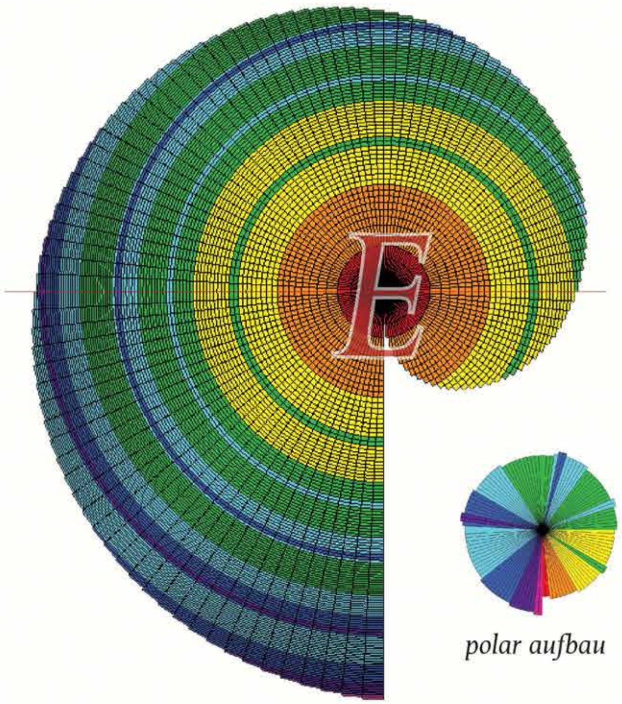
E
polar aufbau

polar energy spirals courtesy of Rene Cormier

Identifying electron rest Matter topologies as velocity invariant we can re-arrange the component Planck mass-energy geometry formulation of periodic elements to

$$h\left[\underbrace{72[v^2]}_{\text{Deuteron rest mass}} + \underbrace{v}_{\text{Spectral lines}} + \underbrace{1.20\text{ e}20\text{ v}}_{\text{electron rest mass}}\right]$$

reveal a quadratic formulation for all Z numbers

nuclei per shell

$$\sum_{K}^{R}$$

STEP ONE

Periodic summation follows the atomic shell electron config

$${}_{P}\sum_{K}^{R} Z$$

Periodic Summation

Periodic summation is a notation developed for Tetryonic theory to model the geometric series addtion of Z[n²] energy level Deuterium nuclei that form the periodic elements

$$\sum_{Z\ 1}^{120}$$

element number

STEP TWO

Periodic elements build up following the aufbau sequence

1 R
2
3
4
4
3
2
1 K

$${}_{P}\sum_{K}^{R} 2(x^2) =$$

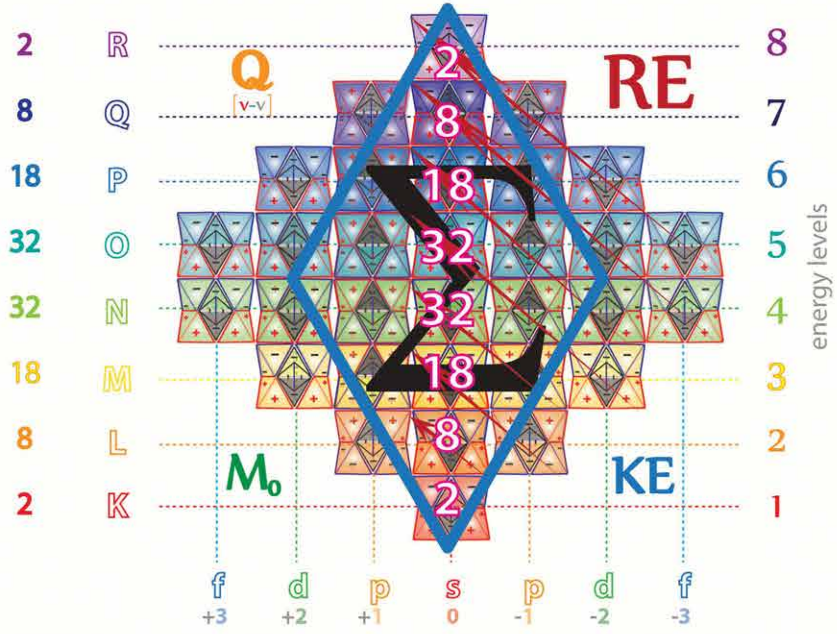

Each atomic shell can hold only a fixed number of deuterium nuclei

${}_{P}\sum R = 2$	2 nuclei [74.496 ea] +	120	Unbinilium
${}_{P}\sum Q = 8$	8 nuclei [69,780 ea] +	118	Ununoctium
${}_{P}\sum P = 18$	18 nuclei [65,232 ea] +	110	Darmstadtium
${}_{P}\sum O = 32$	32 nuclei [60,852 ea] +	92	Uranium
${}_{P}\sum N = 32$	32 nuclei [56,640 ea] +	60	Neodymuim
${}_{P}\sum M = 18$	18 nuclei [52,596 ea] +	28	Argon
${}_{P}\sum L = 8$	8 nuclei [48,720 ea] +	10	Neon
${}_{P}\sum K = 2$	2 nuclei [45,012 ea]	2	Helium
		0	Hydrogen

THe LHS of the notation determine the number of nuclei in each atomic shell, from the periodic mass-energy levels for atoms, and the RHS follows the aufbau building principle to determine the rest mass-Matter of any specific element

Each periodic element is made of Z [n² energy] deuterium nuclei

Aufbau

Z# [z Protons [24-12]
z Neutrons [18-18]
z electrons [0-12]] n1-8

Planck mass-energies form the surface integral of rest Matter topologies for each periodic element

Proton - Neutron Curve

The graph below is a plot of neutron number against proton number.
It is used as rule to determine which nuclei are stable or unstable.

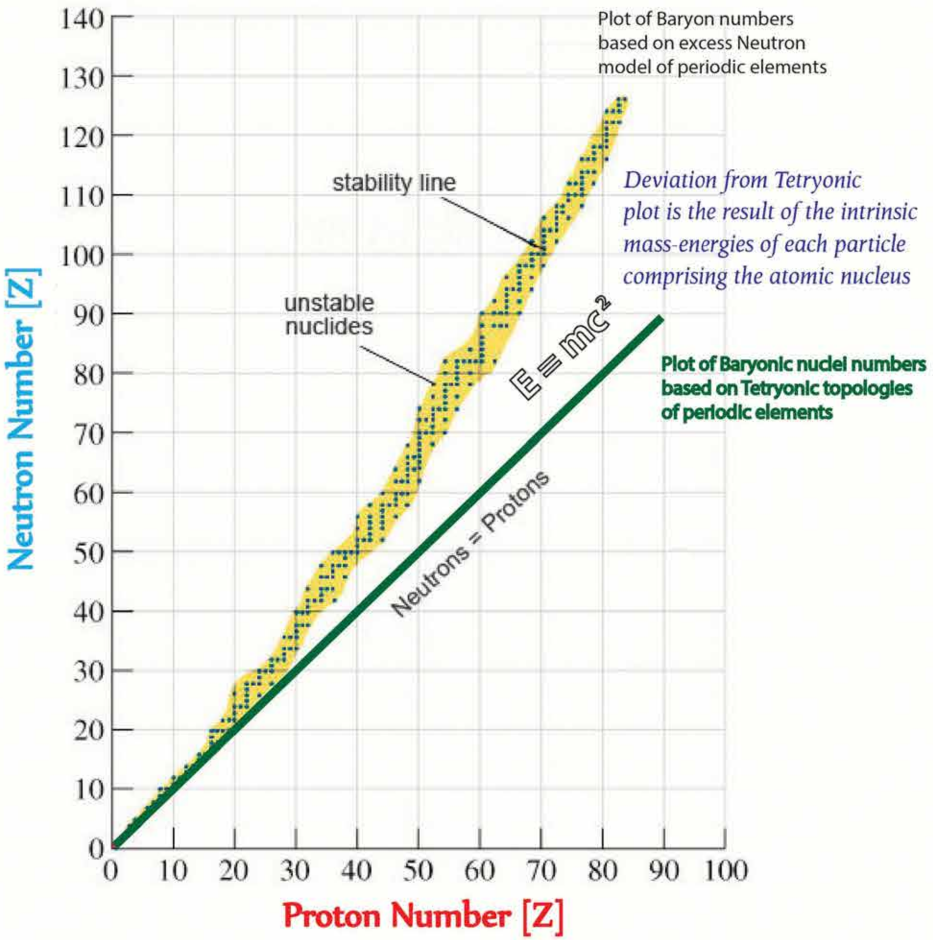

Historically, Proton-electron numbers are viewed as being equivalent in neutral elementary matter with the excess molar mass measured being the result of 'excess or extra' Neutrons in the atom

Atomic Nuclei Numbers

All periodic elements have an EQUAL number of Protons, Neutrons & Electrons with their molar mass-Matter being determined by their quantum level mass-energies

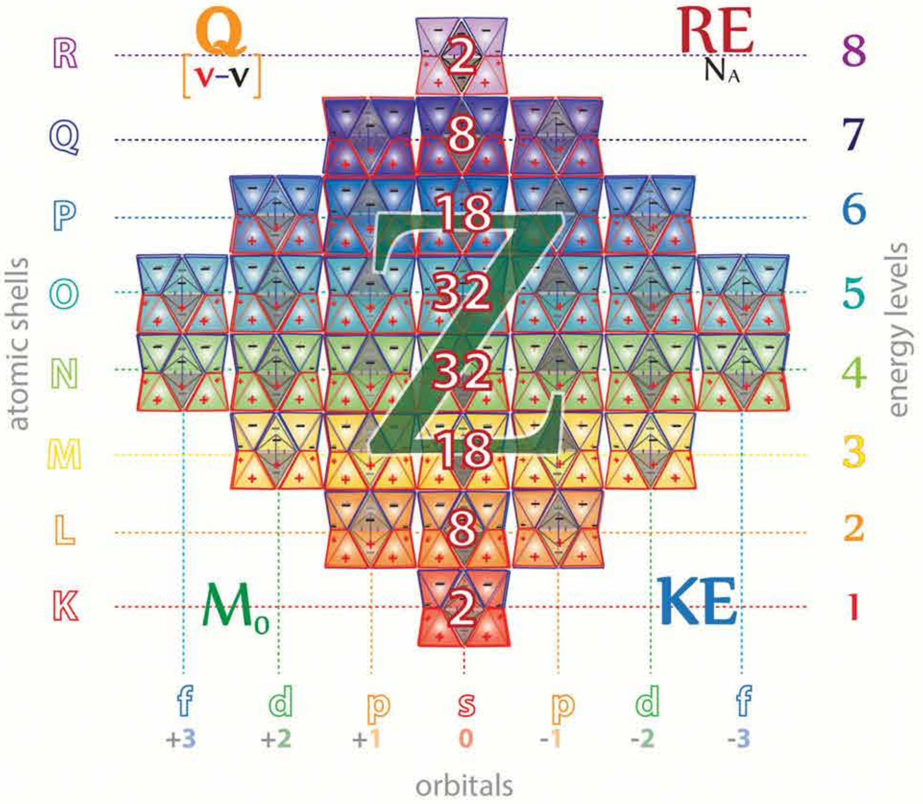
R
Q
P
O
N
M
L
K
atomic shells
Q
[v-v]
RE
N_A
2
8
18
32
Z
32
18
8
2
M₀
KE
8
7
6
5
4
3
2
1
energy levels
f
+3
d
+2
p
+1
s
0
p
-1
d
-2
f
-3
orbitals

Tetryonic modelling of the charged mass-ENERGY-Matter topologies of elementary atoms and the nuclei that comprise them, reveals a DIRECT LINEAR relationship for the number of Protons-electrons-Neutrons in all periodic elements and nuclear isotopes

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Planck mass-energy contributions to elementary Matter and isotopes

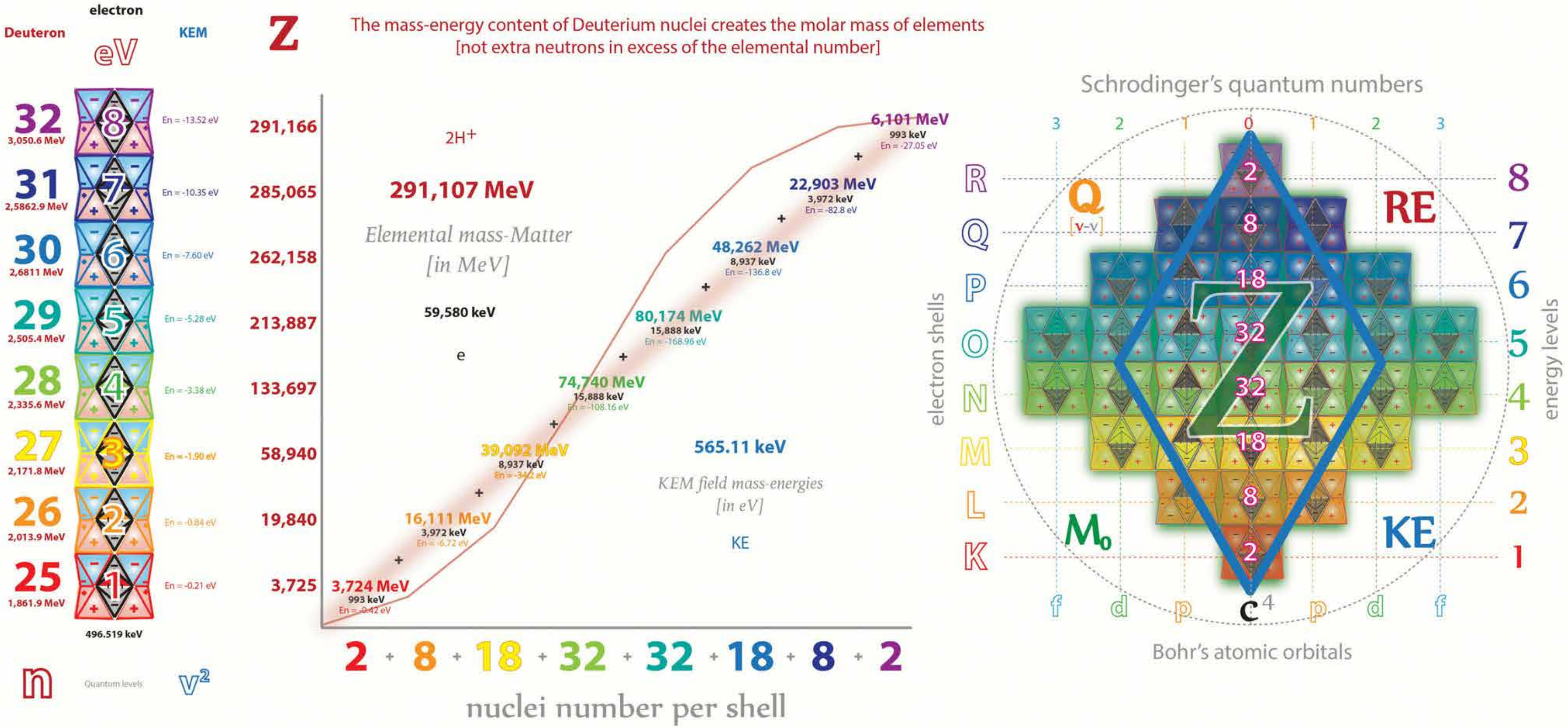

The mass-energy content of Deuterium nuclei creates the molar mass of elements
[not extra neutrons in excess of the elemental number]

Deuteron
electron
eV
KEM
Z
32
3,050.6 MeV
31
2,5862.9 MeV
30
2,6811 MeV
29
2,505.4 MeV
28
2,335.6 MeV
27
2,171.8 MeV
26
2,013.9 MeV
25
1,861.9 MeV
8
7
6
5
4
3
2
1
En = -13.52 eV
En = -10.35 eV
En = -7.60 eV
En = -5.28 eV
En = -3.38 eV
En = -1.90 eV
En = -0.84 eV
En = -0.21 eV
291,166
285,065
262,158
213,887
133,697
58,940
19,840
3,725
496.519 keV
n
Quantum levels
V²
2H+
291,107 MeV
Elemental mass-Matter
[in MeV]
59,580 keV
e
6,101 MeV
993 keV
En = -27.05 eV
22,903 MeV
3,972 keV
En = -82.8 eV
48,262 MeV
8,937 keV
En = -136.8 eV
80,174 MeV
15,888 keV
En = -168.96 eV
74,740 MeV
15,888 keV
En = -108.16 eV
39,092 MeV
8,937 keV
En = -34.2 eV
16,111 MeV
3,972 keV
En = -6.72 eV
3,724 MeV
993 keV
En = -0.42 eV
565.11 keV
KEM field mass-energies
[in eV]
KE
2 + 8 + 18 + 32 + 32 + 18 + 8 + 2
nuclei number per shell
electron shells
R
Q
P
O
N
M
L
K
Schrodinger's quantum numbers
3
2
1
0
1
2
3
Q
[v-v]
RE
M0
KE
2
8
18
32
32
18
8
2
Z
c⁴
f
d
p
p
d
f
Bohr's atomic orbitals
8
7
6
5
4
3
2
1
energy levels

n1
Elementary nuclei

are comprised of equal numbers of
Protons, Neutrons & electrons
with varying energy levels

Baryons		electrons		KEM fields
930.947 MeV	+	496.519 keV	+	13.525 ev

The mass-energy content of Matter topologies is velocity invariant

The mass-energy content of Baryons determines the KEM field of electrons

All elements are comprised of n level Duetrium nuclei

Baryons **KEM fields** **electrons**

$$Z\,[[72n^2] + [12v^2] + [1.2e20]]$$

1,861,949 MeV **13.525 eV** **496,519 keV**

The atomic shell energy levels of Deuterium nuclei in elements

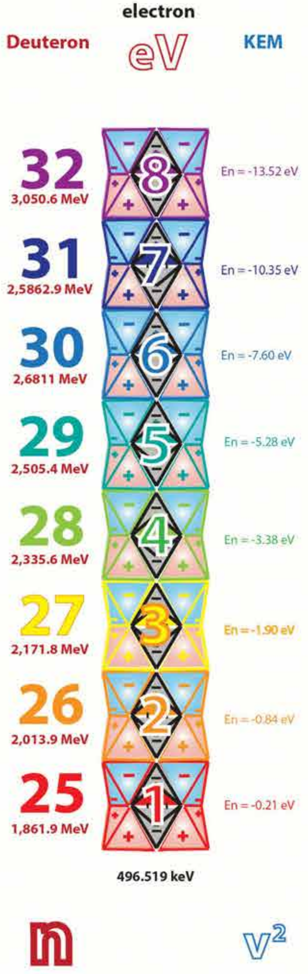
electron
Deuteron
eV
KEM
32
3,050.6 MeV
8
En = -13.52 eV
31
2,5862.9 MeV
7
En = -10.35 eV
30
2,6811 MeV
6
En = -7.60 eV
29
2,505.4 MeV
5
En = -5.28 eV
28
2,335.6 MeV
4
En = -3.38 eV
27
2,171.8 MeV
3
En = -1.90 eV
26
2,013.9 MeV
2
En = -0.84 eV
25
1,861.9 MeV
1
En = -0.21 eV
496.519 keV
n
v²

Determines the spectral line [KEM field energies] of electrons bound to them

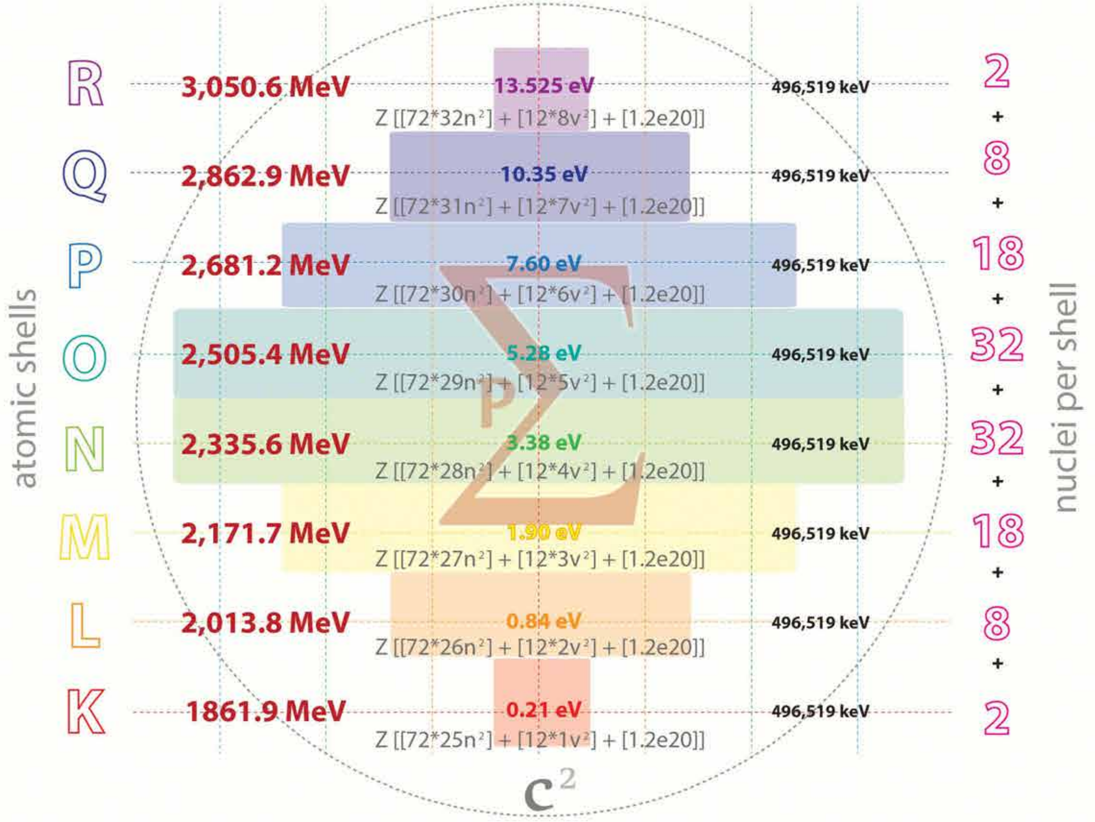
atomic shells
nuclei per shell
p
Σ
c²

R	3,050.6 MeV	13.525 eV $Z\,[[72*32n^2] + [12*8v^2] + [1.2e20]]$	496,519 keV	2	+
Q	2,862.9 MeV	10.35 eV $Z\,[[72*31n^2] + [12*7v^2] + [1.2e20]]$	496,519 keV	8	+
P	2,681.2 MeV	7.60 eV $Z\,[[72*30n^2] + [12*6v^2] + [1.2e20]]$	496,519 keV	18	+
O	2,505.4 MeV	5.28 eV $Z\,[[72*29n^2] + [12*5v^2] + [1.2e20]]$	496,519 keV	32	+
N	2,335.6 MeV	3.38 eV $Z\,[[72*28n^2] + [12*4v^2] + [1.2e20]]$	496,519 keV	32	+
M	2,171.7 MeV	1.90 eV $Z\,[[72*27n^2] + [12*3v^2] + [1.2e20]]$	496,519 keV	18	+
L	2,013.8 MeV	0.84 eV $Z\,[[72*26n^2] + [12*2v^2] + [1.2e20]]$	496,519 keV	8	+
K	1861.9 MeV	0.21 eV $Z\,[[72*25n^2] + [12*1v^2] + [1.2e20]]$	496,519 keV	2	

$2H^+$ Z γ

$[72n^2]$ $[M_e v^2]$

Elemental mass-Matter [in MeV]

6,101 MeV
993 keV
En = -27.05 eV
+
22,903 MeV
3,972 keV
En = -82.8 eV
+
48,262 MeV
8,937 keV
En = -316.8 eV
+
80,174 MeV
15,888 keV
En = -168.96 eV
+
74,740 MeV
15,888 keV
En = -108.16 eV
+
39,092 MeV
8,937 keV
En = -34.2 eV
+
16,111 MeV
3,972 keV
En = -6.72 eV
+
3,724 MeV
993 keV
En = -0.42 eV

[1.2e20]]

e

the rest mass-Matter of bound photo-electrons is velocity invariant

The relativistic rest mass-energy-Matter of all periodic elements

is the sum of the mass-energies of all atomic nuclei and spectral lines that comprise its mass-Matter topology as measured in any spatial co-ordinate system per unit of time

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Ionisation energies

Fractional quantum differentials

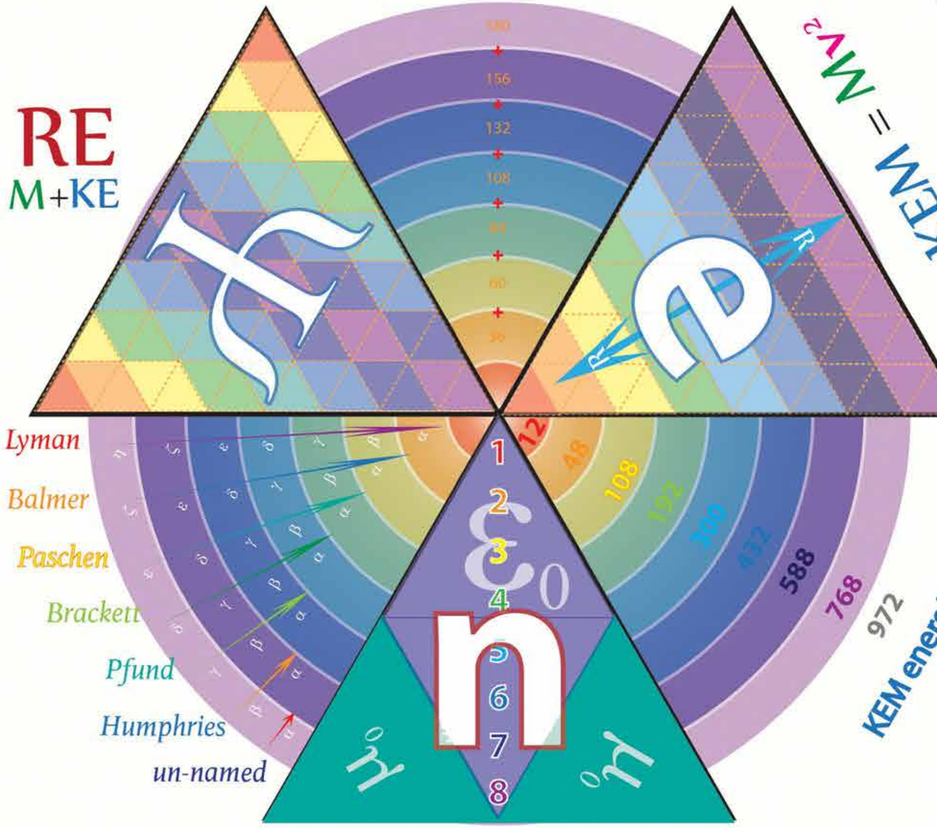
RE
M+KE
180
156
132
108
84
60
36
p² = KEM = Mv²
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
12
48
108
192
300
432
588
768
972
KEM energies
1
2
3
4
5
6
7
8
ε0
n

$$hf = \Delta M v = \Delta p$$

spectral lines are produced by accelerating electrons

Note: this is an Illustrative schema for modelling KEM field energies
All KEM fields possess the same physical spatial geometry
in radial-time defined spatial co-ordinate systems

c^2 c^4

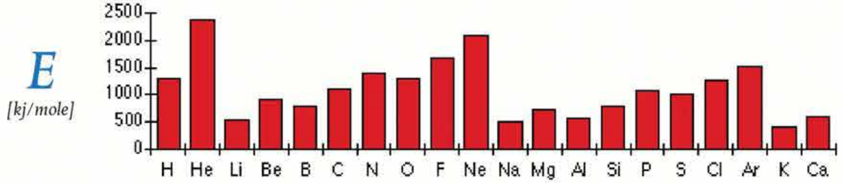

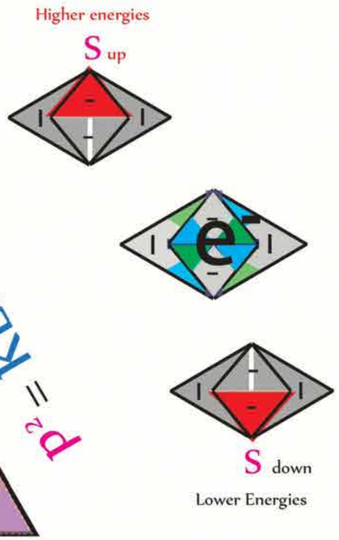
Higher energies
S up
e⁻
S down
Lower Energies

Photo-electrons absorb/emit spectral energies

$$E = eV = \frac{1}{4\pi\epsilon_0}\frac{ne^2}{a}$$

photo-electronic energy momenta

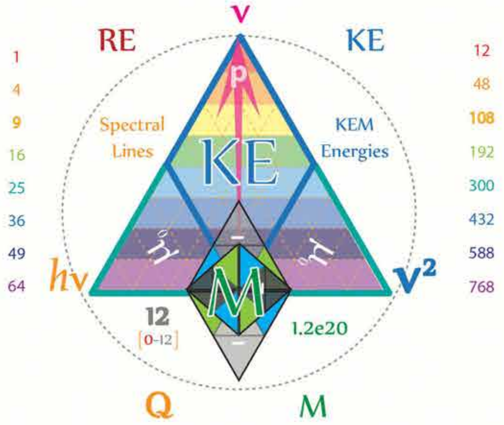
v
RE
KE
1
4
9
16
25
36
49
64
12
48
108
192
300
432
588
768
Spectral Lines
KEM Energies
p
KE
M
hv
v²
12
[0-12]
1.2e20
Q
M

Mapping photo-electron transition energies
to Tetryonic energy momenta geometries
reveals many key facts about the
ionisation energies of nuclei

$$E = -\frac{Z^2}{n^2}\frac{ke^2}{2a_0} = -\frac{13.6Z^2}{n^2}eV$$

The differing fractional KEM field energy momenta of electrons
that results from their transitions to specific energy nuclei
in elements results in differing QAM quanta and
produces spectral lines and fine line splitting

Spectral
line transitions

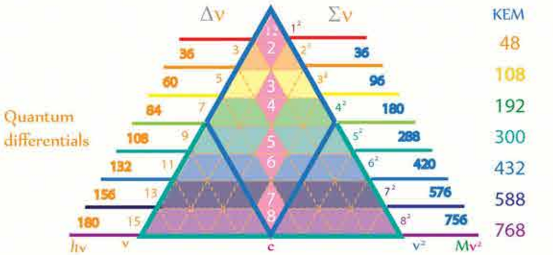
Δv
Σv
KEM
Quantum differentials
36
60
84
108
132
156
180
3
5
7
9
11
13
15
1
2
3
4
5
6
7
8
1²
2²
3²
4²
5²
6²
7²
8²
36
96
180
288
420
576
756
48
108
192
300
432
588
768
hv
v
c
v²
Mv²

hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

uniting classical physics and relativity
through equilateral geometry

Element numbers

Nuclei per shell in elements follow
a 'periodic summation rule'
that is reflective of
photonic energies

$$P\sum_{K\,1}^{R\,1} 2(x^2) = 2+8+18+32+32+18+8+2$$

1 R
2
3
4
4
3
2
1 K

Z

Z	Element	Level
120	Unbinilium	n8 ◆
119	Ununennium	
118	Ununoctium	n7 ◆
87	Francium	
112	Copernicium	n6 ◆
55	Caesium	
102	Nobelium	n5 ◆
37	Rubidium	
70	Ytterbuim	n4 ◆
19	Potassium	
30	Zinc	n3 ◆
11	Sodium	
10	Neon	n2 ◆
3	Lithium	
2	Helium	n1 ◆
1	Deuterium	
0	Hydrogen	

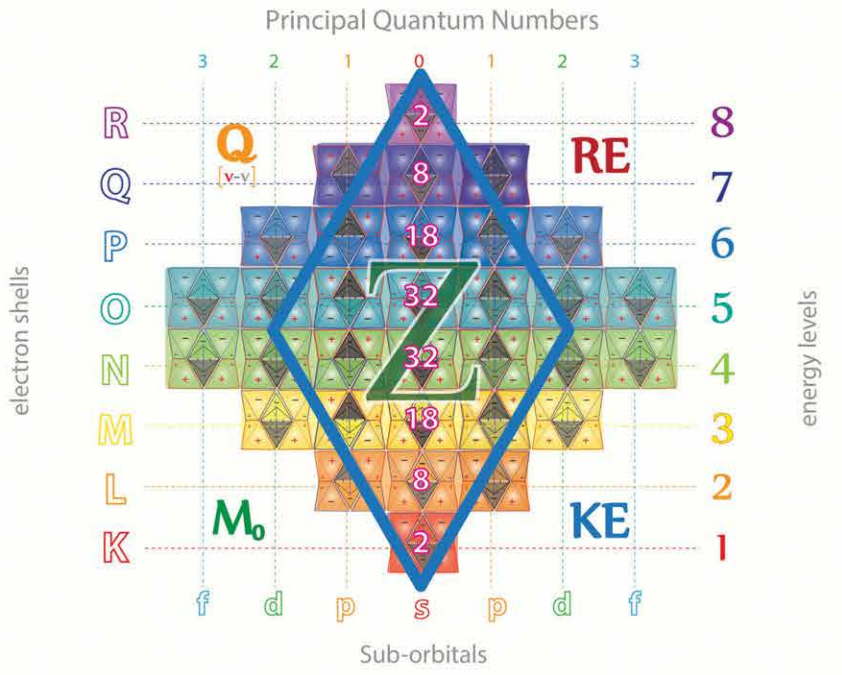
Principal Quantum Numbers
3 2 1 0 1 2 3
R Q P O N M L K
electron shells
8 7 6 5 4 3 2 1
energy levels
Q
[v-v]
RE
M0
KE
2
8
18
32
Z
32
18
8
2
f d p s p d f
Sub-orbitals

Periodic mass-ENERGY-Matter

Following periodic summation rules for shell filling
n[1-8] quantum energy deuterium nuclei
combine to form elementary Matter

Baryon rest masses lepton rest mass KEM

$$\boxed{{}^{R}_{K}P\sum_{25}^{32}\Big[[72(n)^2]+[12e19]+[m_e v^2]\Big]_1^8}$$

Deuterium mass-energy per shell

The measured weight of Matter in gravitational fields is the result of planar mass-energies in tetryonic standing-wave geometries

The periodicity of all the elements,
along with their exact molar rest mass-energies and
quantum wavefunctions can be described with Tetryonic geometries

Ionisation energies

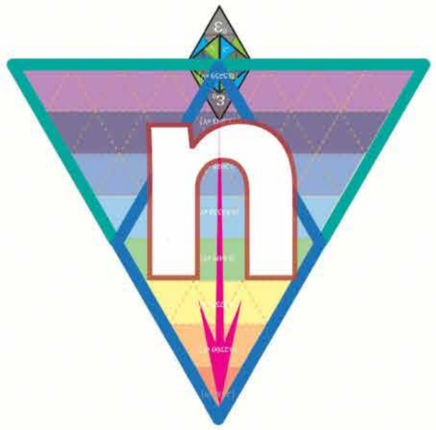

γ

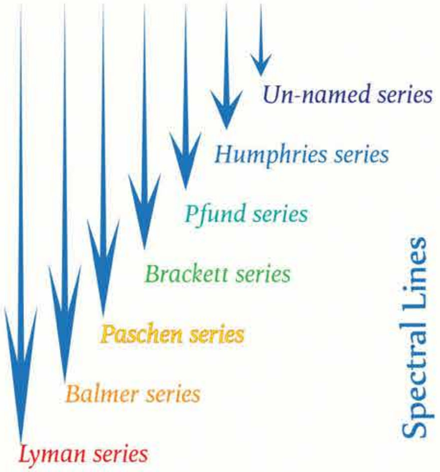
Un-named series
Humphries series
Pfund series
Brackett series
Paschen series
Balmer series
Lyman series
Spectral Lines

$$\boxed{Mv^2 = KEM = hcR_H}$$

Photon emission/absorption

Spectral line differentials

$$\Delta hv = \Delta Mv = \Delta p$$

changes to energy momenta

accelerate photo-electrons

$$\frac{1}{\lambda} = \frac{R_H}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Ryberg's formula is
a mathematical description
of Tetryonic energy geometry

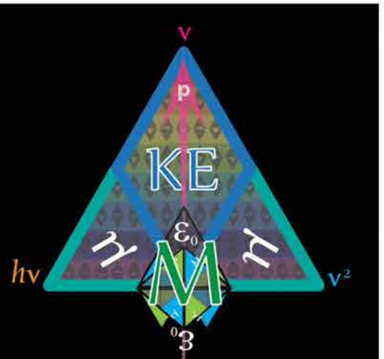
v
p
KE
ε_0
M
hv
v^2
3

& produces spectral lines

Δhf

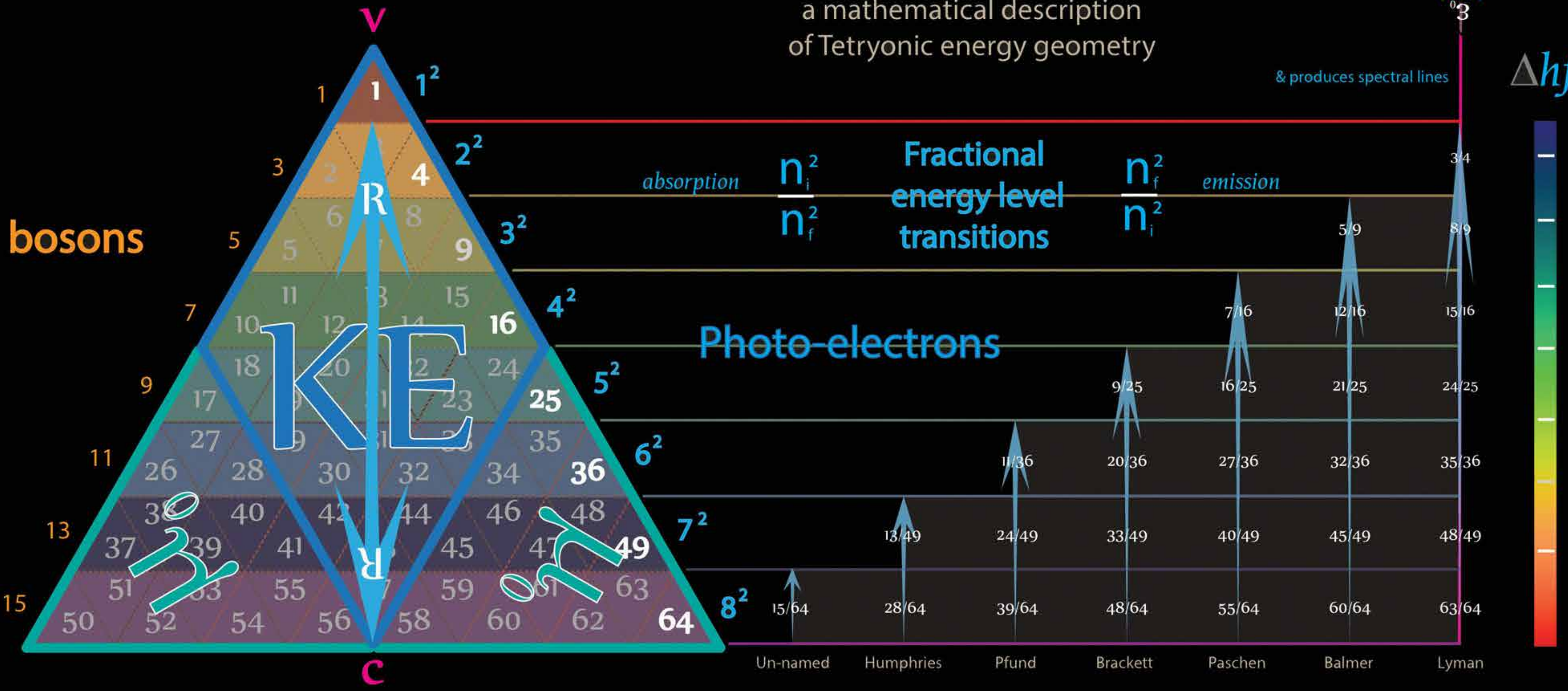
v
c
1
3
5
7
9
11
13
15
1^2
2^2
3^2
4^2
5^2
6^2
7^2
8^2
1
4
9
16
25
36
49
64
KE
R
3/4
8/9
15/16
24/25
35/36
48/49
63/64
5/9
12/16
21/25
32/36
45/49
60/64
7/16
16/25
27/36
40/49
55/64
9/25
20/36
33/49
48/64
11/36
24/49
39/64
13/49
28/64
15/64
Un-named
Humphries
Pfund
Brackett
Paschen
Balmer
Lyman

bosons

absorption

$$\frac{n_i^2}{n_f^2}$$

Fractional energy level transitions

$$\frac{n_f^2}{n_i^2}$$

emission

Photo-electrons

Ryberg's constant reflects the changing
energy momentum of a transitioning electron

$$Mv^2 = KEM = hcR$$

All of the transitions of photo-electrons
bound to Hydrogen atoms can now be
revealed in the fractional geometry
of KEM field energies

KEM field energies

Fermat's method of Factoring

also known as 'the difference of two squares' is used to factorise large numbers

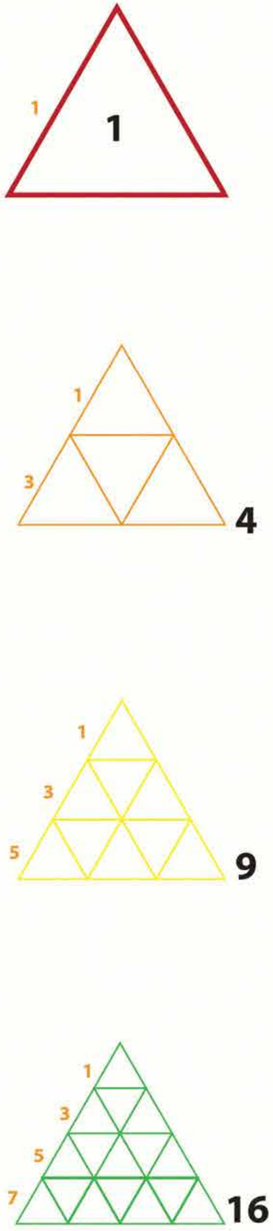
1
1
1
3
4
1
3
5
9
1
3
5
7
16

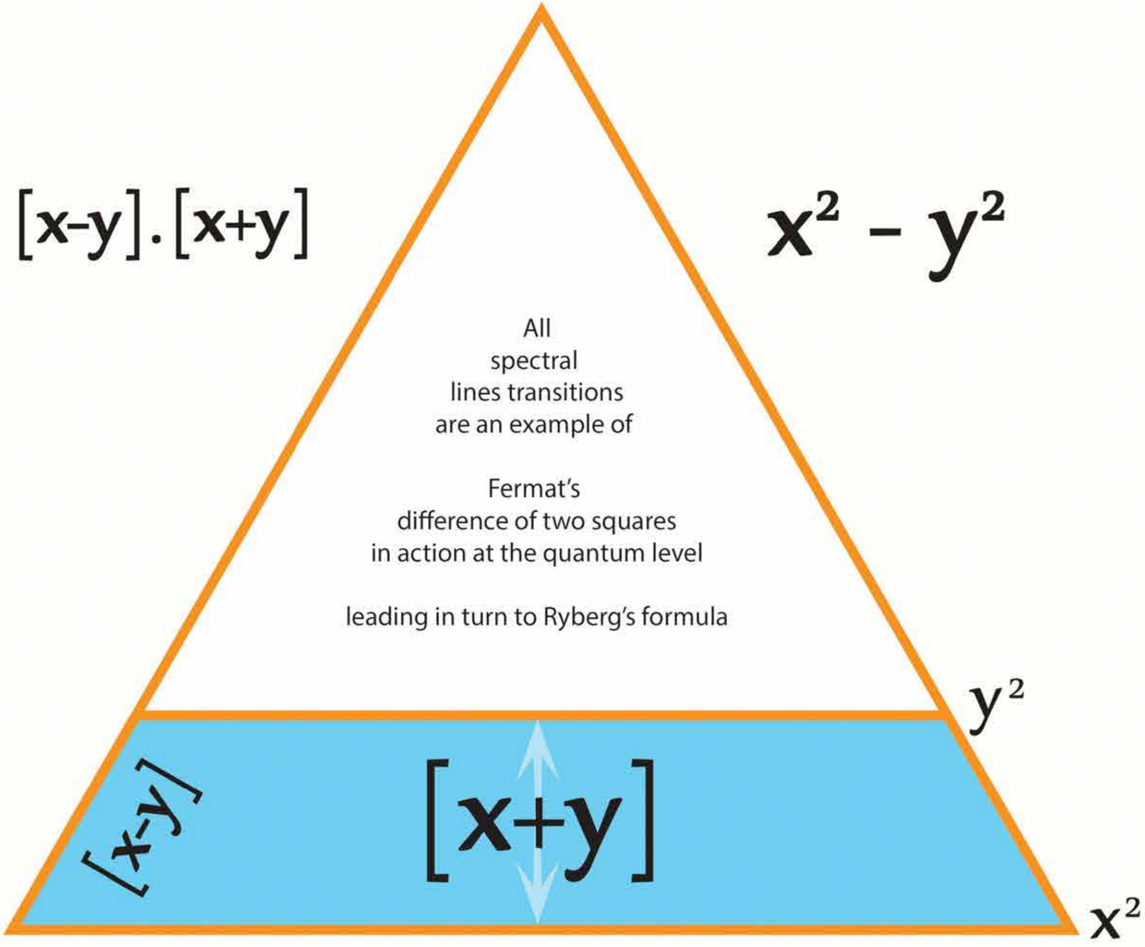

$$[x-y].[x+y]$$

$$x^2 - y^2$$

All
spectral
lines transitions
are an example of

Fermat's
difference of two squares
in action at the quantum level

leading in turn to Ryberg's formula

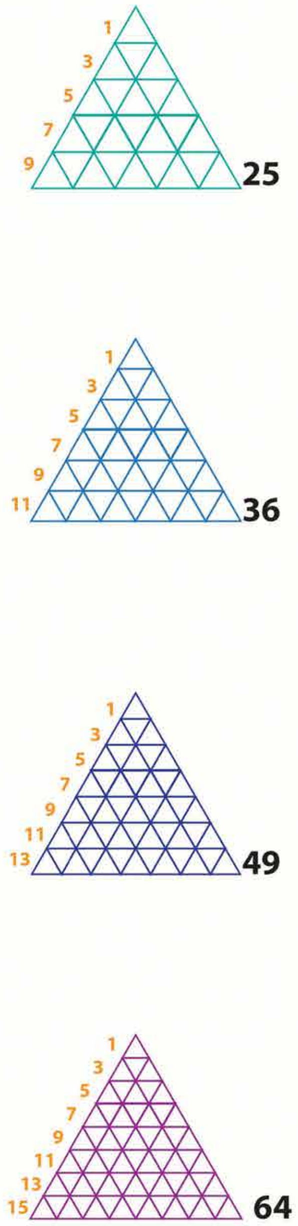
1
3
5
7
9
25
1
3
5
7
9
11
36
1
3
5
7
9
11
13
49
1
3
5
7
9
11
13
15
64

Fermat knew that every odd number could be written as the difference of two squares
or as revealed geometrically through Tetryonic theory's equilateral geometry,
every 'SQUARE' number is the sequential sum of ODD numbers

Fractions

A fraction is a number that shows how many equal parts there are

In quantum mechanics fractions appear in quantum steps
as a result of the equilateral geometry of Planck energy momenta

3/4

24/25

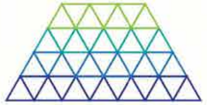

40/49

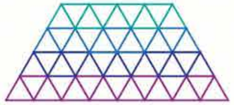

48/64

80/81

.987654321

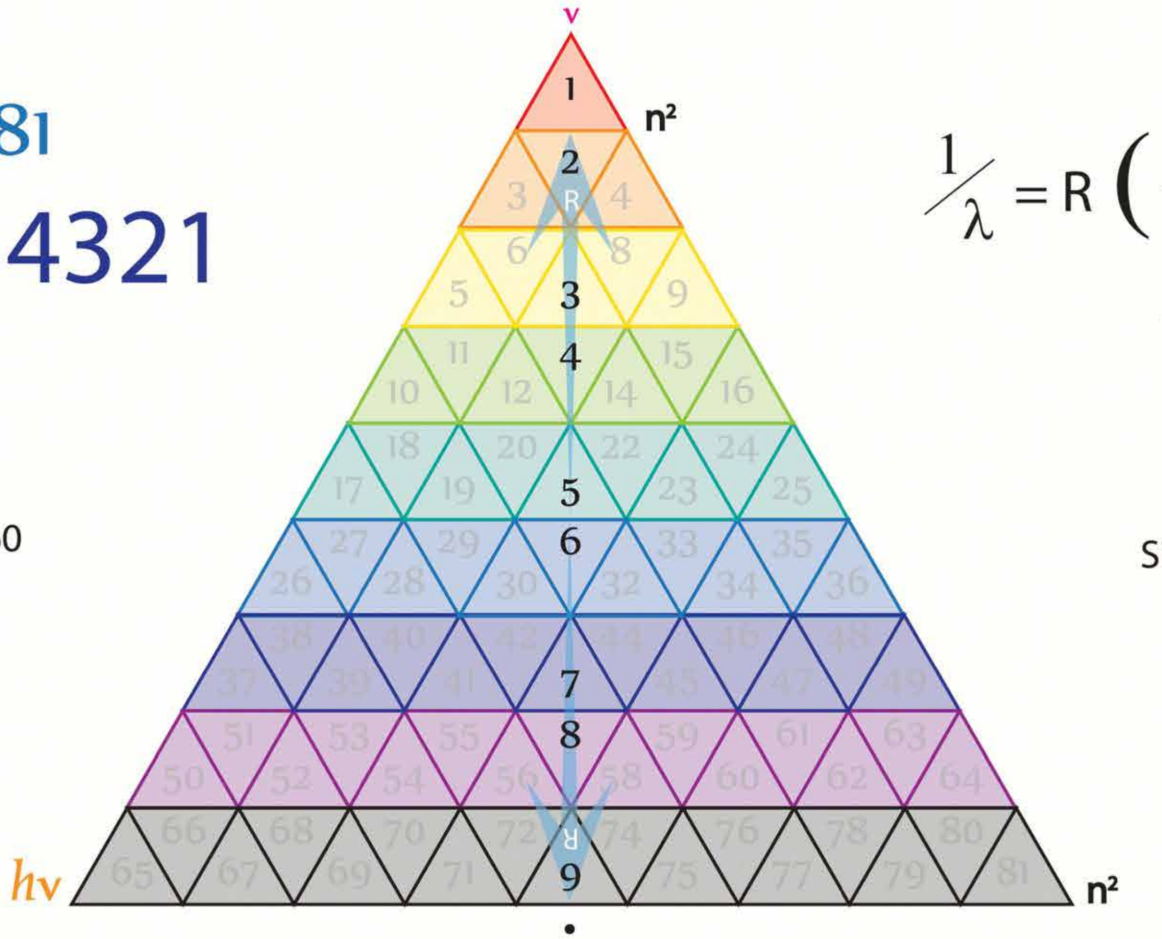
v
n²
1
2
3
4
5
6
7
8
9
R
R
n²
hv
3 4
5 6 8 9
10 11 12 14 15 16
17 18 19 20 22 23 24 25
26 27 28 29 30 32 33 34 35 36
37 38 39 40 41 42 44 45 46 47 48 49
50 51 52 53 54 55 56 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 74 75 76 77 78 79 80 81

$$\frac{1}{\lambda} = R\left(\frac{1}{1} - \frac{1}{81}\right)$$

.987654321

Cos 60

.5

1/2

Sin 60

.866025403

$\sqrt{3}/2$

Tetryonic geometry explains the fractional mathematics of Rydberg's formula

Lyman spectral transitions

$$\Delta h\nu \;=\; \mathrm{KEM} \;=\; hcR$$

Planck — 13.525 eV — Rydberg

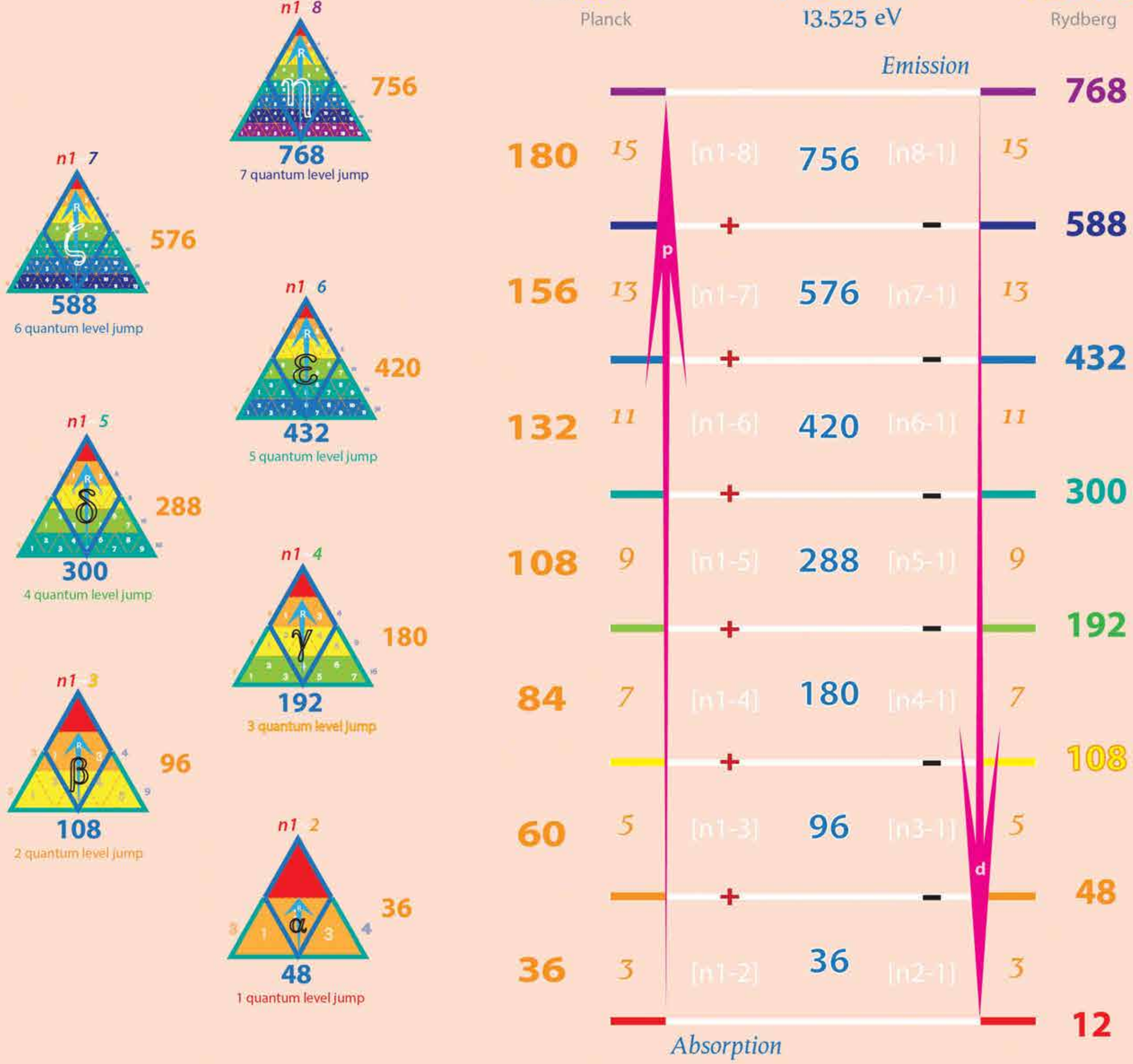
n1 8
756
768
7 quantum level jump
n1 7
576
588
6 quantum level jump
n1 6
420
432
5 quantum level jump
n1 5
288
300
4 quantum level jump
n1 4
180
192
3 quantum level jump
n1 3
96
108
2 quantum level jump
n1 2
36
48
1 quantum level jump
Emission
768
180 15 [n1-8] 756 [n8-1] 15
588
156 13 [n1-7] 576 [n7-1] 13
432
132 11 [n1-6] 420 [n6-1] 11
300
108 9 [n1-5] 288 [n5-1] 9
192
84 7 [n1-4] 180 [n4-1] 7
108
60 5 [n1-3] 96 [n3-1] 5
48
36 3 [n1-2] 36 [n2-1] 3
12
+
−
p
d
Absorption

			λ (nm)	$\tilde{\nu}$ (m-1)	f (Hz)	E (eV)	Ω (m²/s)		
768	63/64	.9843	93.17075598	10,732,981.5	3.217666905 x 10^{15}	13.31395504	27.93188995	$R\left(\frac{1}{1}-\frac{1}{64}\right)$	.984375
588	48/49	.9795	93.62569132	10,680,829.01	3.202031983 x 10^{15}	13.24926138	28.06827613	$R\left(\frac{1}{1}-\frac{1}{49}\right)$	.9795
432	35/36	.9722	94.33539043	10,600,475.55	3.177942622 x 10^{15}	13.14958523	28.28103857	$R\left(\frac{1}{1}-\frac{1}{36}\right)$	.9722
300	24/25	.9600	95.53641971	10,467,212.43	3.137991343 x 10^{15}	12.98427616	28.64109809	$R\left(\frac{1}{1}-\frac{1}{25}\right)$	.96
192	15/16	.9375	97.82929378	10,221,5587.14	3.064444671 x 10^{15}	12.67995718	29.32848443	$R\left(\frac{1}{1}-\frac{1}{16}\right)$	.9375
108	8/9	.8888	103.1793333	9,691,863.362	2.90554754 x 10^{15}	12.02247792	30.91238594	$R\left(\frac{1}{1}-\frac{1}{9}\right)$	.888
48	3/4	.7500	122.2866172	8,177,509.712	2.451555737 x 10^{15}	10.14396575	36.66660556	$R\left(\frac{1}{1}-\frac{1}{4}\right)$	.75
12									

$$\Delta M v^2$$

Balmer spectral transitions

$\Delta h\nu$ = KEM = hcR

Planck — 3.381 eV — Rydberg

768
6 quantum level jump

588
5 quantum level jump

432
4 quantum level jump

300
3 quantum level jump

192
2 quantum level jump

108
1 quantum level jump

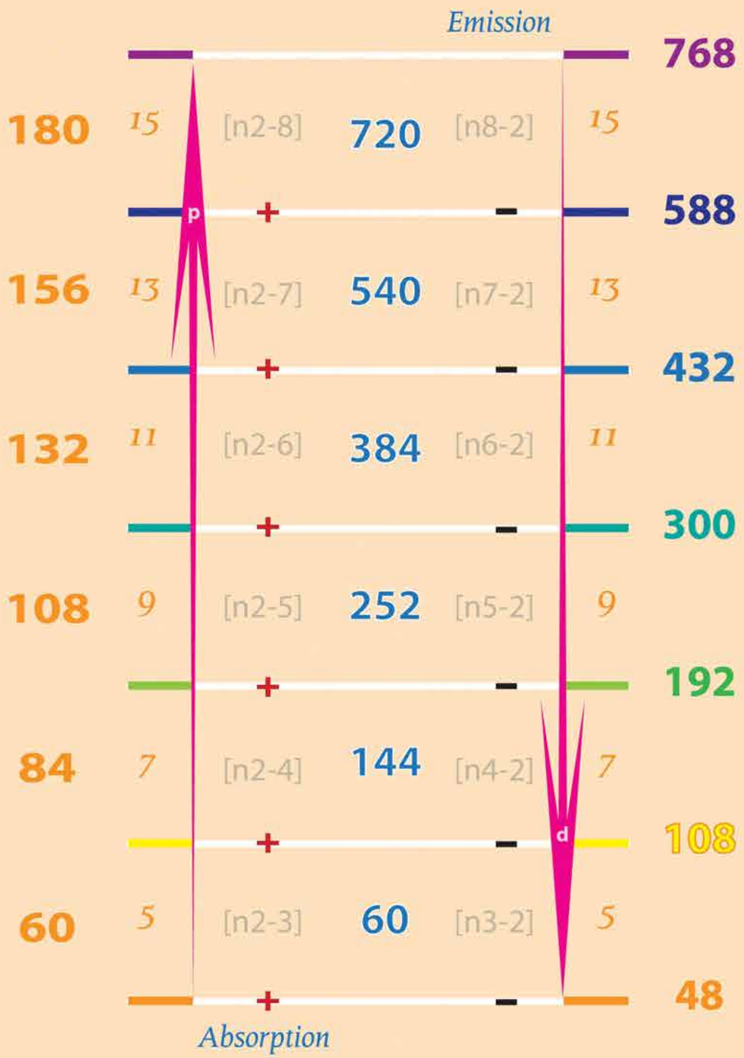

		Absorption		Emission		Level
						768
180	15	[n2-8]	720	[n8-2]	15	
						588
156	13	[n2-7]	540	[n7-2]	13	
						432
132	11	[n2-6]	384	[n6-2]	11	
						300
108	9	[n2-5]	252	[n5-2]	9	
						192
84	7	[n2-4]	144	[n4-2]	7	
						108
60	5	[n2-3]	60	[n3-2]	5	
						48

Level		λ (nm)	$\tilde{\nu}$ (m-1)	f (Hz)	E (eV)	Ω (m²/s)	
768	60/64 .2343	391.3171751	2,555,471.1785	7.661111677 x 10^{14}	3.169989296	103.1079531	$R\left(\frac{1}{4}-\frac{1}{64}\right)$ .2343
588	45/49 .2295	399.4696163	2,5033,319.299	7.50476246 x 10^{14}	3.105295637	101.0037092	$R\left(\frac{1}{4}-\frac{1}{49}\right)$ .2295
432	32/36 .2222	412.7173331	2,422,965.84	7.26386885 x 10^{14}	3.00561948	97.76161483	$R\left(\frac{1}{4}-\frac{1}{36}\right)$ .2222
300	21/25 .2100	436.7379187	2,289,702.719	6.864356063 x 10^{14}	2.840310409	92.38472601	$R\left(\frac{1}{4}-\frac{1}{25}\right)$ .21
192	12/16 .1875	489.1464689	2,044,377.428	6.128889342 x 10^{14}	2.535991437	82.48636251	$R\left(\frac{1}{4}-\frac{1}{16}\right)$ .1875
108	5/9 .138	660.347733	1,514,353.65	4.539918031 x 10^{14}	1.878512175	61.10100927	$R\left(\frac{1}{4}-\frac{1}{9}\right)$ .138
48							

$\Delta M v^2$

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Paschen spectral transitions

$$\Delta h\nu = \text{KEM} = hcR$$

Planck

1.502 eV

Rydberg

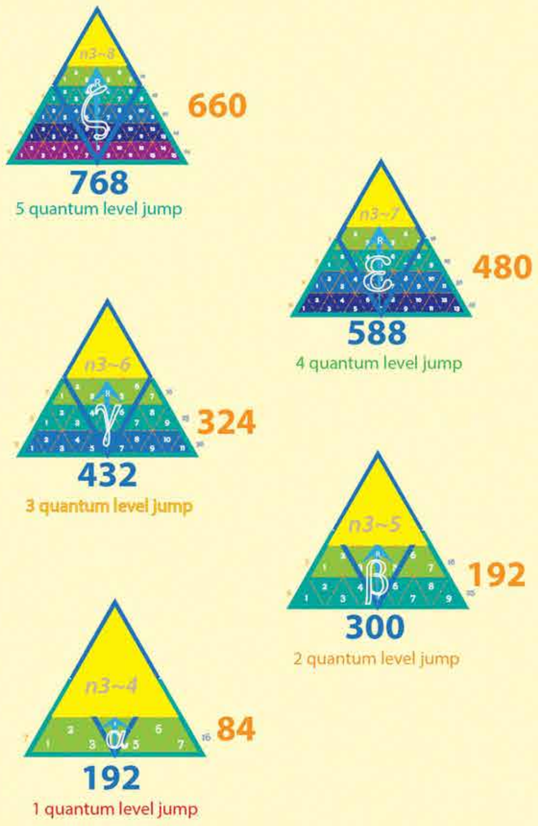

660

768

5 quantum level jump

480

588

4 quantum level jump

324

432

3 quantum level jump

192

300

2 quantum level jump

84

192

1 quantum level jump

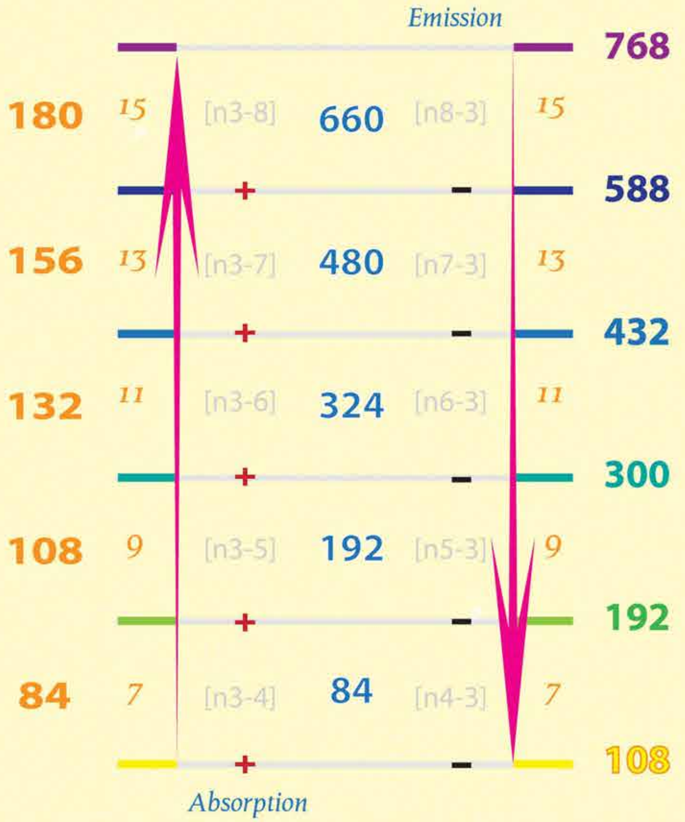

Emission

							768
180	15	[n3-8]	660	[n8-3]	15		
		+		−			588
156	13	[n3-7]	480	[n7-3]	13		
		+		−			432
132	11	[n3-6]	324	[n6-3]	11		
		+		−			300
108	9	[n3-5]	192	[n5-3]	9		
		+		−			192
84	7	[n3-4]	84	[n4-3]	7		
		+		−			108

Absorption

55/64

.0954

λ	960.5057935	nm
ṽ	1,041,118.135	m-1
ƒ	3.121193646 x 10^{14}	Hz
E	**1.29147712**	**eV**
Ω	287.9523928	m^2/s

$R\left(\frac{1}{9}-\frac{1}{64}\right)$

.09548

40/49

.0907

λ	1,011.157466	nm
ṽ	988,965.6492	m-1
ƒ	2.9464844428 x 10^{14}	Hz
E	**1.226783461**	**eV**
Ω	303.1373822	m^2/s

$R\left(\frac{1}{9}-\frac{1}{49}\right)$

.0907

27/36

.8033

λ	1,100.579555	nm
ṽ	908,612.1902	m-1
ƒ	2.723950819 x 10^{14}	Hz
E	**1.127107305**	**eV**
Ω	329.94545	m^2/s

$R\left(\frac{1}{9}-\frac{1}{36}\right)$

.0833

16/25

.0711

λ	1,289.741666	nm
ṽ	775,349.069	m-1
ƒ	2.324438032 x 10^{14}	Hz
E	**0.961798233**	**eV**
Ω	386.6548243	m^2/s

$R\left(\frac{1}{9}-\frac{1}{25}\right)$

.0711

7/16

.0486

λ	1,886.707809	nm
ṽ	530,023.7776	m-1
ƒ	1.588971311 x 10^{14}	Hz
E	**0.657479261**	**eV**
Ω	565.6207715	m^2/s

$R\left(\frac{1}{9}-\frac{1}{16}\right)$

.0486

ΔMv^2

Brackett spectral transitions

$$\Delta h\nu = \text{KEM} = hcR$$

Planck 0.8451 eV Rydberg

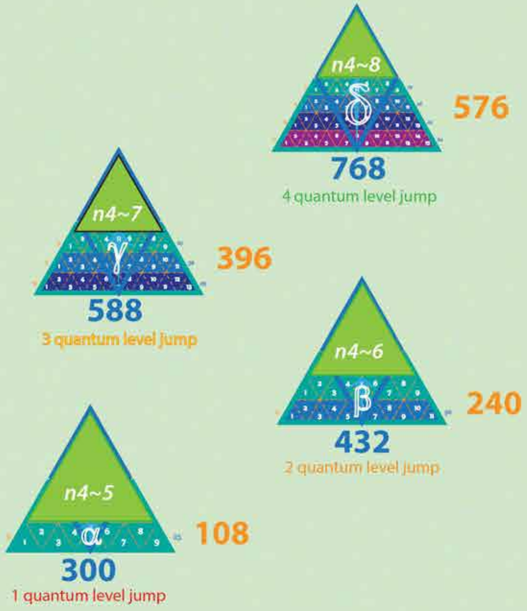
n4~8
δ
576
768
4 quantum level jump
n4~7
γ
396
588
3 quantum level jump
n4~6
β
240
432
2 quantum level jump
n4~5
α
108
300
1 quantum level jump

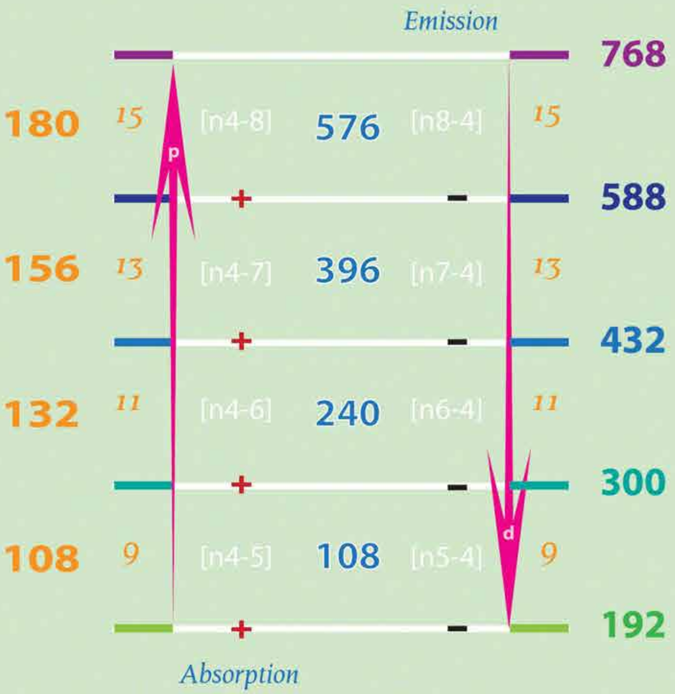
Emission
768
180
15
p
[n4-8]
576
[n8-4]
15
588
156
13
[n4-7]
396
[n7-4]
13
432
132
11
[n4-6]
240
[n6-4]
11
300
108
9
[n4-5]
108
[n5-4]
9
d
192
+
−
Absorption

48/64
.0468

λ	1.956.585876	nm
ṽ	511,094.357	m-1
ƒ	1.532222335 x 10 ¹⁴	Hz
E	**0.634001085**	**eV**
Ω	586.569689	m²/s

$R\left(\frac{1}{16}-\frac{1}{64}\right)$ .0468

33/49
.04209

λ	2,178.92518	nm
ṽ	458,941.8716	m-1
ƒ	1.375873118 x 10¹⁴	Hz
E	**0.569307096**	**eV**
Ω	653.2253354	m²/s

$R\left(\frac{1}{16}-\frac{1}{49}\right)$ .04209

20/36
.0347

λ	2.641.390932	nm
ṽ	378,588.4126	m-1
ƒ	1.134979508 x 10¹⁴	Hz
E	**0.469630433**	**eV**
Ω	791.8690801	m²/s

$R\left(\frac{1}{16}-\frac{1}{36}\right)$ .0347

9/25
.0225

λ	4,076.220574	nm
ṽ	245,325.2914	m-1
ƒ	7.35466721x 10 ¹³	Hz
E	**0.30432052**	**eV**
Ω	1,222.020185	m²/s

$R\left(\frac{1}{16}-\frac{1}{25}\right)$ .0225

ΔMv^2

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Pfund spectral transitions

$$\Delta h\nu = \mathrm{KEM} = hcR$$

Planck P — 0.541 eV — Rydberg

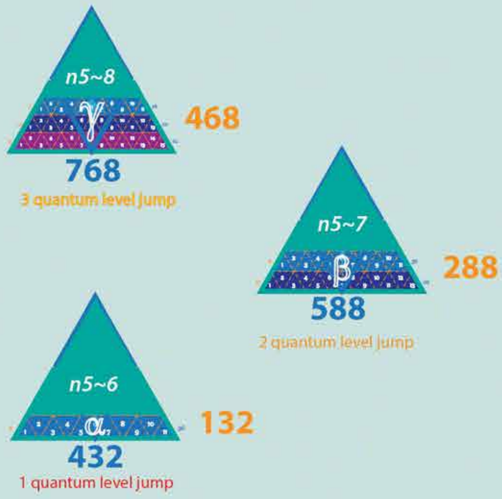

n5~8
γ
468
768
3 quantum level jump
n5~7
β
288
588
2 quantum level jump
n5~6
α
132
432
1 quantum level jump

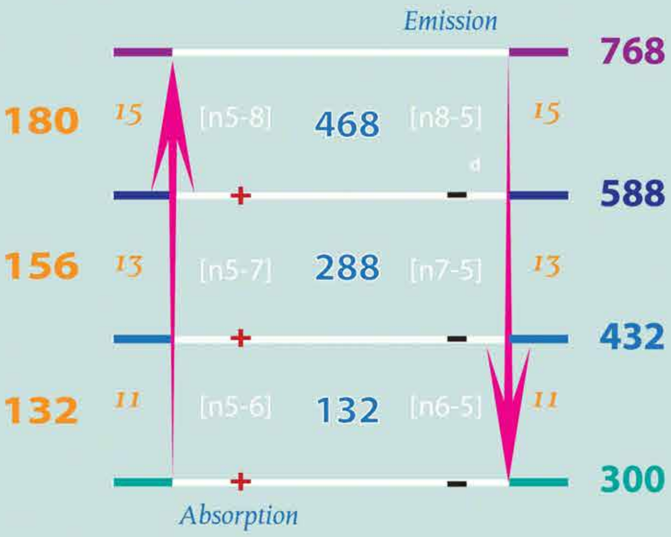

Emission
768
588
432
300
180
156
132
15
13
11
[n5-8]
468
[n8-5]
[n5-7]
288
[n7-5]
[n5-6]
132
[n6-5]
+
−
d
Absorption

39/64

.0243

λ	3,762.665146	nm
$\tilde{\nu}$	265,769.0656	m-1
f	7.967556145 x 10^{13}	Hz
E	**0.329678886**	**eV**
Ω	1,128.018633	m^2/s

$$R\left(\frac{1}{25}-\frac{1}{64}\right)$$

.0243

24/49

.0195

λ	4,681.284566	nm
$\tilde{\nu}$	213,616.5802	m-1
f	6.404063965 x 10^{13}	Hz
E	**0.264985227**	**eV**
Ω	1,403.413807	m^2/s

$$R\left(\frac{1}{25}-\frac{1}{49}\right)$$

.01959

11/36

.0122

λ	7,503.951512	nm
$\tilde{\nu}$	133,263.1212	m-1
f	3.995127867 x 10^{13}	Hz
E	**0.165309071**	**eV**
Ω	2,249.628068	m^2/s

$$R\left(\frac{1}{25}-\frac{1}{36}\right)$$

.0122

$$\Delta M v^2$$

Humphreys spectral transitions

$$\Delta h\nu \;=\; \text{KEM} \;=\; hcR$$

Planck

0.375 eV

Rydberg

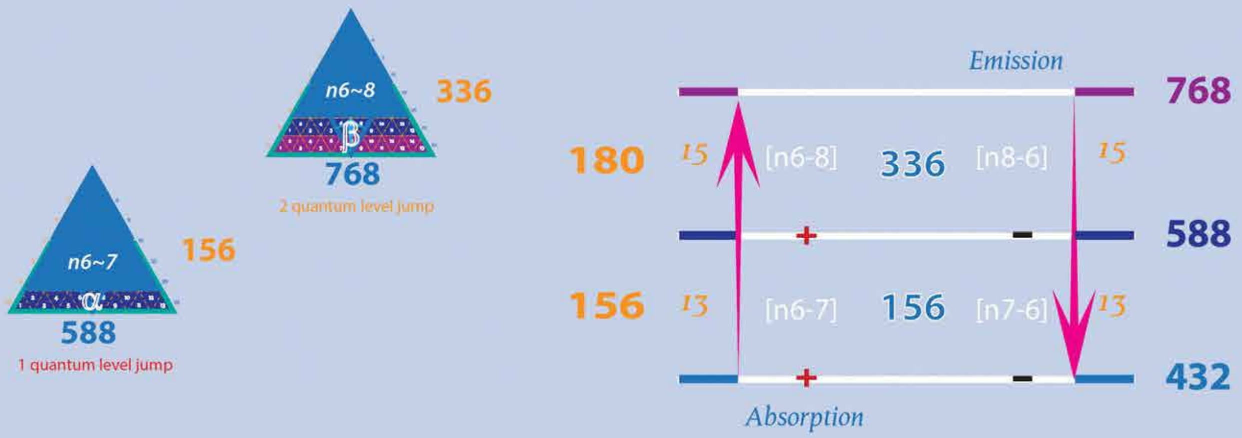
n6~8
β
336
768
2 quantum level jump
n6~7
α
156
588
1 quantum level jump
Emission
Absorption
180
15
156
13
[n6-8]
336
[n8-6]
15
[n6-7]
156
[n7-6]
13
+
−
+
−
768
588
432

28/64

.01215

λ	7,546.831235	nm
$\tilde{\nu}$	132,505.9444	m-1
ƒ	$3.972428277 \times 10^{13}$	Hz
E	0.164369815	eV
Ω	1,128.018633	m^2/s

$$R\left(\frac{1}{36} - \frac{1}{64}\right)$$

.01215

13/49

.00733

λ	12,445.01497	nm
$\tilde{\nu}$	80,353.459	m-1
ƒ	$2.4089936098 \times 10^{13}$	Hz
E	0.099676156	eV
Ω	1,403.413807	m^2/s

$$R\left(\frac{1}{36} - \frac{1}{49}\right)$$

.0073

$\Delta M v^2$

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Un-named spectral transition

$$\Delta h\nu \quad = \quad \text{KEM} \quad = \quad hcR$$

Planck — 0.276 eV — Rydberg

$\Delta\nu$ $\quad$ $\Sigma\nu$ $\quad$ $M\nu^2$

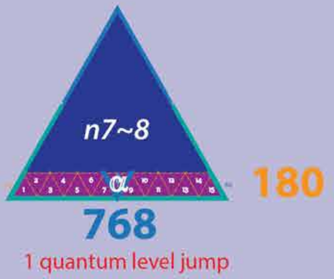
n7~8
1
2
3
4
5
6
7
α
9
10
11
12
13
14
15
180
768
1 quantum level jump

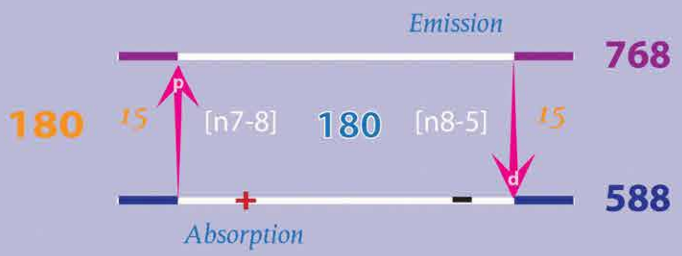
Emission
768
180
15
p
[n7-8]
180
[n8-5]
15
d
+
-
588
Absorption

15/64

.0047

λ	19,174.54158	nm
$\tilde{\nu}$	52,152.48541	m-1
f	$1.563492179 \times 10^{13}$	Hz
E	0.064693658	eV
Ω	5,748.382952	m²/s

$$R\left(\frac{1}{49}-\frac{1}{64}\right)$$

.0047

$\Delta M\nu^2$

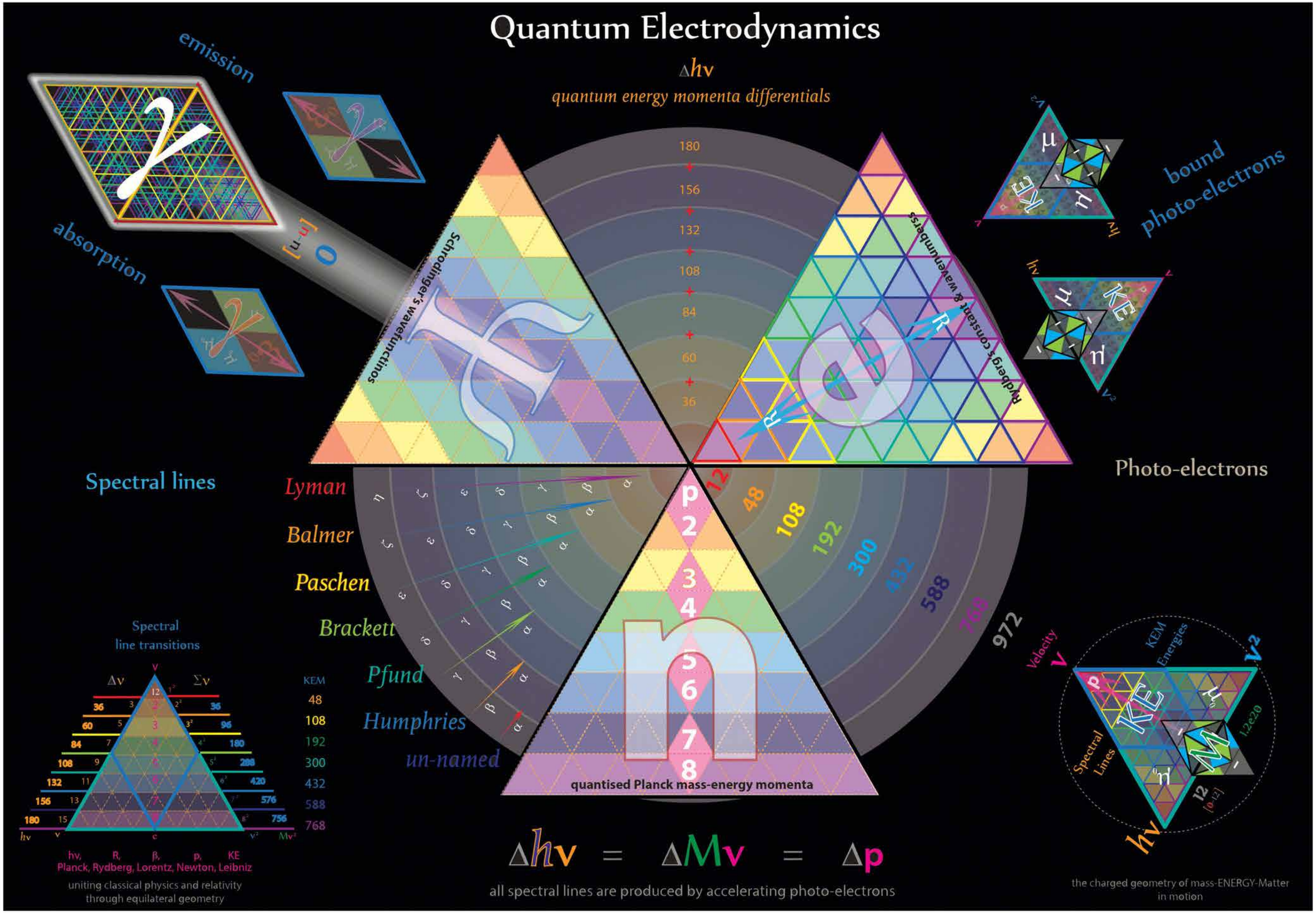

Quantum Electrodynamics

Δhv

quantum energy momenta differentials

$$\Delta hv = \Delta Mv = \Delta p$$

all spectral lines are produced by accelerating photo-electrons

emission
absorption
[n-u]
0
Schrodinger's wavefunctions
Rydberg's constant & wavenumbers
R
R
180
156
132
108
84
60
36
bound
photo-electrons
KE
μ
hv
v
v²
Photo-electrons
Spectral lines
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
α
β
γ
δ
ε
ζ
η
p
2
3
4
5
6
7
8
n
quantised Planck mass-energy momenta
12
48
108
192
300
432
588
768
972
Velocity
v
KEM
Energies
v²
Spectral
Lines
KE
M
1.2e20
12
[Φ 12]
hv
the charged geometry of mass-ENERGY-Matter
in motion
Spectral
line transitions
Δv
Σv
v
12
1²
2²
3²
4²
5²
6²
7²
8²
3
5
7
9
11
13
15
36
60
84
108
132
156
180
36
96
180
288
420
576
756
KEM
48
108
192
300
432
588
768
hv
v
c
v²
Mv²
hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz
uniting classical physics and relativity
through equilateral geometry

Tetryonics 96.11 - Atomic spectral series transitions

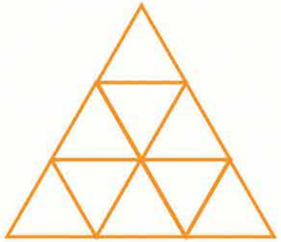

ninths

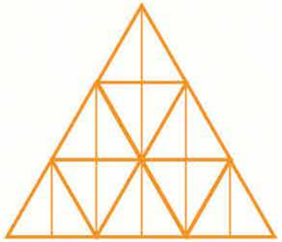

eigteenths

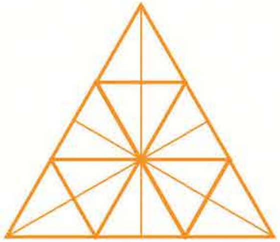

Eighteenths

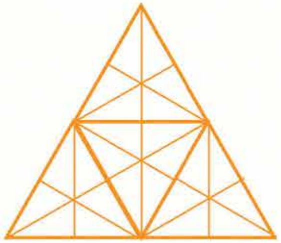

Twenty-fourths

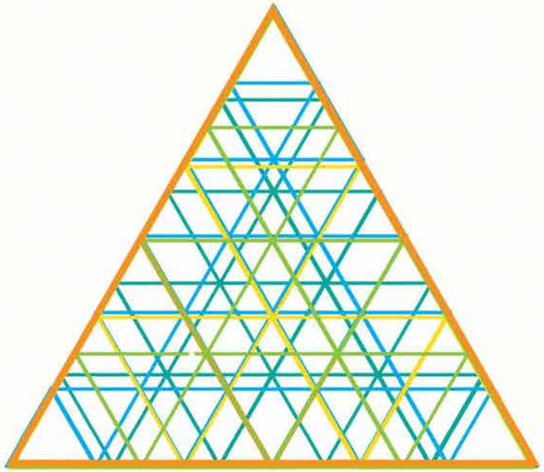

Fractionals and fractals

White light
[EM radiation]
is comprised of many
superpositioned
frequencies

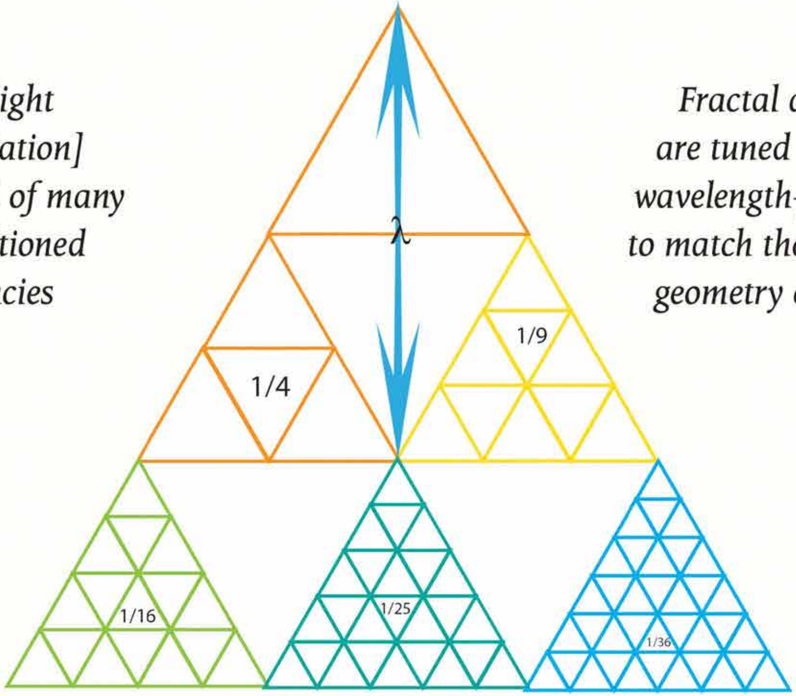

Fractal antennas
are tuned to specific
wavelength-frequencies
to match the equilateral
geometry of photons

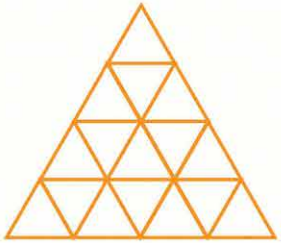

Sizteenths

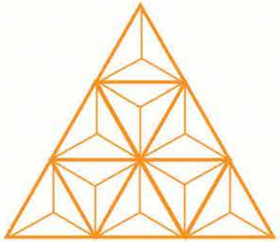

Twenty-sevenths

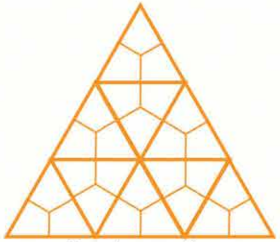

Twenty-sevenths

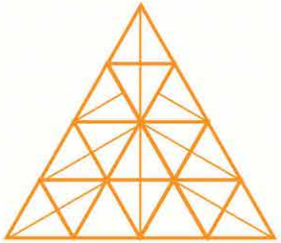

Thirty-seconds

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Polygons and Angles

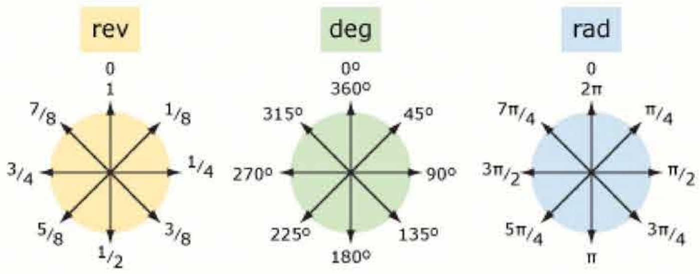
rev
0
1
1/8
1/4
3/8
1/2
5/8
3/4
7/8
deg
0°
360°
45°
90°
135°
180°
225°
270°
315°
rad
0
2π
π/4
π/2
3π/4
π
5π/4
3π/2
7π/4

polygon exterior and interior angles

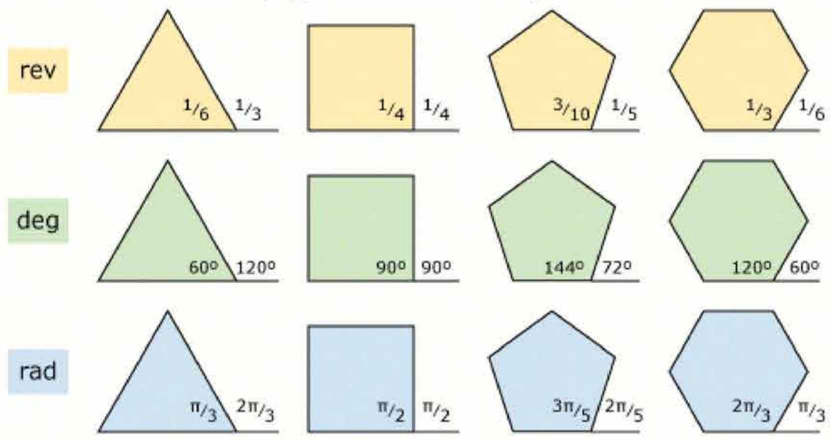
rev
1/6
1/3
1/4
1/4
3/10
1/5
1/3
1/6
deg
60°
120°
90°
90°
144°
72°
120°
60°
rad
π/3
2π/3
π/2
π/2
3π/5
2π/5
2π/3
π/3

dividing the circle

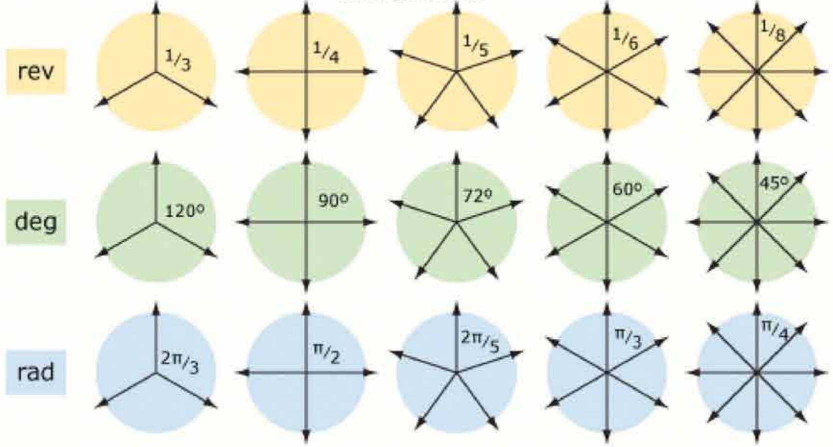
rev
1/3
1/4
1/5
1/6
1/8
deg
120°
90°
72°
60°
45°
rad
2π/3
π/2
2π/5
π/3
π/4

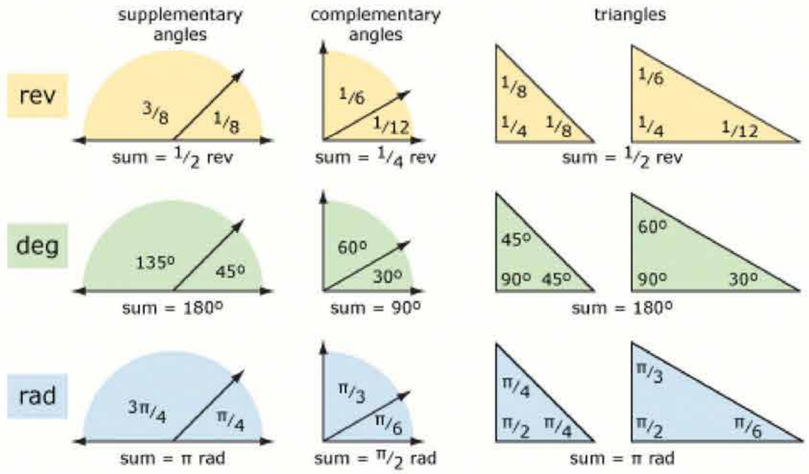
supplementary angles
complementary angles
triangles
rev
3/8
1/8
sum = 1/2 rev
1/6
1/12
sum = 1/4 rev
1/8
1/4
1/8
1/6
1/4
1/12
sum = 1/2 rev
deg
135°
45°
sum = 180°
60°
30°
sum = 90°
45°
90°
45°
60°
90°
30°
sum = 180°
rad
3π/4
π/4
sum = π rad
π/3
π/6
sum = π/2 rad
π/4
π/2
π/4
π/3
π/2
π/6
sum = π rad

Pi vs Tau

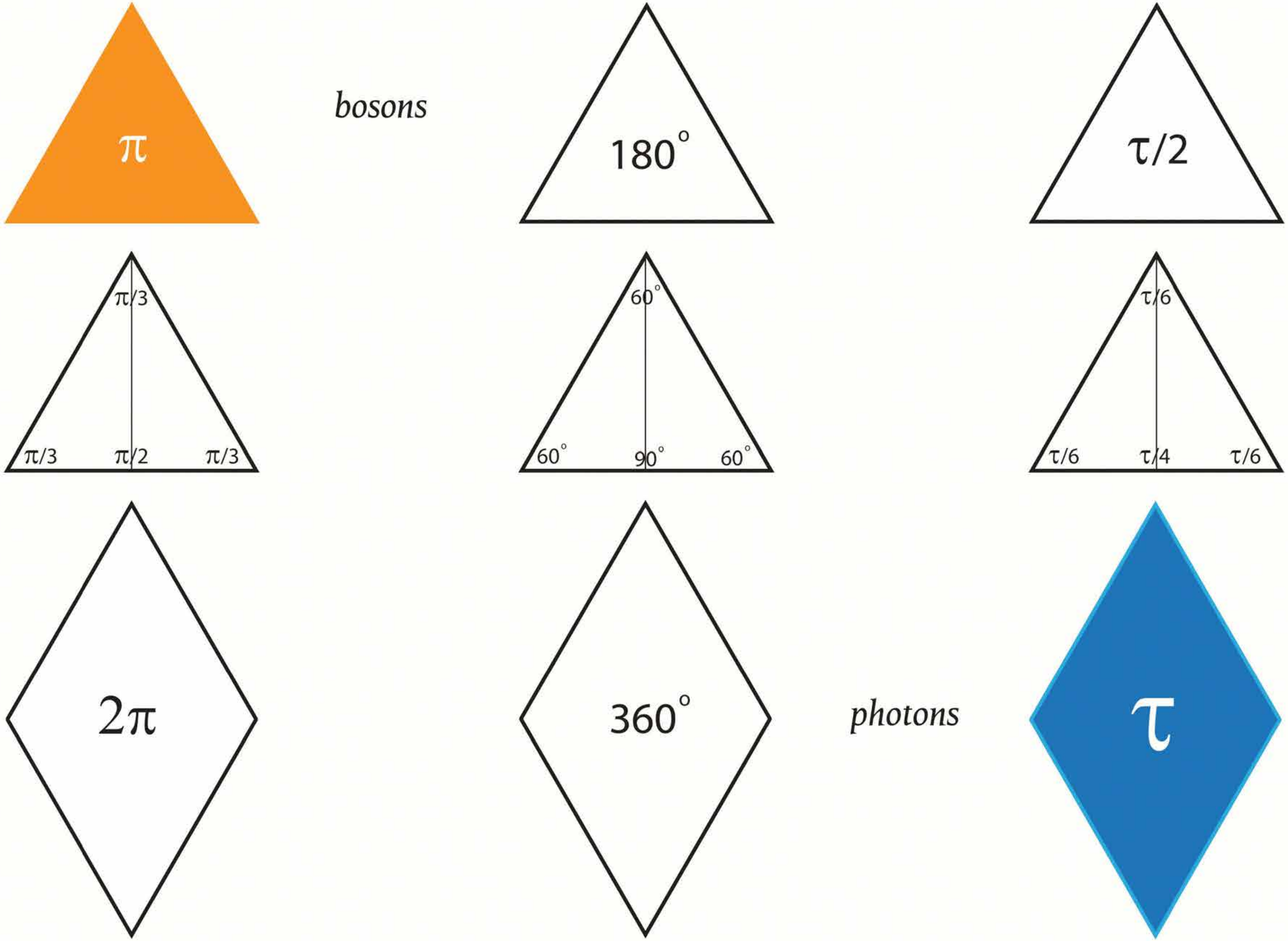
π
bosons
180°
τ/2
π/3
π/3
π/2
π/3
60°
60°
90°
60°
τ/6
τ/6
τ/4
τ/6
2π
360°
photons
τ

Triangular dissection of an equilateral triangle

is a way of dividing up a original triangle into smaller equilateral triangles,
such that none of the smaller triangles overlap

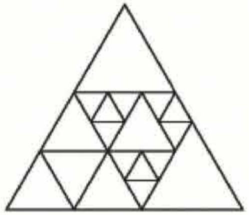

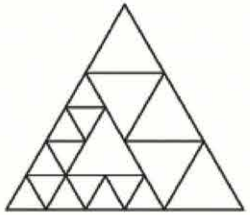

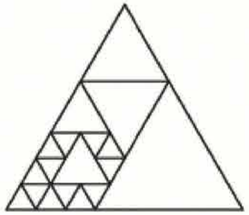

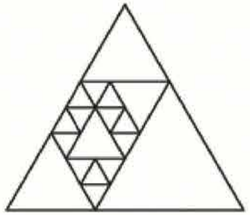

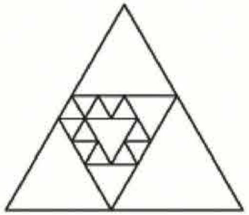

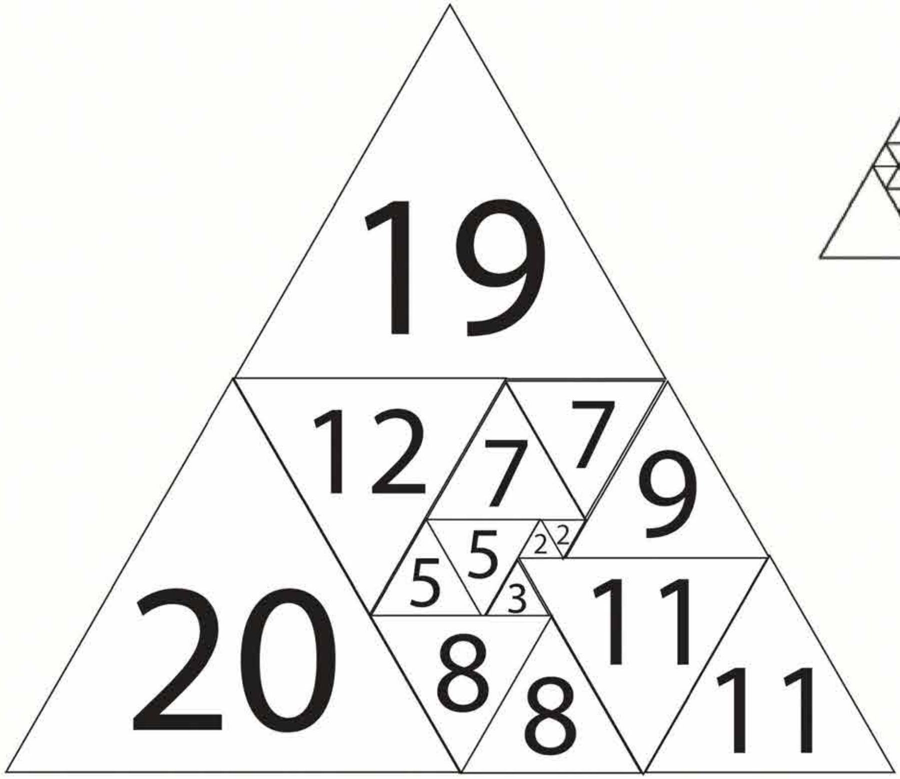

lowest order perfect equilateral triangle dissected by equilateral triangles

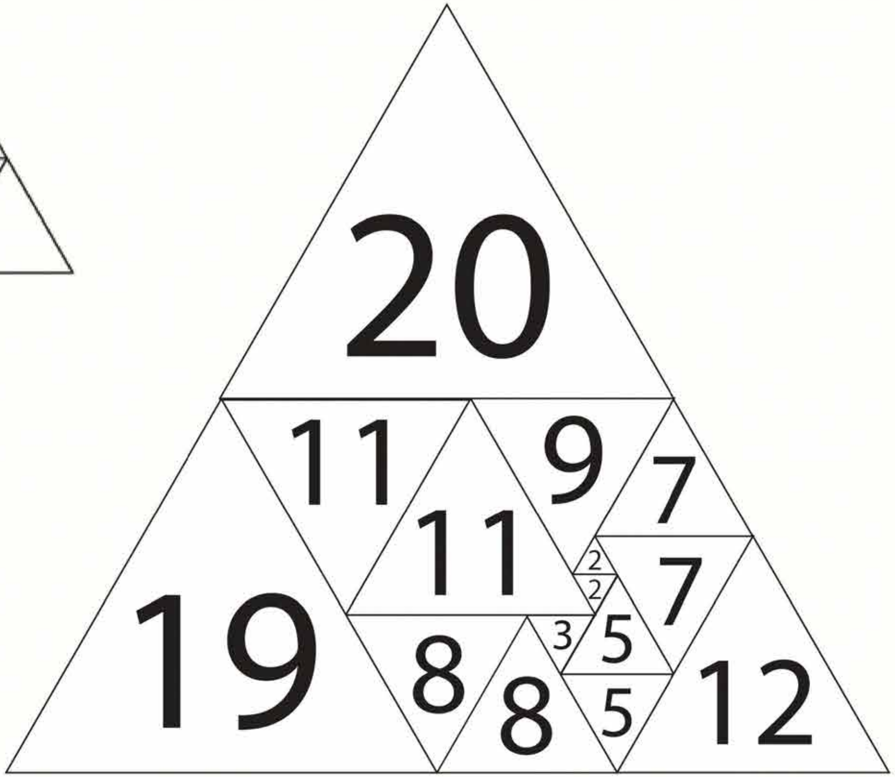

lowest order perfect dissected equilateral triangle, an isomer of the first

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Golden mean Spirals

Golden Mean Spiral – This spiral is derived via the golden rectangle, a unique rectangle which has the golden ratio.
This form is found everywhere in nature: the Nautilus Shell, the face of a Sunflower, fingerprints, our DNA, and the shape of the Milky Way

Golden spiral

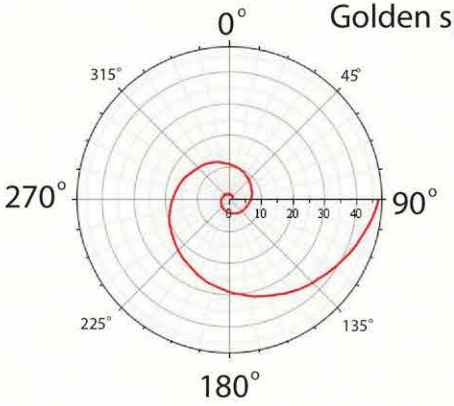

$0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, \ldots$

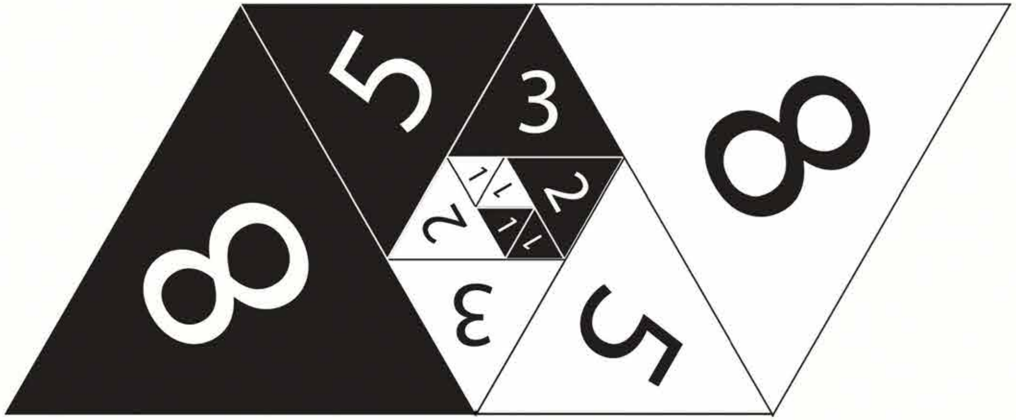

Golden spirals

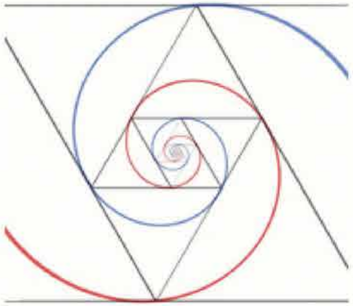

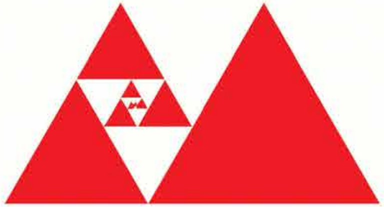

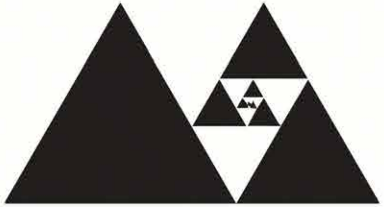

Continued fractions and the Fibonacci sequence

The convergence of the continued fractions

$$1+\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\frac{1}{1+}\cdots$$

are:

$$\frac{2}{1},\ \frac{3}{2},\ \frac{5}{3},\ \frac{8}{5},\ \frac{13}{8},\ \frac{21}{13},\ \frac{34}{21},\ \frac{55}{34},\ \frac{89}{55},\ \frac{144}{89},\ \frac{233}{144},\ \frac{377}{233},\ \frac{610}{377},$$

The Golden Ratio (Golden Mean, Golden Section)
is defined mathematically as:

$$\varphi = \frac{1+\sqrt{5}}{2} = 1.6180339887\ldots.$$

Koch fractal Curve

Niels Fabian Helge von Koch (January 25, 1870 – March 11, 1924) was a Swedish mathematician who gave his name to one of the earliest fractal curves ever known

He described the Koch curve, or Koch snowflakes as it popularly known, in a 1904 paper entitled "On a continuous curve without tangents constructible from elementary geometry"

Von Koch wrote several papers on number theory . One of his results was a 1901 theorem proving that the Riemann hypothesis is equivalent to a strengthened form of the prime number theorem.

Three Koch curves form the snowflake.

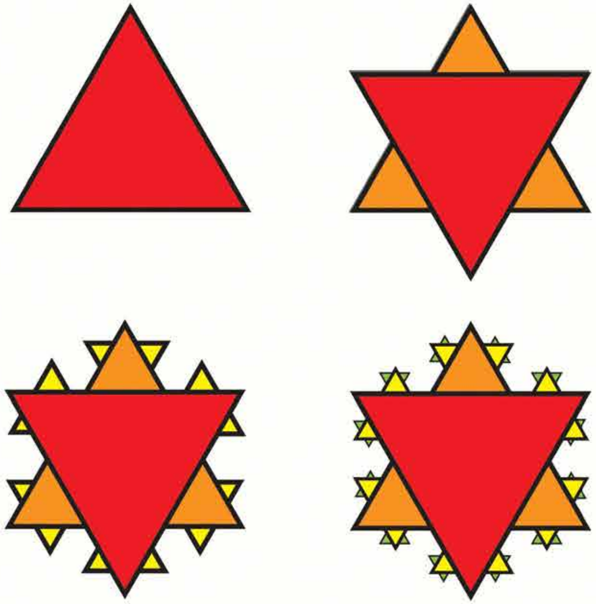

The Koch snowflake (or Koch star) is a mathematical curve and one of the earliest fractal curves to have been described.

Actually Koch described what is now known as the Koch curve, which is the same as the now popular snowflake, except it starts with a line segment instead of an equilateral triangle.

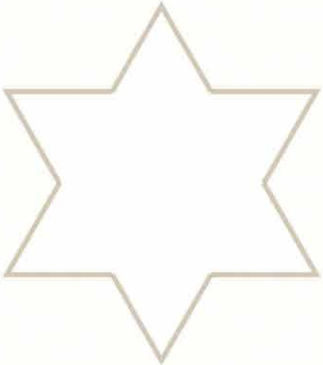

$$a = \frac{1}{2} + \frac{i}{\sqrt{12}}$$

The Koch curve is a special case of the Cesaro curve where:

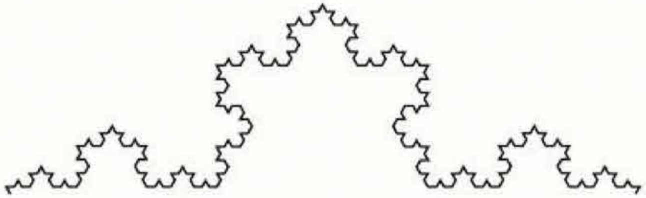

which is in turn a special case of the de Rham curve.

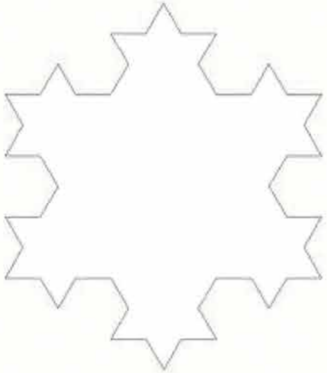

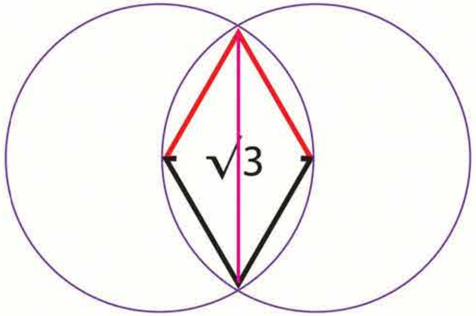

vesica piscis

$$\frac{1351}{780} > \sqrt{3} > \frac{265}{153}.$$

Koch snowflake

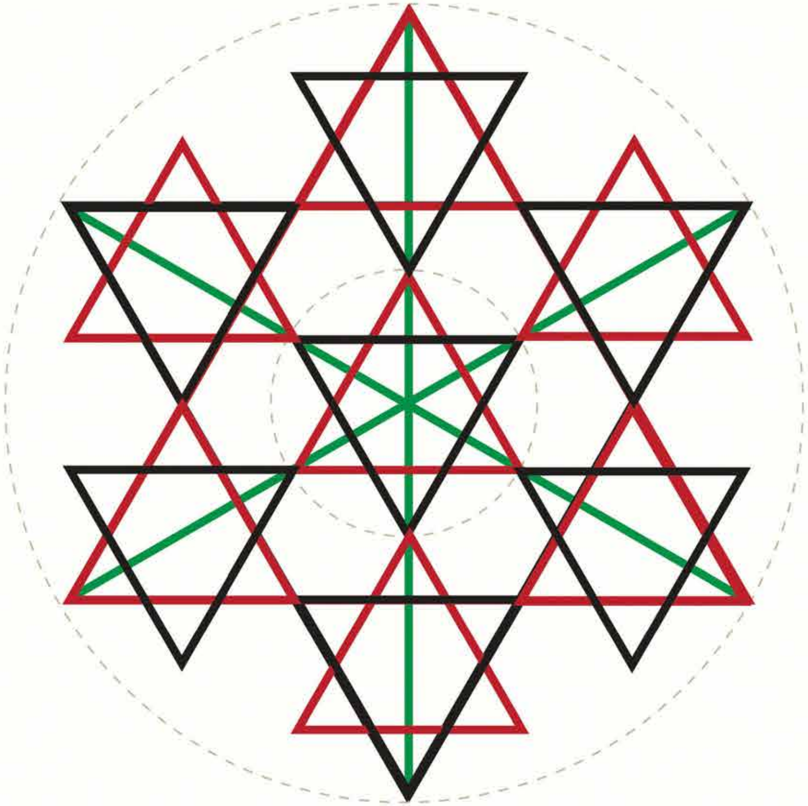

space-time

star tetrahedron

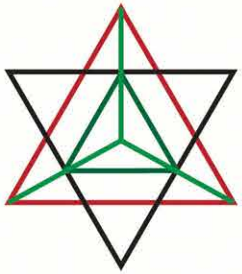

Flower of Life

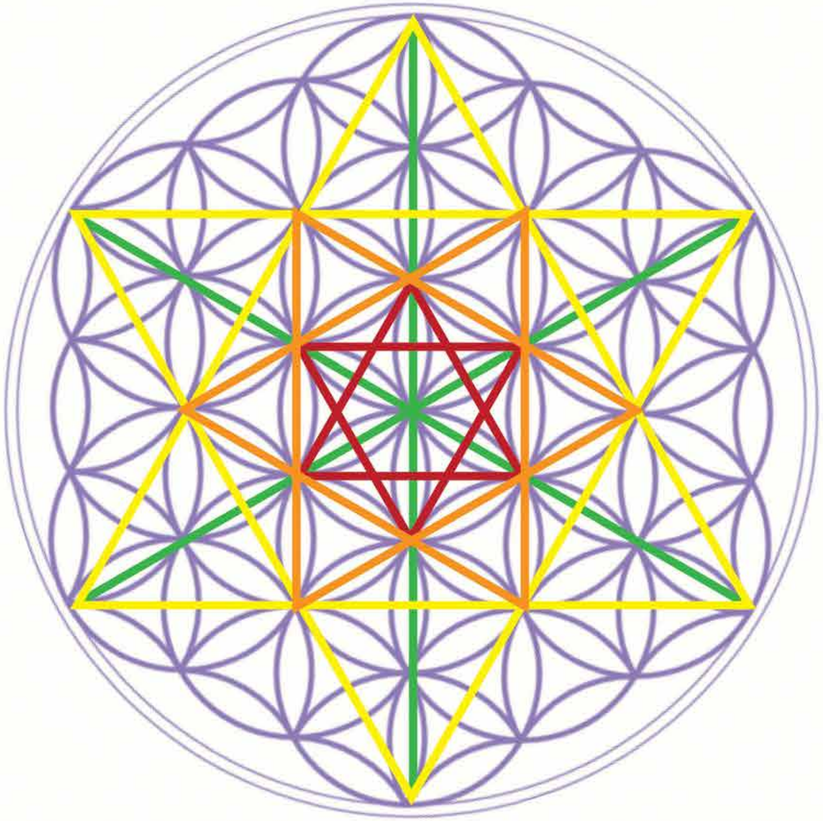

The Flower of Life is a name for a geometrical figure composed of multiple evenly-spaced, overlapping circles.

Unit circles - SINE WAVES - Photons

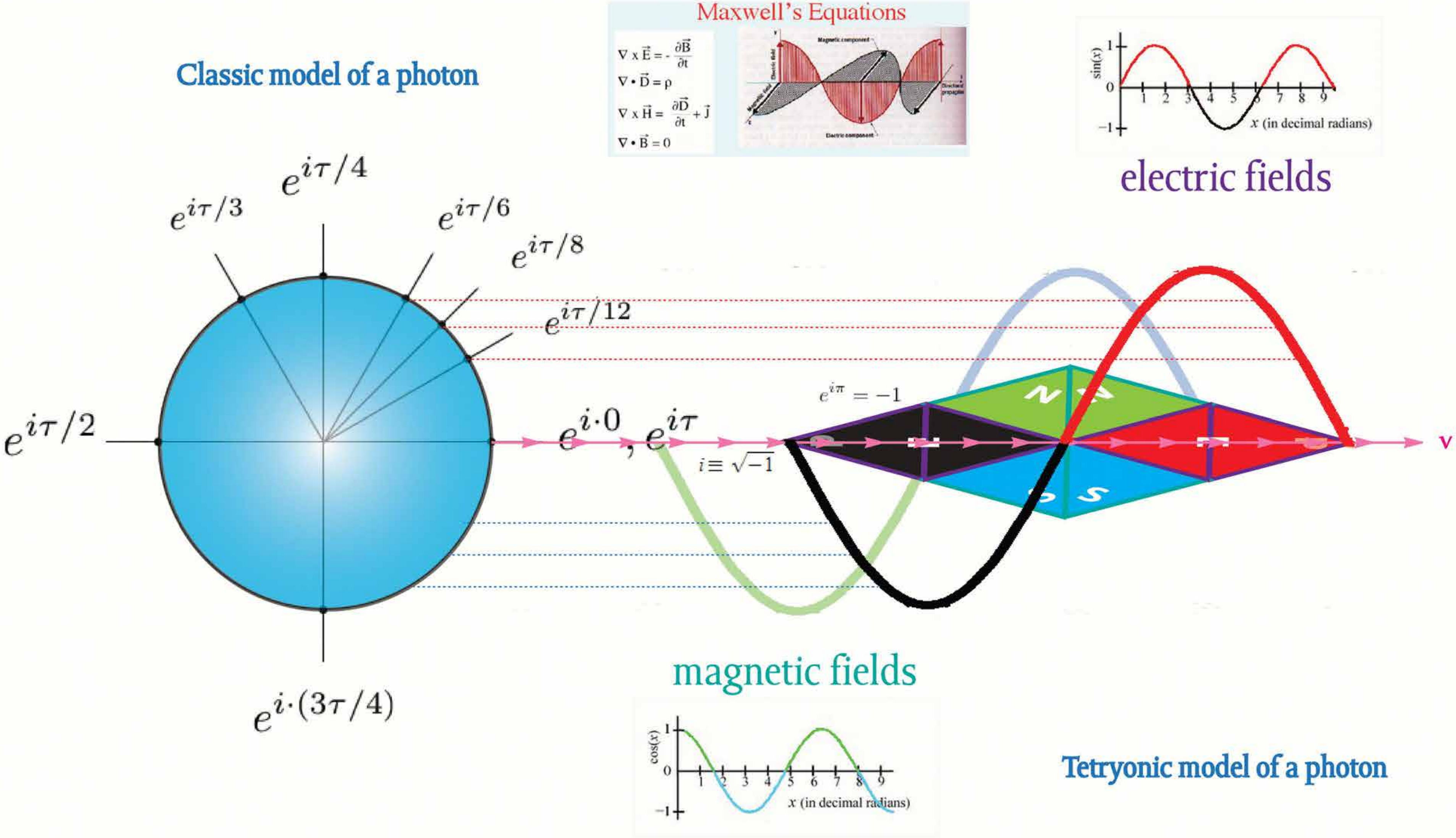

Classic model of a photon

Maxwell's Equations

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{D} = \rho$$

$$\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} + \vec{J}$$

$$\nabla \cdot \vec{B} = 0$$

electric fields

magnetic fields

Tetryonic model of a photon

Magnetic component
Electric component
Direction of propagation
$\sin(x)$
1
0
−1
1 2 3 4 5 6 7 8 9
x (in decimal radians)
$e^{i\tau/4}$
$e^{i\tau/3}$
$e^{i\tau/6}$
$e^{i\tau/8}$
$e^{i\tau/12}$
$e^{i\tau/2}$
$e^{i\cdot 0}, e^{i\tau}$
$e^{i\pi} = -1$
$i \equiv \sqrt{-1}$
N
N
S
S
v
$e^{i\cdot(3\tau/4)}$
$\cos(x)$
1
0
−1
1 2 3 4 5 6 7 8 9
x (in decimal radians)

Magnetic waveforms are 90 degrees out of phase with Electric waveforms

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Boson distributions in monochromatic EM waves

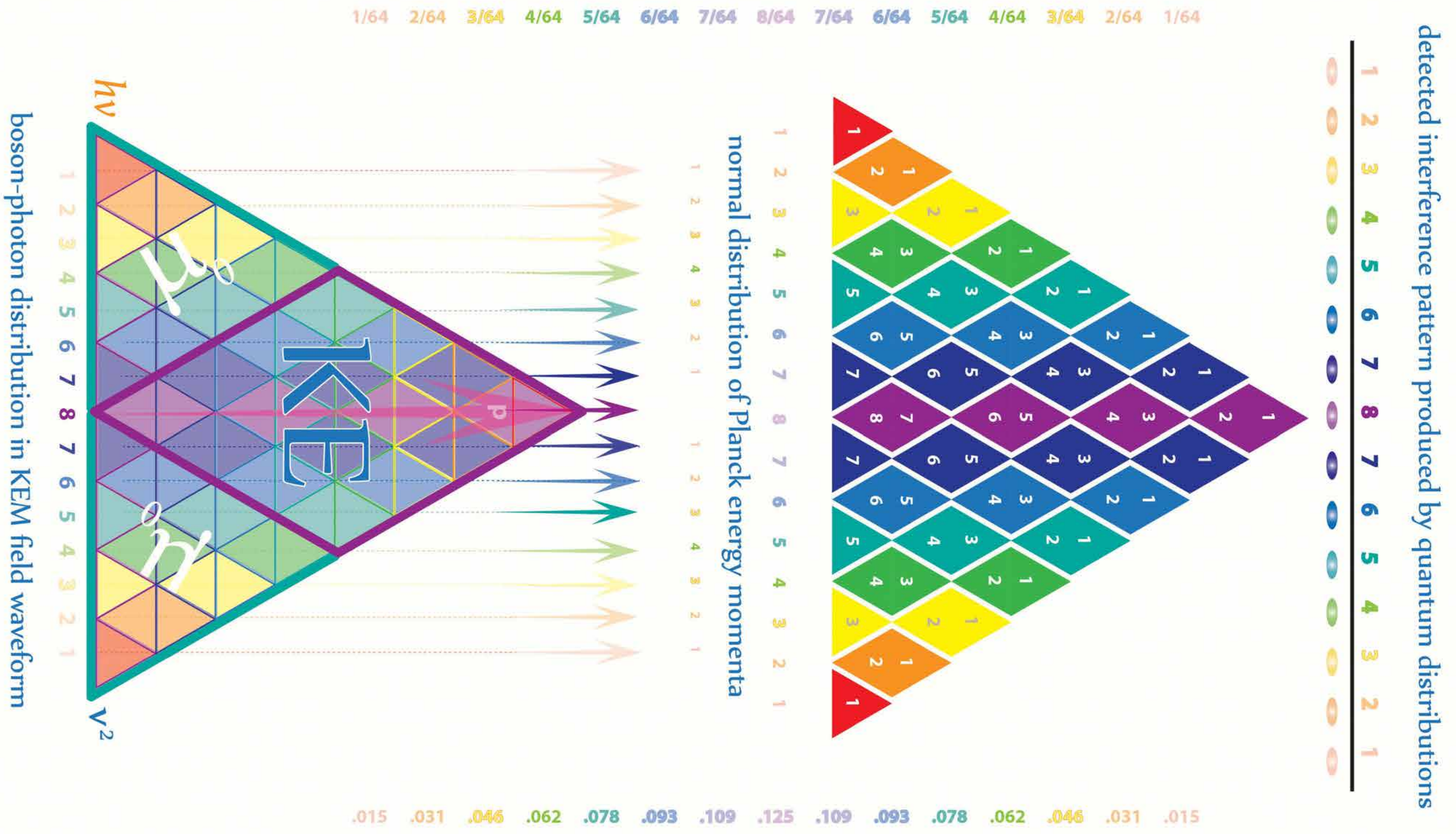
1/64 2/64 3/64 4/64 5/64 6/64 7/64 8/64 7/64 6/64 5/64 4/64 3/64 2/64 1/64
hν
v²
μ₀
ε₀
KE
p
boson-photon distribution in KEM field waveform
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
normal distribution of Planck energy momenta
detected interference pattern produced by quantum distributions
.015 .031 .046 .062 .078 .093 .109 .125 .109 .093 .078 .062 .046 .031 .015

Probability distributions of monochromatic EM waves

Tetryonics 98.02 - Boson distributions in monochromatic EM waves

Wave interference patterns

The double-slit experiment, sometimes called Young's experiment, is a demonstration that matter and energy can display characteristics of both waves and particles, and demonstrates the fundamentally probabilistic nature of quantum mechanical phenomena and Establishes the quantum interference principle known as wave–particle duality.

Matter particles are stopped by the barrier but the [K]EM wave passes through both slits and is diffracted by them producing weaker EM waves that then superposition with each other to produce interference patterns

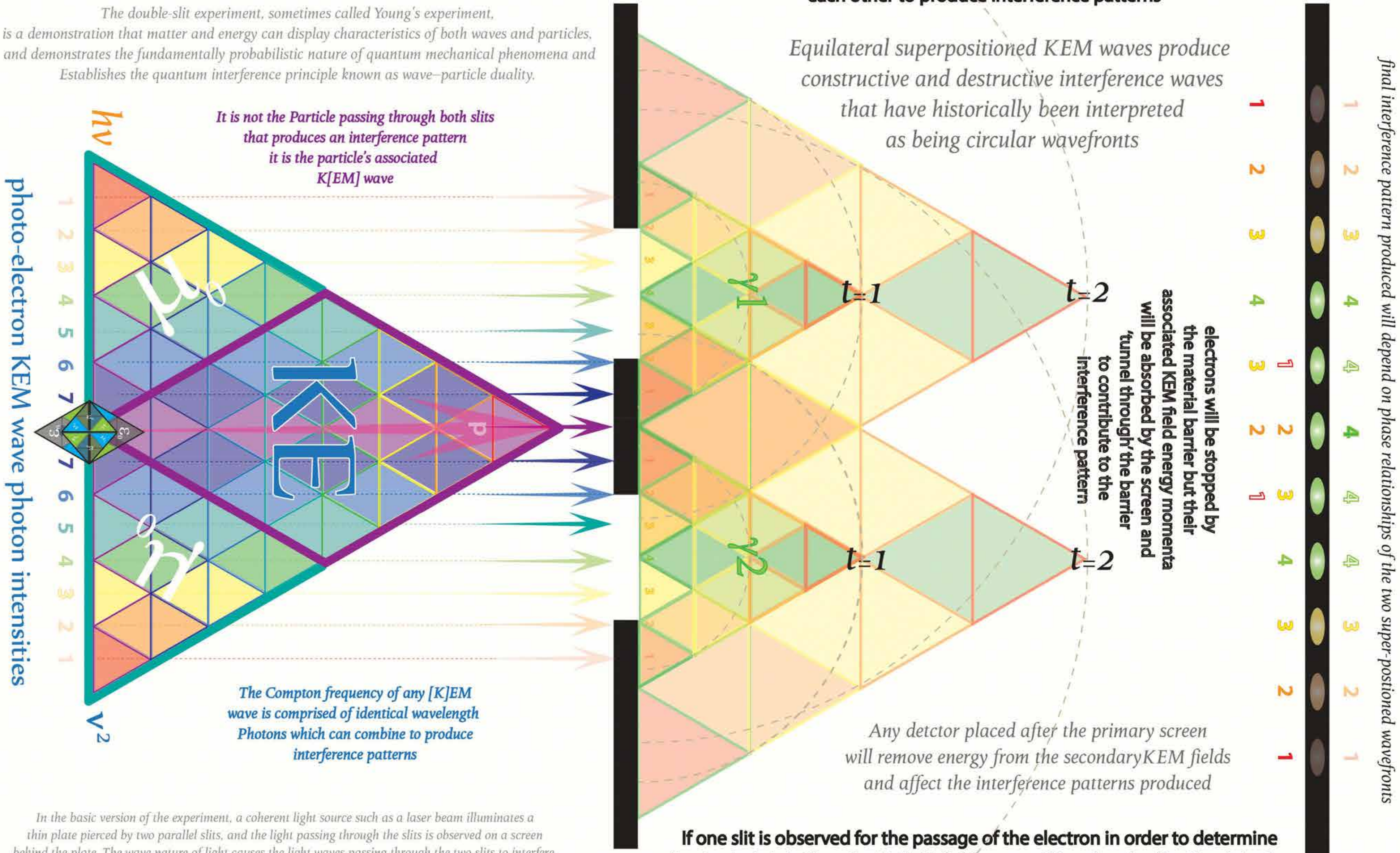

It is not the Particle passing through both slits that produces an interference pattern it is the particle's associated K[EM] wave

Equilateral superpositioned KEM waves produce constructive and destructive interference waves that have historically been interpreted as being circular wavefronts

electrons will be stopped by the material barrier but their associated KEM field energy momenta will be absorbed by the screen and 'tunnel through' the barrier to contribute to the interference pattern

final interference pattern produced will depend on phase relationships of the two super-postioned wavefronts

The Compton frequency of any [K]EM wave is comprised of identical wavelength Photons which can combine to produce interference patterns

Any detctor placed after the primary screen will remove energy from the secondaryKEM fields and affect the interference patterns produced

If one slit is observed for the passage of the electron in order to determine its physical state then the its KEM field wave will be absorbed by the detector resulting in only one wave remaining, enforcing a classical particle outcome

In the basic version of the experiment, a coherent light source such as a laser beam illuminates a thin plate pierced by two parallel slits, and the light passing through the slits is observed on a screen behind the plate. The wave nature of light causes the light waves passing through the two slits to interfere, producing bright and dark bands on the screen — a result that would not be expected if light consisted strictly of particles. However, on the screen, the light is always found to be absorbed as though it were composed of discrete particles or photons.

Quantum computing via EM wave super-positioning

BY superpositioning two beams
of EM radiation the resultant 'colours'
will perform quantum level computations
that can be read via the resultant
interference patterns produced

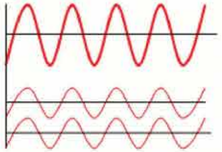

In phase

constructive interference

additive in-phase EM waves

Additive

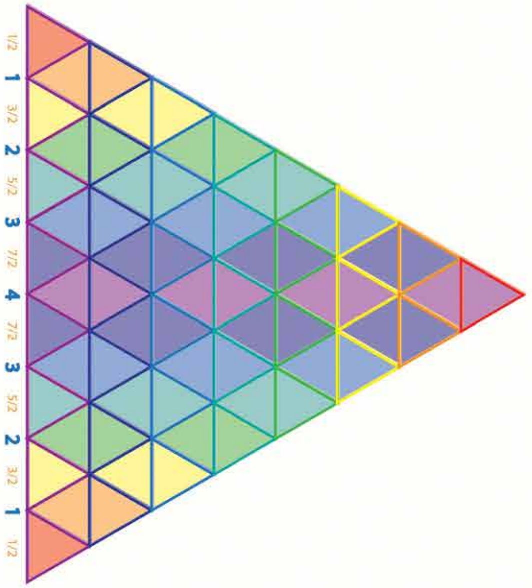
1/2
1
3/2
2
5/2
3
7/2
4
7/2
3
5/2
2
3/2
1
1/2

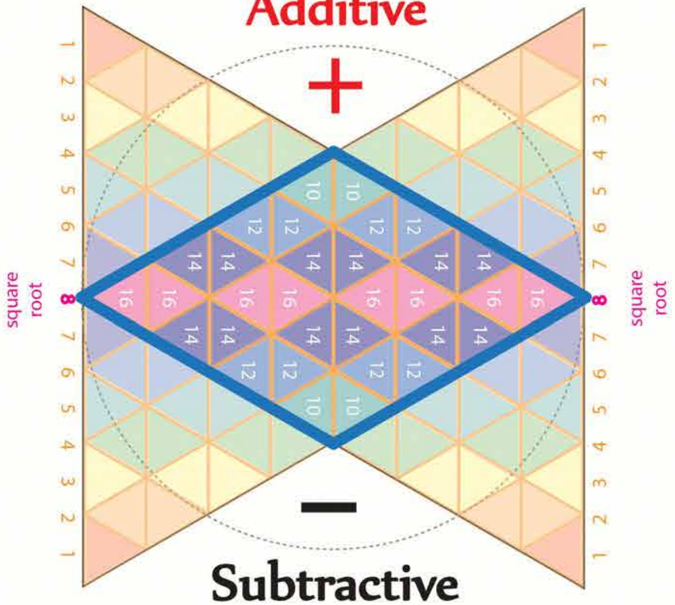
+
1
2
3
4
5
6
7
8
7
6
5
4
3
2
1
square root
10
12
14
16
−

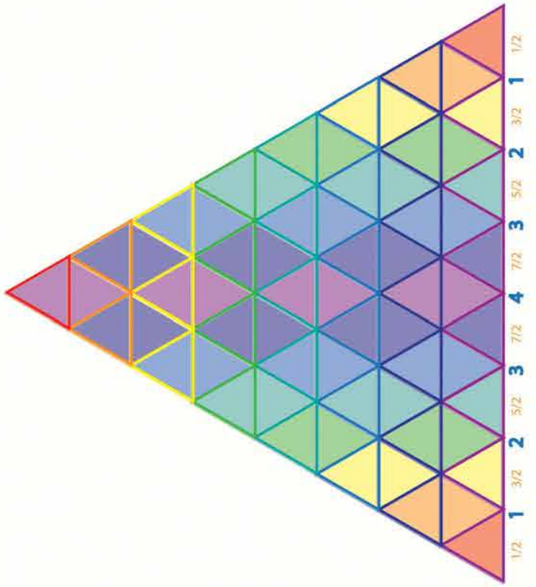
1/2
1
3/2
2
5/2
3
7/2
4
7/2
3
5/2
2
3/2
1
1/2

Subtractive

Out of phase

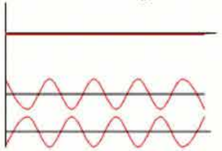

destructive interference

subtractive out-of-phase EM waves

Various basic operations, such as
ADDITION, SUBTRACTION and
SQUARE ROOTS etc
are all easily computed using
EM wave super-positioning

The lines of Force

By utilising the statiscal distribution of equilateral Planck energy momenta quanta in EM waves
Tetryonic theory provides a practical geometric solution to quantum computing problems

q

bosons

P vs. NP

The set of all decision problems for which an algorithm exists which can be carried out by a deterministic Turing machine in ***polynomial*** *time*

the set of all decision problems for which an algorithm exists which can be carried out by a ***non-deterministic*** *Turing machine in* ***polynomial*** *time*

E

photons

An algorithm of time complexity $O(n)$ is one which increases in time linearly as the "size of the problem" (whatever n stands for) increases.

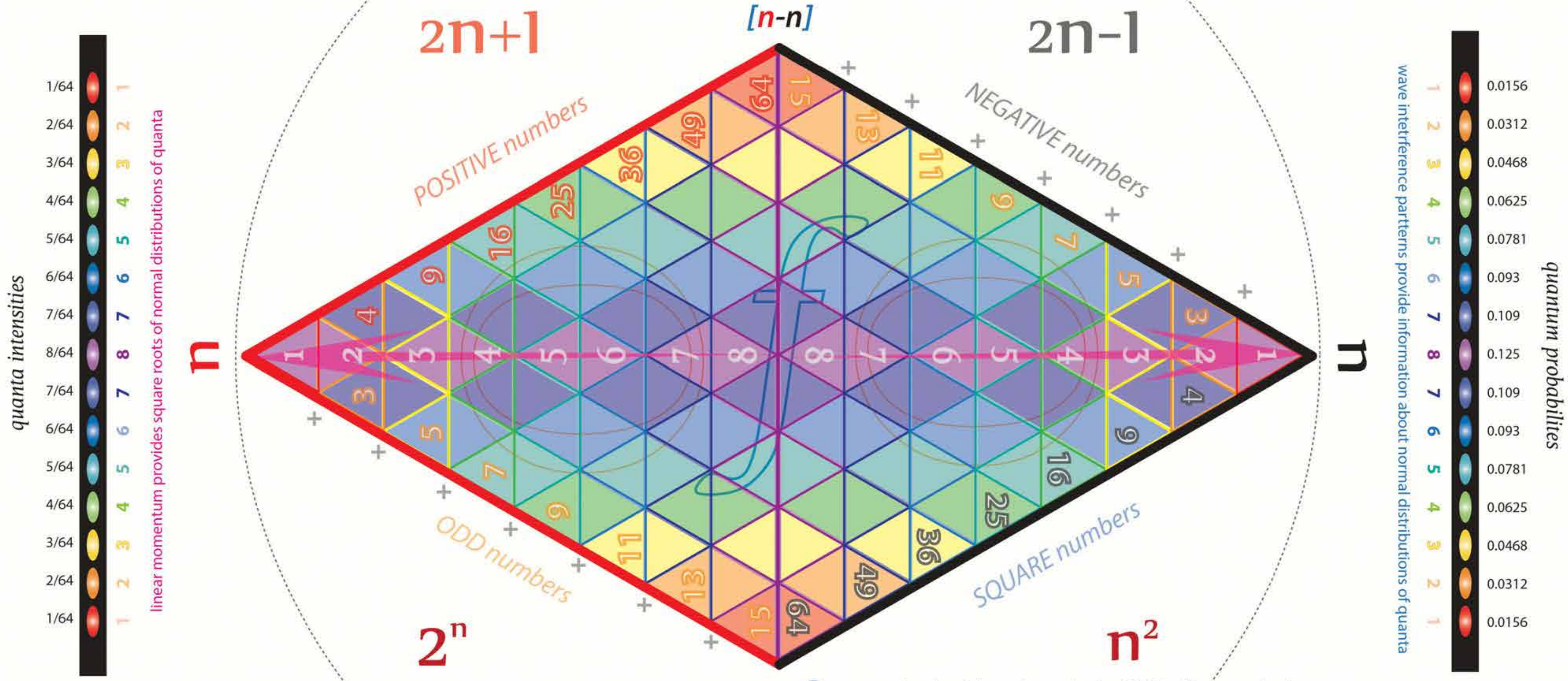
2n+1
[n-n]
2n-1
POSITIVE numbers
NEGATIVE numbers
ODD numbers
SQUARE numbers
n
n
2^n
n^2
f
1 2 3 4 5 6 7 8
8 7 6 5 4 3 2 1
4 9 16 25 36 49 64
3 5 7 9 11 13 15
64 49 36 25 16 9 4
15 13 11 9 7 5 3
quanta intensities
1/64
2/64
3/64
4/64
5/64
6/64
7/64
8/64
7/64
6/64
5/64
4/64
3/64
2/64
1/64
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
linear momentum provides square roots of normal distributions of quanta
wave interference parterns provide information about normal distributions of quanta
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
0.0156
0.0312
0.0468
0.0625
0.0781
0.093
0.109
0.125
0.109
0.093
0.0781
0.0625
0.0468
0.0312
0.0156
quantum probabilites

$2n^2$

An algorithm of complexity $O(2^n)$ utlises exponential quanta; increasing n by 1 will double the quanta required

An algorithm of complexity $O(n^2)$ utilises quadratic quanta, meaning that if you double n it will use four times as many quanta.

n^{o}

Unlike Math treatise on P vs Np that require exponential polynomial time $O(n^k)$ Tetryonic geometry of EM fields utilise exponential energies per second

2hv

1 second

hf

By relating p to the number of equilateral wave fields in any EM wave very large [pn^2] data sets can be modelled and processed every second

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Quantum Cryptography

If the numerical sequences were applied to amplitude modulation
their non-repeating numerical sequences would appear
to be purely random noise

Using Tetryonic geometry
advanced non-repeating cyphers
of any complexity
can be easily developed

The level of encryption can
be easily increased (without limit)
by increasing the dimensions
of the cypher geometry

eg: number of quanta
2D vs 3D geometries

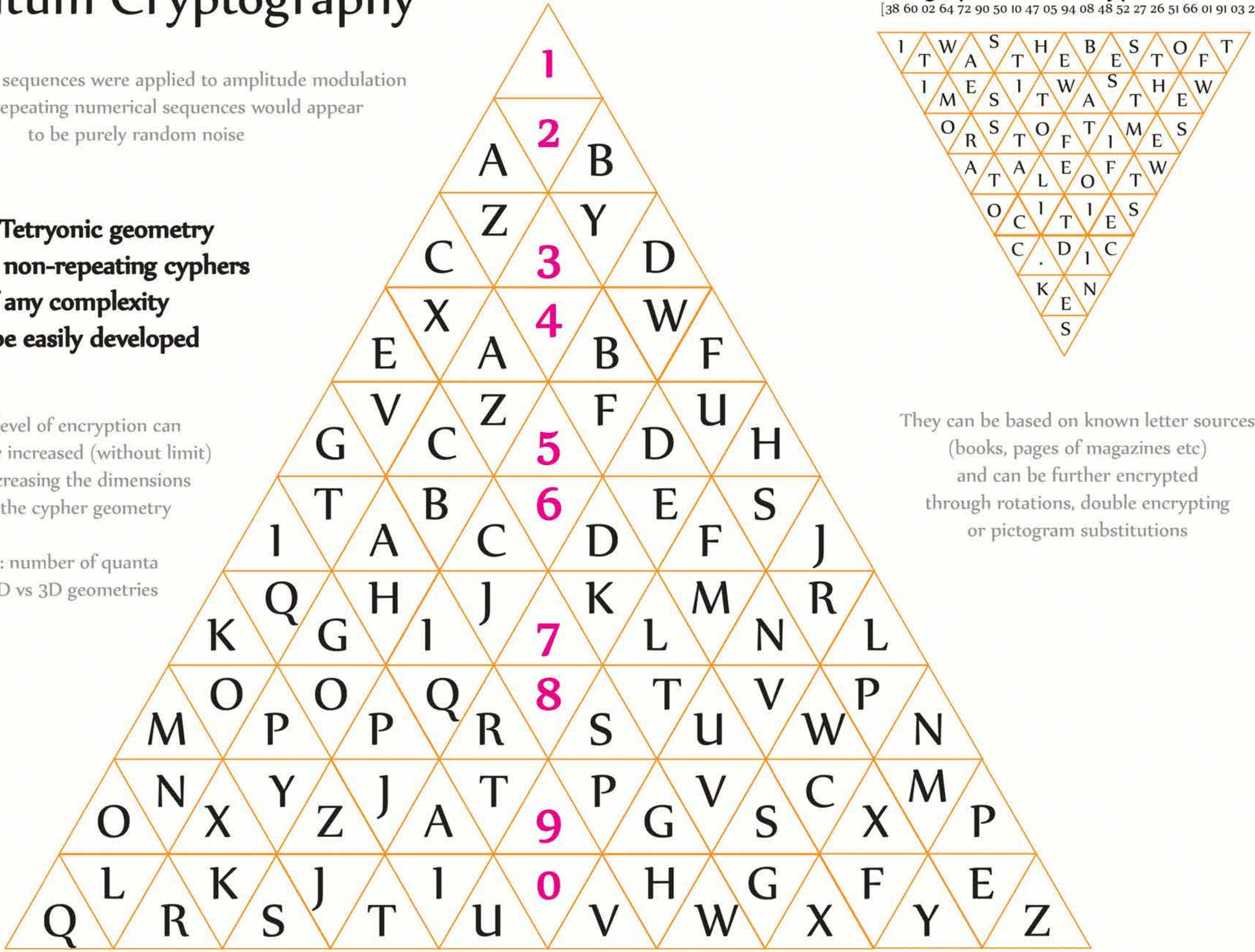
1
A 2 B
C Z 3 Y D
E X A 4 B W F
G V C Z 5 F D U H
I T A B C 6 D E F S J
K Q G H I J 7 K L M N R L
M O P O P Q R 8 S T U V W P N
O N X Y Z J A T 9 P G V S C X M P
Q L R K S J T I U 0 V H W G X F Y E Z

eg: quantum encryption 1024
[38 60 02 64 72 90 50 10 47 05 94 08 48 52 27 26 51 66 01 91 03 20]

I T W A S T H E B E S T O F T
I M E S I T W A S T H E W
O R S T O F T I M E S
A T A L E O F T W
O C I T I E S
C . D I C
K E N
S

They can be based on known letter sources
(books, pages of magazines etc)
and can be further encrypted
through rotations, double encrypting
or pictogram substitutions

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Quantum Computing

The Proton/Neutron geometries of atomic nuclei can be built at the quantum scale
to create an atomic nuclei that can operate as a Opto-memory-transistive computing element,
many elements can then be combined in lattices to create super computers no larger than bacterium

Spin UP

Energy can be gated through individual nuclei
using the centre Baryon as the base transistor element,
in turn effecting the energies of bound photo-electrons

Spin DOWN

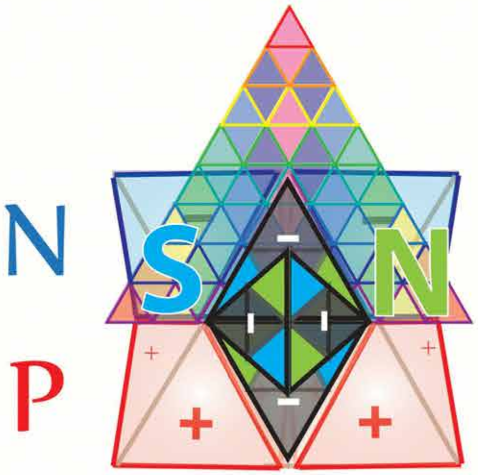

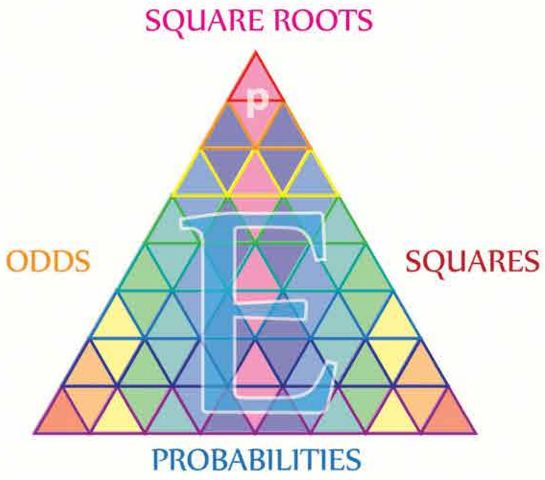

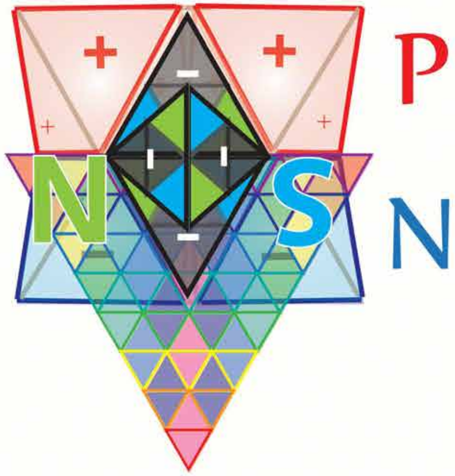

Q-bits

1

photo-electronic transitions can be used to directly recieve
or emit memory states through the absorption and emission
of spectral photons of specific energy momenta

0

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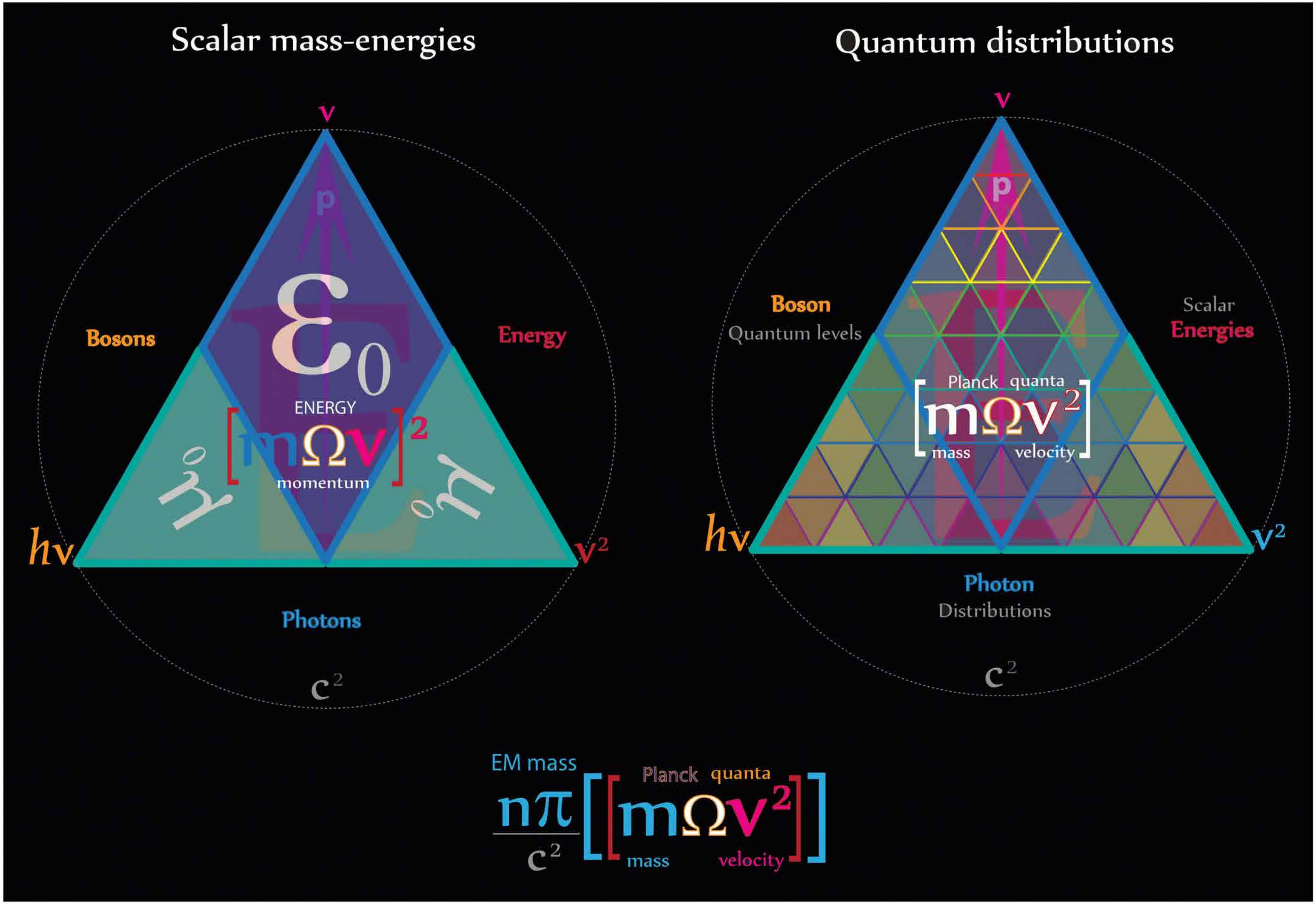
Scalar mass-energies
v
p
Bosons
Energy
ε0
ENERGY
[mΩv]2
momentum
μ0
ε0
hv
v2
Photons
c2
Quantum distributions
v
p
Boson
Quantum levels
Scalar
Energies
Planck quanta
[mΩv2]
mass
velocity
hv
v2
Photon
Distributions
c2
EM mass
nπ/c2
Planck quanta
[[mΩv2]]
mass
velocity

2D mass

$$\overset{\text{EM mass}}{\frac{n\pi}{c^2}}\left[\left[\underbrace{m}_{\text{mass}}\overset{\text{Planck quanta}}{\Omega}\underbrace{v^2}_{\text{velocity}}\right]\right]$$

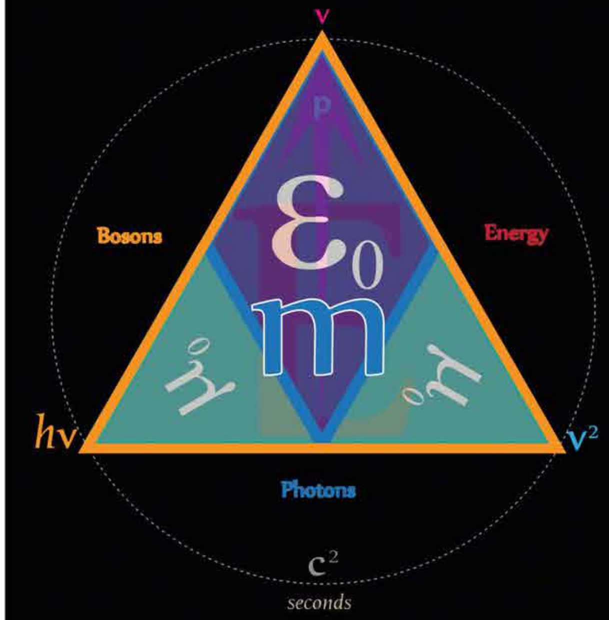
v
p
ε_0
m
μ_0
Bosons
Energy
hv
v^2
Photons
c^2
seconds

Measure of planar energies
in a nπ radiant wave
geometry
[per second]

mass quantum
7.376238634 e-51 kg

ENERGY

$$\overset{\text{ENERGY}}{n\pi}\left[\left[\underbrace{m\Omega v^2}_{\text{momenta}}\right]\right]$$

Equilateral energy momenta
has a mass equivalence
per unit of Time

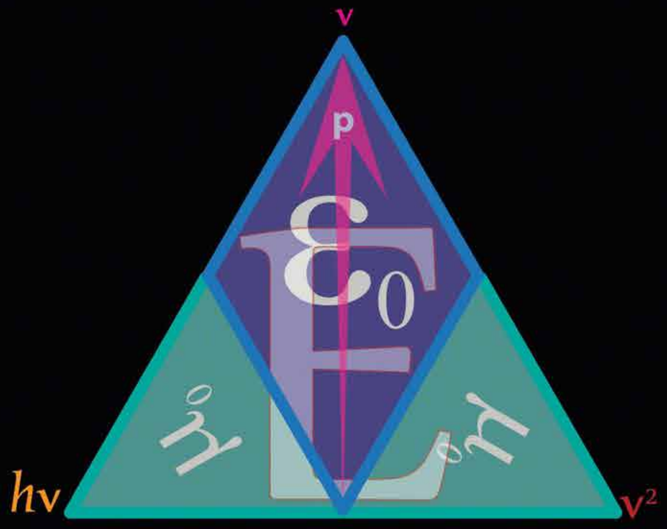
v
p
ε_0
E
μ_0
hv
v^2

c^2 is the radial geometry
created by radiant energy
in 1 second

Planck Constant
6.629432672 e-34 J.s

3D Matter

$$\overset{\text{Matter}}{\frac{T\pi}{c^4}}\left[\left[\underbrace{m}_{\text{mass}}\overset{\text{Planck quanta}}{\Omega}\underbrace{v^2}_{\text{velocity}}\right]\right]$$

Measure of mass-energy
in a 4nπ standing wave
topology
[per second squared]

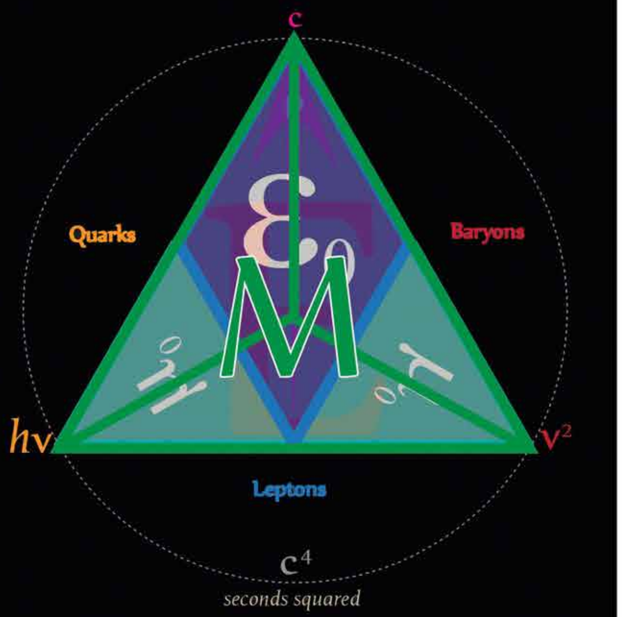
c
ε_0
M
μ_0
Quarks
Baryons
hv
v^2
Leptons
c^4
seconds squared

Matter quantum
2.9504955454 e-50 kg

Planck's constant - the quantum of Action

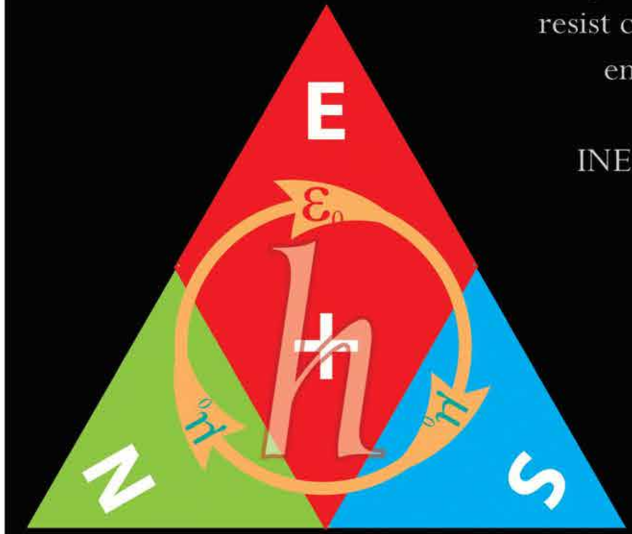
E
ε0
h
μ0
μ0
N
S

all ideal quantum inductive loops
resist changes to their
energy levels

INERTIAL mass

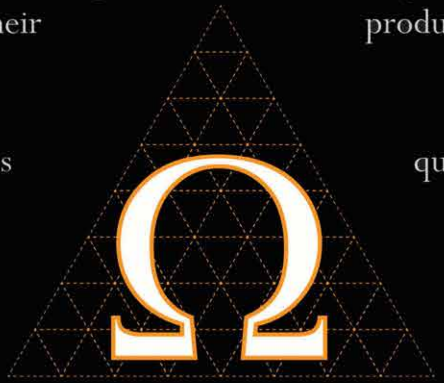

all equilateral energy momenta
produce square root vector
Forces

quantum of WORK

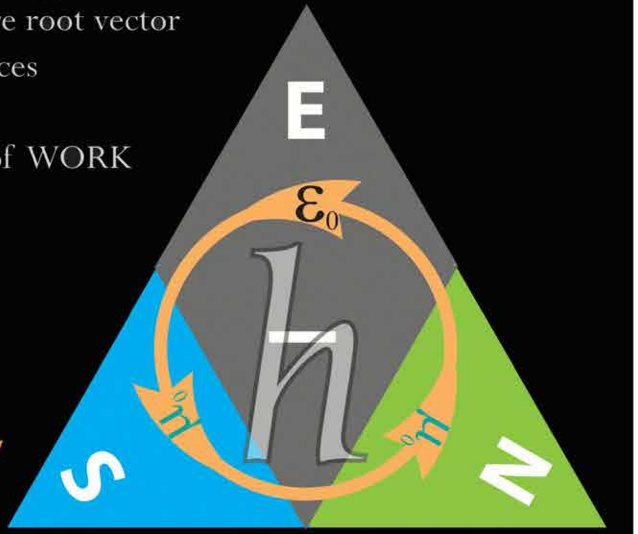
E
ε0
h
μ0
μ0
S
N

Quantised angular momentum is equilateral geometry

The two sides of Planck's Constant

The square root of all Energy is linear momentum

Equilateral
energy quanta
per second

mass

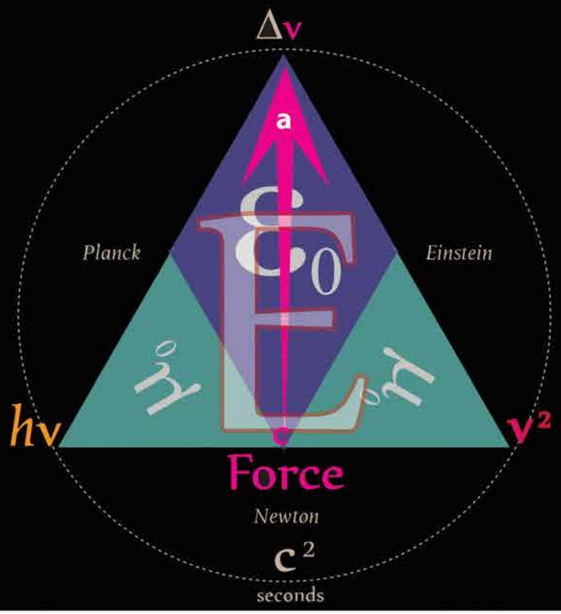
Δv
a
ε0
E
Planck
Einstein
μ0
μ0
hv
v²
Force
Newton
c²
seconds

Quantised
angular momenta
per second

time

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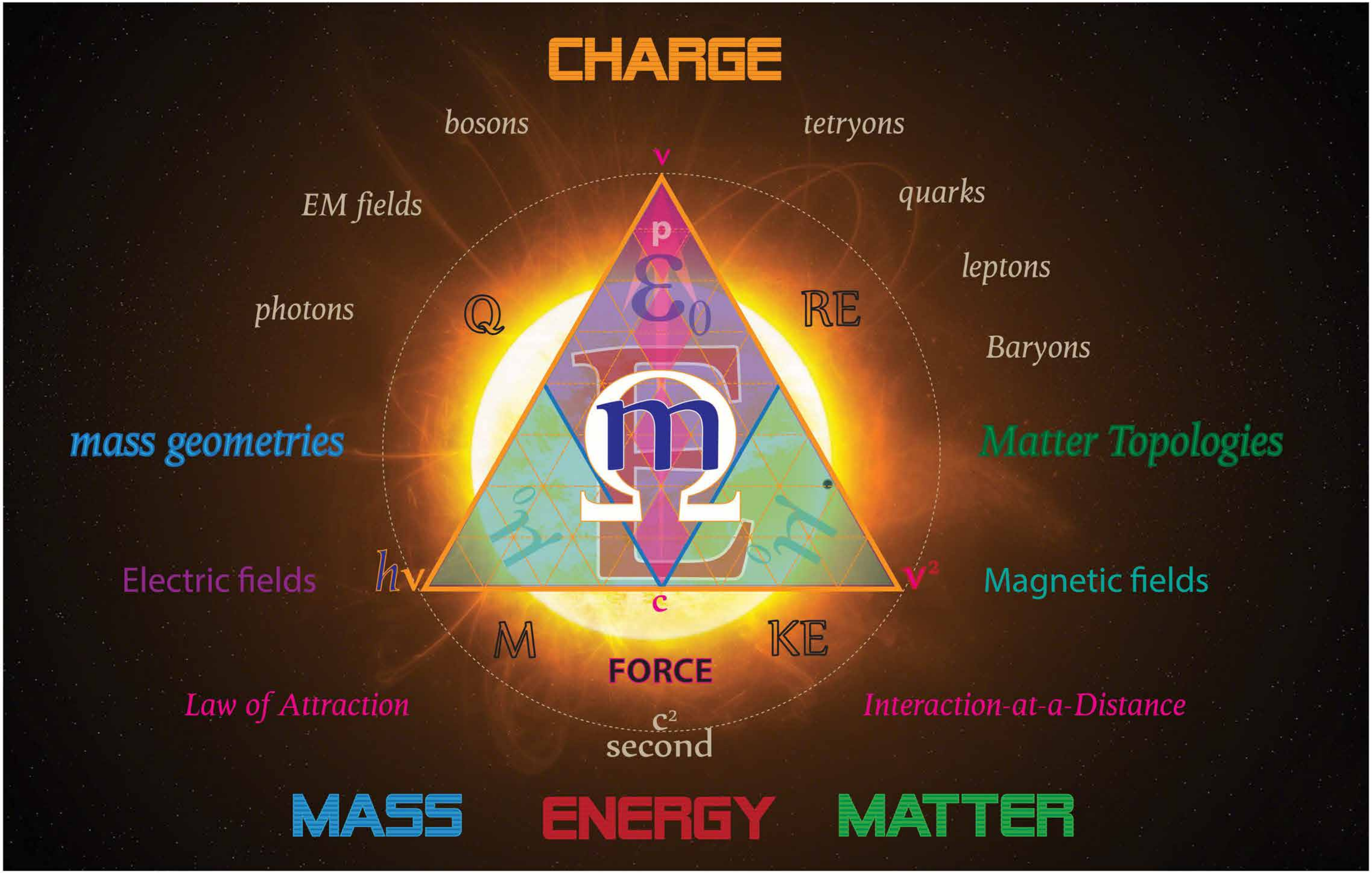
CHARGE
bosons
tetryons
v
EM fields
quarks
p
leptons
ε_0
photons
Q
RE
Baryons
E
m
Ω
mass geometries
Matter Topologies
μ_0
Electric fields
hv
v^2
Magnetic fields
c
M
KE
FORCE
Law of Attraction
Interaction-at-a-Distance
c^2
second
MASS
ENERGY
MATTER

Tetryonics 99.04 - Charged Planck mass-ENERGY-Matter

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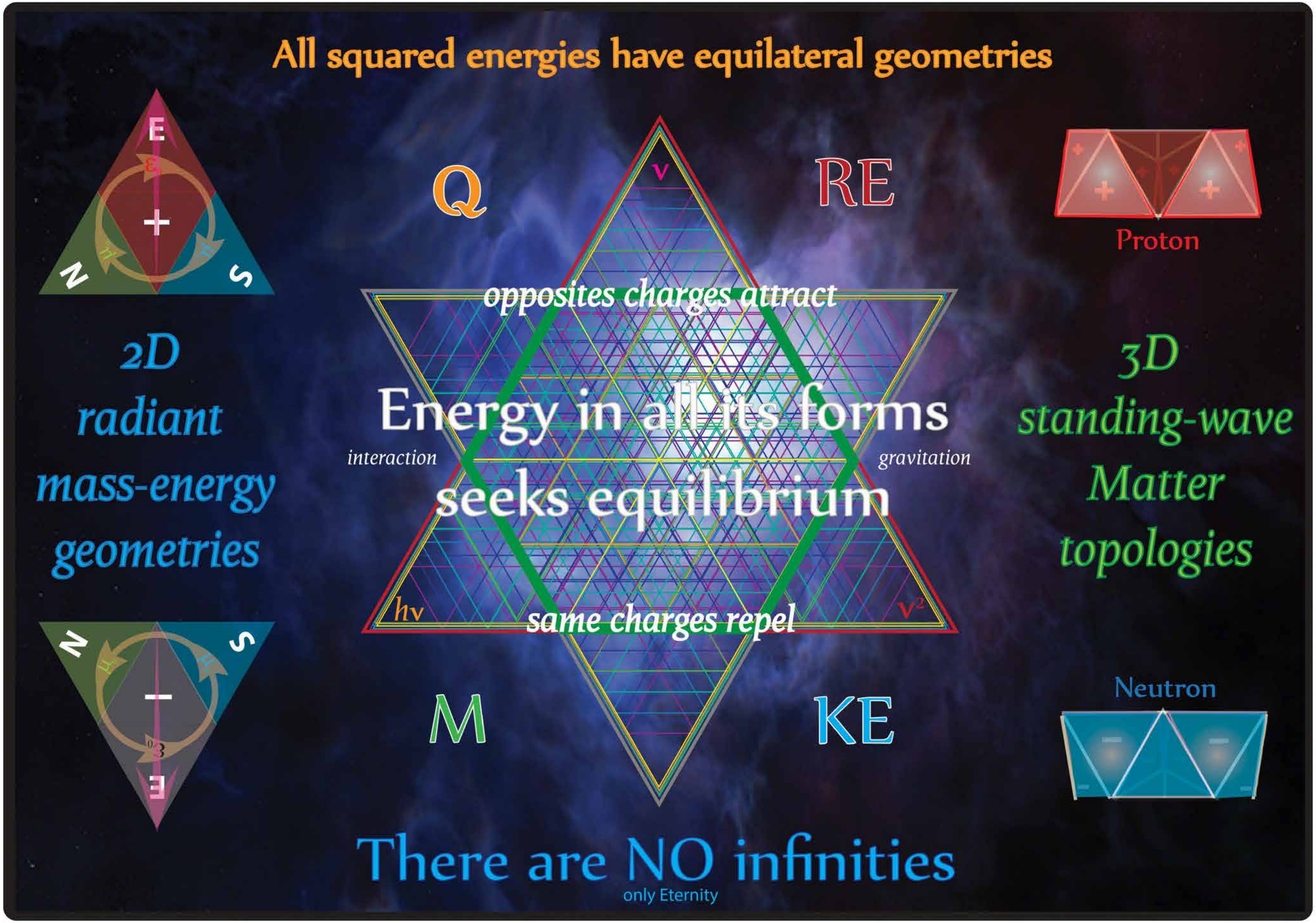
E
ε
+
N
μ
S
ν
Q
RE
+
Proton
interaction
gravitation
hν
ν²
N
μ
S
−
ε
E
M
KE
Neutron
−

All squared energies have equilateral geometries

2D
radiant
mass-energy
geometries

opposites charges attract

Energy in all its forms seeks equilibrium

same charges repel

3D
standing-wave
Matter
topologies

There are NO infinities

only Eternity

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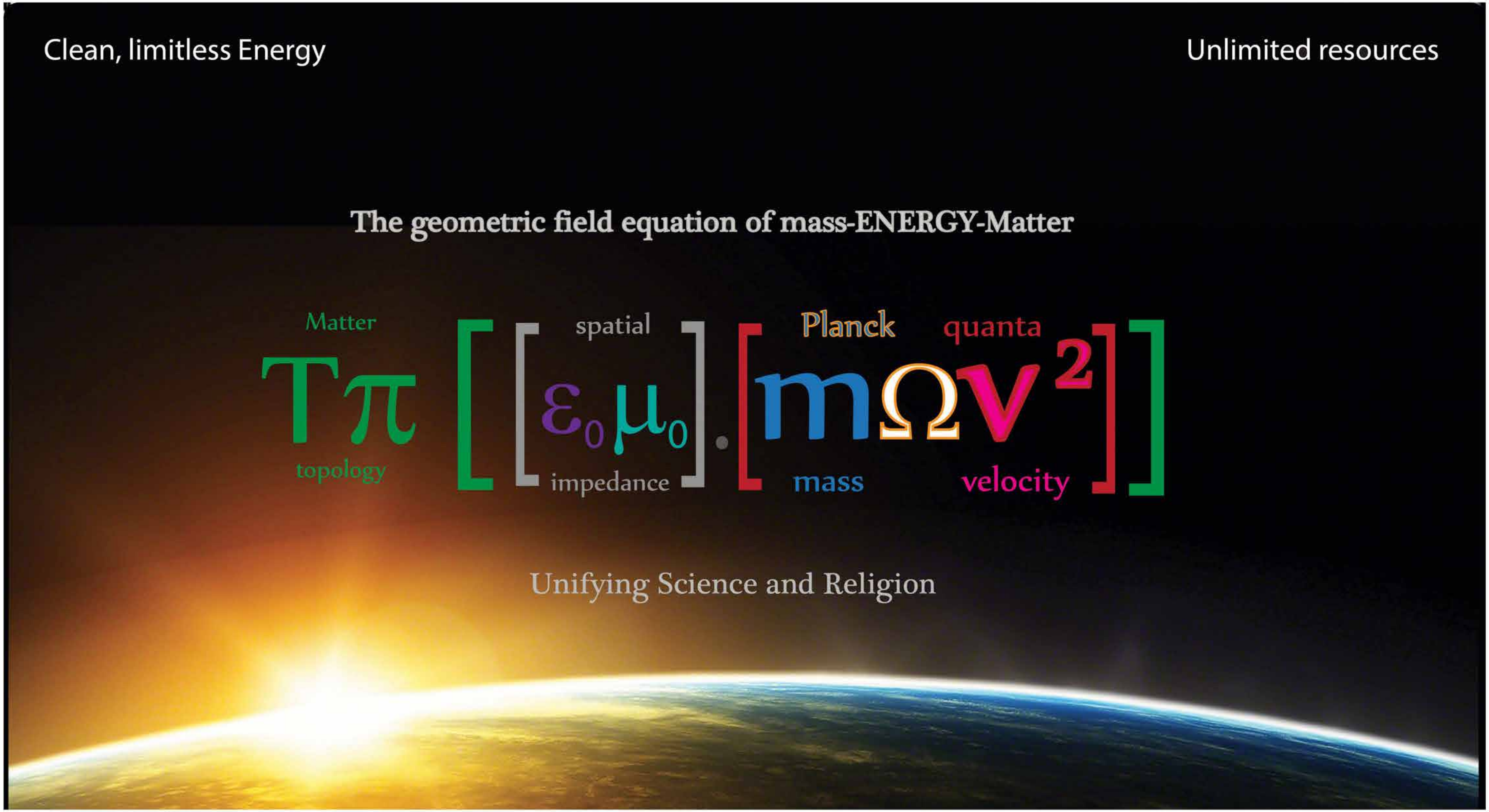

Clean, limitless Energy

Unlimited resources

The geometric field equation of mass-ENERGY-Matter

Matter

$$T\pi\left[\left[\varepsilon_0\mu_0\right]\cdot\left[m\Omega v^2\right]\right]$$

topology

spatial

impedance

Planck

quanta

mass

velocity

Unifying Science and Religion

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Tetryonic Theory

All EM mass, energy momenta & Matter can be measured and geometrised with respect to equilateral Quantised Angular Momenta

charged Planck quanta

Bosons

$$\frac{\text{ODD}\,\pi}{c^2}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

Total Relativistic energies

ENERGY

$$n\pi\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

Quantum Mechanics

Quantum Cosmology

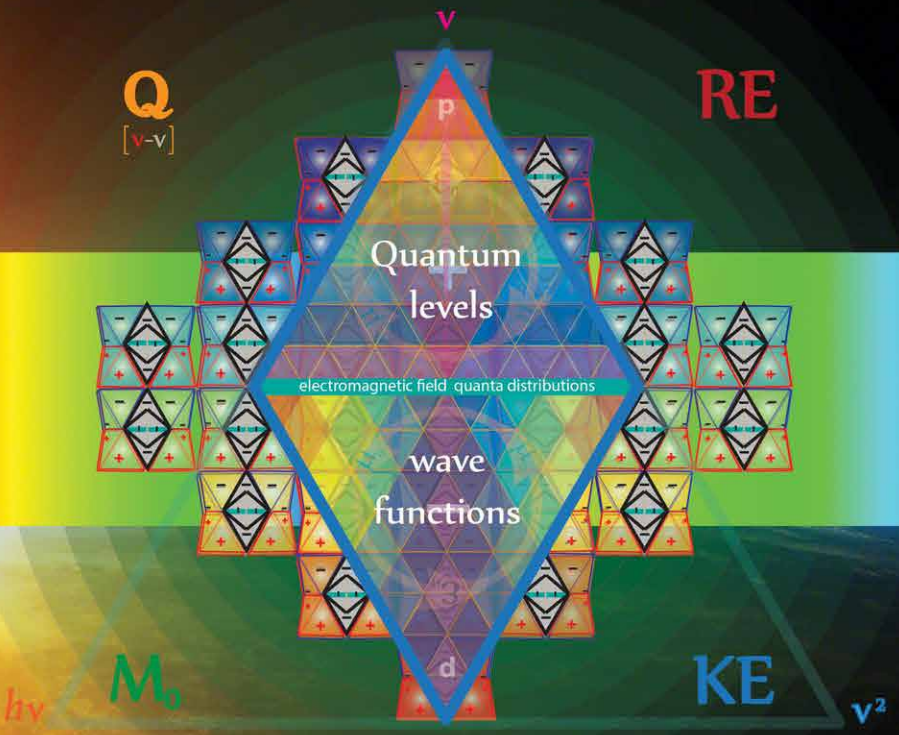

standing-wave mass-Matter

radiant EM mass-energies

Quantum Chemistry

Electrodynamics

Matter

$$\frac{T\pi}{c^4}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

EM waves

$$\frac{\text{EVEN}\,\pi}{c^2}\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

3D standing-wave mass/Matter topologies

2D radiant mass-energy geometries

The application of equilateral QAM geometries covers all of the Physical disciplines

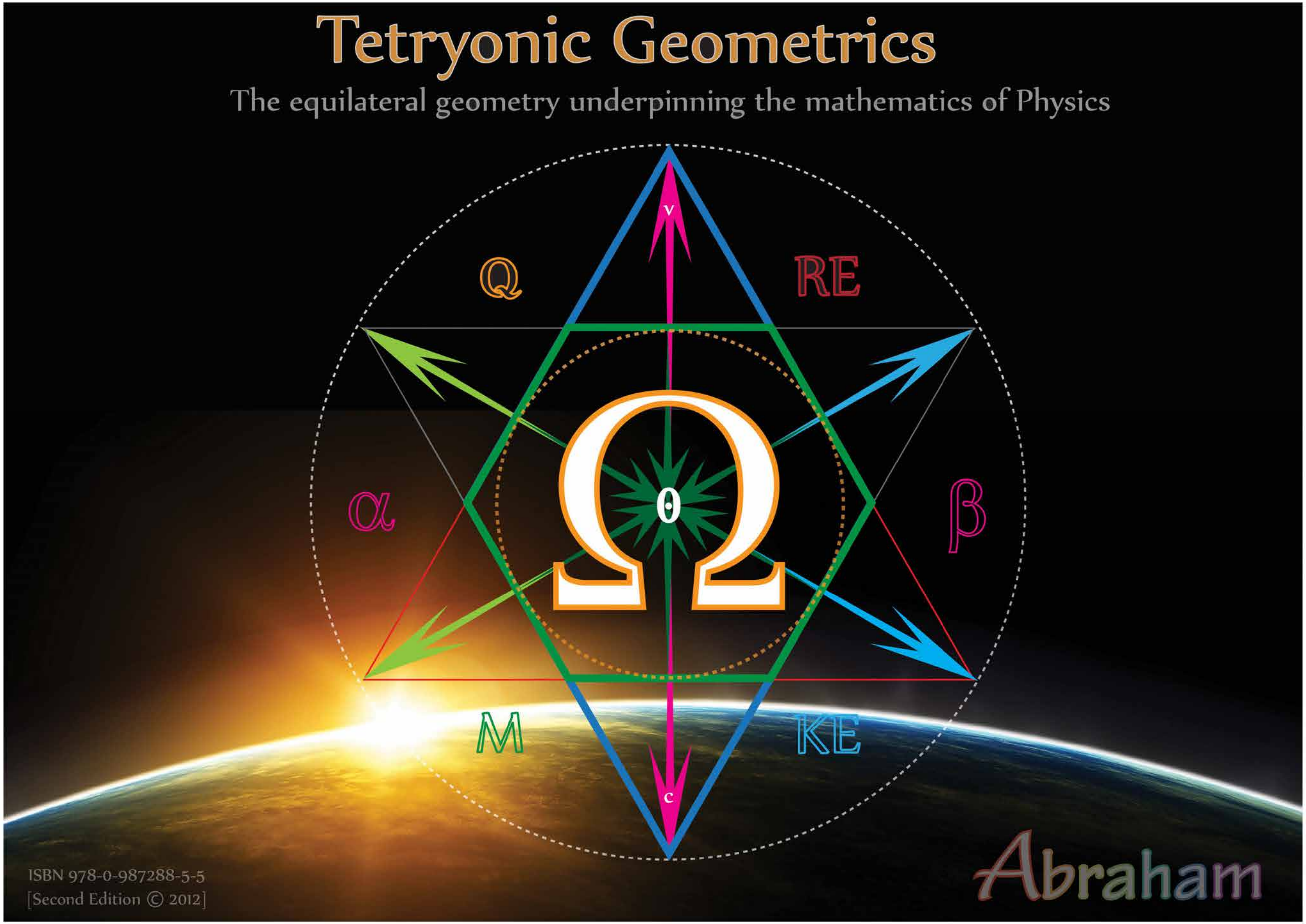

Tetryonic Geometrics

The equilateral geometry underpinning the mathematics of Physics

ISBN 978-0-987288-5-5
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Abraham

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TETRYONICS

The charged topology of periodic & compound Matter

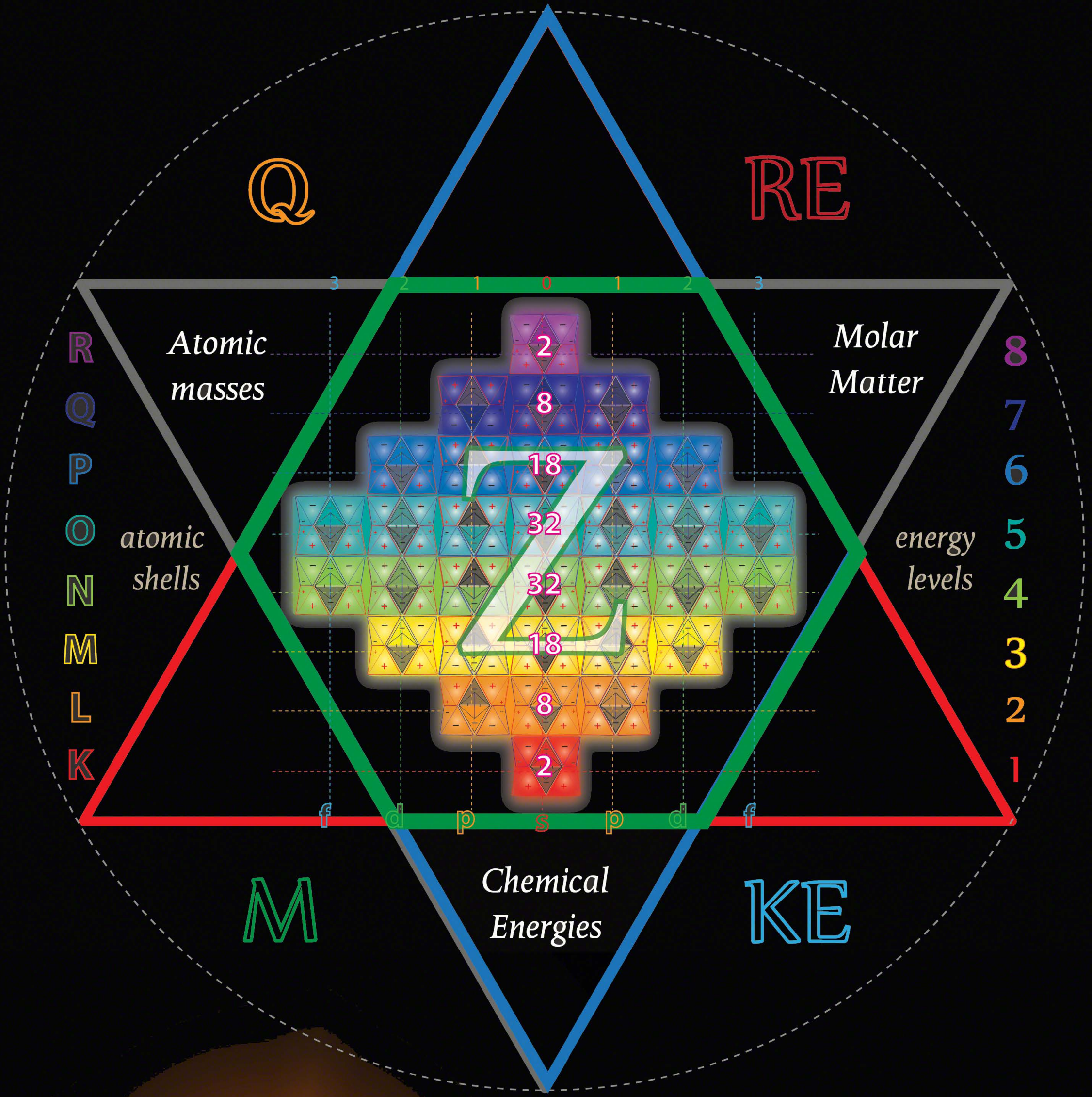
Q
RE
3 2 1 0 1 2 3
Atomic masses
Molar Matter
R Q P O N M L K
8 7 6 5 4 3 2 1
2
8
18
32
Z
32
18
8
2
atomic shells
energy levels
f d p s p d f
M
KE
Chemical Energies

Foundational Quantum Chemistry

Abraham

ISBN 978-0-987288-3-1
[Second Edition © 2012]

Residual Electro-Magnetic Forces

allow Neutrons and Protons to attract via the opposite Electric charge points
created by their constituent Quarks in order to create Elementary Nuclei

Protons **+** *Neutrons*

u+d+u d+u+d

All electrons, quarks and Baryons are made up of 4n+ (Tetryonic) standing-wave EM fields.

As well as having nett Tetryonic charged topologies ranging between [+24] ~ [-12] they all posses distinct ELECTRIC FIELDS that are concentrated in 3 apex points as indicated in the illustrations

These points result from the orientation of Electric apexes and orthagonal Magnetic dipole field edges that make up each particle's externalised EM fields.

The Positive and Negative electric apex points, obey the Law of Interaction forcing separated nuceli to combine due to their individual nett Tetryonic charges and provide a means of orienting nuclei to each other to create larger particles [elements, allotropes and compounds]

External Magnetic (H) fields can interact with the integral magnetic (B) dipoles of Tetryonic particles forcing them to orientate in specific directions to facilite chemical bonding [nuclear forces]

Additionally, external Electric fields can interect with the integral electric fields attracting or repelling them depending on the polarity of the external electric field [Electrostatics]

External energies can be induced into these integral EM fields via inductive coupling or the absorption of spectral photons in turn leading to an increase in the strengthes of the integral EM apexes in turn increasing the Strong Nuclear Force.

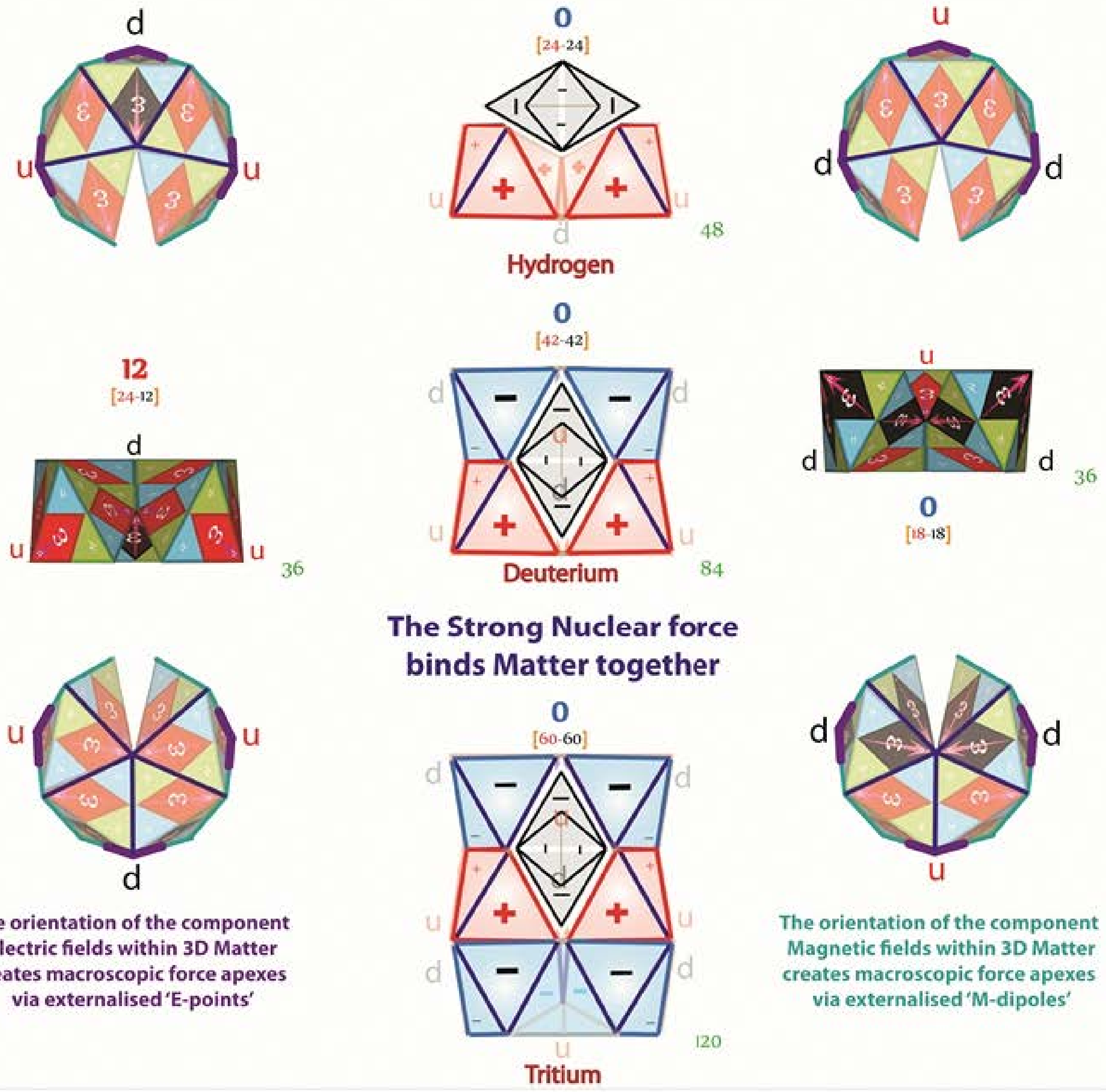

The Strong Nuclear force binds Matter together

The orientation of the component Electric fields within 3D Matter creates macroscopic force apexes via externalised 'E-points'

The orientation of the component Magnetic fields within 3D Matter creates macroscopic force apexes via externalised 'M-dipoles'

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Nucleonic residual EM force

The attraction between Baryonic E&M field apexs, a result of their component Quark arrangements, results in the formation of heavier and more complex Nuclei

The residual e-field apexes and m-field dipoles form two rings of residual EM fields around the circumference of atomic nuclei

Neutrons

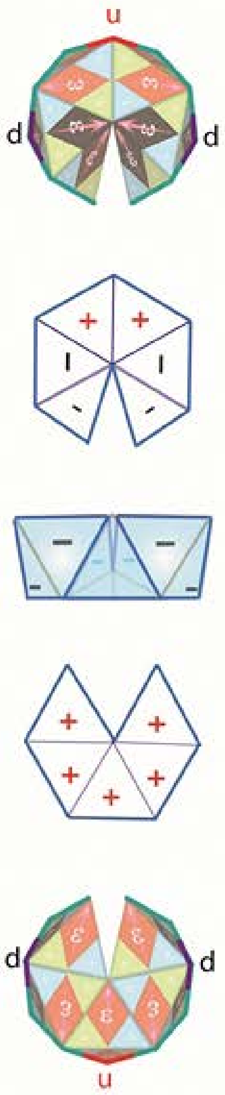

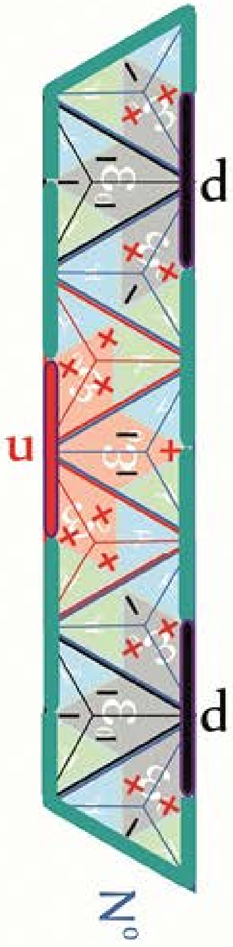

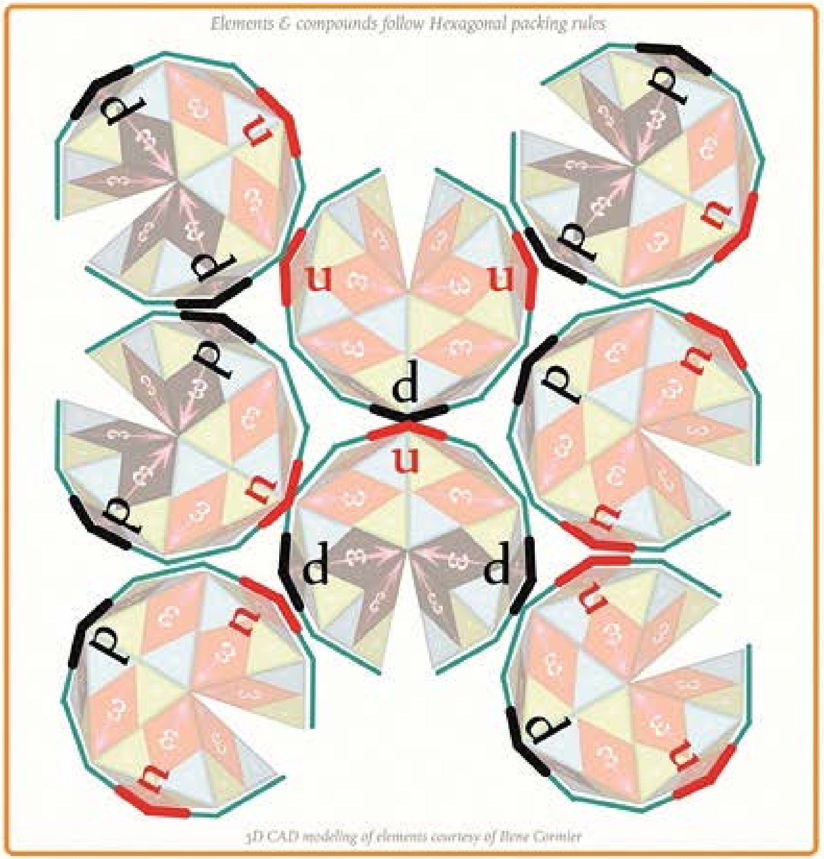
Elements & compounds follow Hexagonal packing rules
p
u
p
p
u
u
p
p
p
n
d
u
p
n
n
d
d
n
p
n
u
p
n
n
3D CAD modeling of elements courtesy of Ilene Cormier

Protons

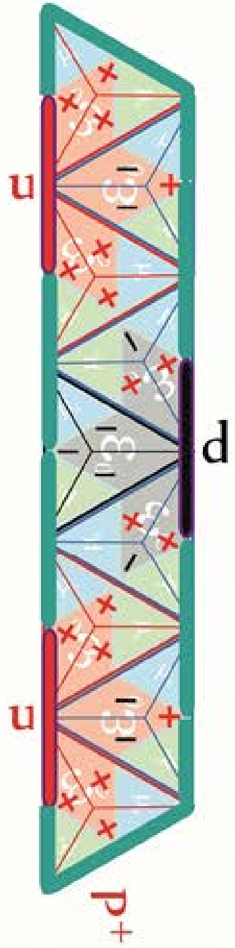

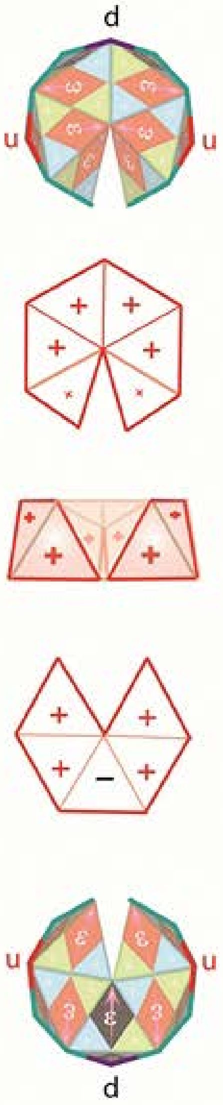

E-field apexes and their polarities highlight the quark alignment of all atomic nuclei and elements

UP Quark
Positive Electric field apex

DOWN Quark
Negative Electric field apex

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Insulators and Conductors

The position of electrons in Nuclei within Atomic Elements
results in the properties of Insulators or Conductors

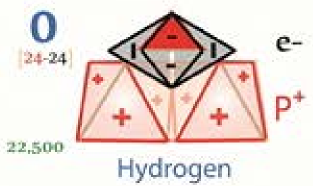
0
[24-24]
e-
P+
22,500
Hydrogen

Coloumbic forces

*Electrons are attracted to the residual EM
net (+12) positive charge of Protons or
n[+12] unbalanced Ionic charges of nuclei*

Conductor

Electrical energies move around
the material via boson exchanges
and electron movement

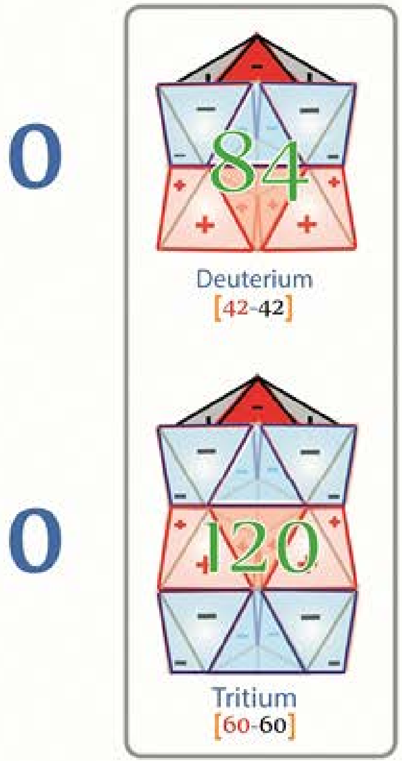
0
84
Deuterium
[42-42]
0
120
Tritium
[60-60]

≈

Insulator

Electrical energy is fixed within the nucleus
as electrostatic charges & released upon demand
via electron rotation/motion within the nucleus

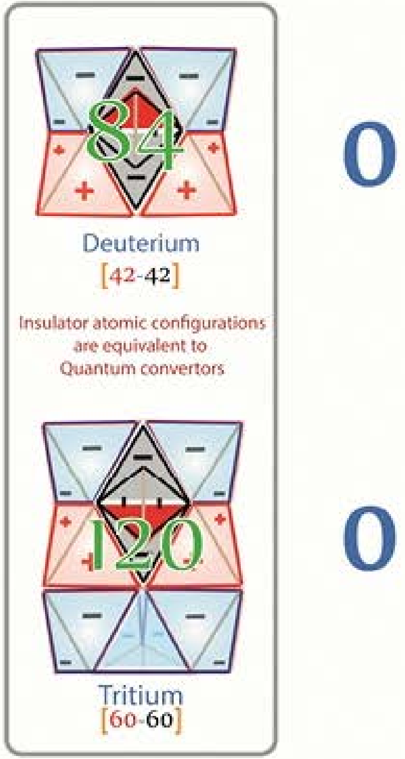
84
Deuterium
[42-42]
0
120
Tritium
[60-60]
0

Insulator atomic configurations
are equivalent to
Quantum convertors

Ions

Charge (energy) is moved around
material via electron movement

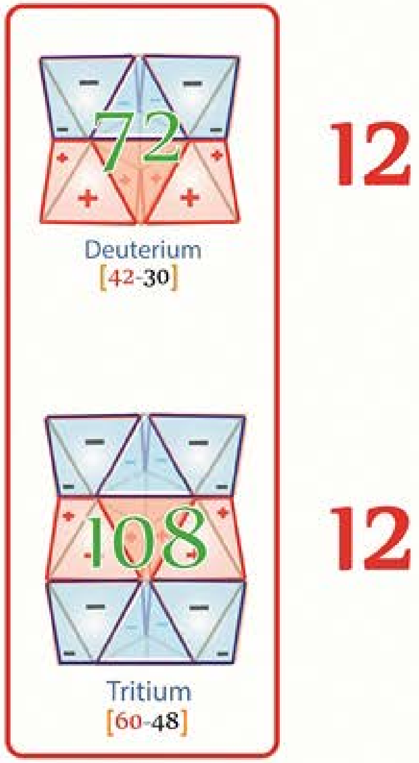
72
Deuterium
[42-30]
12
108
Tritium
[60-48]
12

**Conductive materials contain 'free' electrons that
can be readily or easily moved within the material**

**Insulator materials have electrons that are 'bound' tightly to the atoms
and store charges locally where they are applied**

**Materials that have been ionised are
more likely to become Conductors
as they easily attract and bind
free electrons to them**

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Nucleon Quark Arrangement

The nuclei arrangement of each atomic shell [quantum level] is the result of quark EM field interactions

Quantum levels

Atomic shells

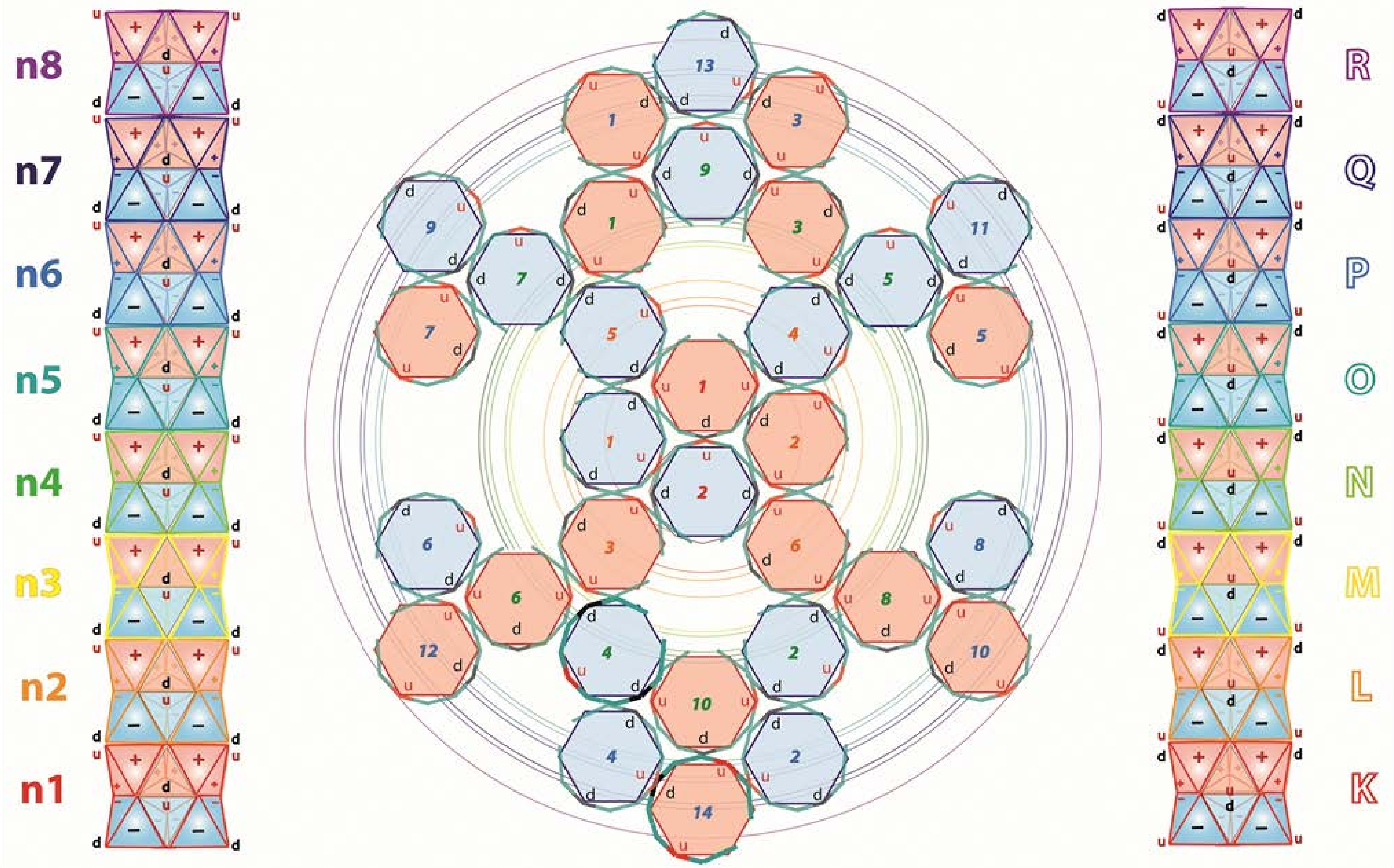
n8
n7
n6
n5
n4
n3
n2
n1
R
Q
P
O
N
M
L
K
u
d
+
−
13
1
3
9
1
3
9
11
7
5
7
5
5
4
1
1
2
2
6
3
6
8
6
8
4
2
12
10
10
4
2
14

Nucleon Charges and Bonding

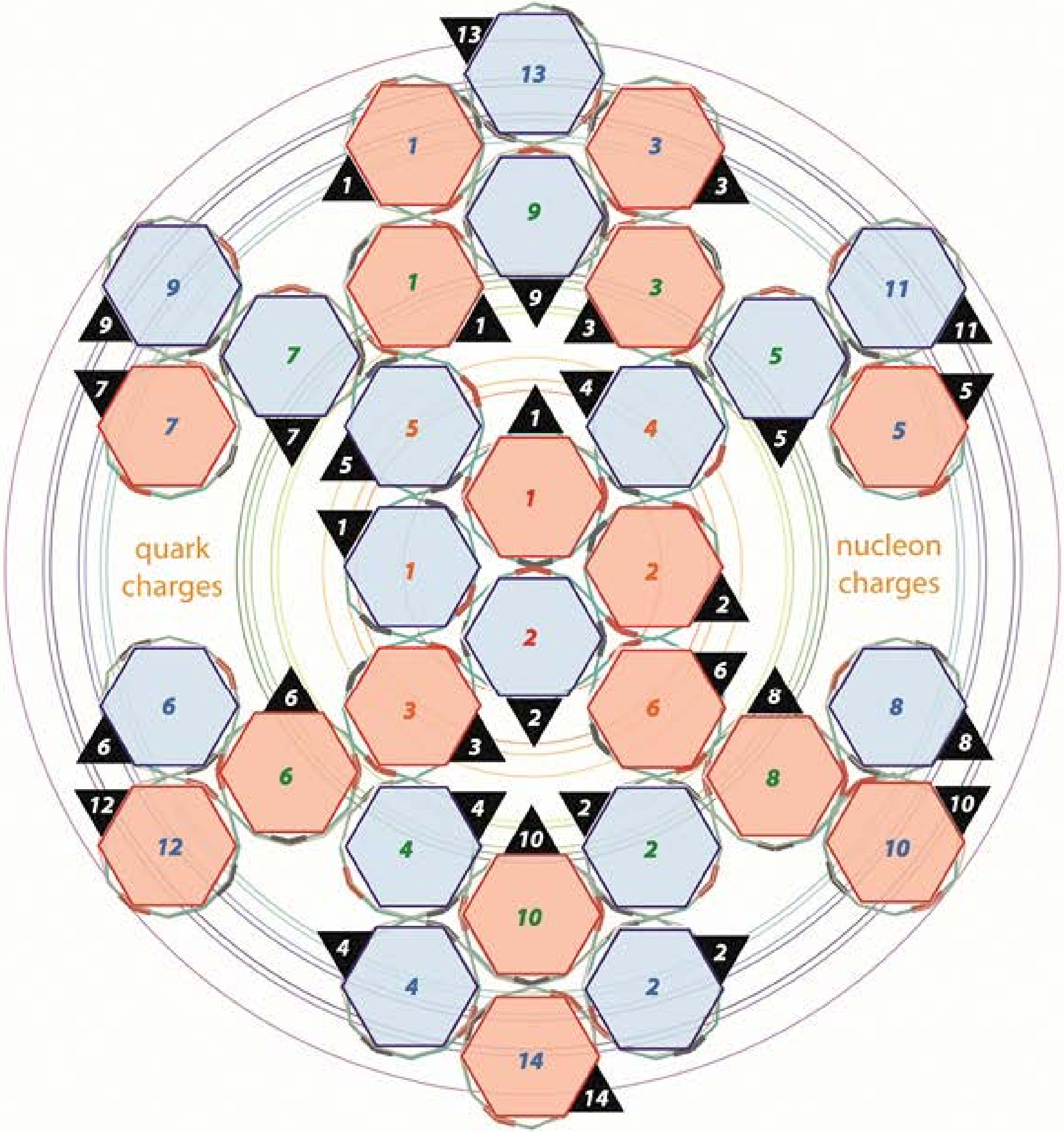
quark
charges
nucleon
charges

(Strong force - topological Electric Points)

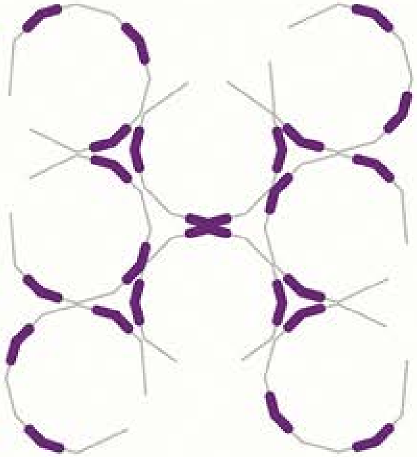

residual EM forces

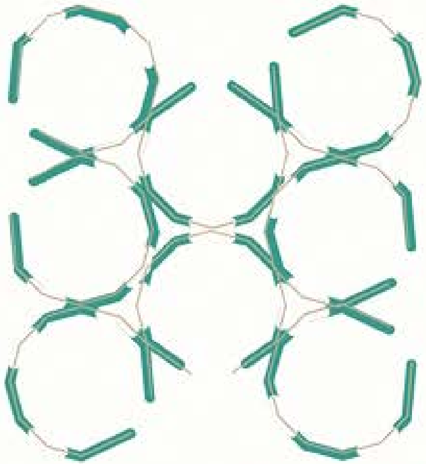

(Strong force - topological Magnetic dipoles)

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Bound electron arrangements

Externally bound electrons produce sub-orbital patterns different to the electron orbitals of internally bound electrons

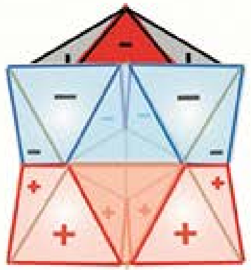

Deuterium

electrons are externally bound to the Deuteron nuclei

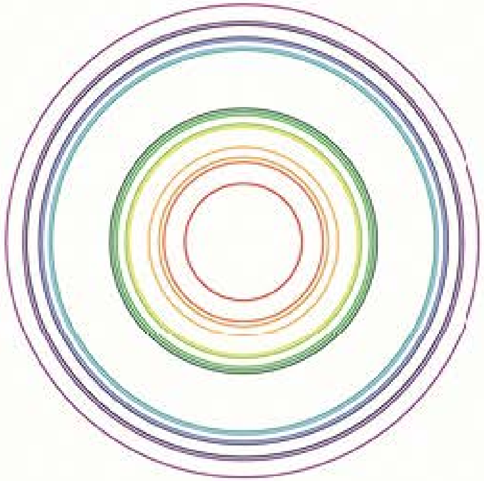

Conductors

Charges are free to move and equalise

electrons require less energy to 'break free' from Nuclei

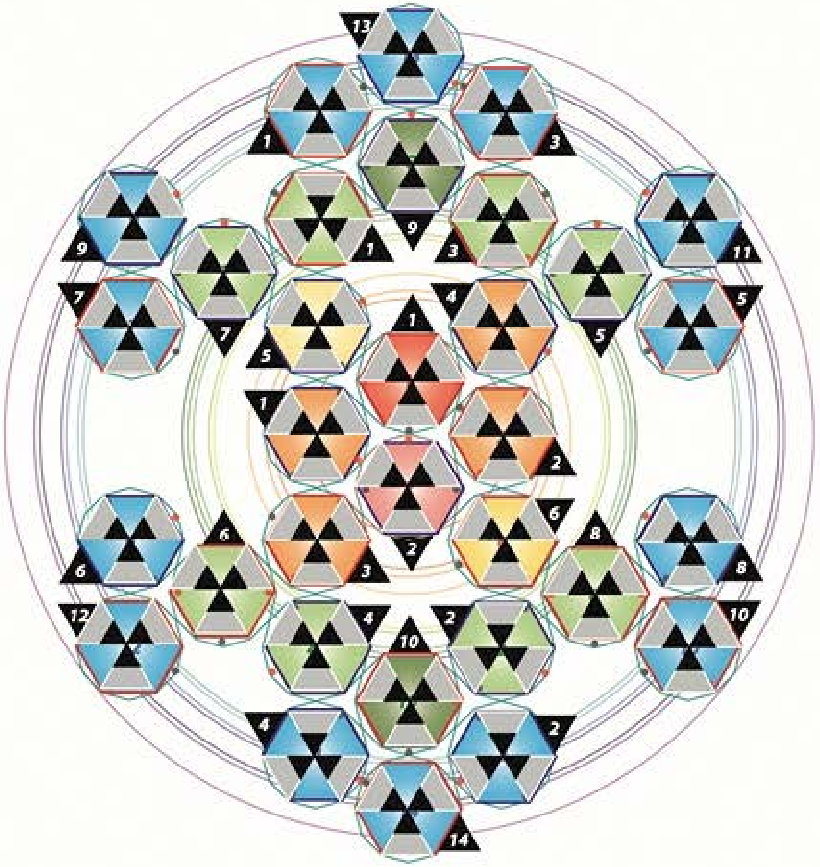

The electron orbitals of conductors are lower energies than those of insulators

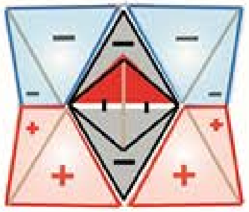

Deuterium

electrons are internally bound in the Deuteron nuclei

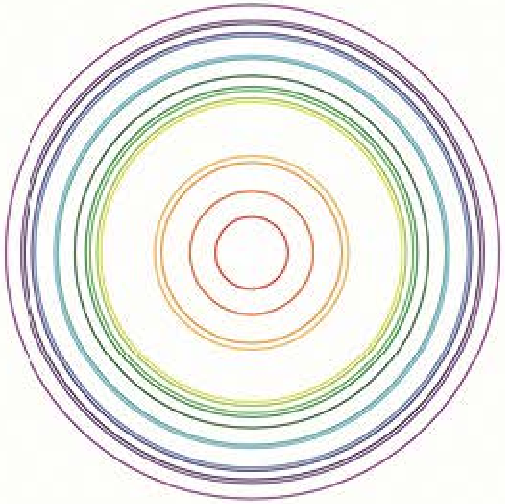

Insulators

Charges are bound to specific locations

electrons require more energy to 'break free' from Nuclei

2D mass-energy geometries form the fabric of 3D Matter topologies

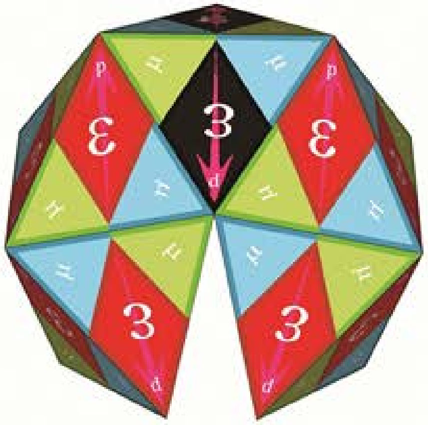

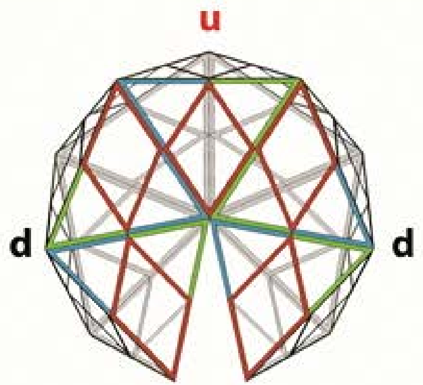

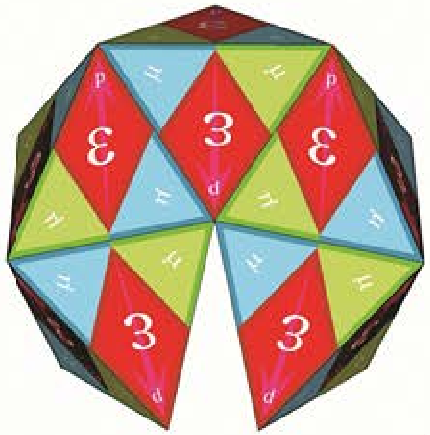

Proton

12

[24-12]

nett Charge

component charges

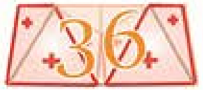

charged mass-energy geometry

20π

Matter topology

12

[42-30]

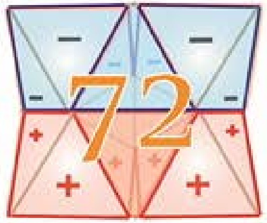

40π

Deuteron

nett Charge

component charges

0

[18-18]

charged mass-energy geometry

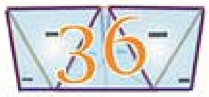

Matter topology

20π

Neutron

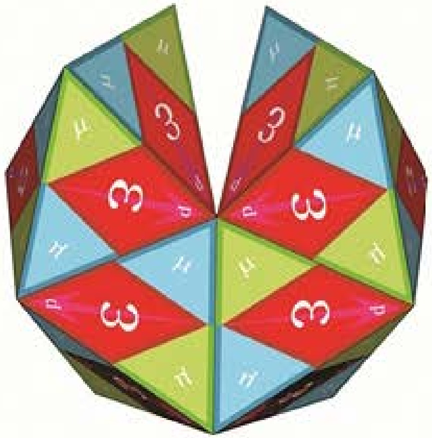

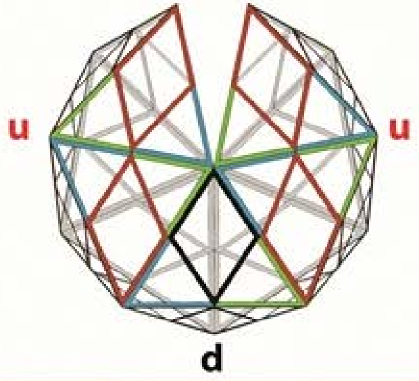

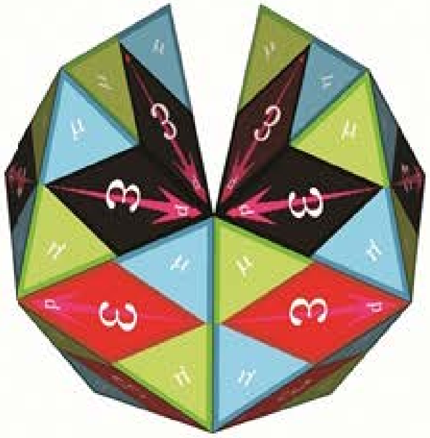

Charge provides the framework for the mass-energy geometry of Matter

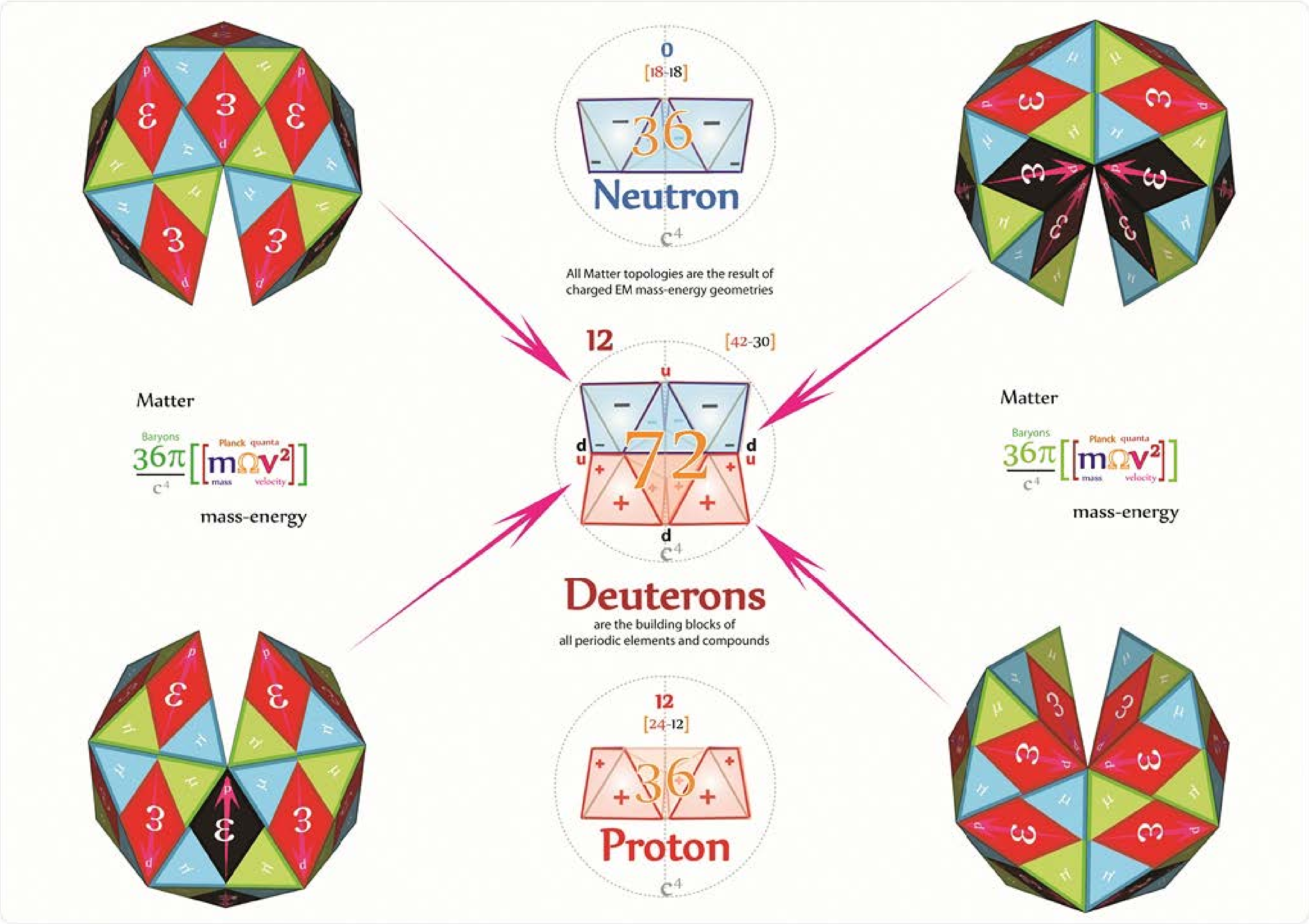
0
[18-18]
36
Neutron
c^4
12
[42-30]
u
d
u
d
u
72
d
c^4
Deuterons
12
[24-12]
36
Proton
c^4
Matter
Baryons
Planck
quanta
mass
velocity
mass-energy
Matter
Baryons
Planck
quanta
mass
velocity
mass-energy

All Matter topologies are the result of charged EM mass-energy geometries

Deuterons are the building blocks of all periodic elements and compounds

Matter

$$\frac{36\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass-energy

Strong Forces and Nuclear Bonding

How do Baryons with Positive and Neutral charges
attract each other and bind to form stable elements ?

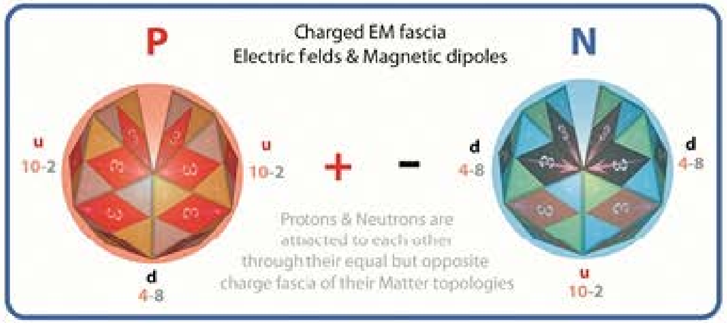
P
N
u
10-2
u
10-2
d
4-8
+
-
d
4-8
d
4-8
u
10-2

Charged EM fascia
Electric fields & Magnetic dipoles

Protons & Neutrons are
attracted to each other
through their equal but opposite
charge fascia of their Matter topologies

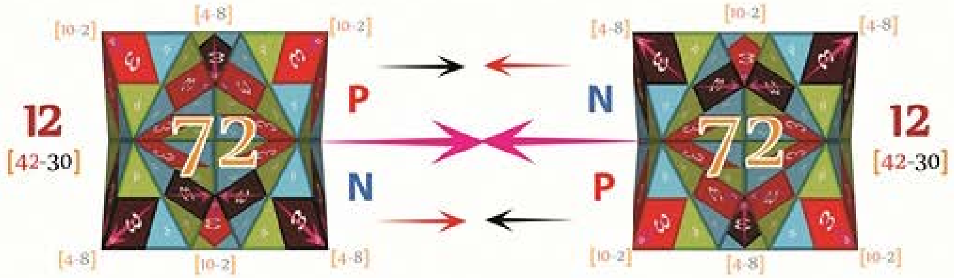
[10-2]
[4-8]
[10-2]
12
[42-30]
72
P
N
[4-8]
[10-2]
[4-8]
N
P
[4-8]
[10-2]
[4-8]
72
12
[42-30]
[10-2]
[4-8]
[10-2]

Once nuclei have been created their external
electric fields & magnetic dipoles continue to
attract and bind individual nuclei together via
the Residual EM Force as nuclei seek charge
equilibrium by combining with each other
and electrons to form neutral elements

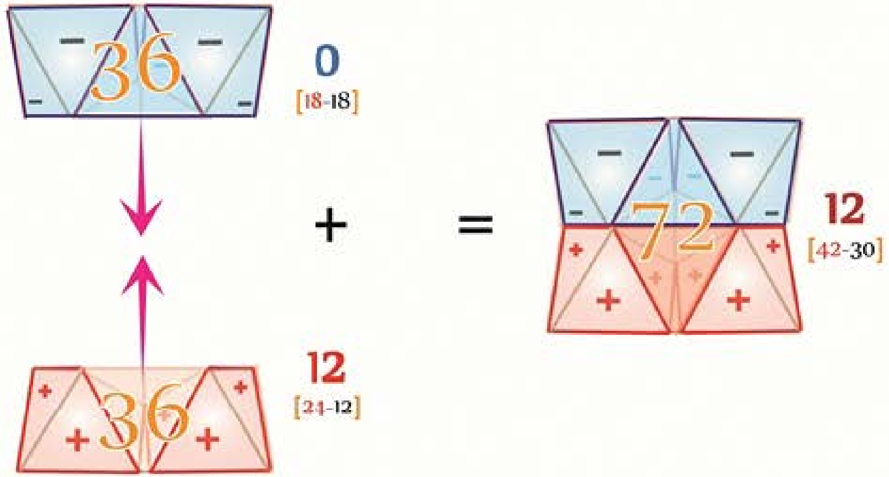
36
0
[18-18]
+
=
72
12
[42-30]
36
12
[24-12]

The attraction and binding of Protons and Neutrons
through their electric charge imbalances
creates Deuterons which have +12 charges

The residual Z[+12] charge is what attracts electrons
to form neutral atomic nuclei via Coulombic attraction

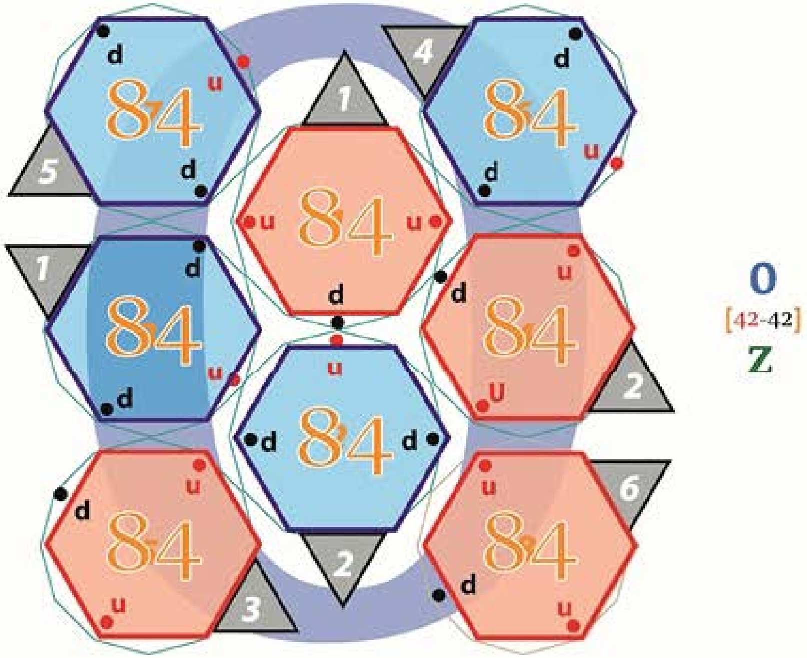
84
84
84
84
84
84
84
84
d
u
1
2
3
4
5
6
0
[42-42]
Z

Strong Nucleonic Bonding

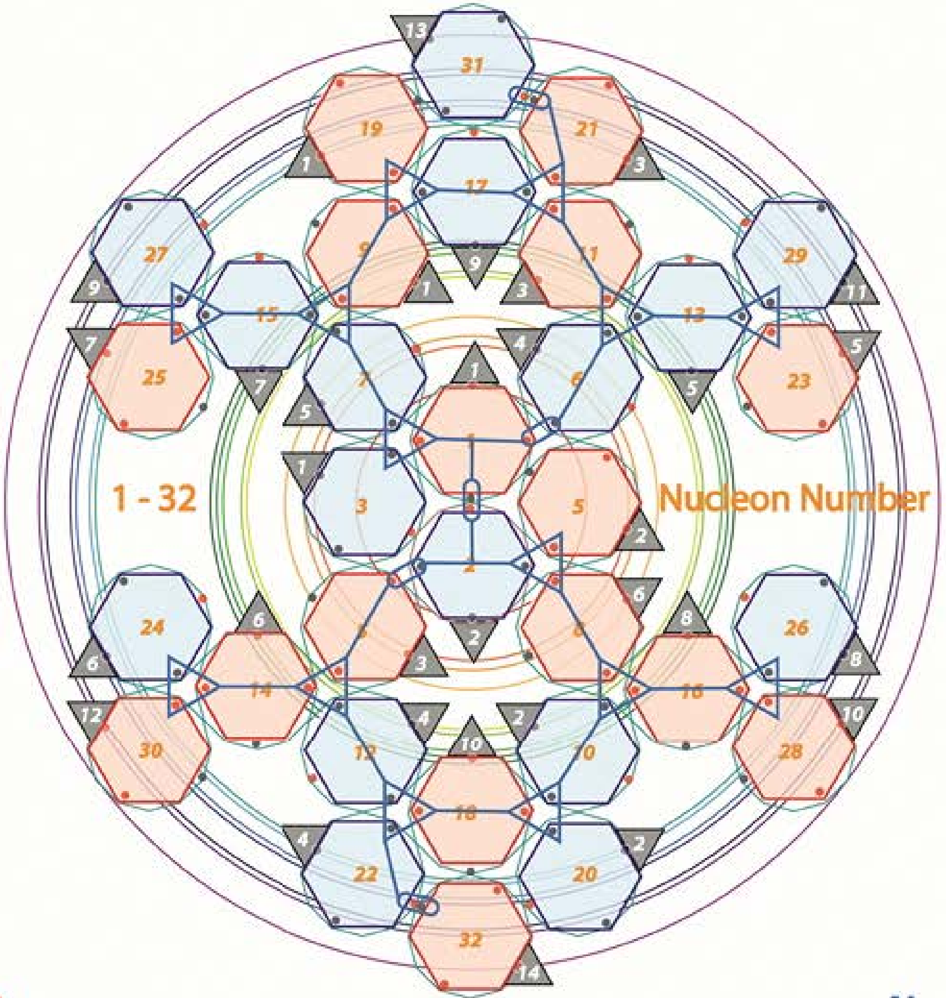

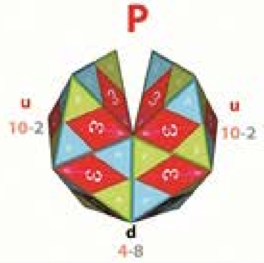

+

In addition to the Strong colour force
a separate residual binding force arises
from the external apexes formed by
Positive and Negative Electric points of quarks
in each Baryon [nuclear-chemical bonds]

-

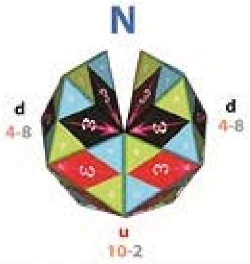

All energy seeks equilibrium

Strong E-force
nuclear linkages

External Electric field points
bind via Charge fascia interactions
with Plus and Minus Electric points
combining and sharing energy
throughout the resultant nuclei

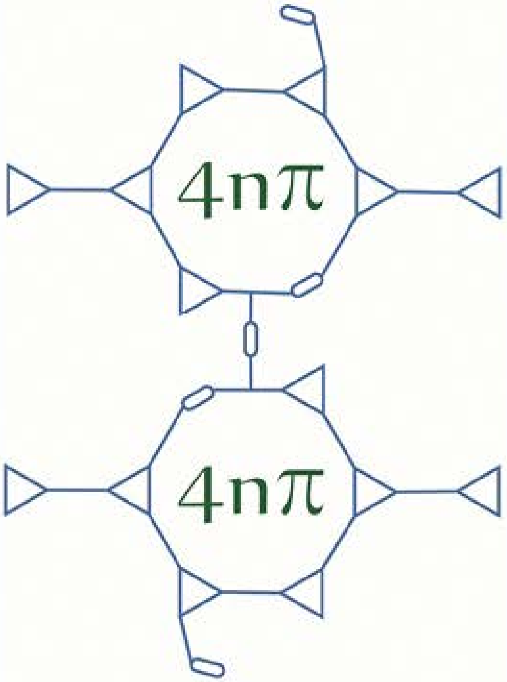

● *Positive Electric field apex*

Negative Electric field apex ●

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Hydrogenic vs Nucleonic electron binding

If a unbound Proton attracts an Electron
the Electron can be bound to the nuclei
in a number of differing orientations
[each with differing spin energies]

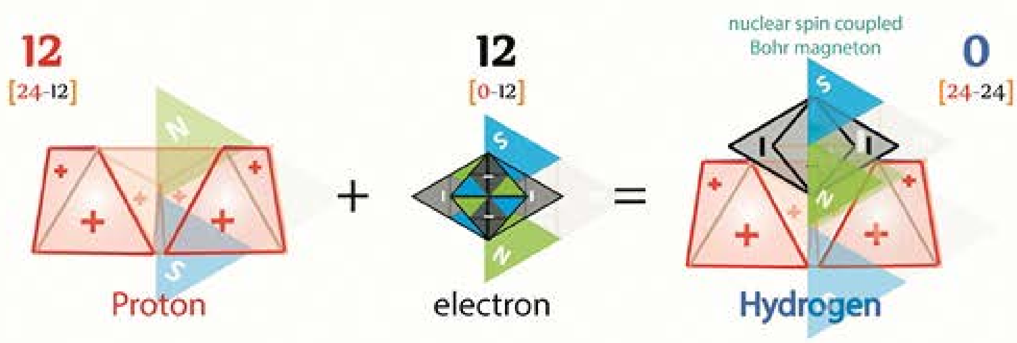
12
[24-12]
Proton
+
12
[0-12]
electron
=
nuclear spin coupled
Bohr magneton
0
[24-24]
Hydrogen

The energy levels of Baryons determines the KEM field energy of bound electrons

All atomic nuclei (and elements) are Deuteron'ic nuclei with a mixture of *orthagonal*, parallel and anti-paralllel spin orientations

(this is why Rydberg is less accurate for elemental nuclei compared to Hydrogenic atoms - see QM spin)

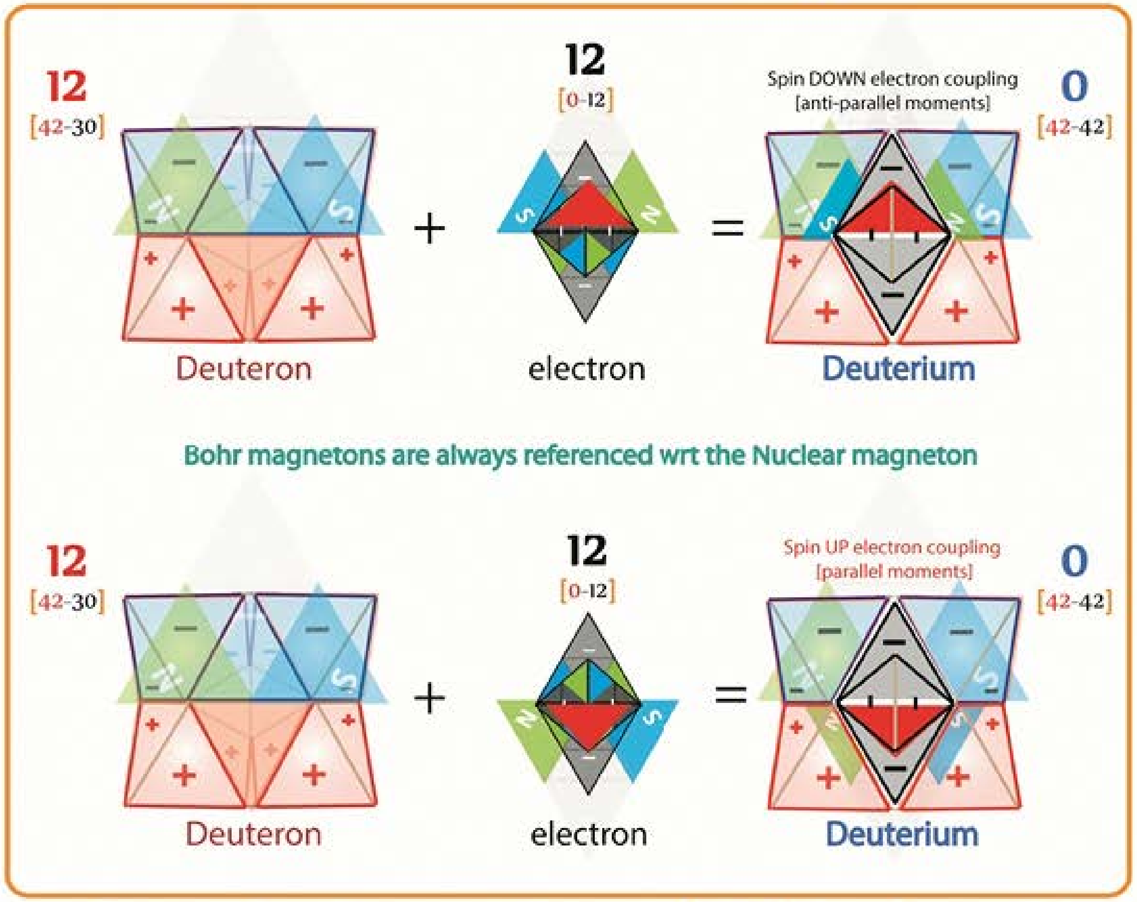
12
[42-30]
Deuteron
+
12
[0-12]
electron
=
Spin DOWN electron coupling
[anti-parallel moments]
0
[42-42]
Deuterium
12
[42-30]
Deuteron
+
12
[0-12]
electron
=
Spin UP electron coupling
[parallel moments]
0
[42-42]
Deuterium

Bohr magnetons are always referenced wrt the Nuclear magneton

Electrons can be bound to deuteron nuclei
in four distinct orientations [2 horizontal & 2 vertical]
with each spin coupling orientation producing
differing energy electron orbitals
[wrt to the nuclear magnetic moments]

Ejecting electrons from atomic nuclei
by adding energies to their KEM fields
[the Photoelectric effect]
creates Positive Ions

Vertically orientated electrons
within Proton-Neutron Nuclei [Deuterons]
create quantum synchronous convertor geometries

electrons produce stronger magnetic moments due to their mass-charge quotient

Atomic Nucleus Master Template

Nucleon Number		
Z	1 Proton	[24-12]
	1 electron	[0-12]
	1 Neutron	[18-18]

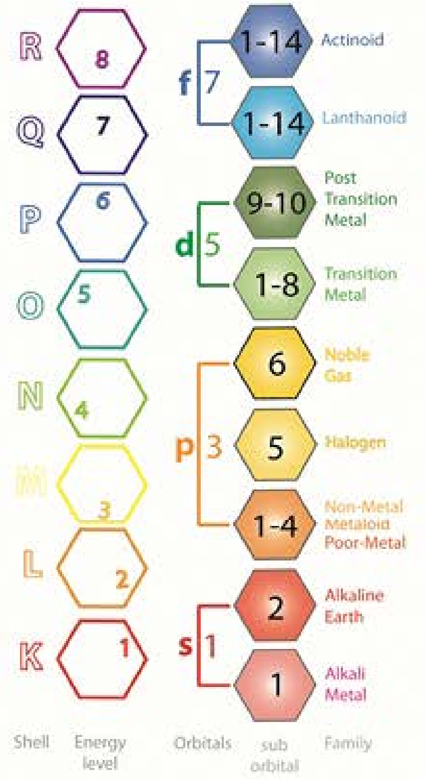
R 8
Q 7
P 6
O 5
N 4
M 3
L 2
K 1
f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metalloid Poor-Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Shell
Energy level
Orbitals
sub orbital
Family

○	s	1 sub-Orbital	(2 electrons max)
○	p	3 sub-Orbitals	(6 electrons max)
○	d	5 sub-Orbitals	(10 electrons max)
○	f	7 sub-Orbitals	(14 electrons max)

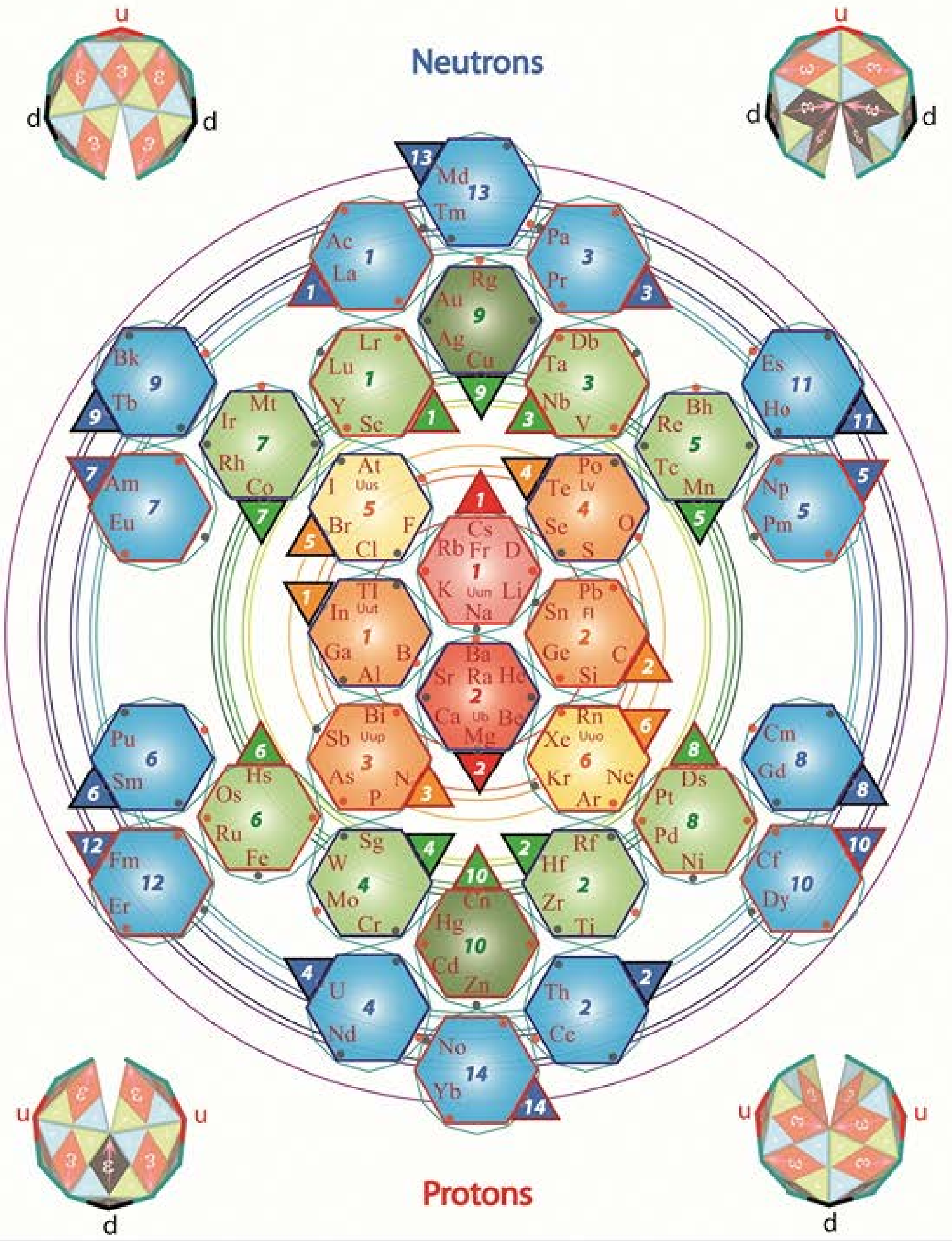
u
d
d
u
d
d
Neutrons
13 Md 13 Tm
1 Ac 1 La
3 Pa 3 Pr
Rg Au 9 Ag Cu 9
Lr Lu 1 Y Sc 1
Db Ta 3 Nb V 3
9 Bk 9 Tb
11 Es 11 Ho
Mt Ir 7 Rh Co 7
Bh Re 5 Tc Mn 5
7 Am 7 Eu
5 Np 5 Pm
At I Uus 5 Br Cl F 5
4 Po Te Lv 4 Se S O
1 Cs Rb Fr D 1 K Uun Li Na
1 Tl In Uut 1 Ga Al B
Pb Sn Fl 2 Ge Si C 2
Ba Sr Ra He 2 Ca Ub Be Mg 2
Bi Sb Uup 3 As P N 3
6 Rn Xe Uuo 6 Kr Ne Ar
6 Pu 6 Sm
8 Cm 8 Gd
6 Hs Os 6 Ru Fe
8 Ds Pt 8 Pd Ni
12 Fm 12 Er
10 Cf 10 Dy
4 Sg W 4 Mo Cr
2 Rf Hf 2 Zr Ti
10 Cn Hg 10 Cd Zn
4 U 4 Nd
2 Th 2 Ce
No 14 Yb 14
u
u
d
u
u
d
Protons

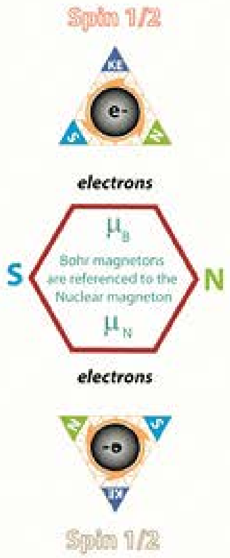
Spin 1/2
e-
electrons
μB
Bohr magnetons are referenced to the Nuclear magneton
μN
S
N
electrons
-e
Spin 1/2

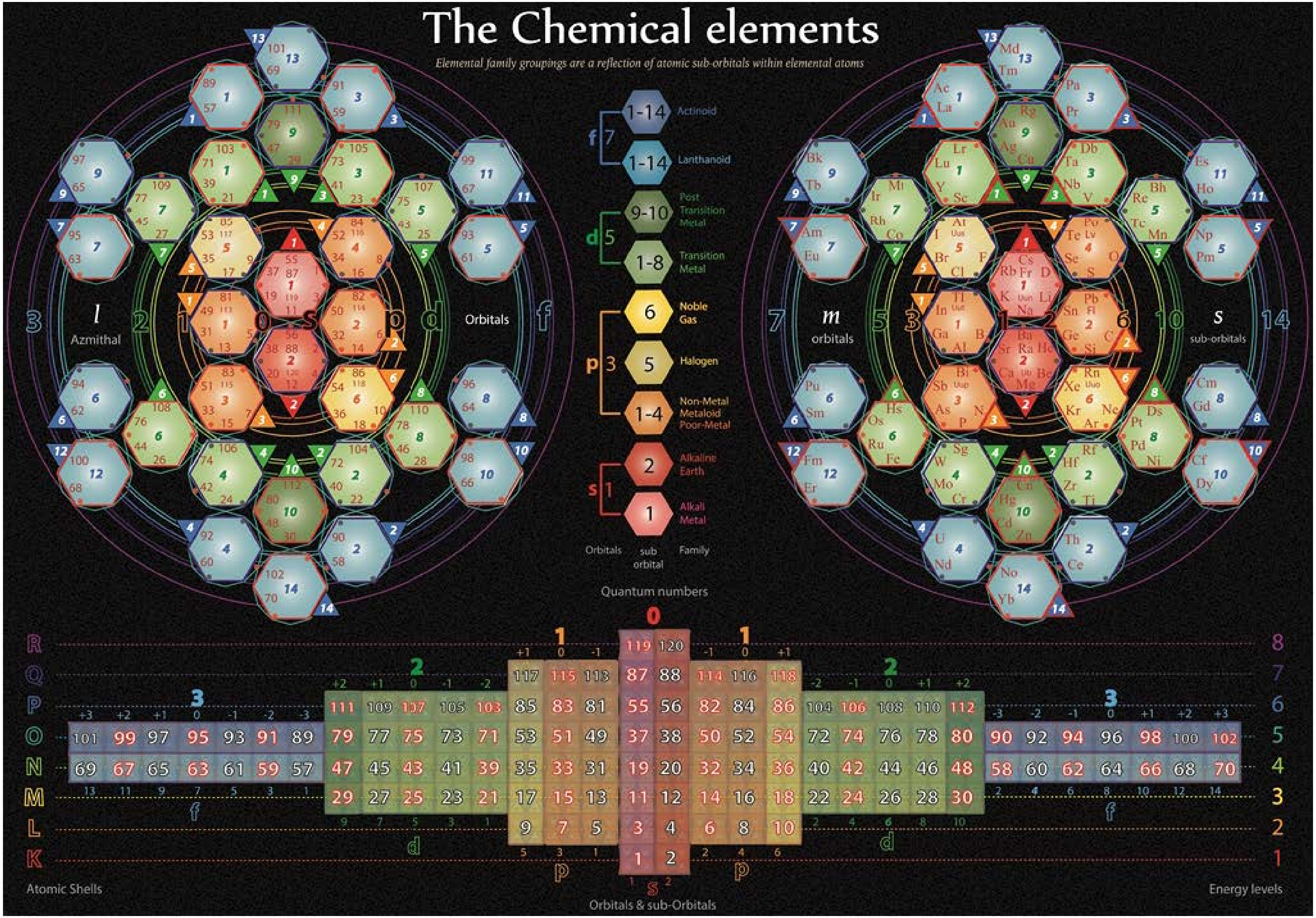

The Chemical elements

Elemental family groupings are a reflection of atomic sub-orbitals within elemental atoms

f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metaloid Poor-Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Orbitals
sub orbital
Family
Quantum numbers
3
l
Azmithal
2
1
0
s
p
d
Orbitals
f
7
m
orbitals
5
3
1
2
6
10
s
sub-orbitals
14
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

	3							2					1			0		1			2					3							
	+3	+2	+1	0	-1	-2	-3	+2	+1	0	-1	-2	+1	0	-1			-1	0	+1	-2	-1	0	+1	+2	-3	-2	-1	0	+1	+2	+3	
R																119	120																8
Q													117	115	113	87	88	114	116	118													7
P								111	109	107	105	103	85	83	81	55	56	82	84	86	104	106	108	110	112								6
O	101	99	97	95	93	91	89	79	77	75	73	71	53	51	49	37	38	50	52	54	72	74	76	78	80	90	92	94	96	98	100	102	5
N	69	67	65	63	61	59	57	47	45	43	41	39	35	33	31	19	20	32	34	36	40	42	44	46	48	58	60	62	64	66	68	70	4
M								29	27	25	23	21	17	15	13	11	12	14	16	18	22	24	26	28	30								3
L													9	7	5	3	4	6	8	10													2
K																1	2																1
	13	11	9	7	5	3	1	9	7	5	3	1	5	3	1	1	2	2	4	6	2	4	6	8	10	2	4	6	8	10	12	14	
	f							d					p			s		p			d					f							

Element Numbers

Z *
1 Proton [24-12]
1 Neutron [18-18]
1 electron [0-12]

Each elemental nuclei is made from Deuterium

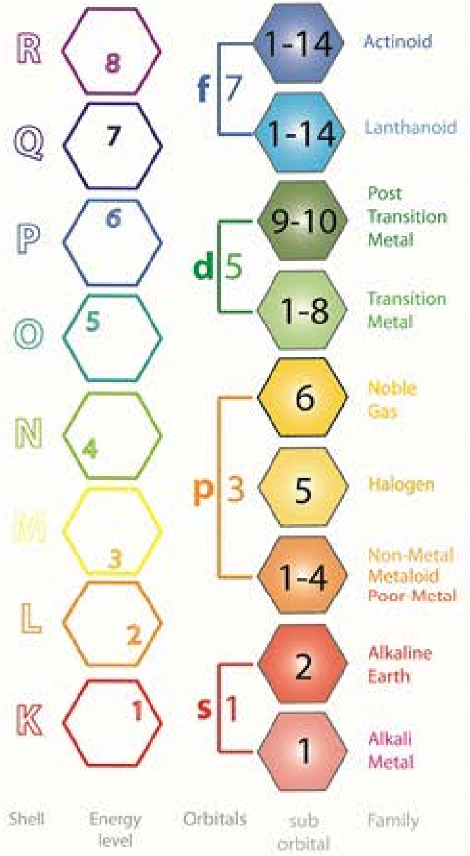
R 8
Q 7
P 6
O 5
N 4
M 3
L 2
K 1
f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metaloid Poor Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Shell
Energy level
Orbitals
sub orbital
Family

s 1 sub-Orbital (2 electrons max)
p 3 sub-Orbitals (6 electrons max)
d 5 sub-Orbitals (10 electrons max)
f 7 sub-Orbitals (14 electrons max)

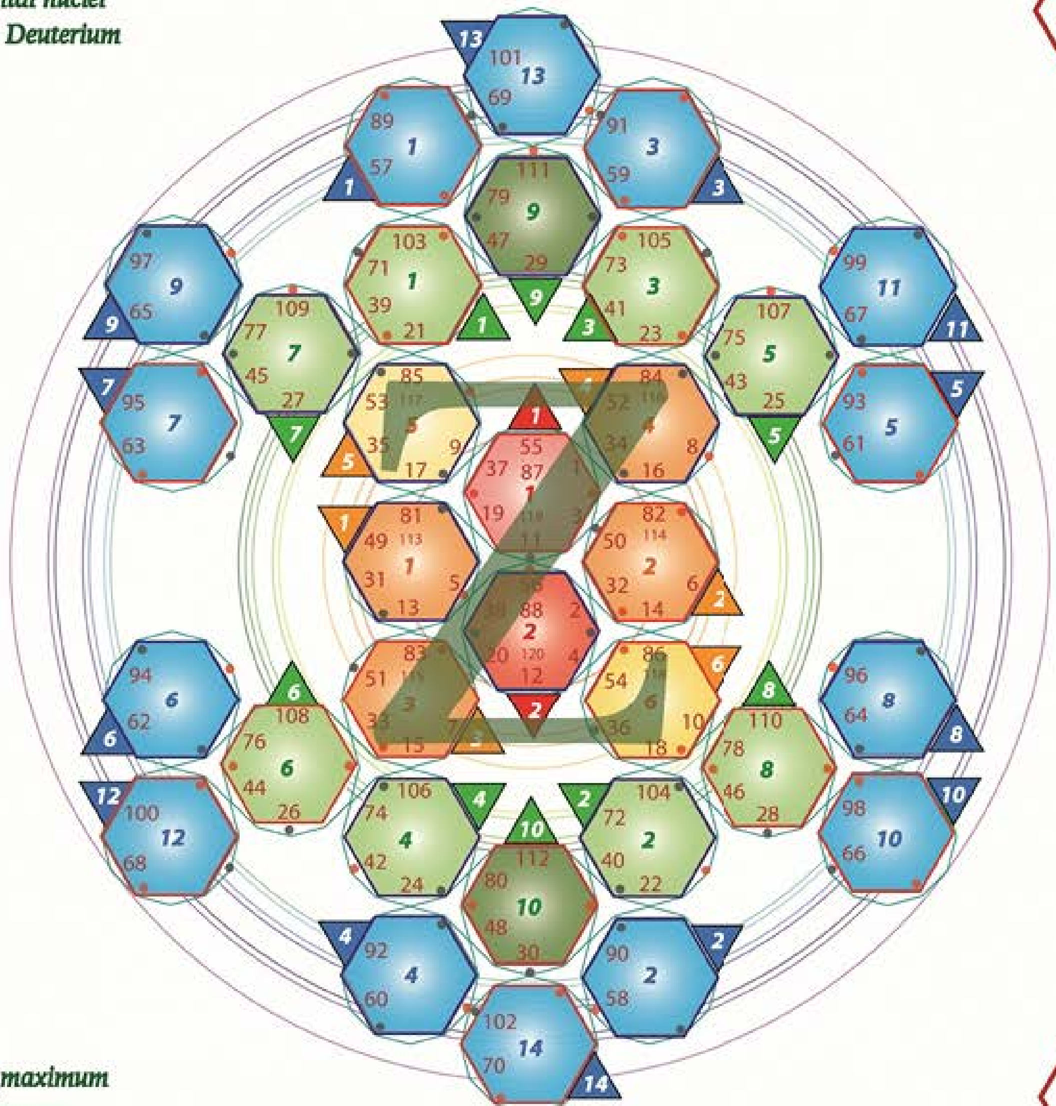
13 101 13 69
89 1 57 1
91 3 59 3
111 79 9 47 29 9
103 71 1 39 21 1
105 73 3 41 23 3
97 9 65 9
99 11 67 11
109 77 7 45 27 7
107 75 5 43 25 5
95 7 63 7
93 5 61 5
85 53 117 5 35 17 9 5
84 52 116 4 34 16 8 4
1 55 37 87 1 19 119 11 3
81 49 113 1 31 13 5 1
82 50 114 2 32 14 6 2
56 38 88 2 20 120 12 4 2
83 51 115 3 33 15 7 3
86 54 118 6 36 18 10 6
94 6 62 6
96 8 64 8
108 76 6 44 26 6
110 78 8 46 28 8
100 12 68 12
98 10 66 10
106 74 4 42 24 4
104 72 2 40 22 2
10 112 80 10 48 30
92 4 60 4
90 2 58 2
102 14 70 14
Z

There are a maximum of 120 elements possible

Atomic shells

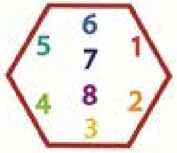

Energy levels

Element Names

Z * 1 Proton [24-12]
1 Neutron [18-18]
1 electron [0-12]

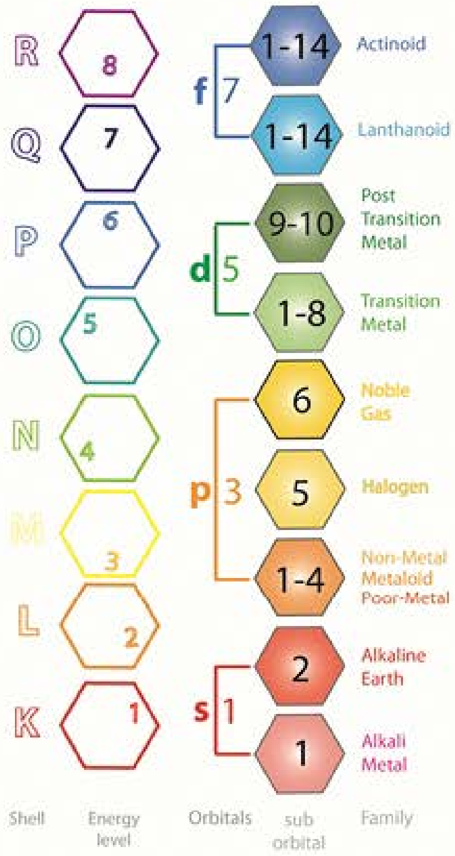
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
f 7
d 5
p 3
s 1
1-14
Actinoid
1-14
Lanthanoid
9-10
Post Transition Metal
1-8
Transition Metal
6
Noble Gas
5
Halogen
1-4
Non-Metal Metaloid Poor-Metal
2
Alkaline Earth
1
Alkali Metal
Shell
Energy level
Orbitals
sub orbital
Family

o s 1 sub-Orbital (2 electrons max)

O p 3 sub-Orbitals (6 electrons max)

O d 5 sub-Orbitals (10 electrons max)

O f 7 sub-Orbitals (14 electrons max)

There are a maximum of 120 elements possible

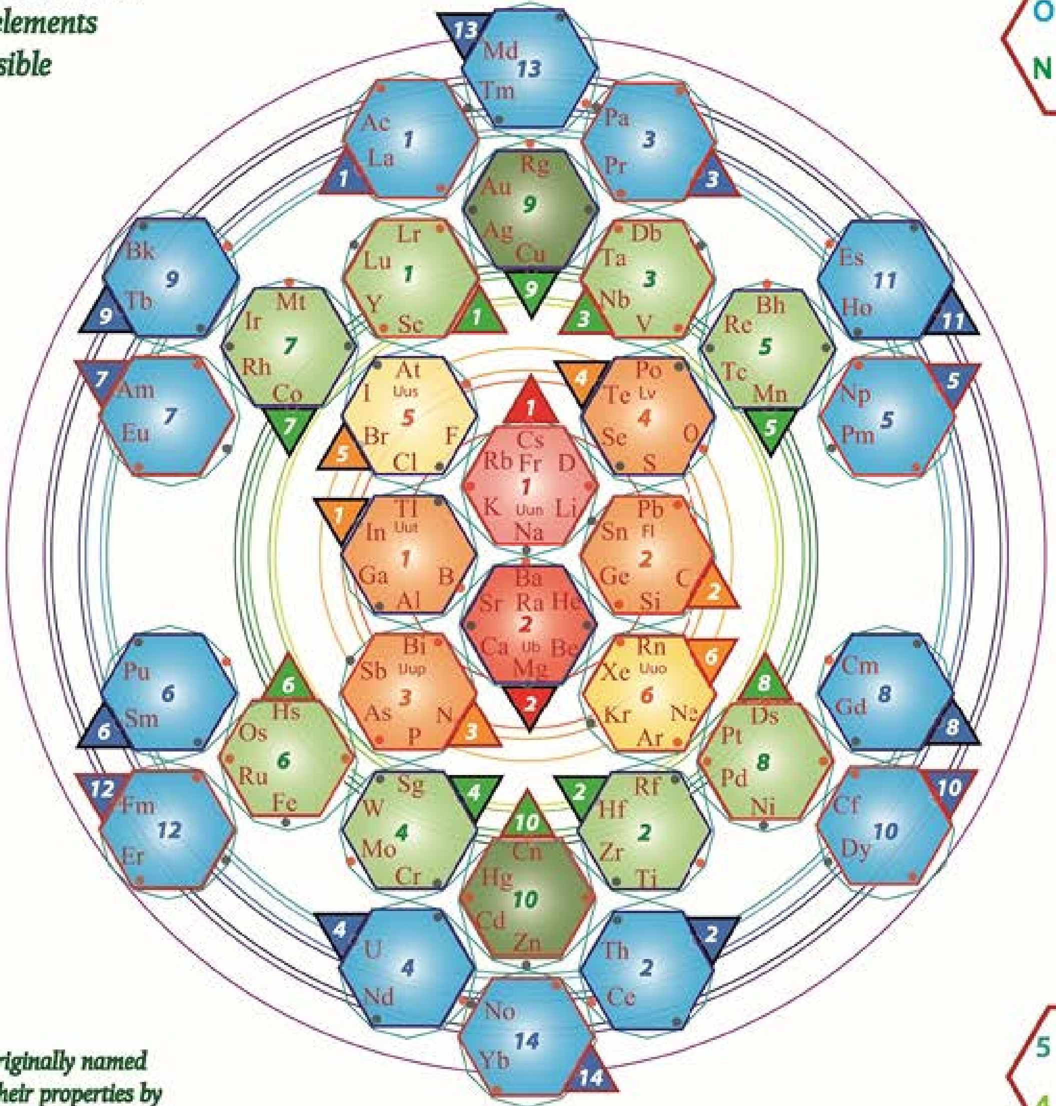
13 Md 13 Tm 13
Ac 1 La 1
Pa 3 Pr 3
Rg Au 9 Ag Cu 9
Lr Lu 1 Y Sc 1
Db Ta 3 Nb V 3
Bk 9 Tb 9
Mt Ir 7 Rh Co 7
Bh Re 5 Tc Mn 5
Es 11 Ho 11
7 Am 7 Eu
Np 5 Pm 5
At I Uus 5 Br Cl F 5
1 Cs Rb Fr D 1 K Uun Li Na
4 Po Te Lv 4 Se O S
1 Tl In Uut 1 Ga B Al
Pb Sn Fl 2 Ge C Si 2
Ba Sr Ra He 2 Ca Ub Be Mg 2
Bi Sb Uup 3 As N P 3
Rn Xe Uuo 6 Kr Ne Ar 6
Pu 6 Sm 6
6 Hs Os 6 Ru Fe
8 Ds Pt 8 Pd Ni
Cm 8 Gd 8
12 Fm 12 Er
Sg W 4 Mo Cr 4
10 Cn Hg 10 Cd Zn
2 Rf Hf 2 Zr Ti
Cf 10 Dy 10
4 U 4 Nd
Th 2 Ce 2
No 14 Yb 14

Atomic shells
P
O
Q
K
N
R
L
M

They were originally named according to their properties by their discoverer but have recently been named after famous scientists

6
5
7
1
4
8
2
3
Energy levels

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Electron orbital configurations

A huge number of differing d and f orbital configurations are possible given the number of nuclei and bond points created by elemental topologies

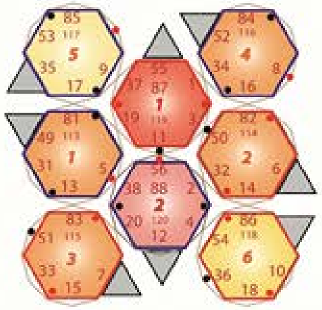
85
53
117
5
35
9
17
84
52
116
4
34
8
16
55
37
87
1
19
119
3
11
81
49
113
1
31
5
13
82
50
114
2
32
6
14
56
38
88
2
2
20
120
4
12
83
51
115
3
33
7
15
86
54
118
6
36
10
18

As the number of nucleons increases so does the complexity of the electron orbitals possible

quantum snowflakes

However all have a stable 'core' grouping of nuclei comprised of s and p electron orbitals

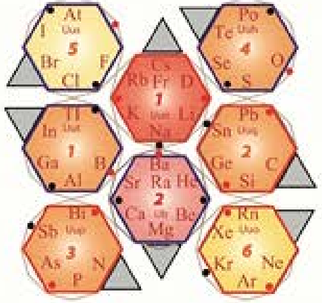
At
I
Uus
5
Br
F
Cl
Po
Te
Uuh
4
Se
O
S
Cs
Rb
Fr
D
1
K
Uue
Li
Na
Tl
In
Uut
1
Ga
B
Al
Pb
Sn
Uuq
2
Ge
C
Si
Ba
Sr
Ra
He
2
Ca
Ubn
Be
Mg
Bi
Sb
Uup
3
As
N
P
Rn
Xe
Uuo
6
Kr
Ne
Ar

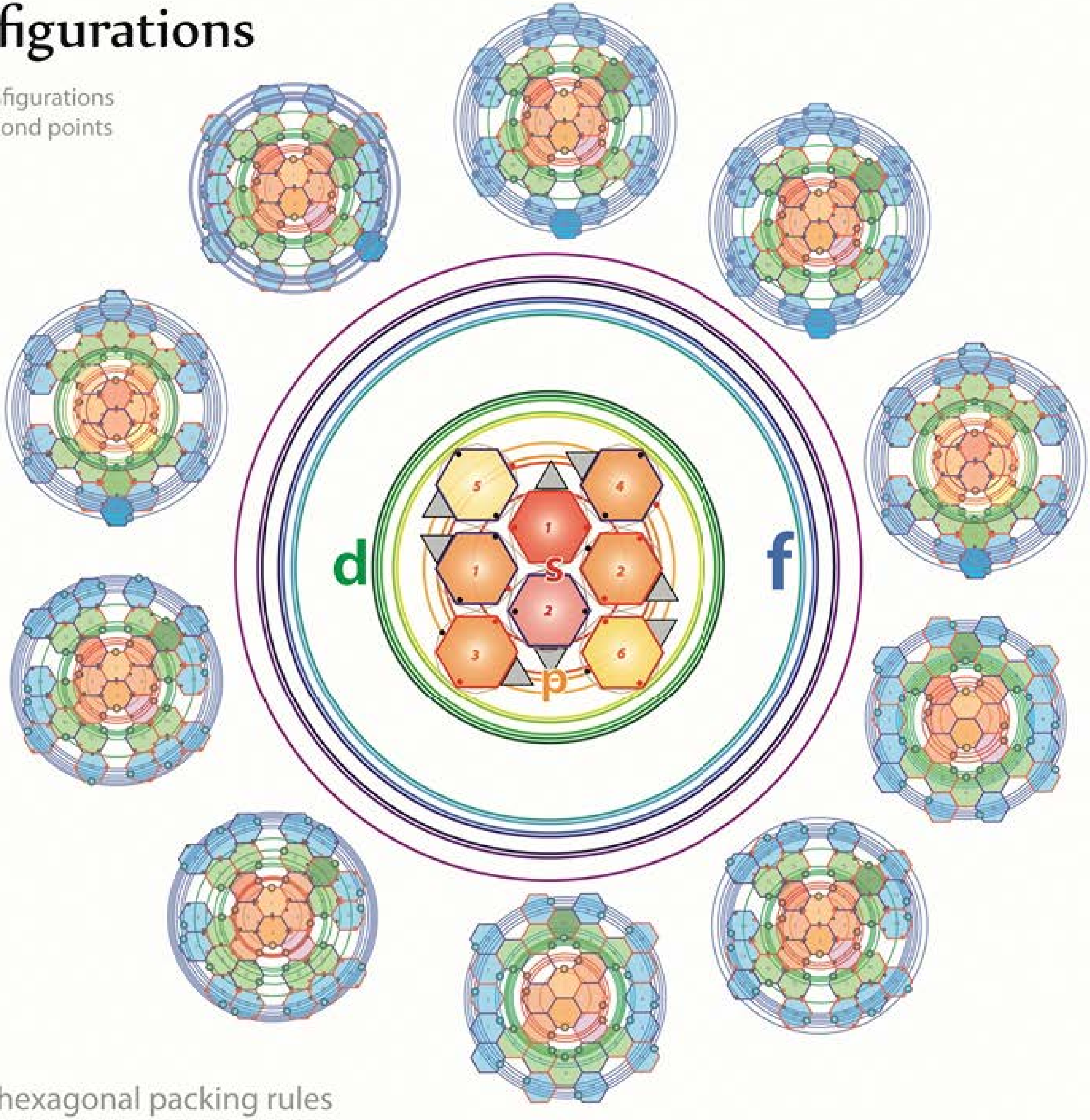
d
f
s
p
5
4
1
1
2
2
3
6

All nuclei bonding closely follows hexagonal packing rules

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Atomic Nucleus
Exploded view

1 Proton	[24-12]
1 electron	[0-12]
1 Neutron	[18-18]

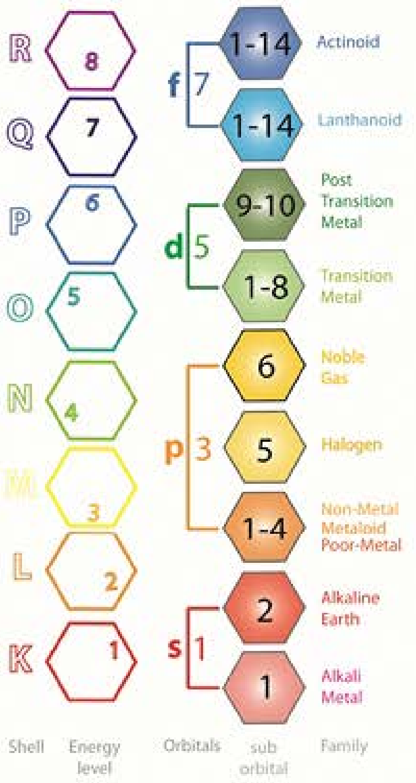
R
8
Q
7
P
6
O
5
N
4
M
3
L
2
K
1
f 7
1-14
Actinoid
1-14
Lanthanoid
d 5
9-10
Post Transition Metal
1-8
Transition Metal
p 3
6
Noble Gas
5
Halogen
1-4
Non-Metal Metaloid Poor-Metal
s 1
2
Alkaline Earth
1
Alkali Metal
Shell
Energy level
Orbitals
sub orbital
Family

○ s *1 sub-Orbital (2 electrons max)*

○ p *3 sub-Orbitals (6 electrons max)*

○ d *5 sub-Orbitals (10 electrons max)*

○ f *7 sub-Orbitals (14 electrons max)*

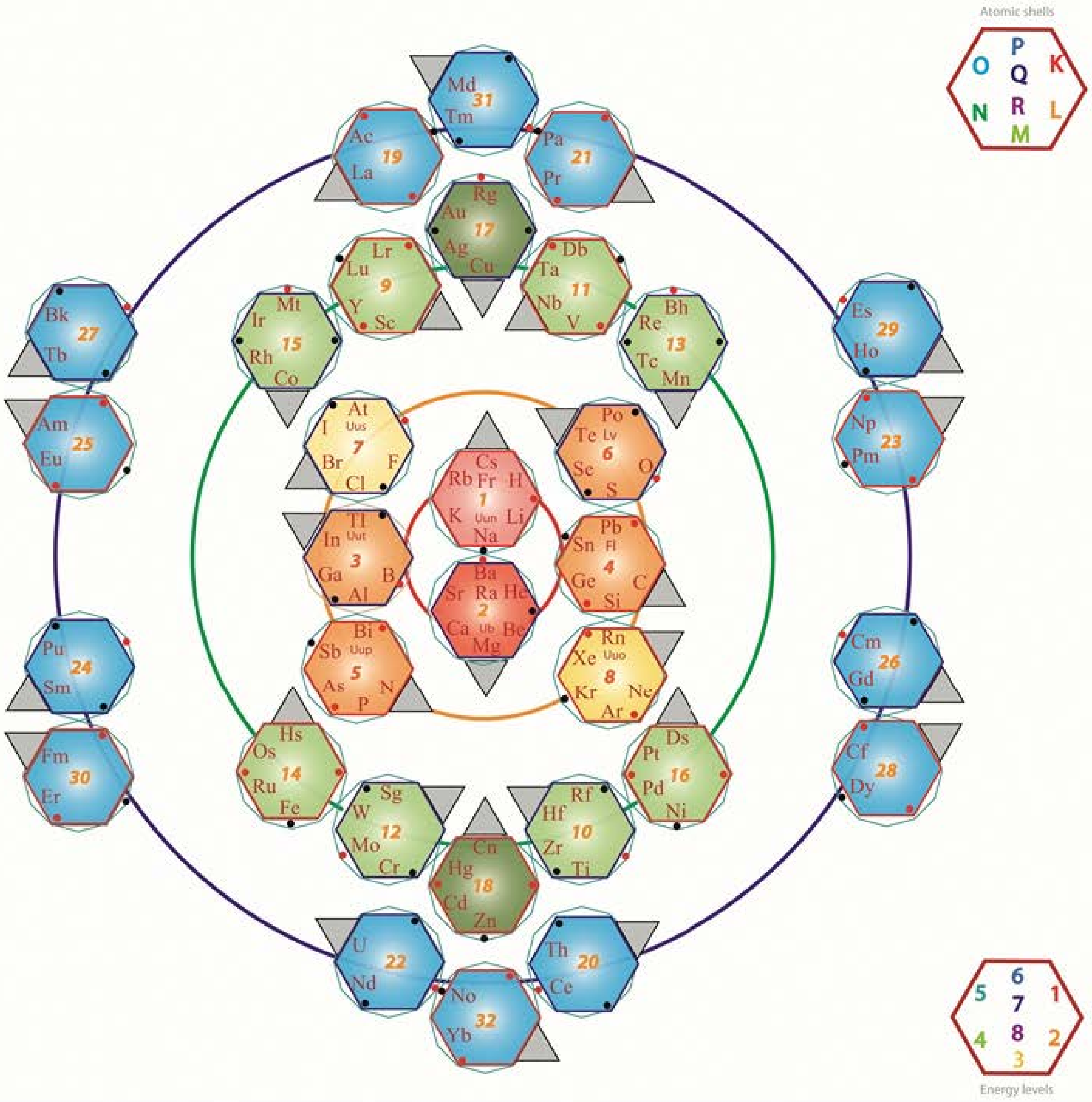
Atomic shells
P
O
Q
K
N
R
L
M
Md 31 Tm
Ac 19 La
Pa 21 Pr
Rg Au 17 Ag Cu
Lr Lu 9 Y Sc
Db Ta 11 Nb V
Mt Ir 15 Rh Co
Bh Re 13 Tc Mn
Bk 27 Tb
Es 29 Ho
Am 25 Eu
Np 23 Pm
At I Uus 7 Br F Cl
Po Te Lv 6 Se O S
Cs Rb Fr H 1 K Uun Li Na
Tl In Uut 3 Ga B Al
Pb Sn Fl 4 Ge C Si
Ba Sr Ra He 2 Ca Ub Be Mg
Bi Sb Uup 5 As N P
Rn Xe Uuo 8 Kr Ne Ar
Pu 24 Sm
Cm 26 Gd
Fm 30 Er
Cf 28 Dy
Hs Os 14 Ru Fe
Ds Pt 16 Pd Ni
Sg W 12 Mo Cr
Rf Hf 10 Zr Ti
Cn Hg 18 Cd Zn
U 22 Nd
Th 20 Ce
No 32 Yb
6
5
7
1
4
8
2
3
Energy levels

Tetryonics 43.06 - Exploded Atomic Nucleus

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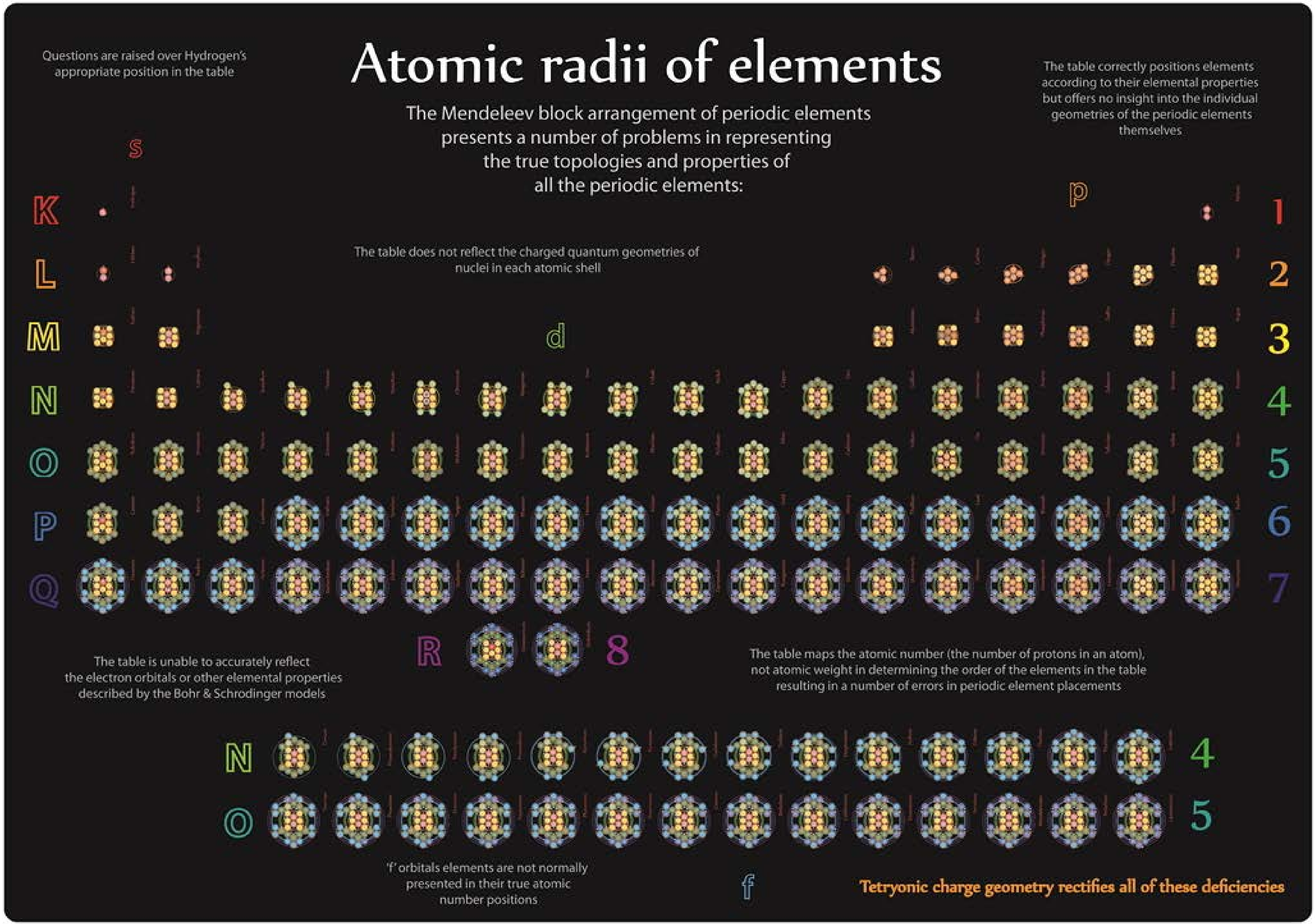

Atomic radii of elements

The Mendeleev block arrangement of periodic elements
presents a number of problems in representing
the true topologies and properties of
all the periodic elements:

Questions are raised over Hydrogen's appropriate position in the table

The table correctly positions elements according to their elemental properties but offers no insight into the individual geometries of the periodic elements themselves

The table does not reflect the charged quantum geometries of nuclei in each atomic shell

The table is unable to accurately reflect the electron orbitals or other elemental properties described by the Bohr & Schrodinger models

The table maps the atomic number (the number of protons in an atom), not atomic weight in determining the order of the elements in the table resulting in a number of errors in periodic element placements

'f' orbitals elements are not normally presented in their true atomic number positions

Tetryonic charge geometry rectifies all of these deficiencies

Tetryonics 43.07 - Atomic radii of elements

PERIODIC TABLE OF ELEMENTS

modelled on the polar view of the charge topologies of periodic elements

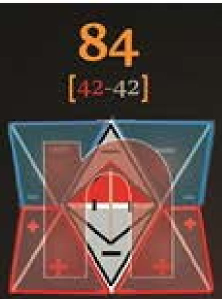

Deuterium [not Hydrogen] is the building block of all elements

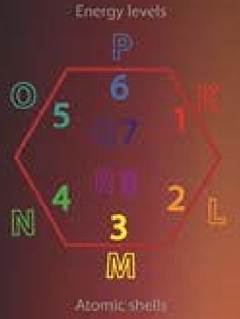
Energy levels
P
6
O
5
Q 7
K
1
R 8
4
2
N
L
3
M
Atomic shells

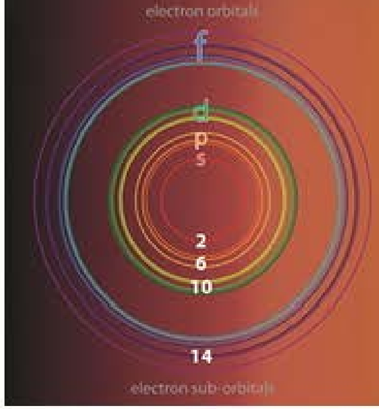
electron orbitals
f
d
p
s
2
6
10
14
electron sub-orbitals

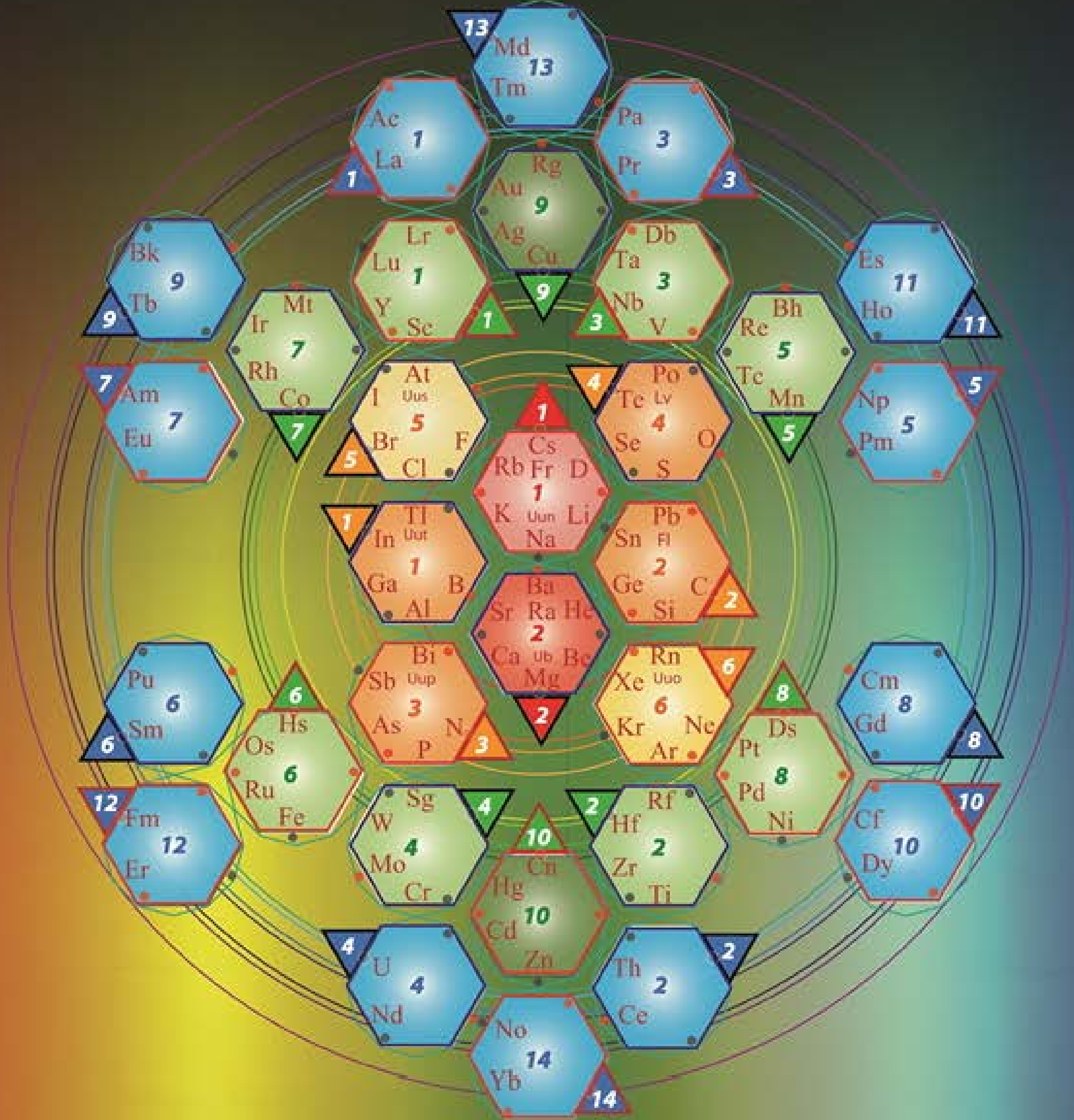
13 Md 13 Tm
1 Ac 1 La
Rg Au 9 Ag Cu 9
3 Pa 3 Pr
9 Bk 9 Tb
1 Lr Lu 1 Y Sc
3 Db Ta 3 Nb V
11 Es 11 Ho
7 Mt Ir 7 Rh Co
5 Bh Re 5 Tc Mn
7 Am 7 Eu
5 At I Uus 5 Br Cl F
1 Cs Rb Fr D 1 K Uun Li Na
4 Po Te Lv 4 Se O S
5 Np 5 Pm
1 Tl In Uut 1 Ga B Al
2 Ba Sr Ra He 2 Ca Ub Be Mg
2 Pb Sn Fl 2 Ge C Si
6 Pu 6 Sm
6 Hs Os 6 Ru Fe
3 Bi Sb Uup 3 As N P
6 Rn Xe Uuo 6 Kr Ne Ar
8 Ds Pt 8 Pd Ni
8 Cm 8 Gd
12 Fm 12 Er
4 Sg W 4 Mo Cr
10 Cn Hg 10 Cd Zn
2 Rf Hf 2 Zr Ti
10 Cf 10 Dy
4 U 4 Nd
2 Th 2 Ce
No 14 Yb 14

Periodic element families

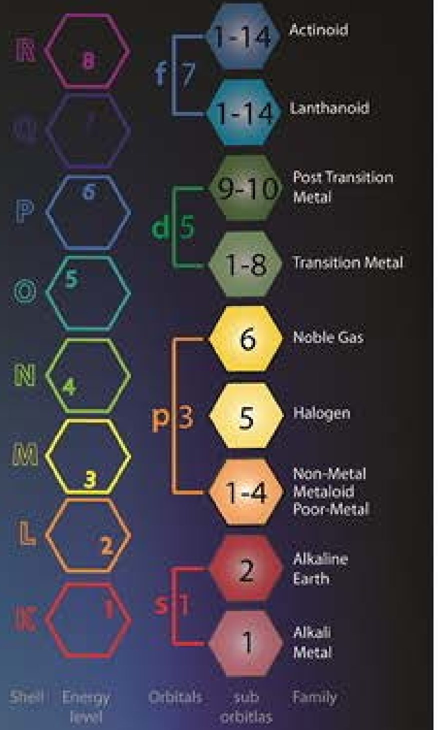
R 8
Q 7
P 6
O 5
N 4
M 3
L 2
K 1
f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metaloid Poor-Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Shell
Energy level
Orbitals
sub orbitlas
Family

3D quantum charge geometry of periodic element nuclei

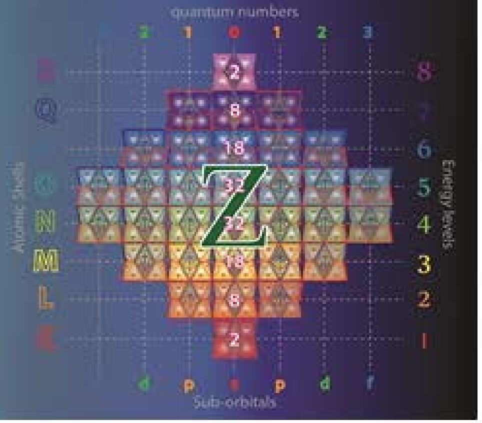
quantum numbers
3 2 1 0 1 2 3
R Q P O N M L K
Atomic shells
2 8 18 32 32 18 8 2
Z
8 7 6 5 4 3 2 1
Energy levels
d p s p d f
Sub-orbitals

THE ATOMIC NUCLEUS

the charged quantum mass-energy geometry of periodic element topologies

Neils Bohr

(7 October 1885 – 18 November 1962)

Erwin Schrödinger

[12 August 1887 – 4 January 1961]

NEILS BOHR

SCHRÖDINGER

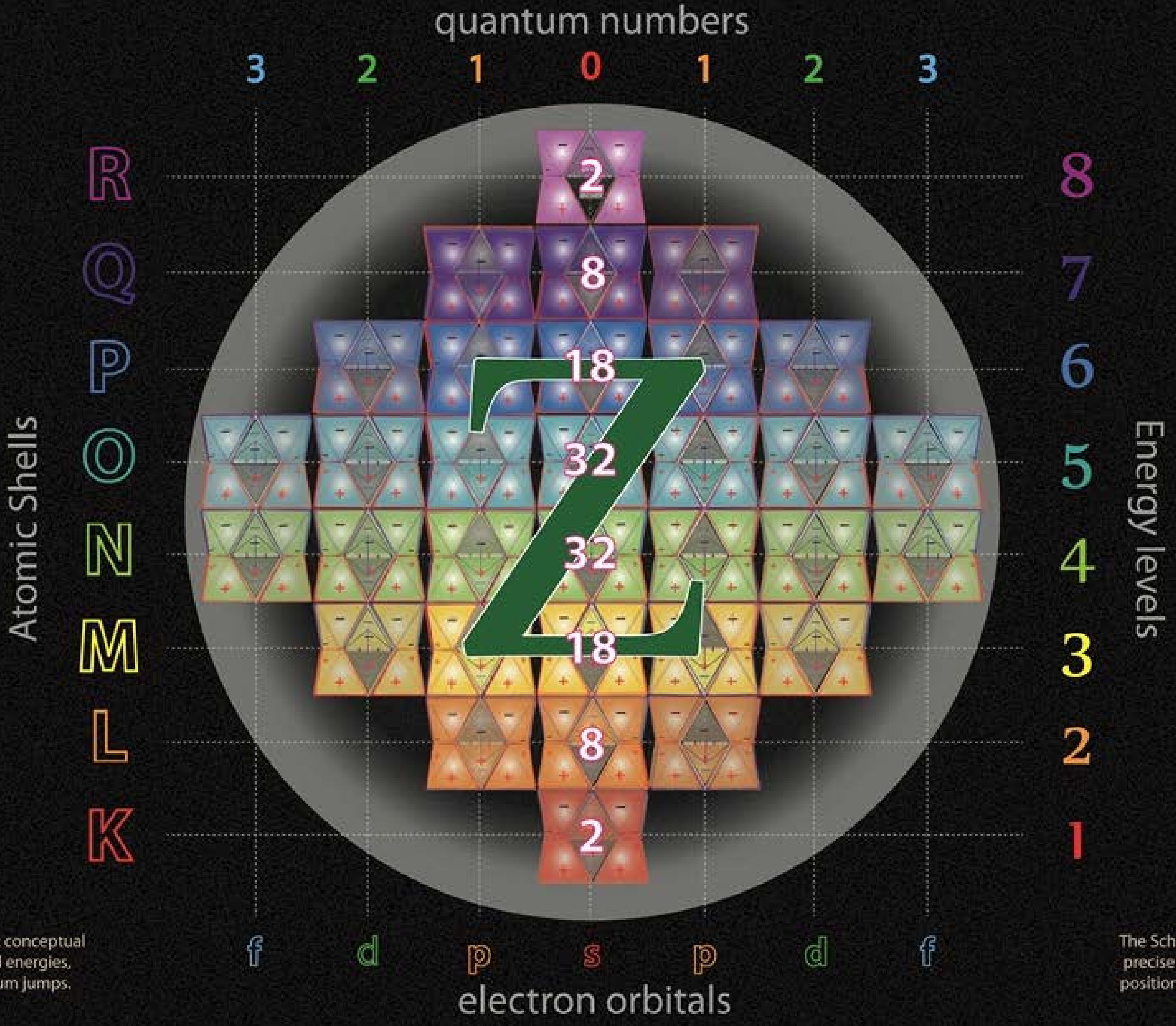
quantum numbers
3
2
1
0
1
2
3
Atomic Shells
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
Z
8
7
6
5
4
3
2
1
Energy levels
f
d
p
s
p
d
f
electron orbitals

The Bohr model gives us a basic conceptual model of electrons orbits and energies, along with the idea of quantum jumps.

The Schrondinger wave equation gives precise details of spectra and electron position and motions within the nuclei

The uncertainty principle erroneously dictates that position and momentum cannot be simultaneously determined.

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Periodicity of atomic elements

An electron shell may be thought of as an orbit followed by electrons around an atom's nucleus.
The closest shell to the nucleus is called the "1 shell" (also called "K shell"), followed by the
"2 shell" (or "L shell"), then the "3 shell" (or "M shell"), and so on further and further from the nucleus.
The shell letters K, L, M, ... are alphabetical

Each shell can contain only a
fixed number of deuterium nuclei
[Protons, Neutrons & electrons]

Each shell consists of one or more
electron orbitals, and each orbital consists
of one or more sub-orbitals.

8
atomic
energy shells
with electrons

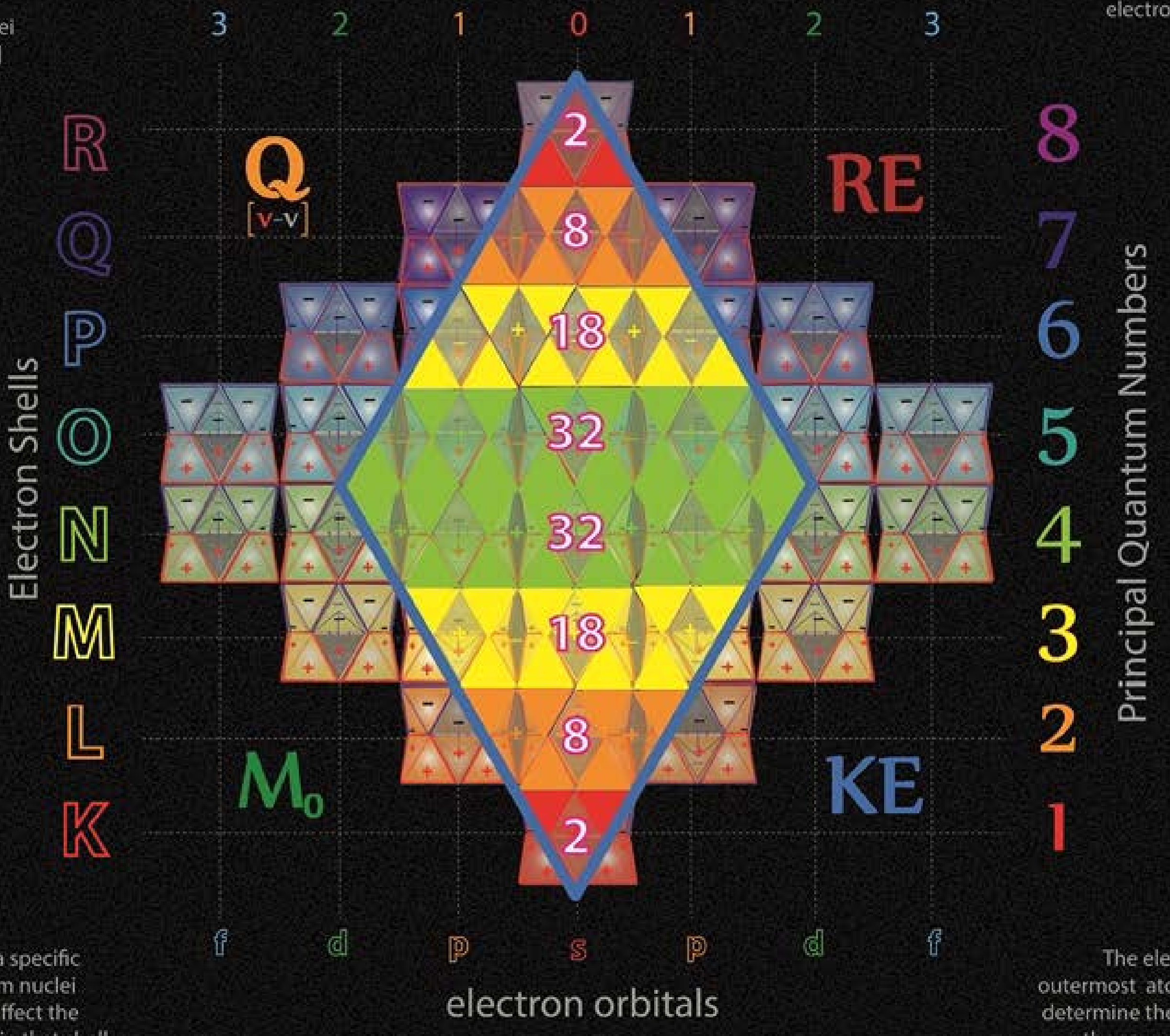

120
periodic
elements
in total

The number of deuterium nuclei that form each atomic shell in an
elemental atom number is double that of Photon energy levels

Each atomic shell equates to a specific
energy level for the Deuterium nuclei
that comprise it with in turn affect the
angular momentum of electrons in that shell

The electrons in the partially filled
outermost atomic shell [or highest energy level]
determine the chemical properties of the atom;
they are called valence shell electrons.

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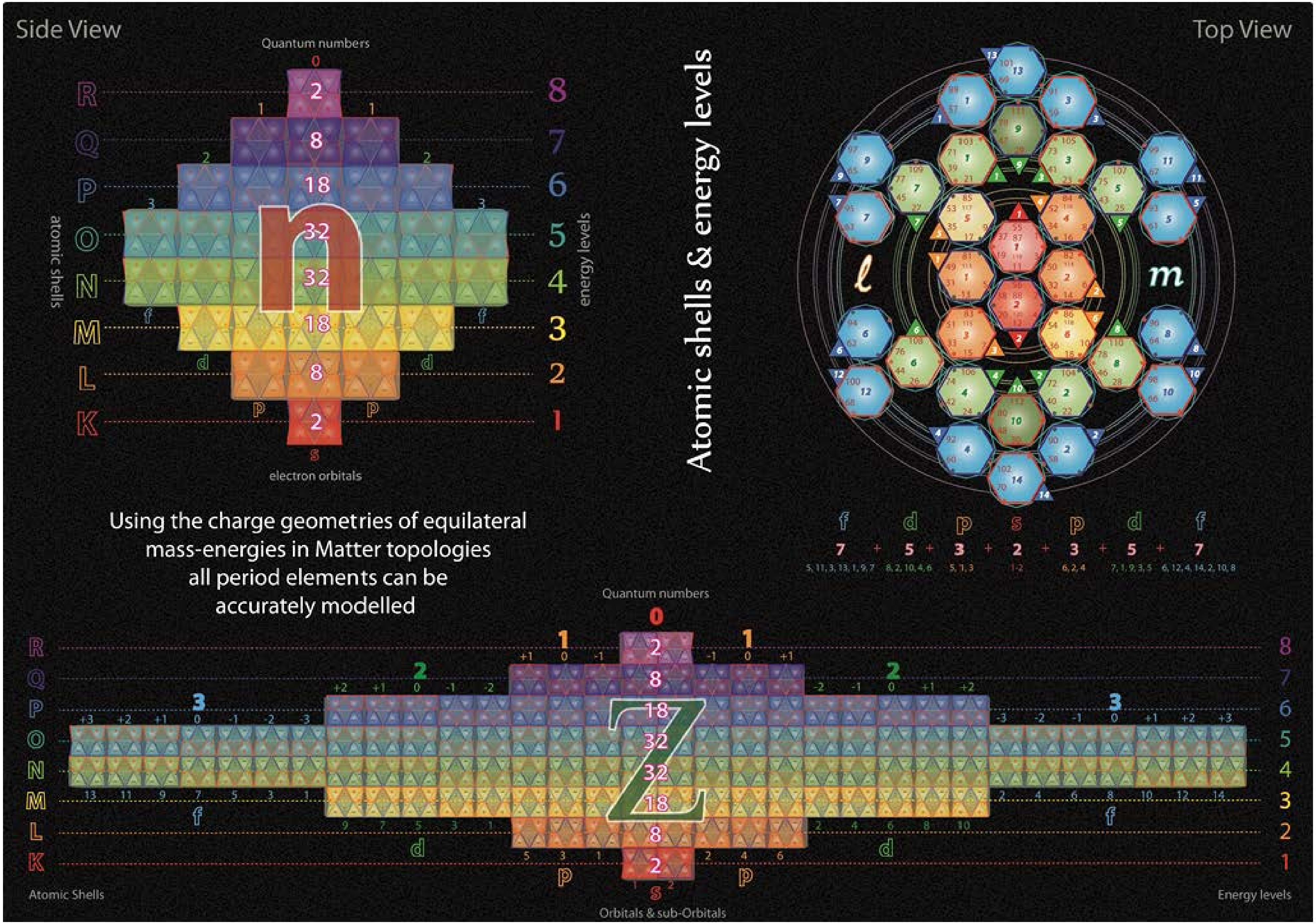

Atomic shells & energy levels

Using the charge geometries of equilateral mass-energies in Matter topologies all period elements can be accurately modelled

Side View
Quantum numbers
0
1
2
3
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
n
8
7
6
5
4
3
2
1
atomic shells
energy levels
f
d
p
s
electron orbitals
Top View
ℓ
m
f d p s p d f
7 + 5 + 3 + 2 + 3 + 5 + 7
Quantum numbers
+1 0 -1
+2 +1 0 -1 -2
+3 +2 +1 0 -1 -2 -3
Z
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
2 4 6 8 10 12 14
2 4 6 8 10
2 4 6
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

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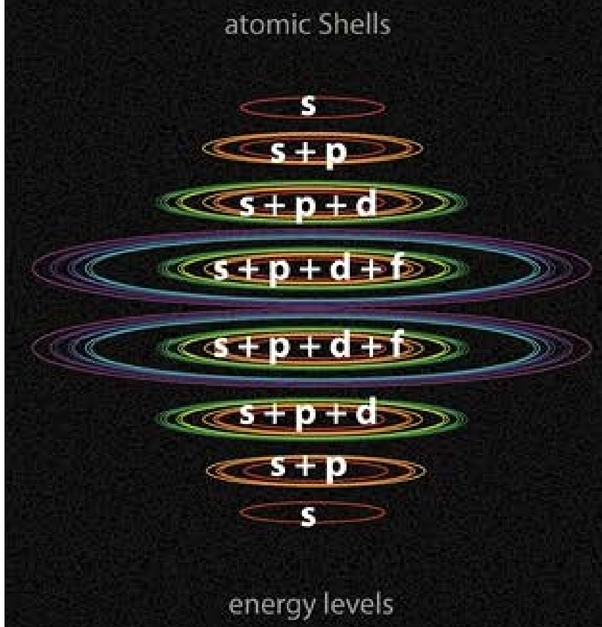
atomic Shells
s
s + p
s + p + d
s + p + d + f
s + p + d + f
s + p + d
s + p
s
energy levels

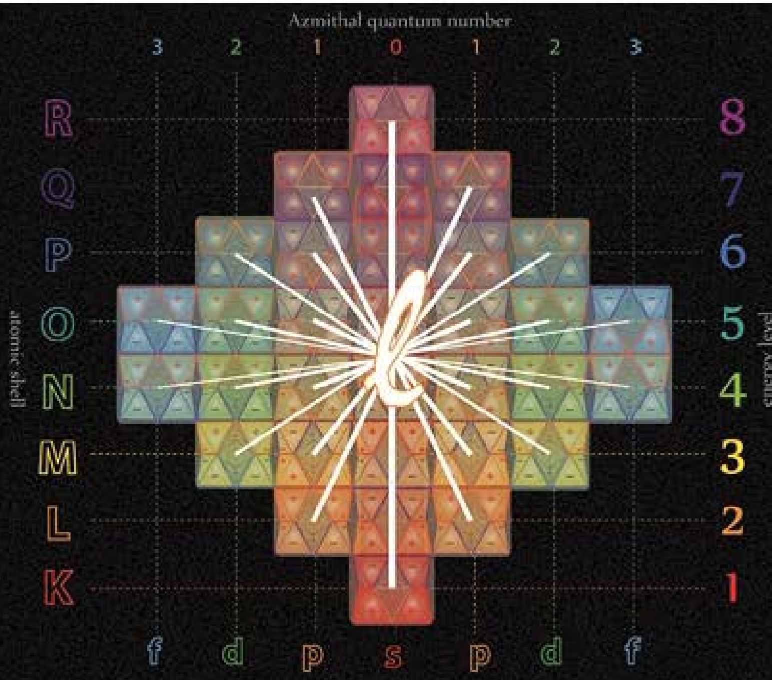
Azmithal quantum number
3 2 1 0 1 2 3
R Q P O N M L K
atomic shell
8 7 6 5 4 3 2 1
energy level
ℓ
f d p s p d f

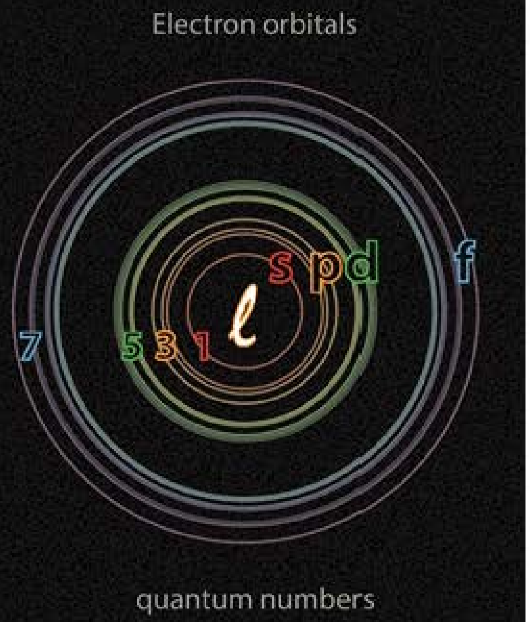
Electron orbitals
s p d f
ℓ
1 3 5 7
quantum numbers

Each electron's location in an elemental nuclei is defined by its quantum numbers

All atoms have shells comprised of concentric s, p, d & f electron orbitals

electron orbitals

each electron orbital can hold a maximum of two spin opposed electrons

a core s-orbital
surrounded by
3 p-orbitals
5 d-orbitals and
7 f-orbitals

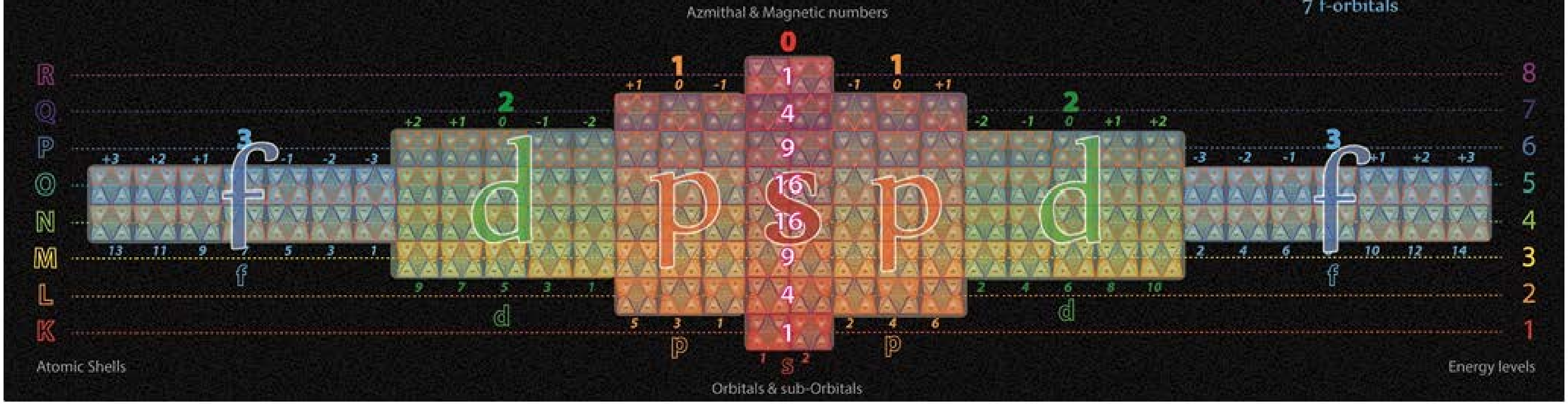
Azmithal & Magnetic numbers
0
1 1
+1 0 -1 -1 0 +1
2 2
+2 +1 0 -1 -2 -2 -1 0 +1 +2
3 3
+3 +2 +1 -1 -2 -3 -3 -2 -1 +1 +2 +3
R Q P O N M L K
8 7 6 5 4 3 2 1
f d p s p d f
1 4 9 16 16 9 4 1
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 s 2
f d p p d f
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Tetryonics 44.04 - Electron Orbitals

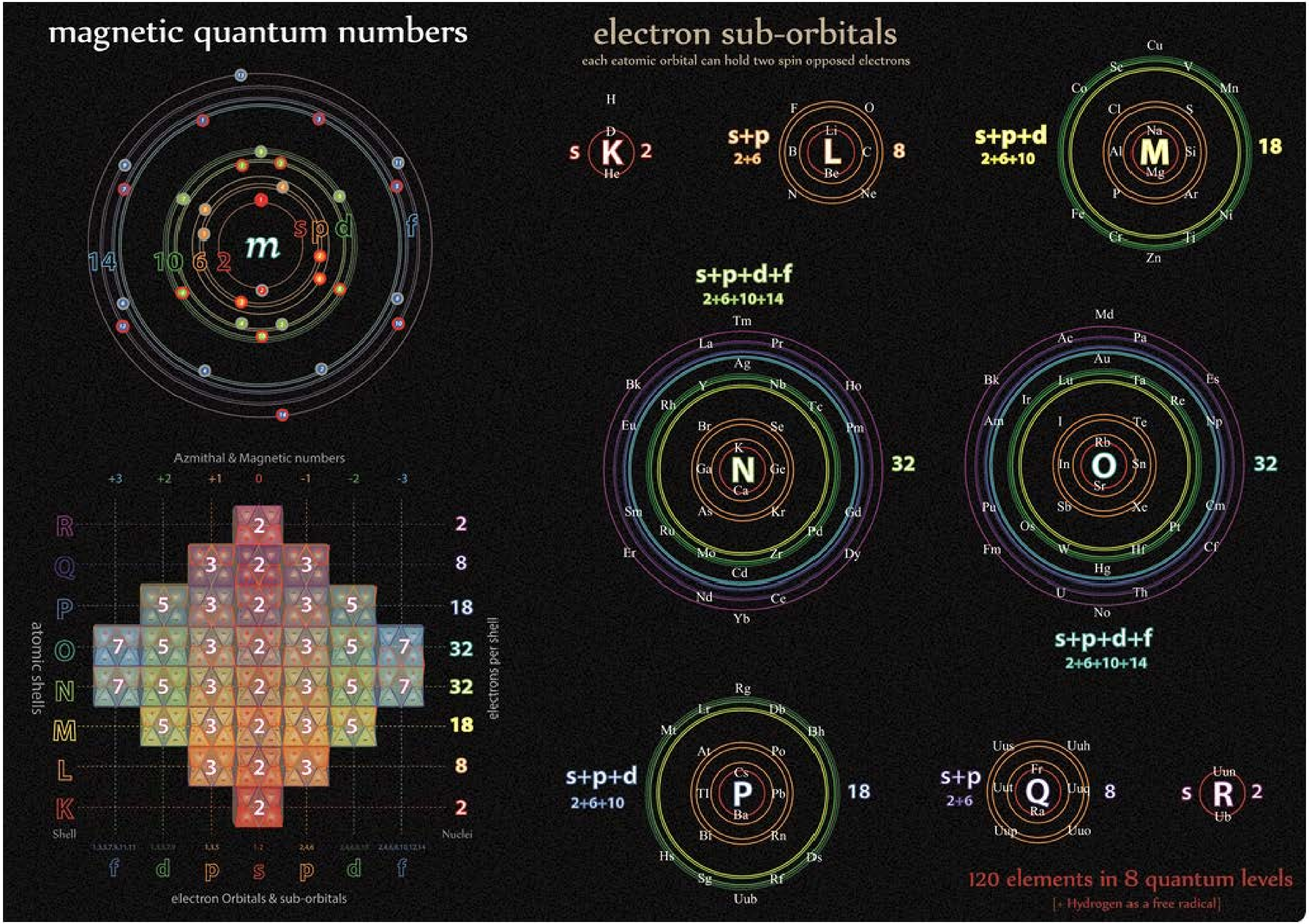
magnetic quantum numbers
m
s p d f
14 10 6 2
Azmithal & Magnetic numbers
+3 +2 +1 0 -1 -2 -3
R Q P O N M L K
Shell
atomic shells
2 8 18 32 32 18 8 2
electrons per shell
Nuclei
f d p s p d f
electron Orbitals & sub-orbitals
electron sub-orbitals
each eatomic orbital can hold two spin opposed electrons
s K 2
H D He
s+p 2+6 L 8
s+p+d 2+6+10 M 18
s+p+d+f 2+6+10+14 N 32
s+p+d+f 2+6+10+14 O 32
s+p+d 2+6+10 P 18
s+p 2+6 Q 8
s R 2
120 elements in 8 quantum levels
[+ Hydrogen as a free radical]

Tetryonics 44.05 - Electron sub-Obitals

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Electron SPIN in atoms

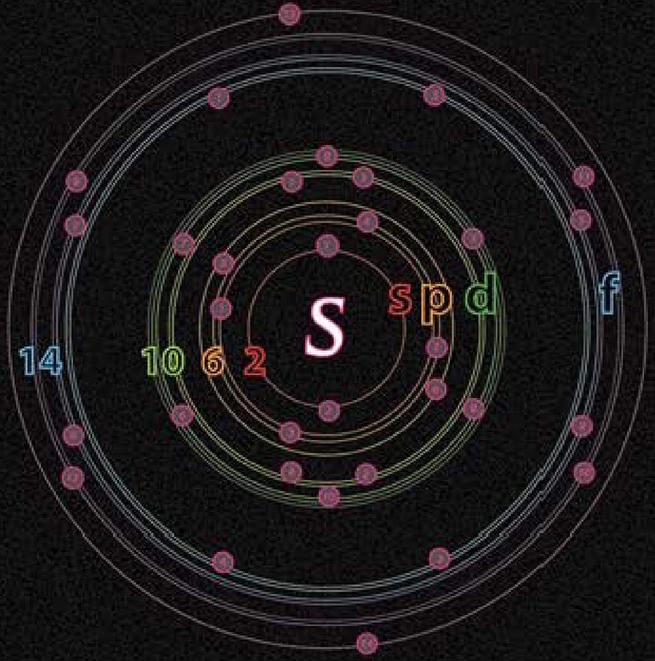
S
s
p
d
f
14
10
6
2

1 sub-Orbit	s	2 electrons
3 sub-Orbits	p	6 electrons
5 sub-Orbits	d	10 electrons
7 sub-Orbits	f	14 electrons

Hund's Rule
Each electron sub-orbital (Azimuthal number)
can not have electrons with the same spin direction

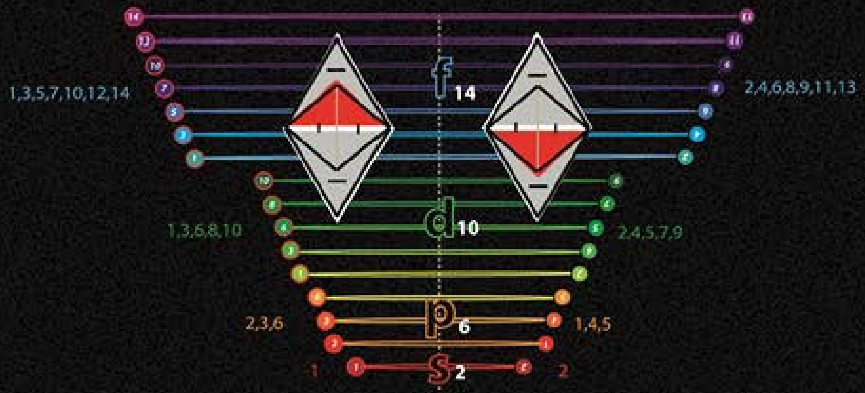
1,3,5,7,10,12,14
f
14
2,4,6,8,9,11,13
1,3,6,8,10
d
10
2,4,5,7,9
2,3,6
p
6
1,4,5
1
s
2
2

electron spin is always referenced to the Nuclear magneton

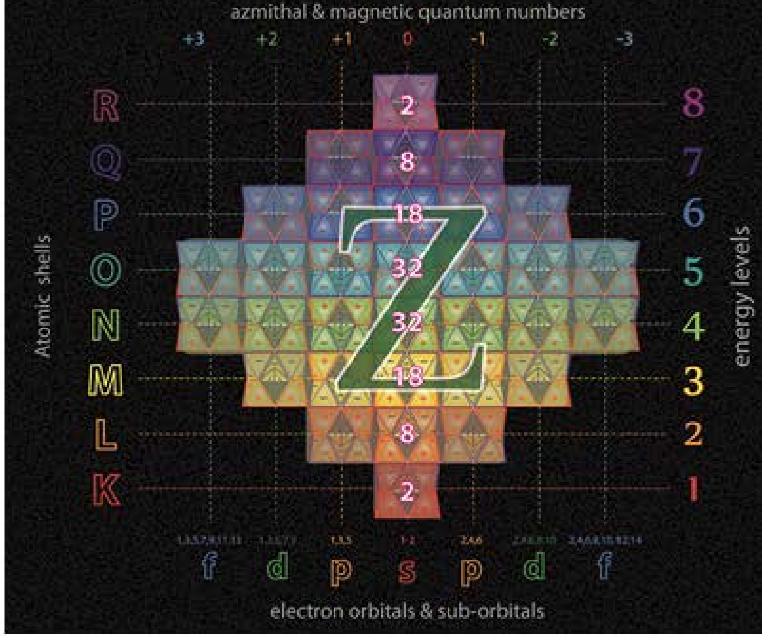
azmithal & magnetic quantum numbers
+3
+2
+1
0
-1
-2
-3
Atomic shells
R
Q
P
O
N
M
L
K
Z
2
8
18
32
32
18
8
2
8
7
6
5
4
3
2
1
energy levels
1,3,5,7,9,11,13
1,3,5,7,9
1,3,5
1-2
2,4,6
2,4,6,8,10
2,4,6,8,10,12,14
f
d
p
s
p
d
f
electron orbitals & sub-orbitals

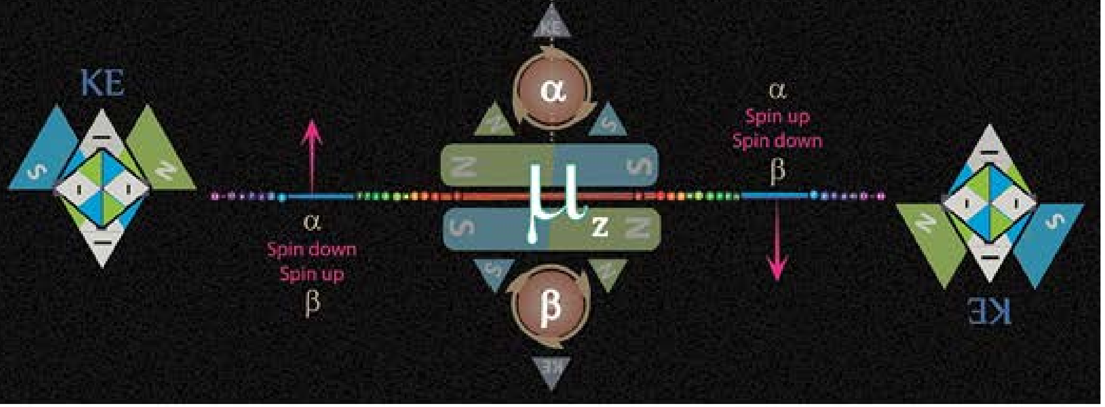
KE
S
N
α
Spin down
Spin up
β
KE
α
β
N
S
S
N
μ
z
α
Spin up
Spin down
β
KE
N
S
KE

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Quantum numbers

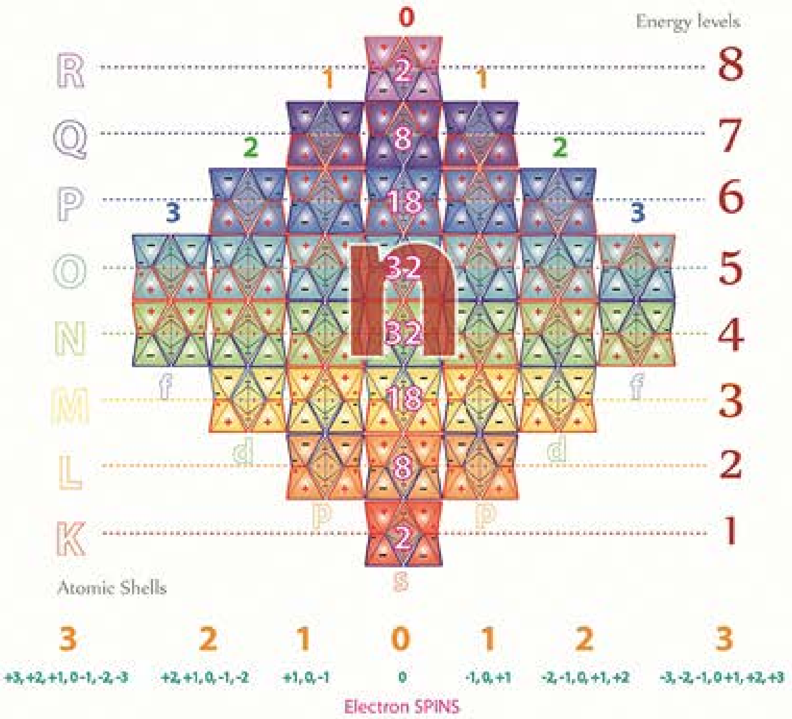
Energy levels
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
2
3
3
2
8
18
32
n
32
18
8
2
f
f
d
d
p
p
s
Atomic Shells
3
2
1
0
1
2
3
+3, +2, +1, 0 -1, -2, -3
+2, +1, 0, -1, -2
+1, 0, -1
0
-1, 0, +1
-2, -1, 0, +1, +2
-3, -2, -1, 0 +1, +2, +3
Electron SPINS

These four numbers, n, ℓ, m and s can be used to describe any electron in a stable atom [and can be mapped back to the classical terminology of Shells and electron orbitals].

The properties of every atom's specific electron configuration can be described by four quantum numbers:

n (1-8)
Principal
(n = 1, 2, 3, 4 ...)

ℓ (0-3)
Azimuthal
(l = 0, 1 ... n−1)

m (2ℓ+1)
Magnetic
(ml = −l, −l+1 ... 0 ... l−1, l)

s ± ½
electron Spin
(ms = −1/2 or +1/2),

The Bohr model was a one-dimensional model that used one quantum number to describe the distribution of electrons

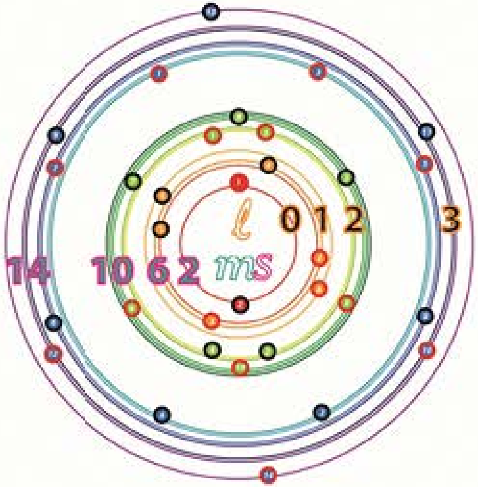
ℓ
0
1
2
3
14
10
6
2
ms

The three coordinates that come from Schrödinger's wave equations are the principal (n), angular (l), and magnetic (m) quantum numbers.

These quantum numbers describe the size, shape, and orientation in space of the orbitals of any particular atom mathematically.

Each electron's quantum numbers are unique and cannot be shared by another electron in that atom.

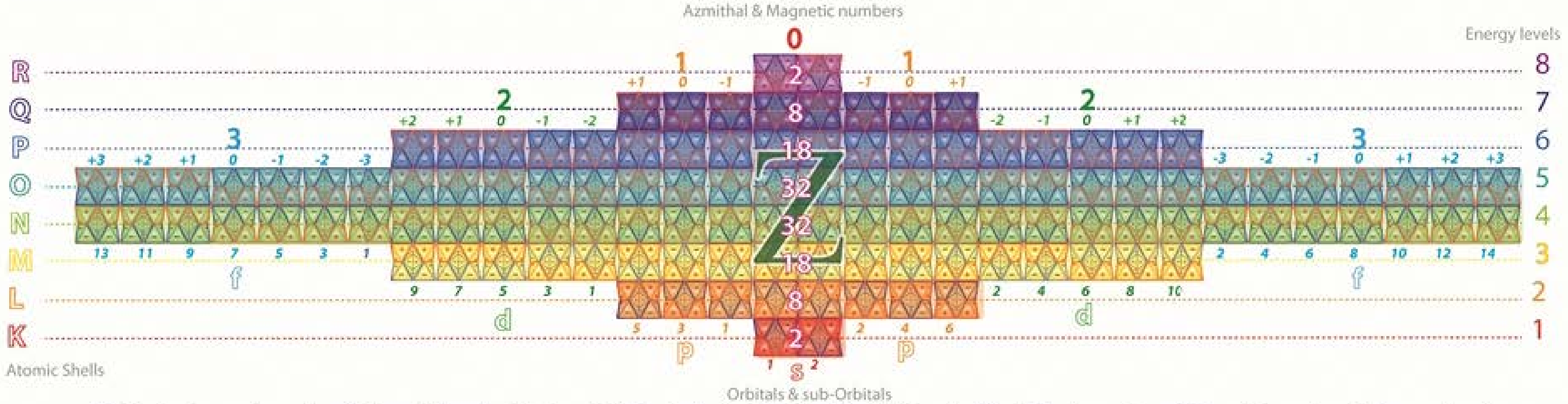
Azmithal & Magnetic numbers
Energy levels
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
2
3
3
+1 0 -1
-1 0 +1
+2 +1 0 -1 -2
-2 -1 0 +1 +2
+3 +2 +1 0 -1 -2 -3
-3 -2 -1 0 +1 +2 +3
2
8
18
32
32
18
8
2
Z
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
f
f
d
d
p
p
s
Atomic Shells
Orbitals & sub-Orbitals

A stable atom has equal numebrs of Protons, electrons [and Neutrons], all following the Pauli Exclusion Principle thus orientating their spins so that each element has a unique electron configuration

PRINCIPAL quantum number

The first describes the electron shell, or energy level, of an atom.

This is the only quantum number introduced by the Bohr model

The principal quantum number can only have positive integer values

atomic shells

n(1-8)

(n = 1, 2, 3, 4 ...)

energy levels

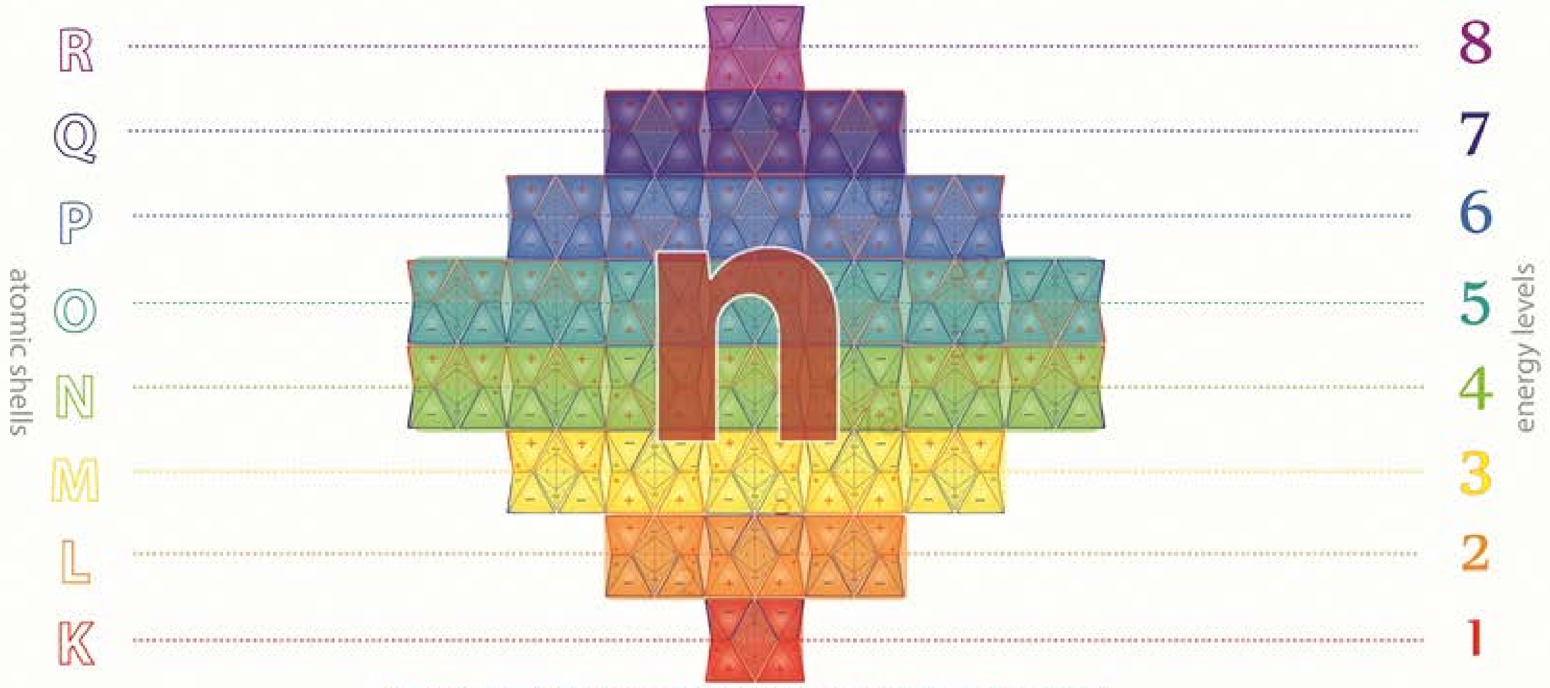

As energies of the Baryons comprising the atomic nuclei increases, the electron bound to each nuclei also possesses more KEM field energies and is therefore less tightly bound to the nucleus

Atomic Shells

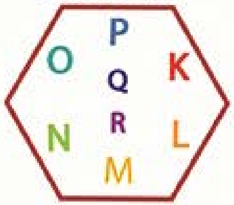

(K, L, M, N, O, P, Q, R)

Atomic shells relate directly to Principal quantum numbers

(1, 2, 3, 4, 5, 6, 7, 8)

Energy levels

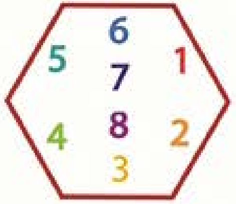

AZMITHAL quantum number

The azimuthal quantum number is a quantum number assigned to any atomic orbital that describes its orbital angular momentum and determines the shape of the electron orbital

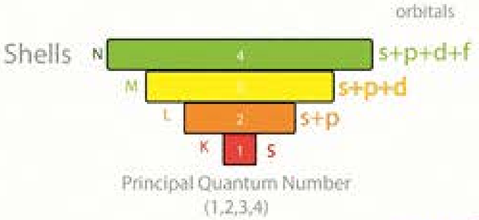
orbitals
Shells
N
4
s+p+d+f
M
3
s+p+d
L
2
s+p
K
1
s
Principal Quantum Number
(1,2,3,4)

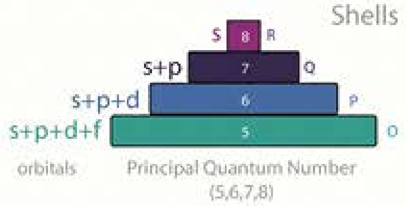
Shells
S
8
R
s+p
7
Q
s+p+d
6
P
s+p+d+f
5
O
orbitals
Principal Quantum Number
(5,6,7,8)

s p d f

electron orbitals

(l = 0, 1 ... n−1)

ℓ (0-7)

Azimuthal

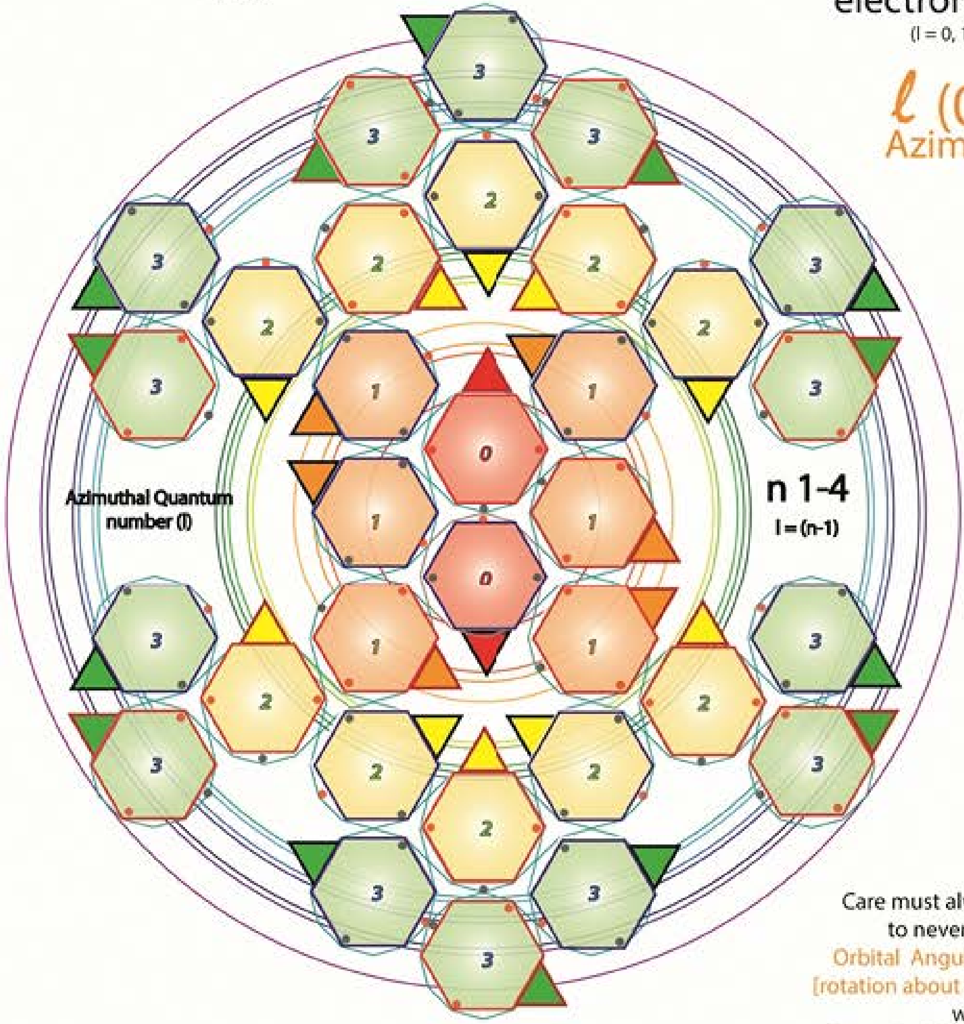
Azimuthal Quantum number (l)
n 1-4
l = (n-1)
0
1
2
3

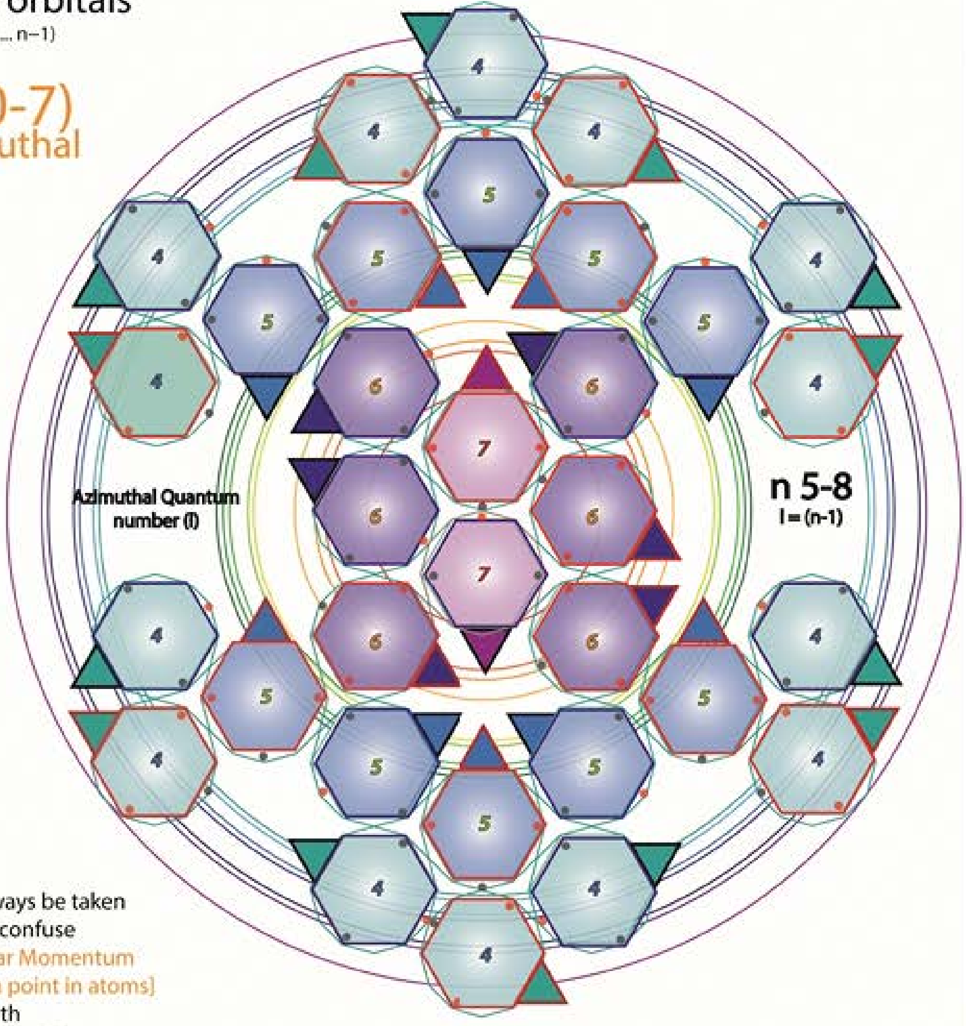
Azimuthal Quantum number (l)
n 5-8
l = (n-1)
4
5
6
7

Care must always be taken
to never confuse
Orbital Angular Momentum
[rotation about a point in atoms]
with
Quantised Angular Momenta
[equilateral Planck energy geometries]

MAGNETIC quantum number

The magnetic quantum number denotes the energy levels available within any subshell

Magnetic numbers do not continue to increase as the Principal numbers increase
instead they reverse after n4 to reflect the charged quanutm geometry of Elements
and do not follow the current computer models in popular use

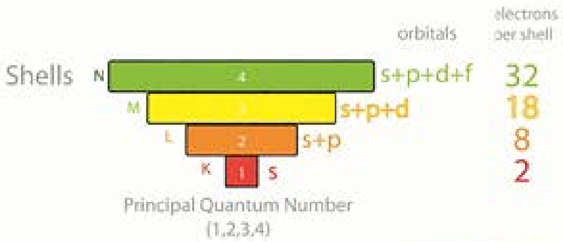
Shells
orbitals
electrons per shell
N
4
s+p+d+f
32
M
3
s+p+d
18
L
2
s+p
8
K
1
s
2
Principal Quantum Number
(1,2,3,4)

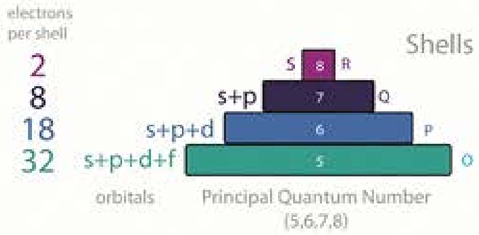
elections per shell
Shells
2
S
8
R
8
s+p
7
Q
18
s+p+d
6
P
32
s+p+d+f
5
O
orbitals
Principal Quantum Number
(5,6,7,8)

s p d f

electron sub-orbitals

(ml = –l, –l+1 ... 0 ... l–1, l)

$m\ell(2\ell+1)$

Magnetic

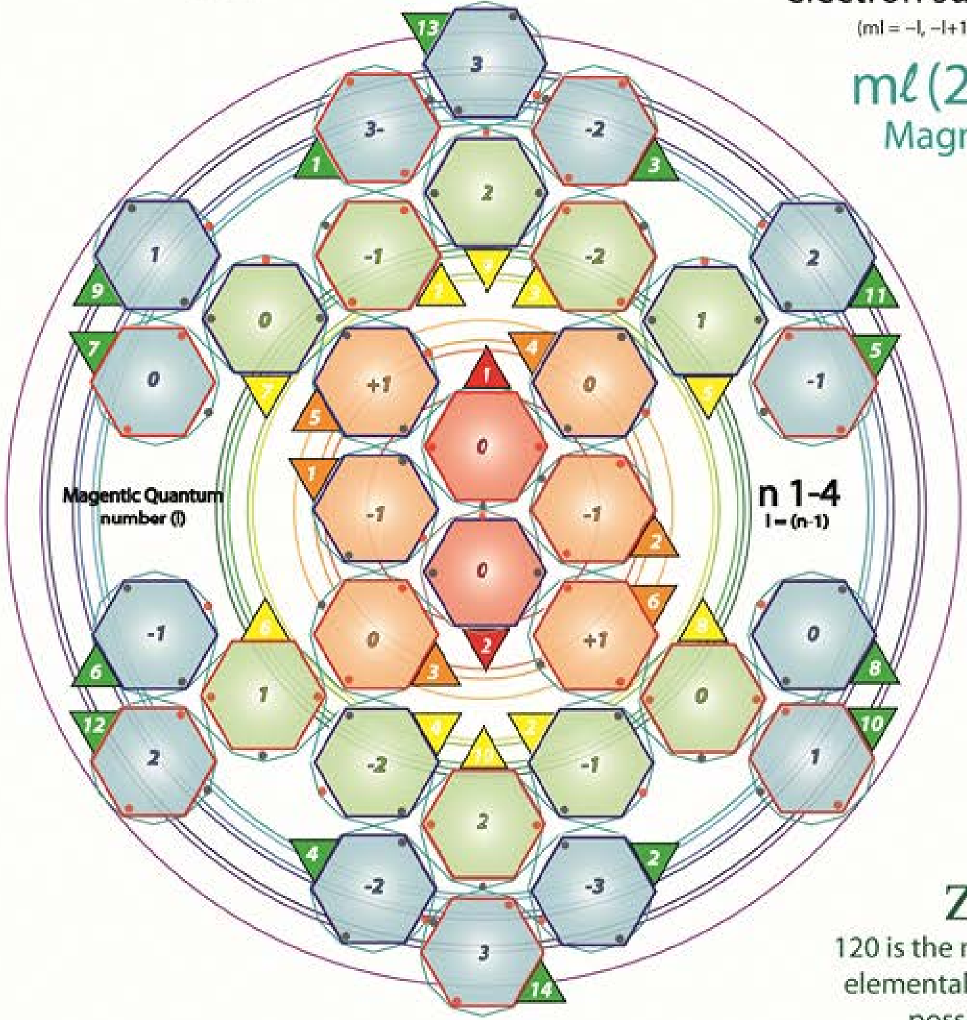
Magentic Quantum number (l)
n 1-4
l = (n-1)

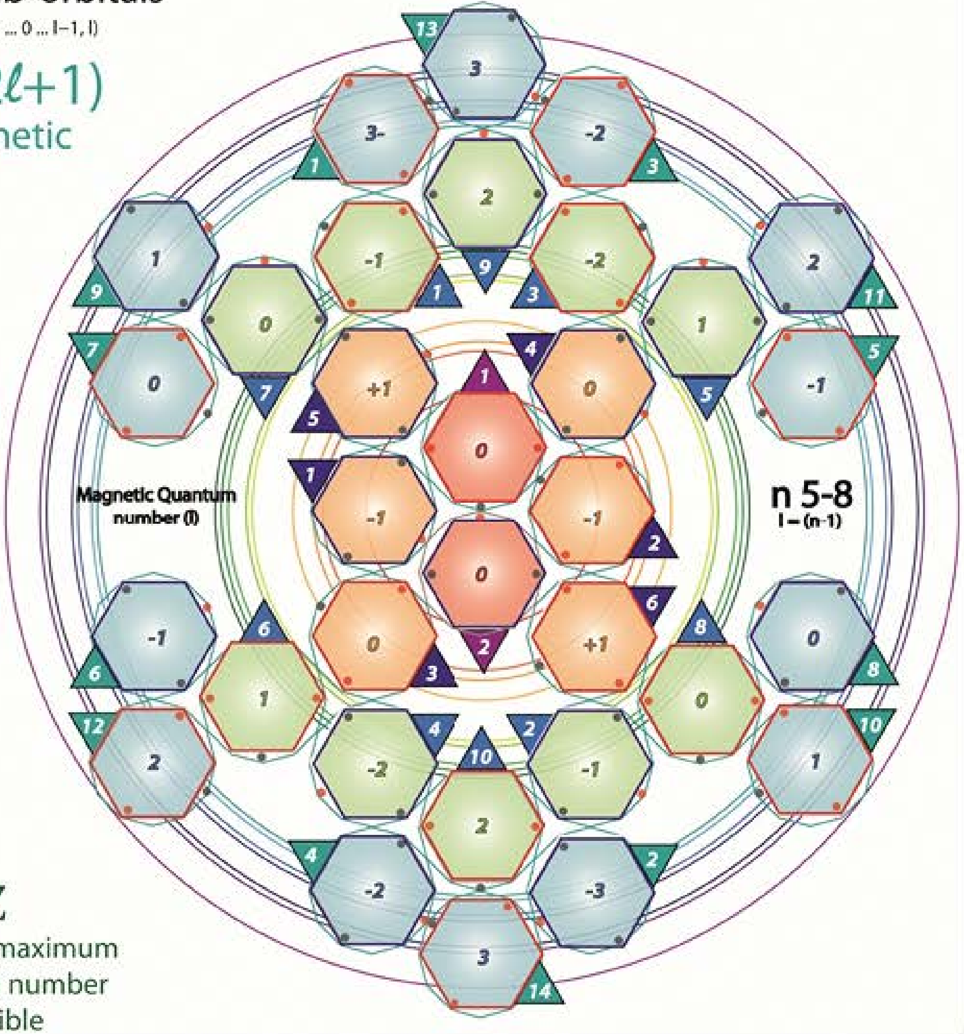
Magentic Quantum number (l)
n 5-8
l = (n-1)

Z

120 is the maximum
elemental number
possible

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parallel magnetic moments

Spin UP

higher coupling energies

SPIN quantum number

The spin quantum number is a quantum number that parameterizes
the intrinsic angular momentum (or spin angular momentum),
of any given electron anywhere in an atomic nucleus

anti-parallel magnetic moments

Spin DOWN

lower coupling energies

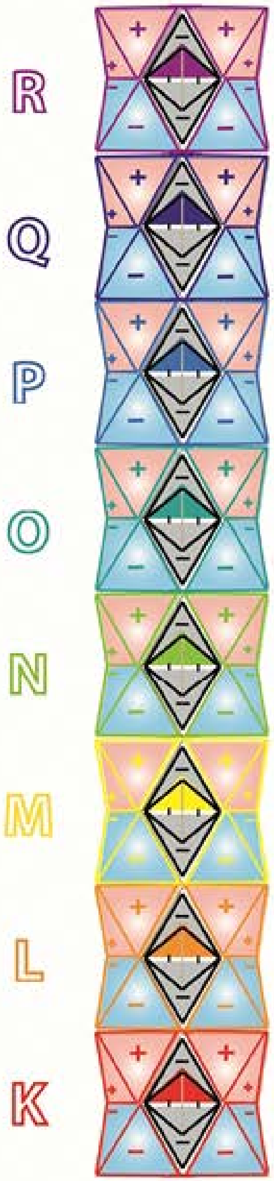

Electron spin can orientate in either direction within Nuclei, providing the nett spins follow the Hund rule and Pauli exclusion principle

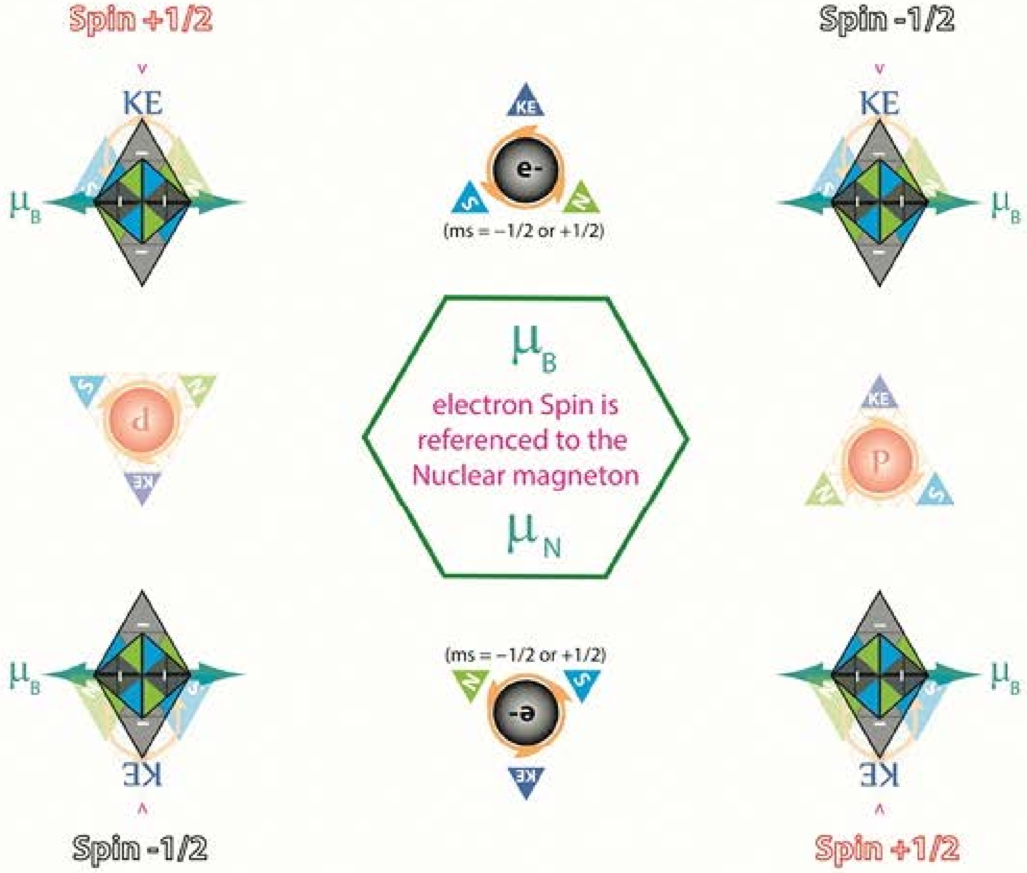
Spin +1/2
KE
μ_B
Spin -1/2
KE
μ_B
KE
e-
(ms = −1/2 or +1/2)
d
P
μ_B
μ_N
(ms = −1/2 or +1/2)
-e
μ_B
KE
Spin -1/2
μ_B
KE
Spin +1/2

electron Spin is referenced to the Nuclear magneton

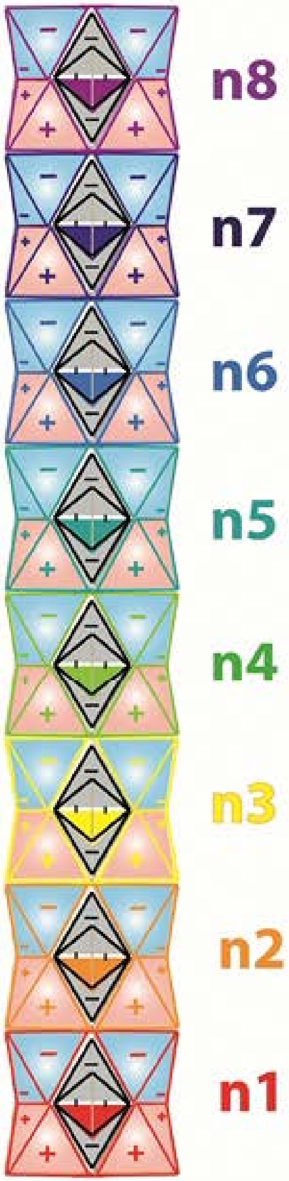
n8
n7
n6
n5
n4
n3
n2
n1

The nuclear energy levels of the Baryons comprising Elemental nuclei determine the energy-momenta of electrons bound to them

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Modifying Hund's Rule

Electrons fill orbitals in an alternating sequential numbering pattern due to nucleon placement creating opposed direction electron spins

The increased stability of the atom, most commonly manifested in a lower energy state, arises because the high-spin state forces the unpaired electrons to reside in different spatial orbitals.

A commonly given reason for the increased stability of high multiplicity states is that the different occupied spatial orbitals create a larger average distance between electrons, reducing electron-electron repulsion energy. In reality, it has been shown that the actual reason behind the increased stability is a decrease in the screening of electron-nuclear attractions[1].

The total spin state is calculated as the total number of unpaired electrons + 1, or twice the total spin + 1 written as 2s+1.

As a result of Hund's rule, constraints are placed on the way atomic orbitals are filled using the Aufbau principle.

Before any two electrons occupy an orbital in a subshell, other orbitals in the same subshell must first each contain one electron. Also, the electrons filling a subshell will have parallel spin before the shell starts filling up with the opposite spin electrons (after the first orbital gains a second electron).

As a result, when filling up atomic orbitals, the maximum number of unpaired electrons (and hence maximum total spin state) is assured

s	p	d	f
▲ 1 **1** 2 ▼	▼ 1 **1** 2 ▲	▲ 1 **1** 2 ▼	▲ 1 **1** 2 ▼
	▲ 3 **2** 4 ▼	▲ 3 **2** 4 ▼	▲ 3 **2** 4 ▼
	▼ 5 **3** 6 ▲	▼ 5 **3** 6 ▲	▲ 5 **3** 6 ▼
		▼ 7 **4** 8 ▲	▲ 7 **4** 8 ▼
		▼ 9 **5** 10 ▲	▼ 9 **5** 10 ▲
			▼ 11 **6** 12 ▲
			▼ 13 **7** 14 ▲

▲

Hund's rule of orbital filling
must be modified to reflect
the true orbital filling order

▼

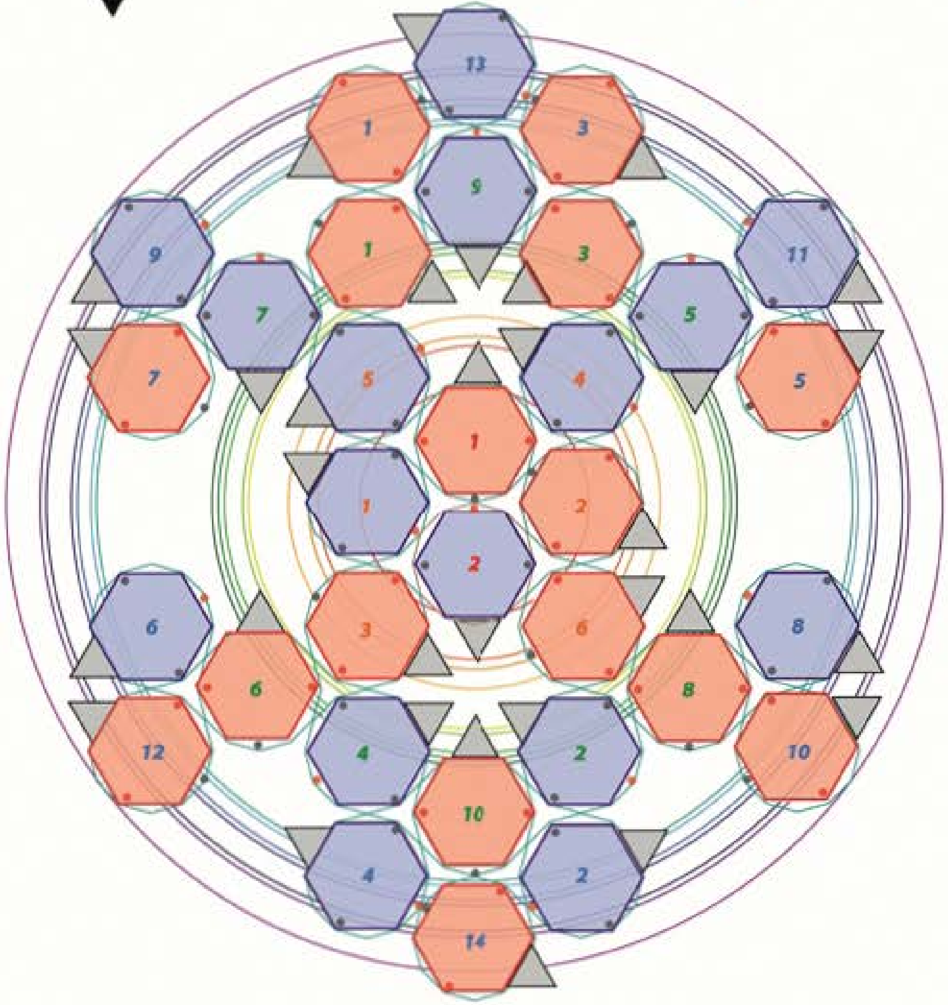

Sub-orbitals fill in order of numbering

Electrons spins pair
before next orbital
is filled

ie.
p1 [DOWN] and p2 [UP] fill
before
p3 [UP] and p4 [DOWN]
before
p5 [DOWN] and p6 [UP] etc

Principle quantum Energies

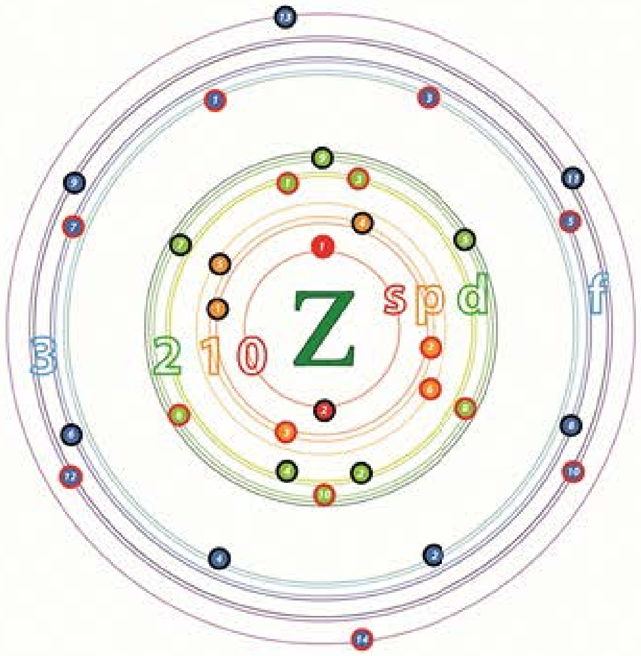

In an atom - electron energies are proportional to their intrinsic Kinetic Energies - which in turn are directly proportional to the quantum energy level of the nuclei which the electron binds to in their respective atomic shells

In a nucleus, lower energy orbits have less 'paired' nuclei supplying energy. The more energy you give a nuclei the faster it casuses the bound electron to rotate. If you give the nuclei enough energy, it will impart eneough energy to its electron for it to leave the system entirely.

The same is true for an electron orbital. Higher values of n mean more energy for the electron and the corresponding KEM field enegies of the electron is larger, resulting in increased angular momentum.

Values of n start at 1 and go up by integer amounts.

If enough energy is added to the system by incident Photons a electron will leave the atom creating a positively charged nuclei [ionisation].

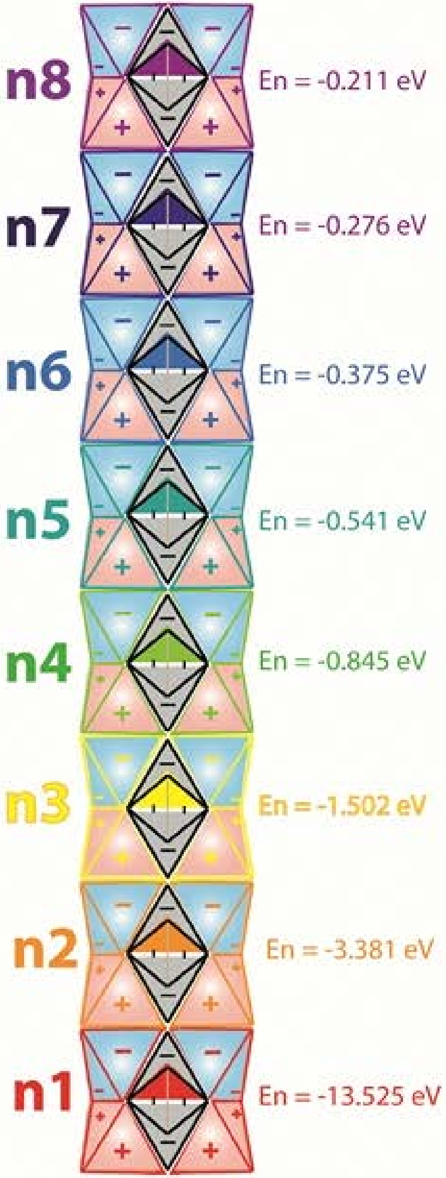

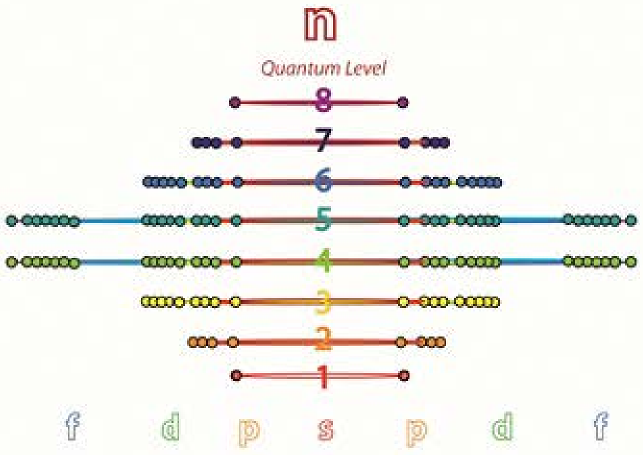

s orbits	n1-8
p orbits	n2-7
d orbits	n3-6
f orbits	n4-5

Eigenstate value

KEM field energy [per n] required to exceed 13.525 eV at which point the photo-electron has sufficient KE to break free of the Nucleus

$$E_n = \frac{E_1}{n^2} = \frac{-13.6eV}{n^2}, n = 1, 2, 3...$$

The possible Kinetic Energies (quantum levels) of an electron are directly related to the energy level of the Nuclei in each Quantum Level

Quantum Level 1

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
1	1s1	Deuterium	1	1	1
2	1s2	Helium	2	2	2

2

Deuterium [not Hydrogen] is the building block of elements

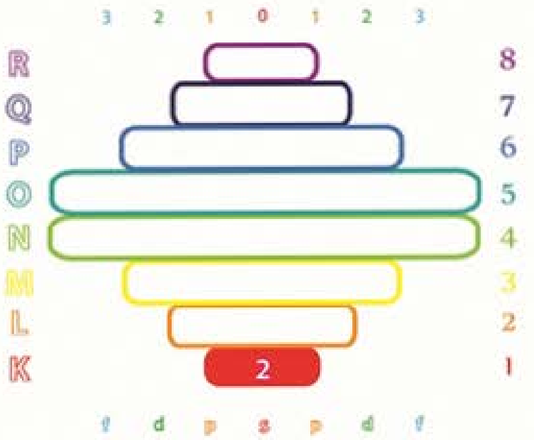
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
f
d
p
s
p
d
f

Z #		Name	Protons	electrons	Neutrons
1	1s1	Hydrogen	1	1	0

Hydrogen is a free radical element

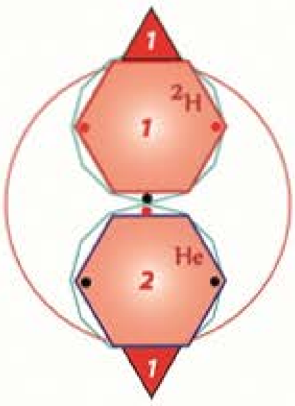

K shell

n1

Ground State electron

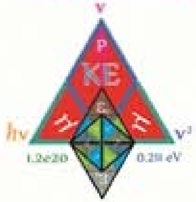
v
P
KE
hv
v^2
1.2e20
0.28 eV

$iE = -13.313\ eV$

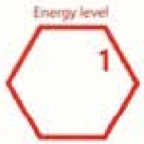
Energy level
1

n1

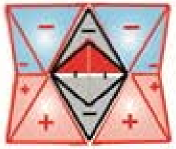

Quantum Level 2

L shell

n2

Ground State electron

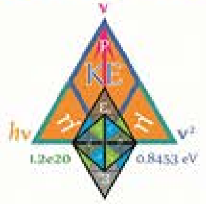
v
KE
hv
v²
1.2e20
0.8453 eV

$iE = -12.679\ eV$

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
3	*2s1*	Lithium	3	3	3
4	*2s2*	Beryllium	4	4	4
5	*1p1*	Boron	5	5	5
6	*1p2*	Carbon	6	6	6
7	*1p3*	Nitrogen	7	7	7
8	*1p4*	Oxygen	8	8	8
9	*1p5*	Fluorine	9	9	9
10	*1p6*	Neon	10	10	10

8

Deuterium [not Hydrogen] is the building block of elements

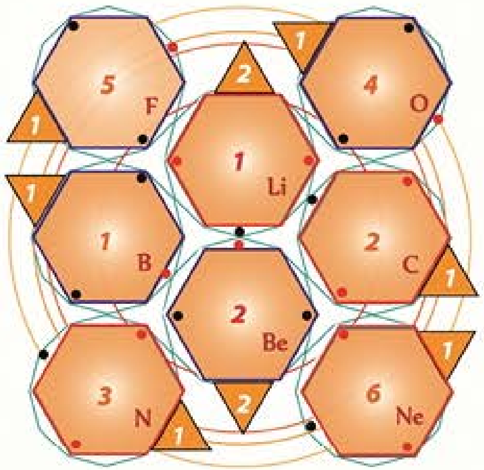
5
F
2
1
4
O
1
1
Li
1
1
B
2
C
1
2
Be
3
N
1
2
6
Ne
1

Energy level

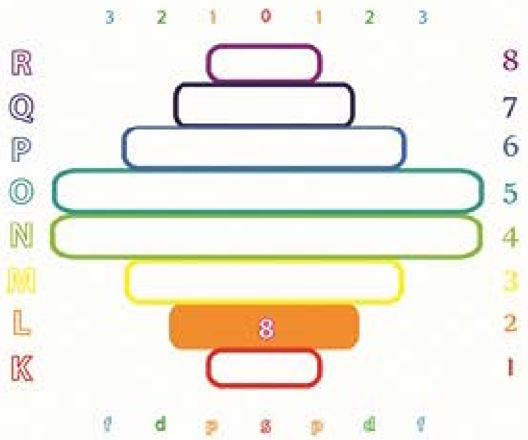
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
8
f d p s p d f

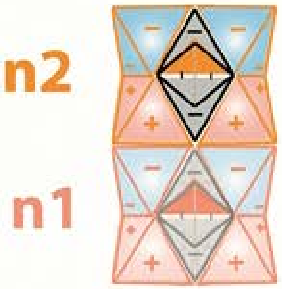

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Quantum Level 3

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
11	3s1	Sodium	11	11	11
12	3s2	Magnesium	12	12	12
13	2p1	Aluminium	13	13	13
14	2p2	Silicon	14	14	14
15	2p3	Phosphorus	15	15	15
16	2p4	Sulfur	16	16	16
17	2p5	Chlorine	17	17	17
18	2p6	Argon	18	18	18
21	3d1	Scandium	21	21	21
22	3d2	Titanium	22	22	22
23	3d3	Vanadium	23	23	23
24	3d4	Chromium	24	24	24
25	3d5	Manganese	25	25	25
26	3d6	Iron	26	26	26
27	3d7	Cobalt	27	27	27
28	3d8	Nickel	28	28	28
29	3d9	Copper	29	29	29
30	3d10	Zinc	30	30	30

18

Deuterium [not Hydrogen] is the building block of elements

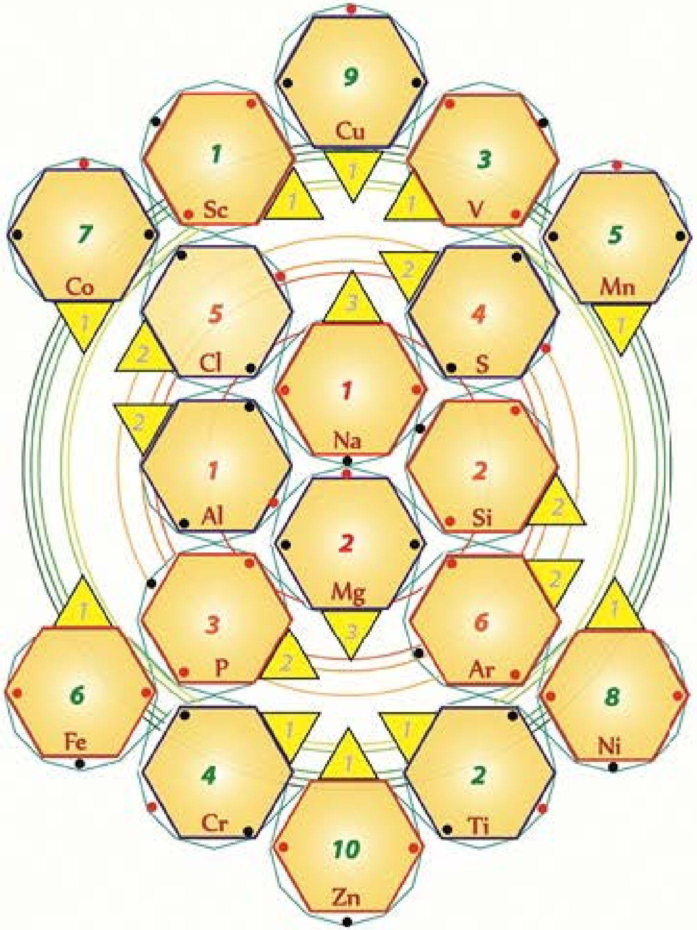
9
Cu
1
Sc
3
V
7
Co
5
Mn
5
Cl
4
S
1
Na
1
Al
2
Si
2
Mg
3
P
6
Ar
6
Fe
8
Ni
4
Cr
2
Ti
10
Zn

M shell

n3

Ground State electron

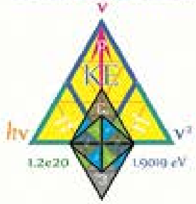
v
KE
hv
v²
1.2e20
1.9019 eV

$iE = -11.623\ eV$

Energy level

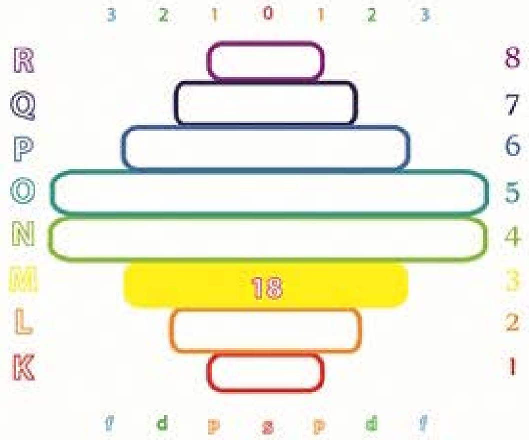
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
18
f
d
p
s
p
d
f

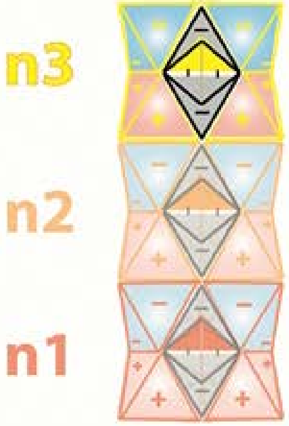

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Quantum Level 4

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
19	4s1	Potassium	19	19	19
20	4s2	Calcium	20	20	20
31	4p1	Gallium	31	31	31
32	4p2	Germanium	32	32	32
33	4p3	Arsenic	33	33	33
34	4p4	Selenium	34	34	34
35	4p5	Bromine	35	35	35
36	4p6	Krypton	36	36	36
39	4d1	Yttrium	39	39	39
40	4d2	Zirconium	40	40	40
41	4d3	Niobium	41	41	41
42	4d4	Molybdenum	42	42	42
43	4d5	Technetium	43	43	43
44	4d6	Ruthenium	44	44	44
45	4d7	Rhodium	45	45	45
46	4d8	Palladium	46	46	46
47	4d9	Silver	47	47	47
48	4d10	Cadmium	48	48	48
57	4f1	Lanthanum	57	57	57
58	4f2	Cerium	58	58	58
59	4f3	Praseodymium	59	59	59
60	4f4	Neodymium	60	60	60
61	4f5	Promethium	61	61	61
62	4f6	Samarium	62	62	62
63	4f7	Europium	63	63	63
64	4f8	Gadolinium	64	64	64
65	4f9	Terbium	65	65	65
66	4f10	Dysprosium	66	66	66
67	4f11	Holium	67	67	67
68	4f12	Erbium	68	68	68
69	4f13	Thulium	69	69	69
70	4f14	Ytterbium	70	70	70

32

Deuterium [not Hydrogen] is the building block of elements

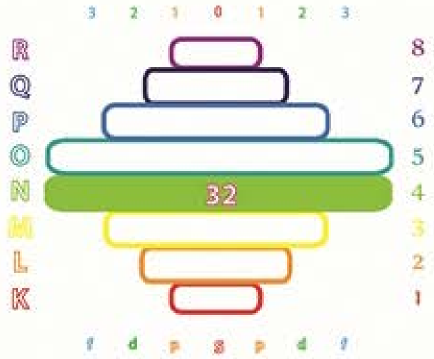
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
32
f d p s p d f

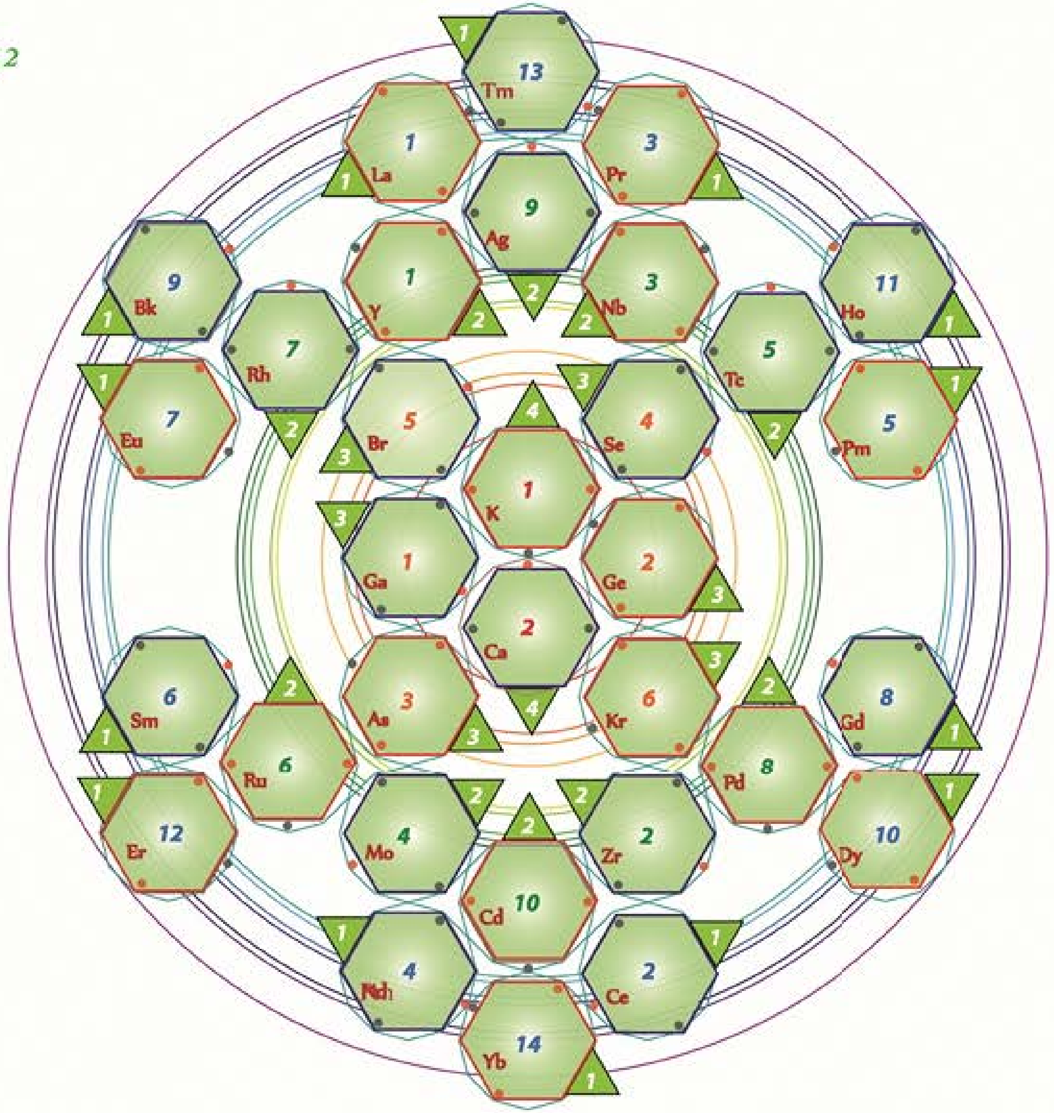
13 Tm
1 La
3 Pr
9 Ag
9 Bk
1 Y
3 Nb
11 Ho
7 Rh
5 Tc
7 Eu
5 Br
4 Se
5 Pm
1 K
1 Ga
2 Ge
2 Ca
6 Sm
3 As
6 Kr
8 Gd
6 Ru
8 Pd
12 Er
4 Mo
2 Zr
10 Dy
10 Cd
4 Ndh
2 Ce
14 Yb

N shell

n4

Ground State electron

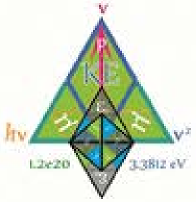
v
KE
hv
v²
1.2e20
3.3812 eV

iE = -10.143 eV

Energy level
4

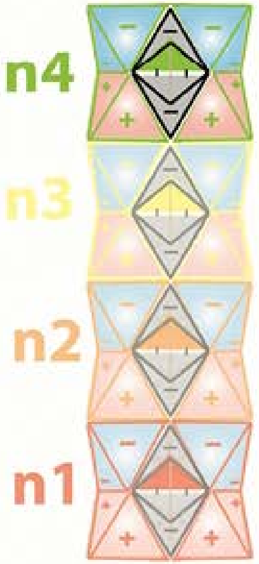

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Quantum Level 5

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
37	5s1	Rubidium	37	37	37
38	5s2	Strontium	38	38	38
49	5p1	Indium	49	49	49
50	5p2	Tin	50	50	50
51	5p3	Antimony	51	51	51
52	5p4	Tellurium	52	52	52
53	5p5	Iodine	53	53	53
54	5p6	Xenon	54	54	54
71	5d1	Lutetium	71	71	71
72	5d2	Hafnium	72	72	72
73	5d3	Tantalum	73	73	73
74	5d4	Tungsten	74	74	74
75	5d5	Rhenium	75	75	75
76	5d6	Osmium	76	76	76
77	5d7	Iridium	77	77	77
78	5d8	Platinum	78	78	78
79	5d9	Gold	79	79	79
80	5d10	Mercury	80	80	80
89	5f1	Actinium	89	89	89
90	5f2	Thorium	90	90	90
91	5f3	Protactium	91	91	91
92	5f4	Uranium	92	92	92
93	5f5	Neptunium	93	93	93
94	5f6	Plutonium	94	94	94
95	5f7	Americium	95	95	95
96	5f8	Curium	96	96	96
97	5f9	Berkelium	97	97	97
98	5f10	Californium	98	98	98
99	5f11	Einsteinium	99	99	99
100	5f12	Fermium	100	100	100
101	5f13	Mendelevium	101	101	101
102	5f14	Nobelium	102	102	102

32

Deuterium [not Hydrogen] is the building block of elements

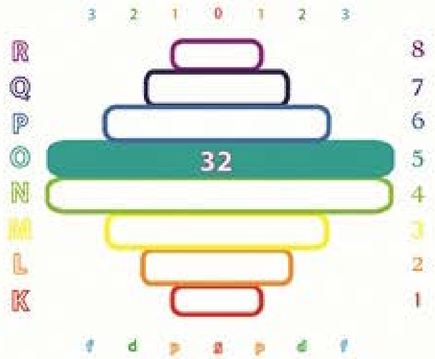
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
32
8
7
6
5
4
3
2
1
f d p s p d f

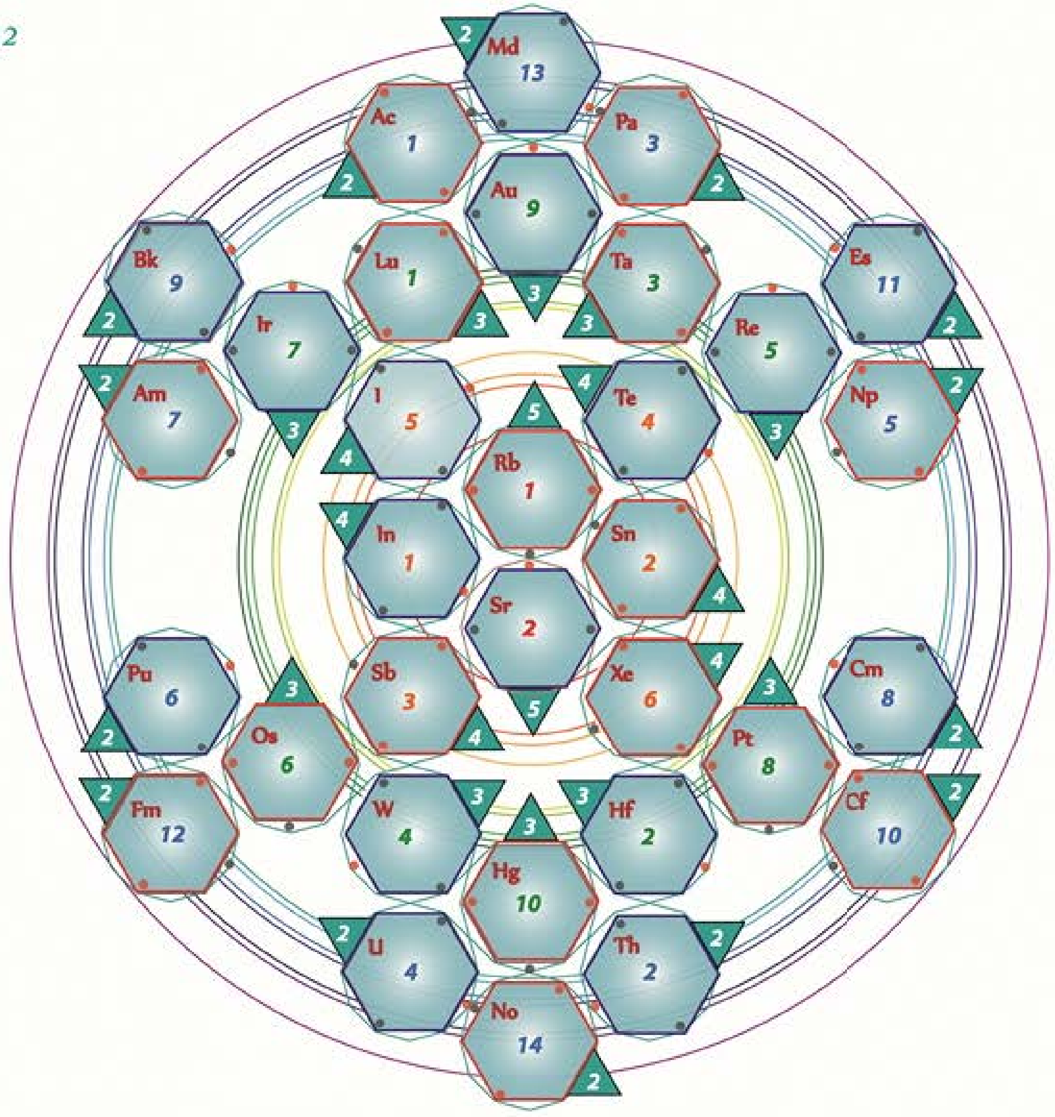
Md 13
Ac 1
Pa 3
Au 9
Bk 9
Lu 1
Ta 3
Es 11
Ir 7
Re 5
Am 7
I 5
Te 4
Np 5
Rb 1
In 1
Sn 2
Sr 2
Pu 6
Sb 3
Xe 6
Cm 8
Os 6
Pt 8
Fm 12
W 4
Hf 2
Cf 10
Hg 10
U 4
Th 2
No 14

O shell

n5

Ground State electron

v
P
KE
hv
v²
1.2e20
5.5282 eV

$iE = -8.241\ eV$

Energy level
5

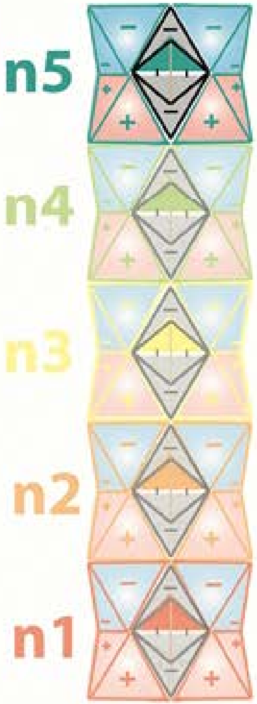
n5
n4
n3
n2
n1

Quantum Level 6

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
55	6s1	Caesium	55	55	55
56	6s2	Barium	56	56	56
81	6p1	Thallium	81	81	81
82	6p2	Lead	82	82	82
83	6p3	Bismuth	83	83	83
84	6p4	Polonium	84	84	84
85	6p5	Astatine	85	85	85
86	6p6	Radon	86	86	86
103	6d1	Lawrencium	103	103	103
104	6d2	Rutherfordium	104	104	104
105	6d3	Dubnium	105	105	105
106	6d4	Seaborgium	106	106	106
107	6d5	Bohrium	107	107	107
108	6d6	Hassium	108	108	108
109	6d7	Meitnerium	109	109	109
110	6d8	Darmstadtium	110	110	110
111	6d9	Roetgenium	111	111	111
112	6d10	Copernicium	112	112	112

18

Deuterium [not Hydrogen] is the building block of elements

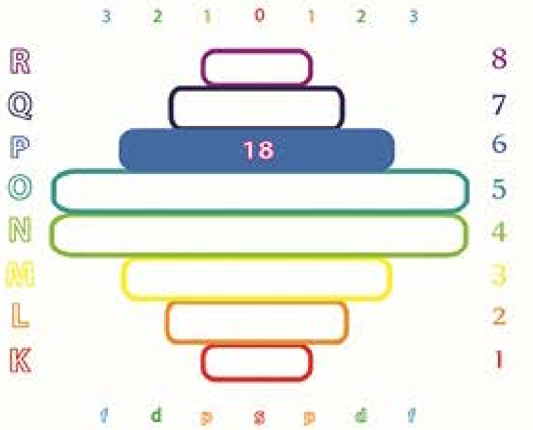
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
18
f
d
p
s
p
d
f

Energy level
6

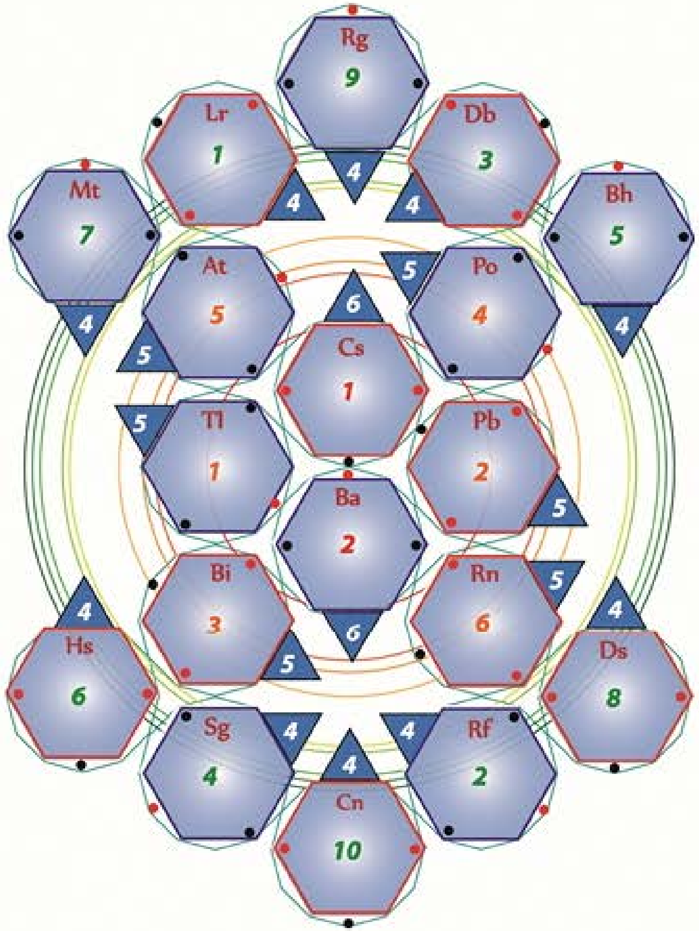
Rg
9
Lr
1
Db
3
Mt
7
Bh
5
At
5
Po
4
Cs
1
Tl
1
Pb
2
Ba
2
Bi
3
Rn
6
Hs
6
Ds
8
Sg
4
Rf
2
Cn
10
4
5
6

P shell

n6

Ground State electron

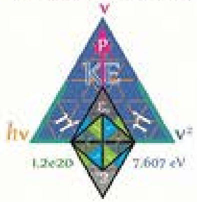
v
P
KE
hv
v²
1.2e20
7.607 eV

iE = -5.917 eV

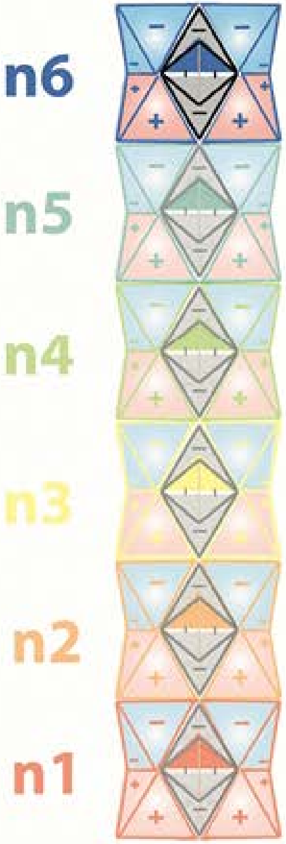
n6
n5
n4
n3
n2
n1

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Quantum Level 7

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
87	7s1	Francium	87	87	87
88	7s2	Radium	88	88	88
113	7p1	Ununtrium	113	113	113
114	7p2	Flerovium	114	114	114
115	7p3	Ununpentium	115	115	115
116	7p4	Livermorium	116	116	116
117	7p5	Ununseptium	117	117	117
118	7p6	Ununoctium	118	118	118

8

Deuterium [not Hydrogen] is the building block of elements

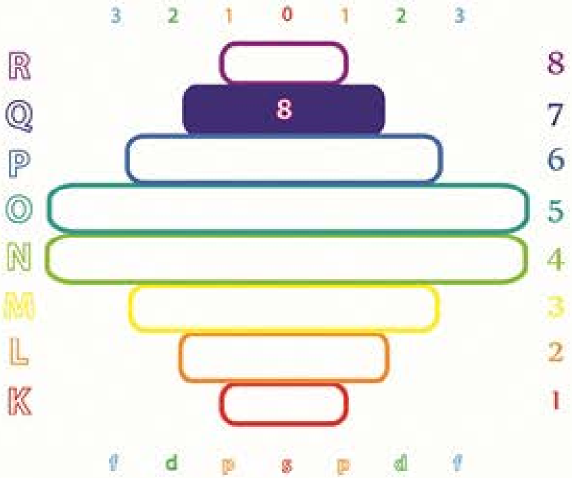
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

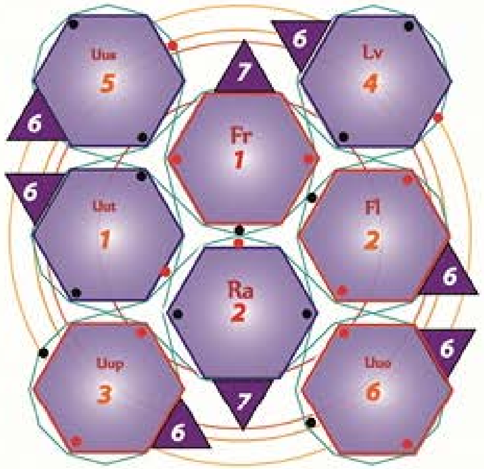
Uus
5
6
6
7
6
Lv
4
Fr
1
6
Uut
1
Fl
2
6
Ra
2
Uup
3
6
7
Uuo
6
6

Q shell

n7

Ground State electron

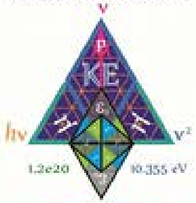
v
P
KE
c
hv
v²
1.2e20
10.355 eV

$iE = -3.169\ eV$

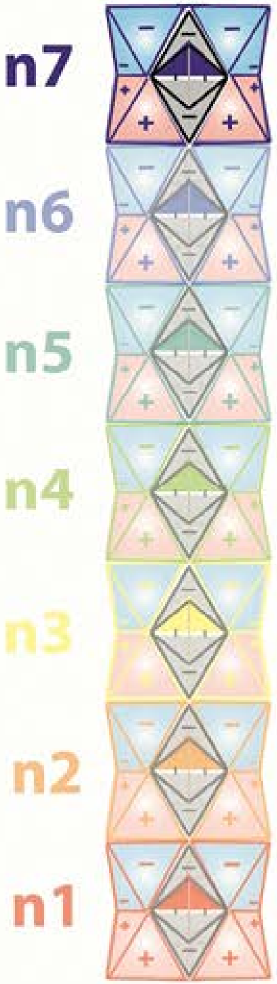
n7
n6
n5
n4
n3
n2
n1

Energy level
7

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Quantum Level 8

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
119	*8s1*	**Ununnonium**	119	119	119
120	*8s2*	**Unbinilium**	120	120	120

2

Deuterium [not Hydrogen] is the building block of elements

R shell

n8

Ground State electron

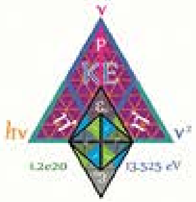
v
P
KE
hv
v²
1.2e20
13.525 eV

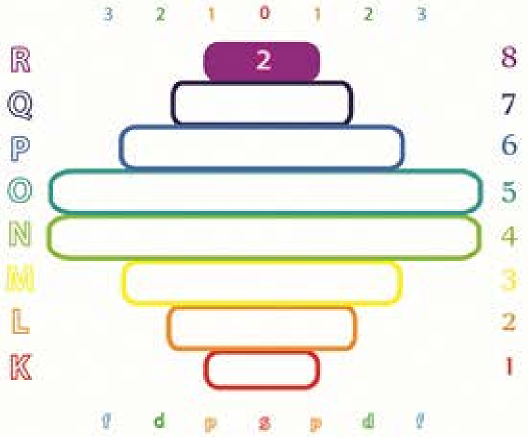
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
2
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

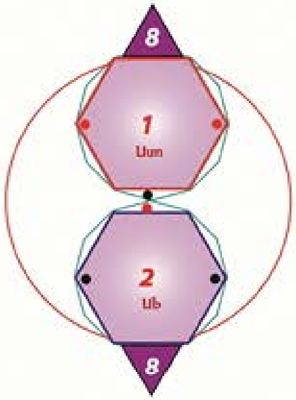

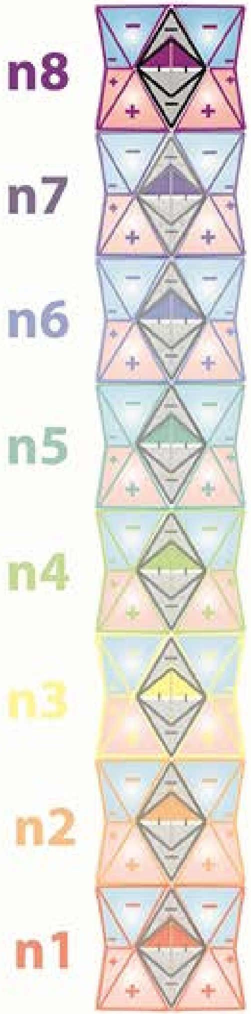
n8
n7
n6
n5
n4
n3
n2
n1

Energy level

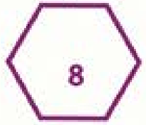

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Spectral line transitions

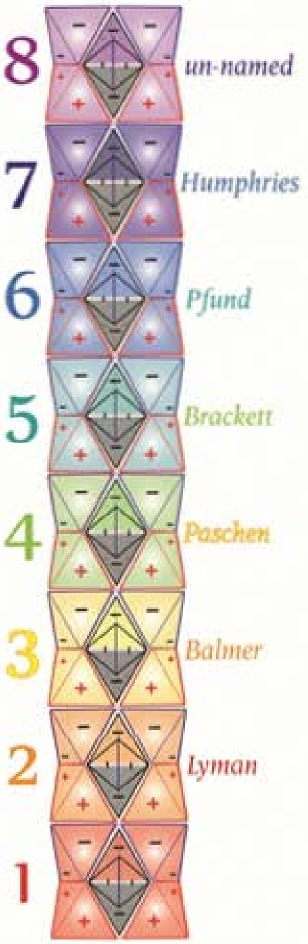
8
un-named
7
Humphries
6
Pfund
5
Brackett
4
Paschen
3
Balmer
2
Lyman
1

Quantum level jumps

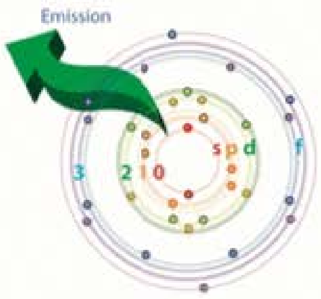
Emission
3
2
1
0
s
p
d
f

Quantum Level Jumps

Photon Absorption and Release

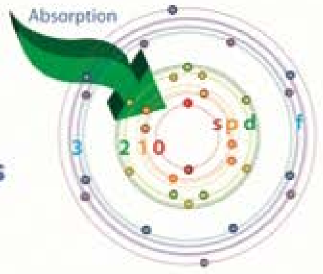
Absorption
3
2
1
0
s
p
d
f

Photo-electrons can only transition between principal energy Baryons in the atomic nuclei in discrete steps [or quantum jumps] because Baryons determine the KEM energy levels of electrons in nuclei

[see Tetryonic QED for full details on spectral line mechanics]

Initial Quantum level

8	768	756	720	660	576	468	336	180	0
7	588	576	540	480	396	288	156	0	
6	432	420	384	324	240	132	0		
5	300	288	252	192	108	0			
4	192	180	144	84	0				
3	108	96	60	0					
2	48	36	0						
1	12	0							
		12	48	108	192	300	432	588	768
		1	2	3	4	5	6	7	8

Final Quantum level

$$\Delta p = \Delta M v = hf$$

accelerating photo-electrons produce spectral lines

Spectral line transitions

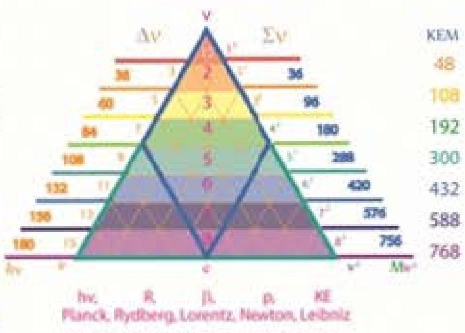
v
Δv
Σv
KEM
48
108
192
300
432
588
768
36
60
84
108
132
156
180
36
96
180
288
420
576
756
2
3
4
5
6
hv
c
Quantum differentials
hv,
R,
β,
p,
KE
Planck, Rydberg, Lorentz, Newton, Leibniz

uniting classical physics and relativity through equilateral geometry

Nuclear energy emission~absorption

If atoms are left undisturbed, their electrons usually fill the lowest available energy levels and stay there, in their "ground state."

Occasionally, however, they may also be pushed up to some higher energy ("become excited") e.g. by a collision with a fast atom or electron, one which got extra speed from an electric voltage or from some source of heat.

An atom/electron elevated to one of its higher "excited levels" soon falls back to a lower level ("undergoes a quantum jump"), emitting a photon whose energy corresponds to the difference between the levels.

That need not be the ground state: the atom/electron might descend to that state in several steps, emitting a photon at each step on the way.

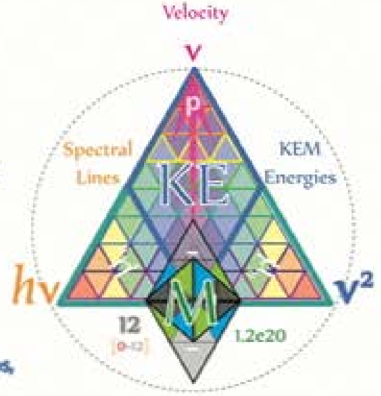
Velocity
v
p
Spectral Lines
KEM Energies
KE
hv
v²
M
12
[0-12]
1.2e20

Quantum transitions

(Orbital Shells - Bound energy states)

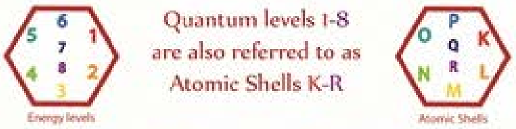
5
6
7
8
1
4
2
3
Energy levels
O
P
Q
R
K
N
L
M
Atomic Shells

Quantum levels 1-8
are also referred to as
Atomic Shells K-R

Photo-electrons can only transition in discrete steps [or quantum jumps] within atomic nuclei shells because Baryons determine the KEM energy levels of electrons in nuclei

Any photo-electron bound in a Deuterium nuclei will have specific quantised KEM field energies and angular momenta

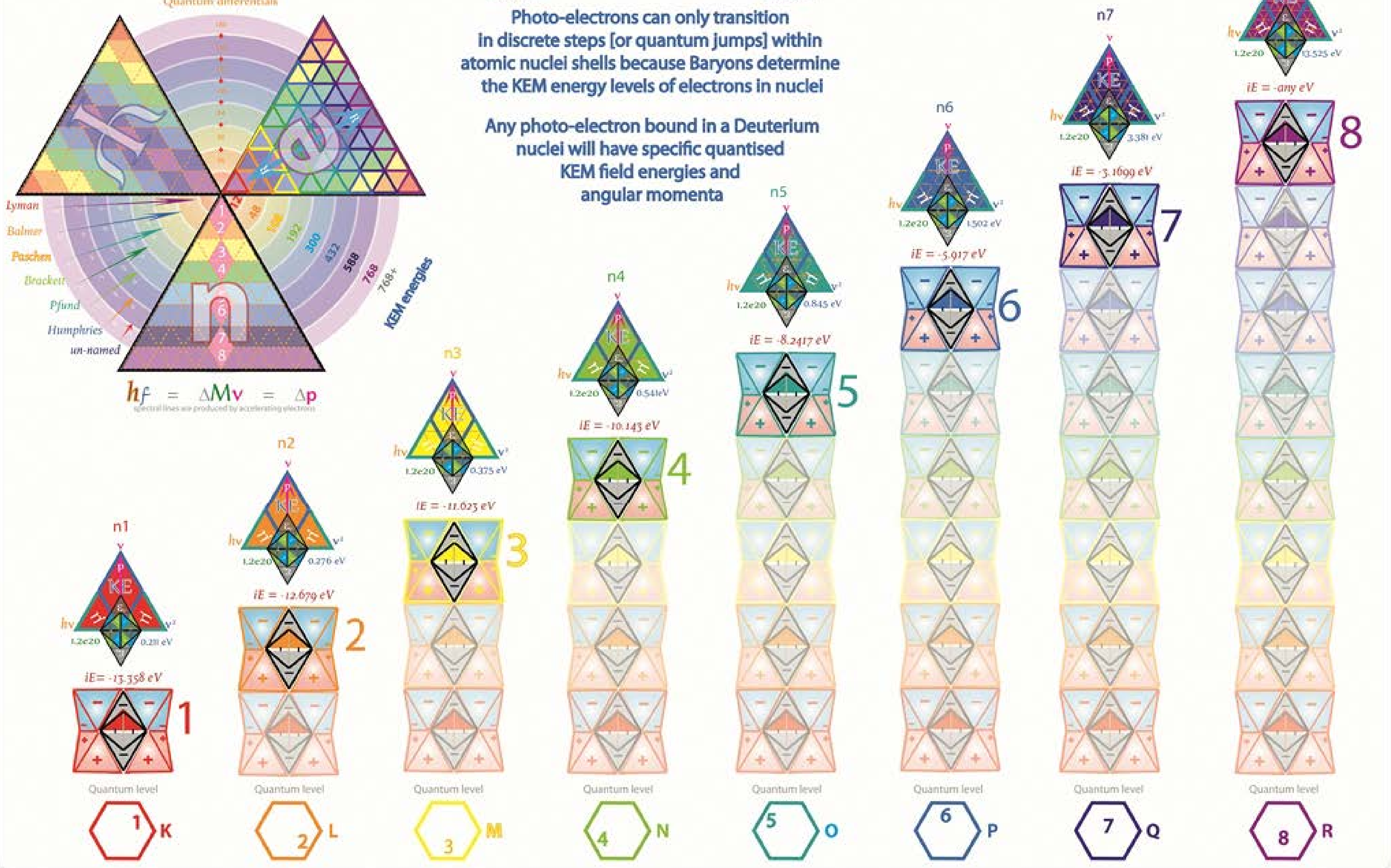
Quantum differentials
h
a
n
1
2
3
4
5
6
7
8
12
48
108
192
300
432
588
768
768+
KEM energies
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
hf = ΔMv = Δp
spectral lines are produced by accelerating electrons
n1
v
P
KE
hv
v²
1.2e20
0.211 eV
iE= -13.358 eV
1
n2
1.2e20
0.276 eV
iE = -12.679 eV
2
n3
1.2e20
0.375 eV
iE = -11.623 eV
3
n4
1.2e20
0.541eV
iE = -10.143 eV
4
n5
1.2e20
0.845 eV
iE = -8.2417 eV
5
n6
1.2e20
1.502 eV
iE = -5.917 eV
6
n7
1.2e20
3.381 eV
iE = -3.1699 eV
7
n8
1.2e20
13.525 eV
iE = -any eV
8
Quantum level
1 K
Quantum level
2 L
Quantum level
3 M
Quantum level
4 N
Quantum level
5 O
Quantum level
6 P
Quantum level
7 Q
Quantum level
8 R

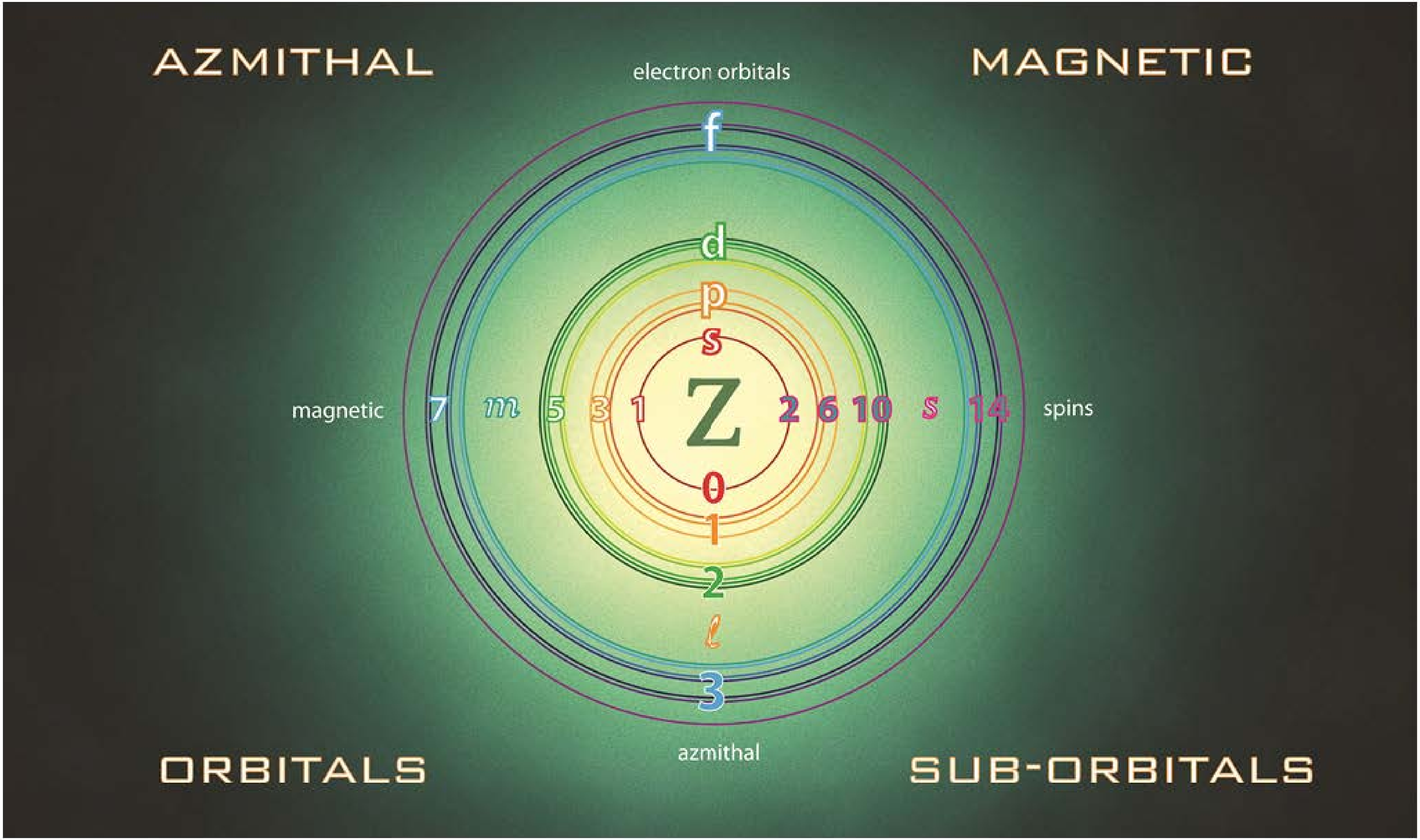
AZMITHAL
MAGNETIC
electron orbitals
f
d
p
s
magnetic
7
m
5
3
1
Z
2
6
10
s
14
spins
0
1
2
l
3
azmithal
ORBITALS
SUB-ORBITALS

Atomic Orbitals

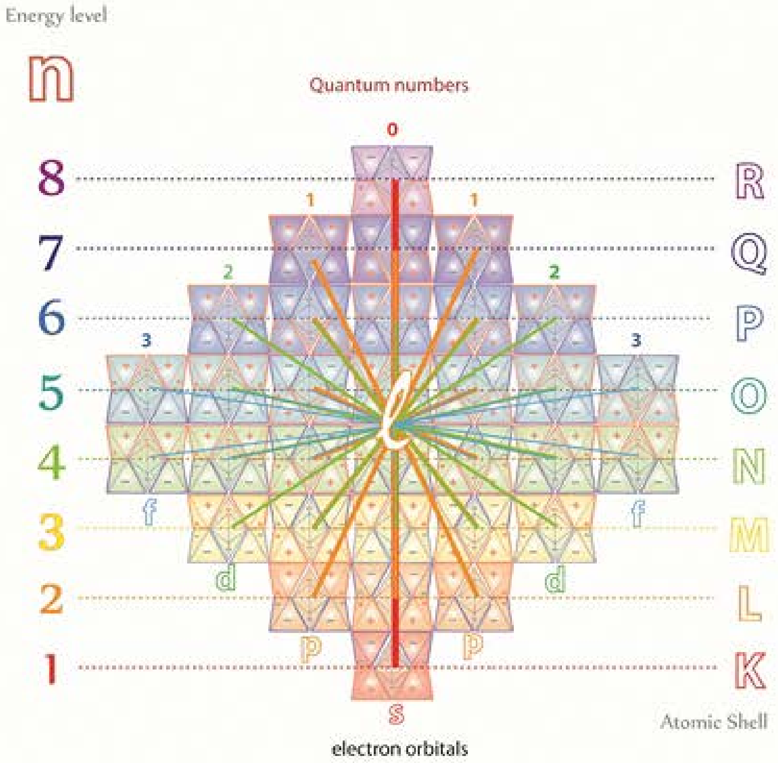
Energy level
n
Quantum numbers
0
1
1
2
2
3
3
8
7
6
5
4
3
2
1
ℓ
f
f
d
d
p
p
s
electron orbitals
R
Q
P
O
N
M
L
K
s
s+p
s+p+d
s+p+d+f
s+p+d+f
s+p+d
s+p
s
Atomic Shell

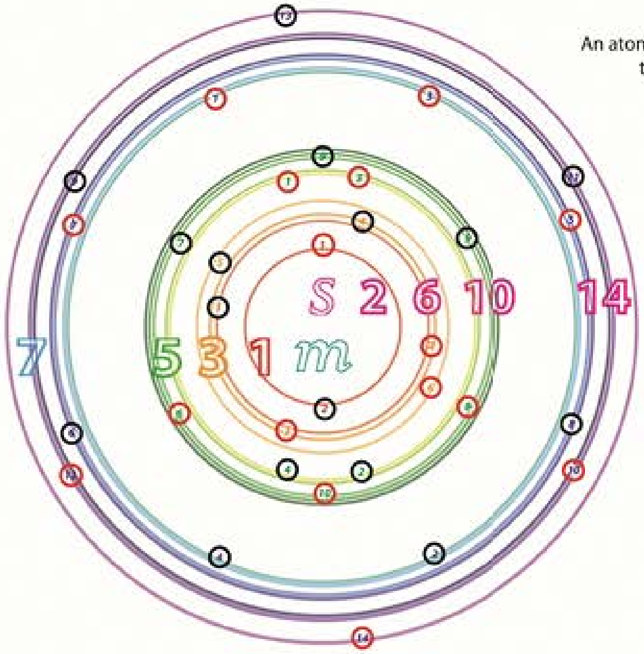
S
2
6
10
14
7
5
3
1
m

An atomic orbital is a mathematical function that describes the wave-like behavior of either one electron or a pair of electrons in an atom

Atomic orbitals are typically categorized by n, l, and m quantum numbers, which correspond to the electron's energy, angular momentum, and an angular momentum vector component, respectively.

Historically used to define the pedagogical electron cloud model of an atom Tetryonics reveals the true geometry of atomic nuclei

Each orbital is defined by a different set of quantum numbers and contains a maximum of two spin opposed electrons.

Aufbau

Azmithal & Magnetic numbers

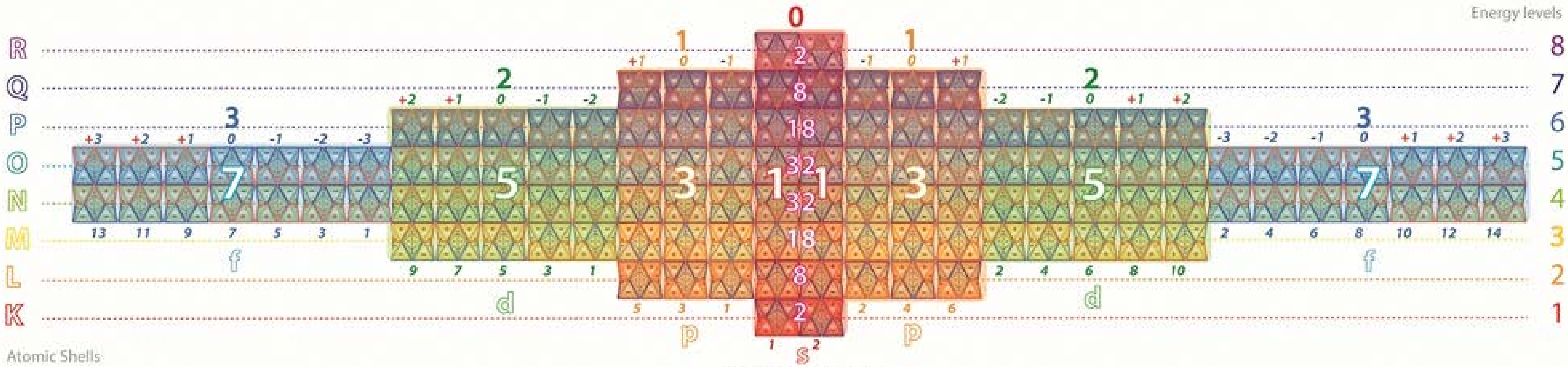
Energy levels
R
Q
P
O
N
M
L
K
Atomic Shells
0
1
1
2
2
3
3
+1 0 -1
-1 0 +1
+2 +1 0 -1 -2
-2 -1 0 +1 +2
+3 +2 +1 0 -1 -2 -3
-3 -2 -1 0 +1 +2 +3
2
8
18
32
32
18
8
2
7
5
3
1
1
3
5
7
13 11 9 7 5 3 1
9 7 5 3 1
5 3 1
1 2
2 4 6
2 4 6 8 10
2 4 6 8 10 12 14
f
d
p
s
p
d
f
8
7
6
5
4
3
2
1

Orbitals & sub-Orbitals

Electron Spins can be either up or down providing they obey the Pauli exclusion principle

s Orbital

1 Orbit (2 electrons max)

Alkali Metals & Alkali Earths

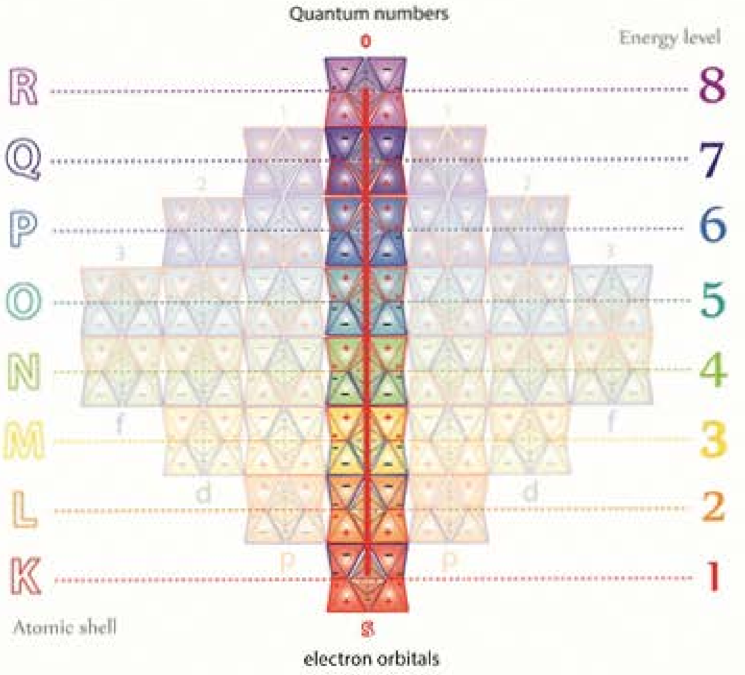
Quantum numbers
0
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
f
d
p
Atomic shell
s
electron orbitals

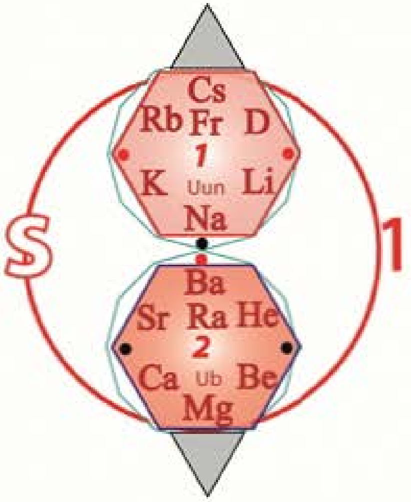
Cs
Rb
Fr
D
1
K
Uun
Li
Na
s
1
Ba
Sr
Ra
He
2
Ca
Ub
Be
Mg

		n
azmithal number	0	ℓ
magnetic numbers	0	m
spins	-1/2 +1/2	s

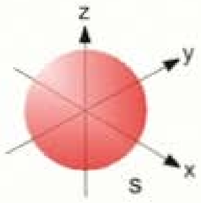

erroneous computer model of 's' electron orbitals

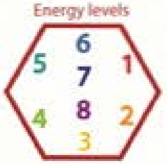
Energy levels
6
5
7
1
8
4
2
3

p Orbital

3 Orbits (6 electrons max)

Non-Metals, Halogens & Nobel gases

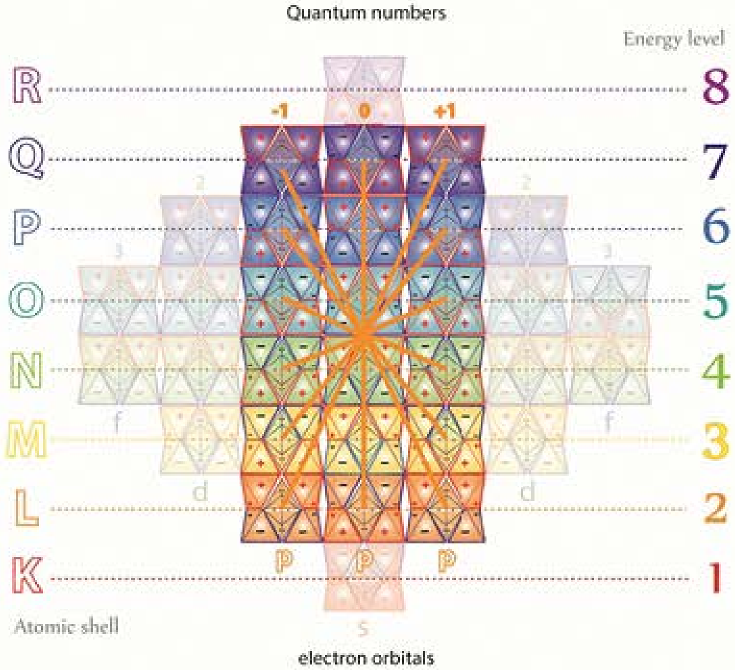
Quantum numbers
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
-1
0
+1
f
d
p
p
p
s
Atomic shell
electron orbitals

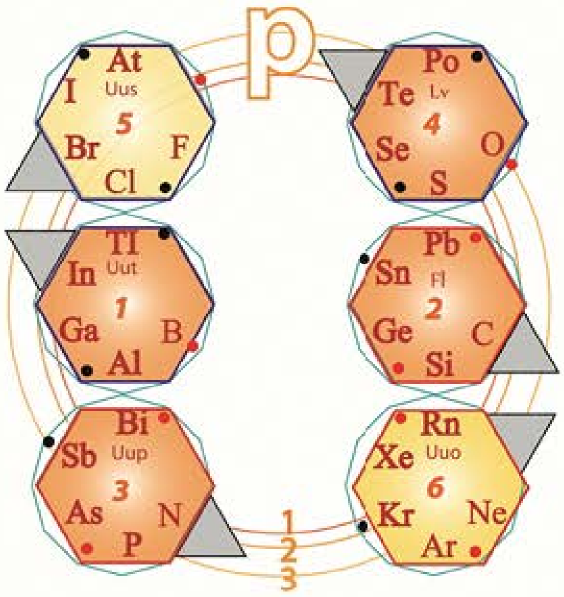
p
At
I
Uus
5
Br
F
Cl
Po
Te
Lv
4
Se
O
S
Tl
In
Uut
1
Ga
B
Al
Pb
Sn
Fl
2
Ge
C
Si
Bi
Sb
Uup
3
As
N
P
Rn
Xe
Uuo
6
Kr
Ne
Ar
1
2
3

n

azmithal number		1		ℓ
magnetic numbers	-1	0	+1	m
spins	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	S

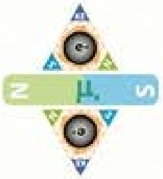

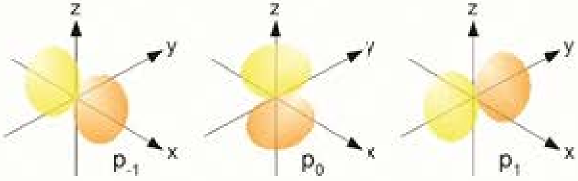
z
y
x
p_{-1}
z
y
x
p_0
z
y
x
p_1

erroneous computer model of 'p' electron orbitals

Quantum levels
6
5
7
4
2
3

d Orbital

5 Orbits (10 electrons max)

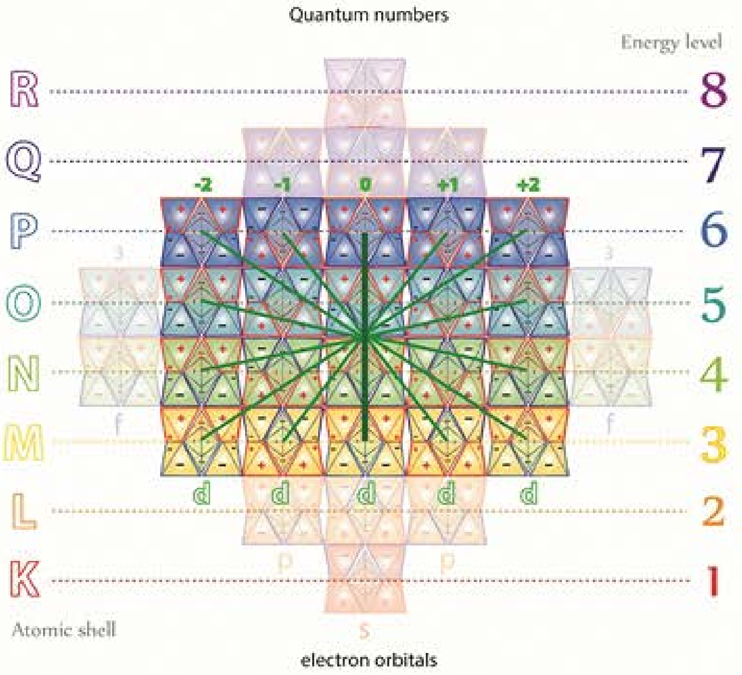
Quantum numbers
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
-2
-1
0
+1
+2
3
3
f
f
d
d
d
d
d
p
p
s
Atomic shell
electron orbitals

Transition & post-Transition Metals

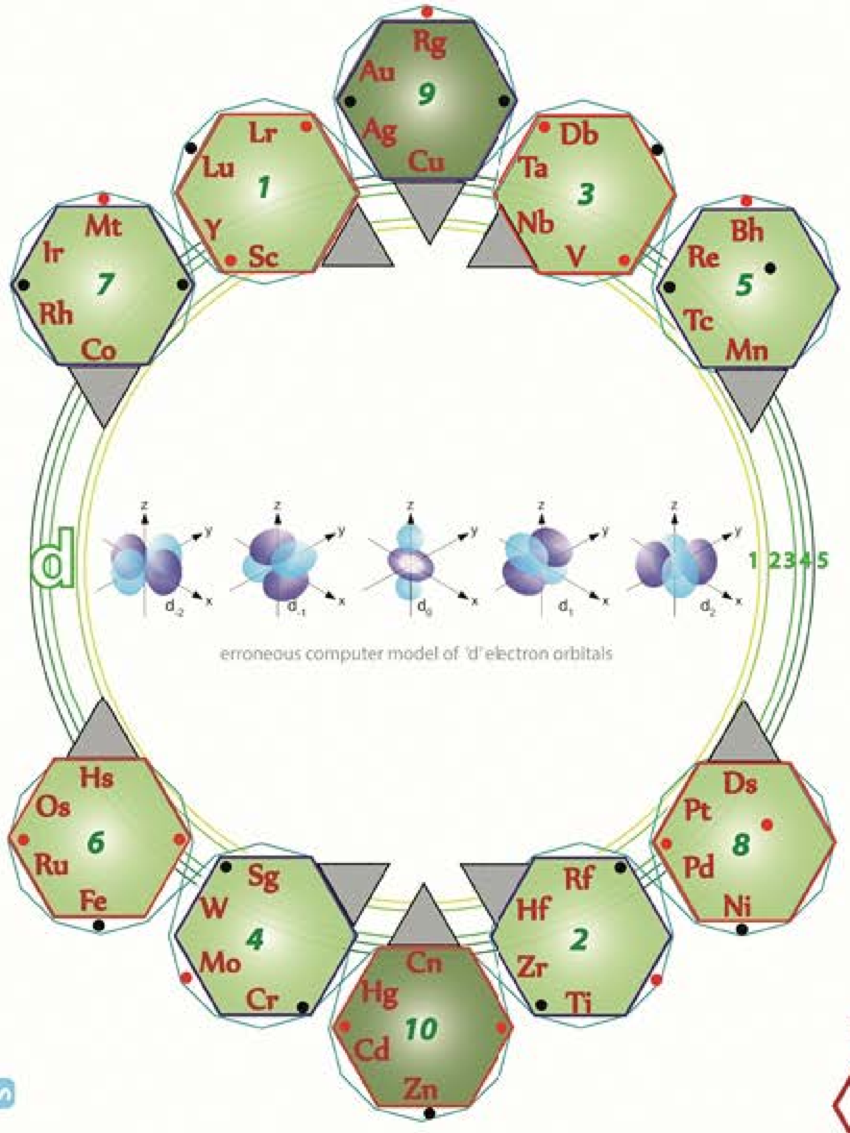
Rg
Au
9
Ag
Cu
Lr
Lu
1
Y
Sc
Db
Ta
3
Nb
V
Mt
Ir
7
Rh
Co
Bh
Re
5
Tc
Mn
d
z
y
x
d_{-2}
d_{-1}
d_0
d_1
d_2
1 2 3 4 5
Hs
Os
6
Ru
Fe
Sg
W
4
Mo
Cr
Cn
Hg
10
Cd
Zn
Rf
Hf
2
Zr
Ti
Ds
Pt
8
Pd
Ni

erroneous computer model of 'd' electron orbitals

						n
azmithal number			2			ℓ
magnetic numbers	-2	-1	0	+1	+2	m
spins	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	s

Quantum levels

f Orbital

7 Orbits (14 electrons max)

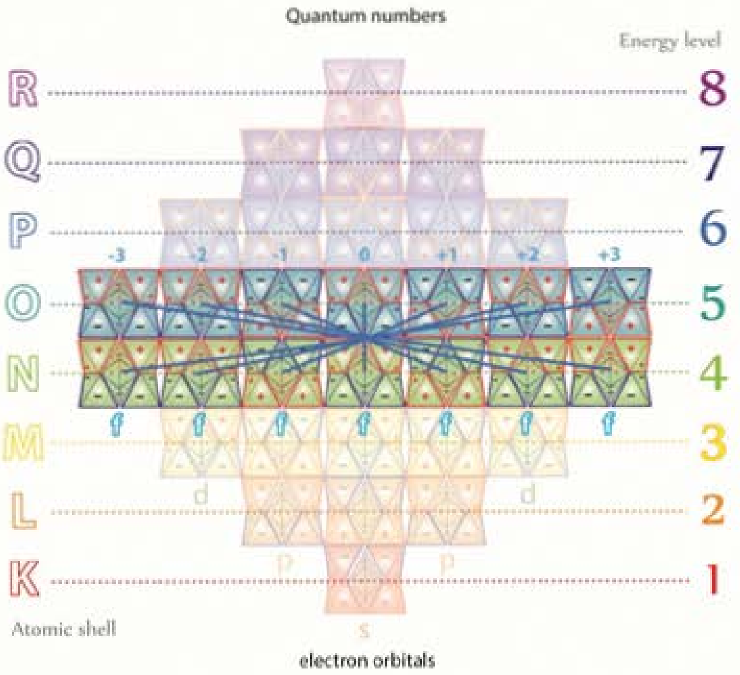
Quantum numbers
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
-3
-2
-1
0
+1
+2
+3
f
d
p
s
Atomic shell
electron orbitals

								n
azmithal number				3				l
magnetic numbers	-3	-2	-1	0	+1	+2	+3	m
spins	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	S

Lanthanoids & Actinoids

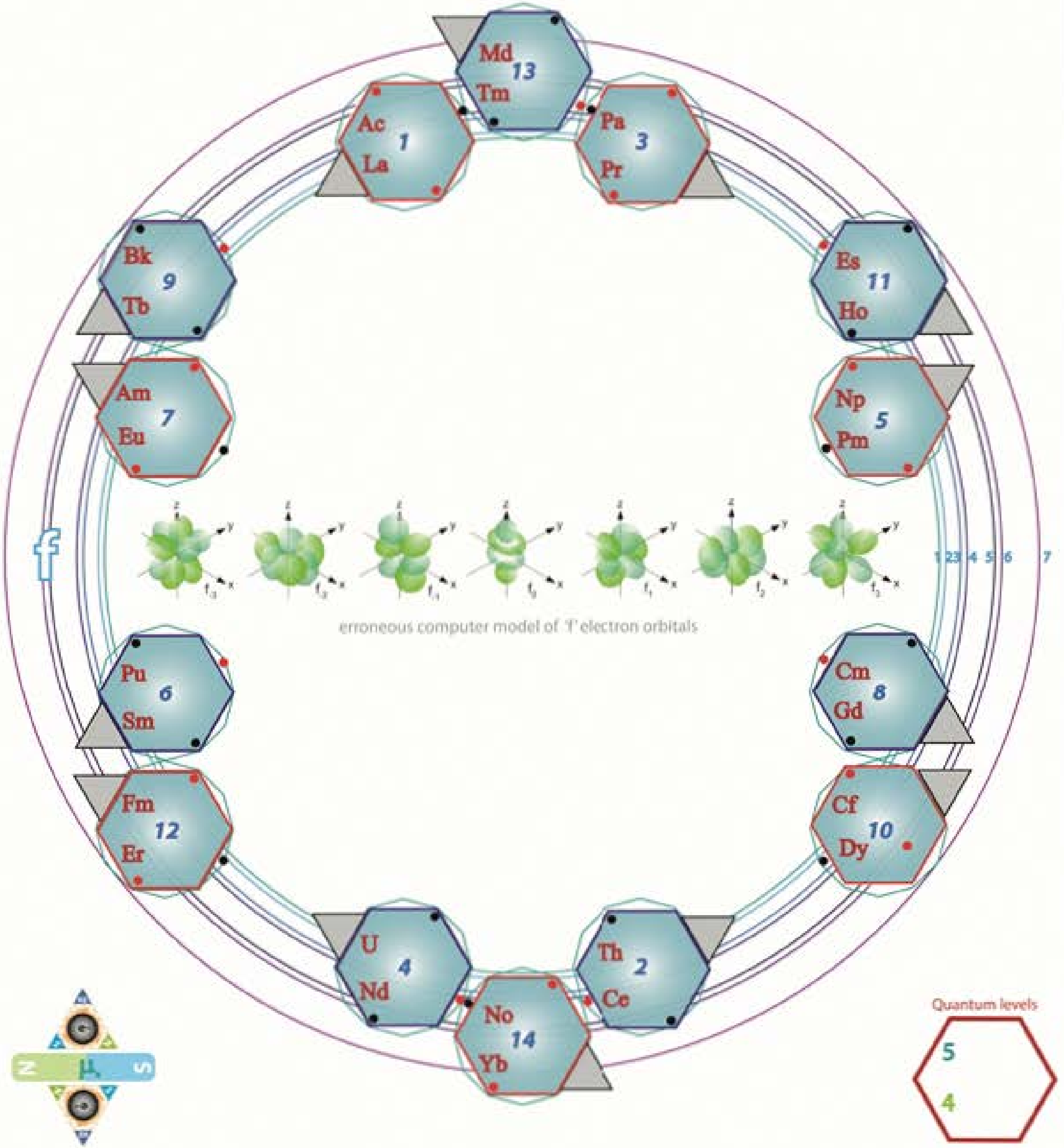
Md
13
Tm
Ac
1
La
Pa
3
Pr
Bk
9
Tb
Es
11
Ho
Am
7
Eu
Np
5
Pm
f
1 2 3 4 5 6
7
Pu
6
Sm
Cm
8
Gd
Fm
12
Er
Cf
10
Dy
U
4
Nd
Th
2
Ce
No
14
Yb
N
μ
S
Quantum levels
5
4

erroneous computer model of 'f' electron orbitals

Orbital energy variations

All Elements have stable core electron configurations of s & p orbitals for each energy level as revealed through diffraction studies

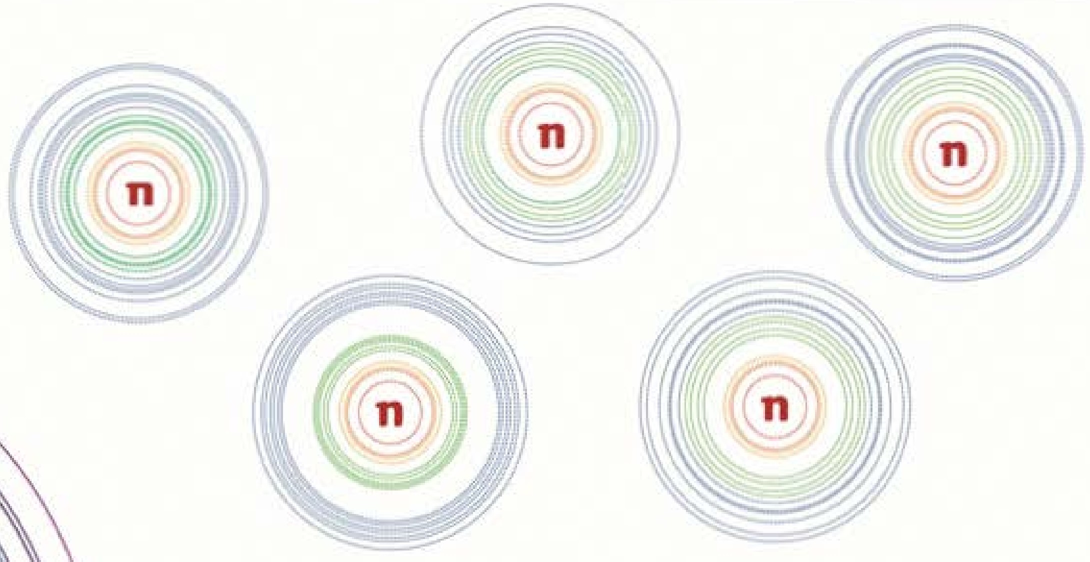

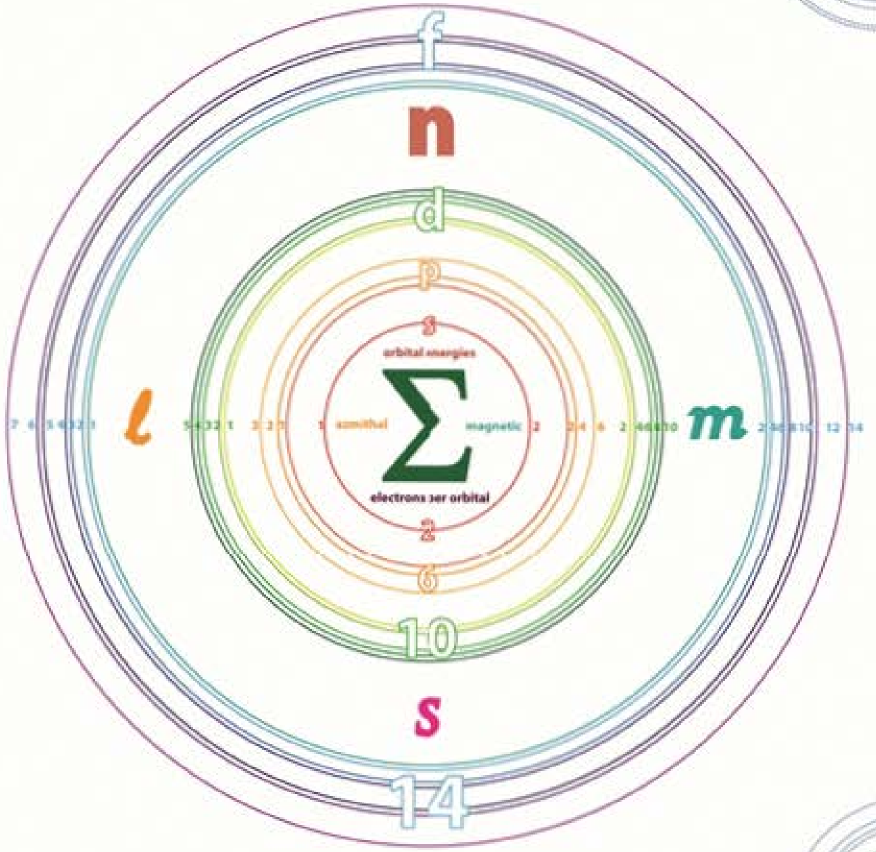
f
n
d
p
s
orbital energies
l
azimithal
Σ
magnetic
m
electrons per orbital
2
6
10
s
14

As additional nuclei bind to form d & f orbitals they can do so by bonding in many positions, with each location producing different orbital energies for each electron that binds to nuclei in that position

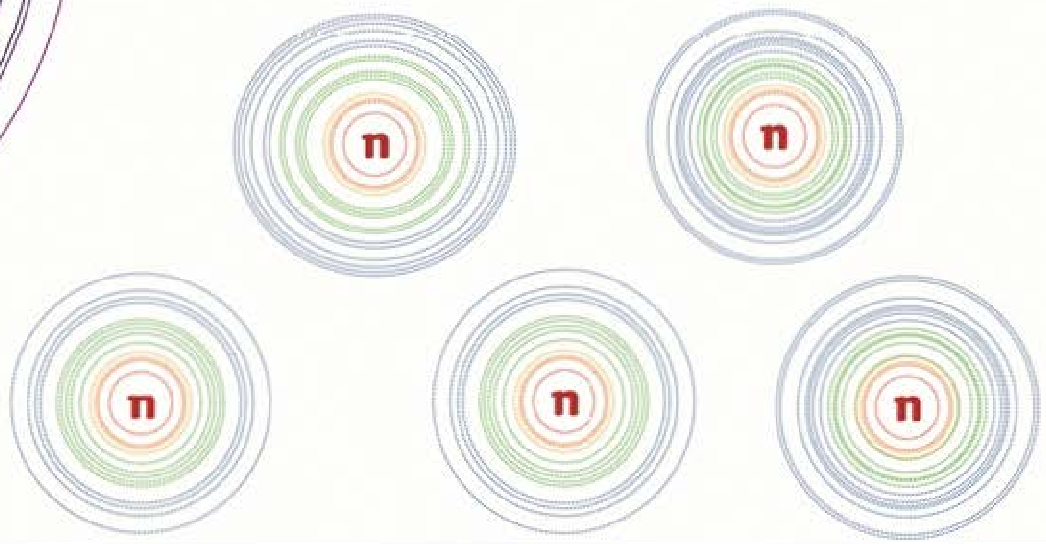

The final energy levels of each orbital is the result of the energy of the Baryons in the nuclei and the spin coupling energies of the photo-electrons bound to them

Electrons per shell

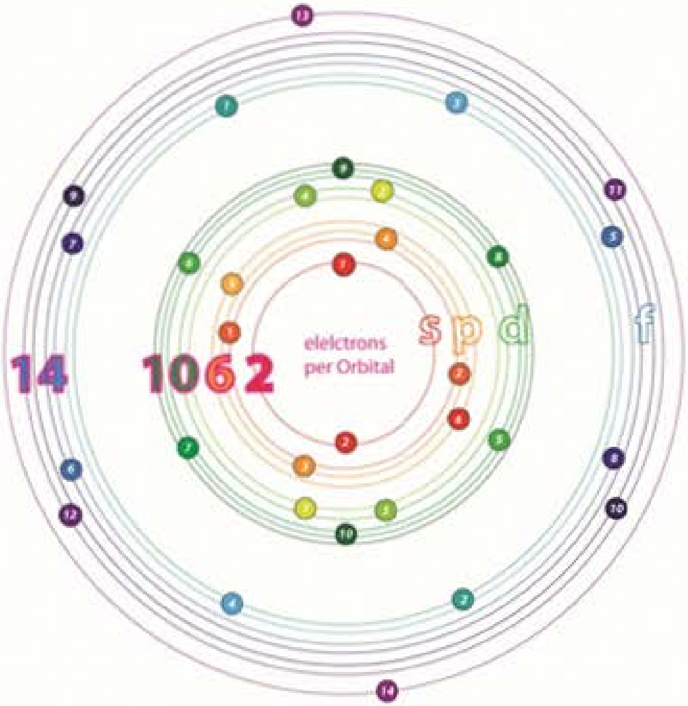
14
10 6 2
elelctrons
per Orbital
s
p
d
f

Each energy shell of a periodic element can hold only a fixed number of electrons

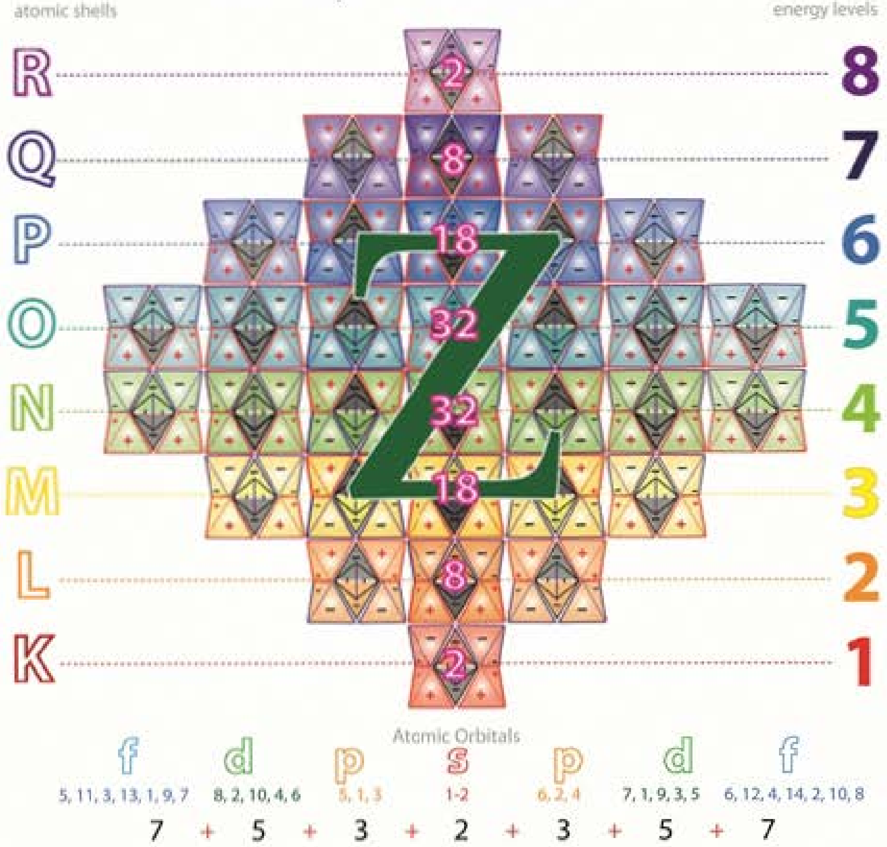
atomic shells
energy levels
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
8
18
32
32
18
8
2
Z
Atomic Orbitals
f
d
p
s
p
d
f
5, 11, 3, 13, 1, 9, 7
8, 2, 10, 4, 6
5, 1, 3
1-2
6, 2, 4
7, 1, 9, 3, 5
6, 12, 4, 14, 2, 10, 8
7 + 5 + 3 + 2 + 3 + 5 + 7

Rules governing the allowed combinations of Quantum Numbers

The three quantum numbers (n, l, and m)
that describe an orbital are integers: 0, 1, 2, 3, and so on

n (1-8) Principal (n = 1, 2, 3, 4 ...)	The principal quantum number (n) cannot be zero.
ℓ (0-3) Azimuthal (l = 0, 1 ... n-1)	The angular quantum number (l) can be any integer between 0 and n - 1.
mℓ (2ℓ+1) Magnetic (ml = -l, -l+1 ... 0 ... l-1, l)	The magnetic quantum number (m) can be any integer between -l and +l.
ms $\pm\frac{1}{2}$ Spin Projection (ms = -1/2 or +1/2)	The Spin of electrons in any nuclear sub-orbital can only be +1/2 (Spin UP) or -1.2 (Spin DOWN).

Z

1, 2, 3, 4, 5, 6, 7, 8

s, p, d, f

1	2
1, 3, 5	2, 4, 6
1, 3, 5, 7, 9	2, 4, 6, 8, 10
1, 3, 5, 7, 9, 11, 13	2, 4, 6, 8, 10, 12, 14
down up	up down

Quantum Numbers

n	4-5	3-6	2-7	1-8	2-7	3-6	4-5
ℓ	3	2	1	0	1	2	3
m	-3	-2	-1	1	+1	+2	+3
s	+1/2 -1/2	+1/2 -1/2	+1/2 -1/2	+1/2 -1/2	+1/2 -1/2	+1/2 -1/2	+1/2 -1/2

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Erwin Schrödinger

(12 August 1887 – 4 January 1961)

Using Tetryonic charged geometries for mass-ENERGY-Matter,
an electron's position and velocity CAN be modelled simultaneously
(but any attempt to measure or interact with it, will affect its component energy-momenta)

Electron Position Uncertainty

Atomic orbitals are typically described as "hydrogen-like" (meaning one-electron) wave functions over any spatial region of measurement, categorized by n, l, and m quantum numbers, which correspond to the electron's energy, angular momentum, and a vector momentum component, respectively

Werner Heisenberg

(5 December 1901 – 1 February 1976)

Lepton's are physically Spin 1 fermion particles that can easily be misconstrued as having entirely different spin numbers without the correct physical topologies to base the observed measurements on

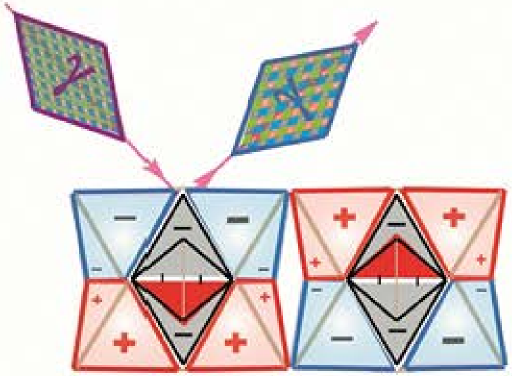

The energies of photo-electrons are determined by the Baryons they bind to & incident photons

Quantum Mechanics is a mathematical representation of equilateral energy momenta interactions and the charged geometries of mass-ENERGY-Matter

Determining the motion of electrons bound to atomic nuclei is akin to measuring the motion of variable speed electric fan blades mounted at various heights within a rotating carousel

Leptons are 12 loop quantum rotors

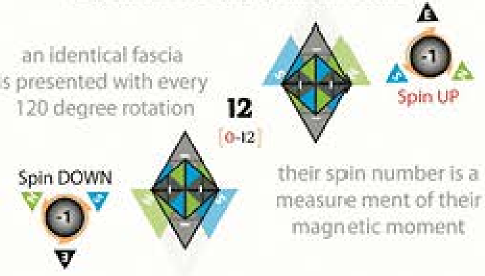

an identical fascia is presented with every 120 degree rotation

their spin number is a measure ment of their magnetic moment

The unique 12 faceted topology of leptons results in an identical EM geometry being oberved for every 120° rotation of the particle

Leading to the interpretation that the Lepton disappears and re-appears when being 'observed' or measured

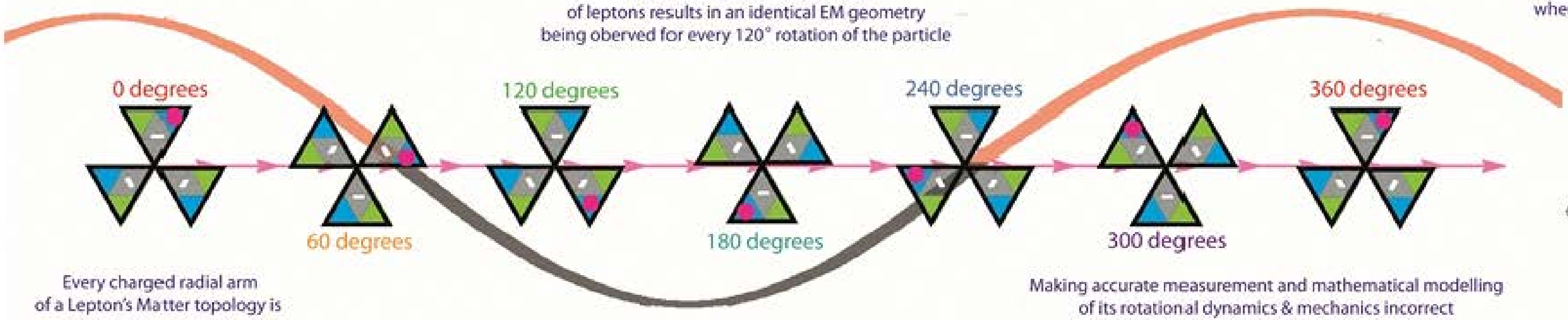

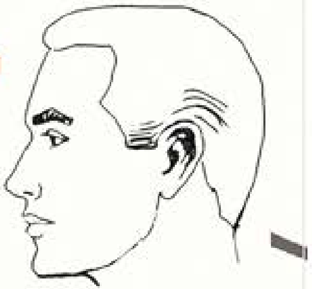

Every charged radial arm of a Lepton's Matter topology is identical to every other

Making accurate measurement and mathematical modelling of its rotational dynamics & mechanics incorrect without the correct physical topologies

Electron modelling & probability calculations

12
[0-12]
RE
S
KE

Electron positional measurements have proven to be historically difficult to accurately model due to the charged 12π rotating topologies of leptons

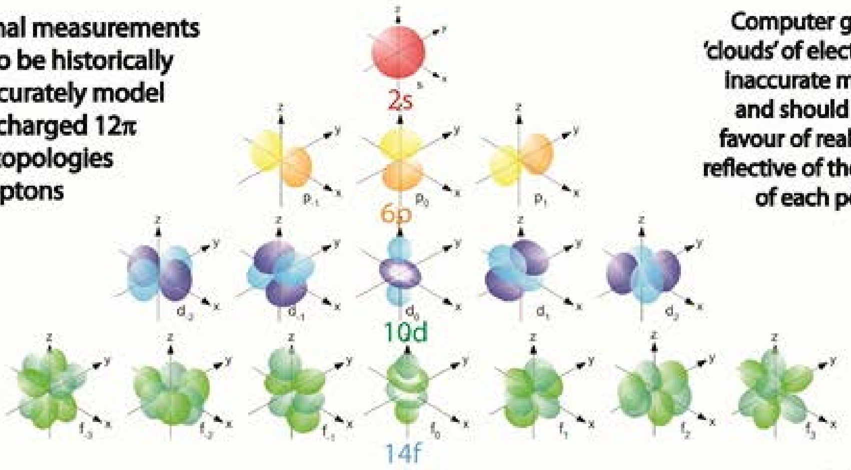

Computer generated plots of 'clouds' of electron probabilites are inaccurate mis-representations and should be abandoned in favour of realistic atomic models reflective of the charged geometry of each periodic element

v
RE
KE
P
KE
hv
Q
M
M
v²
c²

Every elemental atom can be viewed as a quantum carousel with a unique number of oscillating fans positioned around it.

Each fan has 3 blades and a fixed speed n[1-8] related to its height above ground level, AND the carousel is turning around on its axis

All periodic elements are made form Deuterium nuclei

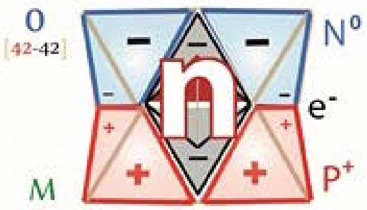

The baryonic energies of nuclei determines the energies of bound photo-electrons

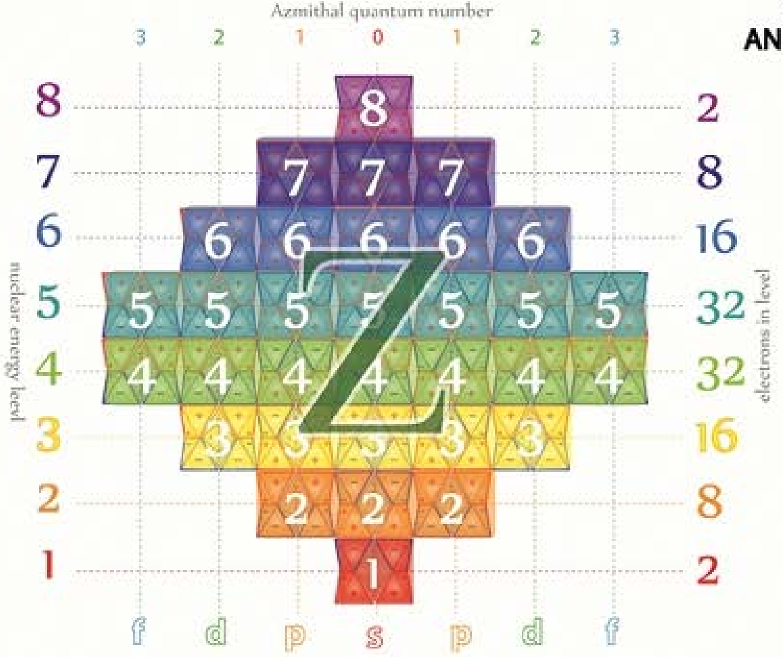

The current computer generated electron probability diagrams in popular use at present can now be show to be a misrepresentative model of mathematical modelling of electron sub-orbital energies

The nuclear quantum levels [n], intrinsic quantised angular momentum [h] and orbital angular momentum [l] of each electron bound within atomic nuclei are all the direct result of the Baryonic energies of the nuclei they are bound to

Each level of the quantum carousel can contain only a limited number of fans each running at a specific speed

Imagine trying to measure (or model) the motion of any 1 quantum scale blade while the carousel rotates

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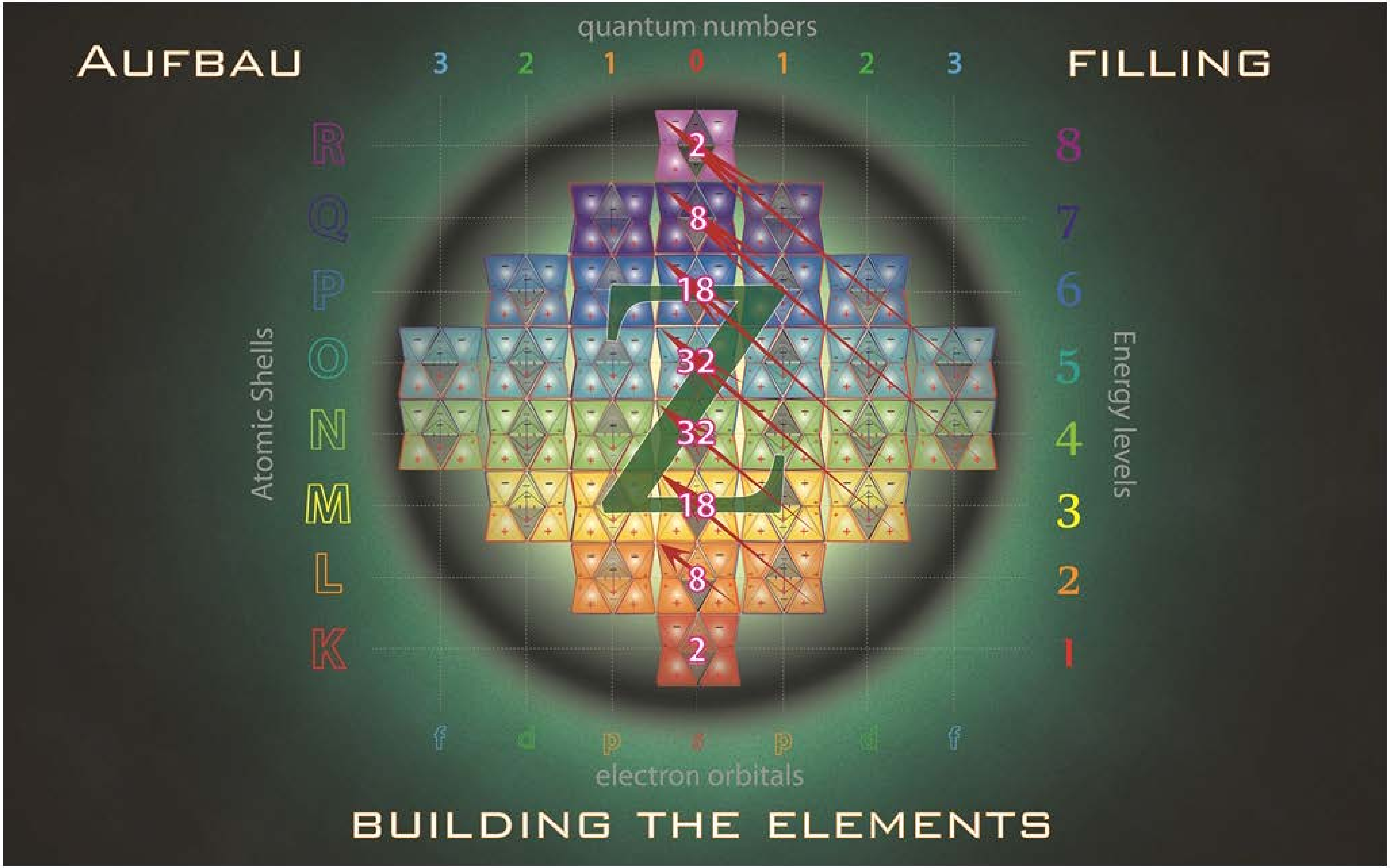
AUFBAU
quantum numbers
3
2
1
0
1
2
3
FILLING
R
Q
P
O
N
M
L
K
Atomic Shells
8
7
6
5
4
3
2
1
Energy levels
2
8
18
32
32
18
8
2
Z
f
d
p
s
p
d
f
electron orbitals
BUILDING THE ELEMENTS

Tetryonics 48.01 - aufbau geometry

Quantum Topologies

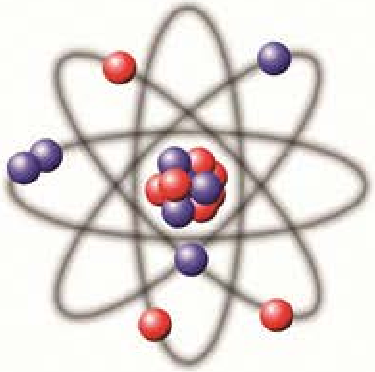

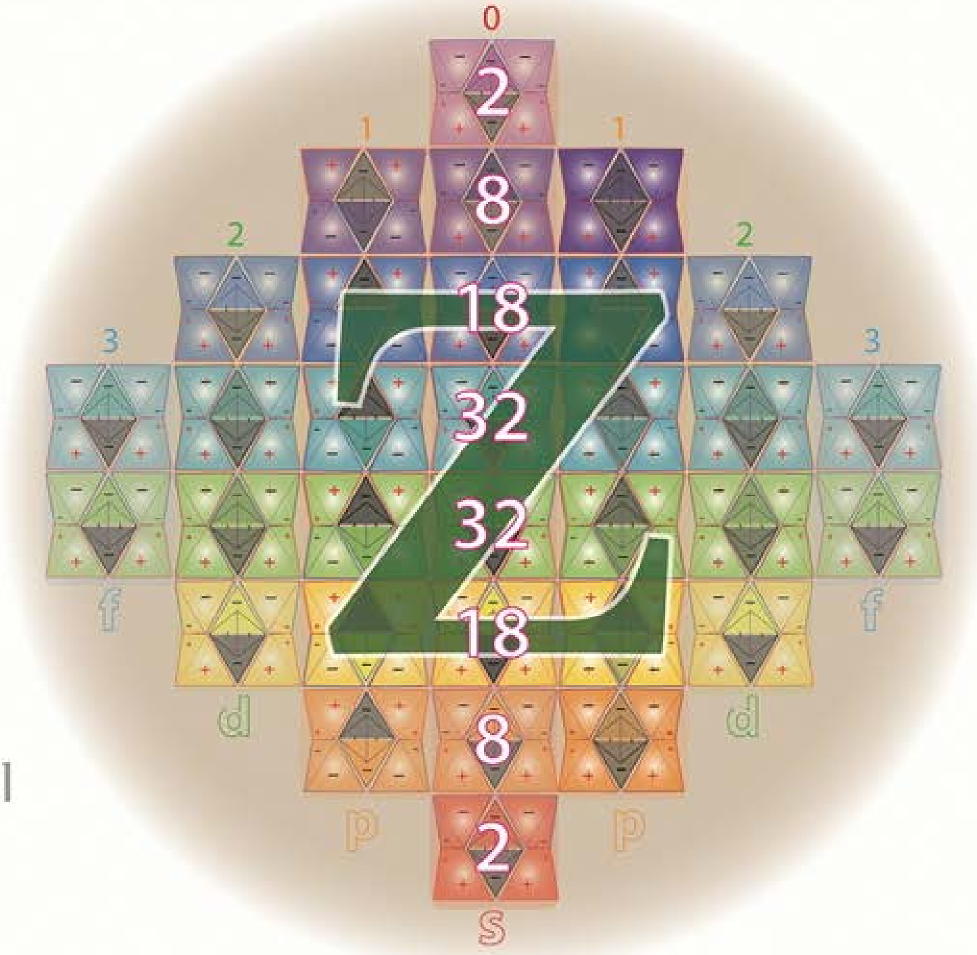
0
1
1
2
2
3
3
2
8
18
32
32
18
8
2
Z
f
f
d
d
p
p
s

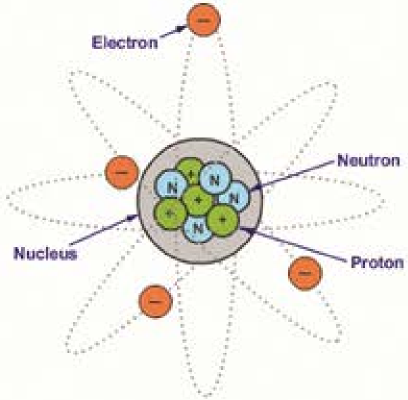
Electron
Neutron
Nucleus
Proton

Dalton Model

Quantum Model

Thomson Model

Rutherford Model

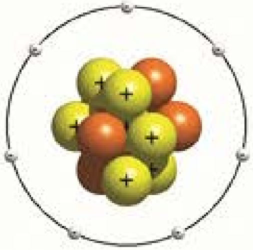

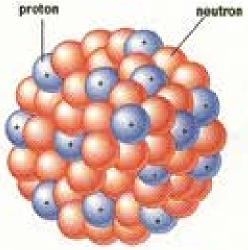
proton
neutron

Historically viewed as a spherical object
Tetryonic charge geometry has finally revealed the
true quantum topology of all atoms

Element numbers

The rule dictating how many nuclei form each Atomic shell is known as the Aufbau principle.

The physical and chemical properties of elements is determined by the atomic structure.
The atomic structure is, in turn, determined by the electrons and
which shells, subshells and orbitals they reside in.

The maximum periodic elemental number is 120

$$Z = \sum_{1,2,3,4,4,3,2,1} 2(n^2) = 2 + 8 + 18 + 32 + 32 + 18 + 8 + 2$$

Number of nuclei per level	Element #
2	120 119
8	118 111
18	110 93
32	92 61
32	60 29
18	28 11
8	10 3
2	2 1

The number of nuclei per quantum level is reflective of photonic energy levels and provides the foundational geometry for all of the periodic elements

The number of possible nuclei in each Quantum level follows aufbau principle 'numbers' which can be determined using the following summation formula

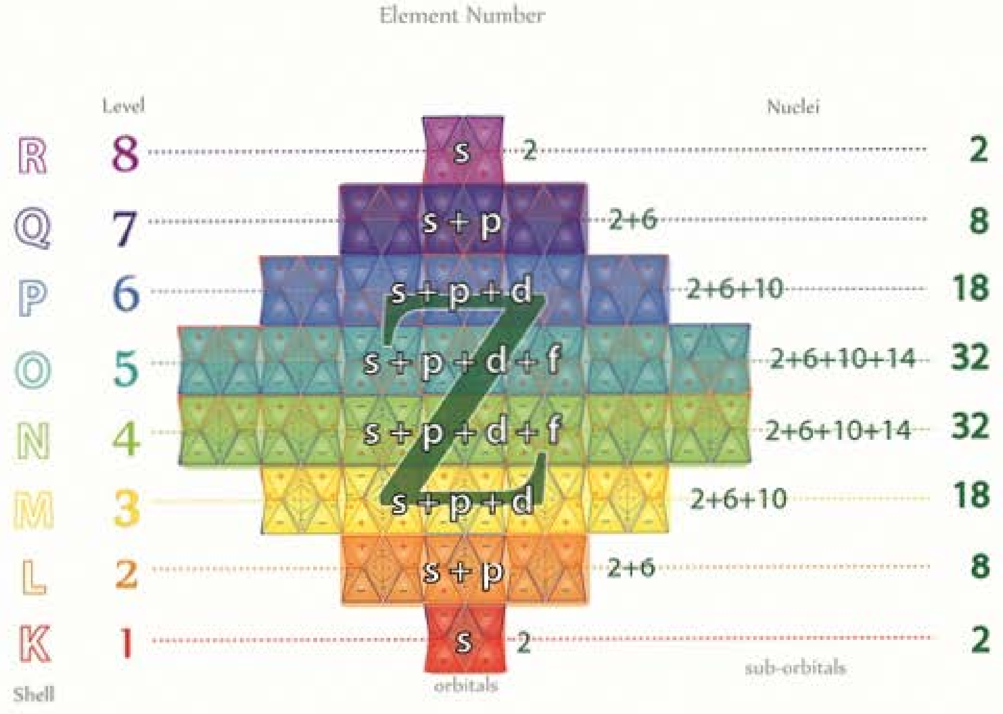

Shell	Level	orbitals	sub-orbitals	Nuclei
R	8	s	2	2
Q	7	s + p	2+6	8
P	6	s + p + d	2+6+10	18
O	5	s + p + d + f	2+6+10+14	32
N	4	s + p + d + f	2+6+10+14	32
M	3	s + p + d	2+6+10	18
L	2	s + p	2+6	8
K	1	s	2	2

Deuterium is the building block of all elements

Each element has equal numbers of Protons, electron & Neutrons with their stored mass-energies making up the molar masses of elements not excess neutron as currently modelled

Aufbau Principle

(Nuclei number and position)

1 Sub-Orbit (2 electrons max) ○ s

3 Sub-Orbits (6 electrons max) ○ p

○ d *5 Sub-Orbits (10 electrons max)*

○ f *7 Sub-Orbits (14 electrons max)*

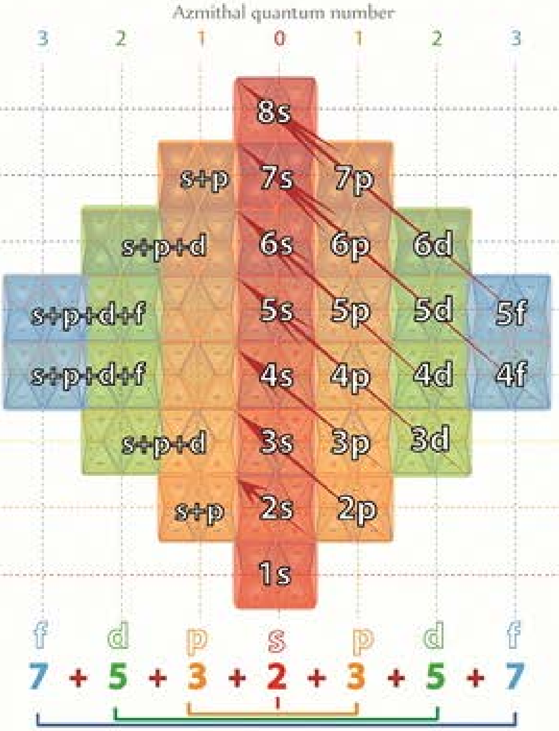

atomic shells			energy level
R	2	2	8
Q	2+6	8	7
P	2+6+10	18	6
O	2+6+10+14	32	5
N	2+6+10+14	32	4
M	2+6+10	18	3
L	2+6	8	2
K	2	2	1

2 6 10 14

Nuclei Shells	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Quantum number	per level
R	119	120																															8	2
Q	87	88	113	114	115	116	117	118																									7	8
P	55	56	81	82	83	84	85	86	103	104	105	106	107	108	109	110	111	112															6	18
O	37	38	49	50	51	52	53	54	71	72	73	74	75	76	77	78	79	80	89	90	91	92	93	94	95	96	97	98	99	100	101	102	5	32
N	19	20	31	32	33	34	35	36	39	40	41	42	43	44	45	46	47	48	57	58	59	60	61	62	63	64	65	66	67	68	69	70	4	32
M	11	12	13	14	15	16	17	18	21	22	23	24	25	26	27	28	29	30															3	18
L	3	4	5	6	7	8	9	10																									2	8
K	1	2																															1	2
sub-orbitals	s1	s2	p1	p2	p3	p4	p5	p6	d1	d2	d3	d4	d5	d6	d7	d8	d9	d10	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12	f13	f14		

A specific nuclear energy is associated with each electron configuration and, upon certain conditions, bound electrons are able to move from one orbital to another by emission or absorption of a quantum of energy, in the form of a photon.

The Aufbau principle can also be used to model the binding configuration of Protons and Neutrons in an atomic nucleus, according to their specific Baryonic Energy levels, in turn revealing the quantum geometry of all periodic Elements

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Wolfgang Pauli

(25 April 1900 – 15 December 1958)

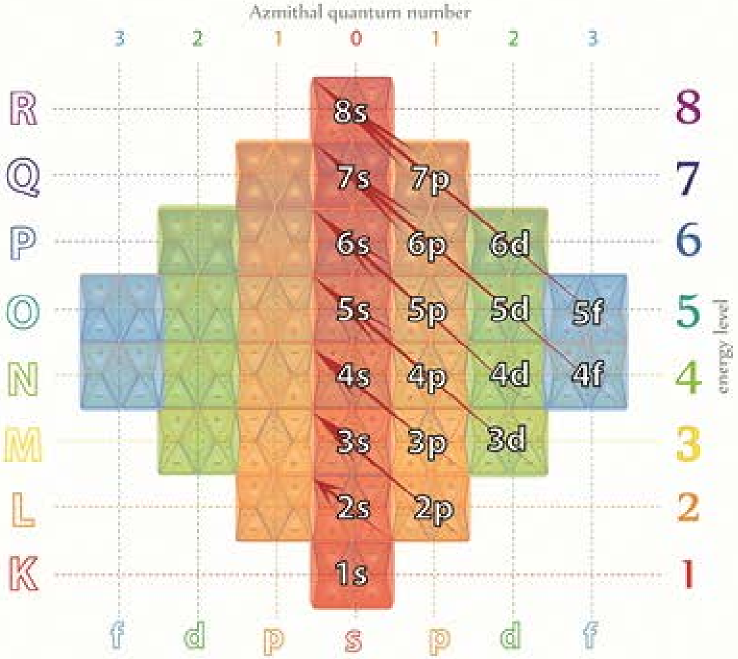
Azmithal quantum number
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8s
7s
7p
6s
6p
6d
5s
5p
5d
5f
4s
4p
4d
4f
3s
3p
3d
2s
2p
1s
8
7
6
5
4
3
2
1
energy level
f
d
p
s
p
d
f

Friedrich Hermann Hund

(4 February 1896 - 31 March 1997)

The orbitals of lower energy are filled in first with the electrons and only then are the higher energy orbitals filled.

aufbau electron orbital filling

Orbitals of equal energy are each occupied by one electron before any orbital is occupied by a second electron, and all electrons in singly occupied orbitals must have the same spin state

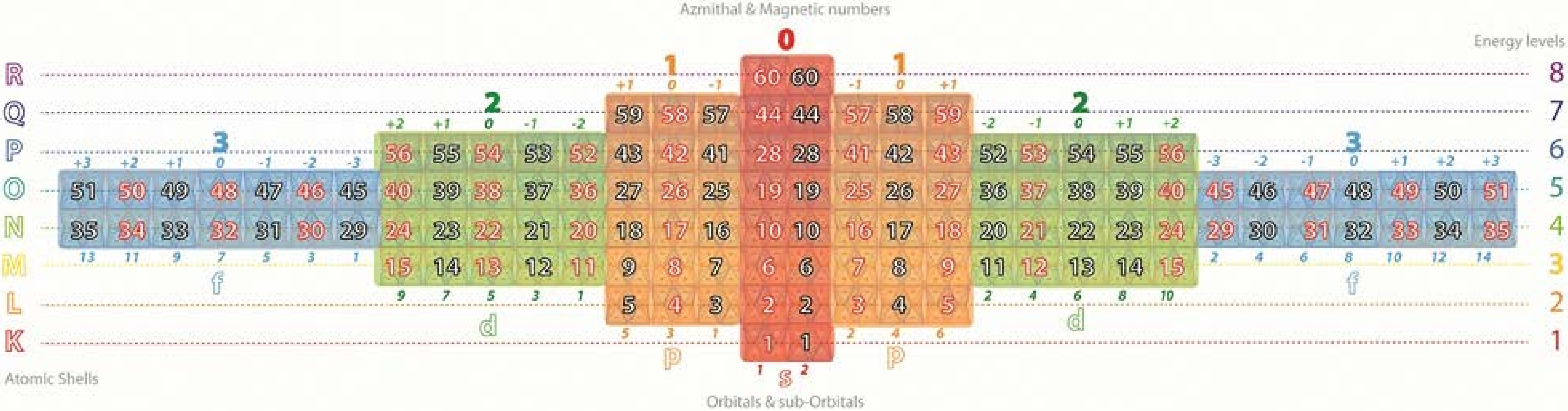
Azmithal & Magnetic numbers
Energy levels
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
2
3
s
p
d
f
Atomic Shells
Orbitals & sub-Orbitals

Aufbau construction

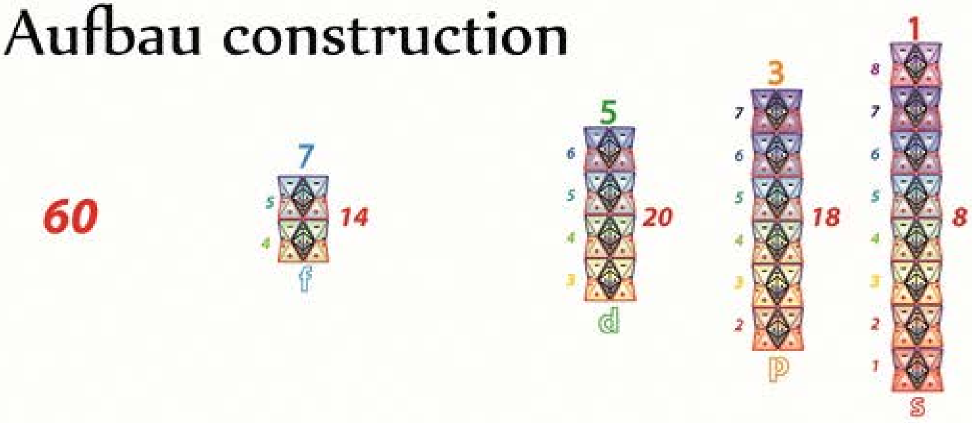
60
7
5
4
14
f
5
6
5
4
3
20
d
3
7
6
5
4
3
2
18
p
1
8
7
6
5
4
3
2
1
8
s

Proton base Hemisphere

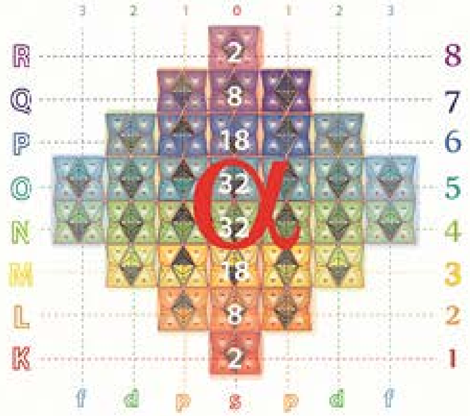
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
α
8
7
6
5
4
3
2
1
f d p s p d f

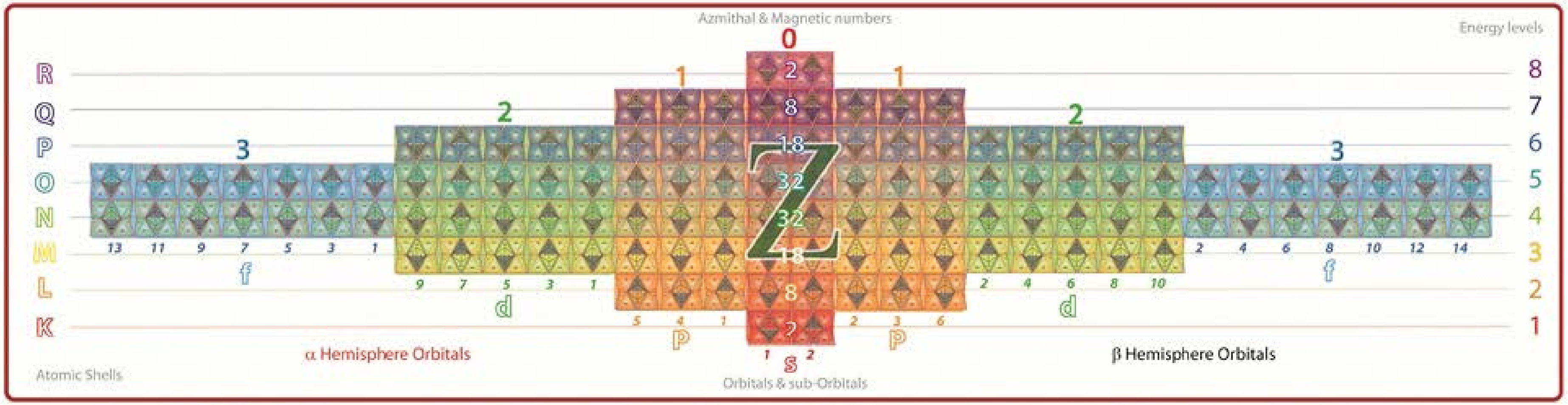
Azmithal & Magnetic numbers
Energy levels
0
1
1
2
2
3
3
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
Z
8
7
6
5
4
3
2
1
13 11 9 7 5 3 1
f
9 7 5 3 1
d
5 4 1
p
1 s 2
2 3 6
p
2 4 6 8 10
d
2 4 6 8 10 12 14
f
α Hemisphere Orbitals
β Hemisphere Orbitals
Atomic Shells
Orbitals & sub-Orbitals

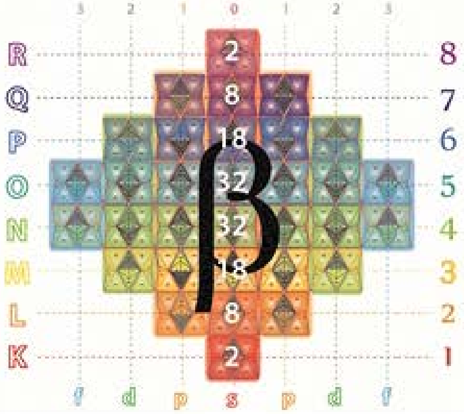
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
β
8
7
6
5
4
3
2
1
f d p s p d f

Neutron base Hemisphere

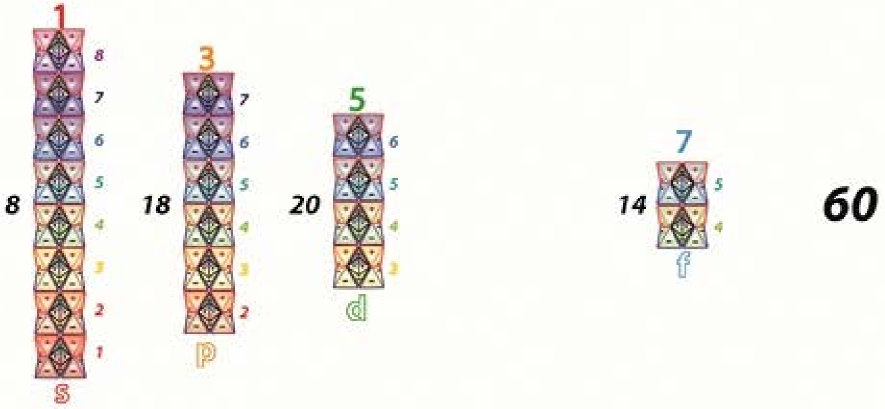
1
8
7
6
5
4
3
2
1
8
s
3
7
6
5
4
3
2
18
p
5
6
5
4
3
20
d
7
14
5
4
f
60

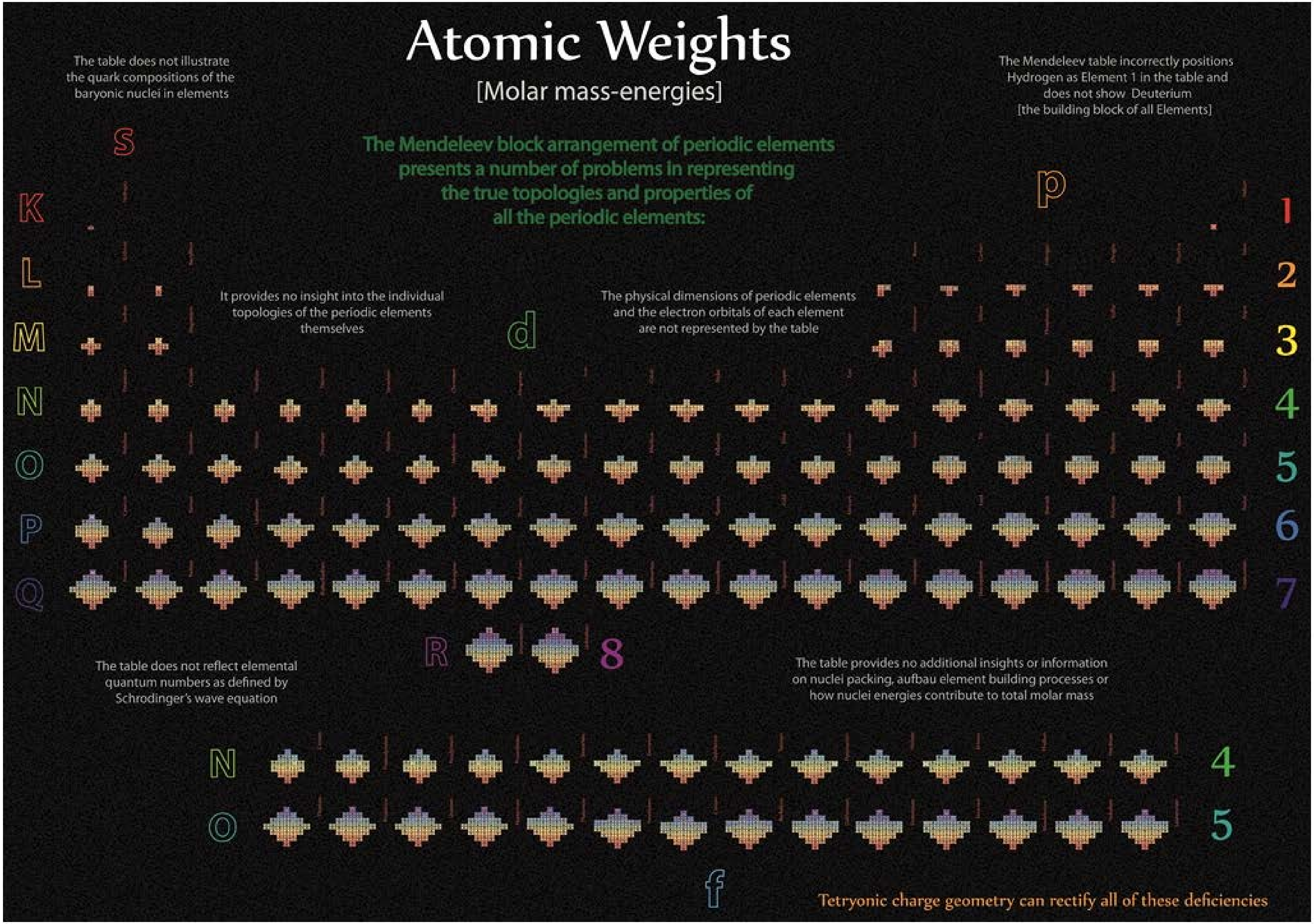

Atomic Weights

[Molar mass-energies]

The table does not illustrate the quark compositions of the baryonic nuclei in elements

The Mendeleev table incorrectly positions Hydrogen as Element 1 in the table and does not show Deuterium [the building block of all Elements]

The Mendeleev block arrangement of periodic elements presents a number of problems in representing the true topologies and properties of all the periodic elements:

It provides no insight into the individual topologies of the periodic elements themselves

The physical dimensions of periodic elements and the electron orbitals of each element are not represented by the table

The table does not reflect elemental quantum numbers as defined by Schrodinger's wave equation

The table provides no additional insights or information on nuclei packing, aufbau element building processes or how nuclei energies contribute to total molar mass

Tetryonic charge geometry can rectify all of these deficiencies

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Baryon mass-energies

n

E

The quantum level mass-energies of Baryons determines the kinetic energies of electrons

1n - 1 e19v

electron KEM field

hv^2

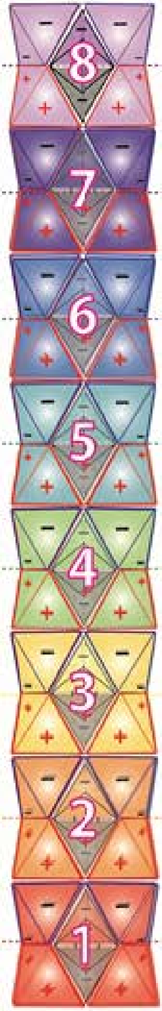

Baryon mass-energies			electron KEM field
73,728	n32	v8	3.268969693 e15
69,192	n31	v7	2.502804921 e15
64,800	n30	v6	1.838795452 e15
60,552	n29	v5	1.276941286 e15
56,448	n28	v4	8.172424232 e14
52,488	n27	v3	4.596988631 e14
48,672	n26	v2	2.043106058 e14
45,000	n25	v1	5.107765145 e13

Compton frequencies

930 MeV

1.2 e20
electron rest Matter
is velocity invariant

496 keV

spectral frequencies

13.6 eV

Atomic nuclei mass-energies

Each element's weight [mass-Matter in a gravitational field] is the result of the total quanta comprising that element

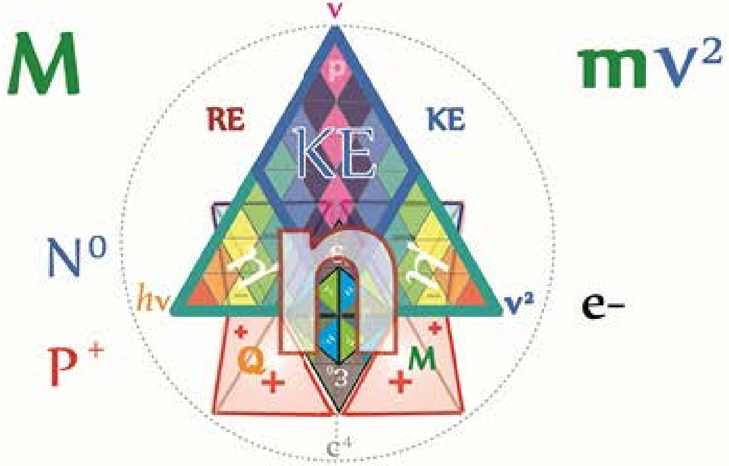

The nuclei forming each atomic shell have specific mass-energy quanta

$$\overset{8}{\underset{1}{n}}\underset{\text{Deuterium mass-energy per shell}}{\left[\overset{\text{Baryon rest masses}}{[72(n)^2]}+\overset{\text{lepton rest mass}}{[12e19]}+\overset{\text{KEM}}{[m_e v^2]}\right]}$$

Despite having differing mass-energies each Deuterium nuclei has the same velocity invariant Matter geometry [84π]

spin orbital coupling in synchronous quantum convertors

Electrons act as quantum scale rotating armatures in atomic nuclei and can only have specific energies reflective of the electron orbital energy level of the Baryons in which they are found

They acheive these energy levels by absorbing or emitting photons to acheive the specific angular momentum required

Tetryonics 49.02 - Quantum level nuclei masses

Hydrogen Ionisation Energies [/n²]

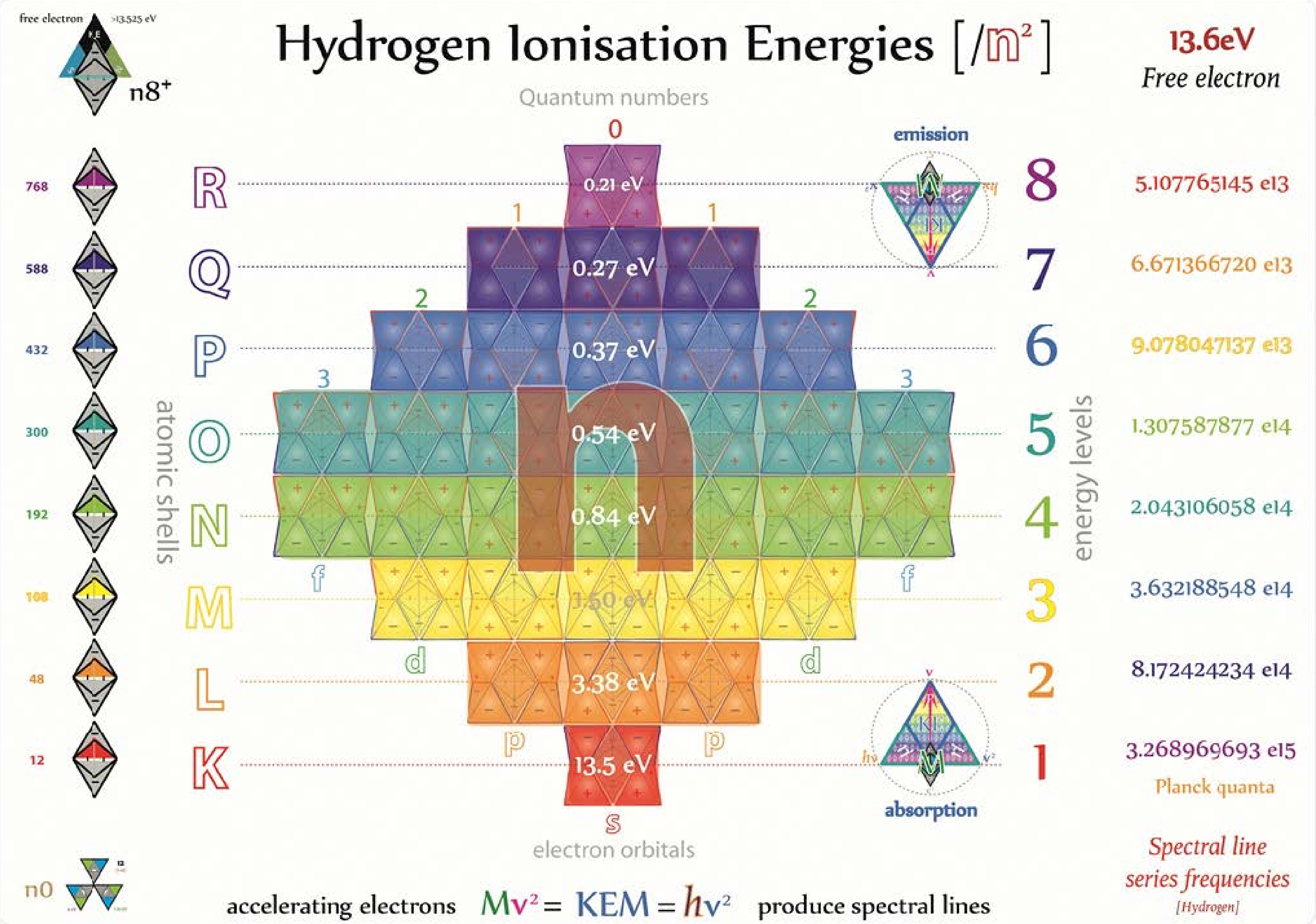
free electron
>13.525 eV
K.E
n8⁺
Quantum numbers
0
1
1
2
2
3
3
f
f
d
d
p
p
s
electron orbitals
atomic shells
n
energy levels
emission
absorption
hv
v²
n0
12

13.6eV

Free electron

768	R	0.21 eV	8	5.107765145 e13
588	Q	0.27 eV	7	6.671366720 e13
432	P	0.37 eV	6	9.078047137 e13
300	O	0.54 eV	5	1.307587877 e14
192	N	0.84 eV	4	2.043106058 e14
108	M	1.50 eV	3	3.632188548 e14
48	L	3.38 eV	2	8.172424234 e14
12	K	13.5 eV	1	3.268969693 e15

Planck quanta

Spectral line series frequencies

[Hydrogen]

accelerating electrons $Mv^2 = KEM = hv^2$ produce spectral lines

Redefining Atomic weights

Atomic weight (symbol: Ar) is a dimensionless physical quantity,
the ratio of the average mass of atoms of an element (from a given source) to
1/12 of the mass of an atom of carbon-12 (known as the unified atomic mass unit)

Carbon 12

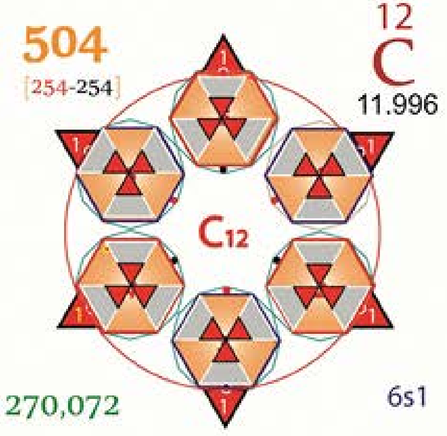

6 Protons [24-12]
6 Neutrons [18-18] n1
6 electrons [0-12]

The 'unified atomic mass unit' currently in use is known to be inaccurate and must be corrected in order to bring clarity & increased accuracy to the atomic weights of all elements

$$\boxed{A_r = 22{,}512 \quad \text{Hydrogen}}$$

Defining Hydrogen as having an exact **atomic Planck mass of 22512_n quanta** *provides uniformity with Tetryonics*

1/12 C_{12}

$A_r = 22{,}506$

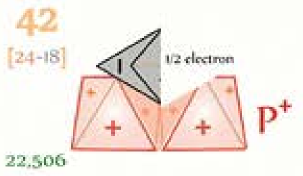

1.660096209e-27 kg

1 Proton [24-12]
.5 electron 0-6 n1

Unified atomic Matter unit

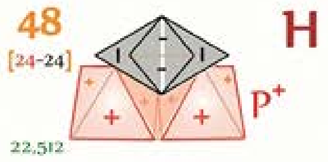

1.660538783e-27 kg

1 Proton [24-12]
1 electron [0-12] n1

Deuterium is the building block of all elements in the period table

$$\boxed{A_r = 45{,}012 \quad \text{Deuterium}}$$

Defining Deuterium as having an exact **atomic Planck mass of 45012_n quanta** *reflects the true charged geometries of all Elements & their topologies*

D

1/6 C

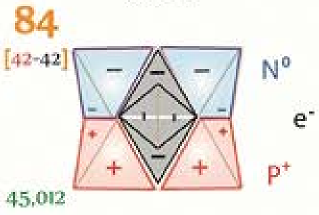

3.320192418e-27 kg

1 Proton [24-12]
1 Neutron [18-18] n1
1 electron [0-12]

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Planck mass-energy units

NAu = 0.001 kg

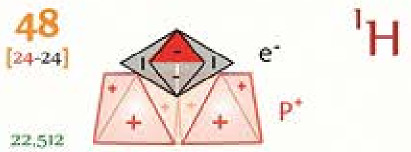
48
[24-24]
22,512
e-
P+
^{1}H

1.660538841 e-27 kg

One Da is approximately equal to the mass of one proton or one neutron

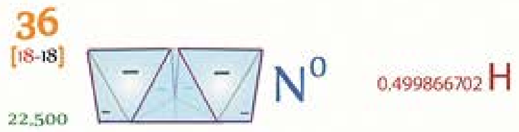
36
[18-18]
22,500
N0
0.499866702 H

1.659653693 e-27 kg

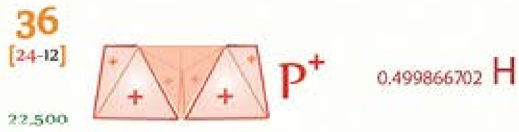
36
[24-12]
22,500
P+
0.499866702 H

Deuterium is the building block of all elements

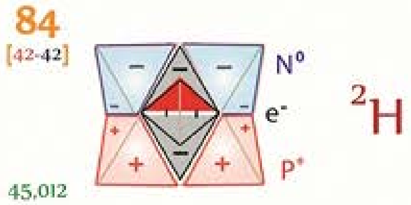
84
[42-42]
45,012
N0
e-
P+
^{2}H

3.320192534 e-27 kg

The unified atomic mass unit (symbol: u) or Dalton (symbol: Da)
is a unit that is used for indicating mass on an atomic or molecular scale

270,072

1/12 the mass of a C12 graphene atom at rest in its electronic ground state

1.660538782(83)×10−27 kg

22,506

is an inaccurate means of determining the exact rest mass of a Hydrogen atom

22,512

Carbon 12 has 270,072n planck quanta
(270,072 / 12 = 22,506)

Hydrogen has a mass of 22,512n (22,500+12) requiring all mass to be calculated directly using the Planck mass-energy quantum (.001kg / N_A / 22,512) & Tetryonic charge geometries

Using Tetryonic theory to define
n Planck mass = 7.376238634 x 10^{-32} Kg
(see Tetryonics QM 15.04)

exact atomic rest masses for all particles, elements and compounds can be determined directly from atomic theory

N_A = 6.02214179 e23

The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12; its symbol is "mol".

NA(12u) = 0.012 kg

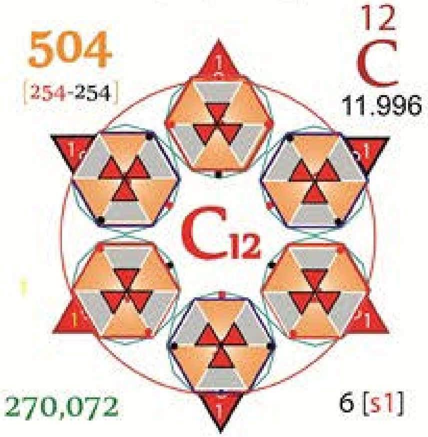
504
[254-254]
12
C
11.996
C12
270,072
6 [s1]

6 Protons	[24-12]	n1
6 Neutrons	[18-18]	
6 electrons	[0-12]	

Carbon has a number of differing atomic configurations (allotropes)

6 Protons	[24-12]	n1-2
6 Neutrons	[18-18]	
6 electrons	[0-12]	

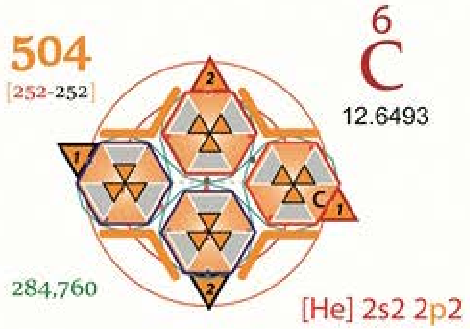
504
[252-252]
6
C
12.6493
284,760
[He] 2s2 2p2

Planck mass-energy contributions to the measured weights of periodic, elementary mass-Matter topologies

36
[18-18]
N^0
45,000n

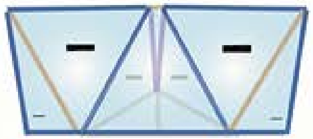

1.659653693 e-27 kg

36
[24-12]
P^+
45,000n

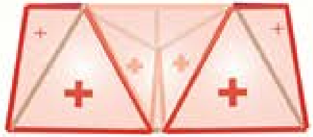

8.851486361 e-31 kg

12
[0-12]
e-
12n

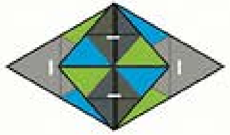

2.41110961l e-35 kg

n
[v-v]
0

Baryons have 2,25e23 Planck quanta comprising their rest Matter topologies

[930.974 MeV]

Δ 1875 x

[496.5 keV]

Leptons have 1.2 e20 Planck quanta comprising their rest Matter topologies

[496.5 keV]

Δ 36,711 x

[13.6 eV]

Photons are planar geometries [Matter-less] (purely Kinetic mass-Energy and momenta)

The Lyman alpha spectral line mass-energy contribution to the mass of a Deuterium nucleus is negligible

Electron quantum level energies are determined by the energy of the Nuclei they bind to in elements

D^+

[1.862 GeV]

84
[42-42]

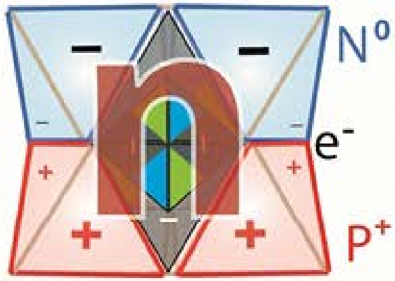

90,012n+

Photons contribute spectral mass-energies to the nuclei mass but are themselves Matterless [2D zero rest mass-energies]

Photons are 2π charge mass-energy geometries

Ionisation energies

Fractional quantum differentials

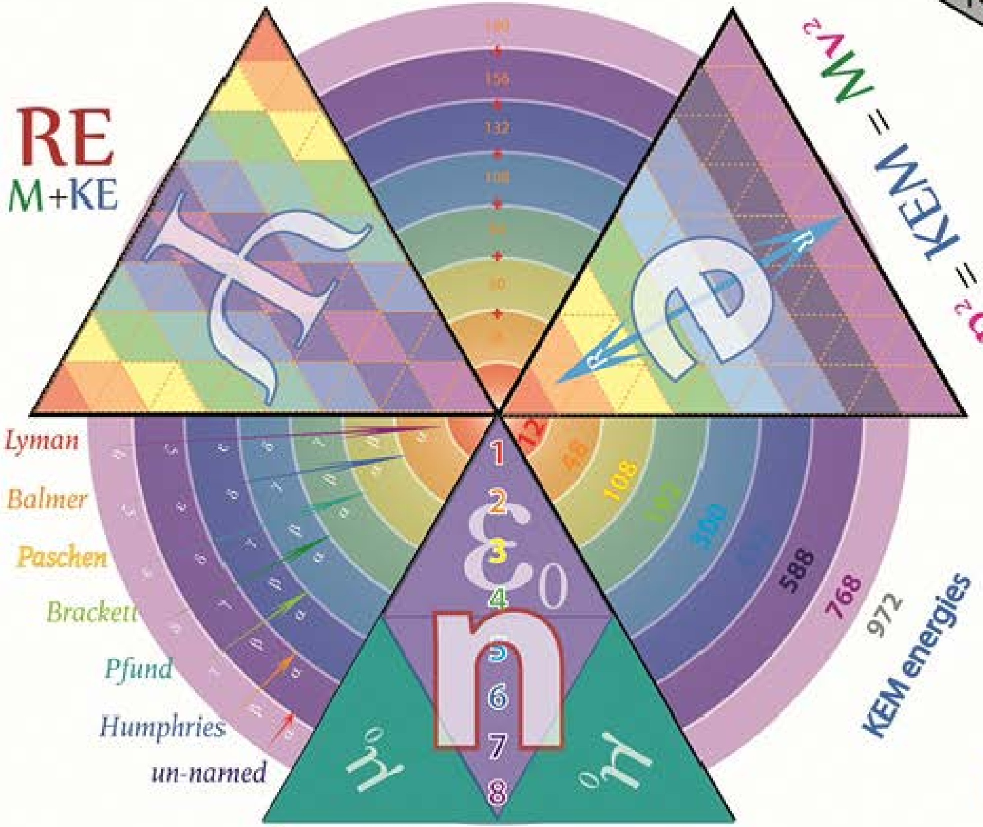
RE
M+KE
$p^2 = KEM = Mv^2$
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
1
2
3
4
5
6
7
8
ε0
n
12
48
108
192
300
432
588
768
972
KEM energies

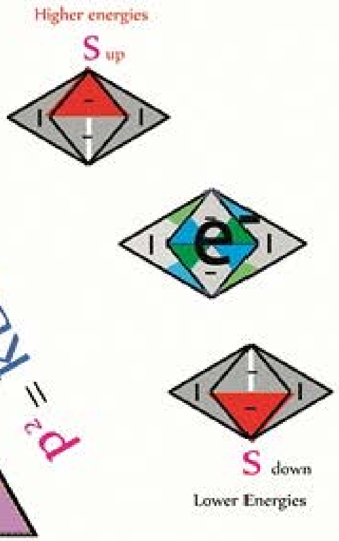
Higher energies
S up
e
S down
Lower Energies

photo-electronic energy momenta

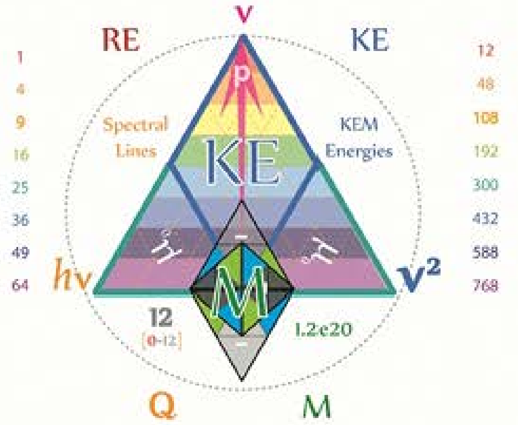
v
RE
KE
p
KE
Spectral Lines
KEM Energies
hv
v^2
M
12
[0-12]
1.2e20
Q
M
1
4
9
16
25
36
49
64
12
48
108
192
300
432
588
768

Mapping photo-electron transition energies to Tetryonic energy momenta geometries reveals many key facts about the ionisation energies of nuclei

$$E = -\frac{Z^2}{n^2}\frac{ke^2}{2a_0} = -\frac{13.6Z^2}{n^2}eV$$

The differing fractional KEM field energy momenta of electrons that results from their transitions to specific energy nuclei in elements results in differing QAM quanta and produces spectral lines and fine line splitting

$$hf = \Delta Mv = \Delta p$$

spectral lines are produced by accelerating electrons

Photo-electrons absorb/emit spectral energies

c^2

Note: this is an Illustrative schema for modelling KEM field energies
All KEM fields possess the same physical spatial geometry
in radial-time defined spatial co-ordinate systems

c^4

Spectral line transitions

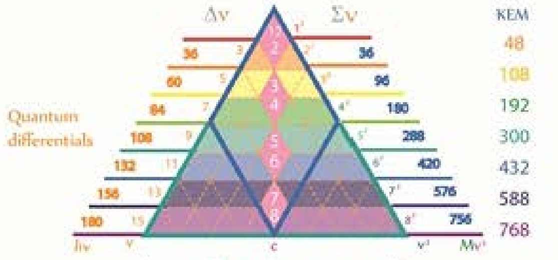
Δv
Σv
KEM
Quantum differentials
36
60
84
108
132
156
180
36
96
180
288
420
576
756
48
108
192
300
432
588
768
hv
v
c
v²
Mv²

hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

uniting classical physics and relativity
through equilateral geometry

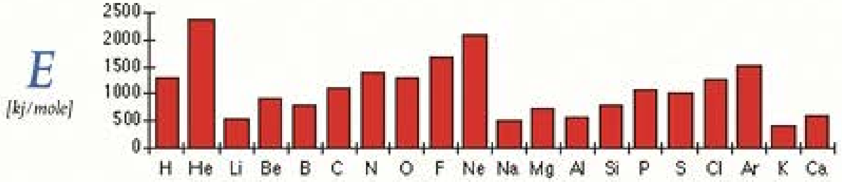

$$E = eV = \frac{1}{4\pi\epsilon_0}\frac{ne^2}{a}$$

Elementary ionisation energies

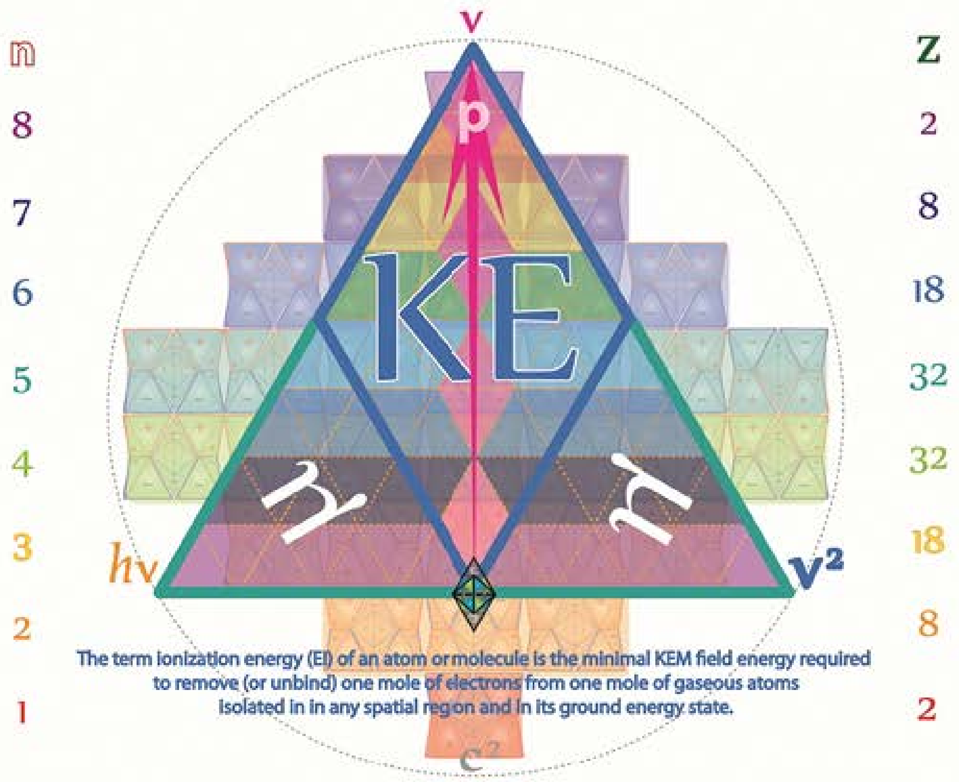

The term ionization energy (EI) of an atom or molecule is the minimal KEM field energy required to remove (or unbind) one mole of electrons from one mole of gaseous atoms isolated in in any spatial region and in its ground energy state.

The term "ionization energy" is sometimes used as a name for the work needed to remove (or un-bind) the highest energy photoelectron from an atom or molecule.

However, due to interactions with surfaces, this value differs from the ionization energy of the atom or molecule in question when it is located by itself in free space.

So, in the case of surface-adsorbed atoms and molecules, it may be better to use the more general term "electron binding energy", in order to avoid confusion.

Both these names are also sometimes used to describe the work needed to remove an electron from a "lower" orbital (i.e., not the topmost orbital) for both free and adsorbed atoms; in such cases it is necessary to specify the orbital from which the electron has been removed

$$E = -\frac{Z^2}{n^2}\frac{ke^2}{2a_0} = -\frac{13.6Z^2}{n^2}eV$$

Every electron in each elementary orbit has a unique ionisation energy

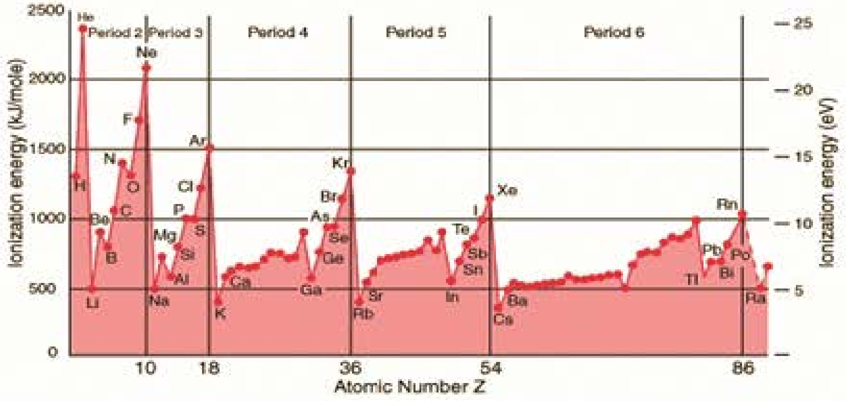

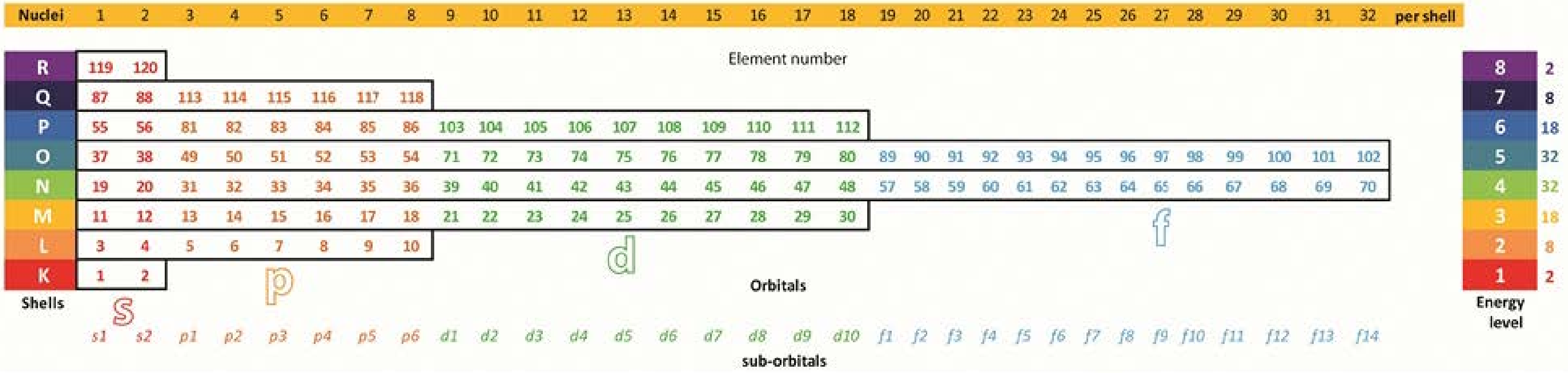

Element number

Nuclei	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Energy level	per shell
R	119	120																															8	2
Q	87	88	113	114	115	116	117	118																									7	8
P	55	56	81	82	83	84	85	86	103	104	105	106	107	108	109	110	111	112															6	18
O	37	38	49	50	51	52	53	54	71	72	73	74	75	76	77	78	79	80	89	90	91	92	93	94	95	96	97	98	99	100	101	102	5	32
N	19	20	31	32	33	34	35	36	39	40	41	42	43	44	45	46	47	48	57	58	59	60	61	62	63	64	65	66	67	68	69	70	4	32
M	11	12	13	14	15	16	17	18	21	22	23	24	25	26	27	28	29	30															3	18
L	3	4	5	6	7	8	9	10																									2	8
K	1	2																															1	2
Shells	s		p						d										f															
sub-orbitals	s1	s2	p1	p2	p3	p4	p5	p6	d1	d2	d3	d4	d5	d6	d7	d8	d9	d10	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12	f13	f14		

Orbitals

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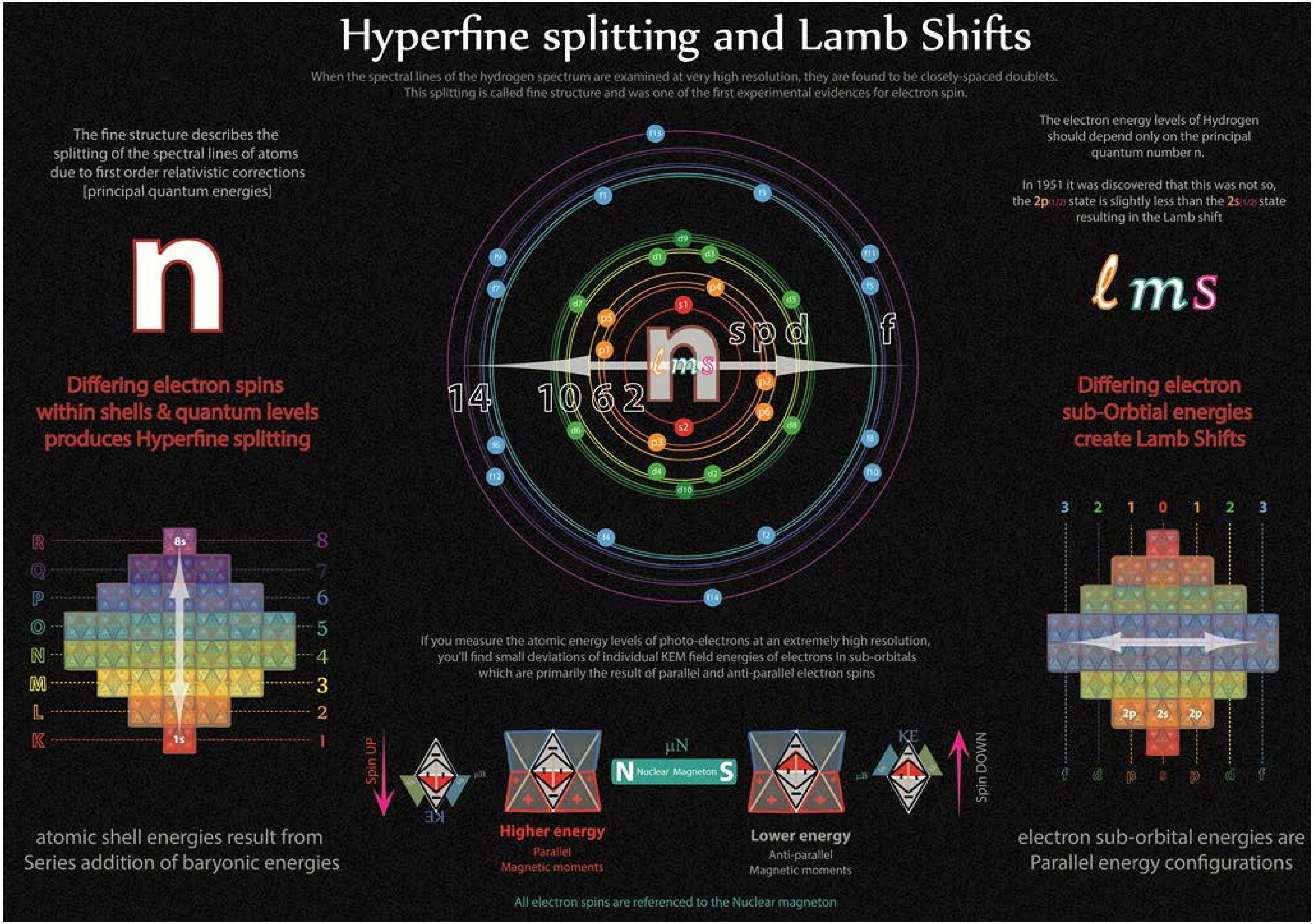

Hyperfine splitting and Lamb Shifts

When the spectral lines of the hydrogen spectrum are examined at very high resolution, they are found to be closely-spaced doublets.
This splitting is called fine structure and was one of the first experimental evidences for electron spin.

The fine structure describes the splitting of the spectral lines of atoms due to first order relativistic corrections [principal quantum energies]

Differing electron spins within shells & quantum levels produces Hyperfine splitting

The electron energy levels of Hydrogen should depend only on the principal quantum number n.

In 1951 it was discovered that this was not so, the $2p_{(1/2)}$ state is slightly less than the $2s_{(1/2)}$ state resulting in the Lamb shift

Differing electron sub-Orbtial energies create Lamb Shifts

If you measure the atomic energy levels of photo-electrons at an extremely high resolution, you'll find small deviations of individual KEM field energies of electrons in sub-orbitals which are primarily the result of parallel and anti-parallel electron spins

atomic shell energies result from Series addition of baryonic energies

Higher energy
Parallel
Magnetic moments

Lower energy
Anti-parallel
Magnetic moments

electron sub-orbital energies are Parallel energy configurations

All electron spins are referenced to the Nuclear magneton

n
R
Q
P
O
N
M
L
K
8s
1s
8
7
6
5
4
3
2
1
f13
f1
f3
f9
f7
f11
f5
d9
d1
d3
d7
d5
p4
p5
p1
s1
s2
p2
p6
p3
d6
d8
d4
d2
d10
f6
f12
f8
f10
f4
f2
f14
n
ℓms
s p d
f
14
10 6 2
ℓms
3 2 1 0 1 2 3
2p 2s 2p
f d p s p d f
Spin UP
KE
μN
Nuclear Magneton
N
S
KE
Spin DOWN

M_0

3D Matter topologies are comprised of charged 2D mass-energies

Energy per second²

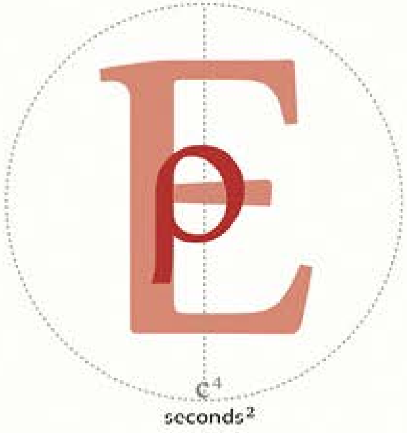

E
ρ
c⁴
seconds²

Matter Planck quanta

$$\frac{T\pi}{c^4}[[m\Omega v^2]]$$

mass velocity

mass-Matter

standing wave mass-energiescreate
the material substance of all chemical elements

RE

Relativistic mass-ENERGY-Matter

Relativity fails at the foundational level to explain and differentiate between mass-ENERGY and Matter in physical systems

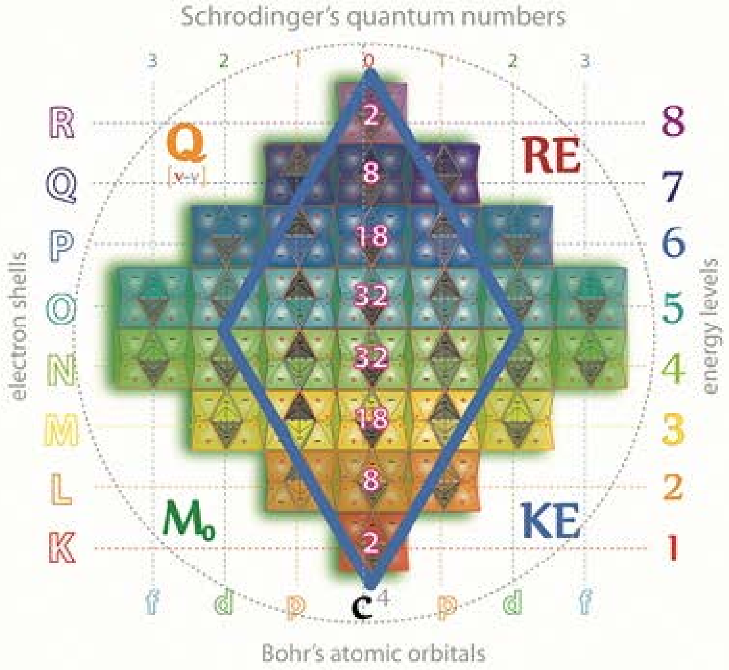

Schrodinger's quantum numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
[v-v]
RE
M₀
KE
2
8
18
32
32
18
8
2
8
7
6
5
4
3
2
1
energy levels
f
d
p
c⁴
p
d
f
Bohr's atomic orbitals

Einstein's relativistic [Lorentz corrected] stress energy tensor aggregates all forms of energy into a single energy density gradient

atomic energies

$$\frac{Tm\mathrm{n}}{c^4} + \frac{mv^2}{c^2}$$

electron spins

3D rest Matter + Lorentz corrected 2D Kinetic Energies = total Relativistic Energies

KE

2D equilateral mass-energies are euclidean geometries

Energy per second

E
ρ
c²
seconds

mass Planck quanta

$$\frac{n\pi}{c^2}[[m\Omega v^2]]$$

mass velocity

mass-energies

radiant planar mass-energies create
EM fields, spectral lines & chemical interactions

Deuterium is the building block of all Elements (save Hydrogen)

The geometry of any Element is determined by its Charge

The Molar Weight of any Element is a measure of its standing wave mass-energies

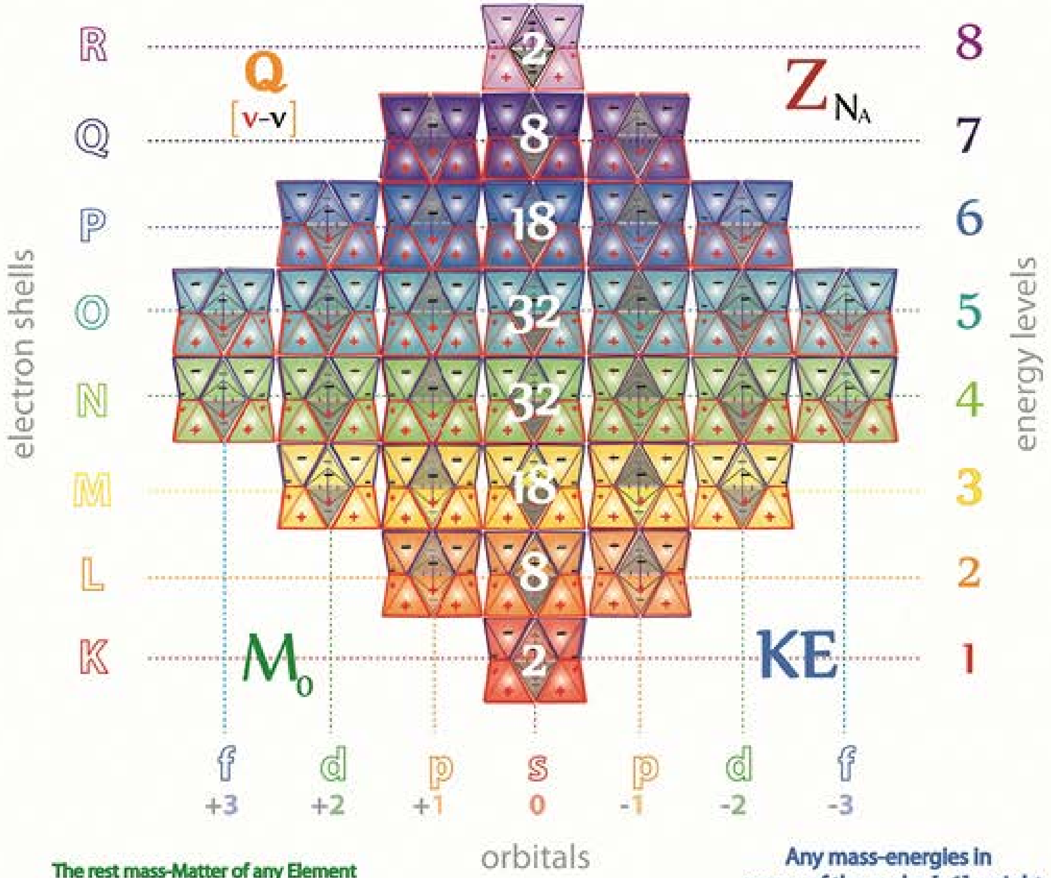

The rest mass-Matter of any Element is determined by the total number of quanta making up the Protons, Neutrons and electrons that comprise them (in their respective energy levels)

Any mass-energies in excess of the molar [n1] weight is a measurement of a element's CHEMICAL energies

Important point to note:

The Kinetic Energy difference between any Element's total [n1] Deuteron mass-energies and its Molar mass has historically been incorrectly explained as resulting from an excess number of Neutrons in the atom it is not. Z# = (number of Protons = number of electrons = number of Neutrons)

Elementary mass-Matter

$$\sum_{K}^{R}$$

	n per nuclei 1e19v = n	
2	2 nuclei [74.496 ea]	120 Unbinilium 119 Ununennium
	+	
8	8 nuclei [69,780 ea]	118 Ununoctium 87 Francium
	+	
18	18 nuclei [65,232 ea]	112 Copernicium 55 Caesium
	+	
32	32 nuclei [60,852 ea]	102 Nobelium 37 Rubidium
	+	
32	32 nuclei [56,640 ea]	70 Ytterbuim 19 Potassium
	+	
18	18 nuclei [52,596 ea]	30 Zinc 11 Sodium
	+	
8	8 nuclei [48,720 ea]	10 Neon 3 Lithium
	+	
2	2 nuclei [45,012 ea]	2 Helium 1 Deuterium

The rest mass-Matter of any Element is the sum total of its constituent Z[n²] energy level Deuterium nuclei

Aufbau

$$Z\#\left[\begin{array}{ll} z \text{ Protons} & [24\text{-}12] \\ z \text{ Neutrons} & [18\text{-}18] \\ z \text{ electrons} & [0\text{-}12] \end{array}\right] n1\text{-}8$$

(ie Calcium [20] = 2+8+10 n level Deuterium nuclei)

Periodic Harmonic motions

$x = A\cos(\omega t + \varphi)$

Circular motion

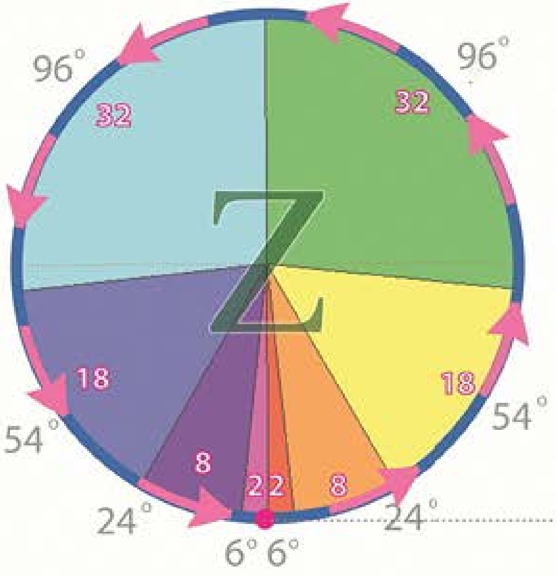
96°
32
32
96°
Z
18
18
54°
54°
8
2 2
8
24°
24°
6° 6°

circular harmonic motion

Circular motions describe the motion of a body with a changing velocity vector [the result of an acceleration force].

Much of the math in of modern physics is predicated on the assumption that π [where it appears] is related to the properties of a circle

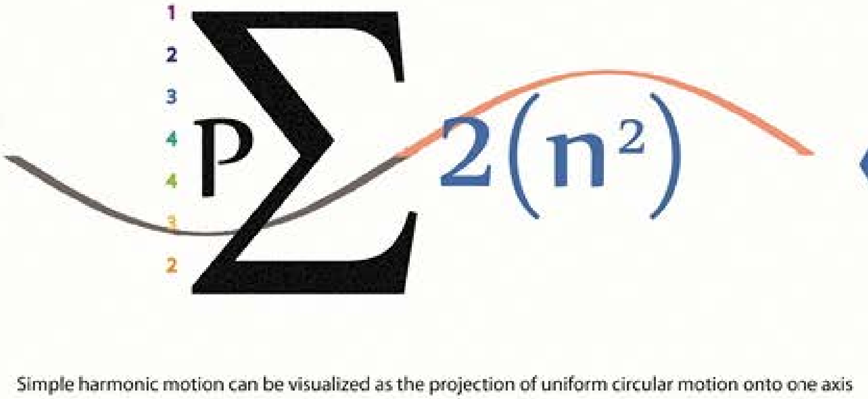
1
2
3
4
4
3
2
$P\sum 2(n^2)$

Simple harmonic motion can be visualized as the projection of uniform circular motion onto one axis

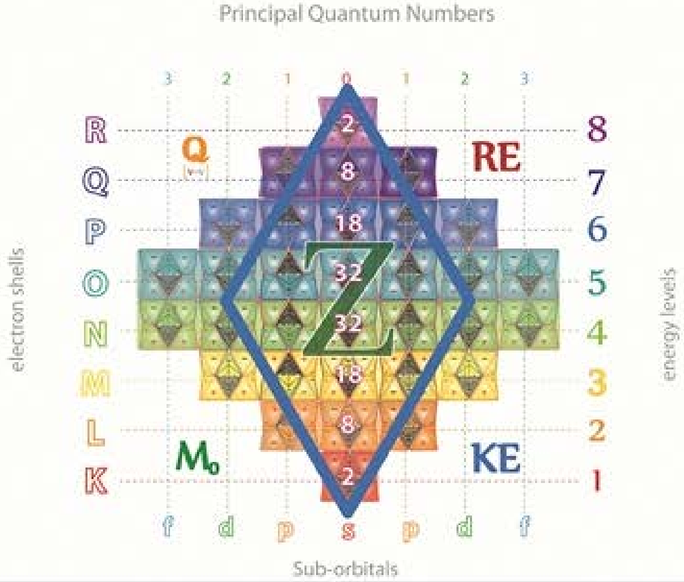
Principal Quantum Numbers
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
Q
RE
M₀
KE
2
8
18
32
32
18
8
2
Z
8
7
6
5
4
3
2
1
electron shells
energy levels
f d p s p d f
Sub-orbitals

$F = -kx$

Linear motion

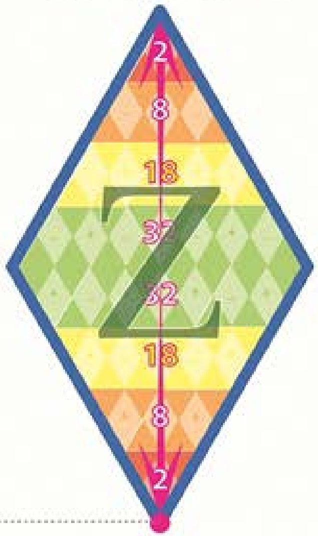
2
8
18
32
32
18
8
2
Z

simple harmonic motion

Nuclei per shell in elements follows a 'periodic summation rule' that is reflective of photonic energies

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$$\sum_{K}^{R}$$

nuclei per shell

STEP ONE

Periodic summation follows the atomic shell electron config

$${}_{P}\sum_{K}^{R} Z$$

Periodic Summation

Periodic summation is a notation developed for Tetryonic theory to model the geometric series addtion of Z[n²] energy level Deuterium nuclei that form the periodic elements

$$\sum_{1}^{120} Z$$

element number

STEP TWO

Periodic elements build up following the aufbau sequence

$${}_{P}\sum_{K}^{R} 2(x^2) =$$

1 2 3 4 4 3 2 1

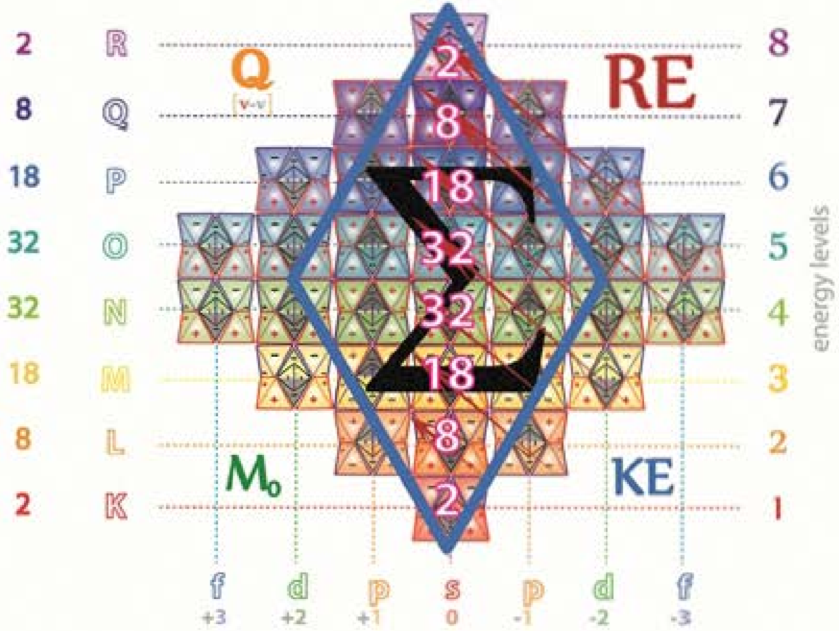

Each atomic shell can hold only a fixed number of deuterium nuclei

$_P\sum R = 2$	2 nuclei [74.496 ea]	120	Unbinilium
	+		
$_P\sum Q = 8$	8 nuclei [69,780 ea]	118	Ununoctium
	+		
$_P\sum P = 18$	18 nuclei [65,232 ea]	110	Darmstadtium
	+		
$_P\sum O = 32$	32 nuclei [60,852 ea]	92	Uranium
	+		
$_P\sum N = 32$	32 nuclei [56,640 ea]	60	Neodymuim
	+		
$_P\sum M = 18$	18 nuclei [52,596 ea]	28	Argon
	+		
$_P\sum L = 8$	8 nuclei [48,720 ea]	10	Neon
	+		
$_P\sum K = 2$	2 nuclei [45,012 ea]	2	Helium
		0	Hydrogen

THe LHS of the notation determine the number of nuclei in each atomic shell, from the periodic mass-energy levels for atoms, and the RHS follows the aufbau building principle to determine the rest mass-Matter of any specific element

Aufbau

Each periodic element is made of Z [n² energy] deuterium nuclei

$$Z\#\left[\begin{array}{ll} z\ \text{Protons} & [24\text{-}12] \\ z\ \text{Neutrons} & [18\text{-}18] \\ z\ \text{electrons} & [0\text{-}12] \end{array}\right] n1\text{-}8$$

Planck mass-energies form the surface integral of rest Matter topologies for each periodic element

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Element numbers

Nuclei per shell in elements follow
a 'periodic summation rule'
that is reflective of
photonic energies

$$\begin{matrix}1\\2\\3\\4\\4\\3\\2\\1\end{matrix}\;{}^{P}\sum_{K}^{R} 2(x^{2}) = 2+8+18+32+32+18+8+2$$

Z

120	Unbinilium	n8
119	Ununennium	
118	Ununoctium	n7
87	Francium	
112	Copernicium	n6
55	Caesium	
102	Nobelium	n5
37	Rubidium	
70	Ytterbuim	n4
19	Potassium	
30	Zinc	n3
11	Sodium	
10	Neon	n2
3	Lithium	
2	Helium	n1
1	Deuterium	

Hydrogen 0

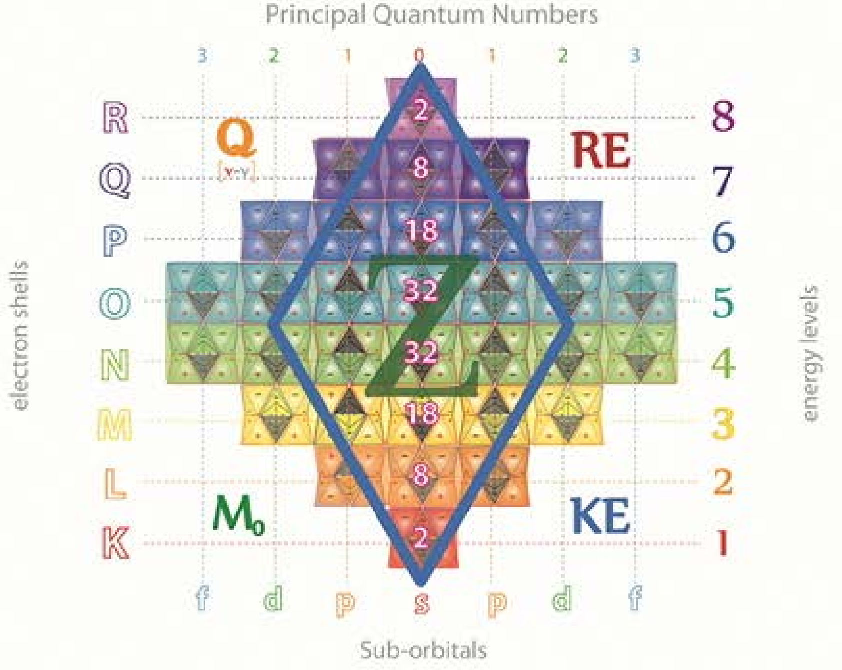
Principal Quantum Numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
[x-y]
RE
M₀
KE
Z
2
8
18
32
32
18
8
2
8
7
6
5
4
3
2
1
energy levels
f
d
p
s
p
d
f
Sub-orbitals

Periodic mass-ENERGY-Matter

Following periodic summation rules for shell filling
n[1-8] quantum energy deuterium nuclei
combine to form elementary Matter

$$\boxed{{}^{P}\sum_{K\;\;25}^{R\;\;32}\left[\overset{\text{Baryon rest masses}}{[72(n)^{2}]}+\overset{\text{lepton rest mass}}{[12e19]}+\overset{\text{KEM}}{[m_{e}v^{2}]}\right]_{1}^{8}}$$

Deuterium mass-energy per shell

The measured weight of Matter in gravitational fields is the result of planar mass-energies in tetryonic standing-wave geometries

The periodicity of all the elements,
along with their exact molar rest mass-energies and
quantum wavefunctions can be described with Tetryonic geometries

Ionisation energies

γ

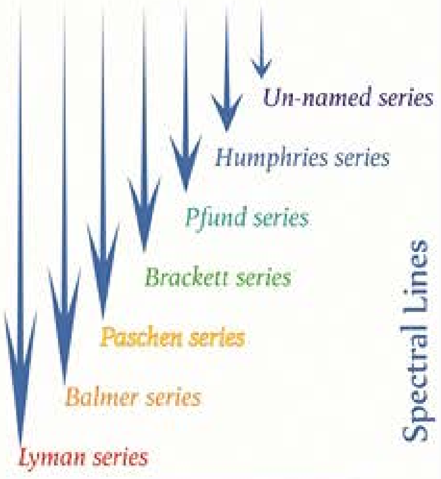
Un-named series
Humphries series
Pfund series
Brackett series
Paschen series
Balmer series
Lyman series
Spectral Lines

$$\boxed{Mv^{2} = KEM = \hbar cR_{H}}$$

Photon emission/absorption

Photo-electron ionisation energies

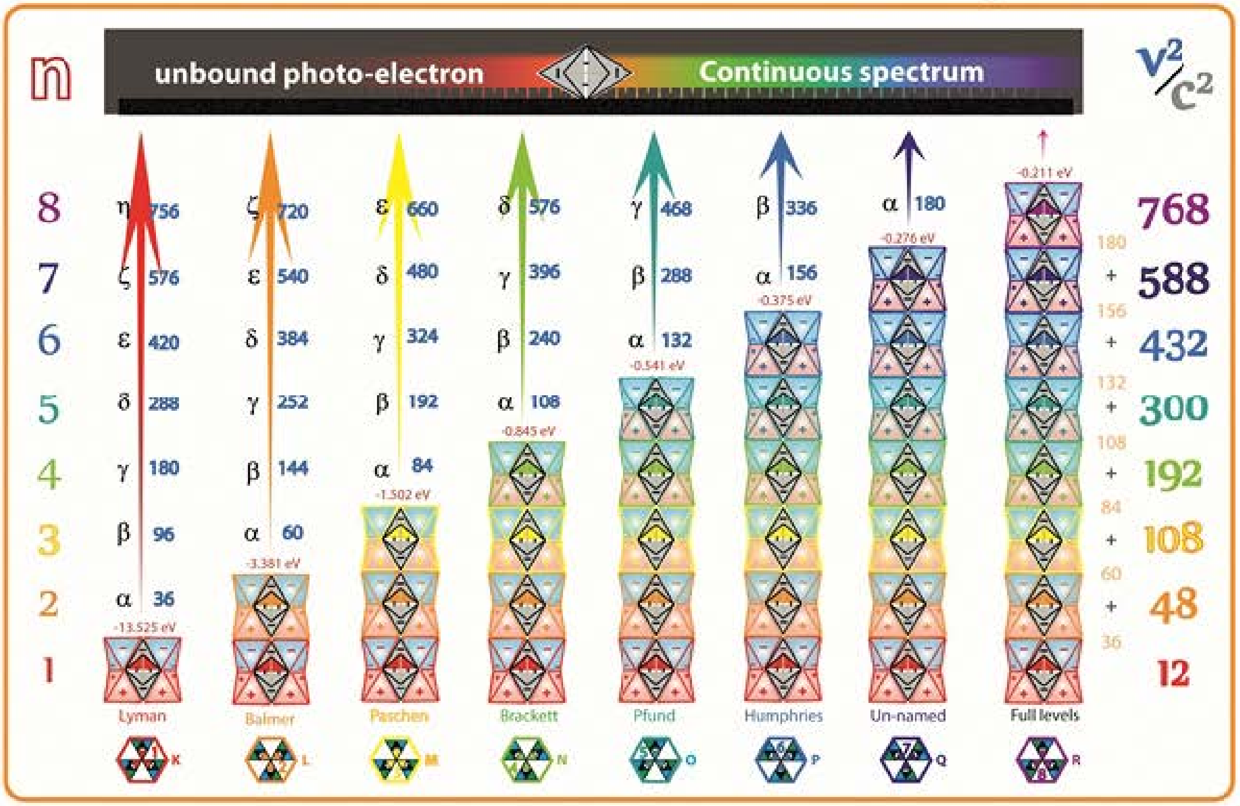
n
unbound photo-electron
Continuous spectrum
v²/c²
8
7
6
5
4
3
2
1
η 756
ζ 576
ε 420
δ 288
γ 180
β 96
α 36
-13.525 eV
Lyman
K
ζ 720
ε 540
δ 384
γ 252
β 144
α 60
-3.381 eV
Balmer
L
ε 660
δ 480
γ 324
β 192
α 84
-1.502 eV
Paschen
M
δ 576
γ 396
β 240
α 108
-0.845 eV
Brackett
N
γ 468
β 288
α 132
-0.541 eV
Pfund
O
β 336
α 156
-0.375 eV
Humphries
P
α 180
-0.276 eV
Un-named
Q
-0.211 eV
Full levels
R
768
180
+
588
156
+
432
132
+
300
108
+
192
84
+
108
60
+
48
36
12

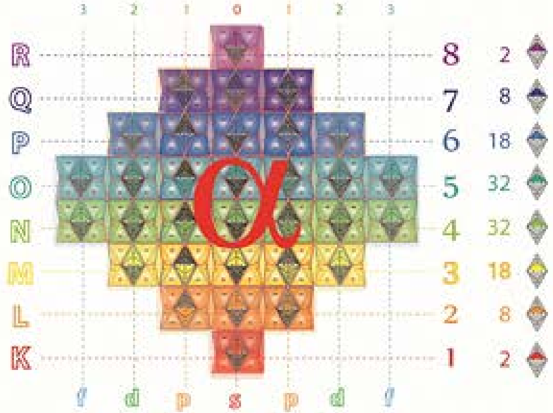
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
α
8 2
7 8
6 18
5 32
4 32
3 18
2 8
1 2
f d p s p d f

Opposed electron spins results in Hyperfine splitting & Lamb shifts

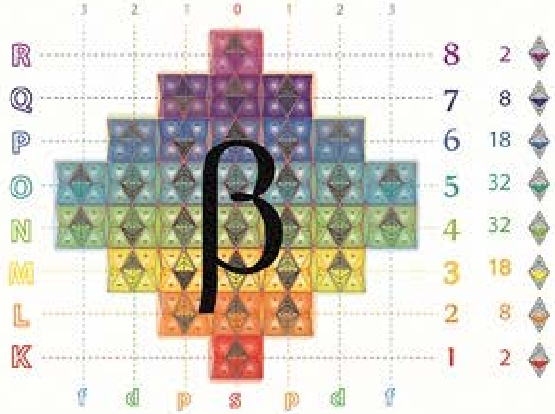
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
β
8 2
7 8
6 18
5 32
4 32
3 18
2 8
1 2
f d p s p d f

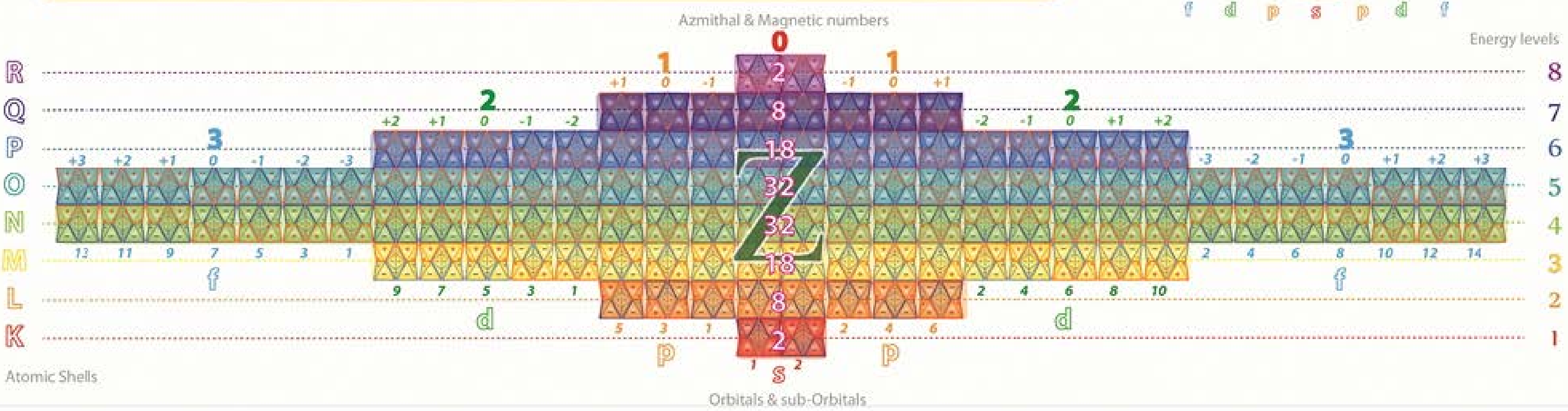
Azmithal & Magnetic numbers
Energy levels
R
Q
P
O
N
M
L
K
0
1
+1 0 -1
1
-1 0 +1
2
+2 +1 0 -1 -2
2
-2 -1 0 +1 +2
3
+3 +2 +1 0 -1 -2 -3
3
-3 -2 -1 0 +1 +2 +3
2
8
18
32
32
18
8
2
Z
13 11 9 7 5 3 1
2 4 6 8 10 12 14
f
f
9 7 5 3 1
2 4 6 8 10
d
d
5 3 1
2 4 6
p
p
1 s 2
8
7
6
5
4
3
2
1
Atomic Shells
Orbitals & sub-Orbitals

Eigenstate - Ionisation energies

Atomic shells
P
Q
R
M
K
L
O
N

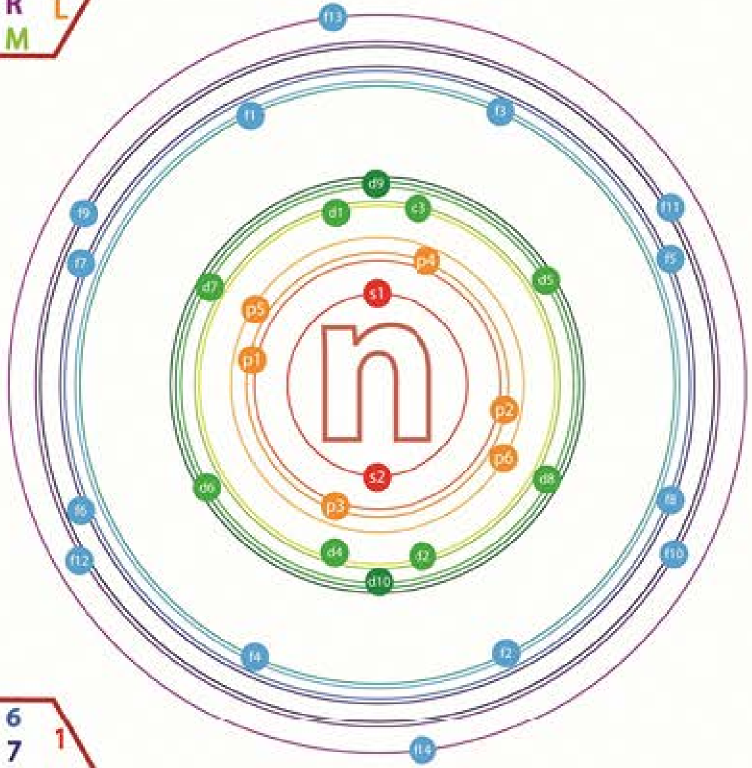
n
s1
s2
p1
p2
p3
p4
p5
p6
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
f1
f2
f3
f4
f5
f6
f7
f8
f9
f10
f11
f12
f13
f14

6
7
8
3
5
4
1
2
Quantum numbers

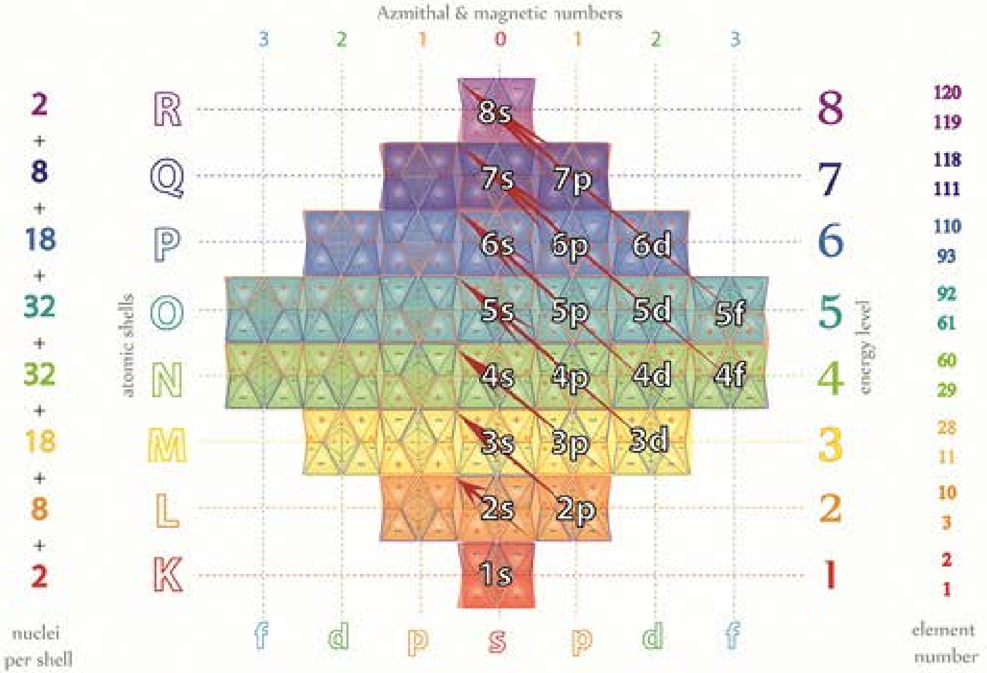
Azmithal & magnetic numbers
3
2
1
0
1
2
3
2
+
8
+
18
+
32
+
32
+
18
+
8
+
2
nuclei per shell
atomic shells
R
Q
P
O
N
M
L
K
8s
7s
7p
6s
6p
6d
5s
5p
5d
5f
4s
4p
4d
4f
3s
3p
3d
2s
2p
1s
f
d
p
s
p
d
f
8
7
6
5
4
3
2
1
energy level
120
119
118
111
110
93
92
61
60
29
28
11
10
3
2
1
element number

The ionisation energies of individual atoms varies due to many factors, namely:
electron spin-orbital coupling with Baryons of specific energies,
the relativistic energies of photo-electrons bound in nuclei
and Zitterbewegung effects on bound electrons

First ionisation energies for all periodic elements

$$E = -\frac{Z^2}{n^2}\frac{ke^2}{2a_0} = -\frac{13.6Z^2}{n^2}eV$$

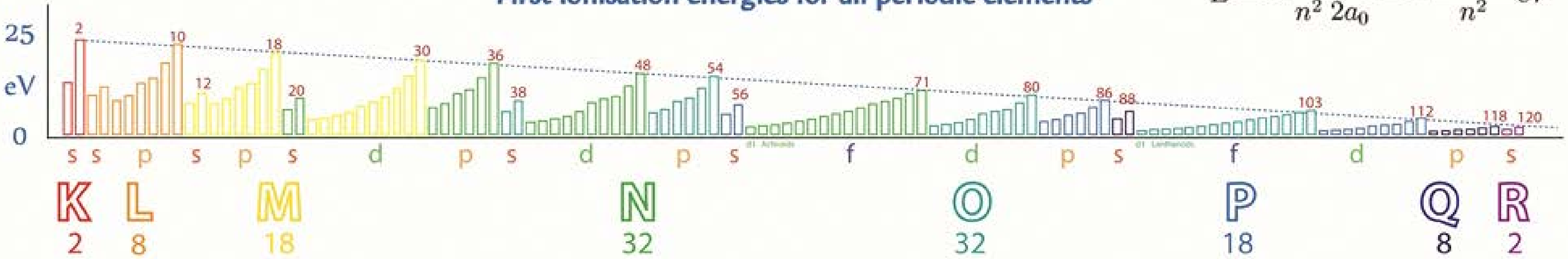

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Proton - Neutron Curve

The graph below is a plot of neutron number against proton number.
It is used as rule to determine which nuclei are stable or unstable.

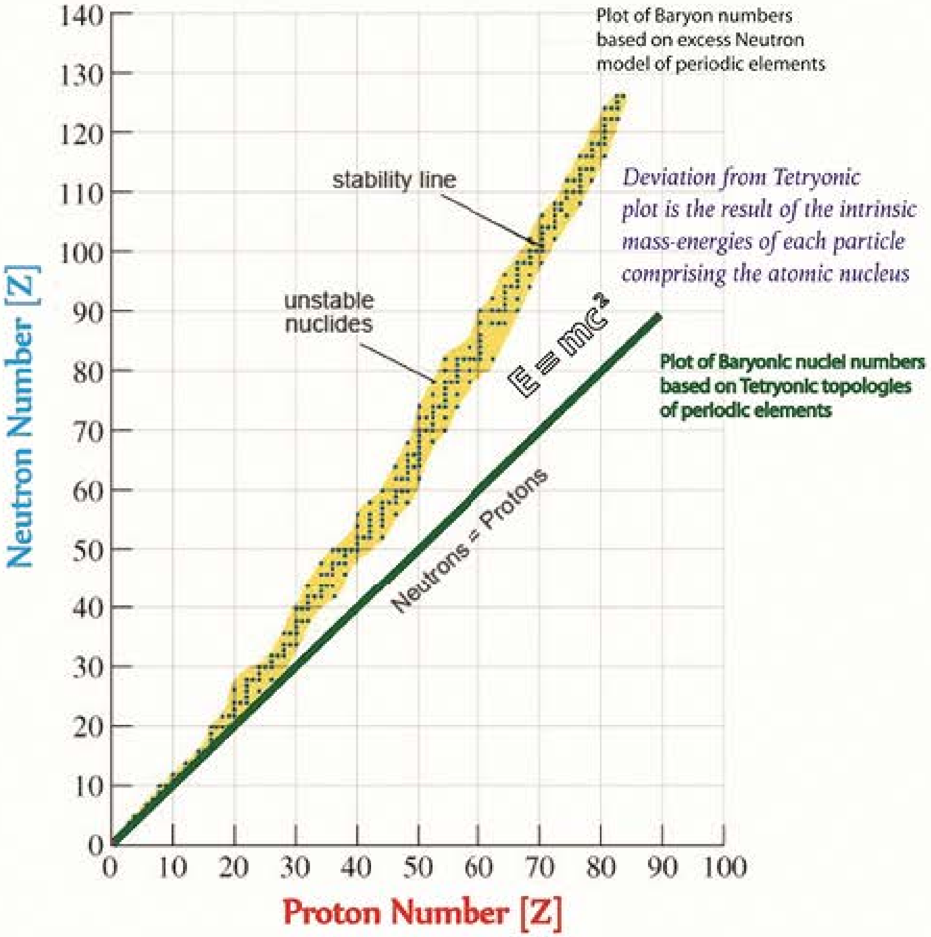

Plot of Baryon numbers based on excess Neutron model of periodic elements

Deviation from Tetryonic plot is the result of the intrinsic mass-energies of each particle comprising the atomic nucleus

Plot of Baryonic nuclei numbers based on Tetryonic topologies of periodic elements

Historically, Proton-electron numbers are viewed as being equivalent in neutral elementary matter with the excess molar mass measured being the result of 'excess or extra' Neutrons in the atom

Atomic Nuclei Numbers

All periodic elements have an EQUAL number of Protons, Neutrons & Electrons with their molar mass-Matter being determined by their quantum level mass-energies

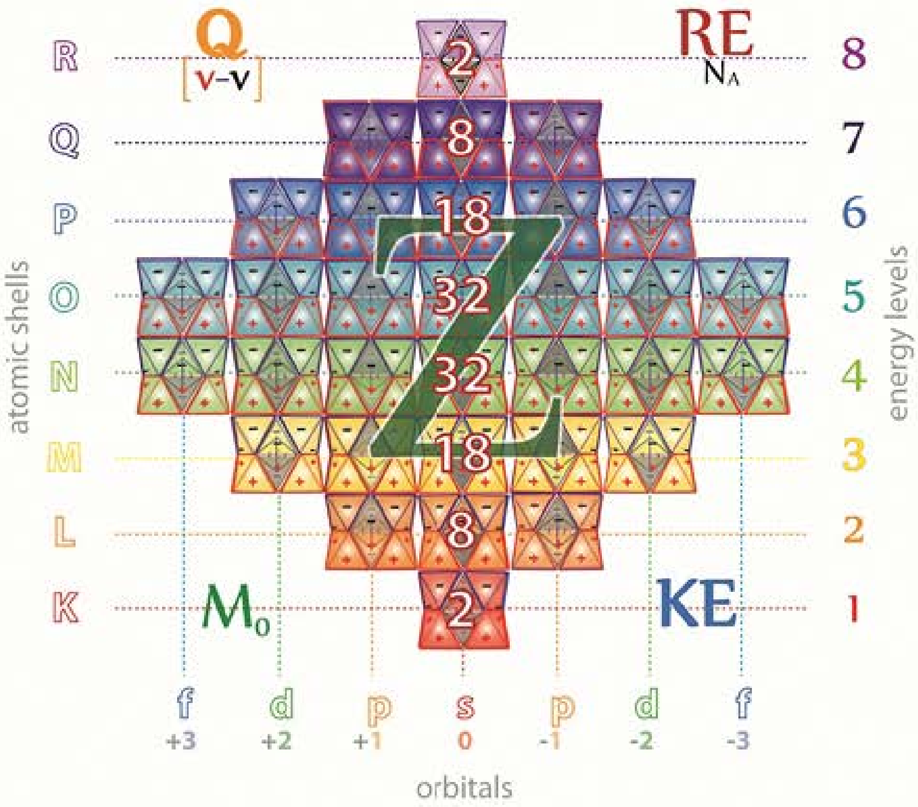

Tetryonic modelling of the charged mass-ENERGY-Matter topologies of elementary atoms and the nuclei that comprise them, reveals a DIRECT LINEAR relationship for the number of Protons-electrons-Neutrons in all periodic elements and nuclear isotopes

Planck mass-energy contributions to elementary Matter and isotopes

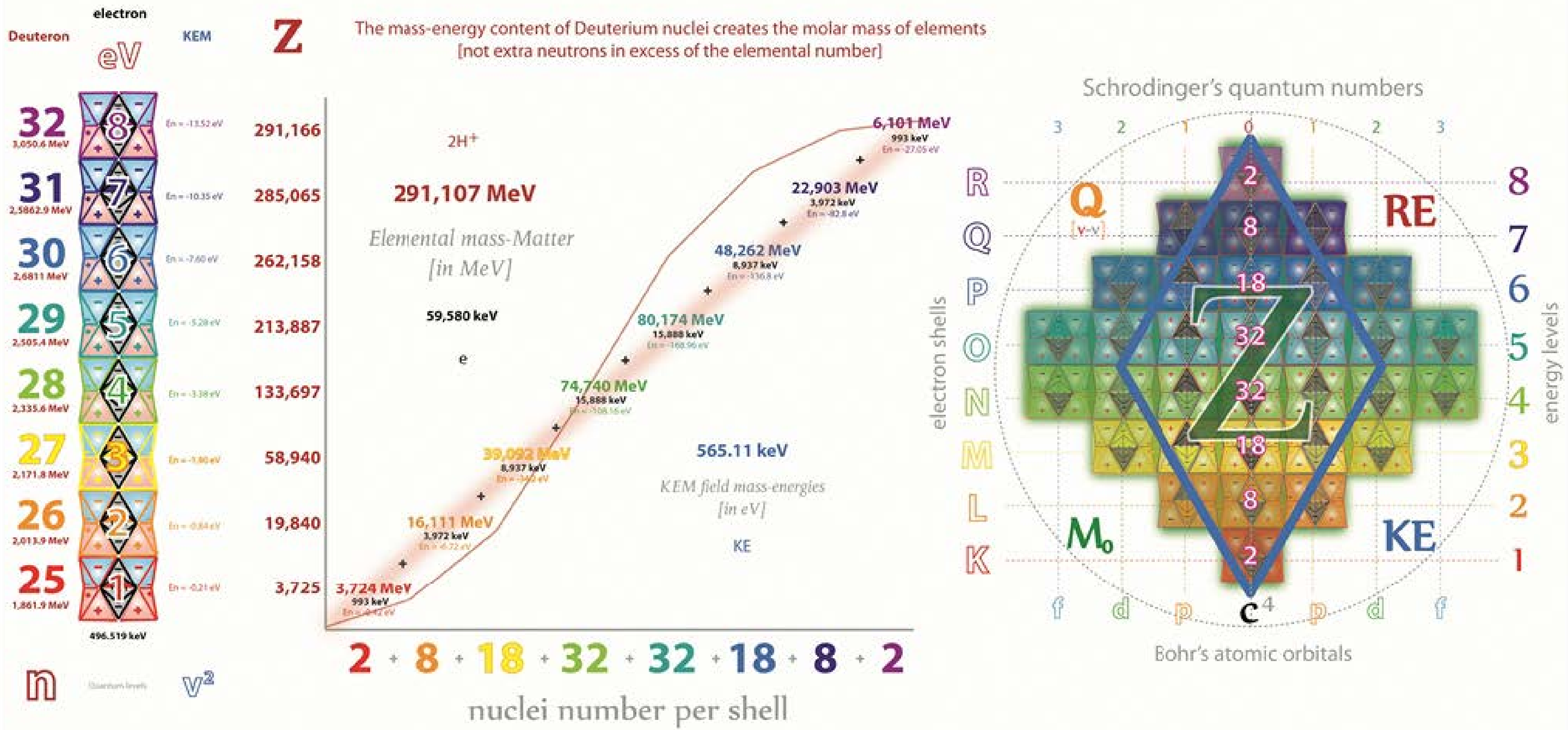
Deuteron
electron
eV
KEM
Z
32
3,050.6 MeV
31
2,5862.9 MeV
30
2,6811 MeV
29
2,505.4 MeV
28
2,335.6 MeV
27
2,171.8 MeV
26
2,013.9 MeV
25
1,861.9 MeV
8
7
6
5
4
3
2
1
En = -13.52 eV
En = -10.35 eV
En = -7.60 eV
En = -5.28 eV
En = -3.38 eV
En = -1.90 eV
En = -0.84 eV
En = -0.21 eV
291,166
285,065
262,158
213,887
133,697
58,940
19,840
3,725
496.519 keV
n
Quantum levels
v²
2H⁺
291,107 MeV
Elemental mass-Matter
[in MeV]
59,580 keV
e
6,101 MeV
993 keV
En = -27.05 eV
22,903 MeV
3,972 keV
En = -82.8 eV
48,262 MeV
8,937 keV
En = -136.8 eV
80,174 MeV
15,888 keV
En = -168.96 eV
74,740 MeV
15,888 keV
En = -108.16 eV
39,092 MeV
8,937 keV
En = -34.0 eV
16,111 MeV
3,972 keV
En = -6.72 eV
3,724 MeV
993 keV
En = -0.42 eV
565.11 keV
KEM field mass-energies
[in eV]
KE
2 + 8 + 18 + 32 + 32 + 18 + 8 + 2
nuclei number per shell
electron shells
R
Q
P
O
N
M
L
K
Schrodinger's quantum numbers
3
2
1
0
1
2
3
Q
[v-v]
RE
M₀
KE
Z
2
8
18
32
32
18
8
2
c⁴
f
d
p
p
d
f
Bohr's atomic orbitals
8
7
6
5
4
3
2
1
energy levels

The mass-energy content of Deuterium nuclei creates the molar mass of elements
[not extra neutrons in excess of the elemental number]

n1 Elementary nuclei

are comprised of equal numbers of
Protons, Neutrons & electrons
with varying energy levels

Baryons		electrons		KEM fields
930.947 MeV	+	496.519 keV	+	13.525 ev

The mass-energy content of Matter topologies is velocity invariant

The mass-energy content of Baryons determines the KEM field of electrons

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Baryons 930.947 MeV + **KEM fields** 13.525 ev + **electrons** 496.519 keV

Mapping Planck mass-energy contributions to elementary Matter and isotopes

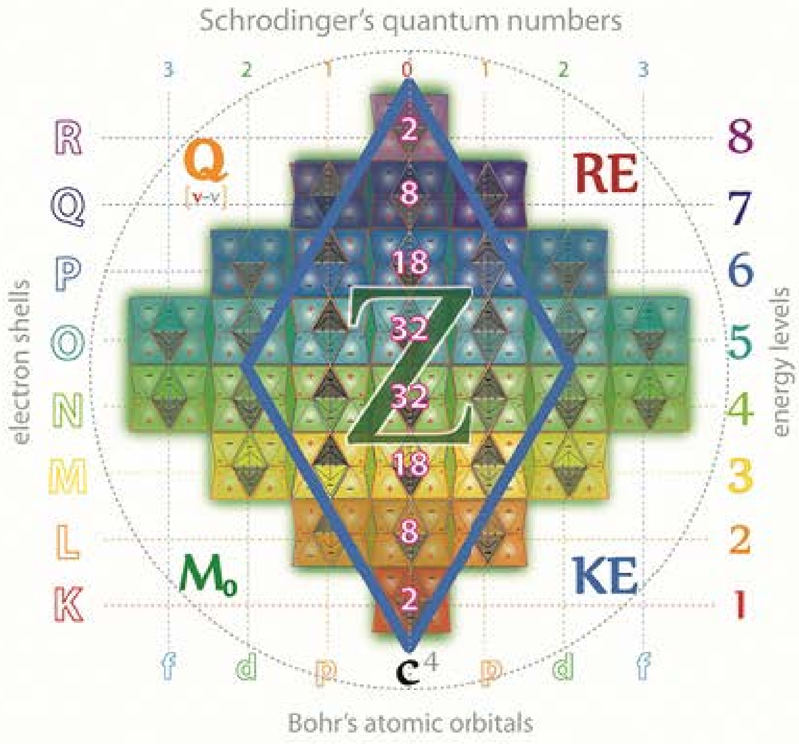
Schrodinger's quantum numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
[v-v]
RE
M_0
KE
Z
2
8
18
32
32
18
8
2
8
7
6
5
4
3
2
1
energy levels
f
d
p
c^4
p
d
f
Bohr's atomic orbitals

$$E = hv^2$$

$$n^2 + v^2 + e = Z$$

general form quatratic equation

$$ax^2 + bx + c = Z$$

$$E = nhv$$

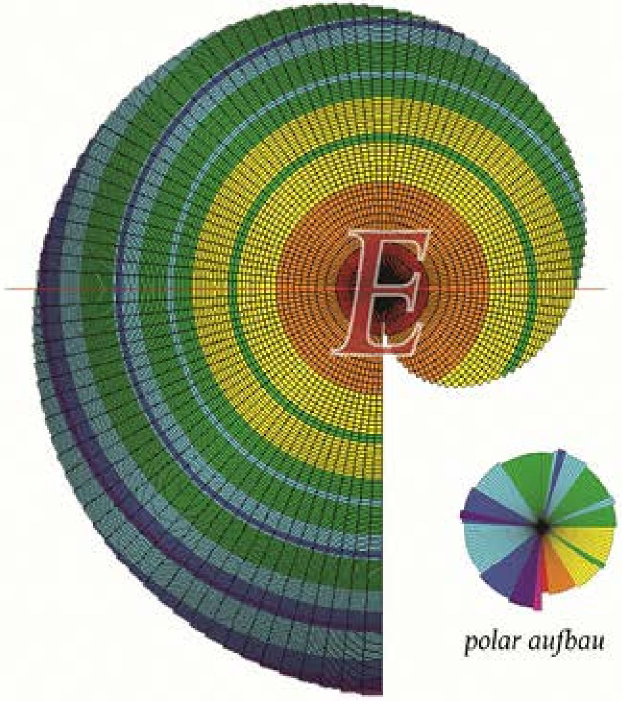
E
polar aufbau

polar energy spirals courtesy of Rene Cormier

Identifying electron rest Matter topologies as velocity invariant we can re-arrange the component Planck mass-energy geometry formulation of periodic elements to

$$h\left[\underbrace{72[v^2]}_{\text{Deuteron rest mass}} + \underbrace{v}_{\text{Spectral lines}} + \underbrace{1.20\text{ e}20\ v}_{\text{electron rest mass}}\right]$$

reveal a quadratic formulation for all Z numbers

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All elements are comprised of n level Duetrium nuclei

Baryons **KEM fields** **electrons**

$$Z\,[[72n^2] + [12v^2] + [1.2e20]]$$

1,861,949 MeV **13.525 eV** **496,519 keV**

The atomic shell energy levels of Deuterium nuclei in elements

electron

Deuteron	eV	KEM
32 3,050.6 MeV		En = -13.52 eV
31 2,5862.9 MeV		En = -10.35 eV
30 2,6811 MeV		En = -7.60 eV
29 2,505.4 MeV		En = -5.28 eV
28 2,335.6 MeV		En = -3.38 eV
27 2,171.8 MeV		En = -1.90 eV
26 2,013.9 MeV		En = -0.84 eV
25 1,861.9 MeV		En = -0.21 eV

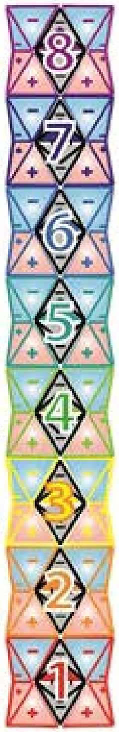

496.519 keV

m v²

Determines the spectral line [KEM field energies] of electrons bound to them

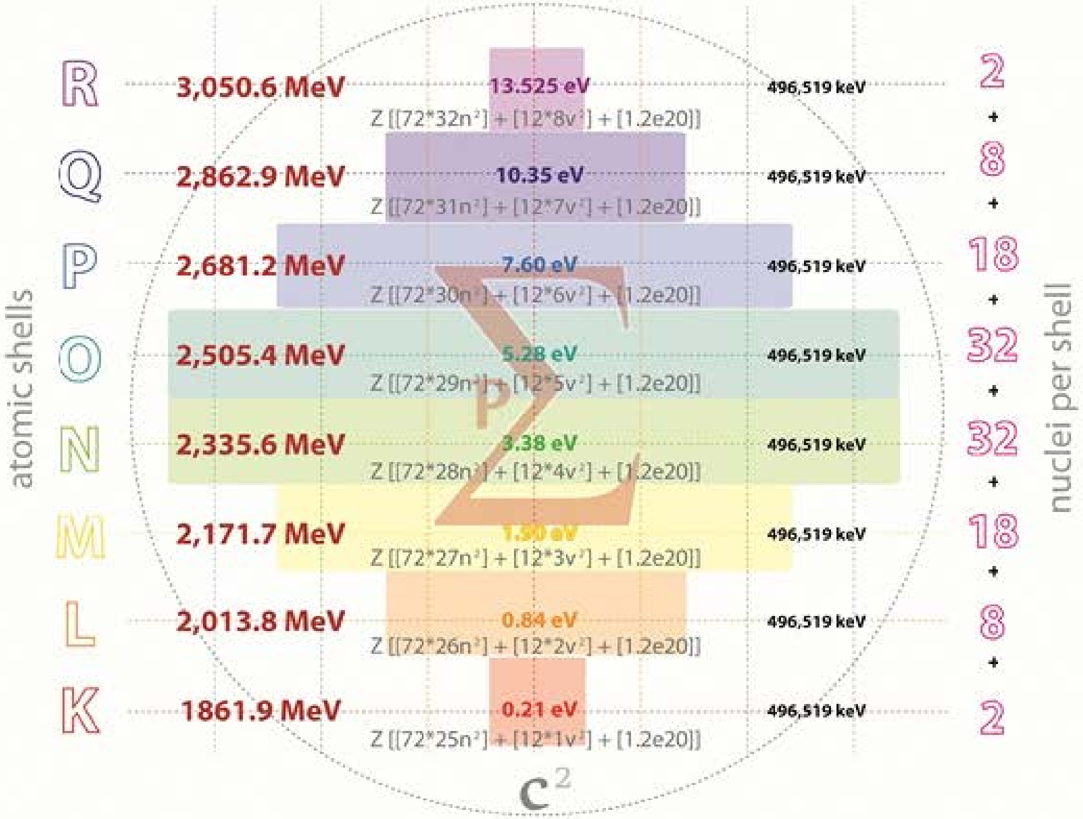

R	3,050.6 MeV	13.525 eV	Z [[72*32n²] + [12*8v²] + [1.2e20]]	496,519 keV	2
					+
Q	2,862.9 MeV	10.35 eV	Z [[72*31n²] + [12*7v²] + [1.2e20]]	496,519 keV	8
					+
P	2,681.2 MeV	7.60 eV	Z [[72*30n²] + [12*6v²] + [1.2e20]]	496,519 keV	18
					+
O	2,505.4 MeV	5.28 eV	Z [[72*29n²] + [12*5v²] + [1.2e20]]	496,519 keV	32
					+
N	2,335.6 MeV	3.38 eV	Z [[72*28n²] + [12*4v²] + [1.2e20]]	496,519 keV	32
					+
M	2,171.7 MeV	1.90 eV	Z [[72*27n²] + [12*3v²] + [1.2e20]]	496,519 keV	18
					+
L	2,013.8 MeV	0.84 eV	Z [[72*26n²] + [12*2v²] + [1.2e20]]	496,519 keV	8
					+
K	1861.9 MeV	0.21 eV	Z [[72*25n²] + [12*1v²] + [1.2e20]]	496,519 keV	2

$2H^+$ $[72n^2]$ **Z** γ $[M_e v^2]$

Elemental mass-Matter [in MeV]

6,101 MeV
993 keV
En = -27.05 eV
+
22,903 MeV
3,972 keV
En = -82.8 eV
+
48,262 MeV
8,937 keV
En = -316.8 eV
+
80,174 MeV
15,888 keV
En = -168.96 eV
+
74,740 MeV
15,888 keV
En = -108.16 eV
+
39,092 MeV
8,937 keV
En = -34.2 eV
+
16,111 MeV
3,972 keV
En = -6.72 eV
+
3,724 MeV
993 keV
En = -0.42 eV

[1.2e20]]

e

the rest mass-Matter of bound photo-electrons is velocity invariant

The relativistic rest mass-energy-Matter of all periodic elements
is the sum of the mass-energies of all atomic nuclei and spectral lines
that comprise its mass-Matter topology as measured in
any spatial co-ordinate system per unit of time

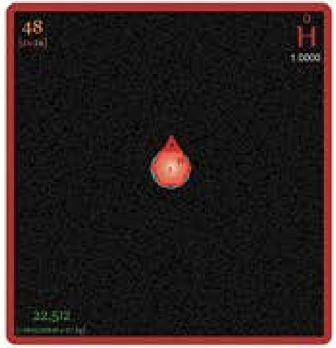

Avagadro's number

6.022141579 e26
atoms in 1KG of Matter

1 KG mass
[of Matter]

1.660538841 e-27 kg
atomic rest mass-Matter

Hydrogen

01

using SI units Avagadro's number can be expressed exactly as the inverse rest mass of Hydrogen

Carbon

12

Weighted atomic mass

5.019789213 e25
atoms in 1KG of Matter

6.02214078 e 23

1.99211552 e-26 kg
atomic rest mass-Matter

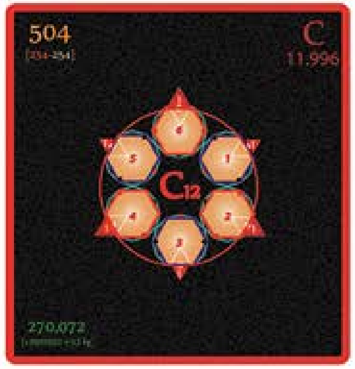

Tetryonic charge geometries make weighted atomic mass measurements and calculations obsolete

22,506 1/12 of Carbon 12 [Graphene] is not equal to 1 Hydrogen atom 22,512
(Deuterium is the building block of all atomic elements)

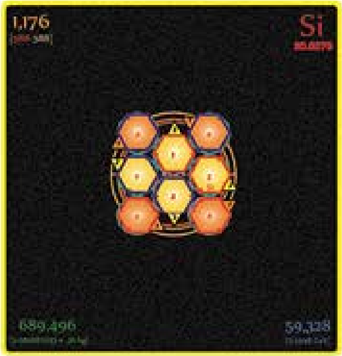

1.966225348 e25
atoms in 1KG of Matter

International Avagadro project

5.085887033 e-26 kg
atomic rest mass-Matter

Silicon

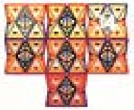

28

The gram was originally defined in 1795 as the mass of one cubic centimeter of water at 4°C,
making the kilogram equal to the mass of one liter of water.

The prototype kilogram, manufactured in 1799 and from which the current kilogram is based
has a mass equal to the mass of 1.000025 liters of water

In recent years two major experiments, namely the Watt balance & Avagadro projects, have been attempting to
measure and define 1KG of mass-Matter in terms of electrical force and the number of atoms respectively
in order to better define 1KG of mass-Matter precisely for all future physical references

Platinum

191

2.817950081 e24
atoms in 1KG of Matter
3.181804449 e23

90% Pt
10% Ir

La Grande K

The La grande K is an alloy of 90% Platinum & 10% Iridium that has been slowly losing mass since its manufacture

3.1893811012 e-25 kg
atomic rest mass-Matter
3.142870708 e-25 kg

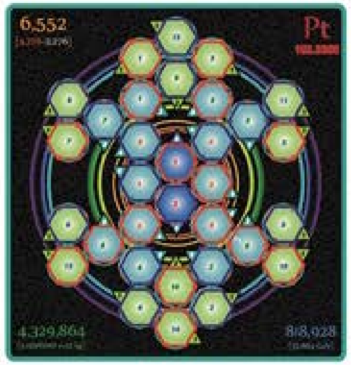

All atomic rest masses are for atoms at absolute zero and any deviation is a measure of the topological Matter's Kinetic energy content [chemical energy, KEM fields and/or spectral lines]

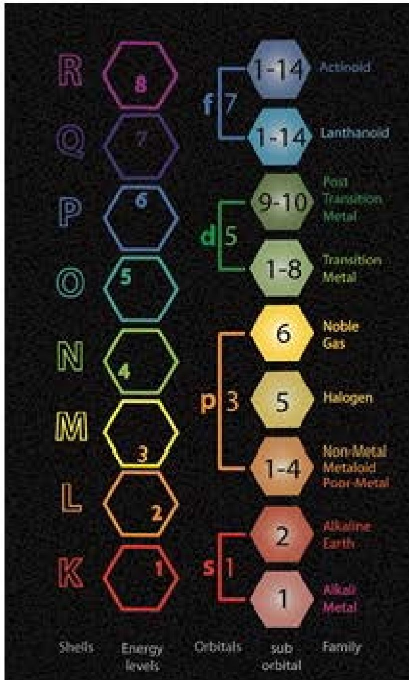
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metaloid Poor-Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Shells
Energy levels
Orbitals
sub orbital
Family

Incorporating

- *Quark configurations*
- *Nuclei geometries*
- *Chemical bond points*
- *Atomic Orbitals*
- *Hund Rule*
- *Pauli exclusion*
- *Aufbau filling principle*
- *Element names, numbers and*
- *Elementary families*

Element placements that reflects the true quantum geometries of periodic elements

● UP Quark

● DOWN Quark

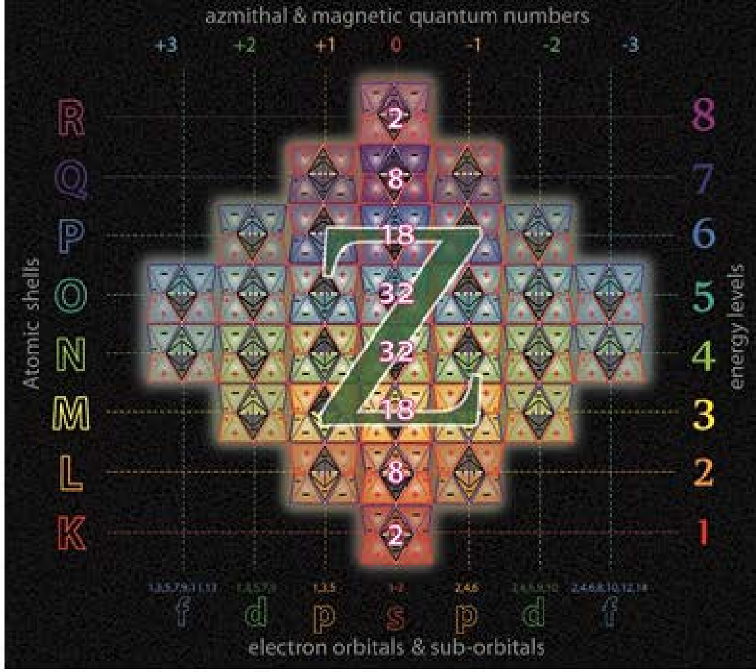
azmithal & magnetic quantum numbers
+3
+2
+1
0
-1
-2
-3
Atomic shells
R
Q
P
O
N
M
L
K
Z
2
8
18
32
32
18
8
2
8
7
6
5
4
3
2
1
energy levels
f
d
p
s
p
d
f
electron orbitals & sub-orbitals

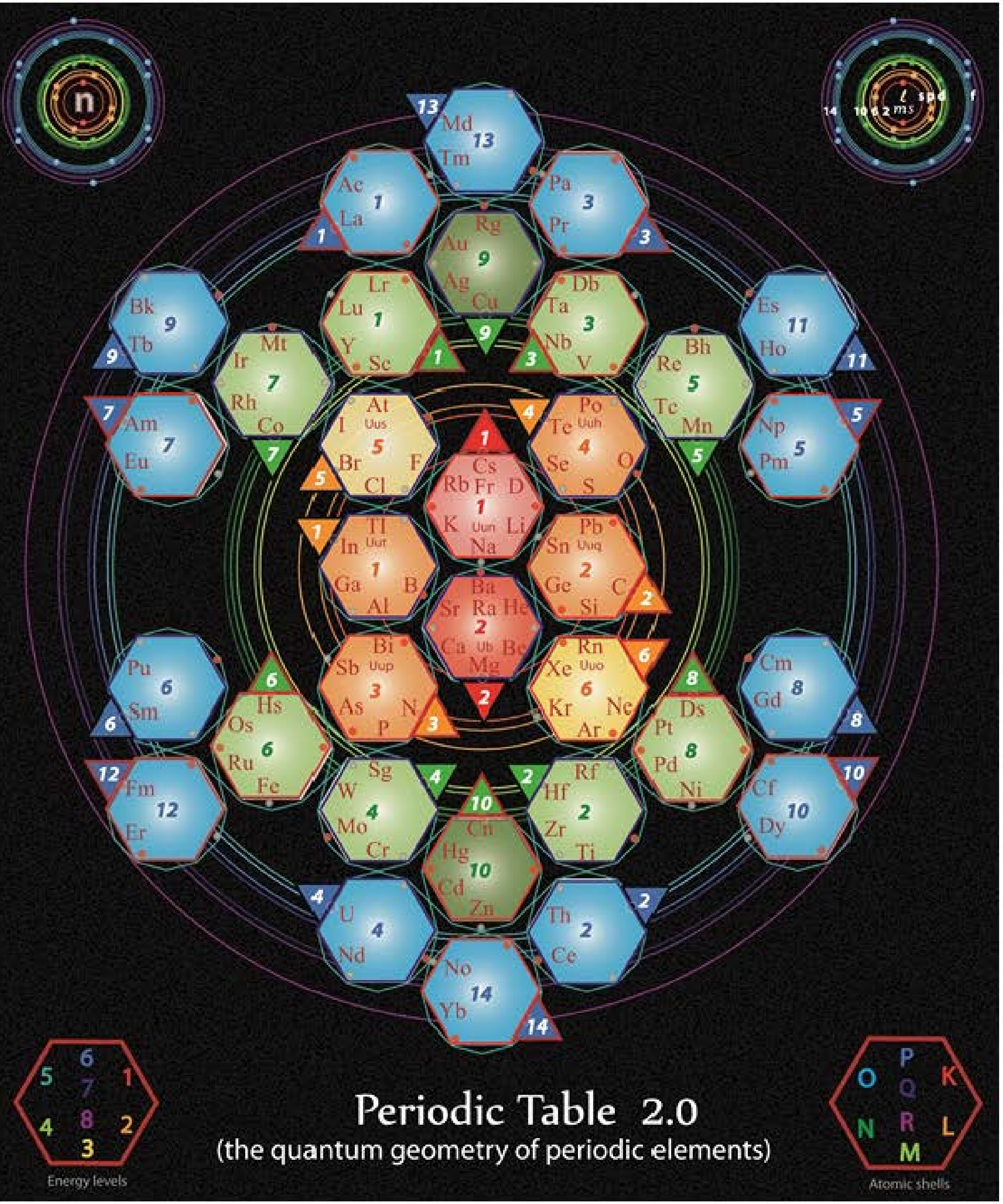
n
Md Tm 13
Ac La 1
Pa Pr 3
Rg Au Ag Cu 9
Bk Tb 9
Lr Lu Y Sc 1
Db Ta Nb V 3
Es Ho 11
Mt Ir Rh Co 7
Bh Re Tc Mn 5
Am Eu 7
At I Uus Br Cl F 5
Cs Rb Fr K Uun Na Li D 1
Po Te Uuh Se S O 4
Np Pm 5
Tl In Uut Ga Al B 1
Ba Sr Ra Ca Ub Mg He Be 2
Pb Sn Uuq Ge Si C 2
Pu Sm 6
Bi Sb Uup As P N 3
Rn Xe Uuo Kr Ar Ne 6
Cm Gd 8
Hs Os Ru Fe 6
Ds Pt Pd Ni 8
Fm Er 12
Sg W Mo Cr 4
Cn Hg Cd Zn 10
Rf Hf Zr Ti 2
Cf Dy 10
U Nd 4
Th Ce 2
No Yb 14
6 5 4 3 8 7 2 1
Energy levels
P O K Q N R L M
Atomic shells

Periodic Table 2.0

(the quantum geometry of periodic elements)

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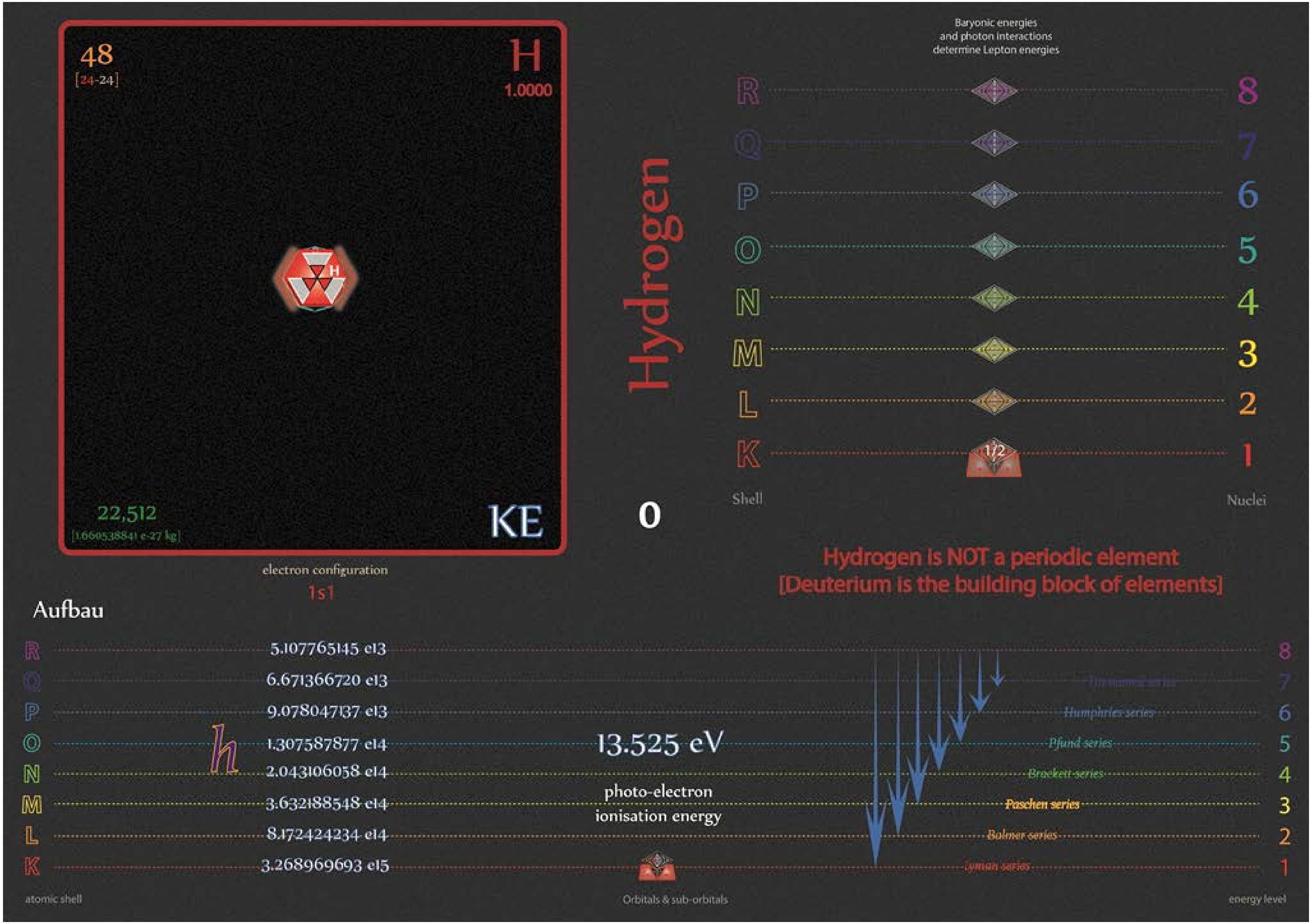
48
[24-24]
H
1.0000
22,512
[1.660538841 e-27 kg]
KE
Hydrogen
0
Baryonic energies
and photon interactions
determine Lepton energies
R
Q
P
O
N
M
L
K
1/2
8
7
6
5
4
3
2
1
Shell
Nuclei
h
Orbitals & sub-orbitals
Humphries series
Pfund series
Brackett series
Paschen series
Balmer series
Lyman series

electron configuration

1s1

Hydrogen is NOT a periodic element
[Deuterium is the building block of elements]

Aufbau

atomic shell		energy level
R	5.107765145 e13	8
Q	6.671366720 e13	7
P	9.078047137 e13	6
O	1.307587877 e14	5
N	2.043106058 e14	4
M	3.632188548 e14	3
L	8.172424234 e14	2
K	3.268969693 e15	1

13.525 eV

photo-electron
ionisation energy

Tetryonics 51.00 - Hydrogen atom

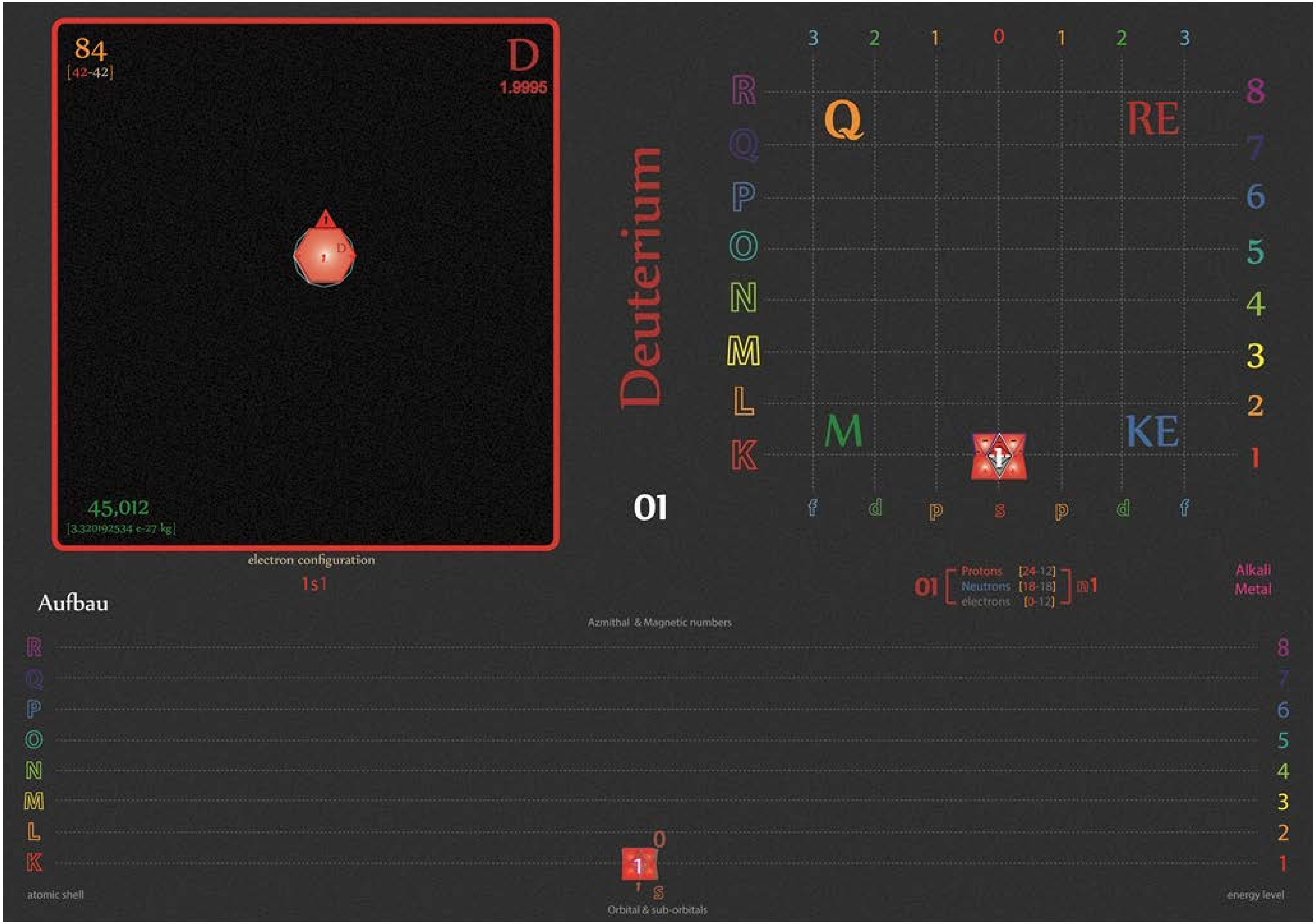
84
[42-42]
D
1.9995
D
1
45,012
[3.320192534 e-27 kg]
electron configuration
1s1
Deuterium
01
Aufbau
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
8
7
6
5
4
3
2
1
1
f
d
p
s
p
d
f
01
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1
Alkali
Metal
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
s
atomic shell
Orbital & sub-orbitals
energy level

Tetryonics 51.01 - Deuterium atom

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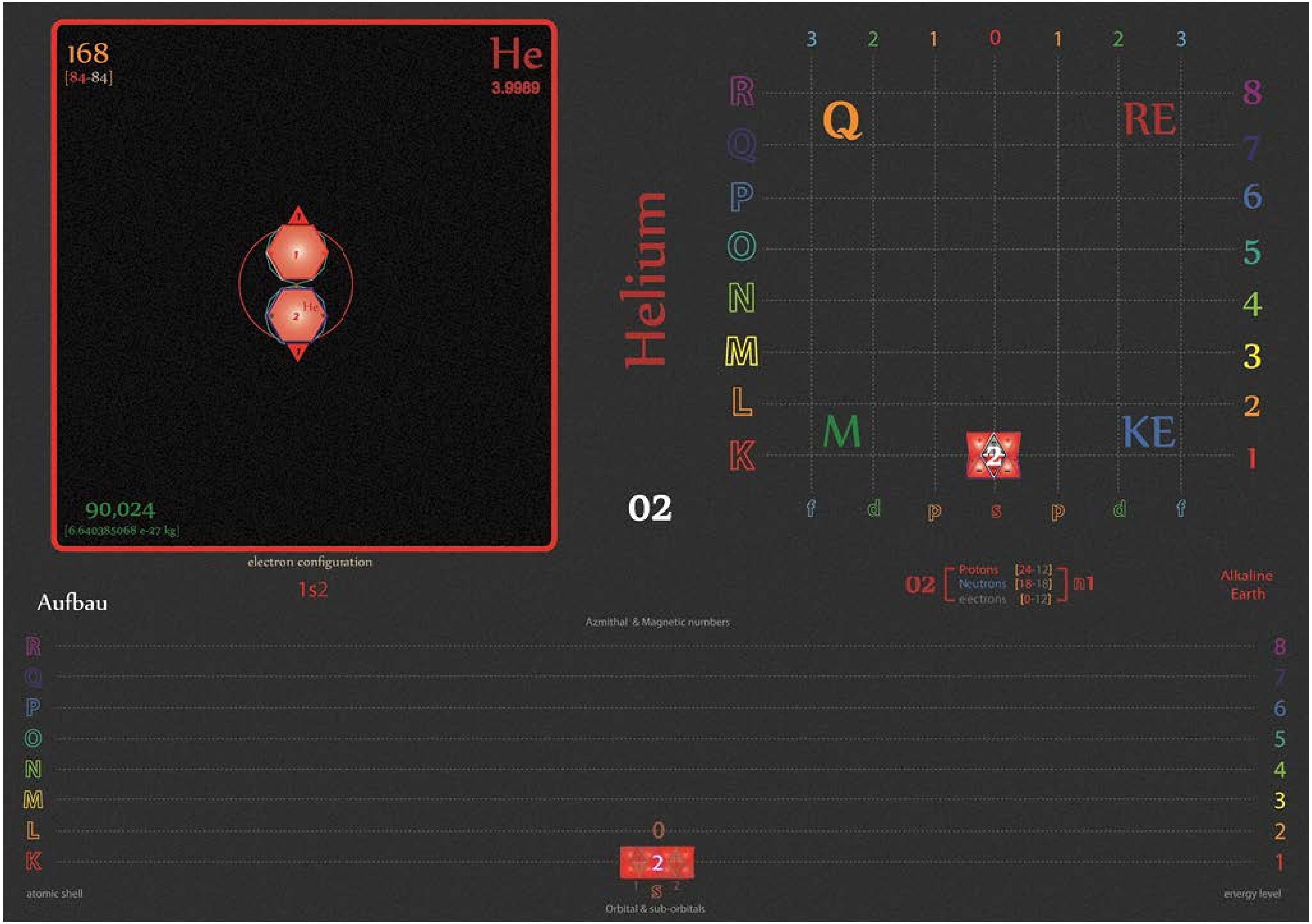
168
[84-84]
He
3.9989
1
2
He
90,024
[6.640385068 e-27 kg]
electron configuration
1s2
Aufbau
Helium
02
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
2
f d p s p d f
02
Potons [24-12]
Neutrons [18-18]
electrons [0-12]
m1
Alkaline Earth
Azmithal & Magnetic numbers
0
2
1 s 2
atomic shell
Orbital & sub-orbitals
energy level

Tetryonics 51.02 - Helium atom

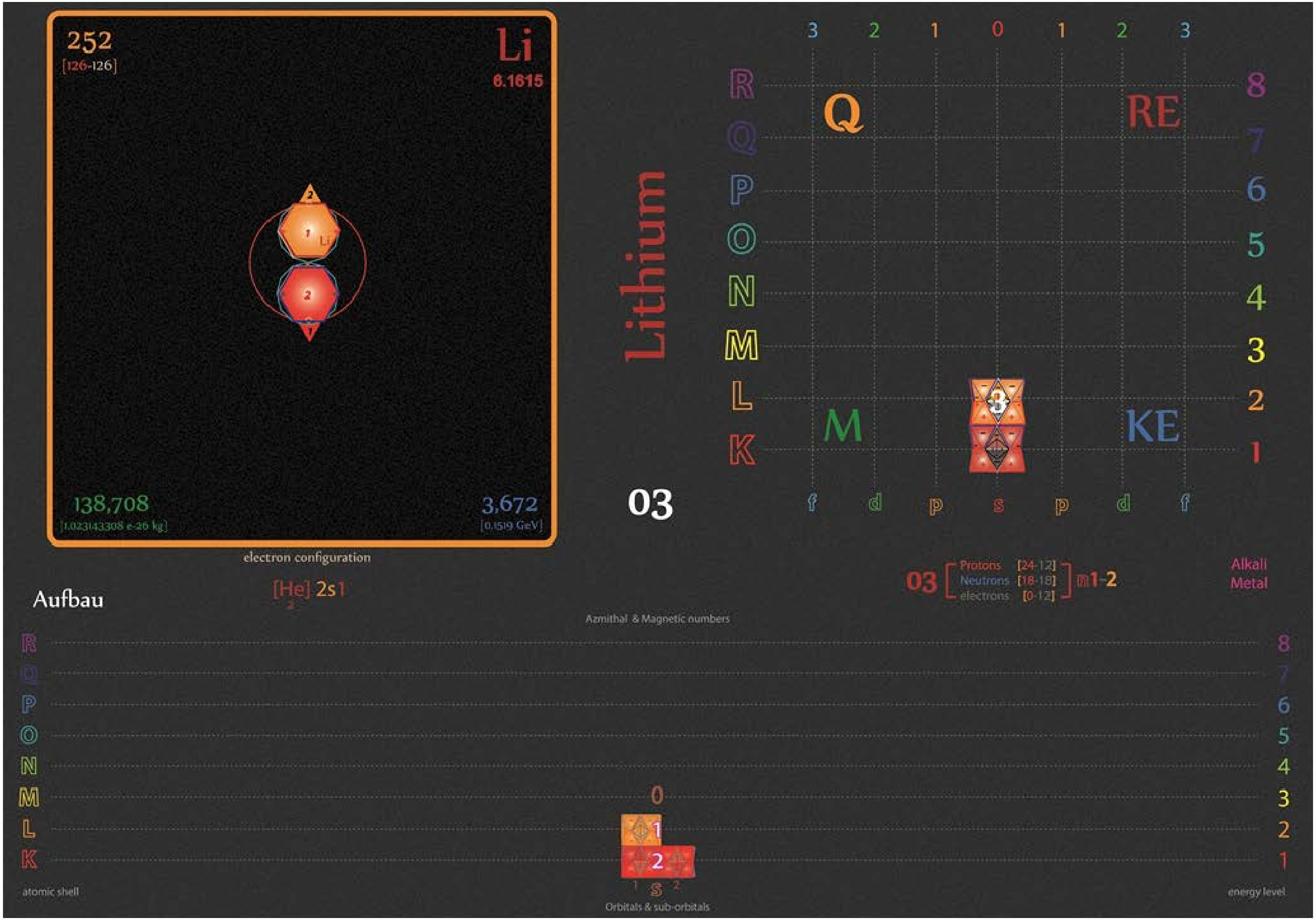
252
[126-126]
Li
6.1615
1
2
Li
138,708
[1.023143308 e-26 kg]
3,672
[0.1519 GeV]
electron configuration
[He] 2s1
2
Aufbau
Lithium
03
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
3
f d p s p d f
03
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-2
Alkali
Metal
Azmithal & Magnetic numbers
0
1
2
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.03 - Lithium atom

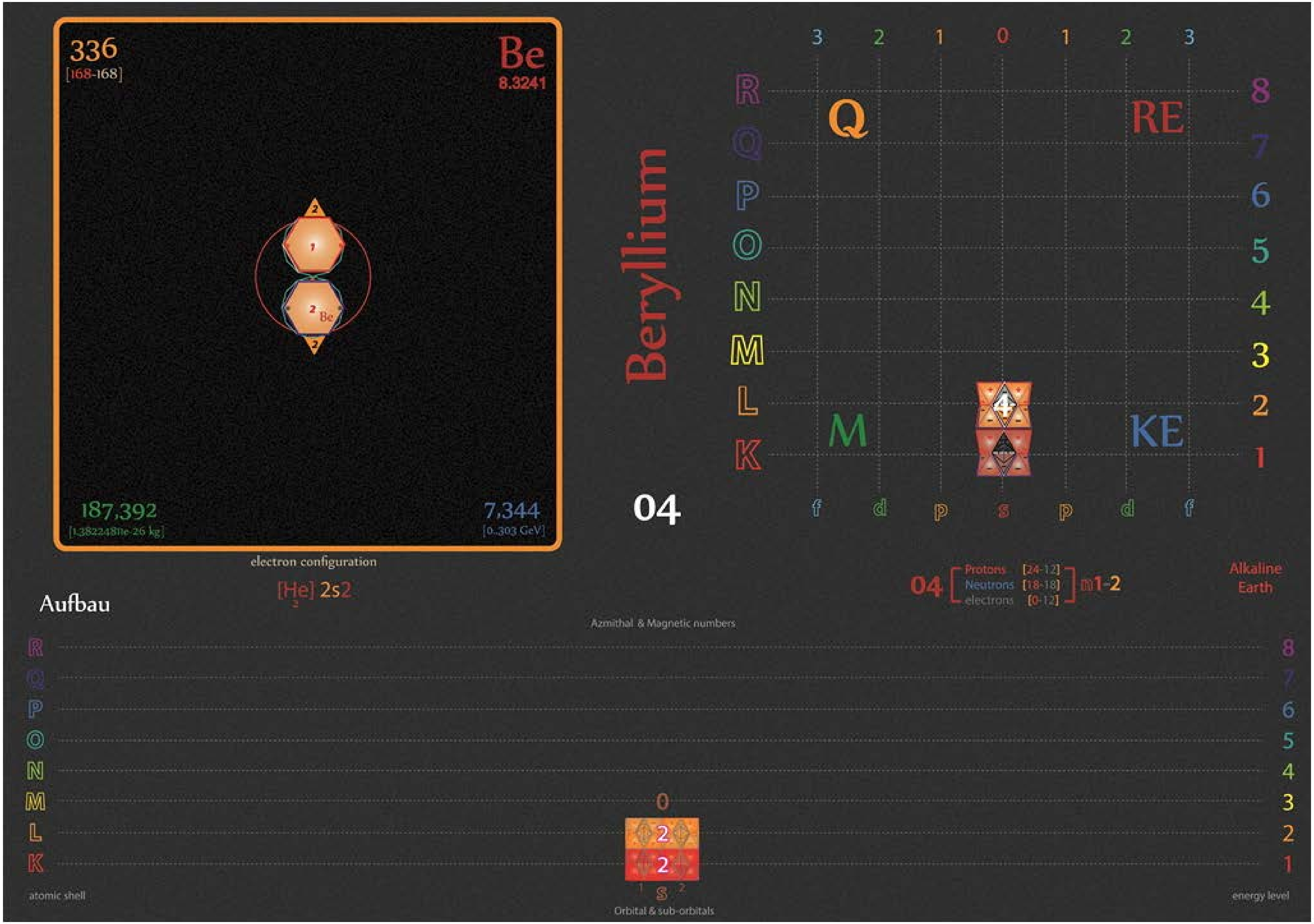
336
[168-168]
Be
8.3241
1
2
2
2
Be
187,392
[1.3822481e-26 kg]
7,344
[0..303 GeV]
electron configuration
[He] 2s2
2
Aufbau
Beryllium
04
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
4
f d p s p d f
Azmithal & Magnetic numbers
04
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-2
Alkaline Earth
R Q P O N M L K
8 7 6 5 4 3 2 1
0
2
2
1 s 2
atomic shell
Orbital & sub-orbitals
energy level

Tetryonics 51.04 - Beryllium atom

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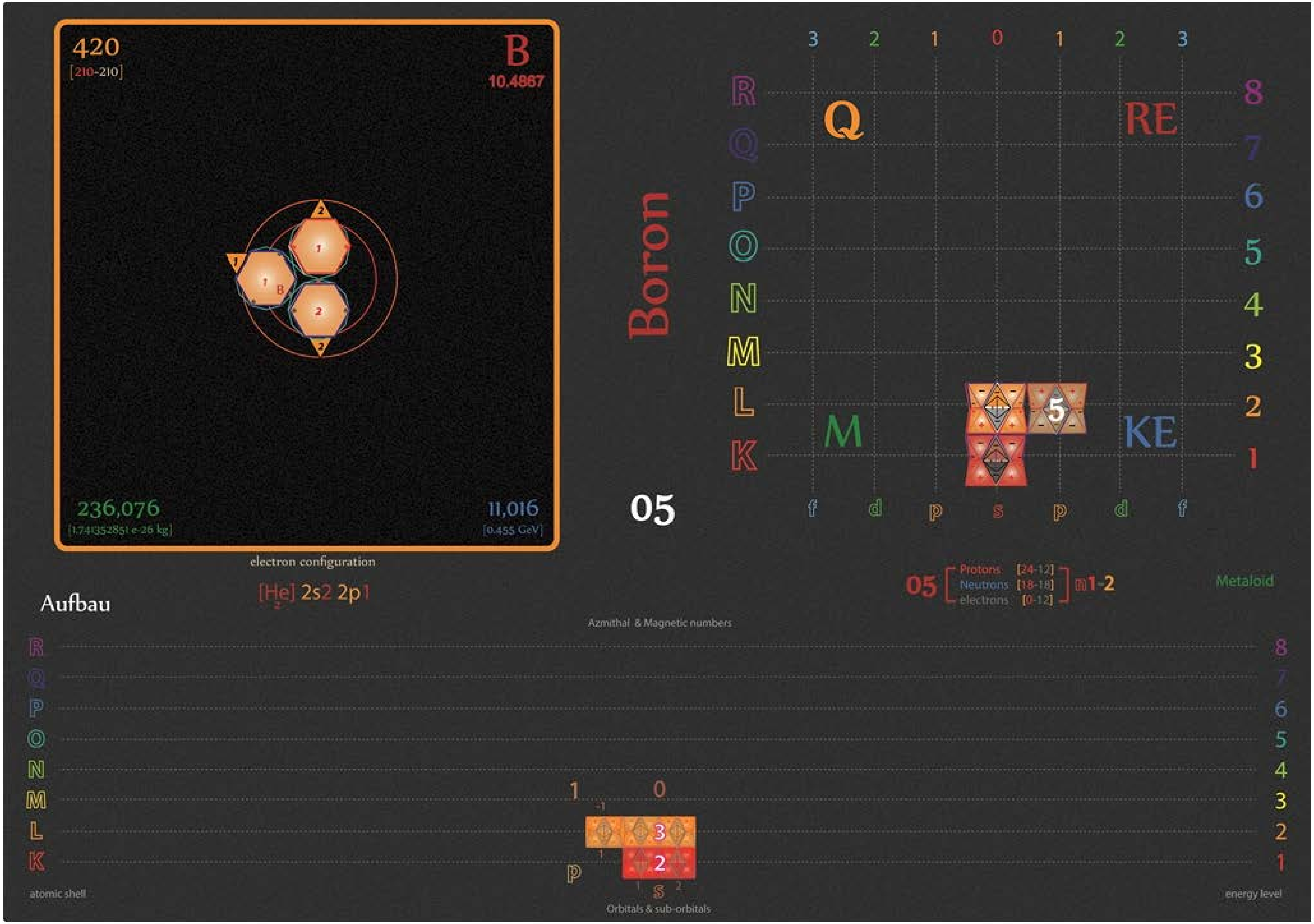
420
[210-210]
B
10.4867
236,076
[1.741352851 e-26 kg]
11,016
[0.455 GeV]
electron configuration
[He] 2s2 2p1
Aufbau
Boron
05
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
5
f d p s p d f
05 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-2
Metaloid
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
1 0
-1
1
3
2
p
1 s 2
Orbitals & sub-orbitals
atomic shell
energy level

Tetryonics 51.05 - Boron atom

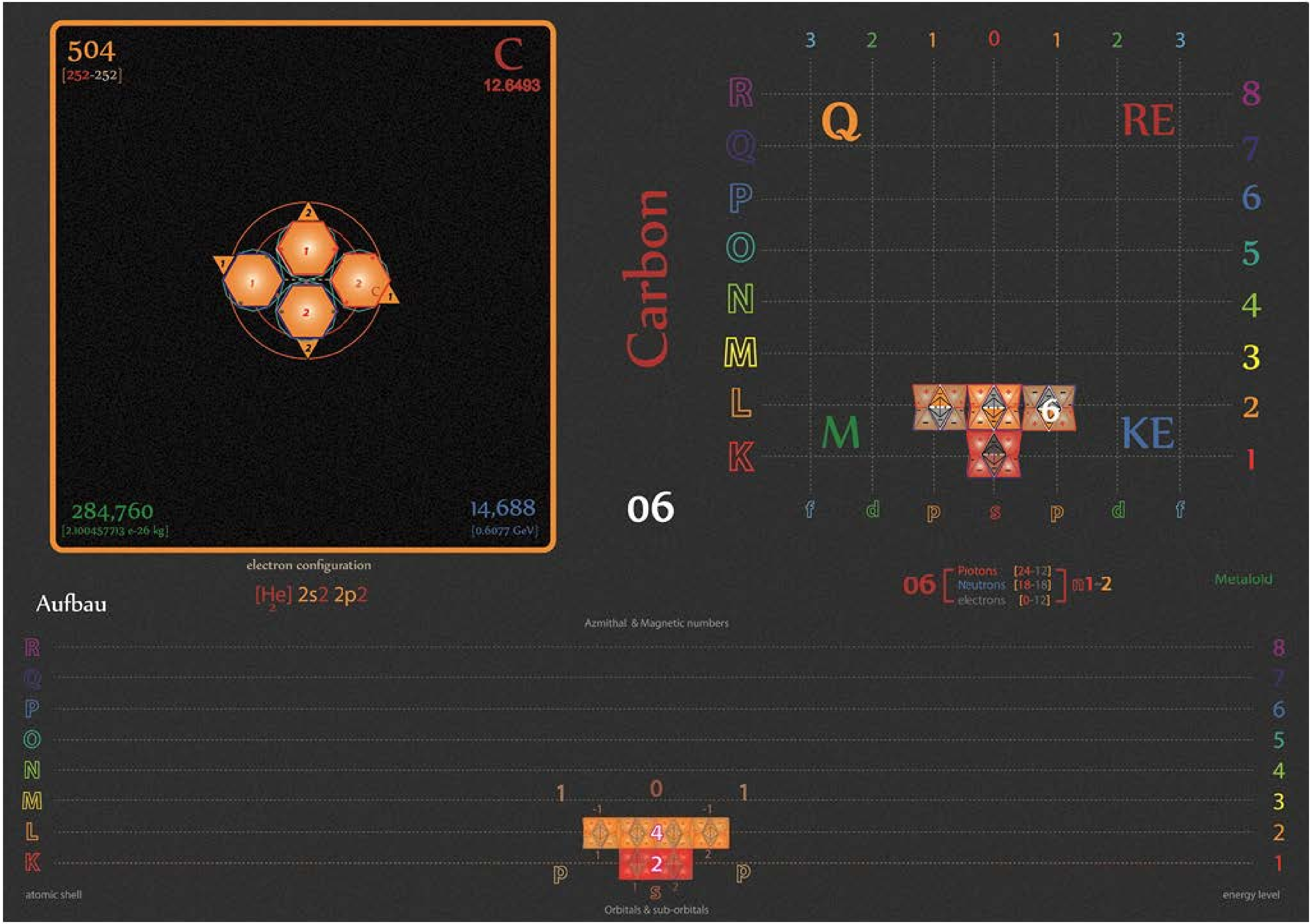
504
[252-252]
C
12.6493
1
2
2
1
284,760
[2.100457713 e-26 kg]
14,688
[0.6077 GeV]
electron configuration
[He] 2s2 2p2
2
Aufbau
Carbon
06
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
6
8
7
6
5
4
3
2
1
f d p s p d f
06 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-2
Metaloid
Azmithal & Magnetic numbers
1 0 1
-1 -1
4
1 2
2
p p
1 2
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.06 - Carbon atom

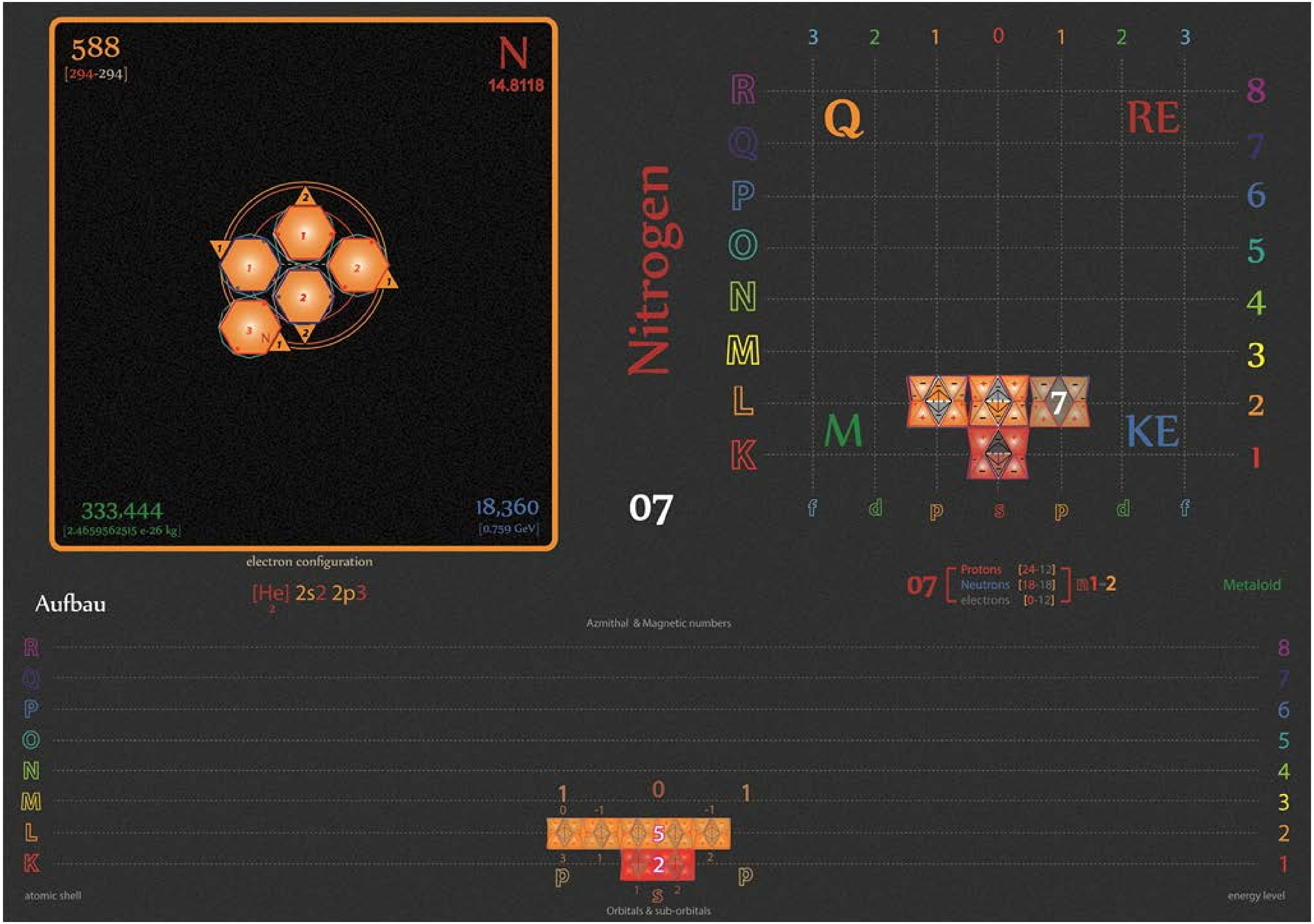
588
[294-294]
N
14.8118
333.444
[2.4659562515 e-26 kg]
18,360
[0.759 GeV]
Nitrogen
07
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
7
f d p s p d f
electron configuration
[He] 2s2 2p3
Aufbau
Azmithal & Magnetic numbers
07 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-2
Metaloid
1 0 1
0 -1 -1
5
2
3 1 2
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.07 - Nitrogen atom

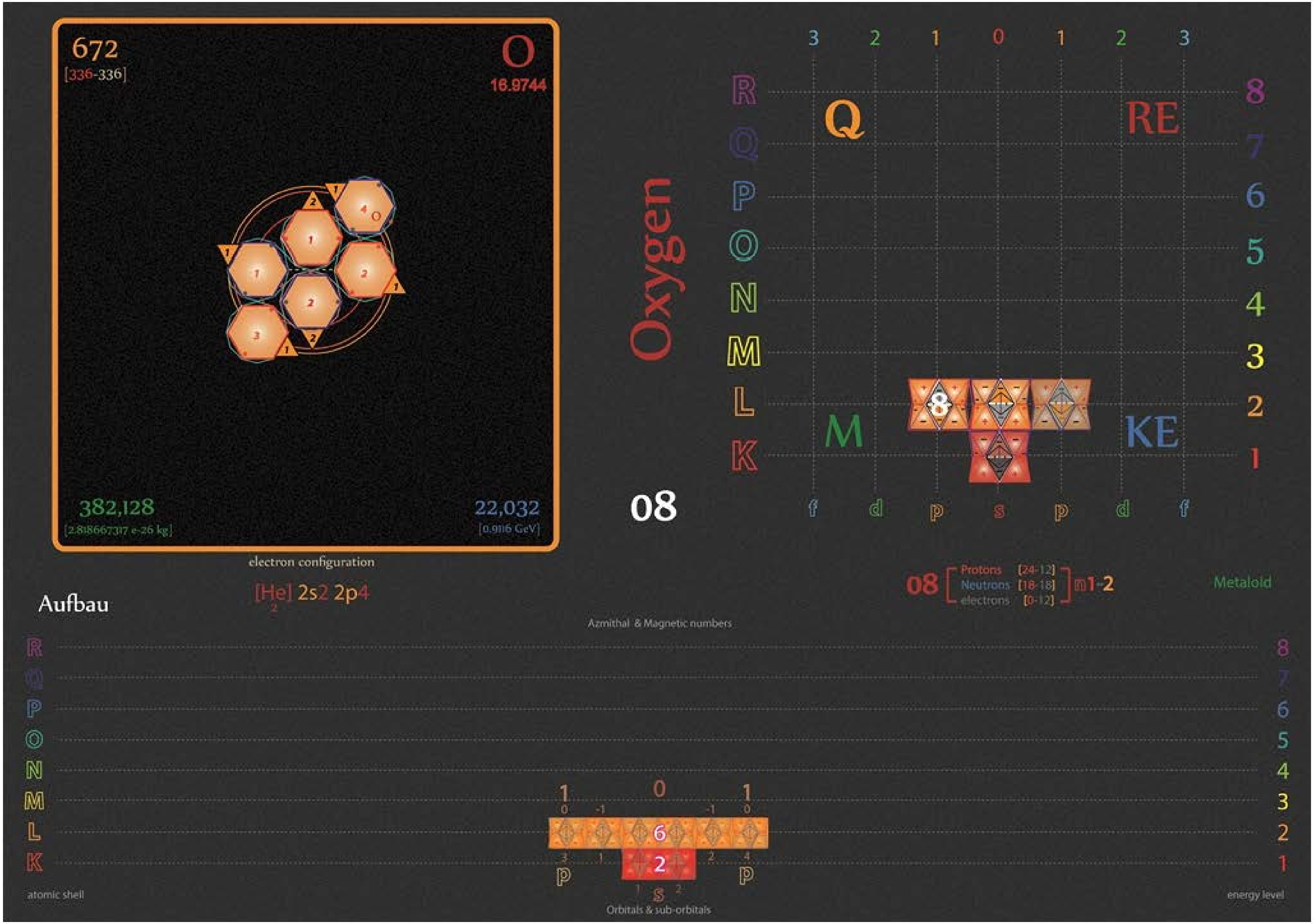
672
[336-336]
O
16.9744
1
2
4 O
1
1
2
2
1
1
2
3
1
2
382,128
[2.818667317 e-26 kg]
22,032
[0.9116 GeV]
Oxygen
08
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
8
f d p s p d f
electron configuration
[He] 2s2 2p4
2
Aufbau
Azmithal & Magnetic numbers
08
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-2
Metaloid
R Q P O N M L K
8 7 6 5 4 3 2 1
1 0 1
0 -1 -1 0
6
2
3 1 2 4
p p
1 s 2
Orbitals & sub-orbitals
atomic shell
energy level

Tetryonics 51.08 - Oxygen atom

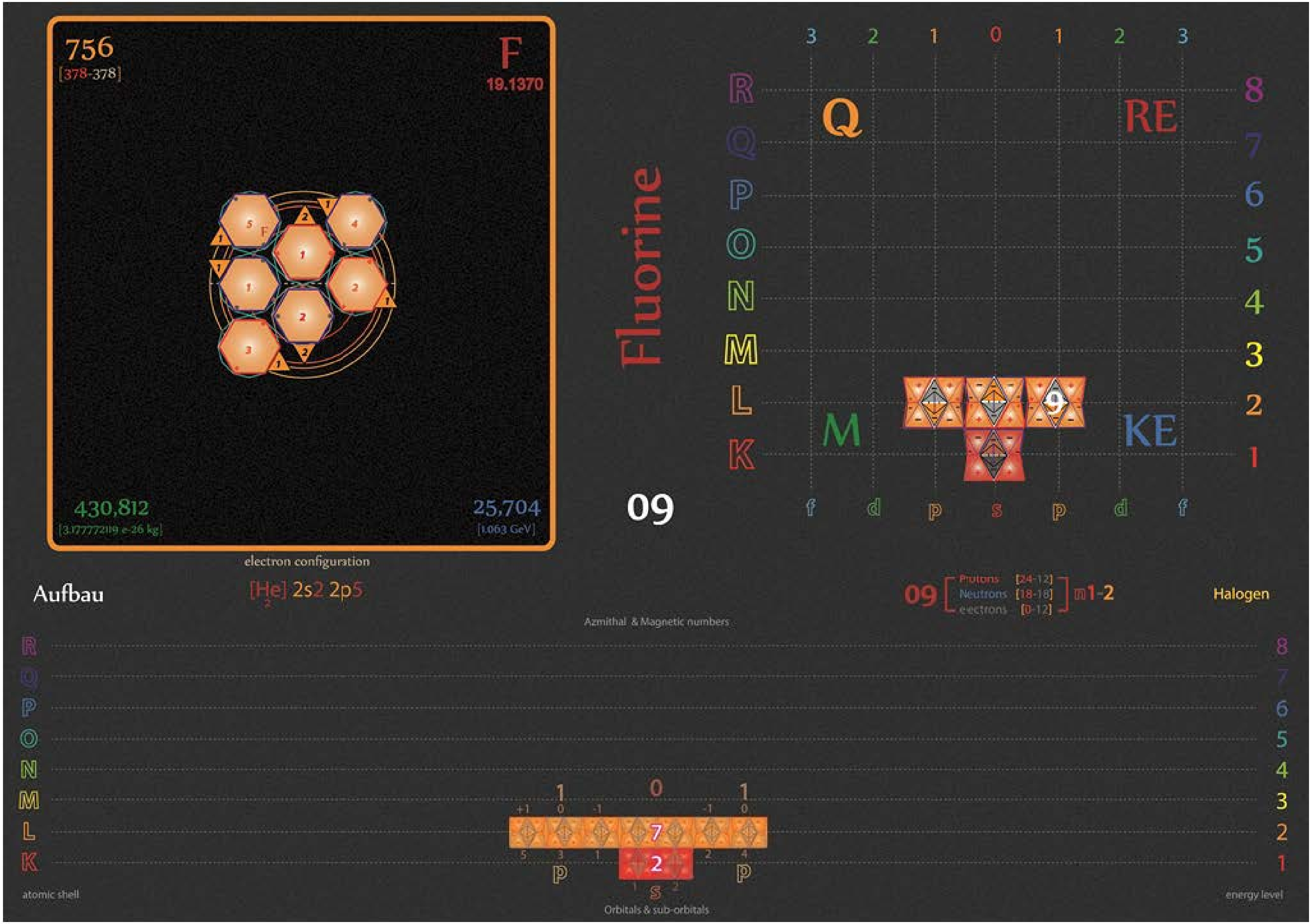
756
[378-378]
F
19.1370
430,812
[3.17777219 e-26 kg]
25,704
[1.063 GeV]
Fluorine
09
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
9
f d p s p d f
electron configuration
Aufbau
[He] 2s2 2p5
Azmithal & Magnetic numbers
09 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-2
Halogen
R Q P O N M L K
8 7 6 5 4 3 2 1
1 0 1
+1 0 -1 -1 0
7
2
5 3 1 2 4
p s p
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.09 - Fluorine atom

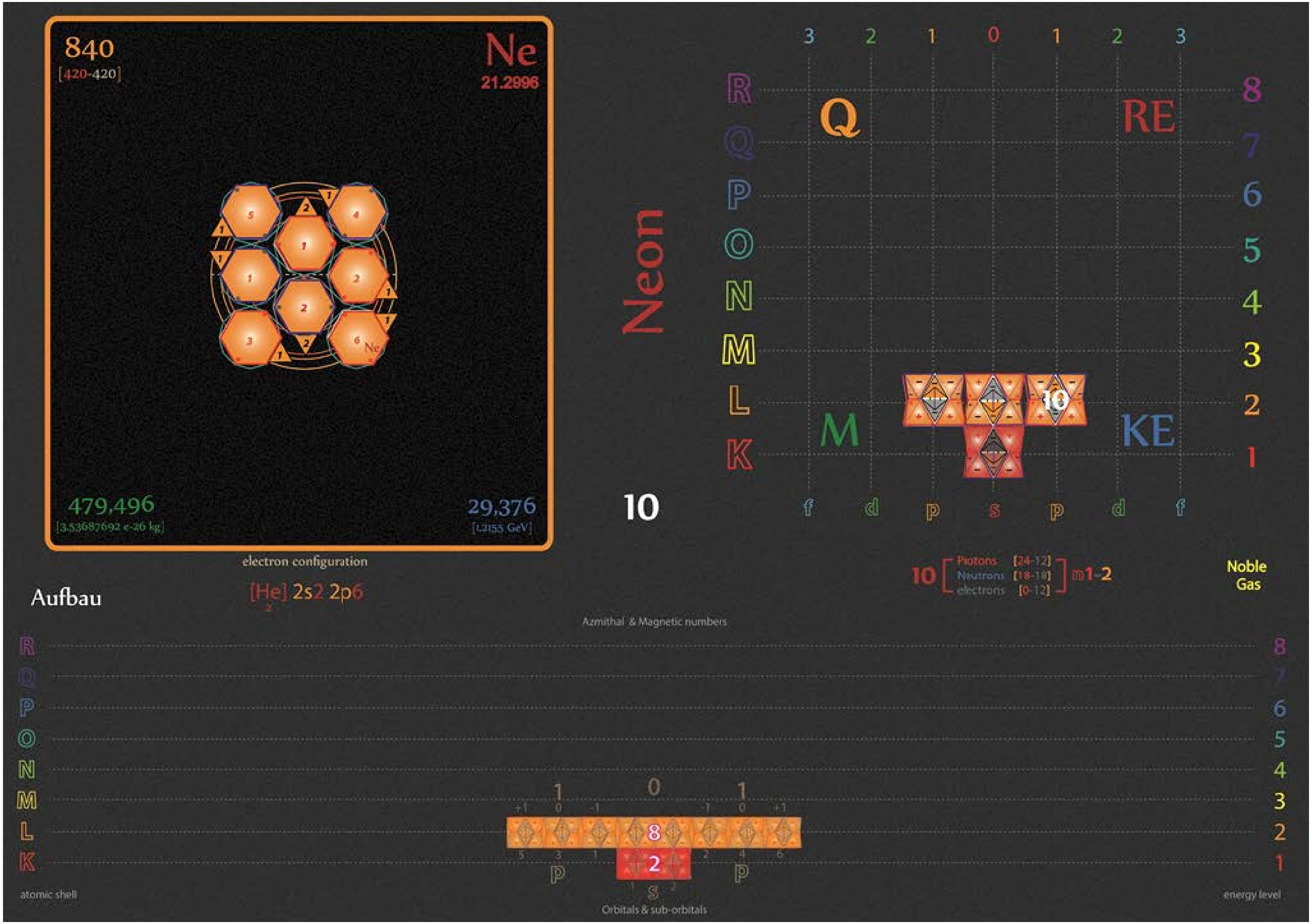
840
[420-420]
Ne
21.2996
479,496
[3.53687692 e-26 kg]
29,376
[1.2155 GeV]
Neon
10
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
10
f d p s p d f
electron configuration
[He] 2s2 2p6
2
Aufbau
10 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-2
Noble Gas
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
1 0 1
+1 0 -1 -1 0 +1
8
2
5 3 1 2 4 6
p p
1 s 2
atomic shell
Orbitals & sub-orbitals
energy level

Tetryonics 51.10 - Neon atom

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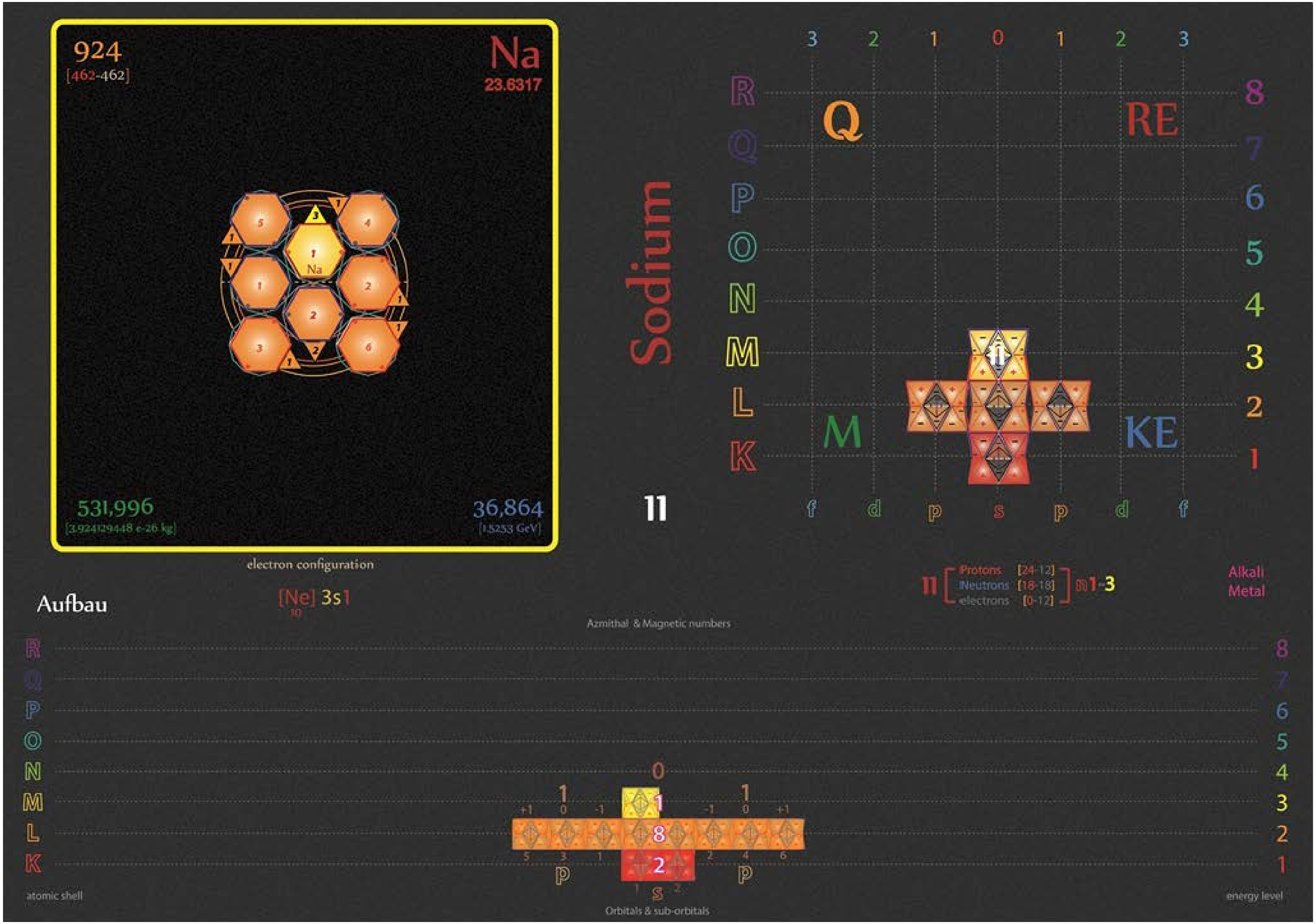
924
[462-462]
Na
23.6317
531,996
[3.924129448 e-26 kg]
36,864
[1.5253 GeV]
Sodium
11
electron configuration
Aufbau
[Ne] 3s1
10
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
11 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-3
Alkali Metal
Azimuthal & Magnetic numbers
0
1 1
+1 0 -1 -1 0 +1
1
8
2
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.11 - Sodium atom

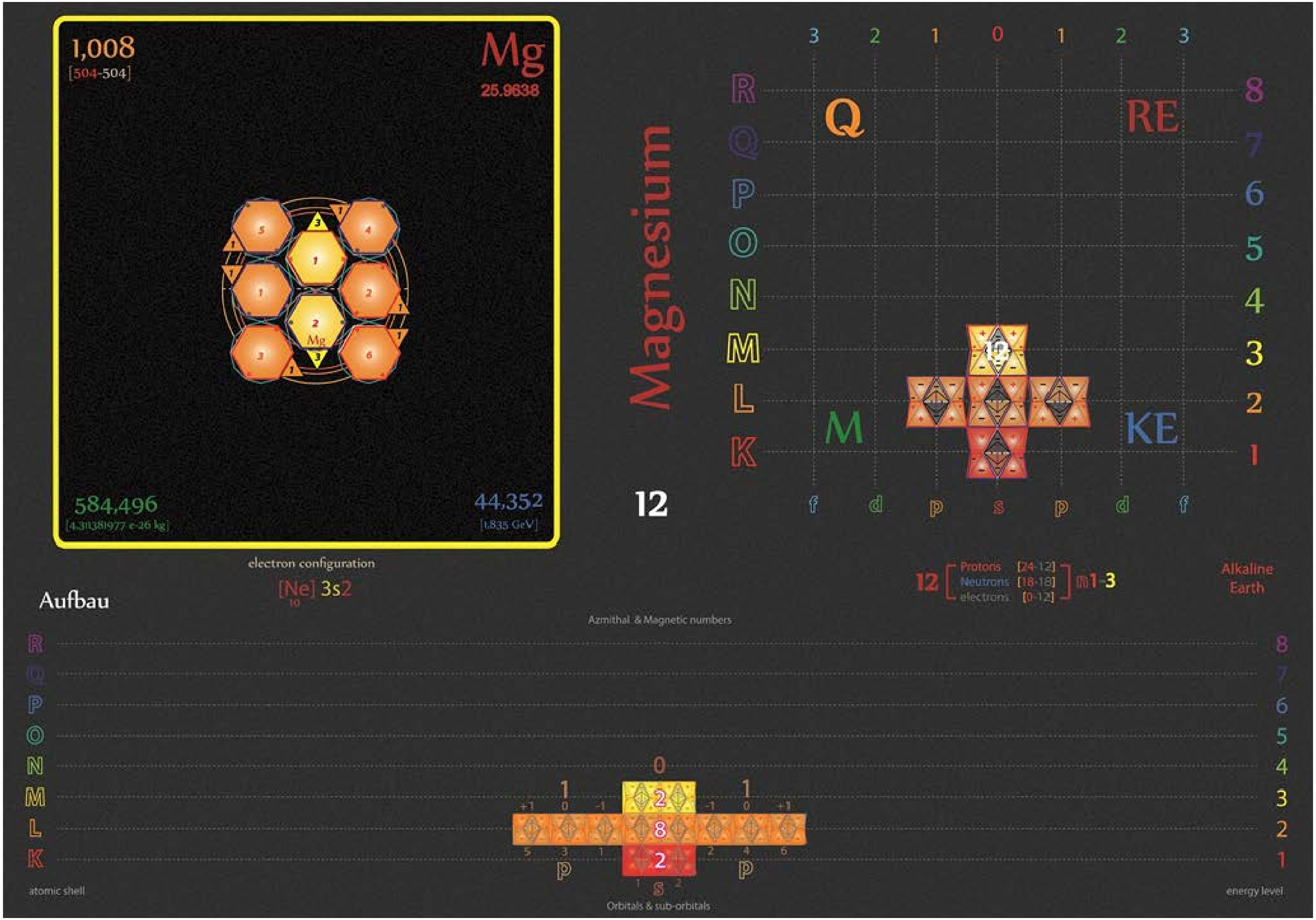
1,008
[504-504]
Mg
25.9638
584,496
[4.311381977 e-26 kg]
44,352
[1.835 GeV]
Magnesium
12
electron configuration
[Ne] 3s2
10
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
12
12 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-3
Alkaline Earth
Azmithal & Magnetic numbers
0
1
1
+1 0 -1
-1 0 +1
2
8
2
5 3 1
2 4 6
p
p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.12 - Magnesium atom

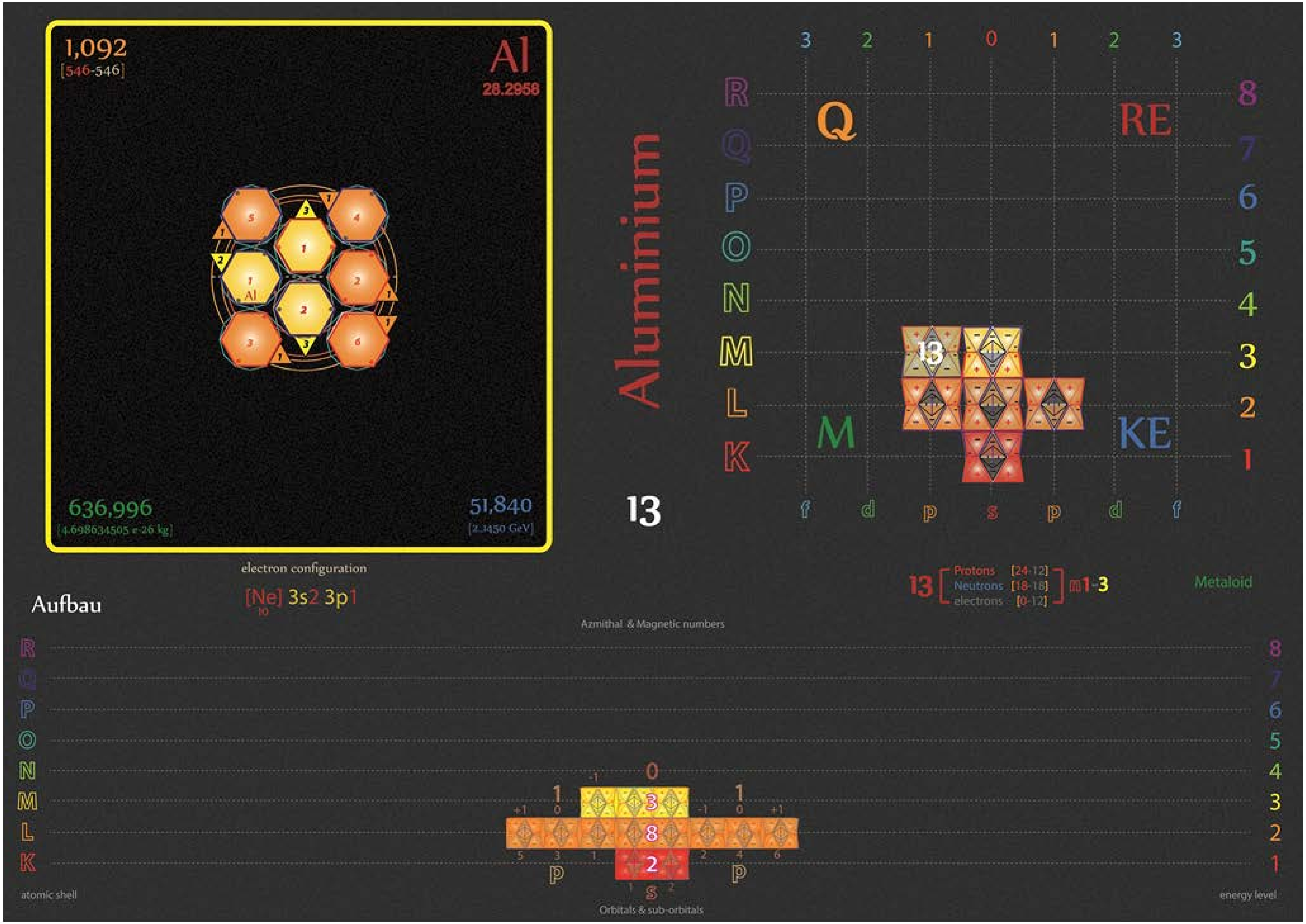
1,092
[546-546]
Al
28.2958
636,996
[4.698634505 e-26 kg]
51,840
[2.3450 GeV]
Aluminium
13
electron configuration
[Ne] 3s2 3p1
10
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
13
13 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-3
Metaloid
Azmithal & Magnetic numbers
0
1
1
-1
+1 0 -1 0 +1
3
8
2
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.13 - Aluminium atom

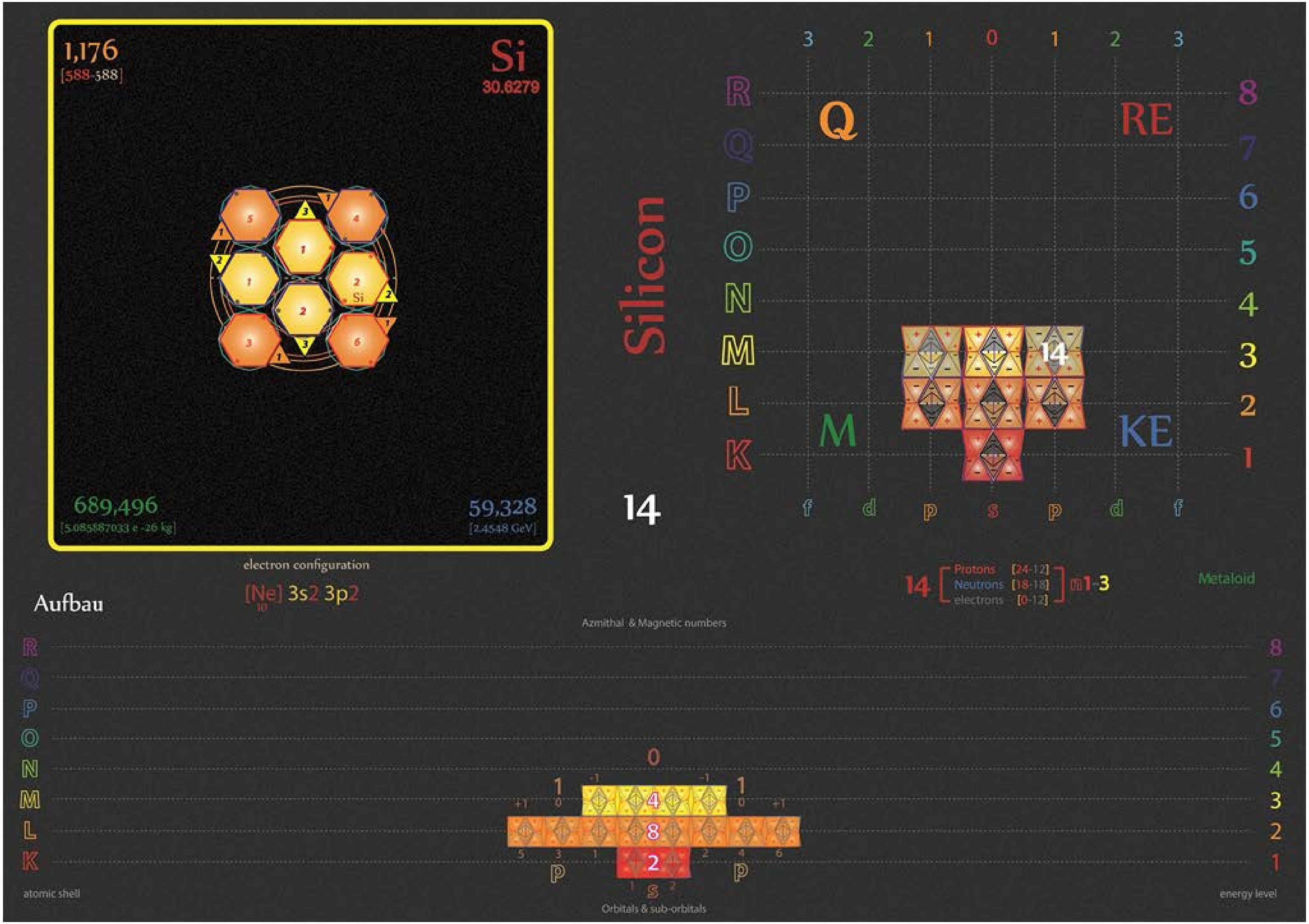
1,176
[588-588]
Si
30.6279
Si
689,496
[5.085887033 e -26 kg]
59,328
[2.4548 GeV]
Silicon
14
electron configuration
[Ne] 3s2 3p2
10
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
14
f d p s p d f
14 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-3
Metaloid
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
1
1
-1
-1
+1
0
0
+1
4
8
2
5 3 1 2 4 6
p
p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.14 - Silicon atom

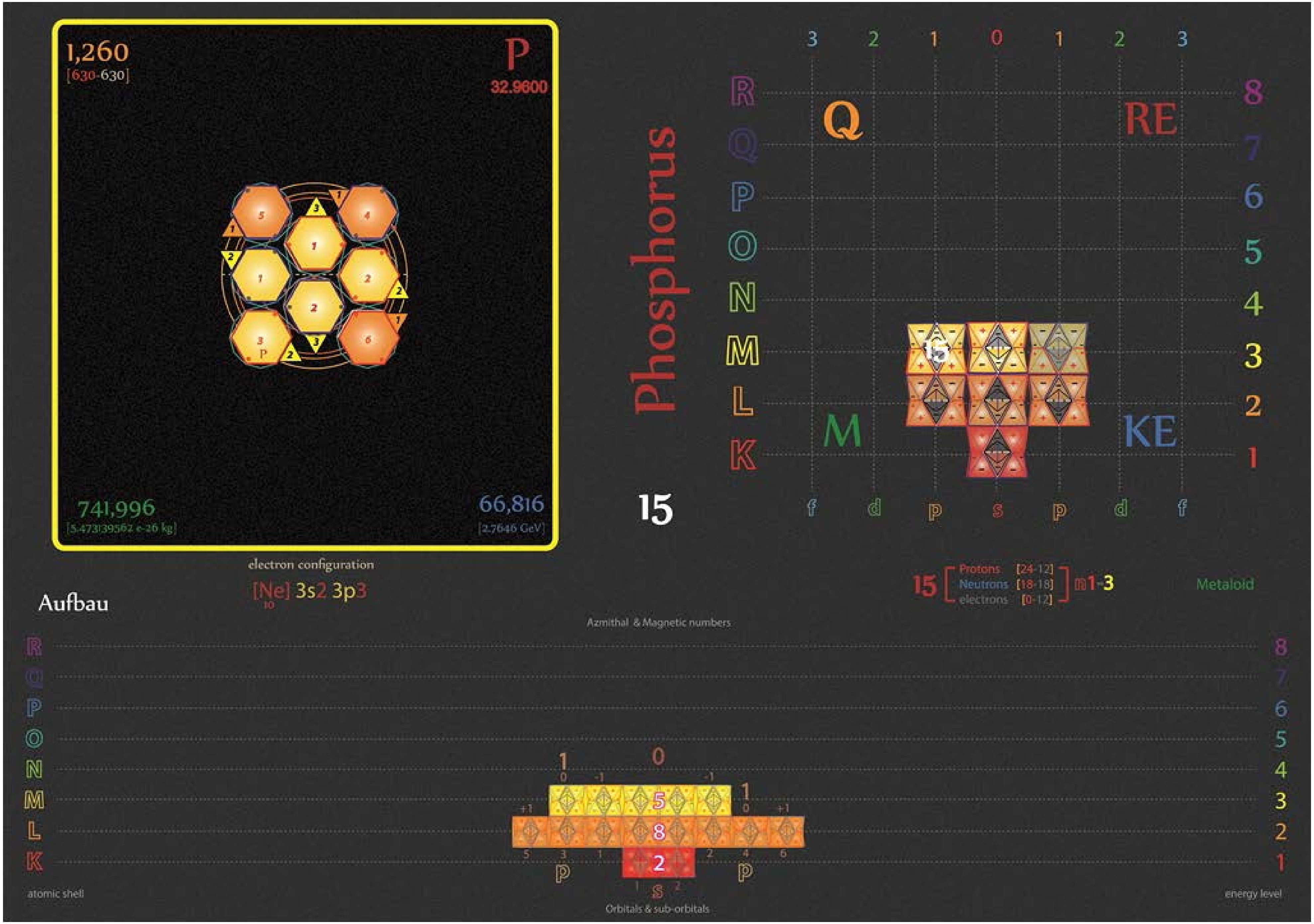
1,260
[630-630]
P
32.9600
741,996
[5.47339562 e-26 kg]
66,816
[2.7646 GeV]
Phosphorus
15
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ne] 3s2 3p3
10
Aufbau
15 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-3
Metaloid
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
1 0 1
0 -1 -1 0
+1 +1
5
8
2
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.15 - Phosphorus atom

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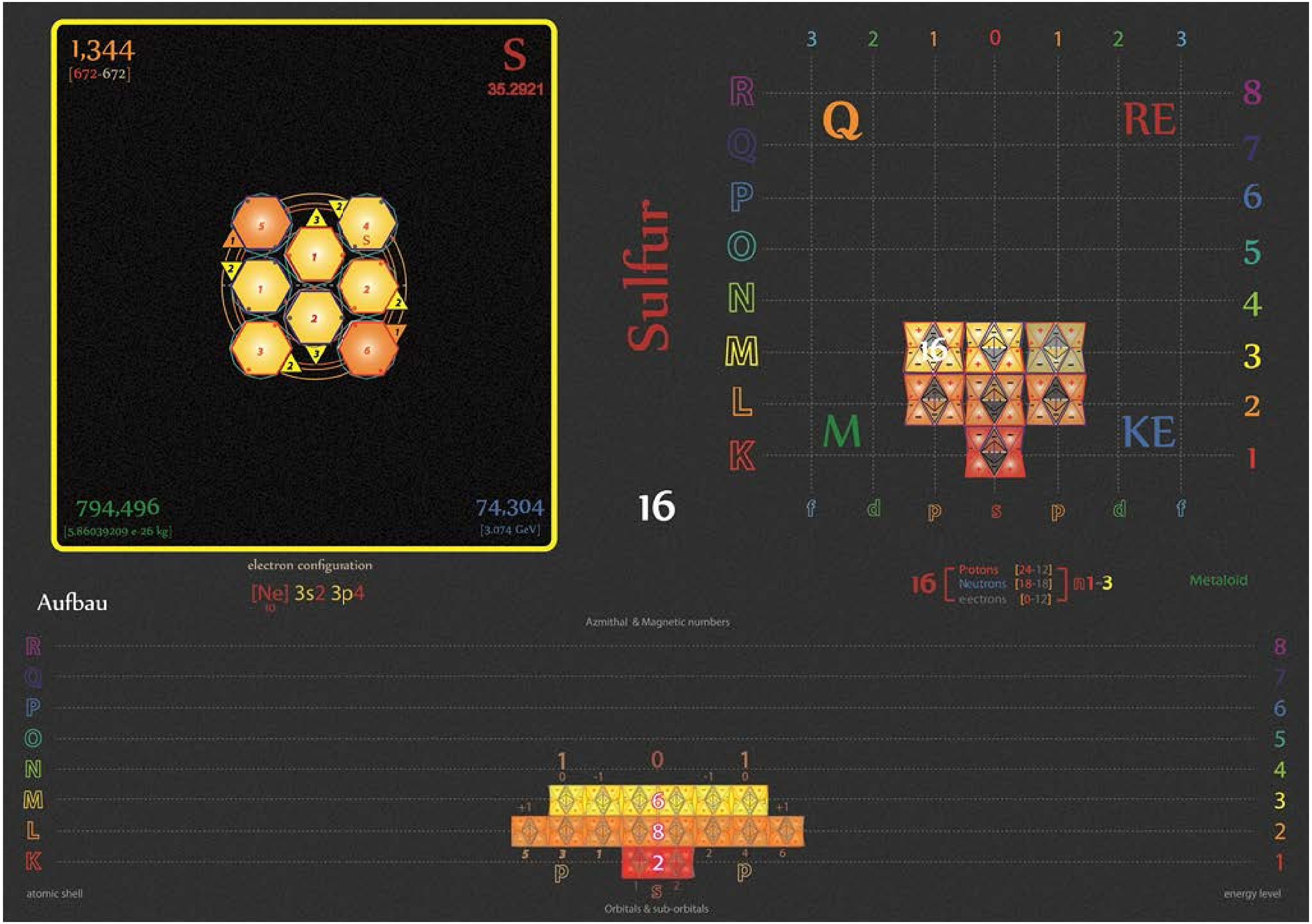
1,344
[672-672]
S
35.2921
794,496
[5.86039209 e-26 kg]
74,304
[3.074 GeV]
Sulfur
16
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ne] 3s2 3p4
10
Aufbau
16 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-3
Metaloid
Azmithal & Magnetic numbers
1 0 1
6
8
2
p s p
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.16 - Sulfur atom

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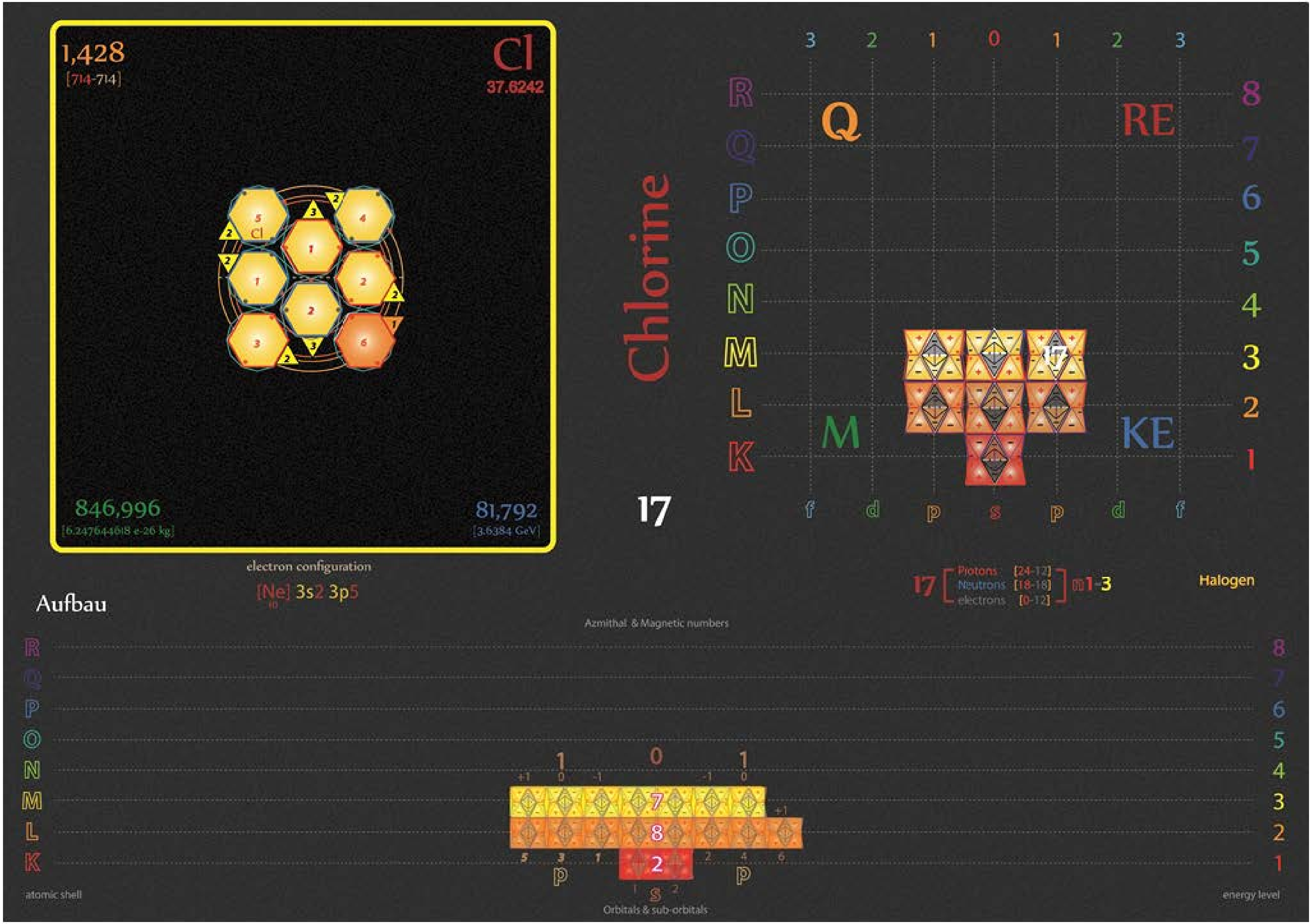
1,428
[714-714]
Cl
37.6242
Cl
846,996
[6.247644618 e-26 kg]
81,792
[3.6384 GeV]
Chlorine
17
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
17
f d p s p d f
17
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-3
Halogen
electron configuration
[Ne] 3s2 3p5
10
Aufbau
Azmithal & Magnetic numbers
1 0 1
+1 0 -1 -1 0 +1
7
8
2
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.17 - Chlorine atom

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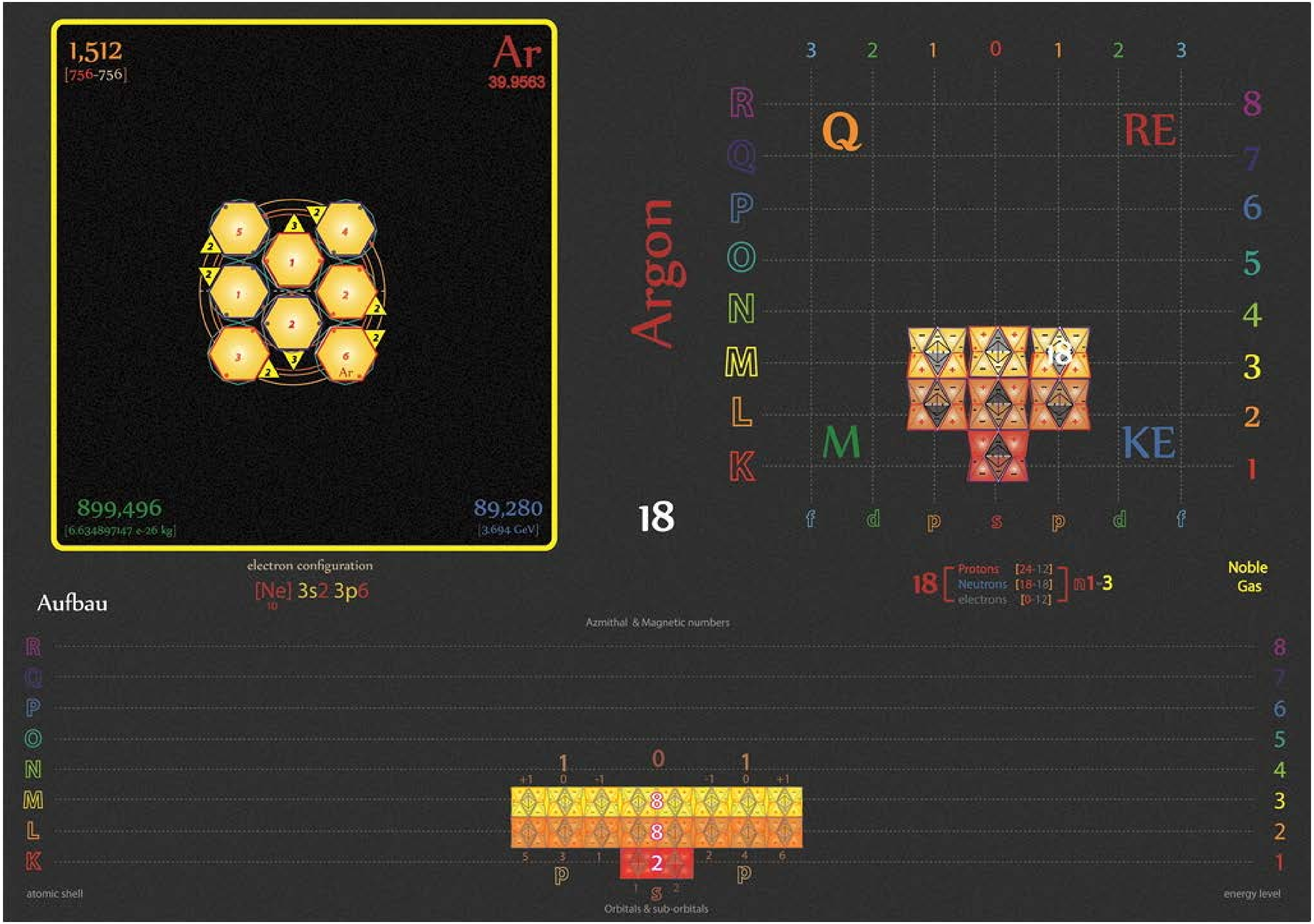
1,512
[756-756]
Ar
39.9563
5
4
3
1
2
1
2
3
6
Ar
899,496
[6.634897147 e-26 kg]
89,280
[3.694 GeV]
Argon
18
3 2 1 0 1 2 3
R Q P O N M L K
Q
RE
M
KE
8 7 6 5 4 3 2 1
18
f d p s p d f
electron configuration
[Ne] 3s2 3p6
10
18 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-3
Noble Gas
Aufbau
Azmithal & Magnetic numbers
R Q P O N M L K
1 0 1
+1 0 -1 -1 0 +1
8
8
2
5 3 1 2 4 6
p p
1 s 2
8 7 6 5 4 3 2 1
atomic shell
Orbitals & sub-orbitals
energy level

Tetryonics 51.18 - Argon atom

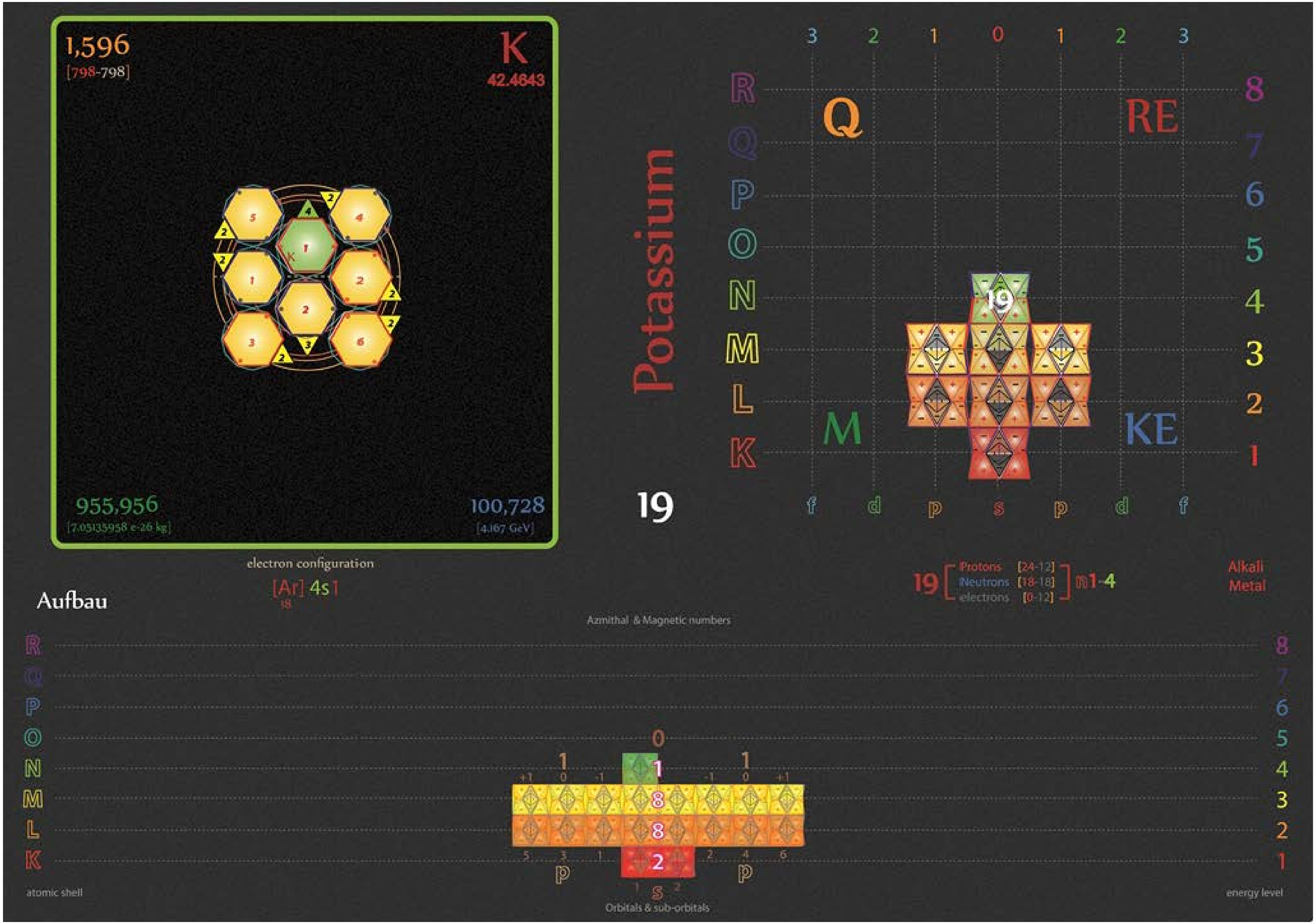
1,596
[798-798]
K
42.4643
955,956
[7.05135958 e-26 kg]
100,728
[4.167 GeV]
Potassium
19
electron configuration
[Ar] 4s1
18
Aufbau
R
Q
P
O
N
M
L
K
3
2
1
0
1
2
3
8
7
6
5
4
3
2
1
Q
RE
M
KE
19
f
d
p
s
p
d
f
19
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-4
Alkali
Metal
Azmithal & Magnetic numbers
0
1
1
+1
0
-1
-1
0
+1
1
8
8
2
5
3
1
2
4
6
p
p
1
s
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.19 - Potassium atom

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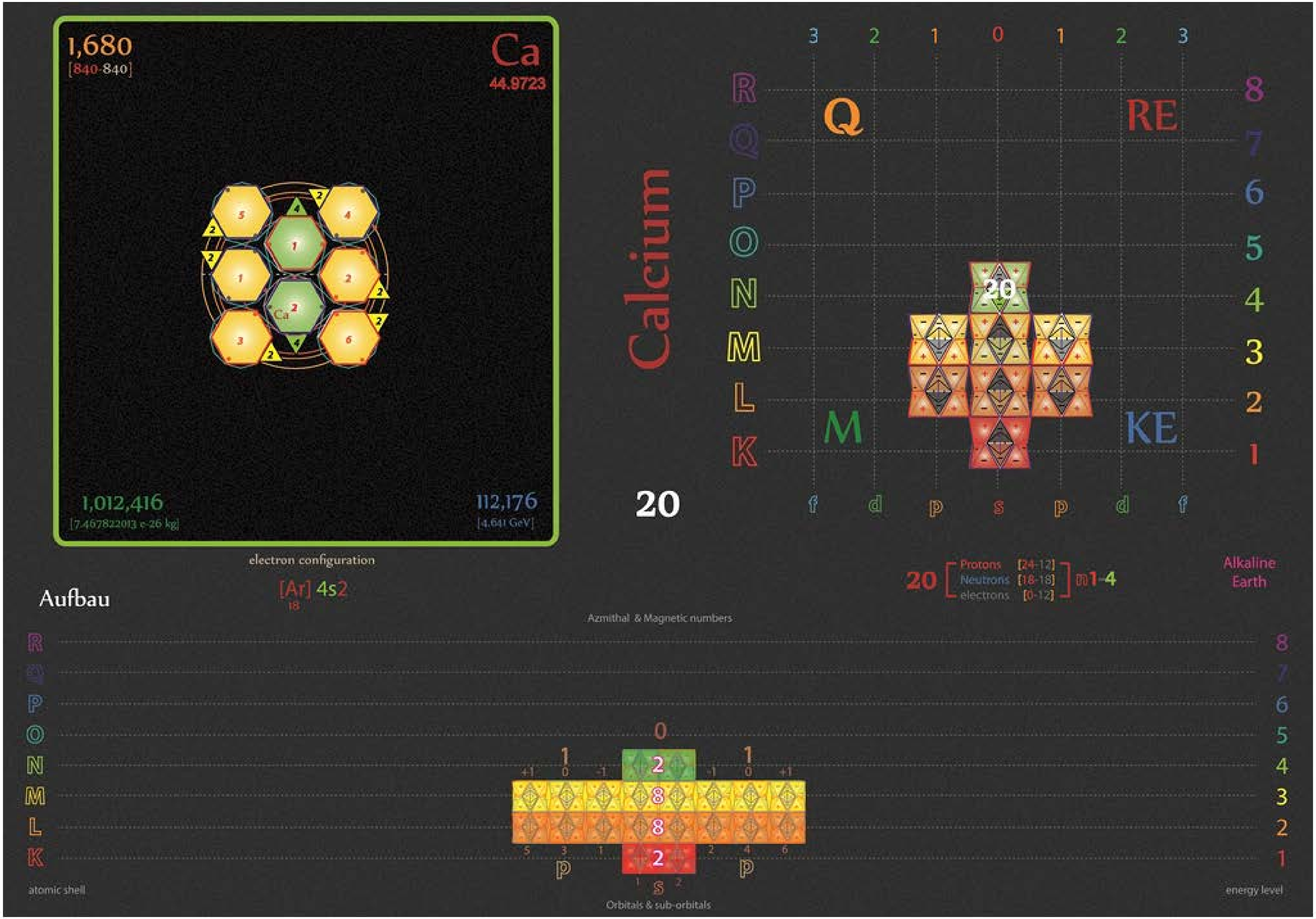
1,680
[840-840]
Ca
44.9723
1,012,416
[7.467822013 e-26 kg]
112,176
[4.641 GeV]
Calcium
20
electron configuration
[Ar] 4s2
18
Aufbau
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
8
7
6
5
4
3
2
1
f d p s p d f
20
20 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Alkaline Earth
Azmithal & Magnetic numbers
0
1
1
+1 0 -1
-1 0 +1
2
8
8
2
5 3 1
2 4 6
p
p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.20 - Calcium atom

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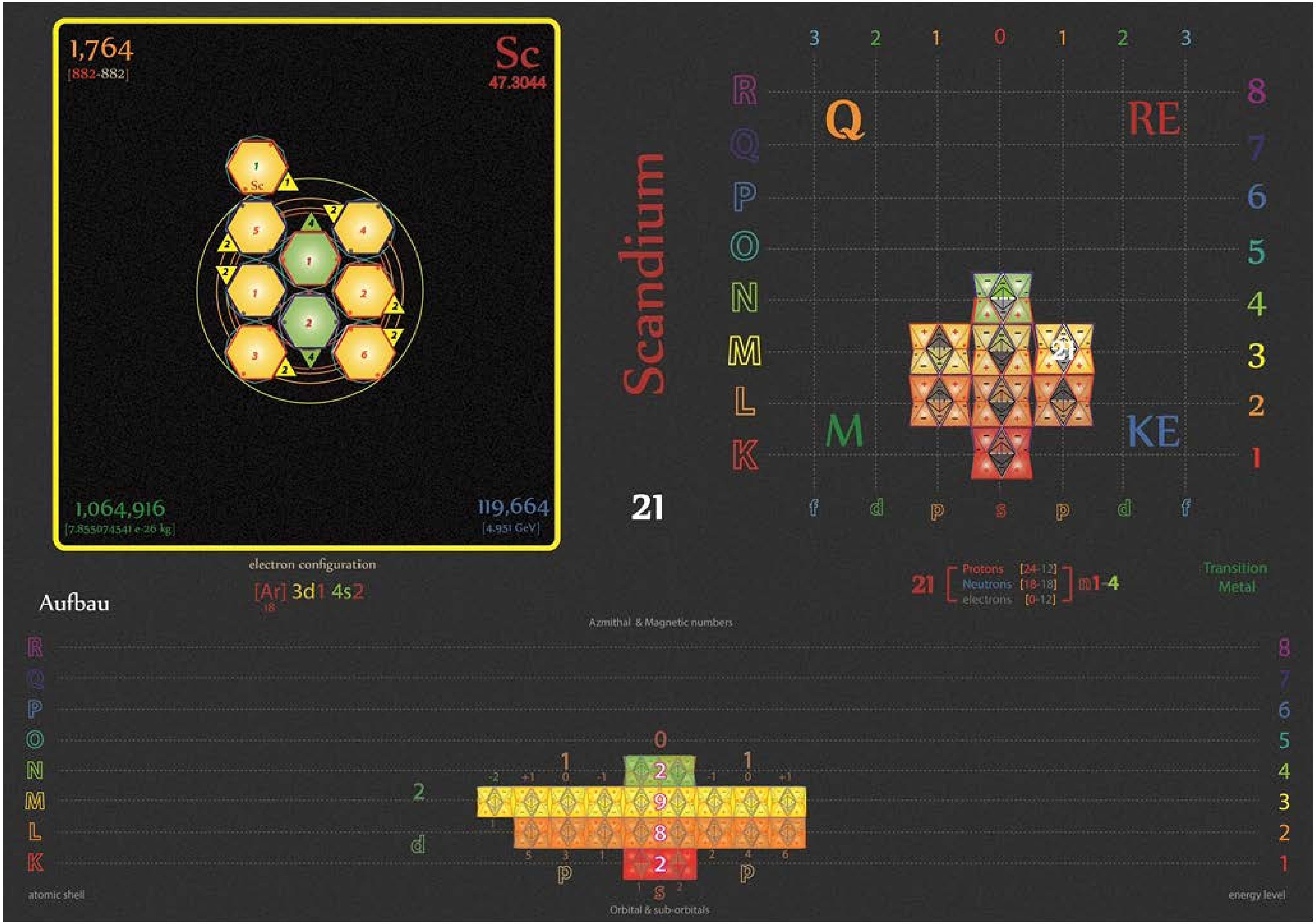
1,764
[882-882]
Sc
47.3044
1,064,916
[7.855074541 e-26 kg]
119,664
[4.951 GeV]
Scandium
21
electron configuration
[Ar] 3d1 4s2
18
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
21
f d p s p d f
21
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-4
Transition Metal
Azmithal & Magnetic numbers
0
1
1
-2 +1 0 -1
-1 0 +1
2
d
2
9
8
2
5 3 1
2 4 6
p
p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.21 - Scandium atom

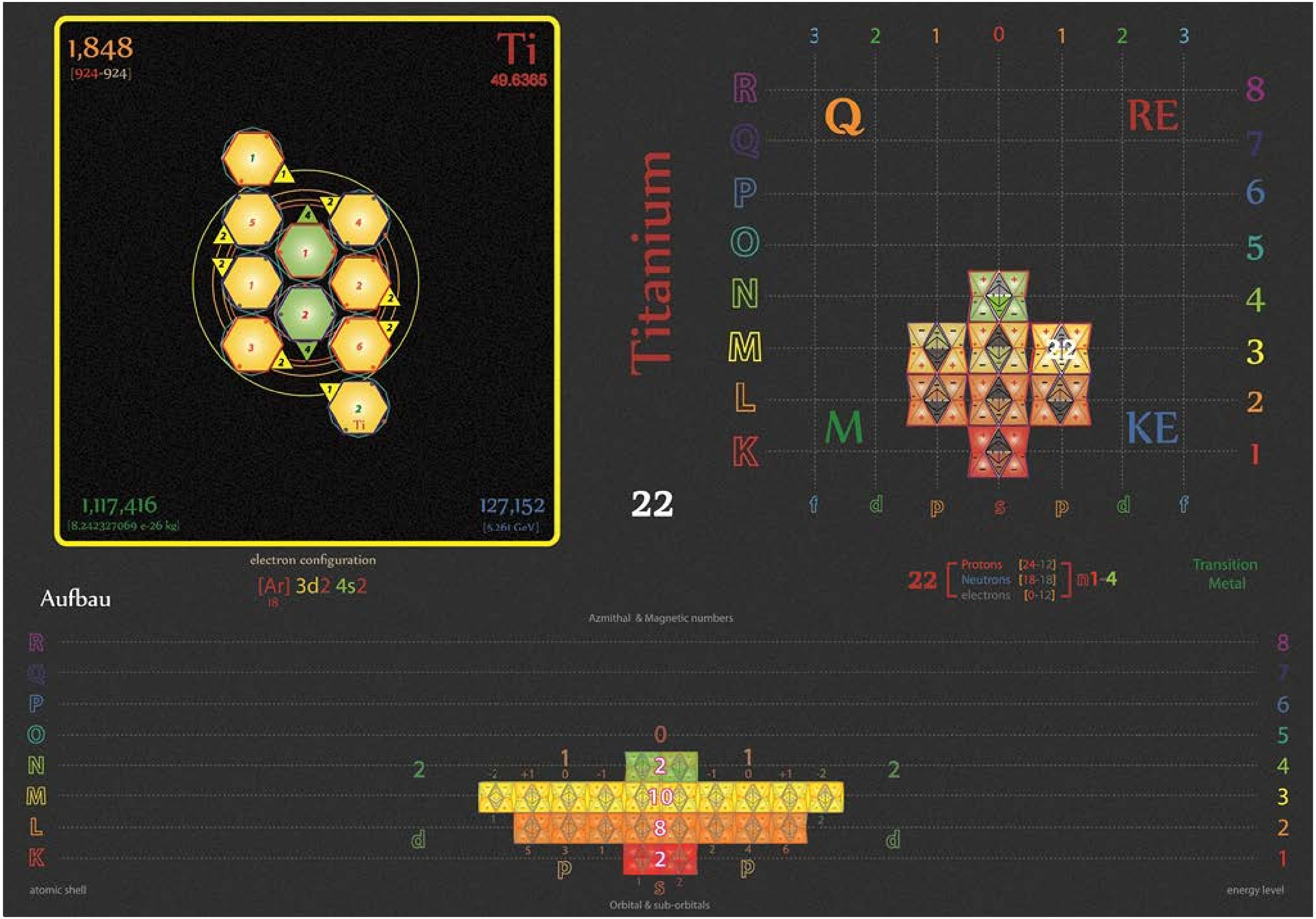
1,848
[924-924]
Ti
49.6365
Ti
1,117,416
[8.242327069 e-26 kg]
127,152
[5.261 GeV]
Titanium
22
3 2 1 0 1 2 3
R Q P O N M L K
Q
RE
M
KE
22
8 7 6 5 4 3 2 1
f d p s p d f
electron configuration
[Ar] 3d2 4s2
18
Aufbau
22
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-4
Transition Metal
Azmithal & Magnetic numbers
R Q P O N M L K
0
2
1
1
2
-2 +1 0 -1
-1 0 +1 -2
2
10
8
2
d
d
p
p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.22 - Titanium atom

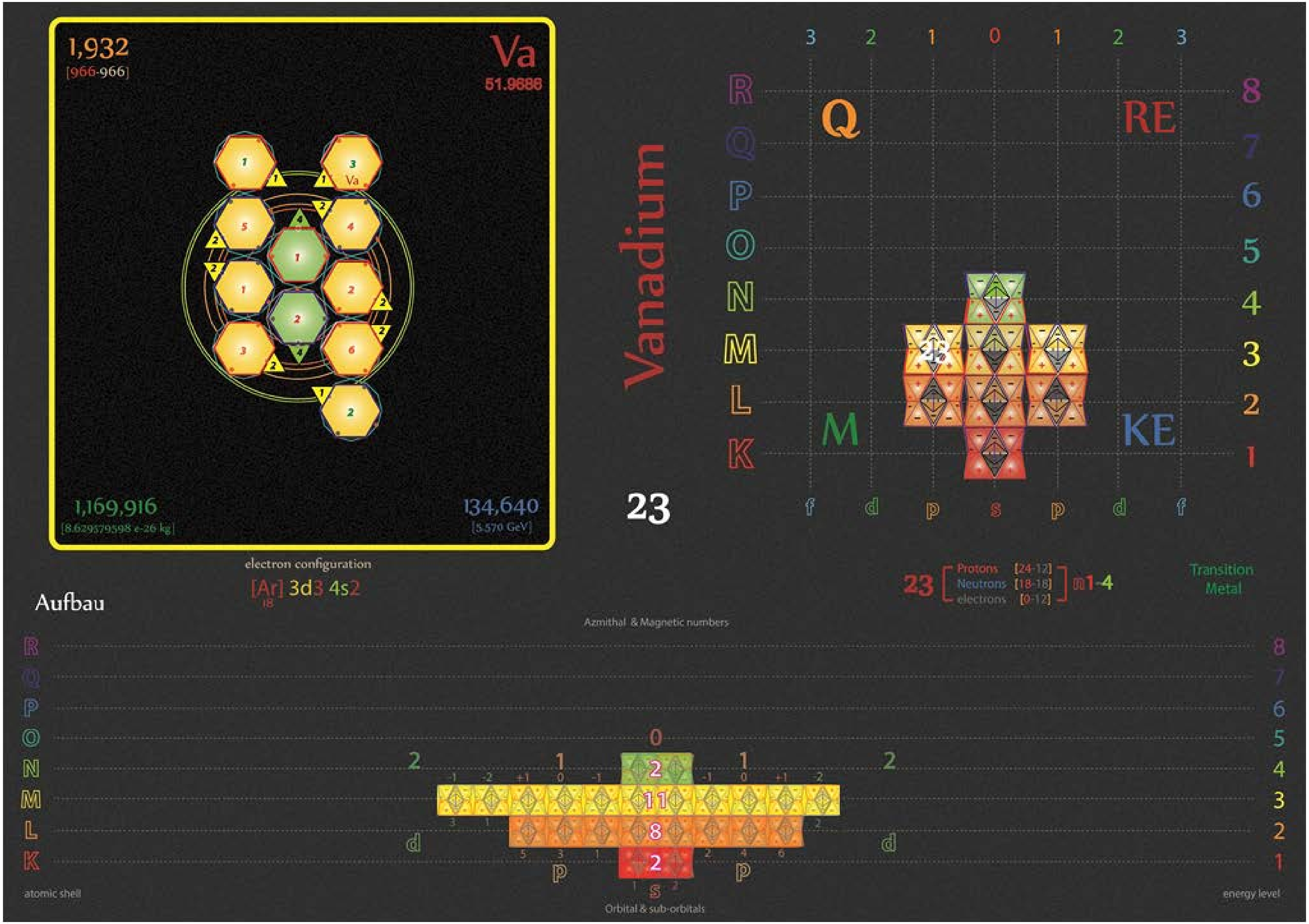
1,932
[966-966]
Va
51.9888
1,169,916
[8.629579598 e-26 kg]
134,640
[5.570 GeV]
Vanadium
23
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ar] 3d3 4s2
18
Aufbau
23 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
-1 -2 +1 0 -1 -1 0 +1 -2
2
11
8
2
d p s p d
Orbital & sub-orbitals
atomic shell
energy level

Tetryonics 51.23 - Vanadium atom

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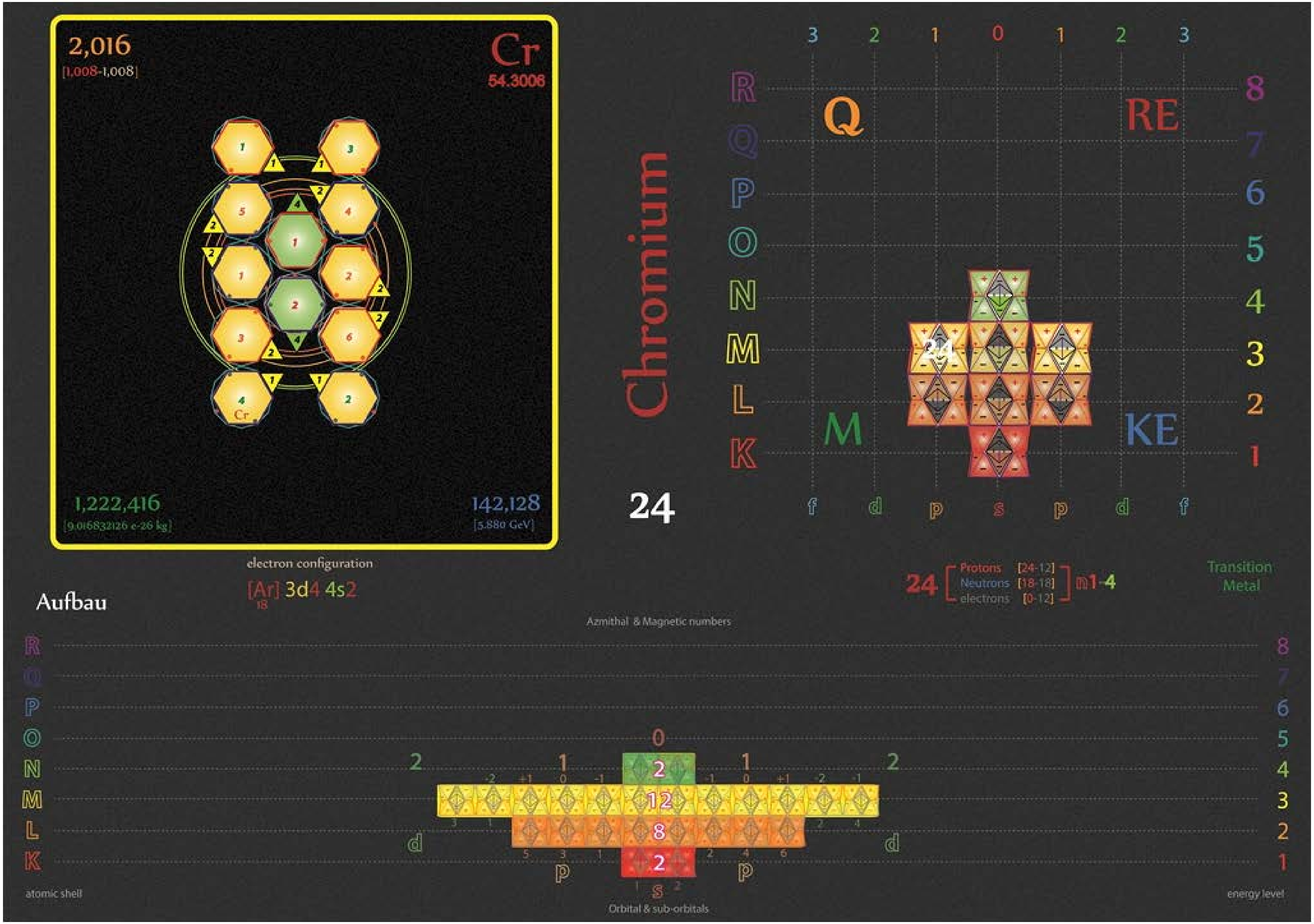
2,016
[1,008-1,008]
Cr
54.3008
1,222,416
[9.016832126 e-26 kg]
142,128
[5.880 GeV]
Chromium
24
electron configuration
[Ar] 3d4 4s2
18
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
24 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Transition Metal
Azmithal & Magnetic numbers
2 1 0 1 2
2
12
8
2
d p s p d
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.24 - Chromium atom

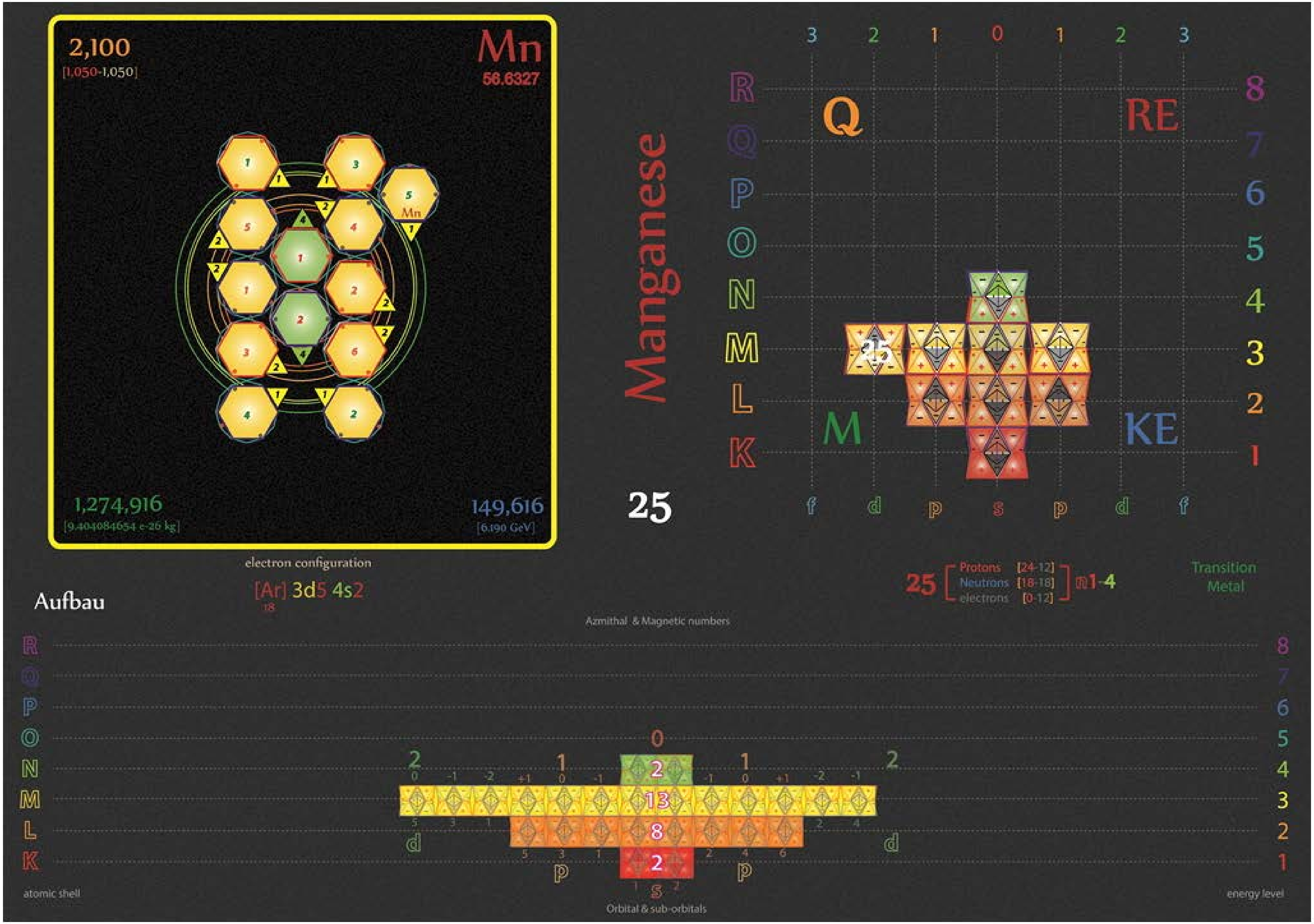
2,100
[1,050-1,050]
Mn
56.6327
1,274,916
[9.404084654 e-26 kg]
149,616
[6.190 GeV]
Manganese
25
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
electron configuration
[Ar] 3d5 4s2
18
Aufbau
Azmithal & Magnetic numbers
25
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-4
Transition Metal
2
13
8
2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.25 - Manganese atom

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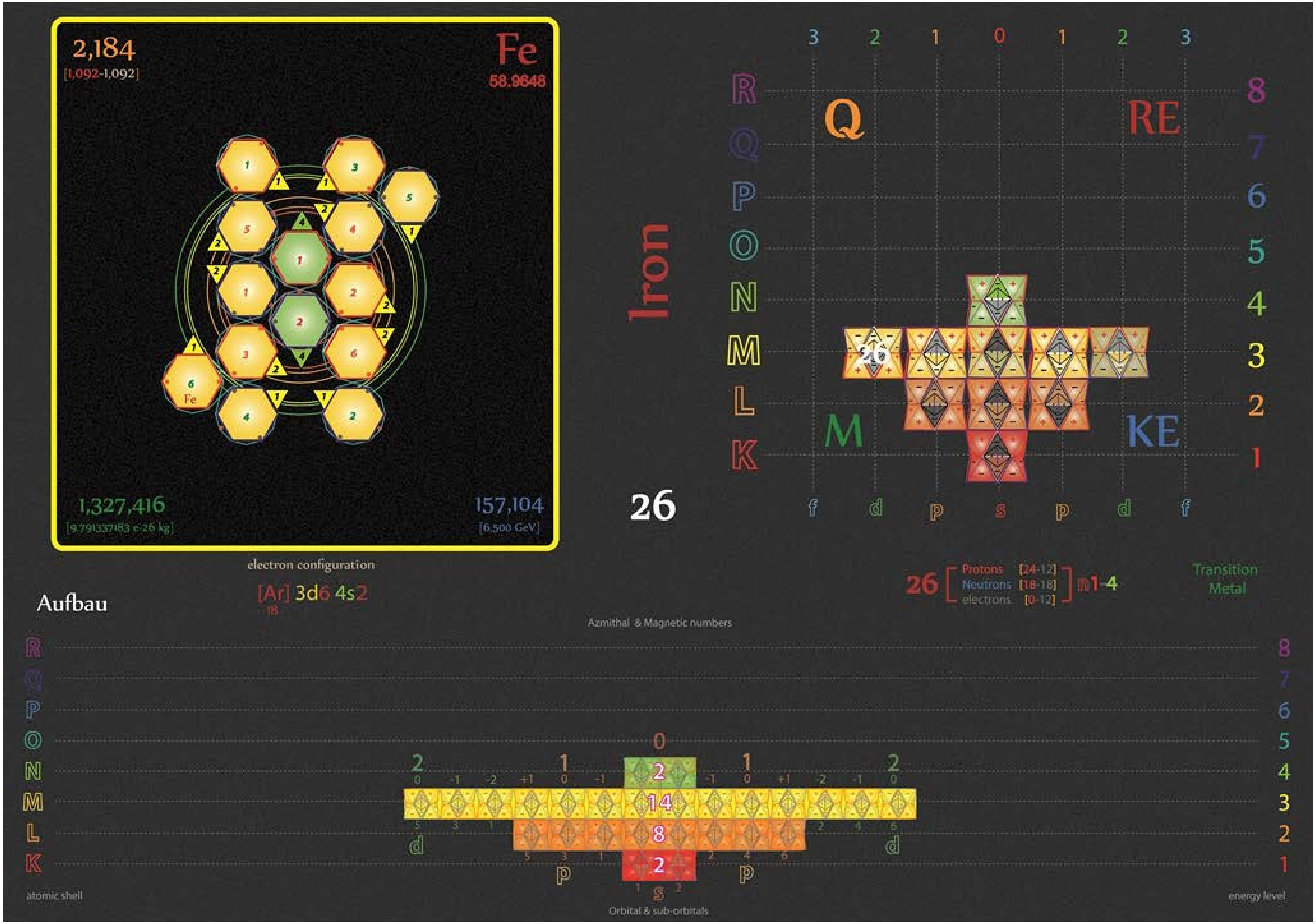
2,184
[1,092-1,092]
Fe
58.9648
1,327,416
[9.791337183 e-26 kg]
157,104
[6,500 GeV]
electron configuration
[Ar] 3d6 4s2
18
Aufbau
Iron
26
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
26 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Transition Metal
Azmithal & Magnetic numbers
2 1 0 1 2
0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0
2
14
8
2
5 3 1 2 4 6
d p s p d
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.26 - Iron atom

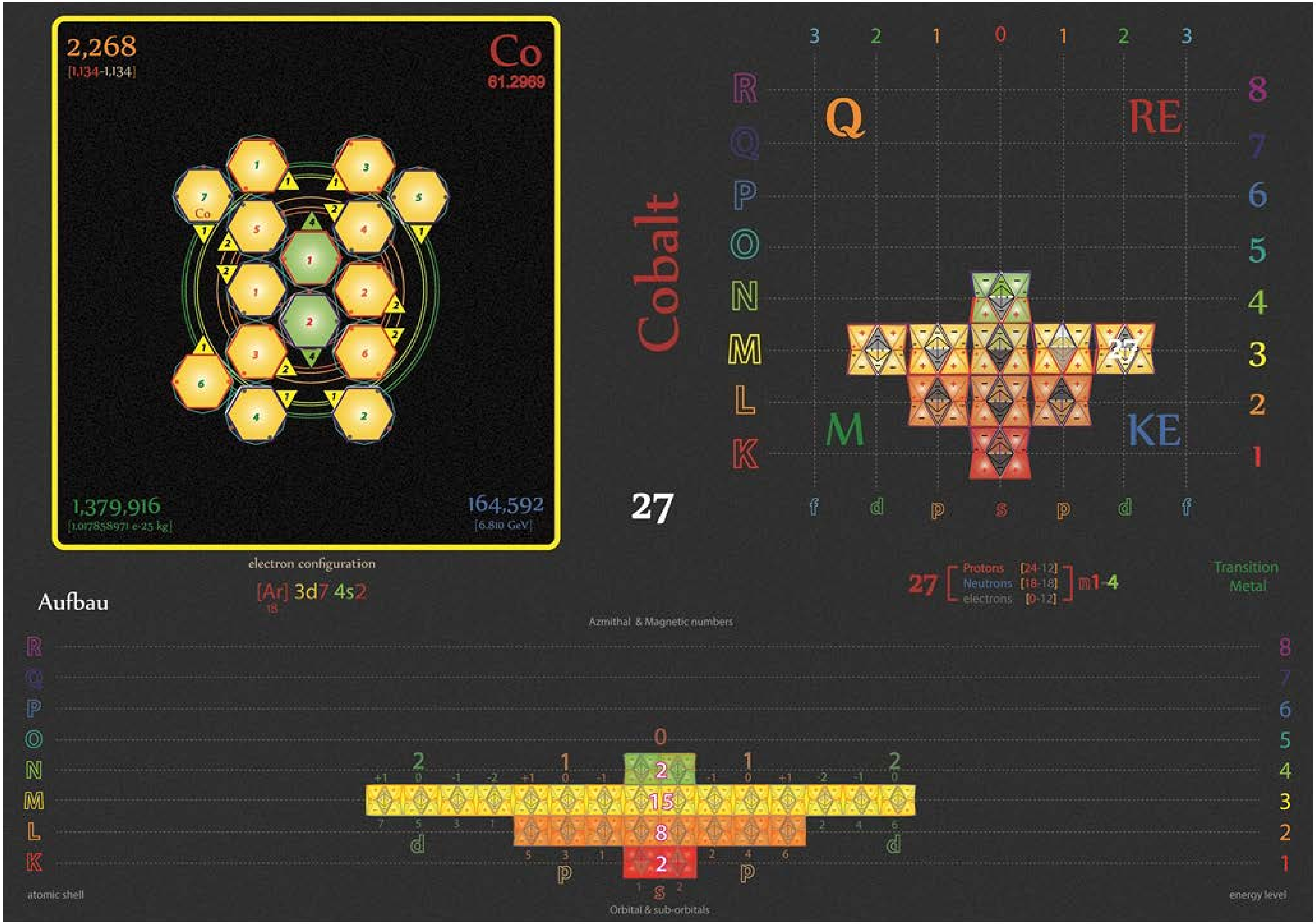
2,268
[1,134-1,134]
Co
61.2969
1,379,916
[1.017858971 e-25 kg]
164,592
[6.810 GeV]
Cobalt
27
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ar] 3d7 4s2
18
Aufbau
Azmithal & Magnetic numbers
27 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Transition Metal
0
2 1 1 2
+1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0
2
15
8
2
7 5 3 1 2 4 6
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.27 - Cobalt atom

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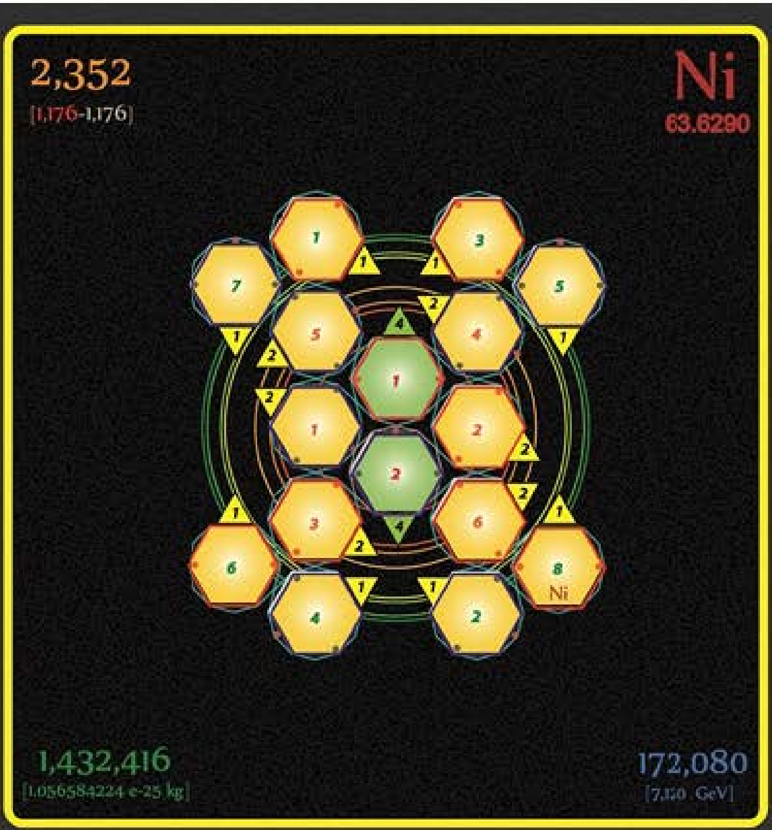
1
3
7
5
5
4
1
2
1
2
3
6
6
8
Ni
4
2

2,352
[1,176-1,176]

Ni
63.6290

1,432,416
[1.056584224 e-25 kg]

172,080
[7,110 GeV]

Nickel

28

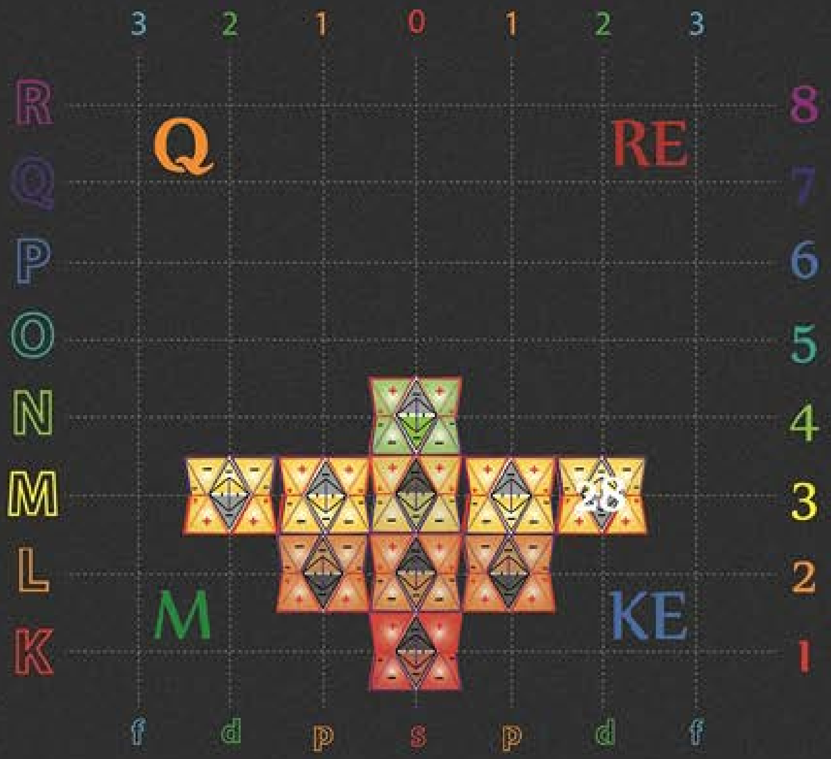
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
28
f
d
p
s
p
d
f

electron configuration

[Ar] 3d8 4s2
18

28 [Protons [24-12]
Neutrons [18-18]
electrons [0-12]] m1-4

Transition
Metal

Aufbau

Azmithal & Magnetic numbers

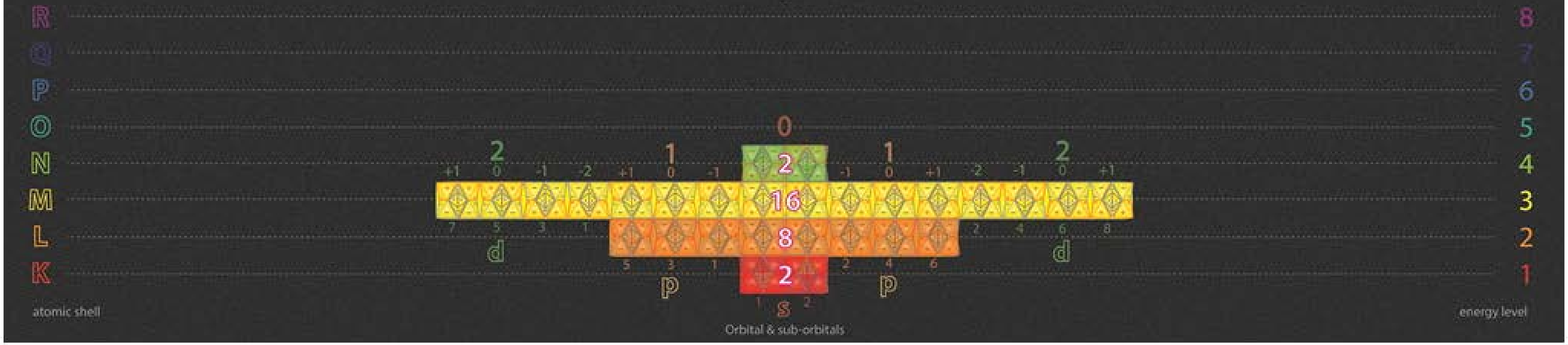
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
2
1
1
2
+1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1
2
16
8
2
7 5 3 1
2 4 6 8
d
d
5 3 1
2 4 6
p
p
1
s
2

atomic shell

energy level

Orbital & sub-orbitals

Tetryonics 51.28 - Nickel atom

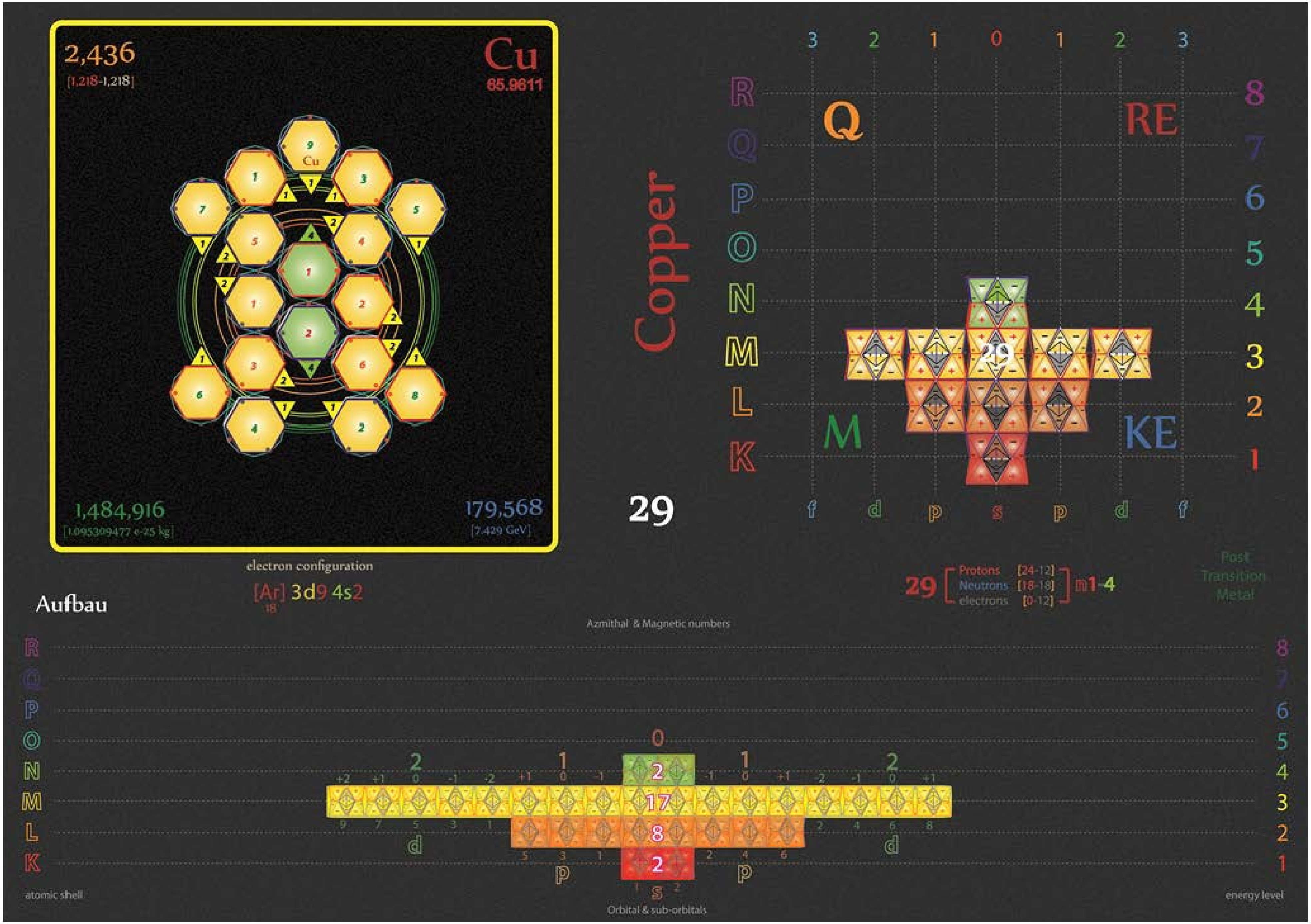
2,436
[1,218-1,218]
Cu
65.9811
9
Cu
1,484,916
[1.095309477 e-25 kg]
179,568
[7.429 GeV]
Copper
29
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
8
7
6
5
4
3
2
1
f d p s p d f
electron configuration
[Ar] 3d9 4s2
18
Aufbau
29 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-4
Post Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1
2
17
8
2
9 7 5 3 1 2 4 6 8
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.29 - Copper atom

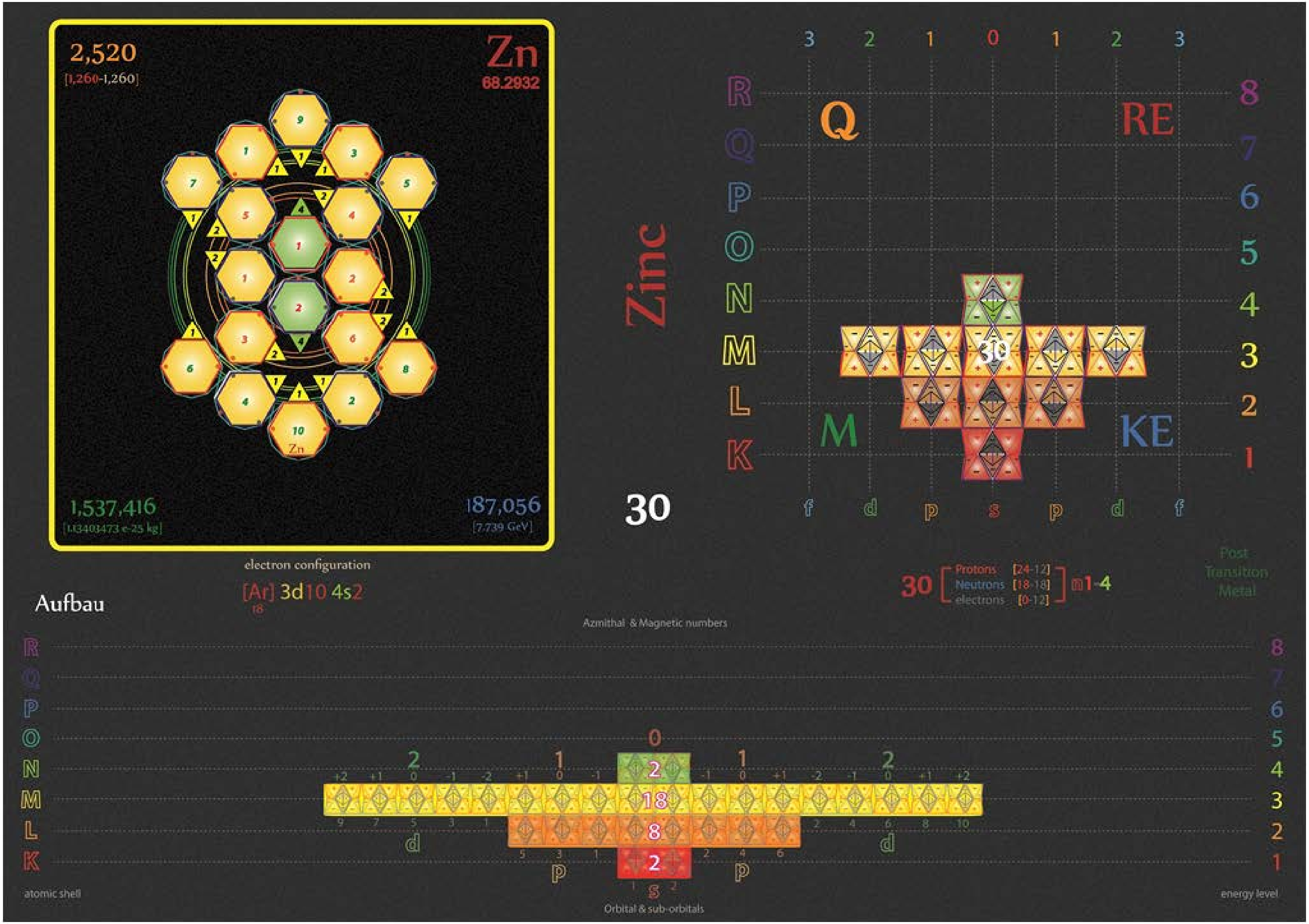
2,520
[1,260-1,260]
Zn
68.2932
Zn
1,537,416
[1.13403473 e-25 kg]
187,056
[7.739 GeV]
Zinc
30
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
30
f d p s p d f
electron configuration
[Ar] 3d10 4s2
18
Aufbau
30 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Post Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
2
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.30 - Zinc atom

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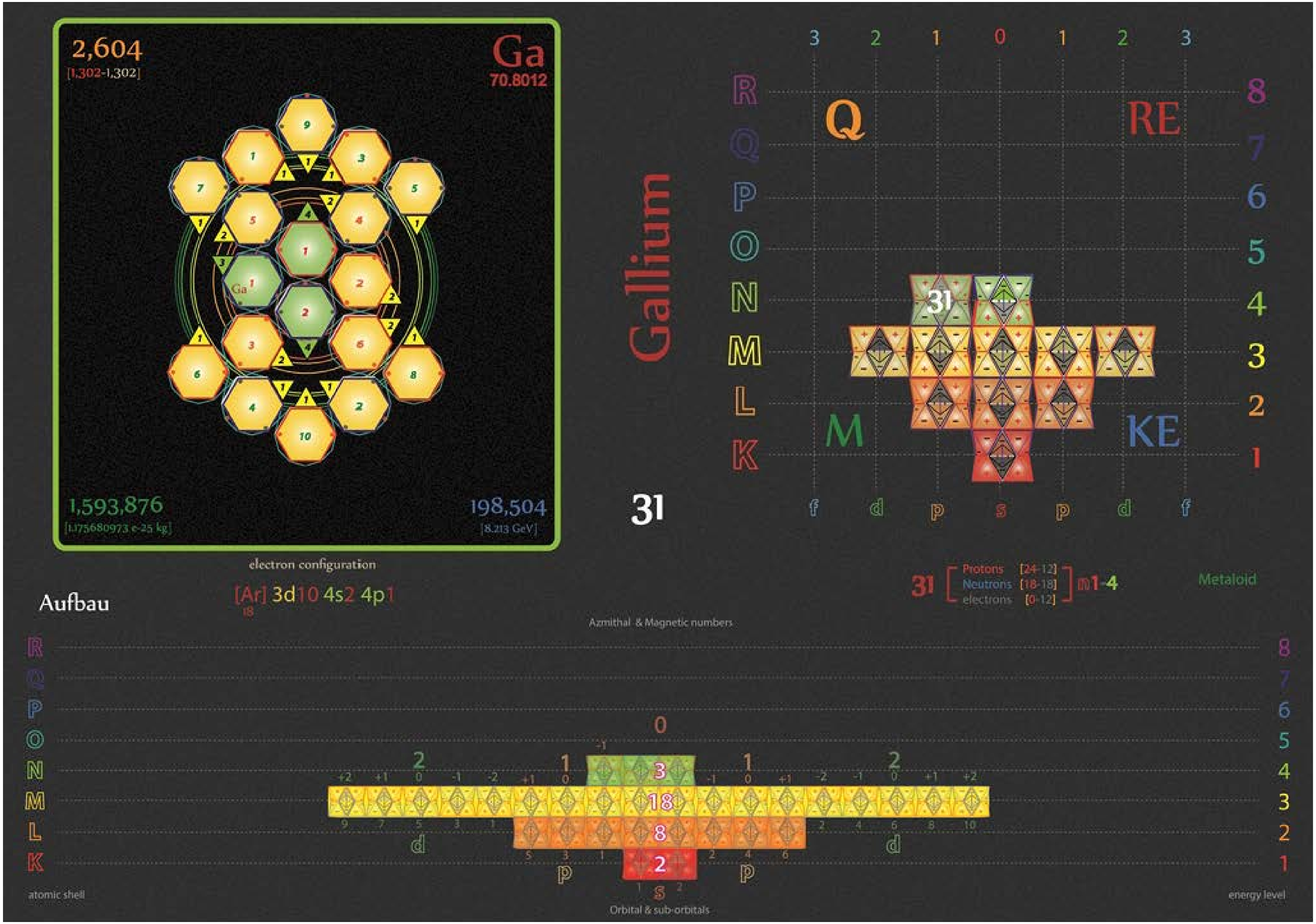
2,604
[1,302-1,302]
Ga
70.8012
1,593,876
[1.175680973 e-25 kg]
198,504
[8.213 GeV]
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
31
f d p s p d f
R Q P O N M L K
8 7 6 5 4 3 2 1
0
2 1 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
3
18
8
2
9 7 5 3 1 2 4 6 8 10
5 3 1 2 4 6
1 2
d p s p d
atomic shell
energy level
Orbital & sub-orbitals

Gallium

31

electron configuration

Aufbau

[Ar] 3d10 4s2 4p1
18

Azmithal & Magnetic numbers

31 [Protons [24-12]
Neutrons [18-18]
electrons [0-12]] m1-4

Metaloid

Tetryonics 51.31 - Gallium atom

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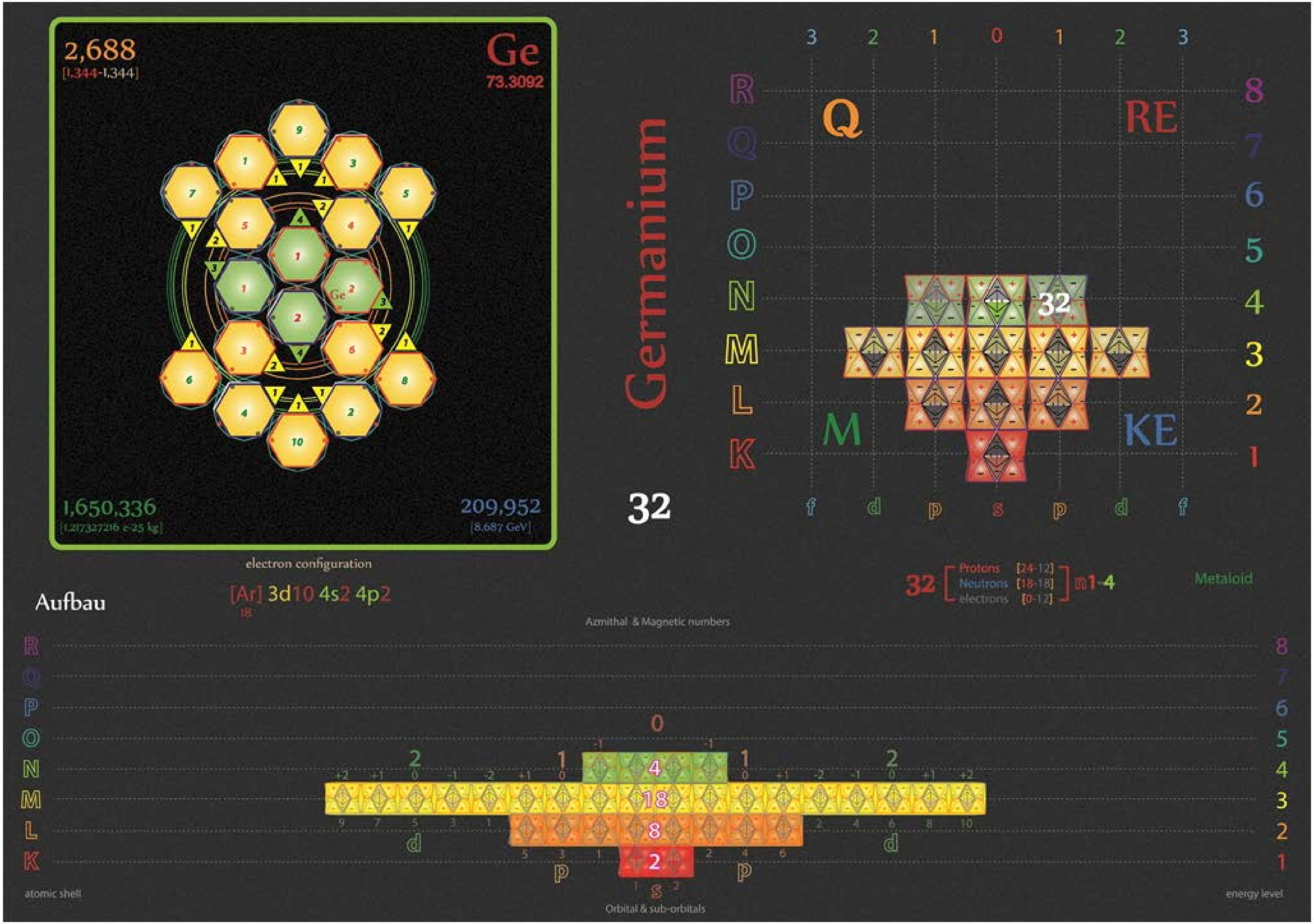
2,688
[1,344-1,344]
Ge
73.3092
1,650,336
[1.217327216 e-25 kg]
209,952
[8,687 GeV]
Germanium
32
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ar] 3d10 4s2 4p2
18
Aufbau
32 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-4
Metaloid
Azmithal & Magnetic numbers
0
2 1 1 2
-1 -1
+2 +1 0 -1 -2 +1 0 0 +1 -2 -1 0 +1 +2
4
18
8
2
9 7 5 3 1 2 4 6 8 10
5 3 1 2 4 6
1 2
d d
p p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.32 - Germanium atom

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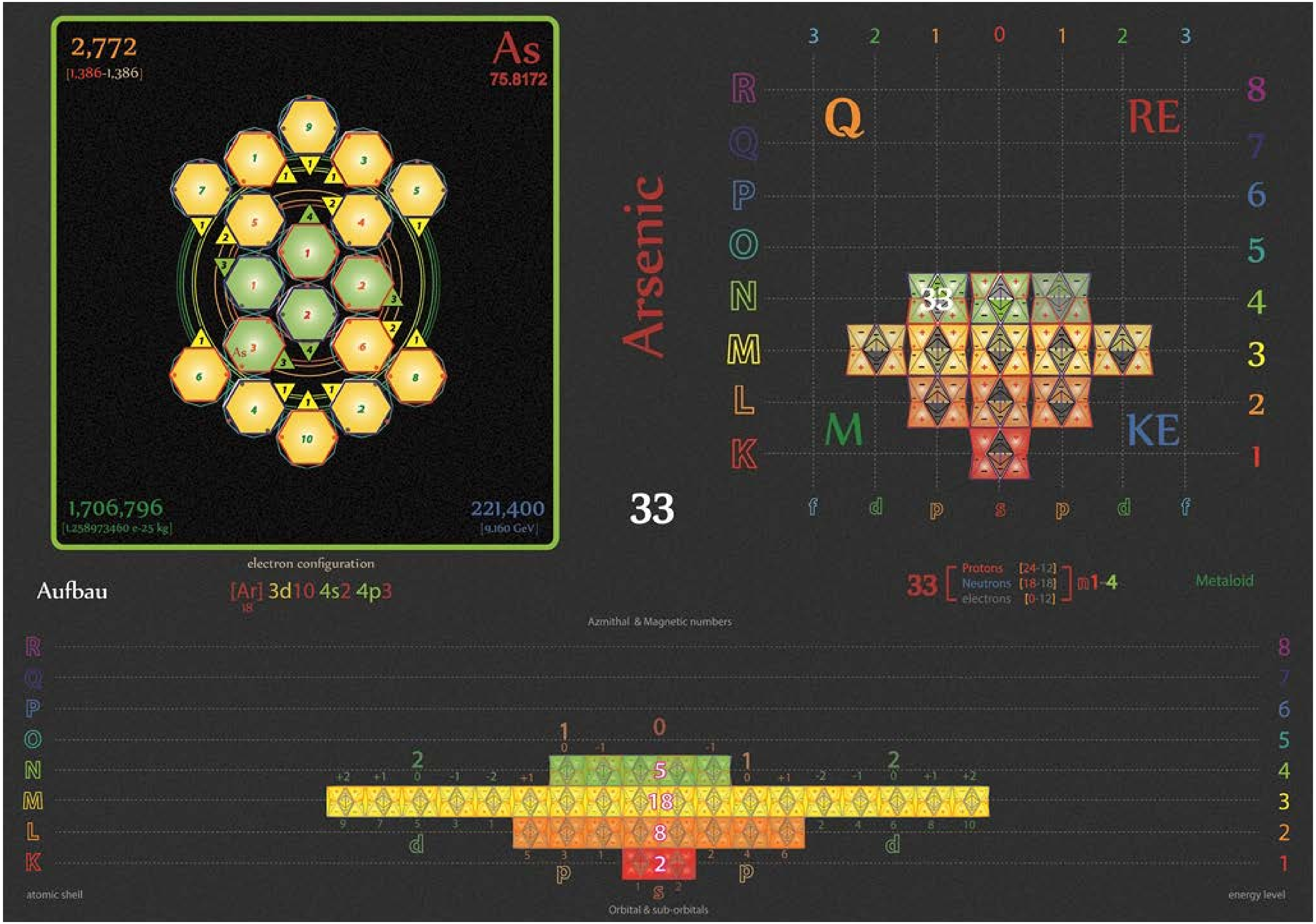
2,772
[1,386-1,386]
As
75.8172
1,706,796
[1.258973460 e-25 kg]
221,400
[9.160 GeV]
Arsenic
33
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Ar] 3d10 4s2 4p3
18
33 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Metaloid
Azmithal & Magnetic numbers
5
18
8
2
d p s p d
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.33 - Arsenic atom

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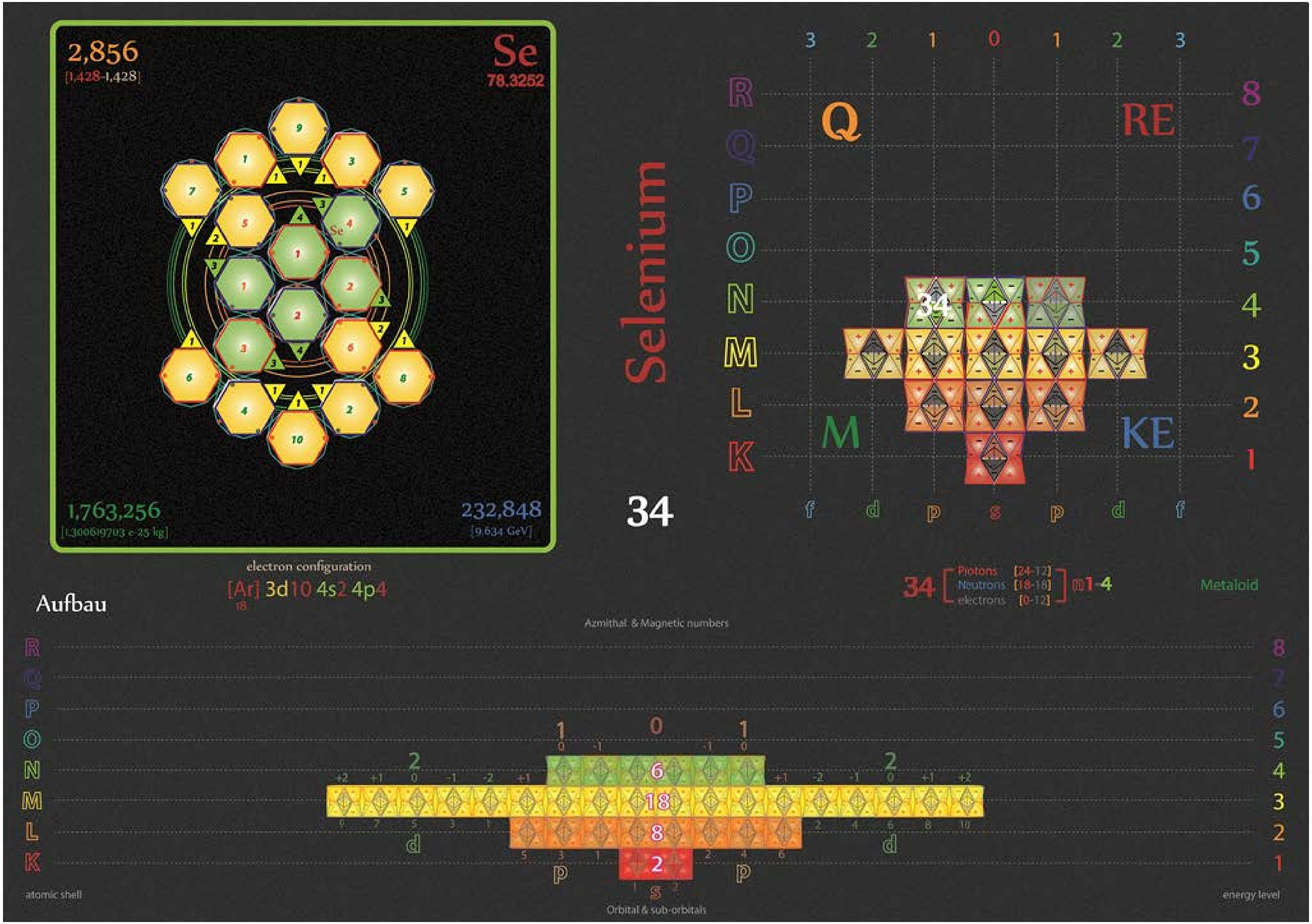
2,856
[1,428-1,428]
Se
78.3252
1,763,256
[1.30069703 e-25 kg]
232,848
[9.634 GeV]
Selenium
34
electron configuration
[Ar] 3d10 4s2 4p4
18
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
34 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Metaloid
Azmithal & Magnetic numbers
2 1 0 1 2
6
18
8
2
d p s p d
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.34 - Selenium atom

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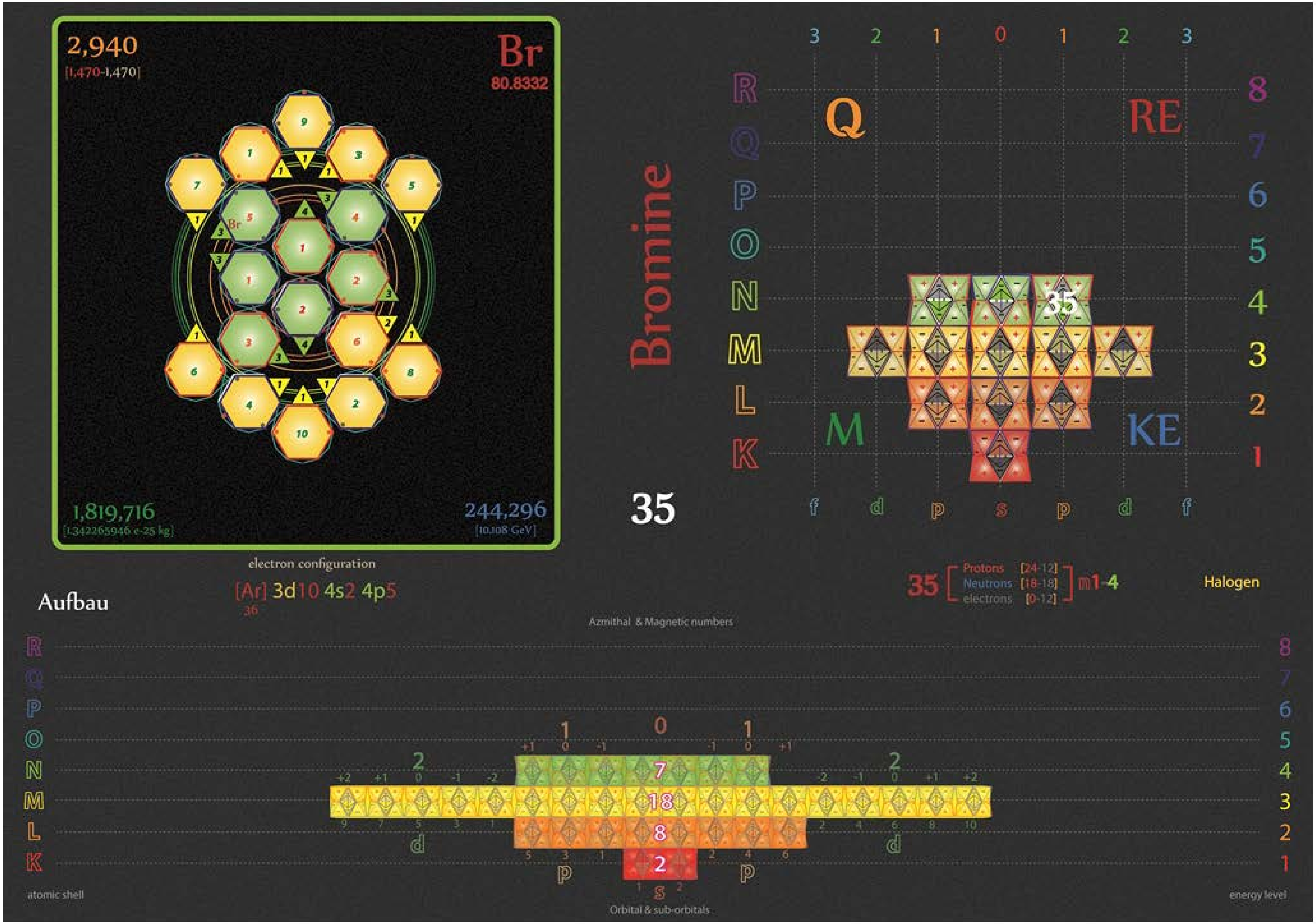
2,940
[1,470-1,470]
Br
80.8332
1,819,716
[1.342265946 e-25 kg]
244,296
[10.108 GeV]
Bromine
35
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ar] 3d10 4s2 4p5
36
Aufbau
Azmithal & Magnetic numbers
35 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Halogen
7
18
8
2
d
p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.35 - Bromine atom

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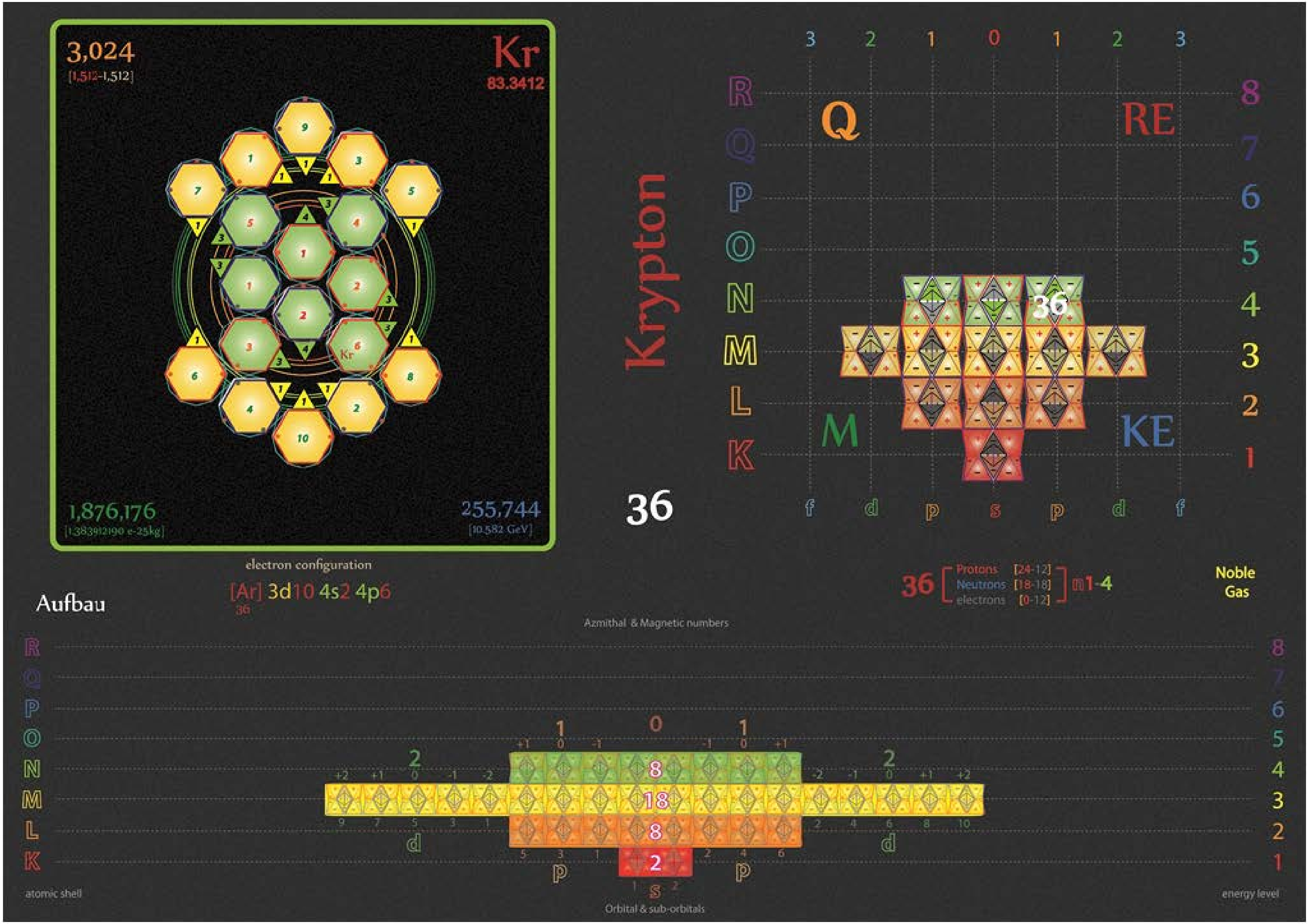
3,024
[1,512-1,512]
Kr
83.3412
1,876,176
[1.383912190 e-25kg]
255,744
[10.582 GeV]
Krypton
36
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ar] 3d10 4s2 4p6
36
Aufbau
36 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Noble Gas
Azmithal & Magnetic numbers
1 0 1
2 2
+1 0 -1 -1 0 +1
+2 +1 0 -1 -2 -2 -1 0 +1 +2
8
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.36 - Krypton atom

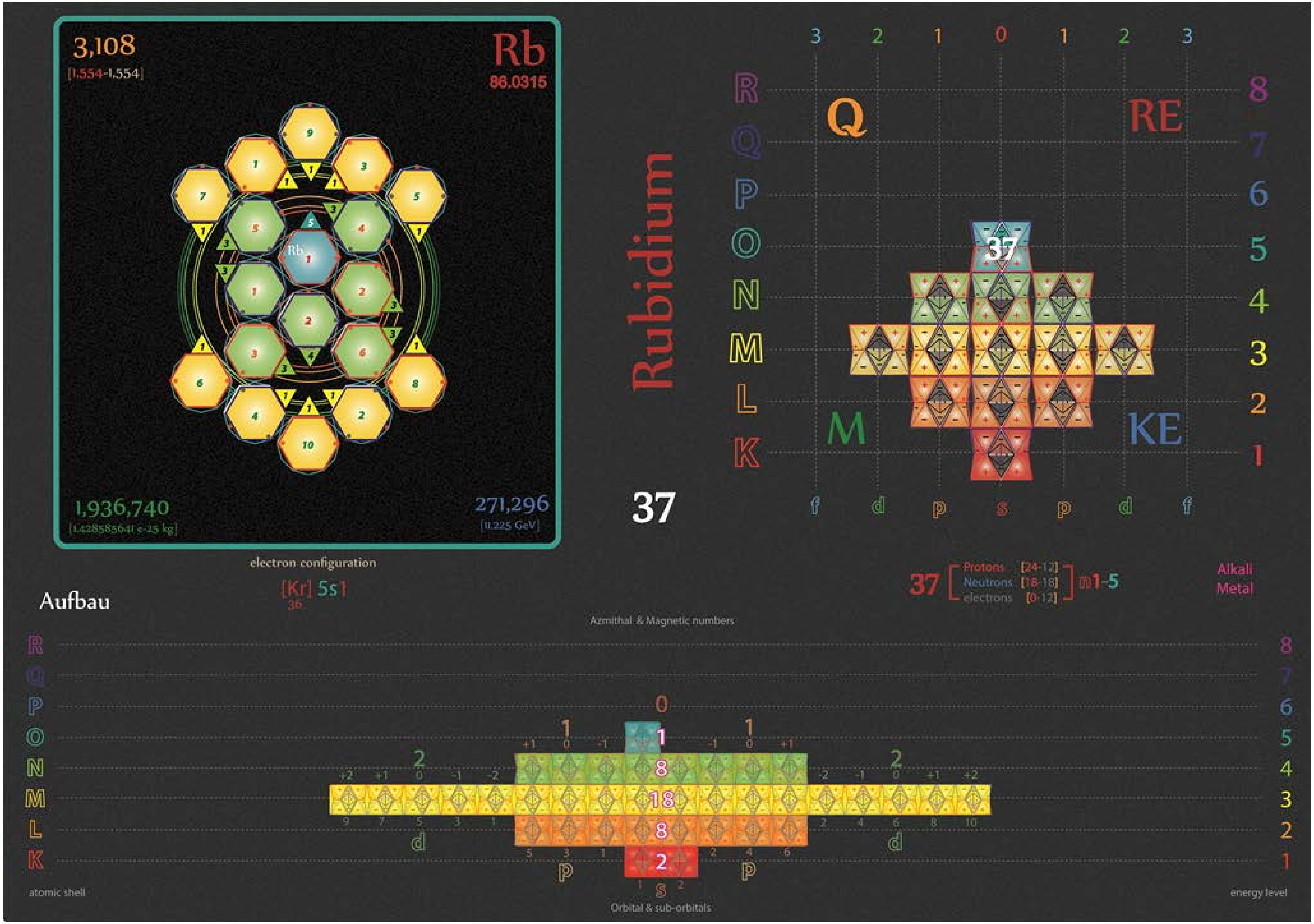
3,108
[1.554-1.554]
Rb
86.0315
1,936,740
[1.428585641 e-25 kg]
271,296
[11.225 GeV]
Rubidium
37
electron configuration
[Kr] 5s1
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
37
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-5
Alkali Metal
Azmithal & Magnetic numbers
atomic shell
energy level
Orbital & sub-orbitals
1
8
18
8
2
s
p
d

Tetryonics 51.37 - Rubidium atom

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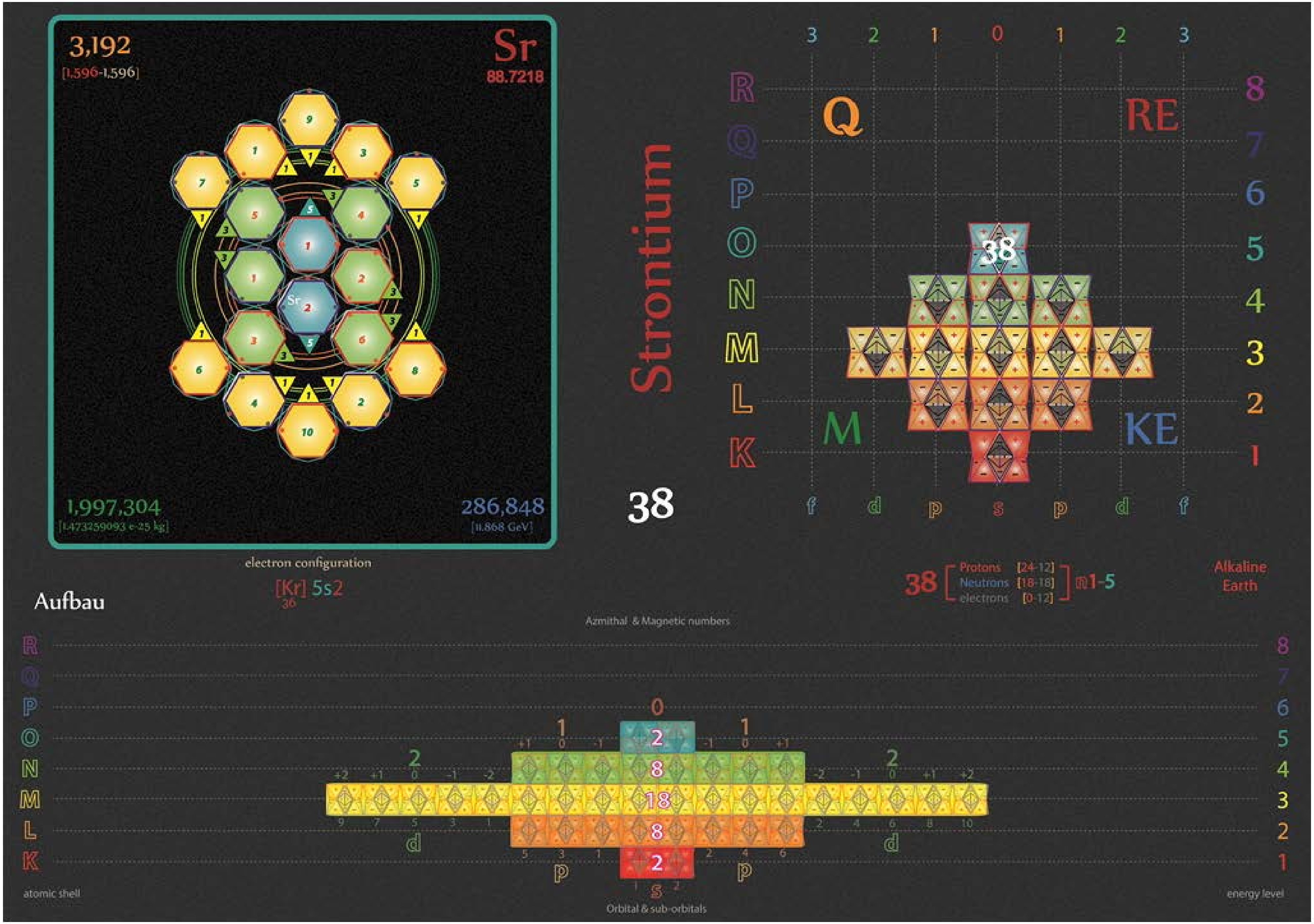
3,192
[1,596-1,596]
Sr
88.7218
1,997,304
[1.473259093 e-25 kg]
286,848
[11.868 GeV]
electron configuration
[Kr] 5s2
36
Strontium
38
Aufbau
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
38 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-5
Alkaline Earth
Azmithal & Magnetic numbers
0
1
1
2
2
+1 0 -1
-1 0 +1
+2 +1 0 -1 -2
-2 -1 0 +1 +2
2
8
18
8
2
9 7 5 3 1
2 4 6 8 10
d
d
5 3 1
2 4 6
p
p
1 2
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.38 - Strontium atom

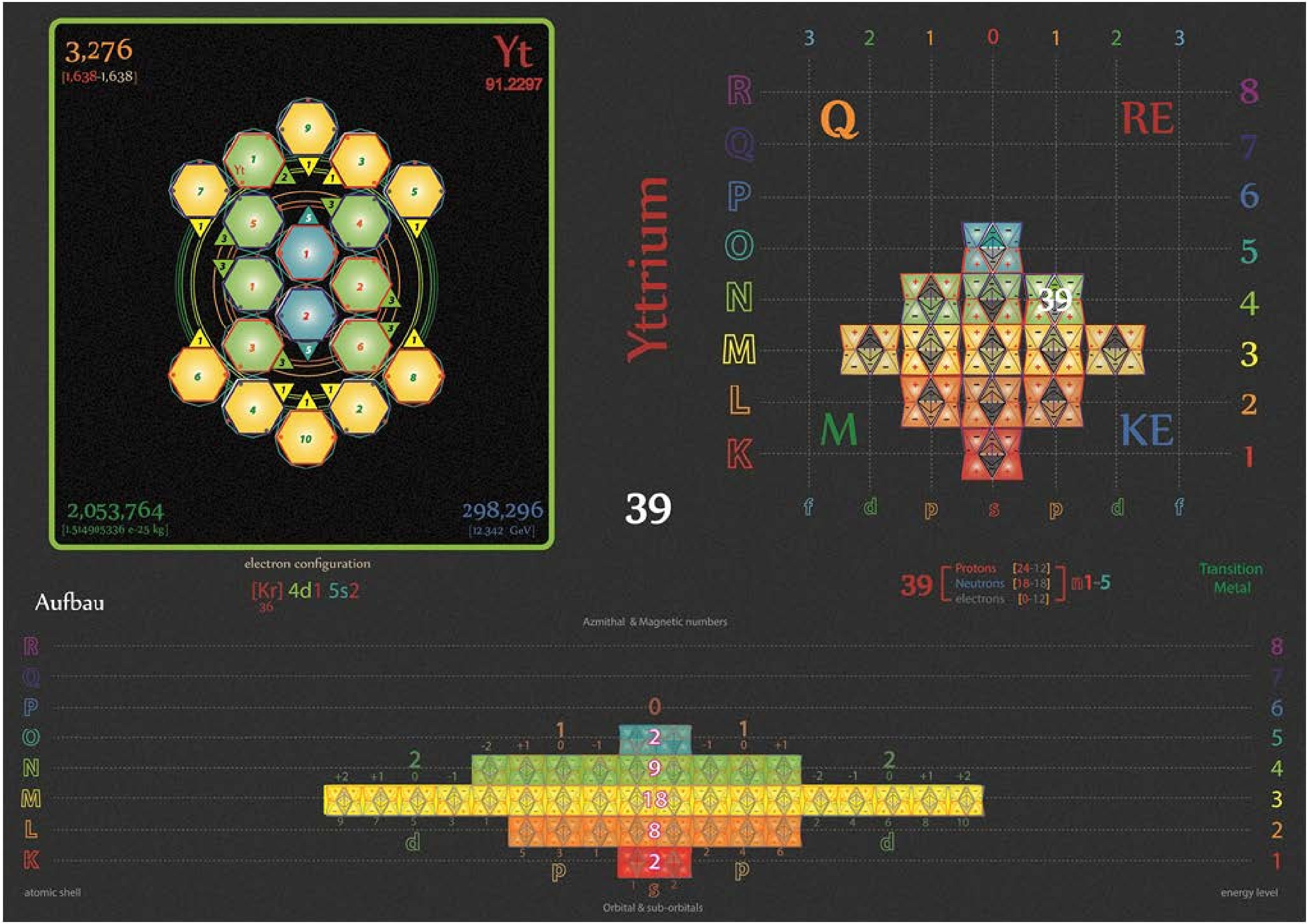
3,276
[1,638-1,638]
Yt
91.2297
2,053,764
[1.514905336 e-25 kg]
298,296
[12.342 GeV]
Yttrium
39
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
39
f d p s p d f
electron configuration
[Kr] 4d1 5s2
36
Aufbau
39
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-5
Transition Metal
Azmithal & Magnetic numbers
0
1
1
2
2
-2 +1 0 -1
-1 0 +1
+2 +1 0 -1
-2 -1 0 +1 +2
2
9
18
8
2
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
d
d
p
p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.39 - Yttrium atom

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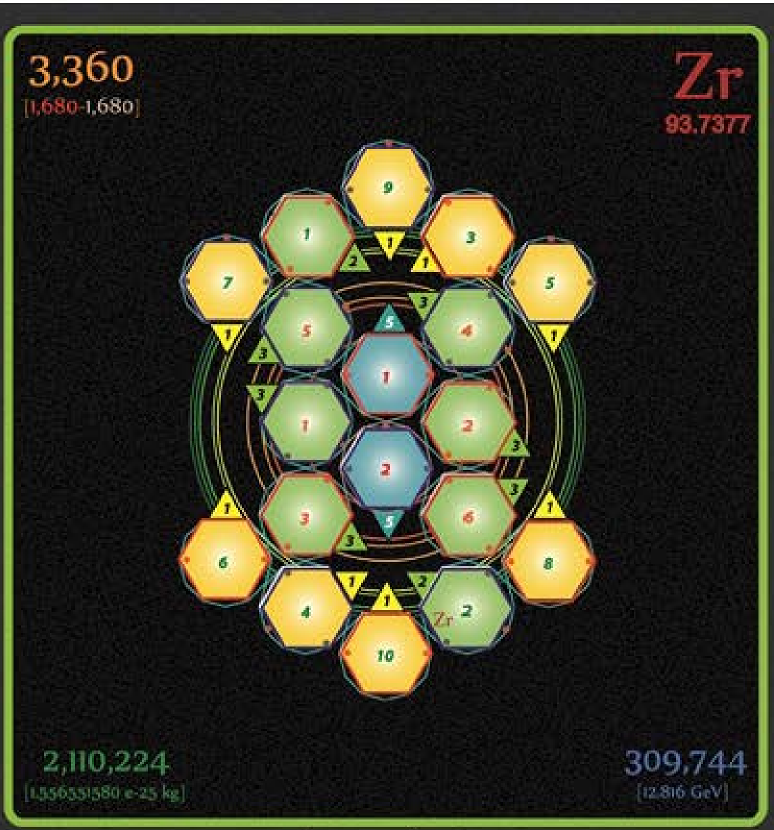
3,360
[1,680-1,680]
Zr
93.7377
9
1
3
7
5
5
4
1
1
2
2
3
6
6
8
4
2
10
Zr
2,110,224
[1,556551580 e-25 kg]
309,744
[12.816 GeV]

Zirconium

40

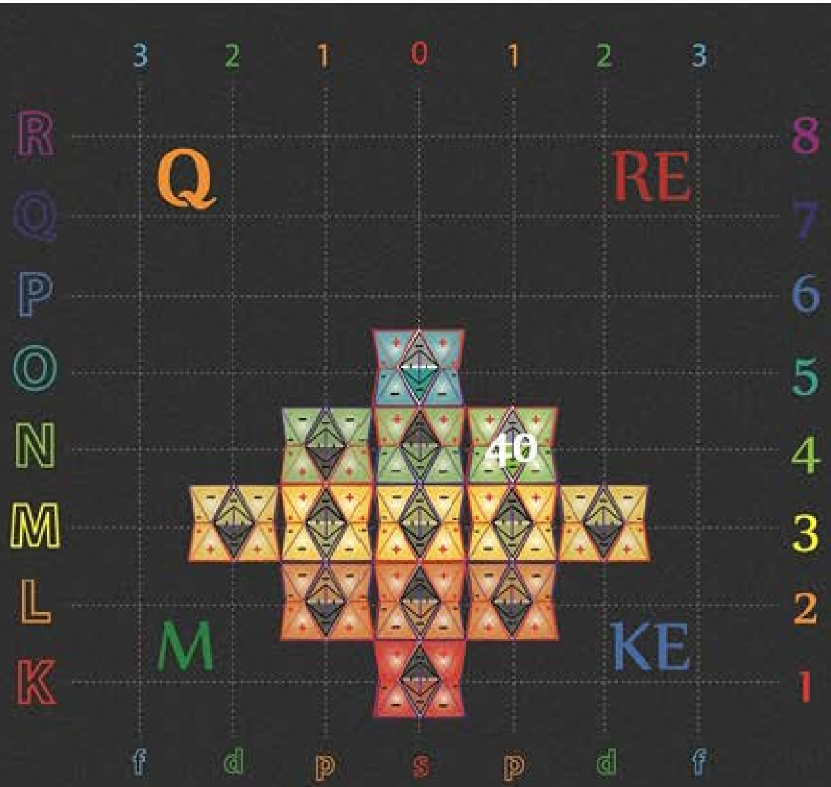
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
40
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

electron configuration

[Kr]$_{36}$ 4d2 5s2

40 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5

Transition Metal

Aufbau

Azmithal & Magnetic numbers

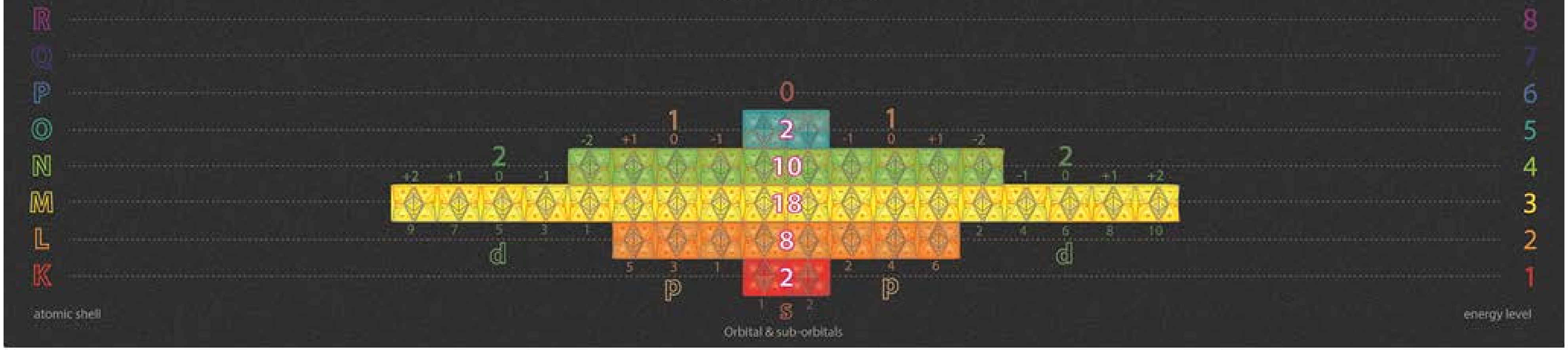
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
2
-2
+1
0
-1
-1
0
+1
-2
+2
+1
0
-1
-1
0
+1
+2
2
10
18
8
2
9
7
5
3
1
2
4
6
8
10
d
d
5
3
1
2
4
6
p
p
1
2
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.40 - Zirconium atom

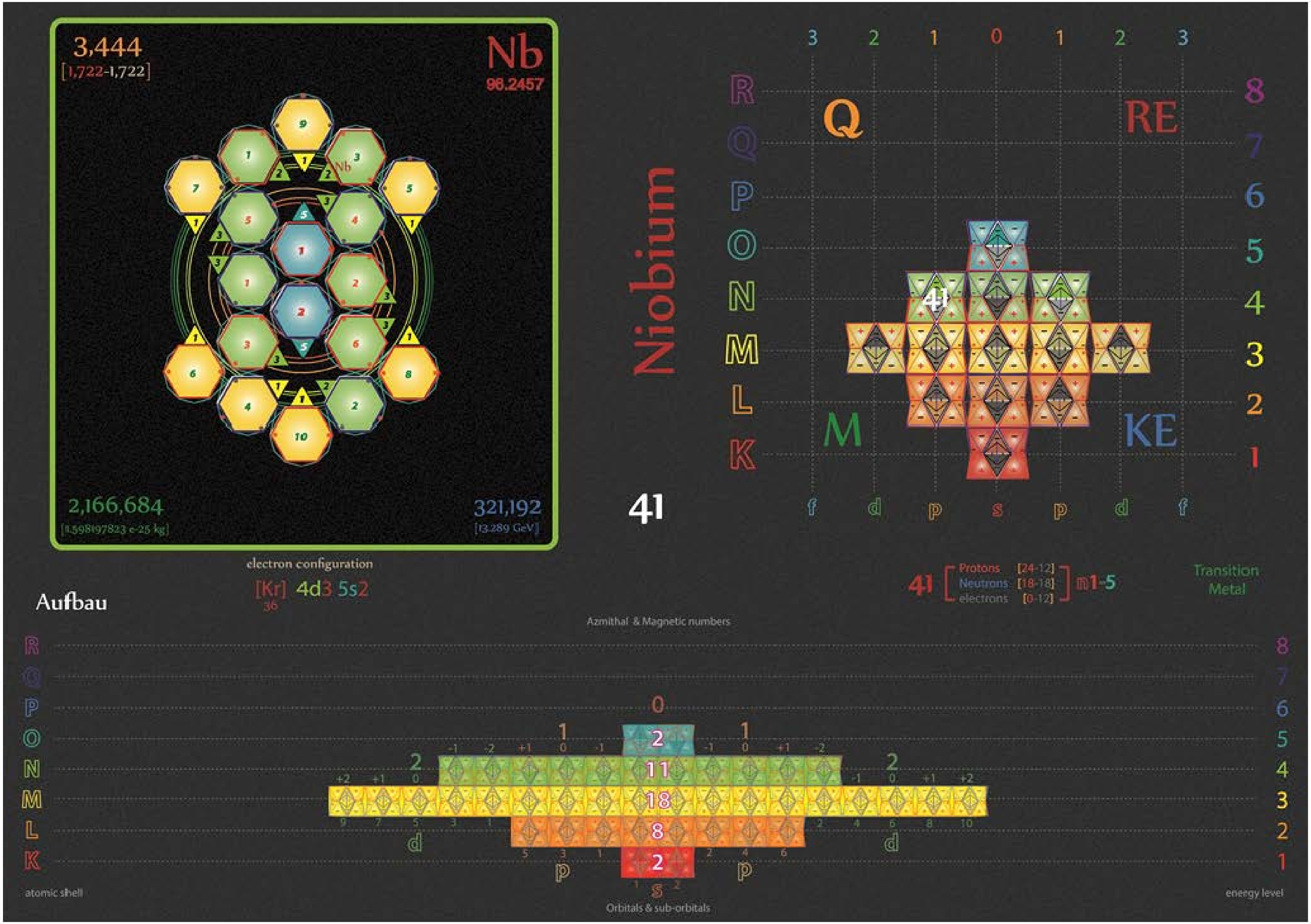
3,444
[1,722-1,722]
Nb
92.2457
Nb
2,166,684
[1.598197823 e-25 kg]
321,192
[13.289 GeV]
Niobium
41
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
41
f d p s p d f
electron configuration
[Kr] 4d3 5s2
36
41 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-5
Transition Metal
Aufbau
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
1
1
2
2
2
11
18
8
2
d
d
p
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.41 - Niobium atom

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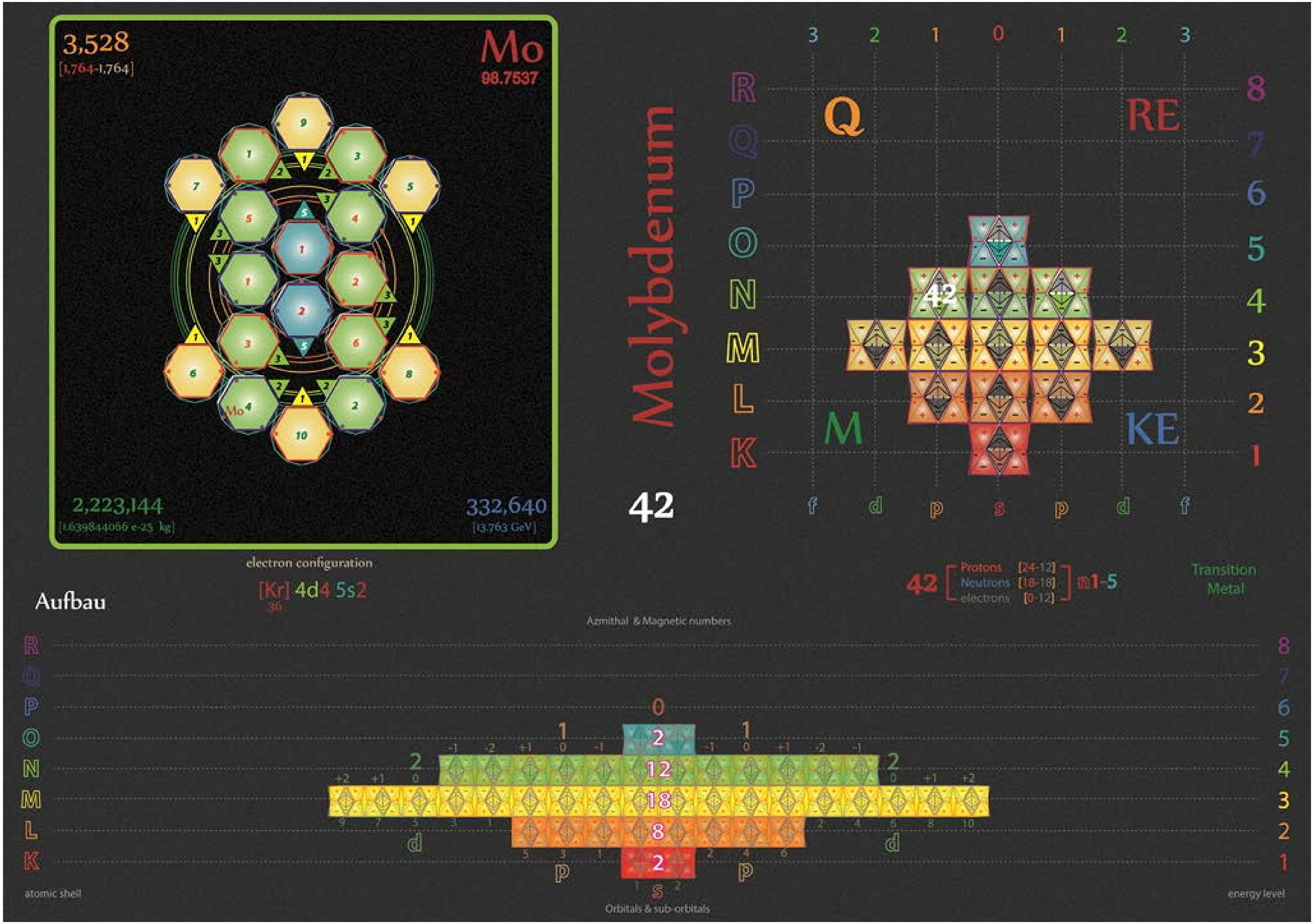
3,528
[1,764-1,764]
Mo
98.7537
2,223,144
[1.639844066 e-25 kg]
332,640
[13.763 GeV]
Molybdenum
42
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
electron configuration
[Kr] 4d4 5s2
36
Aufbau
42 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Transition Metal
Azmithal & Magnetic numbers
0
1
1
2
2
2
12
18
8
2
d
d
p
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.42 - Molybdenum atom

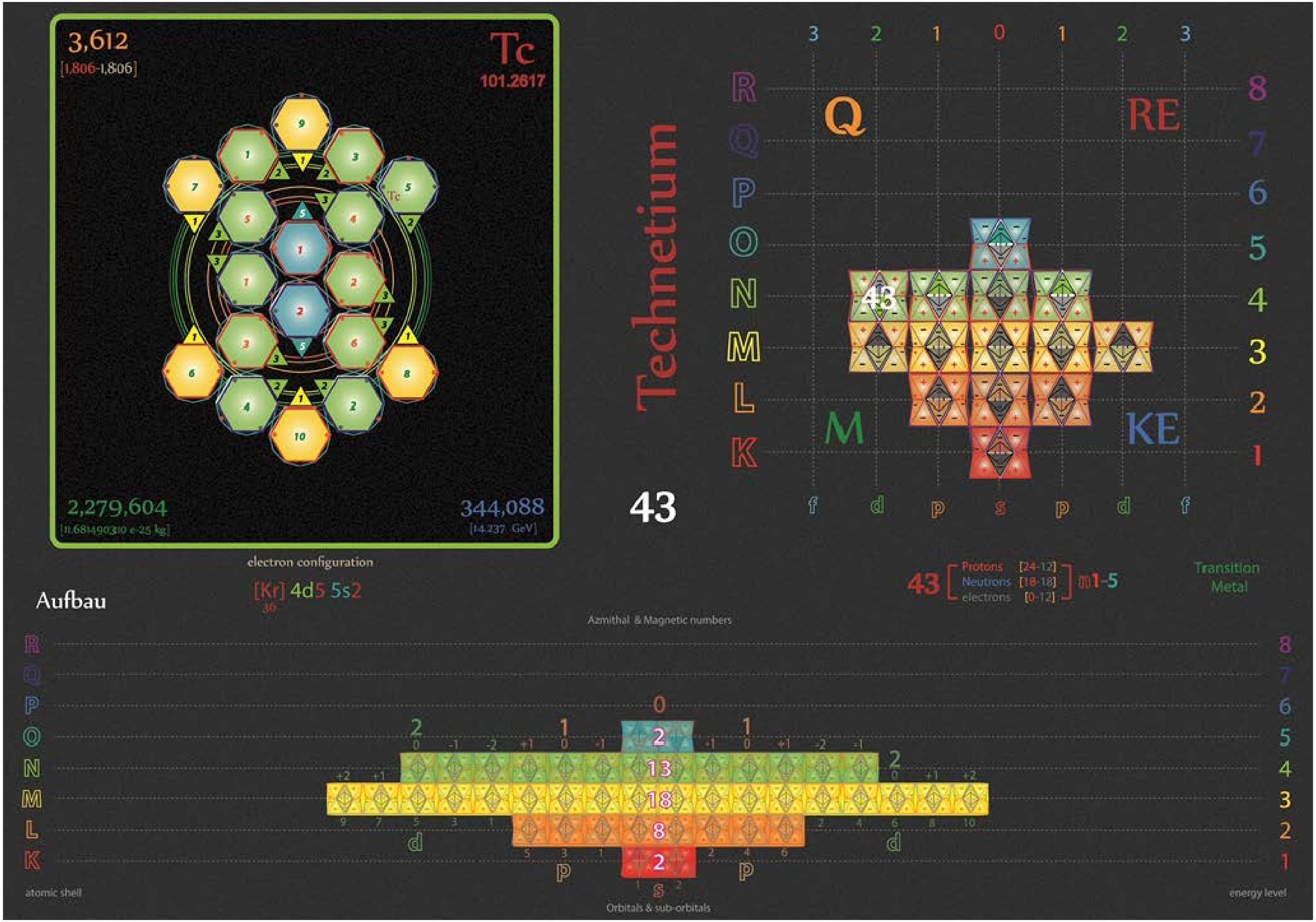
3,612
[1,806-1,806]
Tc
101.2617
Tc
2,279,604
[11.6814903110 e-25 kg]
344,088
[14.237 GeV]
Technetium
43
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
43
f d p s p d f
electron configuration
[Kr] 4d5 5s2
36
Aufbau
43 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Transition Metal
Azmithal & Magnetic numbers
0
2
1
1
2
2
13
18
8
2
d
d
p
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.43 - Technetium atom

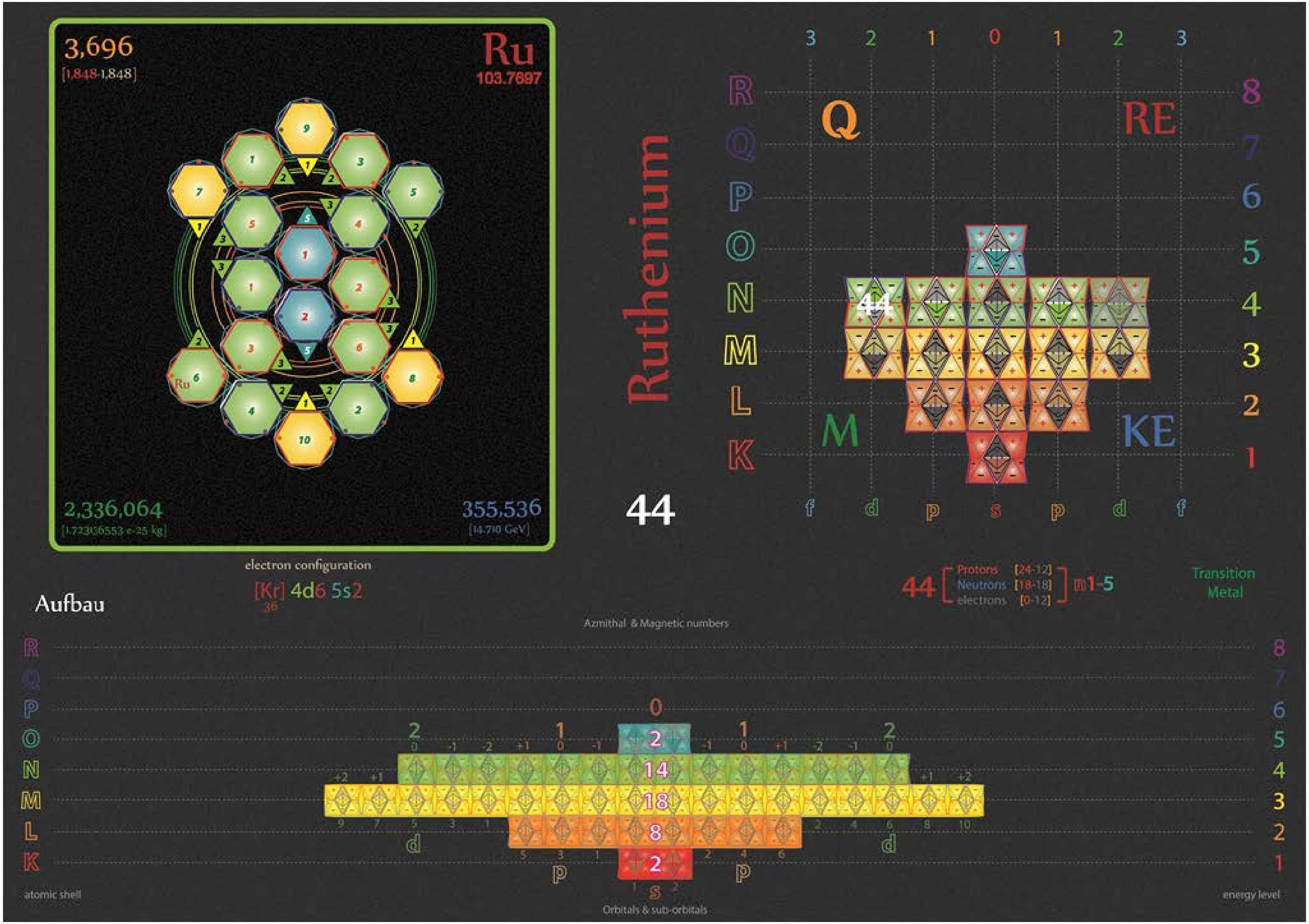
3,696
[1,848-1,848]
Ru
103.7697
2,336,064
[1.72316553 e-25 kg]
355,536
[14.710 GeV]
Ruthenium
44
electron configuration
[Kr] 4d6 5s2
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
44 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Transition Metal
Azmithal & Magnetic numbers
0
2
14
18
8
2
d
p
s
p
d
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.44 - Ruthenium atom

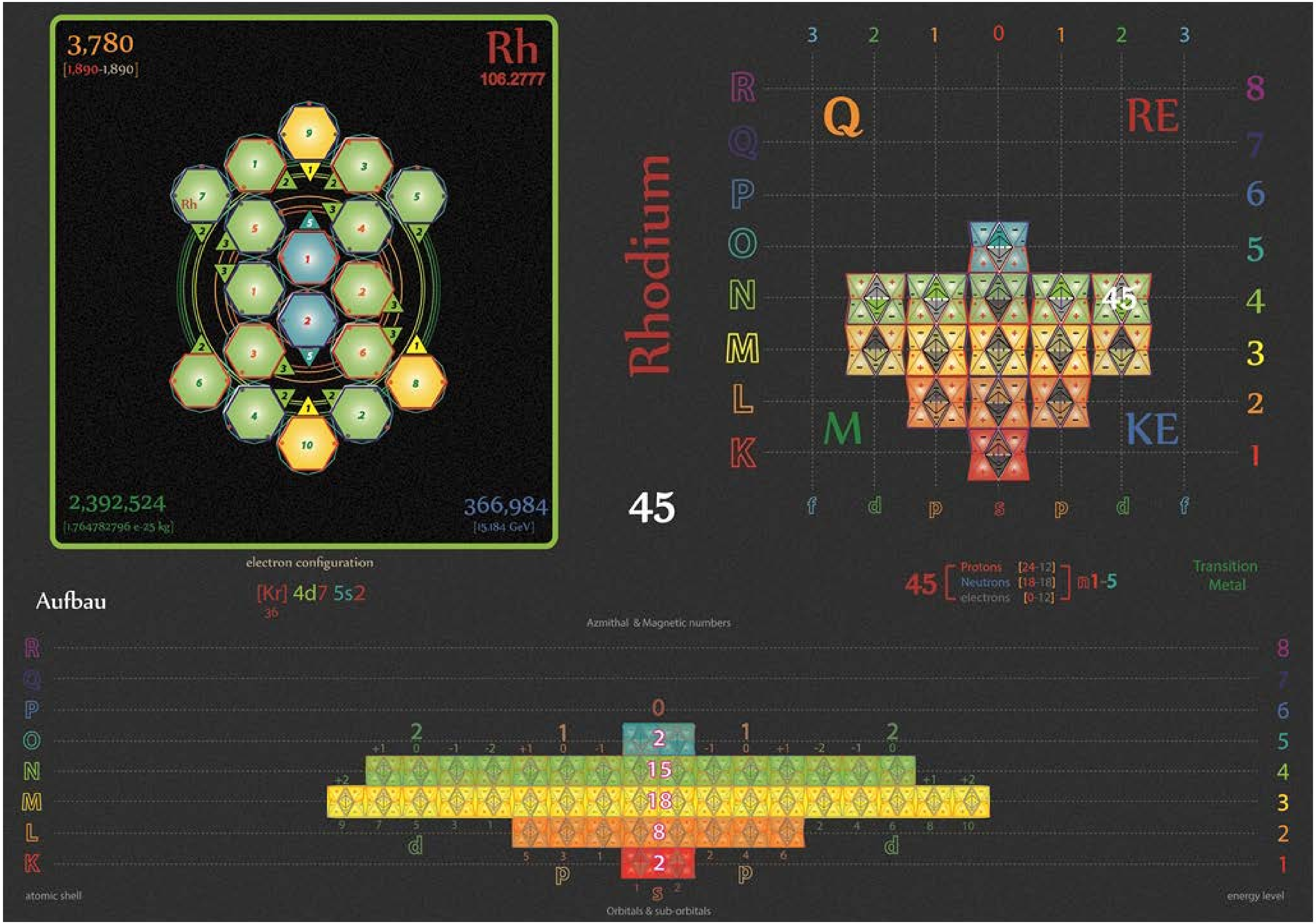
3,780
[1,890-1,890]
Rh
106.2777
Rh
2,392,524
[1.764782796 e-25 kg]
366,984
[15.184 GeV]
Rhodium
45
3 2 1 0 1 2 3
R Q P O N M L K
Q
RE
M
KE
8 7 6 5 4 3 2 1
f d p s p d f
45
electron configuration
[Kr] 4d7 5s2
36
Aufbau
45 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
2
15
18
8
2
d d
p p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.45 - Rhodium atom

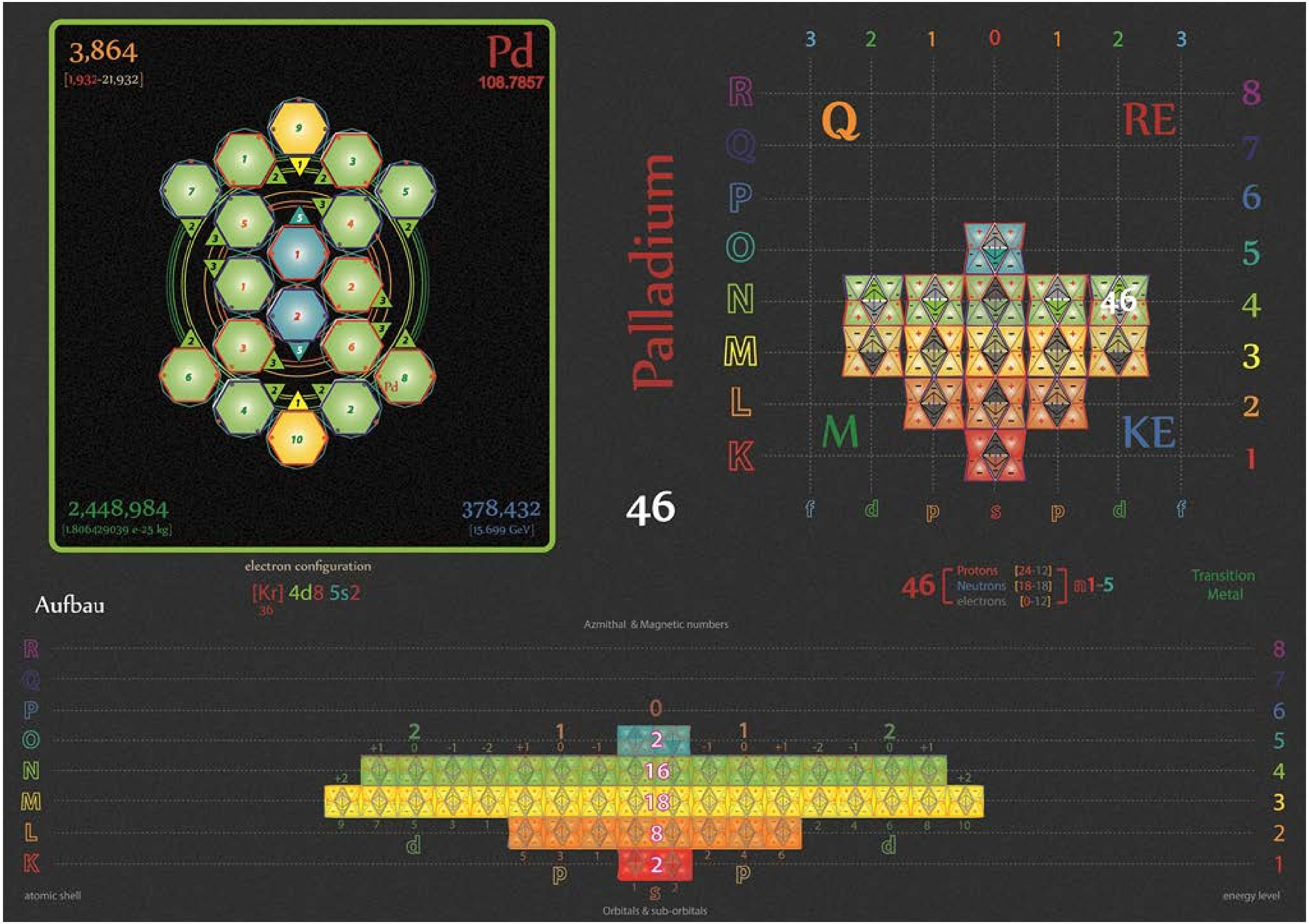
3,864
[1,932-21,932]
Pd
108.7857
2,448,984
[1.806429039 e-25 kg]
378,432
[15.699 GeV]
Palladium
46
electron configuration
[Kr] 4d8 5s2
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
46
f d p s p d f
46 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
2
16
18
8
2
d d
p p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.46 - Palladium atom

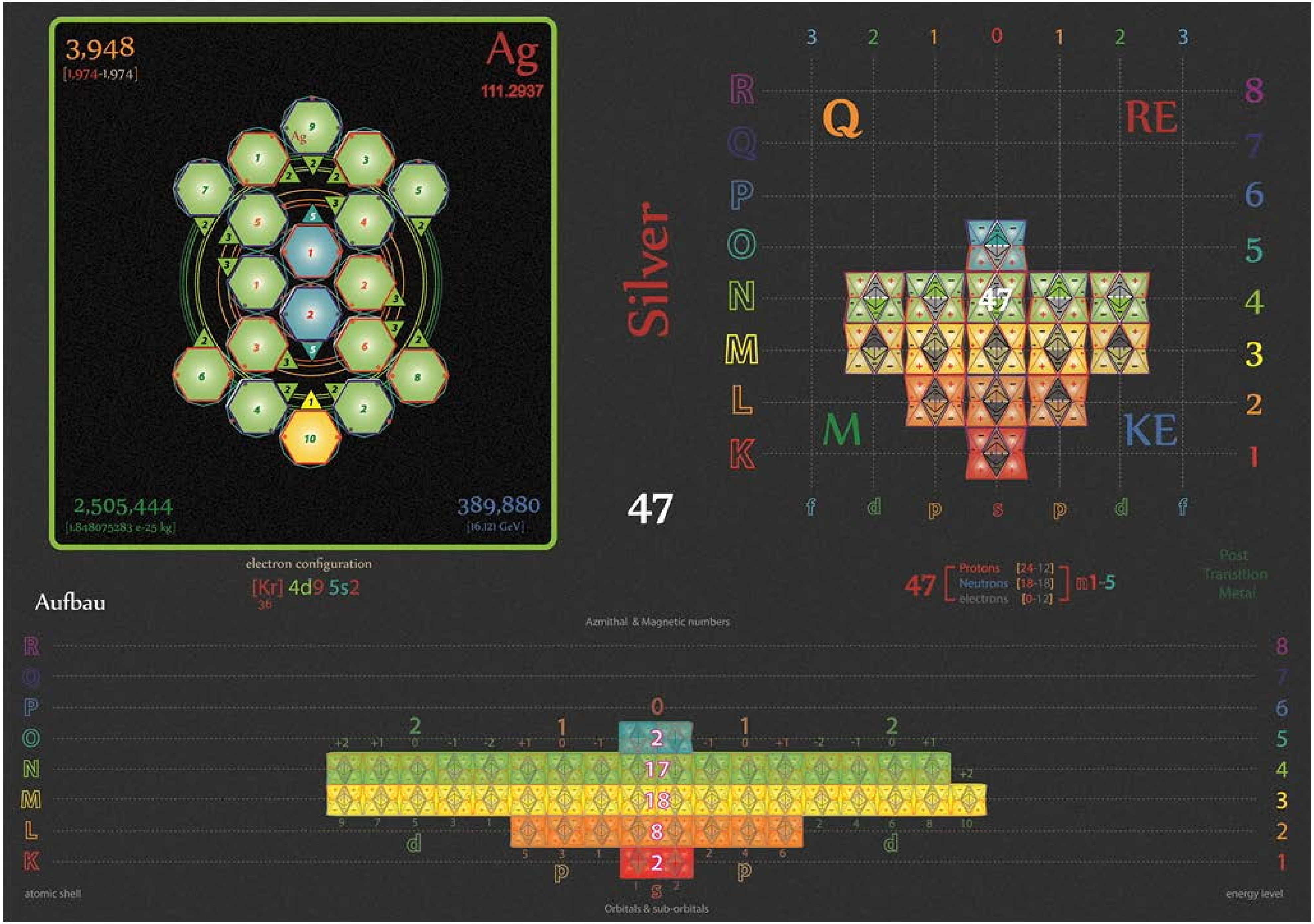
3,948
[1,974-1,974]
Ag
111.2937
2,505,444
[1.848075283 e-25 kg]
389,880
[16.121 GeV]
Silver
47
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
47 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Post Transition Metal
electron configuration
[Kr] 4d9 5s2
36
Aufbau
Azmithal & Magnetic numbers
0
2 1 1 2
2
17
18
8
2
d p s p d
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.47 - Silver atom

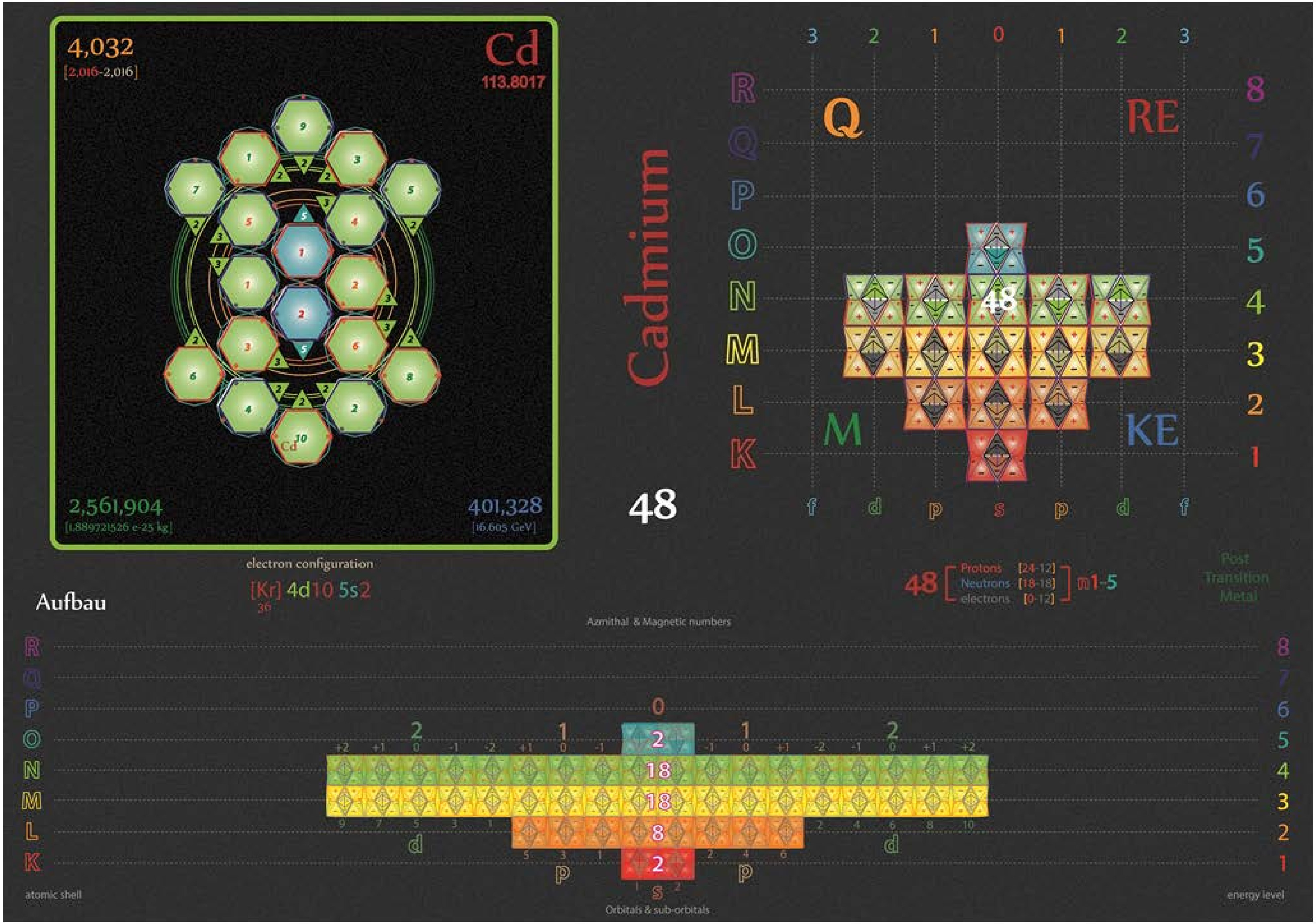
4,032
[2,016-2,016]
Cd
113.8017
Cd 10
2,561,904
[1.889721526 e-25 kg]
401,328
[16.605 GeV]
Cadmium
48
electron configuration
[Kr] 4d10 5s2
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
48
f d p s p d f
48 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Post Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
2
18
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.48 - Cadmium atom

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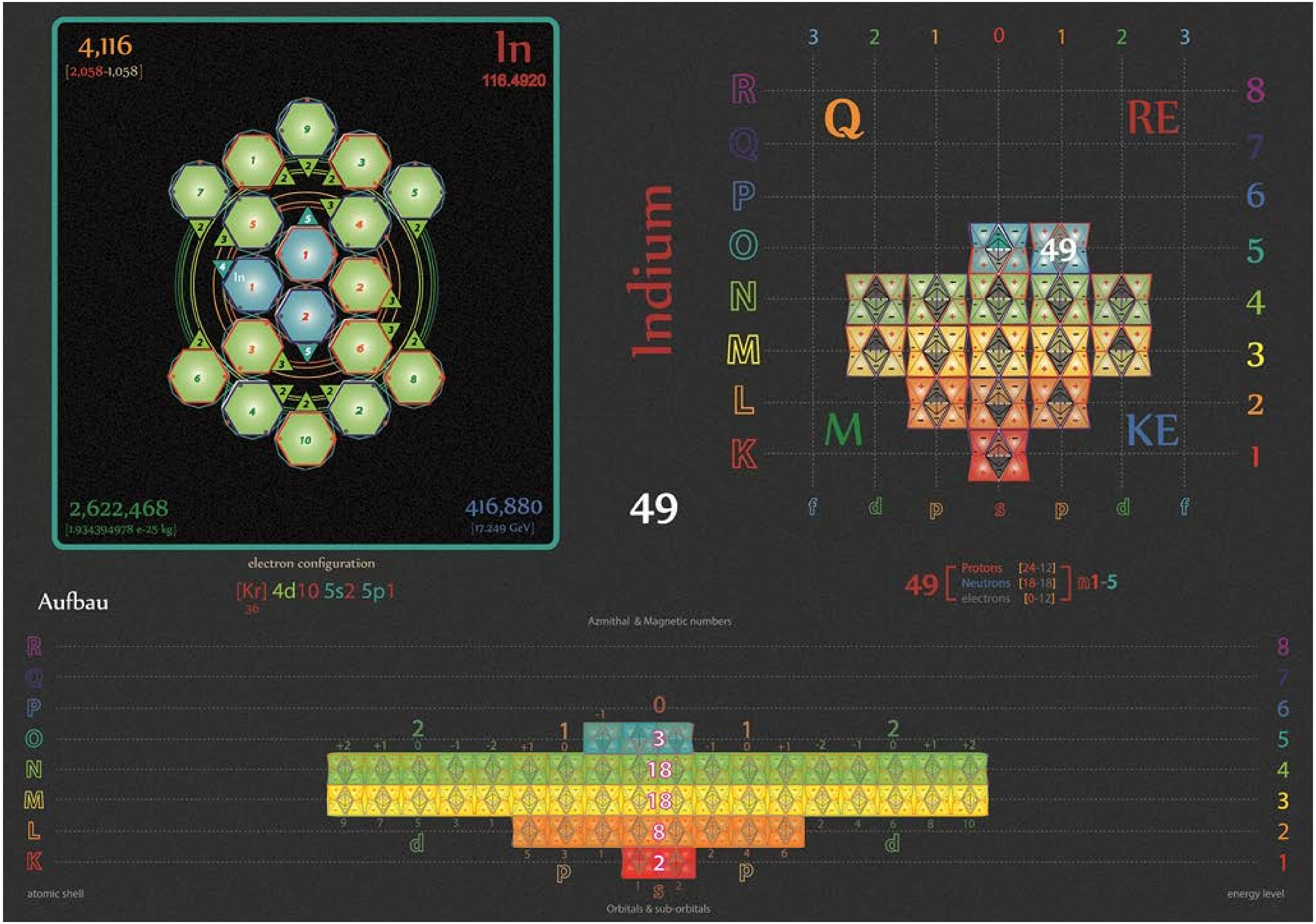
4,116
[2,058-1,058]
In
116.4920
2,622,468
[1.934394978 e-25 kg]
416,880
[17.249 GeV]
Indium
49
electron configuration
[Kr] 4d10 5s2 5p1
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
49
f d p s p d f
49 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Azmithal & Magnetic numbers
0
-1
2 1 1 2
+2 +1 0 -1 -2 +1 0 -1 0 +1 -2 -1 0 +1 +2
3
18
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
Orbitals & sub-orbitals
atomic shell
energy level

Tetryonics 51.49 - Indium atom

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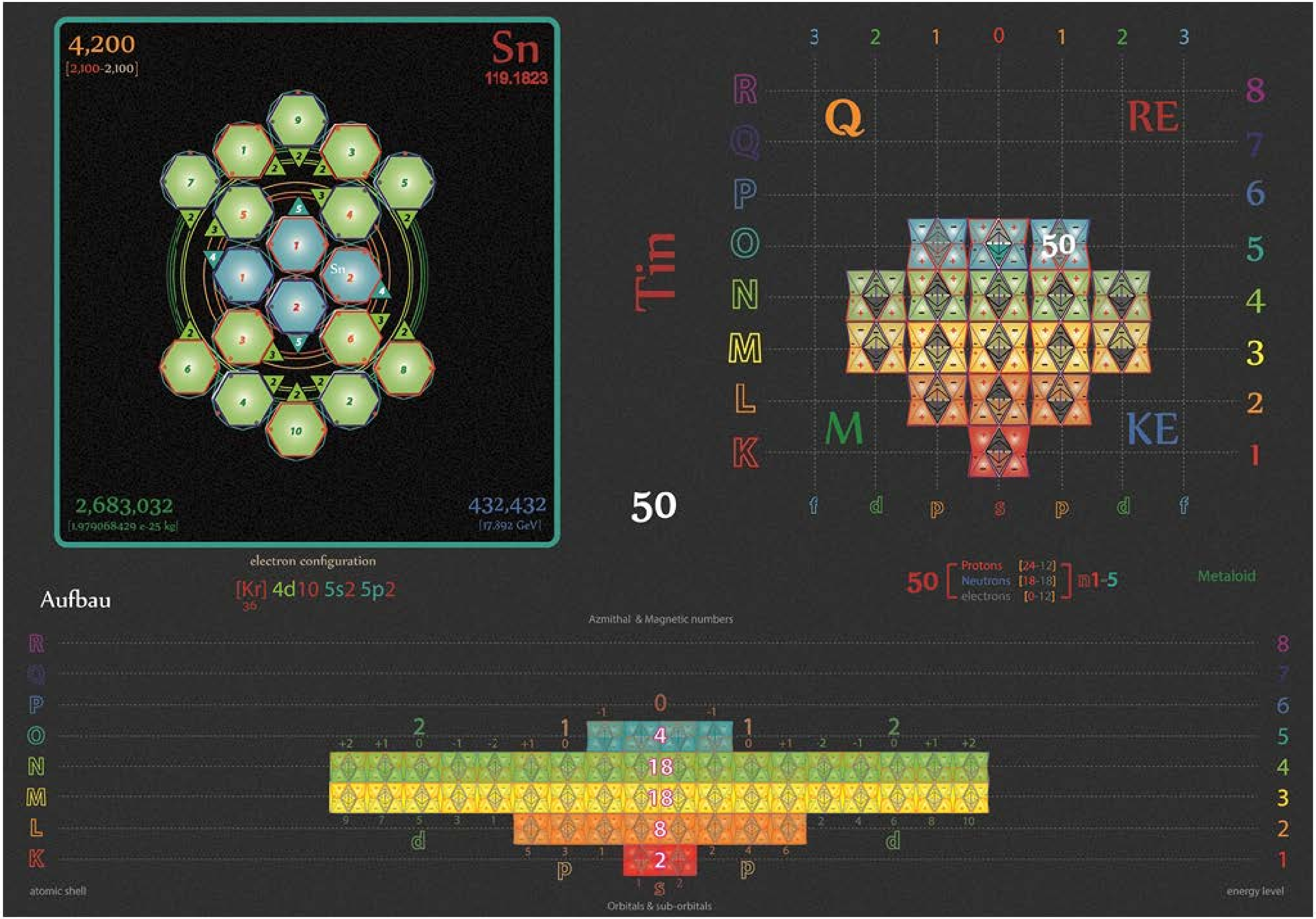
4,200
[2,100-2,100]
Sn
119.1823
2,683,032
[1.979068429 e-25 kg]
432,432
[17.392 GeV]
Tin
50
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
50
electron configuration
[Kr] 4d10 5s2 5p2
36
Aufbau
50 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Metaloid
Azmithal & Magnetic numbers
4
18
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.50 - Tin atom

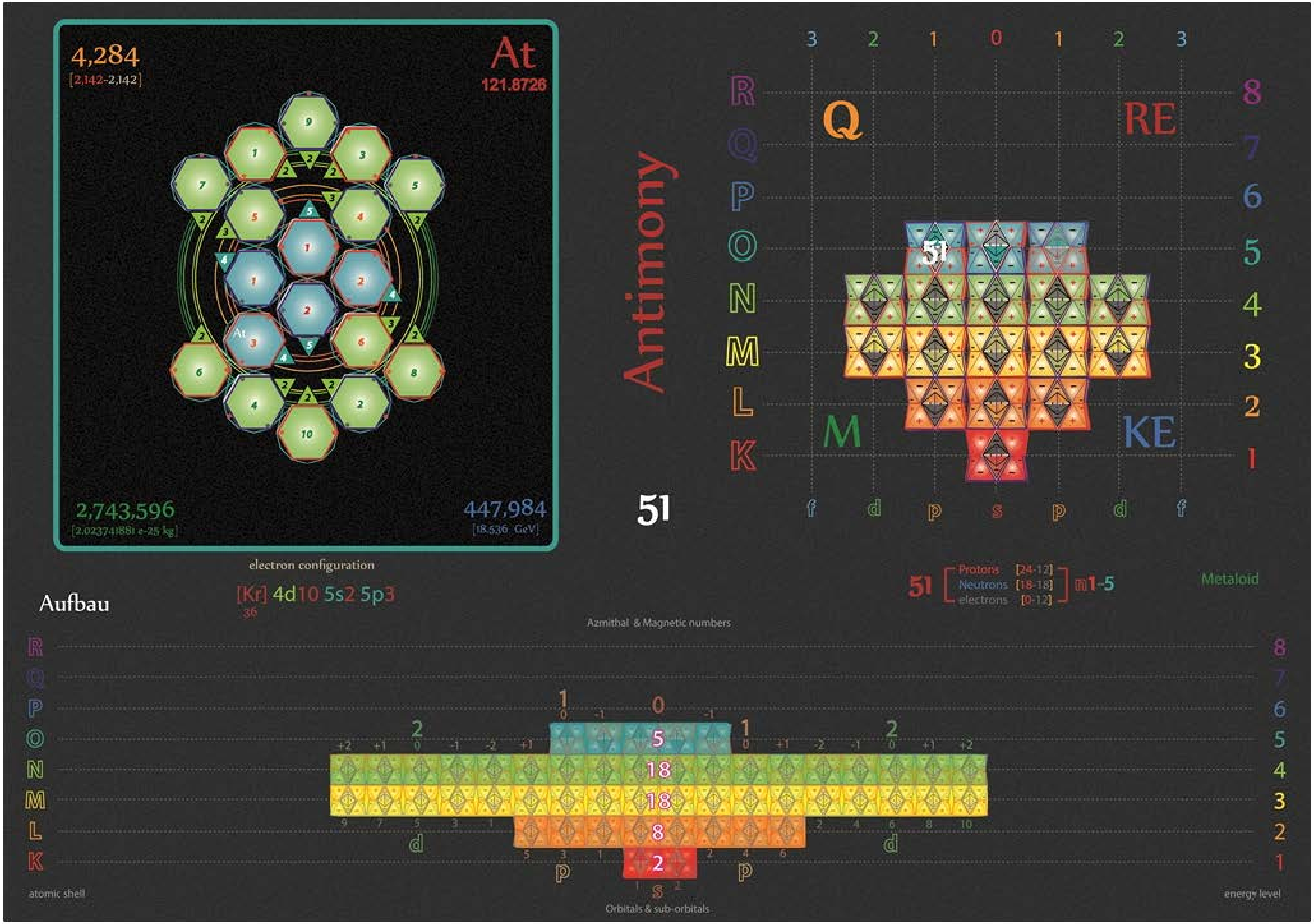
4,284
[2,142-2,142]
At
121.8726
2,743,596
[2.02374188i e-25 kg]
447,984
[18.536 GeV]
Antimony
51
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
51
f d p s p d f
electron configuration
Aufbau
[Kr] 4d10 5s2 5p3
36
51
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-5
Metaloid
Azmithal & Magnetic numbers
5
18
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.51 - Antimony atom

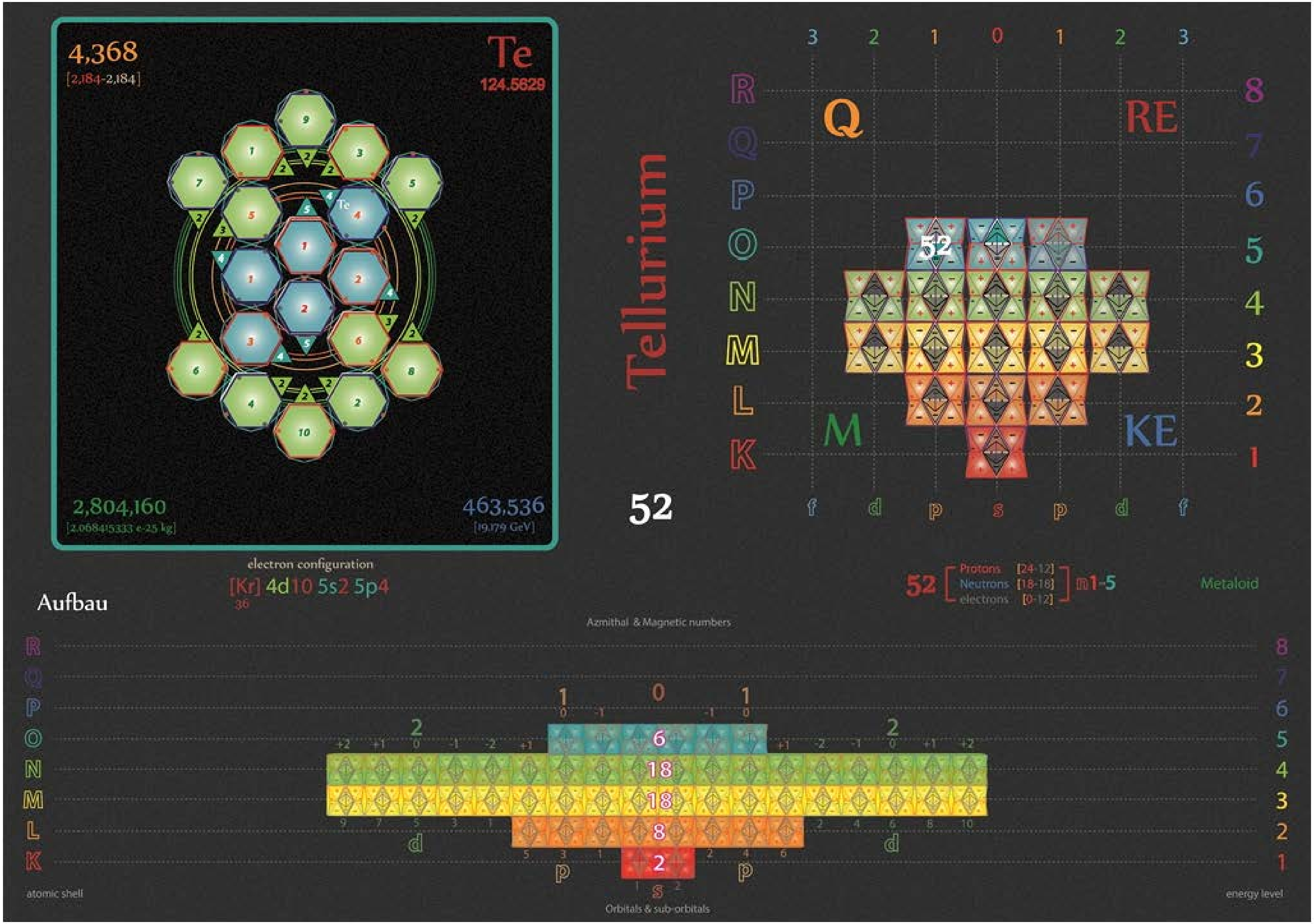
4,368
[2,184-2,184]
Te
124.5629
2,804,160
[2.068415333 e-25 kg]
463,536
[19.179 GeV]
Tellurium
52
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
electron configuration
[Kr] 4d10 5s2 5p4
36
Aufbau
52 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Metaloid
Azmithal & Magnetic numbers
6
18
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.52 - Tellurium atom

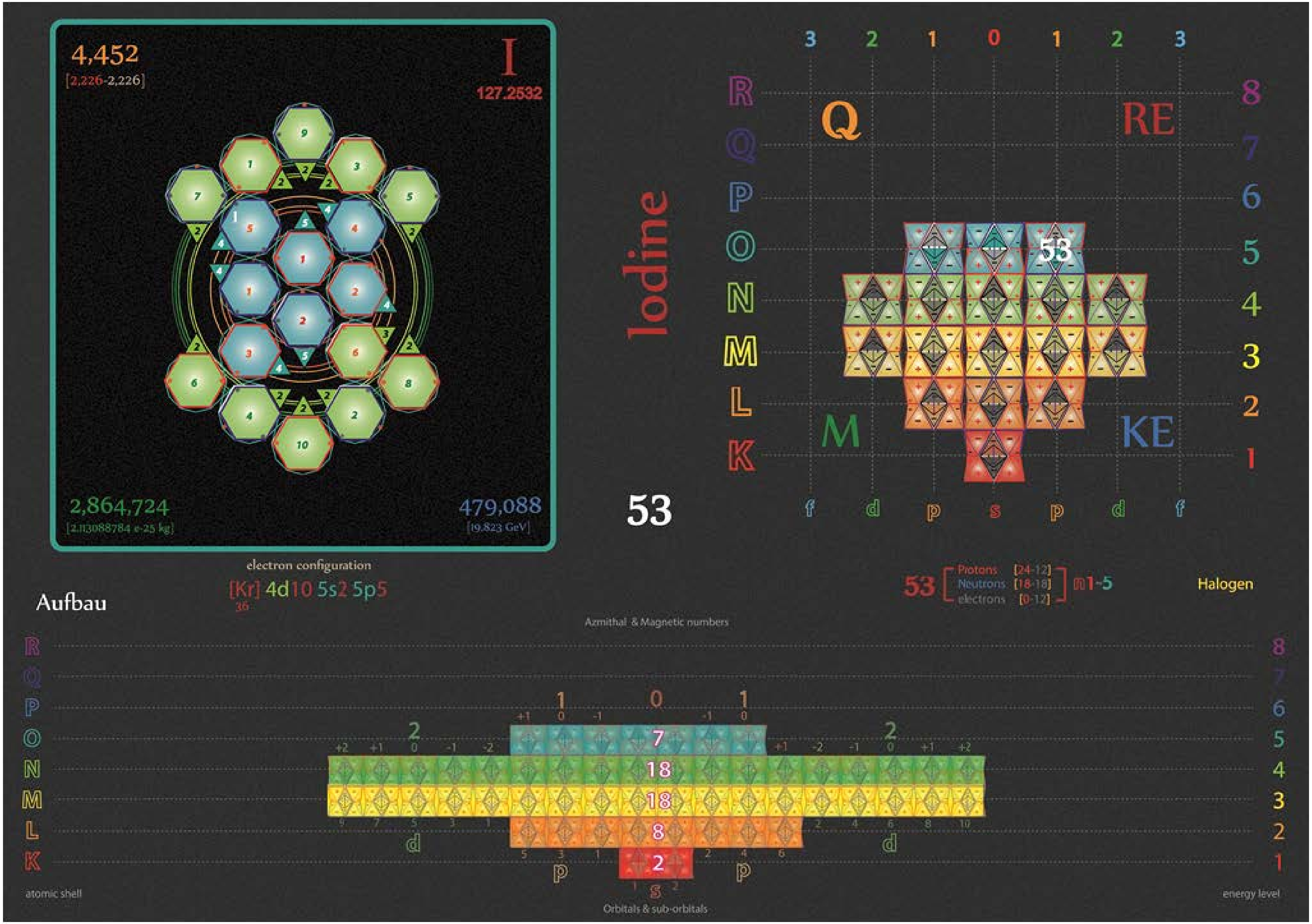
4,452
[2,226-2,226]
I
127.2532
9
1
3
7
5
2
4
2,864,724
[2.113088784 e-25 kg]
479,088
[19.823 GeV]
Iodine
53
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
53
f d p s p d f
electron configuration
[Kr] 4d10 5s2 5p5
36
Aufbau
53 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Halogen
Azmithal & Magnetic numbers
1 0 1
+1 0 -1 -1 0
2 2
+2 +1 0 -1 -2 +1 -2 -1 0 +1 +2
7
18
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.53 - Iodine atom

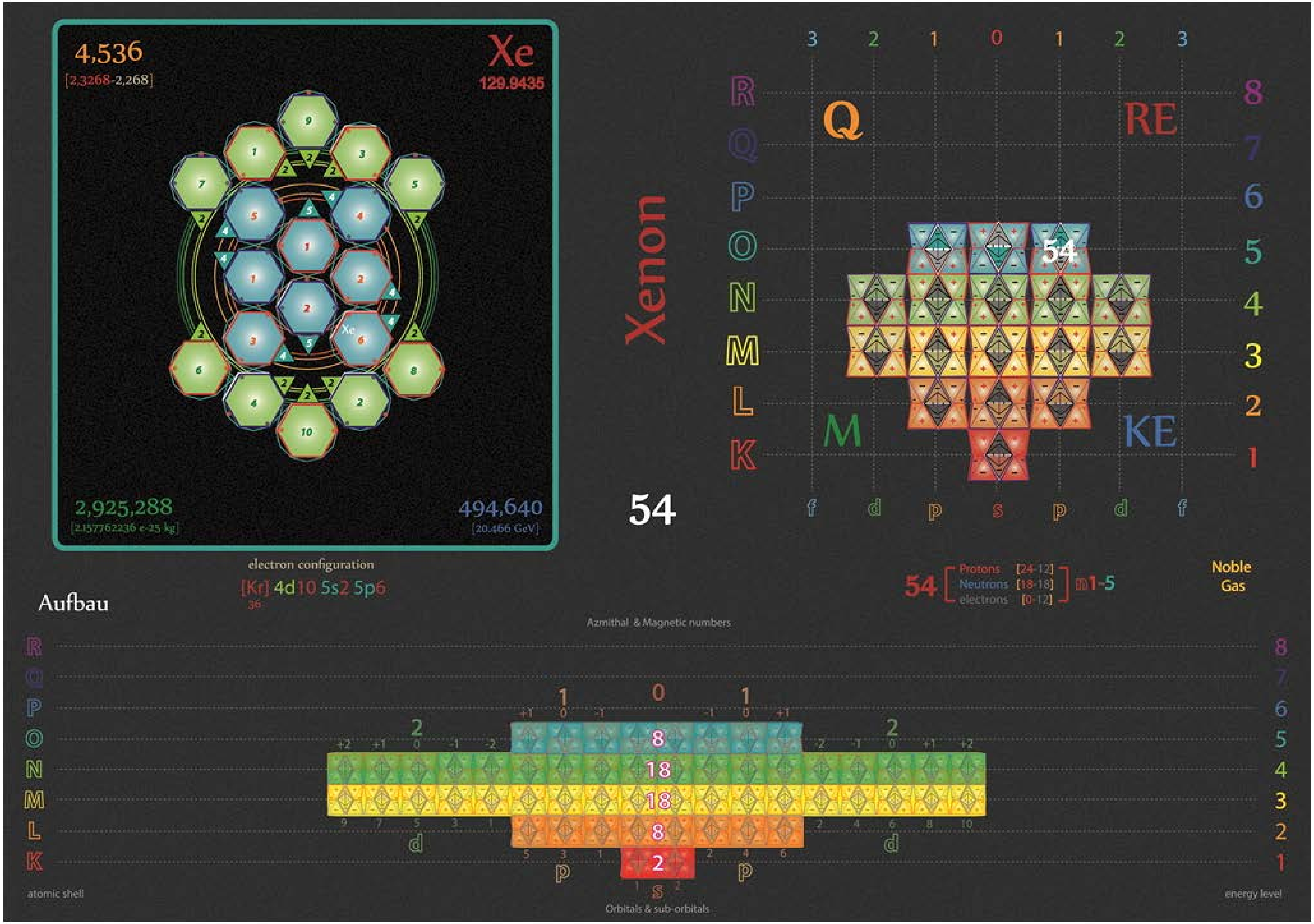
4,536
[2,3268-2,268]
Xe
129.9435
2,925,288
[2.157762236 e-25 kg]
494,640
[20.466 GeV]
Xenon
54
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
54
f d p s p d f
electron configuration
[Kr] 4d10 5s2 5p6
36
Aufbau
54 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Noble Gas
Azmithal & Magnetic numbers
8
18
18
8
2
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.54 - Xenon atom

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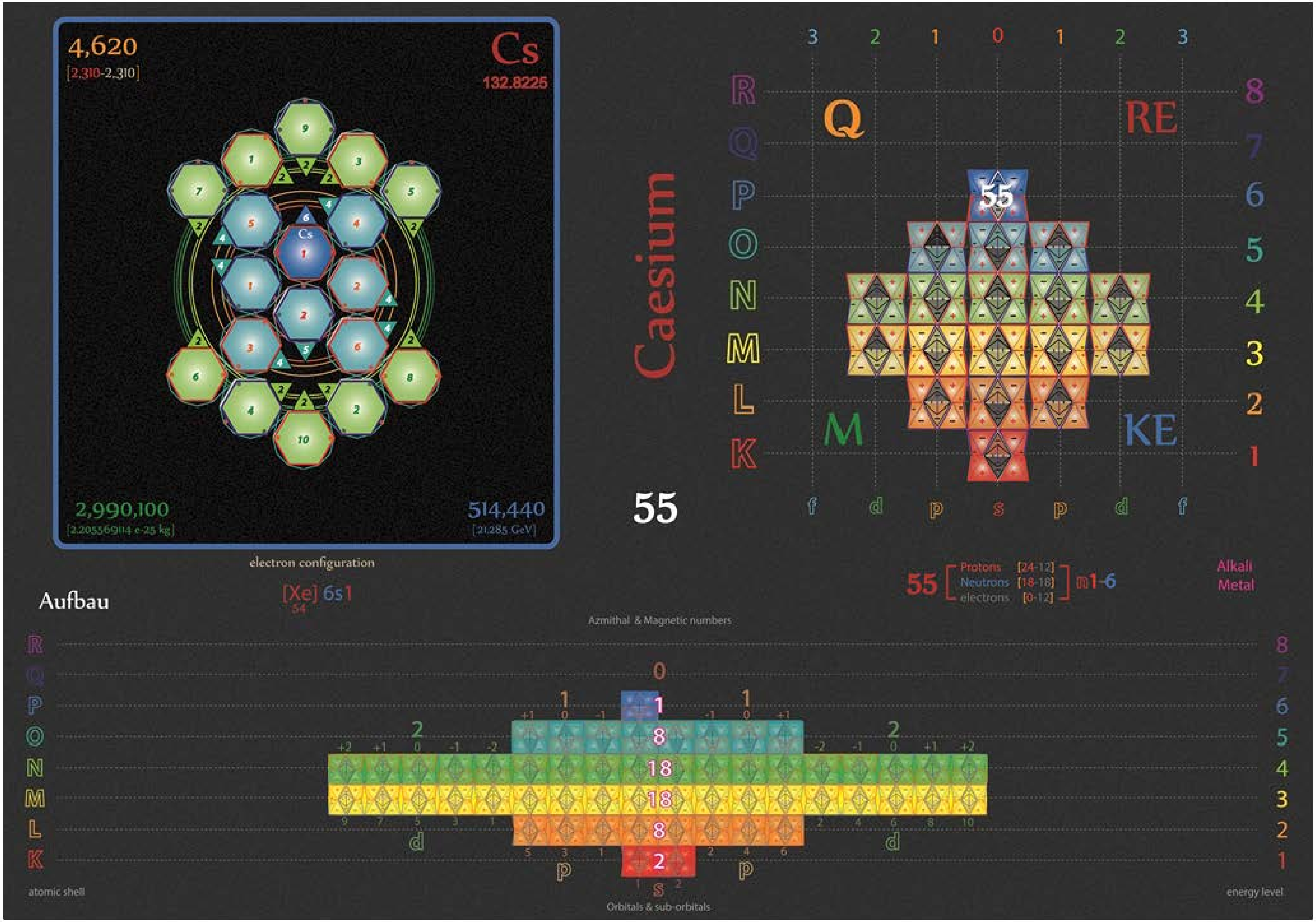
4,620
[2,310-2,310]
Cs
132.8225
Cs
2,990,100
[2.205569114 e-25 kg]
514,440
[21.285 GeV]
electron configuration
[Xe] 6s1
54
Aufbau
Caesium
55
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
55
f d p s p d f
55 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Alkali Metal
Azmithal & Magnetic numbers
0
1 1
+1 0 -1 -1 0 +1
2 2
+2 +1 0 -1 -2 -2 -1 0 +1 +2
1
8
18
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 2
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.55 - Caesium atom

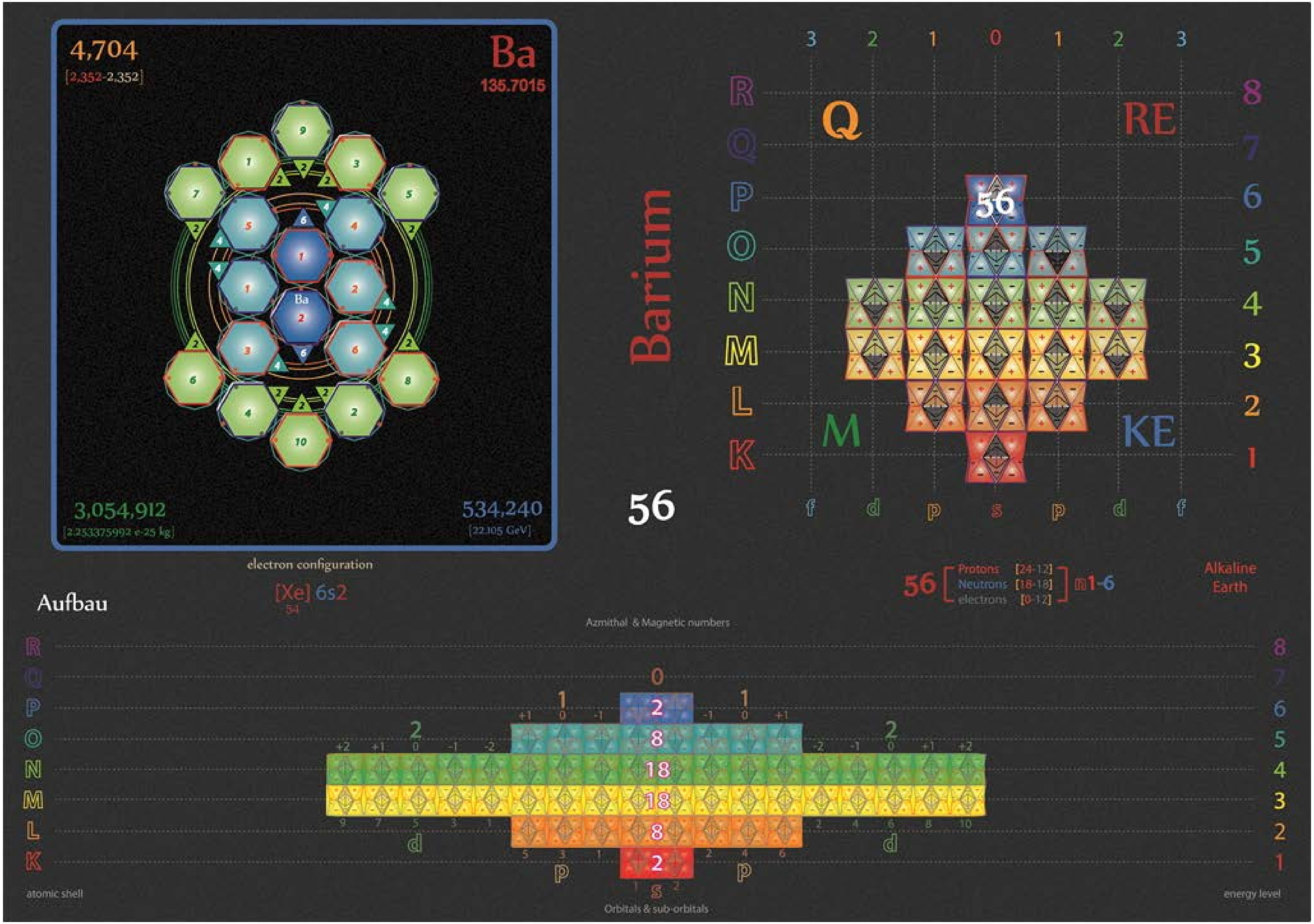
4,704
[2,352-2,352]
Ba
135.7015
9
1
3
7
5
2
6
4
Ba
10
8
3,054,912
[2.253375992 e-25 kg]
534,240
[22.105 GeV]
Barium
56
3 2 1 0 1 2 3
R Q P O N M L K
Q
RE
M
KE
8 7 6 5 4 3 2 1
f d p s p d f
electron configuration
[Xe] 6s2
54
Aufbau
56 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Alkaline Earth
Azmithal & Magnetic numbers
0
1
1
2
2
+1 0 -1
-1 0 +1
+2 +1 0 -1 -2
-2 -1 0 +1 +2
2
8
18
18
8
2
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
d
d
p
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.56 - Barium atom

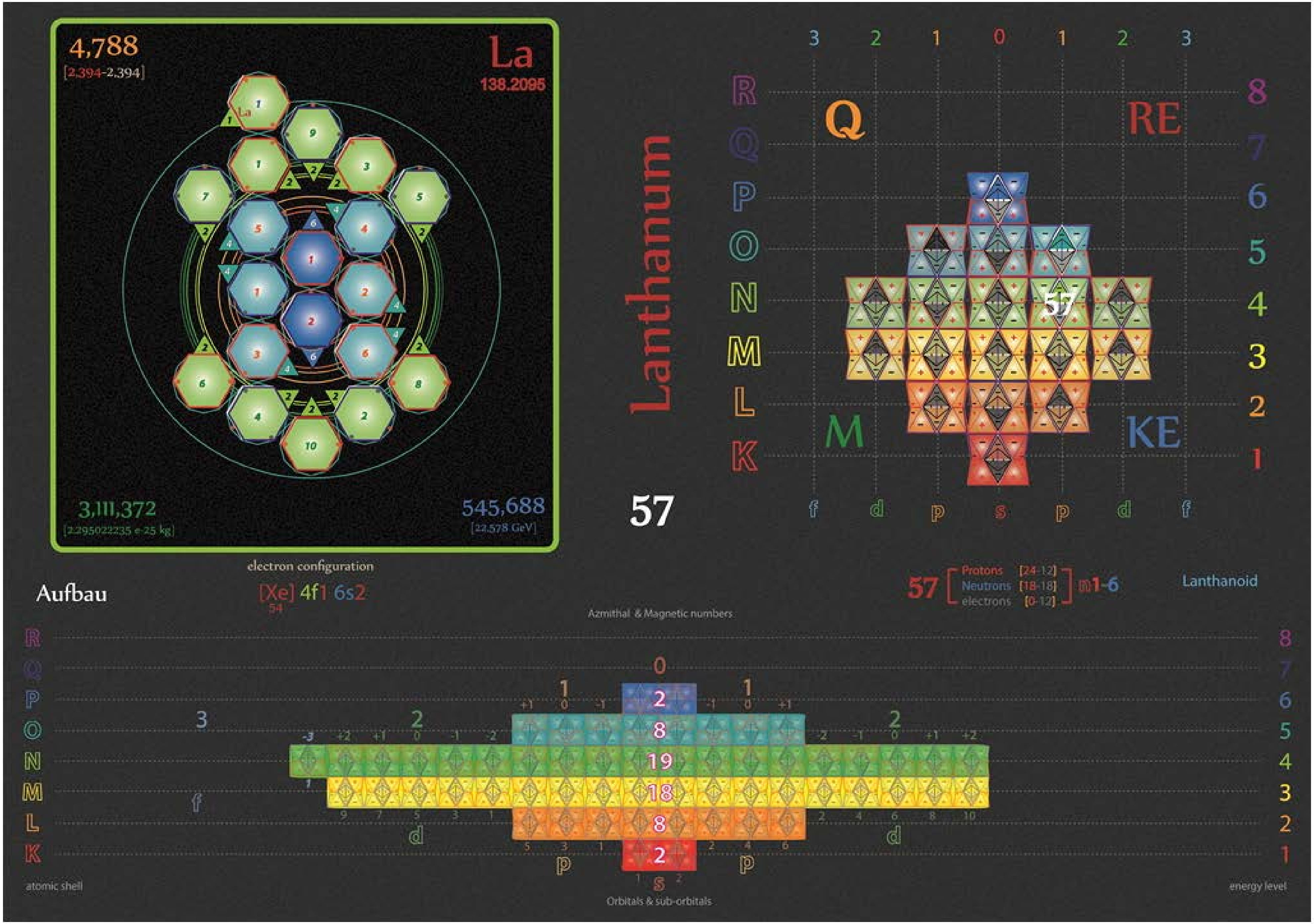
4,788
[2.394-2.394]
La
138.2095
3,111,372
[2.295022235 e-25 kg]
545,688
[22.578 GeV]
Lanthanum
57
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Xe] 4f1 6s2
54
Aufbau
57
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-6
Lanthanoid
Azmithal & Magnetic numbers
0
1 1
2 2
3
+1 0 -1 -1 0 +1
-3 +2 +1 0 -1 -2 -2 -1 0 +1 +2
2
8
19
18
8
2
f
d
p
s
9 7 5 3 1 2 4 6 8 10
5 3 1 2 4 6
1 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.57 - Lanthanum atom

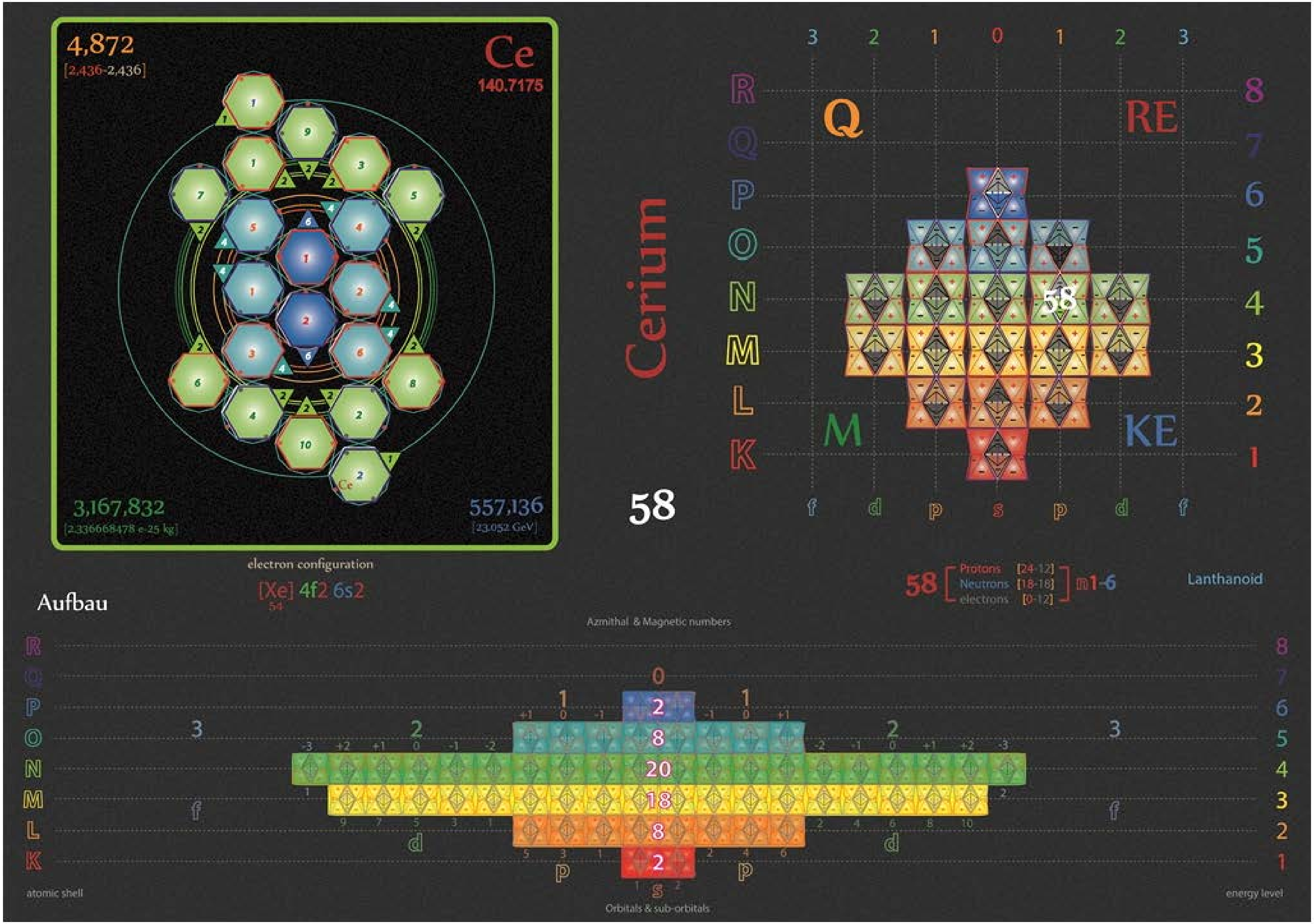
4,872
[2,436-2,436]
Ce
140.7175
3,167,832
[2.336668478 e-25 kg]
557,136
[23.052 GeV]
Cerium
58
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Xe] 4f2 6s2
54
Aufbau
58 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Azmithal & Magnetic numbers
2
8
20
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.58 - Cerium atom

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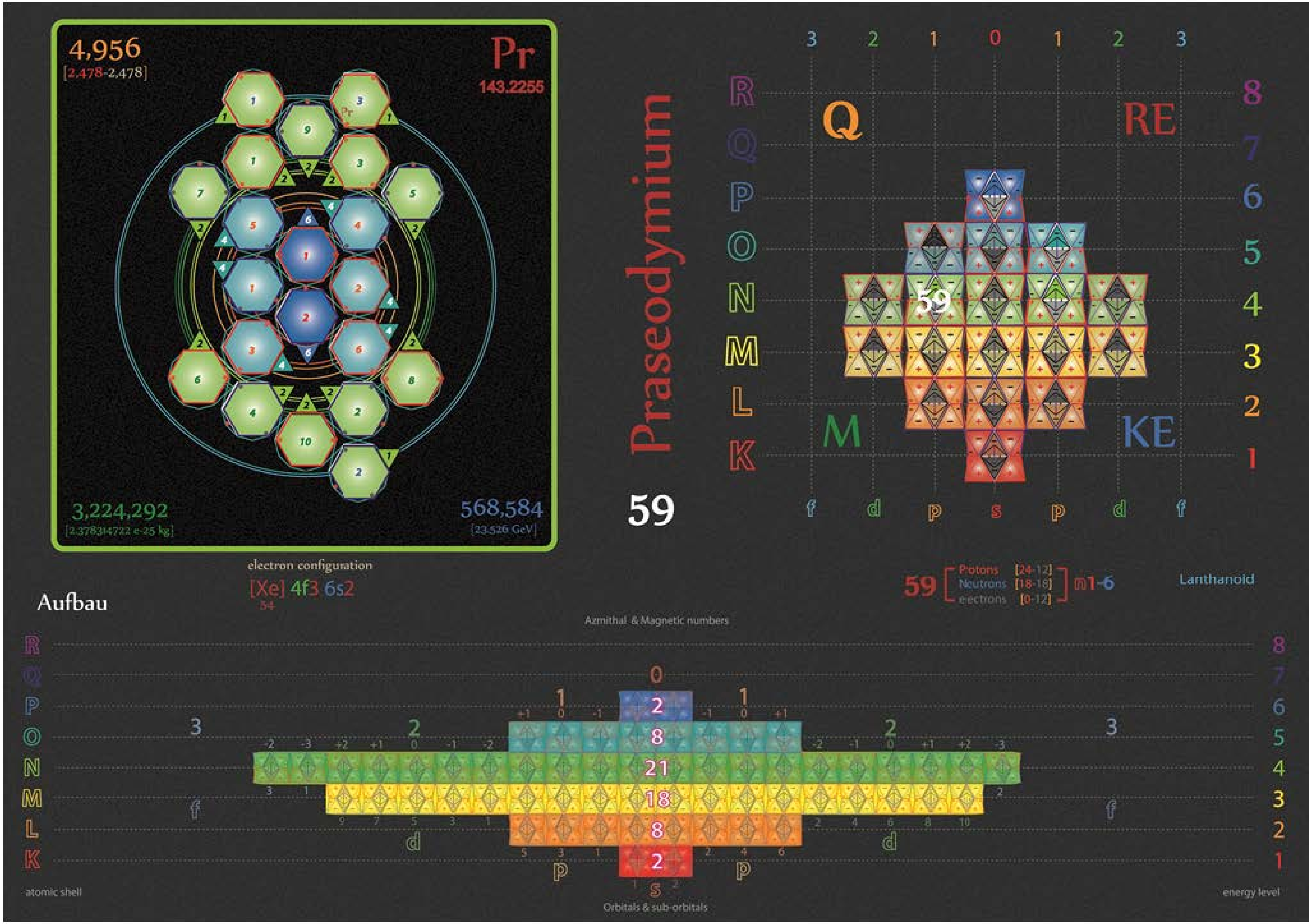
4,956
[2,478-2,478]
Pr
143.2255
3,224,292
[2.378314722 e-25 kg]
568,584
[23.526 GeV]
Praseodymium
59
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
59 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-6
Lanthanoid
electron configuration
[Xe] 4f3 6s2
54
Aufbau
Azmithal & Magnetic numbers
0
2
8
21
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.59 - Praseodymium atom

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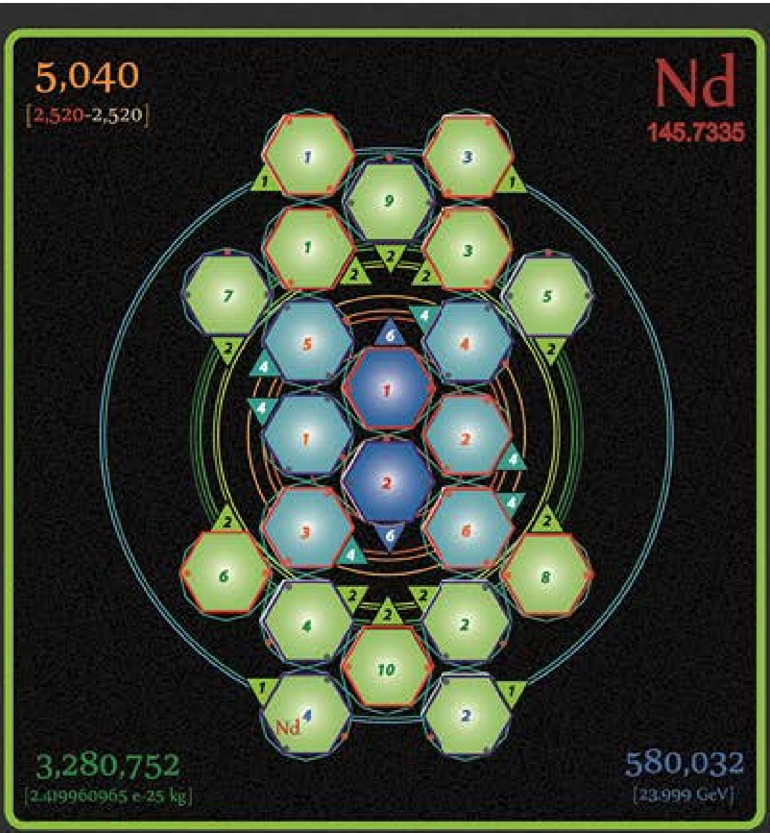
5,040
[2,520-2,520]
Nd
145.7335
1
3
9
1
3
7
5
5
4
6
1
1
2
2
3
6
6
8
4
2
10
Nd
4
2
3,280,752
[2.49960965 e-25 kg]
580,032
[23.999 GeV]

Neodymium

60

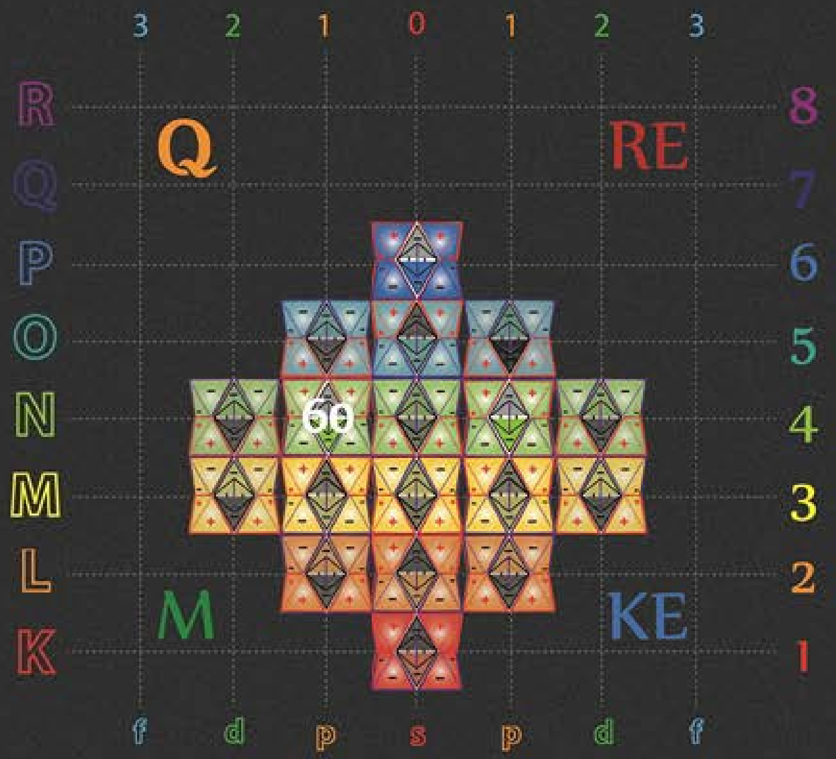
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
60
f
d
p
s
p
d
f

electron configuration

[Xe] 4f4 6s2
54

60 [Protons [24-12] neutrons [18-18] electrons [0-12]] n1-6

Lanthanoid

Aufbau

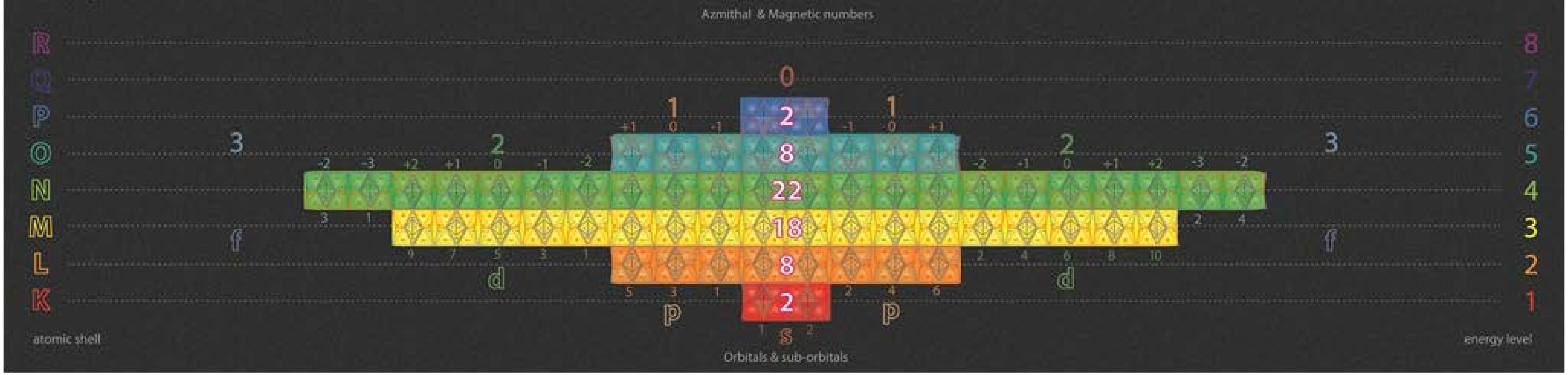
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
3
2
2
3
+1
0
-1
-1
0
+1
-2
-3
+2
+1
0
-1
-2
-2
-1
0
+1
+2
-3
-2
2
8
22
18
8
2
3
1
2
4
9
7
5
3
1
2
4
6
8
10
5
3
1
2
4
6
1
2
f
d
p
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.60 - Neodymium atom

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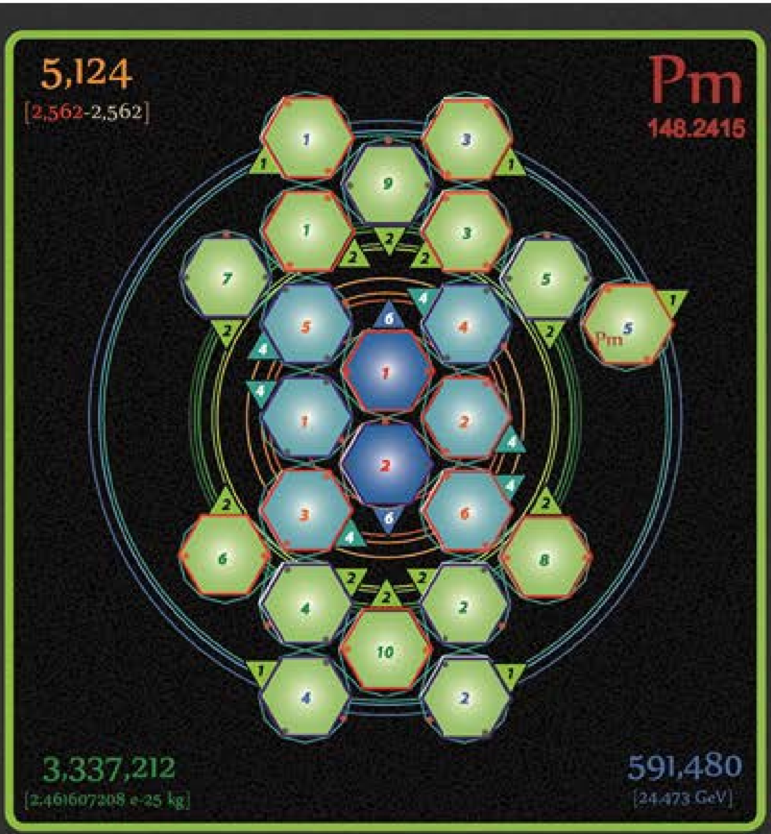

5,124
[2,562-2,562]

Pm
148.2415

3,337,212
[2.461607208 e-25 kg]

591,480
[24.473 GeV]

Promethium

61

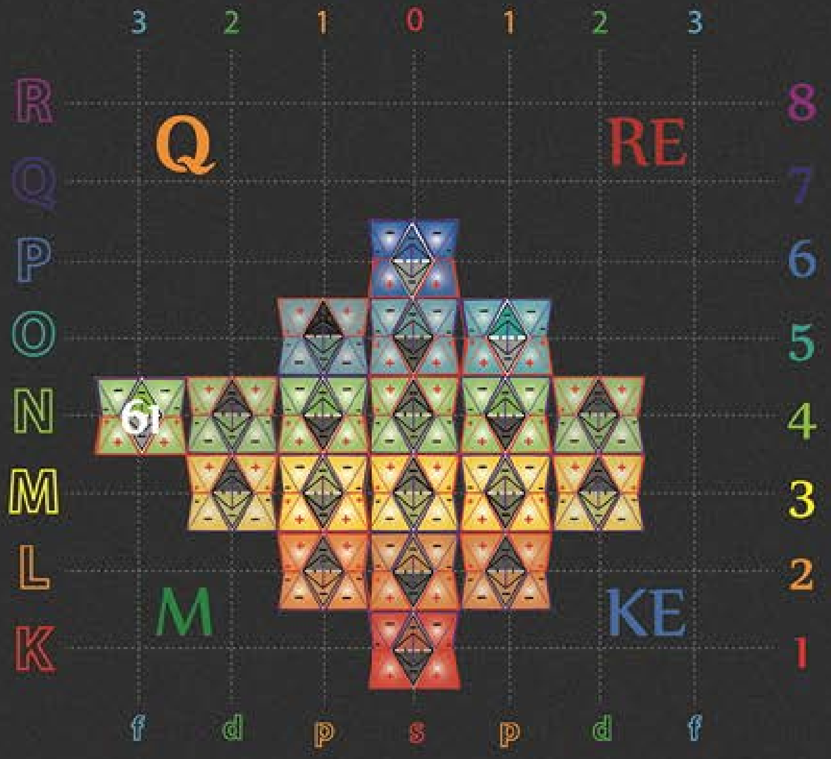
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
61
f
d
p
s
p
d
f

electron configuration
[Xe] 4f5 6s2
54

61 [Potons [24-12] Neutrons [18-18] electrons [0-12]] m1-6

Lanthanoid

Aufbau

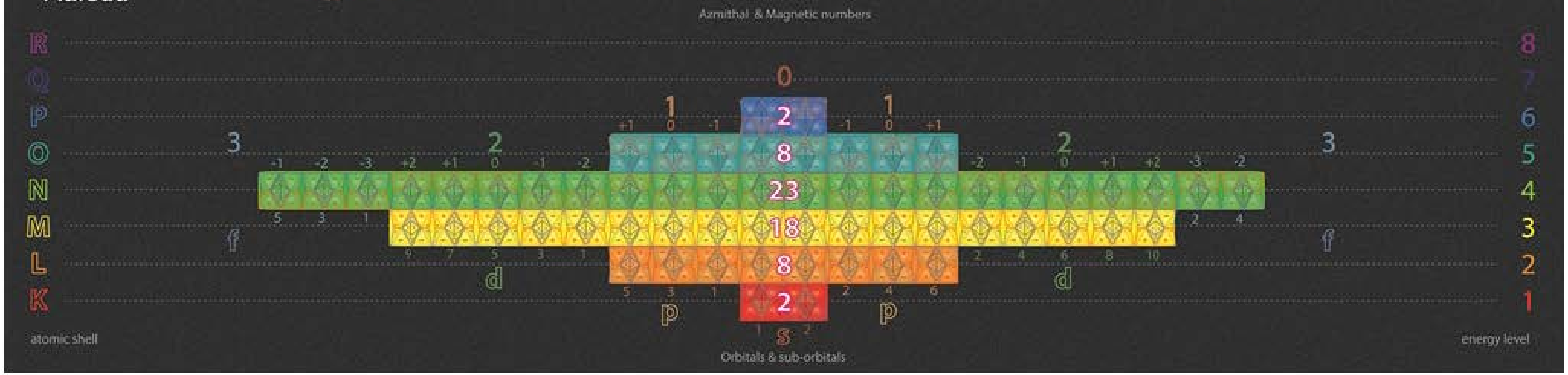
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
2
8
23
18
8
2
1
1
2
2
3
3
f
f
d
d
p
p
s
atomic shell
energy level
Orbitals & sub-orbitals

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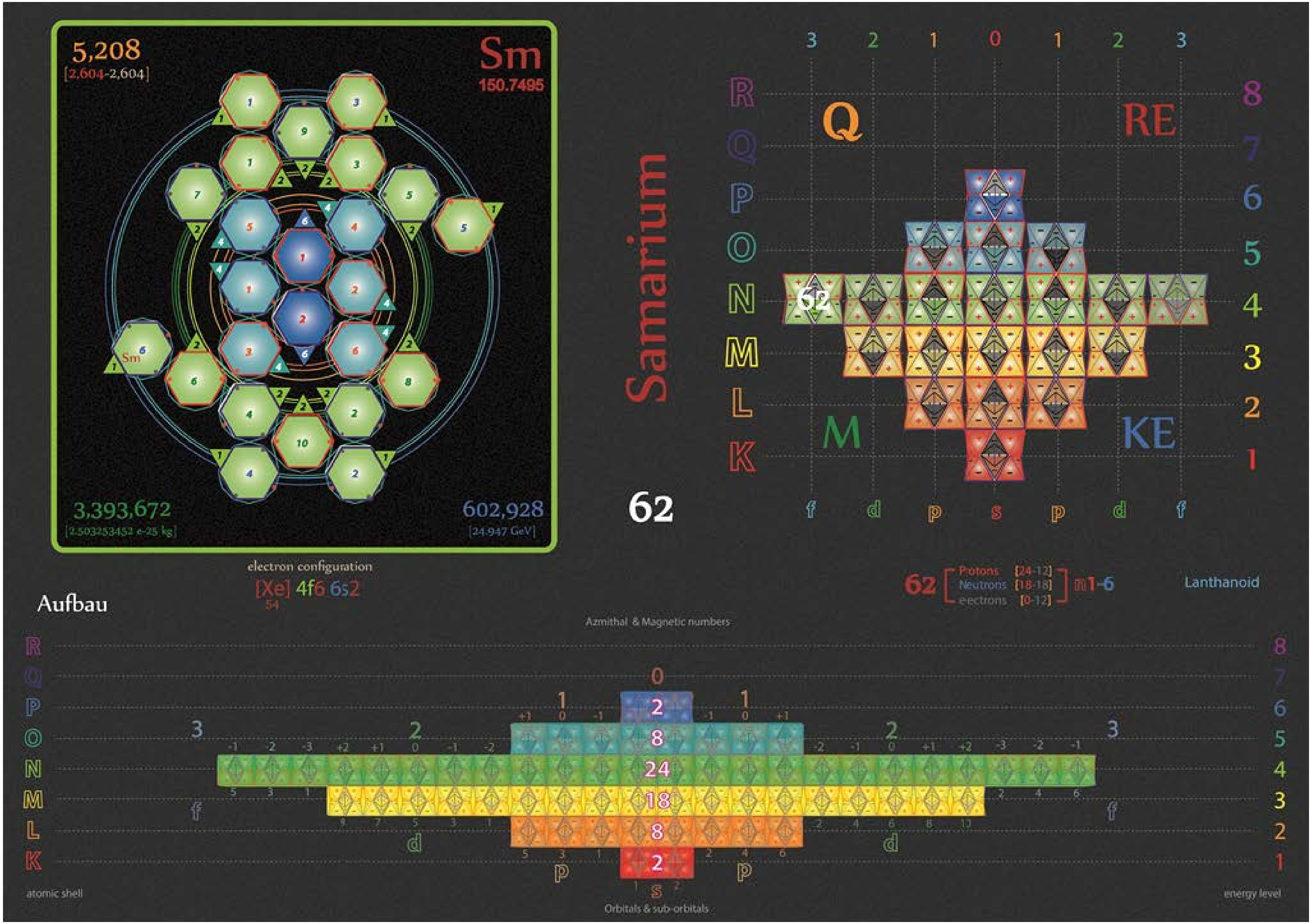
5,208
[2,604-2,604]
Sm
150.7495
3,393,672
[2.503253452 e-25 kg]
602,928
[24.947 GeV]
Samarium
62
electron configuration
[Xe] 4f6 6s2
54
Aufbau
Q
RE
M
KE
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
62 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Azmithal & Magnetic numbers
2
8
24
18
8
2
Orbitals & sub-orbitals
atomic shell
energy level

Tetryonics 51.62 - Samarium atom

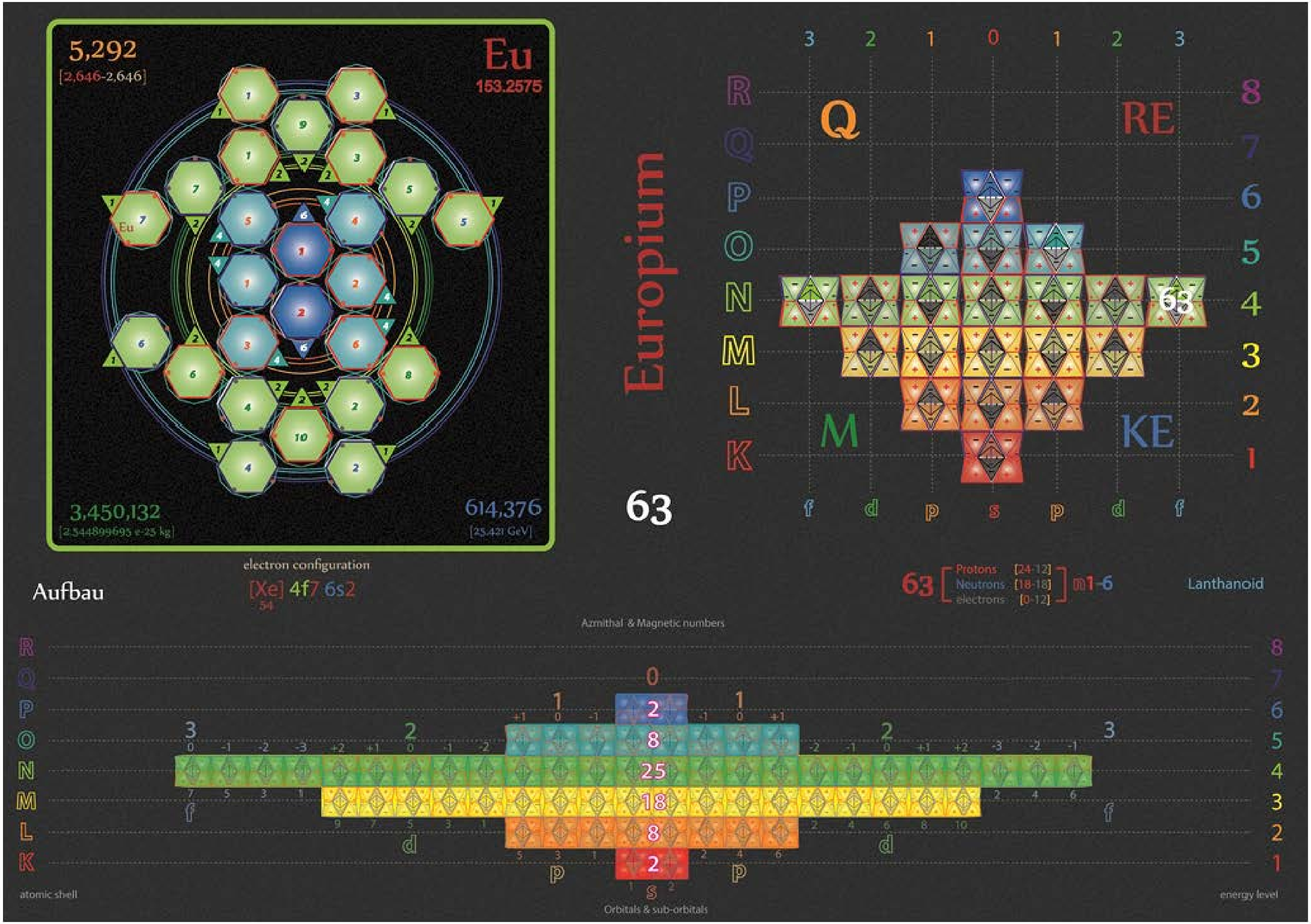
5,292
[2,646-2,646]
Eu
153.2575
3,450,132
[2.544899693 e-25 kg]
614,376
[25.421 GeV]
Europium
63
3 2 1 0 1 2 3
R Q P O N M L K
Q
RE
M
KE
8 7 6 5 4 3 2 1
f d p s p d f
electron configuration
Aufbau
[Xe] 4f7 6s2
54
63 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Azmithal & Magnetic numbers
2
8
25
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.63 - Europium atom

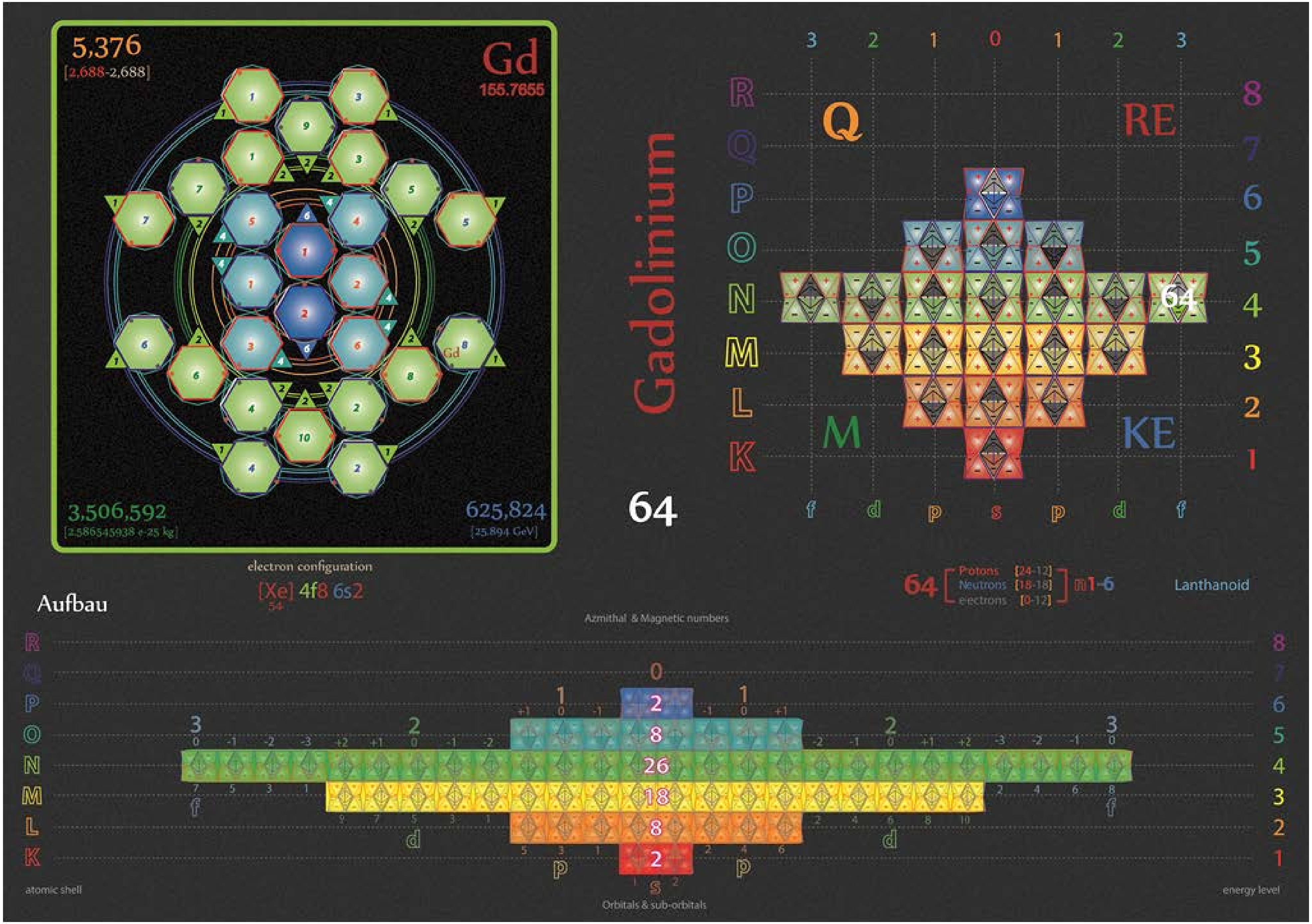
5,376
[2,688-2,688]
Gd
155.7655
3,506,592
[2.586545938 e-25 kg]
625,824
[25.894 GeV]
Gadolinium
64
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Xe] 4f8 6s2
54
Aufbau
64 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Azmithal & Magnetic numbers
2
8
26
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.64 - Gadolinium atom

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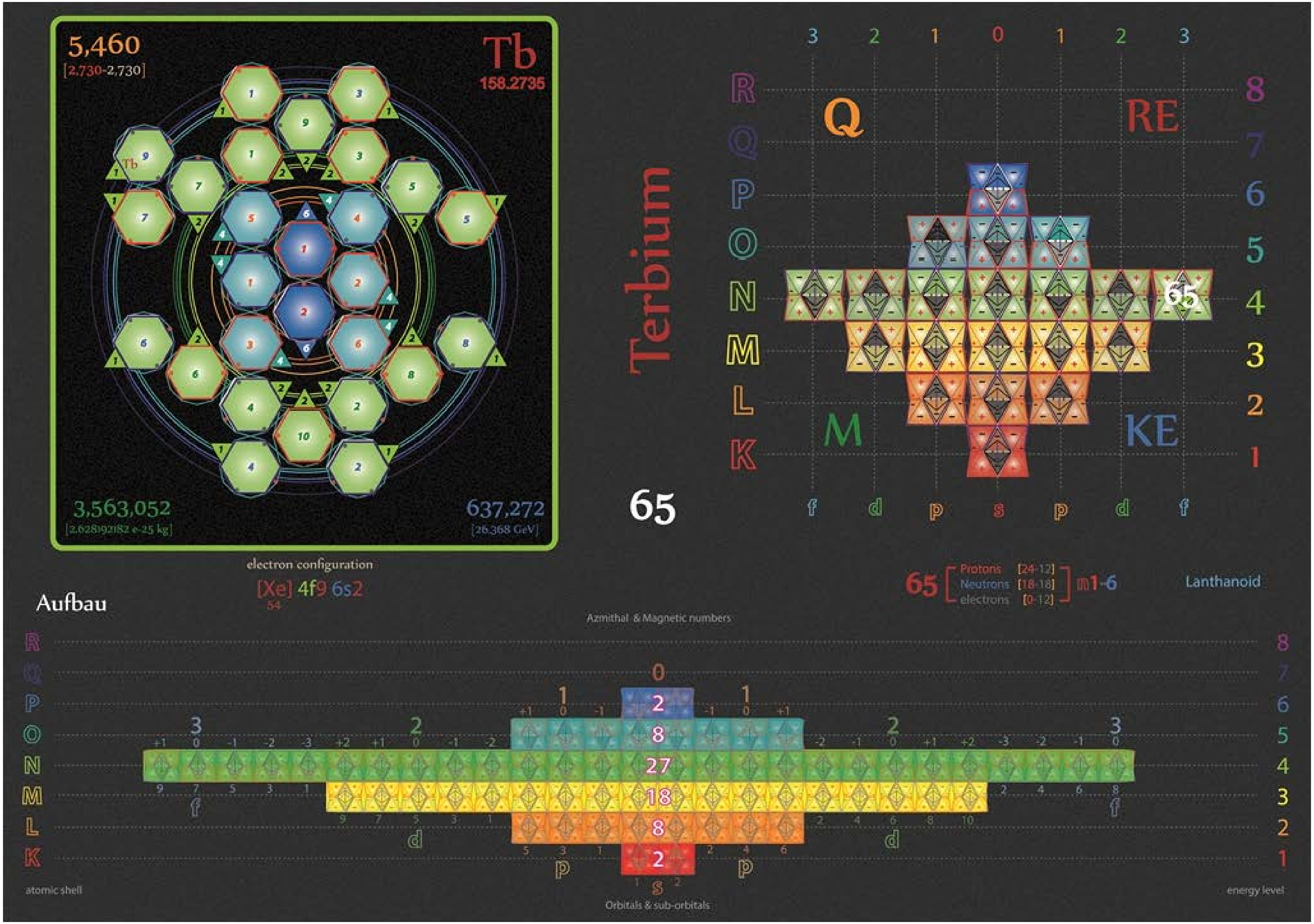
5,460
[2.730-2.730]
Tb
158.2735
3,563,052
[2.628192182 e-25 kg]
637,272
[26.368 GeV]
Terbium
65
electron configuration
[Xe] 4f9 6s2
54
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
65
65 Protons [24-12] Neutrons [18-18] electrons [0-12] m1-6
Lanthanoid
Aufbau
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
2
8
27
18
8
2
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.65 -Terbium atom

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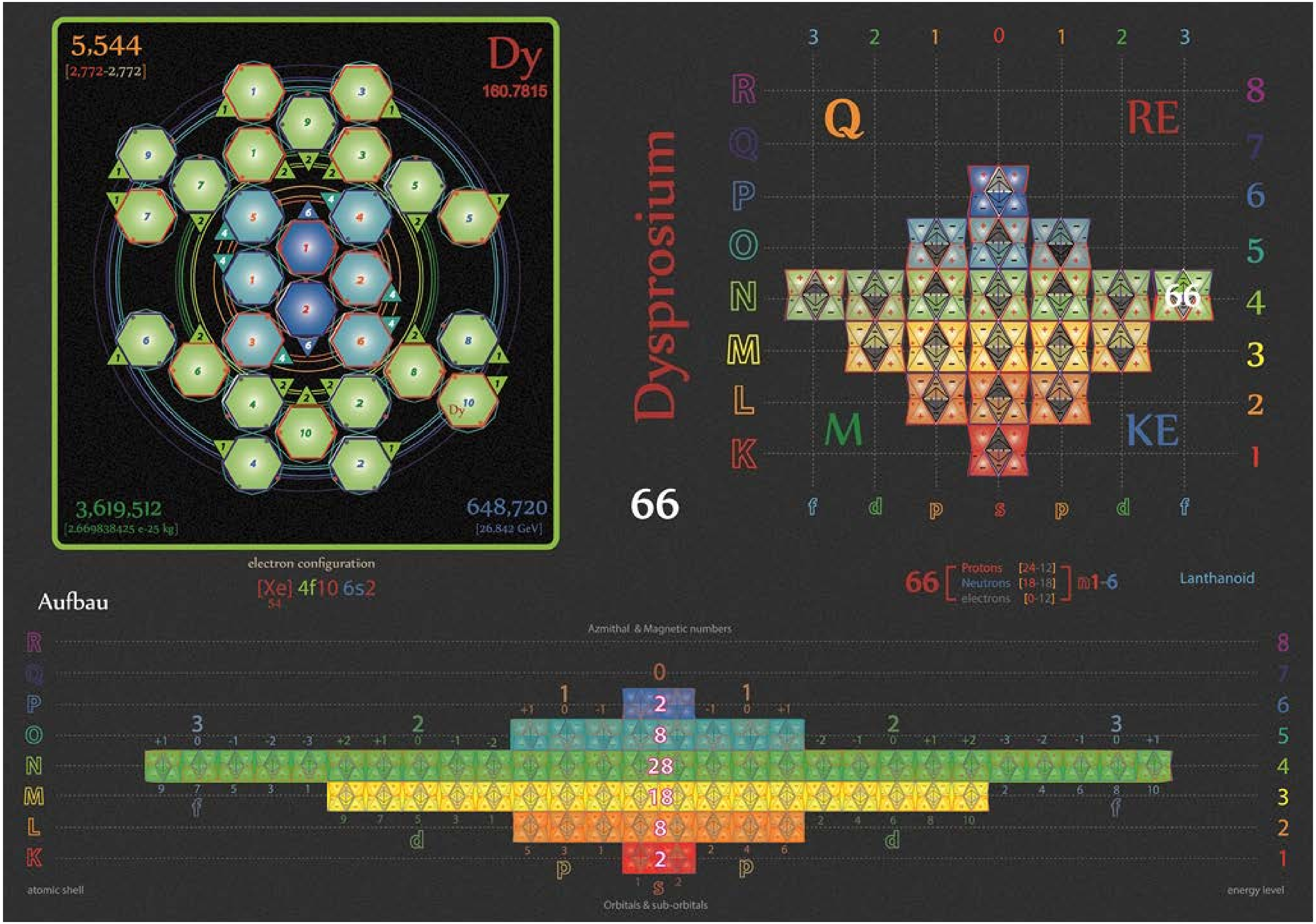
5,544
[2,772-2,772]
Dy
160.7815
3,619,512
[2.669838425 e-25 kg]
648,720
[26.842 GeV]
Dysprosium
66
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
66
f d p s p d f
electron configuration
[Xe] 4f10 6s2
54
66 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Aufbau
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
2
8
28
18
8
2
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.66 - Dysprosium atom

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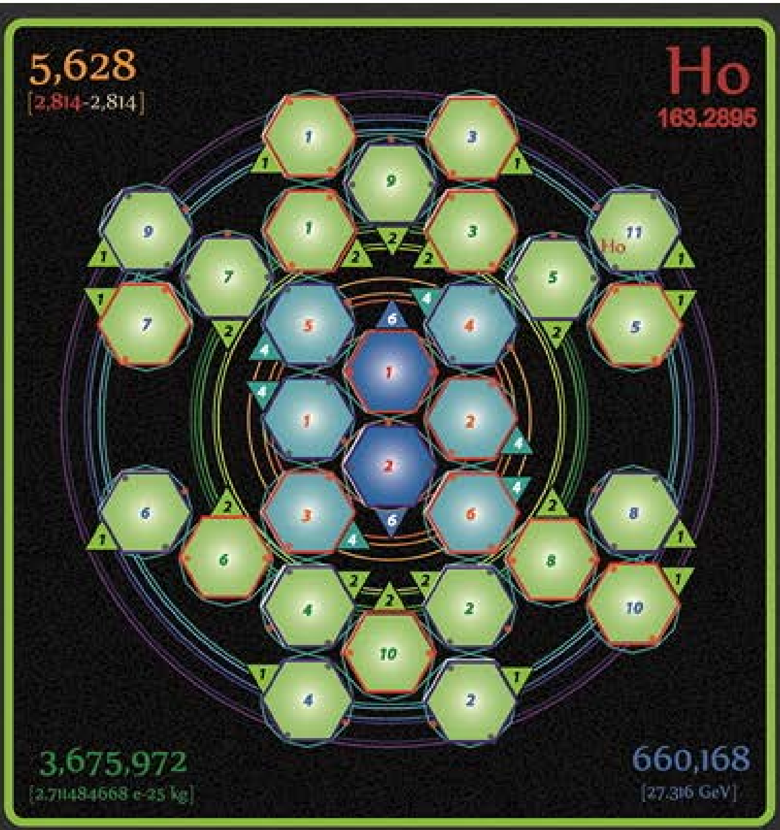

5,628
[2,814-2,814]

Ho
163.2895

3,675,972
[2.71484668 e-25 kg]

660,168
[27.316 GeV]

Holmium

67

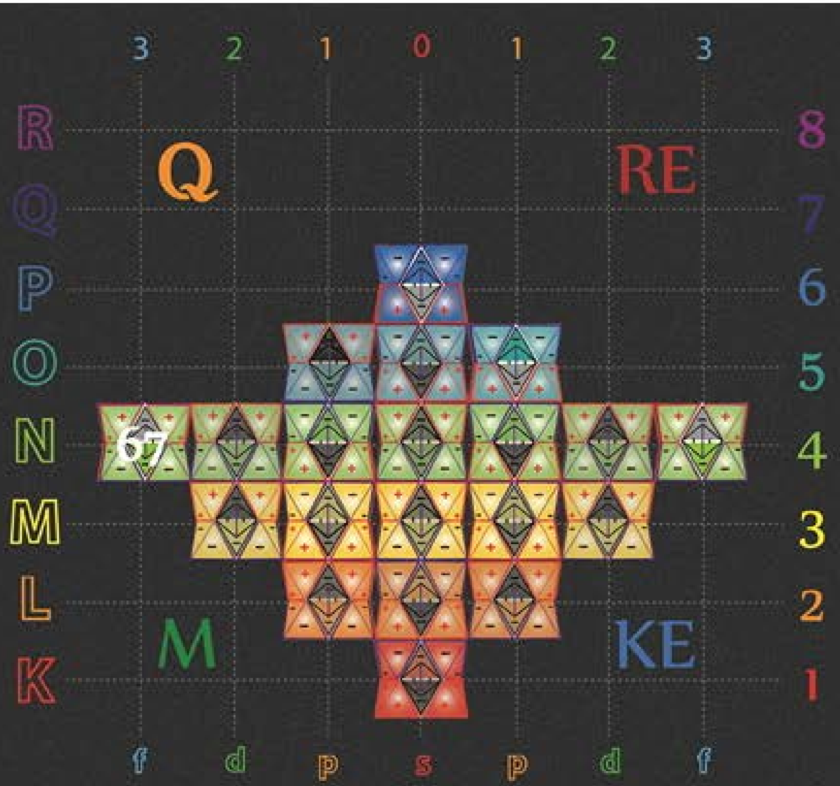
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
67
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

67 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6

Lanthanoid

Aufbau

electron configuration
[Xe] 4f11 6s2
54

Azmithal & Magnetic numbers

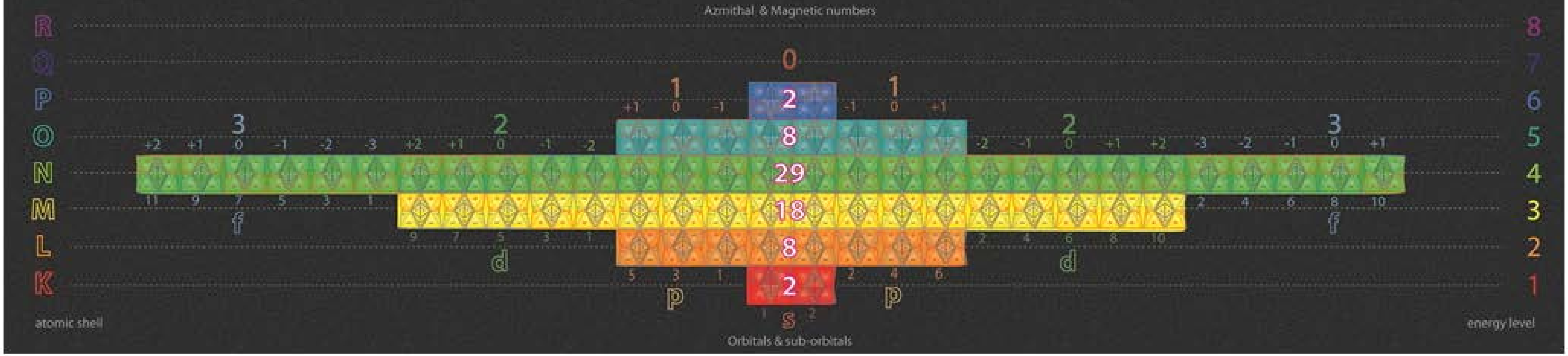
R
Q
P
O
N
M
L
K
0
1
1
2
2
3
3
2
8
29
18
8
2
f
f
d
d
p
p
s
8
7
6
5
4
3
2
1

atomic shell

energy level

Orbitals & sub-orbitals

Tetryonics 51.67 - Holmium atom

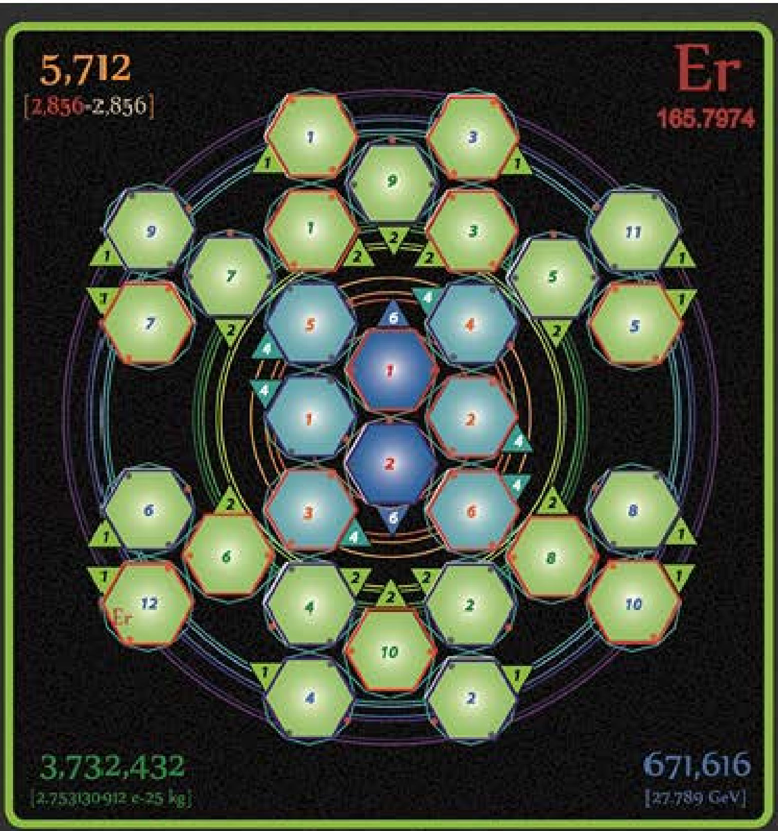

1
3
9
1
3
9
7
7
5
11
5
5
4
6
1
1
2
2
6
3
6
6
8
6
8
12
Er
10
4
2
10
4
2

5,712
[2,856-2,856]

Er
165.7974

3,732,432
[2.753130912 e-25 kg]

671,616
[27.789 GeV]

Erbium

68

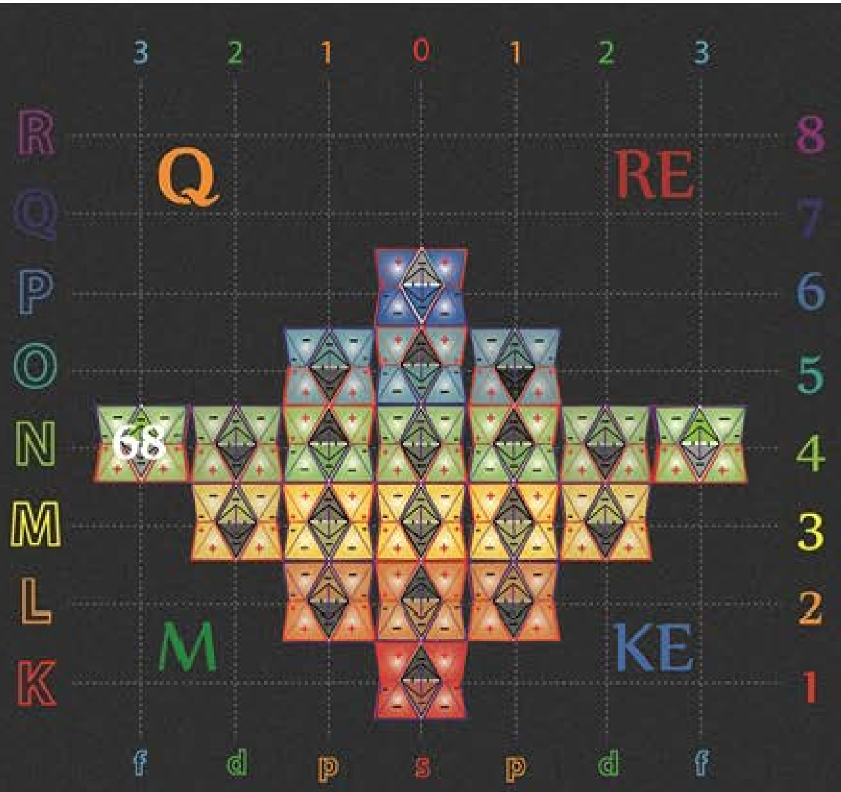

3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
68
M
KE
f
d
p
s
p
d
f

electron configuration

[Xe] 4f12 6s2
54

68 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6

Lanthanoid

Aufbau

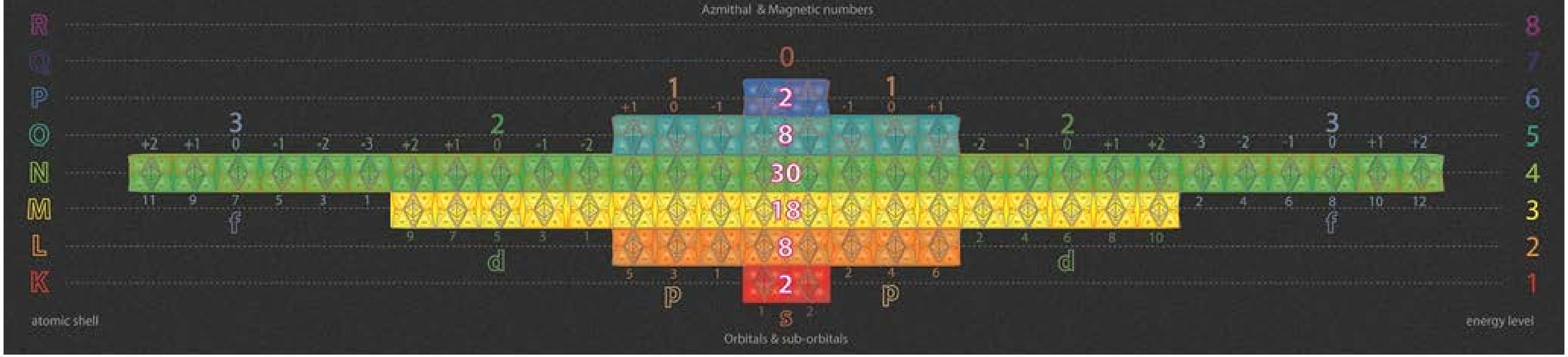

Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
8
30
18
8
2
+1 0 -1
-1 0 +1
3
2
2
3
+2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2
11 9 7 5 3 1
2 4 6 8 10 12
f
f
9 7 5 3 1
2 4 6 8 10
d
d
5 3 1
2 4 6
p
p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.68 - Erbium atom

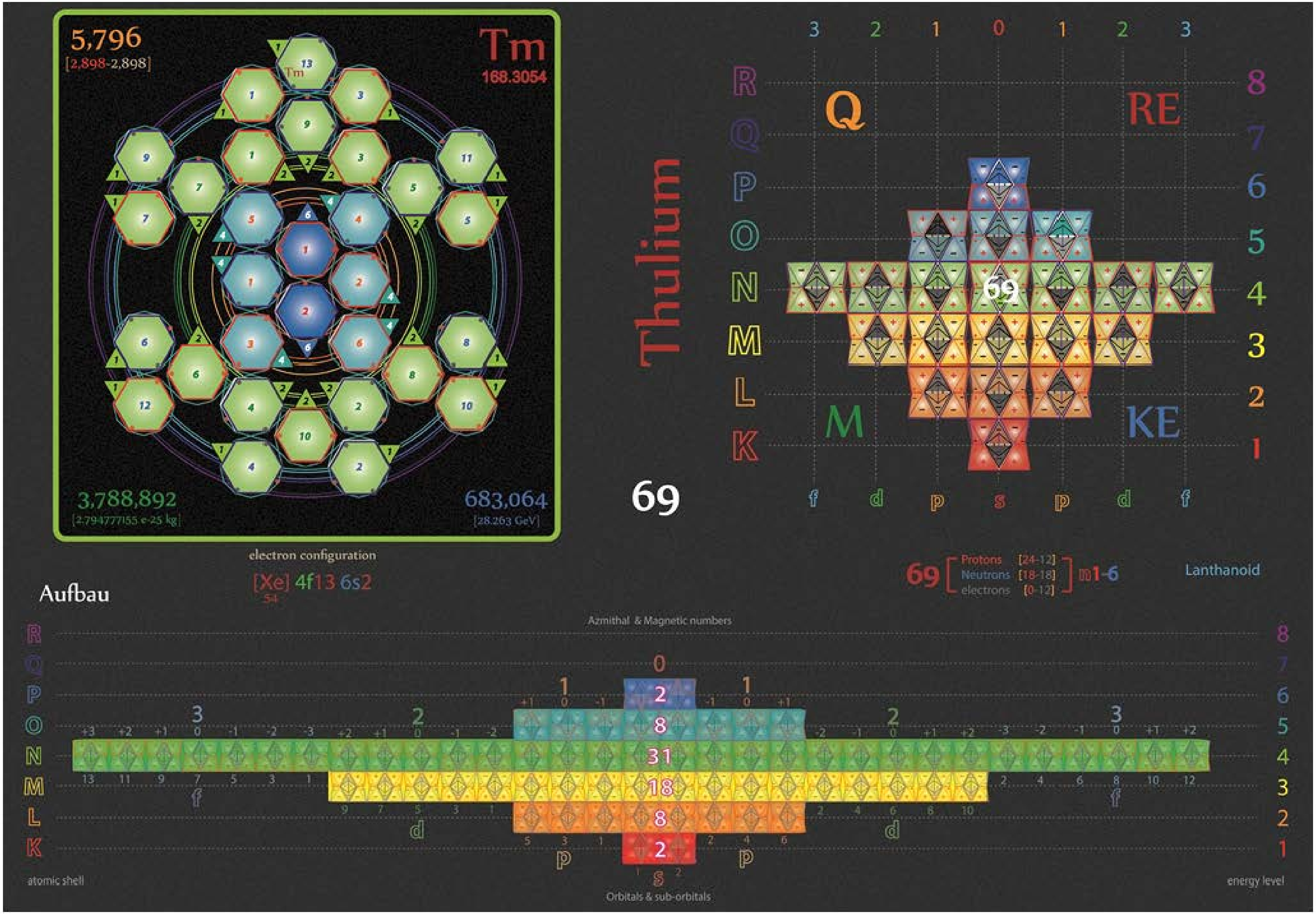
5,796
[2,898-2,898]
Tm
168.3054
3,788,892
[2.794777155 e-25 kg]
683,064
[28.263 GeV]
electron configuration
[Xe] 4f13 6s2
54
Thulium
69
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
69
f d p s p d f
69 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Aufbau
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
2
8
31
18
8
2
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.69 - Thulium atom

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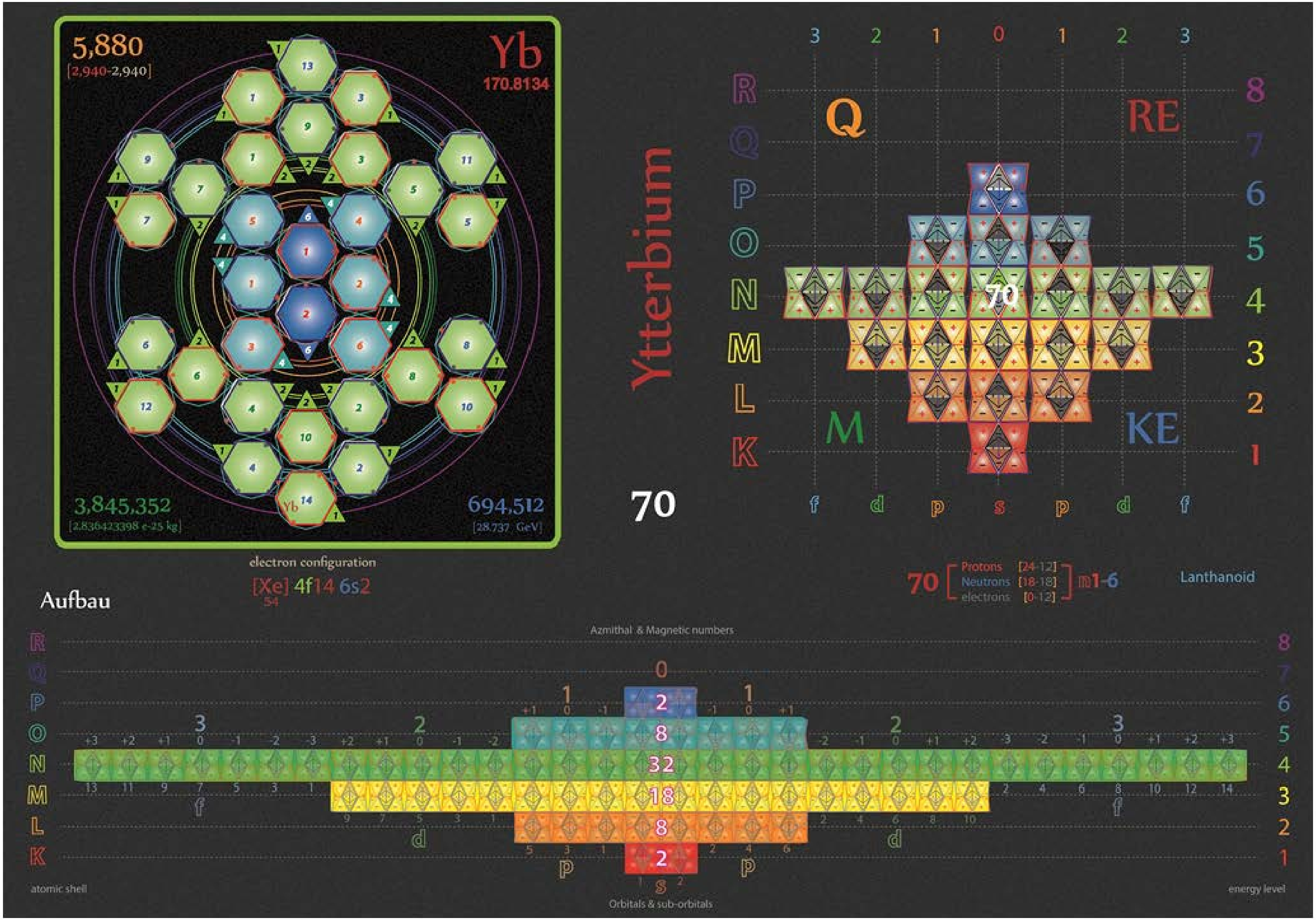
5,880
[2,940-2,940]
Yb
170.8134
3,845,352
[2.836423398 e-25 kg]
694,512
[28.737 GeV]
Ytterbium
70
electron configuration
[Xe] 4f14 6s2
54
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
70
f d p s p d f
70
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-6
Lanthanoid
Azmithal & Magnetic numbers
0
2
8
32
18
8
2
f
d
p
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.70 - Ytterbium atom

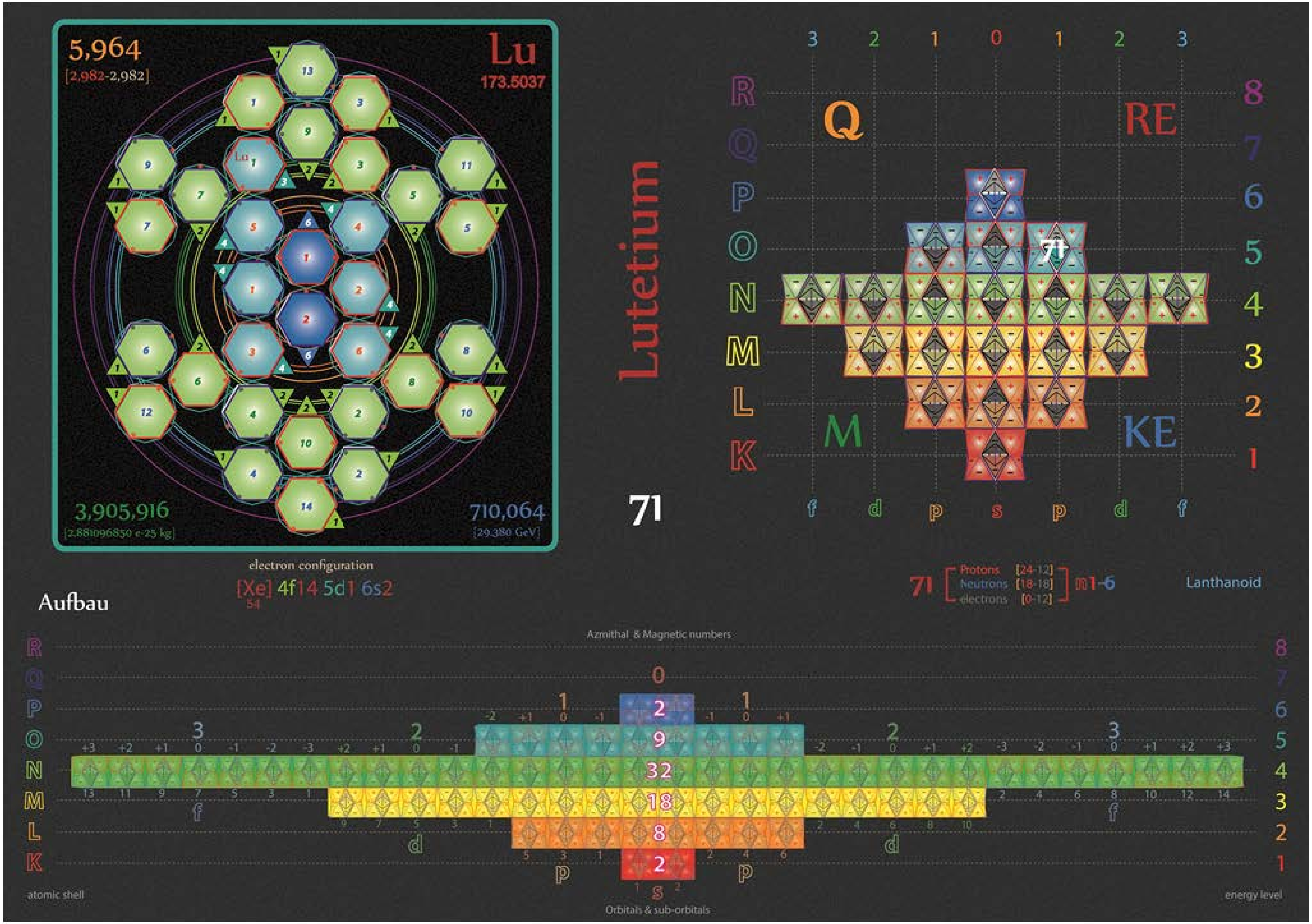
5,964
[2,982-2,982]
Lu
173.5037
3,905,916
[2.881096850 e-25 kg]
710,064
[29.380 GeV]
Lutetium
71
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
71 [Protons [24-12] neutrons [18-18] electrons [0-12]] n1-6
Lanthanoid
electron configuration
[Xe] 4f14 5d1 6s2
54
Aufbau
Azmithal & Magnetic numbers
0
1
2
3
2
9
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals
s
p
d
f

Tetryonics 51.71 - Lutetium atom

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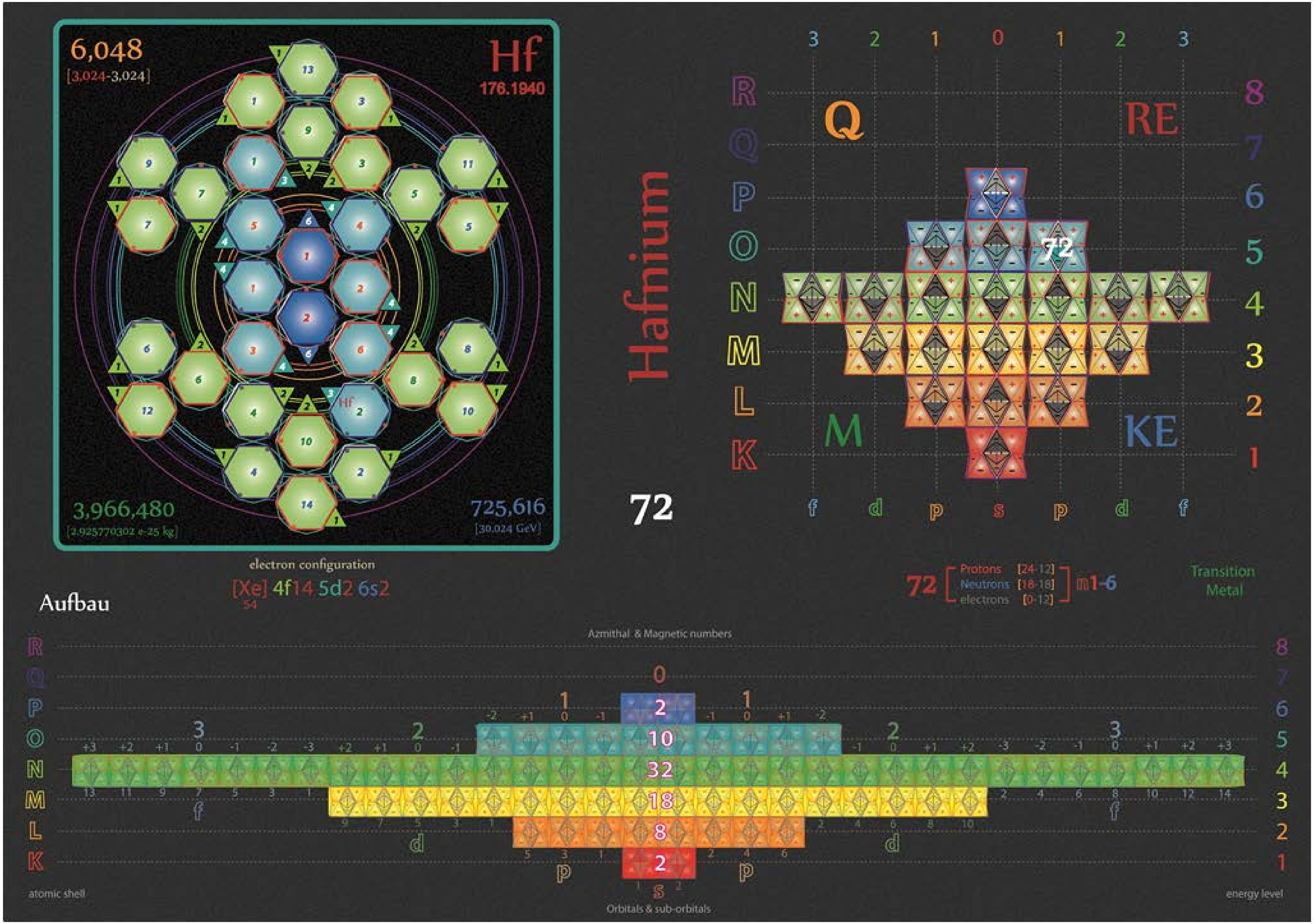
6,048
[3,024-3,024]
Hf
176.1940
3,966,480
[2.925770302 e-25 kg]
725,616
[30.024 GeV]
Hafnium
72
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
8
7
6
5
4
3
2
1
Q
RE
M
KE
f d p s p d f
electron configuration
[Xe] 4f14 5d2 6s2
54
72 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Transition Metal
Aufbau
Azmithal & Magnetic numbers
0
1
2
3
2
10
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.72 - Hafnium atom

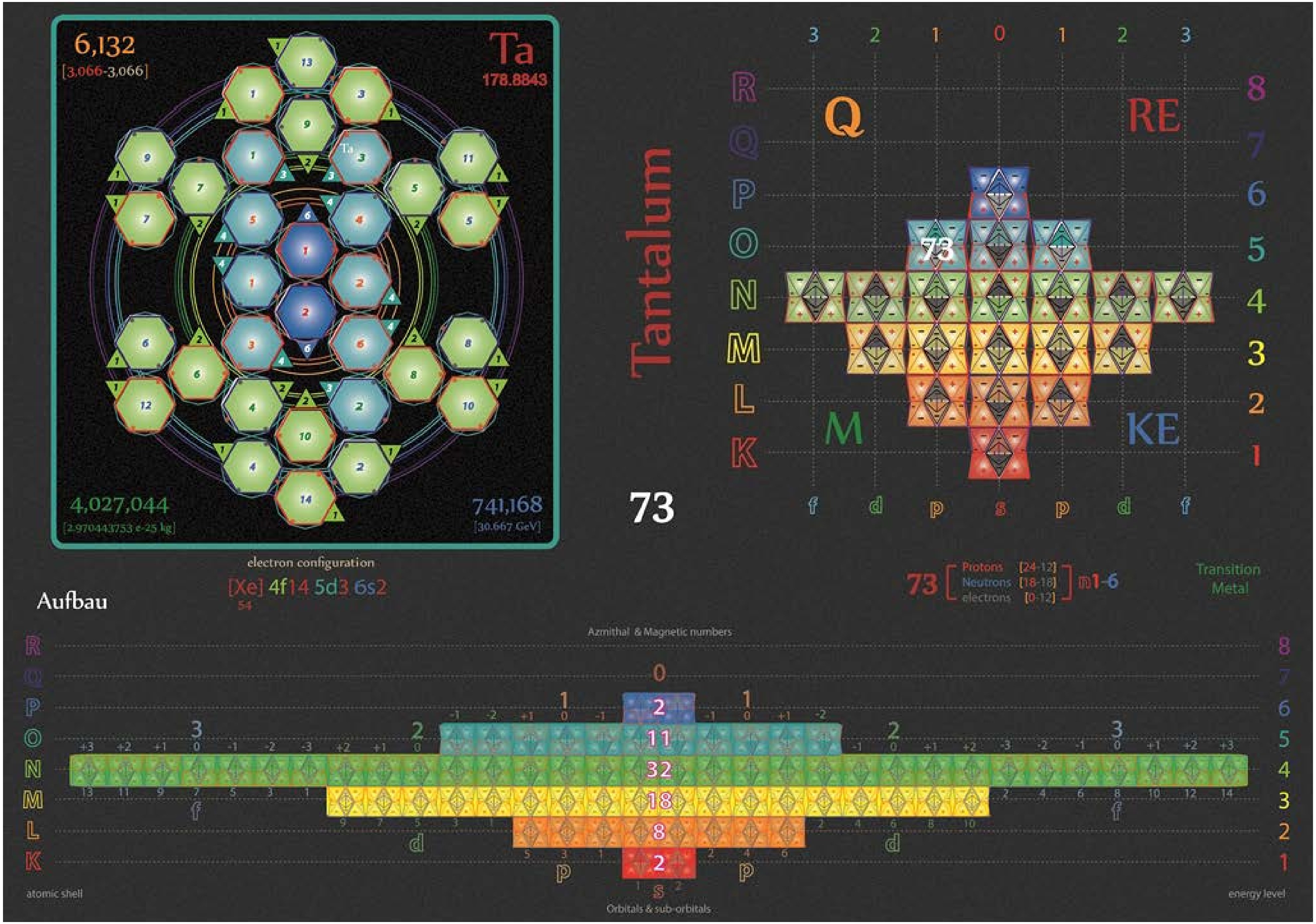
6,132
[3,066-3,066]
Ta
178.8843
4,027,044
[2.970443753 e-25 kg]
741,168
[30.667 GeV]
Tantalum
73
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
73
f d p s p d f
electron configuration
[Xe] 4f14 5d3 6s2
54
73 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Transition Metal
Aufbau
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
2
11
32
18
8
2
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.73 - Tantalum atom

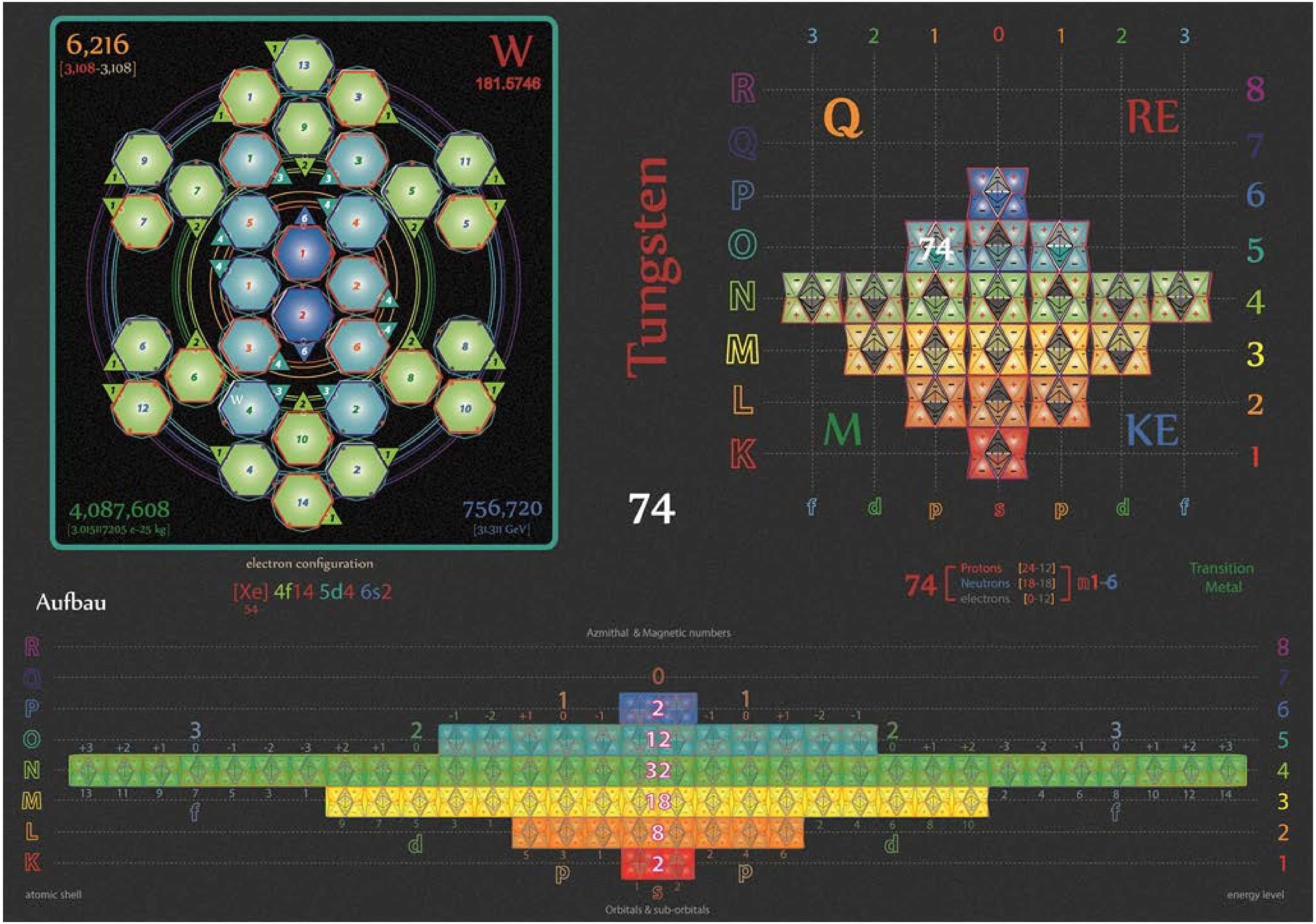
6,216
[3,108-3,108]
W
181.5746
4,087,608
[3.015117205 e-25 kg]
756,720
[31.311 GeV]
Tungsten
74
electron configuration
[Xe] 4f14 5d4 6s2
54
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
74 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Transition Metal
Azmithal & Magnetic numbers
2
12
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.74 - Tungsten atom

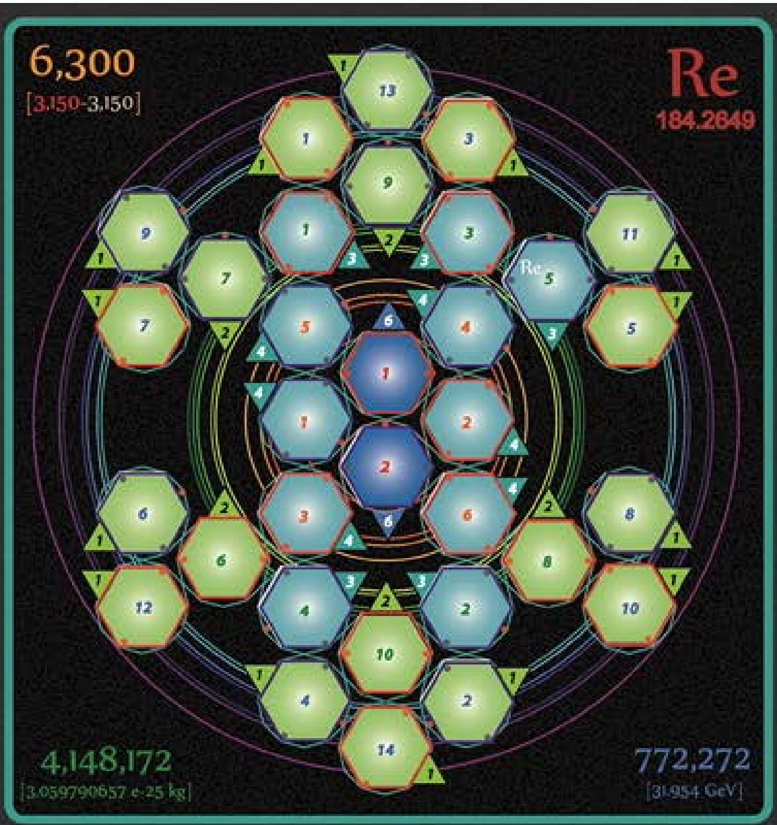
6,300
[3,150-3,150]
Re
184.2849
4,148,172
[3.059790657 e-25 kg]
772,272
[31.954 GeV]

Rhenium

75

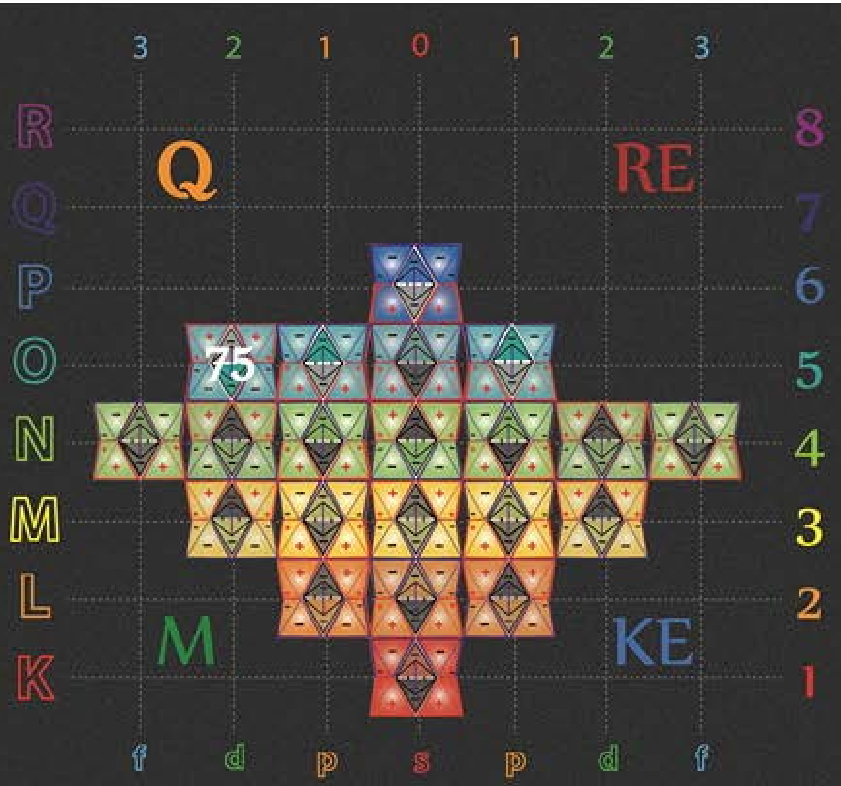
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
75
f d p s p d f

electron configuration

[Xe] 4f14 5d5 6s2
54

75 Protons [24-12] Neutrons [18-18] electrons [0-12] m1-6

Transition Metal

Aufbau

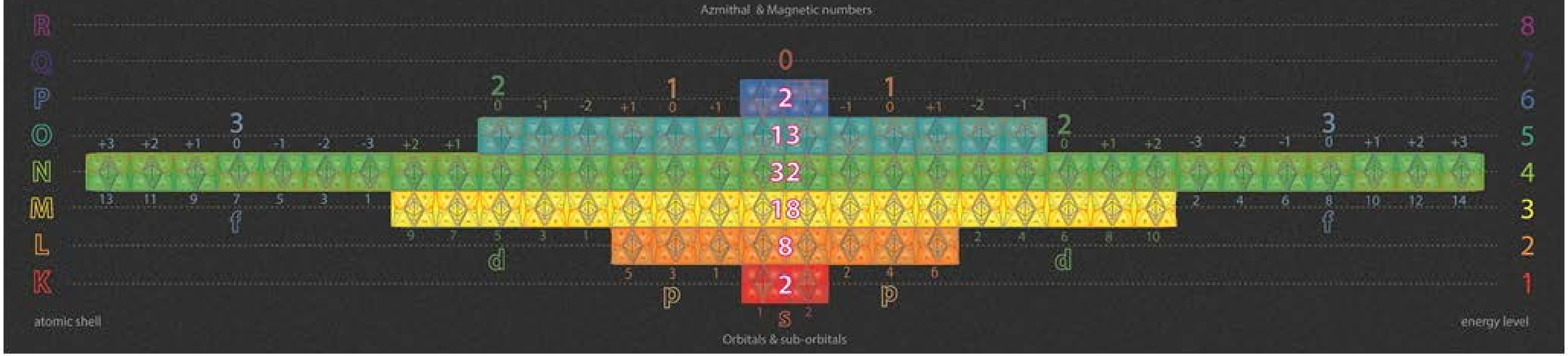
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
2 13 32 18 8 2
3 2 1 1 2 3
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.75 - Rhenium atom

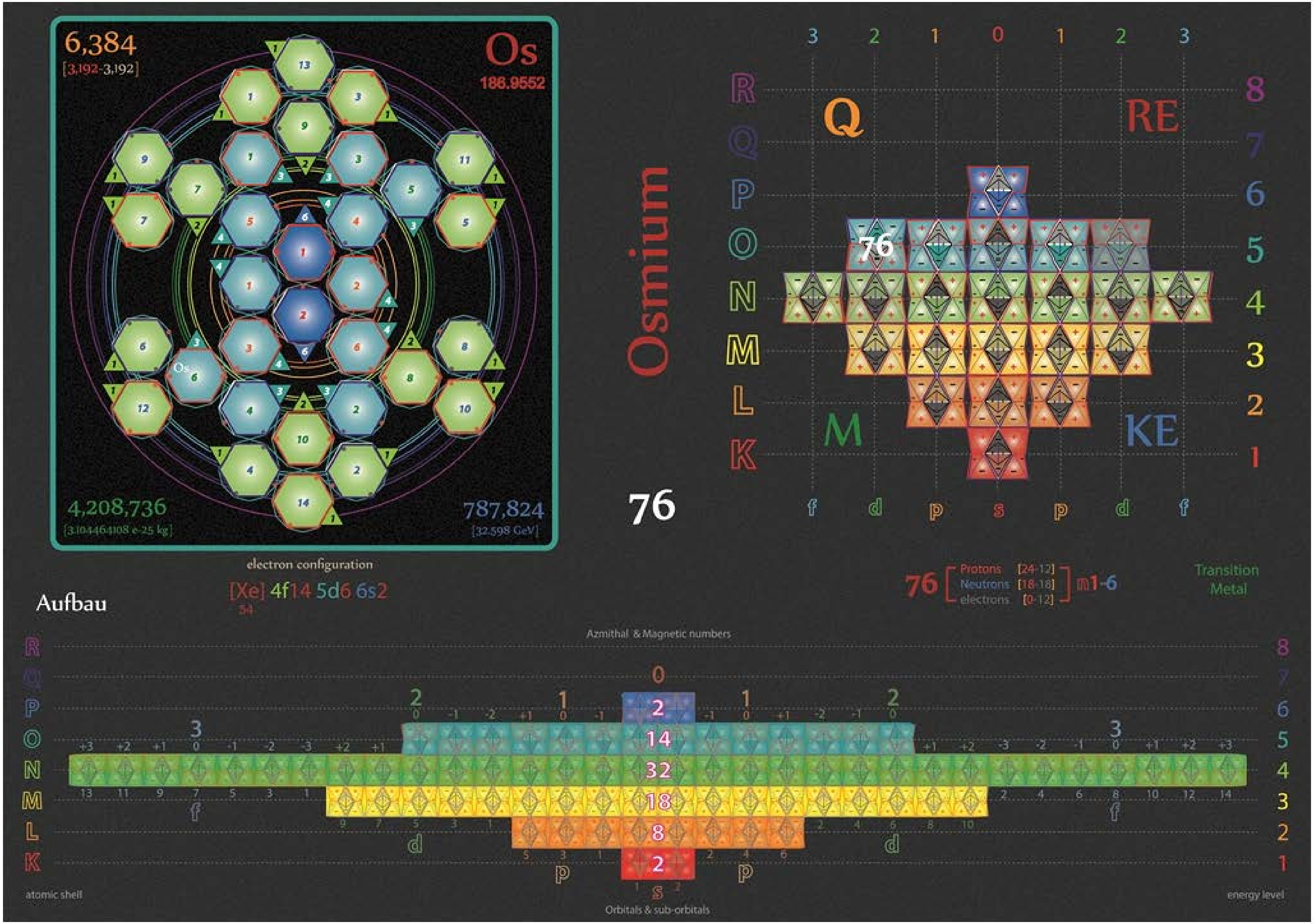
6,384
[3,192-3,192]
Os
186.9552
4,208,736
[3.104464108 e-25 kg]
787,824
[32.598 GeV]
electron configuration
[Xe] 4f14 5d6 6s2
54
Aufbau
Osmium
76
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
76
76 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Transition Metal
Azmithal & Magnetic numbers
Orbitals & sub-orbitals
atomic shell
energy level
2
14
32
18
8
2

Tetryonics 51.76 - Osmium atom

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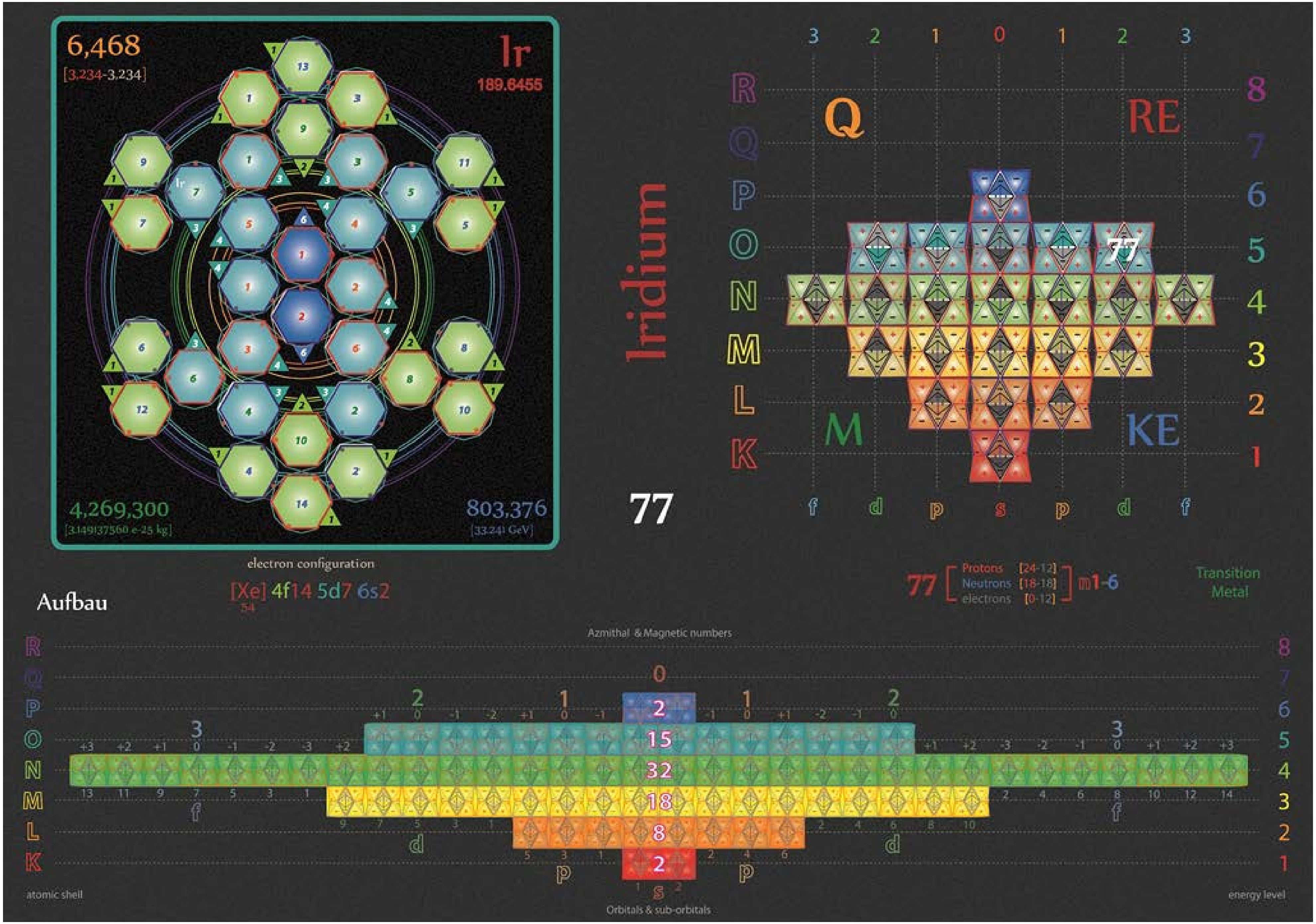
6,468
[3.234-3.234]
Ir
189.6455
4,269,300
[3.149137560 e-25 kg]
803,376
[33.241 GeV]
Iridium
77
electron configuration
[Xe] 4f14 5d7 6s2
54
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
77
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-6
Transition Metal
Azmithal & Magnetic numbers
0
2
15
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.77 - Iridium atom

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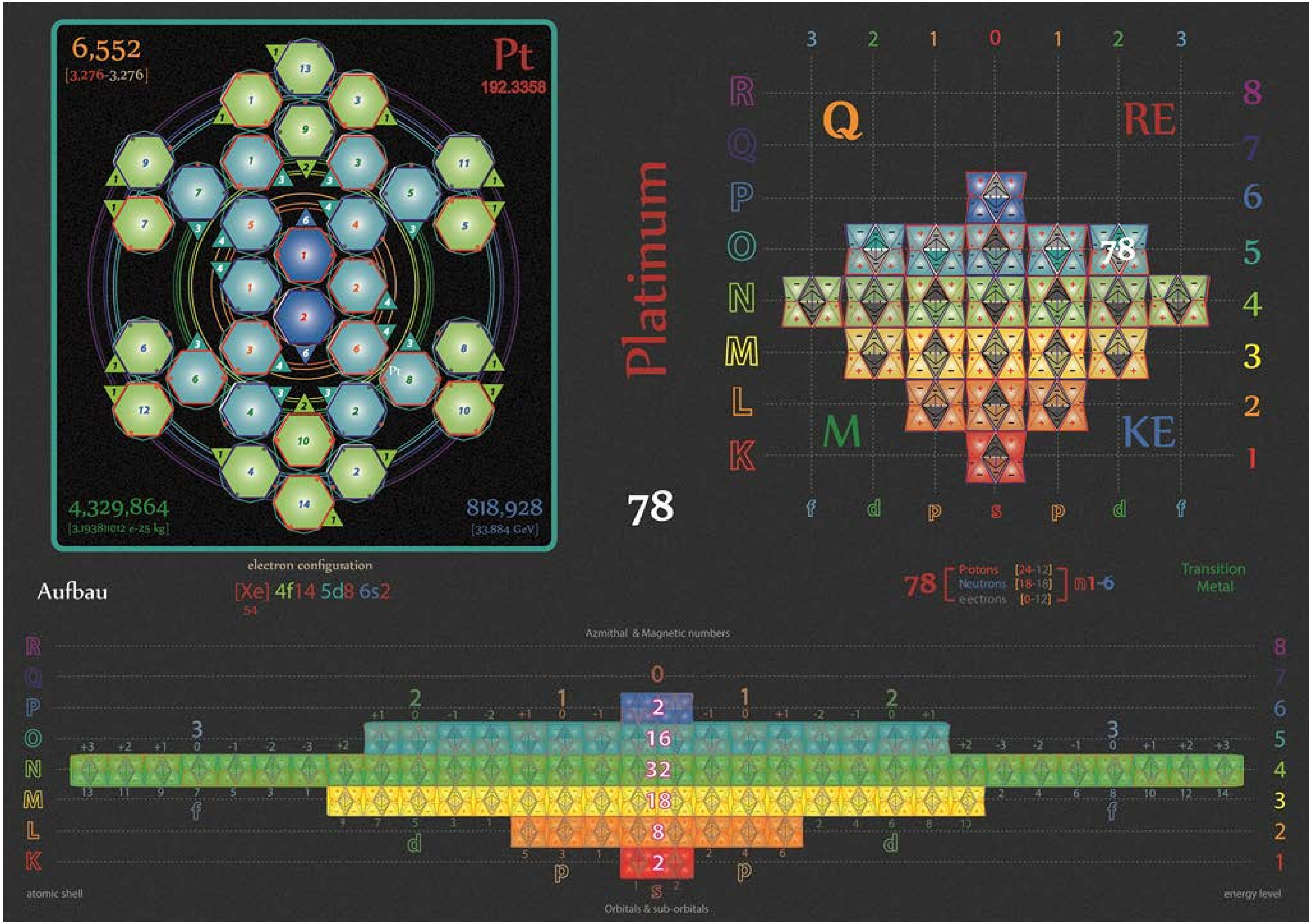
6,552
[3,276-3,276]
Pt
192.3358
4,329,864
[3.19381012 e-25 kg]
818,928
[33.884 GeV]
Platinum
78
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Xe] 4f14 5d8 6s2
54
78 [Potons [24-12] Neutrons [18-18] eectrons [0-12]] m1-6
Transition Metal
Azmithal & Magnetic numbers
2
16
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.78 - Platinum atom

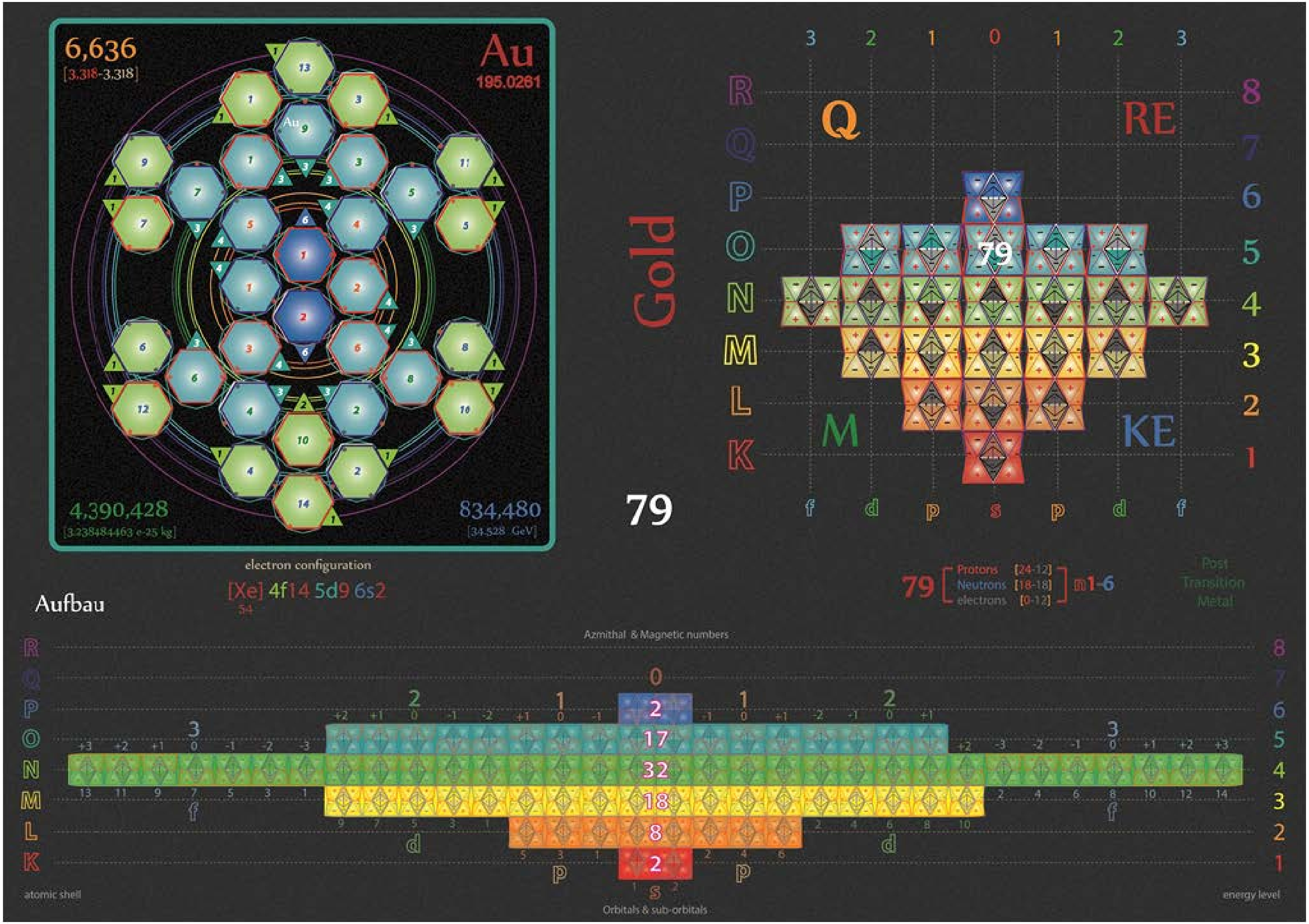
6,636
[3.318-3.318]
Au
195.0261
4,390,428
[3.238484463 e-25 kg]
834,480
[34.528 GeV]
electron configuration
[Xe] 4f14 5d9 6s2
54
Aufbau
Gold
79
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
79
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-6
Post Transition Metal
Azmithal & Magnetic numbers
0
2
17
32
18
8
2
1 2 3
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
f
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.79 - Gold atom

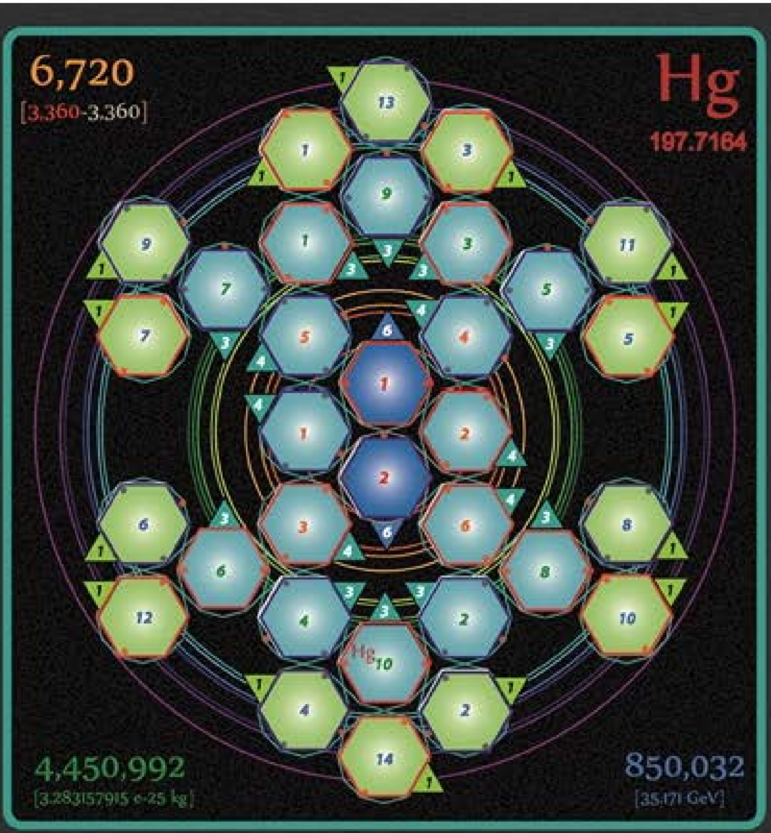
6,720
[3,360-3,360]
Hg
197.7164
13
1
3
9
1
3
9
7
5
11
7
5
5
4
6
1
1
2
2
6
6
3
6
6
8
12
4
2
10
Hg 10
4
2
14
4,450,992
[3.283157915 e-25 kg]
850,032
[35.171 GeV]

electron configuration

[Xe] 4f14 5d10 6s2
54

Mercury

80

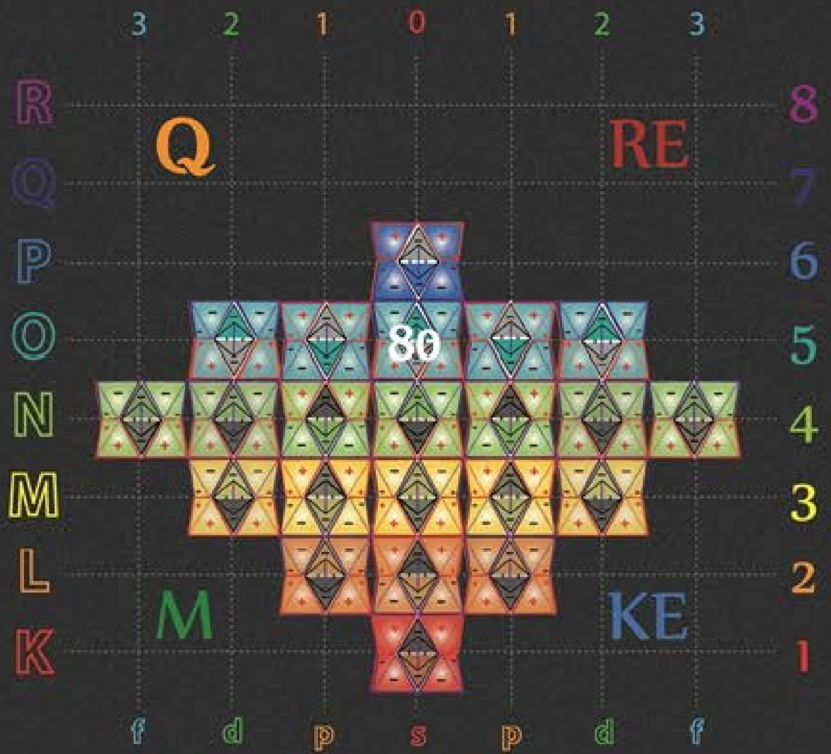
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
80
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

80 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-6

Post Transition Metal

Aufbau

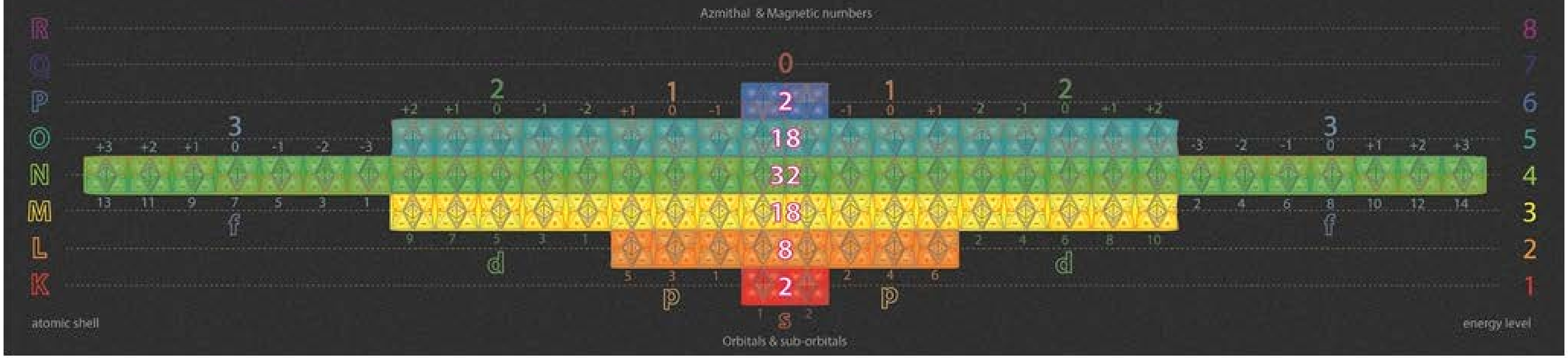
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
0
2
1
1
2
3
3
+2
+1
0
-1
-2
+1
0
-1
-1
0
+1
-2
-1
0
+1
+2
+3
+2
+1
0
-1
-2
-3
-3
-2
-1
0
+1
+2
+3
2
18
32
18
8
2
13
11
9
7
5
3
1
2
4
6
8
10
12
14
f
f
9
7
5
3
1
2
4
6
8
10
d
d
5
3
1
2
4
6
p
p
1
s
2
8
7
6
5
4
3
2
1
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.80 - Mercury atom

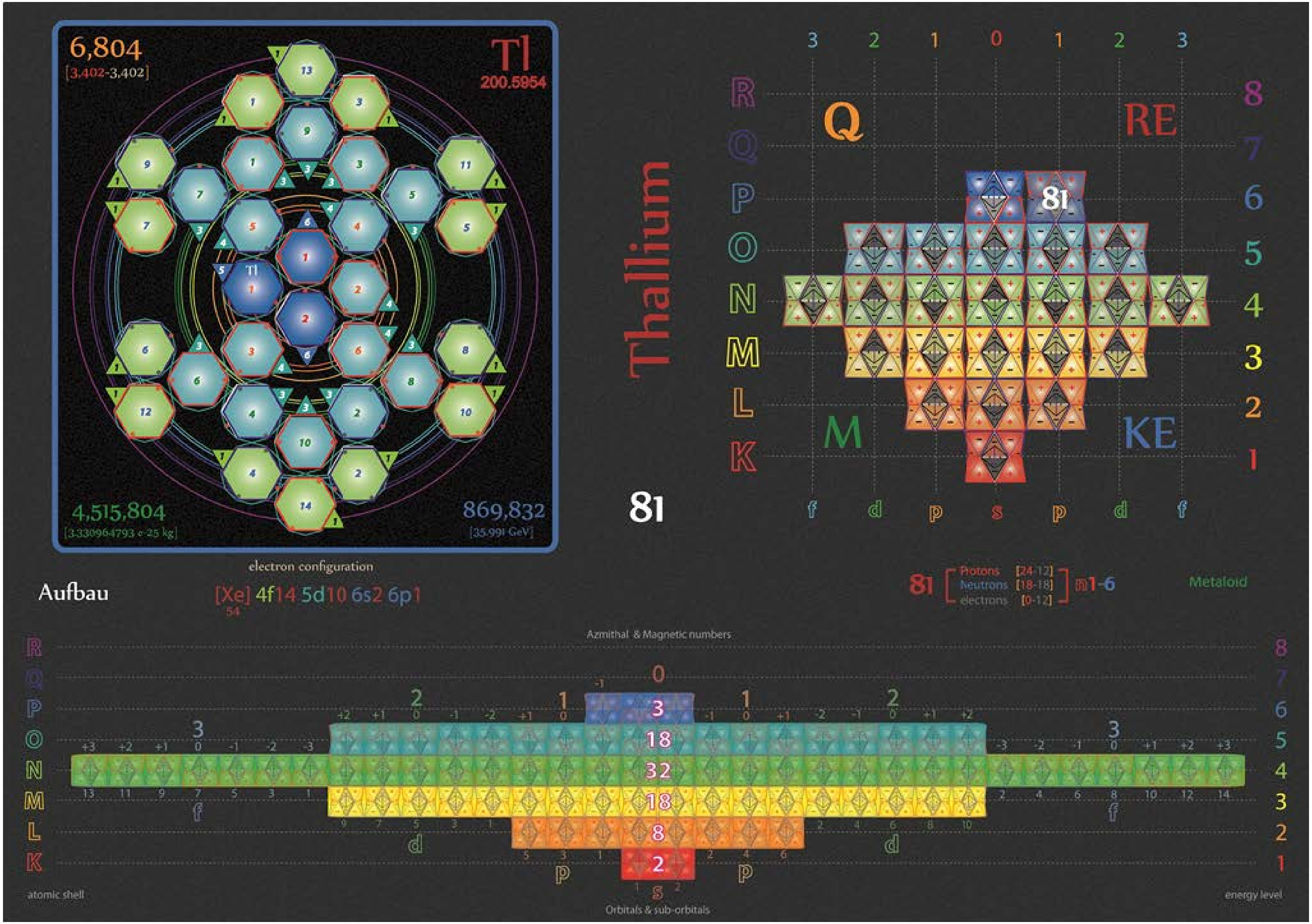
6,804
[3,402-3,402]
Tl
200.5954
4,515,804
[3.330964793 e-25 kg]
869,832
[35.991 GeV]
Thallium
81
R
Q
P
O
N
M
L
K
3
2
1
0
1
2
3
Q
RE
M
KE
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
electron configuration
Aufbau
[Xe] 4f14 5d10 6s2 6p1
54
81 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-6
Metaloid
Azmithal & Magnetic numbers
3
18
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.81 - Thallium atom

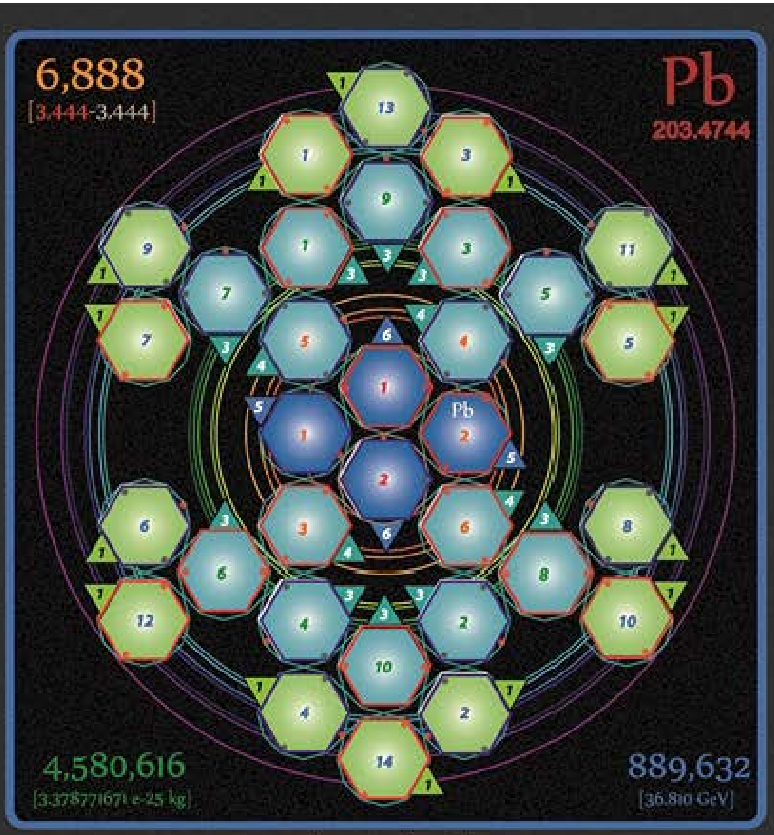
6,888
[3.444-3.444]
Pb
203.4744
13
1
3
9
1
3
9
11
7
5
7
5
5
4
6
1
Pb
2
1
5
2
6
6
3
6
8
6
8
12
10
4
2
10
4
2
14
4,580,616
[3.37877167l e-25 kg]
889,632
[36.810 GeV]

electron configuration

Lead

82

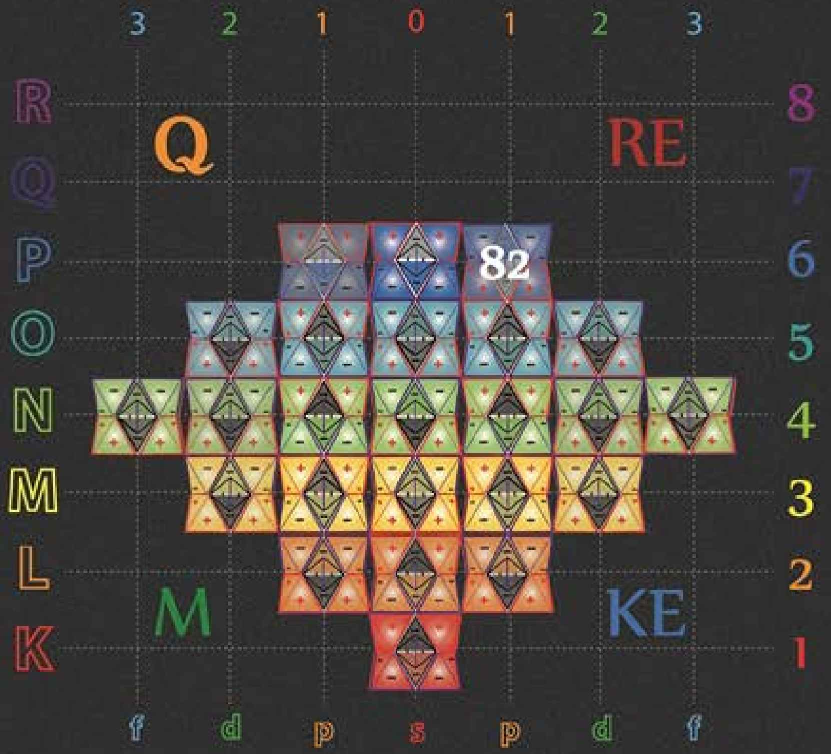
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
82
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

Aufbau

[Xe] 4f14 5d10 6s2 6p2
54

82 [Protons [24-12]
Neutrons [18-18]
electrons [0-12]] m1-6

Metaloid

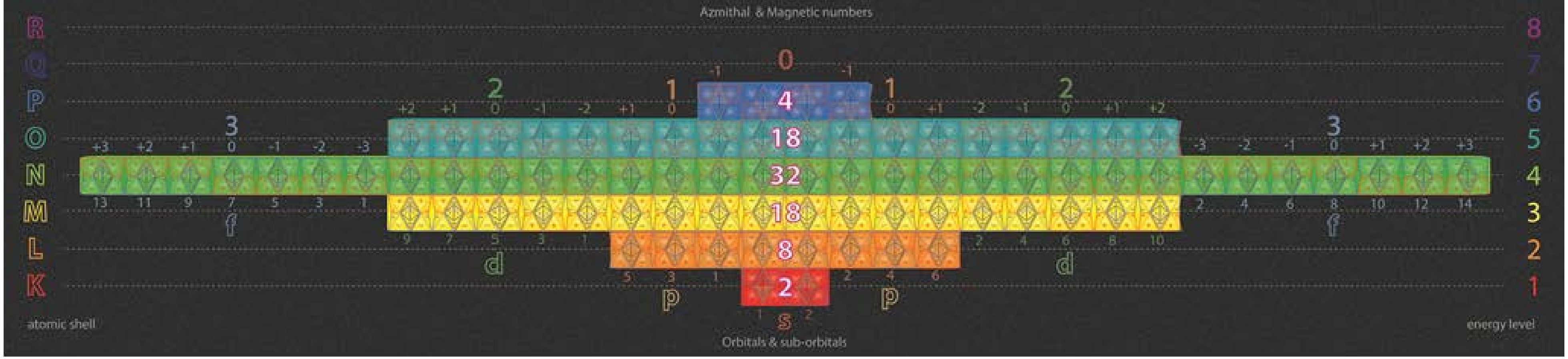
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
0
-1
-1
4
18
32
18
8
2
1
1
2
2
3
3
+3
+2
+1
0
-1
-2
-3
+2
+1
0
-1
-2
+1
0
0
+1
-2
-1
0
+1
+2
-3
-2
-1
0
+1
+2
+3
13
11
9
7
5
3
1
2
4
6
8
10
12
14
f
f
9
7
5
3
1
2
4
6
8
10
d
d
5
3
1
2
4
6
p
p
1
s
2
8
7
6
5
4
3
2
1
atomic shell
energy level
Orbitals & sub-orbitals

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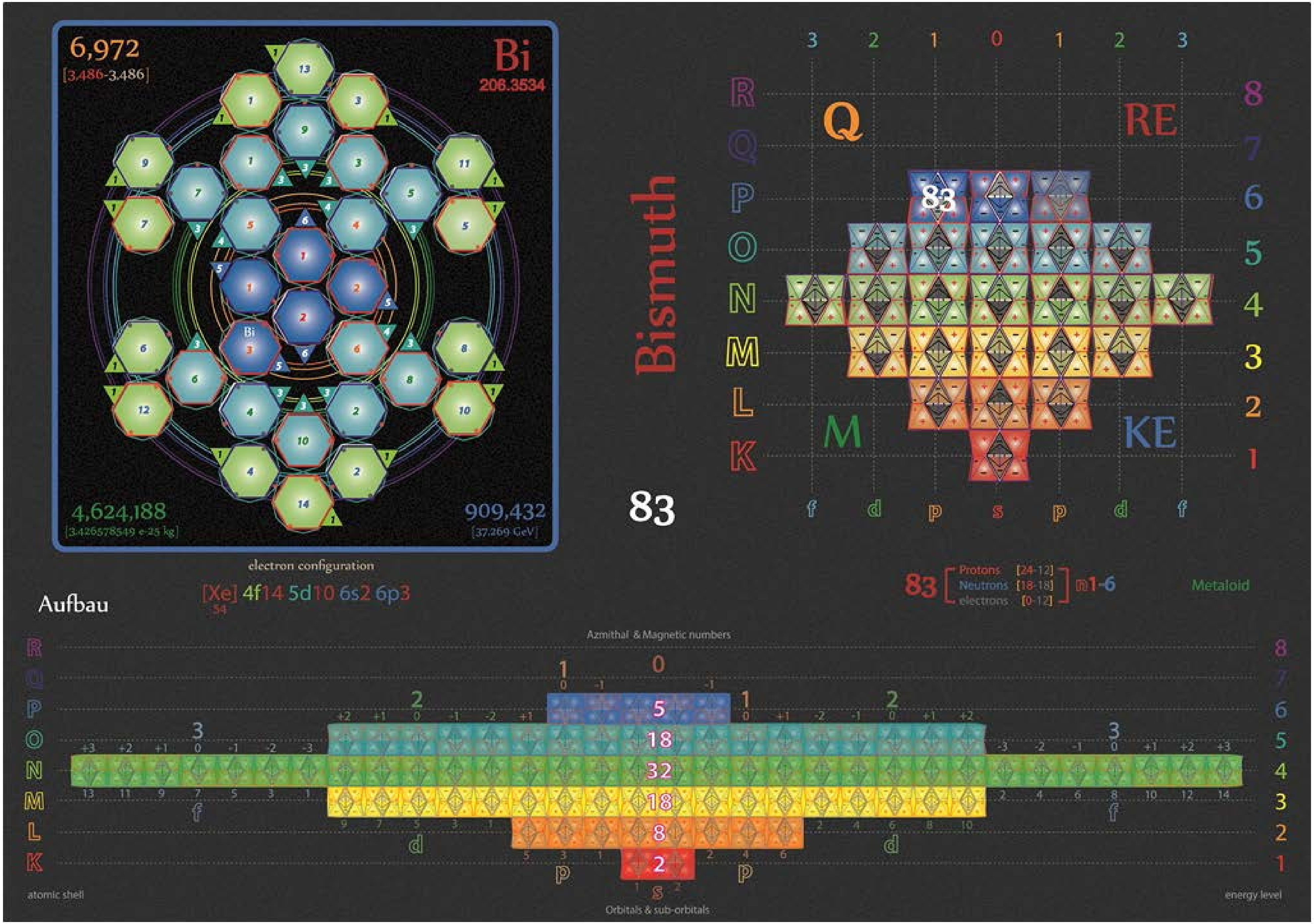
6,972
[3,486-3,486]
Bi
208.3534
4,624,188
[3.426578549 e-25 kg]
909,432
[37.269 GeV]
Bismuth
83
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Xe] 4f14 5d10 6s2 6p3
54
Aufbau
83 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-6
Metaloid
Azmithal & Magnetic numbers
5
18
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.83 - Bismuth atom

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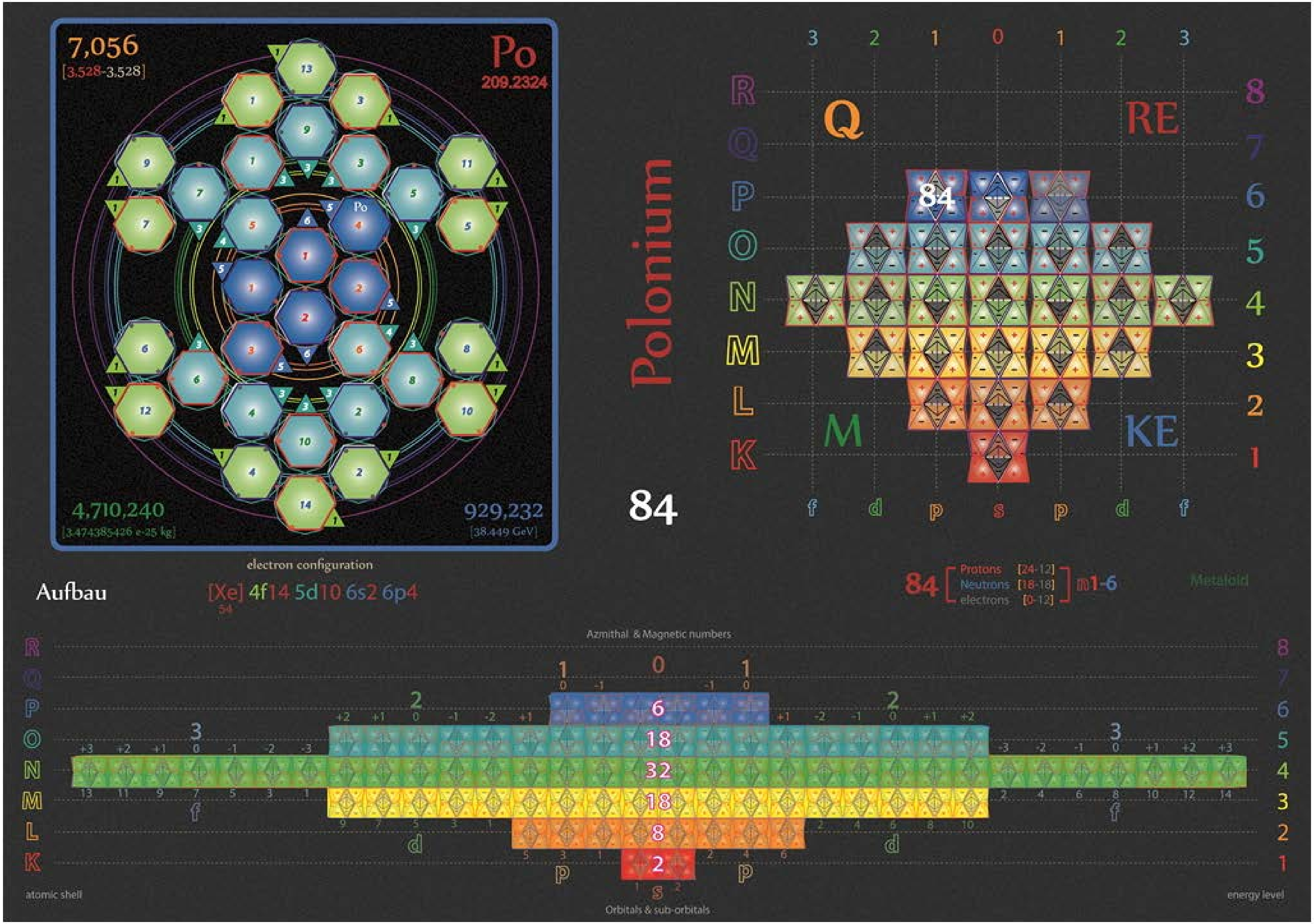
7,056
[3,528-3,528]
Po
209.2324
4,710,240
[3.474385426 e-25 kg]
929,232
[38.449 GeV]
Polonium
84
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Xe] 4f14 5d10 6s2 6p4
54
84 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Metaloid
Azmithal & Magnetic numbers
6
18
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.84 - Polonium atom

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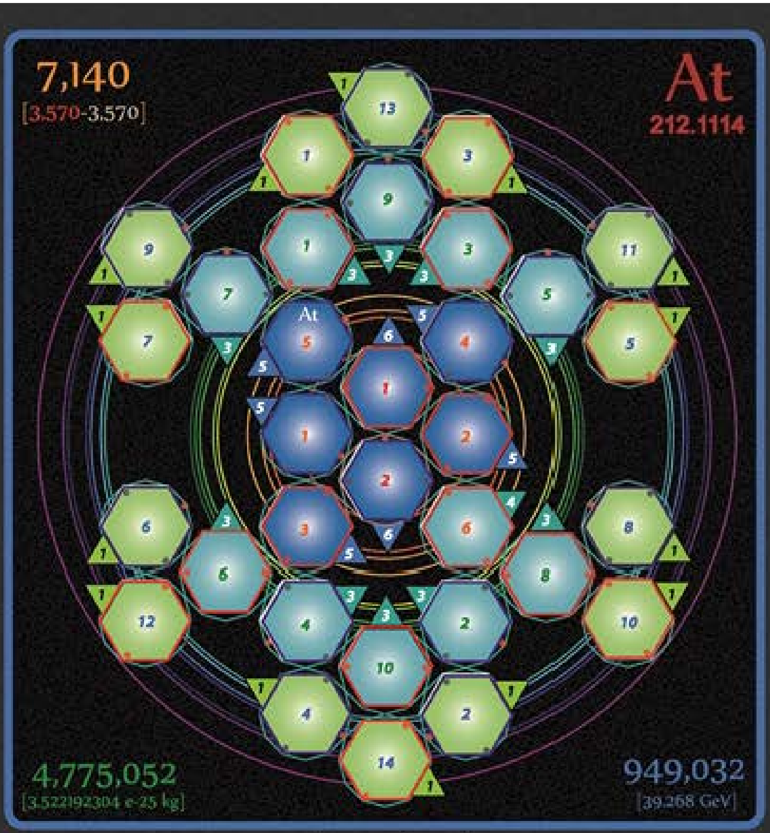
7,140
[3.570-3.570]
At
212.1114
At
4,775,052
[3.522192304 e-25 kg]
949,032
[39.268 GeV]

Astatine

85

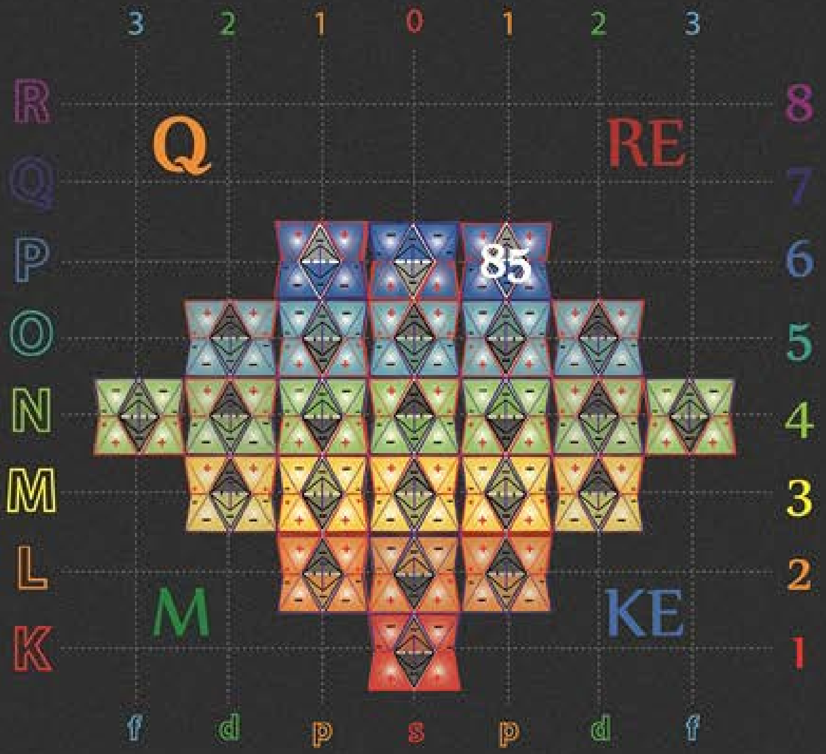
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
85
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

electron configuration

Aufbau

[Xe] 4f14 5d10 6s2 6p5
54

85 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6

Halogen

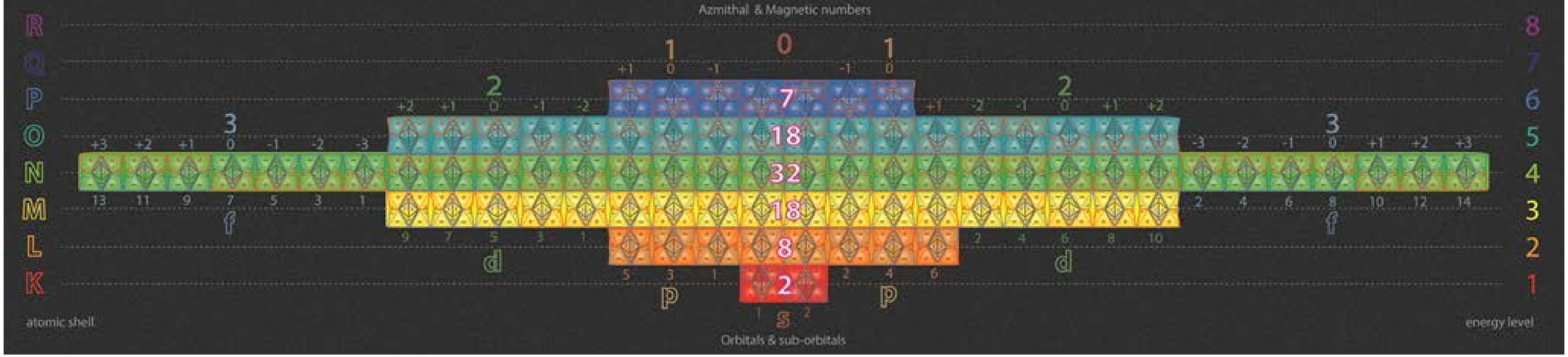
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
7
18
32
18
8
2
3
2
1
0
1
2
3
f
d
p
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.85 - Astatine atom

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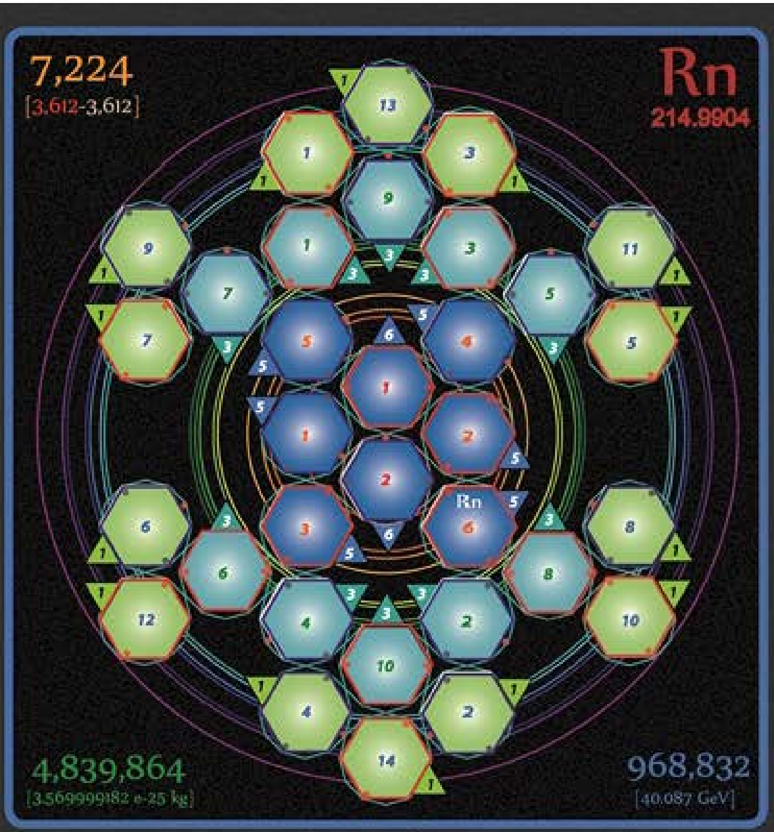
7,224
[3,612-3,612]
Rn
214.9904
4,839,864
[3.569999182 e-25 kg]
968,832
[40.087 GeV]
Rn

Radon

86

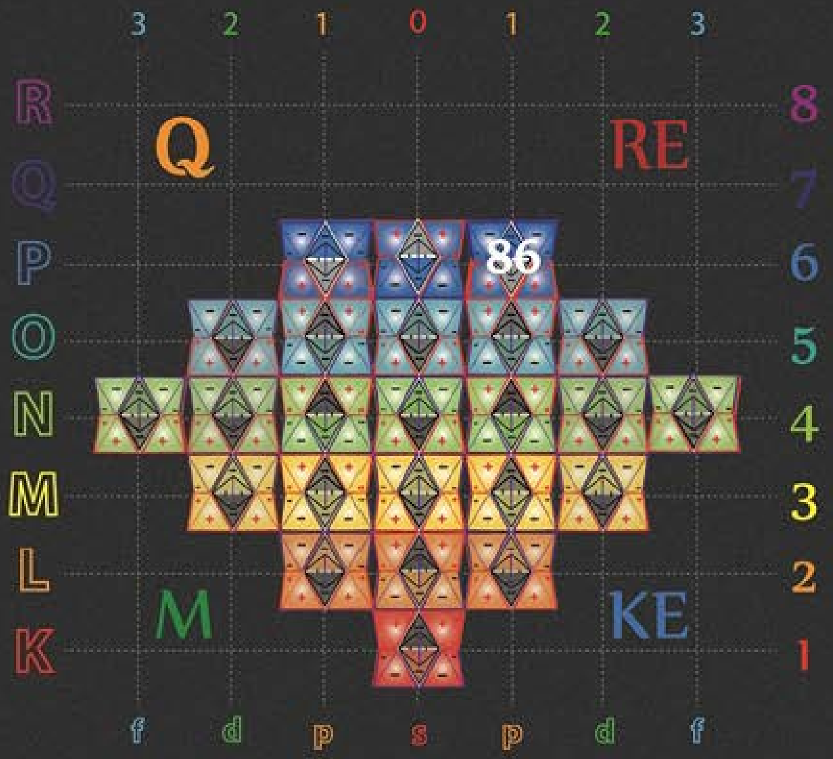
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
86
8
7
6
5
4
3
2
1
f d p s p d f

electron configuration

Aufbau

[Xe] 4f14 5d10 6s2 6p6
54

86 [Protons [24-12]
Neutrons [18-18]
electrons [0-12]] m1-6

Noble
Gas

Azmithal & Magnetic numbers

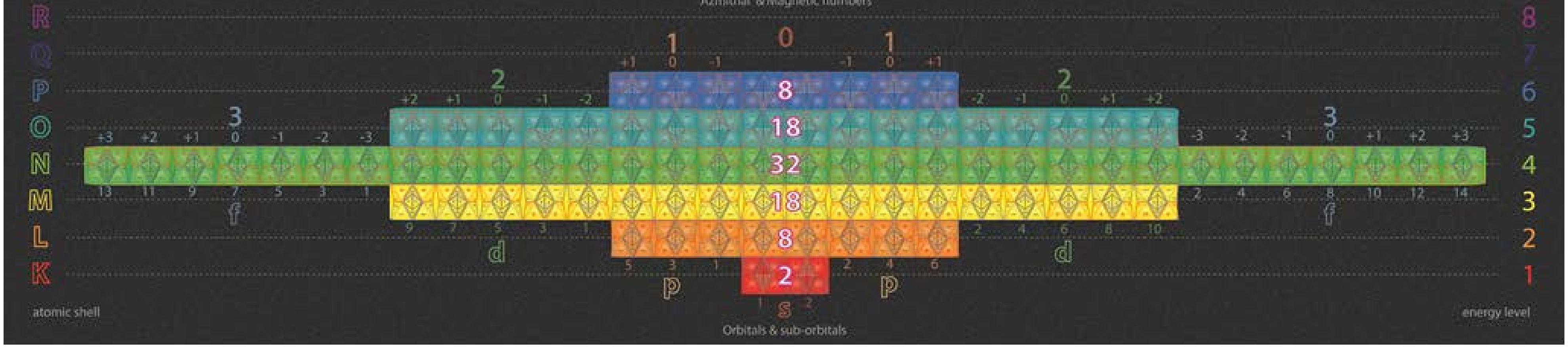
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1 0 1
+1 0 -1 -1 0 +1
2 2
+2 +1 0 -1 -2 -2 -1 0 +1 +2
3 3
+3 +2 +1 0 -1 -2 -3 -3 -2 -1 0 +1 +2 +3
8
18
32
18
8
2
13 11 9 7 5 3 1 2 4 6 8 10 12 14
f f
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 2
s
atomic shell
energy level

Orbitals & sub-orbitals

Tetryonics 51.86 - Radon atom

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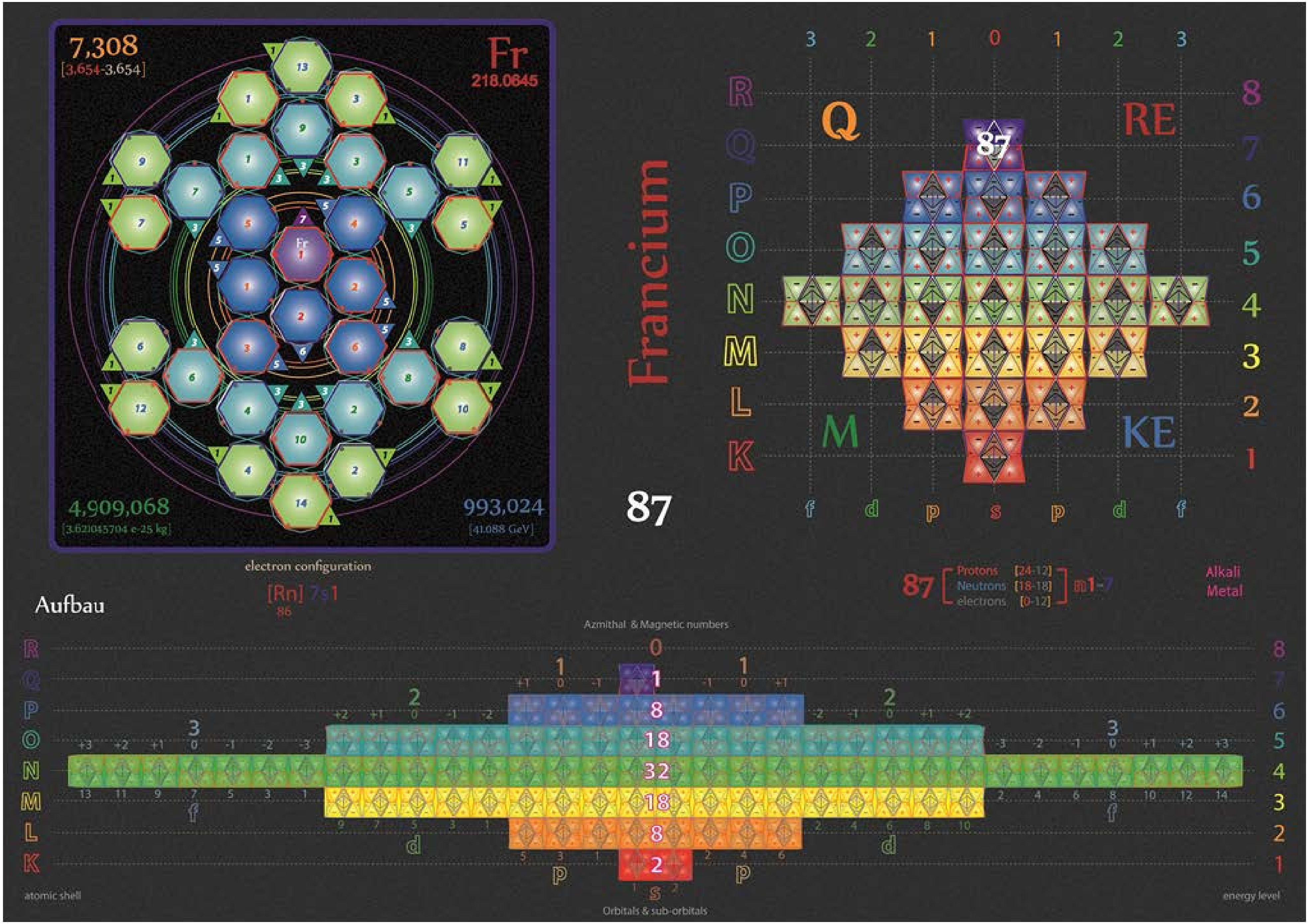
7,308
[3,654-3,654]
Fr
218.0845
4,909,068
[3.62]045704 e-25 kg]
993,024
[41.088 GeV]
Francium
87
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Rn] 7s1
86
Aufbau
87
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Alkali
Metal
Azmithal & Magnetic numbers
0
1
2
3
2
8
18
32
18
8
1
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.87 - Francium atom

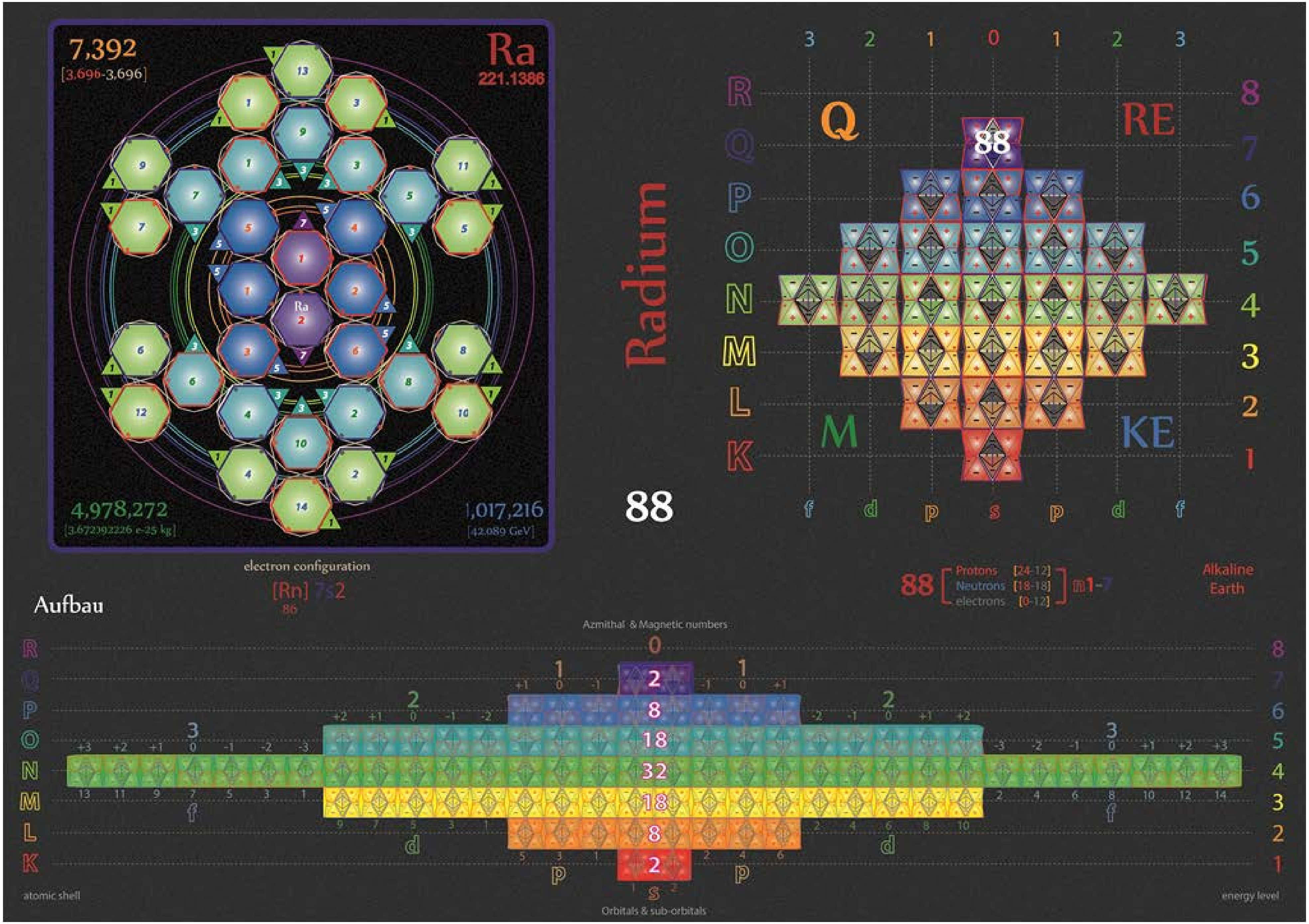
7,392
[3,696-3,696]
Ra
221.1386
Ra
2
4,978,272
[3.672392226 e-25 kg]
1,017,216
[42.089 GeV]
electron configuration
[Rn] 7s2
86
Radium
88
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
88
f d p s p d f
88 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Alkaline Earth
Aufbau
Azmithal & Magnetic numbers
2
8
18
32
18
8
2
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.88 - Radium atom

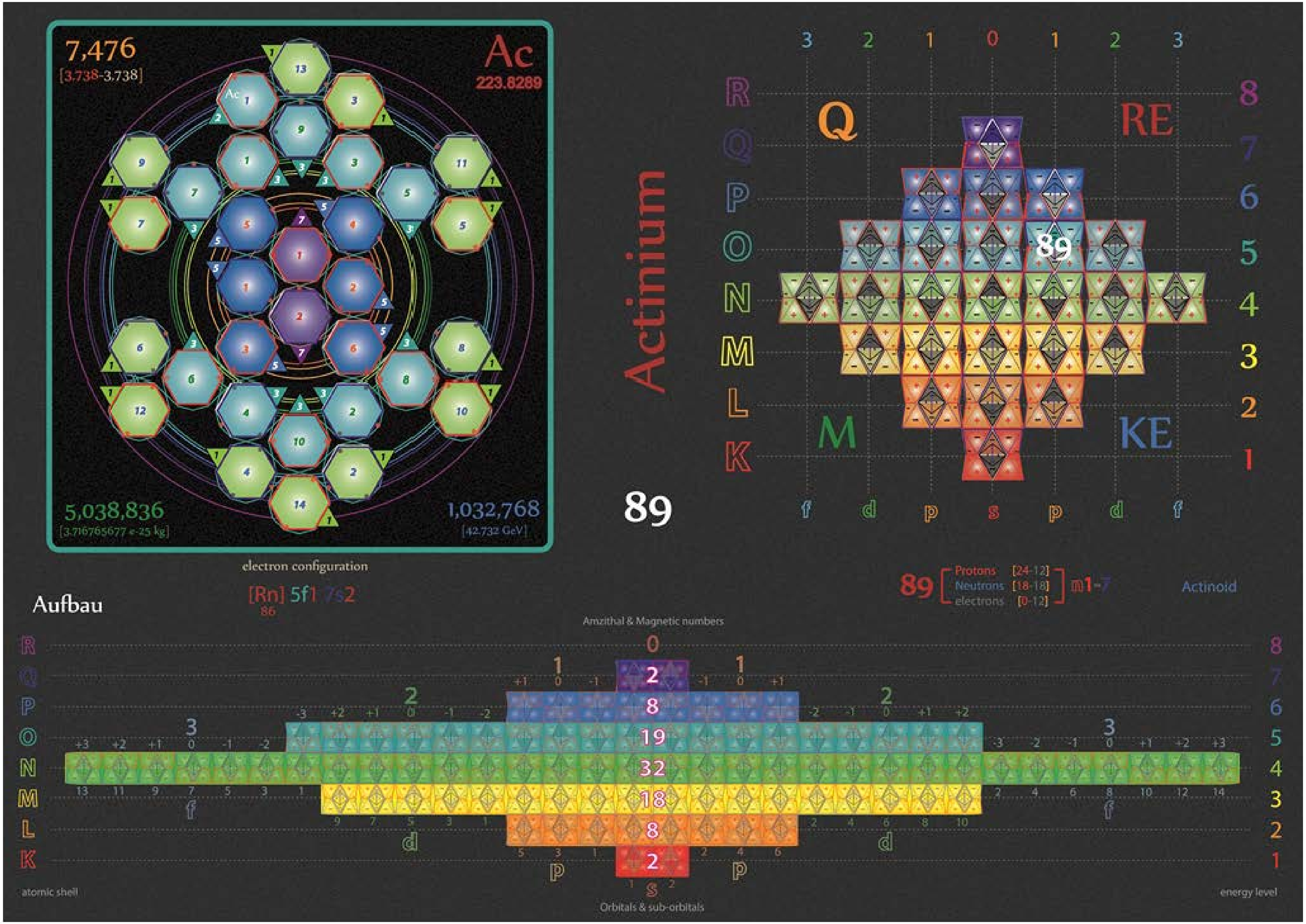
7,476
[3.738-3.738]
Ac
223.8289
5,038,836
[3.716765677 e-25 kg]
1,032,768
[42.732 GeV]
Actinium
89
Q
RE
M
KE
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
8 7 6 5 4 3 2 1
f d p s p d f
89
electron configuration
[Rn] 5f1 7s2
86
Aufbau
89 Protons [24-12] Neutrons [18-18] electrons [0-12] m1-7
Actinoid
Amzithal & Magnetic numbers
2
8
19
32
18
8
2
f
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.89 - Actinium atom

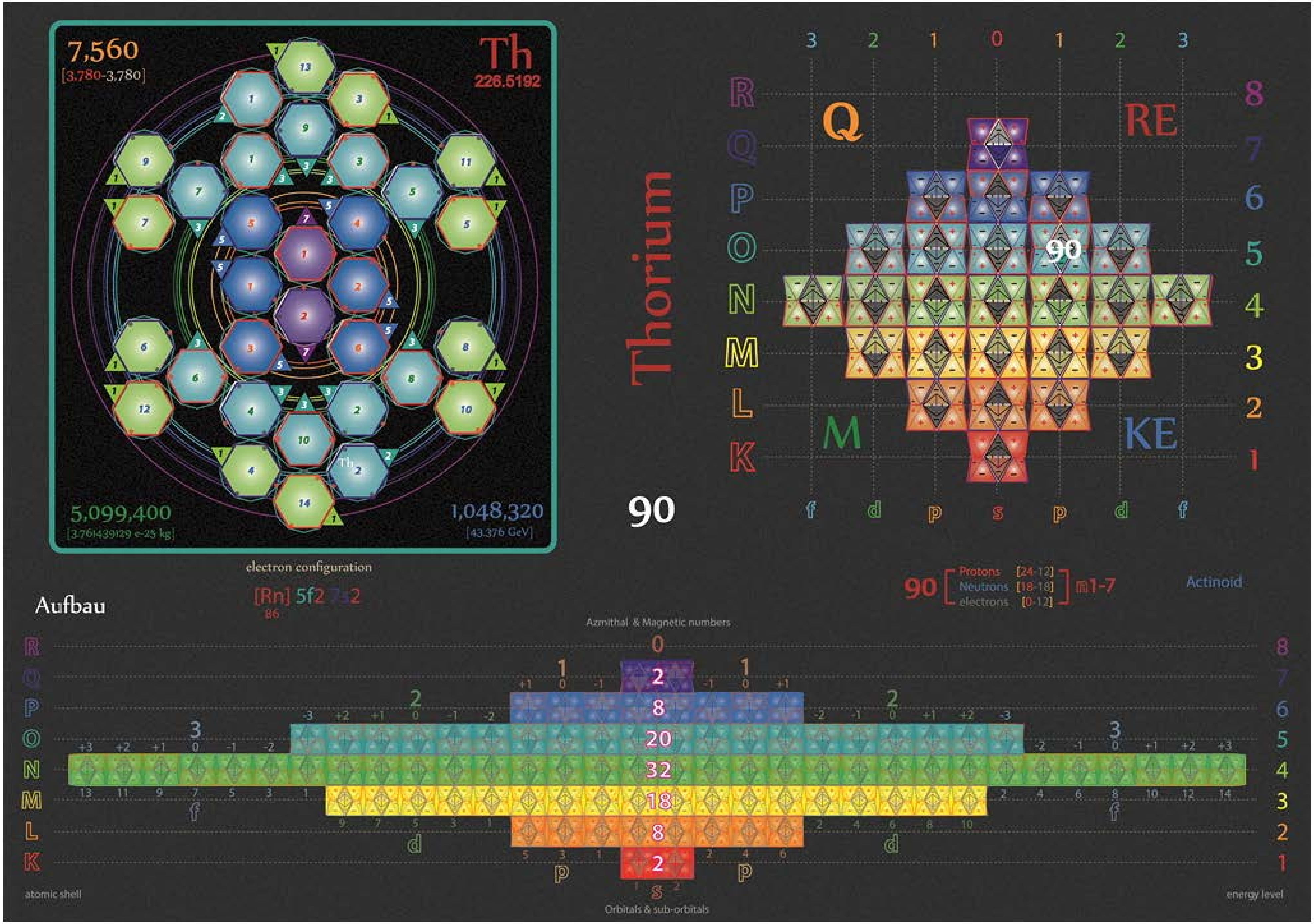
7,560
[3.780-3.780]
Th
226.5192
5,099,400
[3.761439129 e-25 kg]
1,048,320
[43.376 GeV]
electron configuration
[Rn] 5f2 7s2
86
Thorium
90
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
90
f d p s p d f
90
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Actinoid
Aufbau
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
2
8
20
32
18
8
2
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.90 - Thorium atom

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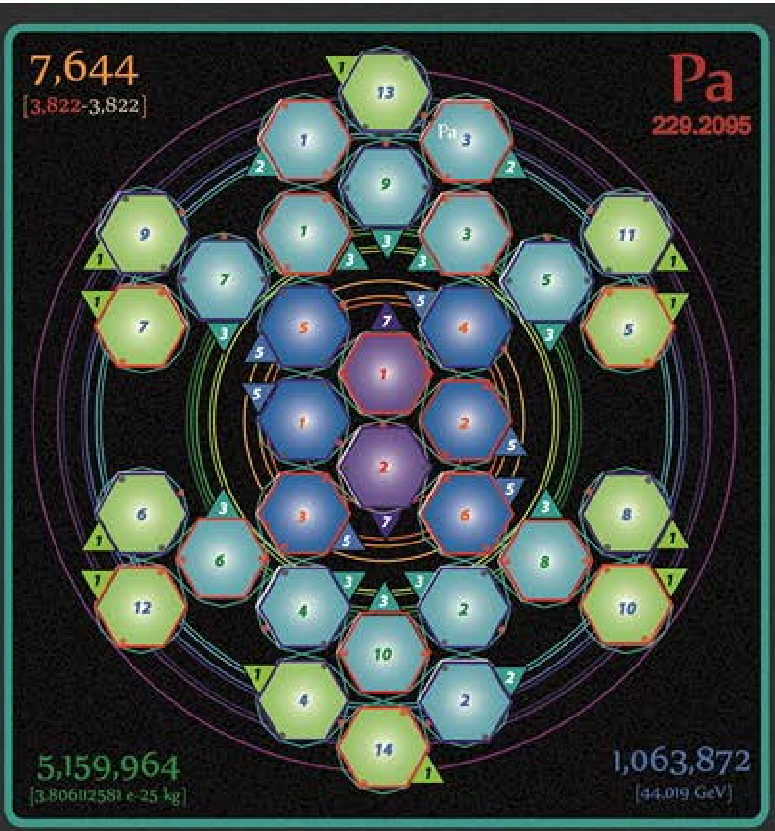
7,644
[3,822-3,822]
Pa
229.2095
5,159,964
[3.806112581 e-25 kg]
1,063,872
[44.019 GeV]

Protactinium

91

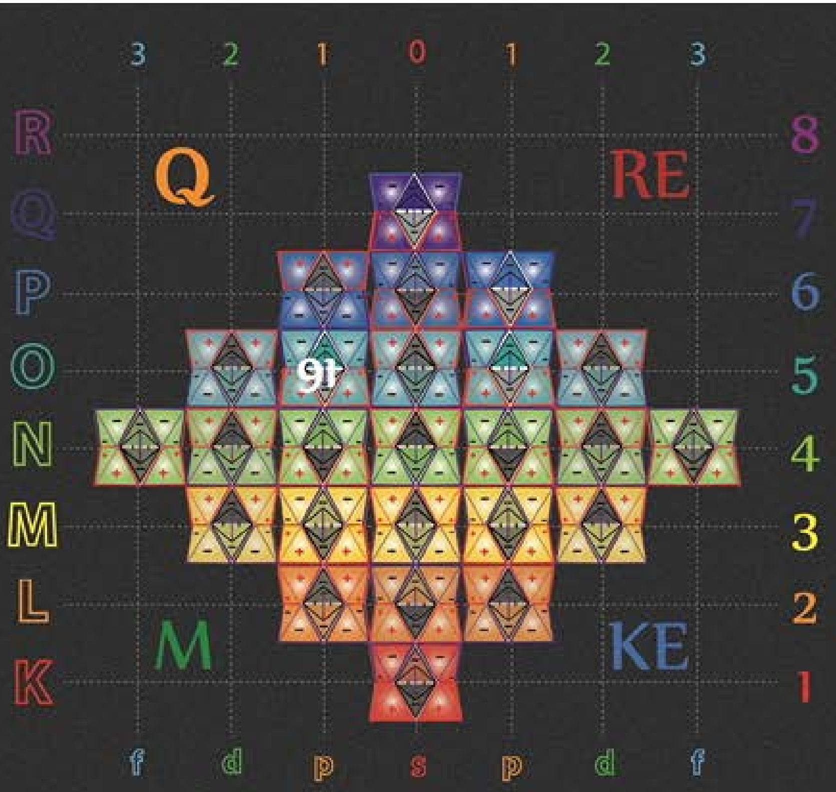
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
91
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

91 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7

Actinoid

Aufbau

electron configuration

[Rn] 5f3 7s2

86

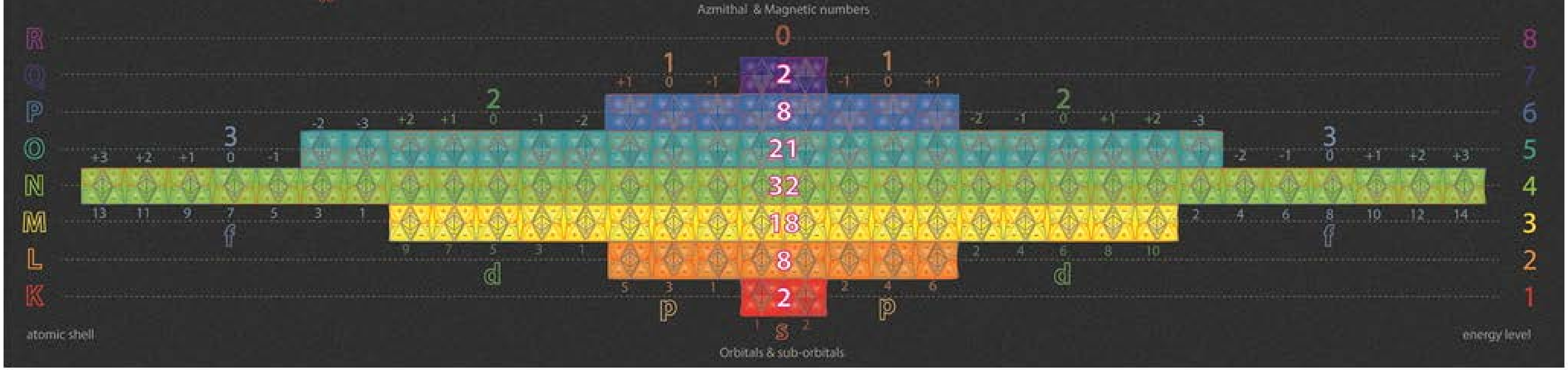
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
2
8
21
32
18
8
2
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.91 - Protactinium atom

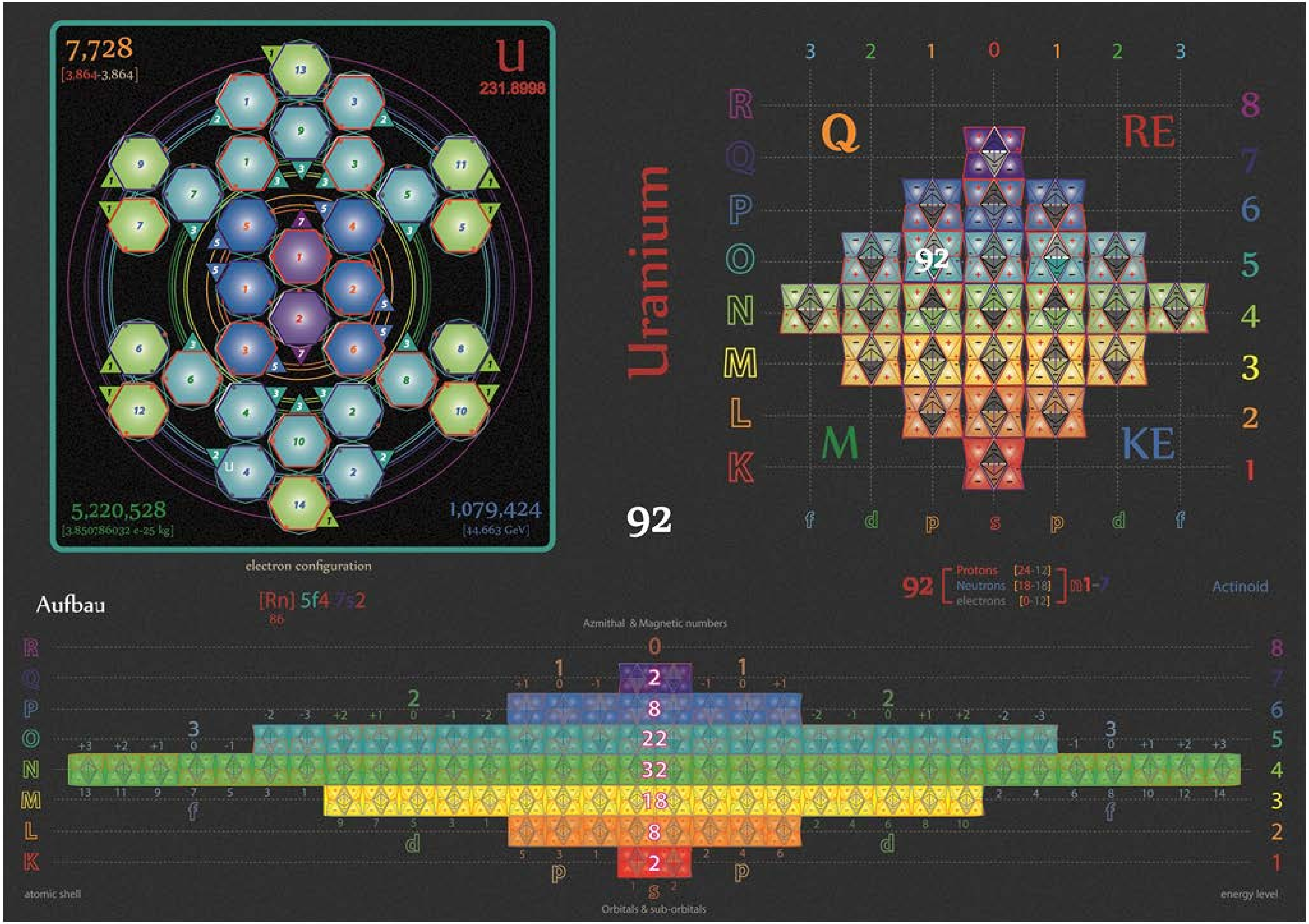
7,728
[3.864-3.864]
U
231.8998
5,220,528
[3.850786032 e-25 kg]
1,079,424
[14.663 GeV]
electron configuration
Uranium
92
Aufbau
[Rn] 5f4 7s2
86
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
92 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
2
8
22
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.92 - Uranium atom

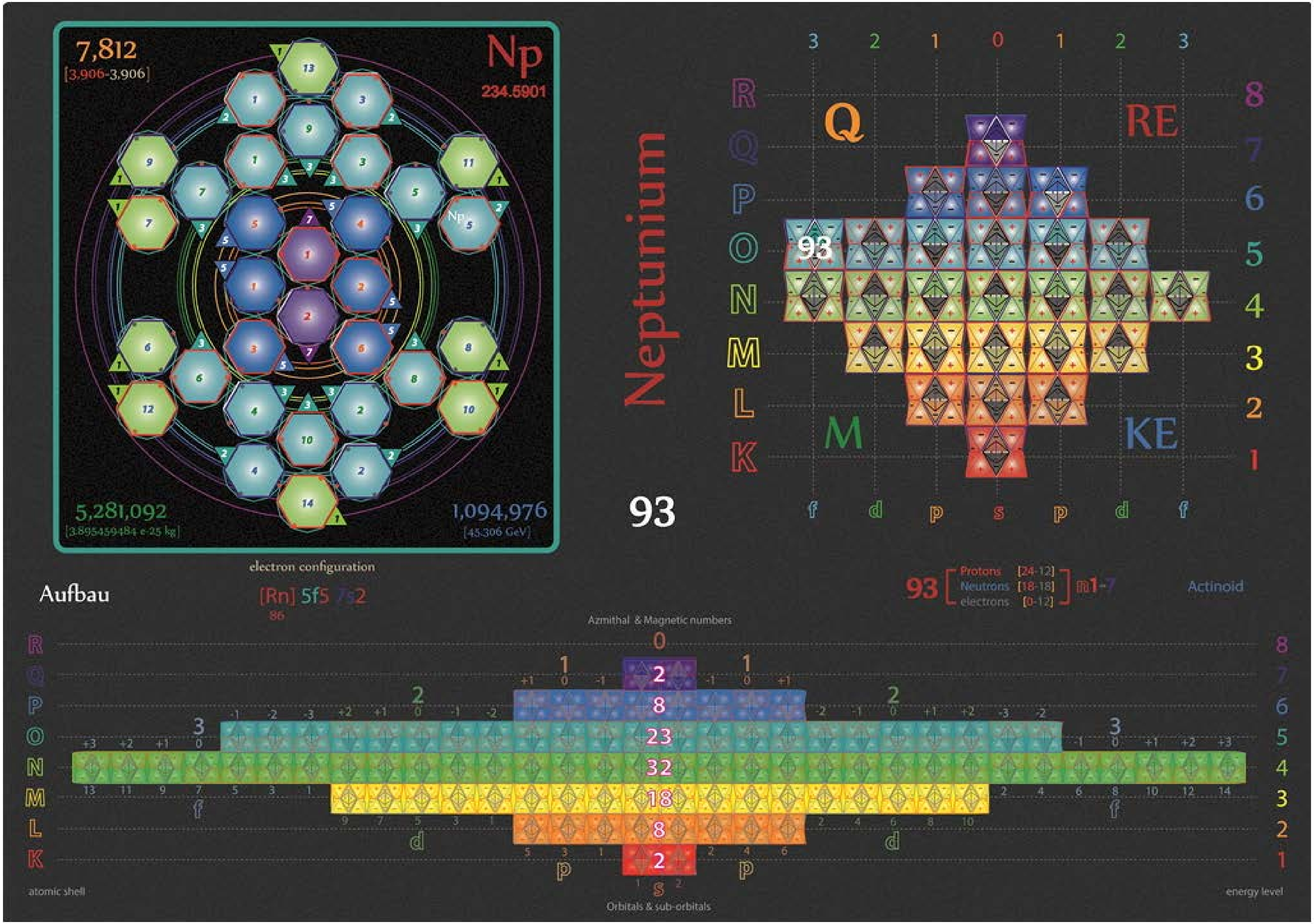
7,812
[3,906-3,906]
Np
234.5901
5,281,092
[3.895459484 e-25 kg]
1,094,976
[45.306 GeV]
Neptunium
93
R
Q
P
O
N
M
L
K
Q
RE
M
KE
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
electron configuration
Aufbau
[Rn] 5f5 7s2
86
93
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Actinoid
Azmithal & Magnetic numbers
2
8
23
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.93 - Neptunium atom

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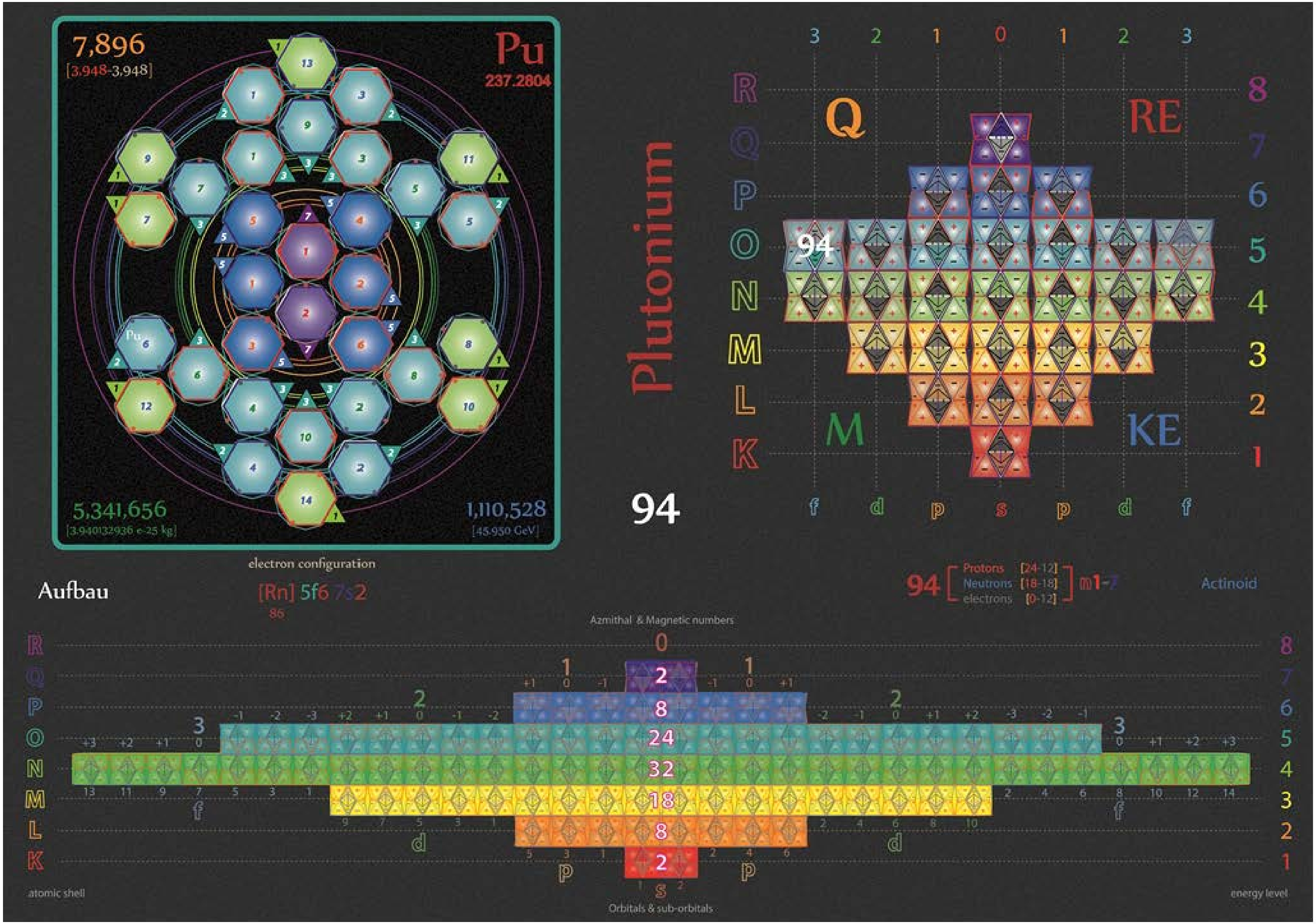
7,896
[3,948-3,948]
Pu
237.2804
5,341,656
[3.940132936 e-25 kg]
1,110,528
[45.950 GeV]
Plutonium
94
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f6 7s2
86
94
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Actinoid
Azmithal & Magnetic numbers
2
8
24
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.94 - Plutonium atom

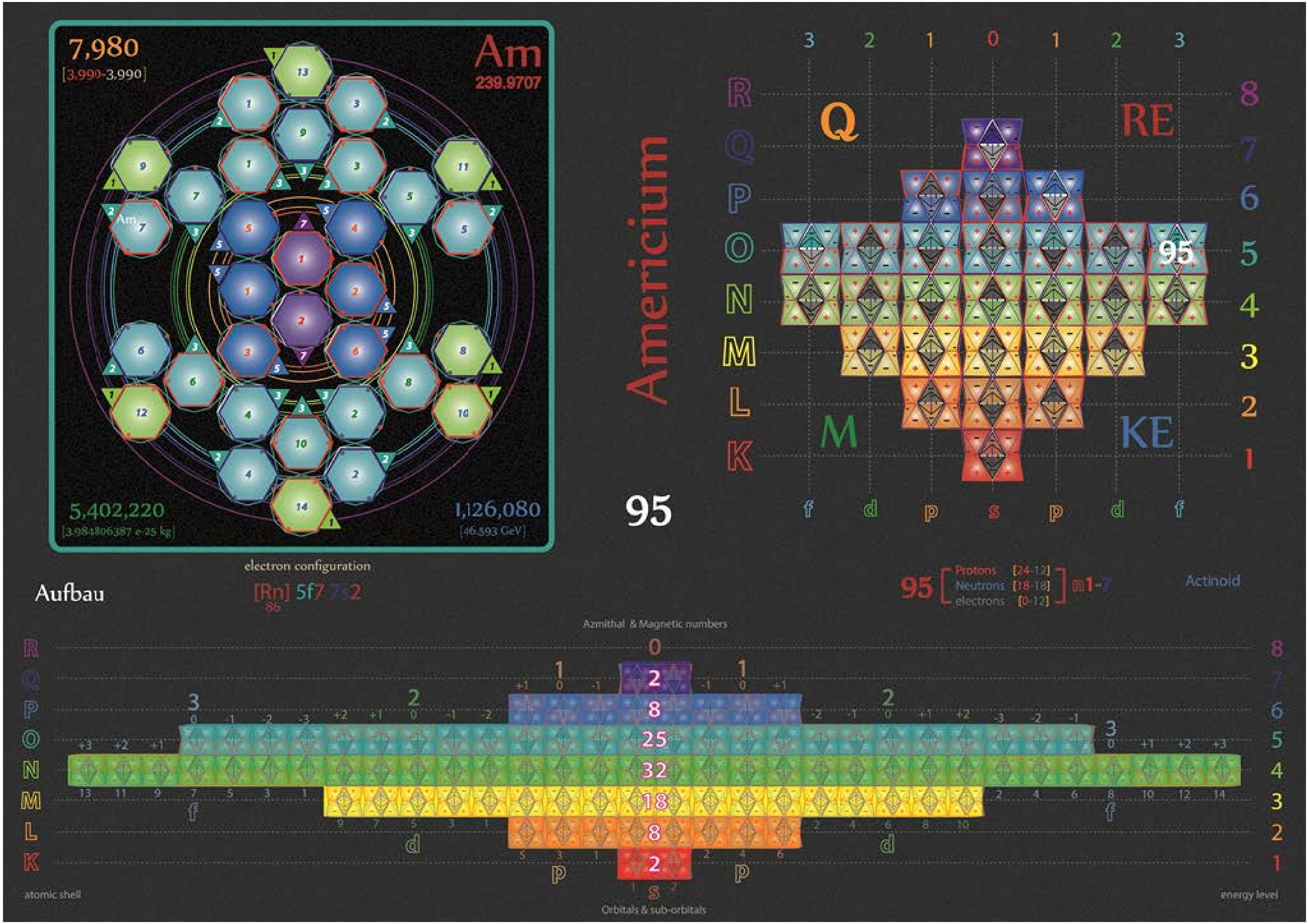
7,980
[3,990-3,990]
Am
239.9707
5,402,220
[3.984806387 e-25 kg]
1,126,080
[46.593 GeV]
Americium
95
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
95
f d p s p d f
electron configuration
[Rn] 5f7 7s2
86
Aufbau
95 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
0
2
8
25
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals
s p d f

Tetryonics 51.95 - Americium atom

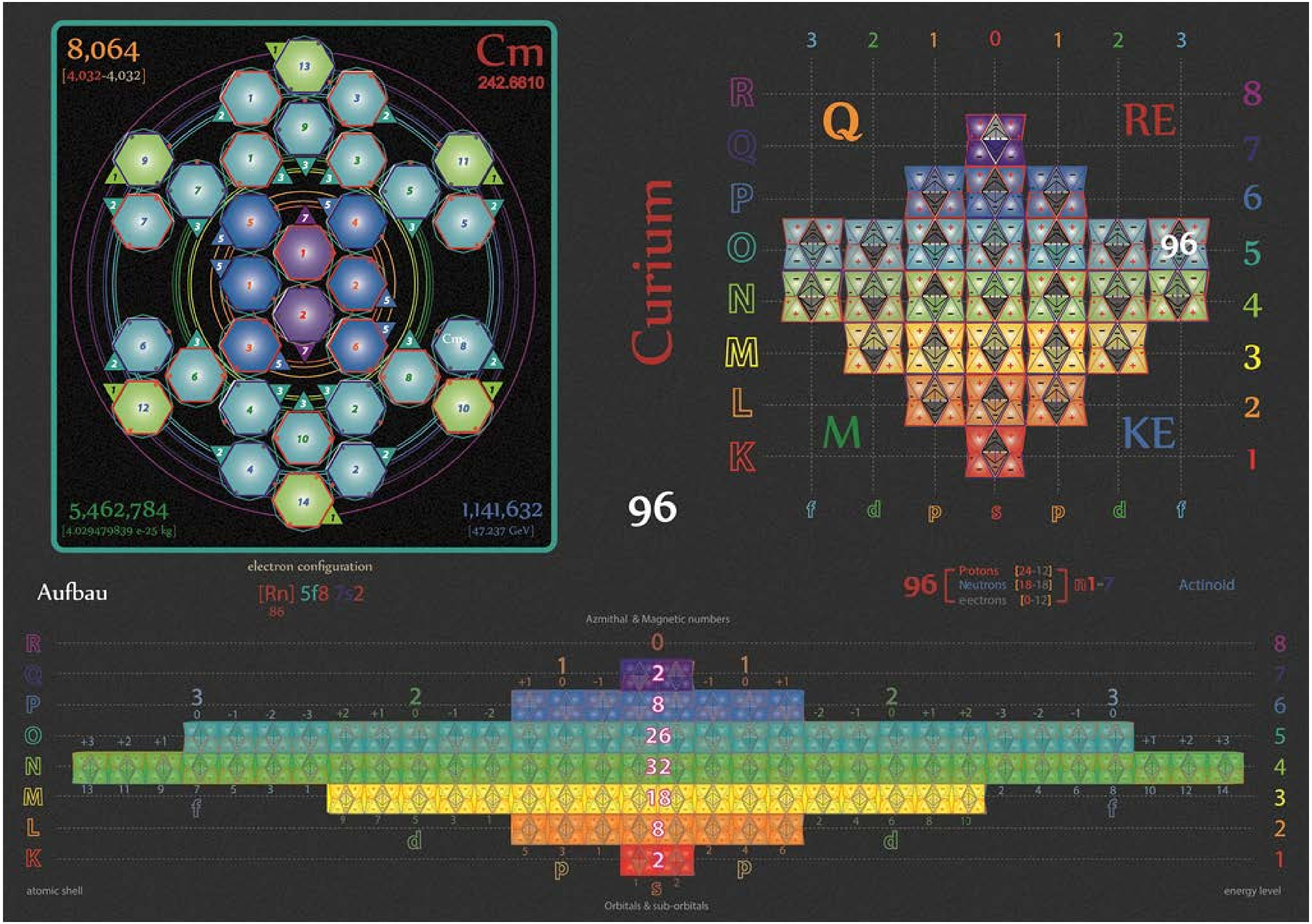
8,064
[4,032-4,032]
Cm
242.6810
5,462,784
[4.029479839 e-25 kg]
1,141,632
[47.237 GeV]
Curium
96
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
3
2
1
0
1
2
3
f
d
p
s
p
d
f
electron configuration
Aufbau
[Rn] 5f8 7s2
86
96 [Potons [24-12] Neutrons [18-18] eectrons [0-12]] n1-7
Actinoid
Azmithal & Magnetic numbers
2
8
26
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.96 - Curium atom

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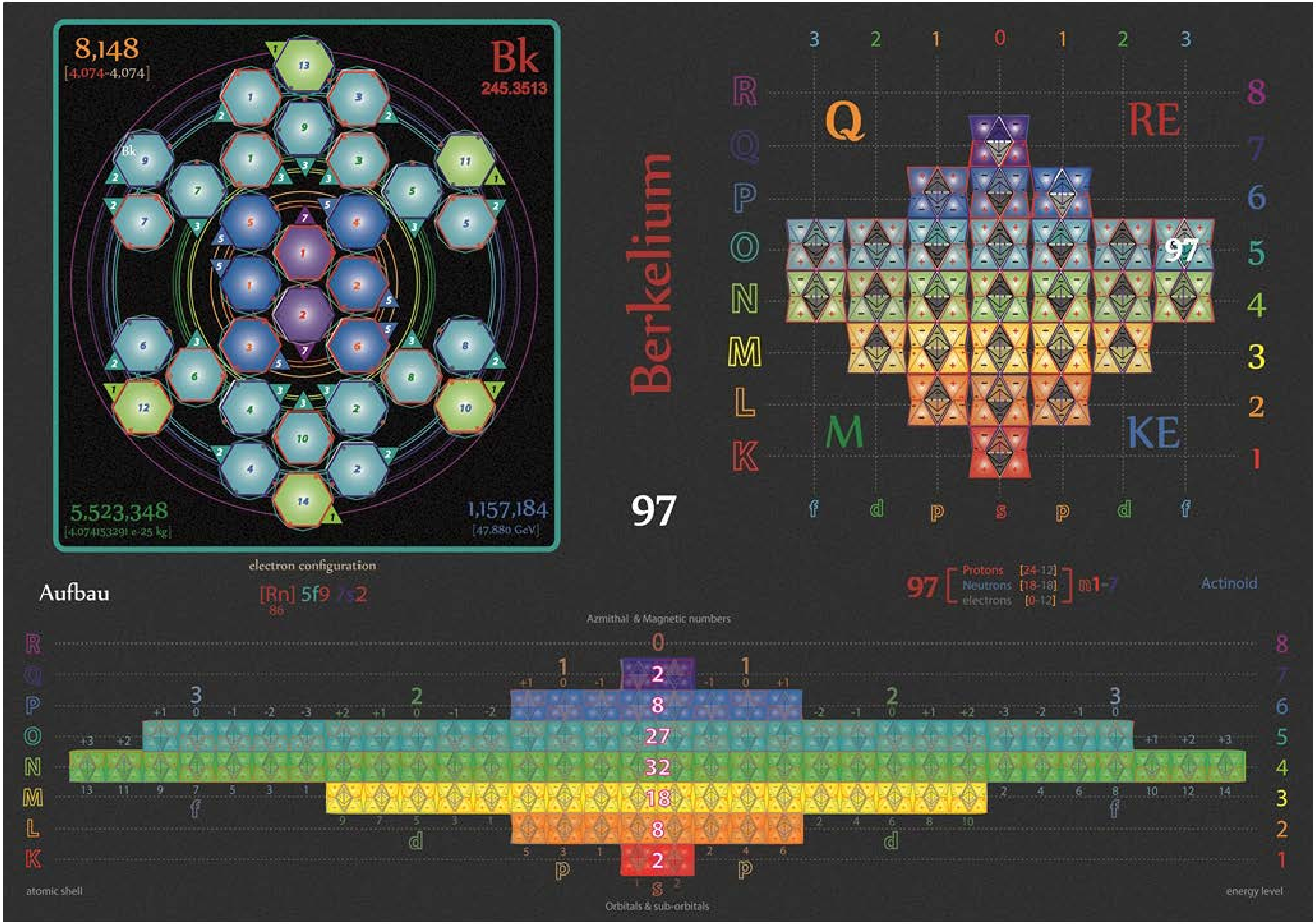
8,148
[4,074-4,074]
Bk
245.3513
5,523,348
[4.074153291 e-25 kg]
1,157,184
[47,880 GeV]
Berkelium
97
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
Q
RE
M
KE
8
7
6
5
4
3
2
1
f d p s p d f
electron configuration
Aufbau
[Rn] 5f9 7s2
86
97
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Actinoid
Azmithal & Magnetic numbers
0
1
2
3
2
8
27
32
18
8
2
f
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.97 - Berkelium atom

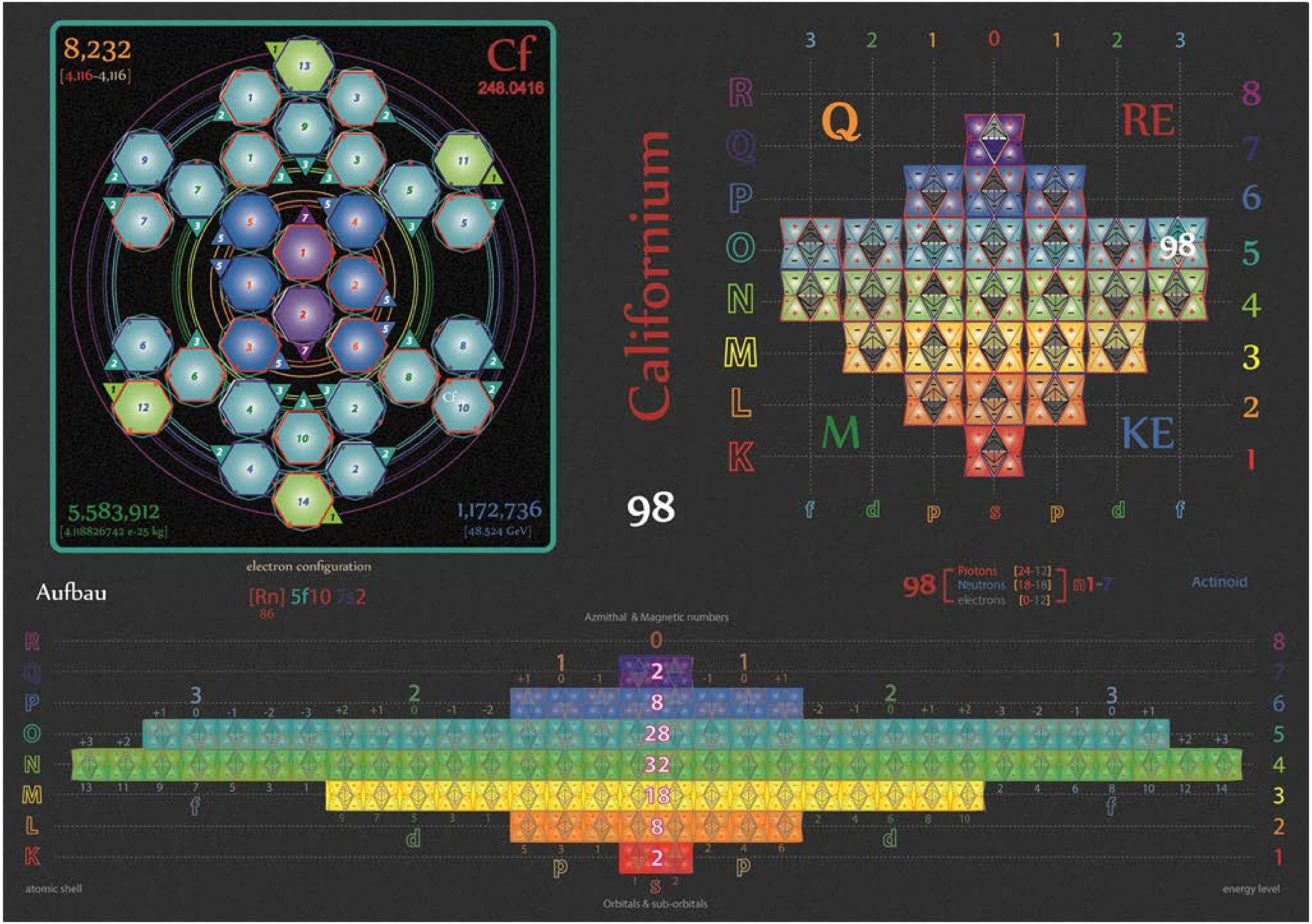
8,232
[4,116-4,116]
Cf
248.0416
5,583,912
[4.118826742 e-25 kg]
1,172,736
[48.524 GeV]
Californium
98
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
98
electron configuration
[Rn] 5f10 7s2
86
Aufbau
98 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
2
8
28
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.98 - Californium atom

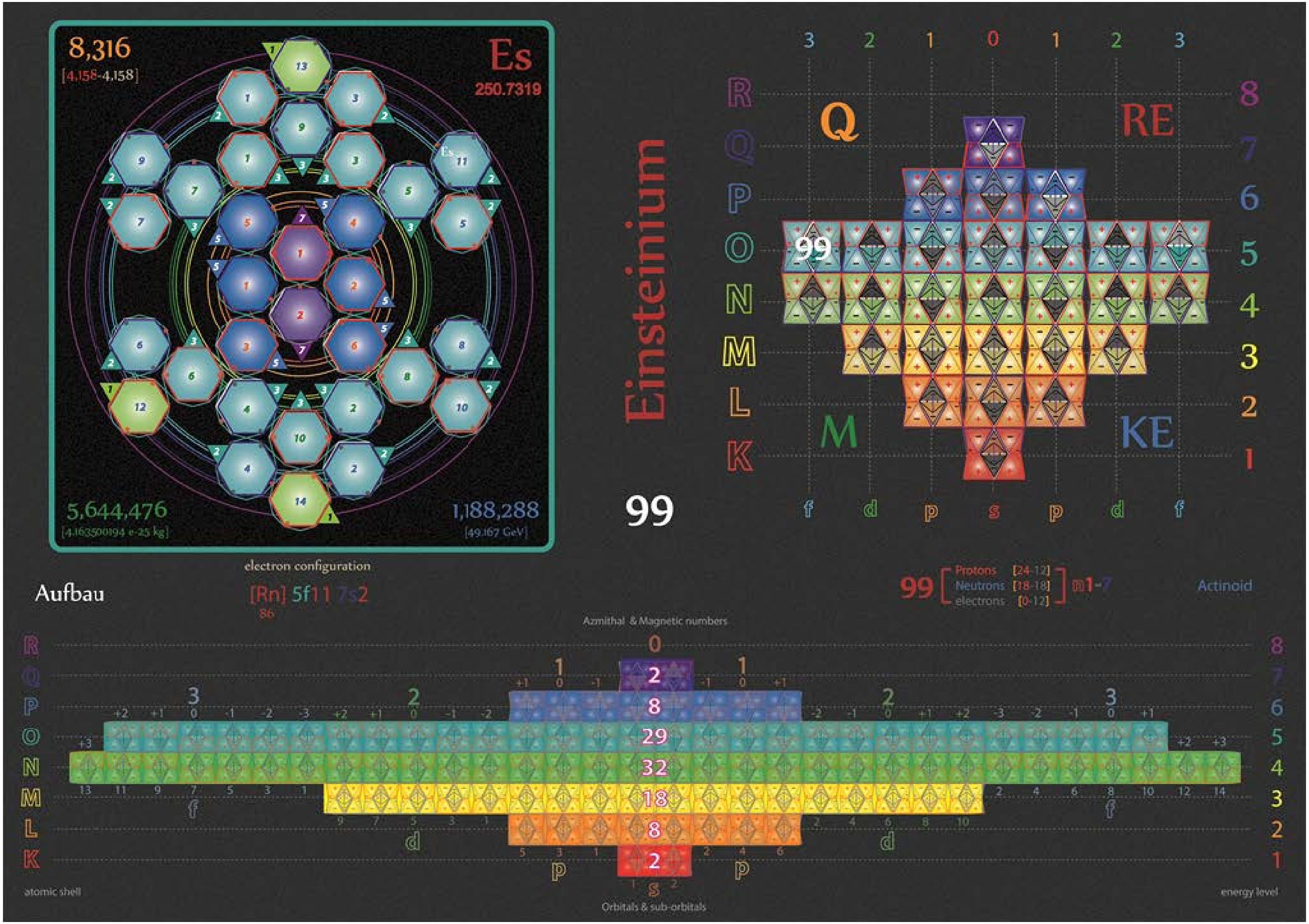
8,316
[4,158-4,158]
Es
250.7319
5,644,476
[4.163500194 e-25 kg]
1,188,288
[49.167 GeV]
Einsteinium
99
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f11 7s2
86
99
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Actinoid
Azimuthal & Magnetic numbers
2
8
29
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.99 - Einsteinium atom

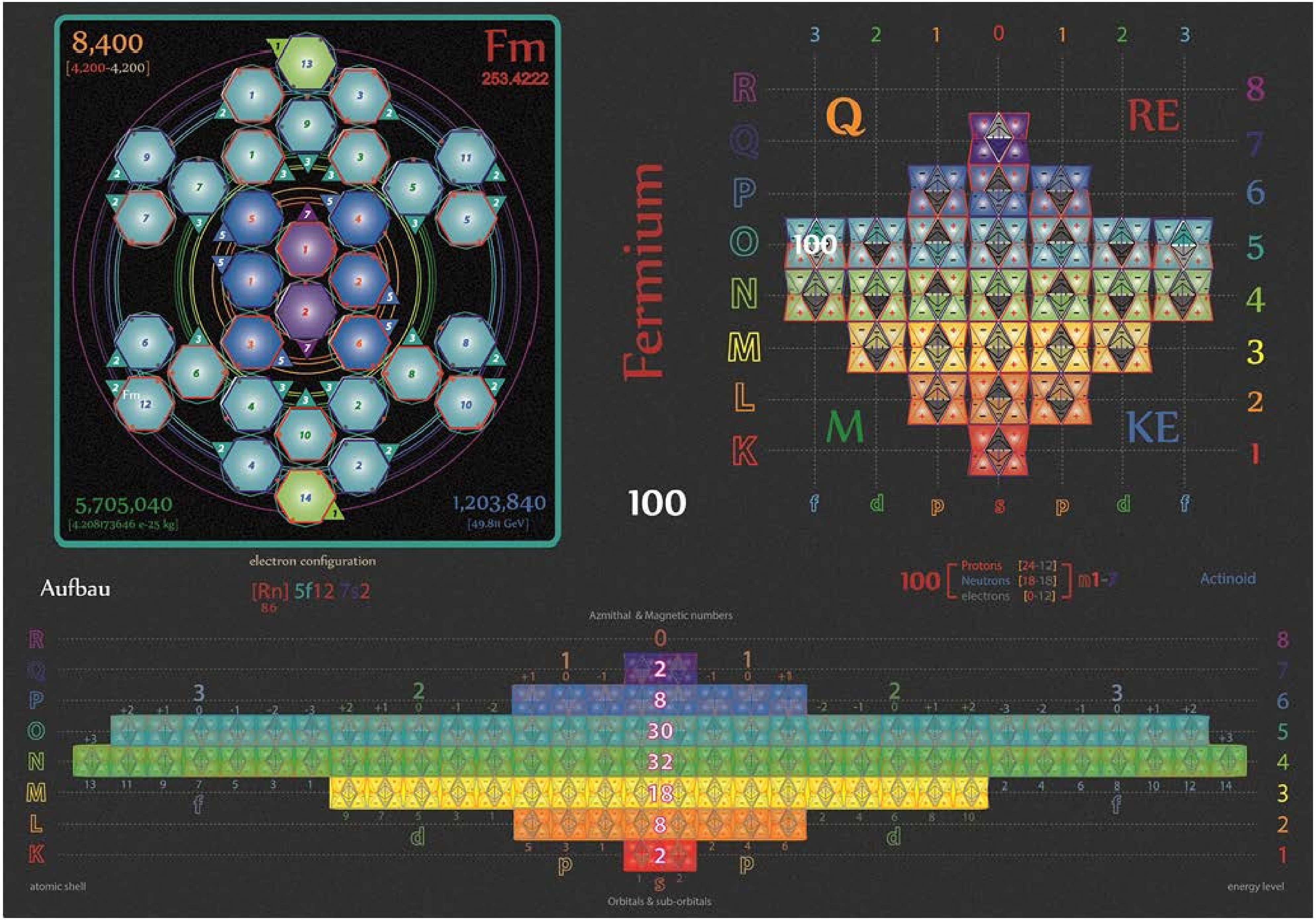
8,400
[4,200-4,200]
Fm
253.4222
5,705,040
[4.208173646 e-25 kg]
1,203,840
[49.811 GeV]
Fermium
100
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3
2
1
0
1
2
3
Q
RE
M
KE
f
d
p
s
p
d
f
electron configuration
[Rn] 5f12 7s2
86
Aufbau
100 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
2
8
30
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.100 - Fermium atom

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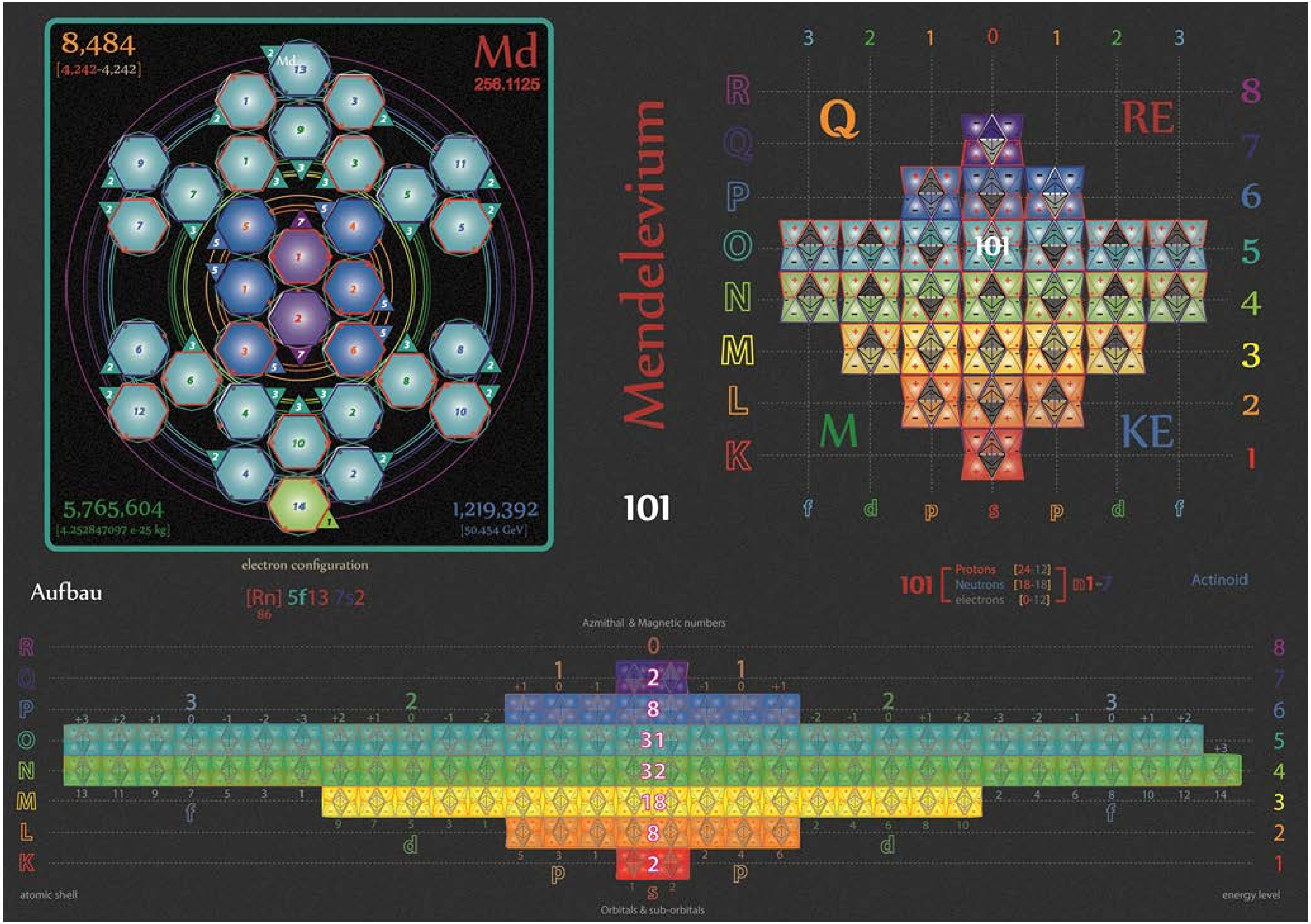
8,484
[4,242-4,242]
Md
256.1125
5,765,604
[4.252847097 e-25 kg]
1,219,392
[50.454 GeV]
Mendelevium
101
R
Q
P
O
N
M
L
K
Q
RE
M
KE
3 2 1 0 1 2 3
8 7 6 5 4 3 2 1
f d p s p d f
electron configuration
Aufbau
[Rn] 5f13 7s2
86
101
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Actinoid
Azmithal & Magnetic numbers
0
1
1
2
3
2
3
2
8
31
32
18
8
2
f
d
p
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.101 - Mendelevium atom

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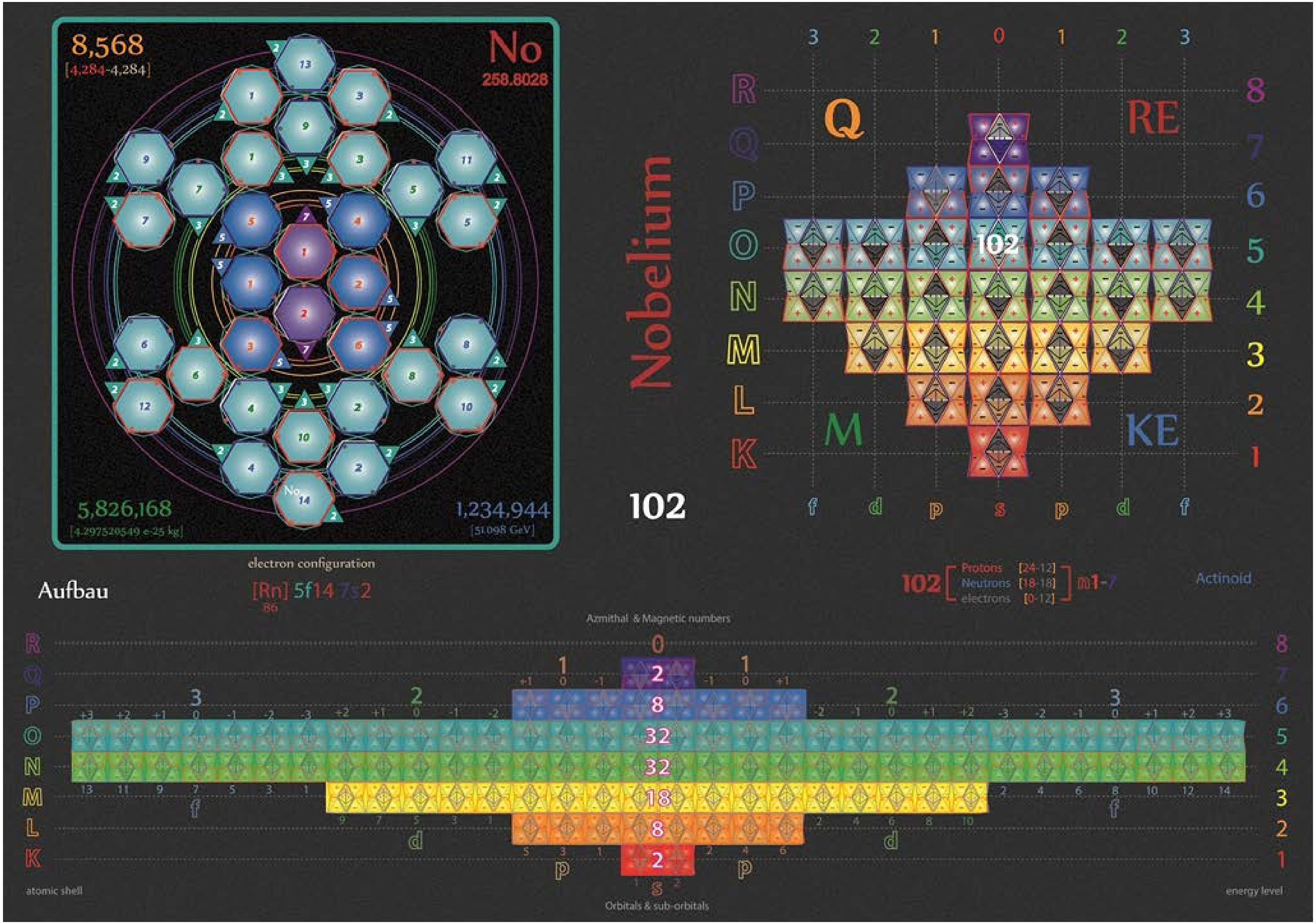
8,568
[4,284-4,284]
No
258.8028
5,826,168
[4.297520549 e-25 kg]
1,234,944
[51.098 GeV]
Nobelium
102
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 7s2
86
102 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
0
1
1
2
8
32
32
18
8
2
3
2
2
3
atomic shell
energy level
f
d
p
s
p
d
f
Orbitals & sub-orbitals

Tetryonics 51.102 - Nobelium atom

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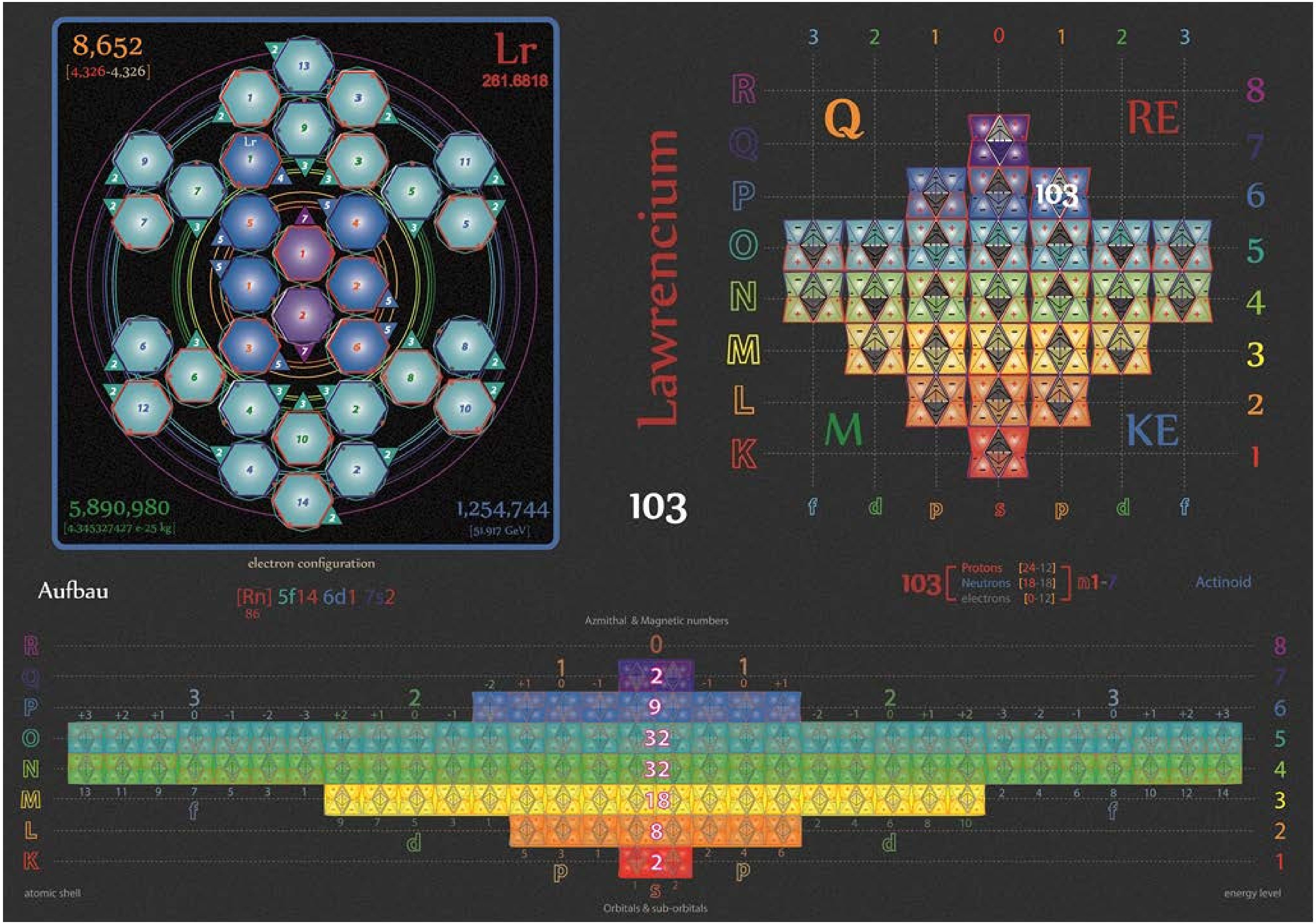
8,652
[4.326-4.326]
Lr
281.6818
5,890,980
[4.345327427 e-25 kg]
1,254,744
[51.917 GeV]
electron configuration
Lawrencium
103
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
Q
RE
M
KE
103
f d p s p d f
Aufbau
[Rn] 5f14 6d1 7s2
86
103
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Actinoid
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
2
9
32
32
18
8
2
f
f
d
d
p
p
s
atomic shell
Orbitals & sub-orbitals
energy level

Tetryonics 51.103 - Lawrencium atom

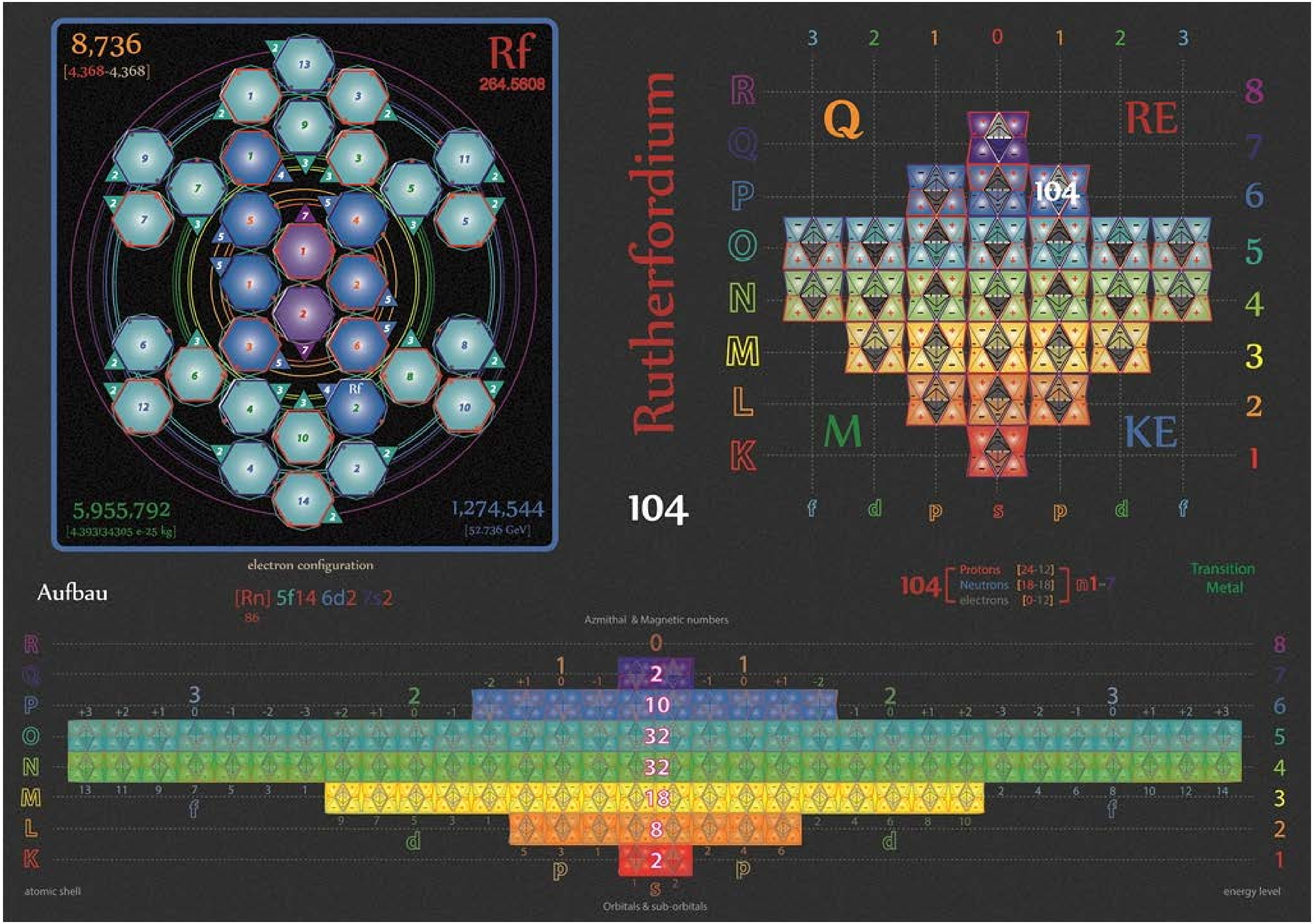
8,736
[4,368-4,368]
Rf
264.5608
5,955,792
[4.393134305 e-25 kg]
1,274,544
[52.736 GeV]
Rutherfordium
104
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
electron configuration
Aufbau
[Rn] 5f14 6d2 7s2
86
104
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-7
Transition Metal
Azmithal & Magnetic numbers
2
10
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.104 - Rutherfordium atom

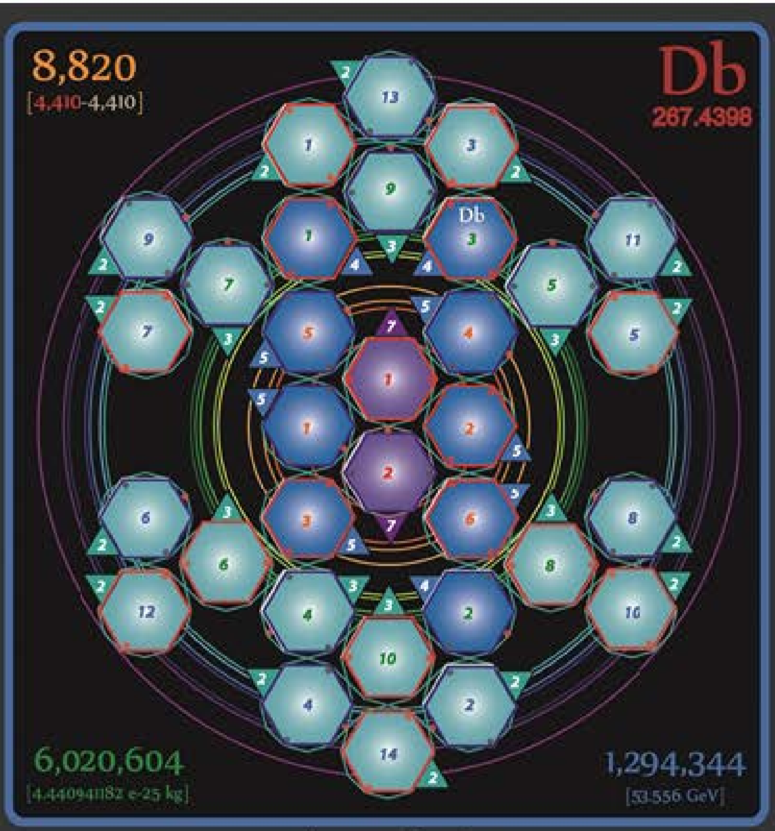
8,820
[4,410-4,410]
Db
267.4398
Db
6,020,604
[4.44094182 e-25 kg]
1,294,344
[53.556 GeV]

Dubnium

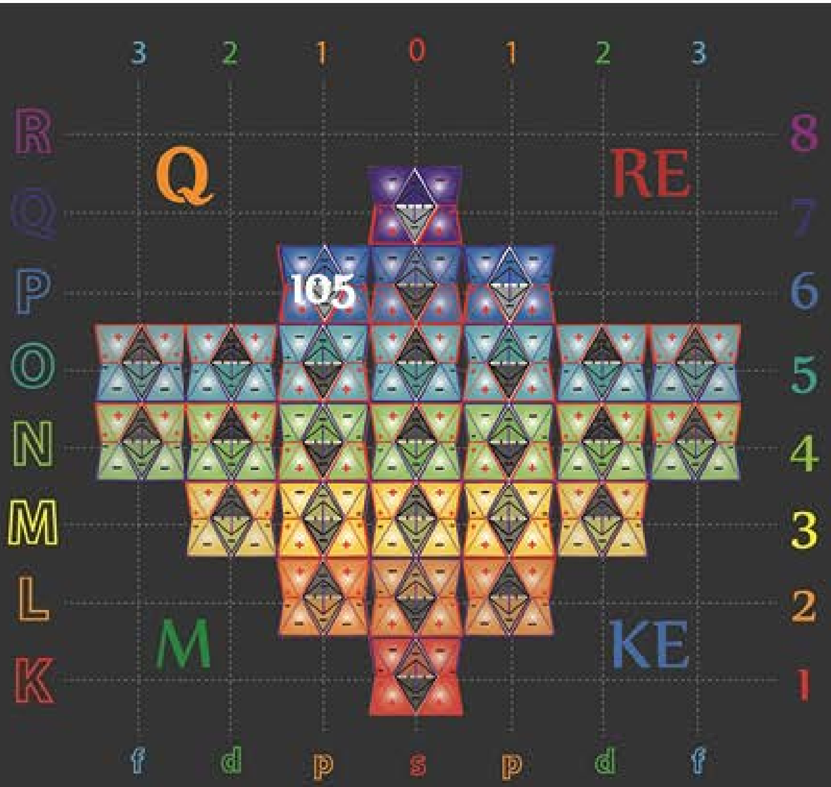
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
105
f
d
p
s
p
d
f

105

electron configuration

Aufbau

[Rn] 5f14 6d3 7s2
86

105 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7

Transition Metal

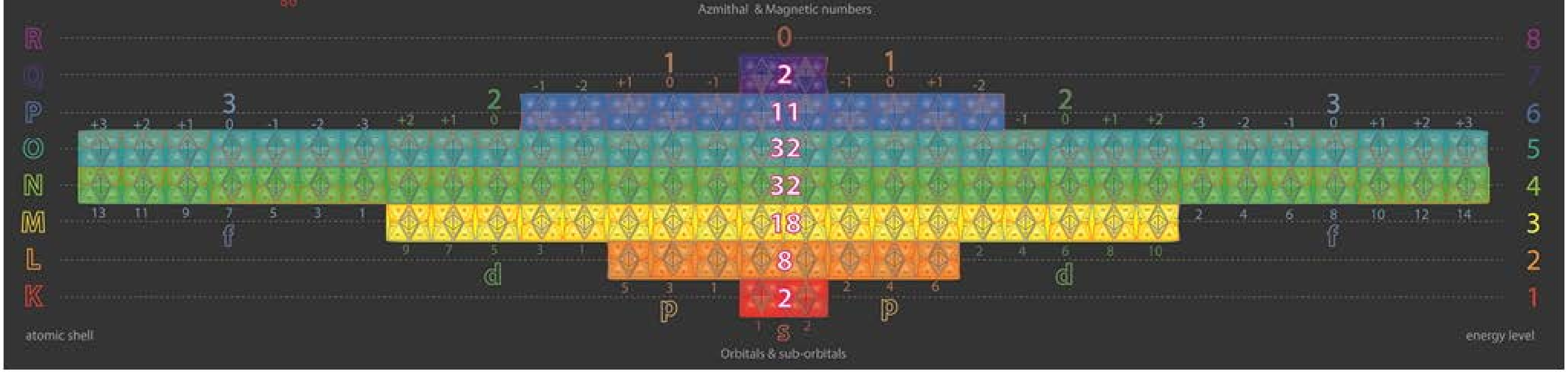
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
2
3
3
2
11
32
32
18
8
2
f
f
d
d
p
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.105 - Dubnium atom

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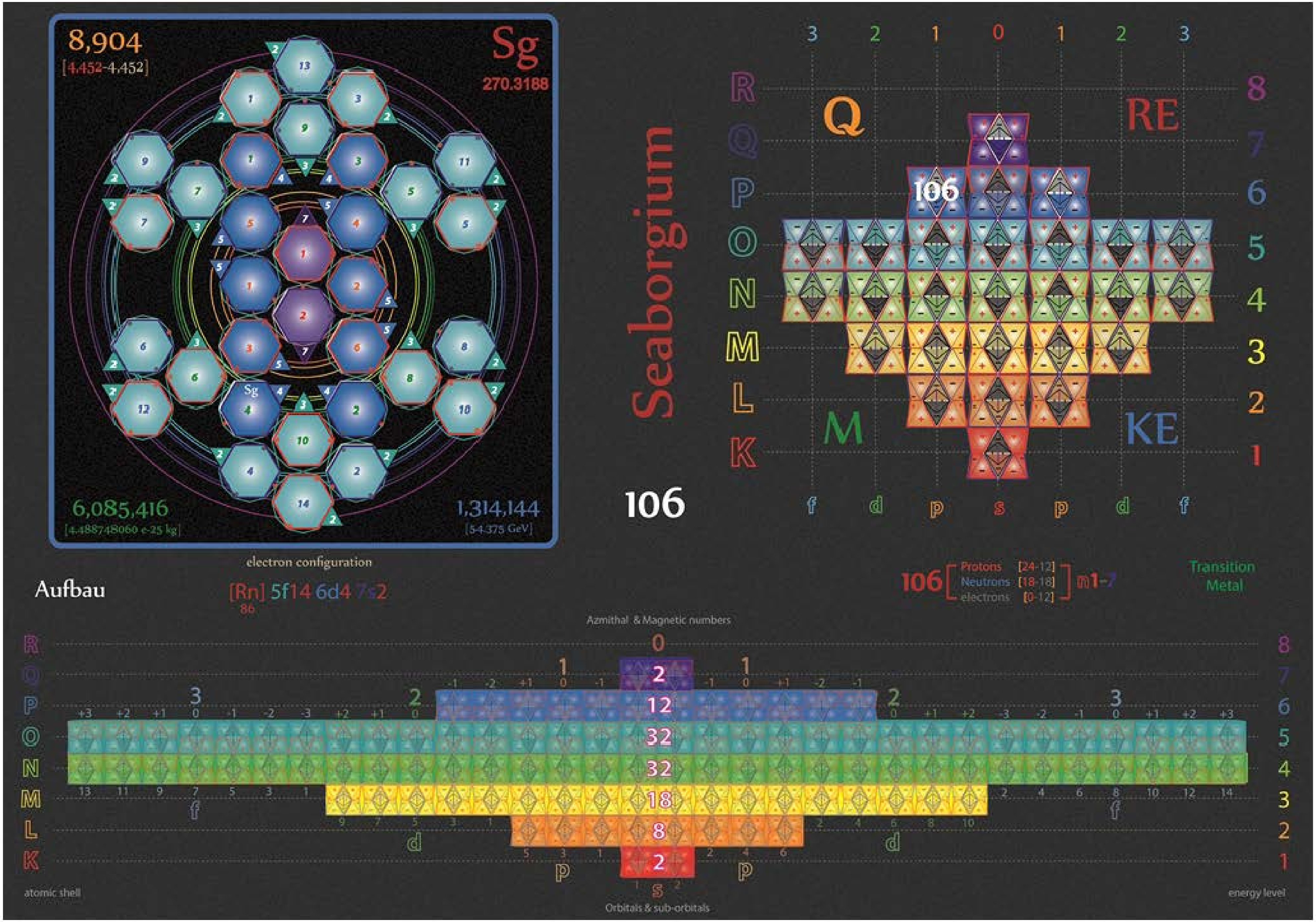
8,904
[4,452-4,452]
Sg
270.3188
6,085,416
[4.488748060 e-25 kg]
1,314,144
[54.375 GeV]
Seaborgium
106
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d4 7s2
86
106 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Transition Metal
Azmithal & Magnetic numbers
2
12
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.106 - Seaborgium atom

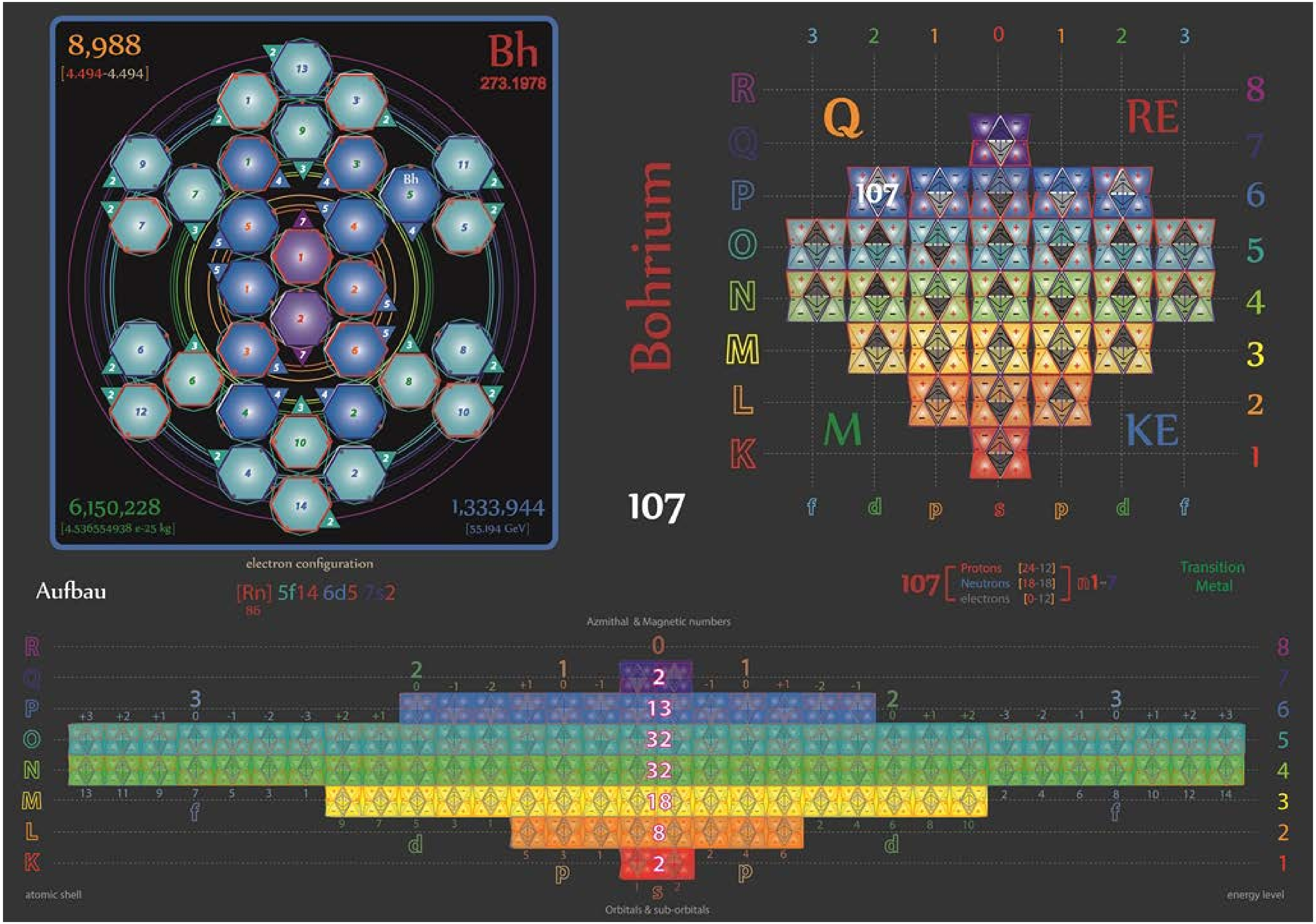
8,988
[4.494-4.494]
Bh
273.1978
6,150,228
[4.536554938 e-25 kg]
1,333,944
[55.194 GeV]
Bohrium
107
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d5 7s2
86
107 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Transition Metal
Azmithal & Magnetic numbers
2
13
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.107 - Bohrium atom

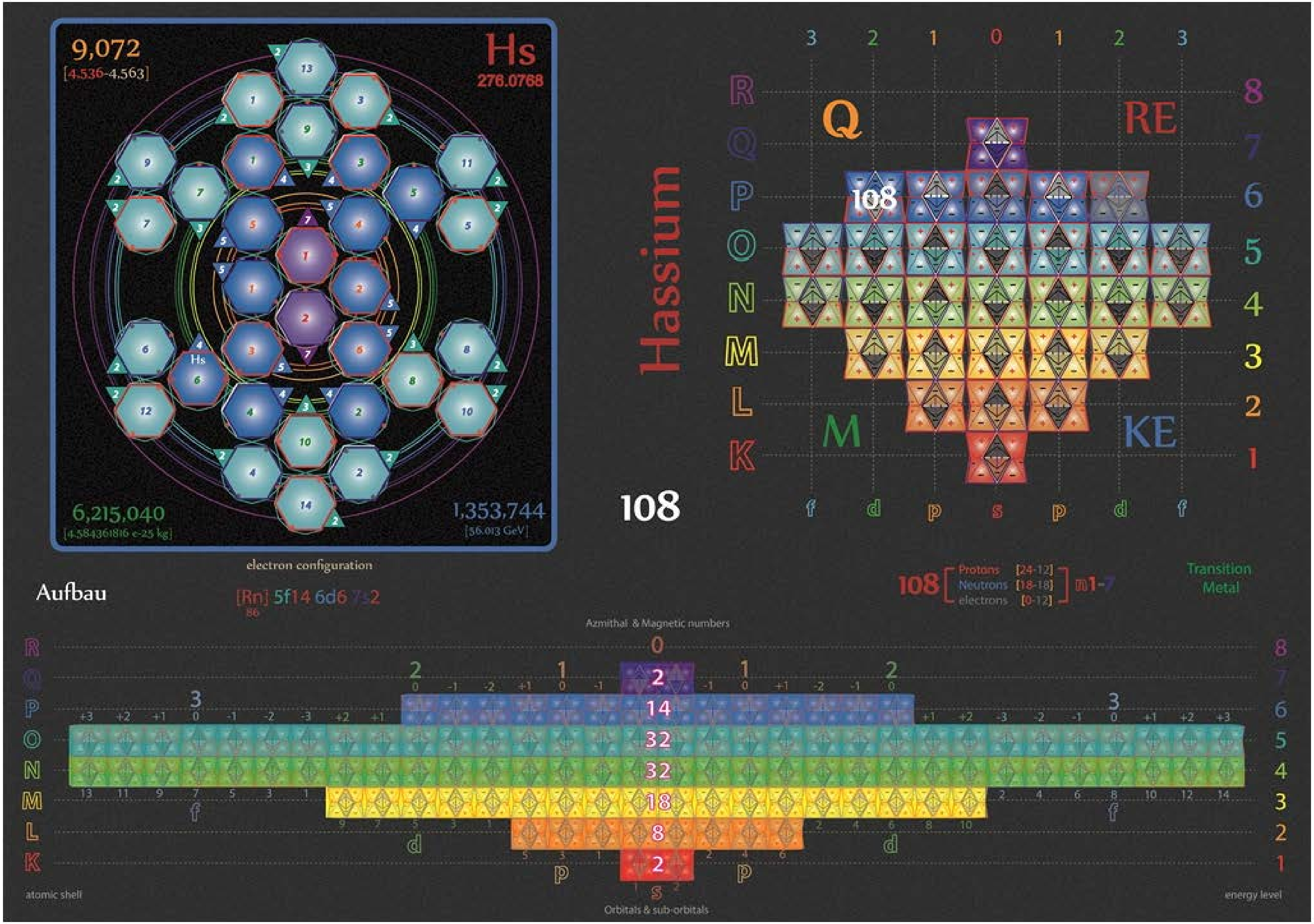
9,072
[4.536-4.563]
Hs
276.0768
6,215,040
[4.584361816 e-25 kg]
1,353,744
[56.013 GeV]
Hassium
108
R
Q
P
O
N
M
L
K
Q
RE
M
KE
3 2 1 0 1 2 3
8 7 6 5 4 3 2 1
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d6 7s2
86
108
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Transition
Metal
Azmithal & Magnetic numbers
2 14 32 32 18 8 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.108 - Hassium atom

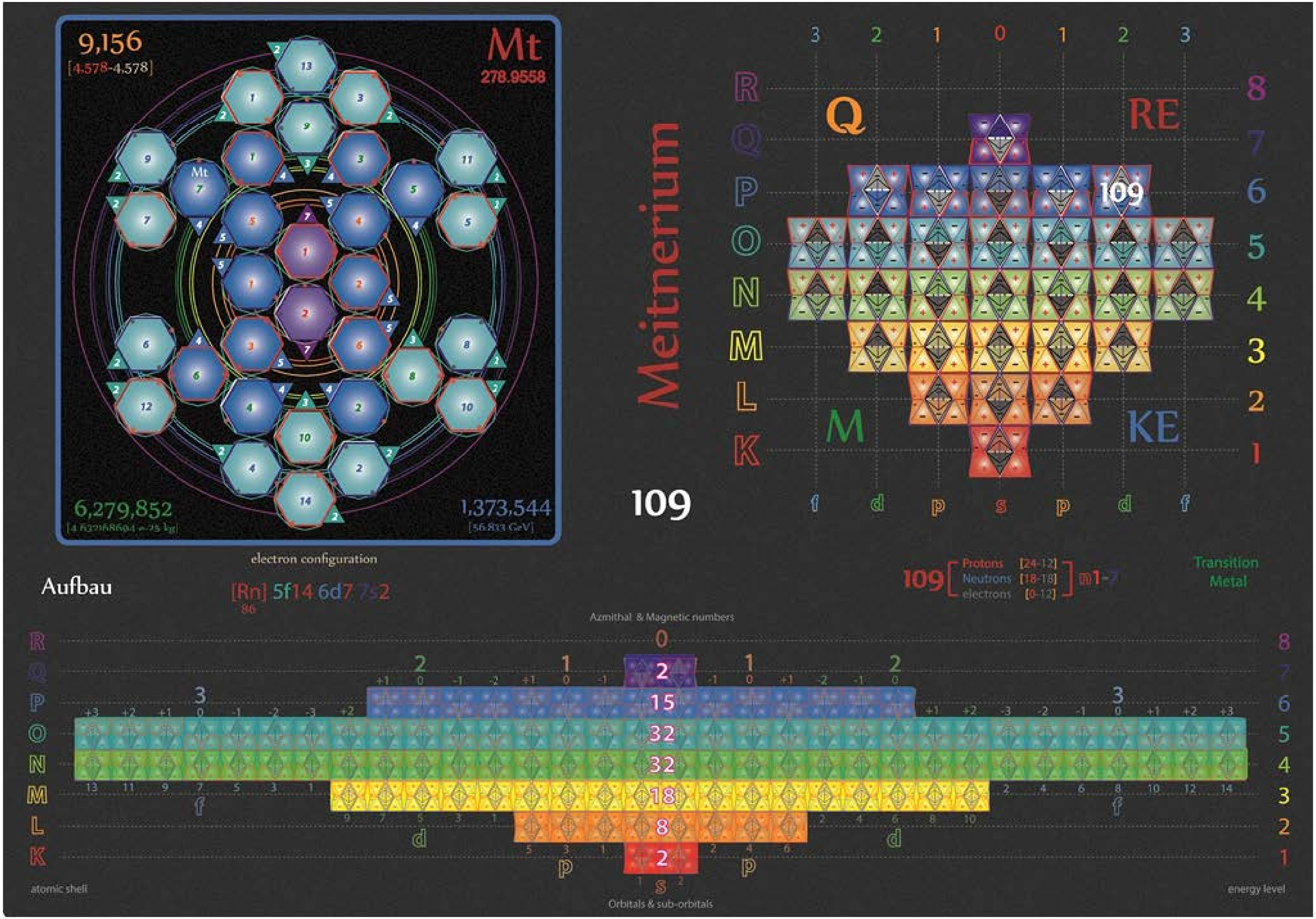
9,156
[4,578-4,578]
Mt
278.9558
6,279,852
[4.632168604 e-25 kg]
1,373,544
[56.833 GeV]
electron configuration
Aufbau
[Rn] 5f14 6d7 7s2
86
Meitnerium
109
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
109
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-7
Transition Metal
Azmithal & Magnetic numbers
0
2
15
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.109 - Meitnerium atom

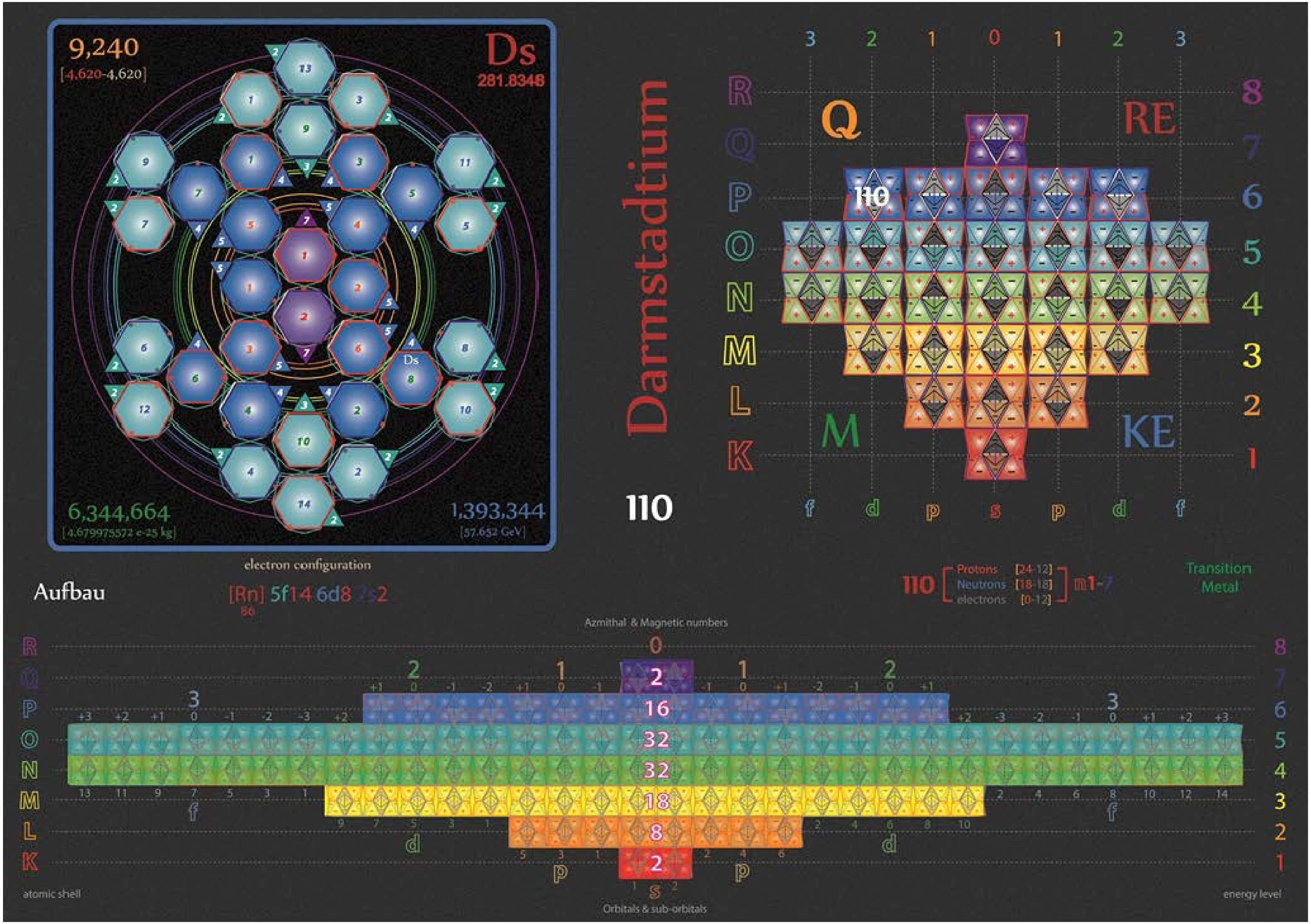
9,240
[4,620-4,620]
Ds
281.8348
6,344,664
[4.679975572 e-25 kg]
1,393,344
[57.652 GeV]
Darmstadtium
110
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d8 7s2
86
110 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Transition Metal
Azmithal & Magnetic numbers
0
2
16
32
32
18
8
2
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
+1 0 -1
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
f
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.110 - Darmstadtium atom

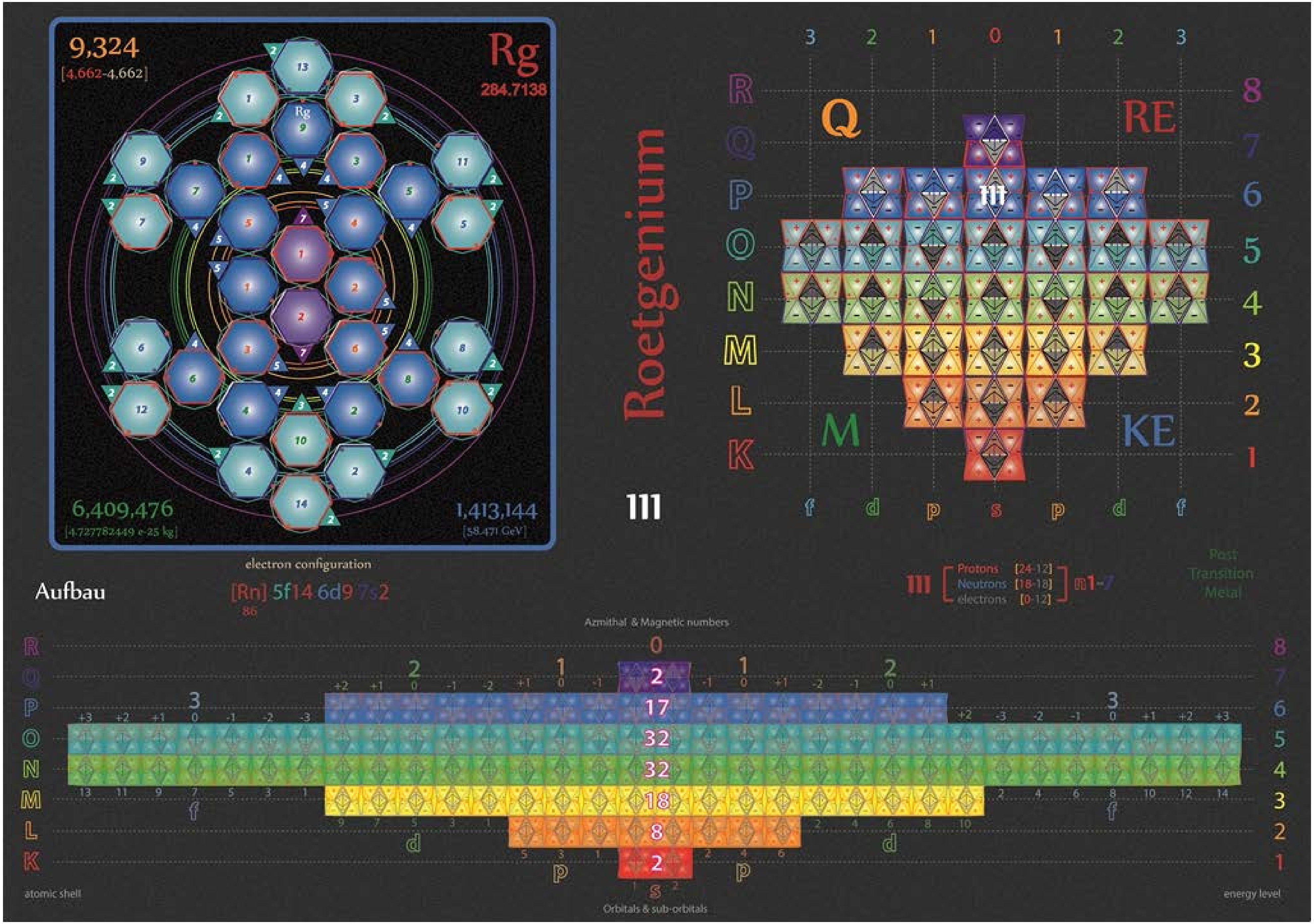
9,324
[4,662-4,662]
Rg
284.7138
6,409,476
[4.727782449 e-25 kg]
1,413,144
[58.471 GeV]
Roetgenium
111
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d9 7s2
86
111 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Post Transition Metal
Azmithal & Magnetic numbers
0
2
17
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.111 - Roetgenium atom

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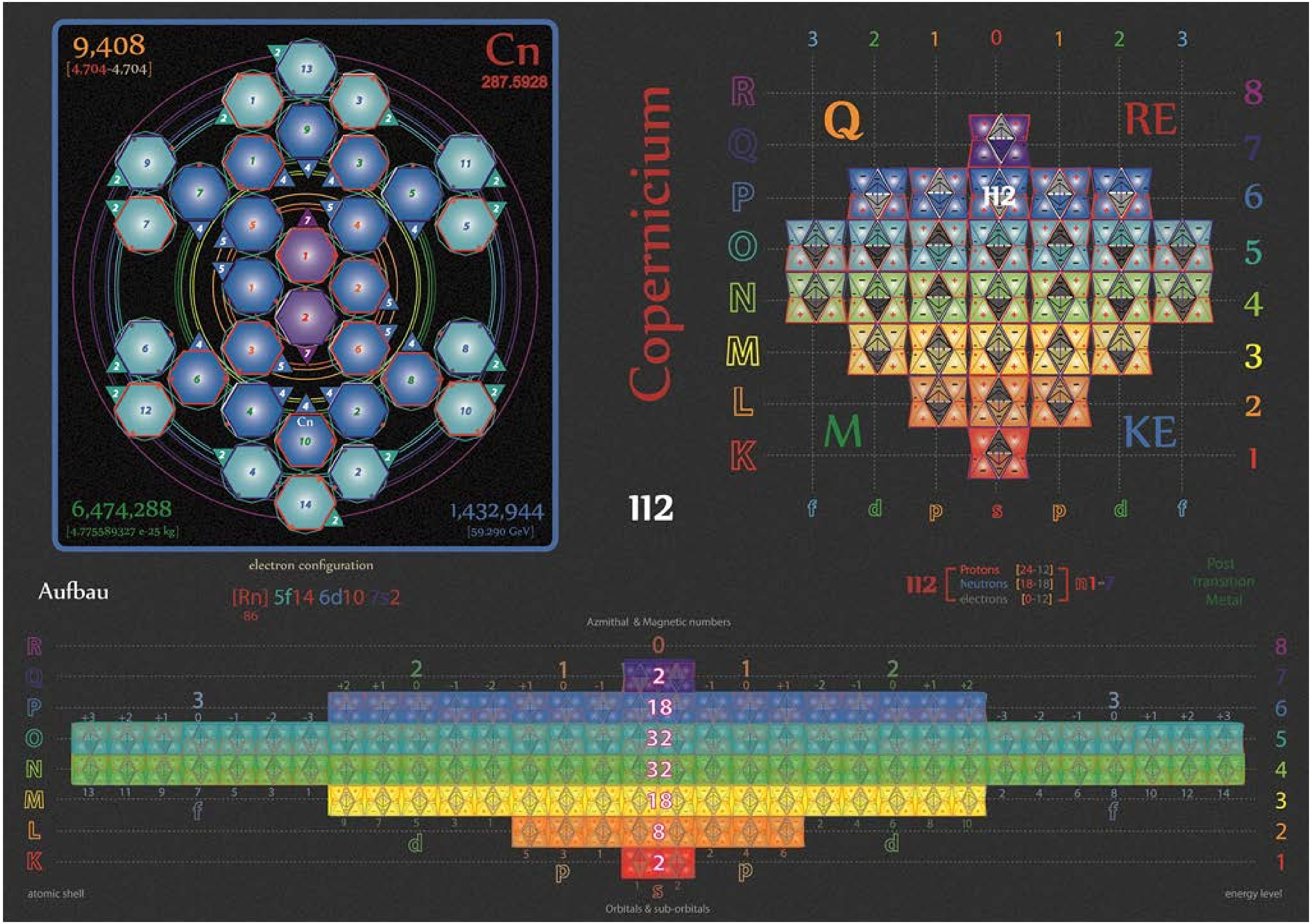
9,408
[4,704-4,704]
Cn
287.5928
6,474,288
[4.775589327 e-25 kg]
1,432,944
[59.290 GeV]
Copernicium
112
electron configuration
Aufbau
[Rn] 5f14 6d10 7s2
86
Q
RE
M
KE
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
112 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-7
Post transition Metal
Azmithal & Magnetic numbers
2
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.112 - Copernicium atom

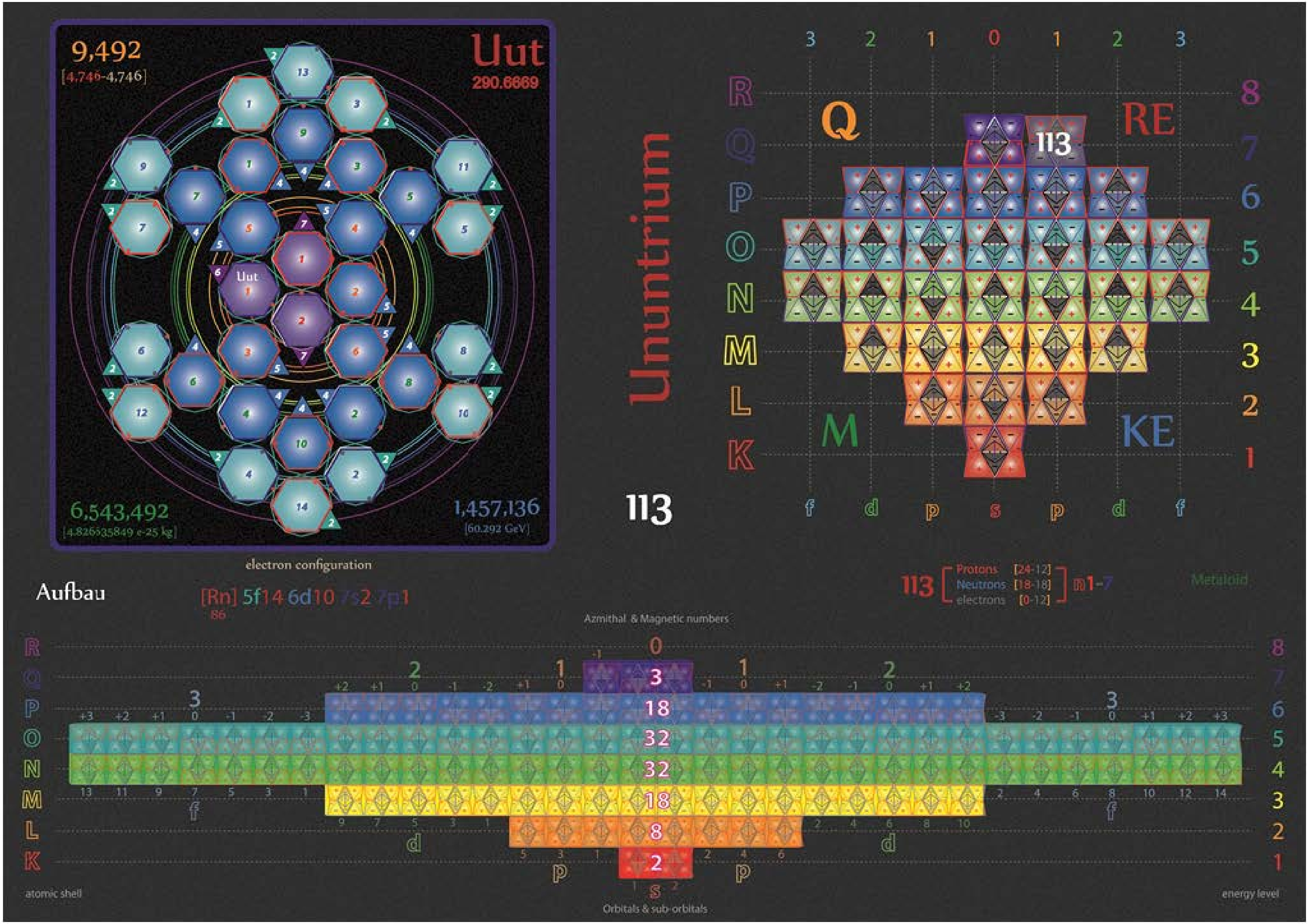
9,492
[4,746-4,746]
Uut
290.6669
Uut
6,543,492
[4.826635849 e-25 kg]
1,457,136
[60.292 GeV]
electron configuration
Ununtrium
113
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
113
f d p s p d f
Aufbau
[Rn] 5f14 6d10 7s2 7p1
86
113
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-7
Metalloid
Azmithal & Magnetic numbers
0
3
18
32
32
18
8
2
f
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.113 - Ununtrium atom

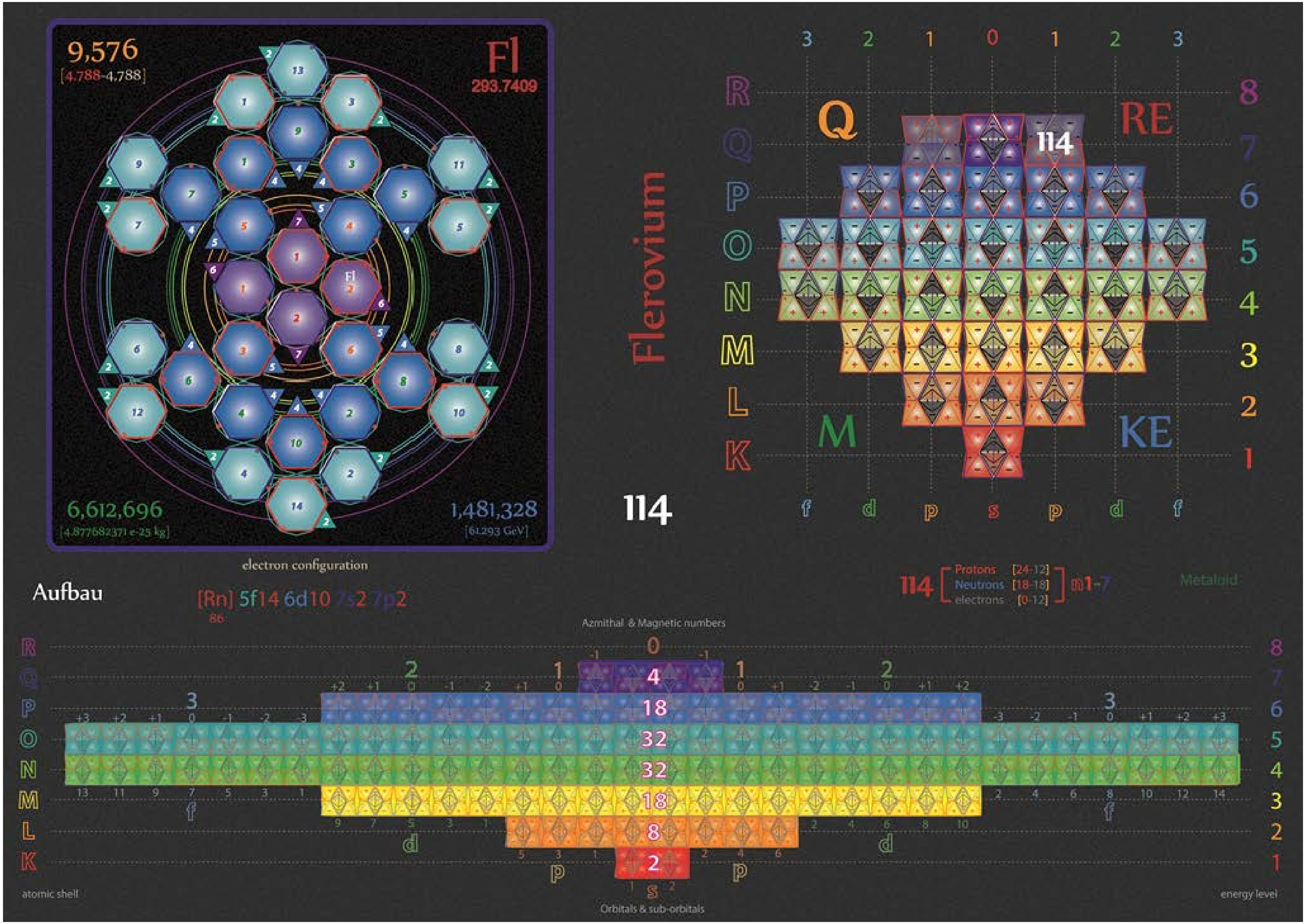
9,576
[4.788-4.788]
Fl
293.7409
6,612,696
[4.877682371 e-25 kg]
1,481,328
[61.293 GeV]
Flerovium
114
R
Q
P
O
N
M
L
K
3
2
1
0
1
2
3
8
7
6
5
4
3
2
1
Q
RE
M
KE
f
d
p
s
p
d
f
electron configuration
Aufbau
[Rn] 5f14 6d10 7s2 7p2
86
114
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Metalloid
Azmithal & Magnetic numbers
4
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.114 - Flerovium atom

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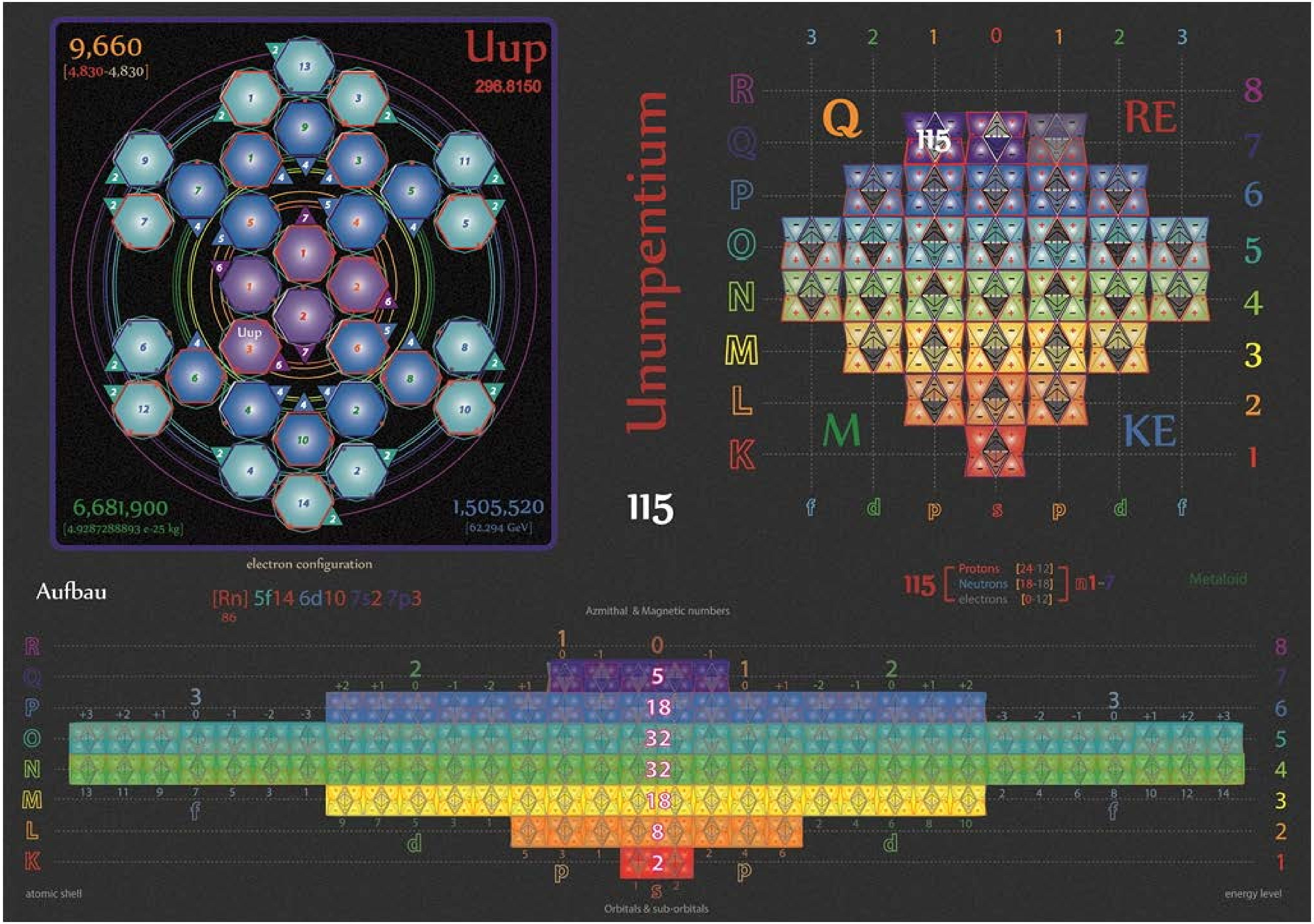
9,660
[4,830-4,830]
Uup
296.8150
6,681,900
[4.9287288893 e-25 kg]
1,505,520
[62.294 GeV]
Uup
Ununpentium
115
Q
RE
M
KE
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
115
electron configuration
Aufbau
[Rn] 5f14 6d10 7s2 7p3
86
115 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-7
Metalloid
Azmithal & Magnetic numbers
5
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.115 - Ununpentium atom

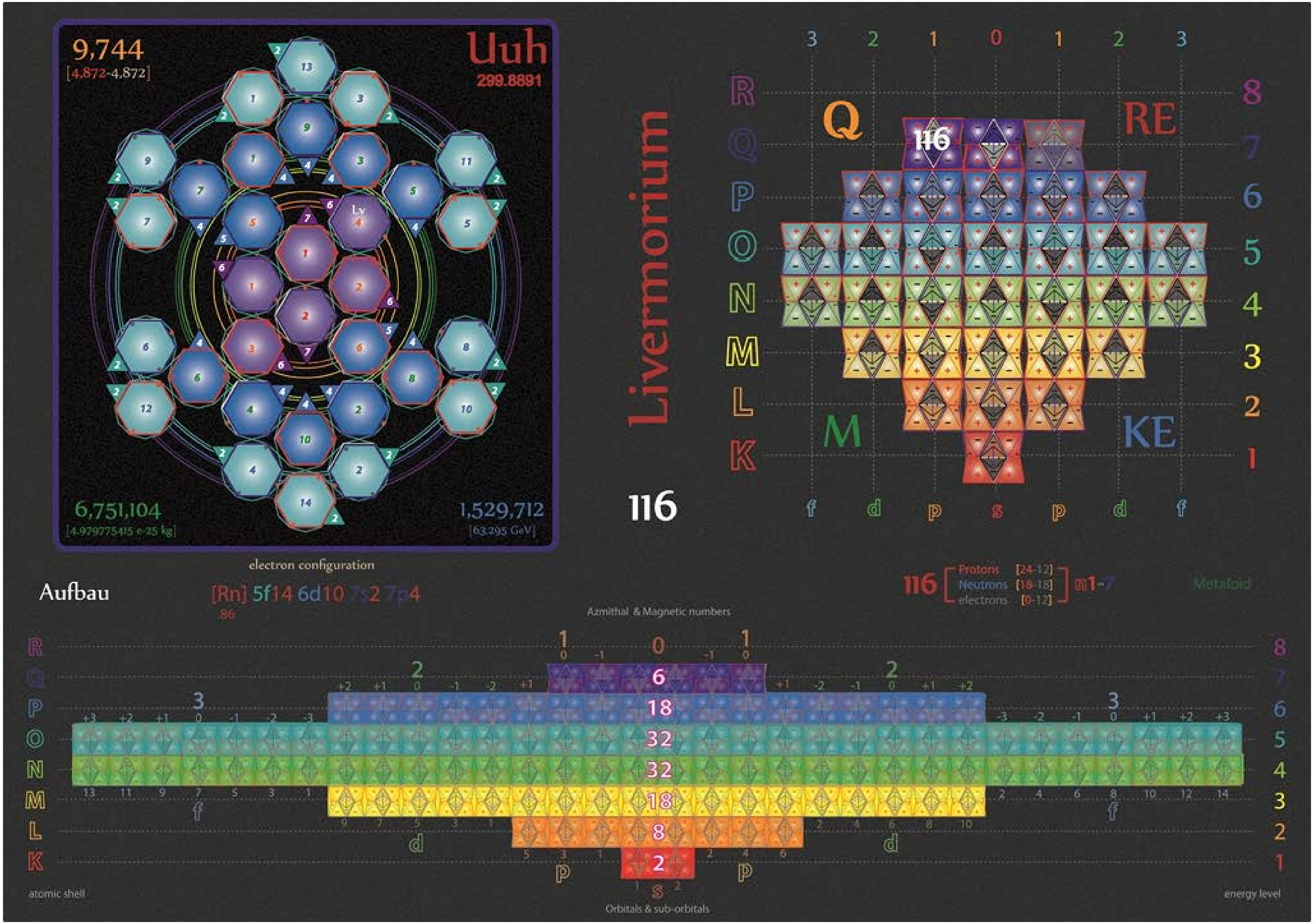
9,744
[4,872-4,872]
Uuh
289.8891
Lv
6,751,104
[4.979775415 e-25 kg]
1,529,712
[63.295 GeV]
electron configuration
Livermorium
116
Q
RE
M
KE
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
Aufbau
[Rn] 5f14 6d10 7s2 7p4
86
116
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-7
Metaloid
Azmithal & Magnetic numbers
6
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.116 - Livermorium atom

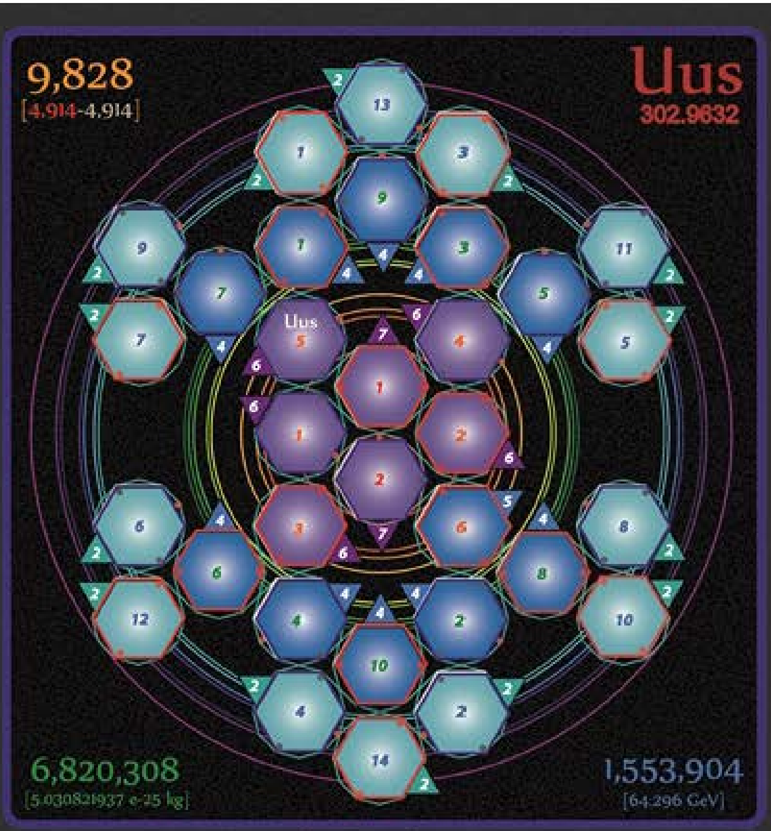

9,828
[4.914-4.914]

Uus
302.9832

6,820,308
[5.030821937 e-25 kg]

1,553,904
[64.296 GeV]

electron configuration

Ununseptium

117

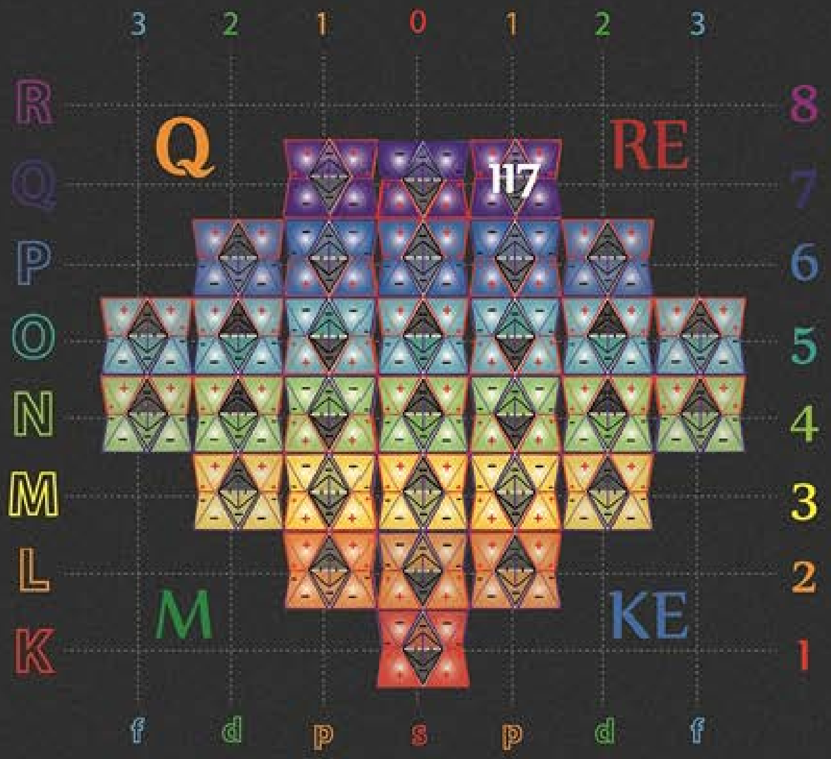
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
117
M
KE
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

117 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7

Halogen

Aufbau

[Rn] 5f14 6d10 7s2 7p5
86

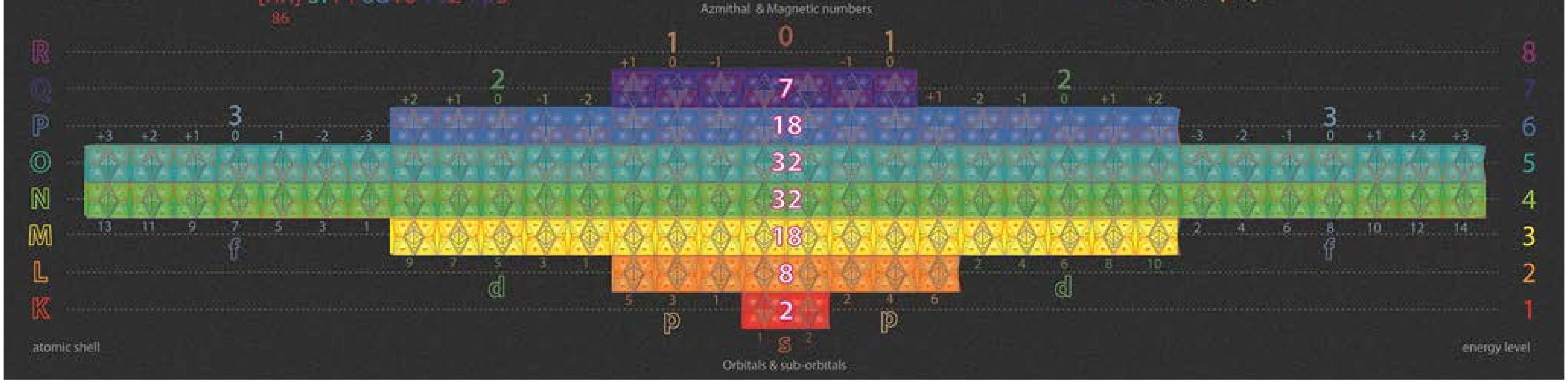
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
0
1
1
2
2
3
3
7
18
32
32
18
8
2
f
d
p
s
p
d
f
8
7
6
5
4
3
2
1
atomic shell
Orbitals & sub-orbitals
energy level

Tetryonics 51.117 - Ununseptium atom

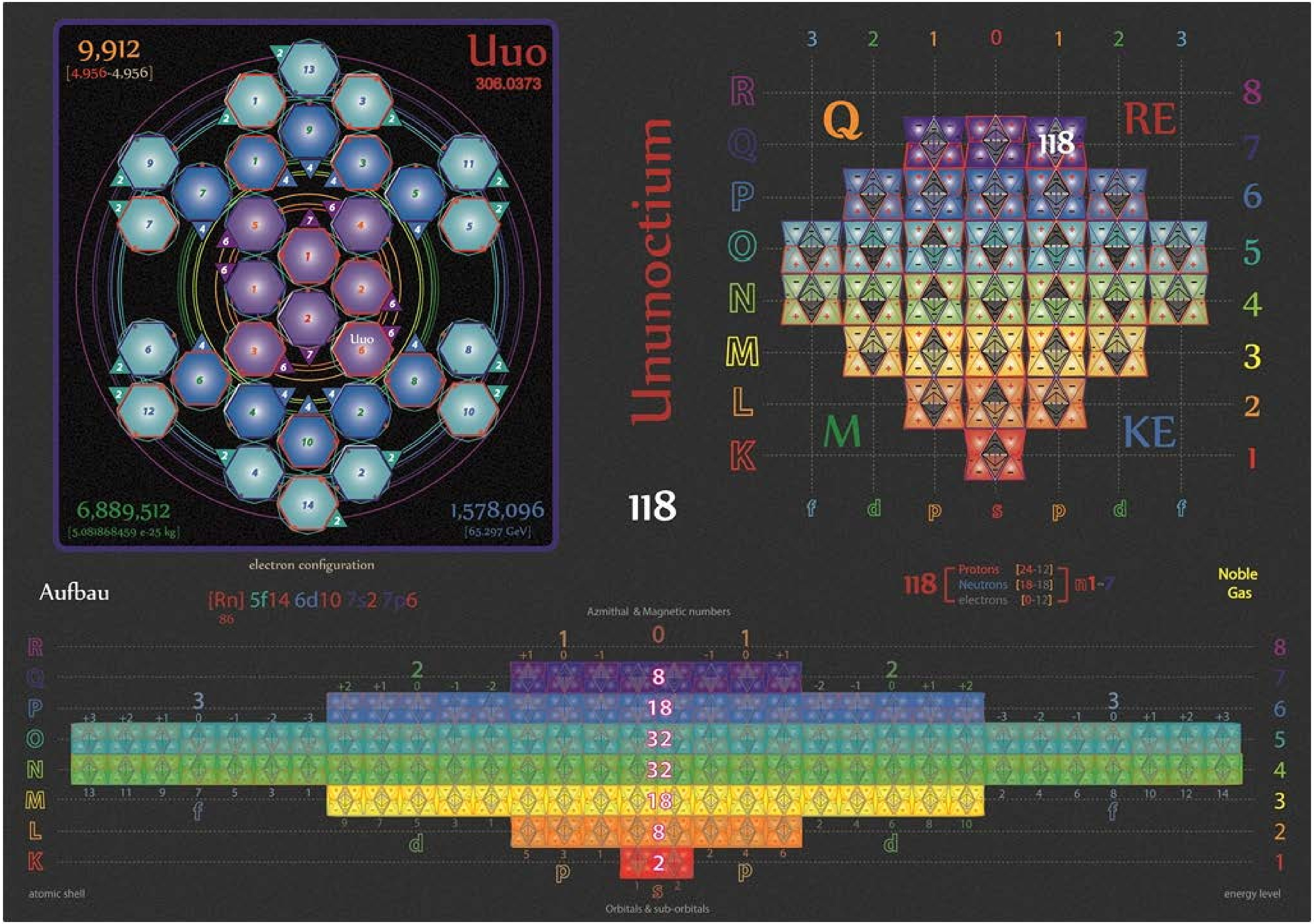
9,912
[4,956-4,956]
Uuo
308.0373
6,889,512
[5.081868459 e-25 kg]
1,578,096
[65.297 GeV]
Ununoctium
118
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
electron configuration
Aufbau
[Rn] 5f14 6d10 7s2 7p6
86
118 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Noble Gas
Azmithal & Magnetic numbers
8
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.118 - Ununoctium atom

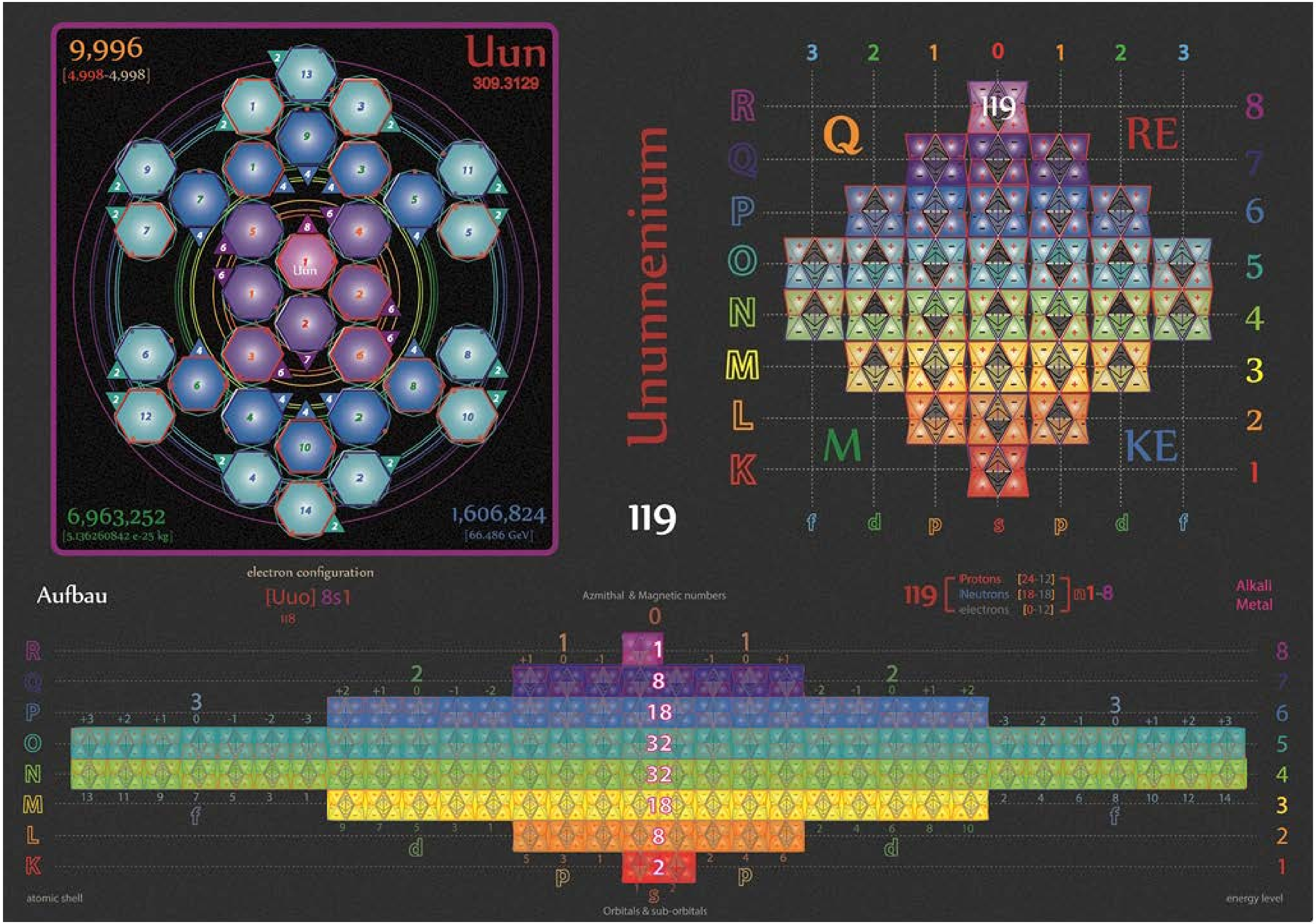
9,996
[4,998-4,998]
Uun
309.3129
6,963,252
[5.136260842 e-25 kg]
1,606,824
[66.486 GeV]
Ununnenium
119
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Uuo] 8s1
118
Azmithal & Magnetic numbers
119 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-8
Alkali Metal
1
8
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.119 - Ununnenium atom

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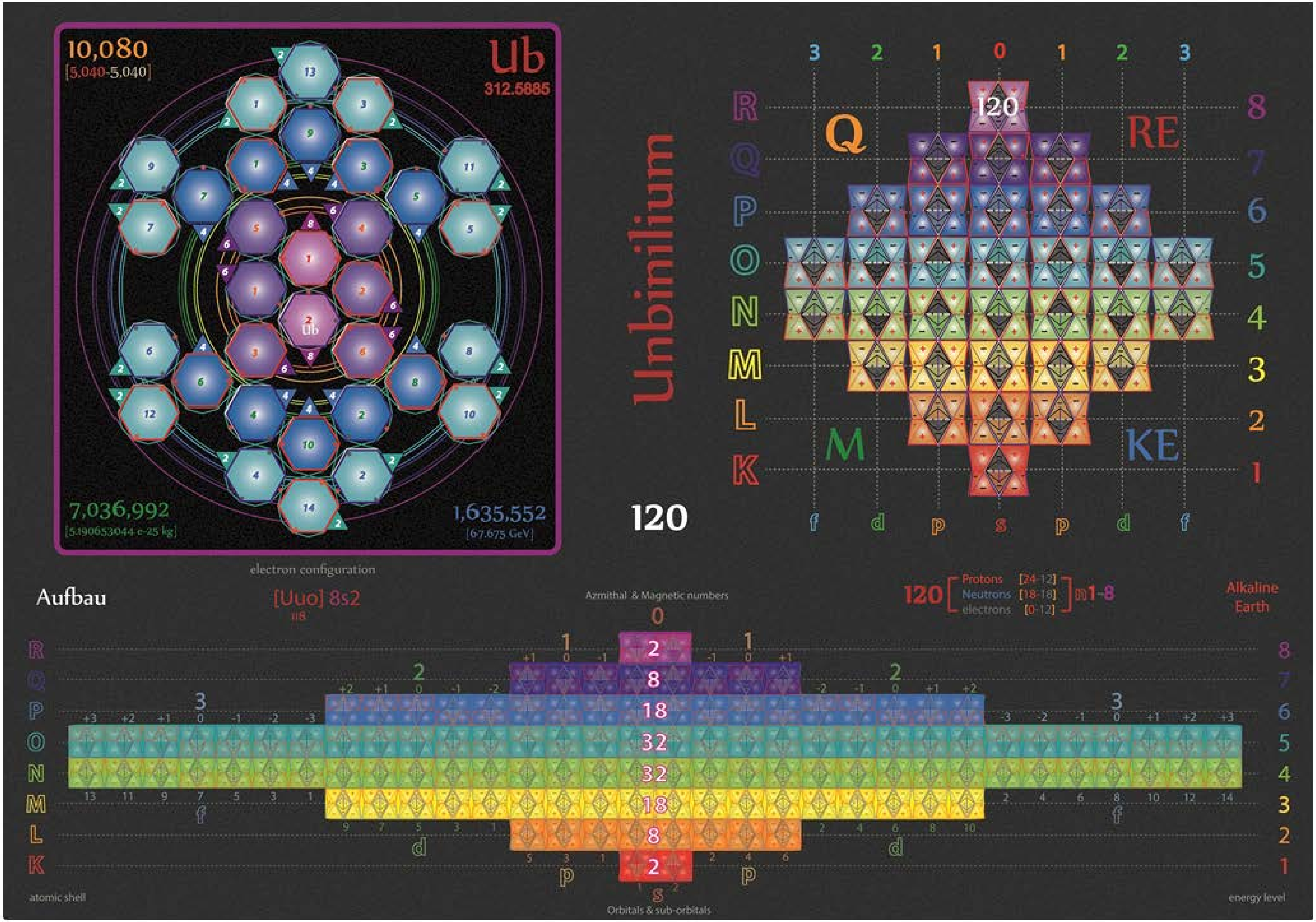
10,080
[5,040-5,040]
Ub
312.5885
7,036,992
[5.190653044 e-25 kg]
1,635,552
[67.675 GeV]
Unbinilium
120
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Uuo] 8s2
118
Azmithal & Magnetic numbers
120 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-8
Alkaline Earth
2
8
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.120 - Unbinilium atom

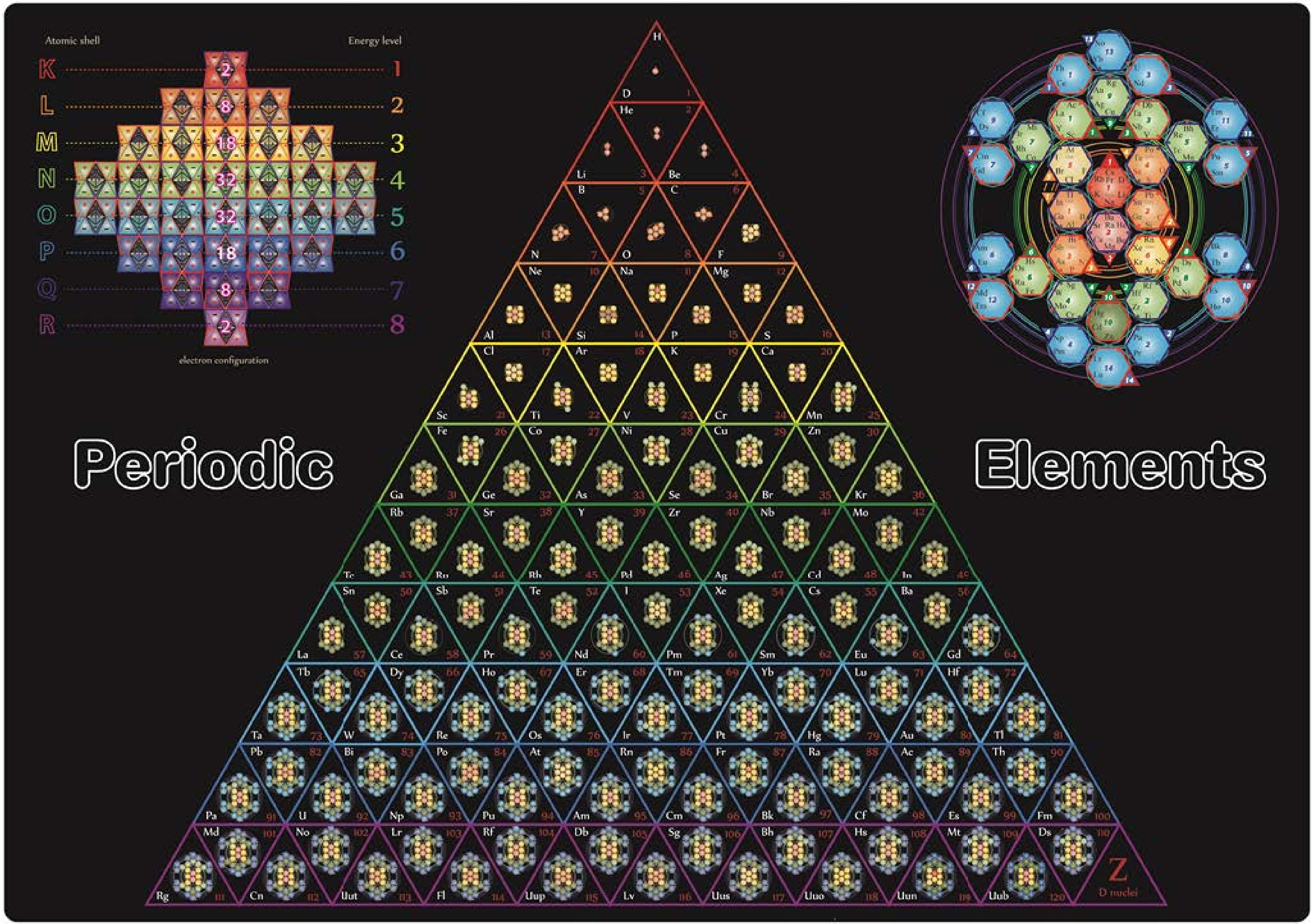
Atomic shell
Energy level
K 1
L 2
M 3
N 4
O 5
P 6
Q 7
R 8
2
8
18
32
32
18
8
2
electron configuration
Periodic
Elements
H
D 1
He 2
Li 3
Be 4
B 5
C 6
N 7
O 8
F 9
Ne 10
Na 11
Mg 12
Al 13
Si 14
P 15
S 16
Cl 17
Ar 18
K 19
Ca 20
Sc 21
Ti 22
V 23
Cr 24
Mn 25
Fe 26
Co 27
Ni 28
Cu 29
Zn 30
Ga 31
Ge 32
As 33
Se 34
Br 35
Kr 36
Rb 37
Sr 38
Y 39
Zr 40
Nb 41
Mo 42
Tc 43
Ru 44
Rh 45
Pd 46
Ag 47
Cd 48
In 49
Sn 50
Sb 51
Te 52
I 53
Xe 54
Cs 55
Ba 56
La 57
Ce 58
Pr 59
Nd 60
Pm 61
Sm 62
Eu 63
Gd 64
Tb 65
Dy 66
Ho 67
Er 68
Tm 69
Yb 70
Lu 71
Hf 72
Ta 73
W 74
Re 75
Os 76
Ir 77
Pt 78
Hg 79
Au 80
Tl 81
Pb 82
Bi 83
Po 84
At 85
Rn 86
Fr 87
Ra 88
Ac 89
Th 90
Pa 91
U 92
Np 93
Pu 94
Am 95
Cm 96
Bk 97
Cf 98
Es 99
Fm 100
Md 101
No 102
Lr 103
Rf 104
Db 105
Sg 106
Bh 107
Hs 108
Mt 109
Ds 110
Rg 111
Cn 112
Uut 113
Fl 114
Uup 115
Lv 116
Uus 117
Uuo 118
Uun 119
Uub 120
Z
D nuclei

Tetryonics 52.01 - Tetryonic Element Table

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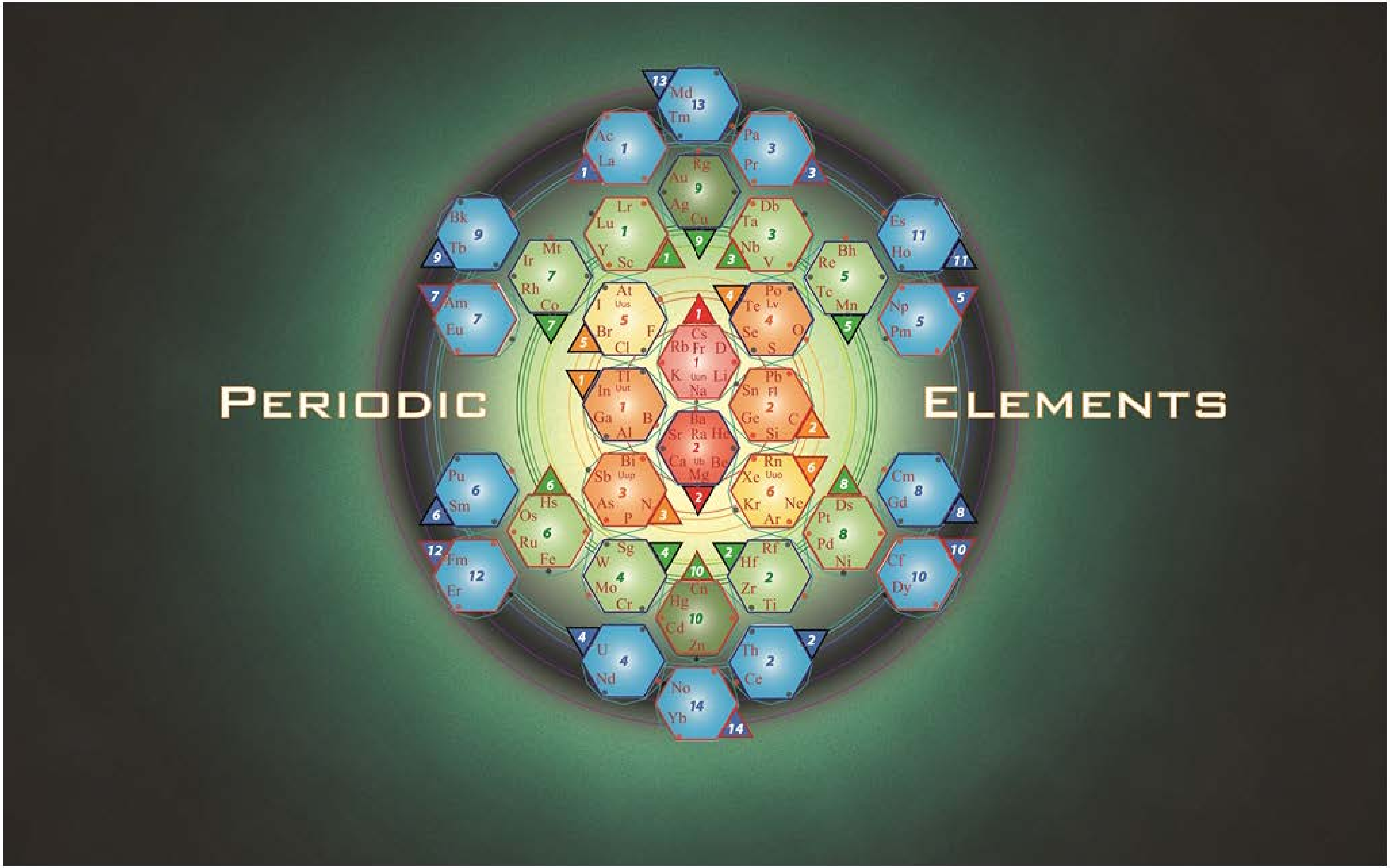
PERIODIC
ELEMENTS
13 Md 13 Tm
Ac 1 La 1
Pa 3 Pr 3
Rg Au 9 Ag Cu 9
Bk 9 Tb 9
Es 11 Ho 11
Lr Lu 1 Y Sc 1
Db Ta 3 Nb V 3
Mt Ir 7 Rh Co 7
Bh Re 5 Tc Mn 5
7 Am 7 Eu
5 Np 5 Pm
At I Uus 5 Br F Cl 5
1 Cs Rb Fr D 1 K Uun Li Na
4 Po Te Lv 4 Se O S
1 Tl In Uut 1 Ga B Al
Pb Sn Fl 2 Ge C Si 2
Ba Sr Ra He 2 Ca Ub Be Mg 2
Bi Sb Uup 3 As N P 3
Rn Xe Uuo 6 Kr Ne Ar 6
Pu 6 Sm 6
Cm 8 Gd 8
6 Hs Os 6 Ru Fe
8 Ds Pt 8 Pd Ni
12 Fm 12 Er
Cf 10 10 Dy
Sg W 4 Mo Cr 4
2 Rf Hf 2 Zr Ti
10 Cn Hg 10 Cd Zn
4 U 4 Nd
Th 2 Ce 2
No 14 Yb 14

Tetryonics 52.02 - Periodic Table [Elements]

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TETRYONICS

The charged geometry of mass-ENERGY-Matter

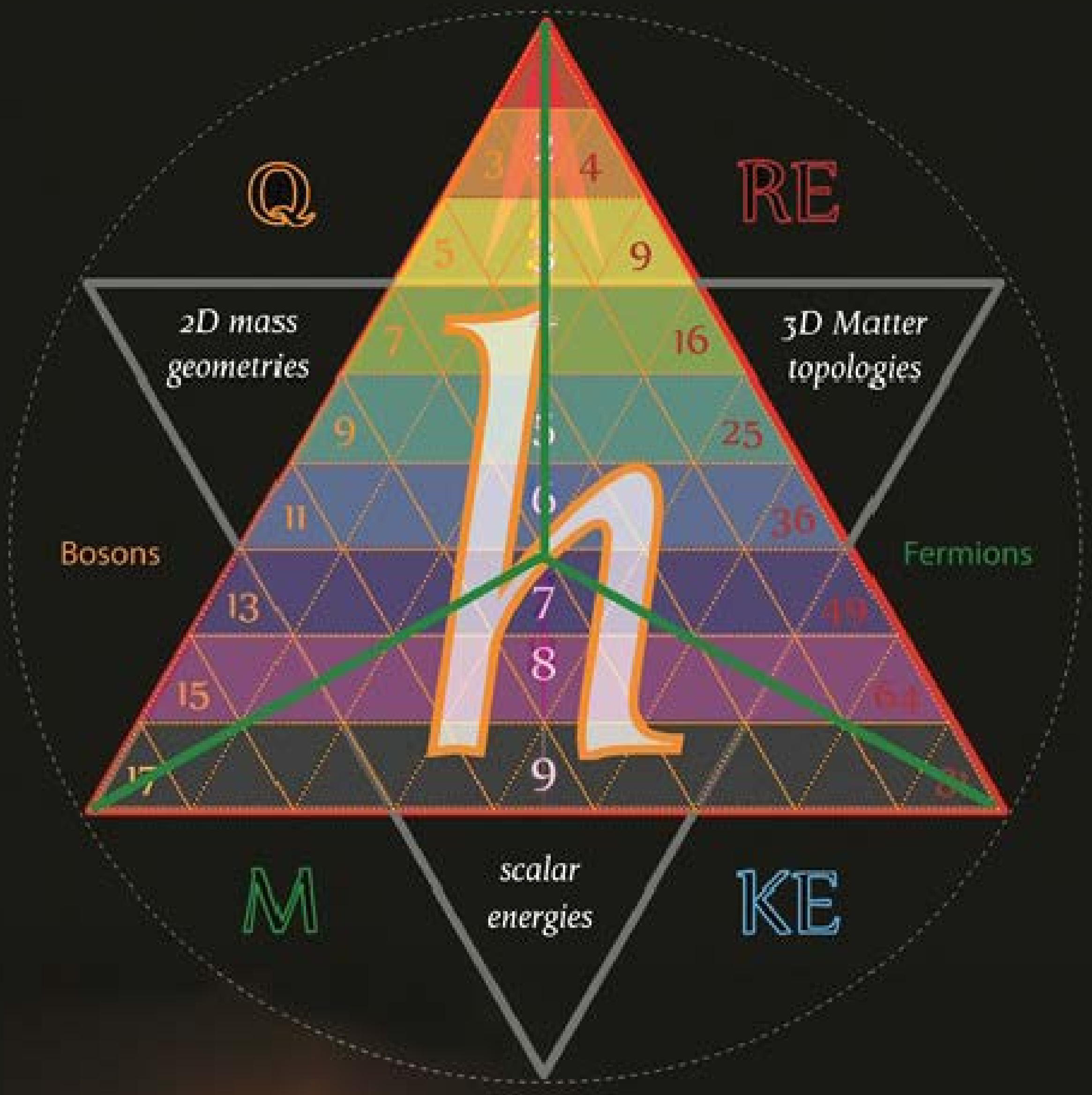
Q
RE
2D mass
geometries
3D Matter
topologies
Bosons
Fermions
M
KE
scalar
energies
h
3
4
5
9
7
16
9
25
11
36
13
49
15
64
17
6
7
8
9

Foundational Quantum Mechanics

Abraham

ISBN 978-0-9872884-1-7
[Second Edition © 2012]

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FUNDAMENTUM QUANTUM MECHANICA

questions **Q**

A answers

[TETRYONICS]

A fundamental re-interpretation of the geometry of quantised angular momentum is required to complete the physics of 'The Standard model'

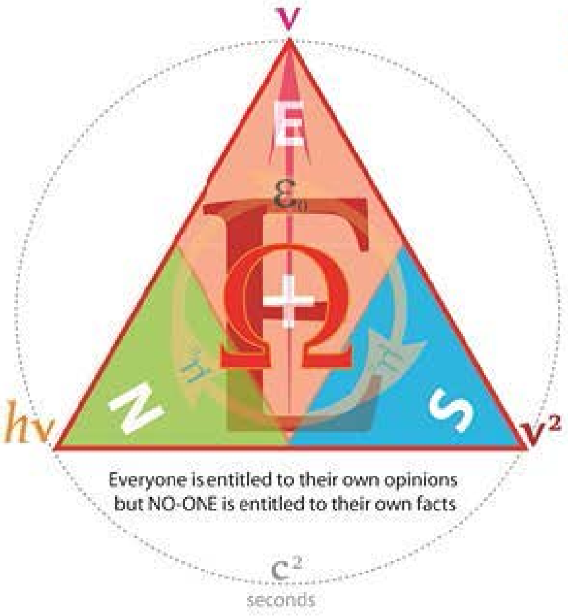

Everyone is entitled to their own opinions but NO-ONE is entitled to their own facts

Mathematics is the language of Physics, and Geometry is its grammar

Philosophiae Naturalis Principia geometricae

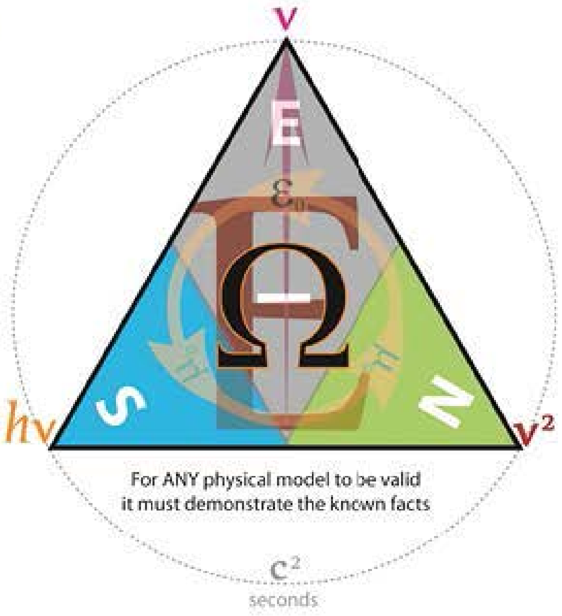

For ANY physical model to be valid it must demonstrate the known facts

Having removed the impossible, anything that remains, however improbable, must be the truth

"...the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the eternally problematic character of his concepts. He uses this conceptual material, or, speaking more exactly, these conceptual tools of thought, as something obviously, immutably given; something having an objective value of truth which is hardly even, and in any case not seriously, to be doubted. ...in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them."

[Albert Einstein]

Science is born from observation, and the reasoning of known facts in search of underlying truths

In the following pages the true geometry of quantum mechanics is revealed, leading scientific endeavour into new realms of understanding

mass-ENERGY-Matter

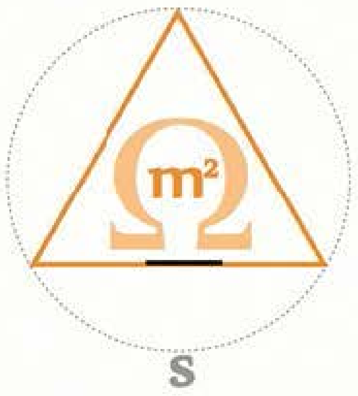

The a-priori revelation of Tetryonic theory is that all square mass-energies possess equilateral momenta geometries

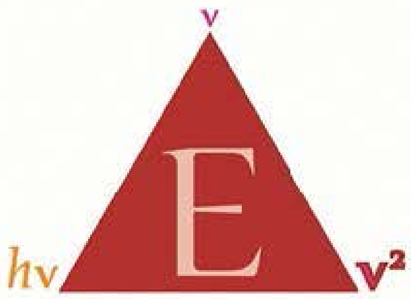

The equilateral Quantised Angular Momentum intrinsic to Planck mass-energy momenta produces charged geometries

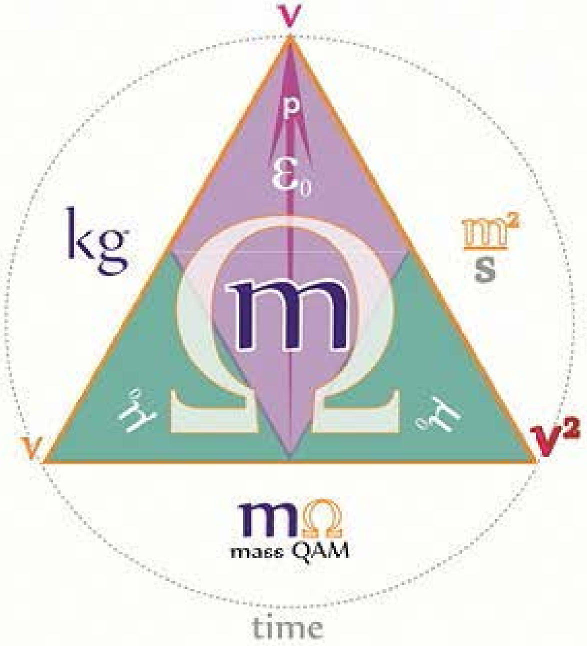
v
p
ε₀
kg
m²
S
m
μ₀
μ₀
v
v²
mΩ
mass QAM
time

The quantum mechanics of velocity, quanta, EM fields and mass-Energy-Matter can be fully revealed through their equilateral geometries

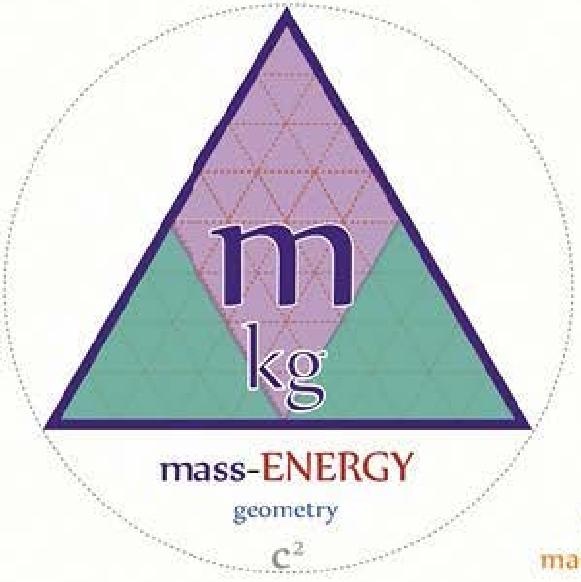
m
kg
mass-ENERGY
geometry
c²

A long hidden topology is revealed

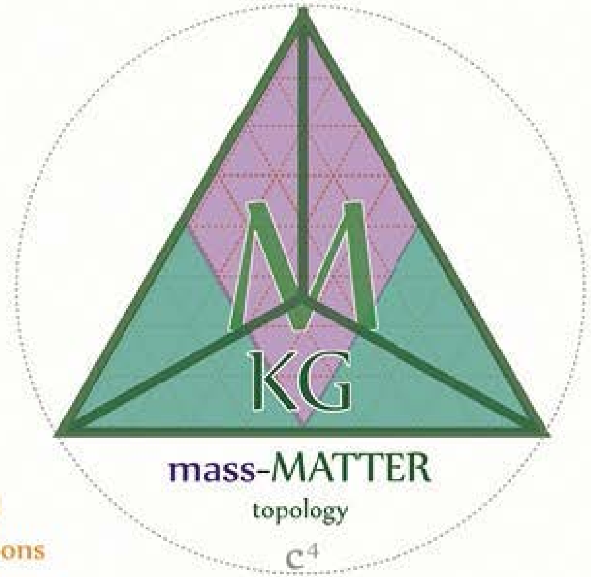
M
KG
mass-MATTER
topology
c⁴

Equilateral triangles are the foundational geometry for all mass-ENERGY-Matter topologies and physical Force interactions

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SQUARED energies in quantum mechanics are EQUILATERAL geometries

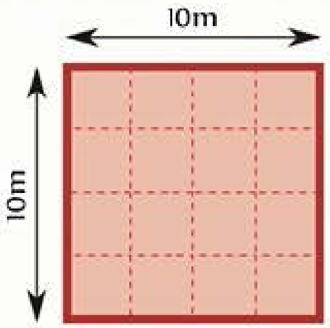

Square

$\text{area} = s^2 = [100]$

Circles

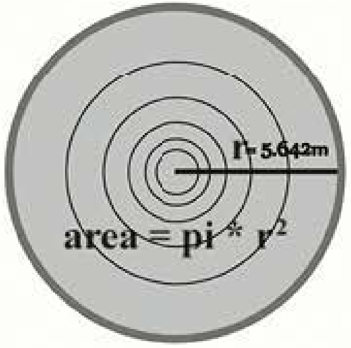
r=5.642m
area = pi * r²

$= \text{pi} * [5.642]^2$
$= 100$

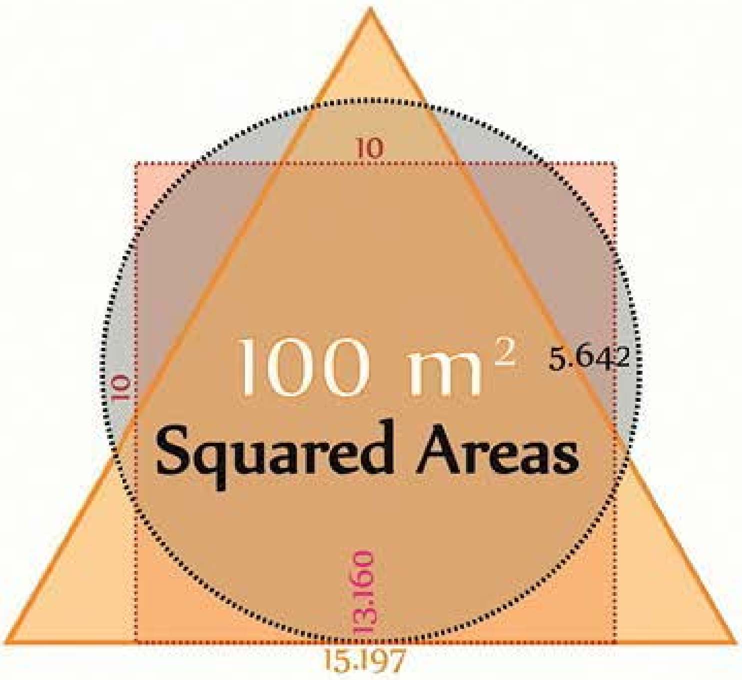
10
10
5.642
13.160
15.197
100 m²
Squared Areas

can be created by a number of planar geometries

For a long time it has been assumed by scientists (and mathematicians) that circular [and squared] geometries are the geometric foundation of all physics, leading to a serioulsy flawed model of particles and forces in quantum mechanics

Tetryonic theory now reveals that quantised equilateral angular momenta creates the foundational geometry of all the mass-Energy-Matter & forces of physics

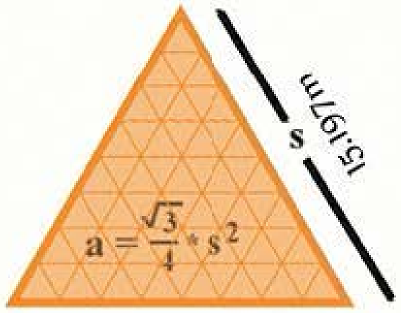

$$a = \frac{\sqrt{3}}{4} * s^2$$

Equilateral

$\text{area} = (\tfrac{1}{2} * b) * h$

Triangles

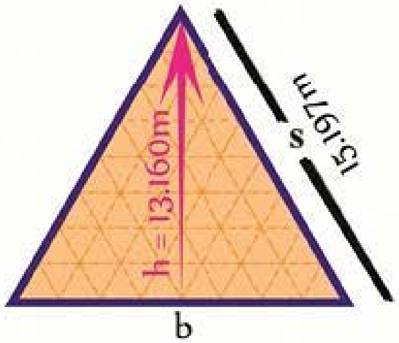
h = 13.160m
s
15.197m
b

$\overset{b}{[.5 \times 15.197]} \times \overset{h}{13.160}$
$= 100$

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Integers

The integers (from the Latin integer), literally "untouched", hence "whole"
in Tetryonics it is the basis for the quantum

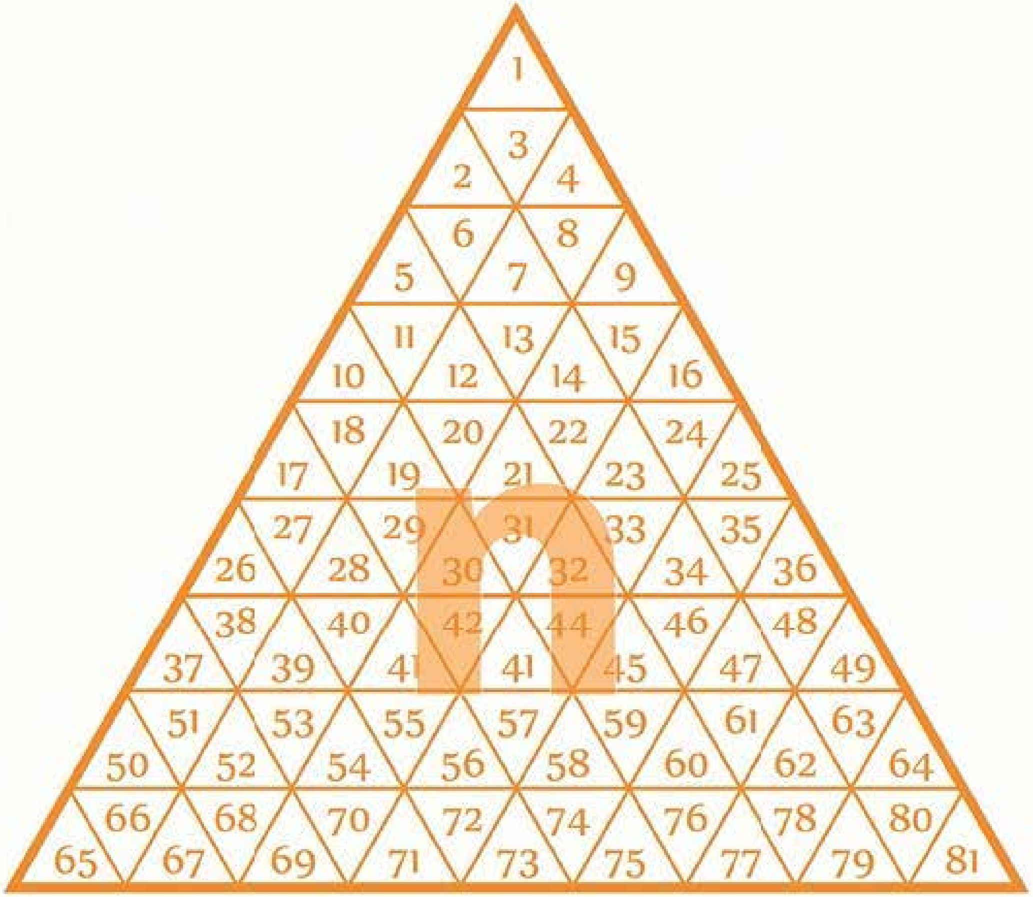
1
2 3 4
5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 41 44 45 46 47 48 49
50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81
n

Viewed as a subset of the real numbers, they are numbers that can be written without a fractional or decimal component

ODD numbers

An odd number is an integer which is not a multiple of two.

$2n-1$

$2n+1$

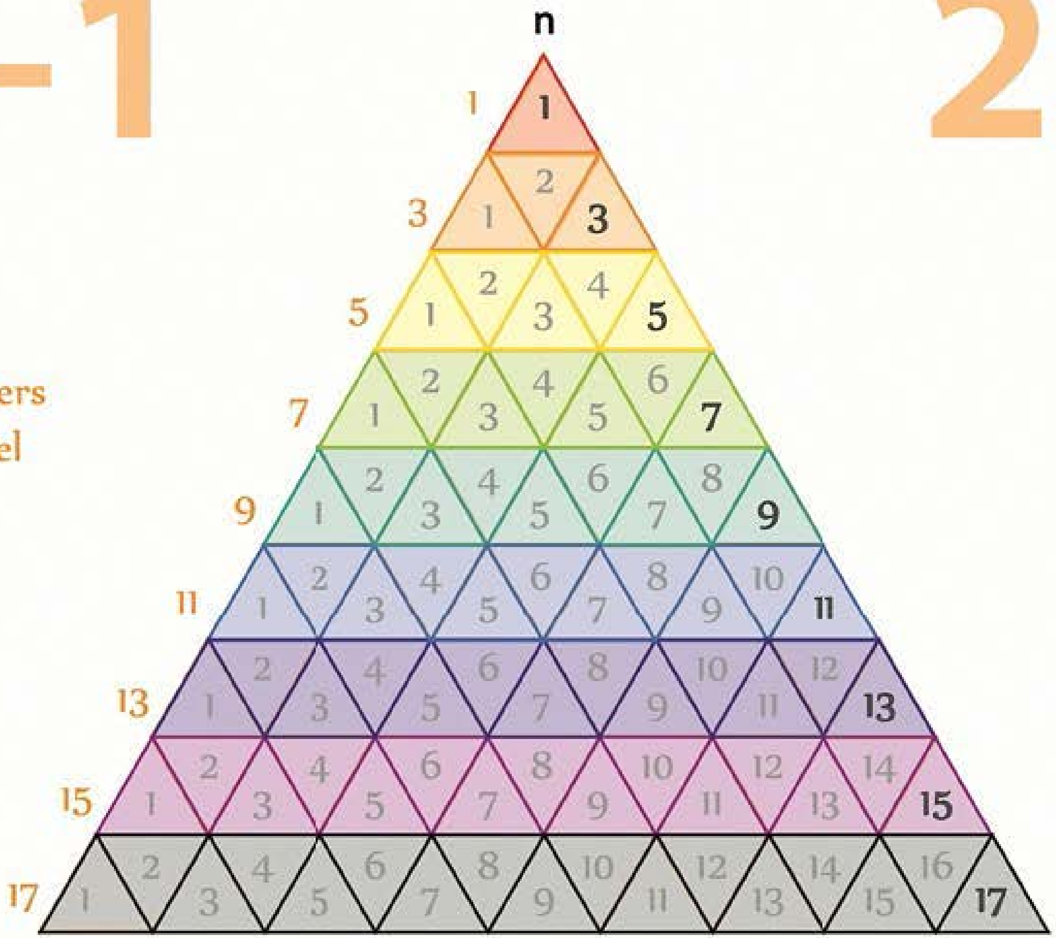
n
1
1
3
1 2 3
5
1 2 3 4 5
7
1 2 3 4 5 6 7
9
1 2 3 4 5 6 7 8 9
11
1 2 3 4 5 6 7 8 9 10 11
13
1 2 3 4 5 6 7 8 9 10 11 12 13
15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
17
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

ODD numbers
in each level

Bosons have
ODD number
quanta

An odd number, when divided by two, will result in a fraction

EVEN numbers

An integer that is not an odd number is an even number.

2

Photons have
EVEN number
quanta

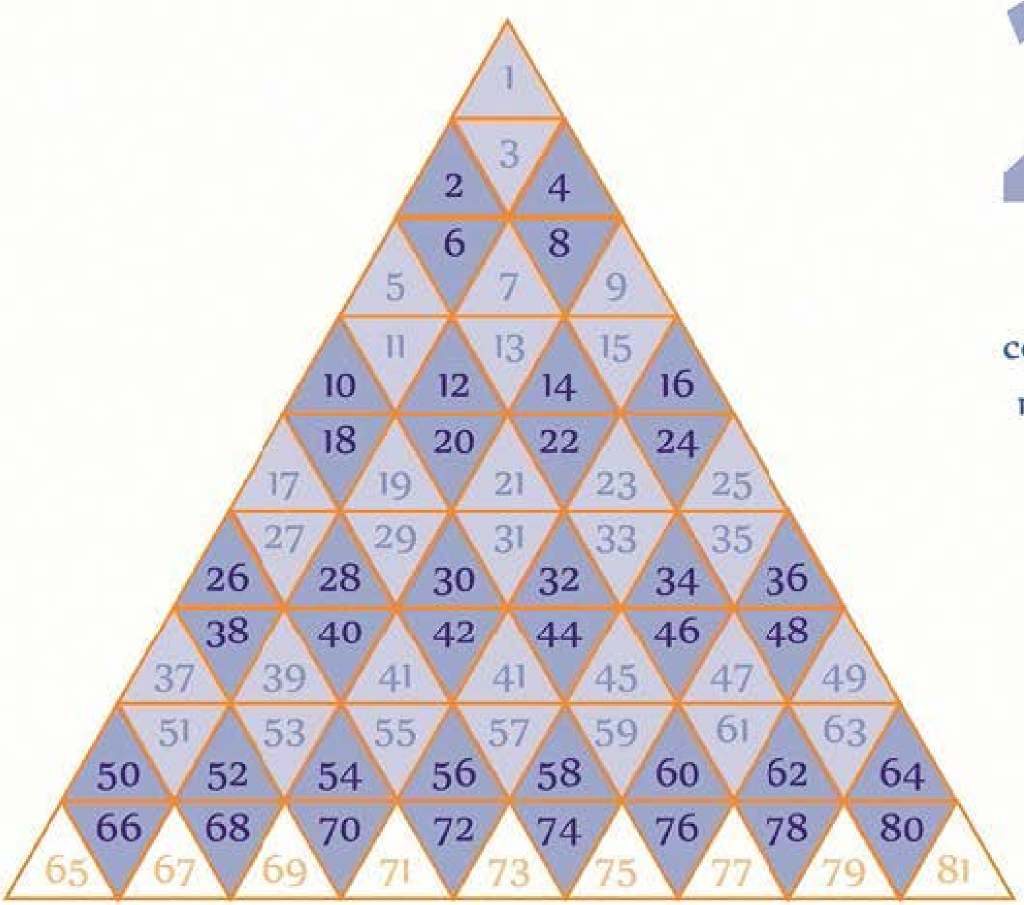
1
2 3 4
5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 41 44 45 46 47 48 49
50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81

2n

EM waves are
comprised of EVEN
numbered quanta

**An even number is defined as a whole number that is a multiple of two.
If an even number is divided by two, the result is another whole number.**

Square numbers

A square number, sometimes also called a perfect square,
is the result of an integer multiplied by itself

2n-1

Quantum levels
have ODD number
geometries

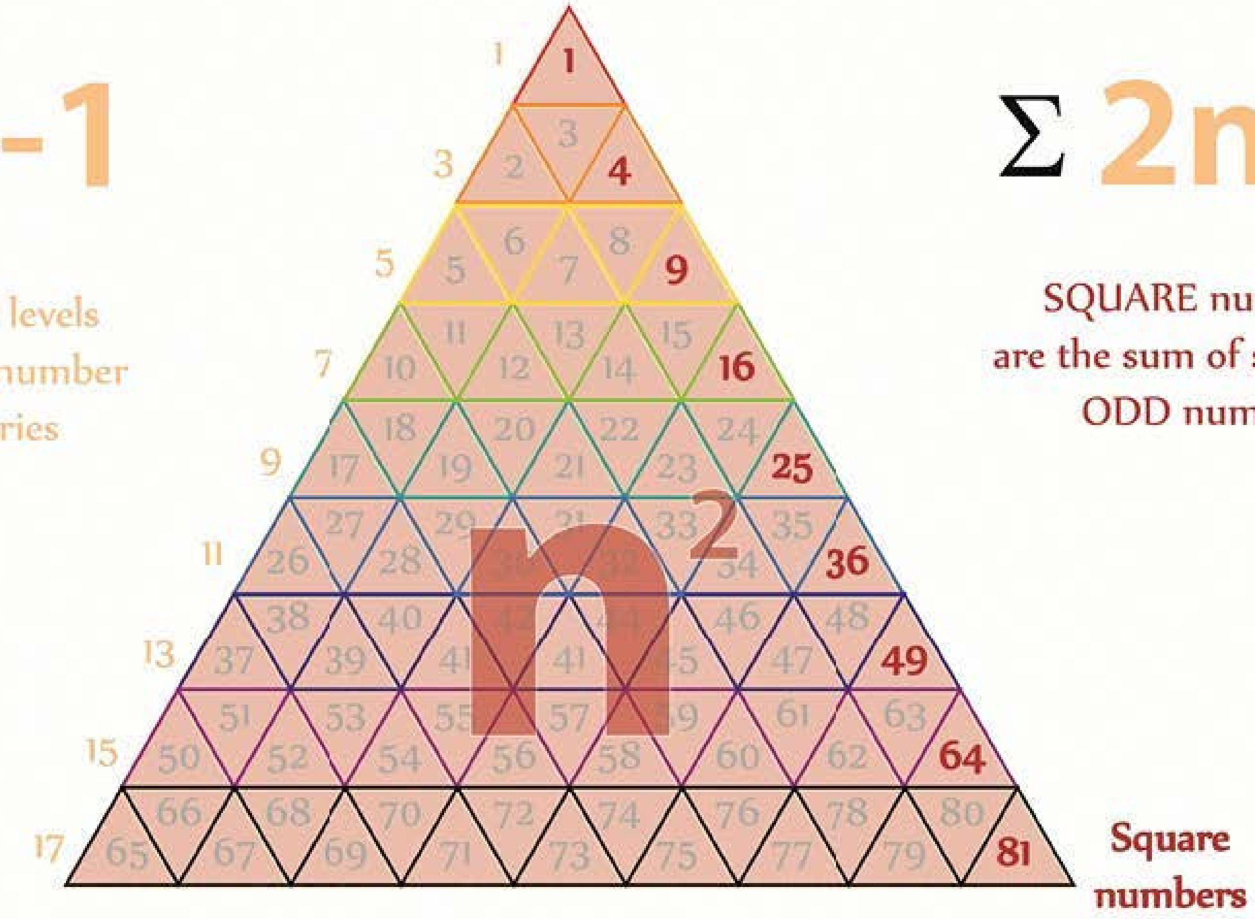
1 | 1
3 | 2 3 4
5 | 5 6 7 8 9
7 | 10 11 12 13 14 15 16
9 | 17 18 19 20 21 22 23 24 25
11 | 26 27 28 29 30 31 32 33 34 35 36
13 | 37 38 39 40 41 42 43 44 45 46 47 48 49
15 | 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
17 | 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81
n^2
Square numbers

Σ 2n-1

SQUARE numbers
are the sum of successive
ODD numbers

In Tetryonics SQUARE numbers are EQUILATERAL geometries

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Square roots

A square root of a number is a number that, when it is multiplied by itself (squared) , gives the first number again.

$-i$ and $+i$

Against Mathematical convention,
square roots of negative numbers
are real numbers

In Physics
every complex number
except 0 has 2 square roots.

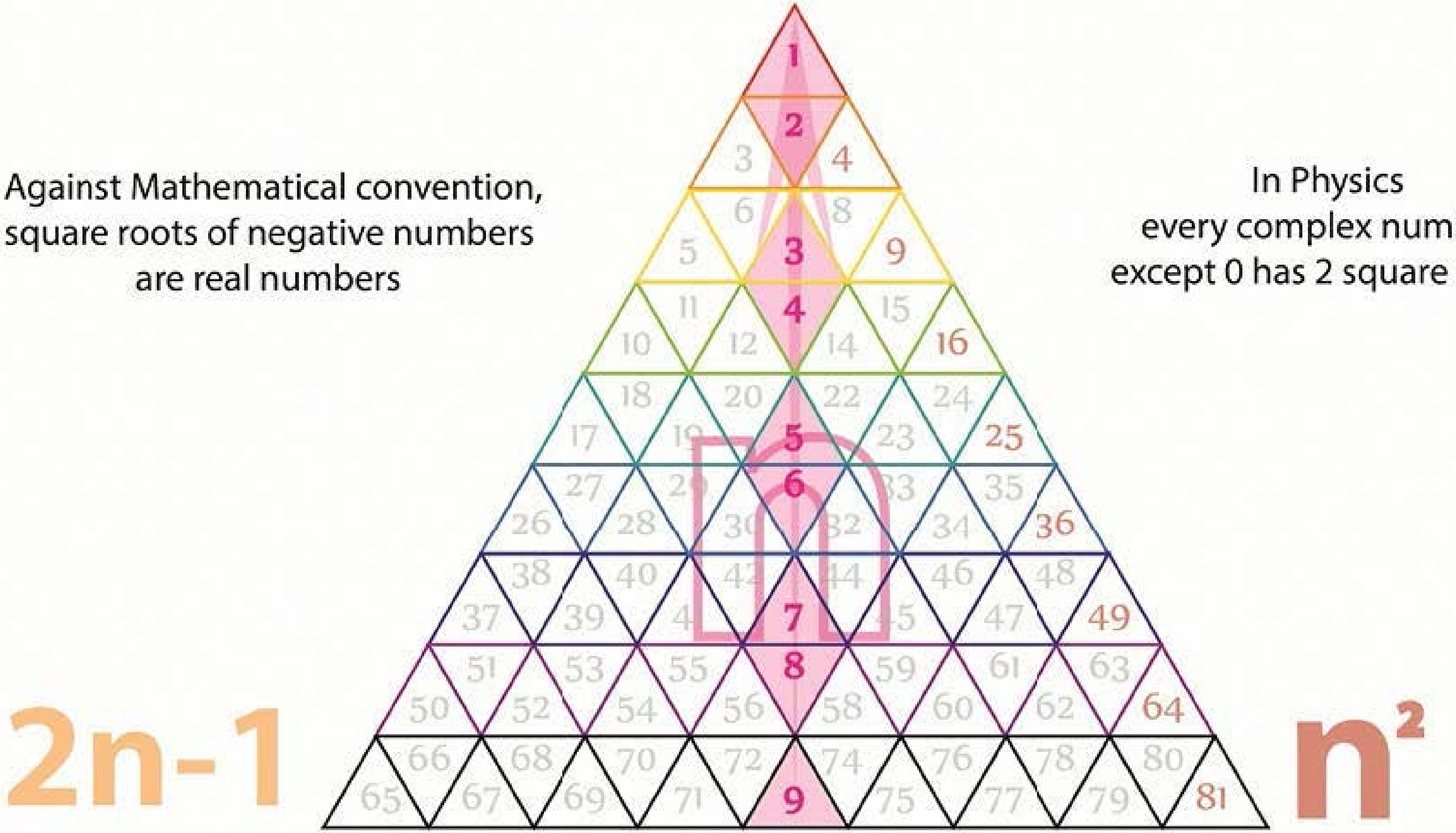
2n-1
1
3
2
4
5
6
3
8
9
10
11
12
4
14
15
16
17
18
19
20
5
22
23
24
25
26
27
28
29
30
6
32
33
34
35
36
37
38
39
40
41
42
7
44
45
46
47
48
49
50
51
52
53
54
55
56
8
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
9
74
75
76
77
78
79
80
81
n²

A whole number with a square root that is also a whole number is called a perfect square

Real Numbers

A real number is a value that represents a quantity along a continuous line.

The real numbers include all the rational numbers,

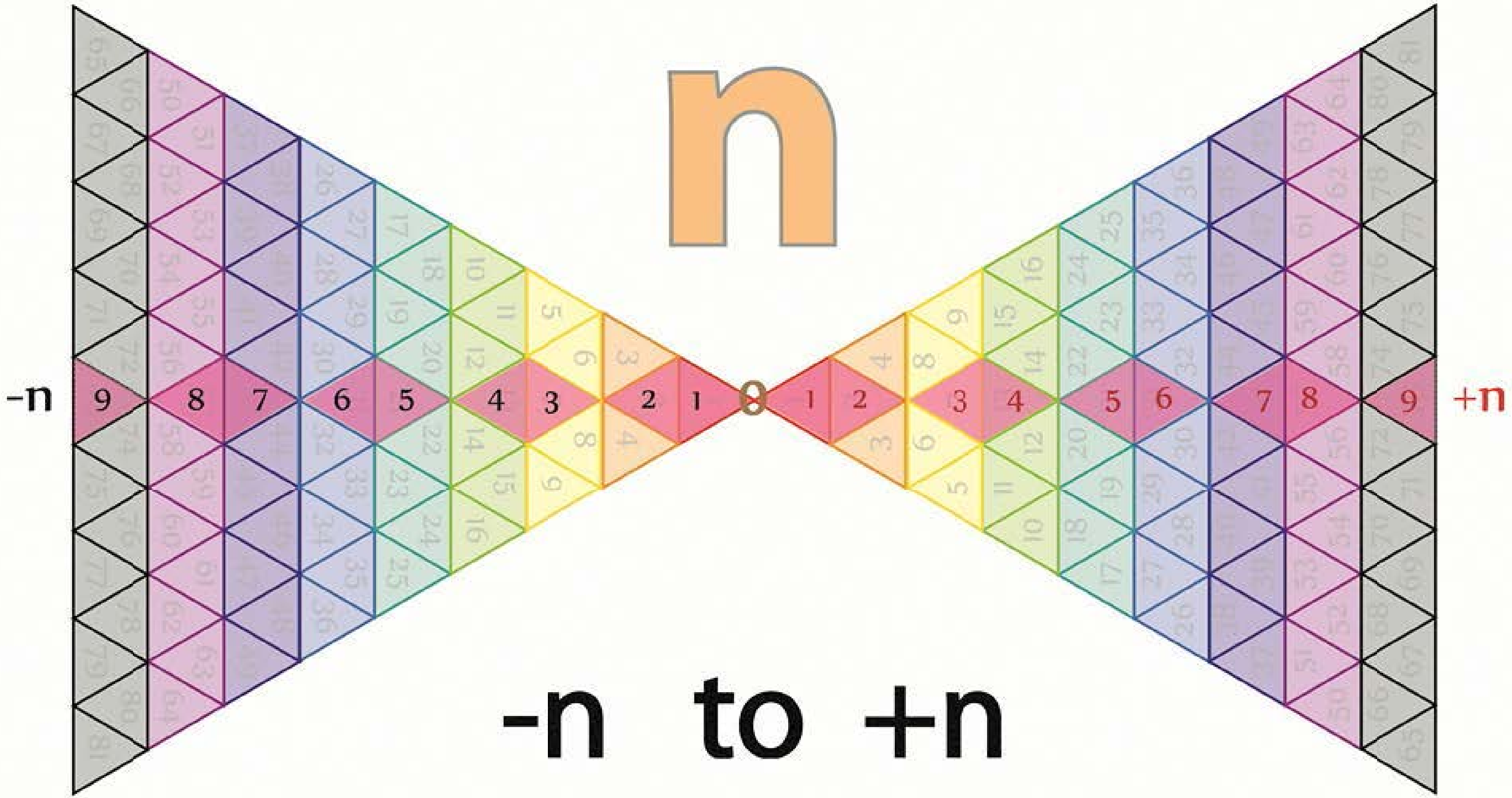

n
-n
+n
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
-n to +n

Irrational Numbers

An irrational number is defined to be any real number that cannot be written as a complete ratio of two integers

$+i$ and $-i$

Well known irrational & imanginary numbers in Math are π and i

π

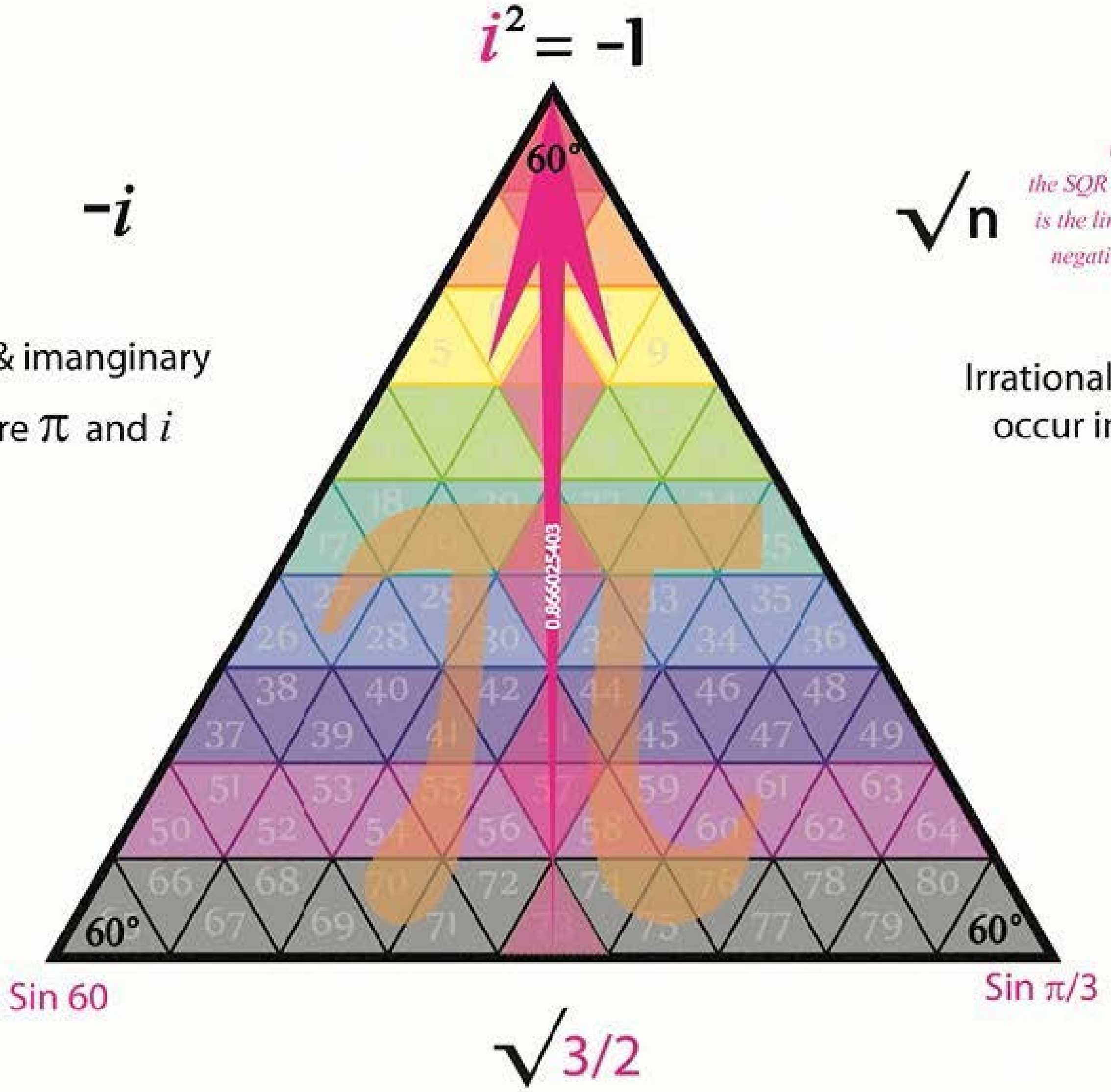
$i^2 = -1$
60°
60°
60°
0.866025403
26
27
28
30
33
34
35
36
37
38
39
40
42
45
46
47
48
49
50
51
52
53
56
59
60
61
62
63
64
66
67
68
69
71
72
77
78
79
80
Sin 60
Sin π/3
$\sqrt{3/2}$

$\sqrt{n}$ *in Tetryonics the SQR of a negative number is the linear momentum of a negative charge EM field* $\sqrt{-n}$

Irrational numbers often occur in mathematics

$\sqrt{-n}$

Tetryonic Colour Code

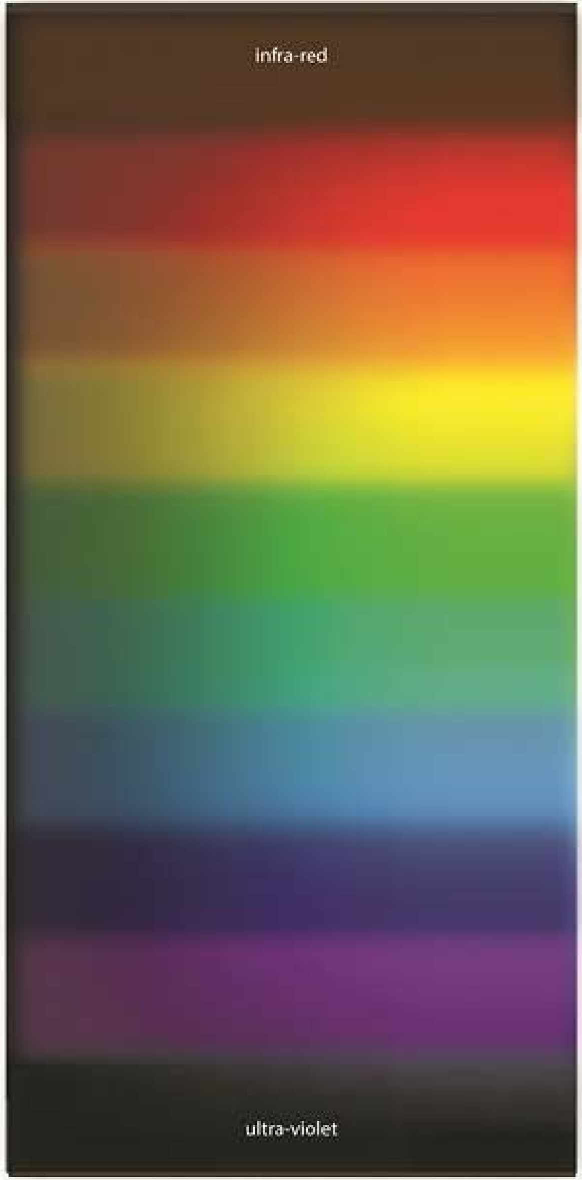
infra-red
ultra-violet

0	Brown
1	Red
2	Orange
3	Yellow
4	Green
5	Aqua
6	Blue
7	Indigo
8	Violet
9	Black

A colour code is used to indicate the varying quantum levels of the numerous forms of mass-ENERGY-Matter and serves to illustrate relationships between various Physical properties.

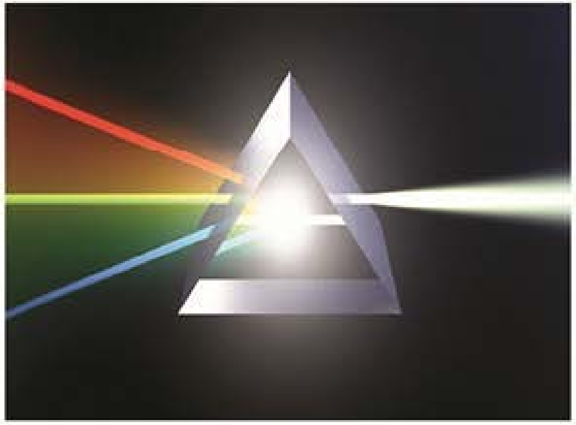

Tetryonics uses a colour code that is based on the spectral colours of dispersed White Light

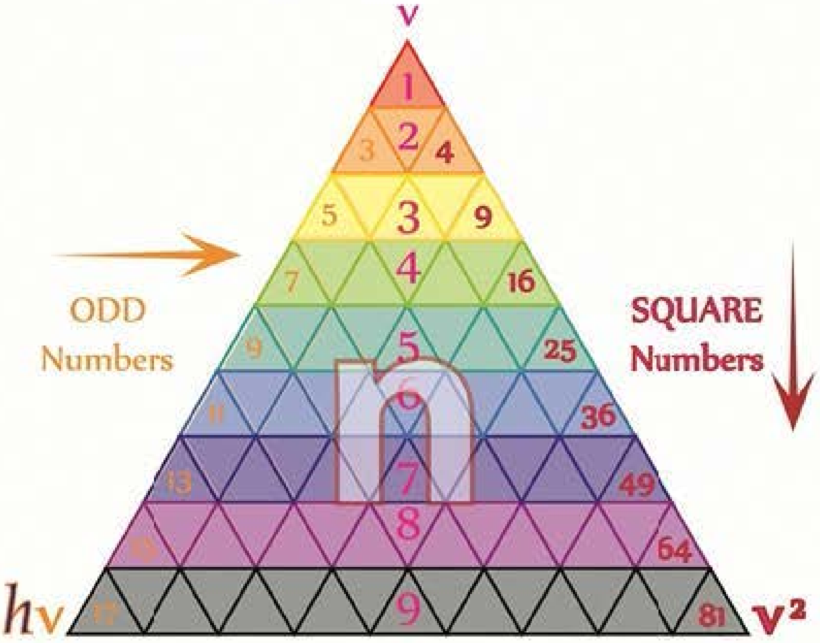
v
1
2
3
4
5
6
7
8
9
3
5
7
9
11
13
15
17
4
9
16
25
36
49
64
81
n
ODD Numbers
SQUARE Numbers
hv
v²

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Free Space

A contiguous volume or area
of any regular geometry
that is free, available, or unoccupied

$$E = 0$$

in any form

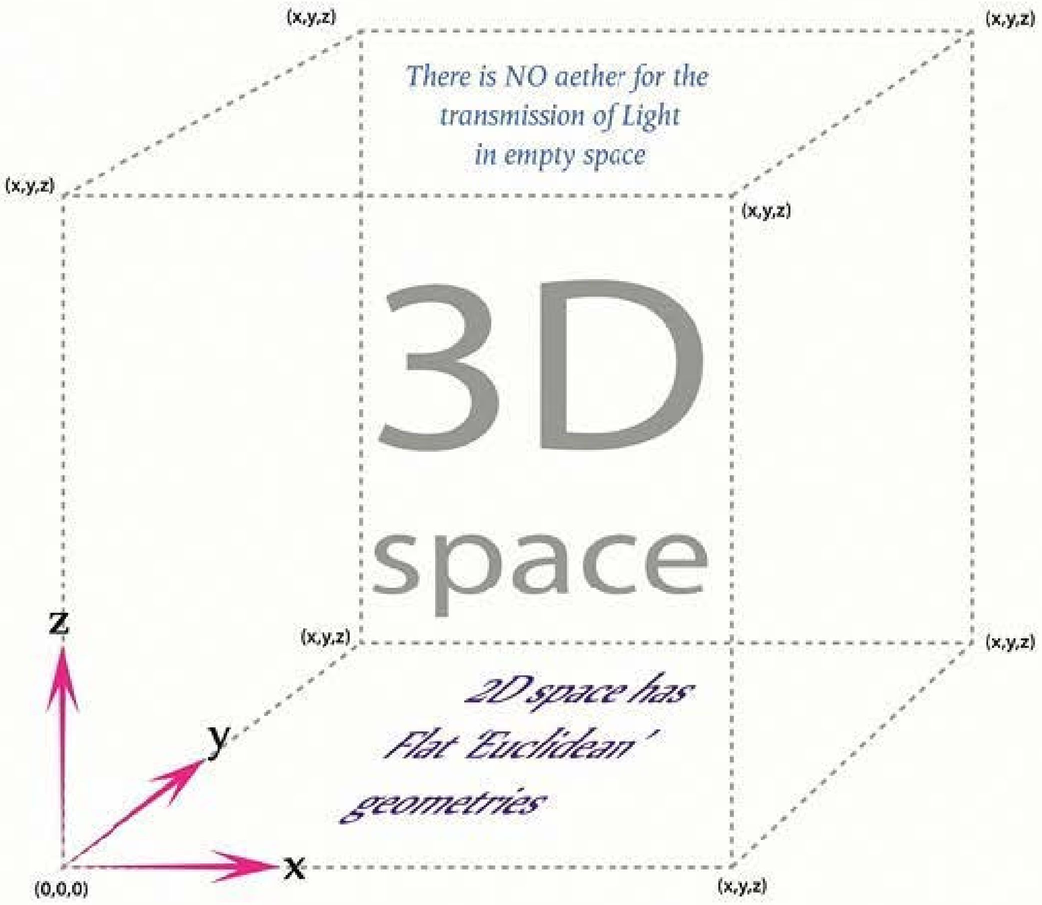

There is NO aether for the transmission of Light in empty space

2D space has Flat Euclidean' geometries

A Spatial region
is defined so as to
measure the physics
of mass-ENERGY-Matter
within its confines

Energy moves through Space
in various forms:
radiant energies, Matter etc

Space can be
Cubic, Spherical or
Tetrahedral as defined by
the spatial co-ordinates
used to define the region

Empty Space is defined as a topology whose volume is devoid of Energy

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Space-Time co-ordinates

The linear vector of divergent Energy forms various co-ordinate systems based on its vector directions per unit of Time

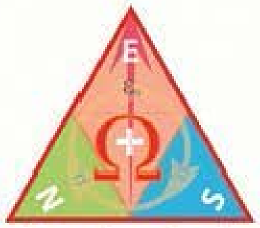

Charge radiates unilaterally in line with its vector linear momentum

Vector forces

Euclidean planar space-time

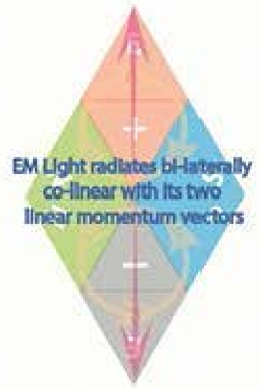

EM Light radiates bi-laterally co-linear with its two linear momentum vectors

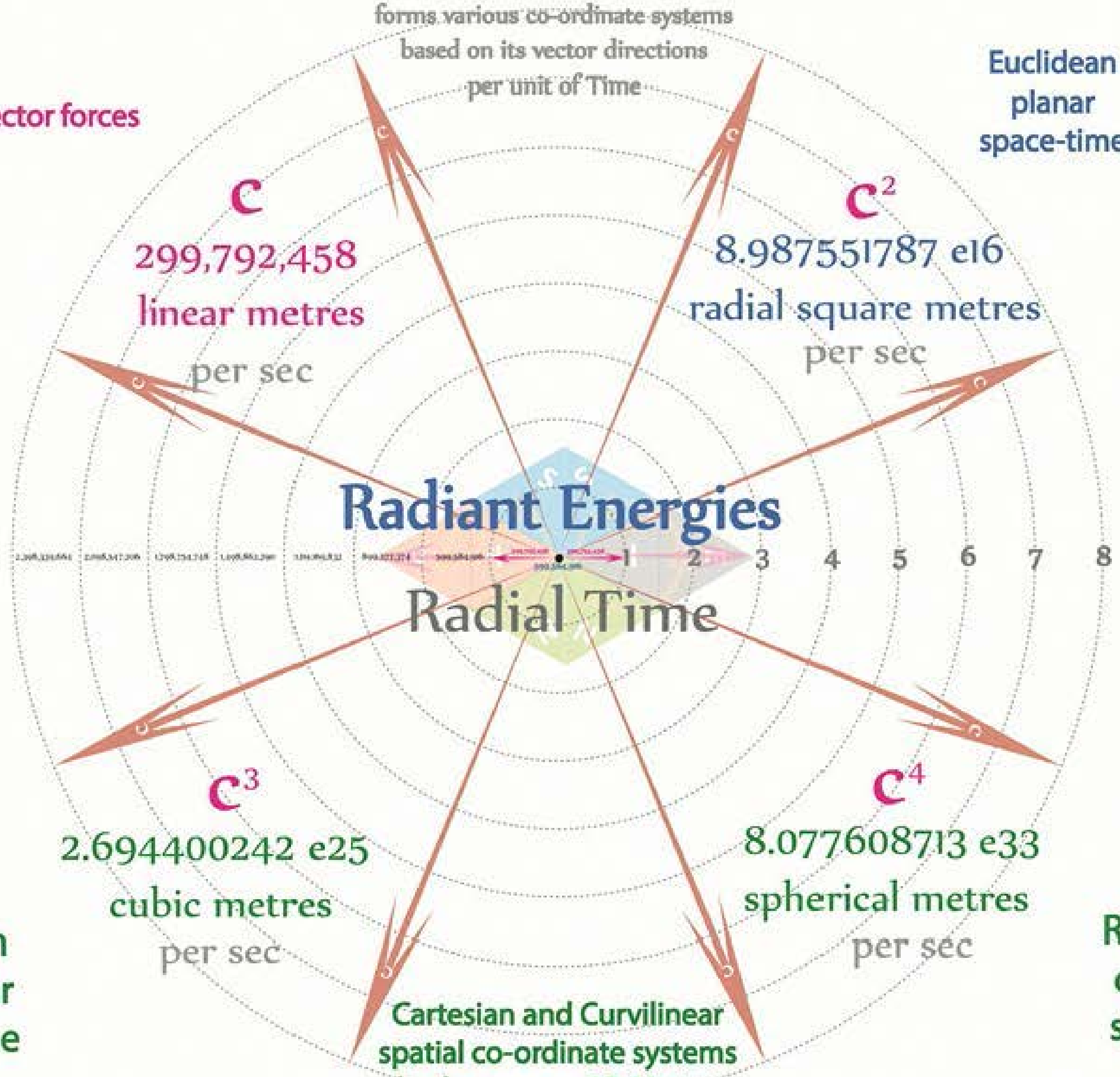

c

299,792,458 linear metres per sec

c^2

8.987551787 e16 radial square metres per sec

c^3

2.694400242 e25 cubic metres per sec

c^4

8.077608713 e33 spherical metres per sec

Time in Physics is a measure of how long it takes for light to travel 299,792,458 metres from its source in a vacuum

$$\frac{\text{metre}}{299{,}792{,}458\ \text{sec}}$$

A metre in Physics is the distance light travels in 1/ 299,792,458 of a second from its source

$$\frac{299{,}792{,}458\ \text{m}}{\text{second}}$$

Cartesian rectilinear space time

Cartesian and Curvilinear spatial co-ordinate systems both measure 3D Matter

Riemannian curvilinear space-time

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Spatial geometries

based on the vector speed of Light
form distinct spatial co-ordinate systems
for the measurement of physics

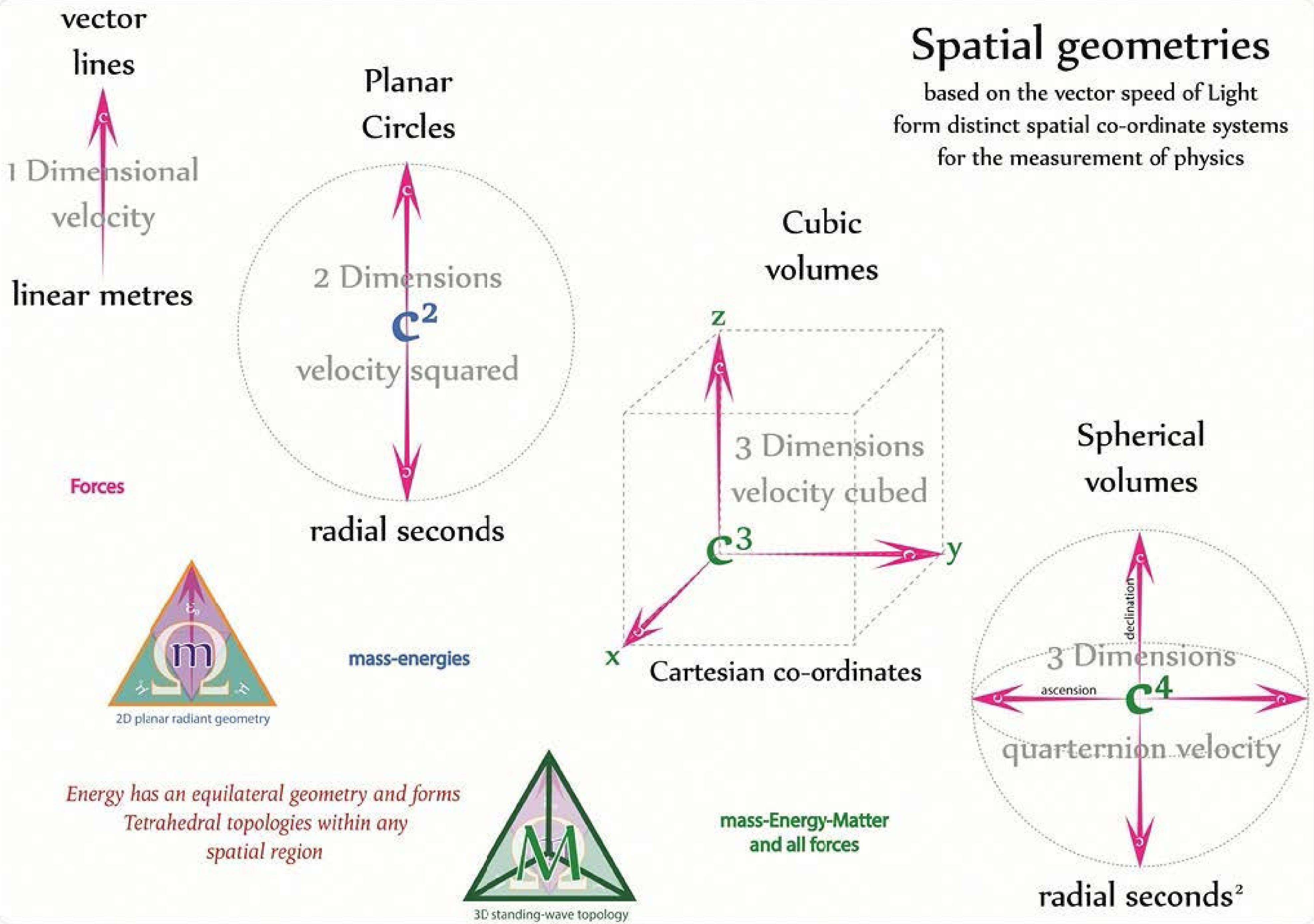

vector lines

1 Dimensional velocity

linear metres

Planar Circles

2 Dimensions

c^2

velocity squared

radial seconds

Cubic volumes

3 Dimensions

velocity cubed

c^3

Cartesian co-ordinates

Spherical volumes

3 Dimensions

c^4

quarternion velocity

radial seconds^2

Forces

mass-energies

2D planar radiant geometry

Energy has an equilateral geometry and forms
Tetrahedral topologies within any
spatial region

3D standing-wave topology

mass-Energy-Matter
and all forces

c is the natural velocity of light

Energy has a 2D
equilateral geometry
[Euclidian]

Time - as a measure
of divergent energies
has a radial geometry

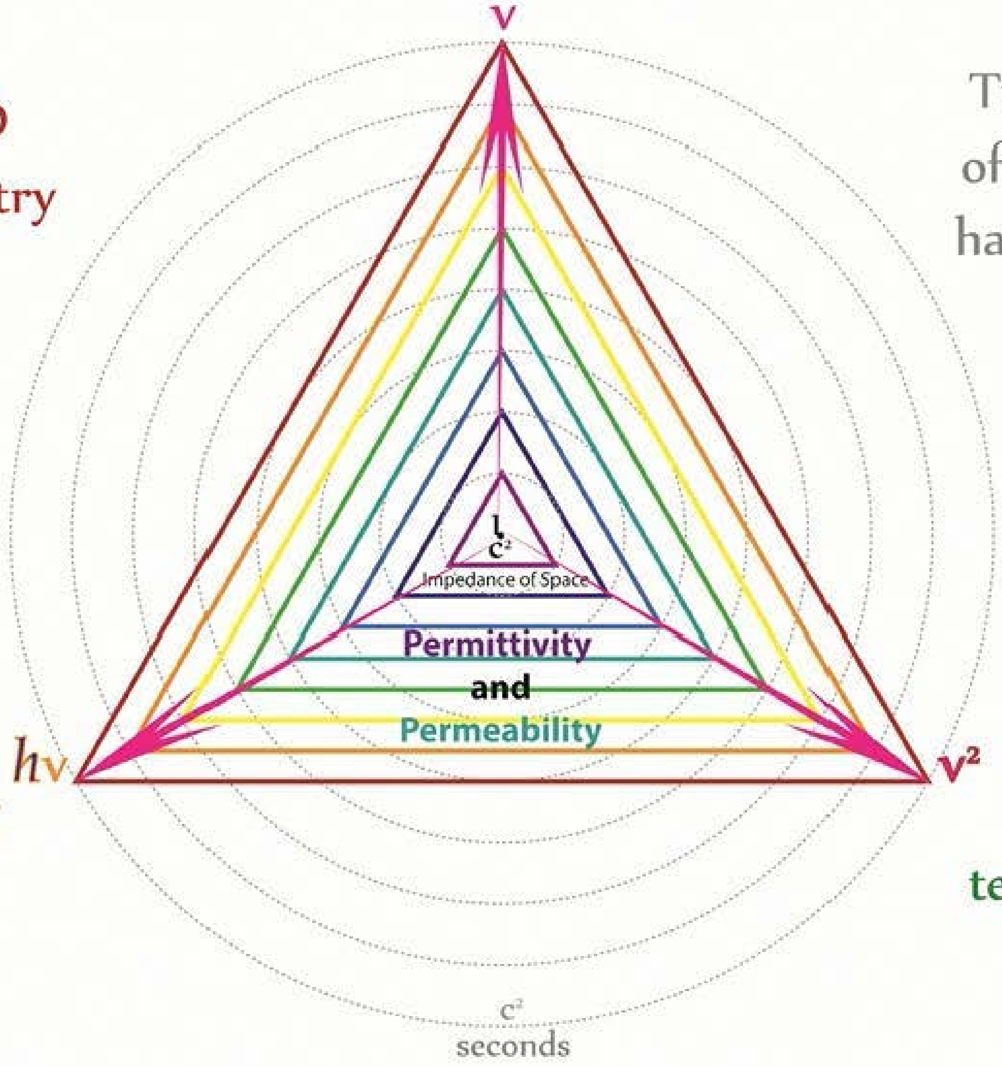
v
$\frac{1}{c^2}$
Impedance of Space
Permittivity
and
Permeability
hv
v²
c²
seconds

Equilateral geometry
is the inverse of
radial geometry

3D Matter has a
tetrahedral mass-energy
topology

The scalar spatial geometry of Energy

Velocity

Velocity is the measurement of the rate and direction of change in the position of an object.

It is a vector physical quantity; both magnitude and direction are required to define it.

The absolute scalar value (magnitude) of velocity is speed, a quantity that is measured in metres per second (m/s or ms–1) when using the SI (metric) system.

$$\frac{m}{s}$$

Speed is the scalar value of the
Distance traveled per unit of TIme

$$\bar{\mathbf{v}} = \frac{\Delta x}{\Delta t}.$$

Velocity is the vector value of the
Distance traveled per unit of Time

$$\frac{\overrightarrow{m}}{s}$$

v Velocity $\frac{m}{s}$

sec
c^2

is a 2D RADIAL
SPACE-TIME
co-ordinate system

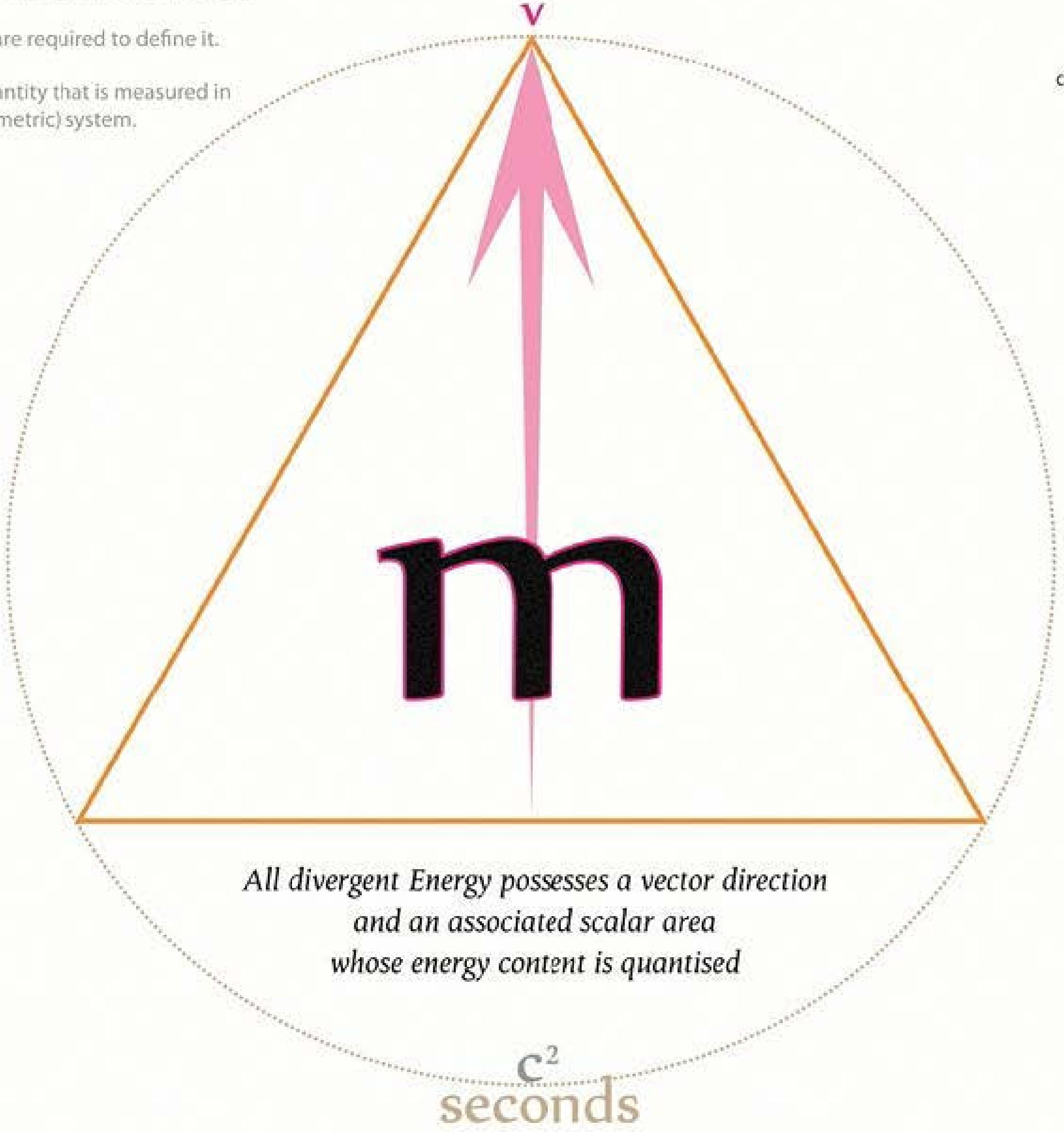

*All divergent Energy possesses a vector direction
and an associated scalar area
whose energy content is quantised*

Acceleration

is a 3D SPHERICAL
SPACE-TIME
co-ordinate system

a acceleration $\frac{m}{s^2}$

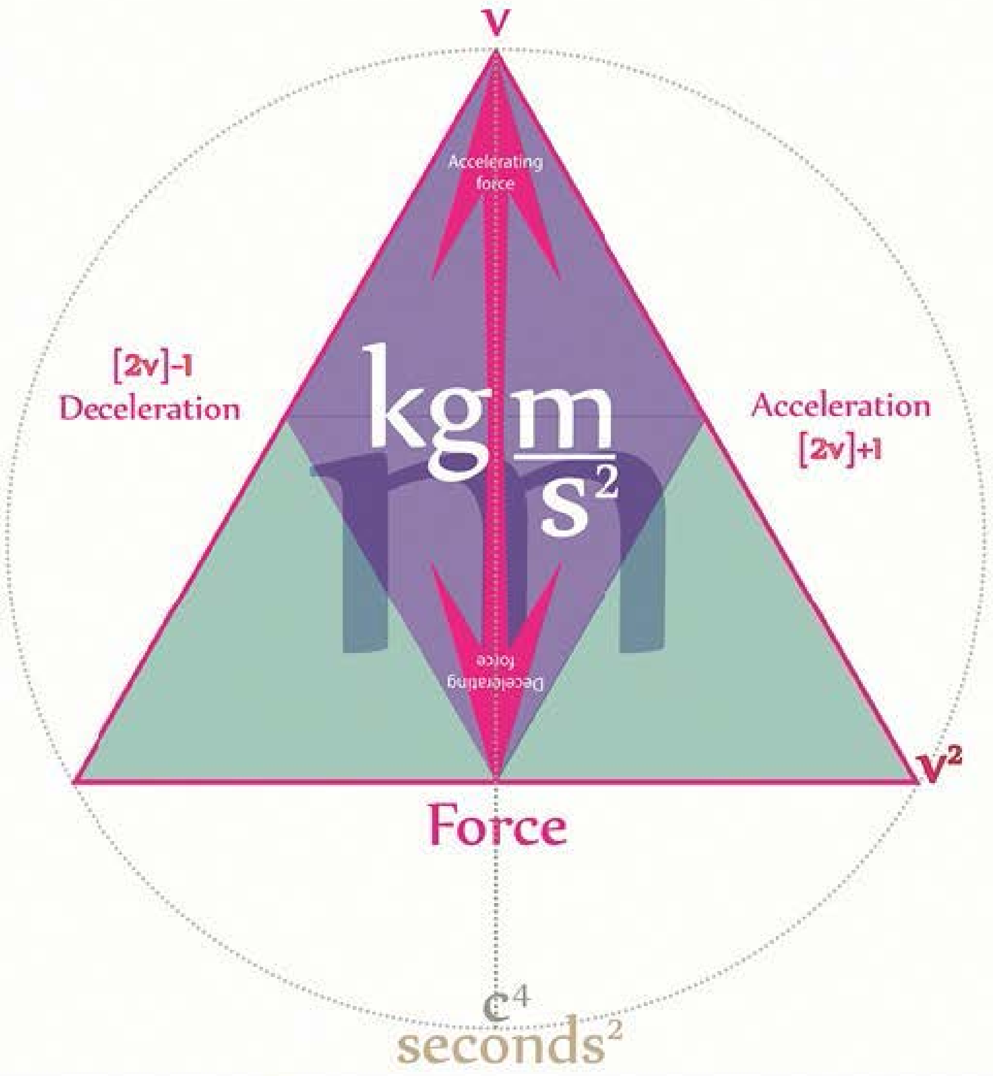
v
Accelerating force
[2v]-1
Deceleration
Acceleration
[2v]+1
$kg\frac{m}{s^2}$
m
Decelerating force
v^2
Force
c^4
$seconds^2$

In physics, acceleration is the rate of change of velocity [dv] over time [dt]

In one dimension, acceleration is the rate at which something speeds up or slows down.

However, since velocity is a vector, acceleration describes the rate of change of both the magnitude and the direction of velocity.

Acceleration has the dimensions [Length]/[Time Squared]
In SI units, acceleration is measured in meters per second squared (m/s^2).

$$a = \frac{\Delta y}{\Delta x} = \frac{\Delta v}{\Delta t}.$$

In classical mechanics, for a body with constant mass,
the acceleration of the body is proportional to the net force acting on it
(Newton's second law)

$$F=ma \longrightarrow a=F/m$$

Force

$$kg\frac{m}{s^2}$$

Additionally, for a mass with constant velocity,
(ie in an inertial frame)
the energy of motion is expressed as its momentum
(acceleration causes changes in Energy-momentum)

$$p = kg\frac{m}{s}$$

Quantised Angular momentum

As it is a physical [equilateral] geometry QAM is conservative in any system where there are no external Forces and serves as the foundational geometric source for all the conservation laws of physics

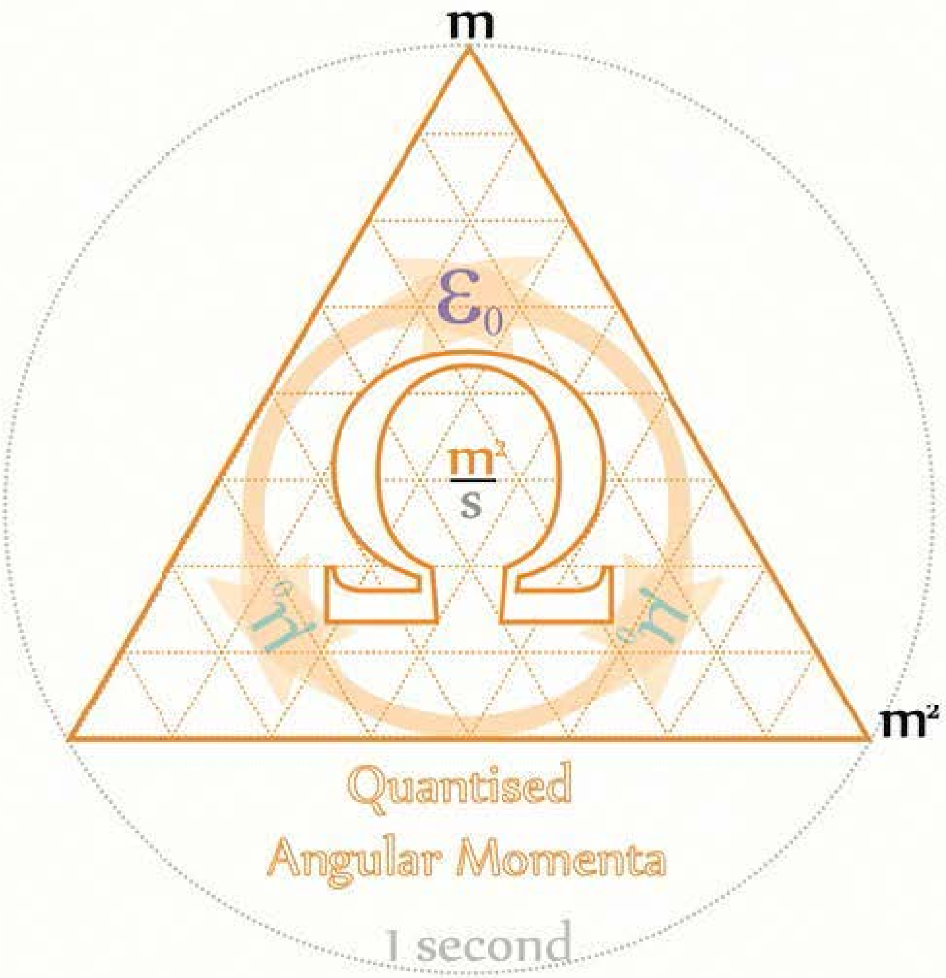
m
ε_0
Ω
$\frac{m^2}{s}$
μ_0
μ_0
m^2
Quantised
Angular Momenta
1 second

Conservation of Quantised Angular momenta

In QFT, angular momentum is is considered to be the rotational analog of linear momentum, in Tetryonics it is revealed to be the equilateral geometry of mass-energy within any defined spatial co-ordinate system

A major re-definition of
quantised angular momenta
in physics is revealed

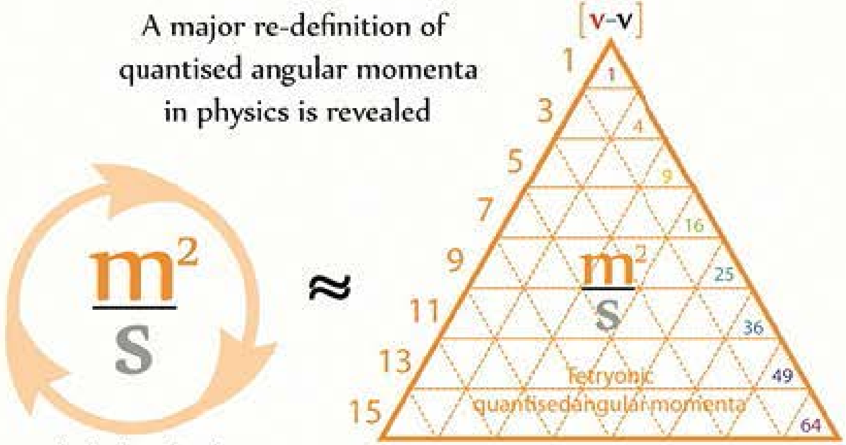
$\frac{m^2}{s}$
≈
[v-v]
1
3
5
7
9
11
13
15
1
4
9
16
25
36
49
64
$\frac{m^2}{s}$
Tetryonic
quantised angular momenta

classical rotational
angular momenta

Tetryonic quantum mechanics

In quantum mechanics, angular momenta is quantised – that is, it cannot vary continuously, but only in ODD number "quantum steps" between the allowed SQUARE nuclear Energy levels

In physics, angular momentum, moment of momentum,
or rotational momentum is a conserved vector quantity
that can be used to describe the overall state of a physical system.

When applied to specific mass-energy-Matter systems
QAM reveals the true quantum geometry and
nature of Energy in our universe

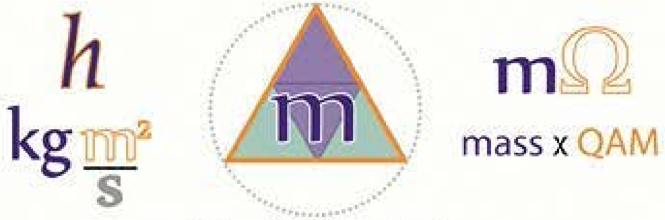
h
$kg\,\frac{m^2}{s}$
m
$m\Omega$
mass x QAM

Planck's Constant

Normally viewed as an expression of rotational momentum
Quantised Angular Momentum [QAM] is in fact a result of
the equilateral geometric quantization of mass-energy

mass - Energy geometry

Newton developed his
Laws using Force
$p = mv$
(linear momentum)

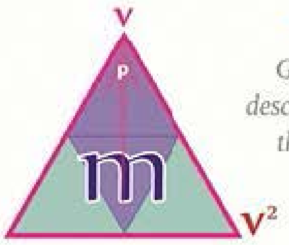

Gottfried Leibniz first described Scalar Energy as the square of velocity

Planck developed his Heat
Law using quantised mass
$h = m\Omega$
(Planck Constant)

Planck's equation for heat energy describes transverse masses [Bosons]

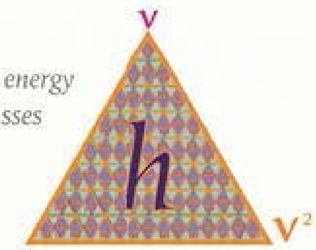

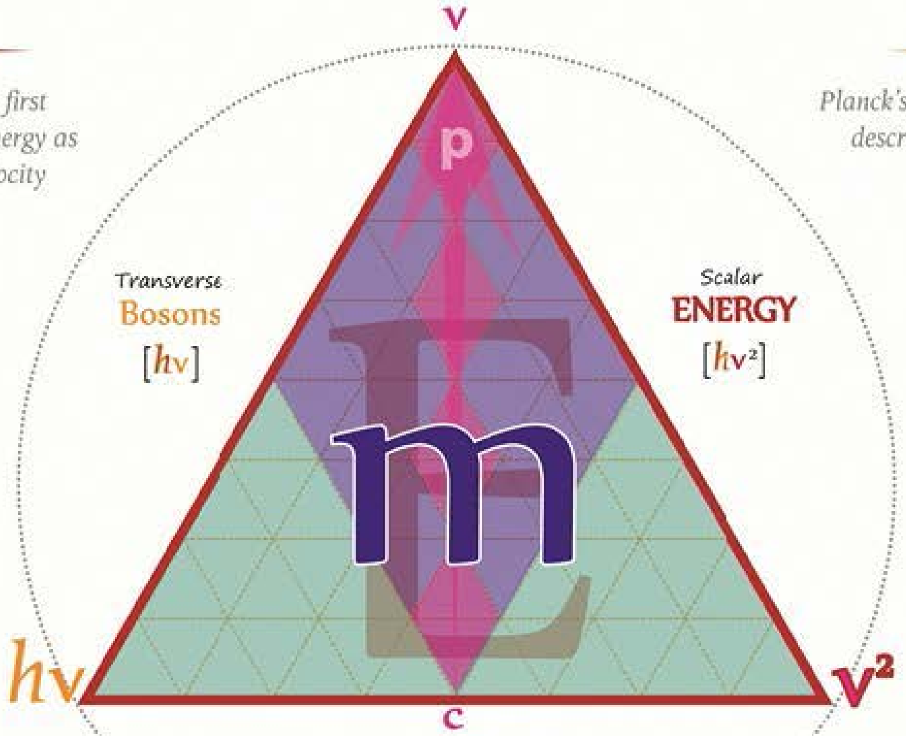

Transverse
Bosons
[hv]

Scalar
ENERGY
[hv^2]

$E = mv^2$

Leibnitz mass-energy equivalence

$E = nhv$

Planck mass-energy equivalence

mass velocity squared

quantised mass per second

$$mv^2 = E = hv^2$$

Leibniz-Planck mass-Energy equivalence

$kg\frac{m^2}{s^2}$

Planck quanta per second

$\left[kg\frac{m^2}{s}\ \frac{1}{s}\right]$

scalar energies can be related to velocity-momenta through mass geometries

mv^2	*scalar* Leibniz-Newton mass-Energy equivalence	$m\Omega v^2$	*quantised* Tetryonic-Planck mass-Energy equivalence	hv^2

mass-Energy Forms

Scalar/Linear forms

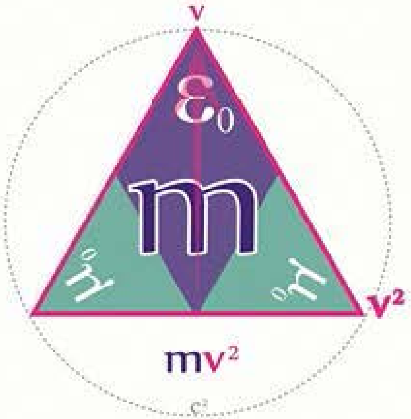

mass x velocity squared

$$kg.\left[\frac{m}{s}\right]^2$$

Energy momentum

Leibniz [and Newton] showed that the Energy of a system can be viewed as a product of its mass x velocity squared or [equally as linear momentum squared], forever linking Energy to velocity through the scalar property of mass

$$mv^2 = E = p^2$$

Energy is the ability to do work in varying forms such as potential, kinetic, & mechanical energies, work, heat, and chemical or electrical energies.

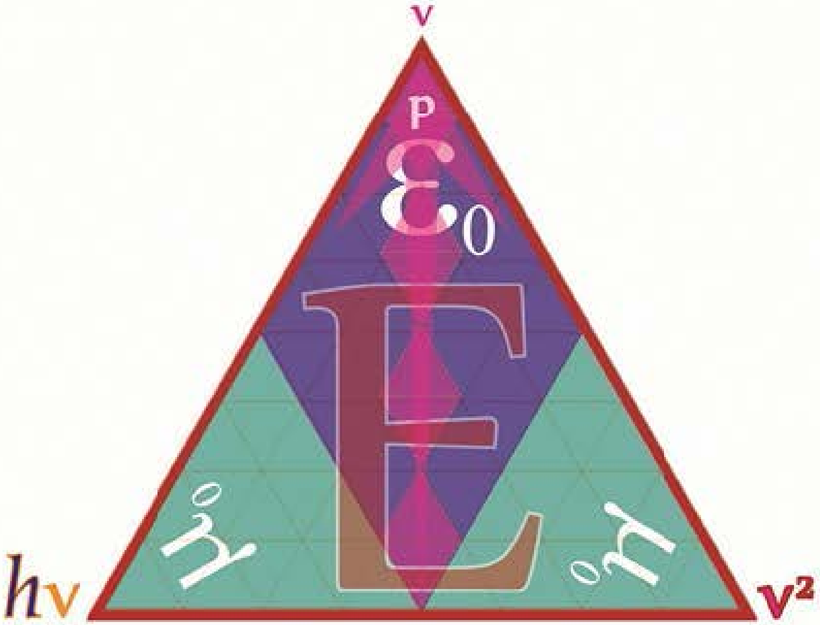

$$\boxed{mv^2 = E = hv^2}$$

The total energy contained in an object is identified with its EM mass, and Energy (like mass), cannot be created or destroyed

Tetryonic reveals mass to be a scalar measurement of quantised [equilateral] energy per unit of Time

$$m[\Omega]v^2$$

Energy is subject to the law of conservation

Quantised form

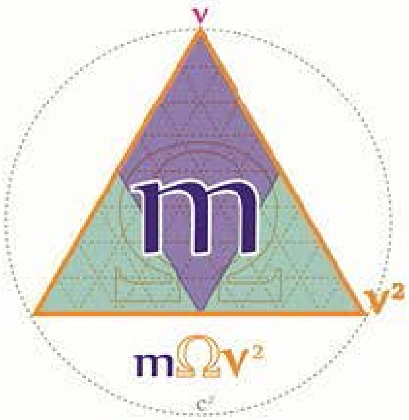

Planck quanta per second

$$\left[kg.\frac{m^2}{s}\right].s^{-1}$$

mass-Energy quanta

Max Planck reveealed that energy was not continuous, it was quantized – only certain energies are allowed. Continuous energy is a scalar propertyo of mass-energy and its quantisation is the result of its equilateral geometry

$$E = hv^2$$

In quantum mechanics energy is defined in terms of the energy operator as a time derivative of the wave function

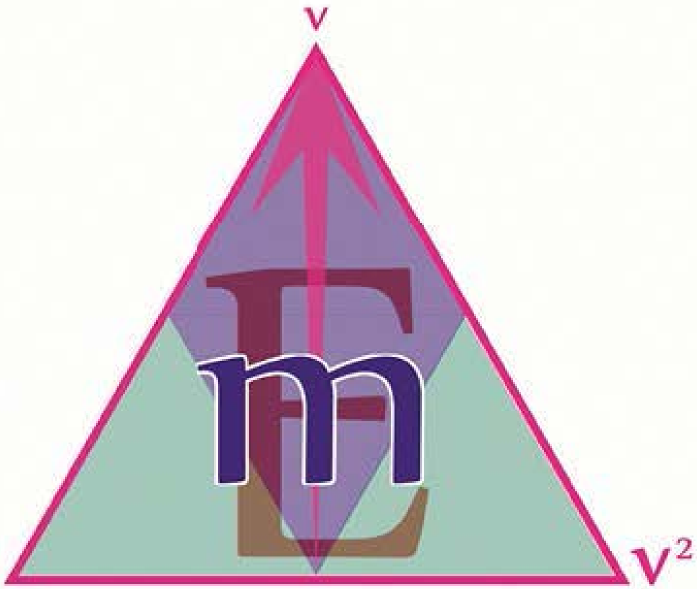

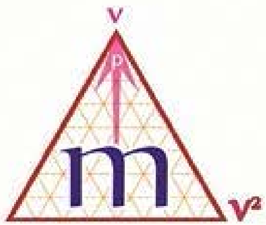

Planck quanta

$$\left[[m\Omega v]^2 \right]$$

mass velocity

linear momentum squared

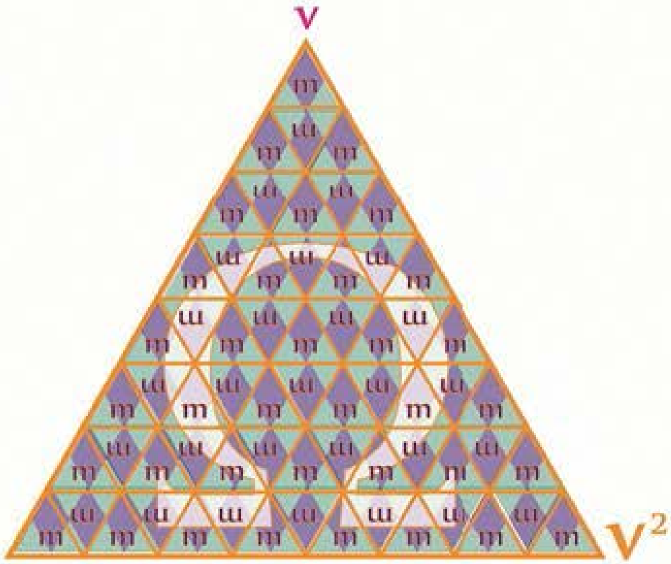

Energy is mass-velocity squared

Everything in our Universe results from the equilateral geometry of quantised mass-energies

Energy is Planck-quanta squared

$$E = mv^2$$

Quantised Energy

$$E = hv^2$$

scalar mass

$$kg$$

Planck quanta per second

$$\left[\left[kg\,\frac{m^2}{s} \right] \frac{1}{s} \right]$$

mass velocity squared

quantised mass

$$kg\,\frac{m^2}{s}$$

$$m = \frac{E}{v^2}$$

Scalar Energy

$$h = \frac{E}{v^2}$$

Note: There is a direct correspondence between Velocity and Planck quanta numbers
(ie as velocity varies, the energy quanta varies as well by the square of the linear change)

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p Momentum $kg\frac{m}{s}$

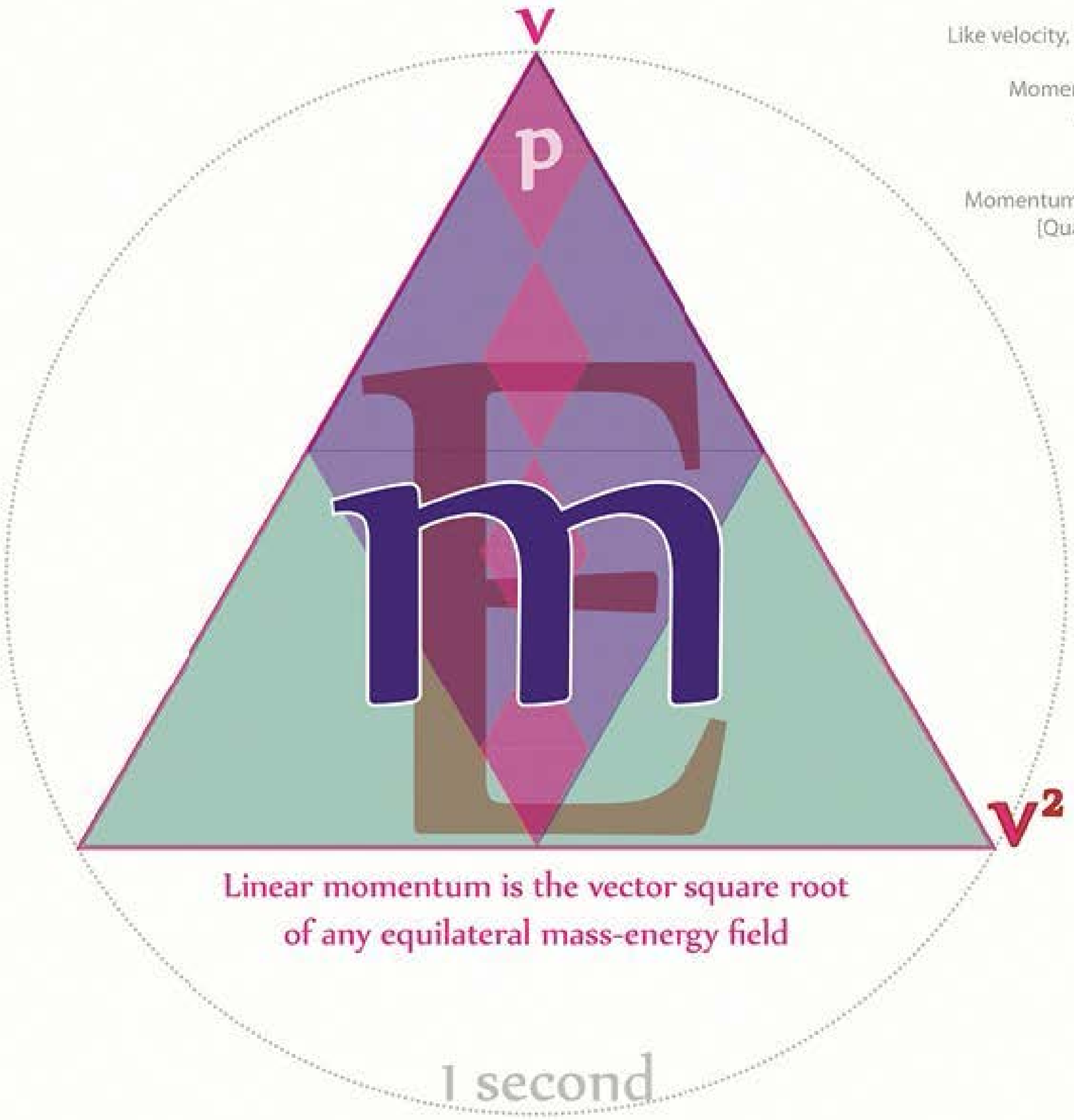

Linear momentum is the vector square root
of any equilateral mass-energy field

Linear Momentum

In classical mechanics, momentum (pl. momenta; SI unit kg·m/s, or, equivalently, N·s) is the product of the mass and velocity of an object (p).

Like velocity, momentum is a vector quantity, possessing a direction as well as a magnitude.

Momentum is a conserved quantity (law of conservation of linear momentum), meaning that if a closed system is not affected by external forces, its total momentum cannot change.

Momentum should be referred to in its specific forms to distinguish it in its various forms [Quantised Angular, Linear, Rotational and quantum/nuclear momentum]

$$\boxed{p = \frac{hv^2}{v} = mv}$$

Although originally expressed in Newton's Second Law, the conservation of momentum also holds in special relativity and, with appropriate definitions, a (generalized) momentum conservation law holds in electrodynamics, quantum mechanics, quantum field theory, and general relativity.

In relativistic mechanics, non-relativistic momentum is further multiplied by the Lorentz factor.

$$p^2 = E = mv^2$$

Energy can be expressed as
the square of linear momentum

$$kg\frac{m^2}{s^2}$$

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Ω

Just as Tetyonic geometry distingushes between angular momenta and linear momentum it also distingushes between linear momentum and the vector velocities it produces

p

Linear Momentum

$p = mv$

Velocity

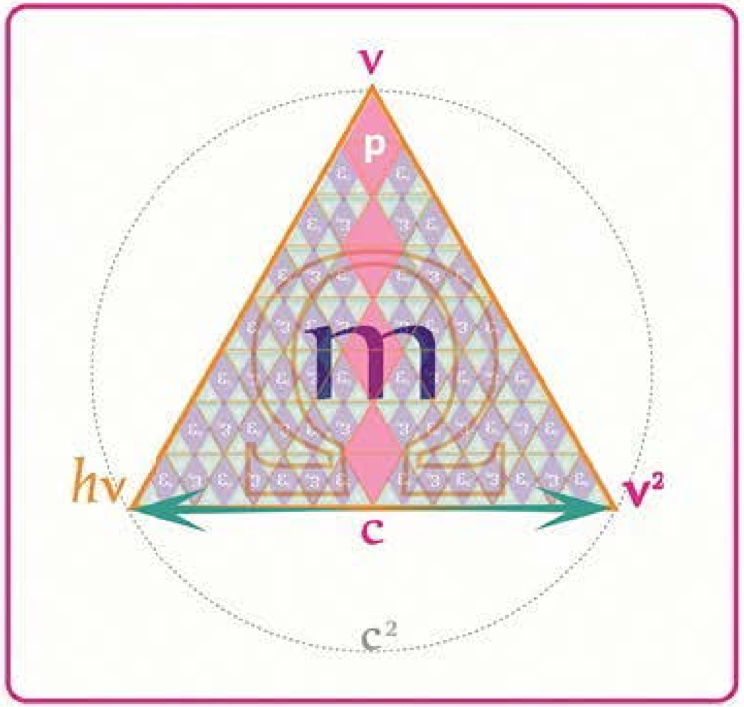

$E = pv$

$E = p^2$

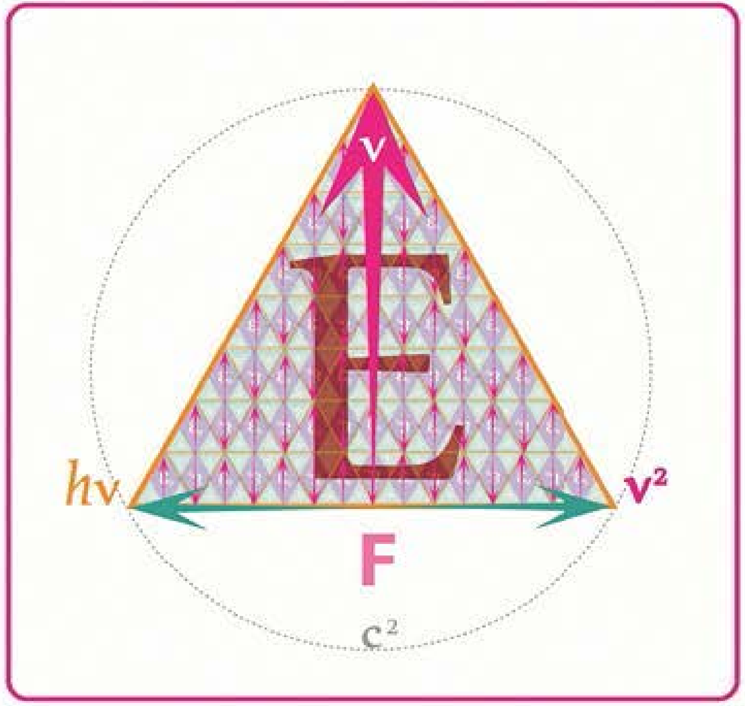

SCALAR square root

Scalars are quantities that are fully described by only their magnitude

$E = mv^2$

VECTOR square root

Vectors fully describe both the magnitude and direction.

p

linear momentum is a scalar component of all equilateral mass-energies that produce vector velocities

v

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Velocity-Quanta equivalence

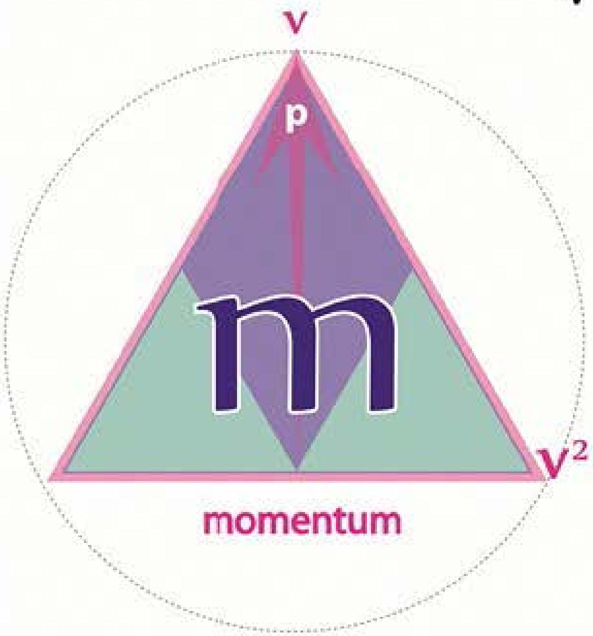

Classically, the Energy of massive bodies was determined using the Newtonian mass-velocity relationship

but most recently Quantum mechanics was developed utilising the Planck's quantised Energy relationship

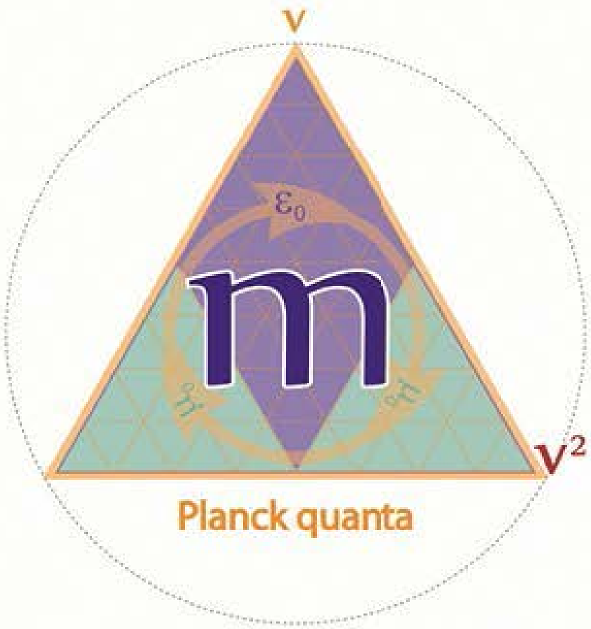

classical vector force

$$mv^2$$

mass

linear velocity

squared

$$kg\left[\frac{m}{s}\right]^2$$

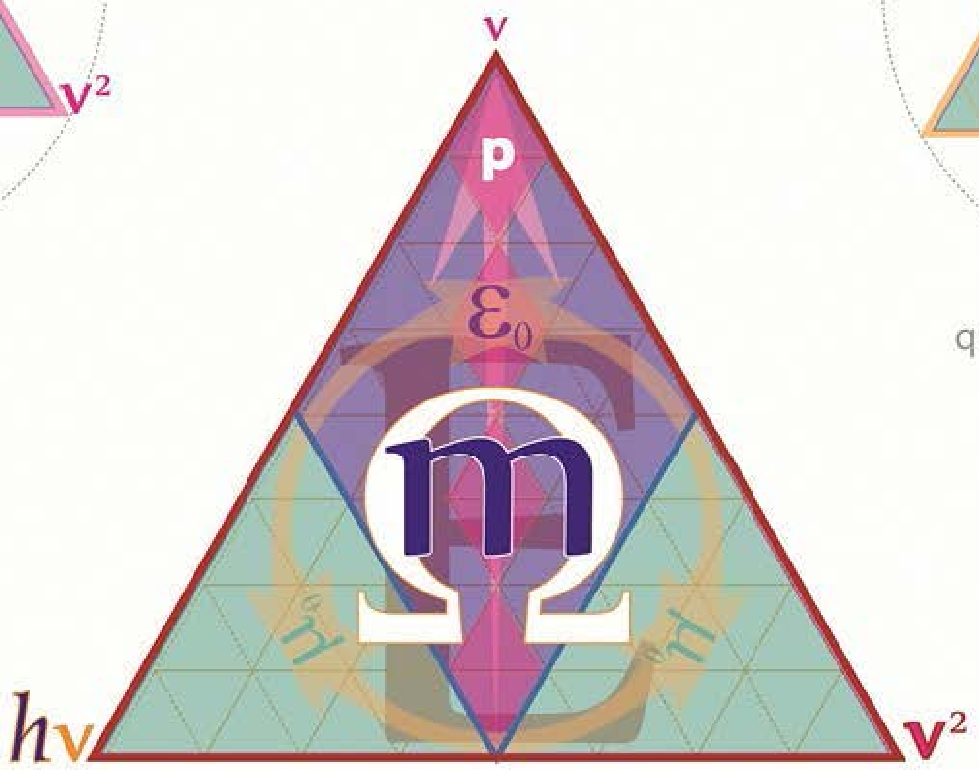

quantised energy momenta

$$hv^2$$

mass

angular momenta

per second

$$kg\left[\frac{m^2}{s}\frac{1}{s}\right]$$

The EM mass-Energy relationship can be revealed either by linear or angular momentum analysis

Energy-momentum relationship

The total number of Planck quanta [mass-angular momenta] in any physical system is directly related to the square of its linear momentum [mass-velocity]

$$h = \frac{E}{v^2}$$

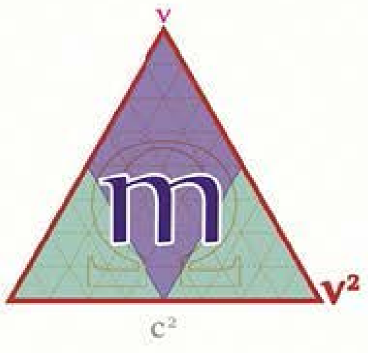

Quantised Energy-momentum

$$E = m\Omega v^2$$

Quantised Angular Momenta is an equilateral geometry

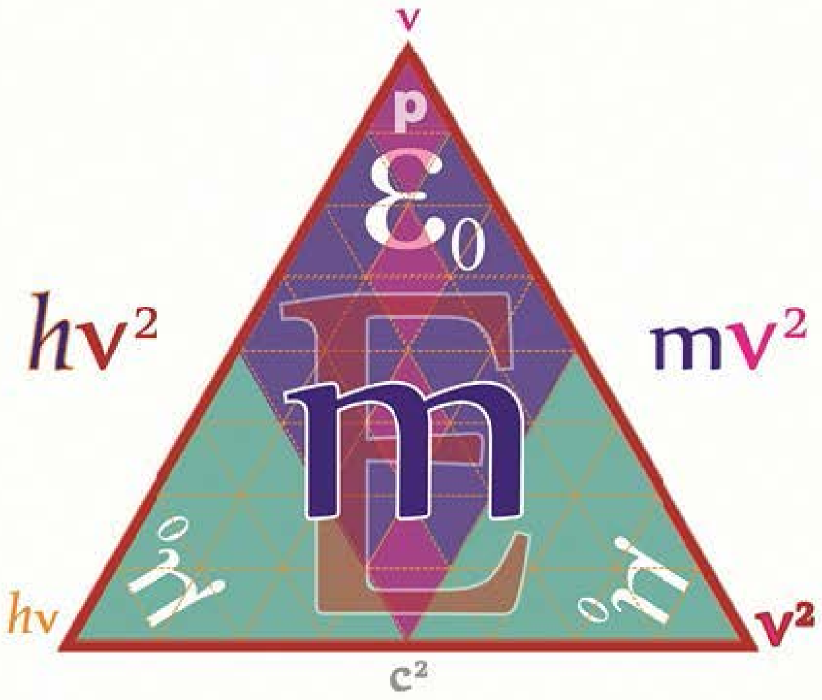

mass-energy momenta

The omega geometry of Energy produces the direct relationships between Planck's constant-quanta and mass-Energy-momentum of any spatio-temporal co-ordinate system

$$m\Omega v^2 = E = mv^2$$

mass is a derived physical property relating Energy momenta to Velocity

$$m = \frac{E}{v^2}$$

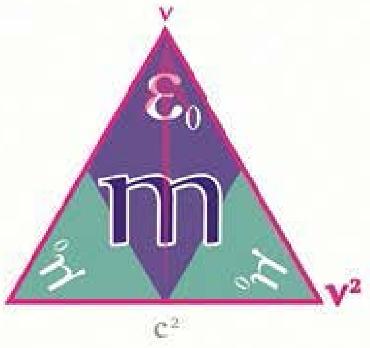

Linear Energy-momentum

$$E = pc$$

Linear momentum is a vector Force

CHARGE

Charge is a measure of mass.QAM/second
[the equilateral geometry of Energy]
that gives form to all physics

ElectroMagnetic Charge
is a quantum property
resulting from the equilateral
QAM geometry of mass-Energy

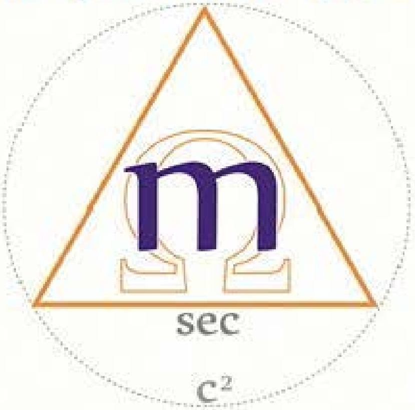

The two ElectroMagnetic charge
geometries possible can be modelled
by the flux of electrical energy
in ideal Inductive loops

It is a measure of the arrangment of Planck quanta
geometries/topologies within any specific
space-time co-ordinate system

q

Clockwise inductive
energy flux

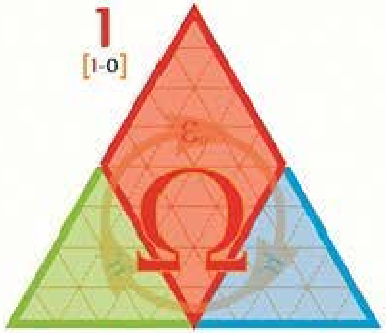

Positive charged
mass-energy momenta

$$\frac{hv}{c^2}$$

$$kg\,\frac{m^2}{s}\,\frac{s^2}{m^2}$$

$$kg.s$$

1.33518 e-20 s

Counter clockwise
energy flux

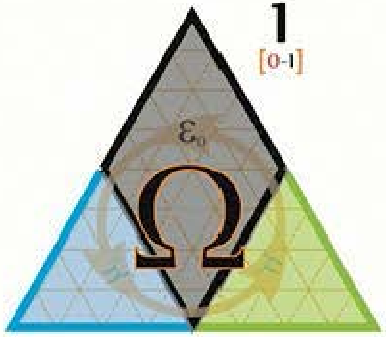

Negative charged
mass-energy momenta

q

Measuring charge geometries

Charge comes in two types, called Negative and Positive
which create the Law of Interaction (historically, the Law of Attraction)

q

quantised Charge

[v] [v]

Q

nett Charge

[v-v]

All charged masses seek equilibrium

Charge geometry is velocity invariant

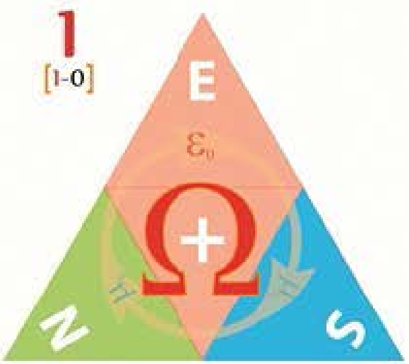

Clockwise Energy flux

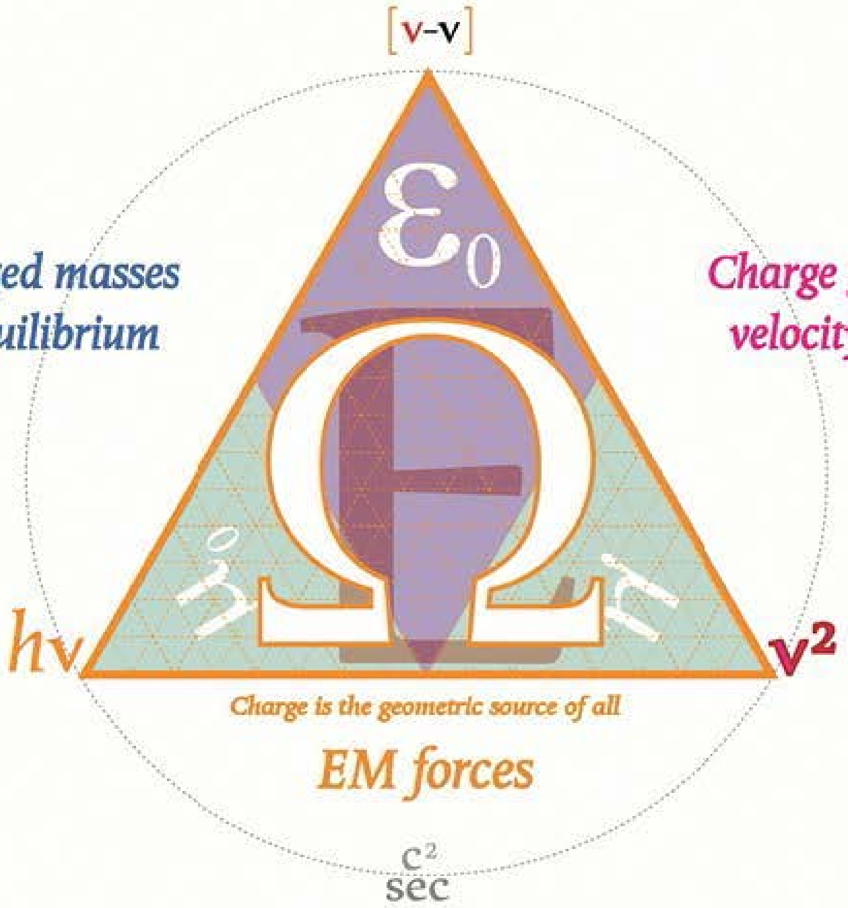

Charge is the geometric source of all

EM forces

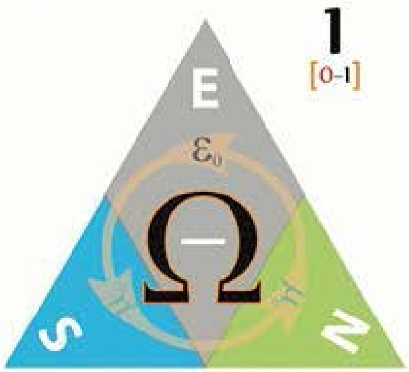

anti-Clockwise Energy flux

Historically defined as a physical property of mass-Matter that causes it to experience a force
charge is actually the result of the equilateral geometry of qantised mass angular momenta
which provides the physical mechanics of mass-ENERGY-Matter differentiation and interaction

The SI unit of quantity of charge is the Coulomb, C ≈ mass seconds ≈ kg.s which can also be expressed as Amp-seconds

EM Field Geometry

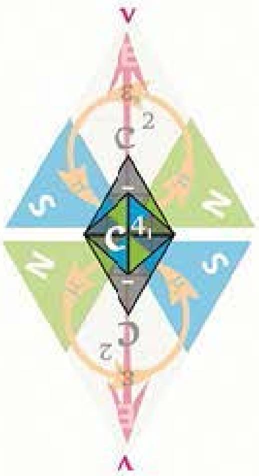
v
c²
S
N
c⁴
N
S
c²
v

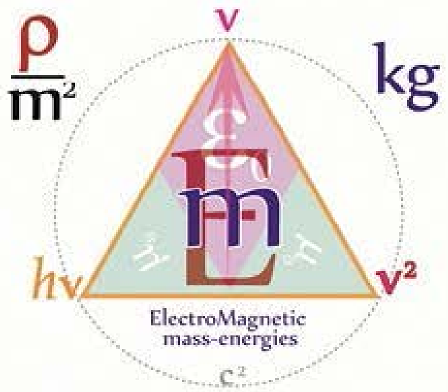
ρ/m²
v
kg
ε
m
E
hv
v²
ElectroMagnetic mass-energies
c²

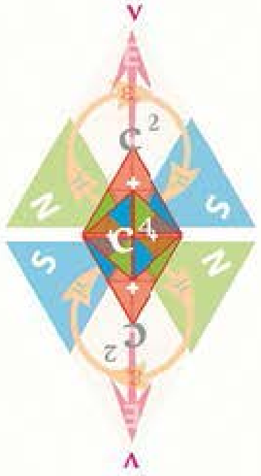
v
c²
N
S
c⁴
S
N
c²
v

mass-energies are 2D radiant EM field geometries

[299,792,458 m/s]

'c' forms a CONSTANT of proportionality
for different spatio-temporal co-ordinate systems
used to measure mass-ENERGY-Matter

All Matter are 3D EM standing wave topologies

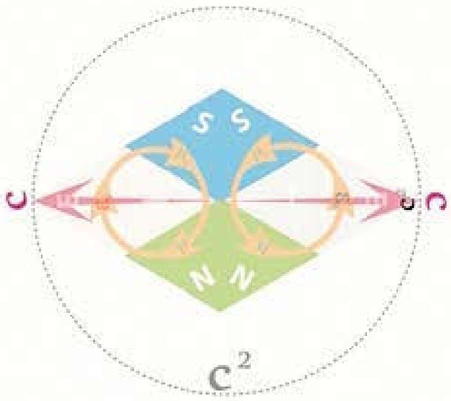

EM fields create
'interaction-at-a-distance'

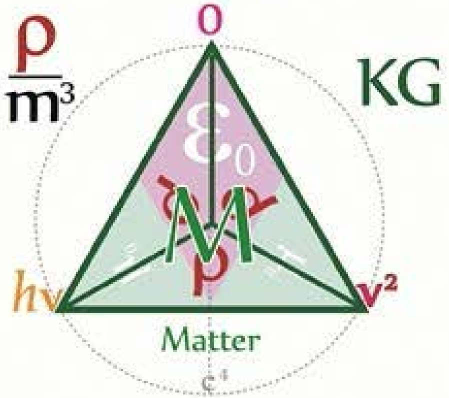
ρ/m³
0
KG
ε0
M
ρ
hv
v²
Matter
c⁴

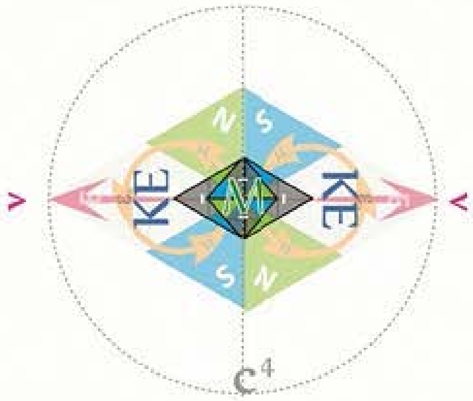
v
KE
N S
M
KE
S N
v
c⁴

Electrostatic Matter has
opposing 2D KEM fields

Energy quantisation

All mass-Energy-Matter can only have certain integer Energy-momenta,
[mass-Energy in all its forms is QUANTISED]

q

Net quanitised angular momenta
[inductive energy flux]
determines Charge

$$m\left[\frac{\Omega}{c^2}\right]$$

$$kg\,\frac{m^2}{s}\cdot\frac{s^2}{m^2}$$

seconds

Transverse quanta
create Quantum Levels

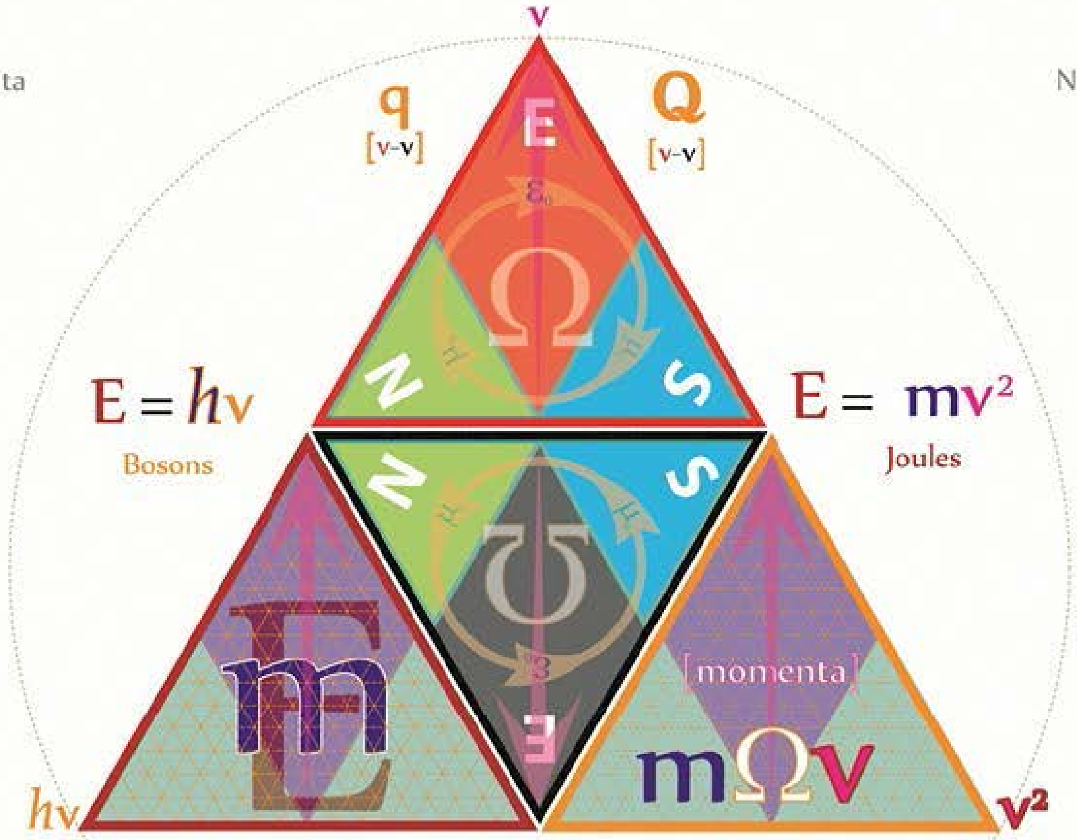

q

Net quanitised angular momenta
[inductive energy flux]
determines Charge

$$m\left[\frac{\Omega}{c^2}\right]$$

$$kg\,\frac{m^2}{s}\cdot\frac{s^2}{m^2}$$

seconds

Scalar (nett) quanta
create Square Energies

$$kg.\frac{m^2}{s}$$

Planck's Constant

The equilateral geometry of
quantised angular momentum
creates charged masses

Planck's Constant is in fact
mass x equilateral QAM $kg.\frac{m^2}{s}$

n.Planck quanta per second is Energy

Planck's Constant
can be described in
a number of differing ways

Scalar Energy x Time $kg.\frac{m^2}{s^2}.\,s$

Linear momentum x Distance $kg.\frac{m}{s}.\,m$

Tetryonic Mnemonics

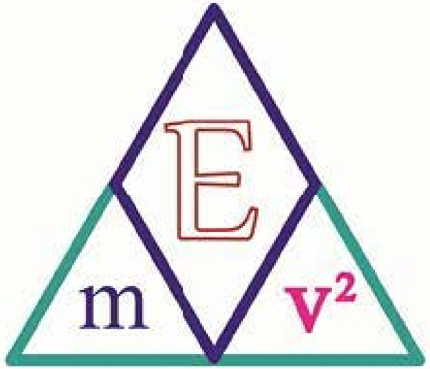

Energy momentum

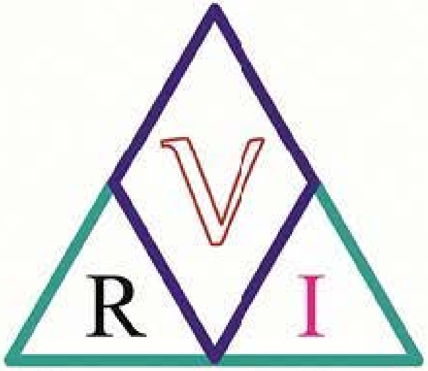

Electrical flow

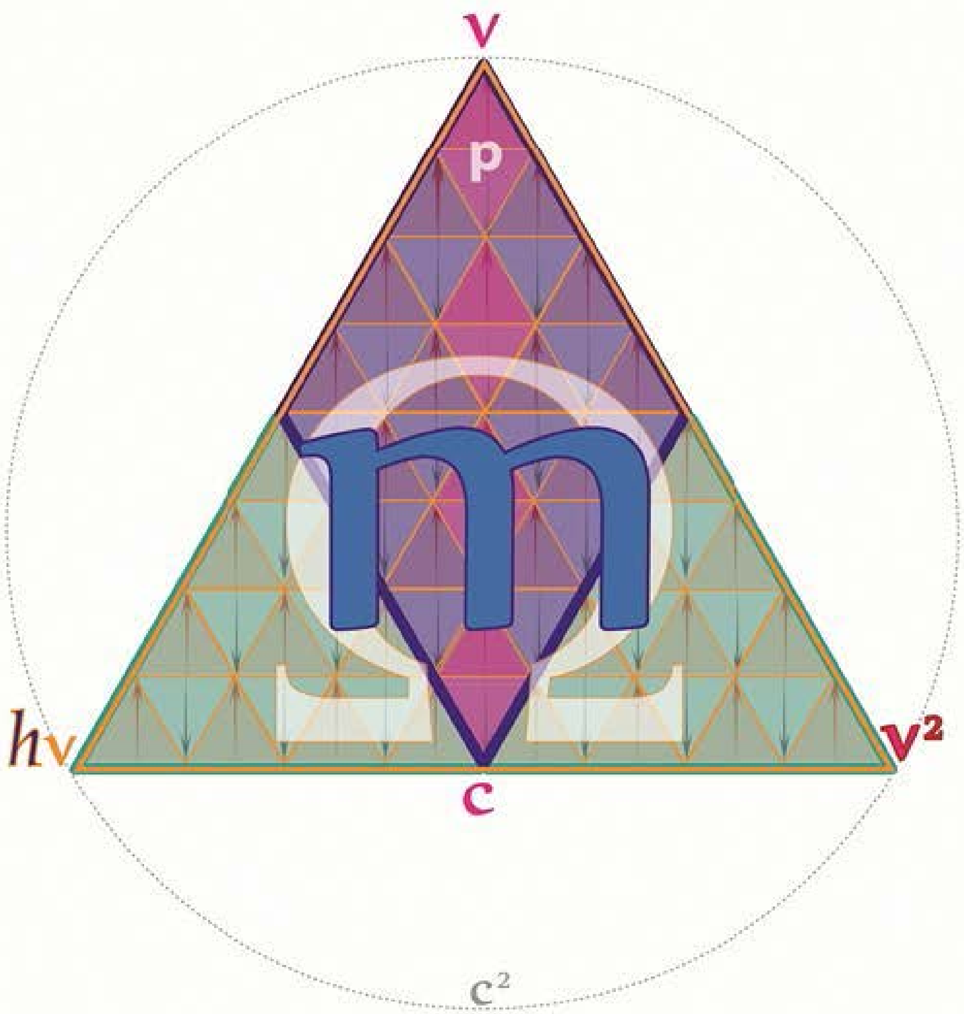
v
p
m
Ω
hv
v^2
c
c^2

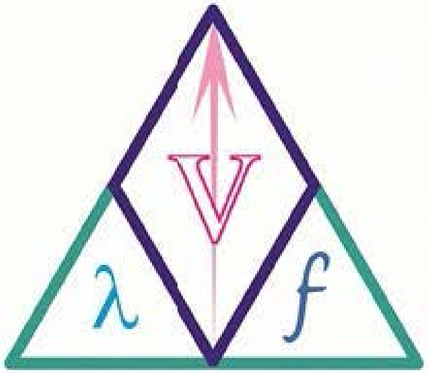

velocity of propagation

Many physical relationships are can be represented with DELTA mnemonics

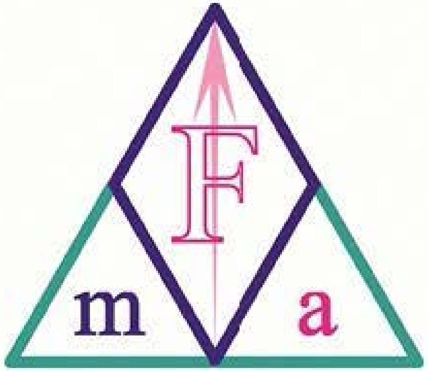

Inertial Force

UNITS OF PHYSICS

λ	Wavelength	m	$\frac{1}{s}$	Frequency	f
v	Velocity	$\frac{m}{s}$	$\frac{m}{s^2}$	Acceleration	a
Ω	Quantised Angular Momentum	$\frac{m^2}{s}$	$kg\,\frac{m^2}{s}$	Planck's Constant	h
$\frac{1}{c^2}$	2D radiant mass-energies	$\frac{s^2}{m^2}$	$\frac{s^4}{m^4}$	3D standing-wave mass-Matter	$\frac{1}{c^4}$
C	As Coulombs	$kg\ s$	KG	$\frac{C}{s}$ Amperes	A
ε_0	Electric Constant	$\frac{F}{m}$	$\frac{H}{m}$	Magnetic Constant	μ_0
p	Momentum	$kg\,\frac{m}{s}$	$kg\,\frac{m}{s^2}$	Force	F
m	*mass-energy geometries*	kg	KG	*mass-Matter topologies*	M

mass

Matter

$N\frac{m^2}{C^2}$

Coloumb's Constant

k

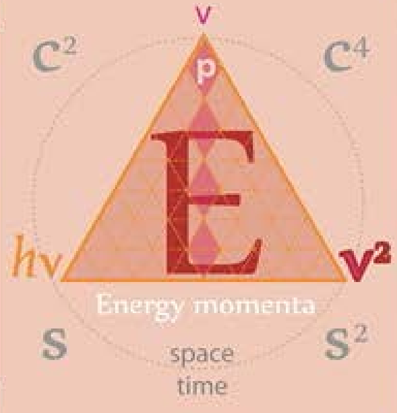

G

Newton's Constant

$N\frac{m^2}{KG^2}$

Physics is filled with numerous units of measurement comprised of various inter-related components of physical measurement

Tetryonic geometry offers a complete geometric understanding of physical terms such as Charge, mass geometries, Energy densities, Matter topologies and spatial impedance along with their roles in physical mechanics

Scalar mass-energies

have an EQUILATERAL geometry
(60°- 60°- 60°)

$\frac{\sqrt{3}}{2}$ **s**

The Area of an Equilateral triangle

½ base x height

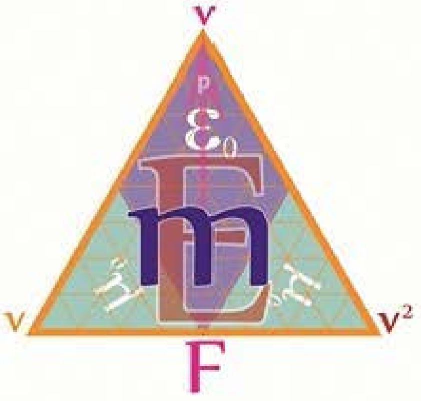
v
p
ε_0
m
E
v
v^2
F

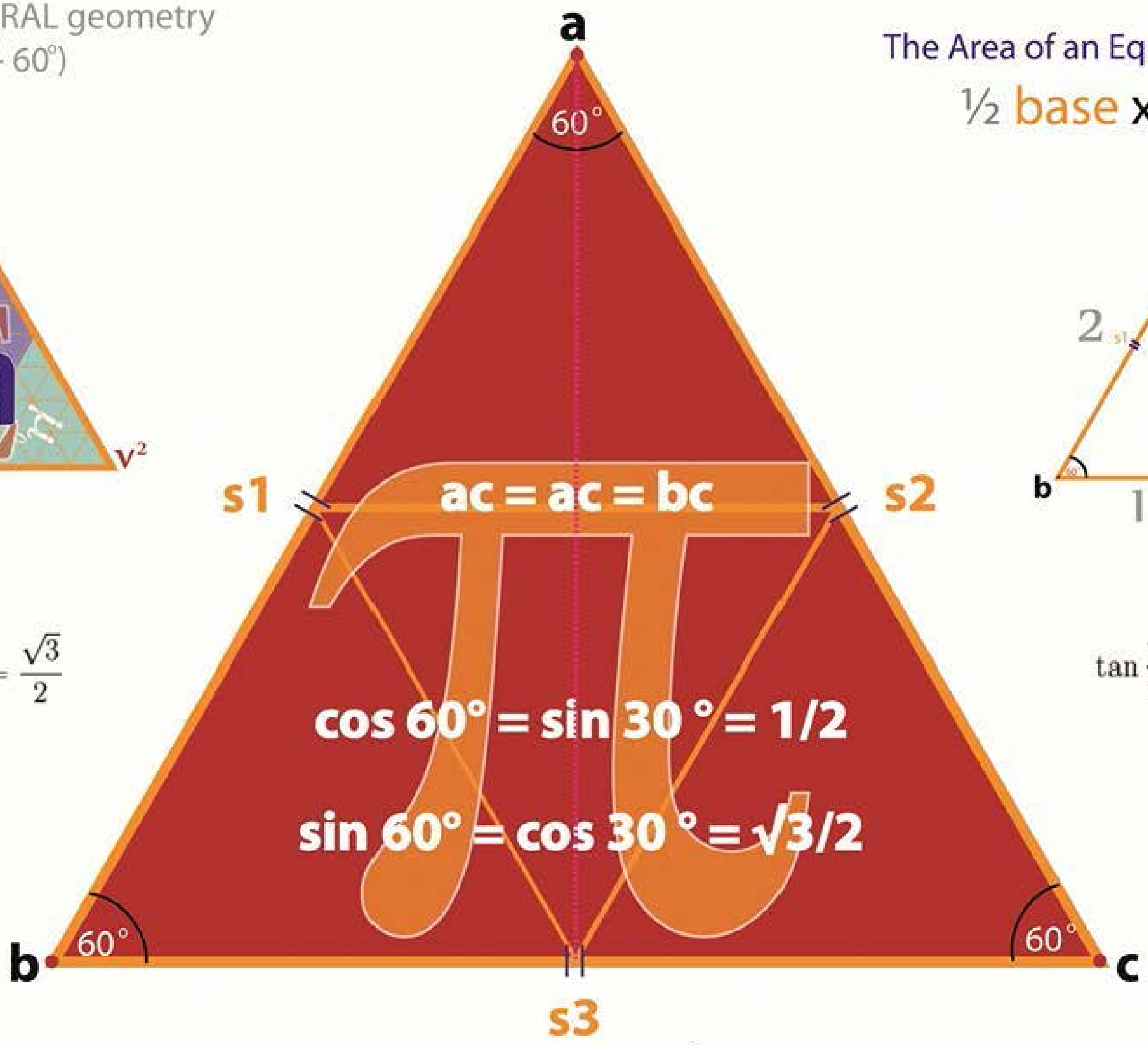
a
60°
s1
ac = ac = bc
s2
cos 60° = sin 30 ° = 1/2
sin 60° = cos 30 ° = √3/2
b
60°
60°
c
s3

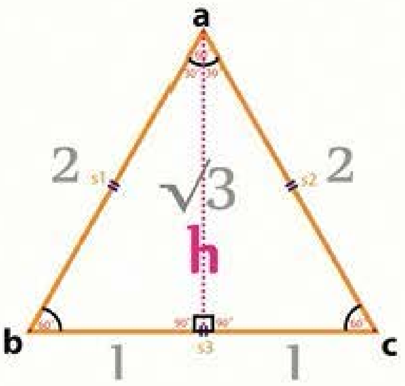

$$\sin\frac{\pi}{3} = \sin 60^\circ = \frac{\sqrt{3}}{2}$$

$$\tan\frac{\pi}{3} = \tan 60^\circ = \sqrt{3}$$

$$\cos\frac{\pi}{3} = \cos 60^\circ = \frac{1}{2}$$

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Pythagorian geometry

Energy geometries within Physics including Special Relativity and Lorentz corrections have historically been incorrectly illustrated as having the geometry of right angled triangles

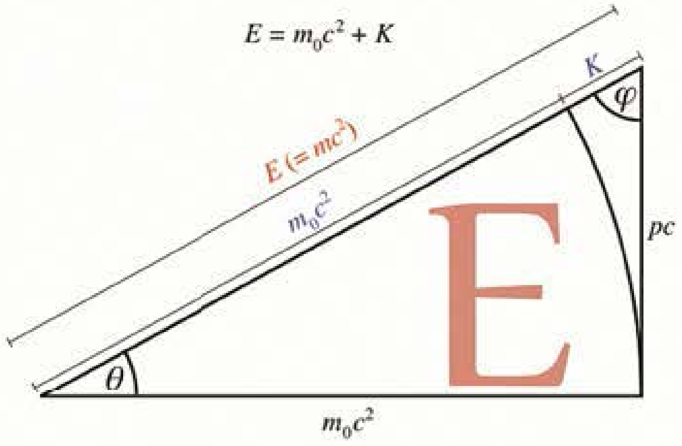

$$E^2 = p^2c^2 + m_0^2c^4$$

Generalizing, we see that the square of the total mass-energies is the sum of the components squared.
[shown incrorectly formulated in this above equation]

We can see an origin of distance in spacetime relating to velocity in pc in which Energy is subject to Lorentz corrections [v/c]

$$E = pc.$$

Additionally, EM mass can be directly related to the energy content of a body by the velocity of Energy

$$E = mc^2$$

Physics is geometry,
one cannot be separated from the other

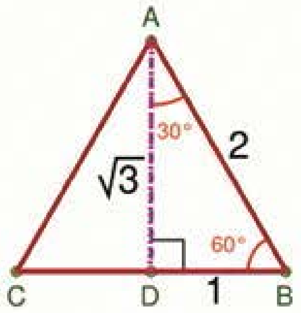

$$mv^2 = E = hv^2$$

There are three ways to look at geometry
– mathematically, verbally, and visually,

Of the three, Visually will be shown to be superior leading to intuitive understandings of Physics, Chemistry, Electrodynamics and Gravitation along with all their related physical attributes

6.629432672 e-34 J

Planck quanta

$$[m\Omega v]^2$$

mass velocity

7.376238634 e-51 kg

$$mv = p$$

Tetryonic geometry

The source of all the physical relationships of mass-Energy momenta & their constants is the geometry of equilateral Planck Triangles (and all texts must be corrected)

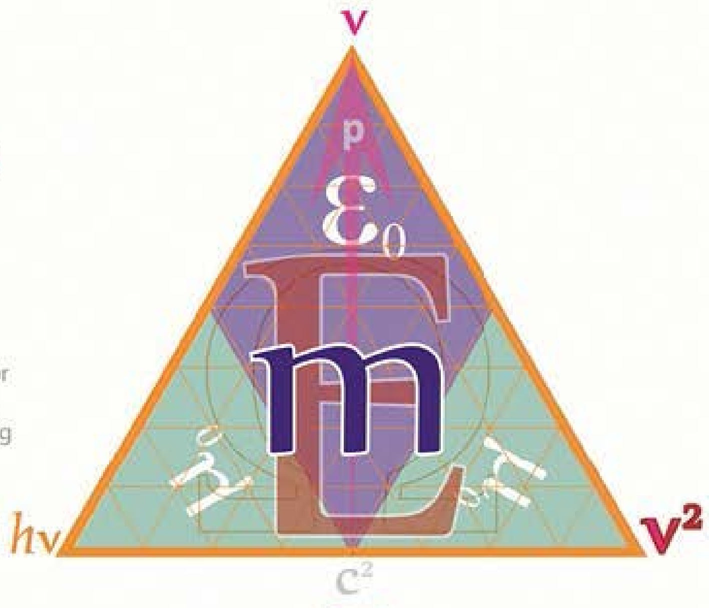

F

$$\sum \mathbf{F} = \frac{d\mathbf{P}}{dt} = m\frac{d\mathbf{v}}{dt} = m\mathbf{a}$$

Newton's Second law of Motion
is based on changes to linear momentum

$$\mathbf{F} = m\mathbf{a}\,.$$

Tetryonics and Pi radians

Although not historically considered a physical constant, π appears routinely in equations describing fundamental principles of the Universe, due in no small part to its relationship to the nature of the circle and, correspondingly, spherical coordinate systems.

The quantised equilateral geometry of mass-energy momenta is measured in π radians

Using units such as Planck units can sometimes eliminate π from formulae.

Heisenberg's uncertainty principle, which shows that the uncertainty in the measurement of a particle's position (Δx) and momentum (Δp) can not both be arbitrarily small at the same time:

$$\Delta x\,\Delta p \geq \frac{h}{4\pi} = \frac{\hbar}{2}$$

Einstein's field equation of general relativity:

$$R_{ik} - \frac{g_{ik}R}{2} + \Lambda g_{ik} = \frac{8\pi G}{c^4}T_{ik}$$

The cosmological constant Λ from Einstein's field equation is related to the intrinsic energy density of the vacuum ρvac via the gravitational constant G as follows:

$$\Lambda = 8\pi G\ \rho_{vac}$$

Coulomb's law for the electric force, describing the force between two electric charges (q1 and q2) separated by distance r:

$$F = \frac{|q_1 q_2|}{4\pi\varepsilon_0 r^2}$$

Magnetic permeability of free space relates the production of a magnetic field in a vacuum by an electric current in units of Newtons (N) and Amperes (A):

$$\mu_0 = 4\pi \cdot 10^{-7}\,\mathrm{N/A}^2$$

Kepler's third law constant, relating the orbital period (P) and the semimajor axis (a) to the masses (M and m) of two co-orbiting bodies:

$$(\frac{2\pi}{P})^2 a^3 = \omega^2 a^3 = G(M+m)$$

and the Gaussian formula for a Normal Distribution:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}}\,e^{-(x-\mu)^2/(2\sigma^2)}$$

$$\pi = \frac{C}{d}.$$

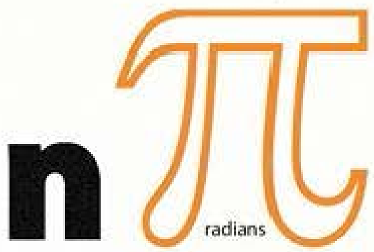

$$\pi = \frac{A}{r^2}.$$

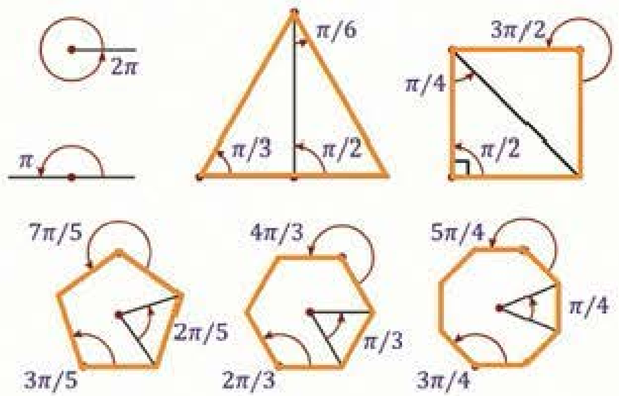

Pi radian mass-energy fascia geometries

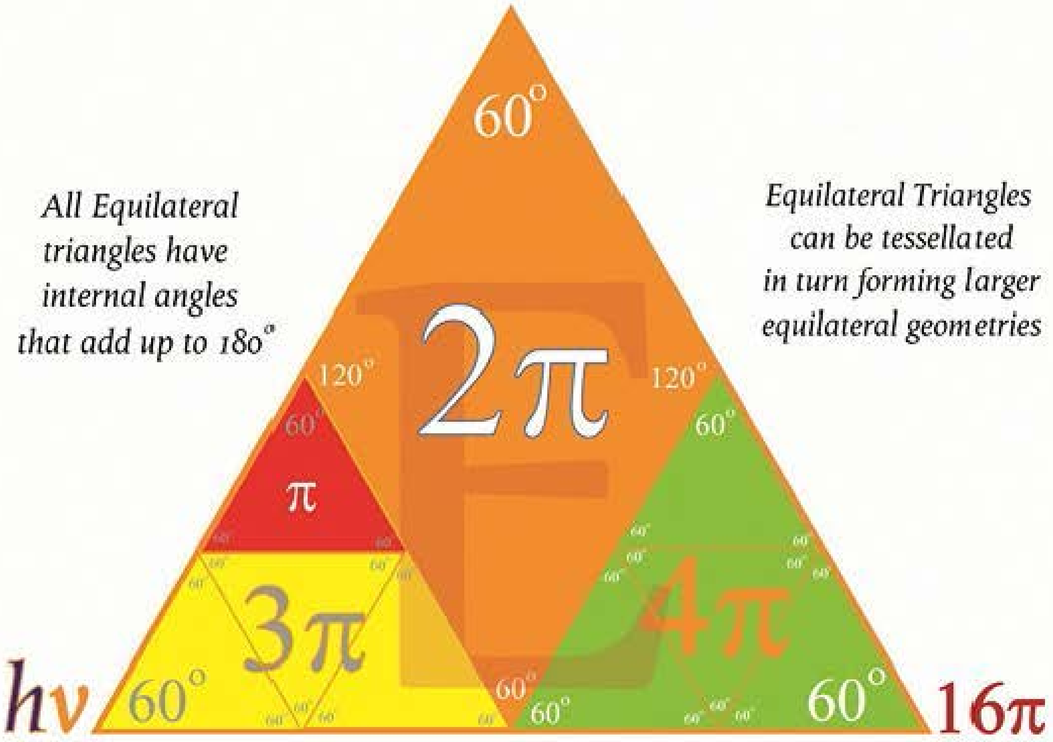

All Equilateral triangles have internal angles that add up to 180°

Equilateral Triangles can be tessellated in turn forming larger equilateral geometries

SQUARED numbers in physics are EQUILATERAL geometries

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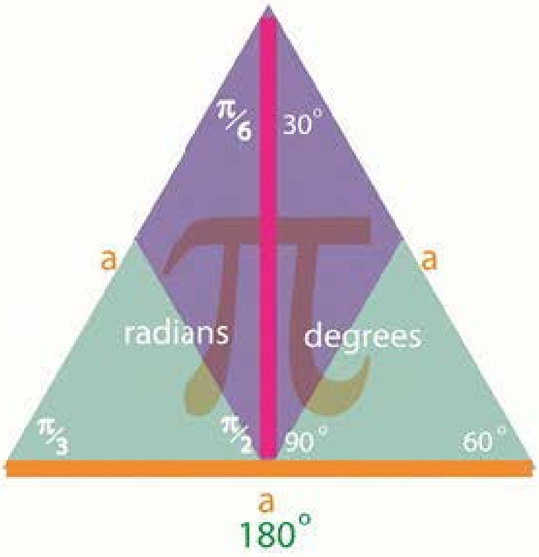
π/6
30°
a
a
π
radians
degrees
π/3
π/2
90°
60°
a
180°

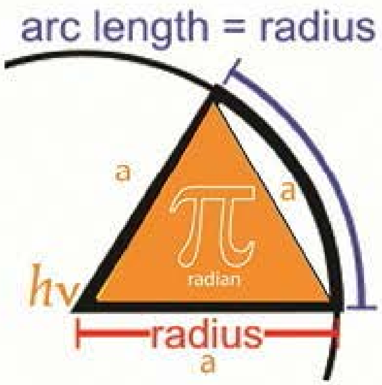
arc length = radius
a
a
π
radian
hv
radius
a

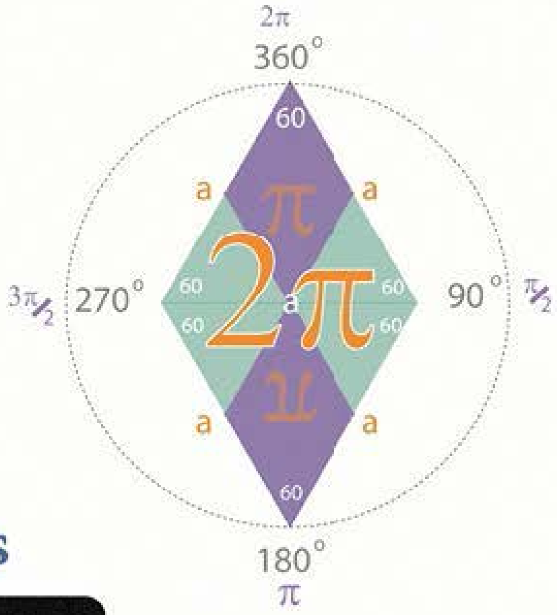
2π
360°
60
a
a
π
3π/2
270°
60
60
2π
a
60
60
90°
π/2
a
a
60
180°
π

nπ mass-energy geometries

180° π An equilateral triangle of mass-energy momenta has a geometry of π radians 2π **360°**

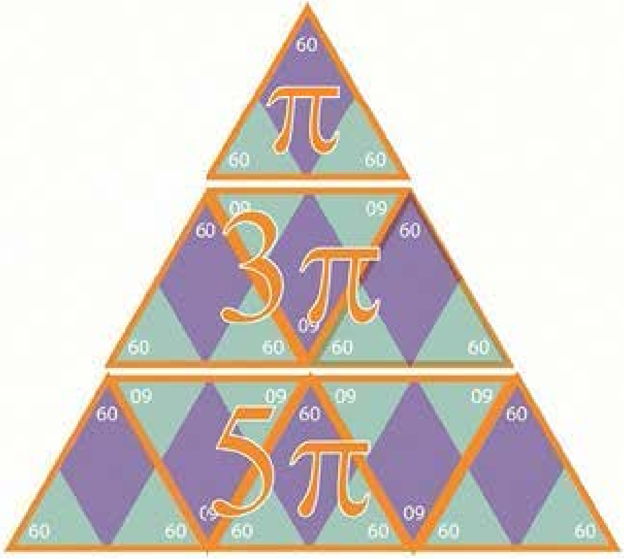
60
π
60
60
3π
5π

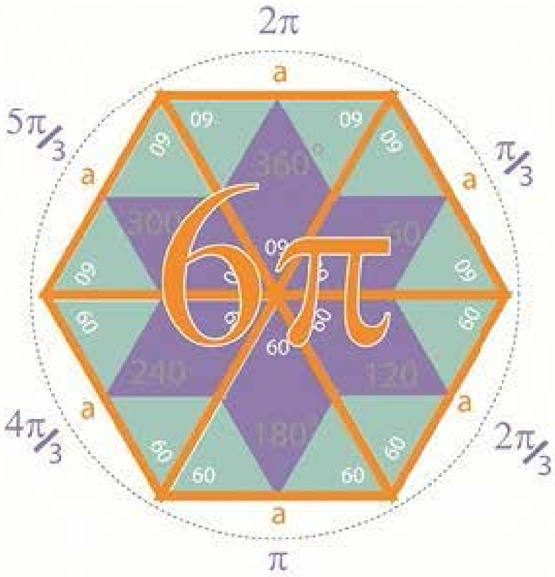
2π
a
5π/3
π/3
a
a
360°
300
60
6π
240
120
180
4π/3
2π/3
a
a
a
π

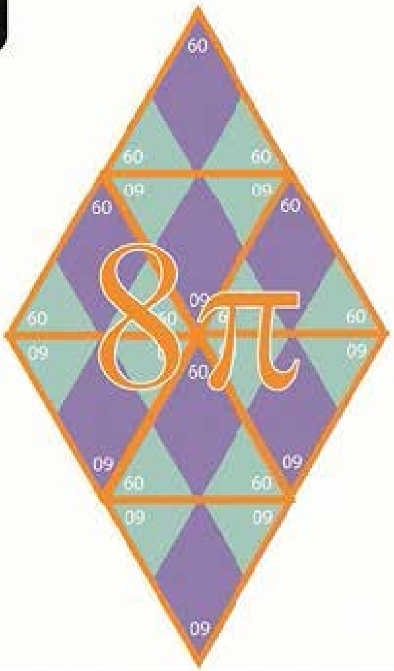

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Tetryonic Cardinal Angles

equilateral mass-energy geometries form tetrahedral mass-Matter topologies

EM Charge

Equilateral energies

Q

E

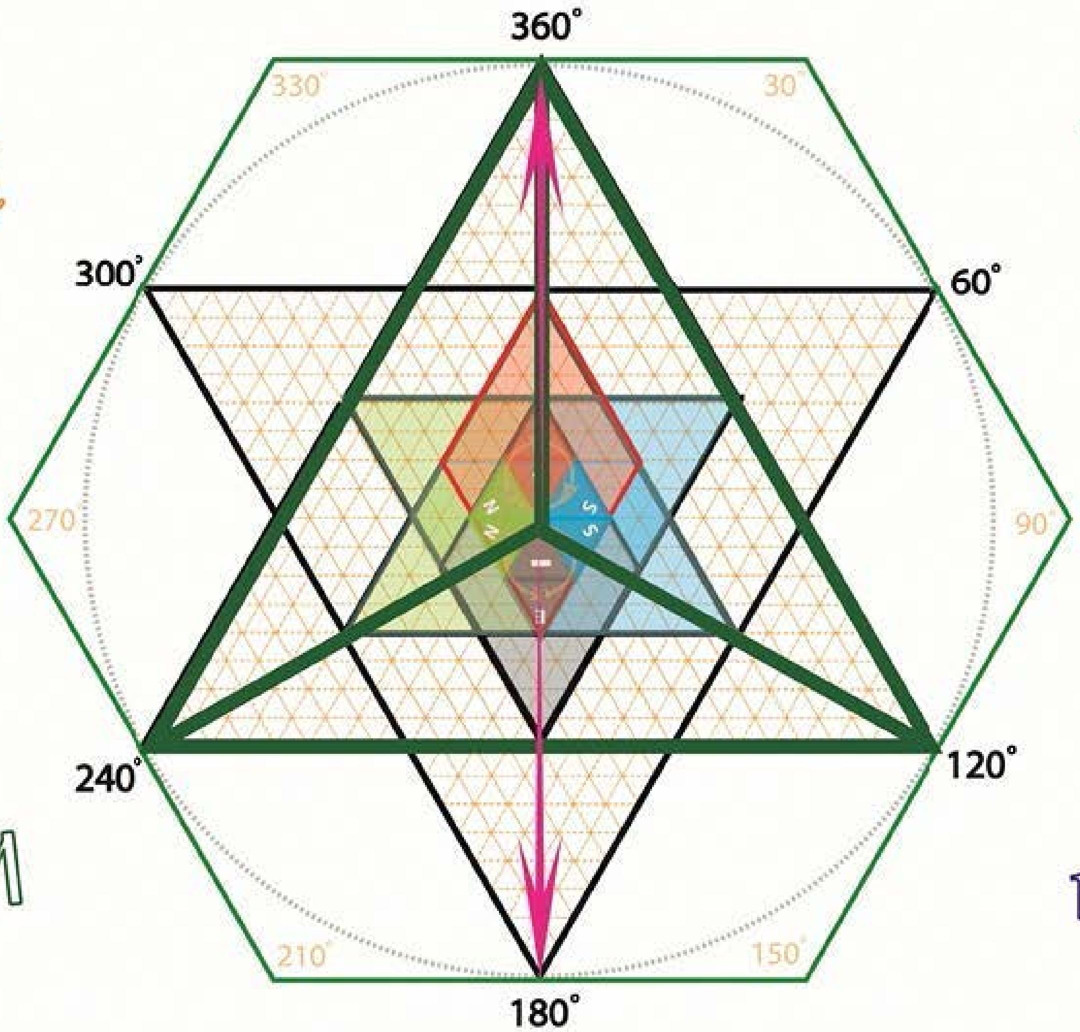
360°
330°
30°
300°
60°
270°
90°
N
N
S
S
-
240°
120°
210°
150°
180°

Space

Time

M

m

Matter topologies

radiant light

mass geometries

in radial spatial co-ordinate systems defined by the speed of light

Charge

EM Field Planck quanta

$$\mathrm{ODD}\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

Bosons & quantum levels

ElectroMagnetic mass velocity

Kinetic Energies

EM Field Planck quanta

$$\mathrm{EVEN}\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

Photons & EM waves

ElectroMagnetic mass velocity

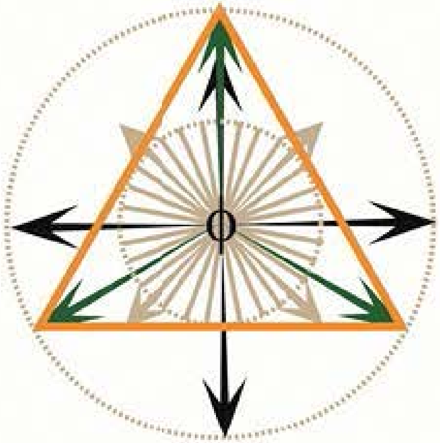

ALL Matter topologies stem from tessellated equilateral mass-energies

Matter

EM Field Planck quanta

$$4n\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

Fermions

ElectroMagnetic mass velocity

Matter's 4π mass-Energies ares Lorentz invariant to accelerations

mass-energy geometries

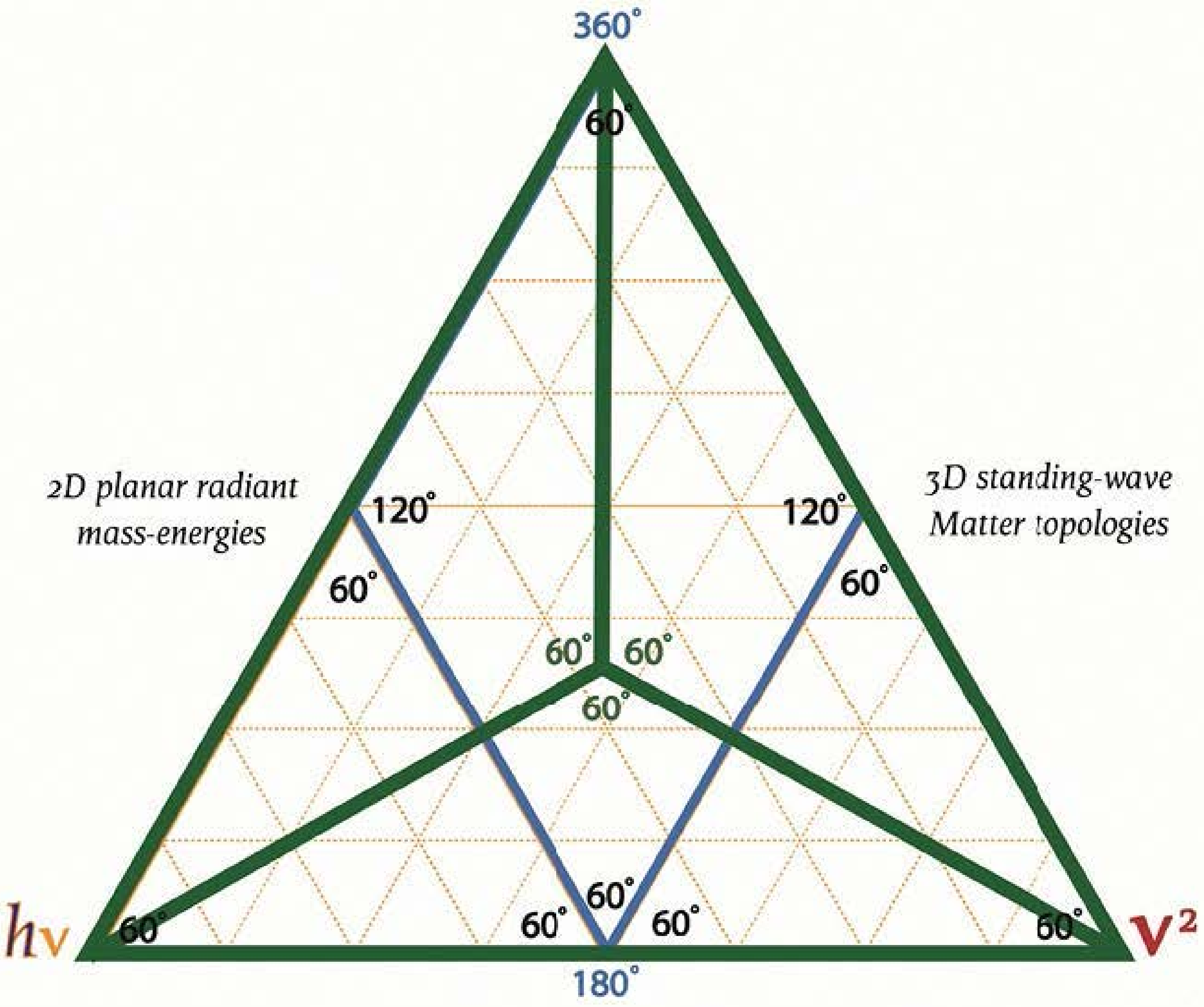
360°
60°
2D planar radiant mass-energies
3D standing-wave Matter topologies
120°
120°
60°
60°
60°
60°
60°
hv
60°
60°
60°
60°
60°
v²
180°

Matter topologies

Tetryonic geometry

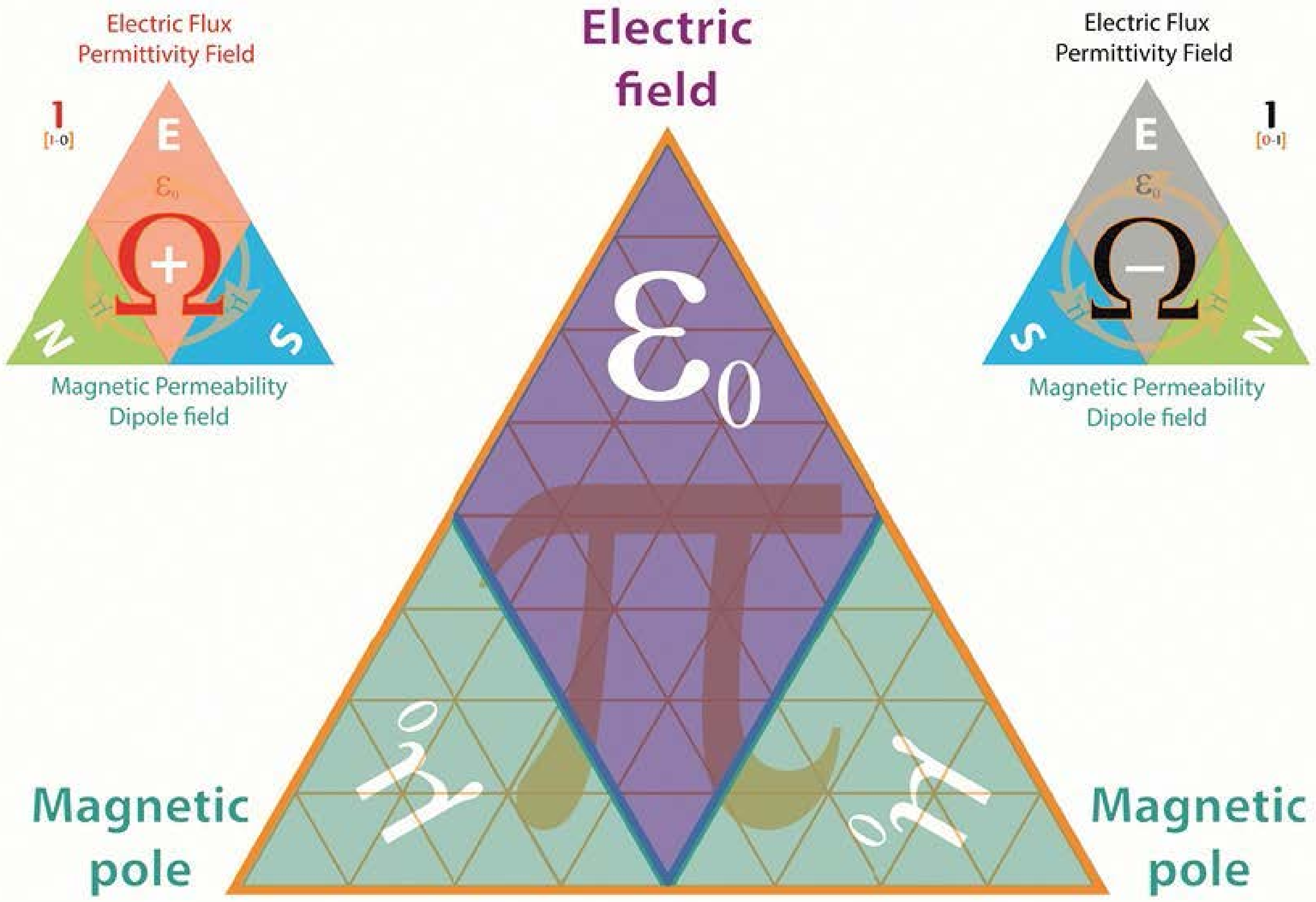
1
[1-0]
E
ε_0
Ω
+
μ_0
N
S
ε_0
π
μ_0
μ_0
1
[0-1]
E
ε_0
Ω
–
μ_0
S
N

Electric Flux
Permittivity Field

Magnetic Permeability
Dipole field

Electric
field

Magnetic
pole

Magnetic
pole

Electric Flux
Permittivity Field

Magnetic Permeability
Dipole field

equilateral quantised angular momenta
is the foundational geometry of all mass-ENERGY-Matter

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The Golden Triangle

Planck's formulation for Energy is imprecise for use in Tetryonics
and does not reflect the velocity-momenta relationship
inherent in the equilateral geometry of Energy

Planck quantum levels

Energy is gained or lost in
whole number multiples of the quantity hv

$$E = n[hv]$$

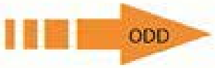

Charge EM Field Planck quanta

$$ODD\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$$

Bosons & quantum levels ElectroMagnetic mass velocity

$$3 = 3.[1]$$
$$9 = 9.[1]$$
$$25 = 25.[1]$$

$$hv$$

The generalise formulation of Plank's heat law
E = nhv is now changed to a specific formulation of
E = [ODD] hv for transverse quantum levels [Bosons]

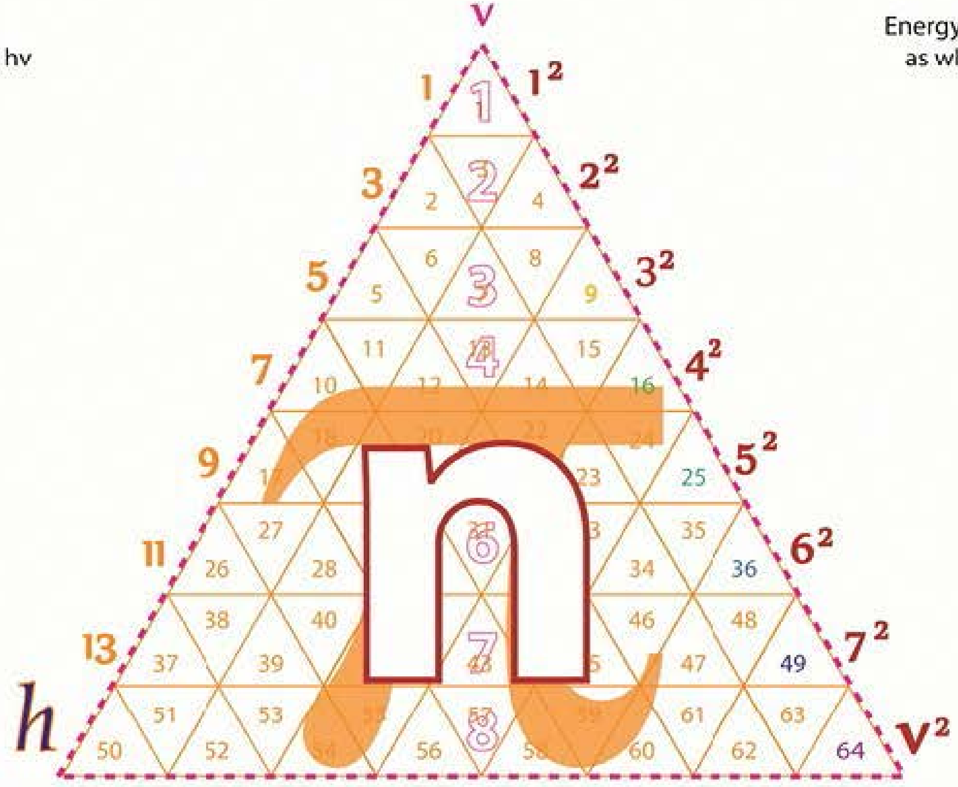

mass-energy momenta are geometrically related to velocity

Tetryonic geometry [nπ] redefines Planck's quantum formulation
for heat energies from a generalised equation for 2D energy momenta
into a geometric formulation for all mass-energy momenta in Matter

[all equilateral [π] geometries contain square number quanta]

Scalar energy quanta

Energy is gained or lost in equilateral geometries
as whole number multiples of the quantity hv²

$$E = n[hv]$$

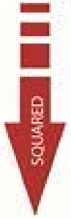

Planck quanta

$$E = n\pi[[m\Omega v^2]]$$

mass velocity

$$3 = 3.[1^2]$$
$$9 = 1.[3^2]$$
$$25 = 1.[5^2]$$

$$hv^2$$

The general formulation of Plank's heat law
is also changed to a specific formulation of
E = hv² for scalar EM waveforms [ENERGY]

Scalar field geometries

All scalar fields are comprised of Transverse and Longitudinal mass-energy momenta all of which are formed from equilateral quantum geometries

Charge is a conserved force

Energy is a conserved quantity

Bosons are transverse ODD planck geometries

$$E = n\pi\left[\left[hv\right]\right]$$

Planck quanta

Energy is scalar SQUARE planck quanta

$$E = n\pi\left[\left[hv^2\right]\right]$$

Planck quanta squared

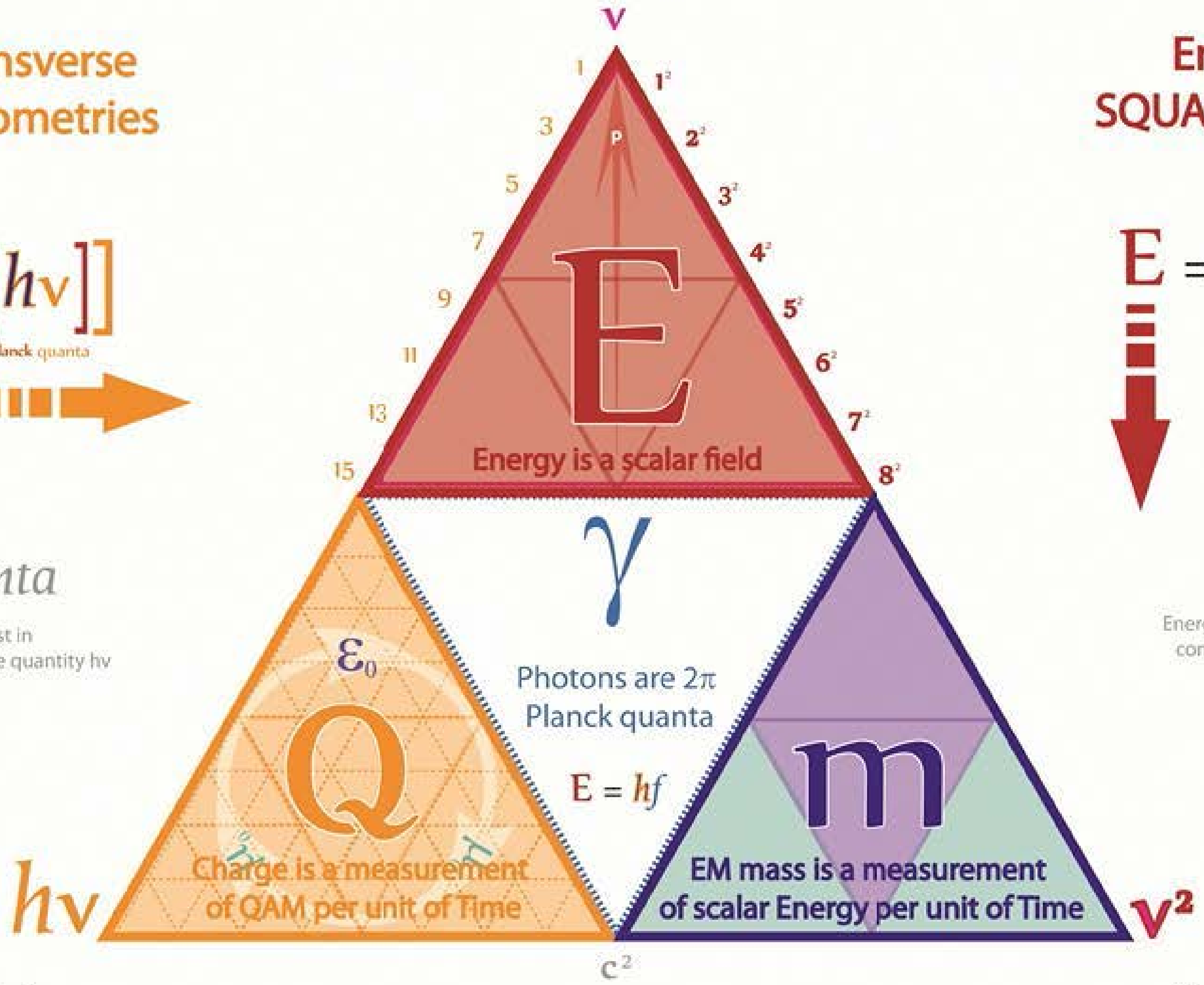
v
1
3
5
7
9
11
13
15
1²
2²
3²
4²
5²
6²
7²
8²
p
E
Energy is a scalar field
γ
Photons are 2π Planck quanta
E = hf
ε₀
Q
Charge is a measurement of QAM per unit of Time
m
EM mass is a measurement of scalar Energy per unit of Time
hv
v²
c²

Planck quanta

Energy is gained or lost in whole number multiples of the quantity hv

Scalar energies

Energy is gained or lost in equilateral quanta containing whole number multiples of hv^2

All energy is comprised of EM fields

All squared energy geometries have component quantum levels

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Squared energy levels in quantum physics

are in fact equilateral Planck mass-energy geometries

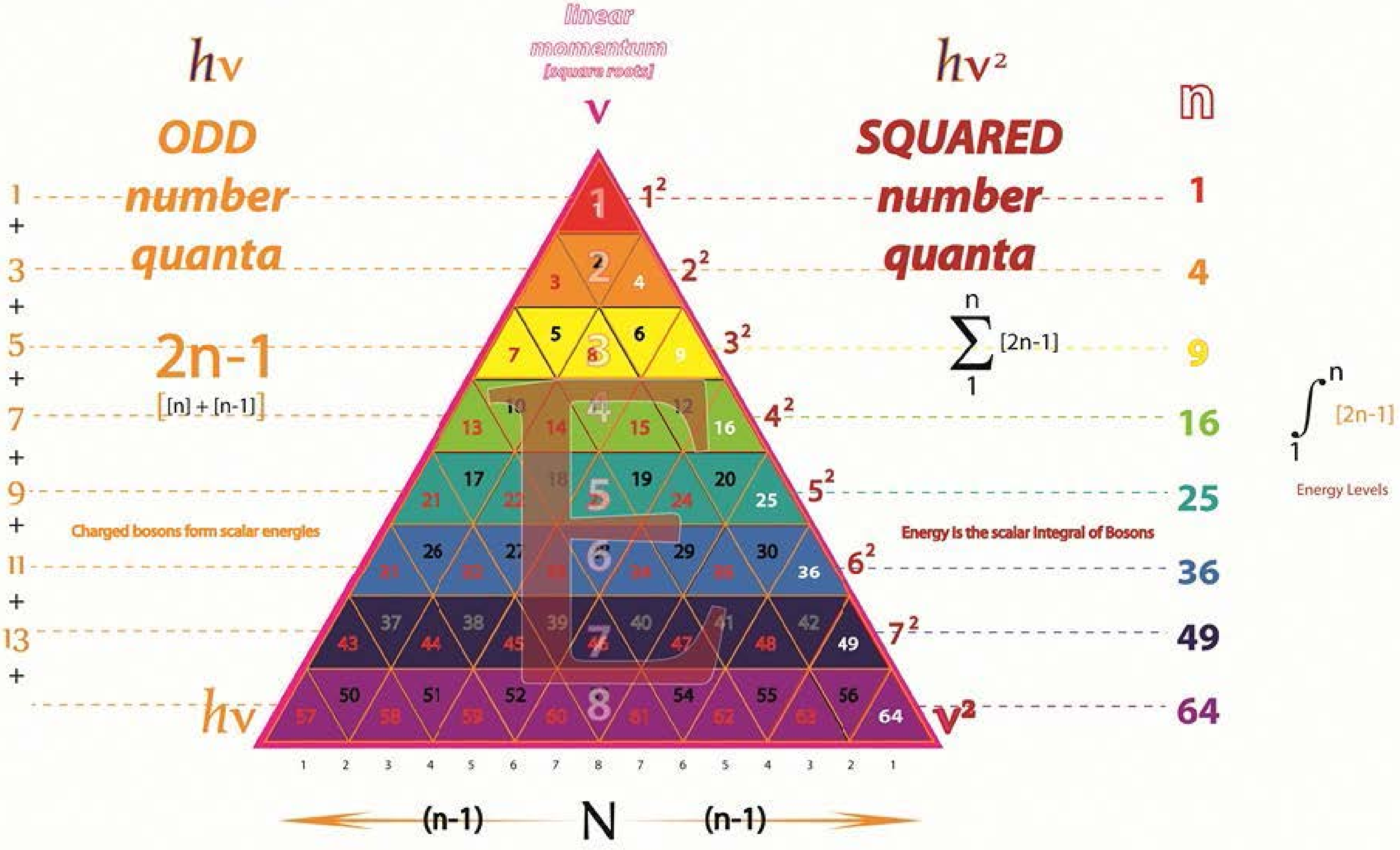
linear
momentum
[square roots]
v
hv
ODD
number
quanta
2n-1
[n] + [n-1]
hv²
SQUARED
number
quanta
n
1 + 3 + 5 + 7 + 9 + 11 + 13 +
1^2
2^2
3^2
4^2
5^2
6^2
7^2
v^2
1
4
9
16
25
36
49
64
$\sum_{1}^{n} [2n-1]$
$\int_{1}^{n} [2n-1]$
Energy Levels
Charged bosons form scalar energies
Energy is the scalar Integral of Bosons
hv
E
1 2 3 4 5 6 7 8
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
(n-1)
N
(n-1)

Cumulative Distribution

NORMAL DISTRIBUTION

['Bell Curve']

Probability Distribution

Energy quanta defined

Quantum levels

Charge is gained or lost in
odd number multiples of the quantity hv

$$E = n\pi\left[\left[hv\right]\right]$$

Planck quanta

transverse

ODD quanta

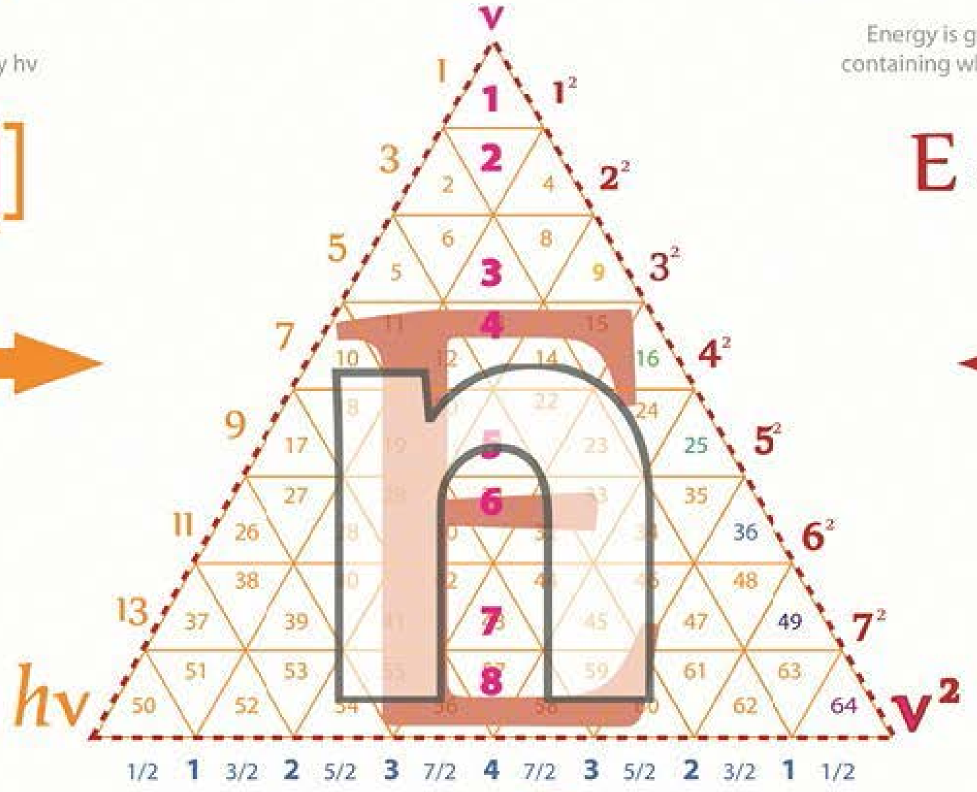
v
hv
v²
1
3
5
7
9
11
13
1²
2²
3²
4²
5²
6²
7²
1
2
3
4
5
6
7
8
1/2
1
3/2
2
5/2
3
7/2
4
7/2
3
5/2
2
3/2
1
1/2

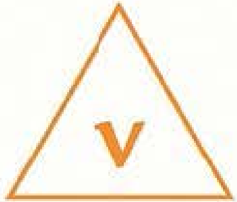

Quantum

The **number** of Planck quanta
in any physical system

$$v = f/2$$

Transverse

Quantum Levels

Longitudinal

Scalar Energies

Energy is gained or lost in equilateral geometries
containing whole number multiples of the quantity hv²

$$E = n\pi\left[\left[hv^2\right]\right]$$

Planck quanta squared

scalar

SQUARE quanta

The number of
repeating waveform **cycles**
in a system

$$2v = f$$

Frequency

EVEN quanta

Tetryonics 02.11 - Energy quanta defined

Tetryonic field equation

$$E$$

$$E = n\pi\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

electromagnetic energy is a scalar

$$E$$

$$m$$

$$\underset{\text{mass}}{n\pi}\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{[\varepsilon_0\mu_0]}}.\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

mass is an inertial constant
that relates Force to acceleration

$$\frac{E}{c^2}$$

$$\overset{[v\text{-}v]}{Q}$$

$$\underset{\text{Bosons \& quantum levels}}{\overset{\text{Charge}}{\text{ODD}\pi}}\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{[\varepsilon_0\mu_0]}}.\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

equilateral charge geometry
is Lorentz invariant

$$\frac{\Omega}{c^2}$$

$$KE$$

$$\underset{\text{Photons \& EM waves}}{\overset{\text{Kinetic Energies}}{\text{EVEN}\pi}}\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{[\varepsilon_0\mu_0]}}.\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

KEM fields mass-energy geometries
are Lorentz variant to accelerations

$$\frac{1}{2}m\left[\frac{v^2}{c^2}\right]$$

$$M$$

$$\underset{\text{Fermions}}{\overset{\text{Matter}}{4n\pi}}\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{[\varepsilon_0\mu_0]}}.\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

Matter's 4π mass-energy topologies
are Lorentz invariant to accelerations

$$4n\pi\left[\frac{E}{c^4}\right]$$

Energy momenta geometry

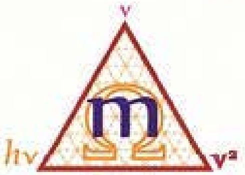

Energy is the total Planck quanta per second

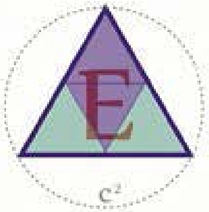

EM mass is scalar energy per unit of Time

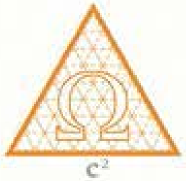

Charge is the nett Angular momentum per spatial co-ordinate system

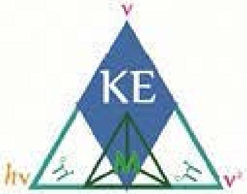

Kinetic Energy is the Electric field
mass-energy of Matter moving at v

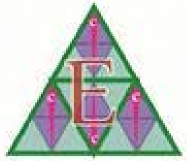

mass-energy geometry

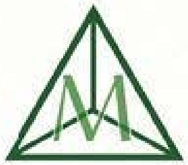

Matter topology

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mass-Energy equivalence

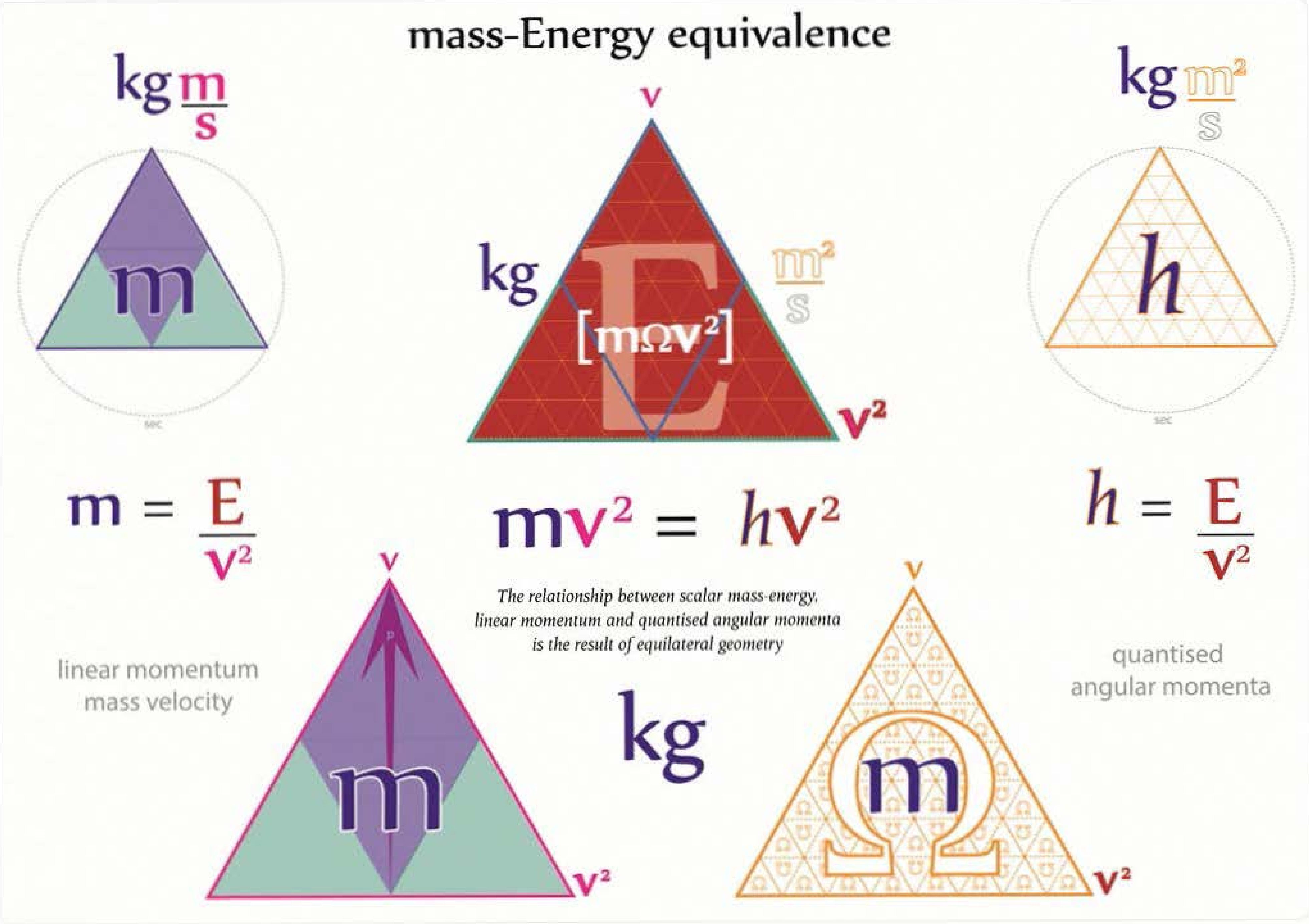
kg m/s
m
sec
v
kg
m²/s
E
[mΩv²]
v²
kg m²/s
h
sec
v
p
m
v²
kg
v
Ω
m
v²

$$m = \frac{E}{v^2}$$

$$mv^2 = hv^2$$

$$h = \frac{E}{v^2}$$

The relationship between scalar mass-energy, linear momentum and quantised angular momenta is the result of equilateral geometry

linear momentum
mass velocity

quantised
angular momenta

Tetryonics 02.13 - mass-Energy equivalance

mass-Energy geometries

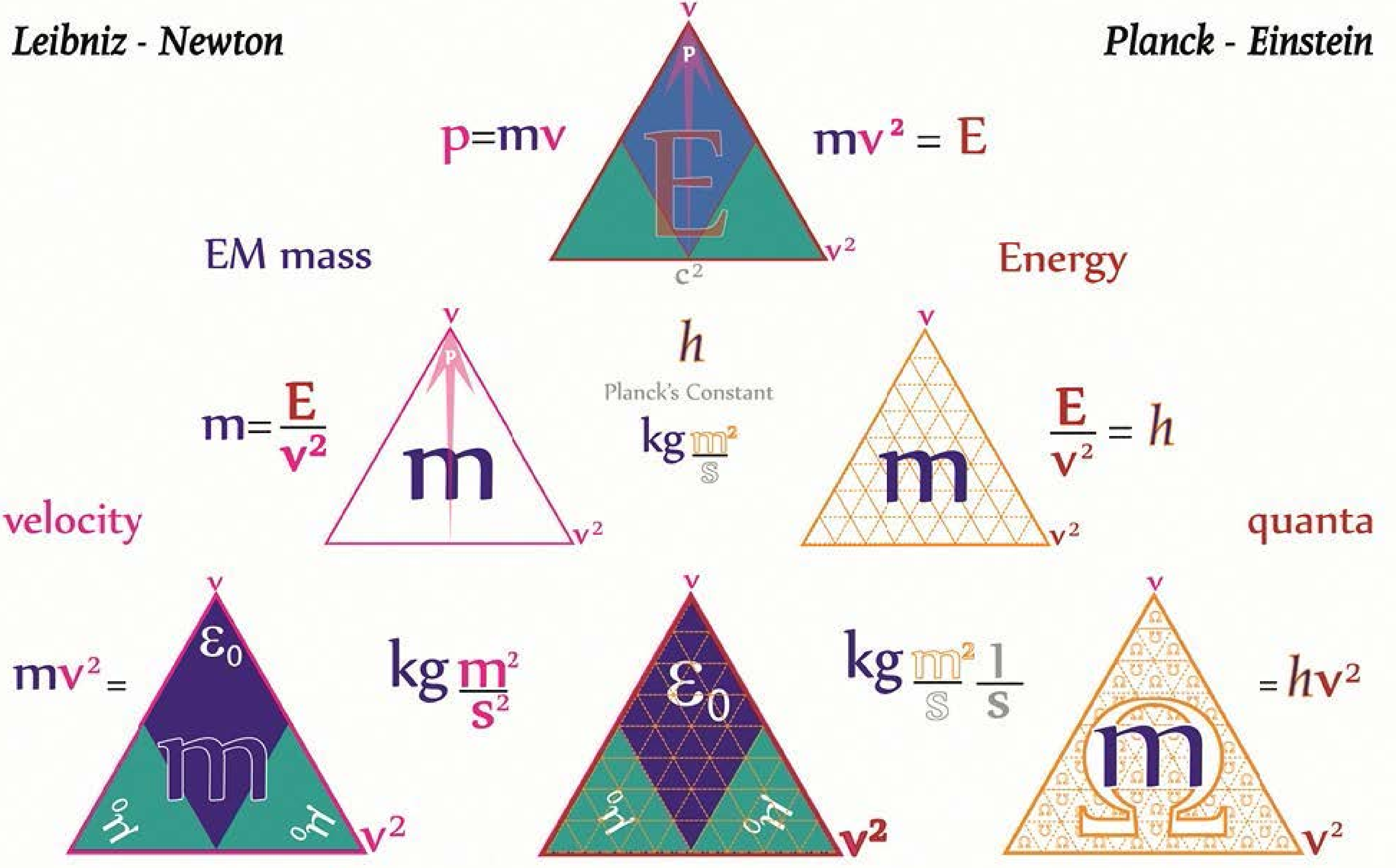
v
P
E
v²
c²
v
P
m
v²
v
m
v²
v
ε0
m
μ0
μ0
v²
v
ε0
μ0
μ0
v²
v
m
Ω
v²

Leibniz - Newton

Planck - Einstein

$p=mv$

$mv^2 = E$

EM mass

Energy

h

Planck's Constant

$kg\frac{m^2}{s}$

$m=\frac{E}{v^2}$

$\frac{E}{v^2} = h$

velocity

quanta

$mv^2 =$

$kg\frac{m^2}{s^2}$

$kg\frac{m^2}{s}\frac{1}{s}$

$= hv^2$

velocity squared

quanta squared

There exists an intrinsic geometric relationship between mass-velocity and the quantisation of Energy momenta

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EM mass-energy

$$E = mc^2$$

EM mass is related to Matter throught the square of the velocity of light of 8.987551787 e16 m²/s² [c²]

EM mass-Matter

$$E = Mc^4$$

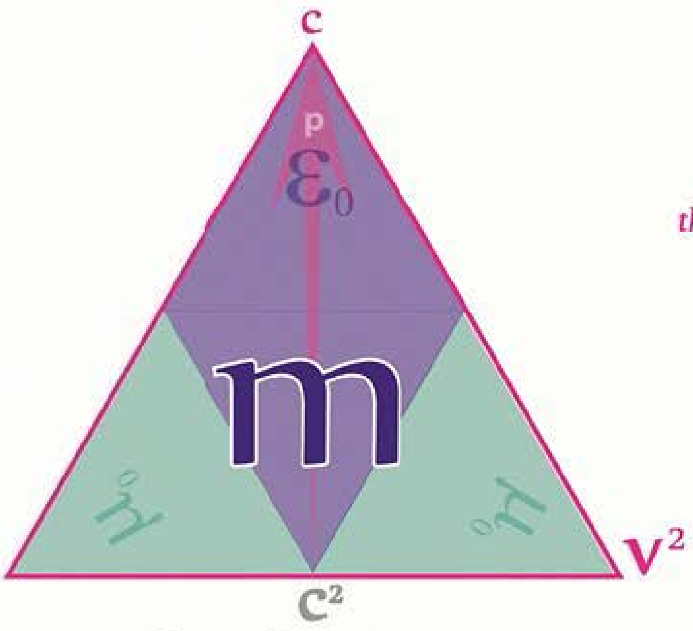
c
p
ε_0
m
μ_0
μ_0
v^2
c^2

Electro-Magnetic mass

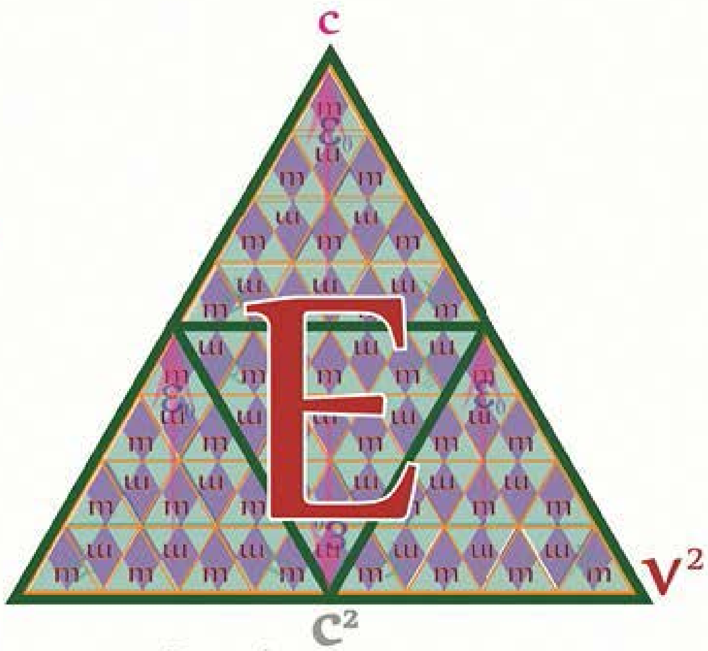
c
E
m
ε_0
v^2
c^2

Matter's energy quanta

scalar EM mass

$$M = \frac{E}{c^4}$$

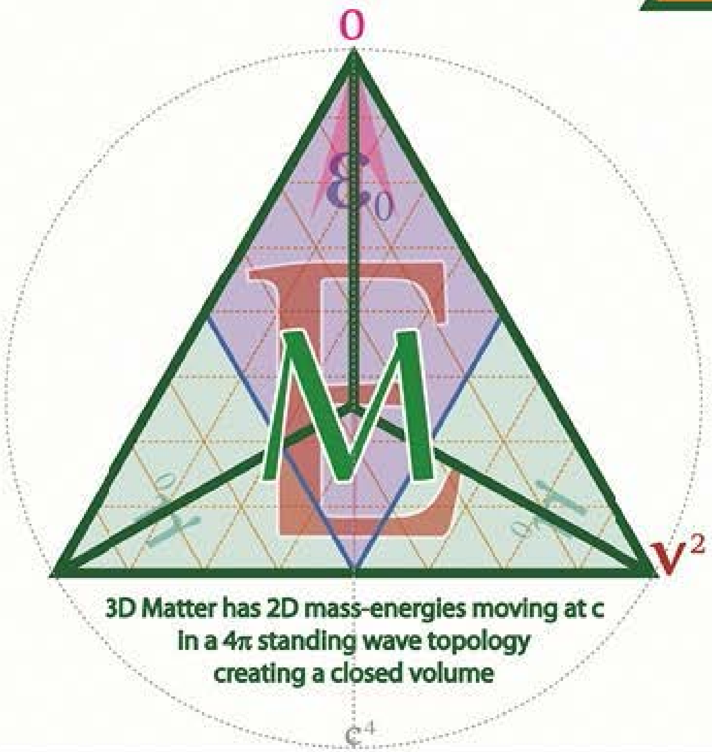
0
ε_0
E
M
μ_0
μ_0
v^2
c^4

3D Matter has 2D mass-energies moving at c in a 4π standing wave topology creating a closed volume

quantised mass

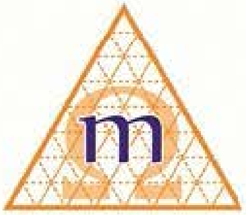

$$h = \frac{E}{v^2}$$

Kinetic Electro-Magnetic fields

[The energies of Motion]

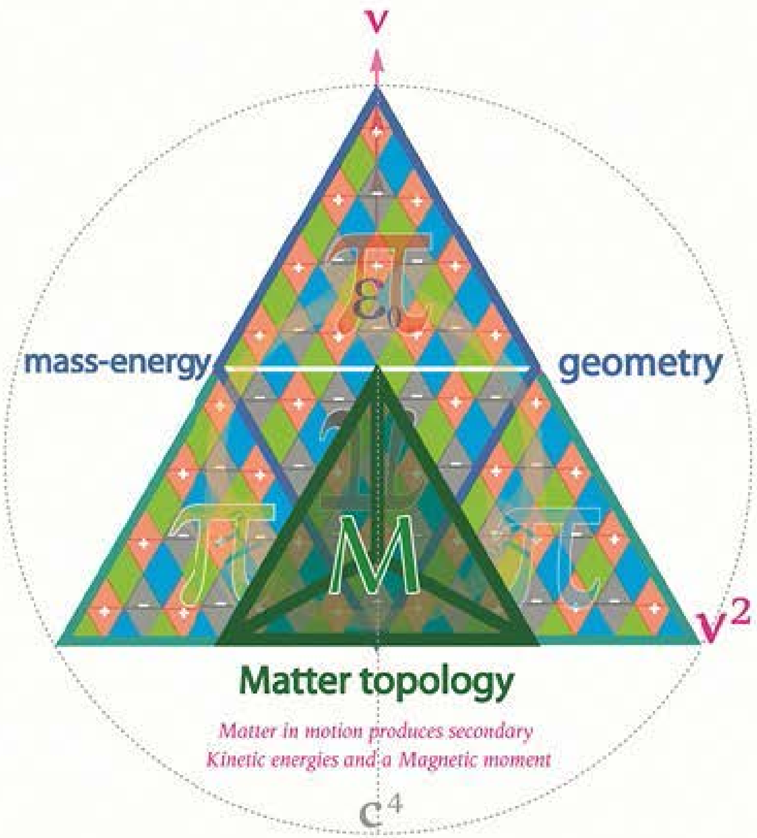
v
ε_0
mass-energy
geometry
M
v^2
c^4

Matter topology

Matter in motion produces secondary Kinetic energies and a Magnetic moment

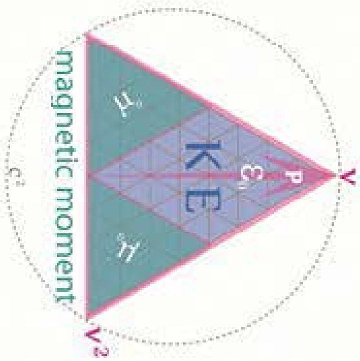
magnetic moment
μ_0
KE
ε_0
p
v
v^2
c^2

$$\mu_B = \frac{1}{2}Mv^2$$

$$KE = \frac{1}{2}Mv^2$$

All Matter in motion possess momenta and kinetic mass-energies in extrinsic KEM fields

$$p^2 = E = Mv^2$$

The Electric field energy in any EM field is equal and orthogonal to the Magnetic field energy

$$p^2 = KEM = Mv^2$$

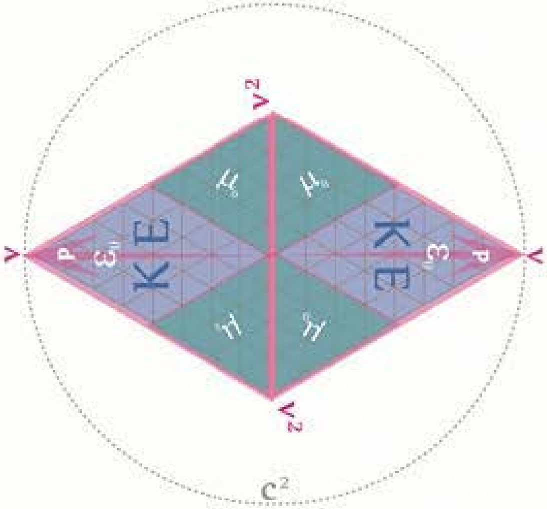
v^2
μ_0
KE
ε_0
p
v
c^2

$$E_\gamma = 2\frac{mv^2}{c^2}$$

These 2D planar fields are subject to Lorentz factor corrections that apply to the KEM field mass-energies of Matter in motion

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Charge & Kinetic EM fields

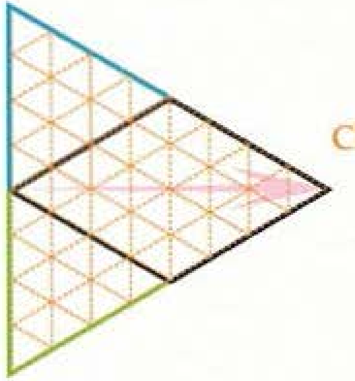

Charges are the result of quantised angular momenta

Kinetic Energies result from Matter in motion

$$mv^2 = E = h\nu^2$$

$$p^2 = E = m\Omega v^2$$

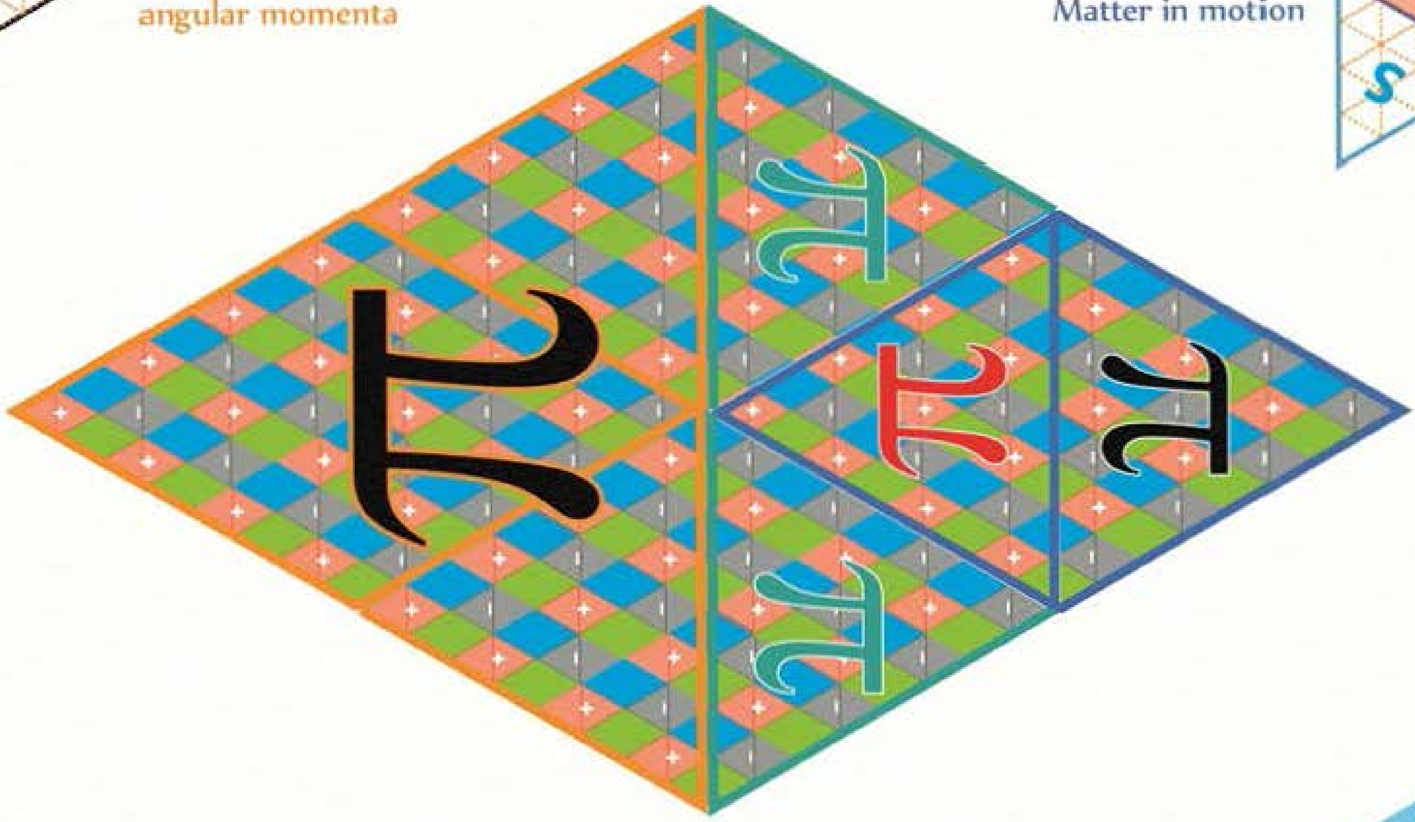

$$KEM = Mv^2$$

$$KE = \tfrac{1}{2}Mv^2$$

EM field energies externalised on the fascia of 3D Matter geometries form the physical property known as elementary Charge

[k]EM energies in amy region of free space are viewed as either a Kinetic energy field with an associated Magnetic moment or a neutral charge Photon of ElectroMagnetic mass-energy

$$m_0 = \frac{E}{c^2}$$

Rest mass is equivalent to
the total quantity of Energy
in a body or system (divided by c²)

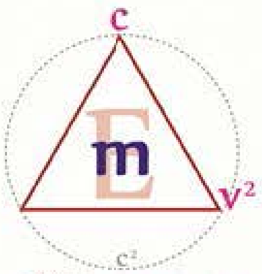

2D fields propagate at c
3D Matter moves at v

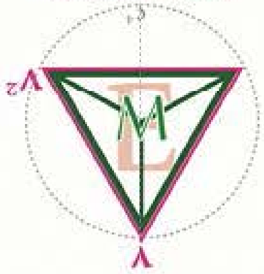

inertial mass

$$m = \frac{F}{a}$$

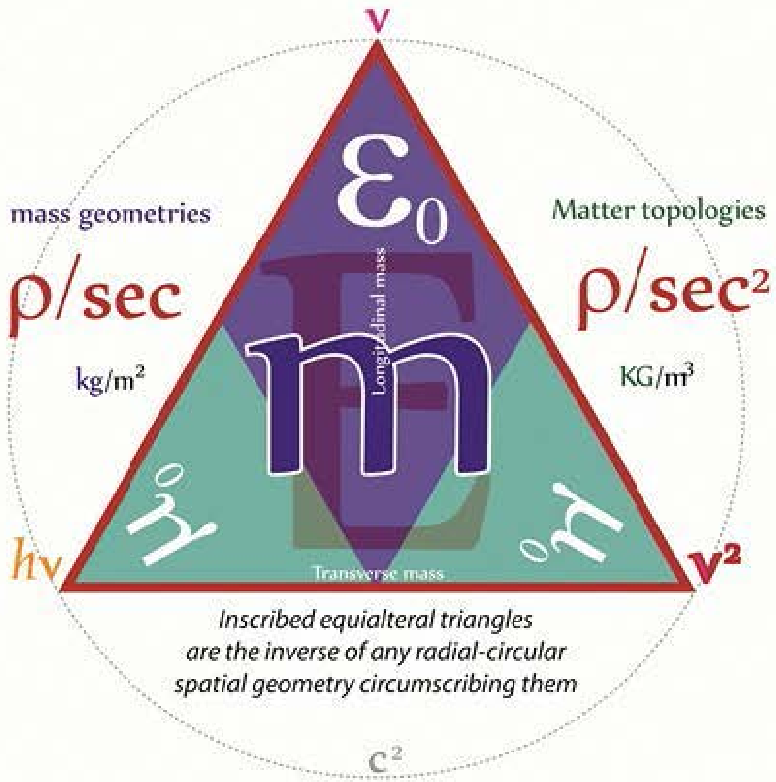

Inscribed equialteral triangles
are the inverse of any radial-circular
spatial geometry circumscribing them

mass must be distinguished from Matter in physics,
because Matter is a poorly-defined concept in modern science,
and although all types of agreed-upon Matter exhibit properties of mass,
it is also the case that there many types of Energy that posses NO Matter topology,
such as potential energy, kinetic energies and electromagnetic radiation (photons)

$$\underset{\text{mass}}{n\pi}\left[\overset{\text{EM Field}}{\underset{\text{ElectroMagnetic}}{[\varepsilon_0\mu_0]}}.\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

The term 'massless' must be re-termed 'Matterless'
to reflect true physical attributes of mass-energy-momenta

EM mass is a planar measurement of 2D energy per unit of time

Thus, all 3D Matter topologies have charged fascia comprised of 2D scalar of mass-energies,
but closed volume 3D topology is not a property of 2D EM mass-energy geometries

mass

$$\rho$$

EM mass is a measure of planar
energy density per second

$$\frac{mv^2}{c^2} \quad \boxed{\frac{m\Omega v^2}{c^2}} \quad \frac{hv^2}{c^2}$$

per unit of time

EM mass geometries
are subject to
Lorentz corrections

$$\frac{m\overset{\text{velocity}}{v^2}}{c^2} = \frac{m\overset{\text{QAM}}{\Omega}\overset{\text{quanta}}{V^2}}{c^2}$$

per unit of time

Gravitational Matter

$$g = G\frac{M}{r^2}$$

Electromagnetic mass-energy

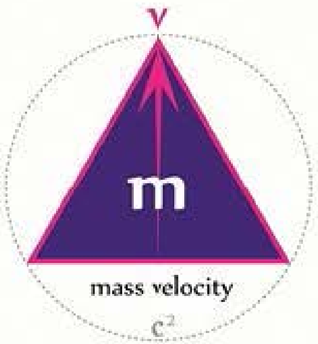

In physics, EM mass-energy equivalence is the concept that the EM mass of a body is a measure of its energy content

Using this concept, EM mass is a property of all Energy, and Energy is a property of all EM mass, and the two properties are connected by a constant.

Using Tetryonic geometry it can be shown that the constant is the equilateral geometry of QAM thus unifying Classical mechanics and Relativisic mechanics

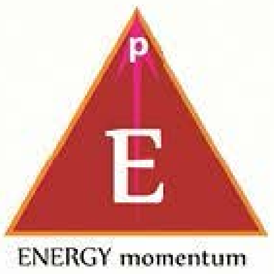

2D mass-ENERGY geometry is NOT 3D Matter topology

$$m = \frac{E}{v^2}$$

Classical mass

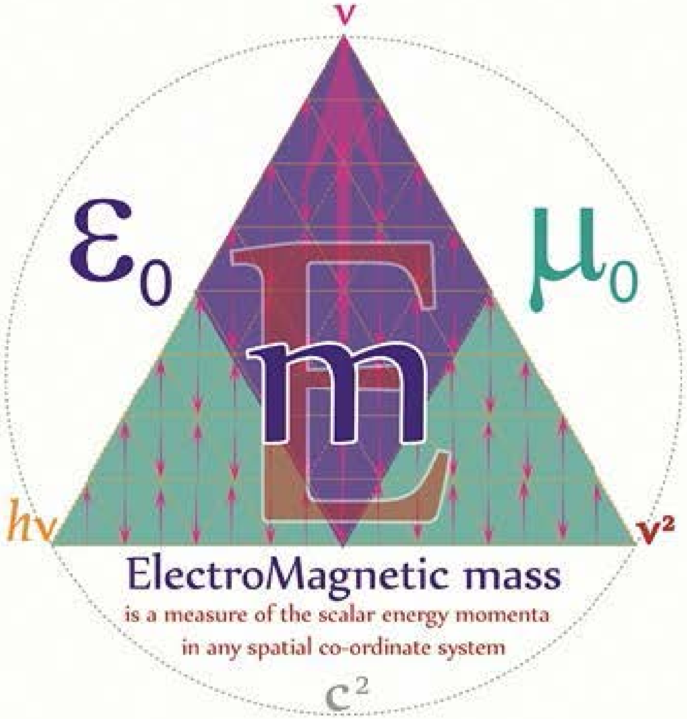

ElectroMagnetic mass

is a measure of the scalar energy momenta in any spatial co-ordinate system

$$m = \frac{E}{c^2}$$

Relativistic mass

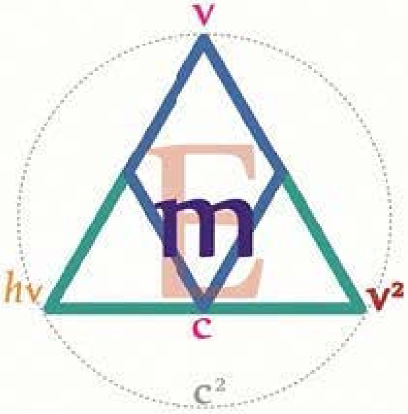

radiant 2D mass-energies
are planar equilateral
energy geometries

Relativity shows that rest mass and rest energy are essentially equivalent, via the well-known relationship ($E=mc^2$)

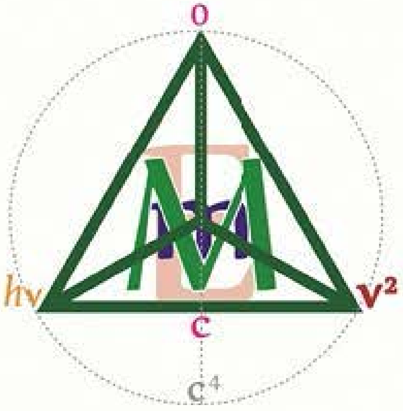

standing-wave 3d mass-Matter
are tetrahedral energy
momenta topologies

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EM mass-Energy-Matter

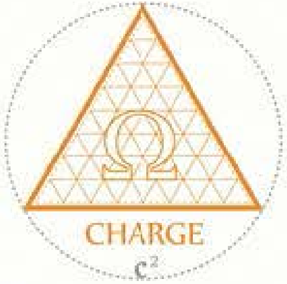

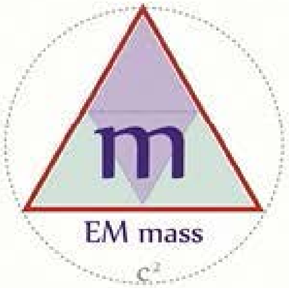

$$\left[\frac{\Omega}{c^2}\right]$$

Charge is a measure of the quantised angular momentum of any physical system

Tetryonic Matter

3D topology

planar spatial Impedance

Planck quanta

$$T\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

ElectroMagnetic 2D mass velocity

Planck quanta

$$\left[m\Omega v\right]^2$$

mass velocity

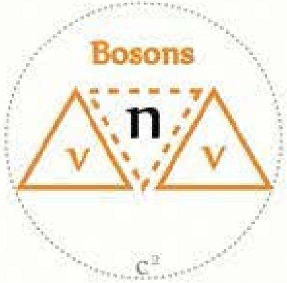
Bosons
v
n
v
c^2

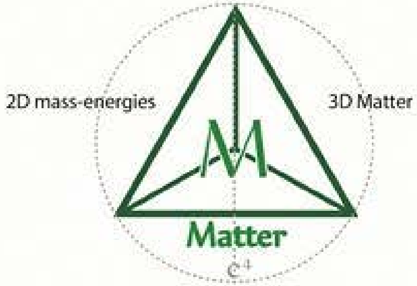
2D mass-energies
3D Matter
M
Matter
c^4

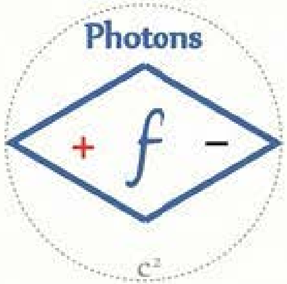
Photons
+
f
–
c^2

$$1\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

ODD quanta

$$4n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

TETRYONS

$$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

EVEN quanta

EM mass-Energy momenta

Planck's Constant

is the 'quantum of Action'

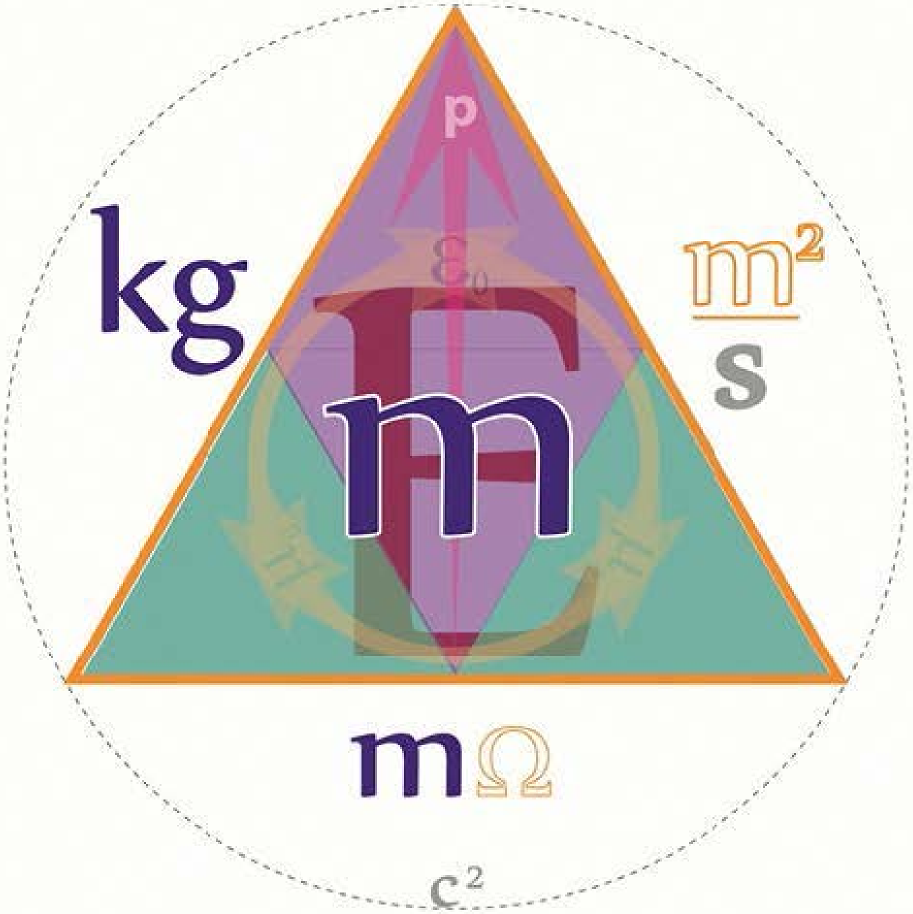

Energy

$$\left[\frac{m\Omega v^2}{s}\right]$$

E

6.629432672 e-34 J

mass-Energy

7.376238634 e-51 kg

m

$$\left[\frac{E}{c^2}\right]$$

mass

quantised angular momenta

$$\left[\frac{m^2}{s}\right]$$

Ω

0.0012 m2/s

Charge-momenta

1.33518 e-20 s

s

$$\left[\frac{\Omega}{c^2}\right]$$

charge

$6.629432672 \times 10^{-34}$ J.s

mass momenta

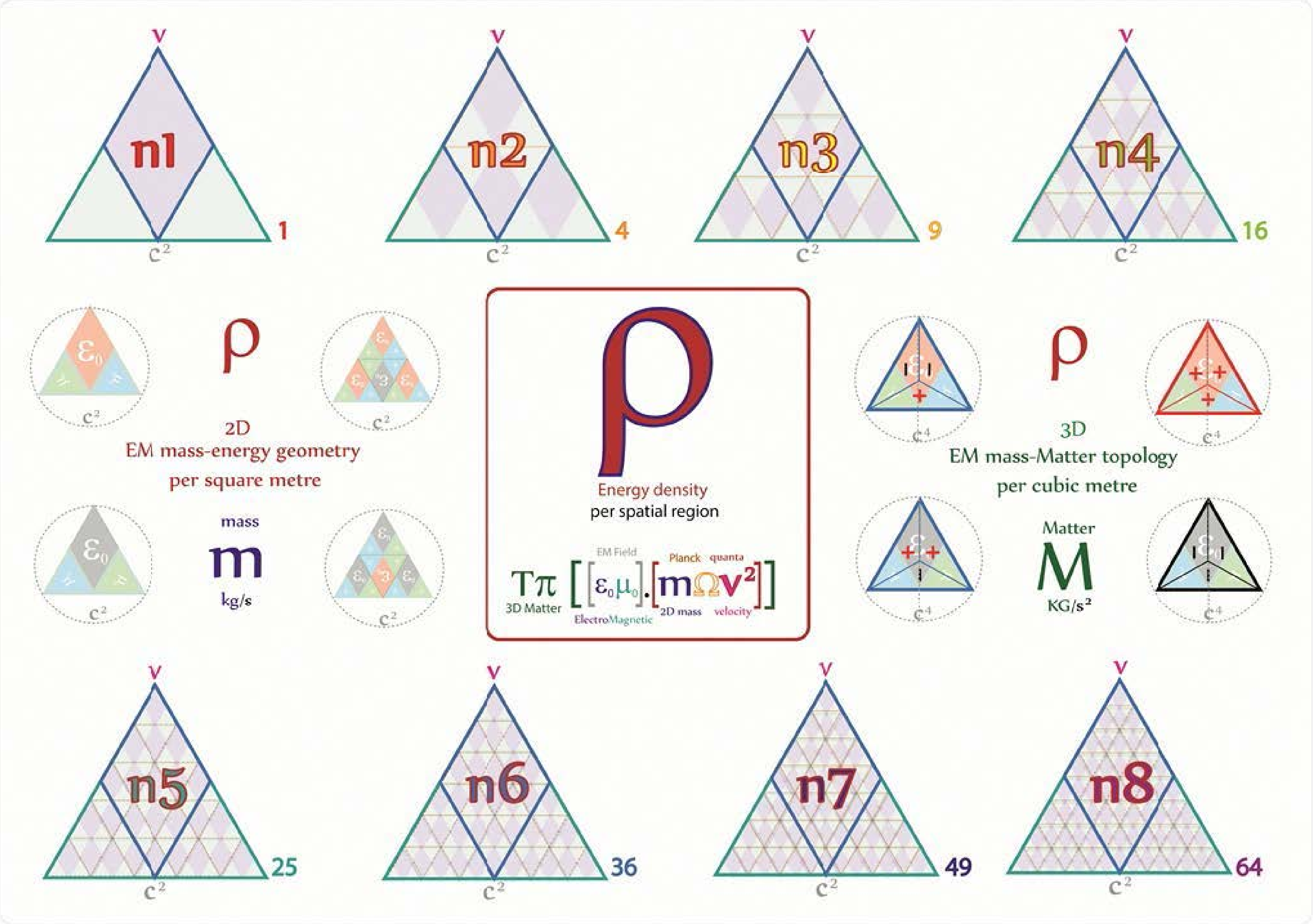
v
n1
1
c²
v
n2
4
c²
v
n3
9
c²
v
n4
16
c²
ρ
c²
c²
mass
m
kg/s
c²
c²
ρ
c⁴
c⁴
Matter
M
KG/s²
c⁴
c⁴
v
n5
25
c²
v
n6
36
c²
v
n7
49
c²
v
n8
64
c²

2D
EM mass-energy geometry
per square metre

ρ

Energy density
per spatial region

$$T\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

EM Field
Planck
quanta
3D Matter
ElectroMagnetic
2D mass
velocity

3D
EM mass-Matter topology
per cubic metre

Tetryonics 02.22 - Energy density [Rho]

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Zero Point Fields [ZPFs]

IDEAL QUANTUM INDUCTORS
(equilateral triangle Energy geometry)

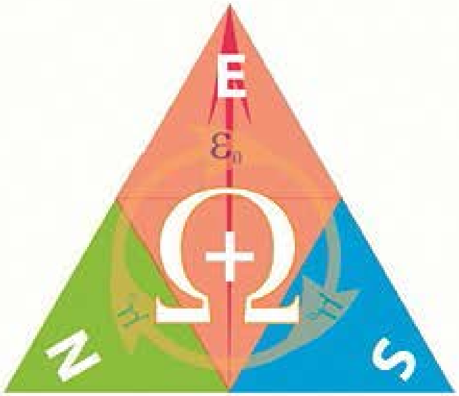

ZPFs are quantum inductive tank circuits
(Short-circuited 'IDEAL' inductors with energy)
ZPFs charge energies do NOT oscillate
[The magnetic dipole vector determines charge]

The EM FIELD

Electric flux fields can propagate in any direction
Magnetic fields are always at 90 degrees to Electric fields

Magnetic dipole fields propagate in 2 directions at
180 degrees to each other (bi-directionally)
forming North and South poles

Electric flux field energy is directly proportional to the resultant Magnetic dipole field energy and vice versa

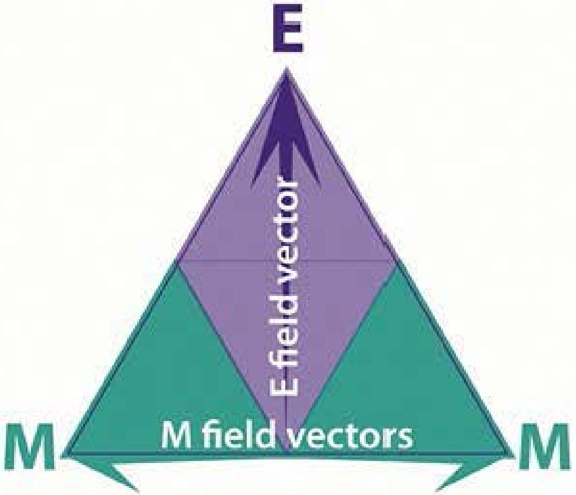

The linear Electric field strength is directly
proportional to its associated transverse
Magnetic field which propagates bi-directionally
from & into the bloch wall of the Zero point field

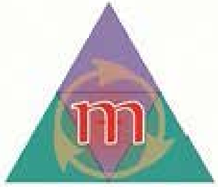

h

Positive Charge ZPF

Nett positive Planck quanta
with North-South m-dipole vector

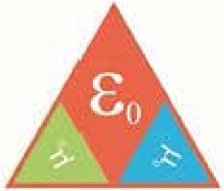

Zero Point Fields consist of
Electric and Magnetic (EM) fields
propagating at 90 degrees
to each other

Magnetic MONOPLES do NOT exist

Energy quanta always form charged Electric fields and dipole Magnetic fields

As localised energy quanta increases
(number of ZPFs per time unit)
the charge geometry remains the same

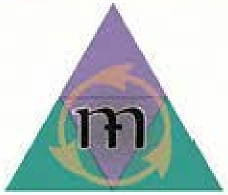

h

Negative Charge ZPF

Nett negative Planck quanta
with South-North m-dipole vector

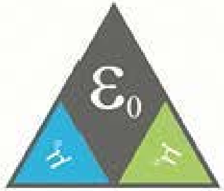

$$mv^2 = E$$

Quantised Angular Momentum

is the equilateral geometry of scalar energy momenta per unit of time

$$E = hv^2$$

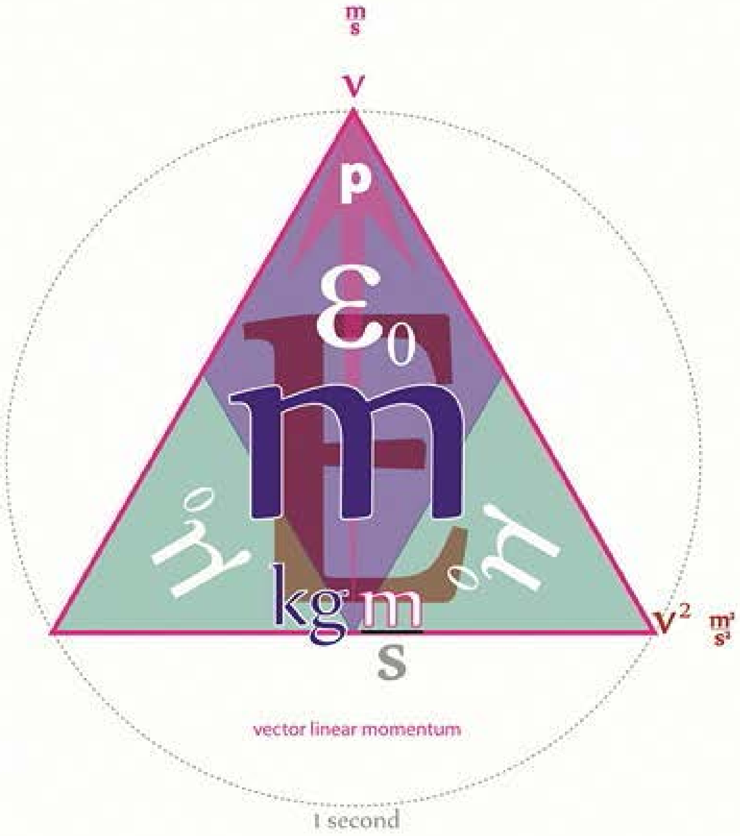

$\frac{m}{s}$
v
p
ε_0
E
m
μ_0
μ_0
kg $\frac{m}{s}$
v^2 $\frac{m^2}{s^2}$

vector linear momentum

1 second

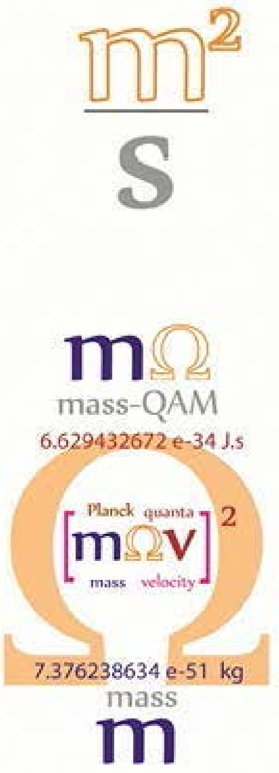

$\frac{m^2}{s}$
mΩ
mass-QAM
6.629432672 e-34 J.s
Planck quanta
$[m\Omega v]^2$
mass velocity
7.376238634 e-51 kg
mass
m

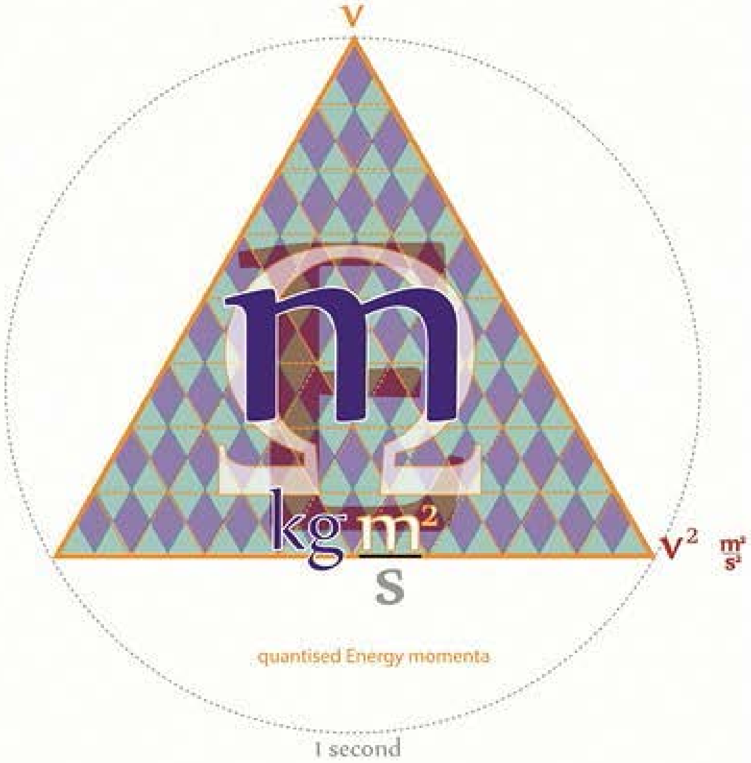

v
Ω
E
m
kg $\frac{m^2}{s}$
v^2 $\frac{m^2}{s^2}$

quantised Energy momenta

1 second

p

linear momentum

kg $\frac{m^2}{s}$

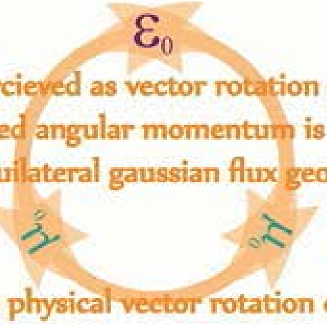

ε_0
μ_0
μ_0

Normally percieved as vector rotation about a point
quantised angular momentum is actually
an equilateral gaussian flux geometry

(there is no physical vector rotation component)

h

Planck's Constant

kg $\frac{m^2}{s}$

Charged mass & Matter in motion

produce differing but related measurments of EM force

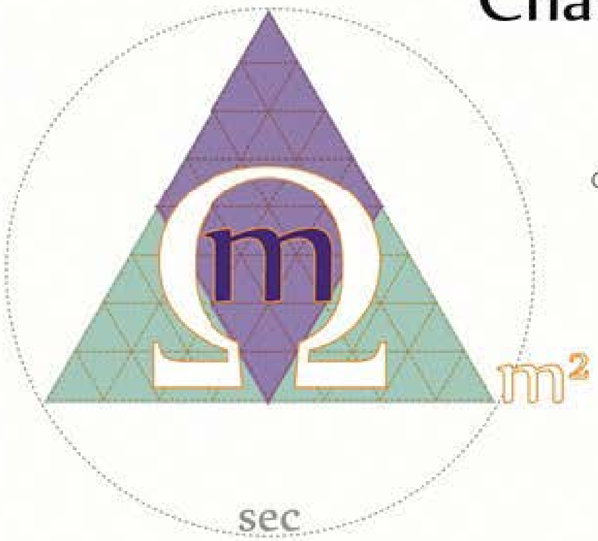

Charged masses per second $\frac{C}{s} \approx kg \approx A$ Charged Matter in motion

Amperes

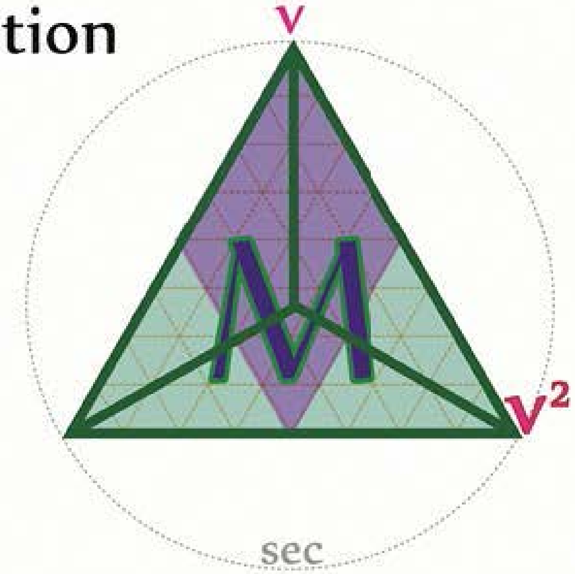

By definition in Tetryonics the quantised angular momentum of mass in any defined spatial co-ordinate system provides the quantum basis for

$$\boxed{kg \frac{m^2}{s}}$$

charged mass-energies

Quantised angular momenta creates CHARGE

Vector linear momentum creates CURRENT

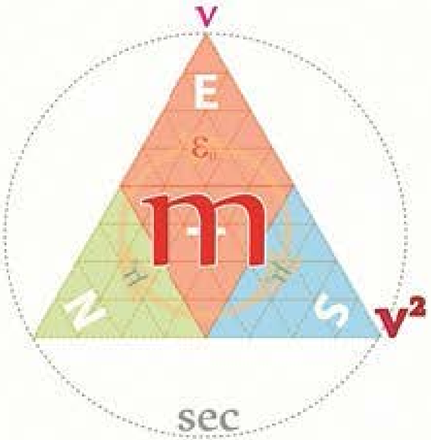

charged mass

$$C \approx kg.s \approx As$$

Coulombs

Amp.sec

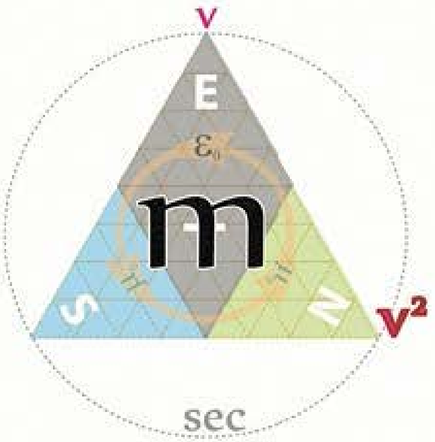

Charge, through its energy interactions, creates the geometric scaffolding for ALL 3D EM mass-Energy-Matter geometries

Charged mass geometry

The symmetry of Charge geometries provides a geometric foundation
for all mass-Energy-Matter particles and physical forces

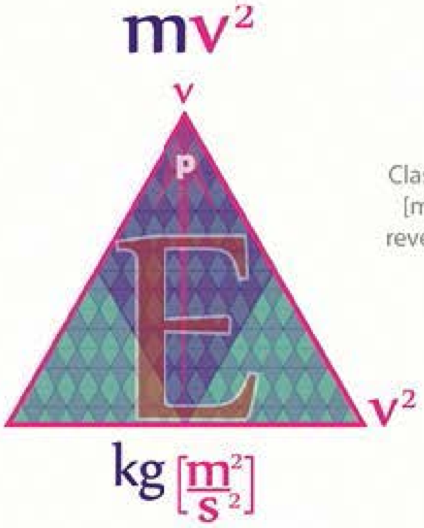

Classical analysis of Energy
[mass velocity] does not
reveal the nature of Charge

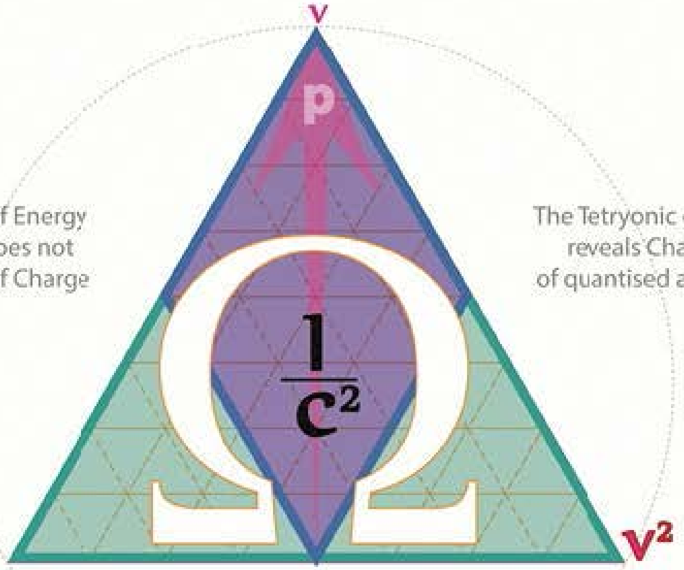

The Tetryonic geometry of Energy
reveals Charge as a product
of quantised angular momentum

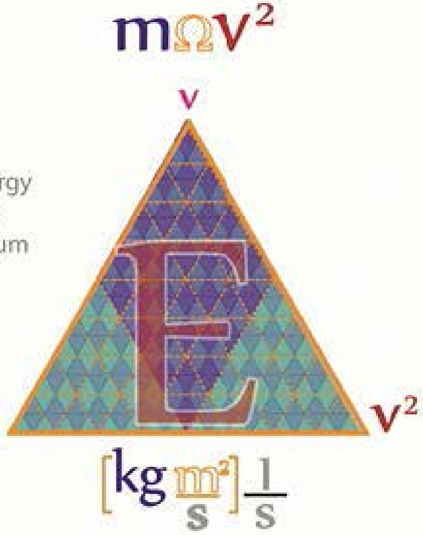

Charge is the result of quantised angular momentum
and can also be modelled electrically as the
uni-directional rotation of inductive energies

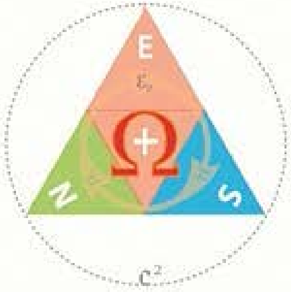

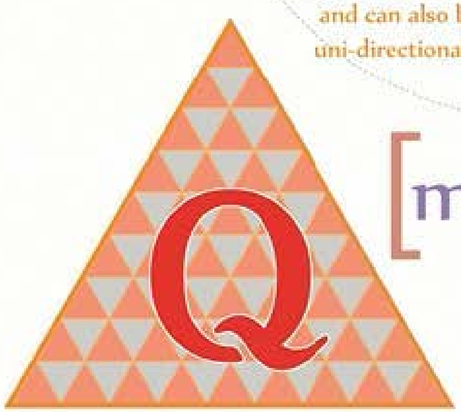

$$\left[m\left[\frac{\Omega}{c^2}\right]v^2\right]$$

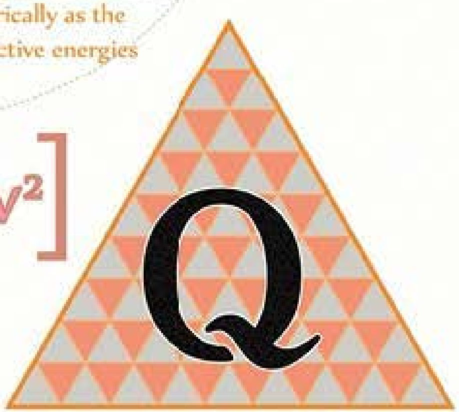

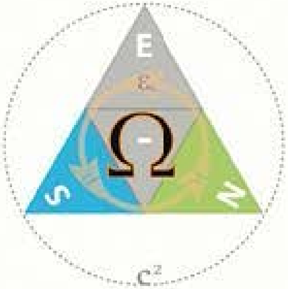

'a un-balanced (broken) energy symmetry resulting from
the nett geometry of equilateral EM mass-energy quanta'

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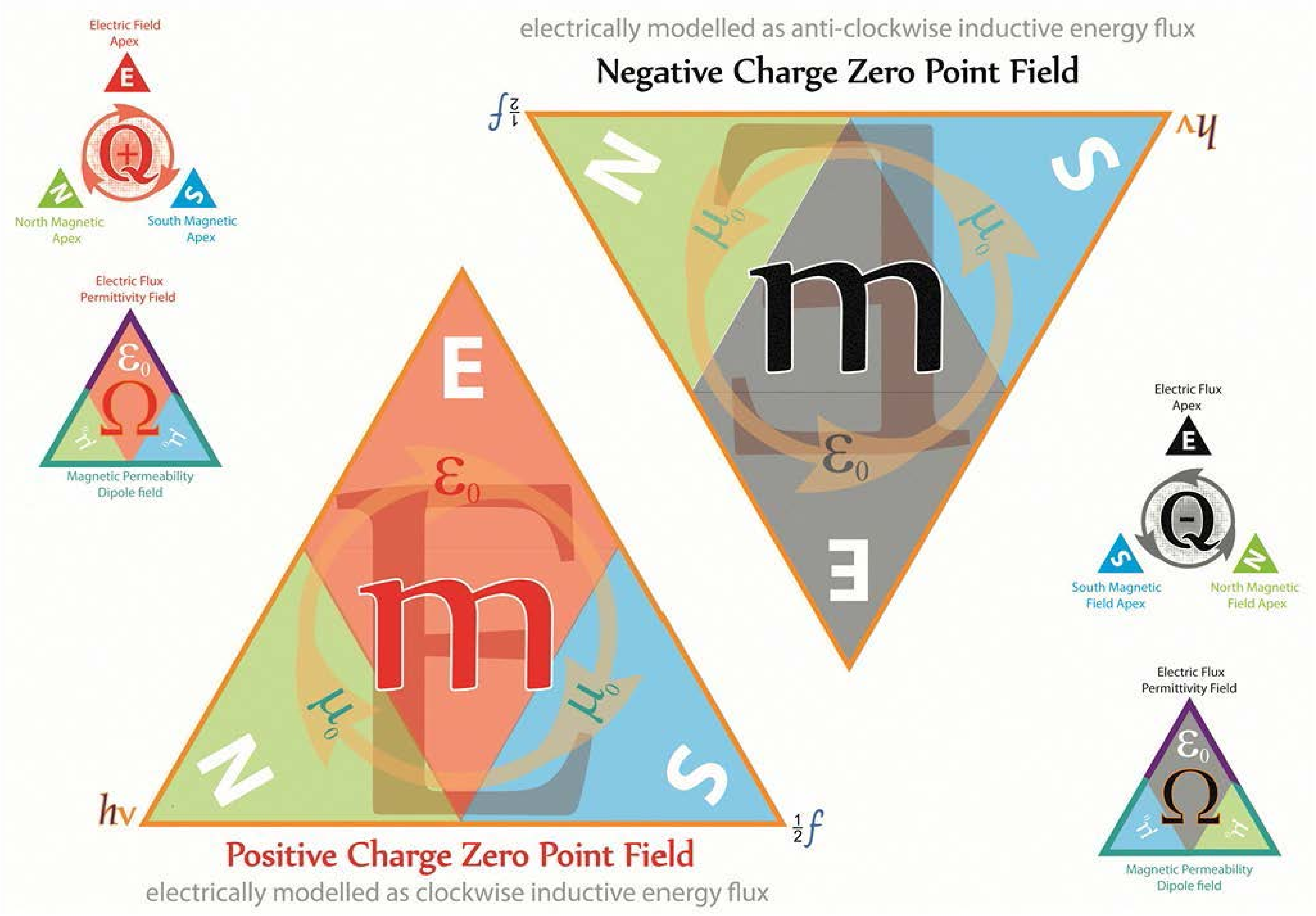

electrically modelled as anti-clockwise inductive energy flux

Negative Charge Zero Point Field

Positive Charge Zero Point Field

electrically modelled as clockwise inductive energy flux

Electric Field Apex
E
Q
+
N
S
North Magnetic Apex
South Magnetic Apex
Electric Flux Permittivity Field
ε_0
Ω
μ_0
Magnetic Permeability Dipole field
$\frac{1}{2}f$
$h\nu$
N
S
μ_0
m
ε_0
E
E
ε_0
m
μ_0
N
S
$h\nu$
$\frac{1}{2}f$
Electric Flux Apex
E
Q
-
S
N
South Magnetic Field Apex
North Magnetic Field Apex
Electric Flux Permittivity Field
ε_0
Ω
μ_0
Magnetic Permeability Dipole field

Elementary and quantum Charges

" All known Fermions have charge topologies that are integer 1/3 multiples of the elementary charge "

ε_0
Ω
μ_0
μ_0

It can be shown that the "quantum of charge"
Is the Intrinsic angular momentum of a Planck mass

It then follows that Quasi-particles
[Tetryons and Quarks]
have charge topologies with nett charges of 0, 4 and 8

Further, It can be shown that the "elementary charge"
applied to Leptons and Baryons (12 times quantum charge)
Is reflective of their nett charged Matter topologies

topology *charge*

$$T\pi[\pm q]$$

geometry

Zero Point Fields

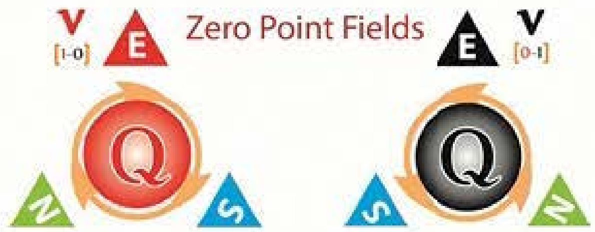

All Charged particles and their respective KEM fields
can be modelled with ZPF field geometries
reflective of their nett Charge topologies

Opposites attract
Similars repel

Quarks

up **anti-down** **down** **anti-up**

Charmed Top	Strange Bottom	Strange Bottom	Charmed Top

Leptons

Positron	neutrino	Muon
Tau anti-electron	Tau neutrino	Tau

Baryons

Proton **Neutron** **Negatron**

quantised Charges

(EM energy flux rotation
within a ZPF geometry)

q
quantum charges

[v] [v]

The elementary charge, usually denoted as e,
is the electric charge carried by a single proton,
or equivalently,
the absolute value of the electric charge
carried by a single electron

[v-v]

Q
Elementary charges

Elementary Charges

are the nett charge created
by mass-energy-Matter
topologies

Tetryons

4	0	4
[4-0]	[2-2]	[0-4]

Quarks

up	down	down	up
8	4	4	8
[10-2]	[8-4]	[4-8]	[2-10]

12	0	0	12
[12-0]	[6-6]	[6-6]	[0-12]
e	νe	νe	e

Leptons

Baryons

Proton	Neutron	Negatron
12	0	12
[24-12]	[18-18]	[12-24]

All Charges seek Equilibrium

Sir Issac Newton

(25 December 1642 – 20 March 1727)

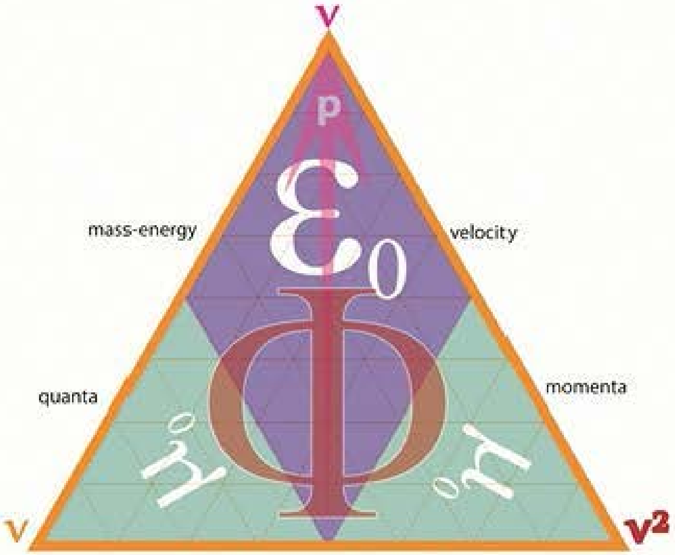

Any changes to velocity
result in changes to Energy-momenta
within a charged geometry

$$\sum \mathbf{F} = 0 \Rightarrow \frac{d\mathbf{v}}{dt} = 0$$

Newton's first law of motion says:
"A body maintains the current state of motion unless acted upon by an external force."

$$F = ma$$

Inertia is the resistance of any physical object to a change in its state of motion or rest, or the tendency of an object to resist any change in its motion.

It is proportional to an object's mass.

Ideal Inductive loops (ZPF quanta) will oppose ANY changes to their energy levels and consequently, Inertia can be viewed as an outcome of quantum ZPF self-Inductance

↑ [v-v] ↓
+

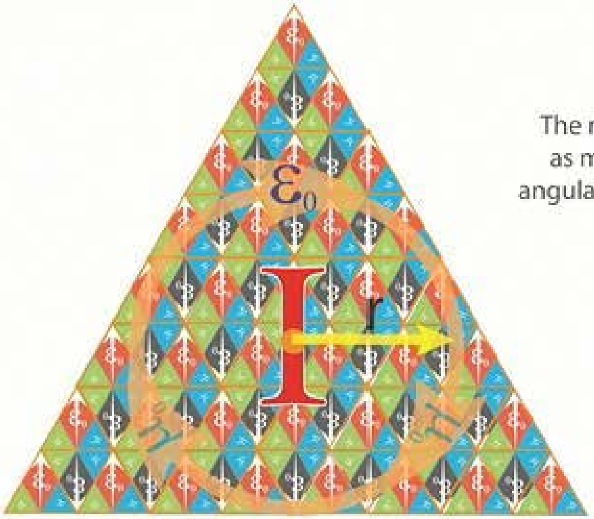

Inertia

The moment of inertia plays much the same role in rotational dynamics as mass does in linear dynamics, describing the relationship between angular momentum and angular velocity, torque and angular acceleration, and several other quantities

The difference between the impeding (inertial) linear momenta and the co-linear (supportive) momenta is a result of the nett Planck mass-energy momenta within the charged geometries of Matter & its KEM fields

↓ [v-v] ↑
−

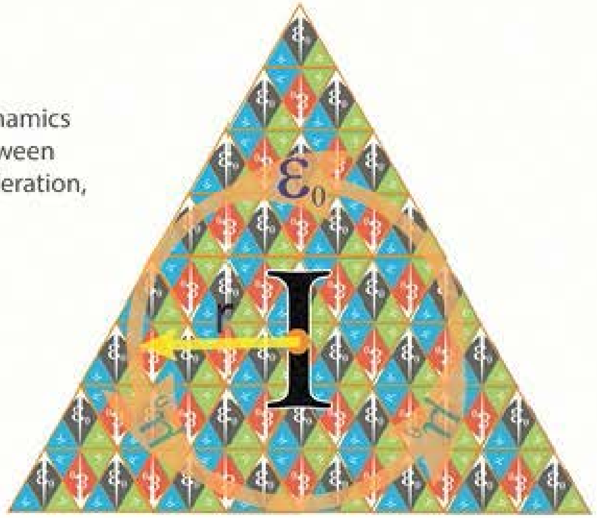

Planck Quanta

are often defined as the "quantum of action"

h

Planck's Constant

$kg\frac{m^2}{s}$

The Planck constant (denoted h), is a geometric constant resulting from QAM in quantum mechanics

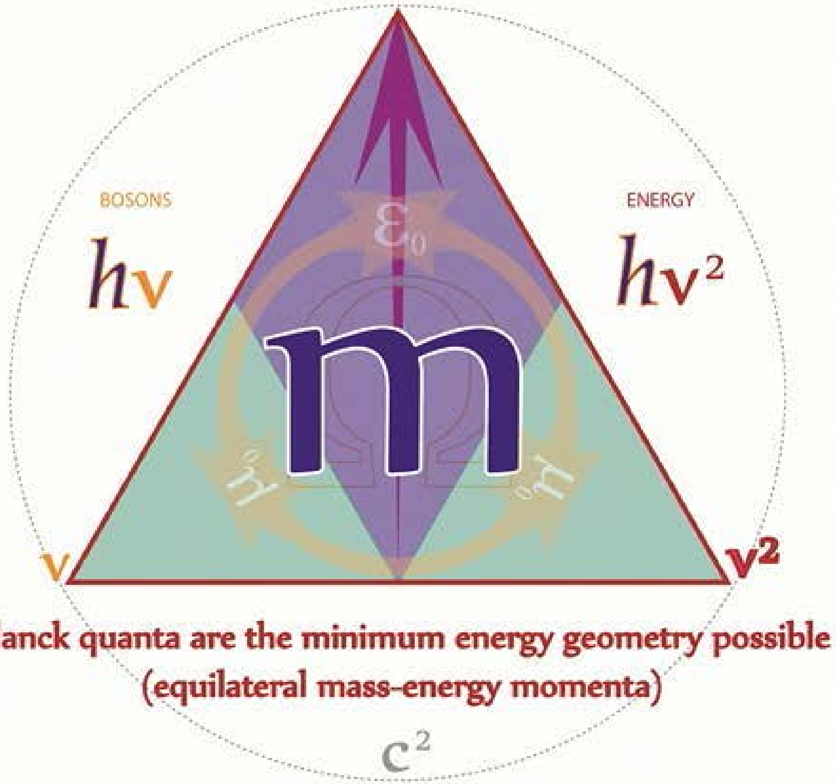
BOSONS
hv
ENERGY
hv²
ε₀
m
v
v²
c²

Planck quanta are the minimum energy geometry possible (equilateral mass-energy momenta)

Charge is a result of QAM geometry

quantised angular momentum is the result of equilateral geometry

rotational
Angular
momentum

$\approx$

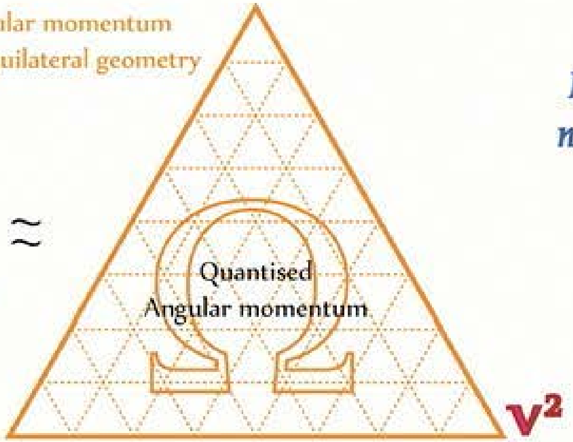
Quantised
Angular momentum
v²

hv

$m\Omega v^2$

Planck quanta per second

$kg.\left[\frac{m^2}{s}\right].s^{-1}$

Planck's constant relates the energy in one quantum (photon) of electromagnetic radiation to the frequency of that radiation

Photons have neutral quanta geometry

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$E = n.hv$

Planck Number

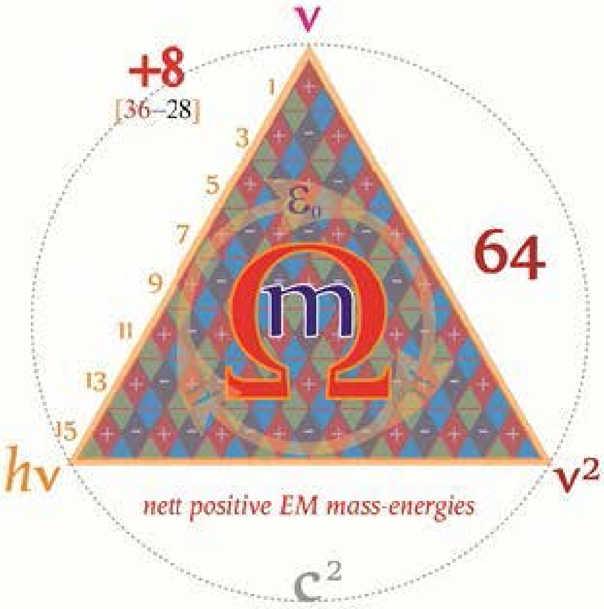
v
+8
[36–28]
1
3
5
7
9
11
13
15
ε_0
m
Ω
64
hv
v²
c²

nett positive EM mass-energies

hv

tranverse
Bosons

Max Planck

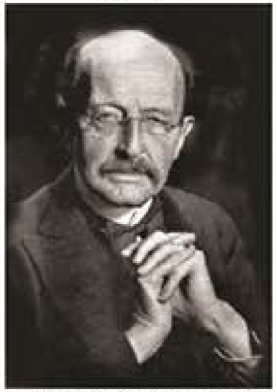

(April 23, 1858 – October 4, 1947)

hf

longitudinal
Photons

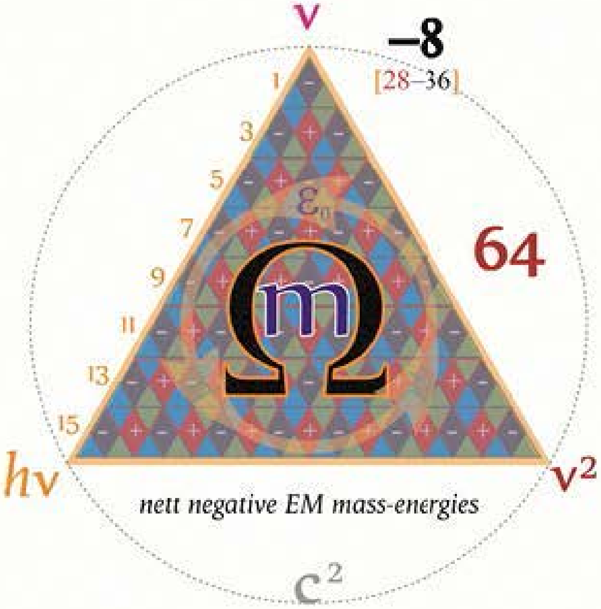
v
–8
[28–36]
1
3
5
7
9
11
13
15
ε_0
m
Ω
64
hv
v²
c²

nett negative EM mass-energies

$1e19v = n = 5e18f$

quantum number

BOSONS
are the quanta of Charge

EM Field · Planck · quanta

$1\pi\,[[\varepsilon_0\mu_0].[m\Omega v^2]]$

Boson · ElectroMagnetic · mass · velocity

Equating **nu**mber of quanta
is the source of a number

$hv \neq hf$

Planck Einstein

EM Field · Planck · quanta

$2\pi\,[[\varepsilon_0\mu_0].[m\Omega v^2]]$

Photon · ElectroMagnetic · mass · velocity

to photon **f**requency
of quantum misconceptions

PHOTONS
are the neutral quanta of EM waves

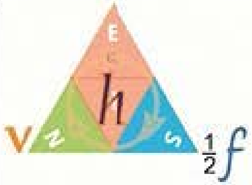
E
h
v
N
S
$\frac{1}{2}f$

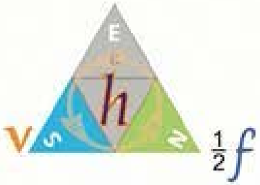
E
h
v
S
N
$\frac{1}{2}f$

The Planck constant was first described as the proportionality constant between
the energy (E) of a photon and the frequency (v) of its associated electromagnetic wave.
[it in fact describes the energy of bosons]

***The zero-point energy for a
simple harmonic oscillator of frequency f
is ½ hf***

The relation between the energy and frequency is called the Planck–Einstein relationship.

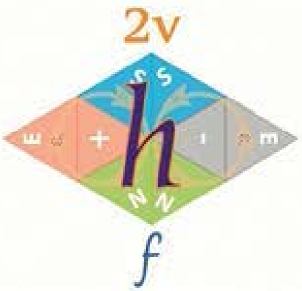
2v
S
S
E
+
h
–
E
N
N
f

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Quantum Inductors

+ ZPF

A positive ZPF can
be viewed as a quantun quoin
or an quantum 'ideal' inductor
with an internalised energy flux
that is the opposite of
a negative ZPF

Clockwise current flow

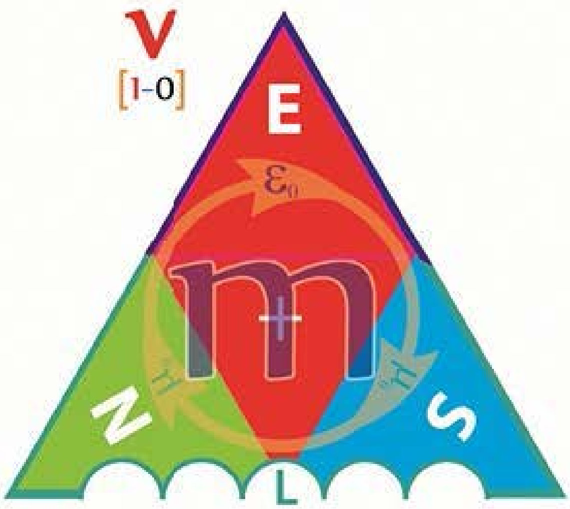

POSITIVE

Quantum L circuit
[quantum inductive circuit]

An "ideal inductor" has inductance,
but no resistance or capacitance, and will not dissipate energy
(until it interacts with other ZPFs or Matter) and forms the basis for
all Charge-Parity-Time [CPT] interactions

A ZPF is fixed in either a + or - state
[Quantum Inductor circuit]

Its energy flux direction as modelled electrically] is relative
to the observer's view or the direction of measurement

Charge polarity is opposed on opposite faces
of the same quoin [quantum coin]

The direction of inherent energy flux
from the presective of the observer
determines ZPF charge polarity

The Quantum Inductor (L) circuit stores
energy as EM mass in π geometries,
it does not oscillate

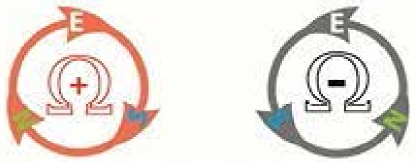

Energy received is stored indefinitely
until its release via weak interaction

[Inductive Magnetic coupling]

The quantum Inductive circuit
is a SINGLE charge tri-field inductive energy loop

It does not oscillate energy between two opposing charges
its differing energy fields are the reuslt of its equilateral QAM geometry
storing Electric energy in its E field, and Magnetic energy in its M field

The direction of the QAM flux that models inertia is relative
to the observer

- ZPF

A negative ZPF can
be viewed as a quantum quoin
or an quantum 'ideal' inductor
with an internalised energy flux
that is the opposite of
a positive ZPF

Counter-Clockwise
Current Flow

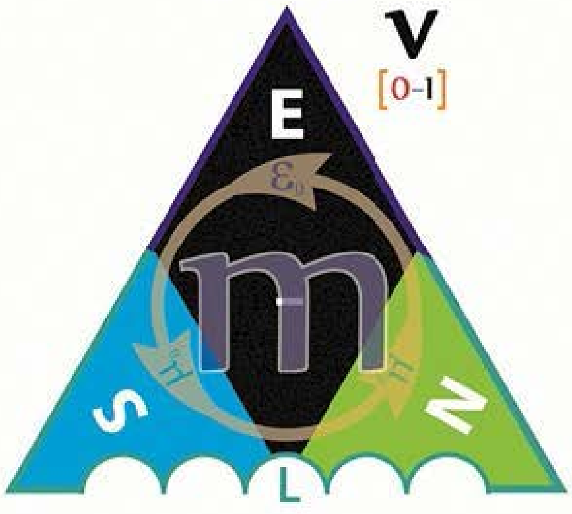

NEGATIVE

Quantum L circuit
[quantum inductive circuit]

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Quantum Inductors and EM energy Levels

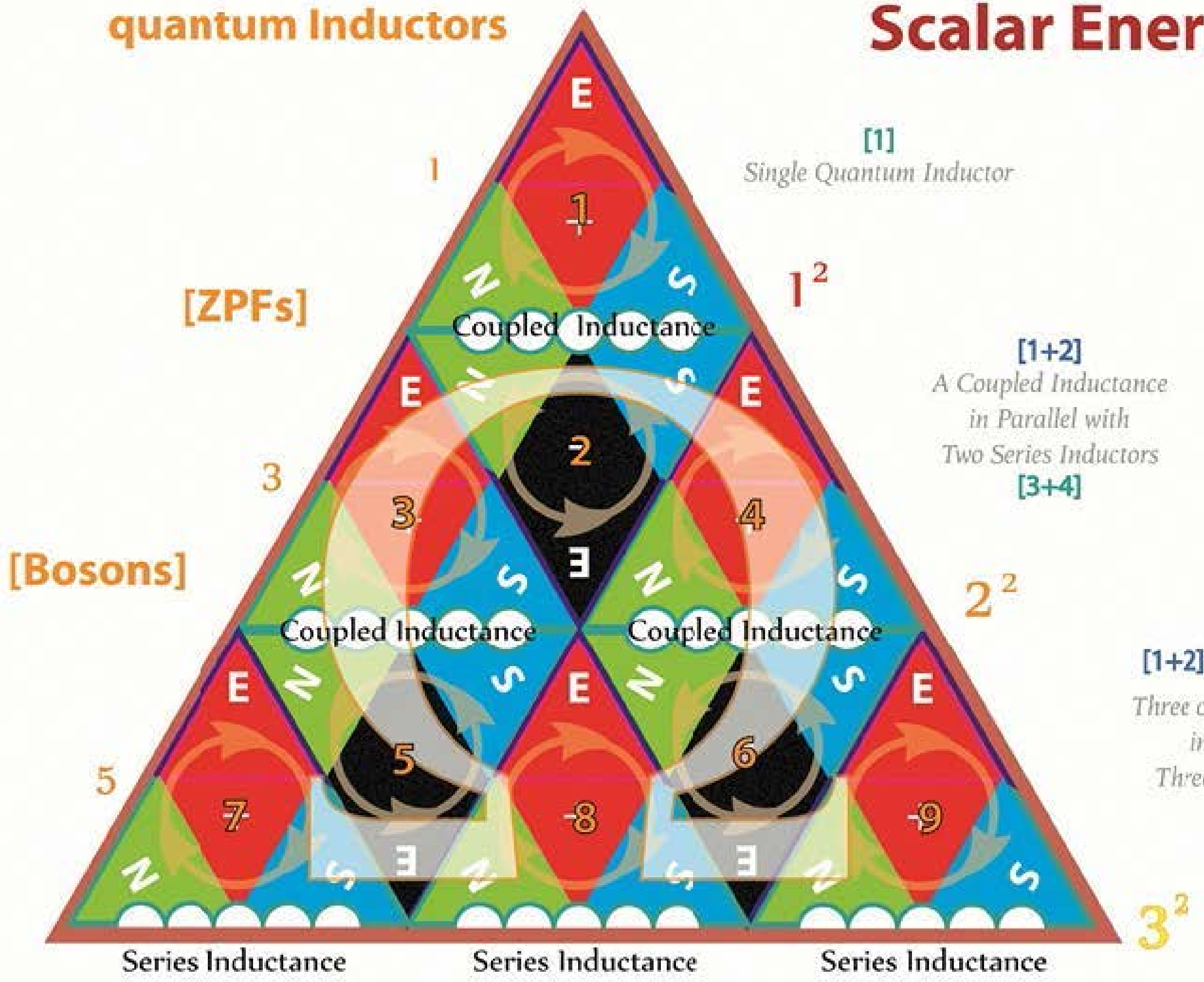
quantum Inductors
[ZPFs]
[Bosons]
1
3
5
1^2
2^2
3^2
E
1
N
S
Coupled Inductance
E
2
E
3
4
Coupled Inductance
Coupled Inductance
E
5
E
6
E
7
8
9
Series Inductance
Series Inductance
Series Inductance

Scalar Energies

[1]
Single Quantum Inductor

[1+2]
Coupled
Quantum Oscillator

[1+2]
A Coupled Inductance
in Parallel with
Two Series Inductors
[3+4]

E

[1+2] [3+5] [4+6]
Three coupled Inductances
in Parallel with
Three Series Inductors
[7+8+9]

All quantum levels form inductive magnetic dipole bases
[Weak Force]

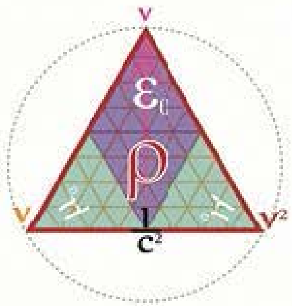
v
ε_0
ρ
μ_0
μ_0
v
v^2
$\frac{1}{c^2}$

coupled ODD# mass-energies
form SQUARE energy geometries

Quantum energy levels
can be viewed as
various combinations
of:

Coupled Inductances

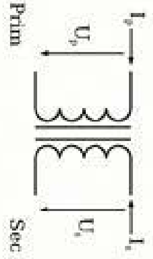
Prim
U_p
I_p
Sec
U_s
I_s

Parallel Inductances

$$L_{total} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \ldots \frac{1}{L_n}}$$

Series Inductances

$$L_{total} = L_1 + L_2 + \ldots L_n$$

The Golden Triangle

Charged mass-energy geometries

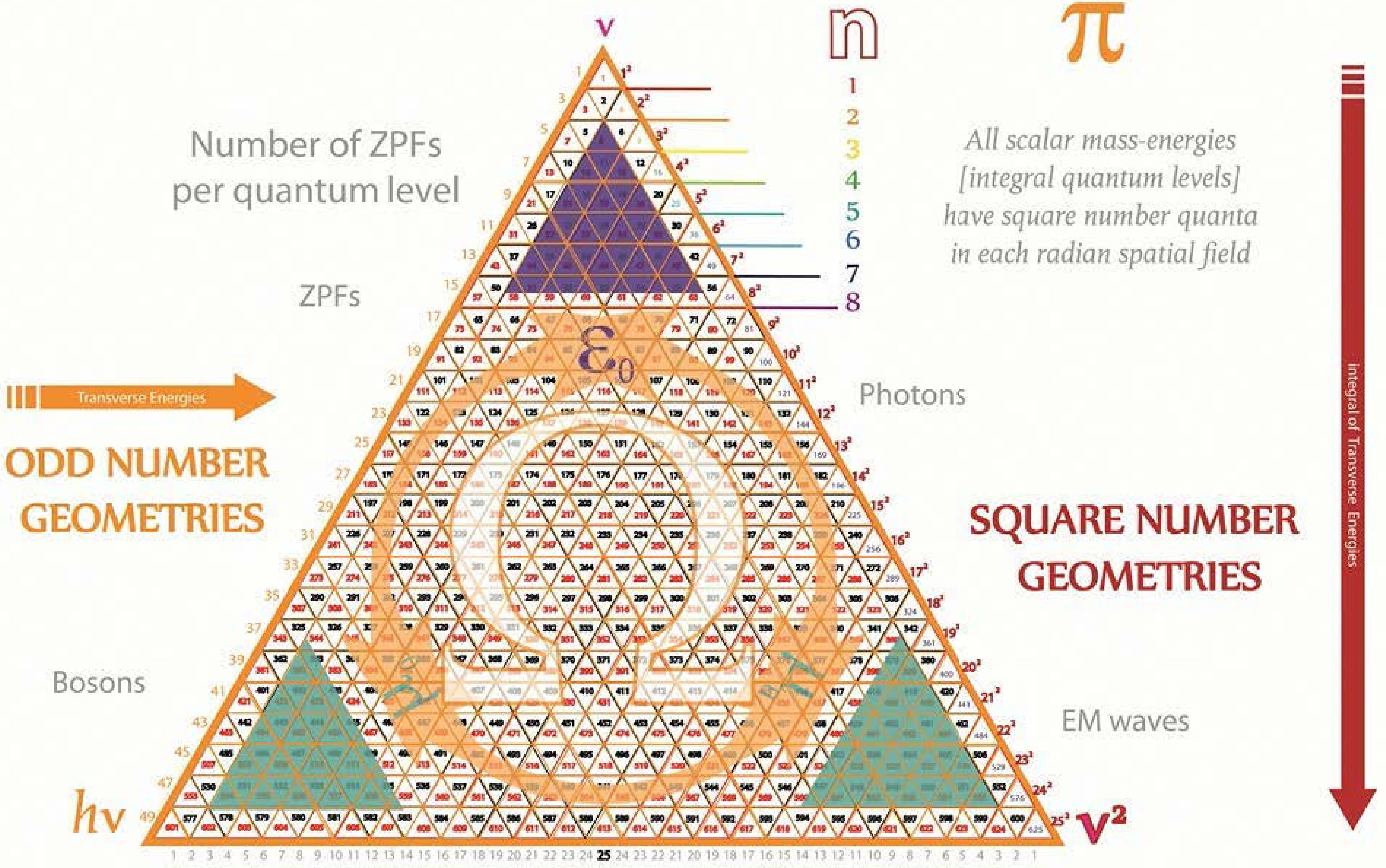
v
n
π
1
2
3
4
5
6
7
8
1^2
2^2
3^2
4^2
5^2
6^2
7^2
8^2
9^2
10^2
11^2
12^2
13^2
14^2
15^2
16^2
17^2
18^2
19^2
20^2
21^2
22^2
23^2
24^2
25^2
ε_0
ZPFs
Photons
Bosons
EM waves
Transverse Energies
Integral of Transverse Energies
hv
v^2
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Number of ZPFs
per quantum level

All scalar mass-energies
[integral quantum levels]
have square number quanta
in each radian spatial field

ODD NUMBER GEOMETRIES

SQUARE NUMBER GEOMETRIES

Probabilities **NORMAL DISTRIBUTIONS** Wavefunctions

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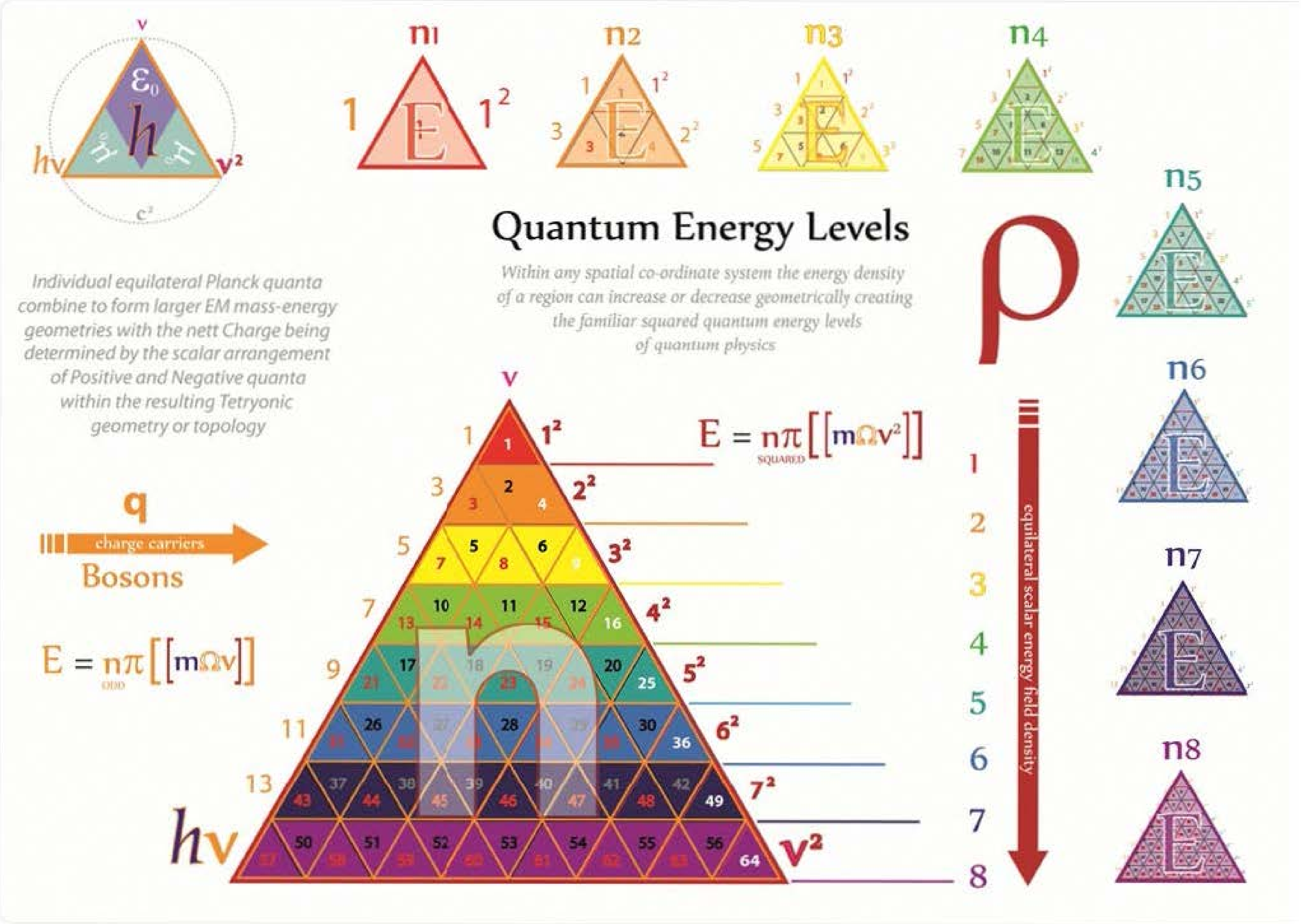
v
ε_0
h
hv
v²
c²
n1
n2
n3
n4
n5
n6
n7
n8
E
1
1²
3
2²
5
3²
7
4²
9
5²
11
6²
13
7²
ρ
q
charge carriers
Bosons
v
hv
v²
n
1
2
3
4
5
6
7
8
equilateral scalar energy field density

Quantum Energy Levels

Within any spatial co-ordinate system the energy density of a region can increase or decrease geometrically creating the familiar squared quantum energy levels of quantum physics

Individual equilateral Planck quanta combine to form larger EM mass-energy geometries with the nett Charge being determined by the scalar arrangement of Positive and Negative quanta within the resulting Tetryonic geometry or topology

$$E = \underset{\text{SQUARED}}{n}\pi\left[\left[m\Omega v^2\right]\right]$$

$$E = \underset{\text{ODD}}{n}\pi\left[\left[m\Omega v\right]\right]$$

Tetryonics 03.13 - Quantum Energy levels

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Magnetic Vectors

Intrinsic Magnetic vectors are transverse to E fields

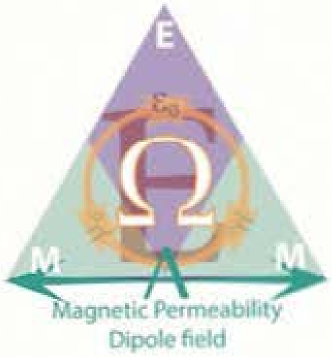
E
ε_0
Ω
M
M
A
Magnetic Permeability
Dipole field

External Magnetic fields are termed B fields

Opposite charges moving in opposing directions produce co-directional Magnetic vectors

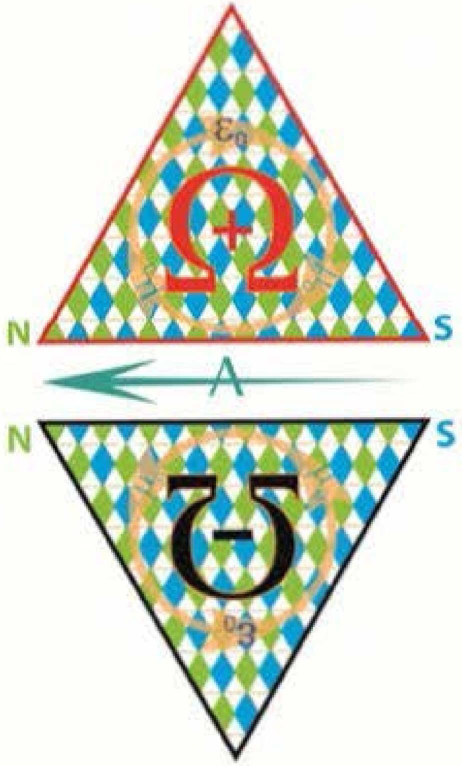
ε_0
Ω
+
N
S
A
N
S
-

Magnetic vectors can be modelled geometrically or electrically through energy field fluxes

[quantised angular momenta]

Within a Magnetic dipole

Magnetic Vector A

energy 'flows' South to North

External to a Magnetic dipole energy 'flows' North to South

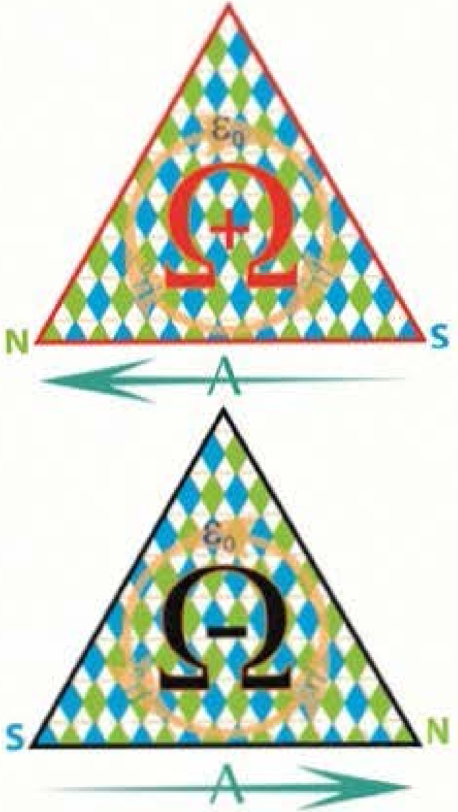
ε_0
Ω
+
N
S
A
ε_0
Ω
-
S
N
A

Opposite charges moving in the same direction produce Magnetic vectors in opposition

Charge Fields

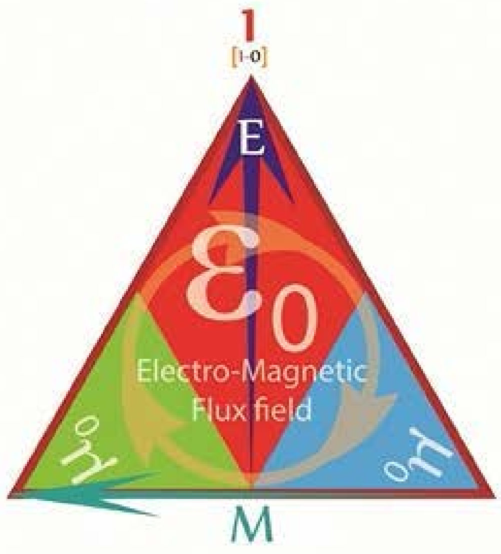
1
[1-0]
E
ε_0
Electro-Magnetic
Flux field
μ_0
μ_0
M

EM energy fluxes in a Positive ZPF flows
are electrically modelled as Clockwise
(from North to South)

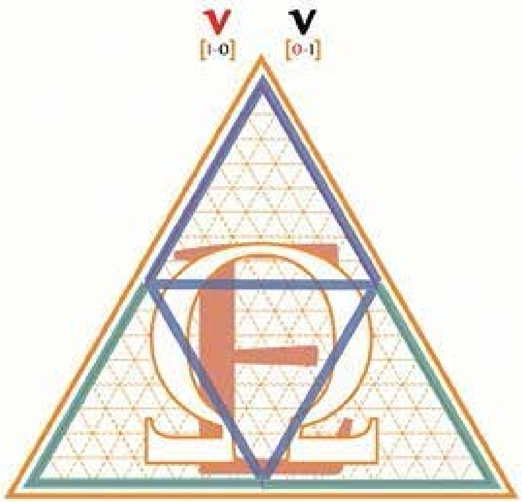

The EM flux directions of Charges
can be modelled vectorially with
Electric and Magnetic vectors

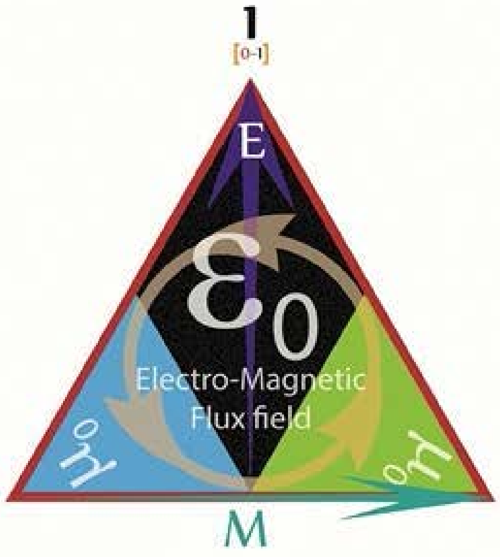
1
[0-1]
E
ε_0
Electro-Magnetic
Flux field
μ_0
μ_0
M

EM energy fluxes in a Negative ZPF
are electrically modelled as counter-Clockwise
(from North to South)

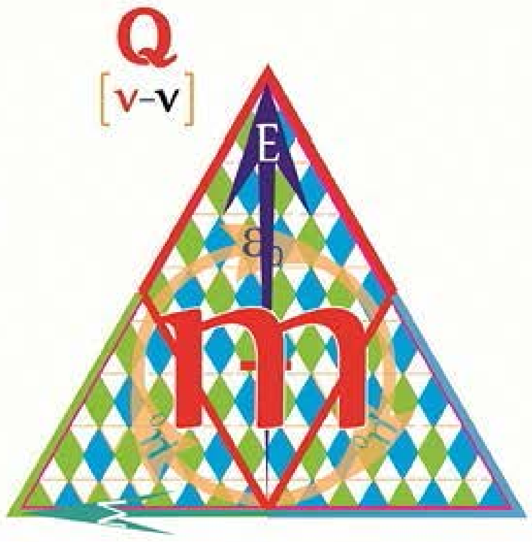
Q
[v-v]
E
ε_0
m
μ_0
μ_0

*All rotational planck energy fluxes
can serve as models for the nett
quantised angular momenta of
any mass-energy geometry*

Polarised
Electric and Magnetic fluxes
in ElectroMagnetic fields arise from
intrinsic quantised angular momentum

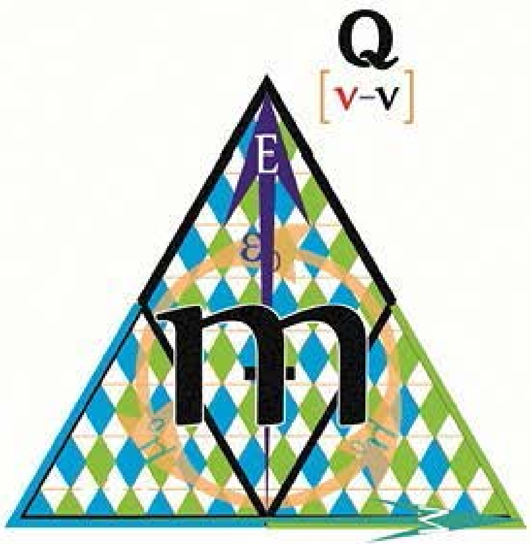
Q
[v-v]
E
ε_0
m
μ_0
μ_0

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EM fields

are the combined Electric & Magnetic fields
resulting from the quantised angular momentum
of mass-energy in any region of free space

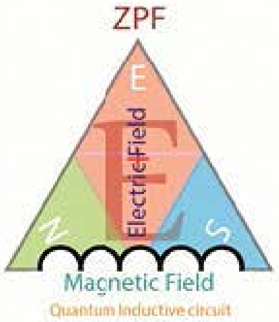
ZPF
E
F
Electric Field
N
S
Magnetic Field
Quantum Inductive circuit

$$\varepsilon_0\mu_0 = \frac{1}{c^2}$$

EM Permittivity-Permeability is a measure of how much resistance
is encountered when the quantised angular momenta of
EM energies form an electro-magnetic field in a vacuum

Celeritas = 299,792,458 $\frac{m}{s}$

$$c_0 = \frac{1}{\sqrt{\mu_0\varepsilon_0}}.$$

EM field Permittivity-Permeability

$$\varepsilon_0\mu_0 = 1.112650056\text{e-}17\ \frac{s^2}{m^2}$$

$$\left[\frac{A^2\ s^4}{kg\ m^3}\cdot\frac{kg}{A^2}\frac{m}{s^2}\right]$$

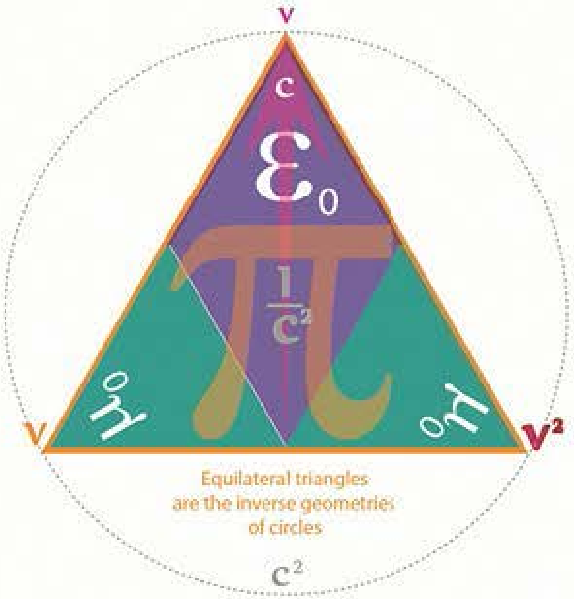
v
c
ε_0
π
$\frac{1}{c^2}$
μ_0
μ_0
v
v²
c²

Equilateral triangles
are the inverse geometries
of circles

$$\mathbf{m} = n\pi\,[\varepsilon_0\mu_0]\,[m\Omega v^2]$$

mass = charged Spatial geometry Energy density

Electric Constant

$$\varepsilon_0 = \frac{1}{\mu_0 c^2}$$

$$= 8.85418785\text{e-}12\ \frac{F}{m}\qquad \frac{A^2\ s^4}{kg\ m^3}$$

The permittivity of empty space, equal to 1 in centimeter-gram-second
electrostatic units and numerically, to 8.854 × 10-12 farad per meter
in International System units, where c is the speed of light in meters per second.
Symbolized ε0.

Magnetic Constant

$$k_0 = \frac{1}{4\pi\varepsilon_0}$$

$$= 1.25663706\text{e-}6\ \frac{H}{m}\qquad \frac{kg\ m}{A^2\ s^2}$$

A measure of the degree to which molecules of some material polarize (align)
under the influence of an electric field; symbol k0, units F/m (farads per metre).

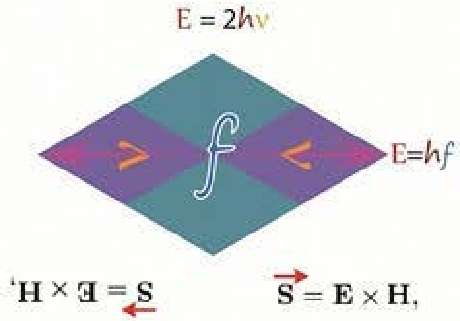
E = 2hν
f
E=hf
$\overset{\leftarrow}{\mathbf{S}} = \mathbf{E} \times \mathbf{H},$
$\vec{\mathbf{S}} = \mathbf{E} \times \mathbf{H},$

The Energy-momenta
of ZPFs form
natural Poynting vectors

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EM field Permittivity

The Electric constant, commonly called
the vacuum permittivity, or permittivity of free space,
relates the units for electric charge to
mechanical quantities such as
length and force.

The name Vacuum Permittivty is a misnomer and should be
replaced with the correct term EM field Permittivity

**The strength of Electric fields
is determined by the
Electrical Permittivity Constant**

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

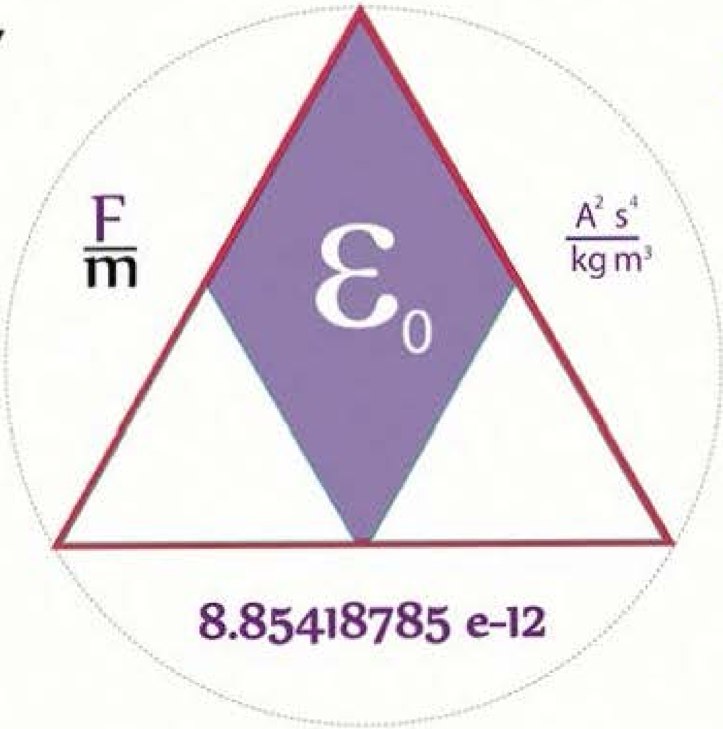

8.85418785 e-12

$$\varepsilon_0 = \frac{1}{\mu_0 c^2}$$

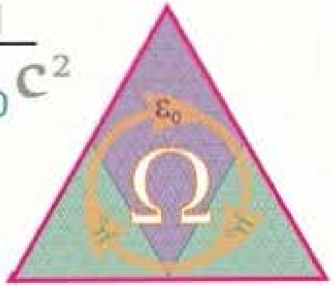

"Ampere's Law states that for any closed loop path, the sum of the quantities (B.ds) for all path elements into which the complete loop has been divided is equal to the product of μ0 and the total current enclosed by the loop."

$$k = \frac{1}{4\pi\varepsilon_0}$$

The permittivity of empty space, equal to 1 in centimeter-gram-second electrostatic units and to 107/4πc2 farads per meter or, numerically, to 8.854 x 10-12 farad per meter in International System units, where c is the speed of light in meters per second.

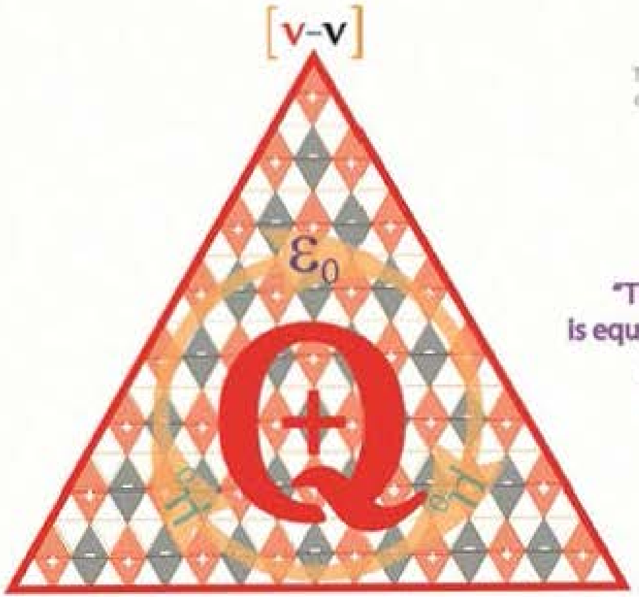

Positive Charge Electric Field

Gauss' Law:

**"The total of the electric flux out of a closed surface
is equal to the charge enclosed divided by the permittivity"**

This applies equally to any geometry chosen to
tessellate a surface area

Superpostioned E fields
gives rise to Coulomb Forces

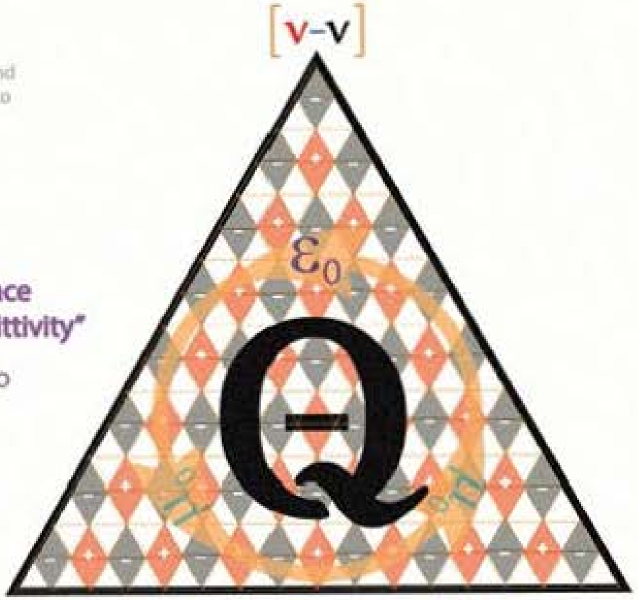

Negative Charge Electric Field

Electric permittivity Fields

Negative externalised Planck quanta
(Counter-clockwise energy fluxs)

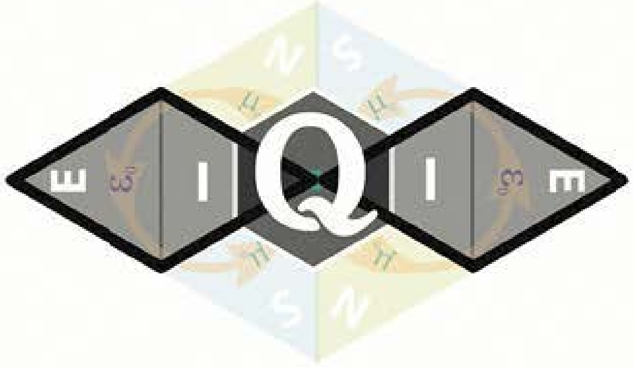

Positive externalised Planck quanta
(Clockwise energy fluxs)

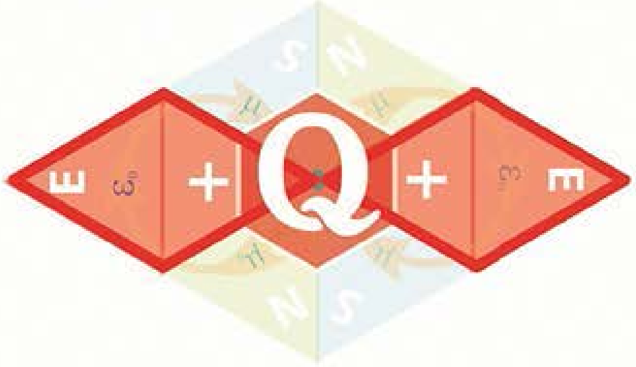

Coupled same charge ZPFs
have **neutralised** Magnetic fields

In Electro-statics superpositioned E fields
with interactive energy momenta
are the interactive mechanism
for Coulombic forces

Electrostatic Particles
in motion have Kinetic energies
resulting in Magnetic moments

Polar view

Negative
E-fields

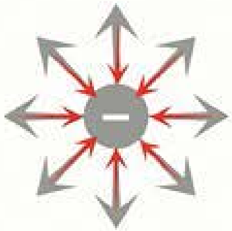

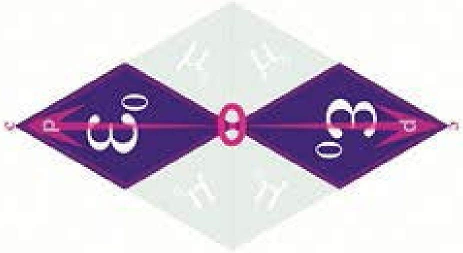

Polar view

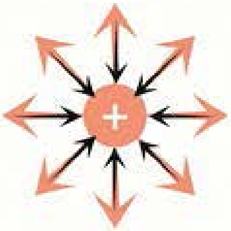

Positive
E-fields

NEGATIVE electrostatic E fields
attract positive charges and
repel negative charges

ε_0

POSITIVE electrostatic E fields
attract negative charges and
repel positive charges

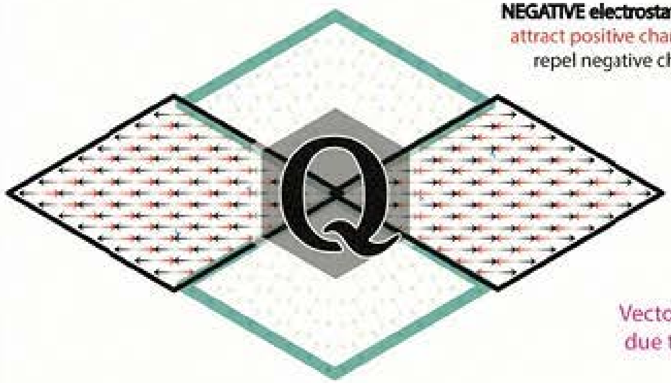

Opposites Attract
Similars Repel

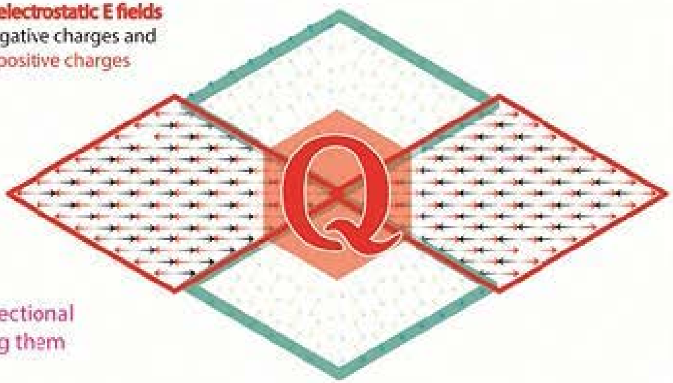

Vectorial momenta forces in EM fields are bi-directional
due to the energy-momenta quanta comprising them

The currently stated 'standard' premise of Electrical Energy flowing from Positive to Negative is misleading (as Energy also flows from Negative to Positive at the same time)

EM field Permeability

The permeability of free space,
also called absolute permeability.

The name Vacuum Permeability is a misnomer and should be replaced with the correct term EM field Permeability

The magnetic constant has the value of
4π × 10-7 henry per meter.

The strength of Magnetic fields is determined by the Magnetic Permeability Constant

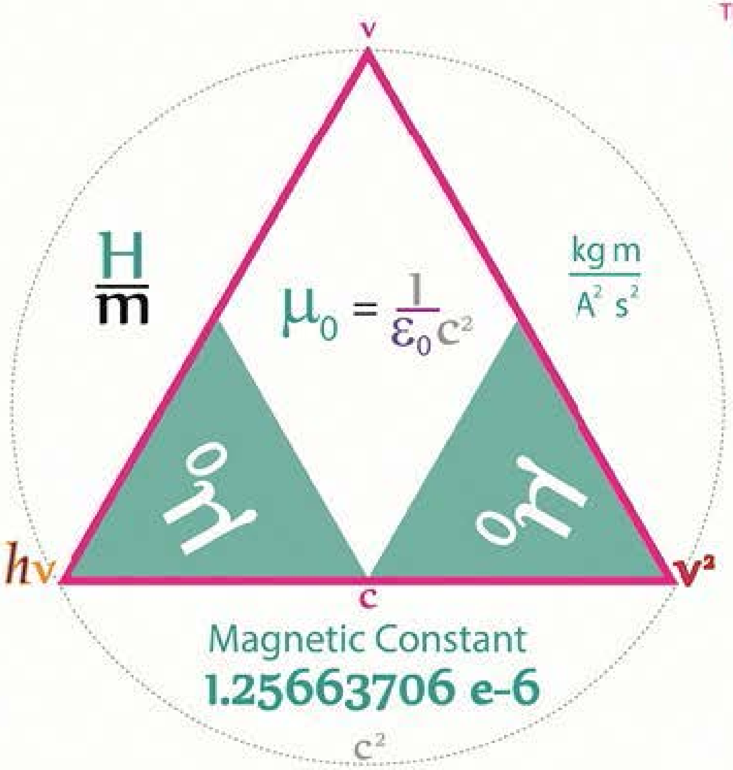

Magnetic Constant
1.25663706 e-6

F

The magnetic field is most commonly defined in terms of the Lorentz force it exerts on moving electric charges.

The magnetic field generated by a steady current (a constant flow of electric charges in which charge is neither accumulating nor depleting at any point) is described by the Biot-Savart law

μ_0

$$B = \mu_0 H$$

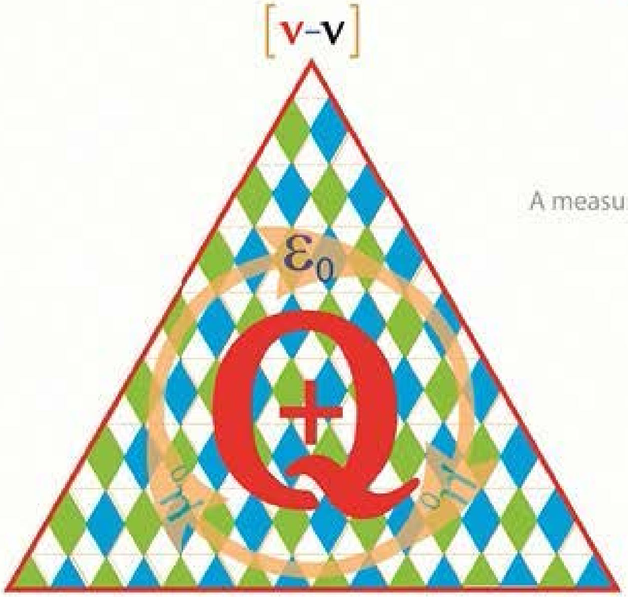

Positive Magnetic Moment

A measure of the degree to which molecules of some material polarize (align) under the influence of an electric field.

Measured in units of units H/m (Henries per metre).

There are NO magnetic monopoles
[not under any condition]

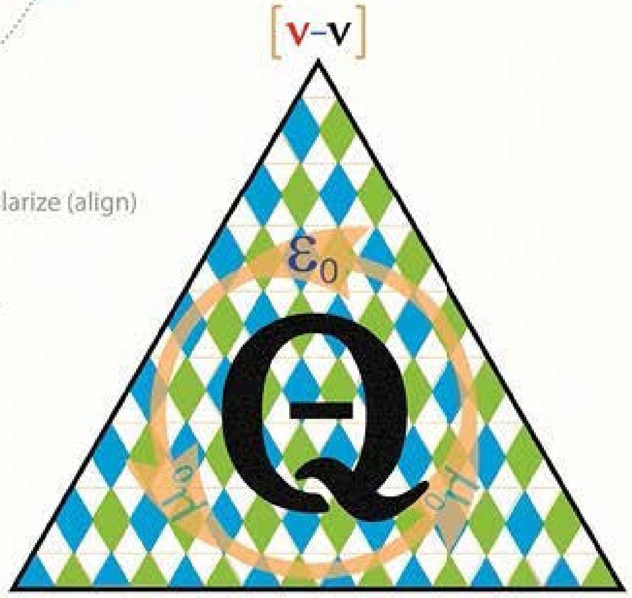

Negative Magnetic Moment

Magnetic permeability Fields

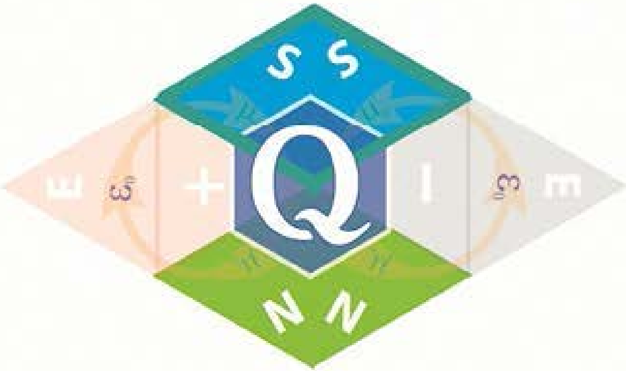
S S
Q
N N
+
-
E
E
ε_0
ε_0

Coupled opposite charge ZPFs
produce **neutralised** Electric fields

*In Magneto statics superpositioned M fields
with interactive energy momenta
are the interactive mechanism
for Lorentz forces*

Magneto-static Particles
have enhanced Magnetic moments

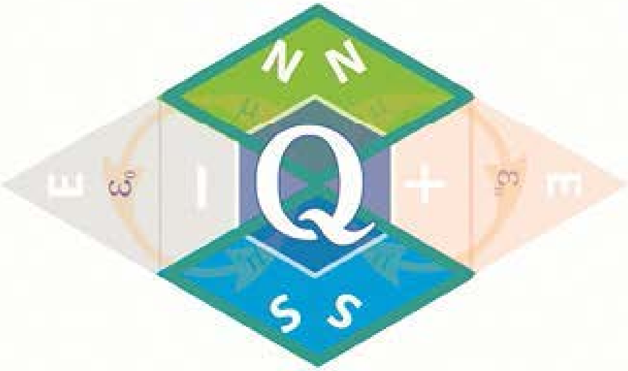
N N
Q
S S
-
+
E
E
ε_0
ε_0

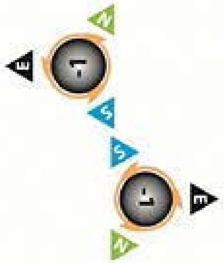

Amperes law

*Current flowing through a wire
will create a magnetic field*

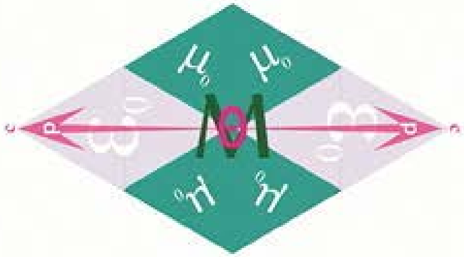
μ_0 μ_0
M
ε_0 ε_0
μ_0 μ_0

*magnetic field forces are
orthagonal to electric Coulomb forces*

Lorentz forces

*charged particles in motion are subject
to forces due to external EM fields*

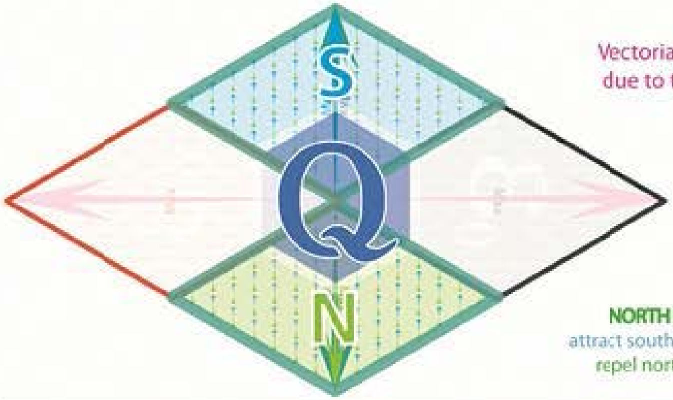

Vectorial momenta forces in EM fields are bi-directional
due to the energy-momenta quanta comprising them

*Opposites Attract
Similars Repel*

NORTH M- fields
attract south M-fields and
repel north M-fields

μ_0

SOUTH M- fields
attract north M-fields and
repel south M-fields

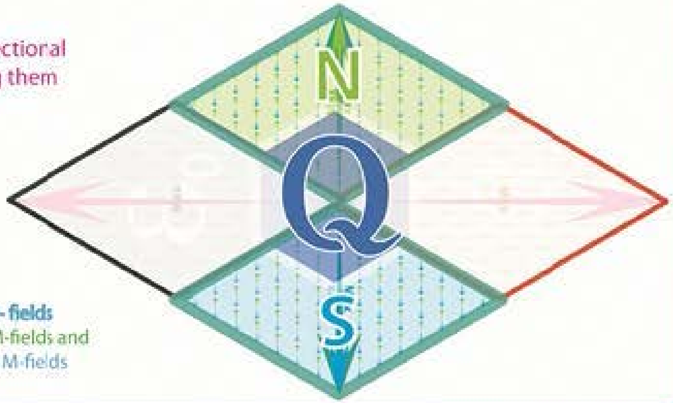

Magentic fields can only exist in conjuction with Electric fields & Electric fields can only exist in conjunction with Magnetic fields

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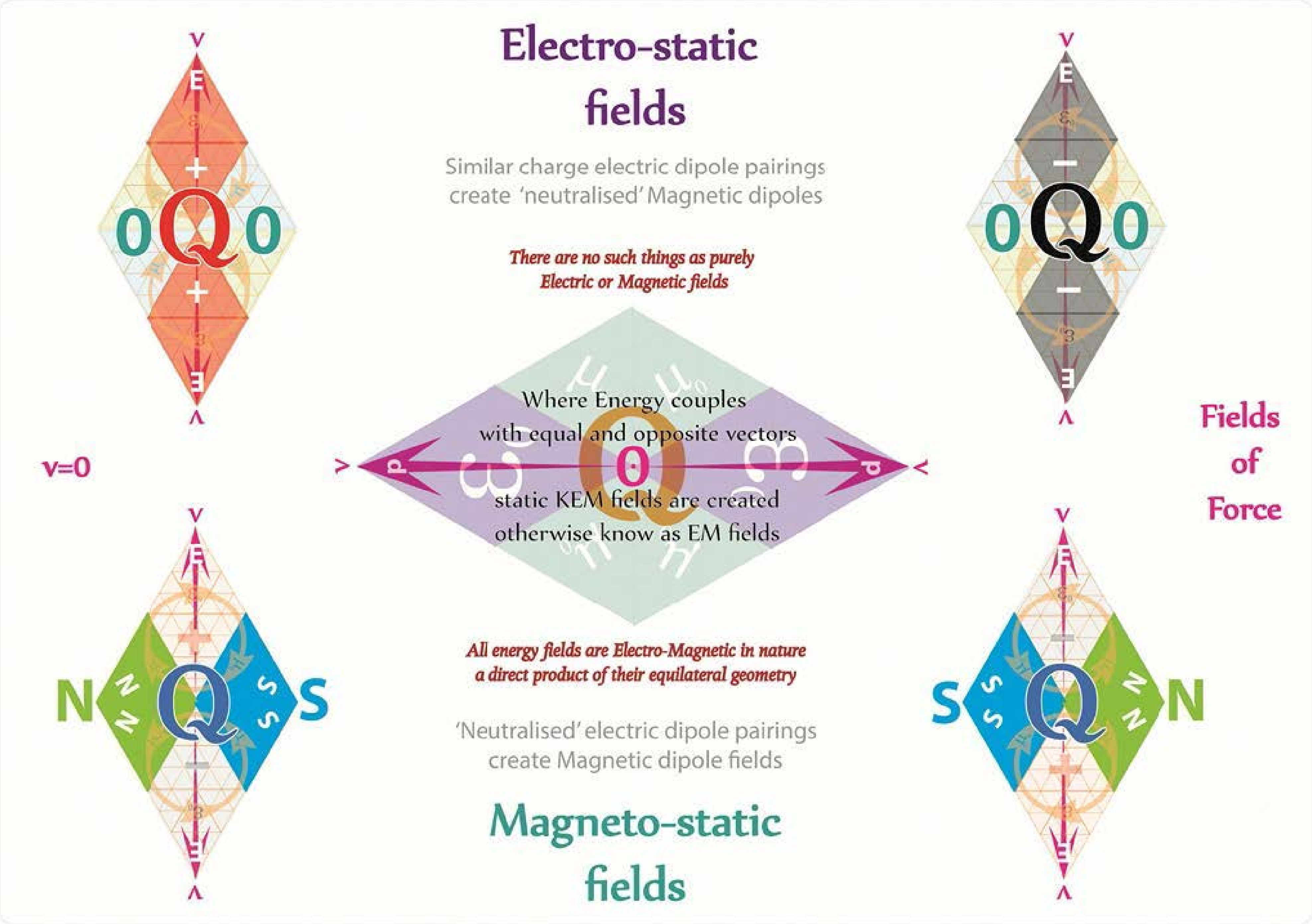

Electro-static fields

Similar charge electric dipole pairings
create 'neutralised' Magnetic dipoles

*There are no such things as purely
Electric or Magnetic fields*

Where Energy couples
with equal and opposite vectors
static KEM fields are created
otherwise know as EM fields

Fields of Force

*All energy fields are Electro-Magnetic in nature
a direct product of their equilateral geometry*

'Neutralised' electric dipole pairings
create Magnetic dipole fields

Magneto-static fields

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Charged EM field geometries

Opposite charge fields
can produce neutral E-fields
(with magnetic moments)

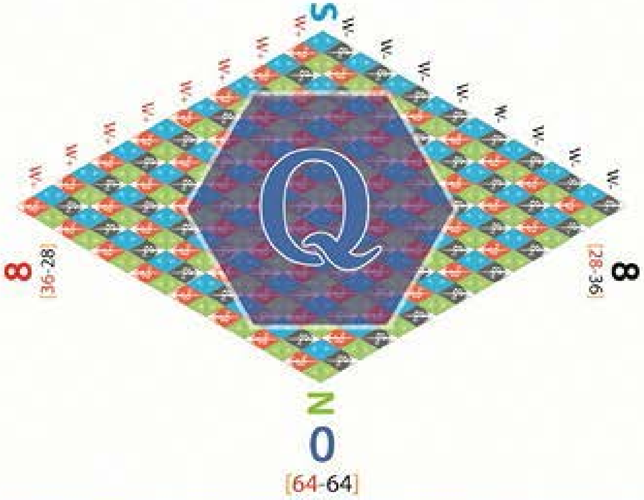

Electrostatic charged matter generate
charged energy fields around them

Moving charged particles generate
Kinetic energy & Magnetic moments

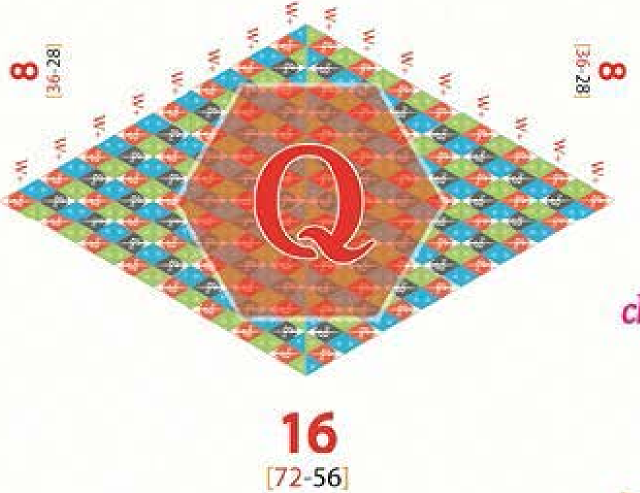

Charged electrostatic fields

accelerate charged particles
vectorally dependent on their quantum
charge mass-energy momenta field geometries

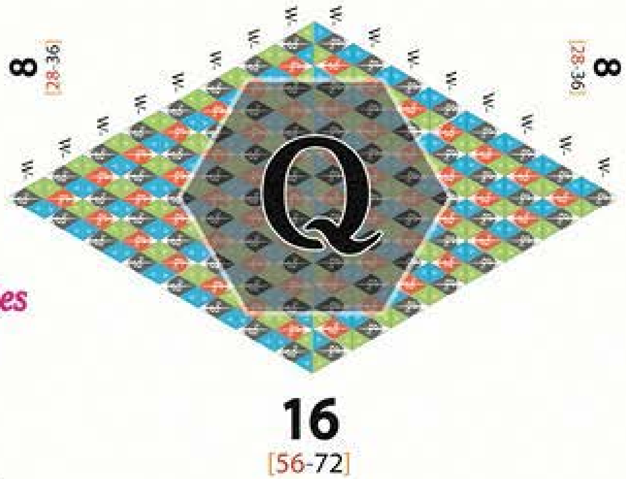

Positive charge electrostatic fields
attract Negative charges
repel Positive charges

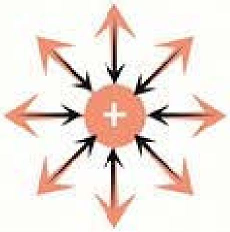

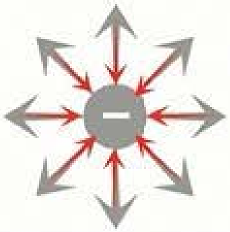

Negative charge electrostatic fields
attract Positive charges
repel Negative charges

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E field acceleration of charged particles

Electric fields can accelerate charged particles within their field geometry dependent on the particle's nett charged mass-Matter topology

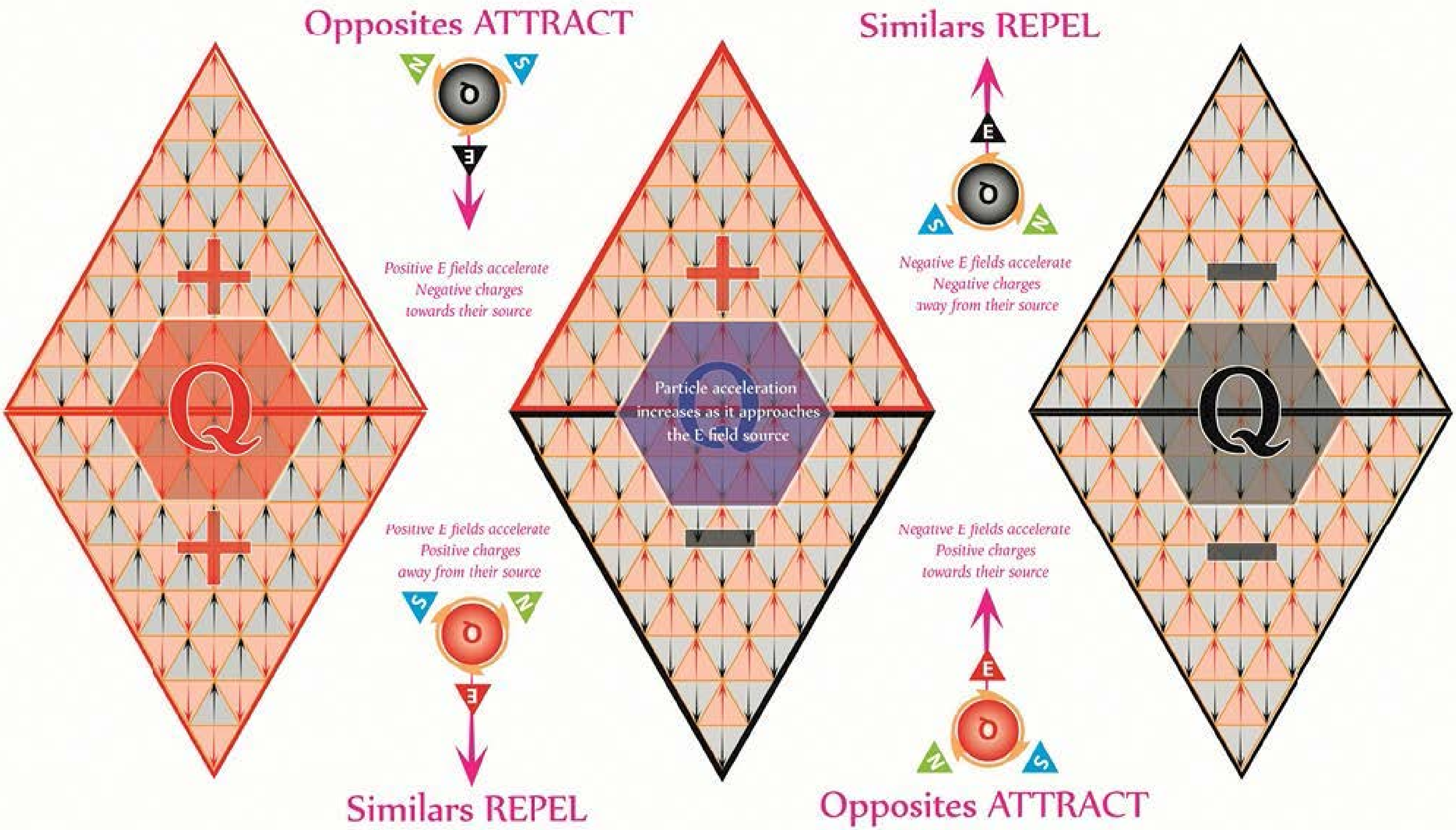

Opposites ATTRACT

Similars REPEL

Positive E fields accelerate Negative charges towards their source

Negative E fields accelerate Negative charges away from their source

Particle acceleration increases as it approaches the E field source

Positive E fields accelerate Positive charges away from their source

Negative E fields accelerate Positive charges towards their source

Similars REPEL

Opposites ATTRACT

The charge quanta within Neutral particles are affected equally by Electric fields

Tetryonics 04.10 - E field acceleration of charged particles

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ZPFs can combine to form
4 distinct static EM fields

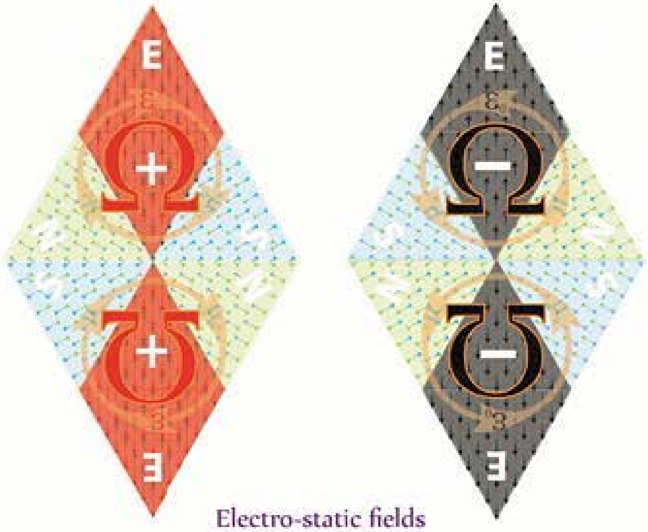

Electro-static fields

ElectroMagnetic fields

Magneto-static fields

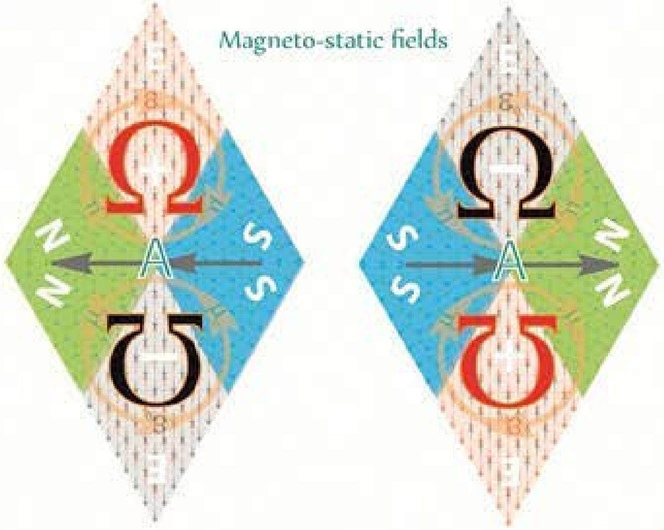

Similars REPEL
[QAM momenta vectors in opposition]

Opposites ATTRACT
[QAM momenta vectors in same direction]

‘THE LAW OF INTERACTION’

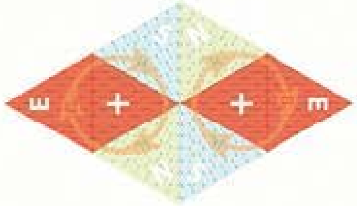

Flux momenta in
opposition

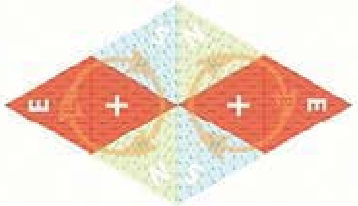

Electro-static fields
$1/r^2$

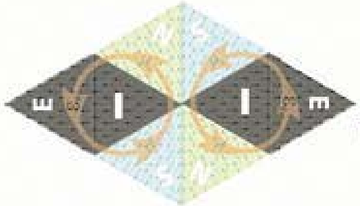

Flux momenta in
the same direction

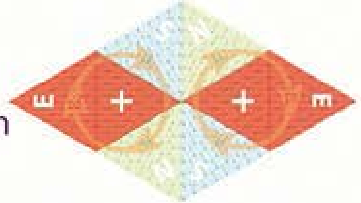

‘FORCES OF INTERACTION’

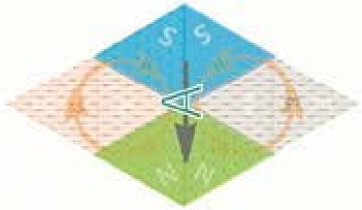

Parallel

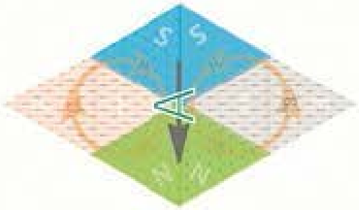

Flux momenta in
the same direction

Magneto-static fields
$1/r^2$

Flux momenta in
opposition

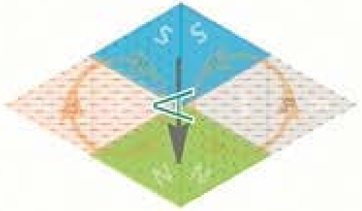

Anti-parallel

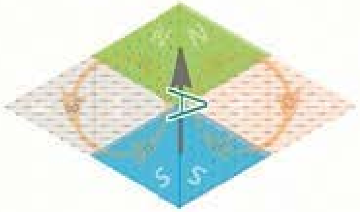

Positive electrostatic fields

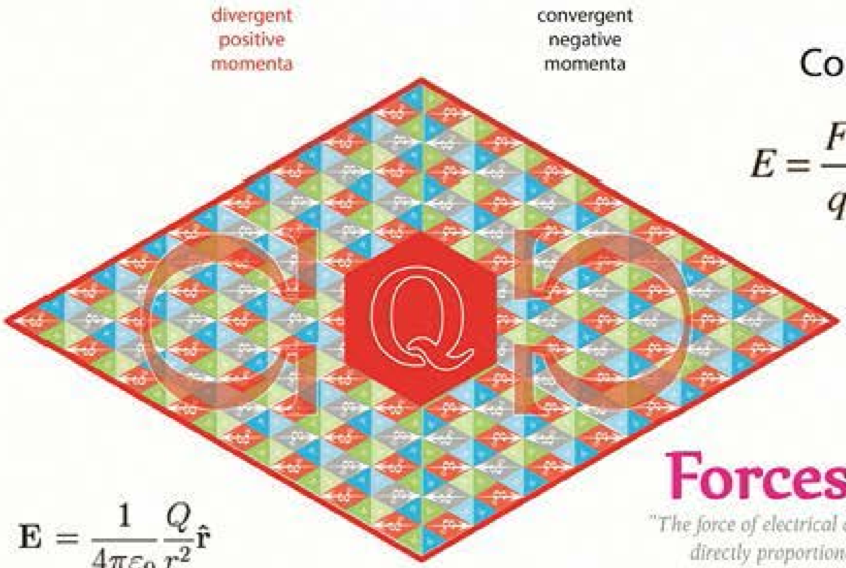
divergent
positive
momenta
convergent
negative
momenta
Q

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{\mathbf{r}}$$

Negative electrostatic fields

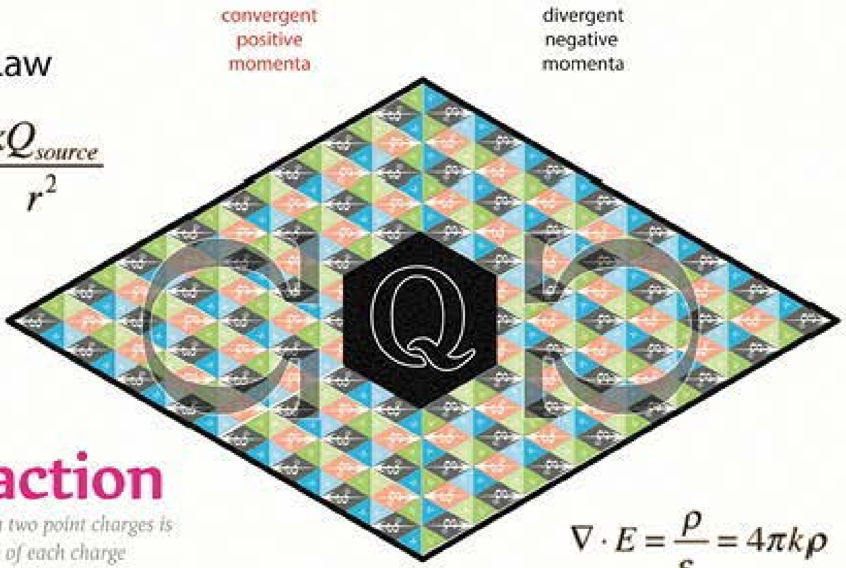
convergent
positive
momenta
divergent
negative
momenta
Q

$$\nabla \cdot E = \frac{\rho}{\varepsilon_0} = 4\pi k\rho$$

Coulomb's Force Law

$$E = \frac{F}{q} = \frac{kQ_{source}q}{qr^2} = \frac{kQ_{source}}{r^2}$$

Forces of Interaction

"The force of electrical attraction or repulsion between two point charges is directly proportional to the product of magnitude of each charge and inversely proportional to the square of distance between them"

attract Negative charged masses
repel Positive charged masses

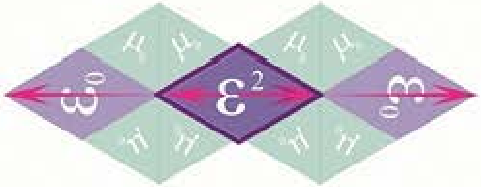
ε_0
ε^2
ε_0
μ

attract Positive charged masses
repel Negative charged masses

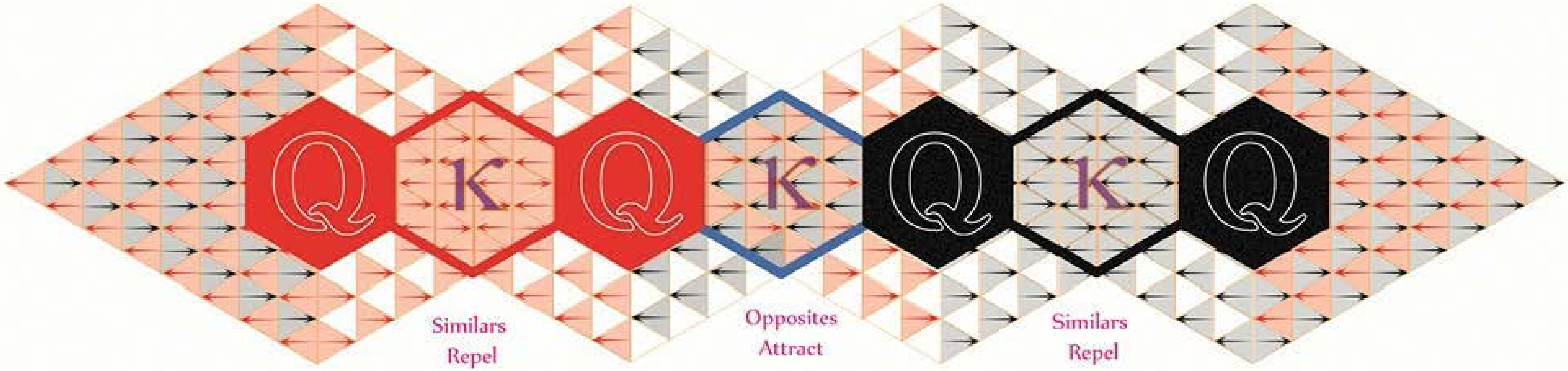
Q
K
Q
K
Q
K
Q
Similars
Repel
Opposites
Attract
Similars
Repel

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Electro-Magnetic field Lines

The magnetic field at any given point is specified by both its direction and magnitude

Magnetic dipoles can be produced by the coupling of opposite electric charge fields

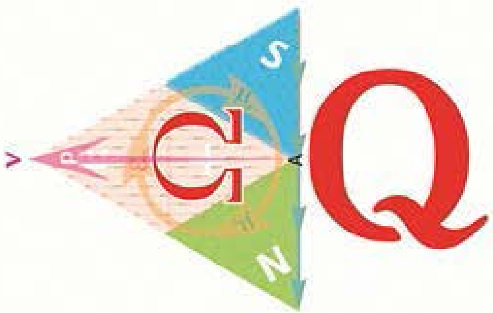

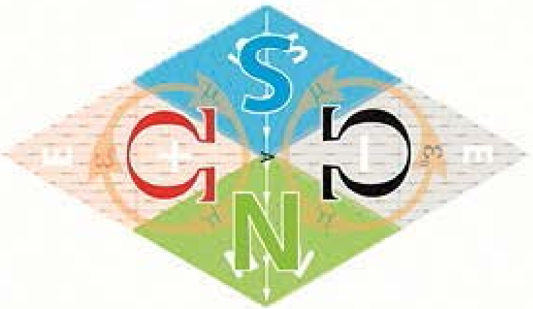

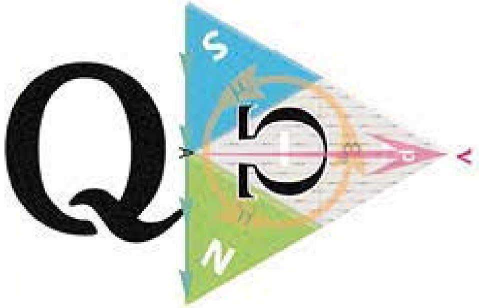

or

by accelerating charged bodies of Matter which in turn produce associated Kinetic energies
[Neutral Electric field and equal strength Magnetic moment]

Magnetic South Poles have divergent south vectors and convergent north vectors

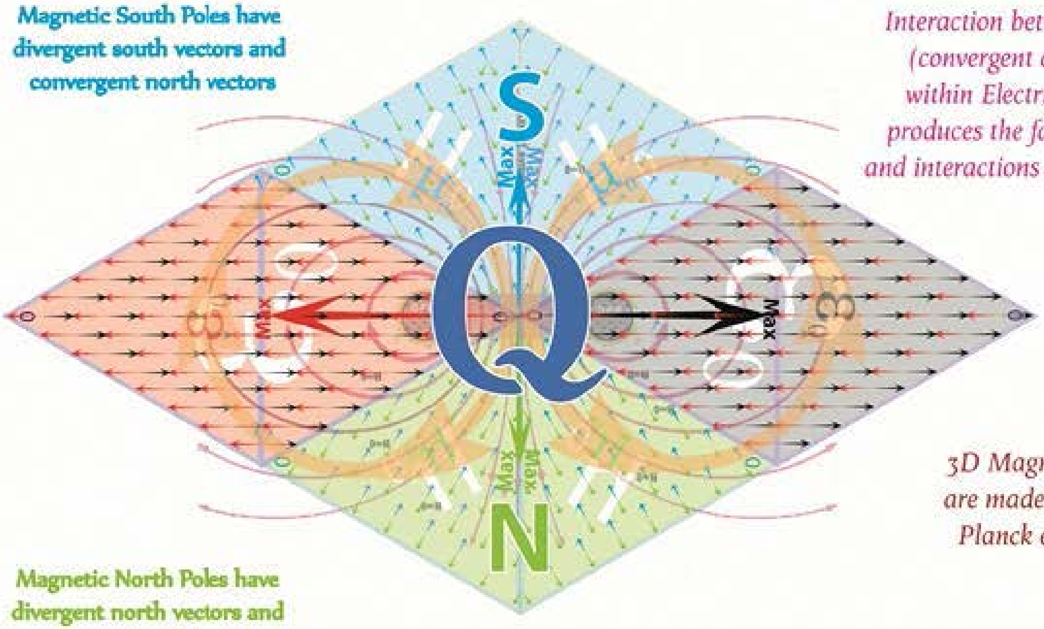

Magnetic North Poles have divergent north vectors and convergent south vectors

Interaction between vectorally opposed (convergent and divergent) vectors within Electric and Magnetic fields produces the familar lines of force and and interactions of Electro-Magnetic fields

3D Magnetic lines of Force are made up of 2D fields of Planck energy momenta

Every particle of Matter in motion possesses intrinsic Planck M-field dipoles becasue of their nett charged quanta which combine to produce a nuclear magneton.

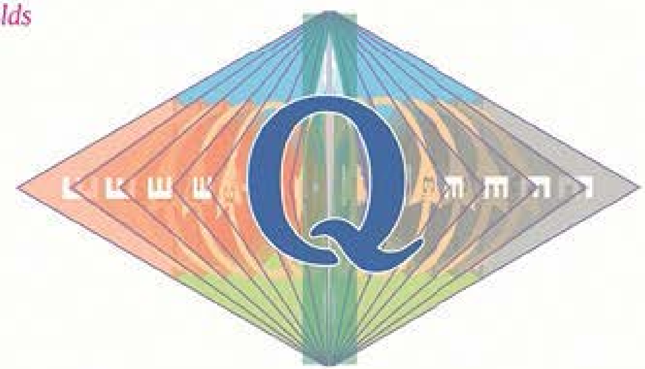

The magnetic field lines of permanent bar magnets are the result of the equilateral charge [QAM] geometry of neutralised quanta that form their electrostatic fields

Magnetic field Forces

$$\frac{m^2 \cdot kg}{s^2 \cdot A^2} = \frac{J}{A^2} = \frac{Wb}{A} = \frac{s^2}{F} = \frac{V \cdot s}{A} = \frac{J/C \cdot s}{C/s} = \frac{J \cdot s^2}{C^2} = \frac{m^2 \cdot kg}{C^2}$$

In physics superpositioned M fields with interactive energy momenta produce Lorentz forces

attractive magnetic forces

Magnetic moments of same charges moving in the same direction

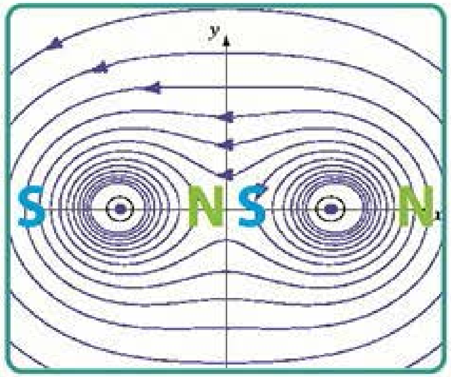

repulsive magnetic forces

Magnetic moments of same charges moving in opposite directions

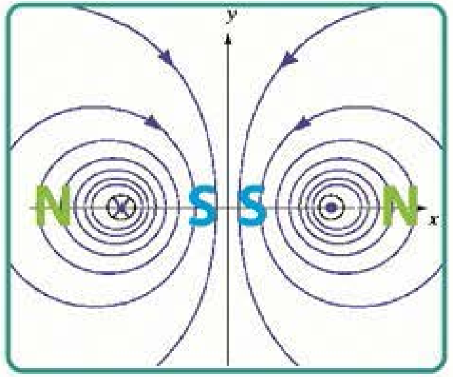

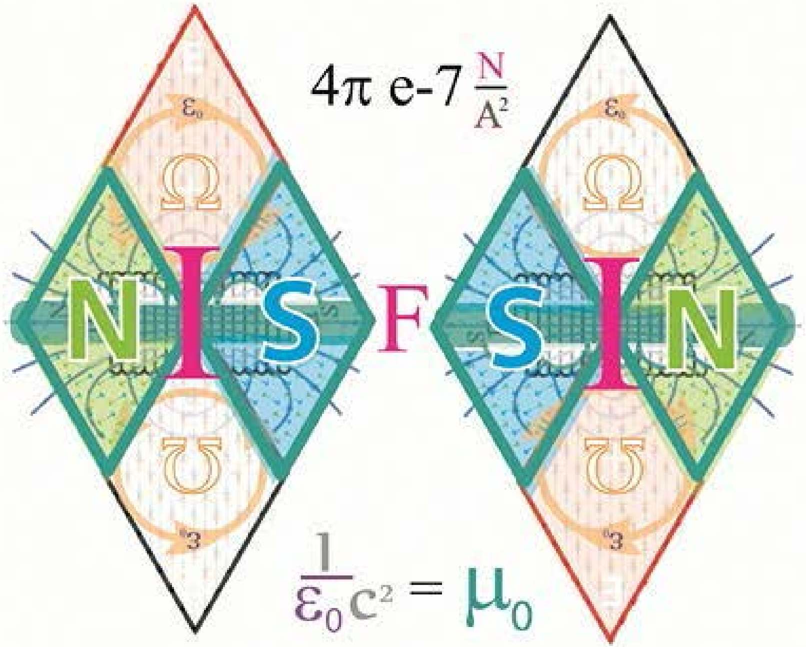
ε₀
Ω
N
I
S
F
S
I
N
Ω
ε₀

$$4\pi \text{ e-7} \frac{N}{A^2}$$

$$\frac{1}{\varepsilon_0 c^2} = \mu_0$$

magnetostatic fields

ε₀
magnetic dipole
Q
μ₀
ε₀

$$H = \frac{B}{\mu_0}$$

Coupled opposite charge EM fields produce Magnetic dipole fields

Joseph Henry

(17 December 1797 – 13 May 1878)

$$\mu_B$$

Electrostatic charged particles in motion create magnetic moments

KE
magnetic moments
Q
μ₀
KE

kinetic EM fields

Magnetic field lines

Magnetostatic Dipole

Magnetic field lines were introduced by
Michael Faraday (1791-1867) who named them
"lines of force"

Michael Faraday

(22 September 1791 – 25 August 1867)

Magnetic South Poles have divergent south vectors and convergent north vectors

External to the dipole field lines run from North to South

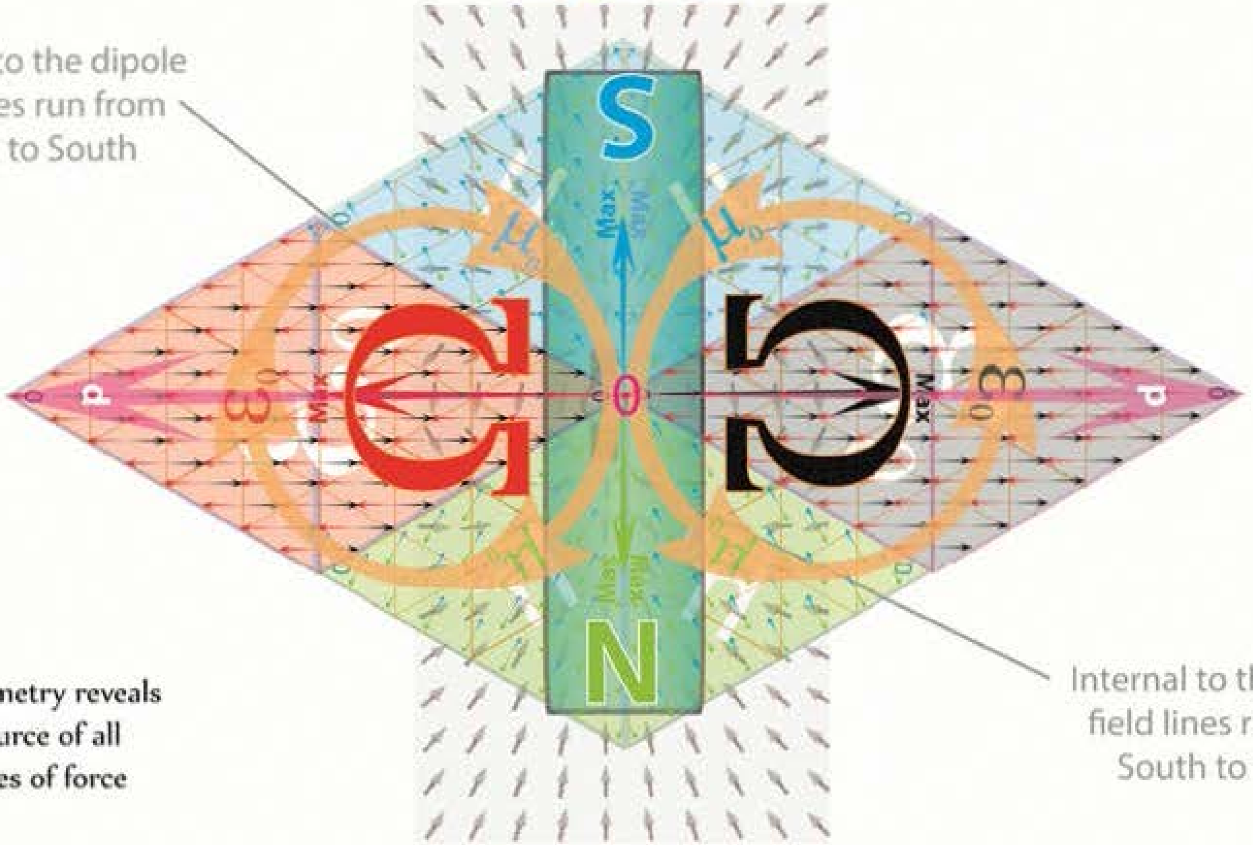

Positive Electric fields have divergent positive E vectors and convergent negative E vectors

Negative Electric fields have divergent negative E vectors and convergent positive E vectors

Internal to the dipole field lines run from South to North

Tetryonic geometry reveals
the true source of all
EM field lines of force

Magnetic North Poles have divergent north vectors and convergent south vectors

Permanent Magnets can be viewed as
neutral charge Electrostatic
EM fields

Similar to conventional vs electron current flows
Magnetic field vectors can be modelled with
two directions of 'magnetic flux'

Parallel Magnetic Dipoles

Michael Faraday

(22 September 1791 – 25 August 1867)

James Clerk Maxwell

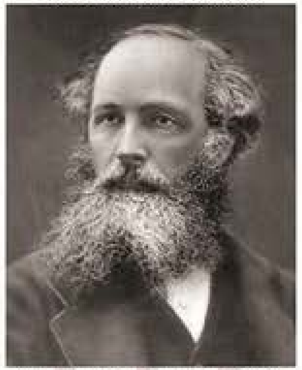

(13 June 1831 – 5 November 1879)

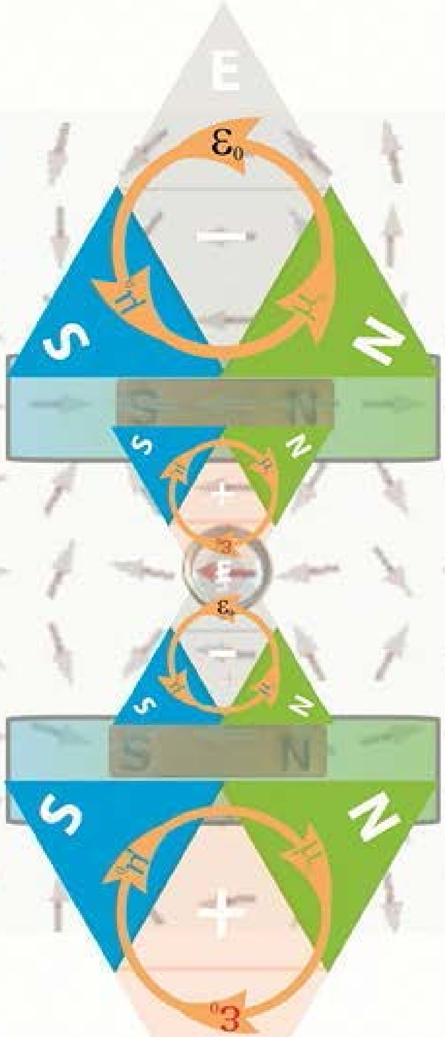

Magnetic lines of force are continuous and will always form closed loops.

Magnetic lines of force will never cross one another.

Parallel magnetic lines of force traveling in the same direction repel one another.

Parallel magnetic lines of force traveling in opposite directions tend to unite with each other and form into single lines traveling in a direction determined by the magnetic poles creating the lines of force.

Magnetic lines of force tend to shorten themselves.

Therefore, the magnetic lines of force existing between two unlike poles cause the poles to be pulled together.

Magnetic lines of force pass through all materials, both magnetic and nonmagnetic.

Magnetic lines of force always enter or leave a magnetic material at right angles to the surface

Maxwell had studied and commented on the field of electricity and magnetism as early as 1855/6 when "On Faraday's lines of force" was read to the Cambridge Philosophical Society.

The paper presented a simplified model of Faraday's work, and how the two phenomena were related. He reduced all of the current knowledge into a linked set of differential equations with 20 equations in 20 variables. [Quarterions]

This work was later published as "On physical lines of force" in March 1861.

In his 1864 paper "A dynamical theory of the electromagnetic field", Maxwell wrote, "The agreement of the results seems to show that light and magnetism are affections of the same substance, and that light is an electromagnetic disturbance propagated through the field according to electromagnetic laws

Maxwell showed that the equations predict the existence of waves of oscillating electric and magnetic fields that travel through empty space at a speed of 310,740,000m/s.

His famous equations, in their modern form of four partial differential equations, first appeared in fully developed form in his textbook A Treatise on Electricity and Magnetism in 1873.

The specific features of Faraday's field concept, in its 'favourite' and most complete form, are that force is a substance, that it is the only substance and that all forces are interconvertible through various motions of the lines of force. These features of Faraday's 'favourite notion' were not carried on by Maxwell in his approach to the problem of finding a mathematical representation for the continuous transmission of electric and magnetic forces. Maxwell considered these electric and magnetic forces to be states of stress and strain in a mechanical aether, a notion further advanced by relativity theory with its 'stress energy' tensor math.

Tetryonics reveals lines of Force to be a direct result of the various superpositioned EM field geometries of equilateral mass-energy momenta

Anti-Parallel Magnetic Dipoles

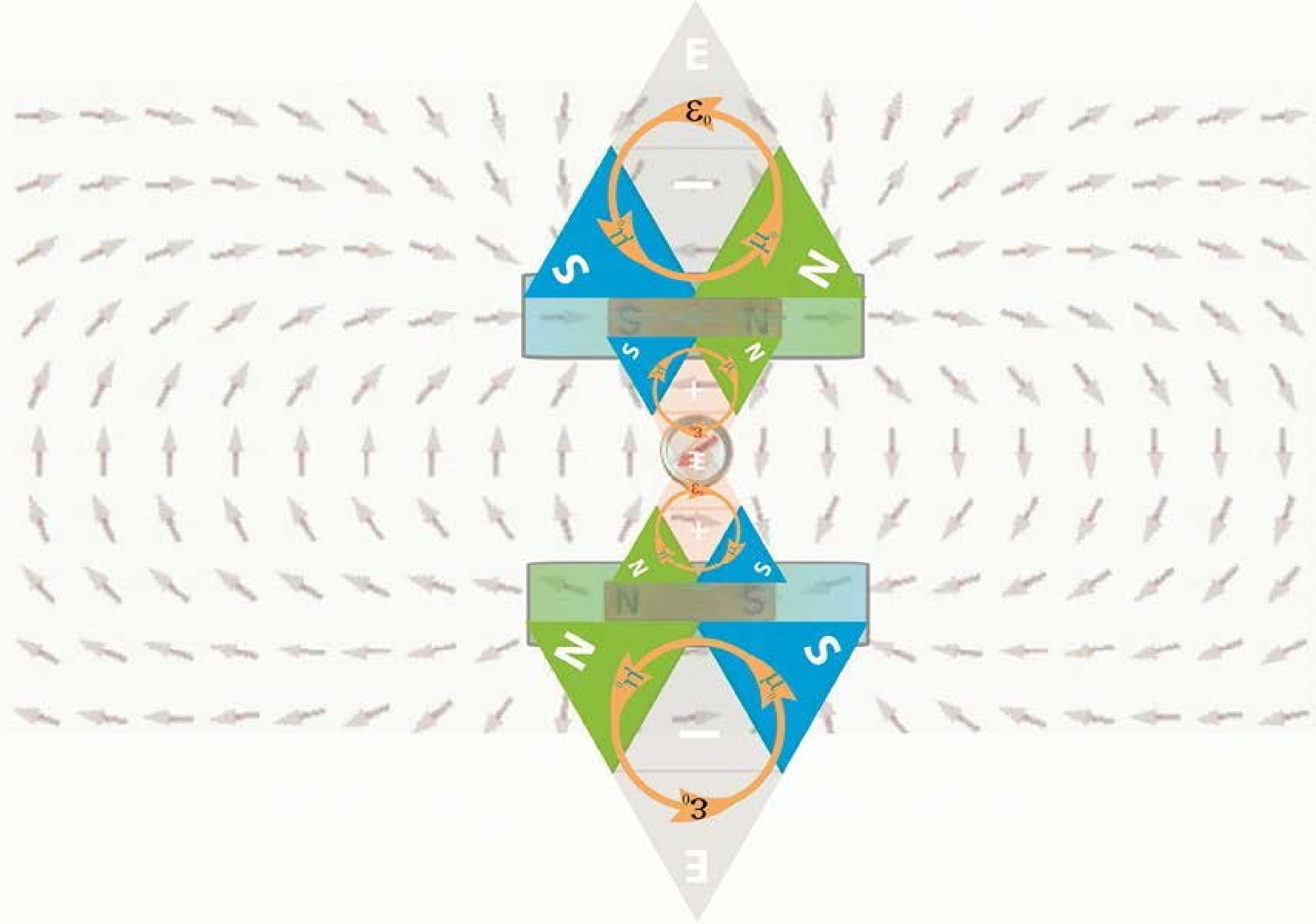
E
ε₀
S
N
μ₀
μ₀
S
N
+
ε₀
N
S
S
N
–
E

Tetryonics 04.17 - Anti-Parallel Magnetic dipoles

Magnetic Moments

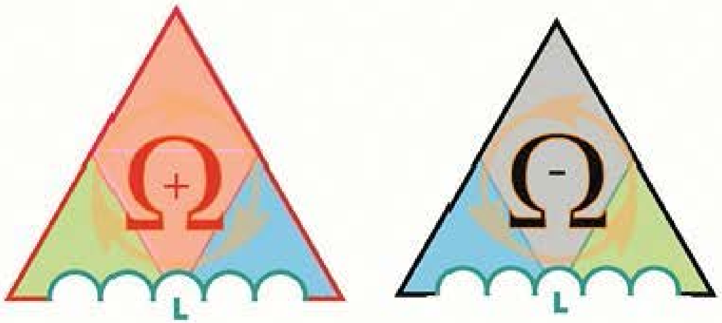

Single ZPFs are
'ideal quantum inductor elements'

1

Electro-static Energies
Charges

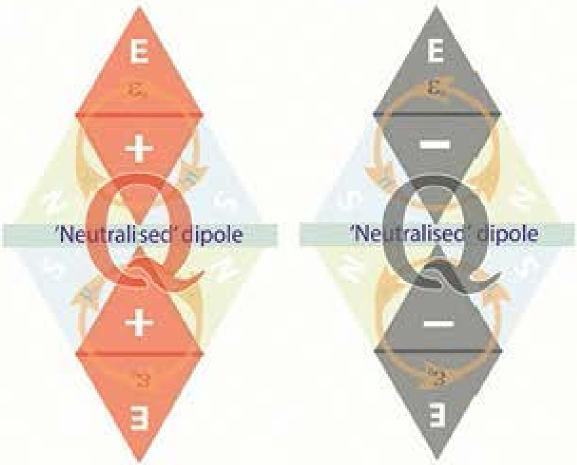
E
ε
+
+
'Neutralised' dipole
N
S
Ǝ
E
ε
–
–
'Neutralised' dipole
S
N
Ǝ

All Matter in motion possesses kinetic energies
which are stored as Planck quanta in their KEM fields

The charge geometry of KEM fields are reflective
of the interactive component of the charged topology
of the particle in motion

Each charge geometry
has distinct Magnetic dipole
alignments

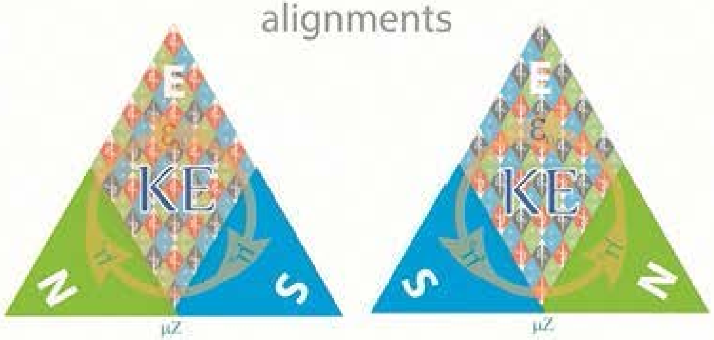
E
ε
KE
N
S
μZ
E
ε
KE
S
N
μZ

which in turn can only create
2 distinct orientations [spins] of
magnetic moments

2

Magneto-static Energies
Kinetic Energies

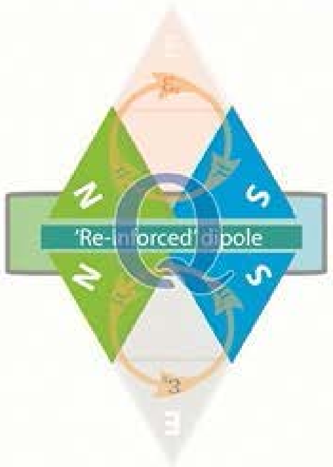
E
ε
N
S
'Re-inforced' dipole
N
S
Ǝ

ZPF sets can form inductively coupled
quantum Harmonic Oscillators

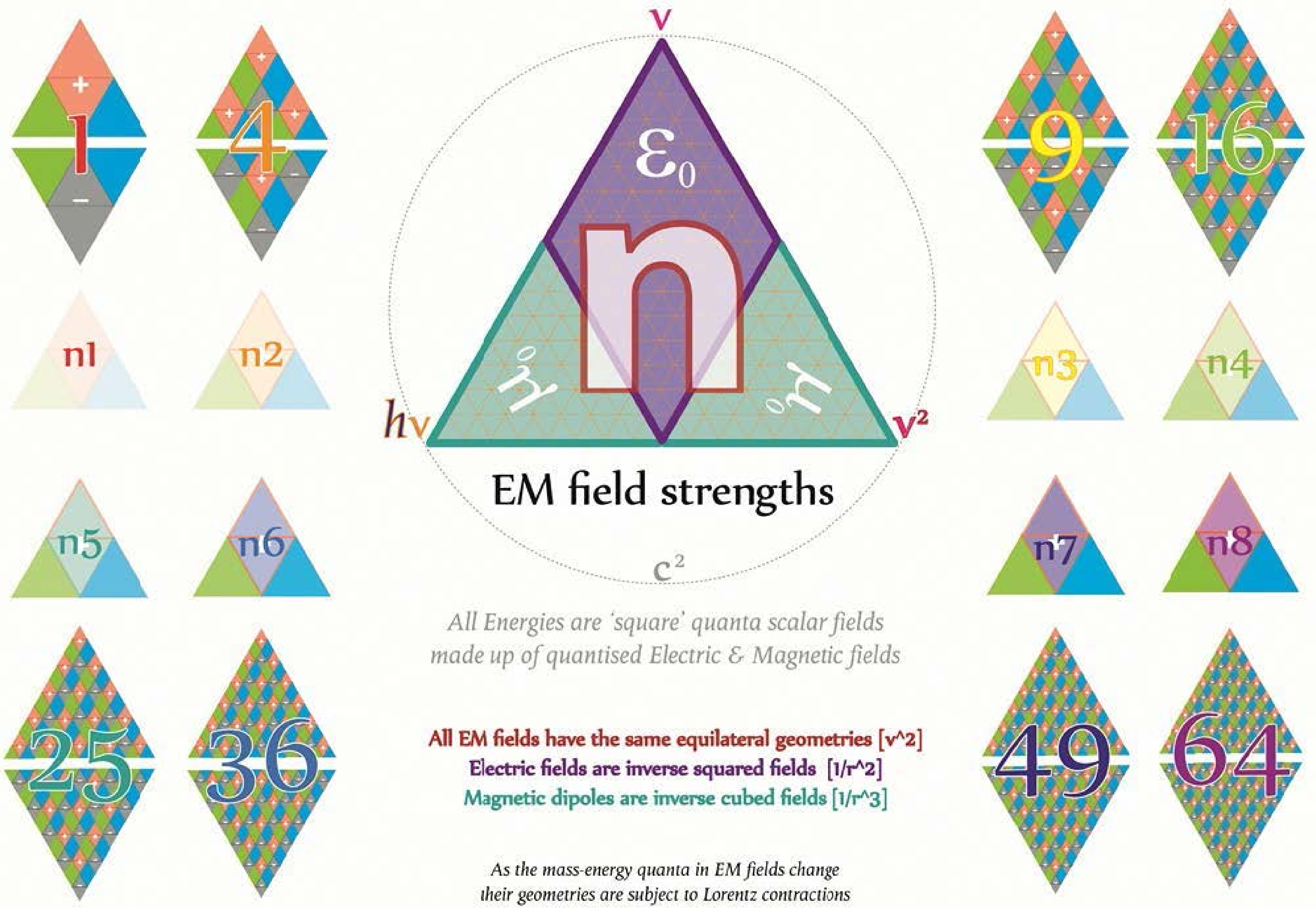
1
4
9
16
n1
n2
n3
n4
n5
n6
n7
n8
25
36
49
64
v
ε0
n
μ0
hv
v²
c²

EM field strengths

All Energies are 'square' quanta scalar fields
made up of quantised Electric & Magnetic fields

All EM fields have the same equilateral geometries [v^2]
Electric fields are inverse squared fields [1/r^2]
Magnetic dipoles are inverse cubed fields [1/r^3]

As the mass-energy quanta in EM fields change
their geometries are subject to Lorentz contractions

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Electrostatic particle modeling

m

EM mass-energy
Tetryonic field geometry

Tetryonic [4np] standing wave charge fields
form electrostatic Particle topologies
[Charged and Neutral Matter]

Matter
tetryonic Matter topology

M

Non-neutral
nett
Tetryonic quanta

Positive
Charge
Particles

Equal numbers
of opposite
Tetryonic quanta

Neutral
Charge
Particles

Non-neutral
nett
Tetryonic quanta

Negative
Charge
Particles

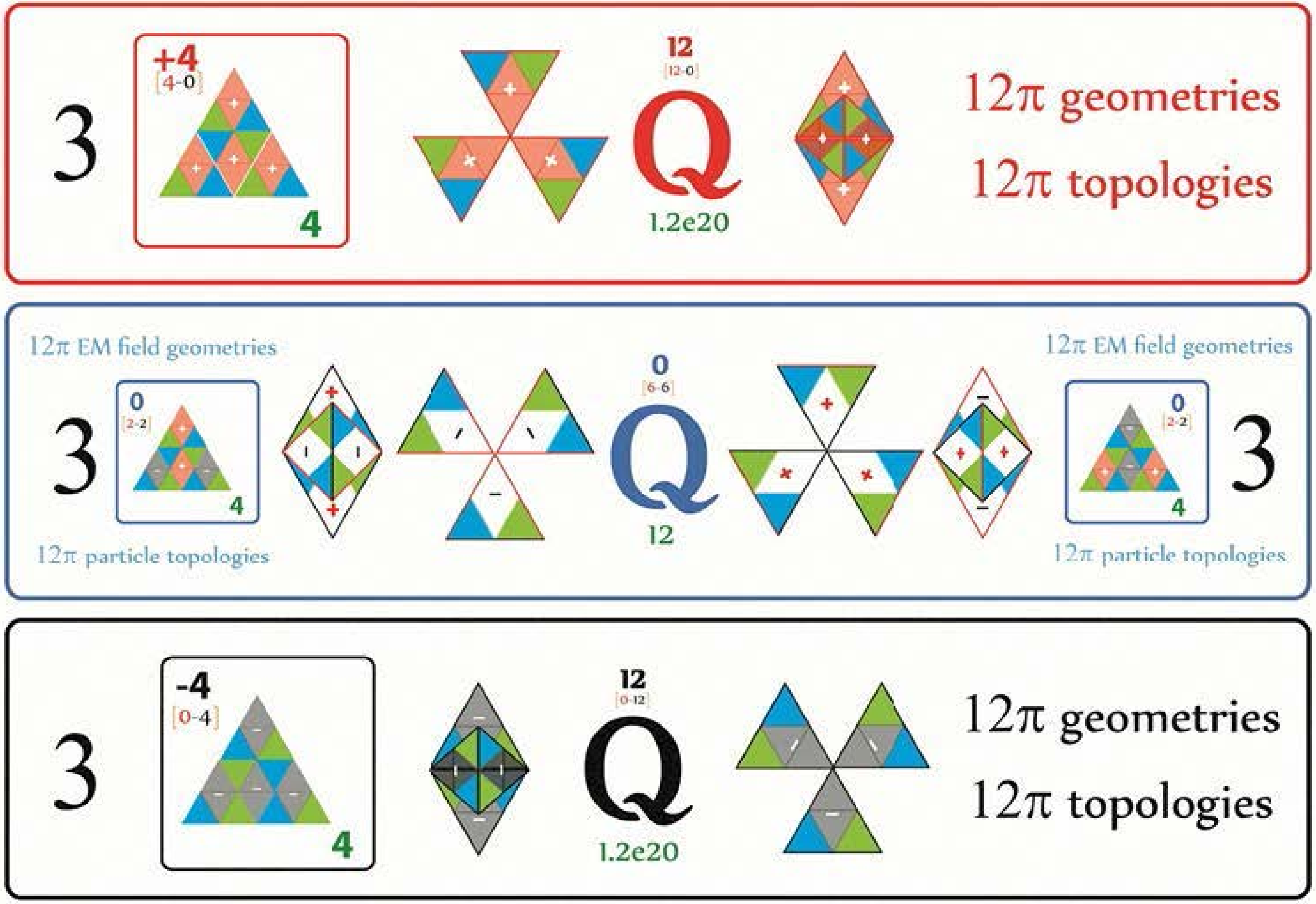
3
+4
[4-0]
4
12
[12-0]
Q
1.2e20
12π geometries
12π topologies
12π EM field geometries
3
0
[2-2]
4
12π particle topologies
0
[6-6]
Q
12
12π EM field geometries
0
[2-2]
4
3
12π particle topologies
3
-4
[0-4]
4
12
[0-12]
Q
1.2e20
12π geometries
12π topologies

All particles in motion create secondary KEM field geometries
[Kinetic energies and Magnetic moments]

Electro-static Fields

Momenta
acting in oppose directions
results in zero velocity

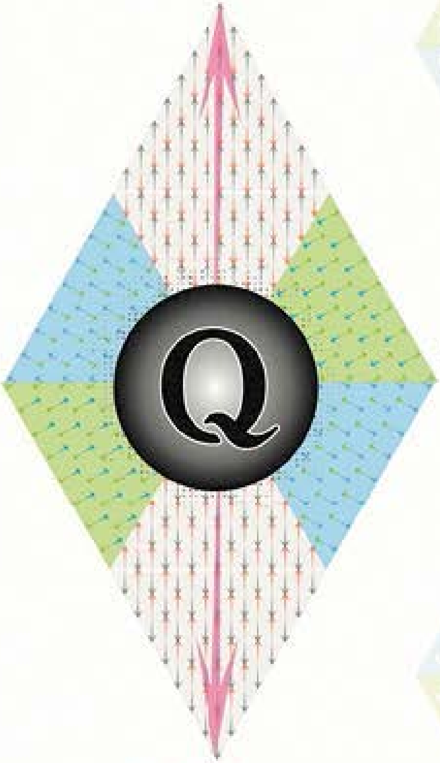

Zero Velocity
equates to
Zero nett Momentum

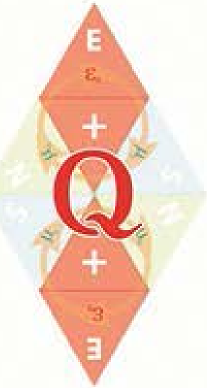

Stationary Charges have neutralised magnetic dipoles

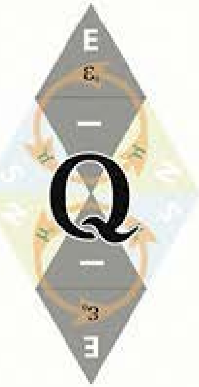

The Kinetic Electric & Magnetic energies are contained in an KEM field extending from a charged particle in motion

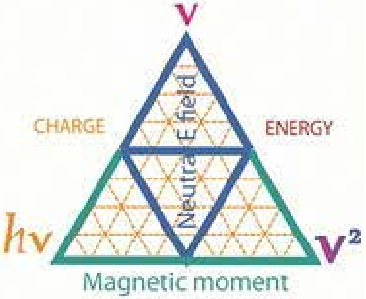
v
CHARGE
ENERGY
Neutral E field
hv
v²
Magnetic moment

Charged particles in motion produce a Magnetic moment

Kinetic EM Fields

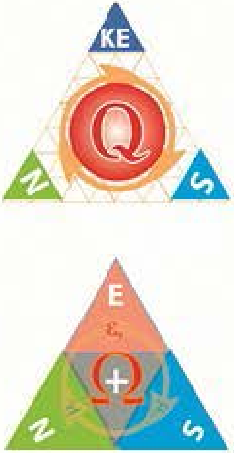

Moving Charges have neutral KE fields and Magnetic moments

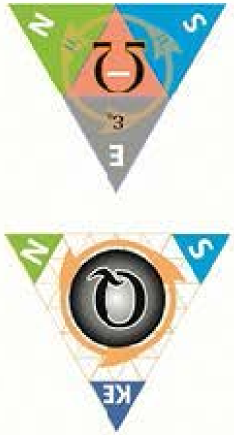

Motion in any direction
produces
Kinetic & Magnetic energies

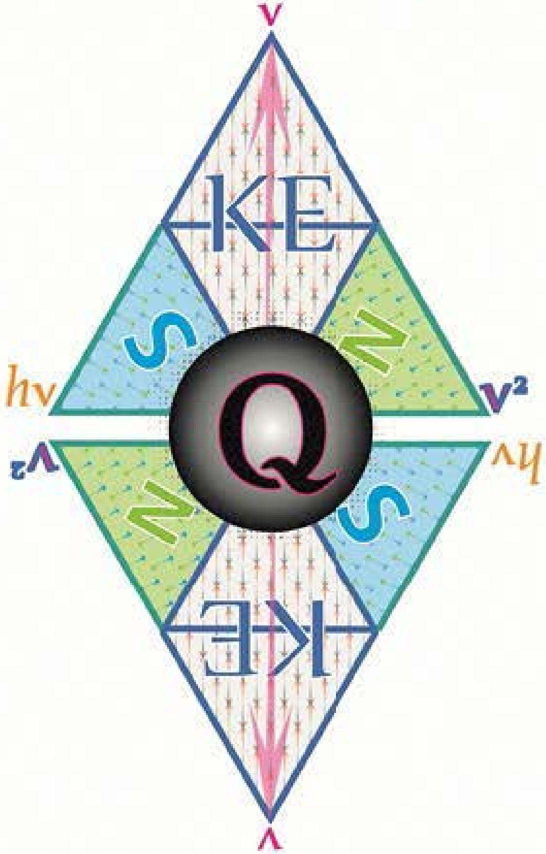
v
KE
S
N
hv
v²
Q
N
S
v²
hv
KE
v

The Strength of the
Kinetic Electric field & Magnetic moment
is directly proportional to
the square of the particle's Velocity

Electric & Kinetic Fields

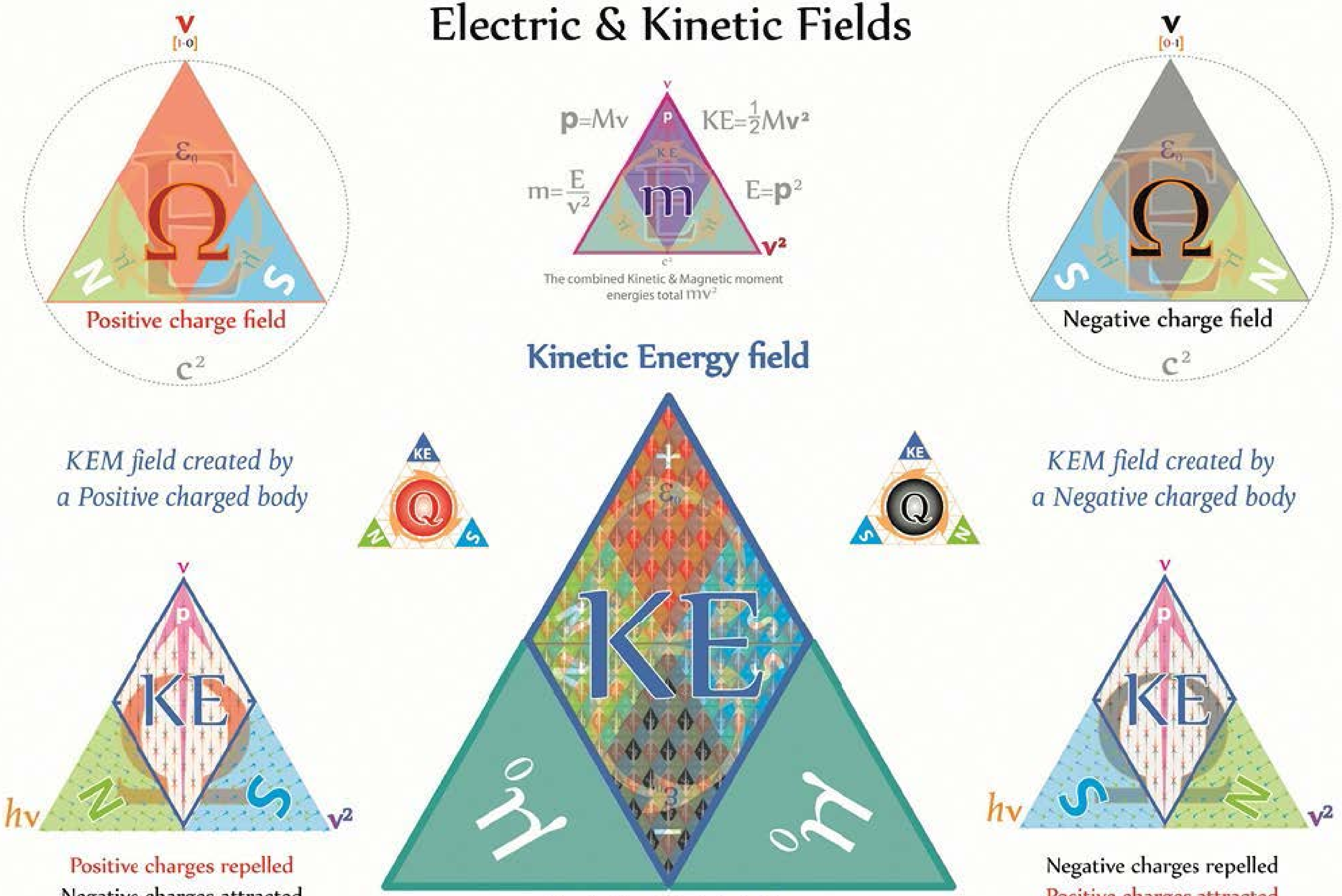
v
[1-0]
Ω
ε_0
N
S
c²
v
[0-1]
v
p
KE
m
v²
c²
KE
Q
+
−
ε_0
KE
hv
v²
p

$p = Mv$

$KE = \frac{1}{2}Mv^2$

$m = \frac{E}{v^2}$

$E = p^2$

The combined Kinetic & Magnetic moment energies total mv^2

Positive charge field

Negative charge field

Kinetic Energy field

KEM field created by a Positive charged body

KEM field created by a Negative charged body

Positive charges repelled
Negative charges attracted

Neutralised Electric fields
Enhanced Magnetic moments

Negative charges repelled
Positive charges attracted

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EM & KEM force vectors

All mass-energy quanta are ideal quantum Inductors

The E&M force vectors create orthogonal equilateral EM Fields

Electric fields propogate orthogonally to the Magnetic dipole field

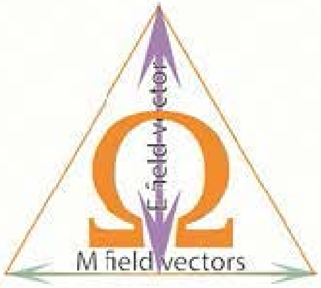

Magnetic flux external to the Magnetic dipole flows from North to South

&

Internal to a Magnetic dipole it flows South to North

When ZFFs combine to form a Magnetostatic dipole they form orthogonal magnetic vectors

Positive charge can be modelled electrically with clockwise EM fluxes [omegas]

Negative charge can be modelled electrically with anti-clockwise EM fluxes [omegas]

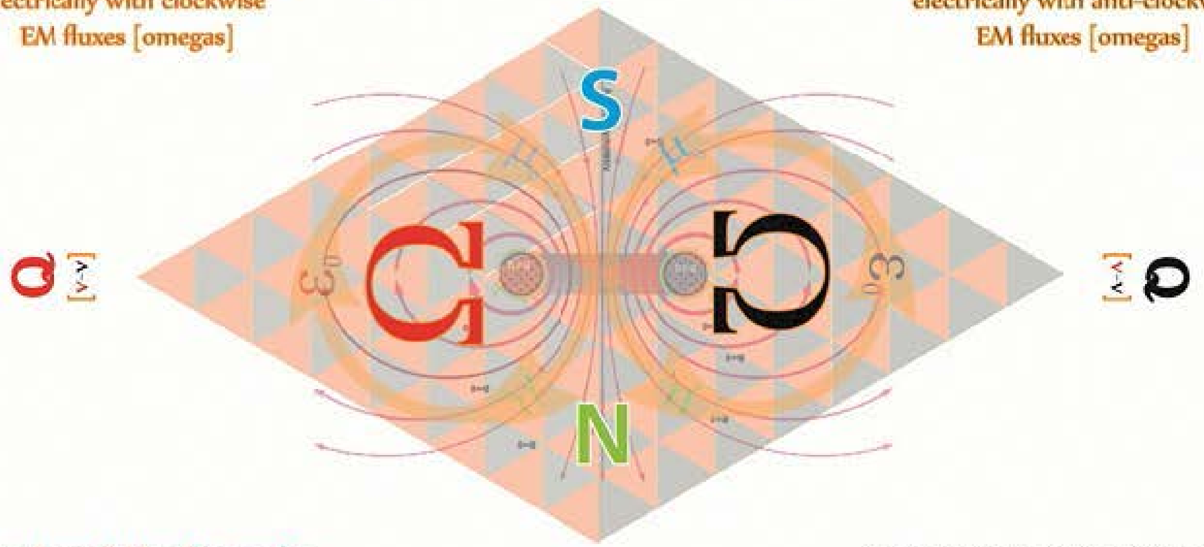

Positive charge fields of interaction result from an excess of divergent positive energy momenta

Equal
energy-momenta in opposition
create static fields

Negative charge fields of interaction result from an excess of divergent negative energy momenta

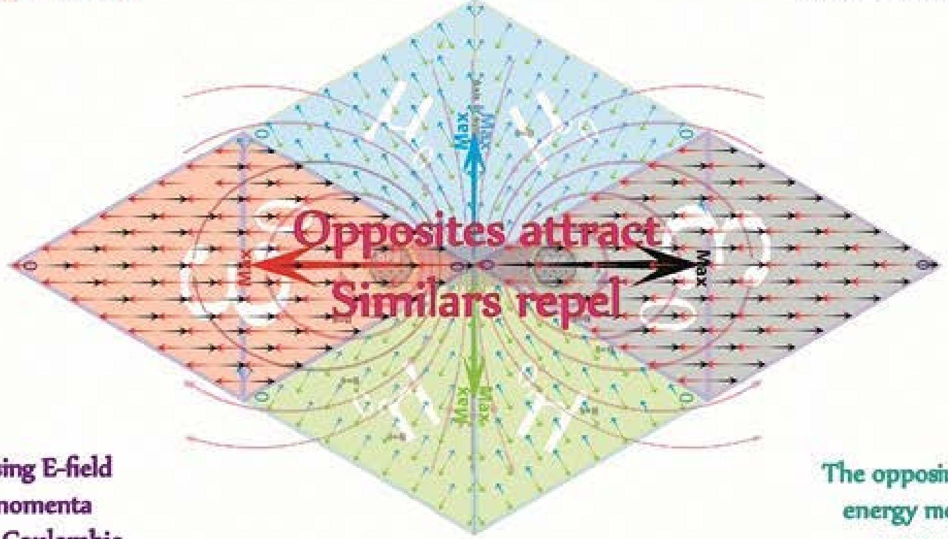

The opposing E-field energy momenta creates the Coulombic Law of Interaction

When E field is at Maximum - B field is at Minimum
when B field is at Maximum - E field is at Minimum

The opposing M-field energy momenta creates the Lorentz Force

EM Forces and ZPFs

ZPF quanta can combine in differing combinations
to produce 3 distinct charged sets

Positive Charges

Magnetic dipole moment

Negative Charges

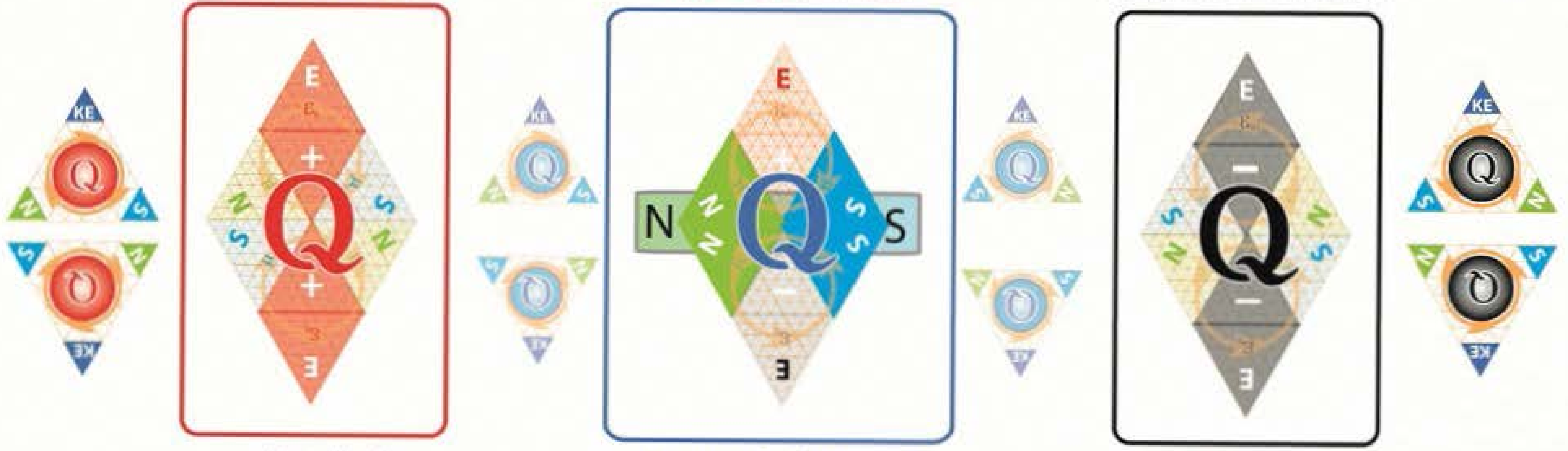

'Neutralised'
Magnetic dipole moment

Neutral Charges

'Neutralised'
Magnetic dipole moment

All EM mass-Energy-Matter & forces can be modelled using Tetryonic geometries

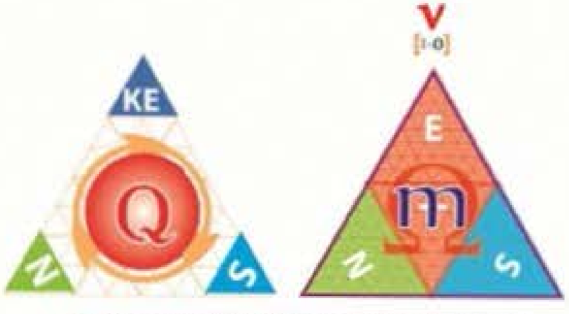

Positive charge particle KE field and magnetic moment

Zero Point Field EM geometry is the foundation for all the EM forces comprising, and acting between particles of Matter

Lorentz force, Lenz's Law, Right/Left Hand rules, etc can all be easily replaced with this simple geometric model

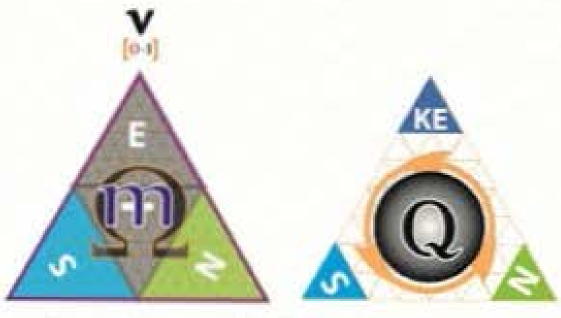

Negative charge particle KE field and magnetic moment

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Kinetic EM fields

All Kinetic EM fields resulting from motion have charge field geometries
resulting from the charged Matter geometry of the particle in motion

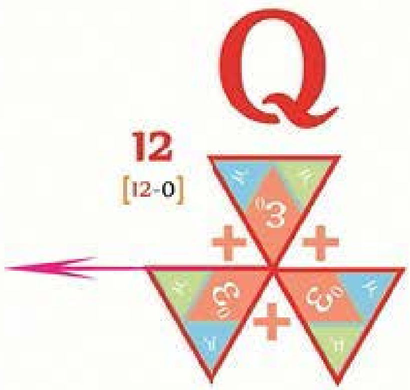
Q
12
[12-0]
+
+
+
ε0
ε0
ε0

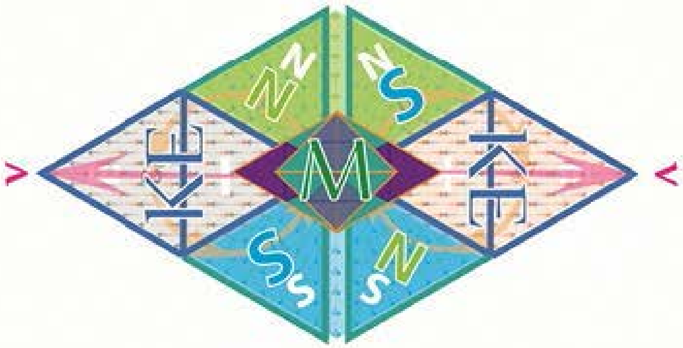
>
<
N
N
N
S
S
S
N
S
KE
KE
M

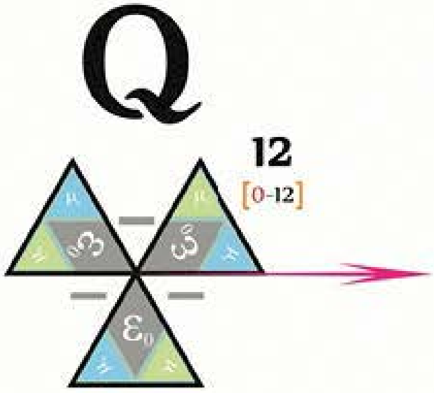
Q
12
[0-12]
ε0
ε0
ε0

Positive charge particle
topologies produce
positive KEM fields

KEM field charge geometries
do not contribute to the nett charge

Negative charge particle
topologies produce
negative KEM fields

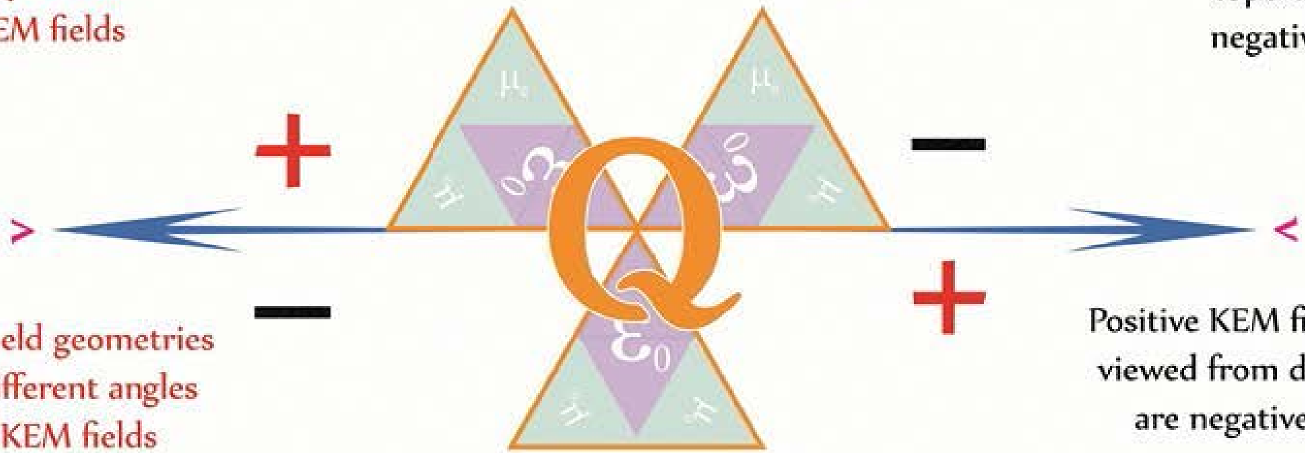
>
<
+
−
−
+
Q
ε0
ε0
ε0
μ0
μ0

Negative KEM field geometries
viewed from different angles
are positive KEM fields

Positive KEM field geometries
viewed from different angles
are negative KEM fields

>
KE
S
N
Q
Magnetic moment

As a direct result of the KEM field being a EM field permeating free space
the symmetry of EM fields results in KEM field geometries being
viewed as having neutral KE fields with a magnetic moment

<
KE
S
N
Q
Magnetic moment

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Point Particles and KEM fields

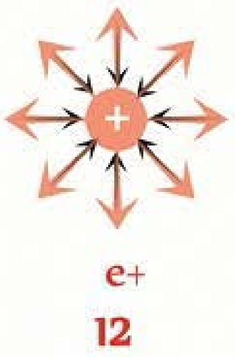

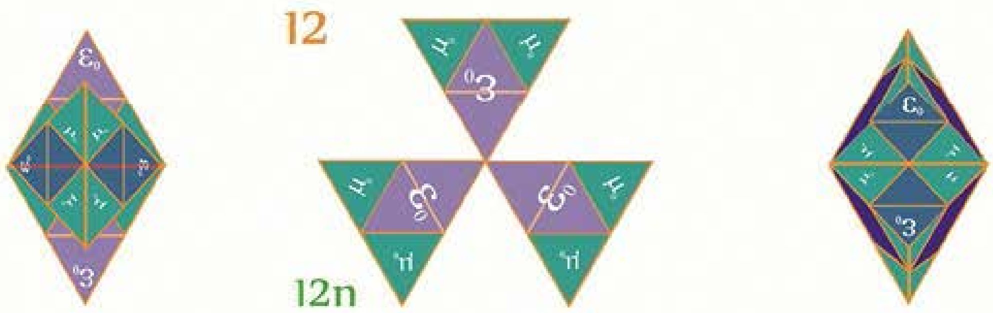

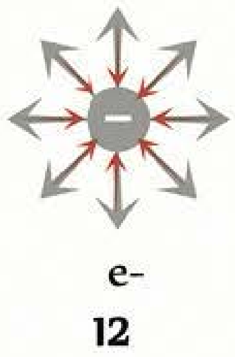

Charged rest mass-Matter topology

Quarks T[8π]
Leptons T[12π]

velocity invariant rest mass-Matter has a standing wave topology

Baryons T[20π]

Charged Leptons at rest are Electric field standing waves
(with neutral Magnetic poles)
KE from motion generates a Magnetic Moment

Bosons nπ [ODD]

Kinetic EM field geometry is divergent from a particle's rest Matter topology

Photons nπ [EVEN]

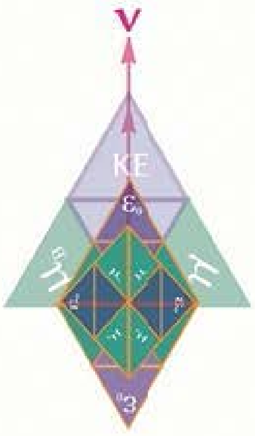

Charge

Q

[v-v]

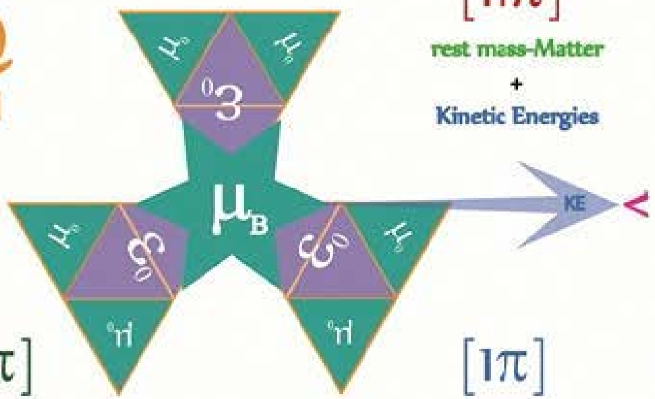

[nπ]

rest mass-Matter
+
Kinetic Energies

[12π]

rest Matter topology

[1π]

Kinetic Energy geometry

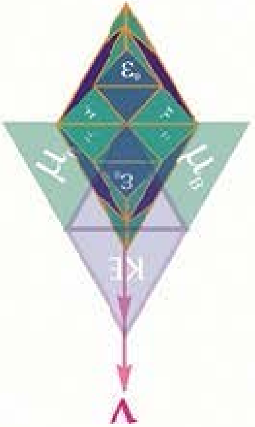

KEM fields of Matter in motion

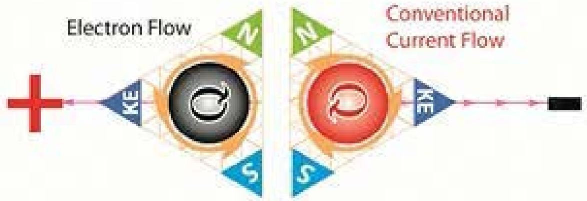
Electron Flow
Conventional Current Flow
+
KE
N
S
N
KE
S
-

ZPFs geometries can be used to model the KEM fields of charged particles

2D charged EM field geometries create Matter topologies

tetryons	[4π]	tetryons	[4π]
quarks	[12π]	quarks	[8π]
leptons	[12π]	leptons	[12π]
Baryons	[36π]	Baryons	[20π]
Elements	[84π]	Elements	[54π]

The mass-energy content of all charged fascia constituting massive particles have momenta that is proportional to the intrinsic velocity [c] of the standing wave

rest Matter

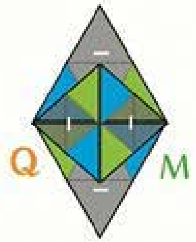

Electro-static particles have neutralised magnetic dipoles

Relativistic mass

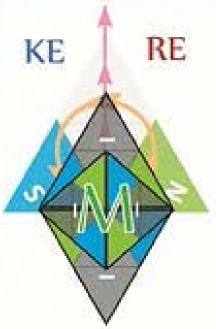

Kinetic motion produces Magnetic moments

Spherical point charges do NOT exist

positron

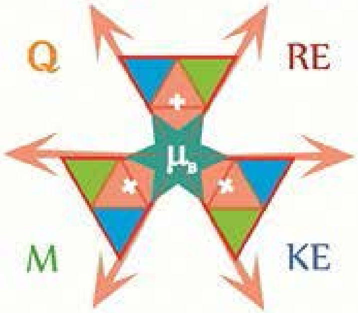

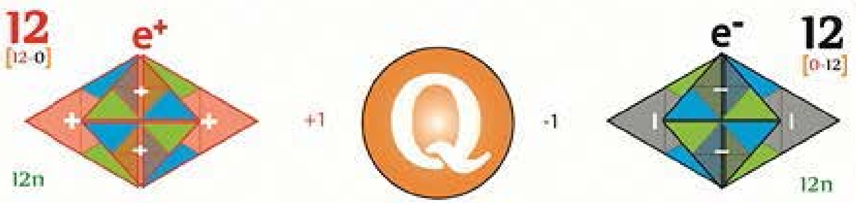
12
[12-0]
e+
12n
+1
Q
-1
e-
12
[0-12]
12n

3D Matter is a standing-wave topology resulting from radiant 2D EM geometries
All leptons and quarks both have 12 charged fasica geometries.
[but differing mass-Matter-particle topologies]

electron

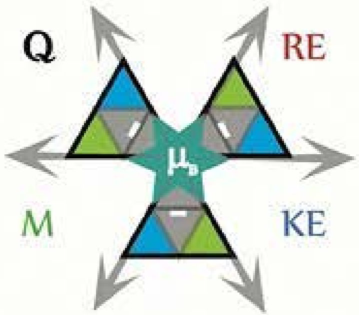

All EM fields resulting from Kinetic Energy (motion) radiate outwards
(the intrinsic KEM fields contain both Negative and Positive Energy momenta quanta)

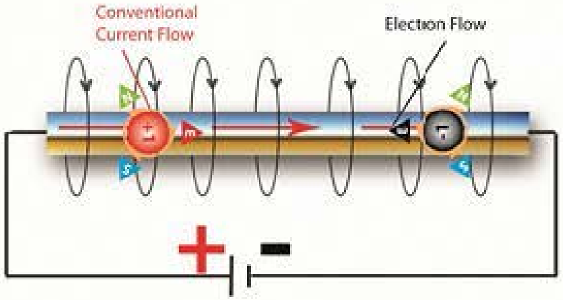
Conventional Current Flow
Electron Flow
+
-

Magnetic field around a current carrying conductor

Magnetic field produced by a Solenoid

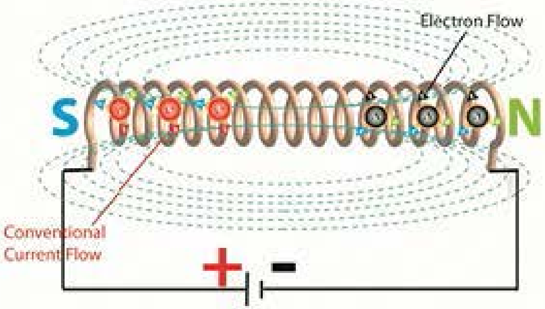
Electron Flow
S
N
Conventional Current Flow
+
-

μ_0 There is an inverse cube relationship between magnetic field strength and magnetic field force with respect to distance from the magnet. ε_0

Biot-Savart Law

is an equation in electromagnetism that describes the magnetic field B generated by an electric current.

The interaction between Magnetostatic fields for which a Magentic dipole exists obeys the inverse CUBED law of attraction and repulsion

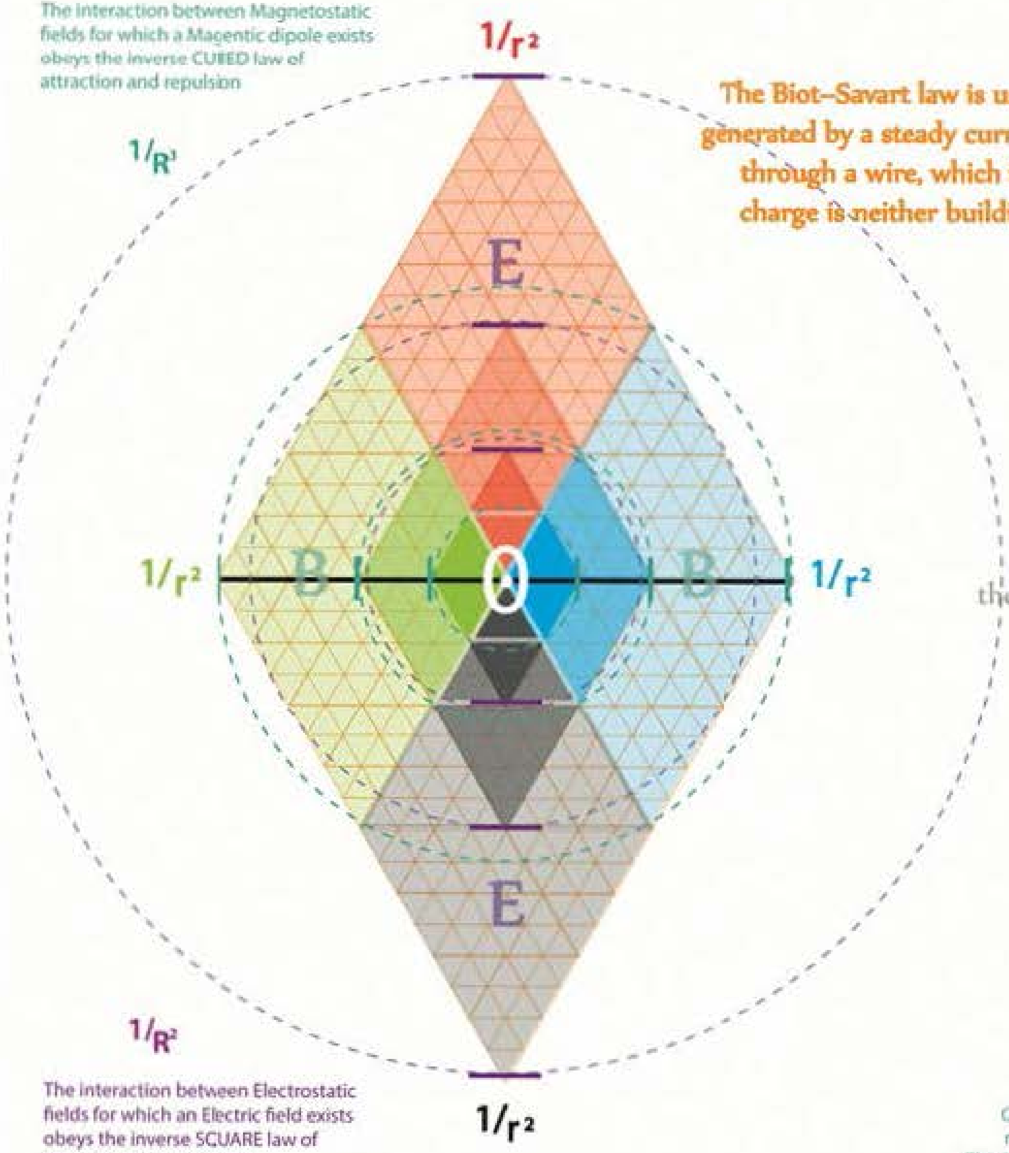

The interaction between Electrostatic fields for which an Electric field exists obeys the inverse SQUARE law of attraction and repulsion

The Biot–Savart law is used to compute the magnetic field generated by a steady current, i.e. a continual flow of charges, through a wire, which is constant in time and in which charge is neither building up nor depleting at any point

$$\mathbf{B} = \int \frac{\mu_0}{4\pi} \frac{I d\mathbf{l} \times \mathbf{r}}{|r|^3},$$

The radial distance between Magnetic dipoles is less than the distance between Electric dipoles

$$\mathbf{B} = \int \frac{\mu_0}{4\pi} \frac{I d\mathbf{l} \times \hat{\mathbf{r}}}{|r|^2},$$

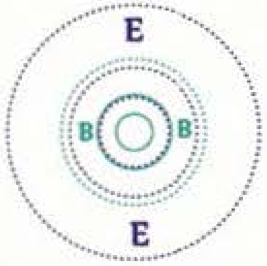

Close to one pole of a magnet, B field strength resembles the inverse square of Electric force. This is because it behaves as a "unipolar magnetic field"

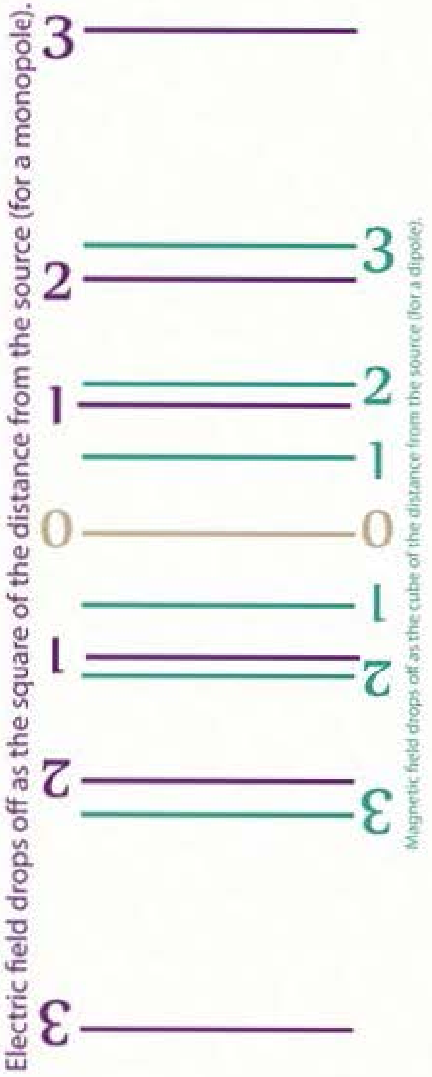

Electric field drops off as the square of the distance from the source (for a monopole).

Magnetic field drops off as the cube of the distance from the source (for a dipole).

Quantum Chirality

Its the equilateral geometry of quantised angular momenta that creates chirality in physics

Mirror imaged Planck quanta
are NOT
identical to each other

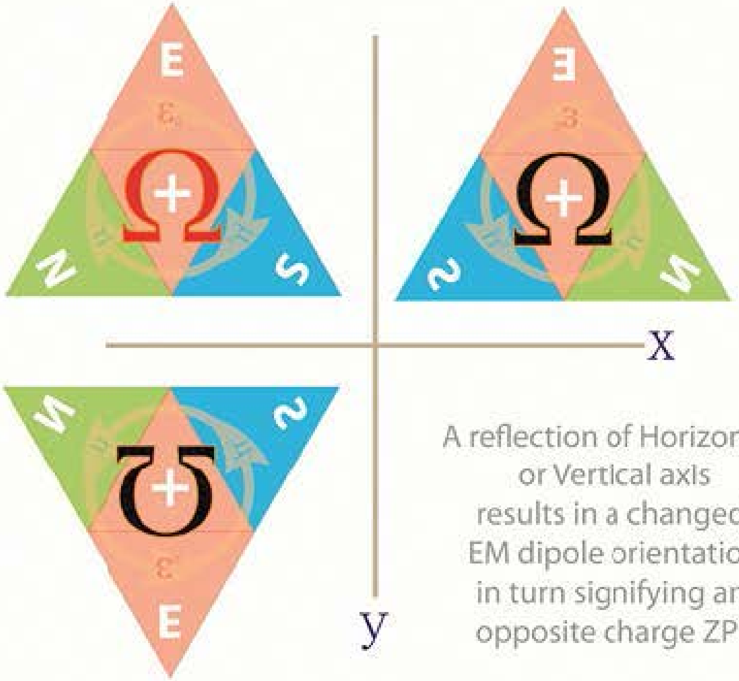

A reflection of Horizontal or Vertical axis results in a changed EM dipole orientation in turn signifying an opposite charge ZPF

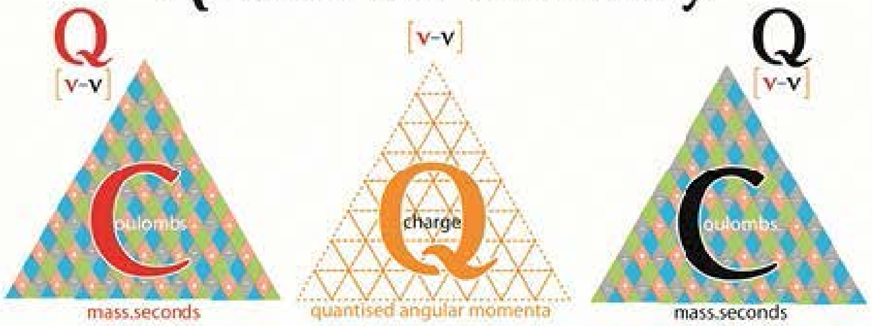
Q
[v-v]
C
oulombs
mass.seconds
[v-v]
Q
charge
quantised angular momenta
Q
[v-v]
C
oulombs
mass.seconds

The equilateral geometry of any EM field or Matter particle is determined by its nett Coulombic charge

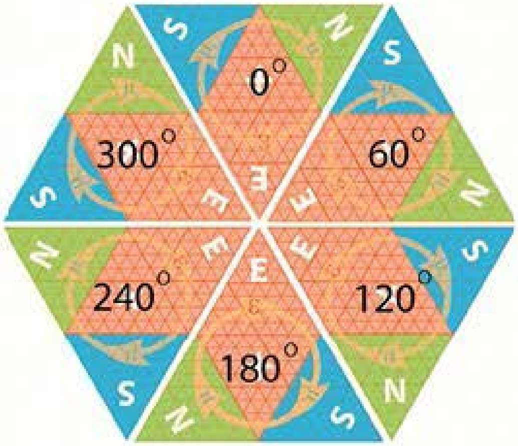
0°
60°
120°
180°
240°
300°
N
S
E
ε

Any nominal rotation about an axis results in a re-orientation of the electromagnetic vectors but does not affect any change to charge etc.

Ω Irrespective of orientation or rotation: Ω

Positive charge fields have clockwise inductive flux geometries

Negative charge fields have counter-clockwise inductive flux geometries

Pi radian - energy momenta geometries

mass-energy momenta

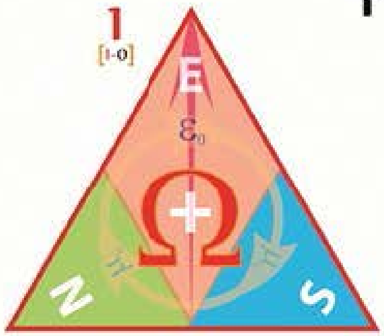
1
[1-0]
E
ε_0
Ω
+
μ_0
N
S

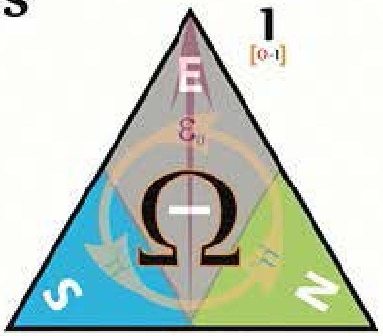
1
[0-1]
E
ε_0
Ω
−
μ_0
S
N

Q

nett charge

[v-v]

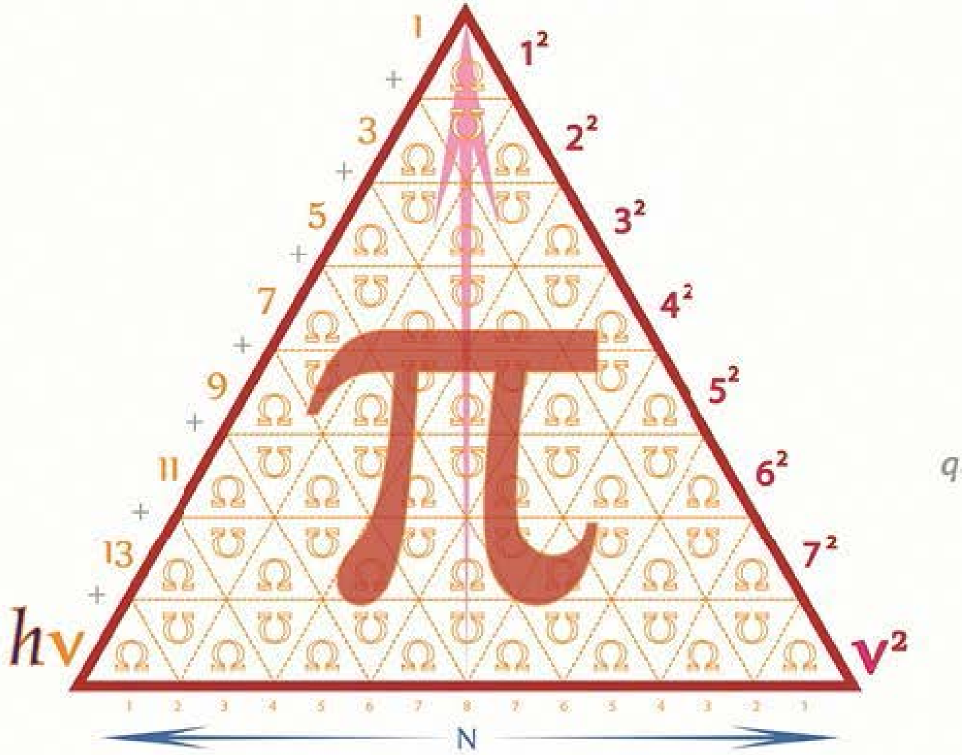
1
1^2
+
3
2^2
+
5
3^2
+
7
4^2
+
9
5^2
+
11
6^2
+
13
7^2
+
hv
v^2
π
Ω
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
N

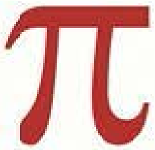

pi radian energy geometries

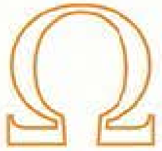

quantised angular momentum

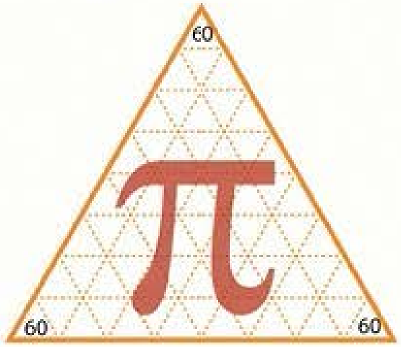

$$\underset{\text{energy}}{n\pi}\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v}\right]^2$$

π radian geometries are comprised of equilateral mass momenta Ω

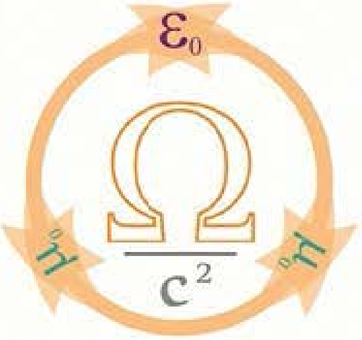
ε_0
Ω
c^2
μ_0
μ_0

ZPFs and Bosons

ZPFs are Planck energy quantum elements

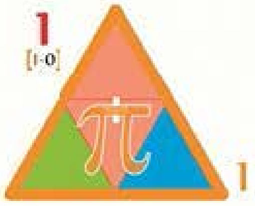

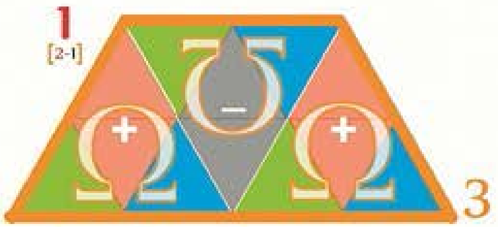

Bosons are transverse Quantum levels

Quantised angular momentum is the foundation for all Tetryonic mass-ENERGY-Matter geometries

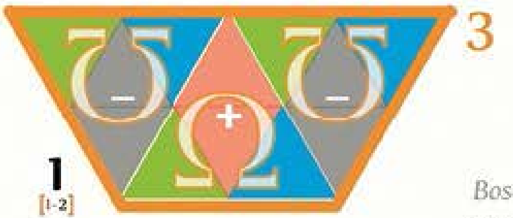

Bosons are the exchange particles for the EM force

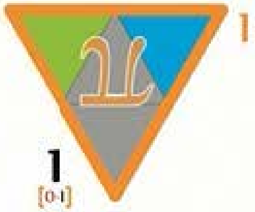

ZPFs are the quanta geometry for Charge, Bosons and Energy

Each Quantum level is an ODD number of quanta (Bosons)

Each 'squared' energy field is the sum of the preceeding Bosons

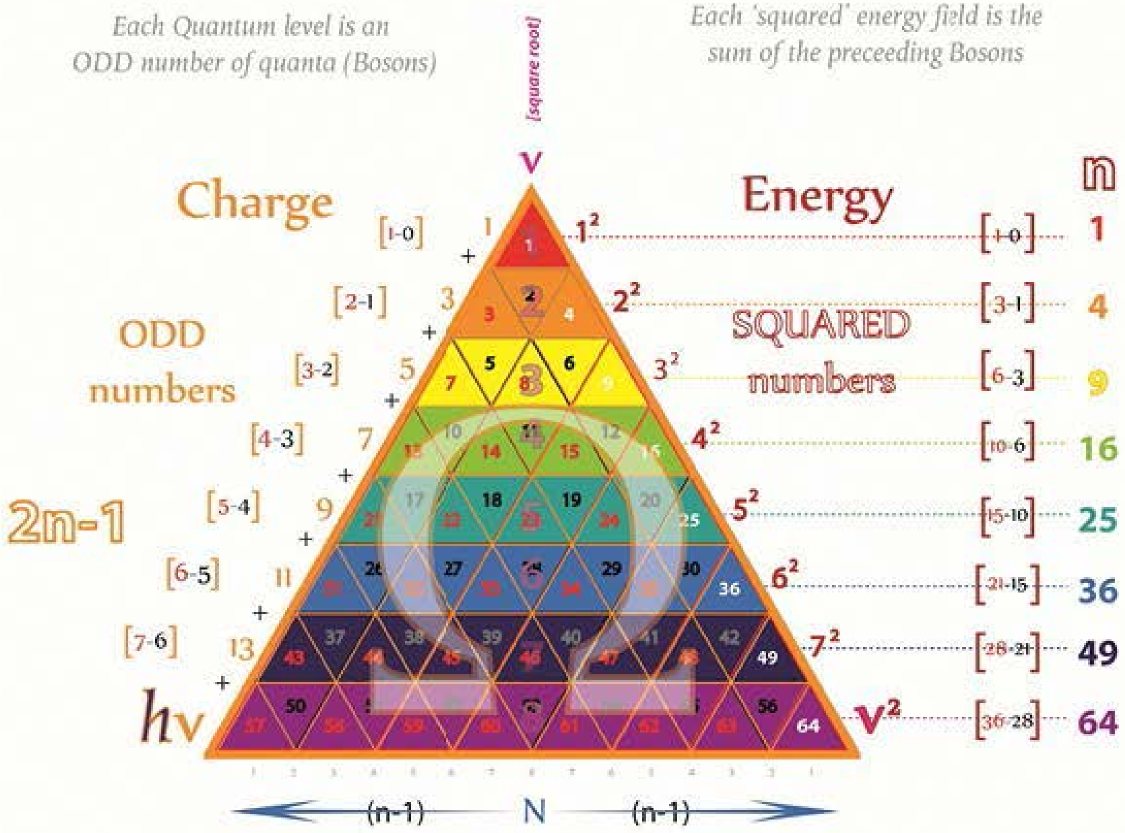
[square root]
v
Charge
Energy
n
ODD numbers
SQUARED numbers
2n-1
hv
[1-0] 1
[2-1] 3
[3-2] 5
[4-3] 7
[5-4] 9
[6-5] 11
[7-6] 13
1² [1-0] 1
2² [3-1] 4
3² [6-3] 9
4² [10-6] 16
5² [15-10] 25
6² [21-15] 36
7² [28-21] 49
v² [36-28] 64
(n-1) N (n-1)

The charged quanta in all mass-Energy geometries create a NORMAL Distributions

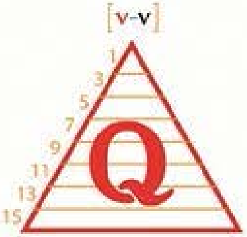
[v-v]
1
3
5
7
9
11
13
15
Q

EM Field Planck quanta

$$\text{ODD}\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Bosons ElectroMagnetic mass velocity

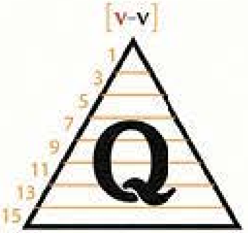
[v-v]
1
3
5
7
9
11
13
15
Q

Bosons form the geometry of Quantum Levels

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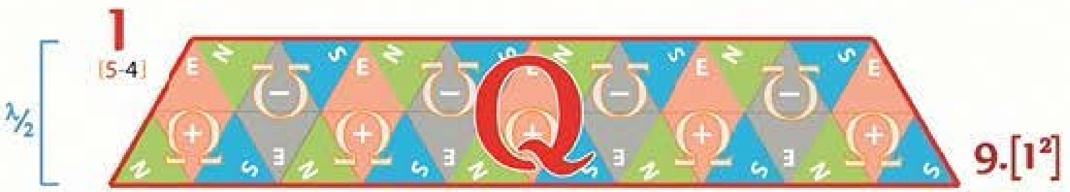

$$W^{+} = n\pi_{ODD}\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^{2}\right]\right]$$

Force carrier for Positive charge particles

W^{+} Boson

EM field Planck quanta

$$ODD\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^{2}\right]\right]$$

Bosons

ElectroMagnetic mass velocity

CHARGE carrier Bosons
are ODD number quanta

Bosons

form unit charge Quantum levels
that facilitate EM induction between
mass-Energy-Matter

Neutral Z Bosons and Photons
are EVEN quanta Bosons

EMField Planck quanta

$$EVEN\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^{2}\right]\right]$$

Photons

ElectroMagnetic mass velocity

Neutral charge parallelogram geometry EM force carriers

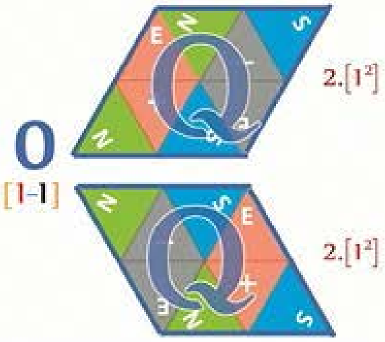

Z^{0} Boson

Neutral Z Bosons can be formed by combining EVEN numbers of W Bosons

They are EVEN numbered alternate geometry Photons

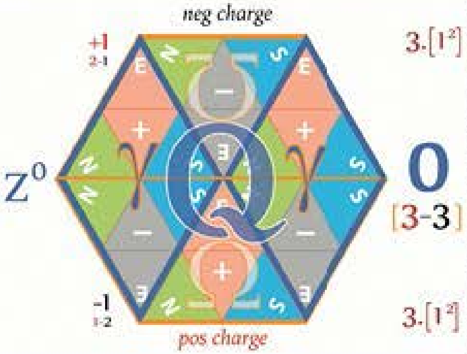

Photons are alternate (diamond) EM geometries formed from Z Bosons

W^{-} Boson

Force carrier for Negative charge particles

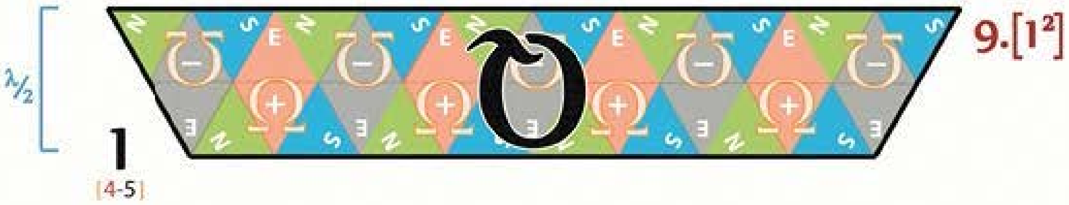

$$W^{-} = n\pi_{ODD}\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^{2}\right]\right]$$

Bosons are charge carriers

[the geometric foundation of quantum levels]

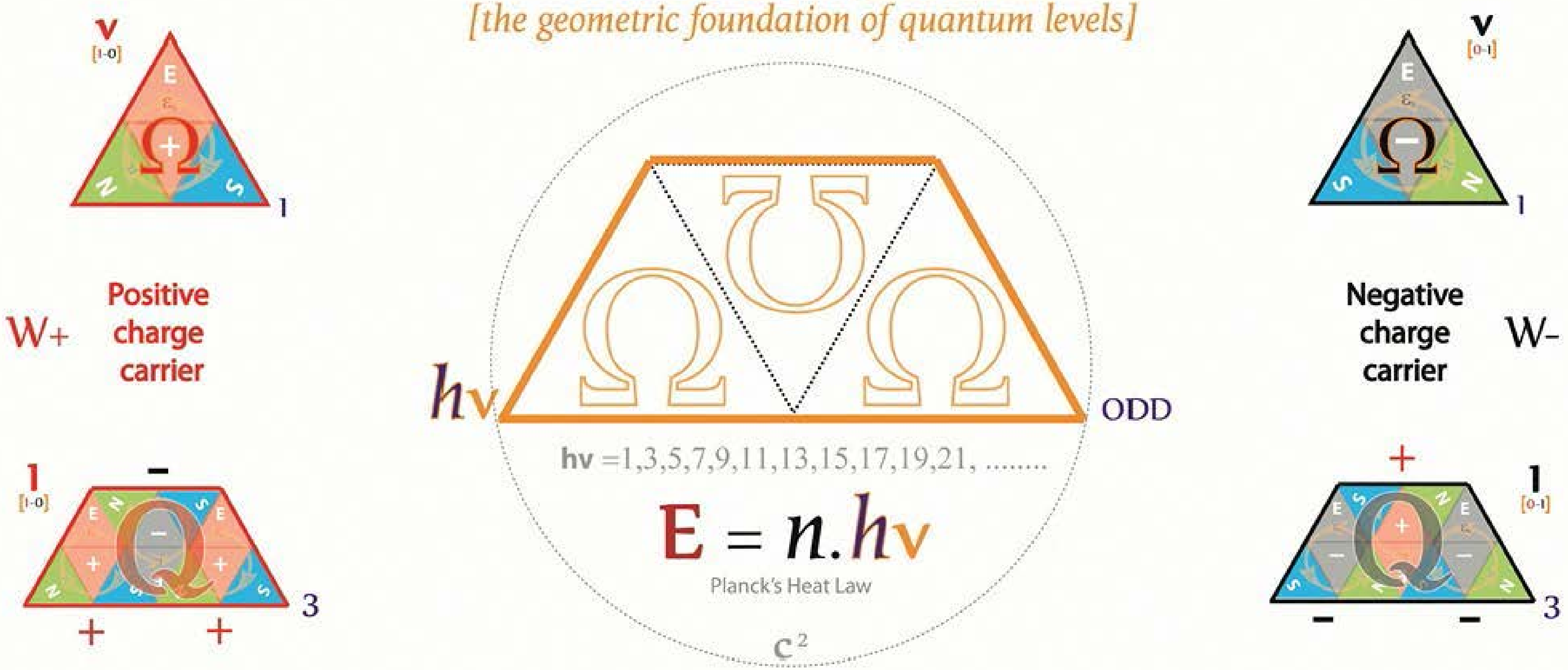
v
[1-0]
E
Ω
+
N
S
1
W+
Positive charge carrier
1
[1-0]
–
E
N
S
+
3
+
+
hv
Ω
Ω
Ω
ODD
c²
v
[0-1]
E
Ω
–
S
N
1
W-
Negative charge carrier
+
1
[0-1]
E
S
N
–
+
3
–
–

hv =1,3,5,7,9,11,13,15,17,19,21, ...

$$E = n.hv$$

Planck's Heat Law

All Bosons have ODD quanta trapazoidal charged EM mass-energy geometries

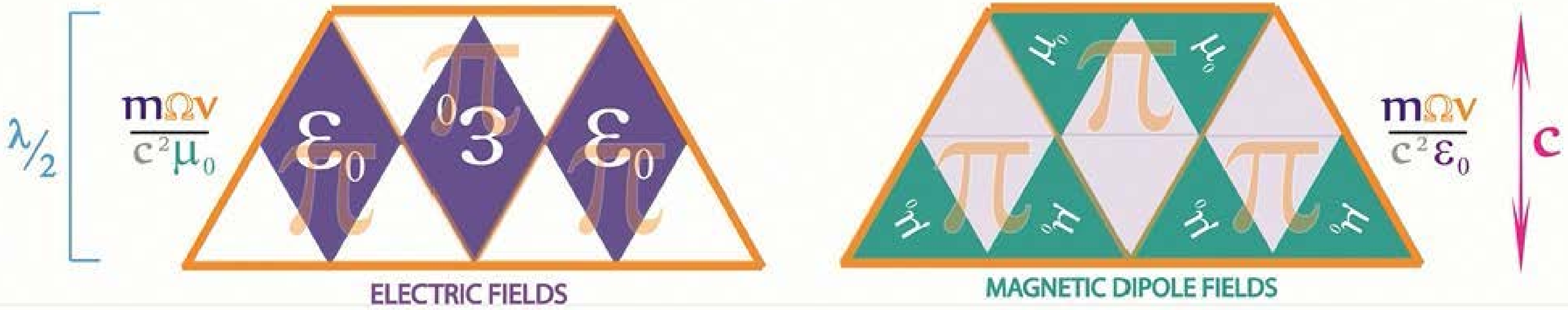
λ/2
$\frac{m\Omega v}{c^2\mu_0}$
ε_0
π
ε_0
ε_0
μ_0
μ_0
μ_0
μ_0
μ_0
μ_0
π
$\frac{m\Omega v}{c^2\varepsilon_0}$
c

ELECTRIC FIELDS

MAGNETIC DIPOLE FIELDS

Boson Frequencies

All Bosons are 1/2 wavelength EM fields with ODD number quanta
They are the geometric basis for transverse EM field Quantum levels

EM Field Planck quanta
ODD $\pi\,[[\varepsilon_0\mu_0].[m\Omega v^2]]$
Bosons ElectroMagnetic mass velocity

W Bosons are comprised of
ODD number quanta

Bosons are TRANSVERSE Charge carriers

ODD #

Q

Planck quanta
$n\pi\,[[m\Omega v^2]]$
mass velocity

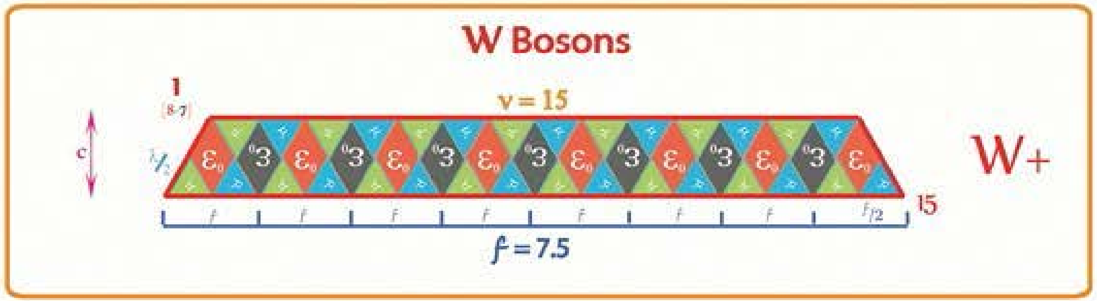
W Bosons
1
[8-7]
v = 15
c
½
15
f
f/2
f = 7.5
W+

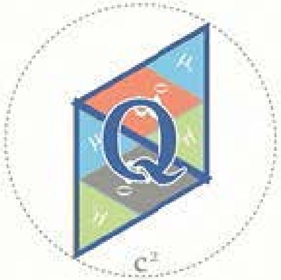

Neutral Z BOSONS and PHOTONS
have differing EM geometries

EVEN #

Q

Planck quanta
$2n\pi\,[[m\Omega v^2]]$
mass velocity

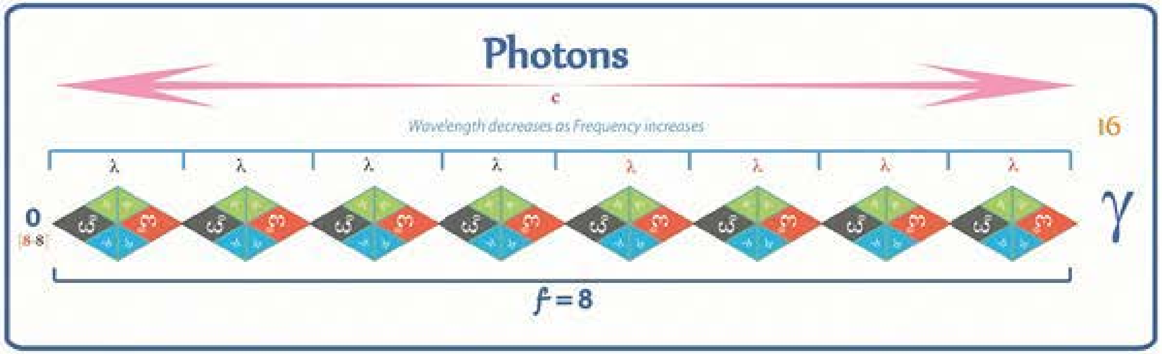
Photons
c
Wavelength decreases as Frequency increases
16
λ
0
[8-8]
f = 8
γ

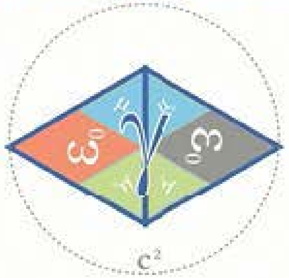

Photons are LONGITUDINAL
neutral EM force carriers
resulting from Bosons

ODD #

Q

Planck quanta
$n\pi\,[[m\Omega v^2]]$
mass velocity

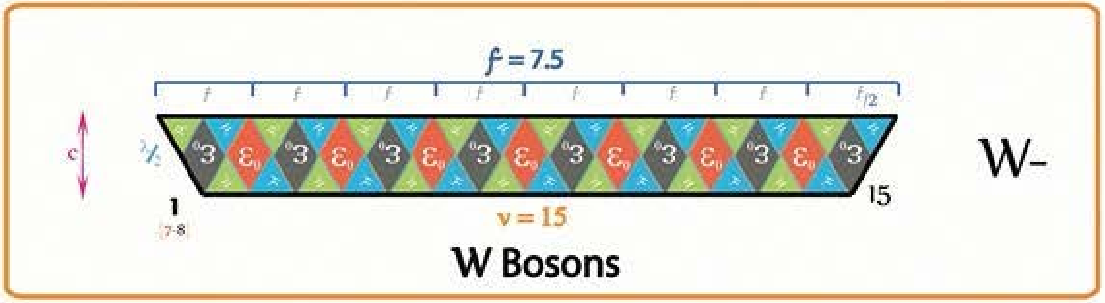
f = 7.5
f
f/2
c
½
15
1
[7-8]
v = 15
W Bosons
W-

EM waves are comprised of
EVEN number quanta [Photons]

EM Field Planck quanta
EVEN $\pi\,[[\varepsilon_0\mu_0].[m\Omega v^2]]$
EM waves ElectroMagnetic mass velocity

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Boson Waveforms

All ODD Ω geometries [bosons]
create a quantum of charge

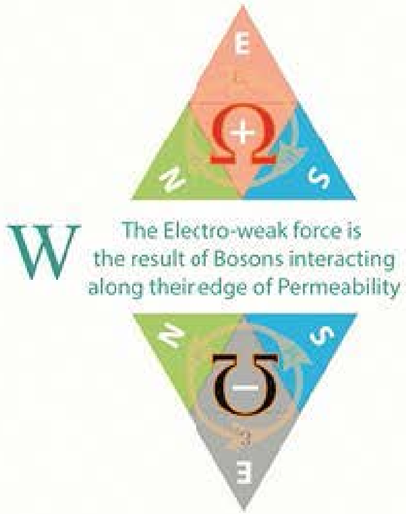

The Electro-weak force is the result of Bosons interacting along their edge of Permeability

Boson exchange is the basis of Electro-Magnetic Induction & Charge transfer

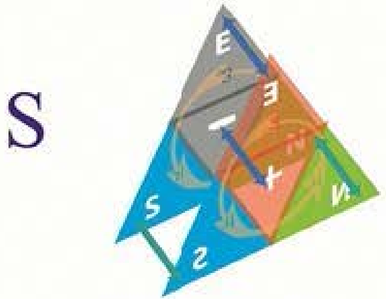

The Strong Colour Force is the result of Bosons interacting via their their Electric charge fascia

Positive charge carrier

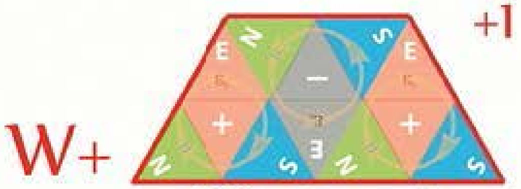

ODD number quanta

All charges are comprised of odd numbered Bosons

[each Boson is a Quantum level]

ODD number quanta

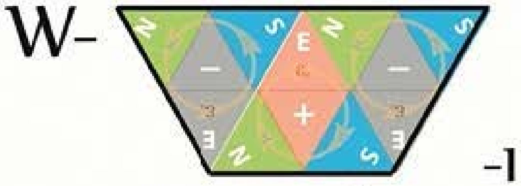

Negative charge carrier

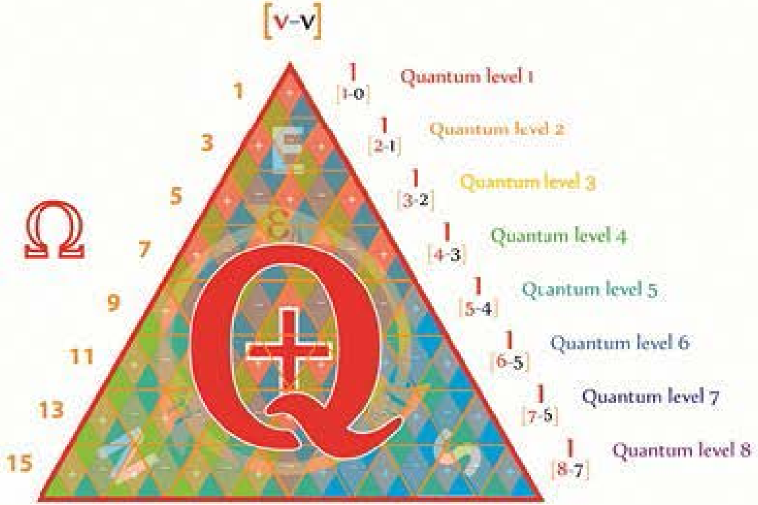
[v-v]
Ω
1
3
5
7
9
11
13
15
Q
+
E
N
S
1 [1-0] Quantum level 1
1 [2-1] Quantum level 2
1 [3-2] Quantum level 3
1 [4-3] Quantum level 4
1 [5-4] Quantum level 5
1 [6-5] Quantum level 6
1 [7-5] Quantum level 7
1 [8-7] Quantum level 8

Integral W Bosons form square Energy geometries

Separated energy geometries create an electromotive force

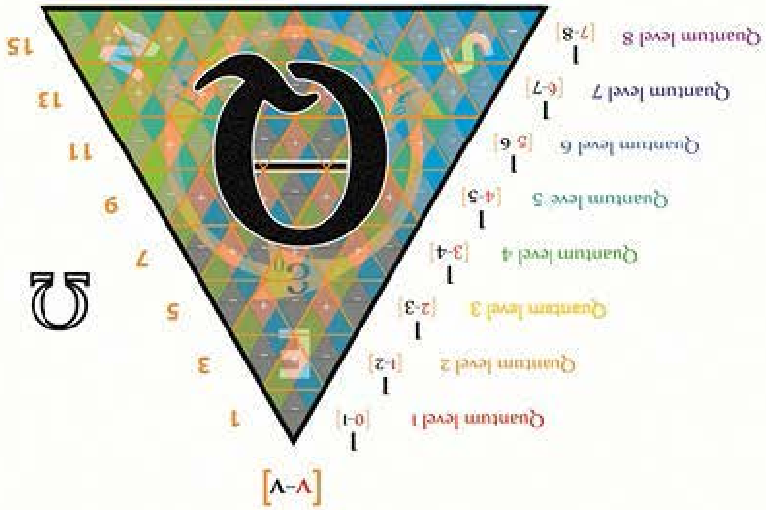
Ʊ
–
[v-v]
1
3
5
7
9
11
13
15
1 [1-0] Quantum level 1
1 [2-1] Quantum level 2
1 [3-2] Quantum level 3
1 [4-3] Quantum level 4
1 [5-4] Quantum level 5
1 [6-5] Quantum level 6
1 [7-6] Quantum level 7
1 [8-7] Quantum level 8

Bosons

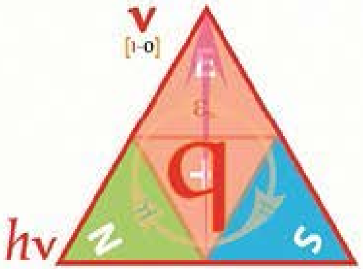

Positive Charges have nett
positive quantised angular momenta

Positive Bosons

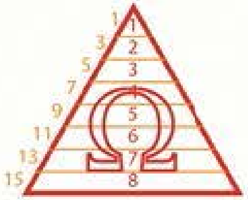
1
3
5
7
9
11
13
15
1
2
3
5
6
7
8
Ω

EM Field Planck quanta

$ODD\,\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$

Bosons ElectroMagnetic mass velocity

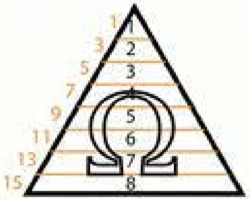
1
3
5
7
9
11
13
15
1
2
3
5
6
7
8
Ω

Bosons are the geometry of Quantum Levels

Negative Bosons

Negative Charges have nett
negative quantised angular momenta

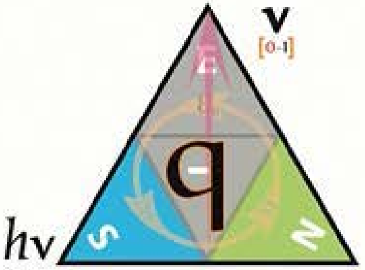

**Bosons are
TRANSVERSE
EM fields [levels]**

Each quantum Level is
a unit of Charge

**nett Charge
is a SCALAR
EM field property**

Charge

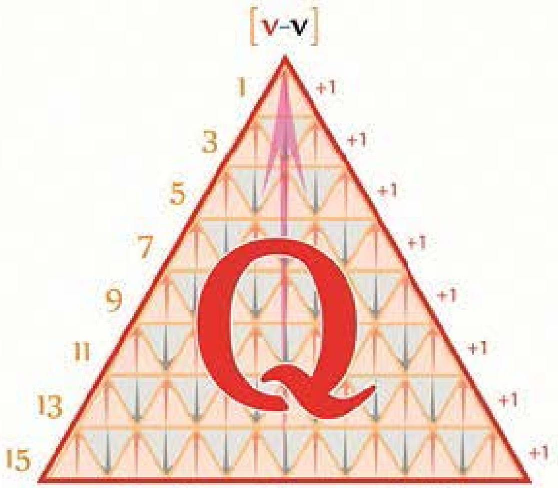
[v-v]
1
3
5
7
9
11
13
15
+1
+1
+1
+1
+1
+1
+1
+1
Q

Positive Charge field

**Charge is a measure of the nett
quantised angular momenta - energy geometry
of any given region of Space-time**

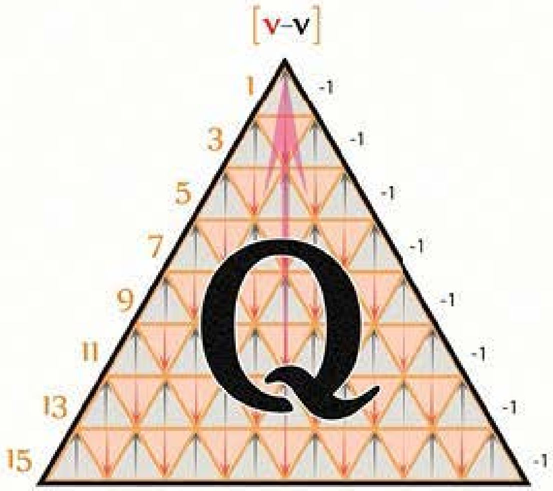
[v-v]
1
3
5
7
9
11
13
15
-1
-1
-1
-1
-1
-1
-1
-1
Q

Negative Charge field

bosons

photon

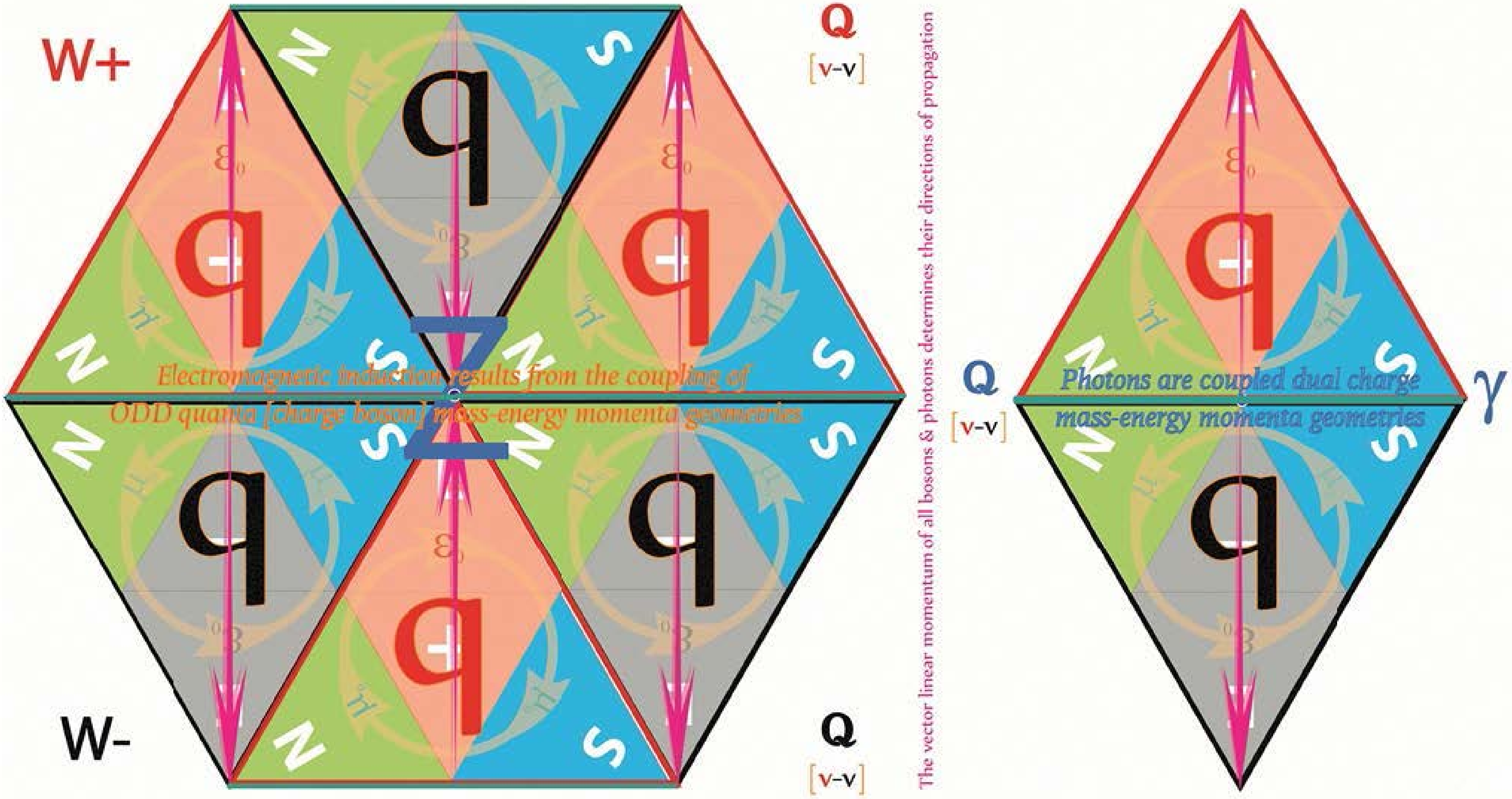

Electromagnetic induction results from the coupling of ODD quanta [charge boson] mass-energy momenta geometries

Photons are coupled dual charge mass-energy momenta geometries

The vector linear momentum of all bosons & photons determines their directions of propagation

ODD π

2nπ

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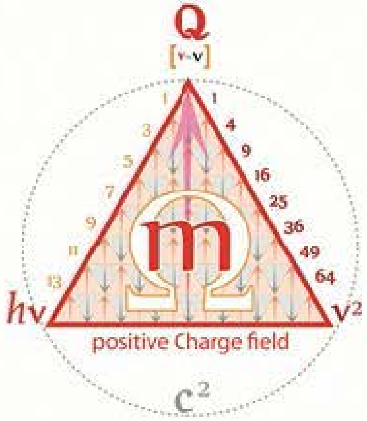
Q
[v-v]
1
1
3
4
5
9
7
16
9
25
11
36
13
49
64
m
Ω
hv
v²
positive Charge field
c²

mass geometries

$$m \qquad n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right] \qquad E$$

mass
energy
spatial field
impedance
Planck
quanta
mass
velocity

mass-energy

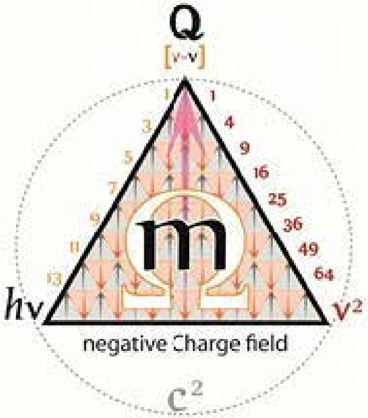
Q
[v-v]
1
1
3
4
5
9
7
16
9
25
11
36
13
49
64
m
Ω
hv
v²
negative Charge field
c²

the distribution of energy momenta in EM fields creates charged fascia

charged planar mass-energy momenta form

radiant 2D equilateral geometries

ρ

mass-energy geometries

m

kg/m²

energy momenta per second

$$\frac{E}{c^2} = m \qquad E \qquad M = \frac{E}{c^4}$$

mass

ENERGY

Matter

energy momenta per second squared

ρ

mass-Matter topologies

M

KG/m³

charged mass-energy geometries form

standing-wave 3D tetrahedral topologies

Matter displacement topologies have internalised strong force fascia partitions

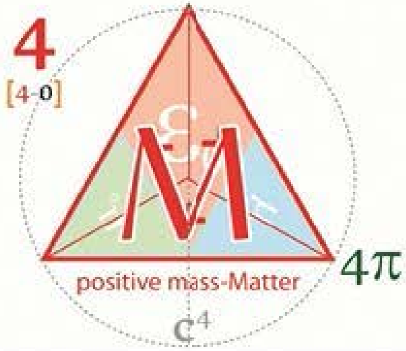
4
[4-0]
ε
M
4π
positive mass-Matter
c⁴

mass-Matter

$$m \qquad 4n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right] \qquad M$$

Matter
spatial field
impedance
Planck
quanta
mass
velocity

Matter topologies

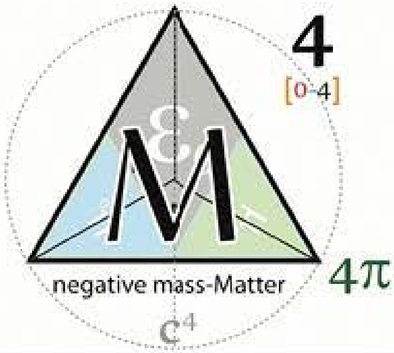
4
[0-4]
ε
M
4π
negative mass-Matter
c⁴

Tetryonics 05.08 - geometric mass-ENERGY-Matter topologies

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Matter

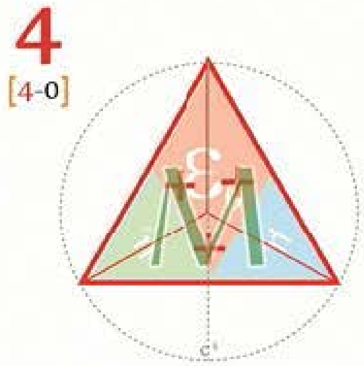

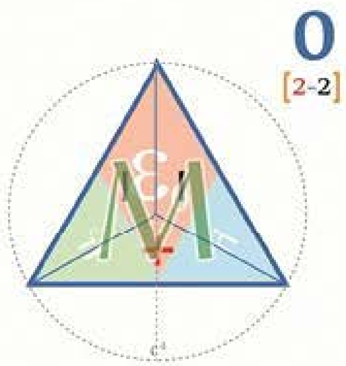

EM mass-energies have
2D planar geometries

$E = mv^2$

2D EM mass-Energy
forms
3D Matter

EM Matter has a
3D Tetrahedral topology

$E = Mc^4$

3D Matter
is comprised of
2D EM mass-Energies

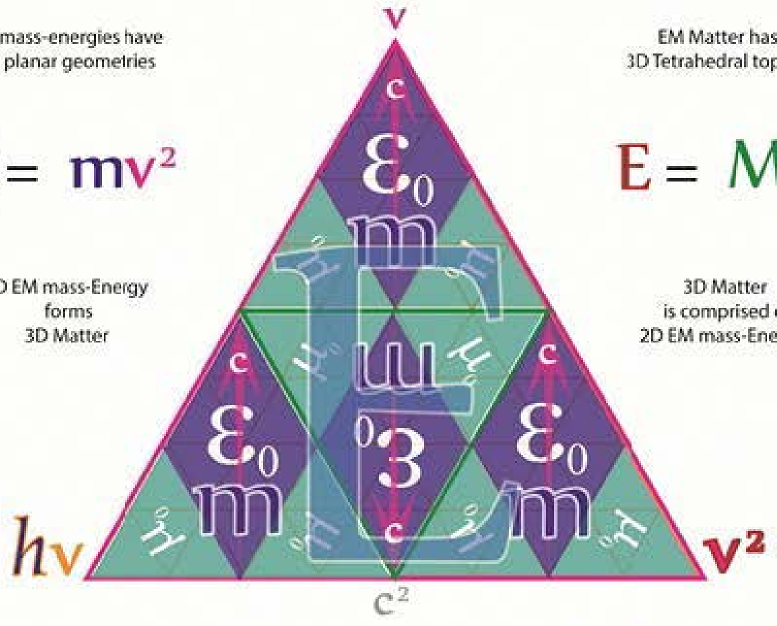

2D

ρ/sec

EM mass-energy per square metre

EM mass geometries

m

kg/m²

3D

ρ/sec^2

EM mass-energy per cubic metre

Matter topologies

M

kg/m³

Matter is comprised of 4nπ mass-energy geometries forming a 3D standing wave topology

Tetryons — EM Field — Planck — quanta

$$4n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Matter quanta — ElectroMagnetic — mass — velocity

Matter is anything that has a closed mass-energy topology and displaces a volume
(the 3D massive building blocks of quantum particles and atomic elements)

The EM mass-energy quanta of Matter can be measured transversely and longitudinally
allowing them to exhibit a number of wave-like and particle-like properties
(de Broglie wavelength & Compton frequency)

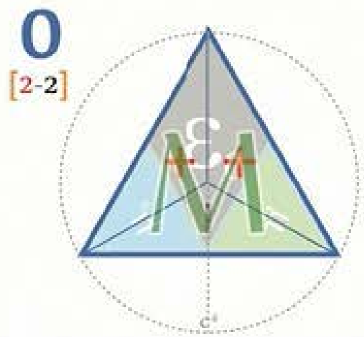

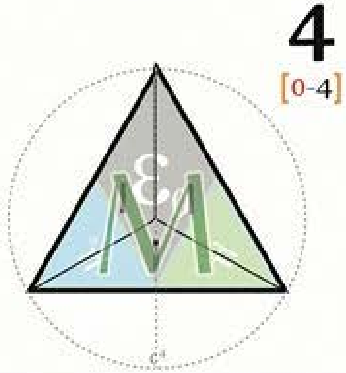

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Tetryons - the quanta of Matter

'massless' is a physics mis-nomer as
all energy exhibits mass equivalence

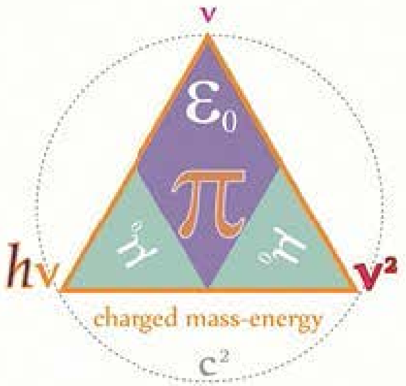
v
ε_0
π
hv
v^2
charged mass-energy
c^2

ZPF

mass-Energy quanta

m

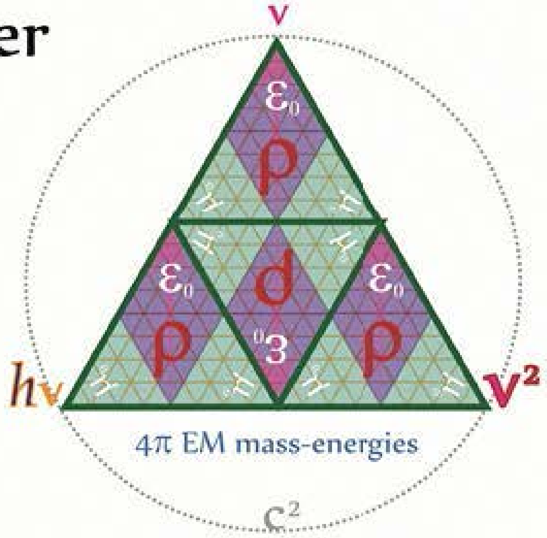
v
ε_0
ρ
d
3
hv
v^2
4π EM mass-energies
c^2

$$m = n\pi\Big[\Big[\overset{\text{spatial}}{\underset{\text{impedance}}{1/c^2}}\Big].\overset{\text{Energy}}{\underset{\text{momenta}}{\Big[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\Big]}}\Big]$$

TETRYONS

Platonic tetrahedrons are the foundational topologies of all 3D Matter

$$T\pi\Big[\Big[\overset{\text{spatial}}{\underset{\text{impedance}}{1/c^4}}\Big].\overset{\text{Energy}}{\underset{\text{momenta}}{\Big[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\Big]}}\Big] = \underset{\text{Matter}}{M}$$

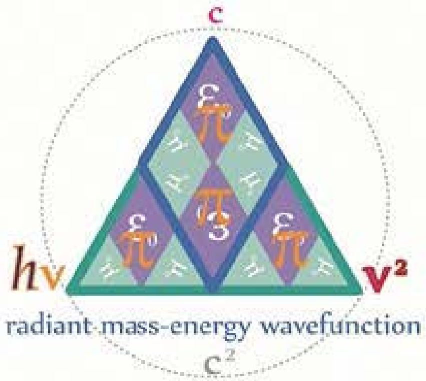
c
ε
π
3
hv
v^2
radiant mass-energy wavefunction
c^2

Tetryon

Matter Quantum

M

2D mass-energy geometries
can be combined to form
3D mass-ENERGY-Matter particles

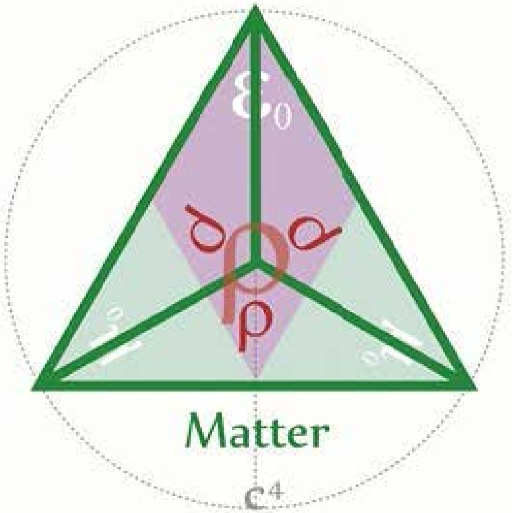
ε_0
d
ρ
Matter
c^4

Standing wave mass-energy geometries and Matter topologies

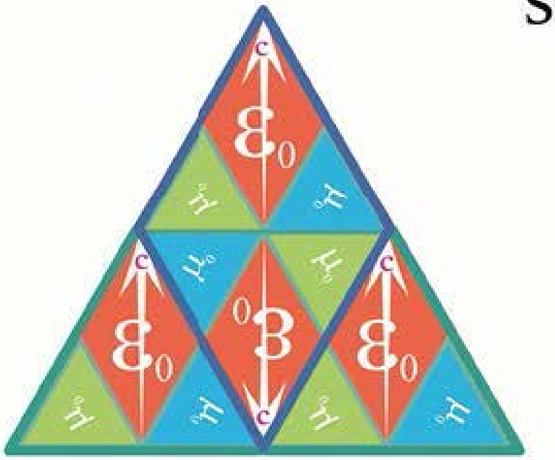
c
ε_0
μ_0

As each charged fascia's E field tries to propagate outwards it interacts with a M field dipole at each apex

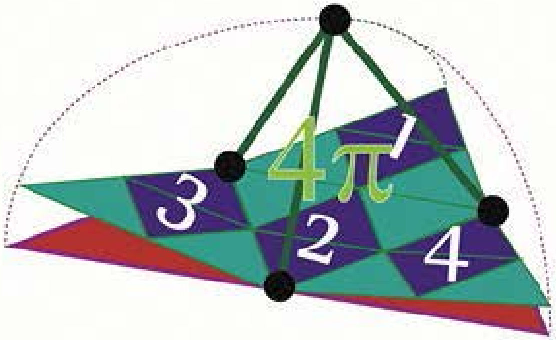

$$\underset{\text{Matter}}{M} = T\pi\left[\left[\overset{\text{spatial}}{\underset{\text{impedance}}{1/c^4}}\right].\overset{\text{Energy}}{\underset{\text{momenta}}{\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\Omega\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]}}\right]$$

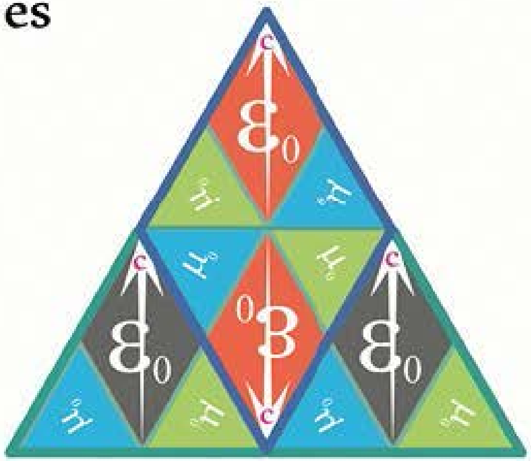
c
ε_0
μ_0

In turn energised M fields supply energy to the E Fields creating a EM standing wave [the EM topology of Matter]

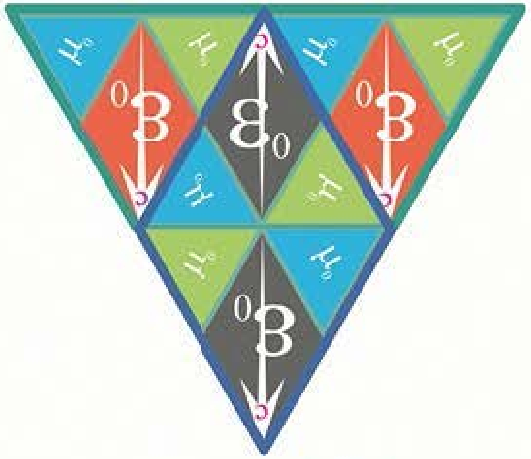
c
ε_0
μ_0

Matter stores EM mass-energies geometries in its 3D Tetrahedral topology

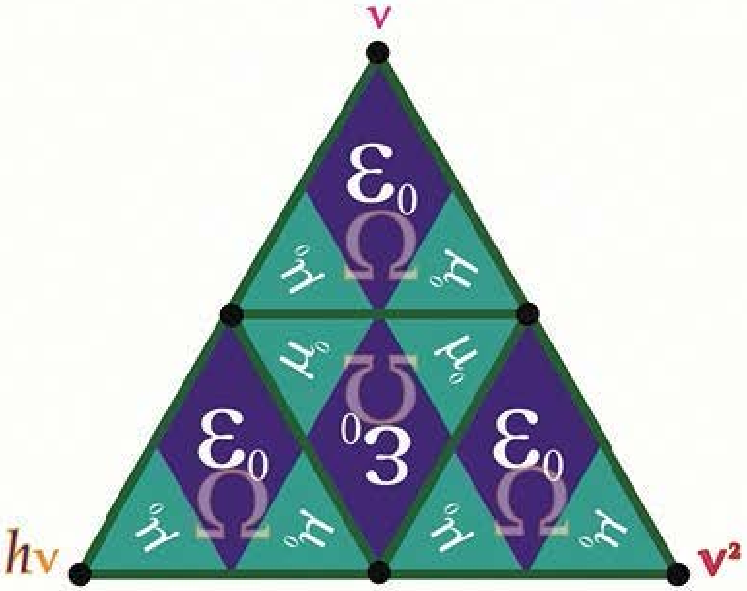
v
hv
v²
ε_0
μ_0
Ω

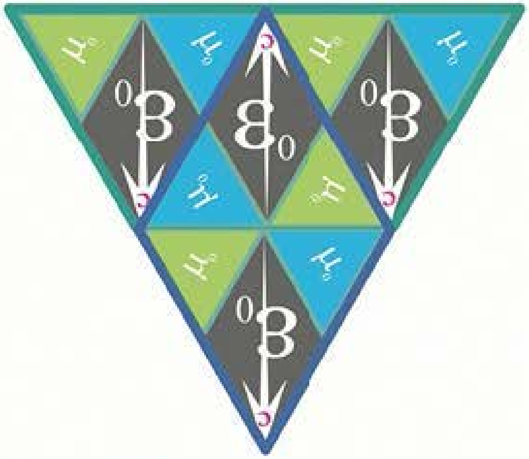
c
ε_0
μ_0

All mass-energy propagate at the speed of light creating linear energy momentum

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Tetryonic charge topologies

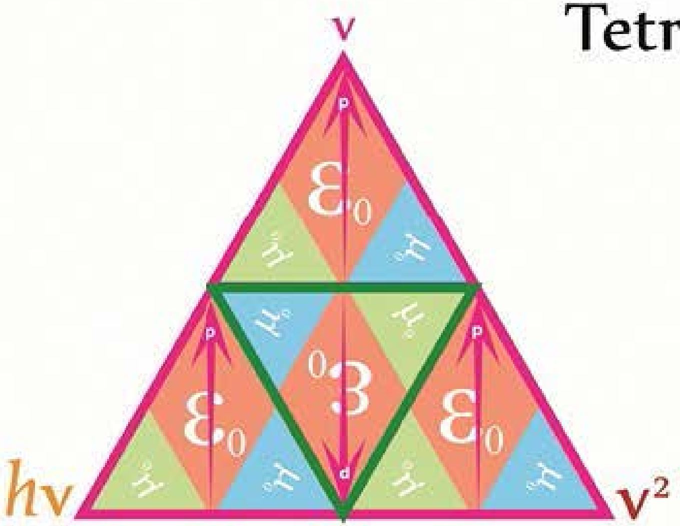

Positive Tetryon

*The 3D Tetryonic volume of Matter
is what distingushes it from
2D EM mass-energies*

Negative Tetryon

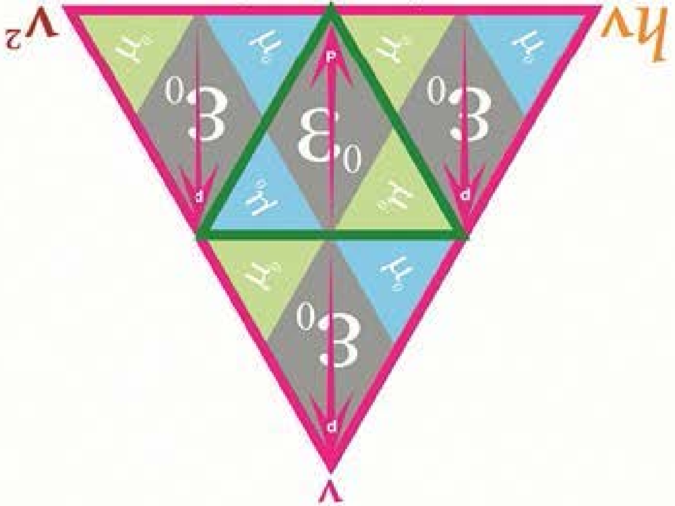

TETRYONS

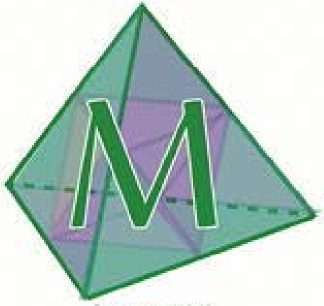

[MATTER]

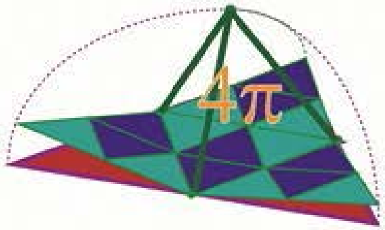

The four EM mass-energy momenta
produced by Tetryonic collapse
must not be confused with
the classical 4 Energy-momenta
(which refers to x,y,z co-ordinates & v)

4pi radiant mass-energies

**Four 2D mass-energy geometries
can combine to form via charge interactions
3D tetrahedral Matter topologies**

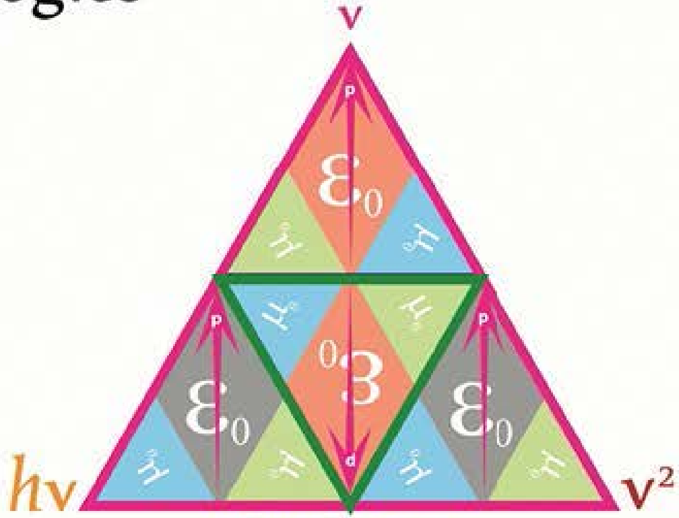

Neutral Tetryon

*A 3D Tetryon can be 'collapsed' into a 2D waveform
radiant four energy momenta EM waveform
that conserves all of its 2D mass-energy-momenta*

Neutral Tetryon

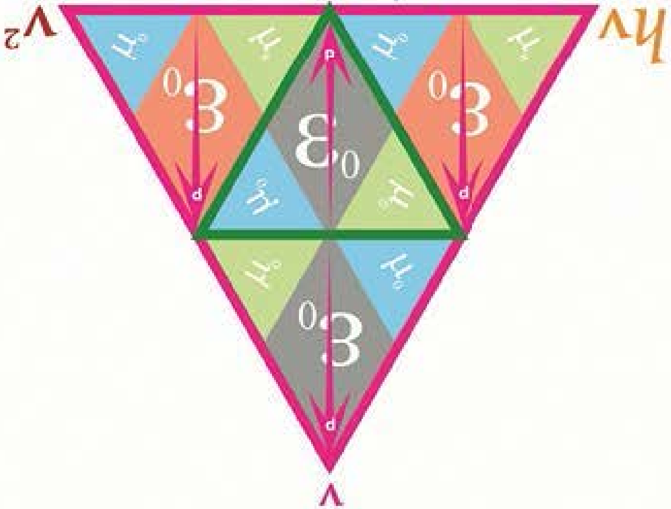

Tetryon Genesis

1. WEAK interaction
Mutual Inductive Coupling
[Magnetic dipoles interact]

ODDπ
charged mass-energies

Non-Zero
nett mass-Energy-momenta
result in Linear momentum

EVENπ
radiant mass-energies

2. *2D EM mass-energies*
interact to form
3D Matter topologies

EM wave momenta
can form standing waves
[Matter geometries]

3. STRONG interaction
Electrostatic Matter attract
via Electric charges and
Magnetic dipoles

4nπ
mass-Matter geometries

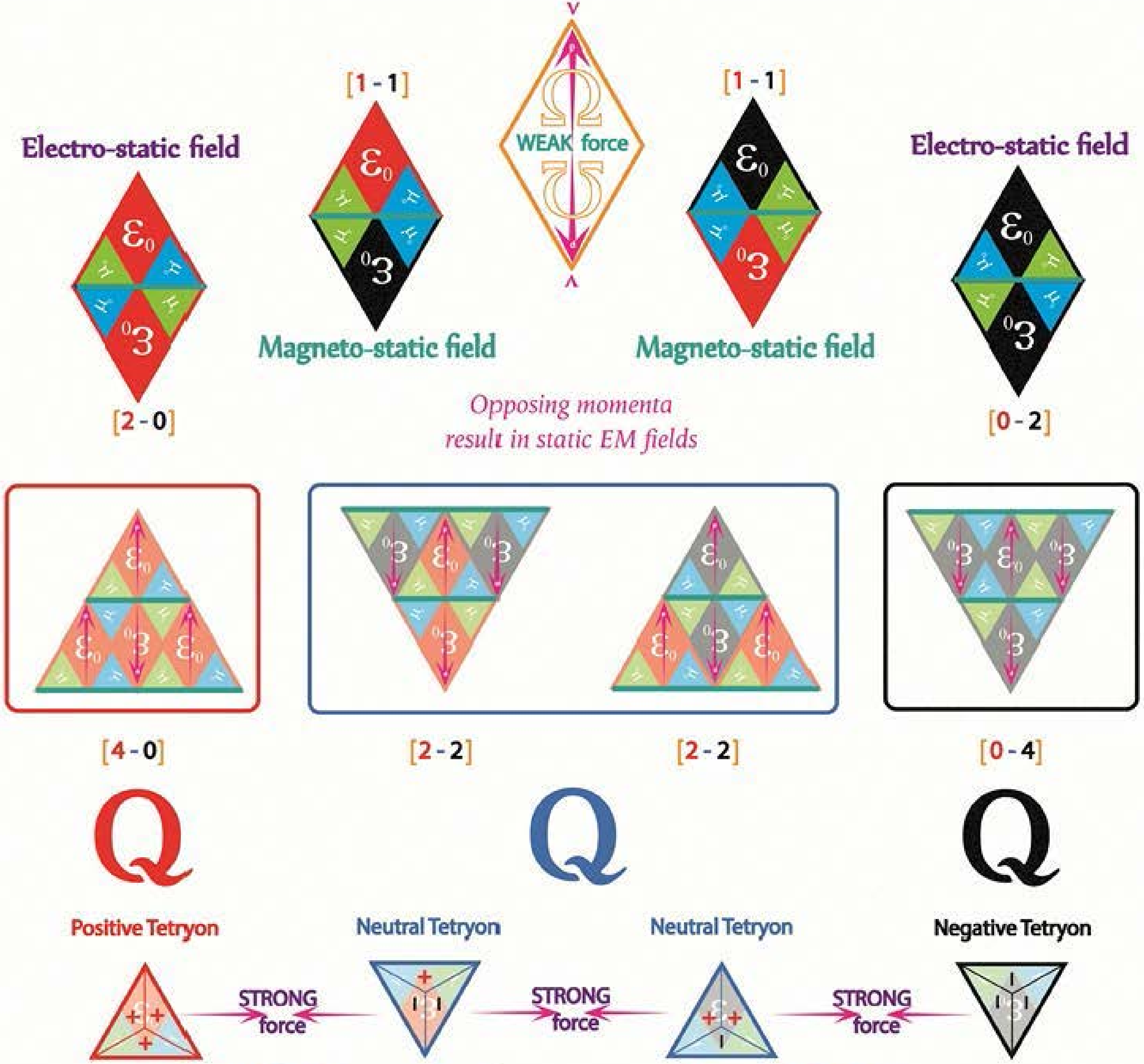
Electro-static field
[1 - 1]
WEAK force
[1 - 1]
Electro-static field
ε_0
μ_0
[2 - 0]
Magneto-static field
Magneto-static field
[0 - 2]
[4 - 0]
[2 - 2]
[2 - 2]
[0 - 4]
Q
Q
Q
Positive Tetryon
Neutral Tetryon
Neutral Tetryon
Negative Tetryon
STRONG force
STRONG force
STRONG force

Opposing momenta
result in static EM fields

All Tetryonic charges seek equilibrium

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Positive Tetryon

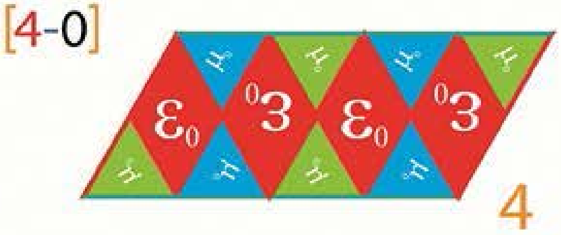

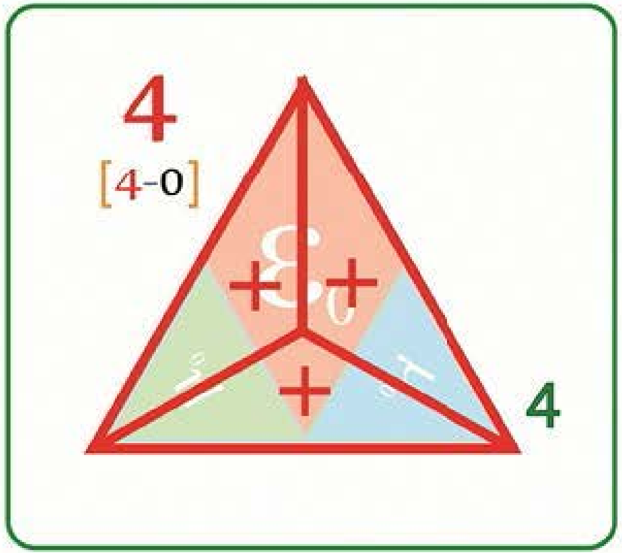

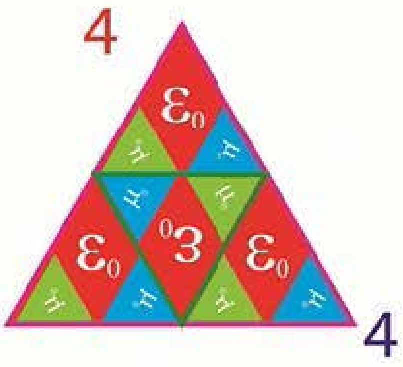

charged boson geometry

standing-wave Matter topology

radiant mass-energy geometries

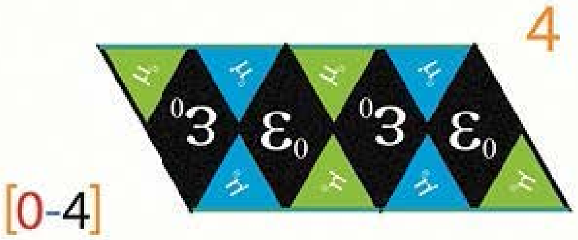

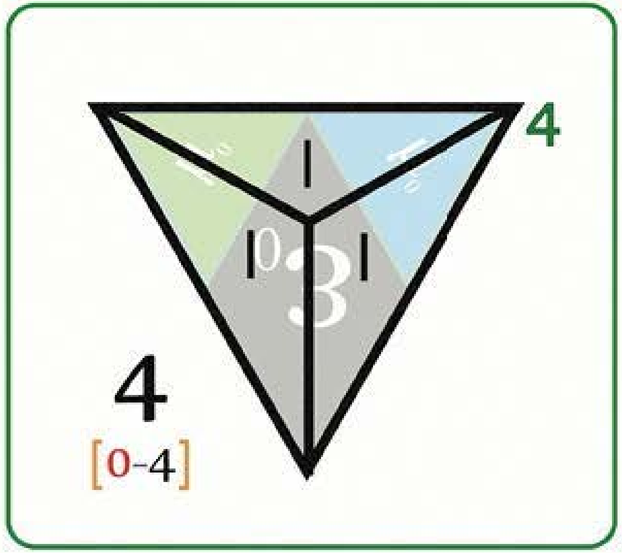

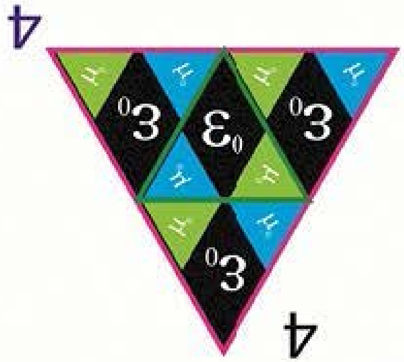

Negative Tetryon

Neutral Tetryons

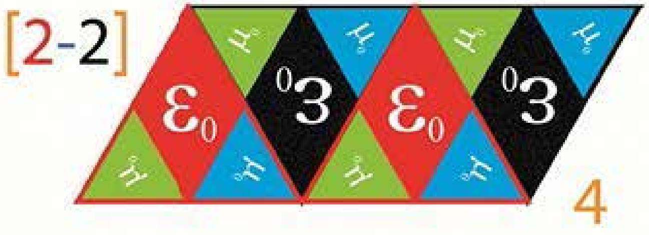
[2-2]
ε_0
μ
4

charged boson geometry

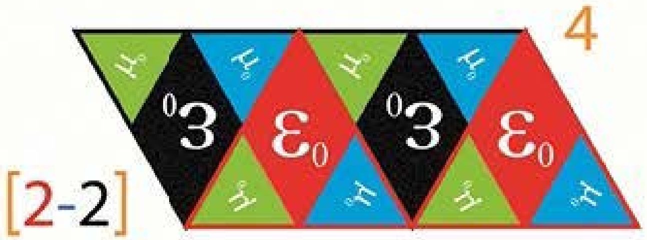
4
ε_0
μ
[2-2]

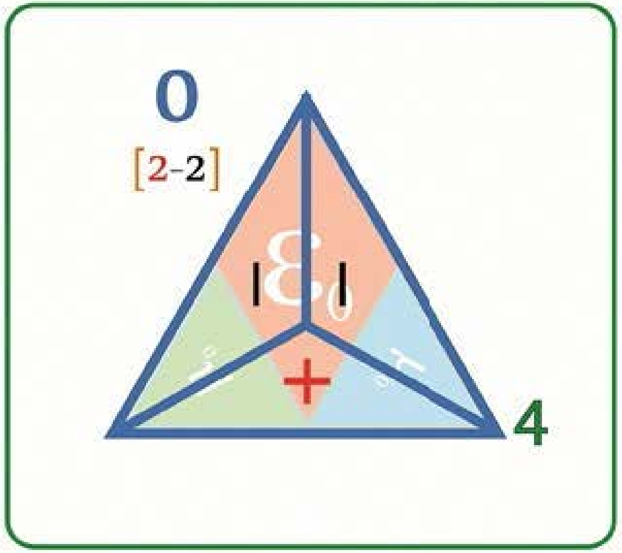
0
[2-2]
ε_0
+
4

standing-wave Matter topology

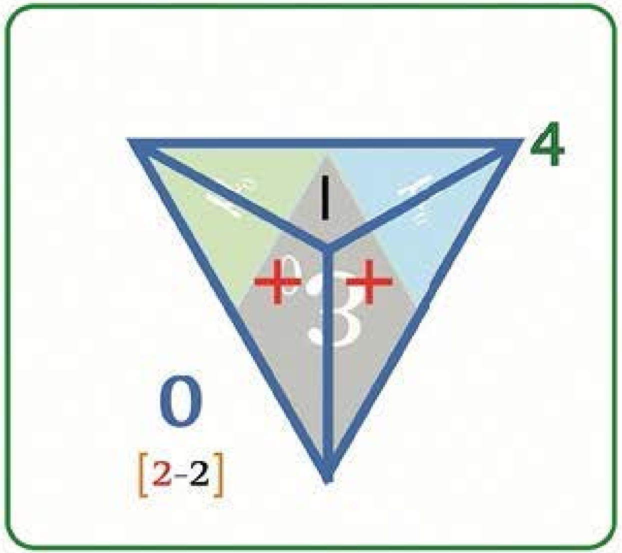

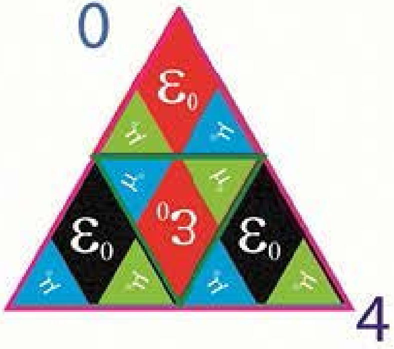
0
ε_0
μ
4

radiant mass-energy geometries

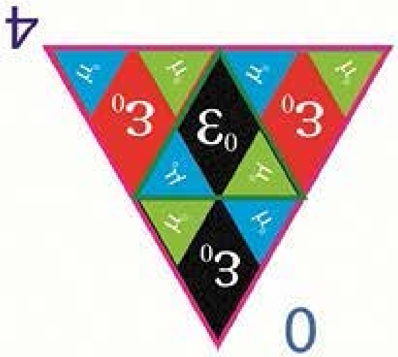
4
ε_0
μ
0

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mass

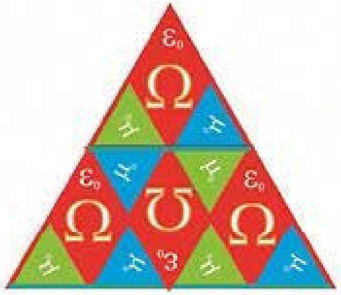

$$\underset{\text{mass}}{m} = n\pi\left[\left[\overset{\text{spatial}}{\underset{\text{impedance}}{1/c^2}}\right].\overset{\text{Energy}}{\underset{\text{momenta}}{\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\Omega\,\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]}}\right]$$

radiant mass-energy geometries

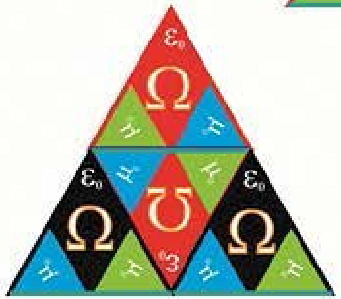

$$E = mc^2$$

Energy per second

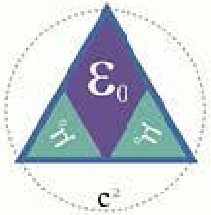

energy

$$n\pi\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\Omega\,\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]$$

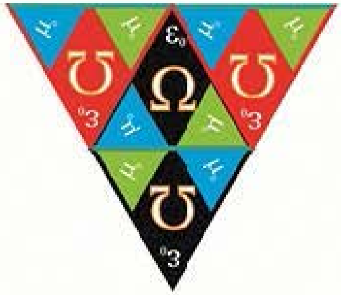

Energy per second ²

$$E = Mc^4$$

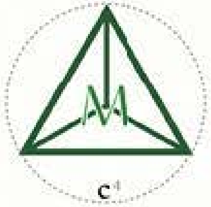

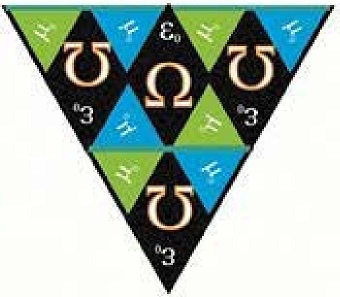

Matter

$$\underset{\text{Matter}}{M} = T\pi\left[\left[\overset{\text{spatial}}{\underset{\text{impedance}}{1/c^4}}\right].\overset{\text{Energy}}{\underset{\text{momenta}}{\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\Omega\,\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]}}\right]$$

standing wave Matter topologies

4
[4-0]

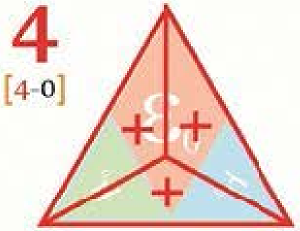

4n

0
[2-2]

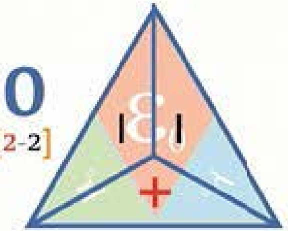

4n

Tetryons

4n

0
[2-2]

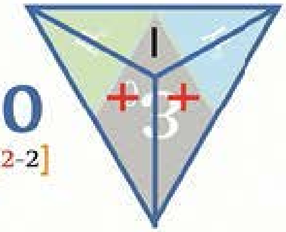

4
[0-4]

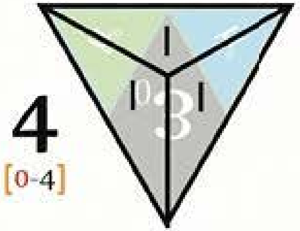

4n

Tetryonics 06.08 - Tetryon family

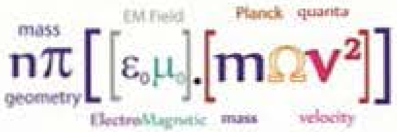

$$n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

mass
geometry
EM Field
ElectroMagnetic
Planck
quanta
mass
velocity

mass-ENERGY-Matter

geometries topologies

ALL EM masss-energies have equilateral geometry

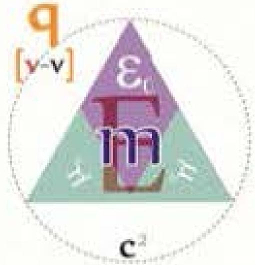

2D mass-energy geometries are a property of 3D Matter topologies

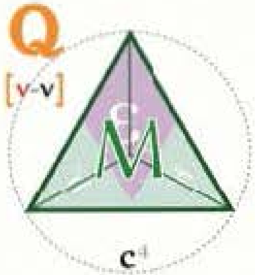

Tetryonic Matter is the building block of all Fermions, elements and compounds

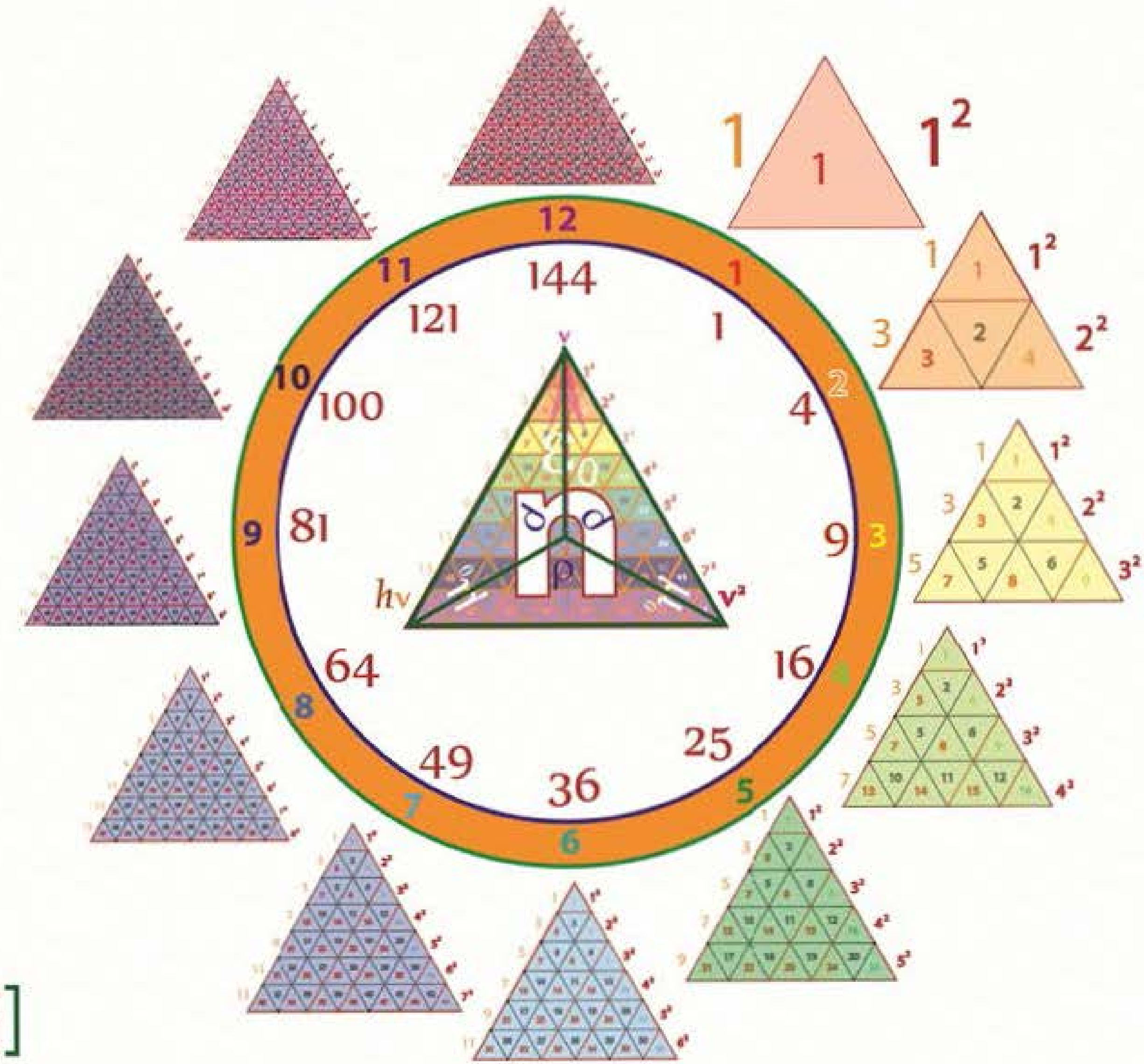
1
1
1²
1
1²
3
2
3
4
2²
1
1²
3
2
3
2²
5
5
6
7
8
3²
12
144
1
11
121
1
2
4
10
100
3
9
9
81
hν
v²
8
64
16
4
7
49
25
5
6
36

Transverse EM mass-energies form bosons [Quantum levels]

Longitudinal EM mass-Energies form Photons

Bosons combine to form SQUARED scalar EM energies

massless is a scientific misnomer

2D [non-Topolgical] EM mass-ENERGY is 'Matterless'

ALL Matter has a 3D topology

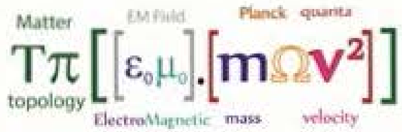

$$T\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Matter
topology
EM Field
ElectroMagnetic
Planck
quanta
mass
velocity

Tetryonic Matter

All quantum Matter has a foundational tetrahedral topology as a result of their equilateral mass-energy geometries [not spherical as has been assumed from the math]

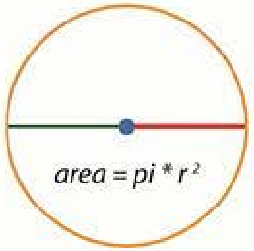

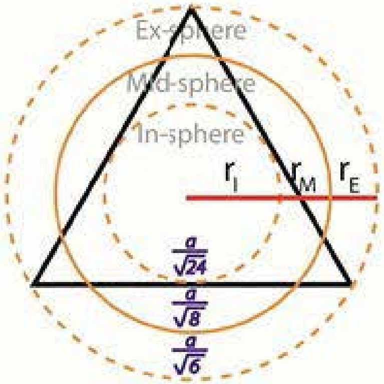
Ex-sphere
Mid-sphere
In-sphere
r_I
r_M
r_E
$\frac{a}{\sqrt{24}}$
$\frac{a}{\sqrt{8}}$
$\frac{a}{\sqrt{6}}$

Sphere

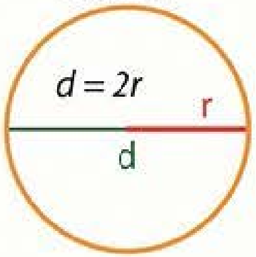

Area sphere= $4\pi r^2$

Surface curvature $= 1/r^2$

Total curvature = 4π

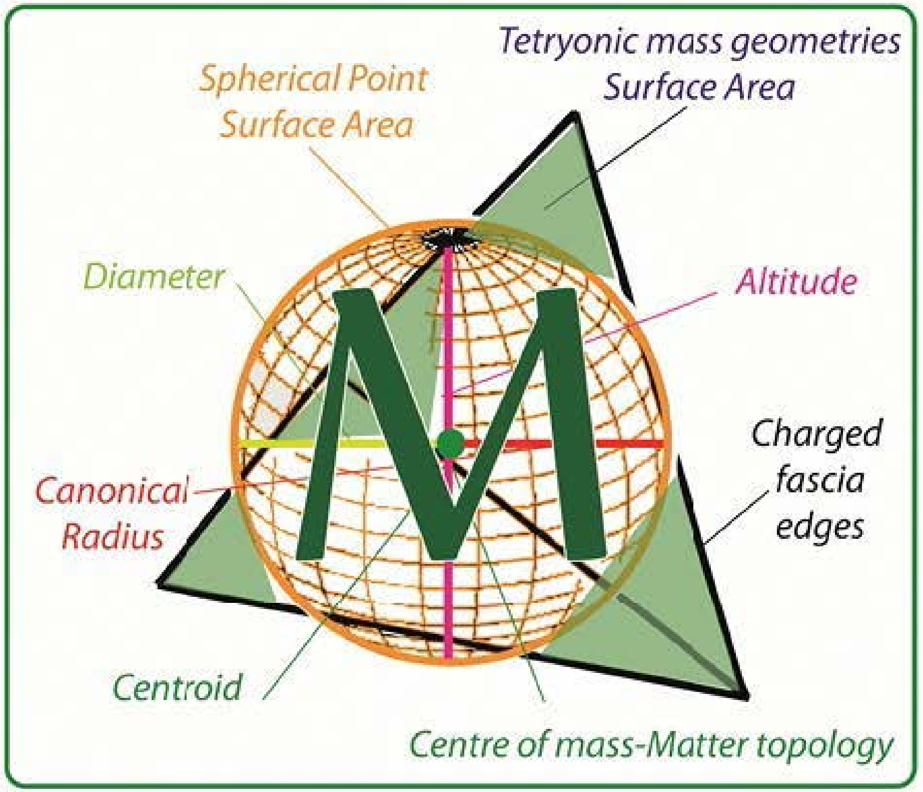
Tetryonic mass geometries
Surface Area
Spherical Point
Surface Area
Diameter
Altitude
Charged
fascia
edges
Canonical
Radius
M
Centroid
Centre of mass-Matter topology

Spheres & Tetrahedra are both 3D Platonic solids with 4π scalar integral Gaussian topologies and physical displacement volumes [Gauss-Bonnet theorem]

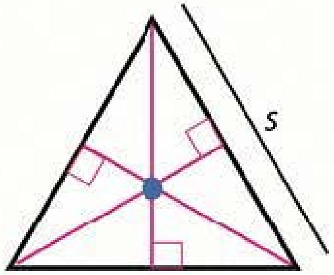

$area = \sqrt{3/4} * a^2$

ZPF fascia

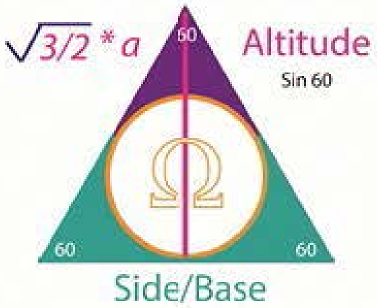
$\sqrt{3/2} * a$
60
Altitude
Sin 60
Ω
60
60

Side/Base

Cos 60

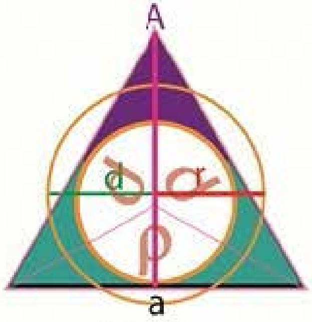

Area Tetryon

$$A = 4\,A_0 = \sqrt{3}a^2$$

Vertex curvature $= \pi$

Total curvature = 4π

Tetryonics 06.10 - Spheres vs. Tetryons

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Dodecyons

while quarks & leptons are comprised of
12π mass-energy geometries
they have differing final Matter topologies

+1/3

up quark

8
[10-2]

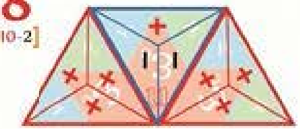

anti-strange quark

+2/3

top quark

charmed quark

8π

strange quark

-1/3

bottom quark

anti-bottom quark

-2/3

8
[2-10]

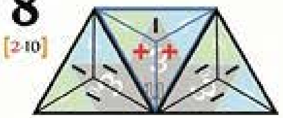

anti-up quark

Quarks have octahedral topologies

anti-down quark

4
[8-4]

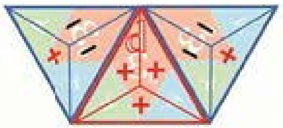

anti-charmed quark

quarks

anti-top quark

4
[4-8]

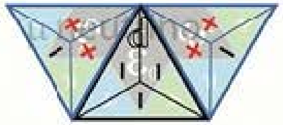

down quark

electron neutrino

0
[6-6]

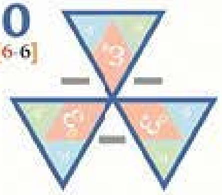

neutrinos

0
[6-6]

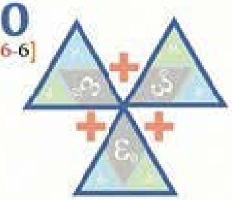

positron neutrino

positron

12
[12-0]

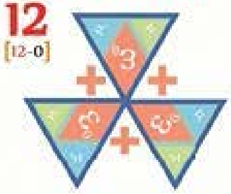

e +1

anti-τ neutrino

anti-μ neutrino

tau

12π

0

muon

muon neutrino

tau neutrino

12
[0-12]

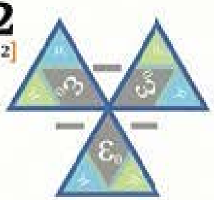

e -1

electron

EM Field Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

ElectroMagnetic mass velocity

Leptons have dodecahedral topologies

anti-up quark

-2/3

quark octahedral topology

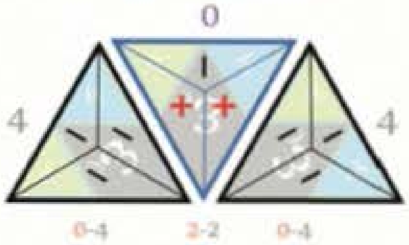

0-4 2-2 0-4

attractive dodecyon geometry

EM Field Planck quanta

$12\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$

dodecyon ElectroMagnetic mass velocity

as mass-energy momenta is added to
Matter topologies & KEM fields of motion
different generations of particles are created

1. **anti-up** quark
2. **anti-charmed** quark
3. **anti-top** quark

u

nett charge

8

[2-10]

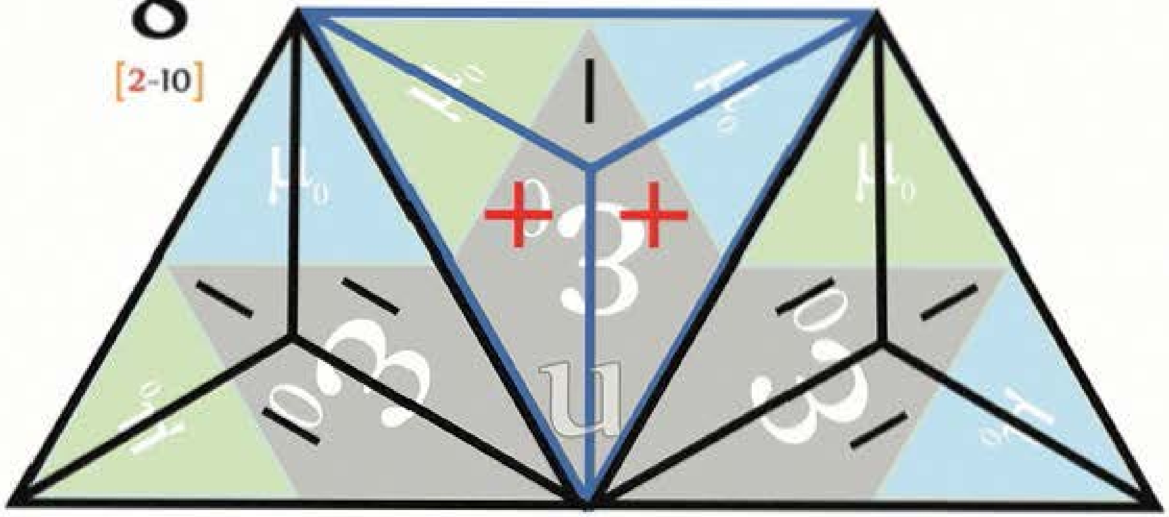
μ_0
μ_0
μ_0
μ_0
μ_0
μ_0
+ +
3
3
3
ε_0
ε_0
ε_0
u

charged
mass-Matter
topology

8π

Quarks have 12 charged fascia - mass-energy geometries

2 Positive 10 Negative

Quarks have octahedral mass-Matter topologies

[-2/3 elementary charge]

down quark

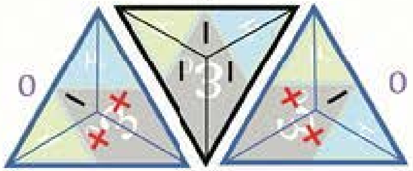
-1/3
quark octahedral topology
4
0
0
3
2-2
0-4
2-2
attractive dodecyon geometry

EM Field Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

docdecyon ElectroMagnetic mass velocity

as mass-energy momenta is added to
Matter topologies & KEM fields of motion
different generations of particles are created

1. **down** quark
2. **strange** quark
3. **bottom** quark

d

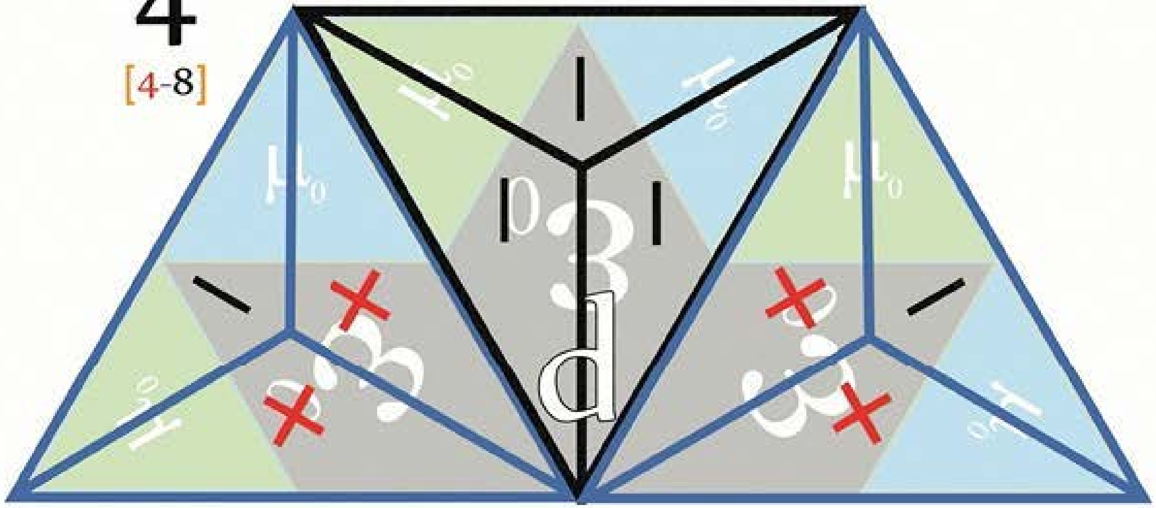
nett charge
4
[4-8]
μ_0
ε_0
3
d
charged mass-Matter topology
8π

Quarks have 12 charged fascia - mass-energy geometries

4 Positive 8 Negative

Quarks have octahedral mass-Matter topologies

[-1/3 elementary charge]

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anti-down quark

+1/3

quark octahedral topology

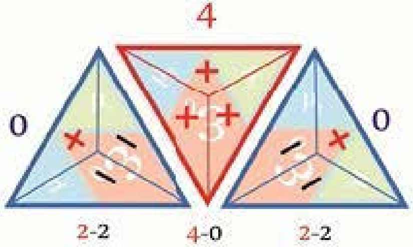

attractive dodecyon geometry

EM Field Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

dodecyon ElectroMagnetic mass velocity

as mass-energy momenta is added to
Matter topologies & KEM fields of motion
different generations of particles are created

1. **anti-down** quark
2. **anti-strange** quark
3. **anti-bottom** quark

d

nett charge

4

[8-4]

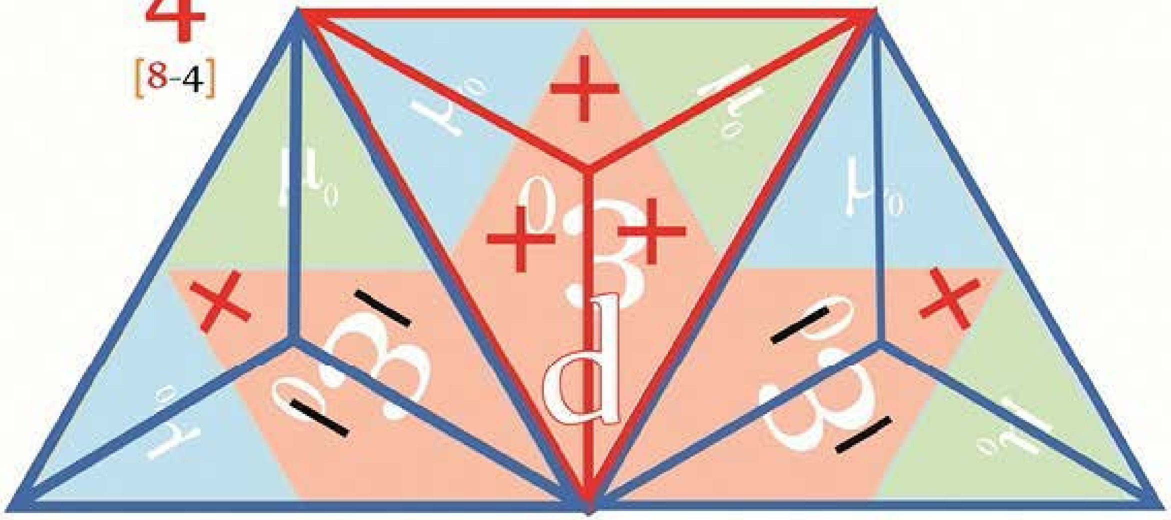

charged mass-Matter topology

8π

Quarks have 12 charged fascia - mass-energy geometries

8 Positive 4 Negative

Quarks have octahedral mass-Matter topologies

[+1/3 elementary charge]

up quark

+2/3

quark octahedral topology

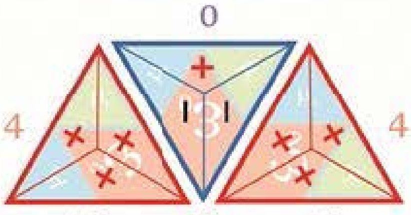

attractive dodecyon geometry

EM Field　Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

dodecyon　ElectroMagnetic　mass　velocity

as mass-energy momenta is added to
Matter topologies & KEM fields of motion
different generations of particles are created

1. **up quark**
2. **charmed** quark
3. **top** quark

u

nett charge

8

[10-2]

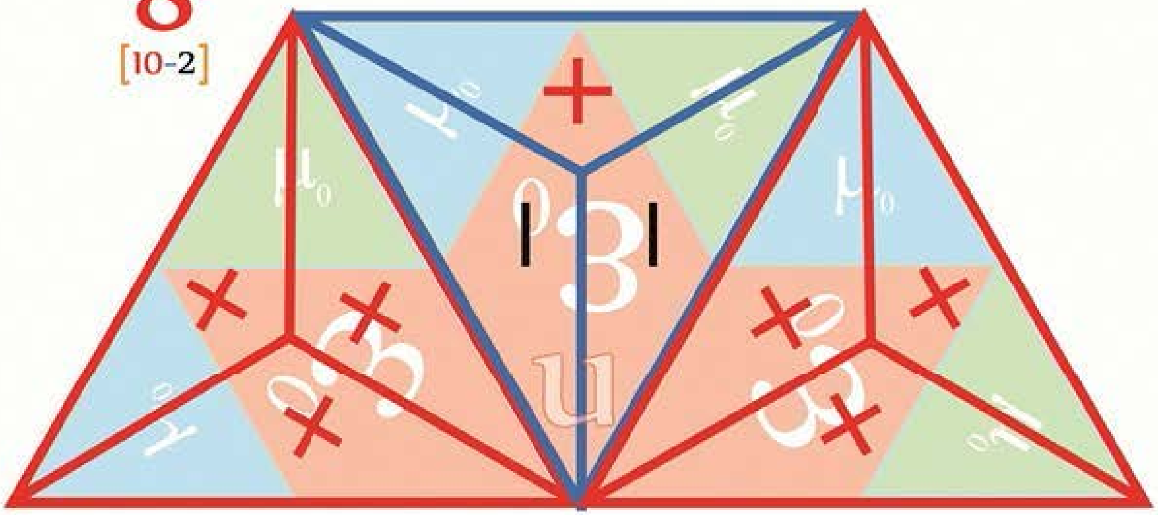

charged
mass-Matter
topology

8π

Quarks have 12 charged fascia - ***mass-energy geometries***

10 Positive　　2 Negative

Quarks have octahedral mass-Matter topologies

[+2/3 elementary charge]

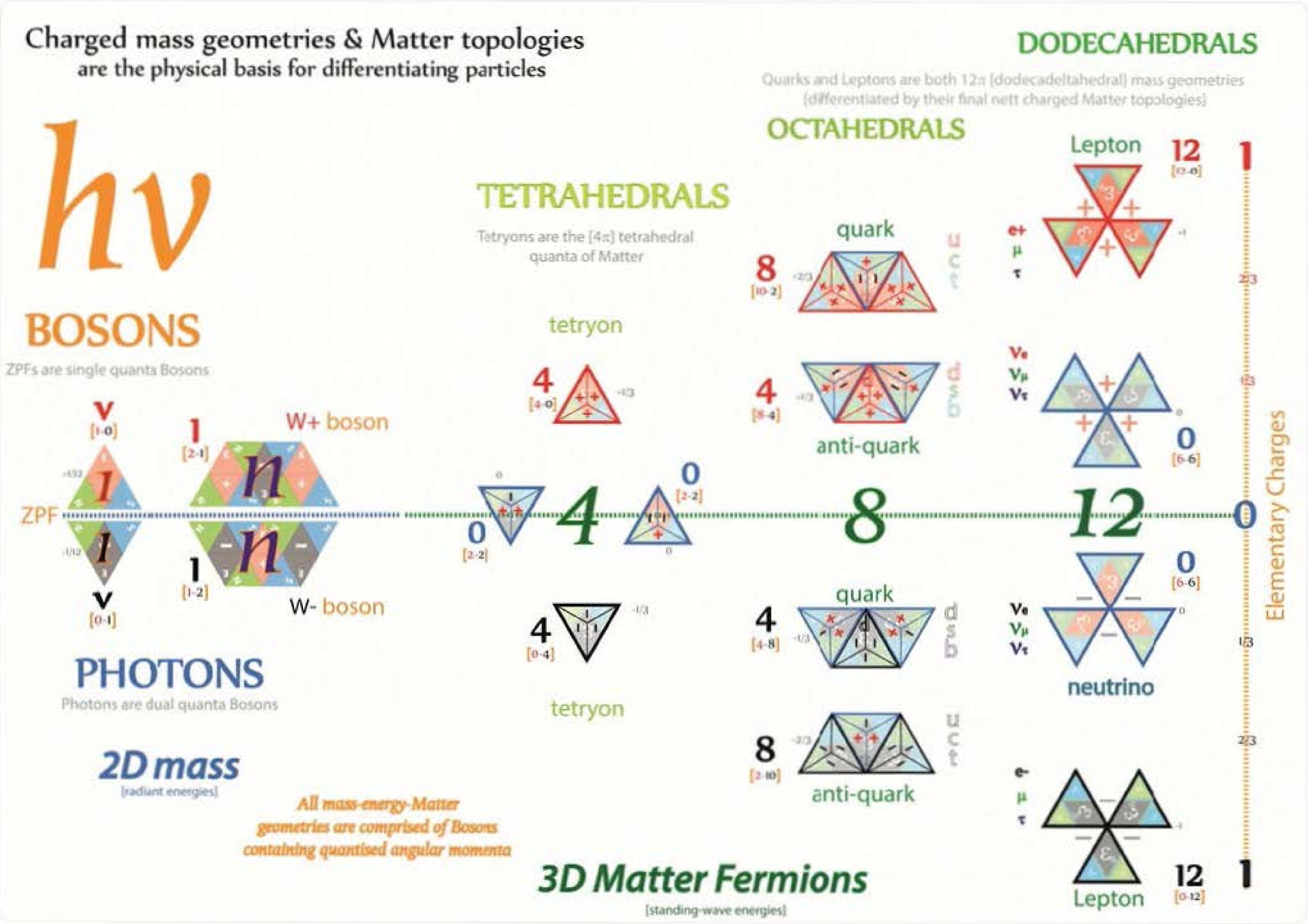

Charged mass geometries & Matter topologies are the physical basis for differentiating particles

DODECAHEDRALS

Quarks and Leptons are both 12π [dodecadeltahedral] mass geometries (differentiated by their final nett charged Matter topologies)

OCTAHEDRALS

TETRAHEDRALS

Tetryons are the [4π] tetrahedral quanta of Matter

BOSONS

ZPFs are single quanta Bosons

PHOTONS

Photons are dual quanta Bosons

2D mass

[radiant energies]

All mass-energy-Matter geometries are comprised of Bosons containing quantised angular momenta

3D Matter Fermions

[standing-wave energies]

hv
v
[1-0]
+1/12
ZPF
-1/12
v
[0-1]
1
[2-1]
W+ boson
1
[1-2]
W- boson
tetryon
4
[4-0]
+1/3
0
0
[2-2]
4
0
[2-2]
0
4
[0-4]
-1/3
tetryon
quark
8
[10-2]
+2/3
u
c
t
4
[8-4]
+1/3
d
s
b
anti-quark
8
quark
4
[4-8]
-1/3
d
s
b
8
[2-10]
-2/3
u
c
t
anti-quark
Lepton
12
[12-0]
1
e+
μ
τ
+1
2/3
νe
νμ
ντ
1/3
0
0
[6-6]
12
0
0
[6-6]
νe
νμ
ντ
0
1/3
neutrino
2/3
e-
μ
τ
-1
12
[0-12]
1
Lepton
Elementary Charges

divergent negative E-fields

electron

convergent negative E-fields

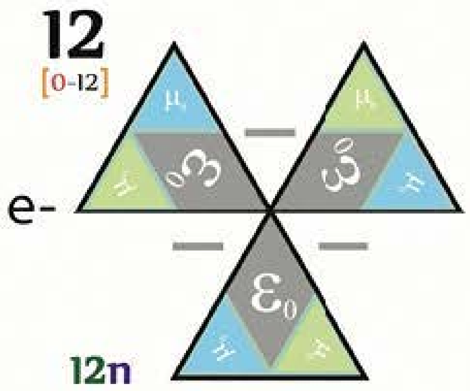

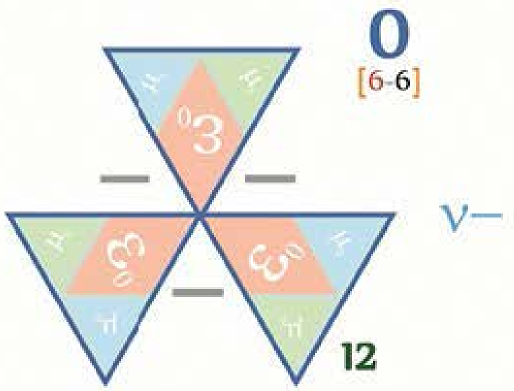

divergent negative E-fields

electron neutrino

convergent positive E-fields

Leptons have 12 charged mass-energy fascia geometries

Repulsive STRONG force creates Lepton topologies

12π

Tetryonic charged fascias creates the Matter topologies of all Leptons

Repulsive STRONG force creates Neutrino topologies

Leptons have dodecadeltahedral mass-Matter topologies

divergent positive E-fields

positron

convergent positive E-fields

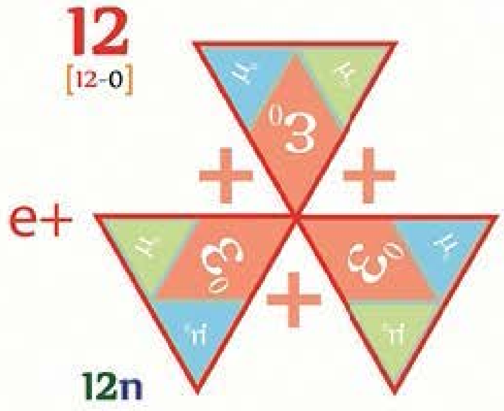

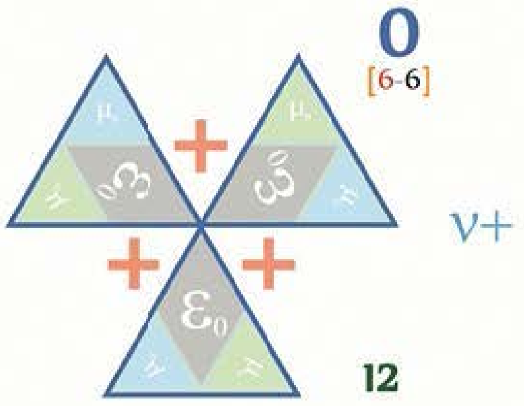

divergent positive E-fields

positron neutrino

convergent negative E-fields

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Charged Leptons

EM Field Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Dodecyon ElectroMagnetic mass velocity

positron

net charge

12

[12-0]

e+

12

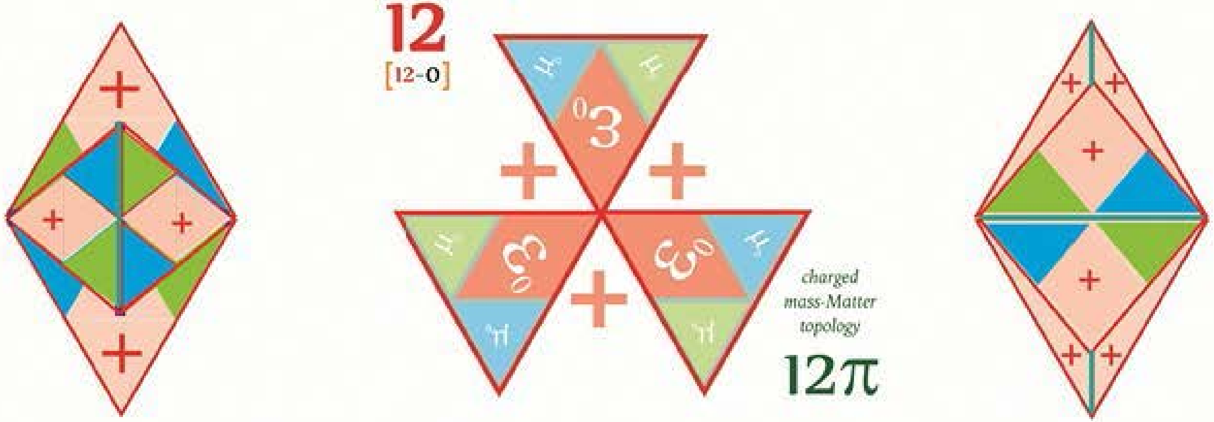
+
+
+
+
ε_0
ε_0
ε_0
μ_0
+
+
+
+
+
+
+
+
+

charged mass-Matter topology

12π

1. **positron**
2. **anti-muon**
3. **anti-tau**

Leptons have 12 charged mass-energy fascia geometries

12 positive charge fascia or 12 Negative charge fascia

repulsive dodecyon geometries

lepton topologies

Charged Leptons have dodecadeltahedral mass-Matter topologies

[1 elementary charge]

net charge

12

[0-12]

e-

12

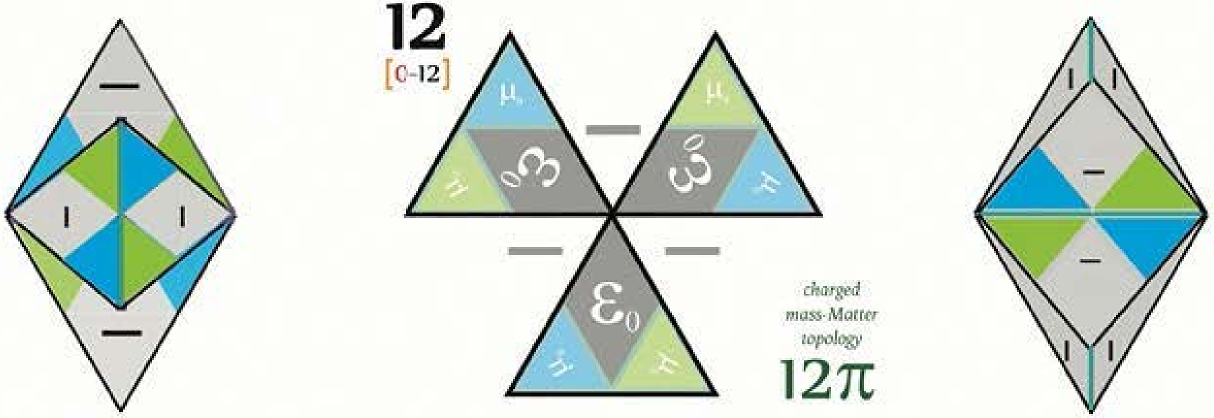
–
–
–
–
–
–
–
ε_0
ε_0
ε_0
μ_0

charged mass-Matter topology

12π

electron

1. **electron**
2. **muon**
3. **tau**

as mass-energy momenta is added to Matter topologies & KEM fields of motion different generations of particles are created

positron

repulsive charge dodecyon geometry

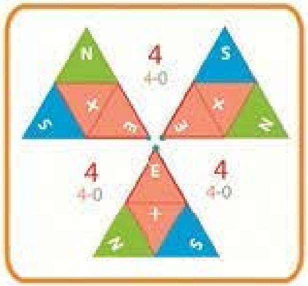
N
S
4
4-0
E
+
4
4-0
4
4-0

lepton mass-Matter topology

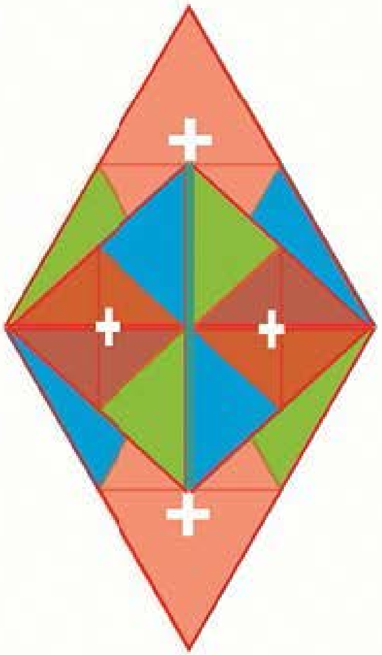

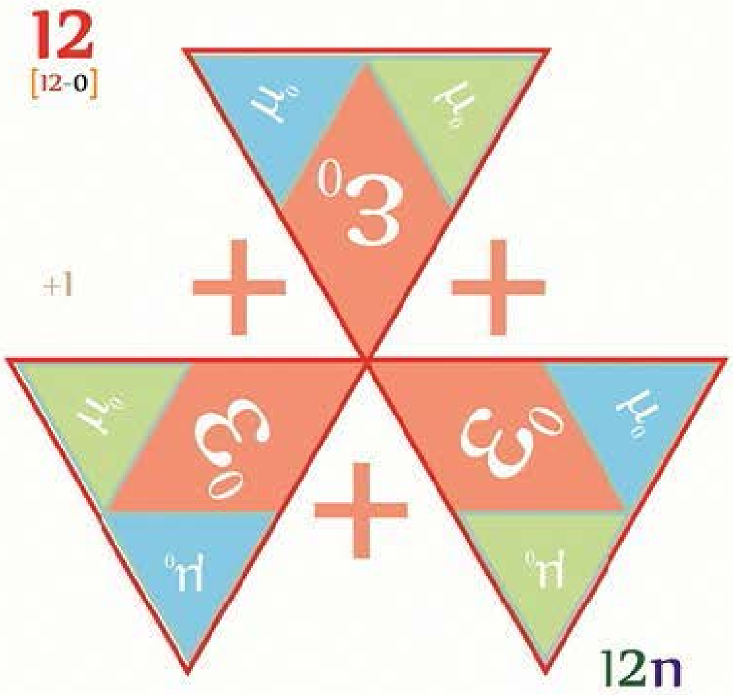
12
[12-0]
+1
μ_0
ε_0
12n

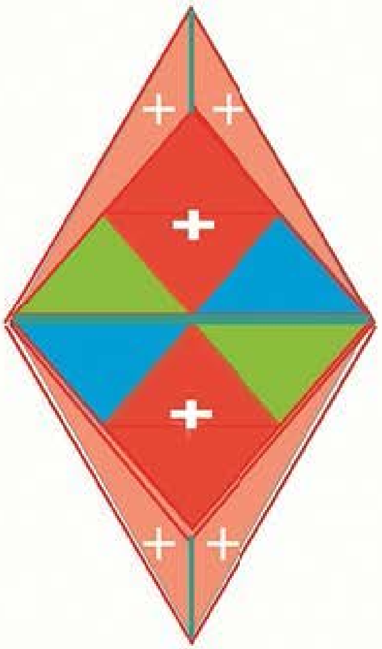

EM Field Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Dodecyon

ElectroMagnetic mass velocity

1. **positron**
2. **anti-muon**
3. **anti-tau**

Neutral Leptons

EM Field Planck quanta

$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Dodecyon ElectroMagnetic mass velocity

ν-
0

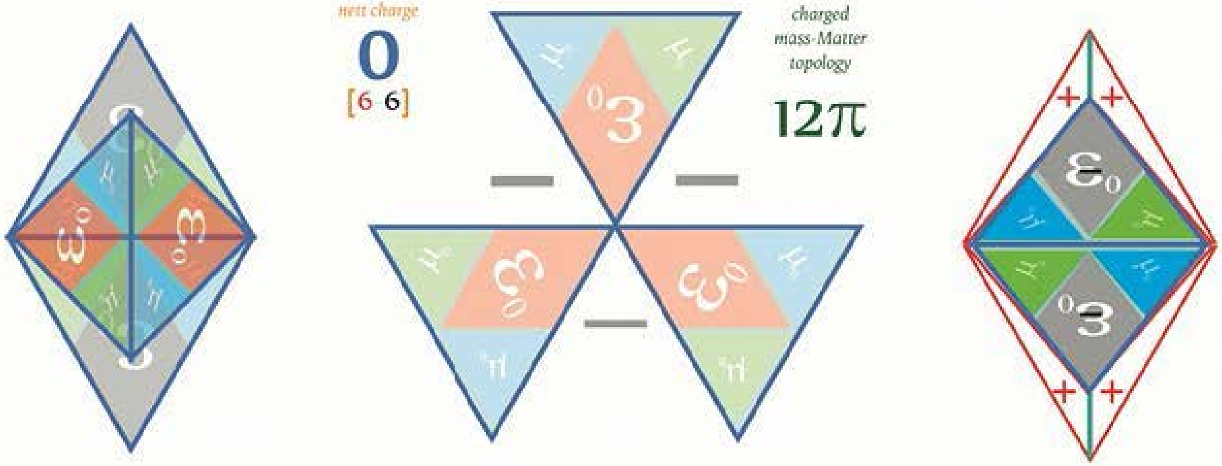
nett charge
0
[6 6]
charged
mass-Matter
topology
12π
ε₀
μ₀

1. electron neutrino
2. muon neutrino
3. tau neutrino

Neutrinos have 12 charged mass-energy fascia geometries

6 Positive & 6 Negative

repulsive dodecyon geometries

lepton topologies

Neutrinos have neutral dodecadeltahedral mass-Matter topologies

[0 elementary charge]

ν+
0

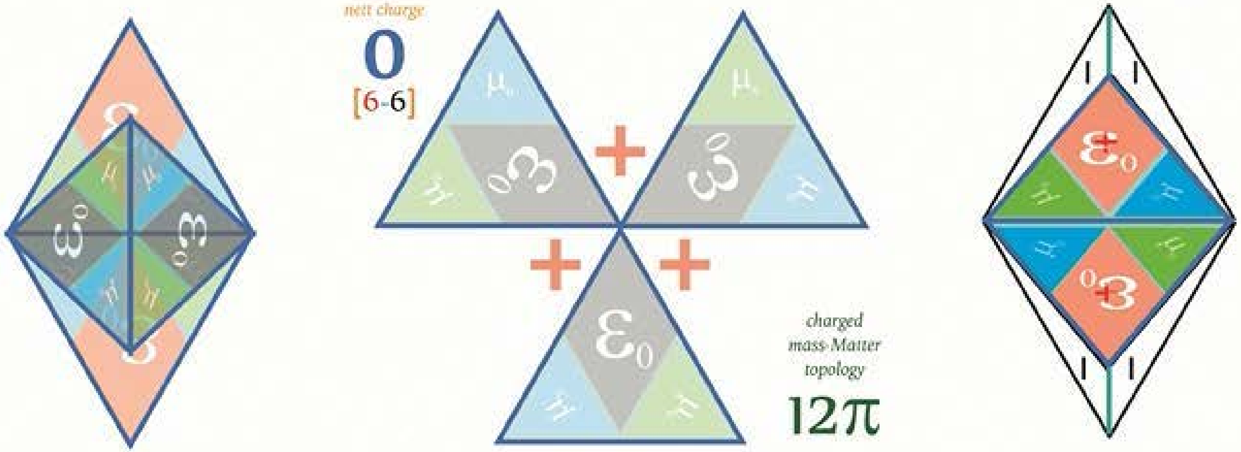
nett charge
0
[6-6]
charged
mass-Matter
topology
12π
ε₀
μ₀

1. positron neutrino
2. anti- muon neutrino
3. anti-tau neutrino

as mass-energy momenta is added to
Matter topologies & KEM fields of motion
different generations of particles are created

electron

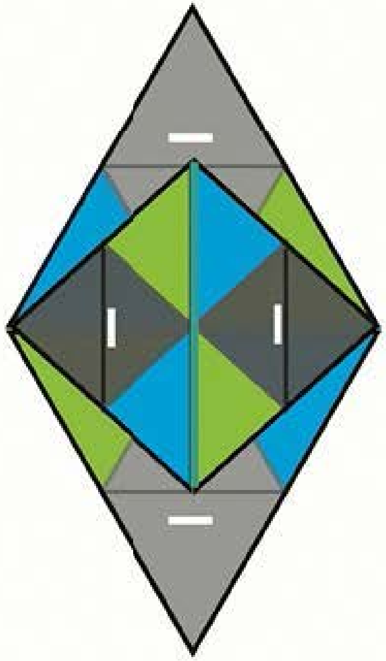

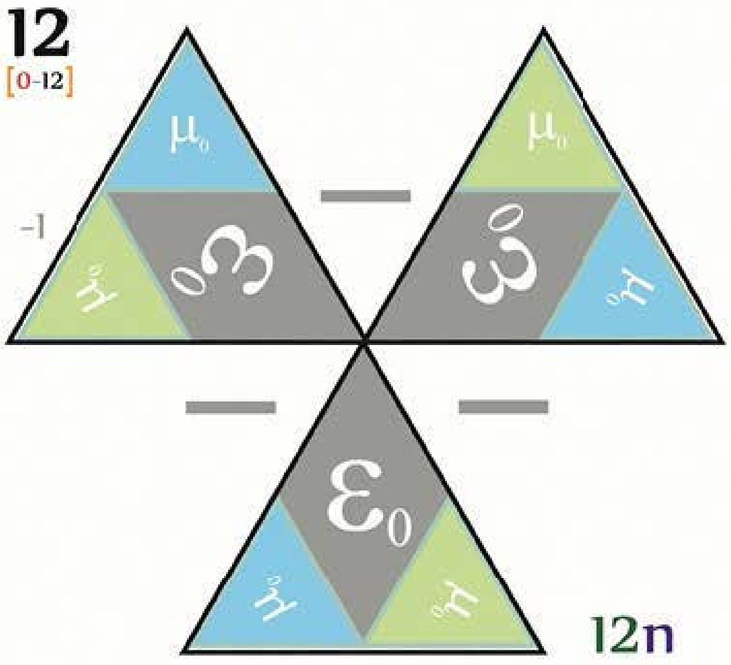
12
[0-12]
-1
μ_0
ε_0
μ_0
ε_0
ε_0
μ_0
μ_0
12n

repulsive charge dodecyon geometry

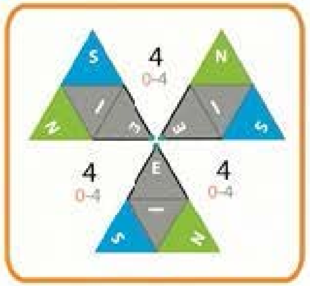
S
N
4
0-4
E
4
0-4
4
0-4

lepton mass-Matter topology

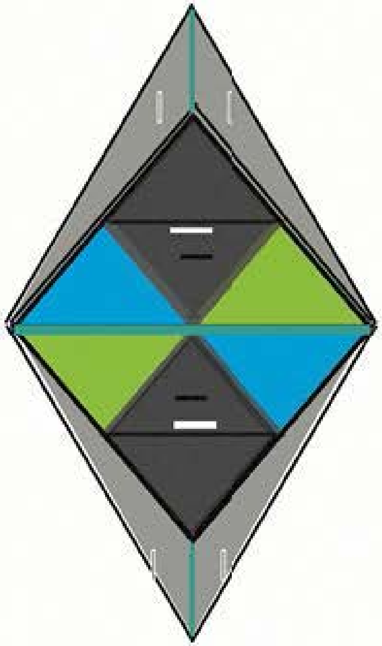

EM Field Planck quanta

$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Dodecyon ElectroMagnetic mass velocity

1. **electron**
2. **muon**
3. **tau**

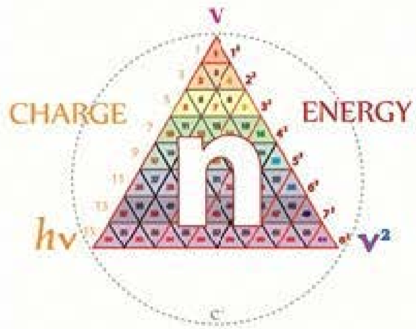
v
CHARGE
ENERGY
n
hv
v²
c

Leptronic Quantum levels

[KEM field mass-energy geometry]

v^2 Total quanta	1e19	n Electron quantum level
1.2e20		1
4.8e20		4
1.08e21		9
1.92e21		16
3.00e21		25
4.32e21		36
5.88e21		49
7.68e21		64

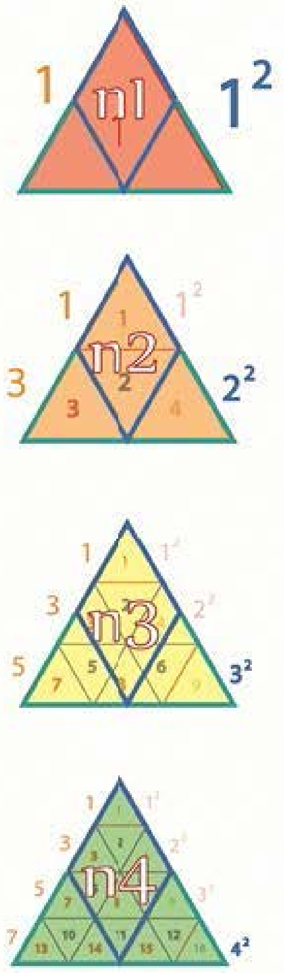
1
n1
1²
1
1²
3
n2
2²
1
3
n3
5
3²
1
3
5
7
n4
4²

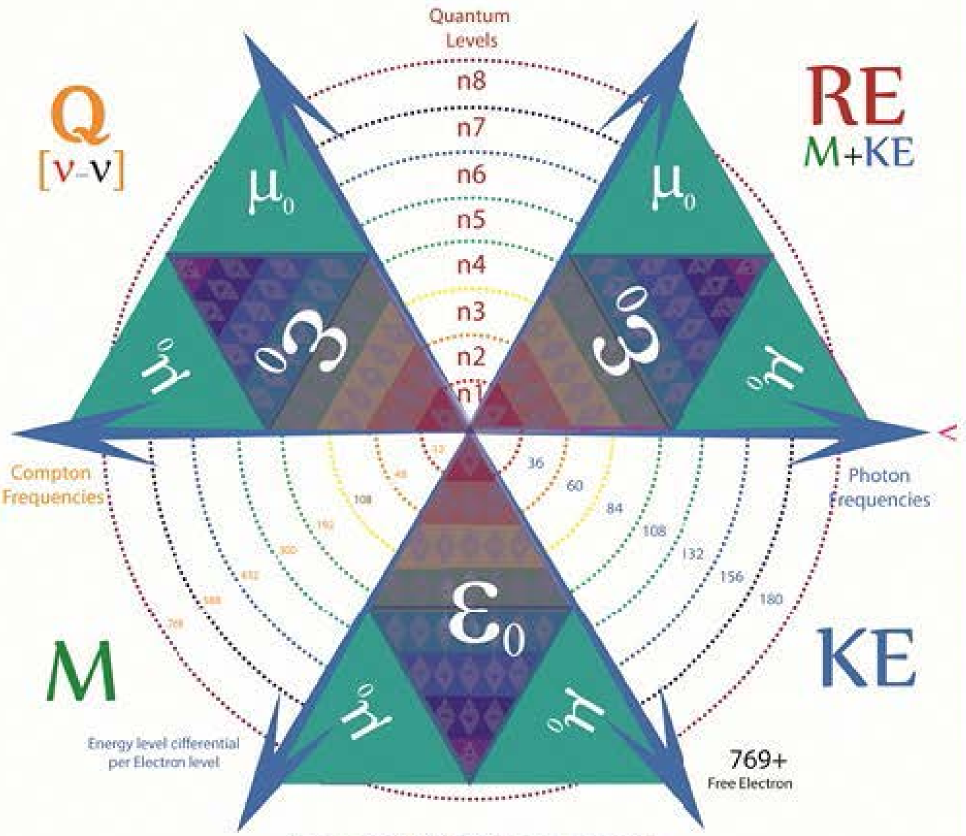
Quantum Levels
n8
n7
n6
n5
n4
n3
n2
n1
Q
[ν-ν]
RE
M+KE
μ0
μ0
ε0
ε0
ε0
μ0
μ0
v
Compton Frequencies
Photon frequencies
36
60
84
108
132
156
180
M
KE
Energy level differential per Electron level
769+
Free Electron

Leptronic KEM field mass-energies

$$p^2 = KEM = Mv^2$$

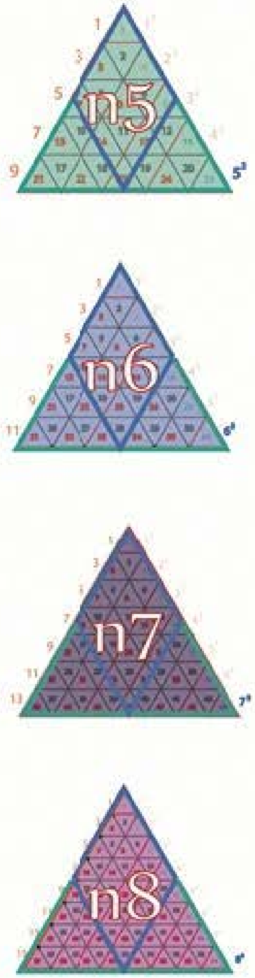
n5
5²
n6
6²
n7
7²
n8
8²

Illustrative schema only: All Leptonic quantum levels have the same equilateral KEM geometry as the compton frequency of the KEM field increases the wavelengths of the quanta decrease

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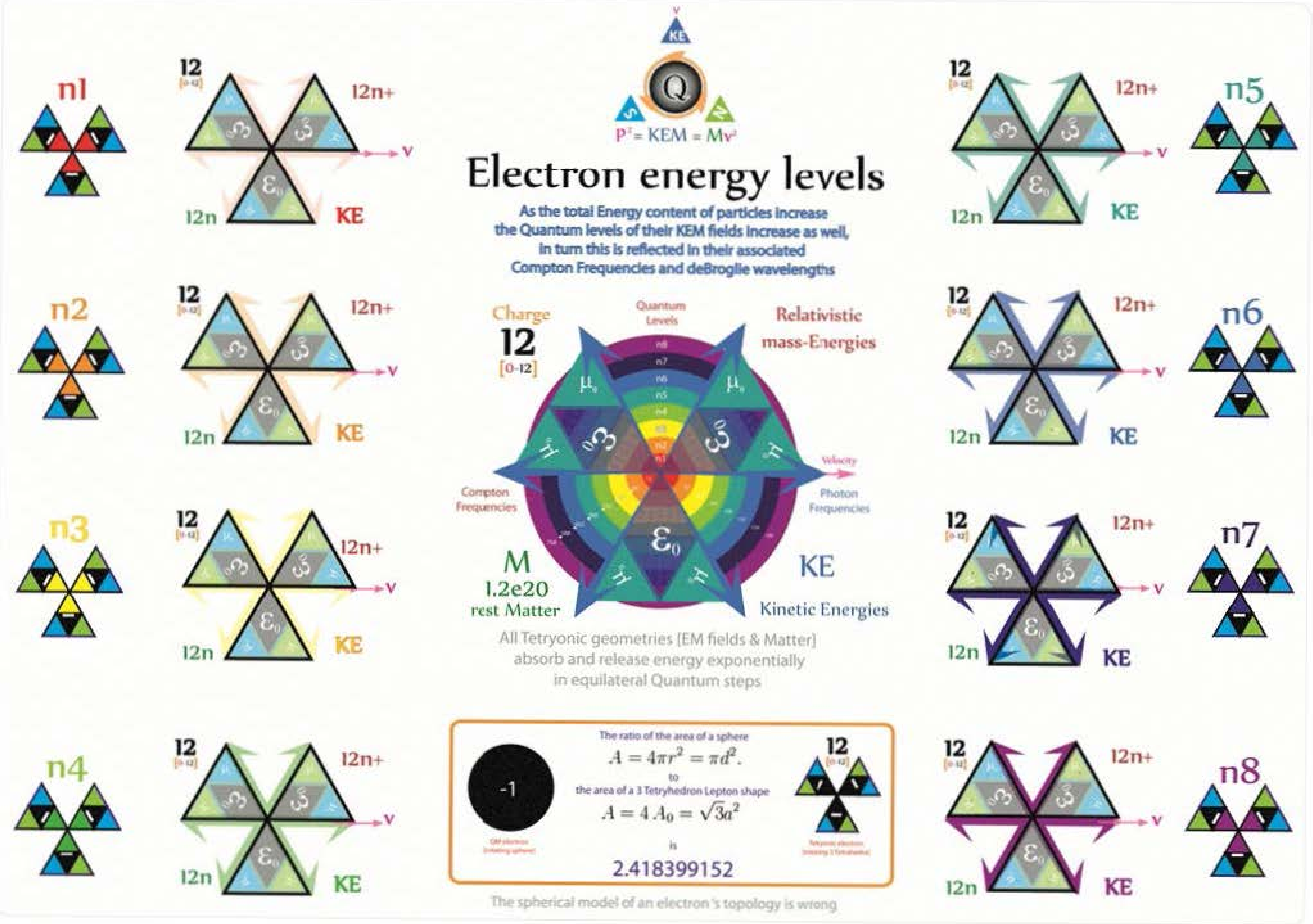

v
KE
Q
S
N
n1
n2
n3
n4
n5
n6
n7
n8
12
[0-12]
12n+
12n
KE
v
Charge
12
[0-12]
Quantum Levels
n8
n7
n6
n5
n4
n3
n2
n1
Relativistic mass-Energies
Velocity
Photon Frequencies
Compton Frequencies
M
1.2e20
rest Matter
KE
Kinetic Energies
-1

P^2 = KEM = Mv^2

Electron energy levels

As the total Energy content of particles increase
the Quantum levels of their KEM fields increase as well,
in turn this is reflected in their associated
Compton Frequencies and deBroglie wavelengths

All Tetryonic geometries [EM fields & Matter]
absorb and release energy exponentially
in equilateral Quantum steps

The ratio of the area of a sphere

$$A = 4\pi r^2 = \pi d^2.$$

to

the area of a 3 Tetryhedron Lepton shape

$$A = 4\,A_0 = \sqrt{3}a^2$$

is

2.418399152

The spherical model of an electron's topology is wrong

Tetryonics 08.07 - Electron energy levels

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Leptronic Kinetic EM Fields

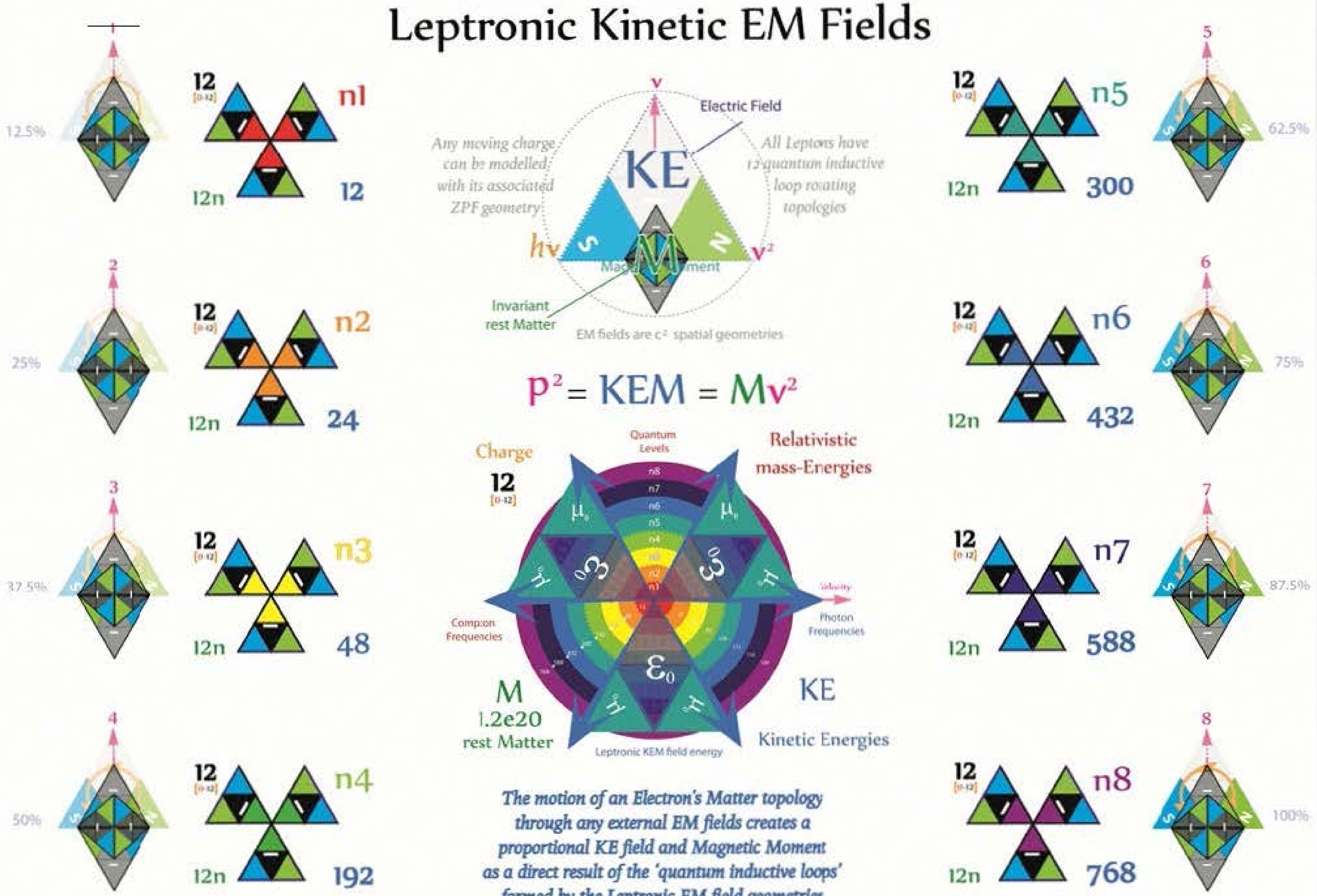
1
12.5%
12
[0-12]
n1
12n
12
2
25%
12
[0-12]
n2
12n
24
3
37.5%
12
[0-12]
n3
12n
48
4
50%
12
[0-12]
n4
12n
192
v
Electric Field
KE
hv
S
M
N
v²
Magnetic Moment
Invariant rest Matter
5
62.5%
12
[0-12]
n5
12n
300
6
75%
12
[0-12]
n6
12n
432
7
87.5%
12
[0-12]
n7
12n
588
8
100%
12
[0-12]
n8
12n
768
Charge
12
[0-12]
Quantum Levels
n8
n7
n6
n5
n4
n3
n2
n1
Relativistic mass-Energies
μ₀
ε₀
Compton Frequencies
Velocity
Photon Frequencies
M
1.2e20
rest Matter
KE
Kinetic Energies
Leptronic KEM field energy

Any moving charge can be modelled with its associated ZPF geometry

All Leptons have 12 quantum inductive loop rotating topologies

EM fields are c² spatial geometries

$$P^2 = KEM = Mv^2$$

The motion of an Electron's Matter topology through any external EM fields creates a proportional KE field and Magnetic Moment as a direct result of the 'quantum inductive loops' formed by the Leptronic EM field geometries

Tetryonics 08.08 - Leptronic KEM fields

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Kinetic field modelling

RE

Mv^2

2D

Kinetic Energy field

$E = mc^2$

3D

rest mass-Matter topology

Tetryonic
Positive Charge
KEM field geometry

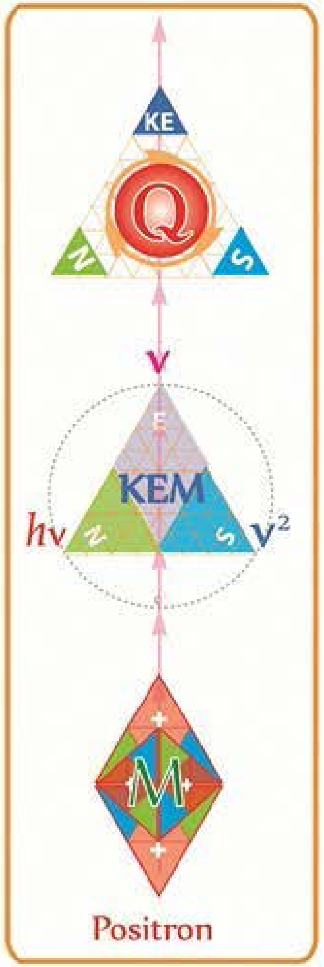

Positron

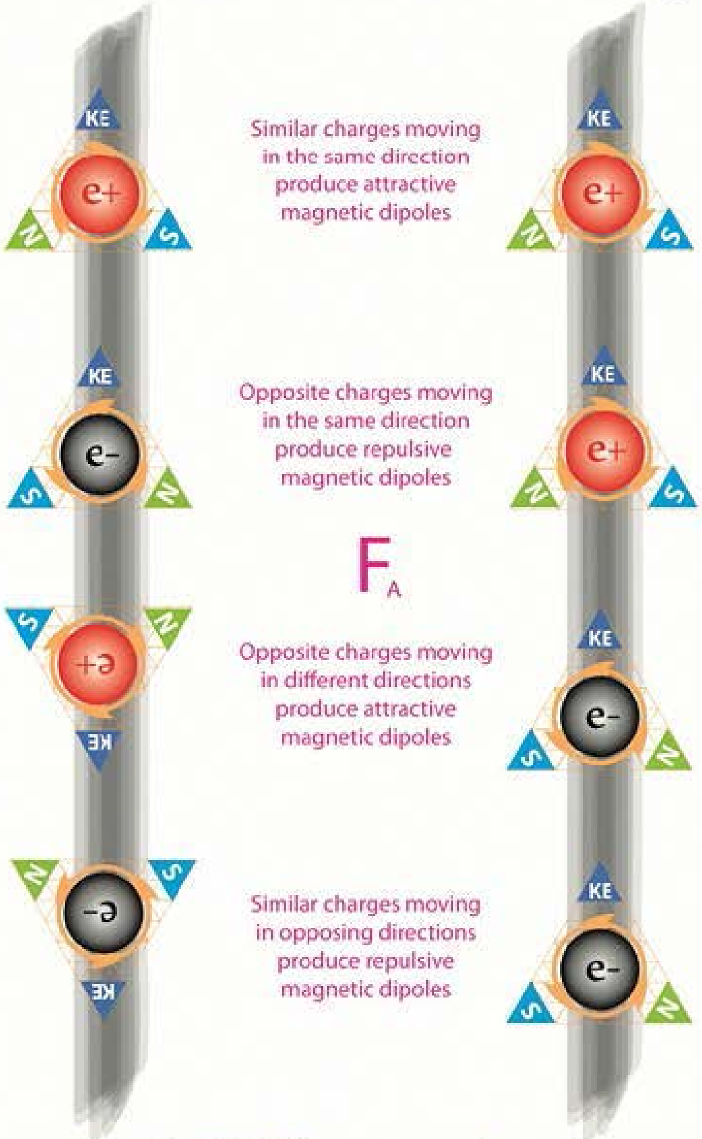

Similar charges moving
in the same direction
produce attractive
magnetic dipoles

Opposite charges moving
in the same direction
produce repulsive
magnetic dipoles

F_A

Opposite charges moving
in different directions
produce attractive
magnetic dipoles

Similar charges moving
in opposing directions
produce repulsive
magnetic dipoles

Tetryonic
Negative Charge
KEM field geometry

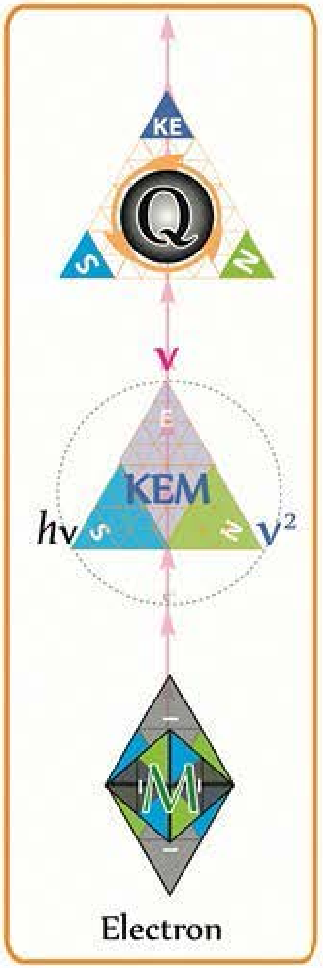

Electron

RE

Mv^2

2D

Kinetic Energy field

$E = mc^2$

3D

rest mass-Matter topology

The KEM fields of all
Matter particles in motion
can be modelled using
ZPF EM geometries

Kinetic EM field geometry determines the Magnetic Moments of all particles in motion

The KEM E-field is reflective
of the nett particle charge
and forms a directional
vector of motion

Lepton Families & Generations

v
KE
M
hv
v²
rest Matter is
invariant
c

Charged Matter topologies in motion creates Kinetic EM field geometries

Charged mass-energy geometries form elementary particle topologies

12π

KEM = Mv²

Total relativistic mass-energies
[rest Matter + KEM]

All high mass-energy particles 'decay' into low mass-energy particles by emitting photons

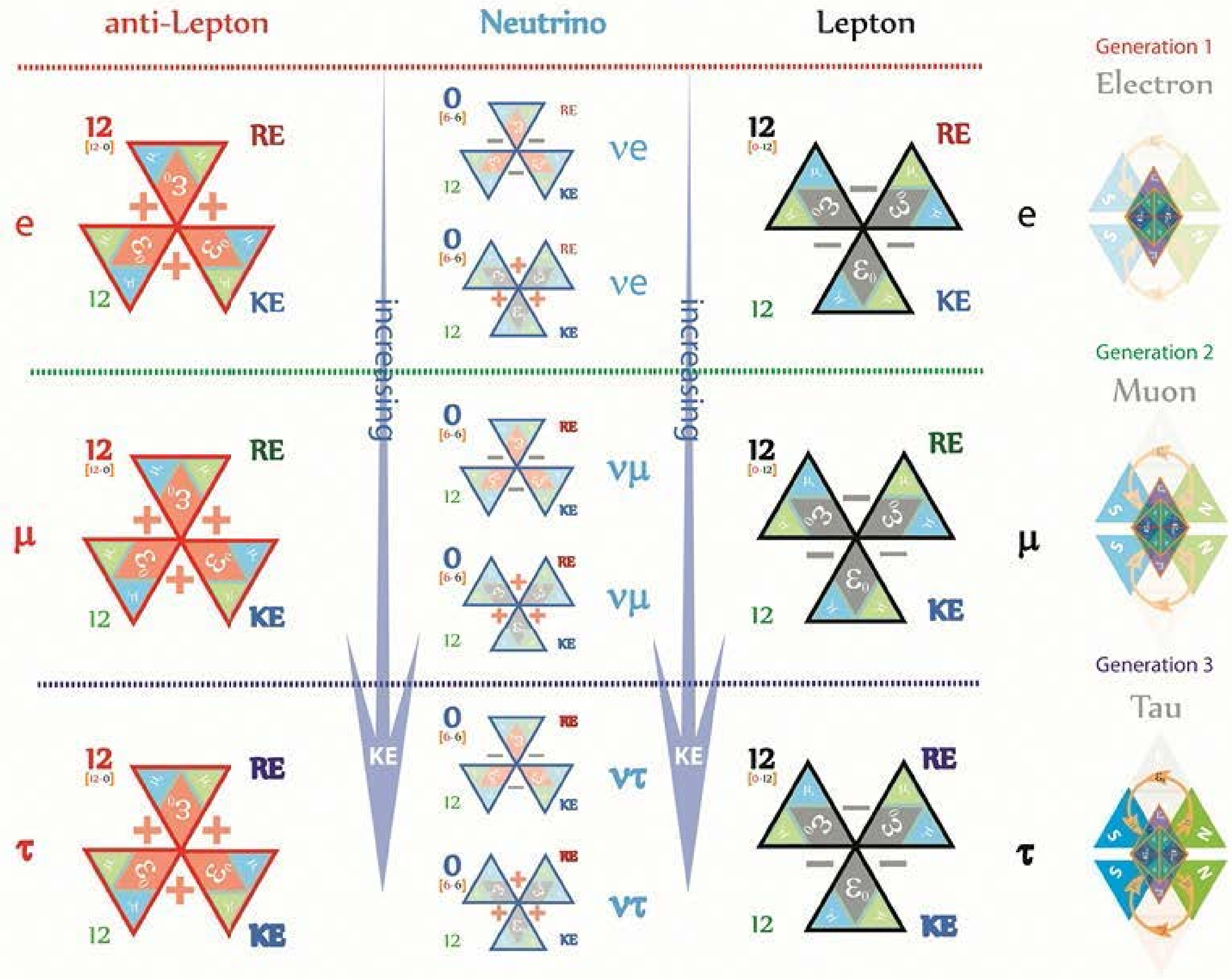
anti-Lepton
Neutrino
Lepton
Generation 1
Electron
e
12
[12-0]
RE
KE
12
0
[6-6]
ve
ve
12
[0-12]
e
Generation 2
Muon
μ
vμ
vμ
μ
Generation 3
Tau
τ
vτ
vτ
τ
increasing
increasing
KE
KE

Note: All Lepton geometries are the same size - only the energy density of the EM field changes

Lepton Helicity and Chirality

Particle Spin and Handedness is always referenced
with respect to the direction of nett total system linear Momentum

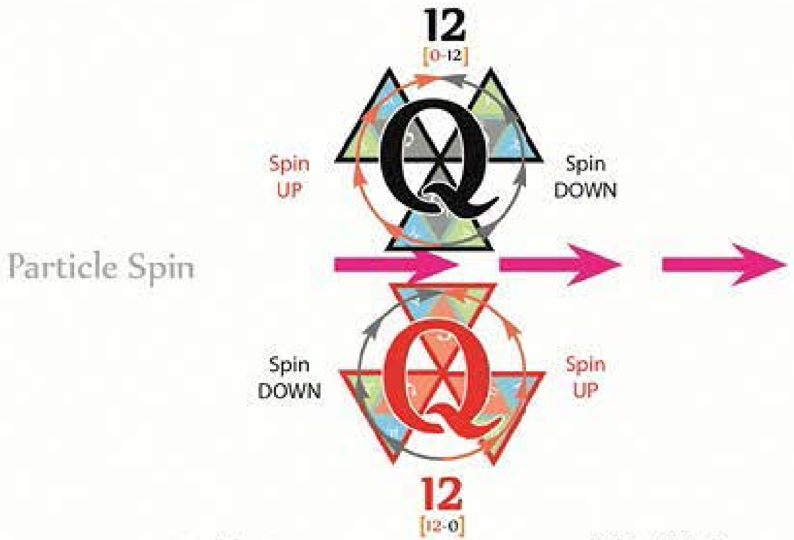
12
[0-12]
Spin
UP
Spin
DOWN
Particle Spin
Spin
DOWN
Spin
UP
12
[12-0]

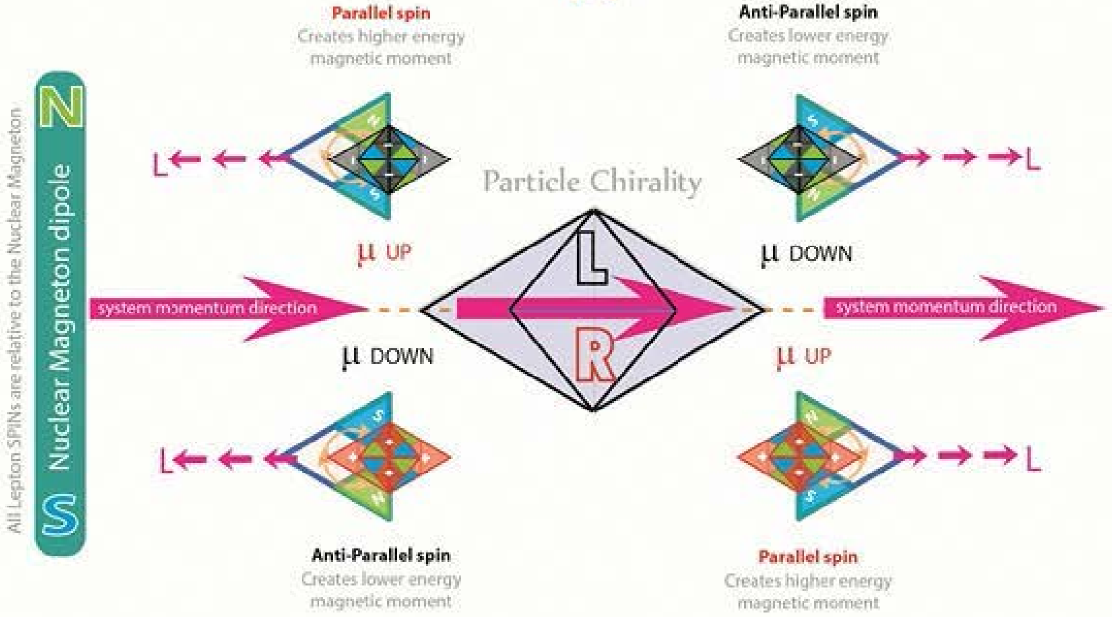
Parallel spin
Creates higher energy
magnetic moment
Anti-Parallel spin
Creates lower energy
magnetic moment
All Lepton SPINs are relative to the Nuclear Magneton
N
Nuclear Magneton dipole
S
L
µ UP
Particle Chirality
L
µ DOWN
system momentum direction
system momentum direction
µ DOWN
µ UP
L
L
R
Anti-Parallel spin
Creates lower energy
magnetic moment
Parallel spin
Creates higher energy
magnetic moment

Particle Chirality

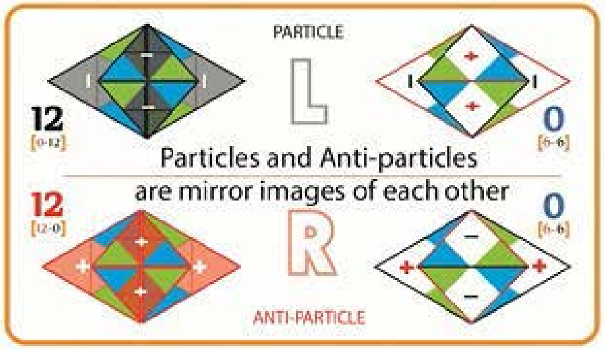
PARTICLE
L
12
[0-12]
0
[6-6]
12
[12-0]
R
0
[6-6]
ANTI-PARTICLE

Particles and Anti-particles
are mirror images of each other

Particle Helicity

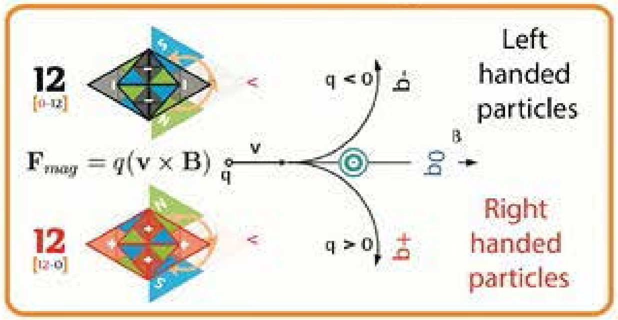
12
[0-12]
q < 0
q-
Left
handed
particles
v
B
q
q0
12
[12-0]
q > 0
q+
Right
handed
particles

$$F_{mag} = q(v \times B)$$

Lorentz Force and Transformation

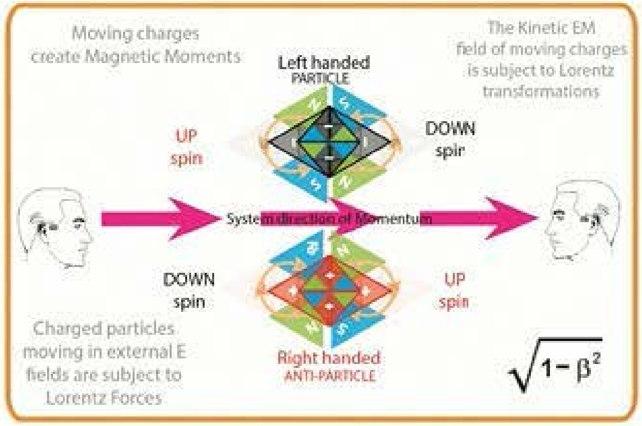
Left handed
PARTICLE
UP
spin
DOWN
spin
System direction of Momentum
DOWN
spin
UP
spin
Right handed
ANTI-PARTICLE

Moving charges
create Magnetic Moments

The Kinetic EM
field of moving charges
is subject to Lorentz
transformations

Charged particles
moving in external E
fields are subject to
Lorentz Forces

$$\sqrt{1-\beta^2}$$

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‘Point Charges’

The only true ‘point charges’ are Zero Point Fields

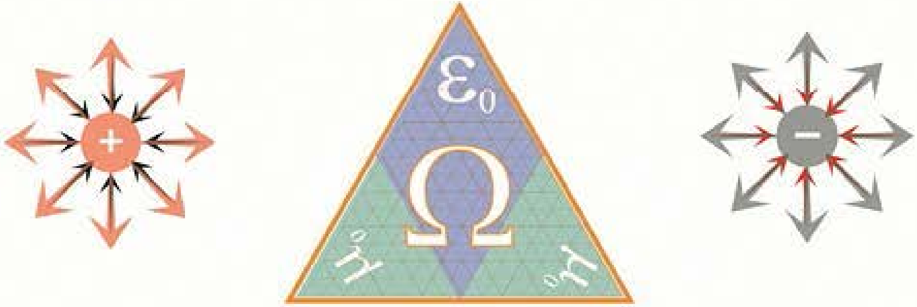
+
ε_0
Ω
μ_0
μ_0
−

Static charge particles have neutral M Fields
Charges in motion have magnetic moments

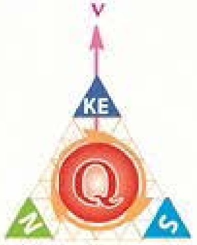

Positive Particles

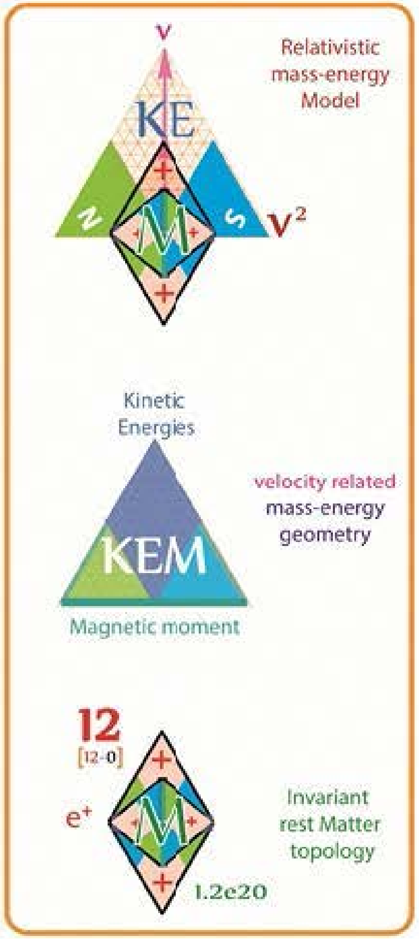
v
KE
N
S
M
v^2
KEM
e+

Relativistic
mass-energy
Model

Kinetic
Energies

velocity related
mass-energy
geometry

Magnetic moment

12
[12-0]

Invariant
rest Matter
topology

1.2e20

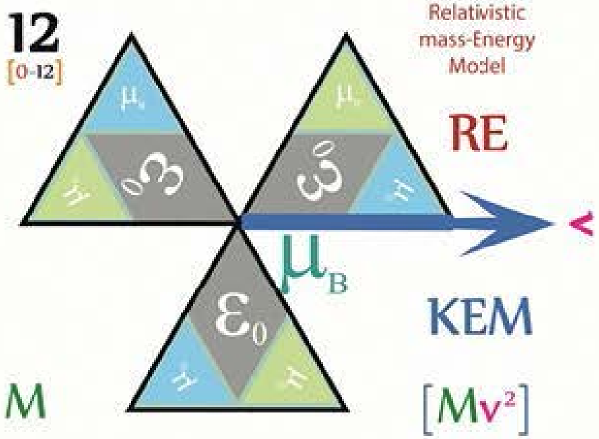
μ_0
ε_0
μ_B
v

12
[0-12]

Relativistic
mass-Energy
Model

RE

KEM

M

[Mv^2]

It is the Kinetic EM field geometry of charged Matter topologies in motion that produces Magnetic Moments

[not a relativistic distortion of speherical charge topologies]

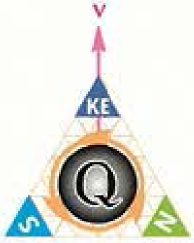

Negative Particles

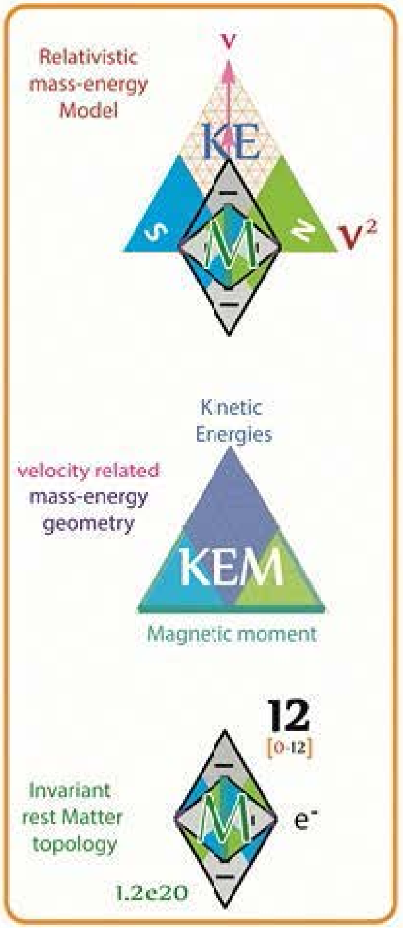
v
KE
S
N
M
v^2
KEM
e-

Relativistic
mass-energy
Model

Kinetic
Energies

velocity related
mass-energy
geometry

Magnetic moment

12
[0-12]

Invariant
rest Matter
topology

1.2e20

Tetryonics 08.12 - Point Charges

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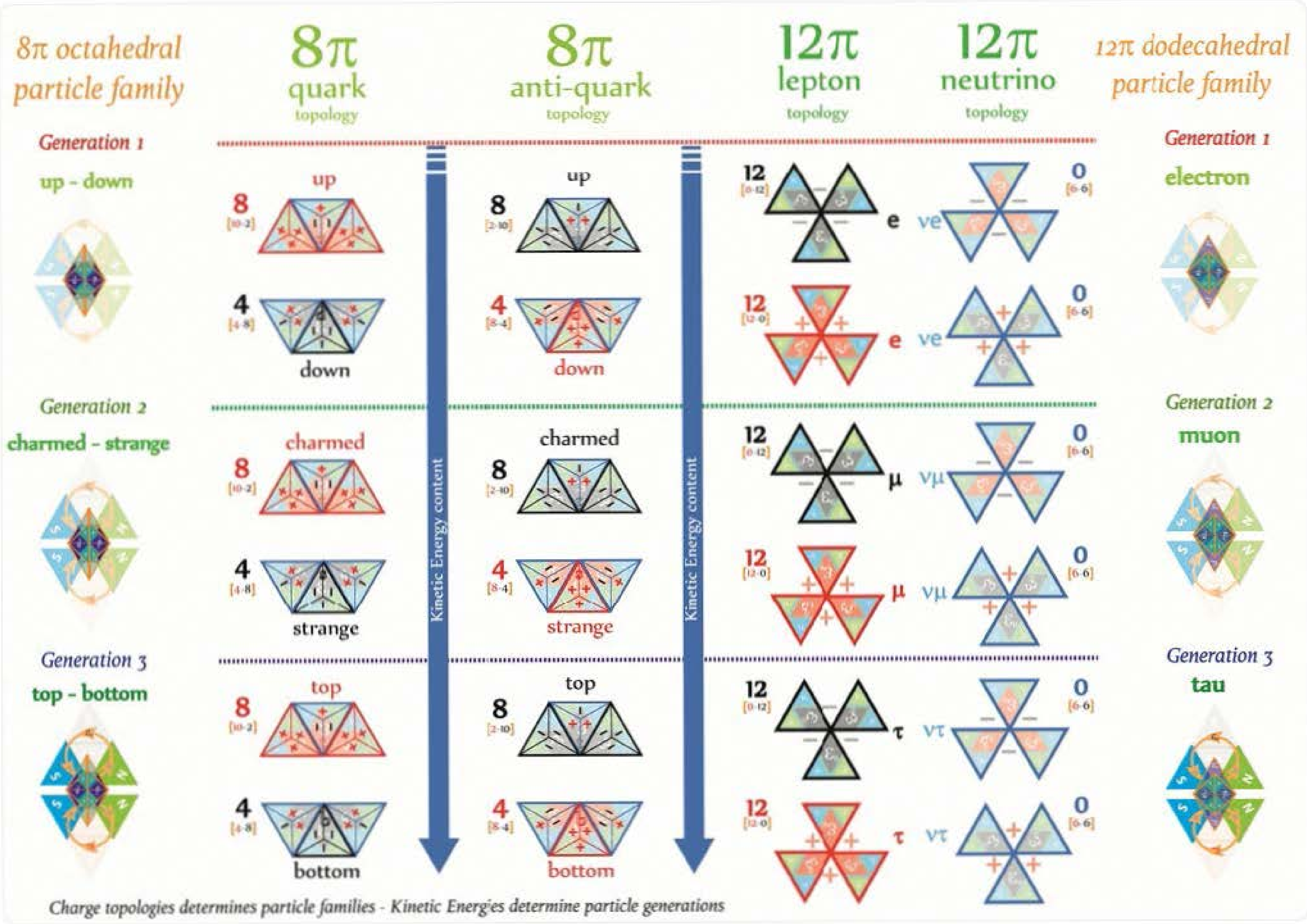
8π octahedral particle family
8π quark topology
8π anti-quark topology
12π lepton topology
12π neutrino topology
12π dodecahedral particle family
Generation 1
up - down
8 [10-2]
up
4 [4-8]
down
8 [2-10]
up
4 [8-4]
down
12 [0-12]
e
ve
0 [6-6]
12 [12-0]
e
ve
0 [6-6]
Generation 1
electron
Generation 2
charmed - strange
8 [10-2]
charmed
4 [4-8]
strange
8 [2-10]
charmed
4 [8-4]
strange
12 [0-12]
μ
νμ
0 [6-6]
12 [12-0]
μ
νμ
0 [6-6]
Generation 2
muon
Generation 3
top - bottom
8 [10-2]
top
4 [4-8]
bottom
8 [2-10]
top
4 [8-4]
bottom
12 [0-12]
τ
ντ
0 [6-6]
12 [12-0]
τ
ντ
0 [6-6]
Generation 3
tau
Kinetic Energy content
Kinetic Energy content

Charge topologies determines particle families - Kinetic Energies determine particle generations

Tetryonics 08.13 - Quark & Lepton families

Mesons

are 24π subatomic mass-Matter particles composed of one quark and one antiquark

$$24\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

EM Field Planck quanta
Mesons ElectroMagnetic mass velocity

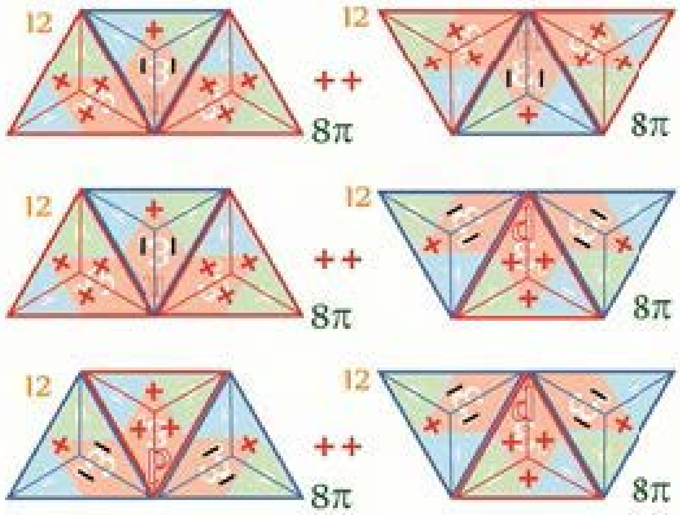
12
12
++
8π
8π
12
12
++
8π
8π
12
12
++
8π
8π

+16 [20-4]

+12 [18-6]

+8 [16-8]

prevented by strong repulives forces

24π charged mass-energy fascia geometries

Pions

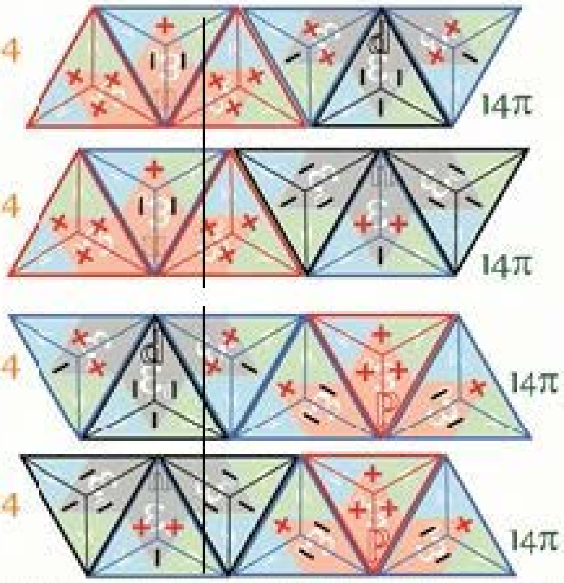
14π
14π
14π
14π

π+	24	+4	[14-10]
πo	24	0	[12-12]
πo	24	0	[12-12]
π-	24	-4	[10-14]

Short lived combinations

14π final mass-Matter topologies

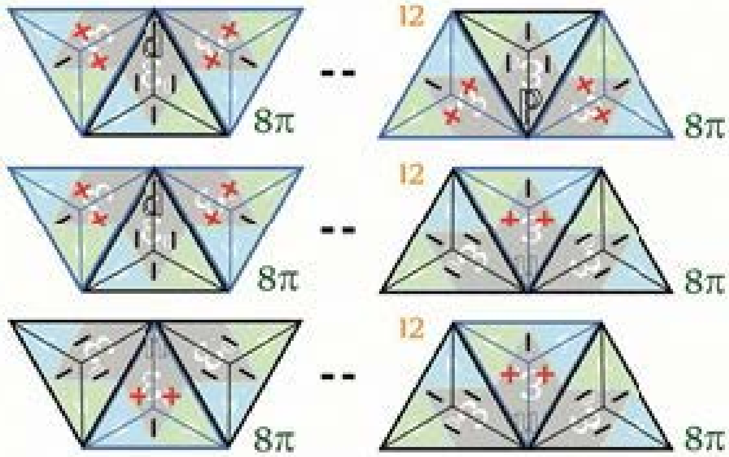
12
12
--
8π
8π
12
12
--
8π
8π
12
12
--
8π
8π

-8 [8-16]

-12 [6-18]

-16 [4-20]

prevented by strong repulives forces

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PION decay

24π dual -quark mass-energy geometries

12π lepton mass-energy geometries

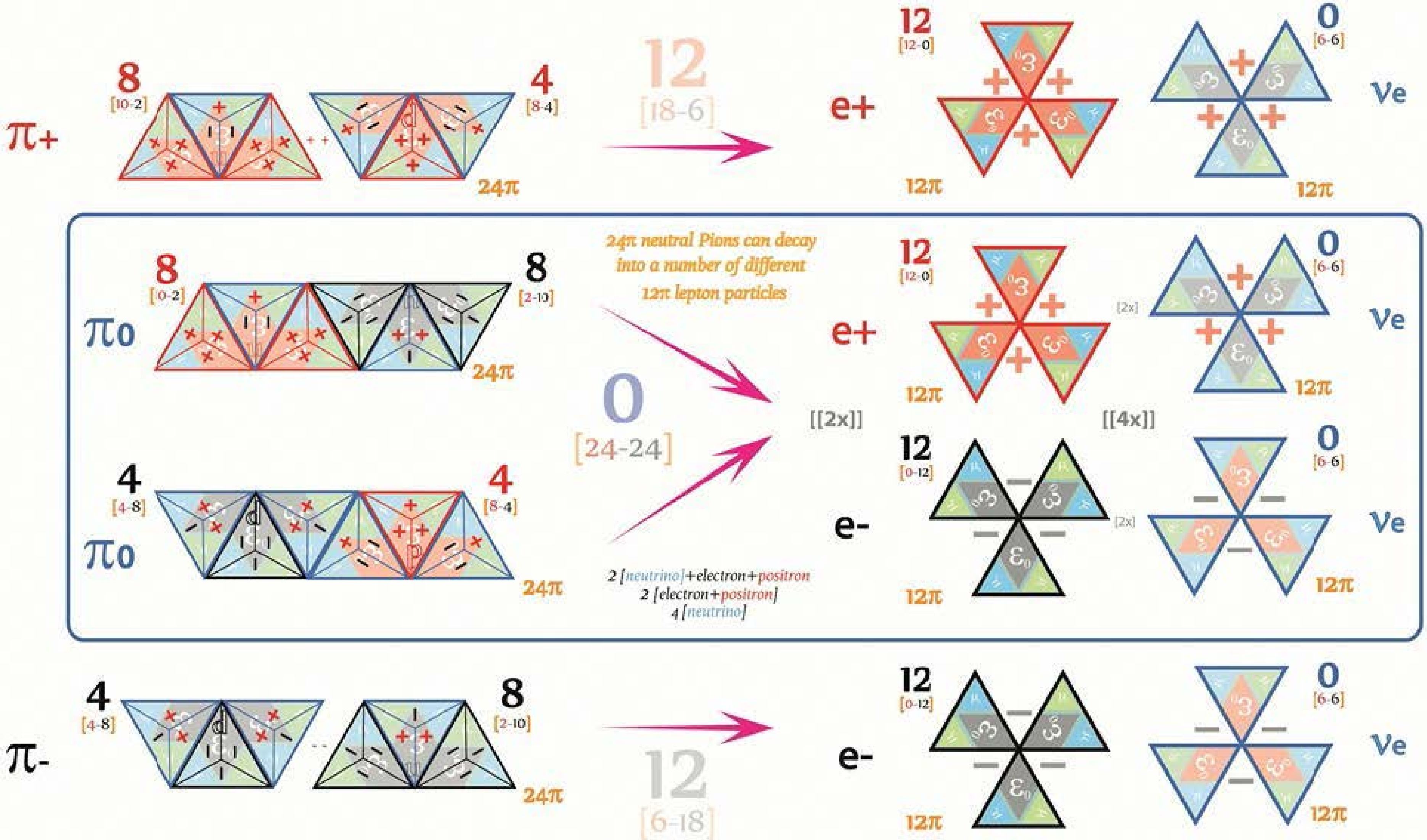
π+
8
[10-2]
4
[8-4]
24π
12
[18-6]
e+
12
[12-0]
12π
0
[6-6]
νe
12π
π0
8
[0-2]
8
[2-10]
24π
0
[24-24]
e+
12
[12-0]
12π
[2x]
0
[6-6]
νe
12π
[[2x]]
[[4x]]
4
[4-8]
4
[8-4]
π0
24π
e-
12
[0-12]
12π
[2x]
0
[6-6]
νe
12π
π-
4
[4-8]
8
[2-10]
24π
12
[6-18]
e-
12
[0-12]
12π
0
[6-6]
νe
12π

24π neutral Pions can decay into a number of different 12π lepton particles

2 [neutrino]+electron+positron
2 [electron+positron]
4 [neutrino]

$$24\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Mesons
EM Field
Planck
quanta
ElectroMagnetic
mass
velocity

24π dual dodecyon geometries

Despite having 24π geometries Mesons have same nett Charges as 36π Baryons

36π tri-dodecyon geometries

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right] + 12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Lepton - Neutrino generational pairing produced is dependent on the mass-energy levels of the interacting Pions

Tetryonics 09.02 - Pion decay

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$$24\pi + 12\pi = 36\pi$$

mesons *charged mass-energy geometries* **Baryons**

Short-lived Particles

All particles seek charge equilibrium

Stable Particles

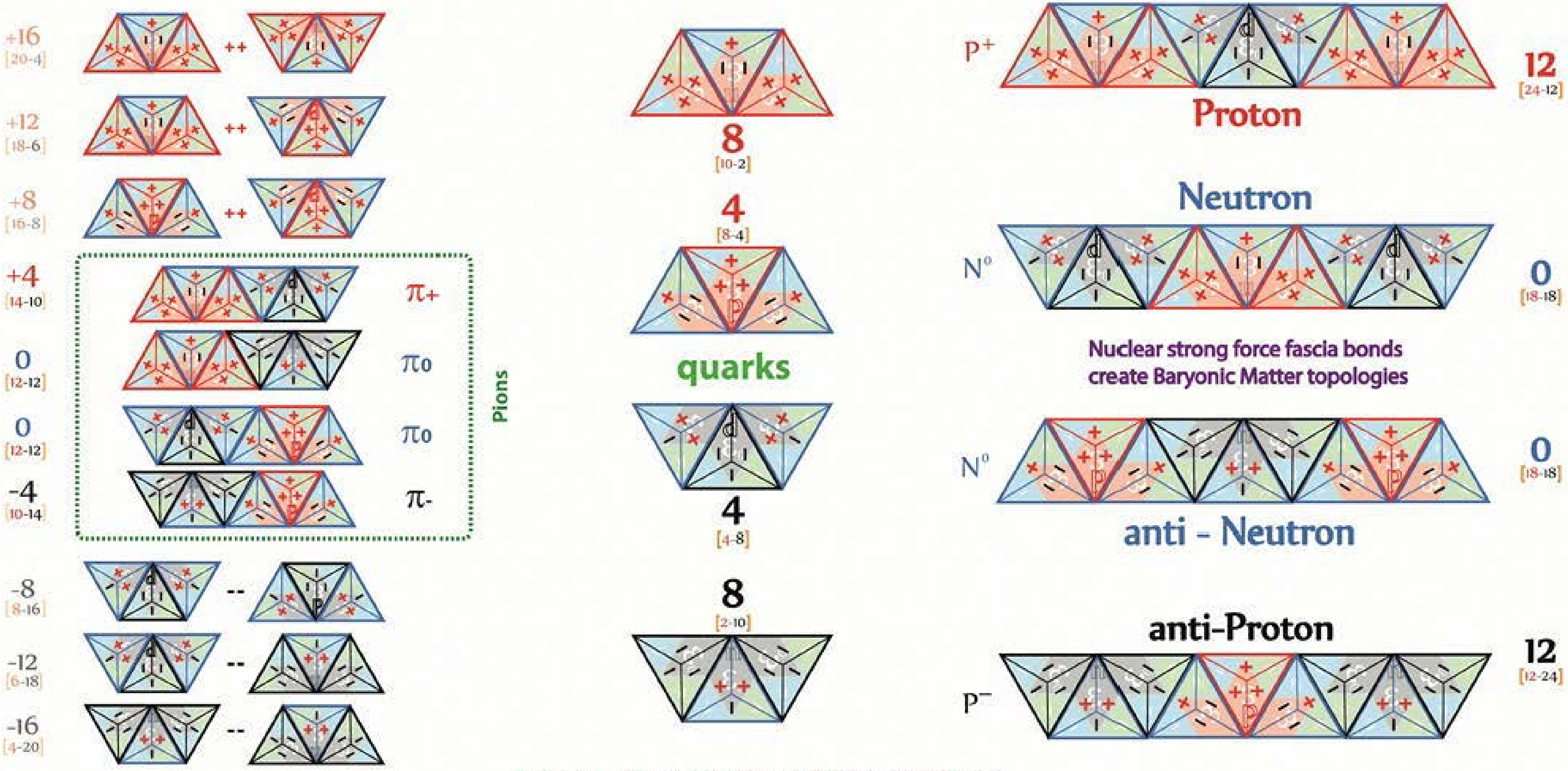
+16
[20-4]
++
+12
[18-6]
++
+8
[16-8]
++
+4
[14-10]
π+
0
[12-12]
πo
0
[12-12]
πo
-4
[10-14]
π-
Pions
-8
[8-16]
--
-12
[6-18]
--
-16
[4-20]
--
8
[10-2]
4
[8-4]
quarks
4
[4-8]
8
[2-10]
P+
Proton
12
[24-12]
Neutron
N°
0
[18-18]
Nuclear strong force fascia bonds
create Baryonic Matter topologies
N°
0
[18-18]
anti - Neutron
anti-Proton
P−
12
[12-24]

All Matter topologies have internalised mass-energy fascia

mesons *mass-Matter topologies* **Baryons**

$$14\pi + 8\pi = 20\pi$$

Tetryonics 09.03 - Baryon Formation [Meson-Quark interactions]

Baryons

Baryons are 36π mass-energy geometries

EM Field Planck quanta

$$36\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

Baryons ElectroMagnetic mass velocity

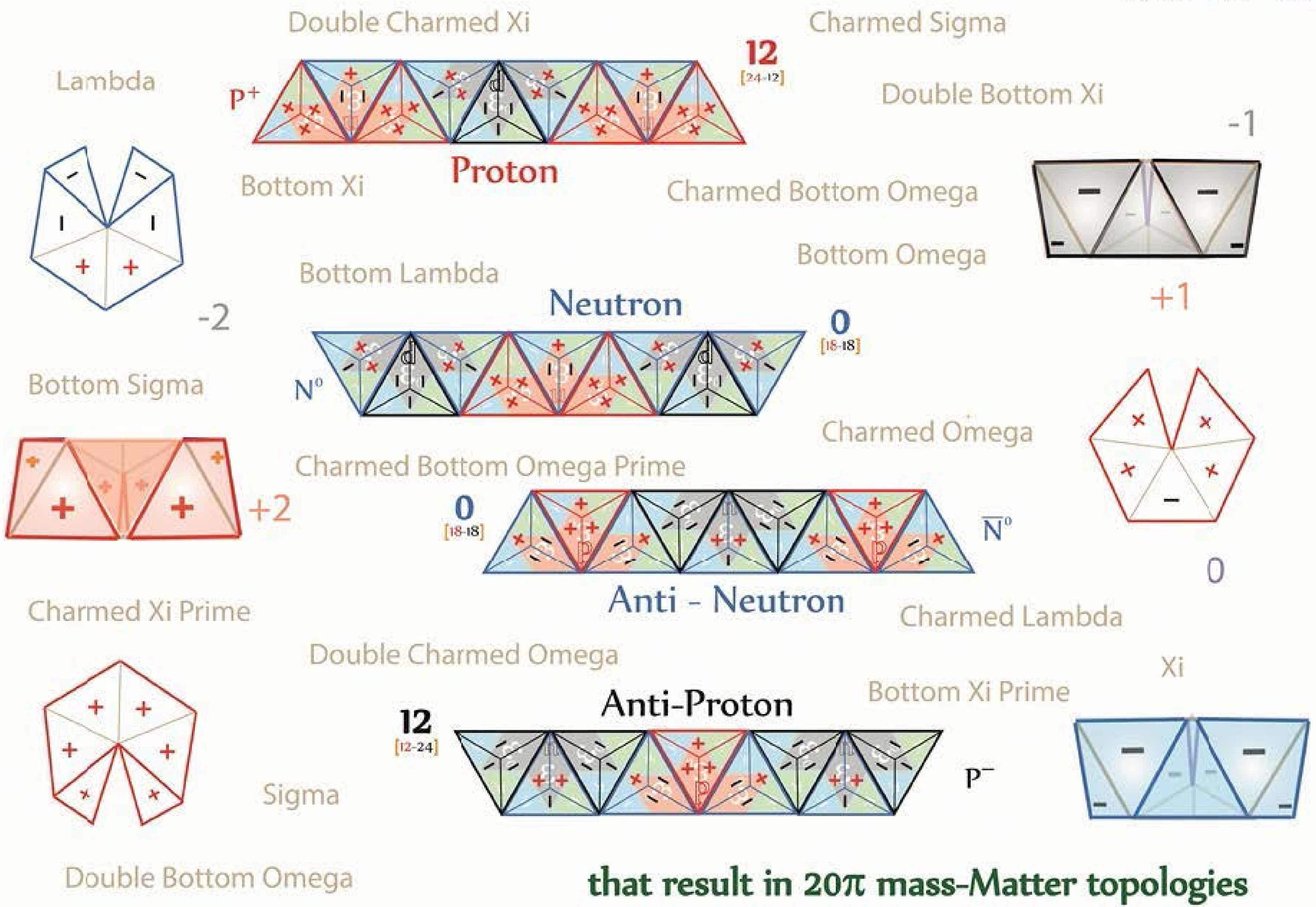

Double Charmed Xi

Charmed Sigma

Lambda

Double Bottom Xi

Bottom Xi

Proton

Charmed Bottom Omega

Bottom Omega

Bottom Lambda

Neutron

Bottom Sigma

Charmed Omega

Charmed Bottom Omega Prime

Charmed Xi Prime

Anti - Neutron

Charmed Lambda

Double Charmed Omega

Xi

Bottom Xi Prime

Anti-Proton

Sigma

Double Bottom Omega

that result in 20π mass-Matter topologies

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Proton

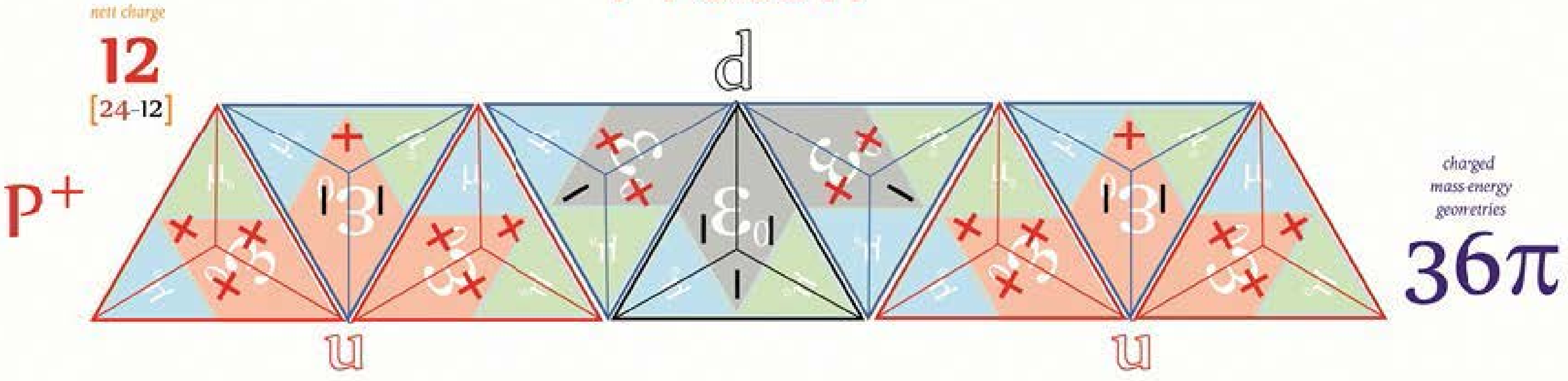
nett charge
12
[24-12]
p+
d
u
u
charged
mass-energy
geometries
36π

Tri-quark mass-energy geometry

EM Field Planck quanta

$$36\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Baryons ElectroMagnetic mass velocity

Baryon mass-Matter topology

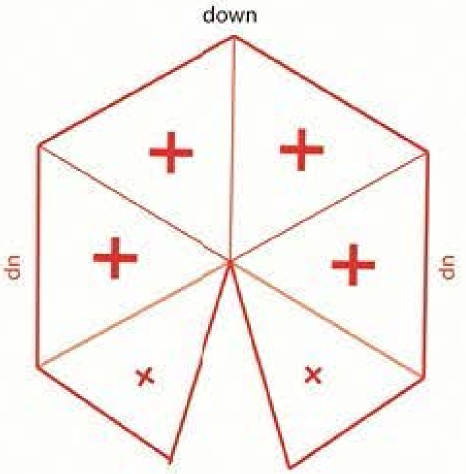

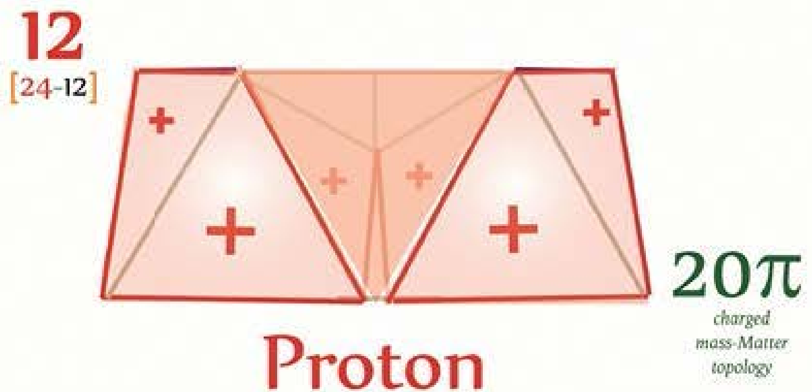
12
[24-12]
20π
charged
mass-Matter
topology

Proton

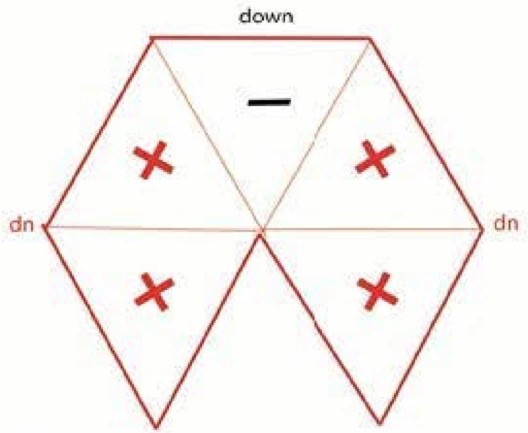

Neutron

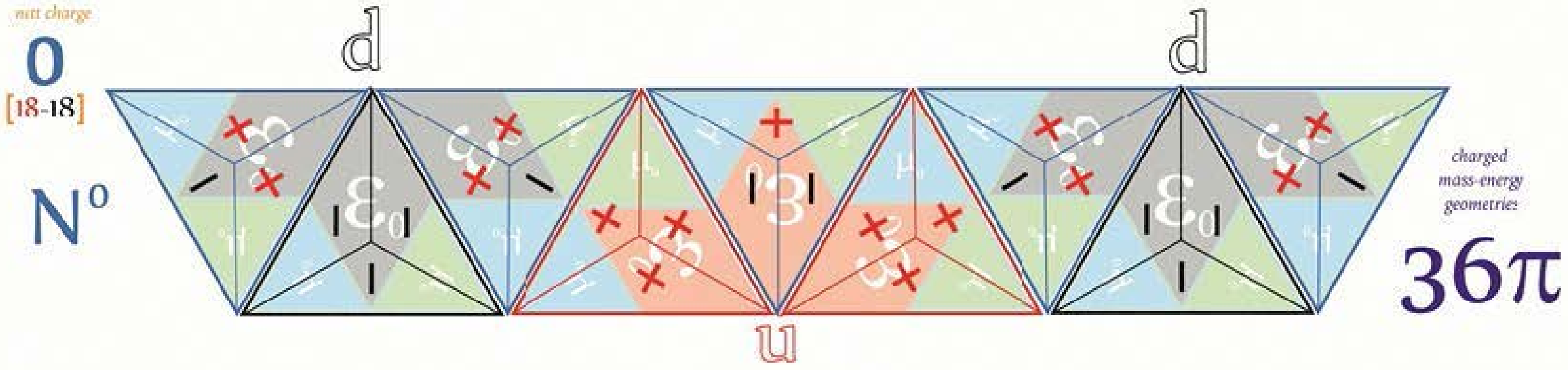
nett charge
0
[18-18]
N°
d
d
u
charged
mass-energy
geometries
36π

Tri-quark mass-energy geometry

EM Field Planck quanta

$$36\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Baryons ElectroMagnetic mass velocity

Baryon mass-Matter topology

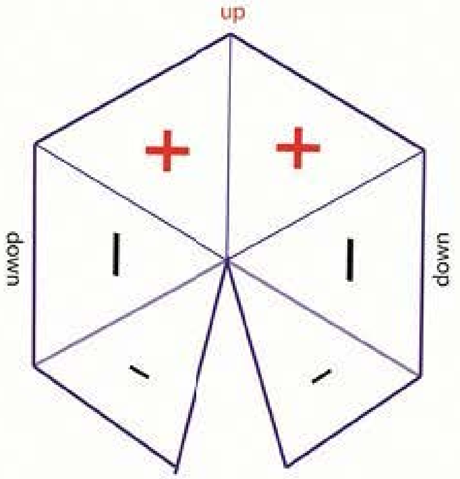
up
down
down

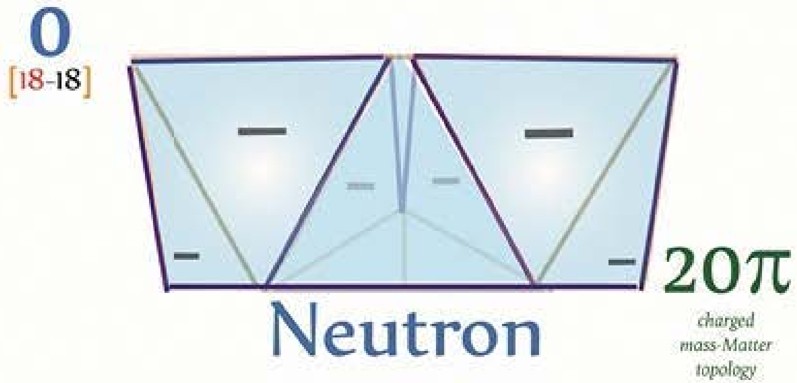
0
[18-18]
Neutron
20π
charged
mass-Matter
topology

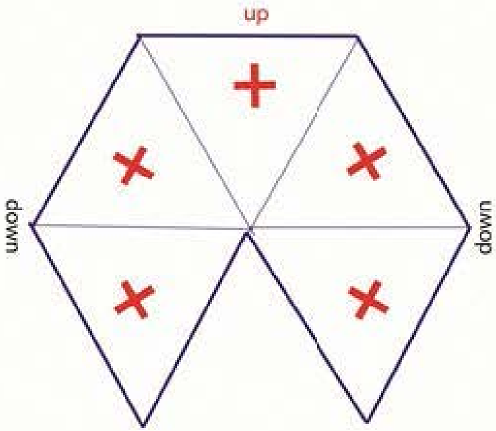
up
down
down

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anti-Neutron

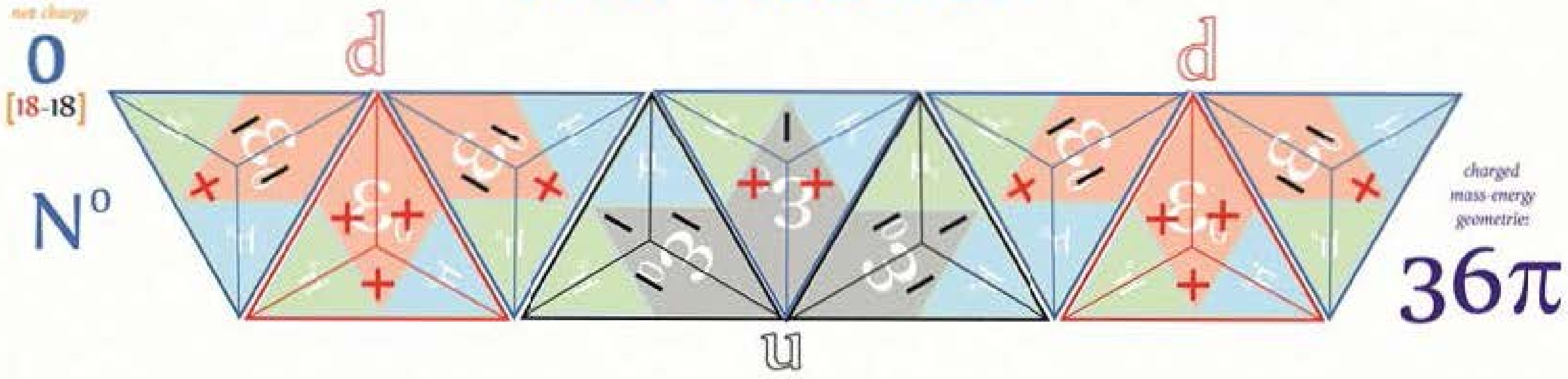
net charge
0
[18-18]
N⁰
d
d
u
charged mass-energy geometries
36π

Tri-quark mass-energy geometry

EM Field Planck quanta

$$36\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

Baryons ElectroMagnetic mass velocity

Baryon mass-Matter topology

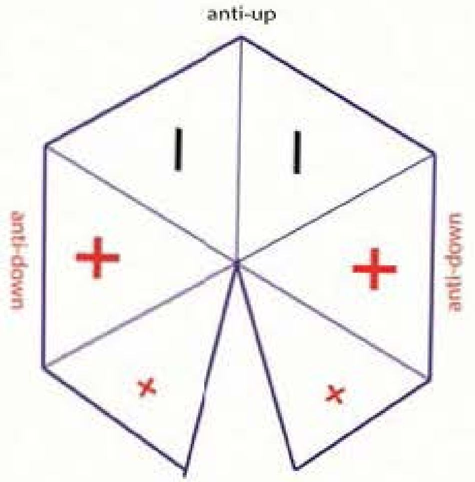
anti-up
anti-down
anti-down

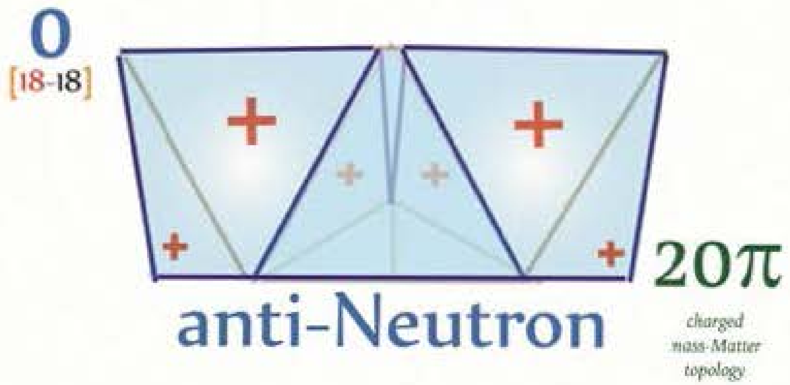
0
[18-18]
anti-Neutron
20π
charged mass-Matter topology

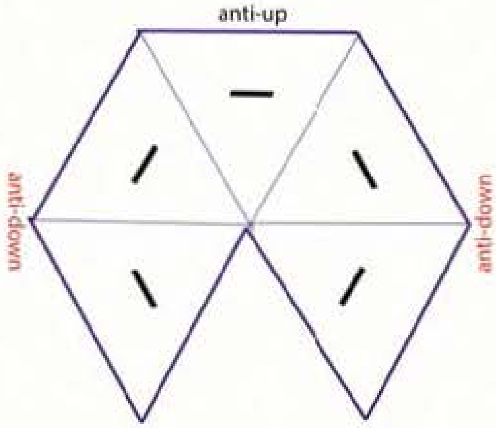
anti-up
anti-down
anti-down

Tetryonics 10.04 - anti-Neutron

anti-Proton

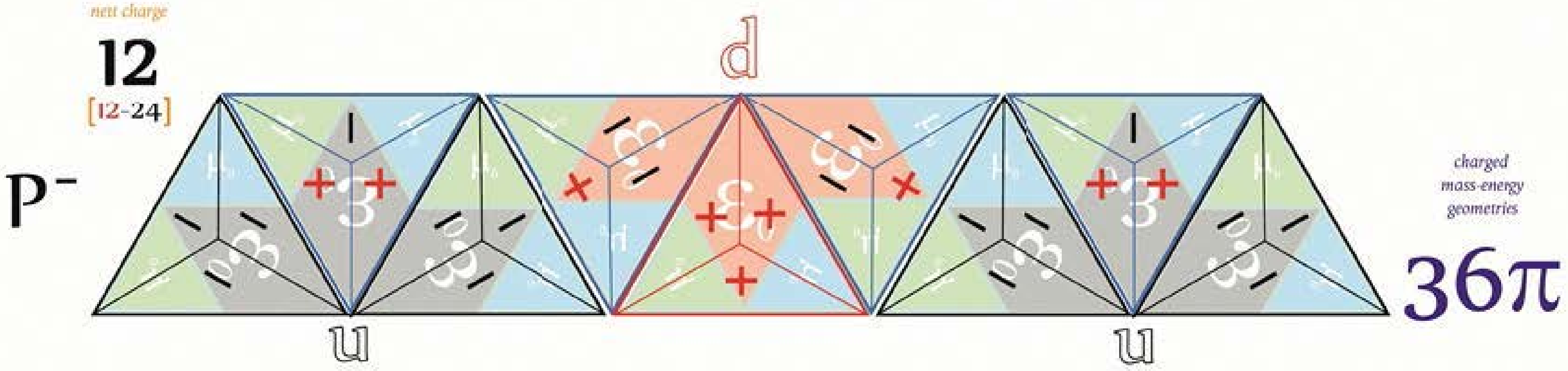
nett charge
12
[12-24]
P⁻
d
u
u
charged
mass-energy
geometries
36π

Tri-quark mass-energy geometry

EM Field · Planck · quanta

$$36\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Baryons · ElectroMagnetic · mass · velocity

Baryon mass-Matter topology

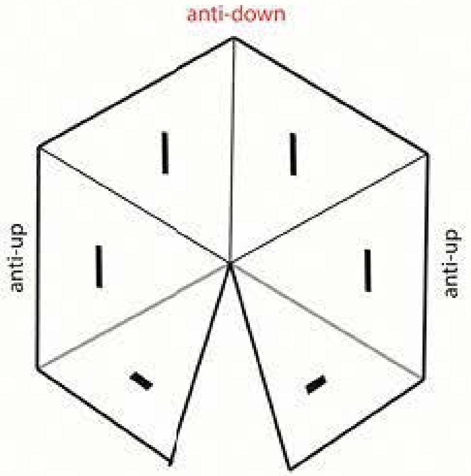
anti-down
anti-up
anti-up

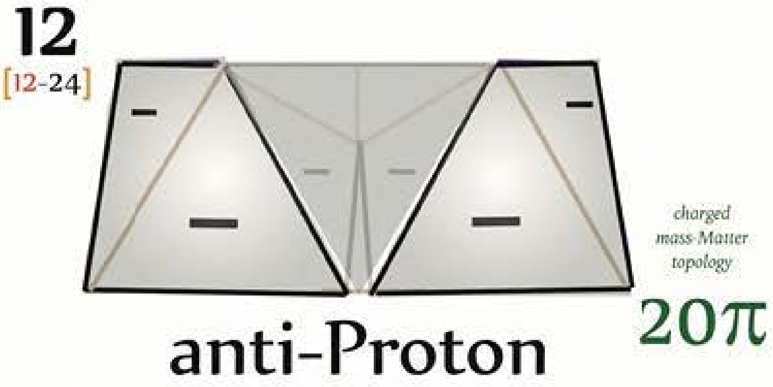
12
[12-24]
anti-Proton
charged
mass-Matter
topology
20π

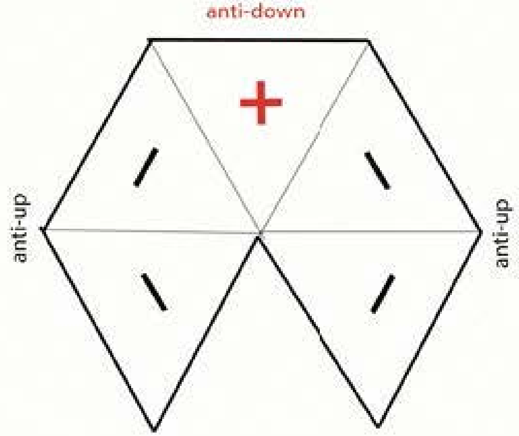
anti-down
anti-up
anti-up

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Baryon geometry

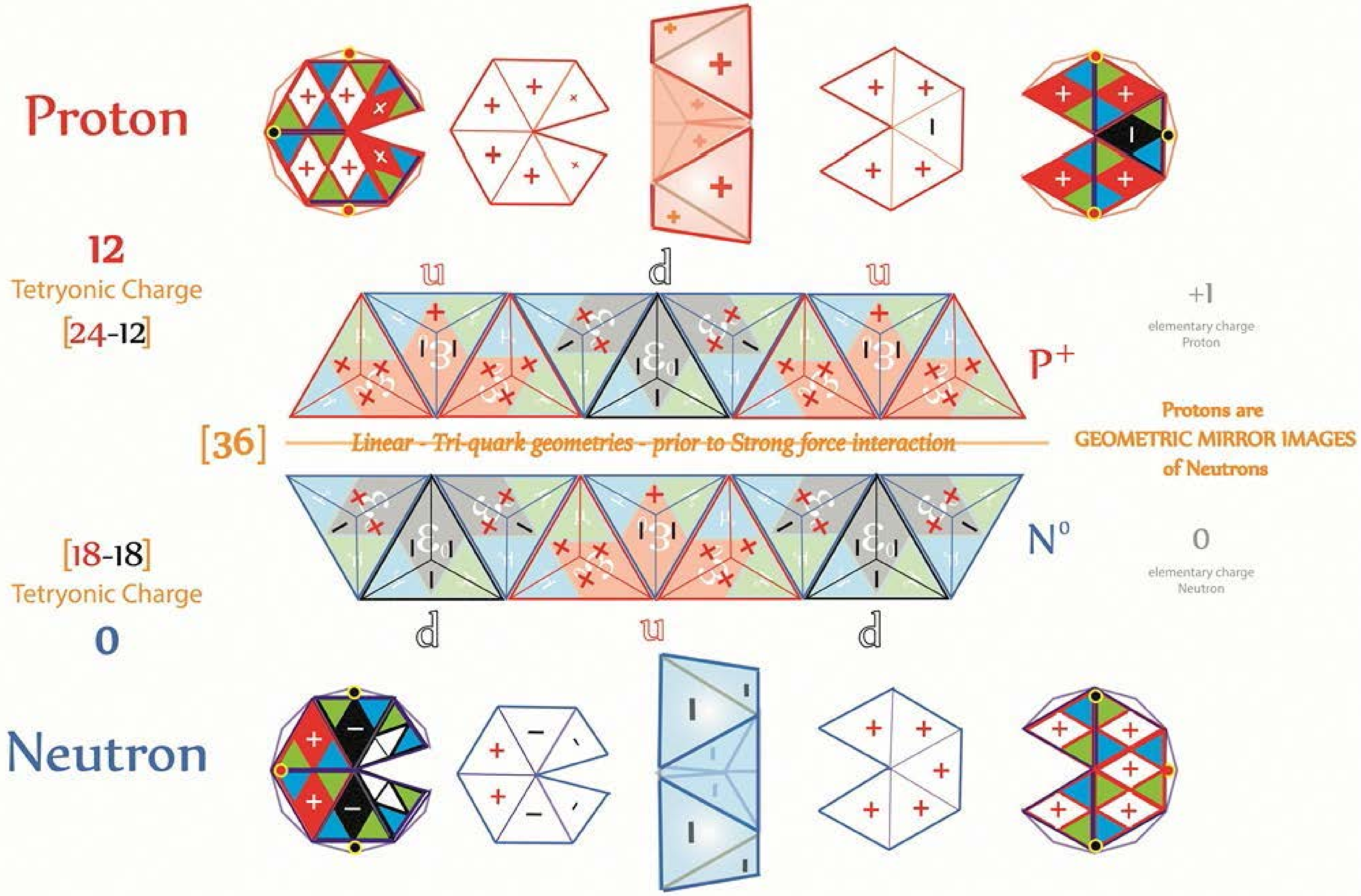

Proton

12
Tetryonic Charge
[24-12]

[36] Linear - Tri-quark geometries - prior to Strong force interaction

+1
elementary charge
Proton

Protons are
GEOMETRIC MIRROR IMAGES
of Neutrons

0
elementary charge
Neutron

[18-18]
Tetryonic Charge
0

Neutron

Tetryonics 10.06 - Baryon geometry

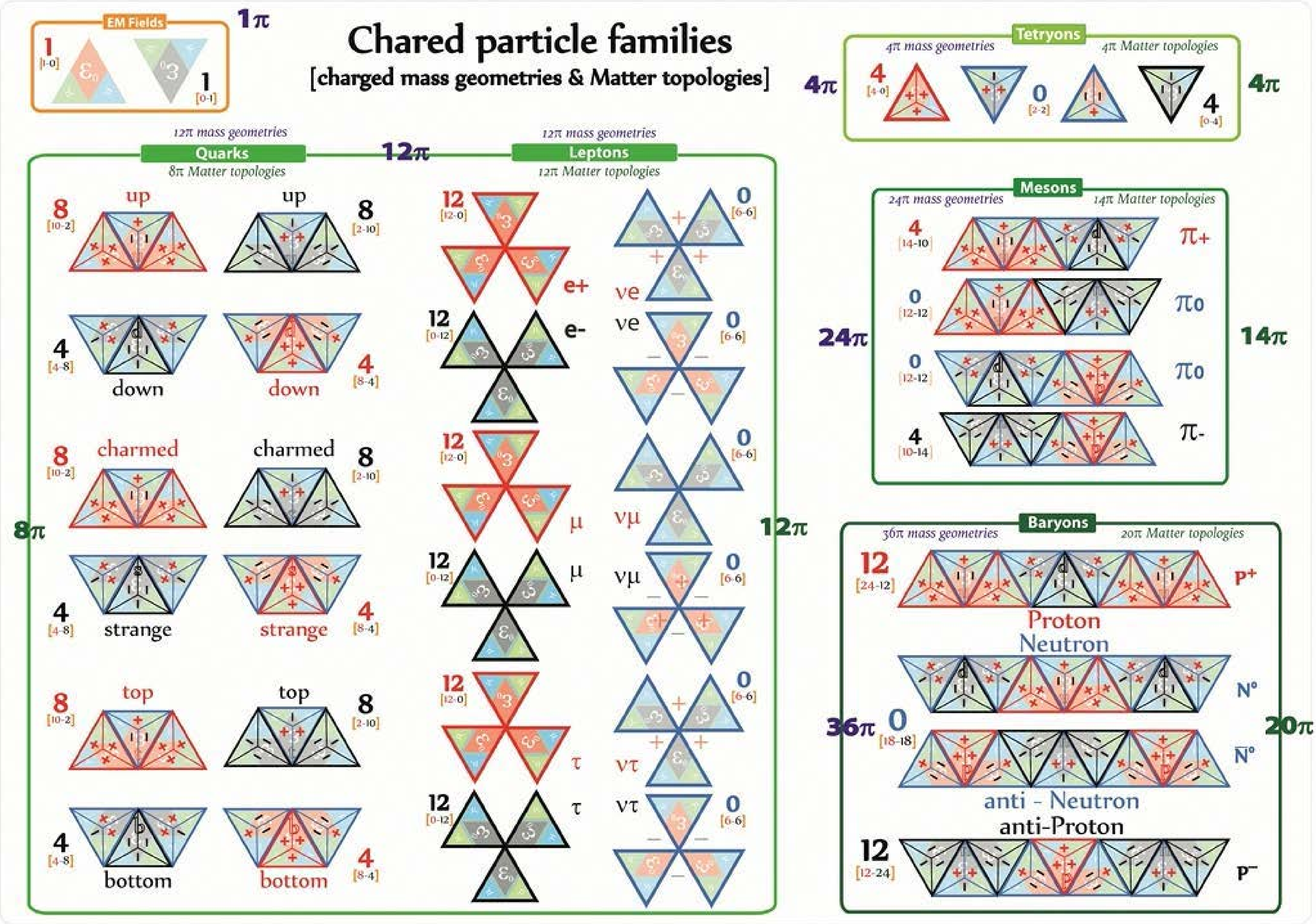

Chared particle families

[charged mass geometries & Matter topologies]

EM Fields
1
[1-0]
1
[0-1]
1π
Tetryons
4π mass geometries
4π Matter topologies
4π
4
[4-0]
0
[2-2]
4
[0-4]
4π
12π mass geometries
Quarks
8π Matter topologies
12π
12π mass geometries
Leptons
12π Matter topologies
8
[10-2]
up
up
8
[2-10]
4
[4-8]
down
down
4
[8-4]
8
[10-2]
charmed
charmed
8
[2-10]
8π
4
[4-8]
strange
strange
4
[8-4]
8
[10-2]
top
top
8
[2-10]
4
[4-8]
bottom
bottom
4
[8-4]
12
[12-0]
e+
νe
0
[6-6]
12
[0-12]
e-
νe
0
[6-6]
12
[12-0]
μ
νμ
0
[6-6]
12
[0-12]
μ
νμ
0
[6-6]
12
[12-0]
τ
ντ
0
[6-6]
12
[0-12]
τ
ντ
0
[6-6]
12π
Mesons
24π mass geometries
14π Matter topologies
24π
4
[14-10]
π+
0
[12-12]
π0
0
[12-12]
π0
4
[10-14]
π-
14π
Baryons
36π mass geometries
20π Matter topologies
12
[24-12]
P+
Proton
Neutron
N°
36π
0
[18-18]
N̄°
20π
anti - Neutron
anti-Proton
12
[12-24]
P−

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Tetryonic Energy levels

$$E = n\pi\left[\left[m\Omega v^2\right]\right]$$

Energy
Planck quanta
mass velocity
momentum

Energy levels

$\mathfrak{m}$

1e19 $h\nu$ = n

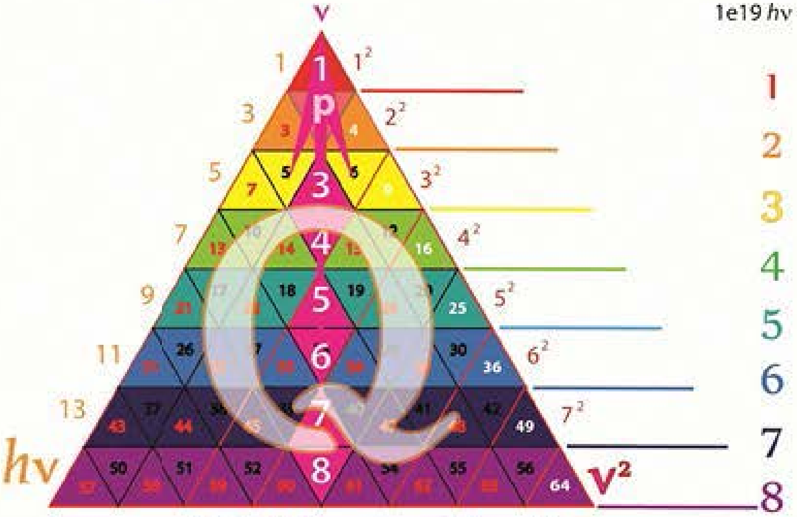
v
1
3
5
7
9
11
13
hv
1^2
2^2
3^2
4^2
5^2
6^2
7^2
v^2
p
1
2
3
4
5
6
7
8
Q

charged field quantisation

Every charged fascia of a Field or Particle holds squared energy levels
[equilateral EM mass-energy geometries & Matter topologies]

rest mass-Matter

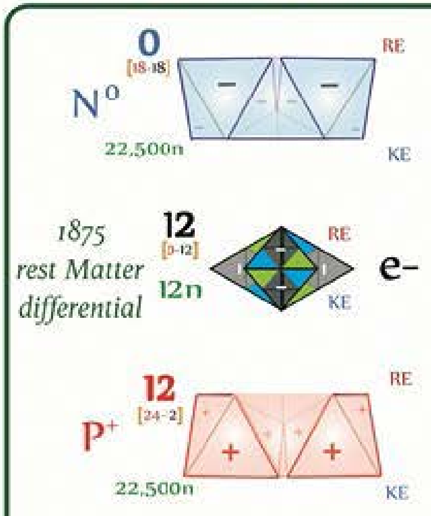
0
[18-18]
N⁰
22,500n
RE
KE
1875
rest Matter
differential
12
[0-12]
12n
RE
KE
e-
12
[24-2]
P⁺
22,500n
RE
KE

The total mass-energy for any particle is its rest mass-Matter + Kinetic Energies

The mass-energies of its charge geometry determines its rest mass-Matter

An electron's nuclear kinetic energy level is determined by the Baryons it binds to (or by incident photons)

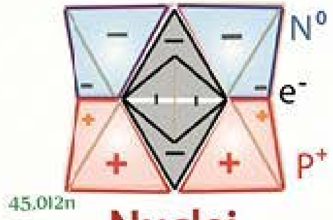
N⁰
e⁻
P⁺
45,012n

Nuclei

Nuclear Quantum Level

electron Kinetic Energy Level

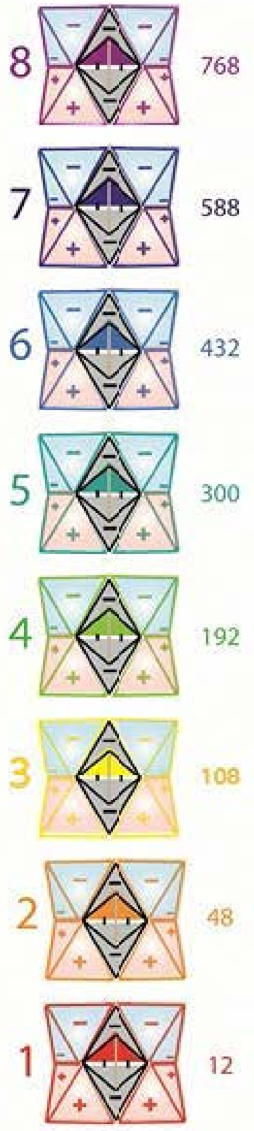
8
768
7
588
6
432
5
300
4
192
3
108
2
48
1
12

As the Nuclei quanutm level increases - so does the electron's energy and tmomenta

The Tetryonic KEM Colour code

As the energy levels of atomic nuclei increase/decrease
the KEM fields of leptons bound to them change accordingly

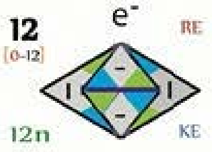
12
[0-12]
e⁻
RE
12n
KE

Electron

1	2	3	4	5	6	7	8
▲	▲	▲	▲	▲	▲	▲	▲
1	4	9	16	25	36	49	64

All energy levels are Tetryonic square number quantas
ie 1, 4 , 9, 16, 25 etc (1,2,3,4,5)

$$KEM = 4\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Kinetic energies
EM Field
ElectroMagnetic mass velocity
Planck quanta

tri-quark charged toplogy combinations

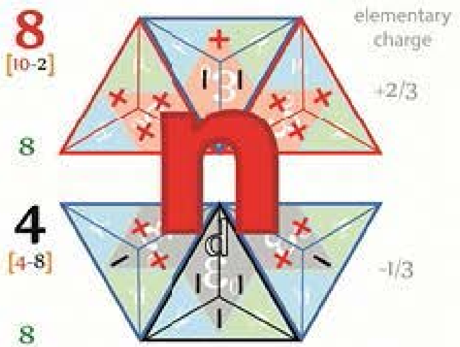

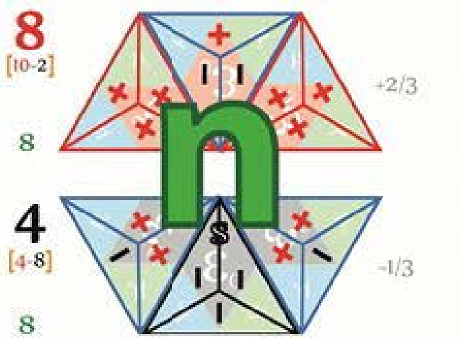

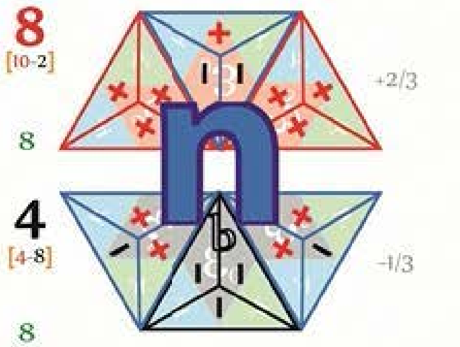

Quarks seek charge equilibrium by
forming Baryonic Matter topologies
as a result of charge interactions
[STRONG nuclear Force]

UP
DOWN] gen 1
CHARMED
STRANGE] gen 2
TOP
BOTTOM] gen 3

[+8 +8 +8] [10-2] [10-2] [10-2] **24** + 2 2/3 2/3 2/3

[+8 -4 +8] [10-2] [4-8] [10-2] **12** + 1 2/3 1/3 2/3

The particle Zoo is the result of tri-quark mass-energy topologies

[-4 +8 -4] [4-8] [10-2] [4-8] **0** 0 0 1/3 2/3 1/3

[-4 -4 -4] [4-8] [4-8] [4-8] **12** - 1 1/3 1/3 1/3

Twice the number of combinations are possible with the inclusion of anti-matter topologies

EM Field Planck quanta

$$36\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Baryons ElectroMagnetic mass velocity

Any combinations of inter-generational quarks results in differing final mass-energies in the created Baryonic Matter due to energy equalisation

The Particle Zoo

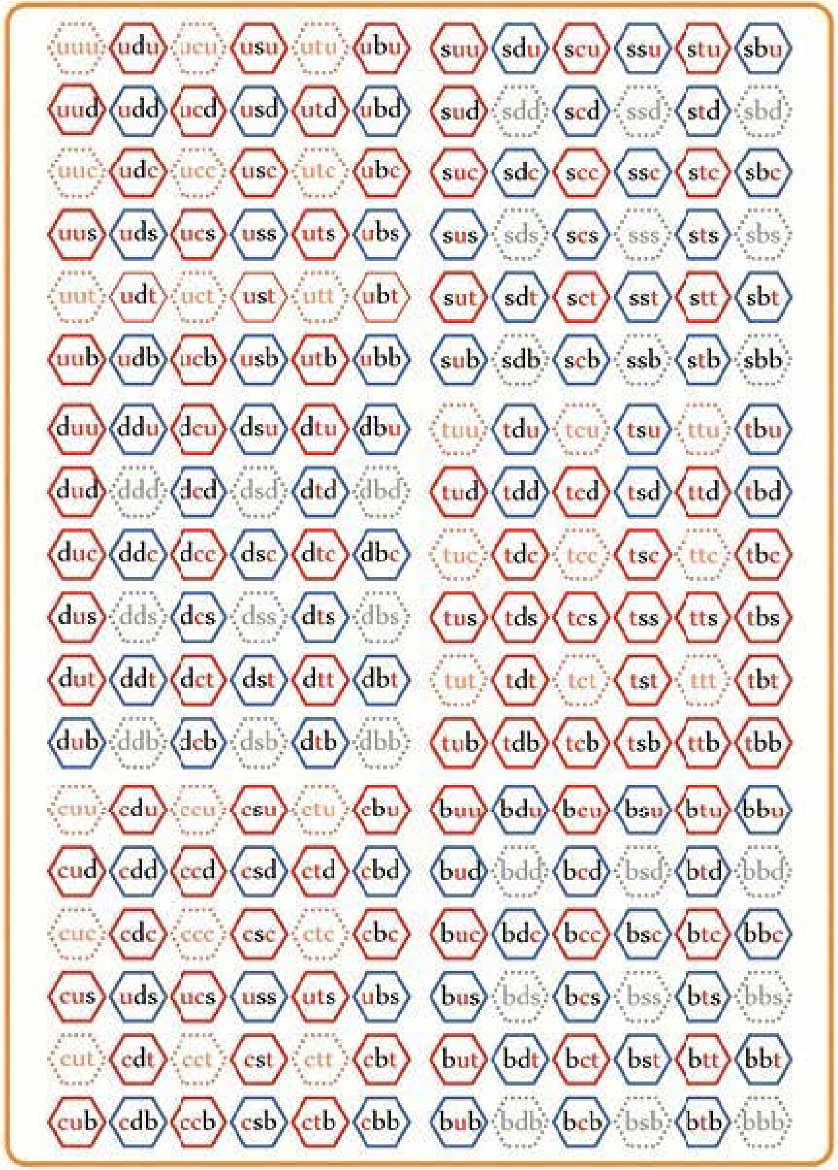

uuu	udu	ucu	usu	utu	ubu	suu	sdu	scu	ssu	stu	sbu
uud	udd	ucd	usd	utd	ubd	sud	sdd	scd	ssd	std	sbd
uuc	udc	ucc	usc	utc	ubc	suc	sdc	scc	ssc	stc	sbc
uus	uds	ucs	uss	uts	ubs	sus	sds	scs	sss	sts	sbs
uut	udt	uct	ust	utt	ubt	sut	sdt	sct	sst	stt	sbt
uub	udb	ucb	usb	utb	ubb	sub	sdb	scb	ssb	stb	sbb
duu	ddu	dcu	dsu	dtu	dbu	tuu	tdu	tcu	tsu	ttu	tbu
dud	ddd	dcd	dsd	dtd	dbd	tud	tdd	tcd	tsd	ttd	tbd
duc	ddc	dcc	dsc	dtc	dbc	tuc	tdc	tcc	tsc	ttc	tbc
dus	dds	dcs	dss	dts	dbs	tus	tds	tcs	tss	tts	tbs
dut	ddt	dct	dst	dtt	dbt	tut	tdt	tct	tst	ttt	tbt
dub	ddb	dcb	dsb	dtb	dbb	tub	tdb	tcb	tsb	ttb	tbb
cuu	cdu	ccu	csu	ctu	cbu	buu	bdu	bcu	bsu	btu	bbu
cud	cdd	ccd	csd	ctd	cbd	bud	bdd	bcd	bsd	btd	bbd
cuc	cdc	ccc	csc	ctc	cbc	buc	bdc	bcc	bsc	btc	bbc
cus	uds	ucs	uss	uts	ubs	bus	bds	bcs	bss	bts	bbs
cut	cdt	cct	cst	ctt	cbt	but	bdt	bct	bst	btt	bbt
cub	cdb	ccb	csb	ctb	cbb	bub	bdb	bcb	bsb	btb	bbb

216 possible Baryon topologies [excluding anti-matter] with each combination producing differing Baryonic nett energy levels

Quarks always form symmetrical [udu] or [dud] charged Baryonic topologies
[same charges never combine except under high energy conditions]
ie. Proton is a [udu] not [uud] as is commonly stated

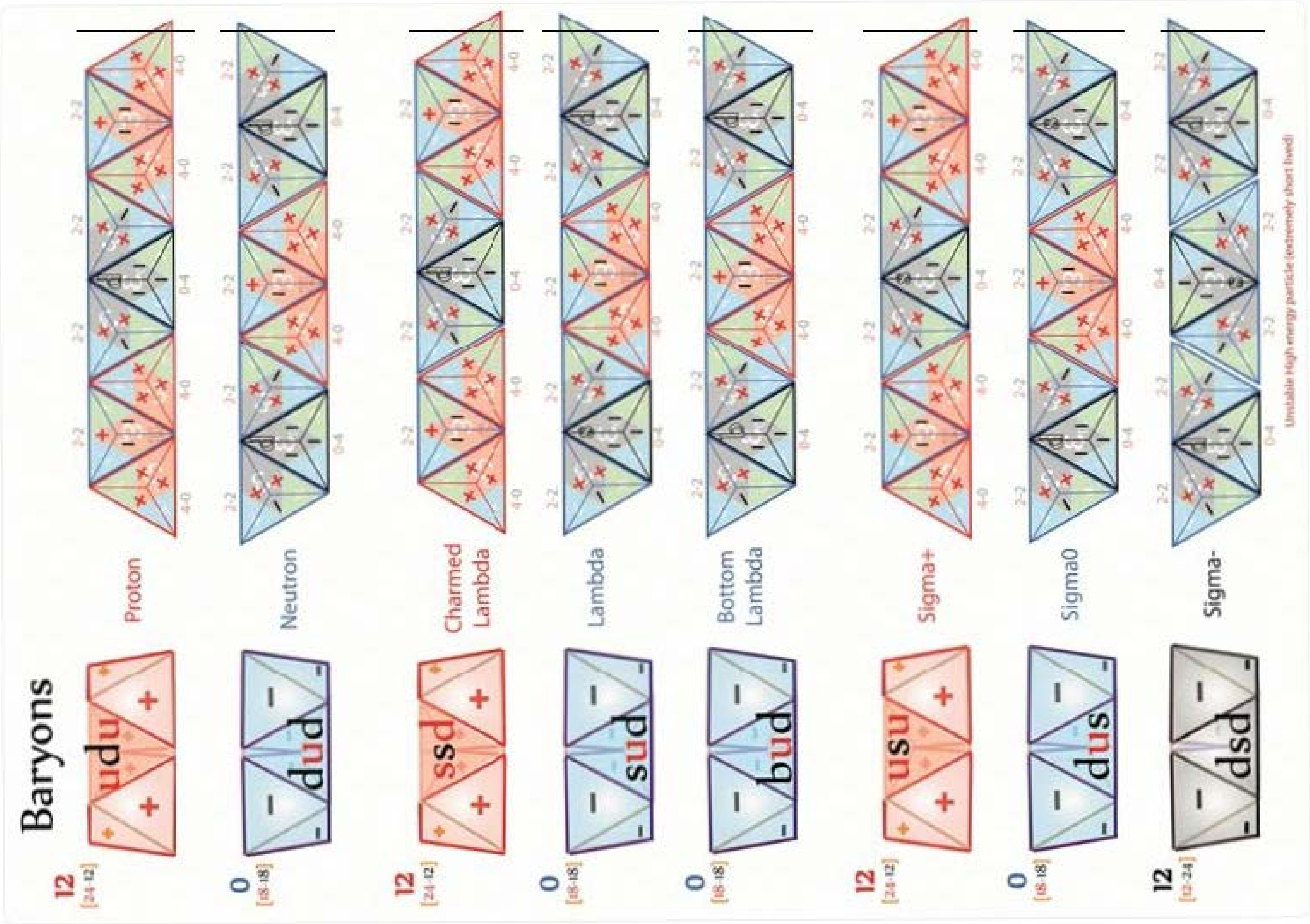
Baryons
12 [24·12]
udu
Proton
0 [18·18]
dud
Neutron
12 [24·12]
ssd
Charmed Lambda
0 [18·18]
sud
Lambda
0 [18·18]
bud
Bottom Lambda
12 [24·12]
usu
Sigma+
0 [18·18]
dus
Sigma0
12 [12·24]
dsd
Sigma-
Unstable High energy particle (extremely short lived)

Tetryonics 10.10 - Proton to Sigma-

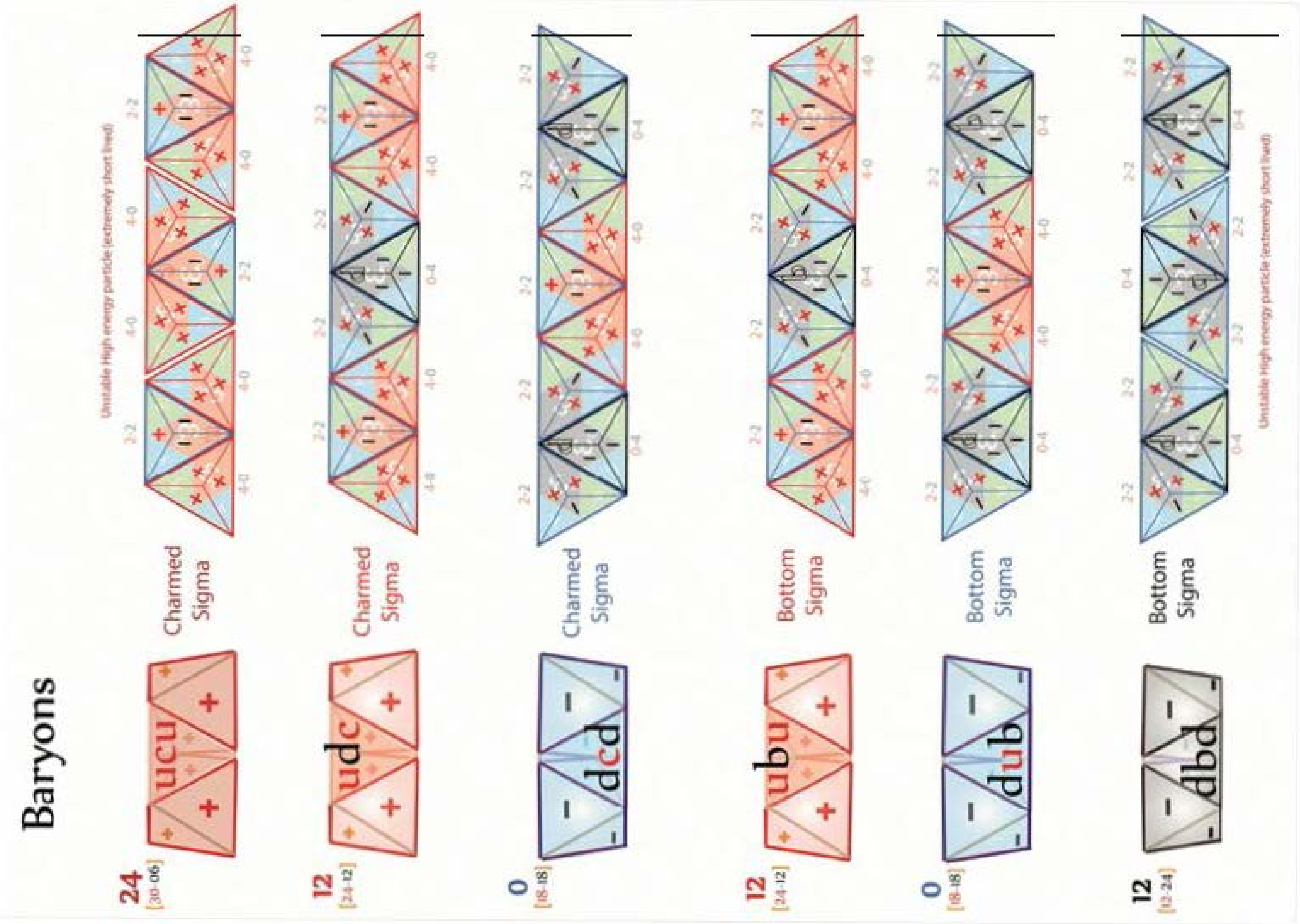
Baryons
24
[30 06]
ucu
Charmed Sigma
Unstable High energy particle (extremely short lived)
12
[24 12]
udc
Charmed Sigma
0
[18 18]
dcd
Charmed Sigma
12
[24 12]
ubu
Bottom Sigma
0
[18 18]
dub
Bottom Sigma
12
[12 24]
dbd
Bottom Sigma
Unstable High energy particle (extremely short lived)

Tetryonics 10.11 - Charmed to Bottom Sigma

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Baryons

0
[18-18]

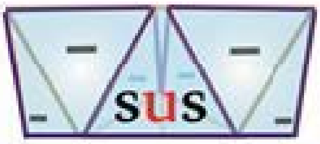

Xi

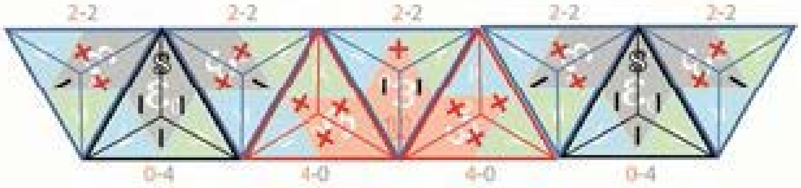
2-2
2-2
2-2
2-2
2-2
s
s
0-4
4-0
4-0
0-4

12
[12-24]

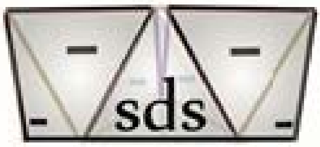

Xi

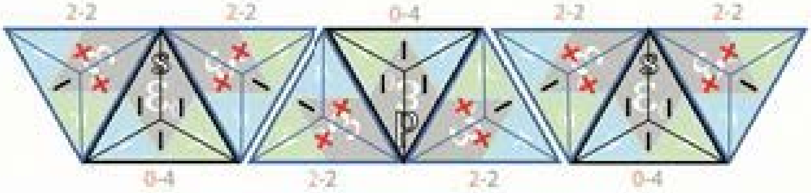
2-2
2-2
0-4
2-2
2-2
s
p
s
0-4
2-2
2-2
0-4

Unstable High energy particle (extremely short lived)

Charmed Xi Prime

12
[24-12]

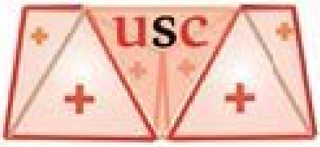

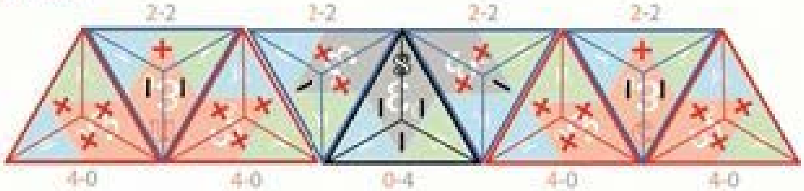
2-2
2-2
2-2
2-2
s
4-0
4-0
0-4
4-0
4-0

Charmed Xi Prime

0
[18-18]

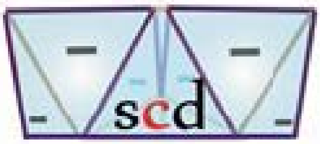

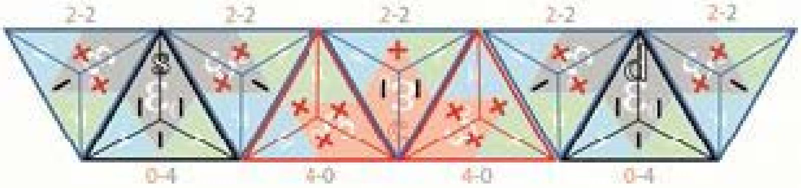
2-2
2-2
2-2
2-2
2-2
s
d
0-4
4-0
4-0
0-4

Double Charmed Xi

24
[30-06]

Unstable High energy particle (extremely short lived)

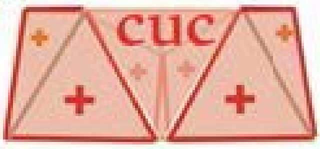

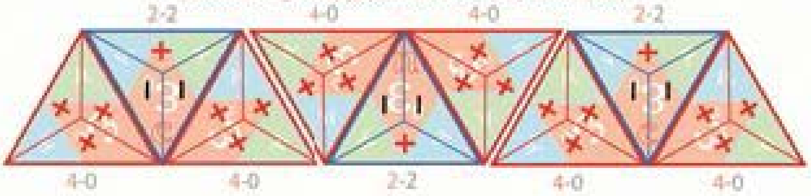
2-2
4-0
4-0
2-2
4-0
4-0
2-2
4-0
4-0

Double Charmed Xi

12
[24-12]

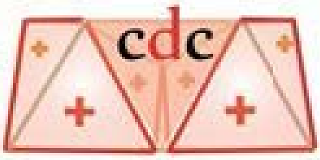

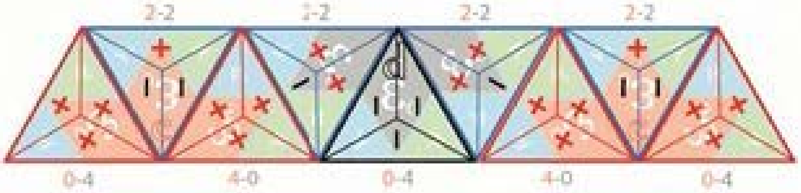
2-2
2-2
2-2
2-2
d
0-4
4-0
0-4
4-0
0-4

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Baryons

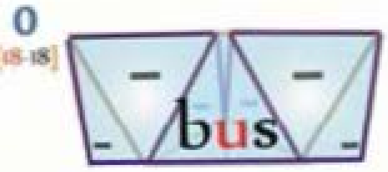

Bottom Xi
(Cascade B)

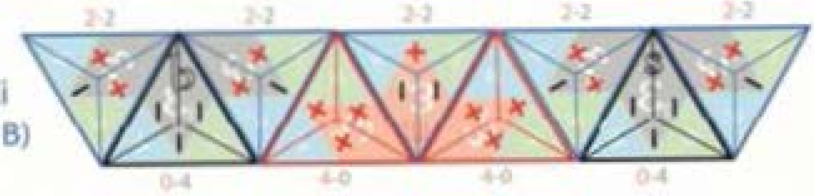
2-2
2-2
2-2
2-2
2-2
0-4
4-0
4-0
0-4

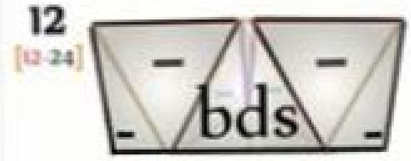

Bottom Xi
(Cascade B)

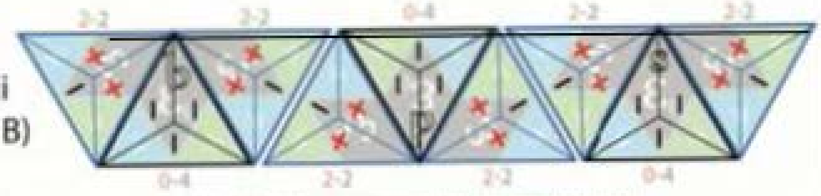
2-2
2-2
0-4
2-2
2-2
0-4
2-2
2-2
0-4

Unstable High energy particle (extremely short lived)

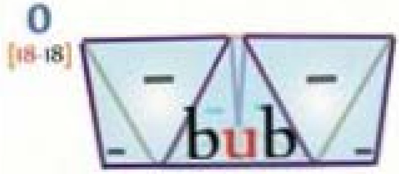

Double
Bottom Xi

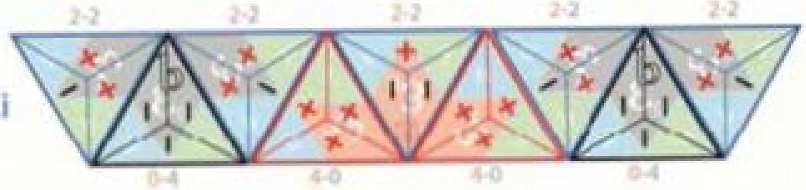
2-2
2-2
2-2
2-2
2-2
0-4
4-0
4-0
0-4

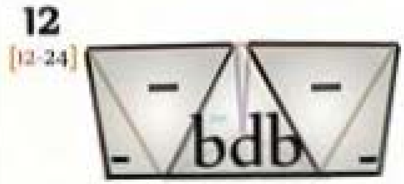

Double
Bottom Xi

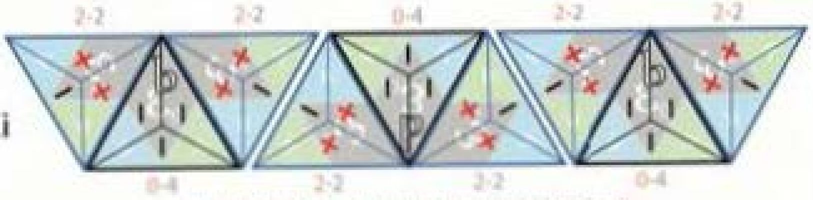
2-2
2-2
0-4
2-2
2-2
0-4
2-2
2-2
0-4

Unstable High energy particle (extremely short lived)

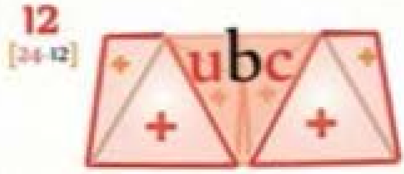

Charmed
Bottom Xi

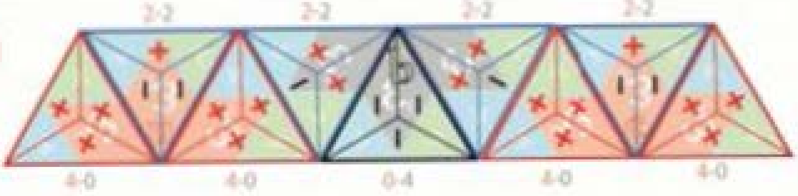
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4-0
0-4
4-0
4-0

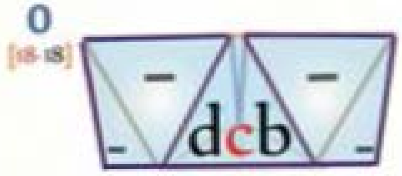

Charmed
Bottom Xi

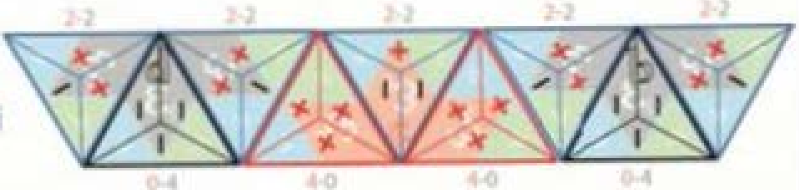
2-2
2-2
2-2
2-2
2-2
0-4
4-0
4-0
0-4

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Baryons

0
[18-18]

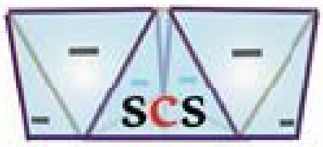

Charmed
Omega

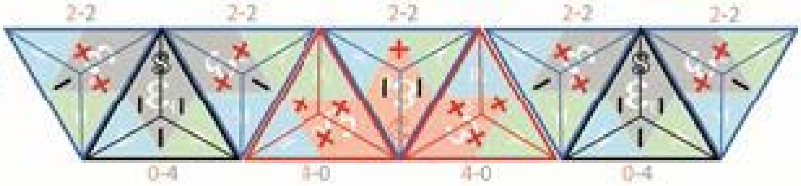
2-2
2-2
2-2
2-2
2-2
0-4
4-0
4-0
0-4

12
[12-24]

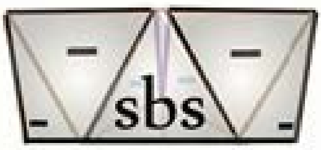

Bottom
Omega

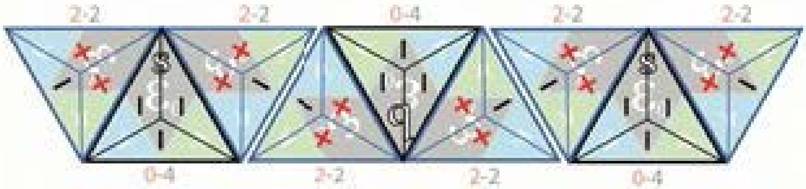
2-2
2-2
0-4
2-2
2-2
0-4
2-2
2-2
0-4

Unstable Highenergy particle (extremely short lived)

12
[24-12]

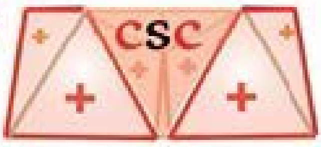

Double
Charmed
Omega

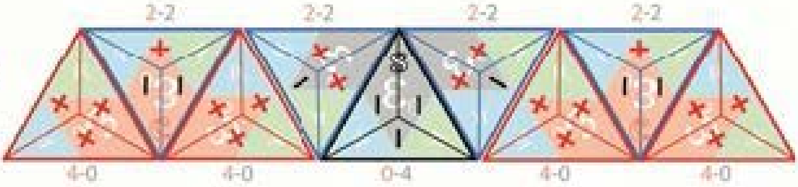
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4-0
4-0
0-4
4-0
4-0

0
[18-18]

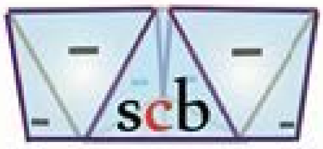

Charmed
Bottom
Omega

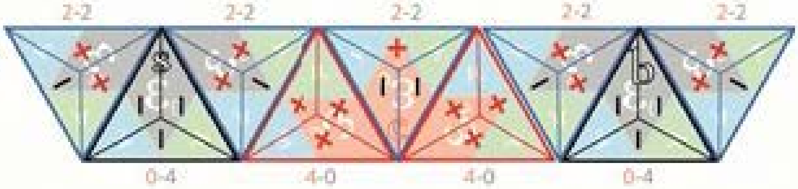
2-2
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2-2
2-2
2-2
0-4
4-0
4-0
0-4

12
[12-24]

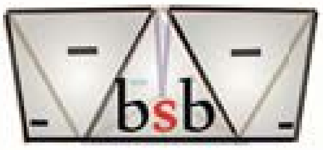

Double
Bottom
Omega

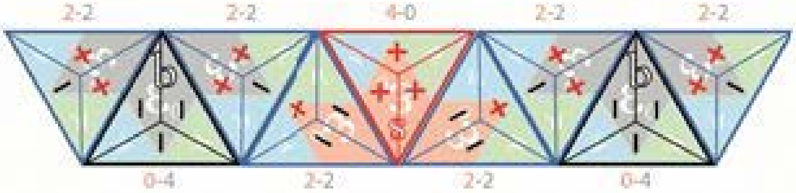
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2-2
4-0
2-2
2-2
0-4
2-2
2-2
0-4

12
[24-12]

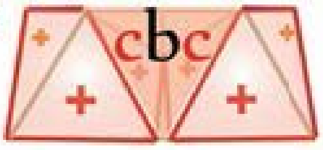

Double
Charmed
Bottom
Omega

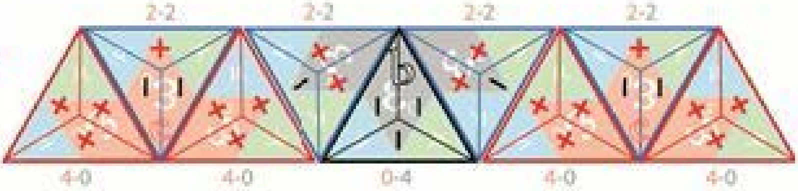
2-2
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2-2
2-2
4-0
4-0
0-4
4-0
4-0

0
[18-18]

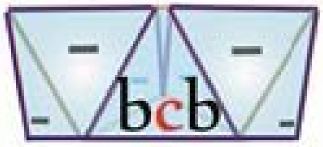

Charmed
Double
Bottom
Omega

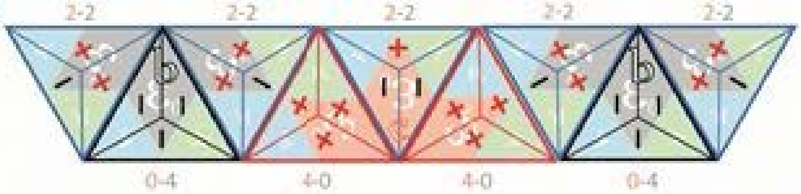
2-2
2-2
2-2
2-2
2-2
0-4
4-0
4-0
0-4

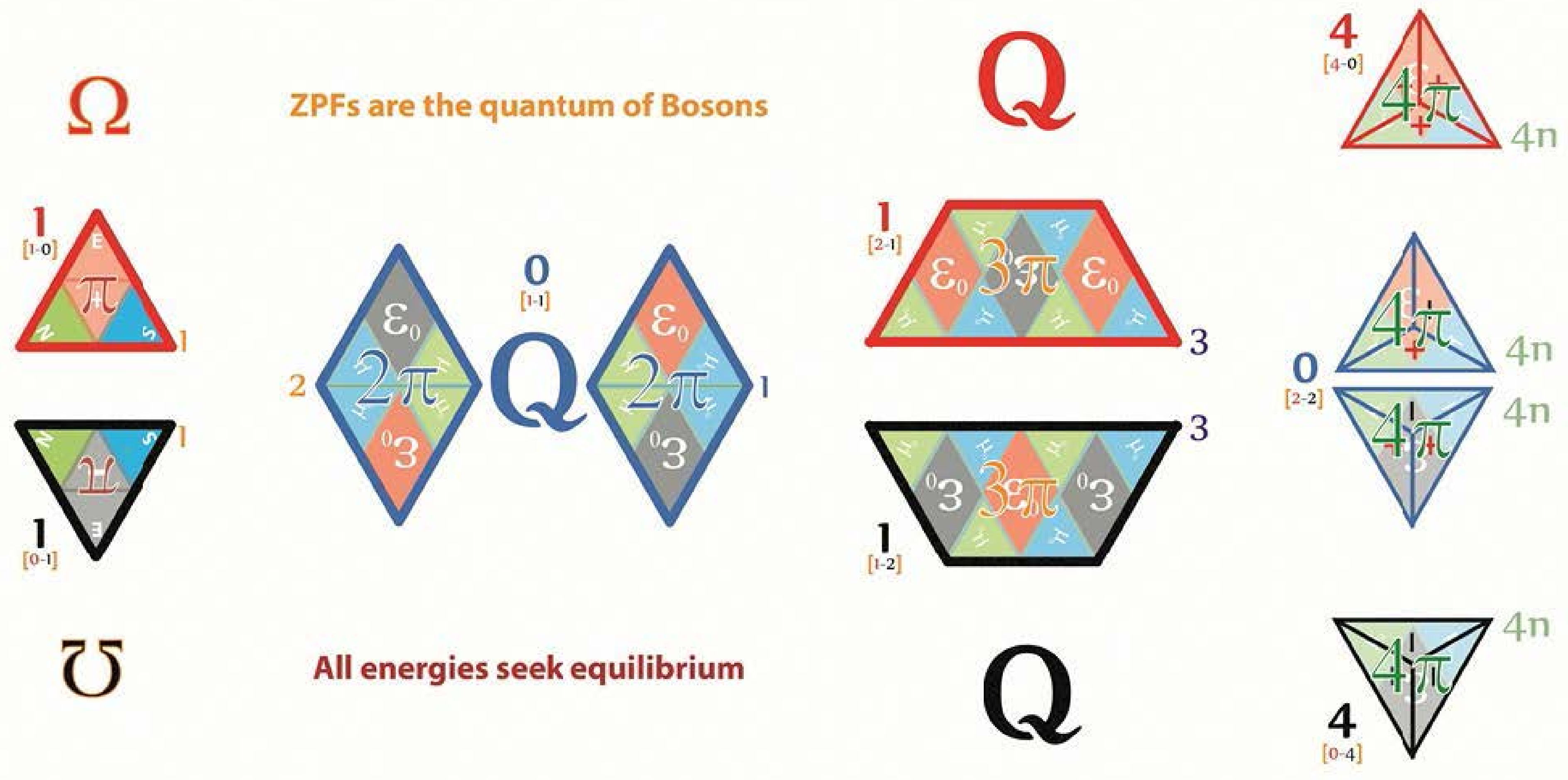

ZPF | **Photons** | **Bosons** | **Tetryons**

$n\pi$ charged mass-Energy-Matter geometries

ZPFs are the quantum of Bosons

All energies seek equilibrium

Ω
1
[1-0]
π
1
1
[0-1]
℧
2
ε0
2π
3
0
[1-1]
Q
ε0
2π
3
1
Q
1
[2-1]
ε0
3π
ε0
3
3
3
3π
3
1
[1-2]
Q
4
[4-0]
4π
4n
0
[2-2]
4π
4n
4π
4n
4π
4n
4
[0-4]

Energy momenta

$n\pi\left[\left[m\Omega v\right]^2\right]$

Energy, Planck quanta, mass, velocity

EM mass-Energies

$\text{EVEN}\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

mass-energy, EM Field, ElectroMagnetic, Planck quanta, mass, velocity

Charges

$\text{ODD}\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Charge, EM Field, ElectroMagnetic, Planck quanta, mass, velocity

Matter

$4n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Matter, EM Field, ElectroMagnetic, Planck quanta, mass, velocity

Tetryonics 11.01 - Charged Energy-Matter geometries

Gluons

The gluon can be considered to be the fundamental exchange particle facilitating the strong interaction between protons and neutrons in a nucleus.

Gluons are the exchange particles for the 'colour' strong force between quarks, analogous to the exchange of photons in the electromagnetic force between two charged particles.

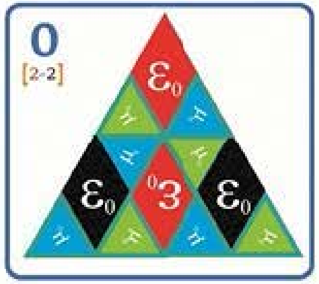
0
[2-2]
ε0
ε0
03
ε0

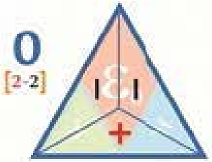

Ω

Gluons are considered to be bi-coloured, carrying a unit of colour and a unit of anti-colour

℧

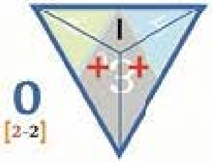

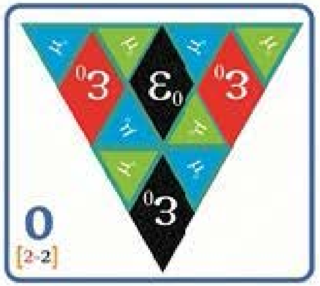
03
ε0
03
03
0
[2-2]

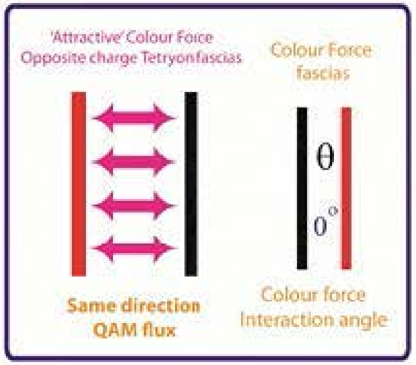
'Attractive' Colour Force
Opposite charge Tetryonfascias
Colour Force fascias
θ
0°
Same direction QAM flux
Colour force Interaction angle

The interaction between neutral Tetryons (Gluons) and all charged Tetryons is the Strong Colour force

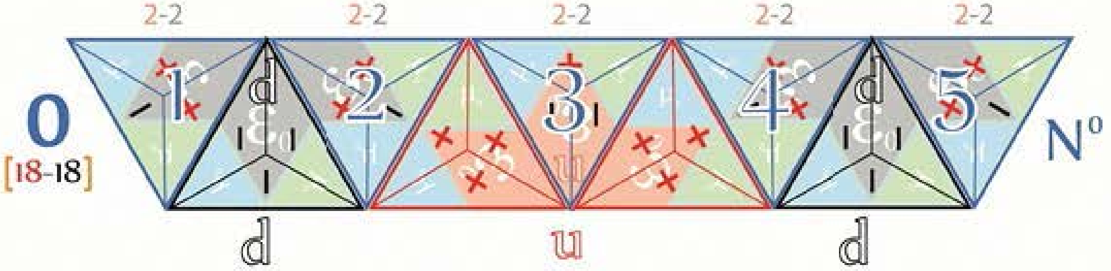
2-2
2-2
2-2
2-2
2-2
0
[18-18]
1
2
3
4
5
N0
d
u
d

Q

Gluons are the neutral Tetryons inside all fermionic Matter topologies

nett charge of Gluons is same as a Neutron

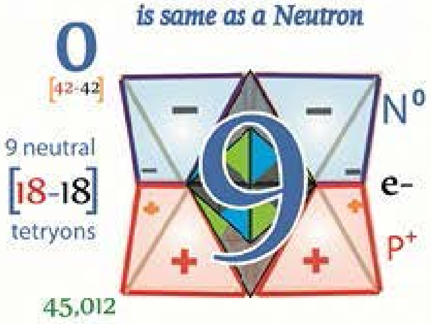
0
[42-42]
9 neutral
[18-18]
tetryons
45,012
9
N0
e-
P+

Electrons contain no Gluons

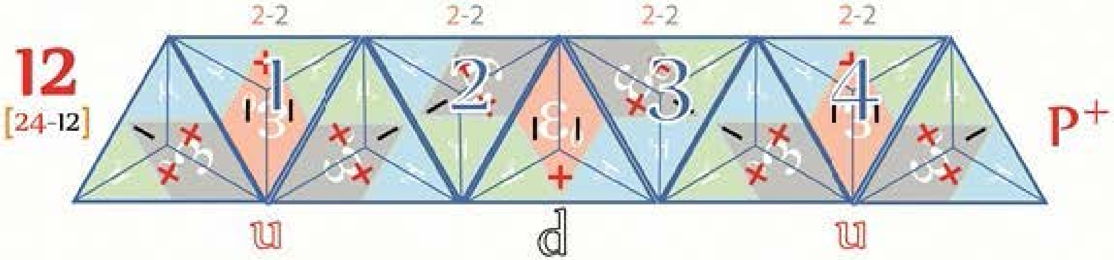
2-2
2-2
2-2
2-2
12
[24-12]
1
2
3
4
P+
u
d
u

They are the neutral charge [di-electric] Tetryons located between charged Tetryons in Matter topologies

[attractive coulombic forces between their opposite charged fascia create the 'colour force]

d d
e- p- u p+
ν^0 u N^0 e+

Neutral Tetryons combine with charged Tetryons to form all Particles

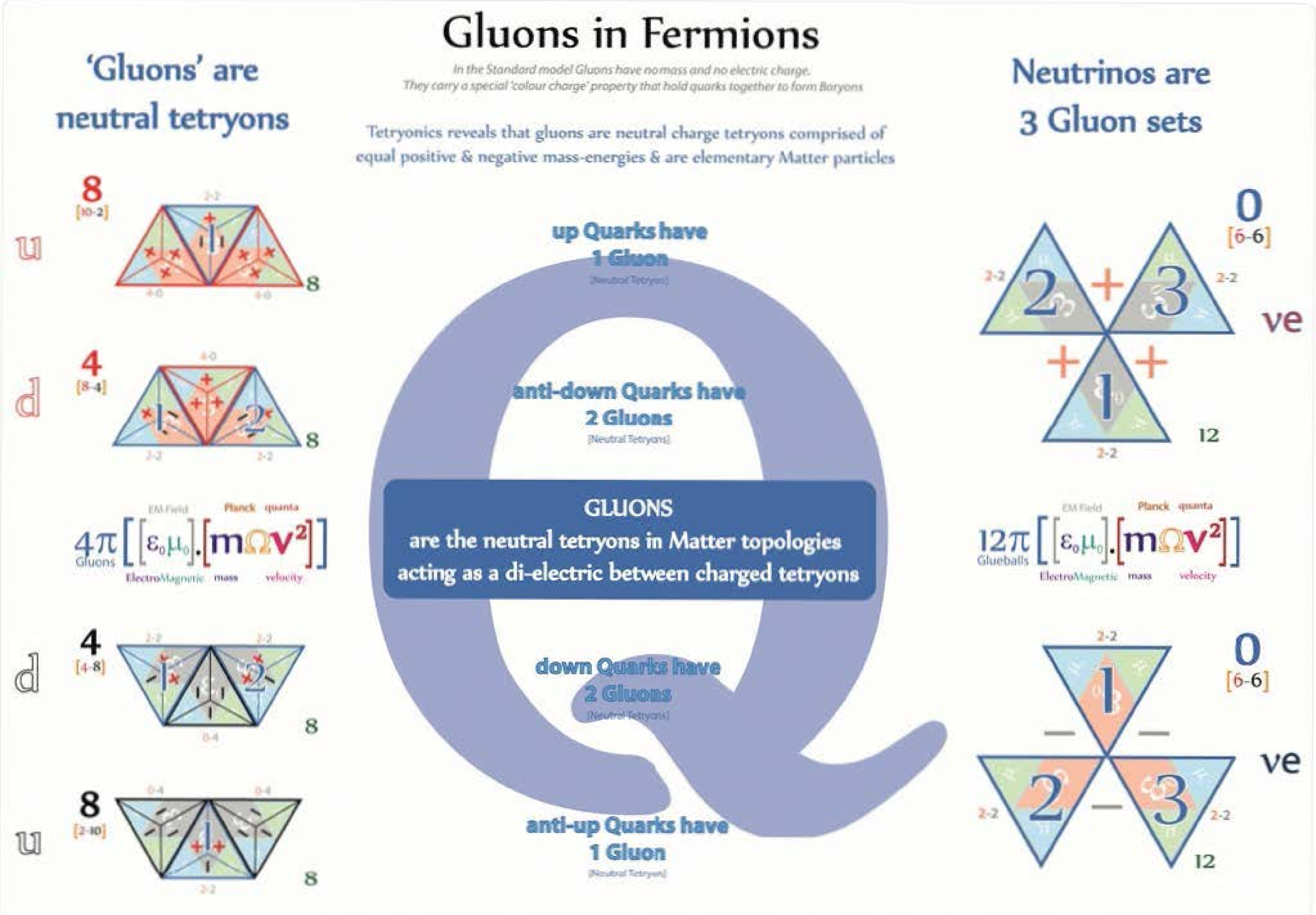

Gluons in Fermions

In the Standard model Gluons have no mass and no electric charge.
They carry a special 'colour charge' property that hold quarks together to form Baryons

Tetryonics reveals that gluons are neutral charge tetryons comprised of equal positive & negative mass-energies & are elementary Matter particles

'Gluons' are neutral tetryons

Neutrinos are 3 Gluon sets

up Quarks have 1 Gluon [Neutral Tetryon]

anti-down Quarks have 2 Gluons [Neutral Tetryons]

GLUONS
are the neutral tetryons in Matter topologies acting as a di-electric between charged tetryons

down Quarks have 2 Gluons [Neutral Tetryons]

anti-up Quarks have 1 Gluon [Neutral Tetryon]

$$4\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Gluons; EM Field; Planck quanta; ElectroMagnetic; mass; velocity

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Glueballs; EM Field; Planck quanta; ElectroMagnetic; mass; velocity

Tetryonics 11.03 - Gluons in Fermions

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Baryonic Gluons

In 'the Standard Model,' Gluons are vector gauge bosons that mediate strong interactions of quarks in quantum chromodynamics (QCD). Unlike the electrically neutral photon of quantum electrodynamics (QED), gluons themselves carry colour charge and therefore participate in the strong interaction in addition to mediating it, making QCD significantly harder to analyze than QED.

They are considered to be elementary particles which act as the exchange particles (or gauge bosons) for the colour force between quarks, analogous to the exchange of photons in the electromagnetic force between two charged particles

Tetryonics simplifies the current definition of Gluons and clearly identifies their geometric properties, along with their role in particle genesis

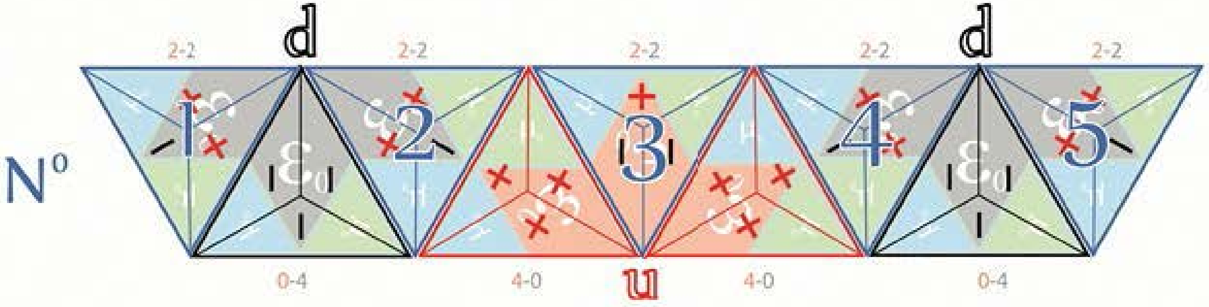

Neutrons have 5 Gluons

[Neutral Tetryons]

0

[18-18]

Deuterium nuclei (being the constituent quanta of all Elements) have 9 neutral Tetryons (Gluons) which in turn contribute to their gravitational mass along with the charged Tetryons

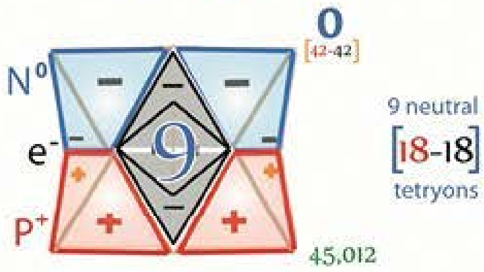

12

[24-12]

Protons have 4 Gluons

[Neutral Tetryons]

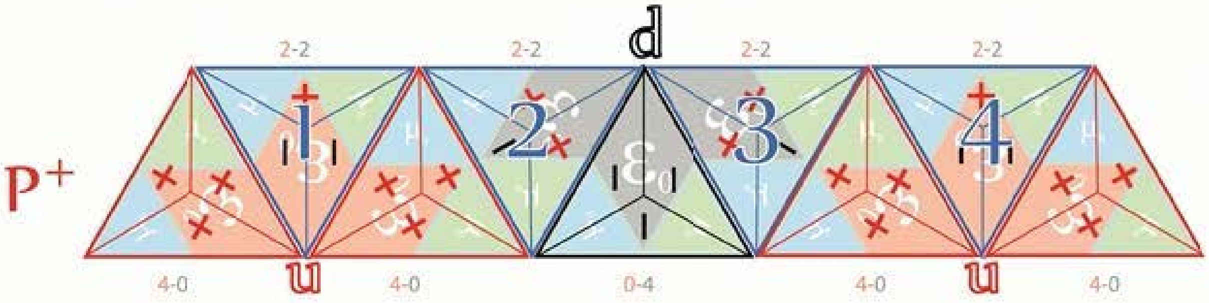

‘Glueballs’

In particle physics, a glueball is a hypothetical composite particle.
It solely consists of gluon particles, without valence quarks.

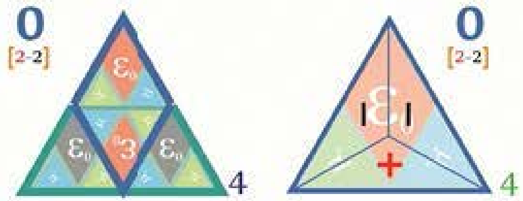

Neutral Tetryons
are the result of equal number
charged EM fields combining to form
neutral charge Tetryonic topologies

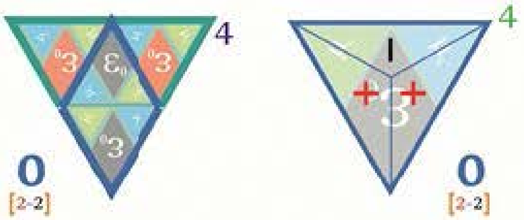

It is conceivable that given the right
conditions (ie a cloud of neutral Tetryons),
that in the absence of charged Tetryons to
interact with, a Glueball topology can be
formed entirely from neutral Tetryons

Note: Despite their total neutral charge
Glueball topologies are polarised

Neutrinos and some exotic neutral charge Baryons
can be considered to be 'Gluon topologies'

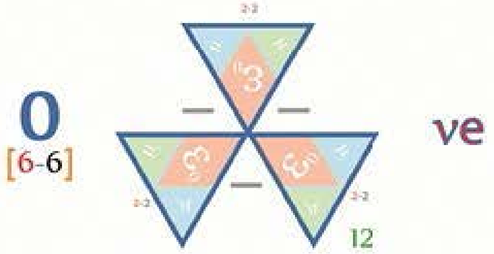

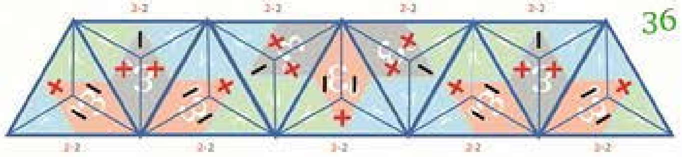

It is possible to create a family
of Baryonic particles comprised
entirely of neutral Tetryons

0
[18-18]

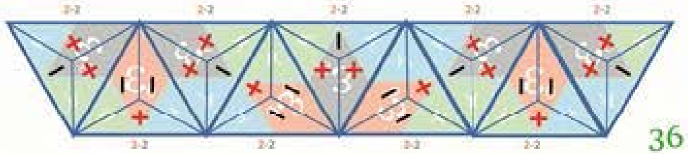

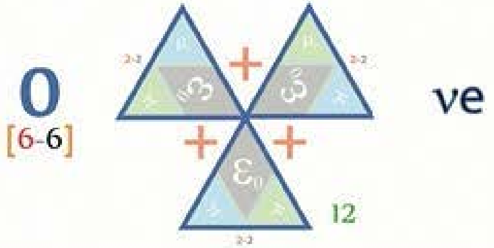

Neutrons are not considered to be Glueballs
as they contain charged Tetryons

OMEGA Particle
Icosahedron Glueball

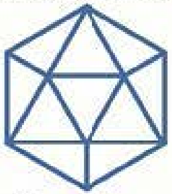

20 Neutral Teryons

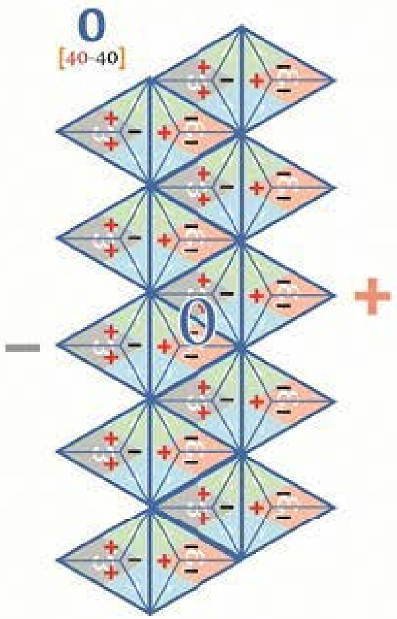

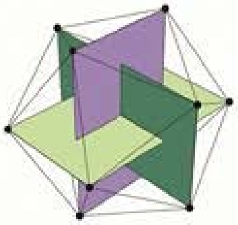

The 3 internalised planes formed by
the external apex points correspond with
the 3 spatial dimensions of Cartesian geometry

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Non-gluonic Baryon formation

Non-neutral 'UP' quark
has +4 charge as opposed
to +8 charge of UP quark

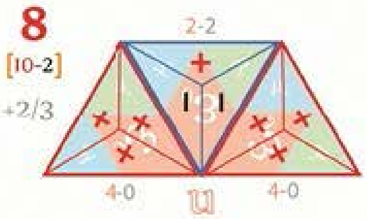
8
[10-2]
+2/3
2-2
4-0
4-0
u

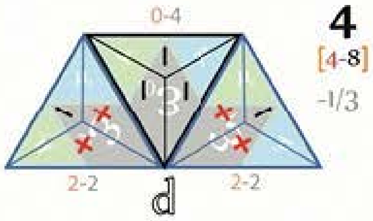
0-4
4
[4-8]
-1/3
2-2
d
2-2

Non-neutral 'DOWN' quark
has +4 charge as opposed
to -4 charge of DOWN quark

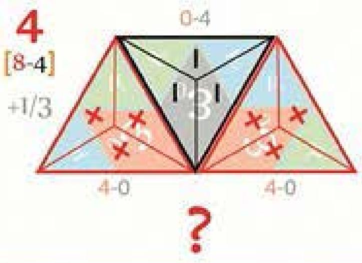
4
[8-4]
+1/3
0-4
4-0
4-0
?

Baryonic Particles can
be formed with non-neutral dielectric Tetryons
in lieu of the usual neutral Tetyrons [Gluons] -
altering the nett charges of the quarks formed

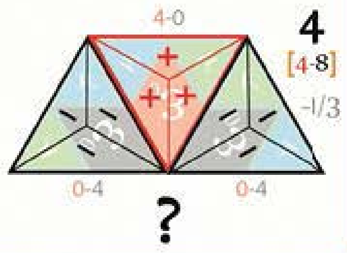
4-0
4
[4-8]
-1/3
0-4
0-4
?

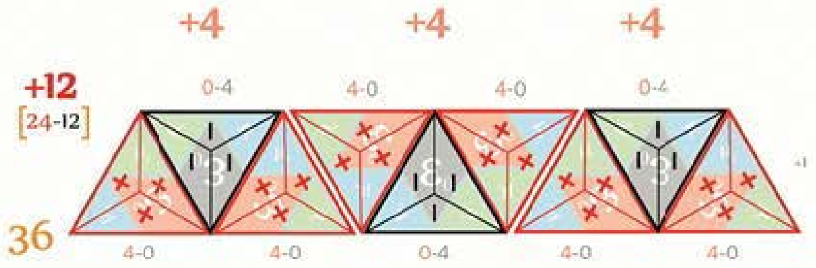
+4
+4
+4
+12
[24-12]
0-4
4-0
4-0
0-4
36
4-0
4-0
0-4
4-0
4-0
+1

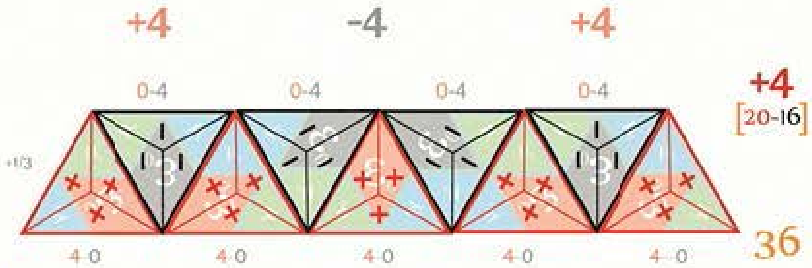
+4
-4
+4
0-4
0-4
0-4
0-4
+4
[20-16]
+1/3
4-0
4-0
4-0
4-0
4-0
36

Un-stable form

[rapidly decays into constituent Quarks]

Resulting in another family of Baryons [CHARGEBALLS]

Stable Form

[possibly mistakenly viewed as Bottom Quarks]

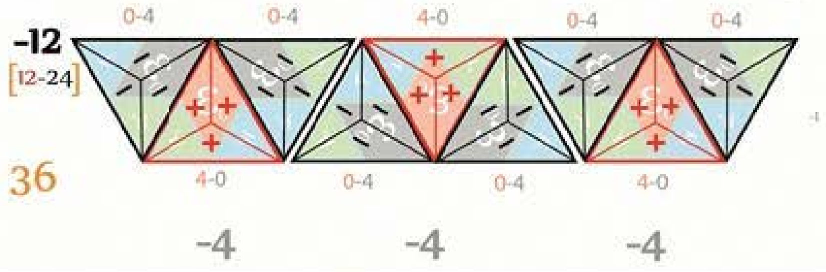
-12
[12-24]
0-4
0-4
4-0
0-4
0-4
36
4-0
0-4
0-4
4-0
-1
-4
-4
-4

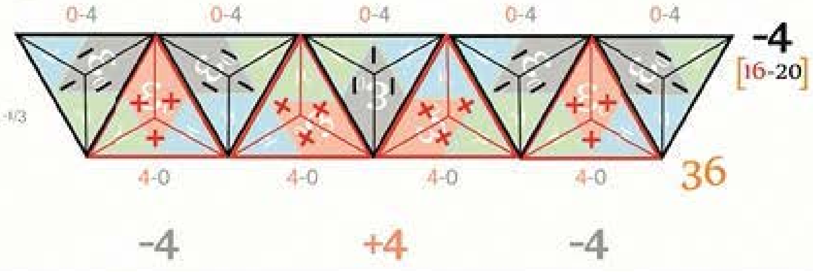
0-4
0-4
0-4
0-4
0-4
-4
[16-20]
-1/3
4-0
4-0
4-0
4-0
36
-4
+4
-4

Electro-Magnetic fields

Quantised Charge
is the nett geometry of mass-Energy-Matter formed
by equilateral ElectroMagnetic fields and can be
modelled with classical vector flux rotations

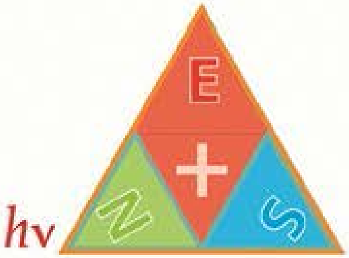

Positive Charge ZPF

Magnetic Monopoles do NOT exist

Negative Charge ZPF

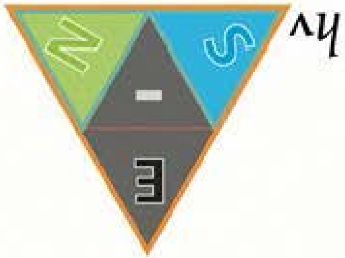

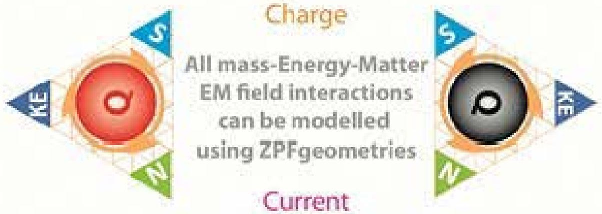

Charge

**All mass-Energy-Matter
EM field interactions
can be modelled
using ZPFgeometries**

Current

ε_0 The charge geometry of all
EM fields determines their
Electric Permittivity and
Magnetic Permeability μ_0

**The 'zero point' field
has scalar EM energies**

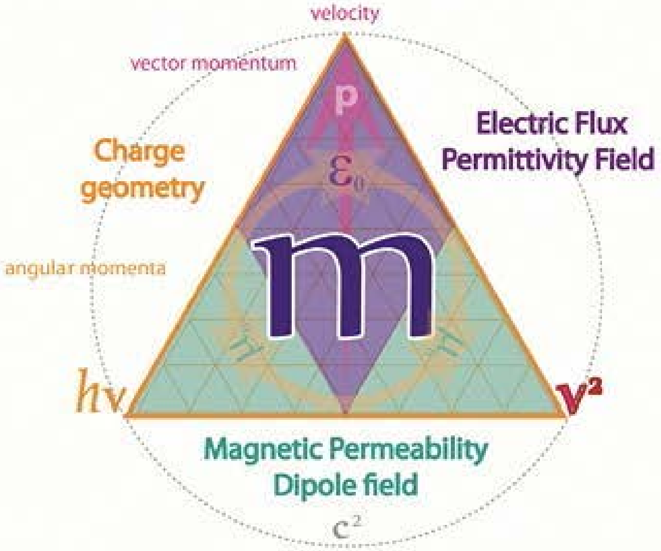

**Electric Flux
Permittivity Field**

**Charge
geometry**

**Magnetic Permeability
Dipole field**

**The EM field is a equilateral waveform with the
Magnetic field always orthogonal to the Electric**

**The Magnetic fields propogate bi-directionally
and the Electric field is responsible for
producing linear momentum**

**The Electric field and Magnetic fields
are equal to each other
and directly proportional
to the velocity of propagation**

Photons
are the neutral quanta of EM waves
they are comprised of two opposite charge
EM field quanta

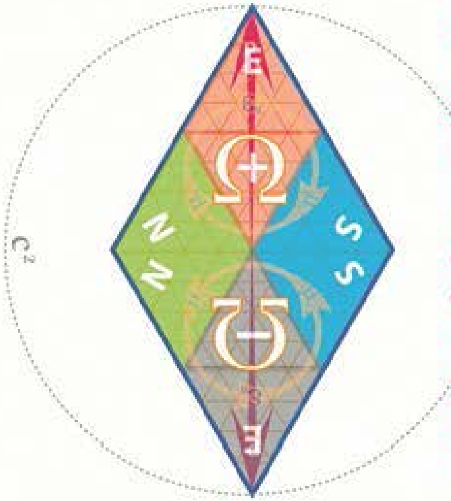

**Electro-Magnetic fields are
the source of all physical Forces**

Zero Point fields are polarised
and are the sources of

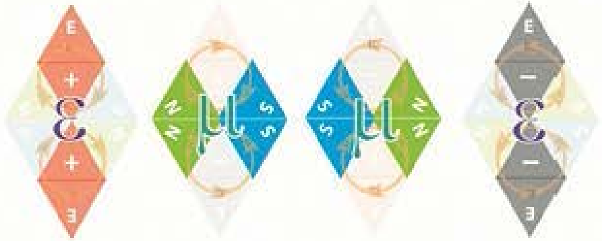

Electro-static and **Magneto-static
fields and particles**

The Weak Force

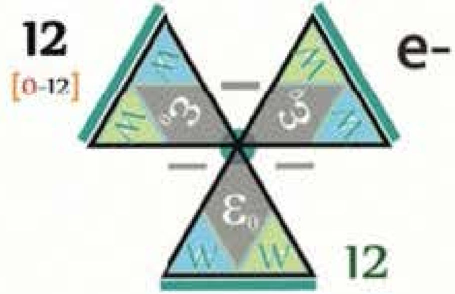
12
[0-12]
e-
12
ε₀
W

6 Inductive 'Weak' edges
(3 internalised)
(3 externalised)

Quantum Energy is stored or released, and
distributed throughout Tetryonic geometries
in ODD number quanta [Bosons]

Quantum Inductive loops

Quantum Tank circuit

Energy received is stored in quantum inductive loops
(until its release via weak interaction - Boson exchange)

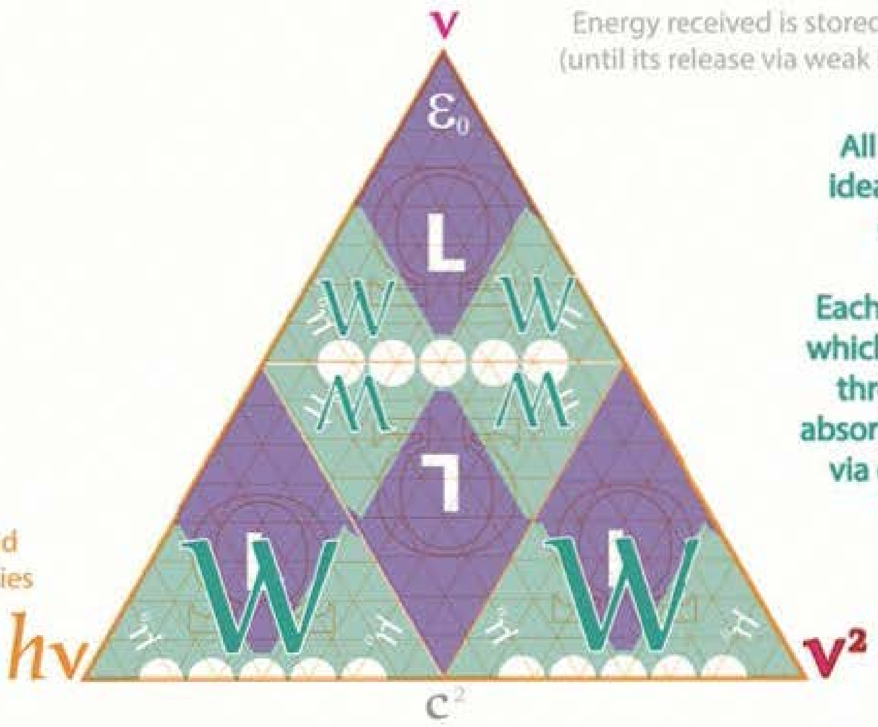
v
ε₀
L
W
W
W
W
W
W
hv
v²
c²

All ElectroMagnetic fields are
ideal quantum inductive loops
of EM energy momenta

Each has a Magnetic edge (base)
which acts as a quantum inductor
through which energy can be
absorbed or released in EM quanta
via electro**Magnetic** induction
[exchange Bosons]

Leptons and Quarks
have the same Tetryonic numbers
but differing Matter topologies

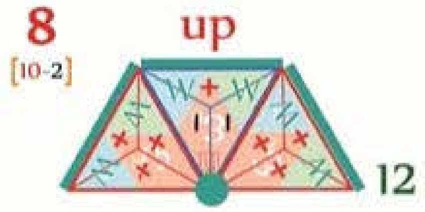

6 Inductive 'Weak' edges

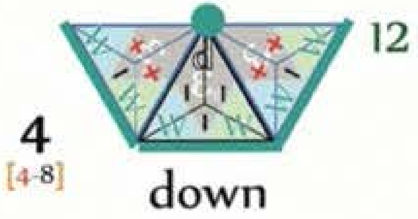

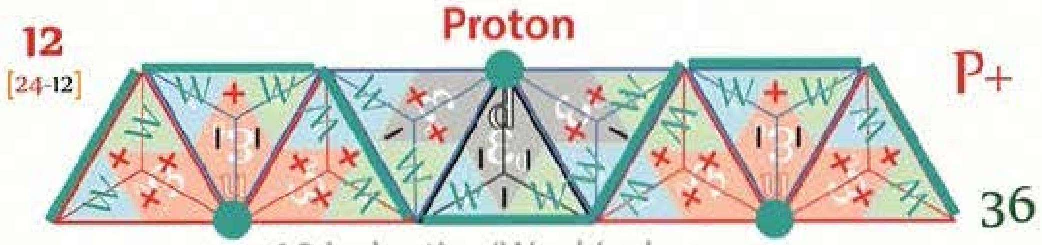
12
[24-12]
Proton
P+
36

18 Inductive 'Weak' edges

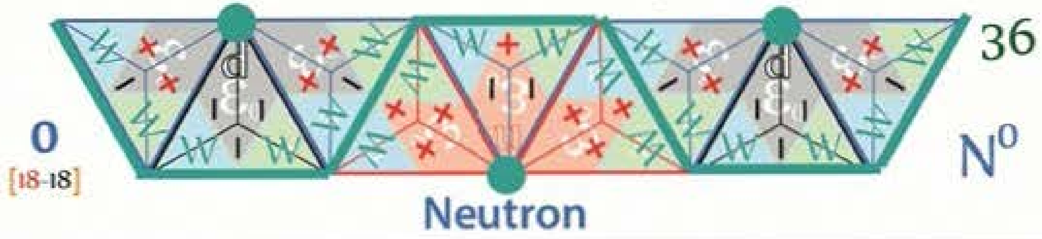
36
0
[18-18]
N⁰
Neutron

The Strong Force

The force resulting from the interaction of 2 Tetryons along their parallel planar (Electric charge) surfaces

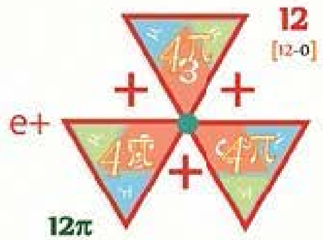
12
[12-0]
e+
+
+
+
4π
4π
4π
12π

Leptons
Repulsive colour Force

Leptons are 'held together' by a radial Weak Force axis

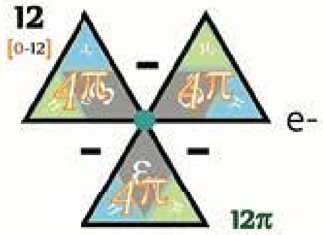
12
[0-12]
e-
-
-
-
4π
4π
4π
12π

Leptons and Quarks result from the Strong 'colour' force interactions in dodeca-deltahedrons

(In Quarks the attractive strong force produces Octahedral topologies)
(In Leptons the repulsive strong force produces Dodecahedral topologies)

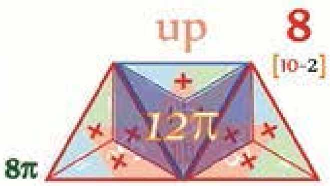
up
8
[10-2]
12π
8π

Quarks
4 Fascia 'Colour' Attraction

Quarks
Attractive colour Force

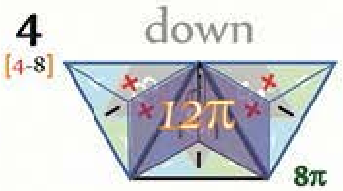
4
[4-8]
down
12π
8π

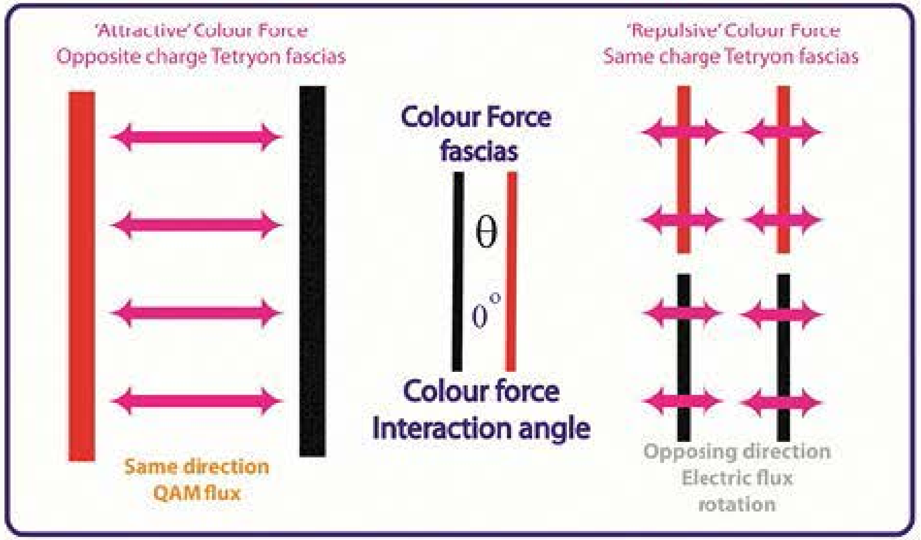
'Attractive' Colour Force
Opposite charge Tetryon fascias
'Repulsive' Colour Force
Same charge Tetryon fascias
Colour Force fascias
θ
0°
Colour force Interaction angle
Same direction QAM flux
Opposing direction Electric flux rotation

Strong Force strength is directly proportional to the nett mass-energy quanta involved
(Increases/decreases as total Tetryon mass-energy quanta increases/decreases)

Proton

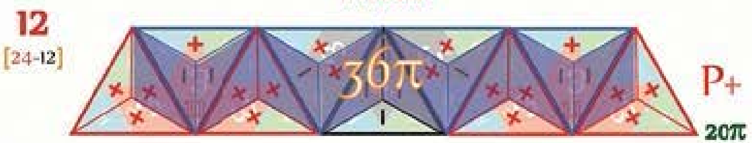
12
[24-12]
36π
P+
20π

Baryons
Attractive colour Forces

Baryon formation
16 Fascia 'Colour' Attraction

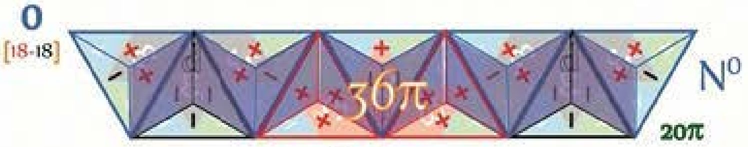
0
[18-18]
36π
N0
20π

Neutron

The Strong Colour Force is the binding force that holds Nuclei together

Tetryonic Fascia (Planar Electric Charge) interaction

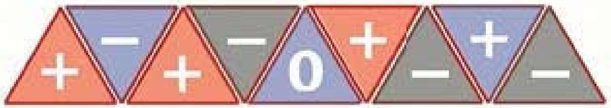

It interacts through oppositely charged Tetryon Fascias in contact with each other in all Matter (save Leptons)

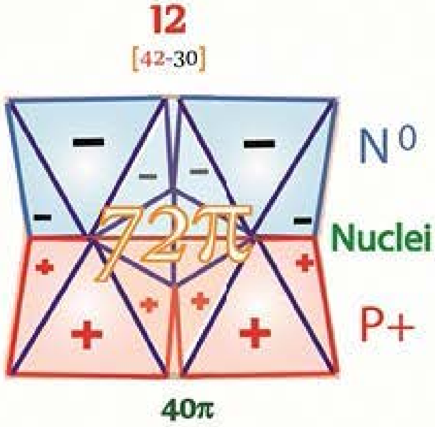
12
[42-30]
72π
N0
Nuclei
P+
40π

Strong Force Interaction

On the smallest scale (less than about 0.8 fm), it is the Electric force (mediated by gluons in nuclei) that holds Tetryons together in order to form Quarks, Protons and Neutrons

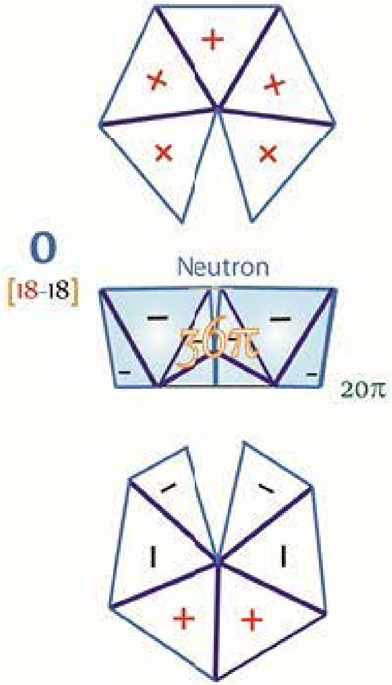
0
[18-18]
Neutron
36π
20π

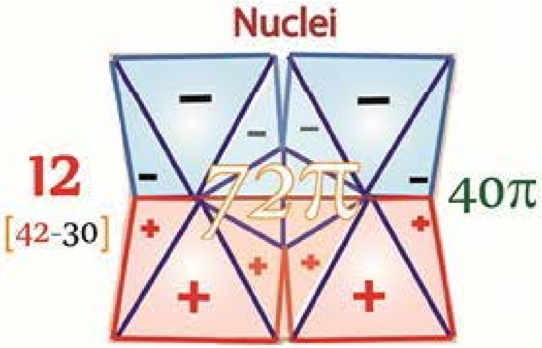
Nuclei
12
[42-30]
72π
40π

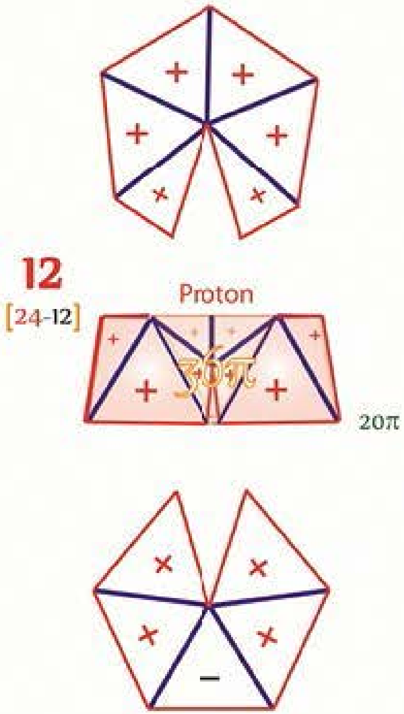
12
[24-12]
Proton
36π
20π

The residual Electric field force produced by the Strong Force is also facilitates the binding of Protons and Neutrons together to form the nucleus of an atom

Attractive Colour Charge Force holding Quarks and Nuclei together

Atomic Nucleus

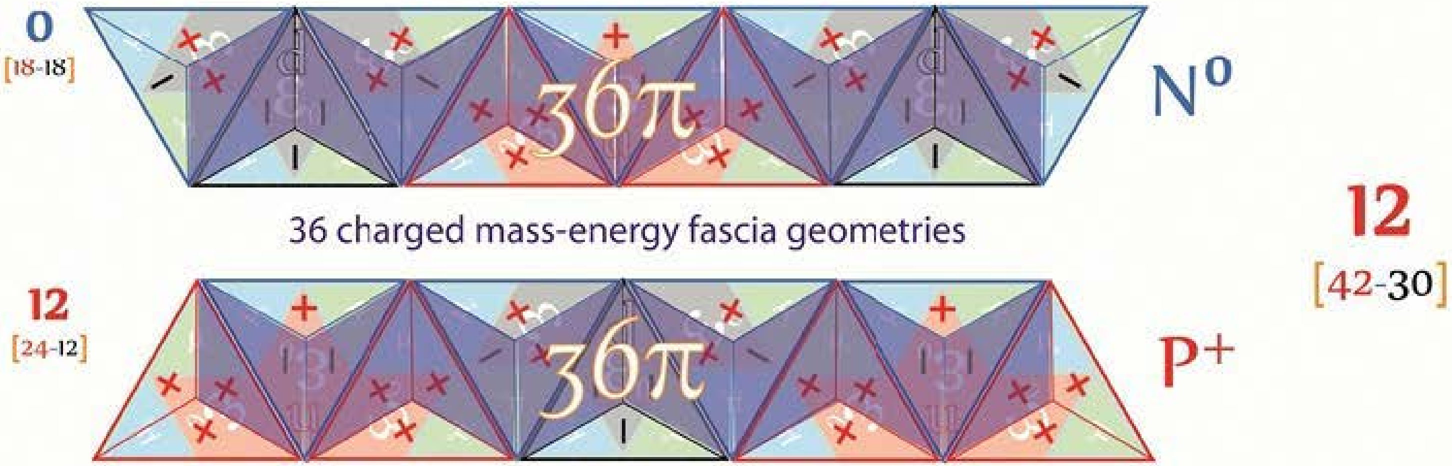
0
[18-18]
36π
N⁰
12
[24-12]
36π
P+
12
[42-30]

36 charged mass-energy fascia geometries

creates an external Baryons topology with 20 charge fascia

Proton Hydrogen ion

36

1 Proton	24-12
Total Charge	24-12 [+12]

H^+

F+ n=25

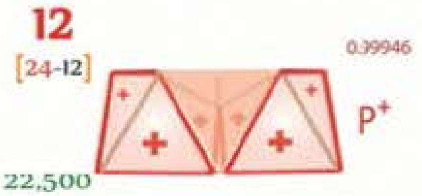

Proton - Hydrogen ion

The Proton is a Baryon with a Positive Tetryonic charge geometry of +12 [24-12] [and a final Matter topology of 20π]

It attracts electrons [0-12] and Neutrons [13-18] through their opposite charged facia in order to reach charge equilibrium

The Proton's opposite charge particle is the electron
If it binds with one or more Neutrons it will still attract electrons in order to acheive Tetryonic charge equilibrium.

As a Hydrogen nuclei it is highly reactive

Neutral Hydrogen

48

1 Proton	24-12
1 electron	0-12
Total Charge	24-24 [0]

H^0

F+ n=25
e- n=1

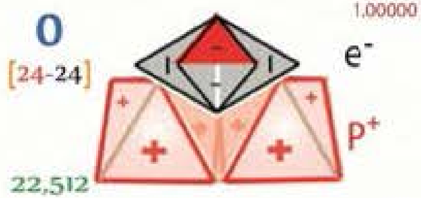

Neutral Hydrogen

Hydrogen is the Second Neutral Tetryonic geometry [Baryon] formed in the creation of Matter

It is a [24-24] NEUTRAL [balanced] Tetryonic charge geometry

The Neutral Hydrogen Atom interacts with Deuterium and other Elements via its external nucleon fascia charges (residual EM Interactions)

Deuterium

84

1 Proton	24-12
1 Neutron	18-18
1 electron	0-12
Total Charge	42-42 [0]

D 1

N° n=25
F+ n=25
e- n=1

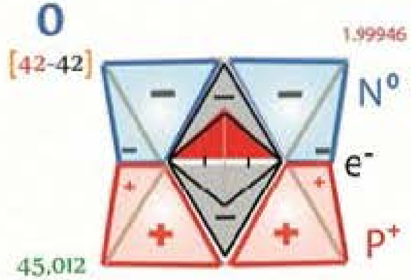

Deuterium

Deuterium has the same nett charge as Neutral Hydrogen but has an increased Tetryonic mass- Matter topology

It has an additional 9 Tetryons in its nucleus (due to the Neutron) and consequently is larger than the Hydrojon nucleus

It has a [42-42] NEUTRAL Tetryonic charge geometry
Deuterium nuclei combine to form all other elements

Tritium

84

1 Proton	24-12
1 Neutron	18-18
1 electron	0-12
Total Charge	42-42 [0]

D 7

N° n=31
F+ n=31
e- n=7
Radioactive Isotope

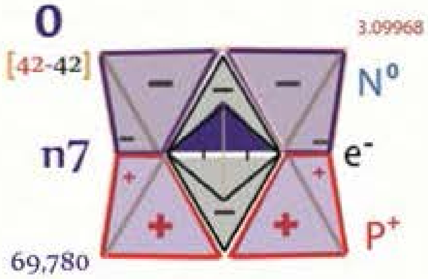

Tritium

(Radioactive Deuterium)

Tritium has the same nett Tetryonic charge as Neutral Hydrogen and Deuterium (D) but due to its higher quantum energy levels it has additional mass-energy quanta in its charged geometry

It has the same 84 charged fascia in its nucleus as Deuterium but its increased mass-energy is equivalent to that of 1 Neutron.

This extra nuclear energy is the source of its radioactivity and ongoing confusion in chemistry where it is released as a variety of decay particles over time

Hydrogen - Helium genesis

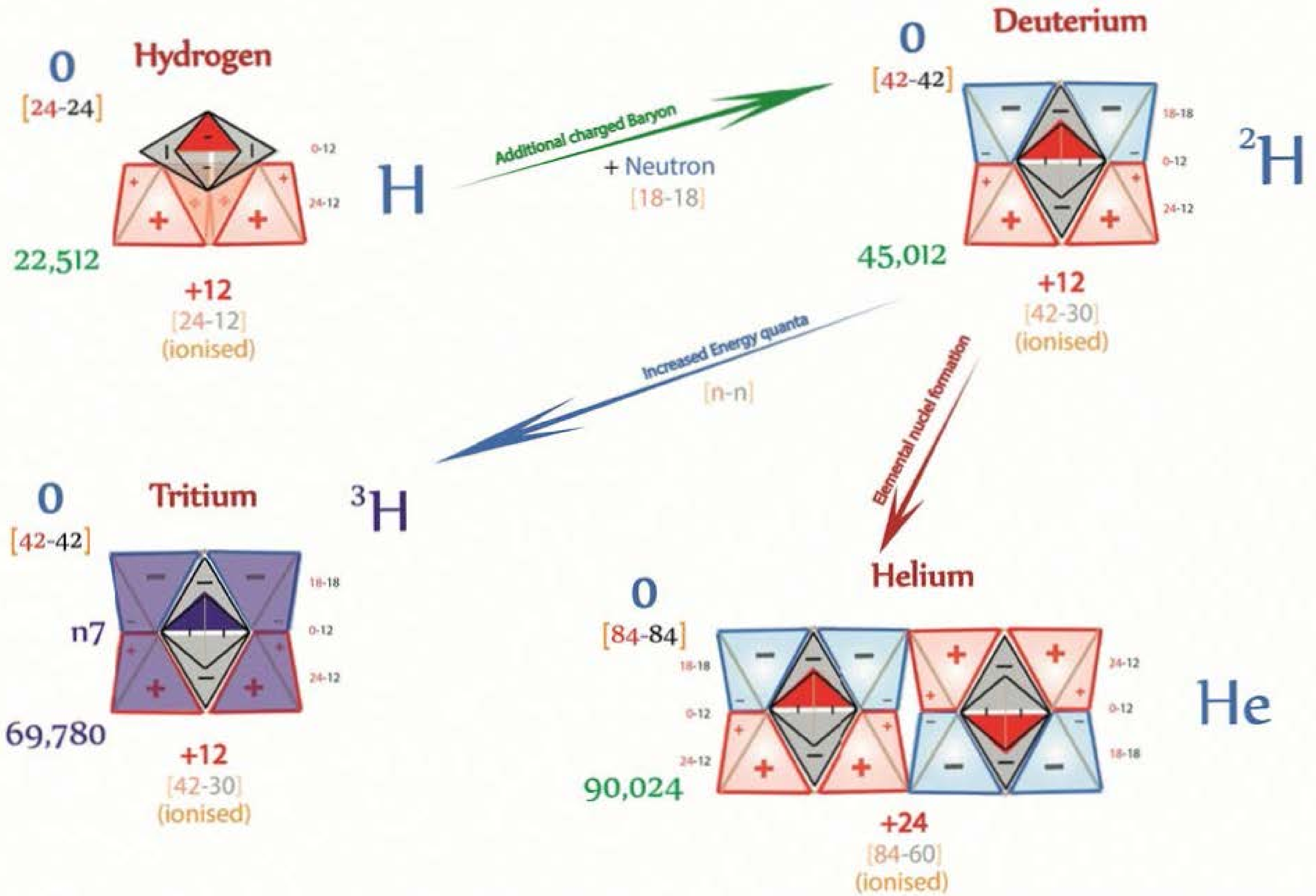
0
Hydrogen
[24-24]
0-12
24-12
H
22,512
+12
[24-12]
(ionised)
Additional charged Baryon
+ Neutron
[18-18]
0
Deuterium
[42-42]
18-18
0-12
24-12
^{2}H
45,012
+12
[42-30]
(ionised)
Increased Energy quanta
[n-n]
Elemental nuclei formation
0
Tritium
^{3}H
[42-42]
18-18
n7
0-12
24-12
69,780
+12
[42-30]
(ionised)
0
Helium
[84-84]
18-18
0-12
24-12
24-12
0-12
18-18
He
90,024
+24
[84-60]
(ionised)

Tetryonics 13.02 - Hydrogen-Helium genesis

Hydrogen Family

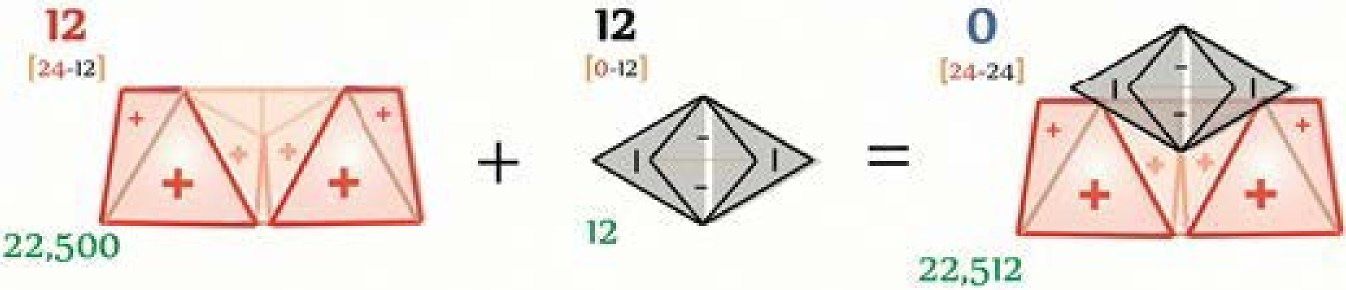
12
[24-12]
22,500
+
12
[0-12]
12
=
0
[24-24]
22,512

Proton	electron	Hydrogen
36π	12π	48π

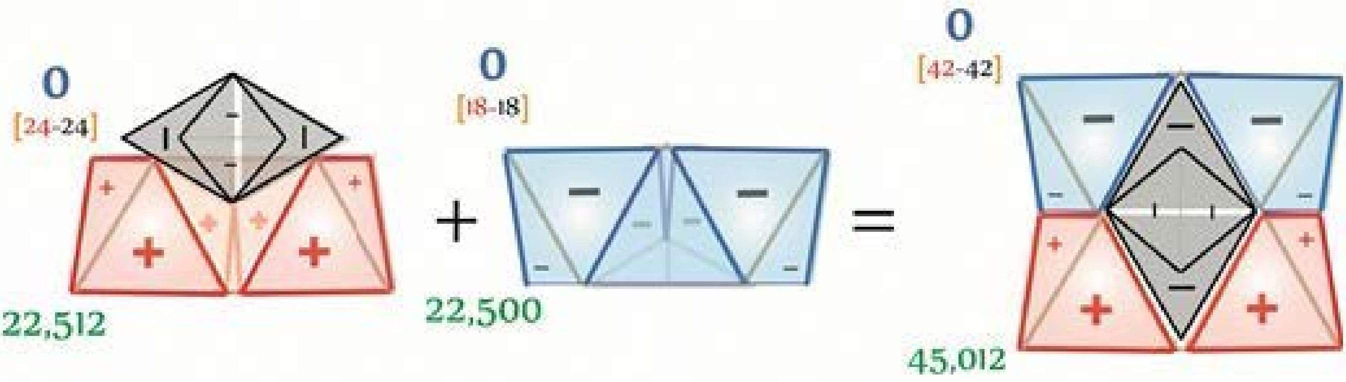
0
[24-24]
22,512
+
0
[18-18]
22,500
=
0
[42-42]
45,012

Hydrogen	Neutron	Deuterium
48π	36π	84π

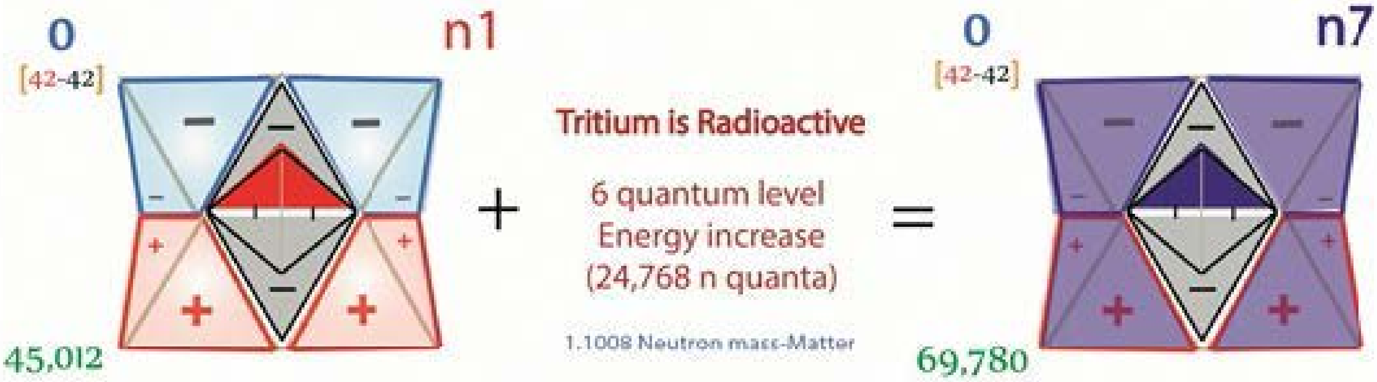
0
[42-42]
n1
45,012
+
=
0
[42-42]
n7
69,780

Tritium is Radioactive

6 quantum level
Energy increase
(24,768 n quanta)

1.1008 Neutron mass-Matter

Deuterium	Tritium
84π	84π

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Hydrogen-Helium3 genesis

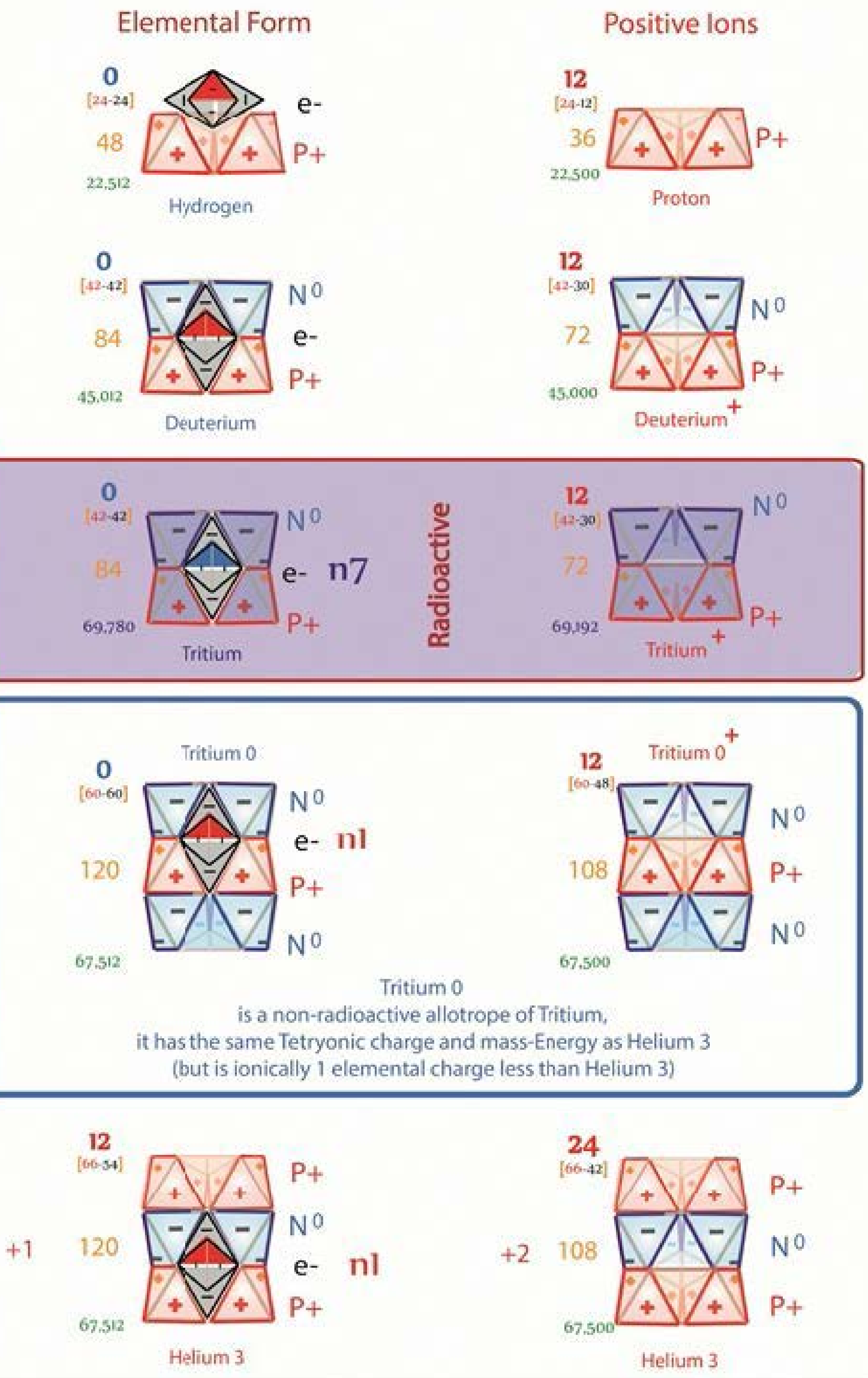
Elemental Form
Positive Ions
0
[24-24]
48
22,512
e-
P+
Hydrogen
12
[24-12]
36
22,500
P+
Proton
0
[42-42]
84
45,012
N0
e-
P+
Deuterium
12
[42-30]
72
45,000
N0
P+
Deuterium+
0
[42-42]
84
69,780
N0
e-
n7
P+
Tritium
Radioactive
12
[42-30]
72
69,192
N0
P+
Tritium+
Tritium 0
0
[60-60]
120
67,512
N0
e-
n1
P+
N0
Tritium 0+
12
[60-48]
108
67,500
N0
P+
N0
12
[66-54]
+1
120
67,512
P+
N0
e-
n1
P+
Helium 3
24
[66-42]
+2
108
67,500
P+
N0
P+
Helium 3

Tritium 0
is a non-radioactive allotrope of Tritium,
it has the same Tetryonic charge and mass-Energy as Helium 3
(but is ionically 1 elemental charge less than Helium 3)

Quantum Batteries

Atomic nuclei can be easily scaled to non-quantum sizes to offer clean, safe and portable long term energy storage devices that can store energy indefinitely and release it on demand anywhere in the World

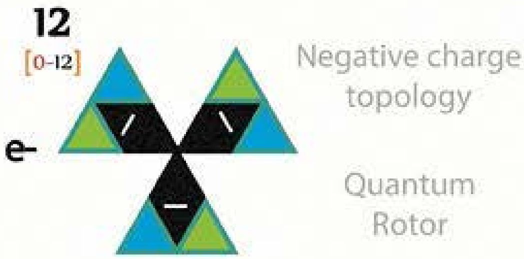
12
[0-12]
e-
Negative charge topology
Quantum Rotor

12 loop quantum inductive rotor

The quantum battery is unique in that in addition to storing energy indefinitely, when the nuclei combine with a lepton it has the ability to release specific energies [photons] by way of its synchronous quantum convertor topology

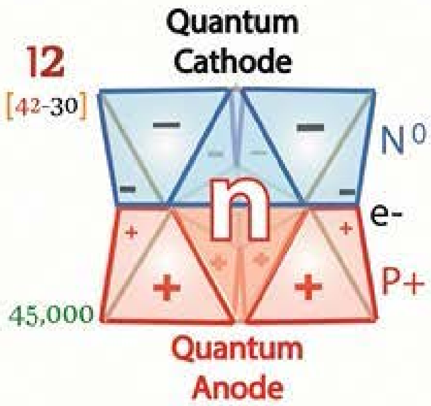
12
[42-30]
Quantum Cathode
N0
n
e-
P+
45,000
Quantum Anode

Energy stored in quantum batteries is measured as mass

(Atomic Nuclei)

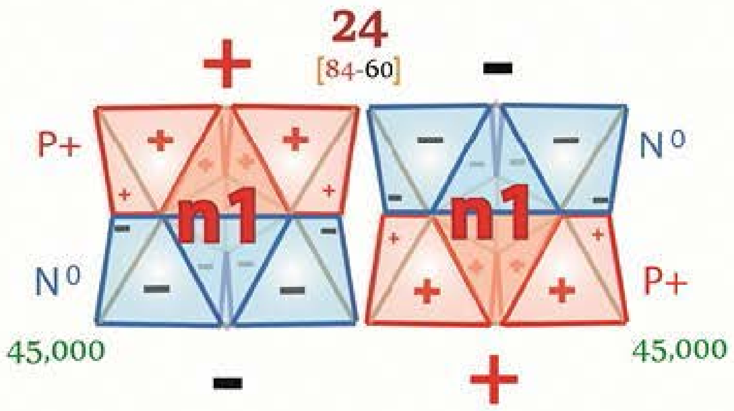
24
[84-60]
+
-
P+
N0
n1
n1
N0
P+
45,000
45,000
-
+

anti-Parallel Configuration

+E90
03-2013
Energizer

The non-neutral charge of atomic nuclei attract free leptons into 'bound' states within the various **n** levels of atomic shells releasing energy as spectral photons

Series Configuration

+E90
03-2013
Energizer

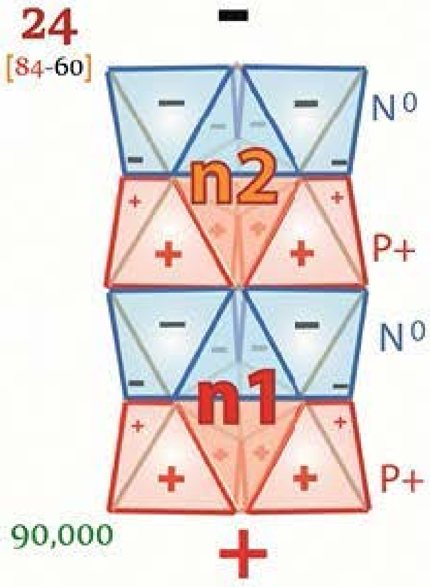
24
[84-60]
-
N0
n2
P+
N0
n1
P+
90,000
+

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Quantum synchronous Converters

With the addition of a quantum rotor (lepton) a quantum battery can be converted from a storage device into a energy distribution device.

And just like the quantum battery, the quantum convertor can be scaled to any size in order to provide tailor-made energy efficient delivery devices

The electron can be viewed as a rotating inductor consisting of 3 negative Tetryons

EM Field Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]^{n8}_{n1}$$

Leptons ElectroMagnetic mass velocity

The electron has a charged Matter topology that is electrically equivalent to a quantum 6 loop inductive rotor

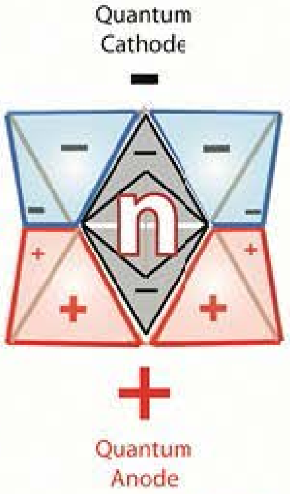

EM Field Planck quanta

$$72\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]^{n32}_{n25}$$

Nuclei ElectroMagnetic mass velocity

EM Field Planck quanta

$$84\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]^{n32}_{n25}$$

Deuterons ElectroMagnetic mass velocity

Where varying levels and frequencies of Energy are transmitted long distances and need to be stored for later release on demand the 'ideal' mechanical device is the rotating (or synchronous) convertor

Changes in energy-momenta results in photon emission/absorption lines photon emission/absorption produces changes in leptronic energy-QAM and results in the quantum transition of electrons in atomic orbitals

Changes in Baryonic energy levels induces a directly proportional change in electron energy levels

3 forms of mass-energy momenta are possessed by quantum convertors

Angular Momentum (motional energy)
linear momentum of Baryons & leptons

Photonic spectral energies (emission/absorption)
KEM fields geometries of photo-electrons

Nuclear mass-energies (stored energy quanta)
standing wave mass-energies of Matter topologies

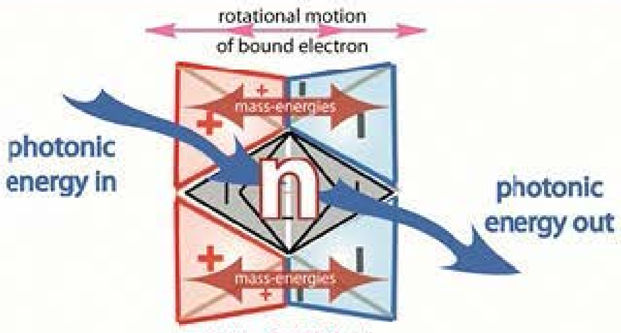

QAM of KEM field creates angular momentum

A change in any 1 of the 3 types of energy in a atom results in a proportional change in the other 2

External EM fields and incident photons can all affect the quantum energy levels of the atomic nuclei

$$Mv^2 = KEM = hv^2$$

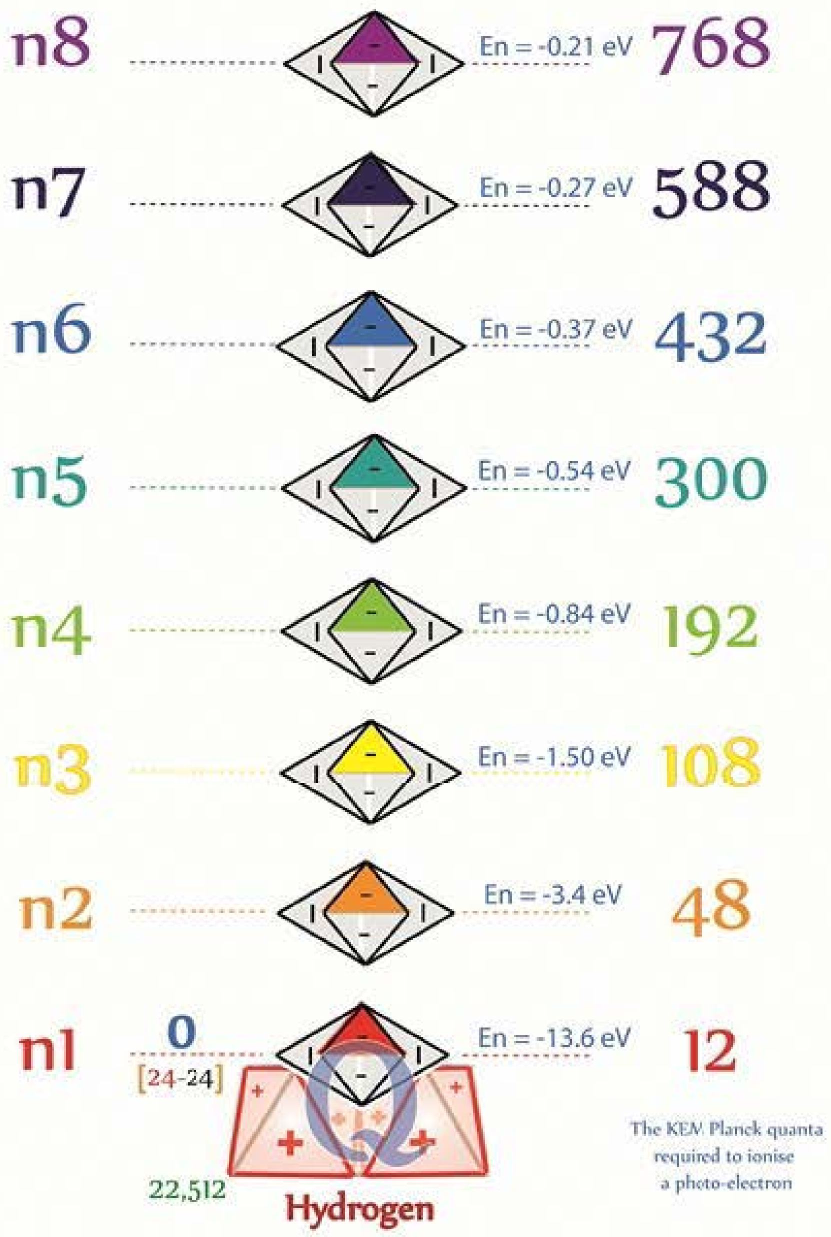
n8
En = -0.21 eV
768
n7
En = -0.27 eV
588
n6
En = -0.37 eV
432
n5
En = -0.54 eV
300
n4
En = -0.84 eV
192
n3
En = -1.50 eV
108
n2
En = -3.4 eV
48
n1
0
[24-24]
En = -13.6 eV
12
22,512
Hydrogen

The KEM Planck quanta required to ionise a photo-electron

Hydrogen Ionisation Energies

The ionisation energy level for each quantum level is proportional to the square of the quantum number

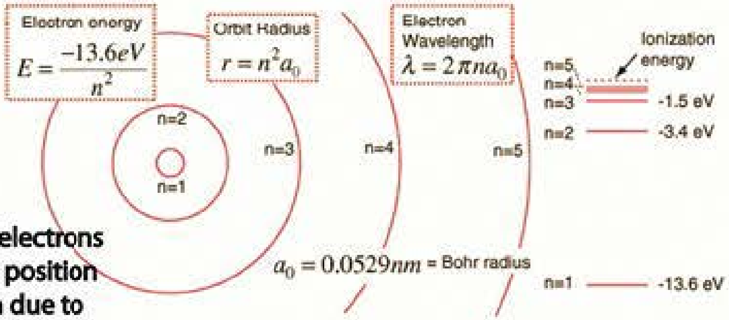
Electron energy
$E = \frac{-13.6eV}{n^2}$
Orbit Radius
$r = n^2 a_0$
Electron Wavelength
$\lambda = 2\pi n a_0$
Ionization energy
n=1
n=2
n=3
n=4
n=5
n=5
n=4
n=3
n=2
n=1
-1.5 eV
-3.4 eV
-13.6 eV
$a_0 = 0.0529nm$ = Bohr radius

In Hydrogen nuclei electrons remain in the same position close to the Proton due to Coulombic attraction.

The established model of electron orbitals having circular radii of increasing size in proportion to their energies is incorrect

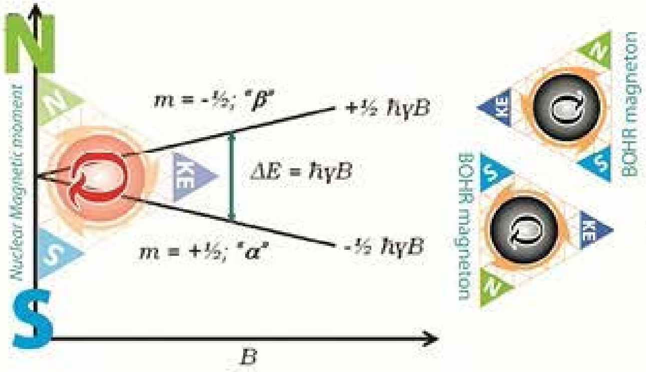
N
S
Nuclear Magnetic moment
$m = -½; "\beta"$
$+½ \hbar\gamma B$
$\Delta E = \hbar\gamma B$
$m = +½; "\alpha"$
$-½ \hbar\gamma B$
B
KE
BOHR magneton
BOHR magneton

Spin UP
Parallel magnetic moments
(higher energy)

Spin DOWN
Anti-parallel magnetic moments
(lower energy)

The intrinsic magnetic moment of the rotating electron couples wrt the nuclear magnetic moment to produce a split in the resulting spectral lines produced by quantum level transitions

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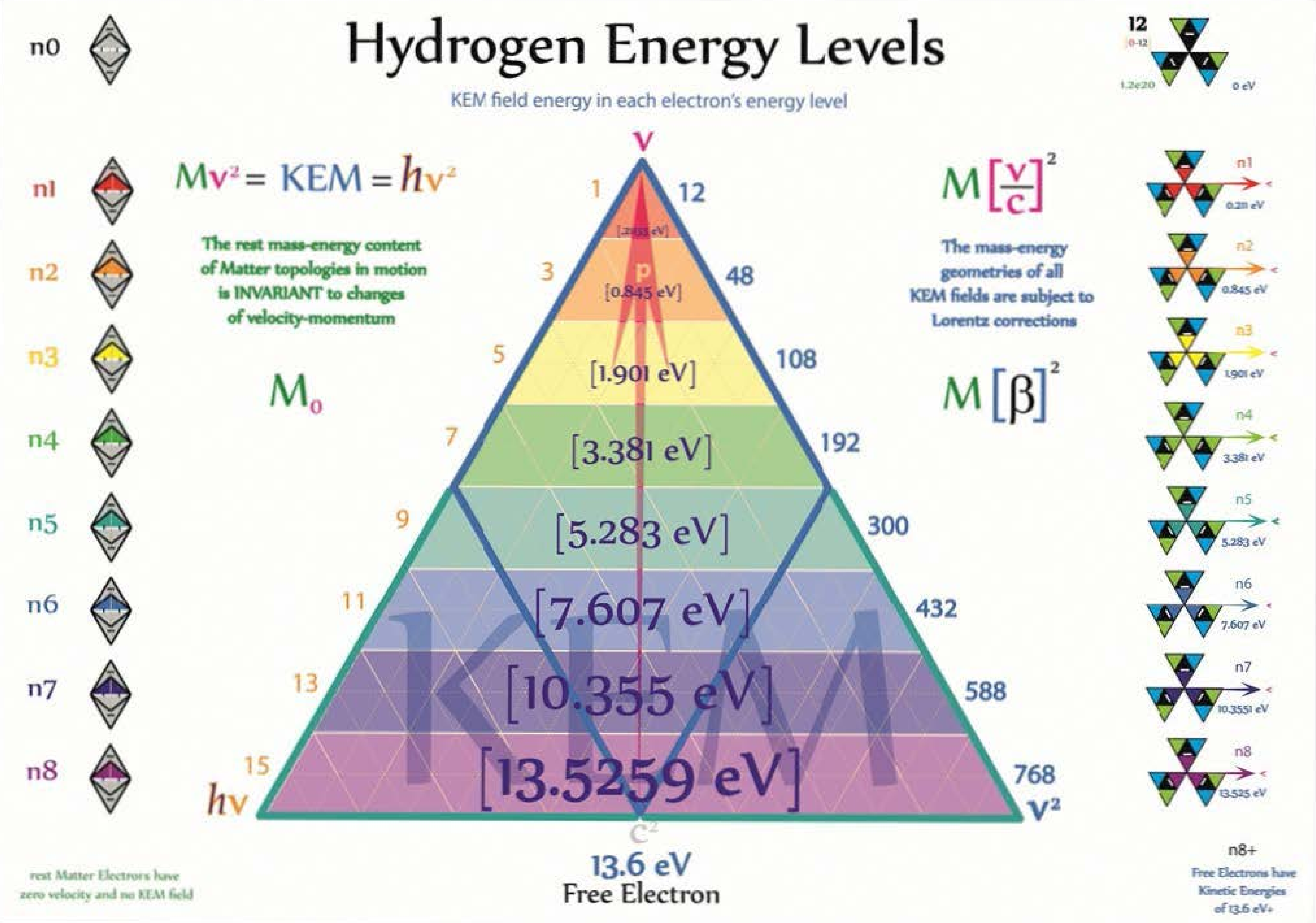

Hydrogen Energy Levels

KEM field energy in each electron's energy level

$Mv^2 = KEM = hv^2$

The rest mass-energy content
of Matter topologies in motion
is INVARIANT to changes
of velocity-momentum

M_0

$M\left[\frac{v}{c}\right]^2$

The mass-energy
geometries of all
KEM fields are subject to
Lorentz corrections

$M[\beta]^2$

13.6 eV
Free Electron

rest Matter Electrons have
zero velocity and no KEM field

n8+
Free Electrons have
Kinetic Energies
of 13.6 eV+

n0
n1
n2
n3
n4
n5
n6
n7
n8
12
0-12
1.2e20
0 eV
v
1
12
[.2113 eV]
p
3
[0.845 eV]
48
5
[1.901 eV]
108
7
[3.381 eV]
192
9
[5.283 eV]
300
11
[7.607 eV]
432
13
[10.355 eV]
588
15
[13.5259 eV]
768
hv
v²
c²
KEM
n1
0.211 eV
n2
0.845 eV
n3
1.901 eV
n4
3.381 eV
n5
5.283 eV
n6
7.607 eV
n7
10.3551 eV
n8
13.525 eV

Tetryonics 13.08 - Hydrogen Energy Levels

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Kinematics

An inertial frame of reference is one in which the motion of a particle not subject to forces and results in motion in a straight line at constant velocity

Deceleration

[Inertial Frame MINUS odd quanta]

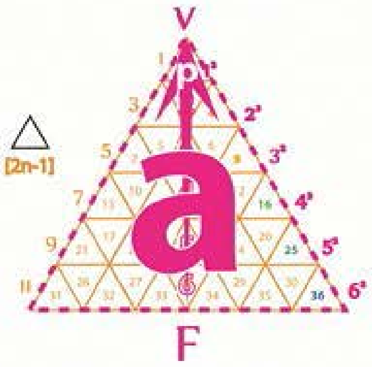
V
p
a
F
△
[2n-1]
1
3
5
7
9
11
1²
2²
3²
4²
5²
6²

Newton's First Law

$$\sum \mathbf{F} = 0 \Rightarrow \frac{d\mathbf{v}}{dt} = 0$$

Every body persists in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by force impressed

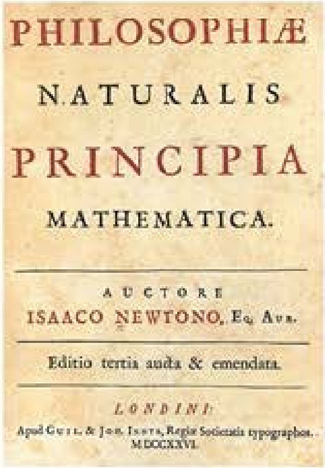

PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

AUCTORE
ISAACO NEWTONO, Eq. Aur.

Editio tertia aucta & emendata.

LONDINI:
Apud Guil. & Joh. Innys, Regiæ Societatis typographos.
MDCCXXVI.

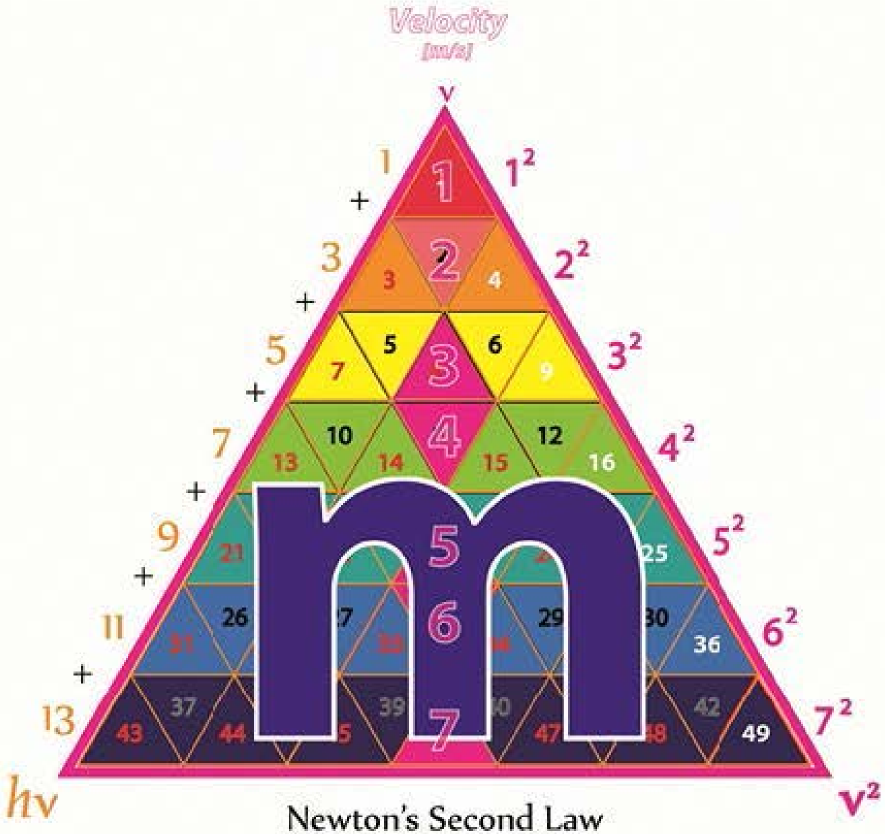
Velocity
[m/s]
v
m
hv
v²
1
+
3
+
5
+
7
+
9
+
11
+
13
1²
2²
3²
4²
5²
6²
7²
1
2
3
4
5
6
7
10
12
13
14
15
16
21
25
26
29
30
36
37
39
42
43
44
47
49

Newton's Second Law

$$\sum \mathbf{F} = \frac{d\mathbf{p}}{dt} = m\frac{d\mathbf{v}_{cm}}{dt} = m\mathbf{a}_{cm}$$

Force creates a change in Momentum over Time

A body of [m]ass subject to a net [F]orce undergoes an [a]cceleration that has the same direction as the force and a magnitude that is directly proportional to the force and inversely proportional to the mass, i.e., F = ma.

Alternatively, the total force applied on a body is equal to the time derivative of linear momentum of the body.

Sir Issac Newton

(25 December 1642 – 20 March 1727)

$$a = \frac{\Delta y}{\Delta x} = \frac{\Delta v}{\Delta t}.$$

$$\mathbf{F} = m\mathbf{a} \quad \rightarrow \quad \mathbf{a} = \mathbf{F}/m$$

Acceleration

[Inertial Frame PLUS odd quanta]

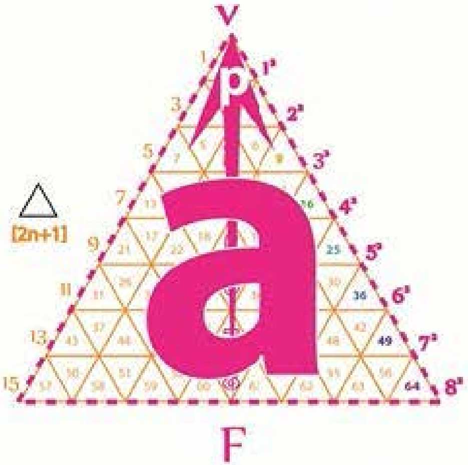
V
p
a
F
△
[2n+1]
1
3
5
7
9
11
13
15
1²
2²
3²
4²
5²
6²
7²
8²

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Inertia and Force

Any change to the energy-momenta content of a closed inductive loop requires a proportional change to the loop's energy density

momentum

The classical definition of Momentum relates the mass of a material body at given velocity (v) to its Momentum (p); it is a proportionality factor in the formula

$$p = mv$$

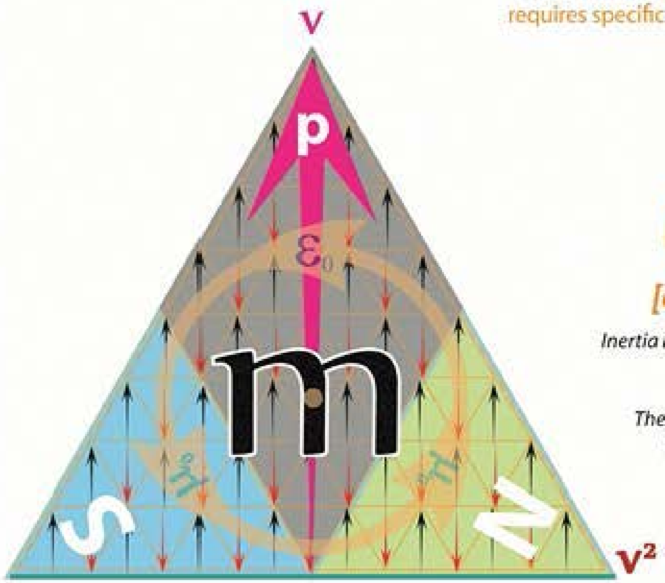

Linear momentum is the nett square root of mass-energy quanta

p

linear quanta forces

divergent ↑ $[v - v]$ ↓ convergent

Transverse Bosons

Any change to energy-momenta levels in Tetryonic geometry requires specific number quanta

Scalar mass-energy

Inertia is resistance to change of energy momenta vectors within spatial geometries

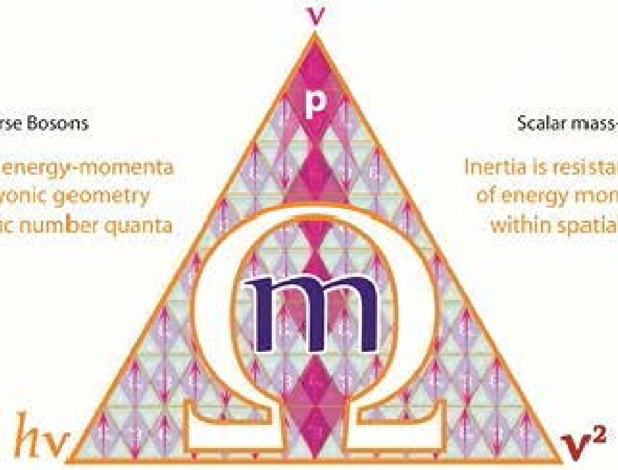

[all inductive loops resist changes to their energy levels]

Inertia is the resistance of any physical object to a change in its state of motion or rest, or the tendency of an object to resist any change in its motion.

The principle of inertia is one of the fundamental principles of classical physics which is used to describe the motion of matter and how it is affected by applied forces

$$E = mv^2$$

Any change in the energy-momenta content of a body of mass-Matter results in a proportional change in its momentum-velocity

Force

This meaning of a body's inertia therefore is altered from the classsical definition of "a tendency to maintain momentum" to a description of the measure of how difficult it is to change the momentum of a body

$$F = ma$$

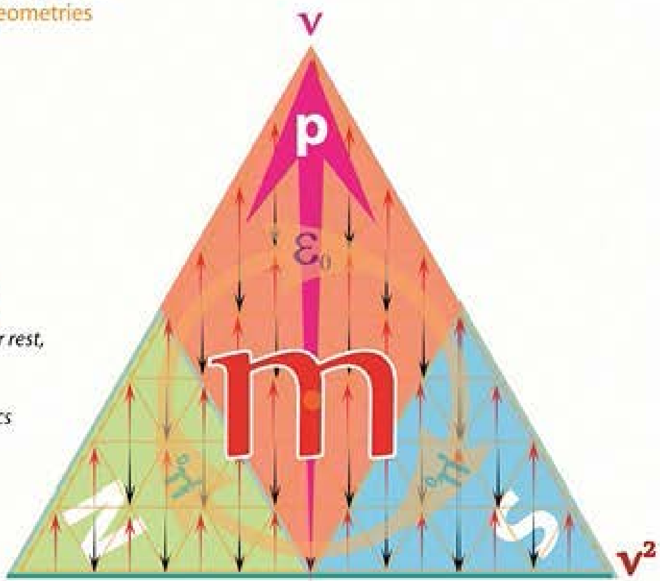

Force is the sum of the linear mass-energy momenta quanta

F

Scalar Energy

Gottfried Wilhelm von Leibniz

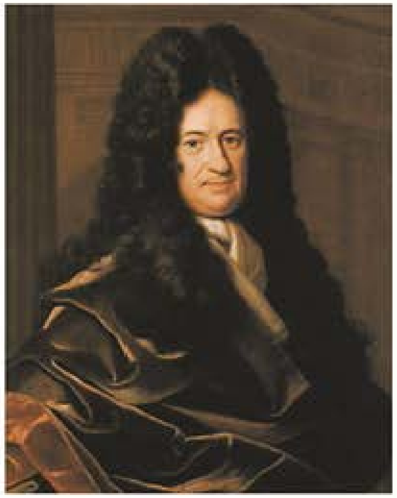

(July 1, 1646 – November 14, 1716)

Leibniz's vis viva (Latin for living force) is mv^2, twice the modern kinetic energy.

He realized that the total energy would be conserved in certain mechanical systems, so he considered it an innate motive characteristic of Matter.

His thinking gave rise to another regrettable nationalistic dispute. His vis viva was seen as rivaling the conservation of linear momentum championed by Newton in England and by Descartes in France; hence academics in those countries tended to neglect Leibniz's idea.

In reality, both energy and momentum are conserved, so the two approaches are equally valid.

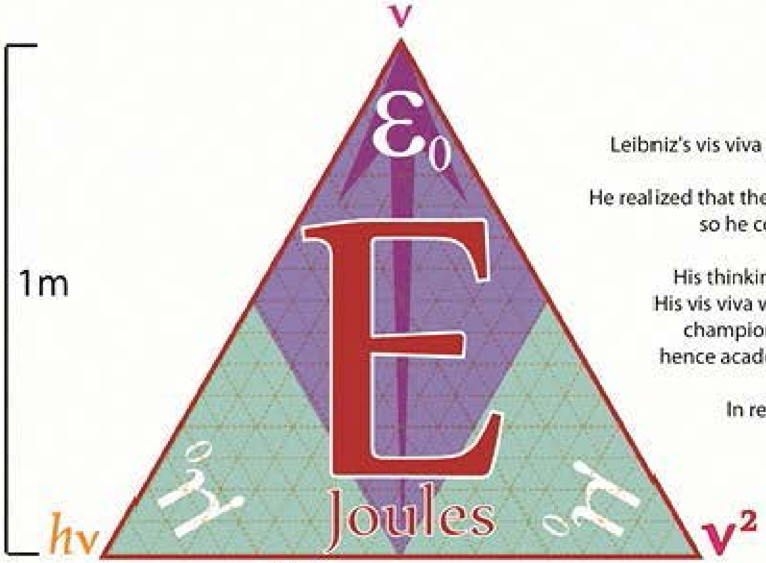

Newtons

of force

The nett direction of Force within energy geometry is UNIDIRECTIONAL
ie the force exerted is the result of the nett linear momenta irrespective of charge

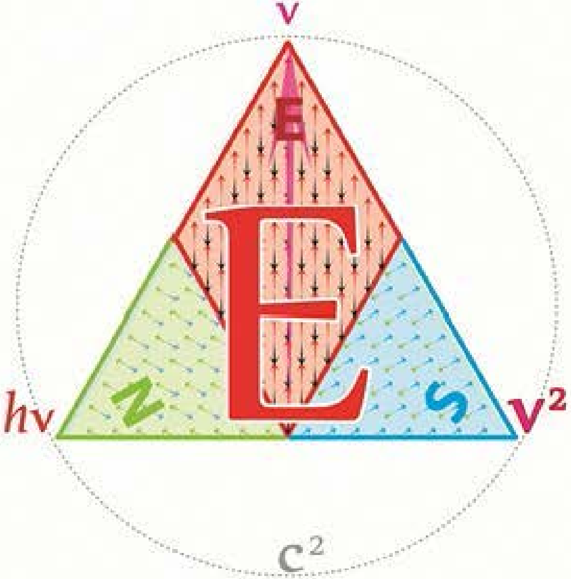

[Joule seconds] per second

mass x velocity squared $kg.\left[\frac{m}{s}\right]^2$

$$\boxed{\text{Energy} \quad kg.\frac{m^2}{s^2}}$$

$$J = \frac{kg \cdot m^2}{s^2} = N \cdot m = Pa \cdot m^3 = W \cdot s$$

A Joule is equal to the energy expended (or work done) in applying a force of one newton through a distance of one metre
(1 newton metre or N·m)

momentum x velocity $\left[kg.\frac{m}{s}\right].\frac{m}{s}$

Planck's quanta per second $\left[kg.\frac{m^2}{s}\right].s^{-1}$

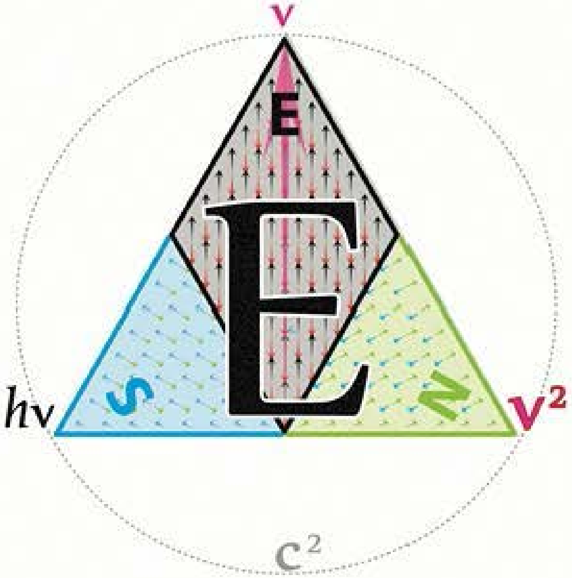

[Joule seconds] per second

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Linear Momentum

Linear momentum is the SQUARE ROOT of equilateral Planck mass-energy geometries and produces a undirectional vector force

The Energy-momentum relationship is a fundamental physical property used to determine the mass of a body

Using the formula for mass-Energy equivalence as it relates to Photons moving at 'c'

$$E = h\nu = \frac{hc}{\lambda} = mc^2$$

Noting that the rest mass in the case of EM fields (Bosons and Photons) is to equal Zero

we can derive a relationship for Momentum - Energy - Wavelength showing that

$$p = E/c$$

Thus momentum in Photons is directly related to the EM energy content of the photon and the mass-energy content of any massive 3D body

$$p = \hbar k = \frac{h\nu}{c} = \frac{h}{\lambda}.$$

and momentum in Particles is related to the total EM Energies of an object (its rest Matter + KE) and the wavelengths associated with those distinct energy levels

$$p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$$

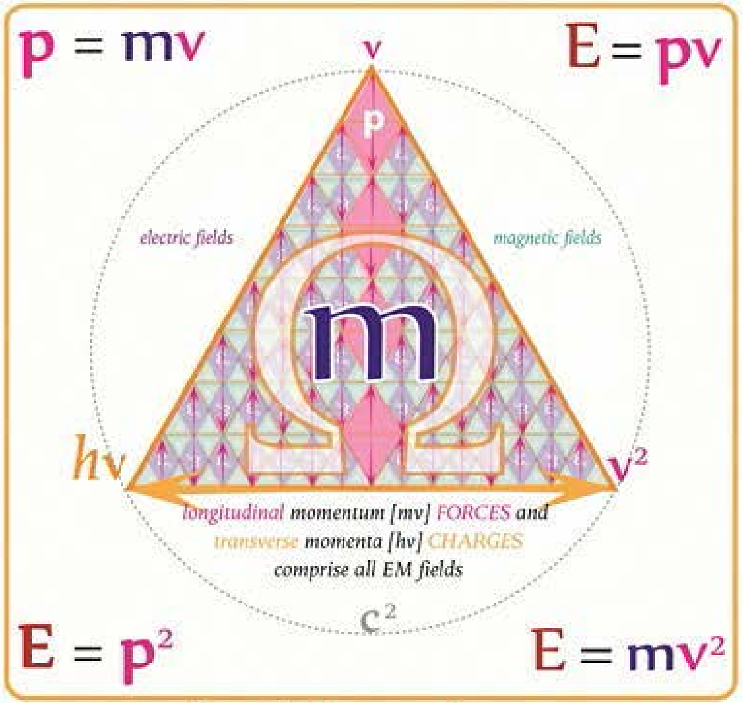

Longitudinal [linear] momentum

Energy

$$p = n\pi\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v}\right]\right]$$

momentum

Momentum is a conserved quantity, meaning that the total momentum of any closed system (one not affected by external forces) cannot change.

Linear Momentum is the intrinsic sqare root vector component of Force

$$p = mv$$

In classical mechanics, momentum is the product of the mass and velocity of an object.

$$\sum \mathbf{F} = \frac{d\mathbf{p}}{dt} = m\frac{d\mathbf{v}}{dt} + \mathbf{v}\frac{dm}{dt}$$

In relativistic mechanics, this quantity is multiplied by the Lorentz factor.

$$p = \frac{n\pi\left[\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]}{v} = mv$$

EM field momentum is a function of its energy density, and is directly proportional to the group velocity

$$\left[\sqrt{\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\overset{\text{quanta}}{\Omega}\underset{\text{velocity}}{v}\right]^2}\,\right]$$

Vector linear momentum

is the square root of the KEM field energies produced by Matter in motion

Energy

$$n\pi\left[\left[m\Omega v\right]\right]$$

momenta

Classical formulation

$$p = mv$$

Linear Momentum
is the vector force of
mass times its velocity

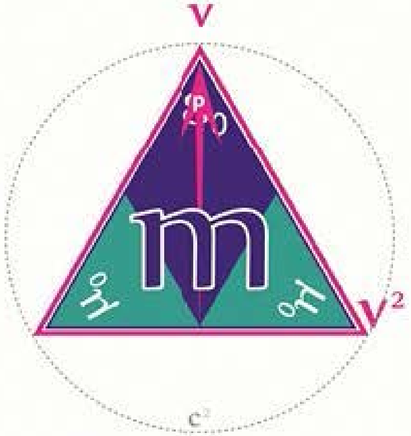

$$\frac{E}{c^2} . v$$

INERTIAL FRAME
(m/s)

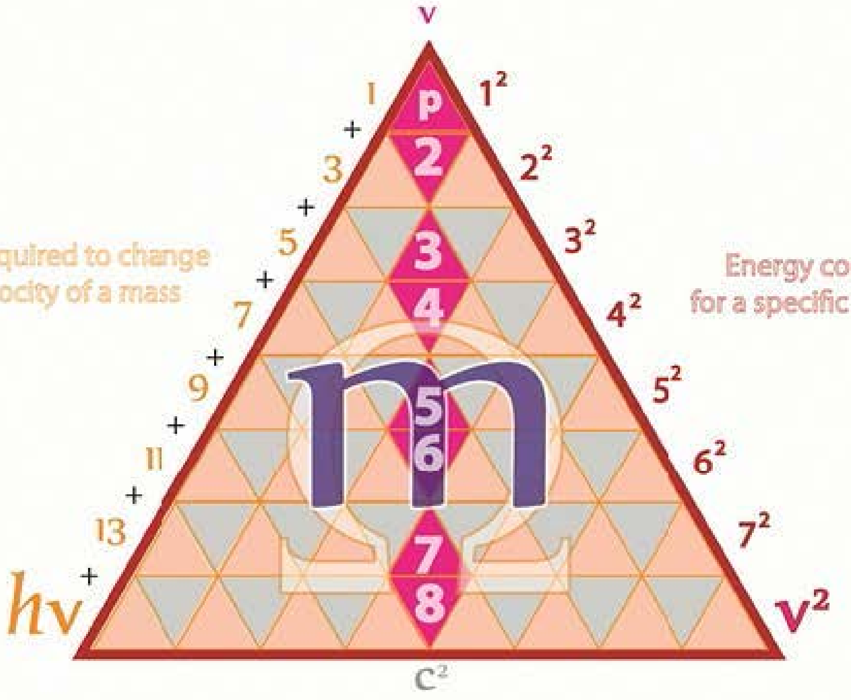

Energy required to change
the velocity of a mass

Energy content
for a specific velocity

$$\mathbf{p} = \sum_{i=1}^{n} m_i \mathbf{v}_i = m_1 \mathbf{v}_1 + m_2 \mathbf{v}_2 + m_3 \mathbf{v}_3 + \cdots + m_n \mathbf{v}_n \,,$$

The linear momentum of a EM field or system of particles is
the vector sum of the linear momenta in the KEM fields
of individual particles in any spatial co-ordinate system

Quantum formulation

$$p = \frac{E}{v}$$

Linear Momentum is
Energy divided by the
square root of its quanta

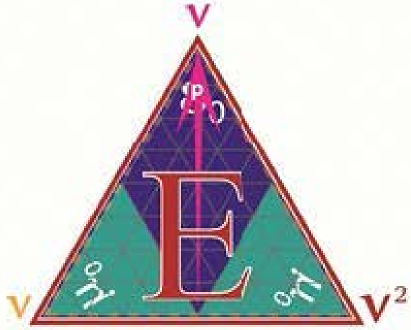

$$\frac{hv^2}{v}$$

Kinetic Energy

is the Electric field energy of Matter in motion

$$1/2\Big[\underset{\text{Matter}}{4n\pi}\Big[\overset{\text{EM Field}}{\underset{\text{ElectroMagnetic}}{[\varepsilon_0\mu_0]}}.[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}]\Big]\Big]$$

Kinetic Energy is the diamond electric field extending from charged Matter topologies as a result of its motion, it follows Tetryonic omega geometry and is proportional to an object's mass-Matter and its vector velocity

Charge

Q

[v-v]

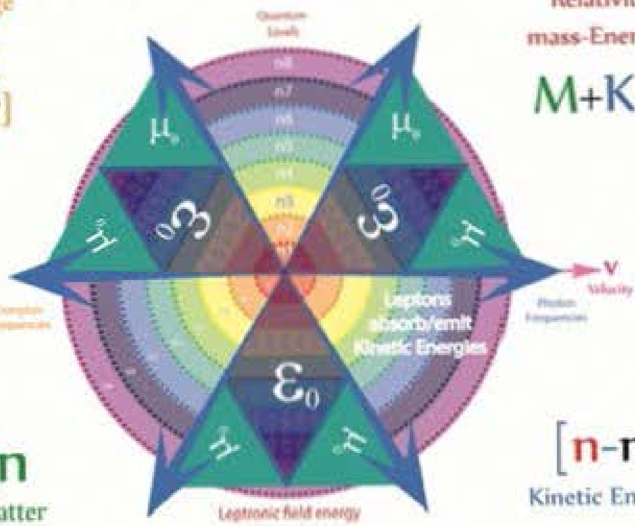
Quantum Levels
n8
n7
n6
n5
n4
n3
n2
n1
μ_0
μ_0
ε_0
ε_0
μ_0
μ_0
ε_0
μ_0
μ_0
v
Velocity
Compton frequencies
Photon frequencies
Leptons absorb/emit Kinetic Energies
Leptonic field energy

12n

rest Matter

Relativitic mass-Energies

M+KE

[n-n]

Kinetic Energies

Kinetic Energy is 1/2 of the secondary KEM field energies created when Matter particles are in motion

$$\frac{2\pi\Big[[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}]\Big]}{\underset{\text{EM Field}}{c^2}}$$

and is shown to be subject to Lorentz corrections

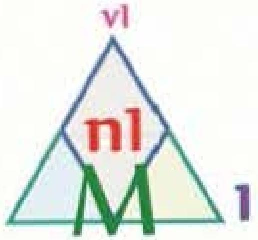

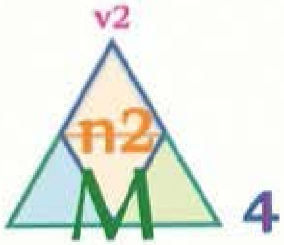

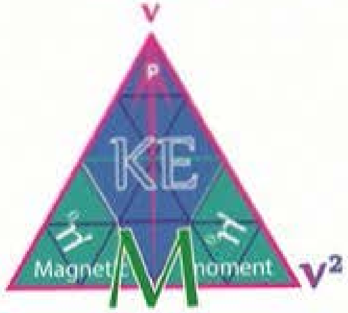
v
P
KE
μ_0
μ_0
Magnetic moment
M
v^2

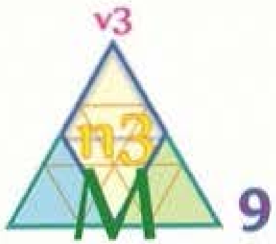

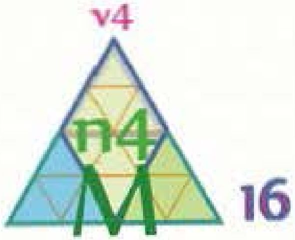

Kinetic Energies
create
Magnetic Moments

$$KE = \frac{1}{2}Mv^2$$

Kinetic energy is a scalar quantity; it does not have a direction.

The Kinetic Energy of an object is the energy which it possesses due to its motion.

It consists of Neutral Electric fields and an associated Magnetic moment

Kinetic Energies are subject to Lorentz corrections

$$E_k = mc^2 - m_0c^2.$$

rest Matter is not

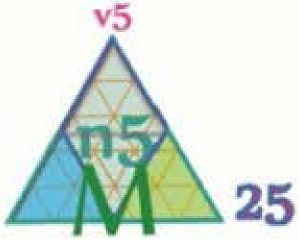

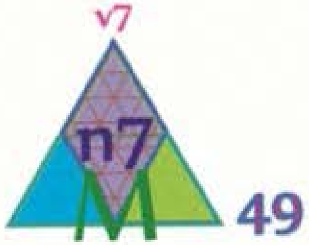

Tetryonics 14.06 - Kinetic Energy

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Kinetic Energy and Magnetic moments

$$Mv^2 = KEM = p^2$$

Unlike charged fields KEM fields have neutralised Electric Fields

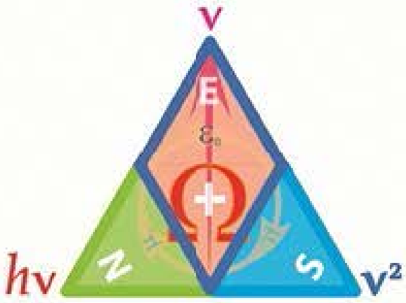
v
E
ε₀
Ω
+
N
S
hv
v²

KEM field geometry of positive charged Matter in motion

$$KE = \frac{1}{2}Mv^2$$

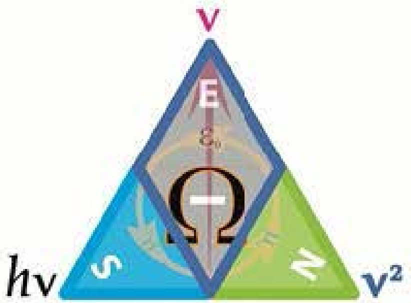
v
E
ε₀
Ω
−
S
N
hv
v²

KEM field geometry of negative charged Matter in motion

Often noted as being two distinct EM energies [Kinetic Energy and Magnetic moments] are shown to be orthogonal aspects of the same KEM field of motion

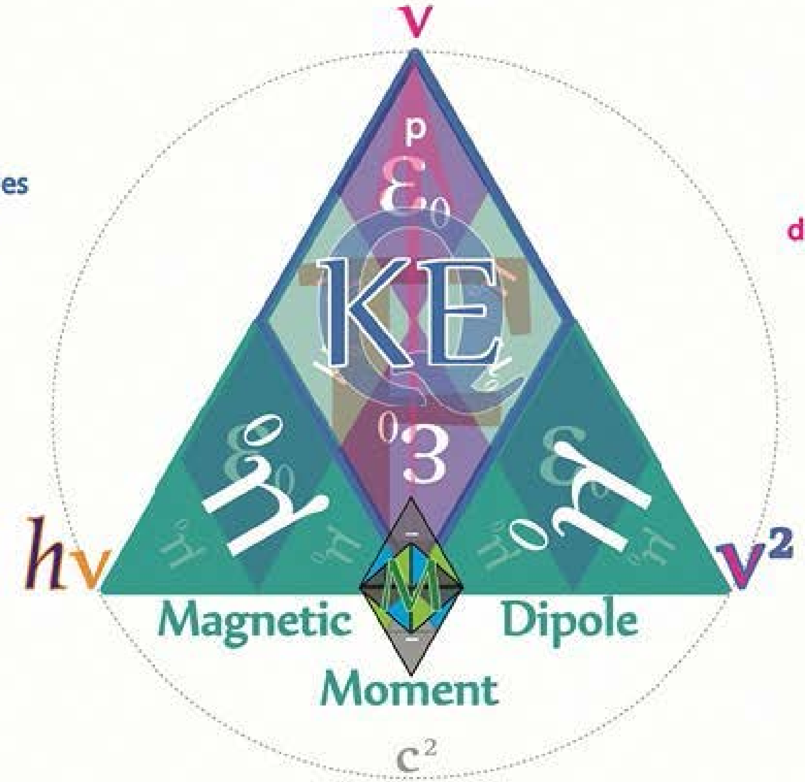
v
p
ε₀
KE
ε₀
ε₀
hv
v²
M
Magnetic
Dipole
Moment
c²

As the velocity of a particle increases so does its Kinetic Energy and Magnetic moment creating Lorentz variable KEM fields

$$\mu_B = \frac{1}{2}Mv^2$$

$$\mu_B = \frac{1}{2}Mv^2$$

Types of Momentum

Ω

quantised angular momenta

$[m^2/s]$

The quantised 'angular momentum' of each Planck mass-energy geometry, gives rise to the two quantum Charges

p

Linear momentum

[kg·m/s]

The square root (v) of each Planck quanta's mass-energy geometry (v^2) is vector Linear Momentum

ℓ

Angular momentum

$[kg \cdot m^2/s]$

The orbital angular momentum of electrons in atoms associated with a given quantum state

... [n-1] [n] [n+1] ...

There are 3 forms of momenta in physics

equilateral charge geometry

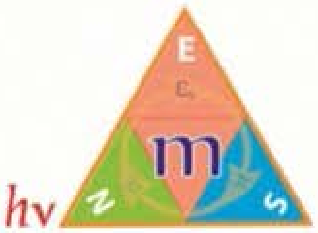
E
ε_0
m
N
S
hv

h

$[kg \cdot m^2/s]$

$m\Omega$

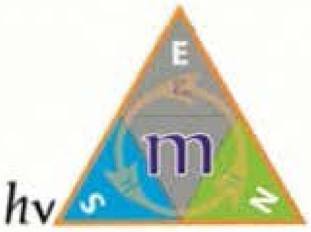
E
ε_0
m
S
N
hv

vector momentum

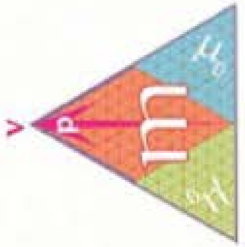
v
p
m
μ_0
ε_0

mv

[kg·m/s]

p

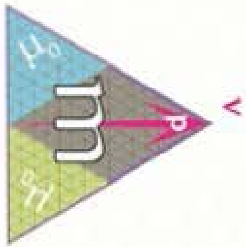
μ_0
m
p
v
ε_0

vector rotation about a point

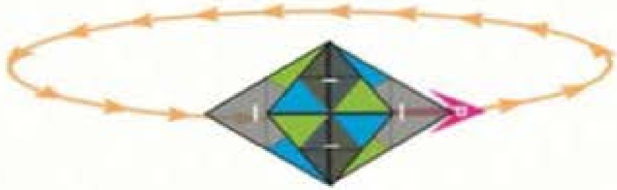

$$L^2 = L_x^2 + L_y^2 + L_z^2$$

Kinetic Energy vs Momentum

An important difference is that Kinetic energy is a scalar quantity - it has no direction in space momentum is a vector quantity - it has a direction in space, momenta combine like forces do.

$$p = Mv$$

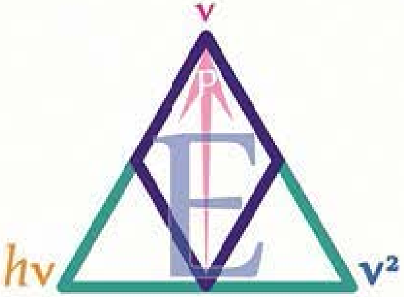

Energy momenta

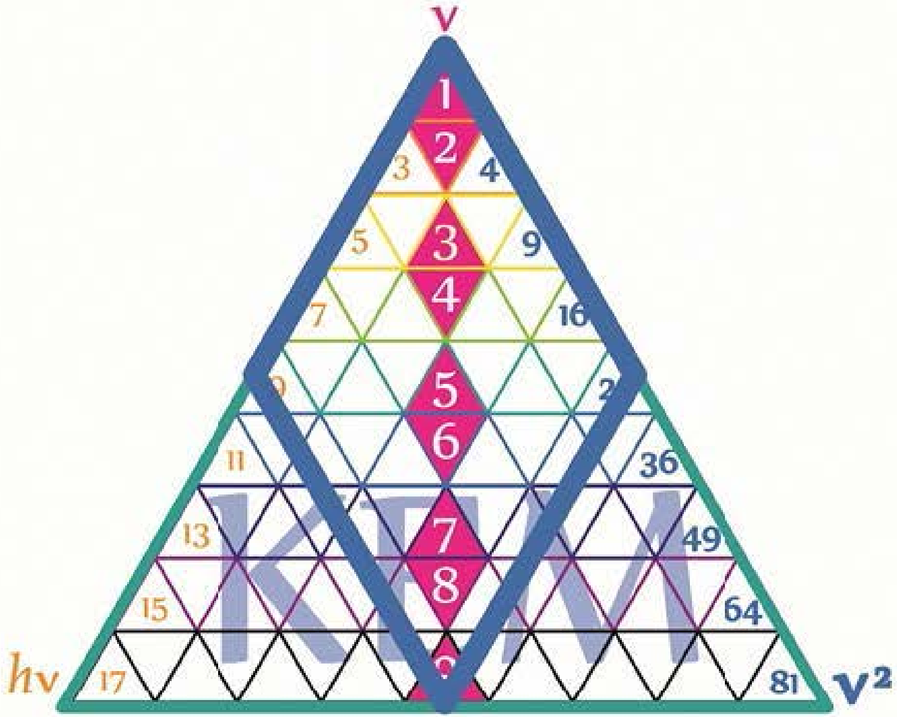

$$KE = 1/2\left[Mv^2\right]$$

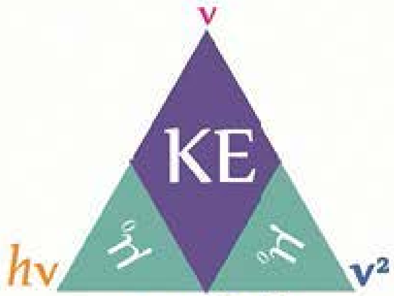

KEM field

$$p = \sqrt{E}$$

$$KEM = Mv^2$$

In Tetryonic geometry, the square root maps the linear momenta [mv] of a field to its ENERGY

$$p^2/_{2m} = KE$$

In Tetryonic geometry, E-field geometry maps the kinetic energy [1/2 mv] of a field to its ENERGY

Linear momentum has a different geometric ENERGY relationship to that of Electric fields

mass-Energy-momentum

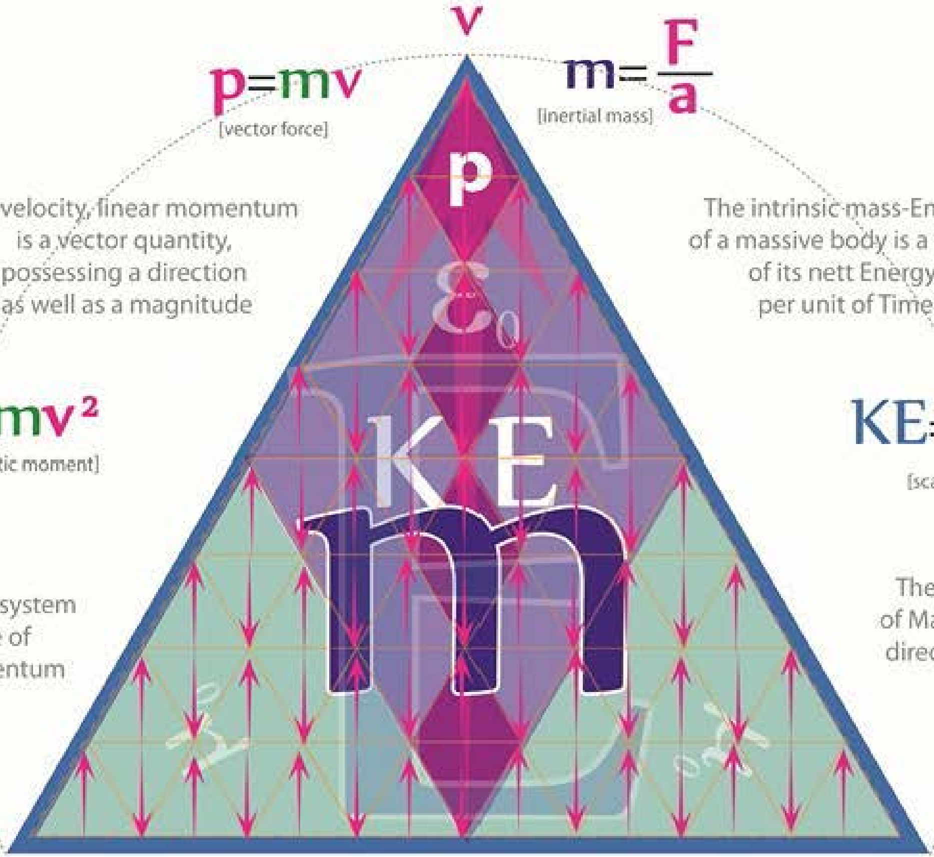

$p=mv$

[vector force]

$m=\frac{F}{a}$

[inertial mass]

Like velocity, linear momentum
is a vector quantity,
possessing a direction
as well as a magnitude

The intrinsic mass-Energy
of a massive body is a result
of its nett Energy
per unit of Time

$KEM=mv^2$

[Kinetic Energy & magnetic moment]

$KE=\frac{1}{2}mv^2$

[scalar E-field]

The Energy of a system
is the square of
its linear momentum

The Kinetic energy
of Matter in motion is
directly related to its
velocity

$E=mv^2$

[scalar KEM field energies
of Matter in motion]

$E=p^2$

[Energy momenta]

Planck quanta

$[m\Omega v]$

mass velocity

acceleration results in
changes to momenta

$F=ma$

Newton's
Second law of Motion

Linear momentum is the square root
of the Energy of a system.

It is the nett linear Force
resulting from Matter in motion
and was used by Newton
as the foundation for
his Laws of motion

Linear momentum is also a conserved quantity, meaning that if a closed system is not affected by external forces, its total linear momentum cannot change. Although originally expressed in Newton's second law, the conservation of linear momentum also holds in special relativity and, with appropriate definitions, a (generalized) linear momentum conservation law holds in electrodynamics, quantum mechanics, quantum field theory, and general relativity. In relativistic mechanics, non-relativistic linear momentum is further multiplied by the Lorentz factor

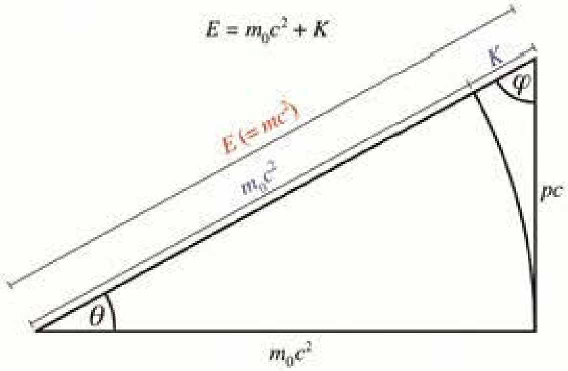

$$E^2 = p^2c^2 + m_0^2c^4$$

Often generalised as having the geometry of
right angled triangles the mass-energy momenta
relationship is fully revealed using
Equilateral geometry

E^2

**is the energy content
of a superpositioned
EM field**

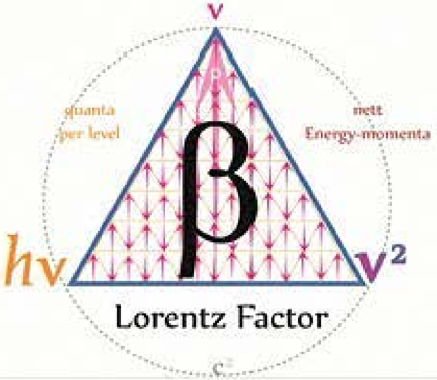

Tetryonics 14.10 - mass-Energy momentum

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Lorentz velocity correction Factor

The Lorentz factor or Lorentz term is an expression which appears in several equations in special relativity. It arises from deriving the Lorentz transformations. The name originates from its earlier appearance in Lorentzian electrodynamics - named after the Dutch physicist Hendrik Lorentz.

Wavelength, momentum

mass-ENERGY

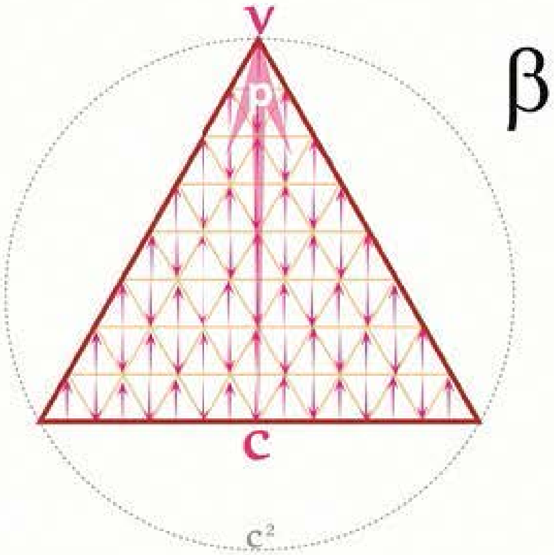

$$\beta = \left[\frac{v}{c}\right]$$

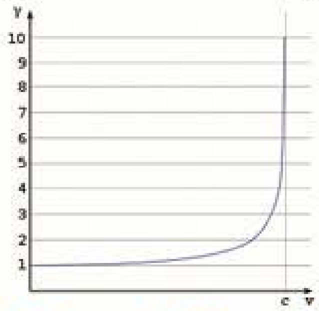

$$\left[\frac{v^2}{c^2}\right] = \beta^2$$

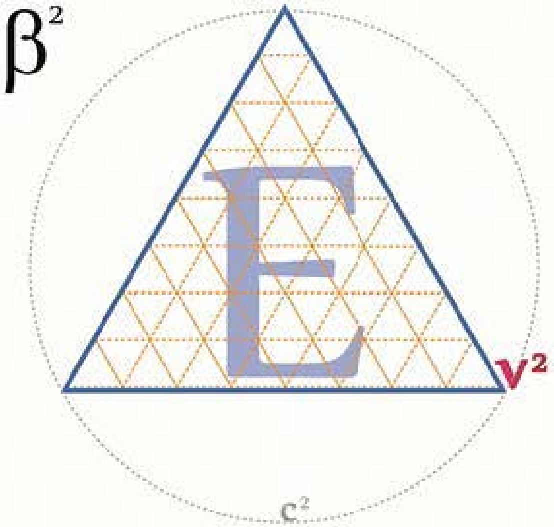

Classically modelled as an infinite series approaching c
Tetryonics reveals it to be a physical property
of equilateral energy-momenta geometries

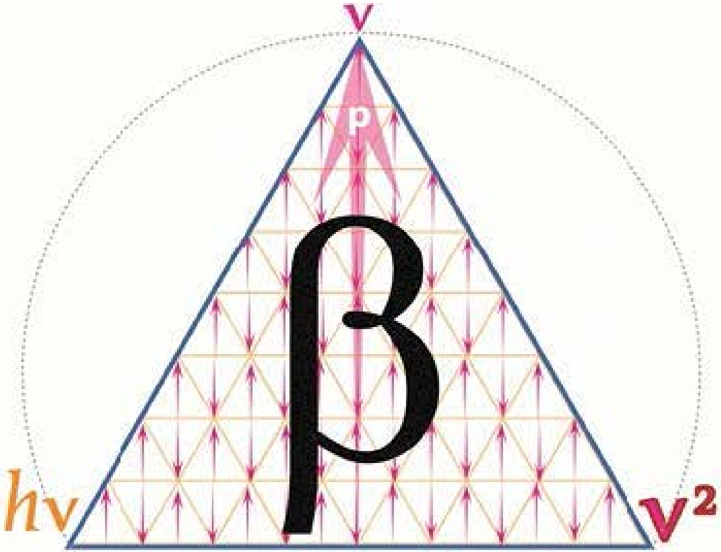

Importantly - Newton's classical velocity addition remains correct, but the energy-momenta required to accelerate Matter to higher velocities increases exponentially in line with the equilateral [Tetryonic] geometry of mass-energies

A vector measure of the Energy content of a waveform

$$\gamma \equiv \frac{c}{\sqrt{c^2 - v^2}} = \frac{1}{\sqrt{1 - \beta^2}} = \frac{dt}{d\tau}$$

γ

A scalar measure of a KEM waveform's energies

$$\gamma = 1/\sqrt{1 - v^2/c^2}$$

Γ

Tetryonics 14.11 - Lorentz velocity correction Factor

Unified Energy momenta geometry

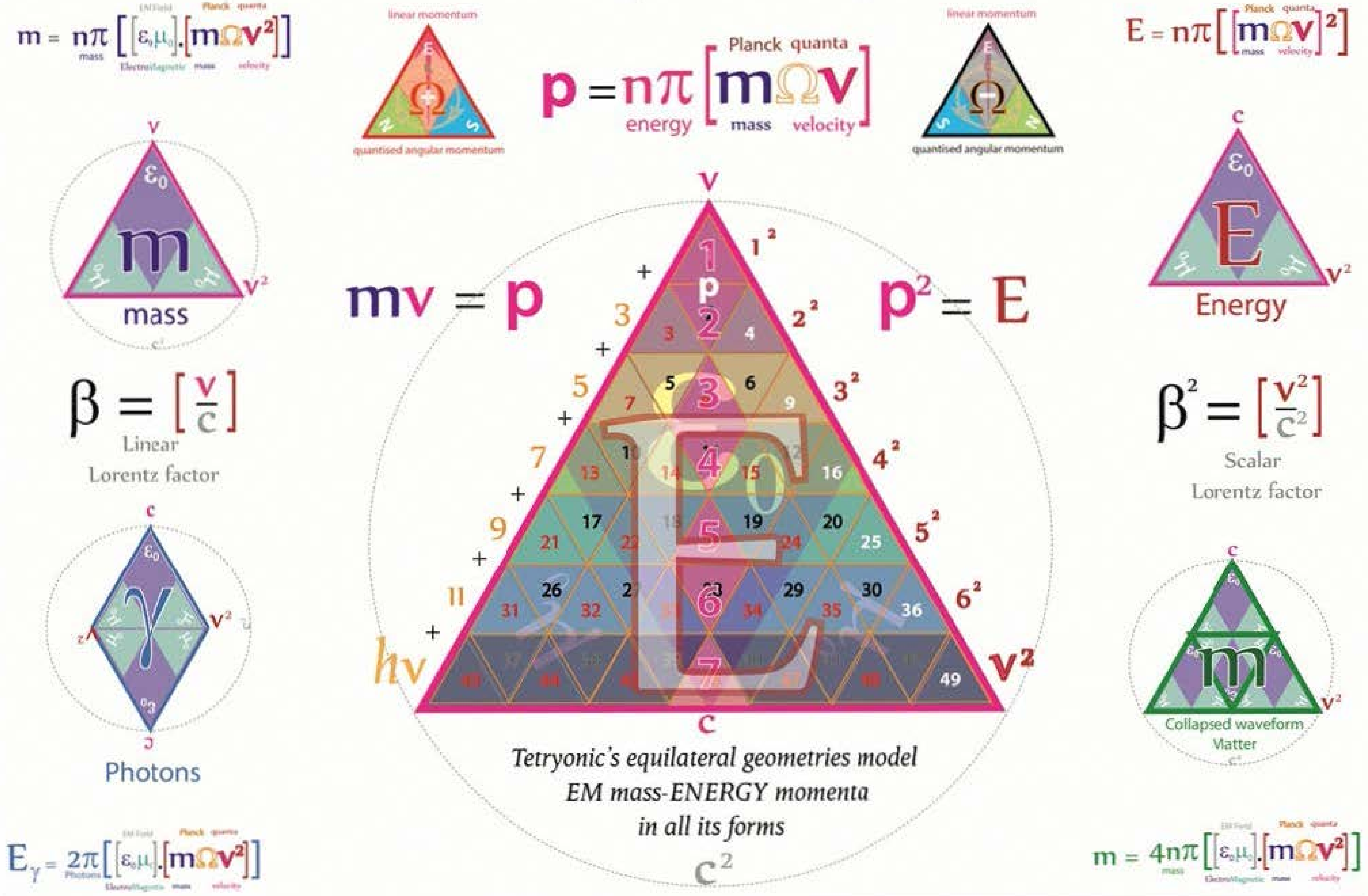

$$m = n\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

$$p = n\pi\left[m\Omega v\right]$$

$$E = n\pi\left[[m\Omega v]^2\right]$$

$$mv = p$$

$$p^2 = E$$

$$\beta = \left[\frac{v}{c}\right]$$

Linear Lorentz factor

$$\beta^2 = \left[\frac{v^2}{c^2}\right]$$

Scalar Lorentz factor

$$E_\gamma = 2\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

$$m = 4n\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

Tetryonic's equilateral geometries model EM mass-ENERGY momenta in all its forms

EM Field
Planck quanta
mass
Electromagnetic
mass
velocity
linear momentum
quantised angular momentum
energy
Planck quanta
mass
velocity
linear momentum
quantised angular momentum
v
ε_0
m
μ_0
v^2
mass
c^2
c
ε_0
E
μ_0
v^2
Energy
v
1^2
2^2
3^2
4^2
5^2
6^2
v^2
1
p
2
3
4
5
6
7
3
5
7
9
11
+
hv
c
c^2
ε_0
E
c
ε_0
γ
μ_0
v^2
Photons
c
ε_0
m
v^2
Collapsed waveform
Matter
c^2
mass
Photons

Squared Energy distributions

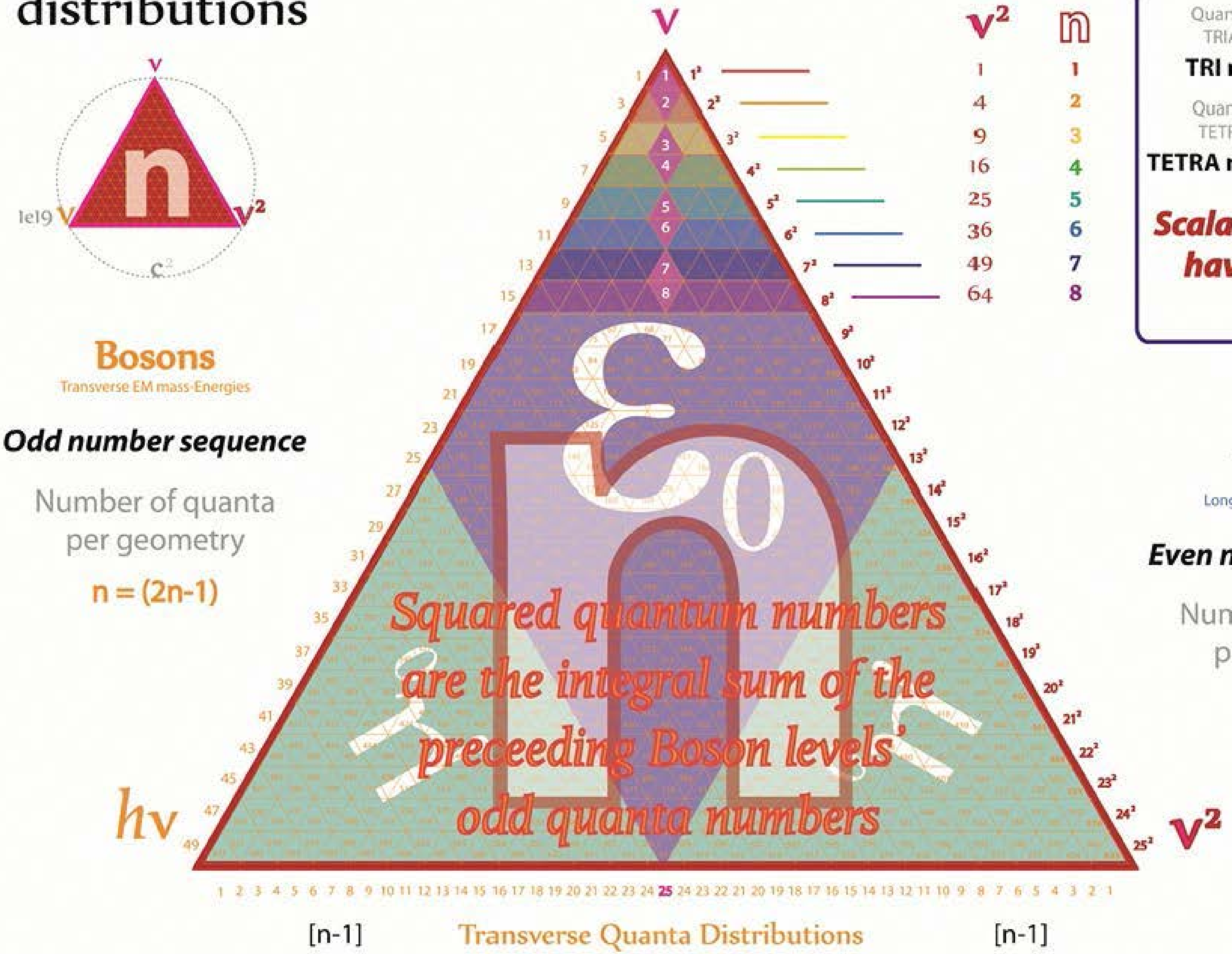
v
n
lel9 v
v²
c²

Bosons

Transverse EM mass-Energies

Odd number sequence

Number of quanta per geometry

n = (2n-1)

v
1
2
3
4
5
6
7
8
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
1² 2² 3² 4² 5² 6² 7² 8² 9² 10² 11² 12² 13² 14² 15² 16² 17² 18² 19² 20² 21² 22² 23² 24² 25²
ε0
n
hv
v²
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
[n-1]
Transverse Quanta Distributions
[n-1]

Squared quantum numbers are the integral sum of the preceeding Boson levels' odd quanta numbers

v²	n
1	1
4	2
9	3
16	4
25	5
36	6
49	7
64	8

EM mass-energy

Quantum numbers are *not* TRIANGULAR NUMBERS

TRI n = (n/2) x (n+1)

Quantum numbers are *not* TETRAHEDRAL NUMBERS

TETRA n = (n/6) (n+1) (n+2)

Scalar energy levels have SQUARED quanta

Photons

Longitudinal EM mass-Energies

Even number sequence

Number of quanta per geometry

n = (2n)

Tetryonics 15.02 - Squared Energy distributions

Tetryonic Energy and Charge relationships

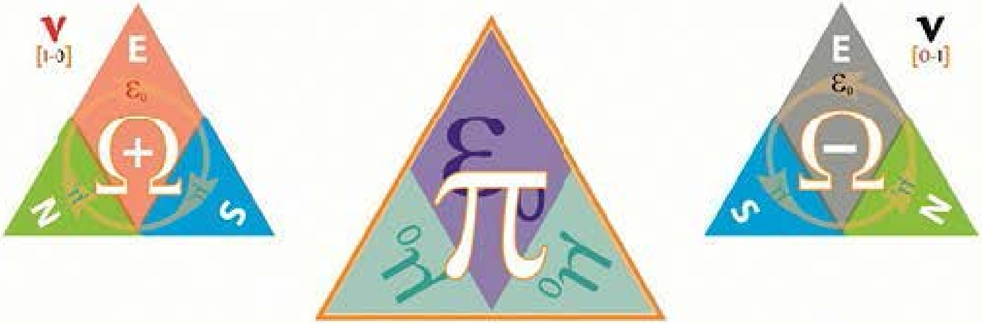
v
[1-0]
E
ε_0
+Ω
N
S
π
ε
μ_0
E
ε_0
−Ω
v
[0-1]
S
N

Quantised angular momenta is the geometric source of all mass-Energy-Matter relationships

Scalar energies
(are 'squared' numbers)

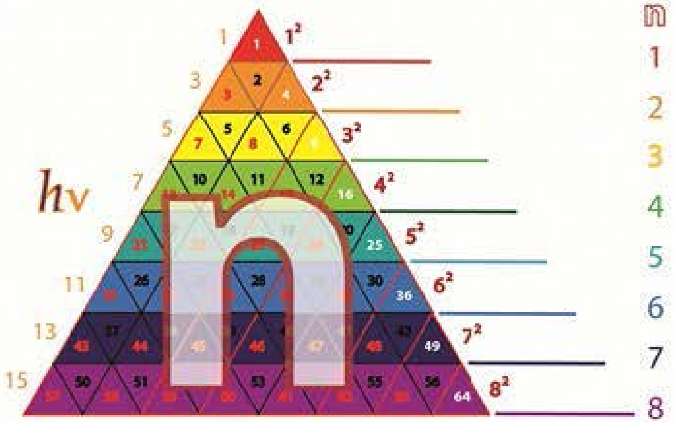
n
hv
1
3
5
7
9
11
13
15
1^2
2^2
3^2
4^2
5^2
6^2
7^2
8^2
1
2
3
4
5
6
7
8
n

The Energy density of a particle's charged fascia geometry determines its mass

m

Charged mass-energy geometry & Matter topology determines a particle's physical characteristics (Type, Family, generation, mass etc)

M

Charge

-12

electron

12
[0-12]

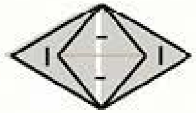

1.2 e20

mass-Matter

e-

8.851486 e-31 KG

Opposite nett elementary charge geometries

1875x
(differential)

differing Matter topologies

+12

12
[24-12]

Proton

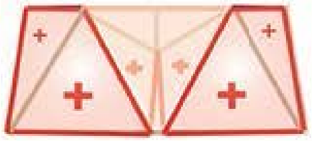

2.25 e23

1.65965 e-27 KG

P+

[v-v]

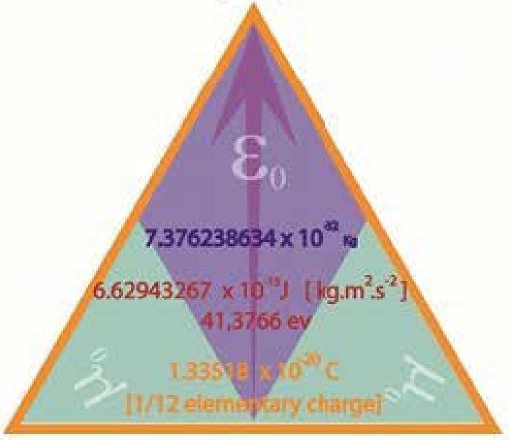
ε_0
$7.376238634 \times 10^{-51}$ kg
$6.62943267 \times 10^{-34}$ J [$kg.m^2.s^{-2}$]
41,3766 ev
1.33518×10^{-20} C
[1/12 elementary charge]
μ_0
μ_0
1

Planck mass-energy

Planck's energy momenta quantum

$\frac{E}{c^2}$

m

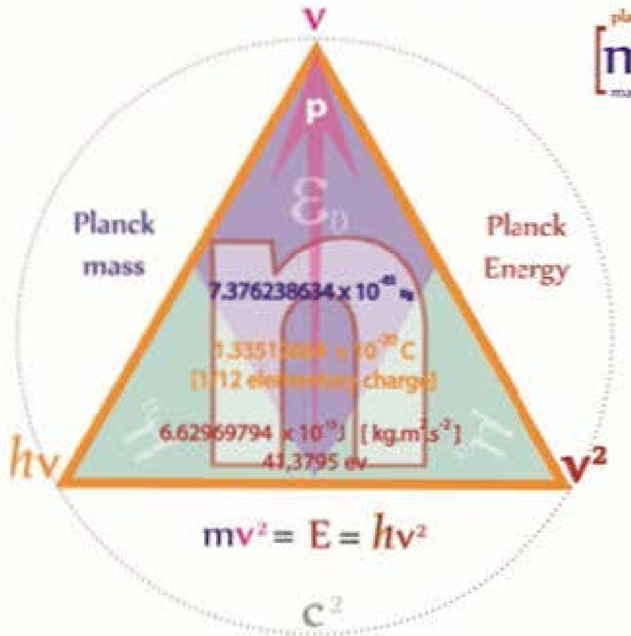

$mv^2 = E = hv^2$

E

planck quanta

$[m\Omega v^2]$

mass velocity

Planck mass	**m**	m - mass quantum
q Planck Charge quantised angular momentum / spatial co-ordinate system	**Ω**	v - quanta of Charge $\frac{\text{elemental charge}}{12}$ **q**
Planck Energy	**E**	E - Energy quantum
v^2 Compton Frequency	$\frac{mc^2}{h}$	1×10^{19} quanta per second
λ de Broglie wavelength	$\frac{h}{mc}$	$2.99792458 \times 10^{-11}$ meters
p Momentum	mc	2.21134×10^{-23} Ns

Planck's constant is the equilateral geometry of rest mass-energy momenta in standing wave Matter topologies

Currently the Atomic masses are calculated using 1/12 of a Molar Carbon12 atom's mass as the reference mass.

Tq [Carbon] - [252-252] **C** 12 [270,072] / 12

Tm [Carbon] - 270,072 22,506

If we calculated for the molar mass of C12 in 12 grams we would get

(.012/N/270072) 7.378205107 x 10 kgrams

this is in error by 1/2 of the mass of an electron

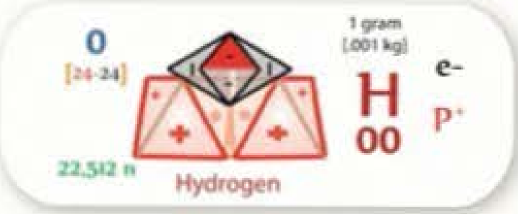

Tetryonic mass [Hydrogen] - 2.2512 e23 v

Using Tetryonic geometry we can solve for an exact Compton frequency of any mass-Matter topology and account exactly for all quantum energy contributions to the rest Matter of all electrons and Baryons in any element thus determining exact molar masses exclusive of blackbody radiation, kinetic energies and energies of measurement and avoiding 'weighted' masses

Defining (N) as the number of rest mass Hydrogen atoms in 1gram exactly and makes Avagadro's number the inverse of this number

$$\text{Molar mass} = \frac{H_1 \text{ Atomic mass}}{\text{Avagadro's No.}}$$

$$\text{mass } H_{mol}/Av = \frac{.001}{6.022141579 \times 10^{23}}$$

rest mass Hydrogen = $1.660538841 \times 10^{-27}$ g/mol

$$H_{mole}/m[H] = \frac{1.660738412 \times 10^{-27}}{22{,}512}$$

n Planck mass = $7.376238634 \times 10^{-32}$ Kg

This is an exact Atomic rest mass as opposed to the current weighted molar Atomic mass estimates (which is incorrect by **1/2** the mass of an electron)

Planck's constant is the 'quantum of action' and also contributes to the mass-energies of radiant EM wave geometries

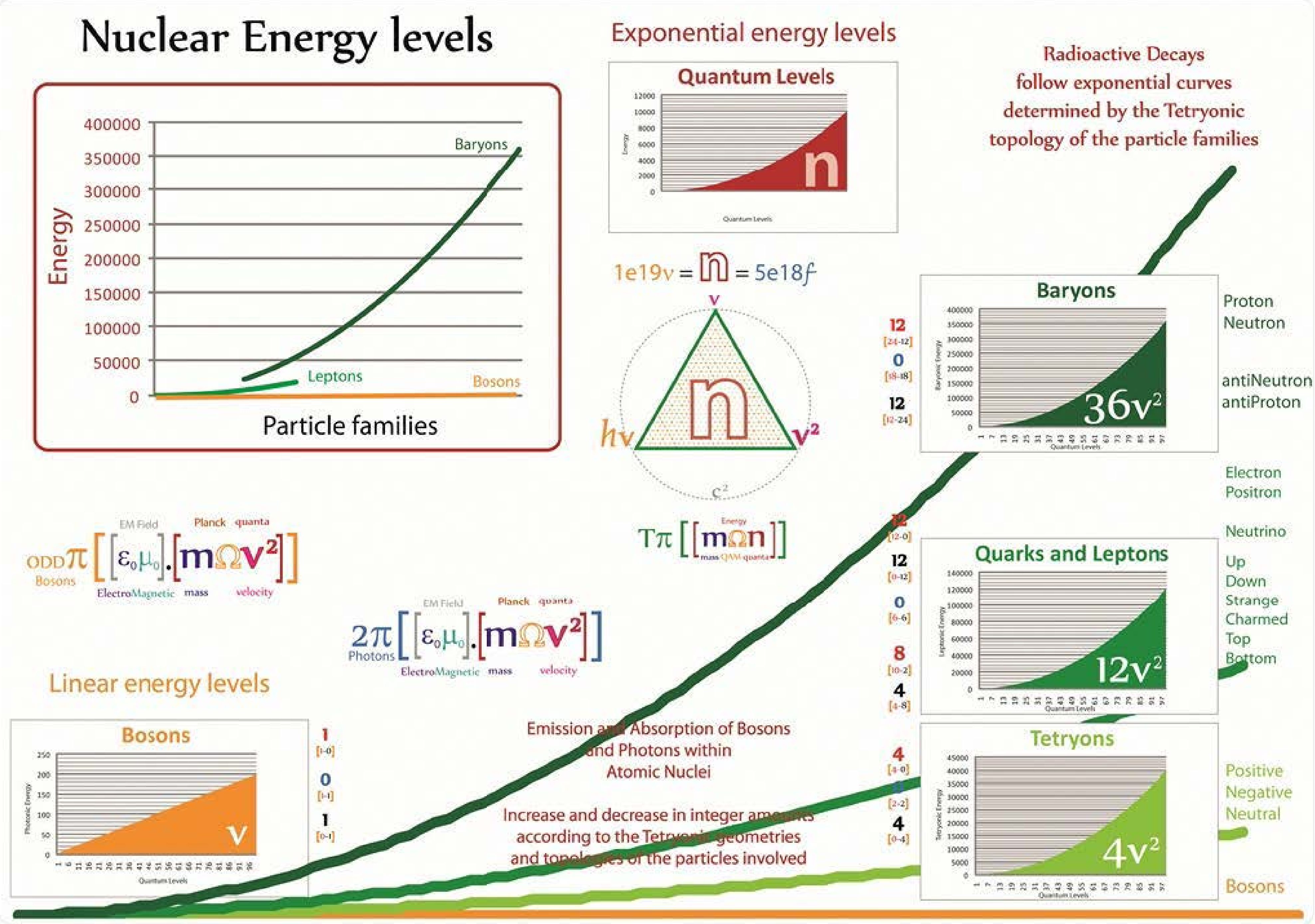

Nuclear Energy levels

Exponential energy levels

Radioactive Decays follow exponential curves determined by the Tetryonic topology of the particle families

Linear energy levels

Emission and Absorption of Bosons and Photons within Atomic Nuclei

Increase and decrease in integer amounts according to the Tetryonic geometries and topologies of the particles involved

$1e19\nu = n = 5e18f$

$\mathrm{ODD}\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$ Bosons

$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$ Photons

$T\pi\left[\left[m\Omega n\right]\right]$

400000
350000
300000
250000
200000
150000
100000
50000
0
Energy
Baryons
Leptons
Bosons
Particle families
Quantum Levels
Energy
n
v
hv
v²
c²
EM Field
Planck
quanta
ElectroMagnetic
mass
velocity
Energy
mass
QAM
quanta
Baryons
Baryonic Energy
36v²
Quantum Levels
Proton
Neutron
antiNeutron
antiProton
12
[24-12]
0
[18-18]
12
[12-24]
Electron
Positron
Neutrino
Quarks and Leptons
Leptonic Energy
12v²
12
[12-0]
12
[0-12]
0
[6-6]
8
[10-2]
4
[4-8]
Up
Down
Strange
Charmed
Top
Bottom
Tetryons
Tetryonic Energy
4v²
4
[4-0]
0
[2-2]
4
[0-4]
Positive
Negative
Neutral
Bosons
Bosons
Photonic Energy
v
Quantum Levels
1
[1-0]
0
[1-1]
1
[0-1]

Energy momenta geometry

m

All mass-energies have equilateral geometries

Ω

Quantised angular momenta facilitates EM interactions

E

mass-Energy

$kg\frac{m^2}{s^2}$

h

Planck's Constant

$kg\frac{m^2}{s}$

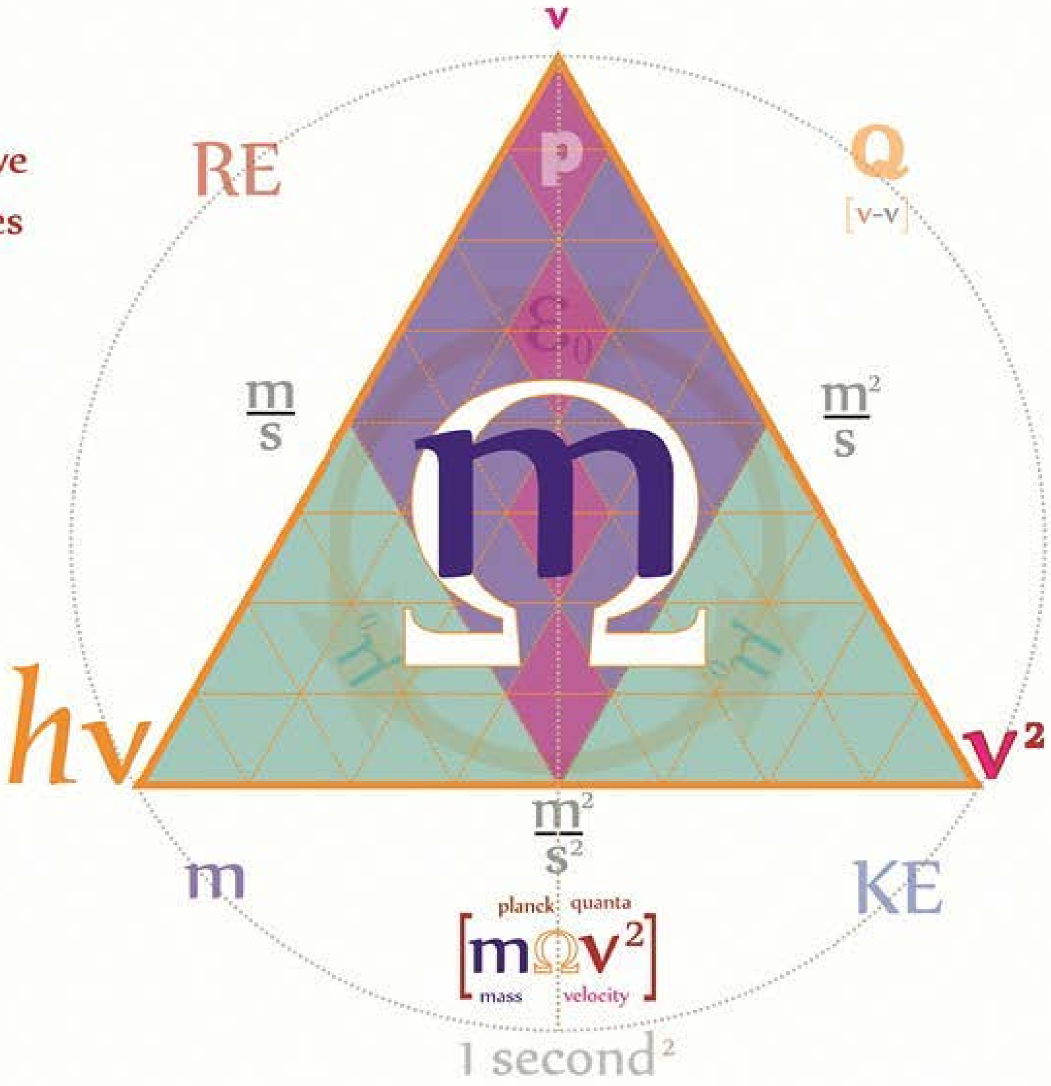
v
RE
p
Q
[v-v]
ε0
m/s
m²/s
m
Ω
μ0
hv
v²
m²/s²
m
KE
planck
quanta
[mΩv²]
mass
velocity
1 second²

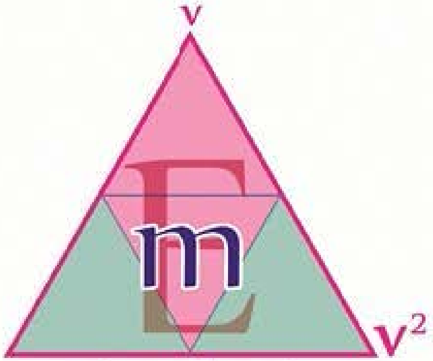

scalar mass velocity squared

$$mv^2 = E = hv^2$$

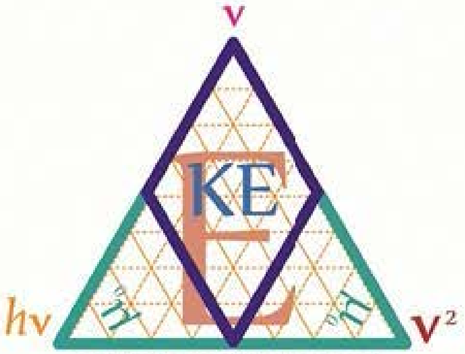
v
KE
E
μ0
ε0
hv
v²

quantised angular momenta per second

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m

mass

E

Energy

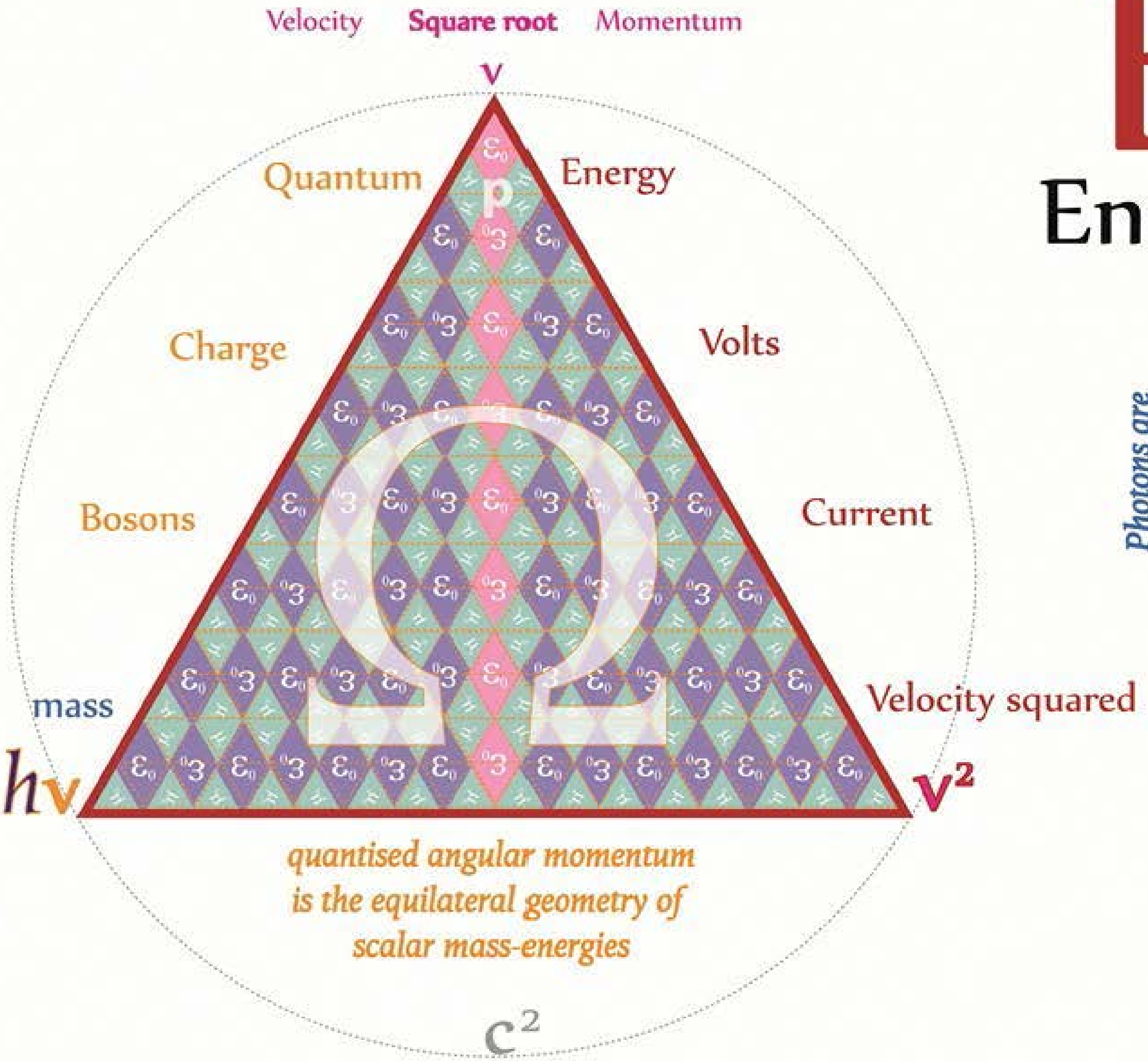
Velocity
Square root
Momentum
v
p
Quantum
Energy
Charge
Volts
Bosons
Current
mass
Velocity squared
$h\nu$
v^2
Ω
c^2

quantised angular momentum is the equilateral geometry of scalar mass-energies

Bosons are transverse EM masses

Photons are longitudinal EM masses

mass is a measure of Energy per spatial co-ordinate system

mass-Energy momenta

Electromagnetic energy is a scalar measurement of mass

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Bosons are Transverse masses

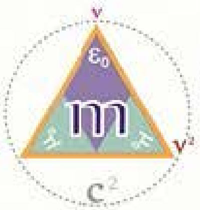

Planck mass

EM Field Planck quanta

$$\text{ODD}\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Bosons

ElectroMagnetic mass velocity

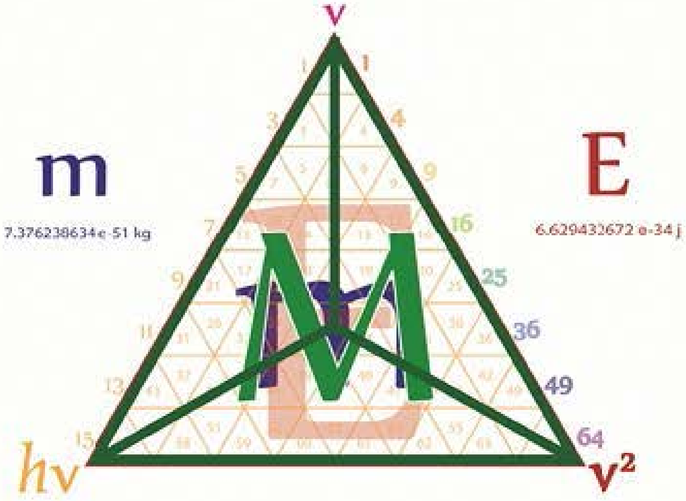

m

7.376238634e-51 kg

E

6.629432672 e-34 j

Photons are Longitudinal masses

Photons

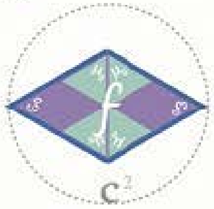

EM Field Planck quanta

$$\text{EVEN}\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Photons

ElectroMagnetic mass velocity

mass-ENERGY-Matter equivalence

LEPTONS

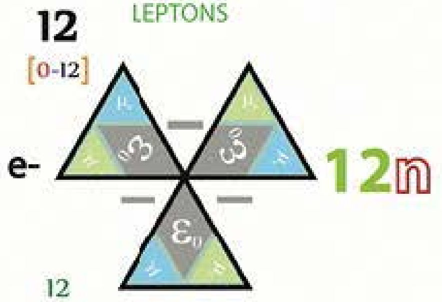

Tetryonic Matter of Electron - 8.851486361 x 10^{-31} Kg

mass-Energy of Electron - 7.955319207x 10^{-14} J

EM Field Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Fermions

ElectroMagnetic mass velocity

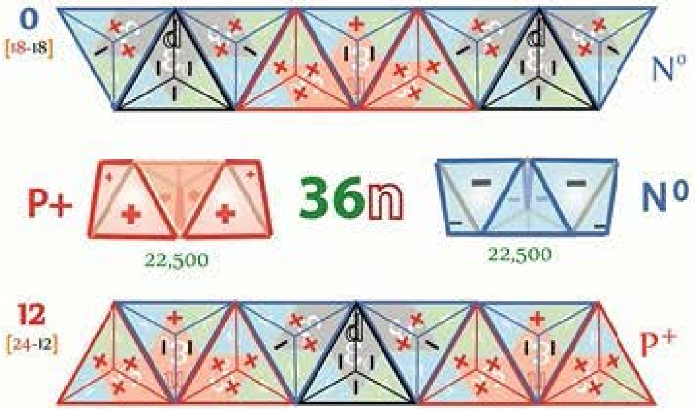

Tetryonic Matter of Proton - 1.659653693 x 10^{-27} Kg

mass-Energy of Proton - 1.491622351 x 10^{-10} J

EM Field Planck quanta

$$36\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Baryons

ElectroMagnetic mass velocity

ELEMENTS

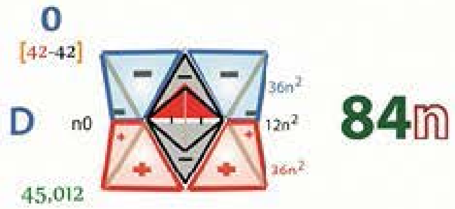

Tetryonic Matter of Deuterium - 3.320192534 x 10^{-27} Kg

mass-Energy of Deuterium - 2.984040234 x 10^{-10} J

EM Field Planck quanta

$$84\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Deuterons

ElectroMagnetic mass velocity

Tetryonics 15.08 - mass-Energy-Matter equivalence

EM mass quanta in Matter

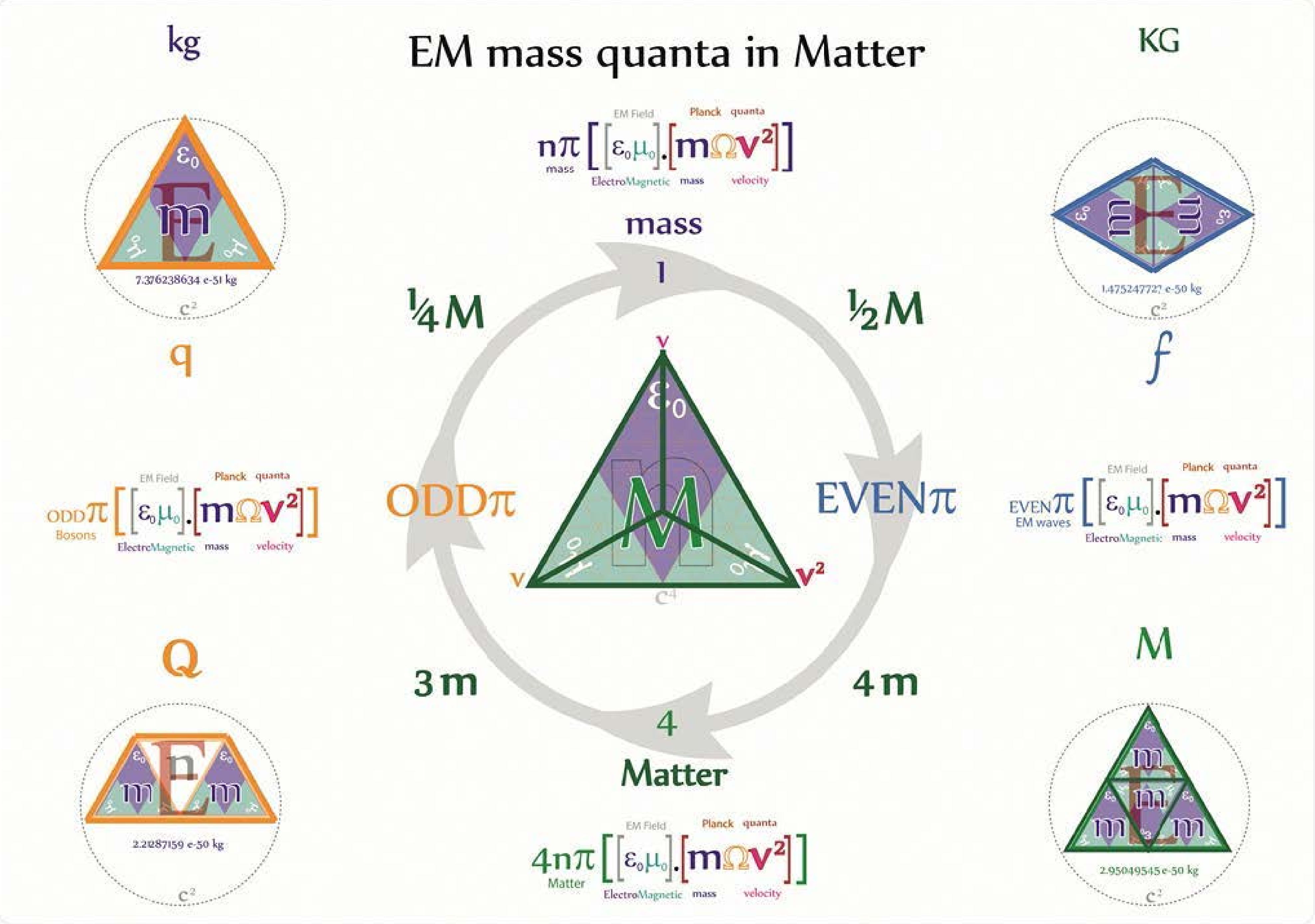
kg
KG
EM Field
Planck
quanta
$n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$
mass
ElectroMagnetic
mass
velocity
mass
1
¼ M
½ M
ε_0
m
E
7.376238634 e-51 kg
c^2
1.475247727 e-50 kg
c^2
q
f
EM Field
Planck
quanta
$ODD\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$
Bosons
ElectroMagnetic
mass
velocity
ODDπ
v
ε_0
M
v
v^2
c^4
EVENπ
EM Field
Planck
quanta
$EVEN\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$
EM waves
ElectroMagnetic
mass
velocity
Q
M
3 m
4 m
4
Matter
2.2287159 e-50 kg
c^2
2.950495545 e-50 kg
c^2
EM Field
Planck
quanta
$4n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$
Matter
ElectroMagnetic
mass
velocity

Tetryonics 15.09 - EM mass quanta in Matter

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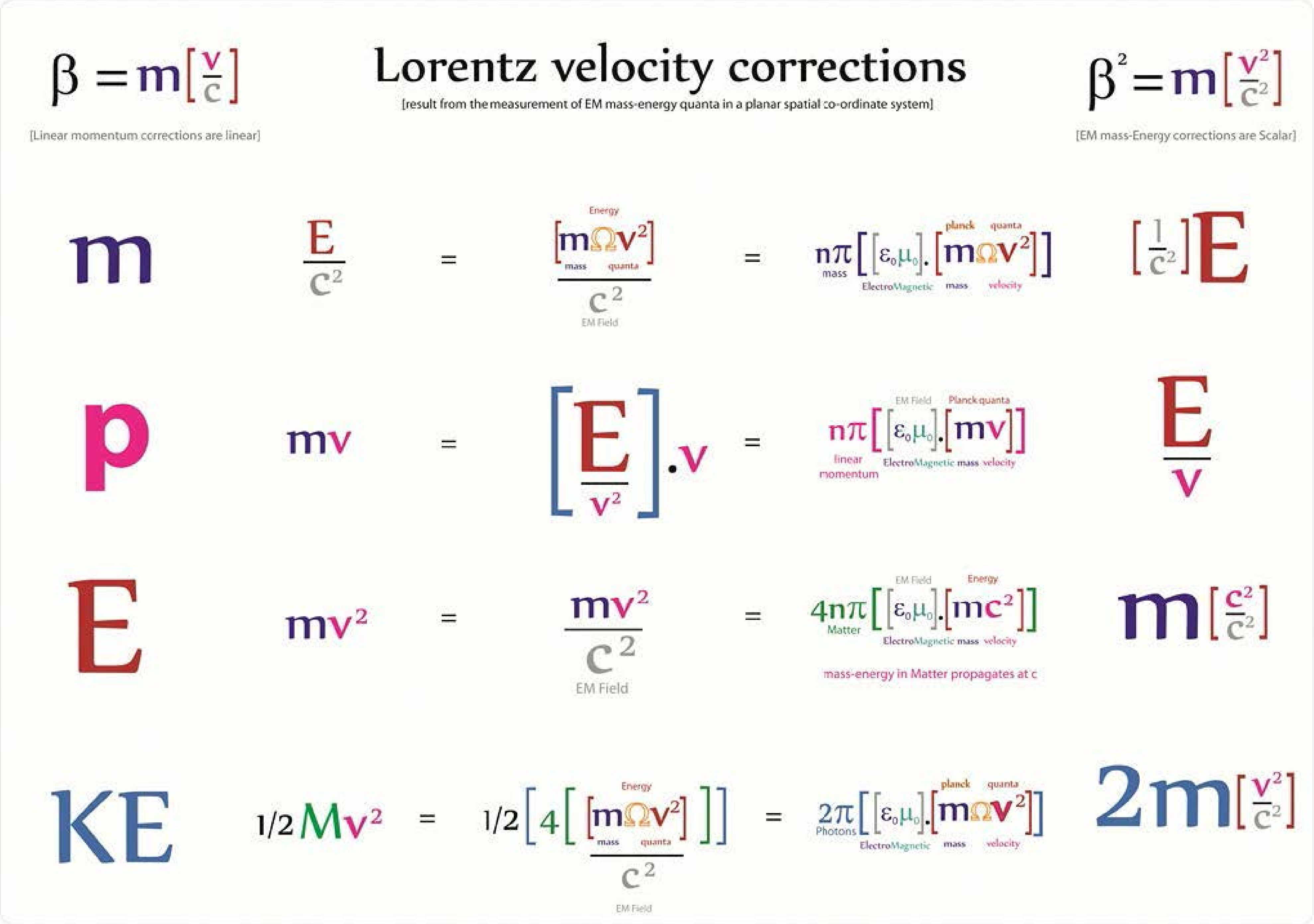

$$\beta = m\left[\frac{v}{c}\right]$$

[Linear momentum corrections are linear]

Lorentz velocity corrections

[result from the measurement of EM mass-energy quanta in a planar spatial co-ordinate system]

$$\beta^2 = m\left[\frac{v^2}{c^2}\right]$$

[EM mass-Energy corrections are Scalar]

$$m \qquad \frac{E}{c^2} = \frac{\overset{\text{Energy}}{\left[\underset{\text{mass}}{m}\underset{\text{quanta}}{\Omega}v^2\right]}}{\underset{\text{EM Field}}{c^2}} = \underset{\text{mass}}{n\pi}\left[\underset{\text{ElectroMagnetic}}{[\varepsilon_0\mu_0]}.\left[\overset{\text{planck}}{\underset{\text{mass}}{m\Omega}}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right] \qquad \left[\frac{1}{c^2}\right]E$$

$$p \qquad mv = \left[\frac{E}{v^2}\right].v = \underset{\text{linear momentum}}{n\pi}\left[\overset{\text{EM Field}}{\underset{\text{ElectroMagnetic}}{[\varepsilon_0\mu_0]}}.\overset{\text{Planck quanta}}{\left[\underset{\text{mass}}{m}\underset{\text{velocity}}{v}\right]}\right] \qquad \frac{E}{v}$$

$$E \qquad mv^2 = \frac{mv^2}{\underset{\text{EM Field}}{c^2}} = \underset{\text{Matter}}{4n\pi}\left[\overset{\text{EM Field}}{\underset{\text{ElectroMagnetic}}{[\varepsilon_0\mu_0]}}.\overset{\text{Energy}}{\left[\underset{\text{mass}}{m}\underset{\text{velocity}}{c^2}\right]}\right] \qquad m\left[\frac{c^2}{c^2}\right]$$

mass-energy in Matter propagates at c

$$KE \qquad 1/2\,Mv^2 = 1/2\left[4\left[\frac{\overset{\text{Energy}}{\left[\underset{\text{mass}}{m}\underset{\text{quanta}}{\Omega}v^2\right]}}{\underset{\text{EM Field}}{c^2}}\right]\right] = \underset{\text{Photons}}{2\pi}\left[\underset{\text{ElectroMagnetic}}{[\varepsilon_0\mu_0]}.\left[\overset{\text{planck}}{\underset{\text{mass}}{m\Omega}}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right] \qquad 2m\left[\frac{v^2}{c^2}\right]$$

Tetryonics 15.10 - Lorentz velocity corrections

The geometry of Constants

Quantised angular momentum is the source of all physical Constants

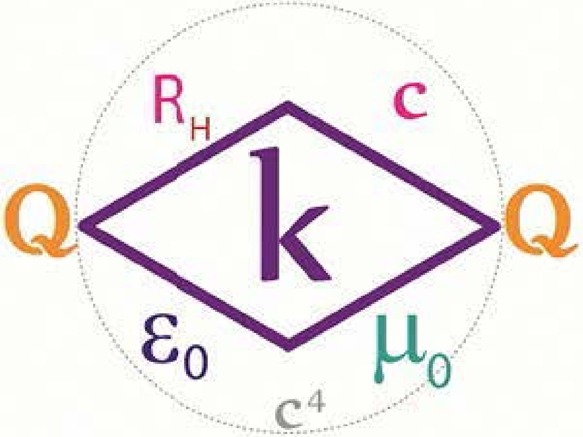
R_H
c
Q
k
Q
ε_0
μ_0
c^4

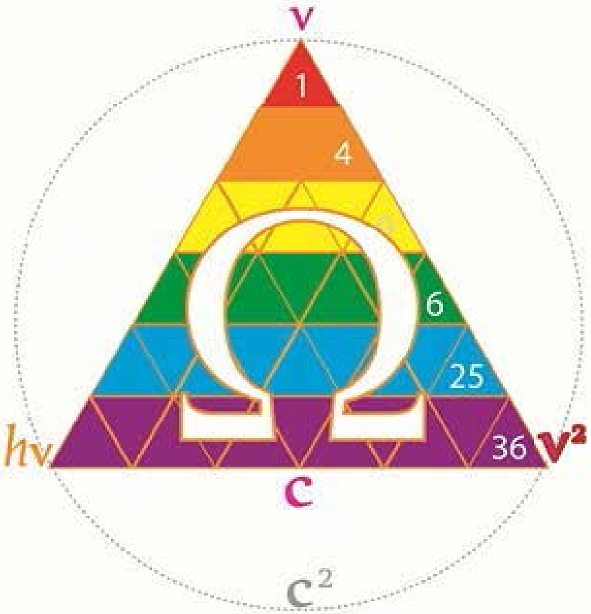
v
1
4
Ω
6
25
36
hv
v²
c
c^2

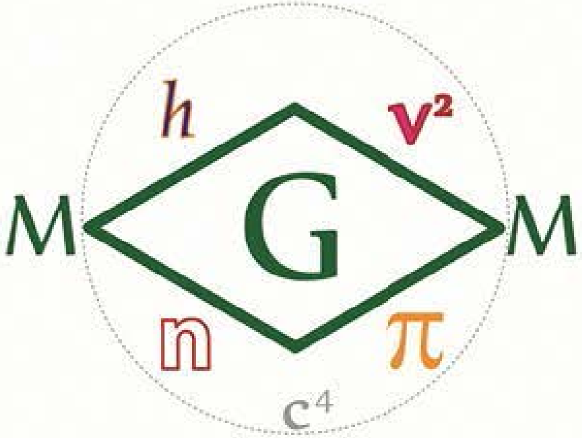
h
v²
M
G
M
n
π
c^4

A physical constant is a physical quantity that is generally believed to be both universal in nature and constant in time.

It can be contrasted with a mathematical constant, which is a fixed numerical value but does not directly involve any physical measurement

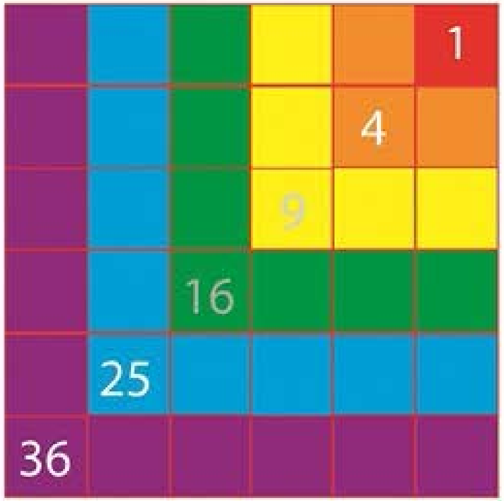

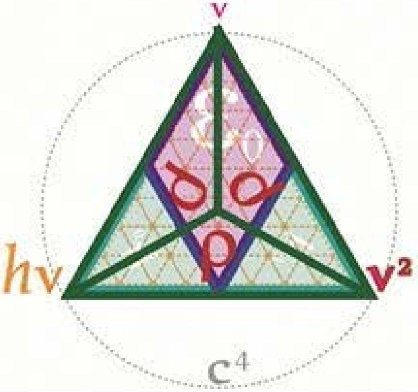

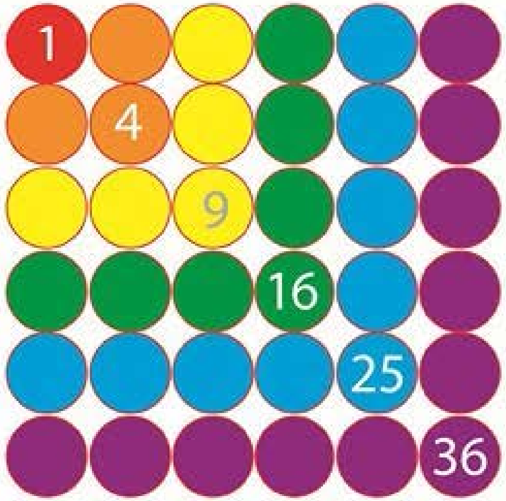

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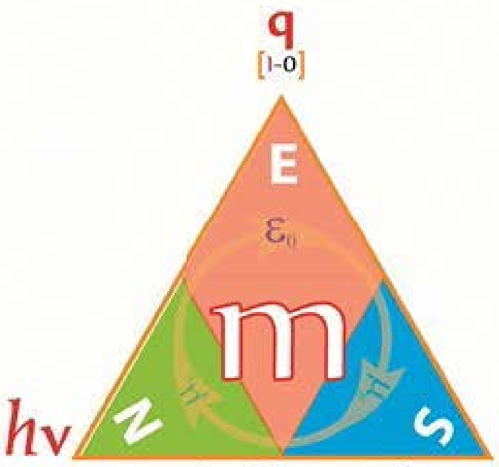
q
[1-0]
E
ε_0
m
N
S
hv

7.376238634 e-51 kg

"To interpret the vibrational energy of N oscillators not as a continuous, infinitely divisible quantity, but as a discrete quantity composed of an integral number of finite equal parts.

Max Planck

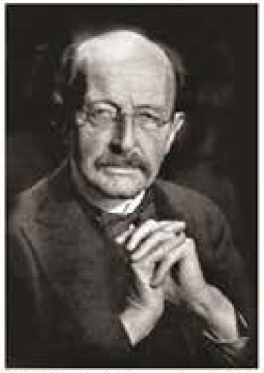

(April 23, 1858 – October 4, 1947)

$\mathcal{E} = nh\nu$

"Let us call each such part of the energy element h"

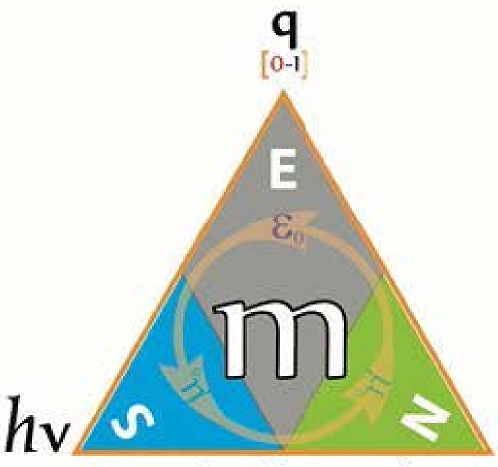
q
[0-1]
E
ε_0
m
S
N
hv

7.376238634 e-51 kg

Planck's Constant

[quantised mass-energy angular momenta]

Solving for Planck's Constant using
the inverse of Avogadros number & Tetryonic geometry
we obtain an exact corrected value of :

$$\pm 6.629432672 \times 10^{-34}\ \text{J.s}$$

$4.137664546 \times 10^{-15}$ eV.s

N_A

1 mole of Hydrogen atoms
has a rest-mass of 1 gram

$$mv^2 = E = h\nu^2$$

A rest mass Hydrogen atom
has a Compton frequency of
2.2512 e23 Planck quanta

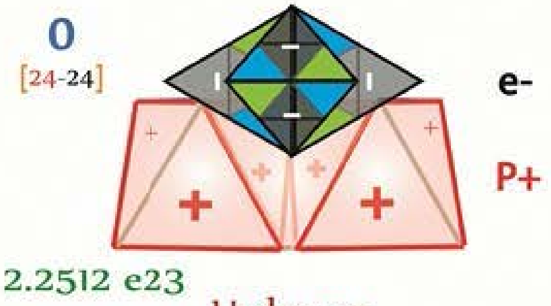
0
[24-24]
e-
P+
2.2512 e23

Hydrogen

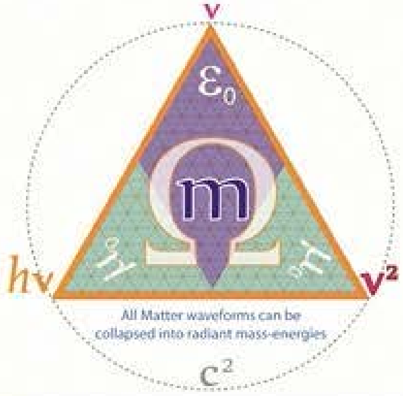
v
ε_0
m
hv
v²
All Matter waveforms can be collapsed into radiant mass-energies
c²

$$T\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

EM Field · Planck · quanta · Matter · ElectroMagnetic · mass · velocity

Planck's constant is the relationship between EM mass-energy and quantised angular momenta that provides the basis for EM charge in Tetryonic geometries

Tetryonics 16.02 - Planck's Constant

Amedeo Avogadro

(9 August 1776 – 9 July 1856)

Avogadro's Number

The number of rest mass Hydrogen atoms in 1 gram
(and the rest molar mass of any element or compound)
can be determined directly from tetryonic theory

[exclusive of any measurement, blackbody or kinetic energies]

Using a Compton frequency of 2.2512 e23 Planck quanta
for a rest mass-Matter Hydrogen atom

atomic mass unit

$$1\ \mathrm{u} = \frac{M_{\mathrm{u}}}{N_{\mathrm{A}}} = 1.660\,538\,782(83) \times 10^{-24}\ \mathrm{g}$$

Avogadro N = 6.022141579 x 10^{23}

$$N^{-1} = \underset{1.660538841 \times 10^{-24}\ \mathrm{g}}{\overset{2.2512\ \mathrm{e}23\ \mathrm{v}}{[\text{Hydrogen mass}]}}$$

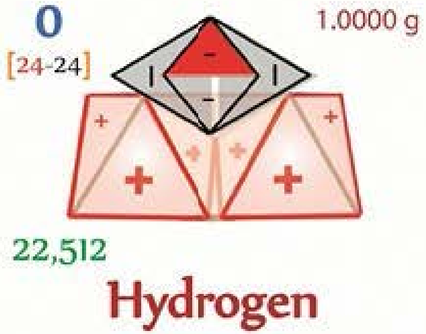

n0 *1 mol = 1 g*

Hydrogen = 1.660538841 x 10^{-27} Kg

n1 *1 mol = 1.000533 g*

n0 *1 mol = 11.996801 g*

Carbon 12 = 1.99211552 x 10^{-26} Kg

n1 *1 mol = 12 g*

Hydrogen's rest Tetryonic mass
is 22,512 n Planck quanta
[Proton - 22,500n + electron 12n]

$$\left[22{,}512\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{[\varepsilon_0\mu_0]}}.\overset{\text{Planck}\quad\text{quanta}}{[\underset{\text{mass}}{m}\Omega\underset{\text{velocity}}{v}^{2}]}\right]\right]^{-1}$$

The inverse mass of Hydrogen is
equal to Avogadro's number

Coulomb's Constant

$$k = \frac{1}{4\pi\varepsilon_0}$$

The proportionality constant ke, called the Coulomb constant (sometimes called the Coulomb force constant), is related to defined properties of EM Energy-momenta and is used to define Electric field forces

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

$$8.987\ e9\ \frac{Nm^2}{C^2}$$

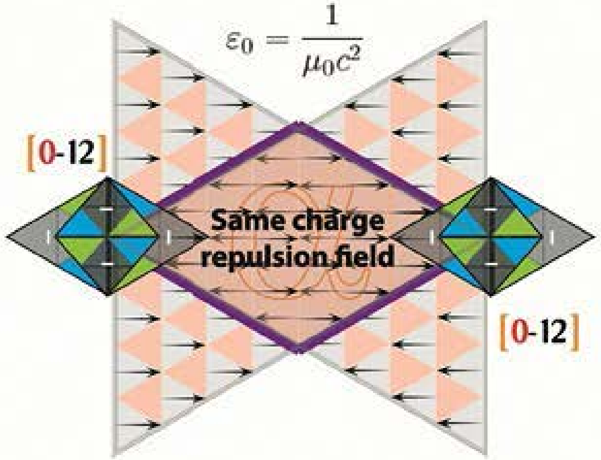
$\varepsilon_0 = \frac{1}{\mu_0 c^2}$
[0-12]
Same charge repulsion field
[0-12]

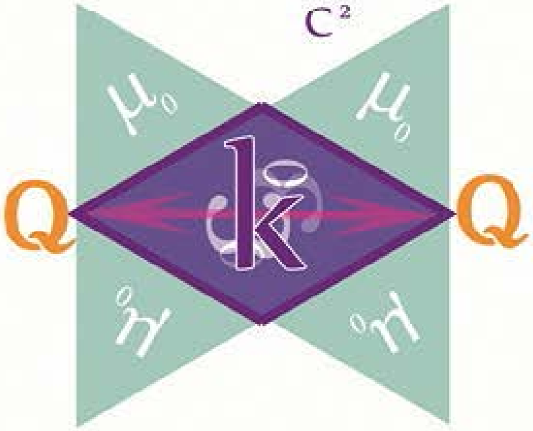
μ_0
μ_0
Q
k
Q
ε_0
ε_0

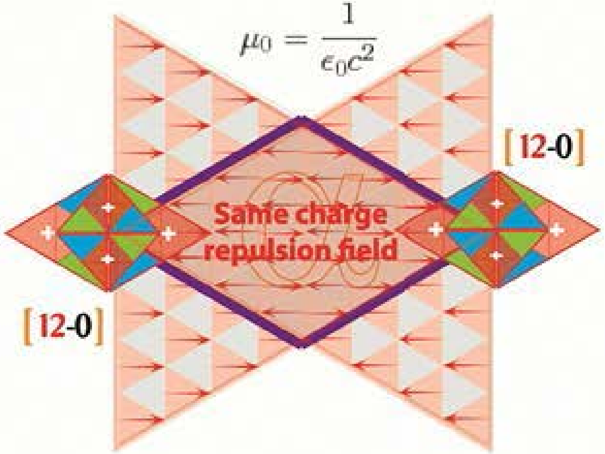
$\mu_0 = \frac{1}{\epsilon_0 c^2}$
[12-0]
Same charge repulsion field
[12-0]

Similars repel

Opposites attract

Similars repel

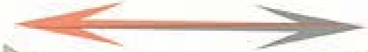

Linear Coulombic force interactions are a result of charged E field linear momenta

Longitudinal E field forces between Charged particles are mediated by Photons

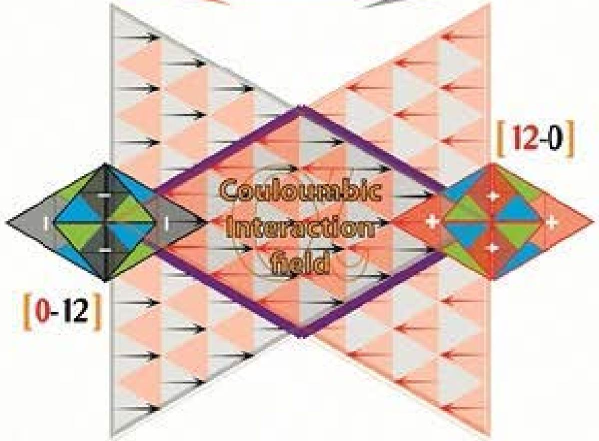
[12-0]
Couloumbic Interaction field
[0-12]

It is a measure of the interactive force produced by the Electric field energy-momenta of two superpositioned charge KEM fields

$$\mathbf{E} = \frac{\mathbf{F}}{q_t}$$

The Electric field can be defined as the longitudinal Force exerted by charged masses

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{\mathbf{r}}$$

The Electric field can also be derived from Coulomb's Law

The Speed of ElectroMagnetic energies

C

The classical behaviour of the electromagnetic field is described by Maxwell's equations, which predict that the speed c with which electromagnetic waves (such as light) propagate through the vacuum is related to the electric constant ε0 and the magnetic constant μ0 by the equation c = 1/√ε0μ0.

Celeritas is a Latin word for "swiftness" or "speed". It is often given as the origin of the symbol c, the universal notation for the speed of light in a vacuum

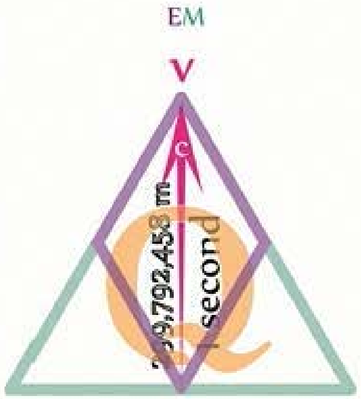

The distance energy travels in 1 second from its source

EM waves and energy momenta can be measured as either Transverse or Longitudinal waveforms with respect to their velocity vector

All EM waves and energy are symmetrical waveforms whose quanta contain ElectroMagnetic mass-energy and momenta

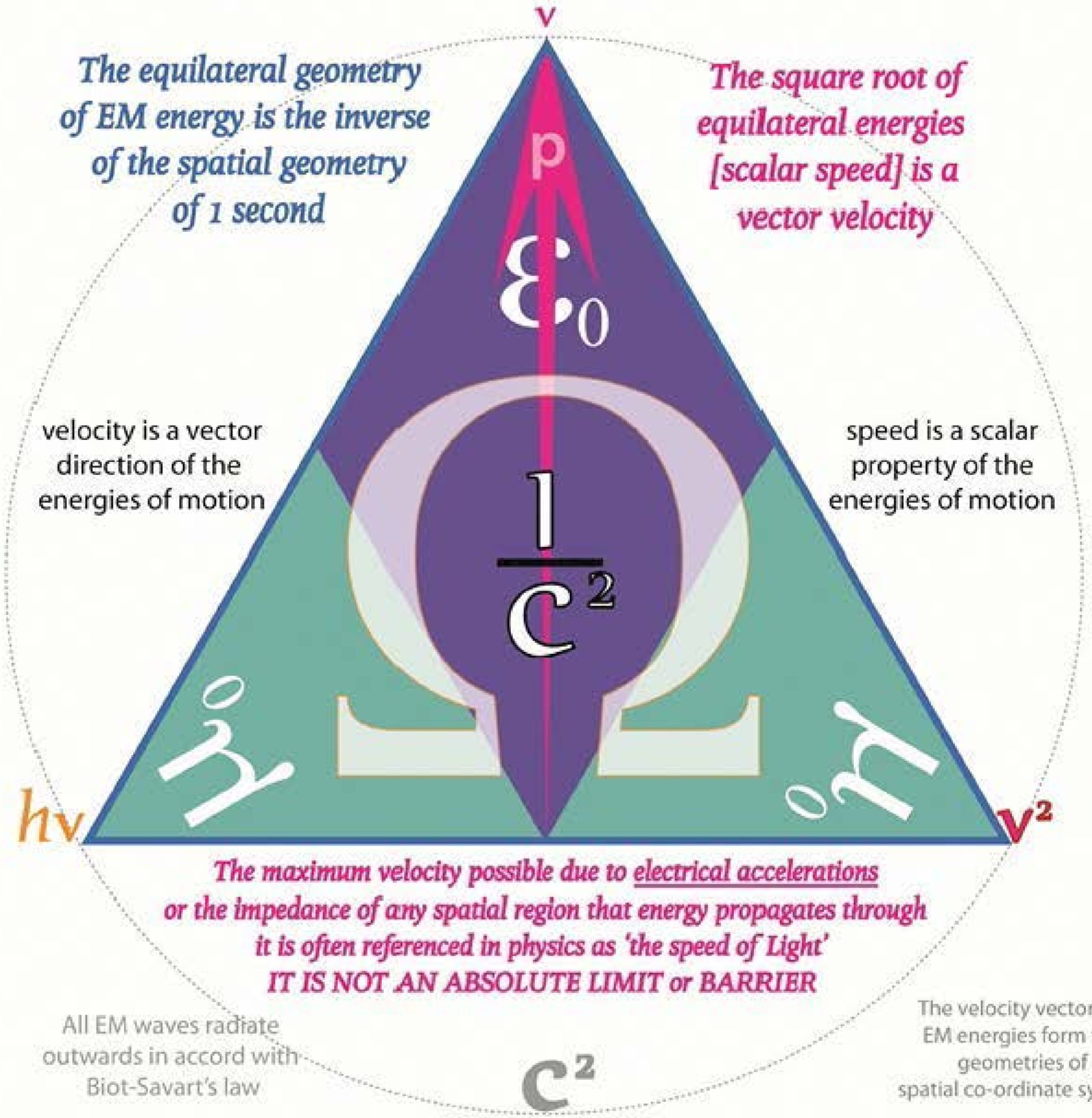

The equilateral geometry of EM energy is the inverse of the spatial geometry of 1 second

The square root of equilateral energies [scalar speed] is a vector velocity

velocity is a vector direction of the energies of motion

speed is a scalar property of the energies of motion

The maximum velocity possible due to electrical accelerations or the impedance of any spatial region that energy propagates through it is often referenced in physics as 'the speed of Light'

IT IS NOT AN ABSOLUTE LIMIT or BARRIER

All EM waves radiate outwards in accord with Biot-Savart's law

The velocity vectors of EM energies form the geometries of spatial co-ordinate systems

The speed of EM energies in a vacuum is defined as 299,792,458 meters per second (1,079,252,848.8 km/h).

$$\frac{K_E}{K_M} = 9e16 \, \frac{\frac{N\,m^2}{c^2}}{\frac{N\,s^2}{c^2}}$$

$$C^2 = 9e16 \, \frac{m^2}{s^2}$$

$$C = 299{,}792{,}458 \, \frac{m}{s}$$

The natural velocity of EM energies can be calculated from the field's EM permittivity & permeability and is affected by the medium it is propagating through

EM waveforms are bidirectional radiant emissions of 2D energy

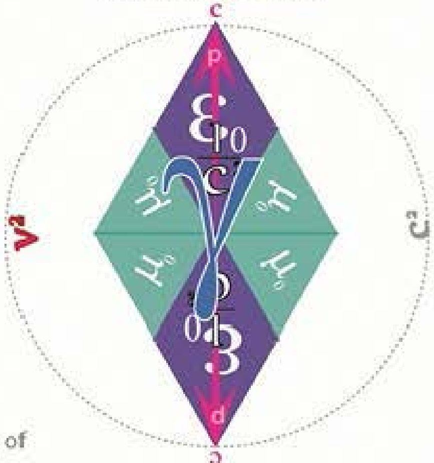

with velocity [Lorentz] variable energy contents

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Quantum masses

mass quanta

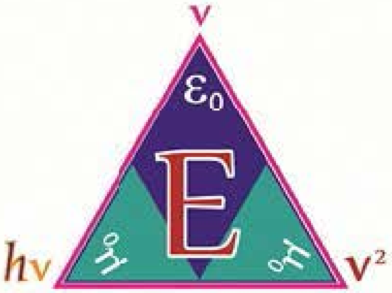

EM mass-energy quanta

Matter is a KEM standing wave propagating at c

EM Field

planck quanta

$$\left[\varepsilon_0\mu_0\right]\left[m\Omega v^2\right]$$

mass velocity

1.112650056 e-17
s2 m-2

6.629432672 e-34
kg m2 s-2

Permittivity x Energy density

$$\frac{E}{c^2} = m$$

v
ε_0
m
v^2
mass
c^2

mass = 7.376238634 x 10^{-51} Kg

Planck-Einstein

$$hv^2 = E = mv^2$$

$$kg\,\frac{m^2}{s}\,\frac{1}{s} \qquad kg\,\frac{m^2}{s^2} \qquad kg\,\frac{m^2}{s^2}$$

The quantum of mass-energy can be derived with several methodolgies using Tetryonic Geometry

Planck mass-energy geometries

quantised energy momenta

h

$$kg\,\frac{m^2}{s}$$

6.629432672 e-34 J

Planck quanta

$$\left[m\Omega v^2\right]$$

mass velocity

7.376238634 e-51 kg

$$kg\,\frac{m^2}{s^2}$$

m

scalar mass-energy

Charged mass-Matter topologies

The mass EM Field Planck quanta

$$T\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

of Matter ElectroMagnetic mass velocity

Matter Quanta

Tetryonic molar mass [Hydrogen] - 1 g

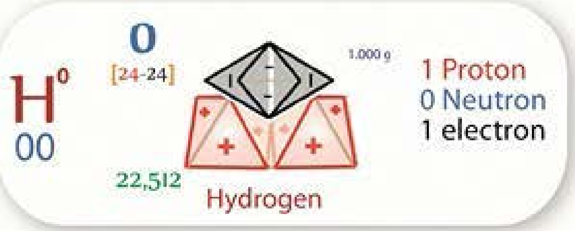

1 Proton
0 Neutron
1 electron

$$\text{Molar mass} = \frac{H_1\ \text{Atomic mass}}{\text{Avagadro's No.}}$$

$$\text{mass}\ H_{mol}/Av = \frac{.001}{6.022141579 \times 10^{23}}$$

$$= 1.660538841 \times 10^{-27}\ \text{g/mol}$$

$$H_{mole}\ /\ \text{m}[H] = \frac{1.660538841 \times 10^{-27}}{22{,}512}$$

mass = 7.376238634 x 10^{-32} KG

Avogadro - Mandeleev

2D mass-Energy equivalence

'The Speed of Light' is the Natural velocity of Energy propagation

Energy

$$mv^2 = hv^2$$

EM mass

$$\frac{mv^2}{c^2}$$

$$\frac{mv^2}{h}$$

$$\frac{c^2}{v^2}$$

8.987551787 e16

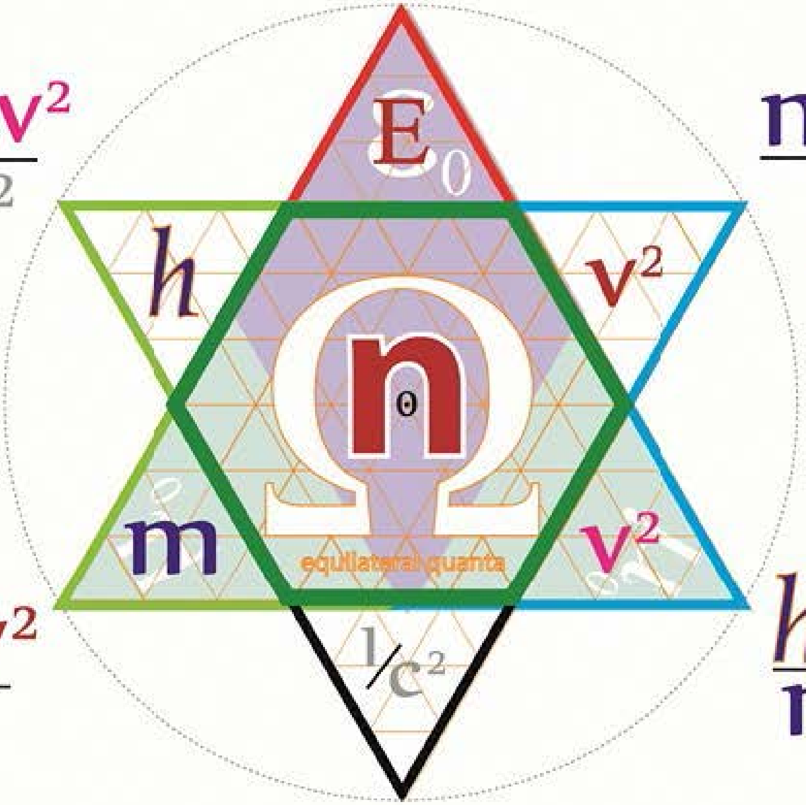
E_0
h
v^2
Ω
n_0
m
v^2
equilateral quanta
$^1/_{c^2}$

1.112650056 e-17

$$\frac{m}{h}$$

$$\frac{hv^2}{c^2}$$

$$\frac{hv^2}{m}$$

$$\frac{m}{hv^2}$$

Photons

Matter

Tetryonics 16.07 - 2D mass-Energy equivalence

Zero Point Fields

EM Field Planck quanta

$n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Quanta ElectroMagnetic mass velocity

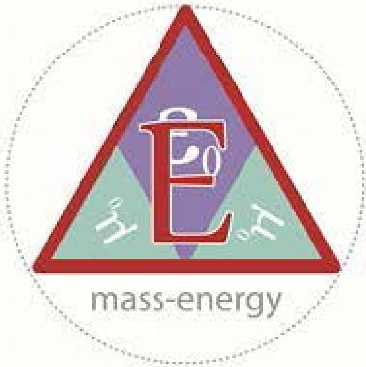

m=1π

[1, 2, 3, 4, 5, 6, 7, 8, 9,10......]

radiant 4π mass-energy geometries

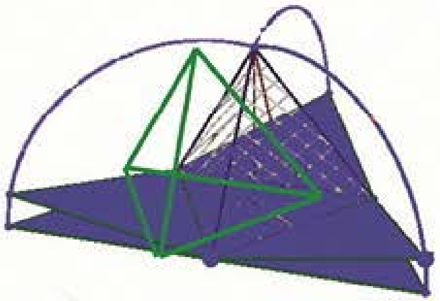

in standing wave topologies are 3D MATTER quanta

[2D EM masses are planar energy momenta]

Photons

EM Field Planck quanta

$2n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Photons ElectroMagnetic mass velocity

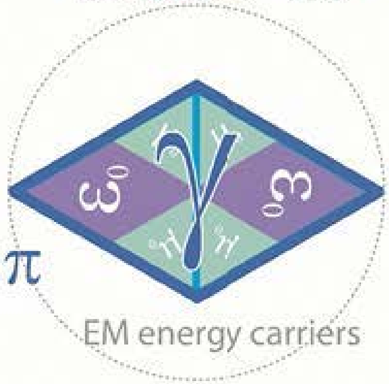

m=2π

[2, 8,18, 32, 50, 72, 98,128......]

The geometry of mass and Matter

[1, 3, 5, 7, 9, 11, 13,15, 17, 19.........]

[3D Matter has mass-energy momenta and volume]

[4, 8,12, 24, 36, 48, 72, 84, 168......]

Charge Carriers

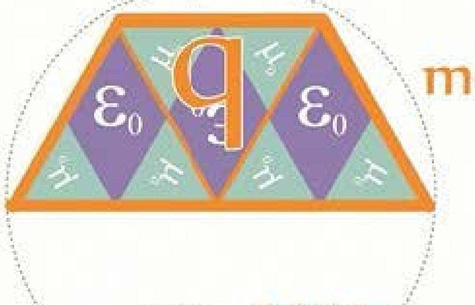

m=3π

EM Field Planck quanta

$\text{ODD}n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Bosons ElectroMagnetic mass velocity

Bosons

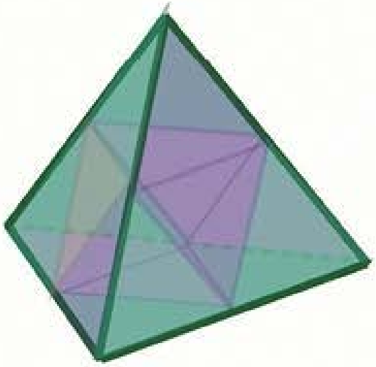

3D Matter topologies are standing waves of 2D mass-energies propagating at c

m=4π

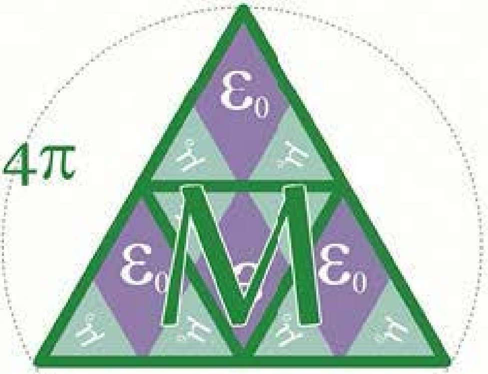

EM Field Planck quanta

$4n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Matter ElectroMagnetic mass velocity

mass-Matter

Tetryonics 17.01 - The geometry of mass and Matter

mass geometries & rest Matter topology

2D

m

mass

kg

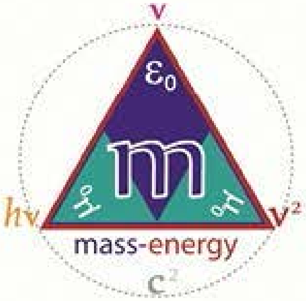
v
ε0
m
hv
v²
mass-energy
c²

M

Matter

KG

3D

Quanta number

1e19 v

Compton frequency

Matter is a three dimensional charged mass-energy topology

EM Field Planck quanta

$$M = 4n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Matter ElectroMagnetic mass velocity

Energy density is mass - the term 'massless particle' is a misnomer

Quantum number

n

Nuclear Level

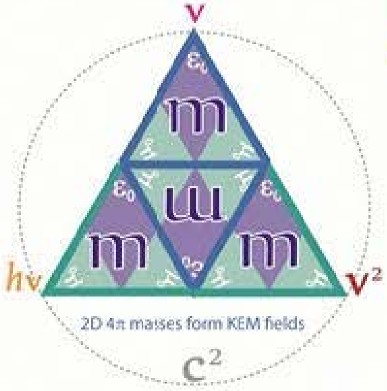
v
ε0
m
ε0
ш
ε0
m
m
hv
v²
2D 4π masses form KEM fields
c²

Kinetic Energies

RE = Matter + KE

Relativistic mass is the total EM energy content of a massive body (or system) in motion

The relativistic rest mass-energies of Matter are velocity invariant as 3D Matter is a EM standing wave with 2D mass- energy fascia whose velocity of propagation is the speed of Light

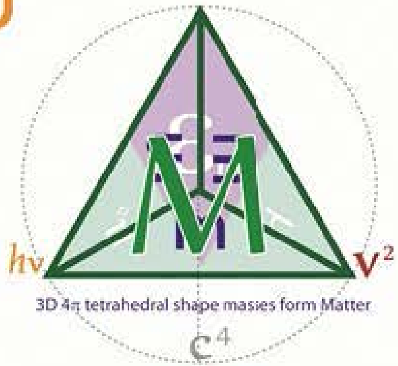
M
hv
v²
3D 4π tetrahedral shape masses form Matter
c⁴

Matter

Tetryonics 17.02 - mass geometries & rest Matter topology

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Charge topologies and rest mass-energies

mass-Matter topologies

mass-energy geometries

12 [0-12]

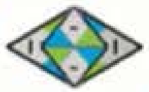

1.2 e20

Electron

n=0

Q

0.00000053 g
molar mass

Tm Electron = 12n

electron Charge	-1.602216081x 10[illegible] c
electron rest mass	8.851486361 x 10[illegible] kg
electron rest energy	7.955319207 x 10[illegible] J 496,519.7 eV [illegible]

12 [24-12]

Proton

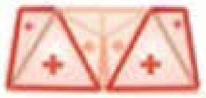

2.25 e23

Q

n=25²

0.000999 g
molar mass

Tm Proton = 22,500n

Proton Charge	+1.602216081 x 10[illegible] c
Proton rest mass	1.659653693 x 10[illegible] kg
Proton rest energy	1.491622351 x 10[illegible] J 930,974,522.8 eV [illegible]

Protons and Neutrons have identical masses to each other
and equivalent topologies but differing charges

0 [18-18]

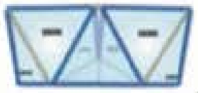

2.25 e23

Neutron

Q

n=25²

0.000999 g
molar mass

Tm Neutron = 22,500n

Neutron Charge	0
Neutron rest mass	1.659653693 x 10[illegible] kg
Neutron rest energy	1.491622351 x 10[illegible] J 930,974,522.8 eV [illegible]

Hydrogen

When Protons and electrons interact to form neutral Hydrogen the electron's KEM quantum field energies increase in direct proportion to the Proton's energy levels

0 [24-24]

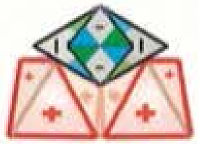

2.2512 e23

n=0

Q

n=25²

1.000533 g
molar mass

Tm Hydrogen = 22,512n

Hydrogen = Proton + electron

H Charge	0
H rest mass	1.660538841 x 10[illegible] kg
H rest energy	1.492417883 x 10[illegible] J 931,967,562.3 eV [931.9MeV]

0 [42-42]

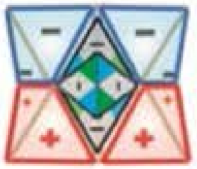

4.5012 e23

quantum synchronous converters

n=0

Q

n=25²

1.999466 g
molar mass

Tm Deuterium = 22,512n

Hydrogen = Proton + electron

H Charge	0
H rest mass	3.320192534 x 10[illegible] kg
H rest energy	2.984040234 x 10[illegible] J 1,862,445,565 eV [illegible]

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In order to make an exact 1kg reference mass-Matter topology

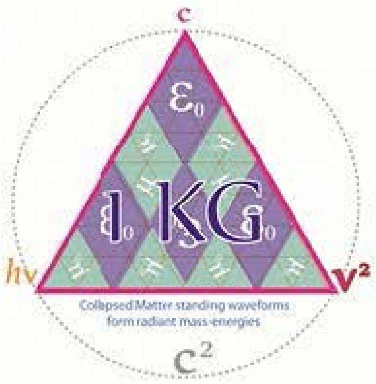
c
ε0
1KG
hv
v²
Collapsed Matter standing waveforms
form radiant mass-energies
c²

mass

$$\frac{n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

Planck quanta mass velocity

mass-energy

Energy per second

$$\boxed{mc^2 = E = hv^2}$$

$$m = E/c^2$$

mass is the scalar integral surface area of Matter topologies

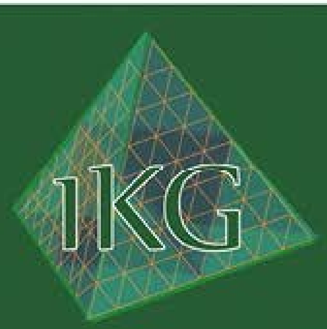

which is equivalent to exactly 1,000 molar Hydrogen masses

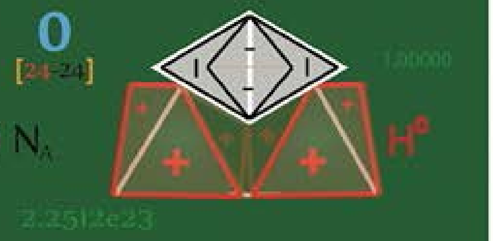
0
[24-24]
1,000 N_A
1.00000
H⁰
2.2512e23

whose Tetryonic Matter topology can be modelled using charged Planck mass-energy geometries

grams per kg

$$M = 1{,}000 \times N_A \, T\pi\left[\left[m\Omega v^2\right]\right]$$

1kg

6.022141579 e23 Avogadro's number

6.629432672 e-34 J Energy

revealing that there are exactly

1.355704512 e50

Planck quanta in standing wave Matter

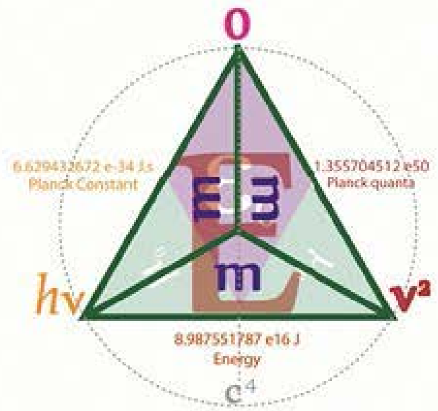
0
6.629432672 e-34 J.s
Planck Constant
1.355704512 e50
Planck quanta
E
m
hv
v²
8.987551787 e16 J
Energy
c⁴

Matter

$$\frac{T\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

Planck quanta mass velocity

Matter-energy

Energy per second squared

$$\boxed{hv^2 = E = Mc^4}$$

$$M = E/c^4$$

Matter topologies are standing-waves of mass-energy

you need to create a standing-EM wave with a specific compton frequency

EM mass and Matter defined

There remains a lot of confusion over the exact definition of EM mass and Matter resulting in the frequent interchanging of one term for the other in physical processes

This must be clarified and the two terms must be properly defined in a manner that explains their derivation and physical properties in detail.

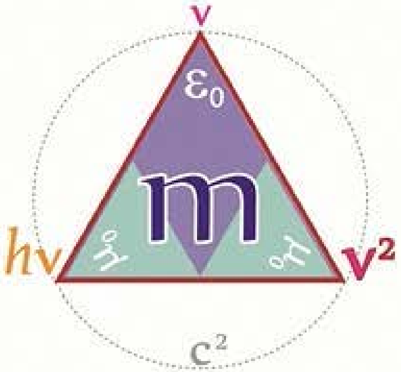

$$m = \frac{E}{c^2}$$

EM mass

3D Matter is comprised of 2D mass-energies
2D mass-energy cannot contain 3D Matter

Matter

$$M = \frac{4\pi E}{c^4}$$

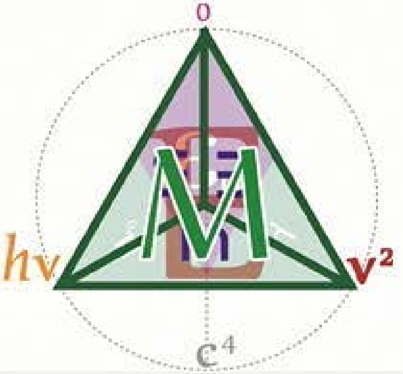

$$n\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

EM Field Planck quanta
mass ElectroMagnetic mass velocity

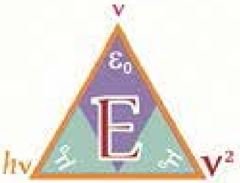

$$n\pi\left[[m\Omega v^2]\right]$$

Planck quanta
Energy mass velocity

2D mass-Energies

EM mass is a measure of equilateral scalar energy per unit of Time

$$\beta = \left[\frac{v}{c}\right]$$

mass is the Lorentzian velocity corrected energy content of Tetryonic geometries

All forms of EM mass-Energy are subject to Lorentz factor relationships

$$\beta^2 = \left[\frac{v}{c}\right]^2$$

Matter is Lorentz invariant as its mass-energies propagate in a 4π standing wave geometry

Bosons and Photons are not 'massless' they are 'Matterless' [2D waveforms]

Bosons

$$m_p = \frac{hv}{c^2}$$

Planck masses

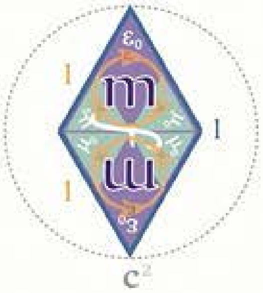

Photons

$$m_\gamma = \frac{hf}{c^2}$$

Photon mass

$$\text{ODD}\,\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

EM Field Planck quanta
Bosons ElectroMagnetic mass velocity

$$\text{EVEN}\,\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

EM Field Planck quanta
EM waves ElectroMagnetic mass velocity

$$4n\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

EM Field Planck quanta
Matter ElectroMagnetic mass velocity

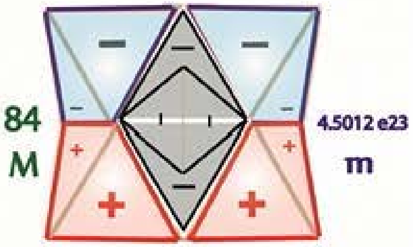

$$84\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

EM Field Planck quanta
Deuterium ElectroMagnetic mass velocity

Matter is the 3D topology of standing wave 2D mass-energies

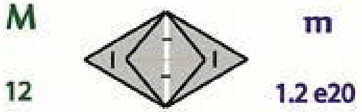

$$12\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right] \quad e-$$

EM Field Planck quanta
electrons

+

$$72\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right] \quad \text{Deuteron}$$

Nuclei ElectroMagnetic mass velocity

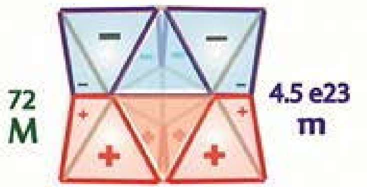

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Charged mass-Matter geometries

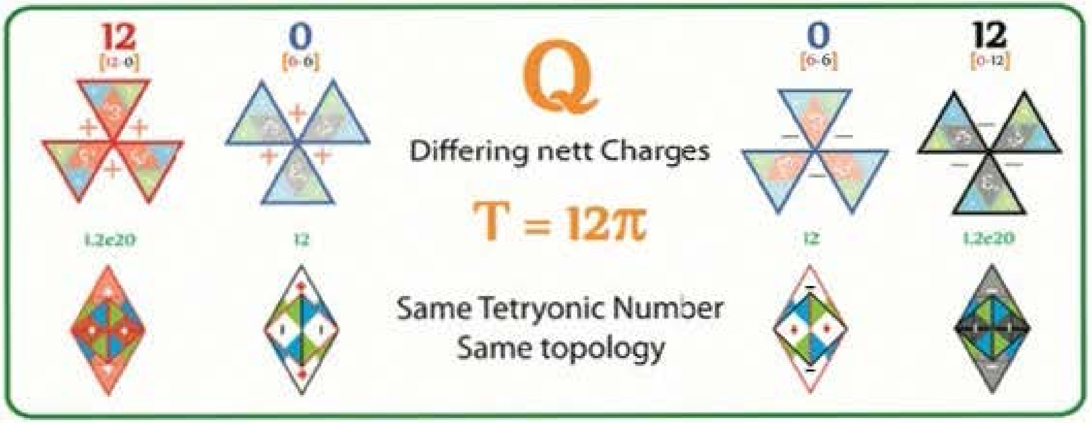

Q

Differing nett Charges

$T = 12\pi$

Same Tetryonic Number
Same topology

Matter Topology is determined by the geometry of charged Planck T[q] quanta

Any measurement of a system's mass is subject to velocity corrections

mass = EM energy density

Planck quanta

$$n\pi\left[\frac{m\Omega v^2}{c^2}\right]$$

mass quanta; mass; velocity; Spatial geometry

n [7.376238634 e-51] kg

EM mass is a measure of 2D planar energies comprising the fascia of charged topologies

ENERGY
Planck quanta

$$n\pi\left[\left[m\Omega v^2\right]\right]$$

mass velocity

m

M

c^2
2D space

The mass - ENERGY - Matter contents of any physical system are all related through the spatial co-ordinate system used [which in turn is determined by the speed of light]

c^4
3D space

mass
Planck quanta

$$\frac{n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

E

Matter
Planck quanta

$$\frac{T\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

The Energy content of any physical system remains the same irrespective of the spatial co-ordinates used

Matter and Charge are velocity invariant properties

Differing Tetryonic charge numbers produce differing particle topologies

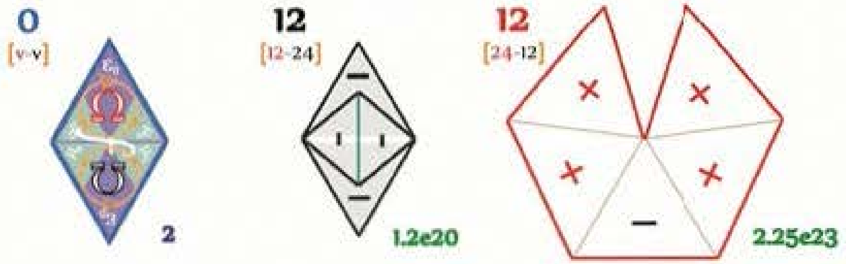

Photons
Planck quanta

$$\frac{2\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

Planck quanta

$$\frac{12\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

Baryons
Planck quanta

$$\frac{36\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

As the energy content [levels] of particles and fields increase their intrinsic Planck quanta and EM mass increases but their charge geometries remain the same

Charged mass-Energies

All 3D Matter particles are comprised of charged fascia whose energy content determines their 2D mass

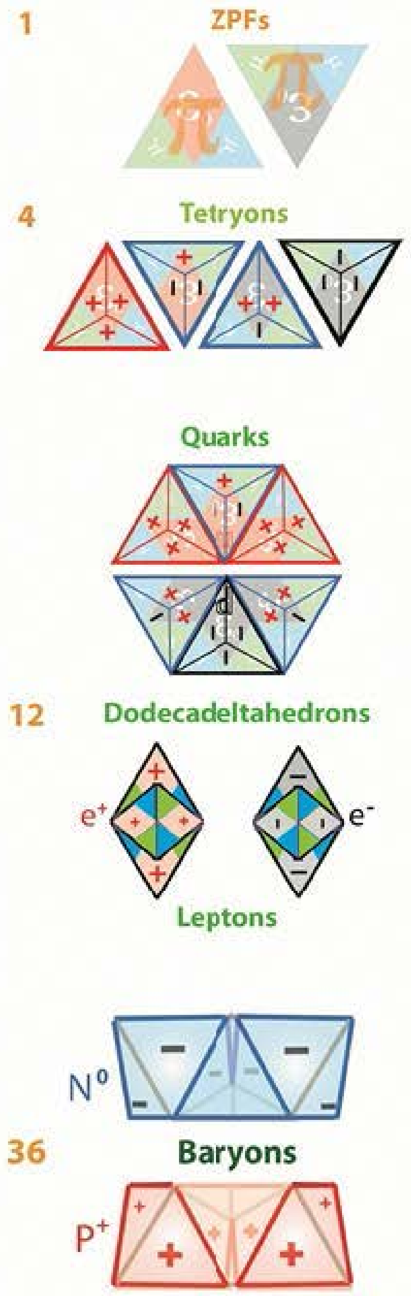
1
ZPFs
4
Tetryons
Quarks
12
Dodecadeltahedrons
e+
e-
Leptons
N0
36
Baryons
P+

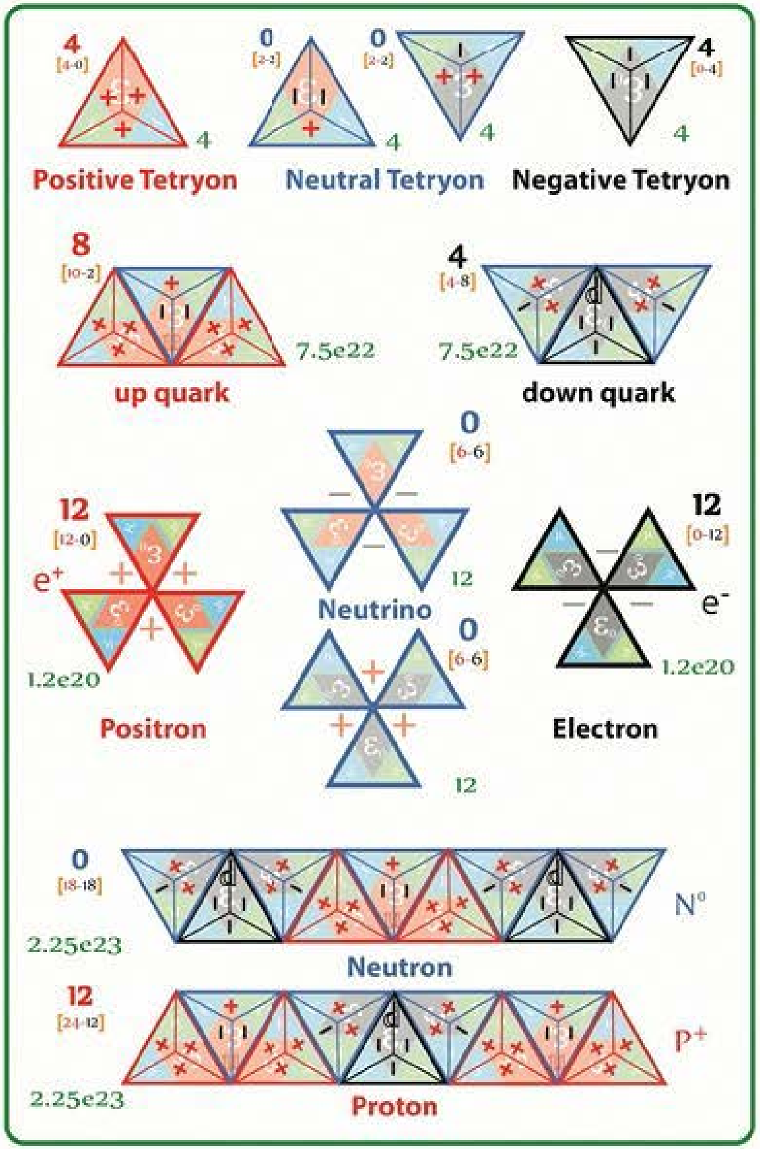
4
[4-0]
4
Positive Tetryon
0
[2-2]
4
0
[2-2]
4
Neutral Tetryon
4
[0-4]
4
Negative Tetryon
8
[10-2]
7.5e22
up quark
4
[4-8]
7.5e22
down quark
0
[6-6]
12
Neutrino
0
[6-6]
12
12
[12-0]
e+
1.2e20
Positron
12
[0-12]
e-
1.2e20
Electron
0
[18-18]
2.25e23
N0
Neutron
12
[24-12]
2.25e23
P+
Proton

3D Matter geometries

Matter Planck quanta

$$\frac{T\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

Tetryons
4 charge fascia

4π $2.651773069 \times 10^{-33}$ J

$2.950495454 \times 10^{-50}$ kg

4 quanta

Quarks
12 charge fascia

12π $4.97207450 \times 10^{-11}$ J

$5.532178976 \times 10^{-28}$ kg

7.5×10^{22} quanta

Neutrinos
12 charge fascia

12π $7.955319207 \times 10^{-33}$ J

$8.851486361 \times 10^{-50}$ kg

12 quanta

Leptons
12 charge fascia

12π $7.955319207 \times 10^{-14}$ J

$8.851486361 \times 10^{-31}$ kg

1.2×10^{20} quanta

Baryons
36 charge fascia

36π $1.491622351 \times 10^{-10}$ J

$1.659653693 \times 10^{-27}$ kg

2.250×10^{23} quanta

Deuterium
72 charge fascia
ion

72π $2.984040234 \times 10^{-10}$ J

$3.320192534 \times 10^{-27}$ kg

4.5012×10^{23} quanta

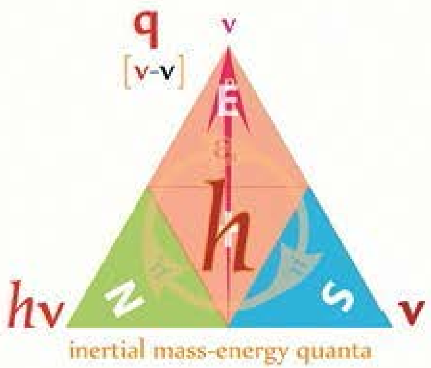
q
[v-v]
v
E
h
hv
N
S
v
inertial mass-energy quanta

In physics there exists
2 forms of energy momenta
[linear momenta &
quantised angular]

MOMENTA

v
ε_0
m

The nett scalar
energy momenta
required to effect
changes in velocity

ENERGY

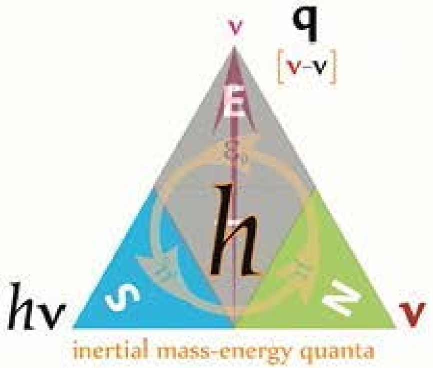
q
[v-v]
v
E
h
hv
S
N
v
inertial mass-energy quanta

Net Charge is reflective of the total energy momenta
of any EM field or Matter subjected to acceleration
[inertial mass]

Inertial resistance to Force

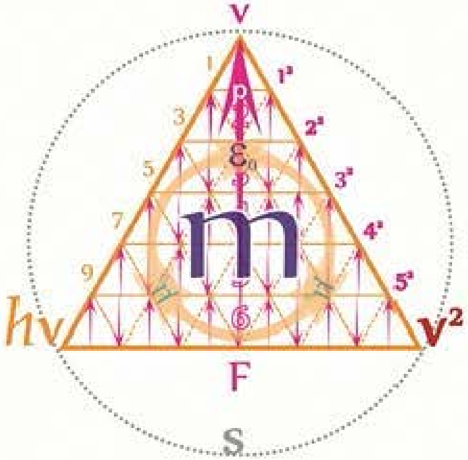
v
1
3
5
7
9
1²
2²
3²
4²
5²
p
ε_0
m
hv
v²
F
S

Any change in motion results in changes to
the Charge geometries creating in turn proportional
changes to the nett KEM mass-energy momenta components

$$F = ma$$

The inductive resistance of quanta in charged EM fields
to any changes to their nett mass-energy geometry
is the source ofwhat we term inertial mass

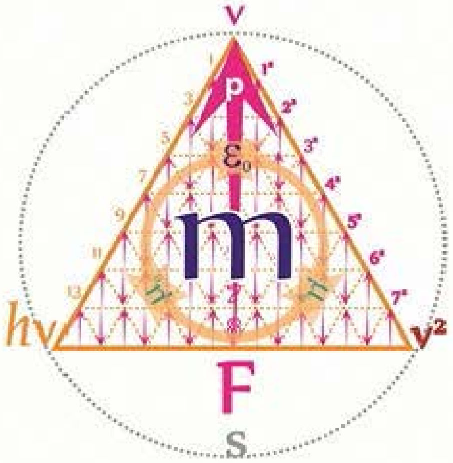
v
1
3
5
7
9
11
13
1²
2²
3²
4²
5²
6²
7²
p
ε_0
m
hv
v²
F
S

**Inertia is the resistance of any physical object
to a change in its state of motion.**

Force does work when it results in movement

$$\boxed{W = F.d = ma.d = E}$$

$$kg\,\frac{m}{s^2}\,m$$

classical mechanics — quantum mechanics

$$\Delta mv = \underset{\text{energies}}{\overset{\text{scalar}}{\Delta E}} = \Delta m\Omega v$$

linear momenta — angular momenta

$$kg\,\frac{m^2}{s^2}$$

The Planck constant is the quantum of Action

$$\boxed{E = m\Omega v^2 = hv^2}$$

$$kg\,\frac{m^2}{s}\,\frac{1}{s}$$

Changing an object's velocity results in a corresponding energy momenta change which relate to each other through its inertial mass

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EM field densities

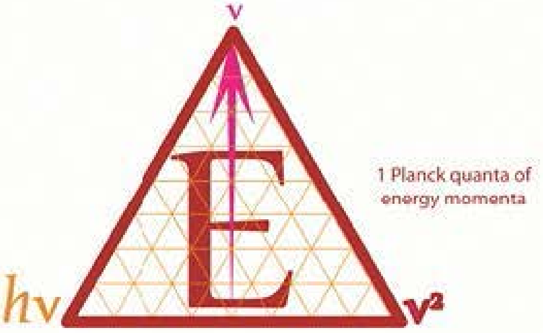
v
E
hv
v²
1 Planck quanta of
energy momenta

EM mass is a measure of the energy
content of any spatial co-ordinate system

$$\beta^2 = \left[\frac{v}{c}\right]^2$$

and is subject to
Lorentz velocity corrections
in 2D EM fields

6.629432672 e-34 J
1 planck quantum has a
EM mass-Energy of
7.376238634 e-51 kg
and
Quantised Angular Momentum
which creates Charge
1.33518 e-20 C

mass-Energy equivalence

mass velocity

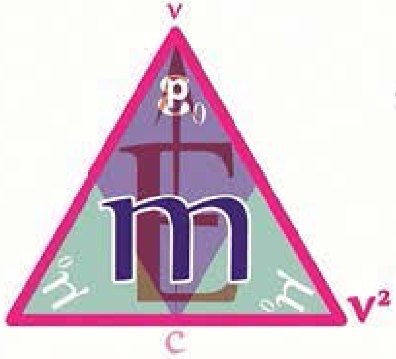
v
ε_0
m
E
c
v²

7.376238634 e-51 kg

6.629432572e-34 j.s

$$mv^2 = E = hv^2$$

8.987551787 e16 [m/s]²

6.629432672 e-34 j

quanta/sec

Matter is only mass-energy in Tetrahedral topologies [T4π+]
[else it is nπ EM mass-energies that propagate away at c]

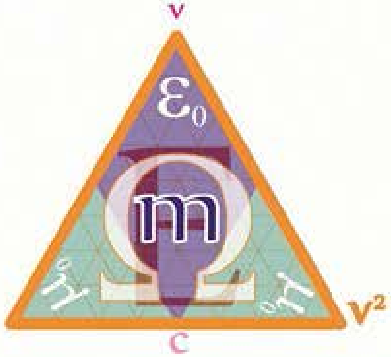
v
ε_0
Ω
m
c
v²

planck quanta

6.629432672 e-34 J

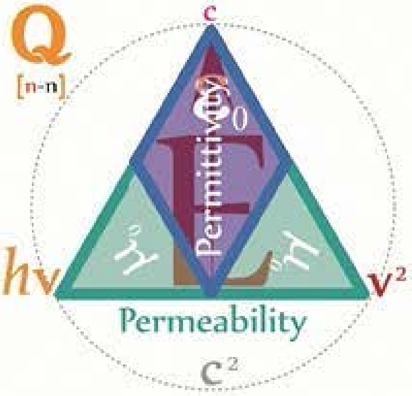
Q
[n-n]
c
ε_0
Permittivity
E
hv
v²
Permeability
c²

7.376238634 e-51 kg
radiant mass-energies

If reduced to a flat Euclidean space geometry
Matter topologies become radiant mass-energies

m
mass

$$\left[\frac{n\pi}{c^2}\rho\right]$$

E
ENERGY

Planck quanta

$$\left[m\Omega v^2\right]$$

mass velocity

M
Matter

$$\left[\frac{4n\pi}{c^4}\rho\right]$$

The inertial properties of electromagnetic mass - ENERGY & Matter
[can all be differentiated as energy densities per unit of time]
in any spatial co-ordinate system

2.984040234 e-10 J

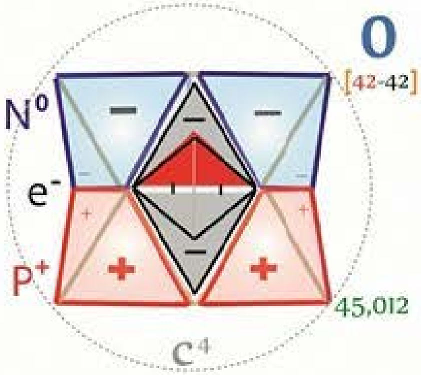
O
[42-42]
N⁰
e⁻
P⁺
45,012
c⁴

3.320192534 e-27 kg
rest mass-Matter

m

[oddπ]hv

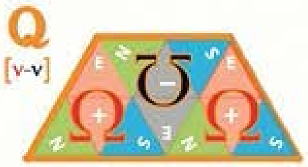

EM Field Planck quanta

$$1\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Charge ElectroMagnetic mass velocity

Bosons

2D

Photons

m

[evenπ]hv

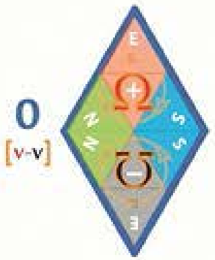

EM Field Planck quanta

$$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Photons ElectroMagnetic mass velocity

EM Field geometries & Matter topologies

M

[4nπ]hv

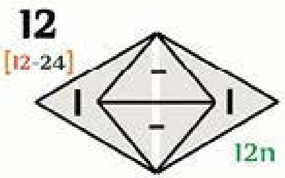

EM Field Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Dodecyon ElectroMagnetic mass velocity

Leptons

3D

Baryons

M

[4nπ]hv

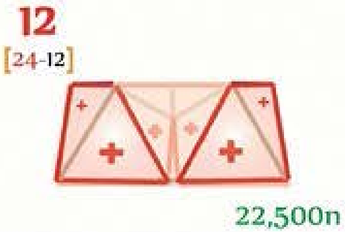

EM Field Planck quanta

$$36\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Baryons ElectroMagnetic mass velocity

2D planar Euclidean electromagnetic mass-energies propagate through the vacuum energy aether without interaction

EM Field Planck quanta

$$n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

mass ElectroMagnetic mass velocity

2D Fields

3D Matter

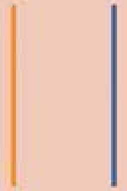

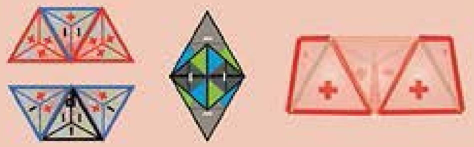

Tetryonic charged geometries provides a clear mechanism for providing all particles with their distinct properties of 2D inertial EM mass-energy and 3D Matter.

EM Field Planck quanta

$$T\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Matter ElectroMagnetic mass velocity

3D standing wave topologies of electromagnetic mass-energies interact with the vacuum energy aether at various angles through their charged [inductive] fascia

Tetryonics 17.10 - EM Field geometries and Matter topologies

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Velocity invariant rest Matter

The Relativistic EM mass-energies of a system in motion is the sum of its invariant rest Matter and Kinetic Energies

Electron rest Matter

Kinetic Energy field

$$RE = \underset{\text{Fermions}}{12\pi}\frac{[[m\Omega v^2]]}{c^4} + \underset{\text{Photons}}{2\pi}\frac{[[m\Omega v^2]]}{c^2}$$

EM fields resulting from motion are subject to Lorentz correction

Electrostatic charges have no Magnetic Moments

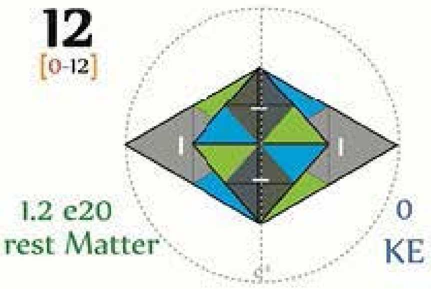

All Matter are 3D standing wave topologies

$$M = \frac{E}{c^4}$$

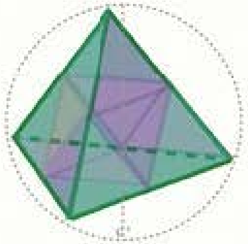

$E = Mc^4$

rest mass-Matter is composed of 4nπ standing wave topologies and is INVARIANT to velociy changes

Kinetic mass-energies are divergent from invariant rest Matter topologies as a result of a particle's motion

At zero velocity the relativistic mass is equal to the invariant mass.

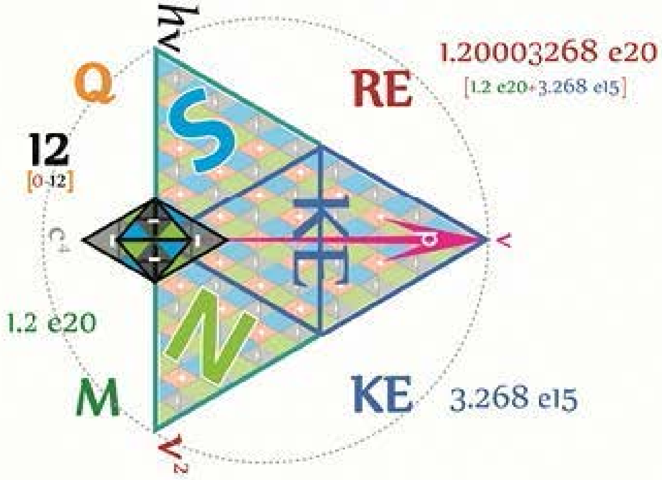

The energy which an object has due to its motion will not add mass into the invariant rest Matter of the particle in motion (It increases the total Planck quanta [EM mass-enegies] of its extended KEM field)

Wavelengths are proportional to EM energy content

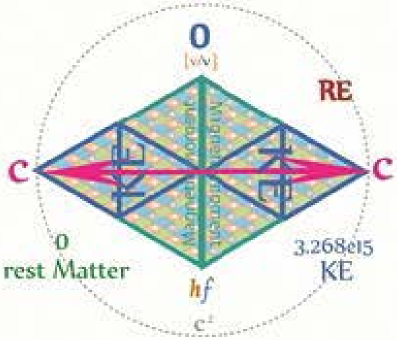

Photons are bidirectional Kinetic EM Fields

$$\frac{E}{c^2} = m$$

Matter in motion has a resultant velocity related Energy field that posseses the physical properties of Kinetic energy and Magnetic moments

$KEM = Mv^2$

KEM field Energy is directly relaıed to the Velocity changes of massive particles

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All 2D EM fields and 3D Matter particles have ElectroMagnetic fields, inertial mass-energies & momenta resulting from their constituent equilateral Planck quanta which possess the additional physical properties of Compton Frequency and De Broglie Wavelength

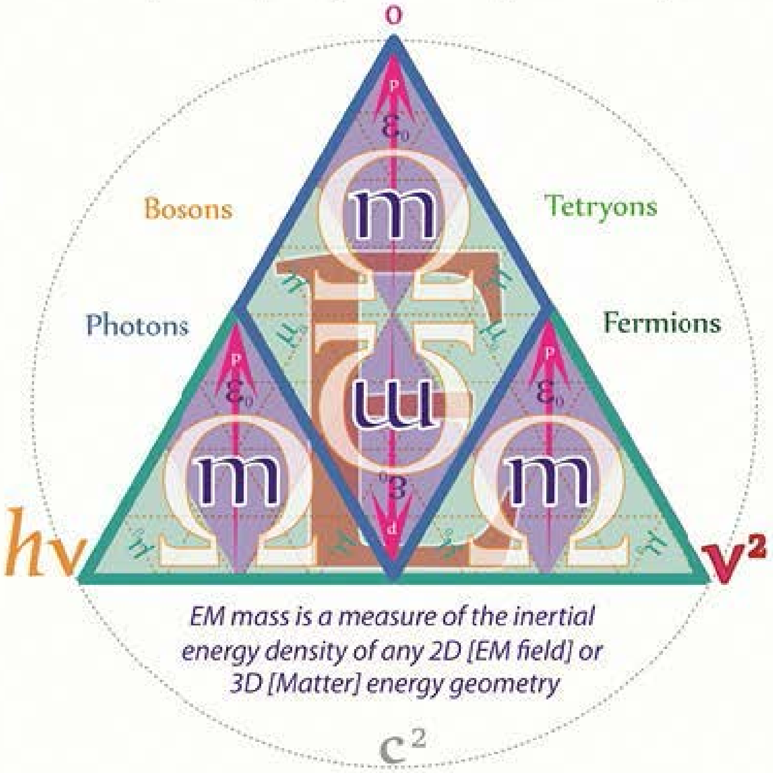

EM mass is a measure of the inertial energy density of any 2D [EM field] or 3D [Matter] energy geometry

$$m\Omega v^2 = E = mv^2$$

EM mass-energy momenta

The EM mass of an object is a fundamental property of the object; a numerical measure of its inertia; a fundamental measure of the energy density of an object.

mass geometries and Matter Topologies

All 3D Matter topologies contain 2D EM mass-energy geometries not all 2D EM mass-energy geometries form 3D Matter topologies

EM mass can be clearly defined as a measure of the energy density of any charged geometry

EM Field Planck quanta

$$T\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

Matter ElectroMagnetic mass velocity

3D Matter is any mass-energy geometry that creates a closed volume Topology (4nπ Tetryonic geometry)

$$\frac{E}{c^2} = m$$

EM waves [FIELDS] are distinguishable from Material Particles [MATTER] through their non-Tetrahedral topologies

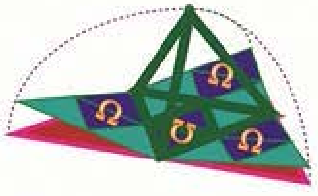

mass-energy is a conserved property
Matter is not conservative

$$M = \frac{E}{c^4}$$

The term 'massless' is a misnomer and should be discontinued in its use as all EM fields and Particles have EM mass [Energy quanta per second] geometries [other alternatives could be 2D, EM field, or Matterless]

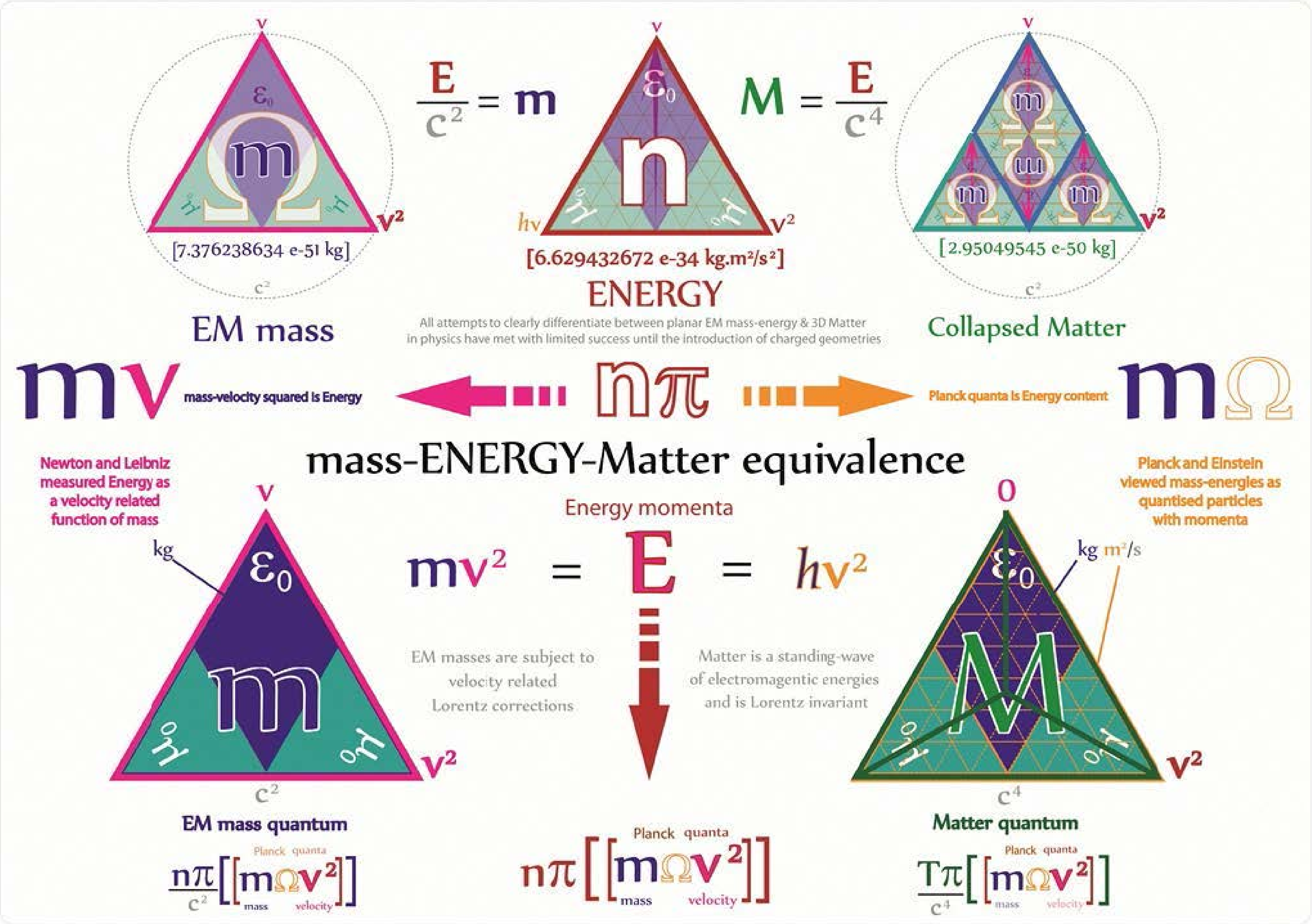

$$\frac{E}{c^2} = m$$

$$M = \frac{E}{c^4}$$

[7.376238634 e-51 kg]

[6.629432672 e-34 kg.m²/s²]

[2.95049545 e-50 kg]

EM mass

ENERGY

All attempts to clearly differentiate between planar EM mass-energy & 3D Matter in physics have met with limited success until the introduction of charged geometries

Collapsed Matter

$m v$ mass-velocity squared is Energy

$n\pi$

Planck quanta is Energy content $m\Omega$

mass-ENERGY-Matter equivalence

Newton and Leibniz measured Energy as a velocity related function of mass

Energy momenta

Planck and Einstein viewed mass-energies as quantised particles with momenta

$$mv^2 = E = hv^2$$

EM masses are subject to velocity related Lorentz corrections

Matter is a standing-wave of electromagentic energies and is Lorentz invariant

EM mass quantum

Planck quanta

$$\frac{n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

Planck quanta

$$n\pi\left[\left[m\Omega v^2\right]\right]$$

mass velocity

Matter quantum

Planck quanta

$$\frac{T\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

Tetryonics 17.13 - EM mass-Energy-Matter equivalence

m

mass geometries

All forms of mass-ENERGY-Matter
are defined by their charged geometries and
the spatial co-ordinate systems used to measure their physics

M

Matter topologies

Unified Field Equation

for Tetryonic EM mass-Energy-Matter

mass — Planck quanta — mass — velocity

$$\frac{n\pi}{c^2}[[m\Omega v^2]]$$

Matter — Planck quanta — mass — velocity

$$\frac{T\pi}{c^4}[[m\Omega v^2]]$$

Tetryonic geometry — EM Field — Planck quanta — ElectroMagnetic mass — velocity

$$T\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$$

EM Field — Planck quanta — ElectroMagnetic mass — velocity

$n\pi$ mass $[[\varepsilon_0\mu_0].[m\Omega v^2]]$

ODDπ Bosons $[[\varepsilon_0\mu_0].[m\Omega v^2]]$

2π Photons $[[\varepsilon_0\mu_0].[m\Omega v^2]]$

EVENπ EM waves $[[\varepsilon_0\mu_0].[m\Omega v^2]]$

bosons & photons

$n\pi$

EM waveforms

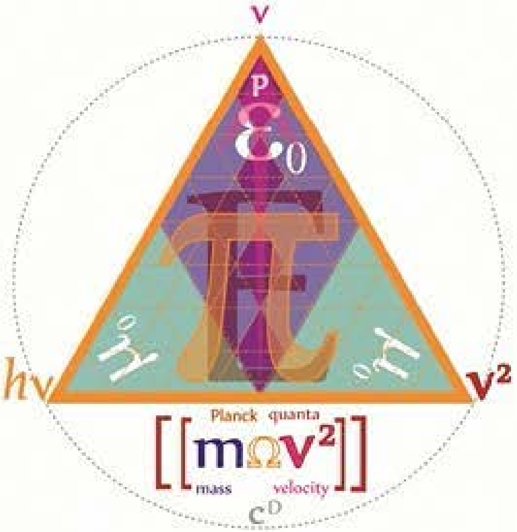

spatial co-ordinate systems
are defined by the velocity of energy

Fermions

$T\pi$

Particles

EM Field — Planck quanta — ElectroMagnetic mass — velocity

4π Tetryons $[[\varepsilon_0\mu_0].[m\Omega v^2]]$

12π Dodecyons $[[\varepsilon_0\mu_0].[m\Omega v^2]]$

24π Mesons $[[\varepsilon_0\mu_0].[m\Omega v^2]]$

36π Baryons $[[\varepsilon_0\mu_0].[m\Omega v^2]]$

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EM mass

Matter

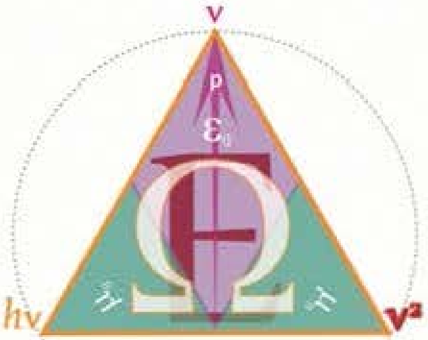

m

M

mass

Planck quanta

$$\frac{n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

Planck quanta

$$n\pi\left[m\Omega v\right]^2$$

energy mass velocity

Matter

Planck quanta

$$\frac{T\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

Classical Mechanics

Quantum Mechanics

Tetryonic unified field Geometry

p

mass velocity

7.376238634 e-51 kg

6.629432672e-34 j.s

$$mv^2 = E = hv^2$$

8.987551787 e16 [m/s]²

6.629432672 e-34 j

quanta/sec

mass-Energy momenta equivalence

planck quanta

h

The equilateral geometry of quantised angular momentum is the key to understanding Energy

$$kg\,\frac{m}{s}$$

mv

mΩ

$$kg\,\frac{m^2}{s}$$

linear momentum

charge

quantised angular momentum

Tetryonics 17.15 - Unified field geometries

$kg\,\frac{m^2}{s}\,\frac{1}{s}$

Planck quanta

$[m\Omega v^2]$

mass velocity

$kg\,\frac{m^2}{s^2}$

E

Energy

m

EM Field Planck quanta

$n\pi\,[[\varepsilon_0\mu_0].[m\Omega v^2]]$

mass ElectroMagnetic mass velocity

kg

ElectroMagnetic field

$[\varepsilon_0\mu_0]$

$\frac{1}{c^2}$

$\frac{s^2}{m^2}$

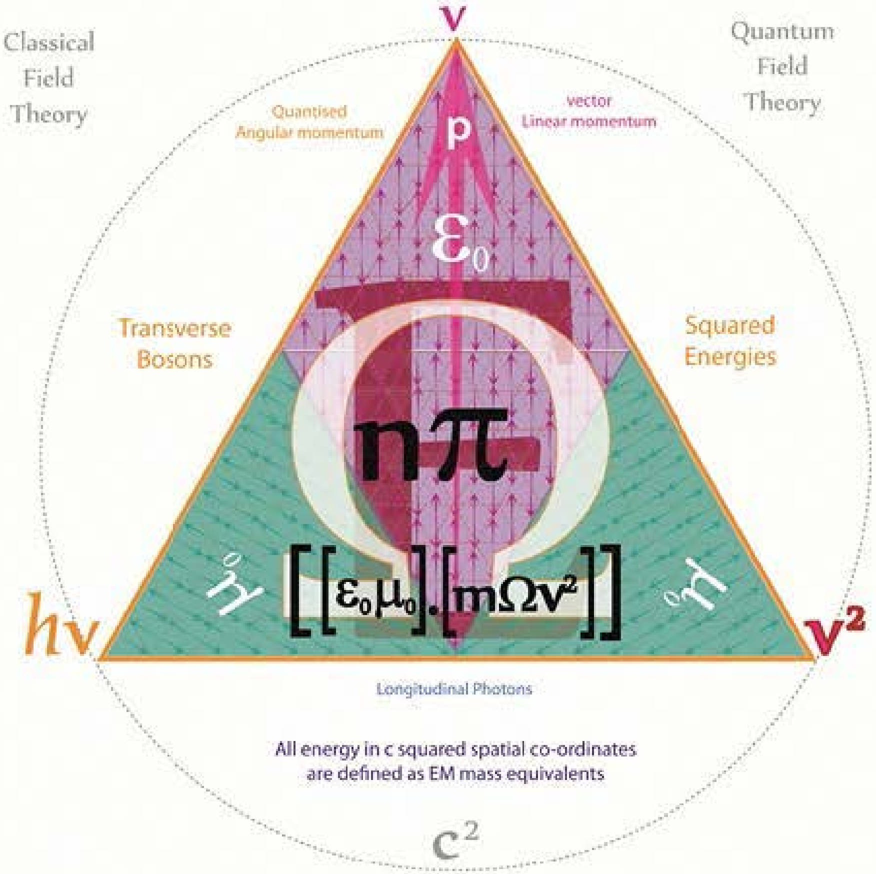
v
Classical Field Theory
Quantum Field Theory
Quantised Angular momentum
vector Linear momentum
p
ε0
Transverse Bosons
Squared Energies
nπ
[[ε0μ0].[mΩv²]]
hv
v²
Longitudinal Photons
All energy in c squared spatial co-ordinates are defined as EM mass equivalents
c²

$\frac{s^2}{m^2}$ $\frac{m}{s^2}$

Q

Charge

Charge

$[\varepsilon_0\mu_0\Omega]$

ElectroMagnetic QAM

s

h

$[m\Omega]$

mass QAM

$kg\,\frac{m^2}{s}$

Unified Field Components

The Unified field equation can be re-arranged to reveal a multitude of physical properties and relationships previously poorly understood.

Highlighting the fact that all of the constants and properties of both Classical and Quantum Mechanics are in fact geometric properties of Energy

QAM

$\frac{m^2}{s}$ Ω

v^2

velocity squared

Velocity - quanta

v^2

quanta/sec

Tetryonics 17.16 - UFE components

EM mass Relationships

v	Velocity	$\frac{m}{s}$
a	Acceleration	$\frac{m}{s^2}$
	m ↓	
p	Momentum	$kg\frac{m}{s}$
F	Force	$kg\frac{m}{s^2}$

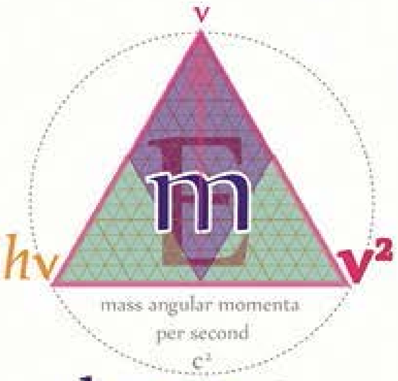

$kg\ \frac{m^2}{s}\ \frac{1}{s}$

EM mass is revealed to be the scalar property of 2D Energy waveforms that is at the core of many important physical processes and measurements

Ω	Quantum Angular Momentum	$\frac{m^2}{s}$
v^2	Celeritas squared	$\frac{m^2}{s^2}$
	m ↓	
h	Planck's Constant	$kg\frac{m^2}{s}$
E	Energy	$kg\frac{m^2}{s^2}$

E/second

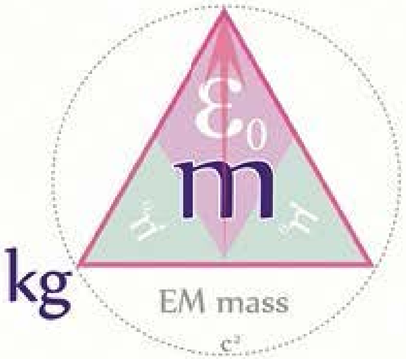

f	Frequency	$\frac{1}{s}$
T	Period	s
	m ↓	
I	Current	$\frac{kg}{s}$
C	Charge	$\frac{s}{kg}$

E/second²

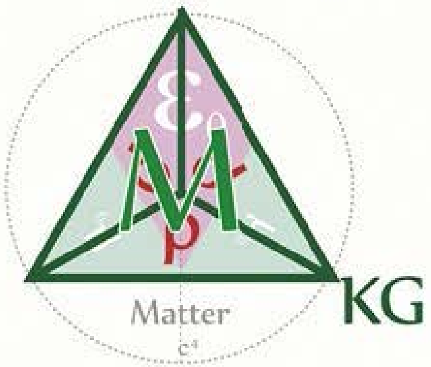

2D mass geometries should never be confused with 3D Matter topoplogies; nor should the terms be used in exchange for each other

Tetryonics 17.17 - EM mass relationships

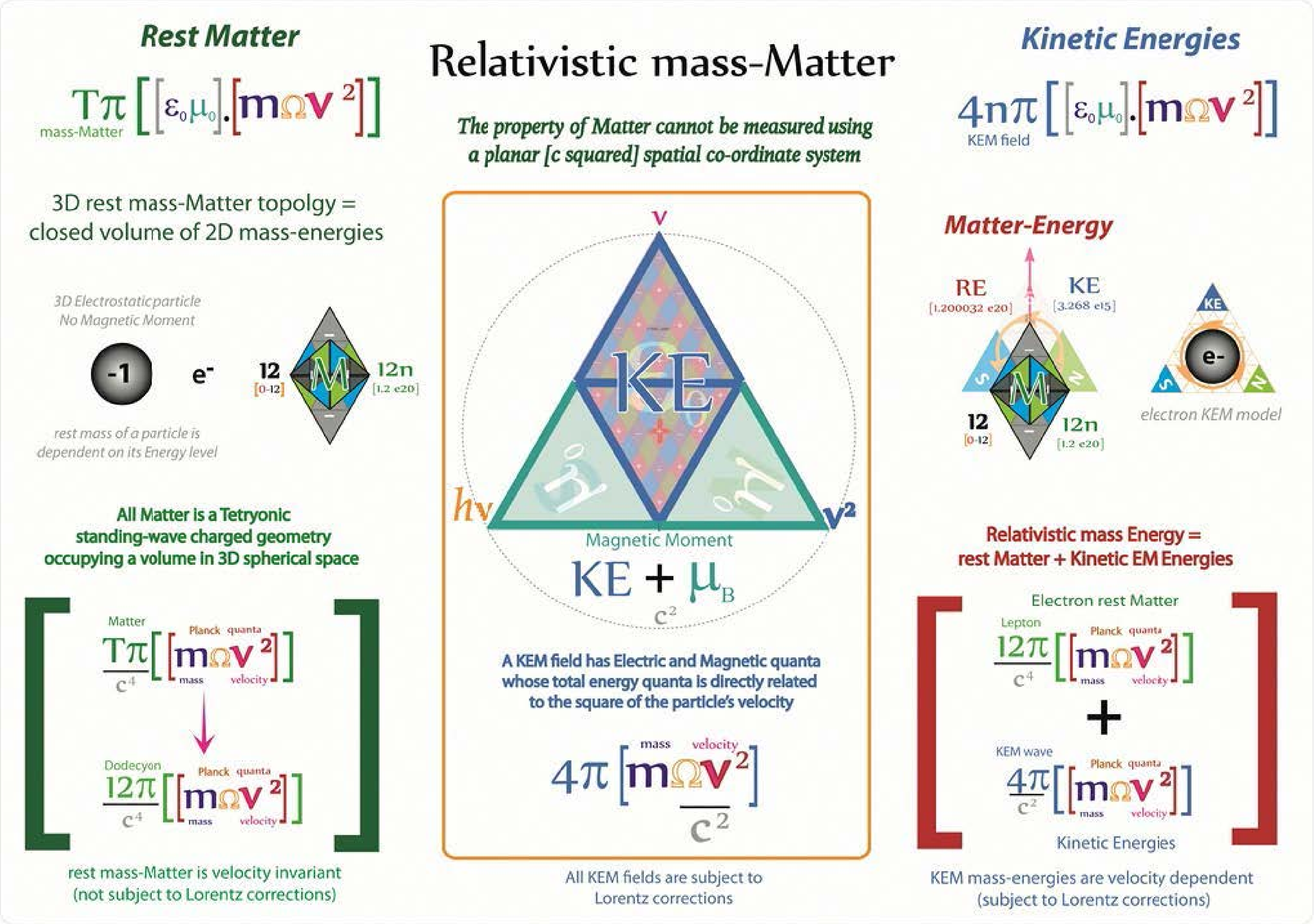

Relativistic mass-Matter

Rest Matter

$$T\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

mass-Matter

3D rest mass-Matter topolgy =
closed volume of 2D mass-energies

3D Electrostatic particle
No Magnetic Moment

rest mass of a particle is
dependent on its Energy level

All Matter is a Tetryonic
standing-wave charged geometry
occupying a volume in 3D spherical space

Matter

$$\frac{T\pi}{c^4}\left[[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}]\right]$$

$$\downarrow$$

Dodecyon

$$\frac{12\pi}{c^4}\left[[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}]\right]$$

rest mass-Matter is velocity invariant
(not subject to Lorentz corrections)

The property of Matter cannot be measured using
a planar [c squared] spatial co-ordinate system

Magnetic Moment

$$\frac{KE + \mu_B}{c^2}$$

A KEM field has Electric and Magnetic quanta
whose total energy quanta is directly related
to the square of the particle's velocity

$$4\pi\left[\frac{\overset{\text{mass}}{m}\Omega \overset{\text{velocity}}{v^2}}{c^2}\right]$$

All KEM fields are subject to
Lorentz corrections

Kinetic Energies

$$4n\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

KEM field

Matter-Energy

electron KEM model

Relativistic mass Energy =
rest Matter + Kinetic EM Energies

Electron rest Matter

Lepton

$$\frac{12\pi}{c^4}\left[[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}]\right]$$

$$+$$

KEM wave

$$\frac{4\pi}{c^2}\left[[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}]\right]$$

Kinetic Energies

KEM mass-energies are velocity dependent
(subject to Lorentz corrections)

Tetryonics 17.18 - Relativistic mass-Matter

Tetryonic mass & Matter

Historically interchanged due to the lack of proper definitions
the physical properties of EM mass & Matter can now be firmly defined
with respect to their energy equivalence and spatial geometries

m

mass is a measure of the 2D planar energy content of any physical system

mass Planck quanta

$$\frac{n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

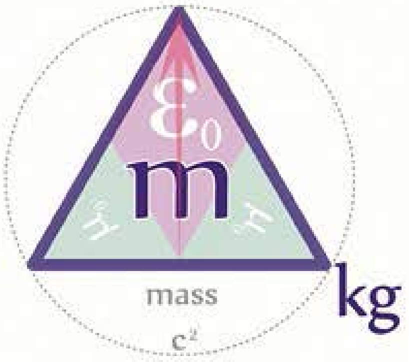

E/second

2D
radiant equilateral geometry
of EM mass-ENERGY momenta
EM mass

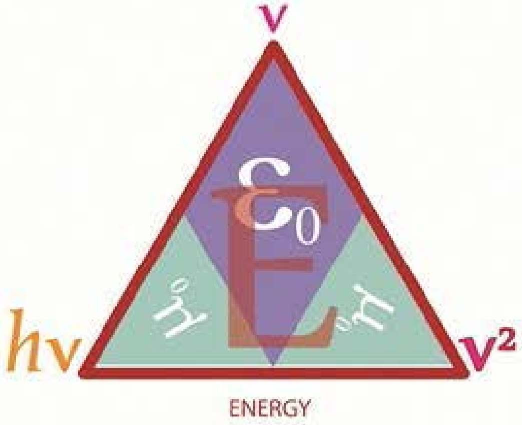

EM mass should replace the generic term mass with reference to ElectroMagnetic energy densities

MATTER is a geometric 4nπ standing wave topology of EM mass-energy geometries

The electromagnetic energies of rest Matter is never 'at rest' as the electromagnetic field energies creating mass-Matter topologies alway propagate at c

M

Matter is a measure of the 3D volumetric energy content of any physical system

Matter Planck quanta

$$\frac{T\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

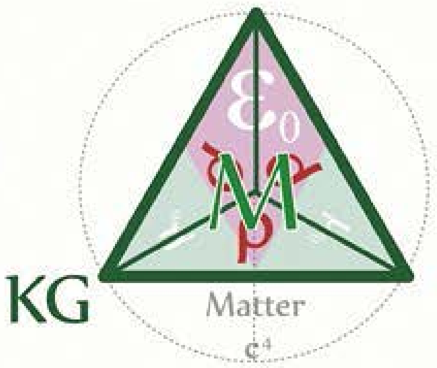

E/second²

3D
standing-wave topology
of EM mass-ENERGY momenta
rest Matter

Tetryonics 17.19 - Tetryonic mass & Matter

Photoelectron KEM fields

The linear momenta produced as a result of energy momenta in KEM fields is converted into angular momentum when leptons are bound to atomic nuclei

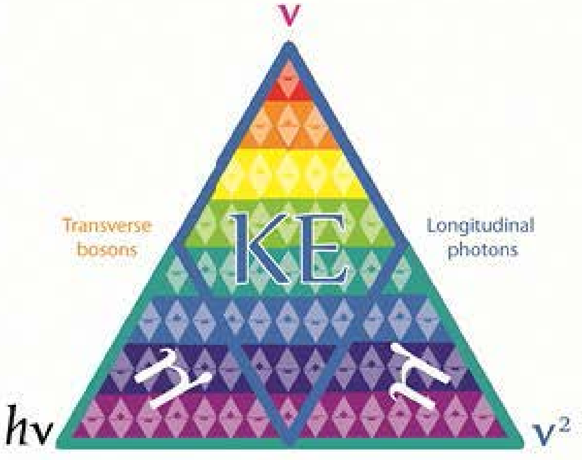
v
Transverse bosons
Longitudinal photons
KE
hv
v²

SPIN UP

The EM mass-energy content of Baryons directly influence the KEM field energy levels of bound Leptons

EM mass-energy-momenta

Changes in the momenta of bound Leptons [linear & quantised angular]

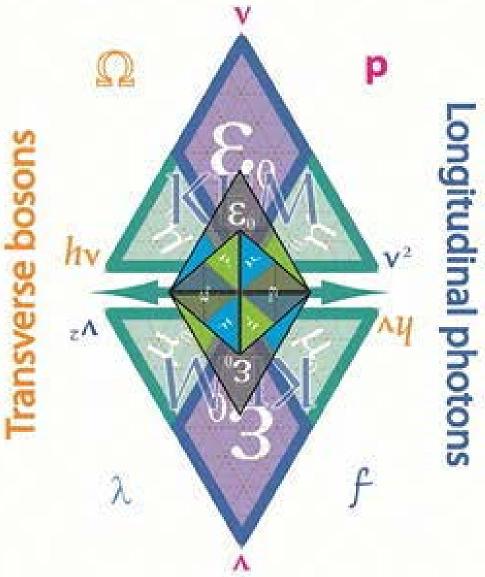
v
Ω
p
Transverse bosons
Longitudinal photons
KEM
hv
v²
v²
hv
KEM
λ
f
v

prouduces spectral lines of varying frequencies

and Spin are always conserved

The motion of leptons within atomic nuclei produces Magnetic moments at various orientations to the nuclear magneton

SPIN DOWN

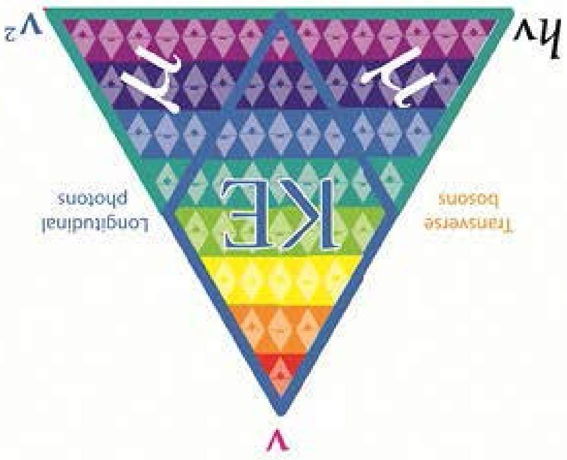
v²
hv
Longitudinal photons
Transverse bosons
KE
v

If an electron is 'ejected' from the Nuclei it will obey conservation of EM mass-energy momentum

ie Its ejected energy-momentum equals the absorbed photon's energy-momenta [minus the work energy required to free it]

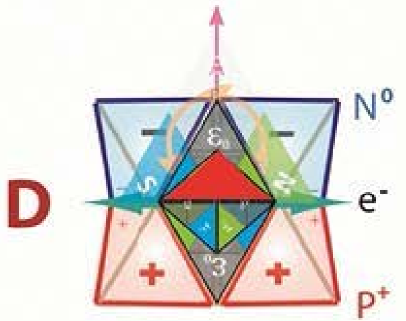

UP spin

Parallel Magnetic Moments

Nuclear magneton
p

DOWN spin

Antiparallel Magnetic moments

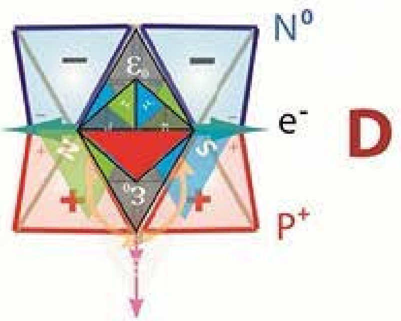

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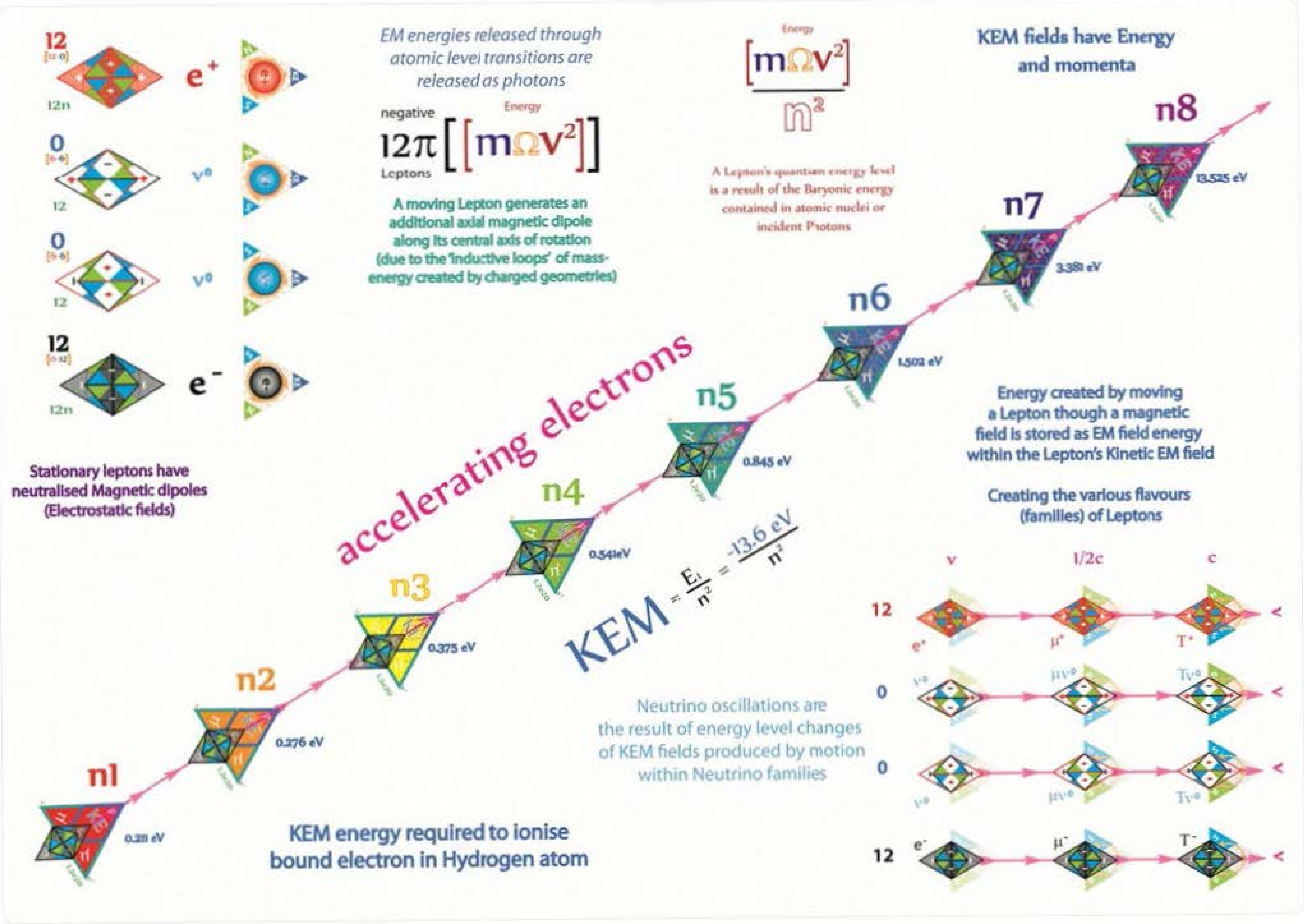
12
[12-0]
12n
e⁺
0
[6-6]
12
ν⁰
0
[6-6]
12
ν⁰
12
[0-12]
12n
e⁻
accelerating electrons
n1
0.211 eV
n2
0.276 eV
n3
0.375 eV
n4
0.541eV
n5
0.845 eV
n6
1.502 eV
n7
3.381 eV
n8
13.525 eV
v
1/2c
c
12
e⁺
μ⁺
T⁺
0
ν⁰
μν⁰
Tν⁰
0
ν⁰
μν⁰
Tν⁰
12
e⁻
μ⁻
T⁻

EM energies released through atomic level transitions are released as photons

$$\text{negative}\ \ 12\pi_{\text{Leptons}}\left[\left[m\Omega v^2\right]\right]^{\text{Energy}}$$

A moving Lepton generates an additional axial magnetic dipole along its central axis of rotation (due to the 'inductive loops' of mass-energy created by charged geometries)

$$\frac{\left[m\Omega v^2\right]^{\text{Energy}}}{n^2}$$

A Lepton's quantum energy level is a result of the Baryonic energy contained in atomic nuclei or incident Photons

KEM fields have Energy and momenta

Stationary leptons have neutralised Magnetic dipoles (Electrostatic fields)

$$KEM \approx \frac{E_1}{n^2} = \frac{-13.6\ \text{eV}}{n^2}$$

Energy created by moving a Lepton though a magnetic field is stored as EM field energy within the Lepton's Kinetic EM field

Creating the various flavours (families) of Leptons

Neutrino oscillations are the result of energy level changes of KEM fields produced by motion within Neutrino families

KEM energy required to ionise bound electron in Hydrogen atom

Tetryonics 18.02 - accelerating electrons

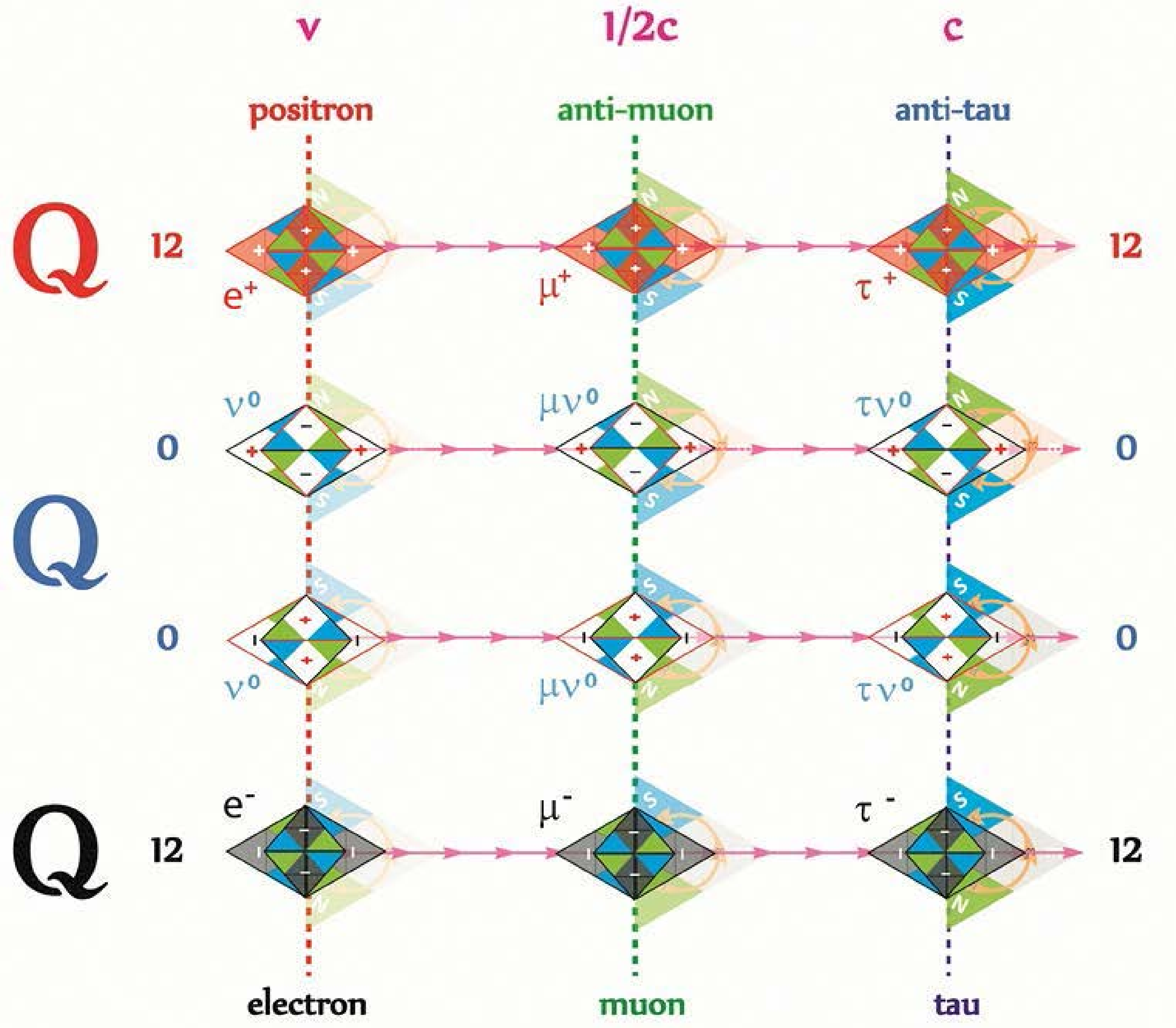
v
1/2c
c
positron
anti-muon
anti-tau
Q
12
e^+
μ^+
τ^+
12
ν^0
$\mu\nu^0$
$\tau\nu^0$
0
0
Q
0
ν^0
$\mu\nu^0$
$\tau\nu^0$
0
Q
12
e^-
μ^-
τ^-
12
electron
muon
tau
N
S

Leptronic Oscillations

Antimatter

EM Field Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Leptons ElectroMagnetic mass velocity

All Leptronic generations, oscillations and types can be accounted for through Tetryonic geometries & energy levels

Matter

Tetryonics 18.03 - Leptronic oscillations

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Principal Quantum levels

$$Mv^2 = \text{KEM} = hv^2$$

Bound electron Eigenstate values

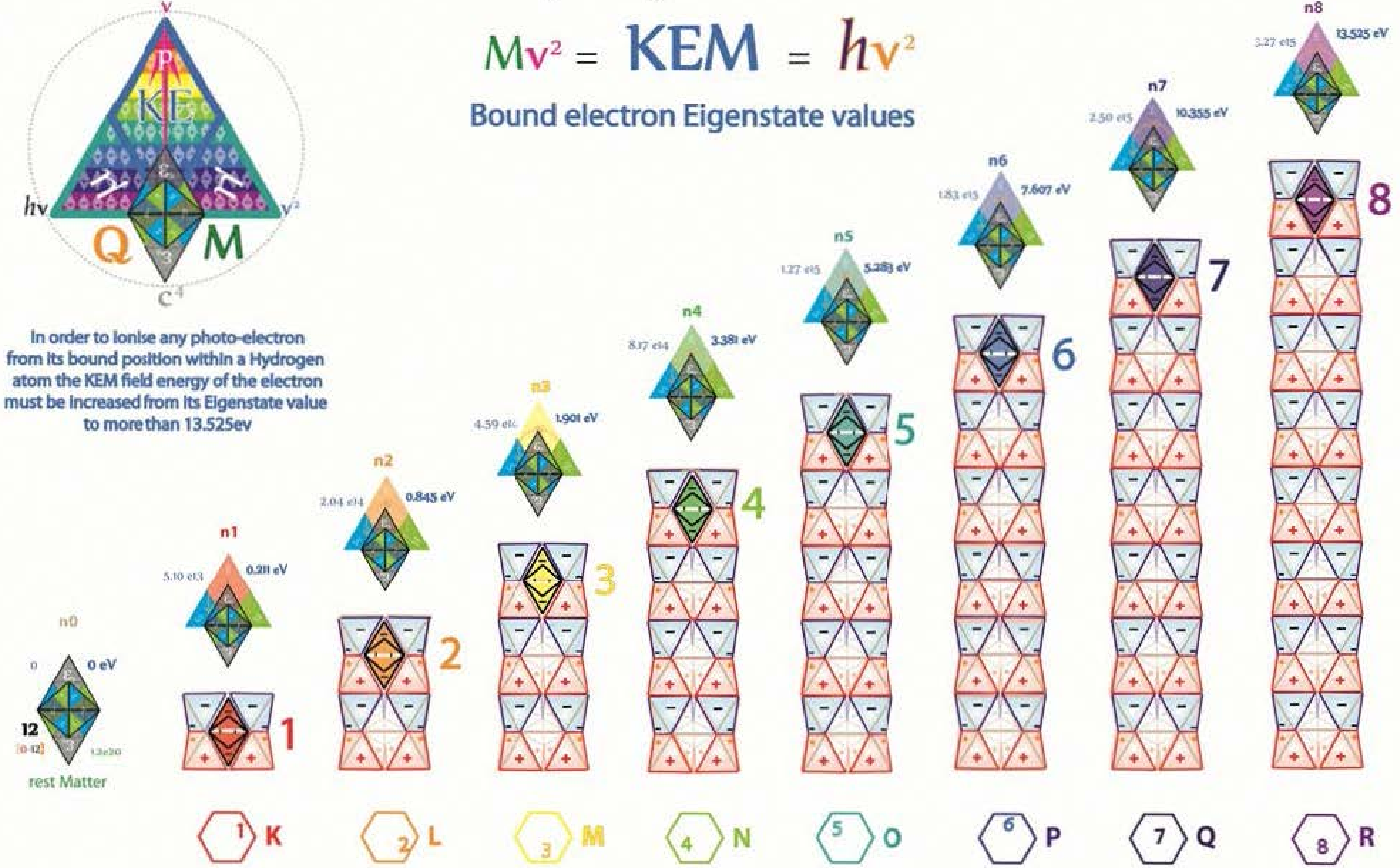
Eigenstate bound energy states
v
P
KE
hv
v²
Q
M
c⁴
n0
0
0 eV
12
[0-12]
1.2e20
rest Matter
n1
5.10 e13
0.211 eV
1
n2
2.04 e14
0.845 eV
2
n3
4.59 e14
1.901 eV
3
n4
8.17 e14
3.381 eV
4
n5
1.27 e15
5.283 eV
5
n6
1.83 e15
7.607 eV
6
n7
2.50 e15
10.355 eV
7
n8
3.27 e15
13.525 eV
8
1 K
2 L
3 M
4 N
5 O
6 P
7 Q
8 R

In order to ionise any photo-electron from its bound position within a Hydrogen atom the KEM field energy of the electron must be increased from its Eigenstate value to more than 13.525ev

The mass-energy content of Baryons comprising atomic nuclei directly determines the Kinetic energy levels of bound Leptons [forming quantum synchronous convertors] (incident Bosons/Photons can increase these levels if they contain the exact quanta required to increase the level to the next square number)

Tetryonics 18.04 - Principal Quantum Levels

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Bohr radius

As the Electron's angular velocity increases the measu'eable Bohr magnetic moment strength increases and its associated KEM field Planck wavelengths decrease (due to the increased Planck quanta).

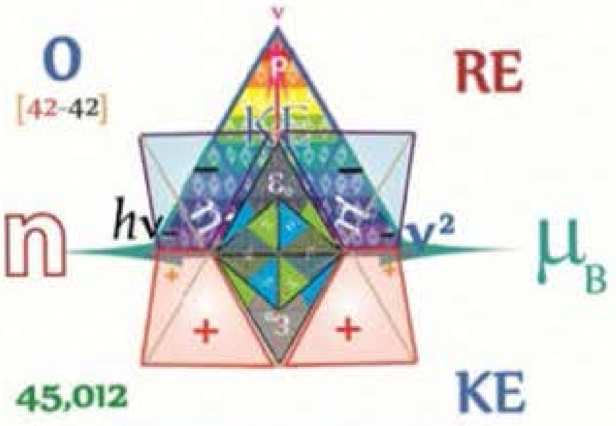
O
[42-42]
RE
n
hv
v²
μ_B
KE
45,012
P
KE
ε
+
+
-
-

The highest quantum number level produces the strongest Magnetic Moment

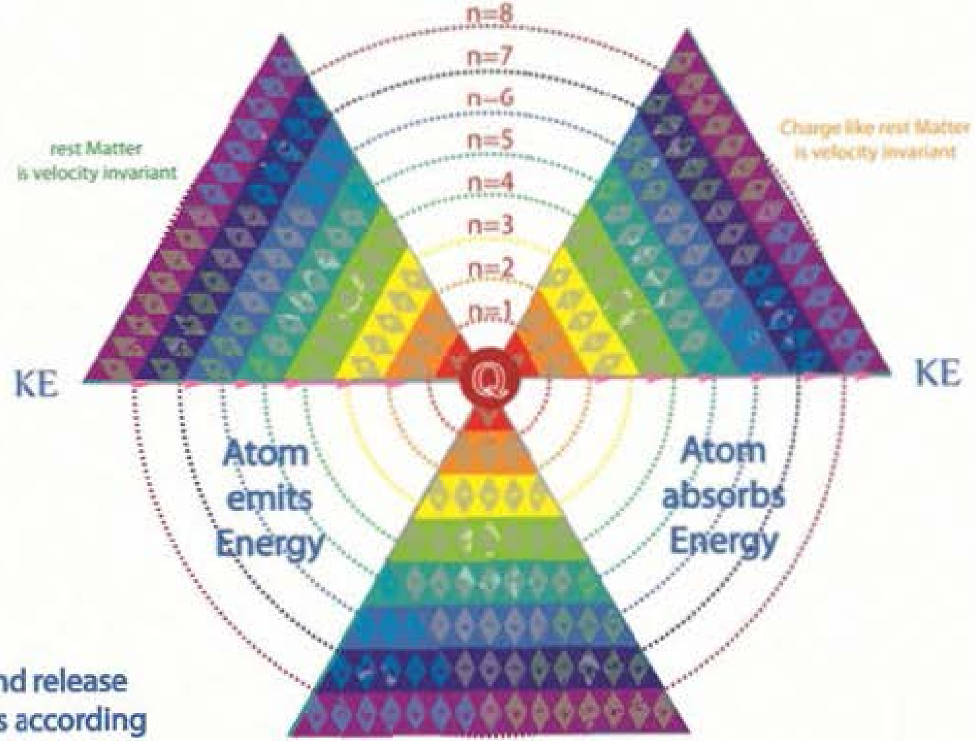
n=8
n=7
n=6
n=5
n=4
n=3
n=2
n=1
rest Matter
is velocity invariant
Charge like rest Matter
is velocity invariant
KE
KE
Q
Atom
emits
Energy
Atom
absorbs
Energy

Model is for illustrative purposes only - actual quanta illustrated are stored in radial KEM fields

All massive particles asbsorb and release energy in discrete quantum steps according to their respective Tetryonic geometries and changes in velocities

n8

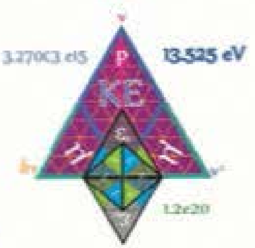
3.27003 e15
13.525 eV
P
KE
ε
hv
v²
1.2e20

n7

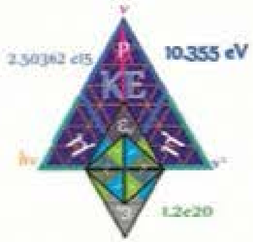
2.50362 e15
10.355 eV
P
KE
ε
hv
v²
1.2e20

n6

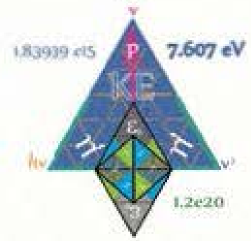
1.83939 e15
7.607 eV
P
KE
ε
hv
v²
1.2e20

n5

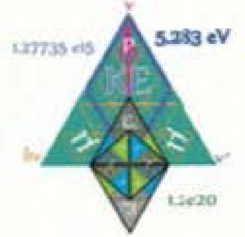
1.27735 e15
5.283 eV
P
KE
ε
hv
v²
1.2e20

Kinetic Energies

n1

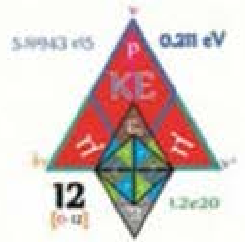
0.211 eV
P
KE
ε
hv
v²
12
[0-12]
1.2e20

n2

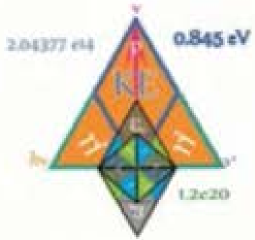
2.04377 e14
0.845 eV
P
KE
ε
hv
v²
1.2e20

n3

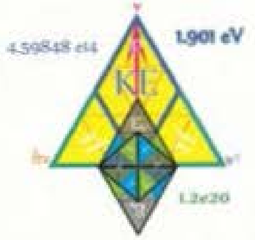
4.59848 e14
1.901 eV
KE
ε
hv
v²
1.2e20

n4

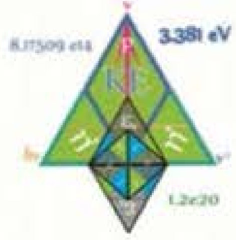
8.17509 e14
3.381 eV
P
KE
ε
hv
v²
1.2e20

Tetryonics 18.05 - Bohr radius

Nuclear Magnetons

are weaker than Bohr magnetons
due to differing mass-charge ratios
and non-parallel Quark magnetons

Baryons

are tri-Dodecyon geometries

EM Field Planck quanta

$$36\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Baryons ElectroMagnetic mass velocity

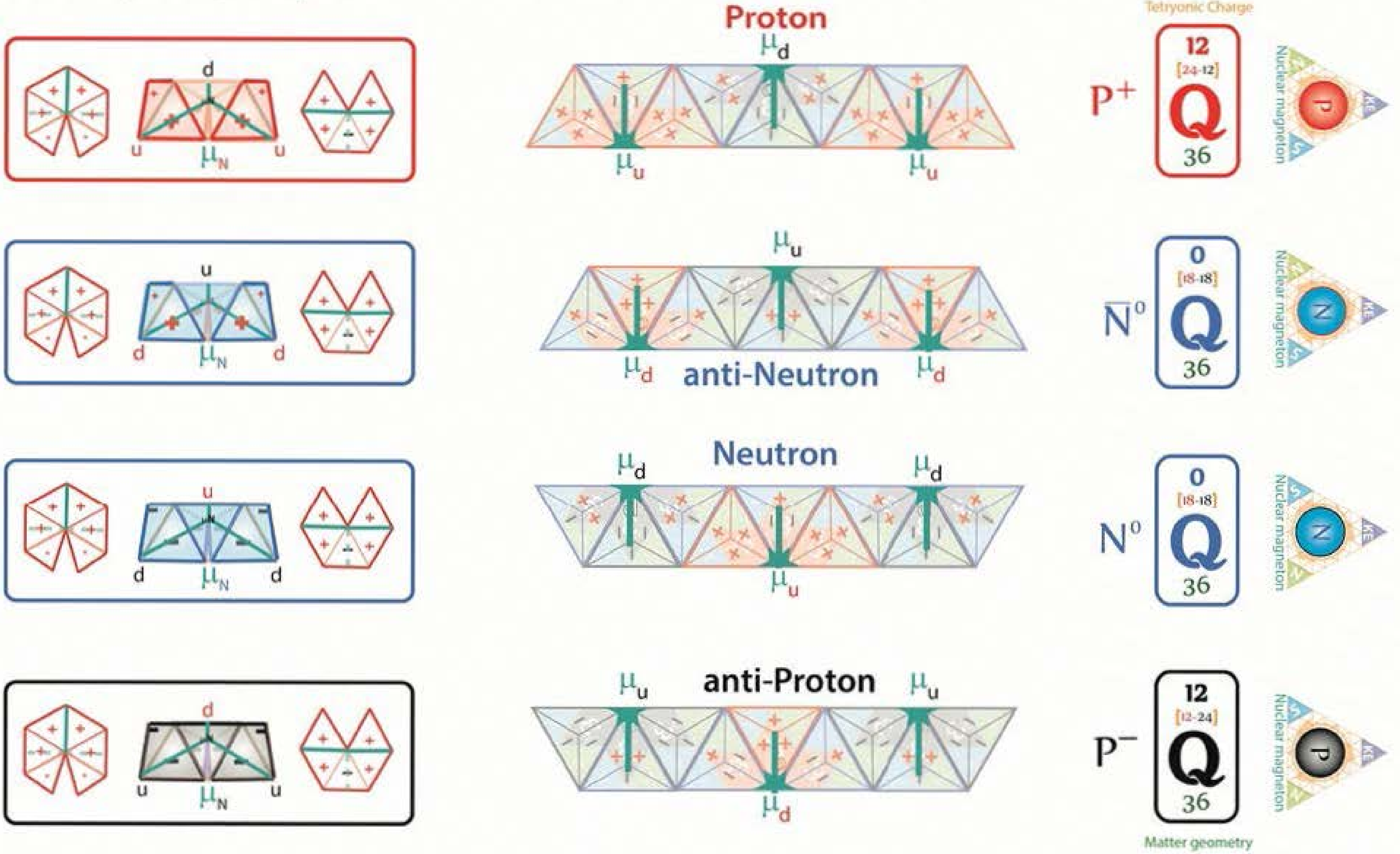
Proton
μ_d
μ_u
μ_u
d
u
u
μ_N
Tetryonic Charge
p^+
12
[24-12]
Q
36
Nuclear magneton
μ_u
μ_d
anti-Neutron
μ_d
u
d
d
μ_N
$\overline{N}^0$
0
[18-18]
Q
36
Nuclear magneton
Neutron
μ_d
μ_d
μ_u
u
d
d
μ_N
N^0
0
[18-18]
Q
36
Nuclear magneton
anti-Proton
μ_u
μ_u
μ_d
d
u
u
μ_N
p^-
12
[12-24]
Q
36
Nuclear magneton
Matter geometry

Baryonic Magnetic Moments

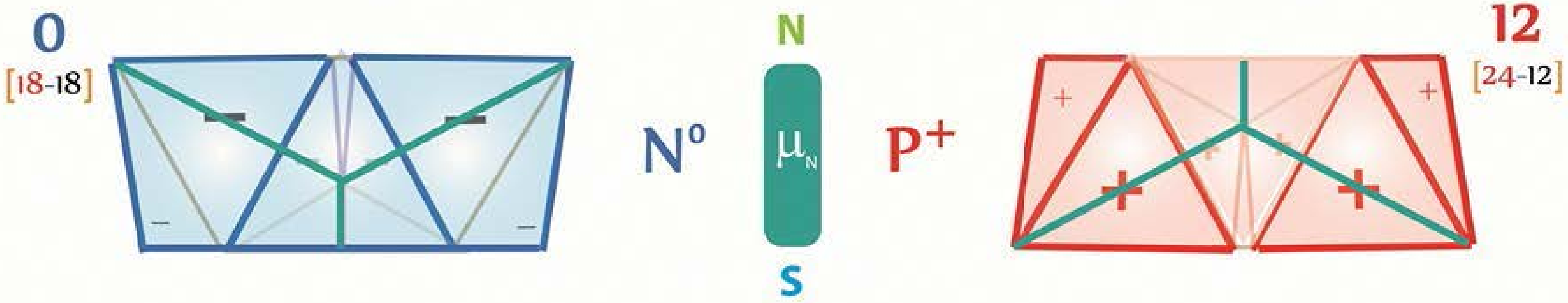
0
[18-18]
N
N^0
μ_N
S
P^+
12
[24-12]

**A Baryon's Magnetic Moment
is a result of the combined non-parallel
Magnetic moments of its Quarks**

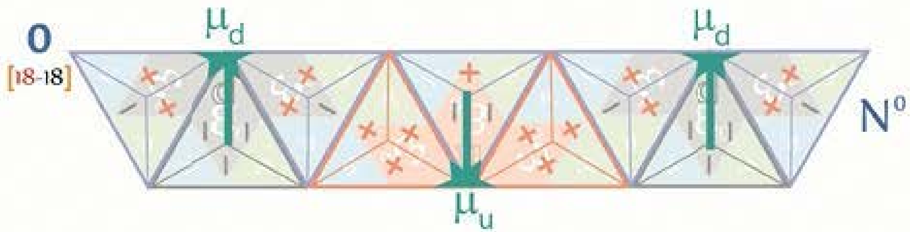
0
[18-18]
μ_d
μ_d
μ_u
N^0

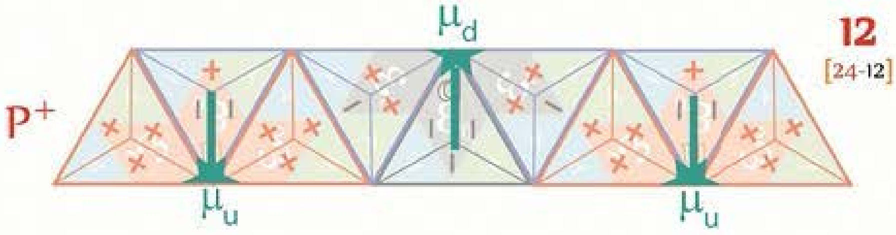
P^+
μ_d
μ_u
μ_u
12
[24-12]

As a result of the 3 non-aligned Quark magnetic moments
resulting from their Tetryonic geometry,
the Nuclear Magneton is considerably weaker than the Bohr Magneton

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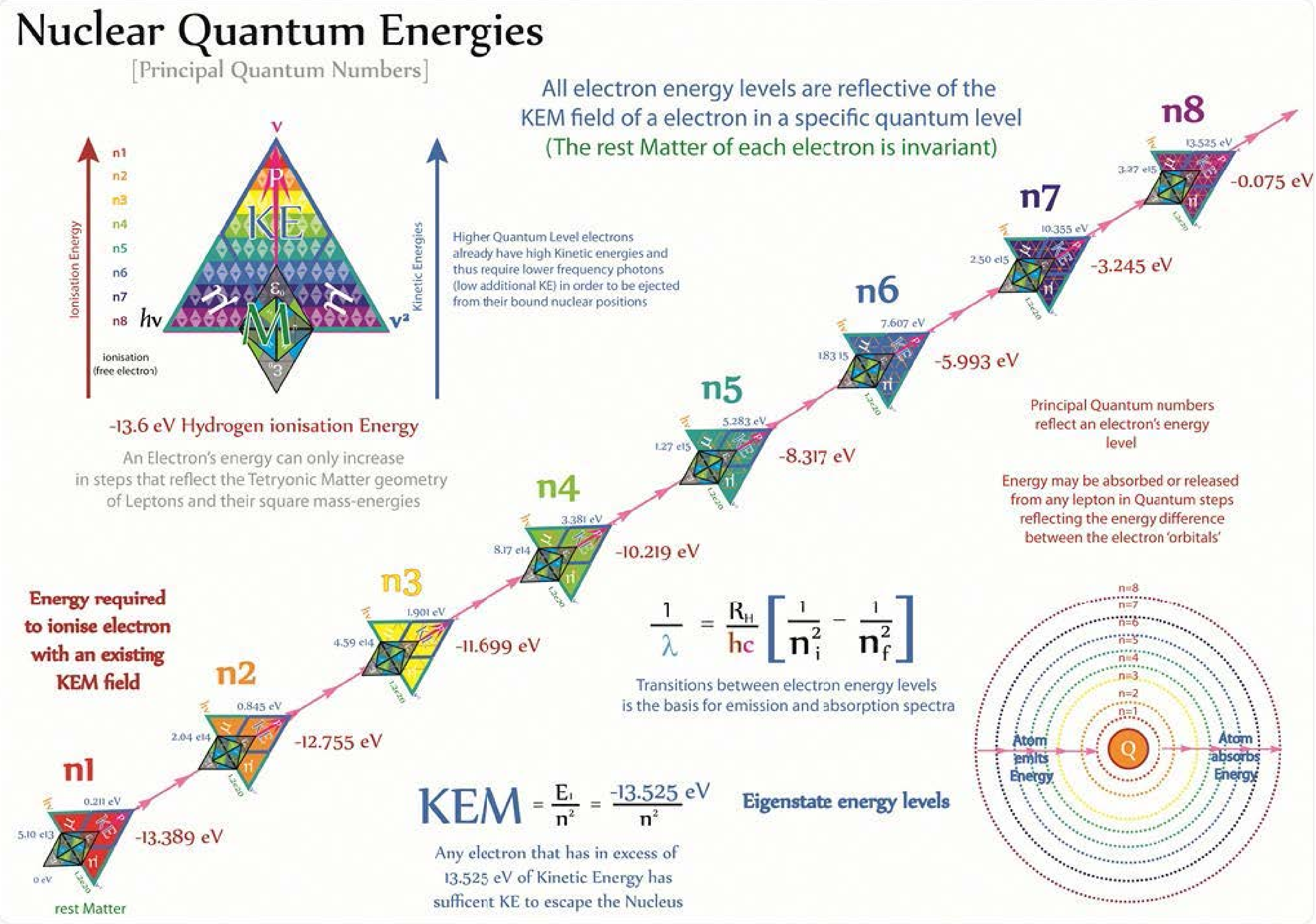
v
P
KE
M
hv
v²
n1
n2
n3
n4
n5
n6
n7
n8
Ionisation Energy
Kinetic Energies
ionisation
(free electron)
n1
0.211 eV
5.10 e13
0 eV
-13.389 eV
n2
0.845 eV
2.04 e14
-12.755 eV
n3
1.901 eV
4.59 e14
-11.699 eV
n4
3.381 eV
8.17 e14
-10.219 eV
n5
5.283 eV
1.27 e15
-8.317 eV
n6
7.607 eV
1.83 15
-5.993 eV
n7
10.355 eV
2.50 e15
-3.245 eV
n8
13.525 eV
3.27 e15
-0.075 eV
rest Matter
n=8
n=7
n=6
n=5
n=4
n=3
n=2
n=1
Q
Atom emits Energy
Atom absorbs Energy

Nuclear Quantum Energies

[Principal Quantum Numbers]

All electron energy levels are reflective of the KEM field of a electron in a specific quantum level

(The rest Matter of each electron is invariant)

Higher Quantum Level electrons already have high Kinetic energies and thus require lower frequency photons (low additional KE) in order to be ejected from their bound nuclear positions

-13.6 eV Hydrogen ionisation Energy

An Electron's energy can only increase in steps that reflect the Tetryonic Matter geometry of Leptons and their square mass-energies

Principal Quantum numbers reflect an electron's energy level

Energy may be absorbed or released from any lepton in Quantum steps reflecting the energy difference between the electron 'orbitals'

Energy required to ionise electron with an existing KEM field

$$\frac{1}{\lambda} = \frac{R_H}{hc}\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]$$

Transitions between electron energy levels is the basis for emission and absorption spectra

$$KEM = \frac{E_i}{n^2} = \frac{-13.525 \text{ eV}}{n^2}$$

Eigenstate energy levels

Any electron that has in excess of 13.525 eV of Kinetic Energy has sufficent KE to escape the Nucleus

Tetryonics 18.08 - Nuclear Quantum Energies

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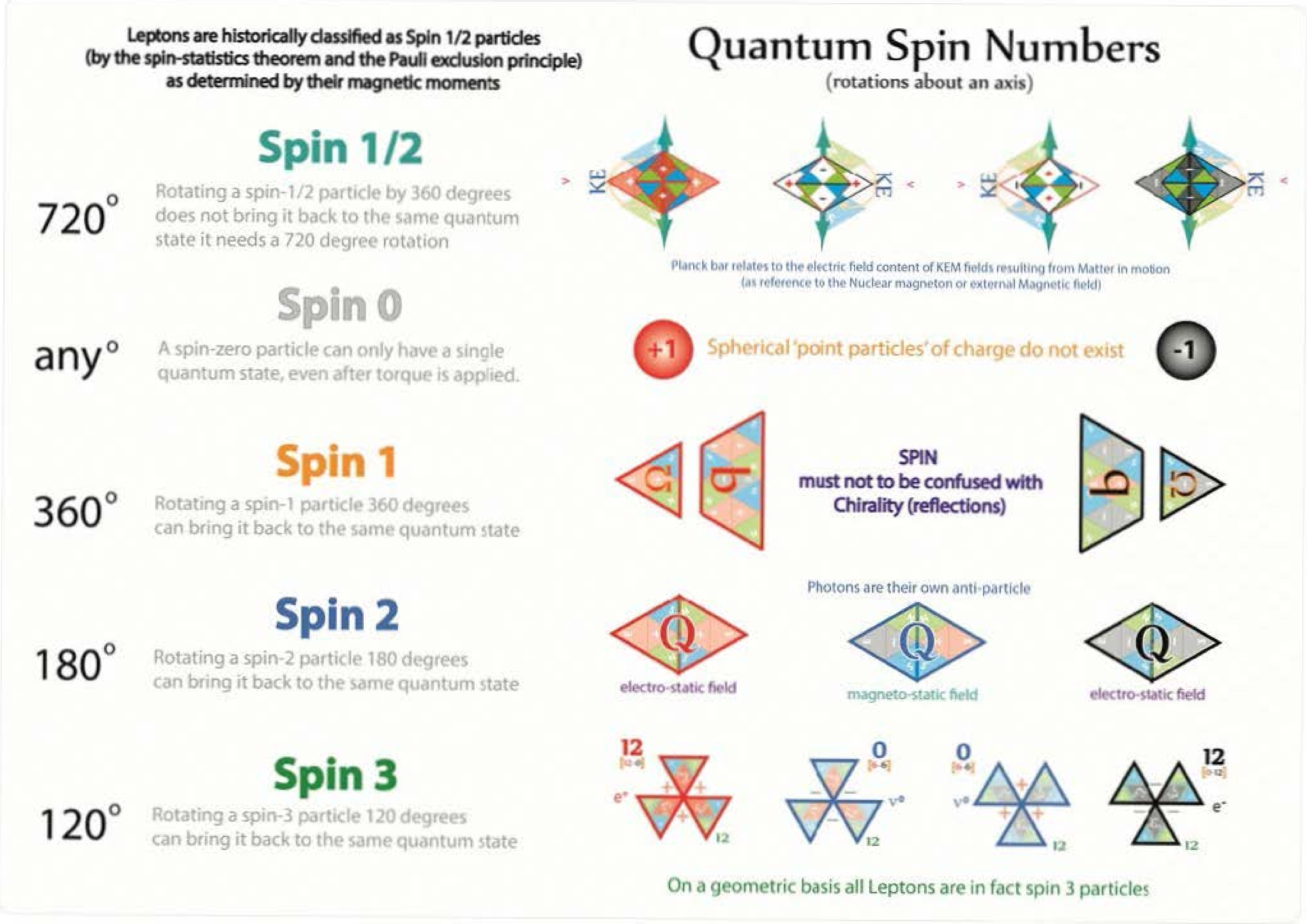

**Leptons are historically classified as Spin 1/2 particles
(by the spin-statistics theorem and the Pauli exclusion principle)
as determined by their magnetic moments**

Quantum Spin Numbers

(rotations about an axis)

Spin 1/2

720°

Rotating a spin-1/2 particle by 360 degrees does not bring it back to the same quantum state it needs a 720 degree rotation

Planck bar relates to the electric field content of KEM fields resulting from Matter in motion
(as reference to the Nuclear magneton or external Magnetic field)

Spin 0

any°

A spin-zero particle can only have a single quantum state, even after torque is applied.

Spherical 'point particles' of charge do not exist

Spin 1

360°

Rotating a spin-1 particle 360 degrees can bring it back to the same quantum state

**SPIN
must not to be confused with
Chirality (reflections)**

Spin 2

180°

Rotating a spin-2 particle 180 degrees can bring it back to the same quantum state

Photons are their own anti-particle

electro-static field

magneto-static field

electro-static field

Spin 3

120°

Rotating a spin-3 particle 120 degrees can bring it back to the same quantum state

On a geometric basis all Leptons are in fact spin 3 particles

Tetryonics 19.01 - Quantum spin numbers

Magnetic moments are determined by the KEM fields created by vector linear momentum

Nuclear Magnetic moments are complicated by the tri-quark magnetons within all Matter topologies

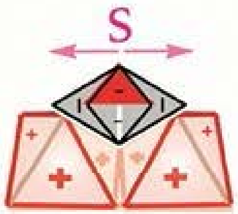

The KEM field of any charged particle in motion is reflective of the particle's nett charge topology

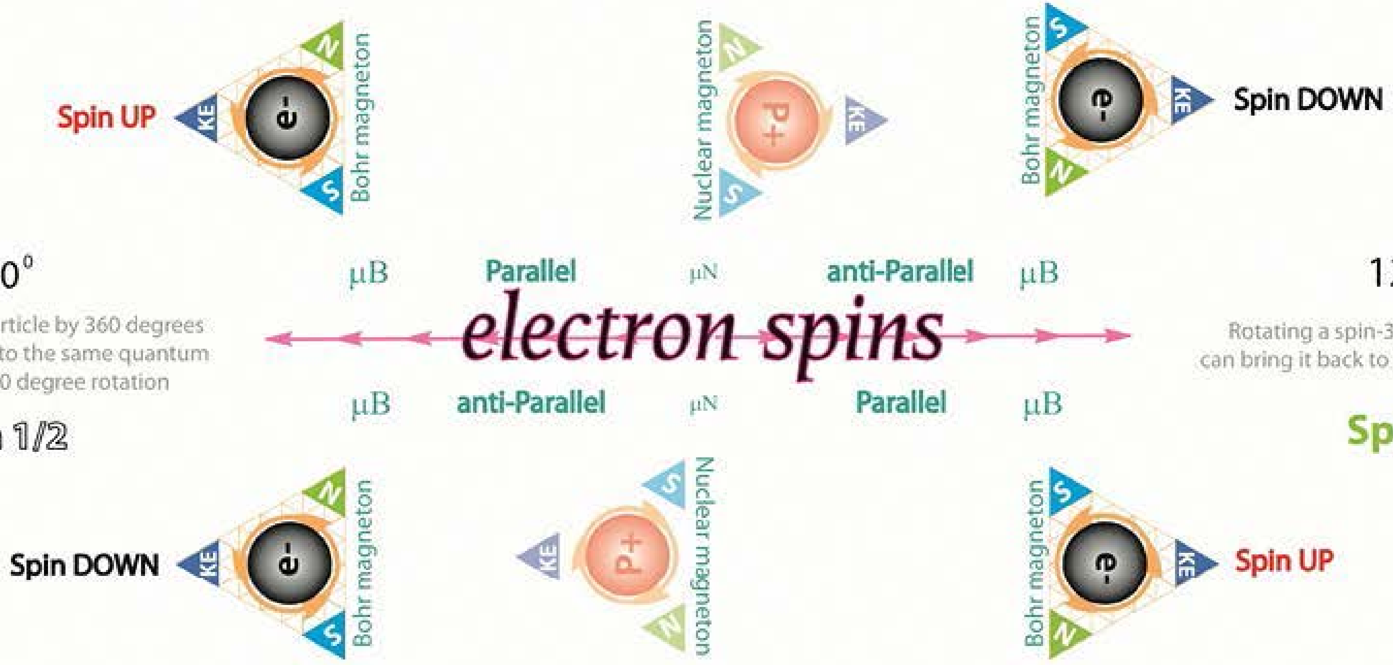
Spin UP
KE
e-
N
S
Bohr magneton
Nuclear magneton
P+
Spin DOWN
μB
Parallel
μN
anti-Parallel
electron spins
Spin DOWN
Spin UP

720°

Rotating a spin-1/2 particle by 360 degrees does not bring it back to the same quantum state it needs a 720 degree rotation

Spin 1/2

120°

Rotating a spin-3 particle 120 degrees can bring it back to the same quantum state

Spin 3

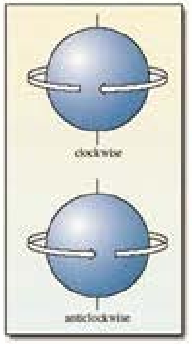
clockwise
anticlockwise

All atomic particles have a particular "spin" analogous to the Earth's rotation on its axis.

$$\mu_B = \left[\frac{Q}{2mv}\right]/\ell$$

An isolated electron has an angular momentum and a magnetic moment resulting from its spin. While an electron's spin is sometimes visualized as a literal rotation about an axis, it is in fact a fundamentally different, quantum-mechanical phenomenon with no true analogue in classical physics.

The quantum mechanical reality underlying spin is complex and still poorly understood Consequently, there is no reason to expect the above classical relation to hold.

$$\mu_B = g\left[\frac{e-}{2mv}\right]S$$

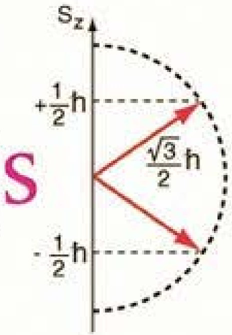
S_z
$+\frac{1}{2}\hbar$
$\frac{\sqrt{3}}{2}\hbar$
$-\frac{1}{2}\hbar$

Tetryonic KEM field geometries reveals the source and orientation of all atomic magnetic moments

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Generating Magnetons

A static Electron has a negative Tetryonic charge [0-12] topology with neutralised magnetic dipoles

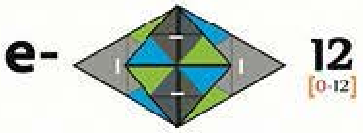

Leptons are 12 loop inductive charge rotors

Tetryonic geometry fully explains Leptronic 'spins'

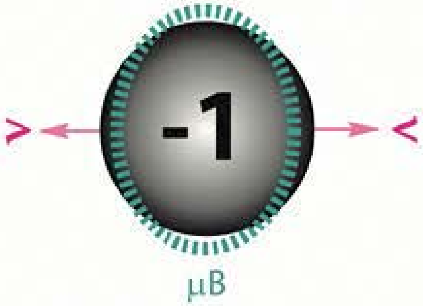

Einstein's Special Relativity model of distorted moving charges producing magnetic moments is incorrect

BOHR Magneton produced by Lorentzian distortion of charges due to relativitistic velocities

$$\mu_B = \frac{e\hbar}{2m_e}$$

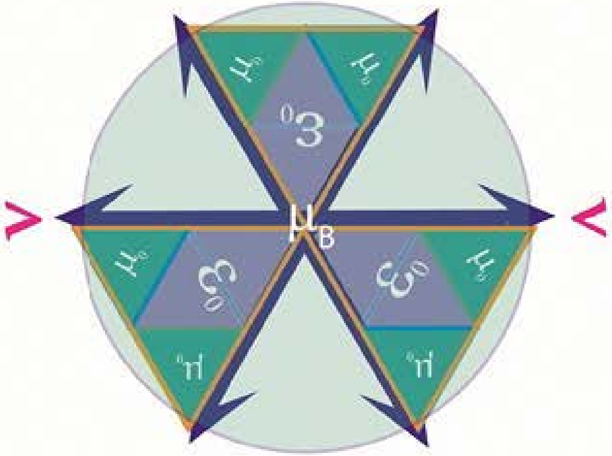

The term "electron spin" can now be taken literally (when modelled with Tetryonic geometries) as an accurate description of the origin of Magnetic moments for all Leptonic [BOHR] magnetons.

The previously held model of the electron as a spinning sphere of charge must be abandoned in favour of the true Tetryonic charge geometries of EM mass-Energy-Matter

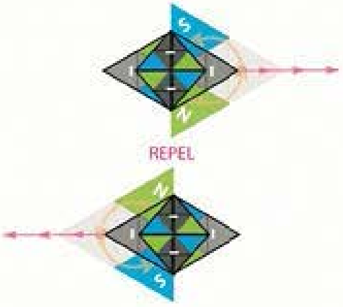

Ampere Force

$$B = \frac{\mu_0 I}{4\pi}\int \frac{d\ell \times \hat{r}}{r^2},$$

$$F = 2k_A \frac{I_1 I_2}{r}$$

$$F = q[E + (v \times B)].$$

Lorentz Force

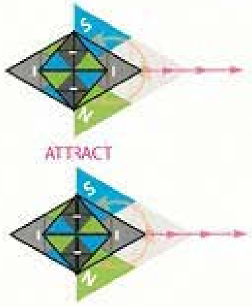

A moving Electron has a KEM field with an Electric field and a Magnetic Moment

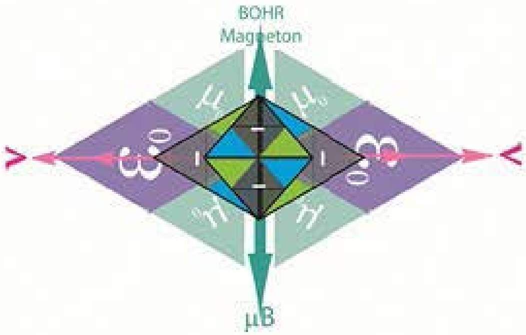

The gyromagnetic ratio of a particle or system is the ratio of its magnetic dipole moment to its angular momentum

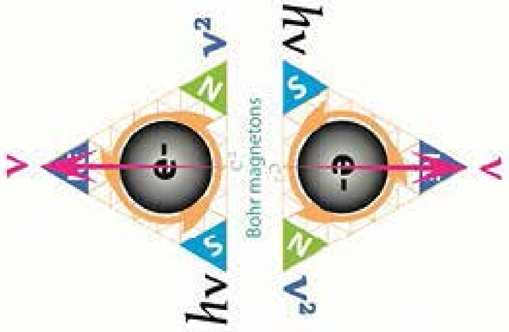

The KEM field energy of an Electron in motion is subject to relativistic corrections due to energy changes resulting from its acceleration

$$\lambda = L'\sqrt{1 - \frac{v^2}{c^2}}$$

WAVE-length contraction of mass-energy quanta of KEM field

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Stern Gerlach Experiment

In 1922 O. Stern and W. Gerlach measured the intrinsic spin angular momentum
of silver atoms and found it to take only two discrete values.
+ h / 2 and - h / 2 commonly called "spin up" and "spin down

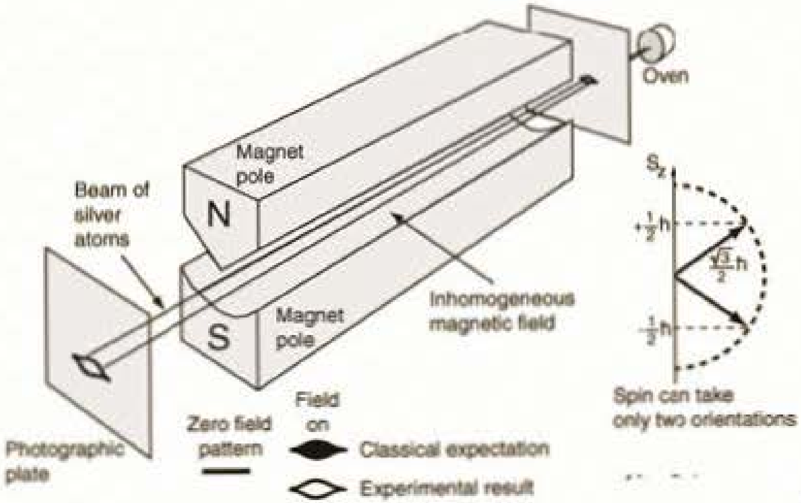
Oven
Magnet pole
N
Beam of silver atoms
S
Magnet pole
Inhomogeneous magnetic field
S_z
$+\frac{1}{2}h$
$\frac{\sqrt{3}}{2}h$
$-\frac{1}{2}h$
Spin can take only two orientations
Photographic plate
Zero field pattern
Field on
Classical expectation
Experimental result

The Stern-Gerlach experiment to determine electron SPIN

The results were interpreted to show that particles
possess an intrinsic angular momentum that is most
closely analogous to the angular momentum of a
classically spinning charged sphere, that takes
on only certain quantized values of angular momentum

Tetryonics shows the results are a product of
the KEM field produced by charge particles in motion,
with all charged particles being able to produce 2 distinct
magneton orientations as a result of the real motion of
their intrinsic quantum inductive loop [Matter]geometries
through external E fields & as referenced to external M moments.

This along with the Lorentz force produced by an external
Magnetic field acting on the KEM magnetons produces
the two results obtained

Any increase in electron energies results in
an increase in quantised angular momenta
and its vector linear momentum

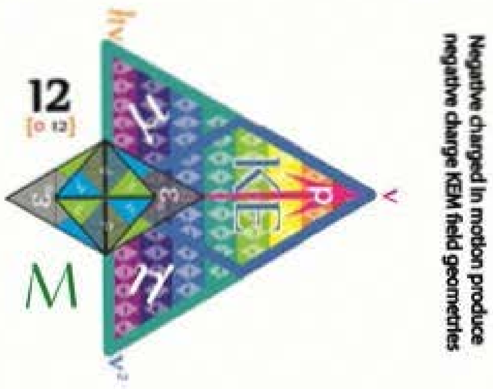
hv
12
[0 12]
M
KE
v
v²
Negative charged in motion produce negative charge KEM field geometries

Any change in the KEM energy level
of an electron results in Photon
emission or absorption

Electron Spins based on the measured Bohr Magnetons of moving electrons are reflected with KEM field geometries

**Electrons
bound in atomic nuclei
increase of decrease their
energy levels dependent
on the energy level of the nuclei
in which they are bound**

**Bound and unbound electrons
can rotate in one of two
directions influenced only by
external magnetic and electric fields
or incident Photons**

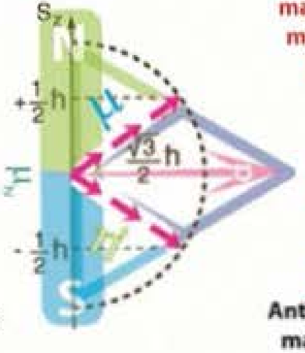
S_z
N
$+\frac{1}{2}h$
$\frac{\sqrt{3}}{2}h$
$-\frac{1}{2}h$
S

N
Parallel magnetic moment
S

μ_B

The BOHR magneton dipole is measured against either the Nuclear Magneton or external magnetic fields

S
Antiparallel magnetic moment
N

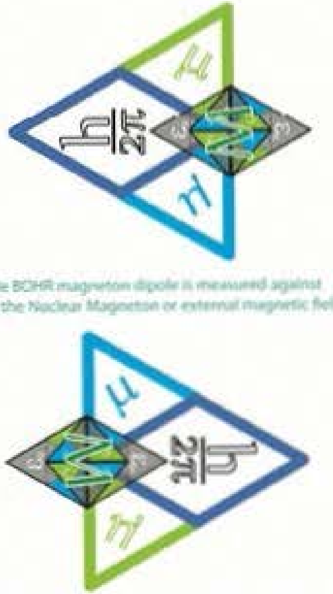
$\frac{h}{2\pi}$
$\frac{h}{2\pi}$

The two separated beams of electrons produced
are defined as having differing SPINS
[UP or DOWN]

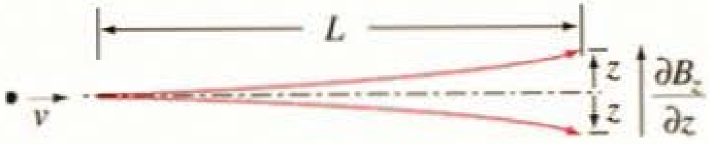
L
v
z
z
$\frac{\partial B_z}{\partial z}$

$$z = \frac{1}{2}at^2 = \frac{1}{2}\frac{F}{m}\left[\frac{L}{v}\right]^2 = \pm\frac{\mu_B L^2}{4KE}\frac{\partial B_z}{\partial z}$$

The orientation of the BOHR magneton wrt the NUCLEAR magneton
determines the 'direction' of electron SPIN

Tetryonics 19.04 - Stern Gerlach experiment

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Bohr Magnetons

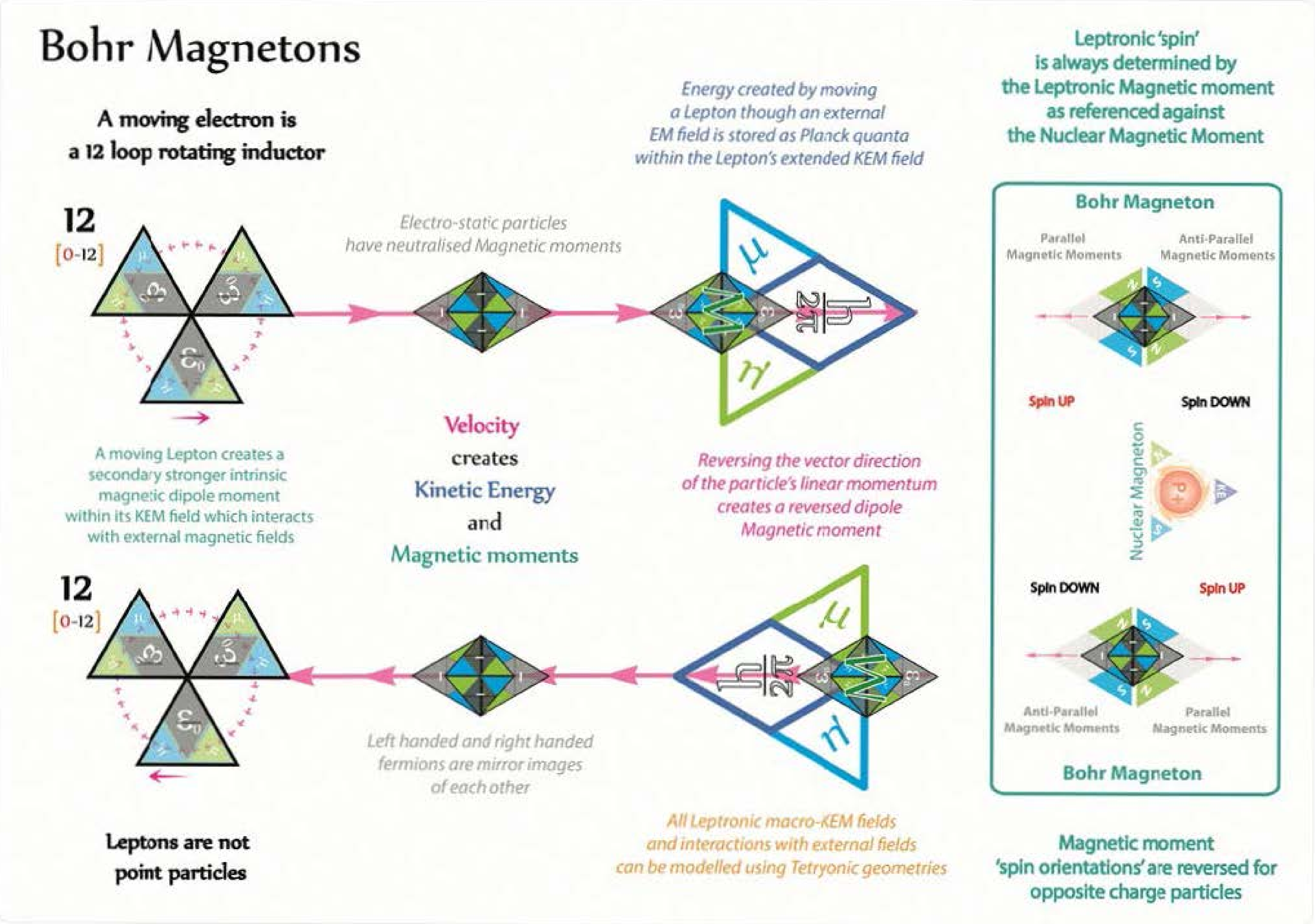

A moving electron is
a 12 loop rotating inductor

Electro-static particles
have neutralised Magnetic moments

Energy created by moving
a Lepton though an external
EM field is stored as Planck quanta
within the Lepton's extended KEM field

Leptronic 'spin'
is always determined by
the Leptronic Magnetic moment
as referenced against
the Nuclear Magnetic Moment

Bohr Magneton

Parallel Magnetic Moments

Anti-Parallel Magnetic Moments

Spin UP

Spin DOWN

Spin DOWN

Spin UP

Anti-Parallel Magnetic Moments

Parallel Magnetic Moments

Bohr Magneton

A moving Lepton creates a
secondary stronger intrinsic
magnetic dipole moment
within its KEM field which interacts
with external magnetic fields

Velocity
creates
Kinetic Energy
and
Magnetic moments

Reversing the vector direction
of the particle's linear momentum
creates a reversed dipole
Magnetic moment

Left handed and right handed
fermions are mirror images
of each other

Leptons are not
point particles

All Leptronic macro-KEM fields
and interactions with external fields
can be modelled using Tetryonic geometries

Magnetic moment
'spin orientations' are reversed for
opposite charge particles

Tetryonics 19.05 - Bohr Magnetons

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Electron Spin orientation

The Bohr magneton dipole produced by Kinetic Energies is located axially about the centre of rotation

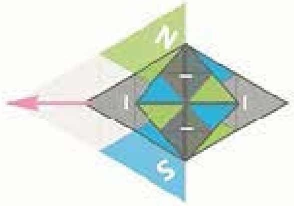

Spin UP

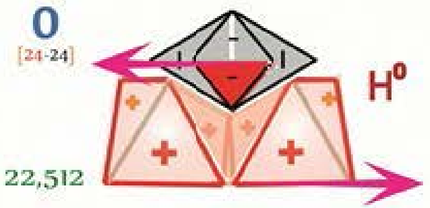
0
[24-24]
H⁰
22,512

Higher energy

Parallel spin

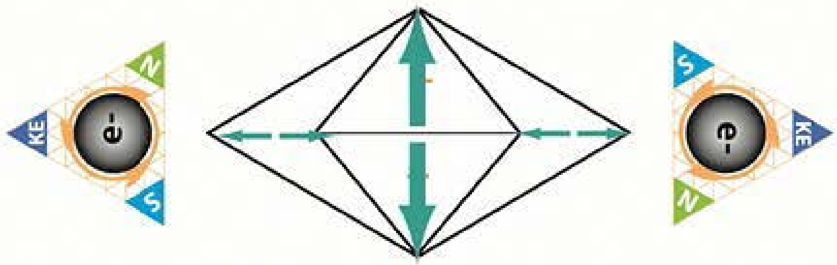
KE
e-
N
S
e-
S
KE
N

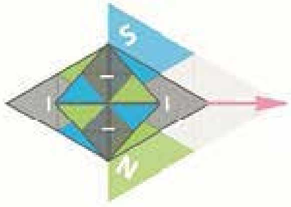

Spin DOWN

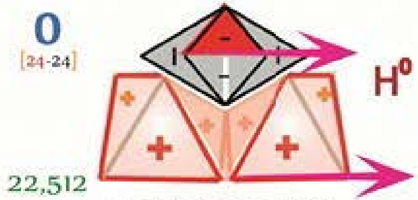
0
[24-24]
H⁰
22,512

Lower energy

Anti-parallel spin

All Leptons have 12 intrinsic neutralised dipole moments and a polarised KEM field Magnetic moment created by the energies of its motion

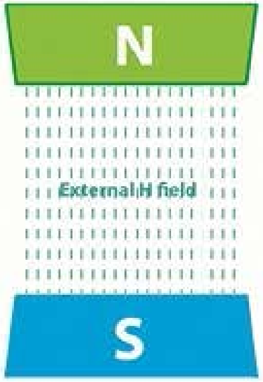
N
External H field
S

Spin UP

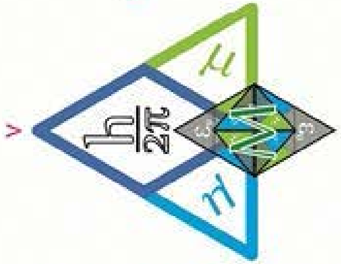

Magnetic field is Parallel to Nuclear Magnetic moment or external Magentic H field

Lepton Magnetic moment

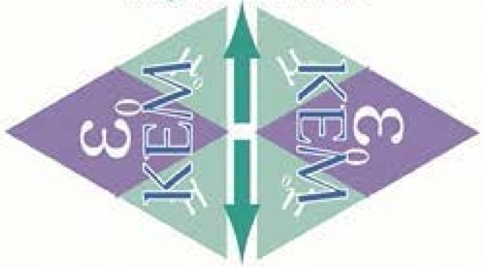

[Bohr Magneton]

$$\mu_B = \frac{e\hbar}{2m_e}$$

Spin DOWN

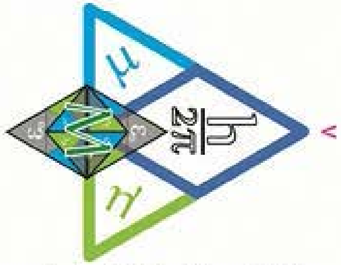

Magnetic field is Antiparallel to Nuclear Magnetic moment or external Magnetic H field

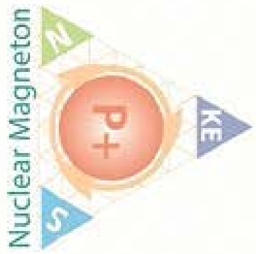
Nuclear Magneton
N
P+
KE
S

Nuclear magnetons are weaker than Bohr magnetons

All Leptronic spin directions are referenced to external Magnetic fields [either Nuclear Magnetons or H fields]

Tetryonics 19.06 - Electron Spin orientation

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Nuclear Spins

are determined by the orientation of Bohr Magneton
with respect to the Nuclear Magneton
[or an external Magnetic field]

*electron Matter geoemtries
are negative charged fascia
which create neutral intrinsic
magnetic dipole configurations*

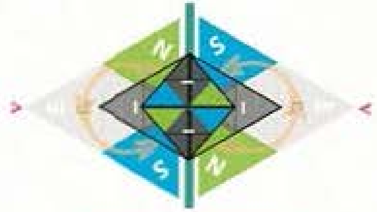

MAGNETIC MOMENT

*In a moving electron
Kinetic energy produces
an axial Magnetic moment*

*In a static electron
all intrinsic dipoles are
neutralised through
their orientations*

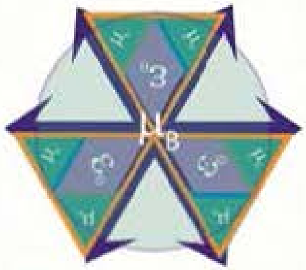

***Quantum Inductive Loops
In motion produce Kinetic Energies
In turn creating Magnetic Moments***

Electron

PARALLEL
Magnetic moments

UP

BOHR
Magneton

ANTIPARALLEL
Magnetic moments

DOWN

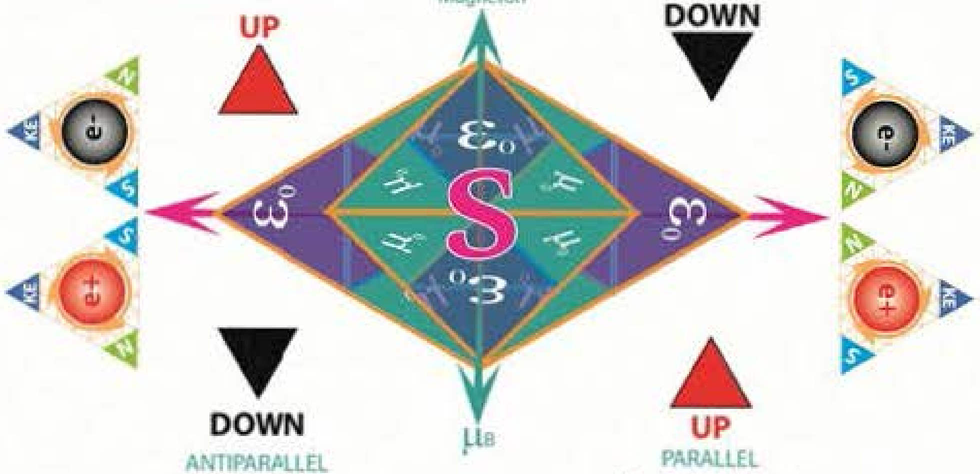

DOWN
ANTIPARALLEL
Magnetic moments

UP
PARALLEL
Magnetic moments

Positron

Spin UP

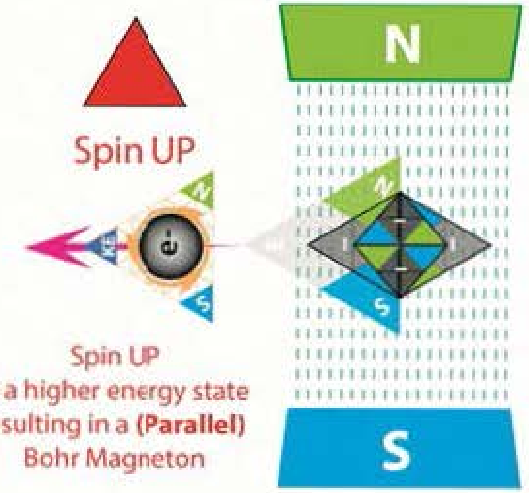

Spin UP
is a higher energy state
resulting in a **(Parallel)**
Bohr Magneton

Nuclear magneton or external Magnetic field

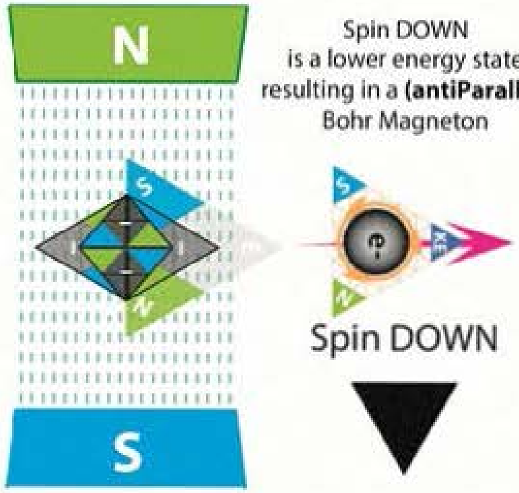

Spin DOWN
is a lower energy state
resulting in a **(antiParallel)**
Bohr Magneton

Spin DOWN

Lorentz Force

**When moving in an
external magnetic field**

The axial dipole
moment of an
electron will experience
torque force
proportional to
its velocity

**Opposites attract
Similars repel**

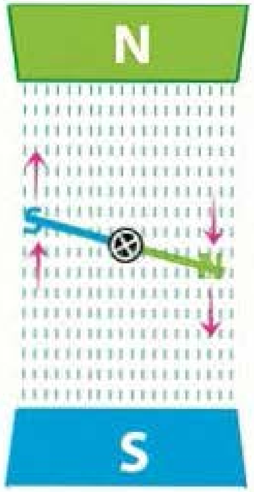

Tetryonics 19.07 - Nuclear spins

Nuclear magnetic Moment

[Nuclear magneton]

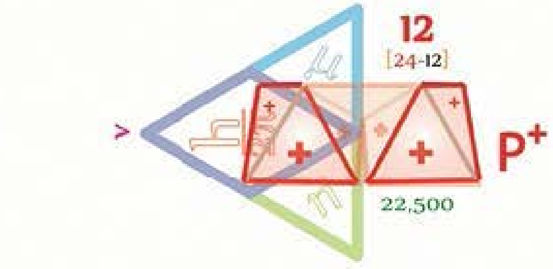
12
[24-12]
P+
22,500
h/2π
μ

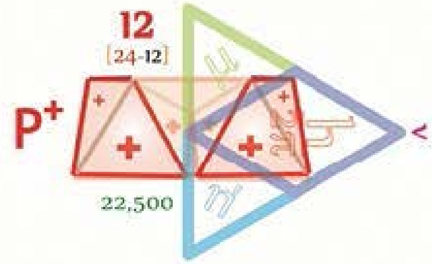
12
[24-12]
P+
22,500
h/2π
μ

NUCLEAR magnetons are much weaker than BOHR magnetons due to the higher charge to mass ratio of electrons

$$\frac{M_p}{M_e} = \frac{1}{1875}$$

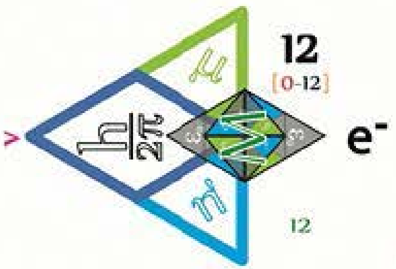
12
[0-12]
e-
12
h/2π
μ

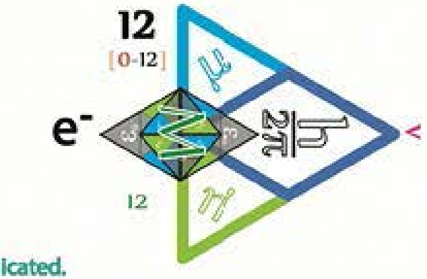
12
[0-12]
e-
12
h/2π
μ

The nuclear spins for individual protons and neutrons parallels the treatment of electron spin, with spin 1/2 and an associated magnetic moment.

For the combination of electron, neutrons and protons in periodic elements, the situation is even more complicated.

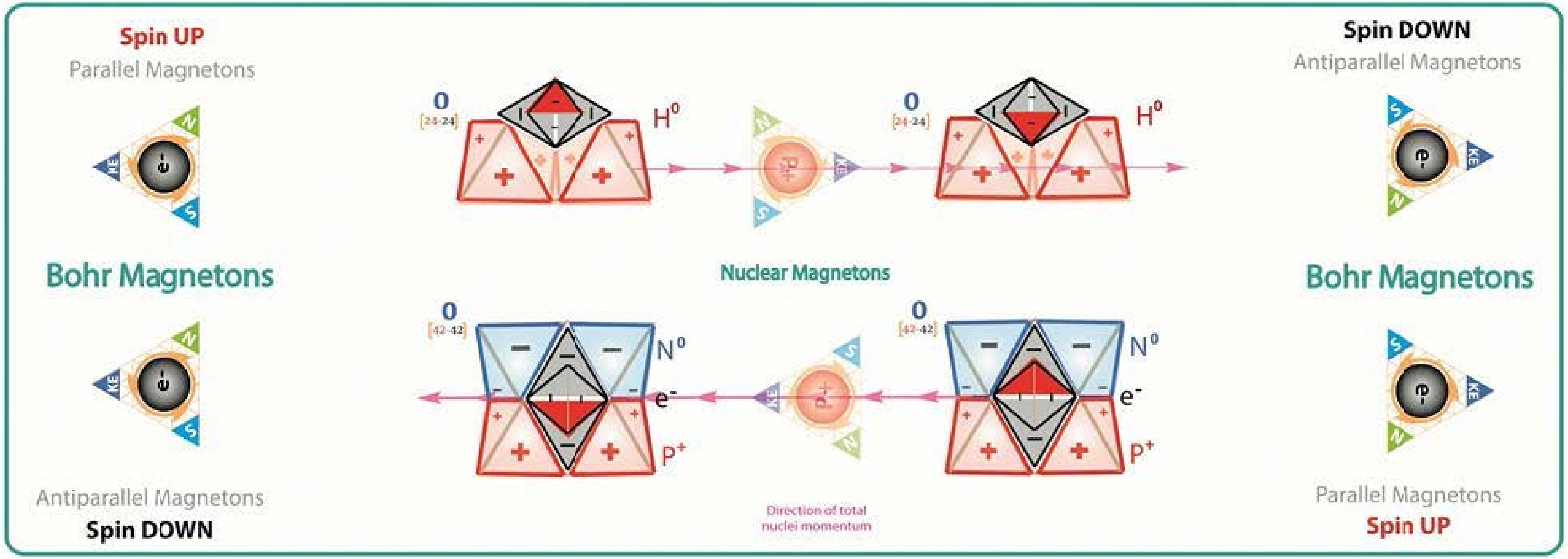
0
[24-24]
H°
0
[24-24]
H°
0
[42-42]
N°
e-
P+
0
[42-42]
N°
e-
P+
N
S
KE
e-
P+

Spin UP

Parallel Magnetons

Spin DOWN

Antiparallel Magnetons

Bohr Magnetons

Nuclear Magnetons

Bohr Magnetons

Antiparallel Magnetons

Spin DOWN

Direction of total nuclei momentum

Parallel Magnetons

Spin UP

Tetryonics 19.08 - Nuclear Magnetic moments

Spin orbital coupling mechanics

The induced magnetic moment of electrons in atomic nuclei combine vectorally with the magnetic moment of the nuclei

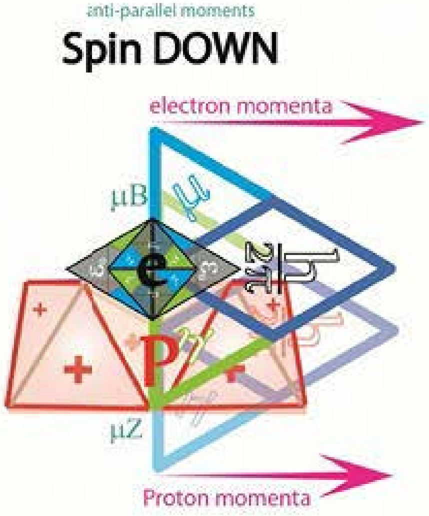
anti-parallel moments
Spin DOWN
electron momenta
μB
μ
e
$\frac{h}{2\pi}$
P
+
μZ
Proton momenta

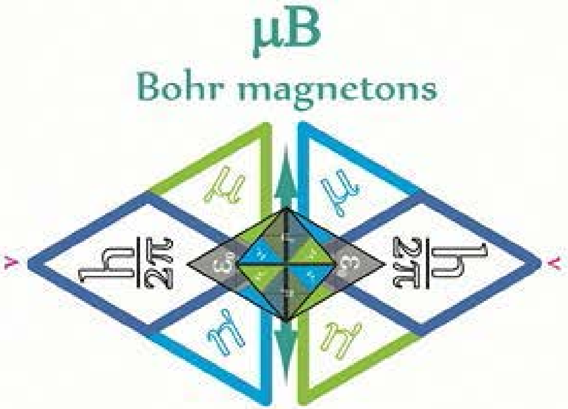
μB
Bohr magnetons
μ
$\frac{h}{2\pi}$

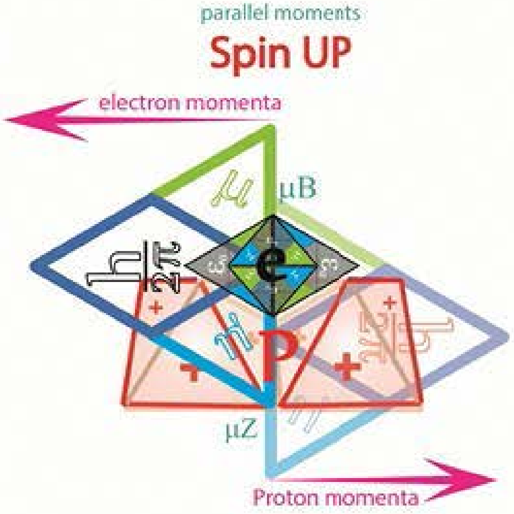
parallel moments
Spin UP
electron momenta
μB
μ
e
$\frac{h}{2\pi}$
P
+
μZ
Proton momenta

The energy level differences created are manifested in Hyperfine-line splitting Zeeman effects etc.

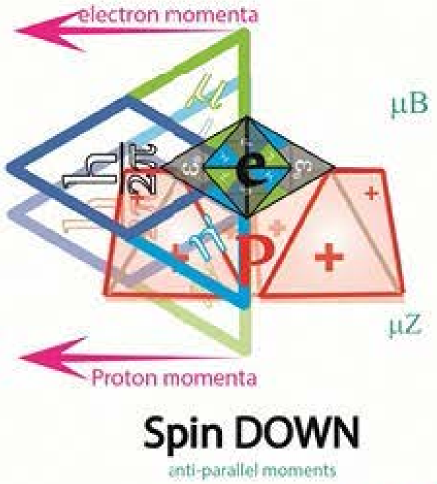
electron momenta
μB
μ
$\frac{h}{2\pi}$
e
P
+
μZ
Proton momenta
Spin DOWN
anti-parallel moments

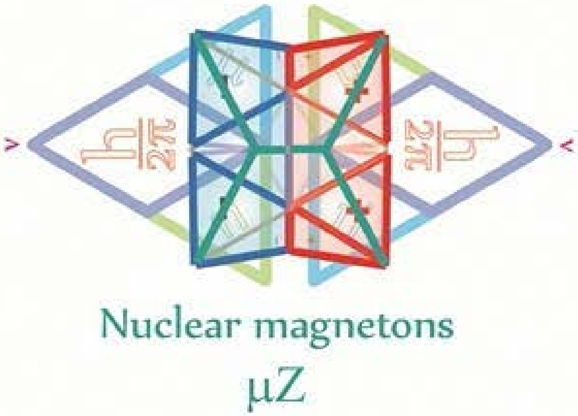
$\frac{h}{2\pi}$
+
Nuclear magnetons
μZ

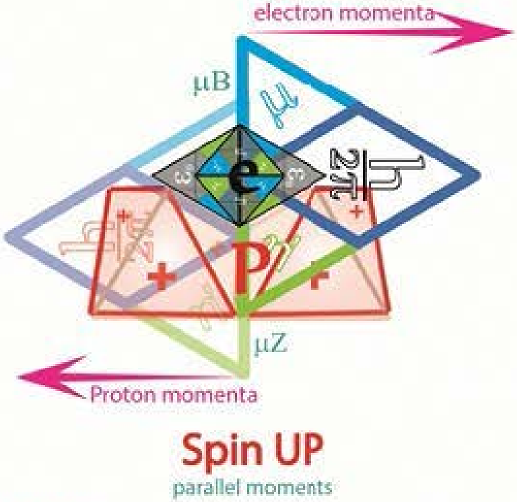
electron momenta
μB
μ
e
$\frac{h}{2\pi}$
P
+
μZ
Proton momenta
Spin UP
parallel moments

The alignment of electron spins in nuclei results in diamagnetic, para-magnetic Matter

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Gyromagnetic Ratio

The electron is a 12 charge quantum rotor
with a uniform charge to mass density ratio,
the ratio of its magnetic moment to
its orbital angular momentum,
also known as gyromagnetic ratio

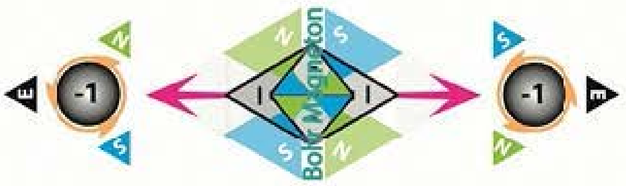
-1
Bohr Magneton
N
S
E
-1

This implies that a more massive
assembly of charges spinning with the
same angular momentum will have a
proportionately weaker magnetic moment,
compared to its lighter counterpart.

12
[0-12]
1.2 e20
1
electron
12π

The Bohr Magneton is determined by the
charged KEM field geometry of Leptons

1875
charged mass-Matter differential

The combined Kinetic energy of Motion [KEM field]
and Electron Spin coupling with Nuclear Magnetons
will effect any measured Gyromagnetic ratios

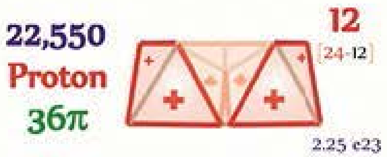
22,550
Proton
36π
12
[24-12]
2.25 e23

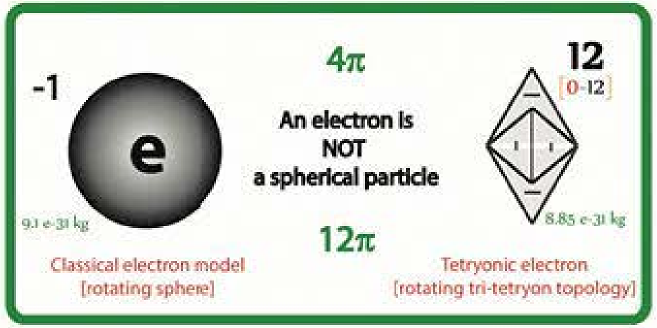
-1
e
9.1 e-31 kg
4π
12π
12
[0-12]
8.85 e-31 kg

An electron is
NOT
a spherical particle

Classical electron model
[rotating sphere]

Tetryonic electron
[rotating tri-tetryon topology]

In physics, the gyromagnetic ratio
(also sometimes known as the magnetogyric ratio in other disciplines)
of a particle or system is the ratio of its magnetic dipole moment to
its angular momentum, and it is often denoted by the symbol γ, gamma.

An isolated electron has an angular momentum and
a magnetic moment resulting from its spin.

Its SI units are radian per second per tesla (s−1·T −1) or,
equivalently, coulomb per kilogram (C·kg−1).

Tetryonic quantum mass to Charge ratio

$$1.810109642 \times 10^{11}$$

The 2006 CODATA
– e / me = -1.758 820 150(44) x 10[11]

Nuclear Magnetons

$$e- \quad \frac{\text{Tetryonic elementary charge } 1.602216081\text{ e-19 coulombs}}{\text{Tetryonic electron mass } 8.851486361\text{ e-31}} \quad \frac{12q}{1.2\text{ e}20}$$

e_m

[q/m]

181,010,964,200 C/kg

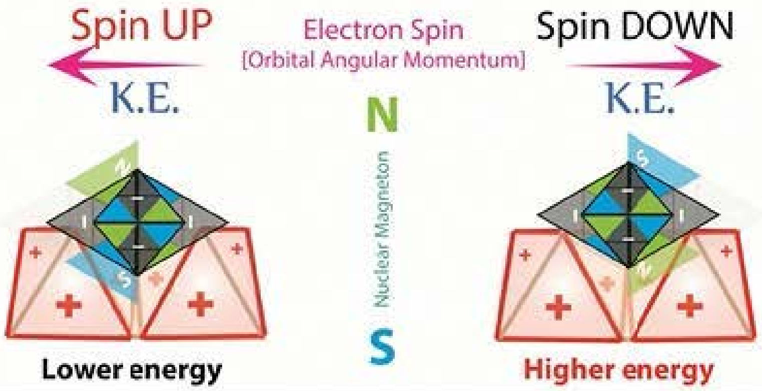
Spin UP
K.E.
Electron Spin
[Orbital Angular Momentum]
Spin DOWN
K.E.
N
Nuclear Magneton
S
Lower energy
Higher energy

$$\frac{12q}{2.25\text{ e}23} \quad \frac{\text{Tetryonic elementary charge } 1.602216081\text{ e-19 coulombs}}{\text{Tetryonic Proton mass } 1.659653693\text{ e-27}} \quad e+$$

P_m

[q/m]

96,539,180.9 C/kg

Tetryonics 19.10 - Gyromagnetic ratio

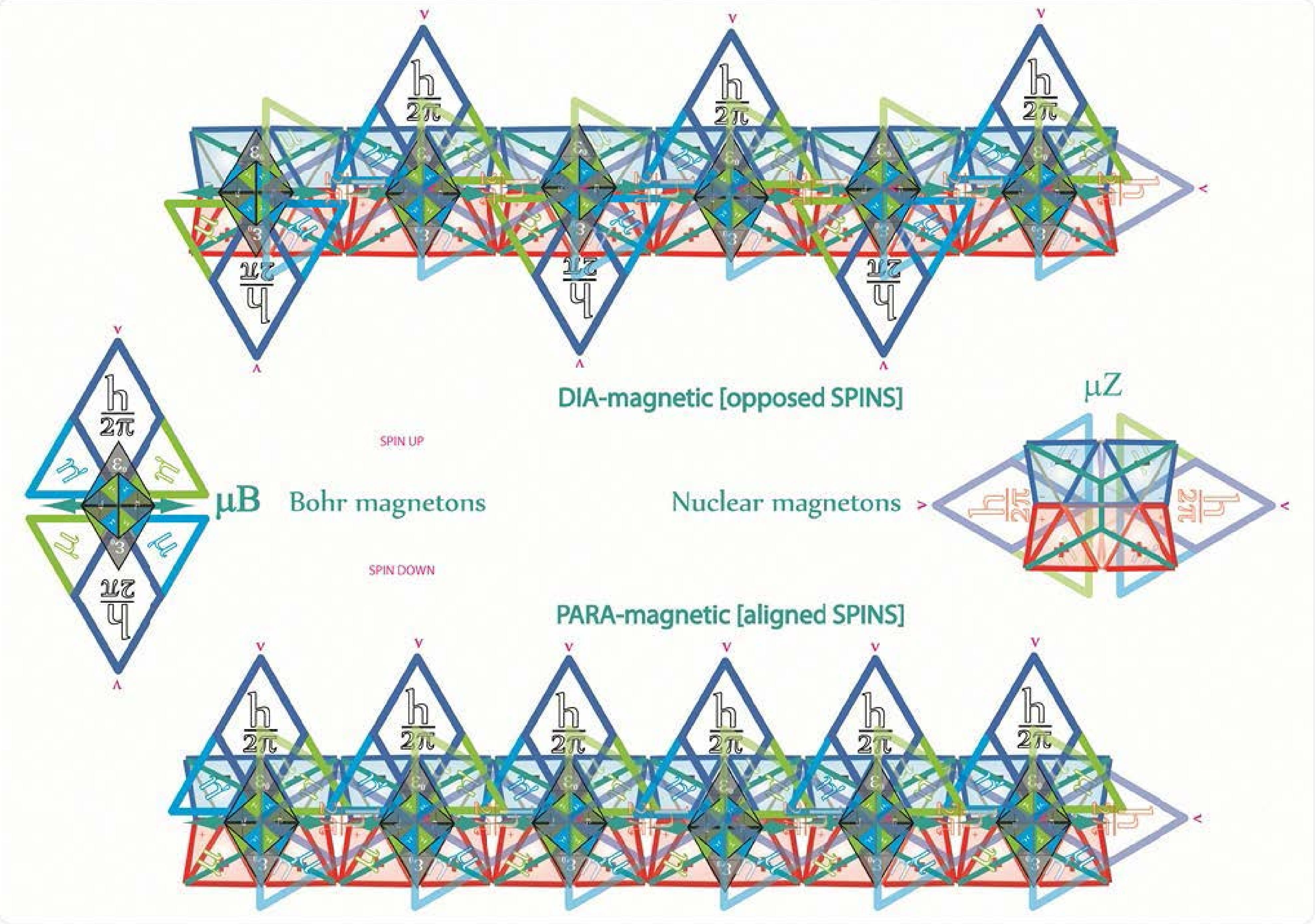
DIA-magnetic [opposed SPINS]
μZ
SPIN UP
μB
Bohr magnetons
Nuclear magnetons
SPIN DOWN
PARA-magnetic [aligned SPINS]

Tetryonics 19.11 - DIA & PARA-magnetic fields

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12
[12-0]
1.2e20

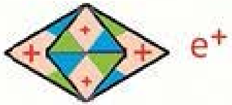

Positron

Leptons

181,010,964,200 C/kg

12
[0-12]
1.2e20

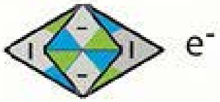

Electron

12
[24-12]
2.25e23

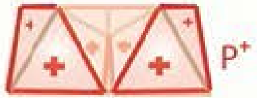

Proton

Baryons

96,539,180.9 C/kg

0
[18-18]
2.25e23

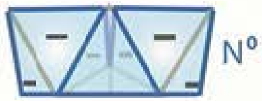

Neutron

All mass-Matter have distinct charge geometries
and once in motion are subject to EM forces
as a result of their geometries & KEM field

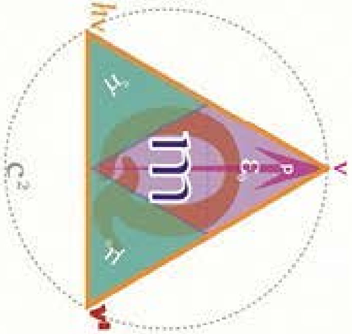

Lorentz force Law

$$\vec{F} = q\vec{E} + q\vec{v} \times B$$

LORENTZ force
Electric force
charge velocity
Magnetic force

all Matter in motion is subject to
NEWTON'S SECOND LAW OF MOTION

$$F = ma$$

Combining
Lorentz's force law & Newton's Third Law
we obtain a EM mass-charge quotient
for any particle of mass-Matter in motion

$$(M/Q)a = E + v \times B$$

mass-charge ratios

1.335180067 e-20 C

1.810109642 e11 $\left[\frac{q}{m}\right]\mathfrak{m}$ 1e19 V

7.376238634 e-51 kg

are the basis for mass spectroscopy

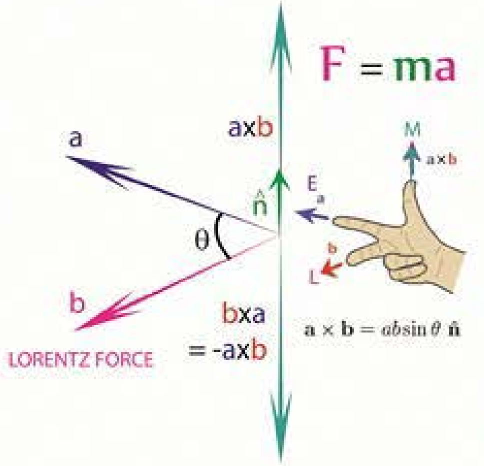

For every action there is an equal and opposite reaction
(NEWTON'S THIRD LAW OF MOTION)

Q *Any two particles with the same EM mass-to-charge ratio follow the same path in a vacuum when subjected to the same external electric field* **M**

Dependent on their generations

Charge/mass

$\left(\frac{q_t}{m_t}\right)$ 181,010,964,200 C/kg $\left(\frac{q_e}{m_e}\right)$

4:4 12:12

Tetryons and Leptons can have identical mass-charge ratios

96,487,720.78 C/kg

Elements

48,256,721.99 C/kg

0
[24-24]
2.2512e23

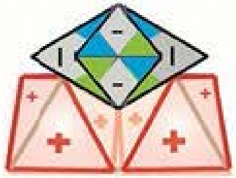

Hydrogen

Deuterium

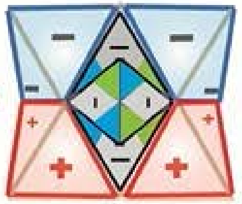

0
[42-42]
4.5012e23

Tetryonic theory shows mass-charge ratios are a measure of mass-energy geometries in Matter topologies

E

Collider particle track physics

A collider is a type of a particle accelerator involving directed beams of particles.

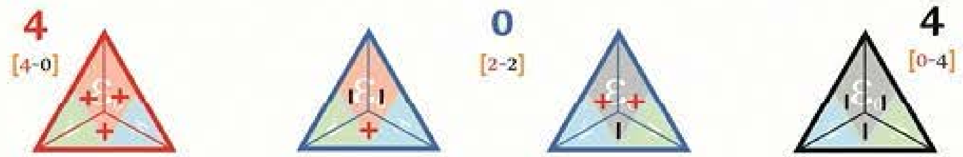

Q

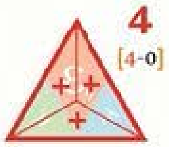

181,010,964,200 C/Kg

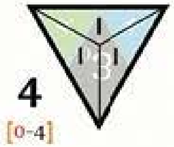

Colliders may either be ring accelerators or linear accelerators,
and may collide a single beam of elementary particles against a stationary target or two beams head-on.

t 4 [0-4]

4 [4-0] t

Tetryons
have the same 1/3
elementary charge
as some Quarks

d 4 [4-8]

4 [8-4] d

m

2D bosons & photons are radiant mass-enery geometries

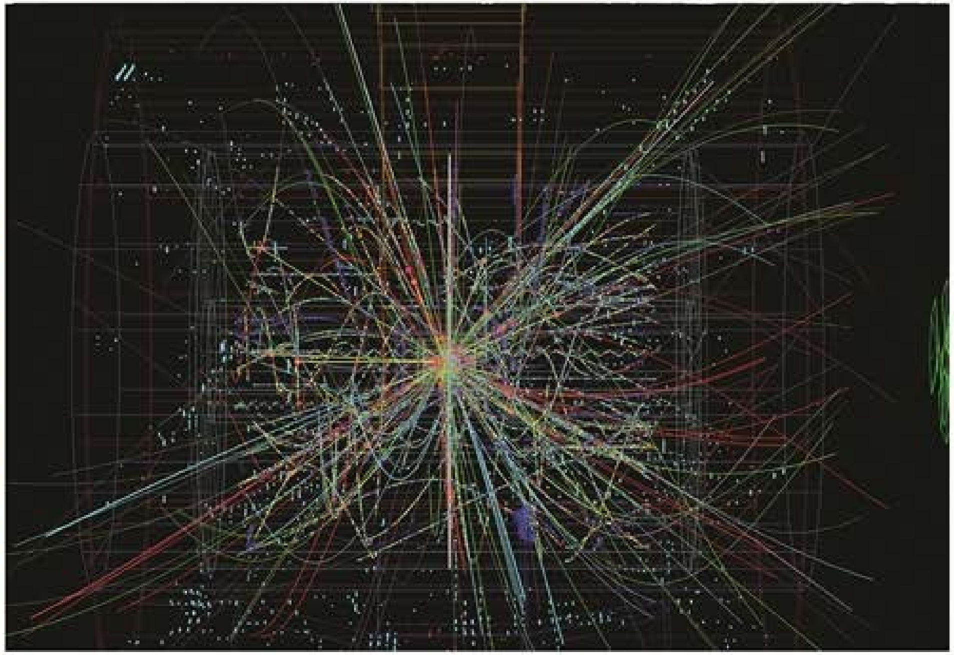

3D Matter Fermions are standing wave mass-energy topologies

Tetryons
can have the same
mass-charge ratios
as Leptons

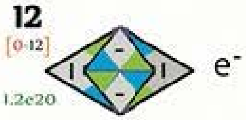

181,010,964,200 C/Kg

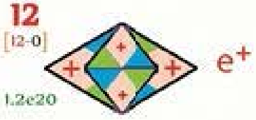

Analysis of the by-products of these collisions without a clear definition of, and distinction between, EM mass-energy geometries & Matter topologies through the charged geometrics of Tetryonics ceates a misleading and erroneous picture of the particles created in high energy collisions within particle physics accelerator experiments

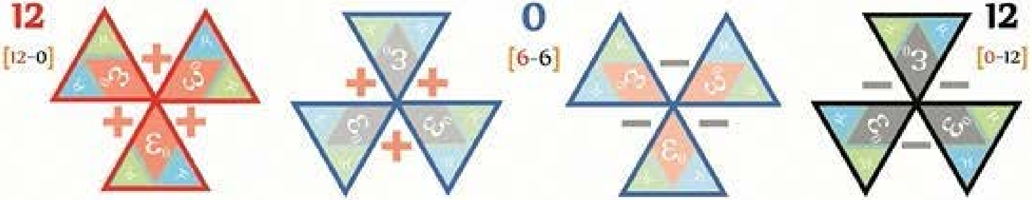

M

Radiant EM mass-energy geometries

mass | Planck quanta

$$\frac{n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass | velocity

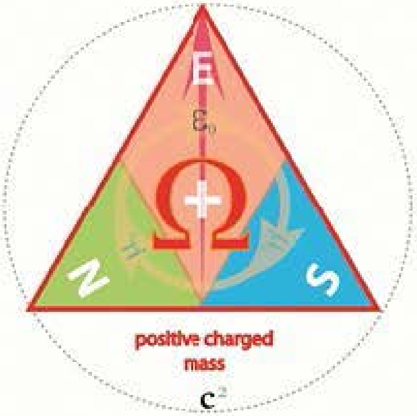

positive charged mass

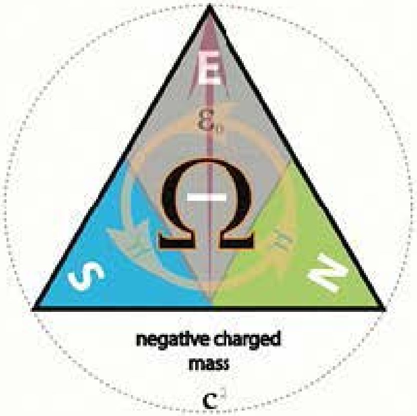

negative charged mass

Charge | Planck quanta

$$\frac{1\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass | velocity

Bosons | Planck quanta

$$\frac{\mathrm{ODD}\,\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass | velocity

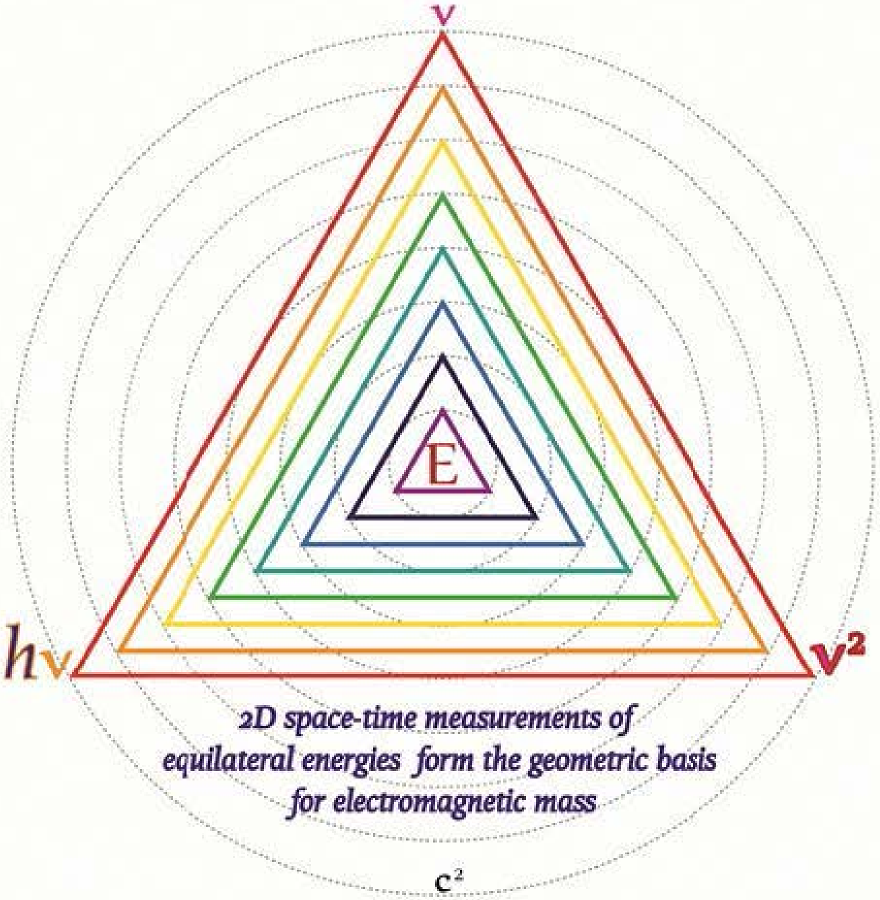

Photons | Planck quanta

$$\frac{2\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass | velocity

EM waves | Planck quanta

$$\frac{\mathrm{EVEN}\,\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$

mass | velocity

2D space-time measurements of equilateral energies form the geometric basis for electromagnetic mass

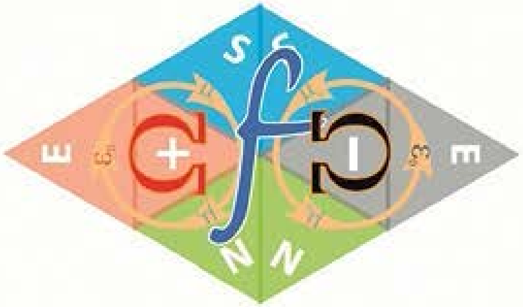

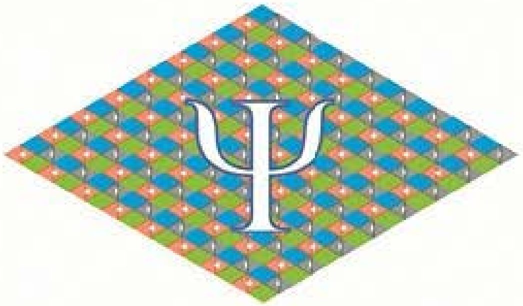

2D Planar divergent EM mass-energies form radiant Electromagnetic waves

ElectroMagnetic mass is a property of Matter
[being the energy content of its charged geometry per unit time]

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ENERGY

2D Equilateral scalar energy-momenta

Q
charge

E
energy

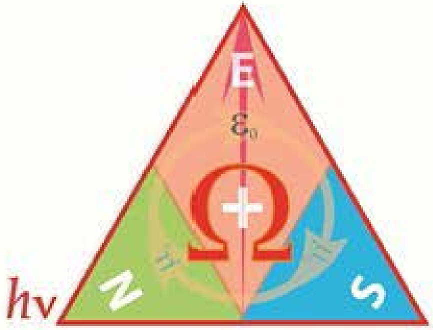
E
ε_0
Ω
+
hν
N
S
π
π

Quantised angular momenta are energy geometries

Planck's constant of
mass-energy momenta
is the source of all physical
constants and force relationships

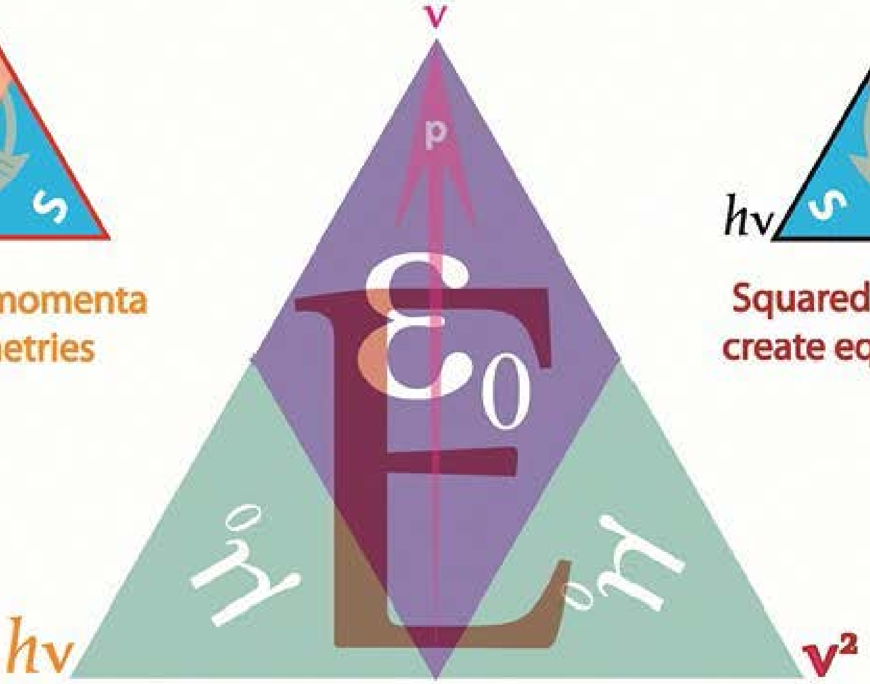
v
p
ε_0
E
π
π
hν
v²

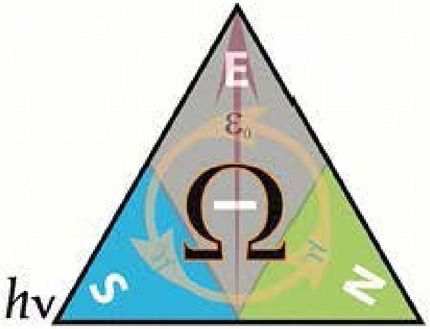
E
ε_0
Ω
−
hν
S
N
π
π

Squared numbers in physics create equilateral geometries

Separated fields of charge
create electromotive forces
accelerating Material bodies
within them

ENERGY
Planck quanta

$$n\pi\left[\left[m\Omega v^{2}\right]\right]$$

mass velocity

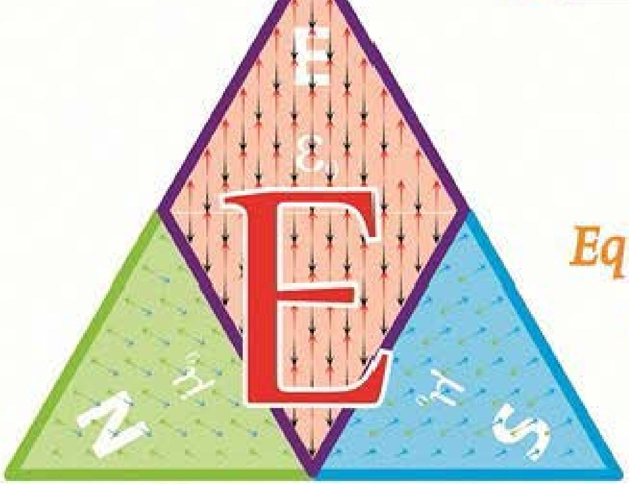

Positive charge energy momenta fields

Equilateral energy-momenta form the foundation of all Forces, EM masses & Matter

All energy seeks equilibrium

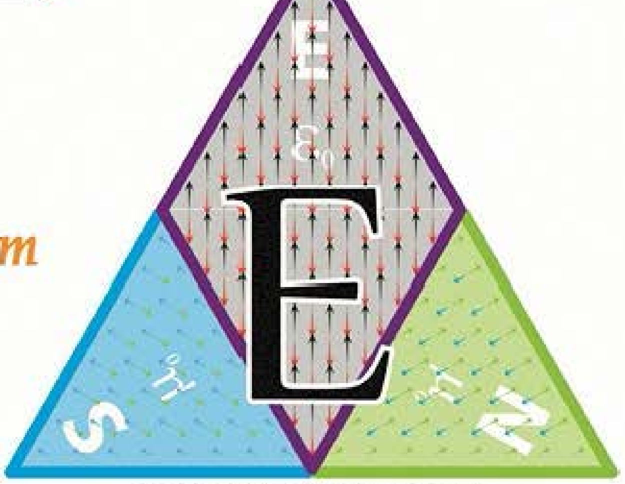
E
ε_0
E
π
π
S
N

Negative charge energy momenta fields

3D Matter topology is NOT a property of 2D ElectroMagnetic mass-energies

it is a measure of the closed 3D standing-wave spatial topology of all fermionic particles created by their charged equilateral mass-energy momenta geometries

Matter displaces vacuum energies to create convergent gravity fields around it

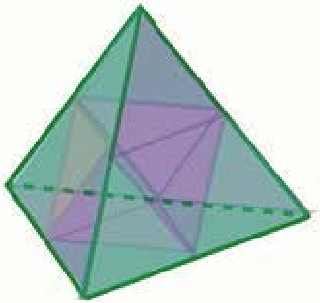

Tetryons are the quantum of Matter

Tetryons

$$\frac{4\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

Fermions

$$\frac{12\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

Mesons

$$\frac{24\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

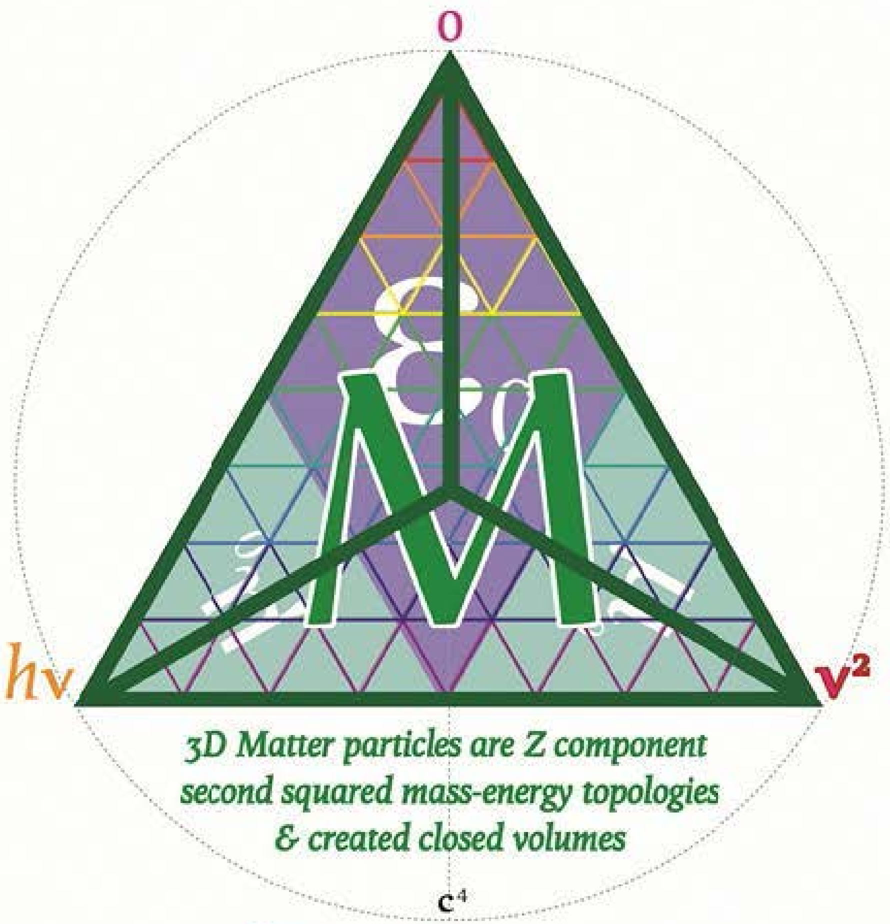

3D Matter particles are Z component second squared mass-energy topologies & created closed volumes

Matter

$$\frac{T\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

The mass-energies of Matter are Lorentz invariant to velocity changes

All Matter is comprised of [and radiates divergent] kEM mass-energies

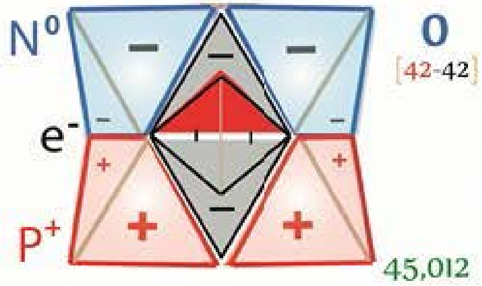

Deuterium is the quantum of all Elements

Baryons

$$\frac{36\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

Nuclei

$$\frac{72\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

Deuterons

$$\frac{84\pi}{c^4}\left[\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

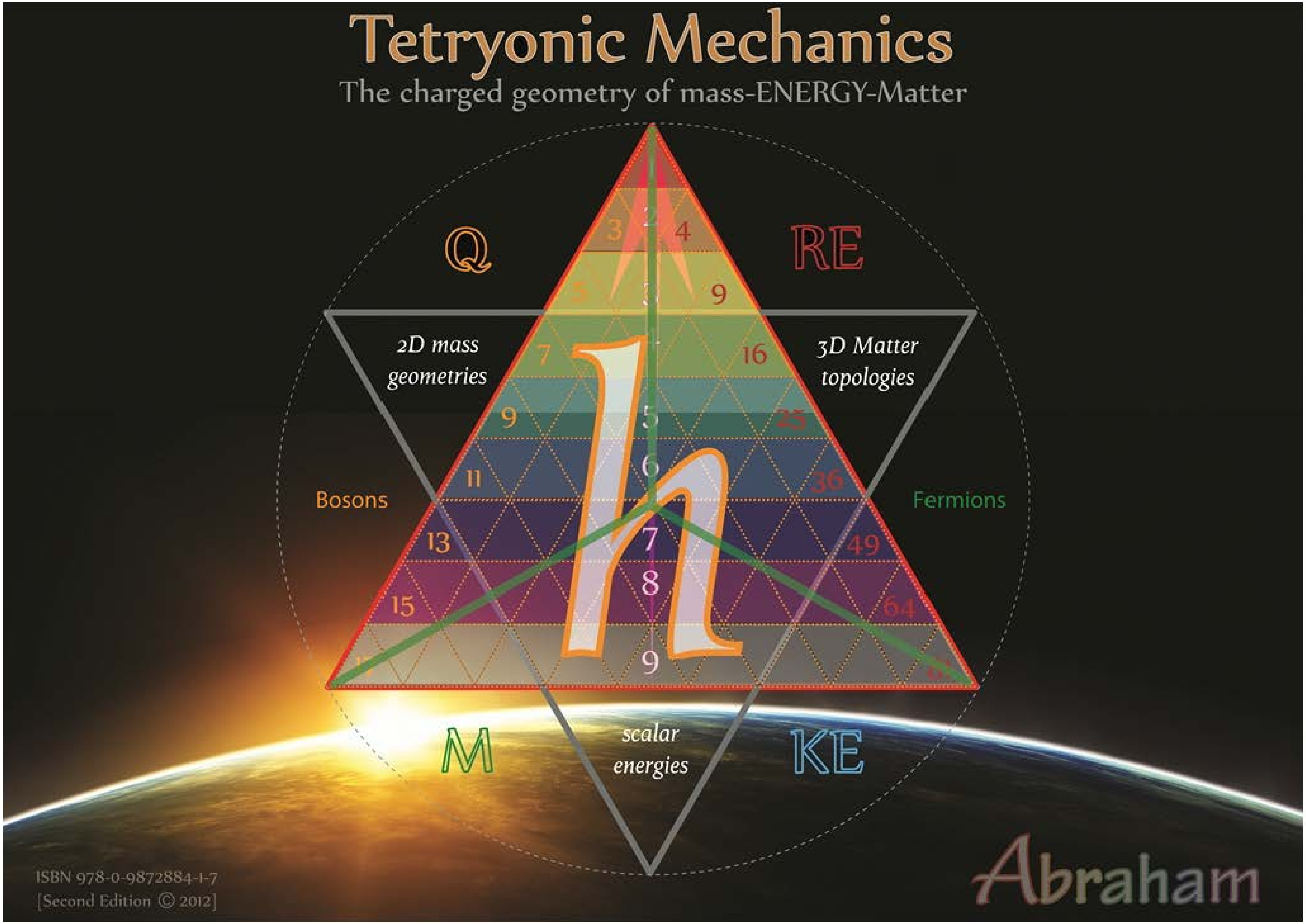

Tetryonic Mechanics

The charged geometry of mass-ENERGY-Matter

Q
RE
2D mass geometries
3D Matter topologies
Bosons
Fermions
M
KE
scalar energies
3
4
5
9
7
16
9
5
25
11
6
36
13
7
49
8
15
64
9
h
Abraham

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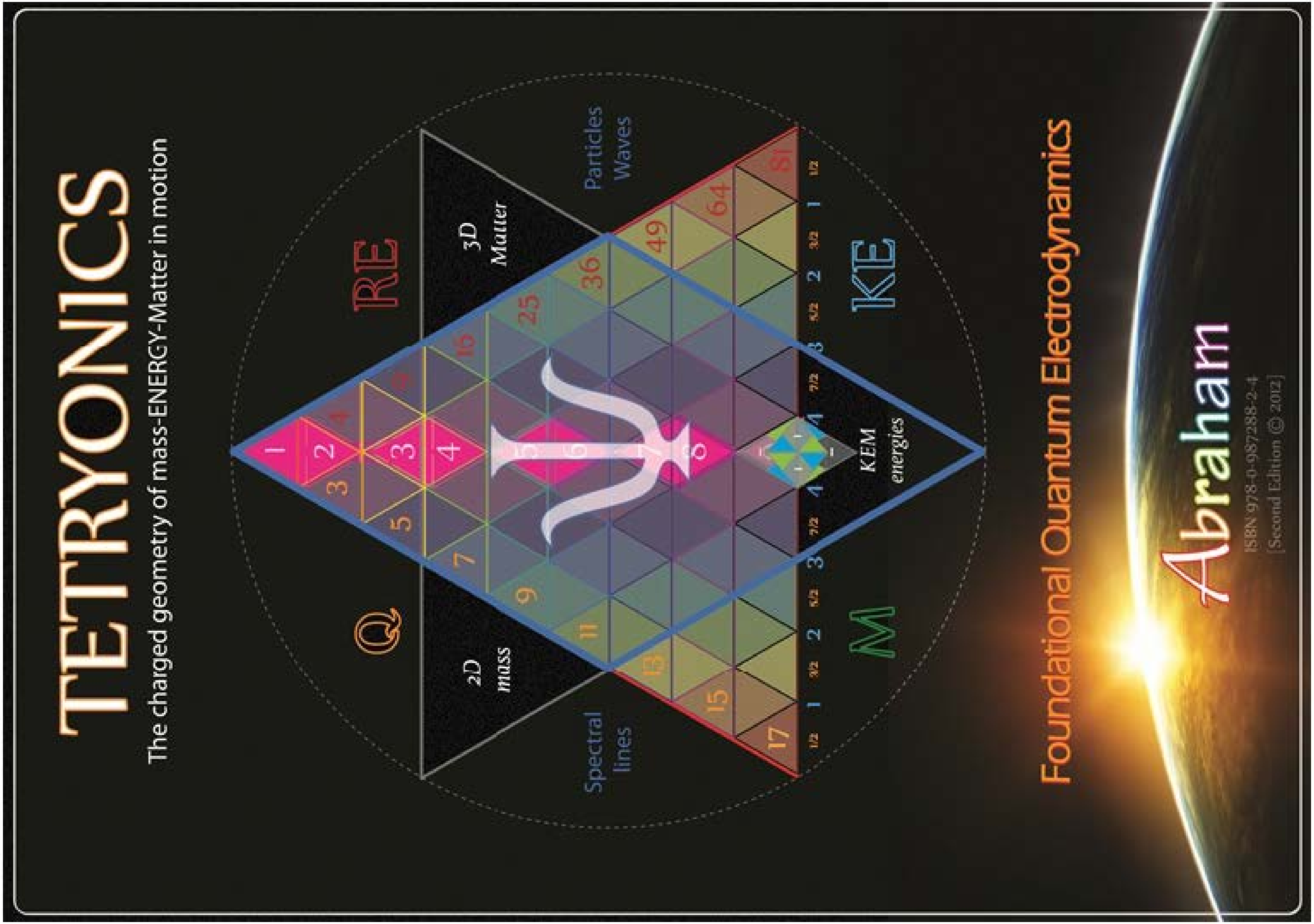

TETRYONICS

The charged geometry of mass-ENERGY-Matter in motion

Foundational Quantum Electrodynamics

Abraham

ISBN 978-0-987288-2-4
[Second Edition © 2012]

RE
Q
KE
M
3D Matter
2D mass
KEM energies
Particles Waves
Spectral lines
1
2
3
4
5
6
7
8
9
11
13
15
17
16
25
36
49
64
81
1/2
1
3/2
2
5/2
3
7/2
4

Tetryonics 21.00 - Tetryonic Electrodynamics title page

James Clerk Maxwell

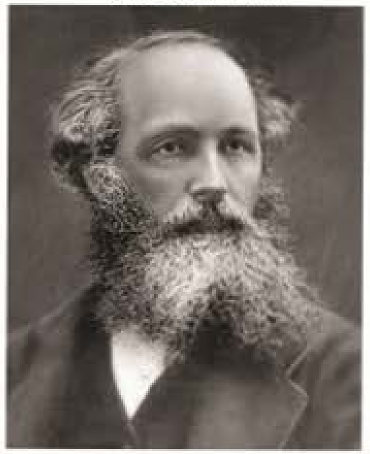

(13 June 1831 – 5 November 1879)

EM Planck Energy

Q
[v-v]

Net Electric charge is the
result of quanta imbalances
in equilateral geometry

E

Electric charge polarity
is determined by the
magnetic dipole vector

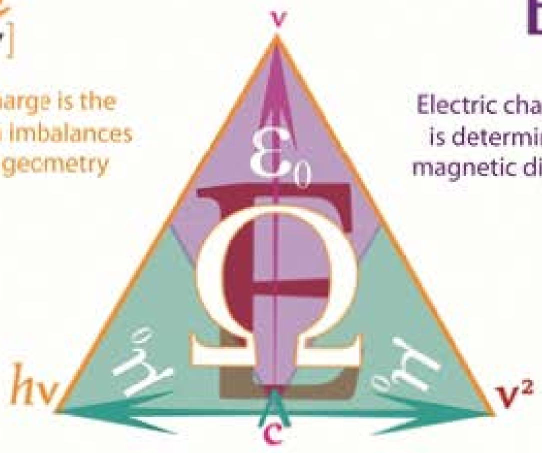

ORTHOGONAL MAGNETIC DIPOLE FIELD

$$\oint \vec{E}\cdot d\vec{A}=\frac{q}{\varepsilon_0}$$

Gauss's Law for Electricity

$$\oint \vec{B}\cdot d\vec{A}=0$$

Gauss's Law for Magnetism

$$\oint \vec{E}\cdot d\vec{s}=\frac{-d\Phi_B}{dt}$$

Faraday's Law

$$\oint \vec{B}\cdot d\vec{s}=\mu_0 i+\frac{\mu_0\varepsilon_0 d\Phi_E}{dt}$$

Ampere's Law

E = electric field
A = area
q = charge
ε_0 = permittivity of free space (a constant)
B = magnetic field intensity
s = path length
Φ_B = magnetic flux
Φ_E = electric flux
t = time
μ_0 = permeability of free space (a constant)
i = current electric charge
$\mu_0\varepsilon_0$ = $1/c^2$, where c=speed of light

Maxwell's equations describe how
Electric and Magnetic fields
are generated and altered by each other
and by charges and currents.

Maxwell's Equations

Maxwell's equations are a set of partial differential equations that, together with the Lorentz force law, form the foundation of classical electrodynamics, classical optics, and electric circuits.

ElectroMagnetic fields in turn provide
the foundation of our modern electrical
and communications technologies.

q
[1-0]

POSITIVE [Ω] CHARGE

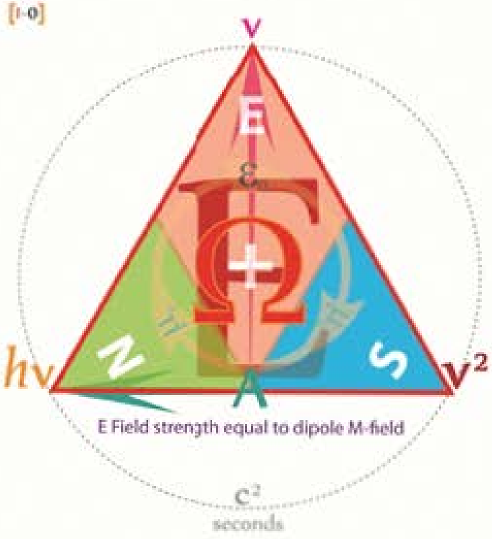

E Field strength equal to dipole M-field

Q

Gauss' Law of Electric Flux

Electric fields diverge from Electric charge,
and produce the Coulomb force.

Q

N

Gauss' Law of Zero Nett Magnetism

there are no isolated Magnetic poles,
but the Henry force acts between
the poles of a magnet.

S

ε_0

Faraday's Law of Inductance

Electric fields are produced by
changing Magnetic fields.

μ_0

Ampere's Circuital Law

circulating Magnetic fields are produced by
moving Electric fields and by electric currents.

NEGATIVE [Ω] CHARGE

q
[0-1]

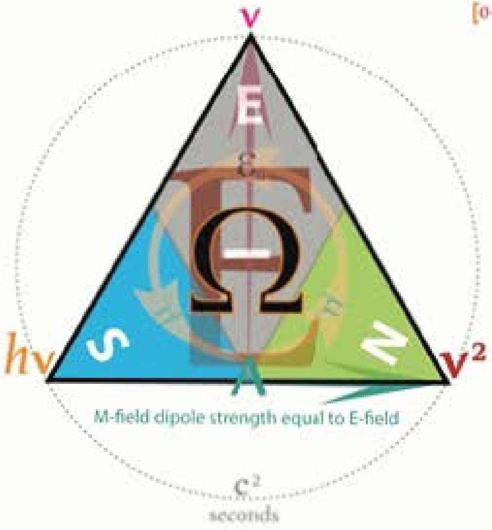

M-field dipole strength equal to E-field

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Gauss' Laws

- Gauss' Law of Electric Flux and
- Gauss' Law of Magnetic dipoles

The laws were formulated by Carl Friedrich Gauss in 1835, but was not published until 1867.

They form two of Maxwell's equations which are the basis of classical electrodynamics.

The other two being:
- Faraday's law of induction, and
- Ampère's law with Maxwell's correction.

Gauss's law can be used to derive Coulomb's law, and vice versa.

Equilateral triangles are the foundational charge geometry of EM mass-Energy and Matter

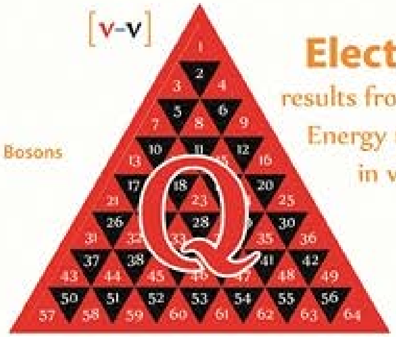

Electric Charge

results from an imbalance of Energy momenta quanta in v^2 geometries

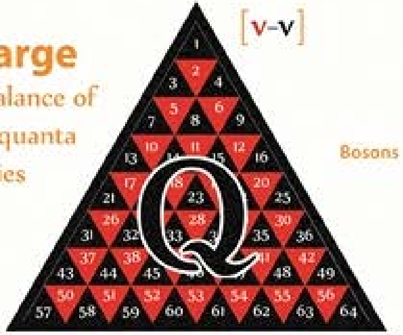

Carl Friedrich Gauss

(30 April 1777 – 23 February 1855)

Integral form

$$\oint \vec{E}\cdot d\vec{A} = \frac{q}{\varepsilon_0} = 4\pi k q$$

Differential form

$$\nabla \cdot E = \frac{\rho}{\varepsilon_0} = 4\pi k \rho$$

Electric fields are divergent from their source

Although originally envisaged as a property applied to spherical geometries and usually illustrated with square sectional boundaries integrating a surface area

$$\Phi = EA = E4\pi r^2 = \frac{Q}{\varepsilon_0}$$

Charge is shown to be the result of the symmetry of equilateral quantised angular momenta

Integral form

$$\oint \vec{B}\cdot d\vec{A} = 0$$

Differential form

$$\nabla \cdot B = 0$$

There are NO Magnetic Monopoles

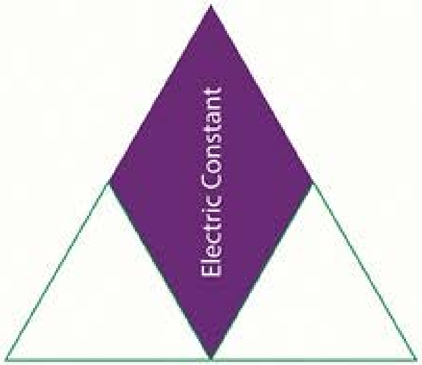

$$\varepsilon_0 = 8.85418785\text{e-}12 \ \frac{\text{F}}{\text{m}}$$

$$\oint \vec{E}\cdot d\vec{A} = \frac{q}{\varepsilon_0}$$

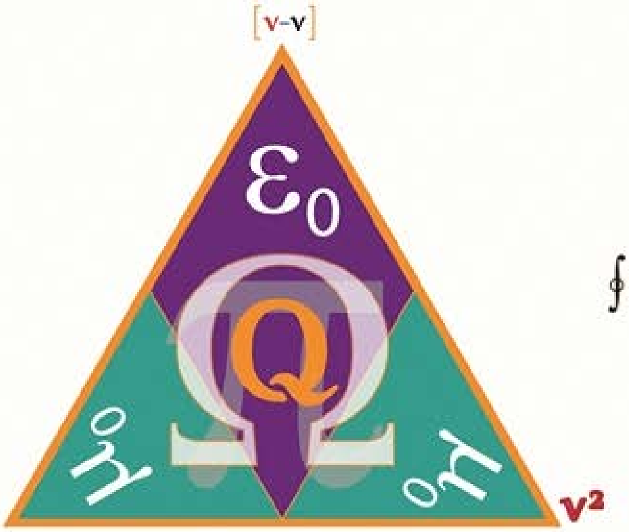

$$\oint \vec{B}\cdot d\vec{A} = 0$$

The electric flux through any closed surface is proportional to the enclosed electric charge

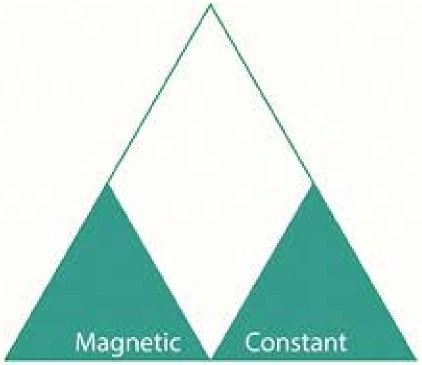

$$\mu_0 = 1.25663706\text{e-}6 \ \frac{\text{H}}{\text{m}}$$

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The Divergent force of Charge

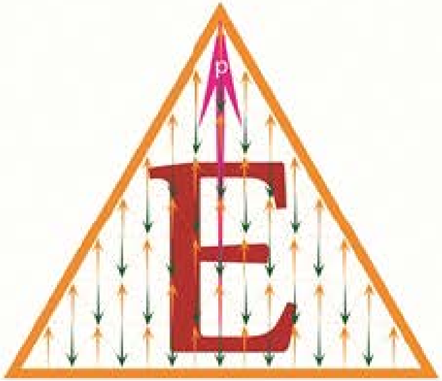

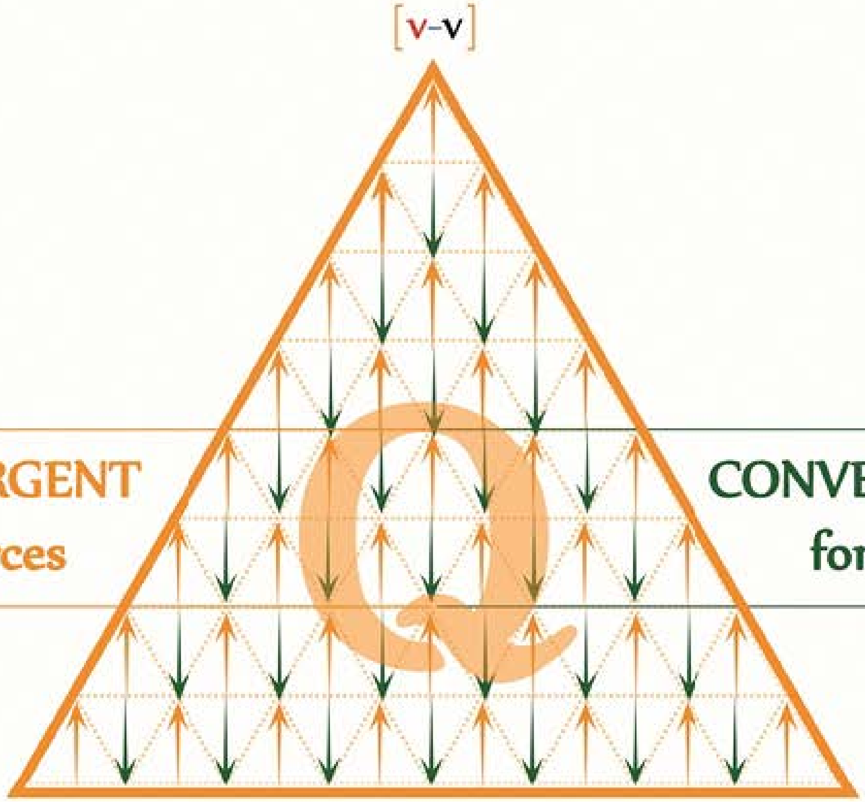
[v-v]
Q
DIVERGENT
forces
CONVERGENT
forces

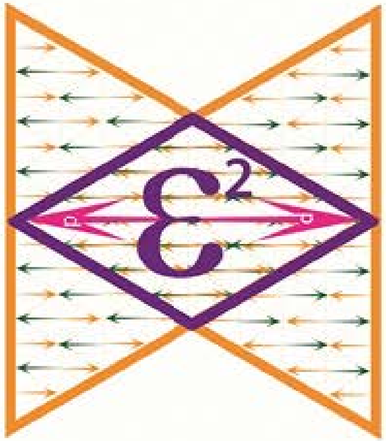

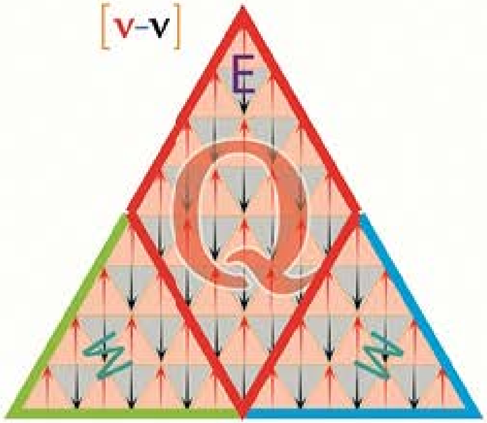

Charged EM fields create a net DIVERGENT force
as a result of their outward radiant energy momenta

but still possess CONVERGENT forces as a result of
their inherent equilateral energy momentum symmetries

Where these radiant charged fields diverge from their source
and overlap their superpositional energy momenta
create the forces of the Law of Interaction

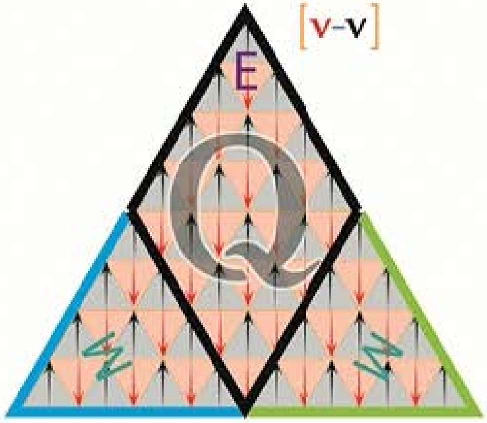

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Coulomb's Law

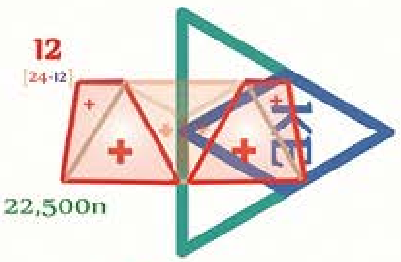
12
[24-12]
22,500n
KE

Proton

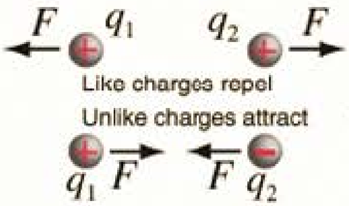
F
q_1
q_2
F
Like charges repel
Unlike charges attract
q_1
F
F
q_2

$$F=\frac{kq_1q_2}{r^2}=\frac{q_1q_2}{4\pi\varepsilon_0 r^2}$$

Coulomb's Law

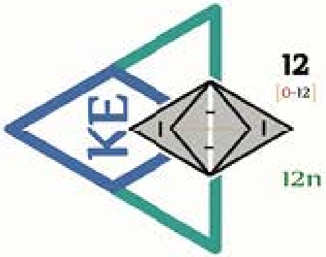
KE
12
[0-12]
12n

Electron

The magnitude of the electrostatic force between two point electric charges is directly proportional to the product of the magnitudes of each of the charges and inversely proportional to the square of the distance between the two charges.

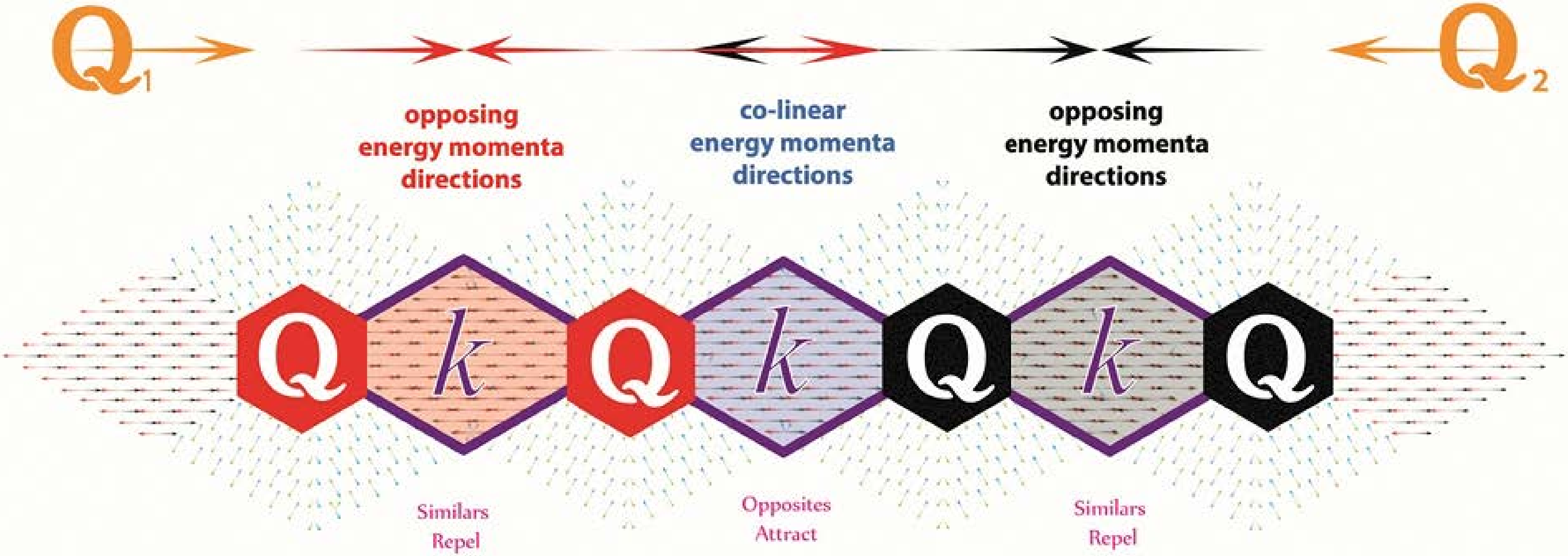
Q_1
Q_2
Q
k
Q
k
Q
k
Q

opposing energy momenta directions

co-linear energy momenta directions

opposing energy momenta directions

Similars Repel

Opposites Attract

Similars Repel

The law of Interaction

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Changing Electric Fields produce changing Magnetic fields

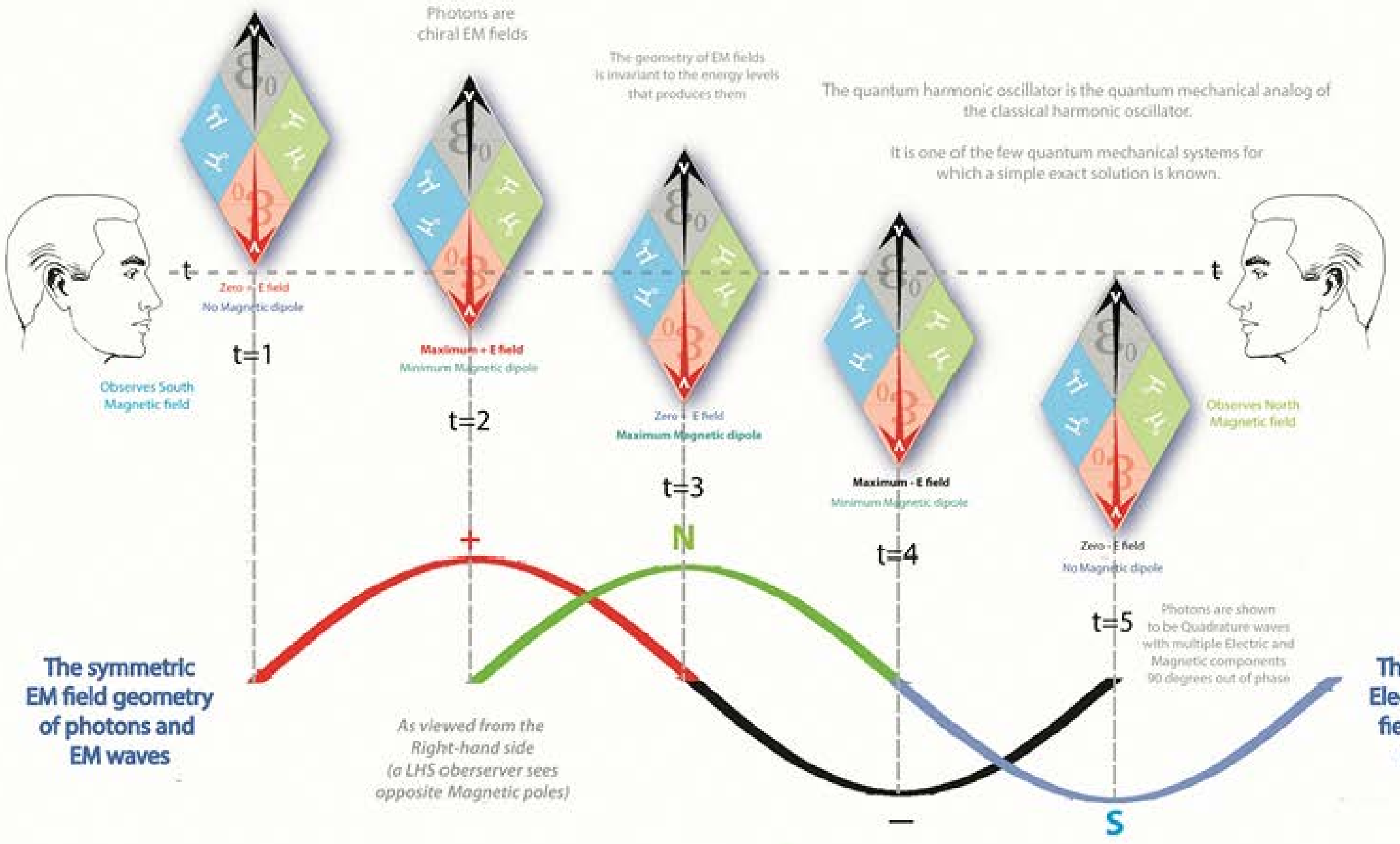
t
Zero + E field
No Magnetic dipole
t=1
Observes South
Magnetic field
Maximum + E field
Minimum Magnetic dipole
t=2
Zero + E field
Maximum Magnetic dipole
t=3
Maximum - E field
Minimum Magnetic dipole
t=4
Zero - E field
No Magnetic dipole
t=5
Observes North
Magnetic field
t
+
N
−
S

Photons are chiral EM fields

The geometry of EM fields is invariant to the energy levels that produces them

The quantum harmonic oscillator is the quantum mechanical analog of the classical harmonic oscillator.

It is one of the few quantum mechanical systems for which a simple exact solution is known.

Photons are shown to be Quadrature waves with multiple Electric and Magnetic components 90 degrees out of phase

As viewed from the Right-hand side (a LHS oberserver sees opposite Magnetic poles)

The symmetric EM field geometry of photons and EM waves

Changing Magnetic fields produce changing Electric fields

The symmetric ElectroMagnetic field strengths measured

Michael Faraday

(22 September 1791 – 25 August 1867)

EM field symmetry

" It is proposed that if a changing magnetic field can make an oscillating electric field, then

a changing electric field (from a oscillating electric charge) should make a changing magnetic field "

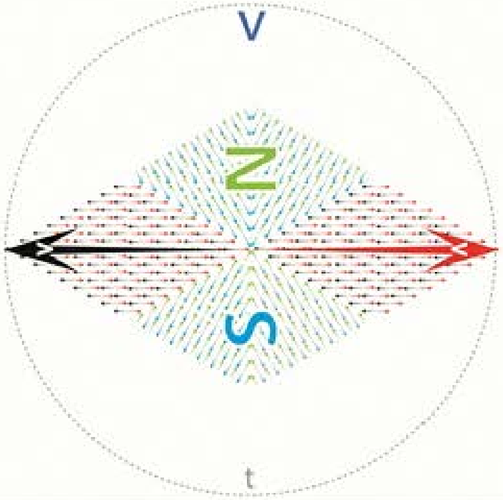

Any change in the magnetic environment of a coil of wire will cause a voltage (emf) to be "induced" in the coil.

No matter how the motional change is produced, a changing electromotive force will be generated.

The change could be produced by
changing the magnetic field strength,
moving a magnet toward or away from the coil,
moving the coil into or out of the magnetic field,
rotating the coil relative to the magnet.

All the resulting changes to the E & M fields and the vector strengths etc are the result of the inherent equilateral geometries of EM fields

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Electromagnetic Induction

All ElectroMagnetic circuits are comprised of quantum inductive fields [ZPFs] and energies that obey Newton's third law and the conservation of energy

Electromagnetic induction is the production of an electric current across a conductor moving through a magnetic field.
It underlies the operation of generators, transformers, induction motors, electric motors, synchronous motors, and solenoids.

EM field coupling

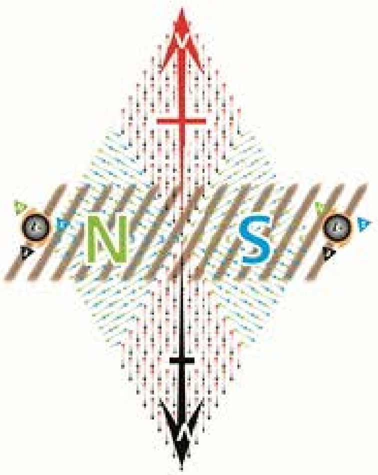

$$|\mathcal{E}| = \left|\frac{d\Phi_B}{dt}\right|$$

Michael Faraday formulated that electromotive force (EMF) produced around a closed path is proportional to the rate of change of the magnetic flux through any surface bounded by that path.

$$\nabla \times \mathbf{E} = -\frac{\partial \mathrm{B}}{\partial t}$$

$$V_p = N_p \frac{d\Phi}{dt}.$$

For the special case of a coil of wire, or a transformer circuit composed of N loops with the same area, Faraday's general equation becomes

$$V_s = N_s \frac{d\Phi}{dt},$$

Inductive Coupling

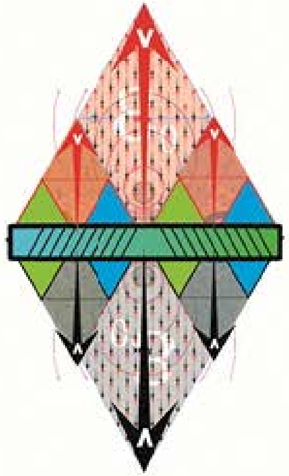

A corollary of Faraday's Law, together with Ampère's law and Ohm's law is Lenz's law: The EMF induced in an electric circuit always acts in such a direction that the current it drives around the circuit opposes the change in magnetic flux which produces the EMF

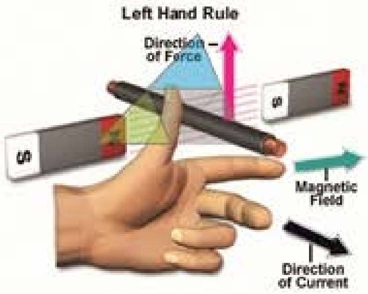

Flemings left hand rule
(for electric motors)

Coil moves UP

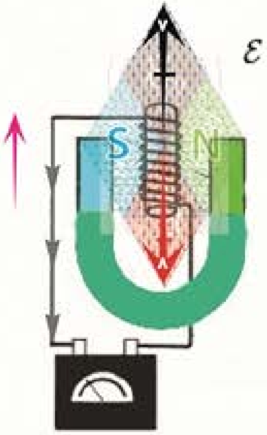

$$\mathcal{E} = -N\frac{d\Phi_B}{dt}.$$

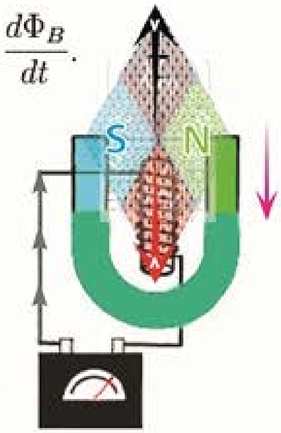

Coil moves DOWN

An electric current passes through a solenoid, resulting in a magnetic field. When you wrap your right hand around the solenoid with your fingers in the direction of the conventional current, your thumb points in the direction of the magnetic north pole.

An electric current passes through a straight wire. Here, the thumb points in the direction of the conventional current (from positive to negative), and the fingers point in the direction of the magnetic lines of flux.

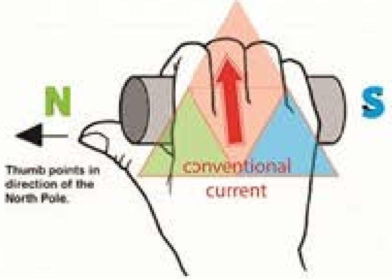
N
S
Thumb points in direction of the North Pole.
conventional
current

Fleming's right hand rule
(for EM induction)

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Faraday's Law of Induction

Michael Faraday

(22 September 1791 – 25 August 1867)

Electromagnetic induction is the production of a potential difference (voltage) across a conductor when it is exposed to a varying magnetic field.

In the frame of a conductor moving relative to the magnet, charged particles in the conductor experience a coulombic force due to the neutralised electric fields of the permanent magnet.

Faraday's law states that:
The induced electromotive force (emf) in any closed circuit is equal to the time rate of change of the magnetic flux through the circuit.

$$\boxed{\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}}$$

The motion of EM fields creates an induced motion in external fields and particles

The linear energy momenta of the neutralised E-fields produces differing directions of induced emf (current flow)

A permanent magnet has a static Magnetic dipole field and neutralised Electric field geometries

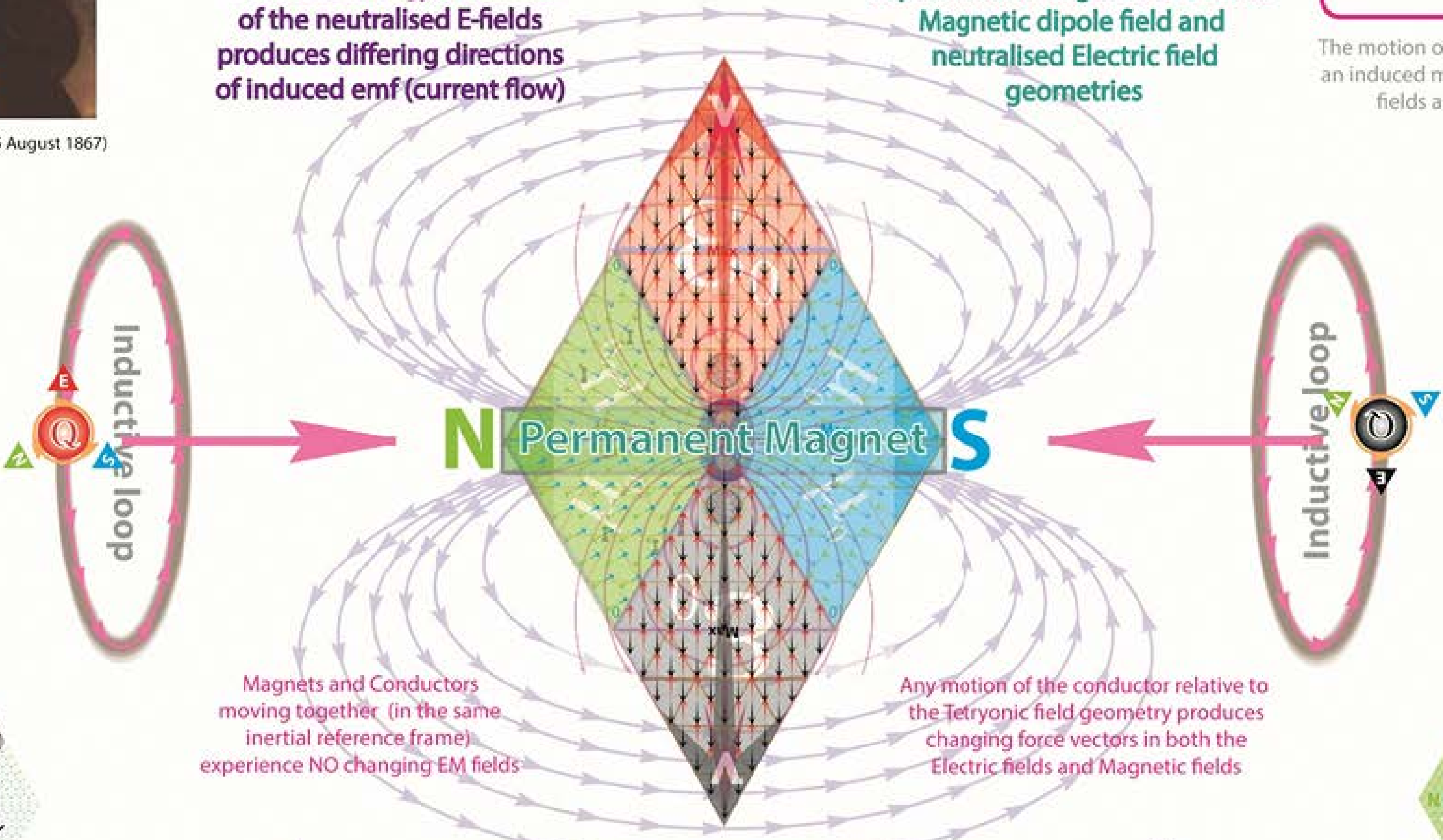

Charged particles in the conductor are subject to voltage emfs

Charged particles in the conductor are subject to voltage emfs

Magnets and Conductors moving together (in the same inertial reference frame) experience NO changing EM fields

Any motion of the conductor relative to the Tetryonic field geometry produces changing force vectors in both the Electric fields and Magnetic fields

An Electrostatic (charged) particle has Electric fields of a particular polarity and neutralised Magnetic fields

Electric Constant

It is impossible (due to the geometry of EM fields) to move either the permanent Magnet or the Conductor without producing variations in the Electric and Magnetic fields

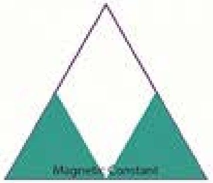

A Magneto-static body of Matter has a dipolar Magnetic field and neutralised Electric fields

Ampere's Law

In classical electromagnetism, Ampère's circuital law, relates the integrated magnetic field around a closed loop to the electric current passing through the loop.

Q

[v-v]

All energy momenta quanta have equilateral geometries, [quantised angular momenta [Ω]] that can be modelled as a continuous steady current within a closed inductive loop

$$\oint \vec{B}\cdot d\vec{s} = \mu_0 i + \frac{1}{c^2}\frac{\partial}{\partial t}\int \vec{E}\cdot d\vec{A}$$

The nett Charge of any particle or surface is the result of the quantised equilateral energy momenta symmetries of its integral surface area

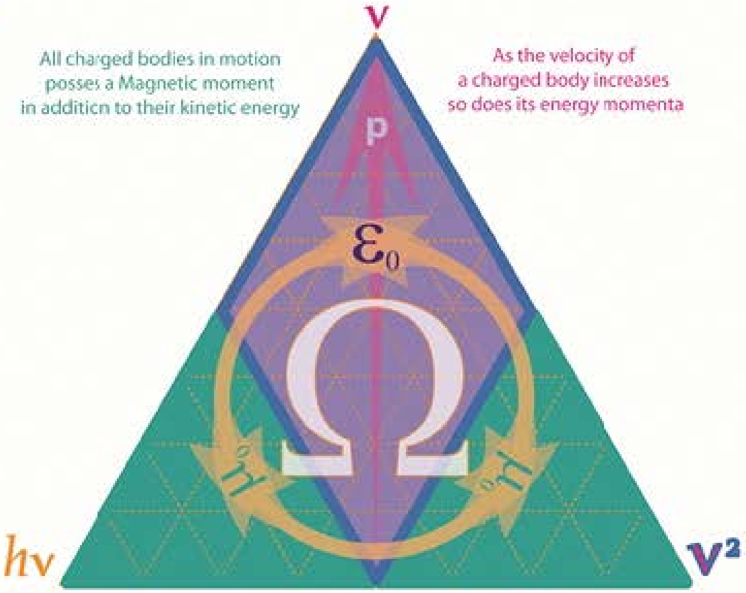
v
p
ε_0
Ω
hv
v²

All charged bodies in motion posses a Magnetic moment in additicn to their kinetic energy

As the velocity of a charged body increases so does its energy momenta

$$\oint_C \mathbf{B}\cdot d\boldsymbol{\ell} = \mu_0 I_{\mathrm{enc}}$$

$$\mathbf{J_f}+\mathbf{J_D}+\mathbf{J_M} = \mathbf{J_f}+\mathbf{J_P}+\mathbf{J_M}+\varepsilon_0\frac{\partial \mathbf{E}}{\partial t} = \mathbf{J}+\varepsilon_0\frac{\partial \mathbf{E}}{\partial t}\,,$$

With the addition of Maxwell's Displacement current to account for time varying electric fields without a physical flow of charged Matter the way forward is paved for Planck, Lorentz and Tetryonics

The Closed circuit or loop can be any geometric shape with Tetryonics dictating equilateral [triangular] Planck energies & quantum charge geometries with Tetrahedral geometries for Matter quanta

Andre Ampere

(20 January 1775 – 10 June 1836)

Ampere's law relates magnetic fields to the electric currents that produce them.

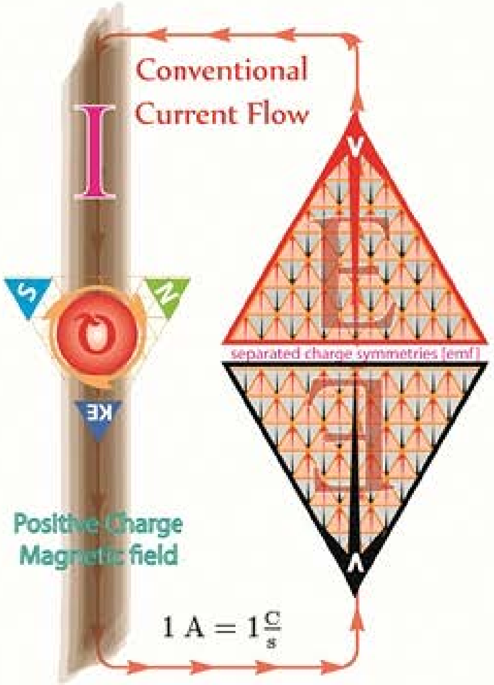
Conventional
Current Flow
I
S
N
KE
v
E
separated charge symmetries [emf]
E
v
Positive Charge
Magnetic field
$1\ \mathrm{A} = 1\frac{\mathrm{C}}{\mathrm{s}}$

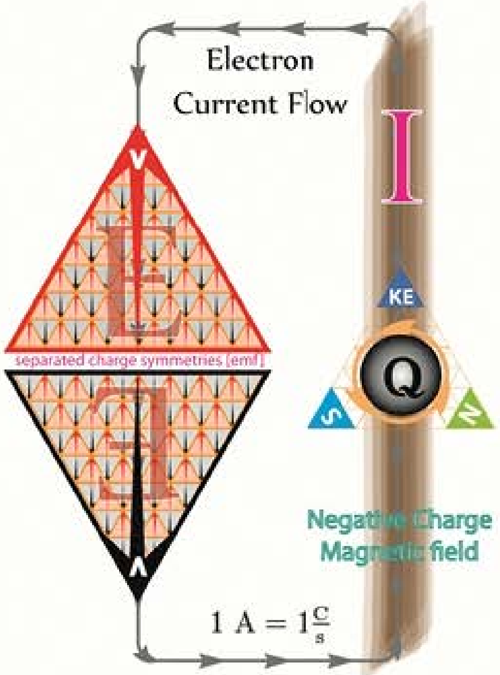
Electron
Current Flow
I
v
E
separated charge symmetries [emf]
E
v
KE
Q
S
N
Negative Charge
Magnetic field
$1\ \mathrm{A} = 1\frac{\mathrm{C}}{\mathrm{s}}$

$$F = 2k_A \frac{I_1 I_2}{r}$$

Ampère's force law states that there is an interactive force between two parallel wires carrying an electric current.

$$\mu_0 \overset{\text{def}}{=} 4\pi\, e\text{-}7\, \frac{N}{A^2}$$

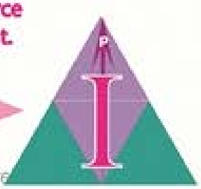

This force is used in the formal definition of the ampere which states that it is "the constant current which will produce an attractive force of 2 × 10–7 newtons per metre of length between two straight, parallel conductors of infinite length and negligible circular cross section placed one metre apart in a vacuum"

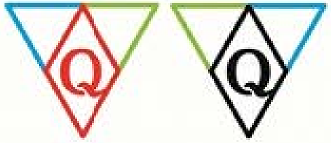

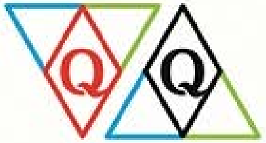

> *These attractions and repulsions between electric currents differ fundamentally from the effects produced by electricity in repose. First, they cease, as chemical decompositions do, as soon as we break the circuit. Second, in ordinary electric attractions and repulsions, opposite charges attract, and like charges repel; in the attractions and repulsions of electric currents, we have precisely the contrary; it is when the two conducting wires are placed parallel in such a way that their ends of the same sign are next to each other that there is attraction, and there is repulsion when the ends of the same sign are as far apart as possible. Third, in the case of attraction, when it is sufficiently strong to bring the movable conductor into contact with the fixed conductor, they remain attached to one another like two magnets, and do not separate after a while, as happens when two conducting bodies, oppositely electrified, come to touch.*
>
> *André Marie Ampère (1775 - 1836)*

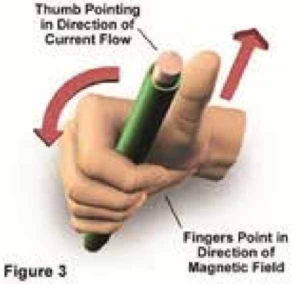
Thumb Pointing in Direction of Current Flow
Fingers Point in Direction of Magnetic Field

Figure 3

$$1\ \mathrm{A} = 1\frac{\mathrm{C}}{\mathrm{s}}$$

Interactive force between Conductors

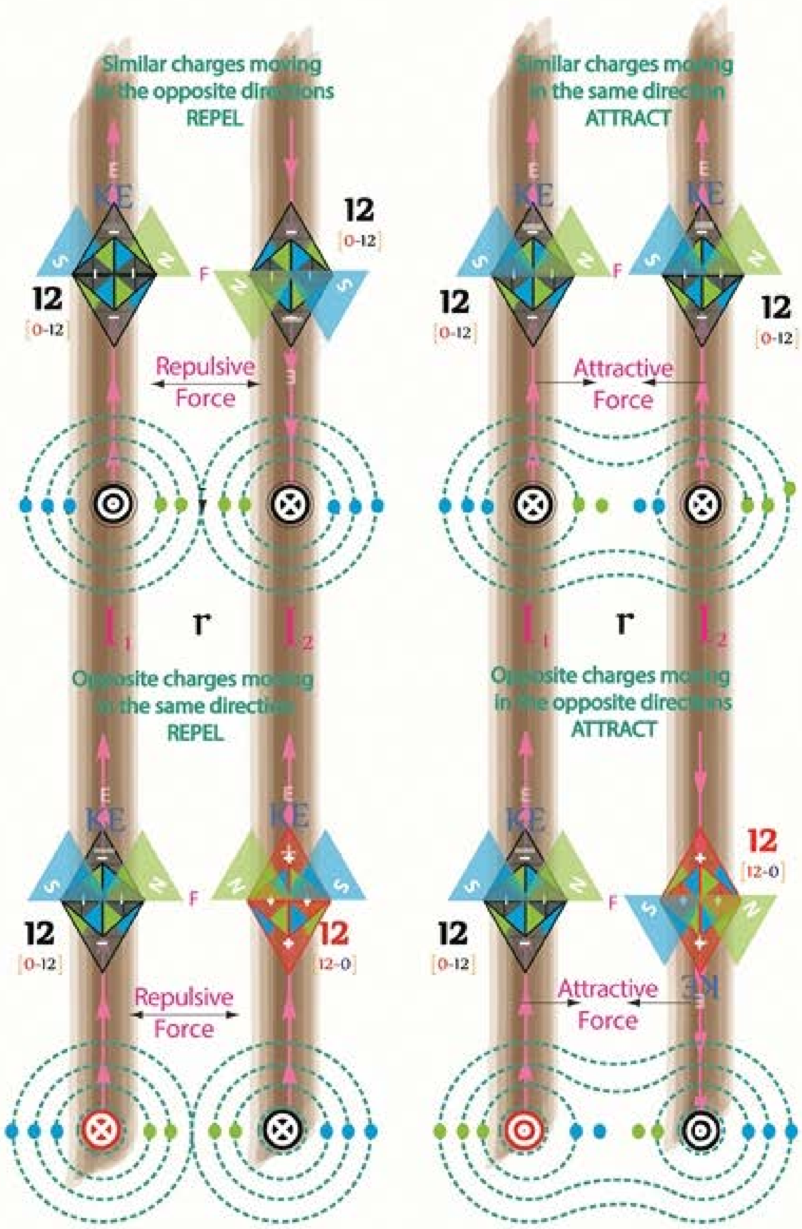
Similar charges moving in the opposite directions
REPEL
Similar charges moving in the same direction
ATTRACT
E
KE
12
[0-12]
12
[0-12]
12
[0-12]
12
[0-12]
F
Repulsive Force
Attractive Force
r
I1
I2
r
I1
I2
Opposite charges moving in the same direction
REPEL
Opposite charges moving in the opposite directions
ATTRACT
12
[0-12]
12
[12-0]
12
[0-12]
12
[12-0]
S
N
Repulsive Force
Attractive Force

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ElectroMotive exchange particles

W

All four of the fundamental forces involve the exchange of ODD numbers of electromagnetic charge bosons so as to transfer discrete energy momenta between separated Matter

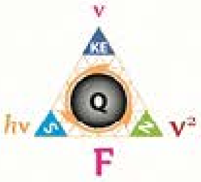

In ElectroMagnetic field or circuits, when charged Matter moves along electric field lines, electrical work is done on them by the electromotive force, whether it involves storing potential energy (negative work) or increasing kinetic energy (positive work)

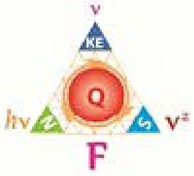

γ

The EM exchange force denotes a force produced by the exchange of force carrier particles, such as the electromagnetic force produced by the exchange of photons between electrons

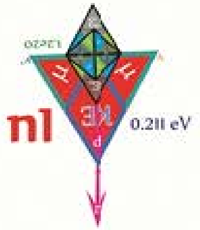

1.2e20
n1
EM
0.211 eV

KEM field energy momenta attracts opposite charges

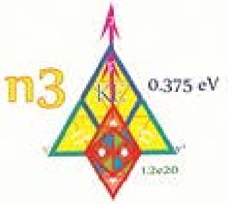

n3
KE
0.375 eV
1.2e20

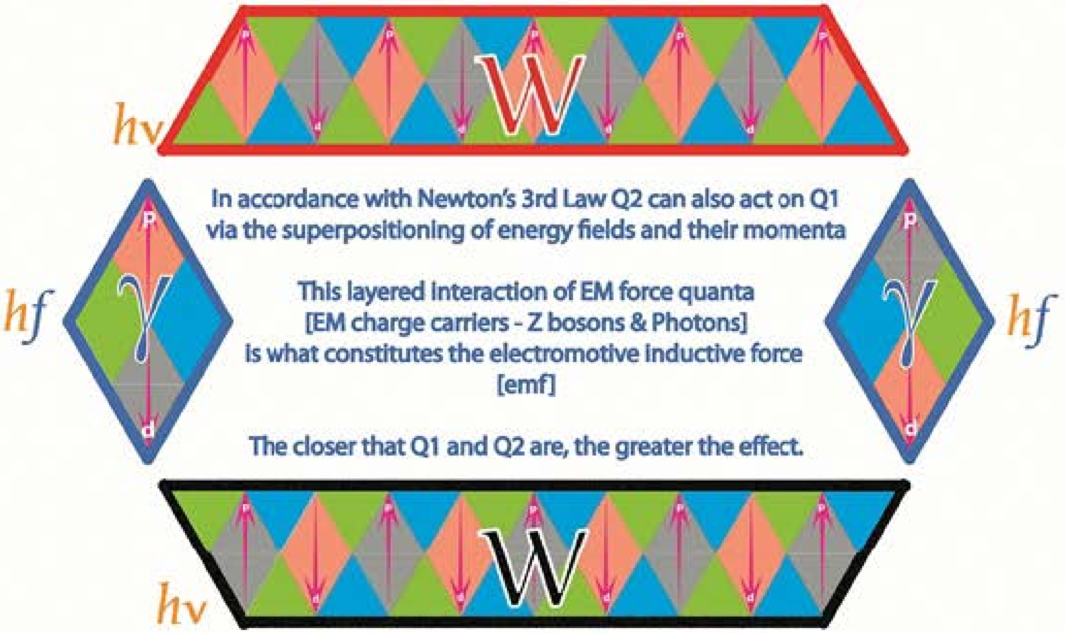

hv
W
hf
γ
hf
γ
W
hv

In accordance with Newton's 3rd Law Q2 can also act on Q1 via the superpositioning of energy fields and their momenta

This layered interaction of EM force quanta
[EM charge carriers - Z bosons & Photons]
is what constitutes the electromotive inductive force
[emf]

The closer that Q1 and Q2 are, the greater the effect.

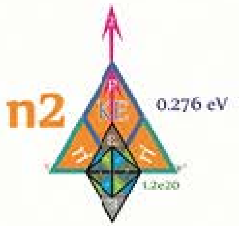

n2
KE
0.276 eV
1.2e20

KEM field energy momenta repels same charge particles

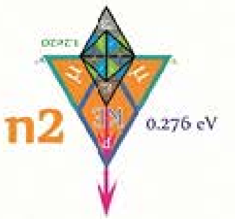

1.2e20
n2
EM
0.276 eV

Bosons

EM Field Planck quanta

$$1\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

Charge ElectroMagnetic mass velocity

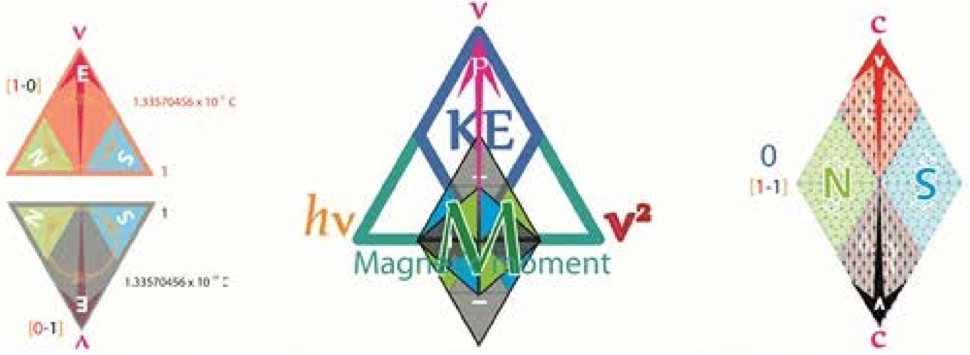

v
[1-0]
E
N
S
1.33570456 x 10 C
1
1
1.33570456 x 10 C
E
[0-1]
v
v
KE
M
hv
v²
Magnetic Moment
C
0
[1-1]
N
S
C

Photons

EM Field Planck quanta

$$2\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

Photons ElectroMagnetic mass velocity

Lorentz Force

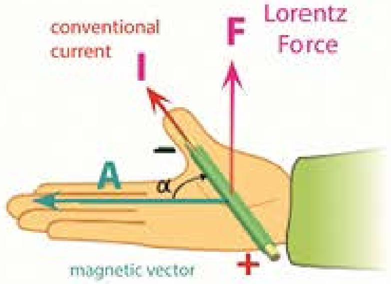
conventional current
I
F
Lorentz Force
A
α
–
+
magnetic vector

In physics, the Lorentz force is the force on a point charge due to electromagnetic fields.

It is given by the following equation in terms of the electric and magnetic fields

The magnetic force component of the Lorentz force manifests itself as the force that acts on a current-carrying wire in a magnetic field.

In that context, it is also called the Laplace force.

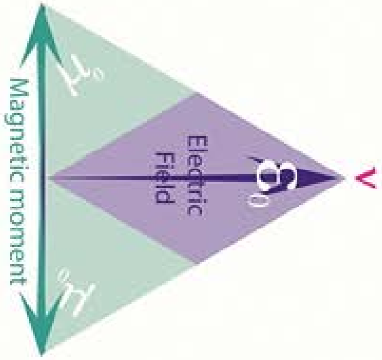
Magnetic moment
μ_0
μ_0
Electric Field
ε_0
v

Hendrik Lorentz

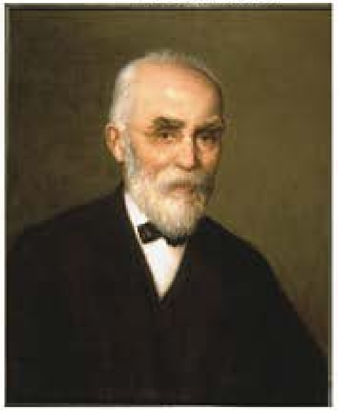

(18 July 1853 – 4 February 1928)

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

LORENTZ force · *Electric force* · *charge velocity* · *Magnetic force*

Magnetic fields created by moving charges are perpendicular to the direction of motion (and can do NO work)

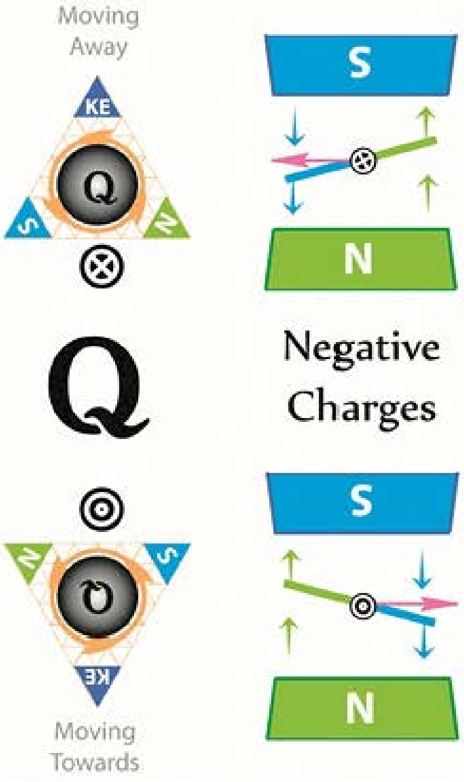
Moving Away
KE
Q
S
N
Negative Charges
Q
KE
Moving Towards

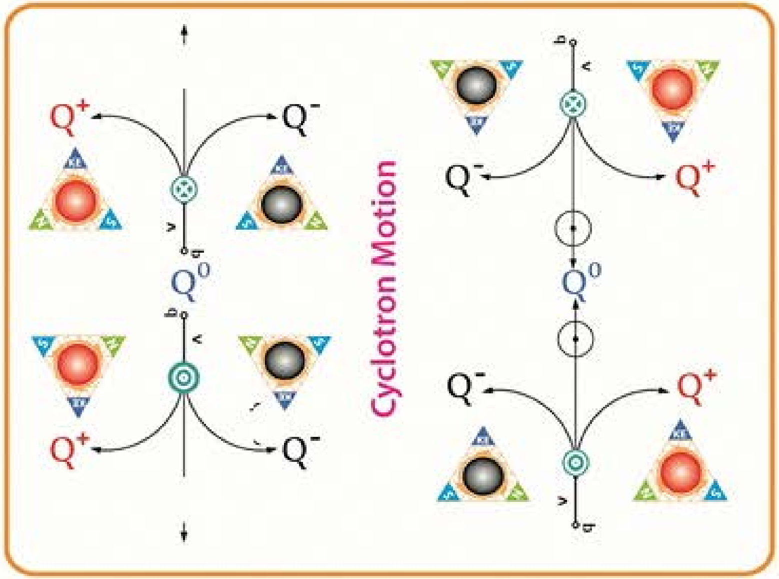
Q+
Q-
Q0
Q+
Q-
Cyclotron Motion
Q-
Q+
Q0
Q-
Q+

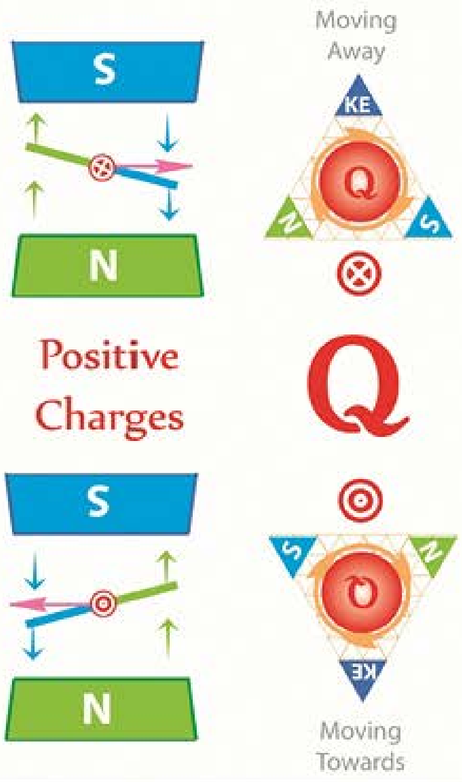
Moving Away
S
N
KE
Q
Positive Charges
Q
S
N
KE
Moving Towards

Up out of page ◎ Magnetic Field ⊗ Down into page

Work - Force - Energy

Work is the result of energy-momenta transfer (by means other than Matter-transfer), and produces changes in the second system's nett energy-momenta

Force $\boxed{ma = \frac{\Delta p}{\Delta t} = \Delta\left[\frac{mv}{t}\right]}$ $kg\,\frac{m}{s^2}$

Momentum is the quantum of Force

Work

refers to an activity involving a force and movement in the directon of the force

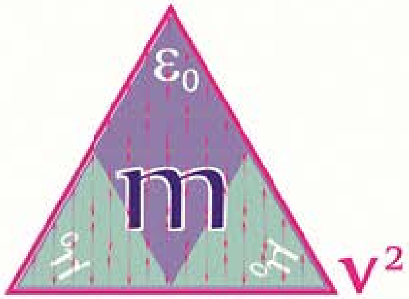
ε_0
m
v^2

Work

$$\boxed{W = F.d = ma.d = E}$$

The Planck constant is the quantum of Action

$$kg\,\frac{m}{s^2}\,m$$

Mechanical work is a scalar quantity that can be described as the product of a force times the distance through which it acts

[Force per meter]

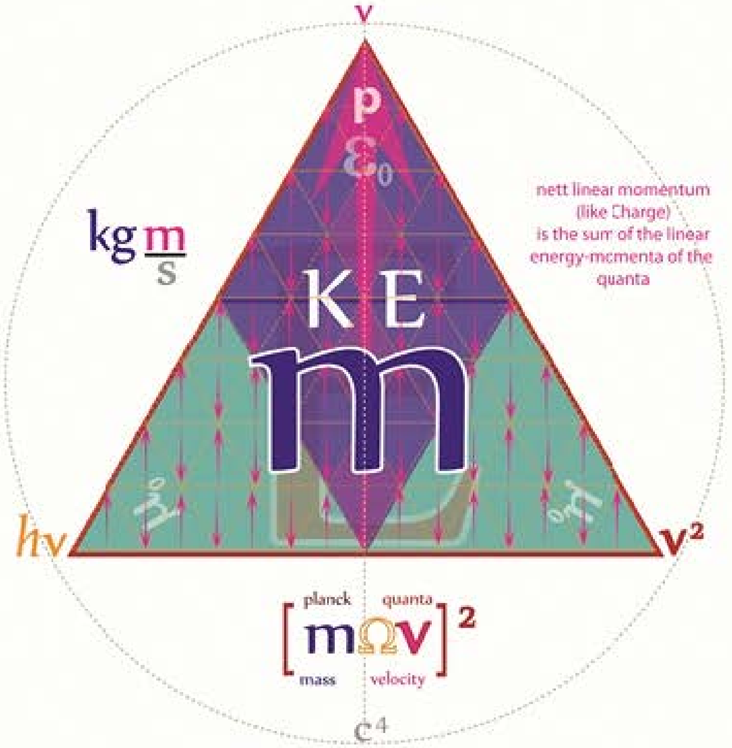
v
p
ε_0
$kg\,\frac{m}{s}$
nett linear momentum (like Charge) is the sum of the linear energy-momenta of the quanta
K E
m
hv
v^2
planck
quanta
$\left[m\Omega v\right]^2$
mass
velocity
c^4

Power is defined as the rate of using Energy or the rate of doing work

Energy

is the scalar capacity to do work
You must have energy to accomplish work

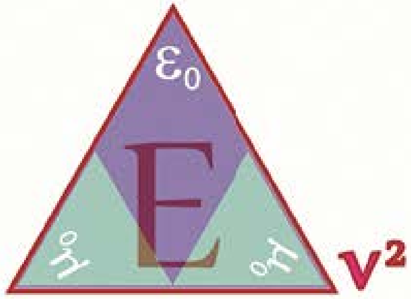
ε_0
E
v^2

Energy

$$\boxed{E = mv^2 = hv^2}$$

Energy is the square of Momentum

$$kg\,\frac{m^2}{s^2}$$

Energy is always equivalent to the ability to exert pulls or pushes against the basic forces of nature, along a path of a certain length.

[mass-energy momentum squared]

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WORK

Force per second

In Classical Mechanics

One watt is the rate at which work is done when an object's velocity is held constant at one meter per second against constant opposing force of one newton.

Work in physics is measured in Joules

Nm/s

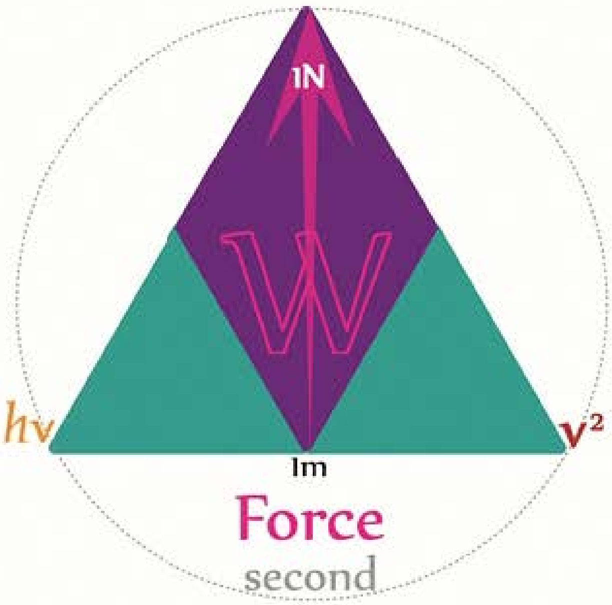

Watts

[Joules per second]

James Watt

(19 January 1736 – 25 August 1819)

The watt second is a unit of energy, equal to the joule

$$W = \frac{J}{s} = \frac{N \cdot m}{s} = \frac{kg \cdot m^2}{s^3}$$

One Watt, defined as one joule per second, measures the rate of energy conversion.

$$W = V.A$$

Energy / second
[Joules/sec]

POWER

Energy per second

In ElectroDynamics

One watt is the rate at which work is done when one ampere (A) of current flows through an electrical potential difference of one volt (V).

Electrical power is measured in Watts

J/s

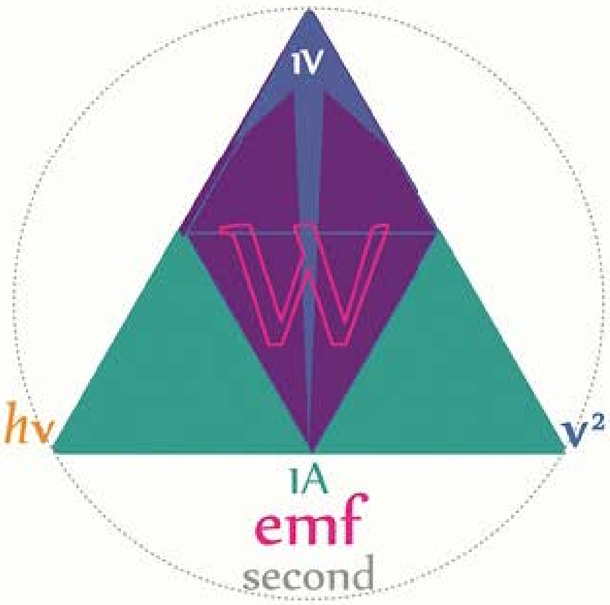

The electromotive Force

The electromotive force, or most commonly emf (seldom capitalized), or (occasionally) electromotance is "that which tends to cause current (actual electrons and ions) to flow.

Electric Fields contain bi-directional energy-momenta

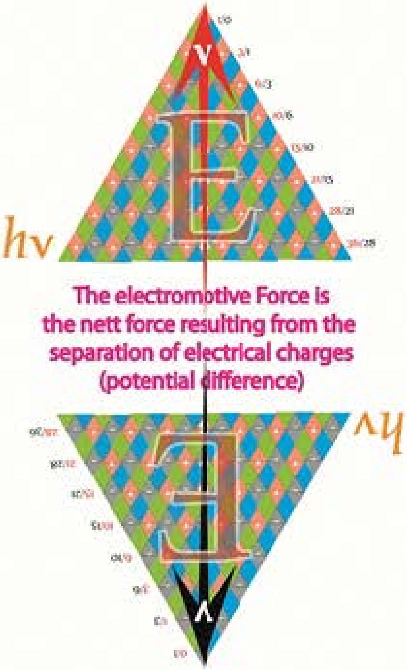

The electromotive Force is the nett force resulting from the separation of electrical charges (potential difference)

All Charges seek Equilibrium

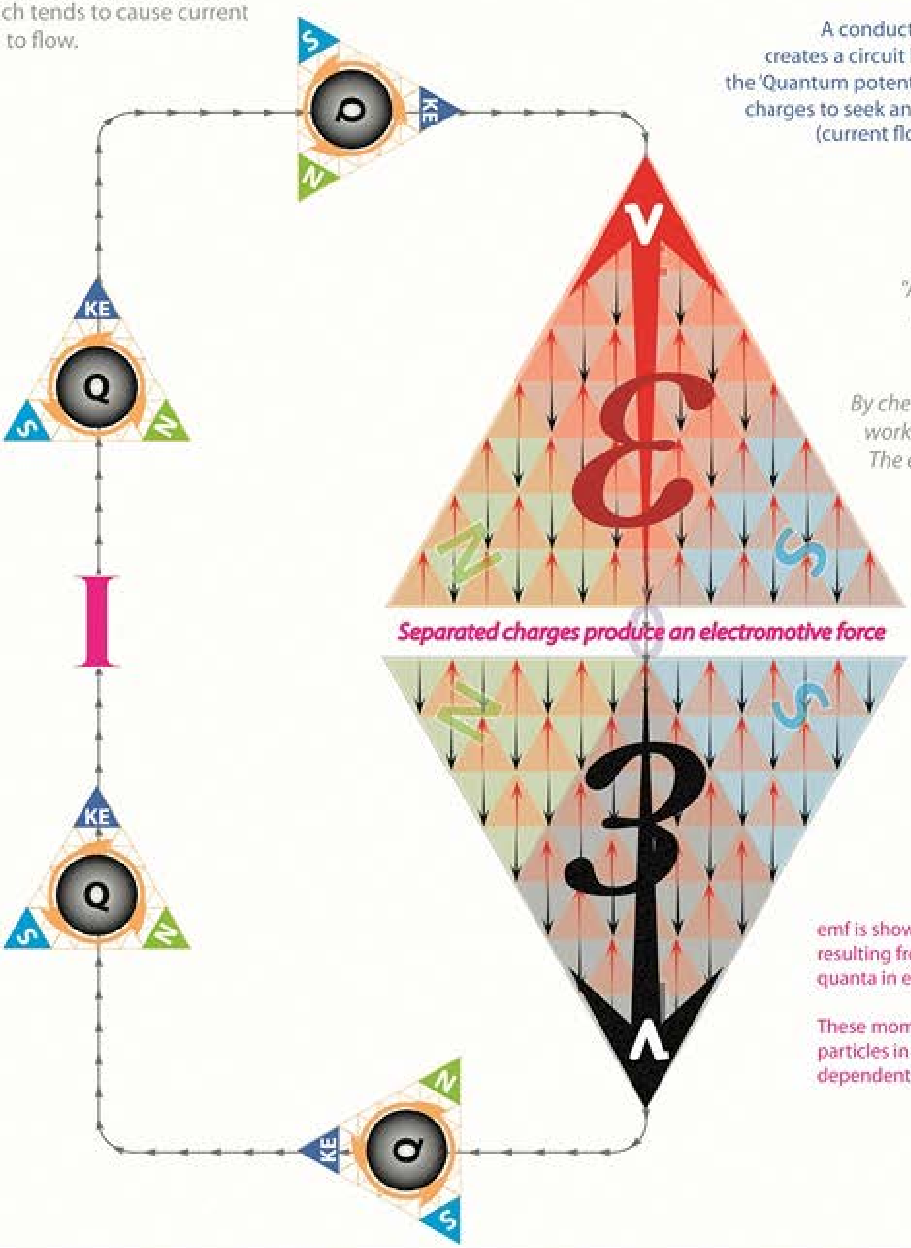

Separated charges produce an electromotive force

A conductor creates a circuit between the 'Quantum potentials' allowing charges to seek an eqilibrium (current flow)

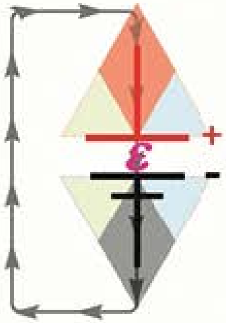

$$\mathcal{E} = -\frac{d\Phi_B}{dt},$$

"A source emf can be thought of as a kind of charge pump that acts to move charge from a point of high potential through its interior to a point of opposite potential. ...

By chemical, mechanical or other means, the source of emf performs work dW on that charge to move it to the high potential terminal. The emf of the source is defined as the work dW done per charge dq: = dW/dq."

A Magnet stores charge quanta (bosons) in static Electro-Magnetic fields that in turn produce a Magnetic dipole

emf is shown to be the nett force resulting from the linear momenta quanta in every Electric 'voltage' field

These momenta accelerate charged particles in one of two directions dependent of the particle's nett charge

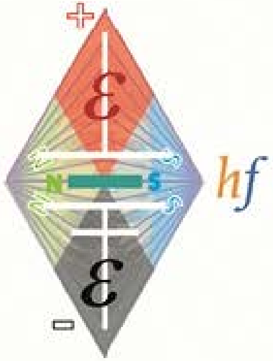

A Magnet can be viewed as a neutralised quantum emf source

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Poynting Vectors

Poynting Field

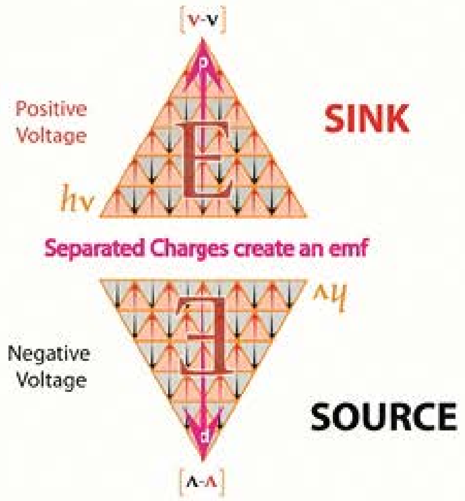
[v-v]
Positive Voltage
SINK
E
hv
Separated Charges create an emf
hv
Negative Voltage
E
SOURCE
[Λ-Λ]

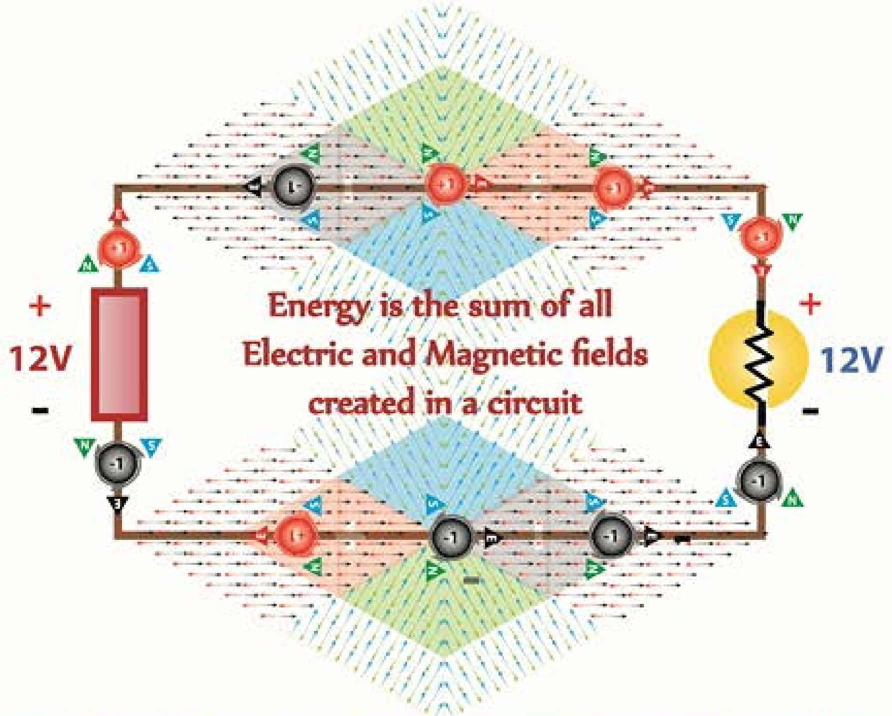
+
12V
-
+
12V
-
-1
+1
N
S

Energy is the sum of all Electric and Magnetic fields created in a circuit

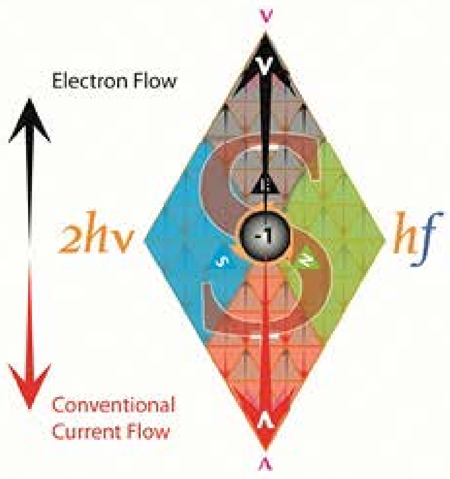
v
Electron Flow
Conventional Current Flow
2hv
hf
S
-1
N
Λ

An test charge placed in an Electric field will experience an acceleration in a direction dependent on the sign of the charge

John Henry Poynting

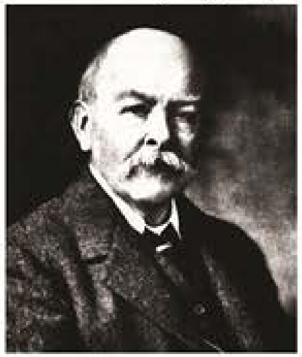

(9 September 1852 – 30 March 1914)

Electrical energy is transferred along a conductive path in an electrical circuit accelerating charged particles and ions in turn imbuing them with Kinetic Energy [voltage leads current]

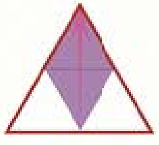

Electric fields

There is an electric field running down the middle of the wire, which extends to just beyond its surface.

This electric field pushes the charges along against the resistance and adds to the electric field caused by the surface charges. The resultant electric field changes its direction around the circuit as the wires form a loop back to the battery.

Energy

$$\mathbf{S} = \mathbf{E} \times \mathbf{H}$$

momenta

Magnetic fields

Moving charged topologies inside the wire create a secondary magnetic field geometry around the wire

Electrons form a conductive path for Energy to flow along

The Electron drift velocity is much less than the speed of electricity(c)

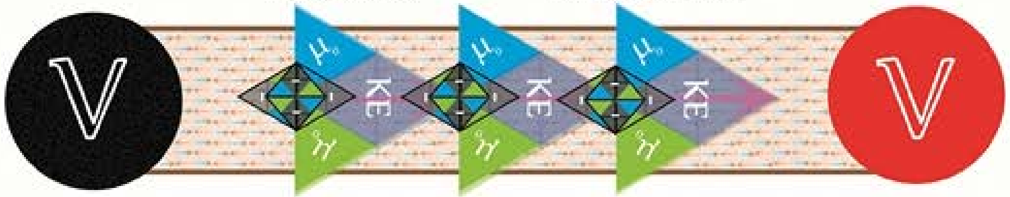
V
μ_0
KE
ϵ_0
V

Despite the very low 'drift' velocity of the Electrons they generate a large Magnetic field as a result of their motion

Energy is transferred through empty space around (and NOT in) the wires of an electric circuit via an electromagnetic field called the Poynting field

It's important to remember that the current doesn't flow in both directions, only the energy does

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Coulomb's Electric Interactions

$$k = \frac{1}{4\pi\varepsilon_0}$$

The proportionality constant ke, called the Coulomb constant (sometimes called the Coulomb force constant), is related to defined properties of linear EM energy momentum and is used to define Electric field forces

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

$$8.987\ e9\ \frac{Nm^2}{C^2}$$

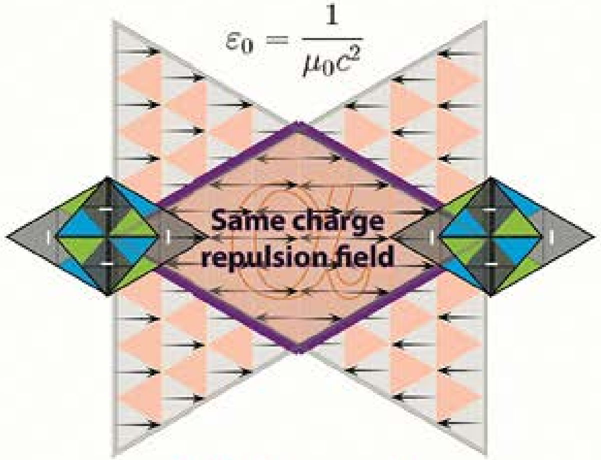

$$\varepsilon_0 = \frac{1}{\mu_0 c^2}$$

Similars repel

Linear Coulombic force interactions are a result of charged E field linear momenta

$$\mathbf{E} = \frac{\mathbf{F}}{q_t}$$

The Electric field can be defined by the Force exerted by a Charge

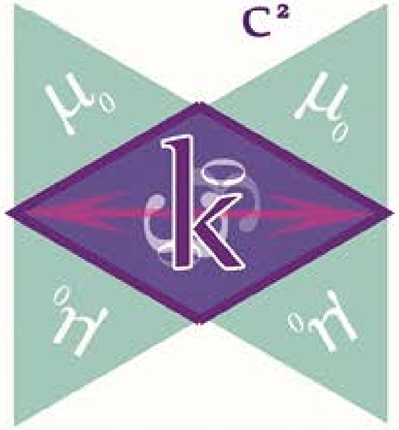

Opposites attract

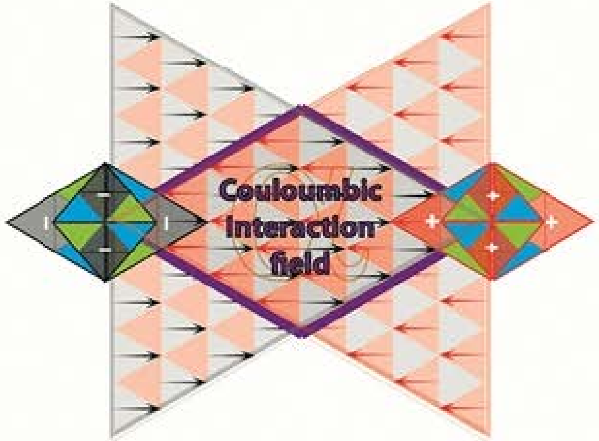

It is a measure of the interactive force produced by the Electric field energy-momenta of two superpositioned charge KEM fields

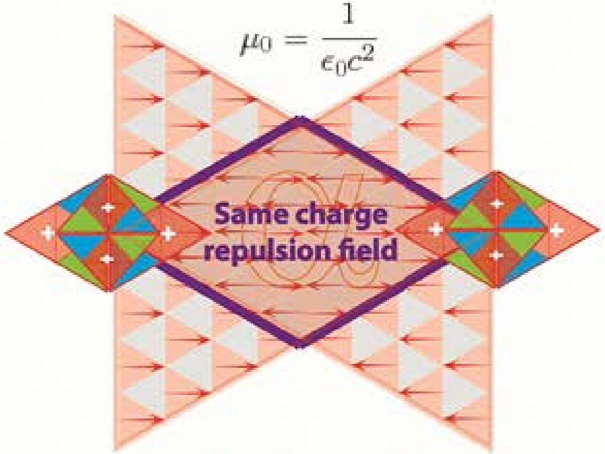

$$\mu_0 = \frac{1}{\epsilon_0 c^2}$$

Similars repel

Longitudinal E field forces between Charged particles are mediated by Photons

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{\mathbf{r}}$$

The Electric field can also be derived from Coulomb's Law

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Coulomb Force

Electric fields produce Coulombic forces

$$F = k\frac{Q_1 Q_2}{r^2}$$

It is defined as the nett Charge transported by a steady current of one Ampere in one second.

C

1 Coulomb of nett charge is comprised of

$(12 \times 1.335180067\ e\text{-}20)^{-1}$

6.240355408 e18 electrons

kg.s

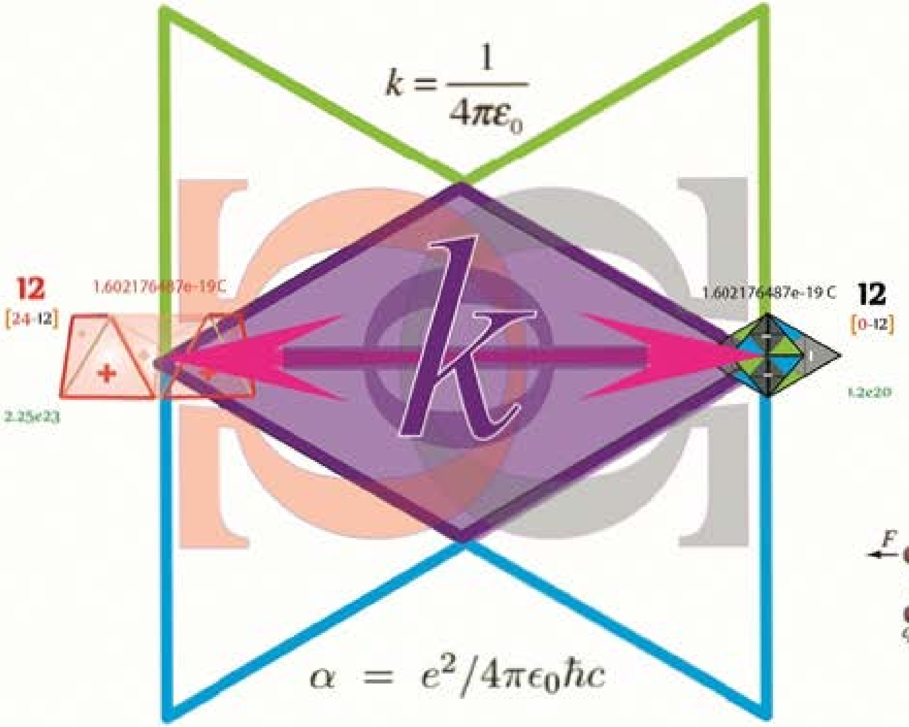

$$k = \frac{1}{4\pi\varepsilon_0}$$

12
[24-12]
1.602176487e-19C
2.25e23
k
1.602176487e-19 C
12
[0-12]
1.2e20

$$\alpha = e^2/4\pi\epsilon_0\hbar c$$

Charles-Augustin de Coulomb

(14 September 1736 – 23 August 1806)

Coulomb's Law is a law of physics describing the electric interaction between any two charged particles (and forms the basis for Ampere's Law)

F
q_1
q_2
F
Like charges repel
Unlike charges attract
q_1
F
F
q_2

$$F = \frac{kq_1q_2}{r^2} = \frac{q_1q_2}{4\pi\varepsilon_0 r^2}$$ *Coulomb's Law*

The interactive linear momenta of super-positioned E-fields creates Coulombic forces

Coulombs

As

$$1\text{C} = 1\text{A} \cdot 1\text{s}$$

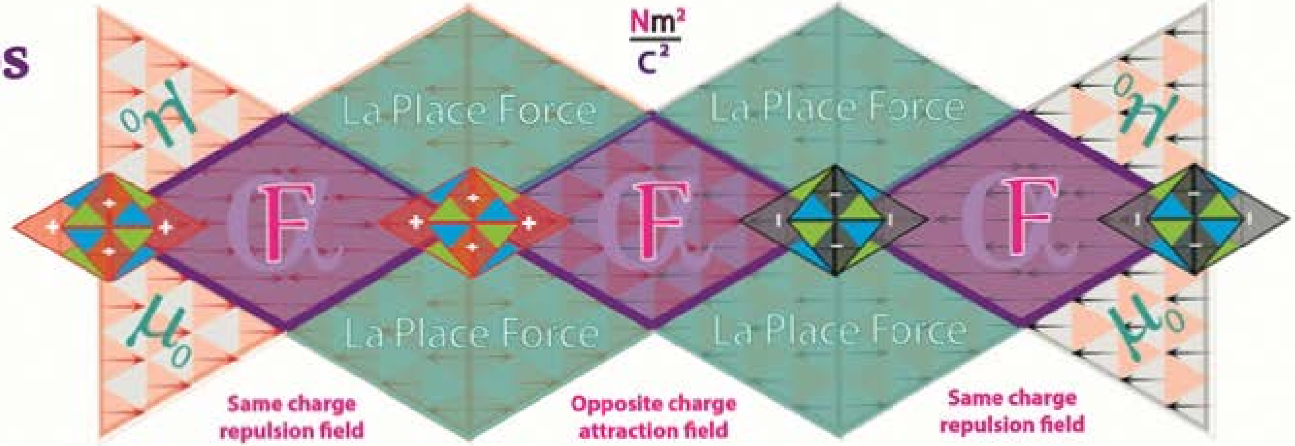

$\frac{\text{Nm}^2}{\text{C}^2}$
ε_0
La Place Force
La Place Force
F
F
F
La Place Force
La Place Force
μ_0
ε_0
μ_0
Same charge repulsion field
Opposite charge attraction field
Same charge repulsion field

Amperes

$$\frac{\text{C}}{\text{s}}$$

$$1\,\text{A} = 1\frac{\text{C}}{\text{s}}$$

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Charles-Augustin de Coulomb

(14 September 1736 – 23 August 1806)

Coulomb force

$$k_c \frac{Q_1 Q_2}{r^2}$$

As

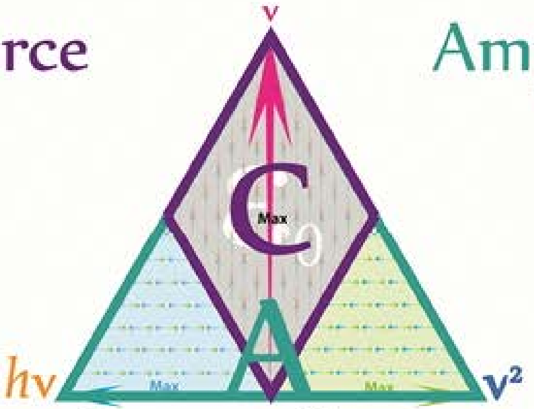
v
C
Max
A
hv
v²
Max
Max

Lorentz Forces

are the forces on a point charge due to external electromagnetic fields

$$\vec{F} = q[\vec{E} + (\vec{v} \times \vec{B})]$$

electric force

velocity

magnetic forces do not accelerate charged particles

Ampere force

$$2k_A \frac{I_1 \; I_2}{r}$$

$$\frac{C}{s}$$

Andre Ampere

(20 January 1775 – 10 June 1836)

Linear acceleration Electric force between charged particles

Q

Same charges

Q

Opposite charges

Q

Same charges

Q

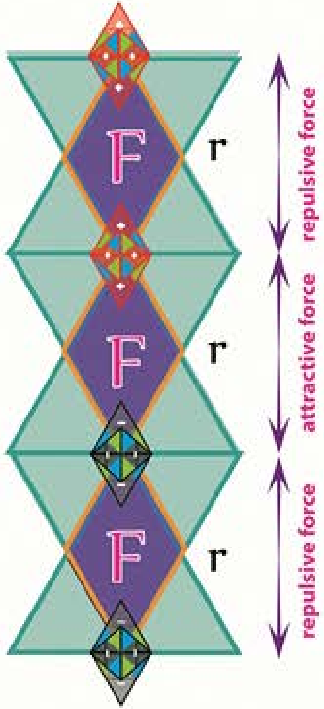
F
r
repulsive force
F
r
attractive force
F
r
repulsive force

I

The amount of charged mass-Matter topologies moving passing a point per unit time

Current

vector momentum

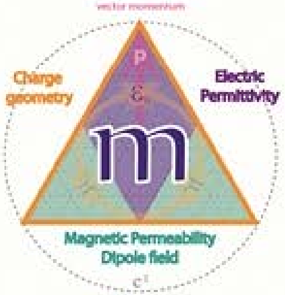
P
&
m
Charge geometry
Electric Permittivity
Magnetic Permeability
Dipole field
c²

Charge

The angular mass momenta possessed by a steady current of one ampere in one second.

Q

Transverse perturbative Magnetic force between charged particles

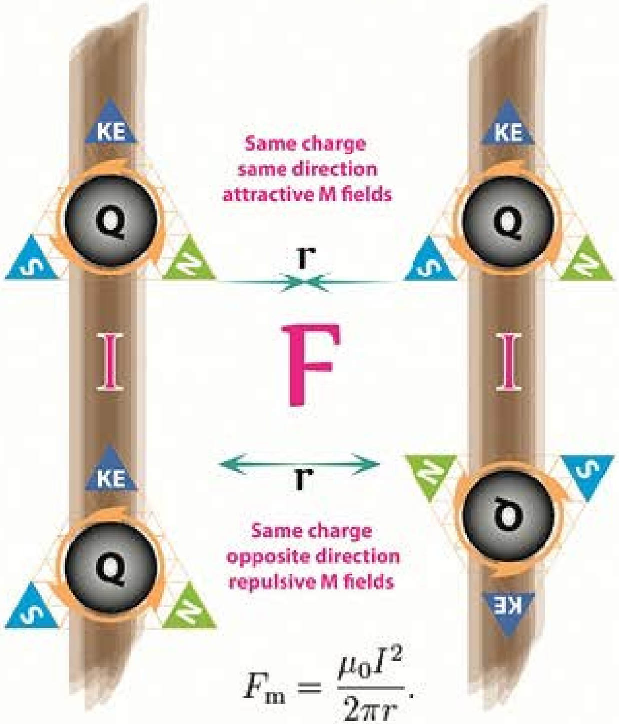
KE
Q
S
N
I
KE
Q
S
N
KE
Q
S
N
I
KE
Q
N
S
Same charge same direction attractive M fields
r
F
r
Same charge opposite direction repulsive M fields

$$F_m = \frac{\mu_0 I^2}{2\pi r}.$$

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Capacitance

Any two electrical conductors separated by a non-conducting (or very high resistance) medium is a capacitor
[these can be plates, conductive wires or coaxial cables etc]

Capacitance is a function only of the physical dimensions (geometry) of conductors and the permittivity of the dielectric separating them

Plate capacitors

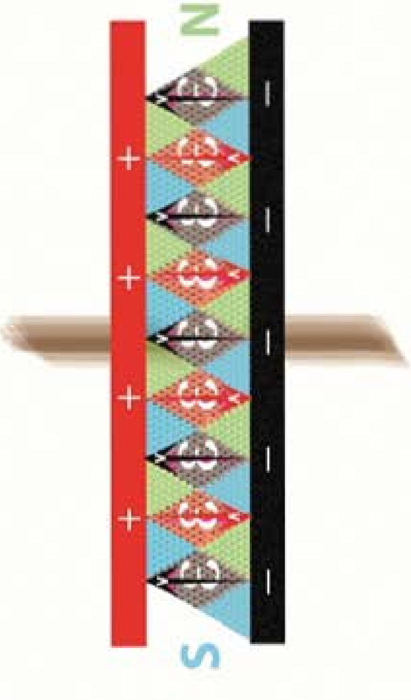

separated conductive cables

In general any separated charges will create a emf voltage

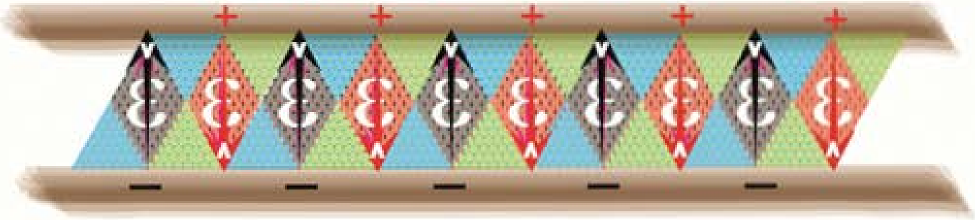

should a current flow in the conductors the capacitive field will be dominated by perpendicular, superpositioned amperian M-fields of greater strength

Coaxial cables

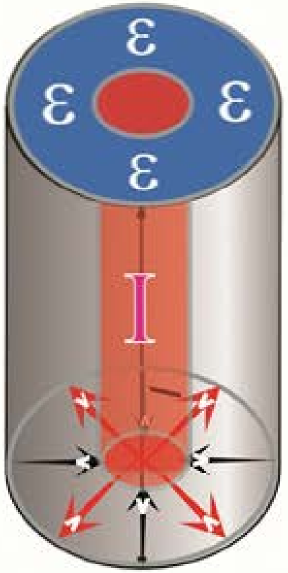

The SI unit of capacitance is the farad (symbol: F)
named after the English physicist Michael Faraday;

Capacitance is the ability of a body to store an electrical charge.

$$C = \frac{Q}{V}$$

Any object that can be electrically charged exhibits capacitance

A 1 farad capacitor when charged with1 coulomb of electrical charge will have a potential difference of 1 volt between its plates.

Amperian Forces

Currents produce magnetic field forces

$$F = 2k_A \frac{I_1 I_2}{r}$$

6.241335 e18 electrons passing a given point per second constitutes one Ampere.

Coulombs are charged masses

m

that produce accelerations

Andre Ampere

(20 January 1775 – 10 June 1836)

Current is charged Matter in motion

M

that produce magnetic fields

A

1 Amp of electrons has a EM mass of

6.241355408 e18 x 8.851486361 e-31

5.524527227 e-12 kg

kg

An Ampere is a Coulomb per second.
a measure of the rate at which charged Matter moves.

A coulomb is the quantity of charge transported by one amp in one second

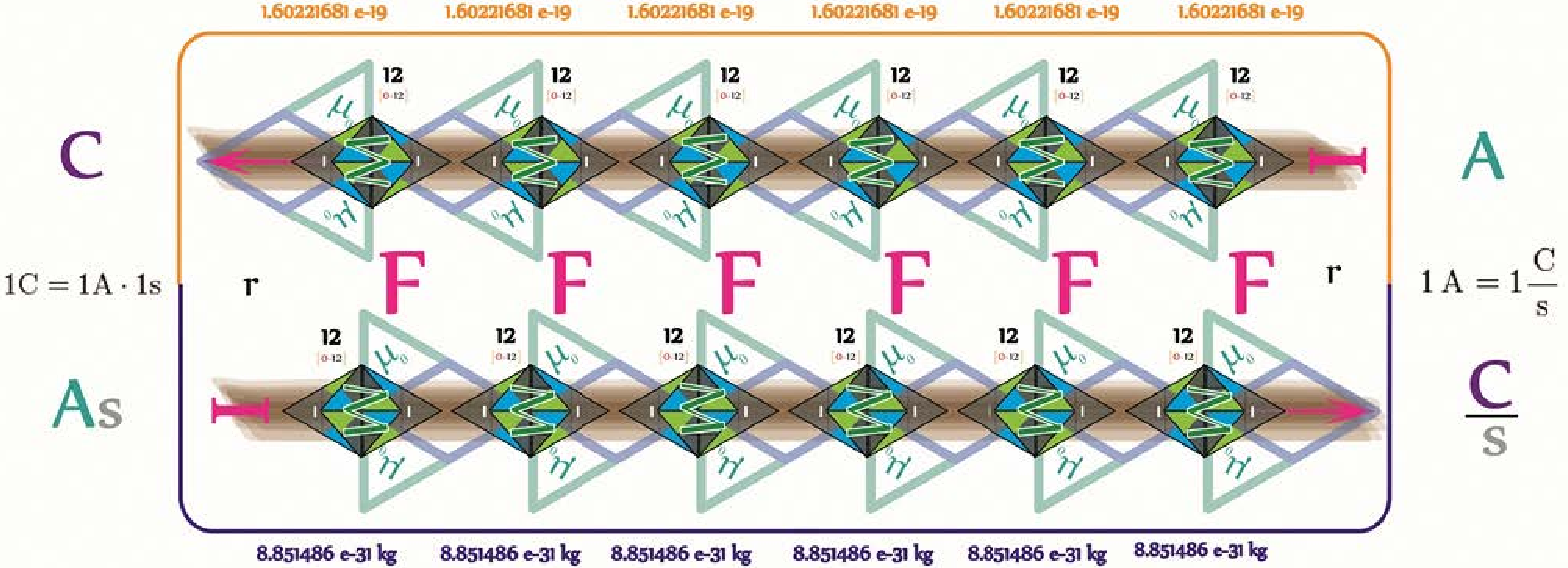
1.60221681 e-19
1.60221681 e-19
1.60221681 e-19
1.60221681 e-19
1.60221681 e-19
1.60221681 e-19
12
[0-12]
μ₀
ε₀
F
r
C
As
A
C/s
8.851486 e-31 kg
8.851486 e-31 kg
8.851486 e-31 kg
8.851486 e-31 kg
8.851486 e-31 kg
8.851486 e-31 kg

$$1C = 1A \cdot 1s$$

$$1\,A = 1\,\frac{C}{s}$$

An ampere is one coulomb per second

Ampere's Magnetic Interactions

the force of attraction or repulsion between two current-carrying wires (see first figure below) is often called Ampère's force law.

The best-known and simplest example of Ampère's force law, which underlies the definition of the ampere, the SI unit of current, states that the force per unit length between two straight parallel conductors is

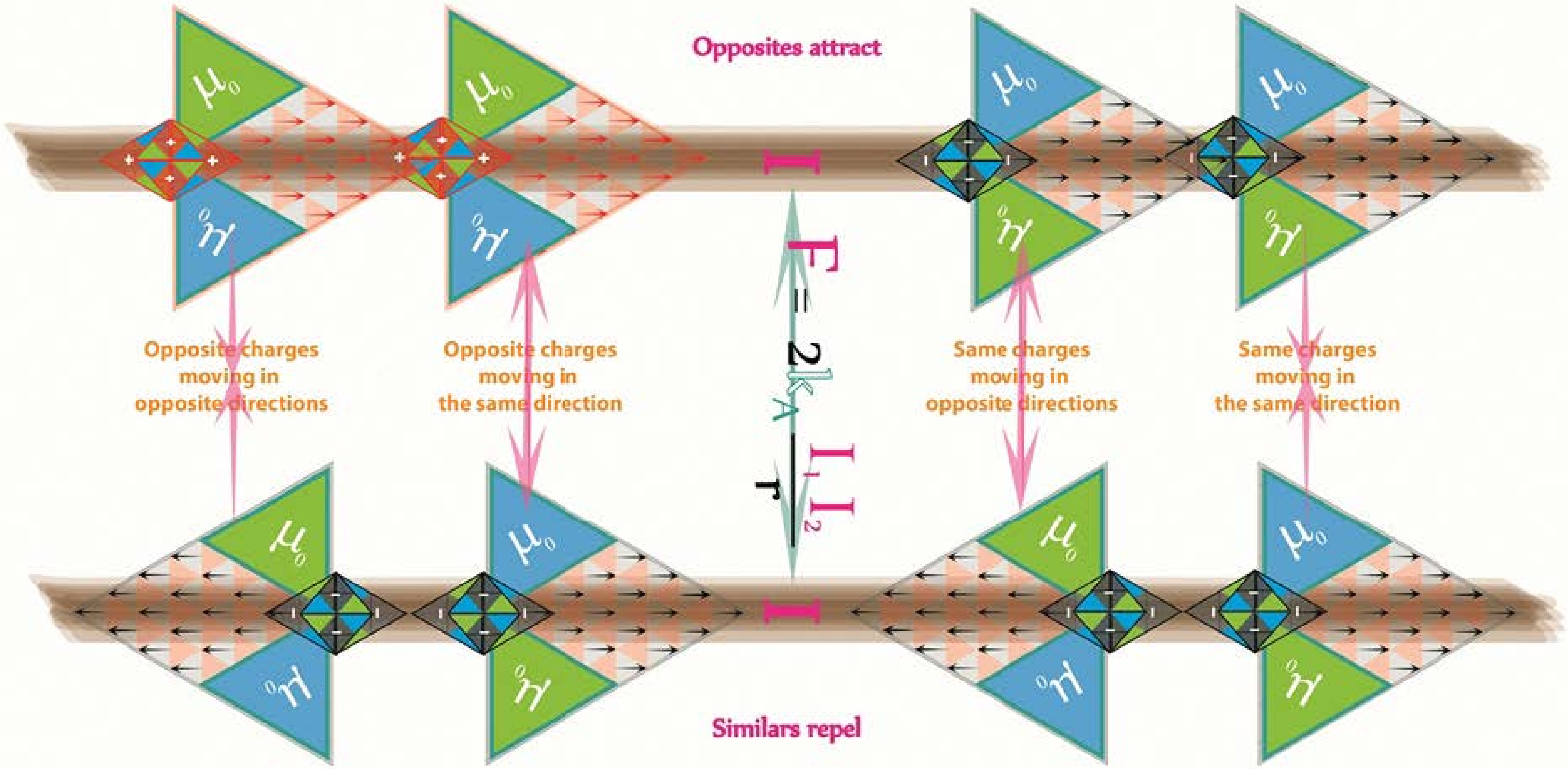

Opposites attract

$$F = 2k_A \frac{I_1 I_2}{r}$$

Opposite charges moving in opposite directions

Opposite charges moving in the same direction

Same charges moving in opposite directions

Same charges moving in the same direction

Similars repel

It is a measure of the interactive force produced by the Magnetic field energy-momenta of two superpositioned KEM field geometries

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2D Electric field geometries accelerate charged particles

Lorentz Forces

If a particle of charge q moves with velocity v in the presence of an electric field E and a magnetic field B, then it will experience a force

3D Matter topologies in motion create magnetic moments

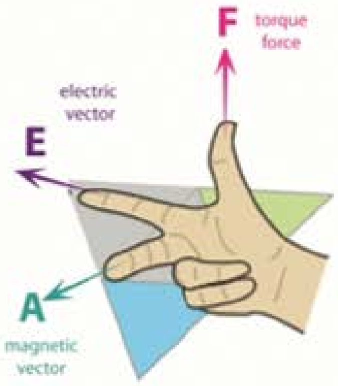
F
torque force
electric vector
E
A
magnetic vector

charged particles
in motion produce KEM fields
with magnetic moments

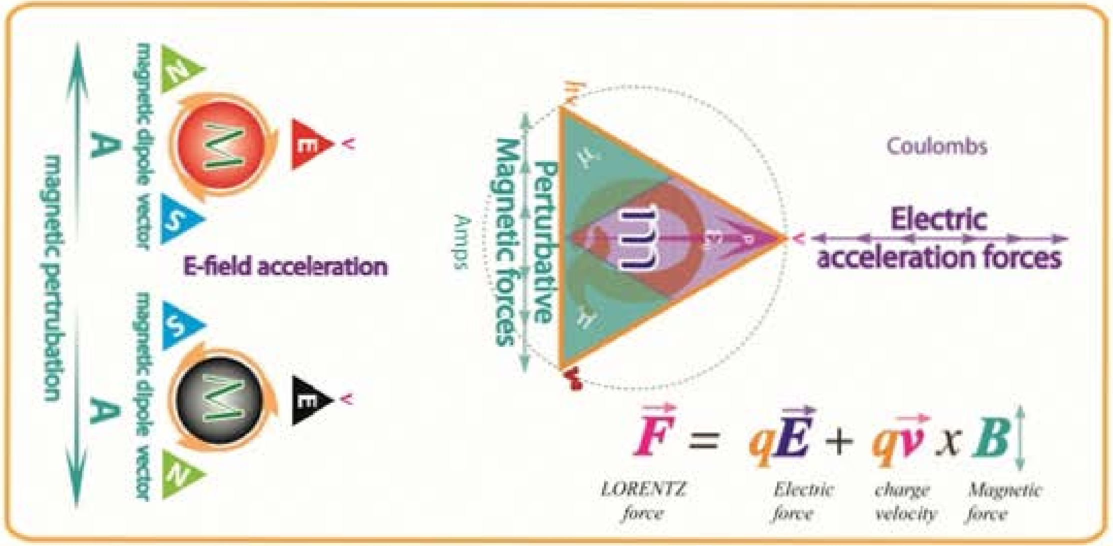
magnetic pertrubation
A
magnetic dipole vector
M
E
S
N
E-field acceleration
A
magnetic dipole vector
M
E
S
N
Amps
Magnetic forces
Perturbative
m
Coulombs
Electric
acceleration forces

$$\vec{F} = q\vec{E} + q\vec{v} \times B$$

LORENTZ force · Electric force · charge velocity · Magnetic force

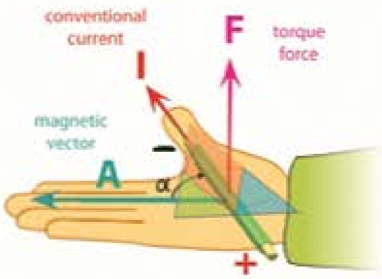
conventional current
I
F
torque force
magnetic vector
A
α
+

external magnetic fields
create torque forces on the
M dipoles of KEM fields

The Lorentz force is the force on a charged particle due to external electromagnetic fields.

Charles-Augustin de Coulomb

(14 September 1736 – 23 August 1806)

Magnetic field upwards through paper ⊙

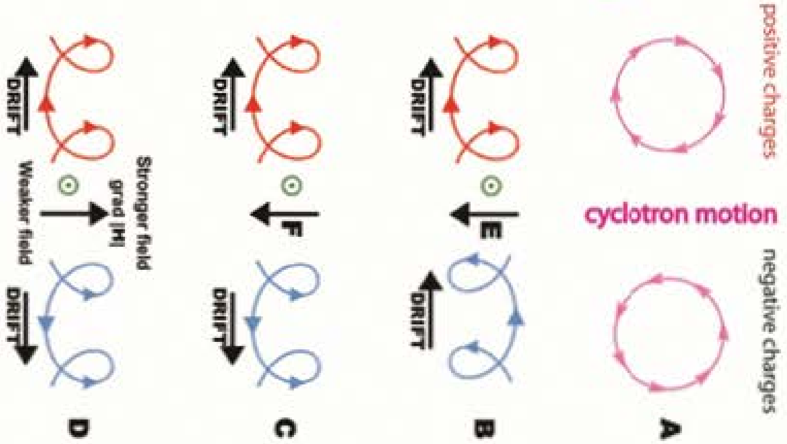
DRIFT
Weaker field
Stronger field grad |M|
DRIFT
DRIFT
F
DRIFT
DRIFT
E
DRIFT
positive charges
cyclotron motion
negative charges
D
C
B
A

All charges in motion are subject to external EM forces on their KEM fields

Andre Ampere

(20 January 1775 – 10 June 1836)

Neutral Particle interactions

Opposites Attract

Classical Forces of interaction
are unable to explain
how Neutral particles
are attracted to other particles

Similars Repel

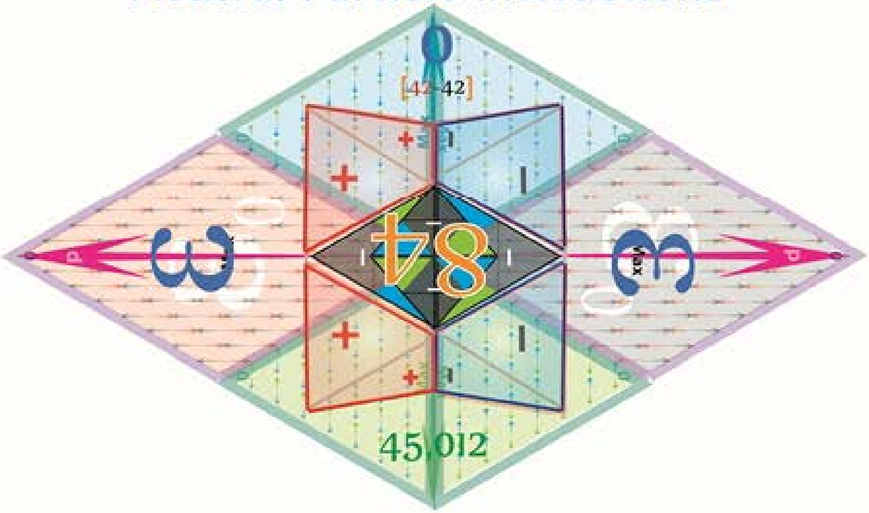
0
[42-42]
84
ε
ε
45,012

Tetryonic charge geometry

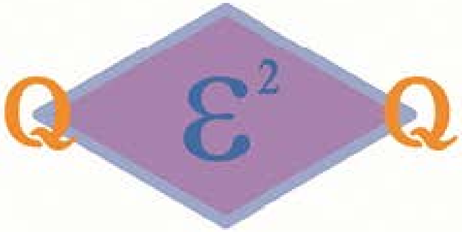
Q
ε^2
Q

reveals the equilateral field mechanics behind
EM induction and all the physical forces

**All Matter topologies are comprised of charged mass-energy quanta
that effect atomic interactions via their KEM field energy momenta**

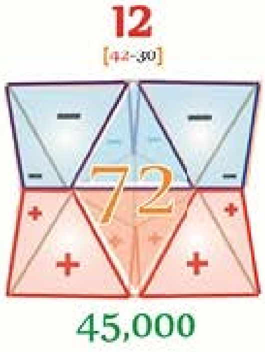
12
[42-30]
72
45,000

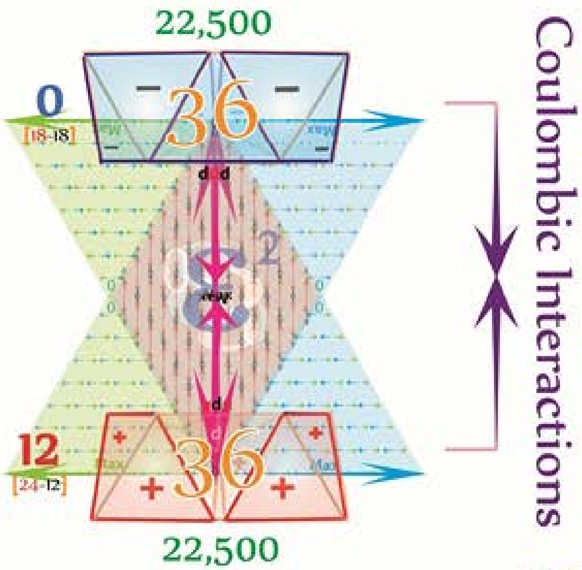
22,500
0
[18-18]
36
12
[24-12]
36
22,500

Coulombic Interactions

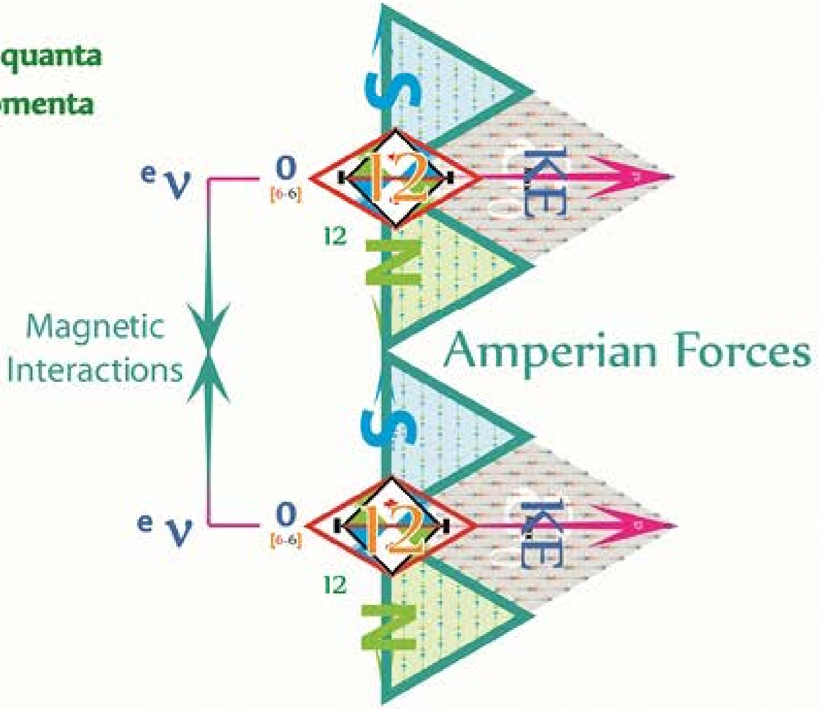
e ν
0
[6-6]
12
12
S
N
KE
Magnetic Interactions
e ν
0
[6-6]
12
12
S
N
KE

Amperian Forces

All Matter in motion produces a secondary interactive KEM field

Coulombs

C

kg.s

Charged mass-Matter

All particles and fields have charged mass-energy geometries

Amperes

A

KG

mass seconds

$$1C = 1A \cdot 1s$$

An elementary charge is 1.602216081 e-19 C

mass-Matter per second

$$1\,A = 1\frac{C}{s}$$

6.241355408 e18 electrons /sec constitutes one ampere.

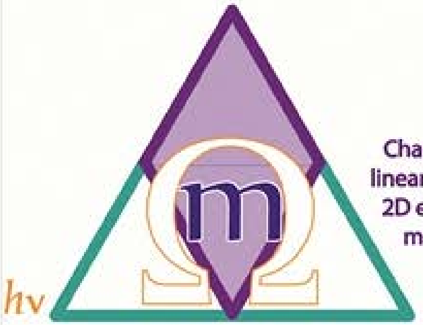

Charge is measured by the linear forces produced by the 2D equilateral geometry of mass-energy momenta

2D kEM angular mass-energy momenta

It is defined as the charge provided by a steady current of one ampere in one second.

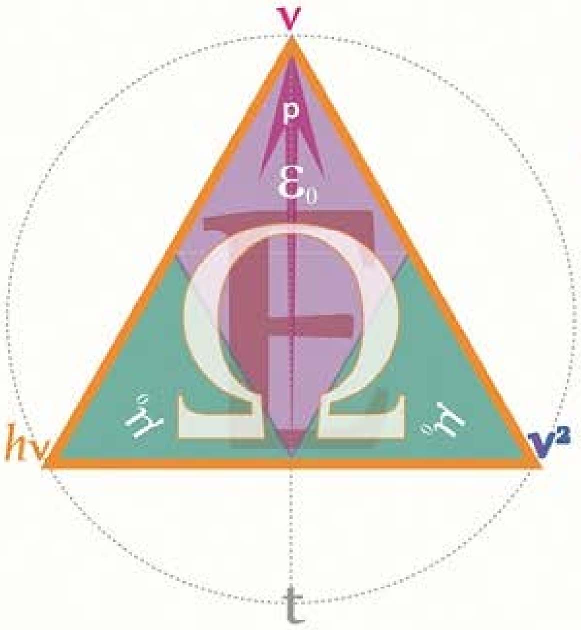

CHARGE

One coulomb of charge flowing per second equals one ampere of current.

CURRENT

$$Q = I \cdot t$$

Charge and Current are related to each other through time

Current is measured by the transverse forces produced by mass-energy momenta of Matter topologies in motion per unit of time

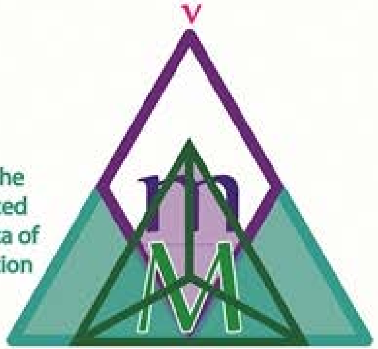

3D mass-Matter momentum

The amount of charged mass- Matter passing a point per unit time

Charge

Q

Current

I

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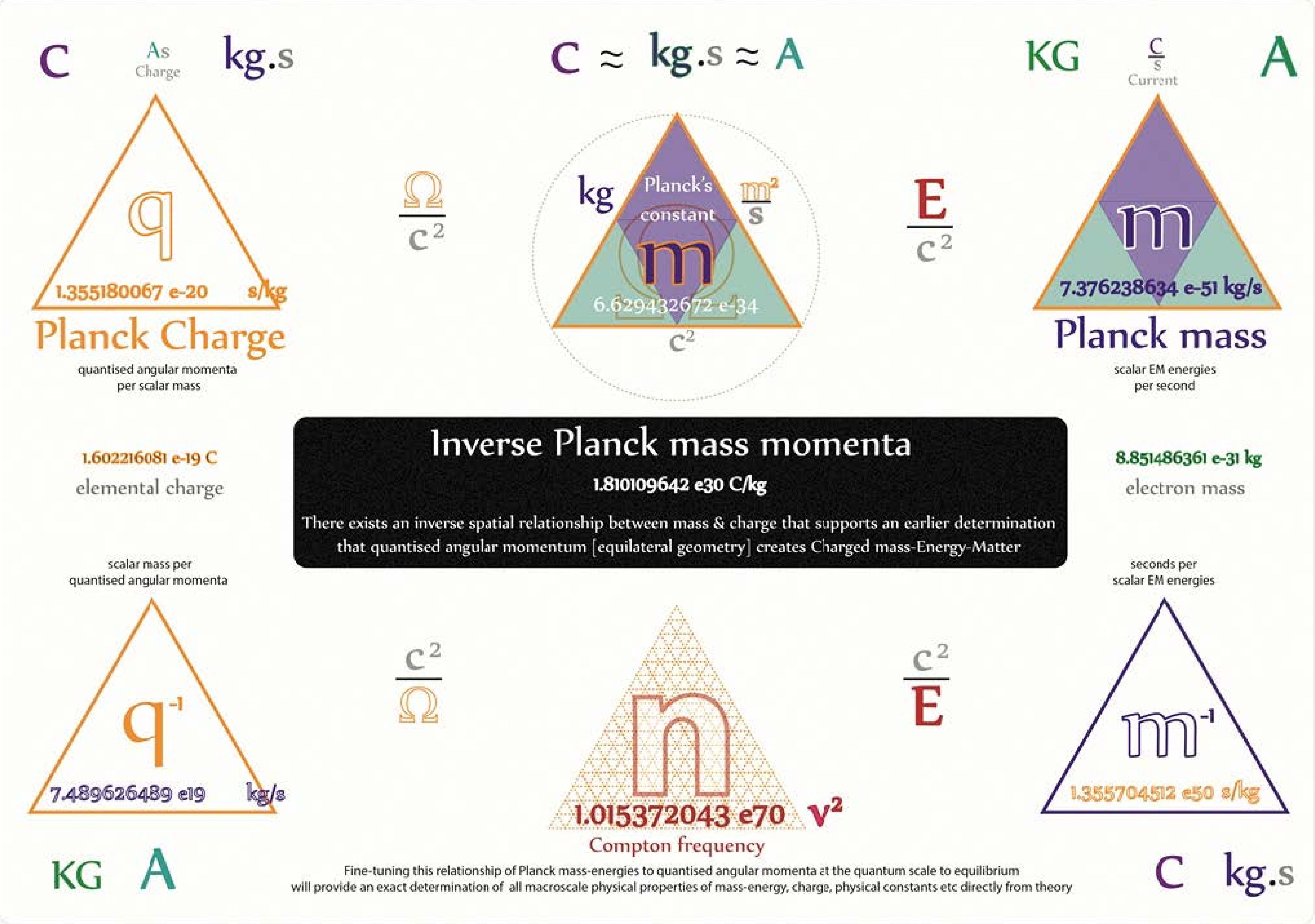

C As Charge kg.s

$C \approx kg.s \approx A$

KG $\frac{C}{s}$ Current A

q

1.355180067 e-20 s/kg

Planck Charge

quantised angular momenta
per scalar mass

$\frac{\Omega}{c^2}$

kg Planck's constant $\frac{m^2}{s}$

m

6.629432672 e-34

c^2

$\frac{E}{c^2}$

m

7.376238634 e-51 kg/s

Planck mass

scalar EM energies
per second

1.602216081 e-19 C

elemental charge

Inverse Planck mass momenta

1.810109642 e30 C/kg

There exists an inverse spatial relationship between mass & charge that supports an earlier determination that quantised angular momentum [equilateral geometry] creates Charged mass-Energy-Matter

8.851486361 e-31 kg

electron mass

scalar mass per
quantised angular momenta

seconds per
scalar EM energies

q^{-1}

7.489626489 e19 kg/s

$\frac{c^2}{\Omega}$

n

1.015372043 e70 v^2

Compton frequency

$\frac{c^2}{E}$

m^{-1}

1.355704512 e50 s/kg

KG A

Fine-tuning this relationship of Planck mass-energies to quantised angular momenta at the quantum scale to equilibrium will provide an exact determination of all macroscale physical properties of mass-energy, charge, physical constants etc directly from theory

C kg.s

Electricity

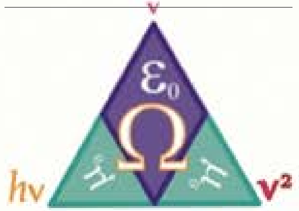

"There exists Negative and Positive electrical quanta"

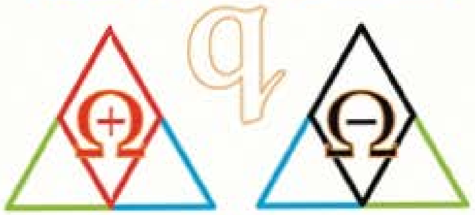

Electromagnetism: a fundamental interaction between the magnetic field and the presence and motion of an electric charge topology.

Electric charge: the geometry of EM energy momenta, also determines their electromagnetic interactions.

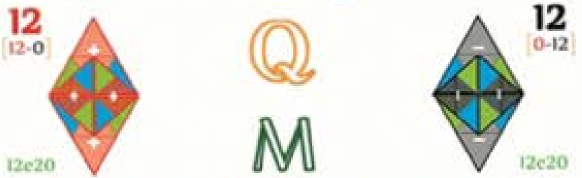

Electrically charged Matter topologies are influenced by, and produce, electromagnetic fields when in motion

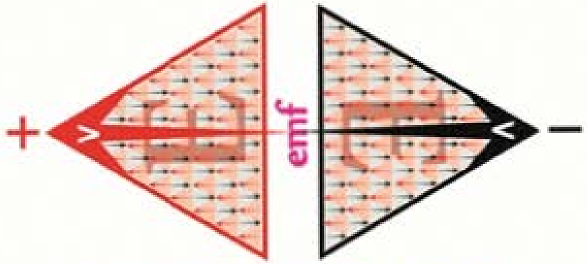

Electric potential: the capacity of an electric field to do work on an electric charge, typically measured in volts..

Benjamin Franklin

(January 17, 1706 – April 17, 1790)

Charles-Augustin_de_Coulomb
(14 September 1736 – 23 August 1806)

Andre Ampere
(20 January 1775 – 10 June 1836)

Georg Simon Ohm
(16 March 1789 – 6 July 1854)

Carl Friedrich Gauss
(30 April 1777 – 23 February 1855)

Heinrich Lenz
(February 12, 1804 – February 10, 1865)

Michael Faraday
(22 September 1791 – 25 August 1867)

James Clerk Maxwell
(13 June 1831 – 5 November 1879)

James Prescott Joule
(24 December 1818 – 11 October 1889)

John Henry Poynting
(9 September 1852 – 30 March 1914)

Nikola Tesla
(10 July 1856 – 7 January 1943)

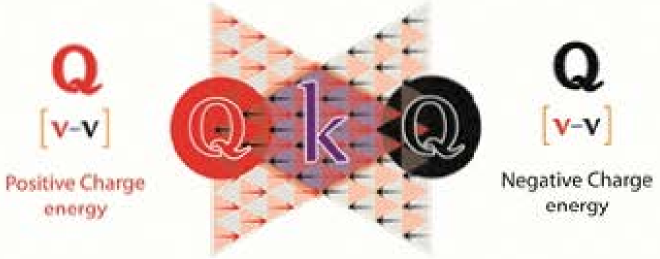

Electric field: an influence produced by one electric charge on other charges in its vicinity.

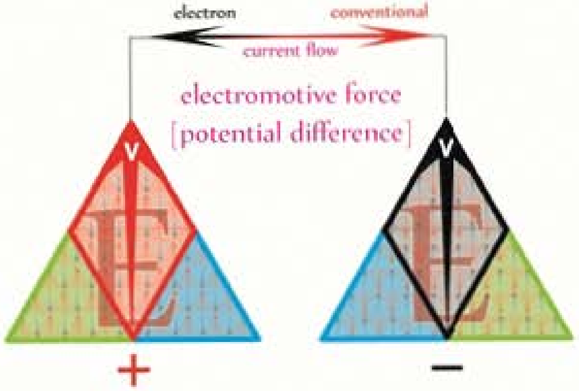

Electricity is the flow of Energy between separated Charge potentials when an electric circuit is formed measured in Volts [Joules/C]

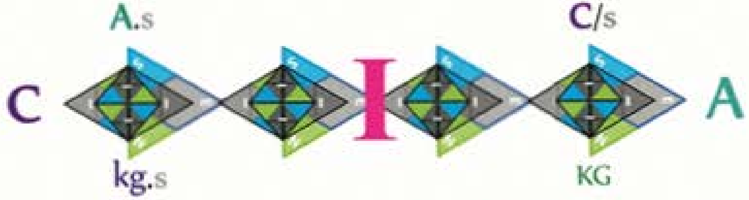

Electric current: is a secondary effect resulting from electrical energy in a circuit. It is the movement or flow of electrically charged particles, typically measured in amperes.

Electricity is a general term encompassing a variety of phenomena resulting from the presence and flow of electric charge.
These include many easily recognizable phenomena, such as lightning, static electricity, and the flow of electrical current in an electrical wire.
In addition, electricity encompasses less familiar concepts such as the electromagnetic field and electromagnetic induction.

EM field Permittivity

The Electric constant, commonly called the vacuum permittivity, or permittivity of free space, relates the units for electric charge to mechanical quantities such as length and force.

The name Vacuum Permittivty is a misnomer and should be replaced with the correct term EM field Permittivity

The strength of Electric fields is determined by the Electrical Permittivity Constant

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

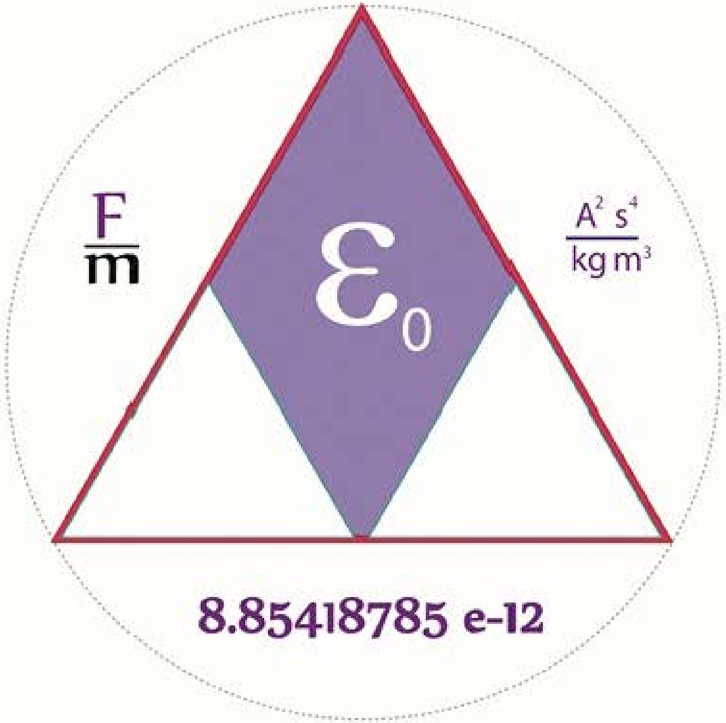

$$\varepsilon_0 = \frac{1}{\mu_0 c^2}$$

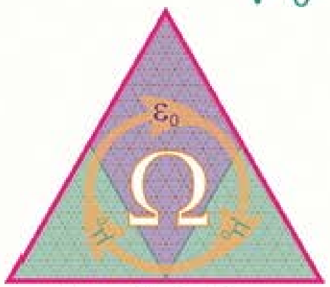

"Ampere's Law states that for any closed loop path, the sum of the quantities (B.ds) for all path elements into which the complete loop has been divided is equal to the product of μ0 and the total current enclosed by the loop."

$$k = \frac{1}{4\pi\varepsilon_0}$$

The permittivity of empty space, equal to 1 in centimeter-gram-second electrostatic units and to 107/4πc2 farads per meter or, numerically, to 8.854 × 10-12 farad per meter in International System units, where c is the speed of light in meters per second.

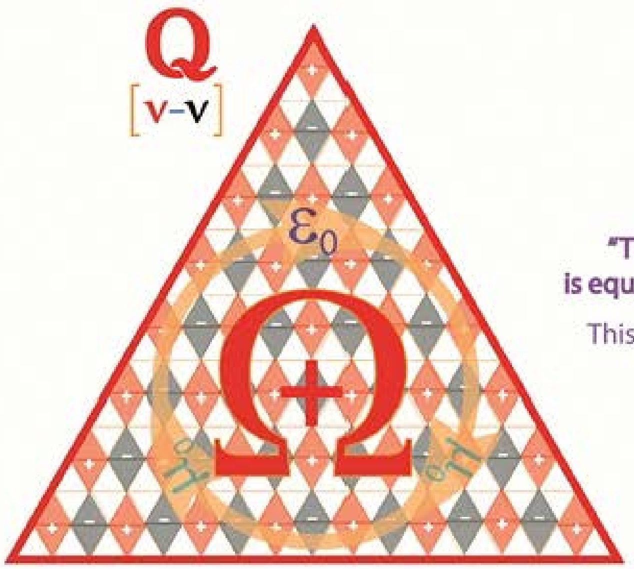

Positive Charge Electric Field

Gauss' Law:

"The total of the electric flux out of a closed surface is equal to the charge enclosed divided by the permittivity"

This applies equally to any integral geometry chosen to tessellate a surface area

Superpostioned E fields gives rise to Coulomb Forces

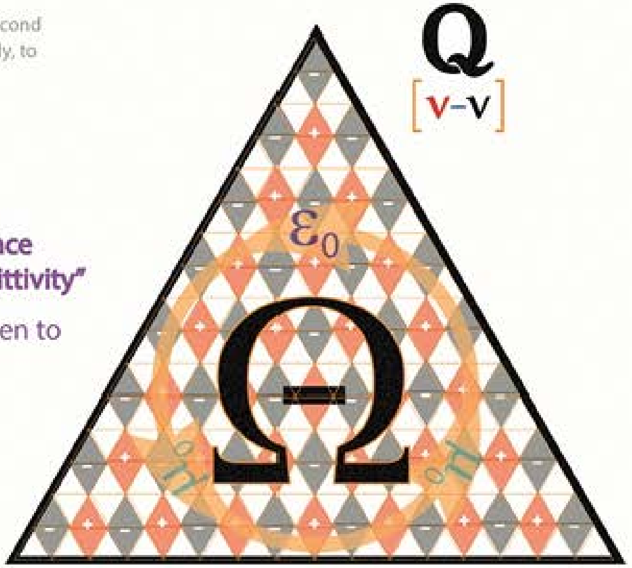

Negative Charge Electric Field

EM field Permeability

The permeability of free space,
also called absolute permeability.

The name Vacuum Permeability is a misnomer and should be replaced with the correct term EM field Permeability

The magnetic constant has the value of
4π × 10-7 henry per meter.

**The strength of Magnetic fields
is determined by the
Magnetic Permeability Constant**

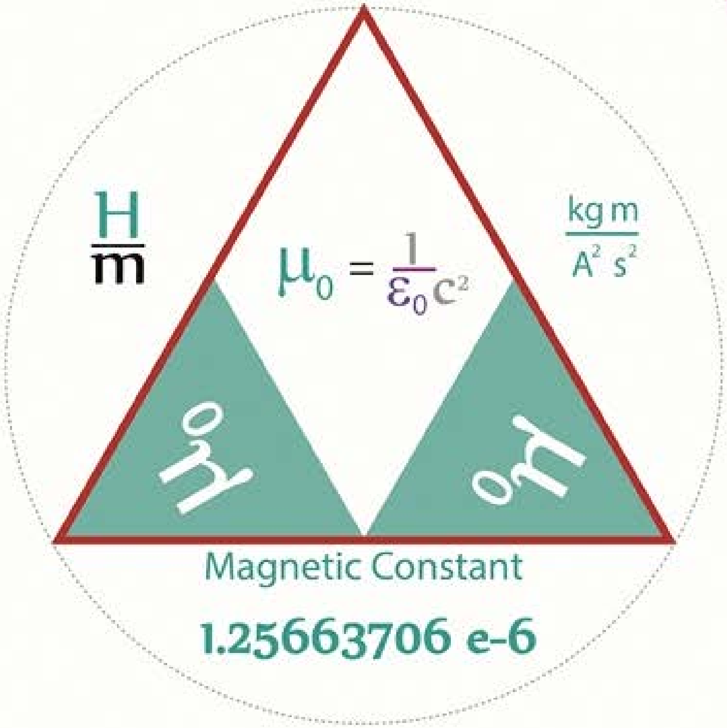

Magnetic Constant

1.25663706 e-6

μ_0

The magnetic field is most commonly defined in terms of the Lorentz force it exerts on moving electric charges.

F

The magnetic field generated by a steady current
(a constant flow of electric charges in which charge
is neither accumulating nor depleting at any point)
as described by the Biot–Savart law

$$B=\mu_0 H$$

ε_0
+Ω
μ_0
μ_0

Positive Magnetic Moment

Magnetic monopoles do NOT exist

**they are a mathematical identity
and not physically possible due to
the equilateral geometry
of Planck energies**

ε_0
-Ω
μ_0
μ_0

Negative Magnetic Moment

James Prescott Joule

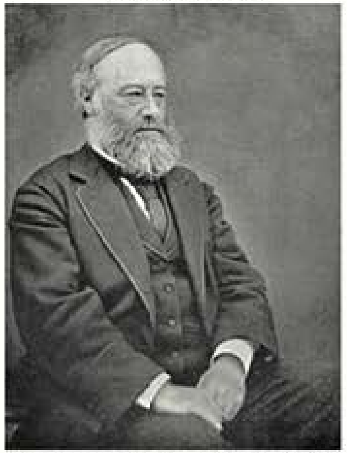

(24 December 1818 – 11 October 1889)

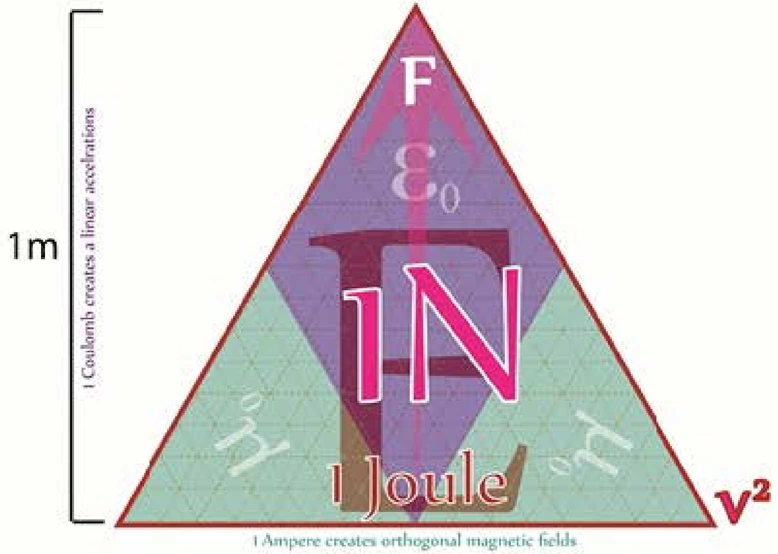
1m
1 Coulomb creates a linear accelrations
F
ε_0
1N
μ_0
μ_0
1 Joule
v^2
1 Ampere creates orthogonal magnetic fields

Joule

A measure of the equilateral charged mass-energy momenta that can to do work

... the mechanical power exerted in turning a magneto-electric machine is converted into the heat evolved by the passage of the currents of induction through its coils; and, on the other hand, that the motive power of the electro-magnetic engine is obtained at the expense of the heat due to the chemical reactions of the battery by which it is worked (1845)

EM Field Planck quanta

$$n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

mass ElectroMagnetic mass velocity

It is equal to the energy expended (or work done) in applying a force of one newton through a distance of one meter (1 newton metre or N·m), or in passing an electric current of one ampere through a resistance of one ohm for one second

$$\boxed{\text{Energy}\quad kg.\frac{m^2}{s^2}}$$

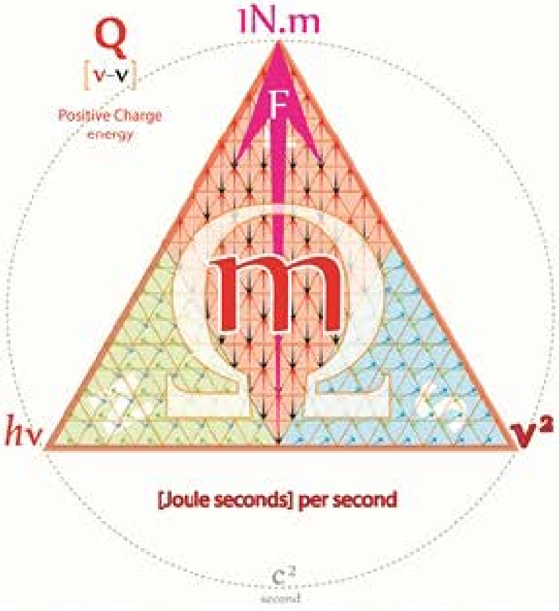
Q
[v-v]
Positive Charge energy
1N.m
F
m
$h\nu$
v^2
[Joule seconds] per second
c^2
second

$$J = \frac{kg \cdot m^2}{s^2} = N \cdot m = Pa \cdot m^3 = W \cdot s$$

Planck's Constant x frequency $\left[kg.\frac{m^2}{s}\right].s^{-1}$

mass x velocity squared $kg.\left[\frac{m}{s}\right]^2$

Momentum x velocity $\left[kg.\frac{m}{s}\right].\frac{m}{s}$

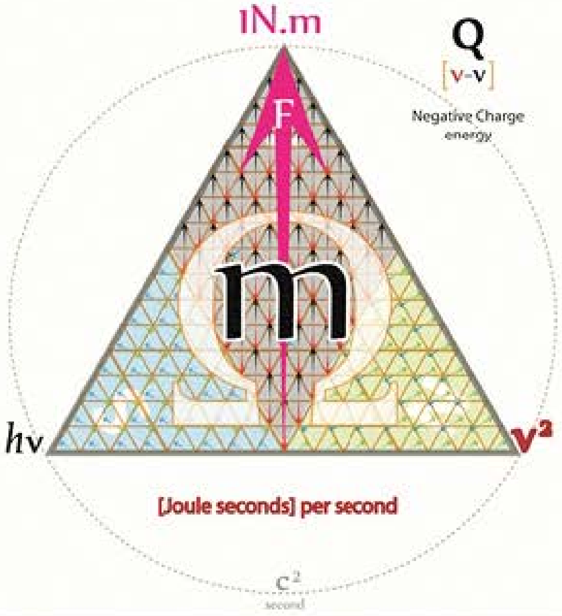
1N.m
Q
[v-v]
Negative Charge energy
F
m
$h\nu$
v^2
[Joule seconds] per second
c^2
second

Volts

[Joules per Coulomb]

The volt is the unit for electric potential (voltage), electric potential difference, and electromotive force.

$$V = \frac{W}{A} = \frac{J}{A \cdot s} = \frac{N \cdot m}{A \cdot s} = \frac{kg\, m^2}{A\, s^3} = \frac{kg \cdot m^2}{C \cdot s^2} = \frac{N \cdot m}{C} = \frac{J}{C}$$

A single volt is defined as the difference in electric potential across a wire when an electric current of one ampere dissipates one watt of power.
It is also equal to the potential difference between two parallel, infinite planes spaced 1 meter apart that create an magnetic field of 1 newton per coulomb.
Additionally, it is the potential difference between two points that will impart one joule of energy per coulomb of charge that passes through it

Positive charge

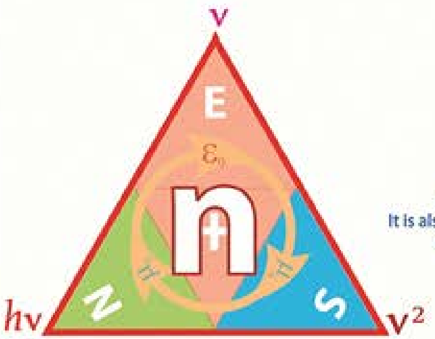
v
E
ε0
n
N
S
hv
v²

$1V = 1J/C$

One Volt is defined as energy consumption of
one joule per electric charge of one coulomb

Negative charge

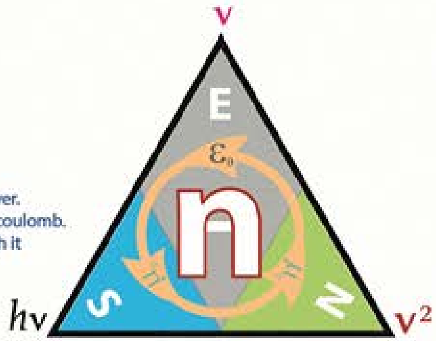
v
E
ε0
n
S
N
hv
v²

$1V = 1A \cdot 1ohm$

One volt is equal to current of 1 amp
times resistance of 1 ohm

Positive voltage

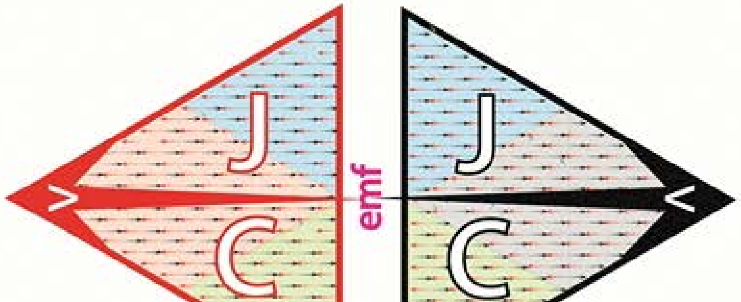

Negative voltage

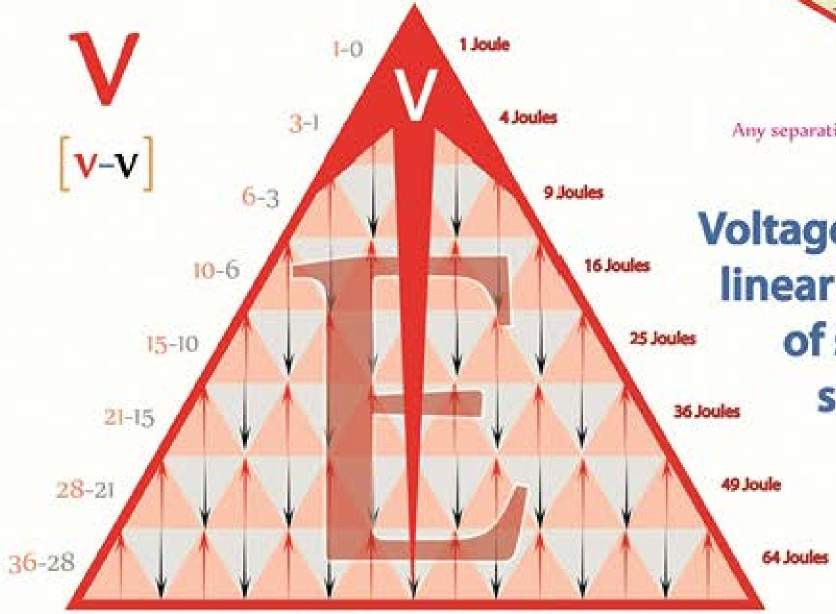
V
[v–v]
1-0
3-1
6-3
10-6
15-10
21-15
28-21
36-28
V
E
1 Joule
4 Joules
9 Joules
16 Joules
25 Joules
36 Joules
49 Joule
64 Joules

[Joules per Coulomb]

Any separation of electrostatic charges, results in a voltage.
[Potential Difference]

Voltage is a scalar measure of linear electromotive forces of separated charges seeking potential equilibrium

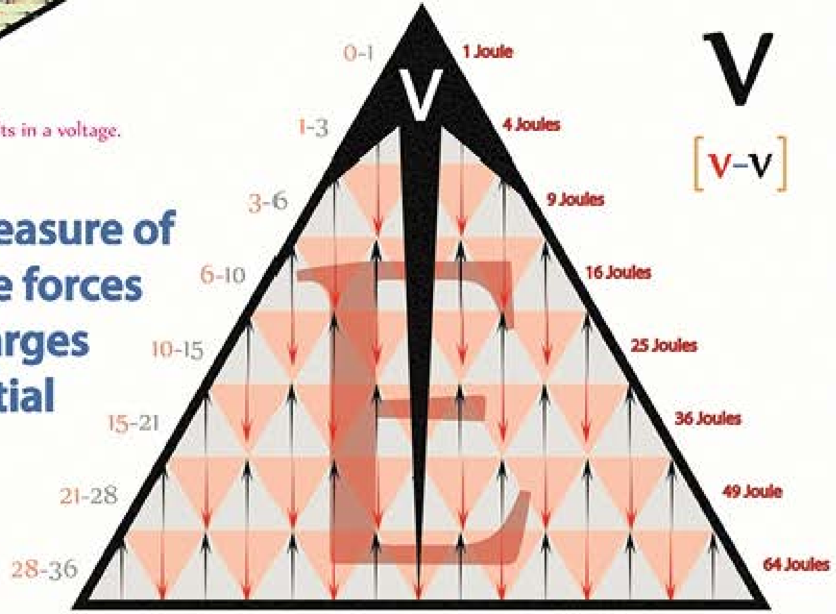
0-1
1-3
3-6
6-10
10-15
15-21
21-28
28-36
V
E
1 Joule
4 Joules
9 Joules
16 Joules
25 Joules
36 Joules
49 Joule
64 Joules
V
[v–v]

[Joules per Coulomb]

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Positive charged mass-energy

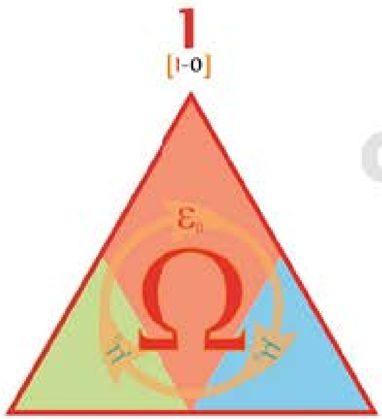

Clockwise inductive energy flux

Charge is the equilateral geometry of Energy that gives form to all mass & Matter

charge

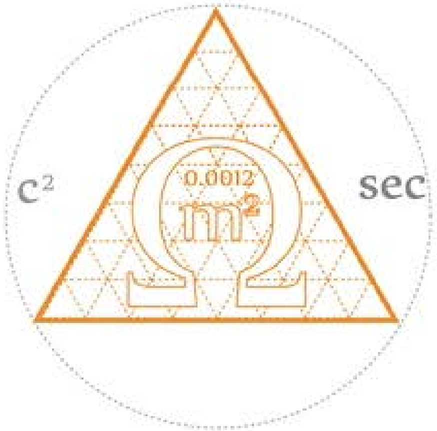

time

Negative charged mass-energy

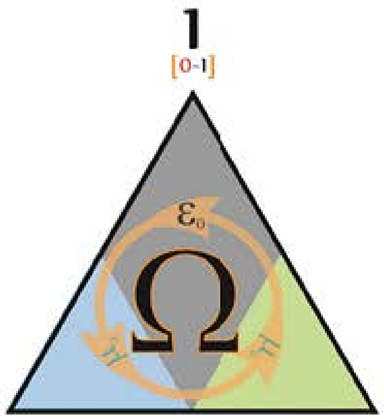

Counter clockwise energy flux

q

q

t

$$\frac{\Omega}{c^2}$$

$$\frac{m^2}{s}\;\frac{s^2}{m^2}$$

$$s$$

seconds

t

ElectroMagnetic Charge is a quantum property resulting from the equilateral QAM geometry of mass-Energy

1.33518 e-20 s

Changes to nett quantised angular momenta [charged mass-energies] within any space-time co-ordinate system forms the basis of time

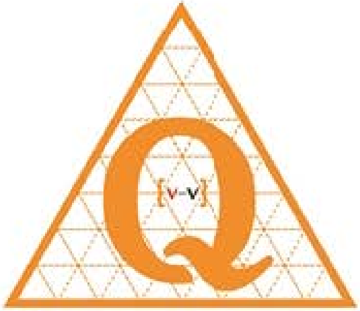

The two ElectroMagnetic charge geometries possible can be created through tesselation of electrical energy in ideal inductive loops

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Coulombs

are a measure of 2D charged mass geometries
and the electromagnetic forces they produce per unit time

W+ boson integrals nett positive charged mass momenta

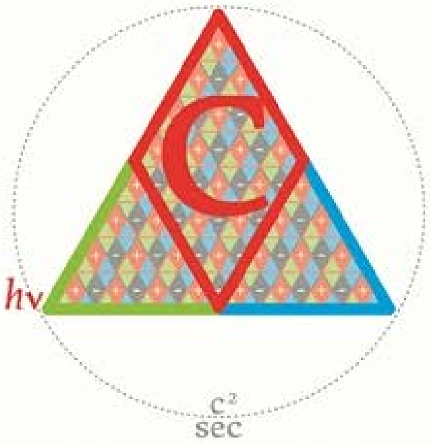

Q
[v-v]

Charles-Augustin de Coulomb

(14 September 1736 – 23 August 1806)

Derived in 1785 Coulomb's Law is a law of physics describing the electrostatic interaction between any two charged particles (and forms the basis for Ampere's Law)

Q
[v-v]

W- boson integrals nett negative charged mass momenta

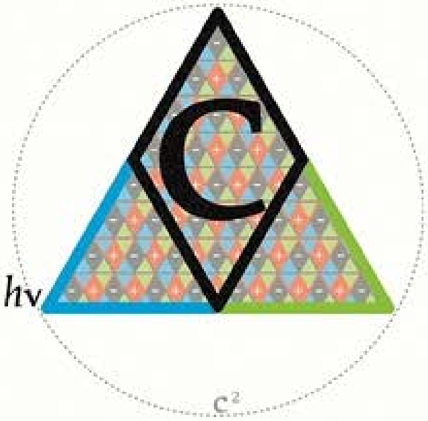

Electric forces

$$m\frac{\Omega}{c^2}$$

Magnetic forces

Coulombs

The coulomb (unit symbol: C) is the SI derived unit of electric charge (symbol: Q or q).
It is defined as the charge transported by a steady current of one ampere in one second:

Amperes

As

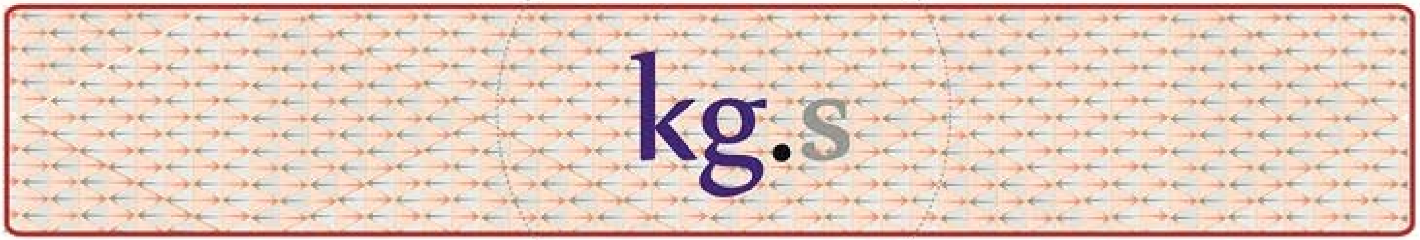

kg.s

$$\frac{C}{s}$$

Interactive linear momenta of super-positioned E-fields creates Coulomb's force law

$\frac{c^2}{sec}$

1A.1s

1F.1V

$1\text{C} = 1\text{A} \cdot 1\text{s}$

1 COULOMB is a measure of linear 2D electric field energy momenta in EM field geometries

1 AMPERE is a measure of orthogonal 2D magnetic field forces produced by Matter topologies in motion

$1\,\text{A} = 1\frac{\text{C}}{\text{s}}$

C

quantised electrical energy momenta

1C is the quantity of charged masses which pass any point in a circuit in which a current of 1A flows for 1s

A

Coulombs

Amperes

kg.s

KG

linear acceleration energy momenta

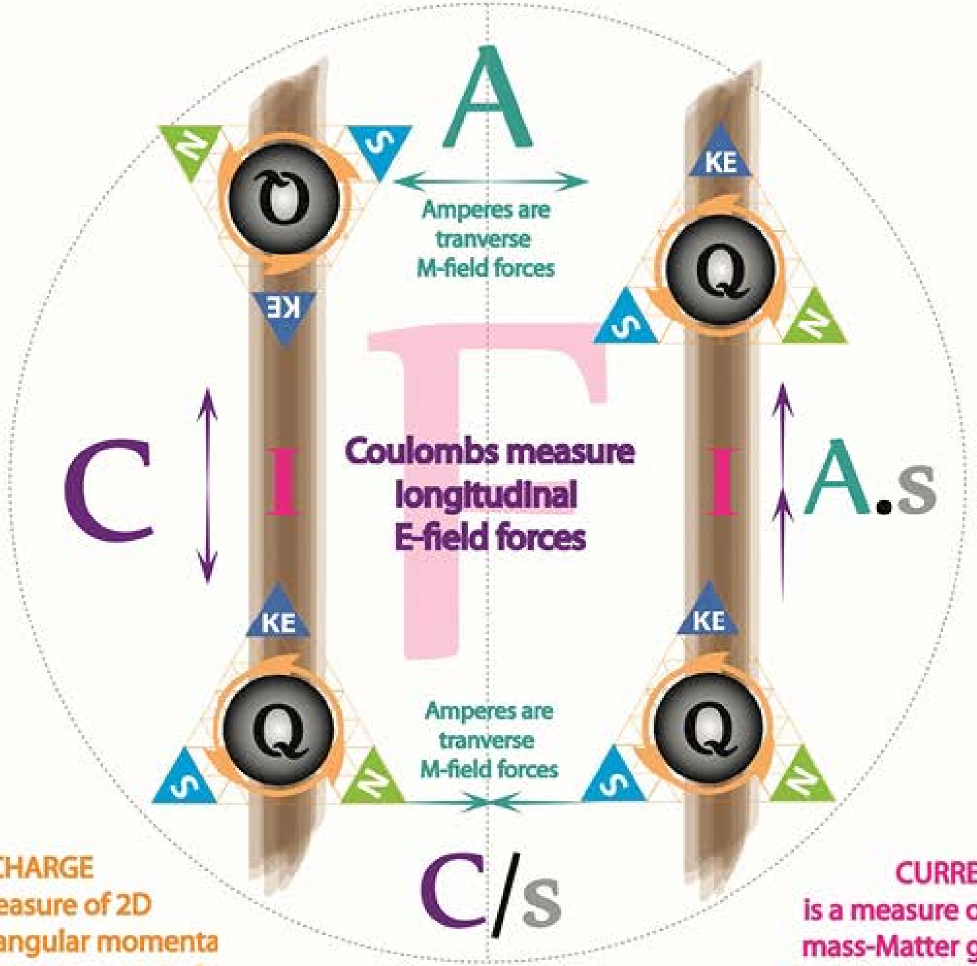
A
N
S
KE
Q
Amperes are tranverse M-field forces
C
I
F
Coulombs measure longitudinal E-field forces
A.s
Amperes are tranverse M-field forces
C/s

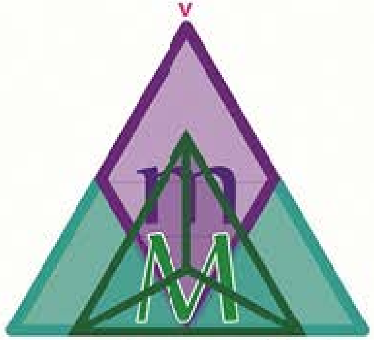

magnetic perturbation energy momenta

Q

Charge

CHARGE is a measure of 2D quantised angular momenta [mass -Matter geometries]

$Q = I.t$

quantity of charge = rate of flow of charge × time

CURRENT is a measure of charged mass-Matter geometries in motion

I

Current

Current

is a measure of charged Matter in motion in a circuit per unit of Time

An elementary charge is
1.602216081 e-19 C

C

It is defined as the charge
transported by a steady current of
one ampere in one second.

Coulombs

Amperes

The amount of electric charge
passing a point per unit time

A

6.2413354 e18 electrons passing a
given point each second constitutes
one ampere.

charged **masses**

kg.s

1.33518 e-20 kg.s

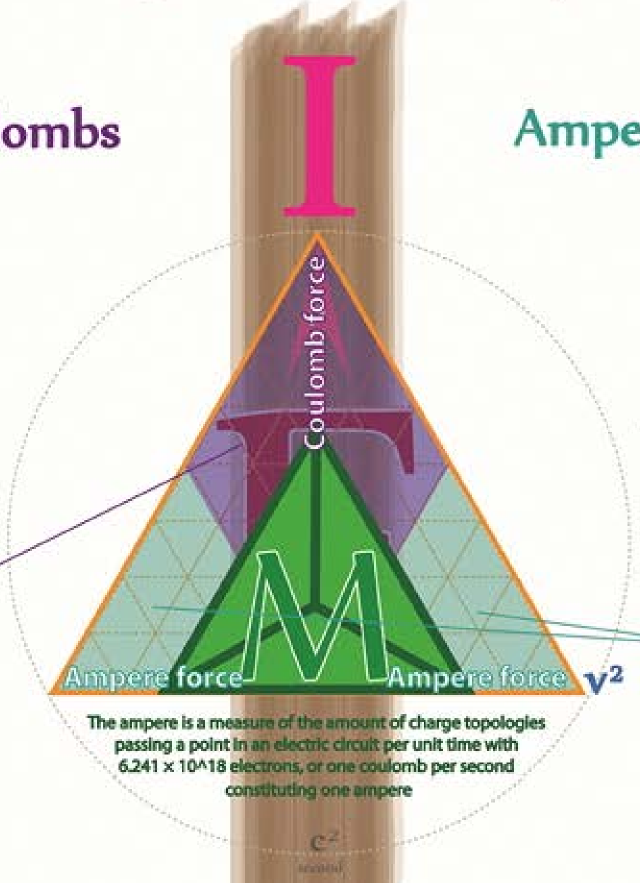

The ampere is a measure of the amount of charge topologies passing a point in an electric circuit per unit time with 6.241 x 10^18 electrons, or one coulomb per second constituting one ampere

7.489626 e19 kg

Matter

KG

The 2D linear mass-energy momenta capable of accelerating charged particles

The transverse magnetic forces produced by Matter in motion

$$1\text{C} = 1\text{A} \cdot 1\text{s}$$

$$1\,\text{A} = 1\frac{\text{C}}{\text{s}}$$

Electric current is a measure of the flow of electrically charged mass-Matter in a circuit as a result of an electrical Voltage potential

As

5.524527227 e-12 kg

Charged mass | 1 second | Matter in motion

6.241355408 e18 electrons

$$\frac{\text{C}}{\text{S}}$$

Voltage [emf] is a measure of the energy momenta per coulomb available to exert a force on charged Matter in a circuit

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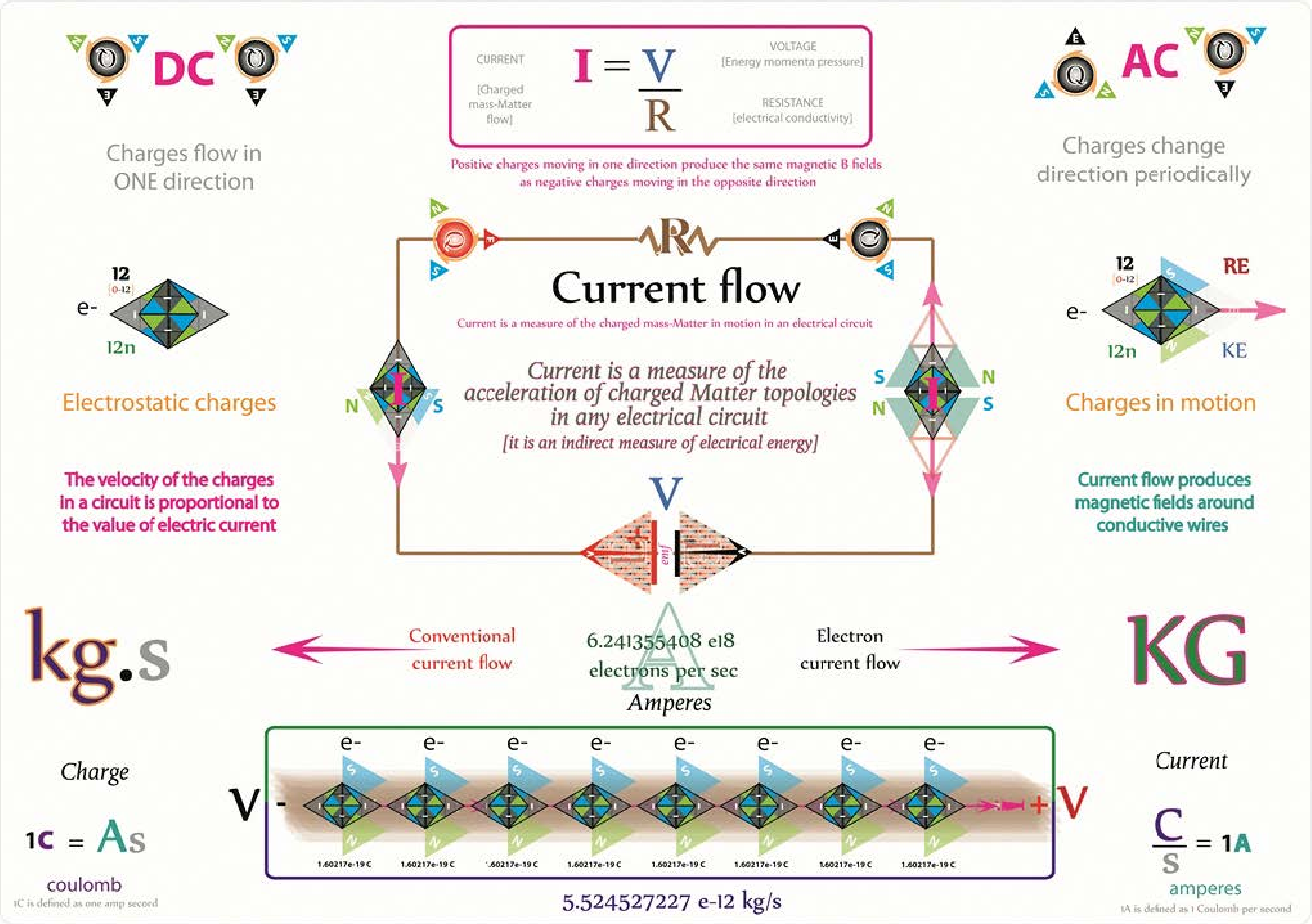
N
S
E
DC
AC
Q
12
(0-12)
e-
12n
RE
KE
N
S
R
I
emf
V
A
V
-
+
V
e-
e-
e-
e-
e-
e-
e-
e-
1.60217e-19 C
1.60217e-19 C
1.60217e-19 C
1.60217e-19 C
1.60217e-19 C
1.60217e-19 C
1.60217e-19 C
1.60217e-19 C

DC

Charges flow in ONE direction

AC

Charges change direction periodically

$$I = \frac{V}{R}$$

CURRENT [Charged mass-Matter flow]

VOLTAGE [Energy momenta pressure]

RESISTANCE [electrical conductivity]

Positive charges moving in one direction produce the same magnetic B fields as negative charges moving in the opposite direction

Current flow

Current is a measure of the charged mass-Matter in motion in an electrical circuit

Current is a measure of the acceleration of charged Matter topologies in any electrical circuit [it is an indirect measure of electrical energy]

Electrostatic charges

Charges in motion

The velocity of the charges in a circuit is proportional to the value of electric current

Current flow produces magnetic fields around conductive wires

kg.s

Conventional current flow

6.241355408 e18 electrons per sec

Amperes

Electron current flow

KG

Charge

1C = As

coulomb

1C is defined as one amp second

5.524527227 e-12 kg/s

Current

$$\frac{C}{s} = 1A$$

amperes

1A is defined as 1 Coulomb per second

Tetryonics 23.10 - Current [Matter in motion]

The electrical resistance of a conductor is a measure of how much it opposes the passage of an electric current through it

OHM's Law

Georg Simon Ohm

(16 March 1789 – 6 July 1854)

resistivity

$$\mathcal{E} = \rho J$$

Electric field

Current density

General vector equation

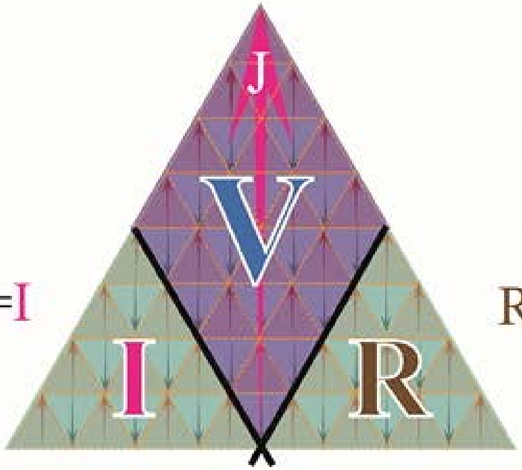

$$\frac{V}{R} = I$$

$$R = \frac{V}{I}$$

$$V = I.R$$

$$P = I.V = I^2.R$$

Power is the amount of current times the voltage level at a given point measured in watts.

Current is the flow of charged mass-Matter resulting from an electromotive force

Resistance determines how much current will flow through a conductor

Current [I.V] Voltage
POWER
Current squared [I^2R] Resistance

Ohm's law states that the current through a conductor between two points is directly proportional to the potential difference across the two points.

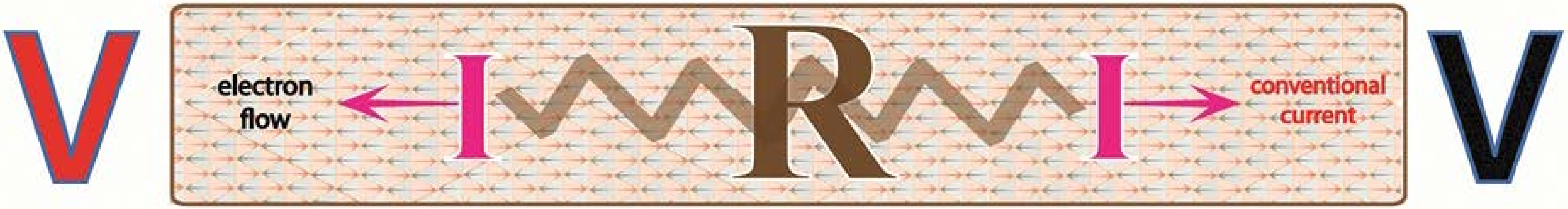

By introducing the constant of proportionality, Resistance, one arrives at the usual mathematical equation that describes this relationship

Voltage is the force motivating charges to "flow" in a circuit, it is measured as the difference in electrical potential between two points in a circuit

Electrical Resistance

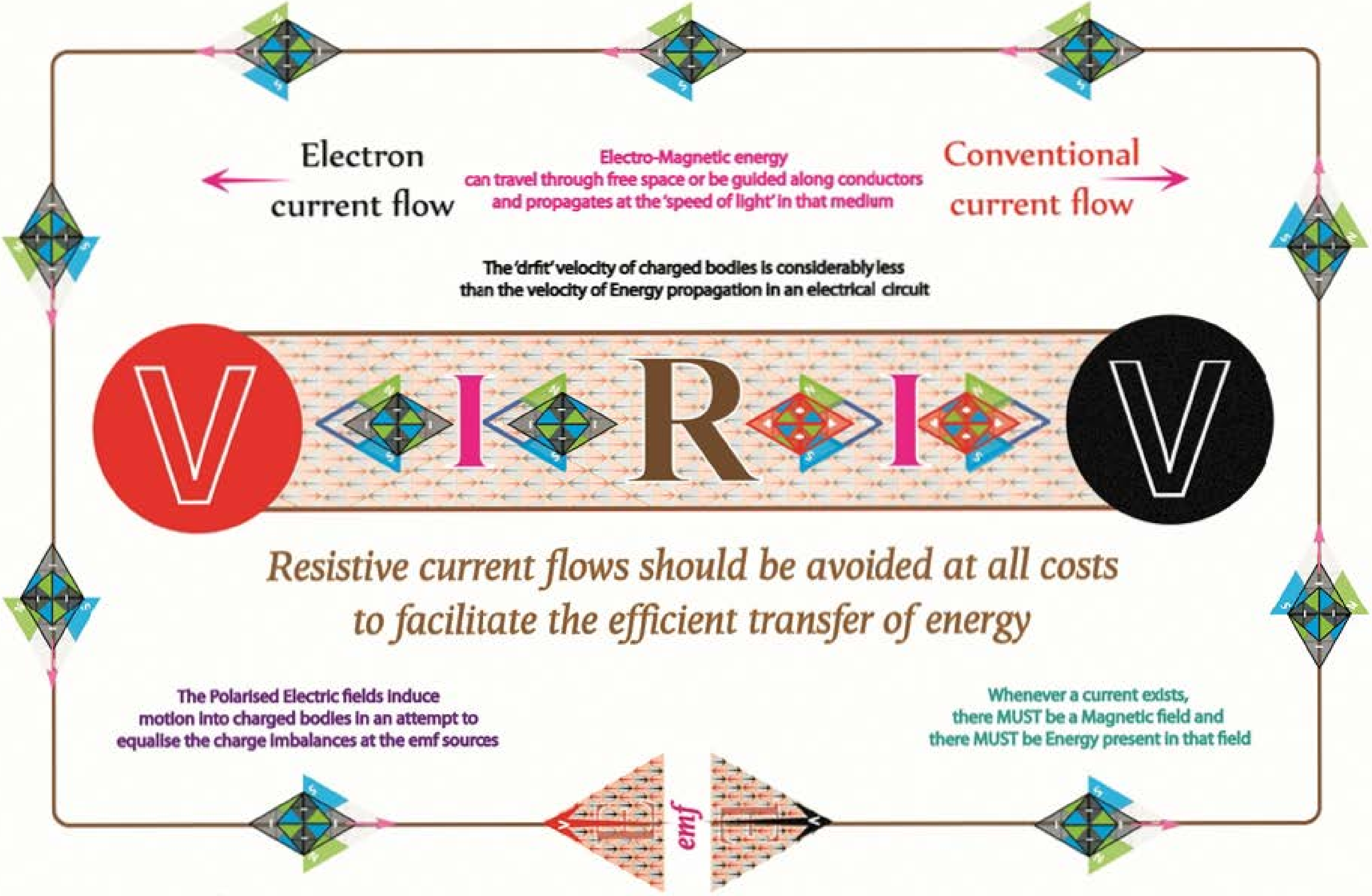

Electron current flow

Electro-Magnetic energy
can travel through free space or be guided along conductors
and propagates at the 'speed of light' in that medium

Conventional current flow

The 'drfit' velocity of charged bodies is considerably less
than the velocity of Energy propagation in an electrical circuit

Resistive current flows should be avoided at all costs
to facilitate the efficient transfer of energy

The Polarised Electric fields induce
motion into charged bodies in an attempt to
equalise the charge imbalances at the emf sources

Whenever a current exists,
there MUST be a Magnetic field and
there MUST be Energy present in that field

The acceleration [change in velocity] of electrons in motion
requires the release [or absorption] of Bosons of energy
from [or to] the equilateral KEM field geometry
[[spectriaaline emission~absorption]

Voltage produces a linear force that motivates
charged Matter topologies into motion in a circuit
as electrical energy geometries seek equilibrium

Power is a measure of the total charge geometry
(electrons) moving past a point along with the energy each
charge geometry (electron) possesses (KE expressed as eV)
$V.I = P = i.R.I$

Tetryonics 23.12 - Resistance

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James Prescott Joule verified Ohm's Law and determined that the heat delivered by a conductor is directly proportional to its resistance and to the square of the current through it.

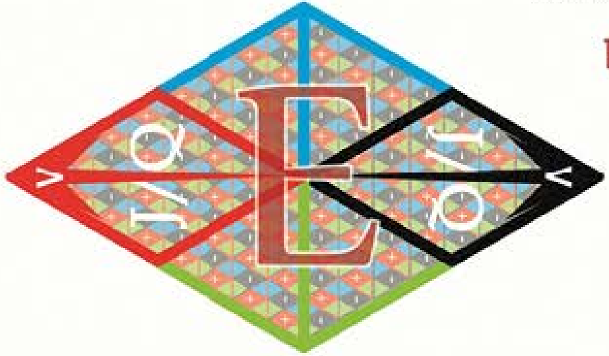

All energy is comprised of 2D charged masses

He defined Power physically to be the rate at which electrical energies are created or transferred in an electric circuit

Electrical Power

Power is the integral of the cross-product of all electrical and magnetic field vectors produced by scalar energy momenta within a specific area defined by time

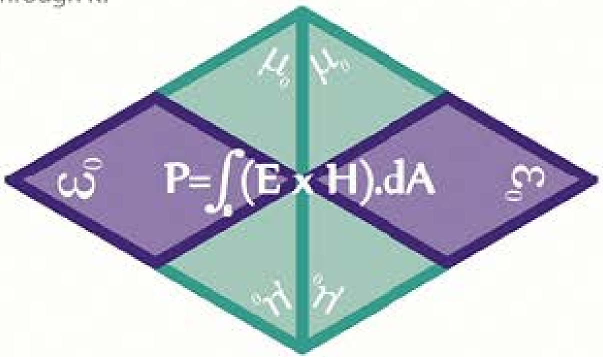
μ_0
μ_0
ε_0
ε_0
$P=\int_s(E \times H).dA$
μ_0
μ_0

The scalar surface integral of the Poynting vector.

The SI unit of power is the watt, one joule per second.

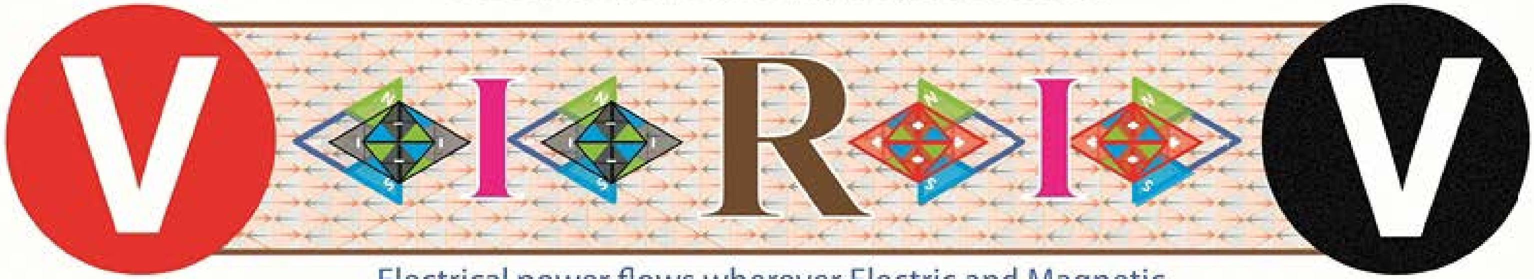

Electrical power flows wherever Electric and Magnetic fields exist together and change over time

emf Voltage

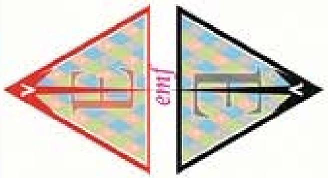

The potential to do work

$$P = V.I$$

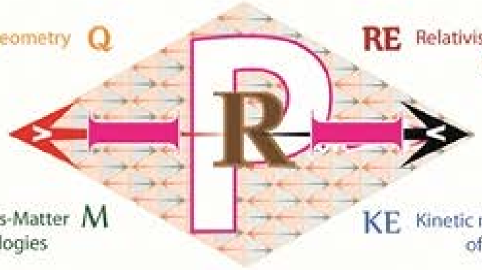
Charge geometry Q
RE Relativistic mass-energies densities
P
R
3D mass-Matter M topologies
KE Kinetic mass-energies of motion

$$I^2.R = \frac{V^2}{R}$$

Resistance

The Inertial mass of Matter

Electrical power propagates at the speed of light in an electrical circuit [dependent on the voltage source] electrons have a vastly slower 'drift' velocity resulting from their inertial interaction with energy momenta of the Voltage [emf] field

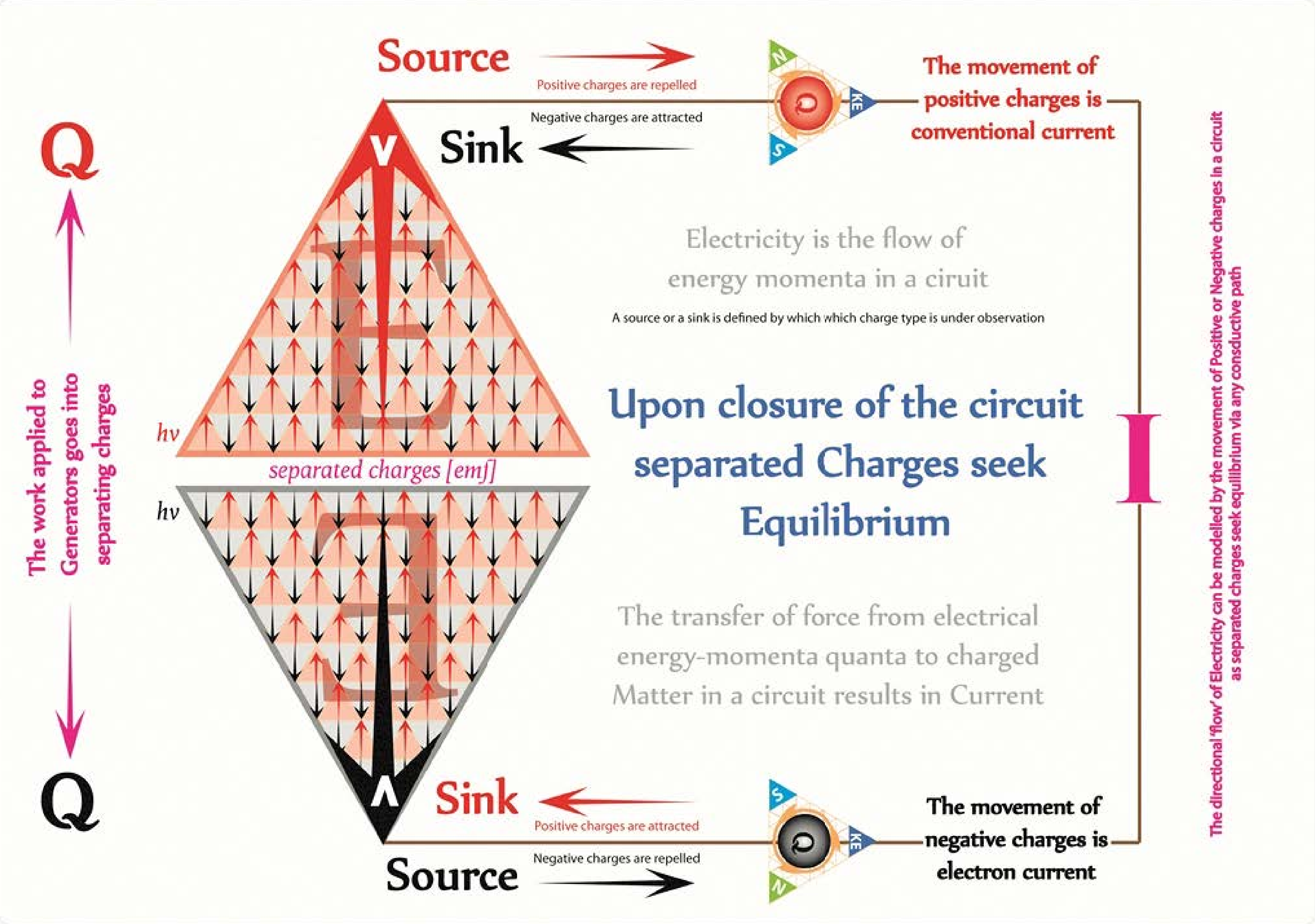

Source

Positive charges are repelled

Negative charges are attracted

Sink

The movement of positive charges is conventional current

Electricity is the flow of energy momenta in a ciruit

A source or a sink is defined by which which charge type is under observation

Upon closure of the circuit separated Charges seek Equilibrium

The transfer of force from electrical energy-momenta quanta to charged Matter in a circuit results in Current

separated charges [emf]

The work applied to Generators goes into separating charges

The directional 'flow' of Electricity can be modelled by the movement of Positive or Negative charges in a circuit as separated charges seek equilibrium via any consductive path

Sink

Positive charges are attracted

Negative charges are repelled

Source

The movement of negative charges is electron current

EM Inductive circuits

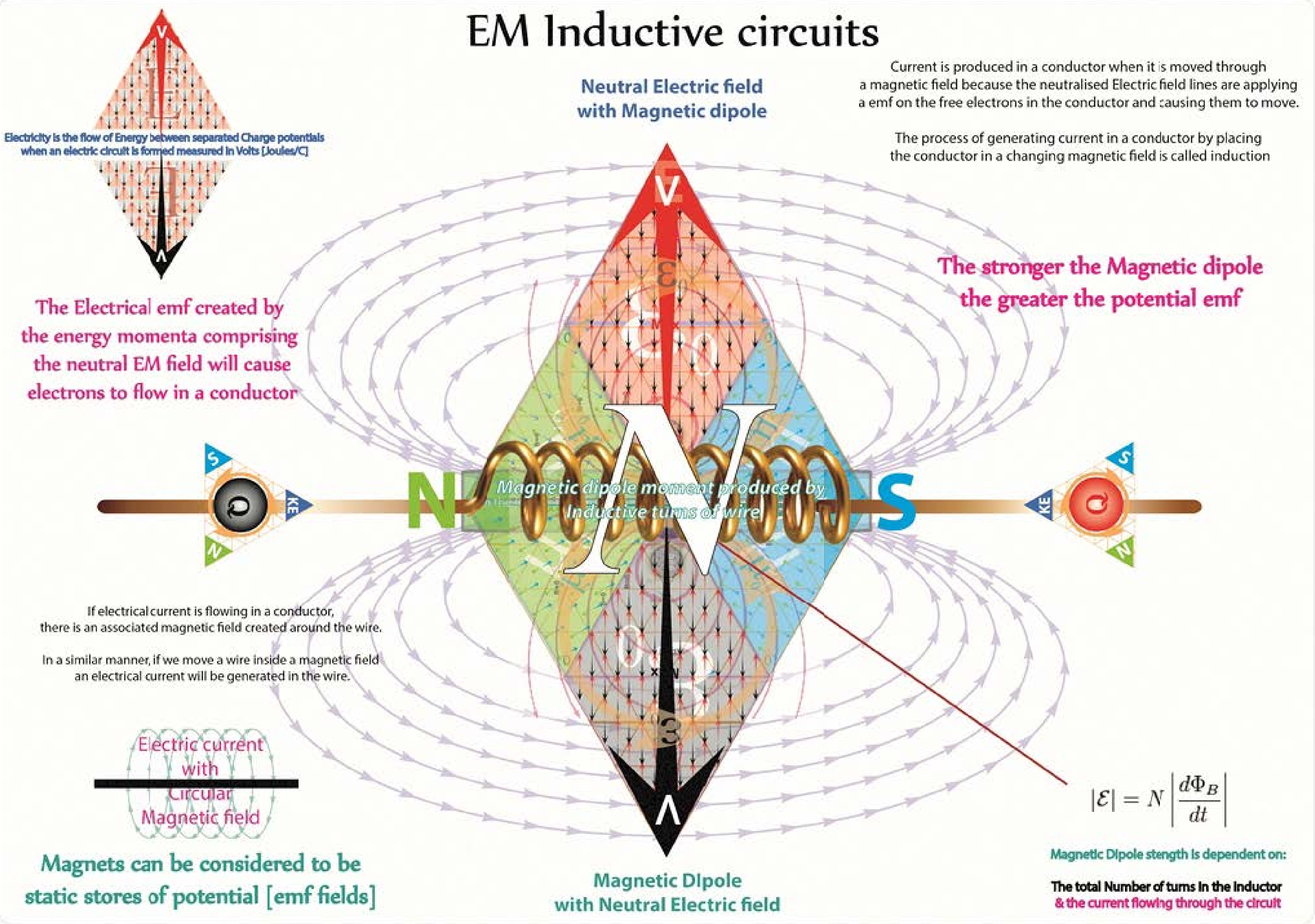

Neutral Electric field with Magnetic dipole

Current is produced in a conductor when it is moved through a magnetic field because the neutralised Electric field lines are applying a emf on the free electrons in the conductor and causing them to move.

The process of generating current in a conductor by placing the conductor in a changing magnetic field is called induction

Electricity is the flow of Energy between separated Charge potentials when an electric circuit is formed measured in Volts [Joules/C]

The Electrical emf created by the energy momenta comprising the neutral EM field will cause electrons to flow in a conductor

The stronger the Magnetic dipole the greater the potential emf

Magnetic dipole moment produced by Inductive turns of wire

If electrical current is flowing in a conductor, there is an associated magnetic field created around the wire.

In a similar manner, if we move a wire inside a magnetic field an electrical current will be generated in the wire.

Electric current with Circular Magnetic field

Magnets can be considered to be static stores of potential [emf fields]

Magnetic Dipole with Neutral Electric field

$$|\mathcal{E}| = N \left| \frac{d\Phi_B}{dt} \right|$$

Magnetic Dipole stength is dependent on:

The total Number of turns in the Inductor
& the current flowing through the circuit

Electron Volts

The electron volt can also be used
as a unit of mass-energy by applying
Einstein's relation $E = mc^2$.

For example, the rest mass-energy of electron
topologies if 496,532 eV (496.532 MeV).

Chemically, for 1 mole of electrons
1 eV ~ 100 kJ mol-1 (96.49 kJ mol-1)

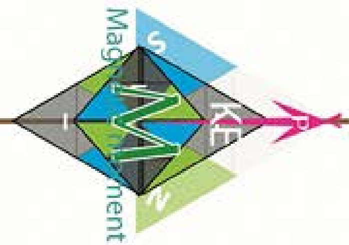
Magnetic moment
S
N
M
KE
P

A Free electron is attracted to
Positive anode of an emf source

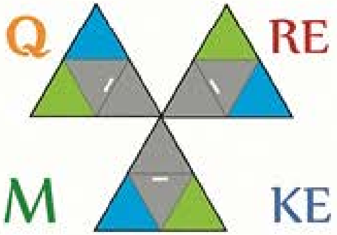

$$\underset{\text{Fermions}}{12\pi}\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{[\varepsilon_0\mu_0]}}.\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]$$

eV

A unit of energy
equal to the work required to move
one electron through a potential
difference of 1 volt.

hv **+** **Separated Charges produce electro-motive forces [emf]** **-** *hv*

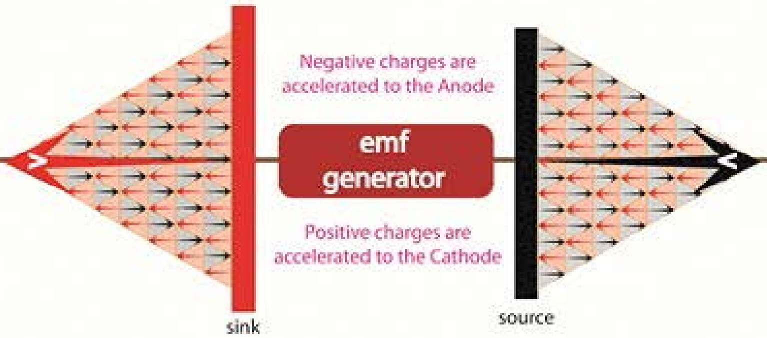
Negative charges are accelerated to the Anode
emf generator
Positive charges are accelerated to the Cathode
sink
source

The application of UFE to Kinetic energy
calculations reveals the underlying processes
of the Photo-electric effect and
Light-Energy interactions
with respect to Kinetic energy

$$\frac{p^2}{2m} = KE = \frac{1}{2}Mv^2$$

By definition, it is equal to the amount of
kinetic energy momenta
gained by a single unbound electron
when it accelerates through an
electric potential difference of one volt.

An Electron Volt is also
a measure of Electrical Kinetic Energy

$$\frac{1}{2}\left[\underset{\text{Tetryons}}{4\pi}\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{[\varepsilon_0\mu_0]}}.\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]\right]$$

As distinct from Matter's ENERGY
Kinetic Energy is 'extended from the
Tetryonic geometry of all Matter in motion
in a separate 2D KEM field

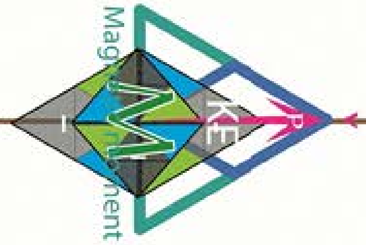
Magnetic moment
M
KE
P

Accelerated electrons have increased
KE, Magnetic moments & momentum

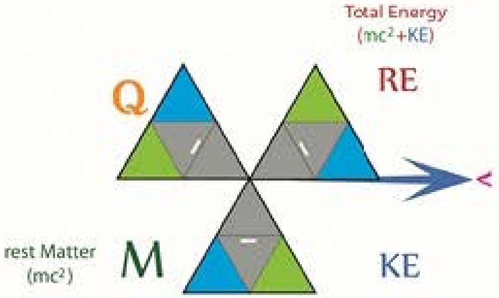
Total Energy
(mc²+KE)
Q
RE
rest Matter
(mc²)
M
KE

(Total Energy = Absolute rest Matter + Kinetic energy)
additionally the Lorentz relativistic correction factor (β)
presents itself naturally from the UFE when velocity is applied

All electro-statically charged
particles in Motion have
Kinetic EM fields

Direct Currents result in atttractive co-linear Magnetic fields

KEM fields facilitate
EM interactions between
charges in motion

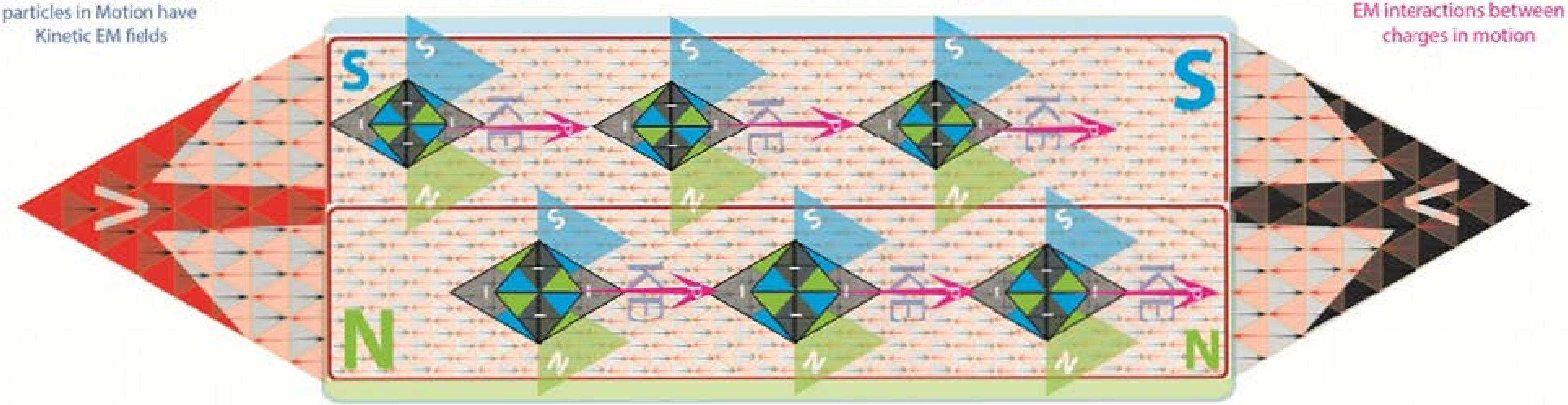

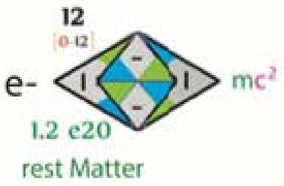

The Skin Effect

Skin effect is the tendency of an alternating electric current (AC) to distribute itself within a conductor with the current density being largest near the surface of the conductor, decreasing at greater depths

Total Energy
KE
mc²+ Mv²

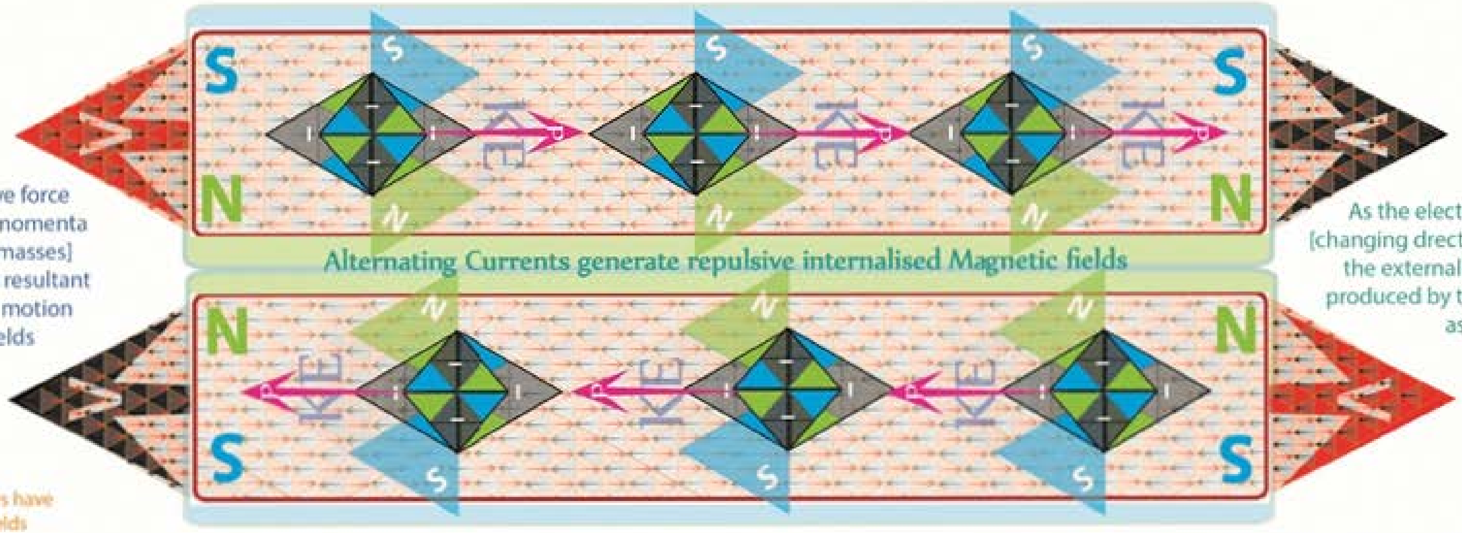

Alternating Currents generate repulsive internalised Magnetic fields

As the electromotove force
[Electric field energy momenta
driving the charged masses]
alternates so does the resultant
electron direction of motion
and their KEM fields

As the electric Current alternates
[changing direction of charge movement]
the external Magnetic field vector
produced by the electronic KEM fields
aslo alternate

Stationary Charged particles have
neutralised Magnetic fields

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EM fields of particles in Motion

Positive changed quanta traveling anti-clockwise
in a solonoid creates a North-South magnetic field
orientated in the direction shown

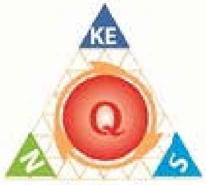

positive ion flow

Negative charged quanta create a
reversed Magnetic dipole field and
reversing the direction of particle motion
also reverses the magnetic vector

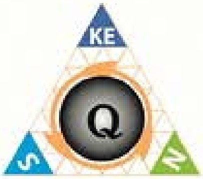

electron flow

Solenoidal Motion

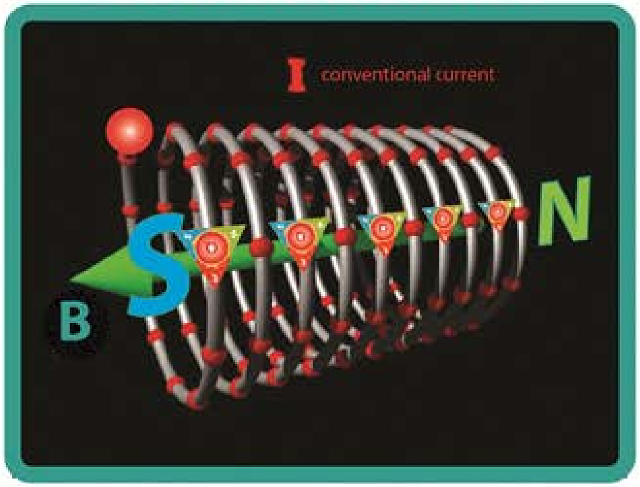

Charged particles moving in a spiral
produce a Circular Magnetic field

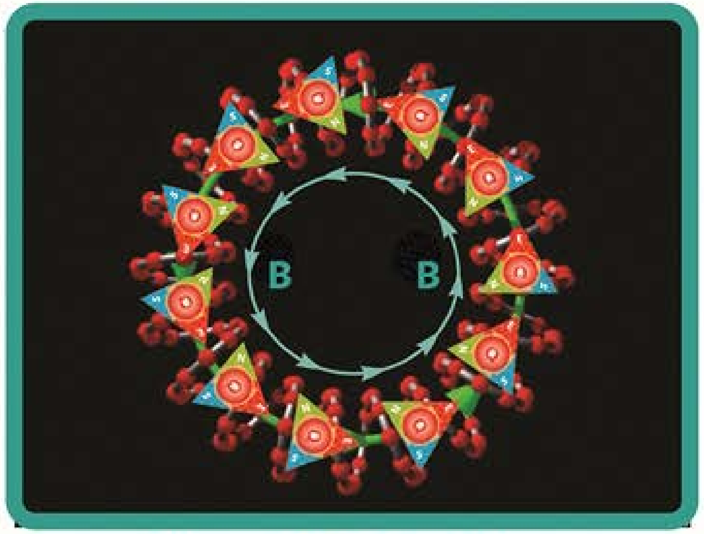

Toroidal Motion

A toroidally wound conductor produces
a Circular Magnetic field

Helical Motion

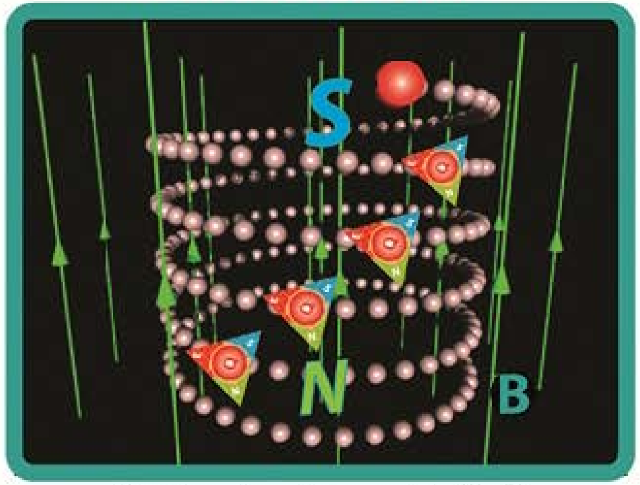

Motion in a Magnetic field

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Inductors

An inductor (also choke, coil, or reactor) is a passive two-terminal electrical component that stores energy in its magnetic field.

For comparison, a capacitor stores energy in an electric field, and a resistor does not store energy but rather dissipates energy as heat

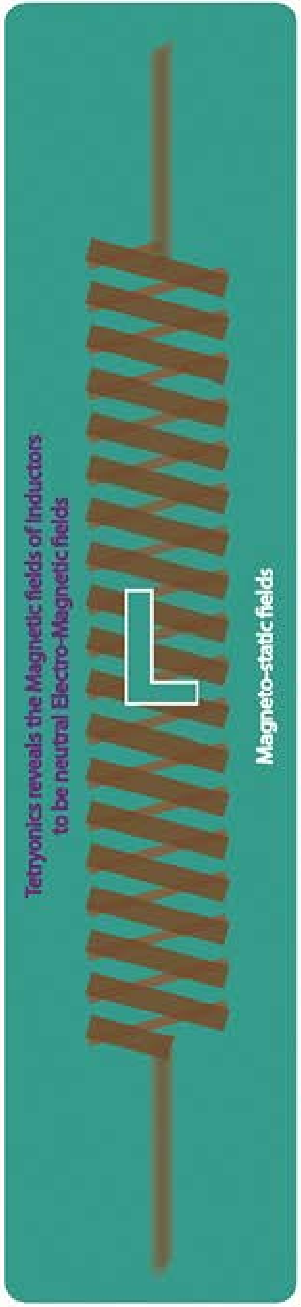

Tetryonics reveals the Magnetic fields of Inductors to be neutral Electro-Magnetic fields

Magneto-static fields

When the current flowing through an inductor changes, a time-varying electromagnetic field is created around the coil, and a changing emf voltage is formed

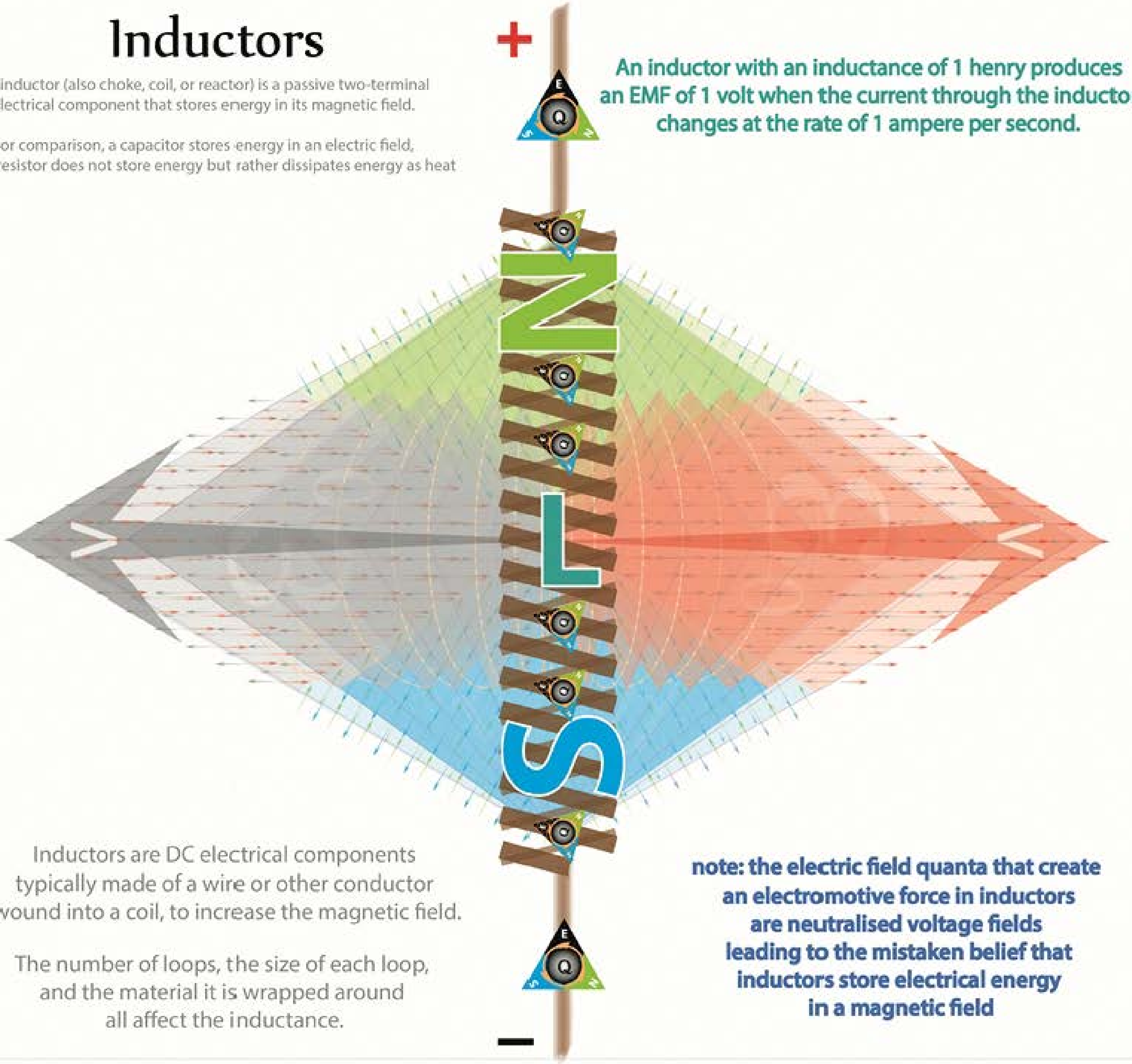

An inductor with an inductance of 1 henry produces an EMF of 1 volt when the current through the inductor changes at the rate of 1 ampere per second.

Inductors are DC electrical components typically made of a wire or other conductor wound into a coil, to increase the magnetic field.

The number of loops, the size of each loop, and the material it is wrapped around all affect the inductance.

note: the electric field quanta that create an electromotive force in inductors are neutralised voltage fields leading to the mistaken belief that inductors store electrical energy in a magnetic field

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Charges moving in an Inductive winding

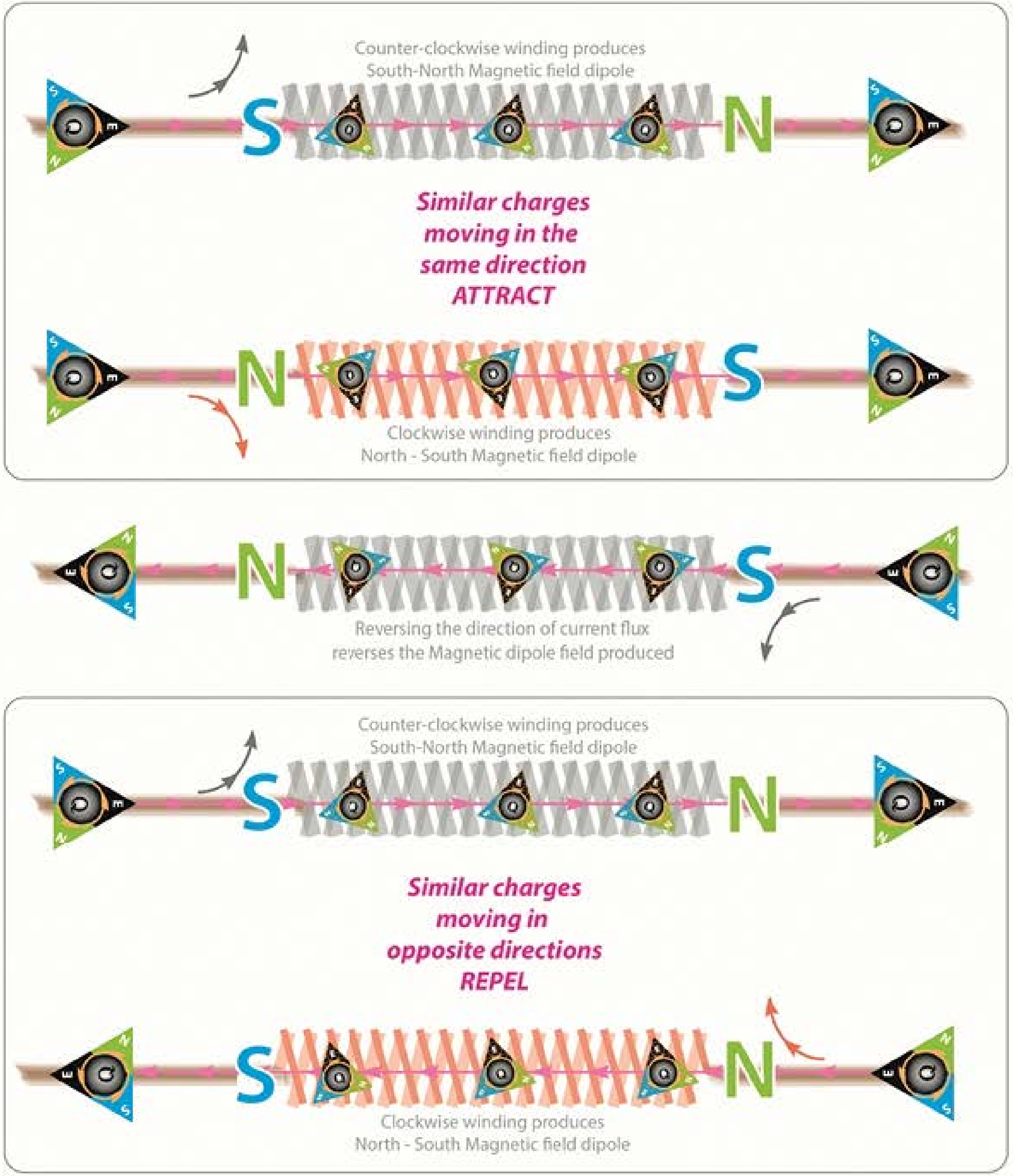

Counter-clockwise winding produces
South-North Magnetic field dipole

Similar charges moving in the same direction ATTRACT

Clockwise winding produces
North - South Magnetic field dipole

Reversing the direction of current flux
reverses the Magnetic dipole field produced

Counter-clockwise winding produces
South-North Magnetic field dipole

Similar charges moving in opposite directions REPEL

Clockwise winding produces
North - South Magnetic field dipole

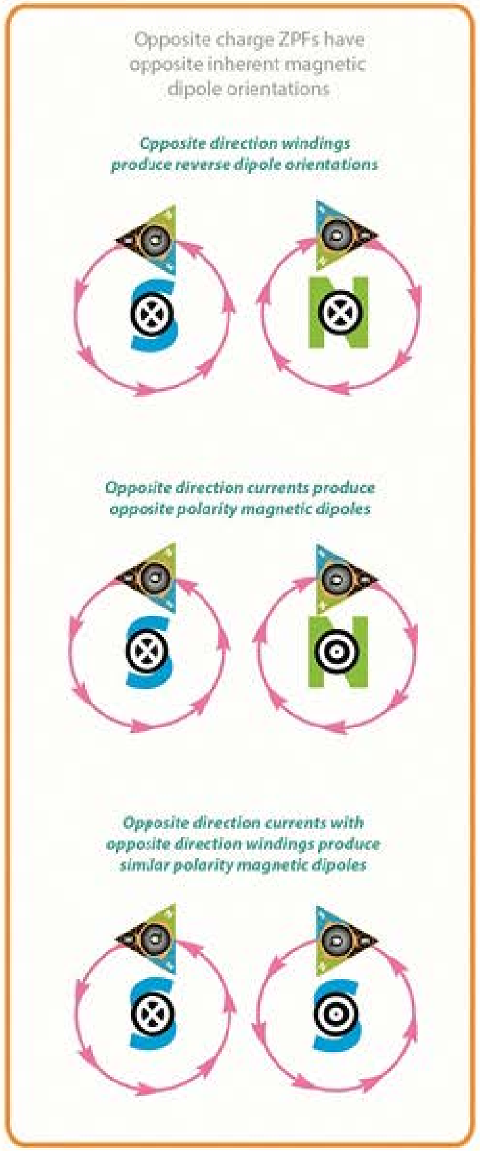

Opposite charge ZPFs have
opposite inherent magnetic
dipole orientations

Opposite direction windings produce reverse dipole orientations

Opposite direction currents produce opposite polarity magnetic dipoles

Opposite direction currents with opposite direction windings produce similar polarity magnetic dipoles

This is best viewed using physical models

Tetryonics 24.07 - Moving charges in an Inductor

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Capacitors

Changing Electric fields
create
changing Magnetic fields

A capacitor is a passive two-terminal AC electrical component used to store alternating electrical energy in an electric field. It blocks the block of direct currents.

Changing Magnetic fields
create
changing Electric fields

Capacitors store & pass electrical energy as charged 2D masses

Capacitors store EM Energy as transverse Bosons

Capacitors store charged masses between their plates

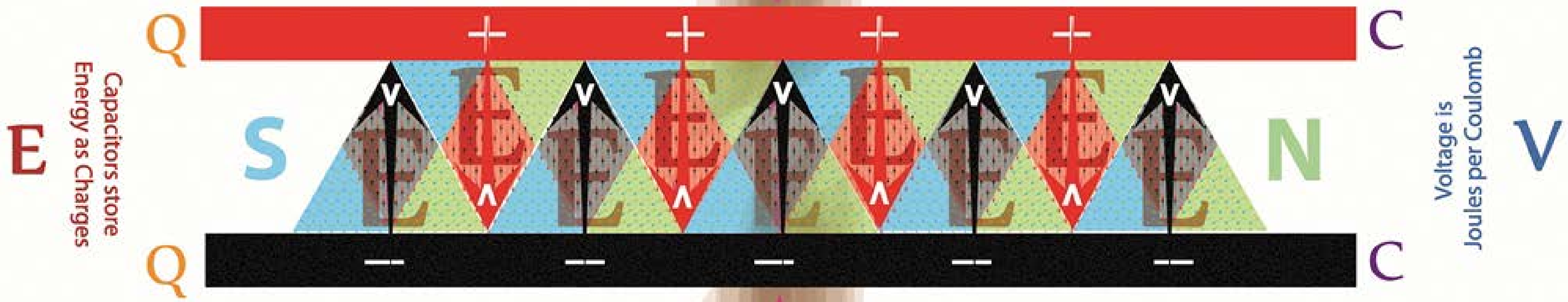
E
Capacitors store Energy as Charges
Q
Q
S
+
+
+
+
V
E
N
C
C
Voltage is Joules per Coulomb
V

Charged Matter [current] does not flow between the plates of a Capacitor

ODD.hv

charge

A common form of energy storage device is a parallel-plate capacitor whose capacitance is directly proportional to the surface area of the conductor plates and inversely proportional to the separation distance between the plates.

volts

hv^2

Capacitance

Capacitance

The SI unit of capacitance is the farad (symbol: F), named after the English physicist Michael Faraday

In general any separated charges will create a emf voltage

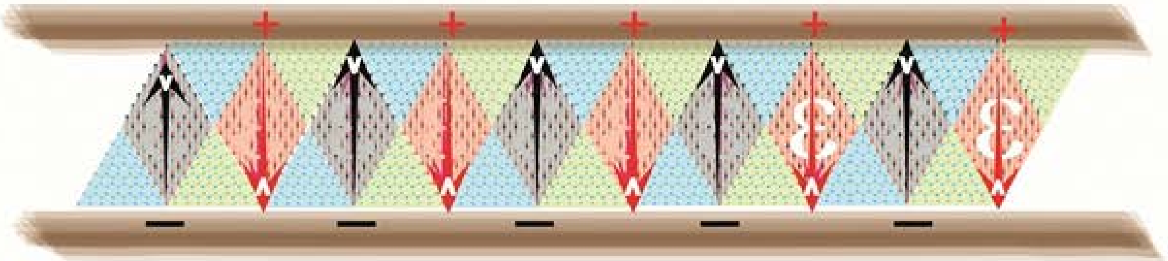

Any two electrical conductors separated by a non-conducting (or very high resistance) medium is a capacitor
[these can be plates, conductive wires or coaxial cables etc]

Plate capacitors

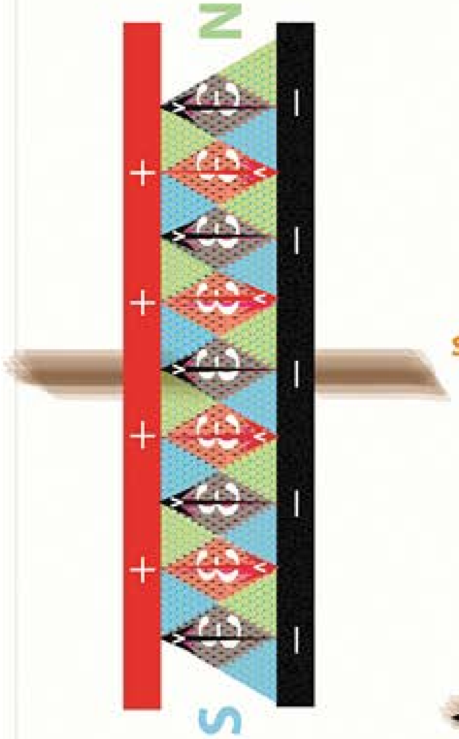

Capacitance is the ability of a body to store an electrical charge.

$$C = \frac{Q}{V}$$

Any object that can be electrically charged exhibits capacitance

Coaxial cables

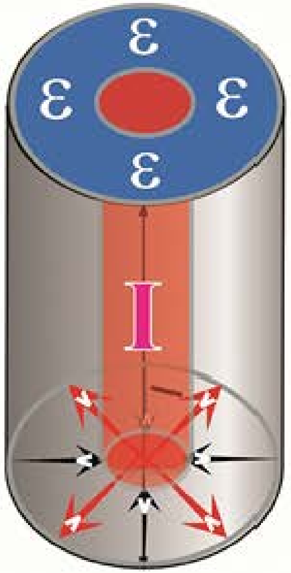

A 1 farad capacitor when charged with1 coulomb of electrical charge will have a potential difference of 1 volt between its plates.

should a current flow in the conductors the capacitive field will be dominated by orthogonal, superpositioned Amperian M-fields of greater strength

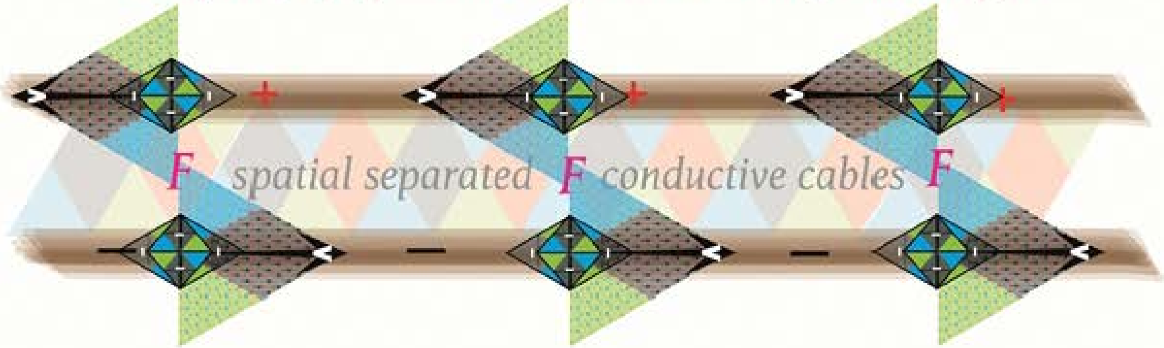

Capacitance is a function only of the physical dimensions (spatial geometry) of conductors and the permittivity of the dielectric separating them

Inductive and Capacitive energy storage

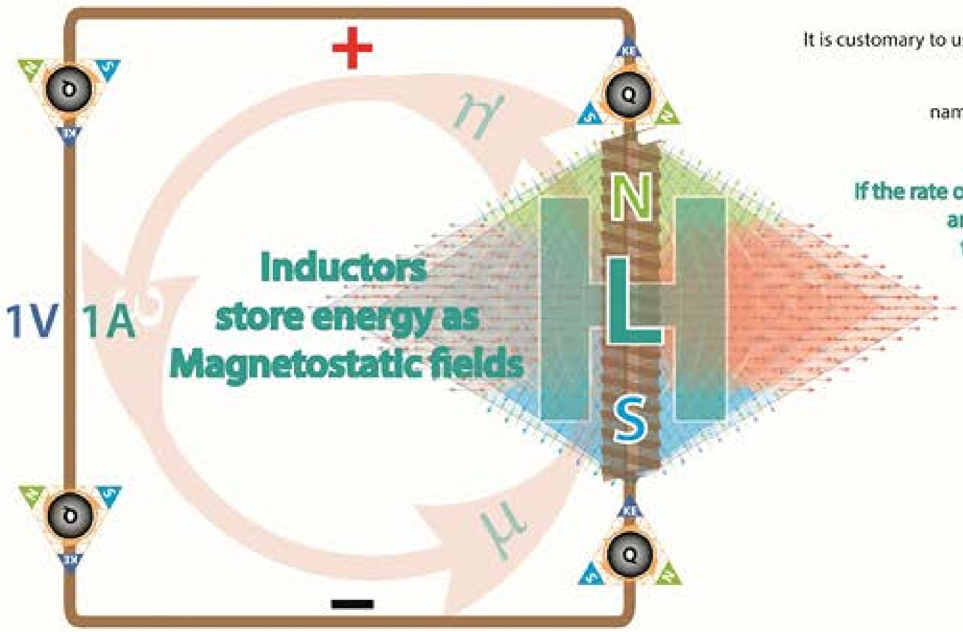

Inductors store energy as Magnetostatic fields

It is customary to use the symbol L for inductance, in honour of the physicist Heinrich Lenz.

In the SI system the unit of inductance is the Henry,
named in honor of the scientist who discovered inductance,
Joseph Henry.

If the rate of change of current in a circuit is one ampere per second and the resulting electromotive force is one volt, then the inductance of the circuit is one henry

$$v_m = \sum_{n=1}^{K} L_{m,n} \frac{di_n}{dt}.$$

The voltage across an inductor
is equal to the product of its
inductance and the time
rate of change of the current through it

Joseph Henry

[17 December 1797 – 13 May 1878]

Michael Faraday

[22 September 1791 – 25 August 1867]

The SI unit of capacitance is the farad (symbol: F),
named after the English physicist Michael Faraday

a 1 farad capacitor when charged with 1 coulomb of electrical charge will have a potential difference of 1 volt between its plates.

$$W_{\text{stored}} = \frac{1}{2}CV^2 = \frac{1}{2}\varepsilon_r\varepsilon_0\frac{A}{d}V^2.$$

Capacitance is the ability of a body to store an electrical charge.
Any object that can be electrically charged exhibits capacitance.

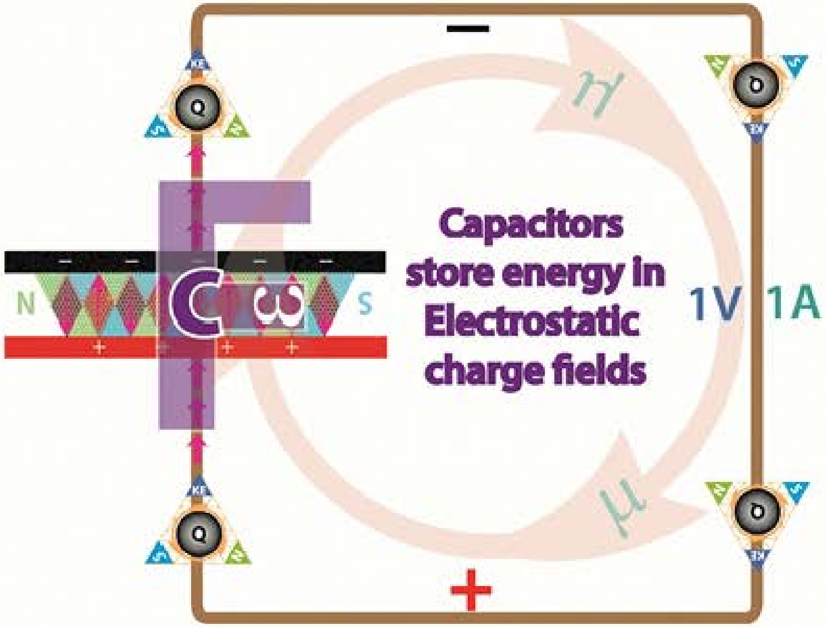

Capacitors store energy in Electrostatic charge fields

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Inductive - Capacitive circuits

An LC circuit, also called a resonant circuit, tank circuit, or tuned circuit,
consists of an inductor, represented by the letter L,
and a capacitor, represented by the letter C.

LC

When connected together, they can act as an electrical resonator,
an electrical analogue of a tuning fork, storing energy
oscillating at the circuit's resonant frequency

These LC circuits are idealised models
assuming there is no dissipation of energy due to resistance over time,
with the circular EM vectors representing electron current flow in the circuit
and its translation between inductive and capacitive forms of energy storage.

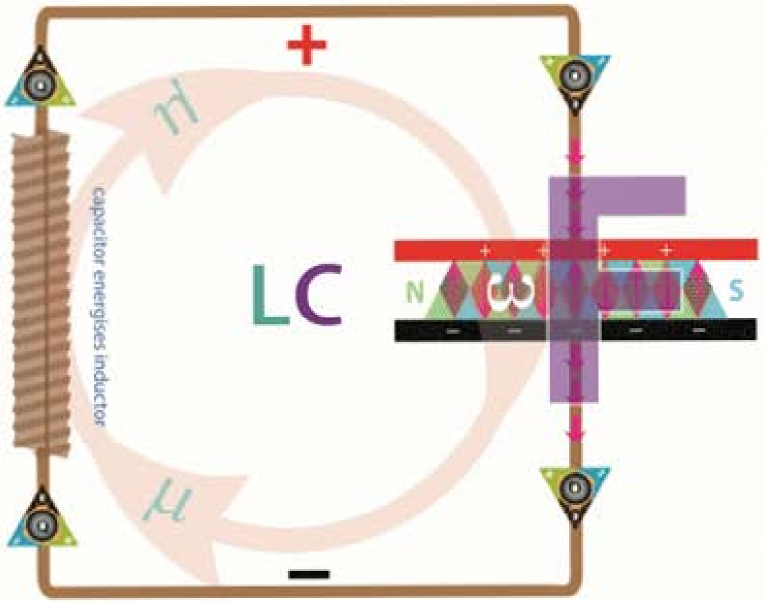

If a charged capacitor is connected across an inductor,
charge will start to flow through the inductor,
building up a magnetic field around it and
reducing the voltage on the capacitor.

Eventually all the charge on the capacitor will be gone
and the voltage across it will reach zero.

However, the current will continue,
because inductors resist changes in current.

The energy to keep it flowing is extracted from the magnetic field,
which will begin to decline.

The current will begin to charge the capacitor
with a voltage of opposite polarity to its original charge.

When the magnetic field is completely dissipated the current will stop
and the charge will again be stored in the capacitor,
with the opposite polarity as before.

Then the cycle will begin again,
with the current flowing in the
opposite direction through the inductor.

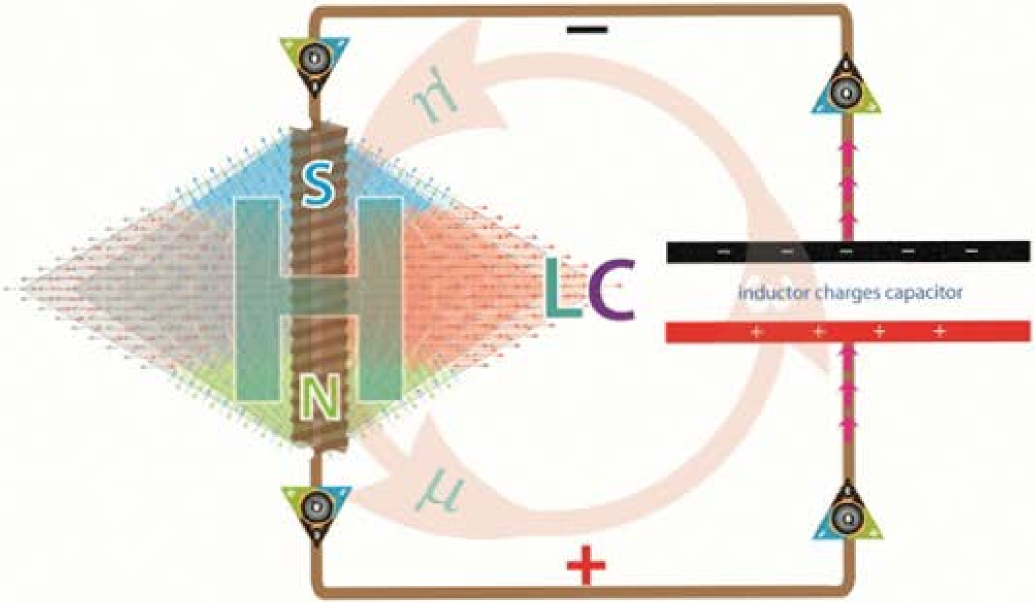

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Capacitors store EM Energy as transverse Bosons

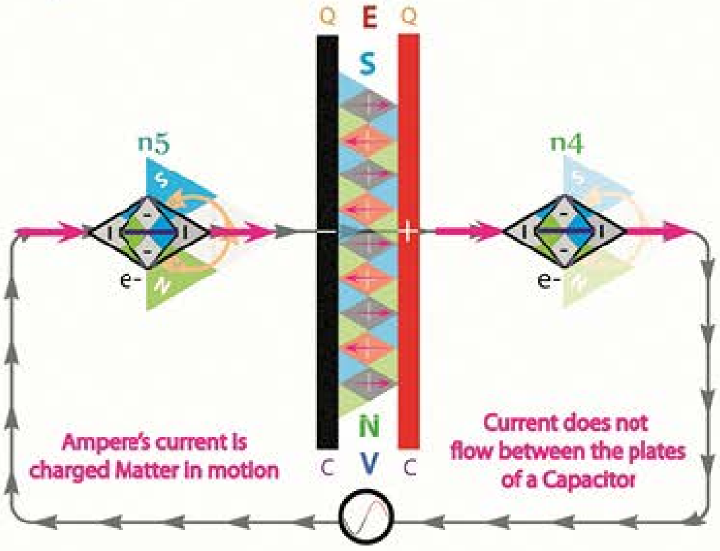

Ampere's current is charged Matter in motion

Current does not flow between the plates of a Capacitor

Capacitors store Energy as Joules per charge

Capacitors store & pass energy as charged masses

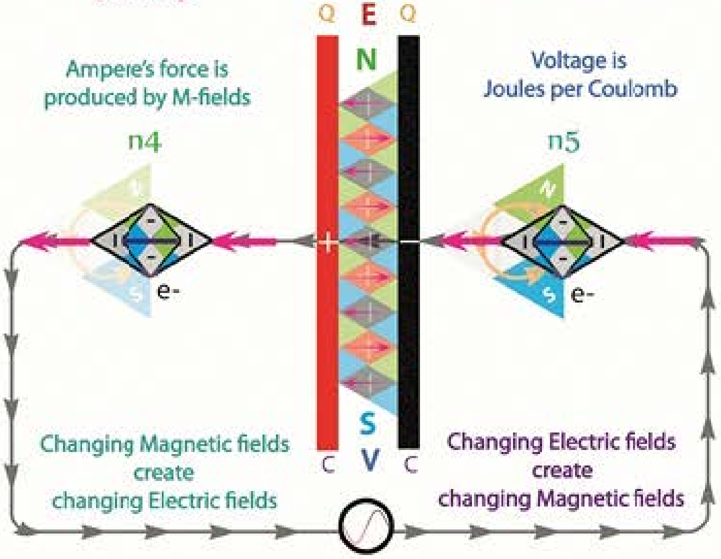

Ampere's force is produced by M-fields

Voltage is Joules per Coulomb

Changing Magnetic fields create changing Electric fields

Changing Electric fields create changing Magnetic fields

Capacitors store charged masses between their plates

Displacement Current

Maxwell's displacement current is better termed a 'displacement voltage' in light of the fact the charged Matter does not move/flow between the charged plates of a capacitor only the charged mass-energies.

Changing Electric fields produce changing Magnetic fields and vice versa as a direct result of their respective E&M field geometries within the Planck quanta of EM fields

$$\nabla \times \mathbf{B} = \epsilon_0 \mu_0 \frac{\partial \mathbf{E}}{\partial t} + \mu_0 \mathbf{J},$$

As opposed to Maxwell's view of a 'stretching ether' that stores energy between the capacitive plates

As the energy content of a charge increases so does its voltage

Equilateral energy momenta is stored compressively in the inductive quantum fields [ZPF] as it increases, and is released via charged exchange W-Bosons

Bosons are transverse stores of energy momenta

Producing a capacitive region of ElectroMagnetic fields and stress energies

$$\mathbf{J}_D = \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

'Displacement Currents' between charged surfaces are produced by a increasing Electric Field component that seeks equilibrium

> *It must be carefully borne in mind that we have made only one step in the theory of the action of the medium. We have supposed it to be in a state of stress, but we have not in any way accounted for this stress, or explained how it is maintained. This step, however, seems to me to be an important one, as it explains, by the action of the consecutive parts of the medium, phenomena which were formerly supposed to be explicable only by direct action at a distance.*
>
> *Maxwell - On Physical Lines of Force (1861)*

$mc^2 = E = Mc^4$

A clear geometric distinction can now be made between **EM mass geometries** and standing wave **Matter topologies**

mass

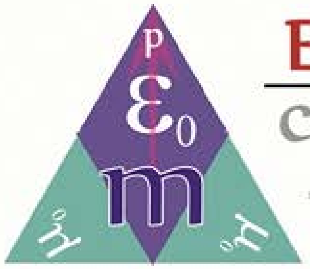

$$\frac{E}{c^2} = m$$

mass-energy momenta in a 2D equilateral geometry

Radiant waveform
EM mass-energies

Matter

$$M = \frac{E}{c^4}$$

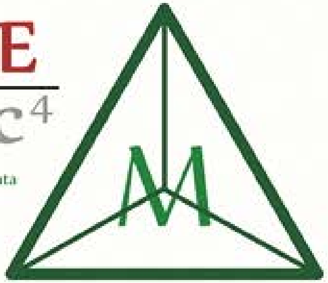

Four mass-energy momenta in a 3D tetrahedral topology

Standing waveform
EM energies

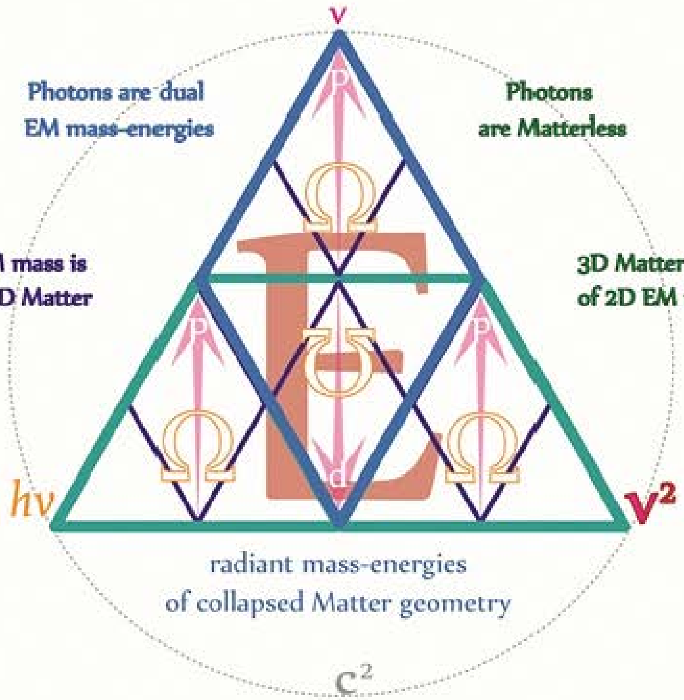

Photons are dual EM mass-energies

Photons are Matterless

2D EM mass is NOT 3D Matter

3D Matter is comprised of 2D EM mass-energies

radiant mass-energies
of collapsed Matter geometry

$$\underset{\text{mass}}{n\pi}\left[\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{\varepsilon_0\mu_0}}\right].\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]$$

$$\underset{\text{Matter}}{T\pi}\left[\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{\varepsilon_0\mu_0}}\right].\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]$$

ρ/second

ρ/second^2

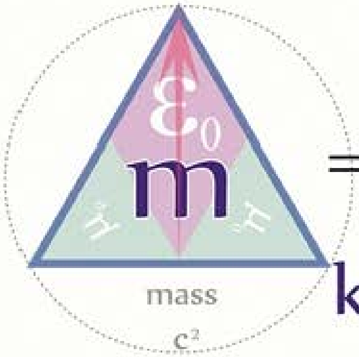

$$= m\Omega\left[\frac{v^2}{c^2}\right]$$

kg

Radiant EM masses

$$\frac{4\pi m}{c^2} = M$$

Standing-wave mass-Matter

$$m\Omega\left[\frac{v^2}{c^4}\right] =$$

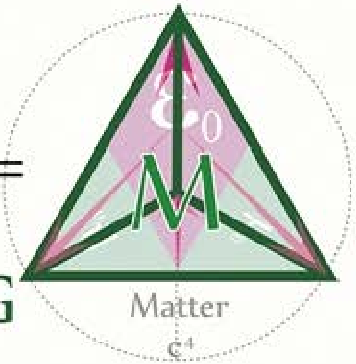

KG

massless particles are a scientific misnomer
and massless must now be re-termed Matterless

de Broglie Matter-waves

EM CHARGE
provides the foundational
interaction geometry for
all mass & Matter

In quantum mechanics, a Matter wave or de Broglie wave is the probabilistic electromagnetic quantum wave-form created by the Planck elements constituting Matter

Relativistic mass-energy is the total sum of all Planck energy momenta in any spatial co-ordinate system

Q

Charged
Planck quanta

RE

M+KE

Relativistic
mass-energies

hv

hv^2

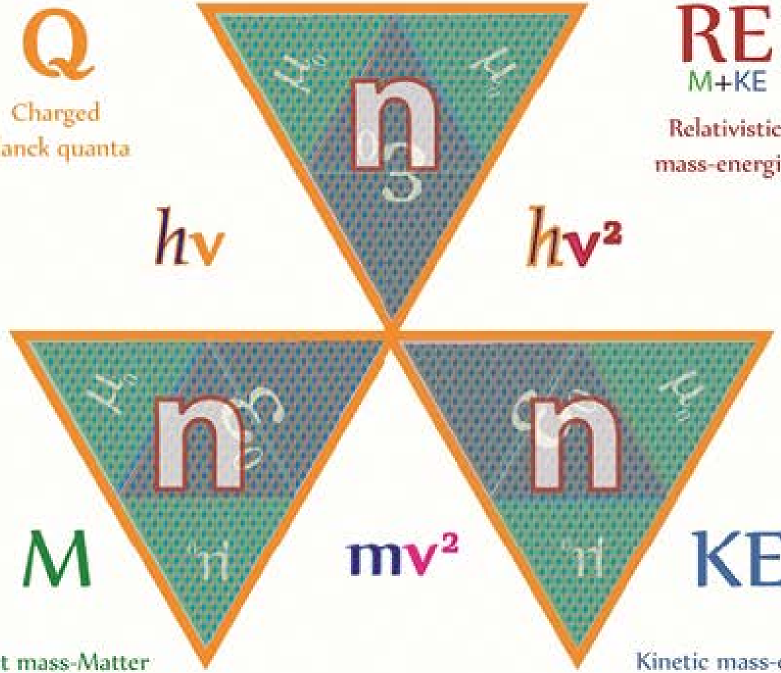

All EM waves and Matter are made up of integral Planck quanta [any imbalance results in Charge] as the number of Planck quanta increases their associated wavelengths decrease

The relativistic stress tensor mass-energies of Matter in motion is the sum of its standing-wave mass-Matter topology and its Lorentz corrected kEM field mass-energy geometries

M

rest mass-Matter
topologies

mv^2

KE

Kinetic mass-energy
geometries

3D MATTER
is the charged topology
created by standing-waves
of 2D mass-energies

Kinetic EM mass-energy levels depend on the velocity of the Matter particle in motion
[in Matter energy travels in a standing wave at the speed of Light]

Kinetic EM fields
are the mass-energy
fields created by
Matter in motion

P
KE
N
S
magnetic moment

The rest mass-energy geometries comprising all Matter topologies are velocity invariant

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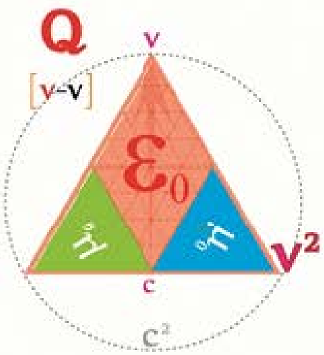

Material EM masses

deBroglie wavelength & Compton frequency

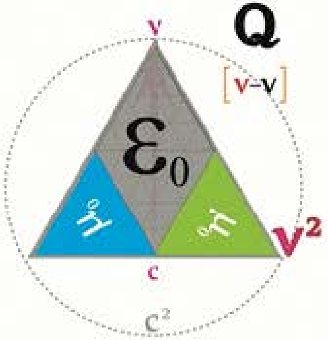

λ

Any increase in Energy quanta results in
a decrease in EM mass quanta wavelengths

v^2

In Matter all energy propagates at c

$$mv^2 = E = hv^2$$

in Standing wave Matter
$v=c$

Number of Quanta comprising rest Matter

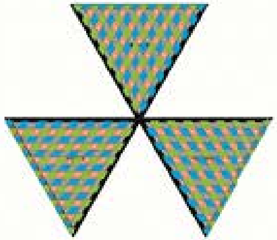

Compton Frequency

$$\frac{mc^2}{h} = 1 \times 10^{19}$$

Electron Compton Frequency

$= 1.2 \times 10^{20}$ quanta

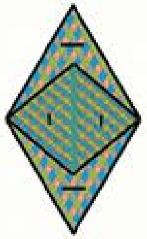

v^2

Wavelength of Quanta comprising rest Matter

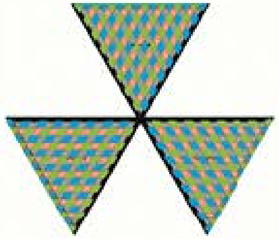

de Broglie wavelength

$$\frac{h}{mc} = 2.99792456 \times 10^{-33} \text{ m}$$

Electron de Broglie wavelength

$= 4.002769142 \times 10^{-11}$ m

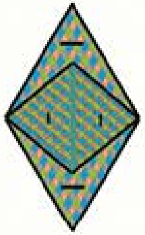

λ

Linear momentum of standing wave Energy comprising Matter

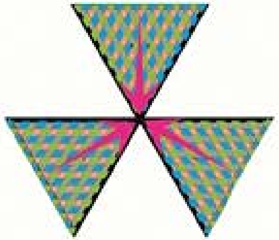

Intrinsic Particle Momenta

$$mc = 2.211340633 \times 10^{-23} \text{ Ns}$$

Intrinsic Electron momenta

$= 2.95253793 \times 10^{-30}$ Ns

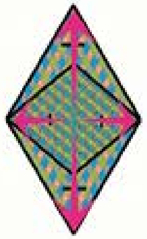

p

The Compton frequency, deBroglie wavelength
and Energy momenta of any physical system
are all related through the speed of Energy [c]

**The examples above are for stationary Electrons
any motion will NOT affect the results for the electron itself
(however a extended KEM field will be produced by the motion
and its properties will be affected by changes in velocity)**

In Lorentz invariant Matter the standing wave
Energy always propagates at the speed of Light [c]
(with the KEM field subject to Lorentz corrections)

KEM Quantum levels

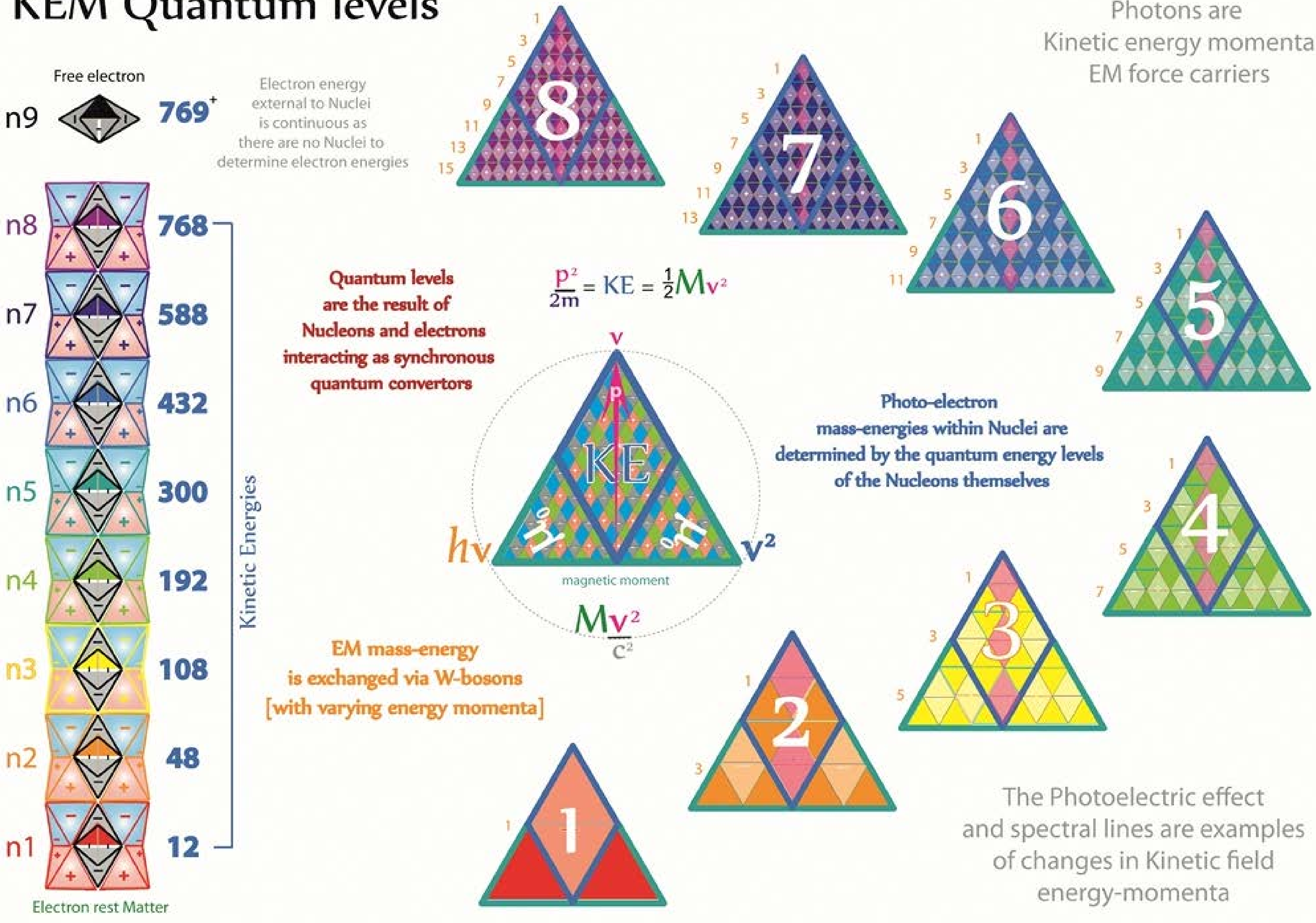
Free electron
n9
769⁺
n8
768
n7
588
n6
432
n5
300
n4
192
n3
108
n2
48
n1
12
Kinetic Energies
Electron rest Matter
8
7
6
5
4
3
2
1
v
p
KE
hv
hv
v²
magnetic moment

Electron energy
external to Nuclei
is continuous as
there are no Nuclei to
determine electron energies

Photons are
Kinetic energy momenta
EM force carriers

Quantum levels
are the result of
Nucleons and electrons
interacting as synchronous
quantum convertors

$$\frac{p^2}{2m} = KE = \frac{1}{2}Mv^2$$

$$\frac{Mv^2}{c^2}$$

Photo-electron
mass-energies within Nuclei are
determined by the quantum energy levels
of the Nucleons themselves

EM mass-energy
is exchanged via W-bosons
[with varying energy momenta]

The Photoelectric effect
and spectral lines are examples
of changes in Kinetic field
energy-momenta

deBroglie relationships

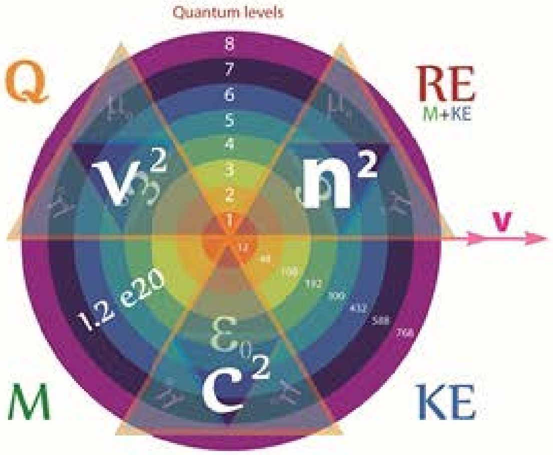
Quantum levels
8
7
6
5
4
3
2
1
Q
RE
M+KE
v²
n²
v
1.2 e20
ε₀
c²
M
KE

rest mass-Matter is velocity invariant

*" The electron which is moving in a sine wave circular path,
will repeat the same sine wave path in each successive orbit.
The sine wave paths in consecutive orbits will exactly overlap.
The electron wave reconnects with itself and is in phase with itself. "*

An electron bound in a atomic nuclei will trace
a toroidal path around the nuclei mapped
by the sine wave motion of any point
on its charged geometric surface

$$\lambda = \frac{h}{p}$$

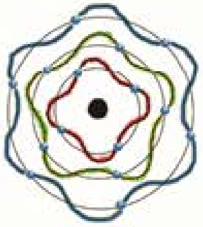

$$f = \frac{E}{h}$$

Louis de Broglie

(15 August 1892 – 19 March 1987)

***The relativistic energy of Matter in motion
is a measure of its standing wave mass-energies,
and the object's velocity related kinetic energy and
magnetic moment in the form of a KEM wave geometry***

$$p = \frac{h}{\lambda} = \frac{h}{2\pi}\frac{2\pi}{\lambda} = \hbar k$$

Although Mathematically correct
the illustrative model commonly used to
depict the deBroglie relationships
is incorrect

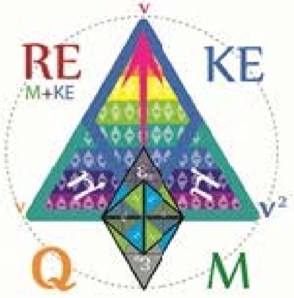
v
RE
M+KE
KE
v
v²
Q
M

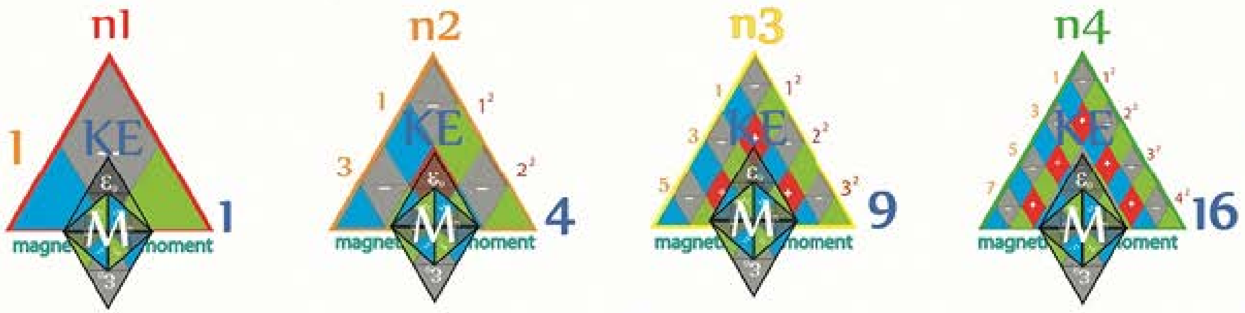
n1
1
KE
1
magnetic moment
M
n2
KE
4
magnetic moment
M
n3
KE
9
magnetic moment
M
n4
KE
16
magnetic moment
M

**The greater the
KEM field energy level
the smaller the
quantum wavelength
of the KEM field's EM mass**

**All mass-Matter topologies are
Lorentz velocity invariant,
only the EM mass-energy content
and quantised angular momentum
of the Kinetic EM fields vary**

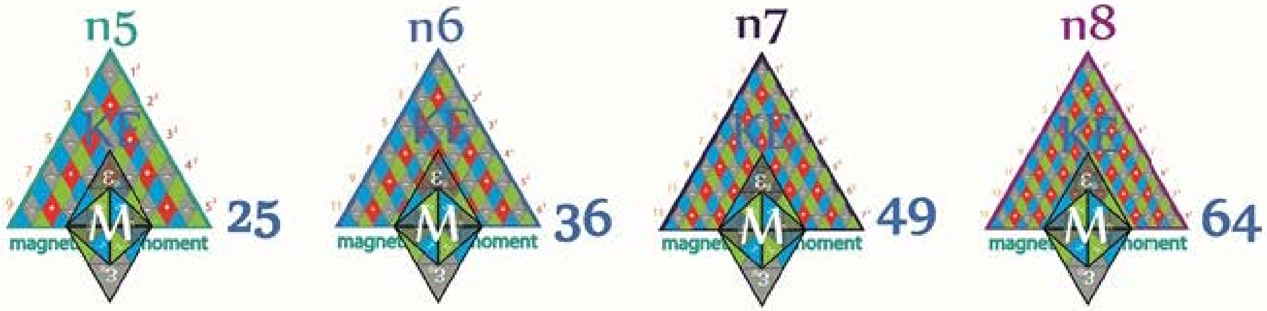
n5
KE
25
magnetic moment
M
n6
KE
36
magnetic moment
M
n7
KE
49
magnetic moment
M
n8
KE
64
magnetic moment
M

Electron Positions in Atomic Orbitals

Werner Heisenberg

(5 December 1901 – 1 February 1976)

Atomic orbitals are typically described as "hydrogen-like" (meaning one-electron) wave functions over space, categorized by n, l, and m quantum numbers, [as covered in Tetryonic Chemistry] which correspond to the electron's energy, angular momentum, and an angular momentum vector component, respectively

Using Tetryonics as a EM field model, an electron's position and velocity CAN be modelled simultaneously (but any attempt to measure or interact with it, will affect its energy levels)

Quantum Mechanics is a statistical [mathematical] representation of equilateral, charged geometries and EM energy interactions

Erwin Schrödinger

(12 August 1887 – 4 January 1961)

The unique 12 facet topology of Leptons results in the same geometry being presented every 120° rotation of the particle

Leacing to the interpretation that the Lepton disappears and re-appears when being measured

Making accurate measurement of its rotational dynamics incorrect without correct models

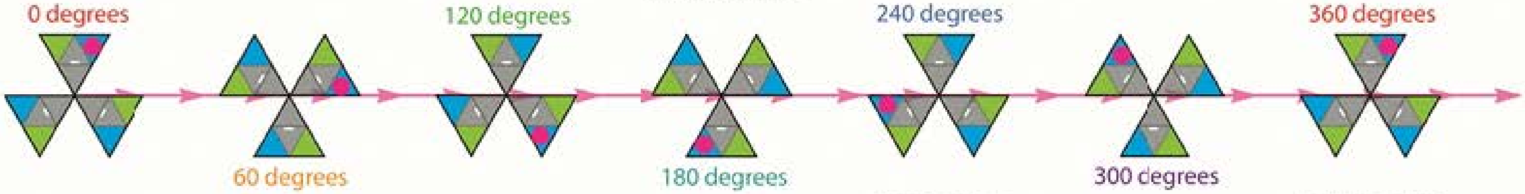

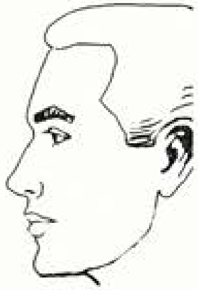

Additionally, every radial arm of the Lepton's topology is identical to every other

Including Electric fields and Magnetic dipole orientations

Tetryonics resolves these issues with an accurate 3D model of Leptons

And Quantum Levels thus providing a solid foundation for explaining Electro-Dynamics

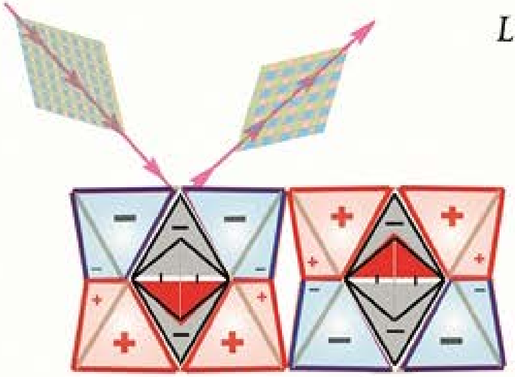

Leptons are 6 loop quantum loop inductive rotors

Lepton's are Spin 1 particles that can easily be misinterpreted as 1/2 or 3 quantum spin numbers without the correct physical models to interpret physcical observations on

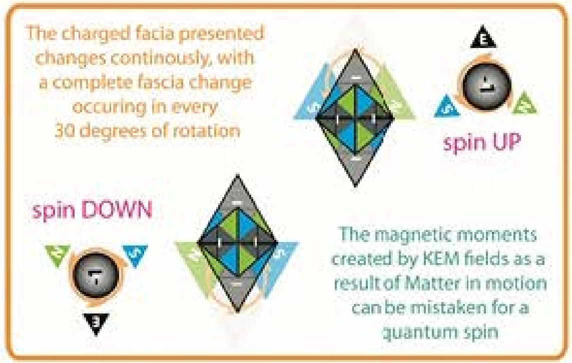

The charged facia presented changes continously, with a complete fascia change occuring in every 30 degrees of rotation

The magnetic moments created by KEM fields as a result of Matter in motion can be mistaken for a quantum spin

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Probabilities are the square of the Amplitude

Distributions and Uncertainty

A Bell Curve (Normal Distribution) is a mathematical reflection of the integral Planck mass-energy momenta quanta distributions found in all equilateral charge geometries

All probabilities are re-normalisable and sum to Unity

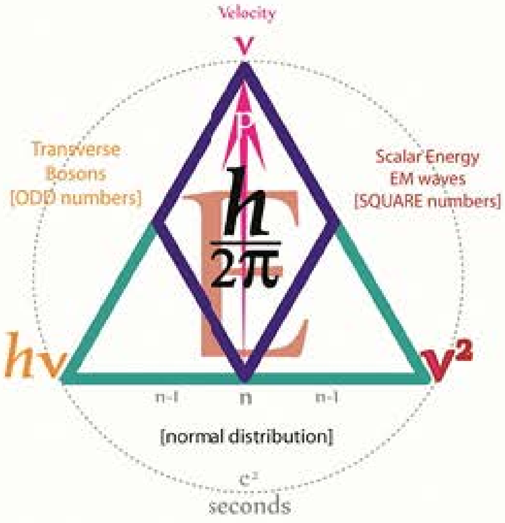
Velocity
v
Transverse
Bosons
[ODD numbers]
Scalar Energy
EM waves
[SQUARE numbers]
$\frac{h}{2\pi}$
E
hv
v²
n-1
n
n-1
[normal distribution]
c²
seconds

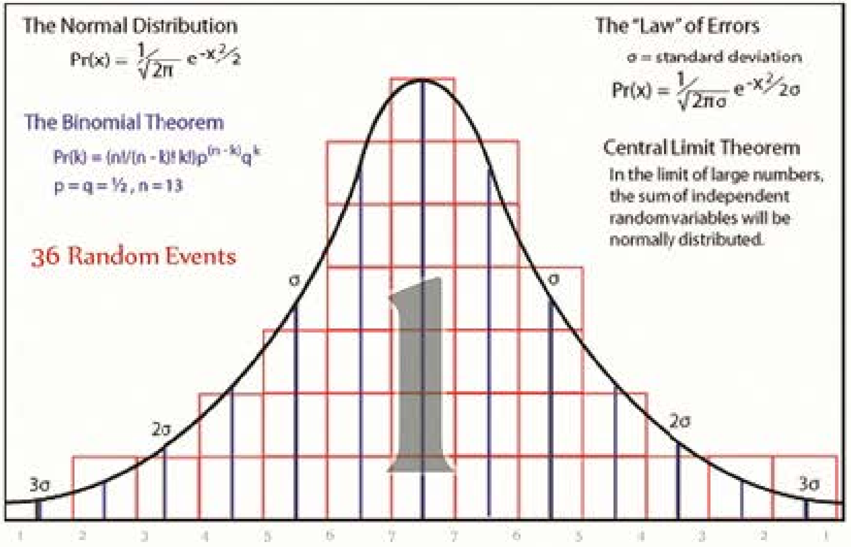
The Normal Distribution

$$\Pr(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2}$$

The Binomial Theorem

$\Pr(k) = (n!/(n-k)!\,k!)p^{(n-k)}q^{k}$

$p = q = ½, n = 13$

36 Random Events

The "Law" of Errors

σ = standard deviation

$$\Pr(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-x^2/2\sigma}$$

Central Limit Theorem

In the limit of large numbers, the sum of independent random variables will be normally distributed.

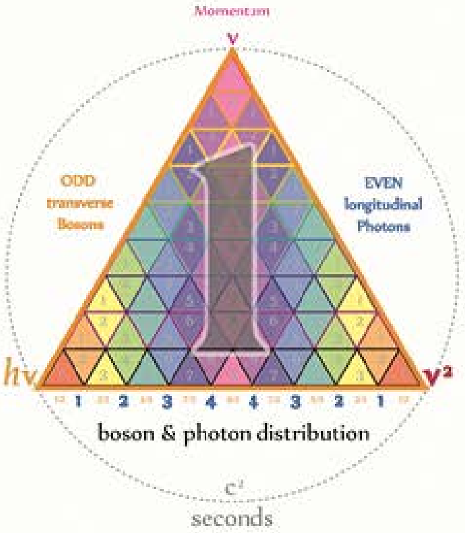
Momentum
v
ODD
transverse
Bosons
EVEN
longitudinal
Photons
1
hv
v²
1 2 3 4 4 3 2 1
boson & photon distribution
c²
seconds

All Matter and EM fields are comprised of equilateral mass-energy momenta and any attempt to measure the system involves the introduction of additional Planck EM quanta into the systems

John Stewart Bell

(28 June 1928 – 1 October 1990)

No physical theory of local hidden variables can reproduce all of the predictions of quantum mechanics.

WRONG

$$\Delta p\, \Delta x \geq \frac{1}{2}\hbar$$

Quantum uncertainty formulation

$$\Delta E\, \Delta t \geq \frac{1}{2}\hbar$$

The more precisely the position is determined, the less precisely the momentum is known in this instant, and vice versa.

Heisenberg, uncertainty paper, 1927

WRONG

Werner Heisenberg

(5 December 1901 – 1 February 1976)

Chance is closely related to the ideas of uncertainty and indeterminacy.
Uncertainty today is best known from Werner Heisenberg's principle in quantum mechanics.
It states that the exact position and momentum of an atomic particle can only be known within certain limits.
The product of the position error and the momentum error is equal to a multiple of Planck's constant of action.
This irreducible randomness in physical processes established the existence of chance and indeterminism in physics

Leptronic Self-energies

As the velocity of a charged particle increases
the energy level of its KEM field increases

Energy
KEM field
$$\frac{4n\pi}{c^2}\left[\left[m\Omega v^2\right]\right]$$
Planck quanta
mass velocity
momenta

mass

radiant energy per second

$$E/c^2$$

KEM field geometries generated as a product of Matter in motion are Lorentz variant

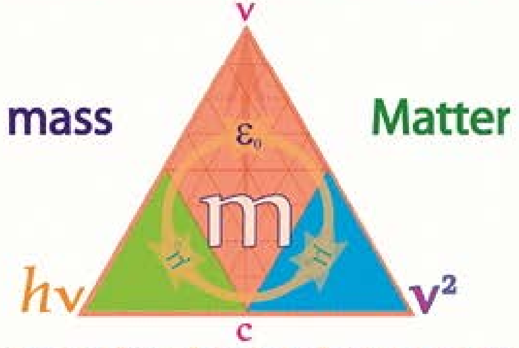

v
mass
Matter
ε_0
m
hv
v^2
c

Quantum inductive loops resist changes to energies contained in their equilateral energy fields [inertial mass]

Energy
Matter
$$\frac{4n\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$
Planck quanta
mass velocity
momenta

Matter

standing-wave energy per second squared

$$E/c^4$$

rest mass-Matter topologies are not affect by changes in velocity [Matter is Lorentz invariant]

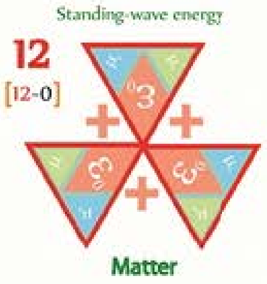

Standing-wave energy
12
[12-0]
+
+
+
ε_0
ε_0
ε_0
Matter

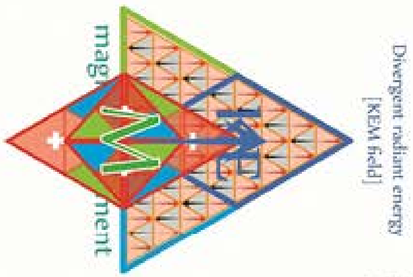

mag
nent
M
KEM
Divergent radiant energy
[KEM field]

The Law of Interaction

The Energy momenta of an electron's KEM field polarises the region surrounding its Matter and creates fields of interaction through the super-positioning of these fields

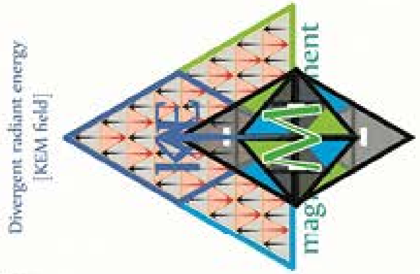

Divergent radiant energy
[KEM field]
KEM
M
nent
mag

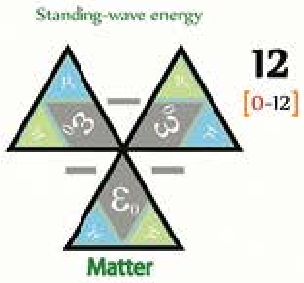

Standing-wave energy
12
[0-12]
−
−
−
ε_0
ε_0
ε_0
Matter

a particle's self-energy represents the contribution to the particle's energy, or effective mass, due to interactions between the particle and the system it is part of.

$$KEM = Mv^2$$

All Matter topologies are made up of quantum inductive loops which extract energy from any EM field they move through

Matter stores energy in its 3D planar facsia as charged mass-energy

additional to creating the familiar laws of interaction
[opposite attract - similars repel]
the KEM fields of leptons can act as tuned antennas
extracting energy from their environment

KEM fields store energy in their 2D planar EM field as neutral divergent mass-energies

$$E = Mc^4$$

All Matter contains EM energy propagating in a standing wave topology at the speed of light (the source of inertial mass)

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Resonant EM fields

Transmitting in order to efficiently recieve
via resonant inductive coupling
of EM fields

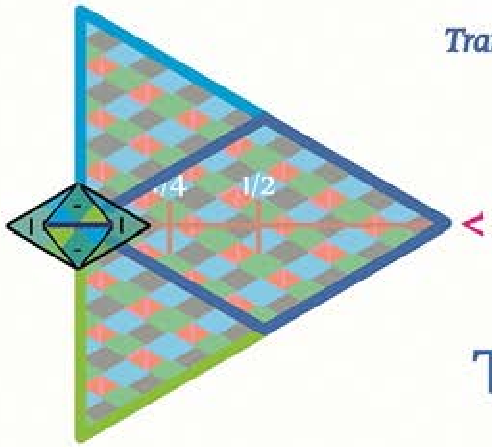

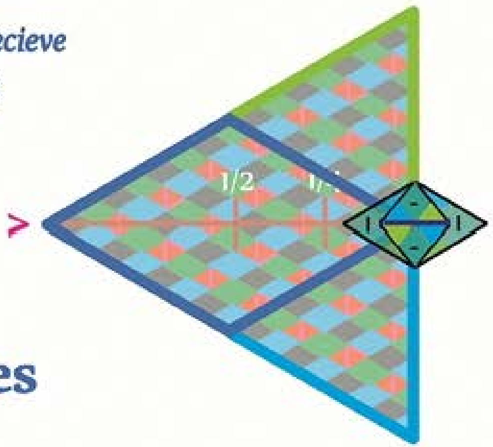

1:1

[or other harmonics]

Tuned KEM waves

Quantum inductive antenna fields

Historically, all recieiving antennas have been mechanically tuned to match the sought EM wavelength
But if power is applied to a small wavelength electrostatic topology it creates a KEM field
that produces a much larger, tuned rhombic antenna field

EM waves are hf geometries

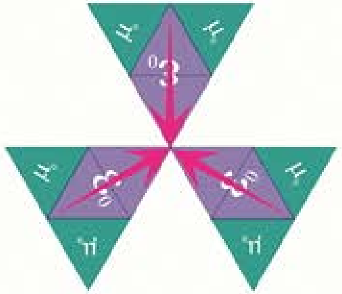

Electron's rest Matter stores EM mass-energy in a standing wave

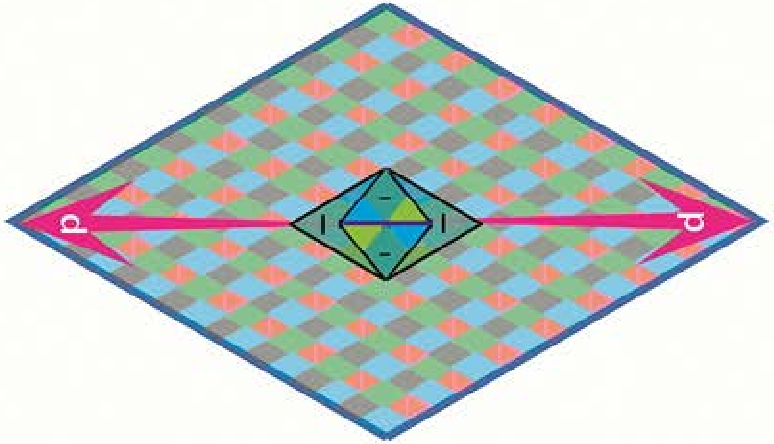

EM bosons have hv geometries

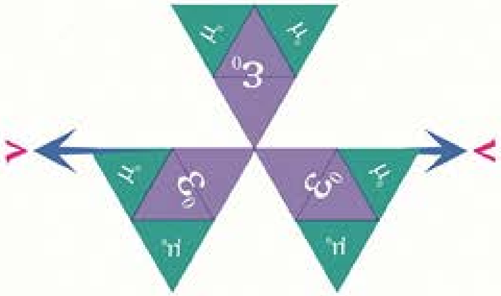

Electrostatic particles of Matter have dual KEM energy fields that can act as resonant antennas

Bosons

All Light is made of transverse EM energy Quanta

$$\underset{\text{Bosons}}{1\pi}\left[\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{\varepsilon_0\mu_0}}\right].\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

Energy is quantised

Max Planck

$$E = n.hv$$

All Photons have mass-Energy and momentum

$$\lambda = \frac{h}{p} = \frac{h}{mv}\sqrt{1-\frac{v^2}{c^2}}$$

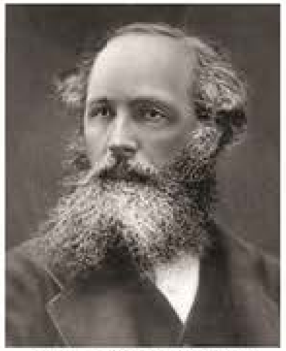

James Clerk Maxwell

$$\nabla\cdot\mathbf{D} = 4\pi\rho$$

$$\nabla\times\mathbf{H} = \frac{4\pi}{c}\mathbf{J} + \frac{1}{c}\frac{\partial\mathbf{D}}{\partial t}$$

$$\nabla\times\mathbf{E} + \frac{1}{c}\frac{\partial\mathbf{B}}{\partial t} = 0$$

$$\nabla\cdot\mathbf{B} = 0$$

ElectroMagnetic waveforms propagate at the speed of light

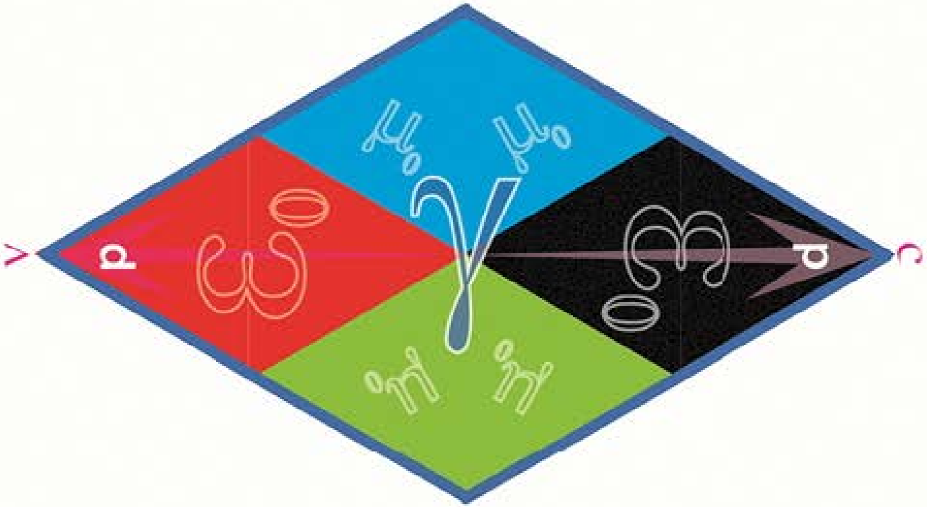

Matter is a probabilistic wave of EM particles

p

Louis de Broglie

Erwin Schrodinger

Ψ

Photons

All Light consists of longitudinal harmonic oscillators

$$\underset{\text{Photons}}{2\pi}\left[\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{\varepsilon_0\mu_0}}\right].\left[\underset{\text{mass}}{m}\,\overset{\text{Planck quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]\right]$$

Photons are particles

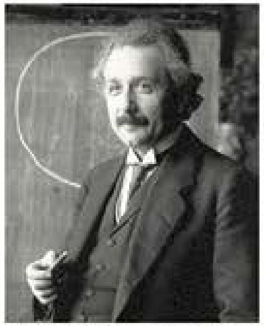

Albert Einstein

$$E = hf$$

All EM waves and Matter exhibit a Wave-Particle duality

$$i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi$$

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Photonic EM fields

In 1865, James Clerk Maxwell's prediction that light was an electromagnetic wave, [which was confirmed experimentally in 1888 by Heinrich Hertz's detection of radio waves], seemed to be the final blow to particle models of light.

James Clerk Maxwell

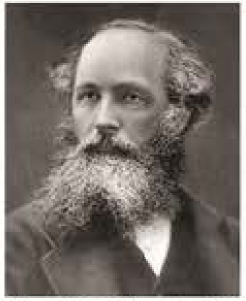

(13 June 1831 – 5 November 1879)

EM Field · Planck · quanta

$$\underset{\text{Photons}}{2\pi}\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

ElectroMagnetic · mass · velocity

8.8541e-12

All EM mass-energy momenta propagates bi-directionally at c [the speed of light] in a vacuum

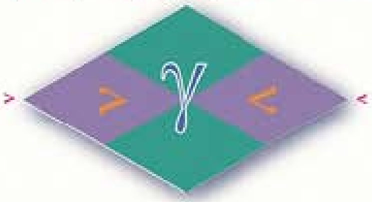

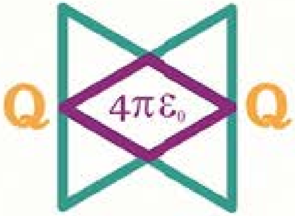

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

$$\frac{K_E}{K_M} = 9e16 \; \frac{\frac{N\,m^2}{C^2}}{\frac{N\,s^2}{C^2}}$$

$$c^2 = 9e16 \; \frac{m^2}{s^2}$$

$$c = 299{,}792{,}458 \; \frac{m}{s}$$

The speed of light can be calculated using the Electric and Magnetic constants

$$\frac{F}{m} \qquad \varepsilon_0 \qquad \frac{A^2\,s^4}{kg\,m^3}$$

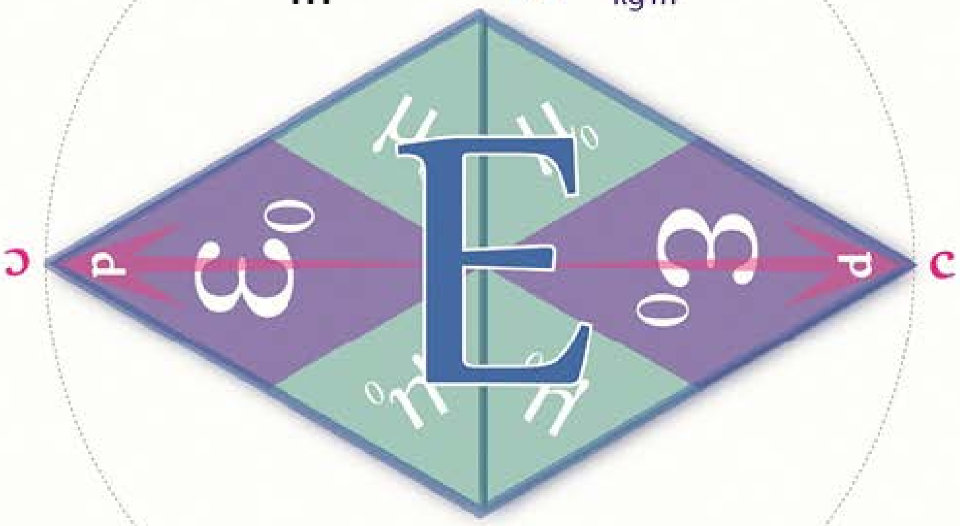

$$\frac{H}{m} \qquad \mu_0 \qquad \frac{kg\,m}{A^2\,s^2}$$

[4π]e-7

Electric field strength

The strength of Electric fields is determined by the Electrical Permittivity Constant

$$\varepsilon_0\mu_0 = \frac{1}{c^2}$$

The strength of Magnetic fields is determined by the Magnetic Permeability Constant

$$B = \mu_0 H$$

The ElectroMagnetic field geometry of Photons

$$2mv^2 = KE = hf$$

$$\underset{\text{Photons}}{2\pi}\left[\overset{\text{EM Field}}{[\varepsilon_0\mu_0]}\cdot\left[\overset{\text{Energy}}{\underset{\text{momenta}}{hv^2}}\right]\right]$$

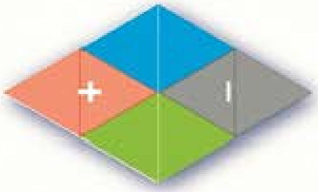

Matter is comprised entirely of
equilateral electromagnetic energies

$$\underset{\text{Matter}}{4n\pi}\left[\overset{\text{EM Field}}{\underset{\text{ElectroMagnetic}}{[\varepsilon_0\mu_0]}}\cdot\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Matter topologies contain
standing-wave EM mass-energies
moving at the speed of light

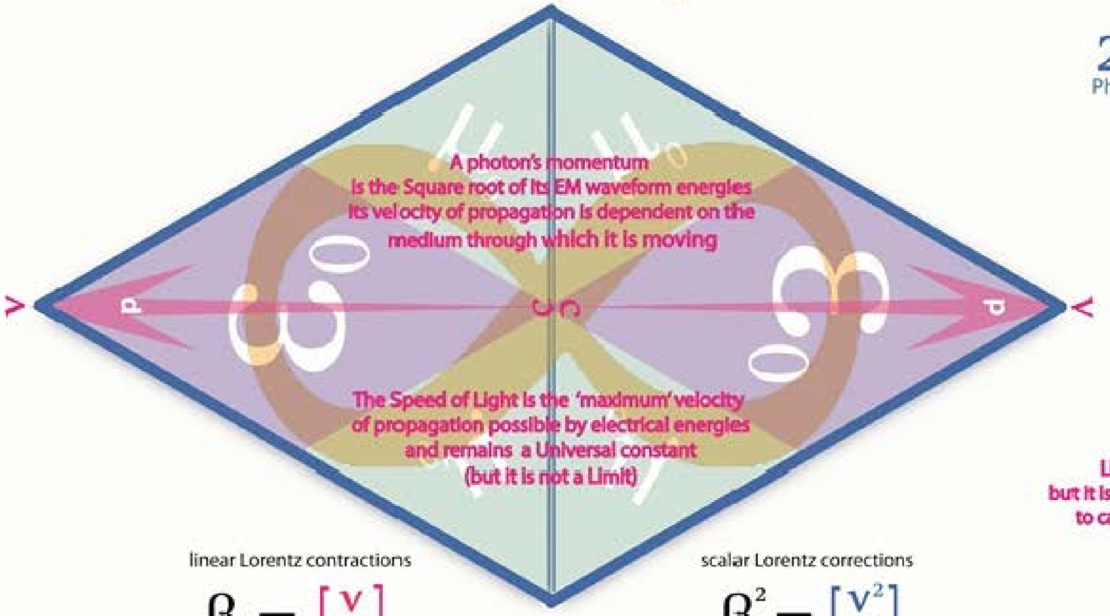

A photon's momentum
is the Square root of its EM waveform energies
its velocity of propagation is dependent on the
medium through which it is moving

The Speed of Light is the 'maximum' velocity
of propagation possible by electrical energies
and remains a Universal constant
(but it is not a Limit)

Photons are diamond geometry
ElectroMagnetic mass-energies

$$\underset{\text{Photons}}{2\pi}\left[\overset{\text{EM Field}}{\underset{\text{ElectroMagnetic}}{[\varepsilon_0\mu_0]}}\cdot\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{0^2}\right]\right]$$

Light cannot have zero velocity or stand still
but it is possible (against Einstein's thought experiment)
to catch up to a photon and observe its waveform

linear Lorentz contractions

$$\beta = \left[\frac{v}{c}\right]$$

scalar Lorentz corrections

$$\beta^2 = \left[\frac{v^2}{c^2}\right]$$

Any addition of energy quanta to
an existing photonic waveform is subject to
relativistic Lorentz velocitycorrections
to the Photon's KEM waveforms

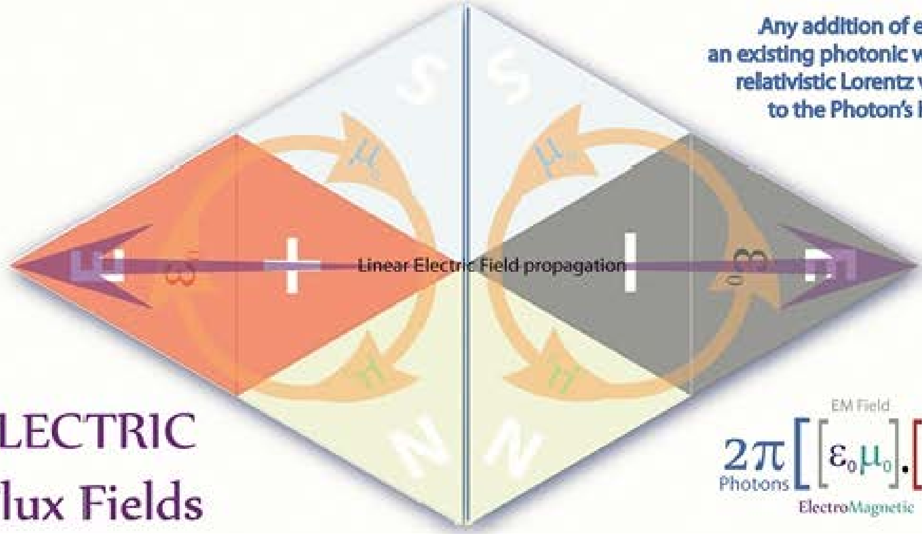

ELECTRIC
Flux Fields

$$\underset{\text{Photons}}{2\pi}\left[\overset{\text{EM Field}}{\underset{\text{ElectroMagnetic}}{[\varepsilon_0\mu_0]}}\cdot\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

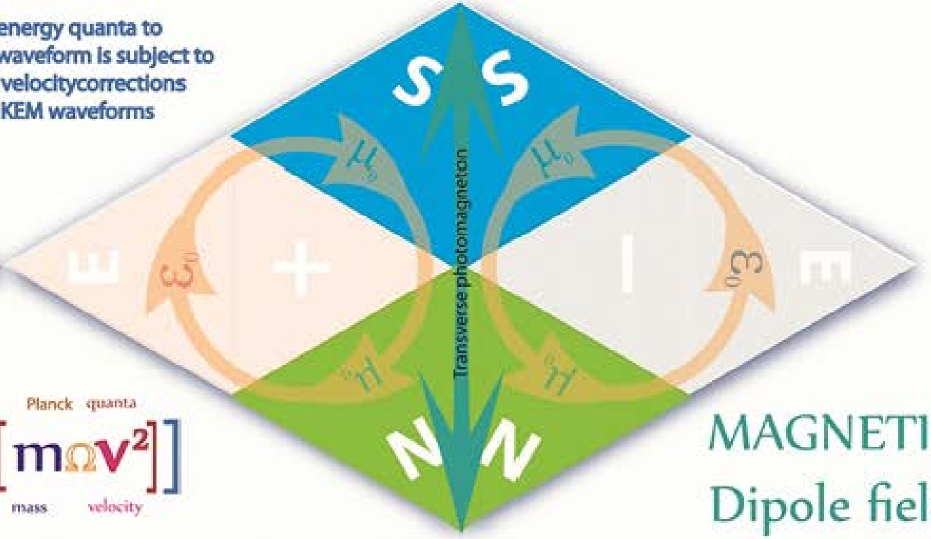

MAGNETIC
Dipole fields

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Photons and Charge bosons

Photons are dual [2π]
neutral charge quanta

$$\underset{\text{Photons}}{2\pi}\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{[\varepsilon_0\mu_0]}}.\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]$$

Their Electric and Magnetic
fields are orthogonal to each other

Bosons are transverse charge carriers
they combine to create ElectroMagnetic
photons which are longitudinal charge carriers

They propagate
in differing mediums
at v/c

$$\underset{\text{EM waves}}{\text{EVEN}\,\pi}\left[\underset{\text{ElectroMagnetic}}{\overset{\text{EM Field}}{[\varepsilon_0\mu_0]}}.\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\underset{\text{velocity}}{\overset{\text{quanta}}{v^2}}\right]\right]$$

nπ electromagnetic waves are comprised of
numerous 2π photons of the same wavelength
(save in superpositioned states - White light)

Photons are dual Boson waveforms

$$E = 2hv$$

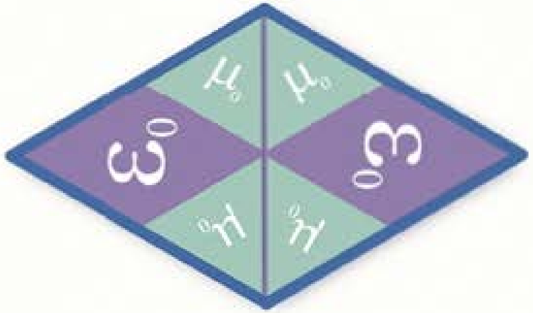

$$E = hf$$

A moving charge creates a magnetic field throughout space
that is perpendicular to the direction of motion.

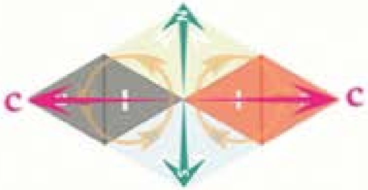

Photons require NO ether to propagate
they are discrete bundles of EM energy-momenta

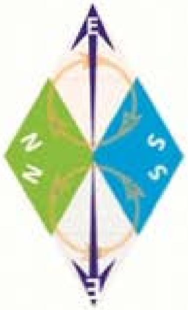

Similarly, a magnet has an intrinsic neutral electric field
that is perpendicular to its Magnetic Dipole.

Photon EM strength vectors

Electric field force vectors

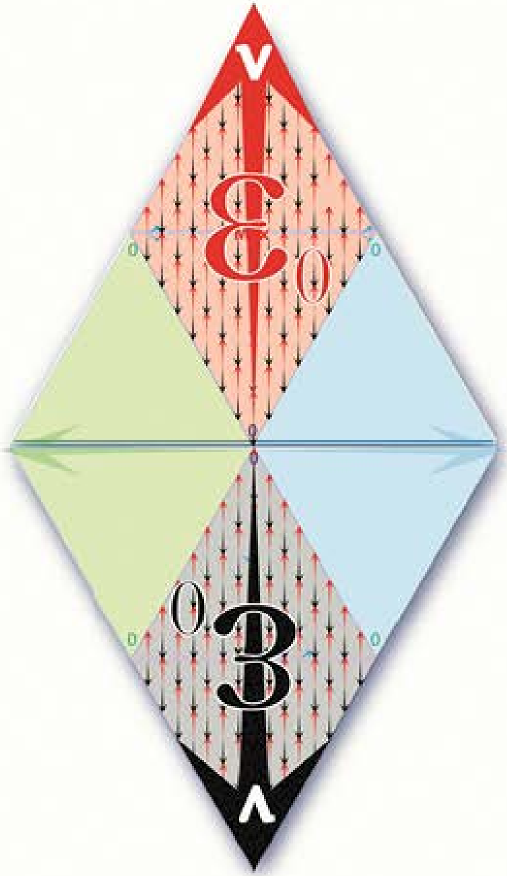

When E field flux is at Maximum
B field flux is at Minimum

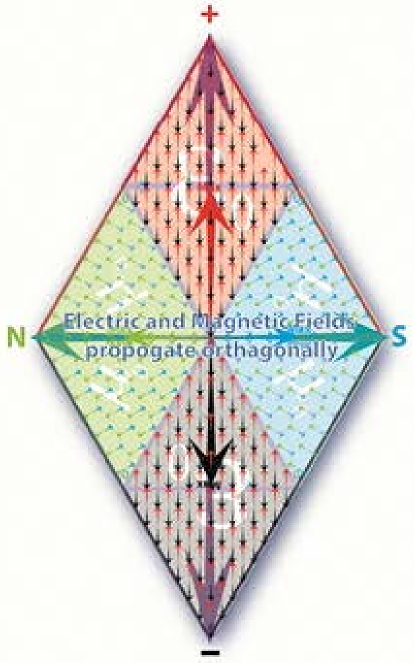
+
N
S
Electric and Magnetic Fields
propogate orthagonally
−

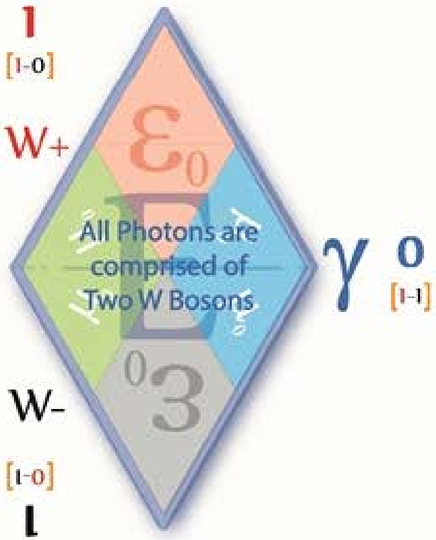
1
[1-0]
W+
ε0
All Photons are
comprised of
Two W Bosons
0ε
γ 0
[1-1]
W-
[1-0]
1

Magnetic field force vectors

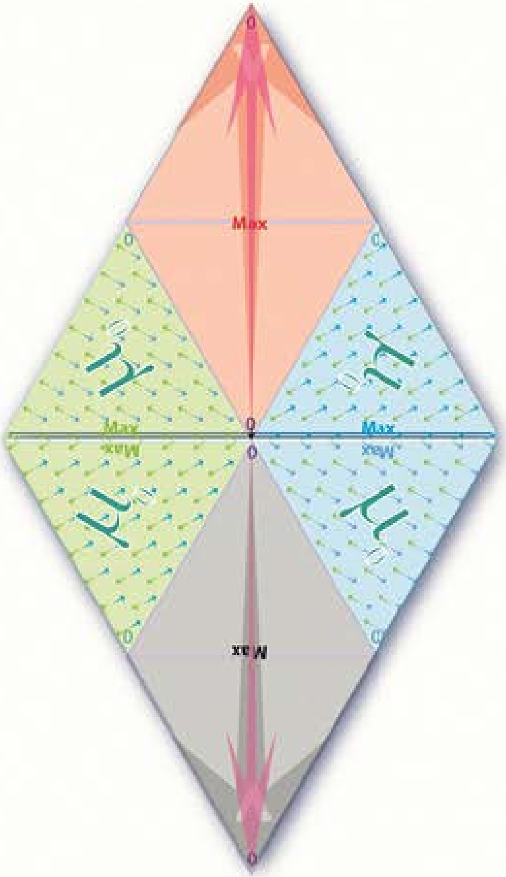
0
Max
0
0
μ0
μ0
Max
Max
μ0
μ0
0
0
Max
0

When B field flux is at Maximum
E field flux is at Minimum

Photons are 2π electromagentic masses possessing:

- Frequency
- Wavelength
- Energy
- Momentum
- Kinetic Energy
- Magnetic Moment
- Probabilistic Properties

and can

- Refract
- Deflect and
- Disperse

ZPFs [Bosons] are
1/2 wavelength photons

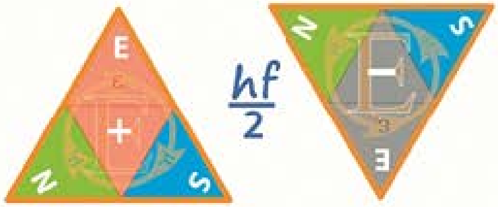

$2v = f$

2π Planck Constants
Photon energy density

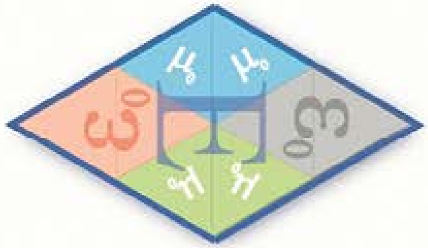

Photon sizes (wavelengths) change in direct proportion to the energy content of any electro-magnetic wave

Wavelength decreases as total EM wave Frequency increases

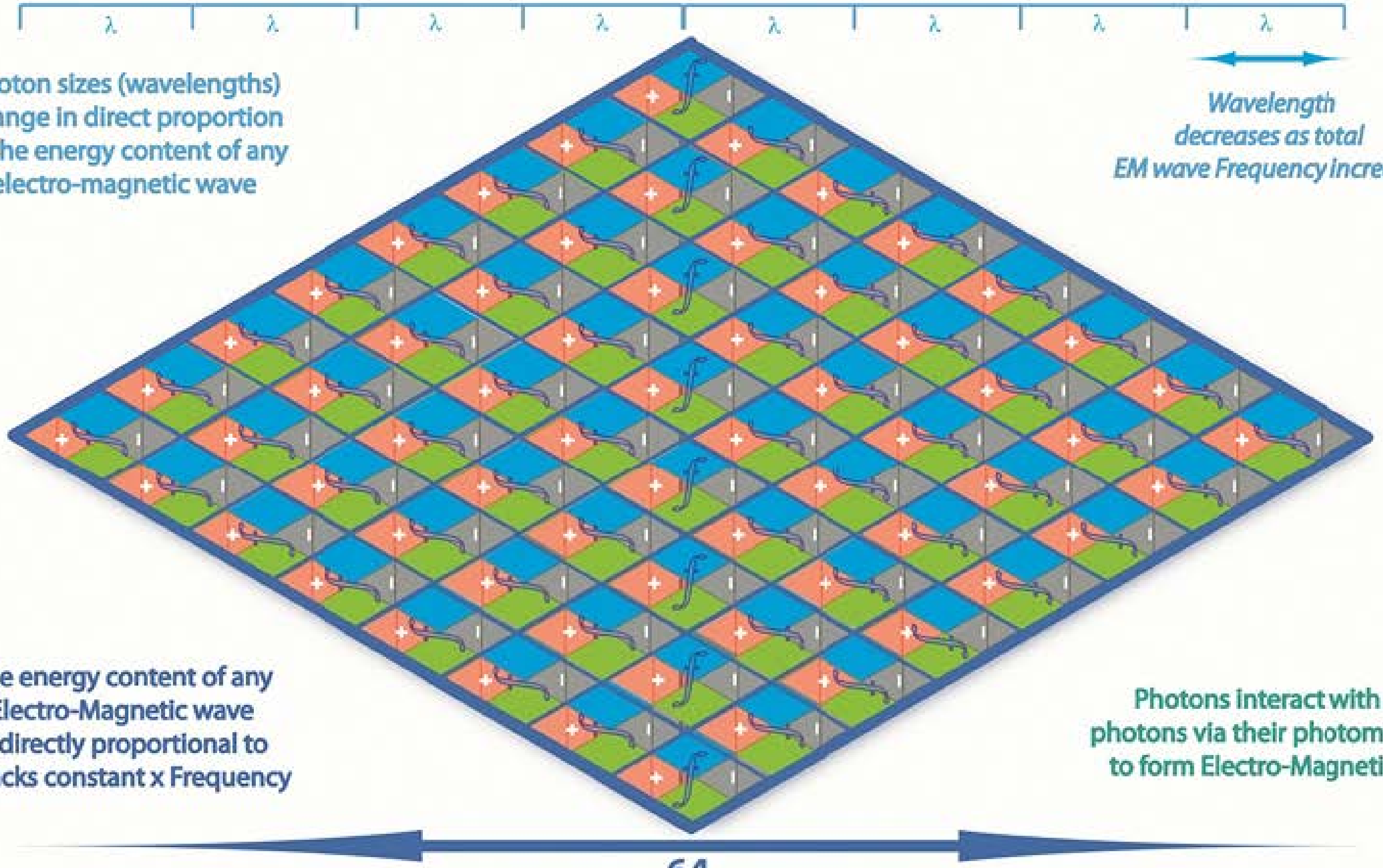

E = hf

Photons

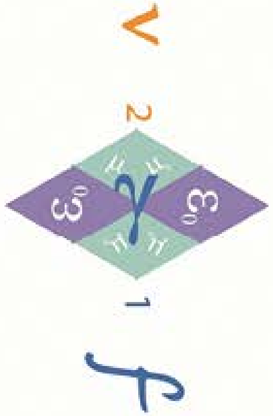

The energy content of any Electro-Magnetic wave is directly proportional to Plancks constant x Frequency

Photons interact with other photons via their photomagnetons to form Electro-Magnetic waves

64
Frequency
Number of Cycles per time unit

Bosons in a EM wave

EM waves are comprised of transverse W Bosons

Odd numbers totaling to a Square number

$E = h\nu$

$\boxed{2\nu = f}$

$E = hf$

Even numbers totaling to a Square number

EM waves are also comprised of longitudinal Photons

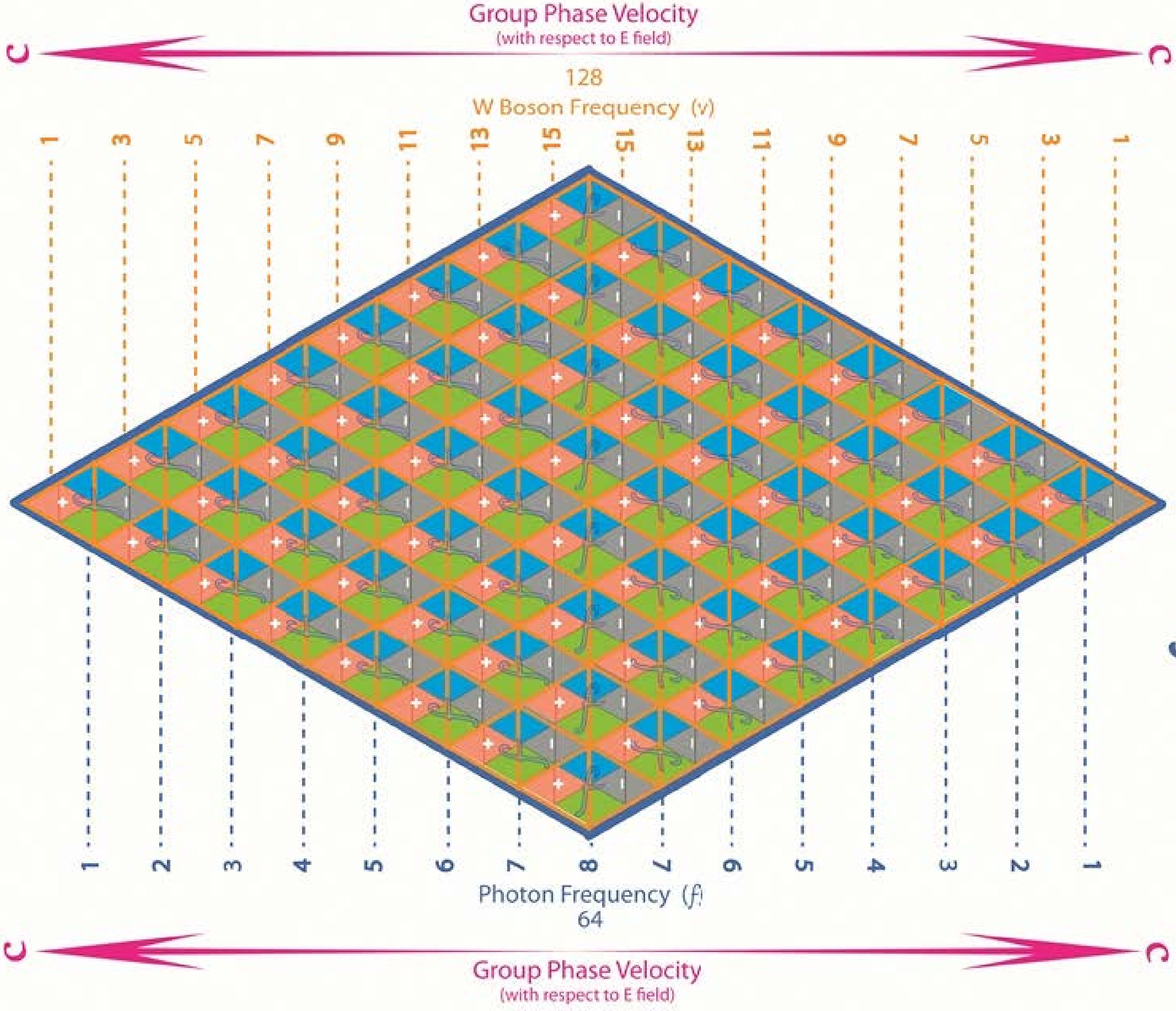
Group Phase Velocity
(with respect to E field)
c
c
128
W Boson Frequency (ν)
1 3 5 7 9 11 13 15 15 13 11 9 7 5 3 1
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
Photon Frequency (f)
64
c
c
Group Phase Velocity
(with respect to E field)

$2h\nu = E = hf$

Tetryonics 26.07 - Bosons in a EM wave

[Bosons]

ODD π

(1,3,5,7,9, ...)

Z BOSONS are 1/2 wavelength quantum levels

$E = h\nu$

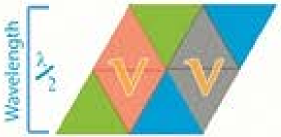

vs.

1:1

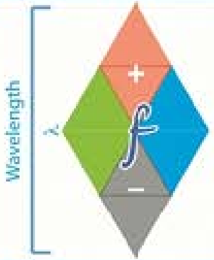

PHOTONS are integer wavelength frequencies

$E = hf$

[Photons]

EVEN π

(2,4,6,8,10, ...)

EM Field Planck quanta

$1\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Bosons ElectroMagnetic mass velocity

ZPFs are Boson quantums

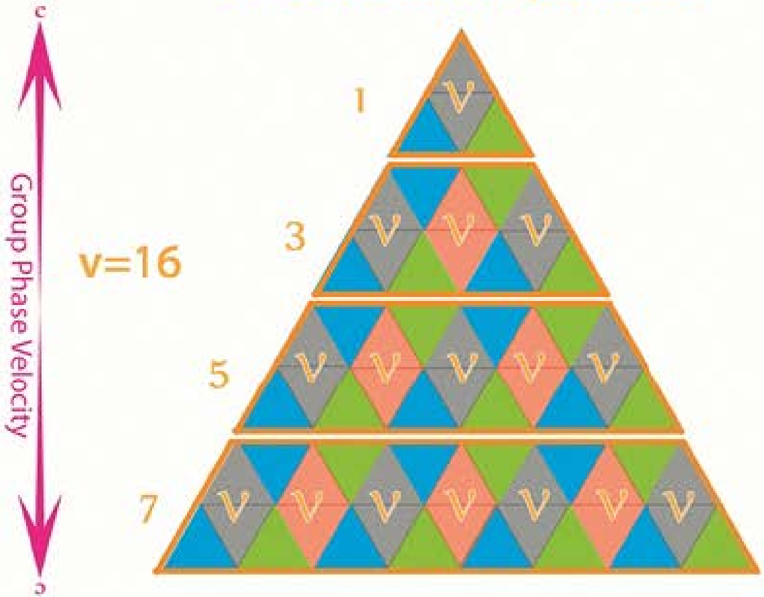

EM Field Planck quanta

$\text{ODD}\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Bosons ElectroMagnetic mass velocity

Charges are comprised of transverse Bosons

Bosons and Photons have differing EM geometries

EM Field Planck quanta

$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Photons ElectroMagnetic mass velocity

Photons are comprised of Bosons

Photons are EVEN number Planck geometries

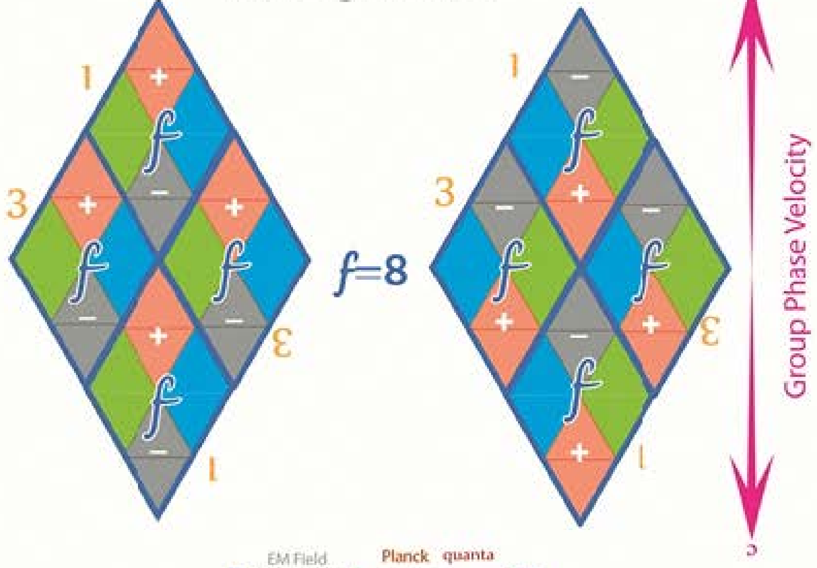

EM Field Planck quanta

$\text{EVEN}\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

EM waves ElectroMagnetic mass velocity

EM waves are comprised of longitudinal Photons

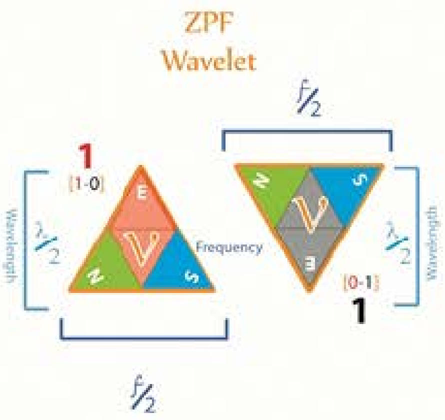
ZPF
Wavelet
1
[1-0]
Wavelength
$\lambda/2$
E
N
S
ν
Frequency
$f/2$
N
S
E
ν
[0-1]
1
Wavelength
$\lambda/2$
$f/2$

Bosons

Charge Carriers
$E = h\nu$

W+ boson

Bosons are half wavelength - non-Integer frequency
waveforms due to their odd ZPF numbers

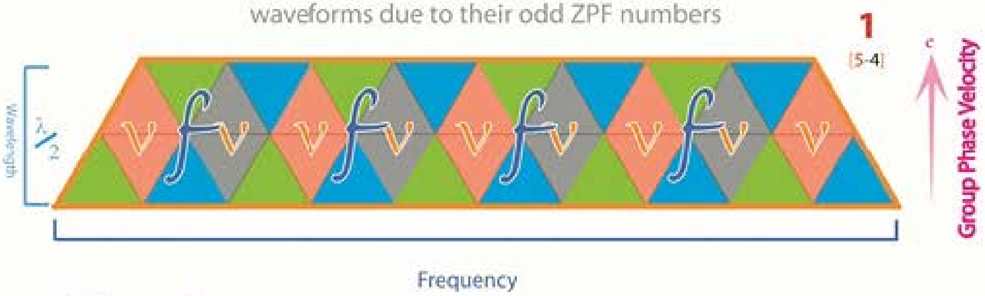
1
[5-4]
Wavelength
$\lambda/2$
ν f ν ν f ν ν f ν ν f ν ν
c
Group Phase Velocity
Frequency

$$mv^2 = E = h\nu^2$$

All Bosons are transverse ODD quanta EM masses

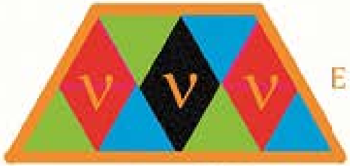

$E = h\nu$

$_{ODD}\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$

The interchanging of Quantum number [ν]

$$2\nu = f$$

with Photon Frequency [f] is a cause of confusion

$E = hf$

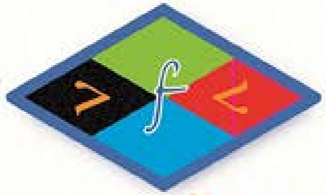

$_{EVEN}\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$

All Photons are longitudinal EVEN quanta EM masses

Transverse Bosons

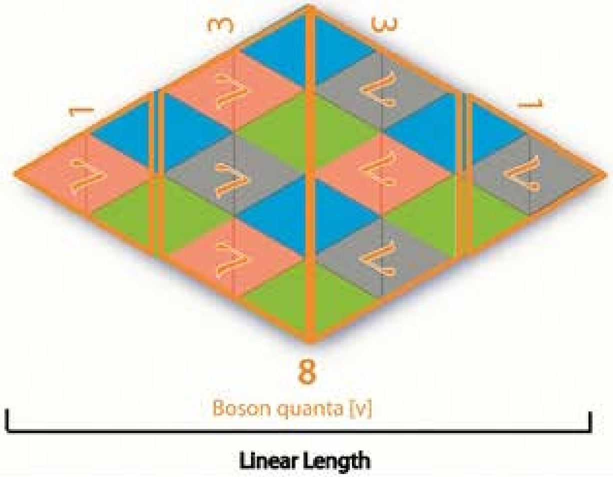
3
3
1
1
ν
ν
ν
ν
ν
ν
ν
ν
8
Boson quanta [ν]
Linear Length

$$2h\nu = E = hf$$

EM Force Carriers
$E = hf$

Photons

Longitudinal Photons

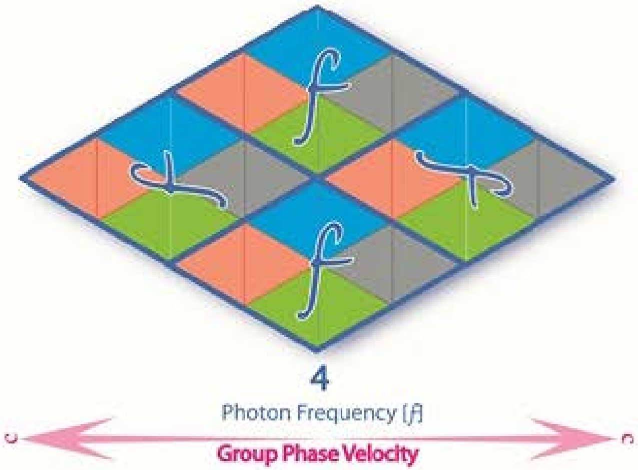
f
f
f
f
4
Photon Frequency [f]
c
c
Group Phase Velocity

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Photonic Energies

$$2p^2 = KE = 2mv^2$$

The equilateral geometries of Quantised Angular Momentum of Planck energy quanta is the source of linear Momentum

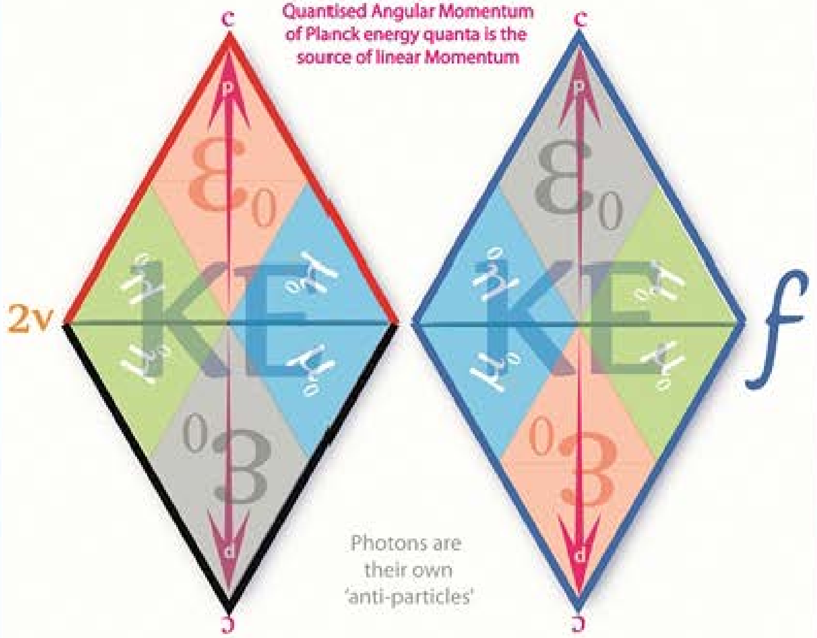

Photons are their own 'anti-particles'

$$2hv = E = hf$$

$$E_\gamma = 2mc^2$$

As Photons are 2D EM energy waveforms they should always be referred to as having EM mass-energy equivalence

γ

EM Field Planck quanta

$$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Photons

ElectroMagnetic mass velocity

Planck quanta

$$2\pi\left[m\Omega v^2\right]$$

mass velocity

Photons are kinetic energy [KE] wave packets:

$KE = (1/2) * m_\gamma * v^2$

$= 1/2 * (E/c^2) * c^2$

$= E/2$

KE

Frequency Number of repeating cycles of energy momenta per time unit

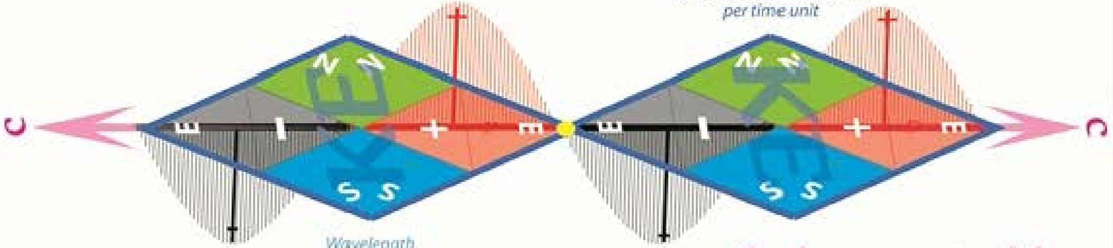

Wavelength decreases as Photon internal Frequency increases

They have momentum [p]:

$p = m_\gamma * v$

$= (E/c^2) * c$

$= E * c$

0

[v-v]

Photons are 2n neutral charge waveforms

Photons are divergent kinetic waveforms

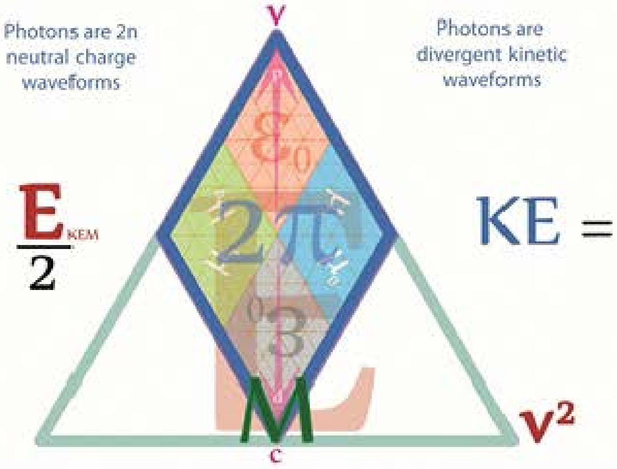

$$KE = \frac{E_{KEM}}{2}$$

$$KE = \frac{1}{2}Mv^2$$

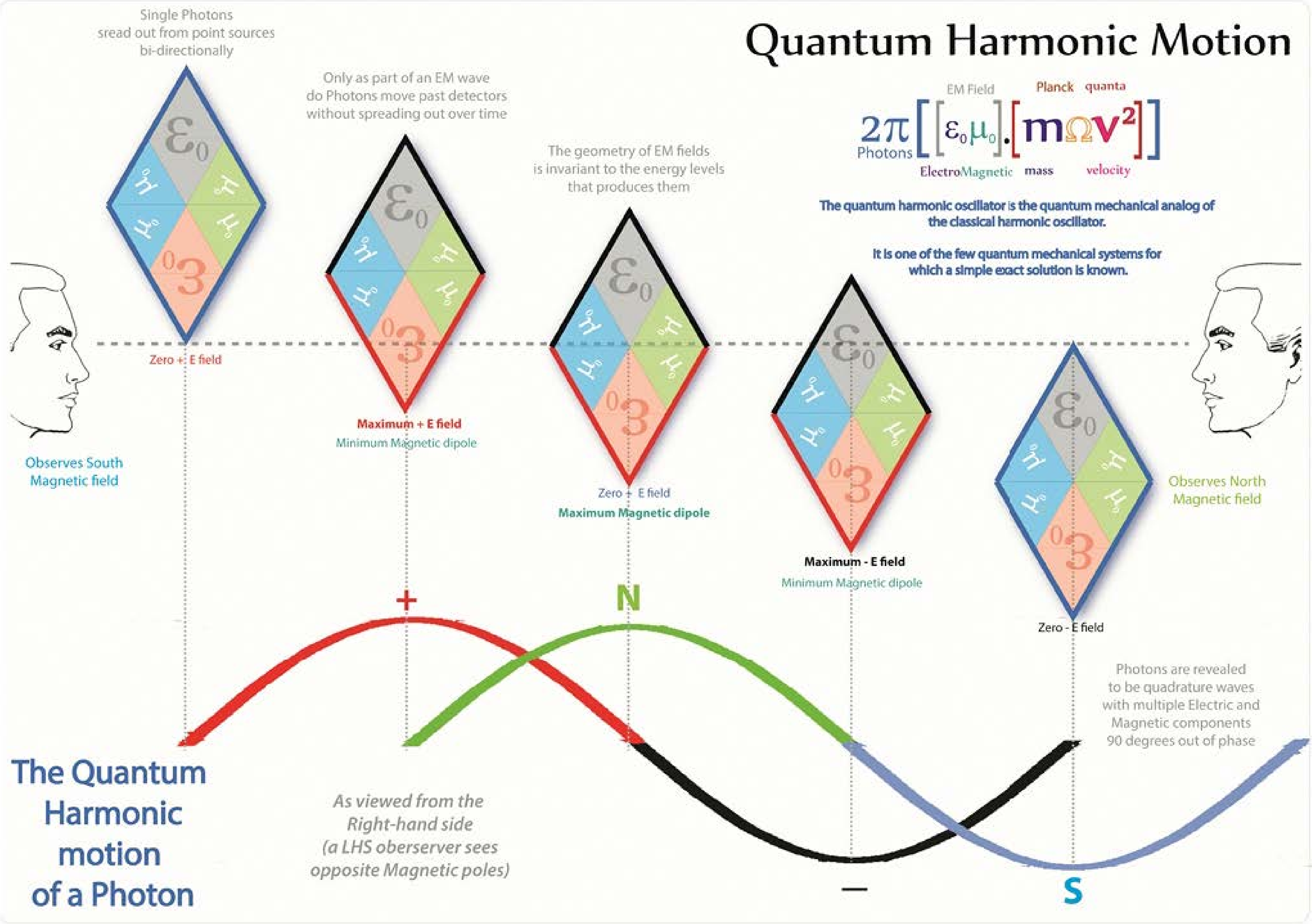

Quantum Harmonic Motion

$$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

EM Field Planck quanta
Photons ElectroMagnetic mass velocity

The quantum harmonic oscillator is the quantum mechanical analog of the classical harmonic oscillator.

It is one of the few quantum mechanical systems for which a simple exact solution is known.

Single Photons sread out from point sources bi-directionally

Only as part of an EM wave do Photons move past detectors without spreading out over time

The geometry of EM fields is invariant to the energy levels that produces them

Photons are revealed to be quadrature waves with multiple Electric and Magnetic components 90 degrees out of phase

As viewed from the Right-hand side (a LHS oberserver sees opposite Magnetic poles)

The Quantum Harmonic motion of a Photon

Zero + E field
Maximum + E field
Minimum Magnetic dipole
Zero + E field
Maximum Magnetic dipole
Maximum - E field
Minimum Magnetic dipole
Zero - E field
Observes South Magnetic field
Observes North Magnetic field
+
N
–
S

Tetryonics 26.11 - Quantum Harmonic Motion

Photonic EM fields

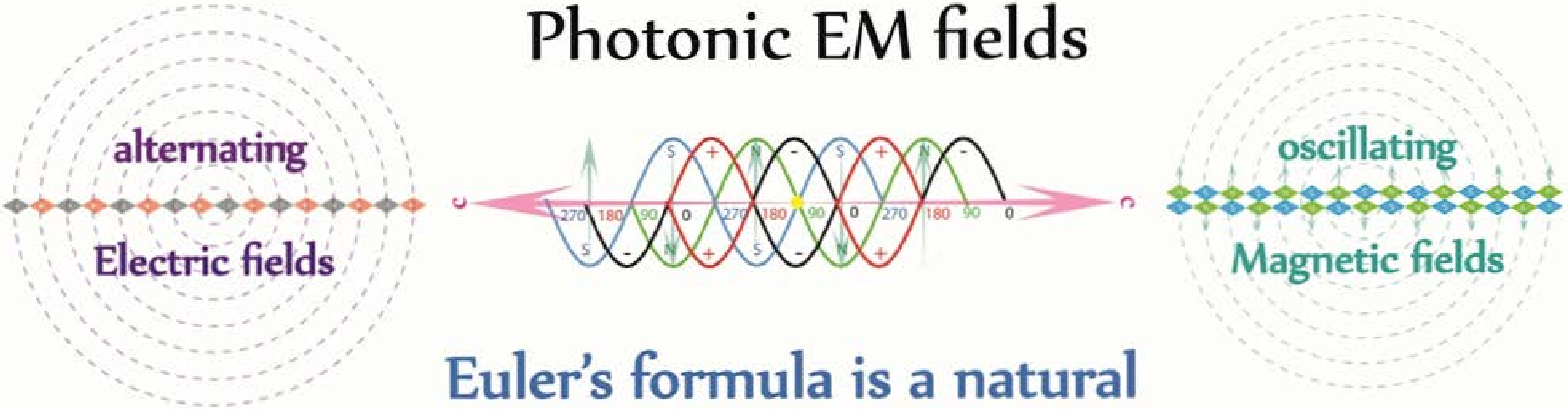

alternating

Electric fields

oscillating

Magnetic fields

S
+
N
-
270
180
90
0
270
180
90
0
270
180
90
0

Euler's formula is a natural geometric expression of electromagnetic waves

$$e^{ix} = \cos x + i \sin x$$

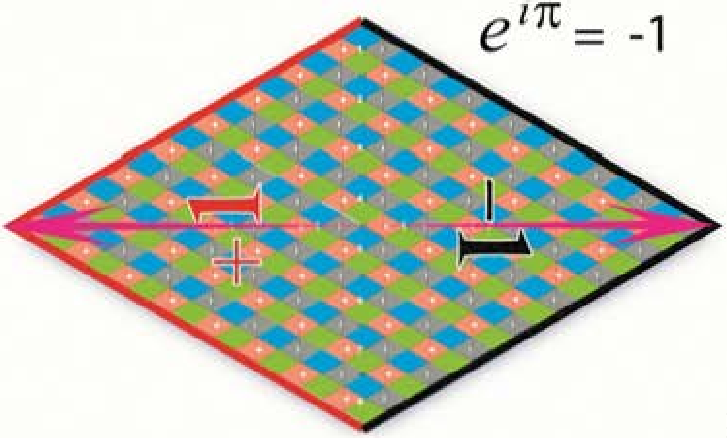

$e^{i\pi} = -1$

$e^{i\pi} + 1 = 0$

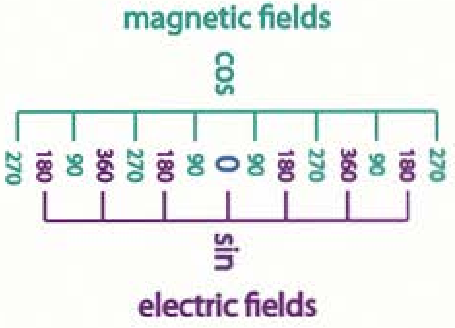

magnetic fields

cos

270
180
90
360
270
180
90
0
90
180
270
360
90
180
270

sin

electric fields

Every field geometry in a EM wave is 90 degrees out of phase with the E or M field adjacent to it

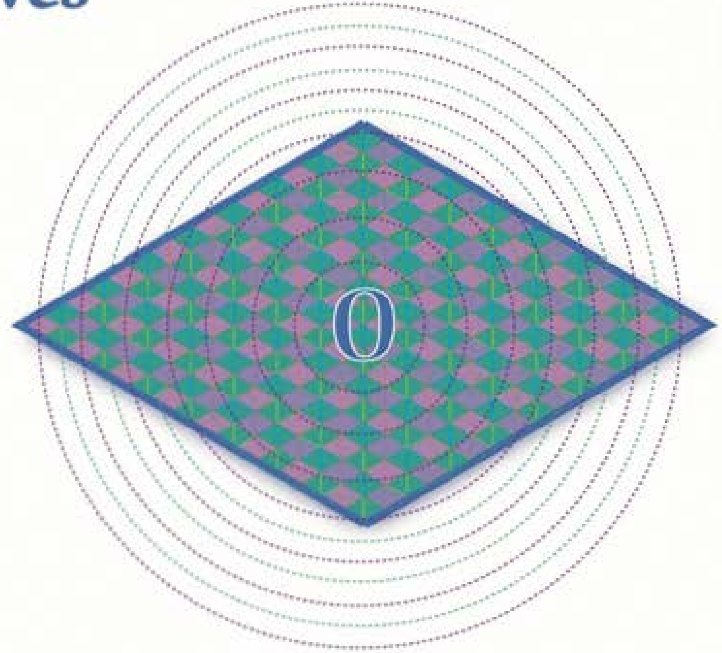

Tetryonics 26.12 - Photonic EM field phases

Euler's Formula

Euler's formula is often considered to be the basis of the complex number system.
In deriving this formula, Euler established a relationship between the
trigonometric functions, sine and cosine, and e raised to a power

$$e^{ix} = \cos(x) + i\sin(x)$$

a mathematical description of EM-Energy waveforms

adjacent EM fields are 90-180° out of phase

$$e^{i\pi} = -1$$

$$e^{i\pi} + 1 = 0$$

Leonhard Euler

(15 April 1707 – 18 September 1783)

Positive E-fields are out of phase with Negative fields

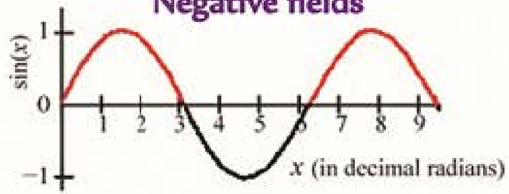

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \ldots$$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \frac{x^5}{5!} + \ldots$$

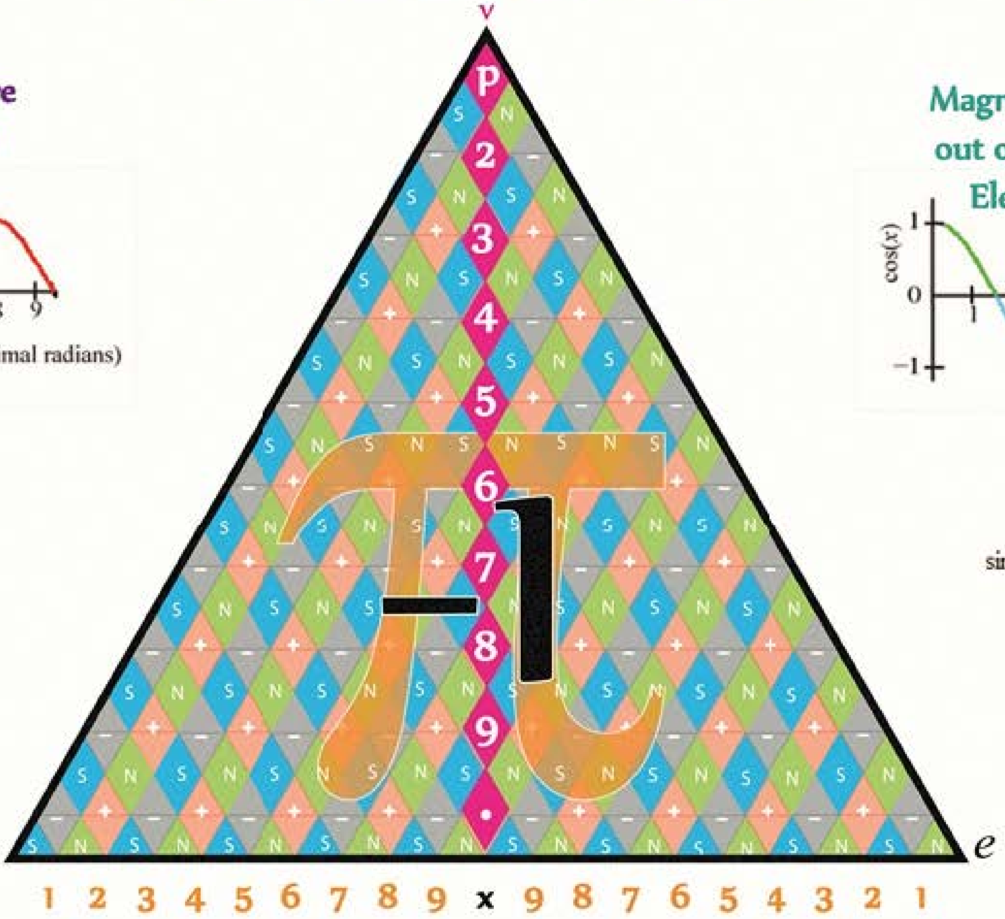

Magnetic fields are out of phase with Electric fields

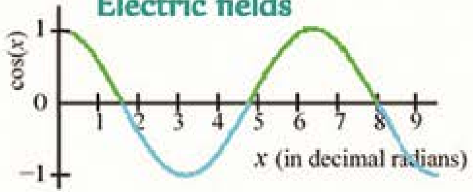

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \ldots$$

$$\sin x + \cos x = 1 + x - \frac{x^2}{2!} - \frac{x^3}{3!} + \frac{x^4}{4!} + \frac{x^5}{5!} + \ldots$$

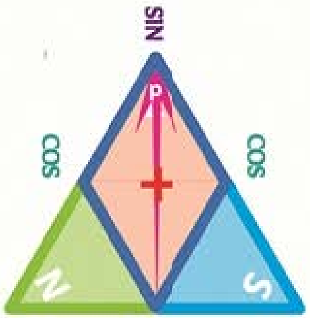

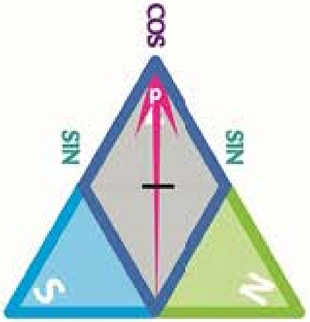

The above geometry is reflective of negative charge energy momenta Planck geometries
the momentum of the nett charged geometry is the Square root of Negative 1

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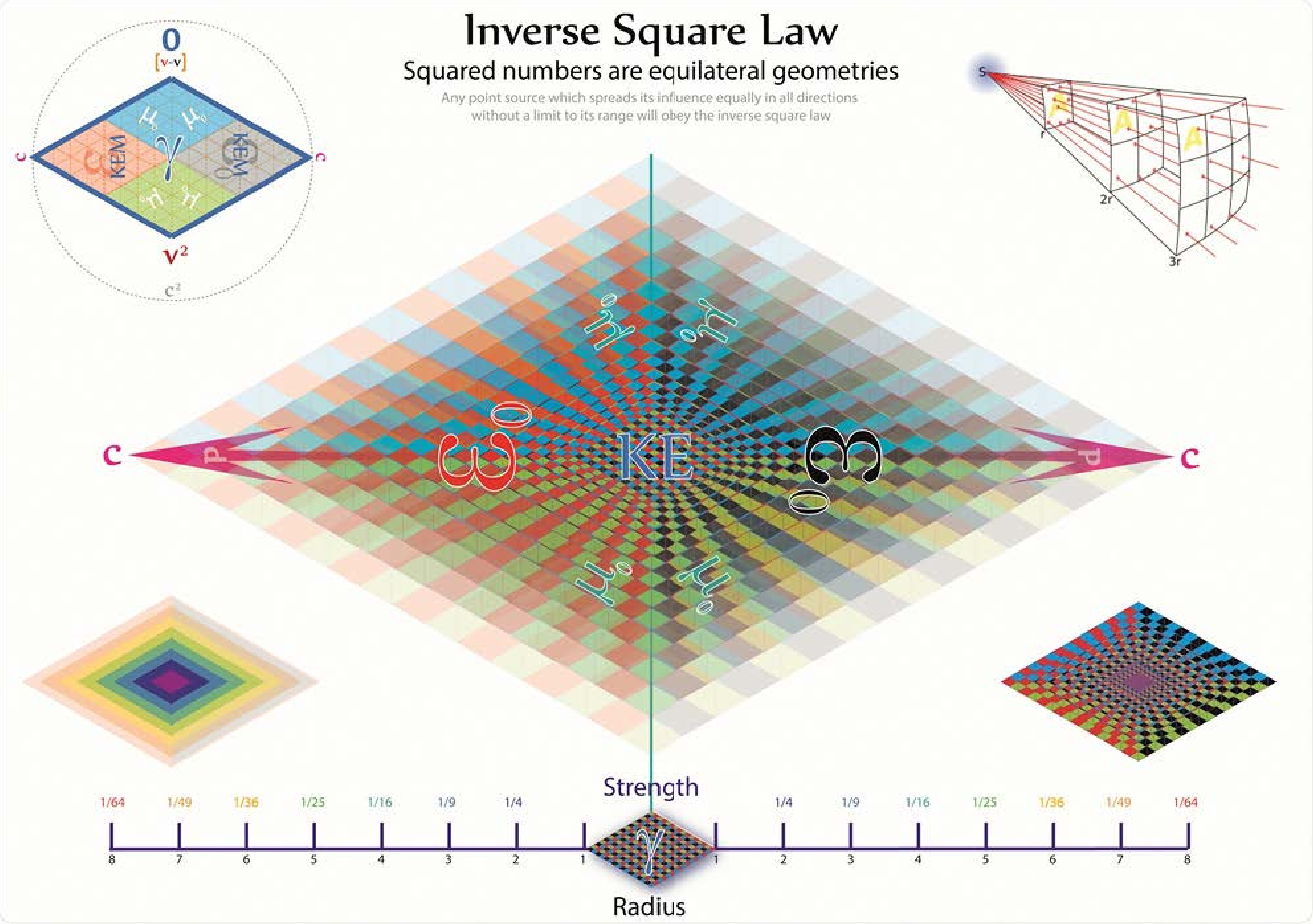

Inverse Square Law

Squared numbers are equilateral geometries

Any point source which spreads its influence equally in all directions
without a limit to its range will obey the inverse square law

0
[v-v]
c
c
KEM
KEM
γ
μ_0
ε_0
v^2
c^2
s
r
2r
3r
A
A
A
c
p
ε_0
KE
ε_0
p
c
μ_0
μ_0
μ_0
μ_0
Strength
1/64
1/49
1/36
1/25
1/16
1/9
1/4
1/4
1/9
1/16
1/25
1/36
1/49
1/64
8
7
6
5
4
3
2
1
γ
1
2
3
4
5
6
7
8
Radius

Tetryonics 26.14 - Inverse Square Law

$$\underset{\text{mass}}{n\pi}\,\left[\left[\overset{\text{EM Field}}{\underset{\text{ElectroMagnetic}}{\varepsilon_0\mu_0}}\right].\left[\underset{\text{mass}}{m}\overset{\text{Planck}}{\Omega}\overset{\text{quanta}}{\underset{\text{velocity}}{v^2}}\right]\right]$$

Throughout history Physicists have sought relationships between EM mass-Energy and momenta in an attempt to discern the true Nature of these physical properties

mass-Energy momenta

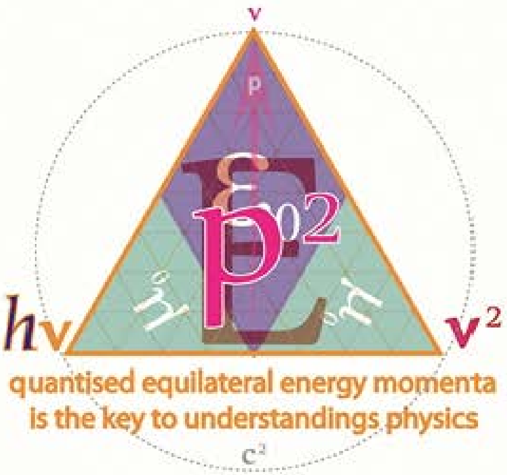

quantised equilateral energy momenta is the key to understandings physics

E

Energy

$$kg\,\frac{m^2}{s^2}$$

Compton Frequency

$$\left[\frac{E}{h}\right]$$

$E = mv$

Newton

$E = mv^2$

Leibnitz

$v = \frac{1}{\sqrt{\varepsilon_0\mu_0}}$

Maxwell

Velocity of Light

$$v = \left[\overset{f}{\left[\frac{c^2}{\Omega}\right]}.\overset{\lambda}{\left[\frac{\Omega}{c}\right]}\right]$$

Scalar Frequency

Linear Wavelength

Planck

$E = hv$

Einstein

$E = hf$

de Broglie

h/p

Planck's Constant

$$kg\,\frac{m^2}{s}$$

de Broglie wavelength

$$\left[\frac{E}{p}\right]$$

Wavelength

p

Linear momentum

$$kg\,\frac{m}{s}$$

Ryberg wavenumber

$$\left[\frac{p}{E}\right]$$

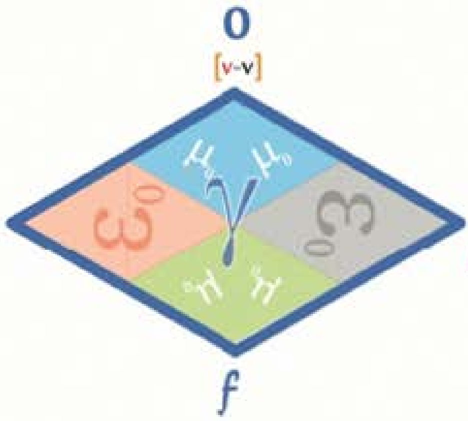

$$mv^2 = KE = hv^2$$

All Photons contain Energy momenta and therefore have electromagnetic mass but they are 'Matterless' geometries

Wavenumber

$$\frac{m}{s}\cdot\frac{s}{m^2}\left[\frac{c}{\Omega}\right]\frac{1}{m}$$

Light cannot have zero velocity (stand still) but it is possible to catch up to a photon and observe its waveform

The Speed of Light is the maximum speed of Electrical energy and remains a Universal constant (but it is not a Limit)

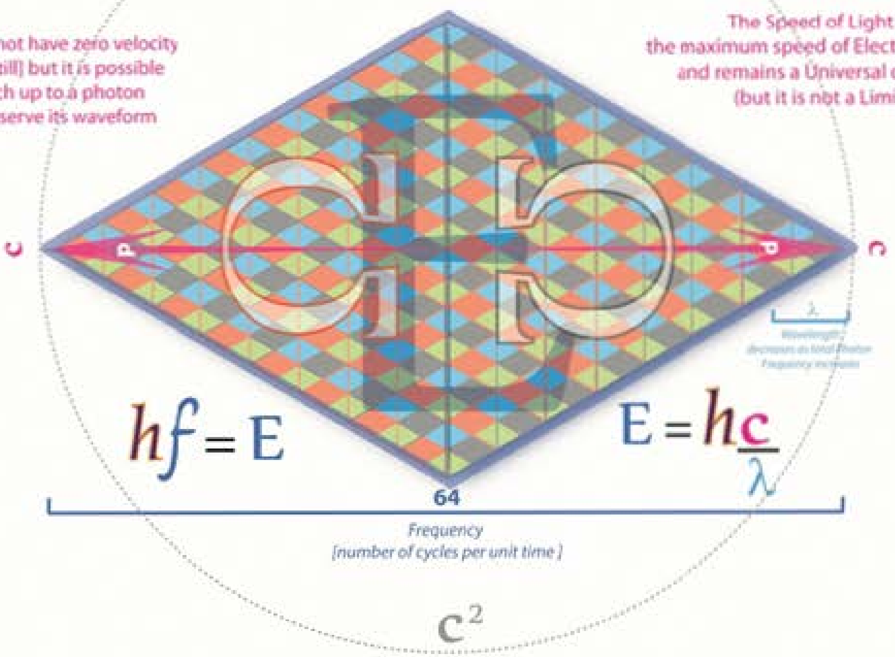
c
p
p
c
λ
Wavelength decreases as total Photon Frequency increases
64
Frequency
[number of cycles per unit time]
c²

$$hf = E$$

$$E = h\frac{c}{\lambda}$$

Celeritas

[Frequency x Wavelength]

EM waves are typically described through any of their following three physical properties:

frequency f,
wavelength λ, or
photon energy E

ElectroMagnetic Fields

$$\varepsilon_0\mu_0 = \frac{1}{c^2}$$

$$1.112650056\text{ e-17 } \frac{s^2}{m^2}$$

Frequency, momentum, and Wavelength are all related through the geometries of c & c²

λ

$$m\left[\frac{\Omega}{c}\right]\frac{m^2}{s}\cdot\frac{s}{m}$$

Wavelength

Velocity of Light

$$c = \left[\overset{f}{\left[\frac{c^2}{\Omega}\right]}\cdot\overset{\lambda}{\left[\frac{\Omega}{c}\right]}\right]$$

Frequency Wavelength

$$v = \frac{1}{\sqrt{\varepsilon_0\mu_0}}$$

f

$$\frac{m^2}{s^2}\cdot\frac{s}{m^2}\left[\frac{c^2}{\Omega}\right]\frac{1}{s}$$

Frequency

Frequency is the number of neutral quanta sets repeating per unit time in a EM wave

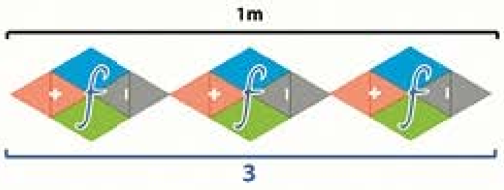

EM waves frequencies [photon number] change in direct proportion to the energy content of any electromagnetic wave

The specific wavelengths and frequencies of energy momenta in KEM fields form the basis for Spectral emission/absorption lines [care must be always taken to specify if quanta or photons are being measured]

$2v = f$

Bosons are charged transverse energy momenta quanta

2 charge quanta

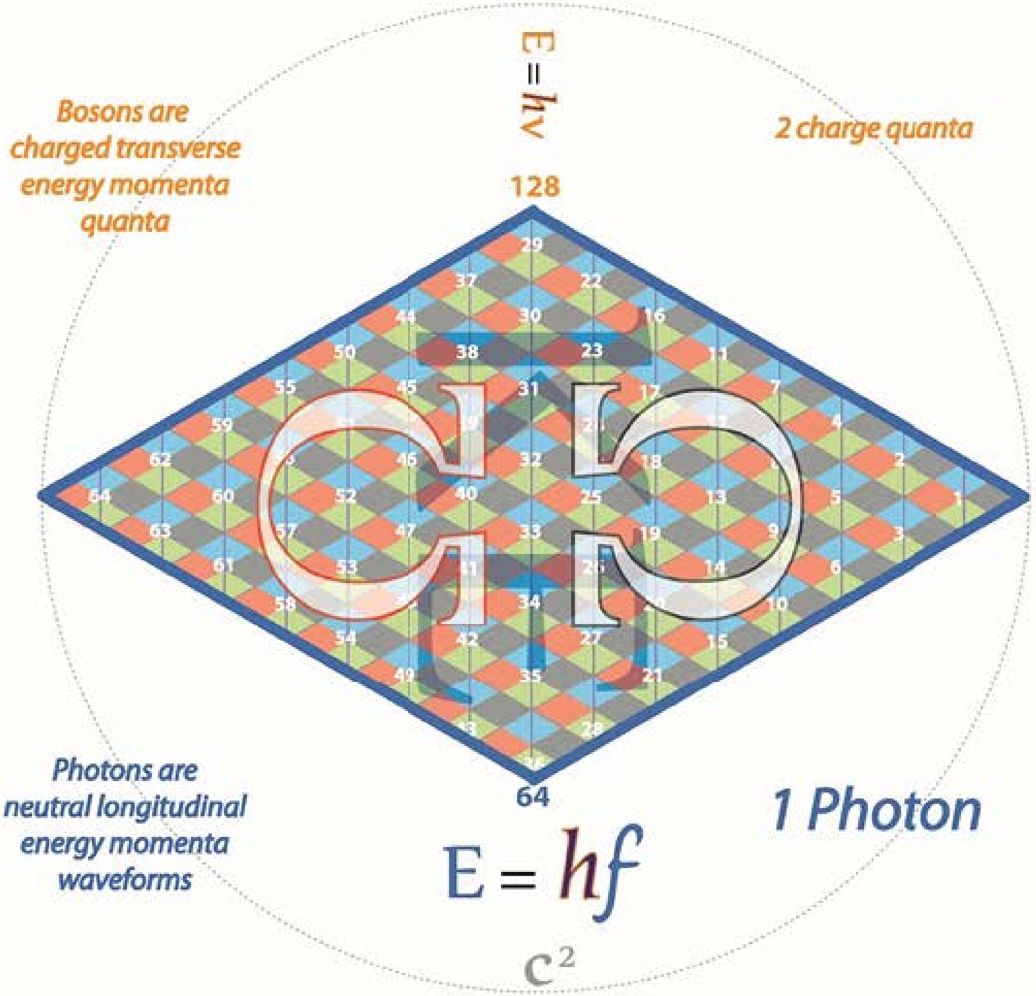

Photons are neutral longitudinal energy momenta waveforms

1 Photon

$E = hf$

c^2

Irrespective of whether its measured as a transverse or longitudinal electromagnetic wave

Frequency is the inverse of Charge

$$f \left[\frac{c^2}{\Omega} \right]$$

Frequency

is directly related to the nett quantised angular momentum of any space time geometry

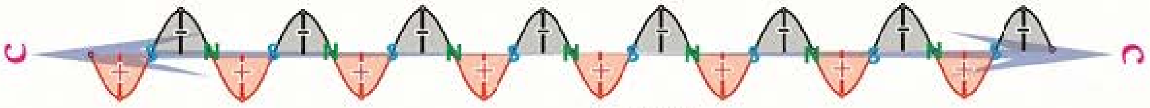

Frequency

[Number of Neutral ZPF sets per unit of time]

λ

Wavelength

Wavelength is a measure of the distance between repetitions of geometric features such as maximums, minimums, or zero-points of Electric and Magnetic fields

λ

$$\left[\frac{\Omega}{c}\right]$$

Wavelength

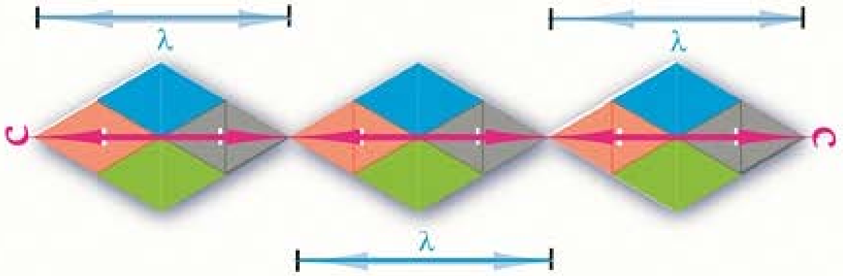

ṽ

Wavelengths are the inverse of Wavenumbers

λ

For additional quantised energy momenta to be added to any spatial geometry their physical wavelengths must decrease

Lorentz velocity dependent length contractions must be correctly retermed electromagnetic WAVE-length contractions

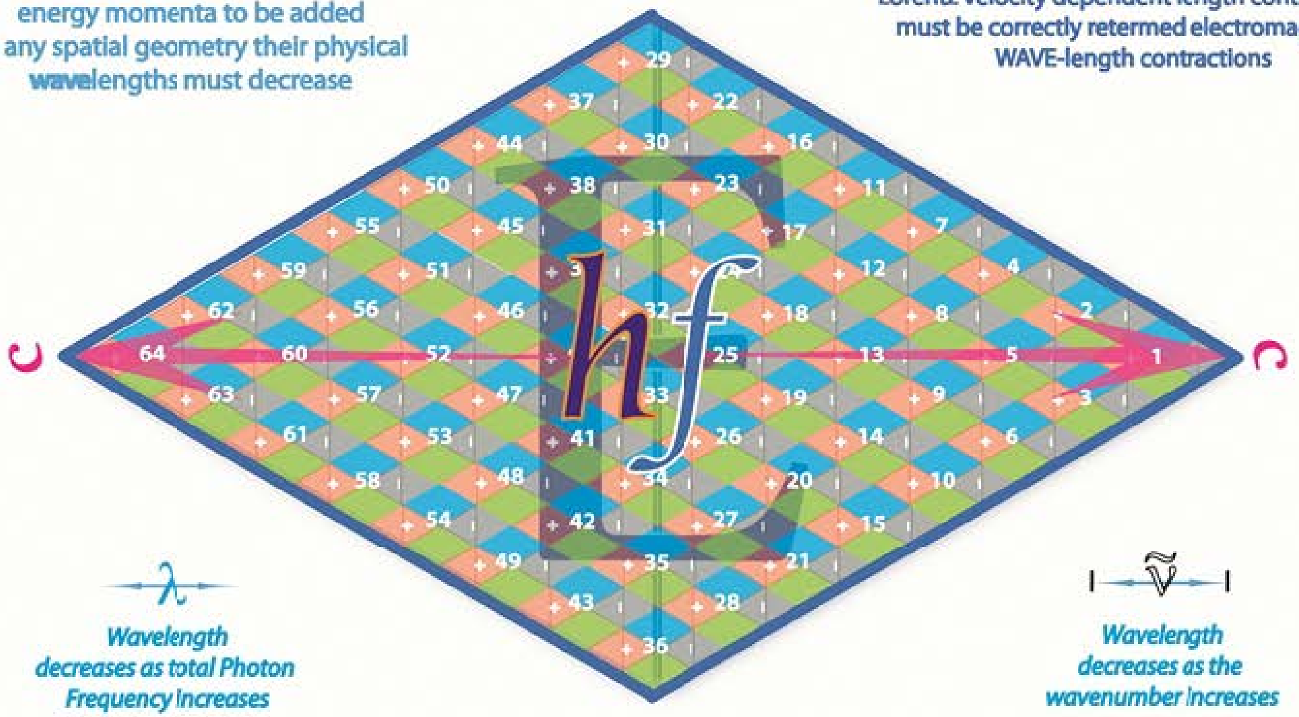
hf
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64

λ

Wavelength decreases as total Photon Frequency Increases

ṽ

Wavelength decreases as the wavenumber Increases

In physics, the wavelength of a sinusoidal wave is the spatial period of the wave – the distance over which the wave's shape repeats. It is usually determined by considering the distance between consecutive corresponding points of the same phase, such as crests, troughs, or zero crossings, and is a characteristic of both traveling waves and standing waves, as well as other spatial wave patterns.

The concept can also be applied to periodic complex or non-sinusoidal waves

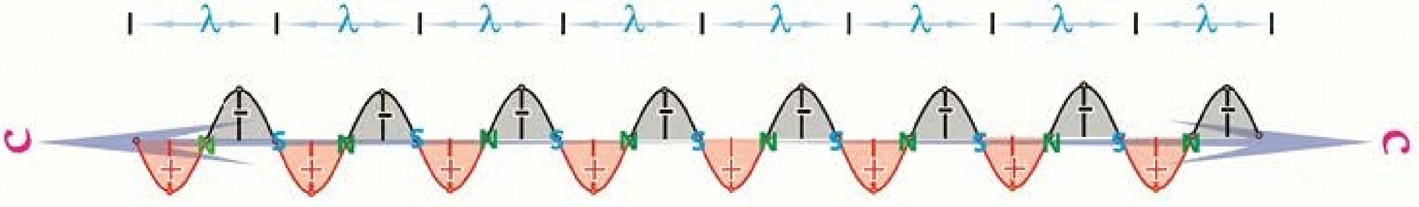

299,792,458
linear metres per second

Wavenumbers

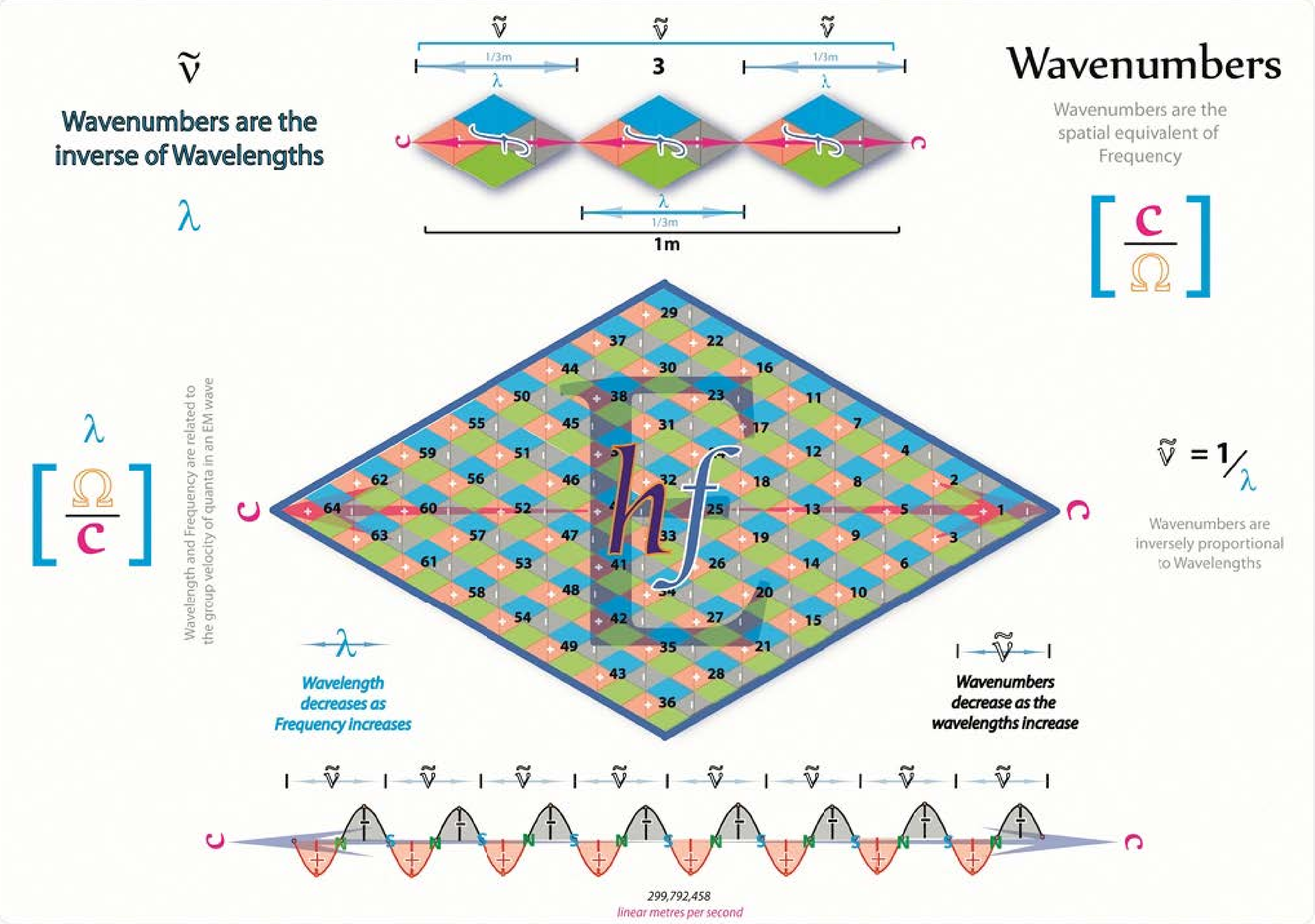
ṽ
ṽ
ṽ
1/3m
3
1/3m
λ
λ
λ
1/3m
1m
c
c
29
37
22
44
30
16
50
38
23
11
55
45
31
17
7
59
51
12
4
62
56
46
32
18
8
2
64
60
52
25
13
5
1
63
57
47
33
19
9
3
61
53
41
26
14
6
58
48
20
10
54
42
27
15
49
35
21
43
28
36
hf
c
c
ṽ
ṽ
ṽ
ṽ
ṽ
ṽ
ṽ
ṽ
ṽ
λ
c
c
N
S

$\tilde{\nu}$

Wavenumbers are the inverse of Wavelengths

λ

Wavenumbers are the spatial equivalent of Frequency

$$\left[\frac{c}{\Omega}\right]$$

λ

$$\left[\frac{\Omega}{c}\right]$$

Wavelength and Frequency are related to the group velocity of quanta in an EM wave

$$\tilde{\nu} = 1/\lambda$$

Wavenumbers are inversely proportional to Wavelengths

Wavelength decreases as Frequency increases

Wavenumbers decrease as the wavelengths increase

299,792,458
linear metres per second

Tetryonics 26.19 - Wavenumbers

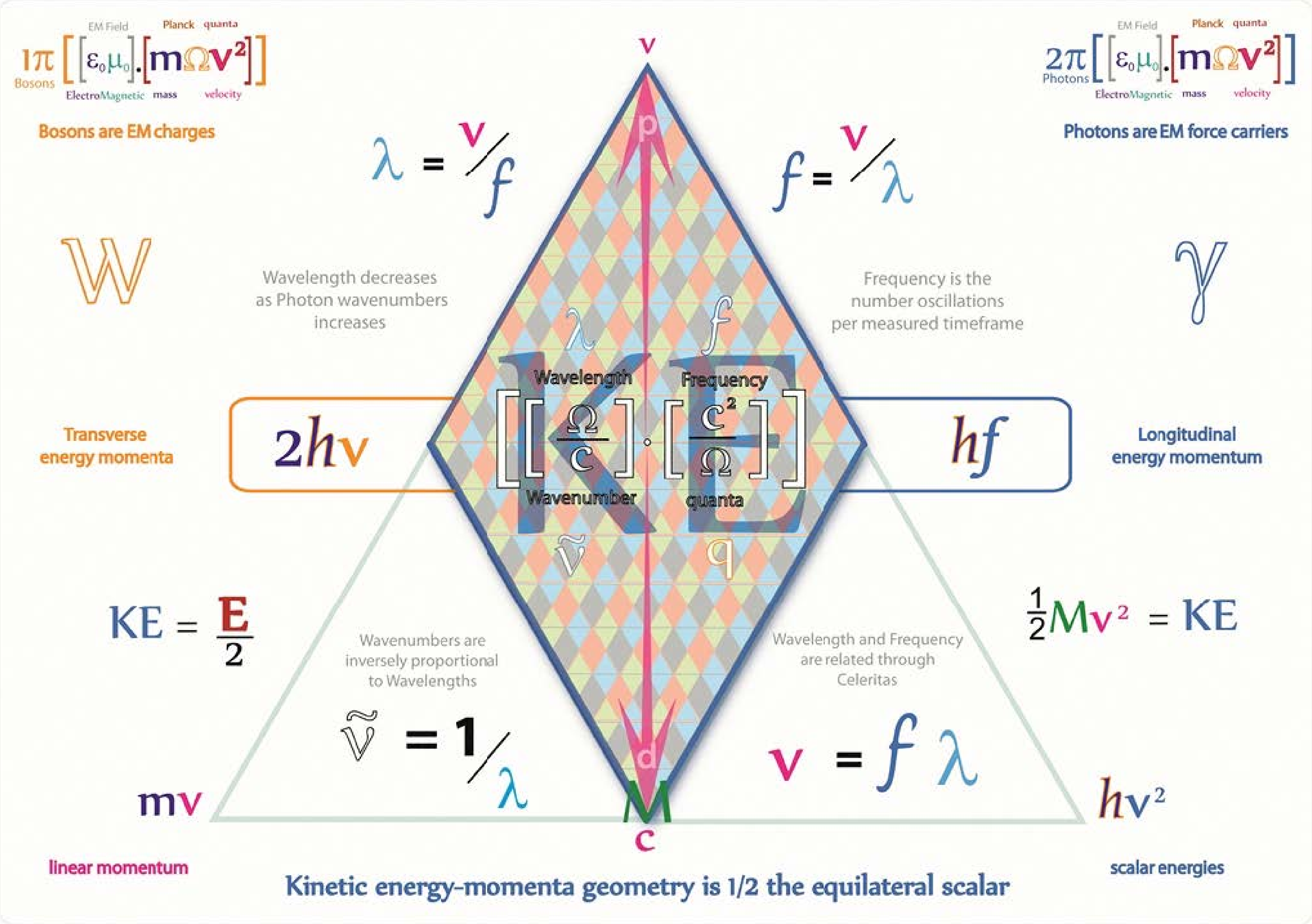

EM Field Planck quanta

$1\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Bosons ElectroMagnetic mass velocity

Bosons are EM charges

EM Field Planck quanta

$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Photons ElectroMagnetic mass velocity

Photons are EM force carriers

$\lambda = {}^{v}/_{f}$

$f = {}^{v}/_{\lambda}$

W

γ

Wavelength decreases as Photon wavenumbers increases

Frequency is the number oscillations per measured timeframe

Transverse energy momenta

$2hv$

$$\left[\left[\frac{\Omega}{c}\right].\left[\frac{c^2}{\Omega}\right]\right]$$

hf

Longitudinal energy momentum

$KE = \frac{E}{2}$

$\frac{1}{2}Mv^2 = KE$

Wavenumbers are inversely proportional to Wavelengths

$\tilde{\nu} = 1/\lambda$

Wavelength and Frequency are related through Celeritas

$v = f\lambda$

mv

hv^2

linear momentum

scalar energies

Kinetic energy-momenta geometry is 1/2 the equilateral scalar

Tetryonics 26.20 - Kinetic energy-momenta

Faraday Rotation

The Faraday effect or Faraday rotation is a Magneto-optical phenomenon, that is, an interaction between light and a magnetic field in a medium. The Faraday effect causes a rotation of the plane of polarization which is linearly proportional to the component of the magnetic field in the direction of propagation.

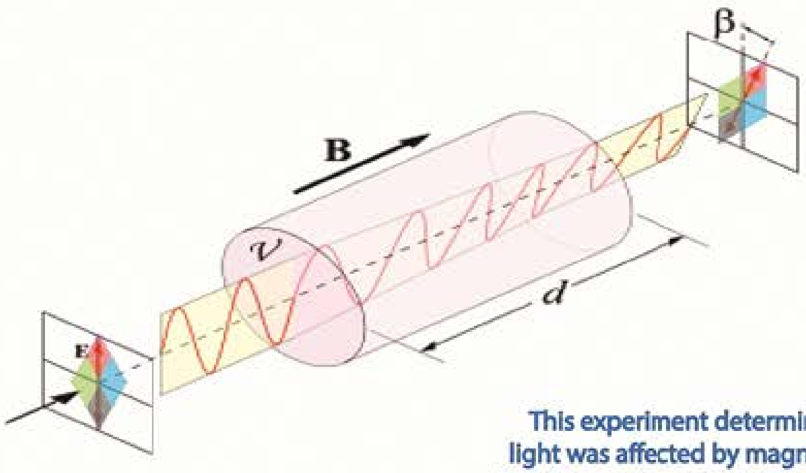

Discovered by Michael Faraday in 1845,
the Faraday effect was the first experimental
evidence that light and electromagnetism are related

Faraday summarized the entire effect as follows:

"Magnetic lines, then, in passing through silicated borate of lead, and a great number of other substances, cause these bodies to act upon a polarized ray of light when the lines are parallel to the ray, or in proportion as they are parallel to it: if they are perpendicular to the ray, they have no action upon it.

They give the diamagnetic the power of rotating the ray; and the law of this action on light is, that if a magnetic line of force be going from a north pole, or coming from a south pole, along the path of a polarized ray coming to the observer, it will rotate that ray to the right-hand; or, that if such a line of force be coming from a north pole, or going from a south pole, it will rotate such a ray to the left hand."

Michael Faraday

(22 September 1791 – 25 August 1867)

Evan's Photomagneton

A photon has a magnetic dipole.
It is an elementary magnet.
Evans discovery of the photon's
longitudinal magnetic field in
1992 is as significant, as Einstein's
discovery of relativity.

It helps in giving a physical
interpretation of wave mechanics,
two-slit interference
and the Faraday effect,

all accounted for in Tetryonic Theory.

This experiment determined that light was affected by magnetic force. This "magneto-optical effect" was later termed the Faraday effect.

Faraday experimented with other substances that yielded similar results.

The resultant effect he termed "diamagnetism" concluding that magnetism was an inherent property of all EM mass-ENERGY-Matter

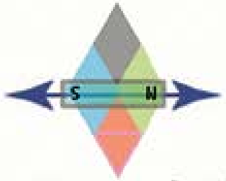

Before the
Magnetic field

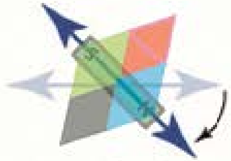

After the
Magnetic field

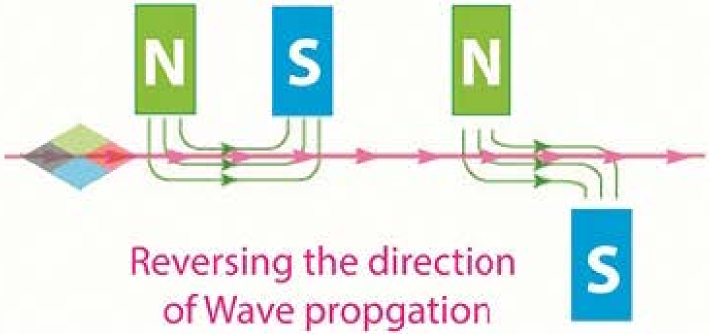

Reversing the direction
of Wave propgation
reverses the rotation
effected by the external
magnetic field

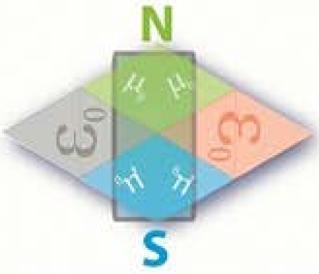

Every Photon and EM wave has polarised magnetic apexes as a result of the Planck quanta constituing them (creating Magnetic moments)

These Photo-Magnetic Moments allow for the interaction of Photons with external magnetic fields resulting in Faraday rotation of Photons and EM fields

Tetryonics 26.21 - Faraday rotation of Photons

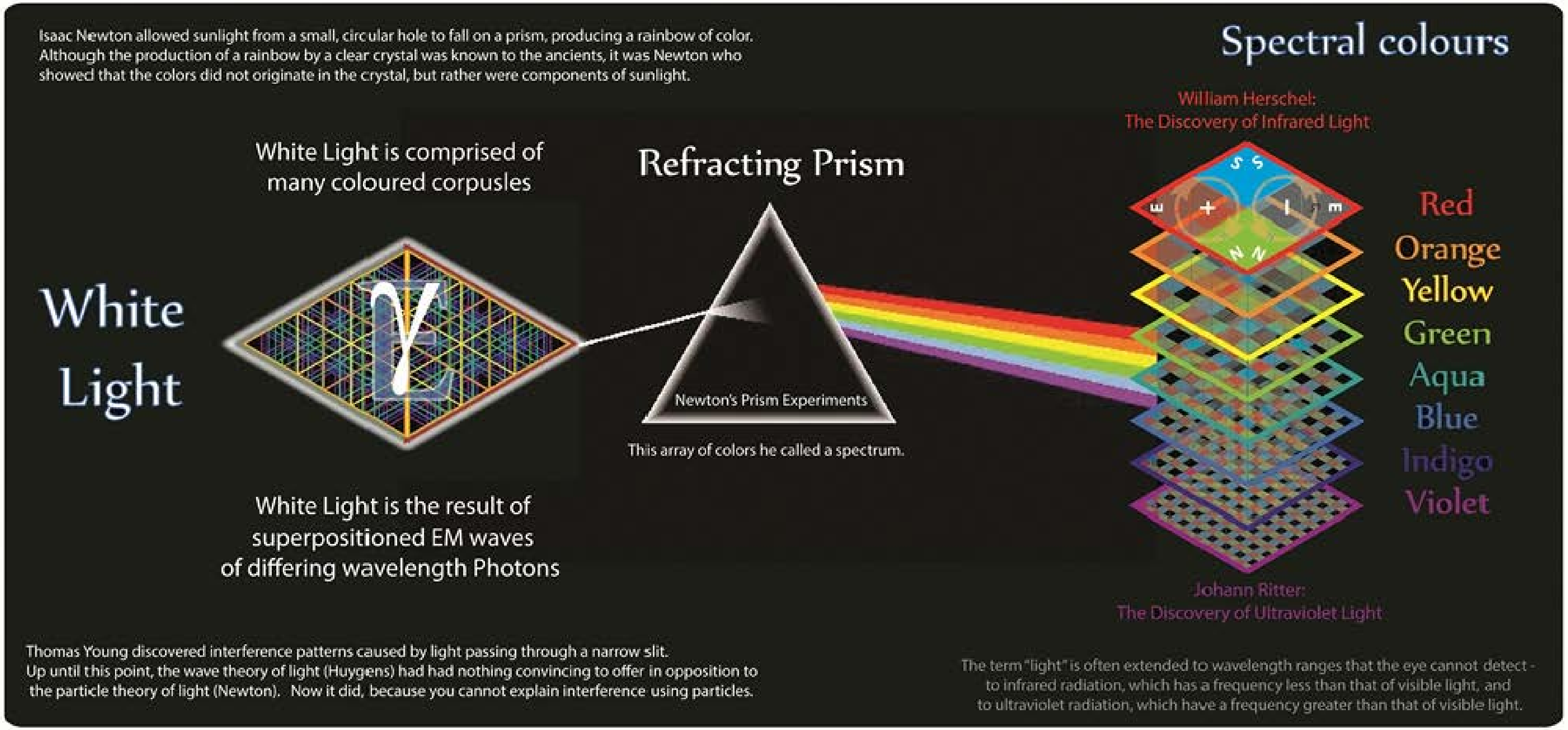

Isaac Newton allowed sunlight from a small, circular hole to fall on a prism, producing a rainbow of color. Although the production of a rainbow by a clear crystal was known to the ancients, it was Newton who showed that the colors did not originate in the crystal, but rather were components of sunlight.

Spectral colours

White Light is comprised of many coloured corpuscles

Refracting Prism

White Light is the result of superpositioned EM waves of differing wavelength Photons

This array of colors he called a spectrum.

White Light
William Herschel: The Discovery of Infrared Light
S S
E + - E
N N
Newton's Prism Experiments
Red
Orange
Yellow
Green
Aqua
Blue
Indigo
Violet
Johann Ritter: The Discovery of Ultraviolet Light

Thomas Young discovered interference patterns caused by light passing through a narrow slit. Up until this point, the wave theory of light (Huygens) had had nothing convincing to offer in opposition to the particle theory of light (Newton). Now it did, because you cannot explain interference using particles.

The term "light" is often extended to wavelength ranges that the eye cannot detect - to infrared radiation, which has a frequency less than that of visible light, and to ultraviolet radiation, which have a frequency greater than that of visible light.

Light has:

Velocity
Angular momenta
Frequency
Wavelength
Relativistic Energy
Linear momentum
Kinetic Energies
Magnetic Moment

and can

Refract
Reflect
Defract
and
Disperse

γ
Transverse Bosons
Probabilities
EM Wavefunction
Quantum levels
Longitudinal Photons
Ψ

All EM waves possess Wavefunctions describing their probabilistic energy properties

Tetryonics 27.01 - EM wavefunctions

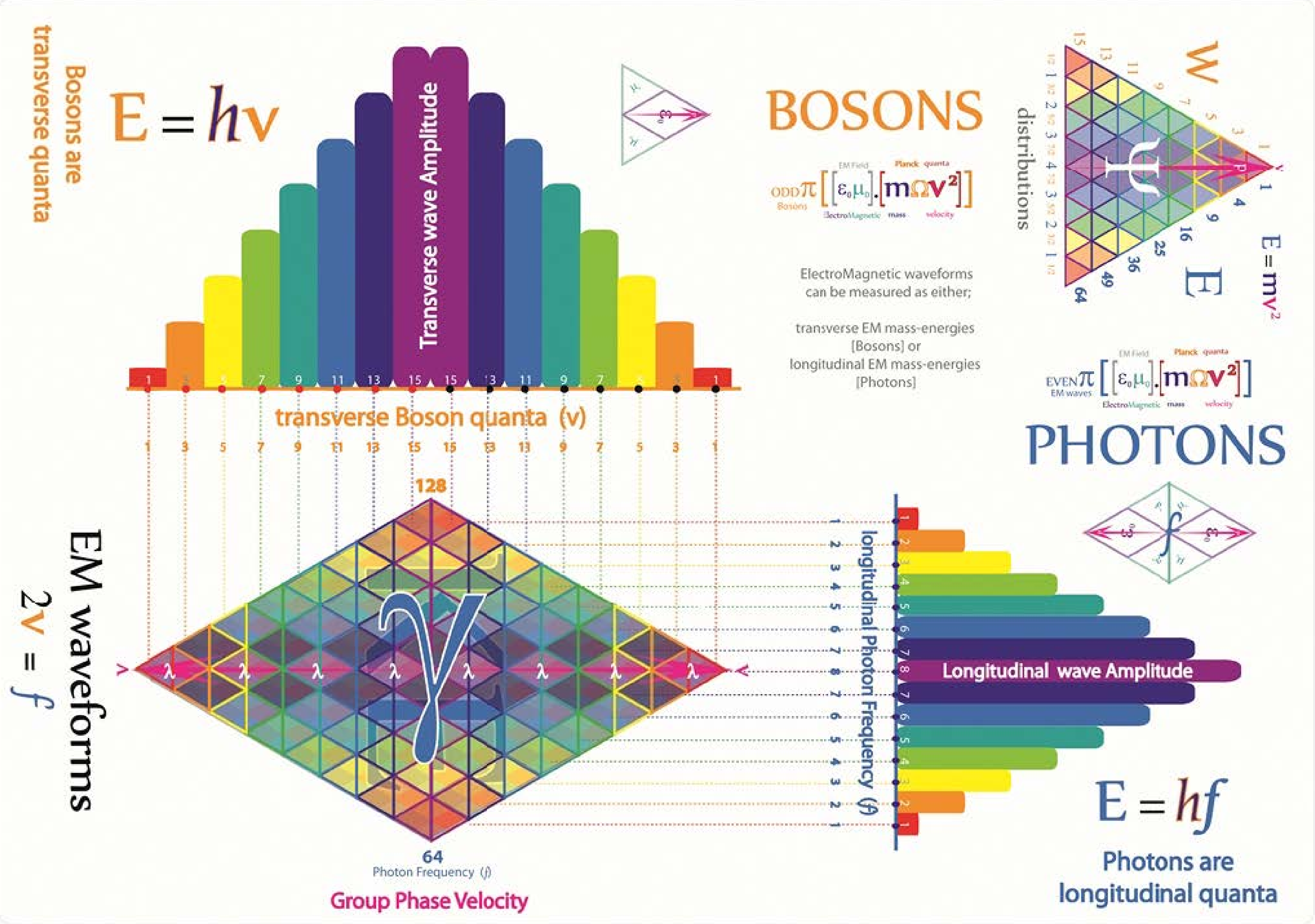
Bosons are transverse quanta
E = hv
Transverse wave Amplitude
1 3 5 7 9 11 13 15 15 13 11 9 7 5 3 1
transverse Boson quanta (v)
128
λ λ λ λ λ λ λ λ
γ
64
Photon Frequency (f)
Group Phase Velocity
EM waveforms
2v = f
longitudinal Photon Frequency (f)
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
Longitudinal wave Amplitude
ε₀ μ₀
W
Ψ
distributions
1 4 9 16 25 36 49 64
E
E = mv²
15 13 11 9 7 5 3 1
EM Field
Planck quanta
ElectroMagnetic
mass
velocity
Bosons
EM waves

BOSONS

$ODD\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

ElectroMagnetic waveforms can be measured as either;

transverse EM mass-energies [Bosons] or longitudinal EM mass-energies [Photons]

$EVEN\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

PHOTONS

E = hf

Photons are longitudinal quanta

Wavefunction probabilites

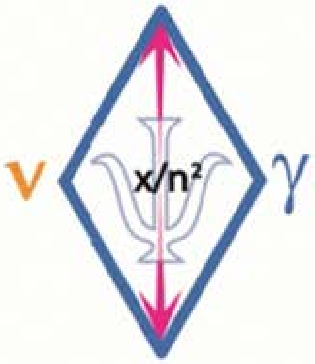

Wave Amplitude

Amplitude = bi-directional Momentum

Probability = $[\text{Amplitude}]^2$

In his 1926 paper, Max Born suggested that the wave function of Schrödinger's wave equation represents the probability density of finding a particle

Probability of finding a Photon in a electromagnetic wave is the Square of its Amplitude

The de Broglie-Schrodinger wave fields should not to be interpreted as a mathematical description of how an event actually takes place in time and space, though, of course, they have reference to such an event.

Rather they are a mathematical description of what we can actually know about the system. They serve only to make statistical statements and predictions of the results of all measurements which we can carry out upon the system.

(Albert Einstein, on Quantum Physics, 1940)

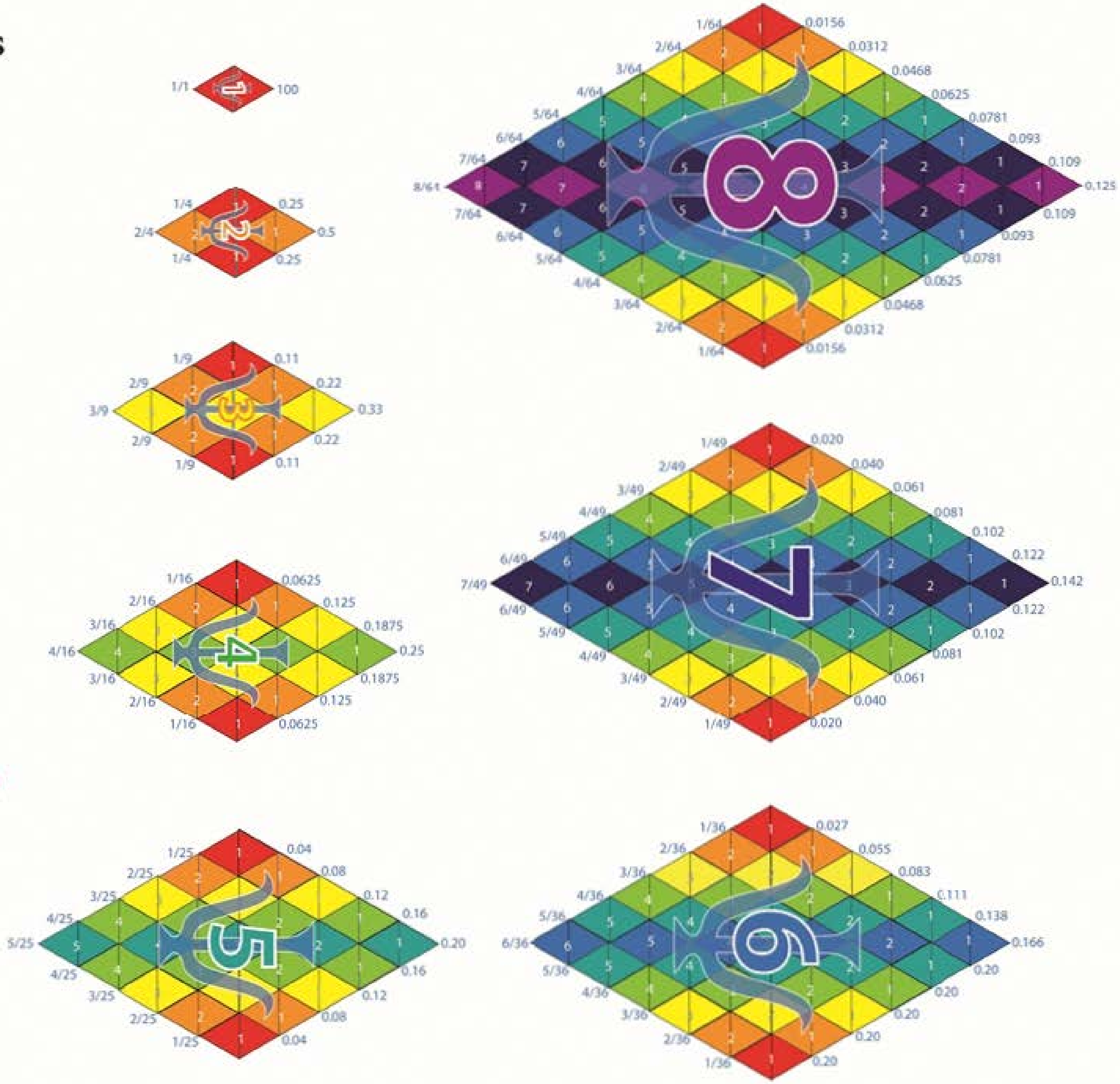
1/1
100
1
1/4
2/4
1/4
0.25
0.5
0.25
2
1/9
2/9
3/9
2/9
1/9
0.11
0.22
0.33
0.22
0.11
3
1/16
2/16
3/16
4/16
3/16
2/16
1/16
0.0625
0.125
0.1875
0.25
0.1875
0.125
0.0625
4
1/25
2/25
3/25
4/25
5/25
4/25
3/25
2/25
1/25
0.04
0.08
0.12
0.16
0.20
0.16
0.12
0.08
0.04
5
1/36
2/36
3/36
4/36
5/36
6/36
5/36
4/36
3/36
2/36
1/36
0.027
0.055
0.083
0.111
0.138
0.166
0.20
0.20
0.20
0.20
0.20
6
1/49
2/49
3/49
4/49
5/49
6/49
7/49
6/49
5/49
4/49
3/49
2/49
1/49
0.020
0.040
0.061
0.081
0.102
0.122
0.142
0.122
0.102
0.081
0.061
0.040
0.020
7
1/64
2/64
3/64
4/64
5/64
6/64
7/64
8/64
7/64
6/64
5/64
4/64
3/64
2/64
1/64
0.0156
0.0312
0.0468
0.0625
0.0781
0.093
0.109
0.125
0.109
0.093
0.0781
0.0625
0.0468
0.0312
0.0156
8

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EM radiation patterns

Quantum wavefunctions mathematically model the statistical probability distributions of electromagnetic mass-energy within EM waves

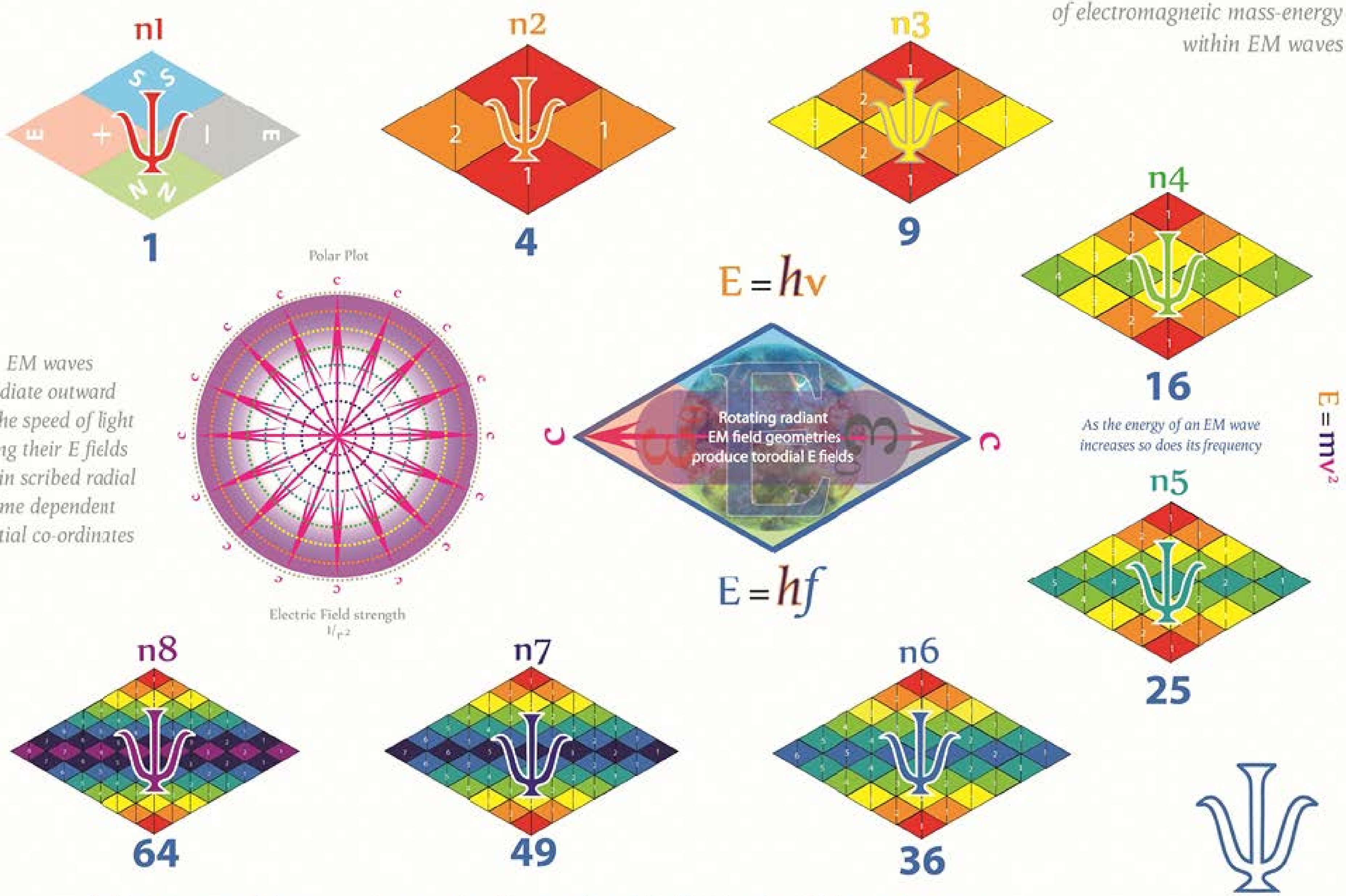
n1
S S
E + Ψ − E
N N
1
n2
2 1
1
4
n3
1 2 1 2 1 1
9
n4
16
n5
25
n6
36
n7
49
n8
64
Polar Plot
c
Electric Field strength $1/r^2$
$E = h\nu$
$E = hf$
$E = mv^2$
c c

EM waves radiate outward at the speed of light along their E fields within scribed radial time dependent spatial co-ordinates

Rotating radiant EM field geometries produce torodial E fields

As the energy of an EM wave increases so does its frequency

As the Energy and frequency increase, the Wavelengths of the Photons in a EM wave decreases

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EM wave geometry

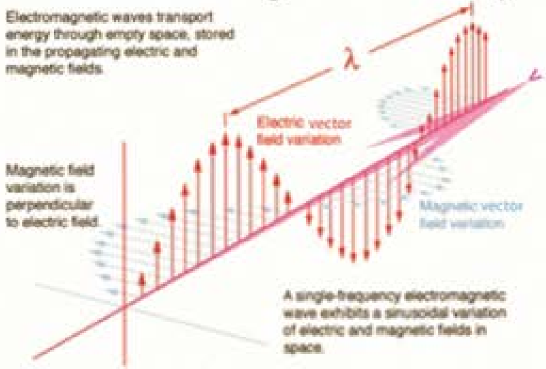

Electromagnetic waves transport energy through empty space, stored in the propagating electric and magnetic fields.

Magnetic field variation is perpendicular to electric field.

A single-frequency electromagnetic wave exhibits a sinusoidal variation of electric and magnetic fields in space.

λ
Electric vector field variation
Magnetic vector field variation

Bosons

$E = h\nu$

transverse mass-energies

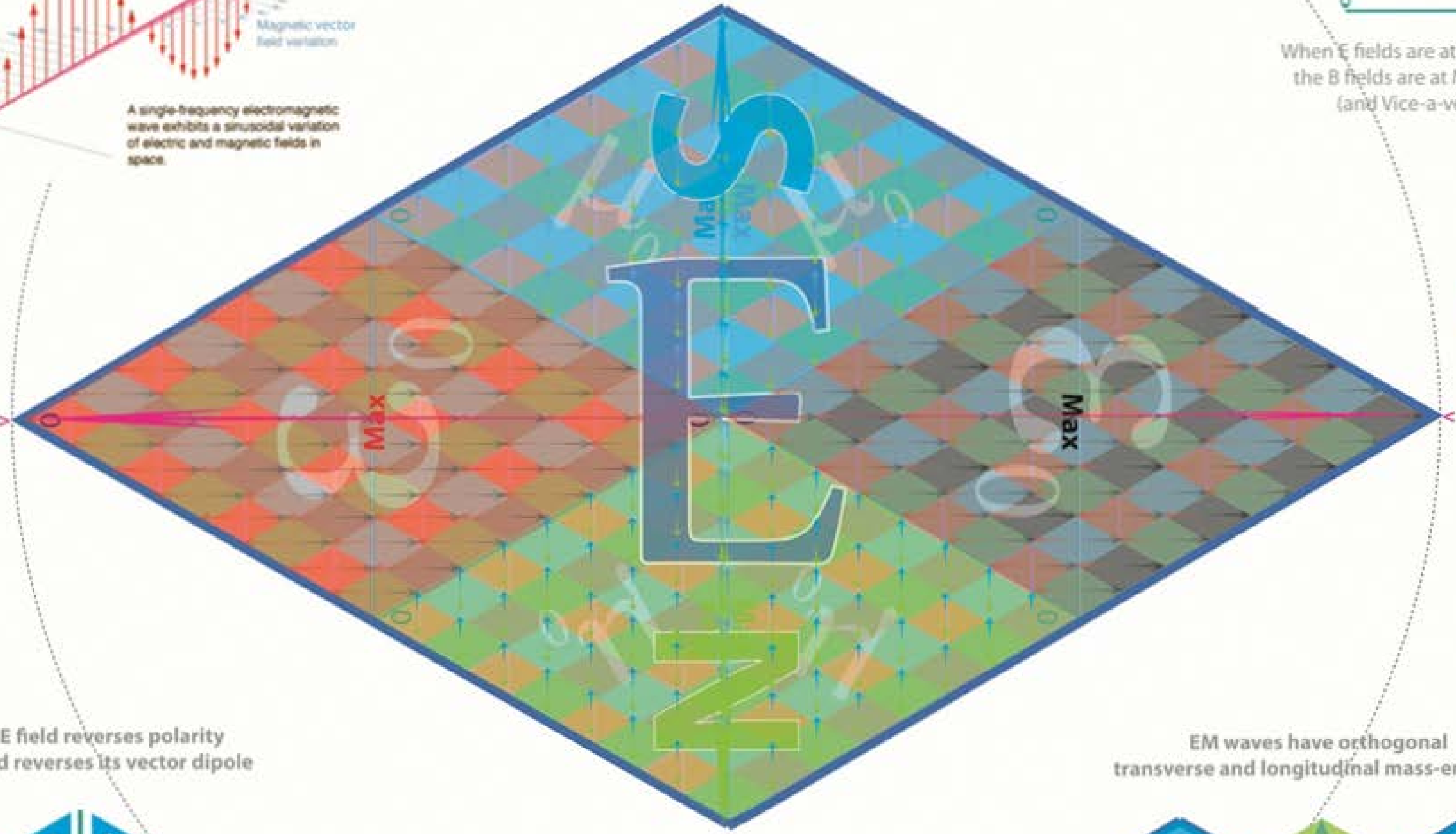
S
E
N
μ0
ε0
Max
0

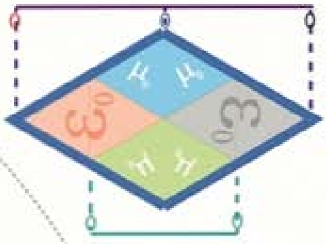

When E fields are at Maximum the B fields are at Minimum (and Vice-a-versa)

Photons

$E = hf$

longitudinal mass-energy frequency

$2v = f$

As the E field reverses polarity the M field reverses its vector dipole

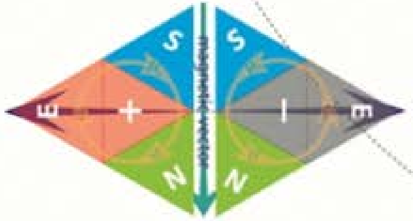
S
S
E
+
−
E
N
N
magnetic vector

E Field oscillations

EM waves are comprised of relativistic photons of mass-energy

$$RE = 2m\frac{v^2}{c^2}$$

EM waves have orthogonal transverse and longitudinal mass-energies

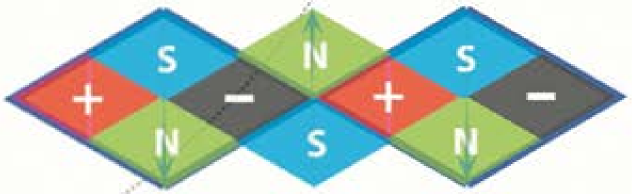

Tetryonics 27.05 - EM wave geometry

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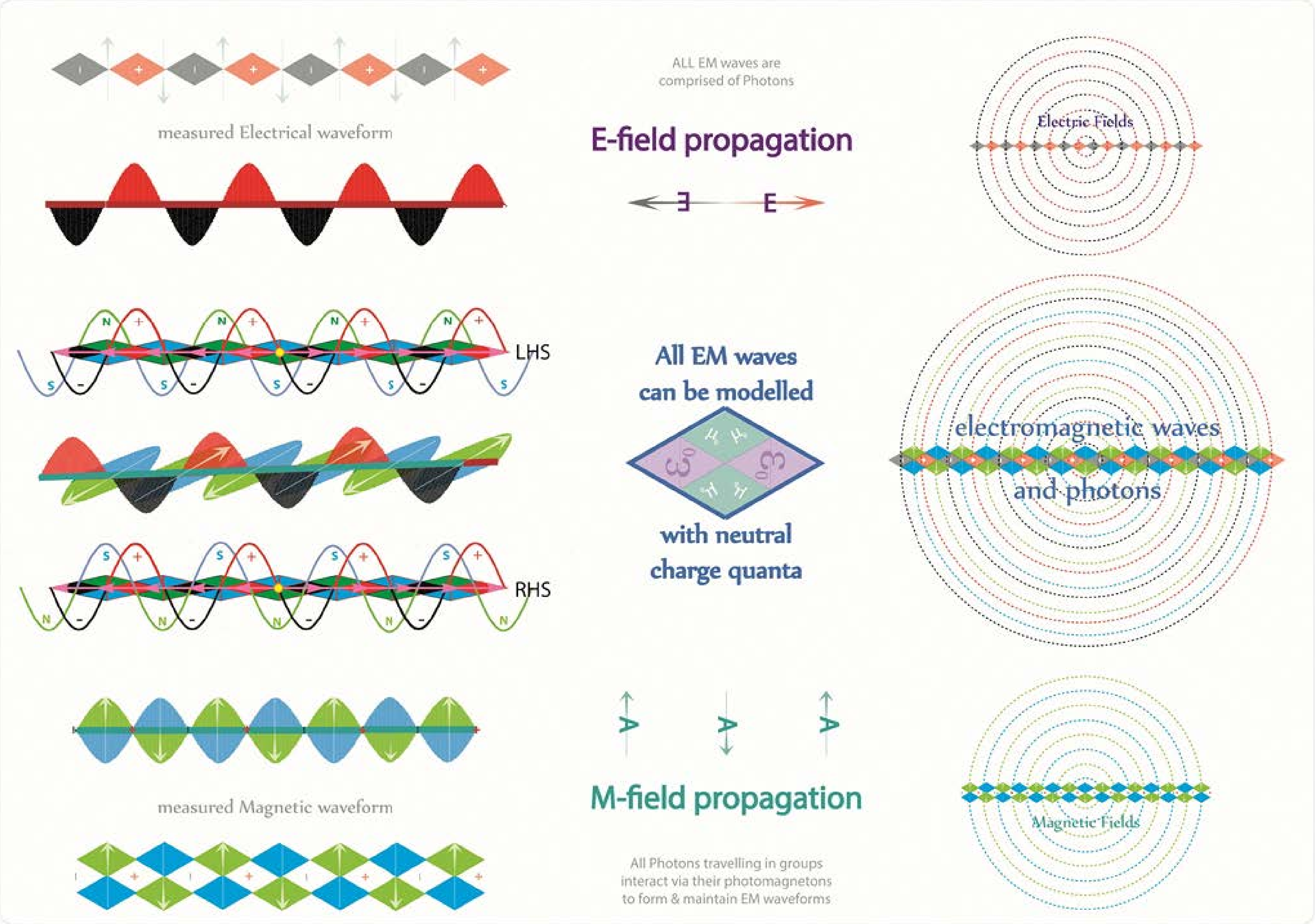
measured Electrical waveform
E
E
Electric Fields
N
S
LHS
RHS
electromagnetic waves
and photons
ε₀
μ₀
A
measured Magnetic waveform
Magnetic Fields

ALL EM waves are
comprised of Photons

E-field propagation

All EM waves
can be modelled
with neutral
charge quanta

M-field propagation

All Photons travelling in groups
interact via their photomagnetons
to form & maintain EM waveforms

Tetryonics 27.06 - E&M wave geometries

Energy momenta in EM waveforms

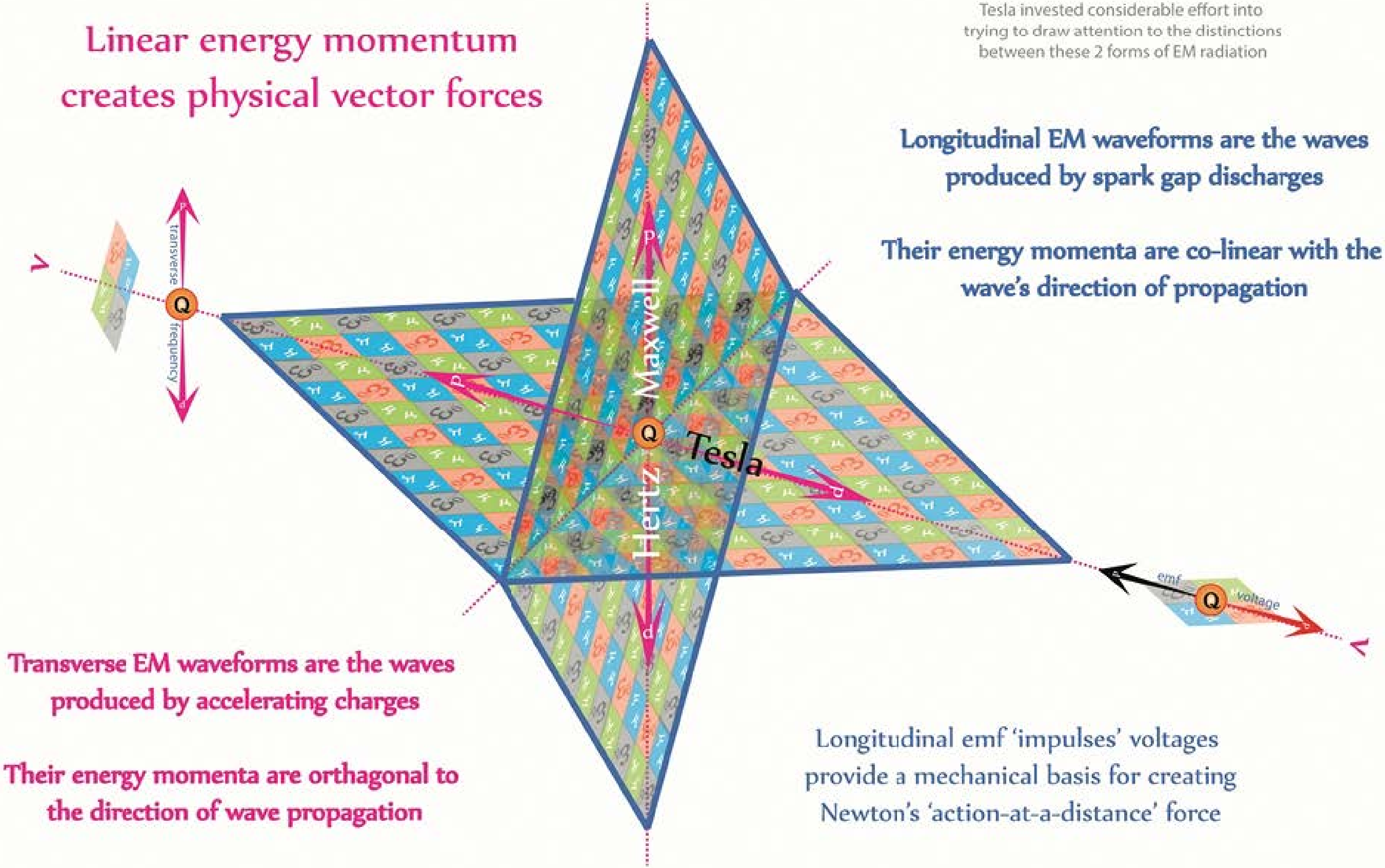

Linear energy momentum
creates physical vector forces

Tesla invested considerable effort into
trying to draw attention to the distinctions
between these 2 forms of EM radiation

Longitudinal EM waveforms are the waves produced by spark gap discharges

Their energy momenta are co-linear with the wave's direction of propagation

Transverse EM waveforms are the waves produced by accelerating charges

Their energy momenta are orthagonal to the direction of wave propagation

Longitudinal emf 'impulses' voltages
provide a mechanical basis for creating
Newton's 'action-at-a-distance' force

Tetryonics 27.07 - Energy momenta in EM waveforms

Producing Longitudinal EM waves

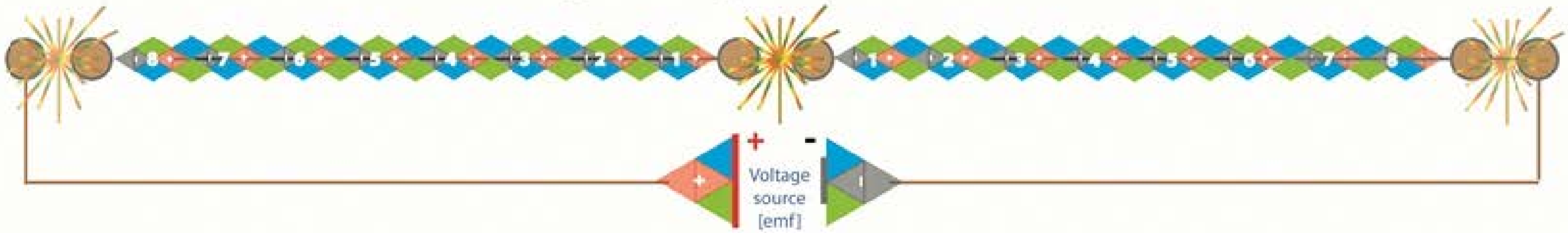

The short circuiting of voltage potentials or spark gap discharges of electrical energy are two ways to produce longitudinal EM waves

After inventing AC electricity
Nikola Tesla began to investigate
disruptive DC discharges

Orthagonal Magnetic fields produce reactive inductance fields

and he was convinced that this
form of EM energy would replace his
AC system and provide wireless
energy to the World without losses

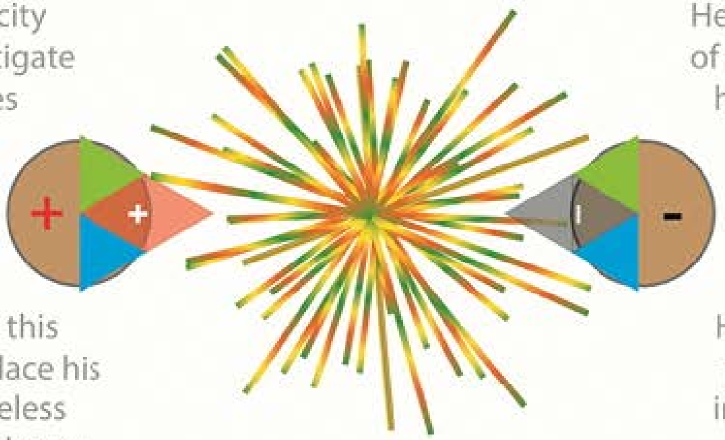

He noted the deadly power
of the spark discharges and
how they 'stung his face'

Longitudinal Electric fields produce lines of force

He strove to point out that
the load circuits must be
inductively coupled to the
transmission circuits

or a combination of the two

Very large Voltage

High frequency

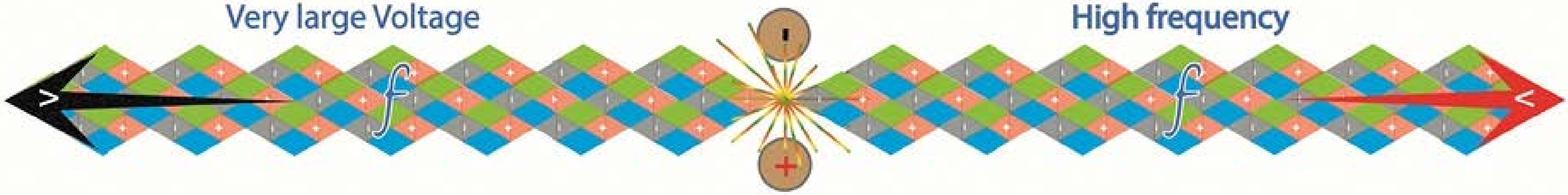

disruptive discharges

Longitudinal energy momenta

Maxwell's equations lead to the prediction of transverse electromagnetic waves as a means of transefering electrical power (where the wave's Electric fields and Magnetic fields vary perpendicularly to their direction of propagation).

Longitudinal Photons & EM waves are 2D electromagnetic waveforms with co-planar energy momenta that is co-linear with their directions of propagation and that can 'cut like a knife'

Longitudinal energy momenta waves [created by the use of spark gap technologies] are the EM energy forms created and radiated by Stars

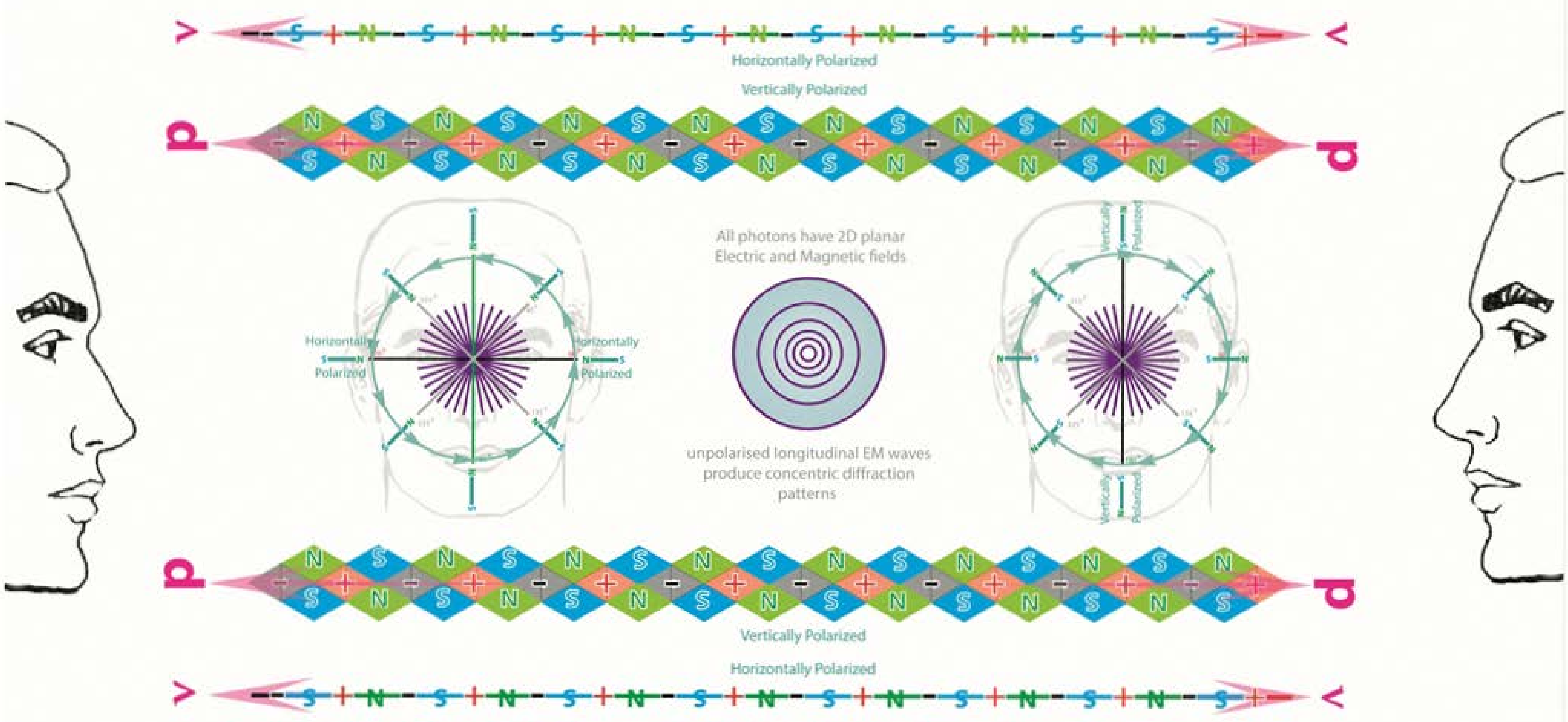
v
v
Horizontally Polarized
Vertically Polarized
p
p
Horizontally Polarized
Horizontally Polarized
Vertically Polarized
Vertically Polarized
p
p
Vertically Polarized
Horizontally Polarized
v
v

All photons have 2D planar Electric and Magnetic fields

unpolarised longitudinal EM waves produce concentric diffraction patterns

The longitudinal alignment of E field momenta with their direction of propagation produces 'action-at-a-distance' and can produce material 'faster than light' velocities, if sufficient energies are inputted

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The velocity of Electrical energy momenta

The velocity of light is the limit for electrical energy acceleration

(the induced velocity of charged particles resulting from electric field energy-momenta interactions)

c

Transverse EM waves
propagate at energy at
the speed of light

Γ

Longitudinal EM waves
can propagate energies & information
in excess of the speed of light

470,912,891 m/s

463,491,072 km/second

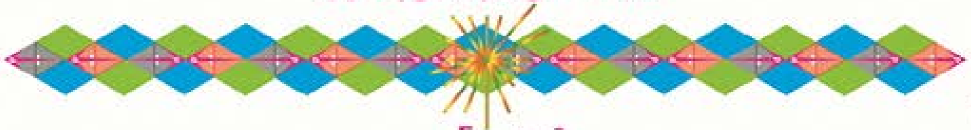

288,000 miles/second

$v = [\pi/2]c$

Longitudinal electrical fields
can create near-instantaneous
'action-at-a-distance' EM fields

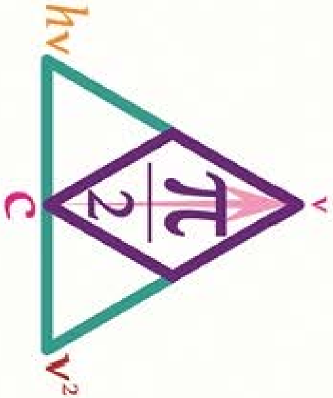

once established, these fields can
transfer momentum and information
at speeds faster than light through
co-linear impulses of momentum

Wheatstone achieved renown by a great experiment
The measurement of the velocity of electrical Energy in a wire.

He cut the wire at the middle, to form a gap which a spark might leap across, and connected its ends to the poles of a Leyden jar filled with electricity. Three sparks were thus produced, one at either end of the wire, and another at the middle. He mounted a tiny mirror on the works of a watch, so that it revolved at a high velocity, and observed the reflections of his three sparks in it.

The points of the wire were so arranged that if the sparks were instantaneous, their reflections would appear in one straight line; but the middle one was seen to lag behind the others, because it was an instant later. The electricity had taken a certain time to travel from the ends of the wire to the middle.

This time was found by measuring the amount of lag, and comparing it with the known velocity of the mirror. Having got the time, he had only to compare that with the length of half the wire, and he could find the velocity of electricity.

His results gave a calculated velocity of 288,000 miles per second,
i.e. faster than what we now know to be the speed of light

Charles Wheatstone

(6 February 1802 – 19 October 1875)

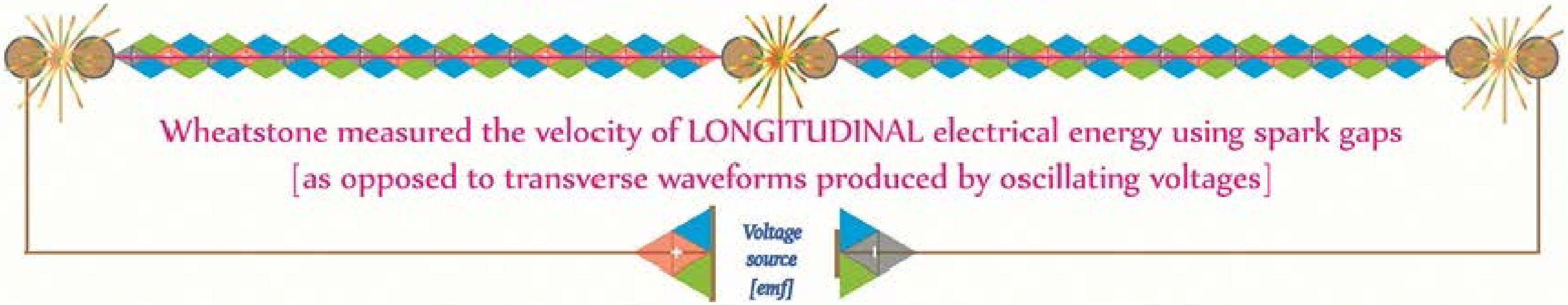

Wheatstone measured the velocity of LONGITUDINAL electrical energy using spark gaps
[as opposed to transverse waveforms produced by oscillating voltages]

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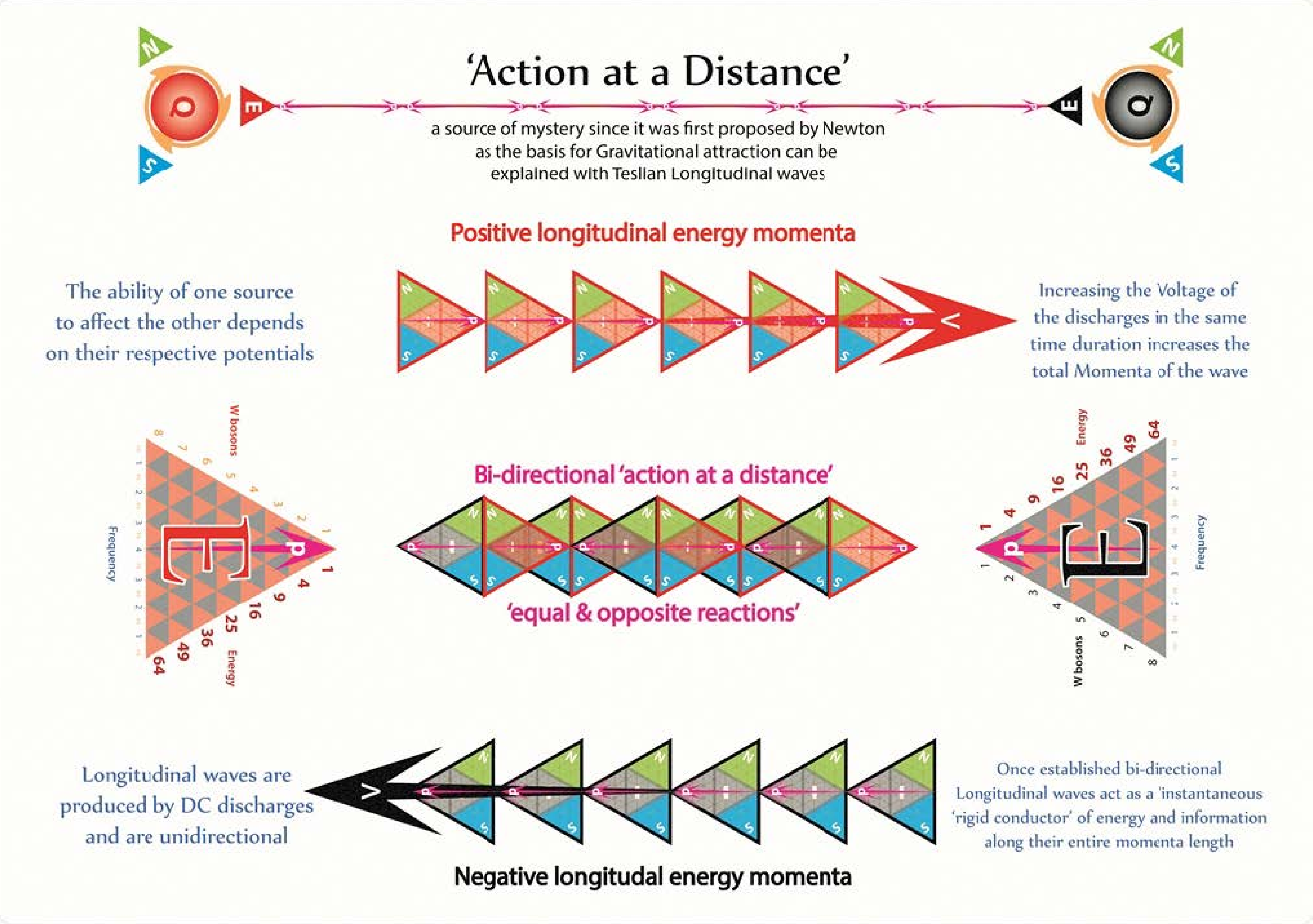

'Action at a Distance'

a source of mystery since it was first proposed by Newton
as the basis for Gravitational attraction can be
explained with Teslian Longitudinal waves

Positive longitudinal energy momenta

The ability of one source
to affect the other depends
on their respective potentials

Increasing the Voltage of
the discharges in the same
time duration increases the
total Momenta of the wave

Bi-directional 'action at a distance'

'equal & opposite reactions'

Longitudinal waves are
produced by DC discharges
and are unidirectional

Once established bi-directional
Longitudinal waves act as a 'instantaneous
'rigid conductor' of energy and information
along their entire momenta length

Negative longitudal energy momenta

Tetryonics 27.11 - Longitudinal 'action at a distance'

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Longitudinal EM waves have their E-fields co-linear with their direction of propagation

Longitudinal Photons & EM waves are produced by disruptive spark gap discharges

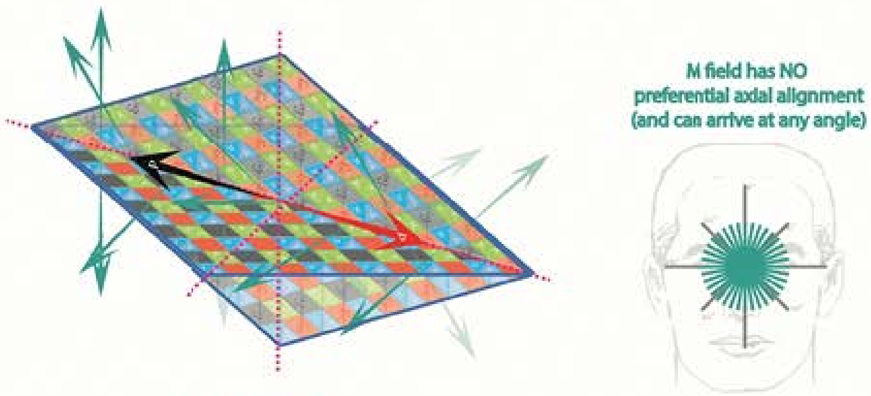
M field has NO
preferential axial alignment
(and can arrive at any angle)

Un-Polarised

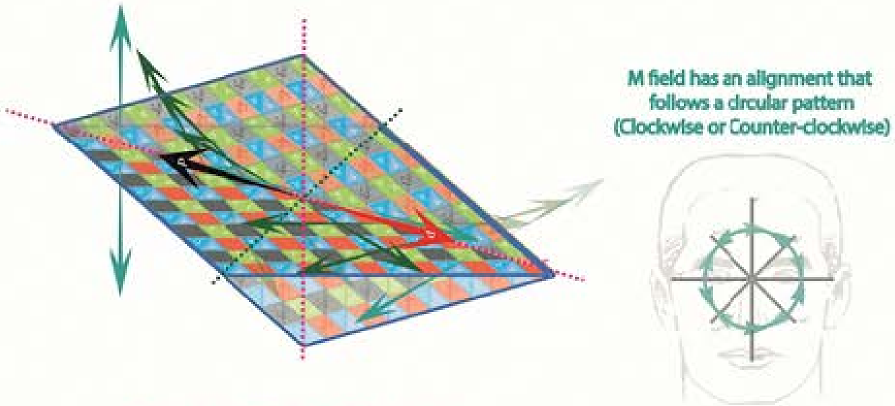
M field has an alignment that
follows a circular pattern
(Clockwise or Counter-clockwise)

Circularly (or Elliptically) Polarised

Longitudinal wave polarisations

emf
Q
voltage

As a convention, the polarization of longitudinal EM waves must be described by specifying the orientation of the wave's magnetic field at a point in space over one period of the oscillation

Longitudinal waves have their linear momenta aligned along their direction of propagation and are extremely efficient at accelerating charges they interact with, creating co-linear accelerations [parallel to their direction of field propagation] - they do not produce charge oscillations along their vector direction of propagation like transverse waves.

Examples of transverse waves include seismic P (primary) waves, and Tesla's longitudinal 'stinging' rays, whose electric fields and energy momenta are both co-linear with each other and parallel to the direction of energy transfer.

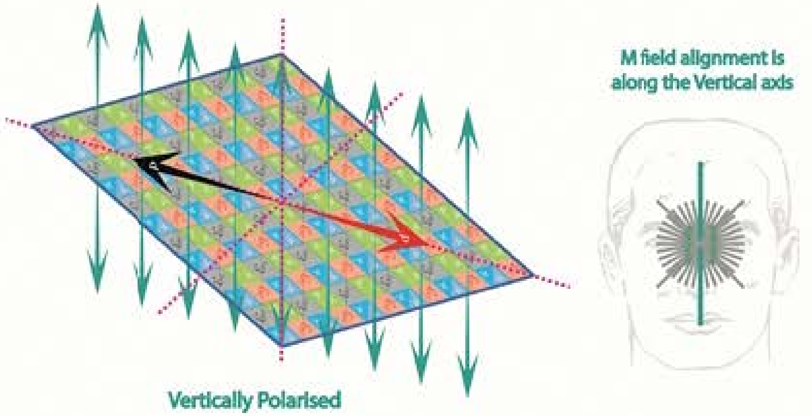
M field alignment is
along the Vertical axis

Vertically Polarised

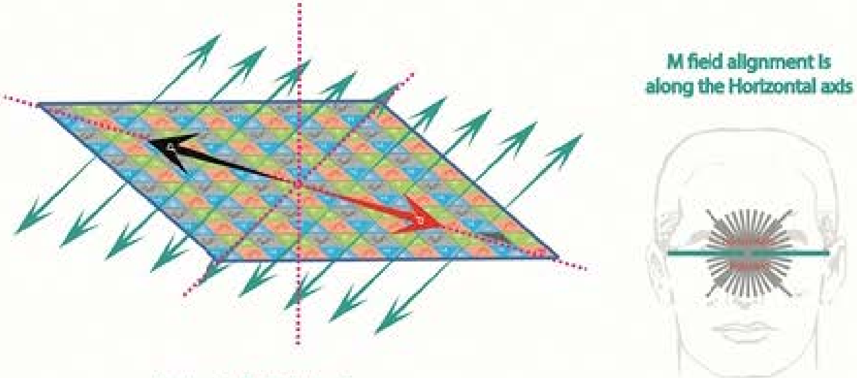
M field alignment is
along the Horizontal axis

Horizontally Polarised

Tetryonics 27.12 - Longitudinal wave polarisation

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ElectroMagnetic waveforms

In Teslian longitudinal waves, produced by disruptive EM discharges, the E fields are co-linear with the direction of propagation

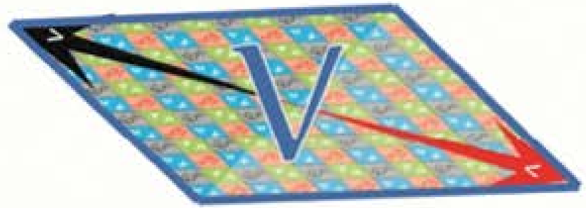

After inventing AC electricity Tesla investigated transferring energy through the air via electrostatic longitudinal waves to receiving devices. and noted the differing 'lethality' of the forces produced by these waves

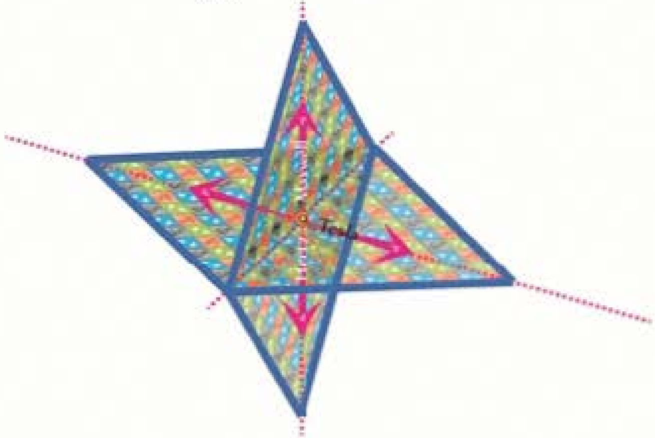

Although comprised of the same energy momenta quanta
EM waves can be formed with Electric fields perpendicular to each other
thus leading to conflicting theories of EM wave propagation

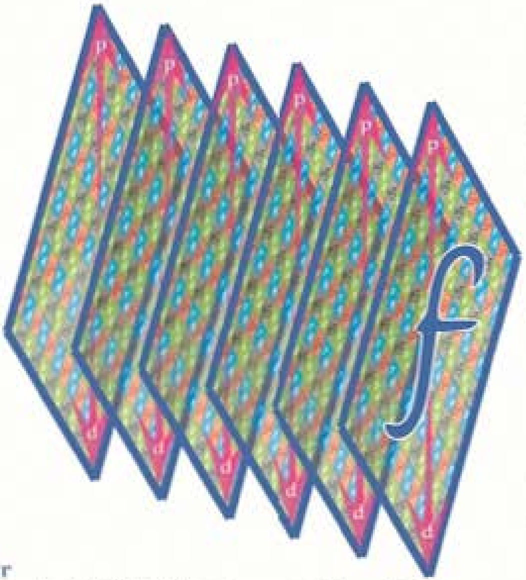

Hertzian transverse waveforms have their EM fields perpendicular to the direction of propagation

In 1887, Heinrich Hertz demonstrated the reality of Maxwell's electromagnetic waves by experimentally generating radio waves in his laboratory

T

Teslian waves transmit Energy in a LONGITUDINAL waveform producing 'action-at-a-distance'

Nikola Tesla

(10 July 1856 - 7 January 1943)

Volt Seconds [per metre²]

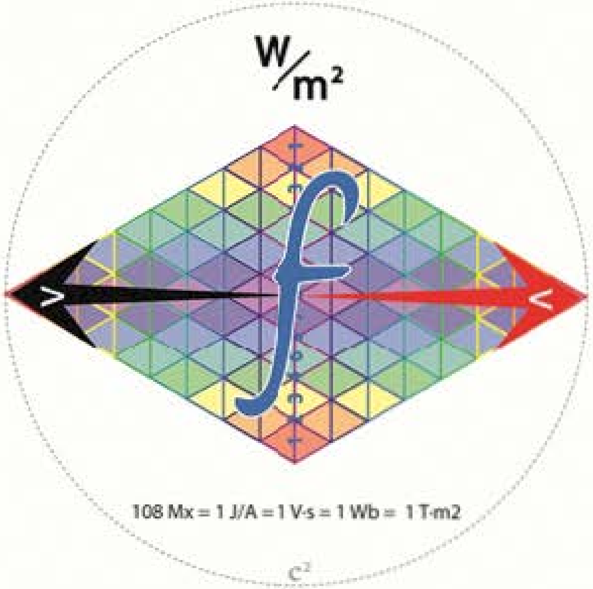

108 Mx = 1 J/A = 1 V·s = 1 Wb = 1 T·m2

$\frac{c^2}{\text{sec}}$

Heinrich Hertz

(22 Feburary 1857 - January 1 1894)

Hz

Hertzian waves transmit Energy in a TRANSVERSE waveform producing 'radio waves'

Cycles per Second

Soon after Hertz's claim of discovering Maxwell's transverse EM waves Tesla visited him and personally demonstrated the experimental error to him. Hertz agreed with Tesla and had planned to withdraw his claim, but varying agendas intervened and set the stage for a major rift in the 'accepted' theories

Transverse EM waves have their E&M fields orthogonal with their direction of propagation

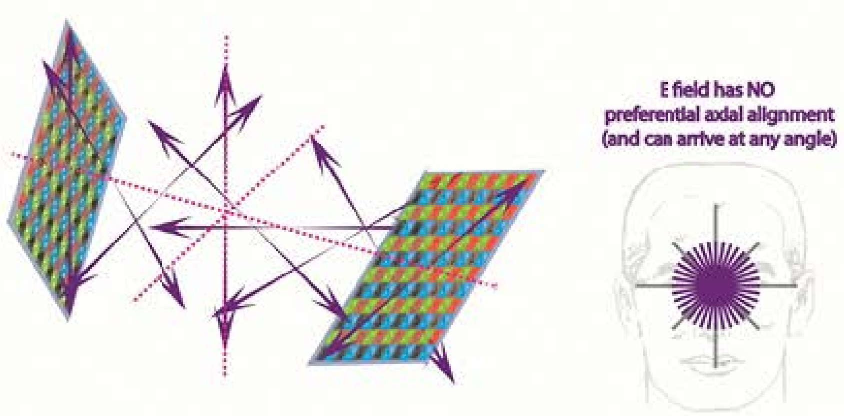

E field has NO
preferential axial alignment
(and can arrive at any angle)

Un-Polarised

Transverse Photons & EM waves are produced by accelerating/oscillating charges

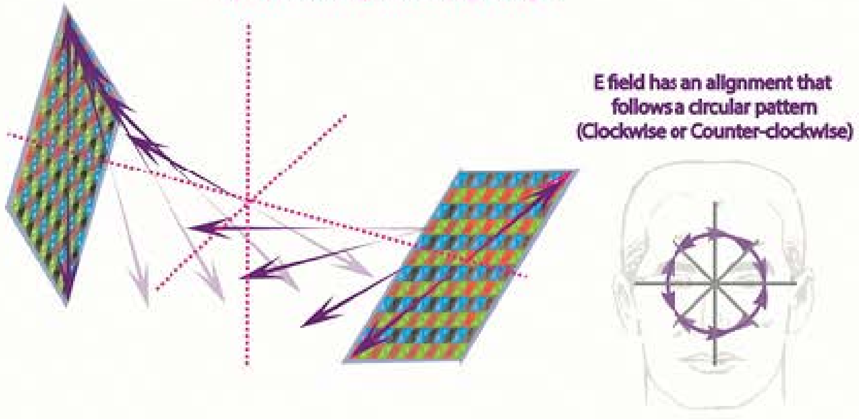

E field has an alignment that
follows a circular pattern
(Clockwise or Counter-clockwise)

Circularly (or Elliptically) Polarised

transverse
Q
frequency

Transverse wave polarisations

By convention, the polarization of EM waves is described by specifying the orientation of the wave's electric field at a point in space over one period of the oscillation

Transverse waves are inefficient propagators of EM energy as they apply their linear momenta tangentially to the charges they interact with, creating lateral accelerations [orthogonal to their direction of field propagation] - they do not accelerate charges along their vector direction of propagation like longitudinal waves.

Examples of transverse waves include seismic S (secondary) waves, and electromagnetic plane wave, whose electric (E) and magnetic (M) fields both oscillate perpendicular to each other and orthogonal to the direction of energy transfer.

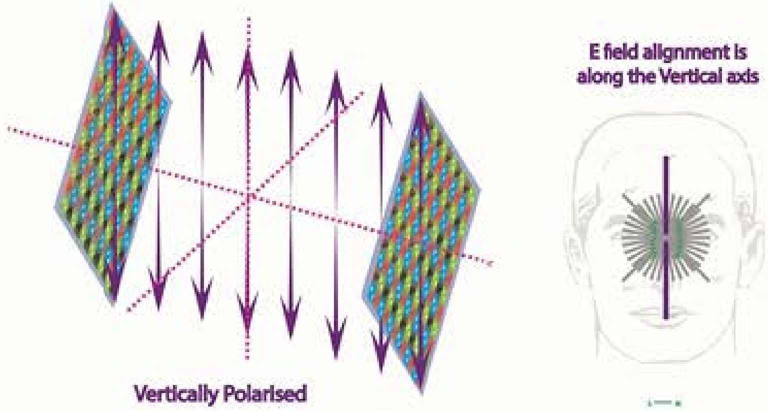

E field alignment is
along the Vertical axis

Vertically Polarised

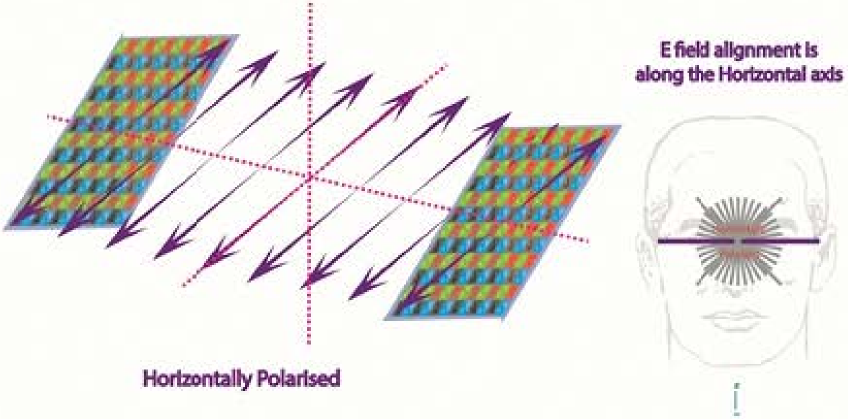

E field alignment is
along the Horizontal axis

Horizontally Polarised

Tetryonics 27.14 - Transverse wave polarisation

EM wave modulations

In telecommunications, modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal which typically contains information to be transmitted

Amplitude modulation

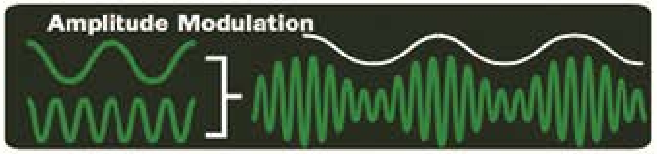
Amplitude Modulation

the amplitude of the carrier signal is varied

In addition to planar Hertzian waves
there exists Longitudinal EM waves

Impulse propagation

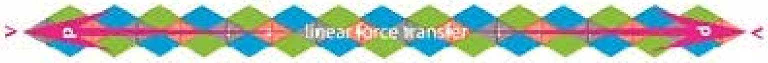
linear force transfer

As the voltage [energy/coulomb] of longitudinal waves increases their co-linear energy-momenta increase and these forces provide a mechanical basis for near instantaneous 'action-at-a-distance'

Impulse propagation is distinct from pulse modulations

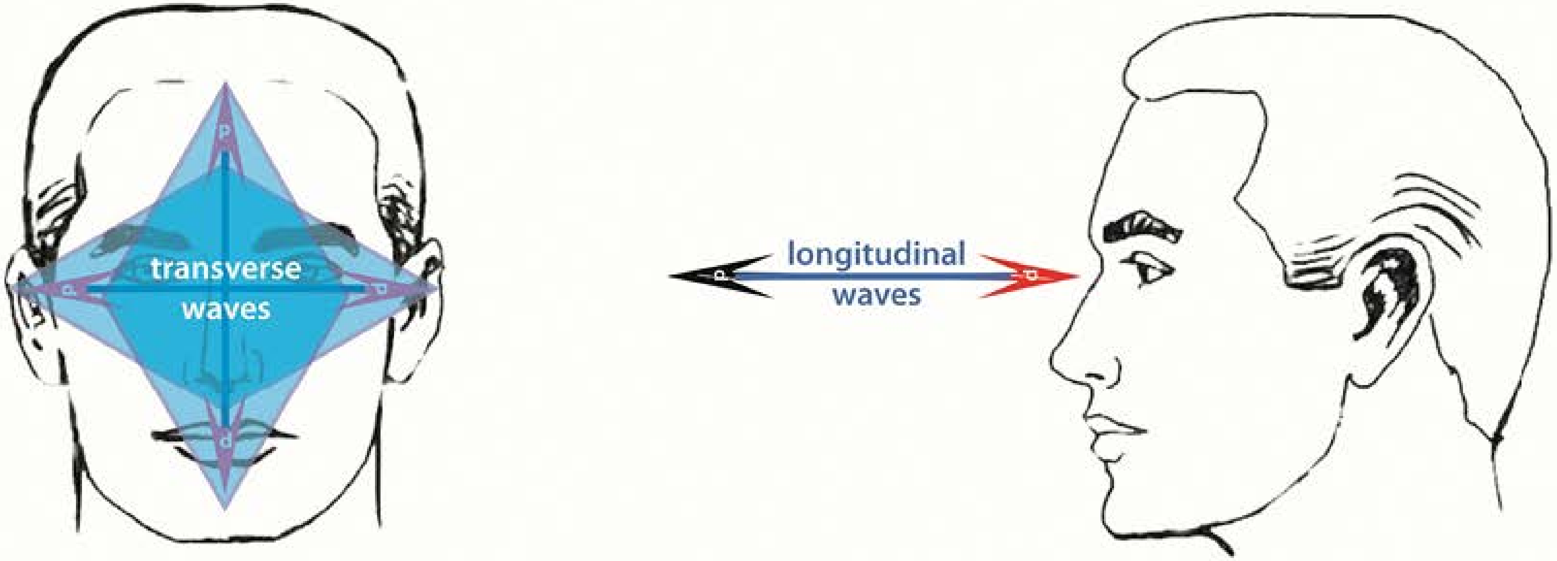
transverse
waves
longitudinal
waves

the frequency of the carrier signal is varied

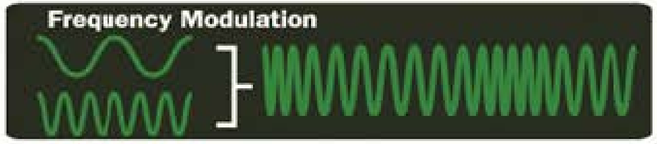
Frequency Modulation

Frequency modulation

a narrowband analog signal is pulsed over an analog baseband channel

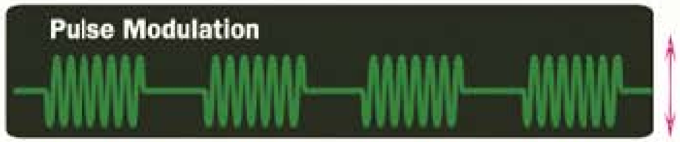
Pulse Modulation

PCM Pulsed modulation TDM

Transverse EM wave production

Alternating the Voltage potentials in an electrical circuit produces an Alternating Current
of electrons with Kinetic EM energies reflective of the Time-Energy duration of the AC circuit

Kinetic Energies from motion
(diverge from rest Matter)

**Alternating Voltages provide an electromotive force to Electrically charged Particles
producing tranverse Kinetic Energy fields with orthagonal Magnetic fields**

$F=ma$

Kinetic
Matter

$$\sum \mathbf{F} = \frac{d\mathbf{p}}{dt} = m\frac{d\mathbf{v}}{dt} + \mathbf{v}\frac{dm}{dt}$$

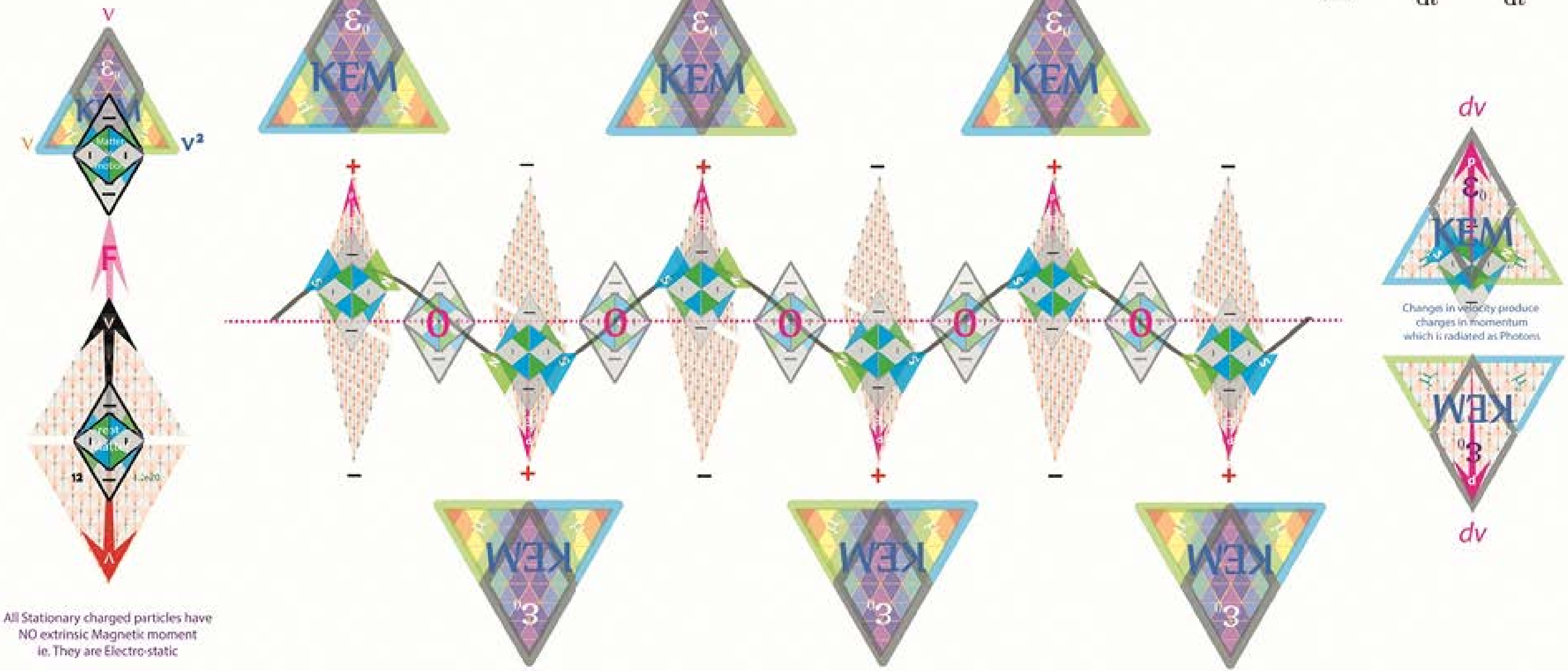

Changes in velocity produce
changes in momentum
which is radiated as Photons

All Stationary charged particles have
NO extrinsic Magnetic moment
ie. They are Electro-static

Charges with constant velocities
produce
REACTIVE [K]EM FIELDS

**Any change to the momentum of a charged particle in motion
requires a corresponding quantum level energy-momentum change through the
emission/absorption of quantised EM mass-ENERGY momenta in the form of W bosons**

Accelerating Charges
produce
RADIANT EM WAVES

Tetryonics 27.16 - Transverse EM wave production

Modelling of planar transverse waves

(of varying amplitudes)

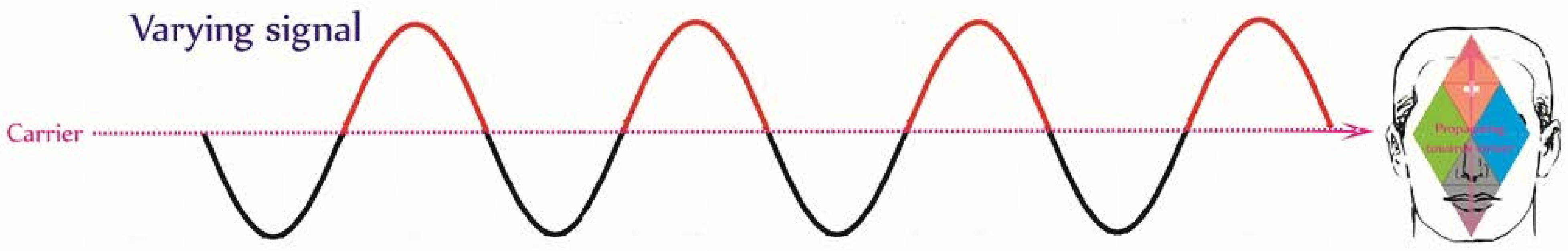
Varying signal
Carrier
Propagating

AM waveform

Amplitude Modulation (AM) works by varying the strength of the transmitted signal in relation to the information being sent.

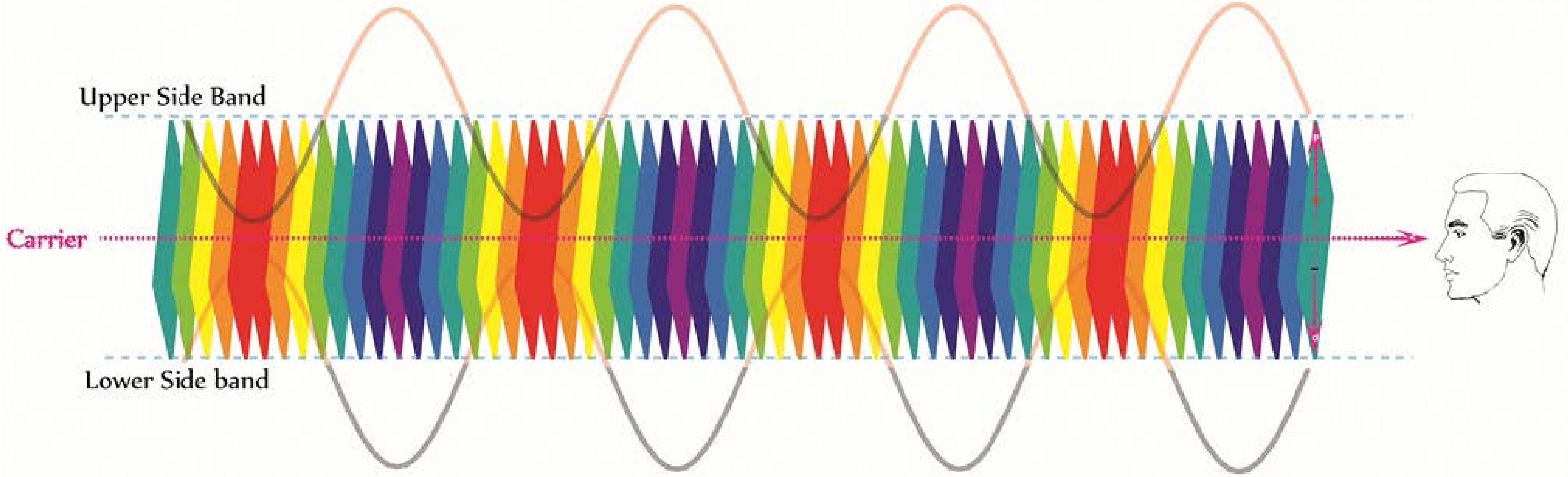
Upper Side Band
Carrier
Lower Side band

Note: In amplitude modulation each colour planar wave contains differing energy momenta [n1-red to n8-violet]

Tetryonics 27.17 - Amplitude Modulation

Modelling of planar transverse waves
(of the same frequencies)

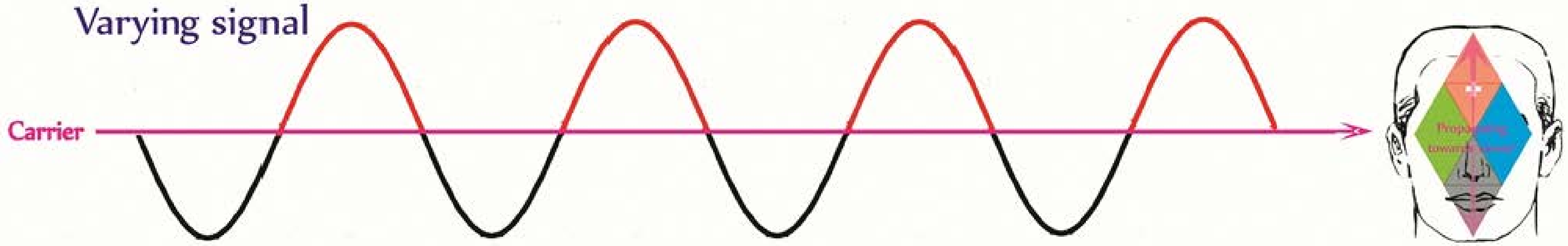

FM waveform

Frequency modulation (FM) is a form of modulation which conveys information over a carrier wave by varying its frequency (in contrast with amplitude modulation, in which the amplitude of the carrier is varied while its frequency remains constant).

In analog applications, the instantaneous frequency of the carrier is directly proportional to the instantaneous value of the input signal

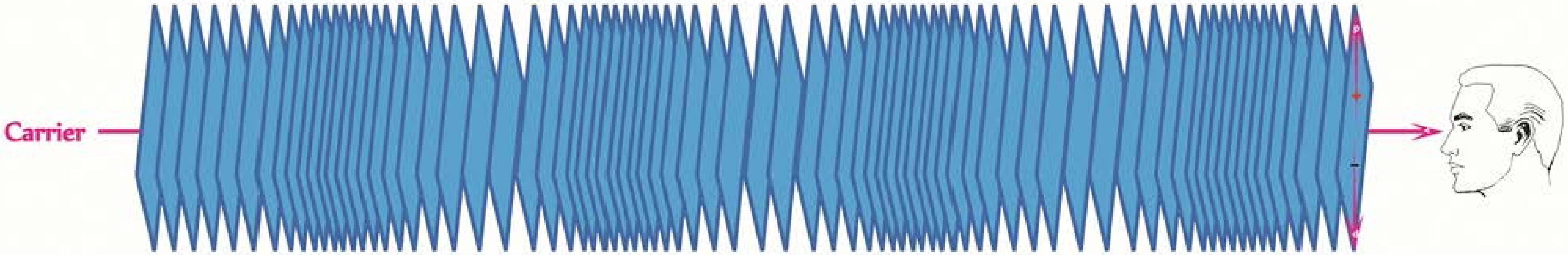

Note: In Frequency modulation all the planar waves have the same energy momenta [only the number of waves per sec varies]

ElectroMagnetic waves

Mathematics alone [without a correct foundational geometry] is insufficent to describe EM radiation
EM waves can be Longitudinal or Transverse with respect to their direction of propagation

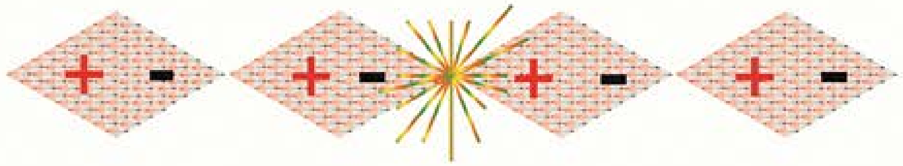

Tesla

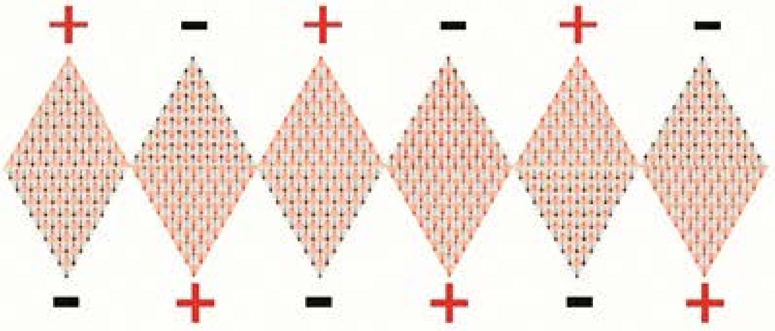

Maxwell - Hertz

It is now clear [using Tetryonic geometry] that both Tela and Maxwell were correct in their opposing theories of EM waveforms
with Tesla proposing Longitudinal waves [from experiment] and Maxwell proposing Transverse waves [from his equations].

The differing opinions on the EM waveforms is shown to be a direct result of the sources of EM wave generation employed in their creation.
After the discovery of the photo-electric effect Hertz and others moved to oscillating charges to produce Transverse [planar] waves
while Tesla continued to investigate and utilise the older spark gap technology to produce Longitudinal waves

**Spark Gaps & Plasma discharges
produce
longitudinal EM radiation**

**Accelerating charges
produce
transverse EM radiation**

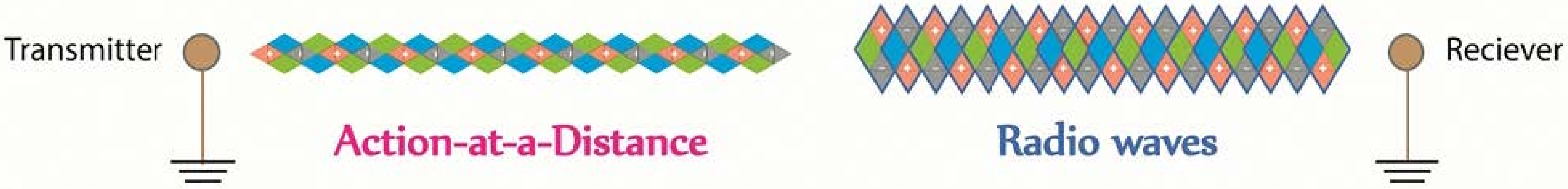

In order to explain and advance our understanding of all EM phenomena we must return to, and utilise, the older discharge technologies

Planar electromagnetic waves

In the physics of wave propagation, a plane wave (also spelled planewave) is a wave whose wavefronts are infinite parallel planes of peak-to-peak amplitude normal to the phase velocity vector.

transverse Radio waves

longitudinal Spectral lines

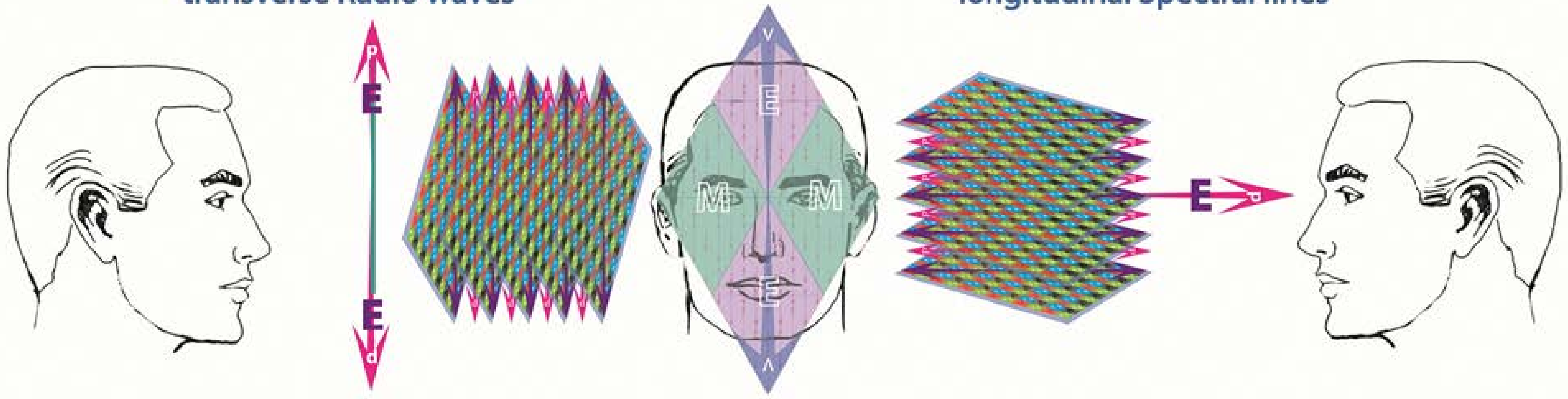
E
P
E
P
V
E
M
M
E
V
E
P

The phase relationships of their EM energy momenta can all be finally visualised and drawn through Tetryonic theory geometries

[with appropriate radian units]

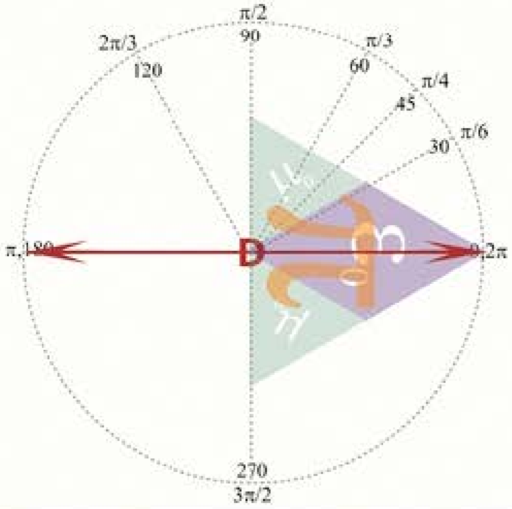
π/2
90
2π/3
120
π/3
60
π/4
45
π/6
30
π,180
0,2π
D
270
3π/2

bosons $2\pi[h\nu] = hf$ photons

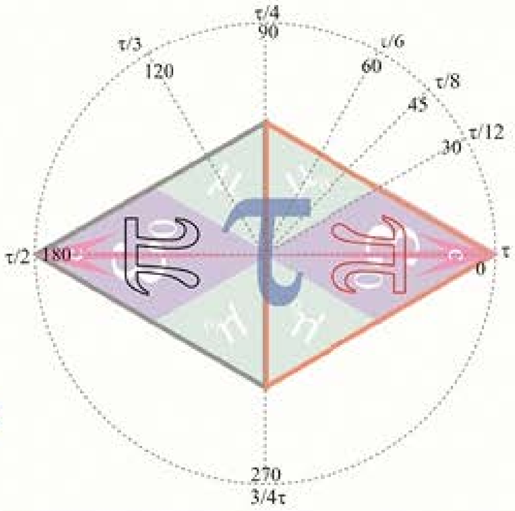
τ/4
90
τ/3
120
τ/6
60
τ/8
45
τ/12
30
τ/2
180
τ
0
τ
270
3/4τ

τ is a more 'natural' radian unit for describing EM waves than π

tau = 2π = 360 degree rotation about a point

Lorentz co-ordinate transforms

In physics, the Lorentz transformation (or transformations) are named after the Dutch physicist Hendrik Lorentz.

The transformations describe how measurements of mass-energies in space and time by two observers are related through mathematics

It was the result of attempts by Lorentz and others to explain how the speed of light was observed to be independent of the reference frame, and to understand the symmetries of the laws of electromagnetism.

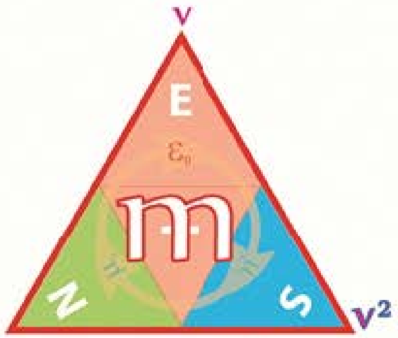

All photons are comprised of two dual-sided equilateral Planck quanta

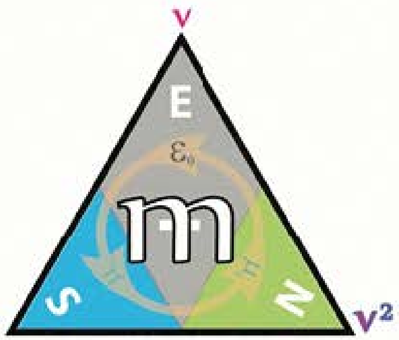

All EM waves are comprised of neutral charge quanta called Photons

Photons are comprised of mass-energies and the term 'mass-less' is not appropriate

Forces add mass-energies to KEM fields resulting in WAVElength changes

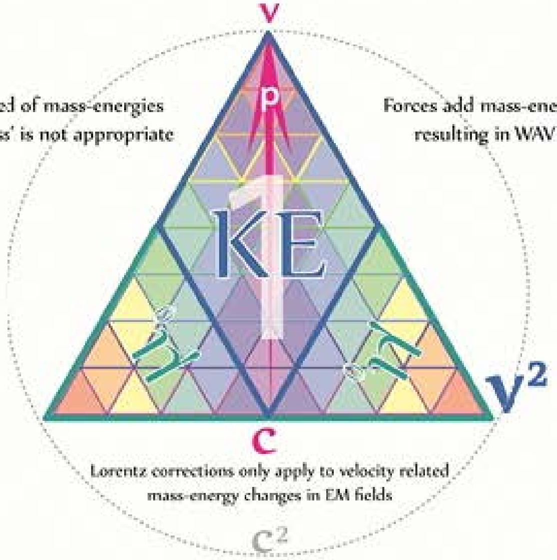

Lorentz corrections only apply to velocity related mass-energy changes in EM fields

Linear correction factor

$$\beta = \left[\frac{v}{c}\right]$$

Linear Lorentz boosts produce changes to the velocity and momenta of a system

Scalar correction factor

$$\beta^2 = \left[\frac{v^2}{c^2}\right]$$

As the velocity and momenta of a system changes so does its scalar energies

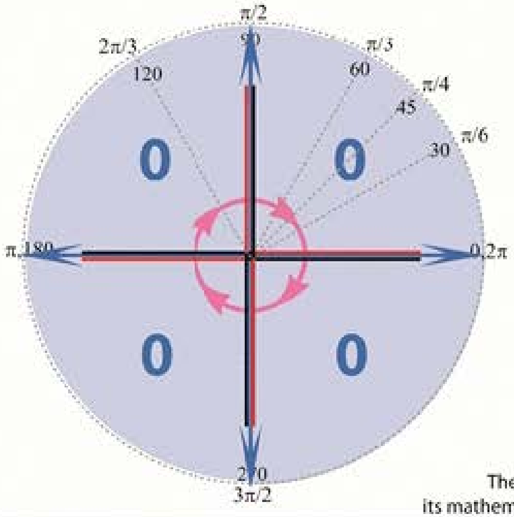

The Lorentz transformation is a linear transformation

It may include a rotation of space;
a rotation-free Lorentz transformation is called a Lorentz boost.

bosons $2\pi[hv] = hf$ photons

π

As photons are neutral charge mass-energy geometries care must alway be taken in identifying and specifying the planar wavefront polarities and direction of wave propagation when developing co-ordinate systems to describe their motions and resulting electromagnetic properites

τ

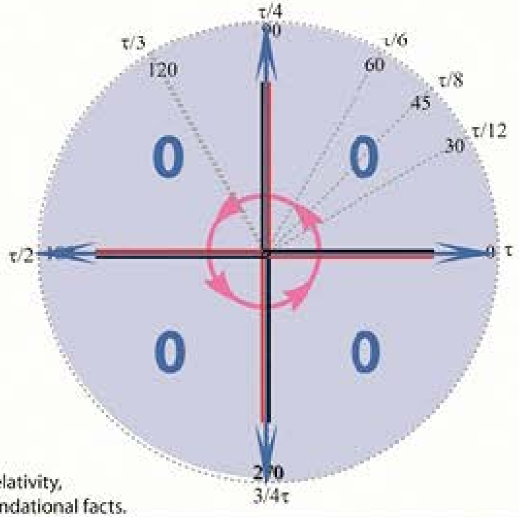

The Lorentz transformation is in accordance with special relativity, but was derived well before special relativity, its mathematical development in relativity theory has resulted in erroneous assumptions being accepted as foundational facts.

Photoelectron KEM fields

As electrons bound to nuclei are accelerated by external forces
their energies of motion are stored in their KEM fields

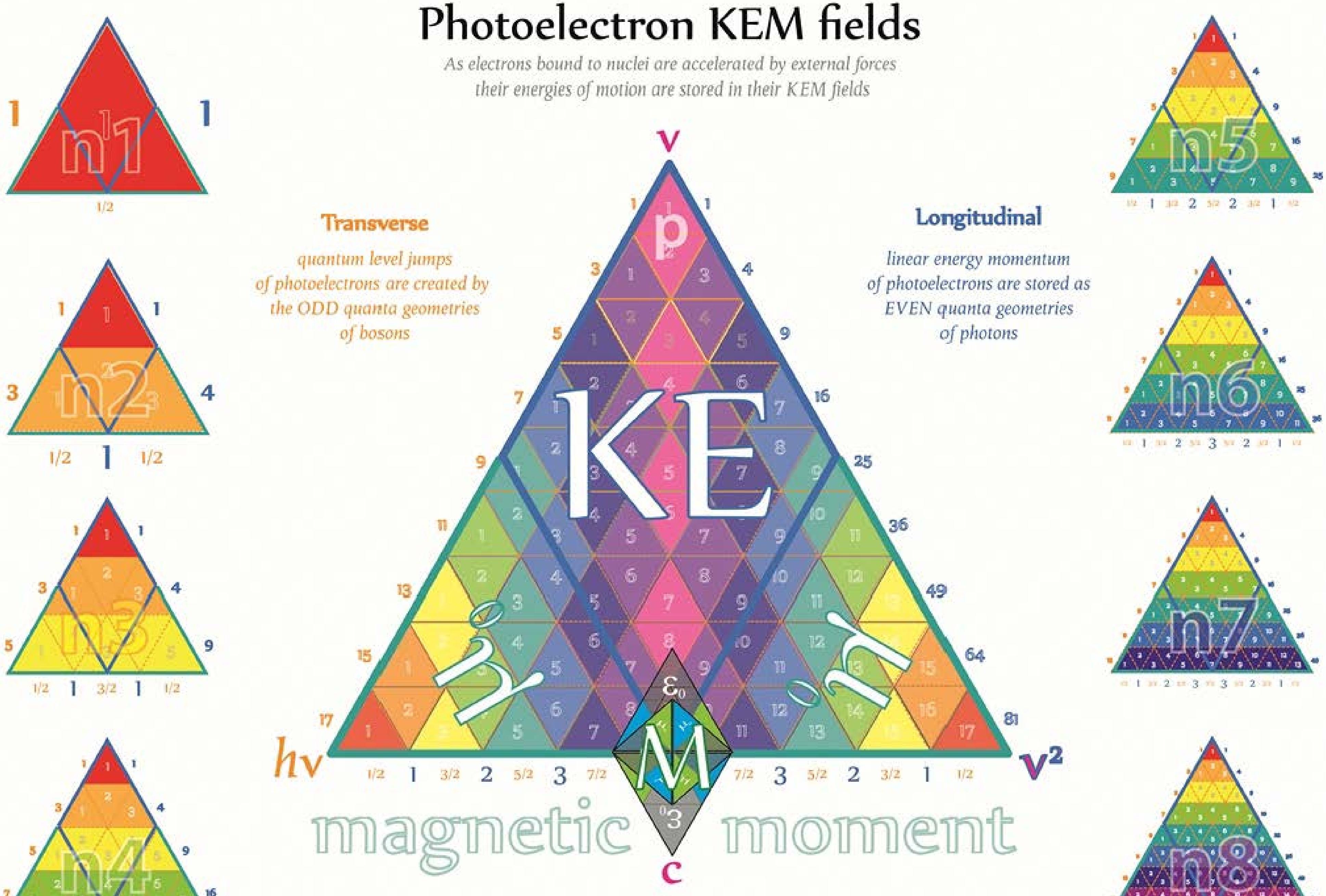
n1
n2
n3
n4
n5
n6
n7
n8
v
p
KE
hv
v²
c
ε0
μ0
M
magnetic moment
1/2 1 3/2 2 5/2 3 7/2
7/2 3 5/2 2 3/2 1 1/2
1 3 5 7 9 11 13 15 17
1 4 9 16 25 36 49 64 81

Transverse

quantum level jumps
of photoelectrons are created by
the ODD quanta geometries
of bosons

Longitudinal

linear energy momentum
of photoelectrons are stored as
EVEN quanta geometries
of photons

KEM mass-energies are subject to velocity related Lorentz corrections and produce magnetic moments

Tetryonics 28.01 - Photoelectron KEM fields

Kinetics & Photons

The photon has several properties that distinguish it from all other subatomic particles.

It is the only elementary particle wherein a high-energy photon can transform/split into two or more low-energy photons.

A photon is a magnetic dipole. It is an elementary magnet. Evans discovery of the photon's longitudinal magnetic field in 1992 is considered as significant as Einstein's discovery of Relativity.

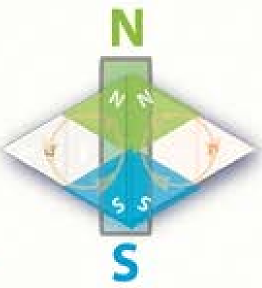

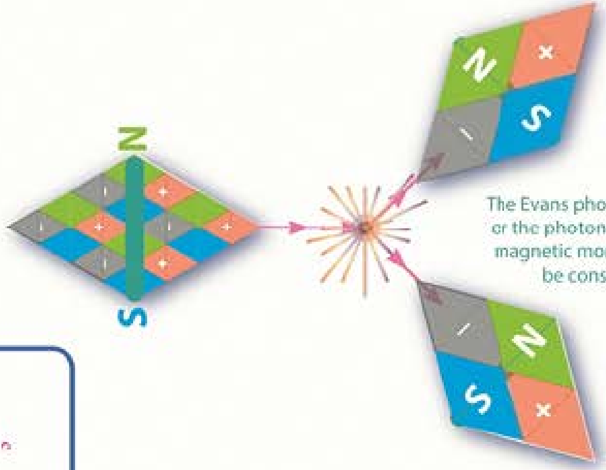

The Evans photomagneton or the photon's transverse magnetic moment has to be conserved.

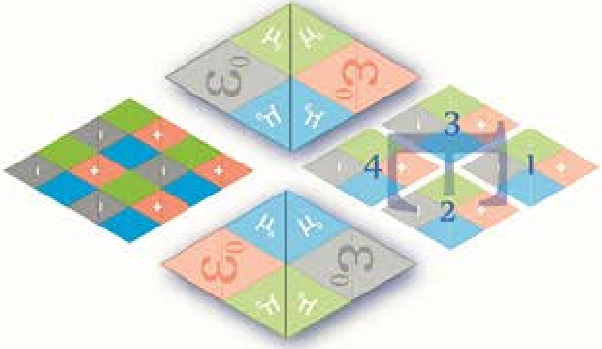

Photons can form super-position EM waves

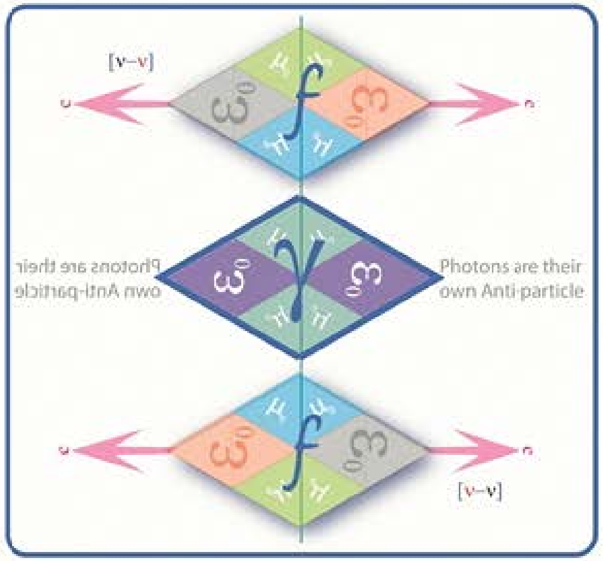

Photons are their own Anti-particle

PAIR PRODUCTION

A photon with sufficient energy can be transformed into a real electron-positron pair.

The EM mass-energy is conserved as per Einstein's equivalence of mass and energy.

The photon's magnetic charge is conserved in the magnetic moments of the created electron-positron pair.

Raised Quantum Level

Absorption

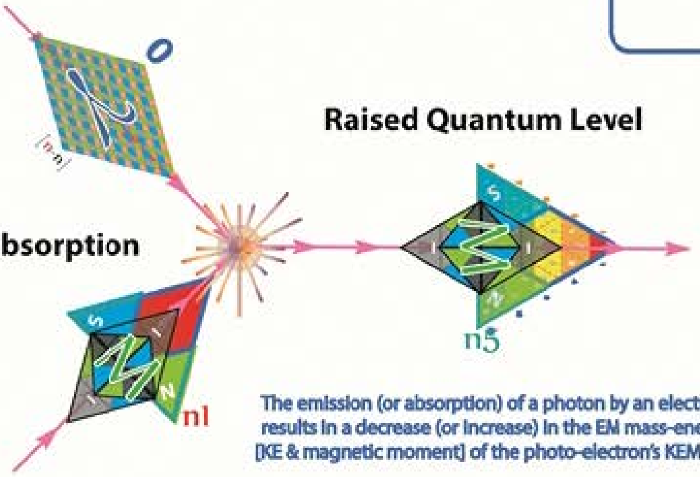

The emission (or absorption) of a photon by an electron, results in a decrease (or increase) in the EM mass-energy [KE & magnetic moment] of the photo-electron's KEM field

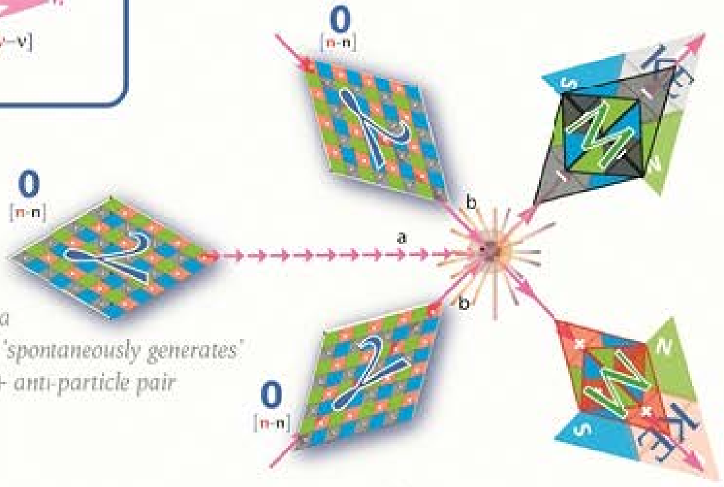

Option a
Photon 'spontaneously generates' a pair + anti-particle pair

Option b
Two Photons combine

Arthur Compton

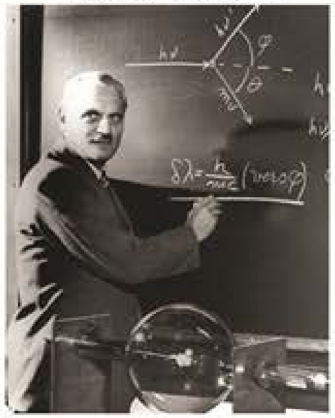

(September 10, 1892 - March 15, 1962)

Compton Scattering

The in-elastic scattering of photons in matter results in a decrease in energy (increase in wavelength) of an X-ray or gamma ray photon and is called the Compton effect.

Part of the energy of the X/gamma ray is transferred to a scattering electron, which recoils and is ejected from its atom (which becomes ionized), and the rest of the energy is taken by the scattered, "degraded" photon.

Compton frequency of photons

$$E = hf = \frac{hc}{\lambda} = mc^2$$

where v = c

Lorentz corrected energies of EM masses in motion

$$n\pi\frac{[m\Omega v^2]}{c^2}$$

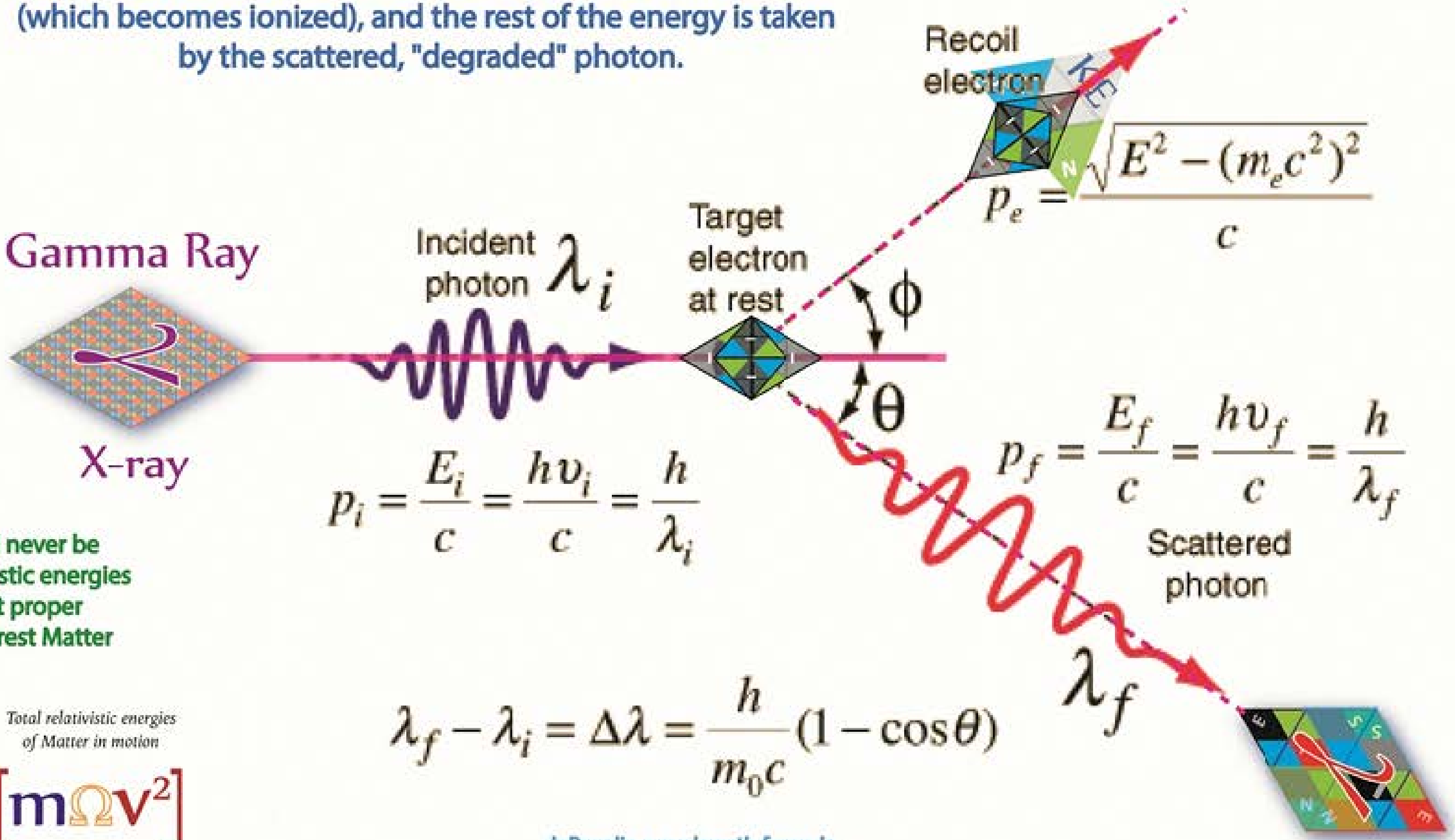
Gamma Ray
X-ray
Incident photon λ_i
Target electron at rest
Recoil electron
KE
N
ϕ
θ
Scattered photon
λ_f
Degraded Photon

$$p_e = \frac{\sqrt{E^2 - (m_e c^2)^2}}{c}$$

$$p_i = \frac{E_i}{c} = \frac{h\upsilon_i}{c} = \frac{h}{\lambda_i}$$

$$p_f = \frac{E_f}{c} = \frac{h\upsilon_f}{c} = \frac{h}{\lambda_f}$$

Compton frequencies should never be calculated from the total relativistic energies of Matter in motion without proper consideration of the invariant rest Matter

Total relativistic energies of Matter in motion

$$n\pi\frac{[m\Omega v^2]}{c^4}$$

$$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$$

deBroglie wavelength formula

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Pair Production

$$mv^2 = E = \tfrac{1}{2}hf$$

A photon with sufficient energy can be transformed into a real, material electron-positron pair.

The EM mass-energies of the system are conserved as per the equivalence of mass and Energy.

W^0

$2v = f$

γ

The photon's magnetic dipole and charges are also conserved (but in differing charge geometries)

Option a
Photon produces 2 particles

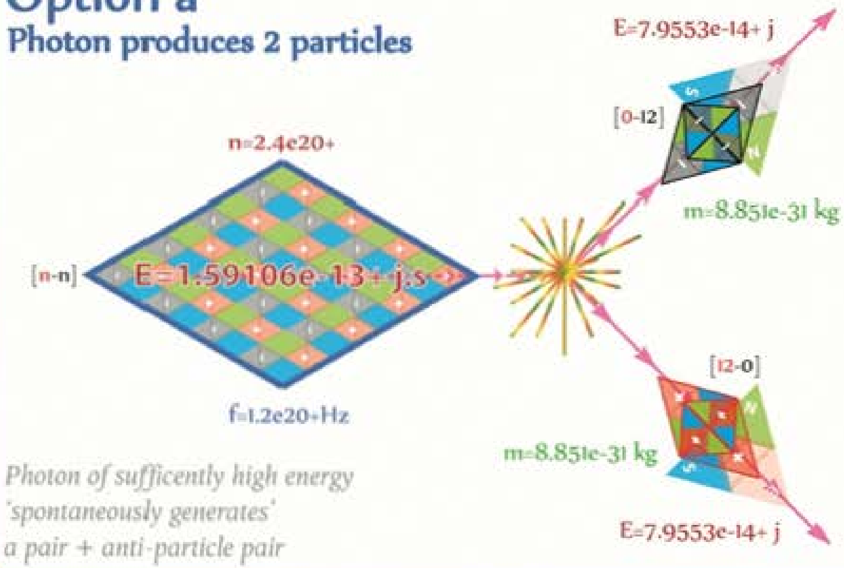

E=7.9553e-14+ j
[0-12]
n=2.4e20+
m=8.851e-31 kg
[n-n]
E=1.59106e-13+ j.s
[12-0]
f=1.2e20+Hz
m=8.851e-31 kg
E=7.9553e-14+ j

Photon of sufficently high energy 'spontaneously generates' a pair + anti-particle pair

Option b
Two Photons combine

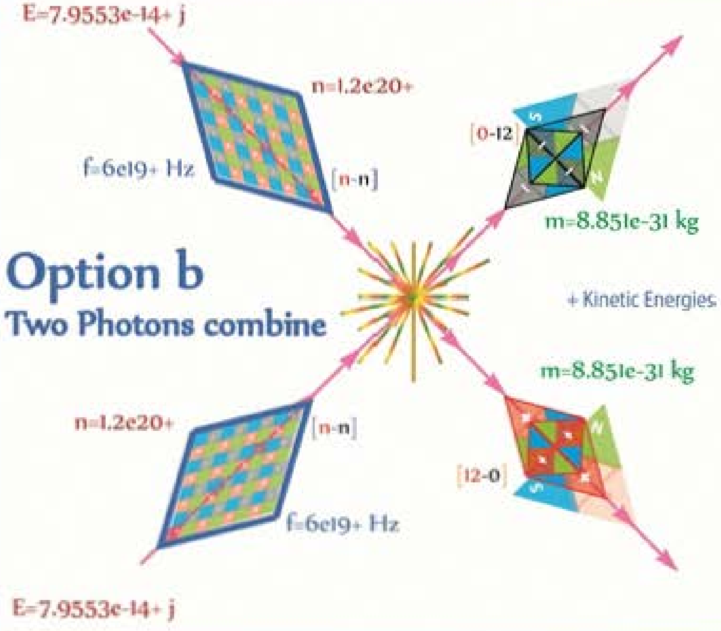

E=7.9553e-14+ j
n=1.2e20+
[0-12]
f=6e19+ Hz
[n-n]
m=8.851e-31 kg
+ Kinetic Energies
m=8.851e-31 kg
n=1.2e20+
[n-n]
[12-0]
f=6e19+ Hz
E=7.9553e-14+ j

Planck's constant	Energy	electron rest mass-Matter
6.62432672 e-34 kgm^2/s	7.9553 e-14 j	8.8514860 e-31 kg

$$n\pi\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right] = E = T\pi\left[\overset{\text{Planck}}{\underset{\text{mass}}{m}}\,\overset{\text{quanta}}{\Omega}\,\underset{\text{velocity}}{v^2}\right]$$

6 e19
photon frequency

1.2 e20
Compton frequency

All pair production - annihilations must follow the mass-Energy-Matter equivalency formula

mass $c^2 \xleftarrow{\text{per second}} E \xrightarrow{\text{per second squared}} c^4$ Matter

Kinetic Energies

$$KE = \frac{1}{2}Mv^2$$

As velocity increases so does the number of energy momenta quanta per spatial geometry

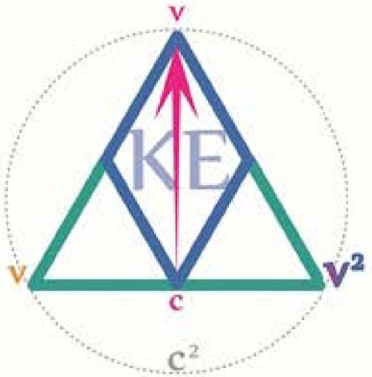

Photons contain Kinetic energies and momentum

Photonic Energy

$$E_\gamma = 2\pi\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck}\ \text{quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

Kinetic Energy and momenta are all related through Tetryonic geometry

Photons

$$p = \frac{h}{\lambda} = \frac{E}{c}$$

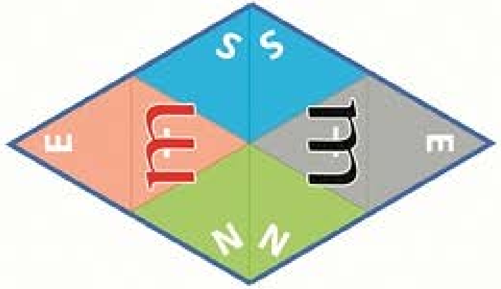

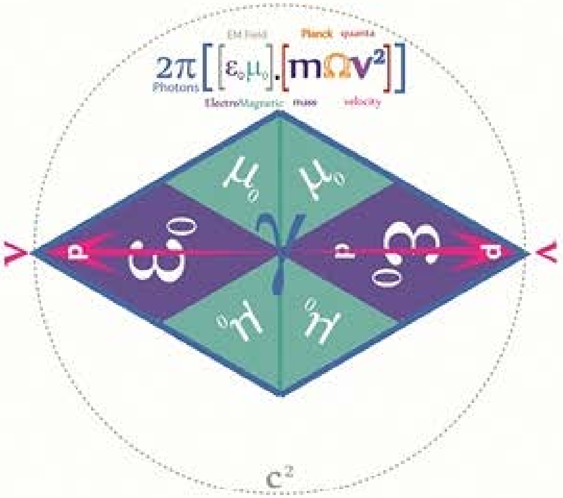
EM Field
Planck quanta
$2\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$
Photons
ElectroMagnetic
mass
velocity
μ_0
μ_0
ε_0
ε_0
γ
p
p
p
p
v
v
μ_0
μ_0
c^2

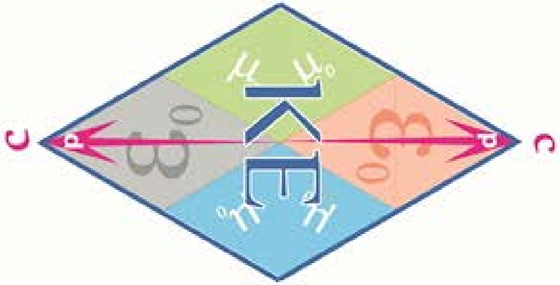
c
p
ε_0
μ_0
KE
ε_0
p
c
μ_0
μ_0

$$E = hf$$

Momentum

$$\frac{p^2}{2m} = KE = \frac{1}{2}Mv^2$$

As the number of Photons increases so does the Momentum

$$p = \frac{n\pi\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck}\ \text{quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]}{v} = E/v$$

All Photons travel at the 'speed of light' in their medium of transmission

$$p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$$

$$p = n\pi\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck}\ \text{quanta}}{\Omega}\underset{\text{velocity}}{v}\right]\right]$$

linear energy-momentum

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Electronic Kinetic Energies

have discrete energy levels within the nucleus and
continuous energy levels in unbound electrons

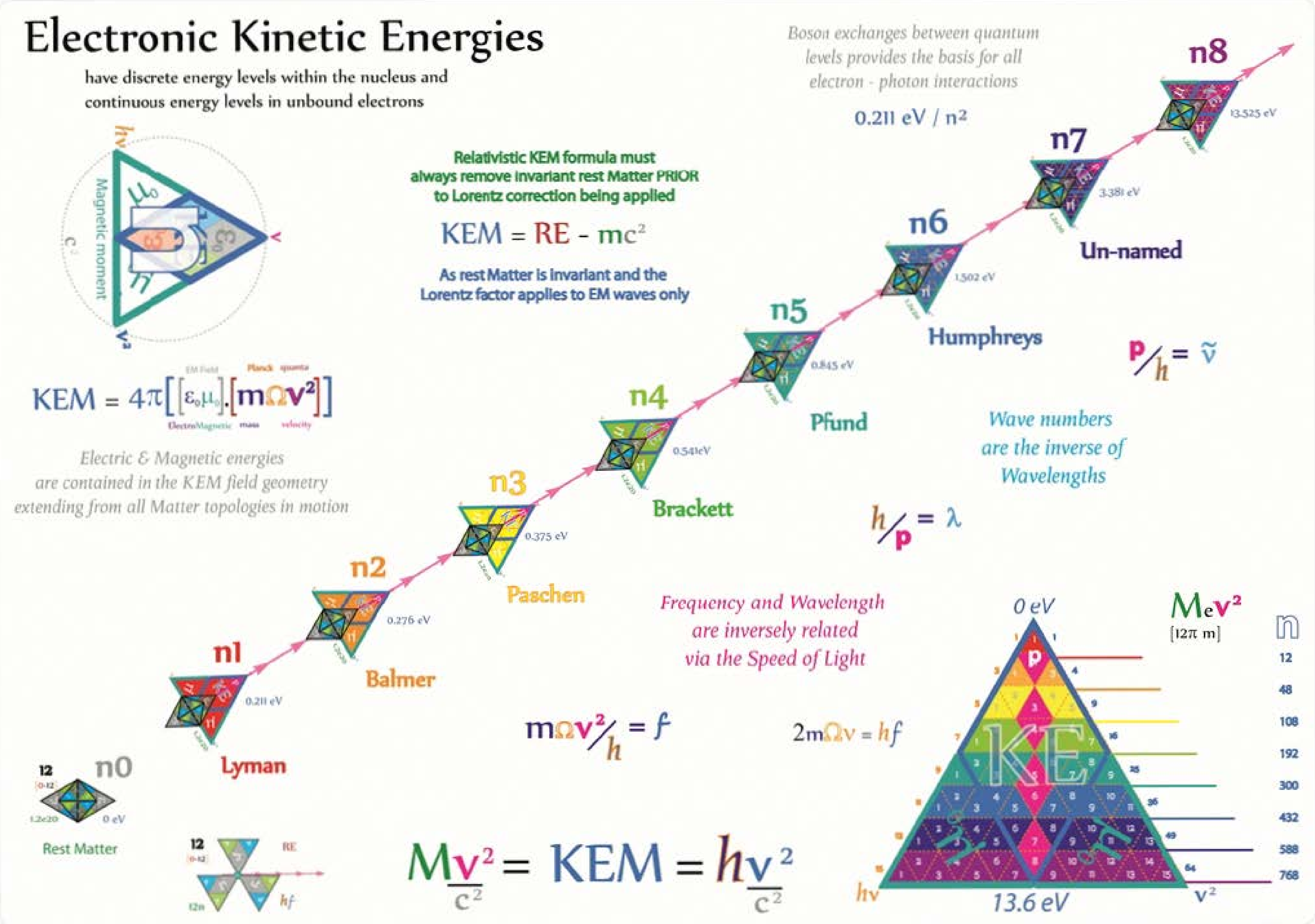

hv
Magnetic moment
μ₀
ε₀
c²
v²
n0
12
Rest Matter
0 eV
n1
0.211 eV
Lyman
n2
0.276 eV
Balmer
n3
0.375 eV
Paschen
n4
0.541eV
Brackett
n5
0.845 eV
Pfund
n6
1.502 eV
Humphreys
n7
3.381 eV
Un-named
n8
13.525 eV
12
RE
hf
0 eV
13.6 eV
hv
v²
KE
n
12
48
108
192
300
432
588
768

Boson exchanges between quantum
levels provides the basis for all
electron - photon interactions

$0.211\ \mathrm{eV} / n^2$

Relativistic KEM formula must
always remove invariant rest Matter PRIOR
to Lorentz correction being applied

$$KEM = RE - mc^2$$

As rest Matter is invariant and the
Lorentz factor applies to EM waves only

$$KEM = 4\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

EM Field, Planck, quanta, ElectroMagnetic, mass, velocity

*Electric & Magnetic energies
are contained in the KEM field geometry
extending from all Matter topologies in motion*

$$p/h = \tilde{\nu}$$

*Wave numbers
are the inverse of
Wavelengths*

$$h/p = \lambda$$

*Frequency and Wavelength
are inversely related
via the Speed of Light*

$$m\Omega v^2/h = f$$

$$2m\Omega v = hf$$

Mev^2
[12π m]

$$\frac{Mv^2}{c^2} = KEM = \frac{hv^2}{c^2}$$

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Photonic energy
momenta of KEM fields

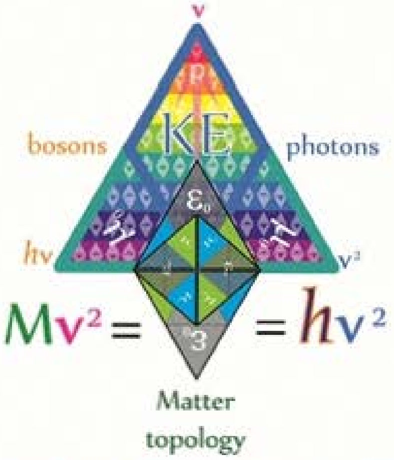
v
R
KE
bosons
photons
ε₀
hv
v²
Mv² =
= hv²
3
Matter
topology

Rydberg's formula is a wavenumber equivalent re-expression of Lorentz's velocity correction formula as it applies to the quantised energy momentum of Photo-electrons bound in atomic nuclei

$$\frac{1}{\lambda} = \frac{R_H}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

The difference of two inverse squared KEM energies

Rydberg		Tetryonic
$R\left(\frac{1}{1} - \frac{1}{4}\right)$	=	$R(36 \diagup 48)$
.75		.75

n1 and n2 are integers greater than or equal to 1 such that n1 < n2

$$\frac{1}{2}Mv^2 = KE = hcR$$

Whereas Rydberg calculated for wavenumbers using the difference of two inverse squared KEM energies. (inverse wavelengths)

$$\left(\frac{1}{1} - \frac{1}{4}\right)$$

.75

A mathematical solution that works but whose physical mechanics has eluded explanation

Tetryonics obtains the same answers geometrically using the difference of the two KEM energies. (quanta differentials)

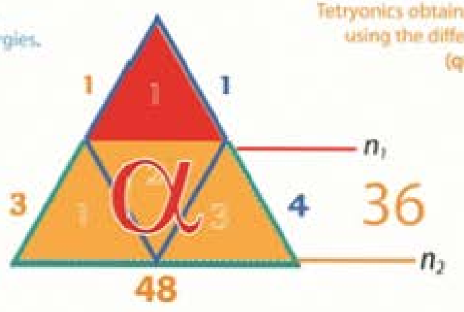
1
1
1
2
3
1
3
α
3
4
n_1
36
n_2
48

(36/48)

.75

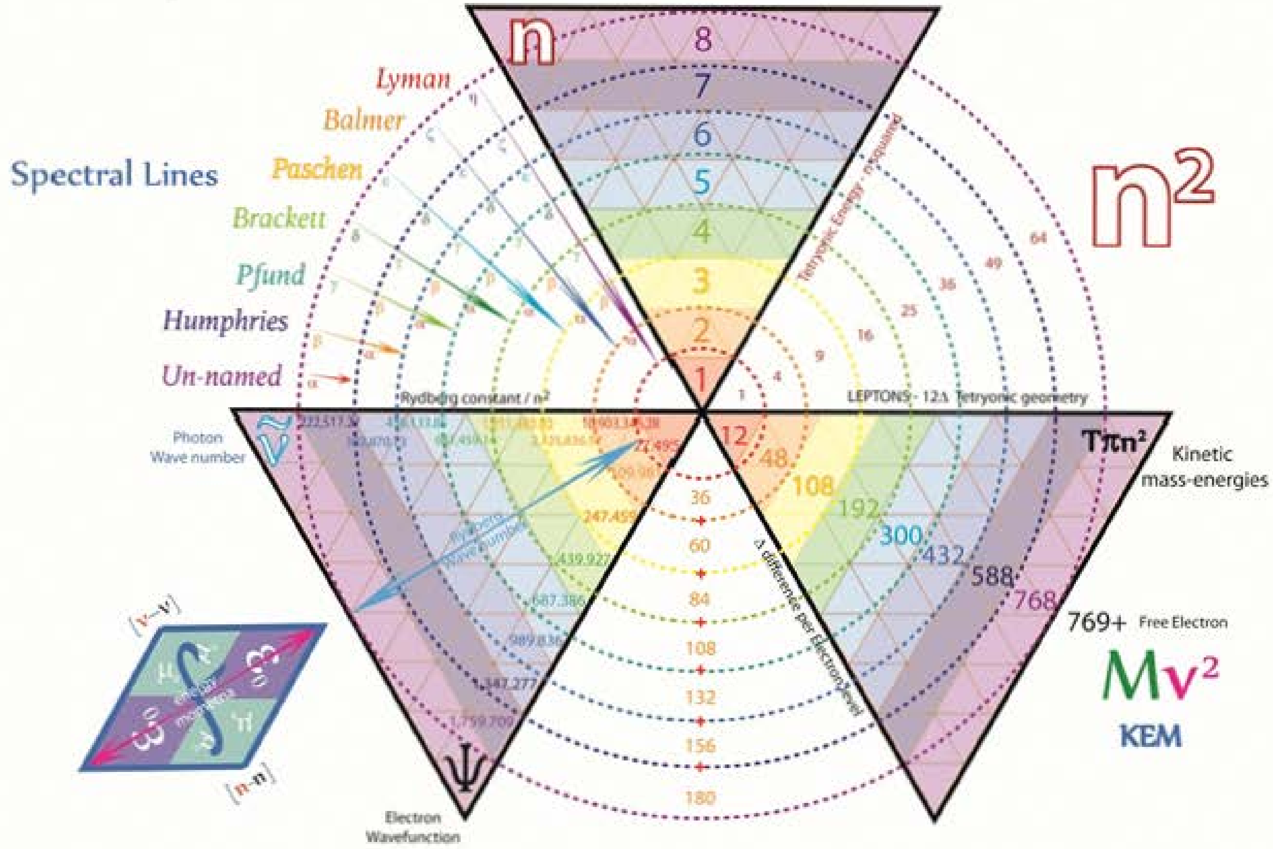
n
8
7
6
5
4
3
2
1
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
Un-named
Spectral Lines
n²
Tetryonic Energy - n squared
1
4
9
16
25
36
49
64
Rydberg constant / n²
LEPTONS - 12Δ Tetryonic geometry
Photon Wave number
Rydberg Wavenumber
Tπn²
Kinetic mass-energies
12
48
108
192
300
432
588
768
769+ Free Electron
Mv²
KEM
36
60
84
108
132
156
180
Δ difference per Electron level
Electron Wavefunction
Ψ
[v–v]
[n–n]
247.459
1,439.927
687.386
989.836
1,347.277
1,759.709

Any changes to the Energy momenta of the electron's KEM field must be reflected in the Energy momenta of the Photo-electrons emitted [absorbed]

$$\pm\Delta h\nu = KEM_i - KEM_f$$

The difference of two KEM energies

Tetryonics 28.07 - Photonic energy momenta of KEM fields

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Kinetic Energies of Photoelectrons

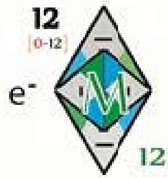
12
[0-12]
e⁻
M
12n

rest Matter

Kinetic energies are DIVERGENT from Matter topologies

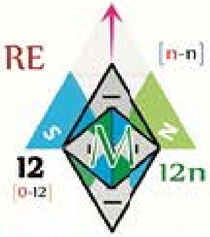
RE
[n-n]
S
N
M
12
[0-12]
12n

Relativistic mass-energies

rest Matter + Kinetic Energies

The total energy of a photon is absorbed into the electron's KEM field geometry

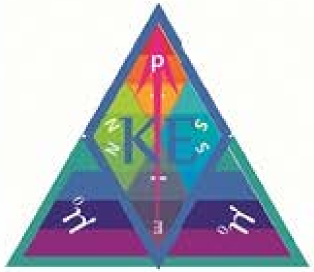

All velocity changes produce changes to mass-energies, momenta and wavefunction relationships

$$KEM = Mv^2$$

rest Matter is velocity invariant

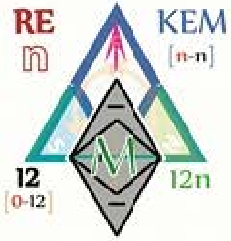
RE
ɱ
KEM
[n-n]
M
12
[0-12]
12n

Iel9ν = ɱ

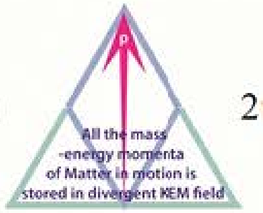
P
All the mass -energy momenta of Matter in motion is stored in divergent KEM field

$2\nu = f$

6.62943 e -34 J.s

13.5252 eV
2.1669 e -18 J

$$E = h\nu^2$$

3.26874 e15 quanta

KEM fields are velocity variant

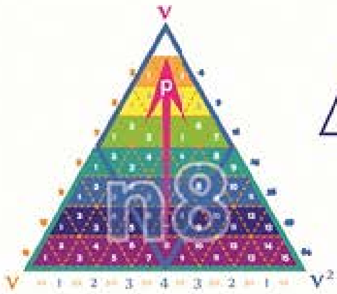
v
P
n8
v
1 2 3 4 3 2 1
v²

Δp

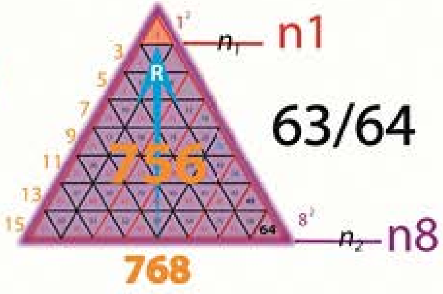
1²
n₁
n1
3
5
7
9
11
13
15
R
756
63/64
64
8²
n₂
n8
768

EM Field   Planck quanta

$$\underset{\text{KEM field}}{4\pi}\left[\underset{\text{ElectroMagnetic}}{\left[\varepsilon_0\mu_0\right]}\cdot\left[\underset{\text{mass}}{m}\Omega\underset{\text{velocity}}{v^2}\right]\right]$$

Electron KEM Quantum levels

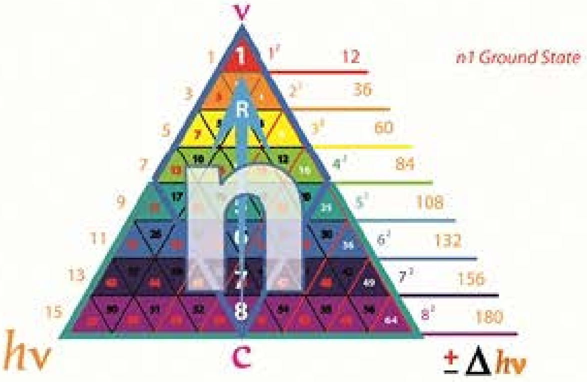
v
1
3
5
7
9
11
13
15
1
R
n
8
1² 12
2² 36
3² 60
4² 84
5² 108
6² 132
7² 156
8² 180
n1 Ground State
hv
c
± Δhv

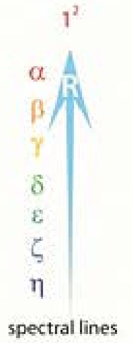
1²
α
β
γ
δ
ε
ζ
η
R
spectral lines

KEM field energies

12
48
108
192
300
432
588
768

Rydberg spectral transition jumps

$$\overset{\text{Rydberg}}{\underset{.984375}{R_H\left(\frac{1}{1}-\frac{1}{64}\right)}} = \frac{1}{\lambda} = \overset{\text{Tetryonic}}{\underset{.984375}{KEM\left(\frac{63/64}{1}\right)}}$$

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Spectral line energies

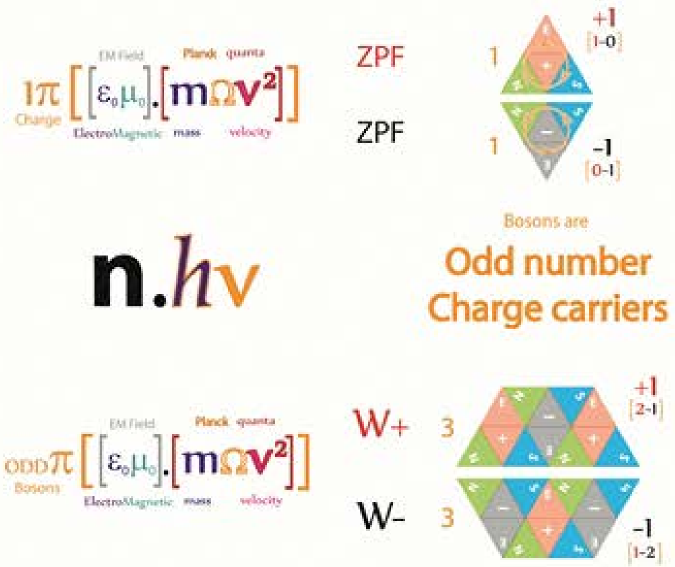

EM Field
Planck quanta
1π [[ε₀μ₀].[mΩv²]]
Charge
ElectroMagnetic mass velocity
ZPF
ZPF
1
1
+1
[1-0]
-1
[0-1]
n.hv
Bosons are
Odd number
Charge carriers
EM Field
Planck quanta
ODD π [[ε₀μ₀].[mΩv²]]
Bosons
ElectroMagnetic mass velocity
W+
W-
3
3
+1
[2-1]
-1
[1-2]

Each quantum level transition requires kinetic energies with an ODD number of EM mass-energy momenta quanta [bosons - charge carriers]

In order to transistion between levels for each emission and absorption leptons must release or absorb specific W bosons (neutral Z bosons - photons) for each KEM field change

Pairs of charged W bosons combine to form neutral bosons / photons [EM induction]

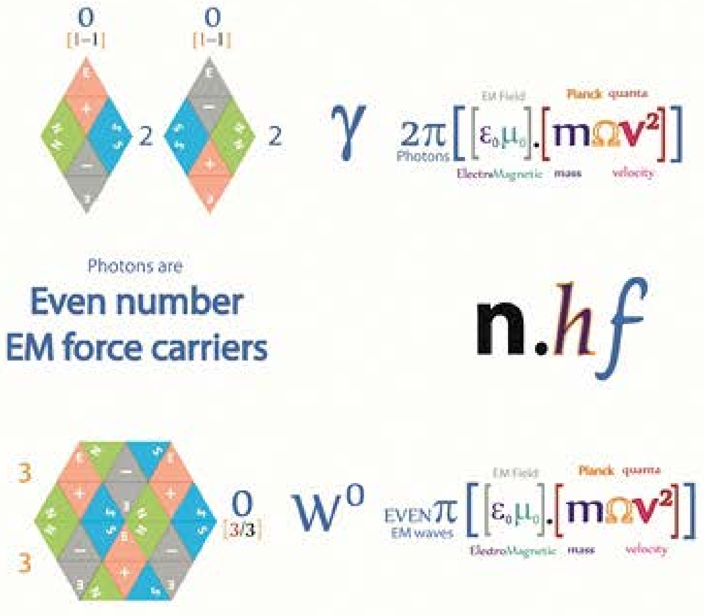

0
[1-1]
0
[1-1]
2
2
γ
EM Field
Planck quanta
2π [[ε₀μ₀].[mΩv²]]
Photons
ElectroMagnetic mass velocity
Photons are
Even number
EM force carriers
n.hf
3
3
0
[3/3]
W⁰
EM Field
Planck quanta
EVEN π [[ε₀μ₀].[mΩv²]]
EM waves
ElectroMagnetic mass velocity

KEM field Differentials

Bosonic quantum level changes

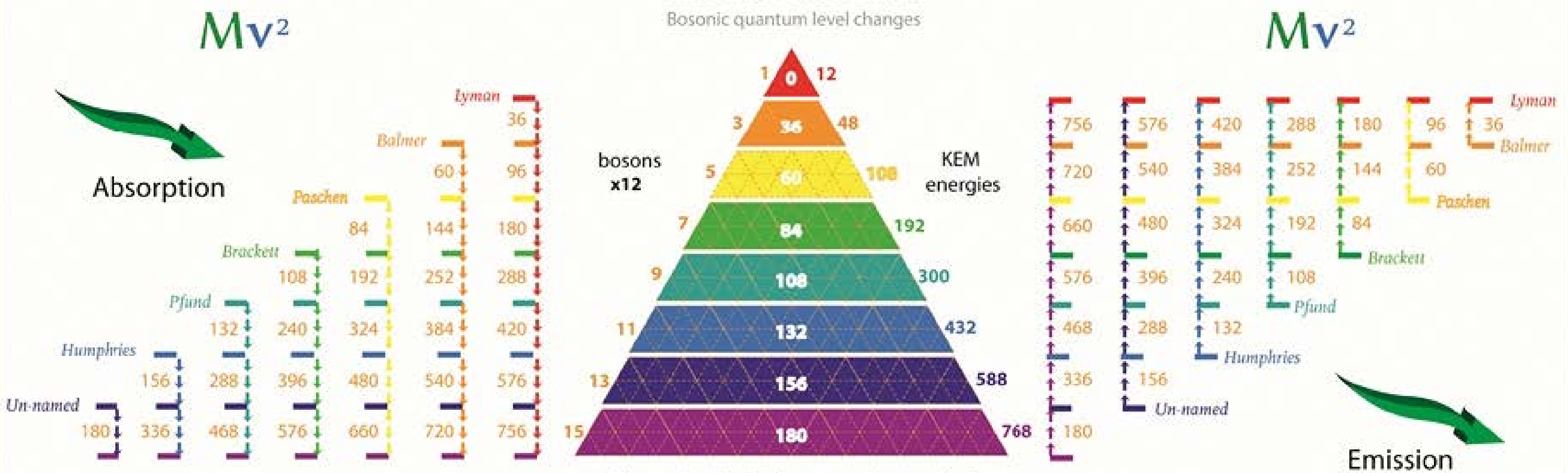

Mv²
Absorption
Lyman
36
Balmer
60 96
Paschen
84 144 180
Brackett
108 192 252 288
Pfund
132 240 324 384 420
Humphries
156 288 396 480 540 576
Un-named
180 336 468 576 660 720 756
bosons x12
KEM energies
1 0 12
3 36 48
5 60 108
7 84 192
9 108 300
11 132 432
13 156 588
15 180 768
Mv²
Lyman
756 576 420 288 180 96 36
Balmer
720 540 384 252 144 60
Paschen
660 480 324 192 84
Brackett
576 396 240 108
Pfund
468 288 132
Humphries
336 156
Un-named
180
Emission

All quantum level changes are the result of boson increases or decreases

Quantum level differentials

The exact number of Kinetic energy quanta (ZPFs)
required for each bound electron transition within a nucleus

$$\frac{1}{\lambda} = \frac{R_H}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Ryberg calculated this as the wavenumber differerential of two inverse squared energies

$$n_f^2 \qquad \underset{.75}{\overset{\text{Rydberg}}{R_H\left(\frac{1}{1} - \frac{1}{4}\right)}} = \underset{.75}{\overset{\text{Tetryonic}}{R_H\left(36 / 48\right)}} \qquad n_i^2$$

Tetryonic geometry reveals it to be sum of ODD integer bosons between two squared KEM energies

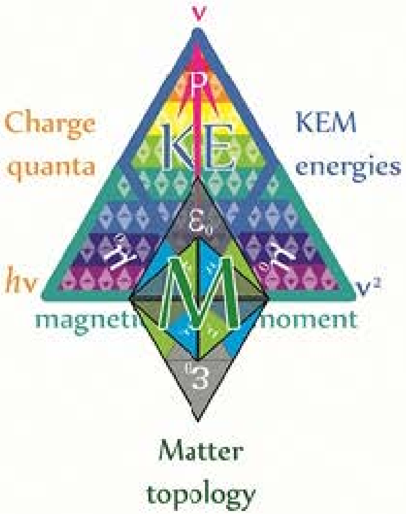
v
P
KE
Charge
quanta
KEM
energies
ε₀
μ₀
hv
v²
M
magnetic moment
3
Matter
topology

Each Quantum level jump within
an Atomic Nuclei is discrete
and requires an exact number
of EM mass-energy quanta

The calculation of the quanta
required is historically done
utilising Rydberg's Constant and
its associated formula

The quantum level [boson] differential
equates it to the release or absorption of
consecutive ODD number Planck quanta
from squared KEM field energy geometries
Δ[hv]

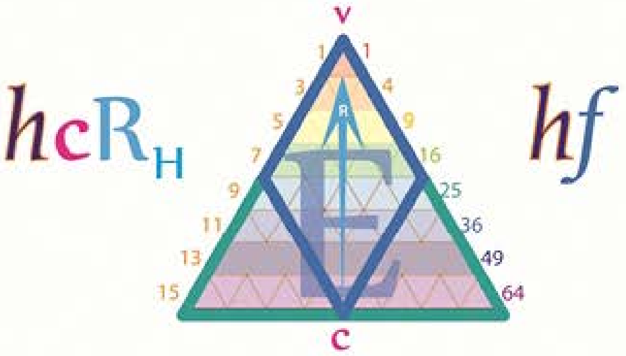
hcR_H
hf
v
c
E
R
1
3
5
7
9
11
13
15
1
4
9
16
25
36
49
64

Rydberg's constant is a LINEAR measurement of wavenumbers
which can be related to squared KEM energies through
the velocity-frequency-wavelength relationship

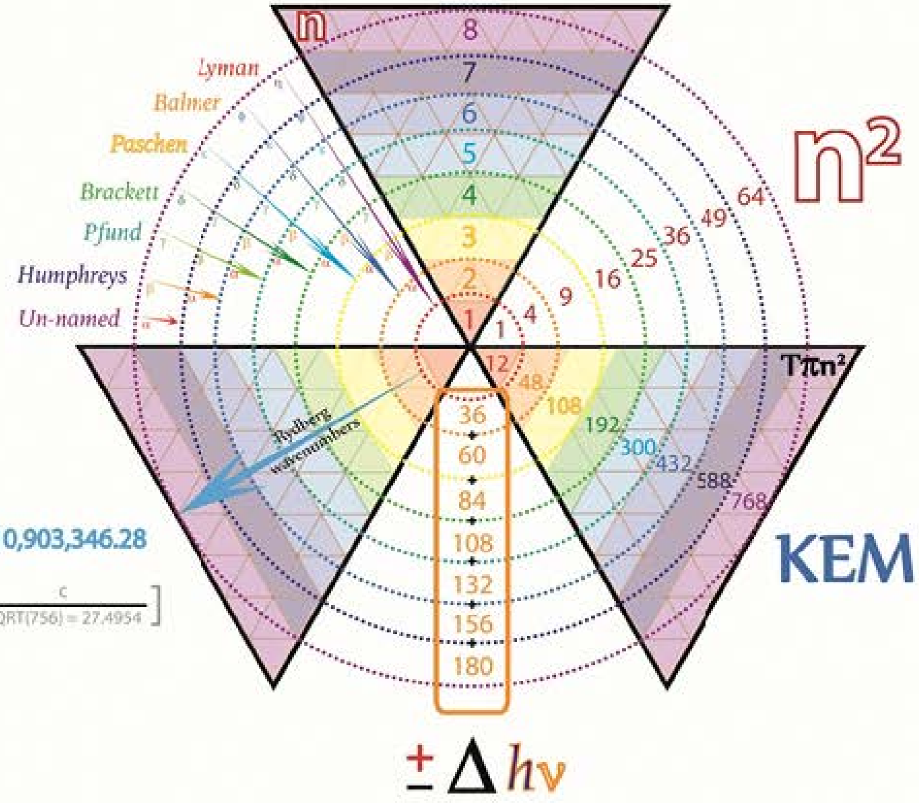
n
8
7
6
5
4
3
2
1
Lyman
Balmer
Paschen
Brackett
Pfund
Humphreys
Un-named
n²
1
4
9
16
25
36
49
64
12
48
108
192
300
432
588
768
Tπn²
36
60
84
108
132
156
180
Rydberg wavenumbers
KEM
±Δhν

R_H = 10,903,346.28

$\left[\frac{c}{\text{SQRT(756)} = 27.4954}\right]$

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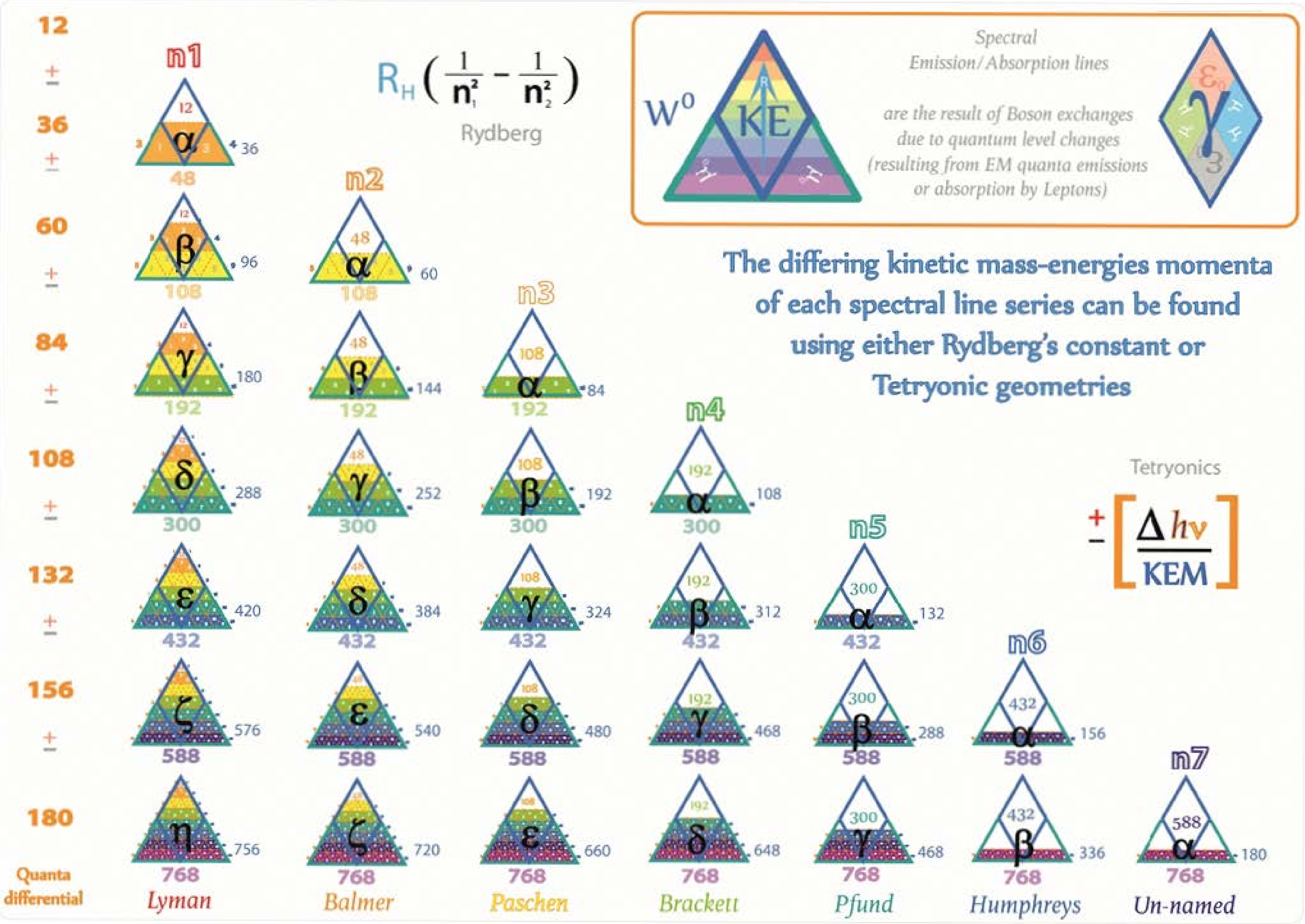
12
±
36
±
60
±
84
±
108
±
132
±
156
±
180
Quanta differential
n1
12
α
36
48
β
96
108
γ
180
192
δ
288
300
ε
420
432
ζ
576
588
η
756
768
Lyman
n2
48
α
60
108
β
144
192
γ
252
300
δ
384
432
ε
540
588
ζ
720
768
Balmer
n3
108
α
84
192
β
192
300
γ
324
432
δ
480
588
ε
660
768
Paschen
n4
192
α
108
300
β
312
432
γ
468
588
δ
648
768
Brackett
n5
300
α
132
432
β
288
588
γ
468
768
Pfund
n6
432
α
156
588
β
336
768
Humphreys
n7
588
α
180
768
Un-named
W0
KE
ε
γ
Tetryonics

$$R_H\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$$

Rydberg

Spectral Emission/Absorption lines are the result of Boson exchanges due to quantum level changes (resulting from EM quanta emissions or absorption by Leptons)

The differing kinetic mass-energies momenta of each spectral line series can be found using either Rydberg's constant or Tetryonic geometries

$$\pm\left[\frac{\Delta h\nu}{KEM}\right]$$

Tetryonics 28.11 - Boson differentials

Absorption~Emission lines

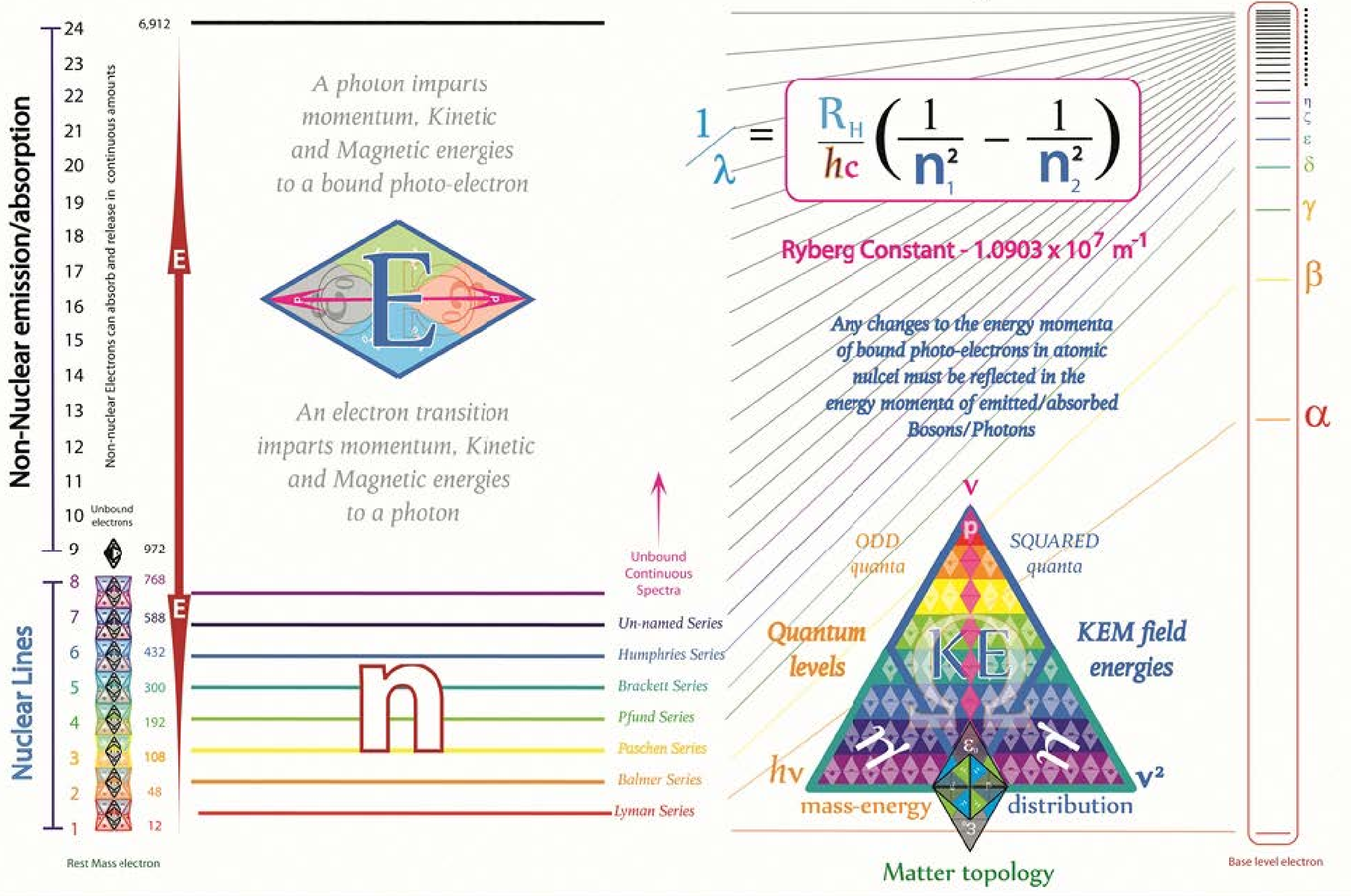

$$E = hf = \frac{hc}{\lambda} = mc^2$$

Spectral line series

$$\frac{1}{\lambda} = \boxed{\frac{R_H}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)}$$

Ryberg Constant - 1.0903 x 10^7 m^{-1}

A photon imparts momentum, Kinetic and Magnetic energies to a bound photo-electron

An electron transition imparts momentum, Kinetic and Magnetic energies to a photon

Any changes to the energy momenta of bound photo-electrons in atomic nulcei must be reflected in the energy momenta of emitted/absorbed Bosons/Photons

Non-Nuclear emission/absorption
Non-nuclear Electrons can absorb and release in continuous amounts
Nuclear Lines
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
6,912
Unbound electrons
972
768
588
432
300
192
108
48
12
Rest Mass electron
E
E
n
Unbound Continuous Spectra
Un-named Series
Humphries Series
Brackett Series
Pfund Series
Paschen Series
Balmer Series
Lyman Series
η
ζ
ε
δ
γ
β
α
Base level electron
v
ODD quanta
SQUARED quanta
Quantum levels
KEM field energies
KE
hv
v²
mass-energy
distribution
Matter topology

Tetryonics 29.01 - Absorption~Emission Lines

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Spectral Lines

Spectral lines are the result of interaction between a quantum system (usually atoms, but sometimes molecules or atomic nuclei) and a single photon. When a photon has exactly the right amount of energy to allow a change in the energy state of the system (in the case of an atom this is usually an electron changing orbitals), the photon is absorbed. Then it will be spontaneously re-emitted, either in the same frequency as the original or in a cascade, where the sum of the energies of the photons emitted will be equal to the energy of the one absorbed (assuming the system returns to its original state). The direction and polarization of the new photons will, in general, correlate with those of the original photon.

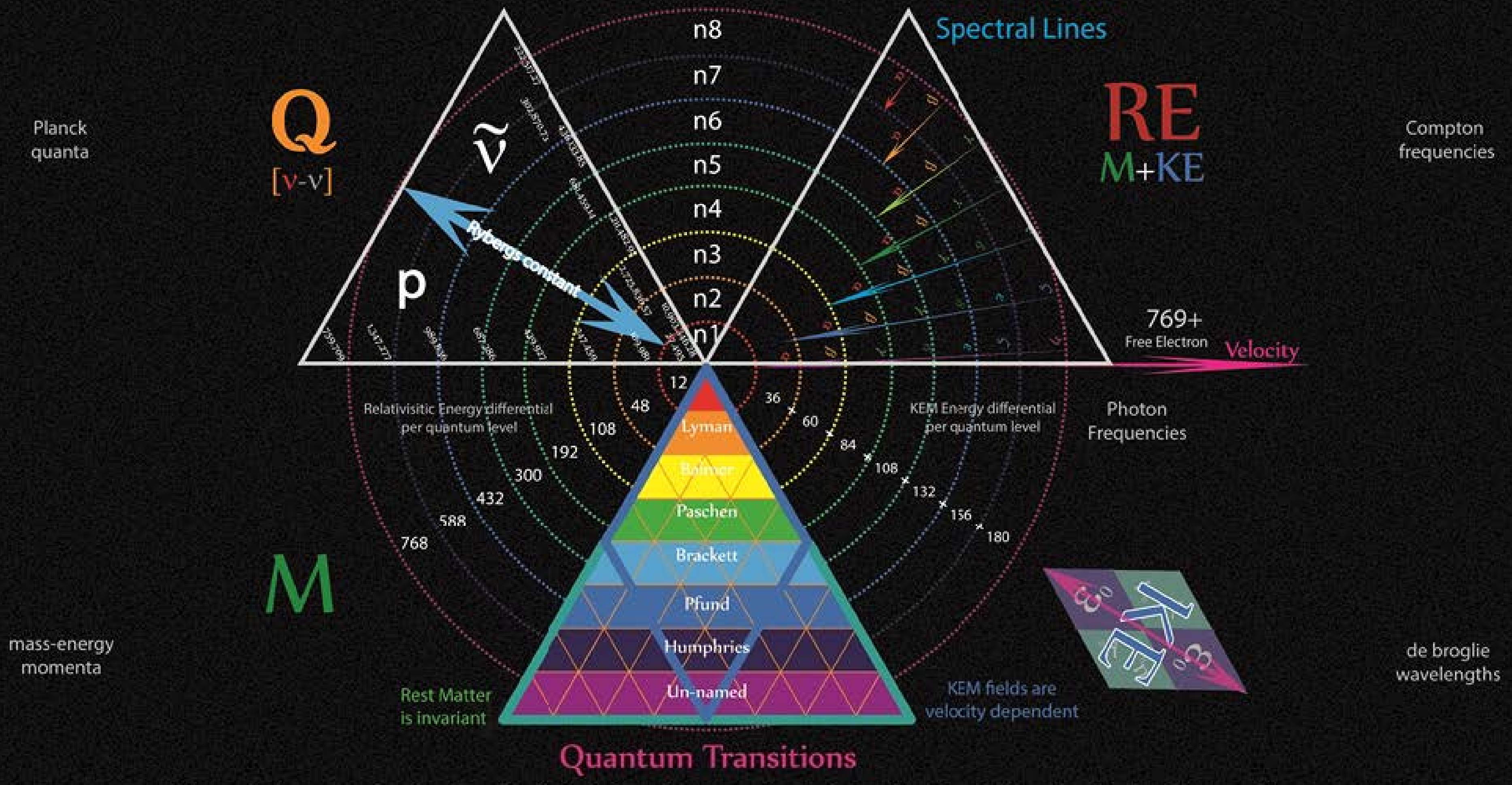
Planck
quanta
Q
[ν-ν]
ν̃
p
Ryberg's constant
n8
n7
n6
n5
n4
n3
n2
n1
Spectral Lines
RE
M+KE
Compton
frequencies
769+
Free Electron
Velocity
12
48
108
192
300
432
588
768
36
60
84
108
132
156
180
Relativisitic Energy differential
per quantum level
KEM Energy differential
per quantum level
Photon
Frequencies
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
Un-named
M
mass-energy
momenta
Rest Matter
is invariant
KEM fields are
velocity dependent
KE
de broglie
wavelengths
Quantum Transitions

Spectral lines are highly atom-specific, and can be used to identify the chemical composition of any medium capable of letting light pass through it (typically gas is used). Several elements were discovered by spectroscopic means, such as Helium [04], Rubidium [37], Cerium [58] and Thallium [81]

Spectral lines also depend on the physical conditions of the gas, so they are widely used to determine the chemical composition of stars and other celestial bodies that cannot be analyzed by other means, as well as many other of their physical properties.

Tetryonics 29.02 - Spectral line production

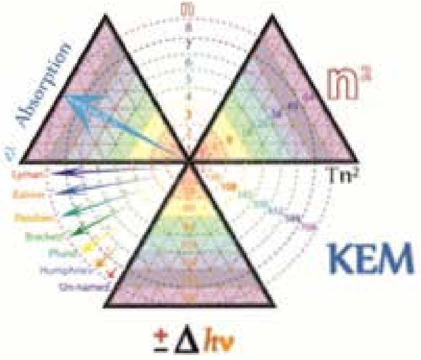
Absorption
n²
Tn²
KEM
±Δhv

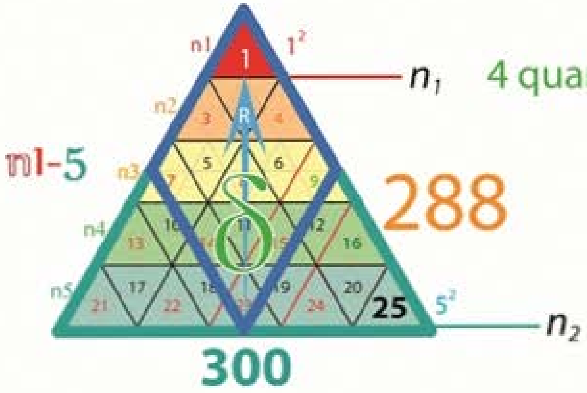
n1
1²
n2
n3
n4
n5
1
3
4
5
6
16
17
20
21
22
25
5²
R
δ
n1-5
288
300
n_1
n_2

4 quantum level jump

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

.96 KEM

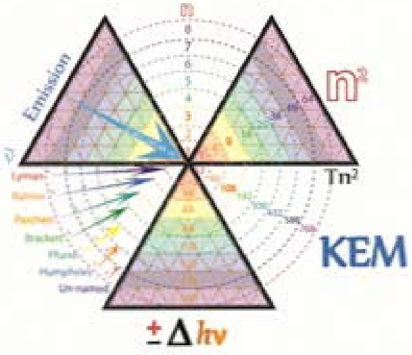
Emission
n²
Tn²
KEM
±Δhv

Photoelectron KEM field changes

The absorption (or emission) of a photon by an electron results in a increase (or decrease) in the Kinetic EM mass-energies of the electron

In the 1880s, Rydberg developed a formula describing the relation between the wavelengths in spectral lines of alkali metals, in turn finding the Rydberg Constant.

The Rydberg constant represents the limiting value of the highest wavenumber (the inverse wavelength) of any photon that can be emitted from the hydrogen atom, or, alternatively, the wavenumber of the lowest-energy photon capable of ionizing the hydrogen atom from its ground state.

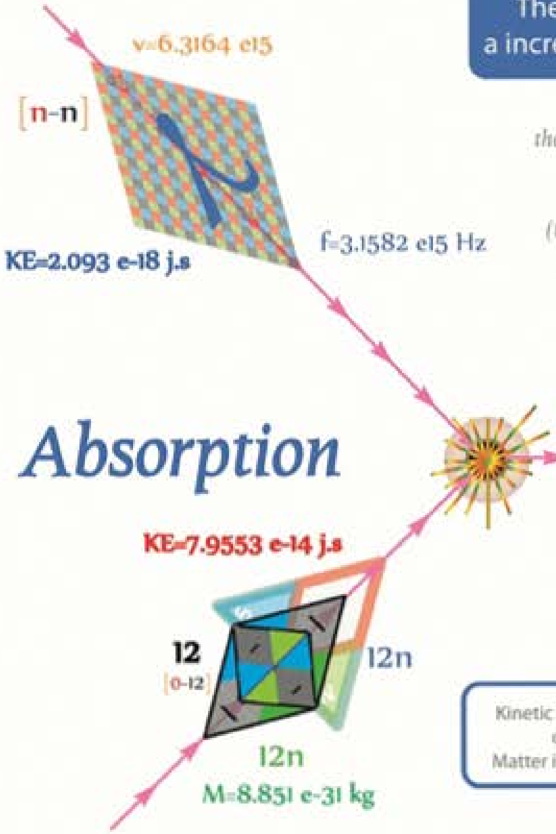
v=6.3164 e15
[n-n]
f=3.1582 e15 Hz
KE=2.093 e-18 j.s
Absorption
KE=7.9553 e-14 j.s
12
[0-12]
12n
12n
M=8.851 e-31 kg

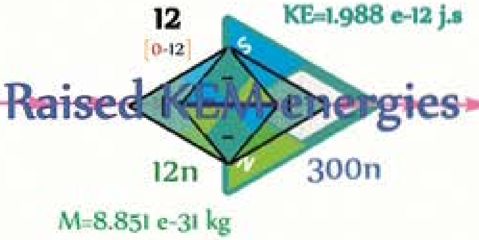
12
[0-12]
KE=1.988 e-12 j.s
Raised KEM energies
12n
300n
M=8.851 e-31 kg

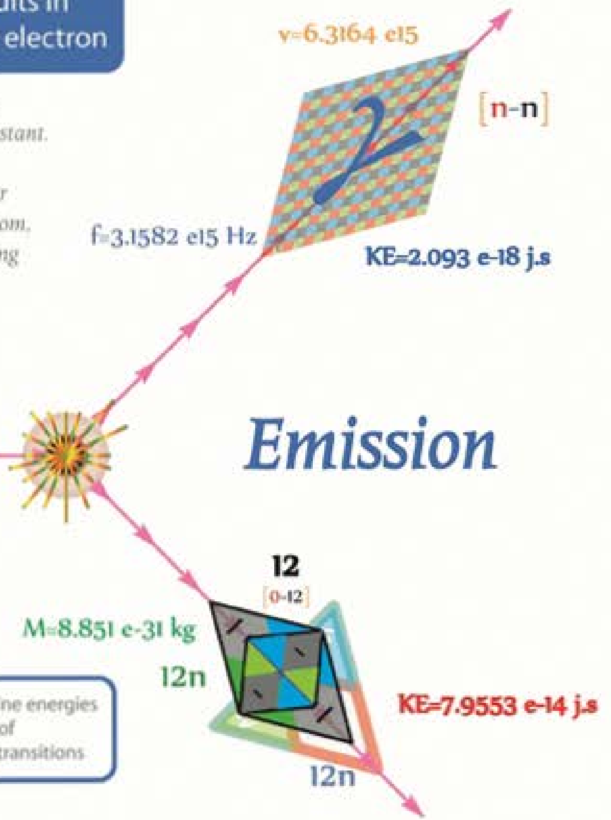
v=6.3164 e15
[n-n]
f=3.1582 e15 Hz
KE=2.093 e-18 j.s
Emission
12
[0-12]
M=8.851 e-31 kg
12n
KE=7.9553 e-14 j.s
12n

Kinetic energies of Matter in motion $Mv^2 = KEM = hv^2$ Spectral line energies of Atomic transitions

Tetryonics 29.03 - Photoelectron KEM changes

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Revealing Rydberg Formula's geometry

The Rydberg formula is used in atomic physics to determine the wavenumber of spectral lines of many chemical elements.

$$\frac{h}{Mv} = \lambda$$

Wavelength is inversely related to Frequency

$$1/\lambda = \frac{R_H}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$p/h = \tilde{\nu}$$

Wavenumbers are a inverse measure of Wavelengths

$$p^2 = E = Mv^2$$

Tetryonic geometry can be applied to Kinetic EM field variations produced by the emission and absorption of Photons by electrons in Nuclear orbits to reveal the geometry behind Rydberg's formula

$$p = \frac{E}{v} = hv$$

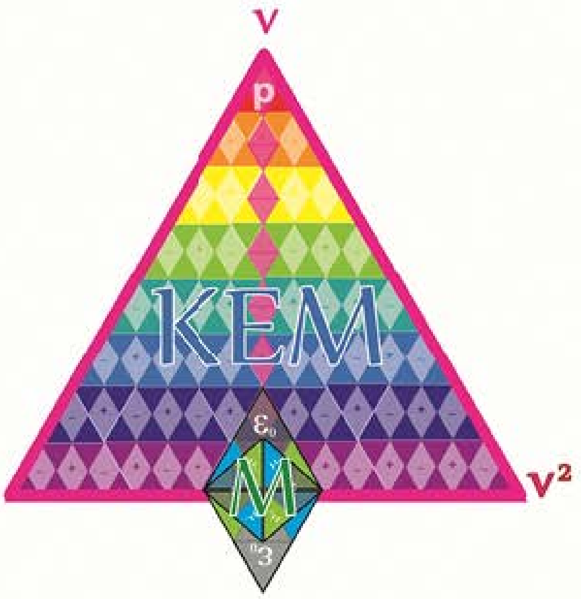

EM Field · Planck quanta

$$12\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Photoelectron KEM fields · ElectroMagnetic · mass · velocity

13.525 eV

$$\underset{\text{linear momentum}}{Mv} = \frac{KEM}{v} = \underset{\text{longitudinal quanta}}{hv}$$

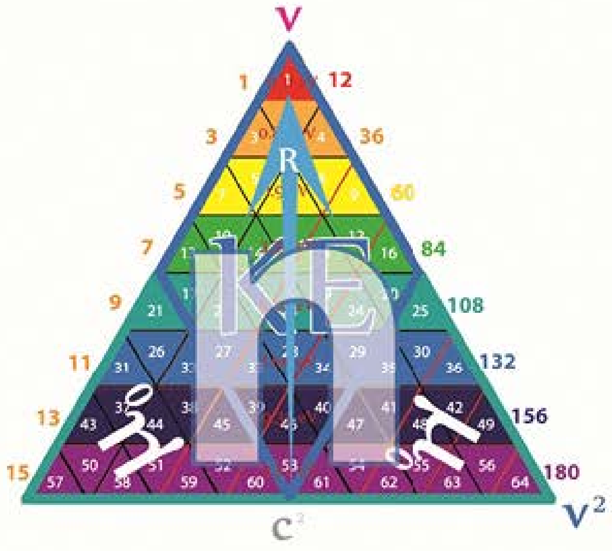

Compton frequency

Spectral line emissions reveals Rydberg's formula to be a measure of longitudinal KEM momenta

Wavelengths and Frequency are related through the velocity of propagation

$$\frac{Mv^2}{h} = f$$

$$KEM = hcR$$

$$\lambda_{KEM} = \frac{f}{v}$$

Hydrogen spectral lines

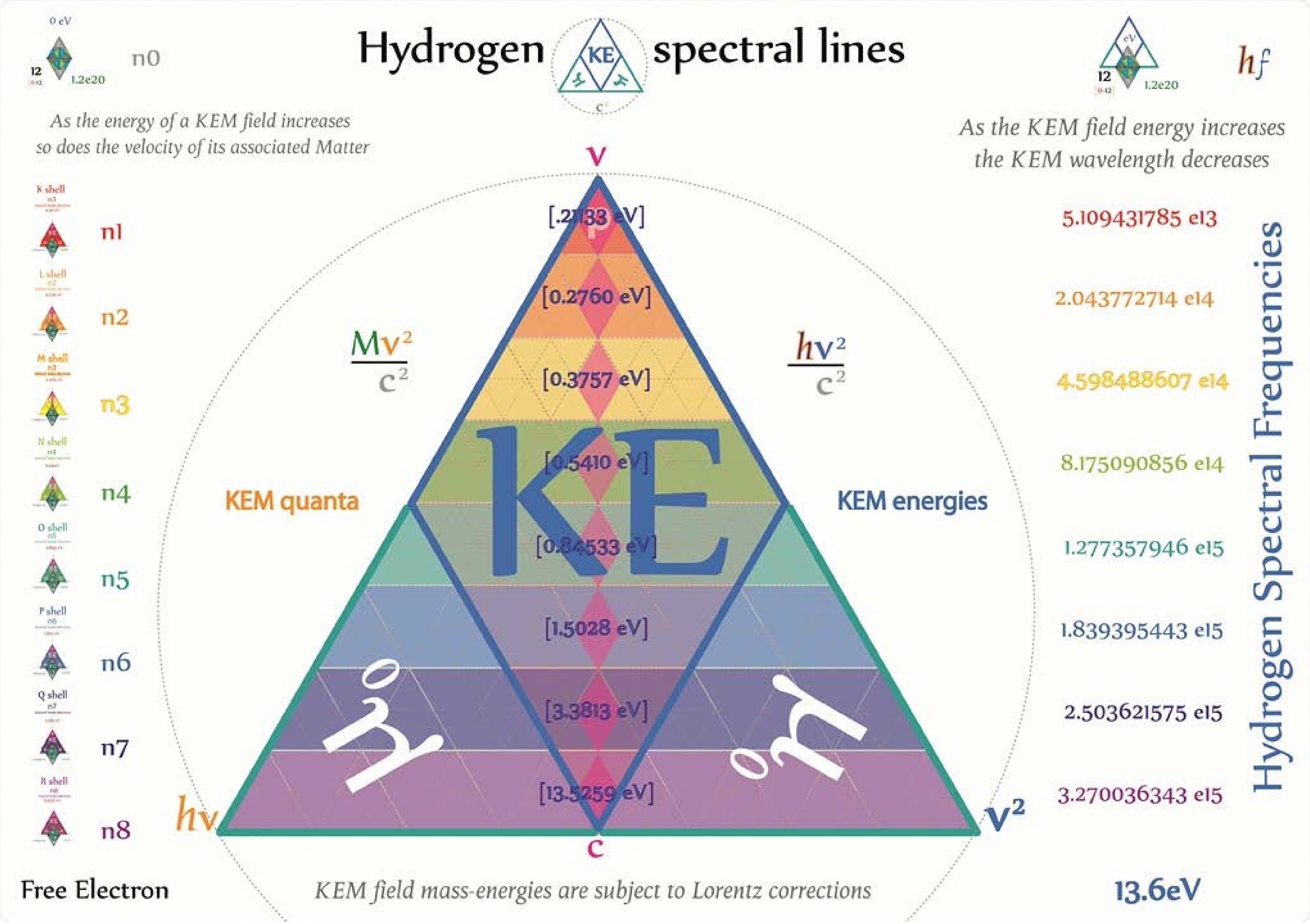
0 eV
12
1.2e20
n0
KE
c
eV
12
1.2e20
hf
v
[.2133 eV]
[0.2760 eV]
[0.3757 eV]
[0.5410 eV]
[0.84533 eV]
[1.5028 eV]
[3.3813 eV]
[13.5259 eV]
KE
Mv²/c²
hv²/c²
KEM quanta
KEM energies
hv
c
v²
K shell
n1
L shell
n2
M shell
n3
N shell
n4
O shell
n5
P shell
n6
Q shell
n7
R shell
n8
5.109431785 e13
2.043772714 e14
4.598488607 e14
8.175090856 e14
1.277357946 e15
1.839395443 e15
2.503621575 e15
3.270036343 e15
Hydrogen Spectral Frequencies

As the energy of a KEM field increases so does the velocity of its associated Matter

As the KEM field energy increases the KEM wavelength decreases

Free Electron

KEM field mass-energies are subject to Lorentz corrections

13.6eV

Tetryonics 29.05 - Hydrogen Spectral Frequencies

Absorption lines

Increase in photo-electronic energies

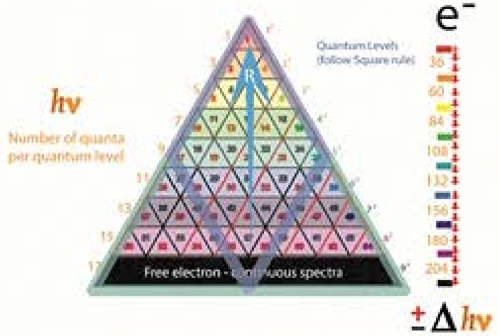
hv
Number of quanta per quantum level
Quantum Levels (follow Square rule)
e⁻
36
60
84
108
132
156
180
204
Free electron - continuous spectra
±Δhv

$$\Delta 2h\nu = E = hf$$

When an electron 'absorbs' a photon of energy momenta it 'jumps' from one energy level to another, dependent on the energy and frequency of the incident photon

$$f = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

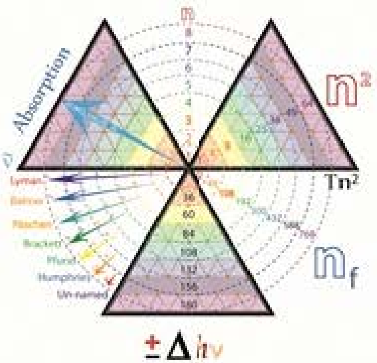
Absorption
n²
Tn²
nf
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
Un-named
36
60
84
108
132
156
180
±Δhv

The quantum level of the nuclei determines the ground quantum level of electrons within the nucleus
All transitions within the nulceus are discrete quantum jumps - outside the nucleus all spectra are continuous

KEM A Hydrogen photo-electron can only exist in specific energy levels below 13.525eV within the nucleus (any excess KE results in a unbound electron with KE - velocity)

KE in excess of 13.525 eV results in unbound electron

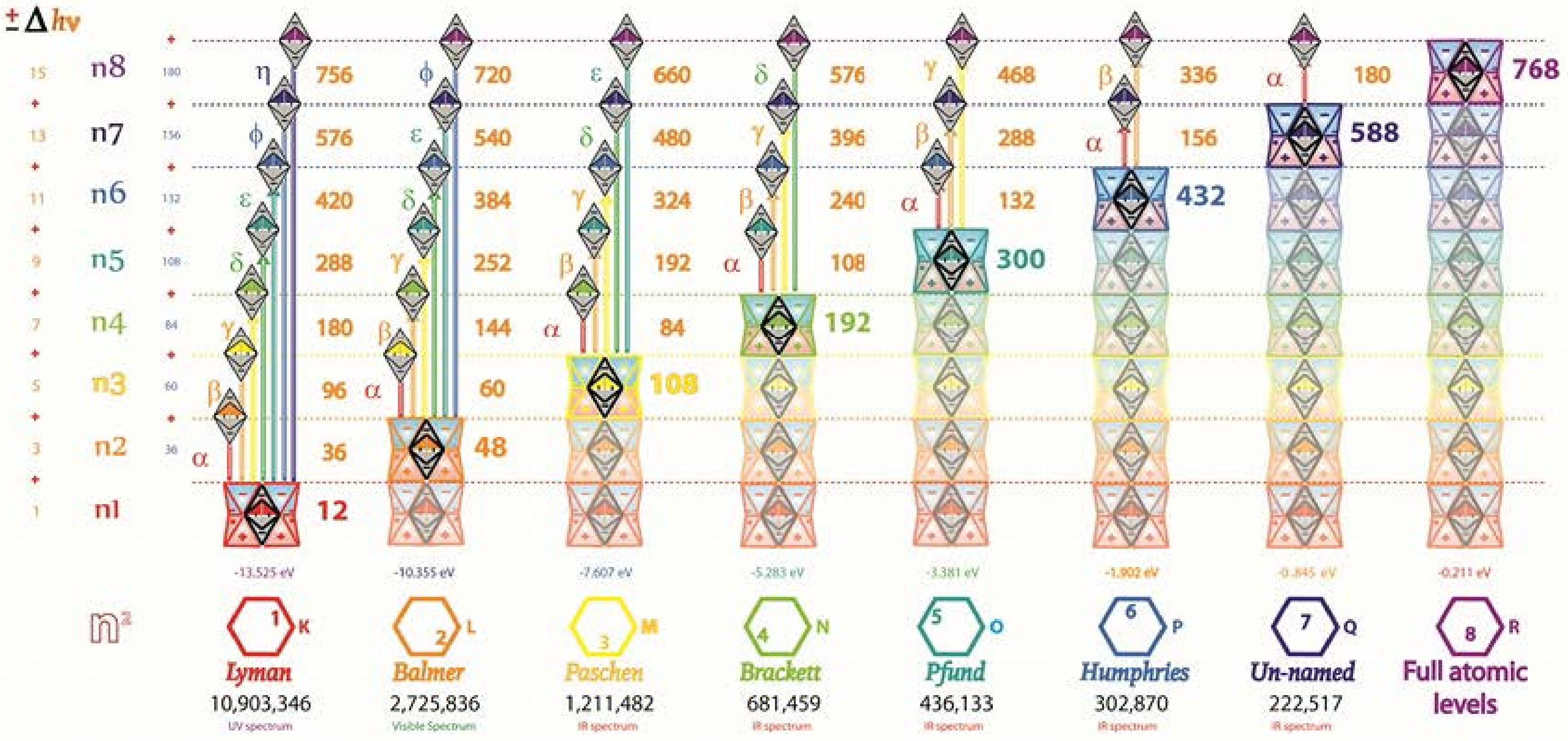
±Δhv
15 n8 180
13 n7 156
11 n6 132
9 n5 108
7 n4 84
5 n3 60
3 n2 36
1 n1
η 756
φ 576
ε 420
δ 288
γ 180
β 96
α 36
12
φ 720
ε 540
δ 384
γ 252
β 144
α 60
48
ε 660
δ 480
γ 324
β 192
α 84
108
δ 576
γ 396
β 240
α 108
192
γ 468
β 288
α 132
300
β 336
α 156
432
α 180
588
768
-13.525 eV
-10.355 eV
-7.607 eV
-5.283 eV
-3.381 eV
-1.902 eV
-0.845 eV
-0.211 eV
n²
1 K
2 L
3 M
4 N
5 O
6 P
7 Q
8 R
Lyman
10,903,346
UV spectrum
Balmer
2,725,836
Visible Spectrum
Paschen
1,211,482
IR spectrum
Brackett
681,459
IR spectrum
Pfund
436,133
IR spectrum
Humphries
302,870
IR spectrum
Un-named
222,517
IR spectrum
Full atomic levels

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KEM fields & quantum jumps

$$Mv^2 = KEM = hv^2$$

$$f = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

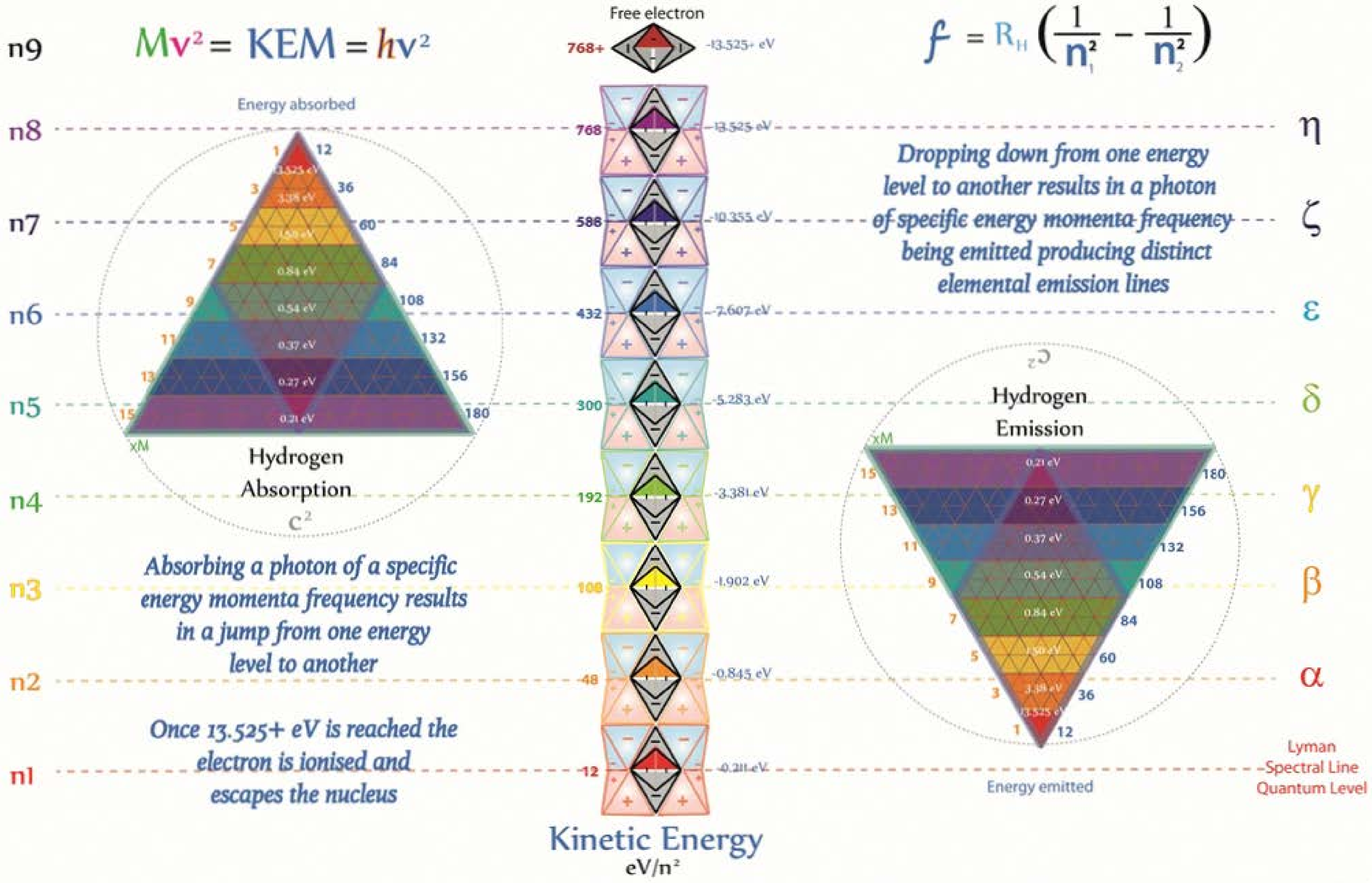
n9
n8
n7
n6
n5
n4
n3
n2
n1
Free electron
768+
-13.525+ eV
768
-13.525 eV
588
-10.355 eV
432
-7.607 eV
300
-5.283 eV
192
-3.381 eV
108
-1.902 eV
48
-0.845 eV
12
-0.211 eV
Energy absorbed
Hydrogen Absorption
c²
xM
1
3
5
7
9
11
13
15
12
36
60
84
108
132
156
180
13.525 eV
3.38 eV
1.50 eV
0.84 eV
0.54 eV
0.37 eV
0.27 eV
0.21 eV
Hydrogen Emission
c²
Energy emitted
η
ζ
ε
δ
γ
β
α
Lyman
Spectral Line
Quantum Level
Kinetic Energy
eV/n²

Dropping down from one energy level to another results in a photon of specific energy momenta frequency being emitted producing distinct elemental emission lines

Absorbing a photon of a specific energy momenta frequency results in a jump from one energy level to another

Once 13.525+ eV is reached the electron is ionised and escapes the nucleus

Tetryonics 29.07 - KEM field & quantum jumps

Emission lines

Decrease in photo-electronic energies

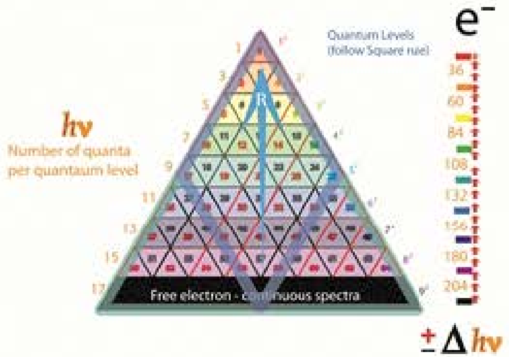
hv
Number of quanta per quantum level
Quantum Levels (follow Square rule)
e^-
36
60
84
108
132
156
180
204
Free electron - continuous spectra
±Δhv

$$\Delta 2hv = E = hf$$

When an electron 'emits' a photon of energy momenta it 'drops' from one energy level to another dependent on the energy and frequency of the ejected photon

$$f = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

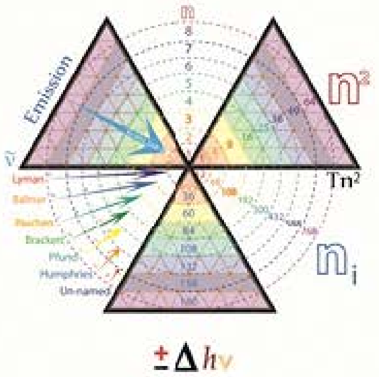
Emission
n^2
Tn^2
n_i
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
Un-named
±Δhv

The quantum level of the nuclei determines the ground quantum level of electrons within the nucleus
All transitions within the nulceus are discrete quantum jumps - outside the nucleus all spectra are continuous

KEM

A Hydrogen electron can only exist in specific energy levels below 13.525eV within the nucleus (any excess KE must be shed as Photons)

KE in excess of 13.525 eV results in unbound electron

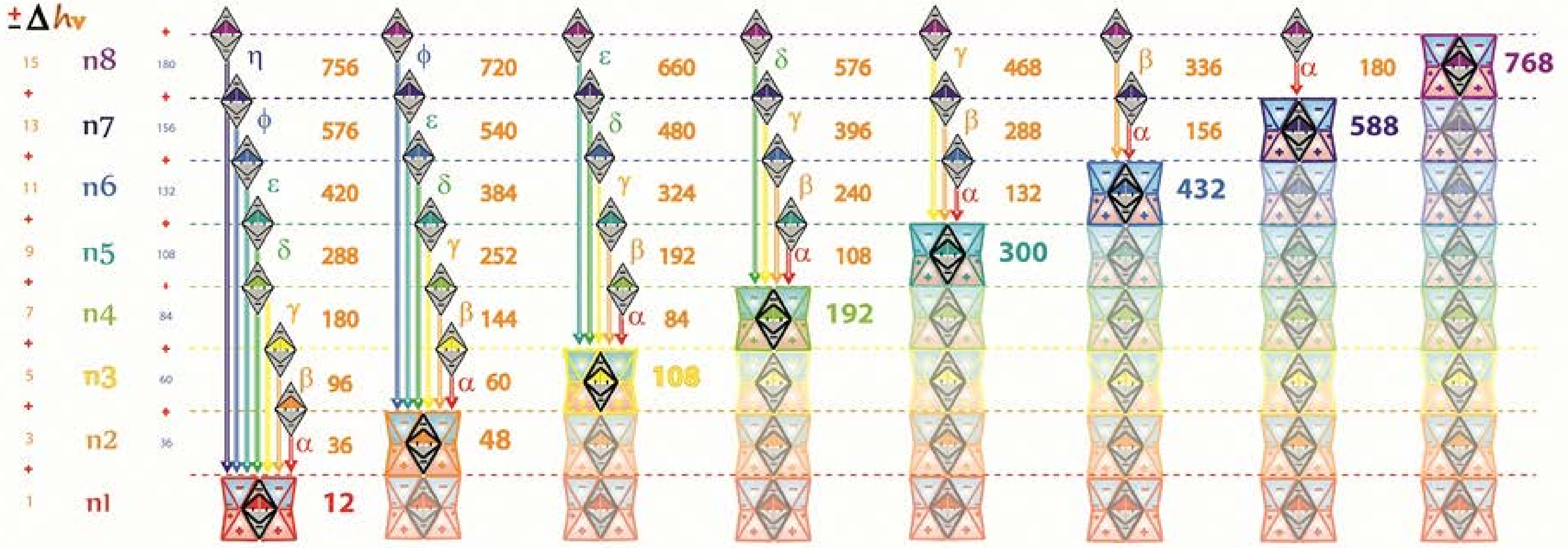
±Δhv
15
13
11
9
7
5
3
1
n8
n7
n6
n5
n4
n3
n2
n1
180
156
132
108
84
60
36
η 756
φ 576
ε 420
δ 288
γ 180
β 96
α 36
12
φ 720
ε 540
δ 384
γ 252
β 144
α 60
48
ε 660
δ 480
γ 324
β 192
α 84
108
δ 576
γ 396
β 240
α 108
192
γ 468
β 288
α 132
300
β 336
α 156
432
α 180
588
768

	-13.525 eV	-10.355 eV	-7.607 eV	-5.283 eV	-3.381 eV	-1.902 eV	-0.845 eV	-0.211 eV
n^2	1 K	2 L	3 M	4 N	5 O	6 P	7 Q	8 R
	Lyman	**Balmer**	**Paschen**	**Brackett**	**Pfund**	**Humphries**	**Un-named**	**Full atomic levels**
	10,903,346	2,725,836	1,211,482	681,459	436,133	302,870	222,517	
	UV spectrum	Visible Spectrum	IR spectrum	IR spectrum	IR spectrum	IR spectrum	IR spectrum	

Spectral line series

(are produced by changes in linear momentum in photo-electric KEM fields due to atomic transitions of electrons between squared energy levels)

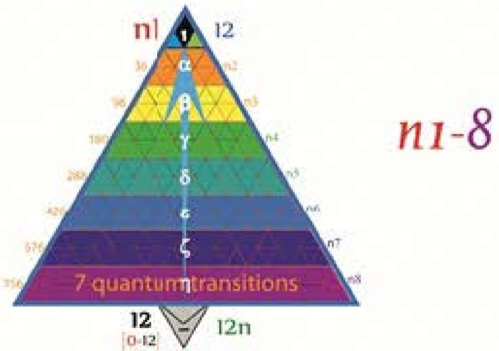
n1
12
1
α
β
γ
δ
ε
ζ
η
7 quantum transitions
12
[0-12]
12n
n1-8

Lyman

Lyman	27.49545417
Balmer	109.9818167
Paschen	247.4590875
Brackett	439.9272667
Pfund	687.3863542
Humphries	989.8363501
Un-named	1,347.277254

Square root of Energy required to transition nuclear quantum levels

$[\sqrt{756}].n^2$

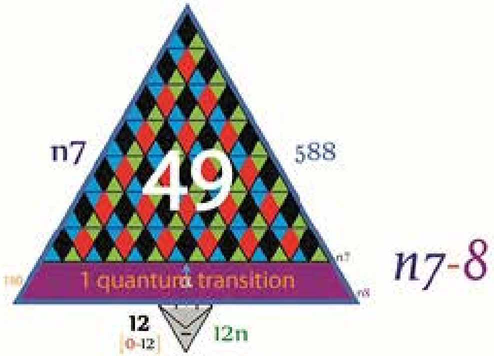
n7
49
588
1 quantum transition
α
12
[0-12]
12n
n7-8

Un-named

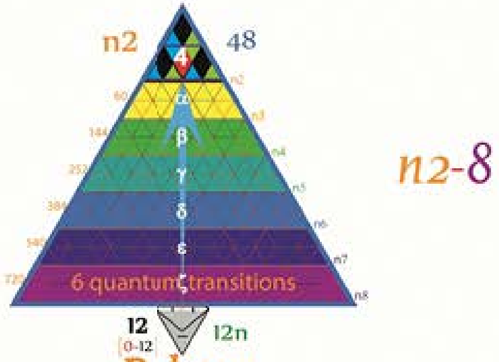
n2
4
48
α
β
γ
δ
ε
ζ
6 quantum transitions
12
[0-12]
12n
n2-8

Balmer

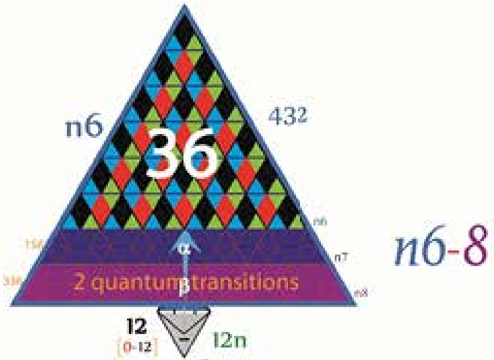
n6
36
432
α
β
2 quantum transitions
12
[0-12]
12n
n6-8

Humphries

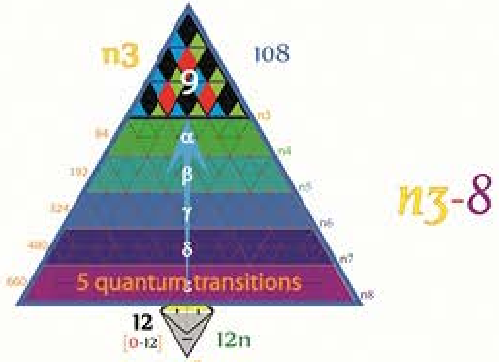
n3
9
108
α
β
γ
δ
ε
5 quantum transitions
12
[0-12]
12n
n3-8

Paschen

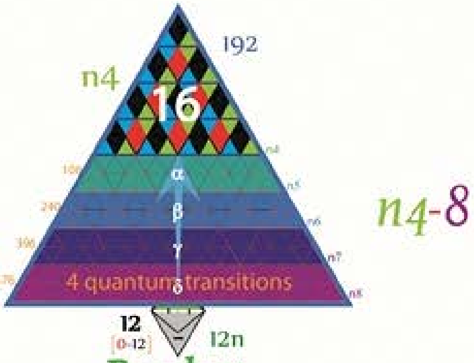
n4
16
192
α
β
γ
δ
4 quantum transitions
12
[0-12]
12n
n4-8

Brackett

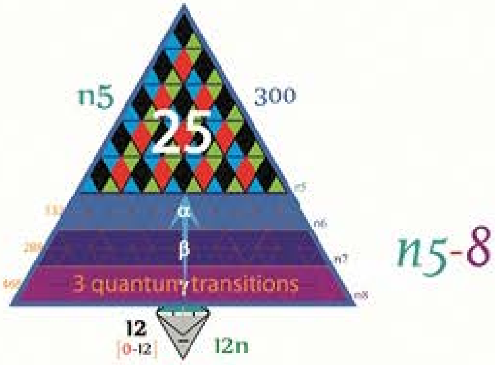
n5
25
300
α
β
γ
3 quantum transitions
12
[0-12]
12n
n5-8

Pfund

Tetryonics 29.09 - Spectral line series

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Johannes Robert Rydberg

(November 8, 1854 – December 28, 1919)

Rydberg's Constant

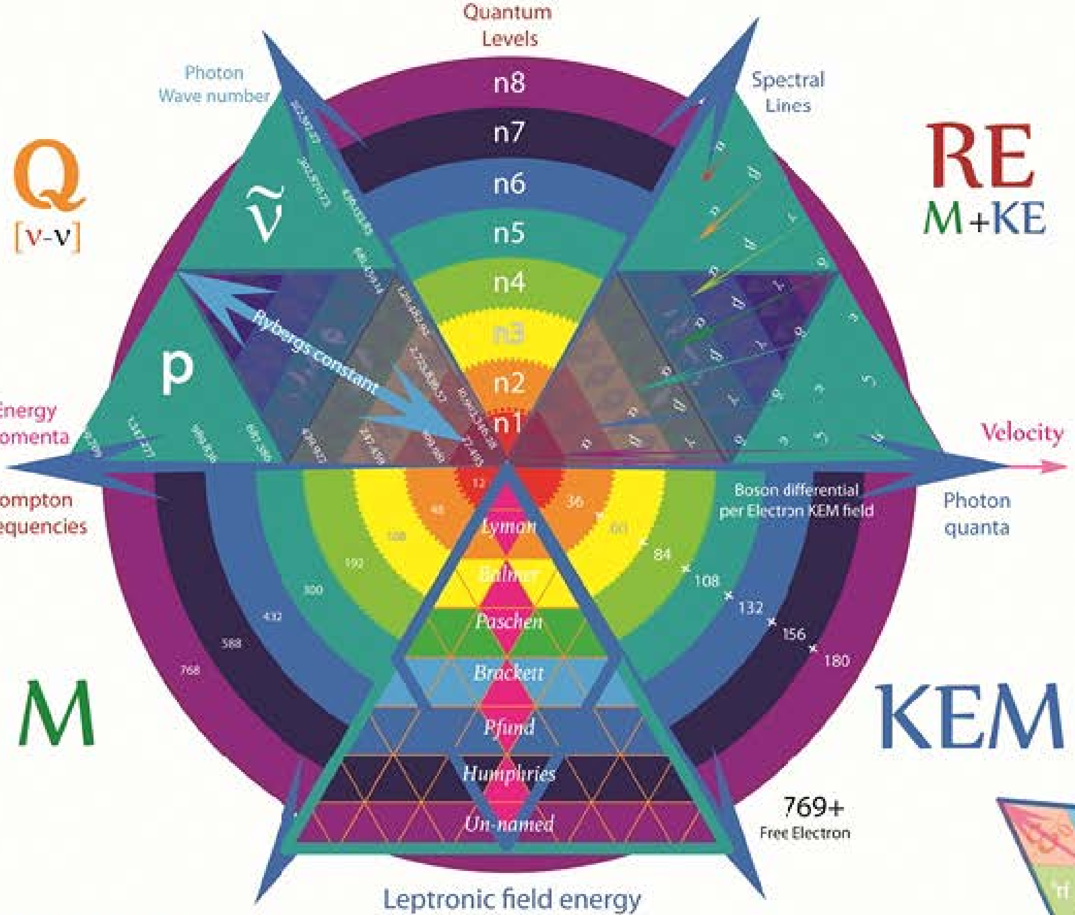
Quantum Levels
n8
n7
n6
n5
n4
n3
n2
n1
Photon Wave number
$\tilde{\nu}$
p
Rybergs constant
Spectral Lines
Energy momenta
Compton Frequencies
Velocity
Photon quanta
Boson differential per Electron KEM field
12
36
48
60
84
108
132
156
180
108
192
300
432
588
768
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
Un-named
769+
Free Electron
Leptronic field energy

Q

$[\nu\text{-}\nu]$

RE

M+KE

M

KEM

$$\tilde{\nu} = \frac{c}{27.49545}$$

$$f = \frac{c^2}{27.49545}$$

$$\lambda = \frac{27.49545}{c}$$

$$p = 27.49545$$

$$R_H = \frac{c}{27.49545}$$

1.0903346.28 x 10^7 m-1

$$R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\lambda = v/f$$

Using the Tetryonic model of a photo-electron and its associated quantum KEM energy levels we see that Rydberg's constant is a linear measure of the photo-electronic KEM field - and in turn directly related to its scalar energy-momenta through 'c'

Currently accepted value - 10,973,731 m^{-1}

Rydberg's Constant can be shown to be the square root of the total number of quanta required to transition a n1 electron to n8
(the highest quantum level possible in elemental nuclei)
as per Planck's heat law

Tetryonic theory value - 10,903,346 m^{-1}

$$p^2 = KEM = Mv^2$$

Quantum Jump

The energy momenta of emitted photons is a function of the photo-electron's KEM wavefunction

27.49545

KE
Photons

$$\boxed{Mv^2 = KEM = hcR_H}$$

Tetryonics 29.10 - Rydberg Constant

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Wavenumbers and Planck's Law

Wavenumbers are revealed to be the number of quanta [nhv] required for a photo-electron to transition between specific quantum levels divided by the speed of light [c]

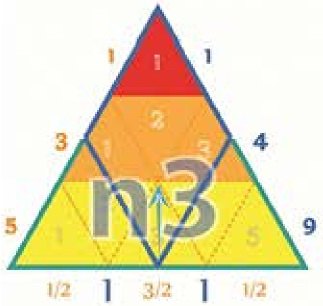
1
1
2
3
4
1
3
5
9
1
5
n3
1/2
1
3/2
1
1/2

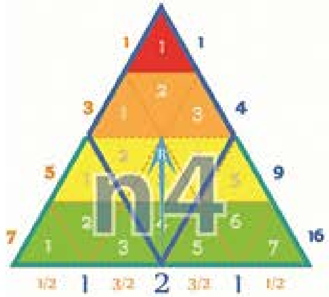
1
1
2
3
4
1
3
5
9
7
16
1
3
5
7
n4
1/2
1
3/2
2
3/2
1
1/2

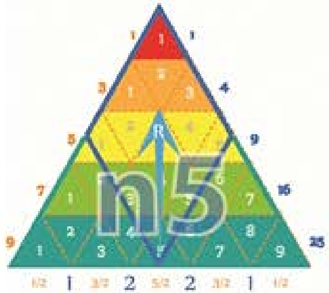
1
3
4
5
9
7
16
9
25
1
3
5
7
9
n5
1/2
1
3/2
2
5/2
2
3/2
1
1/2

Balmer spectral lines [absorption]

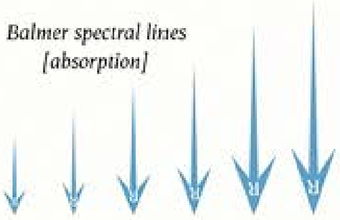

Max Karl Ernst Ludwig Planck

[April 23, 1858 – October 4, 1947]

Balmer spectral lines [emission]

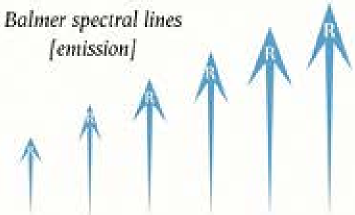

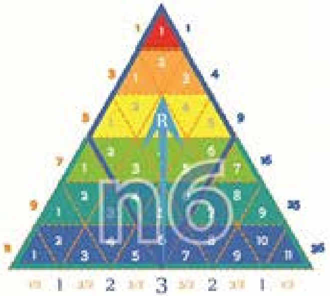

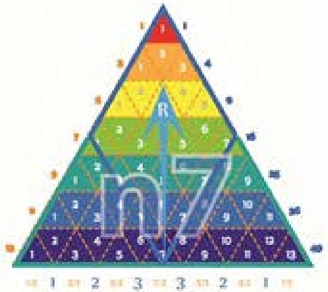

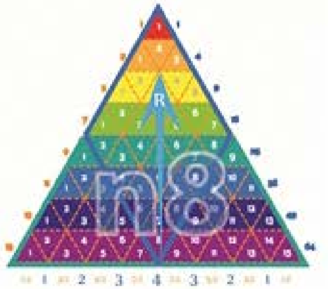

$$E = n[hv]$$

Wavenumbers are the number of Planck quanta required to reach a specific energy level

$$E = hc\tilde{v}$$

Photo-electrons emit and absorb photons to create blackbody radiation

Planck's law describes the electromagnetic radiation emitted by a black body in thermal equilibrium at a specific temperature

$$\Delta[nhv]$$

SQUARED energy levels have ODD numbered quanta in each energy level [bosons]

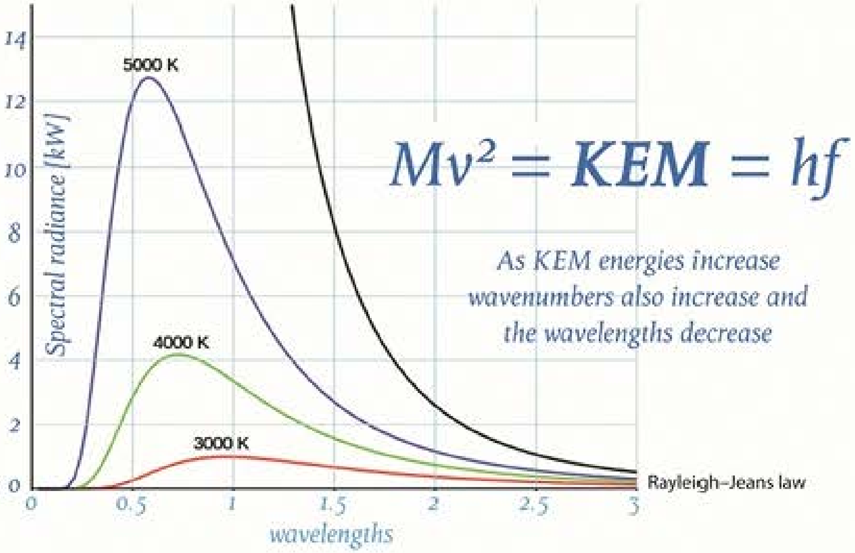

$$Mv^2 = \mathbf{KEM} = hf$$

As KEM energies increase wavenumbers also increase and the wavelengths decrease

Spectral lines can be understood in quantum theory as differences between energy levels and proportional to wavenumber, frequency or wavelengths

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Kinetic mass-energy momenta relationships

Photons are comprised of dual EM masses

Photons are KEM energy-momenta propagating at the speed of Light

EM Field Planck quanta

$$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Photons ElectroMagnetic mass velocity

kg m

f

Q

Photons have neutral charge

[ν-ν]

RE

Photons are Lorentz variant

p $\mathrm{kg}\frac{\mathrm{m}}{\mathrm{s}}$

$\frac{1}{\mathrm{s}}$ f

v $\frac{\mathrm{m}}{\mathrm{s}}$

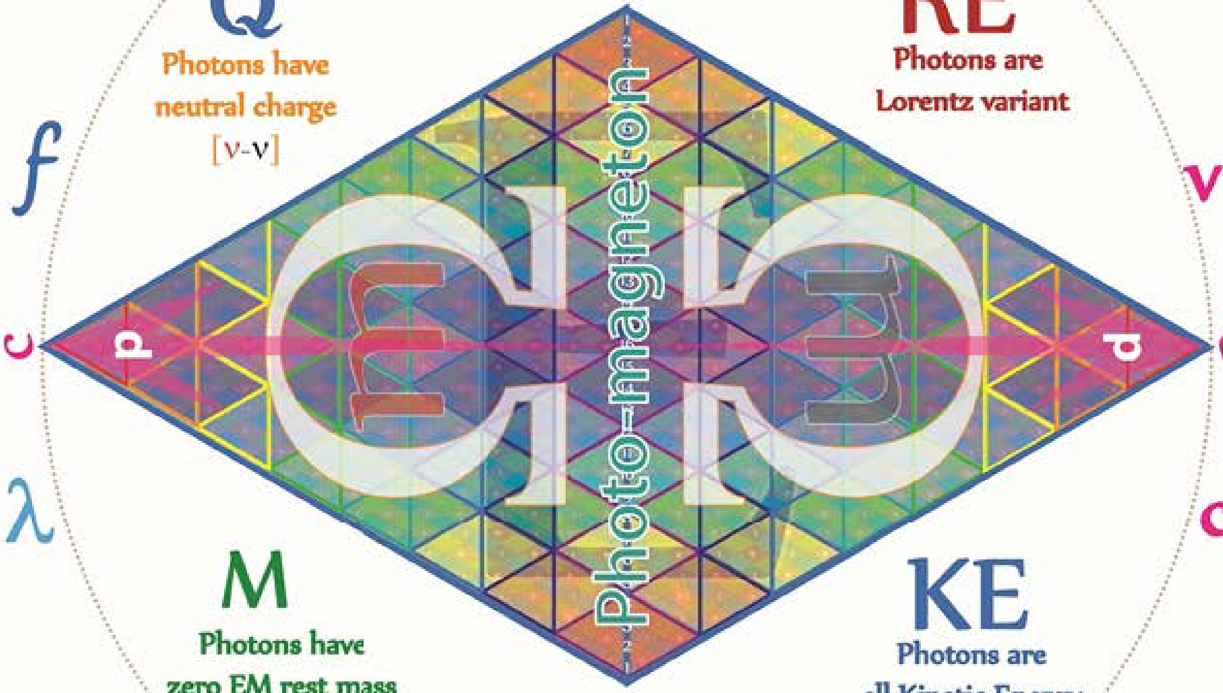

Frequency and Wavelength are related by the natural speed of Energy

c c

'c' is the natural speed of Energy in free space

m λ

c $\frac{\mathrm{m}}{\mathrm{s}}$

M

Photons have zero EM rest mass

KE

Photons are all Kinetic Energy

KG 0

E $\mathrm{kg}\frac{\mathrm{m}^2}{\mathrm{s}^2}$

$$\Delta 2hv = E = hf$$

Planck Einstein

c^2

1 second

Photons are 'Matterless' 2D neutral charge mass-energy geometries

Kinetic Energy is 1/2 the energy created by Matter topologies in motion

Tetryonics 29.12 - Kinetic mass-energy relationships

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Relativistic Lorentz corrections

Hendrik Lorentz

(18 July 1853 – 4 February 1928)

$$\sqrt{1-\beta^2}$$

$$E=\frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$\sqrt{1-\left(\frac{v}{c}\right)^2}$$

The Lorentz transformation was originally the result of attempts by Lorentz and others to explain how the speed of light was observed to be independent of the reference frame and later expanded upon in an attempt to understand the creation of emfs in magnets and symmetries in electromagnetic forces

Einstein inlcuded the transformation in his theory of Special relativity [SR].

The Lorentz transformation supersedes the Galilean transformation of Newtonian physics, which assumes an absolute space and time.

According to special relativity, the Galilean transformation is a good approximation only at relative speeds much smaller than the speed of light.

Tetryonics expands upon all of this revealing this relationship as a result of the geometry of electromagnetic mass-energies in motion

rest mass-Matter

Energy

Planck quanta

$$\frac{4n\pi}{c^4}\left[\left[m\Omega v^2\right]\right]$$

mass velocity

momentum

spatial co-ordinate system

Matter is EM energy propagating at the 'speed of Light' in a standing wave energy topology

One of the greatest mistakes in relativistic mechanics is the application of Lorentz corrections to Matter.

It stems from there being no definition and enforced differentiation between EM mass and Matter

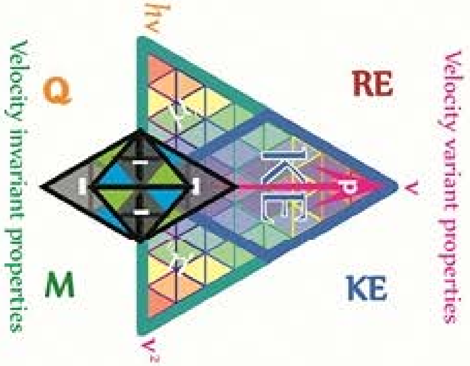

$$m=\frac{E}{c^2}$$

2D planar fields are relativisitic

radiant EM mass geometry

$$\frac{m}{c^2}=M$$

standing-wave Matter topology

3D standing-waves are velocity invariant

$$\frac{E}{c^4}=M$$

mass is a property of Matter - Matter is not a property of mass [they are directly related throught the velocity of light]

$$\beta=\left[\frac{v}{c}\right]$$

velocity is a result of vector forces

All 2D energy waveforms propagate at the 'speed of Light'

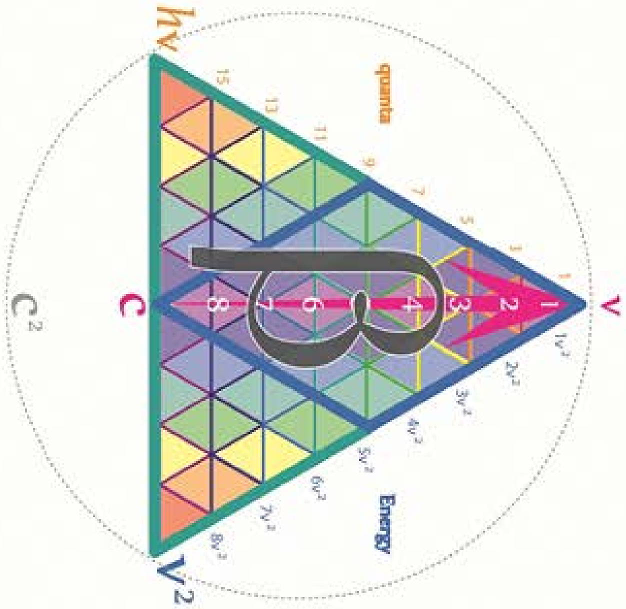

$$\beta^2=\left[\frac{v^2}{c^2}\right]$$

The Kinetic Energy of Matter in motion is directly related to the square of the velocity

$$\gamma\equiv\frac{c}{\sqrt{c^2-v^2}}=\frac{1}{\sqrt{1-\beta^2}}=\frac{dt}{d\tau}$$

The 'speed of Light' is a EM constant and is the limiting velocity acheivable by the electrical acceleration of Matter

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Spectral Energy relationships

$\mathrm{kg}\frac{m^2}{s^2}$ $E = p^2$

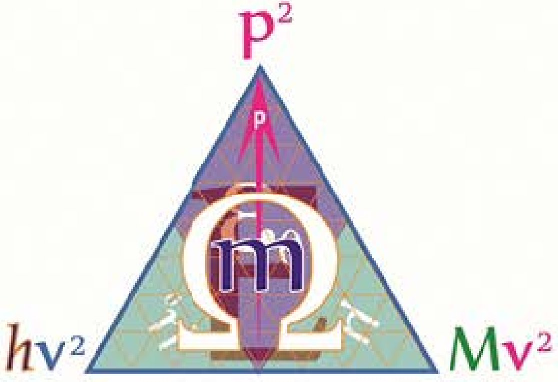
p²
p
m
hv²
Mv²

Scalar EM mass
-energy momenta

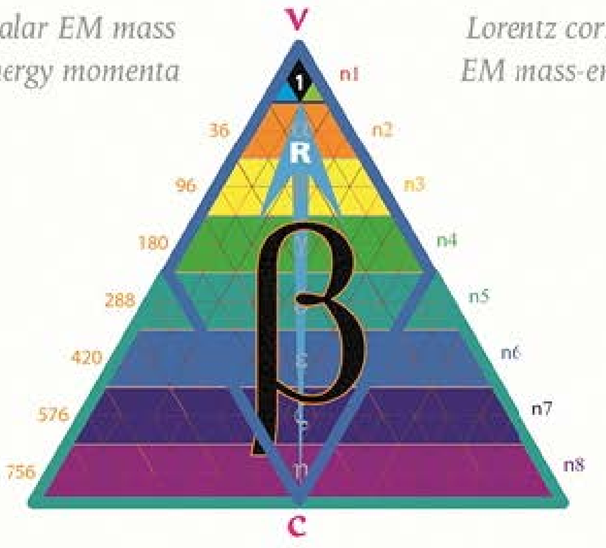
v
1
R
β
36
96
180
288
420
576
756
n1
n2
n3
n4
n5
n6
n7
n8
c

Lorentz corrected
EM mass-energies

$KEM = \frac{mv^2}{c^2}$

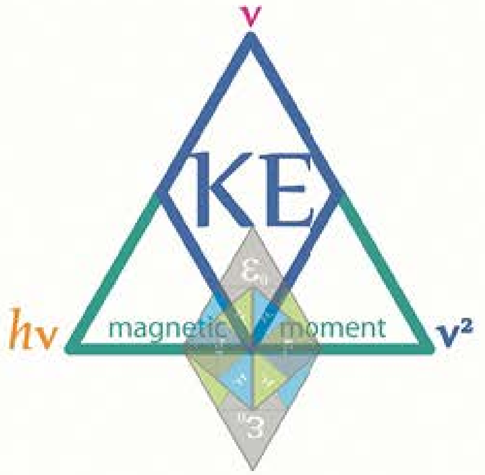
v
KE
hv
magnetic
moment
v²

$$\boxed{Mv^2 = \underset{13.525\ \mathrm{eV}}{KEM} = hcR_H}$$

All Spectral line emissions and absorptions
produce changes in KEM energies, Angular momentum,
Linear momentum, Frequency and Wavelengths

Linear

$$\left[\frac{\Omega}{c}\right] = \lambda$$

de Broglie wavelengths

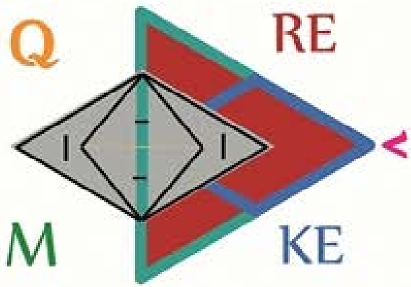

The 'speed of Light' is the maximum velocity acheivable by electrical energies

Scalar

$$f = \left[\frac{c^2}{\Omega}\right]$$

Compton frequencies

Spectral line photon production

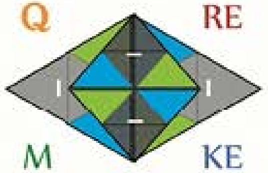

At no time does the 3D rest Matter-energy content of the electron change

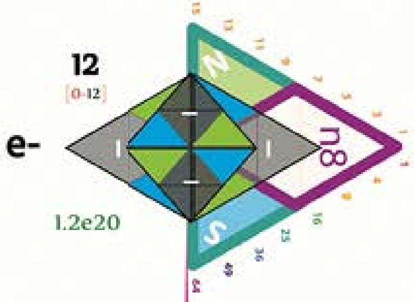
12
[0-12]
e-
n8
1.2e20

An electron transitioning from n8 to n7

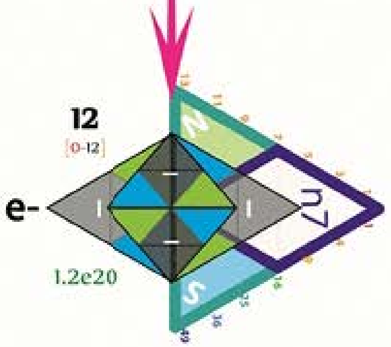
12
[0-12]
e-
n7
1.2e20

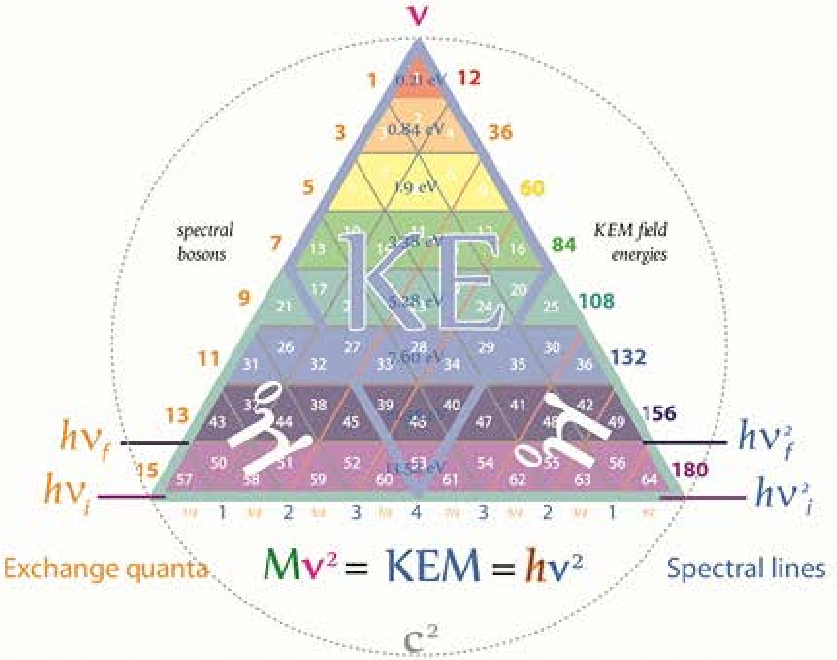
v
1
12
0.21 eV
3
36
0.84 eV
5
60
1.9 eV
7
84
3.38 eV
9
108
5.28 eV
11
132
7.60 eV
13
156
15
180
KE
spectral bosons
KEM field energies
hν_f
hν_i
hν²_f
hν²_i
1 2 3 4 3 2 1
Exchange quanta
Spectral lines
c²

$$Mv^2 = KEM = hv^2$$

$$E = hf$$

As the 3D rest Matter of any particle in motion is Lorentz invariant any changes in velocity-momentum produces changes to the mass-energy momenta content of the 2D KEM field [boson changes are the difference of two squares]

Spectral line wavenumbers

Tetryonic

$$\left(\frac{15 \diagup 49}{64}\right)$$

.0047

$$\frac{1}{\lambda}$$

Rydberg

$$R\left(\frac{1}{49} - \frac{1}{64}\right)$$

.0047

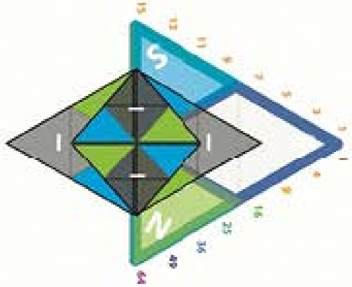

Does so by emitting Kinetic Energy quanta

λ	19,174.54158	nm
ṽ	52,152.48541	m-1
f	1.563492179 x 10 ¹³	Hz
E	0.064693658	eV
Ω	5,748.382952	m²/s

Which are released as photons of specific energy-momenta

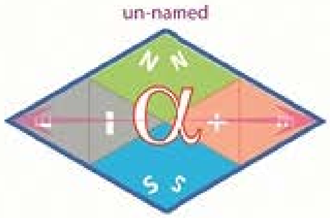

of specific wavelengths (Spectral Lines)

Wavenumbers

are the number of energy momenta wavelengths per unit distance

m

n1 2

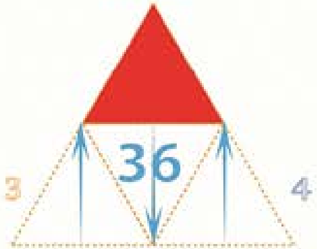

48

1 quantum level jump

α

n1 3

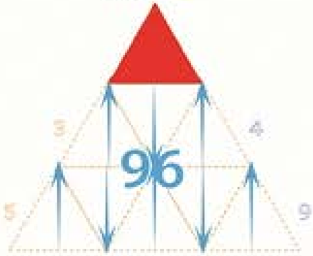

108

2 quantum level jump

β

n1 4

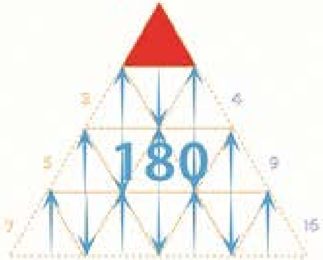

192

3 quantum level jump

γ

m

$\tilde{\nu}$

the wavenumber (also wave number) is the spatial frequency of a wave, either in quanta per distance or nπ radians per unit distance.
It can be envisaged as the number of specific wavesets that exist over a specified distance

$1/\lambda$

m^{-1}

n1 5

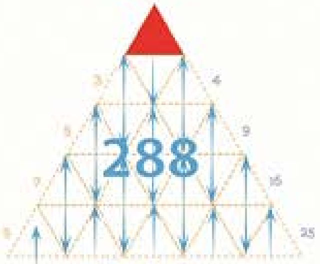

300

4 quantum level jump

δ

n1 6

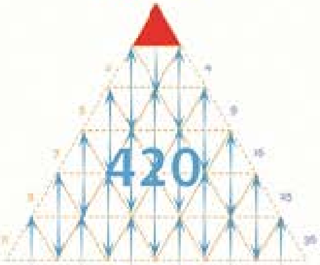

432

5 quantum level jump

ε

n1 7

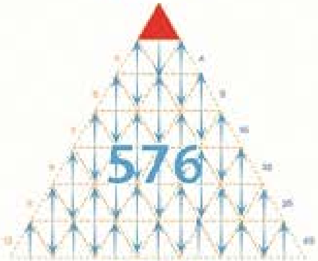

588

6 quantum level jump

ζ

n1 8

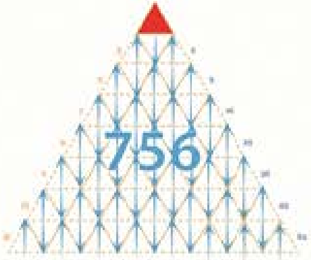

768

7 quantum level jump

η

For electromagnetic radiation in vacuum, wavenumber is proportional to frequency and to photon energy

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Bosons, Photons and quantums of energy momenta

$\tilde{\nu}$ WAVENUMBERS

$E = \Sigma h\nu$

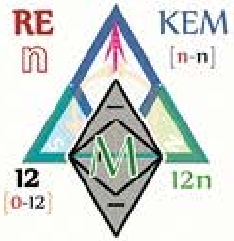
RE
n
KEM
[n-n]
M
12
[0-12]
12n

$KEM = Mv^2$

LINEAR MOMETNUM **p**

γ Spectral lines are produced $\Delta m\Omega v = \Delta mv = \Delta p$ by accelerating electrons **a**

equilateral energy momenta is the foundation of all quantum EM wave-functions

ODD distribution $2\nu = f$ **SQUARED distribution**

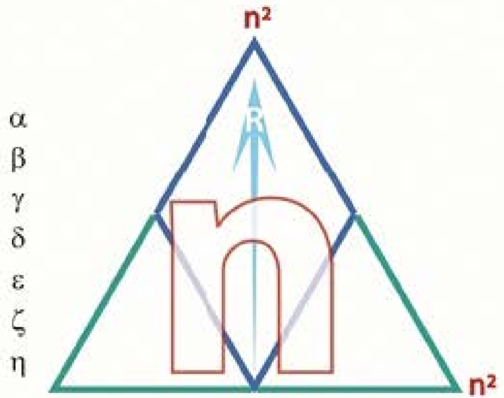
n²
α
β
γ
δ
ε
ζ
η
n
n²

Spectral lines

Bosons

$h\nu$

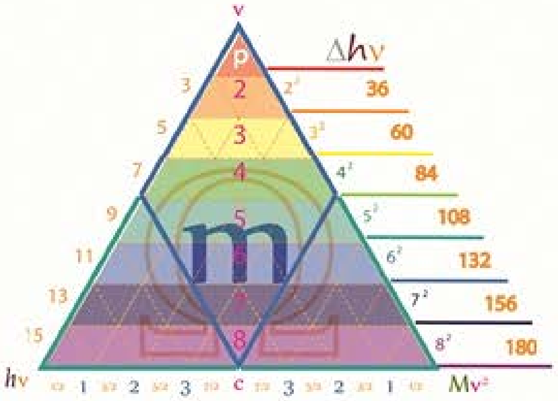
v
Δhν
p
2
3
4
5
6
7
8
m
3
5
7
9
11
13
15
2²
3²
4²
5²
6²
7²
8²
36
60
84
108
132
156
180
hν
1
2
3
c
3
2
1
Mv²

EVEN distribution

hf

Photons

Kinetic energies

$h\nu^2$

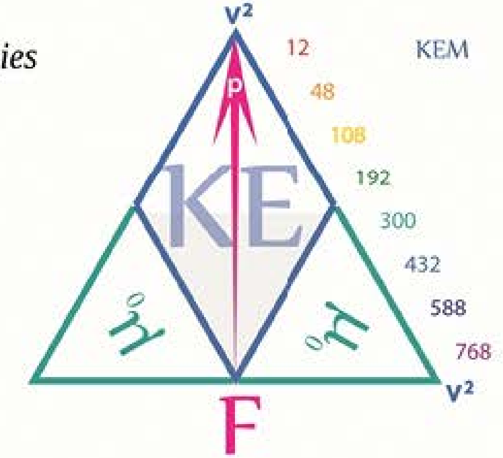
v²
p
12
48
108
192
300
432
588
768
KEM
KE
v²
F

energy momenta

Tetryonics 29.17 - Bosons, Photons and energy momenta

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Spectral Energy - Planck relationships

$$\frac{E}{v^2} = m\Omega = \frac{E}{c^2}$$

deBroglie wavelength λ

f Frequency

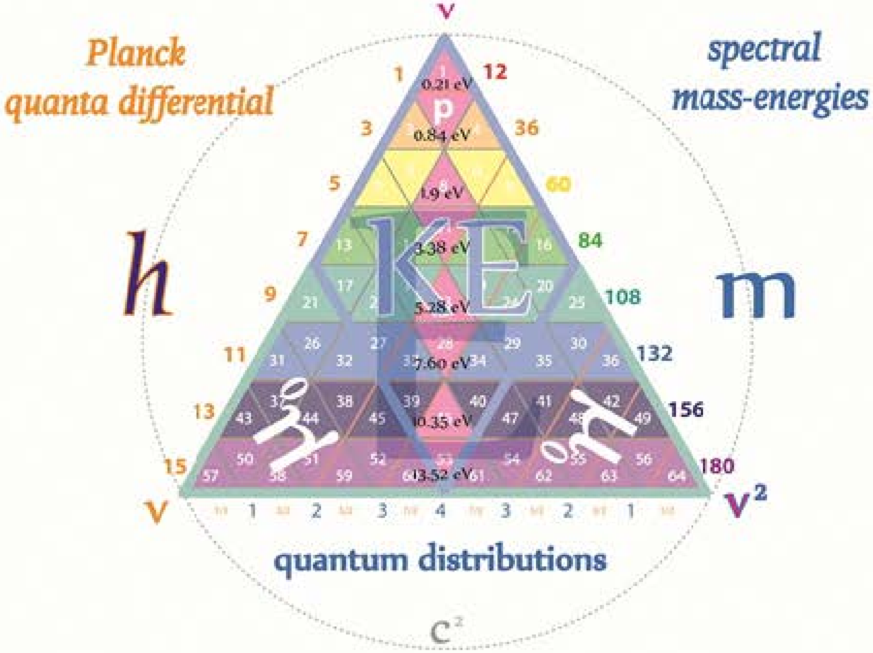
v
Planck quanta differential
spectral mass-energies
1
12
0.21 eV
p
3
36
0.84 eV
5
60
1.9 eV
7
84
3.38 eV
KE
h
m
9
108
5.28 eV
11
132
7.60 eV
13
156
10.35 eV
15
180
13.52 eV
v
v²
1 2 3 4 3 2 1
quantum distributions
c²

p MOMENTUM

ENERGY **E**

Wave number $\tilde{v}$

v^2 Compton Frequency

Applying mass to spectral energy relationships reveals the familiar quantum mechanical wave-particle relationships and properties

	2D waves						3D Matter	
EM wave wavelength	Ω / c	=	planck constant	h / p	linear momentum	=	$m\Omega / mc$	deBroglie wavelength
EM wavenumber	c / Ω	=	linear momentum	p / h	planck constant	=	$mc / m\Omega$	Matter waves
EM wave Frequency	c^2 / Ω	=	kinetic energy	E / h	planck constant	=	$mc^2 / m\Omega$	Compton Frequency

Thus reinforcing the geometric role of quantised angular momenta in Planck's constant

Tetryonics 29.18 - Spectral energy relationships

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White Light

White light is radiated by our SUN and all the stars throughout the Universe.
In fact, most of the energy radiated by the sun is within the visible spectrum, which is most likely why we see this range.

Incandescence is the greatest known generator of white light. The verb incandesce means to glow white. This is also referred to as black-body radiation.

The color of a black body object at high temperatures causes it to glow, and the waves emitted include visible light.
In addition to the sun and common light bulb, molten materials such as metal or glass also glow incandescently.

Hydrogen
Oxygen
Sulfur

Spectroscopy

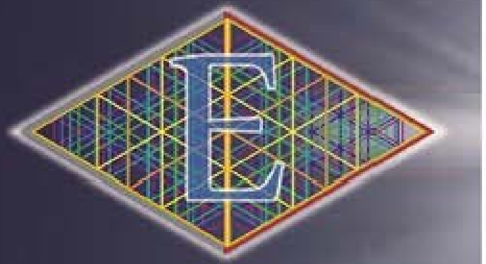

Planck's Heat Law

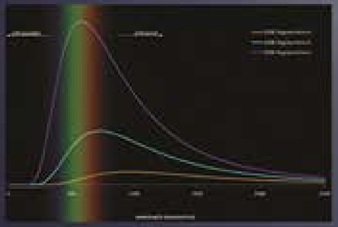

Most light sources are thermal, meaning the type of radiation
they emit is a characteristic of the source's temperature.

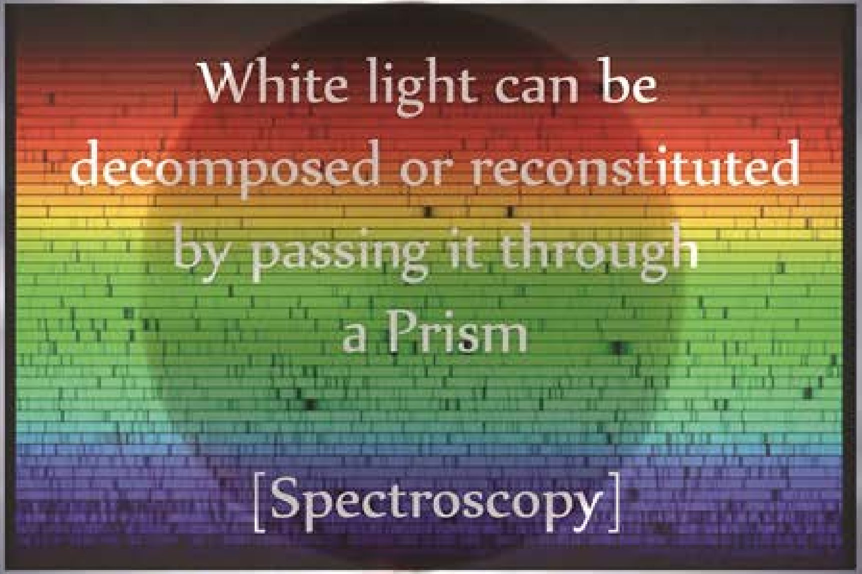

White light can be
decomposed or reconstituted
by passing it through
a Prism

[Spectroscopy]

White light is comprised
of many photons of varying
frequencies and wavelengths

Each colour of light has
a specific frequency
and wavelength

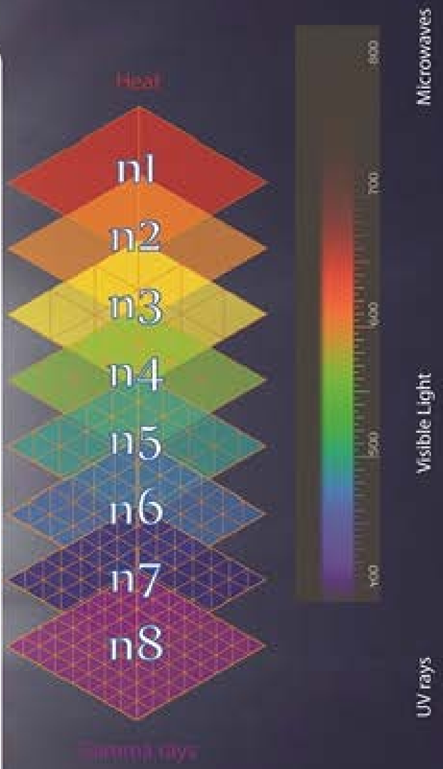

Until Newton's work proved otherwise, most scientists believed that white was the fundamental color of light; and that other colors were formed only by adding something to light. Newton demonstrated this was not true by passing white light through a prism, then through another prism. If the colors were added by the prism, the second prism should have added further colors to the single-colored beam. Since the single-colored beam remained a single color, Newton concluded that the prism merely separated the colors already present in the light.

White light is the result of superpositioning of the visible colors [varying frequencies] of EM waves

White light

Max Karl Ernst Ludwig Planck

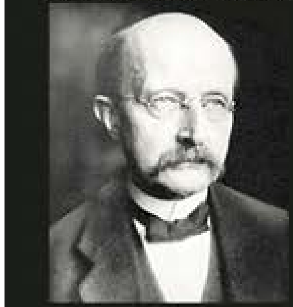

[April 23, 1858 – October 4, 1947]

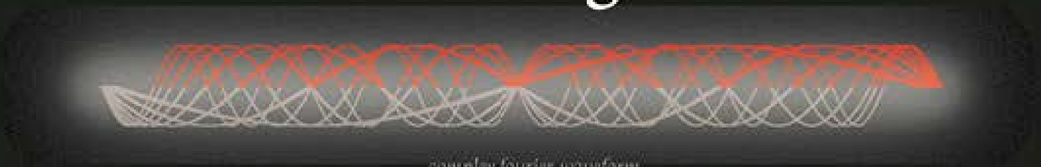

complex fourier waveform

Johannes (Janne) Robert Rydberg

(November 8, 1854 – December 28, 1919)

is comprised of superpositioned differing spectral wavelength photons

spectral lines & colour

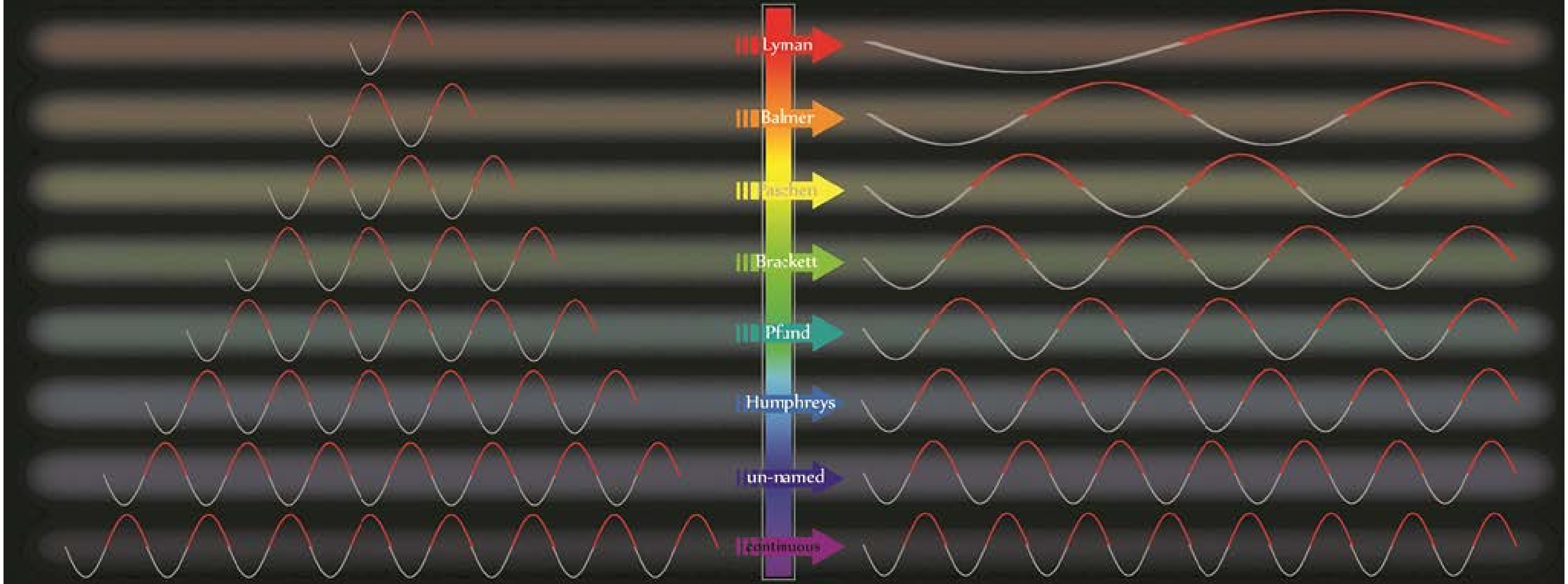
bosons
photons
Lyman
Balmer
Paschen
Brackett
Pfund
Humphreys
un-named
continuous

Instantaneous measurement of energy momenta released

Time measurement of released waveforms [photons]

created by the fractional release of equilateral KEM field energy momenta

Lyman spectral lines

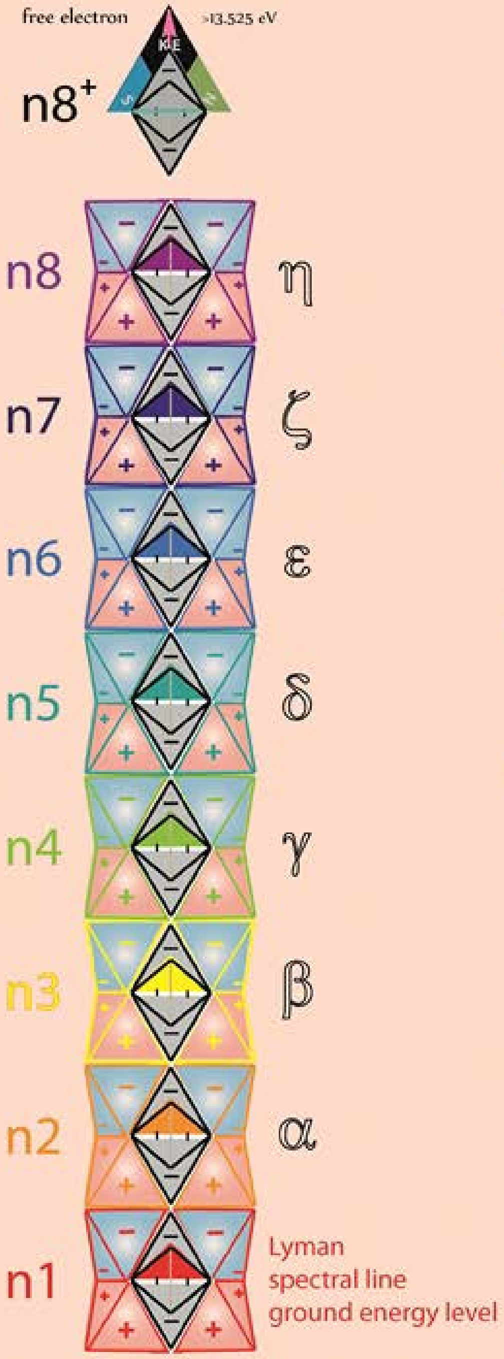
free electron
>13.525 eV
KE
n8⁺
n8
η
n7
ζ
n6
ε
n5
δ
n4
γ
n3
β
n2
α
n1
Lyman
spectral line
ground energy level

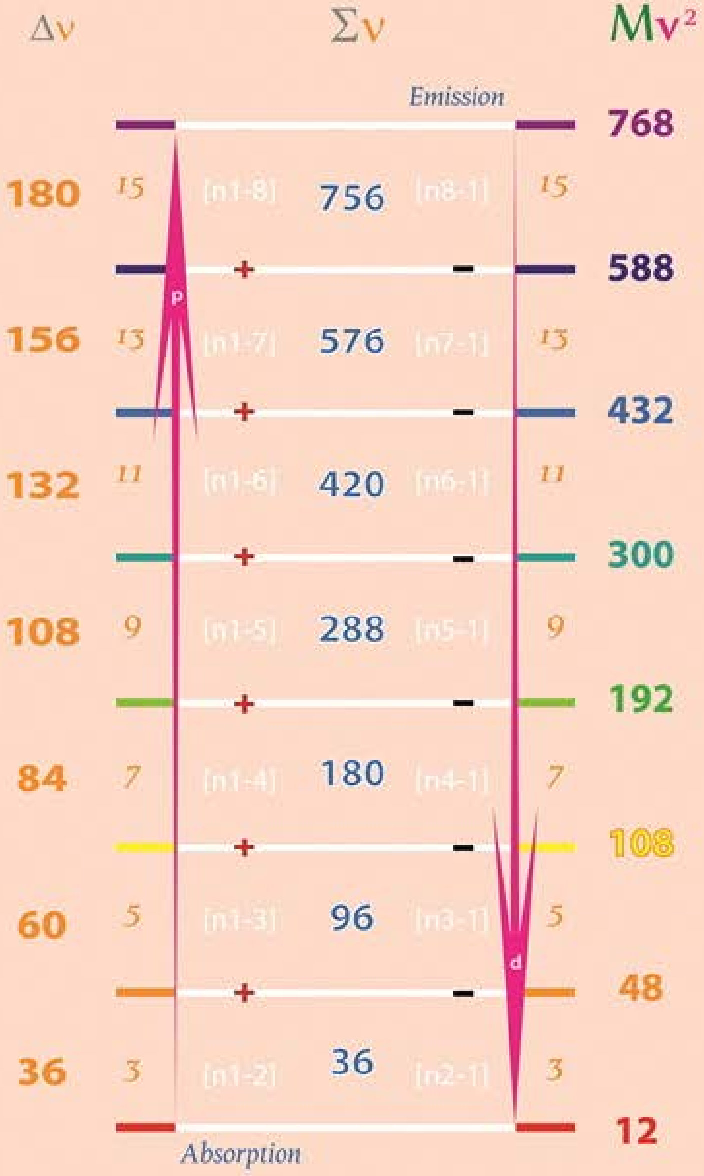
Δν
Σν
Mv²
Emission
768
180
15
[n1-8]
756
[n8-1]
15
588
156
13
[n1-7]
576
[n7-1]
13
432
132
11
[n1-6]
420
[n6-1]
11
300
108
9
[n1-5]
288
[n5-1]
9
192
84
7
[n1-4]
180
[n4-1]
7
108
60
5
[n1-3]
96
[n3-1]
5
48
36
3
[n1-2]
36
[n2-1]
3
12
p
d
Absorption

nl

Ground State

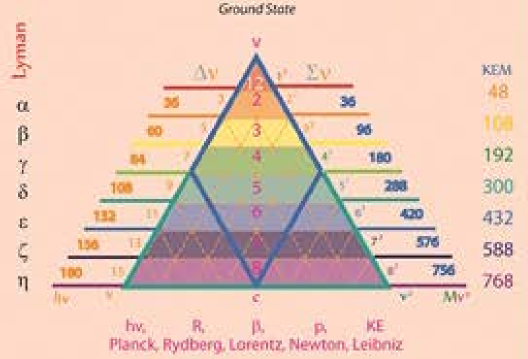
Lyman
α
β
γ
δ
ε
ζ
η
v
Δν
Σν
KEM
36
36
48
60
96
108
84
180
192
108
288
300
132
420
432
156
576
588
180
756
768
hv
c
Mv²
hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

-13.5252 eV

$$KEM = \frac{hf}{n^2}$$

v
nl
KEM
12
1.2e20

K shell

91.714 nm

$$KEM = \frac{hcR}{n^2}$$

$$m.\begin{bmatrix}\Omega/v\\ v/\Omega\\ c^2/\Omega\\ v^2/c^2\end{bmatrix}$$

λ	91.71496292	nm	h/p
ṽ	10,903,346.28	m-1	p/h
f	$3.268740982 \times 10^{15}$	Hz	E/h
E	13.52528	eV	hf
Ω	27.49545417	m²/s	

ground KEM energies

equilateral energy momenta is the foundation of all quantum EM wave-functions

As photo-electrons transition between Mv squared KEM field energy levels in atomic nuclei they release specific [Δhv] W bosons

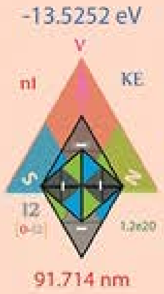
-13.5252 eV
v
nl
KE
12
[0-12]
1.2e20
91.714 nm

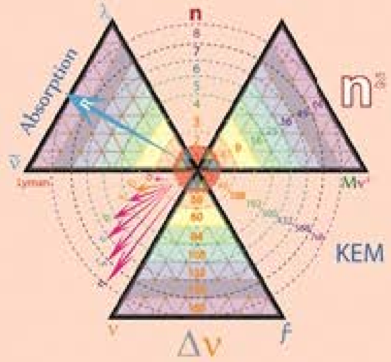
λ
n
Absorption
n²
Lyman
Mv²
KEM
v
Δv
f

Lyman spectral series

α	122.28	n1-2
β	103.18	n1-3
γ	97.83	n1-4
δ	95.53	n1-5
ε	94.33	n1-6
ζ	93.62	n1-7
η	93.17	n1-8

UV spectrum

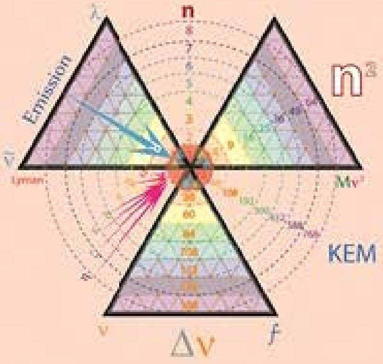
λ
n
Emission
n²
Lyman
Mv²
KEM
v
Δv
f

K shell

Δv

KEM

n1~2

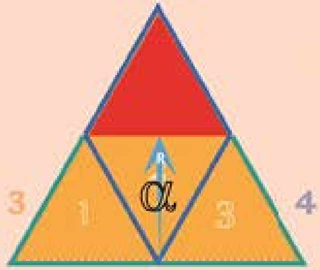

36

48

1 quantum level jump

n1~3

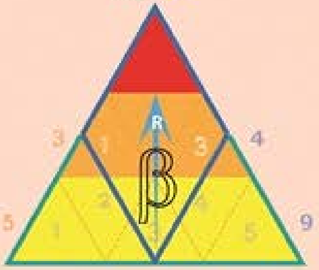

96

108

2 quantum level jump

n1~4

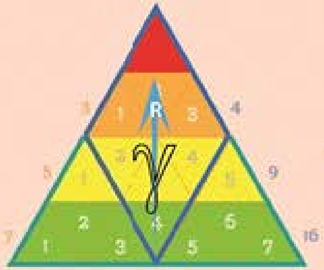

180

192

3 quantum level jump

n1~5

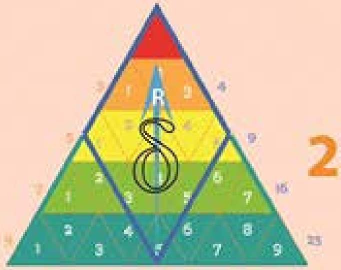

288

300

4 quantum level jump

n1~6

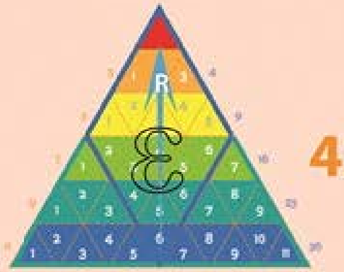

420

432

5 quantum level jump

n1~7

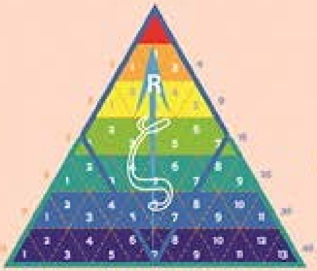

576

588

6 quantum level jump

n1~8

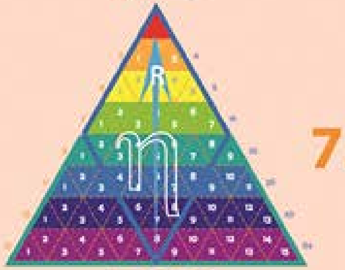

756

768

7 quantum level jump

Tetryonics 30.02 - Lyman quantum transitions

Lyman series energy momenta

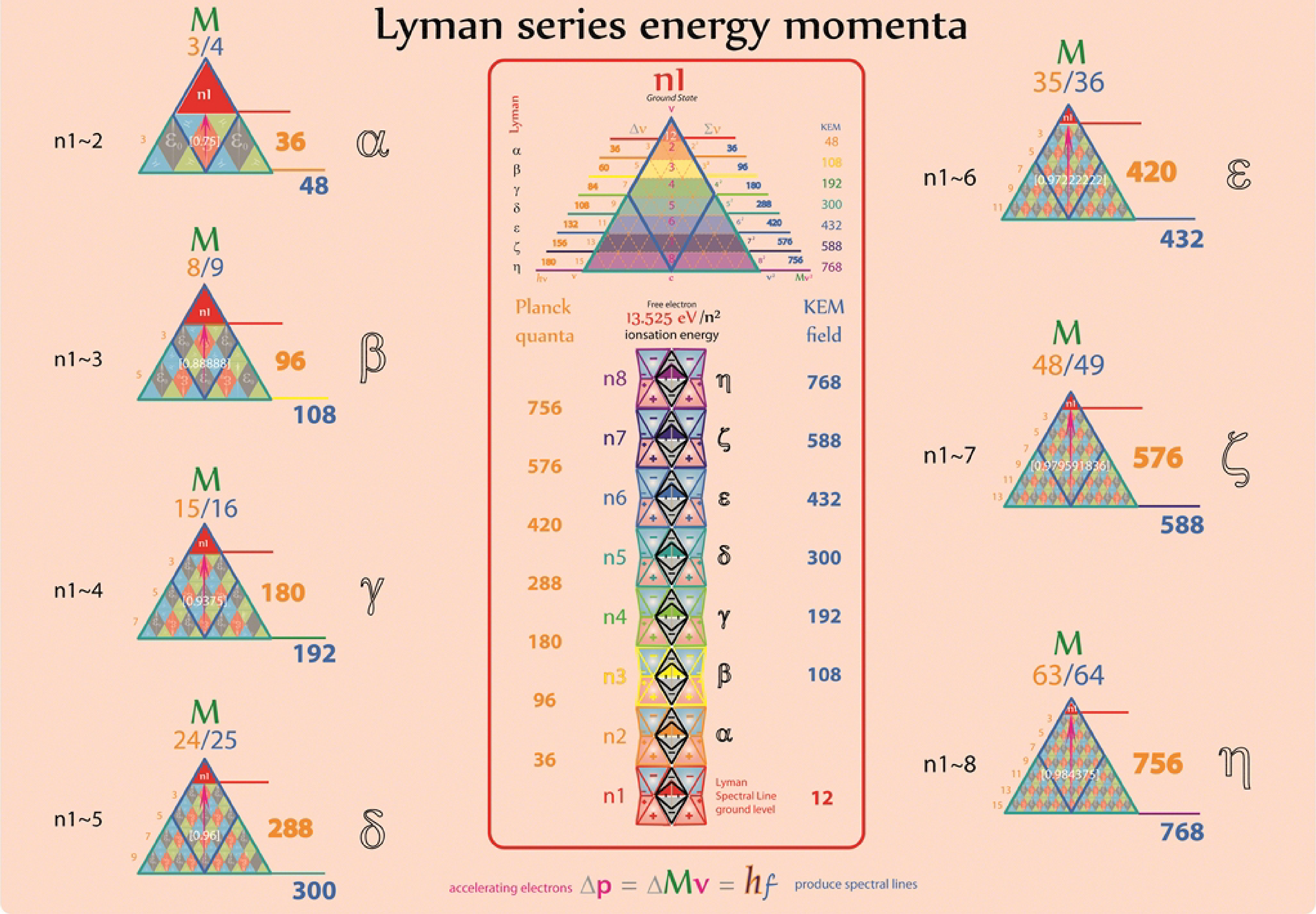
M
3/4
n1~2
[0.75]
36
48
α
M
8/9
n1~3
[0.88888]
96
108
β
M
15/16
n1~4
[0.9375]
180
192
γ
M
24/25
n1~5
[0.96]
288
300
δ
n1
Ground State
Lyman
α
β
γ
δ
ε
ζ
η
Δv
Σv
36
60
84
108
132
156
180
36
96
180
288
420
576
756
KEM
48
108
192
300
432
588
768
Planck quanta
Free electron
13.525 eV /n²
ionsation energy
KEM field
n8
η
768
756
n7
ζ
588
576
n6
ε
432
420
n5
δ
300
288
n4
γ
192
180
n3
β
108
96
n2
α
36
n1
Lyman Spectral Line ground level
12
M
35/36
n1~6
[0.972222222]
420
432
ε
M
48/49
n1~7
[0.979591836]
576
588
ζ
M
63/64
n1~8
[0.984375]
756
768
η

accelerating electrons $\Delta p = \Delta M v = hf$ produce spectral lines

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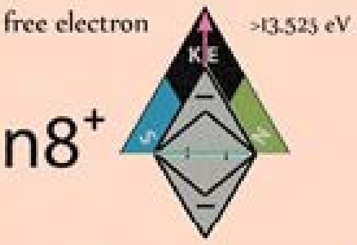

Lyman Series

$$\Delta h\nu \;=\; \text{KEM} \;=\; hcR$$

Tetryonic — 13.525 eV — Rydberg

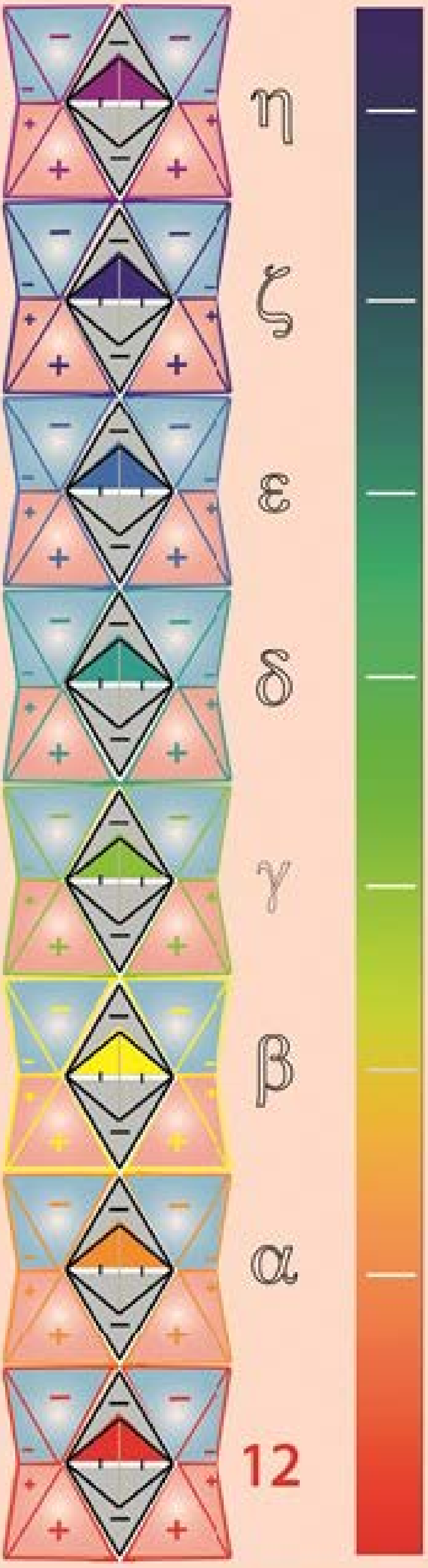

63/64
.9843

λ	93.17075598	nm
ν̃	10,732,981.5	m-1
f	$3.217666905 \times 10^{15}$	Hz
E	**13.31395504**	eV
Ω	27.93180995	m²/s

$R\left(\frac{1}{1}-\frac{1}{64}\right)$ .984375

48/49
.9795

λ	93.62569132	nm
ν̃	10,680,829.01	m-1
f	$3.202031983 \times 10^{15}$	Hz
E	**13.24926138**	eV
Ω	28.06827615	m²/s

$R\left(\frac{1}{1}-\frac{1}{49}\right)$ .9795

35/36
.9722

λ	94.33539043	nm
ν̃	10,600,475.55	m-1
f	$3.177942622 \times 10^{15}$	Hz
E	**13.14958523**	eV
Ω	28.28103857	m²/s

$R\left(\frac{1}{1}-\frac{1}{36}\right)$ .9722

24/25
.9600

λ	95.53641971	nm
ν̃	10,467,212.43	m-1
f	$3.137991343 \times 10^{15}$	Hz
E	**12.98427616**	eV
Ω	28.64199809	m²/s

$R\left(\frac{1}{1}-\frac{1}{25}\right)$ .96

15/16
.9375

λ	97.82929378	nm
ν̃	10,221,5587.14	m-1
f	$3.064444671 \times 10^{15}$	Hz
E	**12.67995718**	eV
Ω	29.32644445	m²/s

$R\left(\frac{1}{1}-\frac{1}{16}\right)$ .9375

8/9
.8888

λ	103.1793333	nm
ν̃	9,691,863.362	m-1
f	$2.90554754 \times 10^{15}$	Hz
E	**12.02247792**	eV
Ω	30.93228594	m²/s

$R\left(\frac{1}{1}-\frac{1}{9}\right)$ .888

3/4
.7500

λ	122.2866172	nm
ν̃	8,177,509.712	m-1
f	$2.451555737 \times 10^{15}$	Hz
E	**10.14396575**	eV
Ω	36.66060556	m²/s

$R\left(\frac{1}{1}-\frac{1}{4}\right)$ .75

ground KEM energies

$$m.\begin{bmatrix} \Omega/v \\ v/\Omega \\ c^2/\Omega \\ v^2/c^2 \end{bmatrix}$$

λ	91.71496292	nm	h/p
ν̃	10,903,346.28	m-1	p/h
f	$3.268740982 \times 10^{15}$	Hz	E/h
E	**13.52528**	eV	hf
Ω	27.49545417	m²/s	

changing energy momenta produces specific frequency spectral lines

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Balmer spectral lines

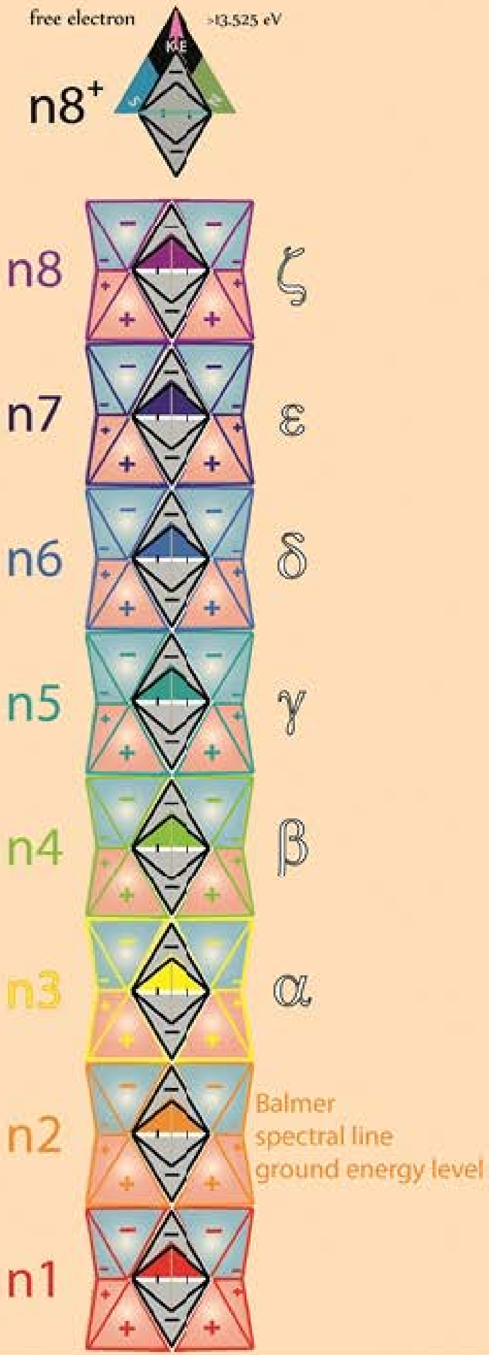
free electron
>13.525 eV
n8+
KE
n8
ζ
n7
ε
n6
δ
n5
γ
n4
β
n3
α
n2
Balmer
spectral line
ground energy level
n1

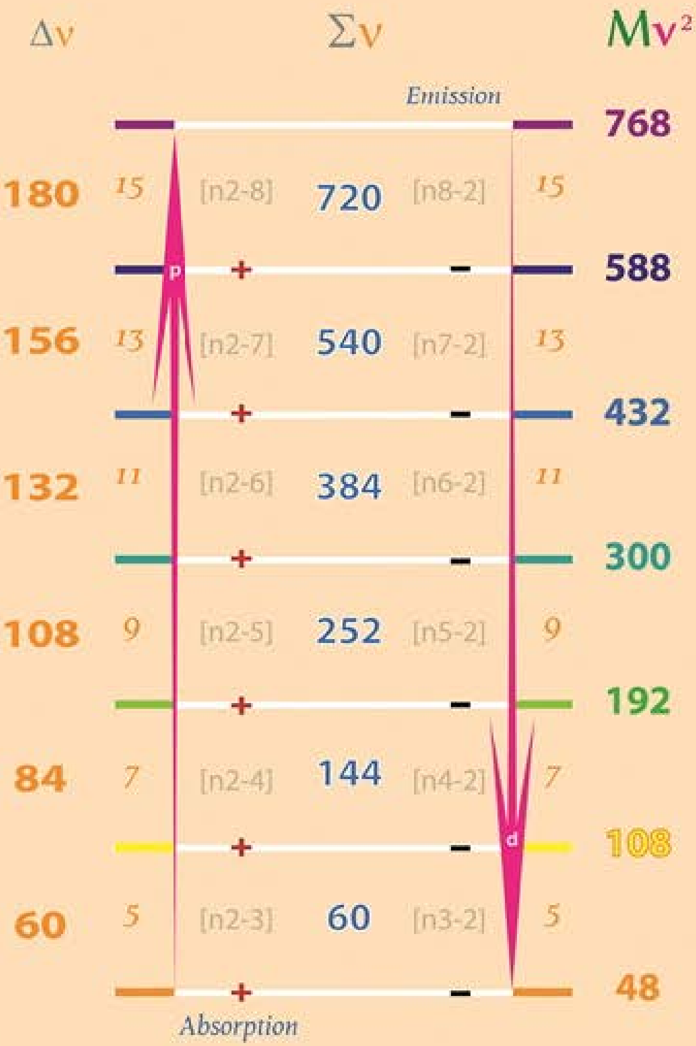
Δv
Σv
Mv²
Emission
768
180
15
[n2-8]
720
[n8-2]
15
p
588
156
13
[n2-7]
540
[n7-2]
13
432
132
11
[n2-6]
384
[n6-2]
11
300
108
9
[n2-5]
252
[n5-2]
9
192
84
7
[n2-4]
144
[n4-2]
7
d
108
60
5
[n2-3]
60
[n3-2]
5
48
Absorption

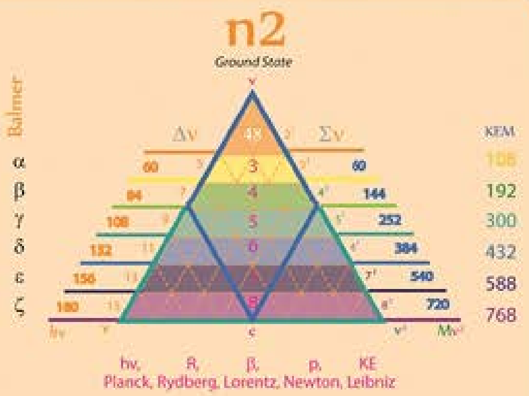
n2
Ground State
Balmer
α
β
γ
δ
ε
ζ
Δv
Σv
48
3
4
5
6
8
60
84
108
132
156
180
60
144
252
384
540
720
KEM
108
192
300
432
588
768
hv
c
v²
Mv²
hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

-3.38125 eV

$$KEM = \frac{hf}{n^2}$$

v
n2
KE
12
1.2e20

L shell

366.859 nm

$$KEM = \frac{hcR}{n^2}$$

m.

Ω/v	λ	366.8598517	nm	h/p
v/Ω	ṽ	2,725,836.571	m-1	p/h
c²/Ω	f	8.171852456 x 10^{14}	Hz	E/h
v²/c²	E	3.381321915	eV	hf
	Ω	109.9818167	m²/s	

ground KEM energies

equilateral energy momenta is the foundation of all quantum EM wave-functions

Tetryonics 31.01 - Balmer spectral lines

As photo-electrons transition between Mv squared KEM field energy levels in atomic nuclei they release specific [Δhν] W bosons

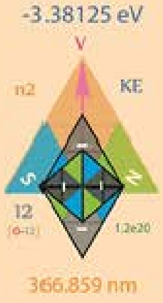
-3.38125 eV
v
n2
KE
12
1.2e20
366.859 nm

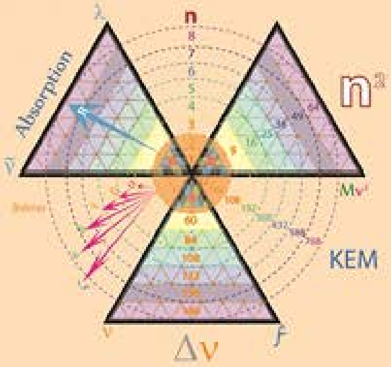
Absorption
λ
n
n²
Mv²
KEM
Δv
v
F

Balmer spectral series

α	660.34	n2-3
β	489.14	n2-4
γ	436.73	n2-5
δ	412.71	n2-6
ε	399.46	n2-7
ϕ	391.31	n2-8

Visible Spectrum

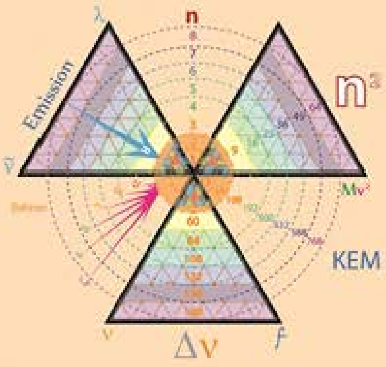
Emission
λ
n
n²
Mv²
KEM
Δv
v
F

L shell

Δν

KEM

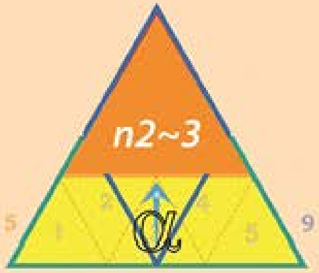

60

108

1 quantum level jump

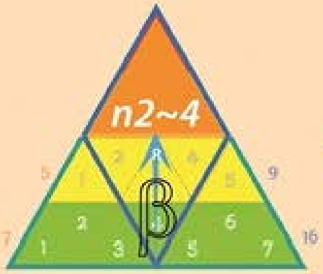

144

192

2 quantum level jump

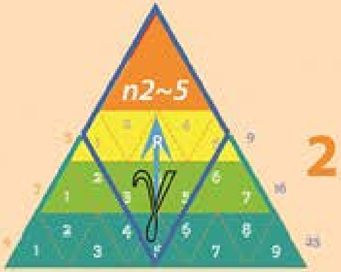

252

300

3 quantum level jump

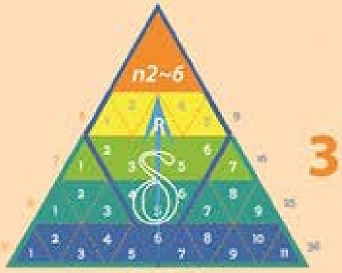

384

432

4 quantum level jump

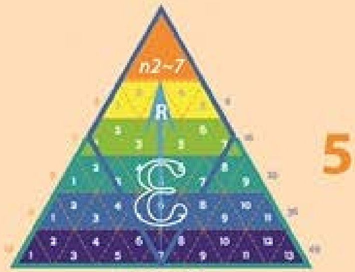

540

588

5 quantum level jump

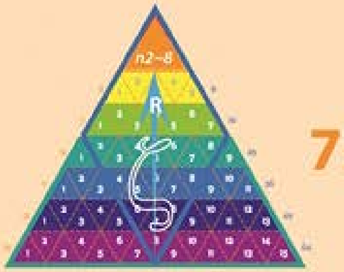

720

768

6 quantum level jump

Tetryonics 31.02 - Balmer quantum transitions

Balmer series energy momenta

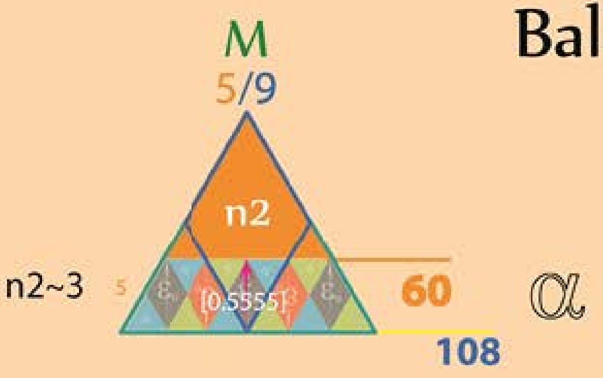
M
5/9
n2
n2~3
5
[0.5555]
60
108
α

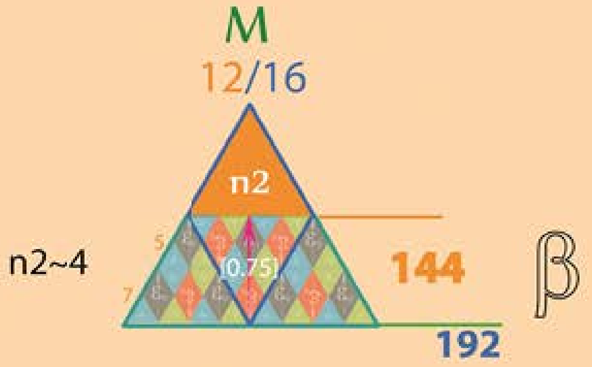
M
12/16
n2
n2~4
5
7
[0.75]
144
192
β

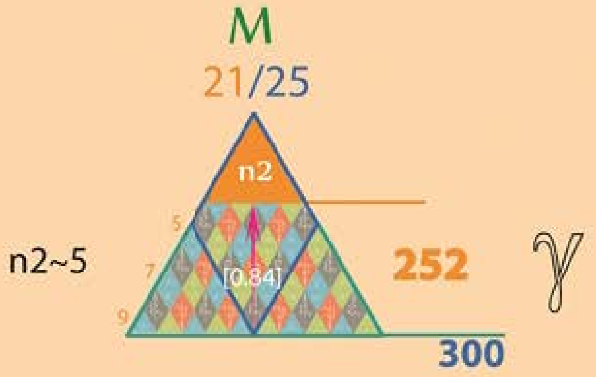
M
21/25
n2
n2~5
5
7
9
[0.84]
252
300
γ

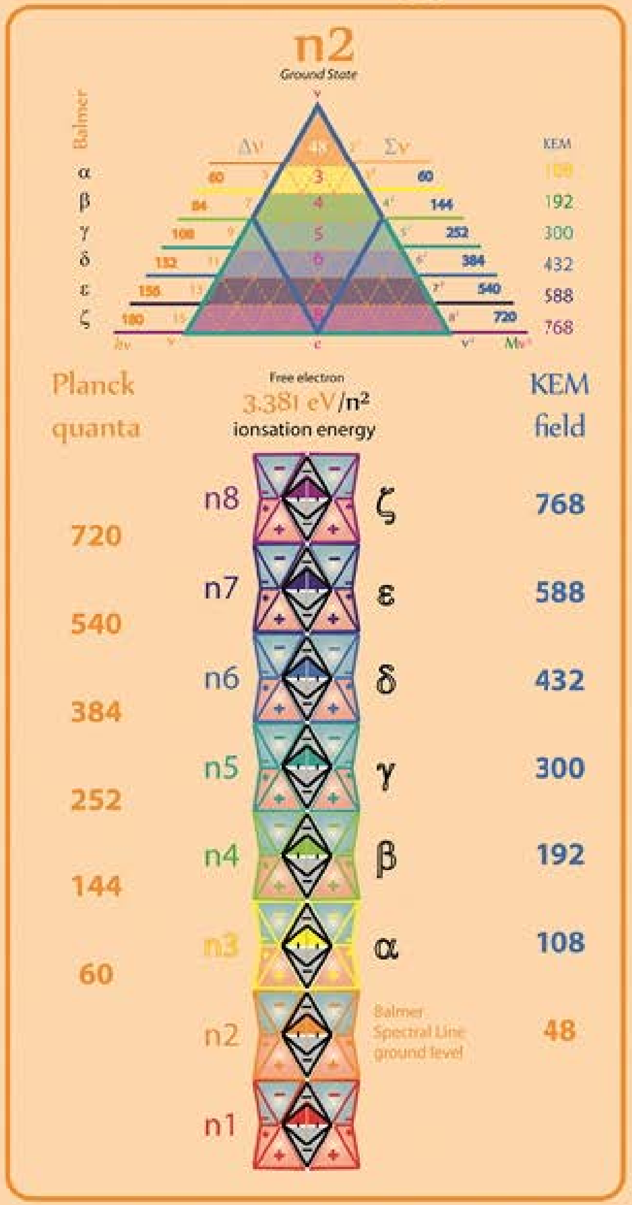
n2
Ground State
Balmer
α
β
γ
δ
ε
ζ
Δv
Σv
KEM
60
84
108
132
156
180
3
4
5
6
60
144
252
384
540
720
108
192
300
432
588
768
hv
v
c
v²
Mv²

Planck quanta	Free electron 3.381 eV/n² ionsation energy		KEM field
720	n8	ζ	768
540	n7	ε	588
384	n6	δ	432
252	n5	γ	300
144	n4	β	192
60	n3	α	108
	n2	Balmer Spectral Line ground level	48
	n1		

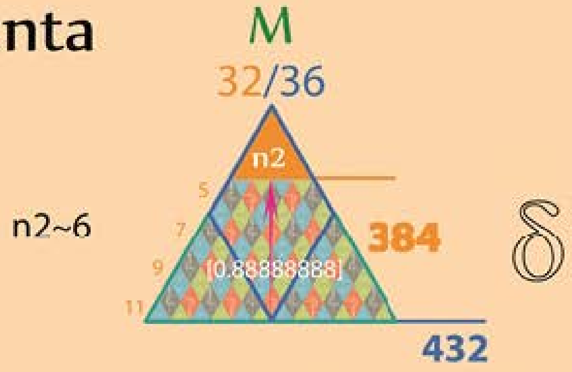
M
32/36
n2
n2~6
5
7
9
11
[0.88888888]
384
432
δ

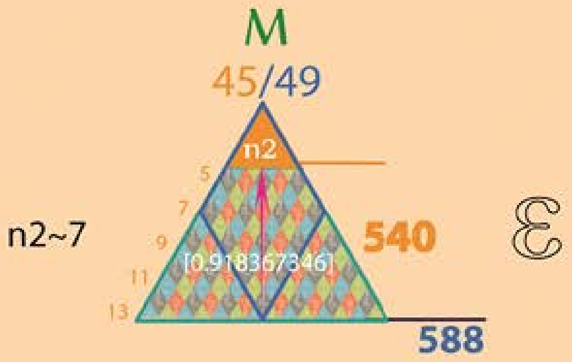
M
45/49
n2
n2~7
5
7
9
11
13
[0.918367346]
540
588
ε

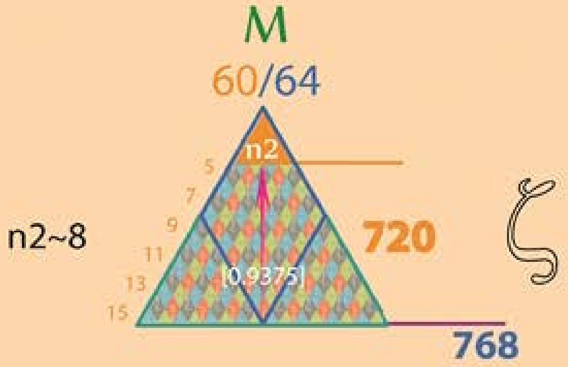
M
60/64
n2
n2~8
5
7
9
11
13
15
[0.9375]
720
768
ζ

accelerating electrons $\Delta p = \Delta M v = hf$ produce spectral lines

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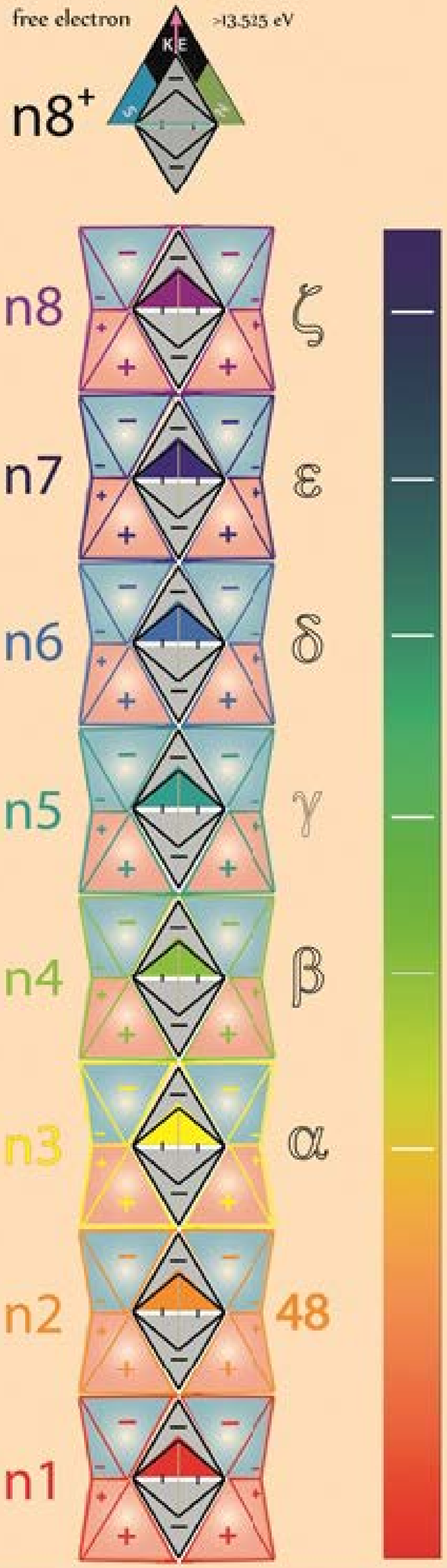

Balmer Series

$\Delta h\nu$ = KEM = hcR

Tetryonic — 3.381 eV — Rydberg

60/64
.2343

λ	391.3171751	nm
ν̃	2,555,471.1785	m-1
ƒ	7.661111677 x 10^{14}	Hz
E	3.169989296	eV
Ω	103.1079531	m²/s

$R\left(\frac{1}{4}-\frac{1}{64}\right)$
.2343

45/49
.2295

λ	399.4696163	nm
ν̃	2,5033,319.299	m-1
ƒ	7.50476246 x 10^{14}	Hz
E	3.105295637	eV
Ω	101.0037092	m²/s

$R\left(\frac{1}{4}-\frac{1}{49}\right)$
.2295

32/36
.2222

λ	412.7173331	nm
ν̃	2,422,965.84	m-1
ƒ	7.26386885 x 10^{14}	Hz
E	3.00561948	eV
Ω	97.76161483	m²/s

$R\left(\frac{1}{4}-\frac{1}{36}\right)$
.2222

21/25
.2100

λ	436.7379187	nm
ν̃	2,289,702.719	m-1
ƒ	6.864358063 x 10^{14}	Hz
E	2.840310409	eV
Ω	92.38472601	m²/s

$R\left(\frac{1}{4}-\frac{1}{25}\right)$
.21

12/16
.1875

λ	489.1464689	nm
ν̃	2,044,377.428	m-1
ƒ	6.128889542 x 10^{14}	Hz
E	2.535991437	eV
Ω	82.48636251	m²/s

$R\left(\frac{1}{4}-\frac{1}{16}\right)$
.1875

5/9
.138

λ	660.347733	nm
ν̃	1,514,353.65	m-1
ƒ	4.539918031 x 10^{14}	Hz
E	1.878512175	eV
Ω	61.10100927	m²/s

$R\left(\frac{1}{4}-\frac{1}{9}\right)$
.138

$$\mathrm{m.}\begin{bmatrix}\Omega/v\\ v/\Omega\\ c^2/\Omega\\ v^2/c^2\end{bmatrix}$$

λ	366.8598517	nm	h/p
ν̃	2,725,836.571	m-1	p/h
ƒ	8.171852456 x 10^{14}	Hz	E/h
E	3.381321915	eV	hƒ
Ω	109.9818167	m²/s	

ground KEM energies

changing energy momenta produces specific frequency spectral lines

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Paschen spectral lines

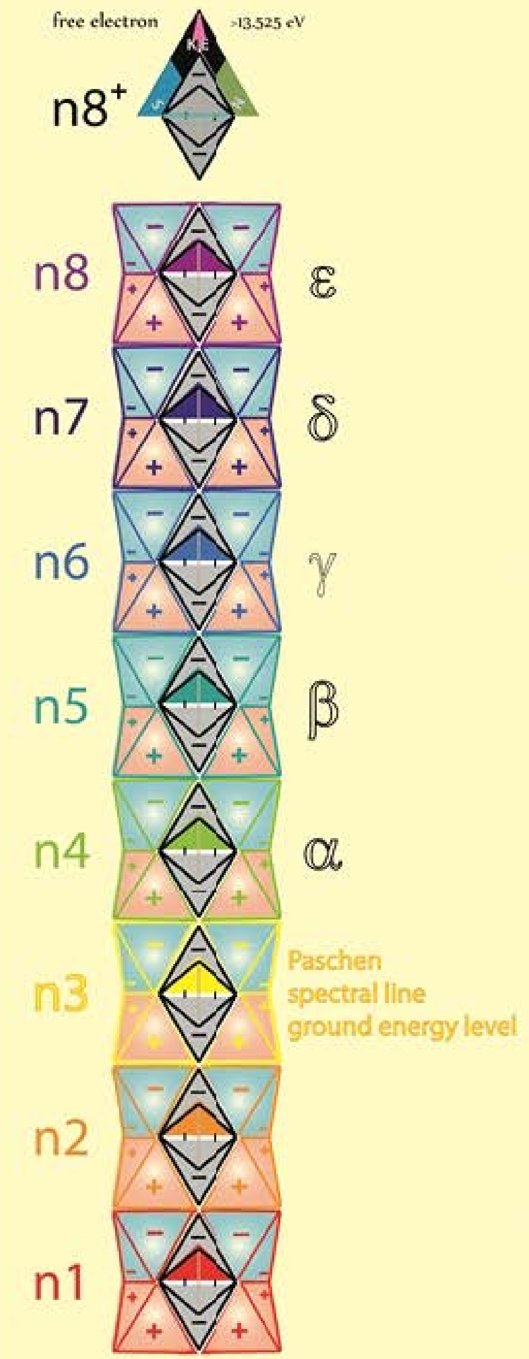
free electron
>13.525 eV
KE
n8⁺
n8
ε
n7
δ
n6
γ
n5
β
n4
α
n3
Paschen
spectral line
ground energy level
n2
n1

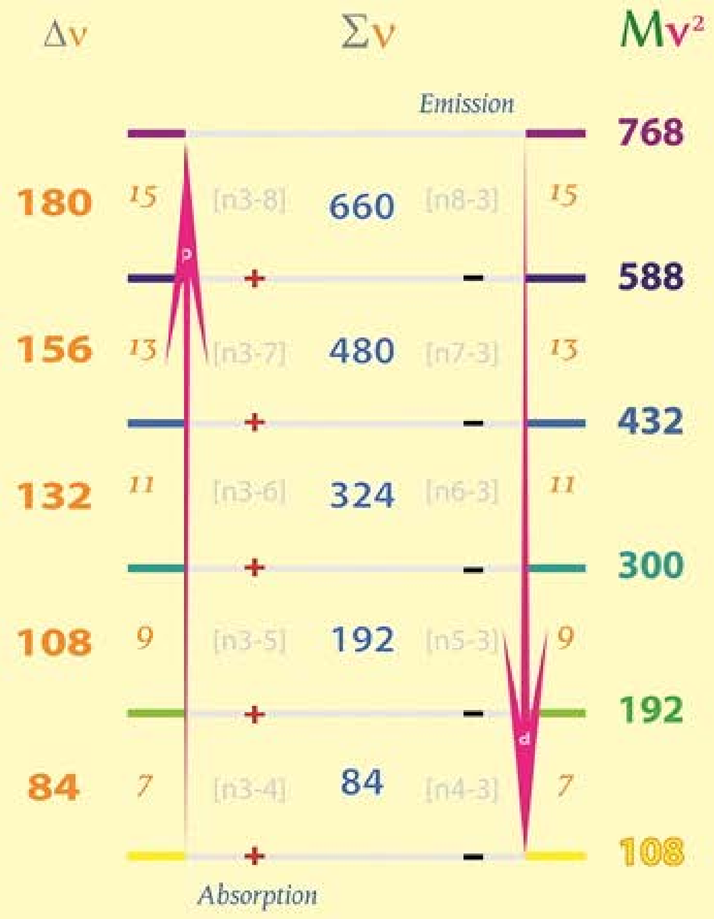
Δv
Σv
Mv²
Emission
768
180
15
[n3-8]
660
[n8-3]
15
588
156
13
[n3-7]
480
[n7-3]
13
432
132
11
[n3-6]
324
[n6-3]
11
300
108
9
[n3-5]
192
[n5-3]
9
192
84
7
[n3-4]
84
[n4-3]
7
108
Absorption

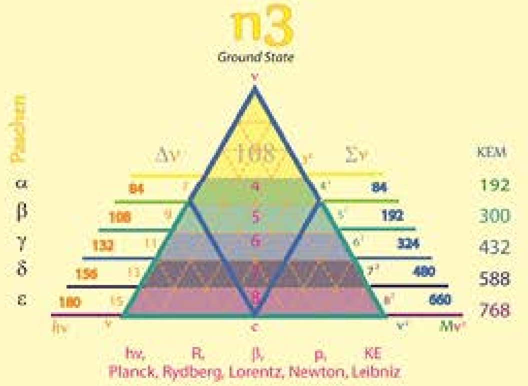
n3
Ground State
Paschen
α
β
γ
δ
ε
Δv
108
Σv
KEM
84
4
84
192
108
5
192
300
132
6
324
432
156
480
588
180
8
660
768
hv
v
c
v²
Mv²
hv,
R,
β,
p,
KE
Planck, Rydberg, Lorentz, Newton, Leibniz

-1.50280974 eV

$$KEM = \frac{hf}{n^2}$$

v
n3
KE
12
[ø α]
1.2e20

M shell

825.434 nm

$$KEM = \frac{hcR}{n^2}$$

m. [Ω/v , v/Ω , c^2/Ω , v^2/c^2]

λ	825.4346663	nm	h/p
$\tilde{v}$	1,211,482.92	m-1	p/h
f	$3.631934425 \times 10^{14}$	Hz	E/h
E	1.50280974	eV	hf
Ω	247.4590875	m²/s	

ground KEM energies

equilateral energy momenta is the foundation of all quantum EM wave-functions

Tetryonics 32.01 - Paschen spectral lines

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As photo-electrons transition between Mv squared KEM field energy levels in atomic nuclei they release specific [Δhv] W bosons

Paschen spectral series

-1.50280974 eV

v
n3
KE
12
[0-12]
1.2e20

825.434 nm

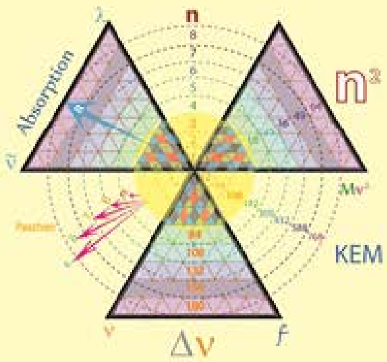
λ
n
Absorption
n²
Mv²
KEM
Paschen
v
Δν
f

α	1,886	n3-4
β	1,289	n3-5
γ	1,100	n3-6
δ	1,011	n3-7
ε	960	n3-8

IR spectrum

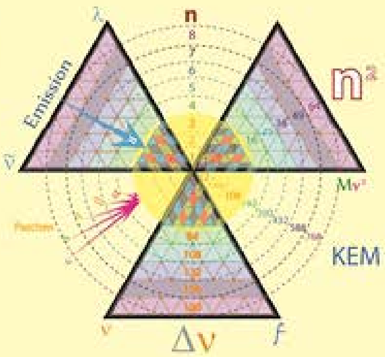
λ
n
Emission
n²
Mv²
KEM
Paschen
v
Δν
f

M shell

Δν

KEM

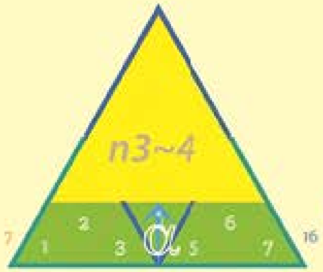

84

192

1 quantum level jump

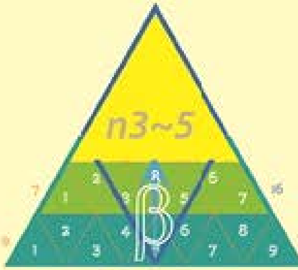

192

300

2 quantum level jump

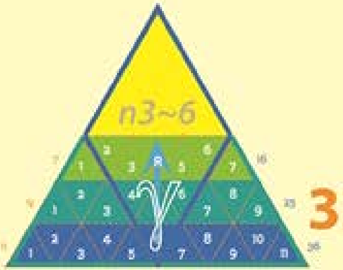

324

432

3 quantum level jump

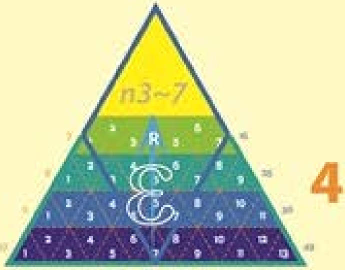

480

588

4 quantum level jump

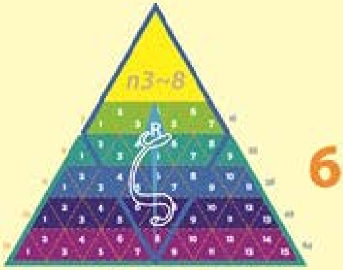

660

768

5 quantum level jump

Tetryonics 32.02 - Paschen quantum transitions

Paschen series energy momenta

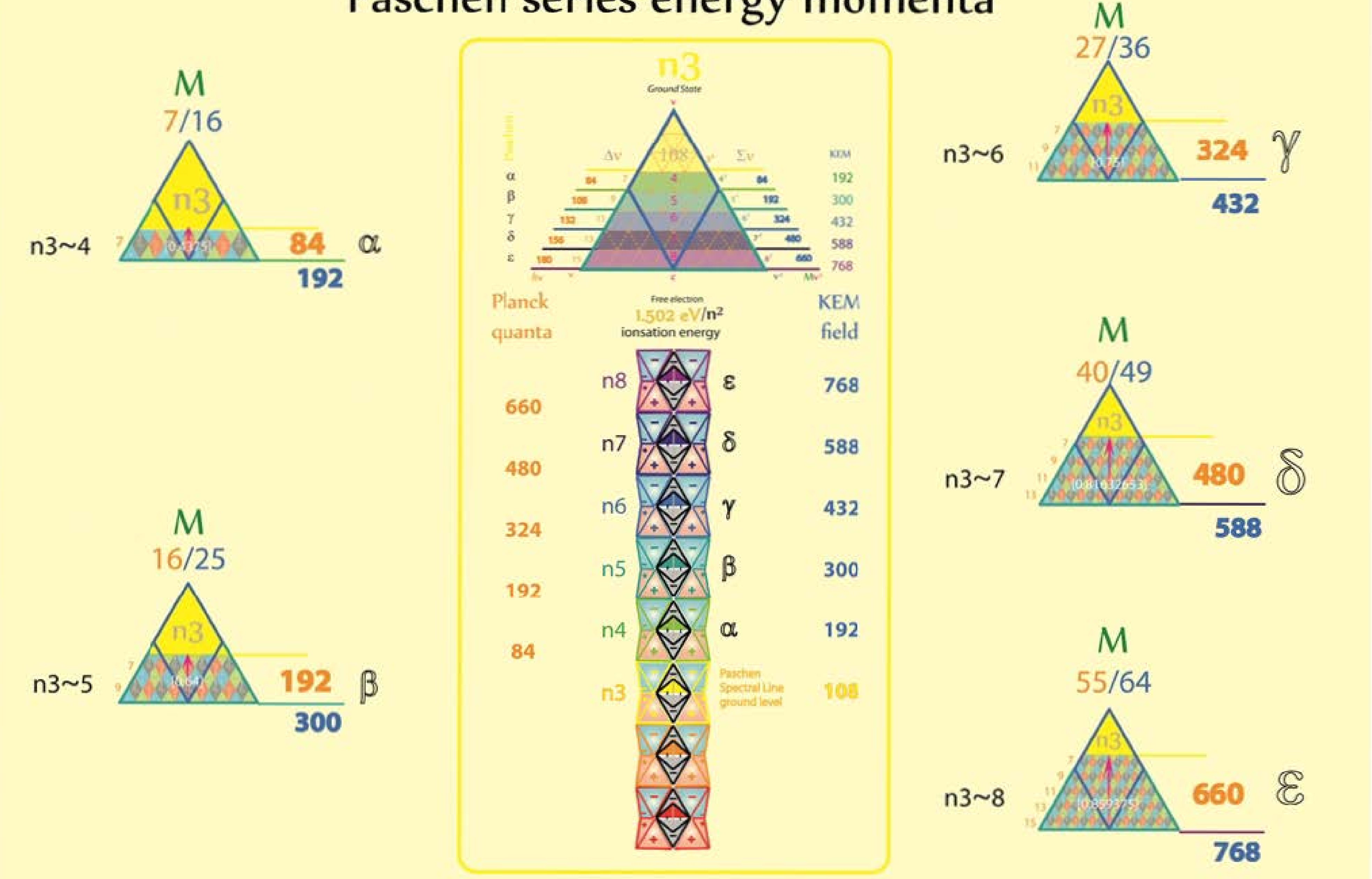
M
7/16
n3
n3~4
84
α
192
M
16/25
n3
n3~5
192
β
300
n3
Ground State
Δv
108
Σv
KEM
α
β
γ
δ
ε
84
108
132
156
180
4
5
6
84
192
324
480
660
192
300
432
588
768
Planck
quanta
Free electron
1.502 eV/n²
ionsation energy
KEM
field
660
480
324
192
84
n8
n7
n6
n5
n4
n3
ε
δ
γ
β
α
Paschen
Spectral Line
ground level
768
588
432
300
192
108
M
27/36
n3
n3~6
324
γ
432
M
40/49
n3
n3~7
480
δ
588
M
55/64
n3
n3~8
660
ε
768

accelerating electrons $\Delta p = \Delta M v = hf$ produce spectral lines

Tetryonics 32.03 - Paschen series energy momenta

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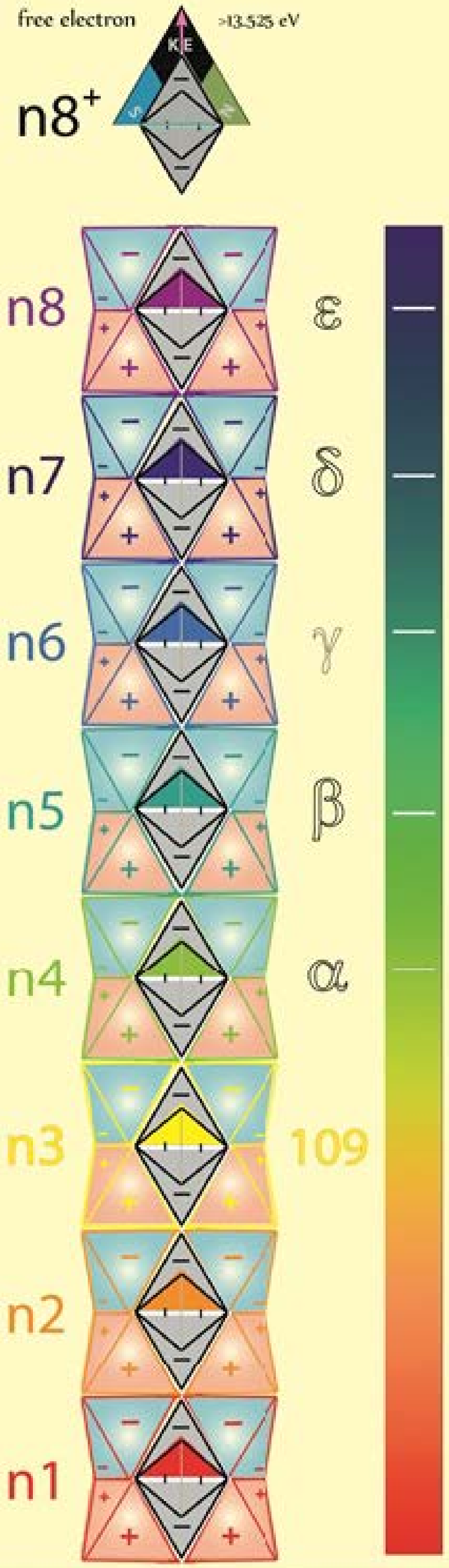

Paschen Series

Δhv = KEM = hcR

Tetryonic
1.502 eV
Rydberg

55/64
.0954

λ	960.5057935	nm
$\tilde{v}$	1,041,118.135	m-1
f	3.121193646 x 10^{14}	Hz
E	1.29147712	eV
Ω	287.9523928	m^2/s

$R\left(\frac{1}{9}-\frac{1}{64}\right)$
.09548

40/49
.0907

λ	1,011.157466	nm
$\tilde{v}$	988,965.6492	m-1
f	2.9464844428 x 10^{14}	Hz
E	1.226783461	eV
Ω	303.1373922	m^2/s

$R\left(\frac{1}{9}-\frac{1}{49}\right)$
.0907

27/36
.8033

λ	1,100.579555	nm
$\tilde{v}$	908,612.1902	m-1
f	2.723950819 x 10^{14}	Hz
E	1.127107305	eV
Ω	329.94545	m^2/s

$R\left(\frac{1}{9}-\frac{1}{36}\right)$
.0833

16/25
.0711

λ	1,289.741666	nm
$\tilde{v}$	775,349.069	m-1
f	2.324438032 x 10^{14}	Hz
E	0.961798233	eV
Ω	386.6548241	m^2/s

$R\left(\frac{1}{9}-\frac{1}{25}\right)$
.0711

7/16
.0486

λ	1,886.707809	nm
$\tilde{v}$	530,023.7776	m-1
f	1.588971311 x 10^{14}	Hz
E	0.657479261	eV
Ω	565.6207715	m^2/s

$R\left(\frac{1}{9}-\frac{1}{16}\right)$
.0486

$$\mathrm{m.}\begin{bmatrix} \Omega/v \\ v/\Omega \\ c^2/\Omega \\ v^2/c^2 \end{bmatrix}$$

λ	825.4346663	nm	h/p
$\tilde{v}$	1,211,482.92	m-1	p/h
f	3.631934425 x 10^{14}	Hz	E/h
E	1.50280974	eV	hf
Ω	247.4590875	m^2/s	

ground KEM energies

changing energy momenta produces specific frequency spectral lines

Brackett spectral lines

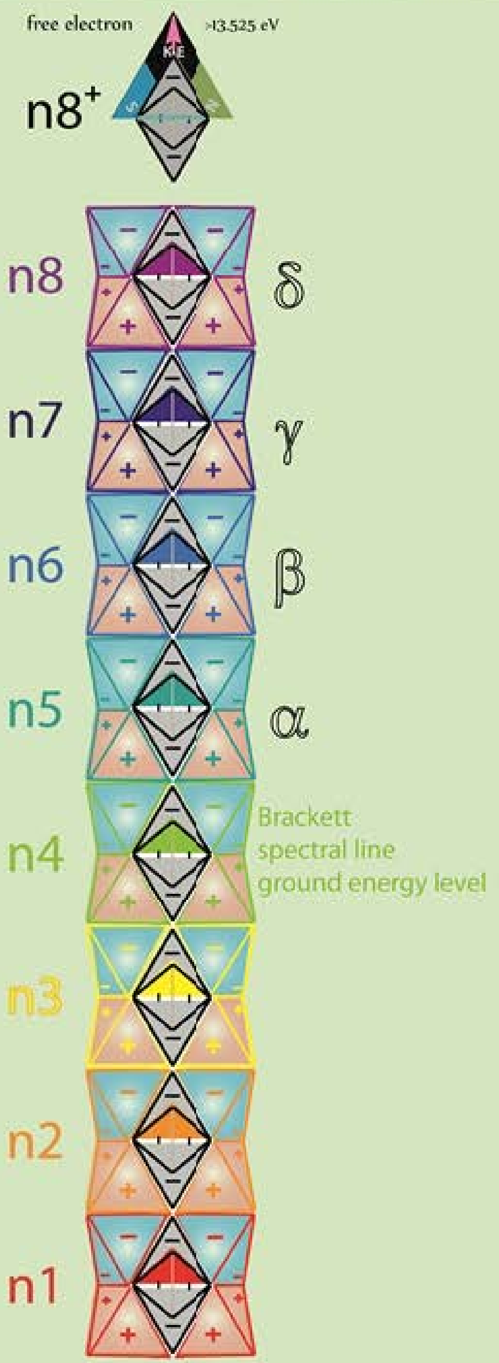
free electron
>13.525 eV
KE
n8+
n8
δ
n7
γ
n6
β
n5
α
n4
Brackett
spectral line
ground energy level
n3
n2
n1

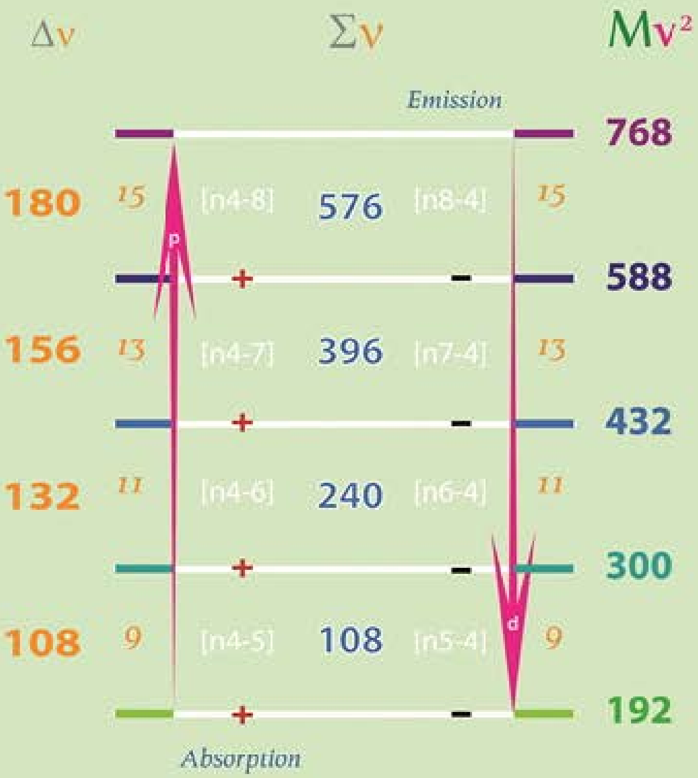
Δv
Σv
Mv²
Emission
768
180
15
[n4-8]
576
[n8-4]
15
588
156
13
[n4-7]
396
[n7-4]
13
432
132
11
[n4-6]
240
[n6-4]
11
300
108
9
[n4-5]
108
[n5-4]
9
192
Absorption

n4

Ground State

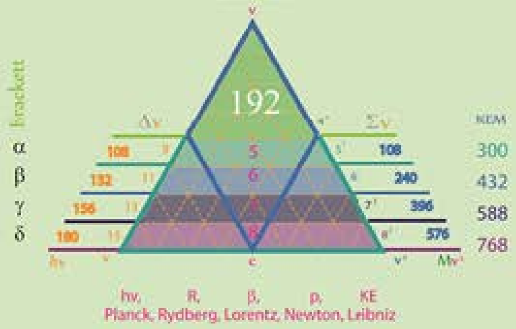
v
192
Δv
Σv
KEM
Brackett
α
β
γ
δ
108
132
156
180
5
6
7
8
108
240
396
576
300
432
588
768
hv
c
v²
Mv²
hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

-0.84533478 eV

$$KEM = \frac{hf}{n^2}$$

v
n4
KE
S
N
12
1.2e20

N shell

1,467.43 nm

$$KEM = \frac{hcR}{n^2}$$

m.

Ω/v	λ	1,467.439407	nm	h/p
v/Ω	ṽ	681,459.1426	m-1	p/h
c²/Ω	f	2.042963114 x 10^{14}	Hz	E/h
v²/c²	E	0.84533478	eV	hf
	Ω	[illegible]	m²/s	

ground KEM energies

equilateral energy momenta is the foundation of all quantum EM wave-functions

As photo-electrons transition between Mv squared KEM field energy levels in atomic nuclei they release specific [Δhv] W bosons

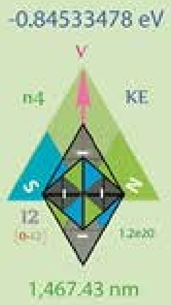
-0.84533478 eV
v
n4
KE
S
N
12
1.2e20
1,467.43 nm

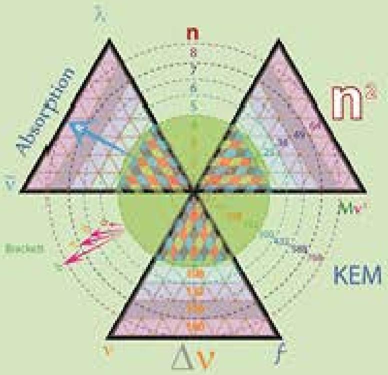
λ
n
Absorption
n²
Mv²
Brackett
KEM
v
Δv
f

Brackett spectral series

α	4,076	n4-5
β	2,641	n4-6
γ	2,178	n4-7
δ	1,956	n4-8

IR spectrum

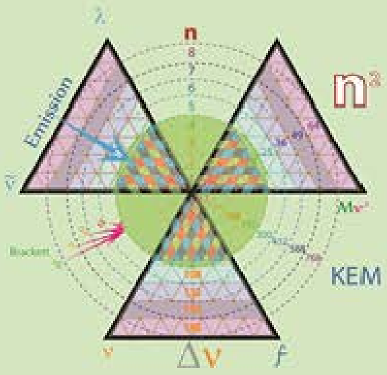
λ
n
Emission
n²
Mv²
Brackett
KEM
v
Δv
f

N shell

Δv

KEM

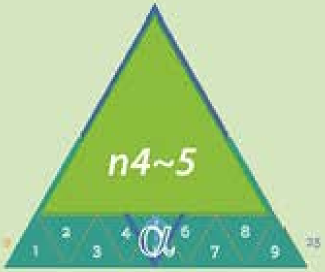

108

300

1 quantum level jump

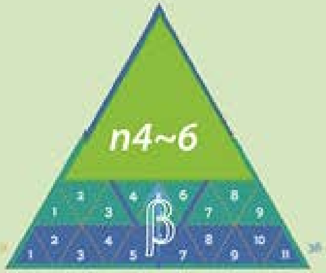

240

432

2 quantum level jump

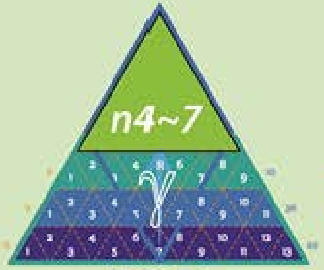

396

588

3 quantum level jump

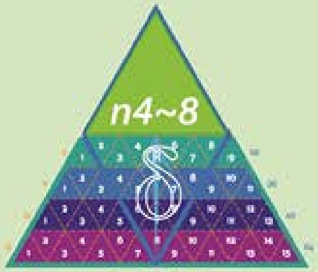

576

768

4 quantum level jump

Tetryonics 33.02 - Brackett quantum transitions

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Brackett series energy momenta

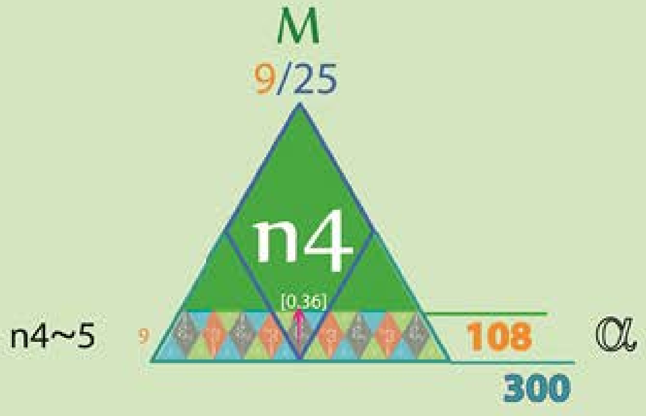
M
9/25
n4
[0.36]
n4~5
9
108
300
α

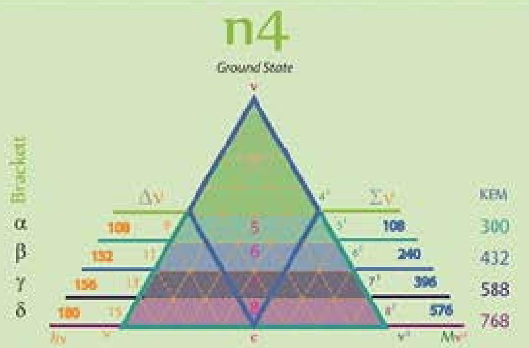
n4
Ground State
Brackett
α
β
γ
δ
Δv
Σv
KEM
108
132
156
180
5
6
108
240
396
576
300
432
588
768

Planck quanta

Free electron
0.845 eV/n²
ionsation energy

KEM field

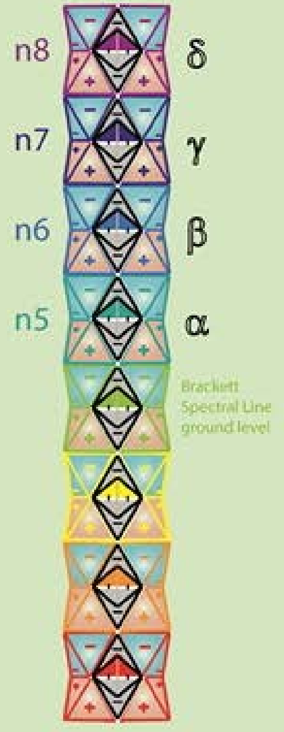
n8
δ
n7
γ
n6
β
n5
α
Brackett Spectral Line ground level

576
396
240
108

768
588
432
300
192

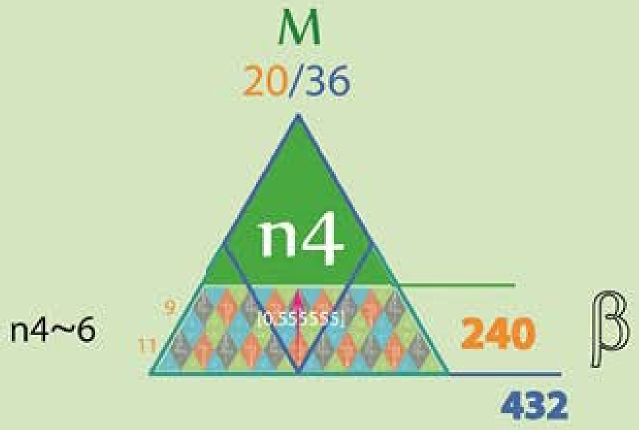
M
20/36
n4
[0.555555]
n4~6
9
11
240
432
β

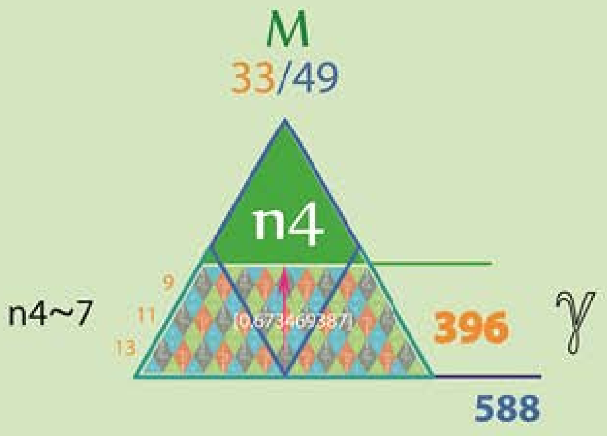
M
33/49
n4
[0.673469387]
n4~7
9
11
13
396
588
γ

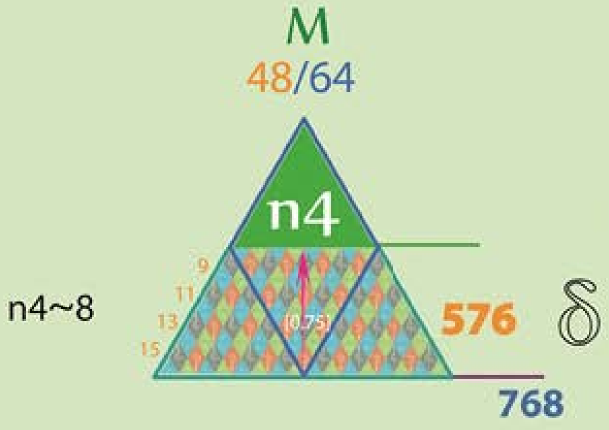
M
48/64
n4
[0.75]
n4~8
9
11
13
15
576
768
δ

accelerating electrons $\Delta p = \Delta Mv = hf$ produce spectral lines

Tetryonics 33.03 - Brackett series energy momenta

Brackett Series

$\Delta h\nu$ = KEM = hcR

Tetryonic   0.845 eV   Rydberg

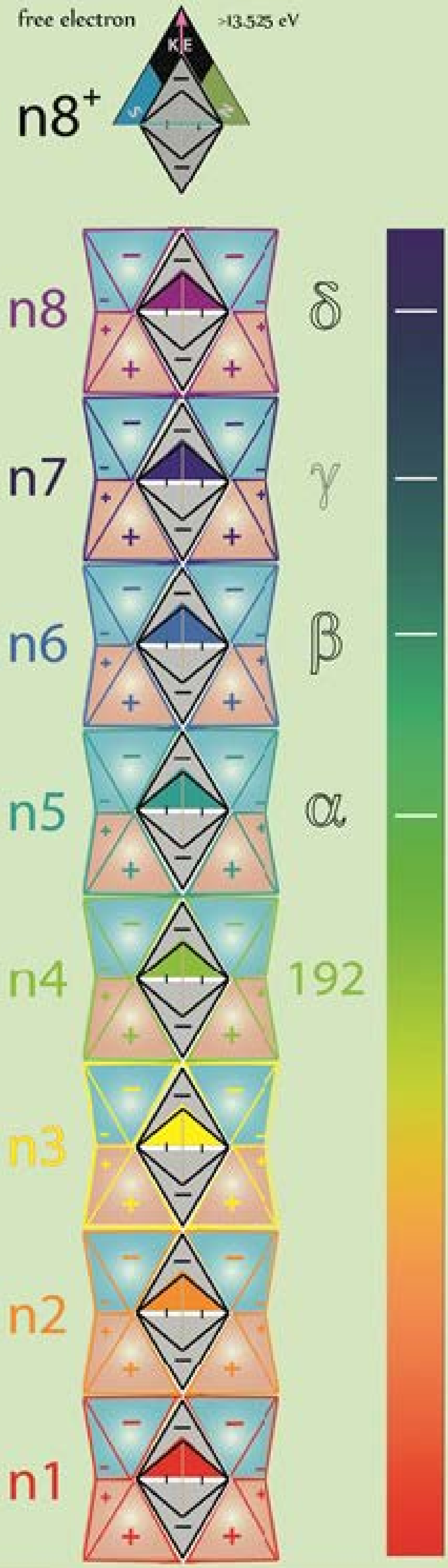

48/64
.0468

λ	1,956.585876	nm
$\bar{\nu}$	511,094.357	m-1
f	1.532222335 x 10^{14}	Hz
E	0.634001085	eV
Ω	586.569689	m²/s

$R\left(\frac{1}{16}-\frac{1}{64}\right)$
.0468

33/49
.04209

λ	2,178.92518	nm
$\bar{\nu}$	458,941.8716	m-1
f	1.375873118 x 10^{14}	Hz
E	0.569307096	eV
Ω	653.2253354	m²/s

$R\left(\frac{1}{16}-\frac{1}{49}\right)$
.04209

20/36
.0347

λ	2,641.390932	nm
$\bar{\nu}$	378,588.4126	m-1
f	1.134979508 x 10^{14}	Hz
E	0.469630433	eV
Ω	791.3690801	m²/s

$R\left(\frac{1}{16}-\frac{1}{36}\right)$
.0347

9/25
.0225

λ	4,076.220574	nm
$\bar{\nu}$	245,325.2914	m-1
f	7.35466721x 10^{13}	Hz
E	0.30432052	eV
Ω	1,222.020185	m²/s

$R\left(\frac{1}{16}-\frac{1}{25}\right)$
.0225

$m.\begin{bmatrix}\Omega/v \\ v/\Omega \\ c^2/\Omega \\ v^2/c^2\end{bmatrix}$

λ	1,467.439407	nm	h/p
$\bar{\nu}$	681,459.1426	m-1	p/h
f	2.042963114 x 10^{14}	Hz	E/h
E	0.84533478	eV	hf
Ω	439.9272667	m²/s	

ground KEM energies

changing energy momenta produces specific frequency spectral lines

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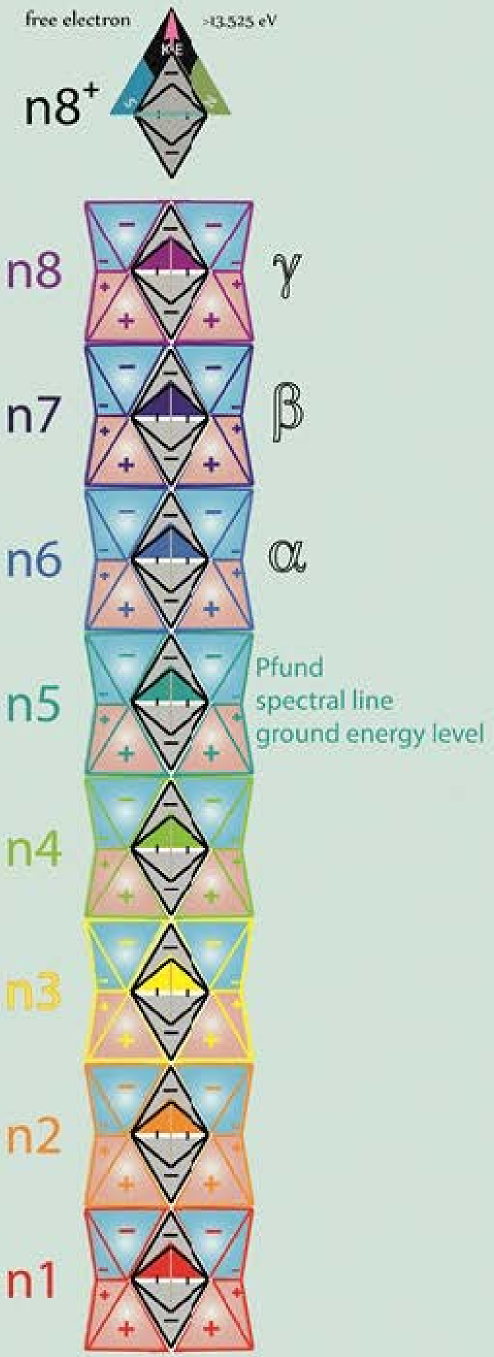
free electron
>13.525 eV
KE
n8⁺
n8
γ
n7
β
n6
α
n5
Pfund
spectral line
ground energy level
n4
n3
n2
n1

Pfund spectral lines

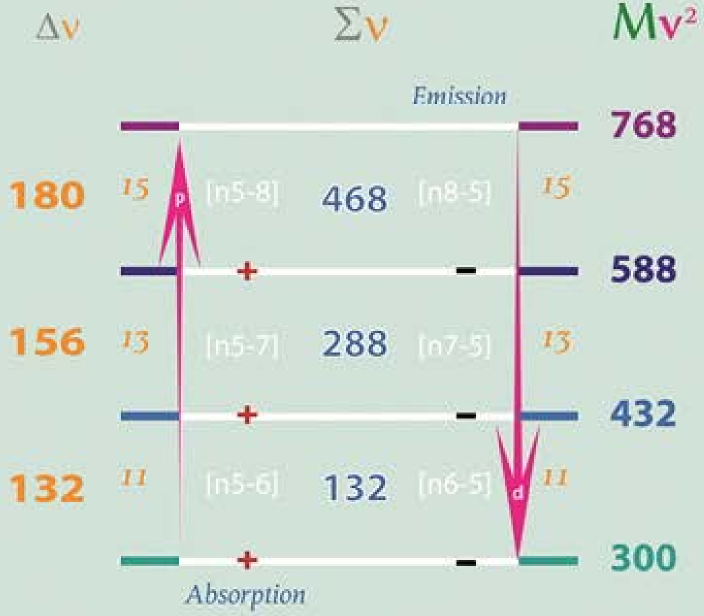
Δv
Σv
Mv²
Emission
768
180
15
p
[n5-8]
468
[n8-5]
15
588
+
-
156
13
[n5-7]
288
[n7-5]
13
432
132
11
[n5-6]
132
[n6-5]
d
11
300
Absorption

n5

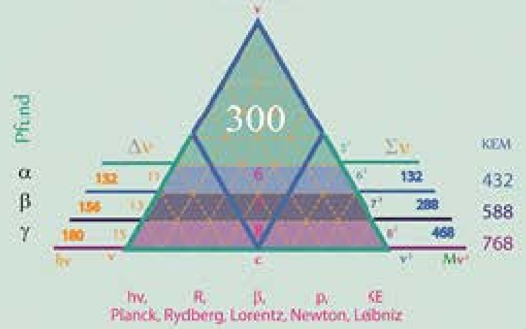
Ground State
Pfund
300
Δv
Σv
KEM
α
β
γ
132
11
6
6²
132
432
156
13
7²
288
588
180
15
8²
468
768
hv
v
c
v²
Mv²
hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

-0.5410115 eV

$$KEM = \frac{hf}{n^2}$$

v
n5
KE
12
1.2e20

O shell

2,292.87 nm

$$KEM = \frac{hcR}{n^2}$$

$$m.\begin{bmatrix} \Omega/v \\ v/\Omega \\ c^2/\Omega \\ v^2/c^2 \end{bmatrix}$$

λ	2,292.874073	nm	h/p
ṽ	436,133.8513	m-1	p/h
ƒ	1.307496393 x 10^{14}	Hz	E/h
E	0.541011506	eV	hƒ
Ω	687.3863542	m^2/s	

ground KEM energies

equilateral energy momenta is the foundation of all quantum EM wave-functions

Tetryonics 34.01 - Pfund spectral lines

As photo-electrons transition between Mv squared KEM field energy levels in atomic nuclei they release specific [Δhv] W bosons

2,292.87 nm

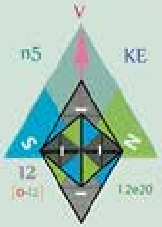

v
n5
KE
12
[o-12]
1.2e20

-0.5410115 eV

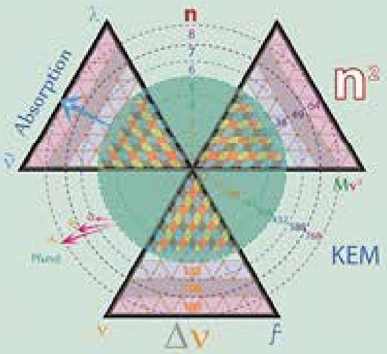

Absorption
n
n²
Mv²
KEM
Δν
f

Pfund spectral series

α	7,503	n5-6
β	4,681	n5-7
γ	3,762	n5-8

IR spectrum

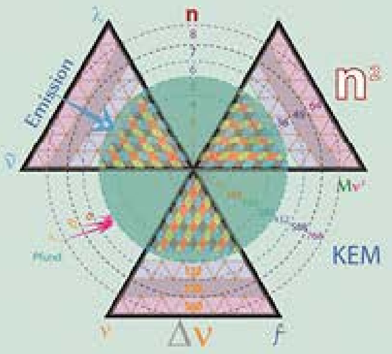

Emission
n
n²
Mv²
KEM
Δν
f

O shell

Δν

KEM

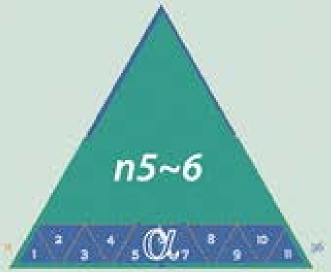

132

432

1 quantum level jump

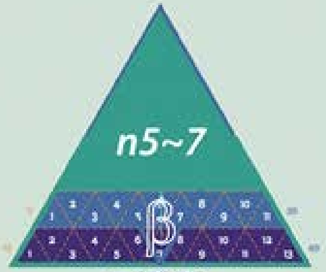

288

588

2 quantum level jump

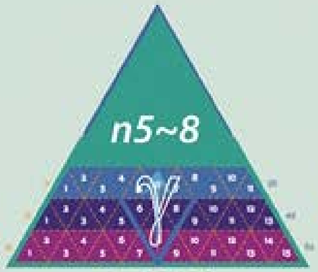

468

768

3 quantum level jump

Tetryonics 34.02 - Pfund quantum transitions

Pfund series energy momenta

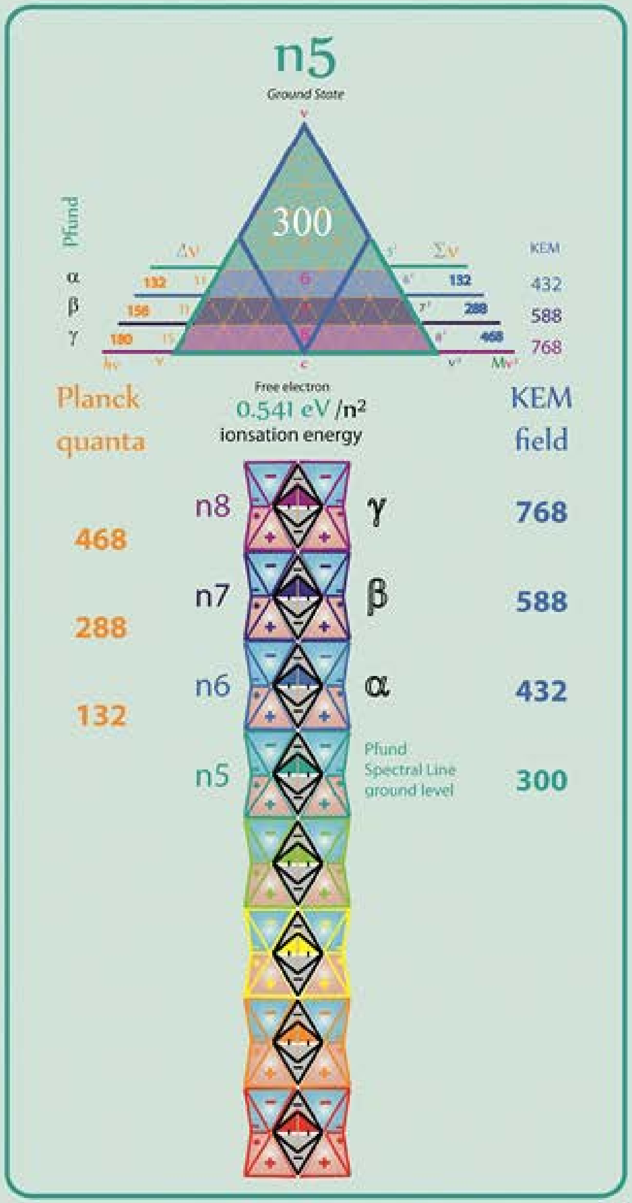
n5
Ground State
300
Pfund
Δv
Σv
KEM
α
β
γ
132
156
180
132
288
468
432
588
768
Planck
quanta
Free electron
0.541 eV /n²
ionsation energy
KEM
field
n8
γ
768
468
n7
β
588
288
n6
α
432
132
n5
Pfund
Spectral Line
ground level
300

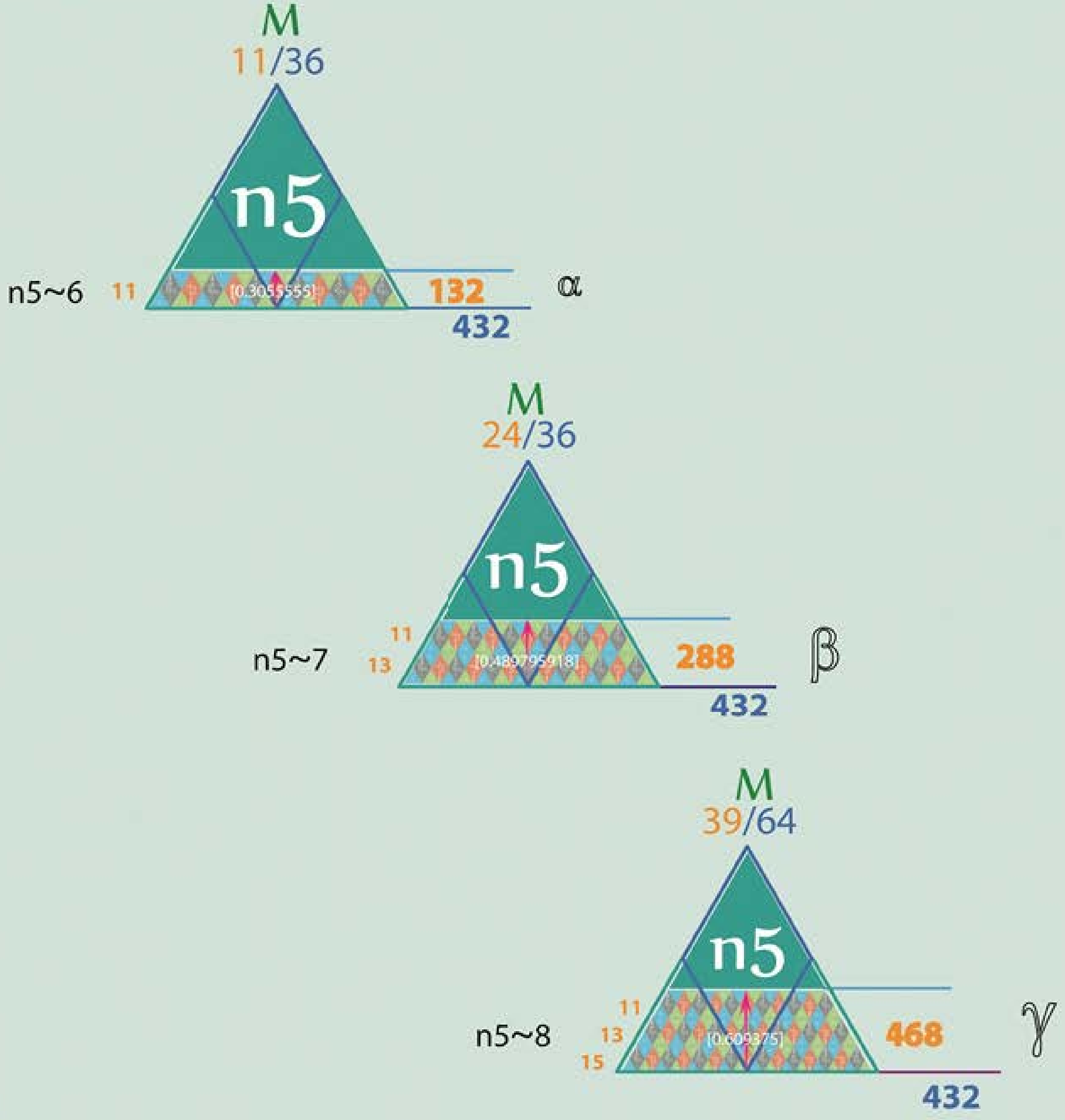
M
11/36
n5
n5~6
11
[0.3055555]
132
432
α
M
24/36
n5
n5~7
11
13
[0.489795918]
288
432
β
M
39/64
n5
n5~8
11
13
15
[0.609375]
468
432
γ

accelerating electrons $\Delta p = \Delta M v = hf$ produce spectral lines

Tetryonics 34.03 - Pfund series energy momenta

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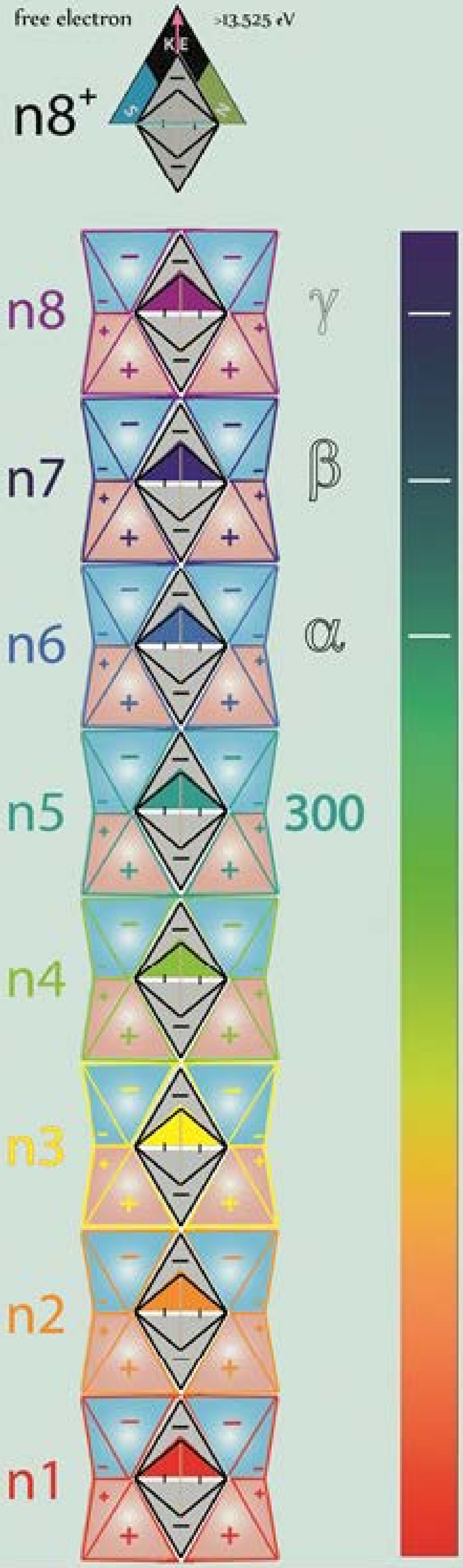

Pfund Series

Δhv = KEM = hcR

Tetryonic — 0.541 eV — Rydberg

39/64

.0243

λ	3,762.665146	nm
$\tilde{v}$	265,769.0656	m-1
f	7.967556145 x 10^{13}	Hz
E	0.329678886	eV
Ω	1,128.018633	m^2/s

$R\left(\frac{1}{25}-\frac{1}{64}\right)$ .0243

24/49

.0195

λ	4,681.284566	nm
$\tilde{v}$	213,616.5802	m-1
f	6.404063965 x 10^{13}	Hz
E	0.264985227	eV
Ω	1,403.413807	m^2/s

$R\left(\frac{1}{25}-\frac{1}{49}\right)$ .01959

11/36

.0122

λ	7,503.951512	nm
$\tilde{v}$	133,263.1212	m-1
f	3.995127867 x 10^{13}	Hz
E	0.165309071	eV
Ω	2,249.628068	m^2/s

$R\left(\frac{1}{25}-\frac{1}{36}\right)$ .0122

$$m.\begin{bmatrix}\Omega/v\\ v/\Omega\\ c^2/\Omega\\ v^2/c^2\end{bmatrix}$$

λ	2,292.874073	nm	h/p
$\tilde{v}$	436,133.8513	m-1	p/h
f	1.307496393 x 10^{14}	Hz	E/h
E	0.541011506	eV	hf
Ω	687.3863542	m^2/s	

ground KEM energies

changing energy momenta produces specific frequency spectral lines

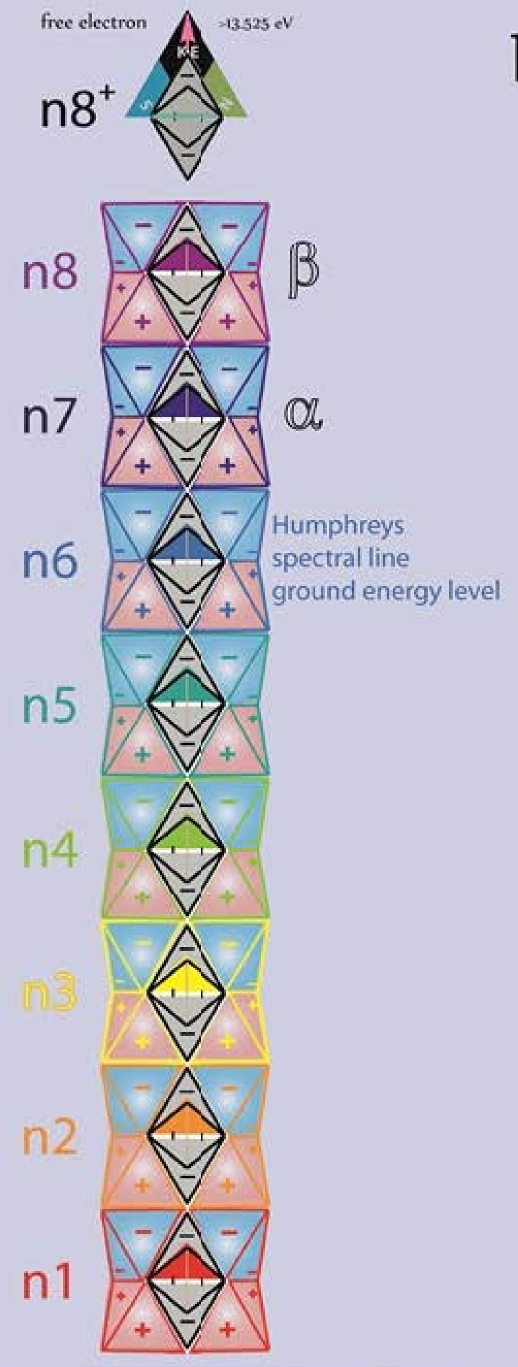
free electron
-13.525 eV
KE
n8⁺
n8
β
n7
α
n6
Humphreys
spectral line
ground energy level
n5
n4
n3
n2
n1

Humphreys spectral lines

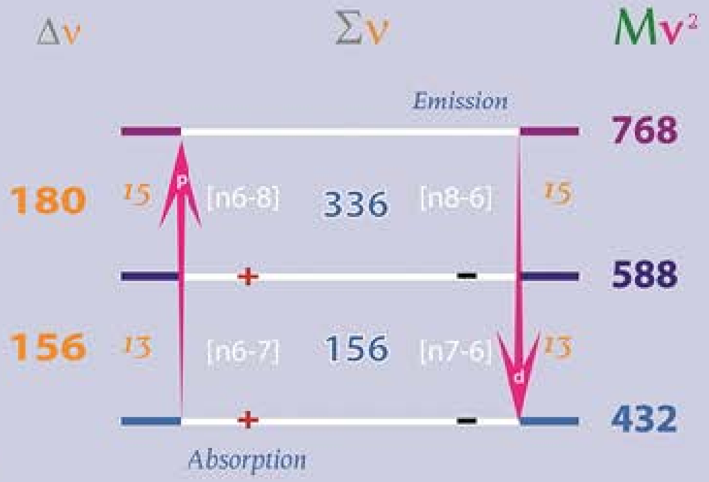
Δv
Σv
Mv²
Emission
768
180
15
[n6-8]
336
[n8-6]
15
588
156
13
[n6-7]
156
[n7-6]
13
432
Absorption

n6

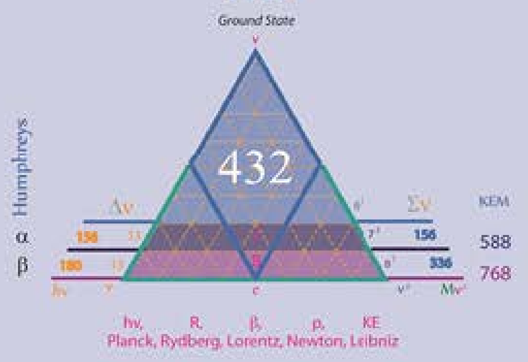
Ground State
v
432
Humphreys
α
β
Δv
Σv
KEM
156
13
7²
156
588
180
15
8²
336
768
hv
v
c
v²
Mv²
hv,
R,
β,
p,
KE
Planck, Rydberg, Lorentz, Newton, Leibniz

-0.375702435 eV

$$\text{KEM} = \frac{hf}{n^2}$$

v
n6
KE
S
N
12
[o-o]
1.2e20

P shell

3,301.73 nm

$$\text{KEM} = \frac{hcR}{n^2}$$

m.	Ω/v	λ	3,301.738665	nm	h/p
	v/Ω	ṽ	302,870.7301	m-1	p/h
	c²/Ω	ƒ	9.079836062 x 10^{13}	Hz	E/h
	v²/c²	E	0.375702435	eV	hƒ
		Ω	989.8363501	m²/s	

ground KEM energies

equilateral energy momenta is the foundation of all quantum EM wave functions

As photo-electrons transition between Mv squared KEM field energy levels in atomic nuclei they release specific [Δhv] W bosons

-0.375702435 eV
v
n6
KE
S
N
12
1.2e20
3,301.73 nm

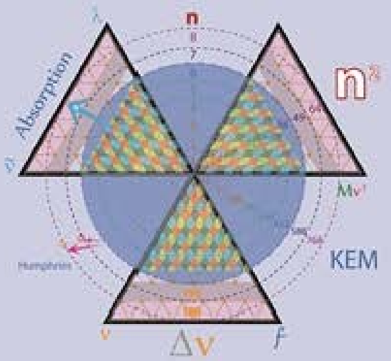
λ
n
Absorption
n²
Mv²
KEM
Humphries
v
Δv
f

Humphries spectral series

α	12,445	n6-7
β	7,546	n6-8
	IR spectrum	

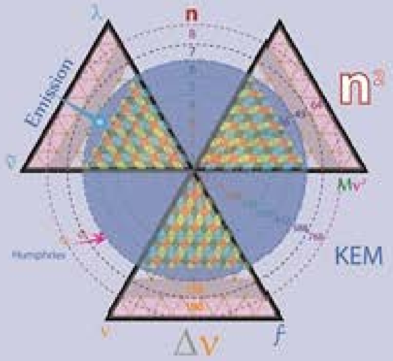
λ
n
Emission
n²
Mv²
KEM
Humphries
v
Δv
f

P shell

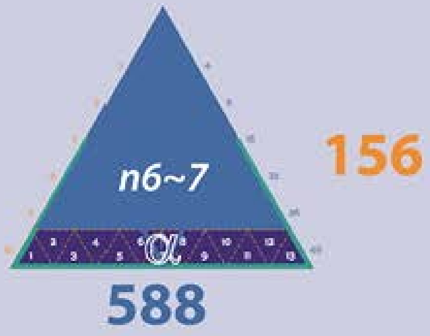
n6~7
156
α
588

1 quantum level jump

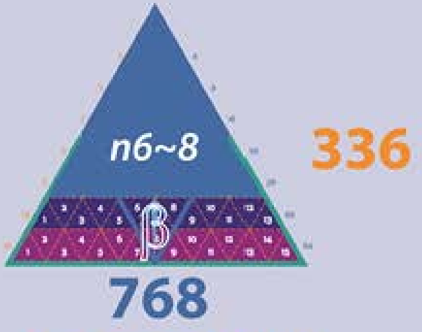
n6~8
336
β
768

2 quantum level jump

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Humphreys series energy momenta

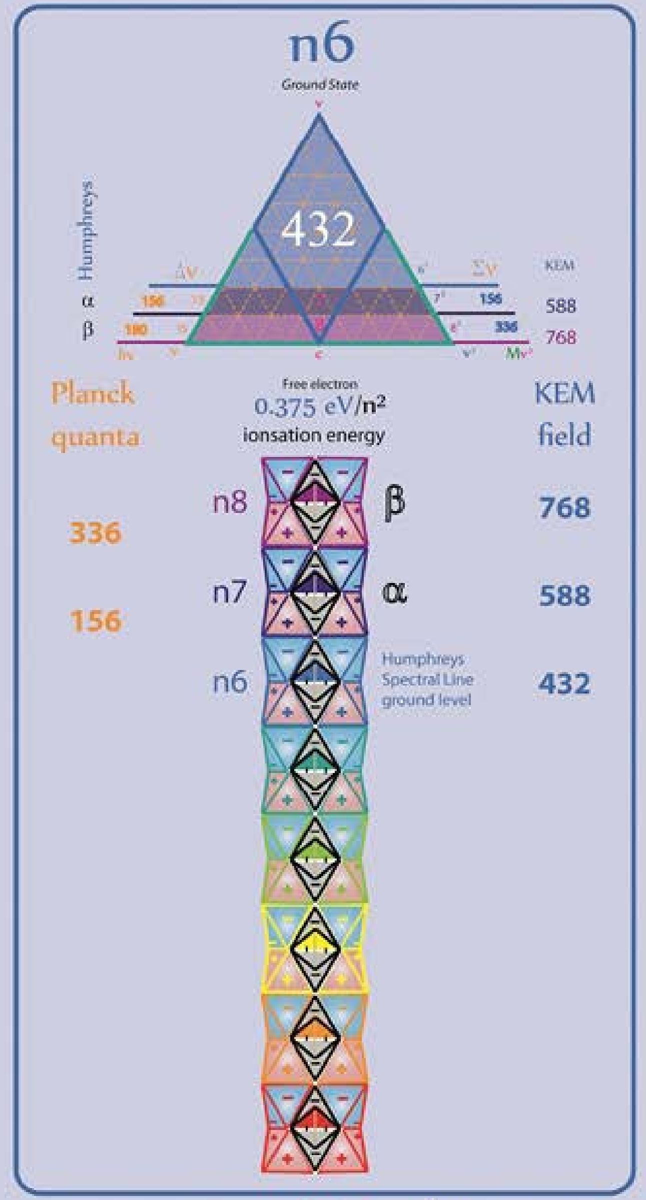
n6
Ground State
Humphreys
α
β
432
Δv
Σv
KEM
156
588
336
768
Mv²
Planck
quanta
Free electron
0.375 eV/n²
ionsation energy
KEM
field
n8
β
336
768
n7
α
156
588
n6
Humphreys
Spectral Line
ground level
432

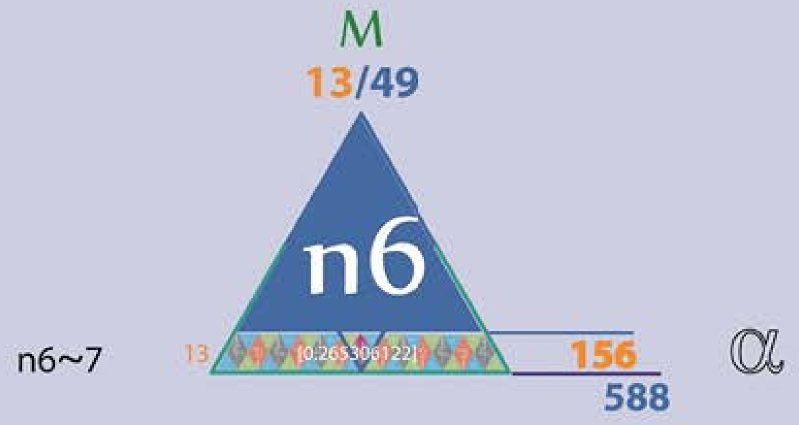
M
13/49
n6
n6~7
13
[0.265306122]
156
588
α

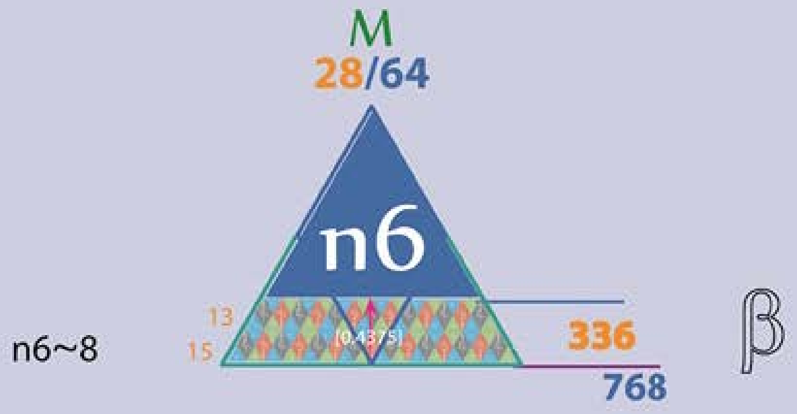
M
28/64
n6
n6~8
13
15
[0.4375]
336
768
β

accelerating electrons $\Delta p = \Delta M v = hf$ produce spectral lines

Tetryonics 35.03 - Humphreys series energy momenta

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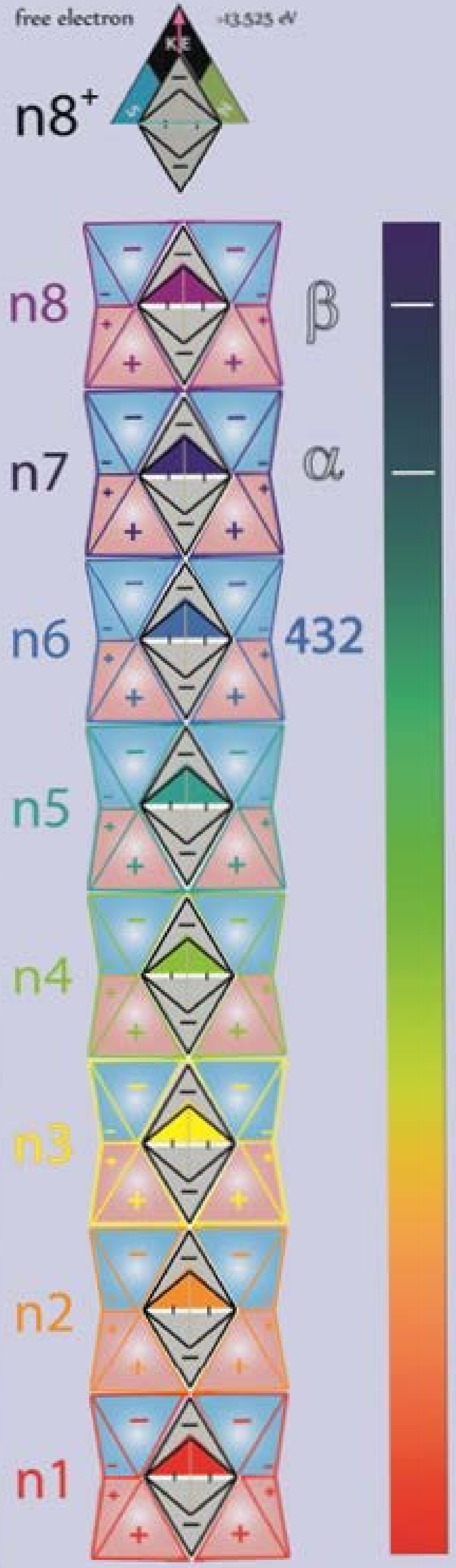

Humphreys Series

$$\Delta h\nu = \mathrm{KEM} = hcR$$

Tetryonic

0.375 eV

Rydberg

28/64
.01215

λ	7,546.831235	nm
$\bar{\nu}$	132,505.9444	m-1
f	$3.972428277 \times 10^{13}$	Hz
E	0.164369815	eV
Ω	1,128.018633	m^2/s

$$R\left(\frac{1}{36} - \frac{1}{64}\right)$$

.01215

13/49
.00733

λ	12,445.01497	nm
$\bar{\nu}$	80,353.459	m-1
f	$2.408993609 \times 10^{13}$	Hz
E	0.099676156	eV
Ω	1,403.413807	m^2/s

$$R\left(\frac{1}{36} - \frac{1}{49}\right)$$

.0073

$$m.\begin{bmatrix} \Omega/v \\ v/\Omega \\ c^2/\Omega \\ v^2/c^2 \end{bmatrix}$$

λ	3,301.738665	nm	h/p
$\bar{\nu}$	302,870.7301	m-1	p/h
f	$9.079836062 \times 10^{13}$	Hz	E/h
E	0.375702435	eV	hf
Ω	889.8363501	m^2/s	

ground KEM energies

changing energy momenta produces specific frequency spectral lines

Un-named spectral line

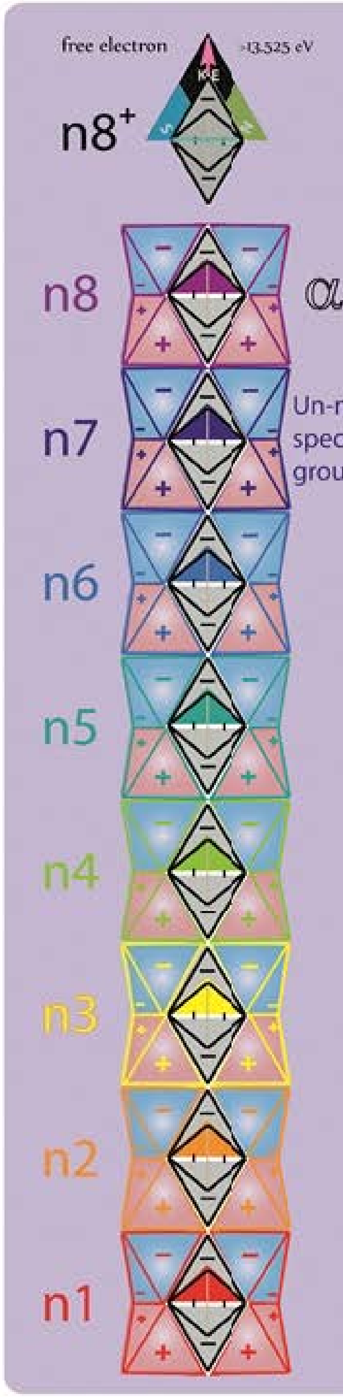
free electron
>13.525 eV
KE
S
N
n8+
n8
α
n7
n6
n5
n4
n3
n2
n1

Un-named
spectral line
ground energy level

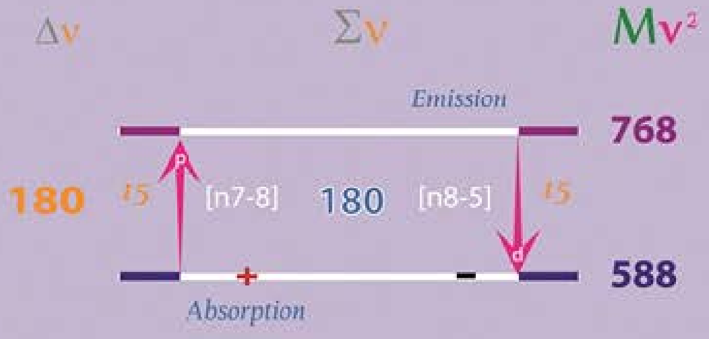
Δv
Σv
Mv²
Emission
768
180
t5
[n7-8]
180
[n8-5]
t5
588
Absorption
p
d

n7

Ground State

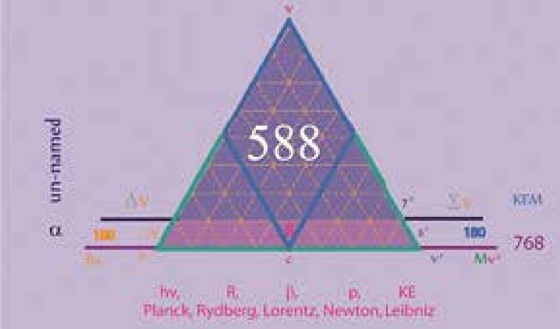
un-named
α
Δv
Σv
KEM
588
180
180
768
Mv²
hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

-0.276026782 eV

$$KEM = \frac{hf}{n^2}$$

Q shell

4,494.03 nm

$$KEM = \frac{hcR}{n^2}$$

$$m.\begin{bmatrix} \Omega/v \\ v/\Omega \\ c^2/\Omega \\ v^2/c^2 \end{bmatrix}$$

λ	4,494.033183	nm	h/p
$\tilde{v}$	222,517.2711	m-1	p/h
f	$6.67089964 \times 10^{13}$	Hz	E/h
E	**0.276026278**	**eV**	hf
Ω	1,347.277254	m^2/s	

ground KEM energies

equilateral energy momenta is the foundation
of all quantum EM wave functions

Tetryonics 36.01 - Un-named spectral line

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This spectral line photo-electrons transition can only release **one** specific [Δhν] W boson of energy

-0.276026782 eV

v
n7
KE
S
N
12
f.2e20

4,494.03 nm

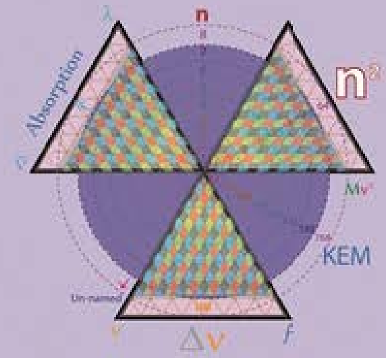
λ
n
Absorption
n²
Mv²
KEM
Un-named
v
Δv
f

Un-named spectral series

α **19,174** n1-8

IR spectrum

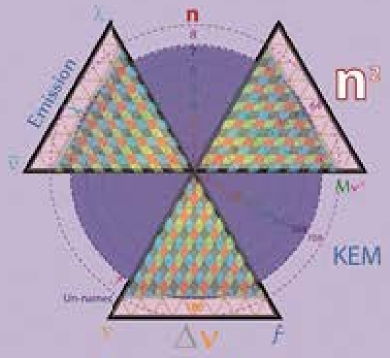
λ
n
Emission
n²
Mv²
KEM
Un-named
v
Δv
f

Q shell

Δν

KEM

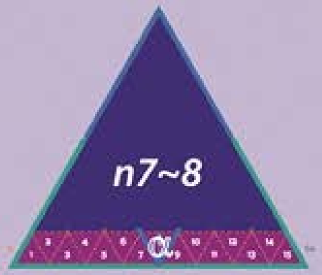

180

768

1 quantum level jump

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Un-named series energy momenta

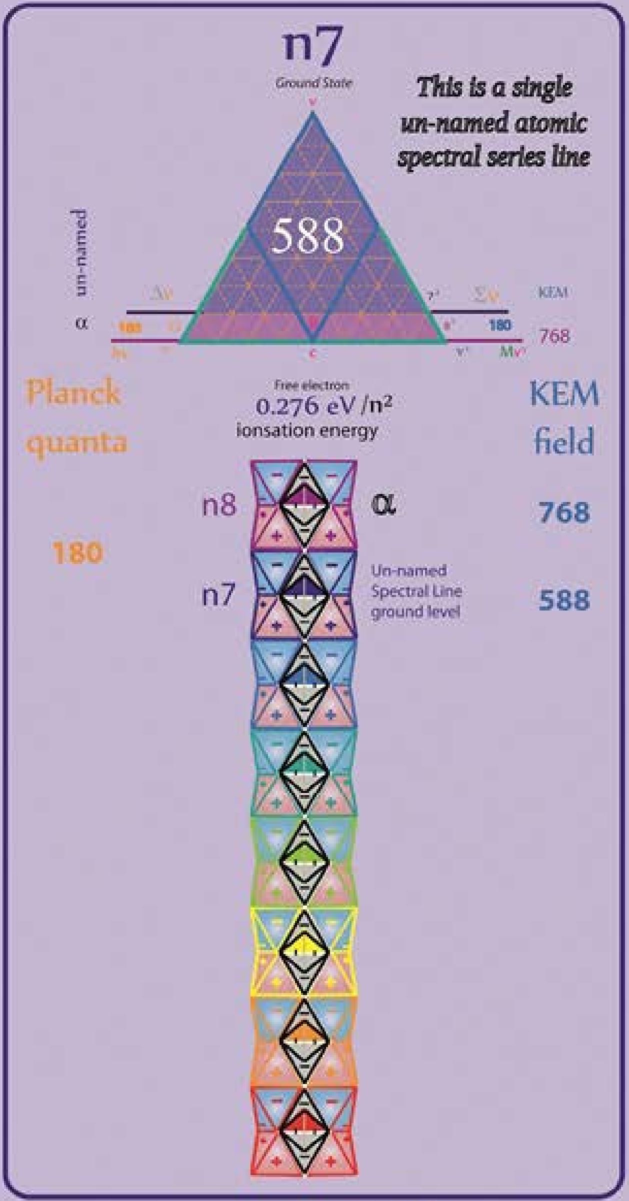
n7
Ground State
This is a single un-named atomic spectral series line
un-named
588
α
180
KEM
180
768
Planck quanta
Free electron
0.276 eV /n²
ionsation energy
KEM field
n8
α
768
180
n7
Un-named Spectral Line ground level
588

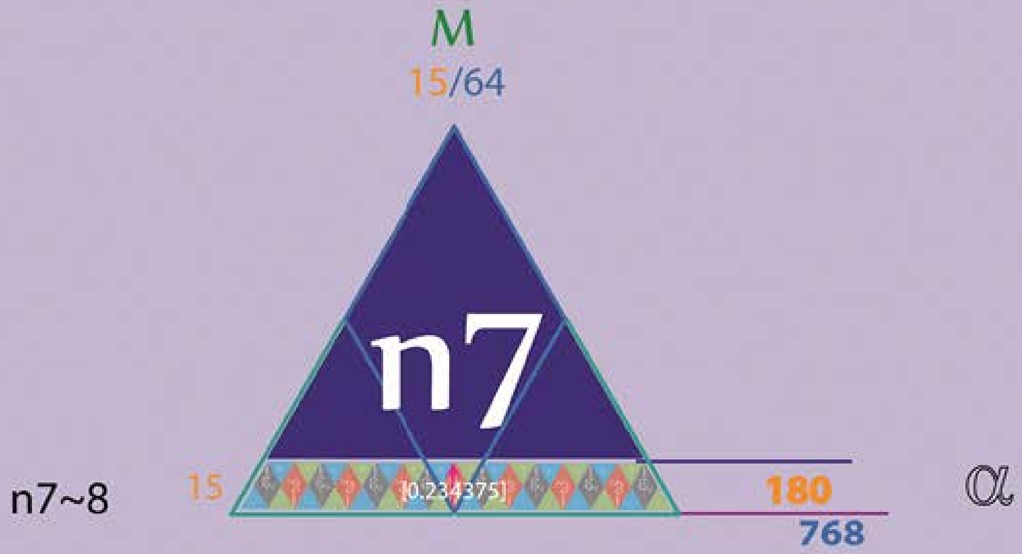
M
15/64
n7
n7~8
15
[0.234375]
180
768
α

accelerating electrons $\Delta p = \Delta Mv = hf$ produce spectral lines

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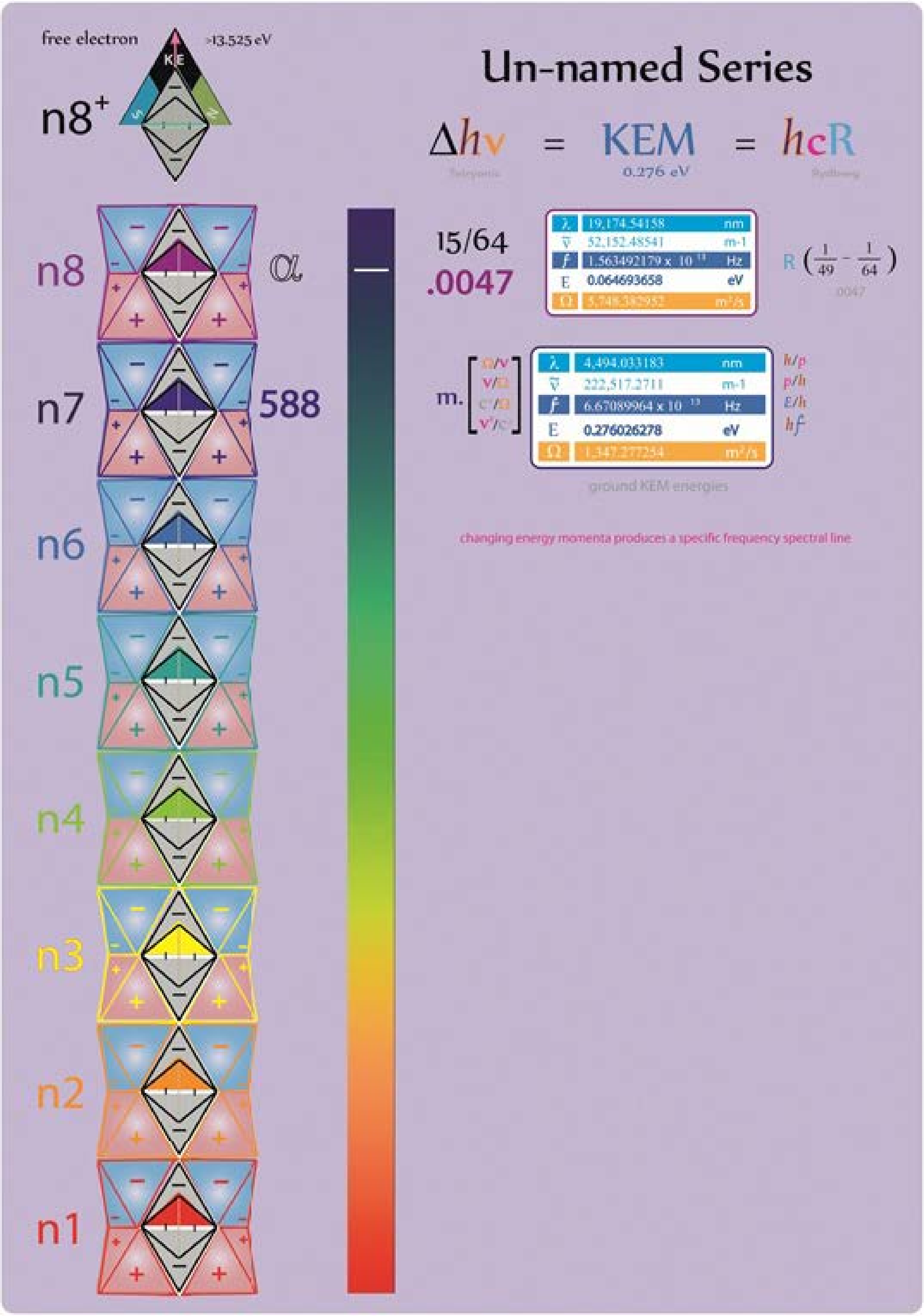

Un-named Series

$$\Delta h\nu = \text{KEM} = hcR$$

Tetryonic — 0.276 eV — Rydberg

15/64
.0047

λ	19,174.54158	nm
$\tilde{\nu}$	52,152.48541	m-1
f	1.563492179 x 10 ^{13}	Hz
E	0.064693658	eV
Ω	5,748.382952	m²/s

$$R\left(\frac{1}{49}-\frac{1}{64}\right)$$

.0047

$$m.\begin{bmatrix}\Omega/v\\ v/\Omega\\ c^2/\Omega\\ v^2/c^2\end{bmatrix}$$

λ	4,494.033183	nm	h/p
$\tilde{\nu}$	222,517.2711	m-1	p/h
f	6.67089964 x 10 ^{13}	Hz	E/h
E	0.276026278	eV	hf
Ω	1,347.277254	m²/s	

ground KEM energies

changing energy momenta produces a specific frequency spectral line

Tetryonics 36.04 - Un-named series maths

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KEM field geometry

v
Q
RE
p
KE
ε0
M
hv
v²

The Lorentz corrected velocity of electron resulting from atomic energy level transitions

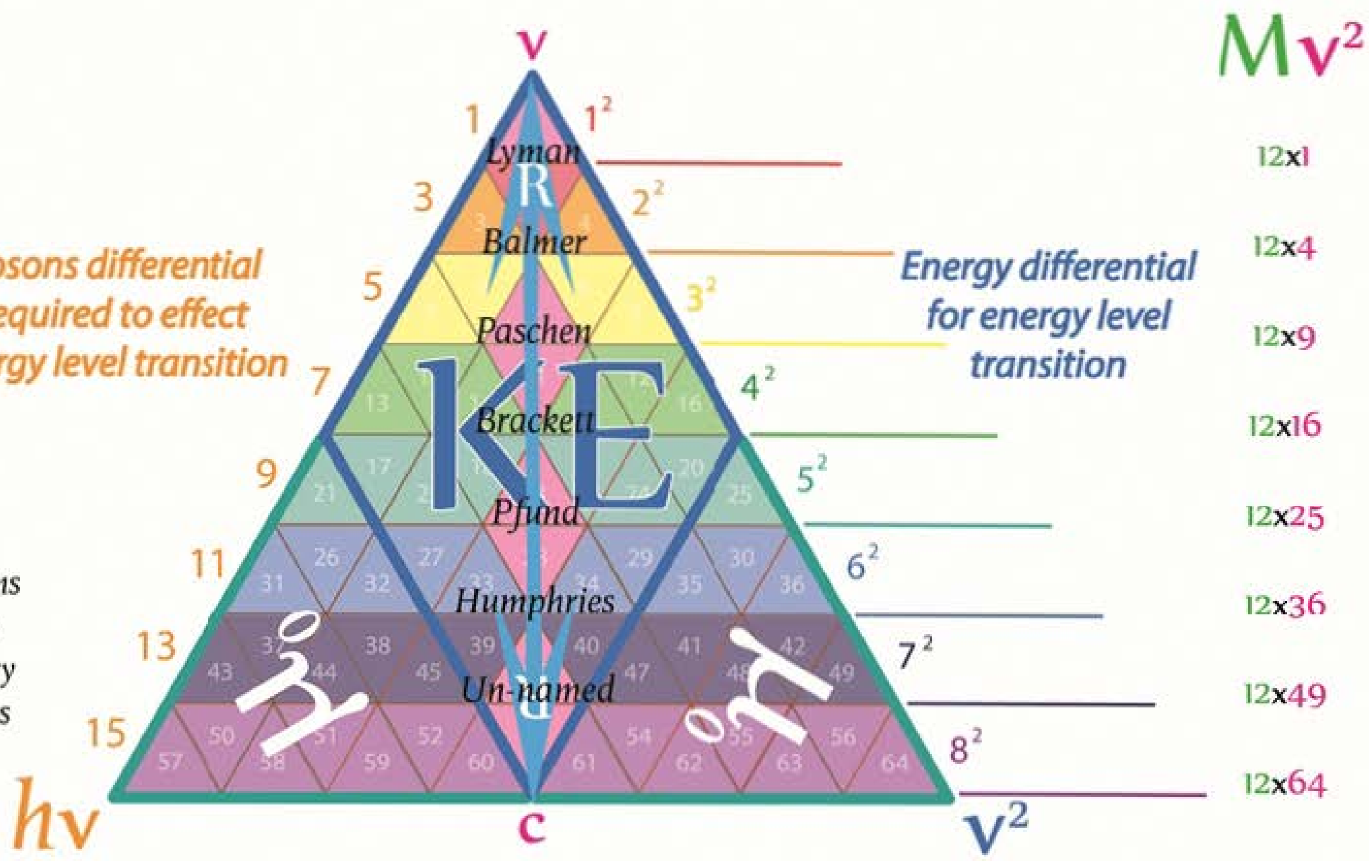
Mv²
v
1
1²
Lyman
R
3
2²
Balmer
5
3²
Paschen
7
4²
KE
13
16
Brackett
9
5²
17
20
21
25
Pfund
11
6²
26
27
29
30
31
32
33
34
35
36
Humphries
13
7²
37
38
39
40
41
42
43
44
45
47
48
49
Un-named
15
8²
50
51
52
54
55
56
57
58
59
60
61
62
63
64
hv
c
v²
12x1
12x4
12x9
12x16
12x25
12x36
12x49
12x64

Bosons differential required to effect energy level transition

Energy differential for energy level transition

All of the quantum jumps of electrons bound in a Hydrogen atom can be summerised in the Tetryonic geometry reflecting the energy level transitions

Ryberg's constant is reflective of the wavelengths and linear momentum of a transitioning electron's KEM field

Ryberg's formula is a mathematical description of Tetryonic energy geometry

$$Mv^2 = KEM = hcR_H$$

KEM field quanta

Tetryonics 37.01 - Spectral Line geometry

Photoelectron transitions

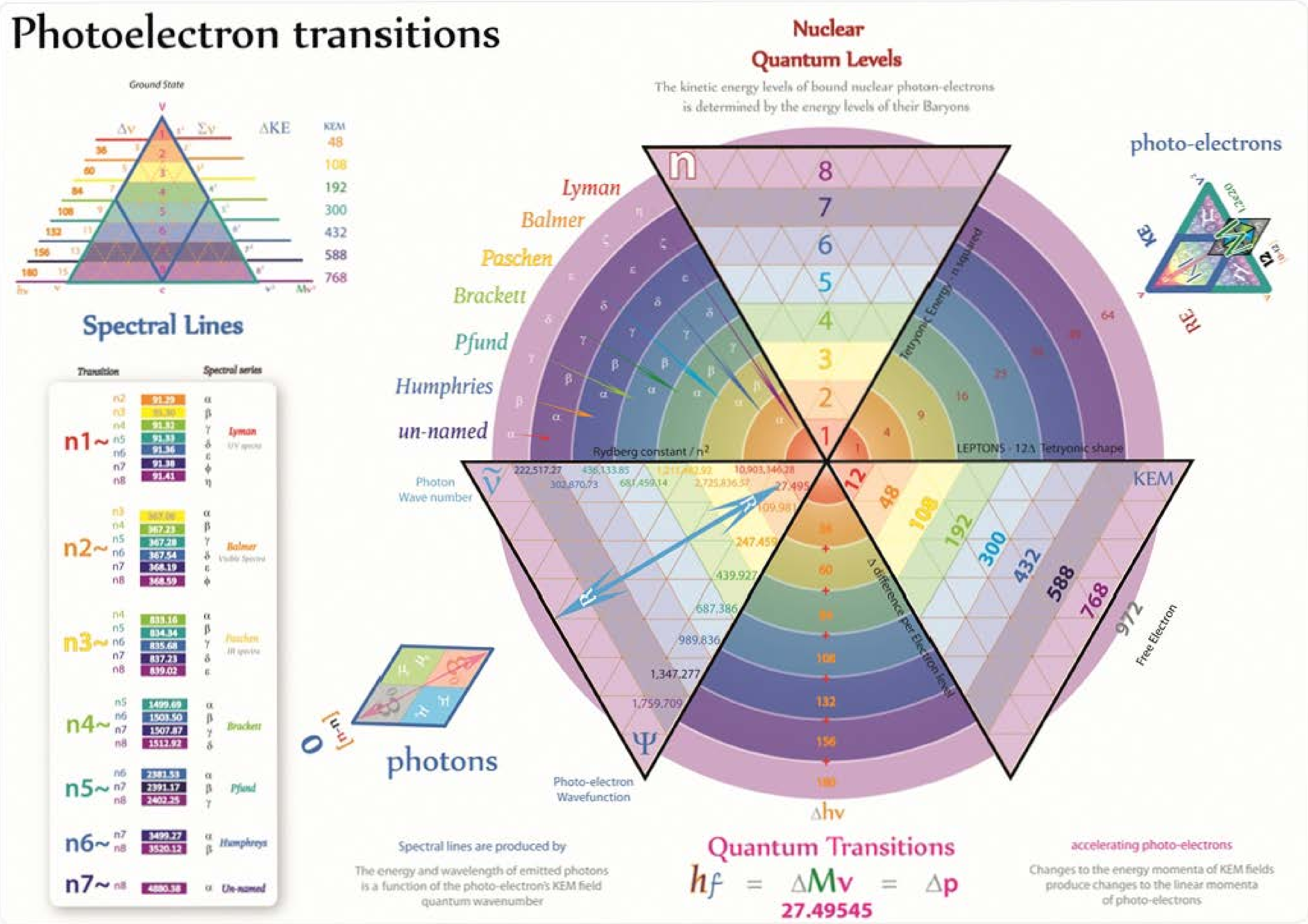
Ground State
v
Δv
Σv
ΔKE
KEM
48
108
192
300
432
588
768
36
60
84
108
132
156
180
1
2
3
4
5
6
7
8
hν
c
Mv²
Nuclear Quantum Levels
n
8
7
6
5
4
3
2
1
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
α
β
γ
δ
ε
ζ
η
Rydberg constant / n²
LEPTONS - 12Δ Tetryonic shape
Tetryonic Energy - n squared
1
4
9
16
25
36
49
64
ν̃
Photon Wave number
222,517.27
302,870.73
436,133.85
681,459.14
1,211,482.92
2,725,836.57
10,903,346.28
27.495
109.981
247.459
439.927
687.386
989.836
1,347.277
1,759.709
Ψ
Photo-electron Wavefunction
12
48
108
192
300
432
588
768
972
KEM
Free Electron
36
60
84
108
132
156
180
Δ difference per Electron level
Δhν
photo-electrons
KE
RE
12
O
[u-u]
photons

The kinetic energy levels of bound nuclear photon-electrons is determined by the energy levels of their Baryons

Spectral Lines

Transition			Spectral series	
n1~	n2	91.29	α	*Lyman* UV spectra
	n3	91.30	β	
	n4	91.32	γ	
	n5	91.33	δ	
	n6	91.36	ε	
	n7	91.38	ϕ	
	n8	91.41	η	
n2~	n3	367.06	α	*Balmer* Visible Spectra
	n4	367.23	β	
	n5	367.28	γ	
	n6	367.54	δ	
	n7	368.19	ε	
	n8	368.59	ϕ	
n3~	n4	833.16	α	*Paschen* IR spectra
	n5	834.34	β	
	n6	835.68	γ	
	n7	837.23	δ	
	n8	839.02	ε	
n4~	n5	1499.69	α	*Brackett*
	n6	1503.50	β	
	n7	1507.87	γ	
	n8	1512.92	δ	
n5~	n6	2381.53	α	*Pfund*
	n7	2391.17	β	
	n8	2402.25	γ	
n6~	n7	3499.27	α	*Humphreys*
	n8	3520.12	β	
n7~	n8	4880.38	α	*Un-named*

Spectral lines are produced by

The energy and wavelength of emitted photons is a function of the photo-electron's KEM field quantum wavenumber

Quantum Transitions

$$hf = \Delta Mv = \Delta p$$

27.49545

accelerating photo-electrons

Changes to the energy momenta of KEM fields produce changes to the linear momenta of photo-electrons

Tetryonics 37.02 - Photoelectron transitions

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Photoelectric energy level transitions

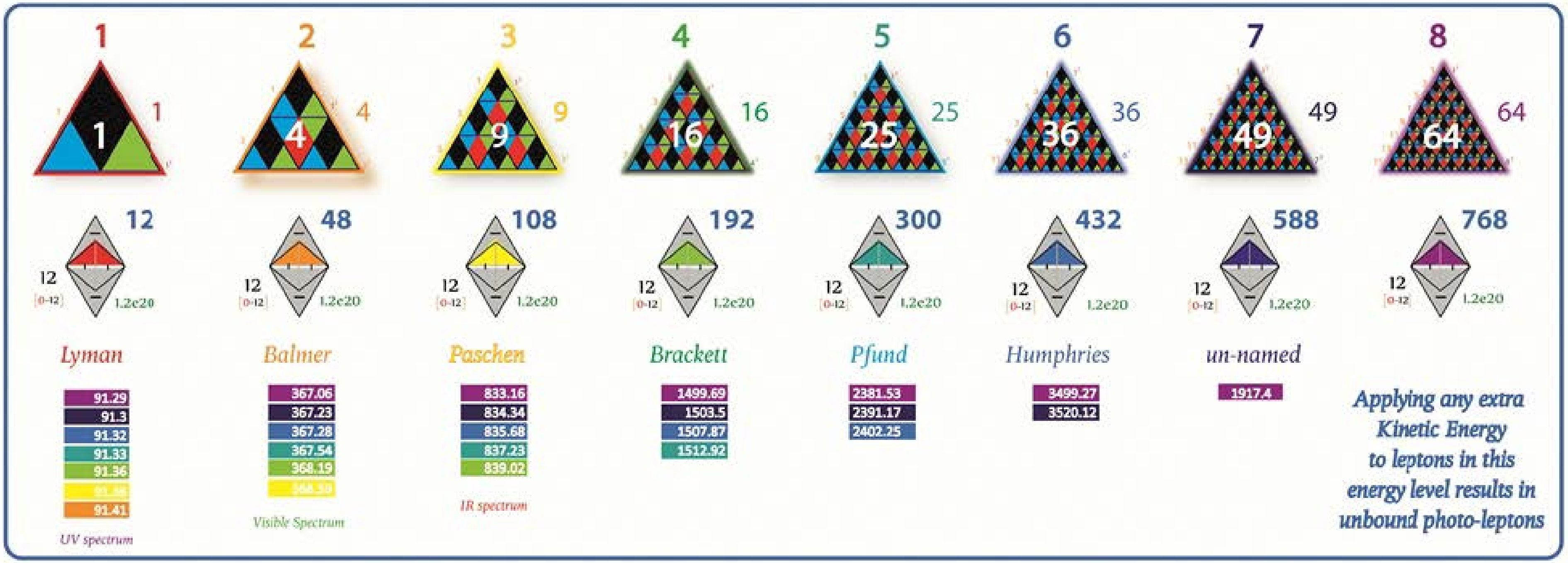
1
1
1
2
4
4
3
9
9
4
16
16
5
25
25
6
36
36
7
49
49
8
64
64
12
48
108
192
300
432
588
768
12
[0-12]
1.2e20

Lyman	Balmer	Paschen	Brackett	Pfund	Humphries	un-named
91.29	367.06	833.16	1499.69	2381.53	3499.27	1917.4
91.3	367.23	834.34	1503.5	2391.17	3520.12	
91.32	367.28	835.68	1507.87	2402.25		
91.33	367.54	837.23	1512.92			
91.36	368.19	839.02				
91.38	368.59					
91.41						
UV spectrum	Visible Spectrum	IR spectrum				

Applying any extra Kinetic Energy to leptons in this energy level results in unbound photo-leptons

$$Mv^2 = KEM = hcR_H$$

These specific quantum level steps create the Photoelectric effect

$$\Delta hv = \phi = hf$$

Photo-electrons bound to atomic nuclei
can only transition between Mv squared KEM energies
as a direct result of the energy levels of Baryons

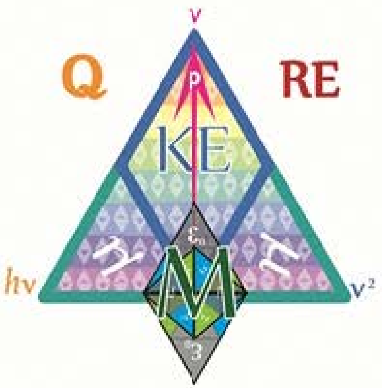
Q
RE
v
p
KE
hv
v²
M

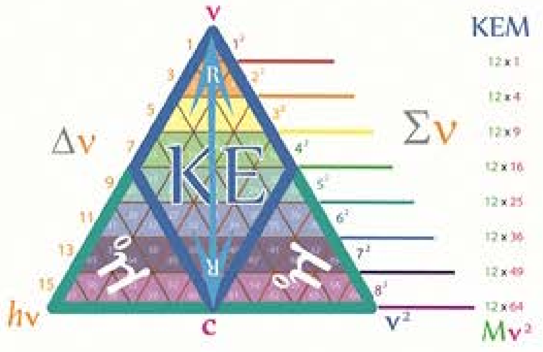
KEM
v
Δv
Σv
KE
R
hv
c
v²
Mv²
12 x 1
12 x 4
12 x 9
12 x 16
12 x 25
12 x 36
12 x 49
12 x 64

Tetryonics 37.03 - Photoelectric spectral energy levels

The Photoelectric effect

The photoelectric effect was first observed in 1887 by Heinrich Hertz (1857-1894) during experiments with a spark-gap generator — the earliest form of radio receiver

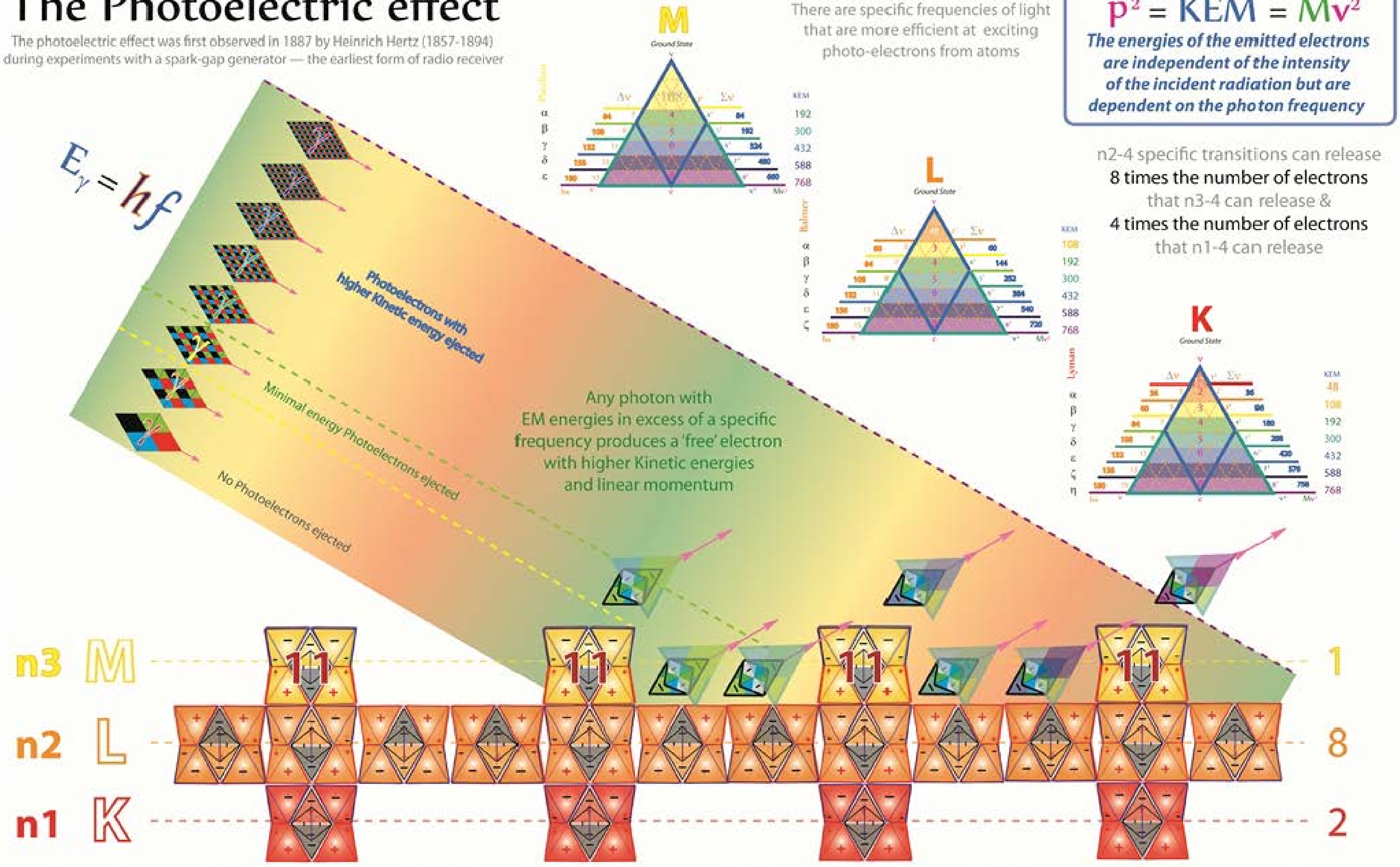
$E_\gamma = hf$
M
Ground State
Paschen
KEM
192
300
432
588
768
L
Ground State
Balmer
KEM
108
192
300
432
588
768
K
Ground State
Lyman
KEM
48
108
192
300
432
588
768
Photoelectrons with higher Kinetic energy ejected
Minimal energy Photoelectrons ejected
No Photoelectrons ejected
n3 M
n2 L
n1 K
11
1
8
2

There are specific frequencies of light that are more efficient at exciting photo-electrons from atoms

$$p^2 = KEM = Mv^2$$

The energies of the emitted electrons are independent of the intensity of the incident radiation but are dependent on the photon frequency

n2-4 specific transitions can release 8 times the number of electrons that n3-4 can release & 4 times the number of electrons that n1-4 can release

Any photon with EM energies in excess of a specific frequency produces a 'free' electron with higher Kinetic energies and linear momentum

Soon after the discovery of Planck's Heat law and the quantisation of energy at the quantum level experiments by others, most notably Robert Millikan (1865-1953), found that light with frequencies below a certain cutoff value, called the threshold frequency, ould not eject photoelectrons from the metal surface no matter how bright the source

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Photonic mass-energy momenta

$$2m\Omega v^2 = E = n.hf$$

All 2D EM waveforms possess mass-energy and momenta

Bosons

EM Field Planck quanta

$$\text{ODD}\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Bosons ElectroMagnetic mass velocity

Photons

EM Field Planck quanta

$$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Photons ElectroMagnetic mass velocity

charged mass-energy-momentum

$$E = mv^2$$

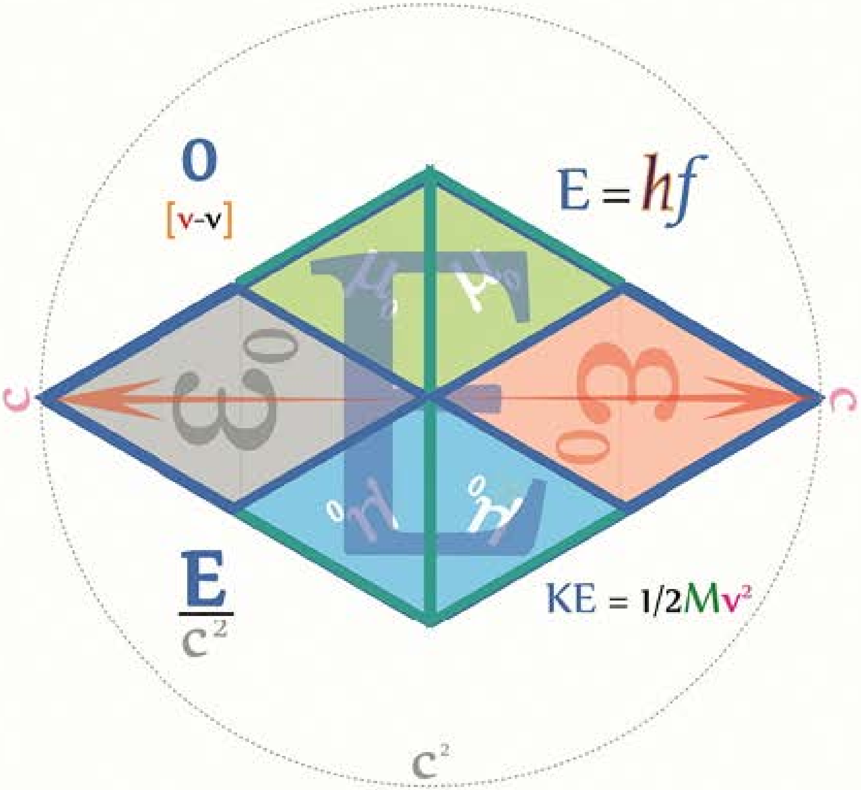

radiant mass-energy momenta

$$E = hv^2$$

Planck energies

All 2D EM waveforms propagate at the speed of light

Velocity of Light

$$v = \left[\left[\frac{c^2}{\Omega}\right]\cdot\left[\frac{\Omega}{c}\right]\right] = c$$

f λ

Speed of Light

scalar frequency

linear wavelength

ε₀
γ
μ₀
μ₀
μ₀
μ₀
ε₀

Tetryonics 37.05 - Photonic mass-Energy equivalence

Wave~Particle duality

First proposed by Christian Huygens in the 1600's, it wasn't until the 1800's that Thomas Young proved this wave-particle duality with the classic double-slit experiment.

In 1678, Dutch physicist, Christiaan Huygens, believed that light was made up of waves vibrating up and down perpendicular to the direction of the light travels, and therefore formulated a way of visualising wave propagation.

This became known as 'Huygens' Principle' and was the successful theory of light wave motion in three dimensions

Sir Isaac Newton, held the theory based on his spetral observations that light was made up of tiny particles or 'corpusles of colour'

English physicist Thomas Young argued that Isaac Newton's theory of particle light was incorrect, and instead argued that light is a transverse wave.

In 1803, Thomas Young studied the interference of light waves by shining light through a screen with two slits equally separated, the light emerging from the two slits, spread out and produced wave-like interference patterns.

Sir Isaac Newton

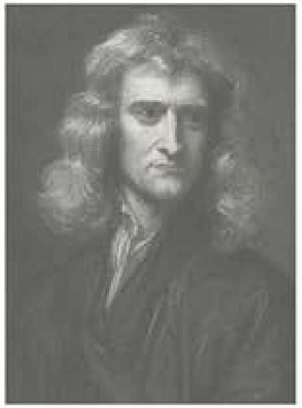

(1643-1727)

Particles

Thomas Young

(1773-1829)

Waves

In 1900
Max Planck proposed the existence of a light quantum, [n.hv] a finite packet of energy which depends on the frequency and spectral energy of the radiation

Light - a Wave, or a Particle?

In 1905
Albert Einstein, suggested that light is composed of tiny particles called photons, and that each photon has energy related to its frequency [hf].

Max Karl Ernst Ludwig Planck

(April 23, 1858 – October 4, 1947)

Bosons

$$nhv = E = hf$$

*Mathematically directly relating the number of **Planck quanta** [n.hv] with **Photon frequencies** [hf] and the frequent interchanging of one term for the other in physics is the source of considerable quantum confusion*

Albert Einstein

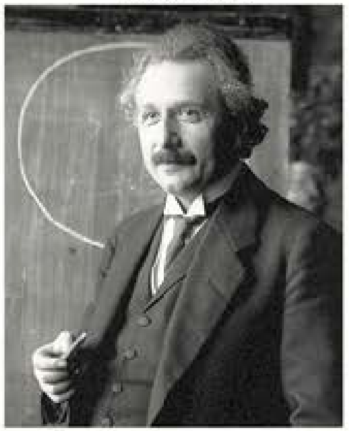

(14 March 1879 – 18 April 1955)

Photons

$$2hv = hf$$

The quantum idea was soon seized upon to explain the photoelectric effect, and became part of the Bohr theory of discrete atomic spectra, quickly becoming part of the foundation of modern quantum theory in turn this led to the quantum wierdness of wave-particle dualty, Heisenberg's Uncertainty principle and Schrodinger's quantum wave equation & wavefunctions.

Wave Particle Mechanics

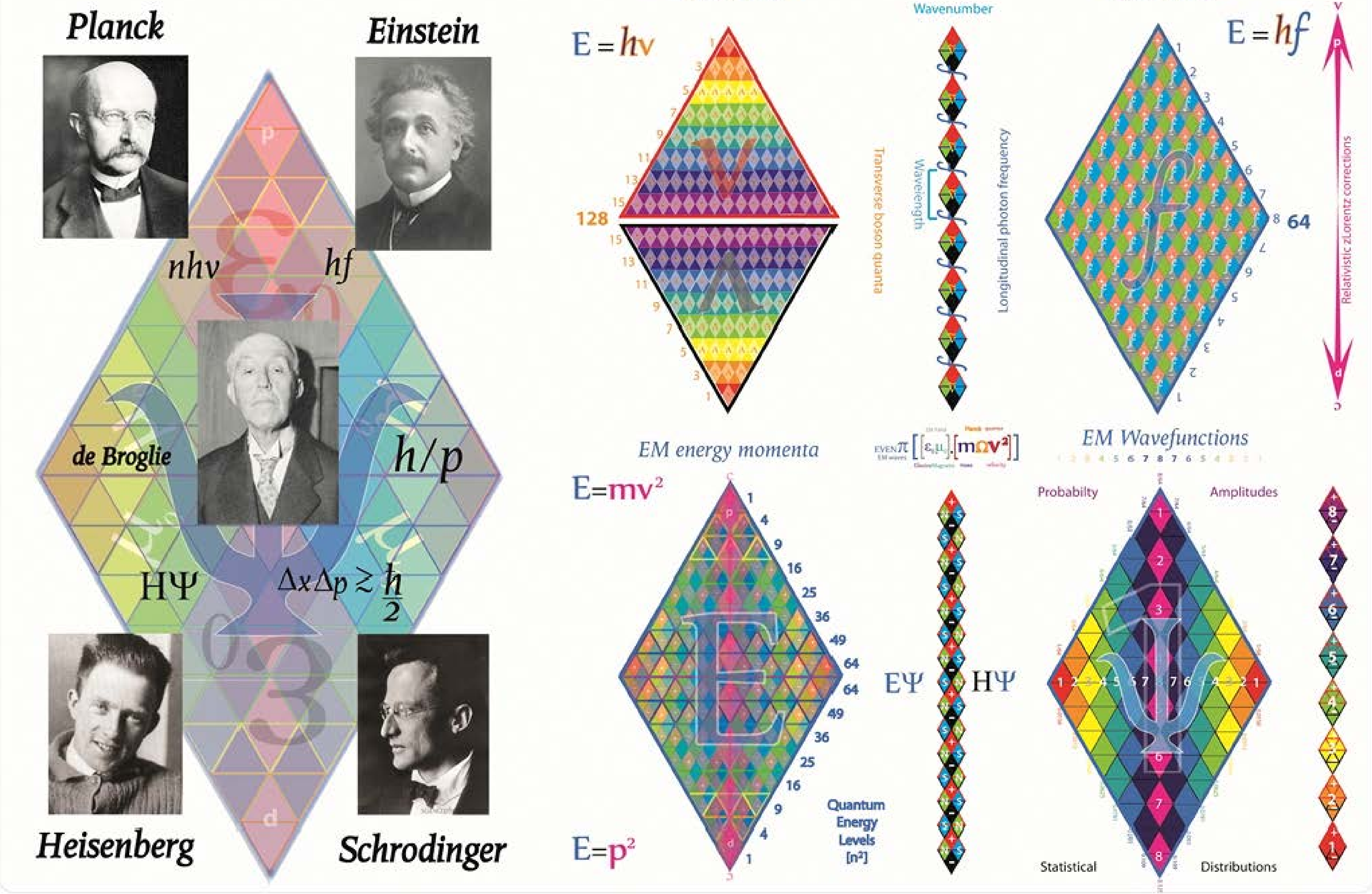
Planck
Einstein
nhv
hf
de Broglie
h/p
HΨ
ΔxΔp ≥ ħ/2
Heisenberg
Schrodinger
E = hν
128
Wavenumber
Transverse boson quanta
Wavelength
Longitudinal photon frequency
E = hf
64
Relativistic zLorentz corrections
EM energy momenta
E=mv²
E=p²
Quantum Energy Levels [n²]
EΨ
HΨ
EM Wavefunctions
Probabilty
Amplitudes
Statistical
Distributions

Tetryonics 38.01 - Wave~Particle Mechanics

Blackbody Radiation

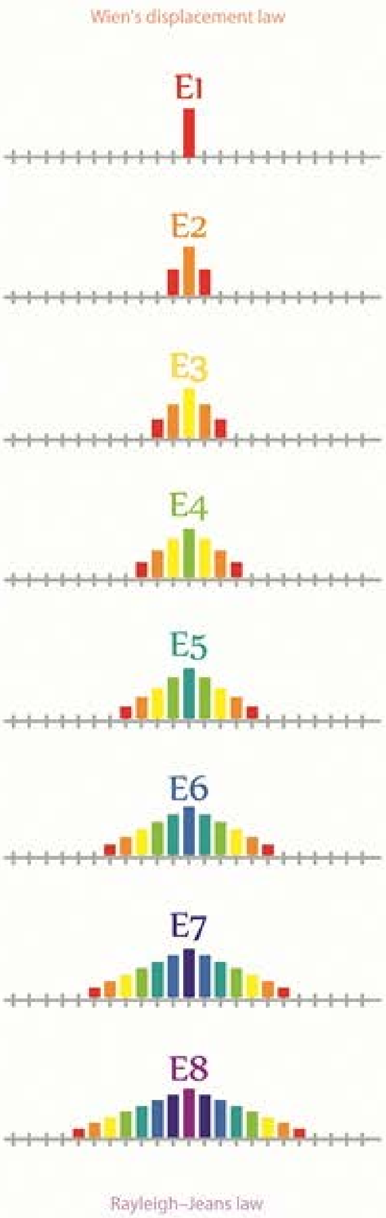
Wien's displacement law
E1
E2
E3
E4
E5
E6
E7
E8
Rayleigh–Jeans law

Max Planck

(April 23, 1858 – October 4, 1947)

In physics, Planck's law describes the amount of electromagnetic energy with a certain wavelength radiated by a black body in thermal equilibrium (i.e. the spectral radiance of a black body).

The law is named after Max Planck, who originally proposed it in 1900. The law was the first to accurately describe black body radiation, and resolved the ultraviolet catastrophe by introducing Planck's Constant.

It is a pioneer result of modern physics and quantum theory leading to mass.QAM being termed Planck's constant.

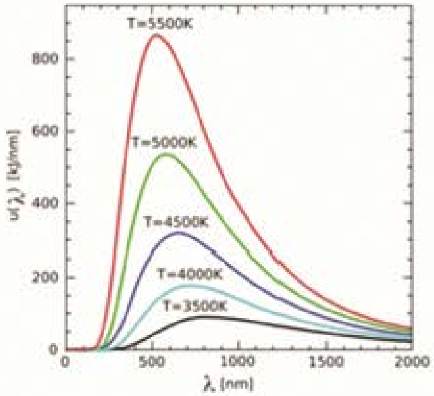

$m\Omega = 6.62943244\ e\text{-}34\ J.s = h$

nhv

All EM waves are comprised of discrete energy quanta

As their frequency increases the wavelength of emitted Photons decreases

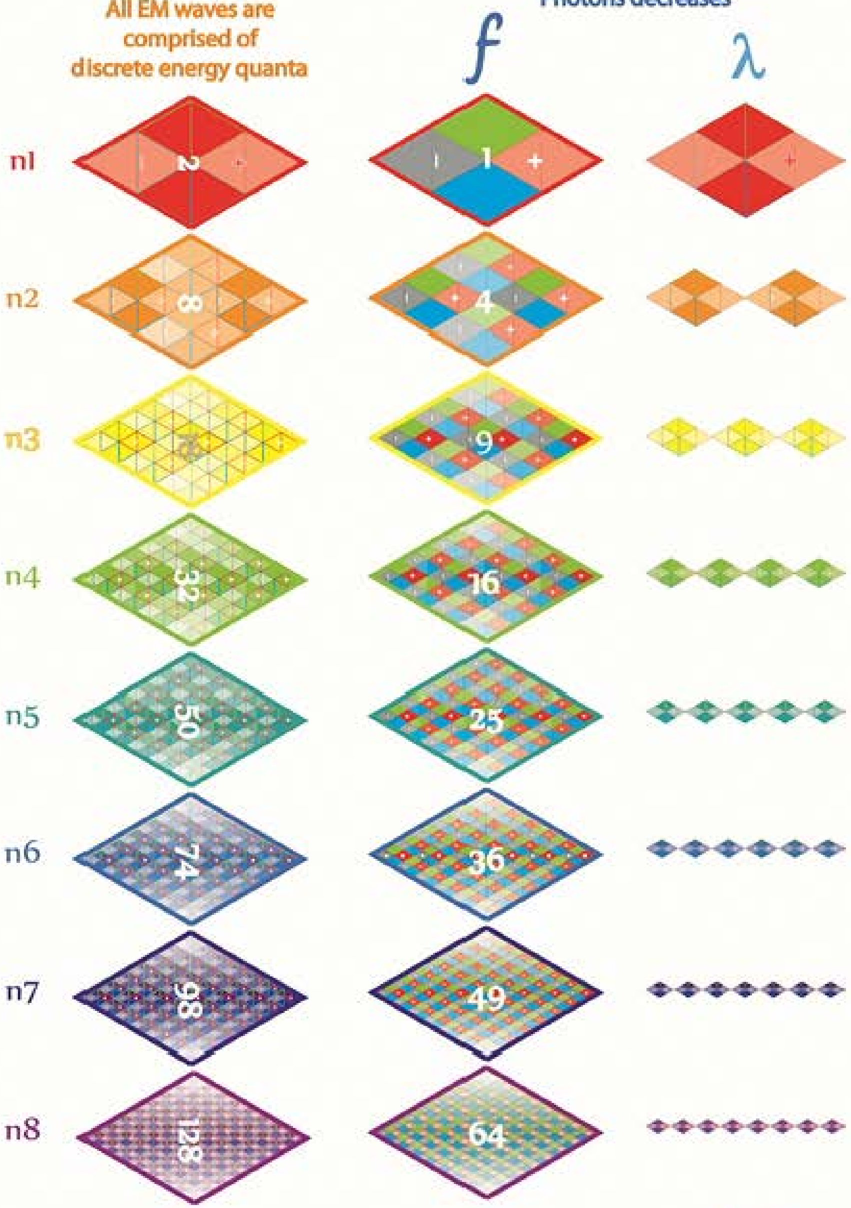
f
λ
n1
n2
n3
n4
n5
n6
n7
n8
2
8
18
32
50
72
98
128
1
4
9
16
25
36
49
64

$2hv = hf = hc\tilde{v}$

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EM field energies

Planck quanta

$$E = n\pi\left[\left[m\Omega v^2\right]\right]$$

mass velocity

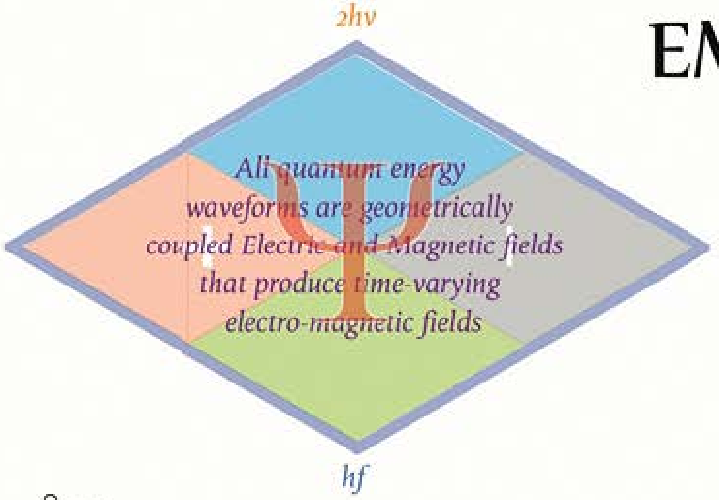

All quantum energy waveforms are geometrically coupled Electric and Magnetic fields that produce time-varying electro-magnetic fields

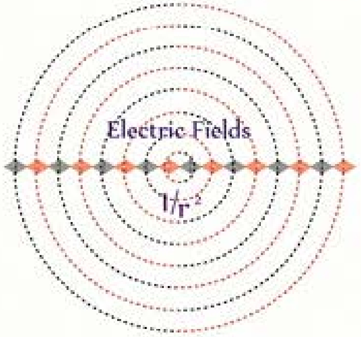
Electric Fields
1/r²

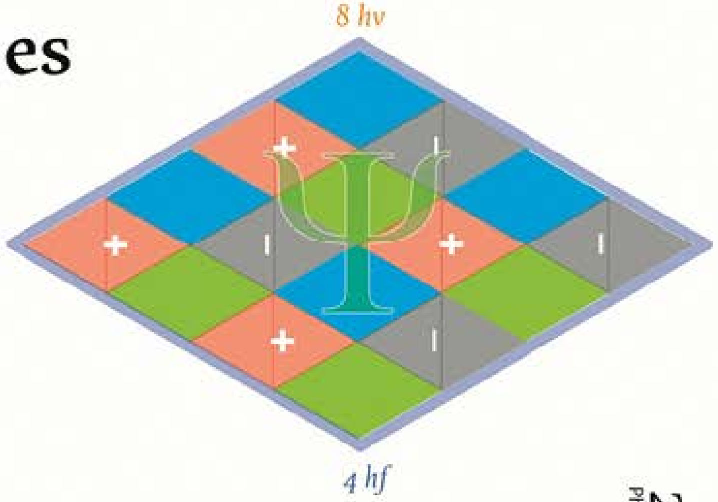

Charge

$$1\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

EM Field Planck quanta

ElectroMagnetic mass velocity

$$E = h\nu$$

EM waves are subject to Lorentz co-ordinate transformations

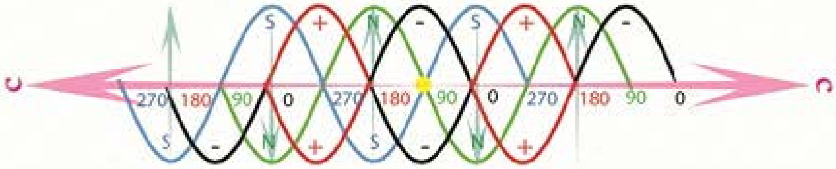
c
S
+
N
-
S
+
N
-
270
180
90
0
270
180
90
0
270
180
90
0
S
-
N
+
S
-
N
+
c

EM waves are a quadrature waveform of bi-directional electromagnetic oscillations

$$E = hf$$

Photons

$$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

EM Field Planck quanta

ElectroMagnetic mass velocity

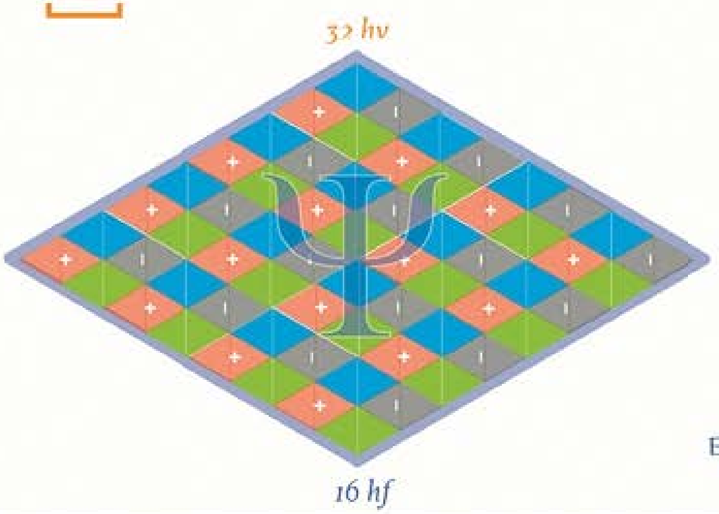

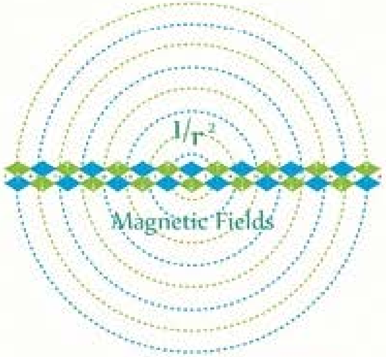
1/r²
Magnetic Fields

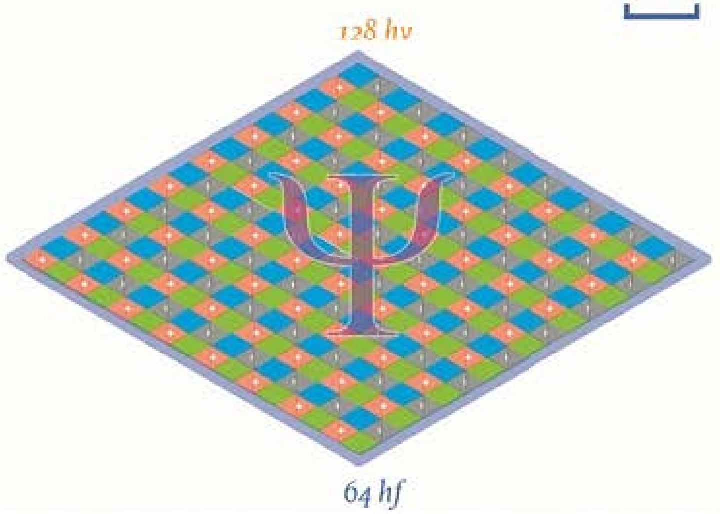

EM Field Planck quanta

$$\text{EVEN}\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

EM waves

ElectroMagnetic mass velocity

Tetryonics 38.03 - EM field Energy

Bosons and Photons in EM waves

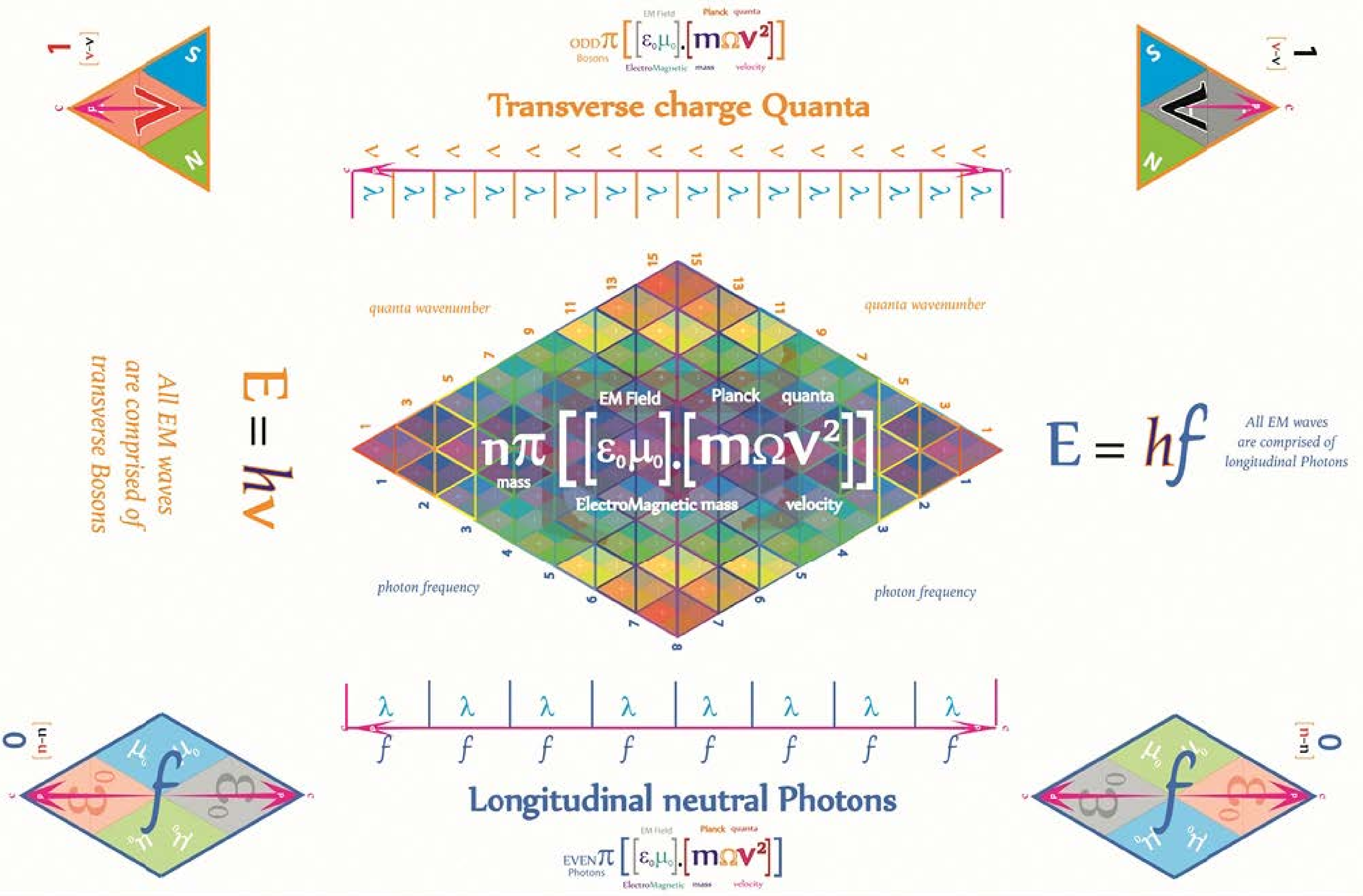

EM Field Planck quanta

$\text{ODD}\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Bosons ElectroMagnetic mass velocity

Transverse charge Quanta

quanta wavenumber

EM Field Planck quanta

$n\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

mass ElectroMagnetic mass velocity

photon frequency

$E = h\nu$

All EM waves are comprised of transverse Bosons

$E = hf$

All EM waves are comprised of longitudinal Photons

Longitudinal neutral Photons

EM Field Planck quanta

$\text{EVEN}\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$

Photons ElectroMagnetic mass velocity

Tetryonics 38.04 - Bosons and Photons in EM waves

EM wave energy quanta

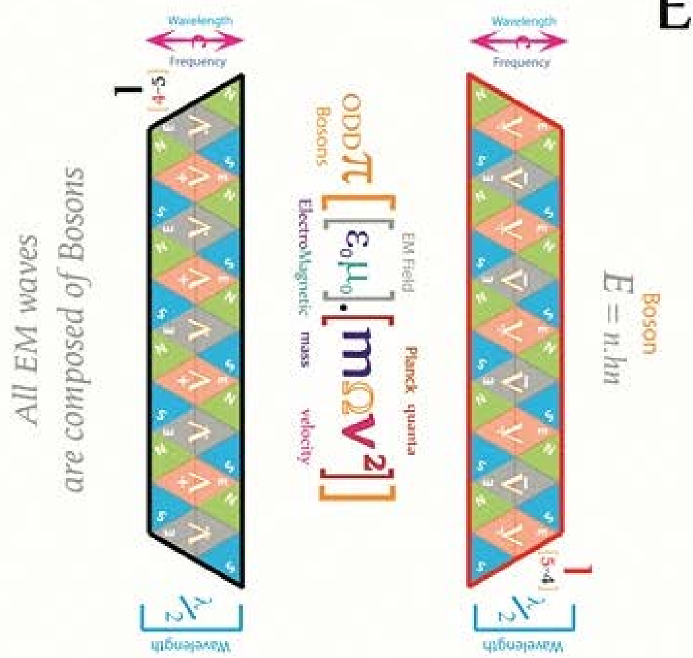
All EM waves
are composed of Bosons
Wavelength
Frequency
1
[4-5]
[5-4]
λ/2
Wavelength
ODD π [[ε₀μ₀].[mΩv²]]
Bosons
EM Field
ElectroMagnetic
mass
Planck quanta
velocity
E = n.hn
Boson

Tranverse Bosons in EM wave energies should be modelled using [n] Planck quanta

Wavefunction

$$i\hbar\frac{\partial}{\partial t}\Psi \quad \Psi \quad \hat{H}\Psi$$

Probability = $|\text{Amplitude}|^2$

The Longitudinal EM wave energies should be modelled using [f] Photon frequencies

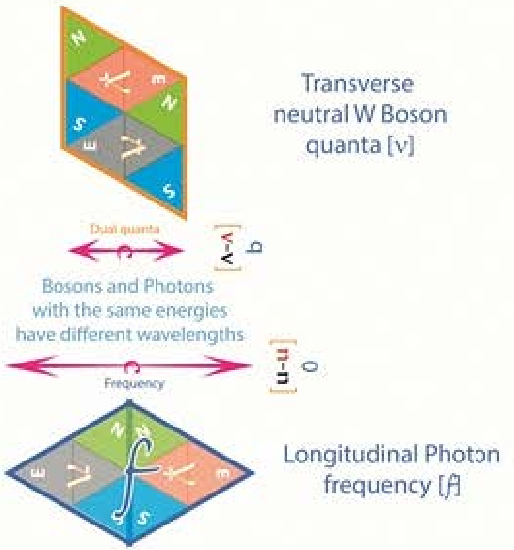
Transverse neutral W Boson quanta [ν]
Dual quanta
[ν-ν]
Bosons and Photons with the same energies have different wavelengths
Frequency
[n-n]
0
Longitudinal Photon frequency [f]

$$E = n\pi[m\Omega v^2]$$

Planck quanta · mass · velocity

All Wave~Particle geometries and mass-energies can be calculated from and modelled with the Tetryonic Unified Field Equation

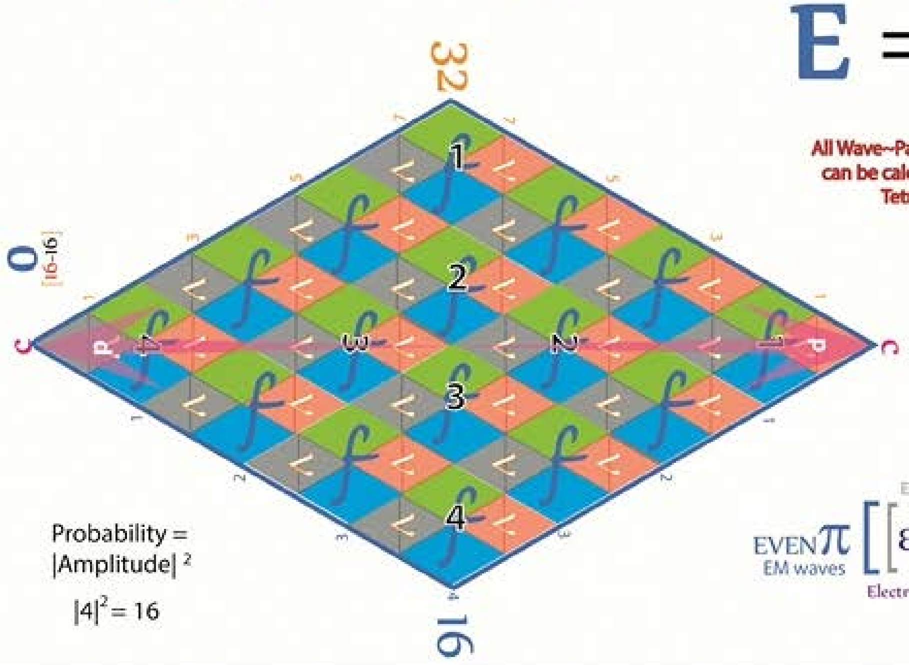
32
0
[16-16]
16
1
2
3
4
Probability = |Amplitude|²
|4|² = 16

E =hf

Photon

$$\text{EVEN}\,\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$$

EM waves · EM Field · ElectroMagnetic · Planck quanta · mass · velocity

All EM waves are composed of Square number Photons

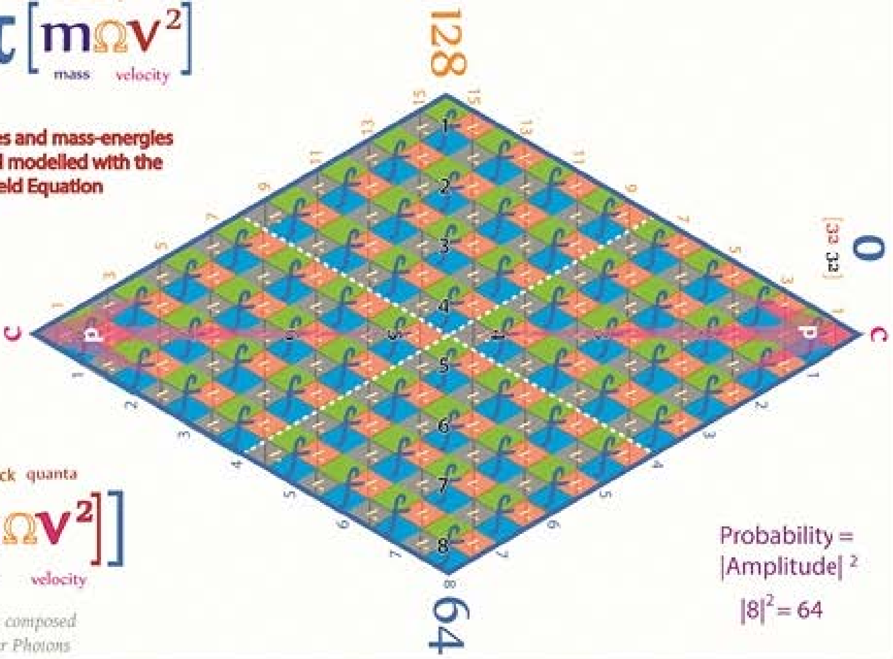
128
0
[32-32]
64
1
2
3
4
5
6
7
8
Probability = |Amplitude|²
|8|² = 64

EM wave properties

Linear momentum is the square root of scalar mass-energies

$$\left[\sqrt{\overset{\text{Energy}}{[\underset{\text{mass}}{m}\,\underset{\text{quanta}}{\Omega}\,v^2]}}\,\right]$$

Transverse waveforms

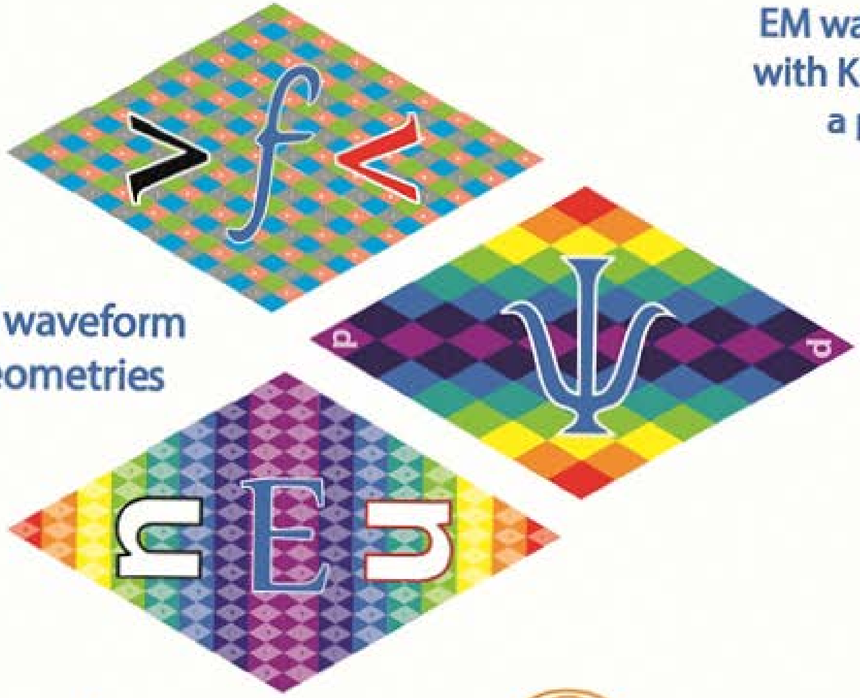

EM waveform geometries

EM waves are comprised of Photons with Kinetic energies, momenta and a photo-magnetic moment

$$p_\gamma = 2\pi\left[\overset{\text{Energy}}{[\underset{\text{momenta}}{m\Omega v}]}\right]$$

Photonic energy-momentum

Longitudinal waveforms

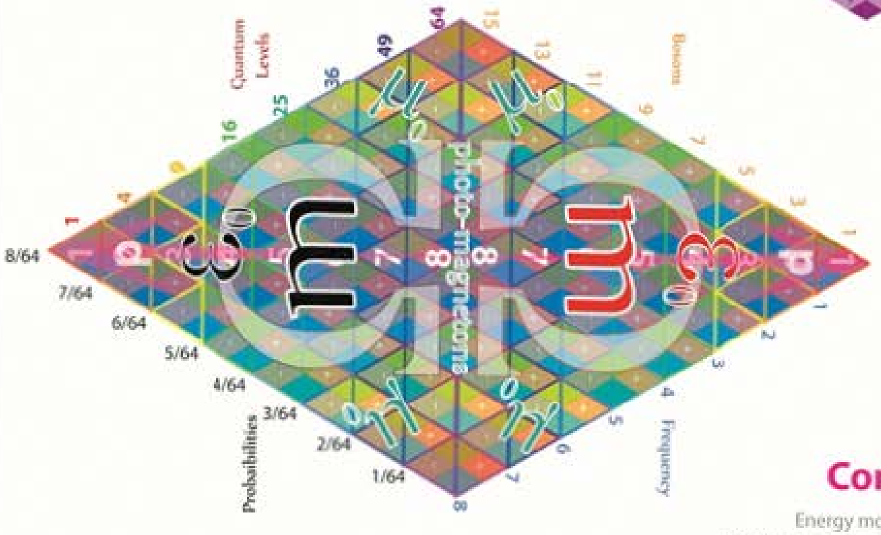
Quantum Levels
1
4
9
16
25
36
49
64
15
13
11
9
7
5
3
1
Bosons
8/64
7/64
6/64
5/64
4/64
3/64
2/64
1/64
Probabilities
1
2
3
4
5
6
7
8
Frequency
photo-magnetons
m
m
ε₀
μ₀
p
p

Scalar Planck quanta
per second
is the scalar source of all
linear energy-momenta

$$p^2$$

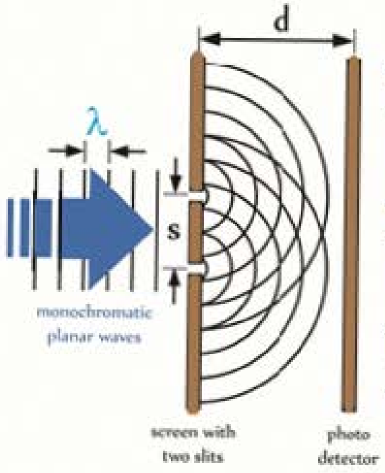
d
λ
s
monochromatic planar waves
screen with two slits
photo detector

Interference is the result of KEM waveform superpositioning

Conservation of Energy momenta

Energy momenta a conserved quantity in physical systems (laws of conservation), meaning that if a closed system is not affected by external forces, its total momentum cannot change

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Statistical probabilities of energy distributions

form the basis for quantum mechanical probabilities and wavefunctions

$E = 2mv$

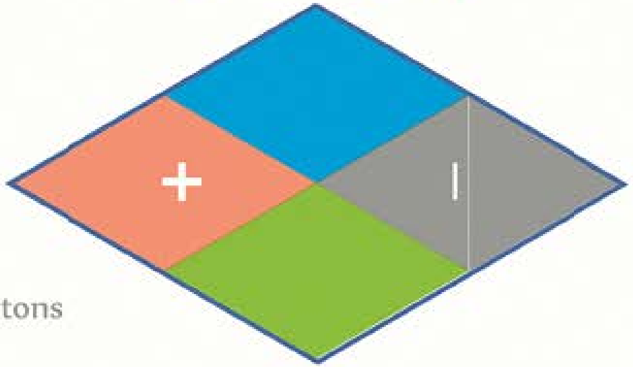

Photons

$E = Mc^4$

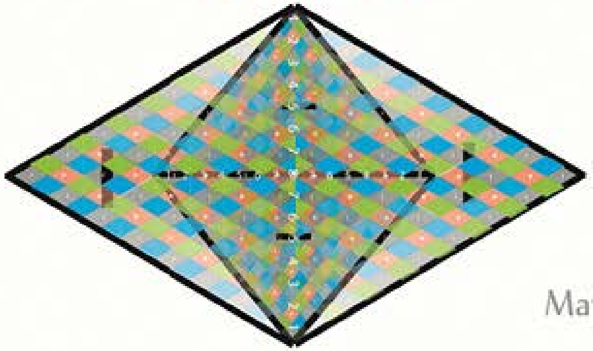

Matter

All ENERGY in motion has probabilistic distribtutions of energy quanta resulting from the equilateral Tetryonic geometries of electromagnetic mass-ENERGY-Matter

EM waves

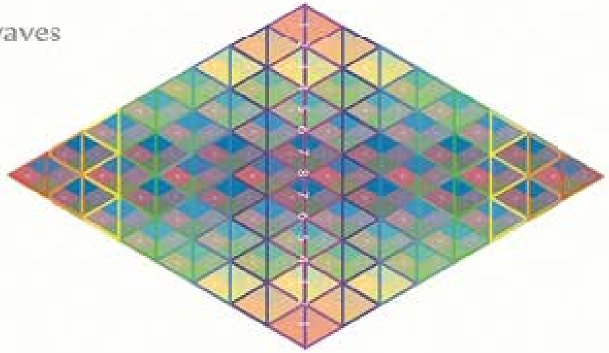

$p^2 = E = mv^2$

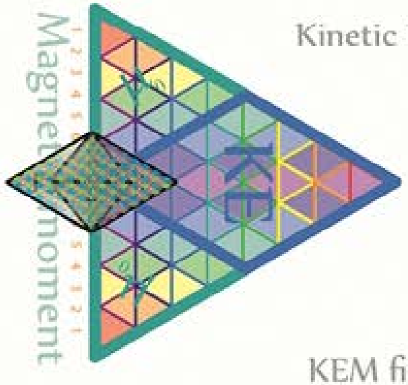

Kinetic Energies

KEM fields

$KE = \frac{1}{2}Mv^2$

$Mv^2 = KEM$

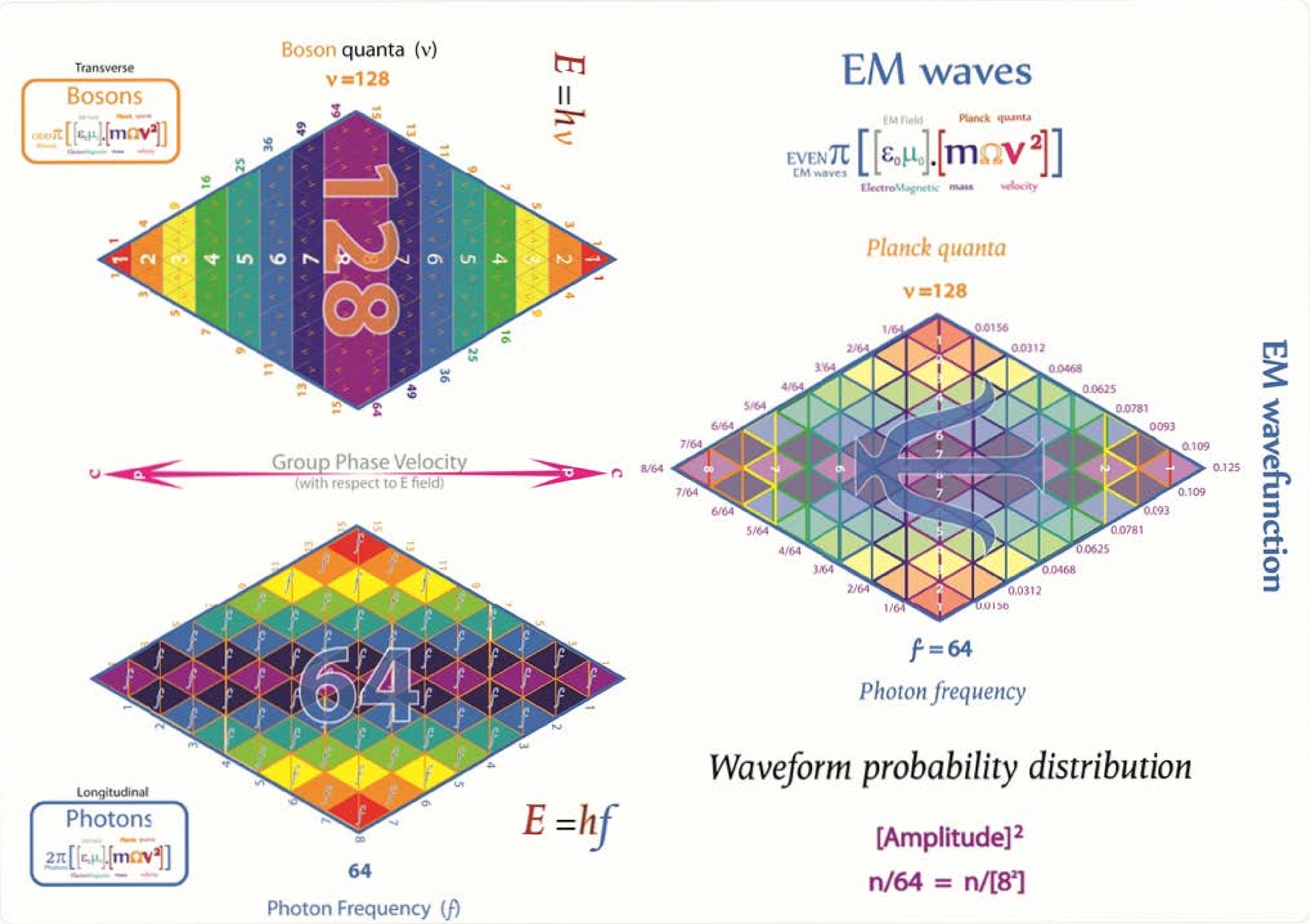
Transverse
Bosons
ODD
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
128
1 4 9 16 25 36 49 64
1 3 5 7 9 11 13 15
C
P
1/64
2/64
3/64
4/64
5/64
6/64
7/64
8/64
0.0156
0.0312
0.0468
0.0625
0.0781
0.093
0.109
0.125
f
64
1 2 3 4 5 6 7 8
Longitudinal
Photons

EM waves

$\text{EVEN}\,\pi\left[[\varepsilon_0\mu_0].[m\Omega v^2]\right]$

EM waves — EM Field — Planck quanta — ElectroMagnetic — mass — velocity

Boson quanta (ν)

ν=128

$E = h\nu$

Bosons $\text{ODD}\,\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$

Group Phase Velocity
(with respect to E field)

Planck quanta

ν=128

EM wavefunction

$f = 64$

Photon frequency

Waveform probability distribution

$[\text{Amplitude}]^2$

$n/64 = n/[8^2]$

Photons $2\pi[[\varepsilon_0\mu_0].[m\Omega v^2]]$

64

Photon Frequency (f)

$E = hf$

Tetryonics 38.08 - EM wavefunctions

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Wave functions

All EM waves and Photons exhibit quantum levels of mass-energy momenta determined by their constituent bosons

Transverse EM Waveforms

Bosons

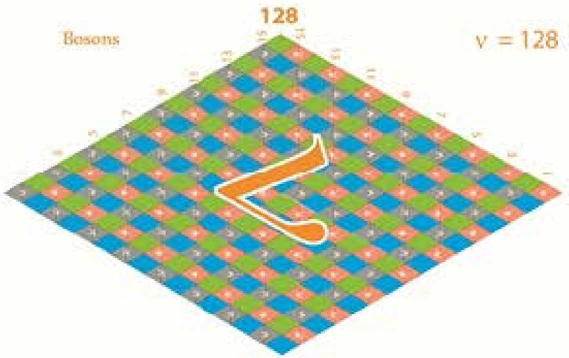
128
Bosons
ν = 128

$$E = h\nu$$

[Planck quanta are single-quanta Bosons]

All EM waves are comprised of Longitudinal Photons which in turn are made up of Transverse Bosons

[Photons are neutral dual-quanta Bosons]

$$E = hf$$

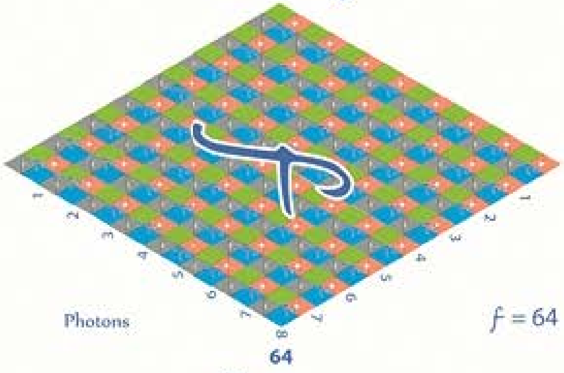
1
2
3
4
5
6
7
8
Photons
f = 64
64

Photons

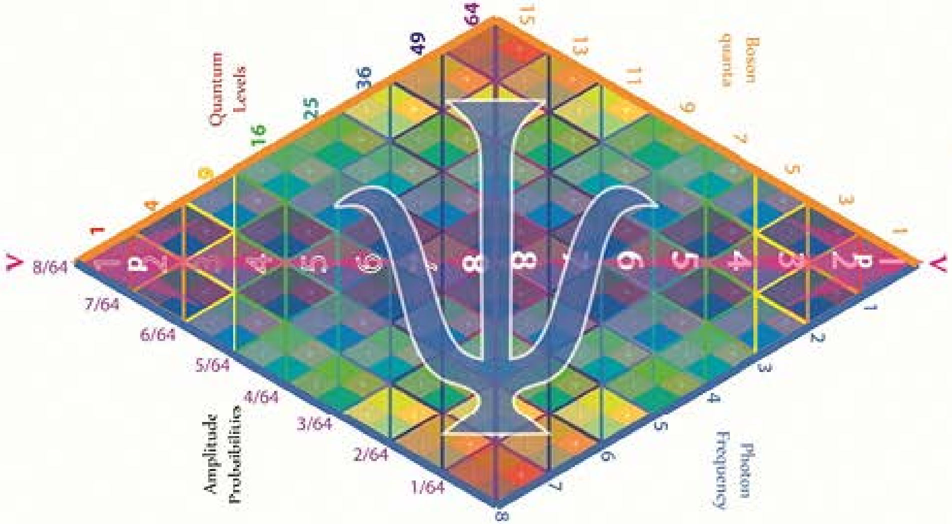
Quantum Levels
1
4
9
16
25
36
49
64
15
13
11
9
7
5
3
1
Boson quanta
v
8/64
7/64
6/64
5/64
4/64
3/64
2/64
1/64
Amplitude Probabilities
1
2
3
4
5
6
7
8
Photon Frequency
v

Longitudinal EM waveforms

All electromagnetic waves exhibit wave probabilities and amplitude functions determined by their constituent photons

Energy levels

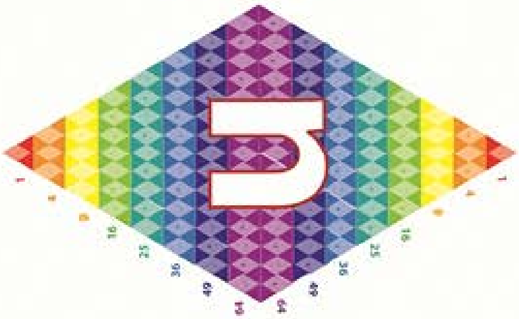
1
4
9
16
25
36
49
64
64
49
36
25
16
9
4
1

Squared numbers

Wave-particle duality holds that light and matter simultaneously exhibit properties of waves as well as particle-like properties (photons).

This concept is a consequence of the mathematical treament of mass-energy physics in quantum mechanics and a comprehensive explanation of this duality has been elusive to Physics since its discovery.

Any attmpt to develop an unified quantum theory must explain the root cause and processes behind Wave-Particle duality and must also explain:

Diffraction, Deflection and Reflection along with Bosons, Photons, EM radiation, energy quantisation and mass-Matter.

Probabilities

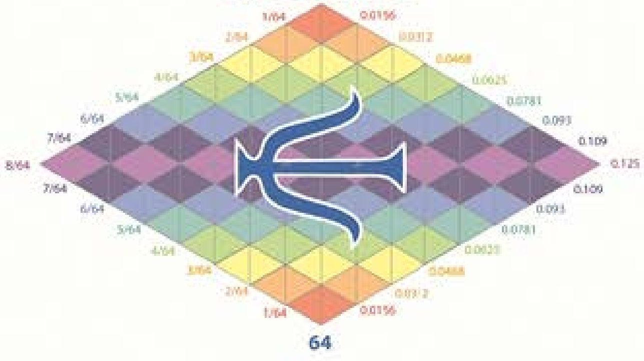
1/64
2/64
3/64
4/64
5/64
6/64
7/64
8/64
7/64
6/64
5/64
4/64
3/64
2/64
1/64
0.0156
0.0312
0.0468
0.0625
0.0781
0.093
0.109
0.125
0.109
0.093
0.0781
0.0625
0.0468
0.0312
0.0156
64

Waves

EM Wavefunctions

The wavefunction for a system contains all the information about the quantum state that a particle/system is in and gives a complete description of that part of the world at any one particular instant in time.

Transverse mass-energy distrbutions

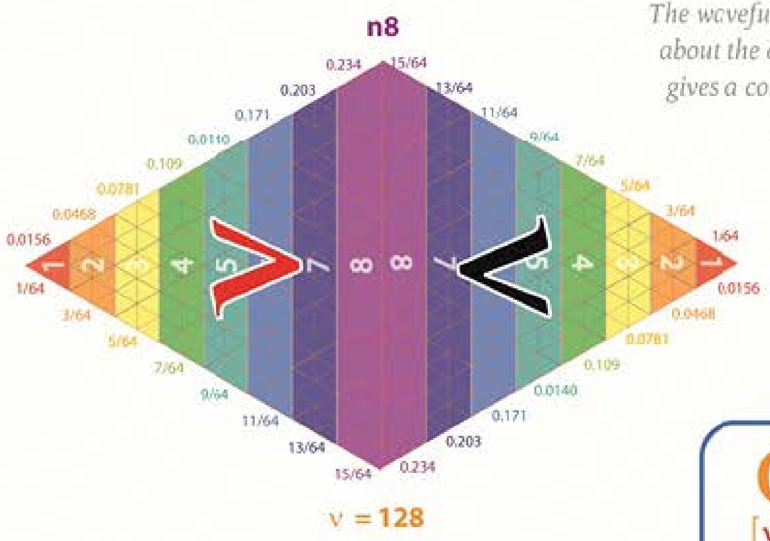
n8
0.234
0.203
0.171
0.0140
0.109
0.0781
0.0468
0.0156
15/64
13/64
11/64
9/64
7/64
5/64
3/64
1/64
1/64
3/64
5/64
7/64
9/64
11/64
13/64
15/64
0.0156
0.0468
0.0781
0.109
0.0140
0.171
0.203
0.234
1
2
3
4
5
7
8
8
7
5
4
3
2
1
v
v
v = 128

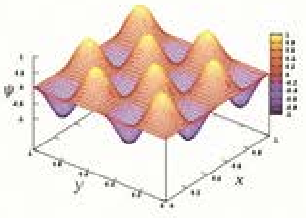

Longitudinal mass-energy distributions

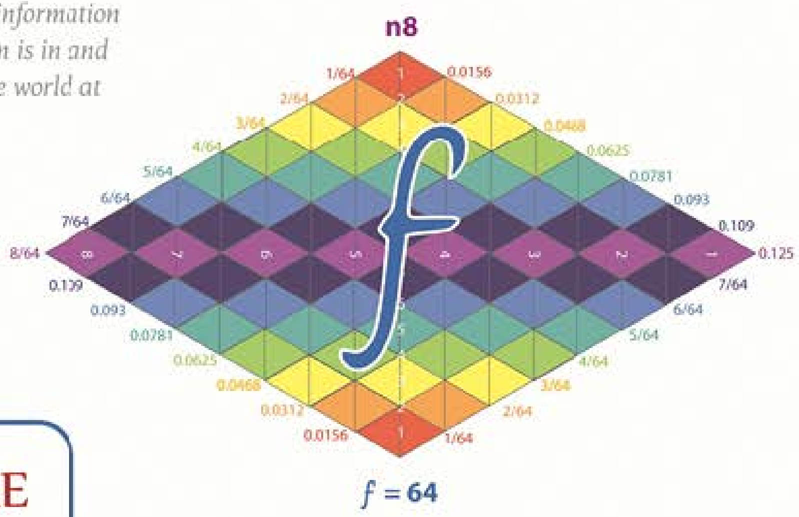
n8
1/64
2/64
3/64
4/64
5/64
6/64
7/64
8/64
0.0156
0.0312
0.0468
0.0625
0.0781
0.093
0.109
0.125
0.109
0.093
0.0781
0.0625
0.0468
0.0312
0.0156
7/64
6/64
5/64
4/64
3/64
2/64
1/64
f
f = 64

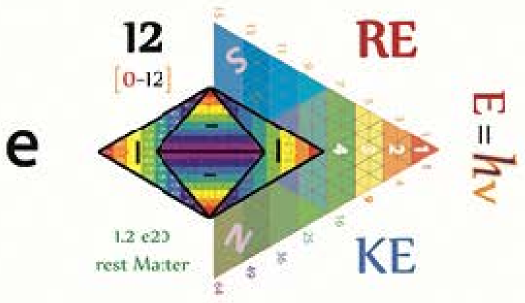
12
[0-12]
RE
e
E = hv
1.2 e20
rest Matter
KE

Quantum Energy Levels

The wavefunction itself is often said to be un-observable. In fact, it can modelled as it is a reflection of the quantas making up the quantum state of any particle and is complex-valued.

As the system evlves over time, the wavefunction also changes, so it can be written as a function of time Ψ(t).

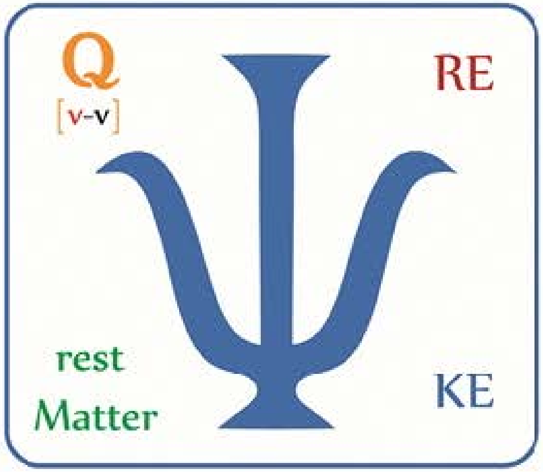
Q
[v-v]
RE
Ψ
rest
Matter
KE

The wavefunction of an EM wave (KEM) geometry is distinct from that of rest mass-Matter toplogies due to the number of Planck quanta contained in it but both can be modelled using Tetryonic geometry

$$\int_{-\infty}^{\infty} |\Psi|^2 \mathrm{d}x = 1.$$

The absolute square of the function must be normalizable

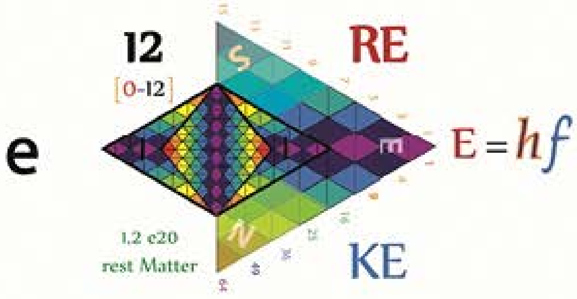
12
[0-12]
RE
e
E = hf
1.2 e20
rest Matter
KE

Wave-Particle Probabilities

The absolute square of the wavefunction is a probability density (the area of highest probability for a measurement to take place.

For example, if the wavefunction is expressed in real space and our system is a particle, the absolute square gives a probability density for the position of the system. Integrating this probability density between some bounds will give the probability that the particle will be found in that region when its position is measured

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Wave~Particle energies

Equilateral energy is the foundational geometry
of Kinetic EM Waveforms [WAVES]
and standing wave Matter [PARTICLES]

**All Matter in motion exhibits
a Wave-Particle duality**

Everything is made up of
***charged mass-energy
quanta***

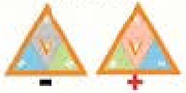

ZPFs combine in ODD
numbers to form
Bosons

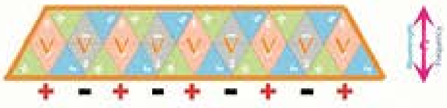

Bosons combine to form
Quantum Levels

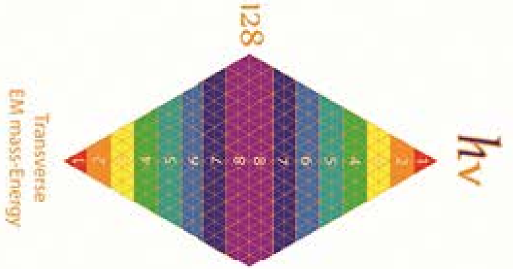
128
Transverse
EM mass-Energy
hv

Wavelength
v
Frequency

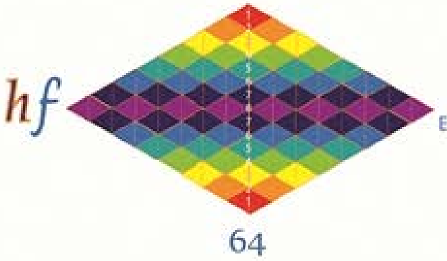

Longitudinal
EM mass-Energy

The quantum Planck quanta tesslation
of Matter can be accurately modelled with
Wave Probability mechanics

Transverse

Bosons

$\text{ODD}\,\pi\,[[\varepsilon_0\mu_0].[m\Omega v^2]]$

$$E = h\nu$$

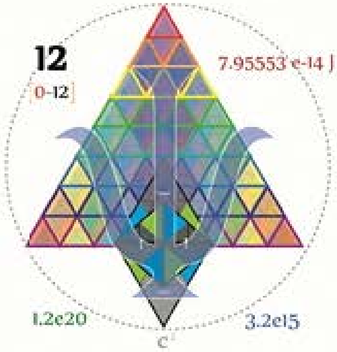
12
[0-12]
7.95553 e-14 J
1.2e20
3.2e15
c²

$$E = hf$$

Photons

$\text{EVEN}\,\pi\,[[\varepsilon_0\mu_0].[m\Omega v^2]]$

Longitudinal

A n8 Electron is a massive particle
which has a Kinetic EM energy field
[6.4e15 planck quanta]

*2D EM field geometries
can combine to form
3D Tetryonic Matter topologies*

ν

Number of ZPFs
per Boson

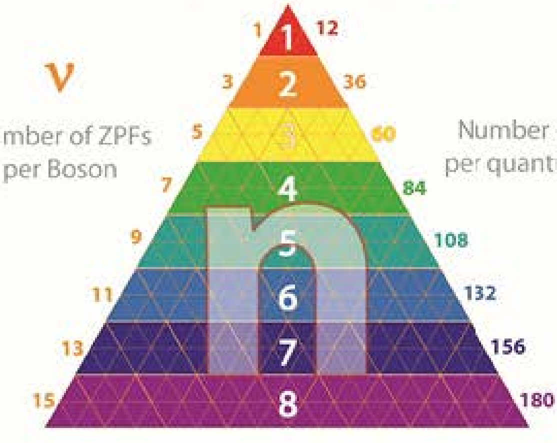
1
2
3
4
5
6
7
8
1
3
5
7
9
11
13
15
12
36
60
84
108
132
156
180
n

n

Number of ZPFs
per quantum level

$|8|^2 \times 12$
[768]

64

Quantum levels are a transverse measurements of energy

**Equivalently, all Matter & EM waves can be viewed either in terms of
their transverse boson or longitudinal photon content and/
or their associated mass-energy momenta geometries**

Square of
Wave function
is
Normalizable

[1]

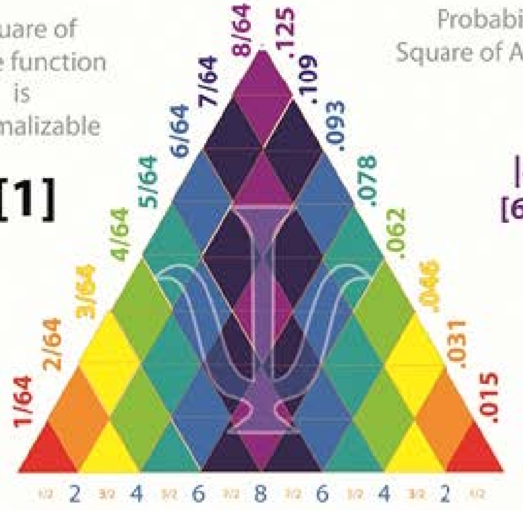
1/64
2/64
3/64
4/64
5/64
6/64
7/64
8/64
.125
.109
.093
.078
.062
.046
.031
.015
1/2
2
3/2
4
5/2
6
7/2
8
7/2
6
5/2
4
3/2
2
1/2

Probability is
Square of Amplitude

$|8|^2$
[64]

32

Wave functions are a linear measurement of photonic energy

Wave-particle Probabilities

All Particles in motion exhibit a Wave-Particle duality
due to the 2D waveform geometry of its KEM wave
and the lorentz velcoity invariant
3D standing wave geometry of its Matter

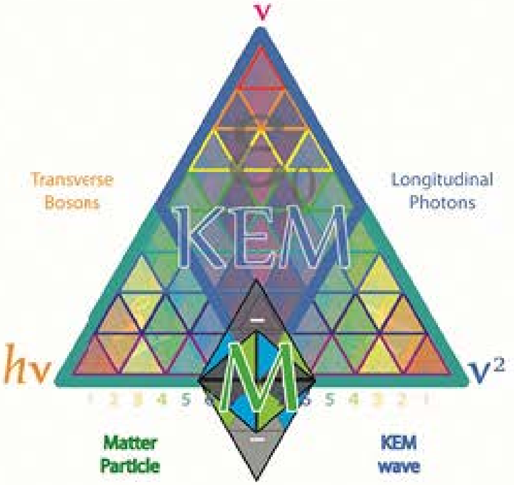
v
Transverse Bosons
Longitudinal Photons
KEM
hv
v^2
M
1 2 3 4 5 6 5 4 3 2 1
Matter Particle
KEM wave

Equilateral energy tesselation
provides the basis for the probabilistic
statisical mechanics and math for
all of Quantum Mechanics

12
[0-12]
RE
e-
Particle
Wave
v
M
KEM

Schrodinger Wavefunction
The Wavefunction of a Particle
equates to its Amplitude

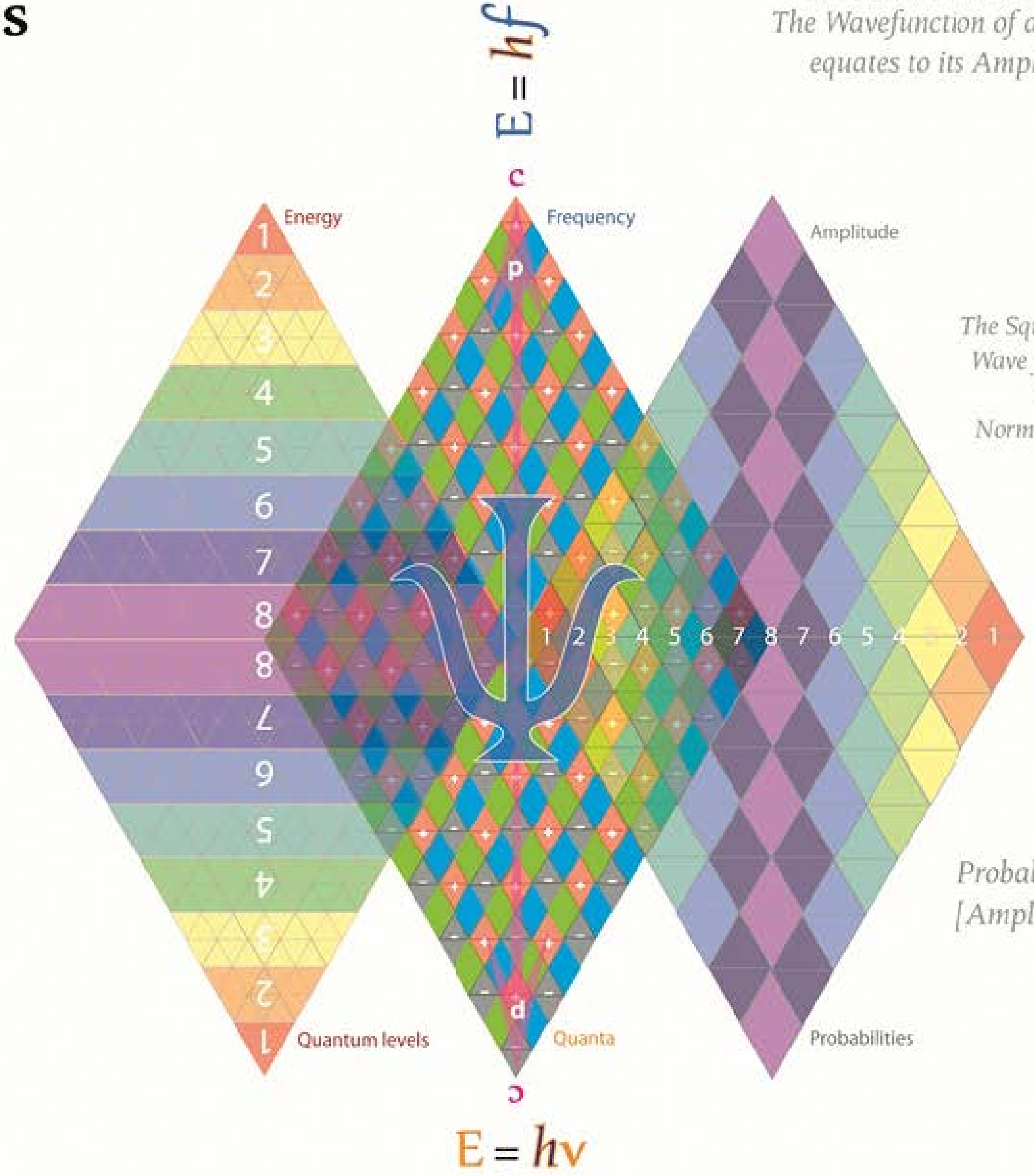
E = hf
c
Energy
Frequency
Amplitude
1 2 3 4 5 6 7 8 8 7 6 5 4 3 2 1
p
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
d
Quantum levels
Quanta
Probabilities
c
E = hv

The Square of a
Wave function
is
Normalizable

Probability =
[Amplitude]^2

Born Probability Rule
The Probability of finding a Particle
is the Square of its Amplitude

Tetryonics 38.12 - Wave~Particle Probabilities

White Light mass-energy momenta waveforms

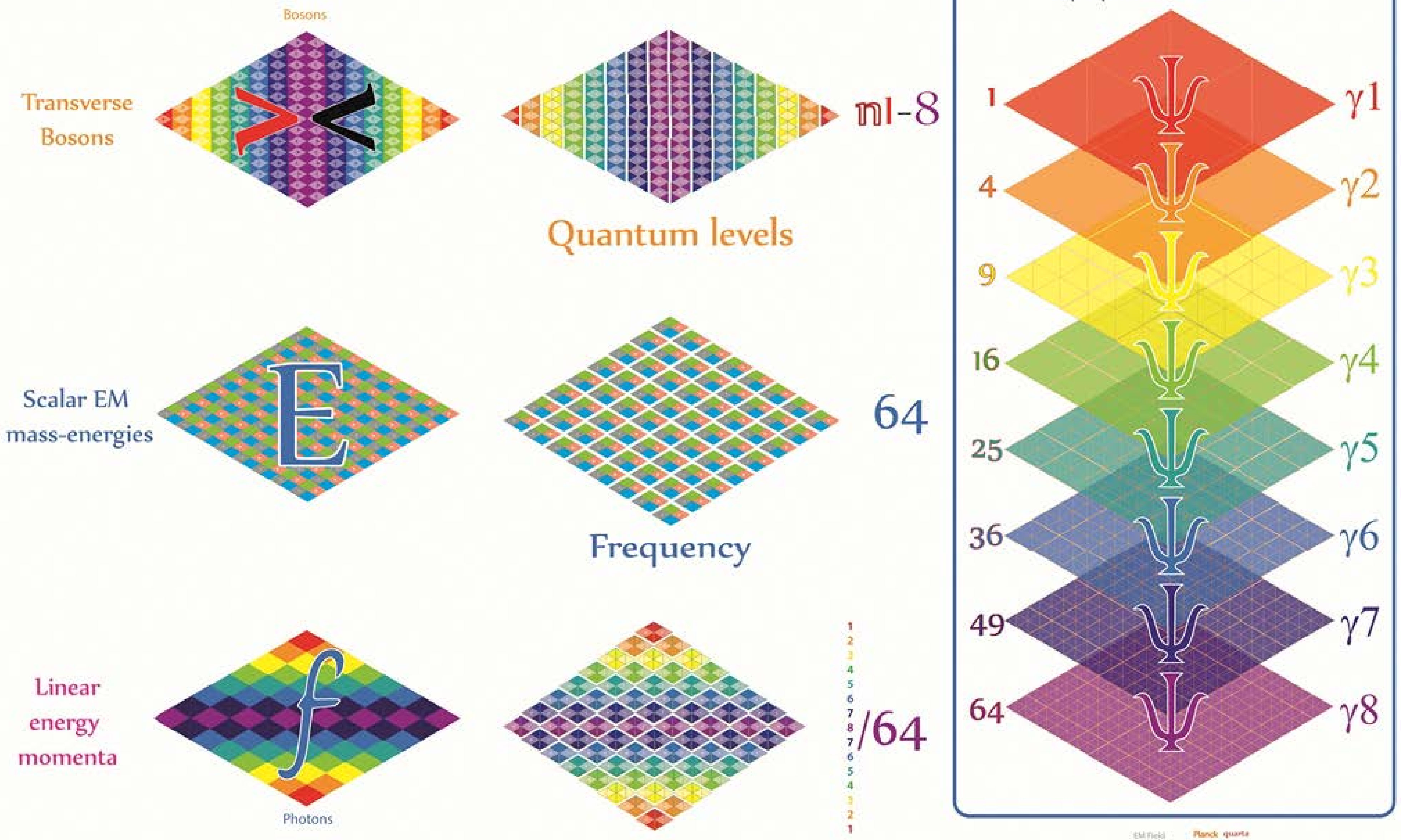

Bosons
Transverse Bosons
ml-8
Quantum levels
Scalar EM mass-energies
E
64
Frequency
Linear energy momenta
f
Photons
1
2
3
4
5
6
7
8
7
6
5
4
3
2
1
/64
Amplitudes
White light is comprised of superpositioned EM waves
1
4
9
16
25
36
49
64
Ψ
γ1
γ2
γ3
γ4
γ5
γ6
γ7
γ8

EM waves EM Field ElectroMagnetic Planck quanta mass velocity

$$\text{EVEN}\,\pi\,[[\varepsilon_0\mu_0].[m\Omega v^2]]$$

Tetryonics 38.13 - White Light waveform geometries

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Bosons and Photons

EM waves are comprised of longitudinal [E=hf] Photons which in turn can also be measured as transverse [E=nhv] Bosons

Electro-Magnetic Fields

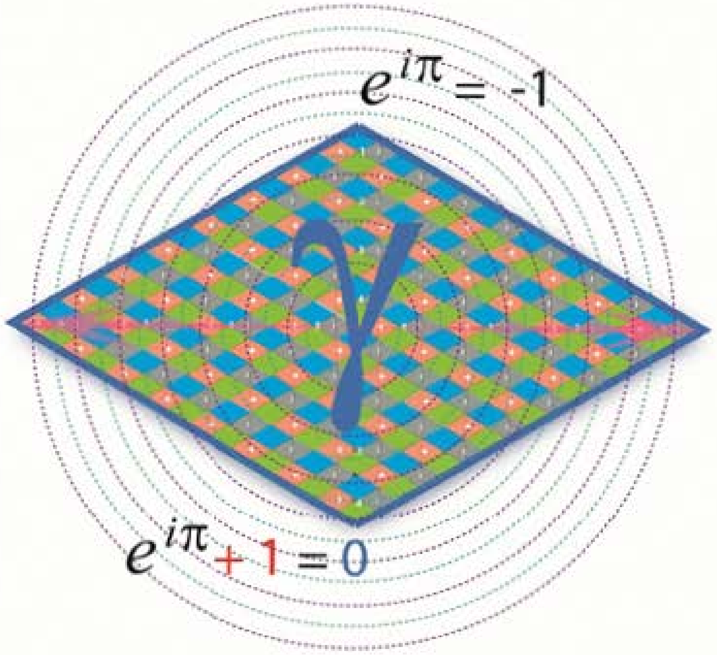

$$e^{i\pi} = -1$$

$$e^{i\pi} + 1 = 0$$

As described by Lorentz co-ordinate transforms the neutral quantum coin [quoin] geometry of all photons and EM waves have mirror E-field charges on each of their opposing fascia

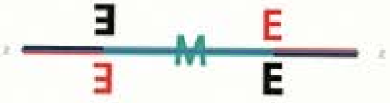

2D planar mass-energy momenta waveforms

EM Field Planck quanta

$$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Photons

ElectroMagnetic mass velocity

Photons and EM waves have dual c^2 space-time geometries
(8.987551787 e16 m/s)

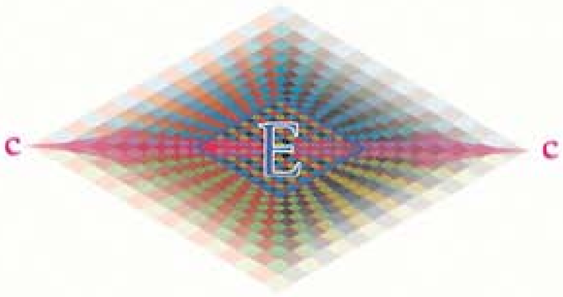

Photons and EM waves propagate outwards from their source at 'c'
(299,792,458 m/s)

EM Field Planck quanta

$$\text{EVEN}\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

EM waves

ElectroMagnetic mass velocity

EM waves are detected as alternating radial electric E-wave radiation fields

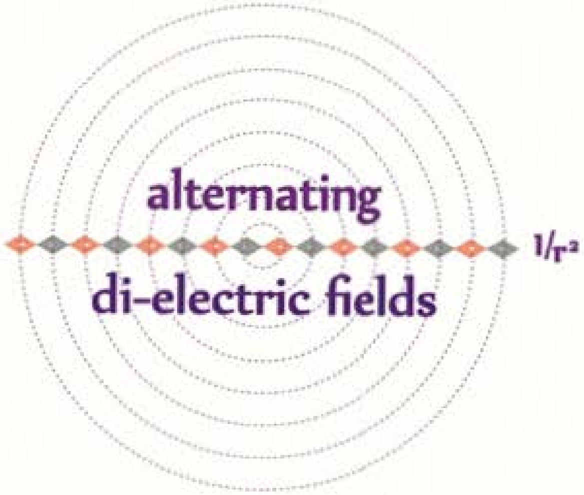

EM wave radiation

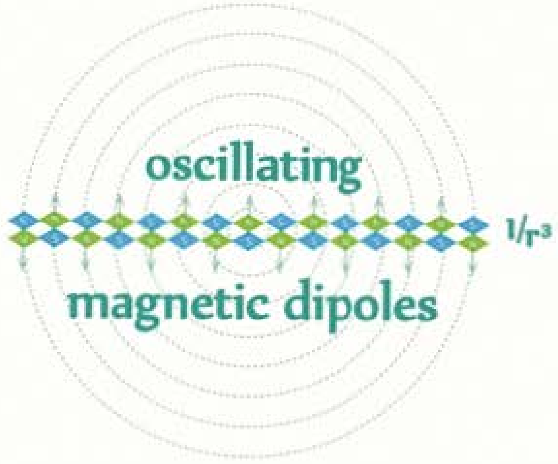

The Magnetic vector of EM energy momenta propagate orthagonally to their E-fields

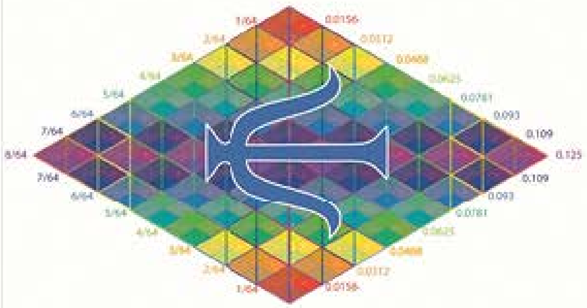
1/64
2/64
3/64
4/64
5/64
6/64
7/64
8/64
0.0156
0.0312
0.0468
0.0625
0.0781
0.093
0.109
0.125

EM wave patterns

Polarised Photons and EM waves produce linear interference patterns

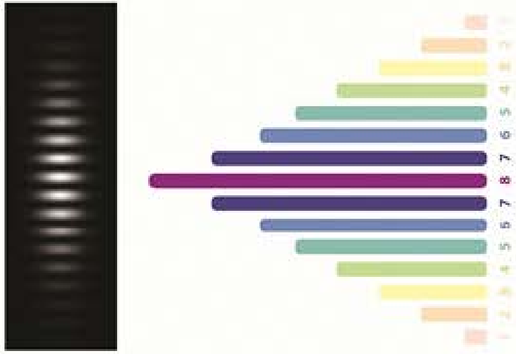
1
2
3
4
5
6
7
8
7
6
5
4
3
2
1

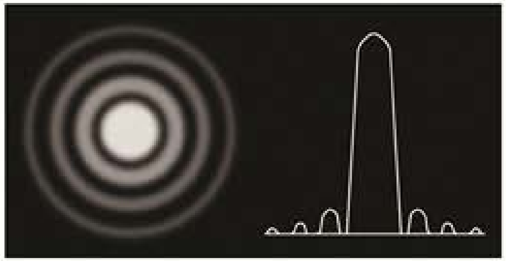

Diffraction occurs whenever propagating waves appear to bend around small obstacles in their path and spread out as smaller waves waves past any openings, its effects are generally most pronounced for waves whose wavelength is roughly similar to the dimensions of the diffracting objects.

If the obstructing object provides multiple, closely spaced openings, a complex pattern of varying intensity can result.

This is due to the superposition, or interference, of different parts of a wave that travels to the observer by different paths

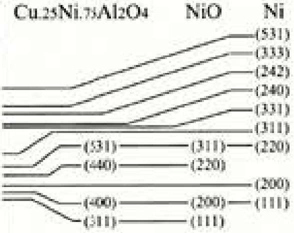
Cu.25Ni.75Al2O4
NiO
Ni
(531)
(333)
(242)
(240)
(331)
(311)
(531)
(311)
(220)
(440)
(220)
(200)
(400)
(200)
(111)
(311)
(111)

atomic diffraction spectroscopy of matter plays an important role in the chemical analysis of elements and compounds

Diffraction occurs with all waves, including sound waves, water waves, as well as with electromagnetic waves such as visible light, X-rays and radio waves.

Un-Polarised Photons and EM waves produce circular diffraction patterns

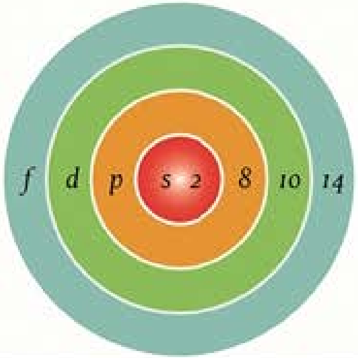
f
d
p
s
2
8
10
14

Richard Feynman once commented that:
"No-one has ever been able to define the difference between interference and diffraction satisfactorily. It is just a question of usage, and there is no specific, important physical difference between them."

Light waves

In order to establish his wave theory of light Young had to overcome the century-old view, expressed by Sir Isaac Newton' in his treatise "Optics", that light is a particle of colour.

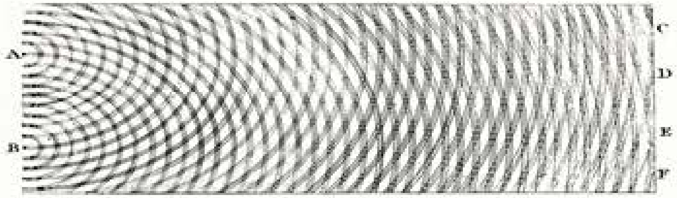

Thomas Young studied the interference of light waves by shining light through a screen with two slits equally separated, where the light emerging from the two slits would spread out and eventually superposition [overlap] each other to produce a distinct interference pattern

Thomas Young

(13 June 1773 – 10 May 1829)

$$E = mv^2$$

"The term energy may be applied, with great propriety, to the product of mass or weight of a body, into the square of the number expressing its velocity.

Thus, if the weight of one ounce moves with a velocity of a foot in a second, we call its energy 1; if a second body of two ounces has a velocity of three feet in a second, its energy will be twice the square of three, or 18."

$$KE = \frac{1}{2}Mv^2$$

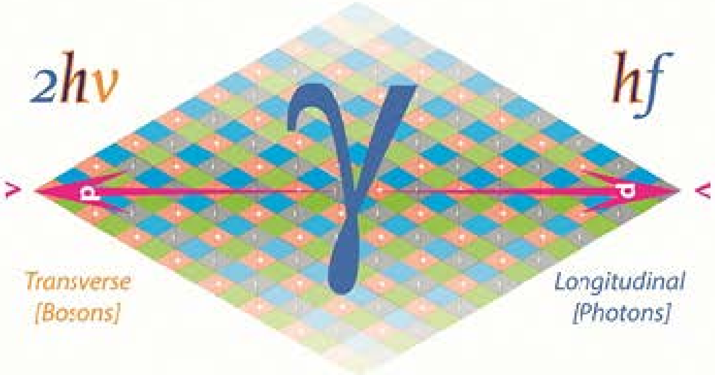

All EM waves have energy momenta geometries whose physical properties can be modeled with statisical probabilities due to their equilateral wavefunctions

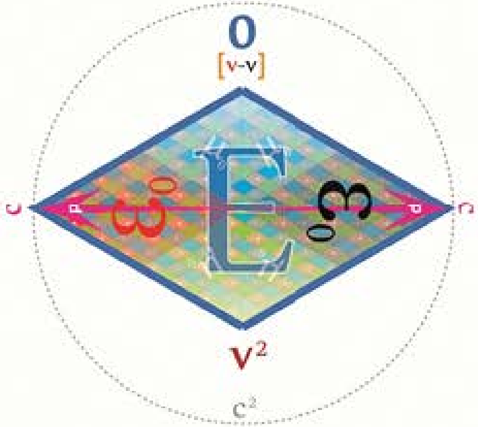

$$E_\gamma = 2mv^2$$

Photons are radiative Kinetic EM mass-energies

$$p^2 = KEM = Mv^2$$

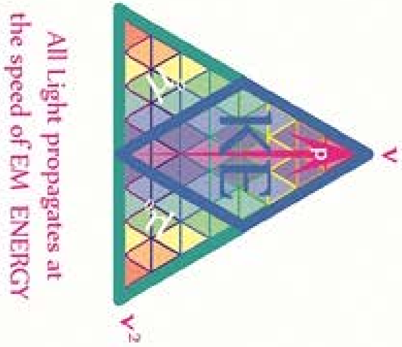

Tetryonics reveals the true geometry of Light

and dispels the misconceptions surrounding its physical properties of wave-length, energy momenta, frequency and associated wave-function

Photon-EM Wave Superpositioning

In physics, the Superposition principle, also known as superposition property, states that, for all linear systems, the net response at a given place and time caused by two or more stimuli is the sum of the responses which would have been caused by each stimulus individually.

$$F(\psi_1+\psi_2)= F(\psi_1) + F(\psi_2)$$

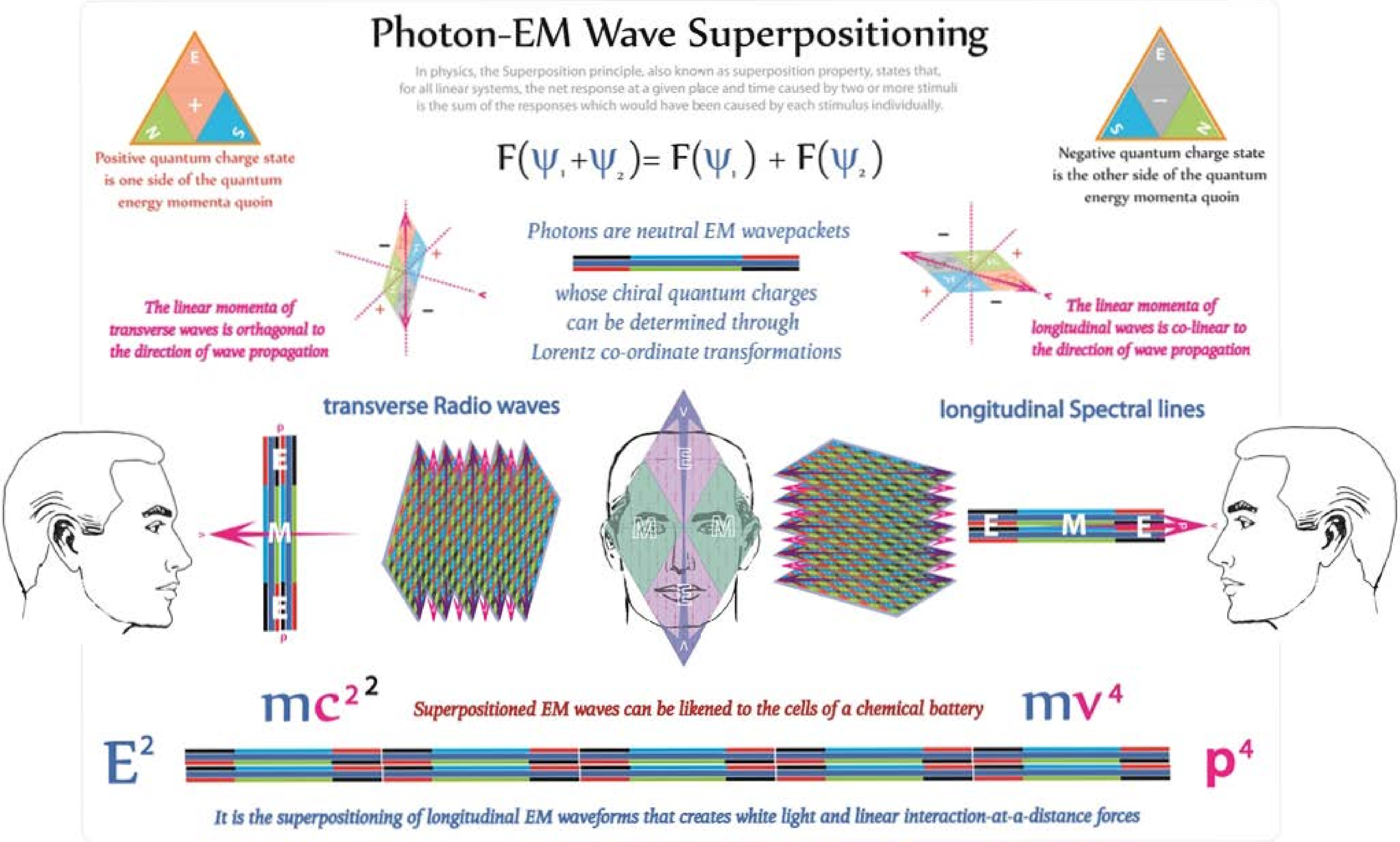

Positive quantum charge state is one side of the quantum energy momenta quoin

Negative quantum charge state is the other side of the quantum energy momenta quoin

Photons are neutral EM wavepackets

whose chiral quantum charges can be determined through Lorentz co-ordinate transformations

The linear momenta of transverse waves is orthagonal to the direction of wave propagation

The linear momenta of longitudinal waves is co-linear to the direction of wave propagation

transverse Radio waves

longitudinal Spectral lines

$mc^{2^{2}}$ **Superpositioned EM waves can be likened to the cells of a chemical battery** mv^4

E^2 p^4

It is the superpositioning of longitudinal EM waveforms that creates white light and linear interaction-at-a-distance forces

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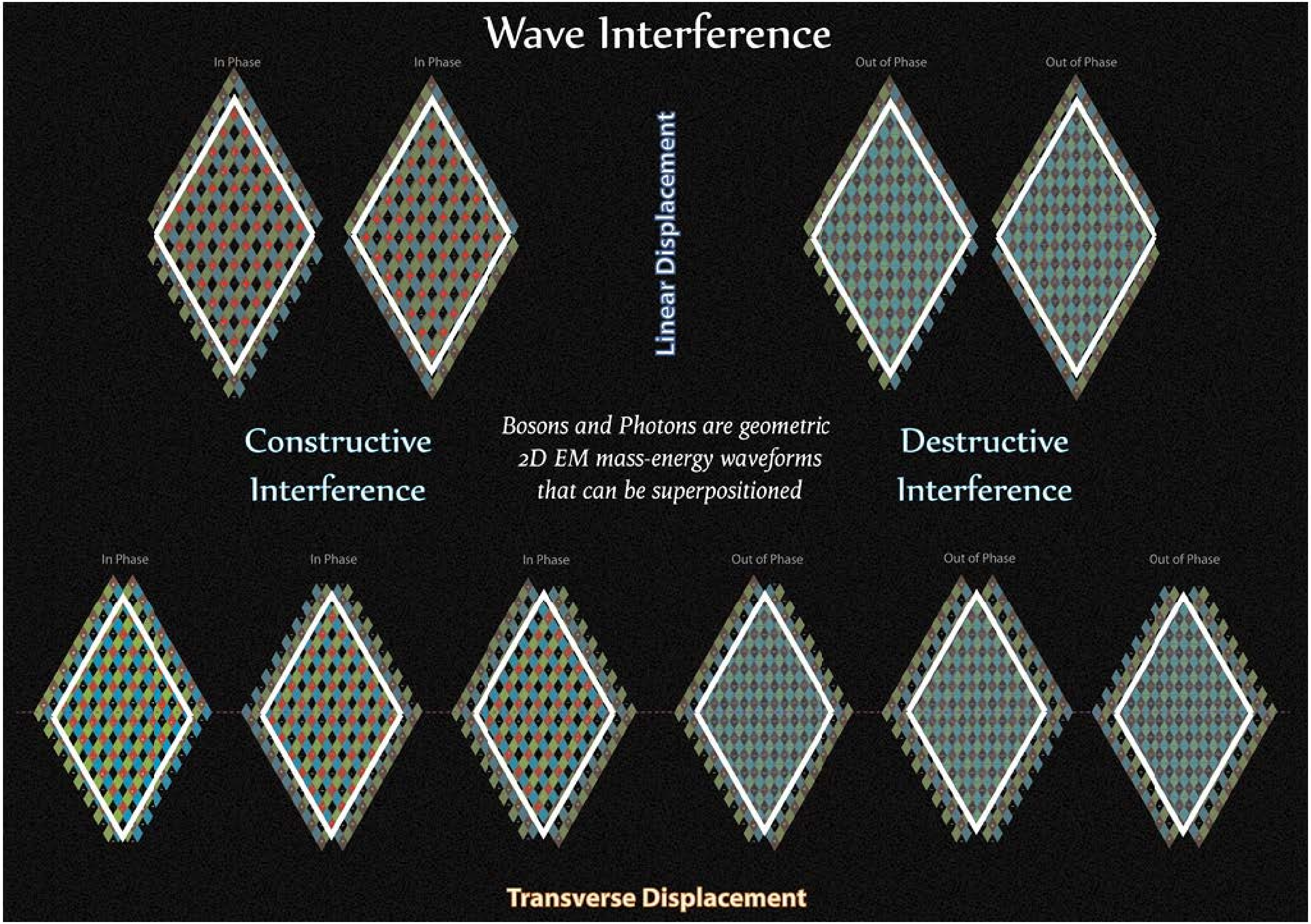

Wave Interference

Constructive Interference

Bosons and Photons are geometric 2D EM mass-energy waveforms that can be superpositioned

Destructive Interference

In Phase
In Phase
Linear Displacement
Out of Phase
Out of Phase
In Phase
In Phase
In Phase
Out of Phase
Out of Phase
Out of Phase
Transverse Displacement

Tetryonics 39.05 - Wave Interference - EM waves

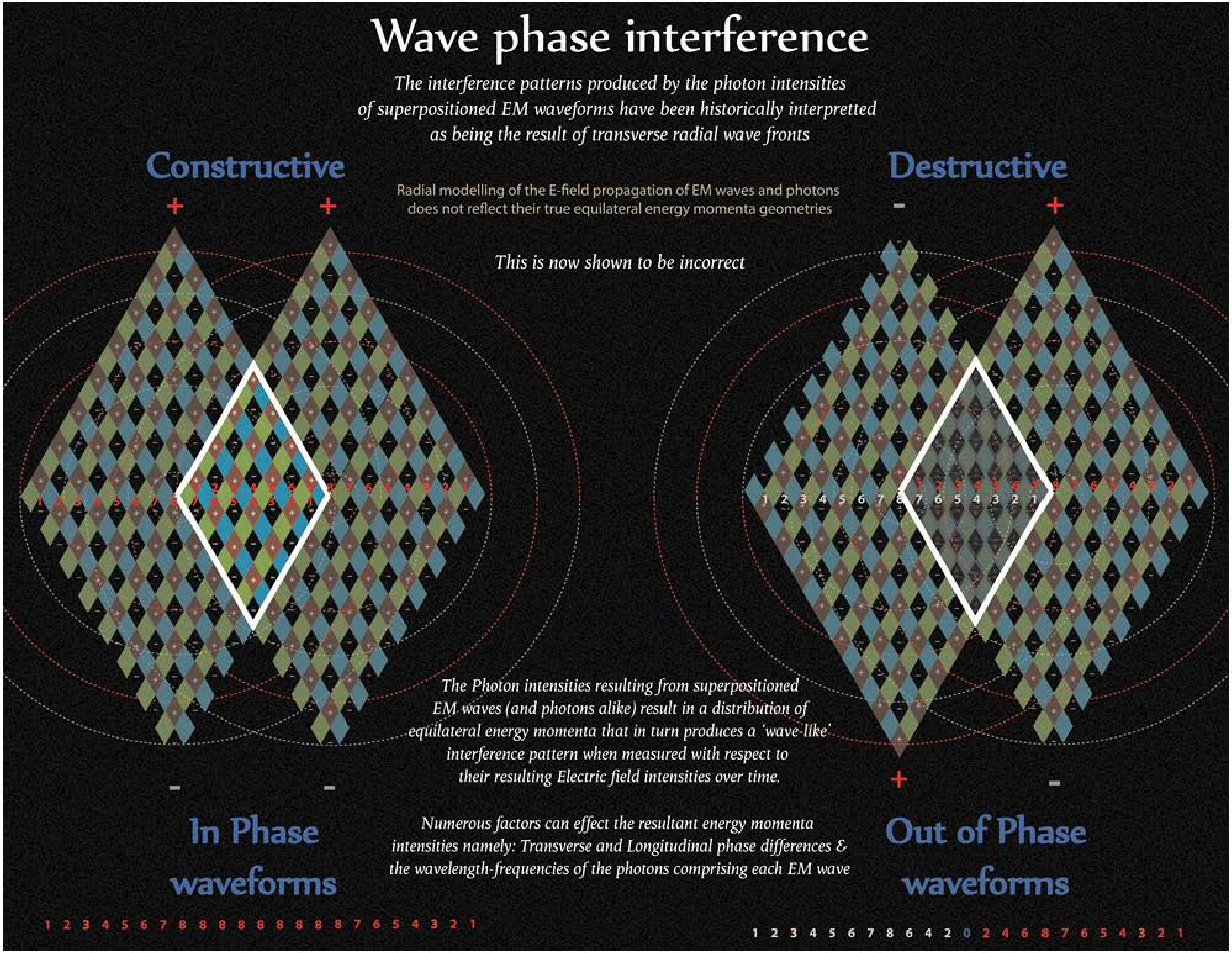

Wave phase interference

The interference patterns produced by the photon intensities of superpositioned EM waveforms have been historically interpretted as being the result of transverse radial wave fronts

Radial modelling of the E-field propagation of EM waves and photons does not reflect their true equilateral energy momenta geometries

This is now shown to be incorrect

Constructive

Destructive

The Photon intensities resulting from superpositioned EM waves (and photons alike) result in a distribution of equilateral energy momenta that in turn produces a 'wave-like' interference pattern when measured with respect to their resulting Electric field intensities over time.

Numerous factors can effect the resultant energy momenta intensities namely: Transverse and Longitudinal phase differences & the wavelength-frequencies of the photons comprising each EM wave

In Phase waveforms

Out of Phase waveforms

Tetryonics 39.06 - Wave phase interference

Matter in motion

Transverse EM mass-energies

Longitudinal EM mass-energies

Historically modeled through relativistic stress energy tensors all Matter in motion is possessive of distinct energy waveforms:

a standing wave mass-energy geometry [Matter particle] &

a divergent kinetic mass-energy field [KEM wave]

$E = hv$

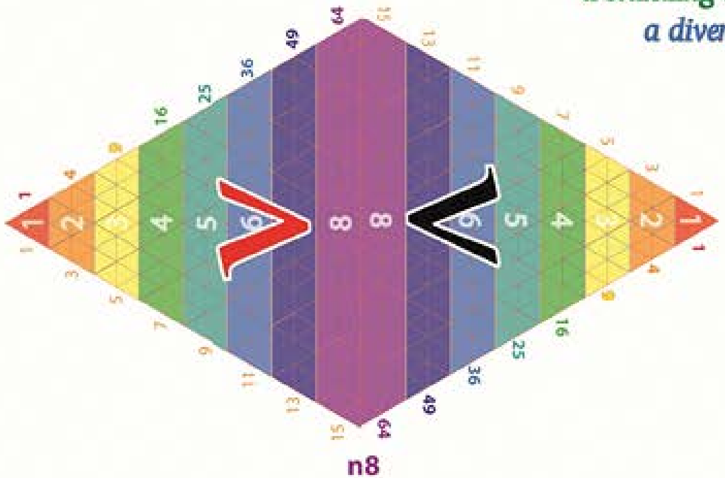

1
4
9
16
25
36
49
64
15
13
11
9
7
5
3
1
2
3
4
5
6
8
8
6
5
4
3
2
1
v
v
n8

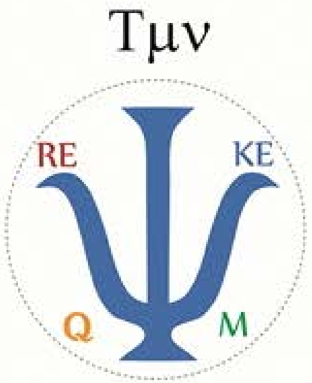

$E = hf$

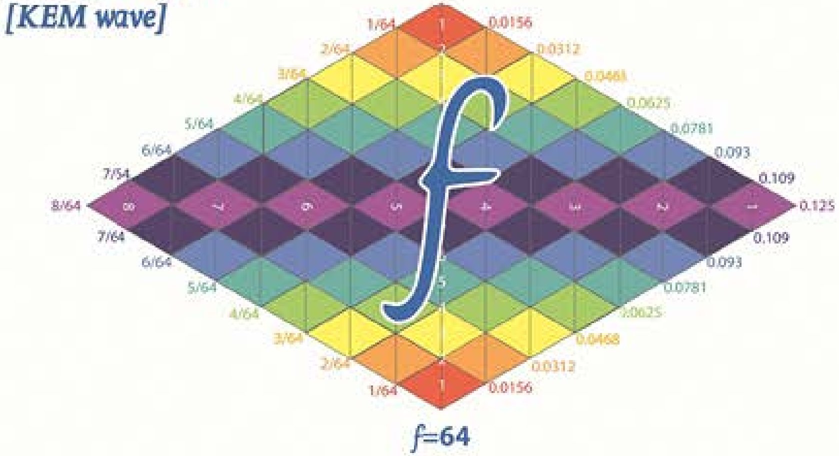

1/64
2/64
3/64
4/64
5/64
6/64
7/64
8/64
0.0156
0.0312
0.0468
0.0625
0.0781
0.093
0.109
0.125
f
f=64

Negative charges in motion

EM induction and forces are effected by neutral bi-directional KEM mass-energy fields with interactive energy momenta

Positive charges in motion

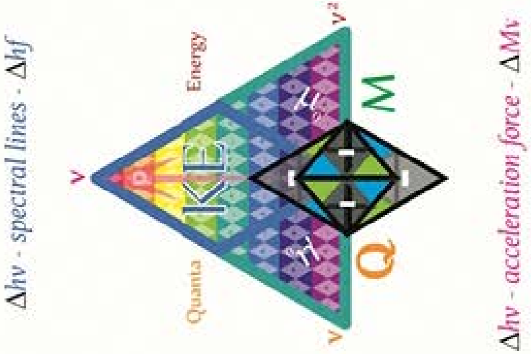

Δhv - spectral lines - Δhf
Energy
Quanta
v
v²
v
KE
M
Q
Δhv - acceleration force - ΔMv

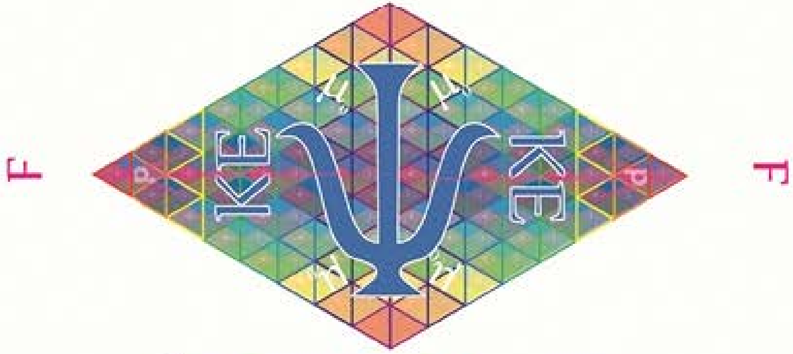

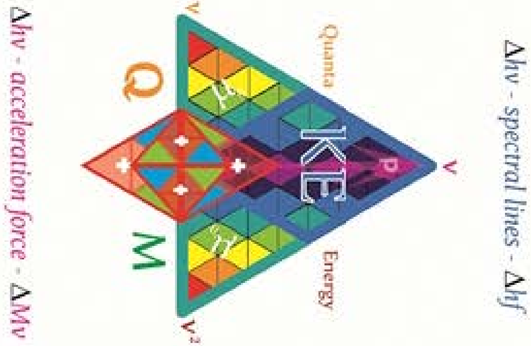

Δhv - acceleration force - ΔMv
Q
M
Quanta
Energy
KE
v
v²
v
Δhv - spectral lines - Δhf

unidrectional negative KEM fields with interactive energy momenta

electromagnetic waves

[neutral bosons and/or photons]

unidirectional positive KEM fields with interactive energy momenta

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All Matter in motion [or not]
has both an intrinsic Matter-wave function
and an extrinsic KEM mass-energy wave function

Transverse boson wavefunction

EM Field Planck quanta

$$\text{ODD}\,\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Bosons

ElectroMagnetic mass velocity

$$E = n.h\nu$$

128

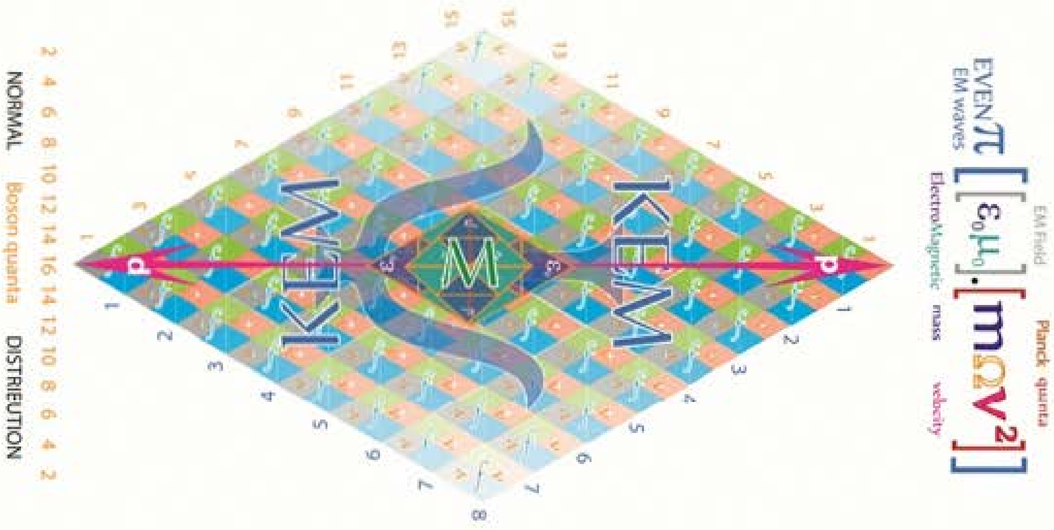
NORMAL
Boson quanta
DISTRIBUTION
2 4 6 8 10 12 14 16 14 12 10 8 6 4 2
KEM
KEM
M
p
p
1 2 3 4 5 6 7 8
EVEN π
EM waves
EM Field
Planck quanta
$\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$
ElectroMagnetic
mass
velocity

64

EM Field Planck quanta

$$2\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Photons

ElectroMagnetic mass velocity

$$E = hf$$

Longitudinal photon wavefunction

Photon Intensity

Photon Intensity is a result of the geometry of EM waves
[which in turn is directly proprtional to the velocity of the mass-Matter]
and can be measured in a number of vaying ways related to
the mass-energy momenta of the EM wave

Wavenumbers, frequency or wavelength
Transverse EM masses [BOSONS]
Longitudinal EM masses [PHOTONS]
Wavefunction probabilities [WAVE-FUNCTIONS]

The wave~particle nature of mass-Matter in motion
has been the subject of much debate since Lucretius in 55BC with the
debate intensitying with Newton's and Young's differing views and the
development of Planck-Einstein quantum mechanics of the photo-electric effect

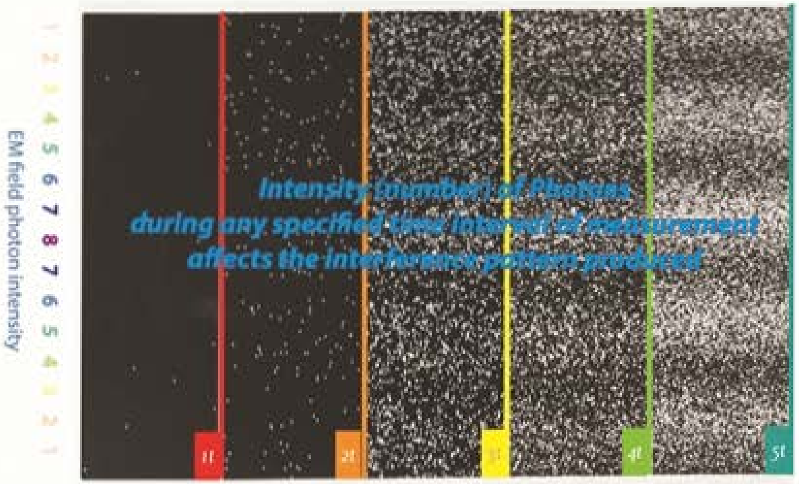

Intensity [number] of Photons
during any specified time interval of measurement
affects the interference pattern produced

The measurement of Photons with the use
of Photo-multipliers and Charge coupled Devices
results in the measurement of the E field properties
of EM waves (producing the long confusing wave-particle
results obtained by diffraction gratings)

In turn these results have been historically misinterpreted
as a waveform property that cannot be attributed to
the particle properties of a Photon.

Tetryonic geometry clears this matter up once and for all.

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Interference Patterns

ε_0

When EM waves pass through
the slits they are detected via their E-fields
as photons of varying strength energy momenta
producing the impression of a interference pattern

μ_0

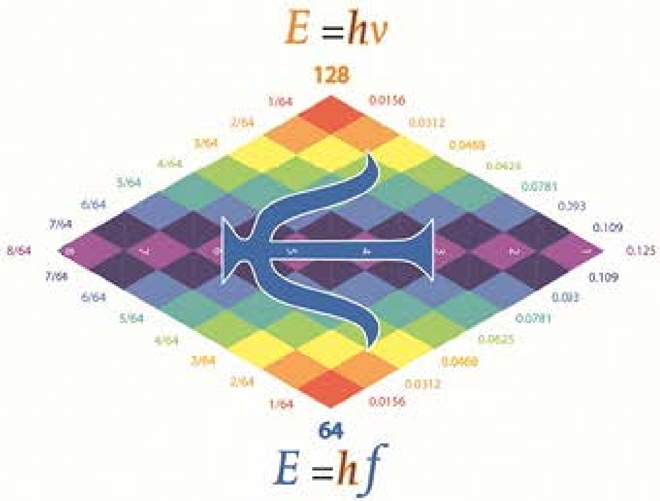

E =hv
128
1/64
2/64
3/64
4/64
5/64
6/64
7/64
8/64
7/64
6/64
5/64
4/64
3/64
2/64
1/64
0.0156
0.0312
0.0468
0.0625
0.0781
0.093
0.109
0.125
0.109
0.093
0.0781
0.0625
0.0468
0.0312
0.0156
64
E =hf

Every EM wave is comprised of
identical, specific wavelength photons
which are arranged in a Normal distribution
resulting from the electromagnetic Wavefunction
with a peak value equal to the wave's amplitude

[the square root of the EM wave's
Wavefunction/Probability amplitude]

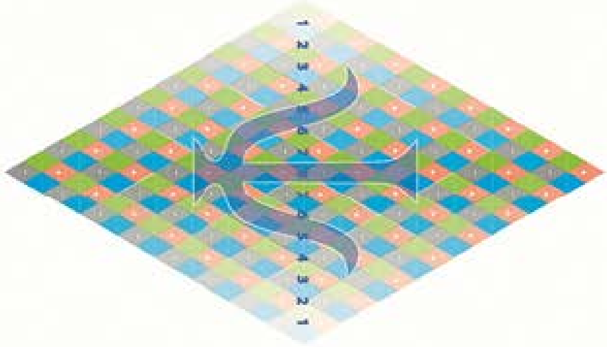

Photons impact screens and
photo-detectors with intensities
that are determined by their
energy momenta distributions

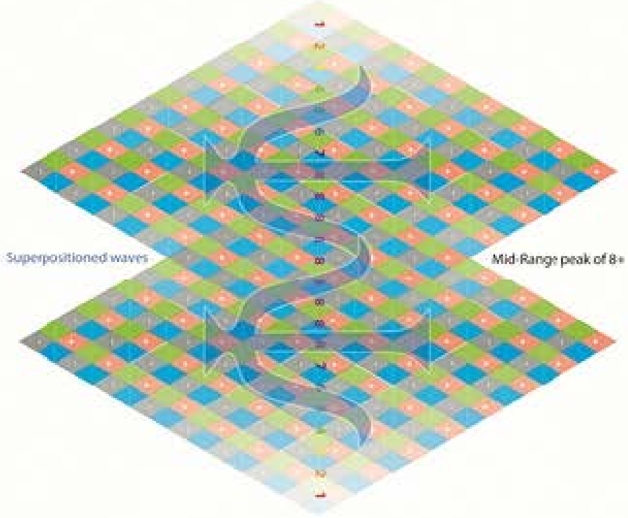

Superpositioned waves
Mid-Range peak of 8+

The resultant amplitudes are a direct result of
the Phase of the Superpositioned photons within EM waves

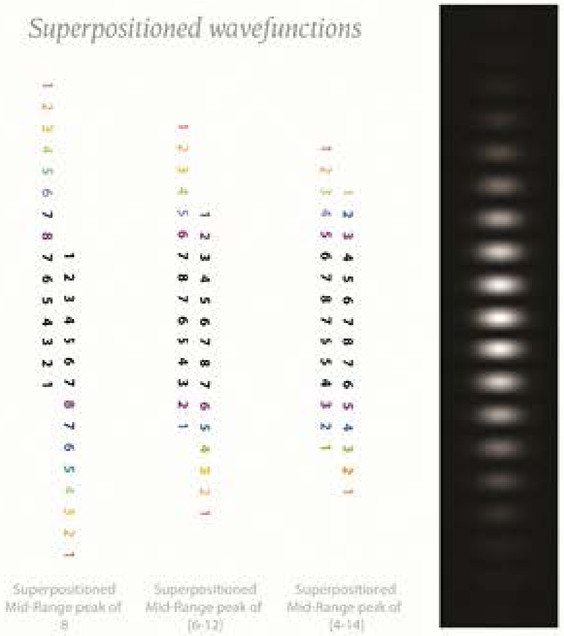

Superpositioned wavefunctions
Superpositioned Mid-Range peak of 8
Superpositioned Mid-Range peak of [6-12]
Superpositioned Mid-Range peak of [4-14]

ALL EM mass-ENERGY Matter geometries
being comprised of energy-momenta quanta
are capable of producing interference patterns

The amplitudes of the detected photons in the resultant interference patterns
are determined by their constructive/destructive superpositioning in each wave
explaining the interference patterns currently accounted for by Young's wave theory

Single slit experiment

If light consisted strictly of ordinary or classical particles, and these particles were fired in a straight line through a slit and allowed to strike a screen on the other side, we would expect to see a pattern corresponding to the size and shape of the slit. However, when this "single-slit experiment" is actually performed, the pattern on the screen is a diffraction pattern with a fairly narrow central band with ever diminishing bands parallel to it on either side

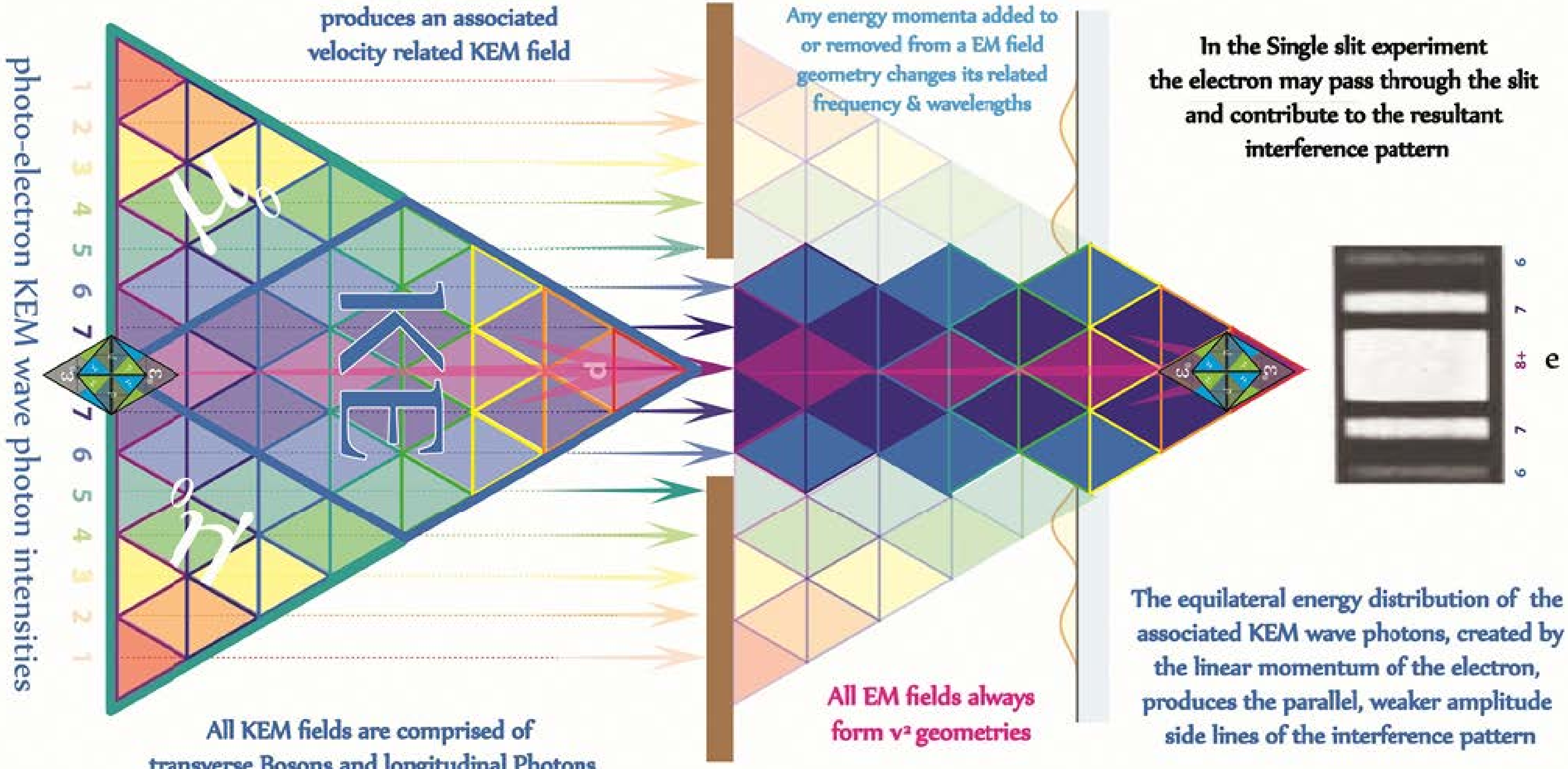

All matter in motion produces an associated velocity related KEM field

Any energy momenta added to or removed from a EM field geometry changes its related frequency & wavelengths

In the Single slit experiment the electron may pass through the slit and contribute to the resultant interference pattern

The equilateral energy distribution of the associated KEM wave photons, created by the linear momentum of the electron, produces the parallel, weaker amplitude side lines of the interference pattern

All KEM fields are comprised of transverse Bosons and longitudinal Photons producing its associated wavefunctions and properties

Δhv - acceleration force - ΔMv

All EM fields always form v² geometries

any interaction between the KEM field and the barrier will affect the energy content of the KEM field and result in velocity changes to the electron

Δhv - spectral lines - Δhf

Tetryonics 39.10 - Single slit experiment

Double slit experiments

The double-slit experiment, sometimes called Young's experiment, is a demonstration that matter and energy can display characteristics of both waves and particles, and demonstrates the fundamentally probabilistic nature of quantum mechanical phenomena and Establishes the quantum interference principle known as wave–particle duality.

Matter particles are stopped by the barrier but the [K]EM wave passes through both slits and is diffracted by them producing weaker EM waves that then superposition with each other to produce interference patterns

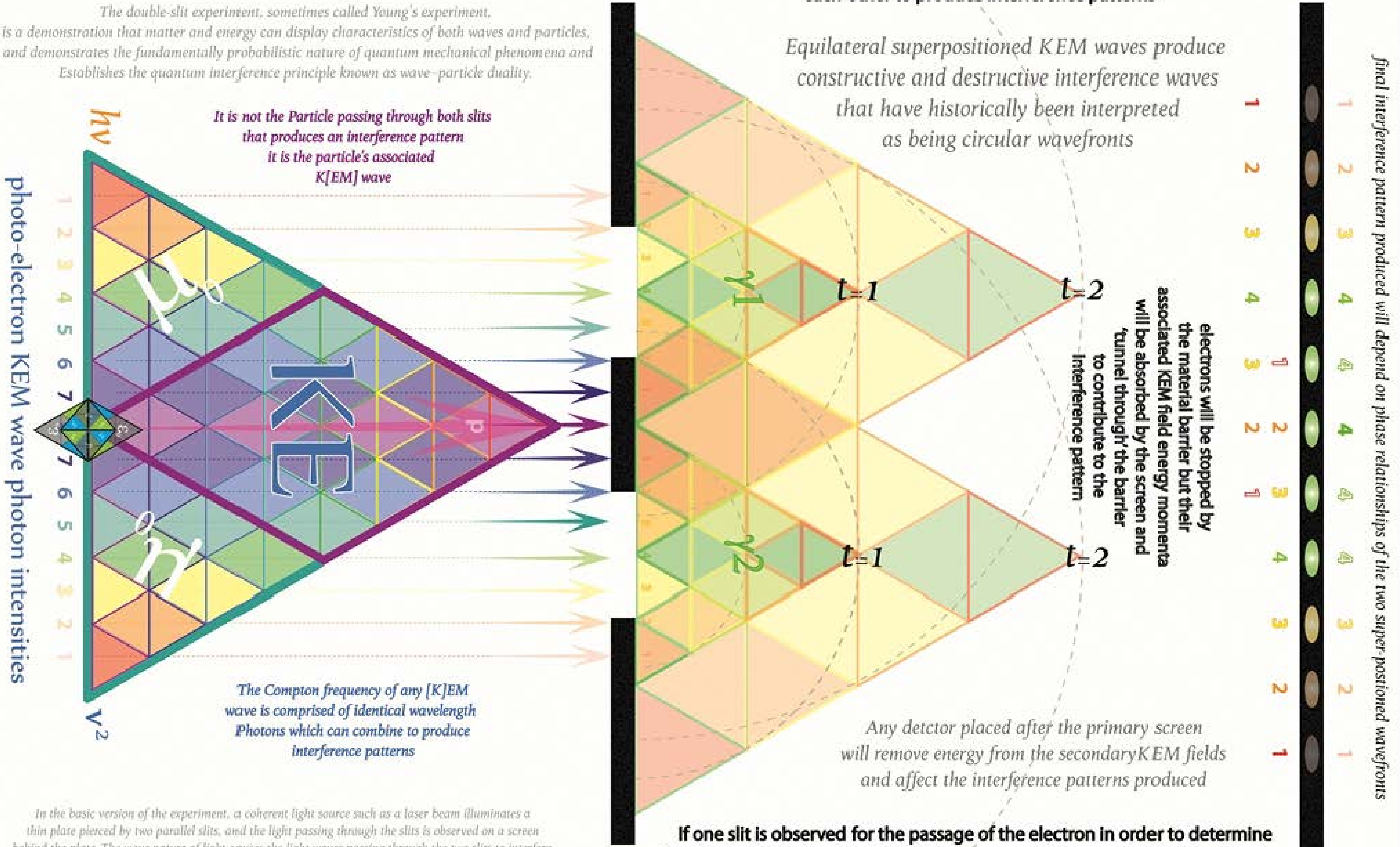

It is not the Particle passing through both slits that produces an interference pattern it is the particle's associated K[EM] wave

Equilateral superpositioned KEM waves produce constructive and destructive interference waves that have historically been interpreted as being circular wavefronts

electrons will be stopped by the material barrier but their associated KEM field energy momenta will be absorbed by the screen and 'tunnel through' the barrier to contribute to the interference pattern

final interference pattern produced will depend on phase relationships of the two super-postioned wavefronts

The Compton frequency of any [K]EM wave is comprised of identical wavelength Photons which can combine to produce interference patterns

Any detector placed after the primary screen will remove energy from the secondary KEM fields and affect the interference patterns produced

If one slit is observed for the passage of the electron in order to determine its physical state then the its KEM field wave will be absorbed by the detector resulting in only one wave remaining, enforcing a classical particle outcome

In the basic version of the experiment, a coherent light source such as a laser beam illuminates a thin plate pierced by two parallel slits, and the light passing through the slits is observed on a screen behind the plate. The wave nature of light causes the light waves passing through the two slits to interfere, producing bright and dark bands on the screen — a result that would not be expected if light consisted strictly of particles. However, on the screen, the light is always found to be absorbed as though it were composed of discrete particles or photons.

Tetryonics 39.11 - Double slit experiment

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Light wave Reflection

Excited (or higher energy)
Atoms and Molecules can
emit light and energy via
Electro-dynamics

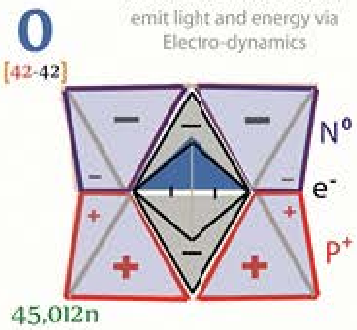

0
[42-42]
N°
e-
P+
45,012n

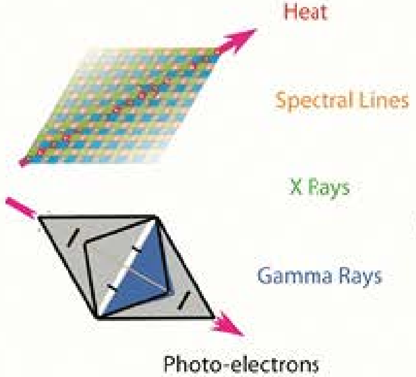

Heat
Spectral Lines
X Rays
Gamma Rays
Photo-electrons

The emitted photon/particle
can go in any direction
so this is the mechanism
for diffuse reflection/radiation.

All Atoms and Molecules
have ANGULAR charged fascia
in their topologies

Incoming light interacts with a surface and may be absorbed, refelected, and/or transmitted.

Materials have a reflectance spectrum which is a function of the angle of incidence of the incoming light.

The color of an object is a function of the color spectrum of the incident light and the reflectance spectrum of the object's surface.

Angle of Incidence
equals
Angle of Reflection

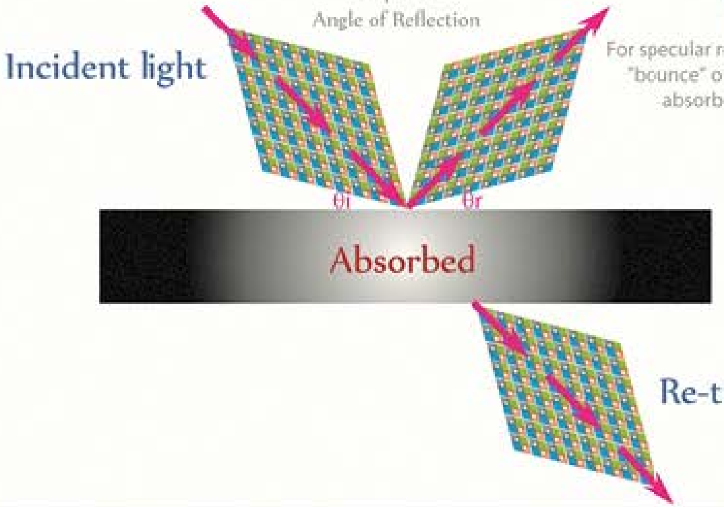

Incident light
θi
θr
Absorbed
Re-transmitted

Reflected

For specular reflection the photons actually
"bounce" off of the surface and are not
absorbed and then re-radiated

Photon Re-Transmission

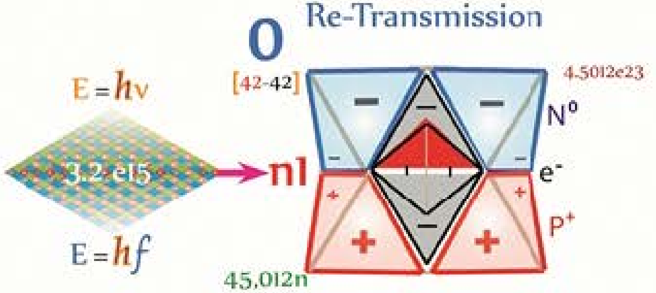

E = hv
3.2e15
E = hf
n1
0
[42-42]
4.5012e23
N°
e-
P+
45,012n

When a photon strikes a atom or molecule
it generally imparts EM energy as heat
and the photon is absorbed

Photon absorption
Photon emission

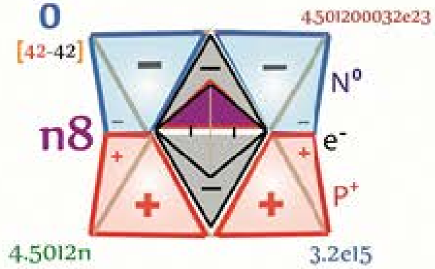

0
[42-42]
4.501200032e23
n8
N°
e-
P+
4.5012n
3.2e15

For some photons their EM energy is equal
to the resonance energy of the molecule.

When this happens the photon is absorbed
and the molecule is put into an excited state

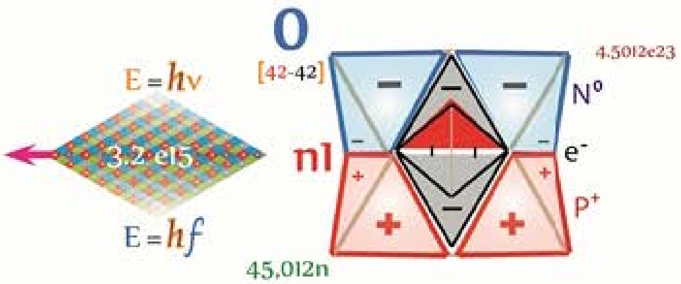

E = hv
3.2e15
E = hf
n1
0
[42-42]
4.5012e23
N°
e-
P+
45,012n

The molecule relaxes from the excited state back to
the ground state by emitting a photon with EM energy
equal to that of the original photon so the photon
appears to have been reflected
(but is actually absorbed then emitted)

Lightwave Refraction

The refraction of light when it passes from a fast medium to a slow medium bends the light ray toward the normal at the boundaries between any two media.

The amount of bending depends on the indices of refraction of the two media and is described quantitatively by Snell's Law.

White light can be refracted into its component spectral colours

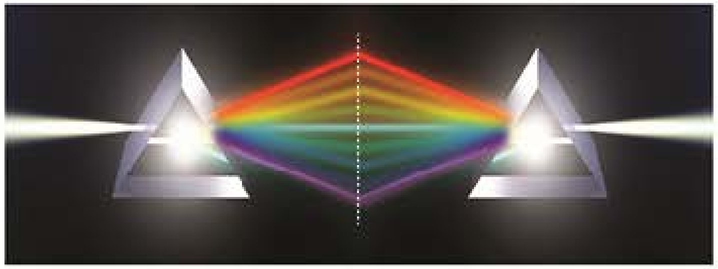

or be re-combined back into white light through superpositioning

The Fresnel equations, deduced by Augustin-Jean Fresnel describe the behaviour of light when moving between media of differing refractive indices

White Light is comprised of superpositioned waves with differing EM wavelengths

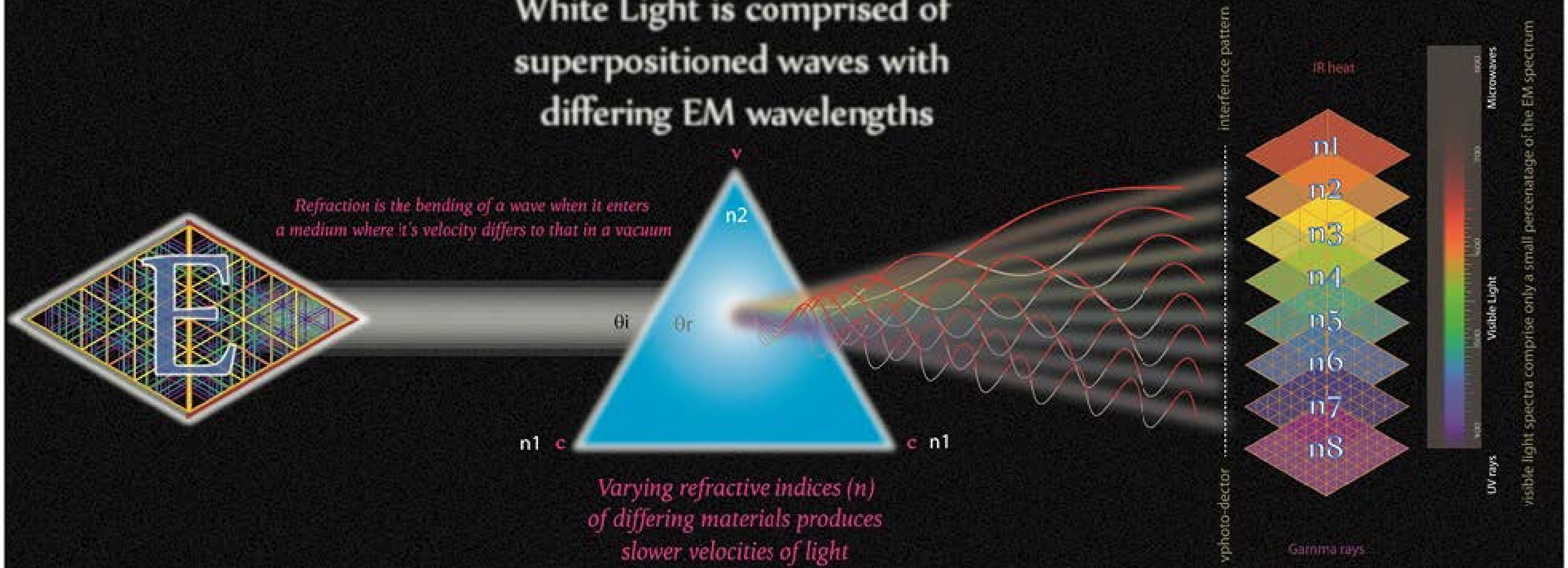
v
n2
θi
θr
n1
c
c
n1
E
interference pattern
vphoto-dector
IR heat
n1
n2
n3
n4
n5
n6
n7
n8
Gamma rays
Microwaves
Visible Light
UV rays
visible light spectra comprise only a small percenatage of the EM spectrum

Refraction is the bending of a wave when it enters a medium where it's velocity differs to that in a vacuum

Varying refractive indices (n) of differing materials produces slower velocities of light in those materials

$c = \lambda . f$

Its wavelength increases or decreases but its frequency remains constant

$v = \lambda . f$

Ball Lightning

An alternative radiant geometry for electromagnetic waves exists

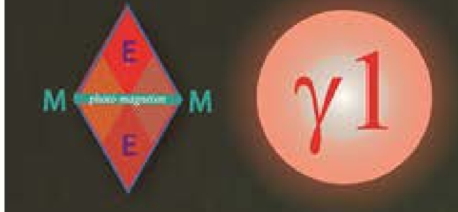

The EM energies in radiant 'ball' lightning are transformer-couplings of energy momenta & self-sustaining until any interaction with Matter topologies occurs

Descriptions of ball lightning vary wildly. It has been described as moving up and down, sideways or in unpredictable trajectories, hovering and moving with or against the wind; attracted to, unaffected by, or repelled from buildings, people, cars and other objects.

Ball lightning has been described as transparent, translucent, multicolored, evenly lit, radiating flames, filaments or sparks, with shapes that vary between spheres, ovals, tear-drops, rods, or disks

Any interaction with a 'ball' of EM energies will result in an explosive discharge of it's EM energy momenta

Nikola Tesla was reportedly able to artificially produce 1.5" (3.8 cm) balls using spark gap technologies

Ball lightning creates a strong Magnetic moment and divergent E fields [similar to a bar magnet without the Matter] creating a "Ball' of light with varying EM energies that is sensitive to external M fields

Wave~Particle interaction-at-a-distance

All Matter in motion has both:

a standing wave energy topology [Particle] and

a divergent relativistic, Lorentz velocity corrected geometric field of mass-energy momenta [KEM Wave]

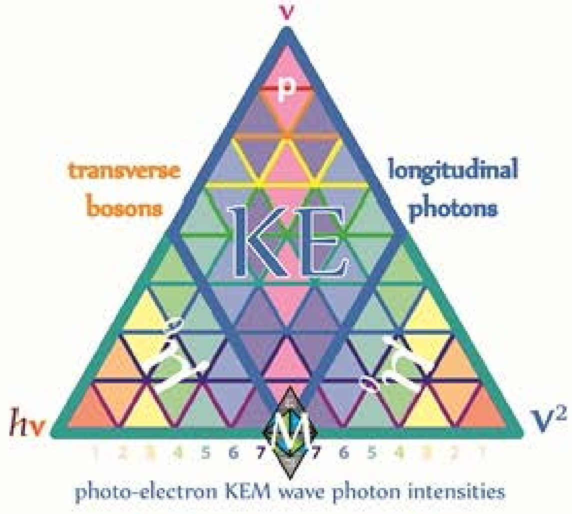
v
p
transverse bosons
longitudinal photons
KE
hv
v²
M
1 2 3 4 5 6 7 7 6 5 4 3 2 1
photo-electron KEM wave photon intensities

Whether it is Light itself or the KEM field of Matter in motion all EM fields are comprised of transverse bosons and longitudinal photons with probabillistic wave geometries

$$RE = M + KEM$$

relativistic energies Matter kinetic energies

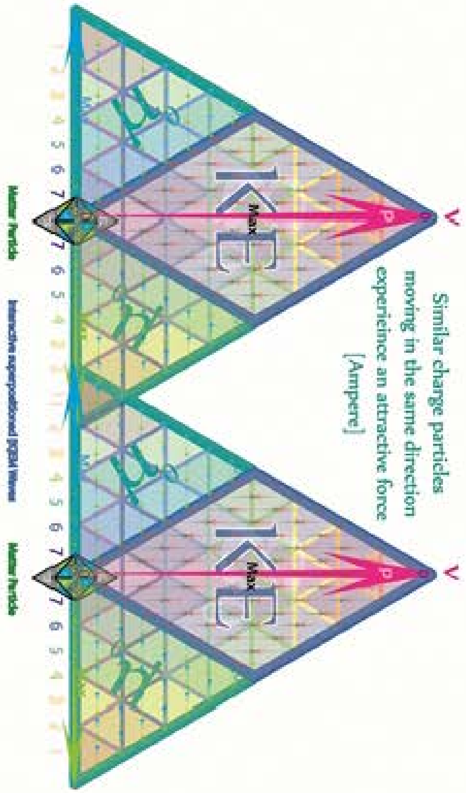
Matter Particle
Interactive superpositioned [K]EM Waves
Matter Particle
KE
Max
p
v
KE
Max
p
v

Similar charge particles moving in the same direction experience an attractive force [Ampere]

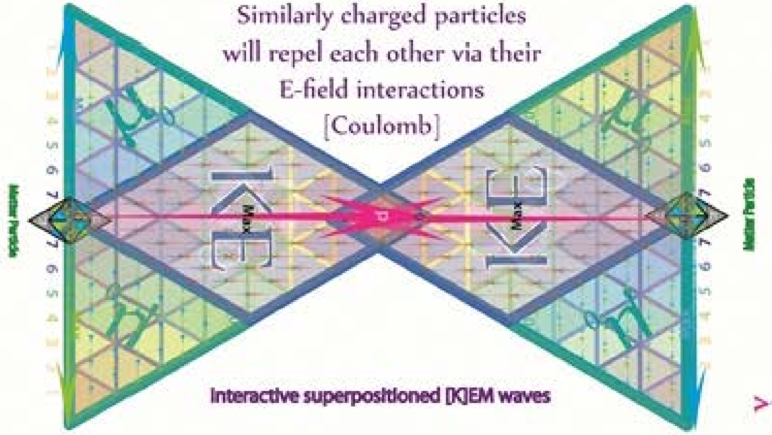
Matter Particle
Matter Particle
KE
Max
KE
Max
p

Similarly charged particles will repel each other via their E-field interactions [Coulomb]

Interactive superpositioned [K]EM waves

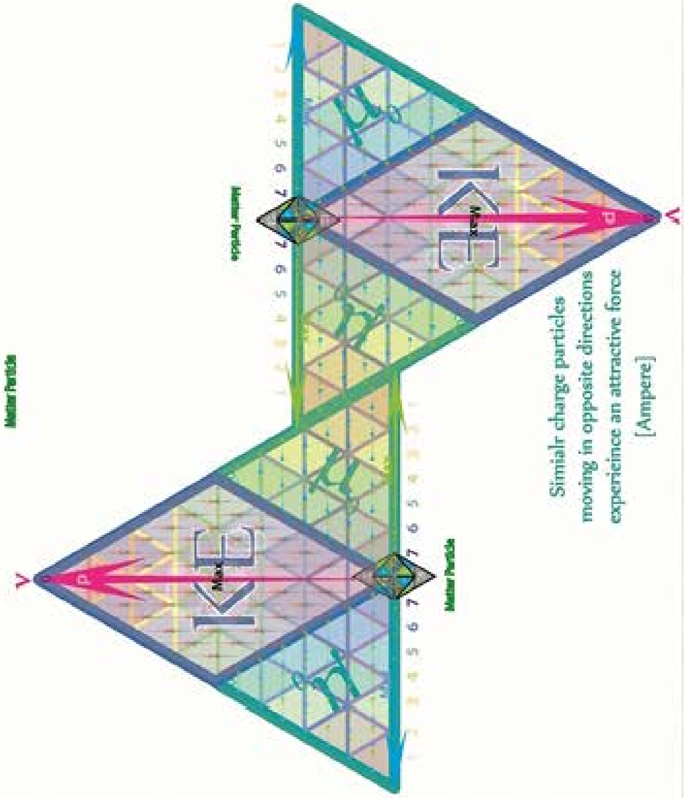
Matter Particle
Matter Particle
KE
Max
p
v
KE
Max
p
v

Simialr charge particles moving in opposite directions experience an attractive force [Ampere]

Force fields and interaction-at-a-distance

All Matter in motion produces an associated Lorentz velocity corrected KEM field of interactive energy momenta photons

Tetryonics 39.15 - Wave~Particle interactions

Quantum Tunnelling

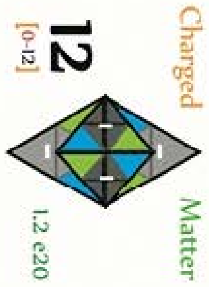

Particles attempting to travel between potential barriers can be compared to a ball trying to roll over a hill; quantum mechanics and classical mechanics differ in their treatment of this scenario.

Classical mechanics predicts that particles that do not have enough energy to classically surmount a barrier will not be able to reach the other side. Thus, a ball without sufficient energy to surmount the hill would roll back down.

Or, lacking the energy to penetrate a wall it would bounce back (reflection) or in the extreme case, bury itself inside the wall (absorption).

In quantum mechanics, these particles can, with a very small probability, tunnel to the other side, thus crossing the barrier.

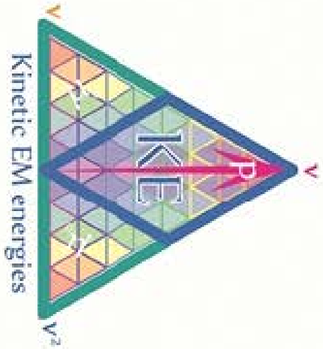

The quantum magician's slight of hand trick is where the incident electron is swapped another

All electrons are IDENTICAL

It is practically impossible to identify a particular electron and track it

even using spin orientations only eliminates half of the total electrons in the barrier

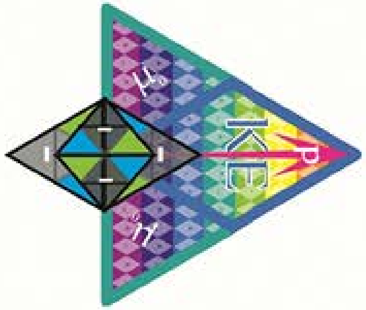

Reflection of Particle

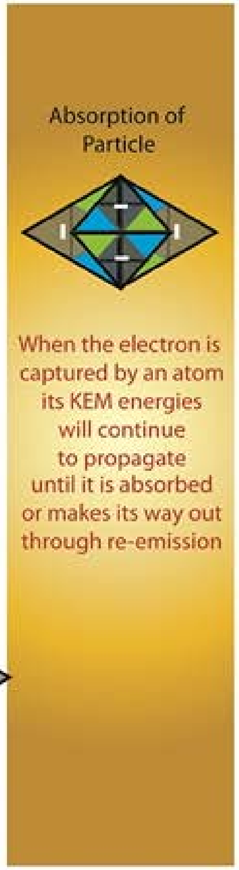

Absorption of Particle

When the electron is captured by an atom its KEM energies will continue to propagate until it is absorbed or makes its way out through re-emission

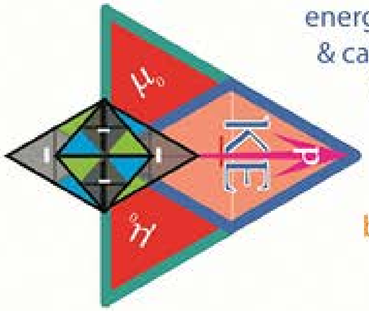

KEM field 'tunnels' out

Quantum KEM field tunnelling is an example of conservation of energy momenta on the atomic scale & can be likened to a unidirectional version of Newton's cradle

Removal of all electrons but the one under measurement is impractical as it would result in an attractive coloumbic force that would trap the electron in the barrier

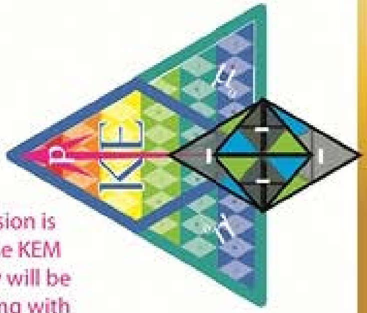

If the collision is inelastic the KEM field energy will be reduced along with the particle's velocity

The most probable explanation of quantum tunneling is that the original electron was bound to atoms in the material barrier and its KEM field propagated through the barrier along its original direction of momentum.

Upon reaching the opposite side/edge of the barrier its remaining energies are able to accelerate any weakly bound electron found there

Quantum 'tunnelling' is revealed to be the result of an electron's KEM wave propagation through the barrier not the electron itself

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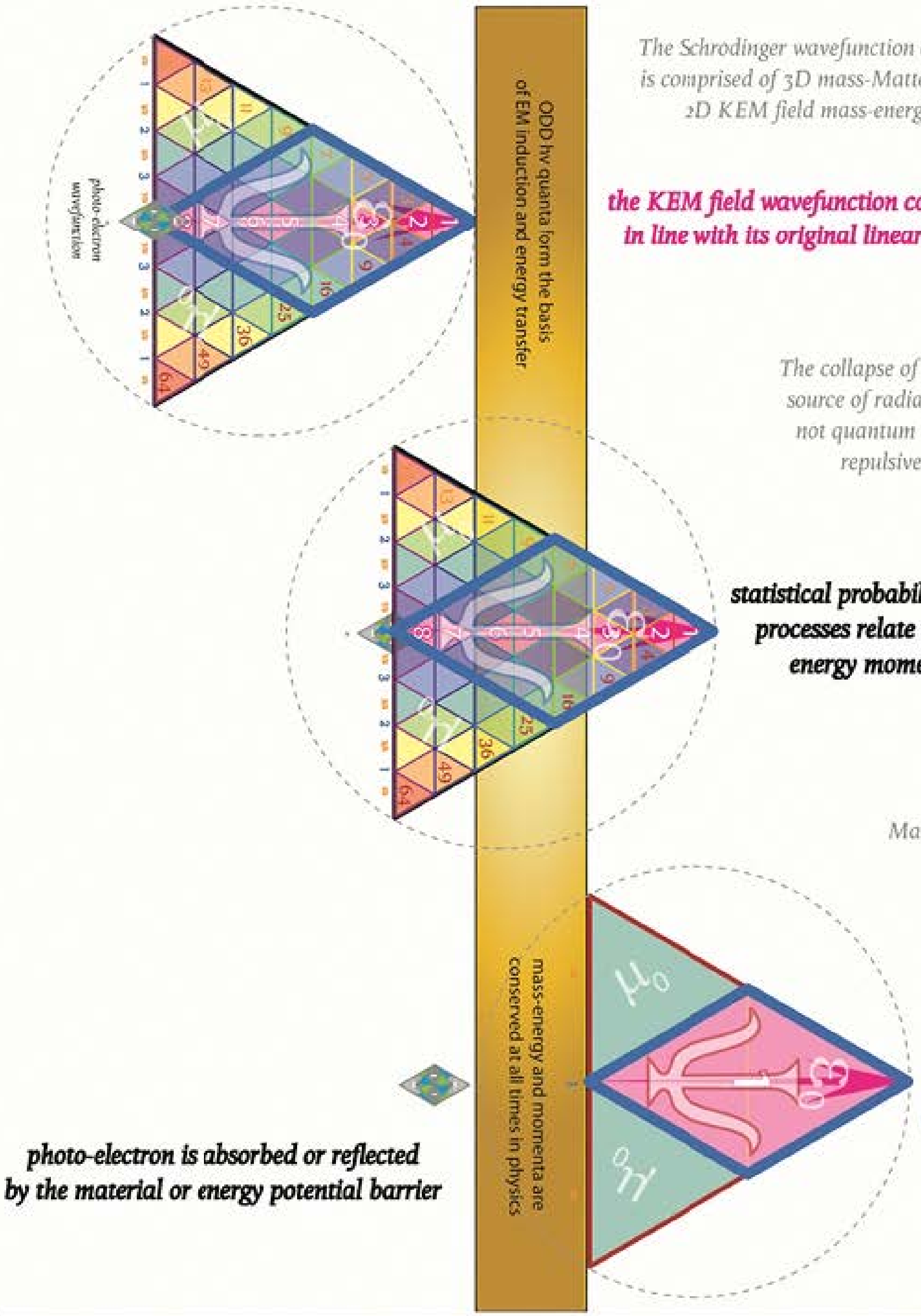
photo-electron wavefunction
1
2
3
4
5
6
7
8
9
16
25
36
49
64
μ0
ε0

ODD hv quanta form the basis of EM induction and energy transfer

mass-energy and momenta are conserved at all times in physics

$$\Delta hf = \Delta Mv = \Delta p$$

The Schrodinger wavefunction of photo-electrons
is comprised of 3D mass-Matter topologies and
2D KEM field mass-energy geometries

the KEM field wavefunction continues to propagate
in line with its original linear momentum vector

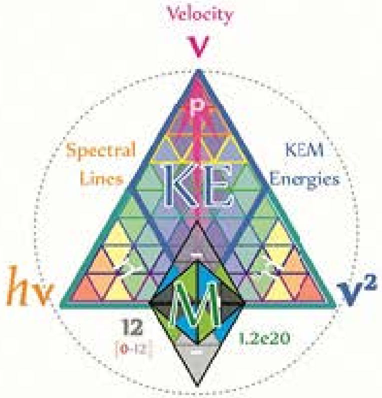
Velocity
v
p
Spectral Lines
KEM Energies
KE
hv
v²
M
12
[0-12]
1.2e20

The collapse of Matter topologies is the
source of radiant stellar mass-energies
not quantum tunnelling to overcome
repulsive Coloumbic forces

statistical probabilities applied to quanutm tunneling
processes relate to the distribution of EM Planck
energy momenta quanta in the KEM field

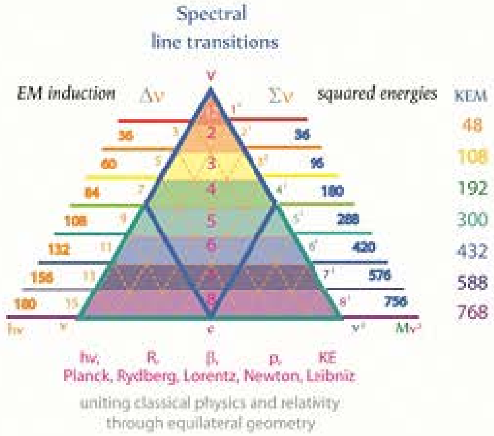
Spectral
line transitions
EM induction
Δv
v
Σv
squared energies
KEM
36
60
84
108
132
156
180
3
5
7
9
11
13
15
1
2
3
4
5
6
7
8
1²
2²
3²
4²
5²
6²
7²
8²
36
96
180
288
420
576
756
48
108
192
300
432
588
768
hv
v
c
v²
Mv²
hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz
uniting classical physics and relativity
through equilateral geometry

Matter-energy conversion via GEM pinches
is the source of stellar energies
released in stars

As Planck energy momenta quanta interact
or are absorbed the KEM field's wavefunction
will entropy accordingly, in turn affecting
the wavelength-frequency-velocity
of the KEM field

photo-electron is absorbed or reflected
by the material or energy potential barrier

Quantum tunneling plays no role
in the 'fusion' of lighter elements
into heavier elements in stars
(which is itself an erroneous process)

Tetryonics 39.17 - mass-energy momenta induction & conservation

All Matter in motion is comprised of:

a mass-Matter standing-wave topology,
and
a KEM mass-energy field geometry

whose quantised energy momenta is reflective of the particle's vector velocity

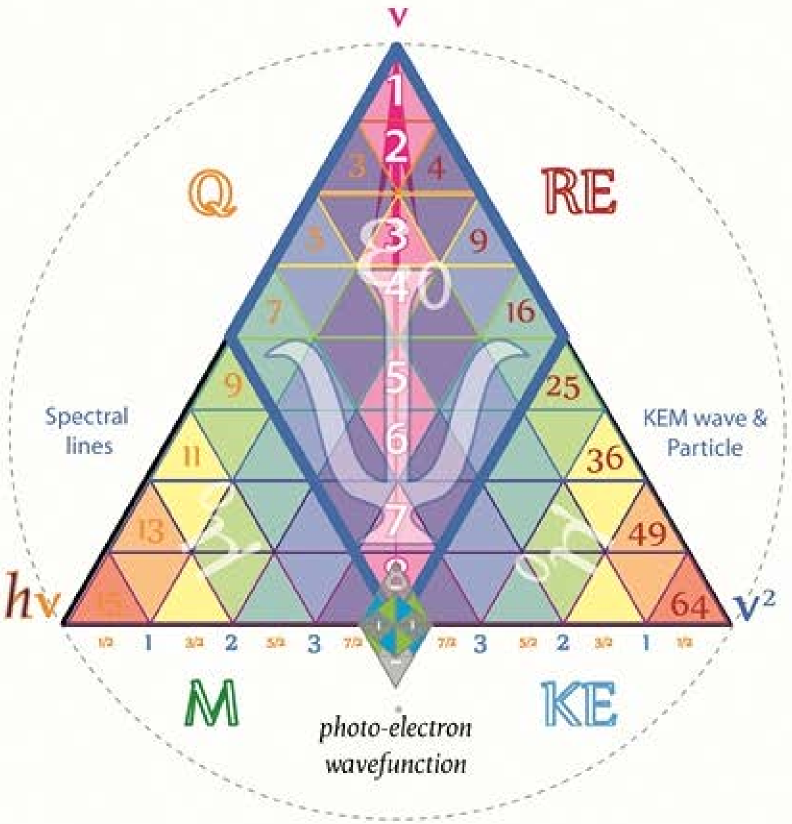
v
Q
RE
1
2
3
4
3
5
9
4
7
16
9
5
25
6
11
36
7
13
49
8
15
64
Spectral lines
KEM wave & Particle
hv
v²
1/2
1
3/2
2
5/2
3
7/2
7/2
3
5/2
2
3/2
1
1/2
M
KE
photo-electron wavefunction

The normal distribution of Planck energy momenta in any KEM field is the quantum foundation for the statistical probability mechanics of quanutm mechanics and quantum electrodynamics

e-

Quantum Tunneling

it makes no difference if the barrier is a EM field or material object

electrons are NOT spherical point particles

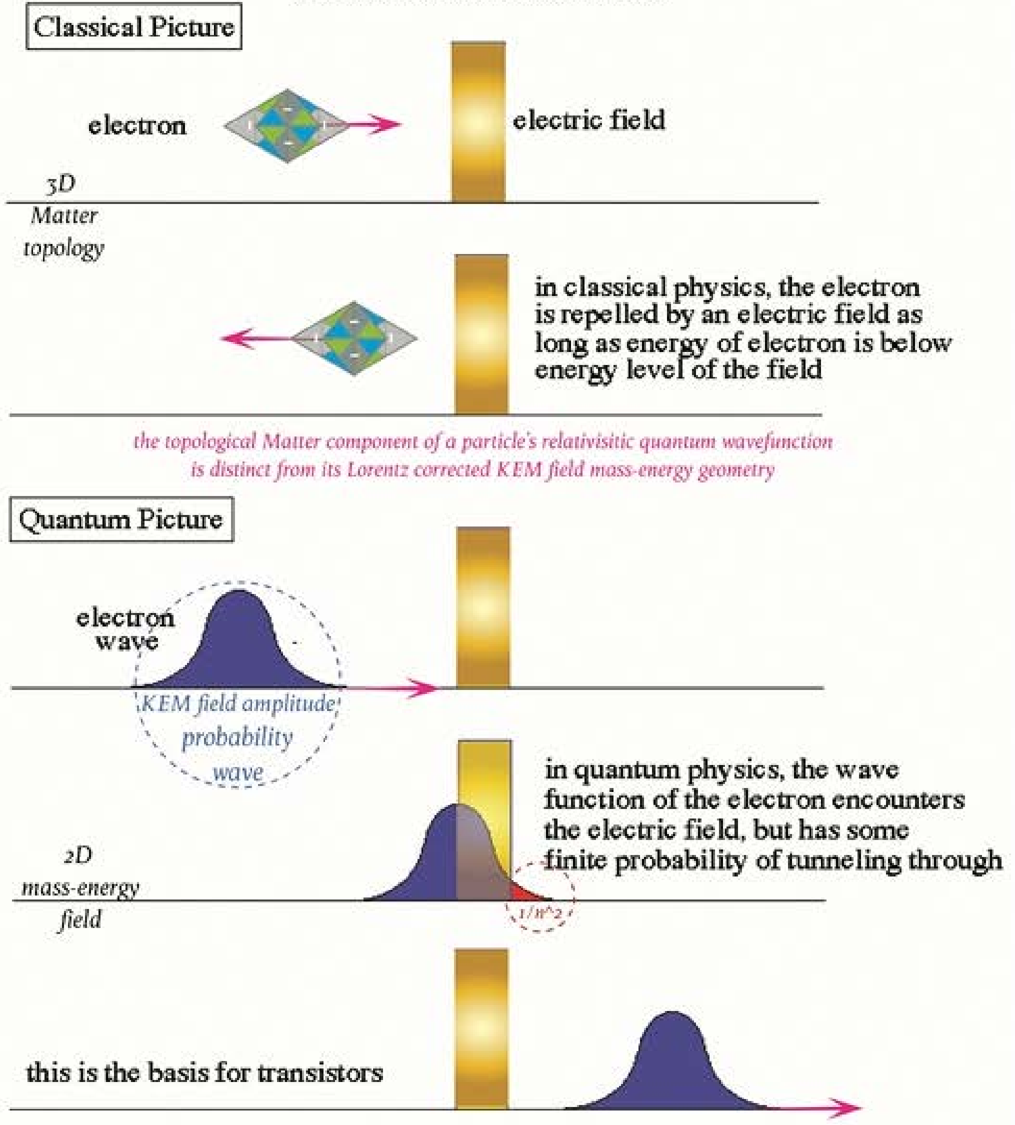
Classical Picture
electron
electric field
3D Matter topology
Quantum Picture
electron wave
KEM field amplitude probability wave
2D mass-energy field
1/n^2

in classical physics, the electron is repelled by an electric field as long as energy of electron is below energy level of the field

the topological Matter component of a particle's relativisitic quantum wavefunction is distinct from its Lorentz corrected KEM field mass-energy geometry

in quantum physics, the wave function of the electron encounters the electric field, but has some finite probability of tunneling through

this is the basis for transistors

quantum tunnelling is often also utilised in modern physics as a means of overcoming Coulombic charge barriers of Protons in stars in order to explain 'fusion' as the source of stellar energy

Tetryonics 39.17 - Quantum Tunnelling wavefunctions

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Relativistic Kinetic Energies

$$KE = \frac{1}{2}M\frac{v^2}{c^2}$$

The relativistic Kinetic mass-energies of all Matter topologies in motion are contained in their KEM fields and are subject to Lorentz velocity corrections

$$p^2 = E = m\frac{v^2}{c^2}$$

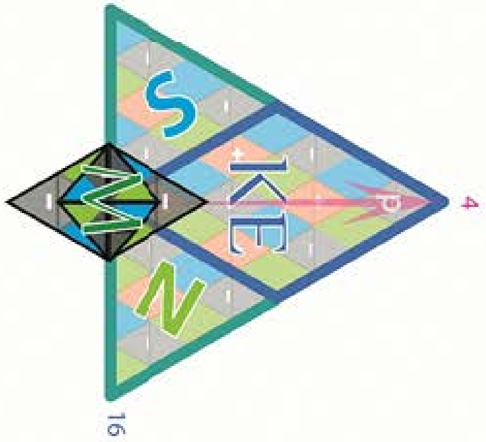

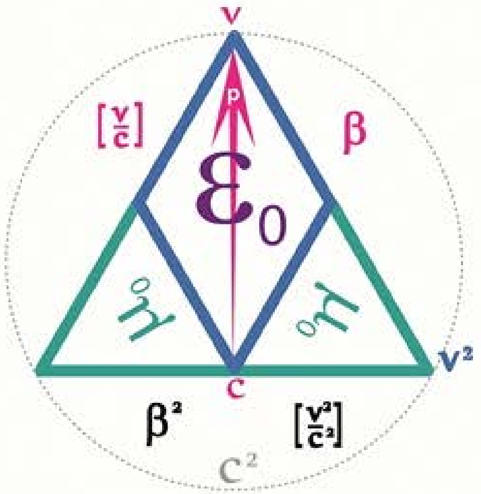
v
[v/c]
β
p
ℇ0
μ0
ε0
v²
c
β²
[v²/c²]
c²

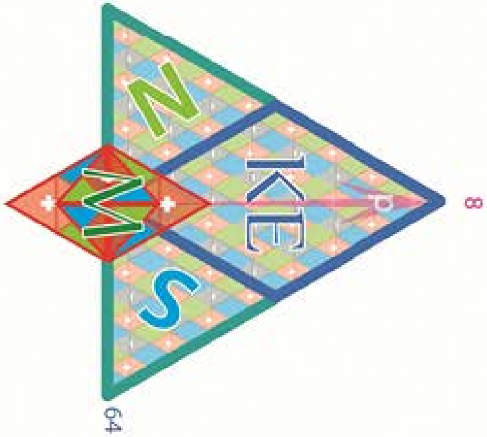

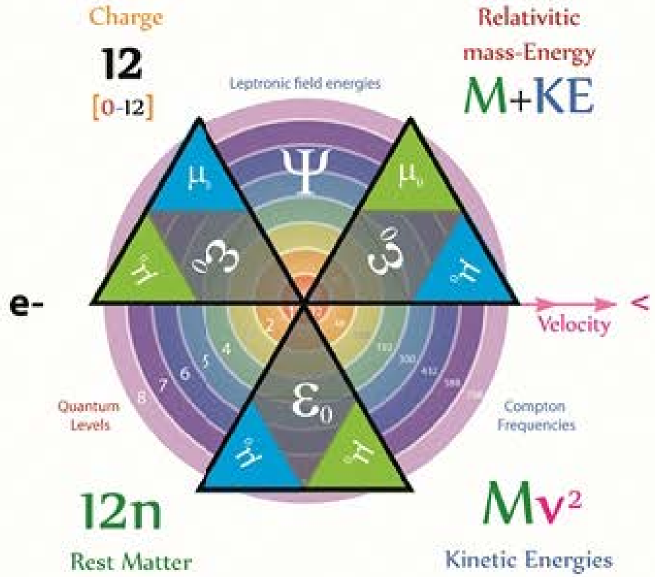
Charge
12
[0-12]
Leptronic field energies
Relativitic mass-Energy
M+KE
Ψ
μ0
ε0
ℇ0
e-
Velocity
v
Quantum Levels
Compton Frequencies
12n
Rest Matter
Mv²
Kinetic Energies

Lorentz contractions only apply to the KEM fields of Matter in motion

The Kinetic Energies of a particle in motion can be expressed in terms of its linear momentum

$$\frac{p^2}{2m} = KE = \frac{1}{2}Mv^2$$

or equally as 1/2 the total relativistic EM mass-energies [exclusive of its invariant rest mass-Matter]

Charge and Matter topologies are Lorentz invariant

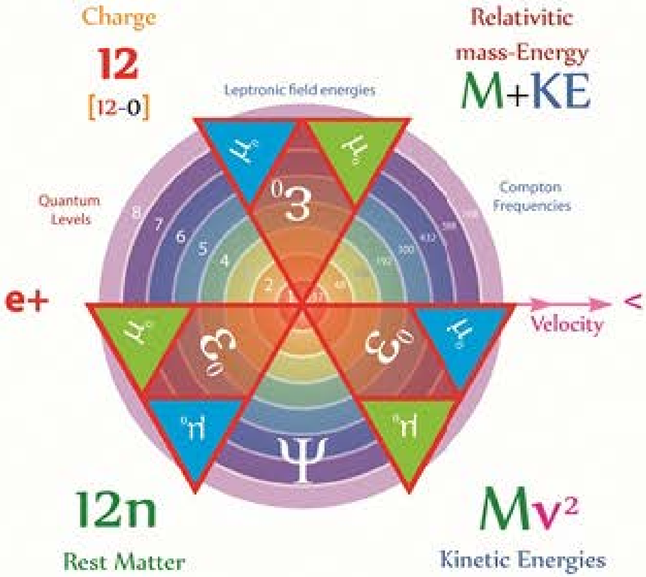
Charge
12
[12-0]
Leptronic field energies
Relativitic mass-Energy
M+KE
Quantum Levels
Compton Frequencies
μ0
ε0
Ψ
e+
Velocity
v
12n
Rest Matter
Mv²
Kinetic Energies

Relativistic Lorentz Corrections

ges their name from their earliest appearance, in Lorentzian electrodynamics
as velocity increases the wavelengths and physical scalar geometries of Planck quanta decreases

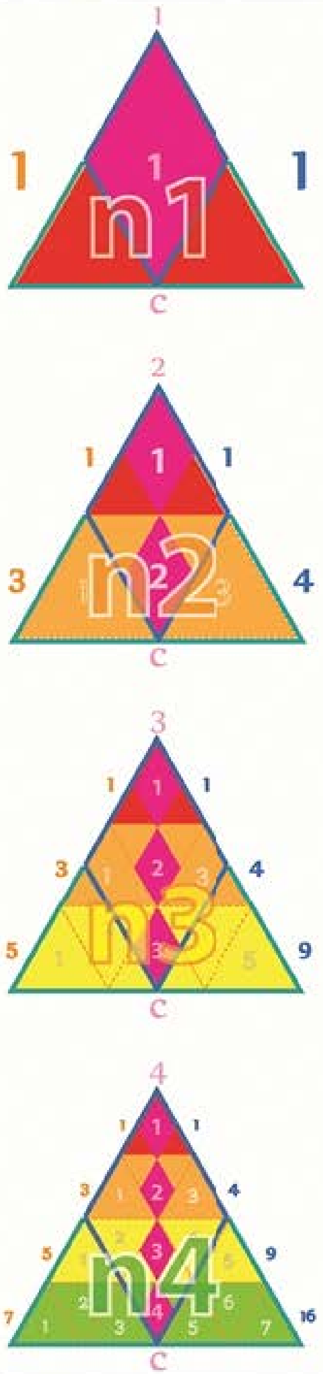
1
1
1
1
n1
c
2
1
1
1
3
4
n2
c
3
1
1
1
3
4
2
5
9
n3
c
4
1
1
1
3
4
2
3
5
9
3
7
16
n4
c

Linear correction factor

$$\beta = \left[\frac{v}{c}\right]$$

Equilateral QAM contractions

$$t' = \frac{t}{\sqrt{1-\frac{v^2}{c^2}}}$$

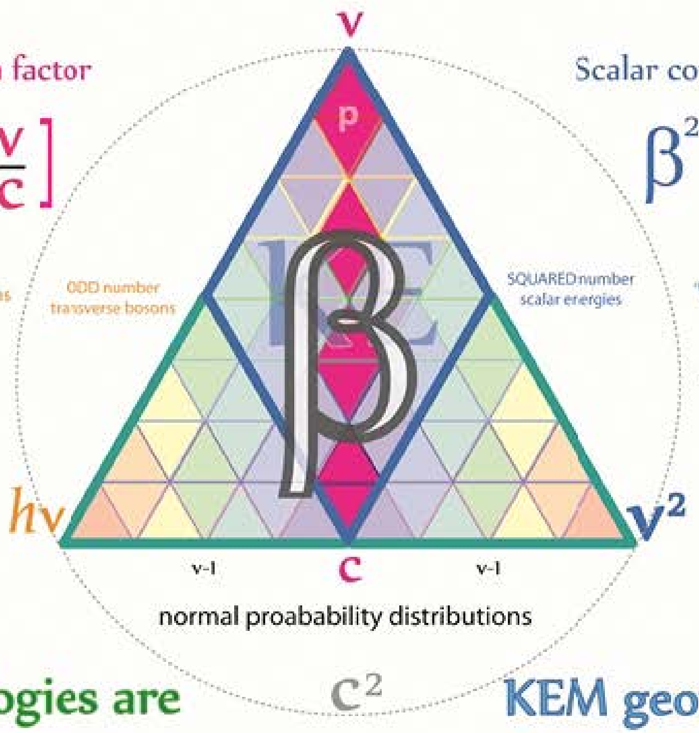
v
p
β
ODD number transverse bosons
SQUARED number scalar energies
hv
v²
v-1
c
v-1
normal proabability distributions
c²

Scalar correction factor

$$\beta^2 = \left[\frac{v^2}{c^2}\right]$$

'WAVE-length' contractions

$$L = L'\sqrt{1-\frac{v^2}{c^2}}$$

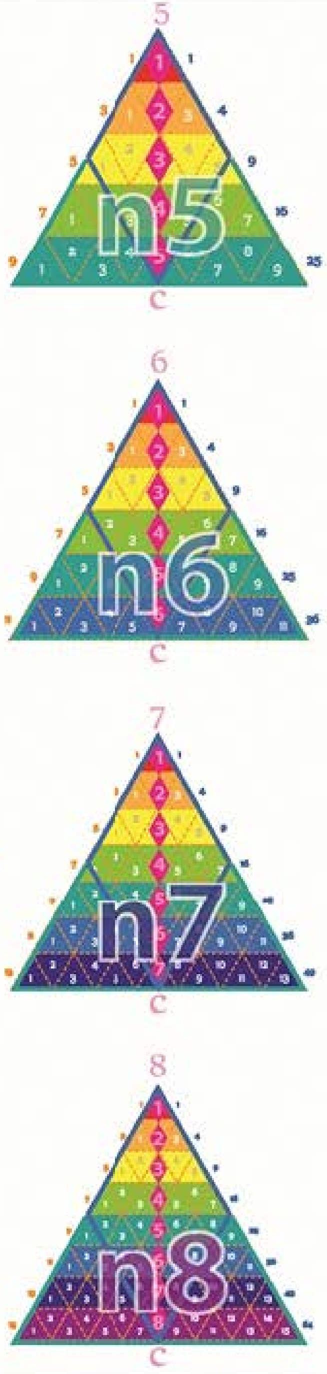
5
n5
c
6
n6
c
7
n7
c
8
n8
c

Matter topologies are Lorentz invariant

KEM geometries are relativistic fields

The poor definitions of EM mass & Matter has led to the incorrect application of Lorentz corrections to Matter

v v^2

all the quantum energy momenta probabilites of wavefunction distributions re-normalise [or sum] to

c c^2

Lorentz contractions apply to [K]EM waveforms only

c is the limiting velocity for the electrical acceleration of Matter

$$\sqrt{1-\beta^2}$$

Incorrectly applied to Matter topologies in motion,
The Lorentz factor or Lorentz term appears in
several equations in special relativity.

$$\sqrt{1-\left(\frac{v}{c}\right)^2}$$

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The Energy of a Magnet

> *It is known that Maxwell's electrodynamics--as usually understood at the present time--when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. The observable phenomenon here depends only on the relative motion of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either the one or the other of these bodies is in motion. For if the magnet is in motion and the conductor at rest, there arises in the neighborhood of the magnet an electric field with a certain definite energy, producing a current at the places where parts of the conductor are situated. But if the magnet is stationary and the conductor in motion, no electric field arises in the neighborhood of the magnet.*
>
> *In the conductor, however, we fiod an electromotive force, to which in itself there is no corresponding energy, but which gives rise--assuming equality of relative motion in the two cases discussed--to electric currents of the same path and intensity as those produced by the electric forces in the former case.* [On the electrodynamics of moving bodies, A. Einstein, 1905]

V

Energy can be removed by placing a conductive loop between any Positive and Negative quanta the EM field thus creating a potential difference & an electro-motive force

ε_0

The neutralised [K]EM fields are divergent from a permanent magnet and create a Magneto-static EM field with neutral Electro-static energies

Investigation of the source of the emf produced by magnets in conductive loops placed around them led to the development of relativity theory

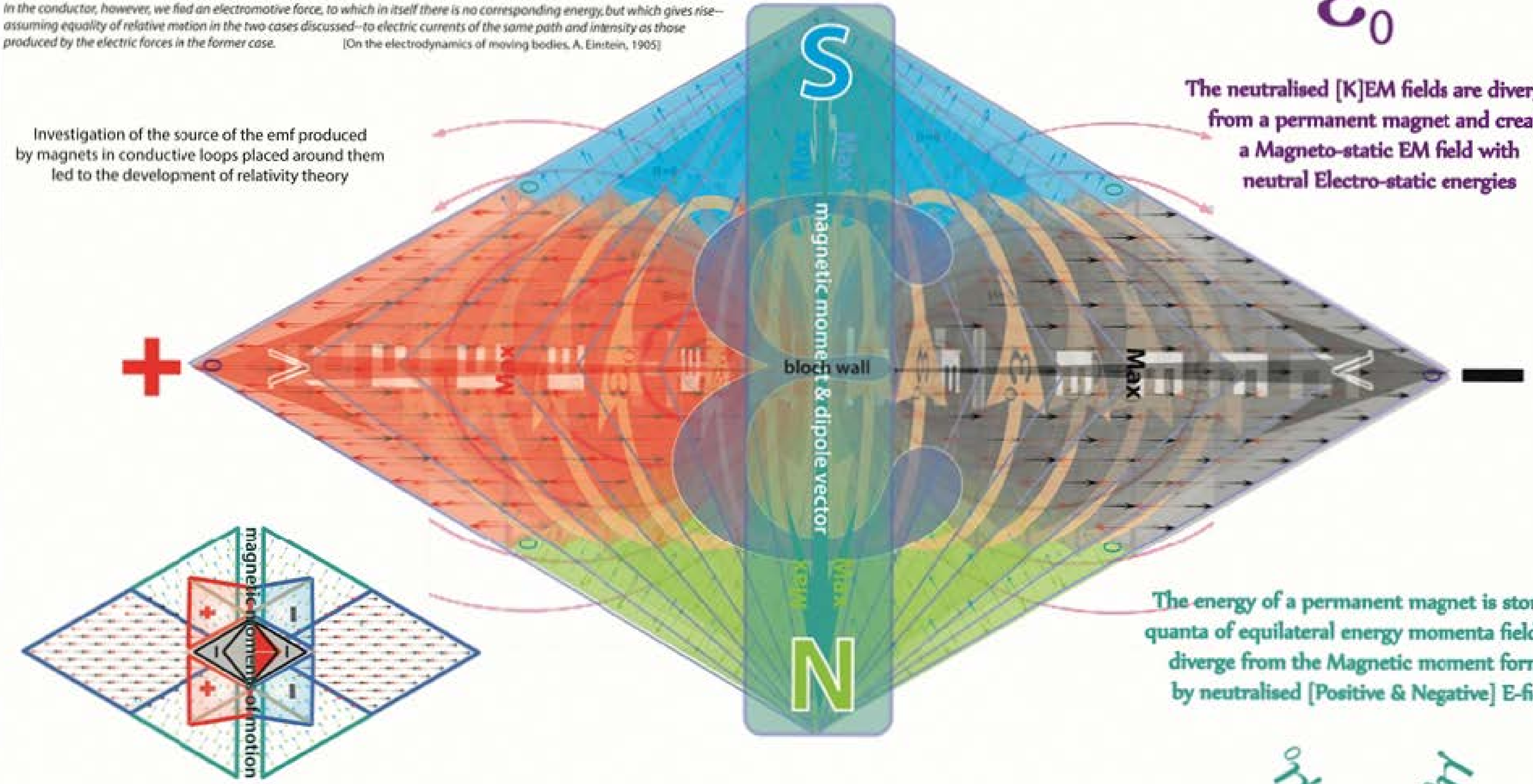

The energy of a permanent magnet is stored in quanta of equilateral energy momenta fields that diverge from the Magnetic moment formed by neutralised [Positive & Negative] E-fields

Magnetic fields are produced by moving electric charges and the intrinsic magnetic moments of elementary particles associated with a fundamental quantum property, their spin. In special relativity, electric and magnetic fields are two interrelated aspects of a single object, called the electromagnetic field tensor; the aspect of the electromagnetic field that is seen as a magnetic field is dependent on the reference frame of the observer. In QED, the electro-magnetic field is quantized and electromagnetic interactions result from the exchange of photons.

Ω

Classically, the energy of a permanent magnet 'circulates in endless loops' from North to South in 3 dimensions around the magnetic moment

$E = h\nu$

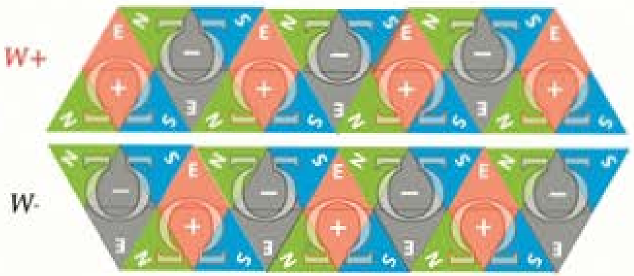

BOSONS are
transverse EM waves
[charge carriers]

PHOTONS are
longitudinal EM waves
[neutral charge carriers]

$E = hf$

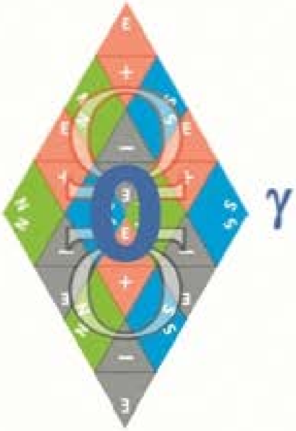

The equilateral geometry of
ALL EM fields in relative motion
to a conductor produces a
time varying emf

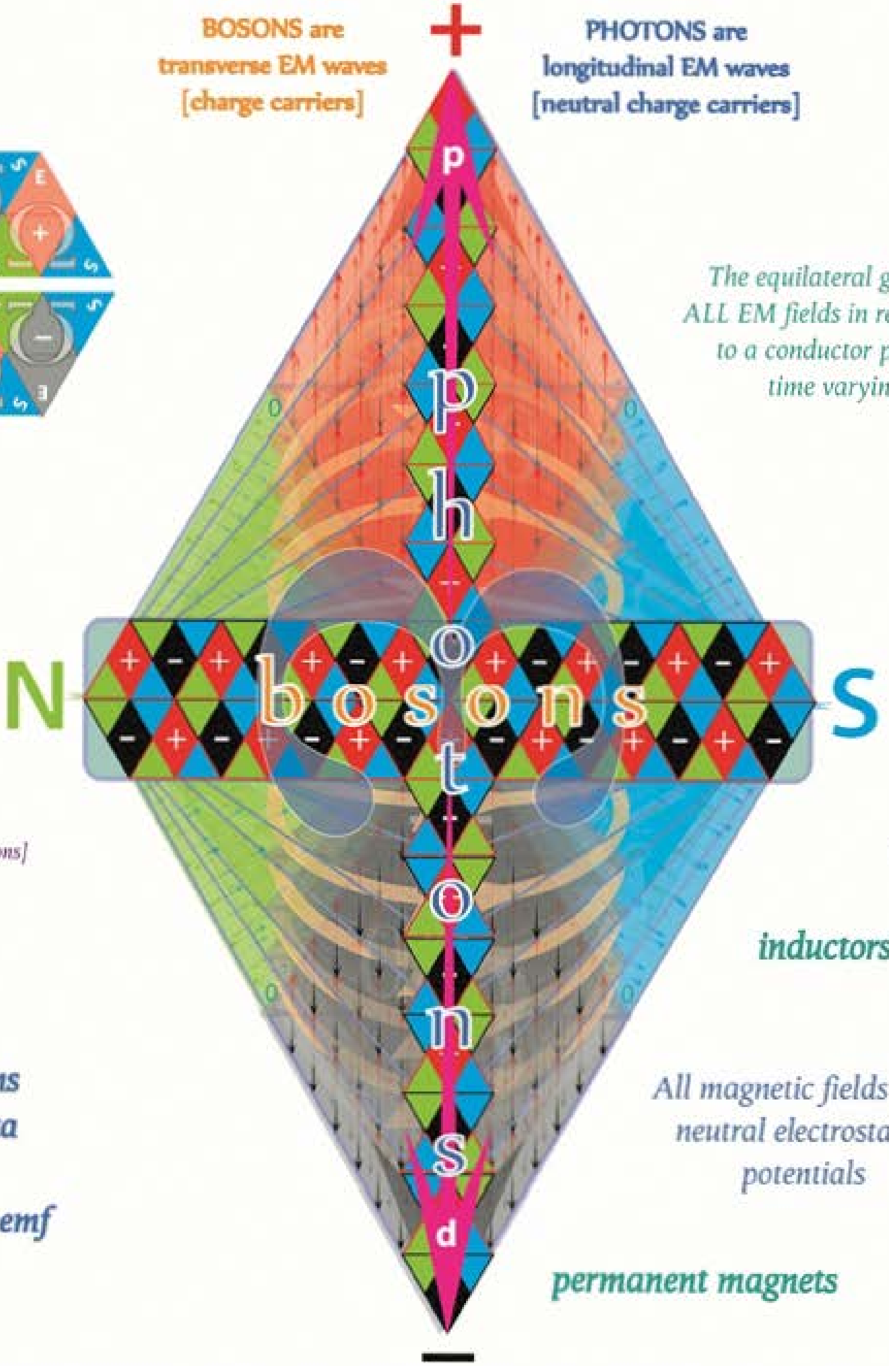

$$B = -\frac{d\phi_\varepsilon}{dt}$$

A changing Electric field
produces
a changing Magnetic field

The is no such entity as a purely Electric field
[all fields are Electro-Magnetic in their geometric foundations]

$$\varepsilon = -\frac{d\phi_B}{dt}$$

A changing Magnetic field
produces
a changing Electric field

The is no such entity as a purely Magnetic field
[all fields are Electro-Magnetic in their geometric foundations]

inductors

All magnetic fields store
neutral electrostatic
potentials

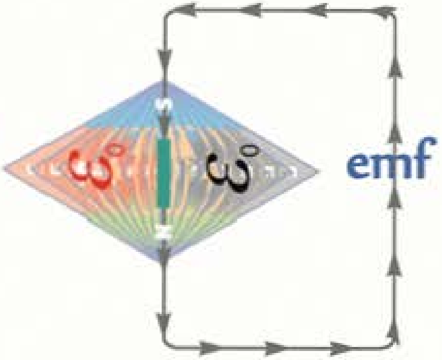

permanent magnets

Any two separated charge bosons
contain charged energy momenta
that once connected via a
conductive circuit will produce an emf

The moving magnet - conductor problem

All permanent magnets are electromagnetic fields comprised of
transverse bosons and longitudinal photons

$$B = -\frac{d\phi_{\varepsilon}}{dt}$$

$$\varepsilon = -\frac{d\phi_{B}}{dt}$$

We see two observers both moving, approaching each other.

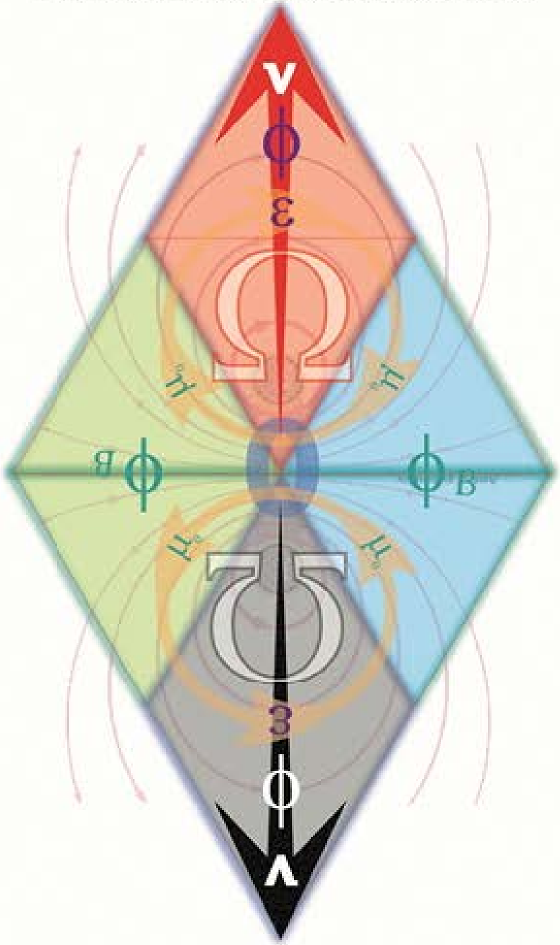

Neutral photon field geometries produce electromotive forces as a result of the charged bosons that make them

Magnet Frame of Reference
(Moving Conductor)

Observer 2 says:

*The magnet is stationary and the loop is moving toward it.
The electrons in the loop, since they are moving with the loop,
generate their own magnetic moments and experience Lorentz forces
as a result of the external magnetic field [F = q v X B],
which drives them around the loop and produces the current in the galvanometer.*

There is no electric field.

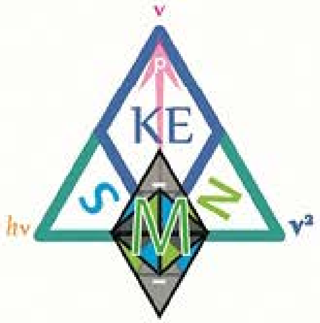

Observer 1 says:

*The conductive loop is stationary and the magnet is moving toward it.
The electrons in the loop are stationary and have no magnetic moments
There is a magnetic field, but it can't produce any force on
the electrons since they are stationary within the loop.*

*Instead, the magnetic field is changing, growing stronger as
the magnet gets closer, and this changing magnetic field
produces an electric field which causes forces on the electrons, and
drives them around the loop producing the current in the galvanometer.*

Conductor Frame of Reference
(Moving Magnet)

Charged boson field geometries contain equilateral energy momenta with transverse magnetic dipoles

Special relativity postulates that electric fields in one reference frame become magnetic fields in another frame

Tetryonic theory shows geometrically that the Electric and Magnetic fields are discrete, invariant geometries
resulting from the equilateral 'inductive' mass-energy [Planck quanta] geometries that comprise all EM fields.
It is the relative motion of these geometries wrt a conductor that creates changing E&M field flux strengths in turn producing an emf.
When there is no relative motion in either the EM field or the conductor, no emf is produced

The Electromotive Force

The electromotive force, [or emf]
or electromotance
is "that which tends to cause
a current (electrons and ions)
to flow in a conductor.

*"A source of emf can be thought of as a kind of charge pump
that acts to move a charge from a point of low potential
through its interior to a point of high potential. …
The emf of the source is defined as the work done per charge
dq: = dW/dq."*

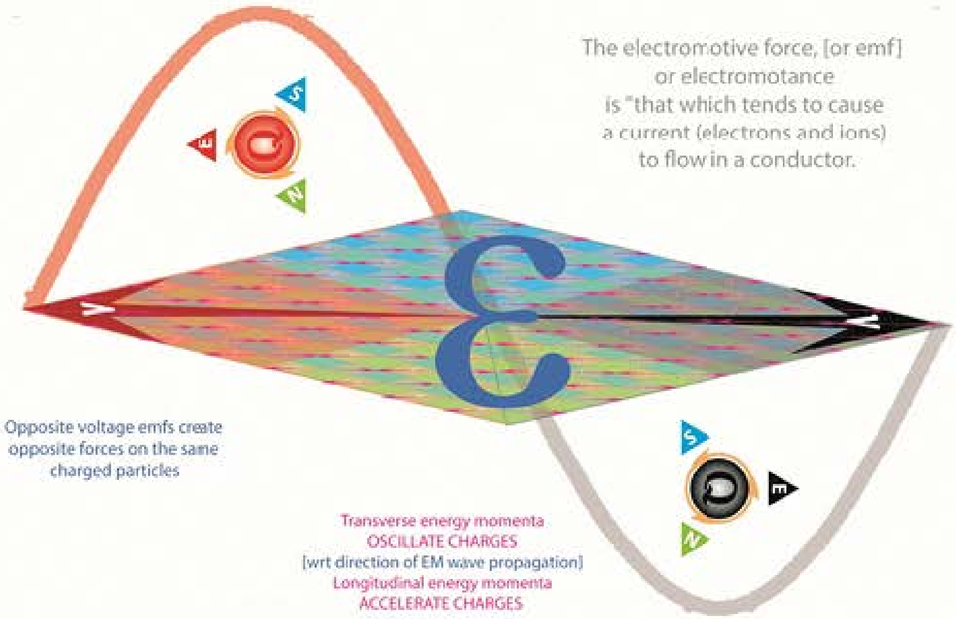

Opposite voltage emfs create
opposite forces on the same
charged particles

Transverse energy momenta
OSCILLATE CHARGES
[wrt direction of EM wave propagation]
Longitudinal energy momenta
ACCELERATE CHARGES

Opposite charged particles
experience opposing forces
due to the emf

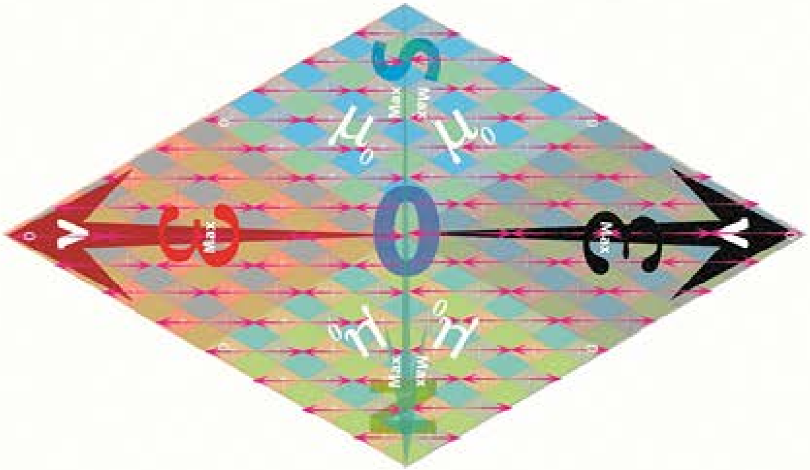

THe magneto-static fields of all Magnets are
comprised of electromagnetic fields of discrete
Planck energy momenta quanta, which
in turn are capable of accelerating
charged particles

All ElectroMagnetic fields have
distinct equilateral electric and
magnetic field geometries that produce
velocity related sinusodal waveforms

$$B = -\frac{d\phi_\varepsilon}{dt}$$

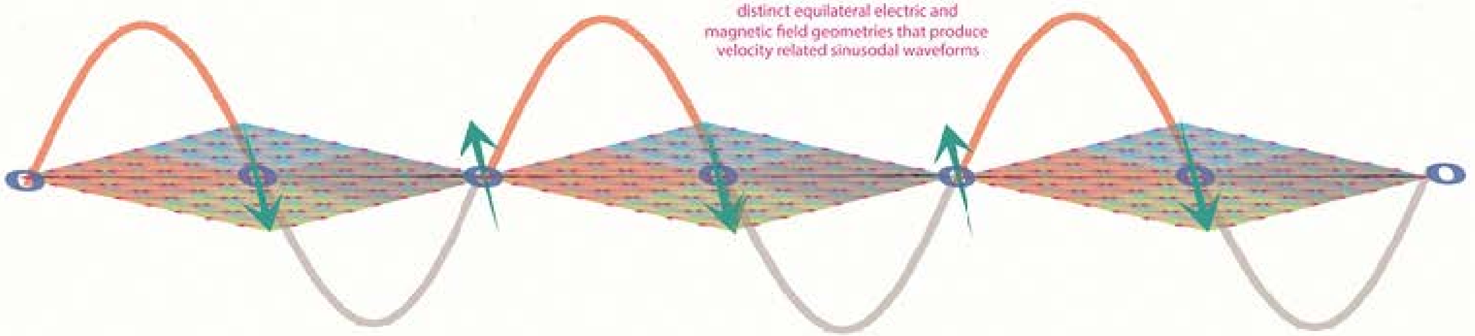

$$\varepsilon = -\frac{d\phi_B}{dt}$$

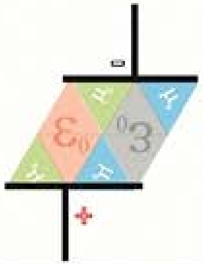

**Charged boson field geometries
can be viewed as transverse
quantum capacitors**

Lenz's law:
***"The emf induced in an electric circuit always acts
in such a direction that the current it drives around
the circuit opposes the change in magnetic flux
which produces the emf."***

**Neutral photon field geometries
can be viewed as longitudinal
quantum batteries**

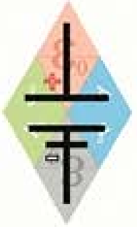

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An electromotive Force results from
the motion of a conductor
relative to a magnetic field

The Moving Magnet problem

A Magnet is really an electrostatic
store of neutralised emf potential differences
[creating an orthagonal Magnetic moment]

The moving magnet and conductor problem
is a famous 19th century thought experiment,
and provides the intersection for classical
and relativistic electromagnetism.

The moving magnet and conductor problem,
along with Michelson-Morley experiment,
formed the basis of Einstein's theory of
special relativity.

Relativistic theory explanation

In the frame of a conductor moving relative to the magnet, the conductor experiences a force due to an electric field.

A Magnetic field is an Electric field viewed in a differing inertial frame

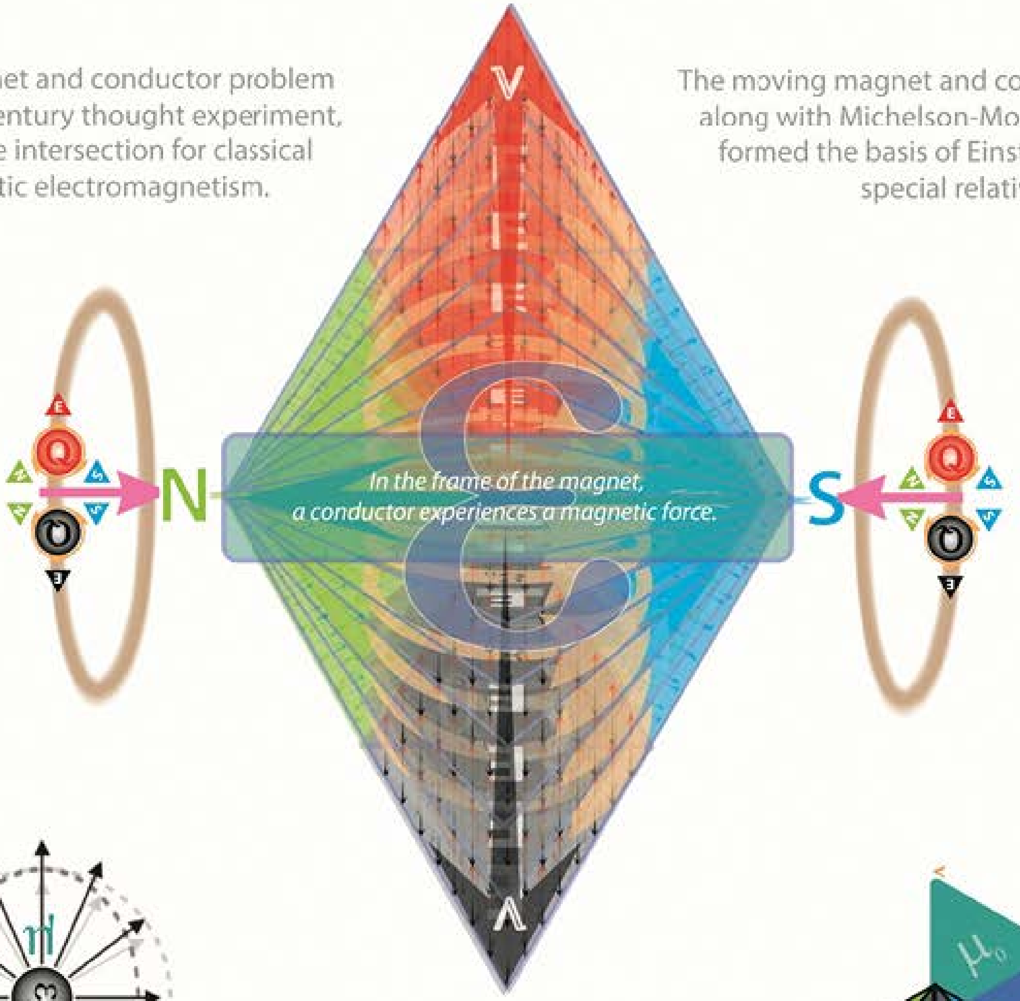

*In the frame of the magnet,
a conductor experiences a magnetic force.*

Tetryonic theory explanation

The conductor moves through continuously changing electric and magnetic field geometries experiencing sinuodal E/M forces that are directly related to each other at all times

Electric and Magnetic fields are discrete geometrically related energies

SR requires that all observers
in inertial frames arrive at the
same form for Maxwell's equations

SR seeks to modify space and time
in a manner such that the forces
and fields transform consistently.

producing expressions that
differ from Newton's law of
motion by a factor of γ

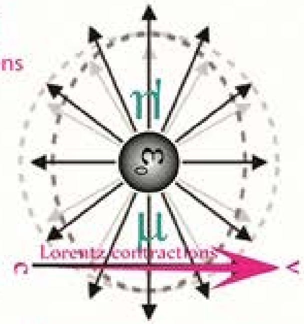

the relativistic distortion of
accelerating spherical point charges
creates magnetic moments

Electrostatic particles have no magnetic moment

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

Electric force

Magnetic force

*Once in motion it posseses a magnetic moment and kinetic enerigies
and is subject to Lorentz forces when it moves throuhg an external EM field*

magnetic moments are
the result of secondary KEM
fields of Matter in motion

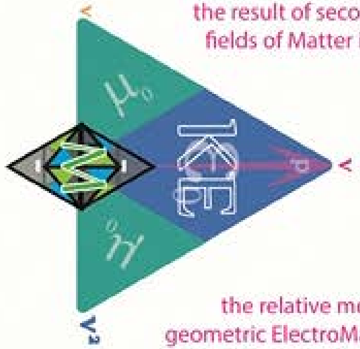

Lorentz corrections
only all to KEM field
mass-energies

the relative motion of
geometric ElectroMagnetic fields
creates changing EM forces

Tetryonics 40.07 - The Moving Magnet problem

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Einstein's Error of perception

rest mass-Matter

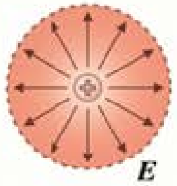

v=0

In its rest frame the electric field of a point charge has the same strength in all directions
and diverges away from the charge.

Electric fields are distorted due to relativistic speed effects to create Magnetic fields
The faster the velocity the greater the Magnetic field
At rest the Magnetic field becomes an Electric field

What led me more or less directly to the special theory of relativity was the convicion that
the electromotive force acting on a body in motion in a magnetic field was nothing else but an electric field

Albert Einstein 1953

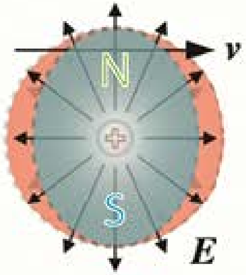

v=.6c

The SR theoretical model of a spherical charged body being relativisitically distorted as the the source of the Magnetic moments for charges in motion is incorrect

Lorentz velocity dependent factors relate only to Kinetic EM mass-energies of motion

M + It is the KEM field mass-energies that produce Magnetic moments in relativistic particles due to the motion of ElectroStatic Matter (12 + loop inductive geometries) = RE

StationaryLeptons are 12pi charged standing waves [Matter] topologies with NO secondary Kinetic EM mass-energies geometries

Matter is Lorentz invariant

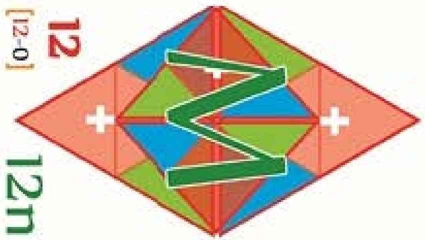

Stationary charges have Electric Fields and neutralised Magnetic fields

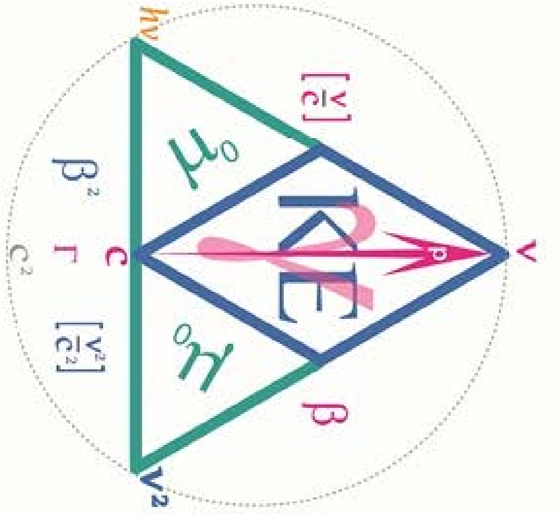

The speed of light in a vacuum [c] is the limit for electrically accelerated particles
Tetryonic geometry reveals it is NOT the limit of acheivable velocities

Moving Leptons are 12pi charged standing waves [Matter] topologies with Kinetic EM mass-energies geometries

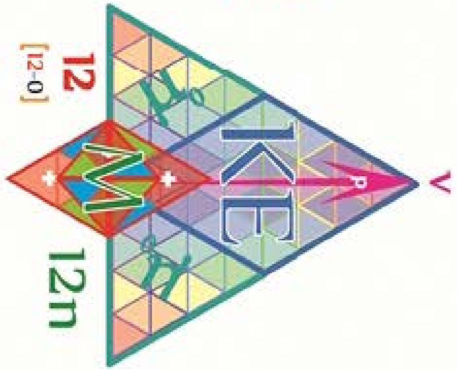

Moving charges have Electric fields and Magnetic moments

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Tetryonic relativistic motion

ε_0

The [K]EM mass-energy content of a particle in motion is velocity dependent
its rest Matter toplogy & charge geometries are velocity invariant

μ_0 μ_0

In a frame in which the particle is at rest, we can detect only electric field

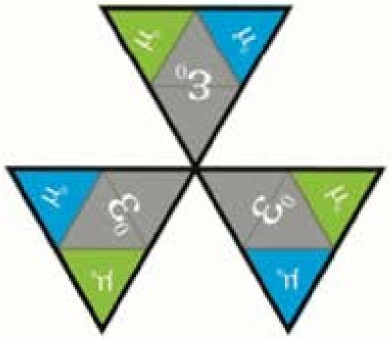

μ_0
μ_0
ε_0 3
μ_0
ε_0
μ_0
μ_0
ε_0
μ_0
μ_0

rest Matter

all Magnetic dipoles are neutral dipole pairs

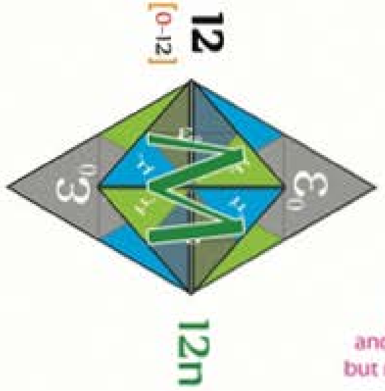

12
[0-12]
ε_0
M
ε_0
12n

Charge is a velocity invariant measure of the quantised angular momenta iof any spatial co-ordinate system

The total EM mass-energy momenta of any particle in motion is velocity dependent and is specific to particular spatial co-ordinate systems

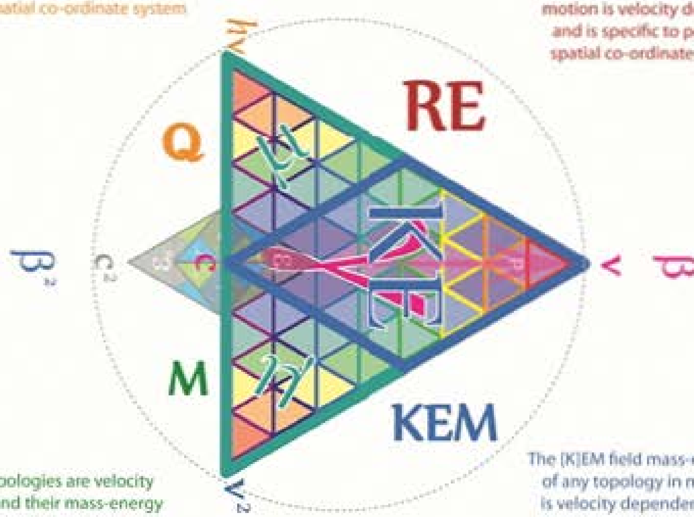

hv
RE
Q
β^2
c^2
KE
v
v
β
M
KEM
v^2

Matter topologies are velocity invariant and their mass-energy content can only be measured in c^4 spatial co-ordinates

The [K]EM field mass-energies of any topology in motion is velocity dependent and subject to Lorentz correction within in its c^2 spatial co-ordinates

It is well demonstrated that the fields of charged particles appear different in different inertial frames

$$Mv^2 = KEM = hv^2$$

Tetryonics has revealed that the Kinetic Electro-Magnetic [KEM] field of a particle in motion has a distinct geometric identity of its own rather than being the relativistic distortion of a charged EM particle

Virtual particles and action-at-a-distance are negatived by Tetryonic KEM field mass-energy momenta and the problem of simultanity is avoided because a second particle responds not directly to the first particle, but rather to the first particle's extended, velocity related [K]EM field generated by its motion at its own position.

In a frame in which the particle is moving, we also see a magnetic field.

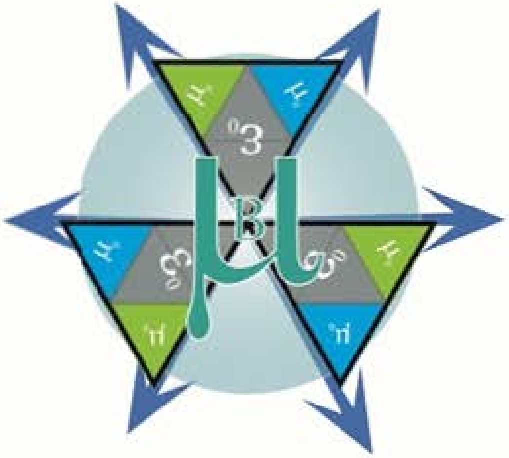

μ_0
μ_0
ε_0 3
μ_B
μ_0
ε_0
ε_0
μ_0
μ_0
μ_0

rest Matter+KEM

relativistic KEM fields produce a secondary magnetic moment

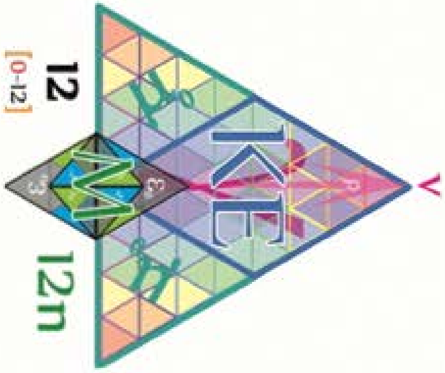

12
[0-12]
μ_0
KE
M
v
μ_0
12n

Quantum level **KEM field**

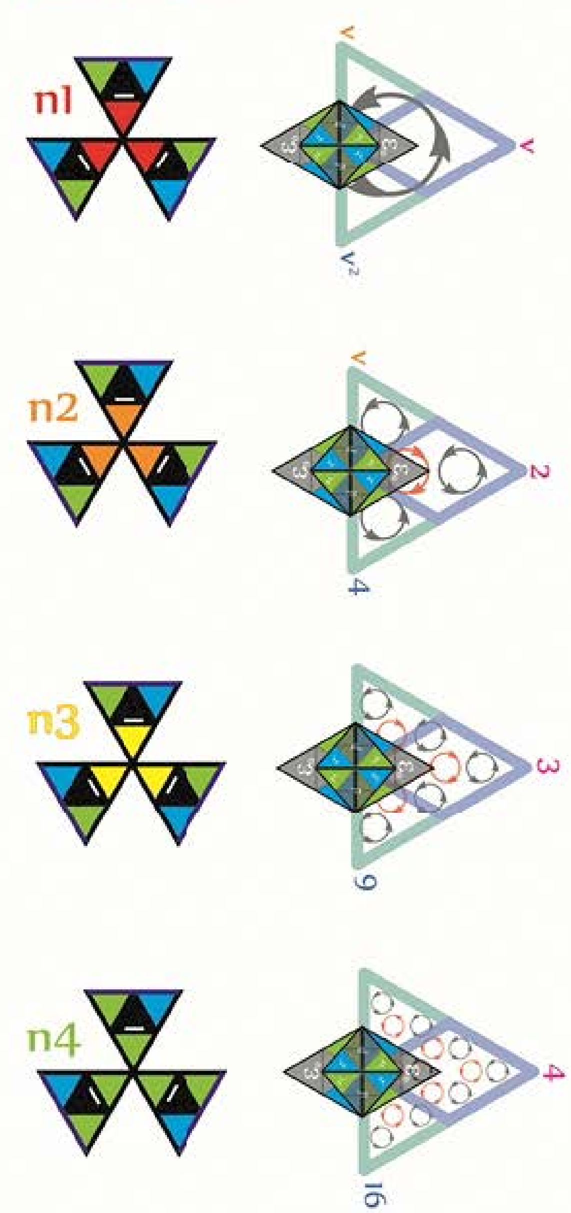

James Clerk Maxwell

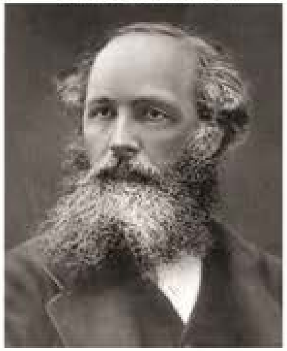

(13 June 1831 – 5 November 1879)

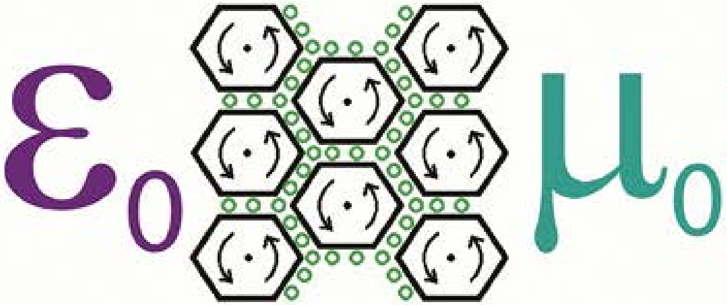

All quantum charge arrangements of EM mass-energy and force fields can be viewed as an arrangement of 'quantum idler wheels

"As early as 1857 Maxwell began to develop the idea of orienting molecular vortices along magnetic field lines, culminating in the publication of his paper 'On physical lines of force'…

He posited a honeycomb of vortices in which each vortex cell was separated from its neighbour by a layer of spherical particles, revolving in the opposite direction to the vortices.

These 'idler wheel' particles communicated the rotatory velocity of the vortices from one part of the field to another. In this ether model, the most famous image in nineteenth-century physics, the analogy provides mechanical correlates for electromagnetic quantities. The angular velocity of the vortices corresponds to the magnetic field intensity, and the translational flow of the idle wheel particles to the flow of an electric current; the field equations are based on the rotation of molecular vortices in the ether.

He emphasized that while the theory was mechanically conceivable, the model itself was provisional and temporary, even awkward, hardly 'a model of connexion existing in nature'

KEM field **Quantum level**

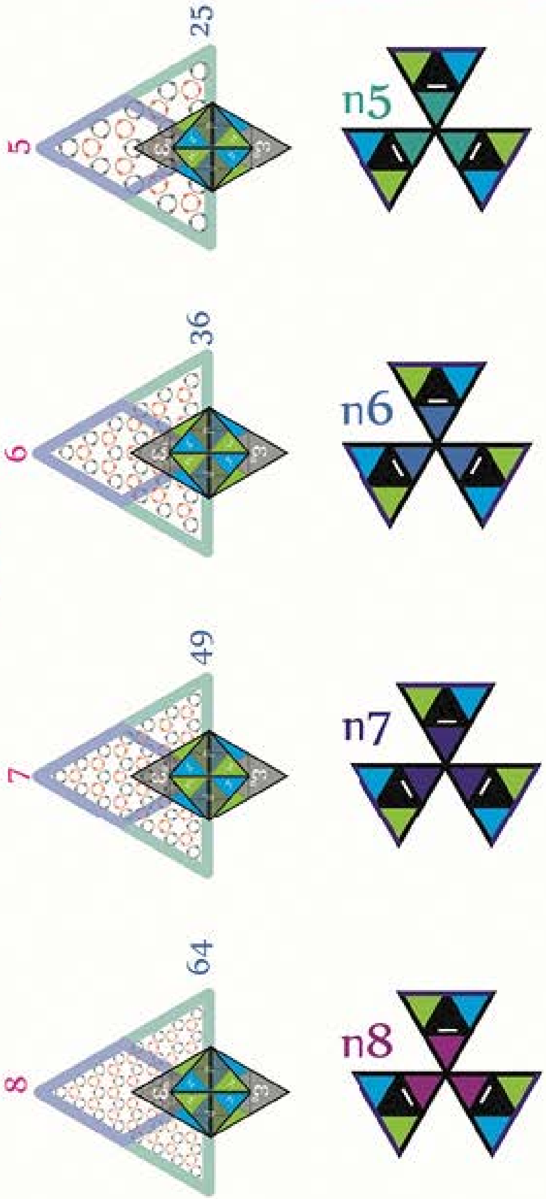

Equating Equilateral geometries to Quantised Angular Momentum reveals a classical mechanical model closely resembling Maxwell's hypothesised idler wheels that be be applied to any EM field of force

Virtual Particles

In physics, a virtual particle is a particle that exists for a limited time and space, it has become a commonplace mechanism in current Physical theories to provide a basis for the Force interactions between particles

Original Feymar diagram illustrating the exchange of a quantum between 2 electrons

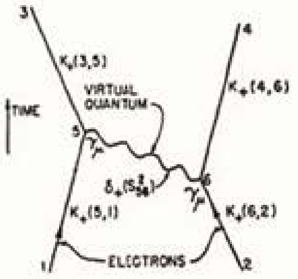

$$m^2c^4 = E^2 - p^2c^2$$

is in-correct for superpositioned 2D KEM fields the real interaction geometry is illustrated below:

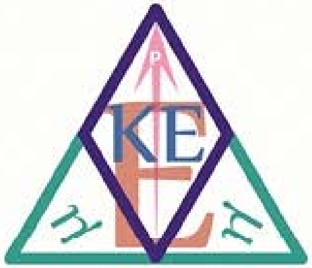

$$mv^2 = E = pv$$

Bohr understood that if you are going to try to be mechanical, you have to show some convincing mechanics.

If you can't show some convincing mechanics, you might as well dodge all mechanics from the beginning, staying with the math.

He had learned this from Maxwell, who had done the same thing 60 years earlier.

In the 1860's, Maxwell had tried to create vortices to explain the field mechanics, but, finding himself under heavy fire from Lord Kelvin and others, he decided to give it up and go to other mathematical alternatives like quaternions instead.

$$\frac{m\Omega^2 v^4}{2} = KE^2 = \frac{p^2v^2}{2}$$

The energy and momentum of a virtual particle are uncertain according to the uncertainty principle.

$$m^2v^4 = E^2 = p^4$$

The degree of uncertainty of each is inversely proportional to time duration (for energy) or to position span (for momentum).

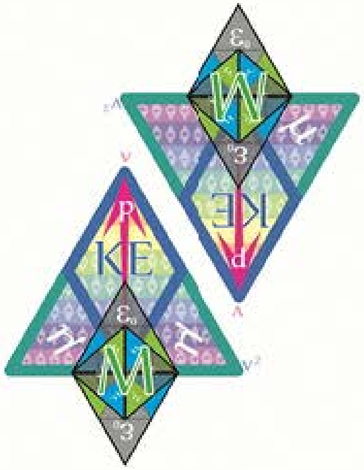

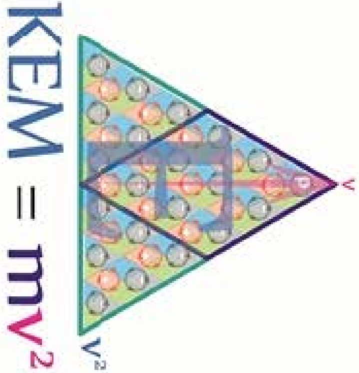

Superpostioned EM interaction fields

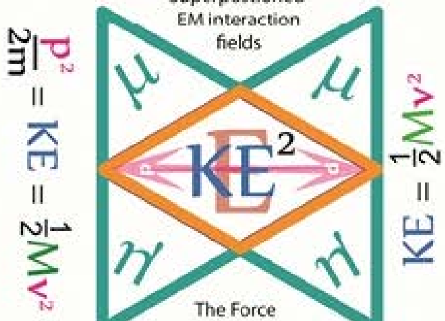

$$\frac{p^2}{2m} = KE = \frac{1}{2}Mv^2$$

$$KE = \frac{1}{2}Mv^2$$

The Force is the geometric mean of the superpositioned [KE] fields

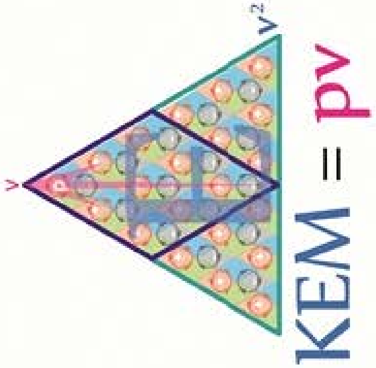

The equilateral energy geometry of Tetryonics clears up this issue once and for all, virutal particles do NOT exist. The Force interactions between all Matter in relative motion is mediated by the equilateral geometries of [K]EM mass-ENERGY momenta that spread out from their source Matter through Space-time

Equilateral geometry - the Hidden Constant

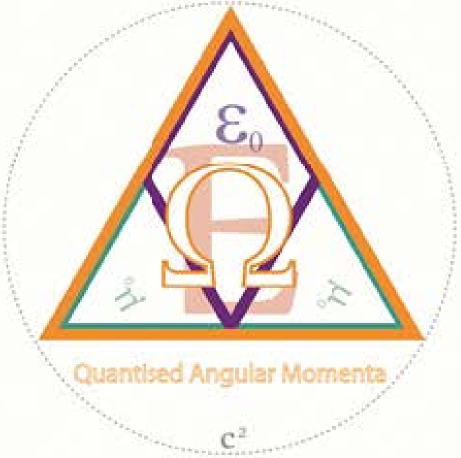
ε_0
Quantised Angular Momenta
c²

$$\overset{kg}{m}\,\Omega\,\frac{m^2}{s} = h \quad kg\,\frac{m^2}{s}$$

Quantised Angular Momenta has an equilateral geometry

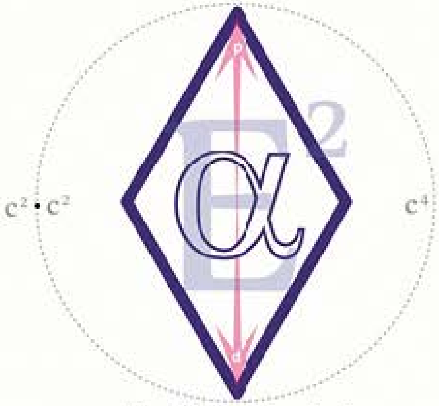

The Alpha Constant

$$1\pi\left[\left[\varepsilon_0\mu_0\right].\left[m\Omega v^2\right]\right]$$

Charge
EM Field
Planck quanta
ElectroMagnetic
mass
velocity

Tetryonics has revealed the equilateral relationships between Charge, Planck energies and the Constants showing quantised angular momentum to be the 'hidden' geometric constant driving the physics of our Universe on all scales

Alpha is the geometric coupling constant between Magnetic and Electrical energies that acts as a scaling constant between Kinetic and Potential quantum energies

It is the source of the quantum charges of all EM mass-energy momentum & inertia

Classically modelled as a 'rotational' vector Quantised Angular Momentum is in fact an Equilateral geometry

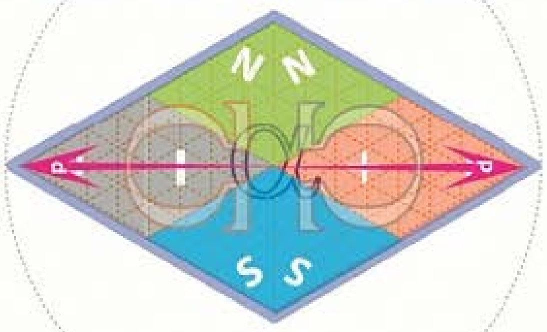

Photons are dual equilateral geometries creating a neutral charge with two opposed coupling constants

c²

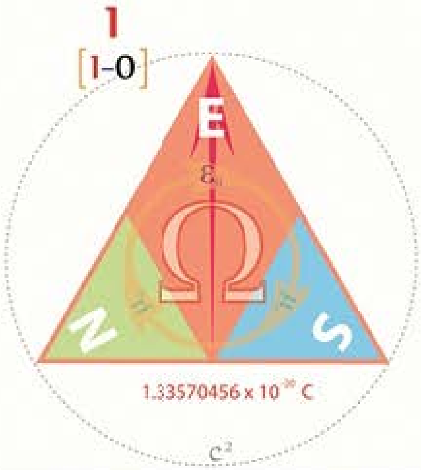
1
[1-0]
E
ε_0
Ω
N
S
$1.33570456 \times 10^{-20}$ C
c²

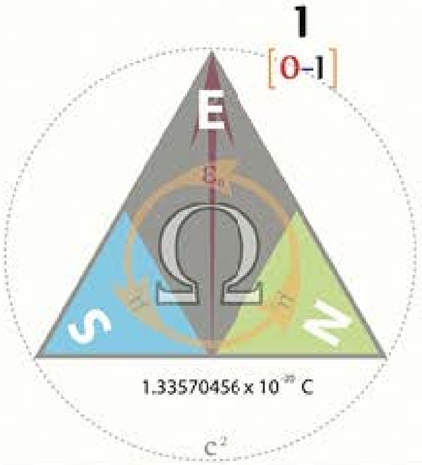
1
[0-1]
E
ε_0
Ω
S
N
$1.33570456 \times 10^{-20}$ C
c²

Quantised Angular Momenta creates charged EM mass-energies

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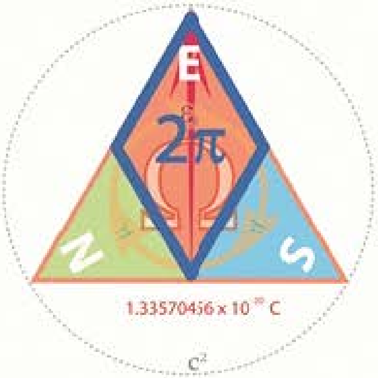

.0012

2π

.007539822

$$\alpha = \frac{e^2}{\hbar c}$$

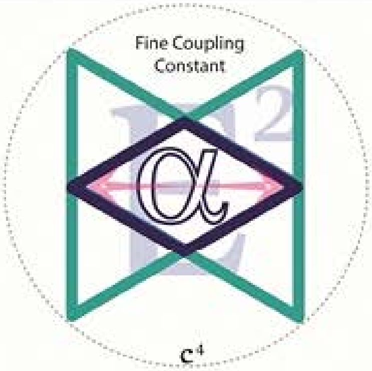

$$\alpha = \frac{e^2}{\hbar c\, 4\pi\varepsilon_0}$$

$7.297\,352\,5376(50) \times 10^{-3}$

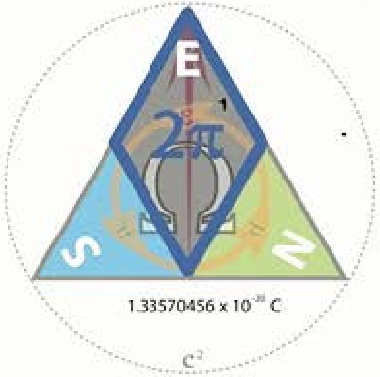

132.6291192^{-1}

The ALPHA Constant is the scalar coupling field of quantised energy momenta in superpositioned EM fields that facilitates Force (linear energy momenta) exchanges, resulting in the familiar Laws of Attraction/Interaction

$$= \frac{1}{137.035\,999\,679}$$

In physics, the fine-structure constant
is a fundamental physical constant,
namely the coupling constant characterizing
the strength of the electromagnetic interaction.

The numerical value of α is the same
in all systems of units, because α is a
dimensionless quantity.

There is a most profound and beautiful question associated with the observed coupling constant,
e the amplitude for a real electron to emit or absorb a real photon.
It is a simple number that has been experimentally determined to be close to 0.08542455.

It has been a mystery ever since it was discovered more than fifty years ago,
and all good theoretical physicists put this number up on their wall and worry about it.

Immediately you would like to know where this number for a coupling comes from:
is it related to pi or perhaps to the base of natural logarithms? Nobody knows.
It's one of the greatest damn mysteries of physics: a magic number that comes to us with no understanding by man.

We know what kind of a dance to do experimentally to measure this number very accurately,
but we don't know what kind of dance to do on the computer to make this number come out, without putting it in secretly

Richard Feynman

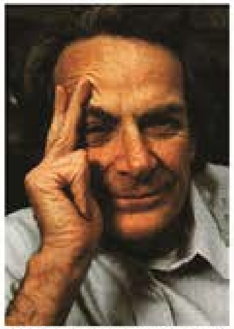

(May 11, 1918 - February 15, 1988)

Superpositioned Fields

equilateral energies

.0012 m²/s

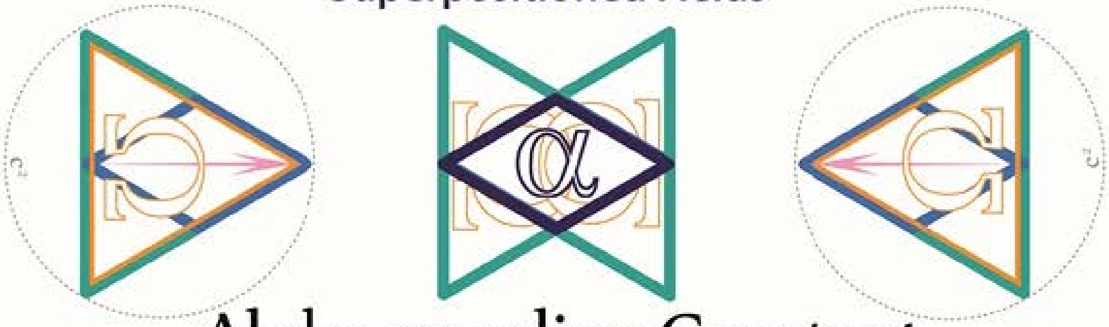

0.007539822

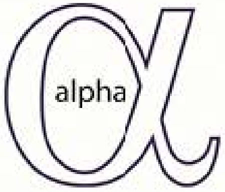

132.6291192^{-1}

Alpha coupling Constant

You might say the "Hand of GOD" wrote that number, but "we don't know how HE pushed his pencil."

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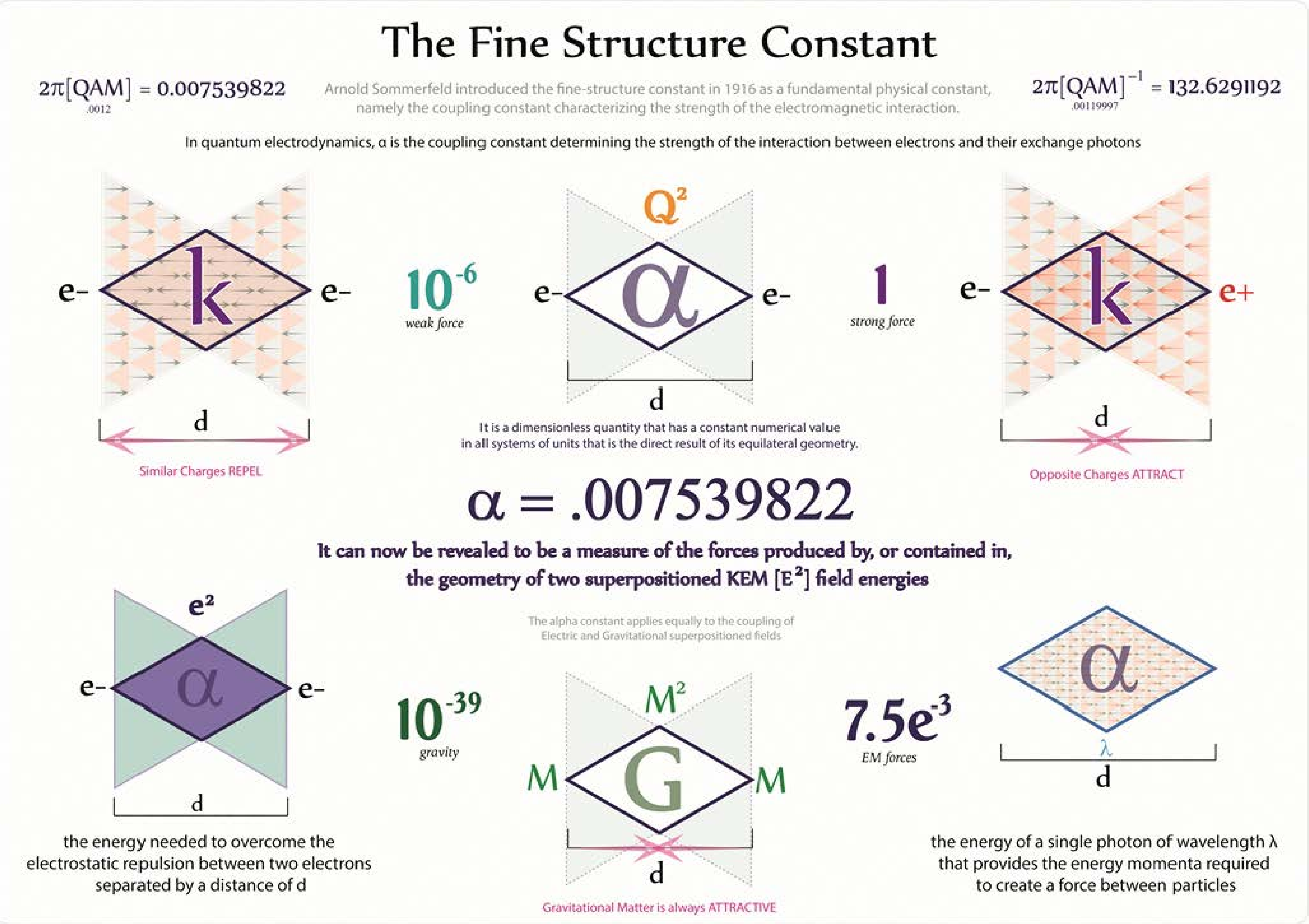

The Fine Structure Constant

$2\pi[QAM]_{.0012} = 0.007539822$

Arnold Sommerfeld introduced the fine-structure constant in 1916 as a fundamental physical constant, namely the coupling constant characterizing the strength of the electromagnetic interaction.

$2\pi[QAM]^{-1}_{.00119997} = 132.6291192$

In quantum electrodynamics, α is the coupling constant determining the strength of the interaction between electrons and their exchange photons

e-
k
e-
d
Similar Charges REPEL
10^{-6}
weak force
Q^2
e-
α
e-
d
1
strong force
e-
k
e+
d
Opposite Charges ATTRACT

It is a dimensionless quantity that has a constant numerical value in all systems of units that is the direct result of its equilateral geometry.

$$\alpha = .007539822$$

It can now be revealed to be a measure of the forces produced by, or contained in, the geometry of two superpositioned KEM $[E^2]$ field energies

The alpha constant applies equally to the coupling of Electric and Gravitational superpositioned fields

e^2
e-
α
e-
d
10^{-39}
gravity
M^2
M
G
M
d
Gravitational Matter is always ATTRACTIVE
$7.5e^{-3}$
EM forces
α
λ
d

the energy needed to overcome the electrostatic repulsion between two electrons separated by a distance of d

the energy of a single photon of wavelength λ that provides the energy momenta required to create a force between particles

Tetryonics 40.14 - The Fine Structure Constant

Coupling Constants

$$k\frac{Q_1Q_2}{r^2}=F$$

Coulomb's [k], the Fine structure constant [α] and Newton's [G] are all reflections of the same coupling constant geometries differing only by the strength of their respective superpositioned energy field densities

$$F=-G\frac{M_1M_2}{r^2}$$

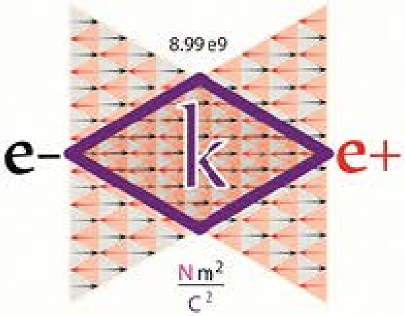

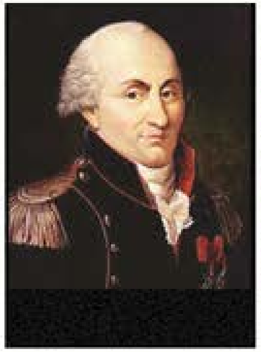

Coulomb's constant

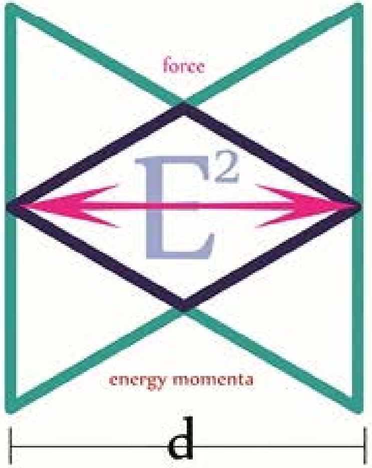

Newton's constant

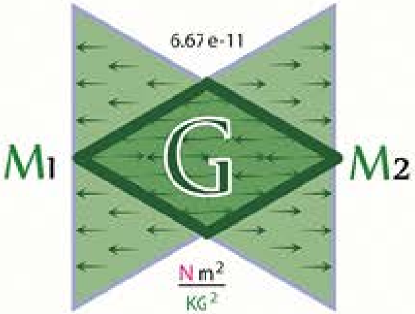

$$\beta=\left[\frac{v}{c}\right]$$

Linear force coupling constant

Coupling Constants
are dimensionless
numbers

In physics, a coupling constant is a number that determines the strength of an interaction for superpositioned Electrical or Gravitational fields between material objects

$$\beta^2=\left[\frac{v^2}{c^2}\right]$$

Scalar energy coupling constant

They are reflective of the linear &
scalar forces produced by
2D mass-energies

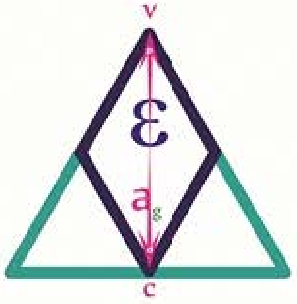

$$\frac{m}{s}\cdot\frac{s}{m}$$

electric charge coupling

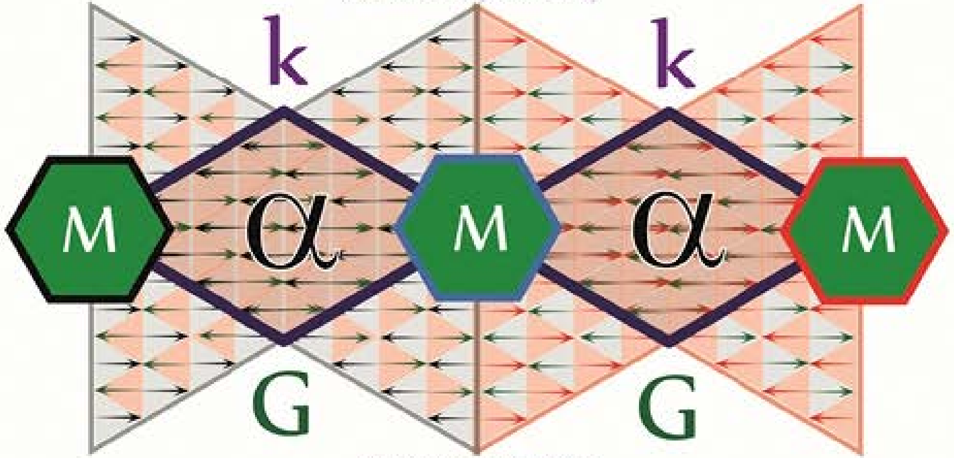

gravitational coupling

Usually the Lagrangian or the Hamiltonian of a system can be separated into a kinetic part and an interaction part.
[For example, the electric charge of a particle is an Electrical coupling constant]

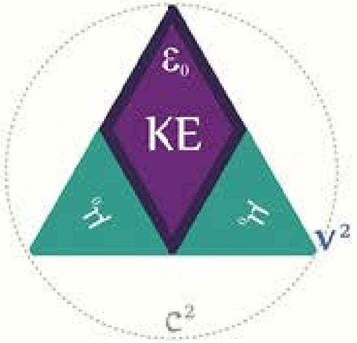

$$\frac{m^2}{s^2}\cdot\frac{s^2}{m^2}$$

Tetryonics 40.15 - Coupling Constants

Opposites
ATTRACT

ElectroMagnetic Charge

[the universal coupling constant]

Similars
REPEL

1.33518 e-20 C

Q

1.33518 e-20 C

Electric charge is a physical property of matter that causes it to experience a force when near other electrically charged matter.
Electric charge comes in two types, called positive and negative

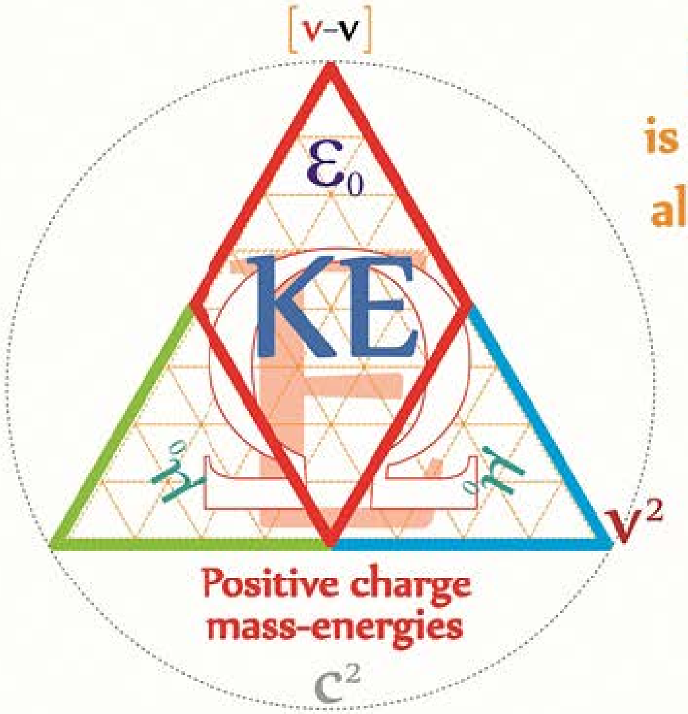

ElectroMagnetic CHARGE
is the equilateral foundation to
all the quantum geometries of
mass-ENERGY-Matter

$$\frac{m\,\Omega\,v^2}{c^2}$$

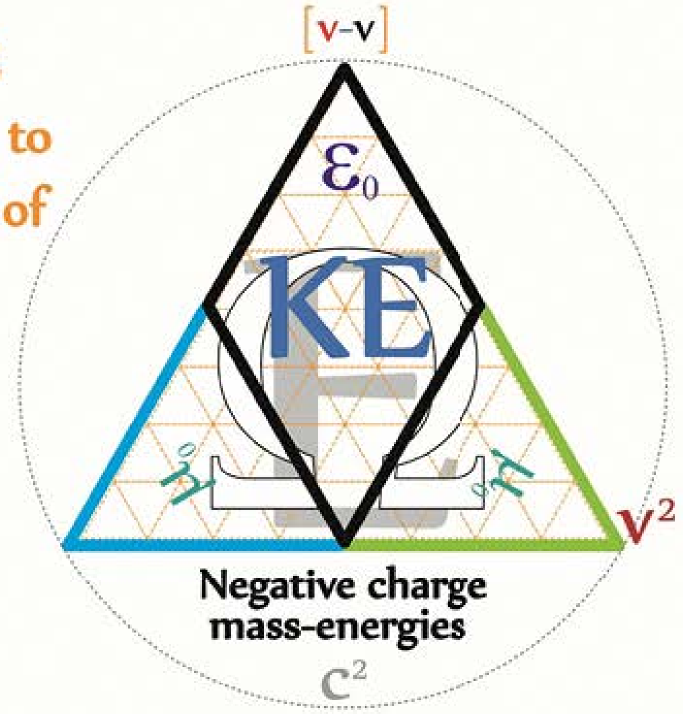

seconds

Changing charge geometries are equivalent to TIME in relativity

seconds

The electric charge is a fundamental conserved property of all subatomic particles, which determines their electromagnetic interaction.
The interaction between a moving charge and an electromagnetic field is the source of the electromagnetic force, which is one of the four fundamental forces

The equilateral geometry of Planck energies creates CPT symmetries in physics,
and provides the foundation for all Matter geometries and their fields of interaction

Tetryonics 40.16 - Charge the universal Coupling Constant

Einstein–Podolsky–Rosen paradox

was a thought experiment that attempted to challenge the Copenhagen interpretation of Quantum physics

Tetryonics provides a complete model of all Energy forms and Wave-Particle interactions, allowing a clear understanding of previously mysterious actions and processes in Quantum Mechanics

Albert Einstein

(14 March 1879 – 18 April 1955)

Showing that it is possible to know the both Position and Momenta of Particles and to model EM wave geometries and interactions in Quantum Physics

Boris Yakovlevich Podolsky

(1896–1966)

Δx

Δp

Nathan Rosen

(March 22, 1909 – December 18, 1995)

The EPR experiment involved two systems that initially interact with each other and are then allowed to separate before being measured.

Measuring the Position of the Electron determines the Position of the Positron

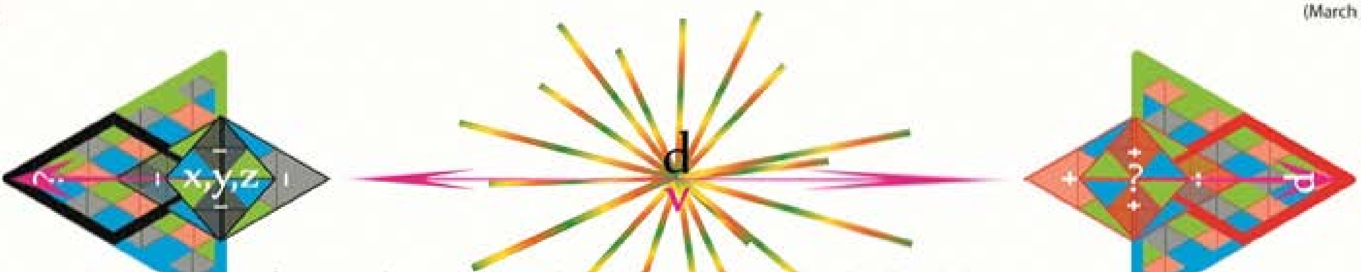

Measuring the Momentum of the Positron determines the Momentum of the Electron

Quantum entanglement occurs when particles such as photons, electrons, etc interact physically and then become separated; this type of interaction is such that each resulting member of a pair is properly described by the same quantum mechanical state, which is indefinite in terms of important factors such as position, momentum, spin, polarization, etc

The EPR paper shows that measuring one feature of a entangled system, e.g., the momentum of one of the pair of particles, will reveal the same feature of the other particle - thus providing a mechanism for determining both the momentum and position of both particles simultaneously

Thus providing a theoretical indication that either the Uncertainty Principle was incorrect or that our understanding of Quantum Mechanics was incomplete

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Spooky interactions-at-a-distance & the transfer of information

Quantum entanglement is sasid to occur when particles such as photons, electrons, and other forms of EM mass-energies interact physically and then become separated;
the type of interaction is such that each resulting member of a pair is properly described by the same quantum mechanical description (state),
which is indefinite in terms of important factors such as position, momentum, spin, polarization, etc.

Through the equilateral geomtry of Tetryonics the mass-energy-Matter of any system of particles can be modelled in order to reveal the true EM mechanics of their quantum interactions

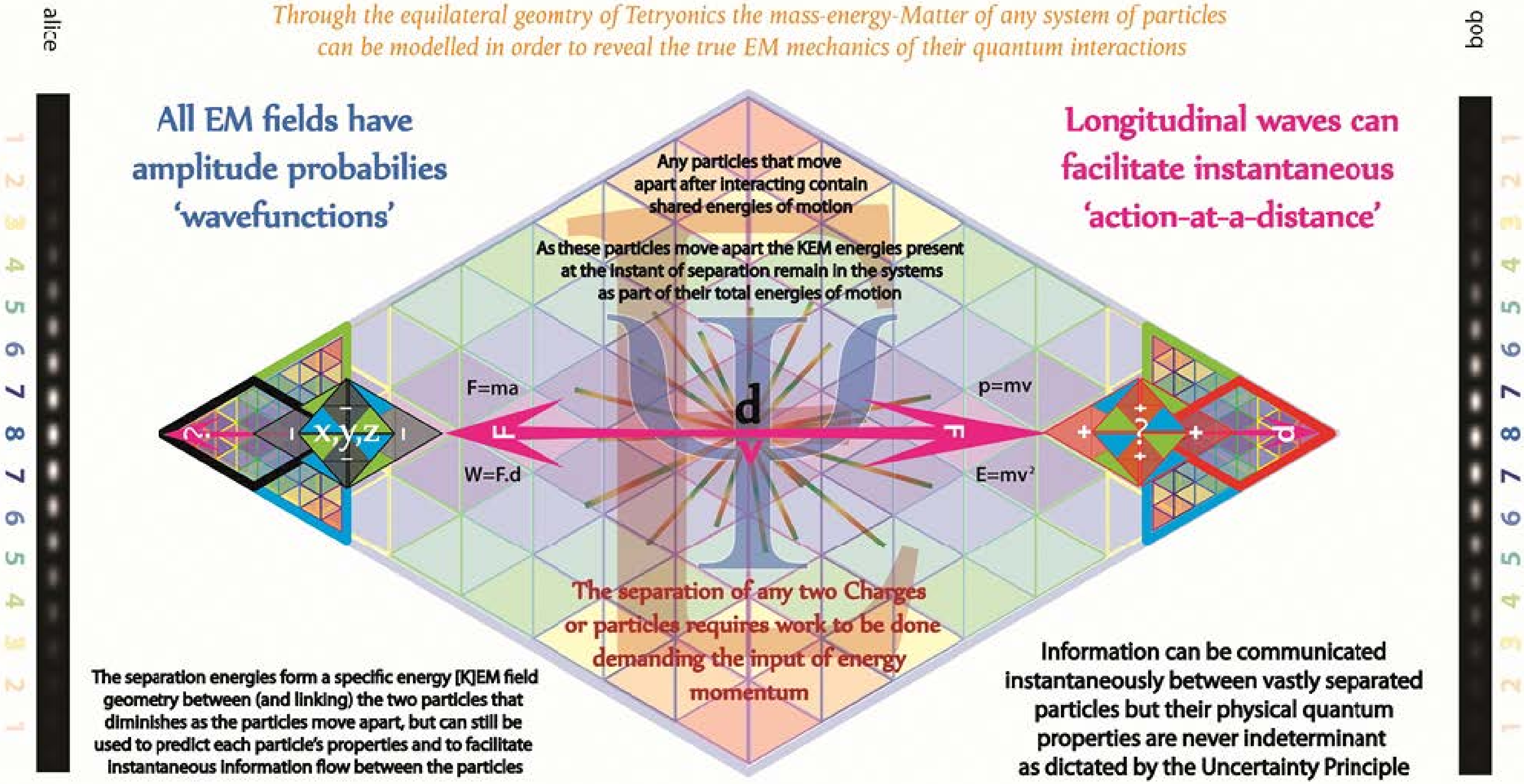

All EM fields have amplitude probabilies 'wavefunctions'

Longitudinal waves can facilitate instantaneous 'action-at-a-distance'

Any particles that move apart after interacting contain shared energies of motion

As these particles move apart the KEM energies present at the instant of separation remain in the systems as part of their total energies of motion

The separation of any two Charges or particles requires work to be done demanding the input of energy momentum

The separation energies form a specific energy [K]EM field geometry between (and linking) the two particles that diminishes as the particles move apart, but can still be used to predict each particle's properties and to facilitate instantaneous information flow between the particles

Information can be communicated instantaneously between vastly separated particles but their physical quantum properties are never indeterminant as dictated by the Uncertainty Principle

When two entangled particles are separated using longitudinal energies, the energy momenta of separation provides a mechanism for the establishment and near-instantaneous communication of the physical wavefunction/properties of one particle to the other, irrespective of the spatial or temporal [space-time] separation of the two 'entangled' partner particles

Spectral line differentials

$$\Delta hv = \Delta Mv = \Delta p$$

changes to energy momenta

accelerate photo-electrons

$$\frac{1}{\lambda} = \frac{R_H}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Ryberg's formula is
a mathematical description
of Tetryonic energy geometry

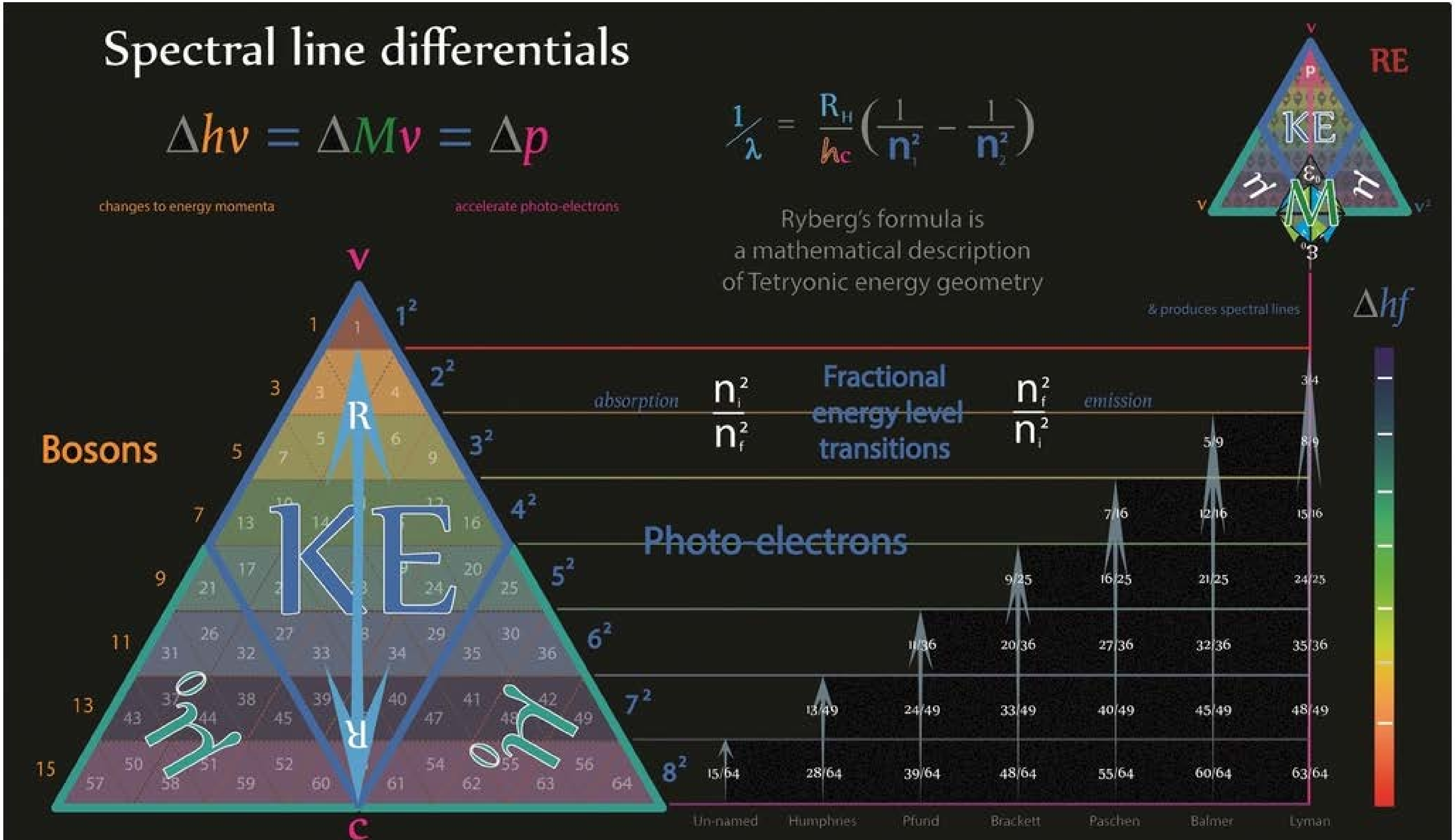

& produces spectral lines

absorption $\frac{n_i^2}{n_f^2}$

Fractional energy level transitions

$\frac{n_f^2}{n_i^2}$ emission

Photo-electrons

	Un-named	Humphries	Pfund	Brackett	Paschen	Balmer	Lyman
2^2							3/4
3^2						5/9	8/9
4^2					7/16	12/16	15/16
5^2				9/25	16/25	21/25	24/25
6^2			11/36	20/36	27/36	32/36	35/36
7^2		13/49	24/49	33/49	40/49	45/49	48/49
8^2	15/64	28/64	39/64	48/64	55/64	60/64	63/64

Ryberg's constant reflects the changing
energy momentum of a transitioning electron

$$Mv^2 = KEM = hcR$$

*All of the transitions of photo-electrons
bound into a Hydrogen atom can be
revealed in the fractional geometry
of KEM field energies*

KEM field energies

Tetryonics 40.19 - Spectral line differentials

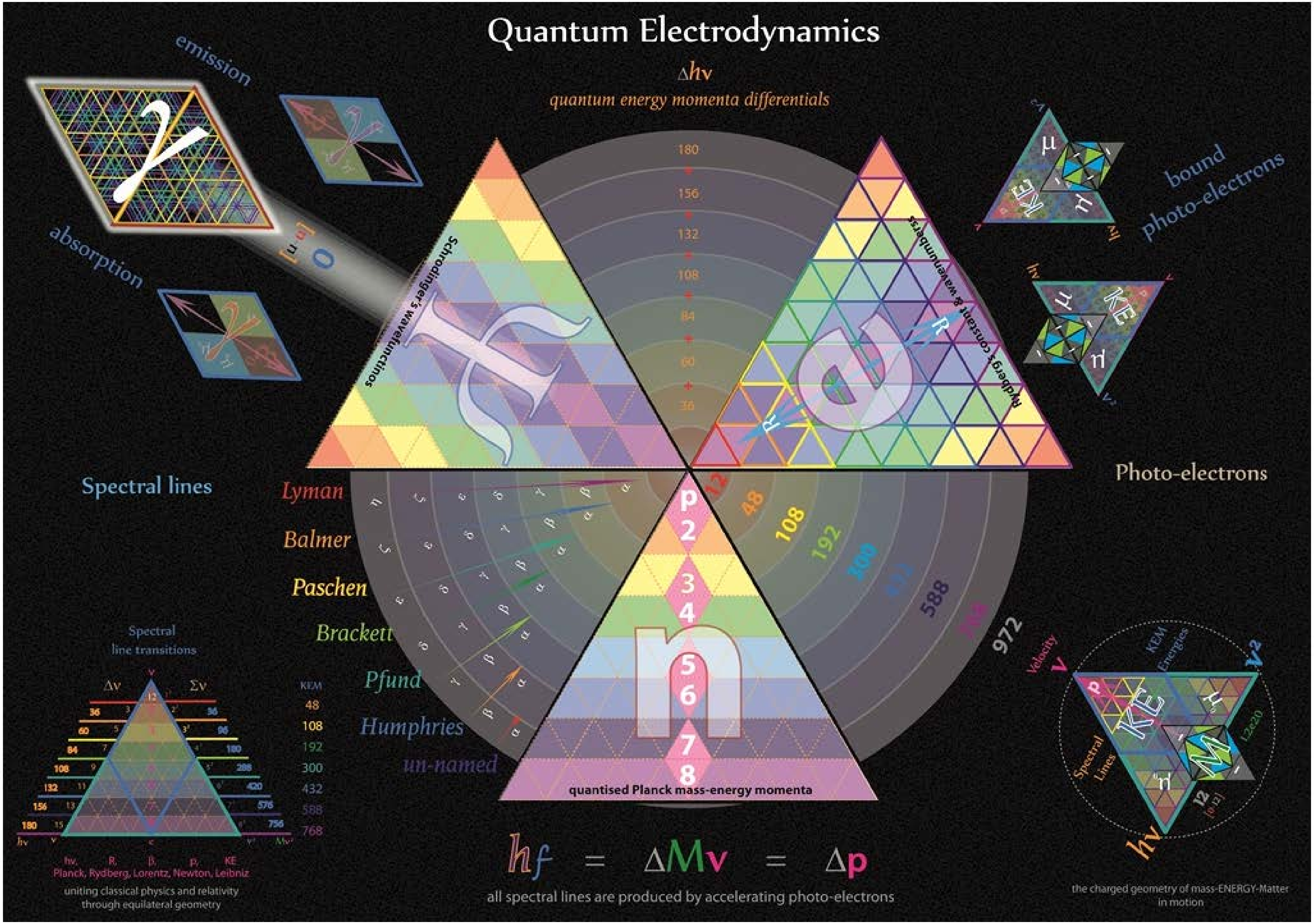

Quantum Electrodynamics

Δhv

quantum energy momenta differentials

emission
absorption
Schrodinger's wavefunctions
Rydberg's constant & wavenumbers
h
R
p
n
bound photo-electrons
μ
KE
Photo-electrons
Spectral lines
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
180
156
132
108
84
60
36
12
48
108
192
300
432
588
768
972
p
2
3
4
5
6
7
8
quantised Planck mass-energy momenta
Spectral line transitions
Δv
Σv
KEM
48
108
192
300
432
588
768
hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz
Velocity v
KEM Energies
v²
Spectral Lines
12
hv

$$hf = \Delta Mv = \Delta p$$

all spectral lines are produced by accelerating photo-electrons

uniting classical physics and relativity through equilateral geometry

the charged geometry of mass-ENERGY-Matter in motion

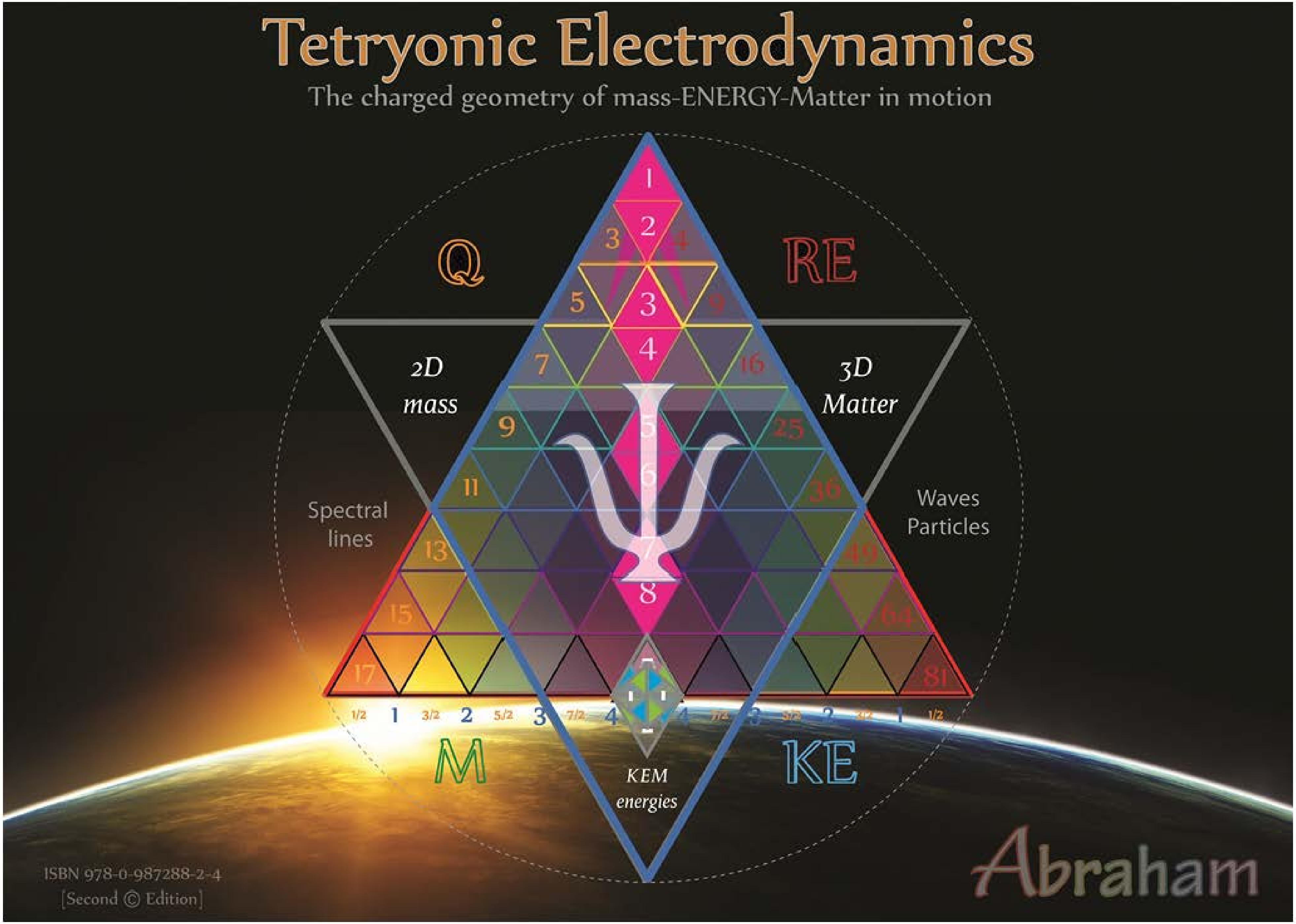
Tetryonic Electrodynamics
The charged geometry of mass-ENERGY-Matter in motion
Q
RE
2D
mass
3D
Matter
Spectral
lines
Waves
Particles
1
2
3
4
5
6
7
8
3
5
7
9
11
13
15
17
4
9
16
25
36
49
64
81
1/2
1
3/2
2
5/2
3
7/2
4
4
7/2
3
5/2
2
3/2
1
1/2
M
KE
KEM
energies
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Tetryonics 40.21 - Quantum Electro-Dynamics

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TETRYONICS

The charged topology of periodic & compound Matter

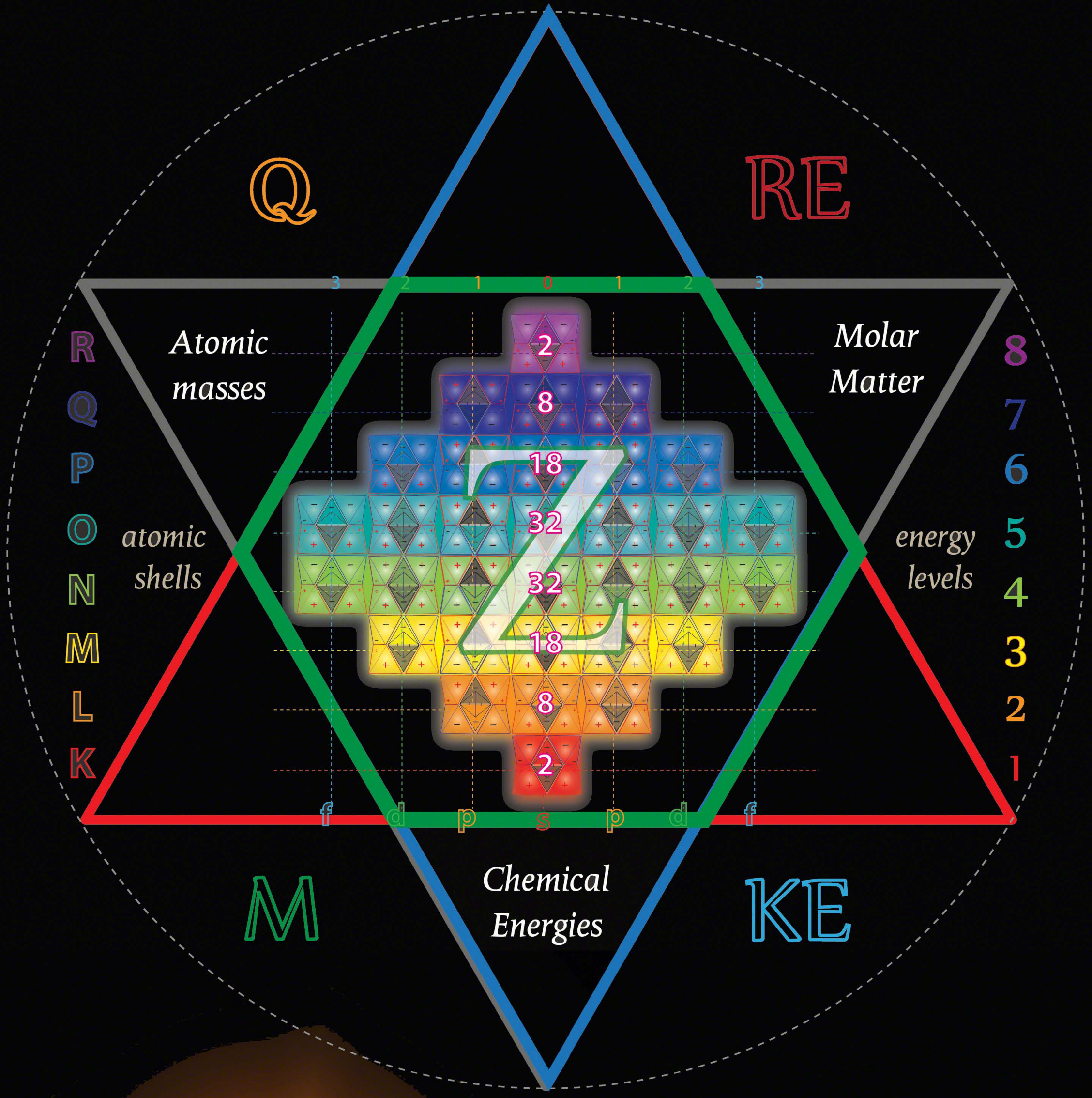
Q
RE
3
2
1
0
1
2
3
Atomic masses
Molar Matter
R
Q
P
O
N
M
L
K
atomic shells
8
7
6
5
4
3
2
1
energy levels
2
8
18
32
32
18
8
2
Z
f
d
p
s
p
d
f
M
KE
Chemical Energies

Foundational Quantum Chemistry

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Protons + *Neutrons*

u+d+u **d+u+d**

All electrons, quarks and Baryons are made up of 4n+ (Tetryonic) standing-wave EM fields.

As well as having nett Tetryonic charged topologies ranging between [+24] ~ [-12] they all posses distinct ELECTRIC FIELDS that are concentrated in 3 apex points as indicated in the illustrations

These points result from the orientation of Electric apexes and orthagonal Magnetic dipole field edges that make up each particle's externalised EM fields.

The Positive and Negative electric apex points, obey the Law of Interaction forcing separated nuceli to combine due to their individual nett Tetryonic charges and provide a means of orienting nuclei to each other to create larger particles [elements, allotropes and compounds]

External Magnetic (H) fields can interact with the integral magnetic (B) dipoles of Tetryonic particles forcing them to orientate in specific directions to facilite chemical bonding [nuclear forces]

Additionally, external Electric fields can interact with the integral electric fields attracting or repelling them depending on the polarity of the external electric field [Electrostatics]

External energies can be induced into these integral EM fields via inductive coupling or the absorption of spectral photons in turn leading to an increase in the strengthes of the integral EM apexes in turn increasing the Strong Nuclear Force.

Residual Electro-Magnetic Forces

allow Neutrons and Protons to attract via the opposite Electric charge points created by their constituent Quarks in order to create Elementary Nuclei

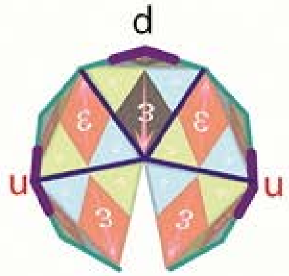

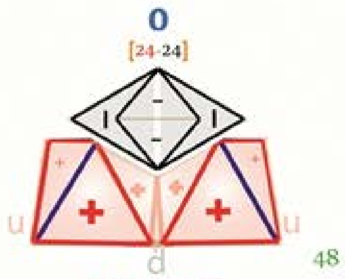

Hydrogen

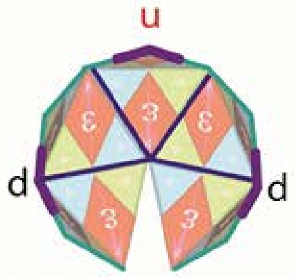

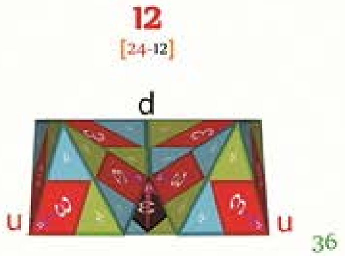

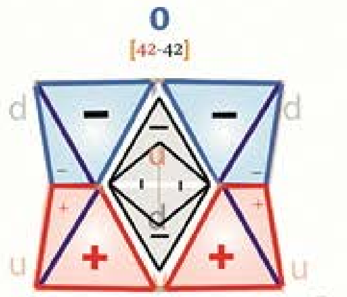

Deuterium

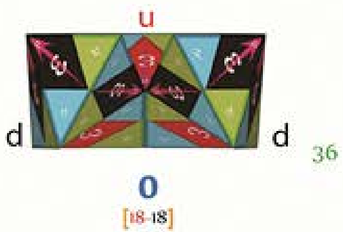

The Strong Nuclear force binds Matter together

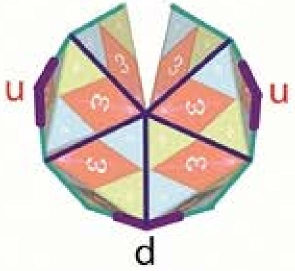

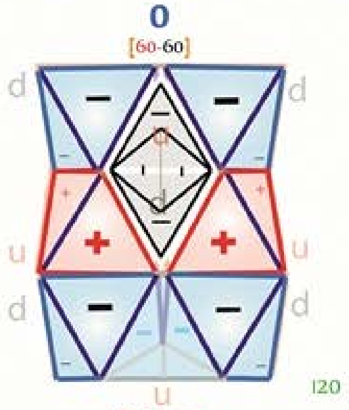

Tritium

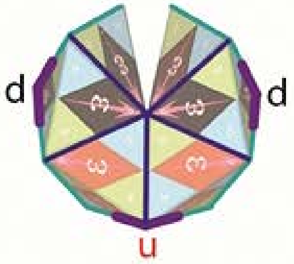

The orientation of the component Electric fields within 3D Matter creates macroscopic force apexes via externalised 'E-points'

The orientation of the component Magnetic fields within 3D Matter creates macroscopic force apexes via externalised 'M-dipoles'

Nucleonic residual EM force

Neutrons

Protons

The attraction between Baryonic E&M field apexs, a result of their component Quark arrangements, results in the formation of heavier and more complex Nuclei

The residual e-field apexes and m-field dipoles form two rings of residual EM fields around the circumference of atomic nuclei

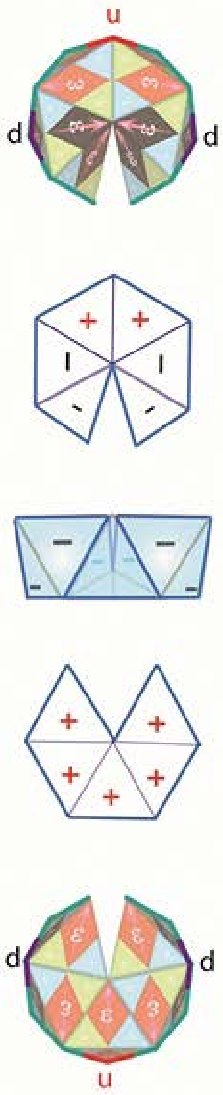

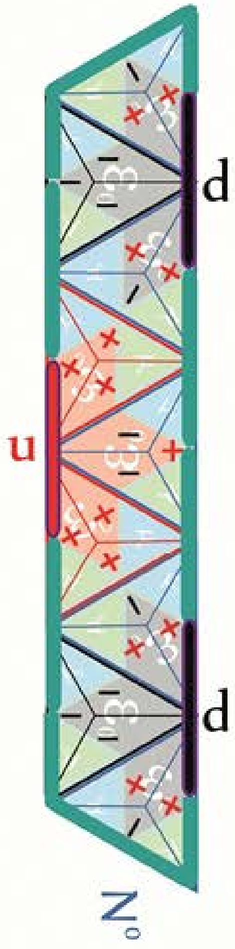

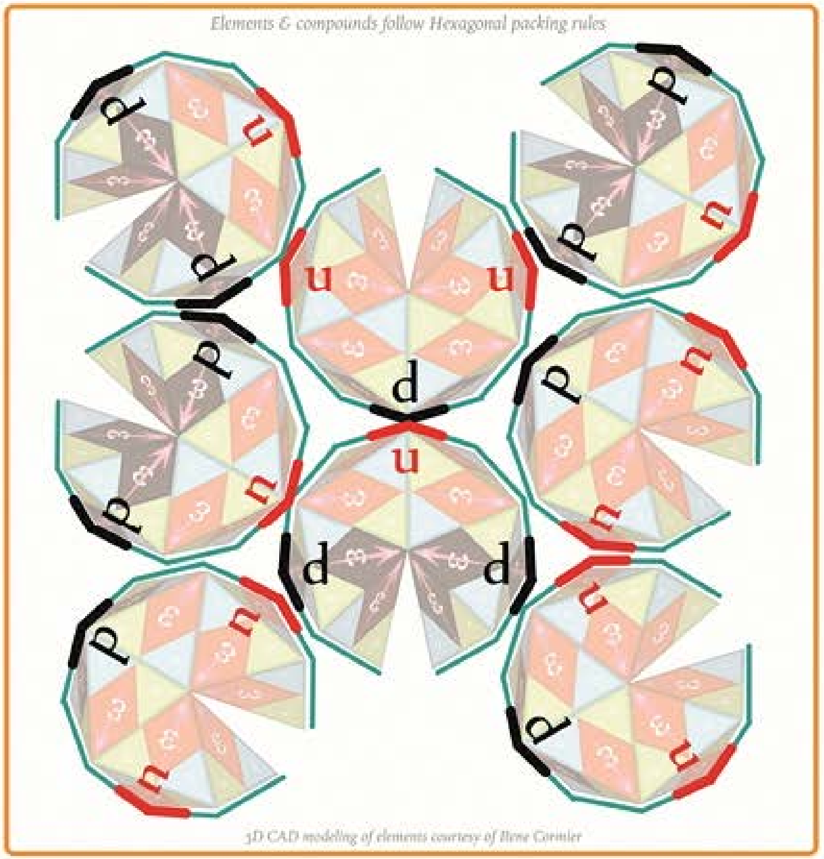
Elements & compounds follow Hexagonal packing rules

3D CAD modeling of elements courtesy of Ilene Cormier

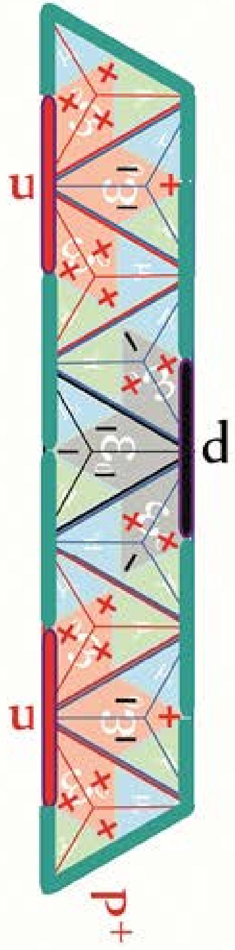

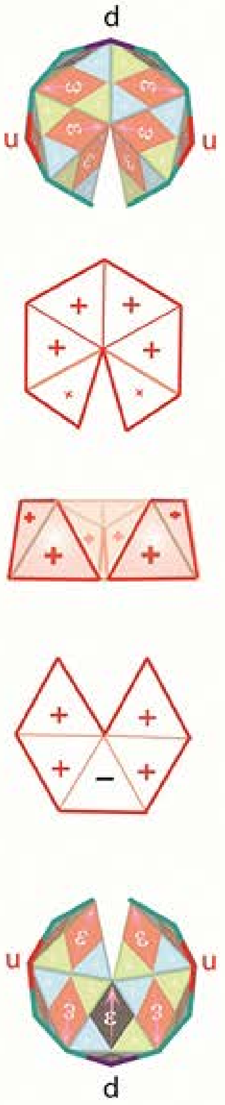

E-field apexes and their polarities highlight the quark alignment of all atomic nuclei and elements

UP Quark
Positive Electric field apex

DOWN Quark
Negative Electric field apex

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Insulators and Conductors

The position of electrons in Nuclei within Atomic Elements
results in the properties of Insulators or Conductors

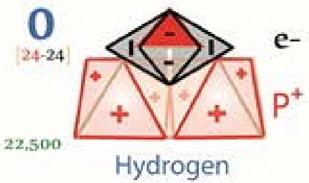
0
[24-24]
e-
P+
22,500
Hydrogen

Coloumbic forces

*Electrons are attracted to the residual EM
net (+12) positive charge of Protons or
n[+12] unbalanced Ionic charges of nuclei*

Conductor

Electrical energies move around
the material via boson exchanges
and electron movement

Insulator

Electrical energy is fixed within the nucleus
as electrostatic charges & released upon demand
via electron rotation/motion within the nucleus

Ions

Charge (energy) is moved around
material via electron movement

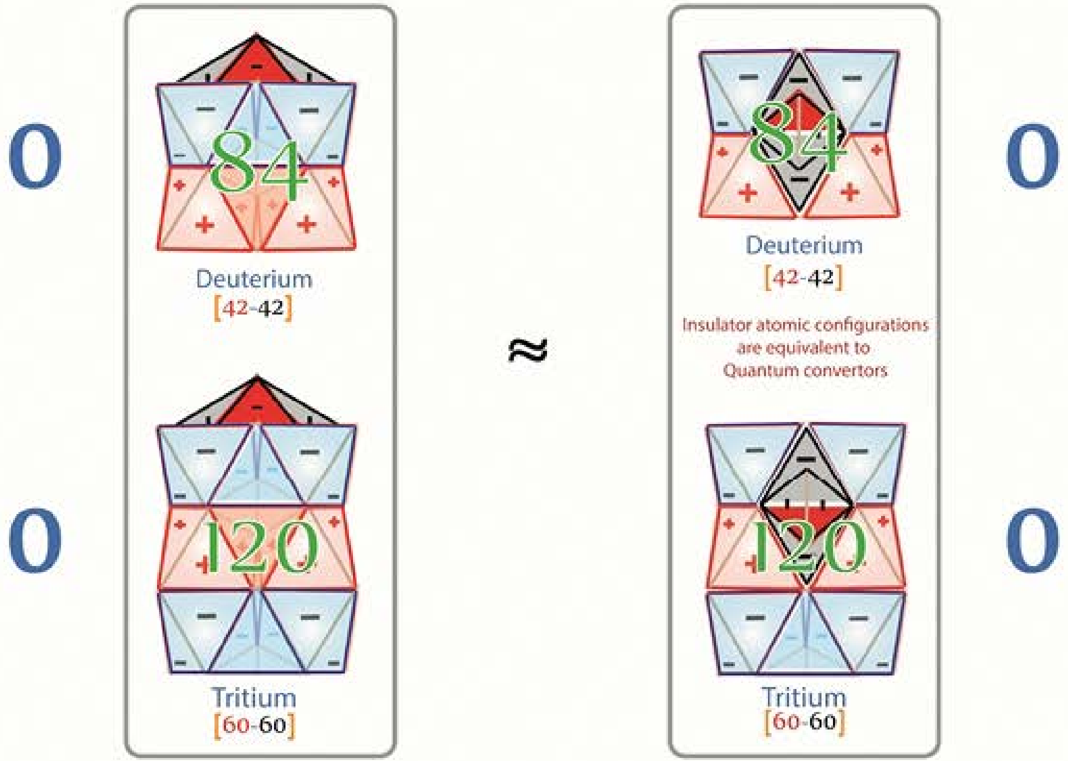
0
84
Deuterium
[42-42]
0
120
Tritium
[60-60]
≈
84
Deuterium
[42-42]
120
Tritium
[60-60]
0
0

Insulator atomic configurations
are equivalent to
Quantum convertors

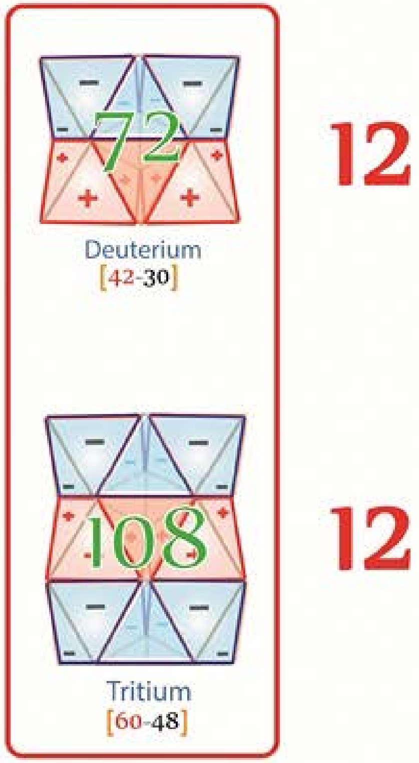
72
Deuterium
[42-30]
12
108
Tritium
[60-48]
12

**Conductive materials contain 'free' electrons that
can be readily or easily moved within the material**

**Insulator materials have electrons that are 'bound' tightly to the atoms
and store charges locally where they are applied**

**Materials that have been ionised are
more likely to become Conductors
as they easily attract and bind
free electrons to them**

Nucleon Quark Arrangement

The nuclei arrangement of each atomic shell [quantum level] is the result of quark EM field interactions

Quantum levels

Atomic shells

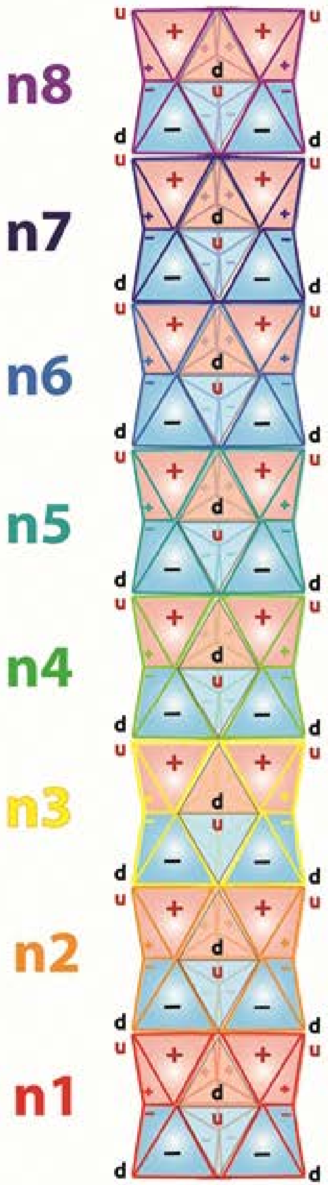
n8
n7
n6
n5
n4
n3
n2
n1
u
d
+
−

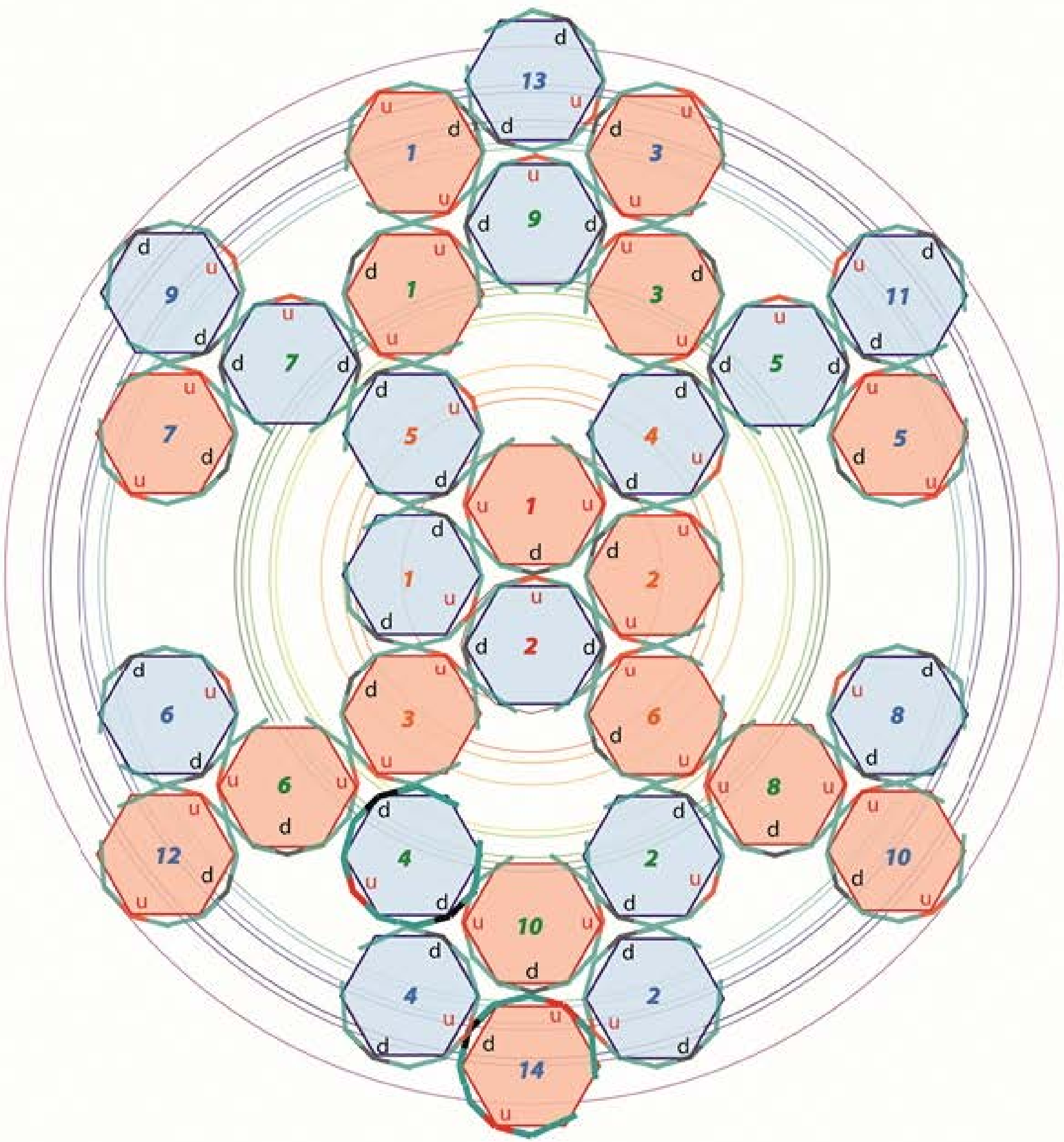
13
1
9
3
9
1
3
11
7
5
7
5
4
5
1
1
2
2
6
3
6
8
6
8
12
4
2
10
10
4
2
14
u
d

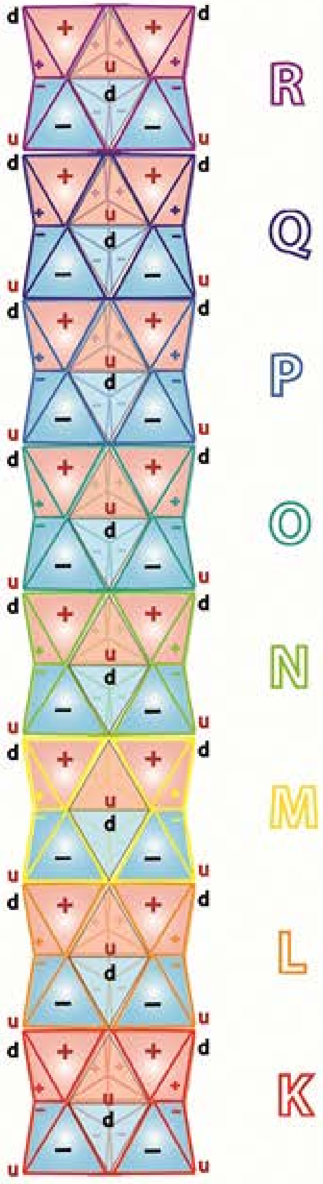
R
Q
P
O
N
M
L
K
u
d
+
−

Nucleon Charges and Bonding

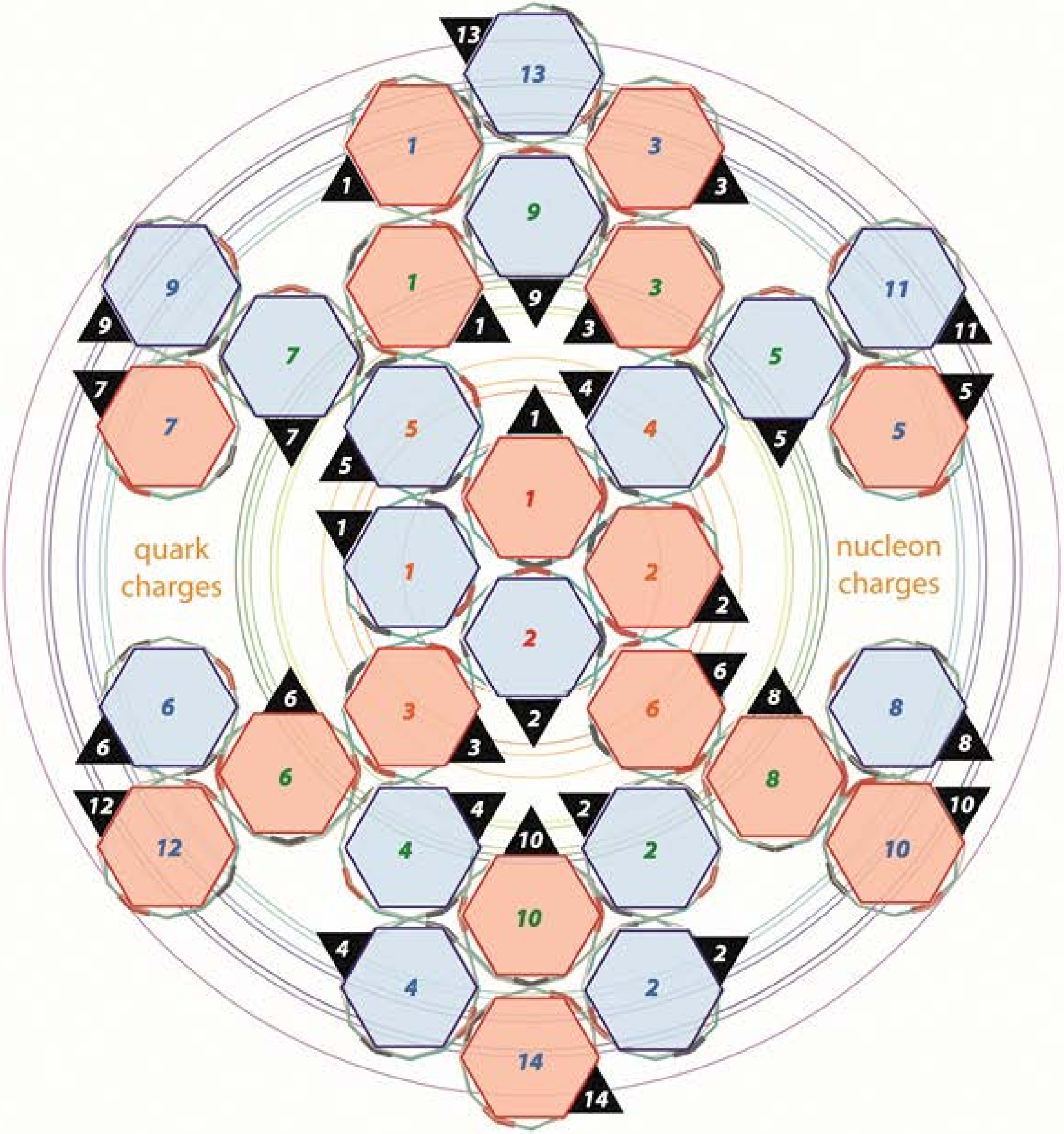
quark charges
nucleon charges

(Strong force - topological Electric Points)

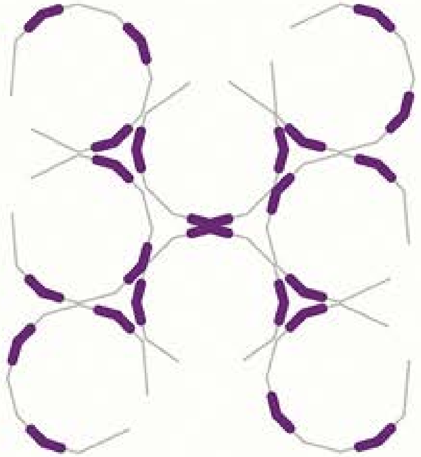

residual EM forces

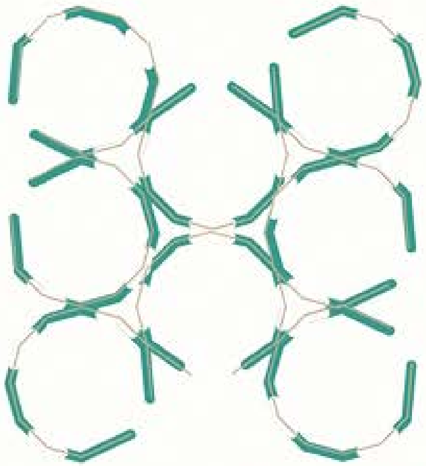

(Strong force - topological Magnetic dipoles)

Bound electron arrangements

Externally bound electrons produce sub-orbital patterns different to the electron orbitals of internally bound electrons

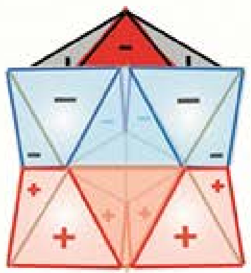

Deuterium

electrons are externally bound to the Deuteron nuclei

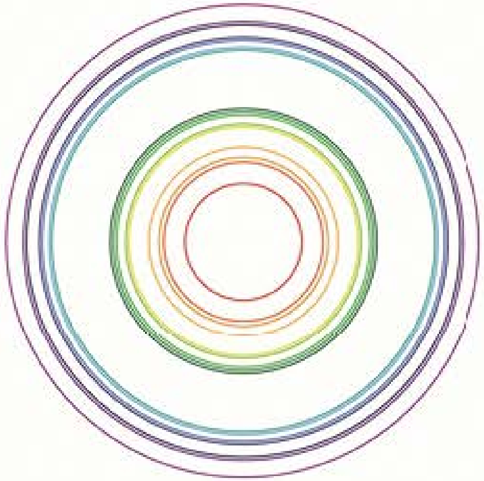

Conductors

Charges are free to move and equalise

electrons require less energy to 'break free' from Nuclei

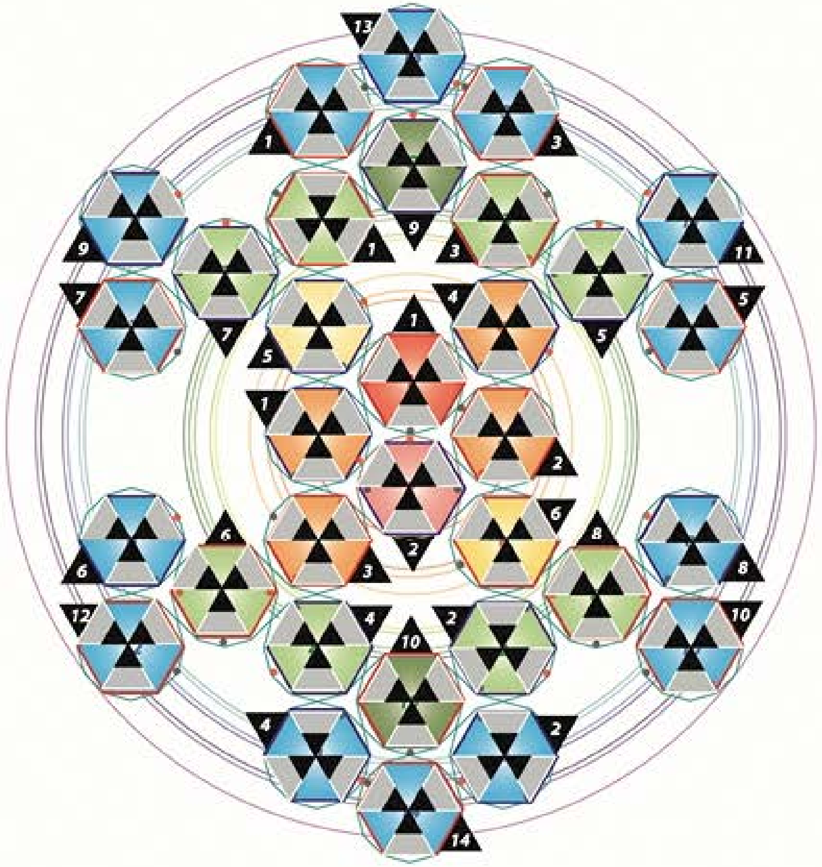

The electron orbitals of conductors are lower energies than those of insulators

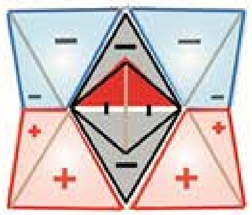

Deuterium

electrons are internally bound in the Deuteron nuclei

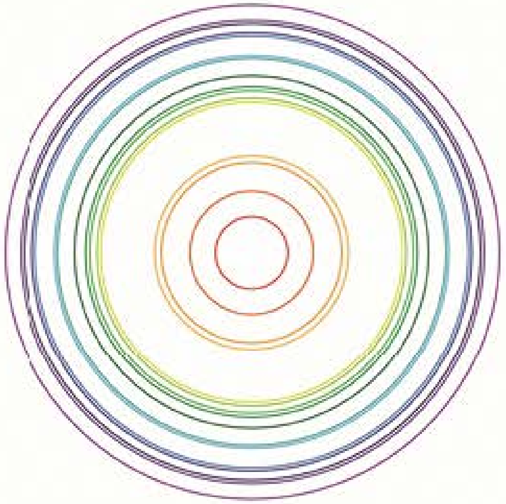

Insulators

Charges are bound to specific locations

electrons require more energy to 'break free' from Nuclei

2D mass-energy geometries form the fabric of 3D Matter topologies

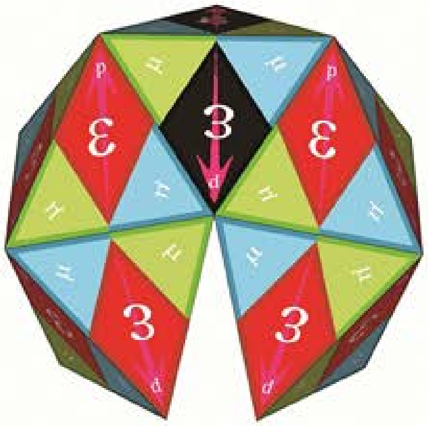

Proton

12
[24-12]

nett Charge
component charges

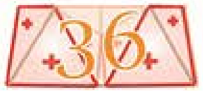

charged mass-energy geometry

20π

Matter topology

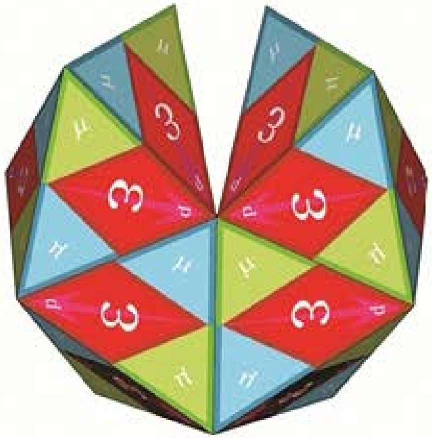

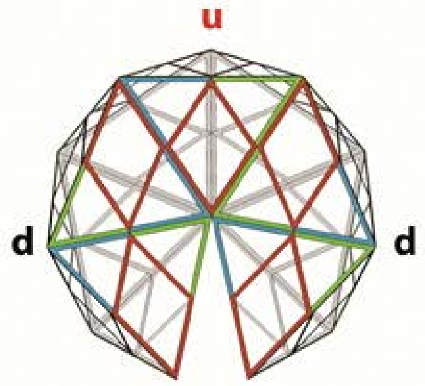

12
[42-30]

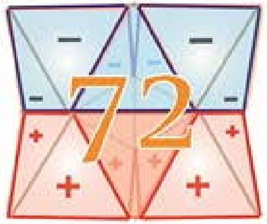

40π

Deuteron

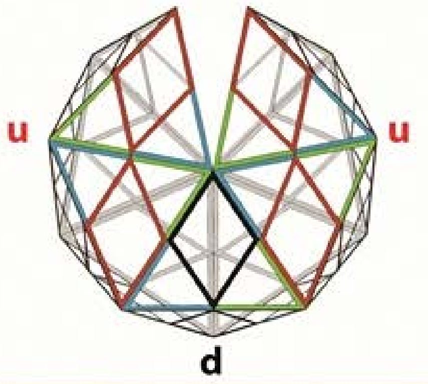

nett Charge
component charges

0
[18-18]

charged mass-energy geometry

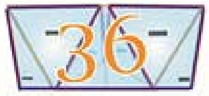

Matter topology

20π

Neutron

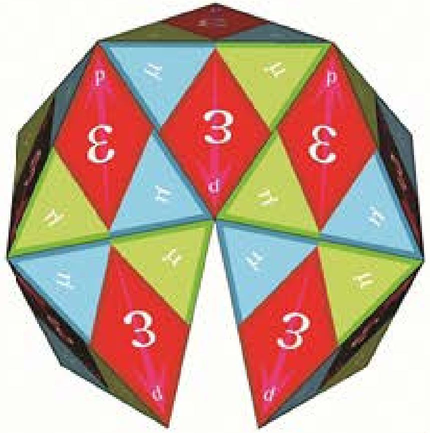

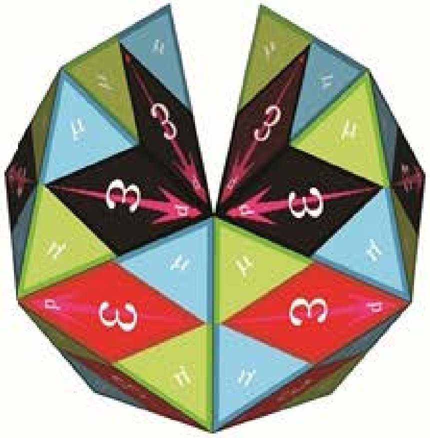

Charge provides the framework for the mass-energy geometry of Matter

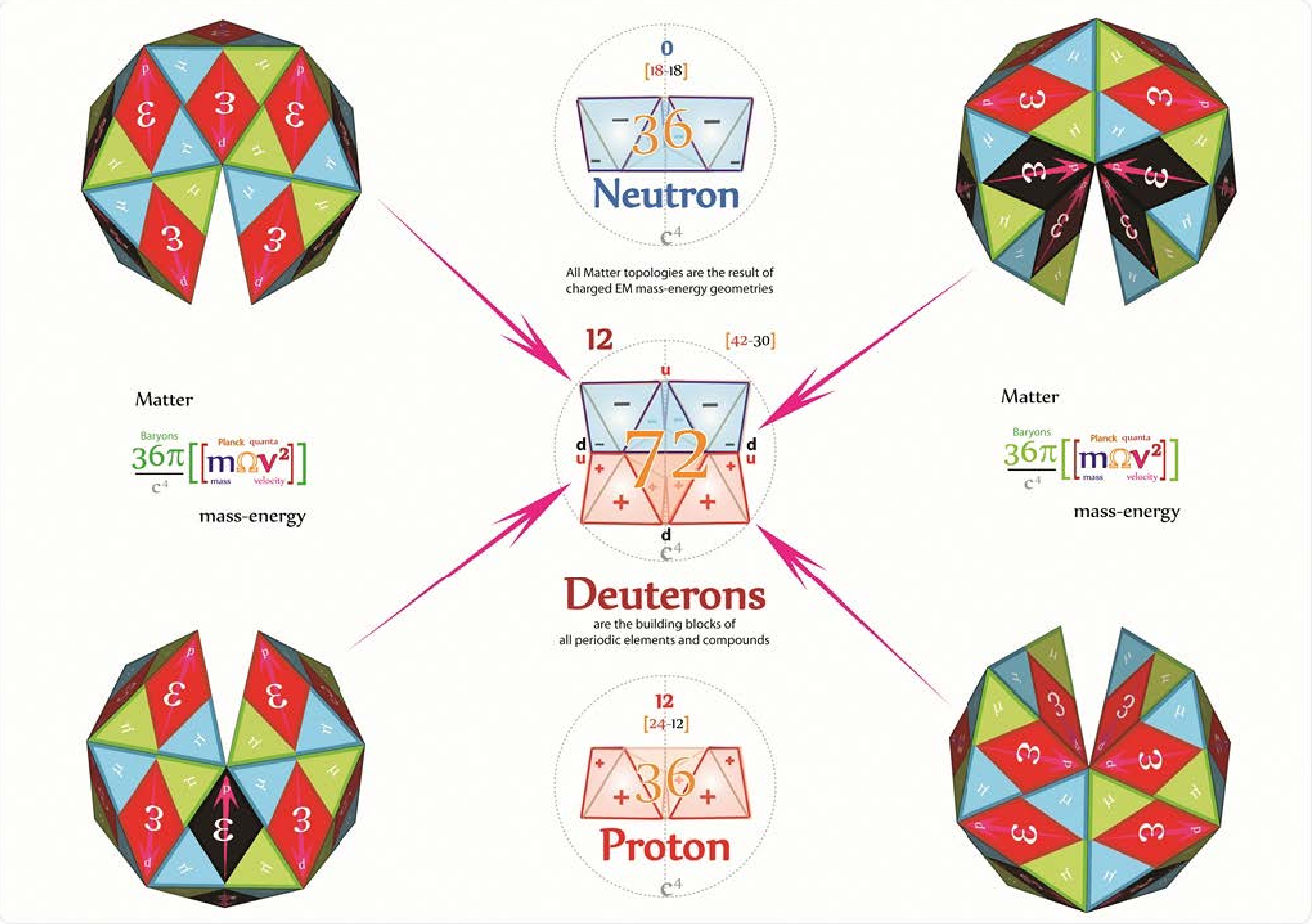

Neutron

All Matter topologies are the result of charged EM mass-energy geometries

Matter

$$\frac{\overset{\text{Baryons}}{36\pi}}{c^4}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

mass-energy

Deuterons

are the building blocks of all periodic elements and compounds

Proton

Strong Forces and Nuclear Bonding

How do Baryons with Positive and Neutral charges attract each other and bind to form stable elements ?

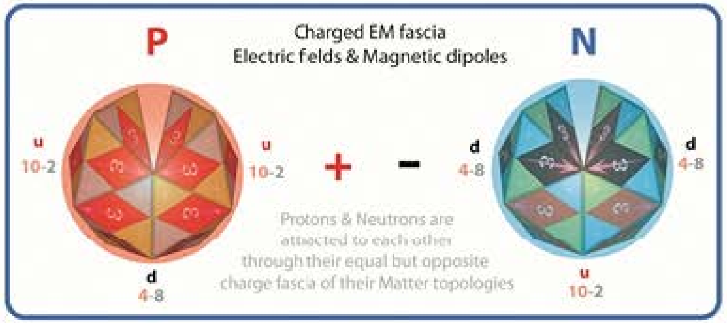

Charged EM fascia
Electric fields & Magnetic dipoles

Protons & Neutrons are attracted to each other through their equal but opposite charge fascia of their Matter topologies

P
N
u
10-2
u
10-2
d
4-8
+
-
d
4-8
d
4-8
u
10-2

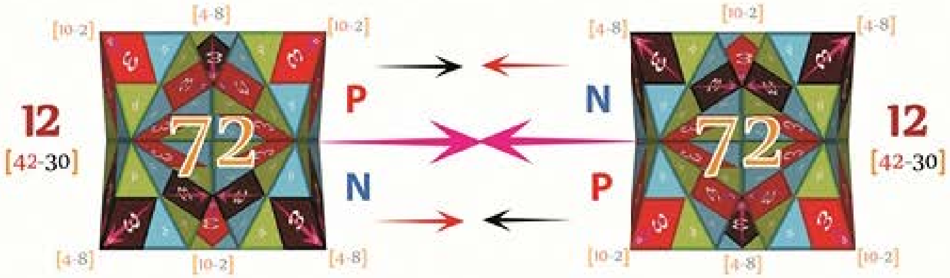
[4-8]
[10-2]
[10-2]
12
[42-30]
72
P
N
N
P
72
12
[42-30]
[4-8]
[10-2]
[4-8]

Once nuclei have been created their external electric fields & magnetic dipoles continue to attract and bind individual nuclei together via the Residual EM Force as nuclei seek charge equilibrium by combining with each other and electrons to form neutral elements

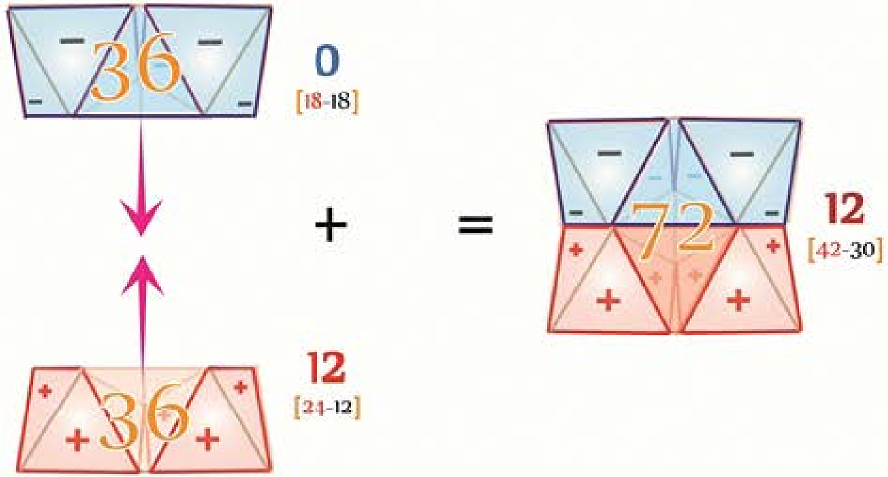
36
0
[18-18]
+
=
72
12
[42-30]
36
12
[24-12]

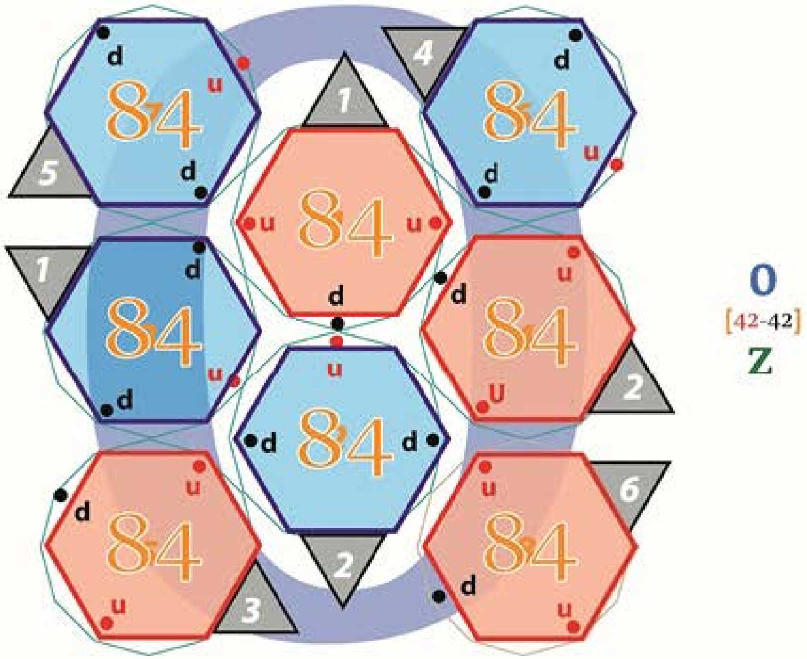
84
d
u
1
2
3
4
5
6
0
[42-42]
Z

The attraction and binding of Protons and Neutrons through their electric charge imbalances creates Deuterons which have +12 charges

The residual Z[+12] charge is what attracts electrons to form neutral atomic nuclei via Coulombic attraction

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Strong Nucleonic Bonding

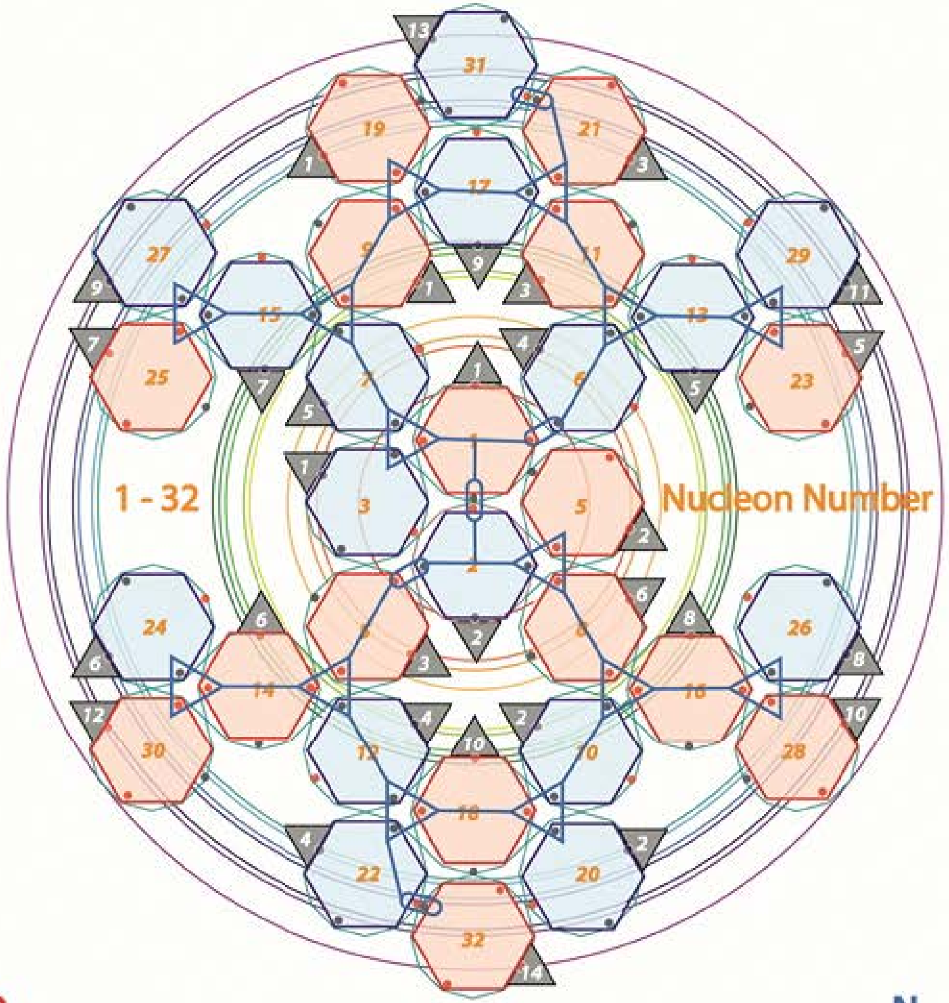

P

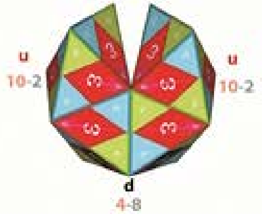

+

In addition to the Strong colour force
a separate residual binding force arises
from the external apexes formed by
Positive and Negative Electric points of quarks
in each Baryon [nuclear-chemical bonds]

-

N

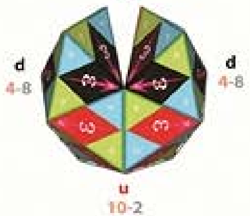

All energy seeks equilibrium

Strong E-force
nuclear linkages

**External Electric field points
bind via Charge fascia interactions
with Plus and Minus Electric points
combining and sharing energy
throughout the resultant nuclei**

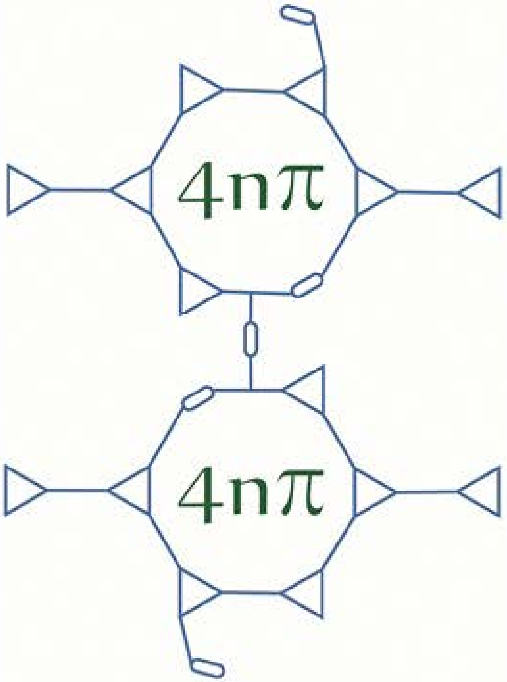

● *Positive Electric field apex*

Negative Electric field apex ●

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Hydrogenic vs Nucleonic electron binding

If a unbound Proton attracts an Electron
the Electron can be bound to the nuclei
in a number of differing orientations
[each with differing spin energies]

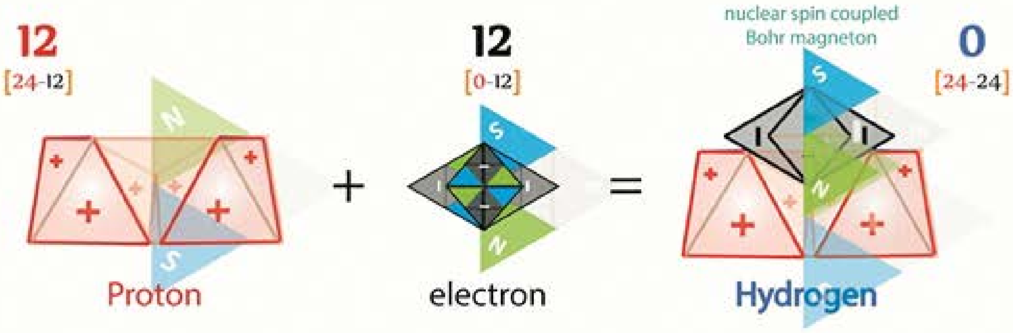
12
[24-12]
Proton
+
12
[0-12]
electron
=
nuclear spin coupled
Bohr magneton
0
[24-24]
Hydrogen
N
S
+
–

The energy levels of Baryons determines the KEM field energy of bound electrons

All atomic nuclei (and elements) are Deuteron'ic nuclei with a mixture of *orthagonal*, parallel and anti-paralllel spin orientations

(this is why Rydberg is less accurate for elemental nuclei compared to Hydrogenic atoms - see QM spin)

Electrons can be bound to deuteron nuclei
in four distinct orientations [2 horizontal & 2 vertical]
with each spin coupling orientation producing
differing energy electron orbitals
[wrt to the nuclear magnetic moments]

Ejecting electrons from atomic nuclei
by adding energies to their KEM fields
[the Photoelectric effect]
creates Positive Ions

Vertically orientated electrons
within Proton-Neutron Nuclei [Deuterons]
create quantum synchronous convertor geometries

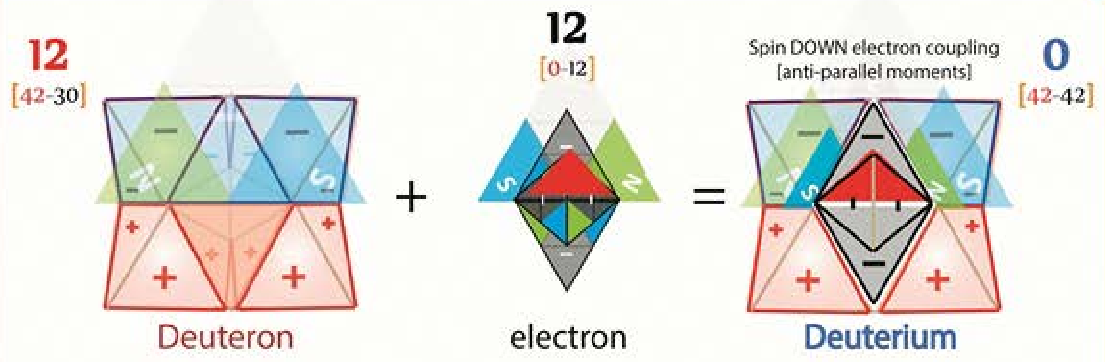
12
[42-30]
Deuteron
+
12
[0-12]
electron
=
Spin DOWN electron coupling
[anti-parallel moments]
0
[42-42]
Deuterium
N
S
+
–

Bohr magnetons are always referenced wrt the Nuclear magneton

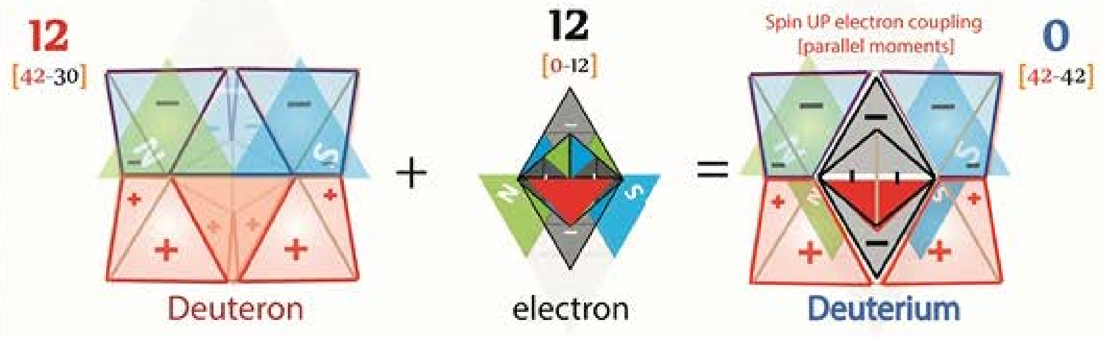
12
[42-30]
Deuteron
+
12
[0-12]
electron
=
Spin UP electron coupling
[parallel moments]
0
[42-42]
Deuterium
N
S
+
–

electrons produce stronger magnetic moments due to their mass-charge quotient

Atomic Nucleus Master Template

Nucleon Number Z

1 Proton [24-12]
1 electron [0-12]
1 Neutron [18-18]

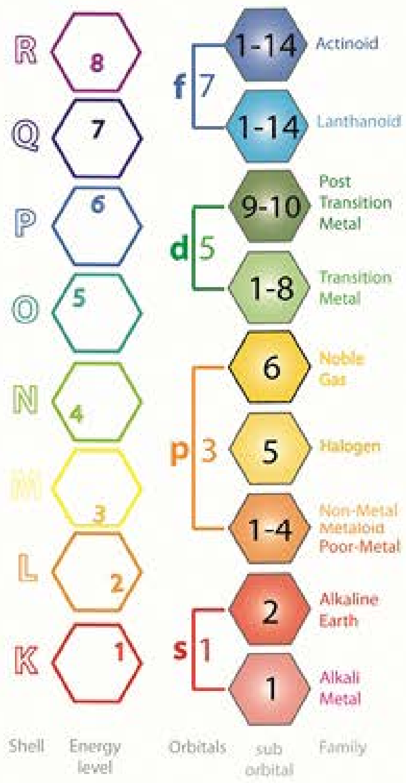
R
8
Q
7
P
6
O
5
N
4
M
3
L
2
K
1
f 7
1-14
Actinoid
1-14
Lanthanoid
d 5
9-10
Post Transition Metal
1-8
Transition Metal
p 3
6
Noble Gas
5
Halogen
1-4
Non-Metal Metaloid Poor-Metal
s 1
2
Alkaline Earth
1
Alkali Metal
Shell
Energy level
Orbitals
sub orbital
Family

○	s	1 sub-Orbital	(2 electrons max)
○	p	3 sub-Orbitals	(6 electrons max)
○	d	5 sub-Orbitals	(10 electrons max)
○	f	7 sub-Orbitals	(14 electrons max)

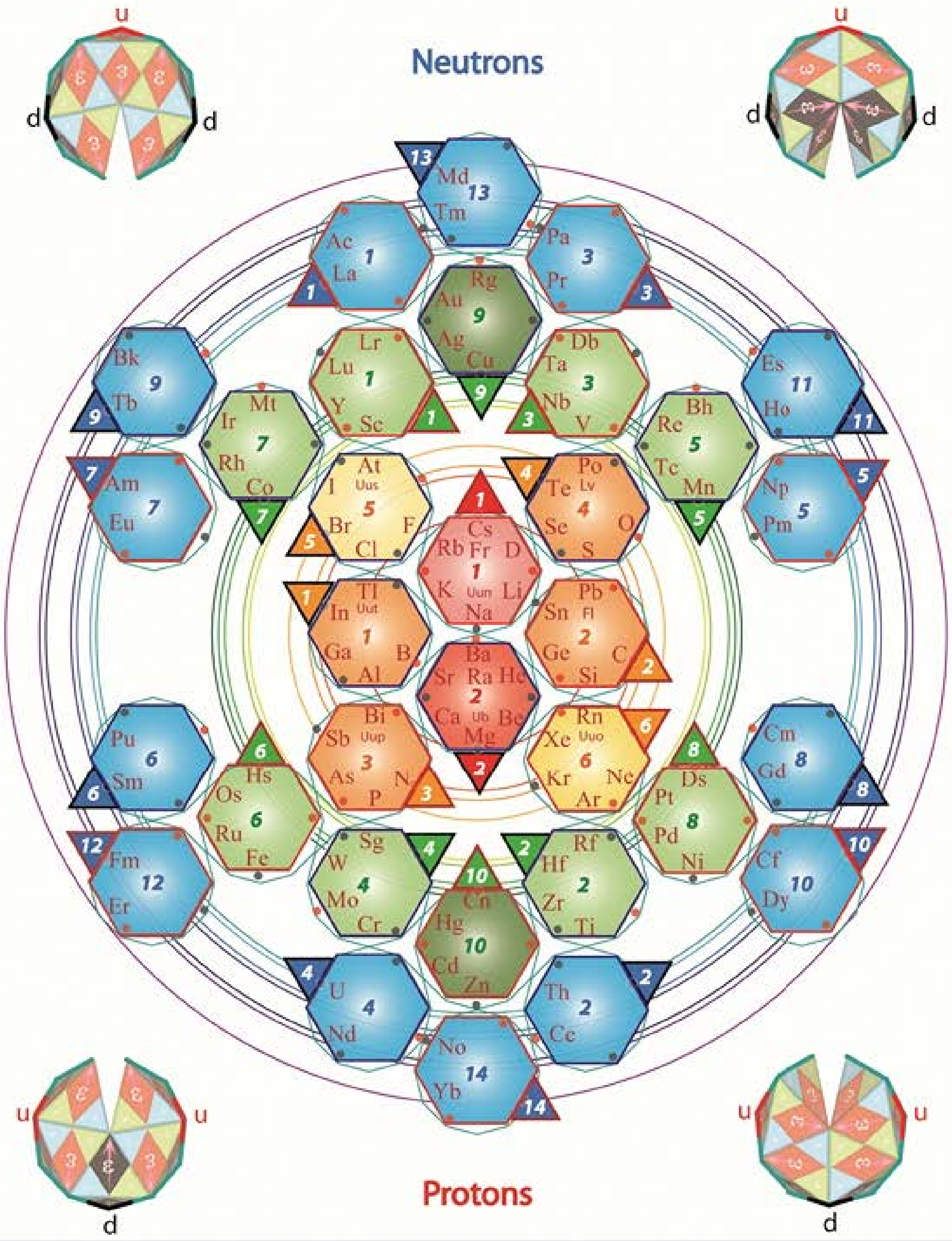
u
d
d
u
d
d
Neutrons
13
Md
Tm
1
Ac
La
3
Pa
Pr
9
Rg
Au
Ag
Cu
9
Bk
Tb
1
Lr
Lu
Y
Sc
3
Db
Ta
Nb
V
11
Es
Ho
7
Mt
Ir
Rh
Co
5
Bh
Re
Tc
Mn
7
Am
Eu
5
At
I
Uus
Br
Cl
F
1
Cs
Rb
Fr
D
K
Uun
Li
Na
4
Po
Te
Lv
Se
O
S
5
Np
Pm
1
Tl
In
Uut
Ga
B
Al
2
Pb
Sn
Fl
Ge
C
Si
2
Ba
Sr
Ra
He
Ca
Ub
Be
Mg
6
Pu
Sm
6
Hs
Os
Ru
Fe
3
Bi
Sb
Uup
As
N
P
6
Rn
Xe
Uuo
Kr
Ne
Ar
8
Ds
Pt
Pd
Ni
8
Cm
Gd
12
Fm
Er
4
Sg
W
Mo
Cr
10
Cn
Hg
Cd
Zn
2
Rf
Hf
Zr
Ti
10
Cf
Dy
4
U
Nd
2
Th
Ce
14
No
Yb
u
u
d
u
u
d
Protons

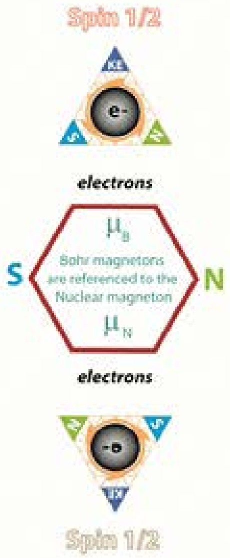
Spin 1/2
e-
electrons
μ_B
Bohr magnetons are referenced to the Nuclear magneton
μ_N
S
N
electrons
-e
Spin 1/2

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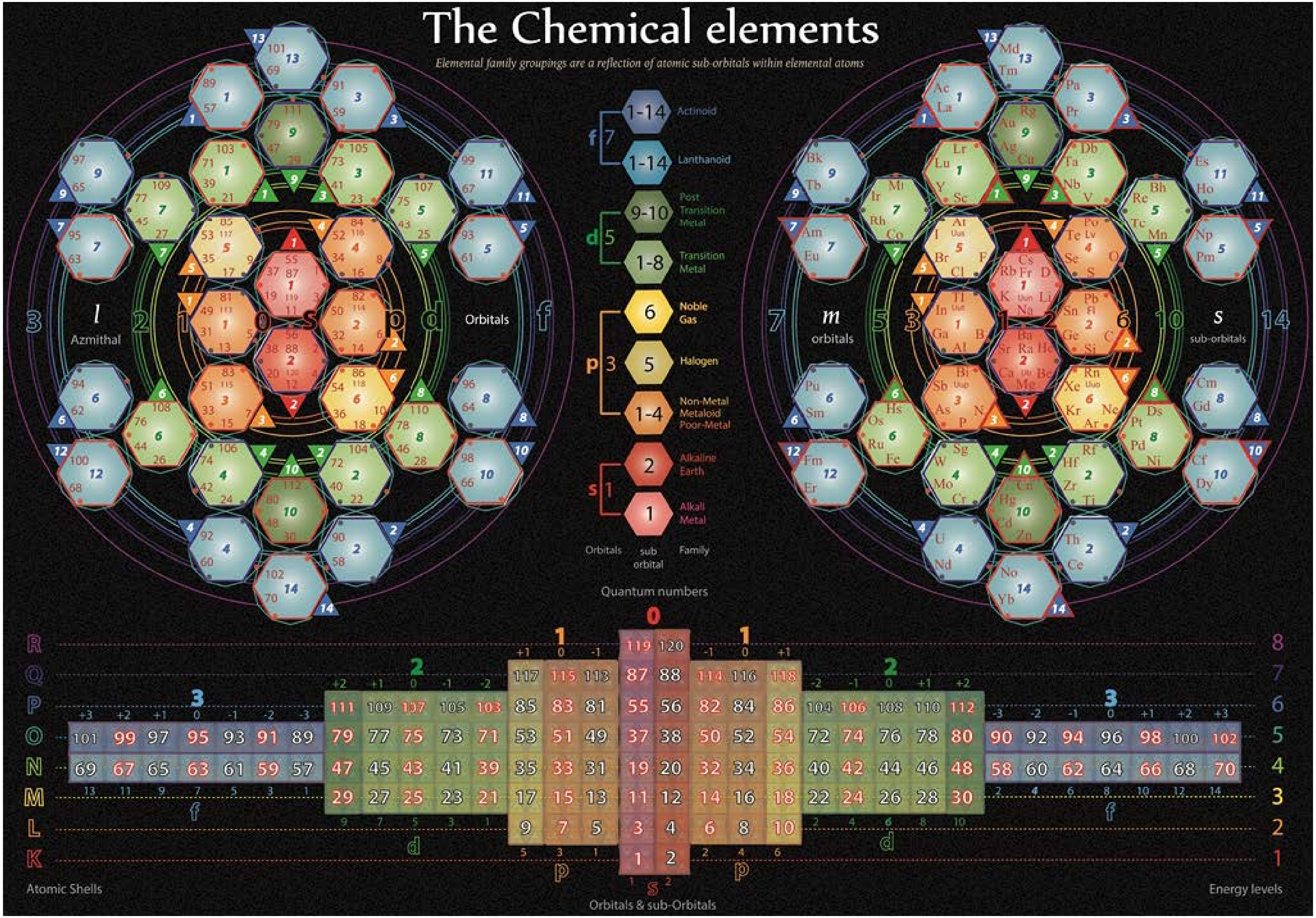

The Chemical elements

Elemental family groupings are a reflection of atomic sub-orbitals within elemental atoms

3
l
Azmithal
2
1
0
s
p
d
Orbitals
f
f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metaloid Poor-Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Orbitals
sub orbital
Family
Quantum numbers
7
m
orbitals
5
3
1
2
6
10
s
sub-orbitals
14
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

	3							2					1			0		1			2					3							
	+3	+2	+1	0	-1	-2	-3	+2	+1	0	-1	-2	+1	0	-1			-1	0	+1	-2	-1	0	+1	+2	-3	-2	-1	0	+1	+2	+3	
R																119	120																8
Q													117	115	113	87	88	114	116	118													7
P								111	109	107	105	103	85	83	81	55	56	82	84	86	104	106	108	110	112								6
O	101	99	97	95	93	91	89	79	77	75	73	71	53	51	49	37	38	50	52	54	72	74	76	78	80	90	92	94	96	98	100	102	5
N	69	67	65	63	61	59	57	47	45	43	41	39	35	33	31	19	20	32	34	36	40	42	44	46	48	58	60	62	64	66	68	70	4
M	13	11	9	7	5	3	1	29	27	25	23	21	17	15	13	11	12	14	16	18	22	24	26	28	30	2	4	6	8	10	12	14	3
L				f				9	7	5	3	1	9	7	5	3	4	6	8	10	2	4	6	8	10				f				2
K										d			5	3	1	1	2	2	4	6			d										1
														p		1	2		p														
																s																	

Tetryonics 43.02 - The Chemical Elements

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Element Numbers

Z *

1 Proton [24-12]
1 Neutron [18-18]
1 electron [0-12]

Each elemental nuclei is made from Deuterium

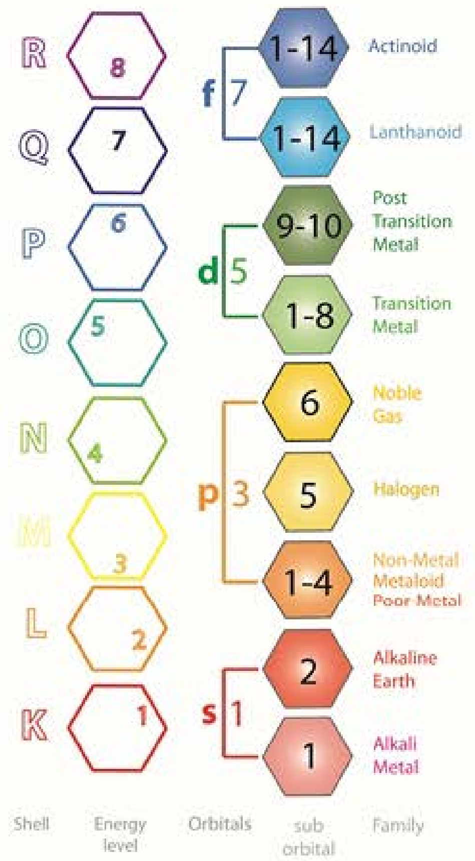
R
8
Q
7
P
6
O
5
N
4
M
3
L
2
K
1
f 7
1-14
Actinoid
1-14
Lanthanoid
d 5
9-10
Post Transition Metal
1-8
Transition Metal
p 3
6
Noble Gas
5
Halogen
1-4
Non-Metal Metaloid Poor Metal
s 1
2
Alkaline Earth
1
Alkali Metal
Shell
Energy level
Orbitals
sub orbital
Family

○ **s** *1 sub-Orbital (2 electrons max)*

○ **p** *3 sub-Orbitals (6 electrons max)*

○ **d** *5 sub-Orbitals (10 electrons max)*

○ **f** *7 sub-Orbitals (14 electrons max)*

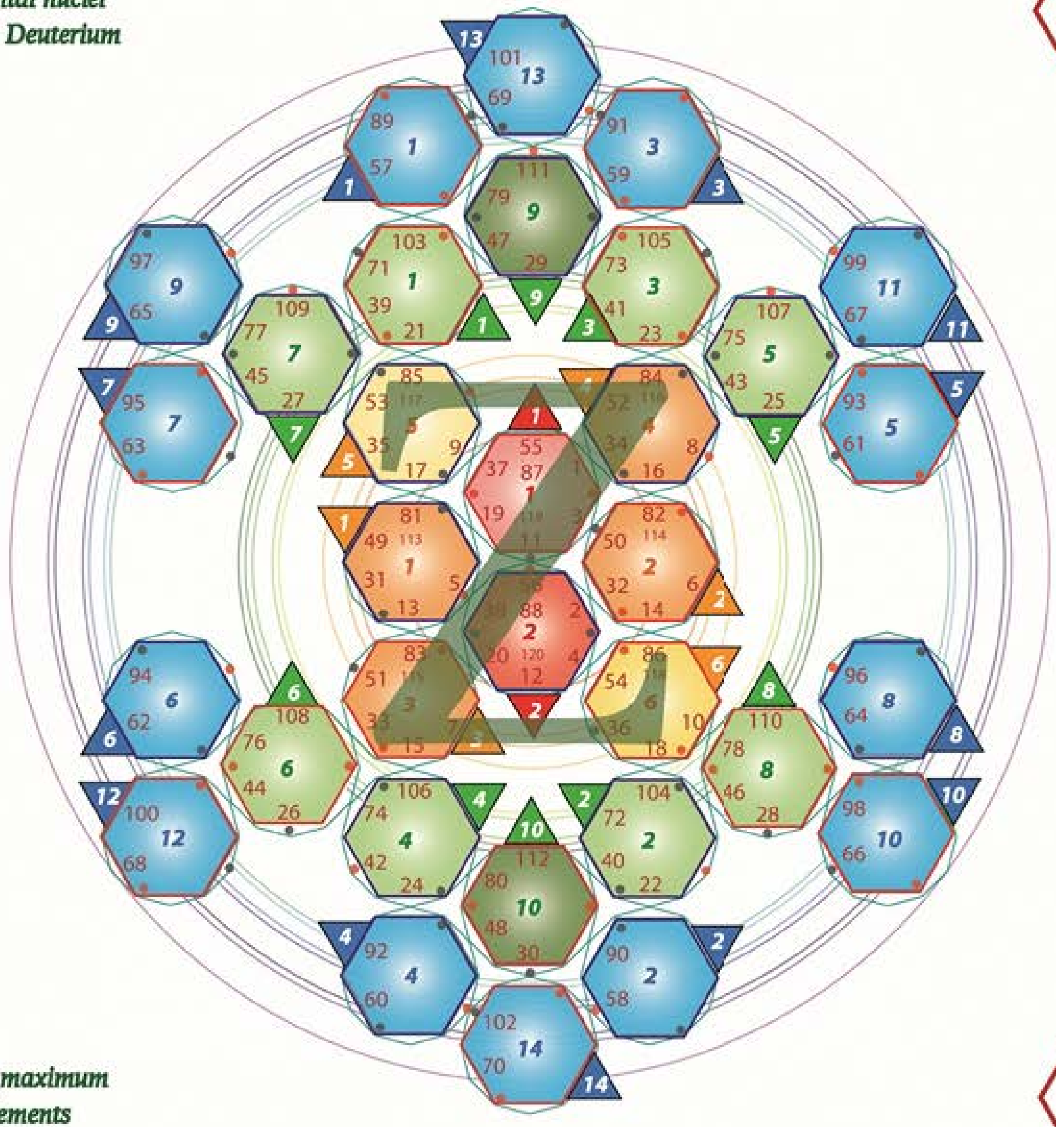
101 13 69
13
89 1 57
1
91 3 59
3
111 79 9 47 29
9
97 9 65
9
109 77 7 45 27
7
103 71 1 39 21
1
105 73 3 41 23
3
107 75 5 43 25
5
99 11 67
11
95 7 63
7
85 53 117 5 35 17 9
5
55 37 87 1 19 119 3 11
1
84 52 116 4 34 16 8
4
93 5 61
5
81 49 113 1 31 13 5
1
82 50 114 2 32 14 6
2
56 38 88 2 20 120 12 4
2
94 6 62
6
108 76 6 44 26
6
83 51 115 3 33 15 7
3
86 54 118 6 36 18 10
6
110 78 8 46 28
8
96 8 64
8
100 12 68
12
106 74 4 42 24
4
104 72 2 40 22
2
98 10 66
10
112 80 10 48 30
10
92 4 60
4
90 2 58
2
102 14 70
14
Z

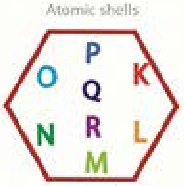
Atomic shells
P
O
K
Q
N
R
L
M

There are a maximum of 120 elements possible

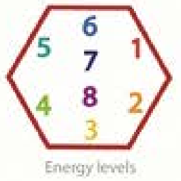
6
5
1
7
4
8
2
3
Energy levels

Element Names

Z * 1 Proton [24-12]
1 Neutron [18-18]
1 electron [0-12]

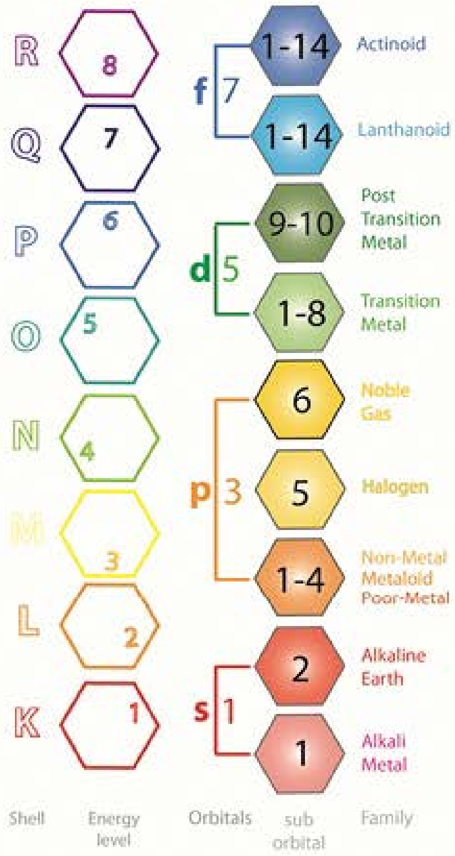
R
8
Q
7
P
6
O
5
N
4
M
3
L
2
K
1
f 7
1-14
Actinoid
1-14
Lanthanoid
d 5
9-10
Post Transition Metal
1-8
Transition Metal
p 3
6
Noble Gas
5
Halogen
1-4
Non-Metal Metaloid Poor-Metal
s 1
2
Alkaline Earth
1
Alkali Metal
Shell
Energy level
Orbitals
sub orbital
Family

o s 1 sub-Orbital (2 electrons max)
O p 3 sub-Orbitals (6 electrons max)
O d 5 sub-Orbitals (10 electrons max)
O f 7 sub-Orbitals (14 electrons max)

There are a maximum of 120 elements possible

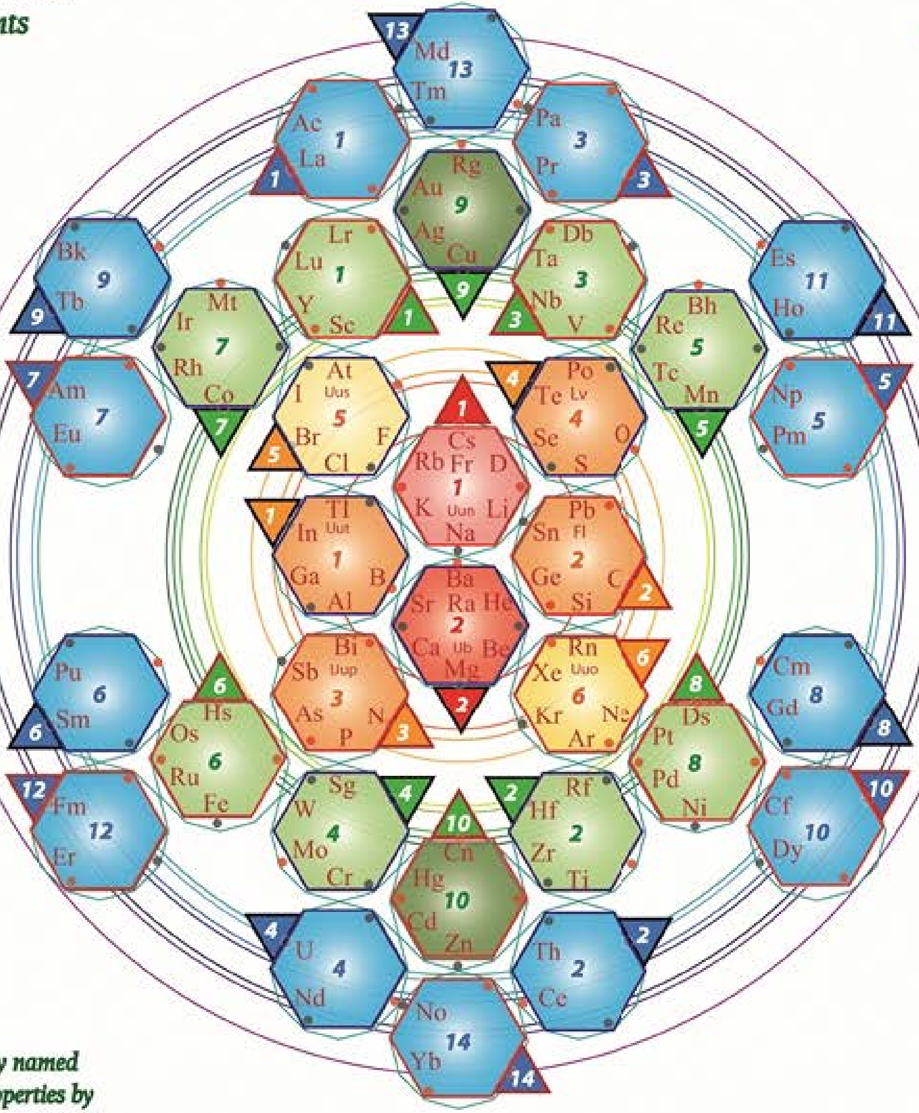
13 Md 13 Tm 13
Ac 1 La 1
Rg Au 9 Ag Cu 9
Pa 3 Pr 3
Bk 9 Tb 9
Lr Lu 1 Y Sc 1
Db Ta 3 Nb V 3
Es 11 Ho 11
Mt Ir 7 Rh Co 7
Bh Re 5 Tc Mn 5
Am 7 Eu 7
At I Uus 5 Br F Cl 5
1 Cs Rb Fr D 1 K Uun Li Na
4 Po Te Lv 4 Se O S
Np 5 Pm 5
1 Tl In Uut 1 Ga B Al
Ba Sr Ra He 2 Ca Ub Be Mg 2
Pb Sn Fl 2 Ge C Si 2
Pu 6 Sm 6
6 Hs Os 6 Ru Fe
Bi Sb Uup 3 As N P 3
Rn Xe Uuo 6 Kr Ne Ar 6
8 Ds Pt 8 Pd Ni
Cm Gd 8 8
12 Fm 12 Er
Sg W 4 Mo Cr 4
10 Cn Hg 10 Cd Zn
2 Rf Hf 2 Zr Ti
Cf 10 Dy 10
4 U 4 Nd
Th 2 Ce 2
No 14 Yb 14

Atomic shells

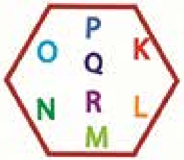

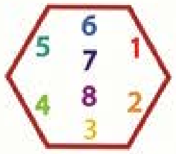

Energy levels

They were originally named according to their properties by their discoverer but have recently been named after famous scientists

Electron orbital configurations

A huge number of differing d and f orbital configurations
are possible given the number of nuclei and bond points
created by elemental topologies

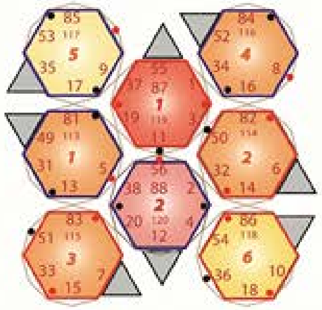
85
53 117
5
35 9
17
84
52 116
4
34 8
16
55
37 87
1
19 119
11
81
49 113
1
31 5
13
82
50 114
2
32 6
14
56
38 88 2
2
20 120 4
12
83
51 115
3
33 7
15
86
54 118
6
36 10
18

As the number of nucleons
increases so does the complexity
of the electron orbitals possible

quantum snowflakes

However all have a stable 'core'
grouping of nuclei comprised of
s and p electron orbitals

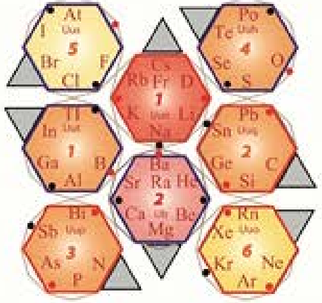
At
I Uus
5
Br F
Cl
Po
Te Uuh
4
Se O
S
Cs
Rb Fr D
1
K Uue Li
Na
Tl
In Uut
1
Ga B
Al
Pb
Sn Uuq
2
Ge C
Si
Ba
Sr Ra He
2
Ca Ubn Be
Mg
Bi
Sb Uup
3
As N
P
Rn
Xe Uuo
6
Kr Ne
Ar

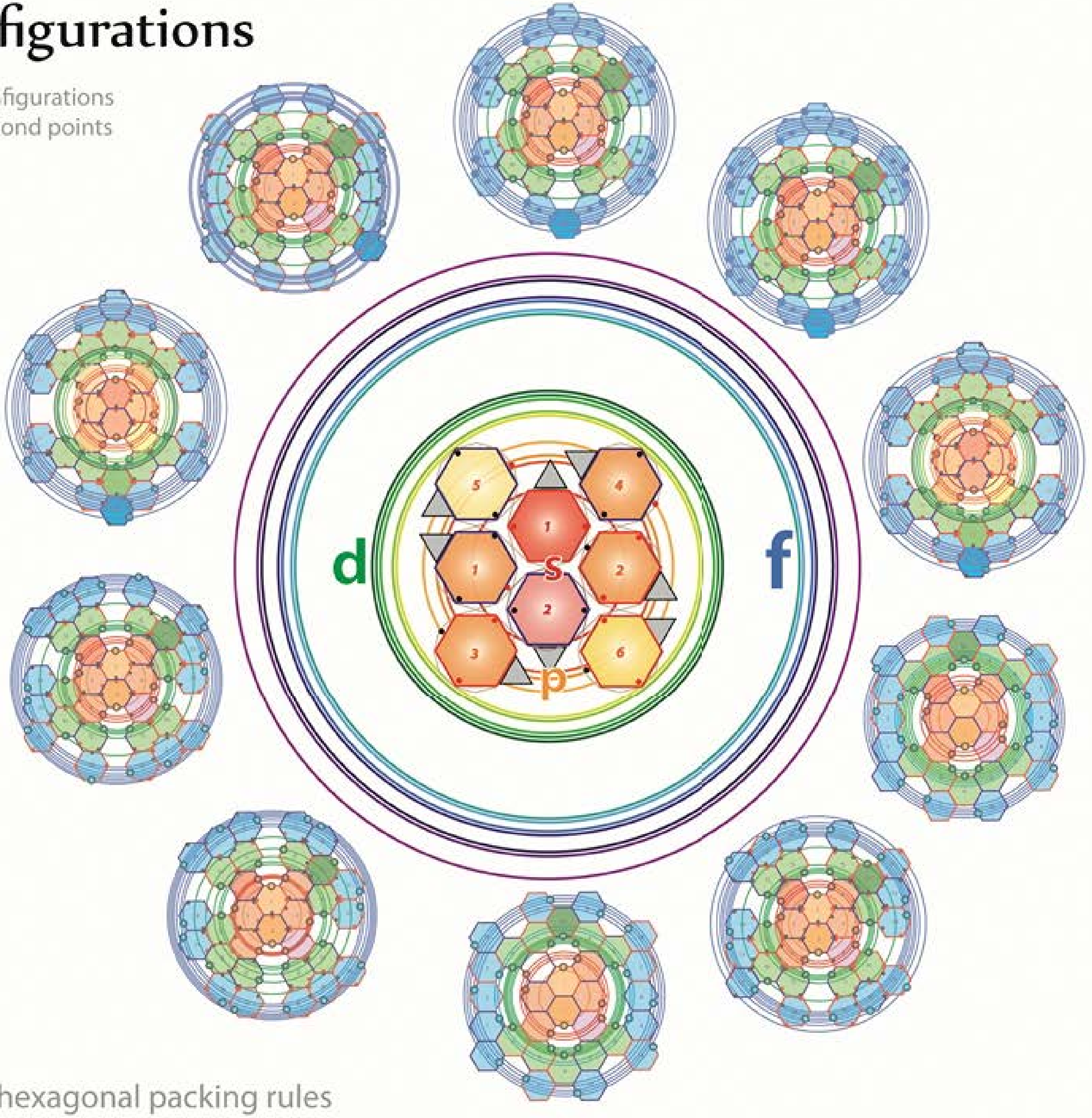
d
f
s
p
5
4
1
1
2
2
3
6

All nuclei bonding closely follows hexagonal packing rules

Atomic Nucleus Exploded view

1 Proton	[24-12]
1 electron	[0-12]
1 Neutron	[18-18]

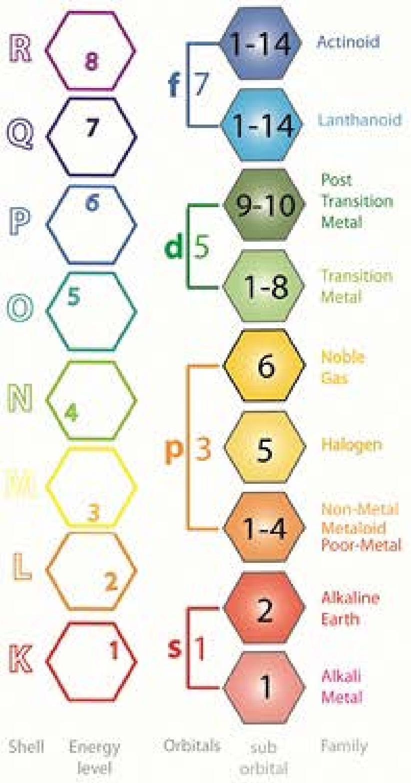

R 8
Q 7
P 6
O 5
N 4
M 3
L 2
K 1
f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metaloid Poor-Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Shell
Energy level
Orbitals
sub orbital
Family

s *1 sub-Orbital (2 electrons max)*

p *3 sub-Orbitals (6 electrons max)*

d *5 sub-Orbitals (10 electrons max)*

f *7 sub-Orbitals (14 electrons max)*

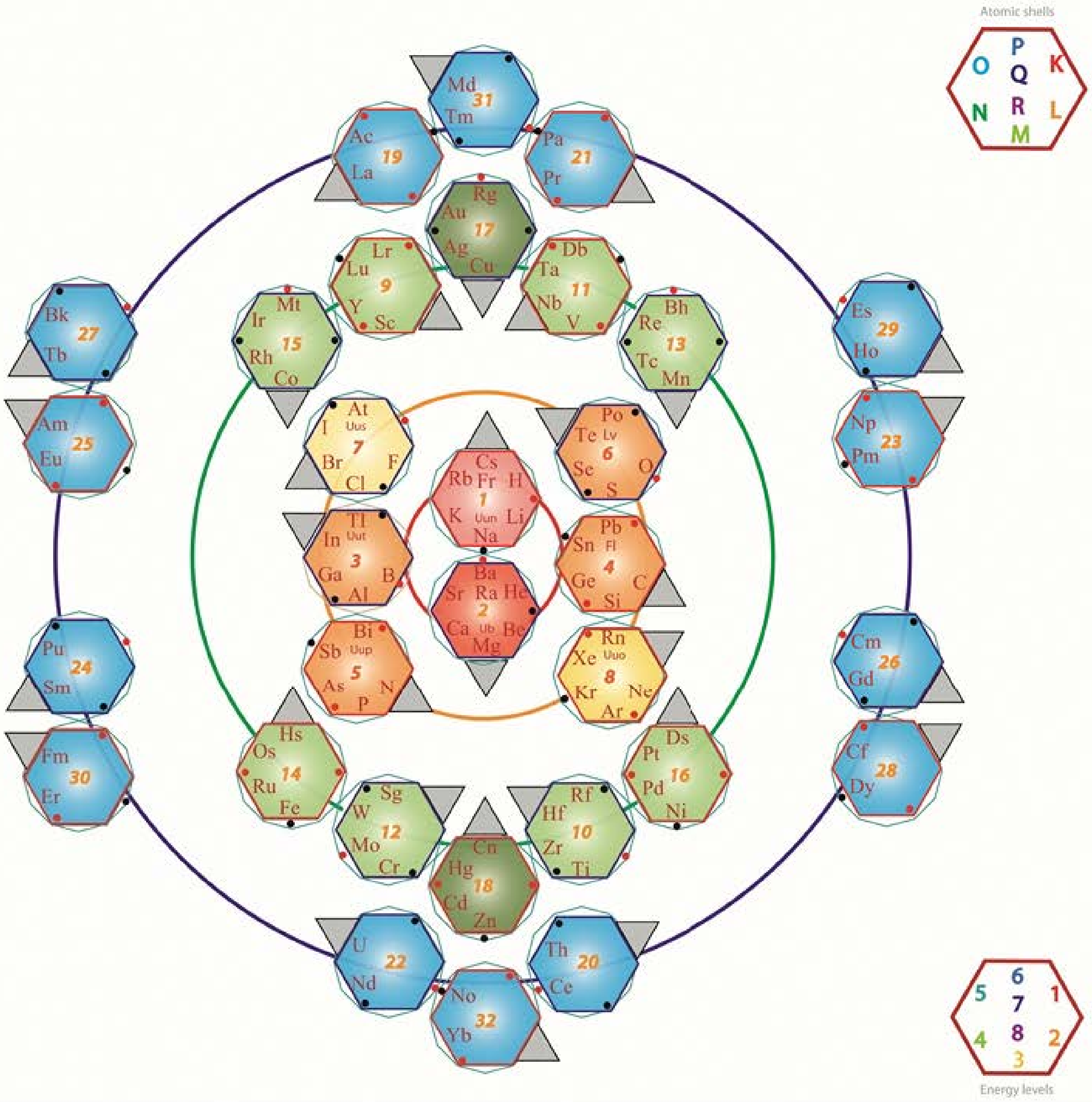

Atomic shells
P
O
Q
K
N
R
L
M
Md Tm 31
Ac La 19
Pa Pr 21
Rg Au Ag Cu 17
Lr Lu Y Sc 9
Db Ta Nb V 11
Mt Ir Rh Co 15
Bh Re Tc Mn 13
Bk Tb 27
Es Ho 29
Am Eu 25
Np Pm 23
At I Uus Br F Cl 7
Po Te Lv Se O S 6
Cs Rb Fr H K Uun Li Na 1
Tl In Uut Ga B Al 3
Pb Sn Fl Ge C Si 4
Ba Sr Ra He Ca Ub Be Mg 2
Bi Sb Uup As N P 5
Rn Xe Uuo Kr Ne Ar 8
Pu Sm 24
Cm Gd 26
Fm Er 30
Cf Dy 28
Hs Os Ru Fe 14
Ds Pt Pd Ni 16
Sg W Mo Cr 12
Rf Hf Zr Ti 10
Cn Hg Cd Zn 18
U Nd 22
Th Ce 20
No Yb 32
6
5
1
7
4
8
2
3
Energy levels

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Atomic radii of elements

The Mendeleev block arrangement of periodic elements presents a number of problems in representing the true topologies and properties of all the periodic elements:

Questions are raised over Hydrogen's appropriate position in the table

The table correctly positions elements according to their elemental properties but offers no insight into the individual geometries of the periodic elements themselves

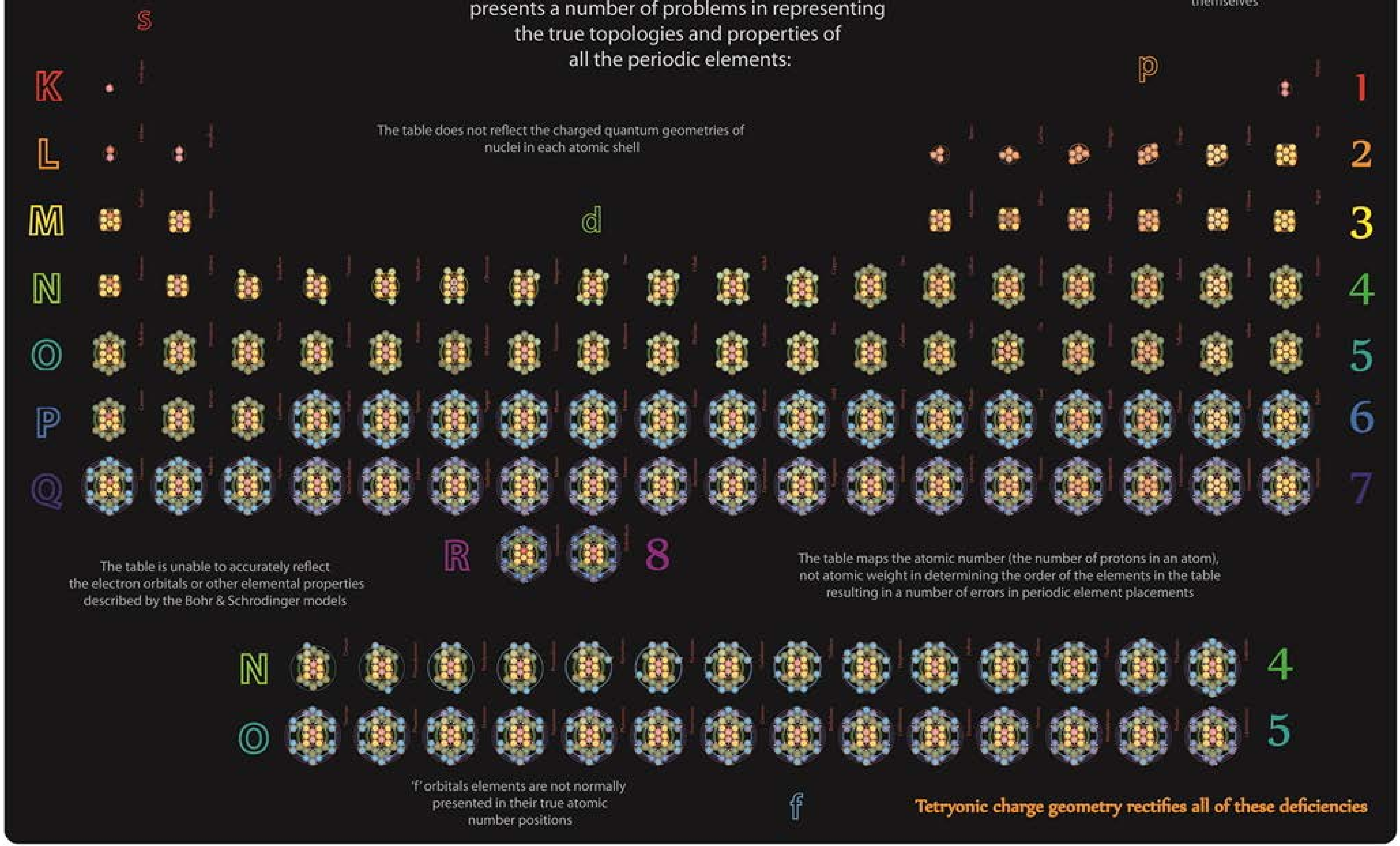

The table does not reflect the charged quantum geometries of nuclei in each atomic shell

The table is unable to accurately reflect the electron orbitals or other elemental properties described by the Bohr & Schrodinger models

The table maps the atomic number (the number of protons in an atom), not atomic weight in determining the order of the elements in the table resulting in a number of errors in periodic element placements

'f' orbitals elements are not normally presented in their true atomic number positions

Tetryonic charge geometry rectifies all of these deficiencies

Tetryonics 43.07 - Atomic radii of elements

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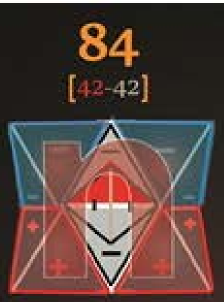

PERIODIC TABLE OF ELEMENTS

modelled on the polar view of the charge topologies of periodic elements

Deuterium
[not Hydrogen]
is the building block
of all elements

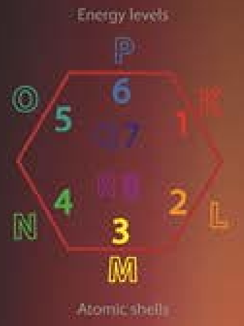
Energy levels
P
6
O
5
Q
7
1
K
R
8
4
2
N
L
3
M
Atomic shells

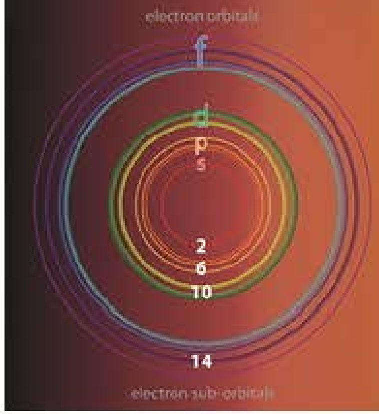
electron orbitals
f
d
p
s
2
6
10
14
electron sub-orbitals

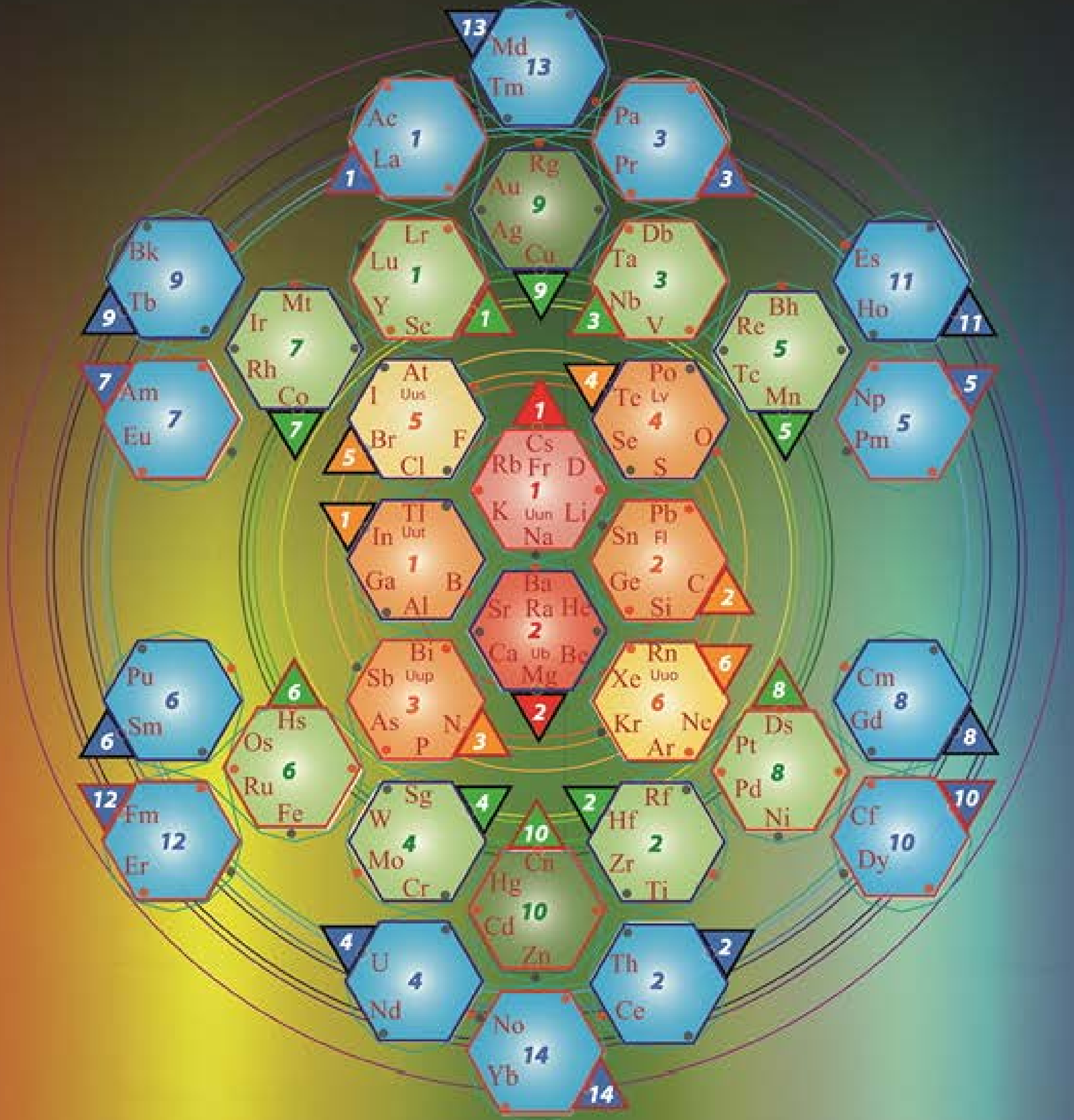
13 Md 13 Tm
Ac 1 La 1
Pa 3 Pr 3
Rg Au 9 Ag Cu 9
Bk 9 Tb 9
Lr Lu 1 Y Sc 1
Db Ta 3 Nb V 3
Es 11 Ho 11
Mt Ir 7 Rh Co 7
Bh Re 5 Tc Mn 5
7 Am 7 Eu
At I Uus 5 Br Cl F 5
1 Cs Rb Fr D 1 K Uun Li Na
4 Po Te Lv 4 Se O S
Np 5 Pm 5
1 Tl In Uut 1 Ga B Al
Pb Sn Fl 2 Ge C Si 2
Ba Sr Ra He 2 Ca Ub Be Mg
Pu 6 Sm 6
6 Hs Os 6 Ru Fe
Bi Sb Uup 3 As N P 3
2
6 Rn Xe Uuo 6 Kr Ne Ar
8 Ds Pt 8 Pd Ni
Cm 8 Gd 8
12 Fm 12 Er
Sg W 4 Mo Cr 4
10 Cn Hg 10 Cd Zn
2 Rf Hf 2 Zr Ti
10 Cf 10 Dy
4 U 4 Nd
Th 2 Ce 2
No 14 Yb 14

Periodic element families

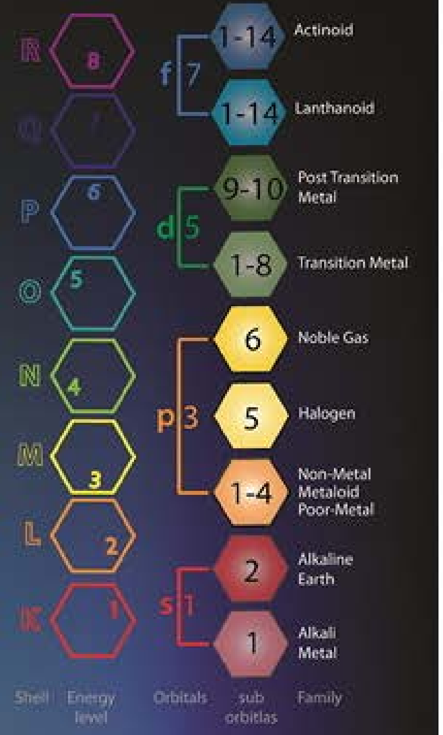
R 8
Q 7
P 6
O 5
N 4
M 3
L 2
K 1
f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metaloid Poor-Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Shell
Energy level
Orbitals
sub orbitlas
Family

3D quantum charge geometry
of periodic element nuclei

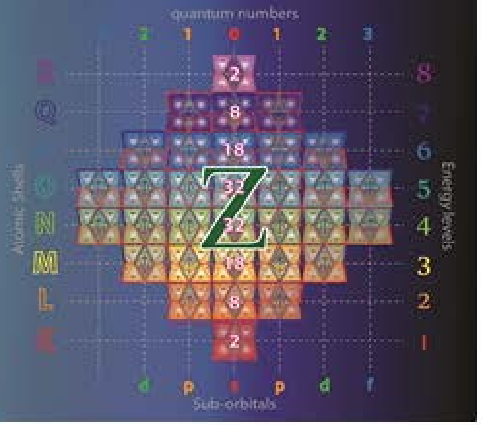
quantum numbers
2
1
0
1
2
3
R
Q
O
N
M
L
K
Atomic Shells
2
8
18
32
Z
32
18
8
2
8
7
6
5
4
3
2
1
Energy levels
d
p
s
p
d
f
Sub-orbitals

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THE ATOMIC NUCLEUS

the charged quantum mass-energy geometry of periodic element topologies

Neils Bohr

(7 October 1885 – 18 November 1962)

NEILS BOHR

Erwin Schrödinger

[12 August 1887 – 4 January 1961]

SCHRÖDINGER

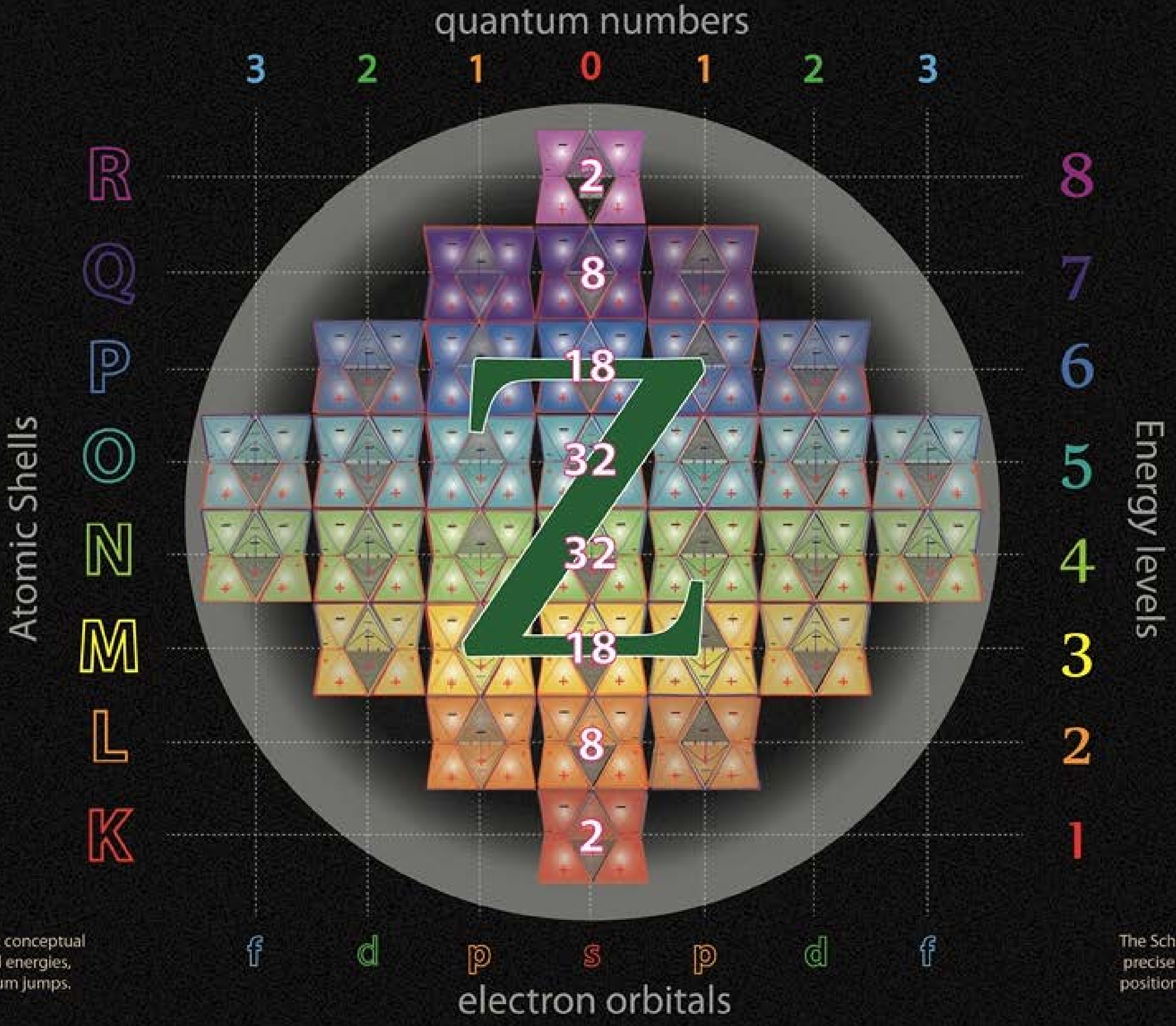
quantum numbers
3
2
1
0
1
2
3
Atomic Shells
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
Z
8
7
6
5
4
3
2
1
Energy levels
f
d
p
s
p
d
f
electron orbitals

The Bohr model gives us a basic conceptual model of electrons orbits and energies, along with the idea of quantum jumps.

The Schrondinger wave equation gives precise details of spectra and electron position and motions within the nuclei

The uncertainty principle erroneously dictates that position and momentum cannot be simultaneously determined.

Periodicity of atomic elements

An electron shell may be thought of as an orbit followed by electrons around an atom's nucleus. The closest shell to the nucleus is called the "1 shell" (also called "K shell"), followed by the "2 shell" (or "L shell"), then the "3 shell" (or "M shell"), and so on further and further from the nucleus. The shell letters K, L, M, ... are alphabetical

Each shell can contain only a fixed number of deuterium nuclei [Protons, Neutrons & electrons]

Each shell consists of one or more electron orbitals, and each orbital consists of one or more sub-orbitals.

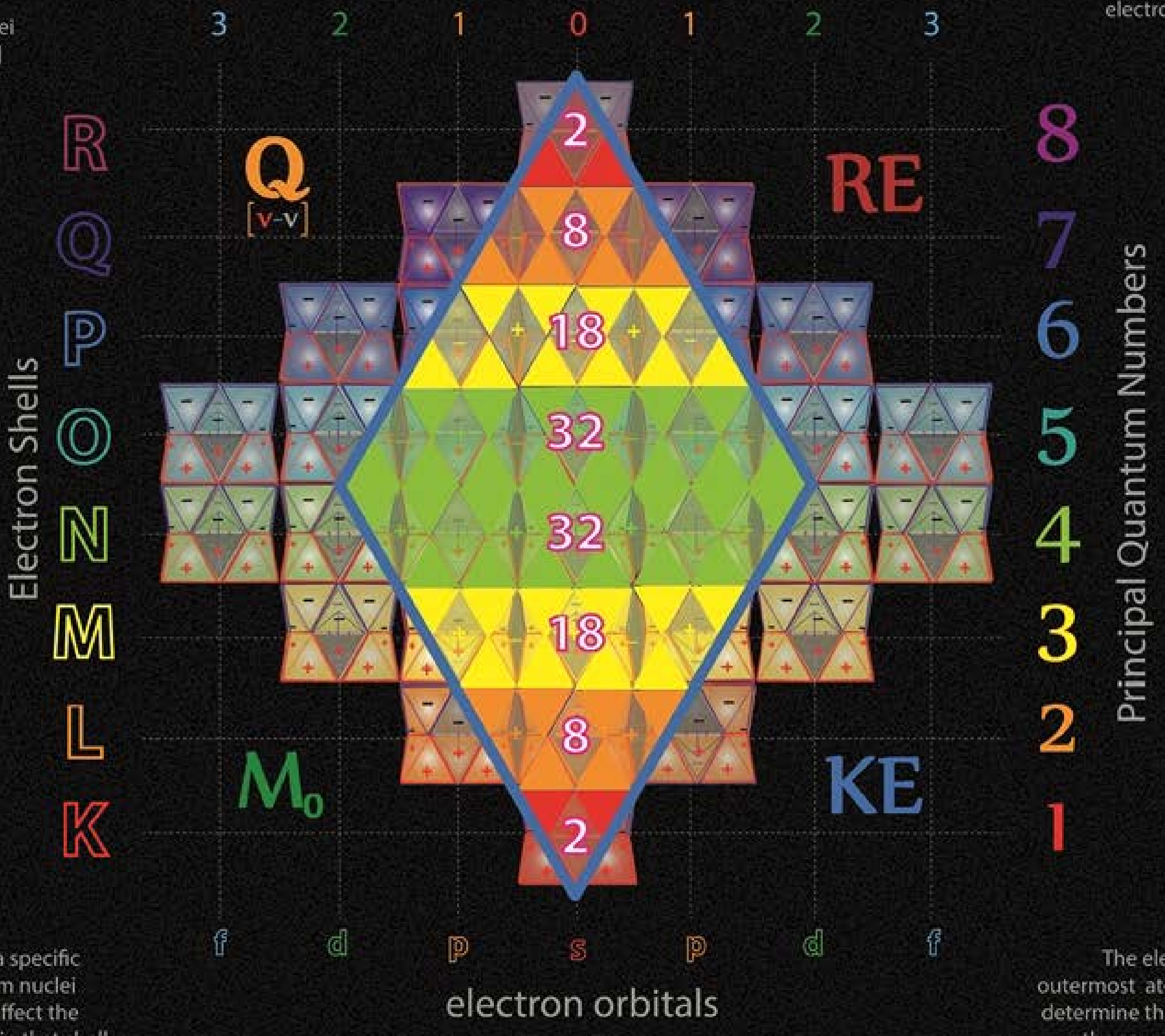

8 atomic energy shells with electrons

120 periodic elements in total

The number of deuterium nuclei that form each atomic shell in an elemental atom number is double that of Photon energy levels

Each atomic shell equates to a specific energy level for the Deuterium nuclei that comprise it with in turn affect the angular momentum of electrons in that shell

The electrons in the partially filled outermost atomic shell [or highest energy level] determine the chemical properties of the atom; they are called valence shell electrons.

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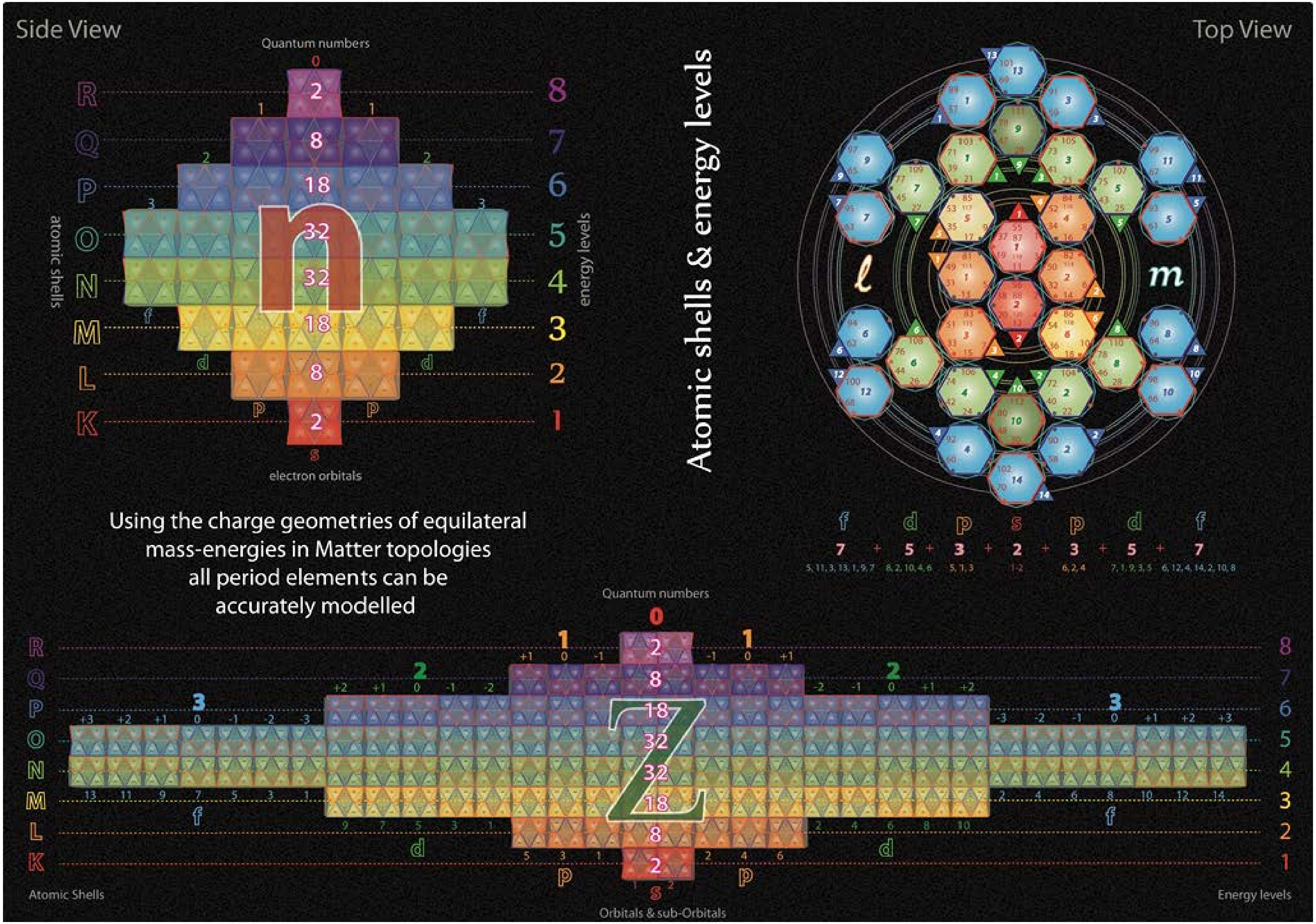
Side View
Quantum numbers
0
1
1
2
2
3
3
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
n
8
7
6
5
4
3
2
1
atomic shells
energy levels
f
f
d
d
p
p
s
electron orbitals
Atomic shells & energy levels
Top View
ℓ
m
f
d
p
s
p
d
f
7 + 5 + 3 + 2 + 3 + 5 + 7
5, 11, 3, 13, 1, 9, 7
8, 2, 10, 4, 6
5, 1, 3
1-2
6, 2, 4
7, 1, 9, 3, 5
6, 12, 4, 14, 2, 10, 8
Quantum numbers
0
1
1
2
2
3
3
+1 0 -1
-1 0 +1
+2 +1 0 -1 -2
-2 -1 0 +1 +2
+3 +2 +1 0 -1 -2 -3
-3 -2 -1 0 +1 +2 +3
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
Z
8
7
6
5
4
3
2
1
13 11 9 7 5 3 1
2 4 6 8 10 12 14
f
f
9 7 5 3 1
2 4 6 8 10
d
d
5 3 1
2 4 6
p
p
1 s 2
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Using the charge geometries of equilateral
mass-energies in Matter topologies
all period elements can be
accurately modelled

Tetryonics 44.03 - Shells & energy levels atomic Shells

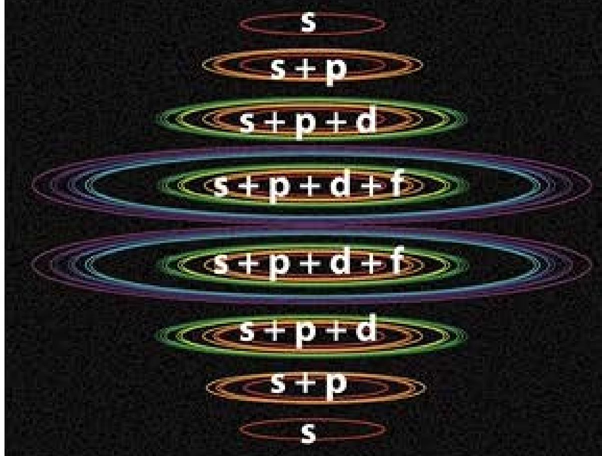
s
s + p
s + p + d
s + p + d + f
s + p + d + f
s + p + d
s + p
s

energy levels

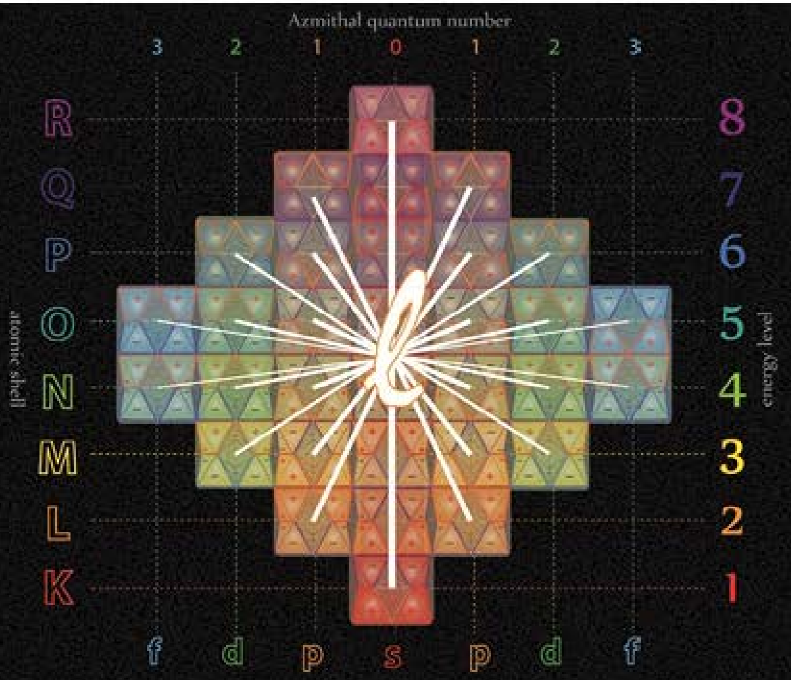
Azmithal quantum number
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
atomic shell
ℓ
8
7
6
5
4
3
2
1
energy level
f
d
p
s
p
d
f

Electron orbitals

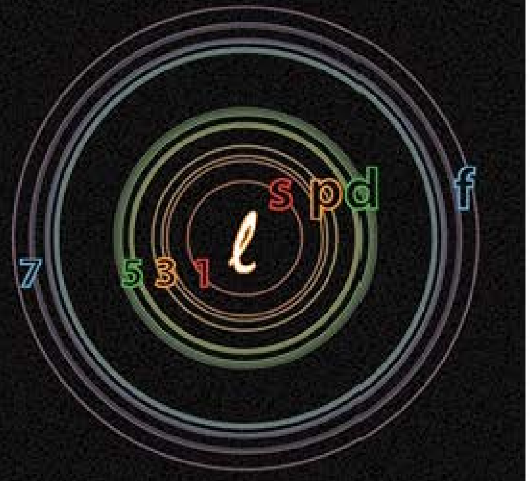

quantum numbers

All atoms have shells comprised of concentric s, p, d & f electron orbitals

electron orbitals

each electron orbital can hold a maximum of two spin opposed electrons

Each electron's location in
an elemental nuclei is defined
by its quantum numbers

a core s-orbital
surrounded by
3 p-orbitals
5 d-orbitals and
7 f-orbitals

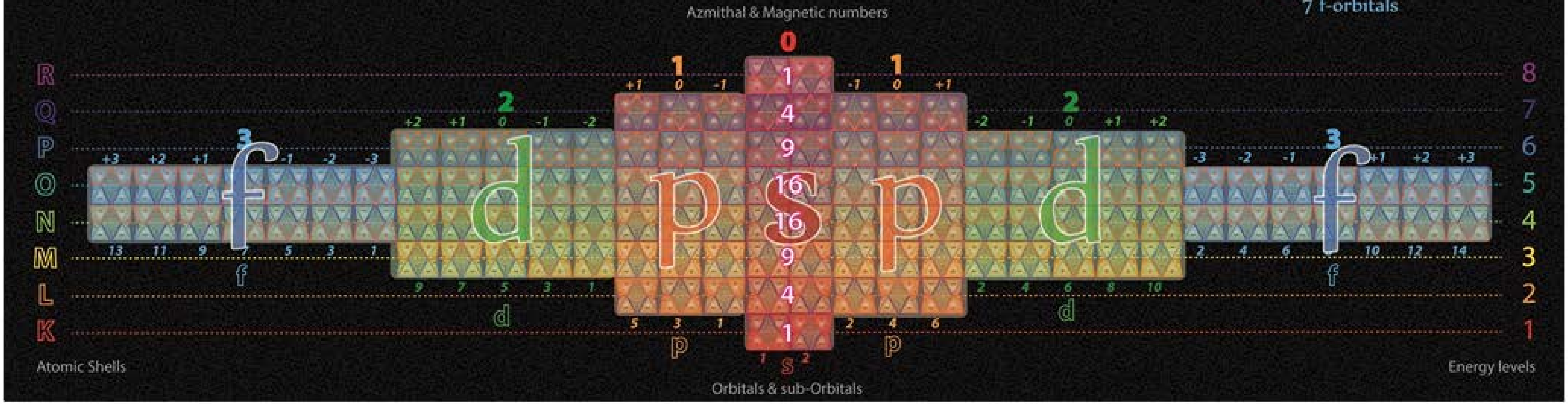
Azmithal & Magnetic numbers
0
1
4
9
16
s
16
9
4
1
1
2
s
1
+1
0
-1
p
5
3
1
p
1
-1
0
+1
p
2
4
6
p
2
+2
+1
0
-1
-2
d
9
7
5
3
1
d
2
-2
-1
0
+1
+2
d
2
4
6
8
10
d
3
+3
+2
+1
f
-1
-2
-3
13
11
9
7
5
3
1
f
3
-3
-2
-1
f
+1
+2
+3
2
4
6
8
10
12
14
f
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Atomic Shells
Energy levels

Orbitals & sub-Orbitals

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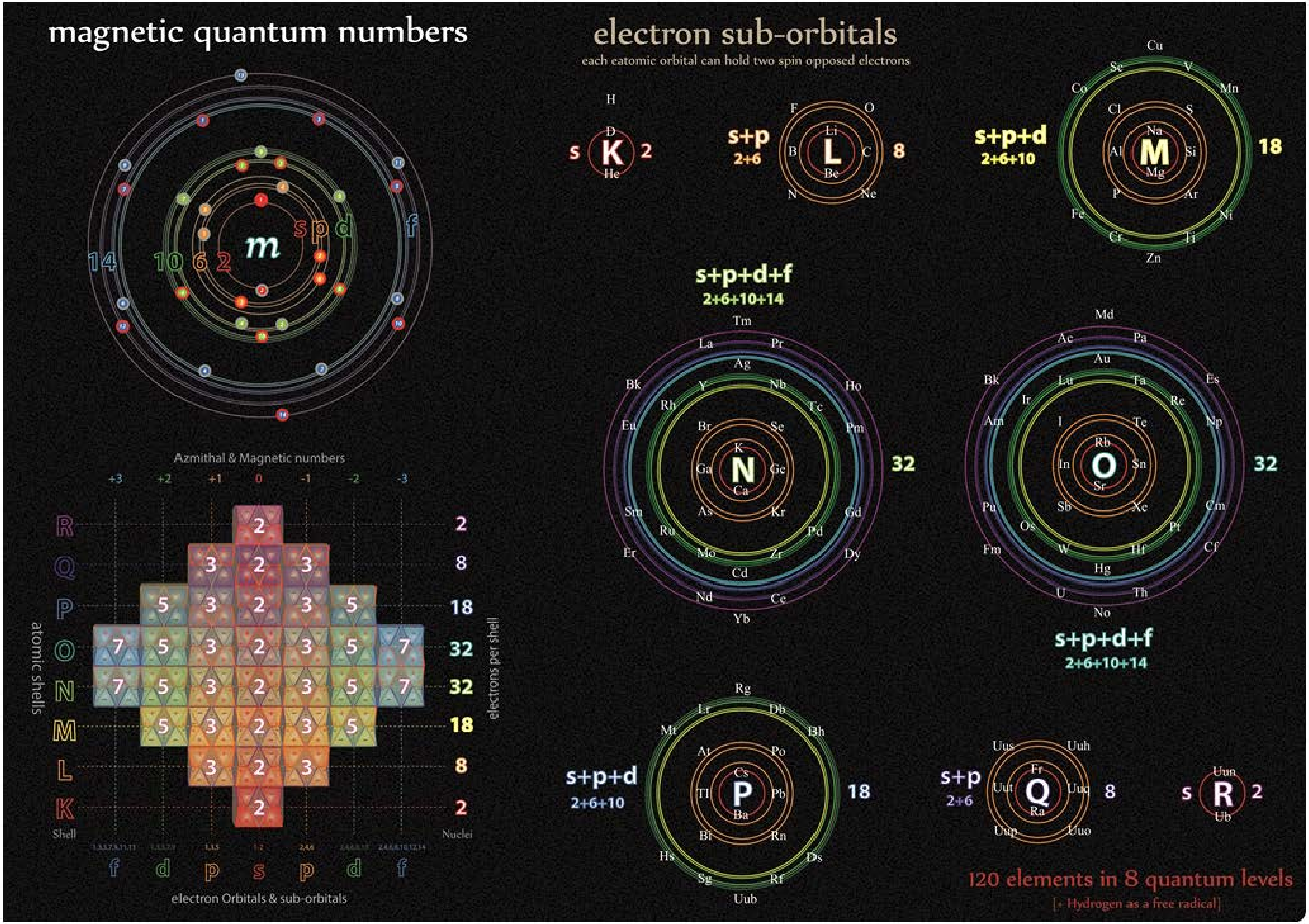
magnetic quantum numbers
m
s p d f
14 10 6 2
Azmithal & Magnetic numbers
+3 +2 +1 0 -1 -2 -3
R Q P O N M L K
Shell
atomic shells
2 8 18 32 32 18 8 2
electrons per shell
Nuclei
f d p s p d f
electron Orbitals & sub-orbitals
electron sub-orbitals
each eatomic orbital can hold two spin opposed electrons
H
s K 2
D He
s+p 2+6 L 8
F O Li B C Be N Ne
s+p+d 2+6+10 M 18
Cu Sc V Co Mn Cl S Na Al Si Mg P Ar Fe Ni Cr Ti Zn
s+p+d+f 2+6+10+14
N 32
Tm La Pr Ag Bk Y Nb Ho Rh Tc Eu Br Se Pm K Ga Ge Ca Sm As Kr Gd Ru Pd Er Mo Zr Dy Cd Nd Ce Yb
O 32
Md Ac Pa Au Bk Lu Ta Es Ir Re Am I Te Np Rb In Sn Sr Pu Sb Xe Cm Os Pt Fm W Hf Cf Hg U Th No
s+p+d+f 2+6+10+14
s+p+d 2+6+10
P 18
Rg Lr Db Mt Bh At Po Cs Tl Pb Ba Bi Rn Hs Ds Sg Rf Uub
s+p 2+6
Q 8
Uus Uuh Fr Uut Uuq Ra Uup Uuo
s R 2
Uun Ub
120 elements in 8 quantum levels
[+ Hydrogen as a free radical]

Tetryonics 44.05 - Electron sub-Obitals

Electron SPIN in atoms

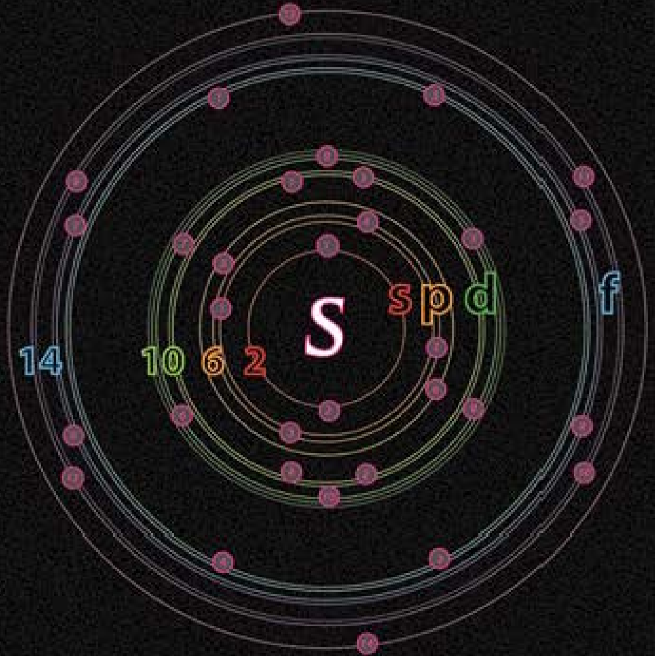
S
s p d f
14
10
6
2

1 sub-Orbit	s	*2 electrons*
3 sub-Orbits	p	*6 electrons*
5 sub-Orbits	d	*10 electrons*
7 sub-Orbits	f	*14 electrons*

Hund's Rule
Each electron sub-orbital (Azimuthal number)
can not have electrons with the same spin direction

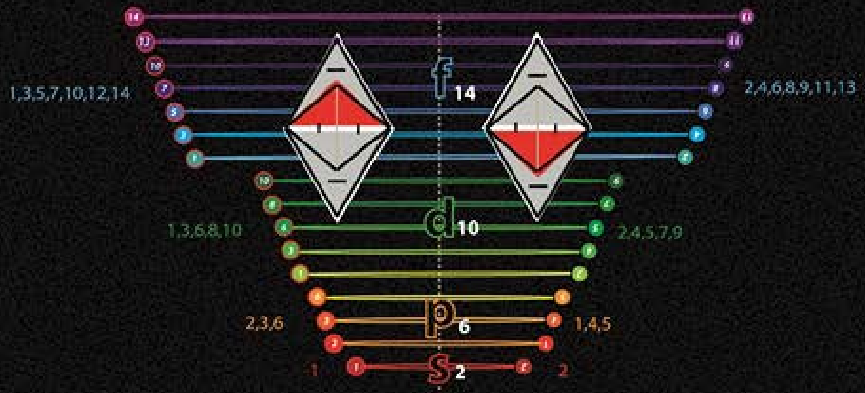
1,3,5,7,10,12,14
f 14
2,4,6,8,9,11,13
1,3,6,8,10
d 10
2,4,5,7,9
2,3,6
p 6
1,4,5
1
s 2
2

electron spin is always referenced to the Nuclear magneton

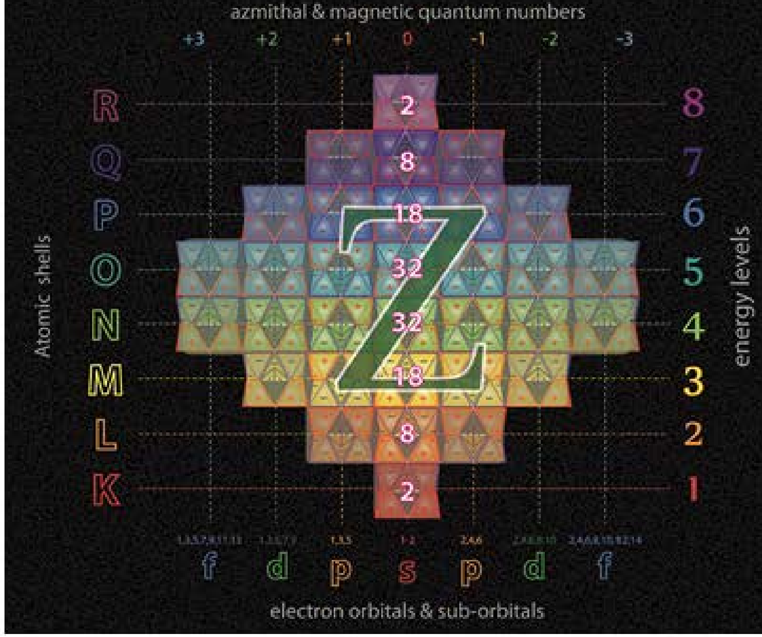
azmithal & magnetic quantum numbers
+3
+2
+1
0
-1
-2
-3
R
Q
P
O
N
M
L
K
Atomic shells
2
8
18
32
32
18
8
2
Z
8
7
6
5
4
3
2
1
energy levels
f
d
p
s
p
d
f
electron orbitals & sub-orbitals

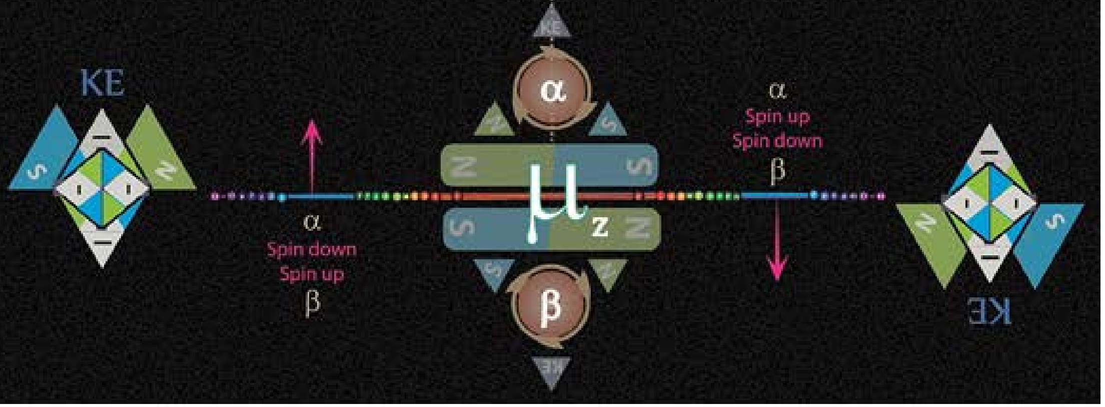
KE
α
Spin down
Spin up
β
α
β
μ
z
α
Spin up
Spin down
β
KE

Quantum numbers

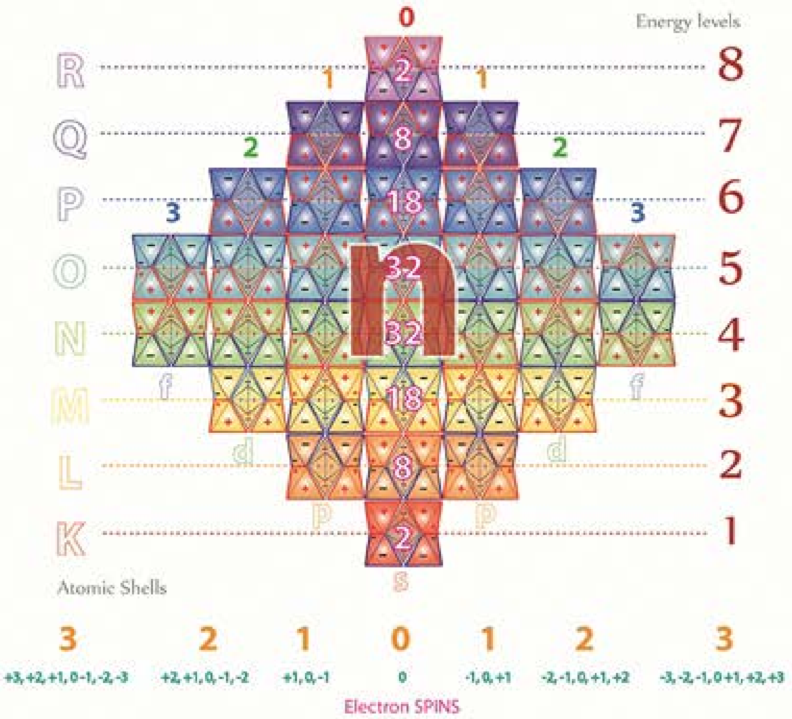
Energy levels
0
R
8
2
1
1
Q
7
8
2
2
P
6
3
18
3
O
5
32
n
N
4
32
M
3
18
f
f
L
2
d
8
d
K
1
p
2
p
s
Atomic Shells
3
2
1
0
1
2
3
+3, +2, +1, 0 -1, -2, -3
+2, +1, 0, -1, -2
+1, 0, -1
0
-1, 0, +1
-2, -1, 0, +1, +2
-3, -2, -1, 0 +1, +2, +3
Electron SPINS

These four numbers, n, ℓ, m and s can be used to describe any electron in a stable atom [and can be mapped back to the classical terminology of Shells and electron orbitals].

The properties of every atom's specific electron configuration can be described by four quantum numbers:

n (1-8)
Principal
(n = 1, 2, 3, 4 ...)

ℓ (0-3)
Azimuthal
(l = 0, 1 ... n−1)

m (2ℓ+1)
Magnetic
(ml = −l, −l+1 ... 0 ... l−1, l)

s ± ½
electron Spin
(ms = −1/2 or +1/2),

The Bohr model was a one-dimensional model that used one quantum number to describe the distribution of electrons

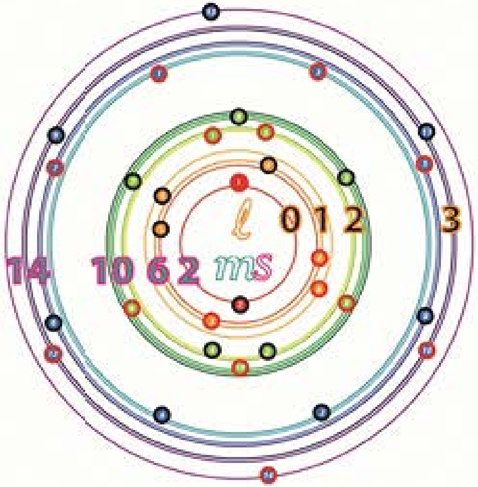
ℓ
0
1
2
3
14
10
6
2
ms

The three coordinates that come from Schrödinger's wave equations are the principal (n), angular (l), and magnetic (m) quantum numbers.

These quantum numbers describe the size, shape, and orientation in space of the orbitals of any particular atom mathematically.

Each electron's quantum numbers are unique and cannot be shared by another electron in that atom.

Azmithal & Magnetic numbers

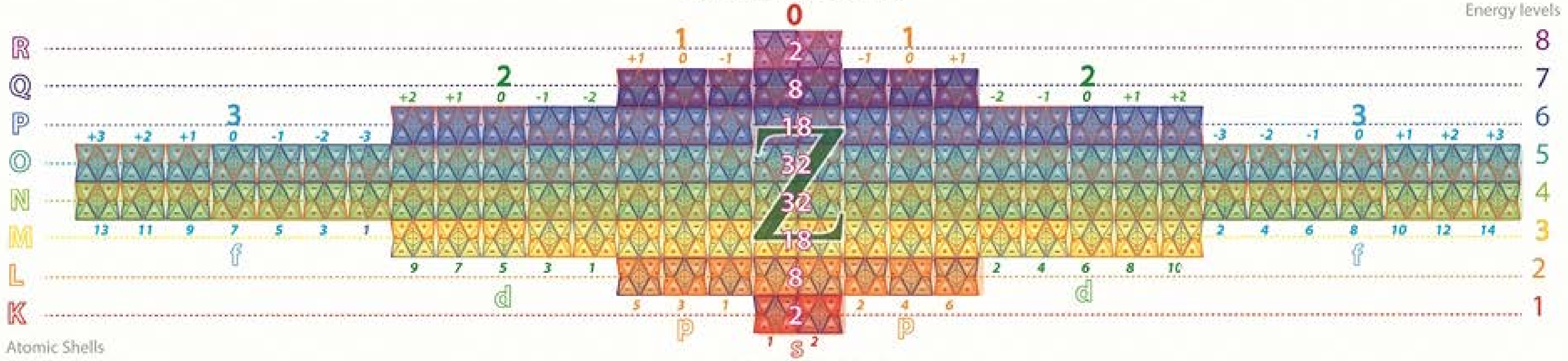
Energy levels
0
R
8
1
1
+1
0
-1
-1
0
+1
2
Q
7
8
2
2
+2
+1
0
-1
-2
-2
-1
0
+1
+2
3
3
P
6
+3
+2
+1
0
-1
-2
-3
18
-3
-2
-1
0
+1
+2
+3
O
5
32
Z
N
4
32
M
3
13
11
9
7
5
3
1
18
2
4
6
8
10
12
14
f
f
L
2
9
7
5
3
1
8
2
4
6
8
10
d
d
K
1
5
3
1
2
2
4
6
p
p
1
s
2
Atomic Shells

Orbitals & sub-Orbitals

A stable atom has equal numebrs of Protons, electrons [and Neutrons], all following the Pauli Exclusion Principle thus orientating their spins so that each element has a unique electron configuration

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PRINCIPAL quantum number

The first describes the electron shell, or energy level, of an atom.

This is the only quantum number introduced by the Bohr model

The principal quantum number can only have positive integer values

atomic shells

n(1-8)

(n = 1, 2, 3, 4 ...)

energy levels

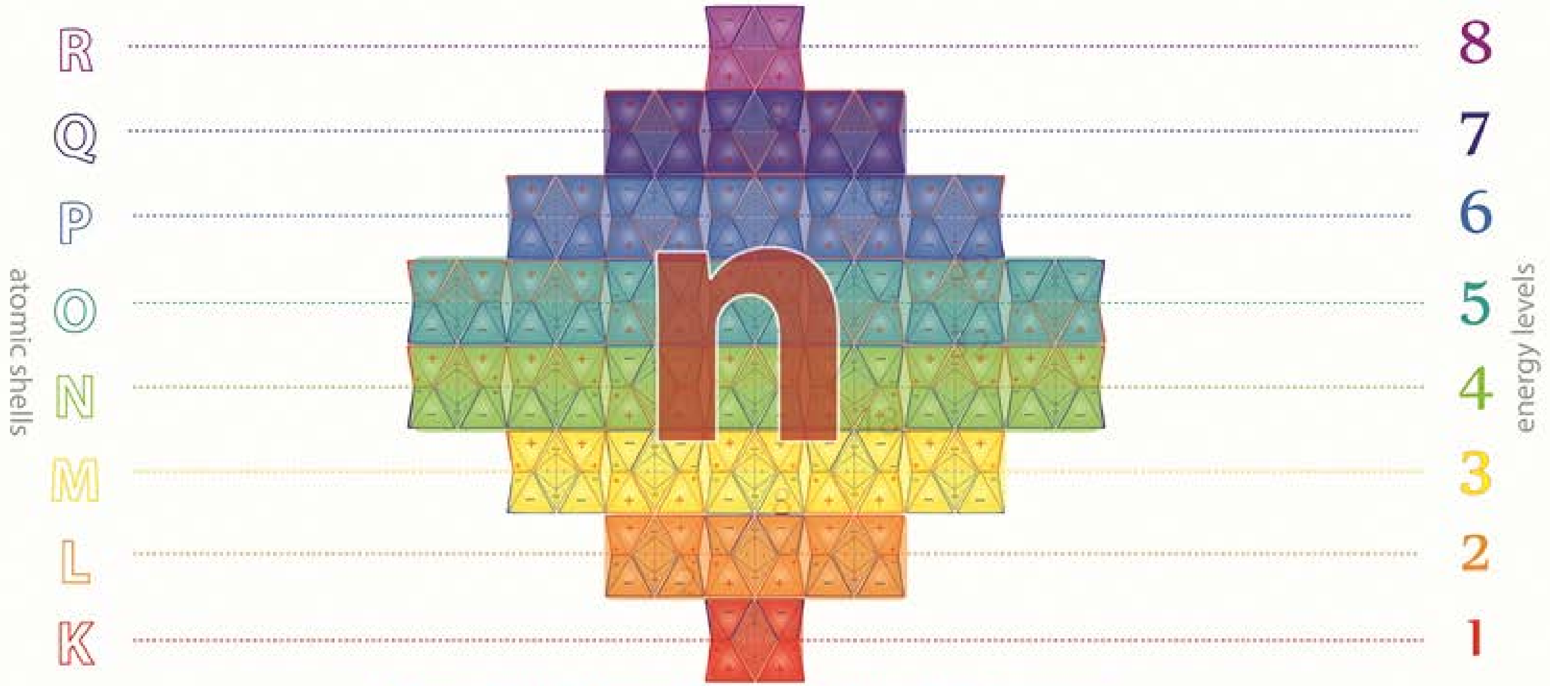

As energies of the Baryons comprising the atomic nuclei increases, the electron bound to each nuclei also possesses more KEM field energies and is therefore less tightly bound to the nucleus

Atomic Shells

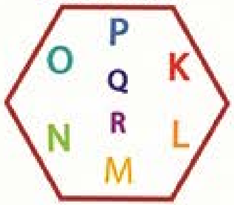

(K, L, M, N, O, P, Q, R)

Atomic shells relate directly to Principal quantum numbers

(1, 2, 3, 4, 5, 6, 7, 8)

Energy levels

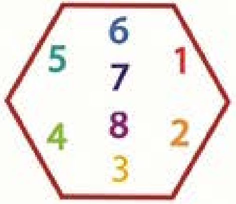

AZMITHAL quantum number

The azimuthal quantum number is a quantum number assigned to any atomic orbital that describes its orbital angular momentum and determines the shape of the electron orbital

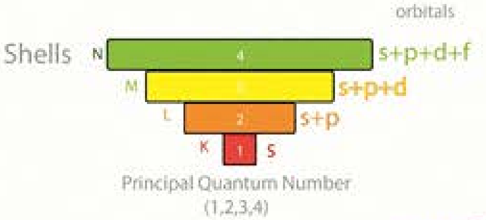

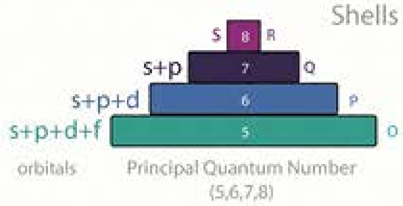

s p d f

electron orbitals

(l = 0, 1 ... n−1)

ℓ (0-7)

Azimuthal

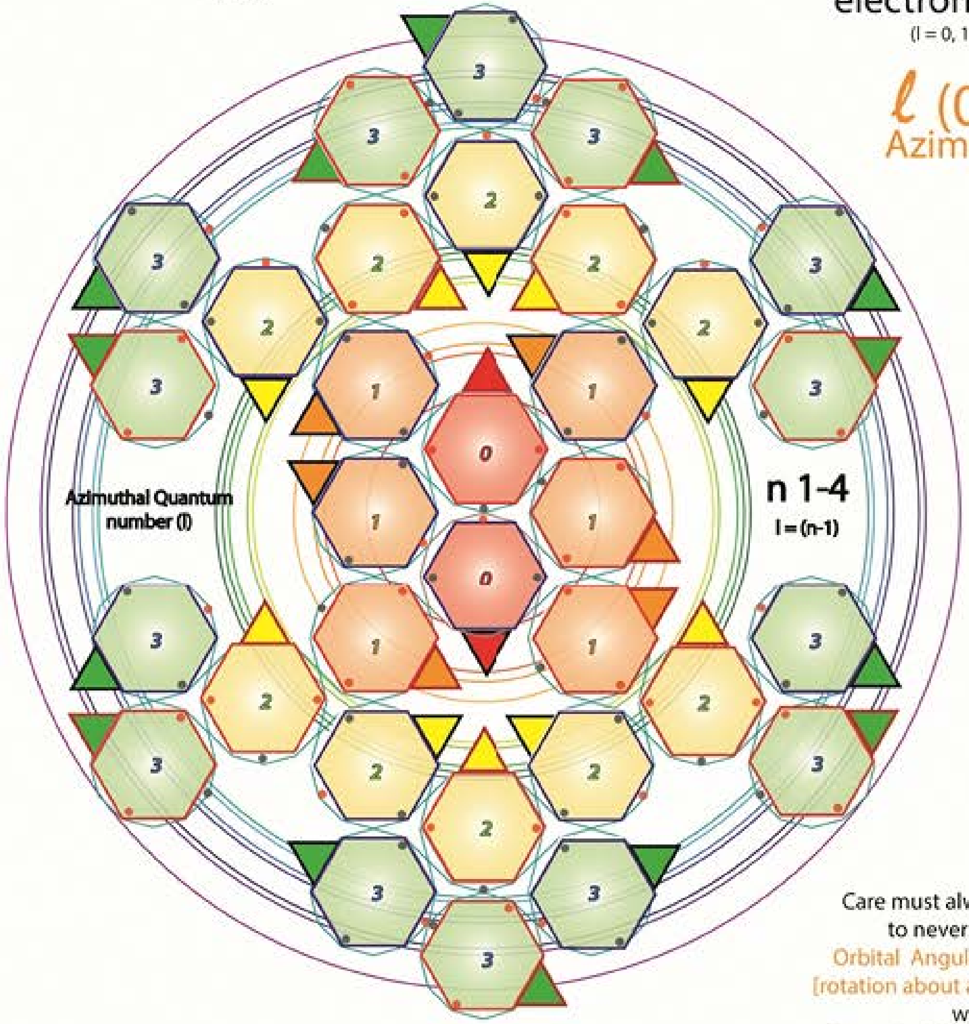
Azimuthal Quantum number (l)
n 1-4
l = (n-1)

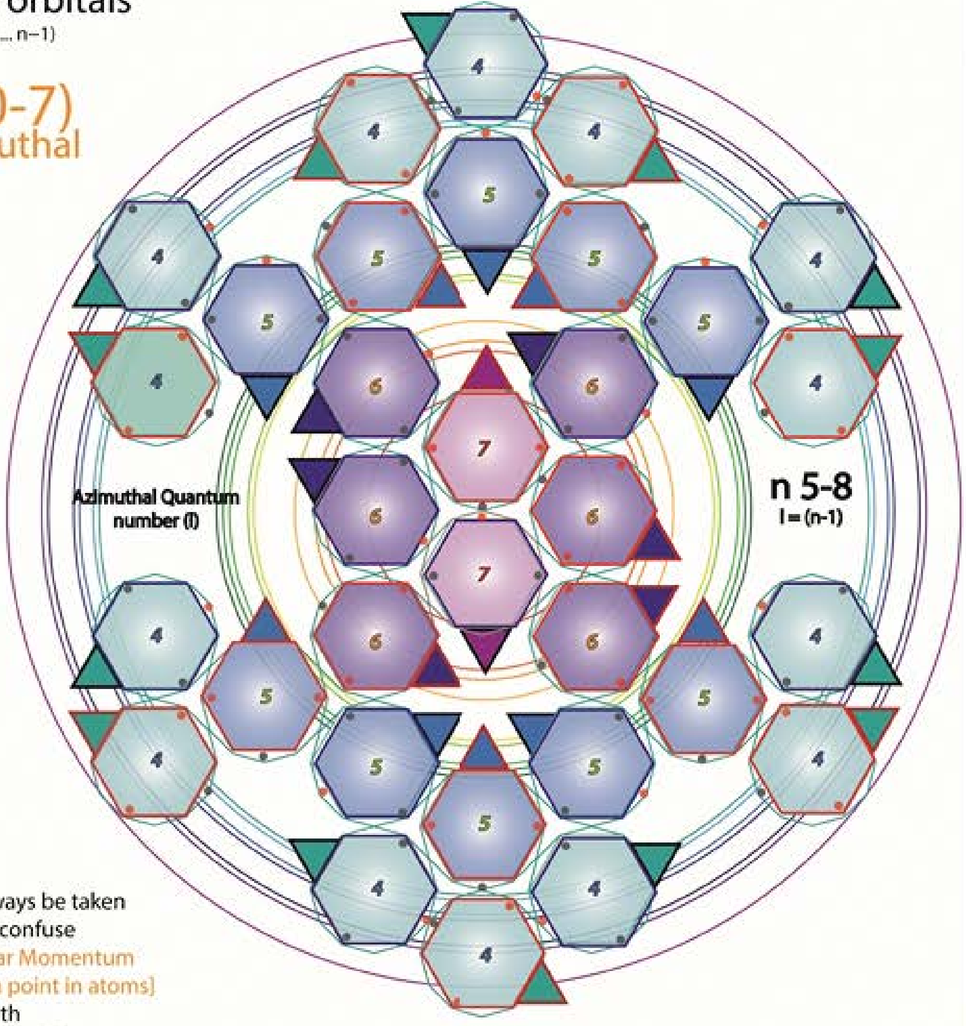
Azimuthal Quantum number (l)
n 5-8
l = (n-1)

Care must always be taken
to never confuse
Orbital Angular Momentum
[rotation about a point in atoms]
with
Quantised Angular Momenta
[equilateral Planck energy geometries]

MAGNETIC quantum number

The magnetic quantum number denotes the energy levels available within any subshell

Magnetic numbers do not continue to increase as the Principal numbers increase
instead they reverse after n4 to reflect the charged quanutm geometry of Elements
and do not follow the current computer models in popular use

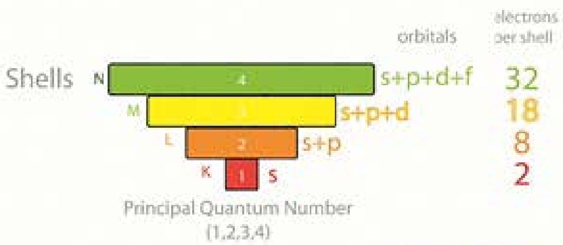
Shells
orbitals
electrons per shell
N
4
s+p+d+f
32
M
3
s+p+d
18
L
2
s+p
8
K
1
s
2
Principal Quantum Number
(1,2,3,4)

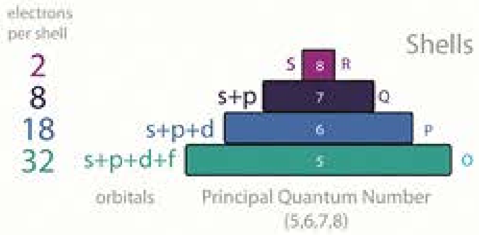
electrons per shell
Shells
2
S
8
R
8
s+p
7
Q
18
s+p+d
6
P
32
s+p+d+f
5
O
orbitals
Principal Quantum Number
(5,6,7,8)

s p d f

electron sub-orbitals

(ml = −l, −l+1 ... 0 ... l−1, l)

mℓ (2ℓ+1)

Magnetic

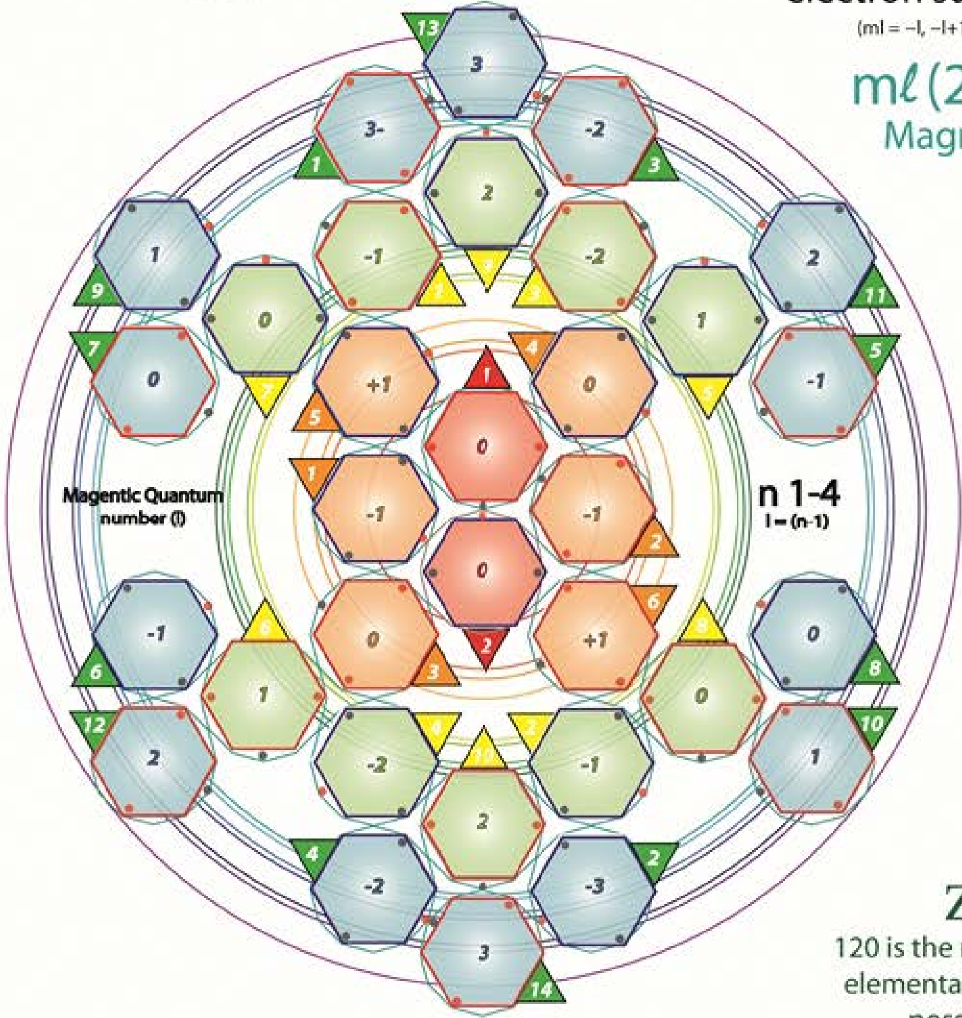
Magentic Quantum number (l)
n 1-4
l – (n-1)

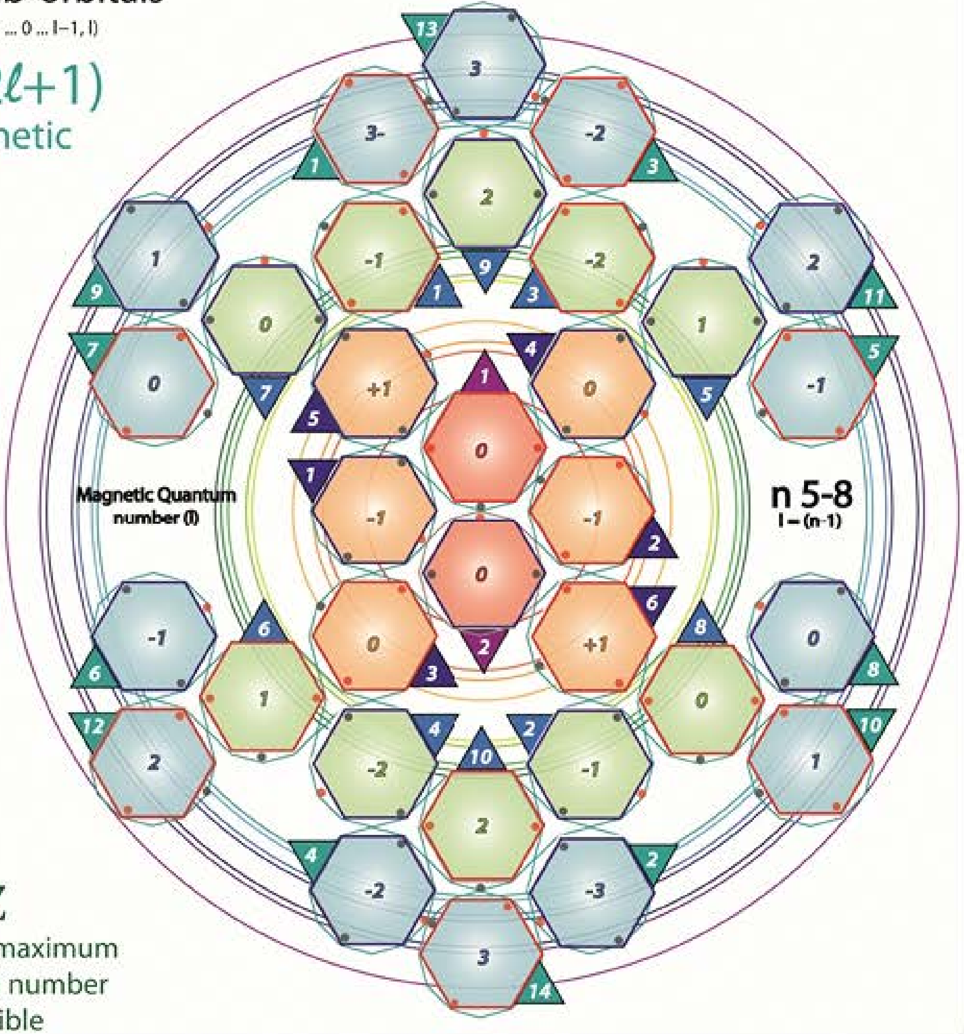
Magentic Quantum number (l)
n 5-8
l – (n-1)

Z

120 is the maximum
elemental number
possible

SPIN quantum number

The spin quantum number is a quantum number that parameterizes
the intrinsic angular momentum (or spin angular momentum),
of any given electron anywhere in an atomic nucleus

parallel magnetic moments

Spin UP

higher coupling energies

anti-parallel magnetic moments

Spin DOWN

lower coupling energies

Electron spin can orientate in either direction within Nuclei, providing the nett spins follow the Hund rule and Pauli exclusion principle

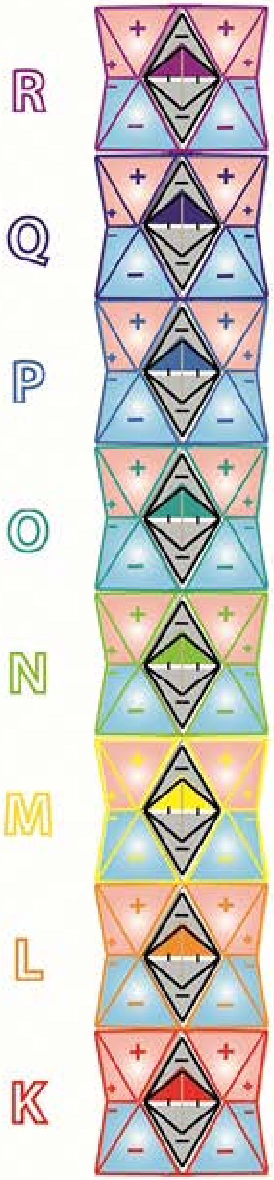

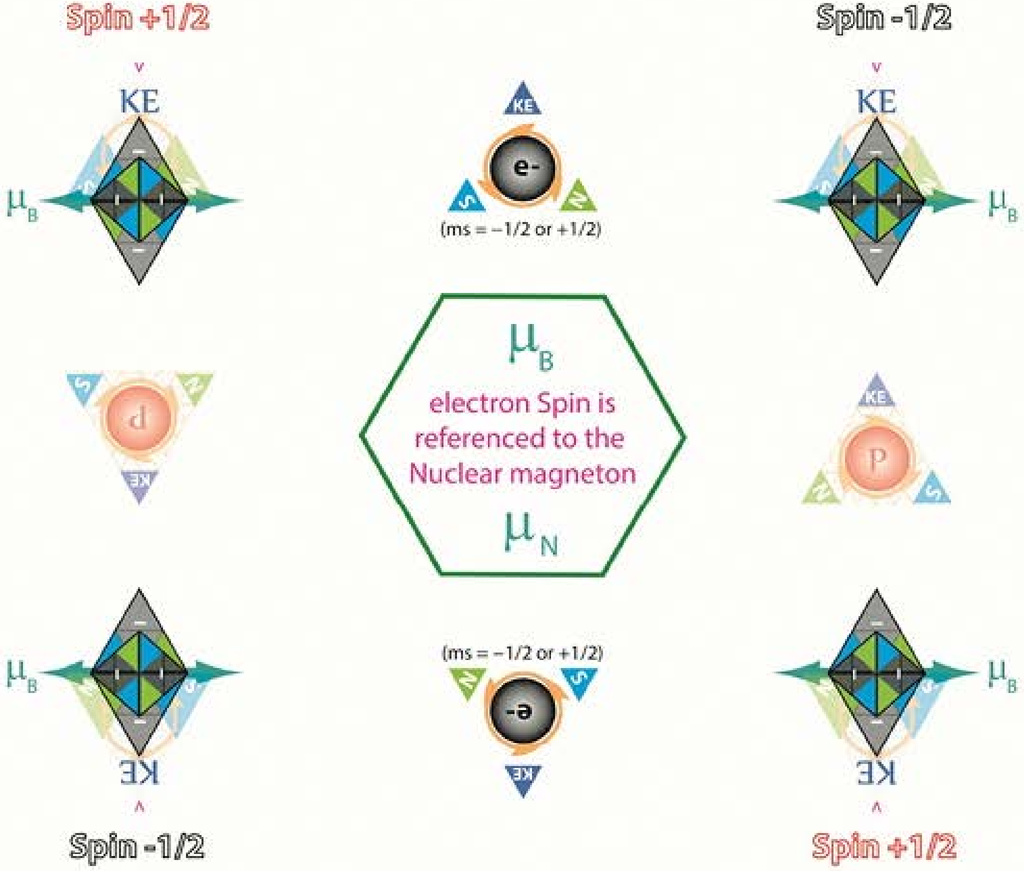
Spin +1/2
KE
μB
e-
KE
(ms = −1/2 or +1/2)
Spin -1/2
KE
μB
d
μB
electron Spin is
referenced to the
Nuclear magneton
μN
P
KE
μB
(ms = −1/2 or +1/2)
-e
KE
μB
KE
Spin -1/2
KE
Spin +1/2

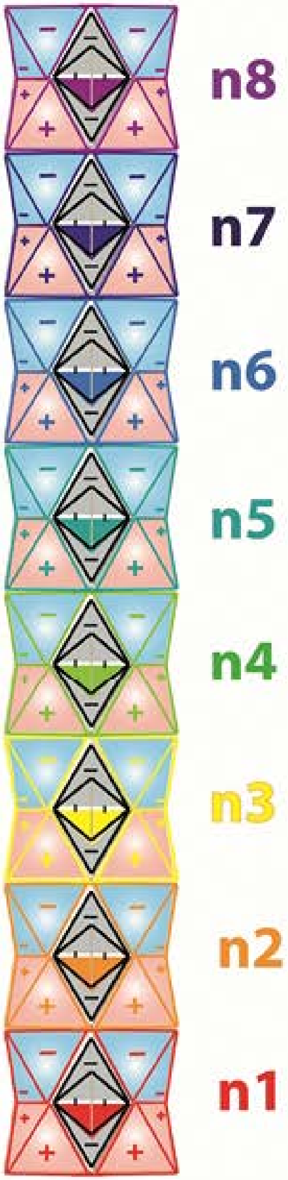
n8
n7
n6
n5
n4
n3
n2
n1
−
+

The nuclear energy levels of the Baryons comprising Elemental nuclei determine the energy-momenta of electrons bound to them

Modifying Hund's Rule

Electrons fill orbitals in an alternating sequential numbering pattern due to nucleon placement creating opposed direction electron spins

The increased stability of the atom, most commonly manifested in a lower energy state, arises because the high-spin state forces the unpaired electrons to reside in different spatial orbitals.

A commonly given reason for the increased stability of high multiplicity states is that the different occupied spatial orbitals create a larger average distance between electrons, reducing electron-electron repulsion energy. In reality, it has been shown that the actual reason behind the increased stability is a decrease in the screening of electron-nuclear attractions[1].

The total spin state is calculated as the total number of unpaired electrons + 1, or twice the total spin + 1 written as 2s+1.

As a result of Hund's rule, constraints are placed on the way atomic orbitals are filled using the Aufbau principle.

Before any two electrons occupy an orbital in a subshell, other orbitals in the same subshell must first each contain one electron. Also, the electrons filling a subshell will have parallel spin before the shell starts filling up with the opposite spin electrons (after the first orbital gains a second electron).

As a result, when filling up atomic orbitals, the maximum number of unpaired electrons (and hence maximum total spin state) is assured

s	p	d	f
▲1 1 2▼	▼1 1 2▲	▲1 1 2▼	▲ 1 1 2 ▼
	▲3 2 4▼	▲3 2 4▼	▲ 3 2 4 ▼
	▼5 3 6▲	▼5 3 6▲	▲ 5 3 6 ▼
		▼7 4 8▲	▲ 7 4 8 ▼
		▼9 5 10▲	▼ 9 5 10 ▲
			▼ 11 6 12 ▲
			▼ 13 7 14 ▲

▲

Hund's rule of orbital filling must be modified to reflect the true orbital filling order

▼

Sub-orbitals fill in order of numbering

Electrons spins pair before next orbital is filled

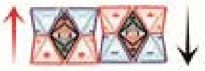

ie.
p1 [DOWN] and p2 [UP] fill
before
p3 [UP] and p4 [DOWN]
before
p5 [DOWN] and p6 [UP] etc

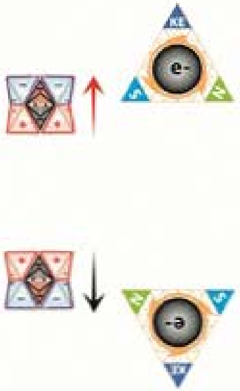

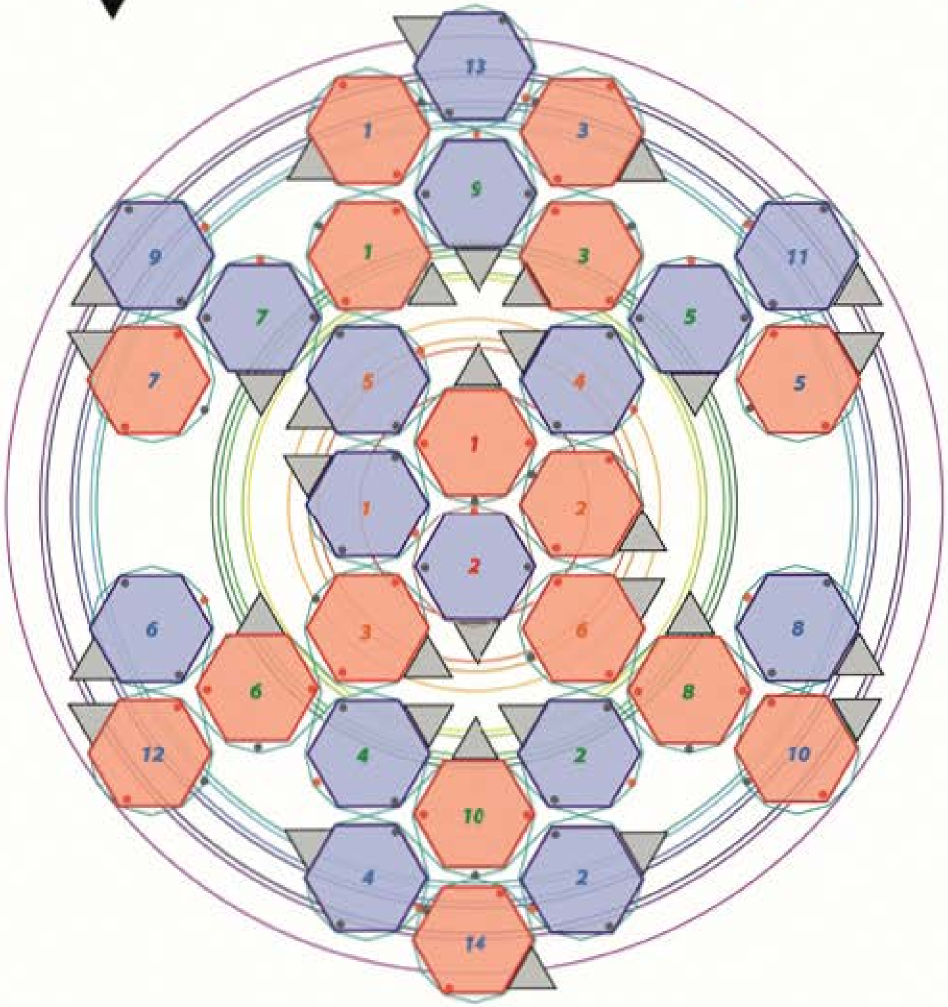

Principle quantum Energies

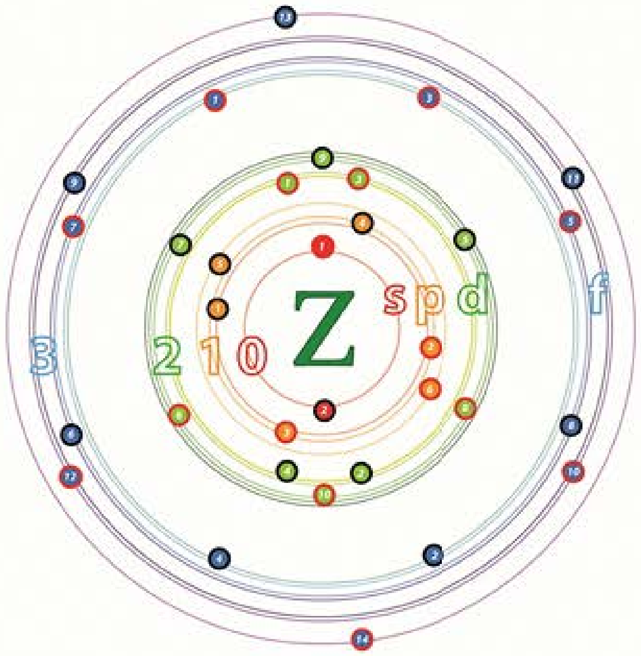

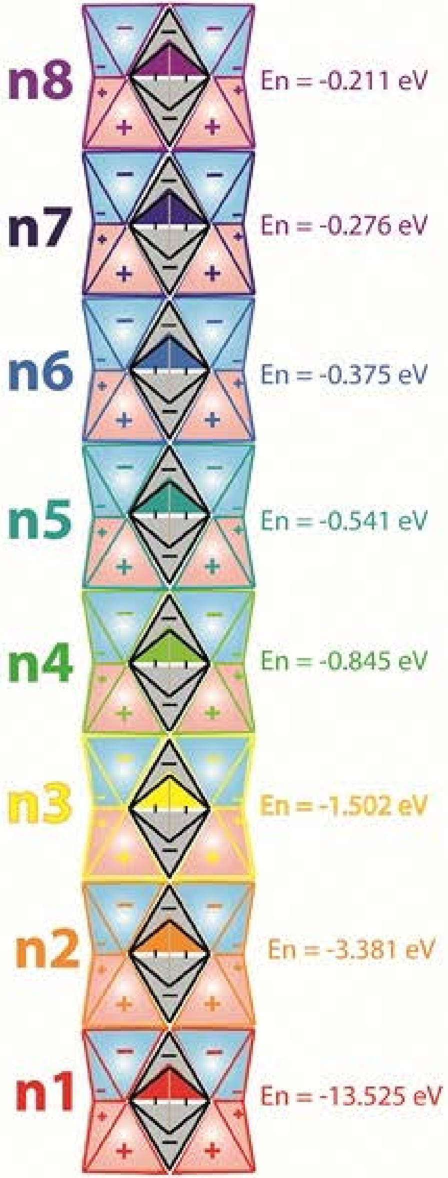

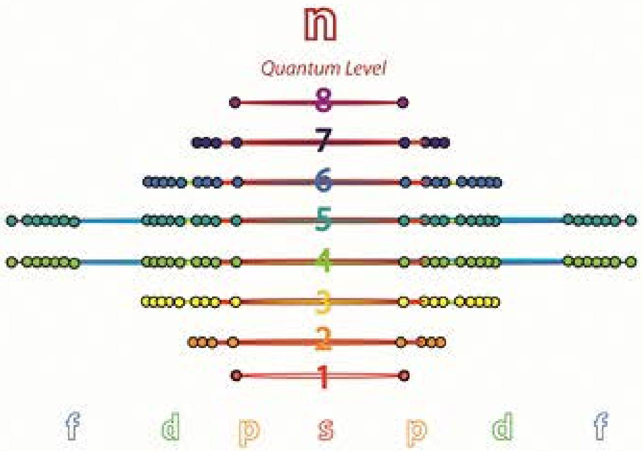

s orbits n1-8
p orbits n2-7
d orbits n3-6
f orbits n4-5

In an atom - electron energies are proportional to their intrinsic Kinetic Energies - which in turn are directly proportional to the quantum energy level of the nuclei which the electron binds to in their respective atomic shel s

In a nucleus, lower energy orbits have less 'paired' nuclei supplying energy. The more energy you give a nuclei the faster it casuses the bound electron to rotate. If you give the nuclei enough energy, it will impart eneough energy to its electron for it to leave the system entirely.

The same is true for an electron orbital. Higher values of n mean more energy for the electron and the corresponding KEM field enegies of the electron is larger, resulting in increased angular momentum.

Values of n start at 1 and go up by integer amounts.

If enough energy is added to the system by incident Photons a electron will leave the atom creating a positively charged nuclei [ionisation].

Eigenstate value

KEM field energy [per n] required to exceed 13.525 eV at which point the photo-electron has sufficient KE to break free of the Nucleus

$$E_n = \frac{E_1}{n^2} = \frac{-13.6eV}{n^2}, n = 1, 2, 3...$$

The possible Kinetic Energies (quantum levels) of an electron are directly related to the energy level of the Nuclei in each Quantum Level

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Quantum Level 1

K shell

n1

Ground State electron

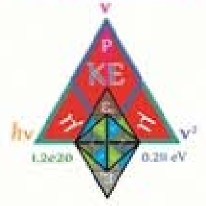
v
P
KE
hv
v^2
1.2e20
0.28 eV

$iE = -13.313\ eV$

The energy levels of bound electrons is determined by Baryons

Z #	Name		Protons	electrons	Neutrons
1	1s1	Deuterium	1	1	1
2	1s2	Helium	2	2	2

2

Deuterium [not Hydrogen] is the building block of elements

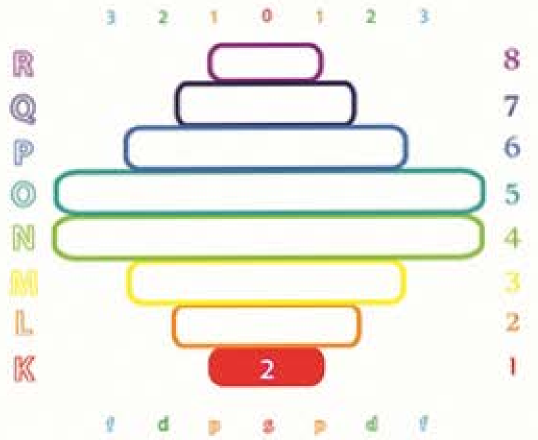
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
f
d
p
s
p
d
f

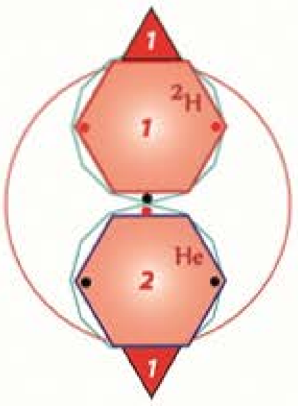

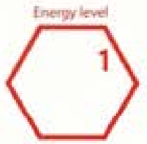
Energy level
1

Z #	Name		Protons	electrons	Neutrons
1	1s1	Hydrogen	1	1	0

Hydrogen is a free radical element

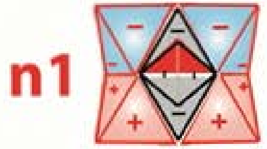

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Quantum Level 2

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
3	2s1	Lithium	3	3	3
4	2s2	Beryllium	4	4	4
5	1p1	Boron	5	5	5
6	1p2	Carbon	6	6	6
7	1p3	Nitrogen	7	7	7
8	1p4	Oxygen	8	8	8
9	1p5	Fluorine	9	9	9
10	1p6	Neon	10	10	10

8

Deuterium [not Hydrogen] is the building block of elements

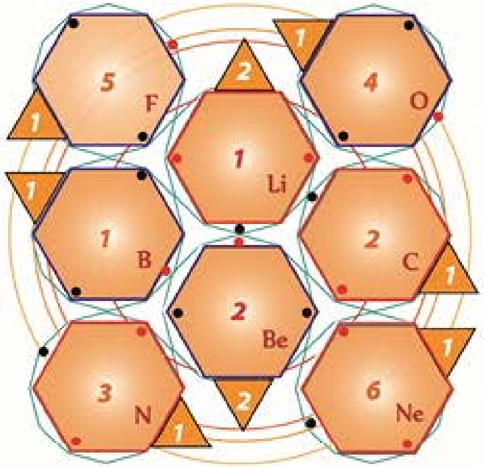
5
F
2
1
4
O
1
1
Li
1
1
B
2
C
1
2
Be
1
3
N
2
1
6
Ne

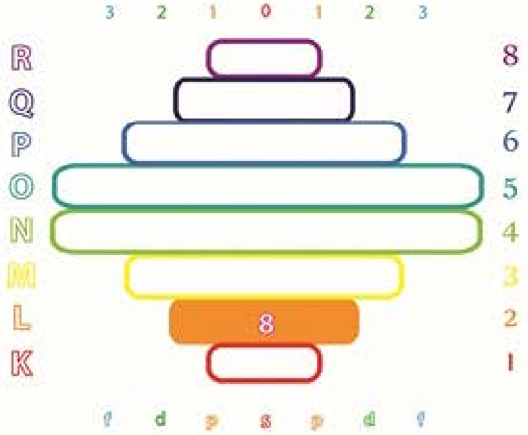
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

L shell

n2

Ground State electron

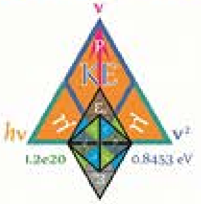
v
KE
hv
v²
1.2e20
0.8453 eV

$iE = -12.679\ eV$

Energy level
2

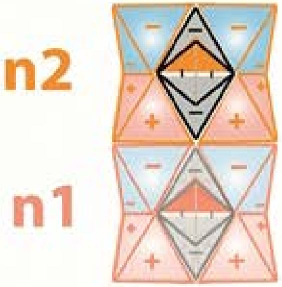

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Quantum Level 3

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
11	3s1	Sodium	11	11	11
12	3s2	Magnesium	12	12	12
13	2p1	Aluminium	13	13	13
14	2p2	Silicon	14	14	14
15	2p3	Phosphorus	15	15	15
16	2p4	Sulfur	16	16	16
17	2p5	Chlorine	17	17	17
18	2p6	Argon	18	18	18
21	3d1	Scandium	21	21	21
22	3d2	Titanium	22	22	22
23	3d3	Vanadium	23	23	23
24	3d4	Chromium	24	24	24
25	3d5	Manganese	25	25	25
26	3d6	Iron	26	26	26
27	3d7	Cobalt	27	27	27
28	3d8	Nickel	28	28	28
29	3d9	Copper	29	29	29
30	3d10	Zinc	30	30	30

18

Deuterium [not Hydrogen] is the building block of elements

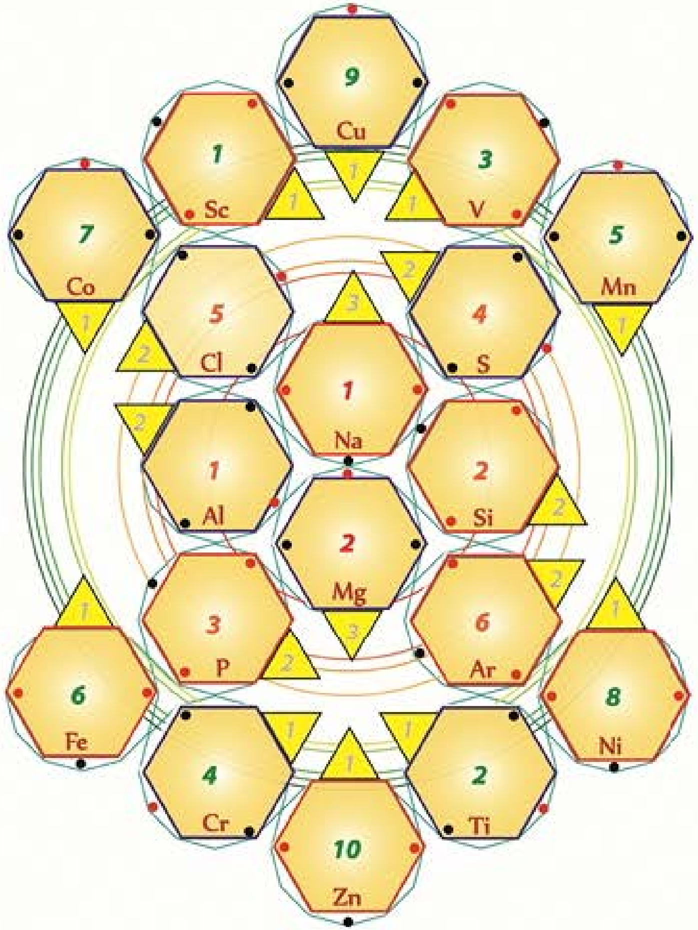
9
Cu
1
Sc
3
V
7
Co
5
Mn
5
Cl
4
S
1
Na
1
Al
2
Si
2
Mg
3
P
6
Ar
6
Fe
8
Ni
4
Cr
2
Ti
10
Zn

M shell

n3

Ground State electron

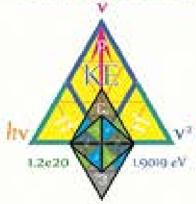
v
KE
hv
v²
1.2e20
1.9019 eV

$iE = -11.623\ eV$

Energy level
3

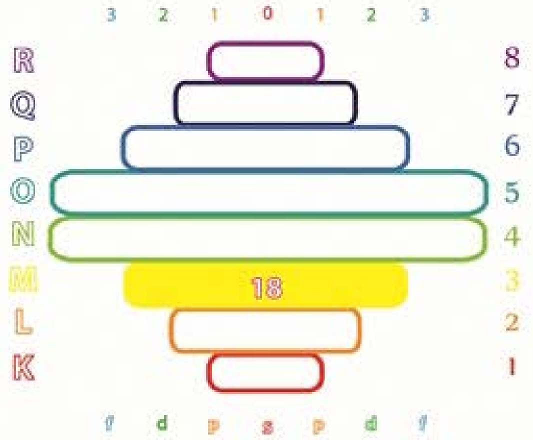
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
18
f
d
p
s
p
d
f

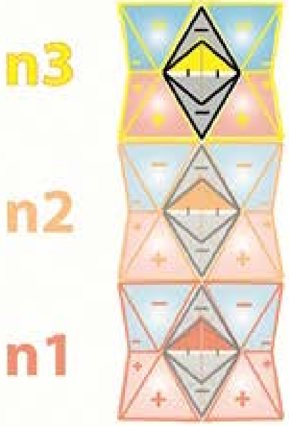

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Quantum Level 4

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
19	4s1	Potassium	19	19	19
20	4s2	Calcium	20	20	20
31	4p1	Gallium	31	31	31
32	4p2	Germanium	32	32	32
33	4p3	Arsenic	33	33	33
34	4p4	Selenium	34	34	34
35	4p5	Bromine	35	35	35
36	4p6	Krypton	36	36	36
39	4d1	Yttrium	39	39	39
40	4d2	Zirconium	40	40	40
41	4d3	Niobium	41	41	41
42	4d4	Molybdenum	42	42	42
43	4d5	Technetium	43	43	43
44	4d6	Ruthenium	44	44	44
45	4d7	Rhodium	45	45	45
46	4d8	Palladium	46	46	46
47	4d9	Silver	47	47	47
48	4d10	Cadmium	48	48	48
57	4f1	Lanthanum	57	57	57
58	4f2	Cerium	58	58	58
59	4f3	Praseodymium	59	59	59
60	4f4	Neodymium	60	60	60
61	4f5	Promethium	61	61	61
62	4f6	Samarium	62	62	62
63	4f7	Europium	63	63	63
64	4f8	Gadolinium	64	64	64
65	4f9	Terbium	65	65	65
66	4f10	Dysprosium	66	66	66
67	4f11	Holium	67	67	67
68	4f12	Erbium	68	68	68
69	4f13	Thulium	69	69	69
70	4f14	Ytterbium	70	70	70

32

Deuterium [not Hydrogen] is the building block of elements

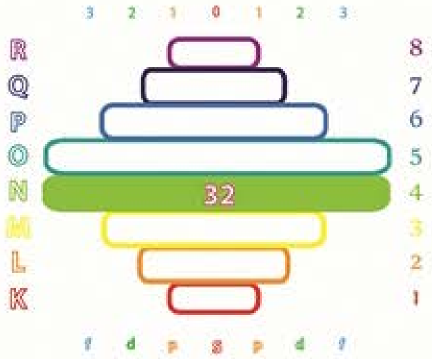
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
32
f d p s p d f

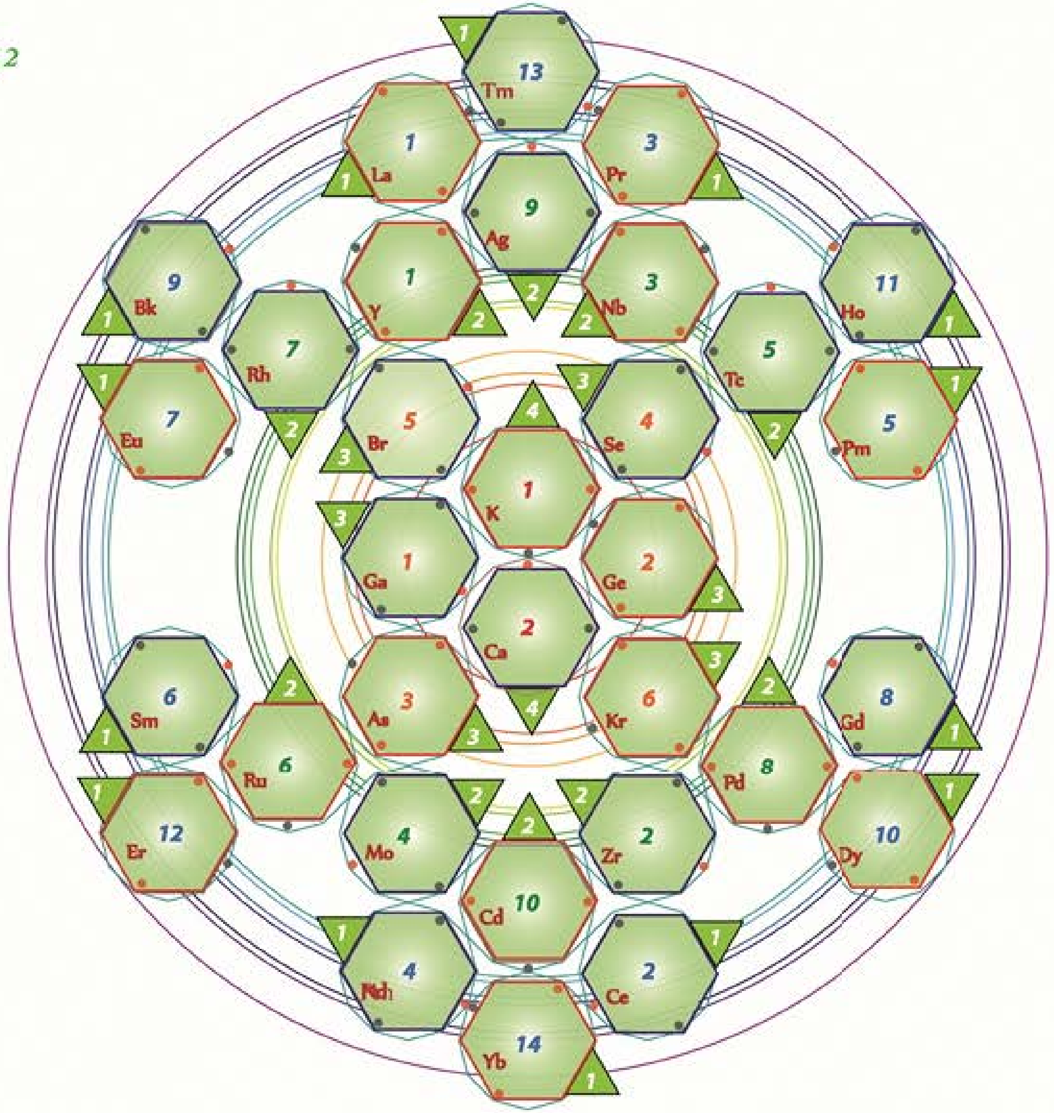
13
Tm
1
La
3
Pr
9
Ag
1
Y
3
Nb
9
Bk
11
Ho
7
Rh
5
Tc
7
Eu
5
Br
4
Se
5
Pm
1
K
1
Ga
2
Ge
2
Ca
6
Sm
3
As
6
Kr
8
Gd
6
Ru
8
Pd
12
Er
4
Mo
2
Zr
10
Dy
10
Cd
4
Nd
2
Ce
14
Yb

N shell

n4

Ground State electron

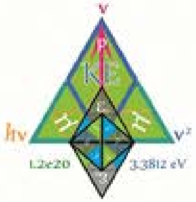
v
KE
hv
v²
1.2e20
3.3812 eV

$iE = -10.143\ eV$

Energy level
4

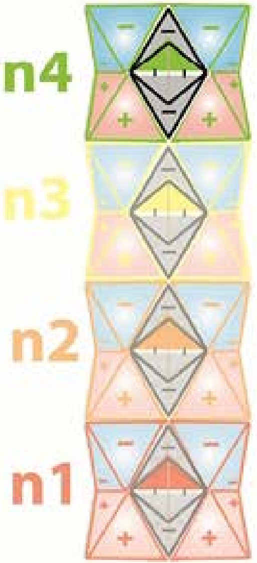

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Quantum Level 5

The energy levels of bound electrons is determined by Baryons

32

Z #		Name	Protons	electrons	Neutrons
37	5s1	Rubidium	37	37	37
38	5s2	Strontium	38	38	38
49	5p1	Indium	49	49	49
50	5p2	Tin	50	50	50
51	5p3	Antimony	51	51	51
52	5p4	Tellurium	52	52	52
53	5p5	Iodine	53	53	53
54	5p6	Xenon	54	54	54
71	5d1	Lutetium	71	71	71
72	5d2	Hafnium	72	72	72
73	5d3	Tantalum	73	73	73
74	5d4	Tungsten	74	74	74
75	5d5	Rhenium	75	75	75
76	5d6	Osmium	76	76	76
77	5d7	Iridium	77	77	77
78	5d8	Platinum	78	78	78
79	5d9	Gold	79	79	79
80	5d10	Mercury	80	80	80
89	5f1	Actinium	89	89	89
90	5f2	Thorium	90	90	90
91	5f3	Protactium	91	91	91
92	5f4	Uranium	92	92	92
93	5f5	Neptunium	93	93	93
94	5f6	Plutonium	94	94	94
95	5f7	Americium	95	95	95
96	5f8	Curium	96	96	96
97	5f9	Berkelium	97	97	97
98	5f10	Californium	98	98	98
99	5f11	Einsteinium	99	99	99
100	5f12	Fermium	100	100	100
101	5f13	Mendelevium	101	101	101
102	5f14	Nobelium	102	102	102

Deuterium [not Hydrogen] is the building block of elements

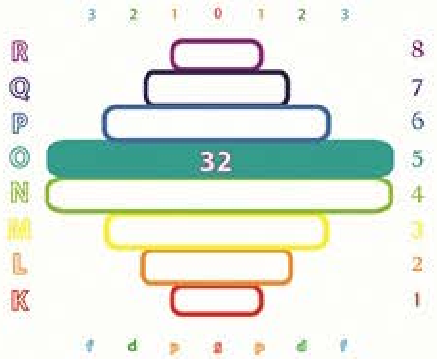
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
32
f d p s p d f

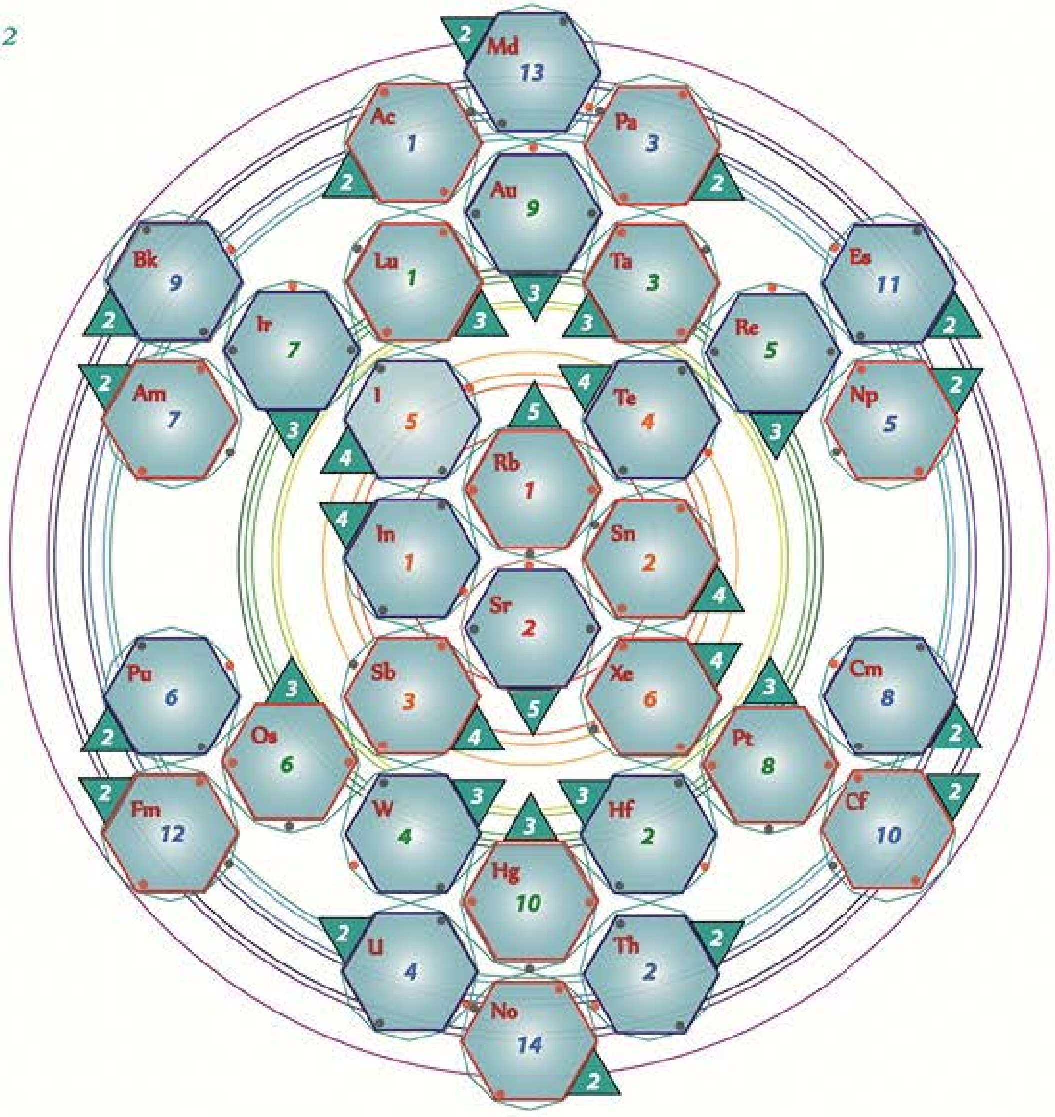
Md 13
Ac 1
Pa 3
Au 9
Bk 9
Lu 1
Ta 3
Es 11
Ir 7
Re 5
Am 7
I 5
Te 4
Np 5
Rb 1
In 1
Sn 2
Sr 2
Pu 6
Sb 3
Xe 6
Cm 8
Os 6
Pt 8
Fm 12
W 4
Hf 2
Cf 10
Hg 10
U 4
Th 2
No 14
2
3
4
5

O shell

n5

Ground State electron

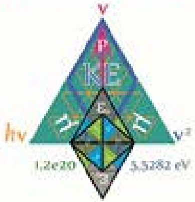
v
P
KE
hv
v²
1,2e20
5,5282 eV

$iE = -8.241\ eV$

Energy level

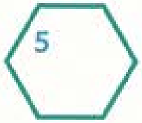

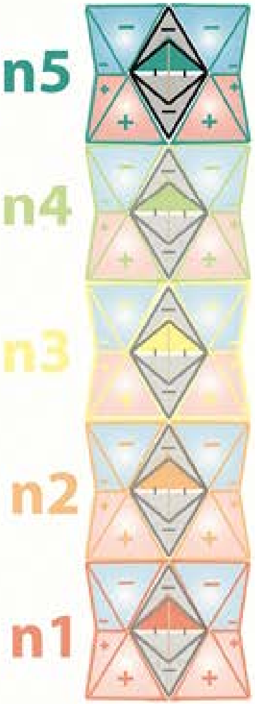
n5
n4
n3
n2
n1
−
+

Quantum Level 6

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
55	6s1	Caesium	55	55	55
56	6s2	Barium	56	56	56
81	6p1	Thallium	81	81	81
82	6p2	Lead	82	82	82
83	6p3	Bismuth	83	83	83
84	6p4	Polonium	84	84	84
85	6p5	Astatine	85	85	85
86	6p6	Radon	86	86	86
103	6d1	Lawrencium	103	103	103
104	6d2	Rutherfordium	104	104	104
105	6d3	Dubnium	105	105	105
106	6d4	Seaborgium	106	106	106
107	6d5	Bohrium	107	107	107
108	6d6	Hassium	108	108	108
109	6d7	Meitnerium	109	109	109
110	6d8	Darmstadtium	110	110	110
111	6d9	Roetgenium	111	111	111
112	6d10	Copernicium	112	112	112

18

Deuterium [not Hydrogen] is the building block of elements

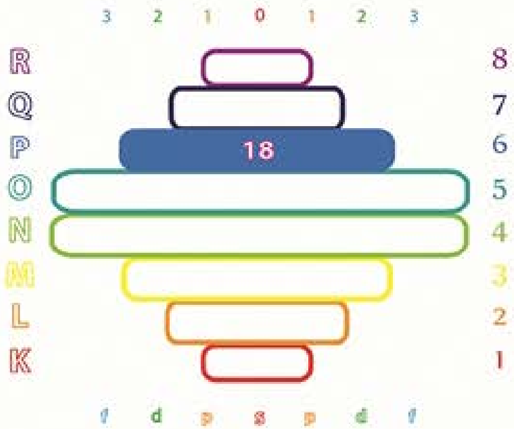
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
18
f
d
p
s
p
d
f

Energy level
6

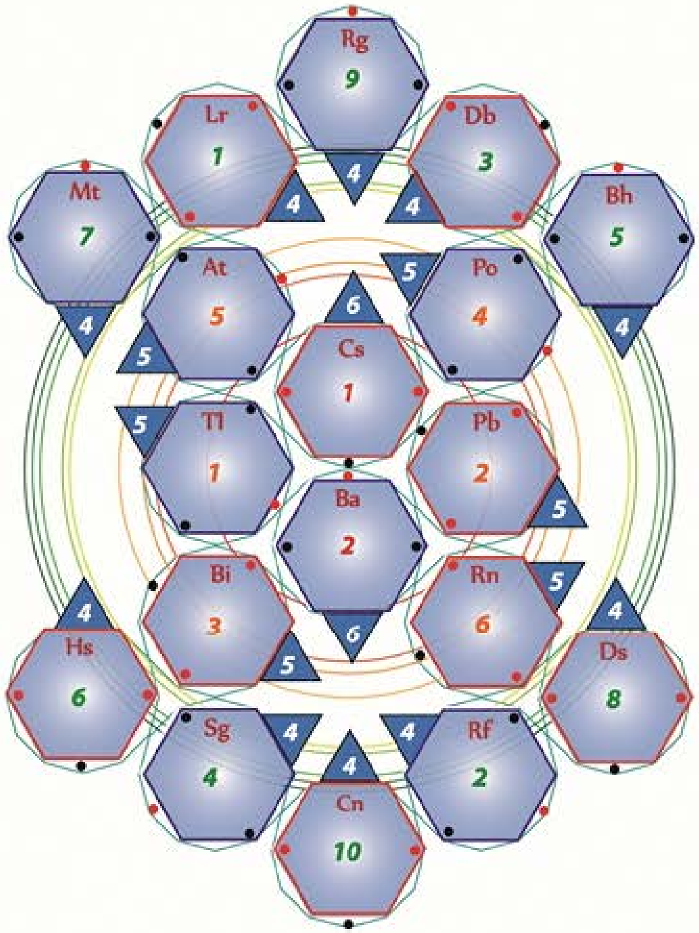
Rg
9
Lr
1
Db
3
Mt
7
Bh
5
At
5
Po
4
Cs
1
Tl
1
Pb
2
Ba
2
Bi
3
Rn
6
Hs
6
Ds
8
Sg
4
Rf
2
Cn
10
4
5
6

P shell

n6

Ground State electron

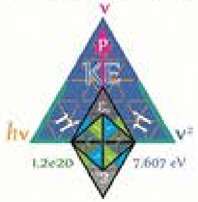
v
P
KE
hv
v²
1.2e20
7.607 eV

$iE = -5.917\ eV$

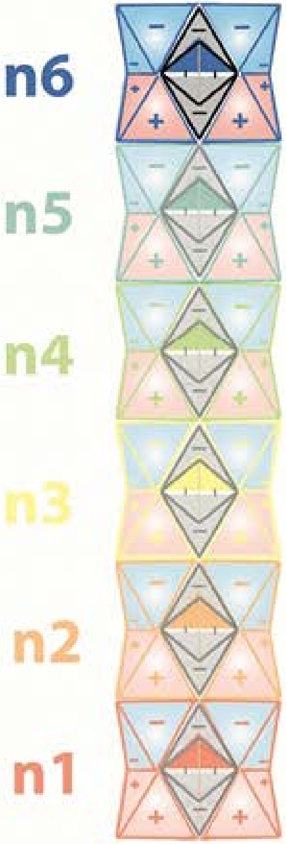
n6
n5
n4
n3
n2
n1

Quantum Level 7

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
87	*7s1*	**Francium**	87	87	87
88	*7s2*	**Radium**	88	88	88
113	*7p1*	**Ununtrium**	113	113	113
114	*7p2*	**Flerovium**	114	114	114
115	*7p3*	**Ununpentium**	115	115	115
116	*7p4*	**Livermorium**	116	116	116
117	*7p5*	**Ununseptium**	117	117	117
118	*7p6*	**Ununoctium**	118	118	118

8

Deuterium [not Hydrogen] is the building block of elements

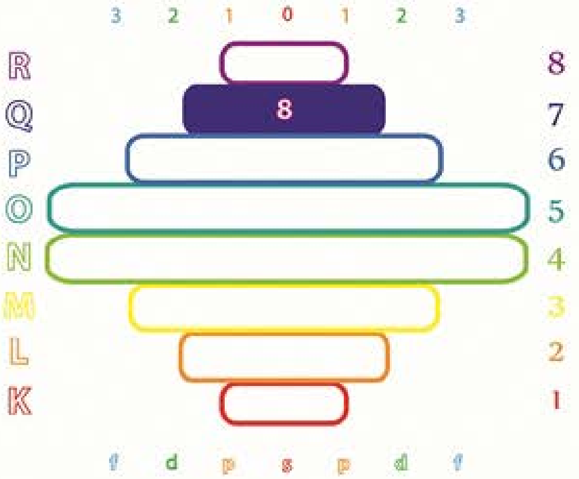
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

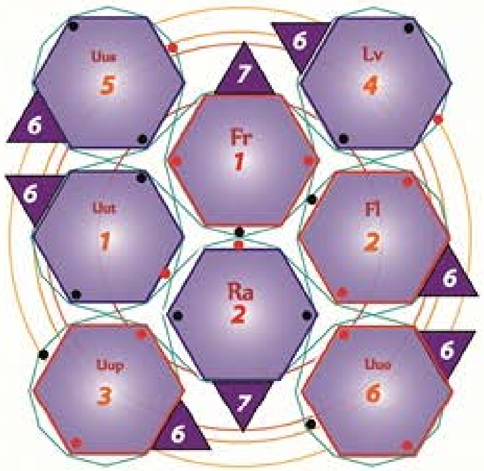
Uus
5
Lv
4
Fr
1
Uut
1
Fl
2
Ra
2
Uup
3
Uuo
6
7
7
6
6
6
6
6
6

Q shell

n7

Ground State electron

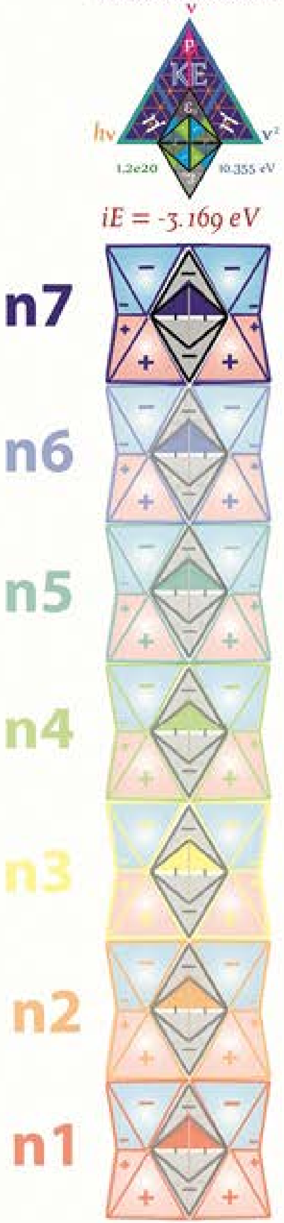
v
p
KE
c
hv
v²
1.2e20
10.355 eV
iE = -3.169 eV
n7
n6
n5
n4
n3
n2
n1
−
+

Energy level
7

Quantum Level 8

The energy levels of bound electrons is determined by Baryons

Z #		Name	Protons	electrons	Neutrons
119	8s1	Ununnonium	119	119	119
120	8s2	Unbinilium	120	120	120

2

Deuterium [not Hydrogen] is the building block of elements

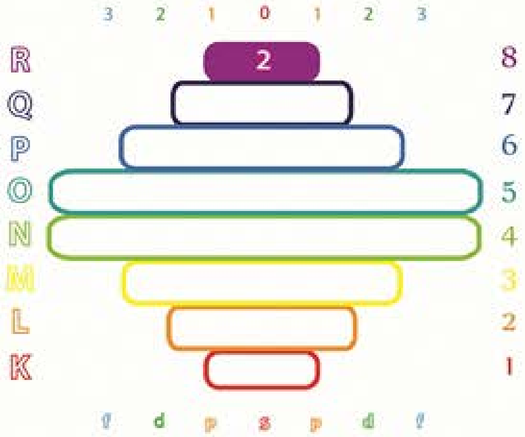
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
2
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

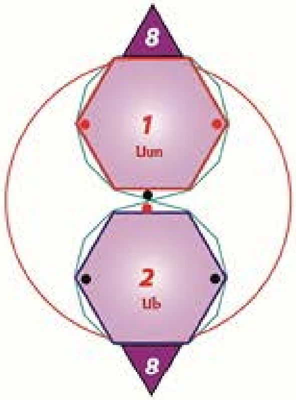

R shell

n8

Ground State electron

v
P
KE
hv
v²
1.2e20
13.525 eV

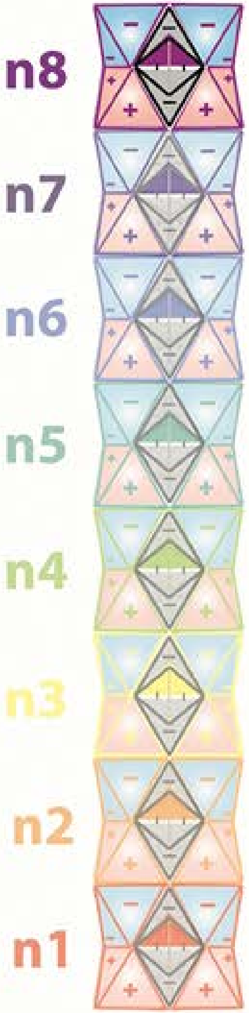
n8
n7
n6
n5
n4
n3
n2
n1

Energy level
8

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Spectral line transitions

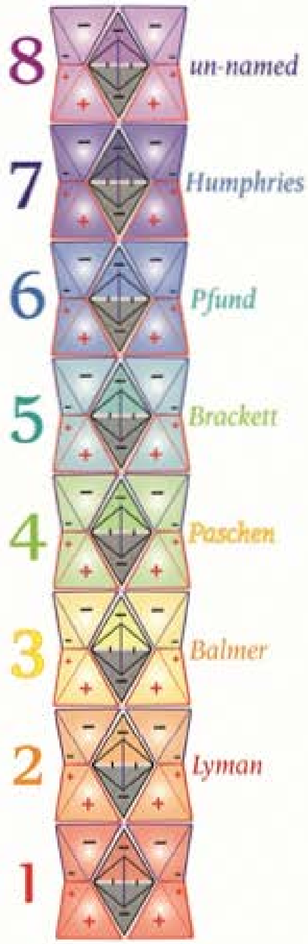
8
un-named
7
Humphries
6
Pfund
5
Brackett
4
Paschen
3
Balmer
2
Lyman
1

Quantum level jumps

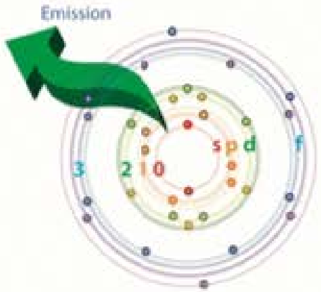
Emission
3 2 1 0 s p d f

Quantum Level Jumps

Photon Absorption and Release

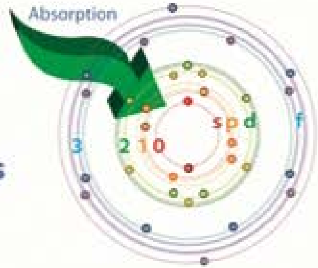
Absorption
3 2 1 0 s p d f

Photo-electrons can only transition between principal energy Baryons in the atomic nuclei in discrete steps [or quantum jumps] because Baryons determine the KEM energy levels of electrons in nuclei

[see Tetryonic QED for full details on spectral line mechanics]

Initial Quantum level

8	768	756	720	660	576	468	336	180	0
7	588	576	540	480	396	288	156	0	
6	432	420	384	324	240	132	0		
5	300	288	252	192	108	0			
4	192	180	144	84	0				
3	108	96	60	0					
2	48	36	0						
1	12	0							
		12	48	108	192	300	432	588	768
		1	2	3	4	5	6	7	8

Final Quantum level

$$\Delta p = \Delta Mv = hf$$

accelerating photo-electrons produce spectral lines

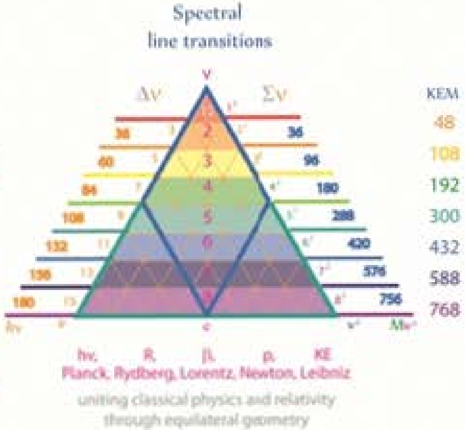
Spectral
line transitions
v
Δv
Σv
KEM
36
60
84
108
132
156
180
36
96
180
288
420
576
756
48
108
192
300
432
588
768
2
3
4
5
6
7
8
hv
Mv²
Quantum
differentials
hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz
uniting classical physics and relativity
through equilateral geometry

Nuclear energy emission~absorption

If atoms are left undisturbed, their electrons usually fill the lowest available energy levels and stay there, in their "ground state."

Occasionally, however, they may also be pushed up to some higher energy ("become excited") e.g. by a collision with a fast atom or electron, one which got extra speed from an electric voltage or from some source of heat.

An atom/electron elevated to one of its higher "excited levels" soon falls back to a lower level ("undergoes a quantum jump"), emitting a photon whose energy corresponds to the difference between the levels.

That need not be the ground state: the atom/electron might descend to that state in several steps, emitting a photon at each step on the way.

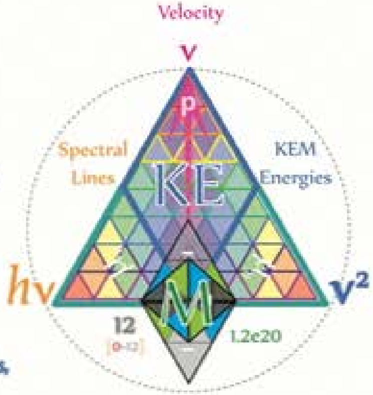
Velocity
v
p
Spectral
Lines
KEM
Energies
KE
hv
v²
M
12
[0-12]
1.2e20

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Quantum transitions

(Orbital Shells - Bound energy states)

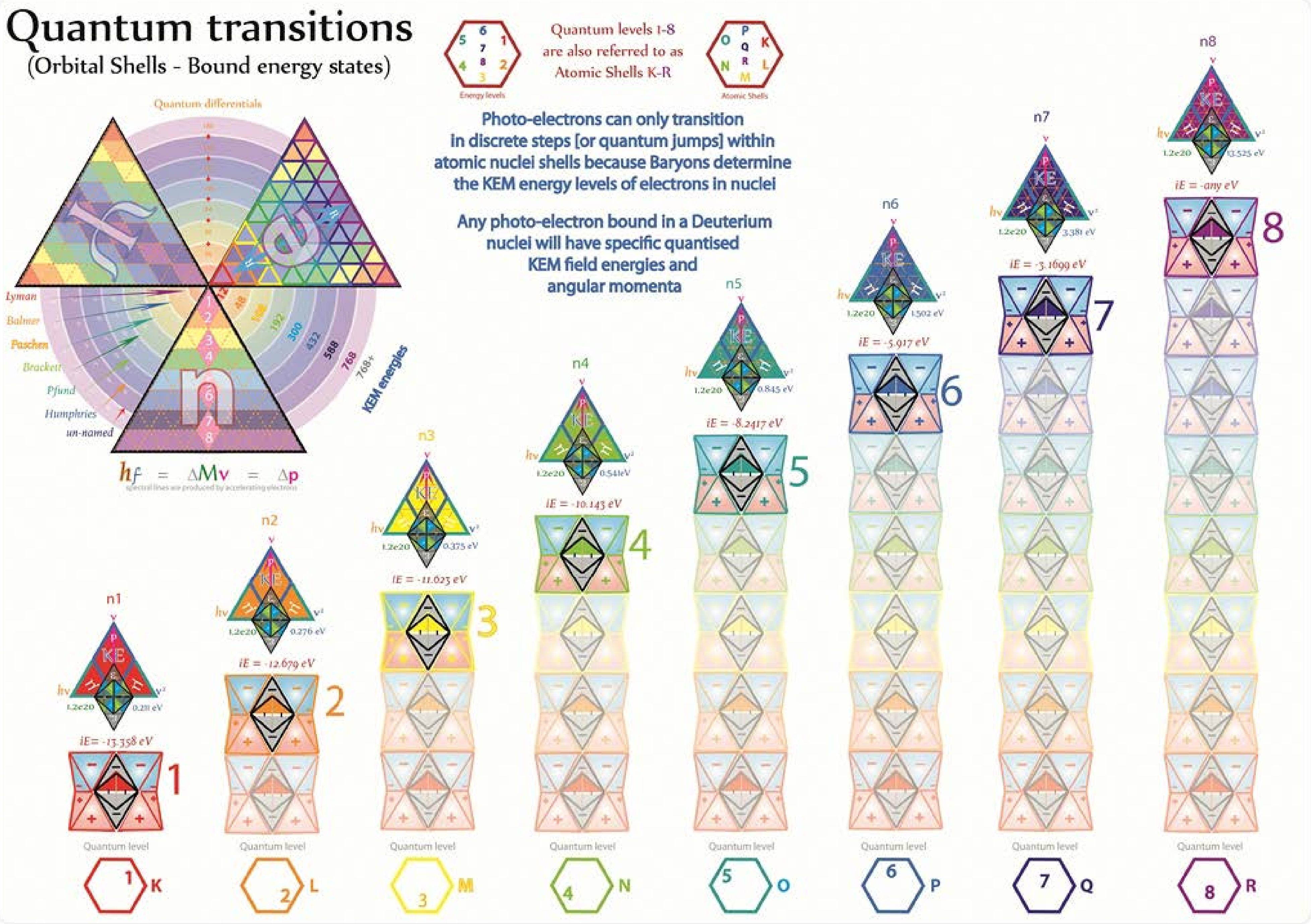

Quantum levels 1-8
are also referred to as
Atomic Shells K-R

Photo-electrons can only transition in discrete steps [or quantum jumps] within atomic nuclei shells because Baryons determine the KEM energy levels of electrons in nuclei

Any photo-electron bound in a Deuterium nuclei will have specific quantised KEM field energies and angular momenta

$hf = \Delta Mv = \Delta p$

spectral lines are produced by accelerating electrons

Energy levels
5
6
7
1
4
8
2
3
Atomic Shells
O
P
Q
K
N
R
L
M
Quantum differentials
h
n
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
12
48
108
192
300
432
588
768
768+
KEM energies
n1
P
KE
hv
v²
1.2e20
0.211 eV
iE= -13.358 eV
1
n2
1.2e20
0.276 eV
iE = -12.679 eV
2
n3
1.2e20
0.375 eV
iE = -11.623 eV
3
n4
1.2e20
0.541eV
iE = -10.143 eV
4
n5
1.2e20
0.845 eV
iE = -8.2417 eV
5
n6
1.2e20
1.502 eV
iE = -5.917 eV
6
n7
1.2e20
3.381 eV
iE = -3.1699 eV
7
n8
1.2e20
13.525 eV
iE = -any eV
8
Quantum level
1 K
2 L
3 M
4 N
5 O
6 P
7 Q
8 R

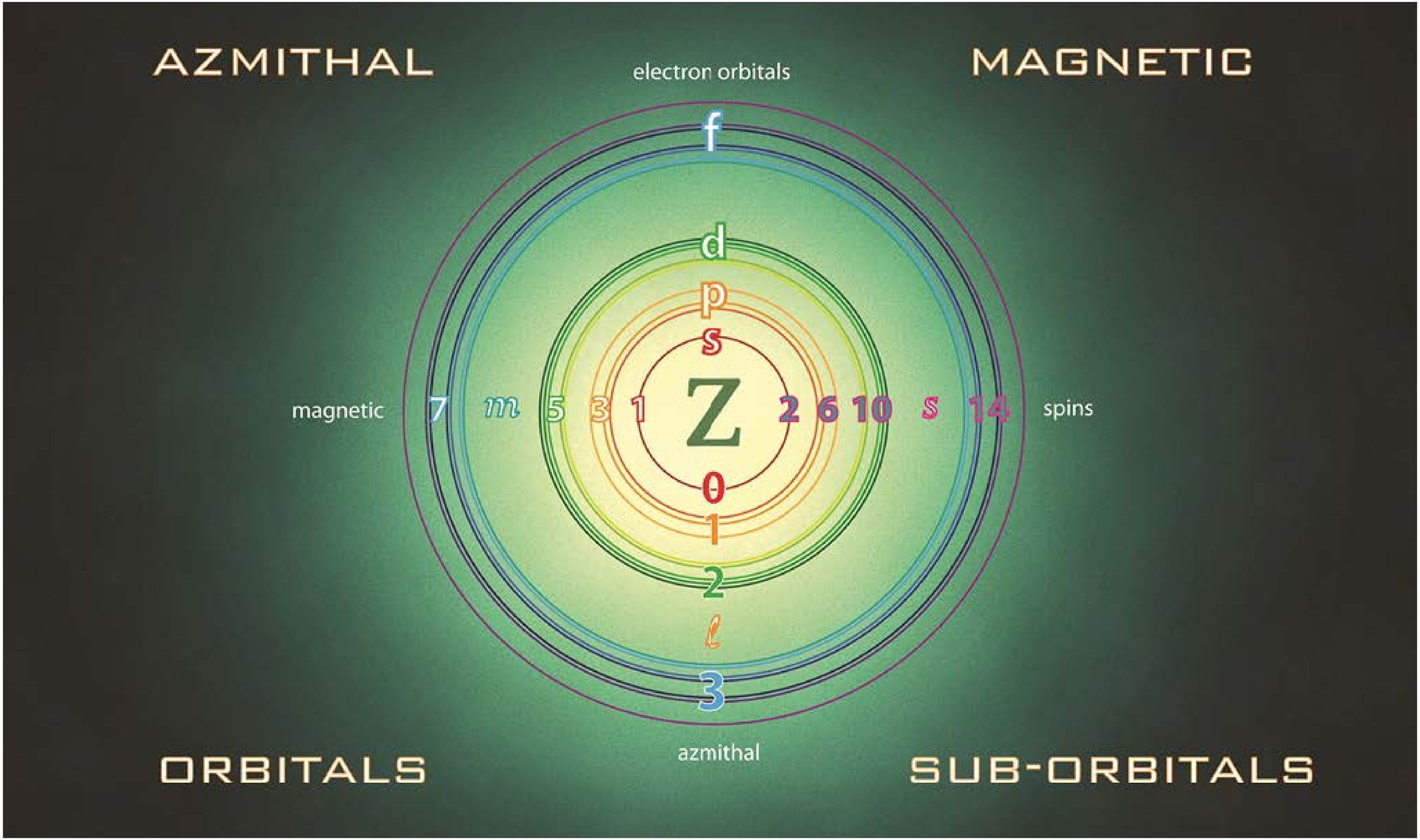
AZMITHAL
MAGNETIC
electron orbitals
f
d
p
s
magnetic
7
m
5
3
1
Z
2
6
10
s
14
spins
0
1
2
ℓ
3
azmithal
ORBITALS
SUB-ORBITALS

Atomic Orbitals

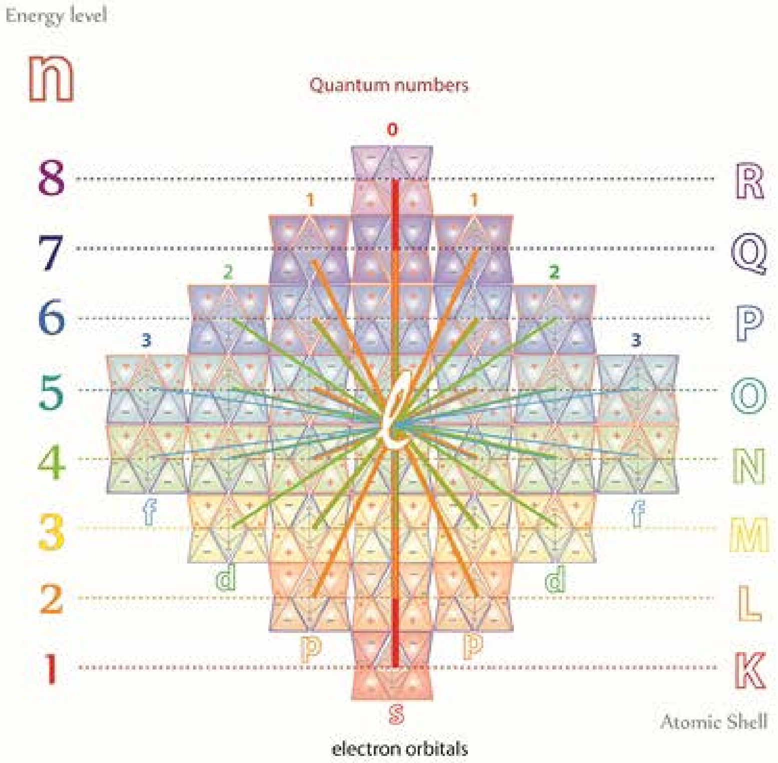
Energy level
n
Quantum numbers
0
1
1
2
2
3
3
8
7
6
5
4
3
2
1
R
Q
P
O
N
M
L
K
s
s+p
s+p+d
s+p+d+f
s+p+d+f
s+p+d
s+p
s
l
f
f
d
d
p
p
s
Atomic Shell
electron orbitals

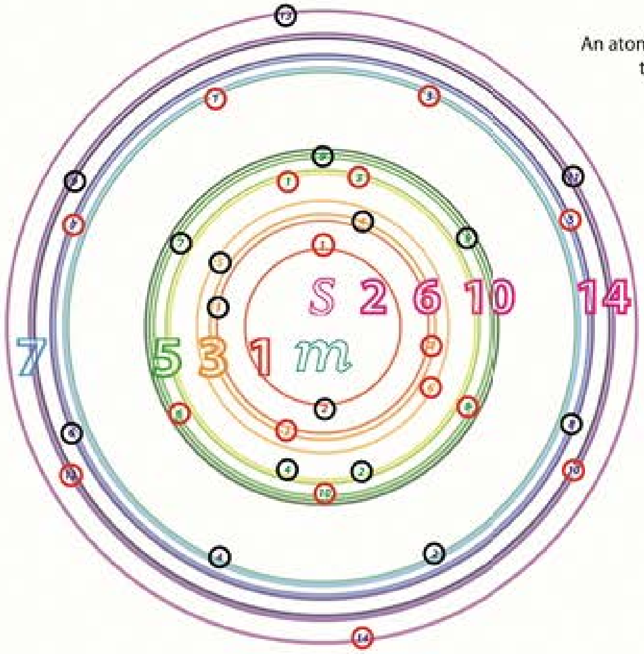
S
2
6
10
14
7
5
3
1
m

An atomic orbital is a mathematical function that describes the wave-like behavior of either one electron or a pair of electrons in an atom

Atomic orbitals are typically categorized by n, l, and m quantum numbers, which correspond to the electron's energy, angular momentum, and an angular momentum vector component, respectively.

Historically used to define the pedagogical electron cloud model of an atom Tetryonics reveals the true geometry of atomic nuclei

Each orbital is defined by a different set of quantum numbers and contains a maximum of two spin opposed electrons.

Aufbau

Azmithal & Magnetic numbers

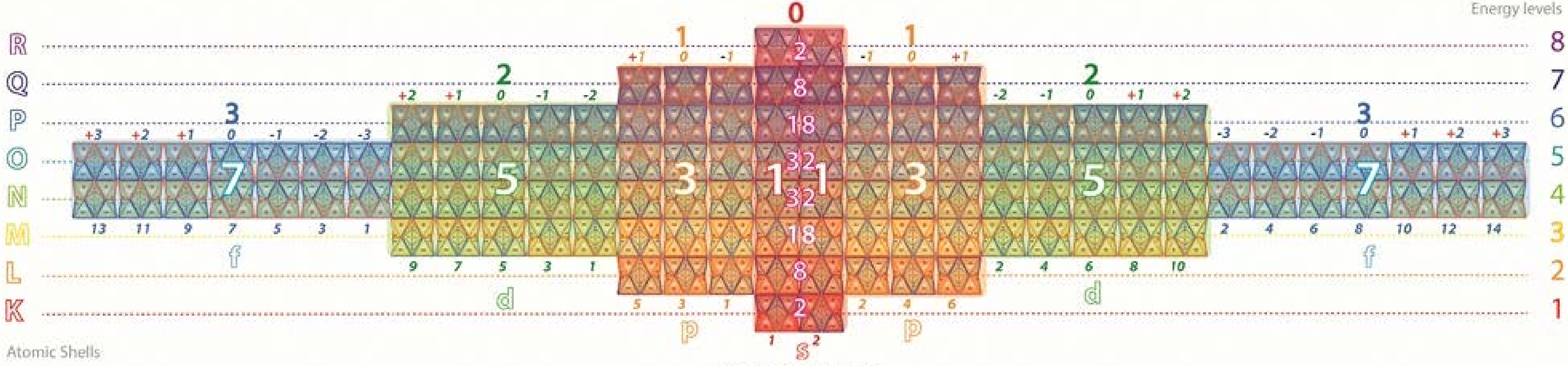
Energy levels
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
2
2
3
3
+1
0
-1
-1
0
+1
+2
+1
0
-1
-2
-2
-1
0
+1
+2
+3
+2
+1
0
-1
-2
-3
-3
-2
-1
0
+1
+2
+3
2
8
18
32
32
18
8
2
7
5
3
1
1
3
5
7
13
11
9
7
5
3
1
9
7
5
3
1
5
3
1
2
4
6
2
4
6
8
10
2
4
6
8
10
12
14
f
d
p
s
p
d
f
1
2
Atomic Shells

Orbitals & sub-Orbitals

Electron Spins can be either up or down providing they obey the Pauli exclusion principle

s Orbital

1 Orbit (2 electrons max)

Alkali Metals & Alkali Earths

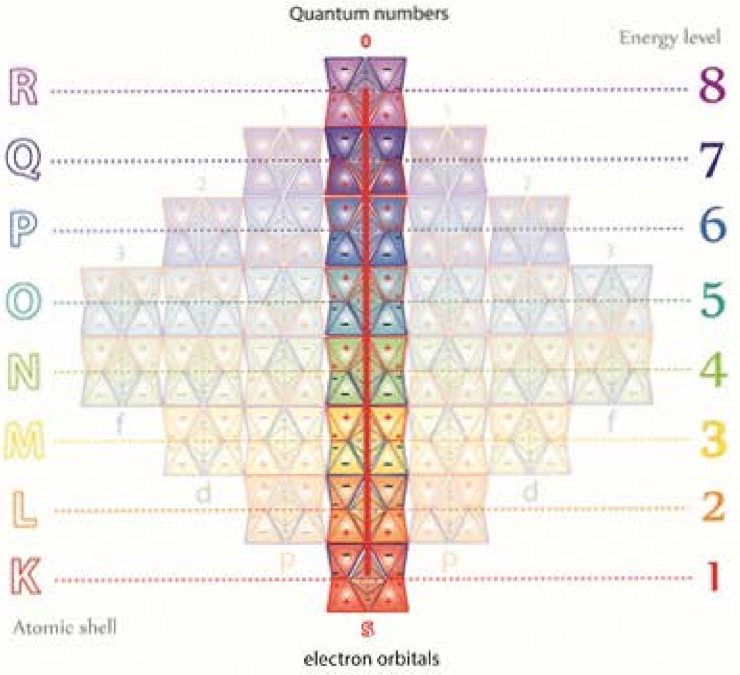
Quantum numbers
0
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
f
d
p
Atomic shell
s
electron orbitals

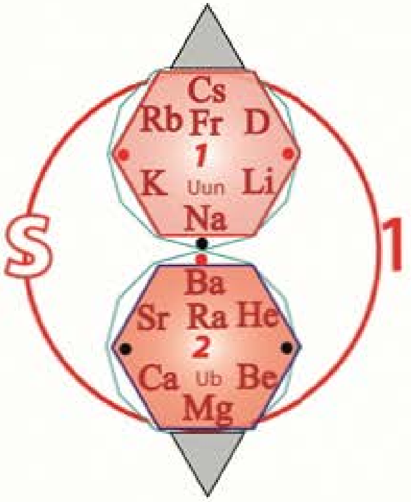
Cs
Rb
Fr
D
1
K
Uun
Li
Na
Ba
Sr
Ra
He
2
Ca
Ub
Be
Mg
s
1

		n
azmithal number	0	l
magnetic numbers	0	m
spins	-1/2 +1/2	s

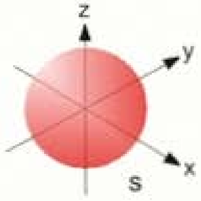

erroneous computer model of 's' electron orbitals

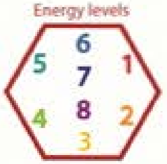
Energy levels
6
5
1
7
8
4
2
3

p Orbital

3 Orbits (6 electrons max)

Non-Metals, Halogens & Nobel gases

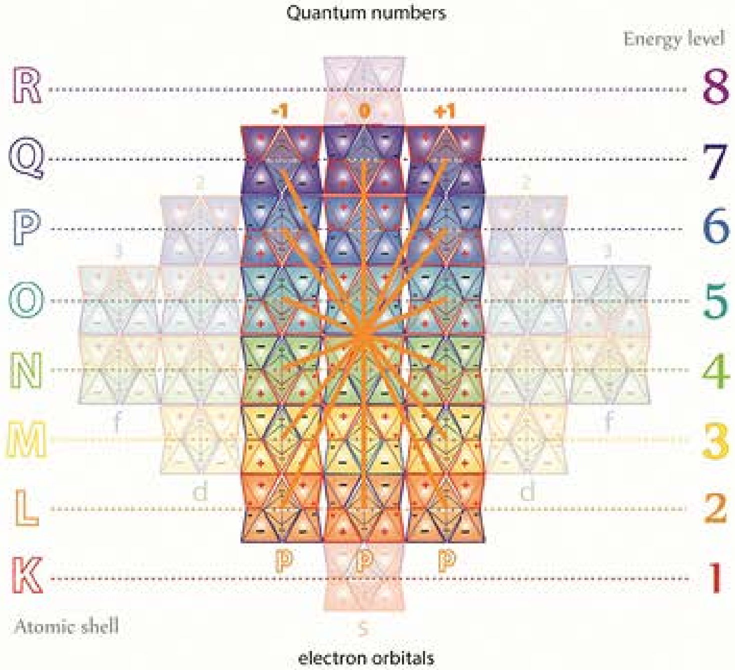
Quantum numbers
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
-1
0
+1
f
d
f
d
p
p
p
s
Atomic shell
electron orbitals

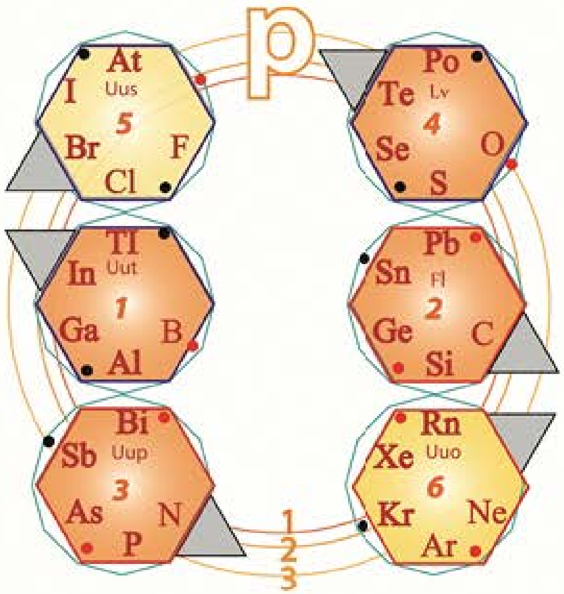
p
At
I
Uus
5
Br
F
Cl
Po
Te
Lv
4
Se
O
S
Tl
In
Uut
1
Ga
B
Al
Pb
Sn
Fl
2
Ge
C
Si
Bi
Sb
Uup
3
As
N
P
Rn
Xe
Uuo
6
Kr
Ne
Ar
1
2
3

n

ℓ

m

S

azmithal number		1	
magnetic numbers	-1	0	+1
spins	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2

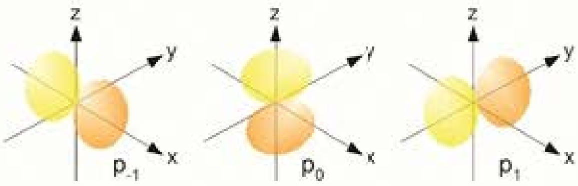
z
y
x
p_{-1}
z
y
x
p_0
z
y
x
p_1

erroneous computer model of 'p' electron orbitals

Quantum levels
6
5
7
4
2
3

d Orbital

5 Orbits (10 electrons max)

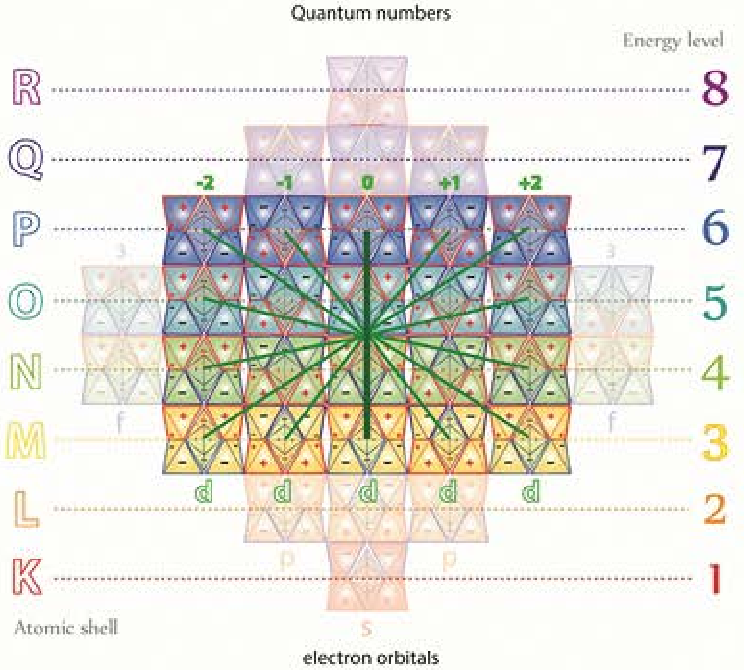
Quantum numbers
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
-2
-1
0
+1
+2
f
f
d
d
d
d
d
p
p
s
Atomic shell
electron orbitals

						n
azimthal number			2			ℓ
magnetic numbers	-2	-1	0	+1	+2	m
spins	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	s

Transition & post-Transition Metals

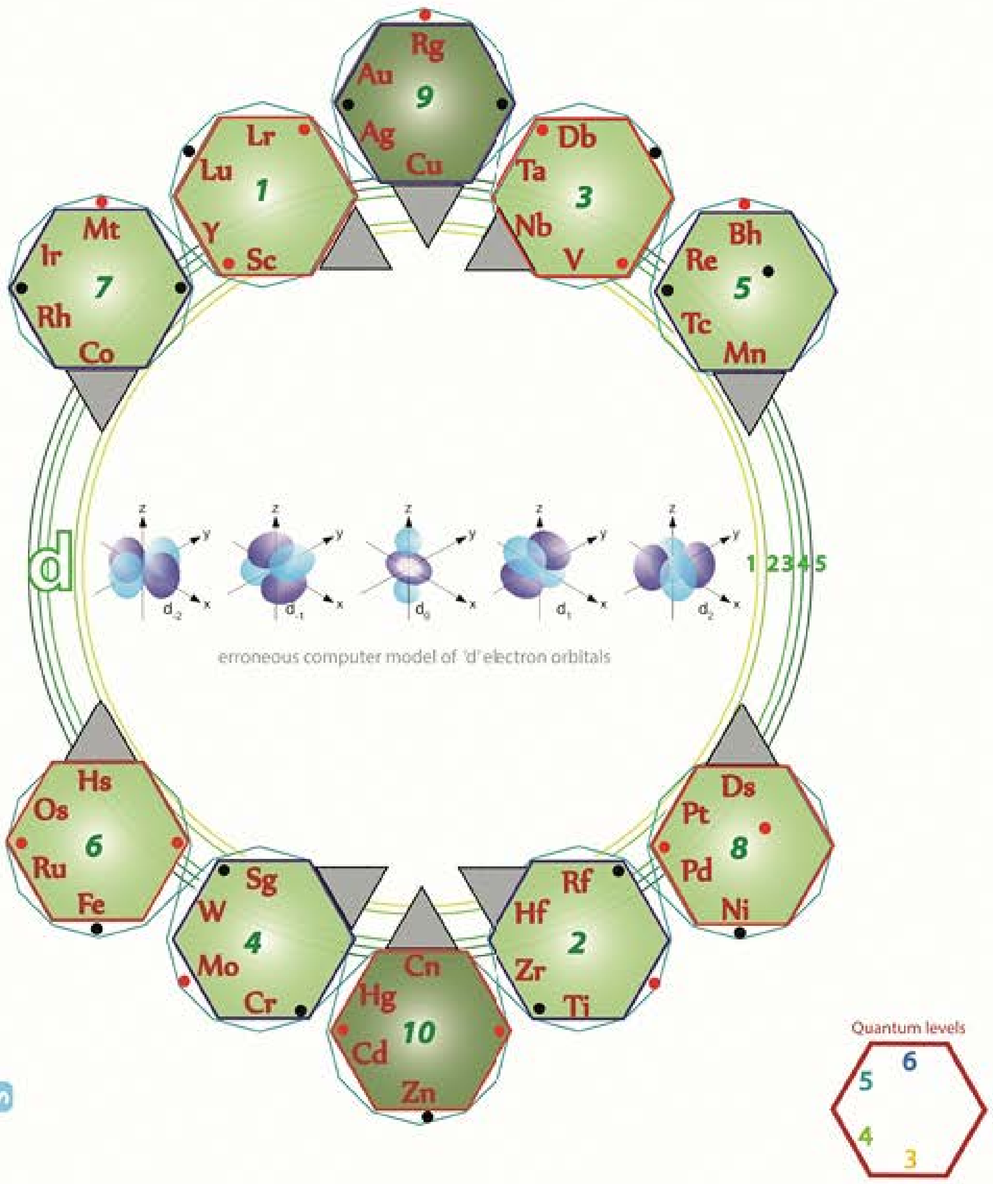
Rg
Au
9
Ag
Cu
Lr
Lu
1
Y
Sc
Db
Ta
3
Nb
V
Mt
Ir
7
Rh
Co
Bh
Re
5
Tc
Mn
d
1 2 3 4 5
erroneous computer model of 'd' electron orbitals
Hs
Os
6
Ru
Fe
Sg
W
4
Mo
Cr
Cn
Hg
10
Cd
Zn
Rf
Hf
2
Zr
Ti
Ds
Pt
8
Pd
Ni
Quantum levels
5
6
4
3

f Orbital

7 Orbits (14 electrons max)

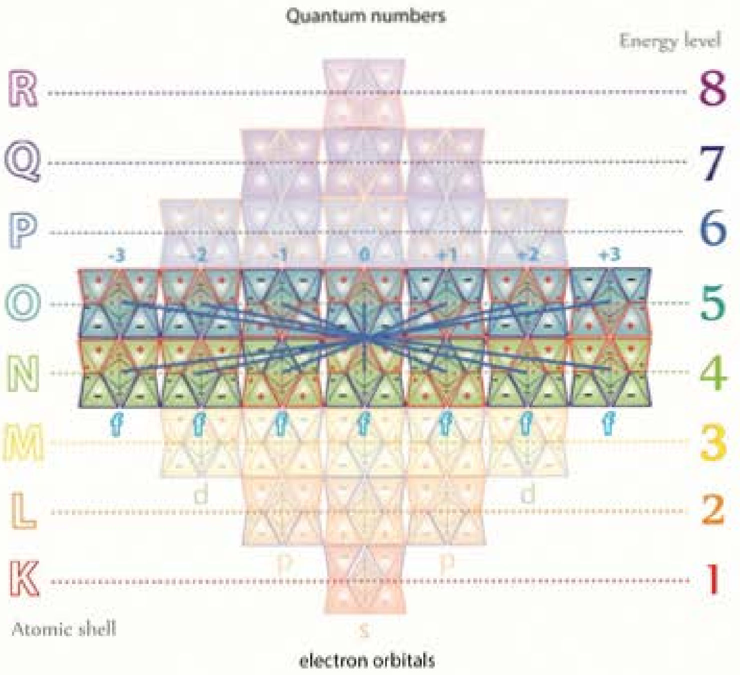
Quantum numbers
Energy level
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
-3
-2
-1
0
+1
+2
+3
f
f
f
f
f
f
f
d
d
p
p
s
Atomic shell
electron orbitals

								n
azmithal number				3				ℓ
magnetic numbers	-3	-2	-1	0	+1	+2	+3	m
spins	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	-1/2 +1/2	s

Lanthanoids & Actinoids

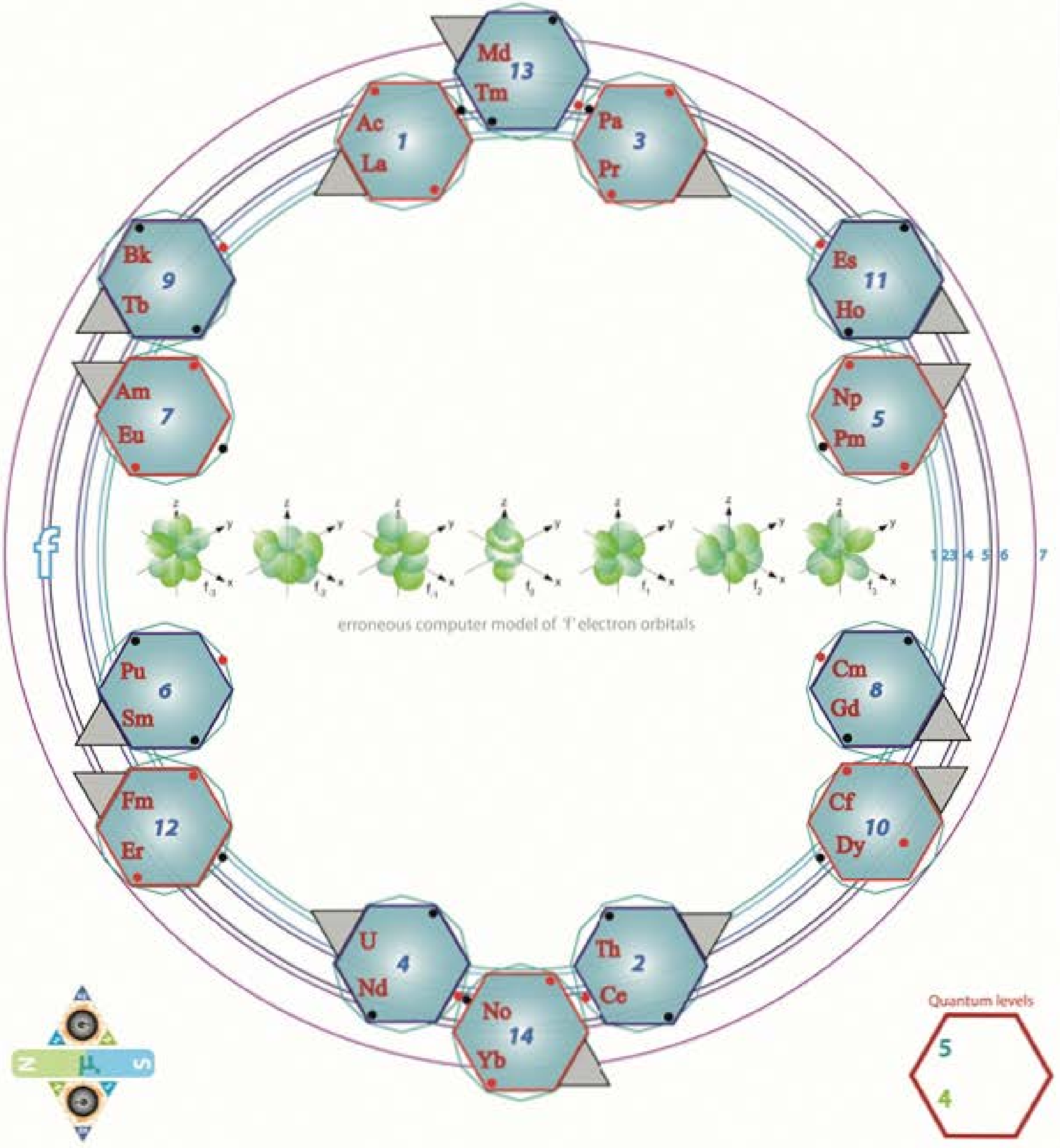
Md
13
Tm
Ac
1
La
Pa
3
Pr
Bk
9
Tb
Es
11
Ho
Am
7
Eu
Np
5
Pm
f
1 2 3 4 5 6
7
Pu
6
Sm
Cm
8
Gd
Fm
12
Er
Cf
10
Dy
U
4
Nd
Th
2
Ce
No
14
Yb
N
μ
S
Quantum levels
5
4

erroneous computer model of 'f' electron orbitals

Orbital energy variations

All Elements have stable core electron configurations of s & p orbitals for each energy level as revealed through diffraction studies

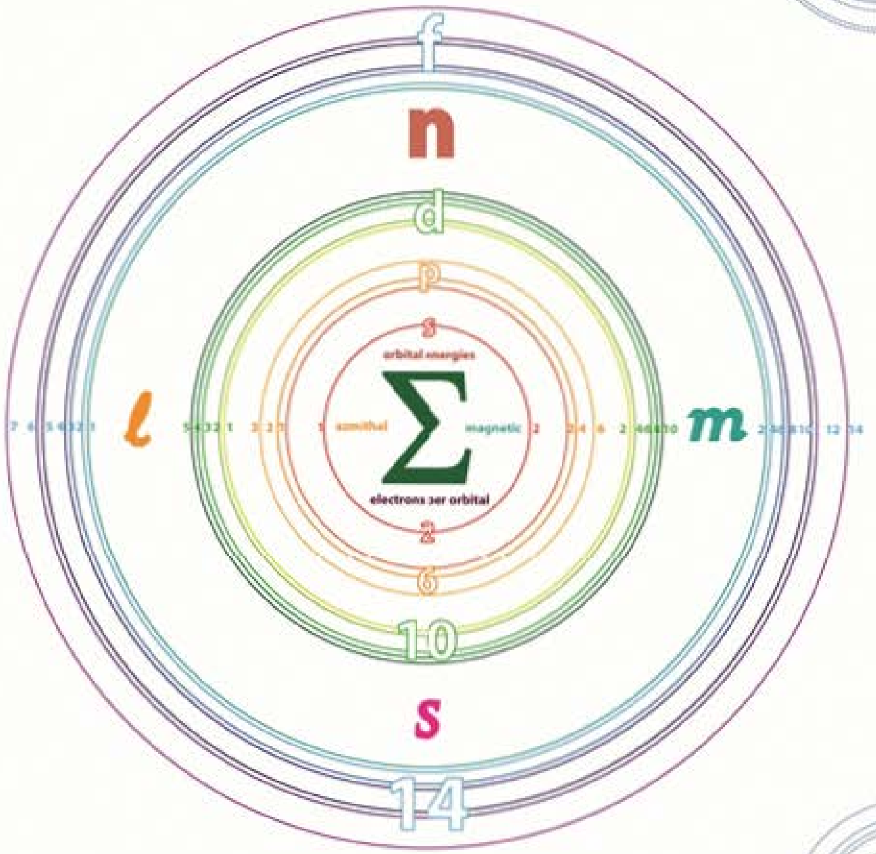
f
n
d
p
s
orbital energies
l
azimuthal
Σ
magnetic
m
electrons per orbital
2
6
10
s
14

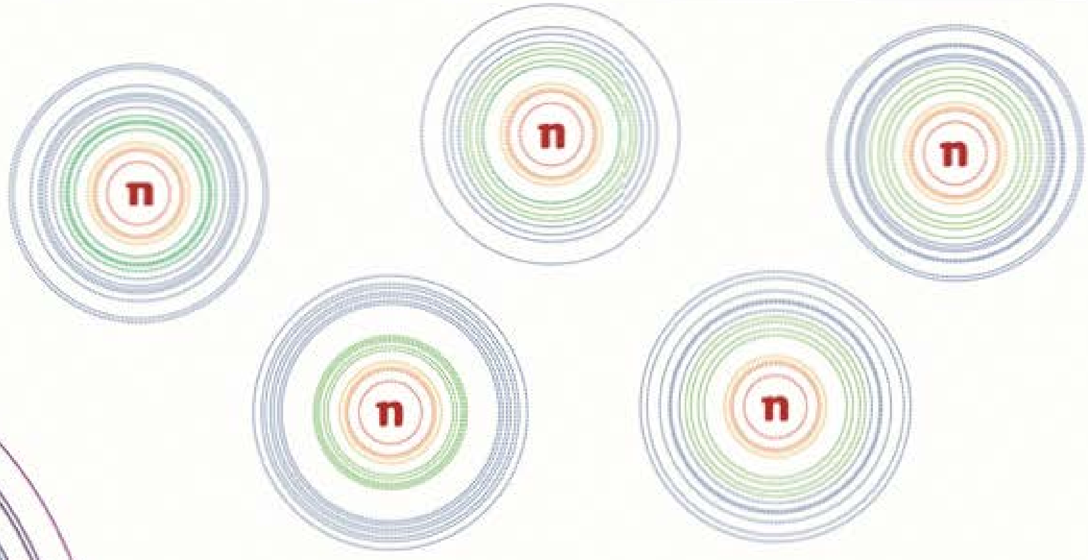

As additional nuclei bind to form d & f orbitals they can do so by bonding in many positions, with each location producing different orbital energies for each electron that binds to nuclei in that position

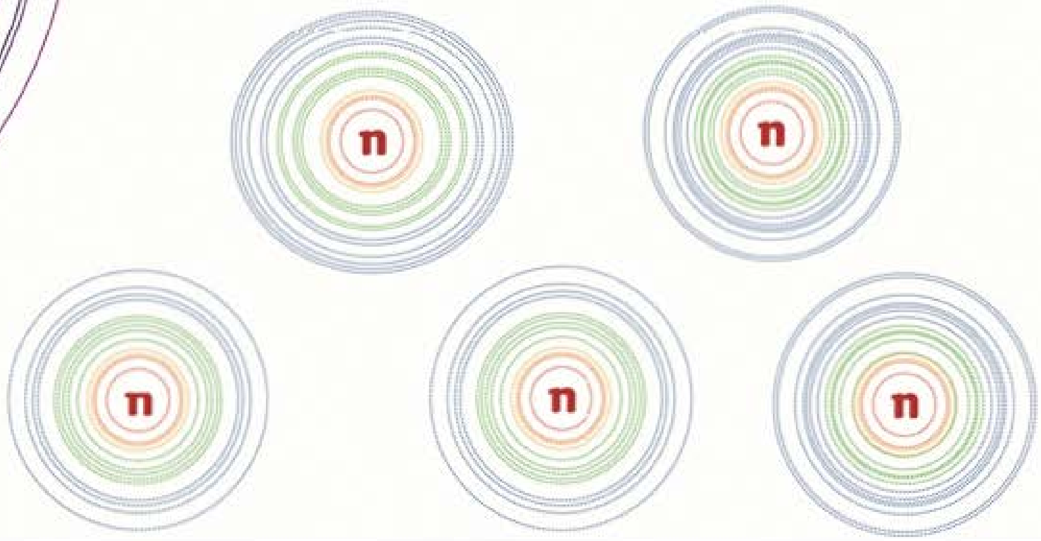

The final energy levels of each orbital is the result of the energy of the Baryons in the nuclei and the spin coupling energies of the photo-electrons bound to them

Electrons per shell

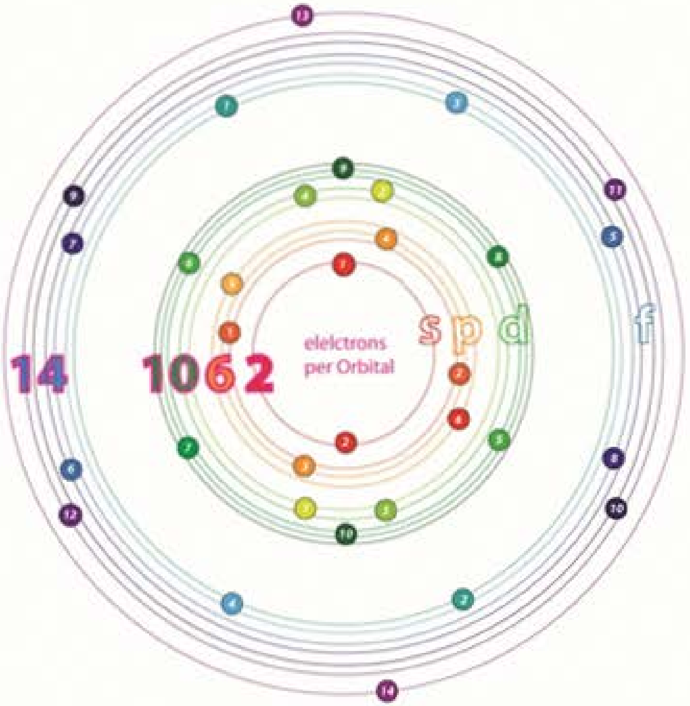
elelctrons
per Orbital
s p d f
14
10 6 2
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Each energy shell of a periodic element can hold only a fixed number of electrons

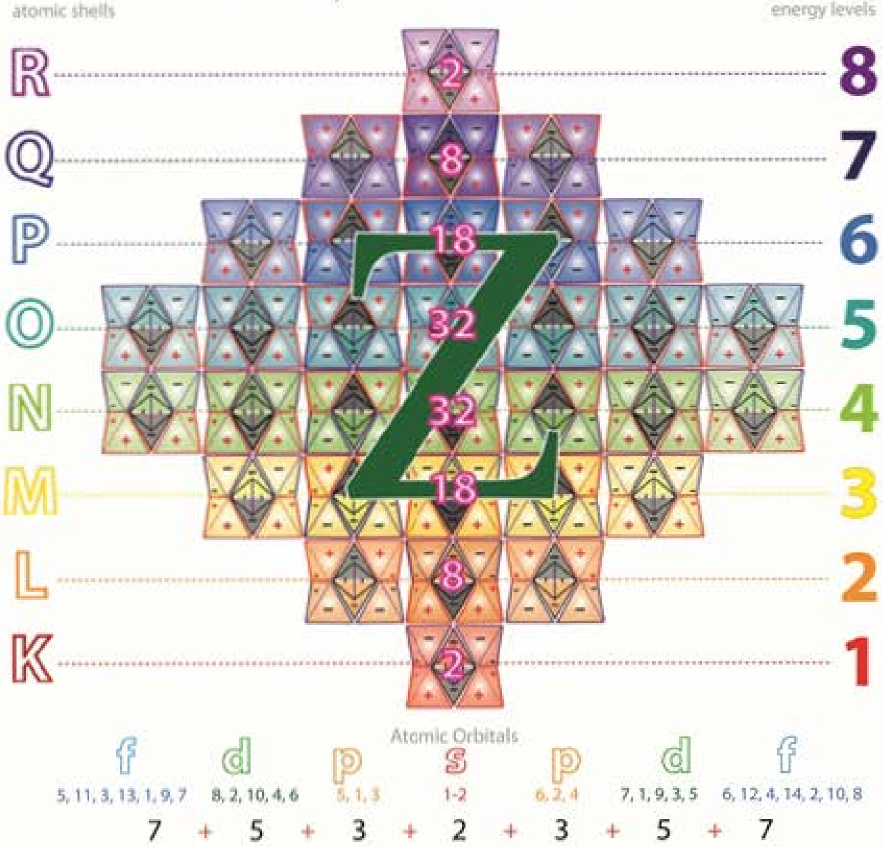
atomic shells
energy levels
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
2
8
18
32
32
18
8
2
Z
Atomic Orbitals
f
d
p
s
p
d
f
5, 11, 3, 13, 1, 9, 7
8, 2, 10, 4, 6
5, 1, 3
1-2
6, 2, 4
7, 1, 9, 3, 5
6, 12, 4, 14, 2, 10, 8
7 + 5 + 3 + 2 + 3 + 5 + 7

Rules governing the allowed combinations of Quantum Numbers

The three quantum numbers (n, l, and m)
that describe an orbital are integers: 0, 1, 2, 3, and so on

n (1-8) Principal (n = 1, 2, 3, 4 ...)	The principal quantum number (n) cannot be zero.
ℓ (0-3) Azimuthal (l = 0, 1 ... n-1)	The angular quantum number (l) can be any integer between 0 and n - 1.
mℓ (2ℓ+1) Magnetic (ml = -l, -l+1 ... 0 ... l-1, l)	The magnetic quantum number (m) can be any integer between -l and +l.
m_s :$^1_2$ Spin Projection (ms = -1/2 or +1/2)	The Spin of electrons in any nuclear sub-orbital can only be +1/2 (Spin UP) or -1.2 (Spin DOWN).

Z

1, 2, 3, 4, 5, 6, 7, 8

s, p, d, f

1	2
1, 3, 5	2, 4, 6
1, 3, 5, 7, 9	2, 4, 6, 8, 10
1, 3, 5, 7, 9, 11, 13	2, 4, 6, 8, 10, 12, 14
down up	up down

Quantum Numbers

n	4-5	3-6	2-7	1-8	2-7	3-6	4-5
ℓ	3	2	1	0	1	2	3
m	-3	-2	-1	1	+1	+2	+3
s	+1/2 -1/2	+1/2 -1/2	+1/2 -1/2	+1/2 -1/2	+1/2 -1/2	+1/2 -1/2	+1/2 -1/2

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Erwin Schrödinger

(12 August 1887 – 4 January 1961)

Using Tetryonic charged geometries for mass-ENERGY-Matter,
an electron's position and velocity CAN be modelled simultaneously
(but any attempt to measure or interact with it, will affect its component energy-momenta)

Electron Position Uncertainty

Atomic orbitals are typically described as "hydrogen-like" (meaning one-electron) wave functions over any spatial region of measurement, categorized by n, l, and m quantum numbers, which correspond to the electron's energy, angular momentum, and a vector momentum component, respectively

Werner Heisenberg

(5 December 1901 – 1 February 1976)

Lepton's are physically Spin 1 fermion particles that can easily be misconstrued as having entirely different spin numbers without the correct physical topologies to base the observed measurements on

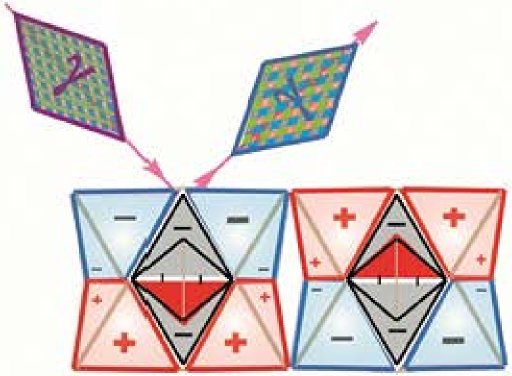

The energies of photo-electrons are determined by the Baryons they bind to & incident photons

Quantum Mechanics is a mathematical representation of equilateral energy momenta interactions and the charged geometries of mass-ENERGY-Matter

Determining the motion of electrons bound to atomic nuclei is akin to measuring the motion of variable speed electric fan blades mounted at various heights within a rotating carousel

Leptons are 12 loop quantum rotors

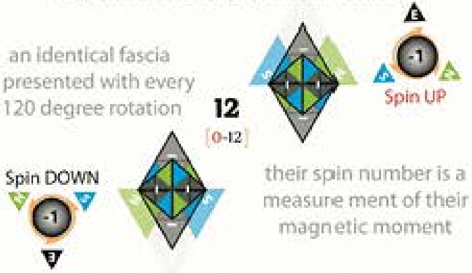

an identical fascia is presented with every 120 degree rotation

their spin number is a measure ment of their magnetic moment

The unique 12 faceted topology of leptons results in an identical EM geometry being oberved for every 120° rotation of the particle

Leading to the interpretation that the Lepton disappears and re-appears when being 'observed' or measured

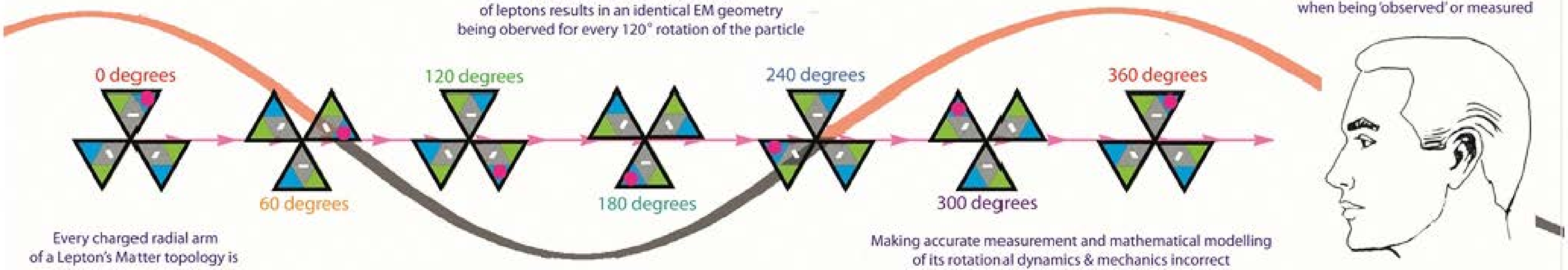

Every charged radial arm of a Lepton's Matter topology is identical to every other

Making accurate measurement and mathematical modelling of its rotational dynamics & mechanics incorrect without the correct physical topologies

Electron modelling & probability calculations

12
[0-12]
RE
S
KE

Electron positional measurements
have proven to be historically
difficult to accurately model
due to the charged 12π
rotating topologies
of leptons

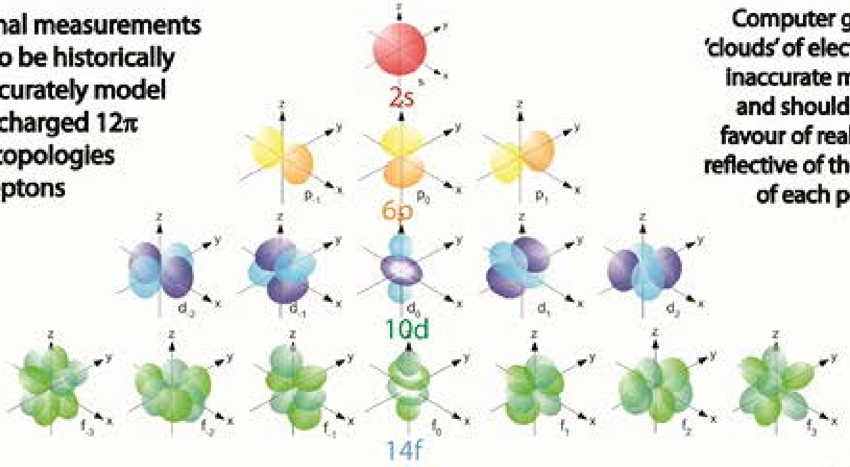

Computer generated plots of
'clouds' of electron probabilites are
inaccurate mis-representations
and should be abandoned in
favour of realistic atomic models
reflective of the charged geometry
of each periodic element

v
RE
KE
P
KE
hv
Q
M
v²
c²

Every elemental atom can be viewed as
a quantum carousel with a unique number
of oscillating fans positioned around it.

Each fan has 3 blades and a fixed speed n[1-8]
related to its height above ground level,
AND the carousel is turning around on its axis

**All periodic elements
are made form
Deuterium nuclei**

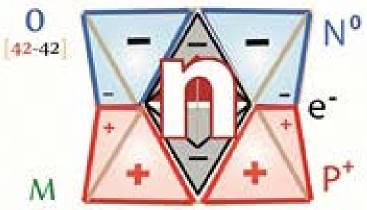

**The baryonic energies of nuclei
determines the energies of
bound photo-electrons**

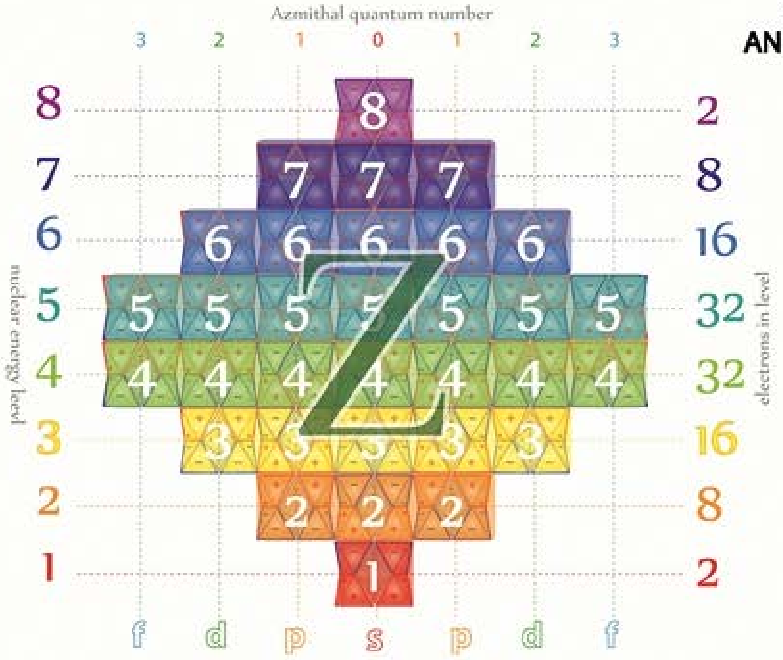

The current computer generated
electron probability diagrams in popular
use at present can now be show to be a
misrepresentative model of mathematical
modelling of electron sub-orbital energies

The nuclear quantum levels [n],
intrinsic quantised angular momentum [h] and
orbital angular momentum [l] of each electron
bound within atomic nuclei are all the direct
result of the Baryonic energies of the nuclei
they are bound to

**Each level of the quantum carousel
can contain only a limited number of
fans each running at a specific speed**

Imagine trying to measure (or model) the motion of any 1 quantum scale blade while the carousel rotates

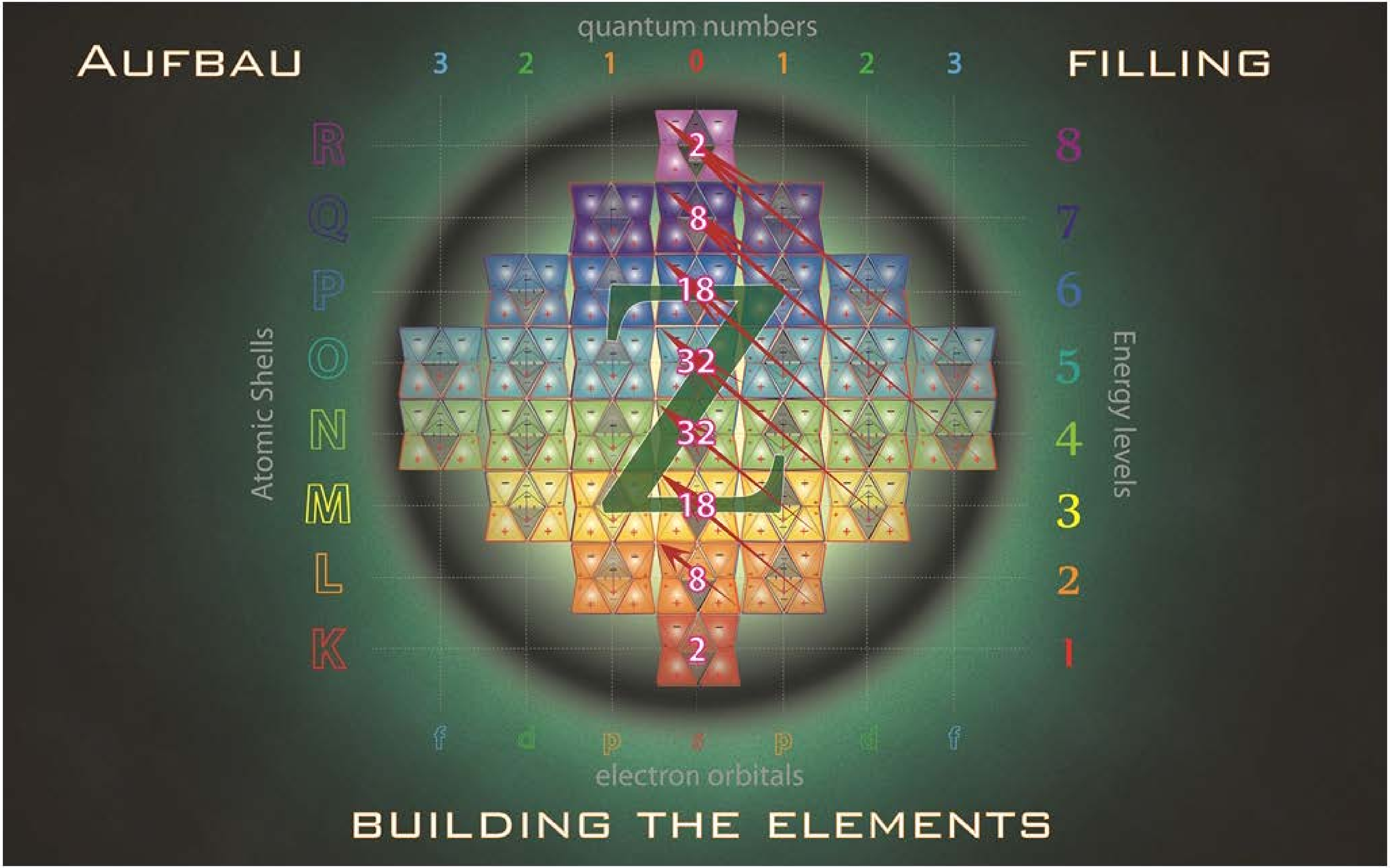
quantum numbers
AUFBAU
FILLING
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Atomic Shells
8
7
6
5
4
3
2
1
Energy levels
2
8
18
32
32
18
8
2
Z
f
d
p
s
p
d
f
electron orbitals
BUILDING THE ELEMENTS

Tetryonics 48.01 - aufbau geometry

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Quantum Topologies

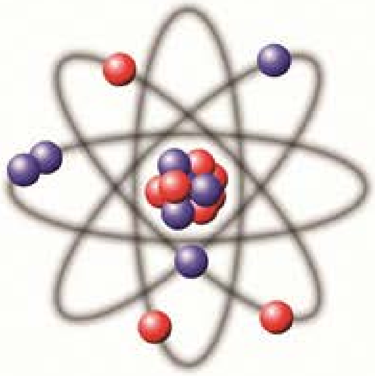

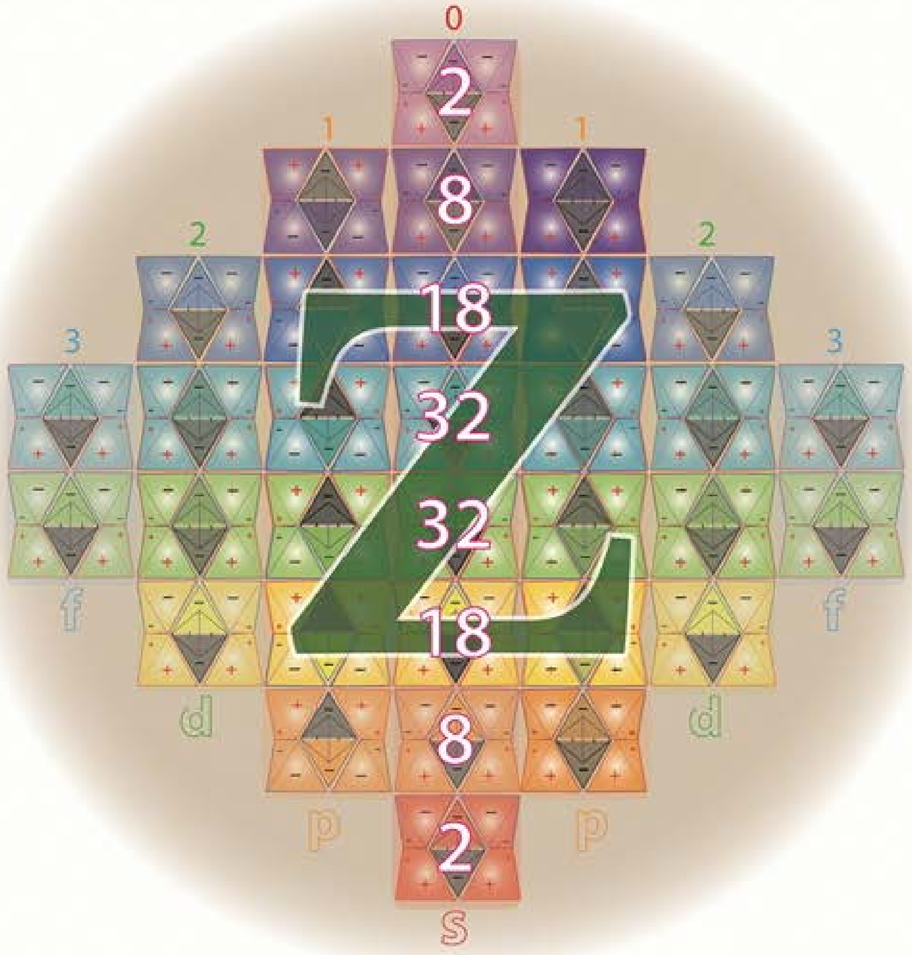
0
2
1
8
1
2
18
2
3
32
3
32
f
f
18
d
d
8
p
p
2
s
Z

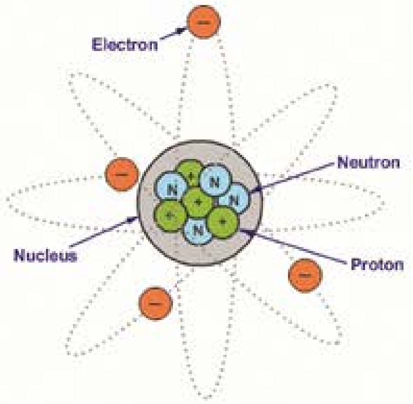
Electron
Neutron
Nucleus
Proton

Dalton Model

Quantum Model

Thomson Model

Rutherford Model

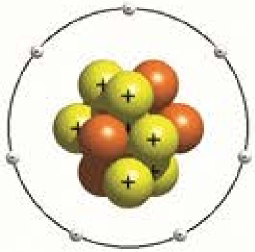

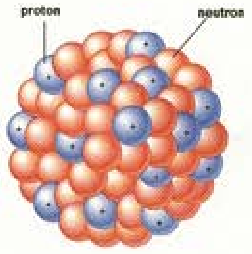
proton
neutron

Historically viewed as a spherical object
Tetryonic charge geometry has finally revealed the
true quantum topology of all atoms

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Element numbers

The rule dictating how many nuclei form each Atomic shell is known as the Aufbau principle.

The physical and chemical properties of elements is determined by the atomic structure.
The atomic structure is, in turn, determined by the electrons and
which shells, subshells and orbitals they reside in.

The maximum periodic elemental number is 120

$$Z = \sum_{1,2,3,4,4,3,2,1} 2(n^2) = 2 + 8 + 18 + 32 + 32 + 18 + 8 + 2$$

Number of nuclei per level	Element #
2	120 119
8	118 111
18	110 93
32	92 61
32	60 29
18	28 11
8	10 3
2	2 1

The number of nuclei per quantum level is reflective of photonic energy levels and provides the foundational geometry for all of the periodic elements

The number of possible nuclei in each Quantum level follows aufbau principle 'numbers' which can be determined using the following summation formula

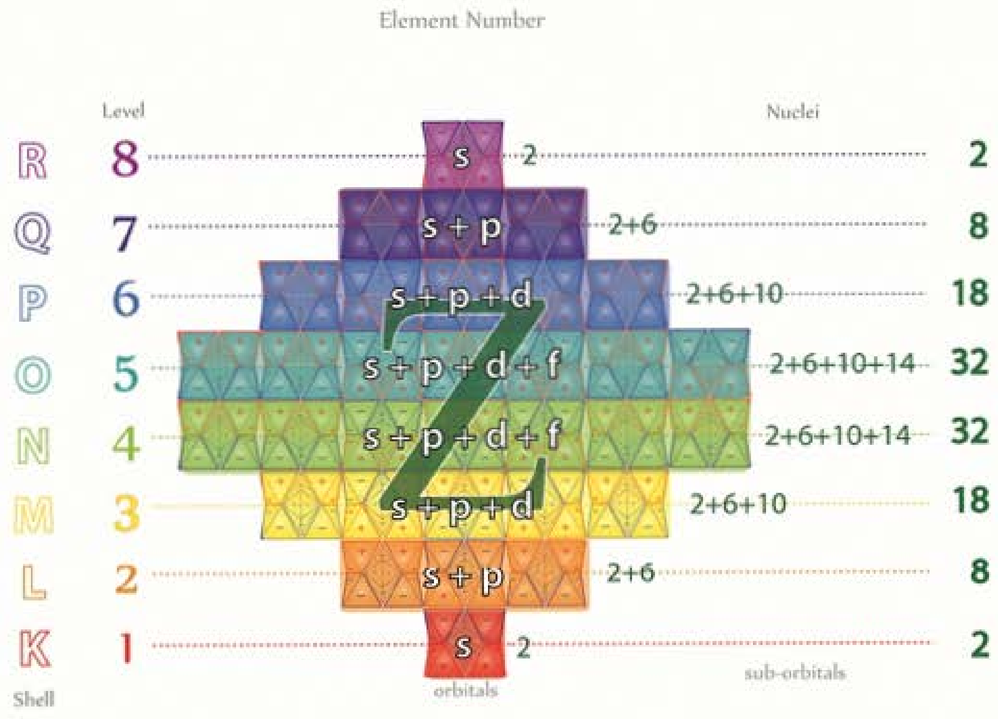
Element Number
Level
Nuclei
R 8 s 2 2
Q 7 s + p 2+6 8
P 6 s + p + d 2+6+10 18
O 5 s + p + d + f 2+6+10+14 32
N 4 s + p + d + f 2+6+10+14 32
M 3 s + p + d 2+6+10 18
L 2 s + p 2+6 8
K 1 s 2 2
Z
Shell
orbitals
sub-orbitals

Deuterium is the building block of all elements

Each element has equal numbers of Protons, electron & Neutrons with their stored mass-energies making up the molar masses of elements not excess neutron as currently modelled

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Aufbau Principle

(Nuclei number and position)

1 Sub-Orbit (2 electrons max) ○ s

3 Sub-Orbits (6 electrons max) ○ p

○ d *5 Sub-Orbits (10 electrons max)*

○ f *7 Sub-Orbits (14 electrons max)*

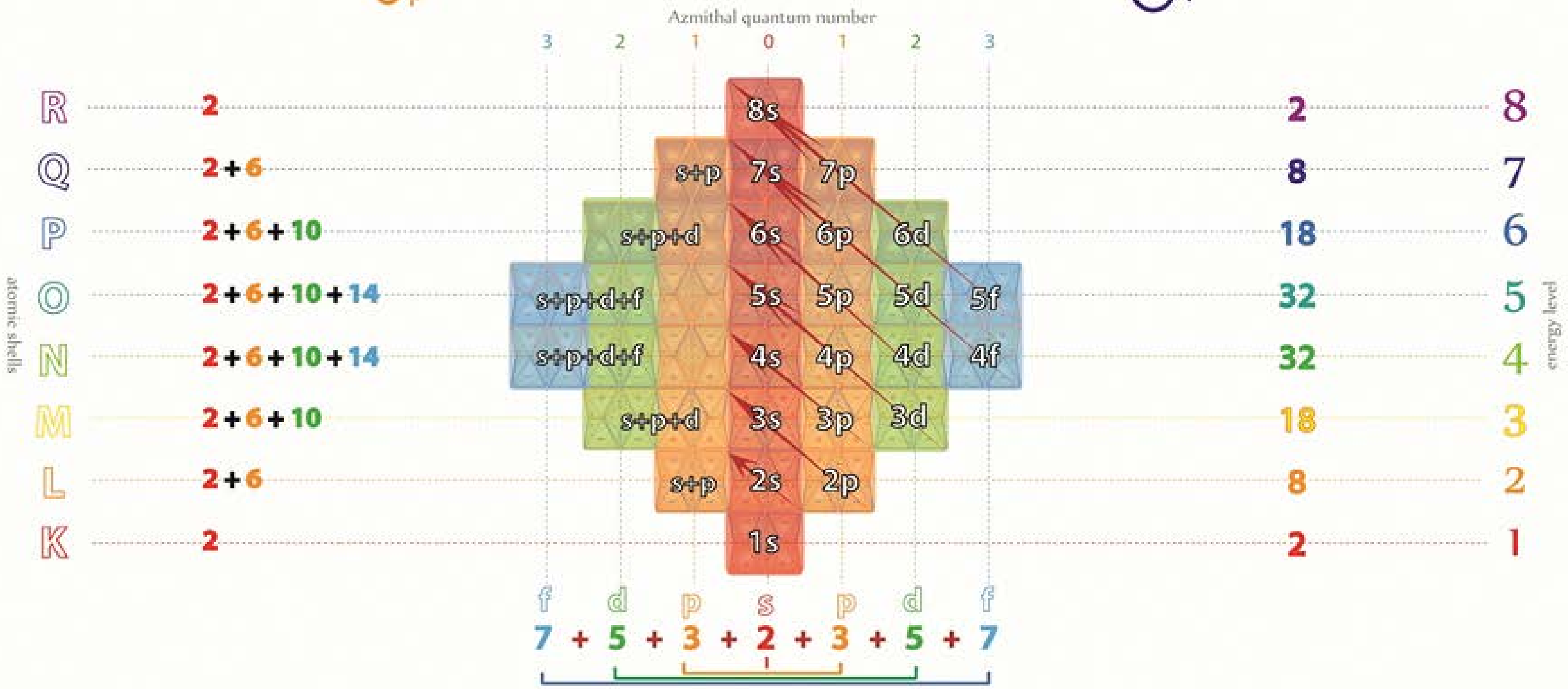
Azmithal quantum number
3 2 1 0 1 2 3
atomic shells
R 2
Q 2+6
P 2+6+10
O 2+6+10+14
N 2+6+10+14
M 2+6+10
L 2+6
K 2
8s
s+p 7s 7p
s+p+d 6s 6p 6d
s+p+d+f 5s 5p 5d 5f
s+p+d+f 4s 4p 4d 4f
s+p+d 3s 3p 3d
s+p 2s 2p
1s
2 8
8 7
18 6
32 5
32 4
18 3
8 2
2 1
energy level
f d p s p d f
7 + 5 + 3 + 2 + 3 + 5 + 7

		2			6								10													14								
Nuclei	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32		per level
R	119	120																															8	2
Q	87	88	113	114	115	116	117	118																									7	8
P	55	56	81	82	83	84	85	86	103	104	105	106	107	108	109	110	111	112															6	18
O	37	38	49	50	51	52	53	54	71	72	73	74	75	76	77	78	79	80	89	90	91	92	93	94	95	96	97	98	99	100	101	102	5	32
N	19	20	31	32	33	34	35	36	39	40	41	42	43	44	45	46	47	48	57	58	59	60	61	62	63	64	65	66	67	68	69	70	4	32
M	11	12	13	14	15	16	17	18	21	22	23	24	25	26	27	28	29	30															3	18
L	3	4	5	6	7	8	9	10																									2	8
K	1	2																															1	2
Shells																																	**Quantum number**	
	s1	*s2*	*p1*	*p2*	*p3*	*p4*	*p5*	*p6*	*d1*	*d2*	*d3*	*d4*	*d5*	*d6*	*d7*	*d8*	*d9*	*d10*	*f1*	*f2*	*f3*	*f4*	*f5*	*f6*	*f7*	*f8*	*f9*	*f10*	*f11*	*f12*	*f13*	*f14*		

sub-orbitals

A specific nuclear energy is associated with each electron configuration and, upon certain conditions, bound electrons are able to move from one orbital to another by emission or absorption of a quantum of energy, in the form of a photon.

The Aufbau principle can also be used to model the binding configuration of Protons and Neutrons in an atomic nucleus, according to their specific Baryonic Energy levels, in turn revealing the quantum geometry of all periodic Elements

Wolfgang Pauli

(25 April 1900 – 15 December 1958)

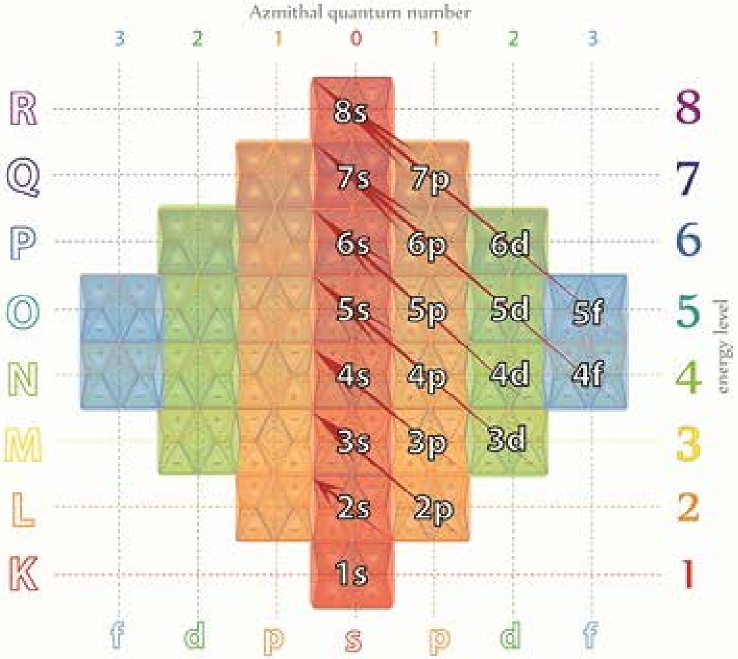
Azmithal quantum number
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8s
7s
7p
6s
6p
6d
5s
5p
5d
5f
4s
4p
4d
4f
3s
3p
3d
2s
2p
1s
8
7
6
5
4
3
2
1
energy level
f
d
p
s
p
d
f

Friedrich Hermann Hund

(4 February 1896 - 31 March 1997)

The orbitals of lower energy are filled in first with the electrons and only then are the higher energy orbitals filled.

aufbau electron orbital filling

Orbitals of equal energy are each occupied by one electron before any orbital is occupied by a second electron, and all electrons in singly occupied orbitals must have the same spin state

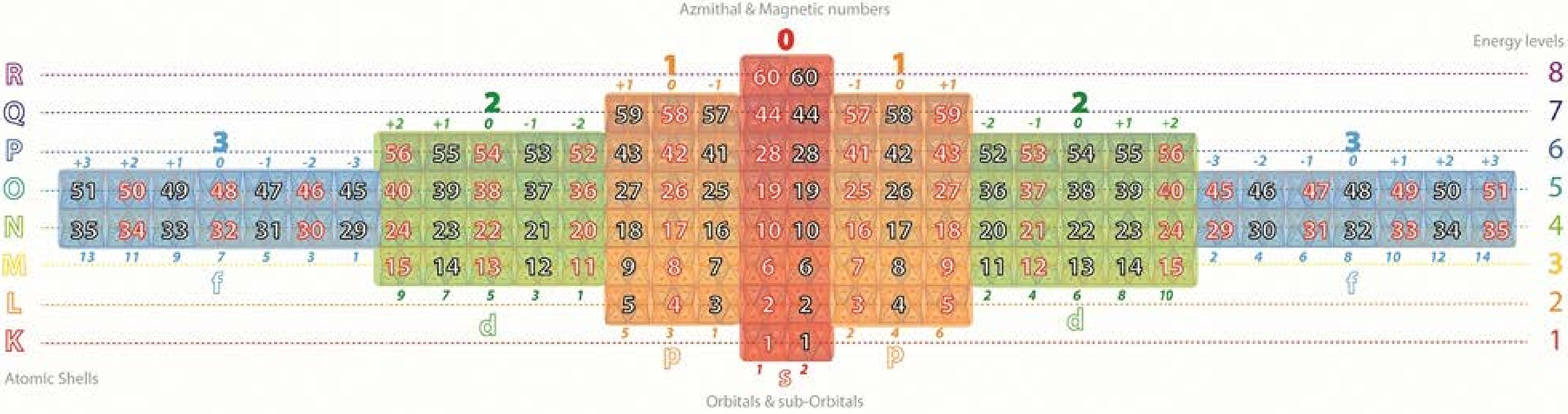

Azmithal & Magnetic numbers

	3							2					1			0		1			2					3							Energy levels
	+3	+2	+1	0	-1	-2	-3	+2	+1	0	-1	-2	+1	0	-1			-1	0	+1	-2	-1	0	+1	+2	-3	-2	-1	0	+1	+2	+3	
R																60	60																8
Q													59	58	57	44	44	57	58	59													7
P								56	55	54	53	52	43	42	41	28	28	41	42	43	52	53	54	55	56								6
O	51	50	49	48	47	46	45	40	39	38	37	36	27	26	25	19	19	25	26	27	36	37	38	39	40	45	46	47	48	49	50	51	5
N	35	34	33	32	31	30	29	24	23	22	21	20	18	17	16	10	10	16	17	18	20	21	22	23	24	29	30	31	32	33	34	35	4
M	13	11	9	7	5	3	1	15	14	13	12	11	9	8	7	6	6	7	8	9	11	12	13	14	15	2	4	6	8	10	12	14	3
L				f				9	7	5	3	1	5	4	3	2	2	3	4	5	2	4	6	8	10				f				2
K										d			5	3	1	1	1	2	4	6			d										1
Atomic Shells														p		1	2		p														
																s																	

Orbitals & sub-Orbitals

Tetryonics 48.05 - electron orbital filling

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Aufbau construction

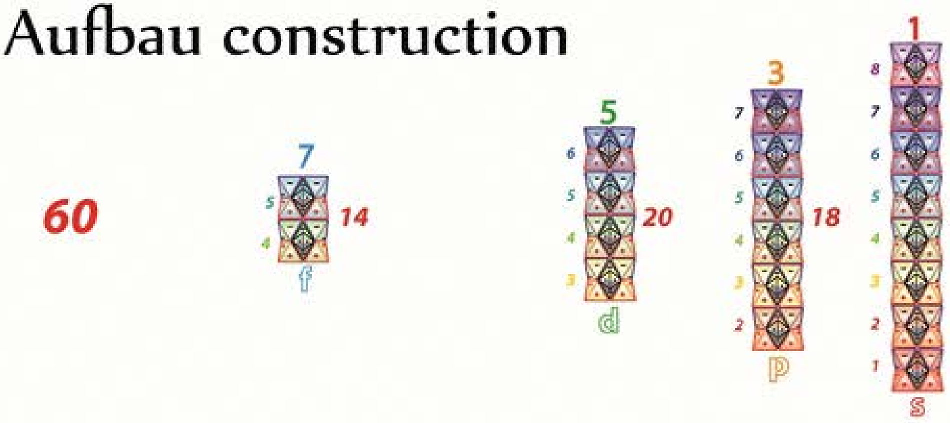
60
7
14
f
5
20
d
3
18
p
1
8
s

Proton
base
Hemisphere

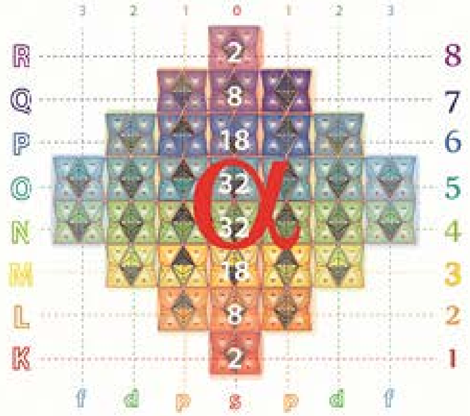
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
α
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

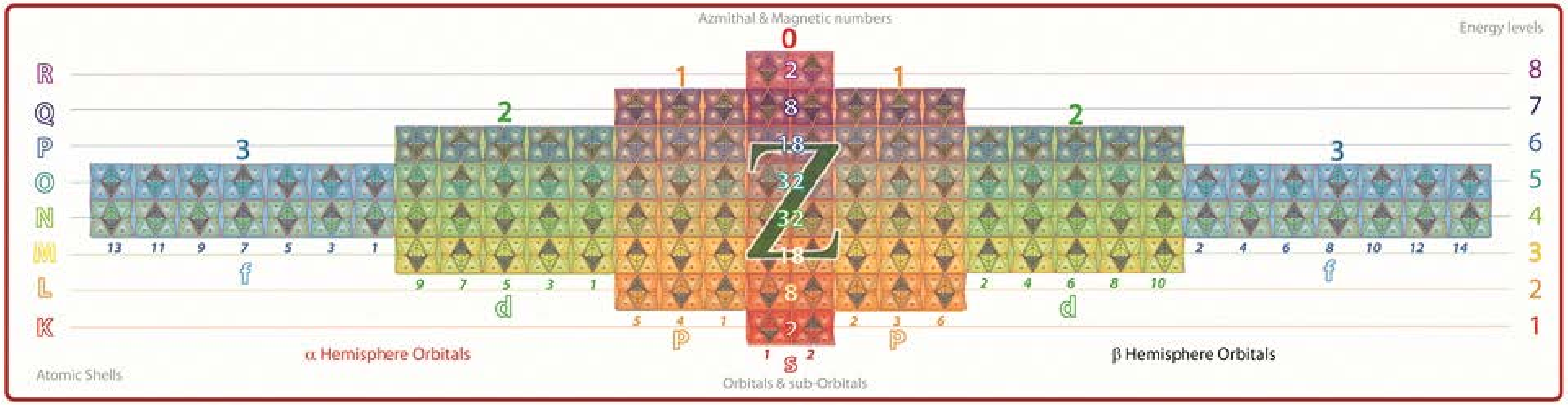
Azmithal & Magnetic numbers
Energy levels
R
Q
P
O
N
M
L
K
0
1
2
3
2
8
18
32
32
18
8
2
Z
13
11
9
7
5
3
1
f
9
7
5
3
1
d
5
4
1
p
1
2
s
2
3
6
p
2
4
6
8
10
d
2
4
6
8
10
12
14
f
8
7
6
5
4
3
2
1
α Hemisphere Orbitals
β Hemisphere Orbitals
Atomic Shells
Orbitals & sub-Orbitals

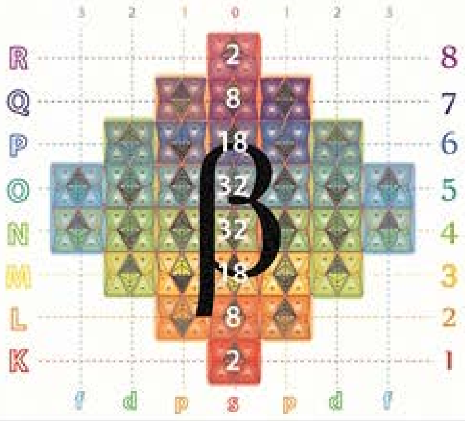
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
β
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

Neutron
base
Hemisphere

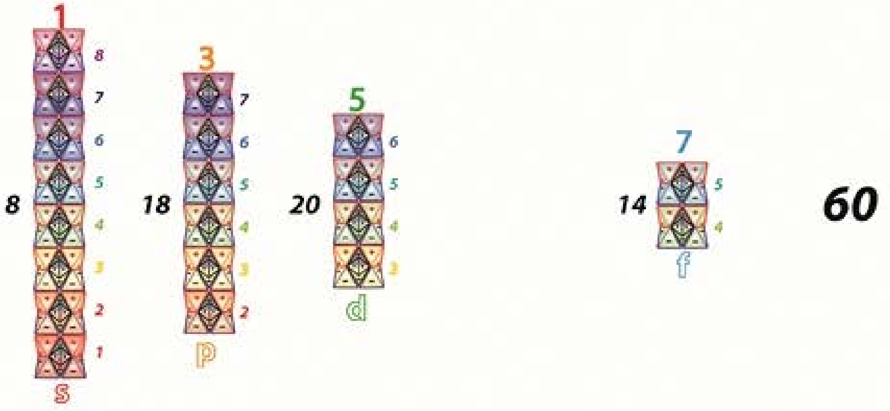
1
8
s
3
18
p
5
20
d
7
14
f
60

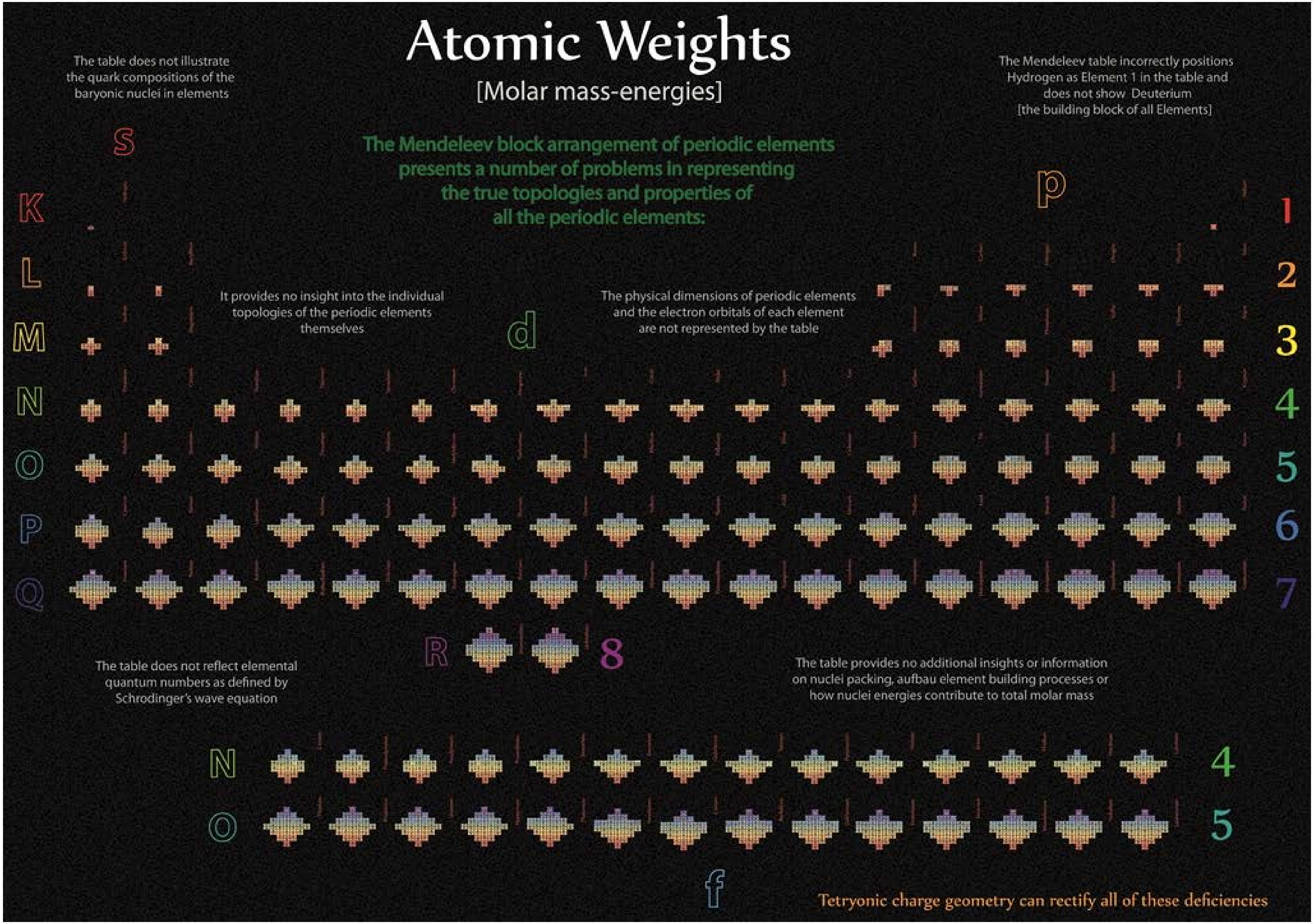

Atomic Weights

[Molar mass-energies]

The table does not illustrate the quark compositions of the baryonic nuclei in elements

The Mendeleev table incorrectly positions Hydrogen as Element 1 in the table and does not show Deuterium [the building block of all Elements]

The Mendeleev block arrangement of periodic elements presents a number of problems in representing the true topologies and properties of all the periodic elements:

It provides no insight into the individual topologies of the periodic elements themselves

The physical dimensions of periodic elements and the electron orbitals of each element are not represented by the table

The table does not reflect elemental quantum numbers as defined by Schrodinger's wave equation

The table provides no additional insights or information on nuclei packing, aufbau element building processes or how nuclei energies contribute to total molar mass

Tetryonic charge geometry can rectify all of these deficiencies

Tetryonics 49.01 - Atomic Weight

Atomic nuclei mass-energies

Each element's weight [mass-Matter in a gravitational field] is the result of the total quanta comprising that element

Baryon mass-energies — n

E — *The quantum level mass-energies of Baryons determines the kinetic energies of electrons*

1n - 1 e19v

electron KEM field — hv^2

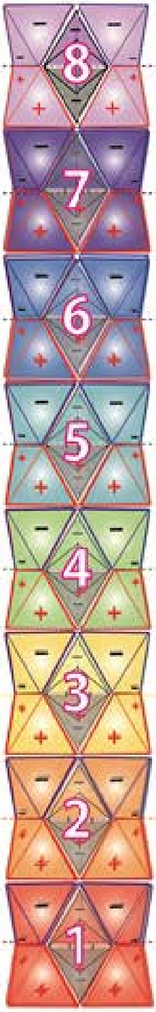

Baryon mass-energies	n	v	electron KEM field
73,728	n32	v8	3.268969693 e15
69,192	n31	v7	2.502804921 e15
64,800	n30	v6	1.838795452 e15
60,552	n29	v5	1.276941286 e15
56,448	n28	v4	8.172424232 e14
52,488	n27	v3	4.596988631 e14
48,672	n26	v2	2.043106058 e14
45,000	n25	v1	5.107765145 e13

Compton frequencies
930 MeV

1.2e20
electron rest Matter is velocity invariant
496 keV

spectral frequencies
13.6 eV

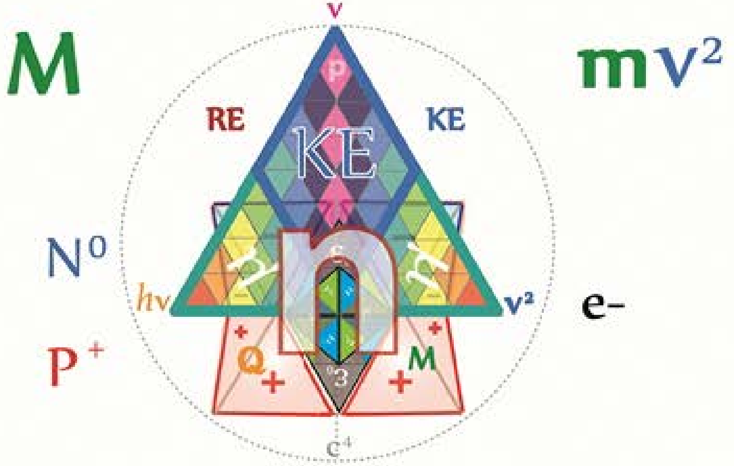

The nuclei forming each atomic shell have specific mass-energy quanta

Baryon rest masses — lepton rest mass — KEM

$$\overset{8}{\underset{1}{n}}\left[\,[72(n)^2]+[12e19]+[m_e v^2]\,\right]$$

Deuterium mass-energy per shell

Despite having differing mass-energies each Deuterium nuclei has the same velocity invariant Matter geometry [84π]

spin orbital coupling in synchronous quantum convertors

Electrons act as quantum scale rotating armatures in atomic nuclei and can only have specific energies reflective of the electron orbital energy level of the Baryons in which they are found

They acheive these energy levels by absorbing or emitting photons to acheive the specific angular momentum required

Hydrogen Ionisation Energies [$/n^2$]

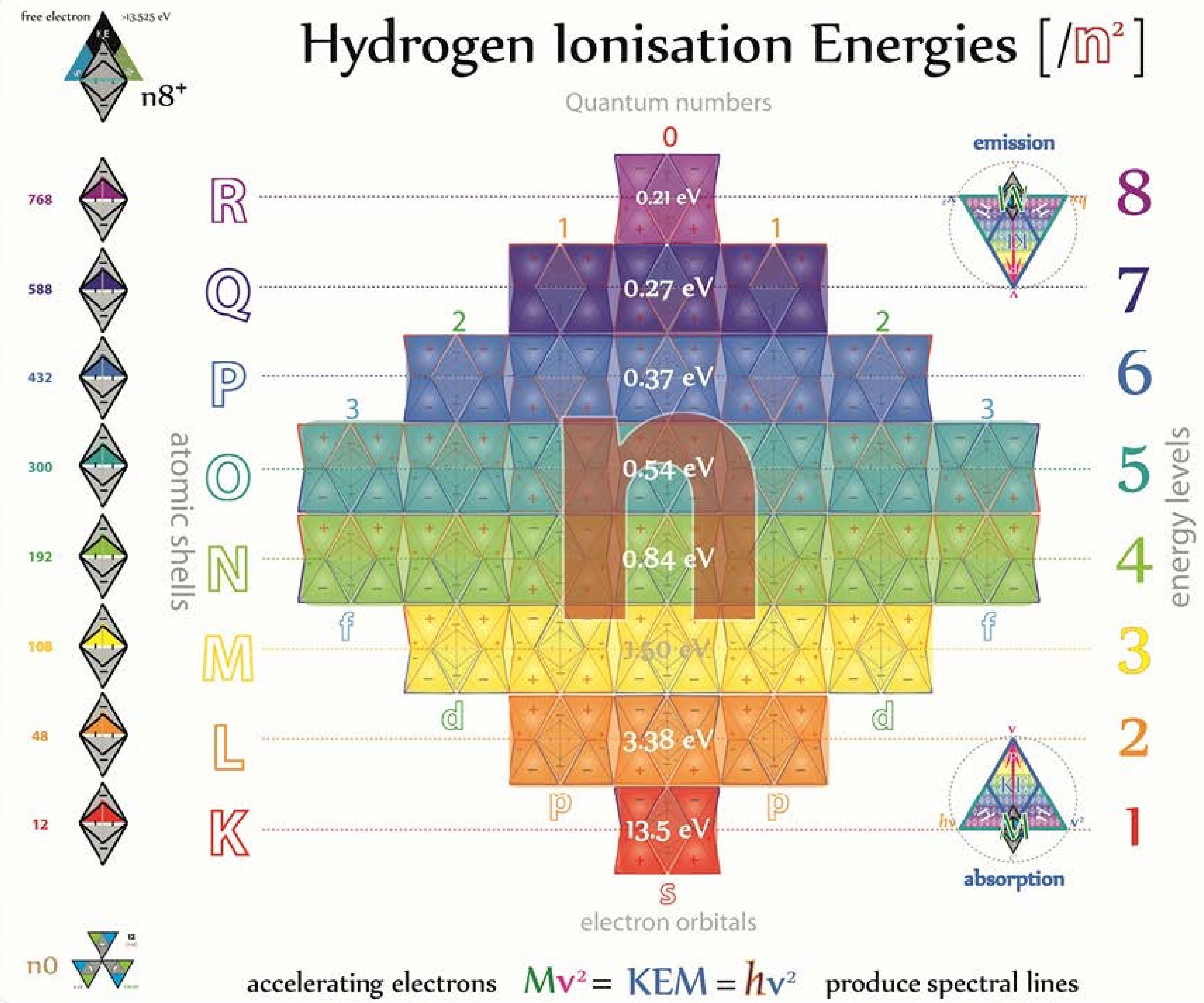
free electron
>13.525 eV
K.E
n8⁺
Quantum numbers
0
1
1
2
2
3
3
768
588
432
300
192
108
48
12
R
Q
P
O
N
M
L
K
atomic shells
0.21 eV
0.27 eV
0.37 eV
0.54 eV
0.84 eV
1.50 eV
3.38 eV
13.5 eV
n
f
f
d
d
p
p
s
electron orbitals
emission
absorption
hν
ν²
8
7
6
5
4
3
2
1
energy levels
n0

accelerating electrons $Mv^2 = KEM = hv^2$ produce spectral lines

13.6eV

Free electron

5.107765145 e13

6.671366720 e13

9.078047137 e13

1.307587877 e14

2.043106058 e14

3.632188548 e14

8.172424234 e14

3.268969693 e15

Planck quanta

Spectral line series frequencies

[Hydrogen]

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Redefining Atomic weights

Atomic weight (symbol: Ar) is a dimensionless physical quantity,
the ratio of the average mass of atoms of an element (from a given source) to
1/12 of the mass of an atom of carbon-12 (known as the unified atomic mass unit)

Carbon 12

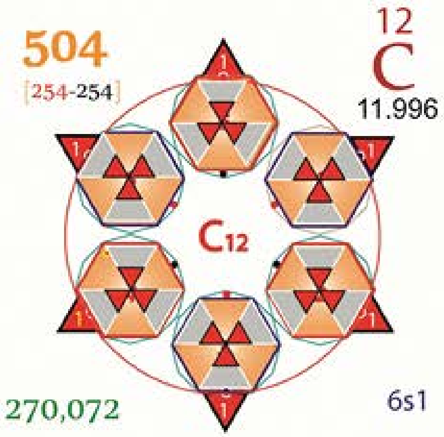

6 Protons [24-12]
6 Neutrons [18-18] n1
6 electrons [0-12]

The 'unified atomic mass unit' currently in use
is known to be inaccurate and must be corrected
in order to bring clarity & increased accuracy
to the atomic weights of all elements

$$A_r = 22,512$$

Hydrogen

Defining Hydrogen as having an exact
atomic Planck mass of 22512n quanta
provides uniformity with Tetryonics

1/12 C_{12}

$A_r = 22,506$

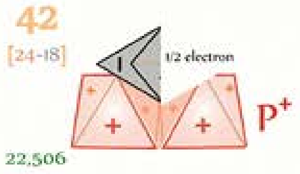

1.660096209e-27 kg

1 Proton [24-12]
.5 electron 0-6 n1

Unified atomic Matter unit

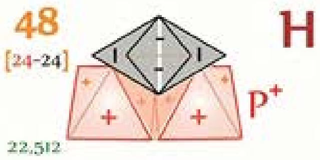

1.660538783e-27 kg

1 Proton [24-12]
1 electron [0-12] n1

Deuterium is the building block of all elements in the period table

$$A_r = 45,012$$

Deuterium

Defining Deuterium as having an exact
atomic Planck mass of 45012n quanta
reflects the true charged geometries
of all Elements & their topologies

D

1/6 C

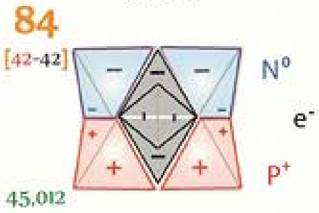

3.320192418e-27 kg

1 Proton [24-12]
1 Neutron [18-18] n1
1 electron [0-12]

Planck mass-energy units

NAu = 0.001 kg

48
[24-24]

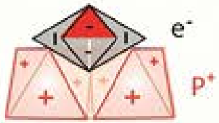

^{1}H

22,512

1.660538841 e-27 kg

One Da is approximately equal to the mass of one proton or one neutron

36
[18-18]

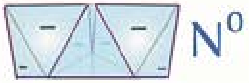

0.499866702 H

22,500

1.659653693 e-27 kg

36
[24-12]

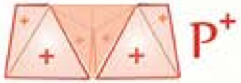

0.499866702 H

22,500

Deuterium is the building block of all elements

84
[42-42]

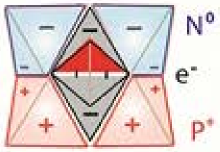

^{2}H

45,012

3.320192534 e-27 kg

The unified atomic mass unit (symbol: u) or Dalton (symbol: Da)
is a unit that is used for indicating mass on an atomic or molecular scale

270,072

1/12 the mass of a C12 graphene atom
at rest in its electronic ground state

1.660538782(83)×10−27 kg

22,506

is an inaccurate means of determining the
exact rest mass of a Hydrogen atom

22,512

Carbon 12 has 270,072n planck quanta
(270,072 / 12 = 22,506)

Hydrogen has a mass of 22,512n (22,500+12)
requiring all mass to be calculated directly using the
Planck mass-energy quantum (.001kg / N_A / 22,512)
& Tetryonic charge geometries

Using Tetryonic theory to define
n Planck mass = 7.376238634 x 10^{-32} Kg
(see Tetryonics QM 15.04)

exact atomic rest masses for all
particles, elements and compounds
can be determined directly from atomic theory

N_A = 6.02214179 e23

The mole is the amount of substance of a system which contains as many elementary entities
as there are atoms in 0.012 kilogram of carbon 12; its symbol is "mol".

NA(12u) = 0.012 kg

504
[254-254]

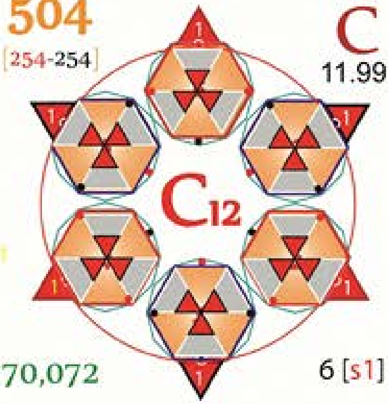

^{12}C
11.996

270,072

6 [s1]

6 Protons [24-12]
6 Neutrons [18-18] n1
6 electrons [0-12]

Carbon has a number of
differing atomic configurations
(allotropes)

6 Protons [24-12]
6 Neutrons [18-18] n1-2
6 electrons [0-12]

504
[252-252]

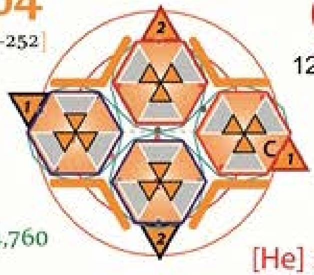

^{6}C
12.6493

284,760

[He] 2s2 2p2

Tetryonics 49.05 - Planck mass-energy quanta

Planck mass-energy contributions to the measured weights of periodic, elementary mass-Matter topologies

36
[18-18]
N^0
45,000n

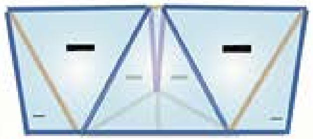

1.659653693 e-27 kg

36
[24-12]
P^+
45,000n

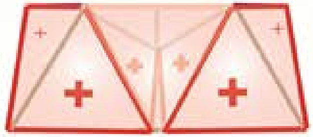

8.851486361 e-31 kg

12
[0-12]
e^-
12n

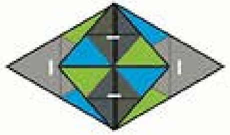

2.41110961 e-35 kg

n
[v-v]

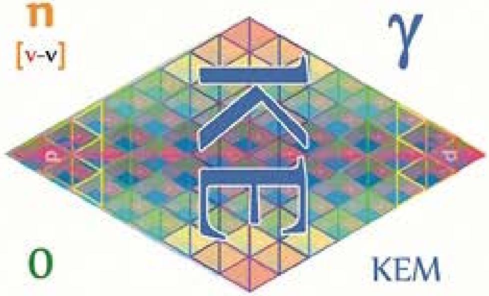

0

Baryons have 2,25e23 Planck quanta comprising their rest Matter topologies

[930.974 MeV]

Δ 1875 x

[496.5 keV]

Leptons have 1.2 e20 Planck quanta comprising their rest Matter topologies

[496.5 keV]

Δ 36,711 x

[13.6 eV]

Photons are planar geometries [Matter-less] (purely Kinetic mass-Energy and momenta)

The Lyman alpha spectral line mass-energy contribution to the mass of a Deuterium nucleus is negligible

Electron quantum level energies are determined by the energy of the Nuclei they bind to in elements

D^+

[1.862 GeV]

84
[42-42]

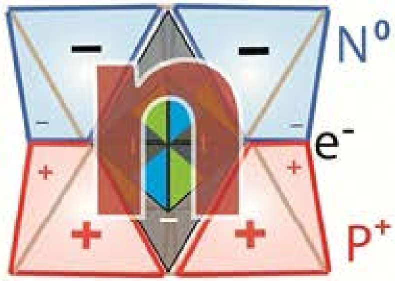

90,012n+

Photons contribute spectral mass-energies to the nuclei mass but are themselves Matterless [2D zero rest mass-energies]

Photons are 2π charge mass-energy geometries

Ionisation energies

Fractional quantum differentials

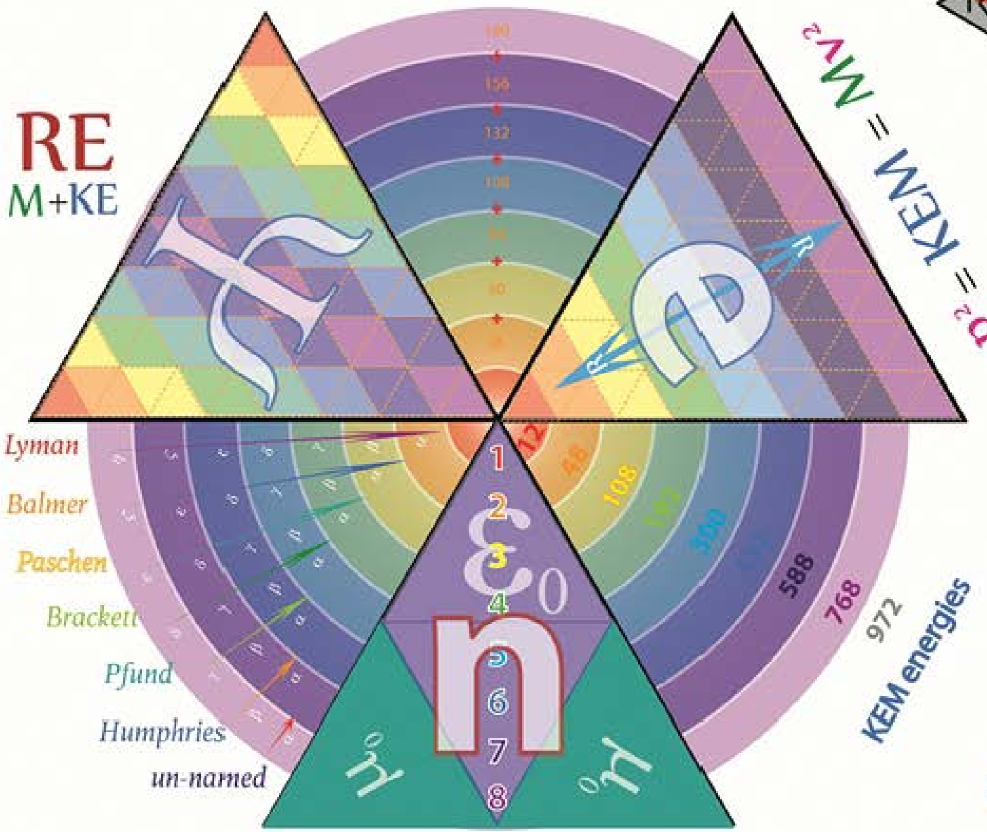
RE
M+KE
h
e
R
R
Mv^2 = KEM = p^2
180
156
132
108
Lyman
Balmer
Paschen
Brackett
Pfund
Humphries
un-named
12
48
108
192
300
432
588
768
972
KEM energies
1
2
3
4
5
6
7
8
ε0
n

$$hf = \Delta Mv = \Delta p$$

spectral lines are produced by accelerating electrons

Note: this is an Illustrative schema for modelling KEM field energies
All KEM fields possess the same physical spatial geometry
in radial-time defined spatial co-ordinate systems

c^2 c^4

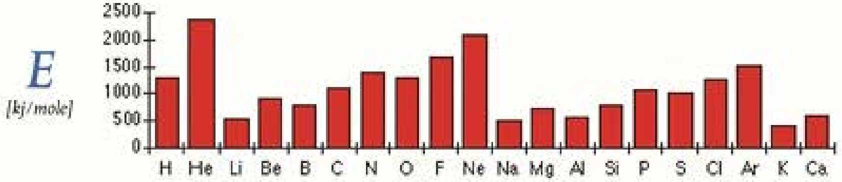

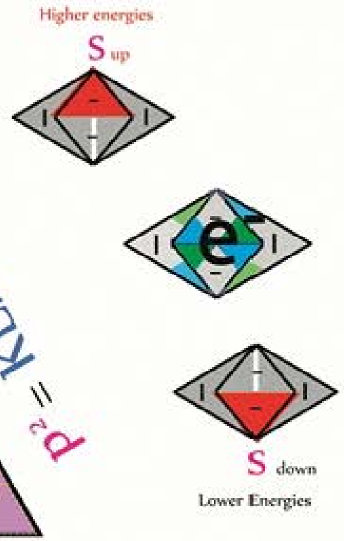
Higher energies
S up
e
S down
Lower Energies

Photo-electrons absorb/emit spectral energies

$$E = eV = \frac{1}{4\pi\epsilon_0}\frac{ne^2}{a}$$

photo-electronic energy momenta

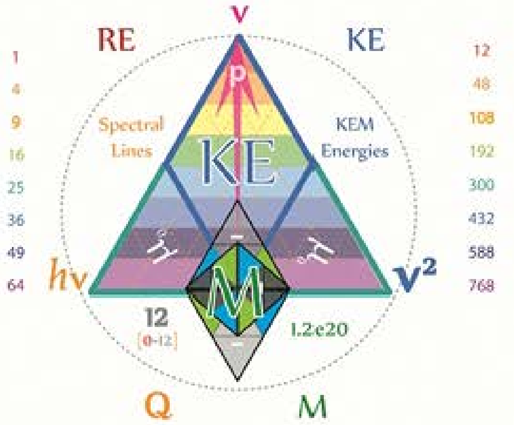
RE
KE
v
p
1
4
9
16
25
36
49
64
12
48
108
192
300
432
588
768
Spectral Lines
KEM Energies
KE
M
hv
v^2
12
[0-12]
1.2e20
Q
M

Mapping photo-electron transition energies
to Tetryonic energy momenta geometries
reveals many key facts about the
ionisation energies of nuclei

$$E = -\frac{Z^2}{n^2}\frac{ke^2}{2a_0} = -\frac{13.6Z^2}{n^2}eV$$

The differing fractional KEM field energy momenta of electrons
that results from their transitions to specific energy nuclei
in elements results in differing QAM quanta and
produces spectral lines and fine line splitting

Spectral line transitions

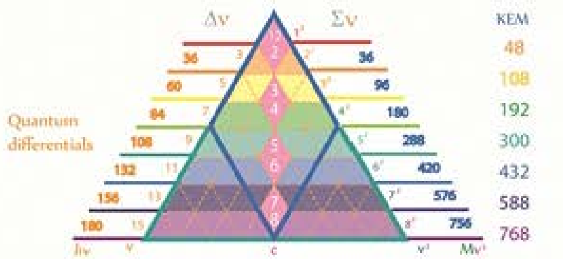
Δv
Σv
KEM
48
108
192
300
432
588
768
36
60
84
108
132
156
180
36
96
180
288
420
576
756
Quantum differentials
hv
v
c
v²
Mv²

hv, R, β, p, KE
Planck, Rydberg, Lorentz, Newton, Leibniz

uniting classical physics and relativity
through equilateral geometry

Elementary ionisation energies

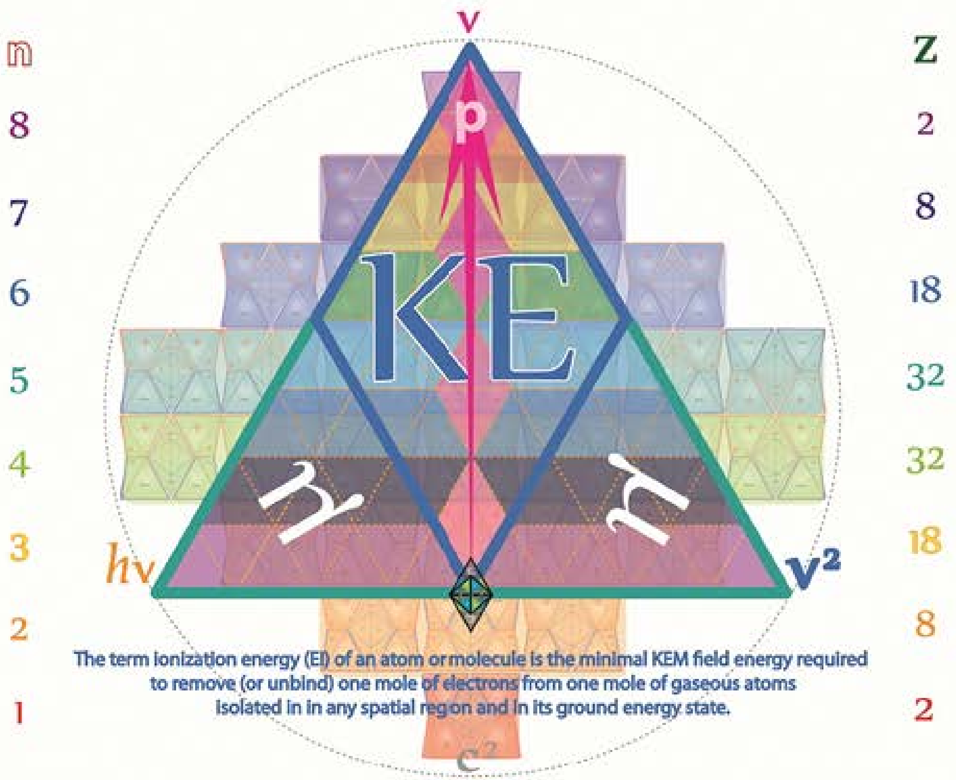

The term ionization energy (EI) of an atom or molecule is the minimal KEM field energy required to remove (or unbind) one mole of electrons from one mole of gaseous atoms isolated in in any spatial region and in its ground energy state.

The term "ionization energy" is sometimes used as a name for the work needed to remove (or un-bind) the highest energy photoelectron from an atom or molecule.

However, due to interactions with surfaces, this value differs from the ionization energy of the atom or molecule in question when it is located by itself in free space.

So, in the case of surface-adsorbed atoms and molecules, it may be better to use the more general term "electron binding energy", in order to avoid confusion.

Both these names are also sometimes used to describe the work needed to remove an electron from a "lower" orbital (i.e., not the topmost orbital) for both free and adsorbed atoms; in such cases it is necessary to specify the orbital from which the electron has been removed

$$E = -\frac{Z^2}{n^2}\frac{ke^2}{2a_0} = -\frac{13.6Z^2}{n^2}eV$$

Every electron in each elementary orbit has a unique ionisation energy

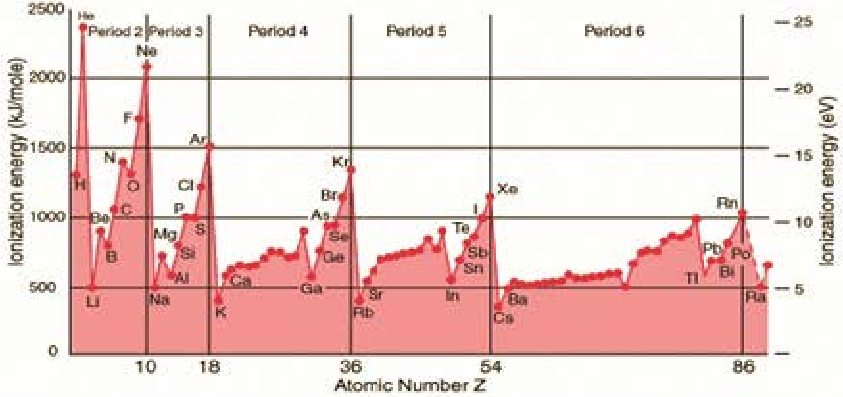

Element number

Nuclei	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Energy level	per shell
R	119	120																															8	2
Q	87	88	113	114	115	116	117	118																									7	8
P	55	56	81	82	83	84	85	86	103	104	105	106	107	108	109	110	111	112															6	18
O	37	38	49	50	51	52	53	54	71	72	73	74	75	76	77	78	79	80	89	90	91	92	93	94	95	96	97	98	99	100	101	102	5	32
N	19	20	31	32	33	34	35	36	39	40	41	42	43	44	45	46	47	48	57	58	59	60	61	62	63	64	65	66	67	68	69	70	4	32
M	11	12	13	14	15	16	17	18	21	22	23	24	25	26	27	28	29	30															3	18
L	3	4	5	6	7	8	9	10																									2	8
K	1	2																															1	2
Shells	s		p						d										f															
sub-orbitals	s1	s2	p1	p2	p3	p4	p5	p6	d1	d2	d3	d4	d5	d6	d7	d8	d9	d10	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12	f13	f14		

Orbitals

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Hyperfine splitting and Lamb Shifts

When the spectral lines of the hydrogen spectrum are examined at very high resolution, they are found to be closely-spaced doublets.
This splitting is called fine structure and was one of the first experimental evidences for electron spin.

The fine structure describes the splitting of the spectral lines of atoms due to first order relativistic corrections [principal quantum energies]

n

Differing electron spins within shells & quantum levels produces Hyperfine splitting

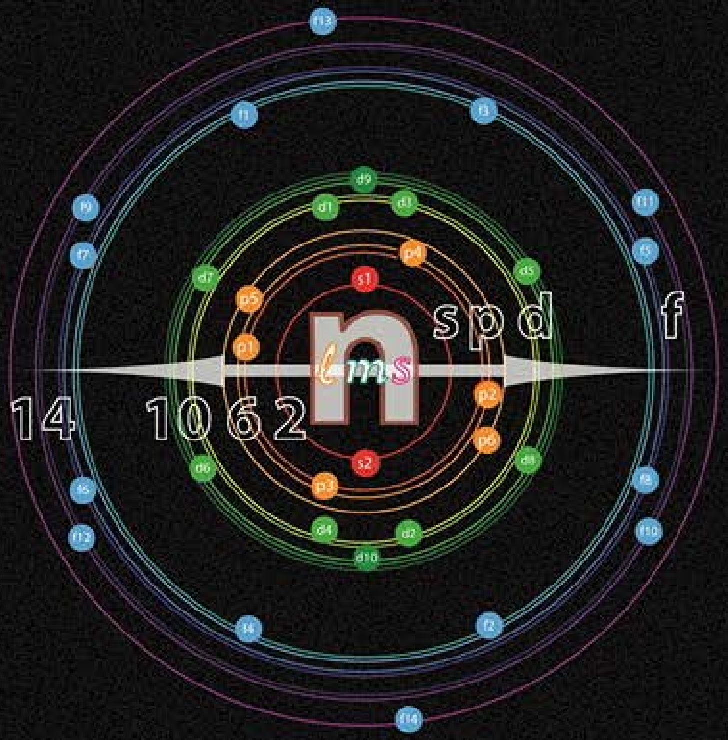
f13
f1
f3
f9
f11
f7
f5
d9
d1
d3
d7
d5
p4
p5
s1
p1
n
lms
s p d
f
14
10 6 2
p2
p6
s2
d6
d8
p3
f6
f8
f12
f10
d4
d2
d10
f4
f2
f14

The electron energy levels of Hydrogen should depend only on the principal quantum number n.

In 1951 it was discovered that this was not so, the $2p_{(1/2)}$ state is slightly less than the $2s_{(1/2)}$ state resulting in the Lamb shift

ℓ m s

Differing electron sub-Orbtial energies create Lamb Shifts

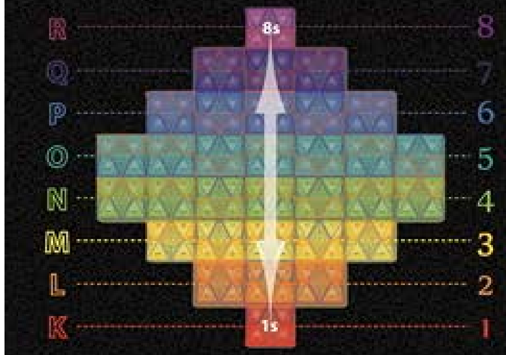
R
Q
P
O
N
M
L
K
8s
1s
8
7
6
5
4
3
2
1

atomic shell energies result from Series addition of baryonic energies

If you measure the atomic energy levels of photo-electrons at an extremely high resolution, you'll find small deviations of individual KEM field energies of electrons in sub-orbitals which are primarily the result of parallel and anti-parallel electron spins

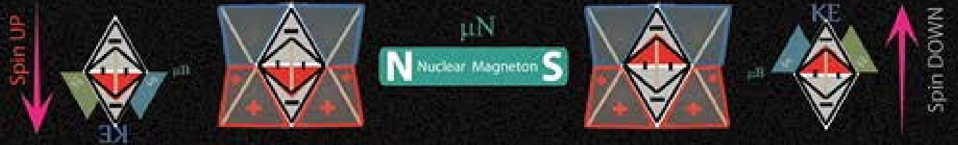
Spin UP
KE
μB
μN
N Nuclear Magneton S
μB
KE
Spin DOWN

Higher energy
Parallel
Magnetic moments

Lower energy
Anti-parallel
Magnetic moments

All electron spins are referenced to the Nuclear magneton

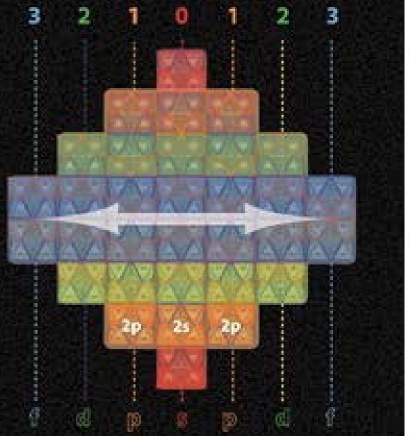
3
2
1
0
1
2
3
2p
2s
2p
f
d
p
s
p
d
f

electron sub-orbital energies are Parallel energy configurations

M_0

3D Matter topologies are comprised of charged 2D mass-energies

Energy per second^2

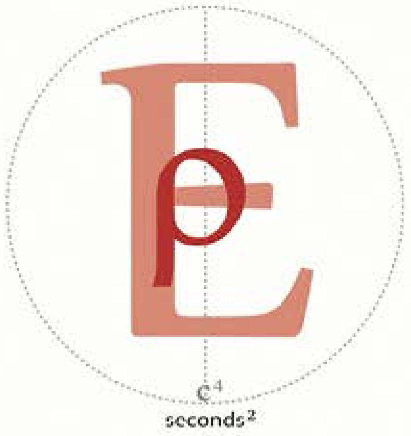
c^4
seconds^2

$$\overset{\text{Matter}}{\frac{T\pi}{c^4}}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

mass-Matter

standing wave mass-energiescreate
the material substance of all chemical elements

RE

Relativistic mass-ENERGY-Matter

Relativity fails at the foundational level to explain and differentiate between mass-ENERGY and Matter in physical systems

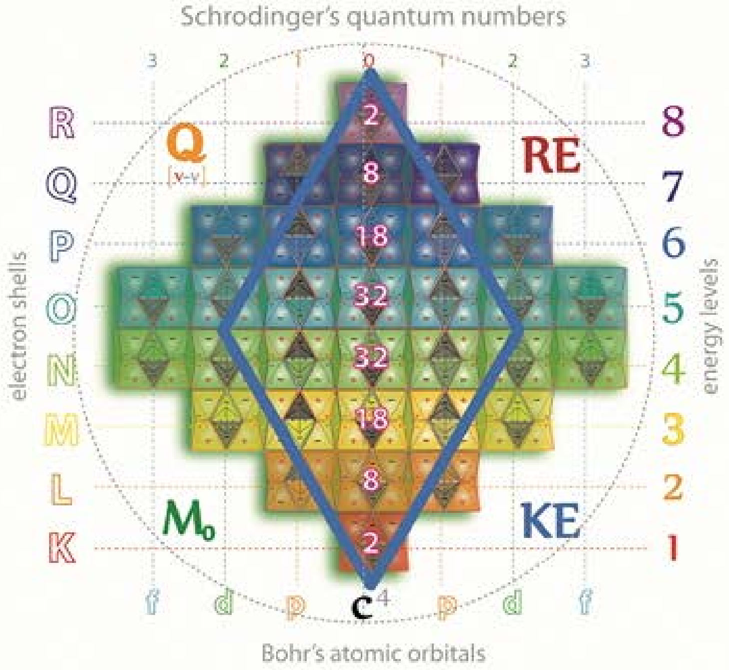
Schrodinger's quantum numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
[v-v]
RE
2
8
18
32
32
18
8
2
M_0
KE
8
7
6
5
4
3
2
1
energy levels
f
d
p
c^4
p
d
f
Bohr's atomic orbitals

Einstein's relativistic [Lorentz corrected] stress energy tensor aggregates all forms of energy into a single energy density gradient

atomic energies

$$\frac{Tm\mathrm{n}}{c^4} + \frac{mv^2}{c^2}$$

electron spins

3D rest Matter + Lorentz corrected 2D Kinetic Energies = total Relativistic Energies

KE

2D equilateral mass-energies are euclidean geometries

Energy per second

$$\overset{\text{mass}}{\frac{n\pi}{c^2}}\left[\left[\underset{\text{mass}}{m}\overset{\text{Planck quanta}}{\Omega}\underset{\text{velocity}}{v^2}\right]\right]$$

mass-energies

radiant planar mass-energies create
EM fields, spectral lines & chemical interactions

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Deuterium is the building block of all Elements (save Hydrogen)

The geometry of any Element is determined by its Charge

The Molar Weight of any Element is a measure of its standing wave mass-energies

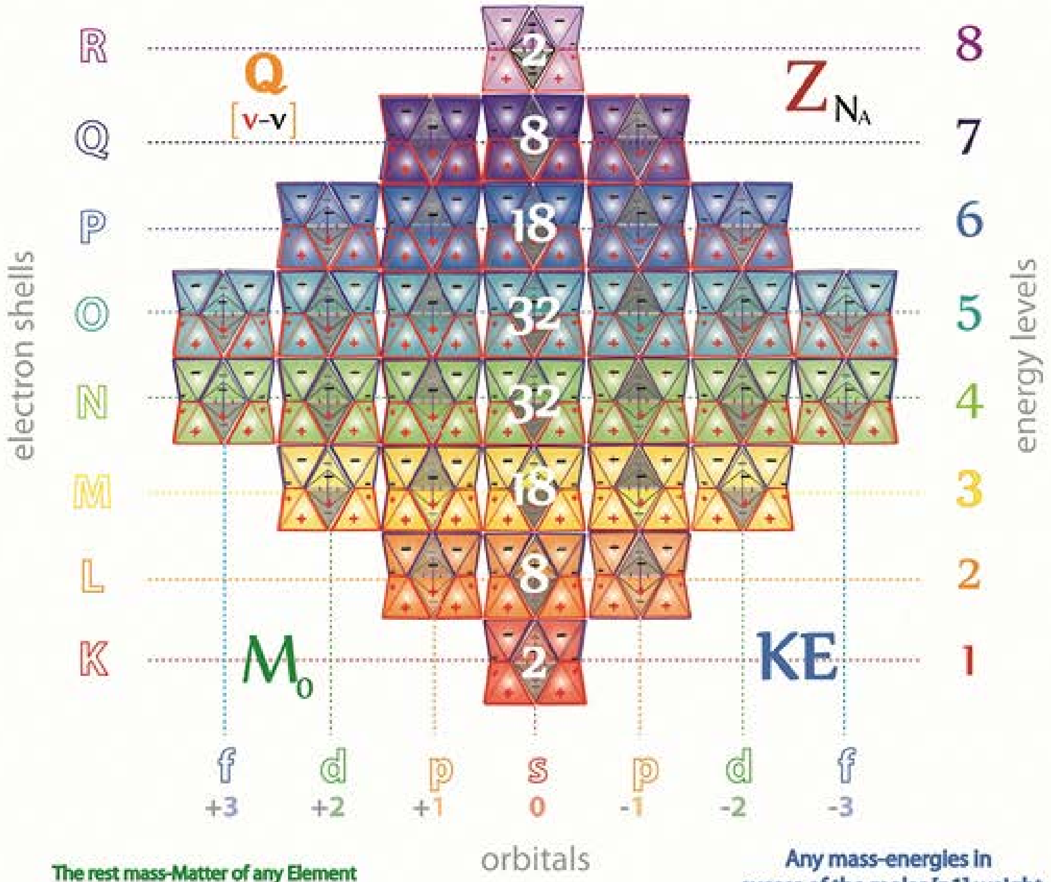

The rest mass-Matter of any Element is determined by the total number of quanta making up the Protons, Neutrons and electrons that comprise them (in their respective energy levels)

Any mass-energies in excess of the molar [n1] weight is a measurement of a element's CHEMICAL energies

Important point to note:

The Kinetic Energy difference between any Element's total [n1] Deuteron mass-energies and its Molar mass has historically been incorrectly explained as resulting from an excess number of Neutrons in the atom it is not. Z# = (number of Protons = number of electrons = number of Neutrons)

Elementary mass-Matter

$$\sum_{K}^{R}$$

	n per nuclei 1e19v = n	
2	2 nuclei [74,496 ea]	120 Unbinilium 119 Ununennium
	+	
8	8 nuclei [69,780 ea]	118 Ununoctium 87 Francium
	+	
18	18 nuclei [65,232 ea]	112 Copernicium 55 Caesium
	+	
32	32 nuclei [60,852 ea]	102 Nobelium 37 Rubidium
	+	
32	32 nuclei [56,640 ea]	70 Ytterbuim 19 Potassium
	+	
18	18 nuclei [52,596 ea]	30 Zinc 11 Sodium
	+	
8	8 nuclei [48,720 ea]	10 Neon 3 Lithium
	+	
2	2 nuclei [45,012 ea]	2 Helium 1 Deuterium

The rest mass-Matter of any Element is the sum total of its constituent Z[n²] energy level Deuterium nuclei

Aufbau

$$Z\#\left[\begin{array}{ll} z\ \text{Protons} & [24\text{-}12] \\ z\ \text{Neutrons} & [18\text{-}18] \\ z\ \text{electrons} & [0\text{-}12] \end{array}\right]n1\text{-}8$$

(ie Calcium [20] = 2+8+10 n level Deuterium nuclei)

Periodic Harmonic motions

$x = A\cos(\omega t + \varphi)$

Circular motion

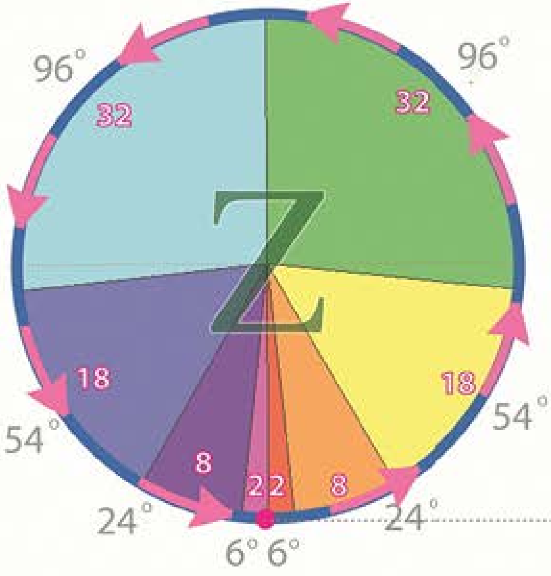
96°
96°
32
32
Z
18
18
54°
54°
8
2
2
8
24°
24°
6° 6°

circular harmonic motion

Circular motions describe the motion of a body with a changing velocity vector [the result of an acceleration force].

Much of the math in of modern physics is predicated on the assumption that π [where it appears] is related to the properties of a circle

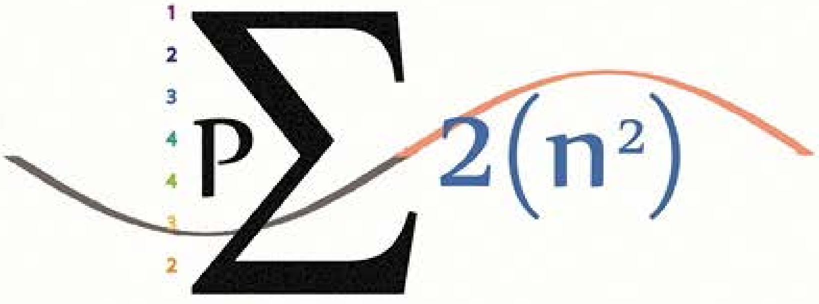

$$P\sum 2(n^2)$$

Simple harmonic motion can be visualized as the projection of uniform circular motion onto one axis

$F = -kx$

Linear motion

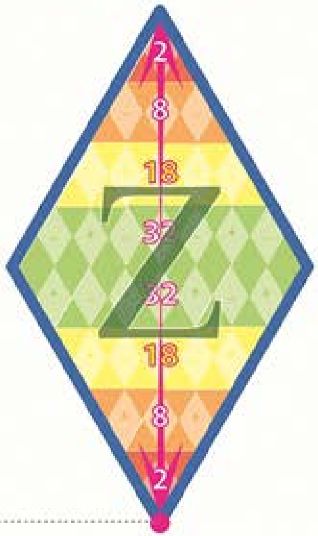
2
8
18
32
32
18
8
2
Z

simple harmonic motion

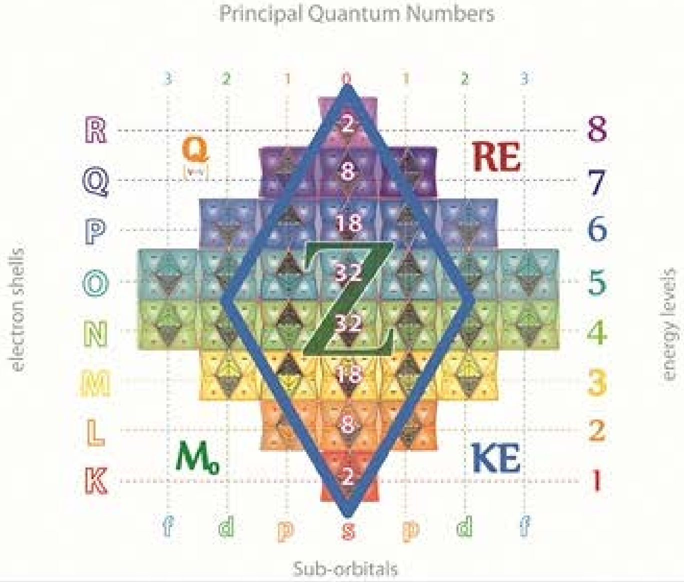
Principal Quantum Numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
RE
M₀
KE
2
8
18
32
32
18
8
2
Z
8
7
6
5
4
3
2
1
energy levels
f
d
p
s
p
d
f
Sub-orbitals

Nuclei per shell in elements follows a 'periodic summation rule' that is reflective of photonic energies

$${}_{K}^{R}P\sum Z$$

Periodic Summation

Periodic summation is a notation developed for Tetryonic theory
to model the geometric series addtion of $Z[n^2]$ energy level
Deuterium nuclei that form the periodic elements

$$\sum_{K}^{R}$$

nuclei per shell

STEP ONE

Periodic summation follows the atomic shell electron config

$$\sum_{Z=1}^{120}$$

element number

STEP TWO

Periodic elements build up following the aufbau sequence

1 R
2
3
4
4
3
2
1 K

$${}_{P}\sum_{K}^{R} 2(x^2) =$$

Each atomic shell can hold only a fixed number of deuterium nuclei

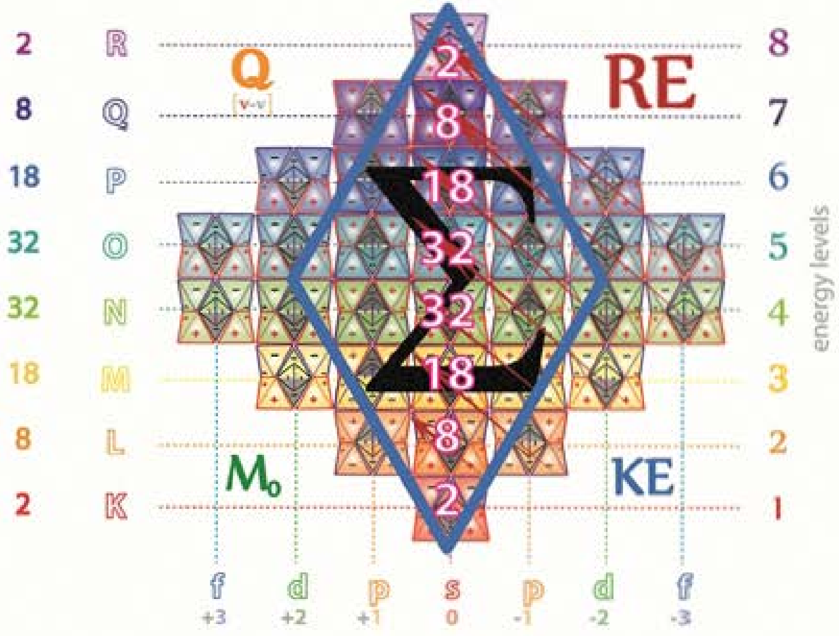

${}_{P}\sum R = 2$	2 nuclei [74,496 ea] +	120	Unbinilium
${}_{P}\sum Q = 8$	8 nuclei [69,780 ea] +	118	Ununoctium
${}_{P}\sum P = 18$	18 nuclei [65,232 ea] +	110	Darmstadtium
${}_{P}\sum O = 32$	32 nuclei [60,852 ea] +	92	Uranium
${}_{P}\sum N = 32$	32 nuclei [56,640 ea] +	60	Neodymuim
${}_{P}\sum M = 18$	18 nuclei [52,596 ea] +	28	Argon
${}_{P}\sum L = 8$	8 nuclei [48,720 ea] +	10	Neon
${}_{P}\sum K = 2$	2 nuclei [45,012 ea]	2	Helium
		0	Hydrogen

THe LHS of the notation determine the number of nuclei in each atomic shell, from the periodic mass-energy levels for atoms, and the RHS follows the aufbau building principle to determine the rest mass-Matter of any specific element

Aufbau

Each periodic element is made of Z [n² energy] deuterium nuclei

$$Z\#\left[\begin{array}{ll} z \text{ Protons} & [24\text{-}12] \\ z \text{ Neutrons} & [18\text{-}18] \\ z \text{ electrons} & [0\text{-}12] \end{array}\right] n1\text{-}8$$

Planck mass-energies form the surface integral of rest Matter topologies for each periodic element

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Element numbers

Nuclei per shell in elements follow
a 'periodic summation rule'
that is reflective of
photonic energies

$$\begin{array}{c}1\\2\\3\\4\\4\\3\\2\\1\end{array}\;{}_{K}^{R}\,P\sum 2(x^2) = 2 + 8 + 18 + 32 + 32 + 18 + 8 + 2$$

Z

120	Unbinilium	n8
119	Ununennium	
118	Ununoctium	n7
87	Francium	
112	Copernicium	n6
55	Caesium	
102	Nobelium	n5
37	Rubidium	
70	Ytterbuim	n4
19	Potassium	
30	Zinc	n3
11	Sodium	
10	Neon	n2
3	Lithium	
2	Helium	n1
1	Deuterium	

Hydrogen 0

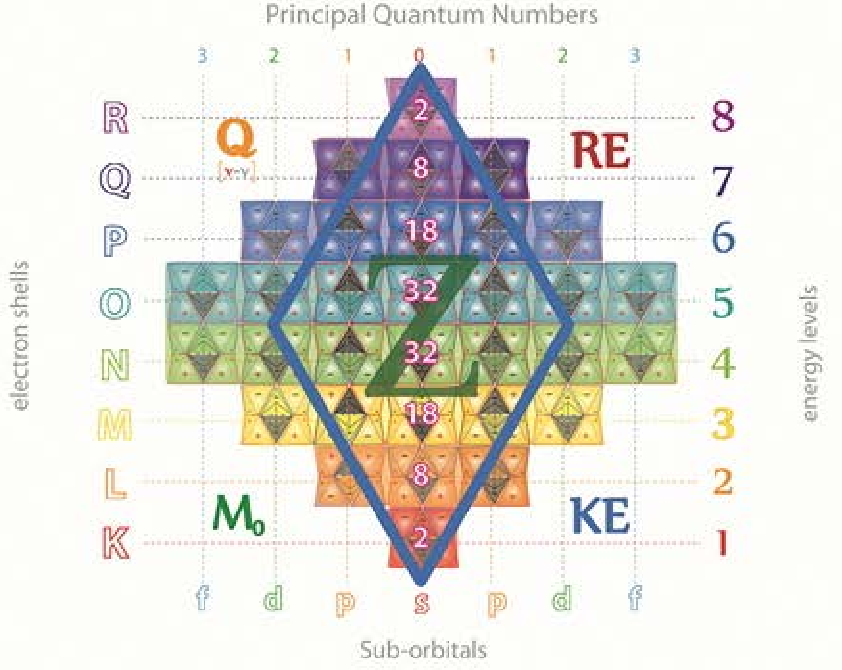
Principal Quantum Numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
[x-y]
RE
M_0
KE
2
8
18
32
32
18
8
2
Z
8
7
6
5
4
3
2
1
energy levels
f
d
p
s
p
d
f
Sub-orbitals

Periodic mass-ENERGY-Matter

Following periodic summation rules for shell filling
n[1-8] quantum energy deuterium nuclei
combine to form elementary Matter

$$\boxed{{}_{K}^{R}\,P\sum_{25}^{32}\Big[\underbrace{\overset{\text{Baryon rest masses}}{[72(n)^2]}+\overset{\text{lepton rest mass}}{[12e19]}+\overset{\text{KEM}}{[m_e v^2]}}_{\text{Deuterium mass-energy per shell}}\Big]_{1}^{8}}$$

The measured weight of Matter in gravitational fields is the result of
planar mass-energies in tetryonic standing-wave geometries

The periodicity of all the elements,
along with their exact molar rest mass-energies and
quantum wavefunctions can be described with Tetryonic geometries

Ionisation energies

γ

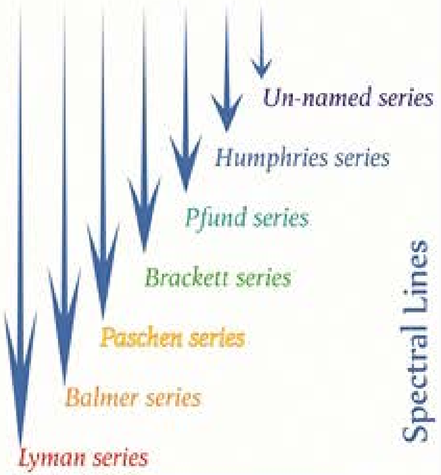
Un-named series
Humphries series
Pfund series
Brackett series
Paschen series
Balmer series
Lyman series
Spectral Lines

$$\boxed{Mv^2 = KEM = \hbar c R_H}$$

Photon emission/absorption

Photo-electron ionisation energies

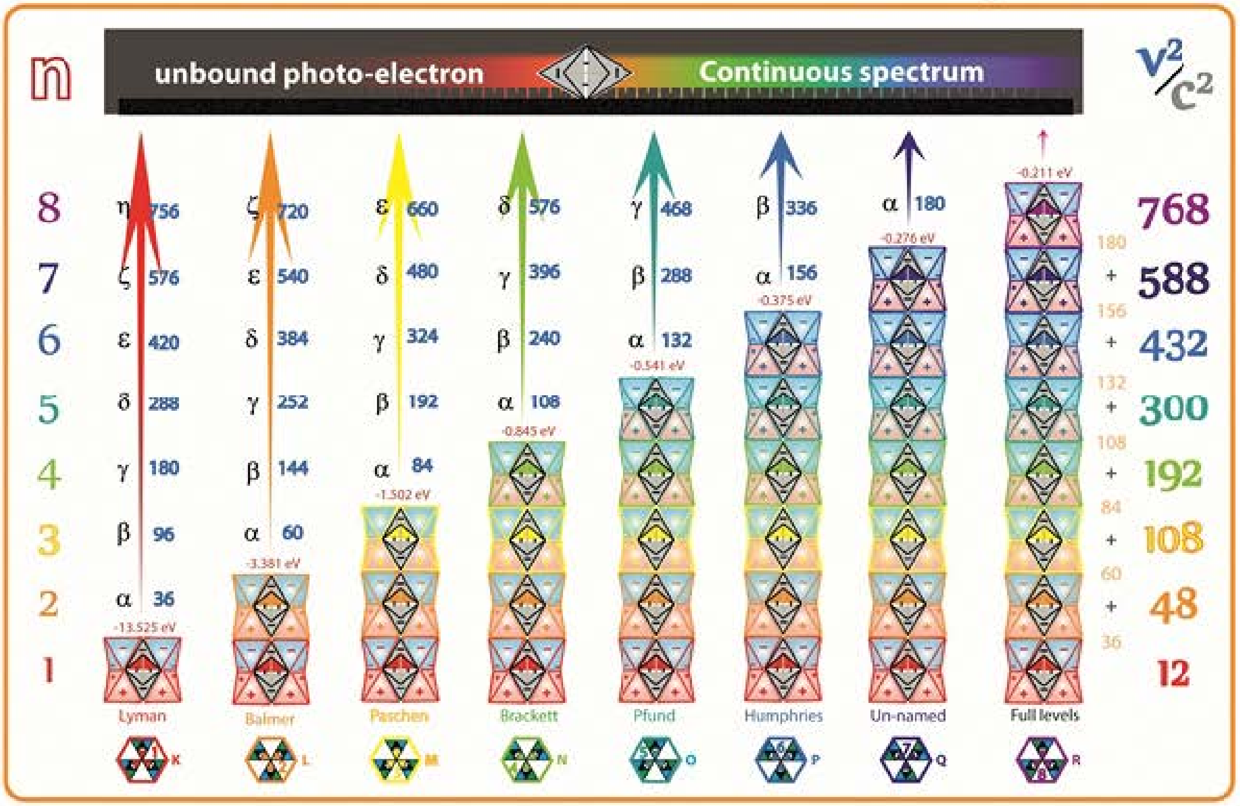
n
unbound photo-electron
Continuous spectrum
v^2/c^2
8
7
6
5
4
3
2
1
η 756
ζ 576
ε 420
δ 288
γ 180
β 96
α 36
-13.525 eV
Lyman
K
ζ 720
ε 540
δ 384
γ 252
β 144
α 60
-3.381 eV
Balmer
L
ε 660
δ 480
γ 324
β 192
α 84
-1.502 eV
Paschen
M
δ 576
γ 396
β 240
α 108
-0.845 eV
Brackett
N
γ 468
β 288
α 132
-0.541 eV
Pfund
O
β 336
α 156
-0.375 eV
Humphries
P
α 180
-0.276 eV
Un-named
Q
-0.211 eV
Full levels
R
180
+
156
+
132
+
108
+
84
+
60
+
36
768
588
432
300
192
108
48
12

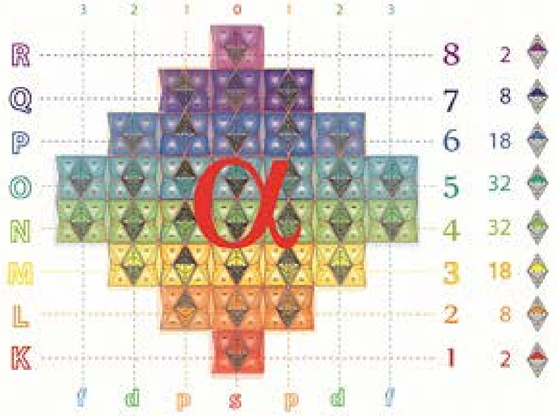
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
α
8 2
7 8
6 18
5 32
4 32
3 18
2 8
1 2
f d p s p d f

Opposed electron spins results in Hyperfine splitting & Lamb shifts

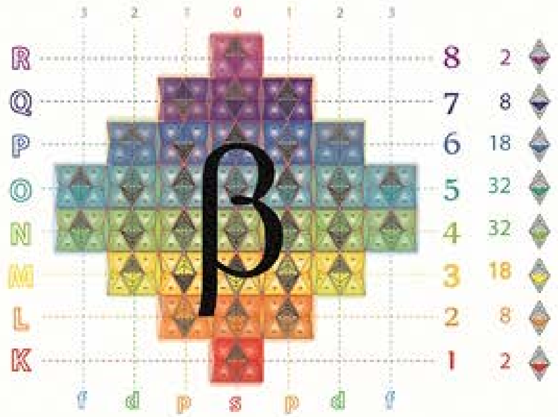
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
β
8 2
7 8
6 18
5 32
4 32
3 18
2 8
1 2
f d p s p d f

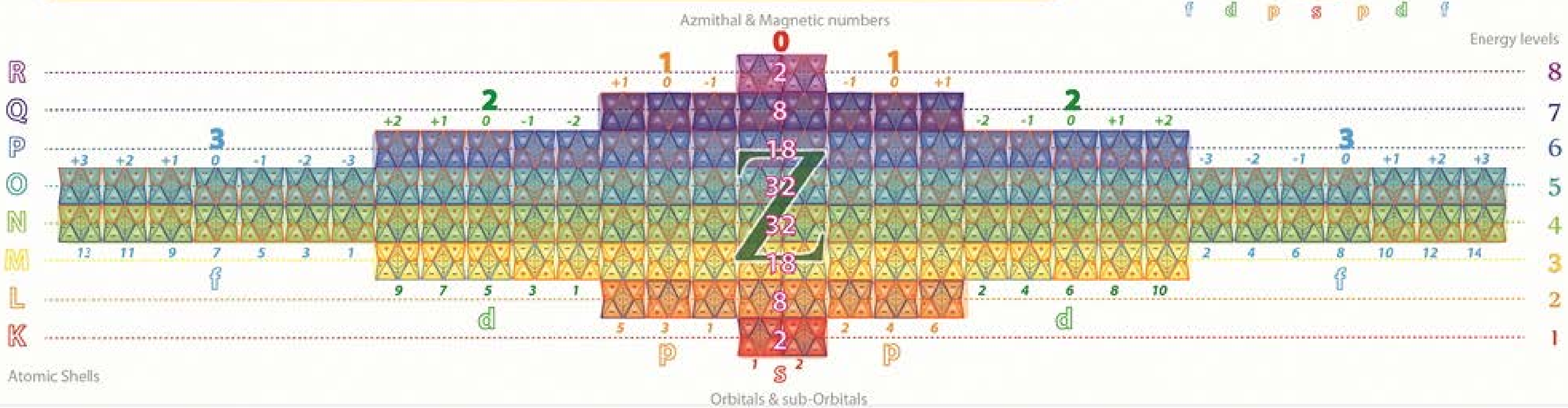
Azmithal & Magnetic numbers
Energy levels
R
Q
P
O
N
M
L
K
0
1
+1 0 -1
1
-1 0 +1
2
+2 +1 0 -1 -2
2
-2 -1 0 +1 +2
3
+3 +2 +1 0 -1 -2 -3
3
-3 -2 -1 0 +1 +2 +3
2
8
18
32
32
18
8
2
Z
13 11 9 7 5 3 1
f
2 4 6 8 10 12 14
f
9 7 5 3 1
d
2 4 6 8 10
d
5 3 1
p
2 4 6
p
1 s 2
8
7
6
5
4
3
2
1
Atomic Shells
Orbitals & sub-Orbitals

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Eigenstate - Ionisation energies

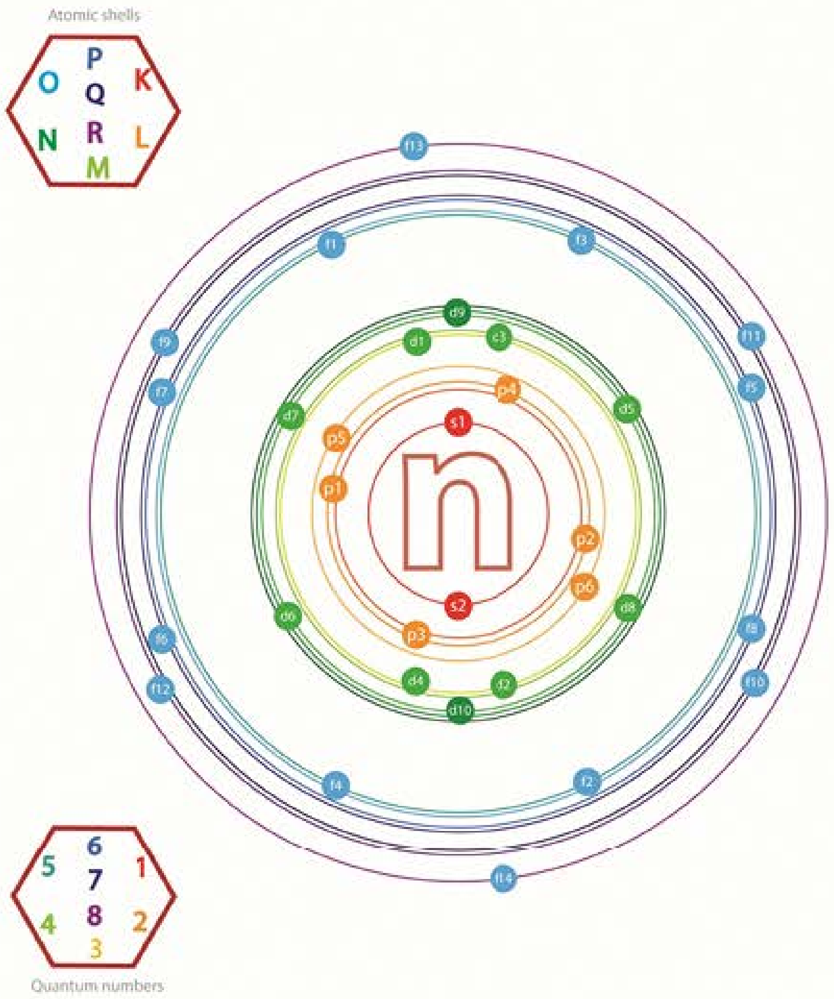
Atomic shells
P
O
Q
K
N
R
L
M
n
s1
s2
p1
p2
p3
p4
p5
p6
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
f1
f2
f3
f4
f5
f6
f7
f8
f9
f10
f11
f12
f13
f14
6
5
7
1
8
4
2
3
Quantum numbers

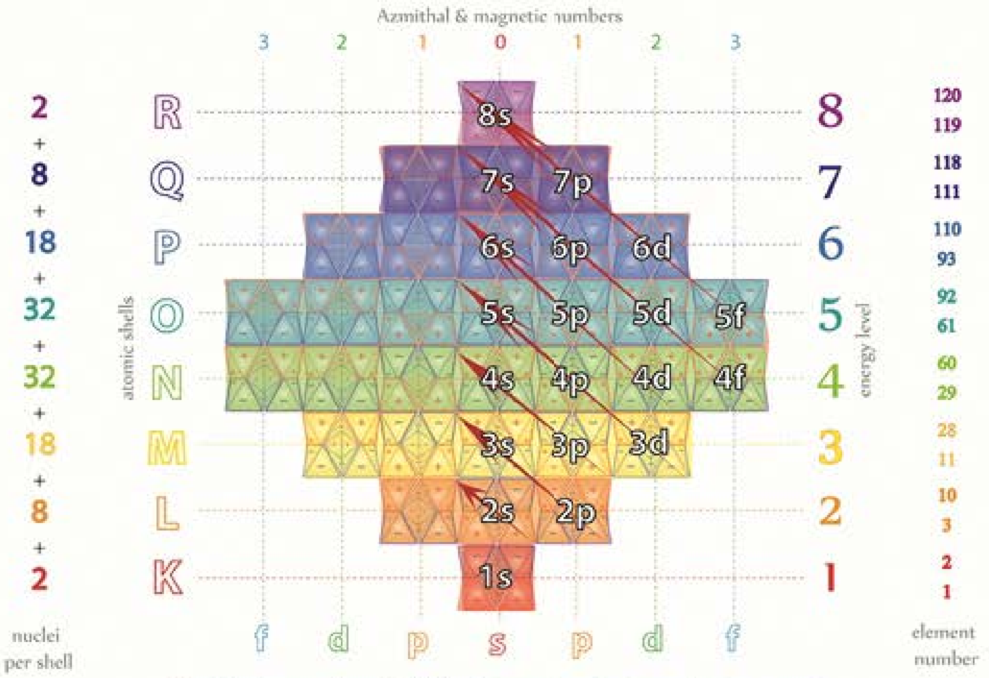
Azmithal & magnetic numbers
3
2
1
0
1
2
3
2
+
8
+
18
+
32
+
32
+
18
+
8
+
2
nuclei per shell
atomic shells
R
Q
P
O
N
M
L
K
8s
7s
7p
6s
6p
6d
5s
5p
5d
5f
4s
4p
4d
4f
3s
3p
3d
2s
2p
1s
8
7
6
5
4
3
2
1
energy level
120
119
118
111
110
93
92
61
60
29
28
11
10
3
2
1
element number
f
d
p
s
p
d
f

The ionisation energies of individual atoms varies due to many factors, namely:
electron spin-orbital coupling with Baryons of specific energies,
the relativistic energies of photo-electrons bound in nuclei
and Zitterbewegung effects on bound electrons

First ionisation energies for all periodic elements

$$E = -\frac{Z^2}{n^2}\frac{ke^2}{2a_0} = -\frac{13.6Z^2}{n^2}eV$$

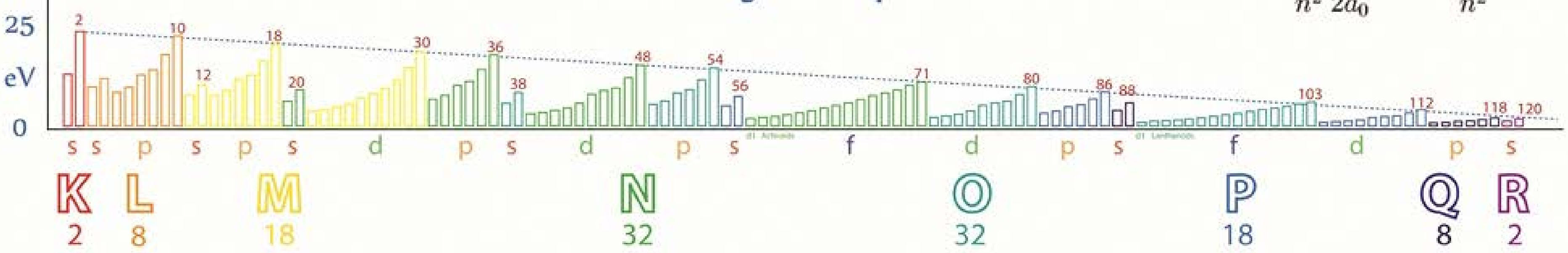

Proton - Neutron Curve

The graph below is a plot of neutron number against proton number.
It is used as rule to determine which nuclei are stable or unstable.

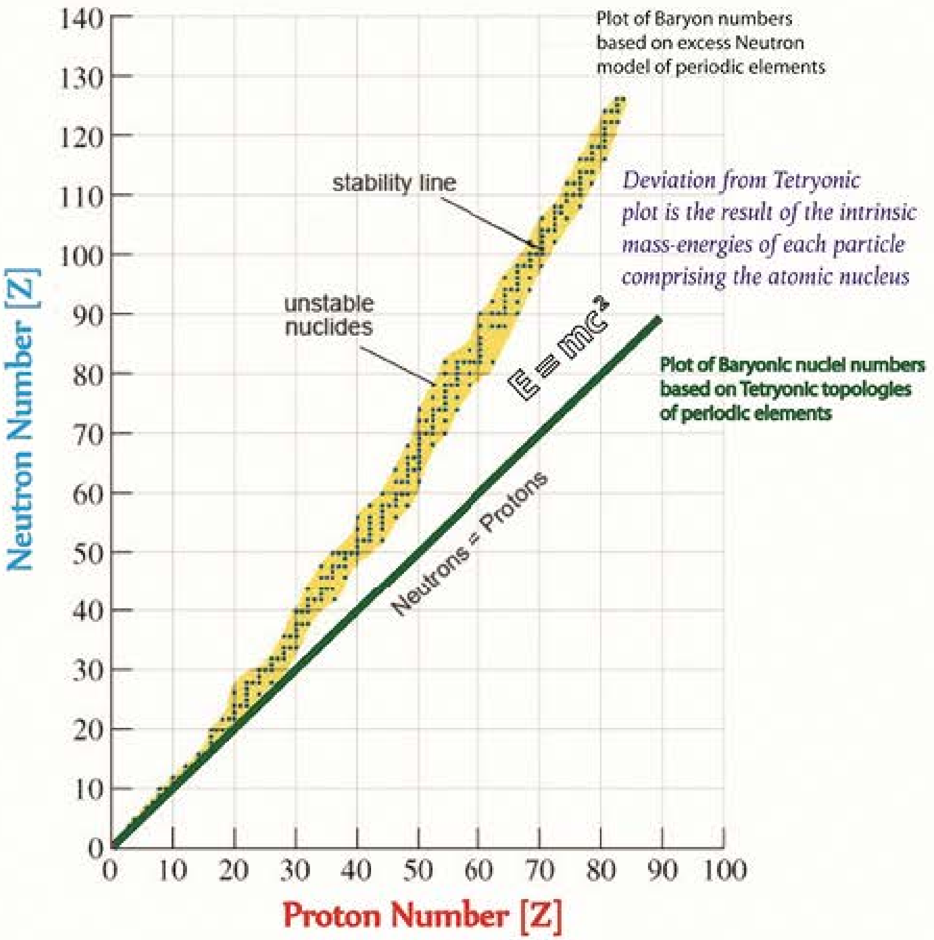

Plot of Baryon numbers based on excess Neutron model of periodic elements

Deviation from Tetryonic plot is the result of the intrinsic mass-energies of each particle comprising the atomic nucleus

Plot of Baryonic nuclei numbers based on Tetryonic topologies of periodic elements

Historically, Proton-electron numbers are viewed as being equivalent in neutral elementary matter with the excess molar mass measured being the result of 'excess or extra' Neutrons in the atom

Atomic Nuclei Numbers

All periodic elements have an EQUAL number of Protons, Neutrons & Electrons with their molar mass-Matter being determined by their quantum level mass-energies

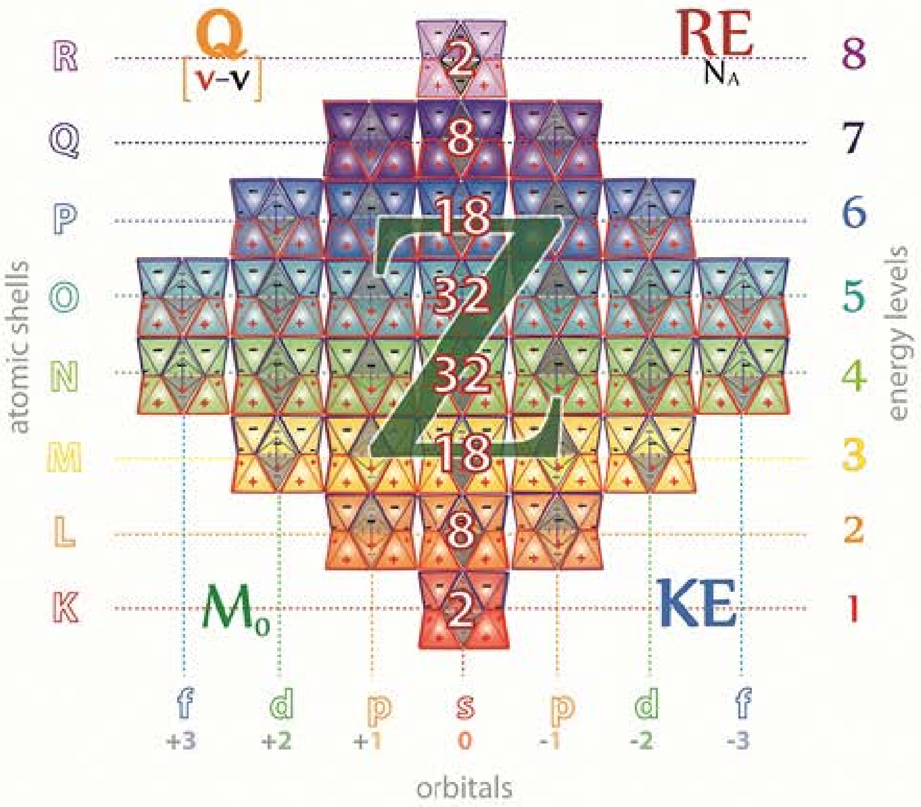

Tetryonic modelling of the charged mass-ENERGY-Matter topologies of elementary atoms and the nuclei that comprise them, reveals a DIRECT LINEAR relationship for the number of Protons-electrons-Neutrons in all periodic elements and nuclear isotopes

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Planck mass-energy contributions to elementary Matter and isotopes

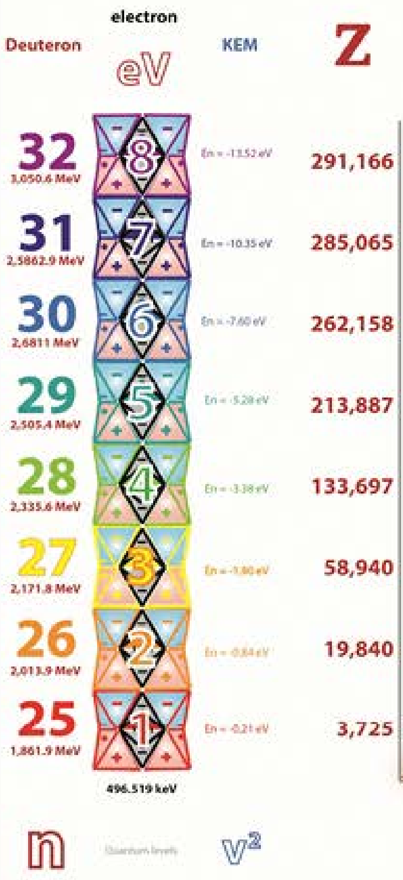
Deuteron
electron
eV
KEM
Z
32
3,050.6 MeV
8
En = -13.52 eV
291,166
31
2,5862.9 MeV
7
En = -10.35 eV
285,065
30
2,6811 MeV
6
En = -7.60 eV
262,158
29
2,505.4 MeV
5
En = -5.28 eV
213,887
28
2,335.6 MeV
4
En = -3.38 eV
133,697
27
2,171.8 MeV
3
En = -1.90 eV
58,940
26
2,013.9 MeV
2
En = -0.84 eV
19,840
25
1,861.9 MeV
1
En = -0.21 eV
3,725
496.519 keV
n
Quantum levels
v²

The mass-energy content of Deuterium nuclei creates the molar mass of elements
[not extra neutrons in excess of the elemental number]

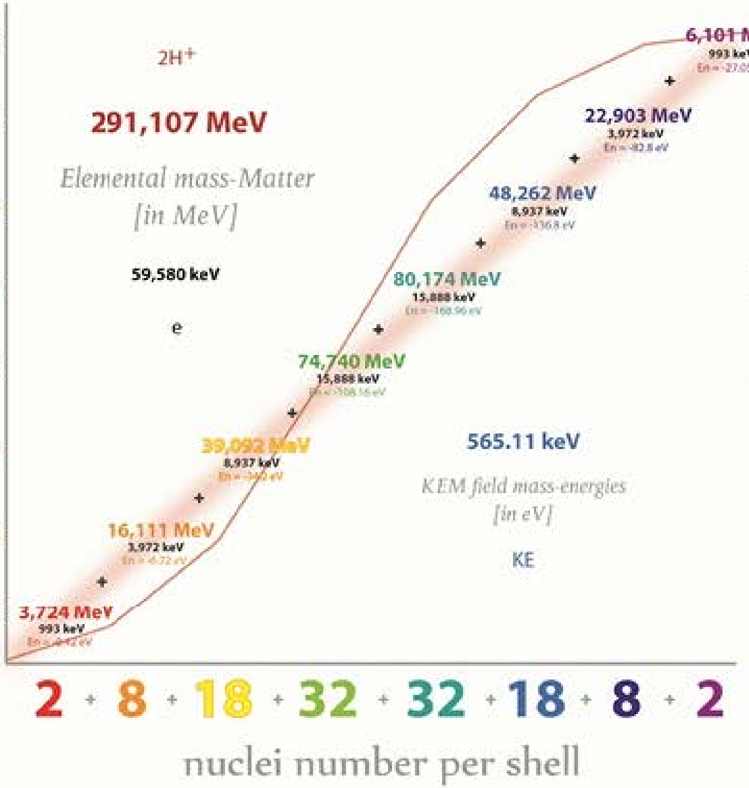

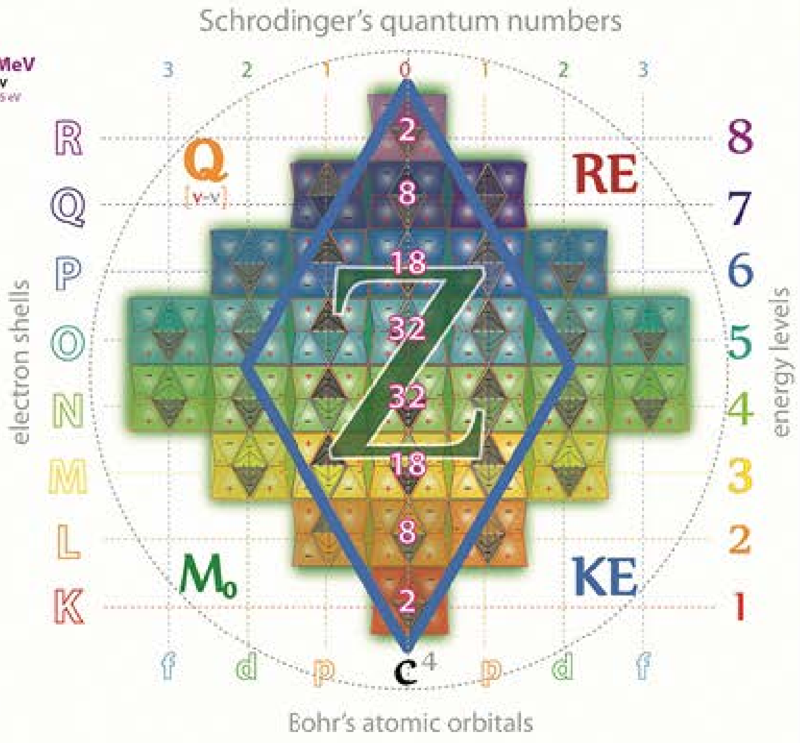
Schrodinger's quantum numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
[v-v]
RE
Z
2
8
18
32
32
18
8
2
Mo
KE
8
7
6
5
4
3
2
1
energy levels
f
d
p
c4
p
d
f
Bohr's atomic orbitals

n1

Elementary nuclei

are comprised of equal numbers of
Protons, Neutrons & electrons
with varying energy levels

Baryons		electrons		KEM fields
930.947 MeV	+	496.519 keV	+	13.525 ev

The mass-energy content of Matter topologies is velocity invariant

The mass-energy content of Baryons determines the KEM field of electrons

Baryons **930.947 MeV** + **KEM fields** **13.525 ev** + **electrons** **496.519 keV**

Mapping Planck mass-energy contributions to elementary Matter and isotopes

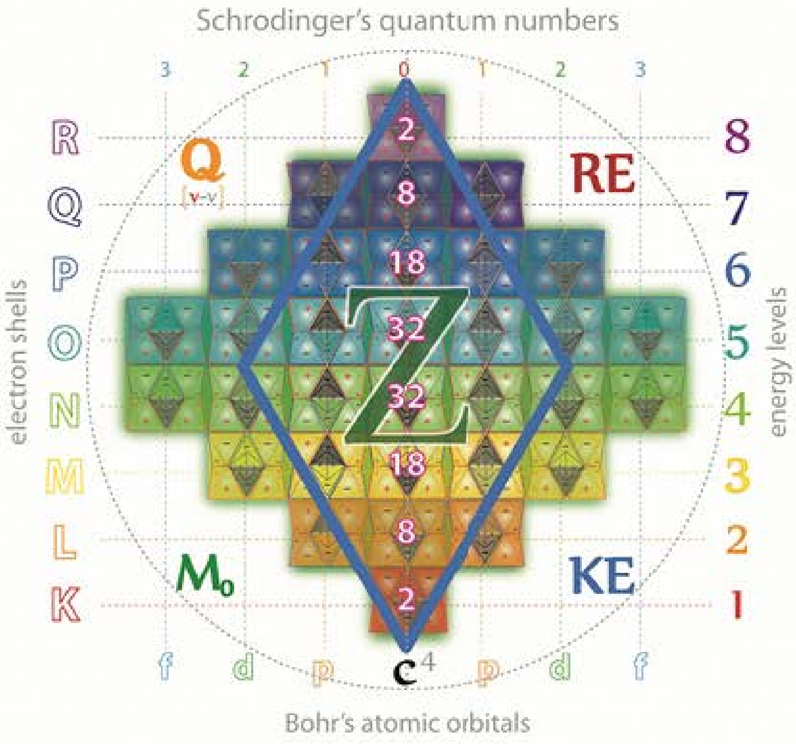
Schrodinger's quantum numbers
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
electron shells
Q
[v-v]
RE
2
8
18
32
Z
32
18
8
2
M_0
KE
8
7
6
5
4
3
2
1
energy levels
f
d
p
c^4
p
d
f
Bohr's atomic orbitals

$$E = hv^2$$

$$n^2 + v^2 + e = Z$$

general form quatratic equation

$$ax^2 + bx + c = Z$$

$$E = nhv$$

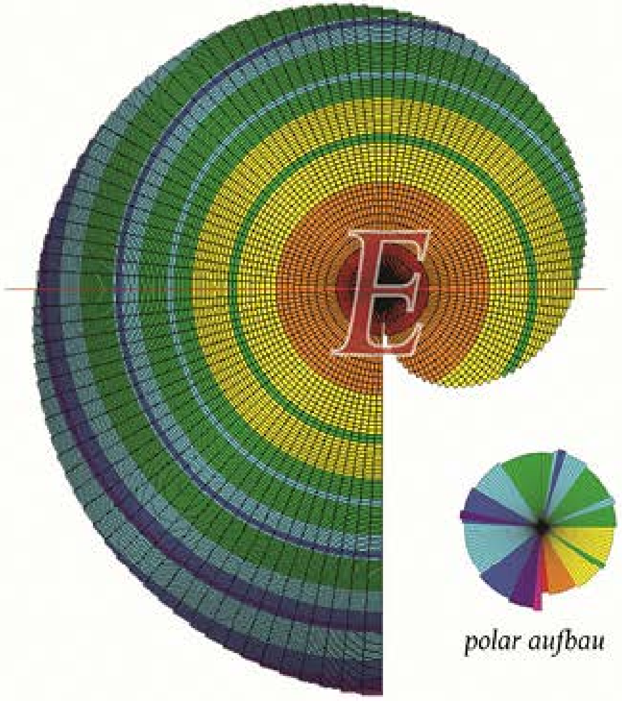
E
polar aufbau

polar energy spirals courtesy of Rene Cormier

Identifying electron rest Matter topologies as velocity invariant we can re-arrange the component Planck mass-energy geometry formulation of periodic elements to

$h[$ **72[v²]** Deuteron rest mass + **v** Spectral lines + **1.20 e20 v** electron rest mass $]$

reveal a quadratic formulation for all Z numbers

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All elements are comprised of n level Duetrium nuclei

Baryons **KEM fields** **electrons**

$$Z\,[[72n^2] + [12v^2] + [1.2e20]]$$

1,861,949 MeV **13.525 eV** **496,519 keV**

$2H^+$

$[72n^2]$

Z

γ

$[M_e v^2]$

Elemental mass-Matter
[in MeV]

The atomic shell energy levels of Deuterium nuclei in elements

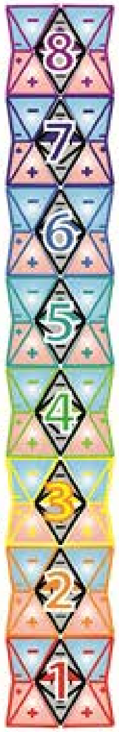

Deuteron	electron eV	KEM
32 3,050.6 MeV	8	En = -13.52 eV
31 2,5862.9 MeV	7	En = -10.35 eV
30 2,6811 MeV	6	En = -7.60 eV
29 2,505.4 MeV	5	En = -5.28 eV
28 2,335.6 MeV	4	En = -3.38 eV
27 2,171.8 MeV	3	En = -1.90 eV
26 2,013.9 MeV	2	En = -0.84 eV
25 1,861.9 MeV	1	En = -0.21 eV

496.519 keV

m

v^2

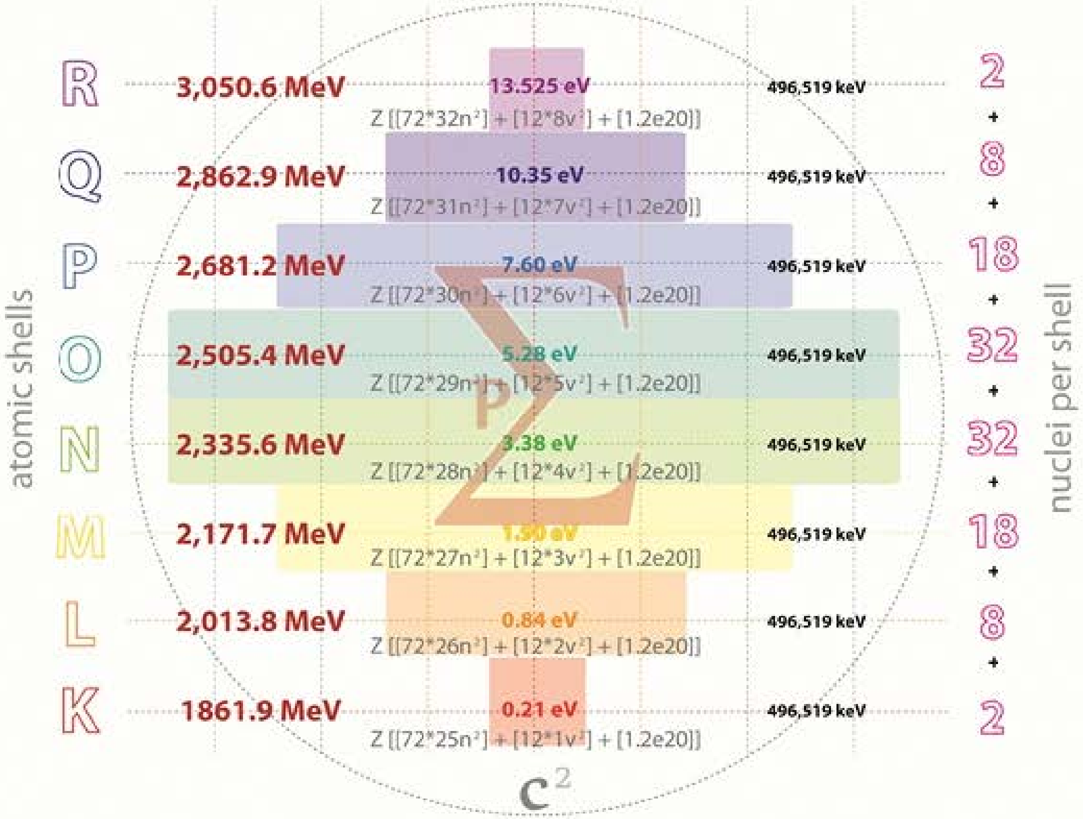

atomic shells					nuclei per shell
R	3,050.6 MeV	13.525 eV	$Z\,[[72*32n^2] + [12*8v^2] + [1.2e20]]$	496,519 keV	2
					+
Q	2,862.9 MeV	10.35 eV	$Z\,[[72*31n^2] + [12*7v^2] + [1.2e20]]$	496,519 keV	8
					+
P	2,681.2 MeV	7.60 eV	$Z\,[[72*30n^2] + [12*6v^2] + [1.2e20]]$	496,519 keV	18
					+
O	2,505.4 MeV	5.28 eV	$Z\,[[72*29n^2] + [12*5v^2] + [1.2e20]]$	496,519 keV	32
					+
N	2,335.6 MeV	3.38 eV	$Z\,[[72*28n^2] + [12*4v^2] + [1.2e20]]$	496,519 keV	32
					+
M	2,171.7 MeV	1.90 eV	$Z\,[[72*27n^2] + [12*3v^2] + [1.2e20]]$	496,519 keV	18
					+
L	2,013.8 MeV	0.84 eV	$Z\,[[72*26n^2] + [12*2v^2] + [1.2e20]]$	496,519 keV	8
					+
K	1861.9 MeV	0.21 eV	$Z\,[[72*25n^2] + [12*1v^2] + [1.2e20]]$	496,519 keV	2

6,101 MeV
993 keV
En = -27.05 eV
+
22,903 MeV
3,972 keV
En = -82.8 eV
+
48,262 MeV
8,937 keV
En = -316.8 eV
+
80,174 MeV
15,888 keV
En = -168.96 eV
+
74,740 MeV
15,888 keV
En = -108.16 eV
+
39,092 MeV
8,937 keV
En = -34.2 eV
+
16,111 MeV
3,972 keV
En = -6.72 eV
+
3,724 MeV
993 keV
En = -0.42 eV

[1.2e20]]

Determines the spectral line [KEM field energies] of electrons bound to them

The relativistic rest mass-energy-Matter of all periodic elements
is the sum of the mass-energies of all atomic nuclei and spectral lines
that comprise its mass-Matter topology as measured in
any spatial co-ordinate system per unit of time

e

the rest mass-Matter of bound photo-electrons is velocity invariant

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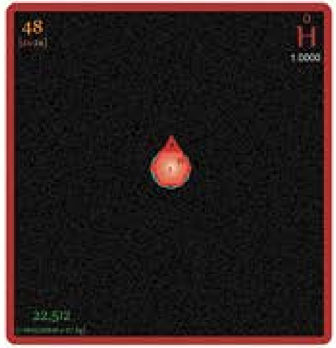

Avagadro's number

6.022141579 e26
atoms in 1KG of Matter

1 KG mass
[of Matter]

1.660538841 e-27 kg
atomic rest mass-Matter

Hydrogen

01

using SI units Avagadro's number can be expressed exactly as the inverse rest mass of Hydrogen

Weighted atomic mass

Carbon

12

5.019789213 e25
atoms in 1KG of Matter

6.02214078 e 23

1.99211552 e-26 kg
atomic rest mass-Matter

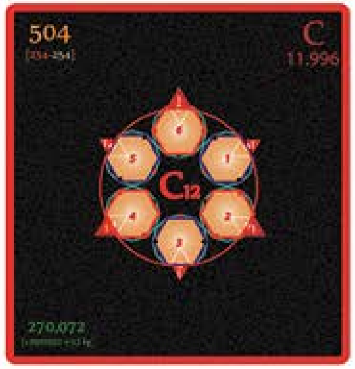

Tetryonic charge geometries make weighted atomic mass measurements and calculations obsolete

22,506 1/12 of Carbon 12 [Graphene] is not equal to 1 Hydrogen atom 22,512
(Deuterium is the building block of all atomic elements]

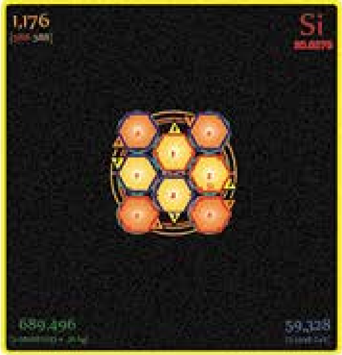

International Avagadro project

1.966225348 e25
atoms in 1KG of Matter

5.085887033 e-26 kg
atomic rest mass-Matter

Silicon

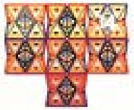

28

The gram was originally defined in 1795 as the mass of one cubic centimeter of water at 4°C,
making the kilogram equal to the mass of one liter of water.

The prototype kilogram, manufactured in 1799 and from which the current kilogram is based
has a mass equal to the mass of 1.000025 liters of water

In recent years two major experiments, namely the Watt balance & Avagadro projects, have been attempting to
measure and define 1KG of mass-Matter in terms of electrical force and the number of atoms respectively
in order to better define 1KG of mass-Matter precisely for all future physical references

Platinum

191

La Grande K

2.817950081 e24 atoms in 1KG of Matter	90%	Pt	3.1893811012 e-25 kg atomic rest mass-Matter
3.181804449 e23	10%	Ir	3.142870708 e-25 kg

The La grande K is an alloy of 90% Platinum & 10% Iridium
that has been slowly losing mass since its manufacture

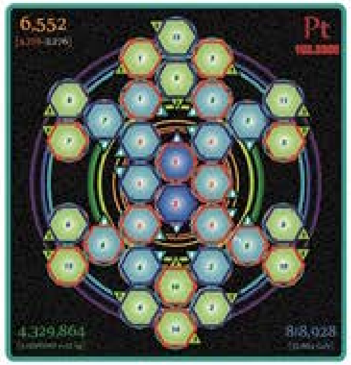

All atomic rest masses are for atoms at absolute zero and any deviation is a measure of
the topological Matter's Kinetic energy content [chemical energy, KEM fields and/or spectral lines]

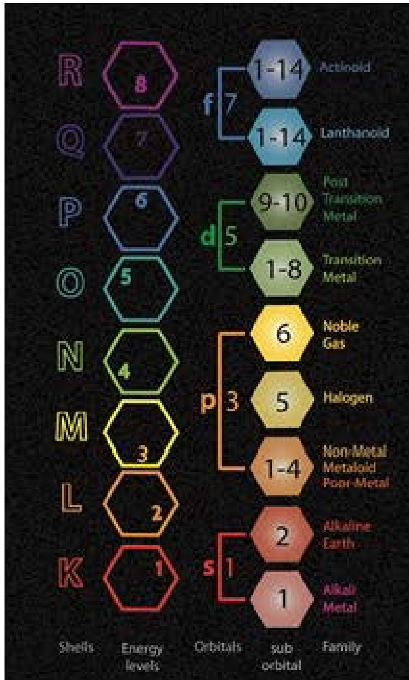
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
f 7
1-14 Actinoid
1-14 Lanthanoid
d 5
9-10 Post Transition Metal
1-8 Transition Metal
p 3
6 Noble Gas
5 Halogen
1-4 Non-Metal Metaloid Poor-Metal
s 1
2 Alkaline Earth
1 Alkali Metal
Shells
Energy levels
Orbitals
sub orbital
Family

Incorporating

- *Quark configurations*
- *Nuclei geometries*
- *Chemical bond points*
- *Atomic Orbitals*
- *Hund Rule*
- *Pauli exclusion*
- *Aufbau filling principle*
- *Element names, numbers and*
- *Elementary families*

Element placements that reflects the true quantum geometries of periodic elements

● UP Quark

● DOWN Quark

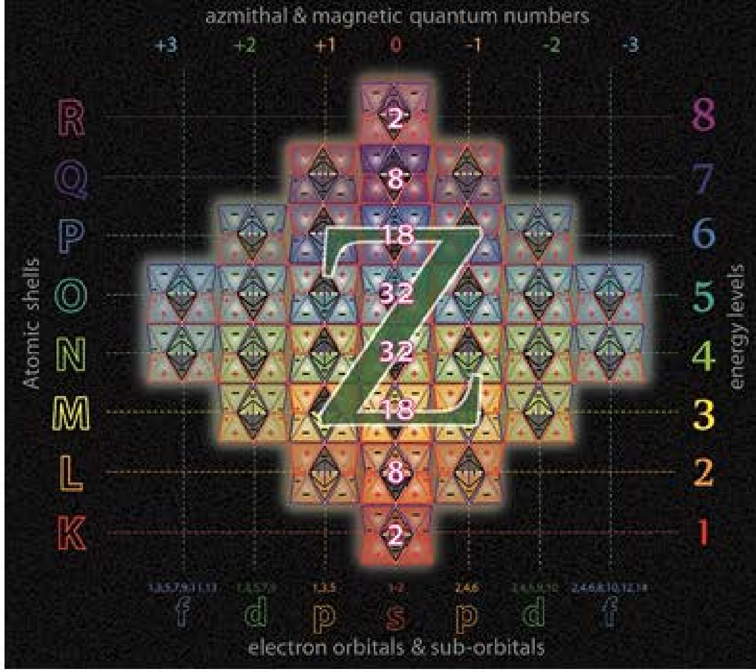
azmithal & magnetic quantum numbers
+3
+2
+1
0
-1
-2
-3
Atomic shells
R
Q
P
O
N
M
L
K
energy levels
8
7
6
5
4
3
2
1
Z
2
8
18
32
32
18
8
2
f
d
p
s
p
d
f
electron orbitals & sub-orbitals

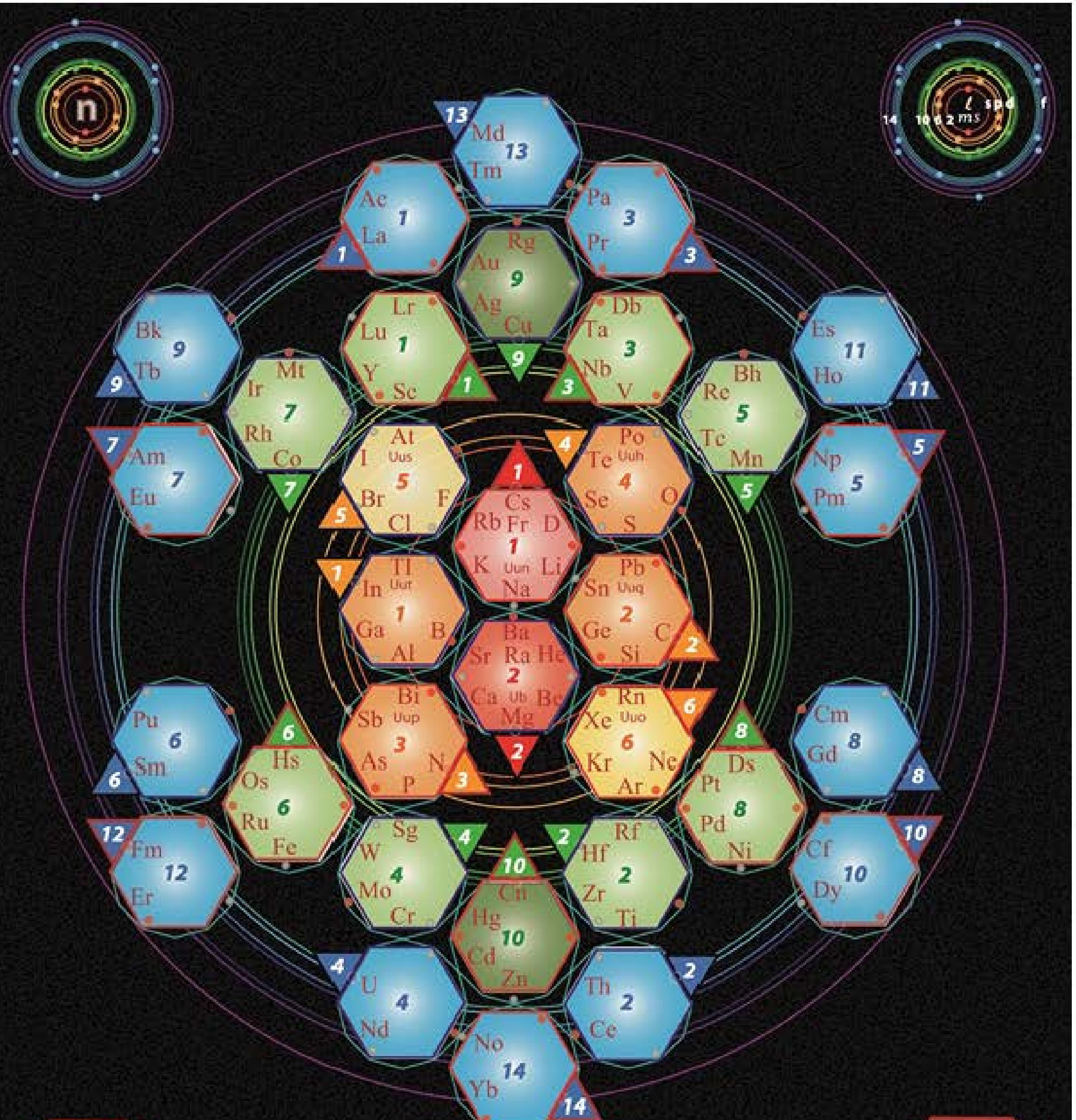
n
Md Tm 13
Ac La 1
Pa Pr 3
Rg Au Ag Cu 9
Bk Tb 9
Lr Lu Y Sc 1
Db Ta Nb V 3
Es Ho 11
Mt Ir Rh Co 7
Bh Re Tc Mn 5
Am Eu 7
At I Uus Br Cl F 5
Cs Rb Fr K Uun Na Li D 1
Po Te Uuh Se S O 4
Np Pm 5
Tl In Uut Ga Al B 1
Ba Sr Ra Ca Ub Mg He Be 2
Pb Sn Uuq Ge Si C 2
Pu Sm 6
Bi Sb Uup As P N 3
Rn Xe Uuo Kr Ar Ne 6
Cm Gd 8
Hs Os Ru Fe 6
Ds Pt Pd Ni 8
Fm Er 12
Sg W Mo Cr 4
Rf Hf Zr Ti 2
Cf Dy 10
Cn Hg Cd Zn 10
U Nd 4
Th Ce 2
No Yb 14

6
5
7
1
4
8
2
3
Energy levels

Periodic Table 2.0

(the quantum geometry of periodic elements)

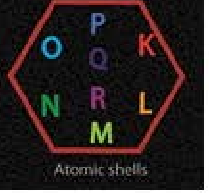
P
O
Q
K
N
R
L
M
Atomic shells

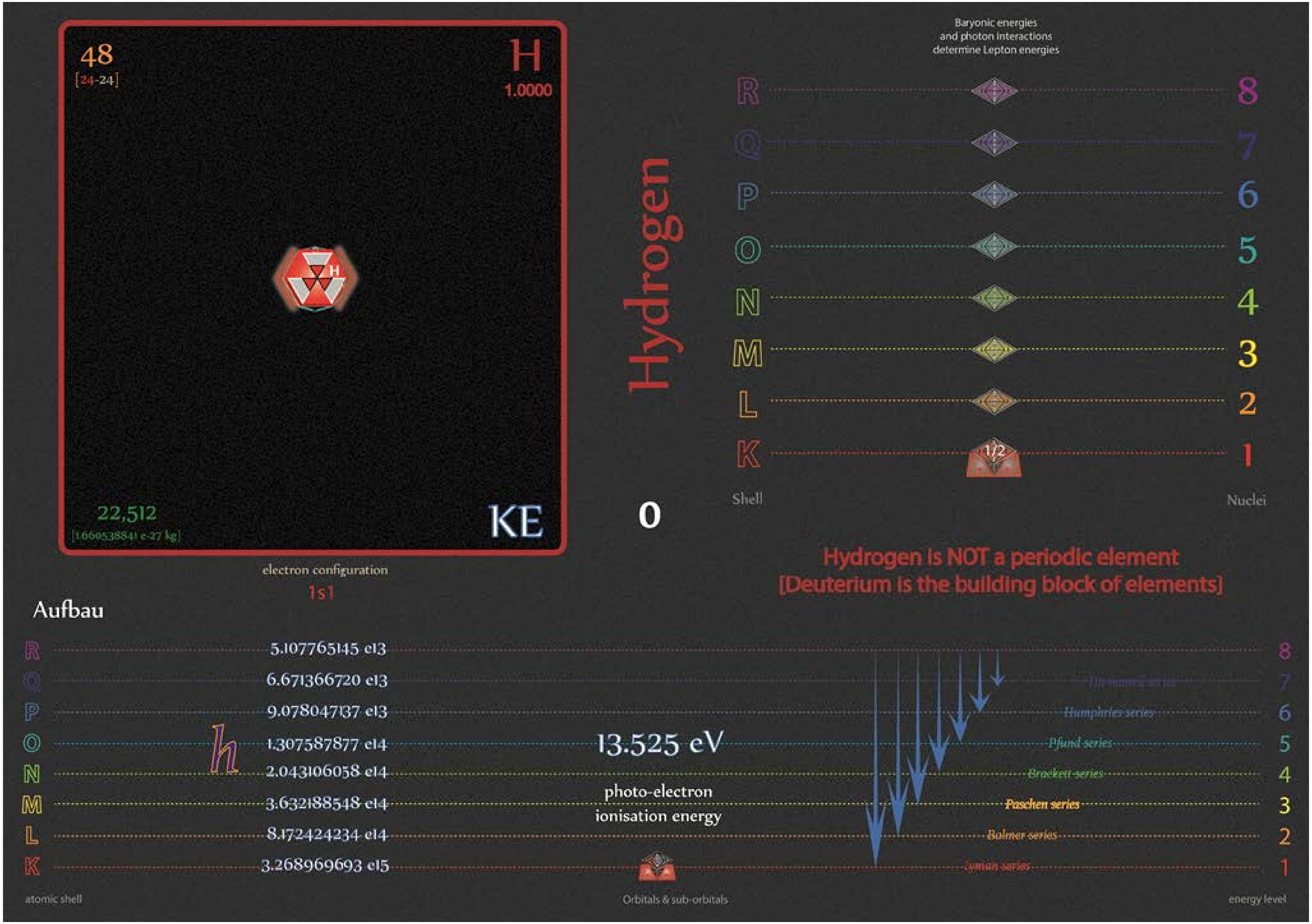

48
[24-24]

H
1.0000

22,512
[1.660538841 e-27 kg]

KE

electron configuration
1s1

Hydrogen

0

Baryonic energies
and photon interactions
determine Lepton energies

Shell		Nuclei
R		8
Q		7
P		6
O		5
N		4
M		3
L		2
K	1/2	1

Hydrogen is NOT a periodic element
[Deuterium is the building block of elements]

Aufbau

atomic shell			energy level
R	5.107765145 e13		8
Q	6.671366720 e13		7
P	9.078047137 e13	Humphries series	6
O	1.307587877 e14	Pfund series	5
N	2.043106058 e14	Brackett series	4
M	3.632188548 e14	Paschen series	3
L	8.172424234 e14	Balmer series	2
K	3.268969693 e15	Lyman series	1

h

13.525 eV

photo-electron
ionisation energy

Orbitals & sub-orbitals

Tetryonics 51.00 - Hydrogen atom

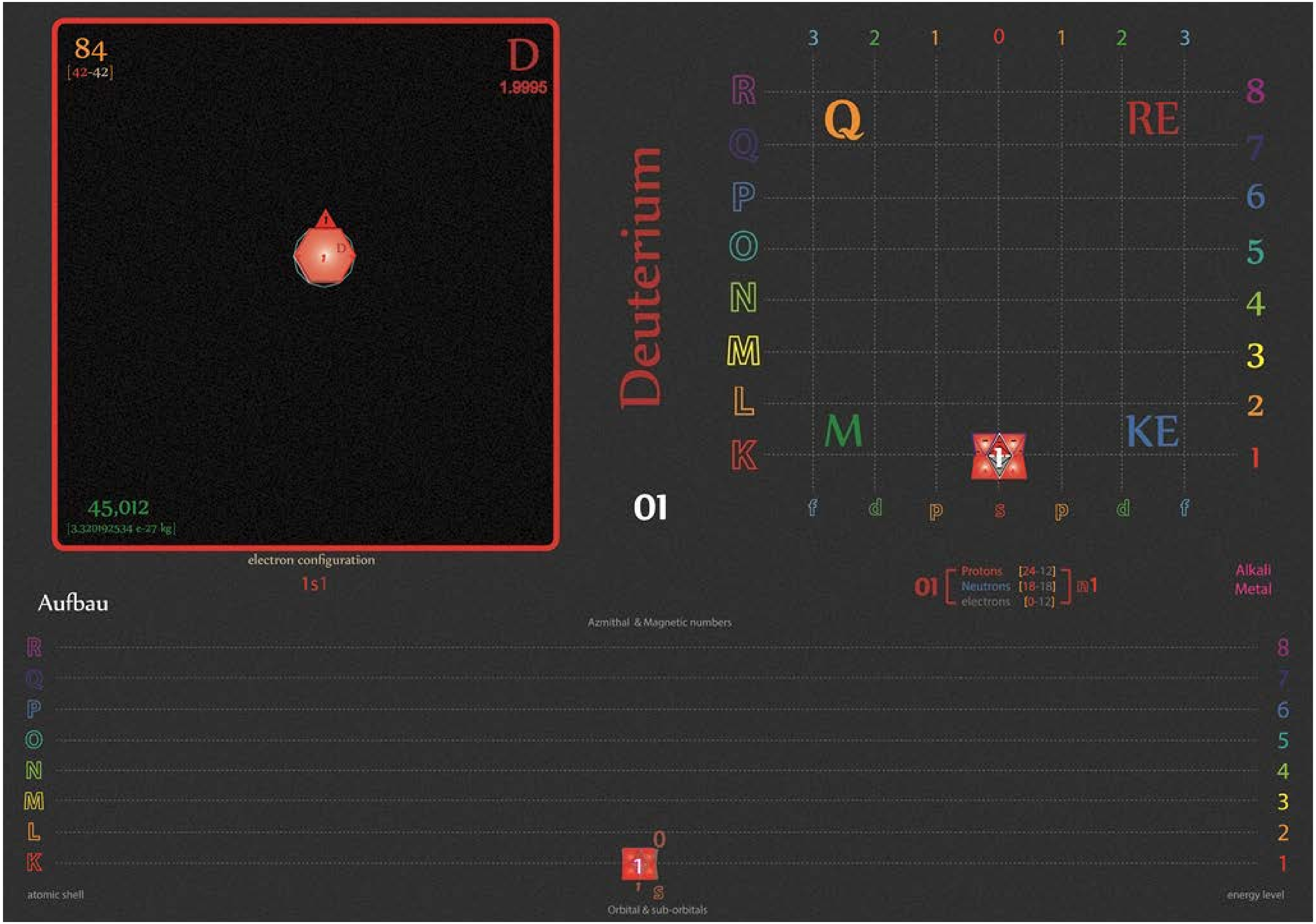
84
[42-42]
D
1.9995
45,012
[3.320192534 e-27 kg]
electron configuration
1s1
Deuterium
01
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
01
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1
Alkali
Metal
Aufbau
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1
0
s
atomic shell
Orbital & sub-orbitals
energy level

Tetryonics 51.01 - Deuterium atom

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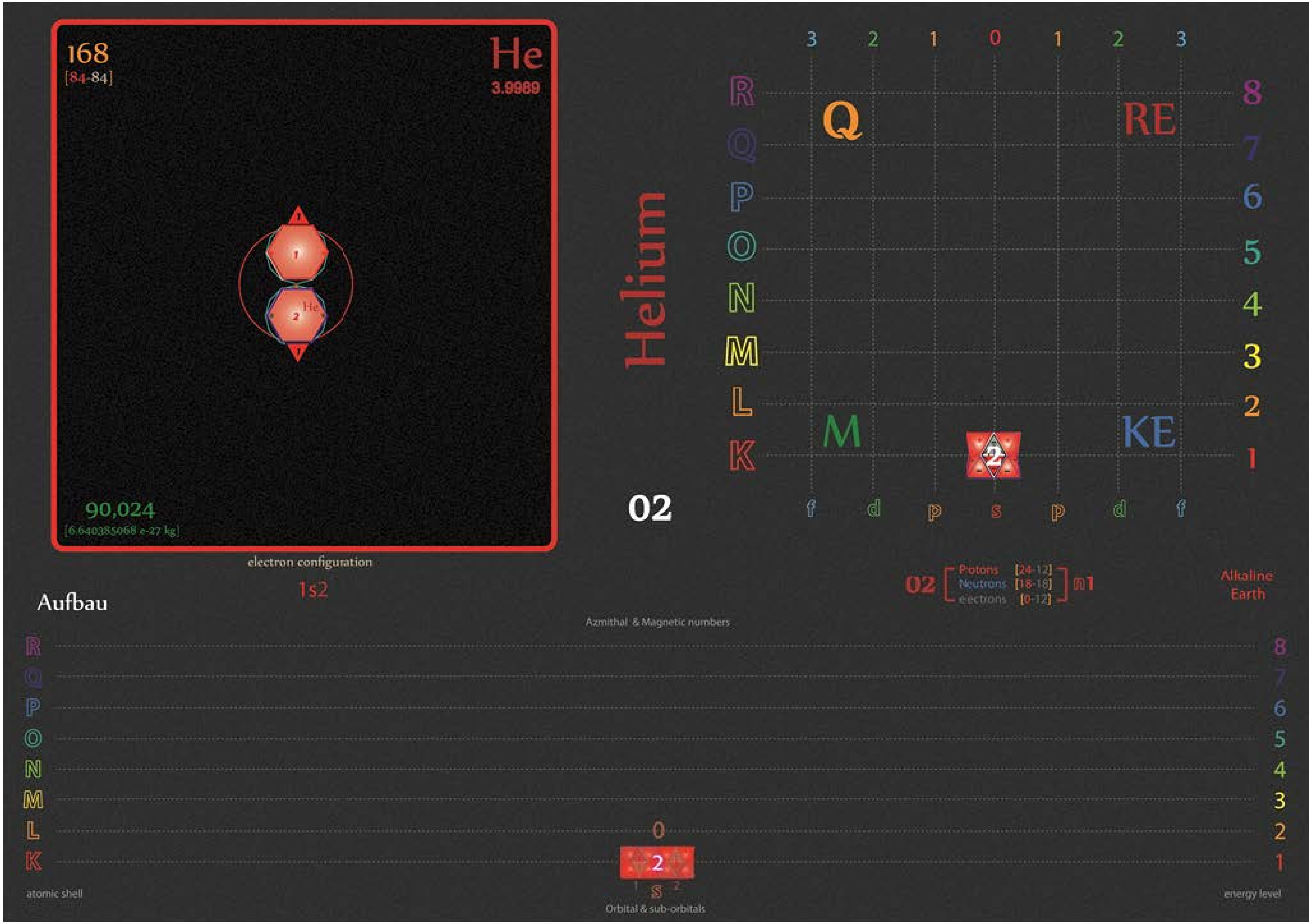
168
[84-84]
He
3.9989
90,024
[6.640385068 e-27 kg]
Helium
02
electron configuration
1s2
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
2
f d p s p d f
02
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1
Alkaline Earth
Azmithal & Magnetic numbers
0
2
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.02 - Helium atom

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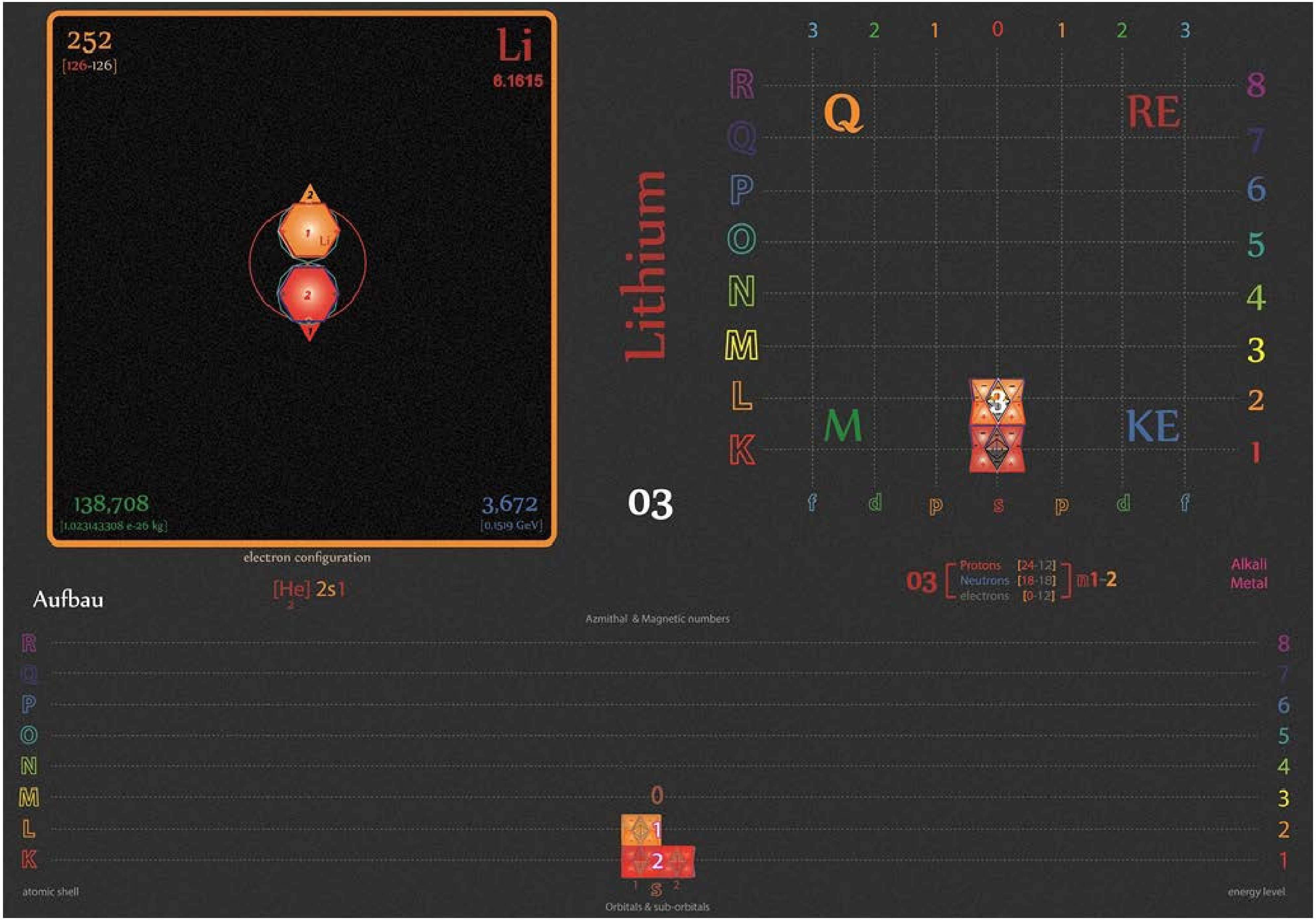
252
[126-126]
Li
6.1615
2
1
Li
2
1
138,708
[1.023143308 e-26 kg]
3,672
[0.1519 GeV]
electron configuration
[He] 2s1
2
Aufbau
Lithium
03
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
3
8
7
6
5
4
3
2
1
f d p s p d f
03
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-2
Alkali
Metal
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
0
1
2
1 s 2
8
7
6
5
4
3
2
1
atomic shell
Orbitals & sub-orbitals
energy level

Tetryonics 51.03 - Lithium atom

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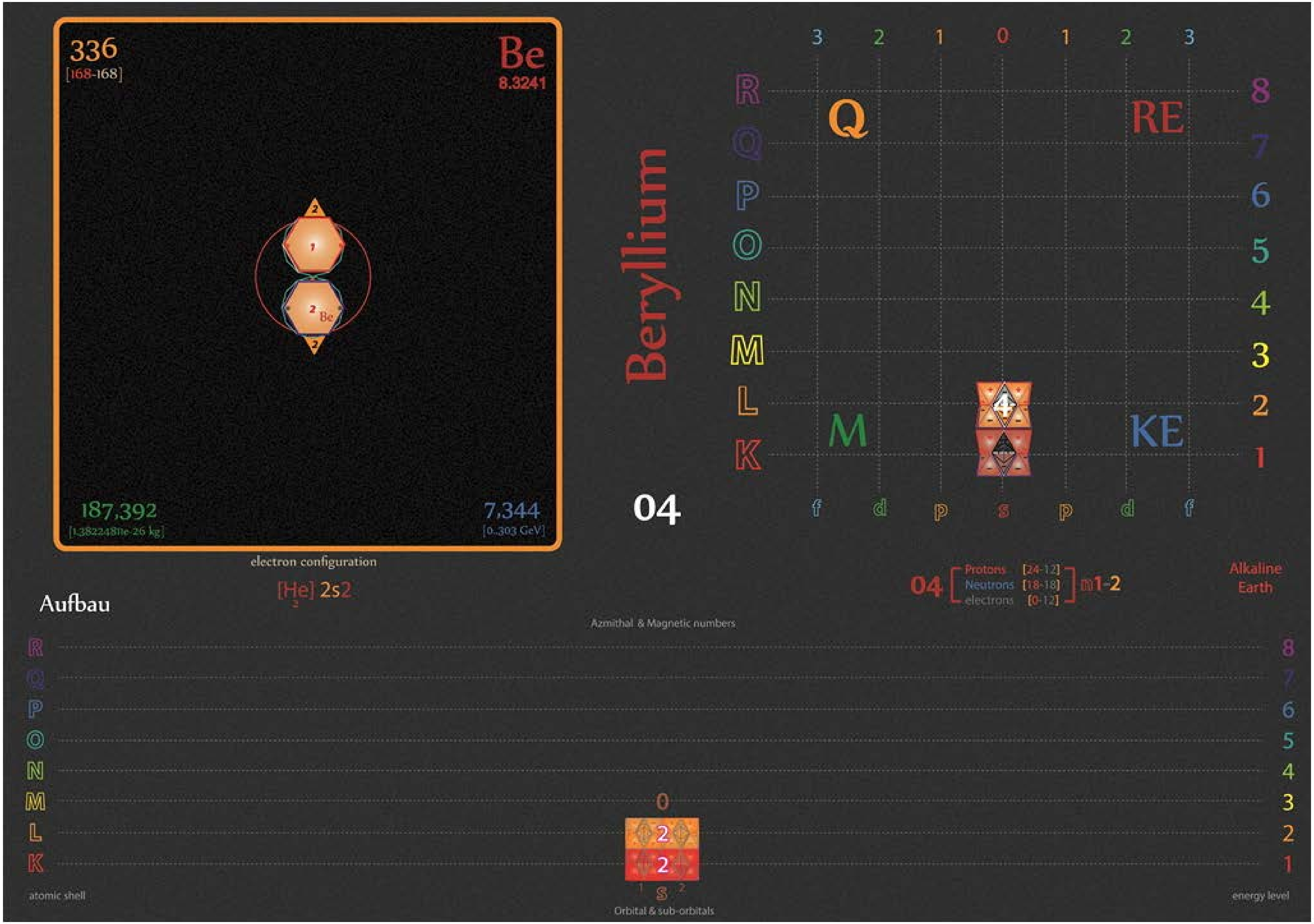
336
[168-168]
Be
8.3241
2
1
2 Be
2
187,392
[1.38224811e-26 kg]
7,344
[0..303 GeV]
Beryllium
04
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
4
KE
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
electron configuration
[He] 2s2
Aufbau
Azmithal & Magnetic numbers
04
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-2
Alkaline Earth
R
Q
P
O
N
M
L
K
0
2
2
1
s
2
8
7
6
5
4
3
2
1
atomic shell
Orbital & sub-orbitals
energy level

Tetryonics 51.04 - Beryllium atom

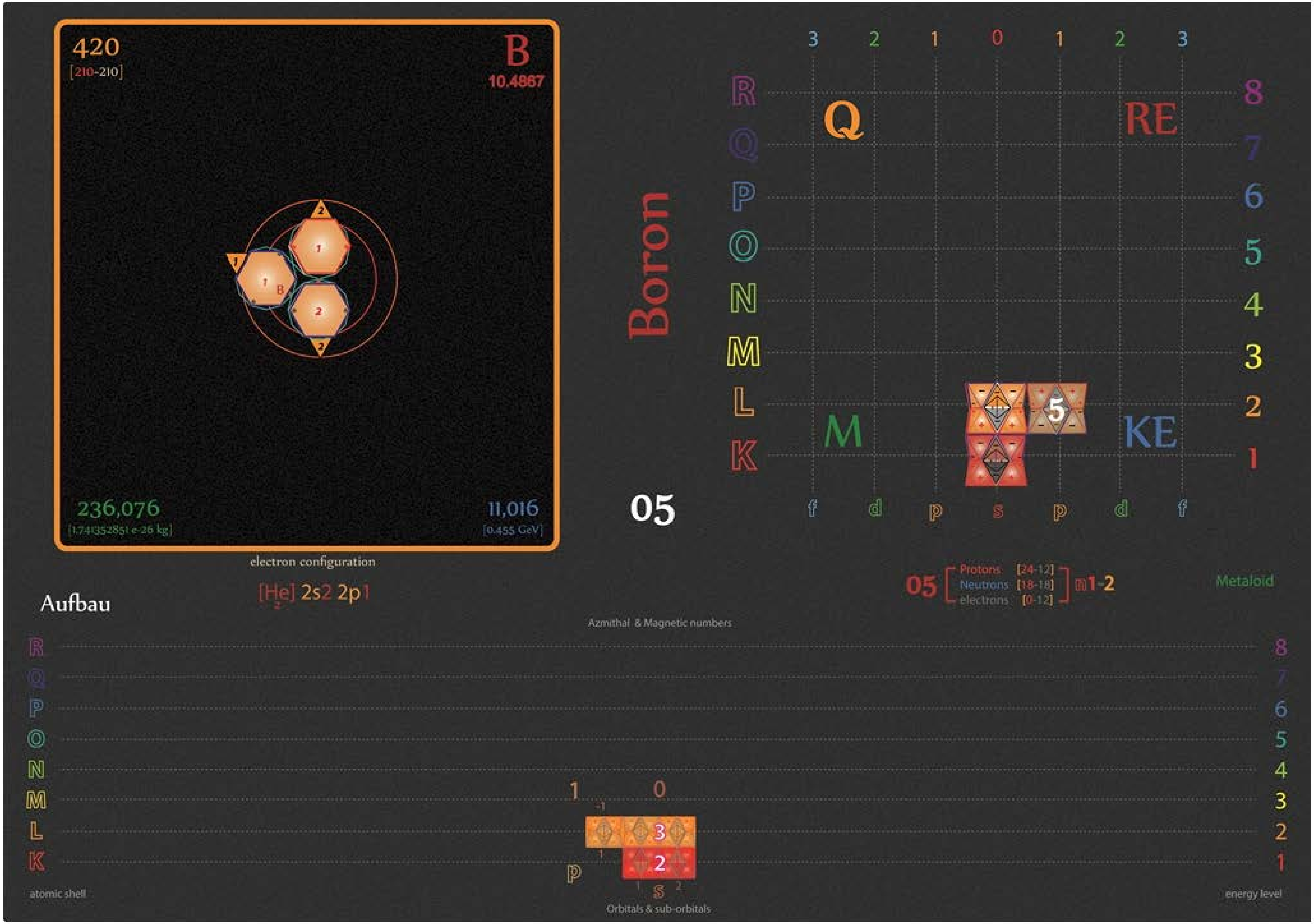
420
[210-210]
B
10.4867
236,076
[1.741352851 e-26 kg]
11,016
[0.455 GeV]
electron configuration
[He] 2s2 2p1
Boron
05
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
5
f d p s p d f
05
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-2
Metaloid
Aufbau
Azmithal & Magnetic numbers
1
0
3
2
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.05 - Boron atom

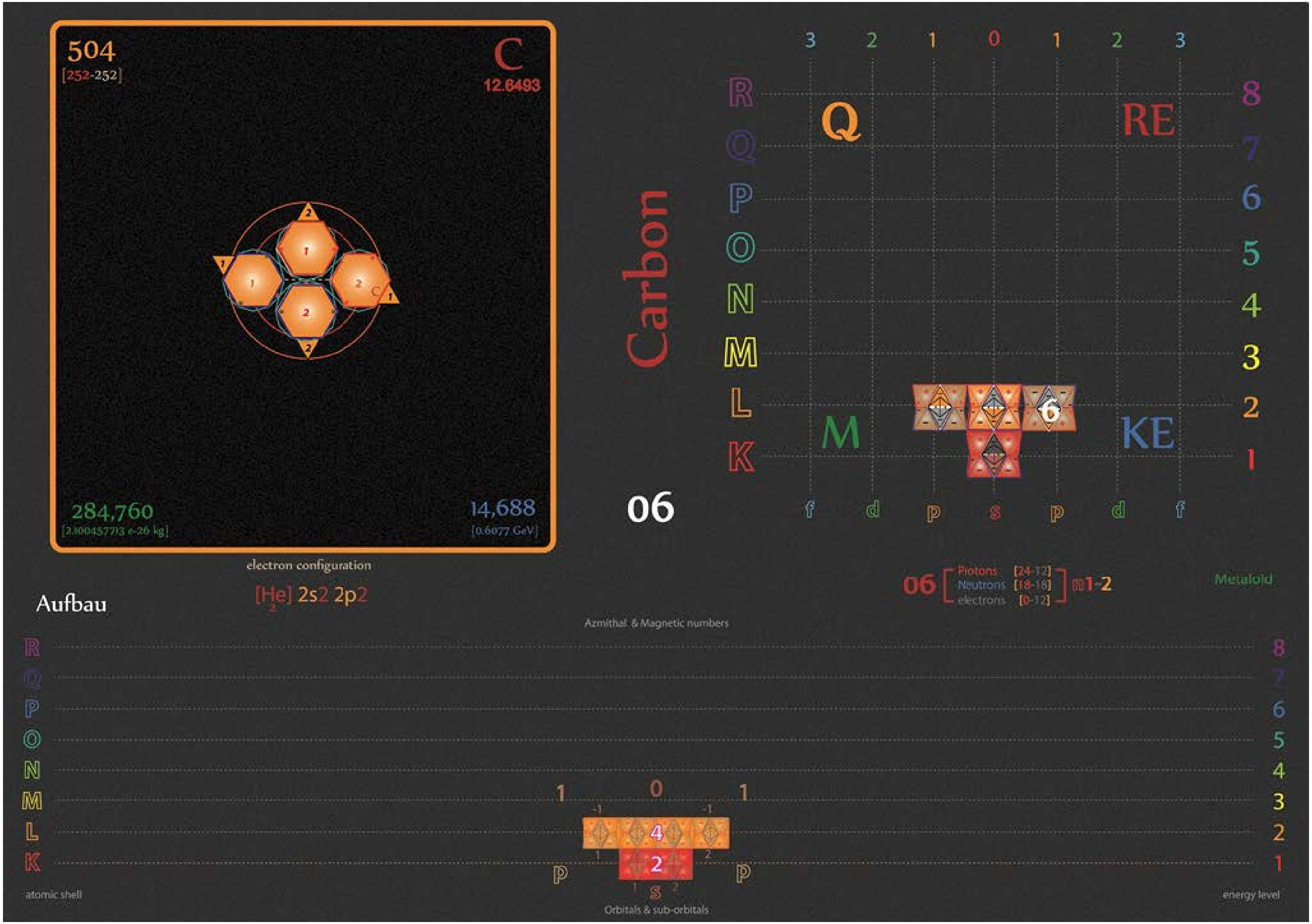
504
[252-252]
C
12.6493
1
2
284,760
[2.100457713 e-26 kg]
14,688
[0.6077 GeV]
electron configuration
[He] 2s2 2p2
Aufbau
Carbon
06
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
6
f d p s p d f
06 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-2
Metaloid
Azmithal & Magnetic numbers
1 0 1
-1 -1
4
2
1 2
p p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.06 - Carbon atom

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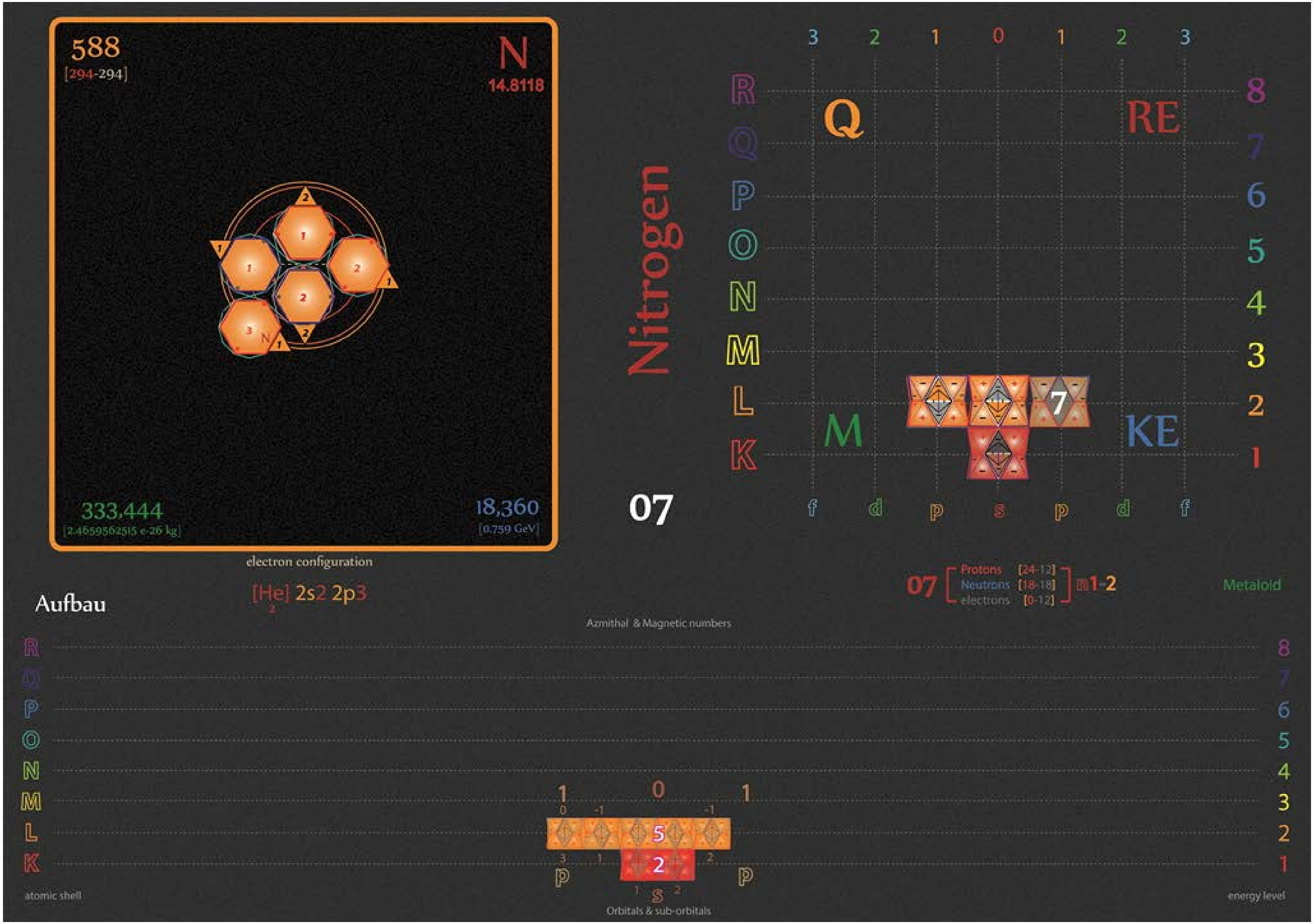
588
[294-294]
N
14.8118
333,444
[2.4659562515 e-26 kg]
18,360
[0.759 GeV]
Nitrogen
07
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
7
f d p s p d f
electron configuration
[He] 2s2 2p3
2
Aufbau
07 Protons [24-12] Neutrons [18-18] electrons [0-12] m1-2
Metaloid
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
1 0 1
0 -1 -1
5
2
3 1 2
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.07 - Nitrogen atom

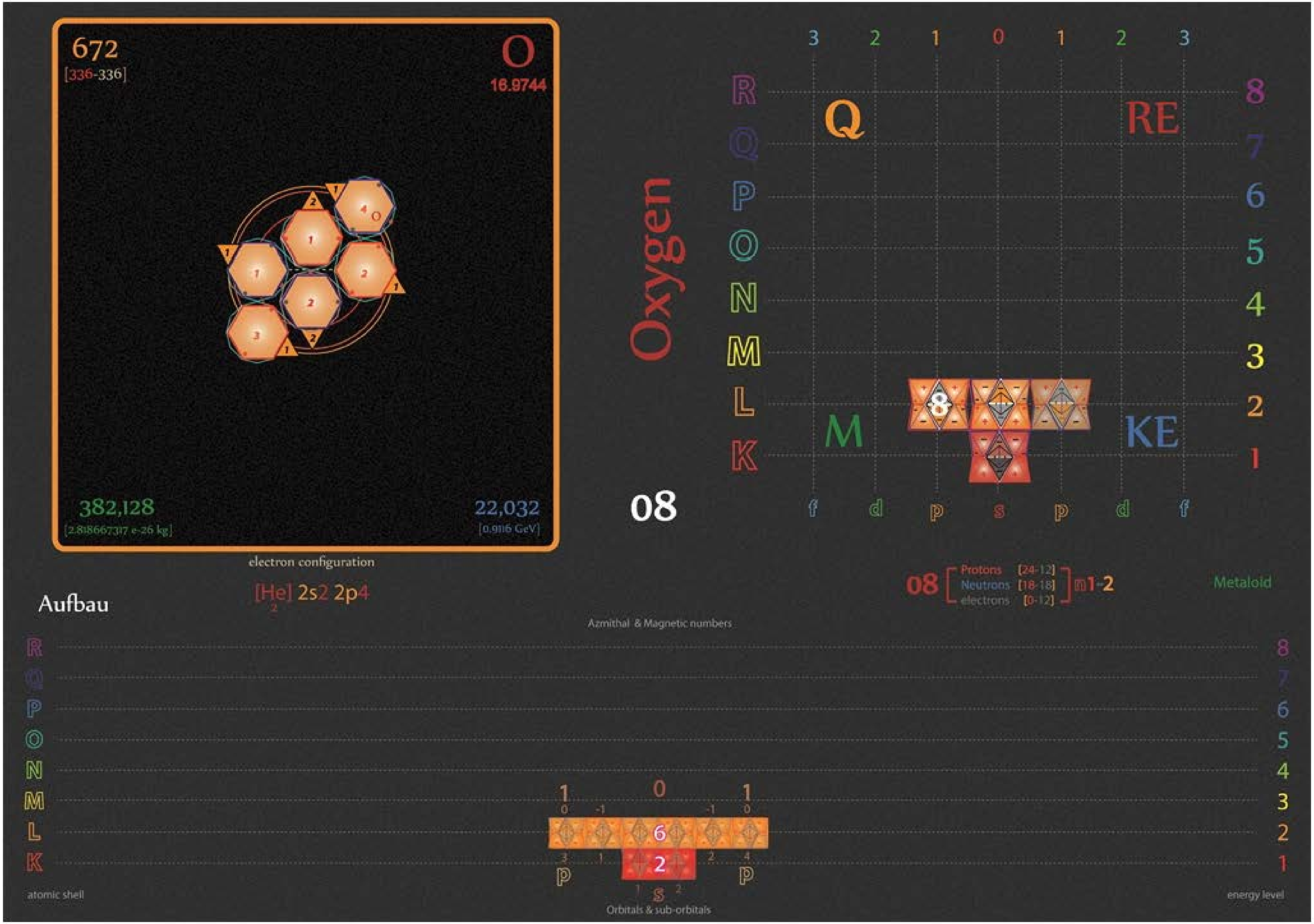
672
[336-336]
O
16.9744
1
2
4
O
1
1
2
2
3
1
2
1
382,128
[2.818667317 e-26 kg]
22,032
[0.9116 GeV]
electron configuration
[He] 2s2 2p4
2
Aufbau
Oxygen
08
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
8
M
KE
f
d
p
s
p
d
f
08
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-2
Metaloid
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1
0
1
0
-1
-1
0
6
2
3
1
2
4
p
p
1
s
2
Orbitals & sub-orbitals
atomic shell
energy level

Tetryonics 51.08 - Oxygen atom

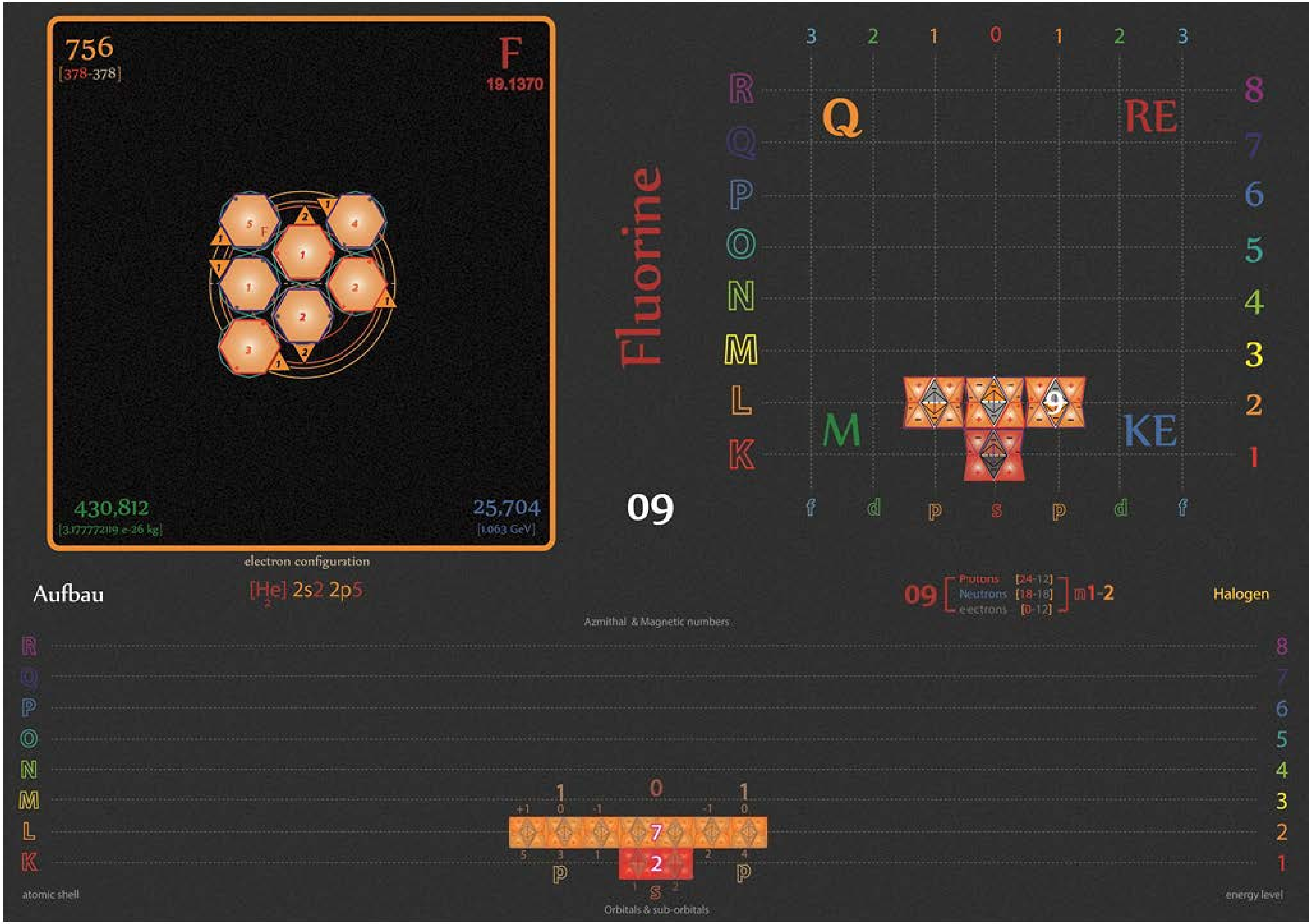
756
[378-378]
F
19.1370
430,812
[3.17777219 e-26 kg]
25,704
[1.063 GeV]
Fluorine
09
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
9
f d p s p d f
electron configuration
Aufbau
[He] 2s2 2p5
Azmithal & Magnetic numbers
09 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-2
Halogen
1 0 1
+1 0 -1 -1 0
7
2
5 3 1 2 4
p s p
1 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.09 - Fluorine atom

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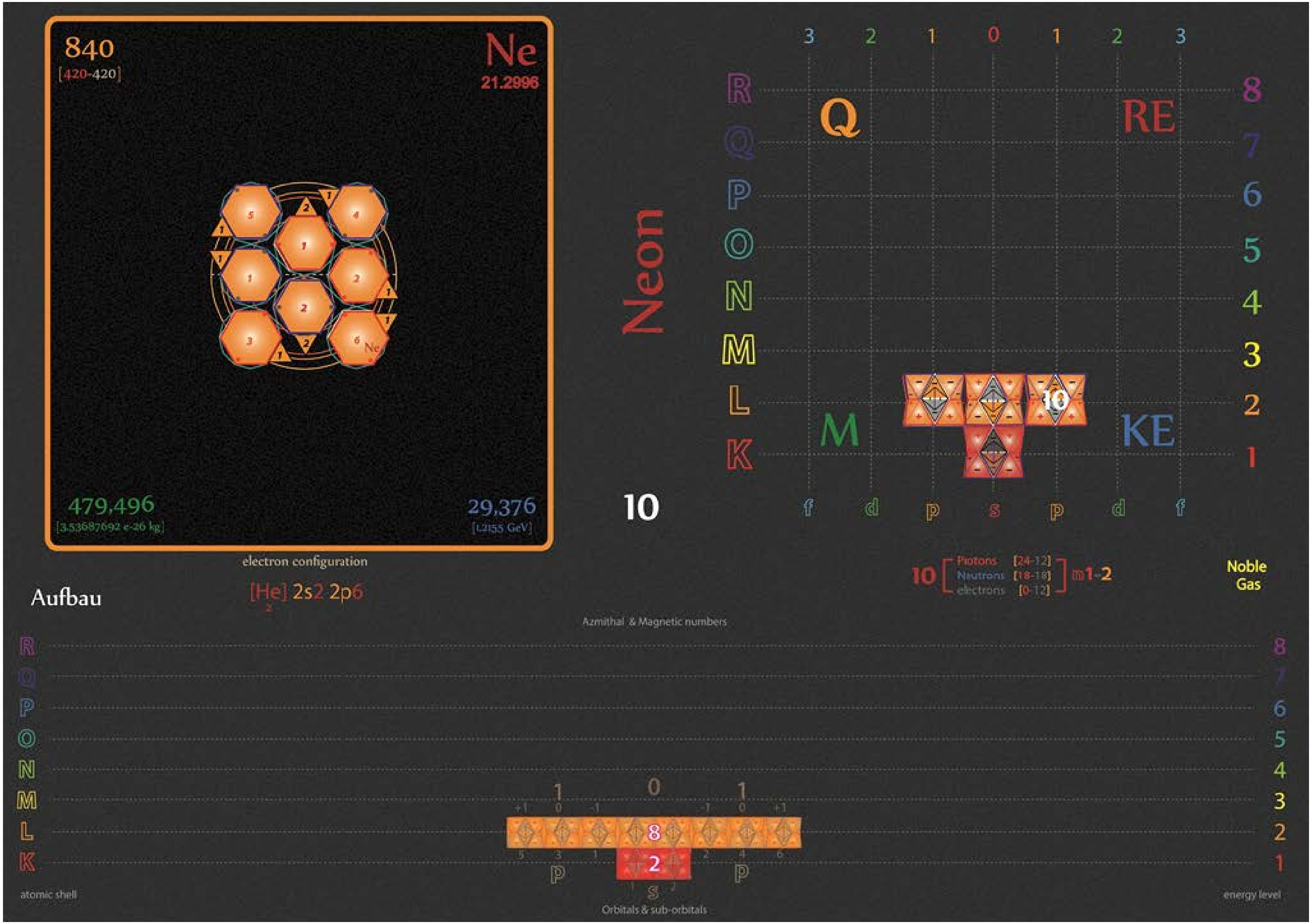
840
[420-420]
Ne
21.2996
479,496
[3.53687692 e-26 kg]
29,376
[1.2155 GeV]
Neon
10
electron configuration
[He] 2s2 2p6
2
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
10
f d p s p d f
10 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-2
Noble Gas
Azmithal & Magnetic numbers
1 0 1
+1 0 -1 -1 0 +1
8
2
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.10 - Neon atom

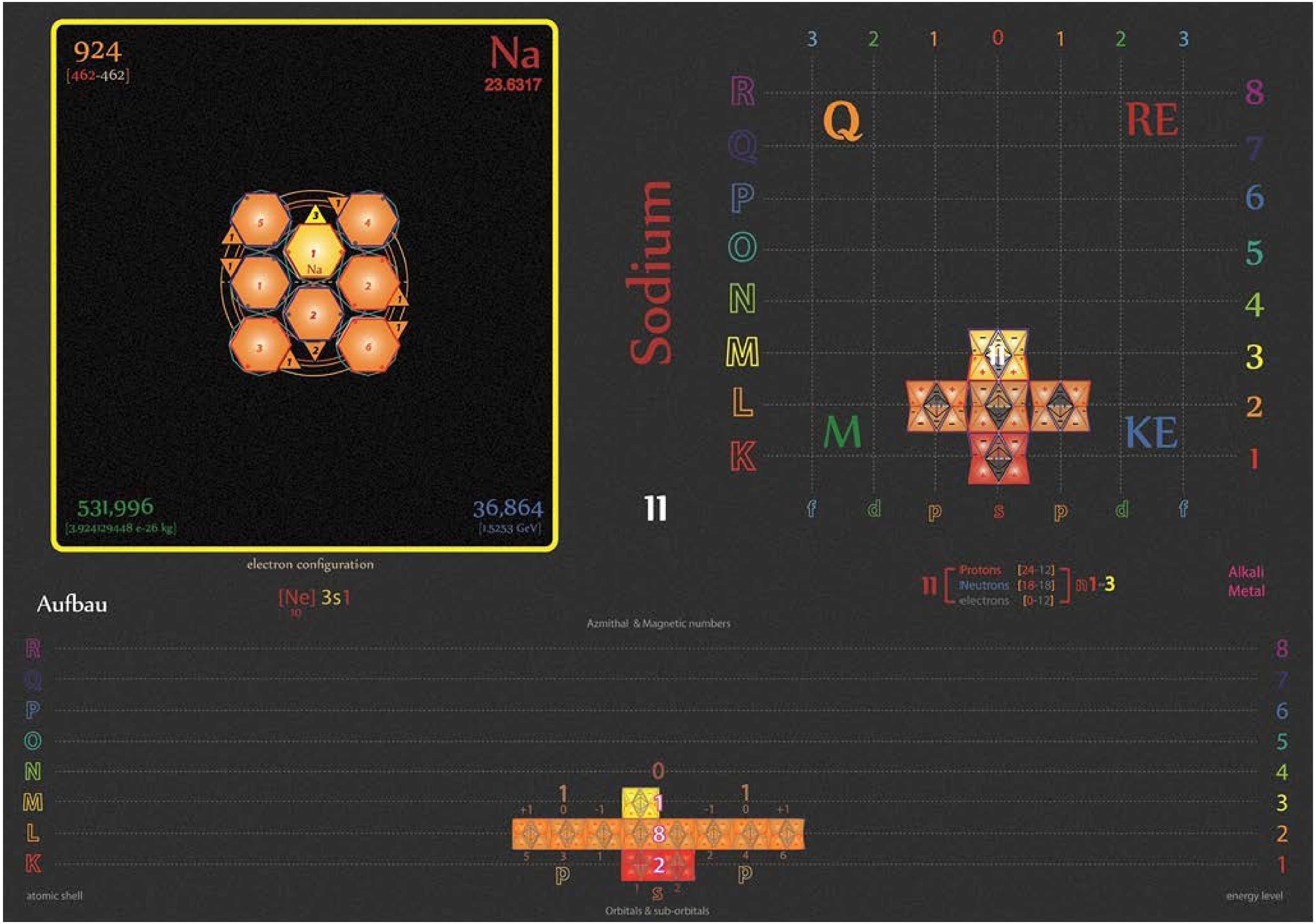
924
[462-462]
Na
23.6317
Na
531,996
[3.924129448 e-26 kg]
36,864
[15253 GeV]
electron configuration
Aufbau
[Ne] 3s1
10
Sodium
11
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
11 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-3
Alkali Metal
Azmithal & Magnetic numbers
0
1 1
+1 0 -1 -1 0 +1
1
8
2
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.11 - Sodium atom

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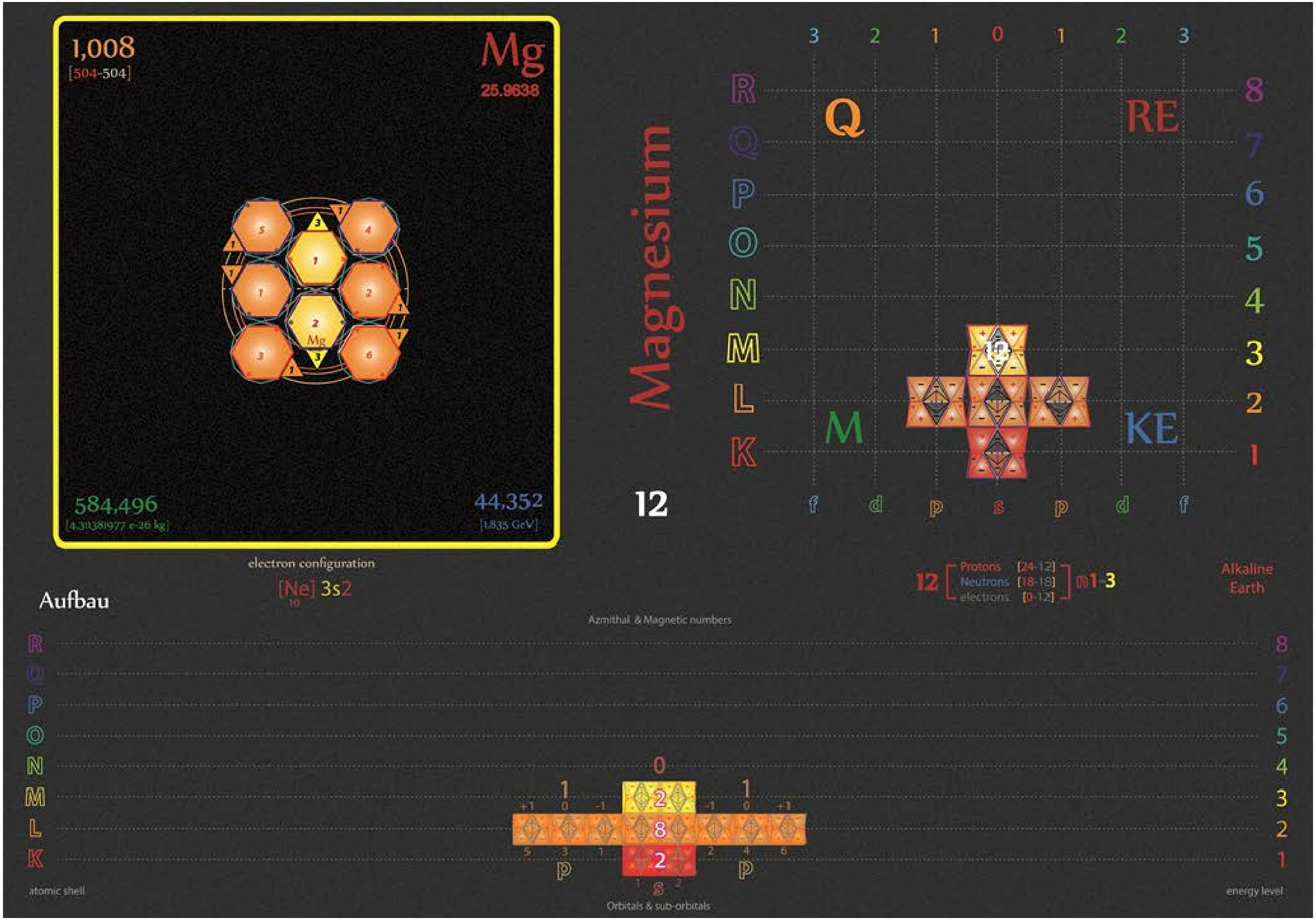
1,008
[504-504]
Mg
25.9638
584,496
[4.31138197 e-26 kg]
44,352
[1.835 GeV]
Magnesium
12
electron configuration
[Ne] 3s2
10
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
12 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-3
Alkaline Earth
Azmithal & Magnetic numbers
0
1
1
+1 0 -1 -1 0 +1
2
8
2
5 3 1 2 4 6
p
p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.12 - Magnesium atom
]

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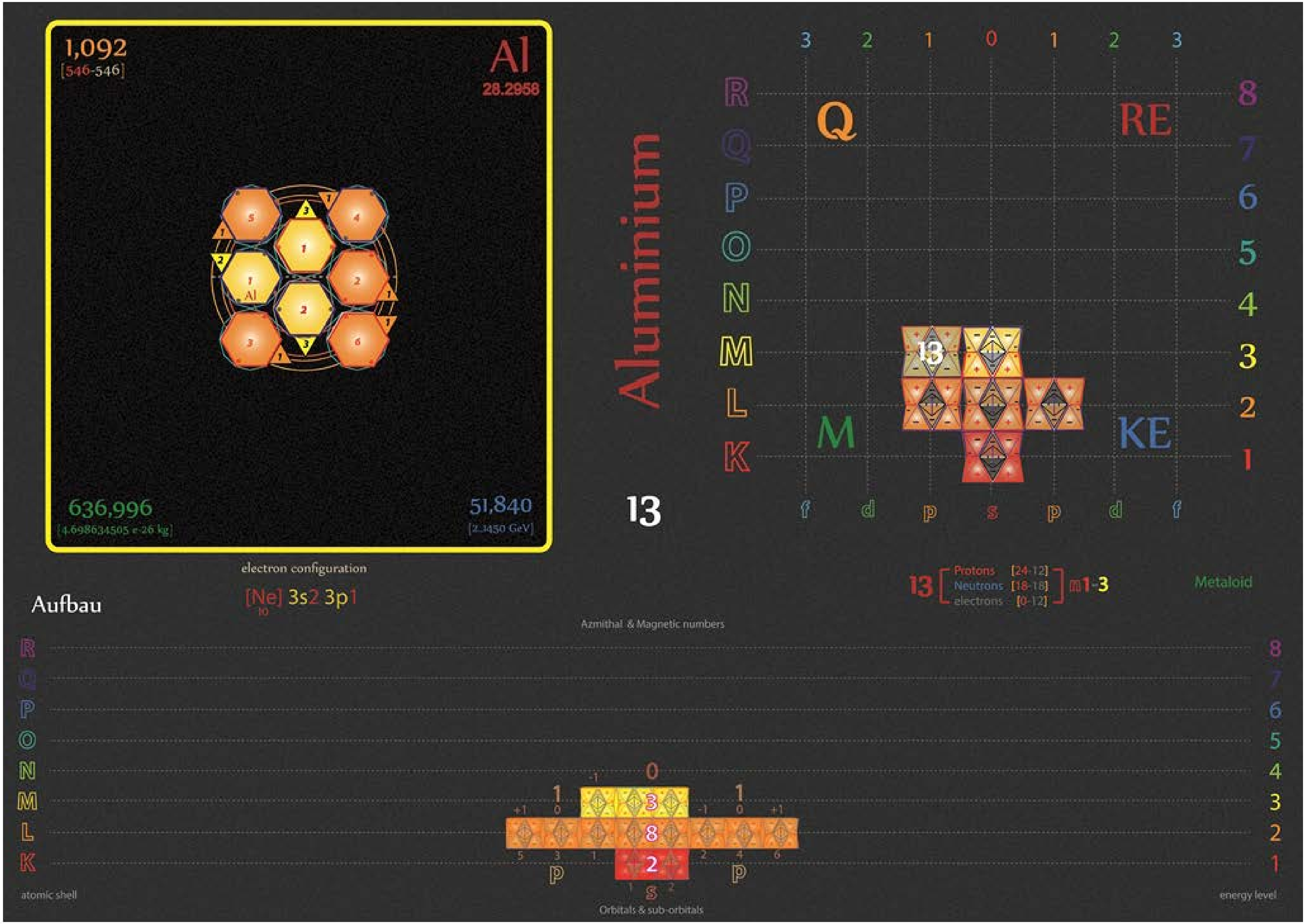
1,092
[546-546]
Al
28.2958
636,996
[4.698634505 e-26 kg]
51,840
[2.1450 GeV]
Aluminium
13
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
13
13 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-3
Metaloid
electron configuration
[Ne] 3s2 3p1
10
Aufbau
Azmithal & Magnetic numbers
atomic shell
energy level
Orbitals & sub-orbitals
0
-1
1
1
+1 0 -1 0 +1
3
8
2
5 3 1 2 4 6
p s p
1 2

Tetryonics 51.13 - Aluminium atom

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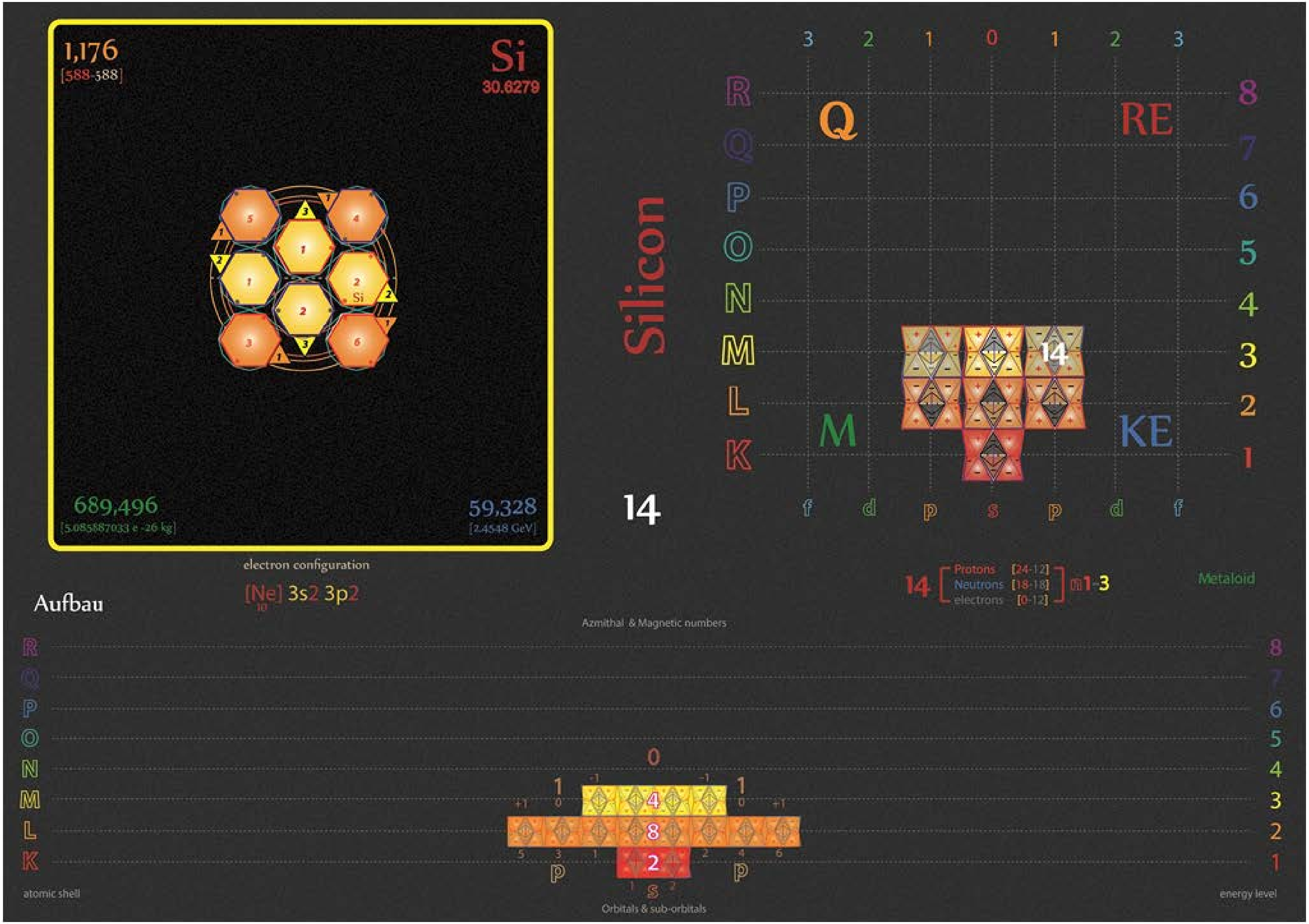
1,176
[588-588]
Si
30.6279
Si
689,496
[5.085887033 e -26 kg]
59,328
[2.4548 GeV]
Silicon
14
electron configuration
[Ne] 3s2 3p2
10
Aufbau
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
14
f d p s p d f
14 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-3
Metaloid
Azmithal & Magnetic numbers
0
1
1
-1
-1
+1
0
0
+1
4
8
2
5 3 1
2 4 6
p
p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.14 - Silicon atom

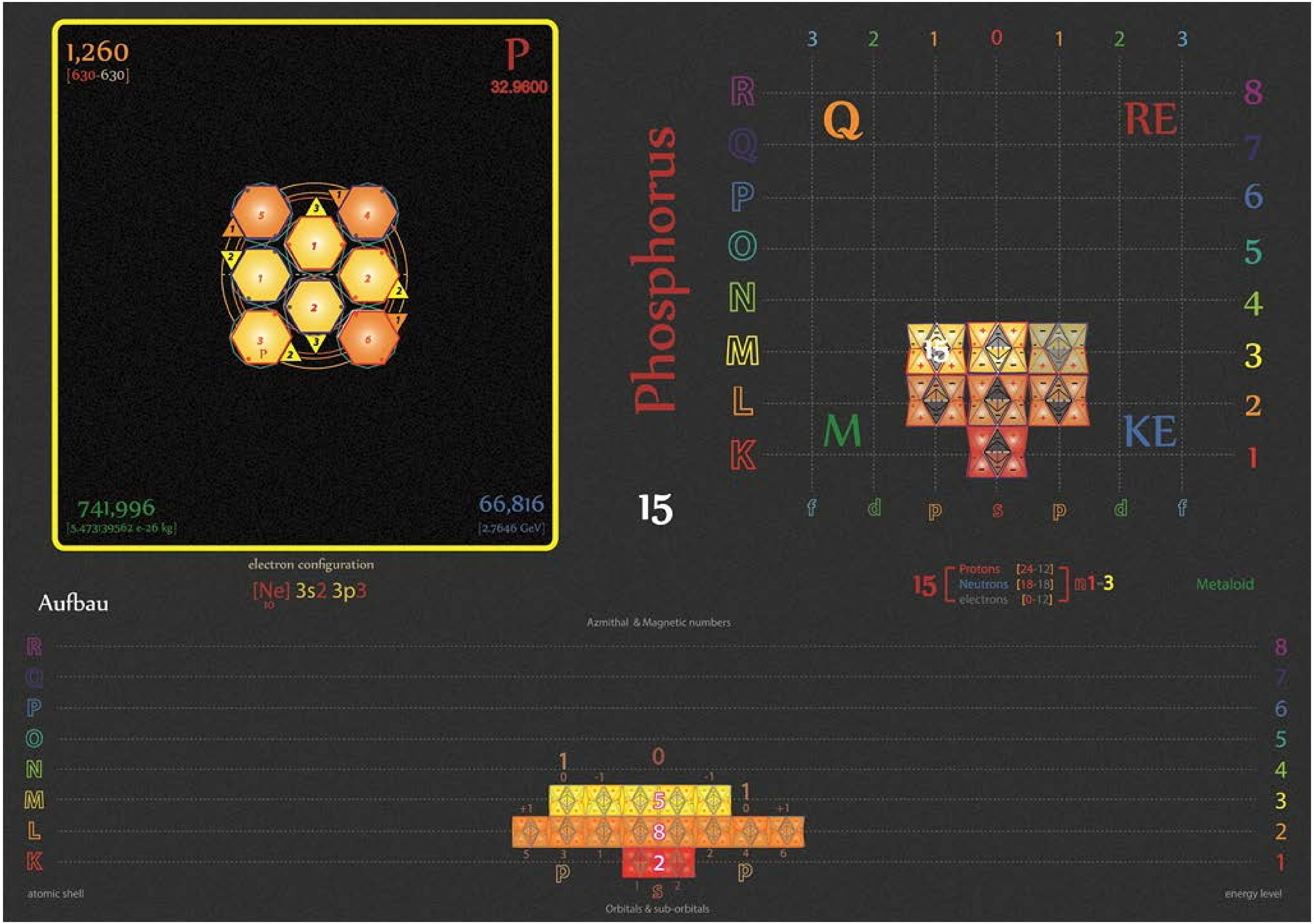
1,260
[630-630]
P
32.9600
741,996
[5.473139562 e-26 kg]
66,816
[2.7646 GeV]
5
4
3
1
1
1
2
2
2
3
P
6
1
3
2
1
3
Phosphorus
15
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
15
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
electron configuration
[Ne] 3s2 3p3
10
Aufbau
15
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-3
Metaloid
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
atomic shell
1
0
0
-1
-1
1
+1
0
+1
5
8
2
5
3
1
2
4
6
p
p
1
s
2
Orbitals & sub-orbitals
8
7
6
5
4
3
2
1
energy level

Tetryonics 51.15 - Phosphorus atom

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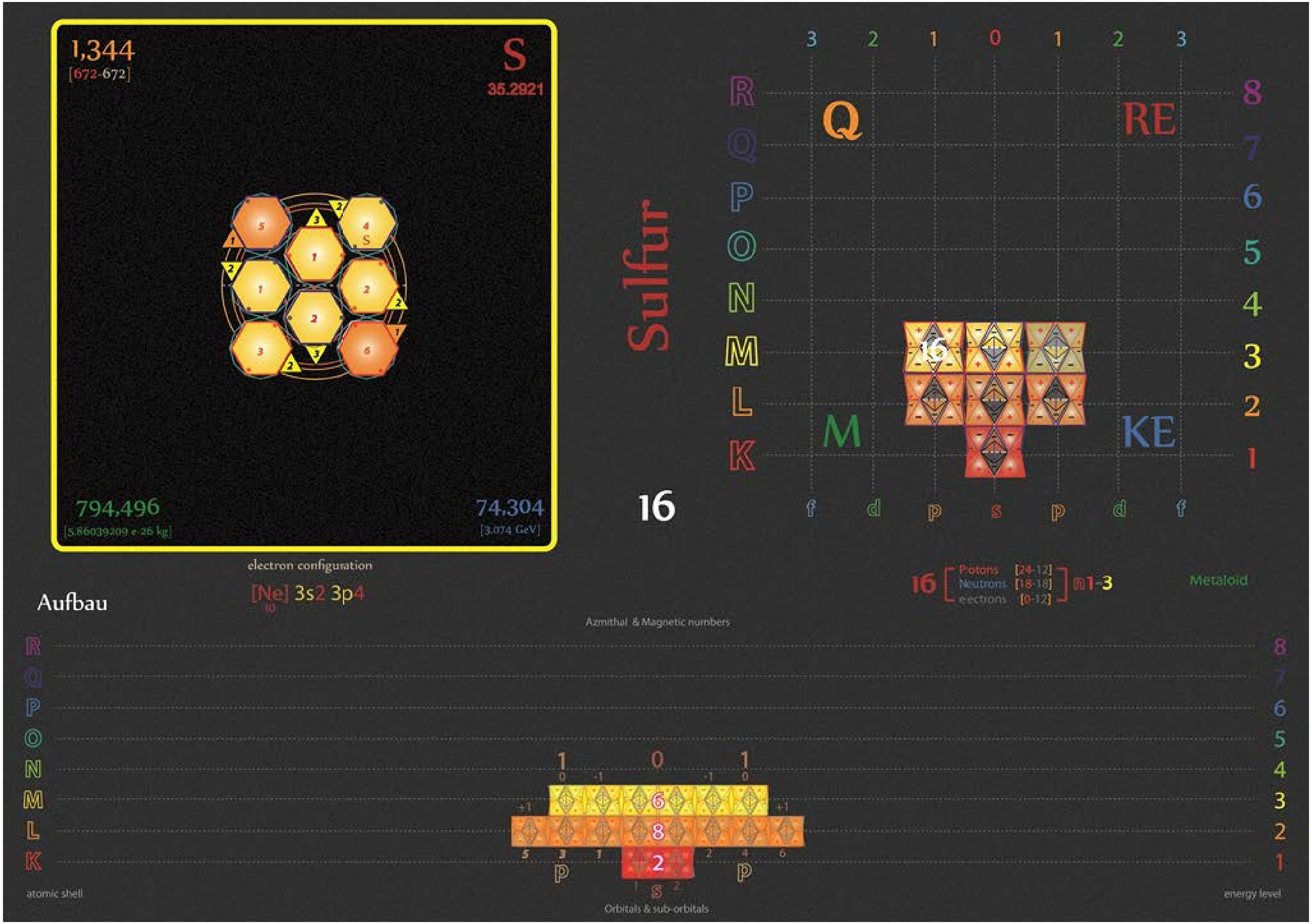
1,344
[672-672]
S
35.2921
794,496
[5.86039209 e-26 kg]
74,304
[3.074 GeV]
Sulfur
16
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ne] 3s2 3p4
10
Aufbau
16 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-3
Metaloid
Azmithal & Magnetic numbers
1 0 1
0 -1 -1 0
+1 +1
6
8
2
5 3 1 2 4 6
p s p
1 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.16 - Sulfur atom

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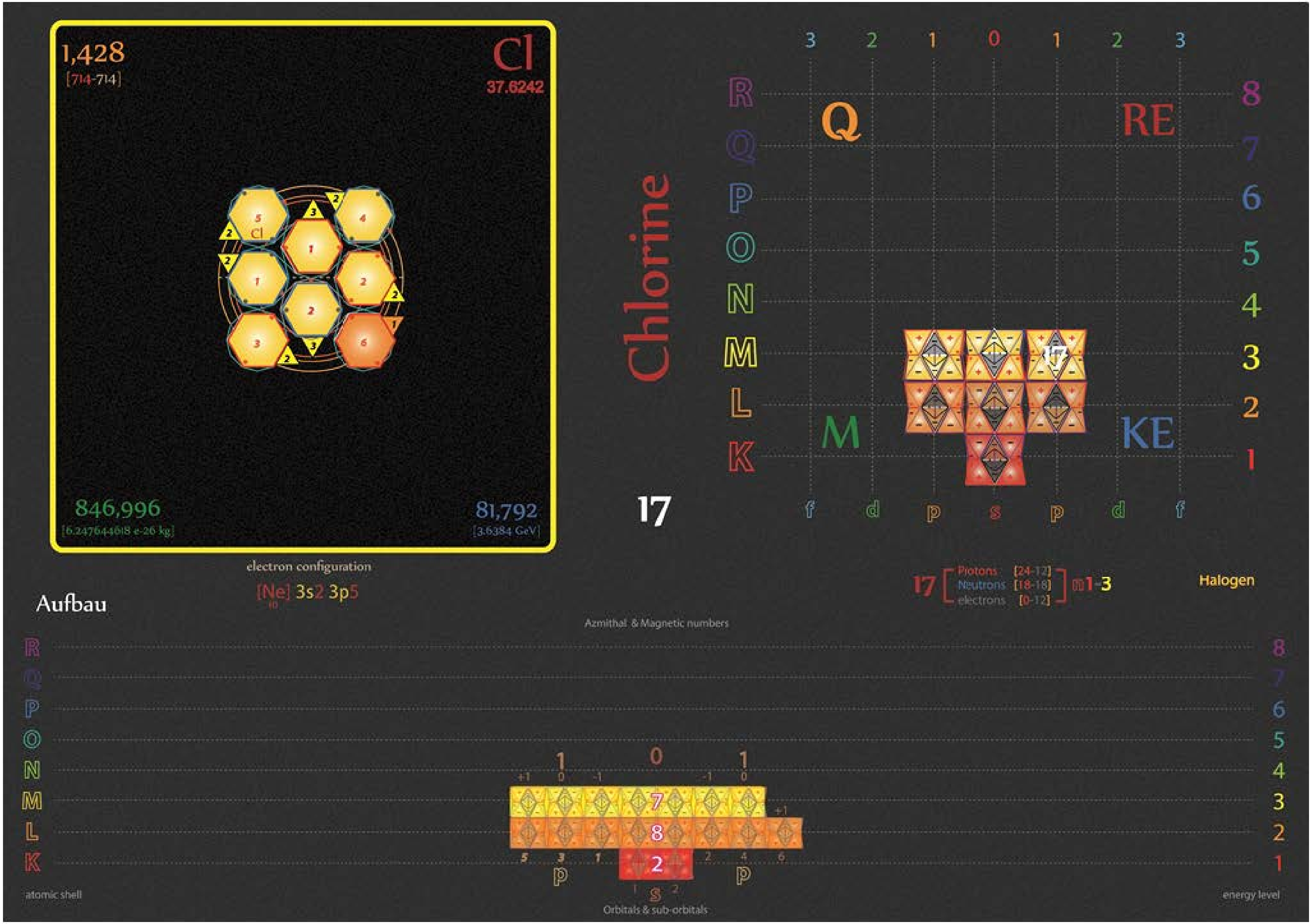
1,428
[714-714]
Cl
37.6242
5
Cl
4
3
2
1
1
2
2
3
6
846,996
[6.247644618 e-26 kg]
81,792
[3.6384 GeV]
electron configuration
[Ne] 3s2 3p5
10
Aufbau
Chlorine
17
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
17
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
17
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-3
Halogen
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1
0
1
+1
0
-1
-1
0
+1
7
8
2
5
3
1
2
4
6
p
p
1
s
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.17 - Chlorine atom

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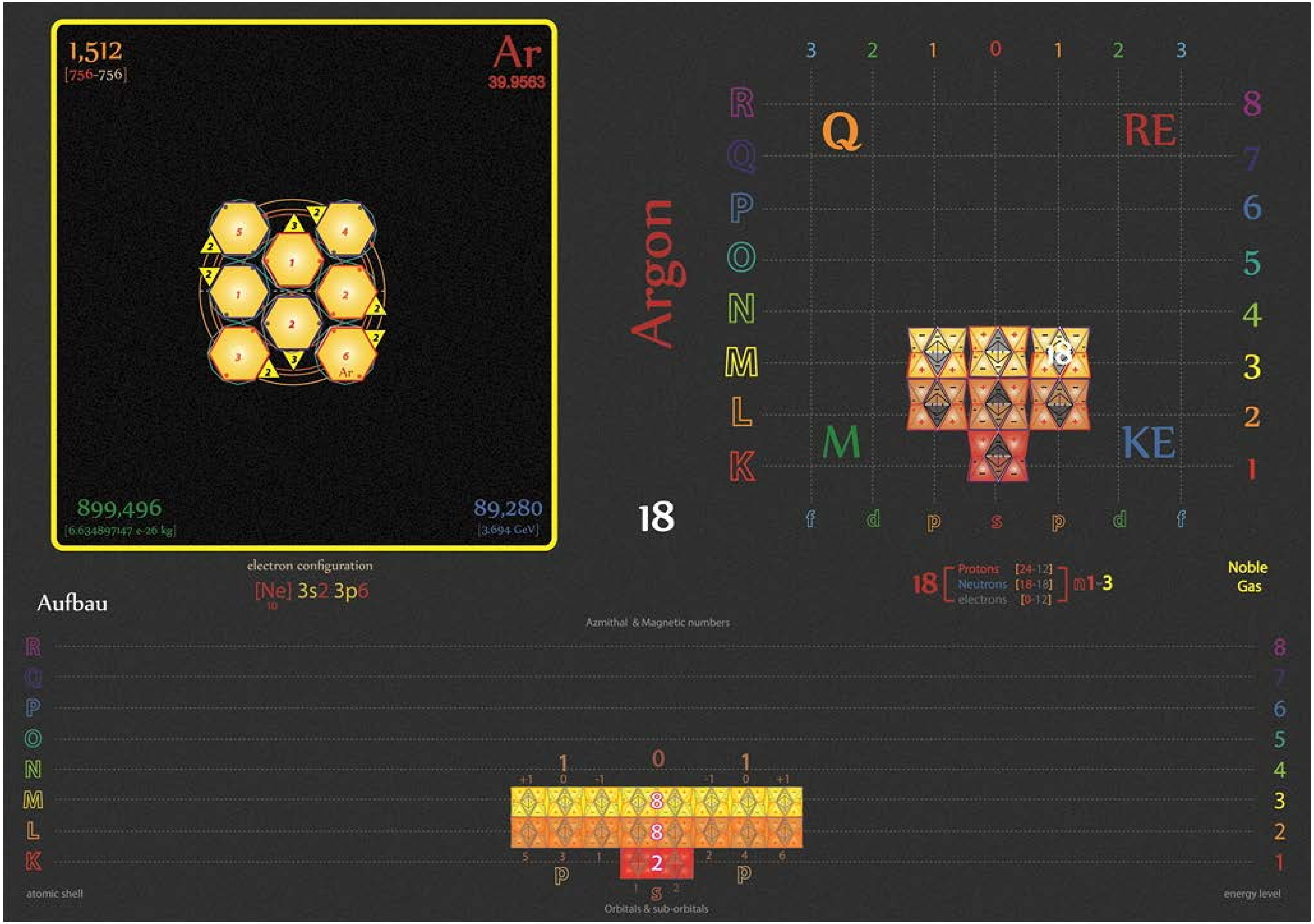
1,512
[756-756]
Ar
39.9563
1
2
3
4
5
6
Ar
899,496
[6.634897147 e-26 kg]
89,280
[3.694 GeV]
Argon
18
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
18
f d p s p d f
electron configuration
[Ne] 3s2 3p6
10
18
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-3
Noble Gas
Aufbau
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
1 0 1
+1 0 -1 -1 0 +1
8
8
2
5 3 1 2 4 6
p p
1 s 2
atomic shell
Orbitals & sub-orbitals
energy level

Tetryonics 51.18 - Argon atom

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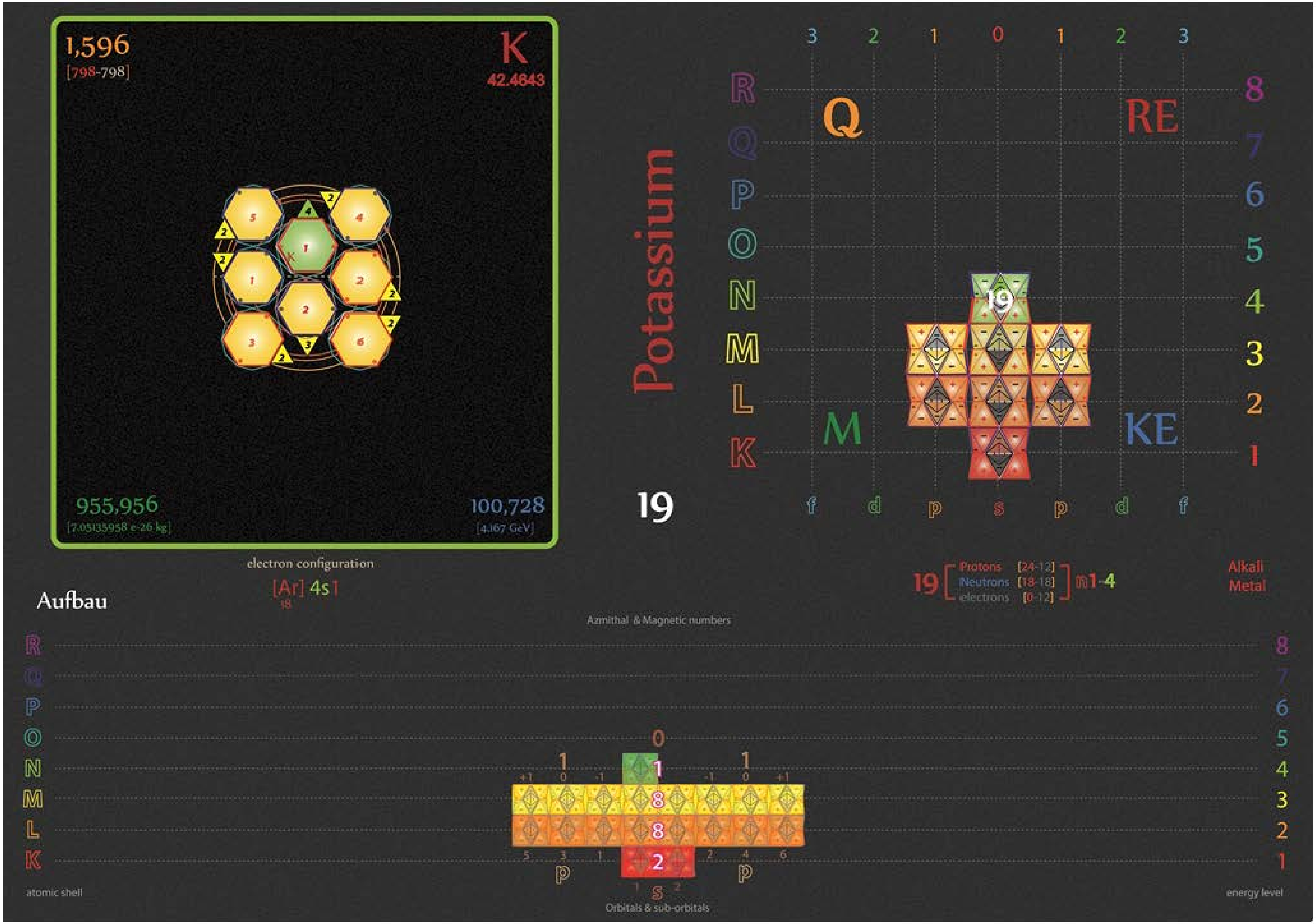
1,596
[798-798]
K
42.4643
955,956
[7.05135958 e-26 kg]
100,728
[4.167 GeV]
Potassium
19
electron configuration
[Ar] 4s1
18
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
19 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-4
Alkali Metal
Azmithal & Magnetic numbers
0
1 1
+1 0 -1 -1 0 +1
1
8
8
2
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.19 - Potassium atom

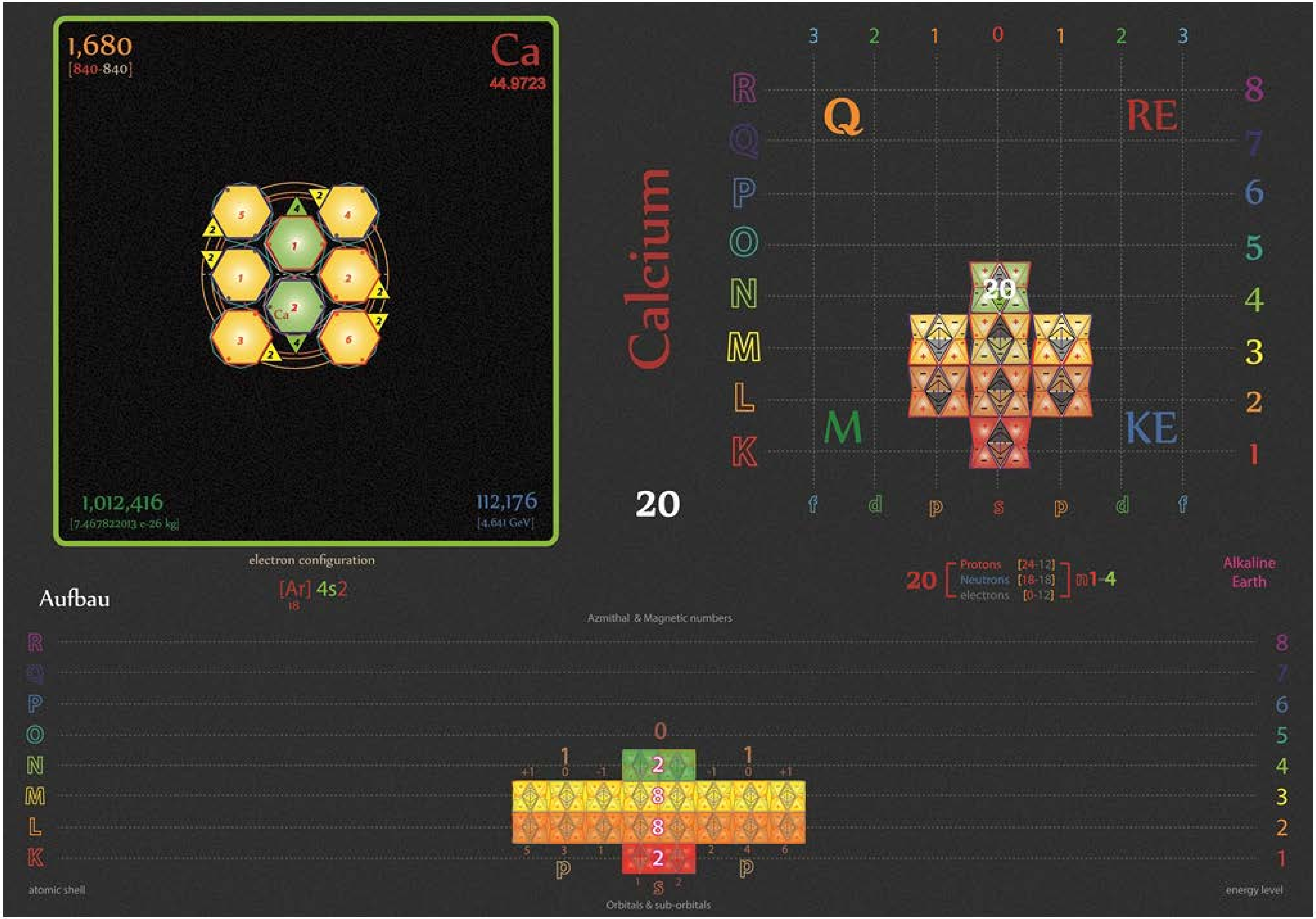
1,680
[840-840]
Ca
44.9723
Ca
1,012,416
[7.467822013 e-26 kg]
112,176
[4.641 GeV]
Calcium
20
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ar] 4s2
18
Aufbau
Azmithal & Magnetic numbers
20
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-4
Alkaline Earth
0
1
1
+1 0 -1
-1 0 +1
2
8
8
2
5 3 1
2 4 6
p
p
1 2
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.20 - Calcium atom

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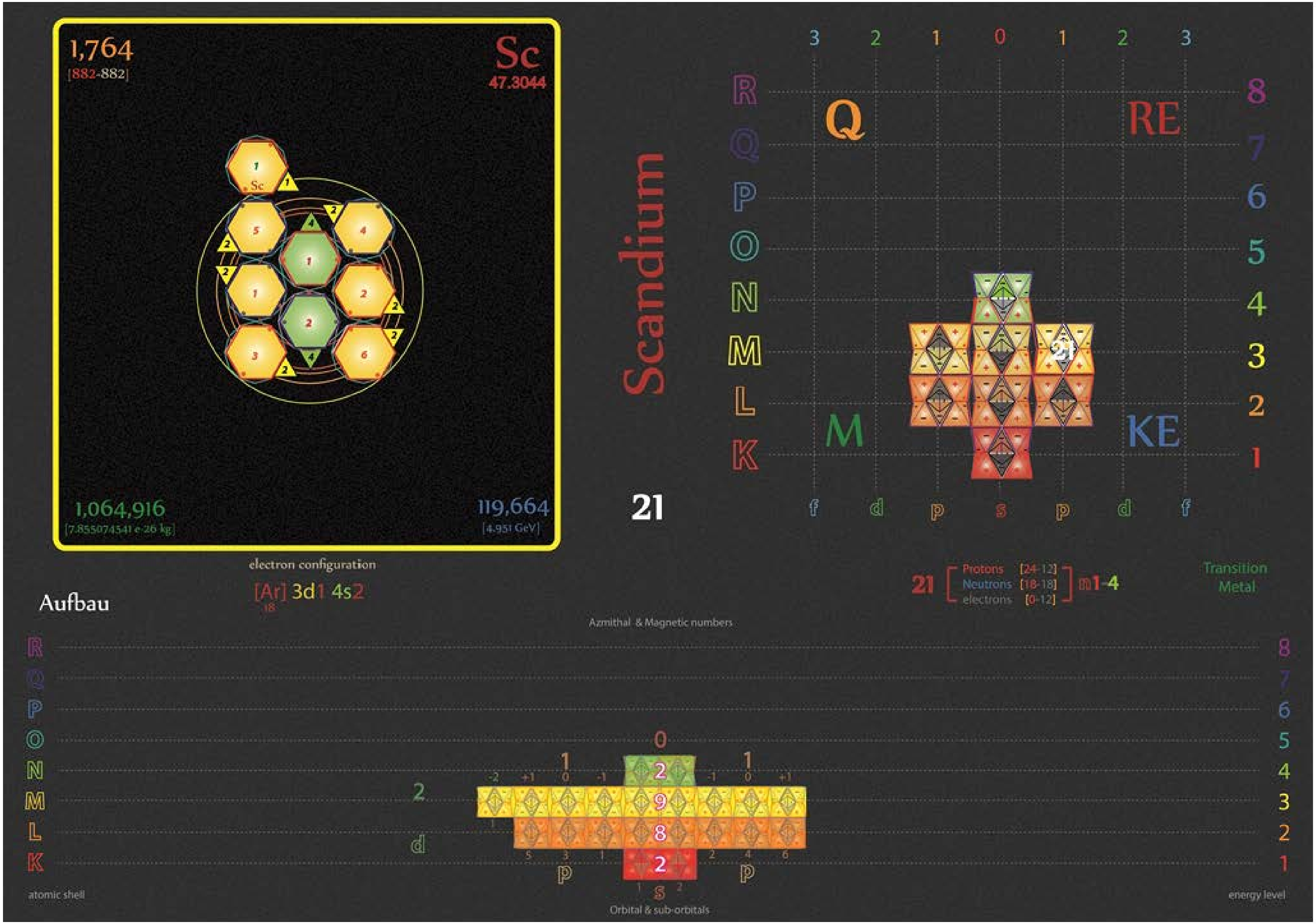
1,764
[882-882]
Sc
47.3044
1,064,916
[7.855074541 e-26 kg]
119,664
[4.951 GeV]
Scandium
21
electron configuration
[Ar] 3d1 4s2
18
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
21
f d p s p d f
21
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-4
Transition Metal
Azmithal & Magnetic numbers
0
1
1
-2 +1 0 -1 -1 0 +1
2
d
2
9
8
2
1
5 3 1 2 4 6
p
p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.21 - Scandium atom

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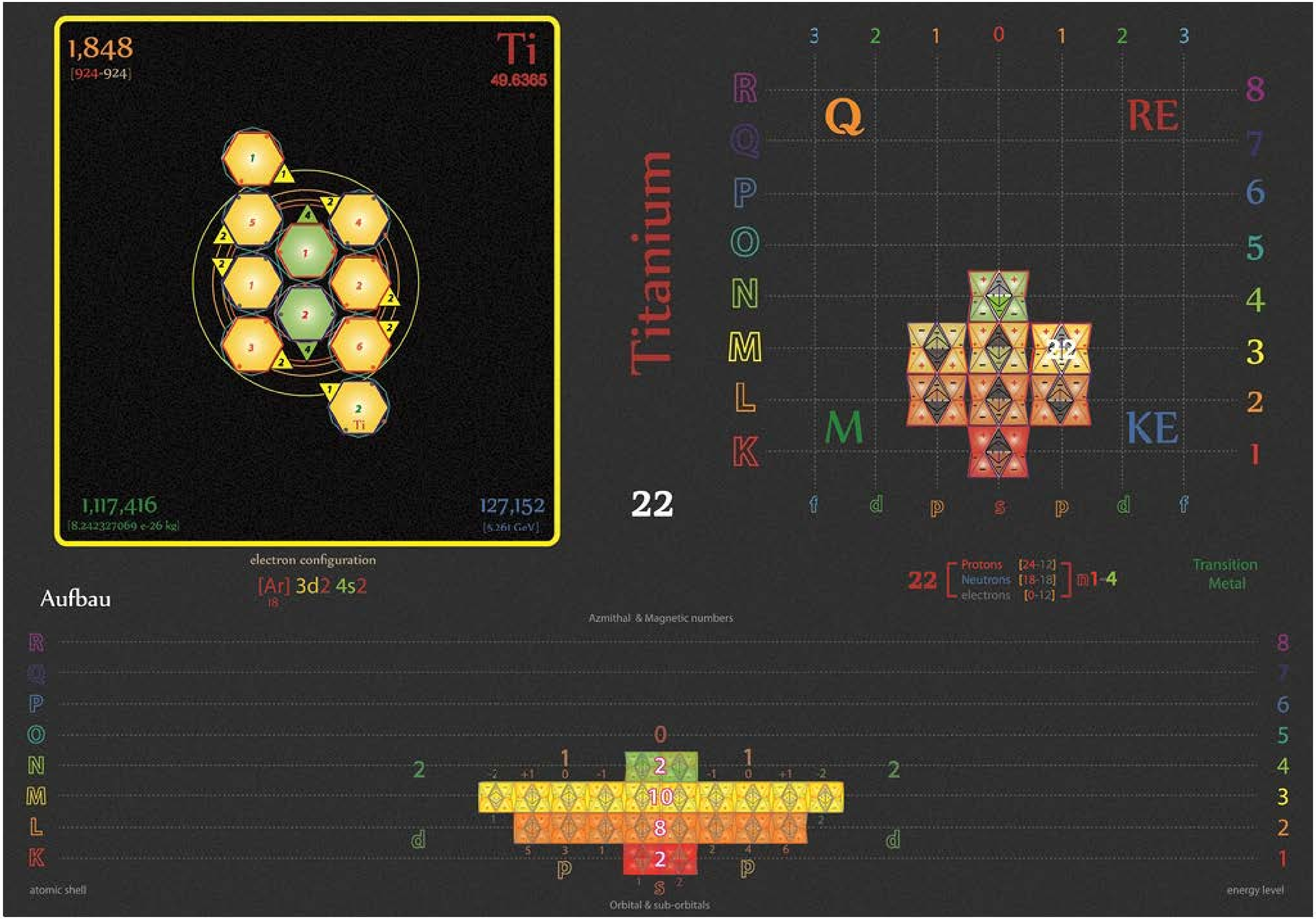
1,848
[924-924]
Ti
49.6365
Ti
1,117,416
[8.242327069 e-26 kg]
127,152
[5.261 GeV]
Titanium
22
electron configuration
[Ar] 3d2 4s2
18
Aufbau
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
Q
RE
M
KE
8
7
6
5
4
3
2
1
22
f d p s p d f
22
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-4
Transition Metal
Azmithal & Magnetic numbers
0
1
1
2
2
2
10
8
2
d
d
p
p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.22 - Titanium atom

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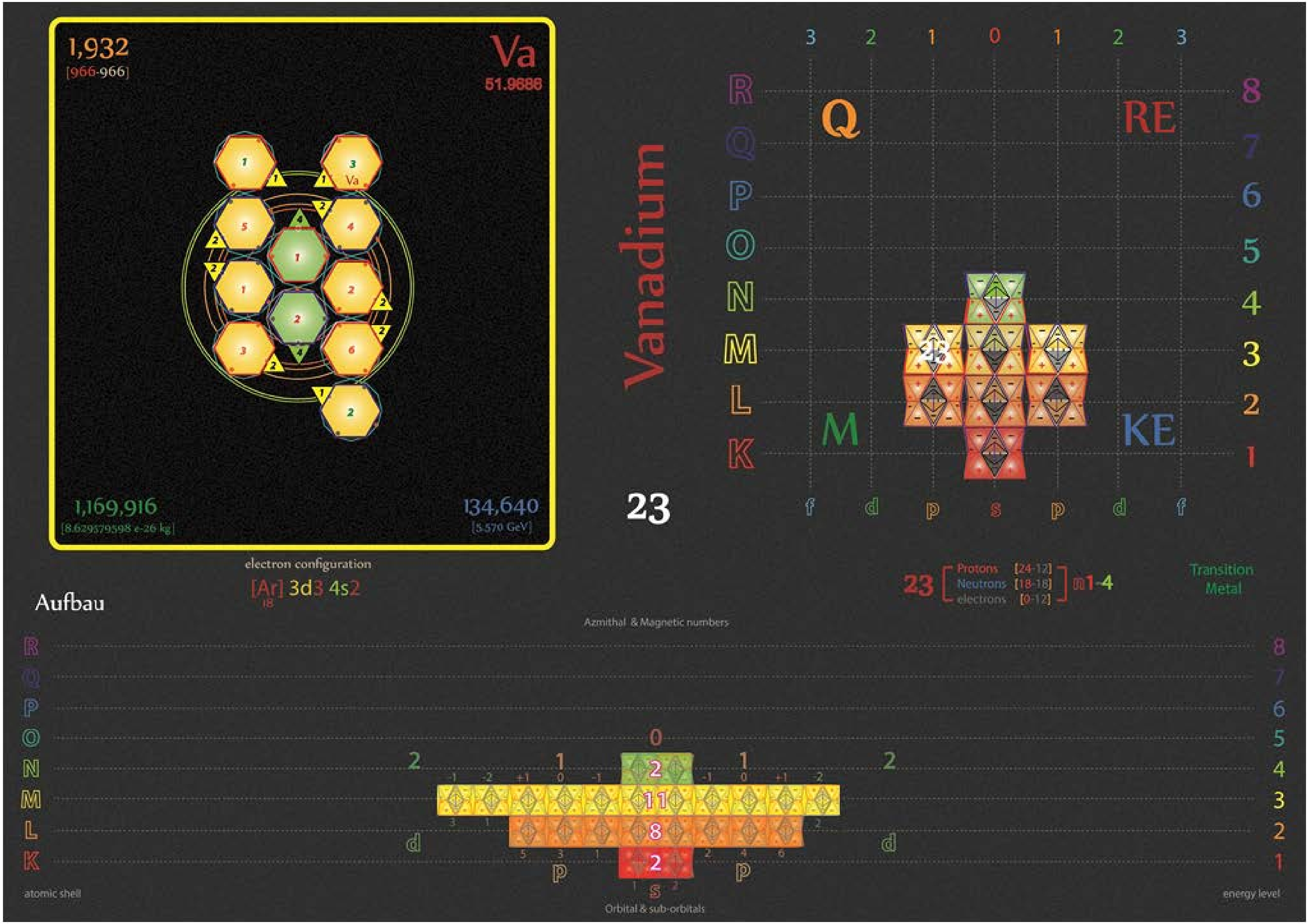
1,932
[966-966]
Va
51.9888
1,169,916
[8.629579598 e-26 kg]
134,640
[5.570 GeV]
Vanadium
23
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ar] 3d3 4s2
18
Aufbau
23 Protons [24-12] Neutrons [18-18] electrons [0-12] m1-4
Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
2
11
8
2
d d
p p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.23 - Vanadium atom

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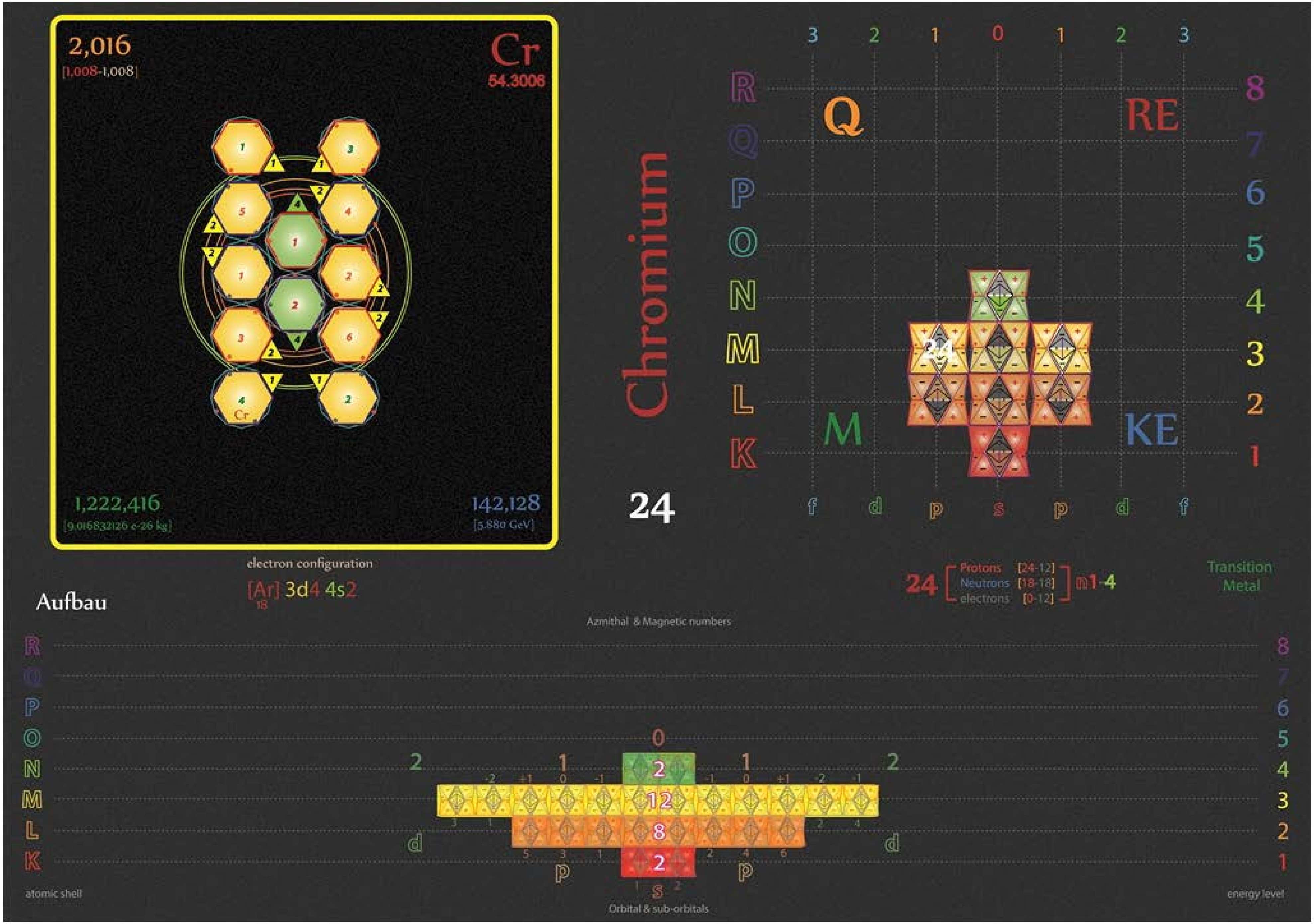
2,016
[1,008-1,008]
Cr
54.3008
1,222,416
[9.016832126 e-26 kg]
142,128
[5.880 GeV]
Chromium
24
electron configuration
[Ar] 3d4 4s2
18
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
24 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
2
12
8
2
d p s p d
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.24 - Chromium atom

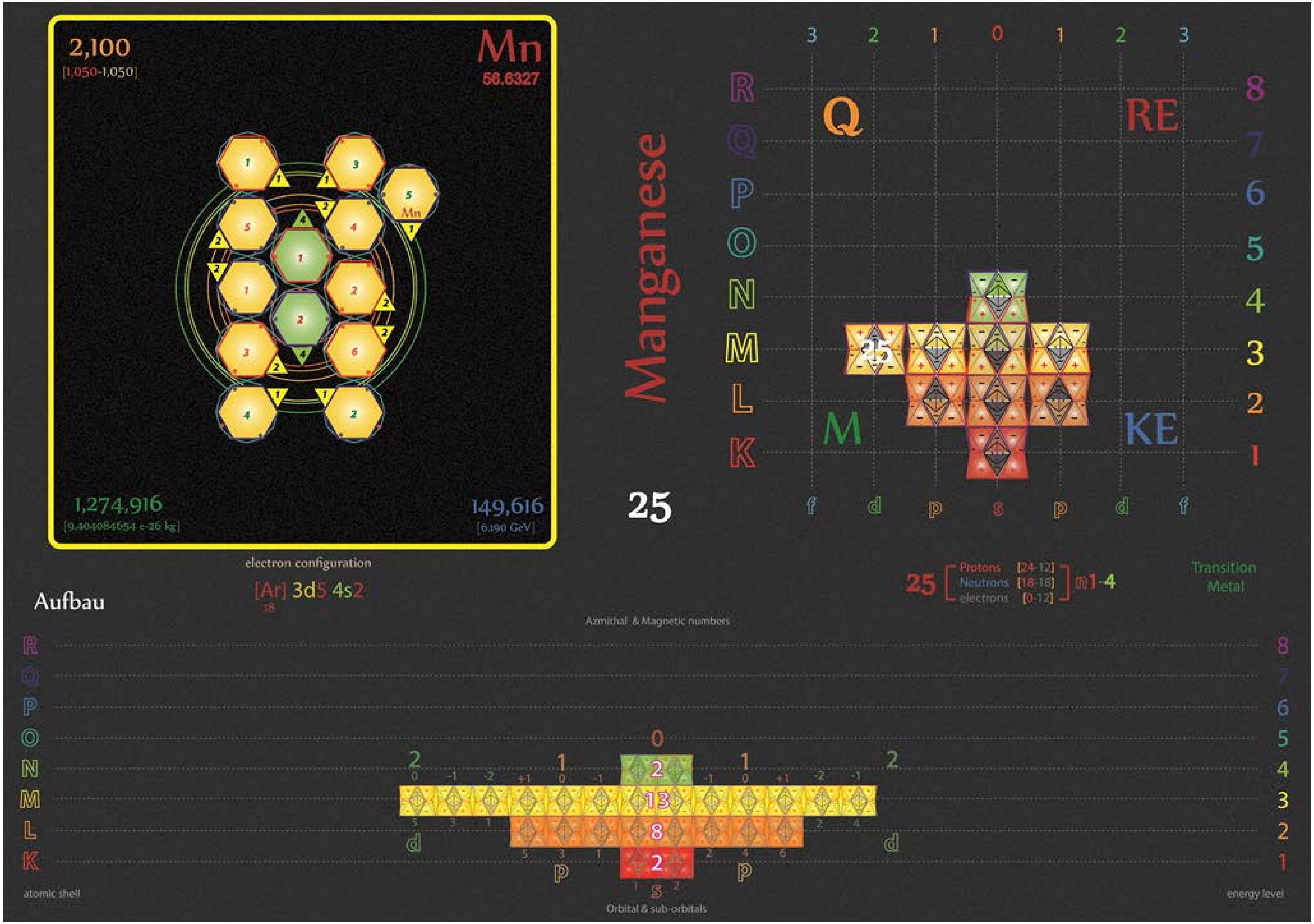
2,100
[1,050-1,050]
Mn
56.6327
1,274,916
[9.404084654 e-26 kg]
149,616
[6.190 GeV]
Mn
Manganese
25
electron configuration
[Ar] 3d5 4s2
18
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
25
f d p s p d f
25 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-4
Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
0 -1 -2 +1 0 -1 -1 0 +1 -2 -1
2
13
8
2
5 3 1 2 4
5 3 1 2 4 6
d d
p p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.25 - Manganese atom

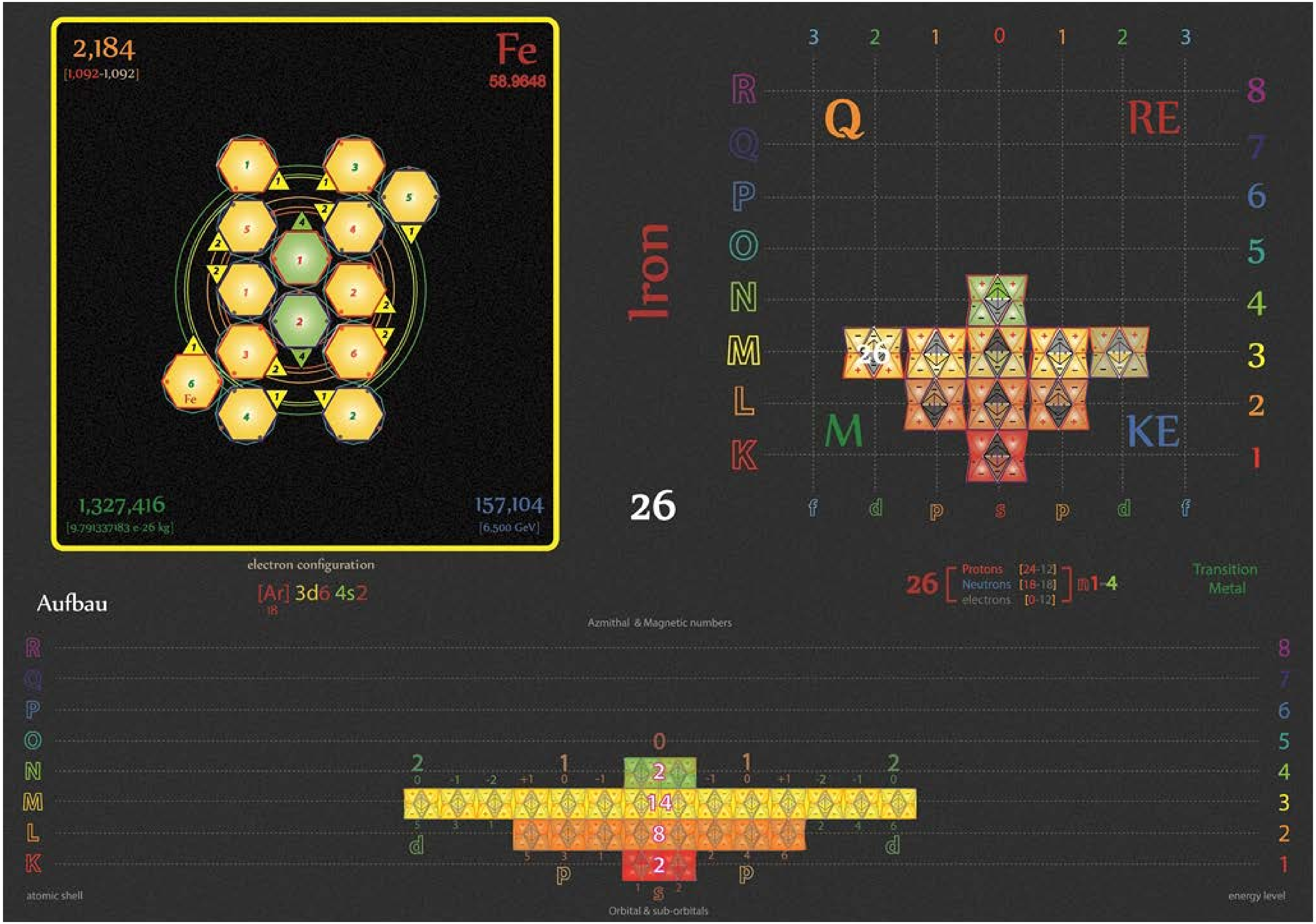
2,184
[1,092-1,092]
Fe
58.9648
6
Fe
1,327,416
[9.791337183 e-26 kg]
157,104
[6,500 GeV]
Iron
26
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ar] 3d6 4s2
18
Aufbau
Azmithal & Magnetic numbers
26 Protons [24-12] Neutrons [18-18] electrons [0-12] m1-4
Transition Metal
0
2 1 1 2
2
14
8
2
d p s p d
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.26 - Iron atom

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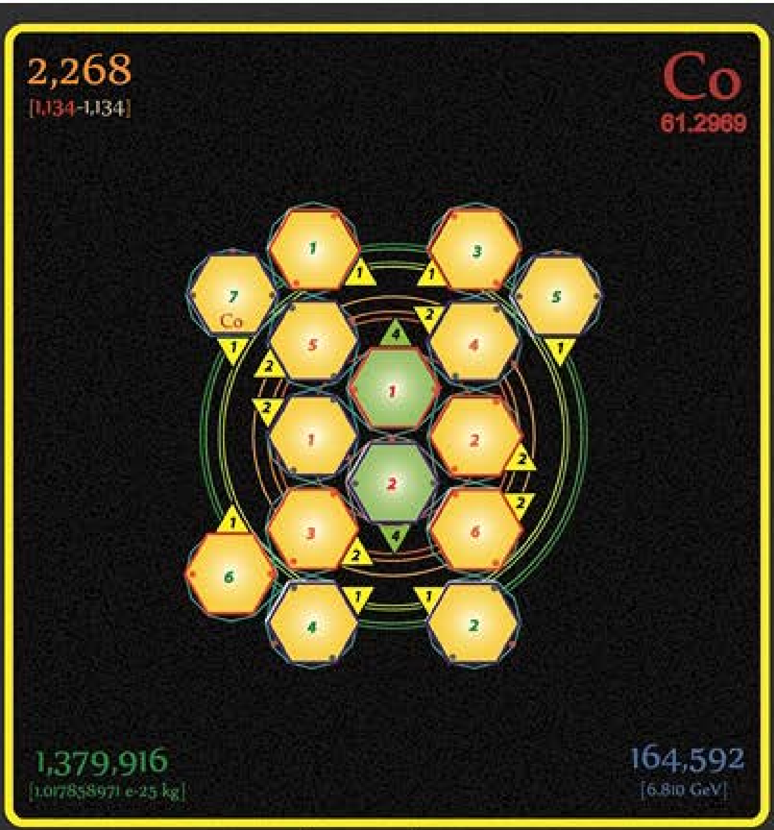
2,268
[1,134-1,134]
Co
61.2969
7
Co
1,379,916
[1.017858971 e-25 kg]
164,592
[6.810 GeV]

Cobalt

27

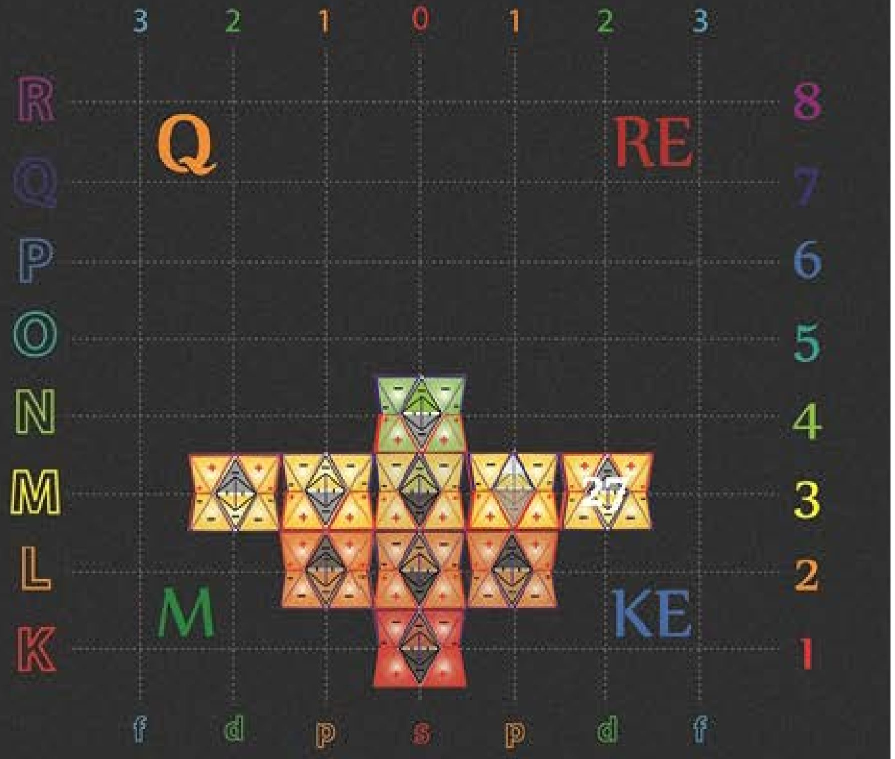
3 2 1 0 1 2 3
R Q P O N M L K
Q
RE
M
KE
27
8 7 6 5 4 3 2 1
f d p s p d f

electron configuration

[Ar] 3d7 4s2
18

27 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4

Transition Metal

Aufbau

Azmithal & Magnetic numbers

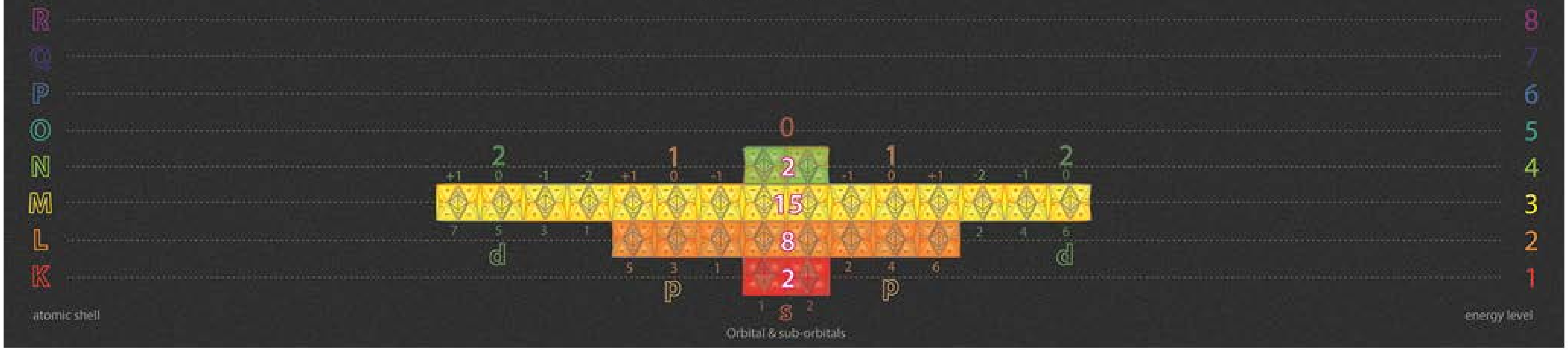
R Q P O N M L K
8 7 6 5 4 3 2 1
0
2 1 1 2
+1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0
2
15
8
2
7 5 3 1 2 4 6
d d
5 3 1 2 4 6
p p
1 2
s
atomic shell
energy level

Orbital & sub-orbitals

Tetryonics 51.27 - Cobalt atom

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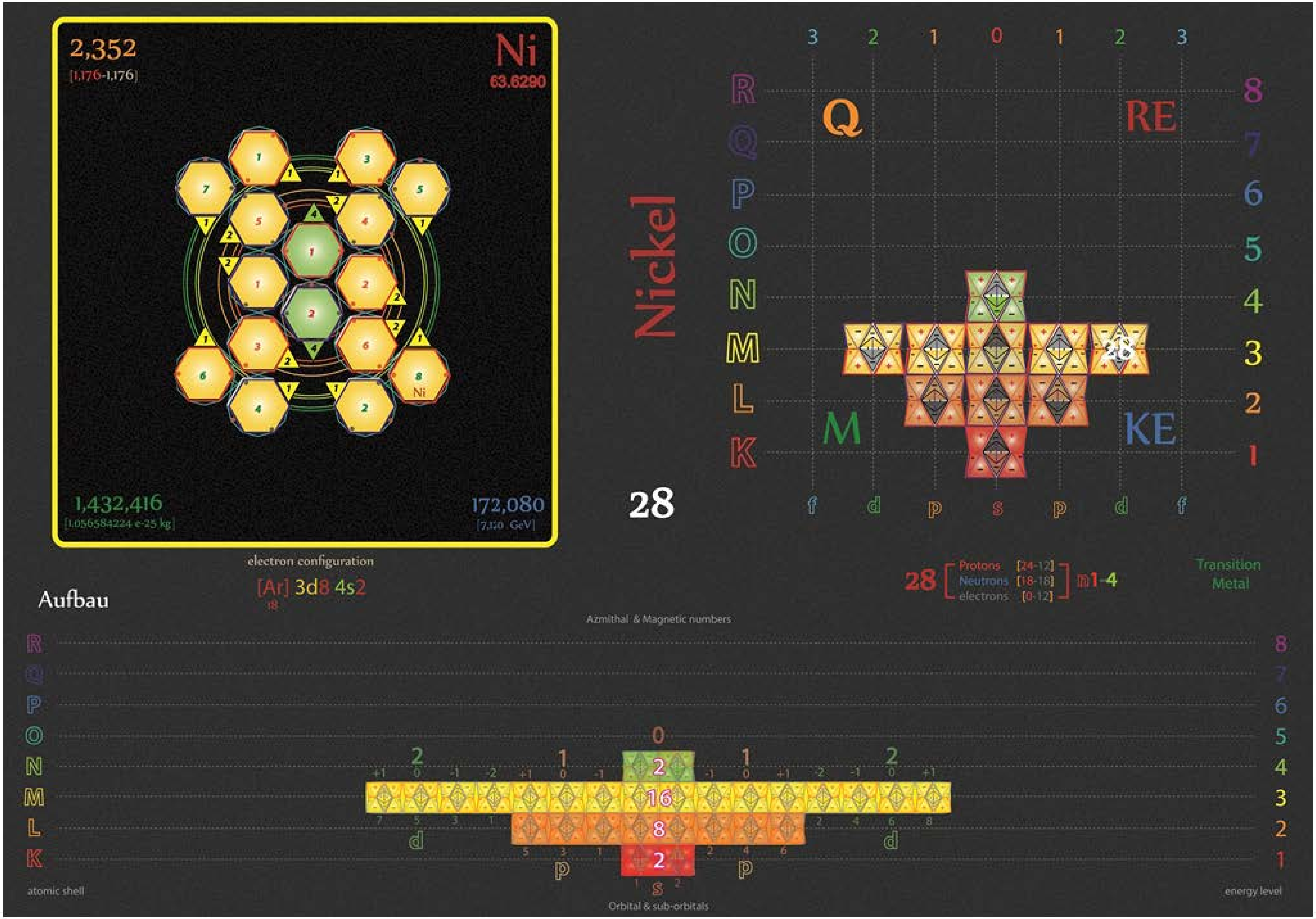
2,352
[1,176-1,176]
Ni
63.6290
1,432,416
[1.056584224 e-25 kg]
172,080
[7,110 GeV]
Nickel
28
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Ar] 3d8 4s2
18
Aufbau
28 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-4
Transition Metal
Azmithal & Magnetic numbers
0
2
16
8
2
d
p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.28 - Nickel atom

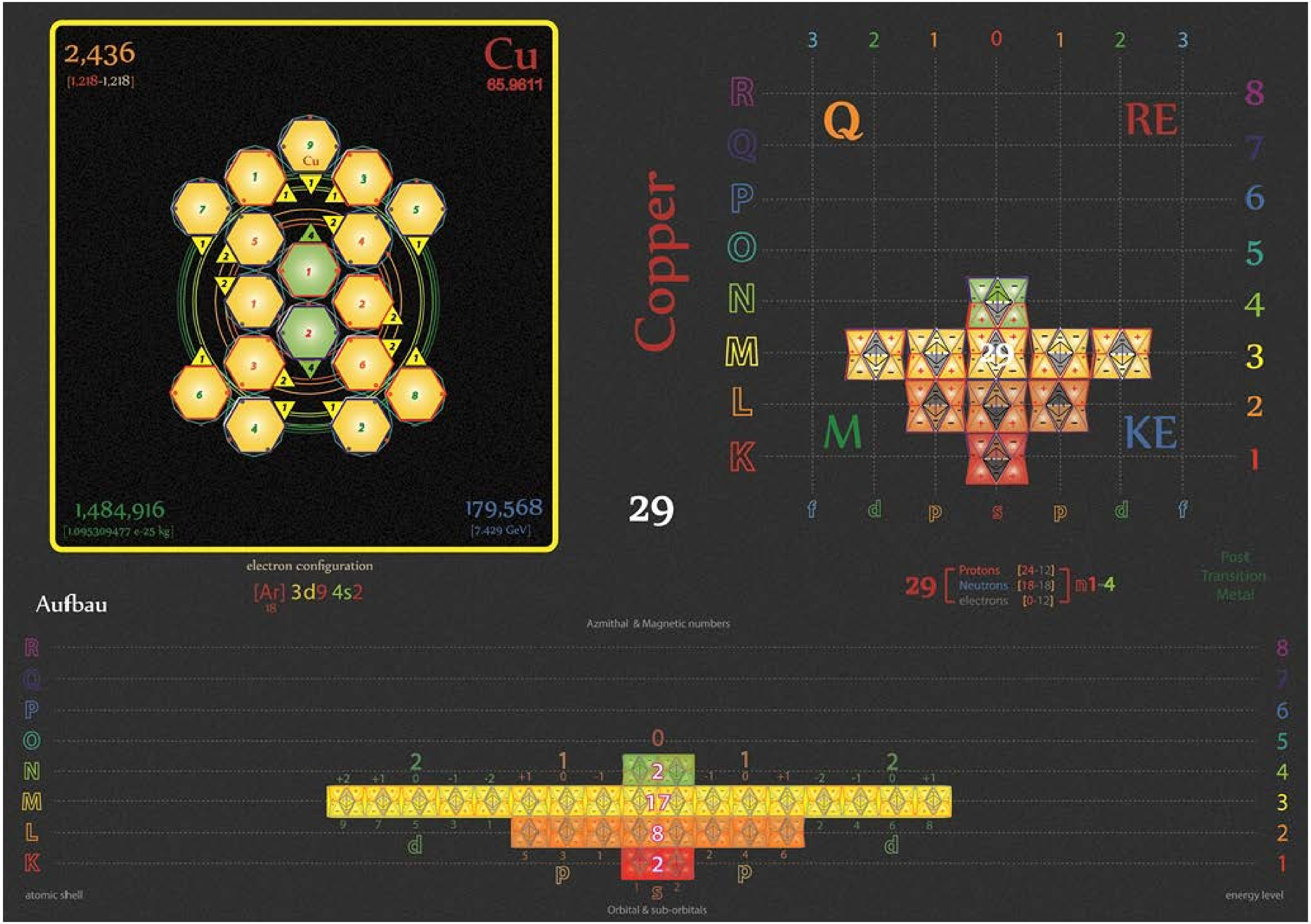
2,436
[1,218-1,218]
Cu
65.9811
Cu
1,484,916
[1.095309477 e-25 kg]
179,568
[7.429 GeV]
Copper
29
electron configuration
[Ar] 3d9 4s2
18
Aufbau
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
29
29
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-4
Post Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1
2
17
8
2
9 7 5 3 1 2 4 6 8
5 3 1 2 4 6
1 2
d d
p p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.29 - Copper atom

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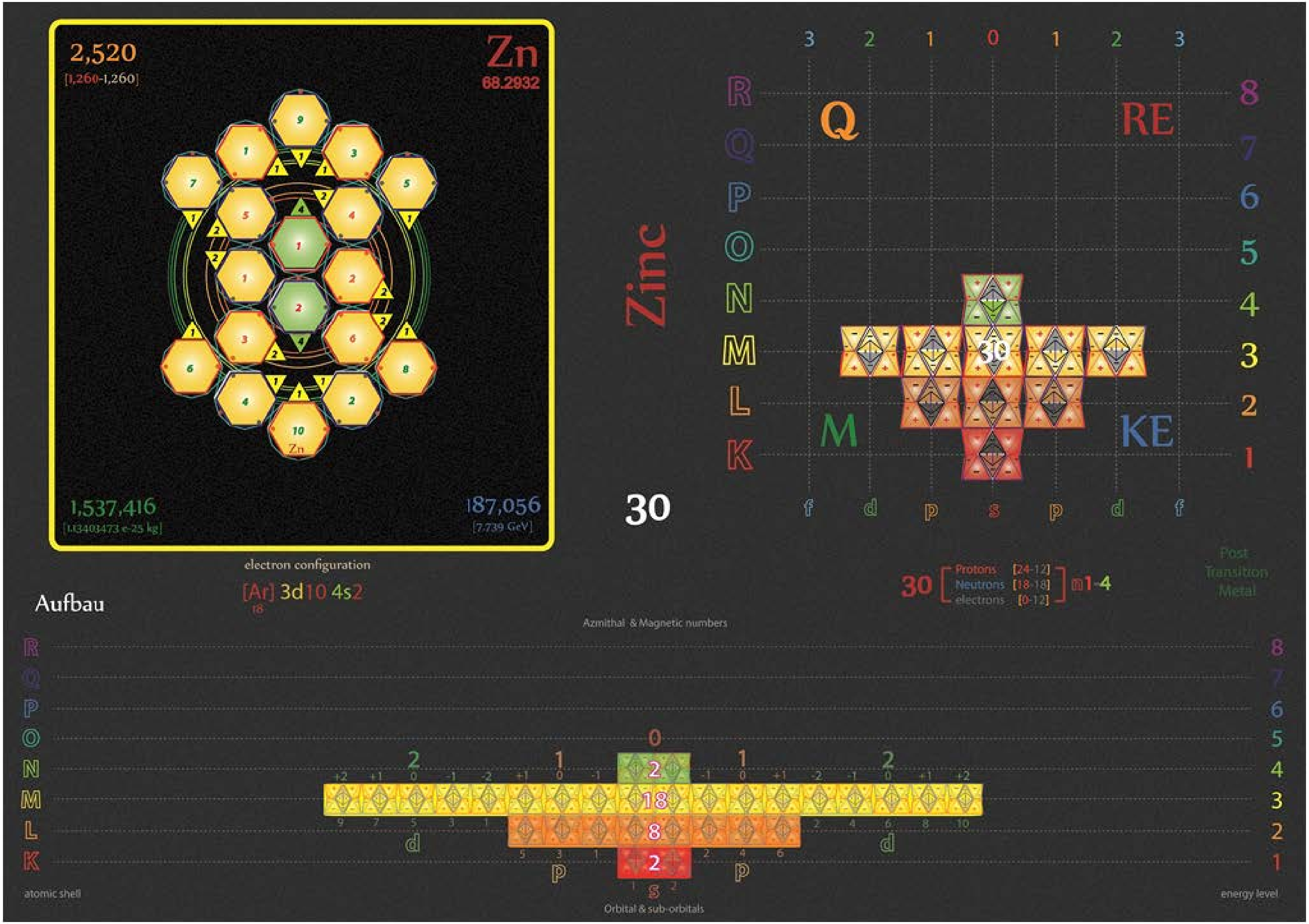
2,520
[1,260-1,260]
Zn
68.2932
Zn
1,537,416
[1.13403473 e-25 kg]
187,056
[7.739 GeV]
electron configuration
[Ar] 3d10 4s2
18
Aufbau
Zinc
30
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
30
f d p s p d f
30 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Post-Transition Metal
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
2 1 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
2
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.30 - Zinc atom

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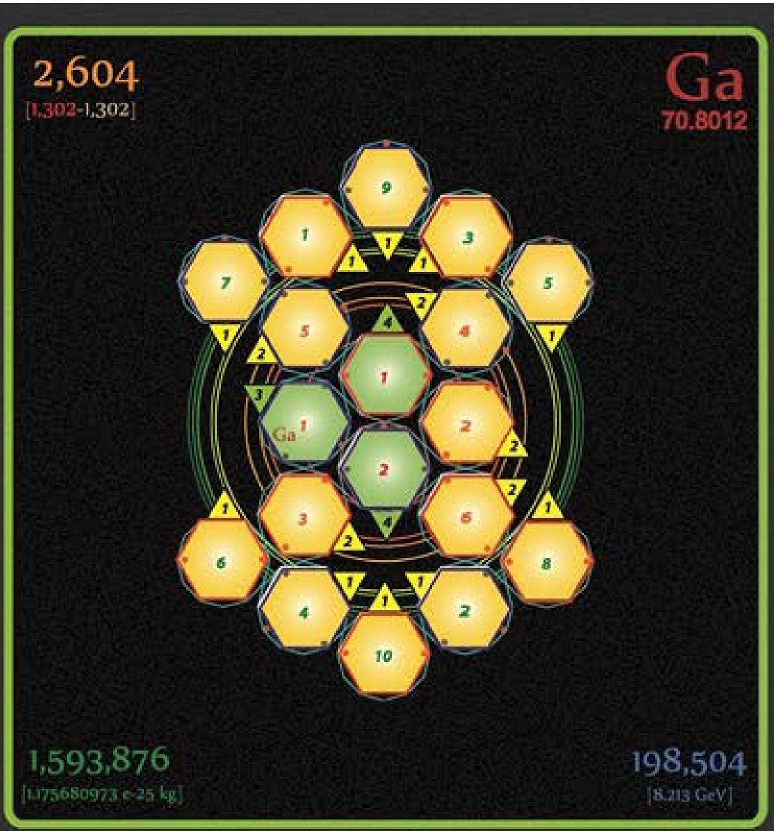
2,604
[1,302-1,302]
Ga
70.8012
9
1
3
7
5
1
1
1
5
2
4
1
1
Ga
1
2
2
3
6
6
8
4
2
10
1,593,876
[1.175680973 e-25 kg]
198,504
[8.213 GeV]

Gallium

31

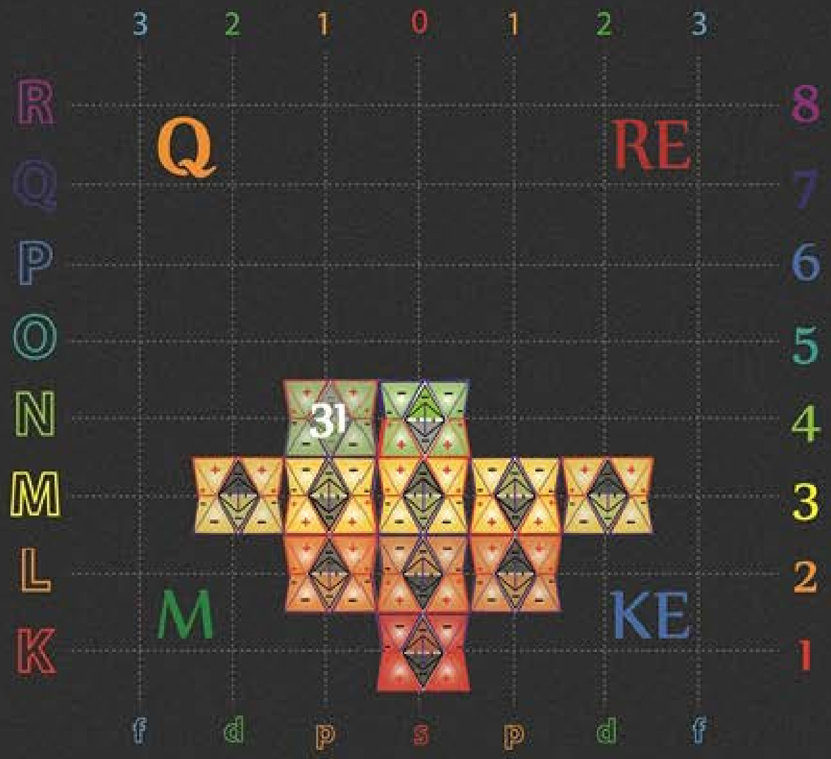
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
31
f
d
p
s
p
d
f

electron configuration

Aufbau

[Ar] 3d10 4s2 4p1
18

31 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4

Metaloid

Azmithal & Magnetic numbers

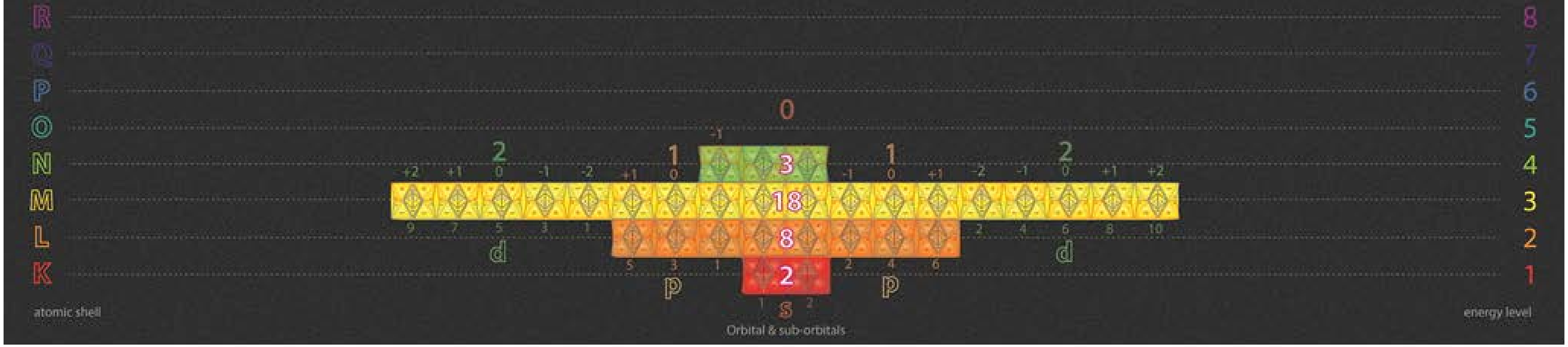
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
-1
2
1
1
2
+2
+1
0
-1
-2
+1
0
-1
0
+1
-2
-1
0
+1
+2
3
18
8
2
9
7
5
3
1
2
4
6
8
10
d
d
5
3
1
2
4
6
p
p
1
2
s
atomic shell
energy level

Orbital & sub-orbitals

Tetryonics 51.31 - Gallium atom

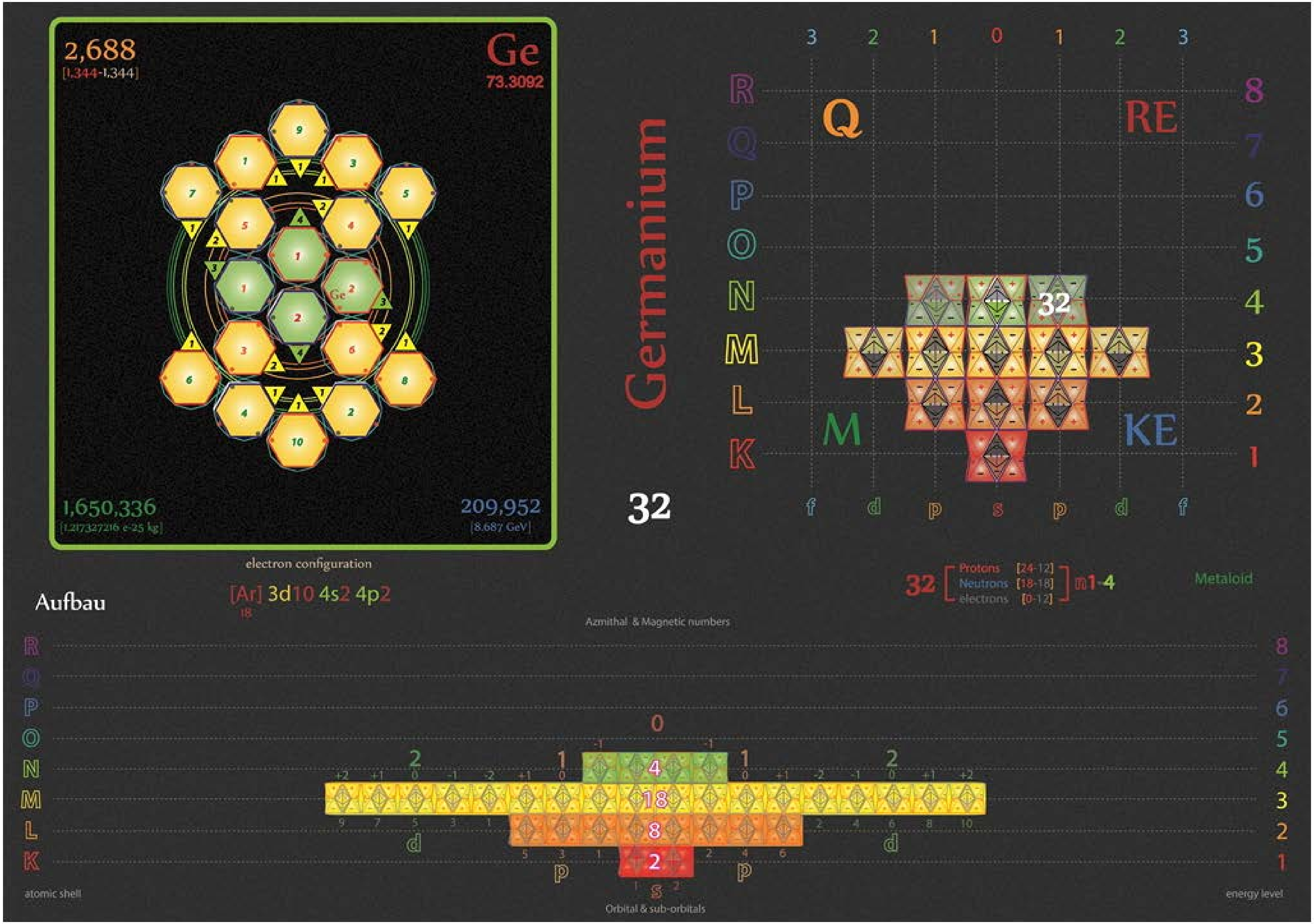
2,688
[1,344-1,344]
Ge
73.3092
Ge
1,650,336
[1.217327216 e-25 kg]
209,952
[8.687 GeV]
Germanium
32
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
32
f d p s p d f
electron configuration
[Ar] 3d10 4s2 4p2
18
Aufbau
32
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-4
Metaloid
Azmithal & Magnetic numbers
0
2 1 1 2
4
18
8
2
d d
p p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.32 - Germanium atom

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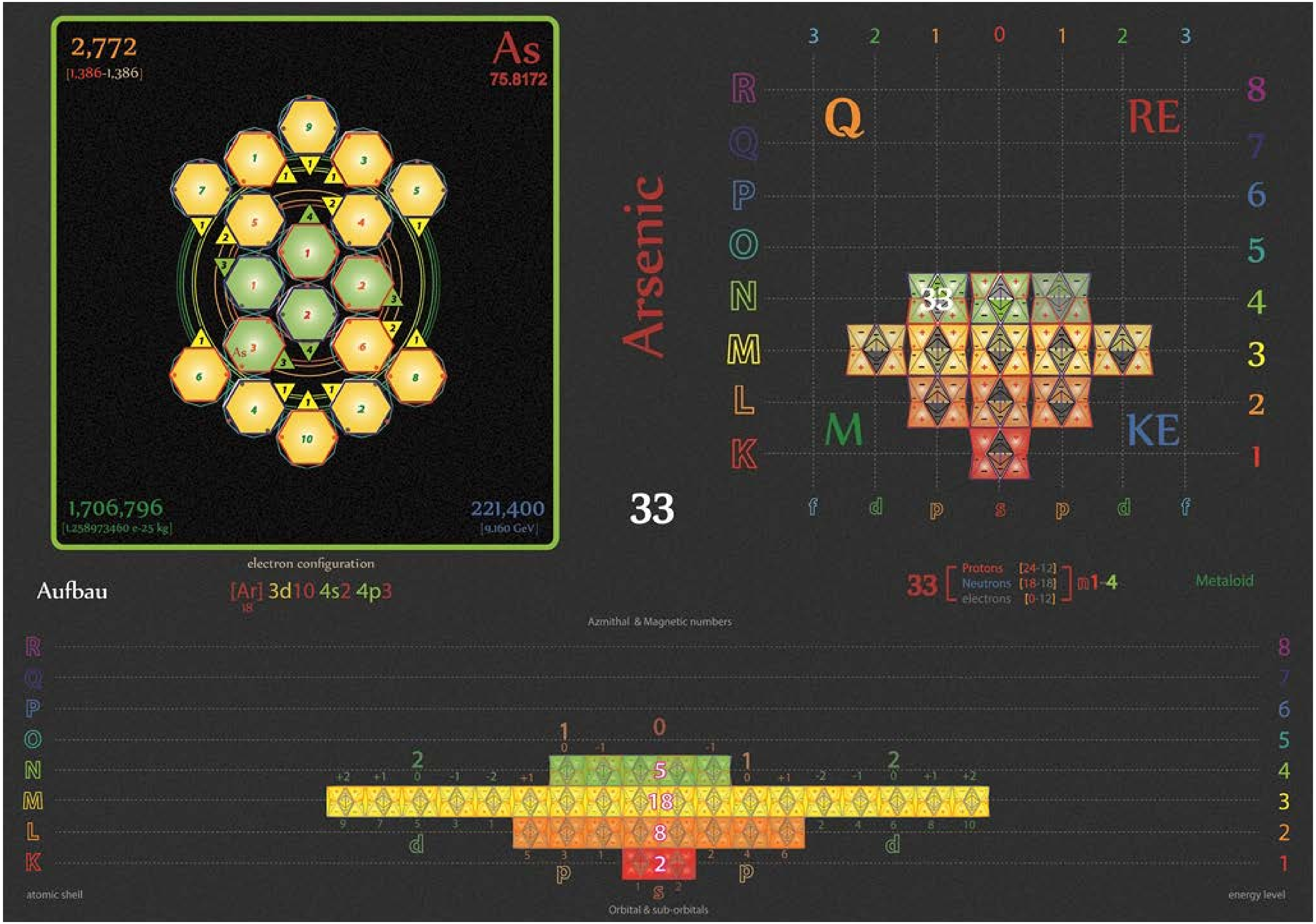
2,772
[1,386-1,386]
As
75.8172
1,706,796
[1.258973460 e-25 kg]
221,400
[9.160 GeV]
Arsenic
33
electron configuration
Aufbau
[Ar] 3d10 4s2 4p3
18
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
33 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Metaloid
Azmithal & Magnetic numbers
2 1 0 1 2
5
18
8
2
d p s p d
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.33 - Arsenic atom

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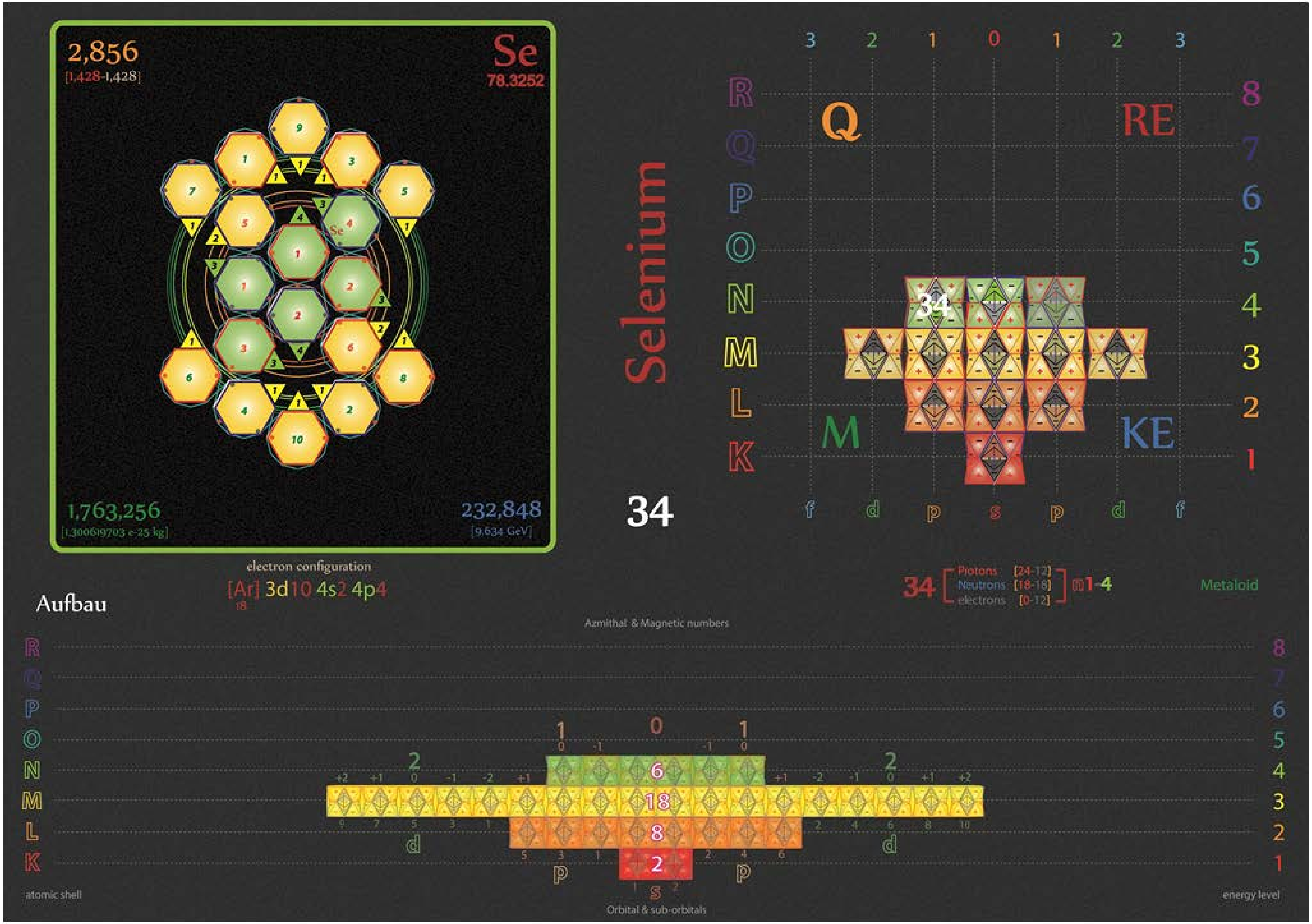
2,856
[1,428-1,428]
Se
78.3252
1,763,256
[1.30069703 e-25 kg]
232,848
[9,634 GeV]
Selenium
34
electron configuration
[Ar] 3d10 4s2 4p4
18
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
34
f d p s p d f
34 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4
Metaloid
Azmithal & Magnetic numbers
1 0 1
2 2
6
18
8
2
d d
p p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.34 - Selenium atom

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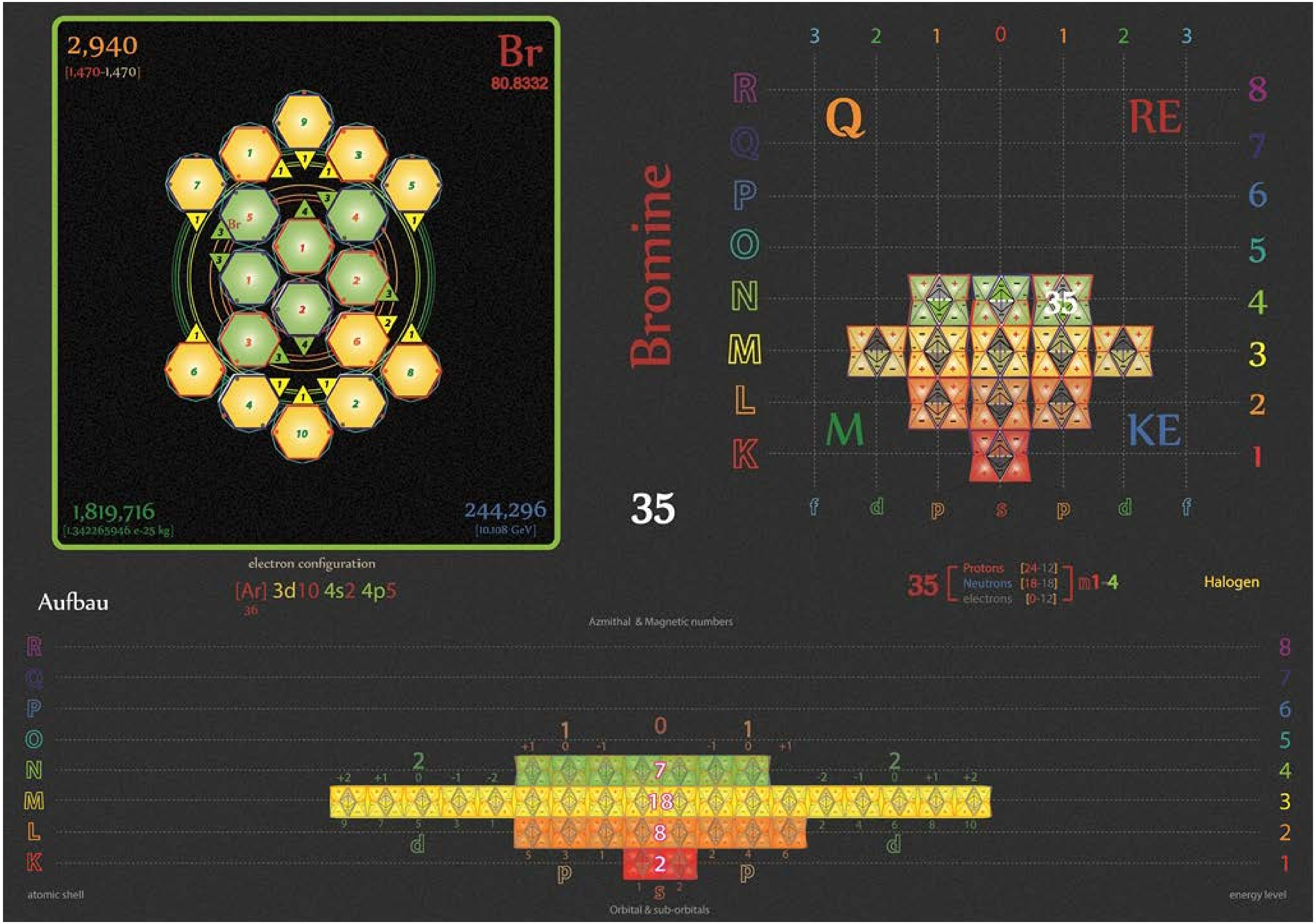
2,940
[1,470-1,470]
Br
80.8332
1,819,716
[1.342265946 e-25 kg]
244,296
[10.108 GeV]
Bromine
35
electron configuration
[Ar] 3d10 4s2 4p5
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
35
35 Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-4
Halogen
Azmithal & Magnetic numbers
2 1 0 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
7
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.35 - Bromine atom

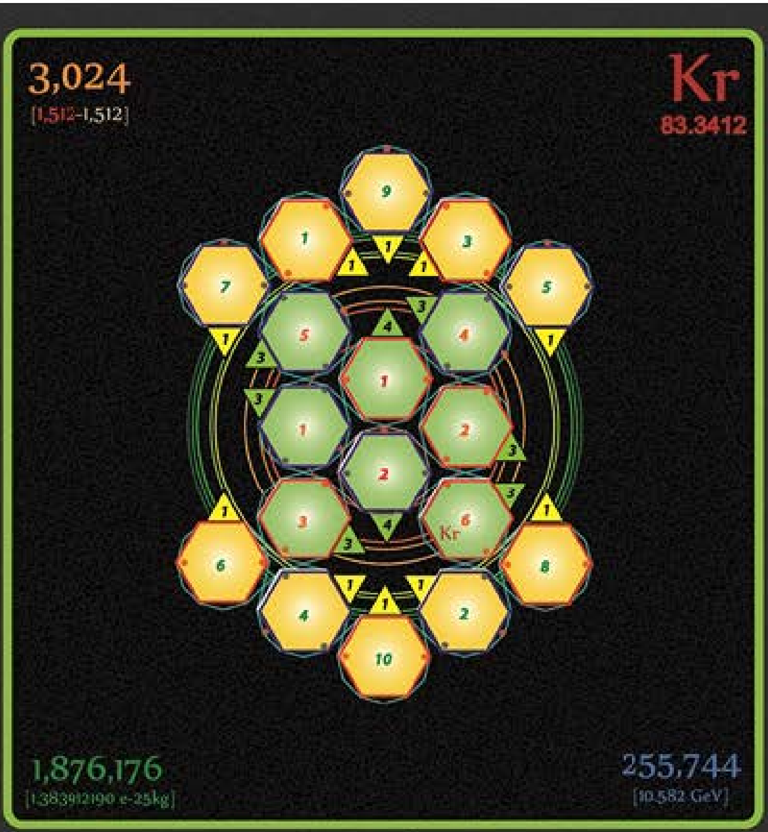
3,024
[1,512-1,512]
Kr
83.3412
9
1
3
7
5
1
1
1
5
4
3
1
1
3
1
2
3
1
2
3
3
1
1
6
8
3
Kr 6
4
4
1
1
1
2
10
1,876,176
[1.383912190 e-25kg]
255,744
[10.582 GeV]

Krypton

36

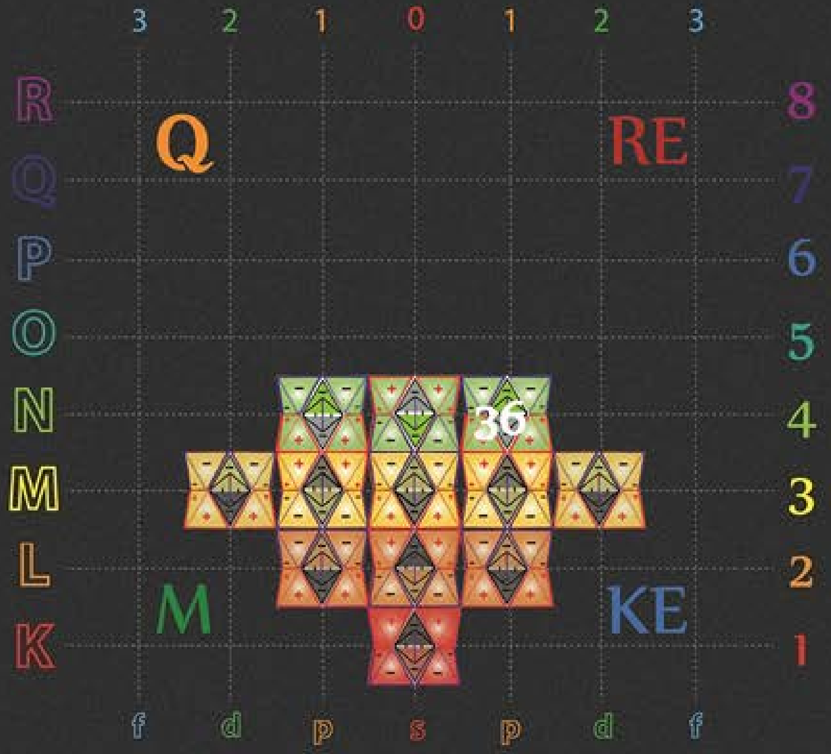
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
36
f
d
p
s
p
d
f

electron configuration

[Ar] 3d10 4s2 4p6
36

Aufbau

36 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-4

Noble Gas

Azmithal & Magnetic numbers

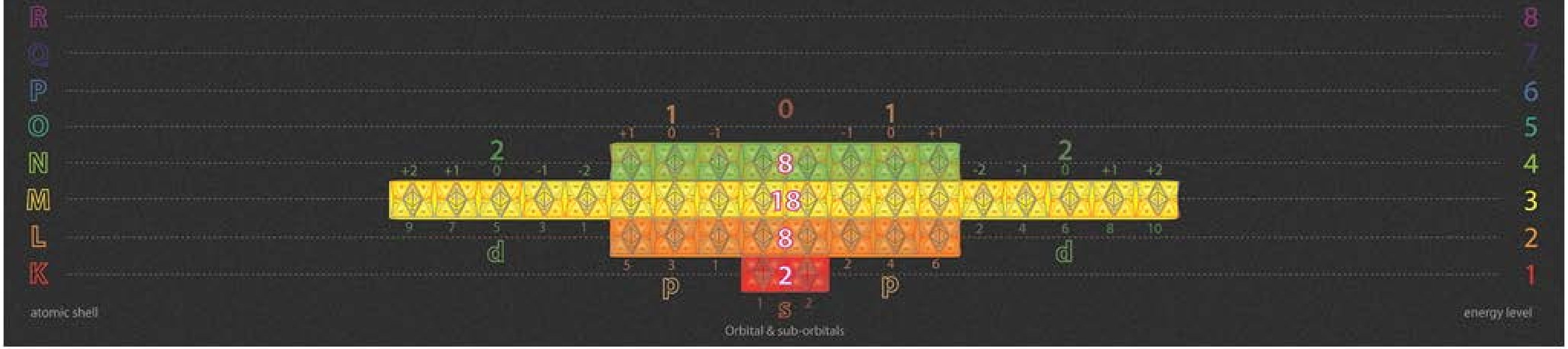
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1
0
1
+1
0
-1
-1
0
+1
2
2
+2
+1
0
-1
-2
-2
-1
0
+1
+2
8
18
8
2
9
7
5
3
1
2
4
6
8
10
d
d
5
3
1
2
4
6
p
p
1
s
2
atomic shell
energy level

Orbital & sub-orbitals

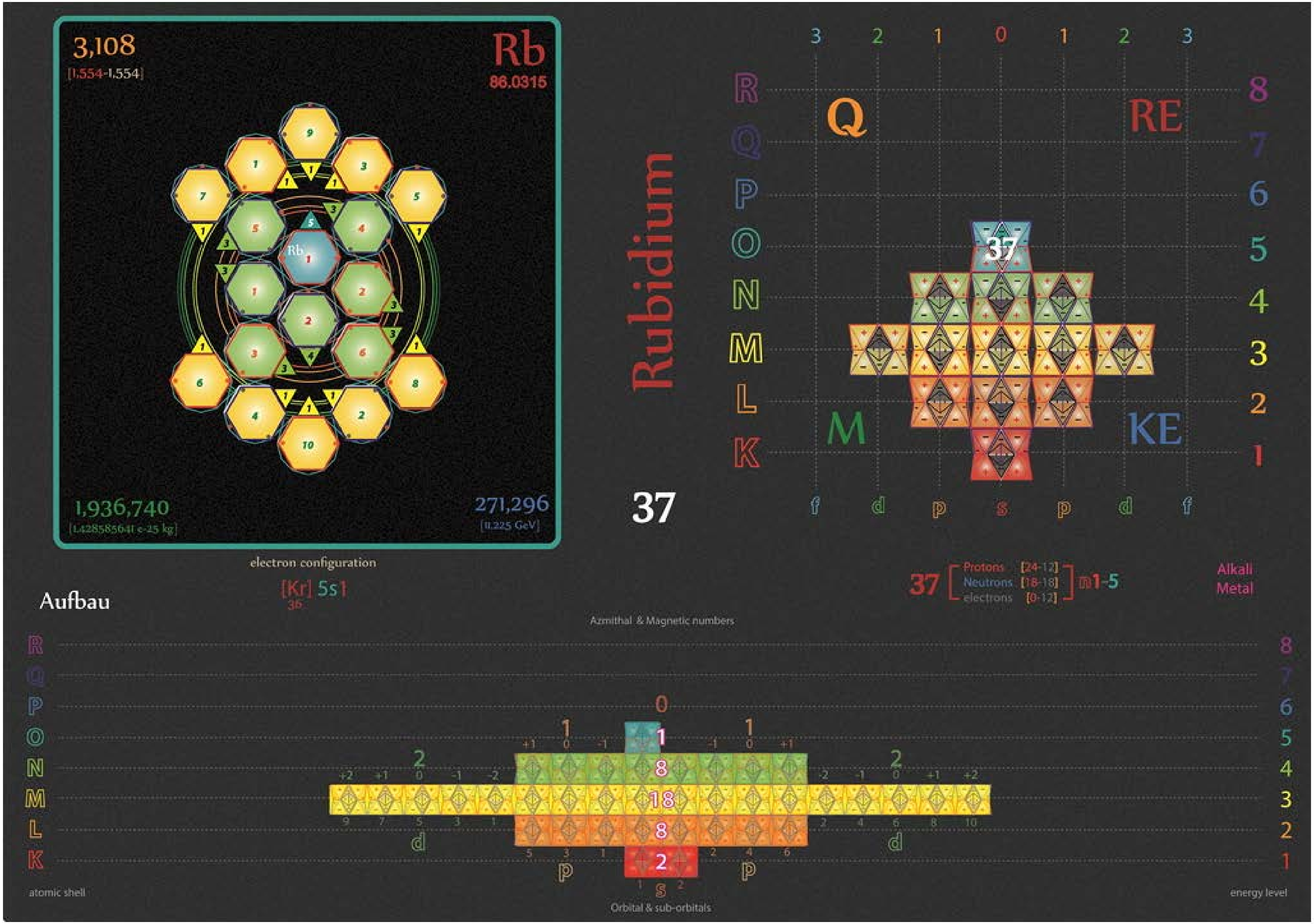
3,108
[1,554-1,554]
Rb
86.0315
Rb
1,936,740
[1.428585641 e-25 kg]
271,296
[11.225 GeV]
Rubidium
37
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
37
f d p s p d f
electron configuration
[Kr] 5s1
36
Aufbau
37
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-5
Alkali
Metal
Azmithal & Magnetic numbers
0
1 1
2 2
+1 0 -1 -1 0 +1
+2 +1 0 -1 -2 -2 -1 0 +1 +2
1
8
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.37 - Rubidium atom

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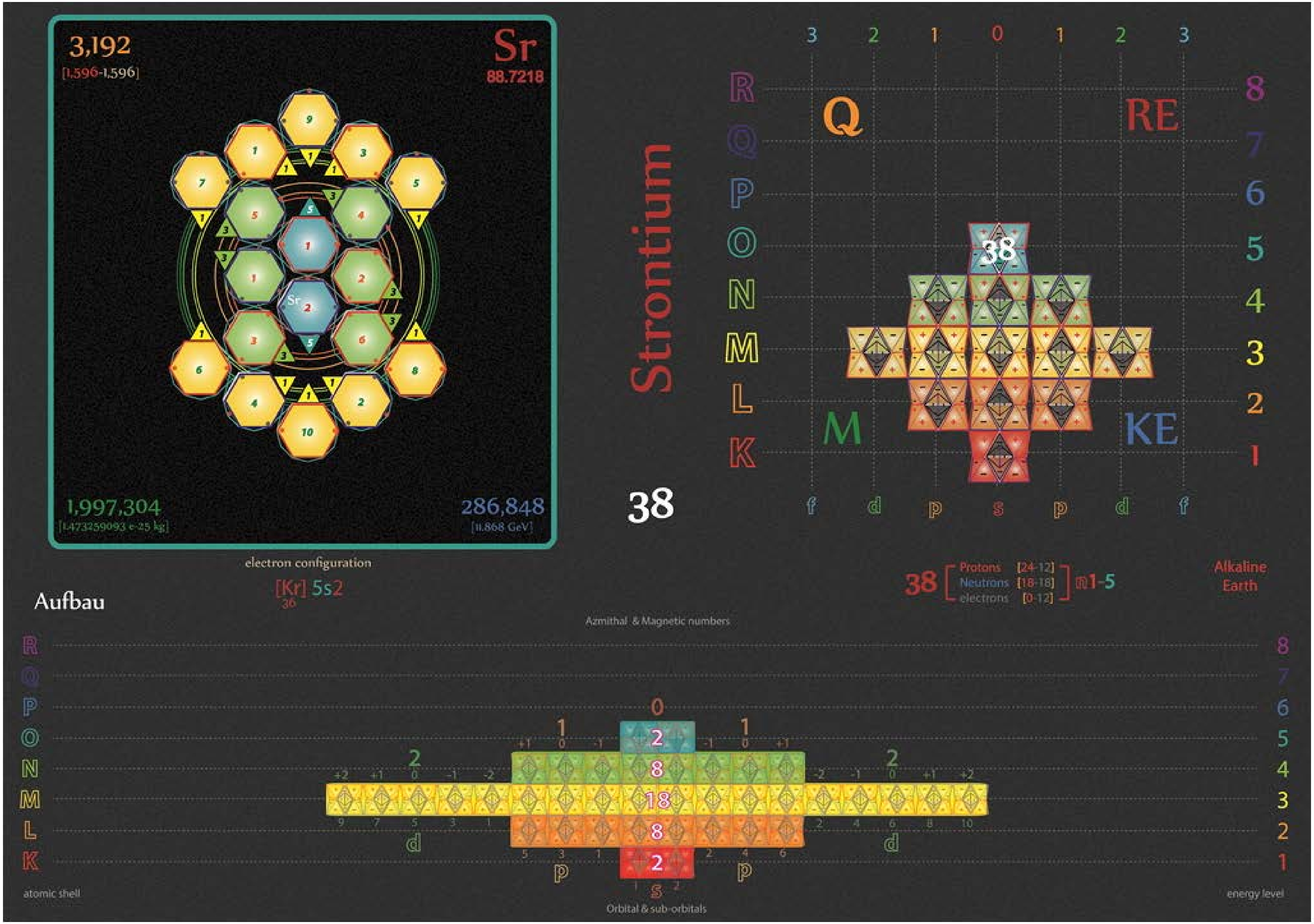
3,192
[1,596-1,596]
Sr
88.7218
1,997,304
[1.473259093 e-25 kg]
286,848
[11.868 GeV]
Strontium
38
electron configuration
[Kr] 5s2
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
38 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-5
Alkaline Earth
Azmithal & Magnetic numbers
0
1 1
2 2
+1 0 -1 -1 0 +1
+2 +1 0 -1 -2 -2 -1 0 +1 +2
2
8
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.38 - Strontium atom

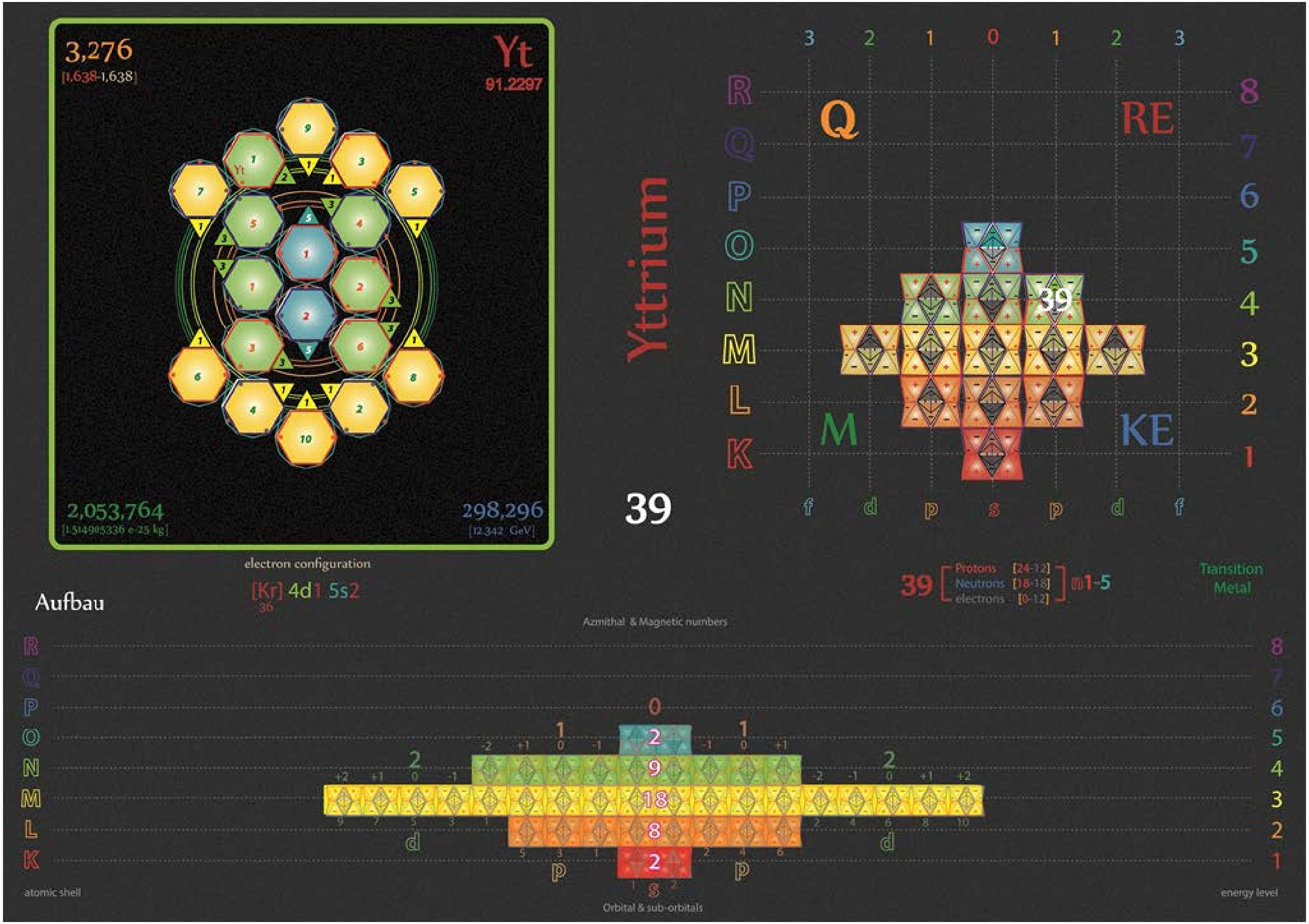
3,276
[1,638-1,638]
Yt
91.2297
2,053,764
[1.514905336 e-25 kg]
298,296
[12.342 GeV]
Yttrium
39
electron configuration
[Kr] 4d1 5s2
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
39
f d p s p d f
39 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Transition Metal
Azmithal & Magnetic numbers
0
1
1
2
2
2
9
18
8
2
-2 +1 0 -1
-1 0 +1
+2 +1 0 -1
-2 -1 0 +1 +2
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
d
d
p
p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.39 - Yttrium atom

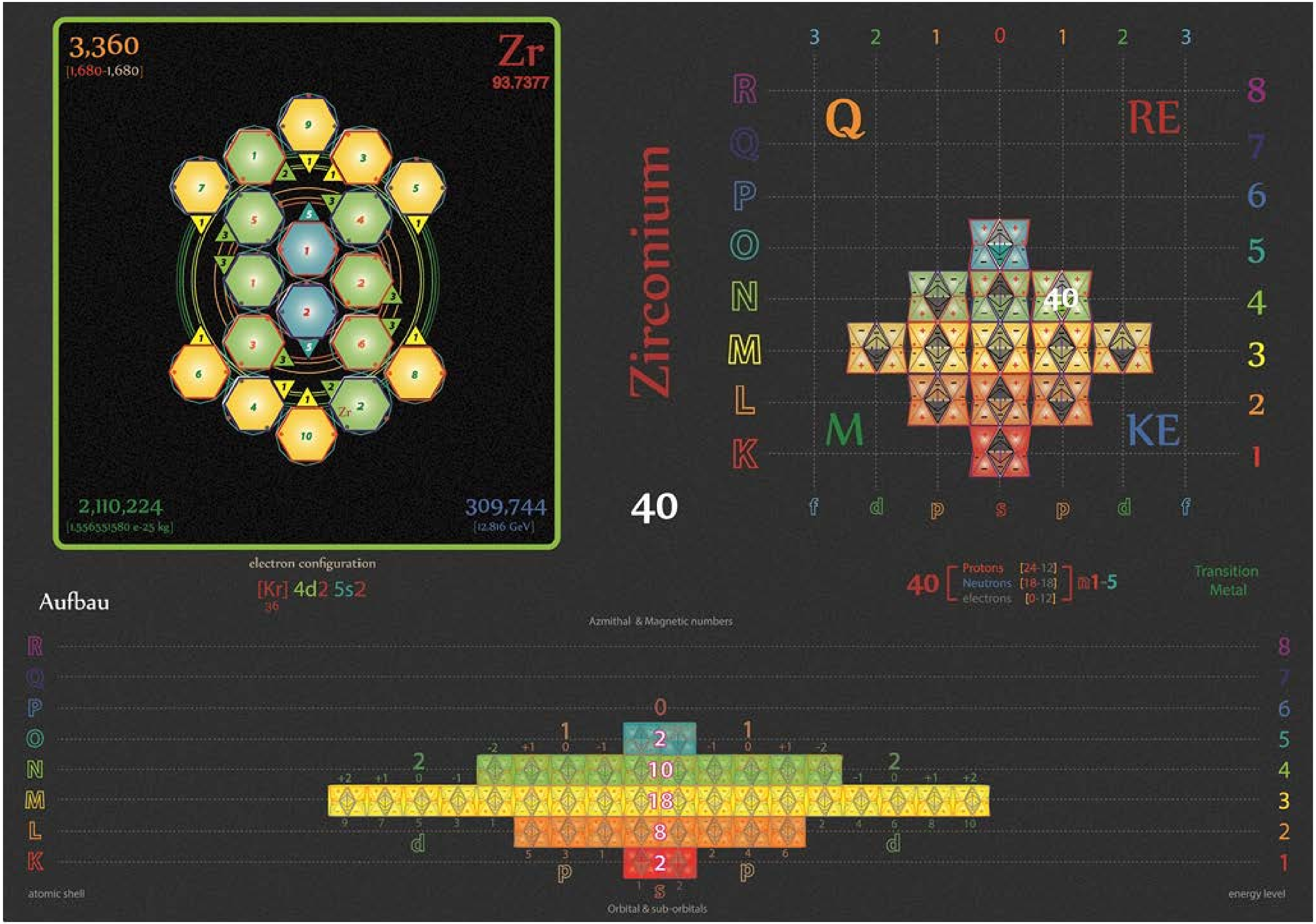
3,360
[1,680-1,680]
Zr
93.7377
2,110,224
[1.556551580 e-25 kg]
309,744
[12.816 GeV]
Zirconium
40
electron configuration
[Kr] 4d2 5s2
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
40
f d p s p d f
40 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Transition Metal
Azmithal & Magnetic numbers
0
1 1
2 2
2
10
18
8
2
d d
p p
s
atomic shell
energy level
Orbital & sub-orbitals

Tetryonics 51.40 - Zirconium atom

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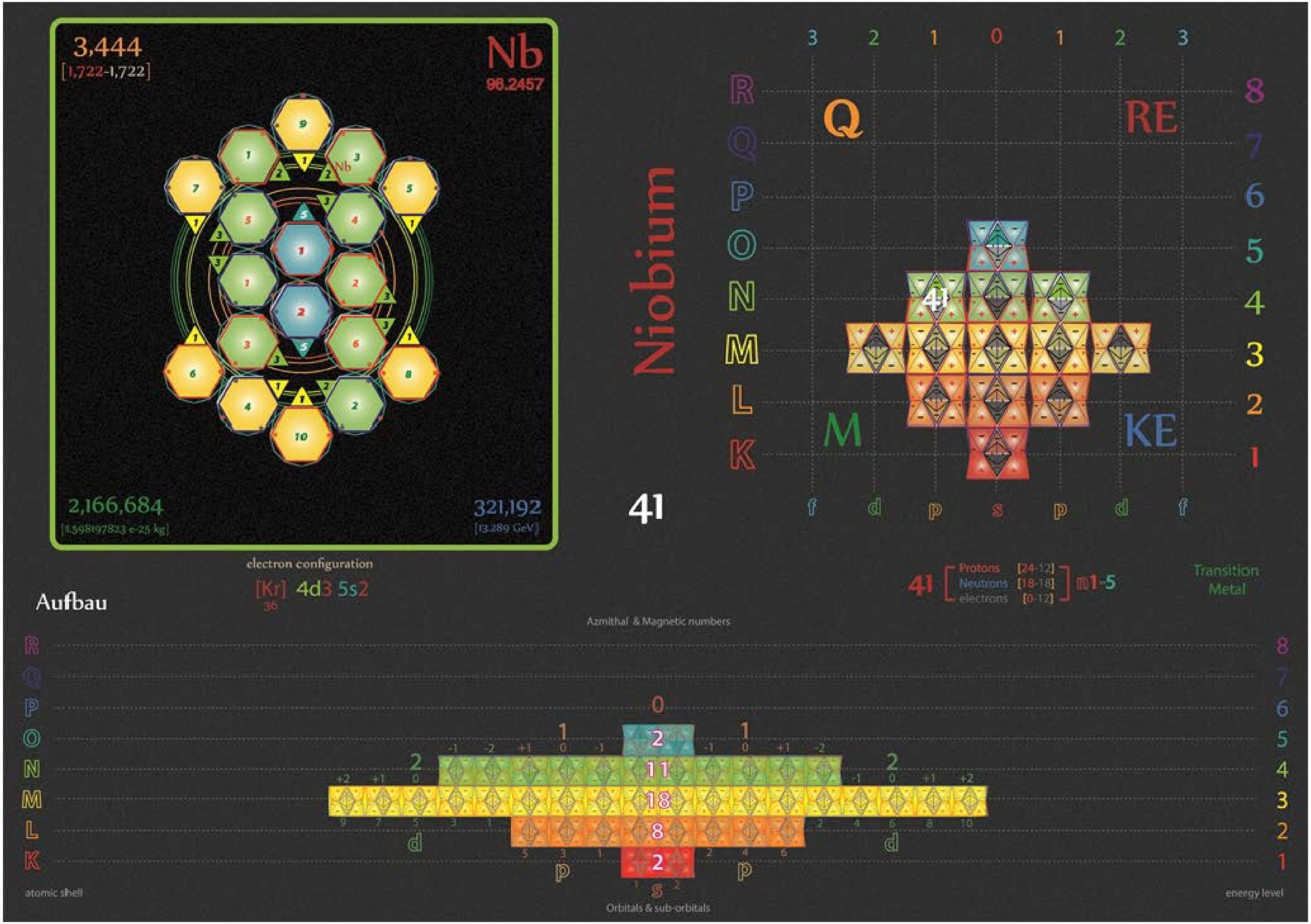
3,444
[1,722-1,722]
Nb
92.2457
2,166,684
[1.598197823 e-25 kg]
321,192
[13.289 GeV]
Niobium
41
electron configuration
[Kr] 4d3 5s2
36
Aufbau
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
41 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Transition Metal
Azmithal & Magnetic numbers
0
1
1
2
2
2
11
18
8
2
d
p
s
p
d
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.41 - Niobium atom

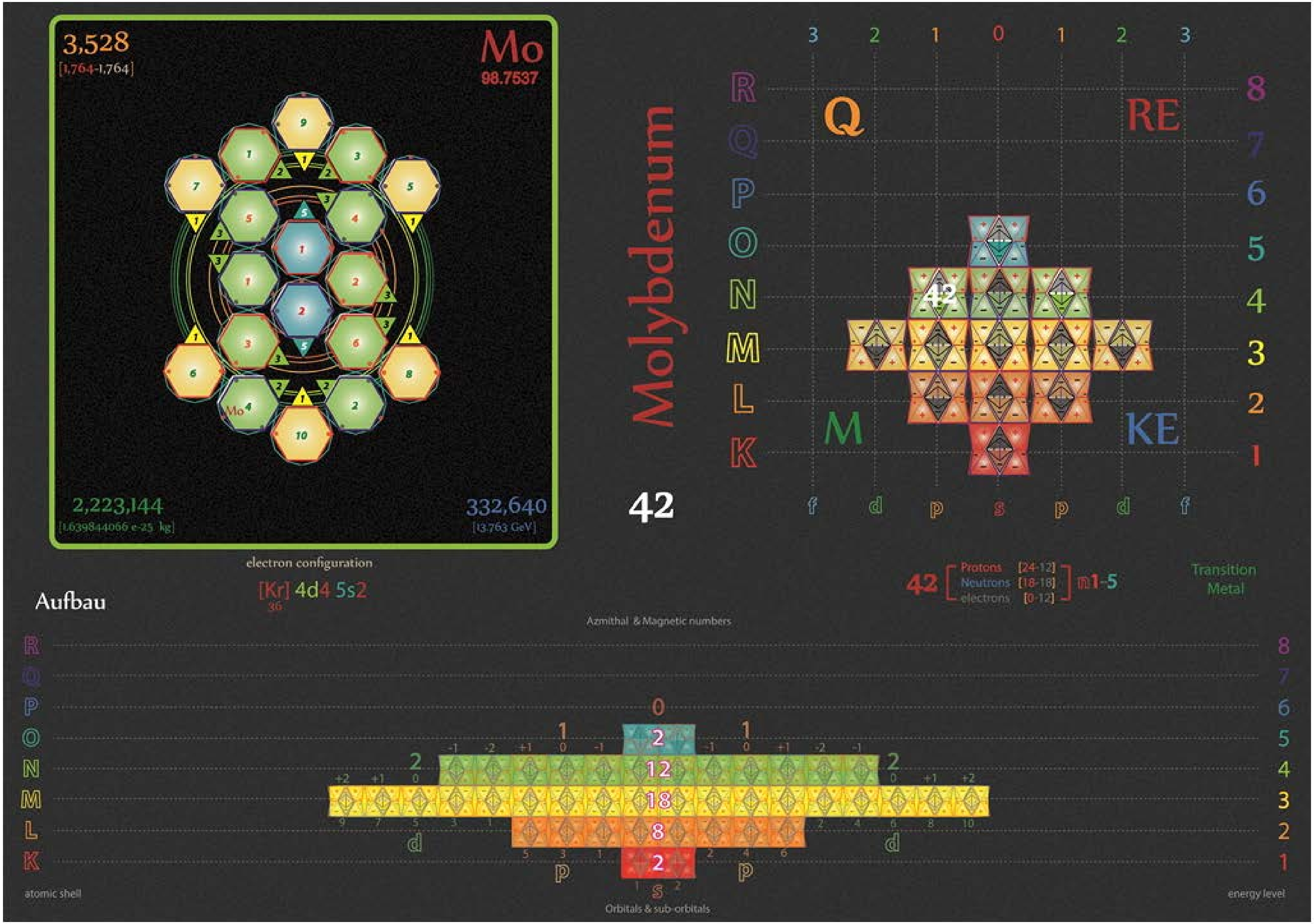
3,528
[1,764-1,764]
Mo
98.7537
2,223,144
[1.639844066 e-25 kg]
332,640
[13.763 GeV]
Molybdenum
42
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
Q
RE
M
KE
8
7
6
5
4
3
2
1
f d p s p d f
42 Protons [24-12] Neutrons [18-18] electrons [0-12] m1-5
Transition Metal
electron configuration
[Kr] 4d4 5s2
36
Aufbau
Azmithal & Magnetic numbers
2
12
18
8
2
d
p
s
p
d
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.42 - Molybdenum atom

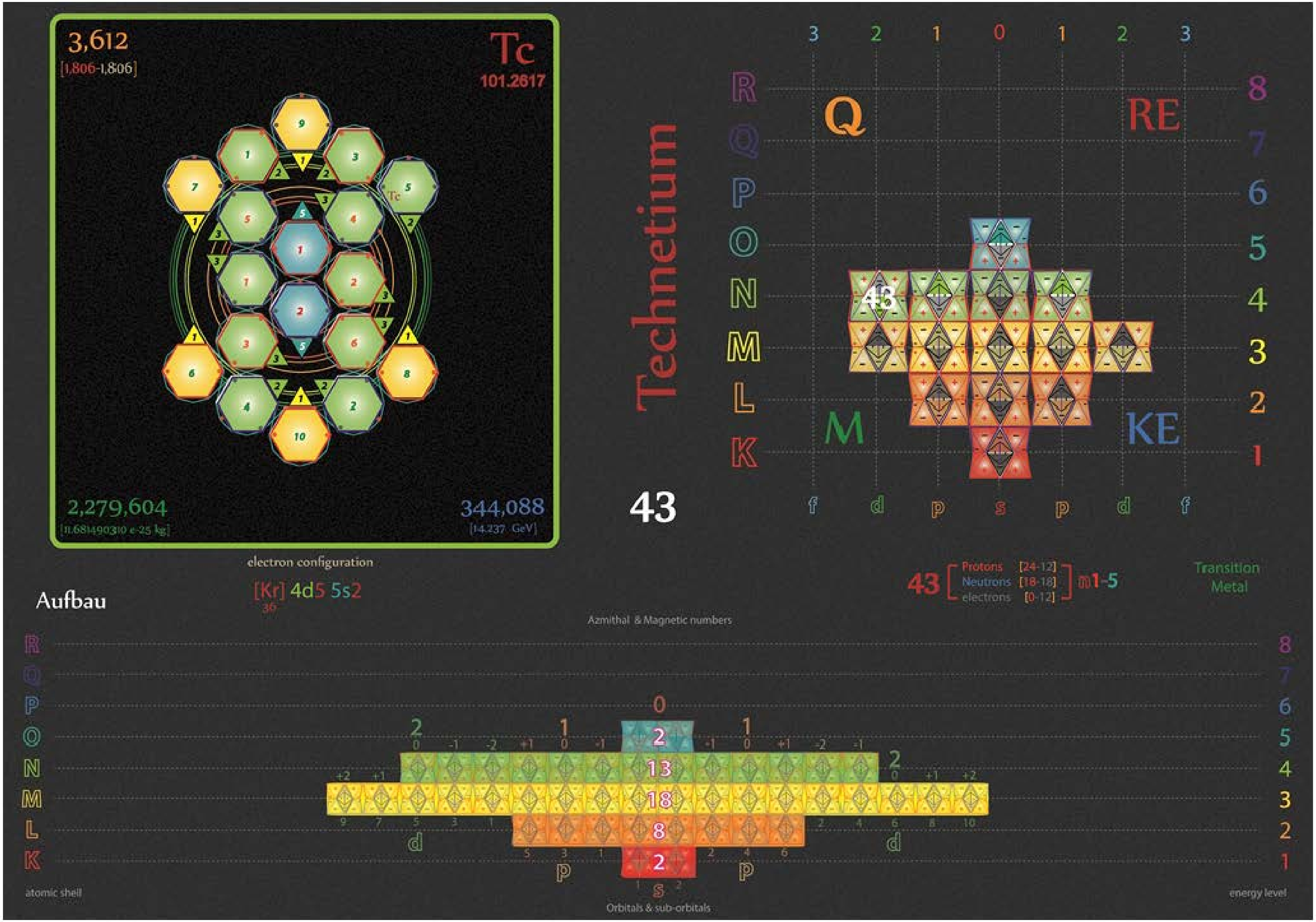
3,612
[1,806-1,806]
Tc
101.2617
Tc
2,279,604
[1.681490310 e-25 kg]
344,088
[14.237 GeV]
Technetium
43
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
43
f d p s p d f
electron configuration
[Kr] 4d5 5s2
36
Aufbau
43 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Transition Metal
Azmithal & Magnetic numbers
0
2
13
18
8
2
d
p
s
Orbitals & sub-orbitals
atomic shell
energy level

Tetryonics 51.43 - Technetium atom

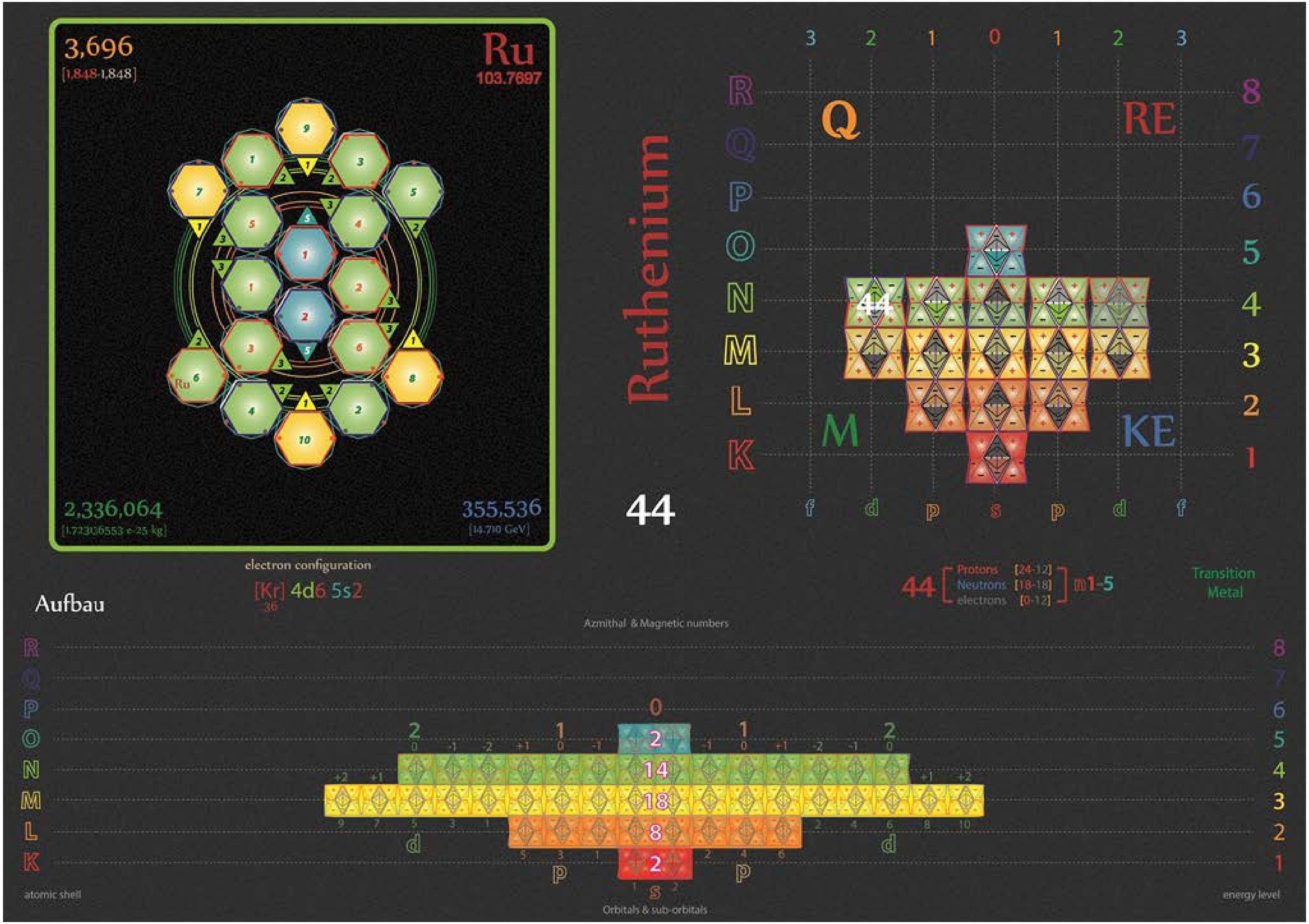
3,696
[1,848-1,848]
Ru
103.7697
2,336,064
[1.7230,6553 e-25 kg]
355,536
[14.710 GeV]
Ruthenium
44
electron configuration
[Kr] 4d6 5s2
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
44 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Transition Metal
Azmithal & Magnetic numbers
0
2
14
18
8
2
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.44 - Ruthenium atom

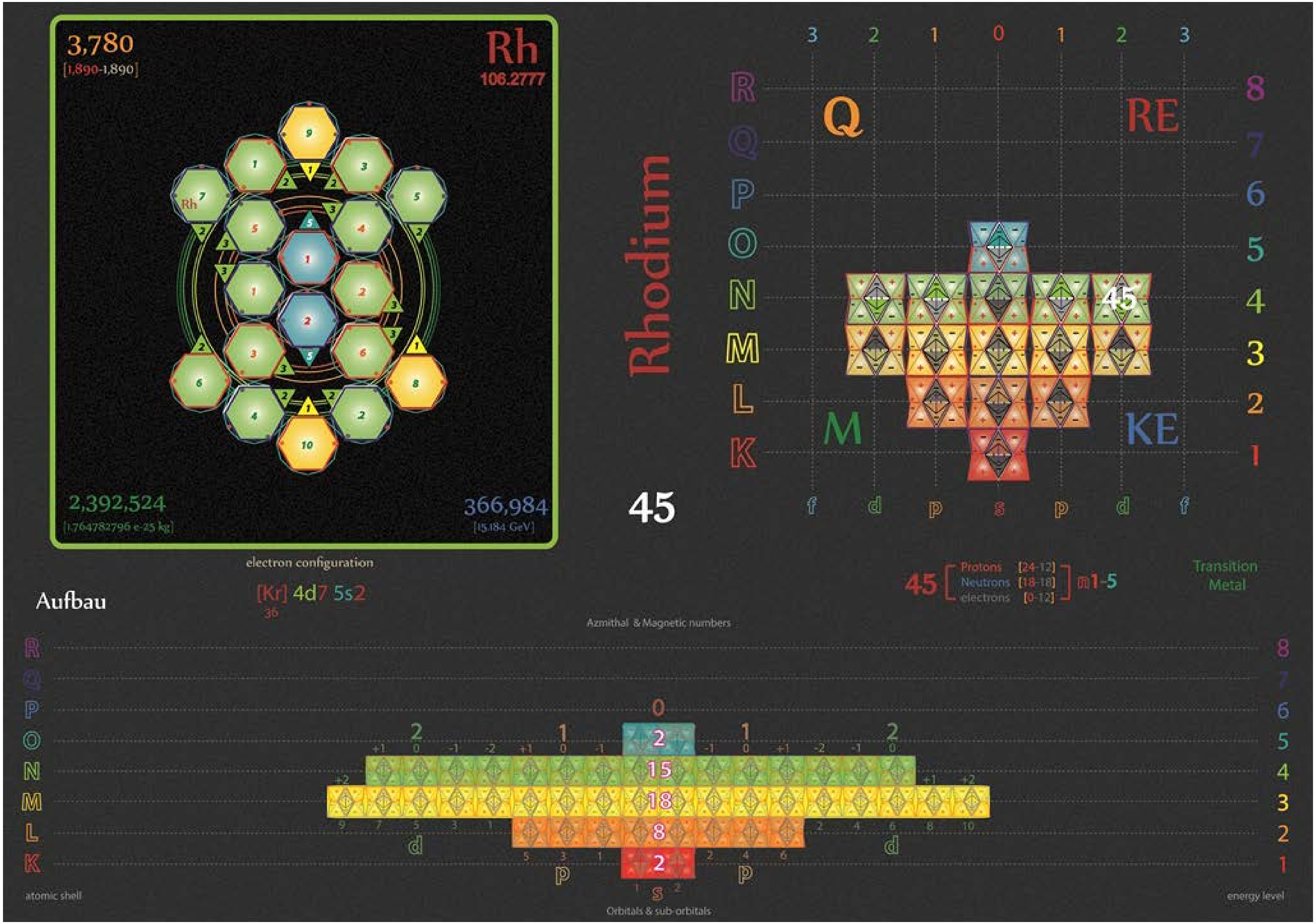
3,780
[1,890-1,890]
Rh
106.2777
Rh
2,392,524
[1.764782796 e-25 kg]
366,984
[15.184 GeV]
Rhodium
45
electron configuration
[Kr] 4d7 5s2
36
Aufbau
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
Q
RE
M
KE
45
f d p s p d f
45
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-5
Transition Metal
Azmithal & Magnetic numbers
0
2
15
18
8
2
d
d
p
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.45 - Rhodium atom

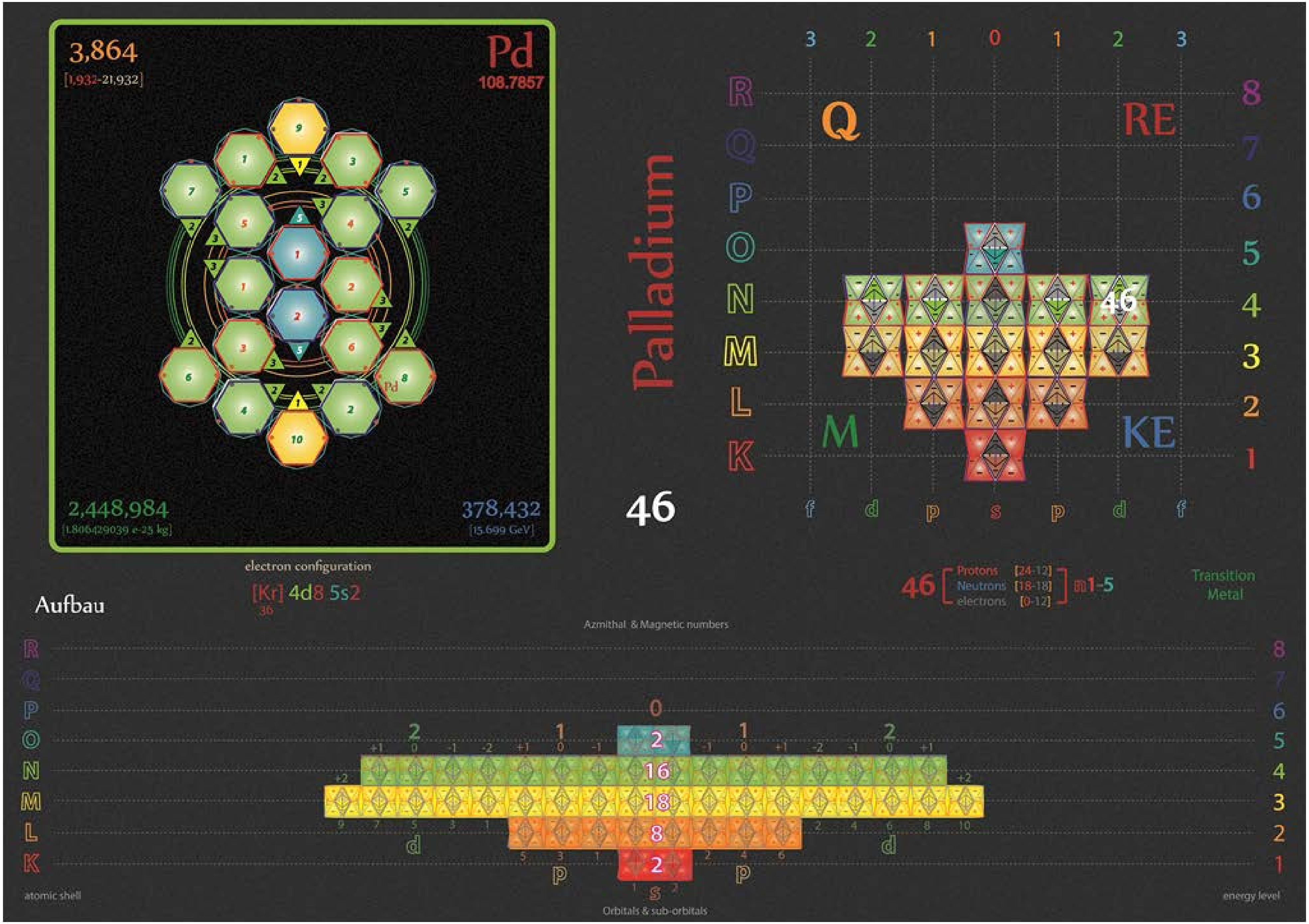
3,864
[1,932-21,932]
Pd
108.7857
2,448,984
[1.806429039 e-25 kg]
378,432
[15.699 GeV]
Palladium
46
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Kr] 4d8 5s2
36
Aufbau
Azmithal & Magnetic numbers
46
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-5
Transition Metal
2
16
18
8
2
d
p
s
d
p
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.46 - Palladium atom

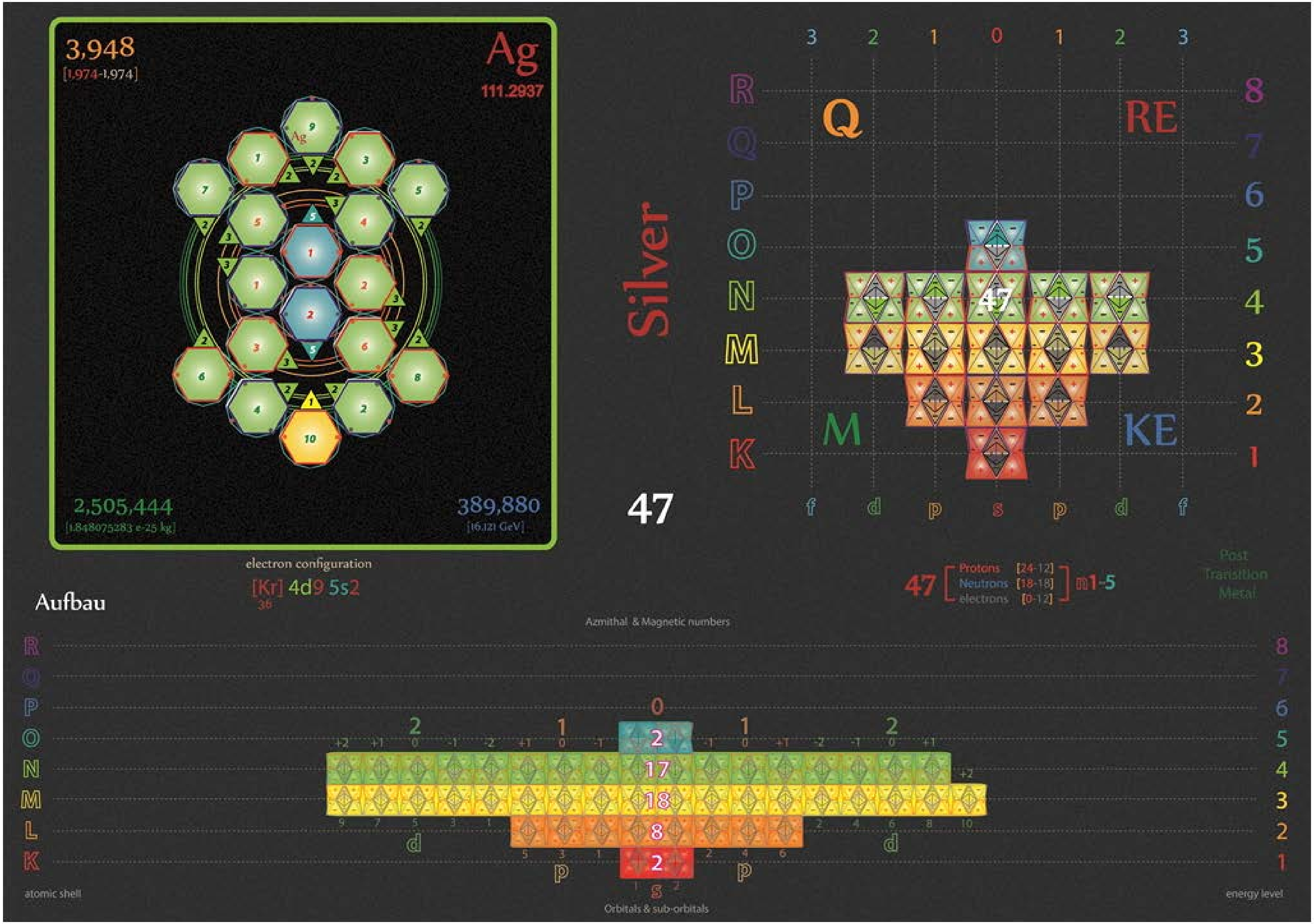
3,948
[1,974-1,974]
Ag
111.2937
2,505,444
[1.848075283 e-25 kg]
389,880
[16.121 GeV]
Silver
47
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
47 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Post Transition Metal
electron configuration
[Kr] 4d9 5s2
36
Aufbau
Azmithal & Magnetic numbers
2 1 0 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
2
17
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.47 - Silver atom

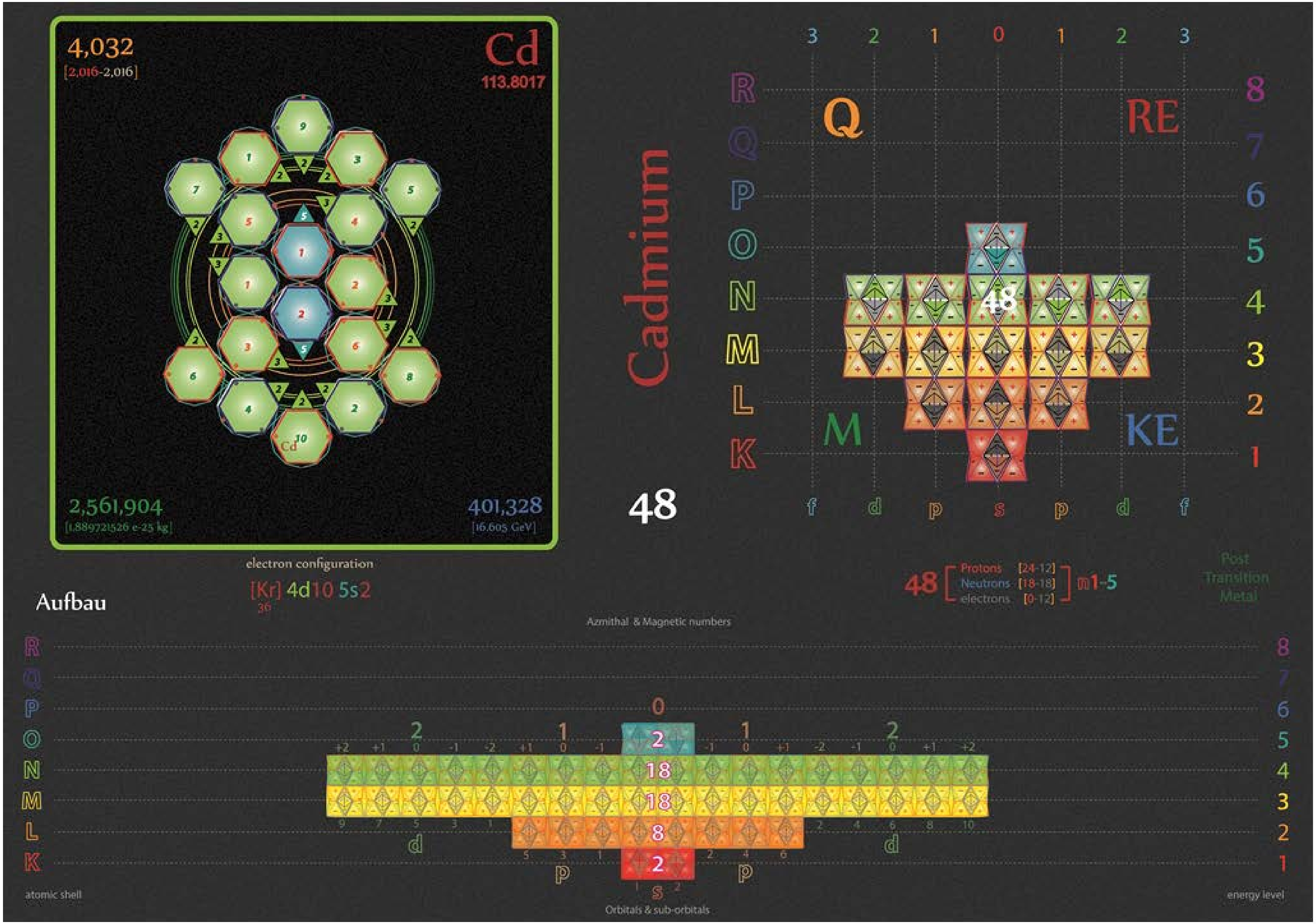
4,032
[2,016-2,016]
Cd
113.8017
2,561,904
[1.889721526 e-25 kg]
401,328
[16.605 GeV]
Cadmium
48
electron configuration
[Kr] 4d10 5s2
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
48 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Post Transition Metal
Azmithal & Magnetic numbers
0
2 1 1 2
+2 +1 0 -1 -2 +1 0 -1 -1 0 +1 -2 -1 0 +1 +2
2
18
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.48 - Cadmium atom

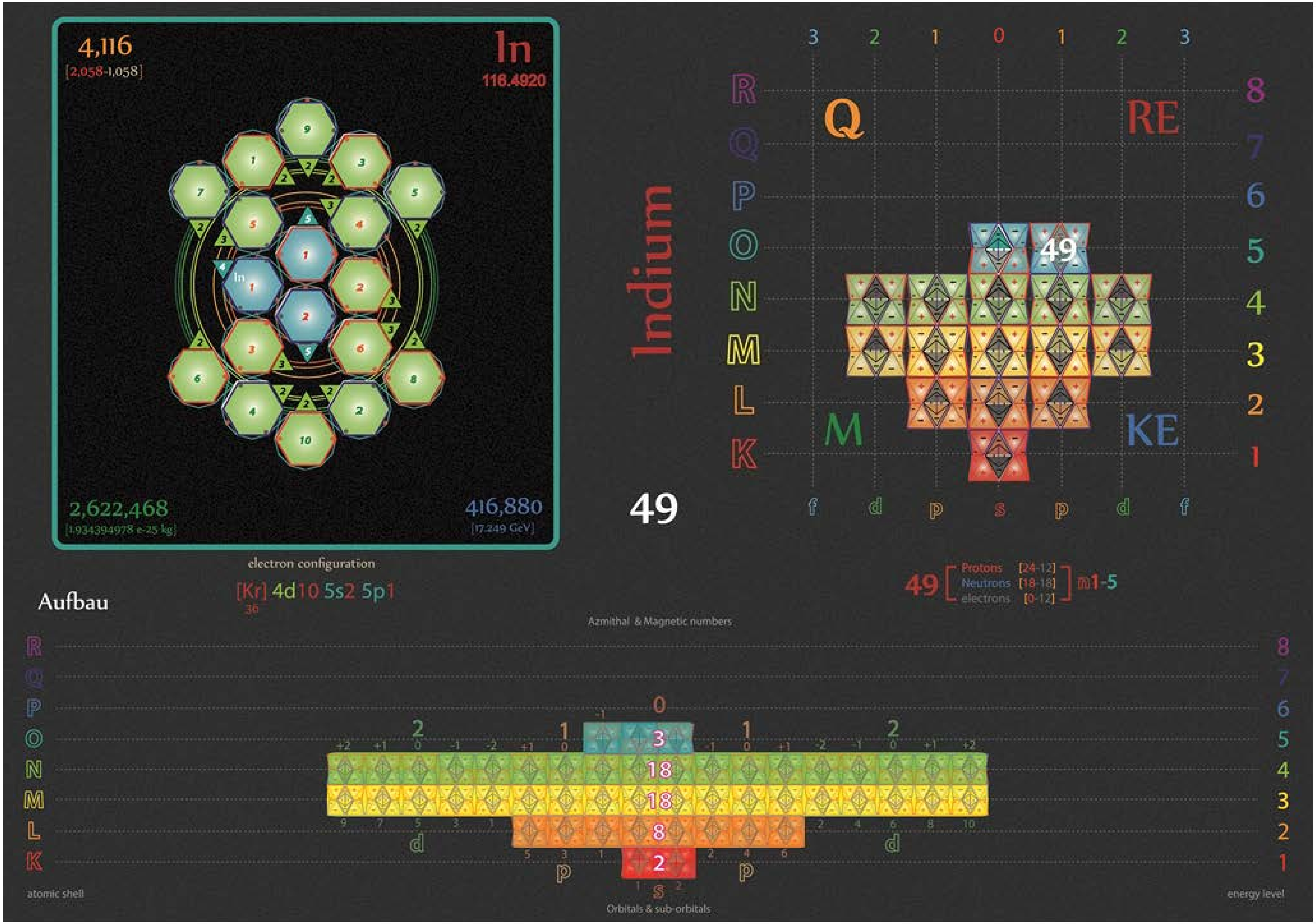
4,116
[2,058-1,058]
In
116.4920
2,622,468
[1.934394978 e-25 kg]
416,880
[17.249 GeV]
Indium
49
electron configuration
[Kr] 4d10 5s2 5p1
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
49
f d p s p d f
49 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Azmithal & Magnetic numbers
3
18
18
8
2
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.49 - Indium atom

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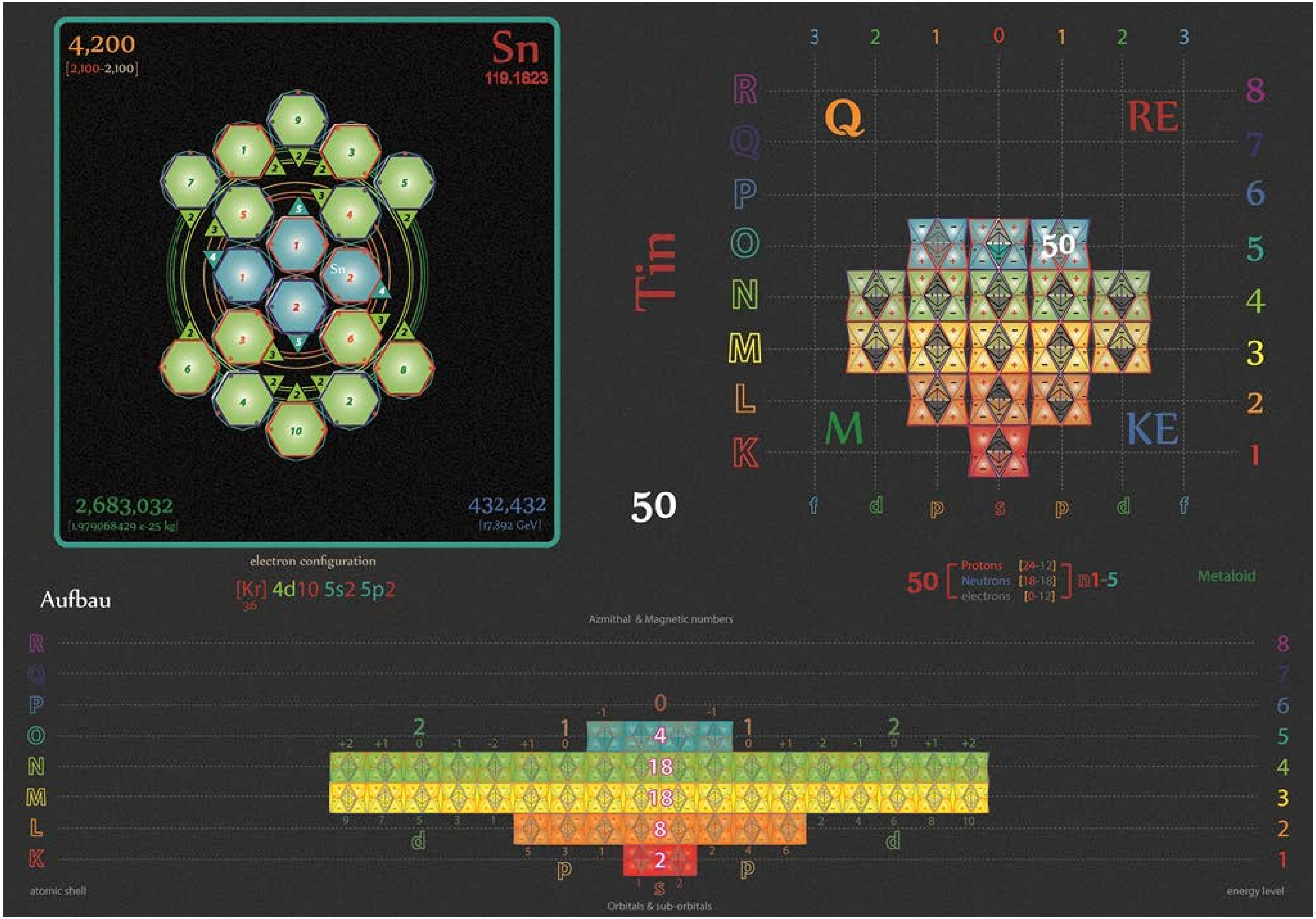
4,200
[2,100-2,100]
Sn
119.1823
2,683,032
[1.979068429 e-25 kg]
432,432
[17.392 GeV]
Tin
50
electron configuration
[Kr] 4d10 5s2 5p2
36
Aufbau
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
50
50 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Metaloid
Azmithal & Magnetic numbers
4
18
18
8
2
d
p
s
p
d
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.50 - Tin atom

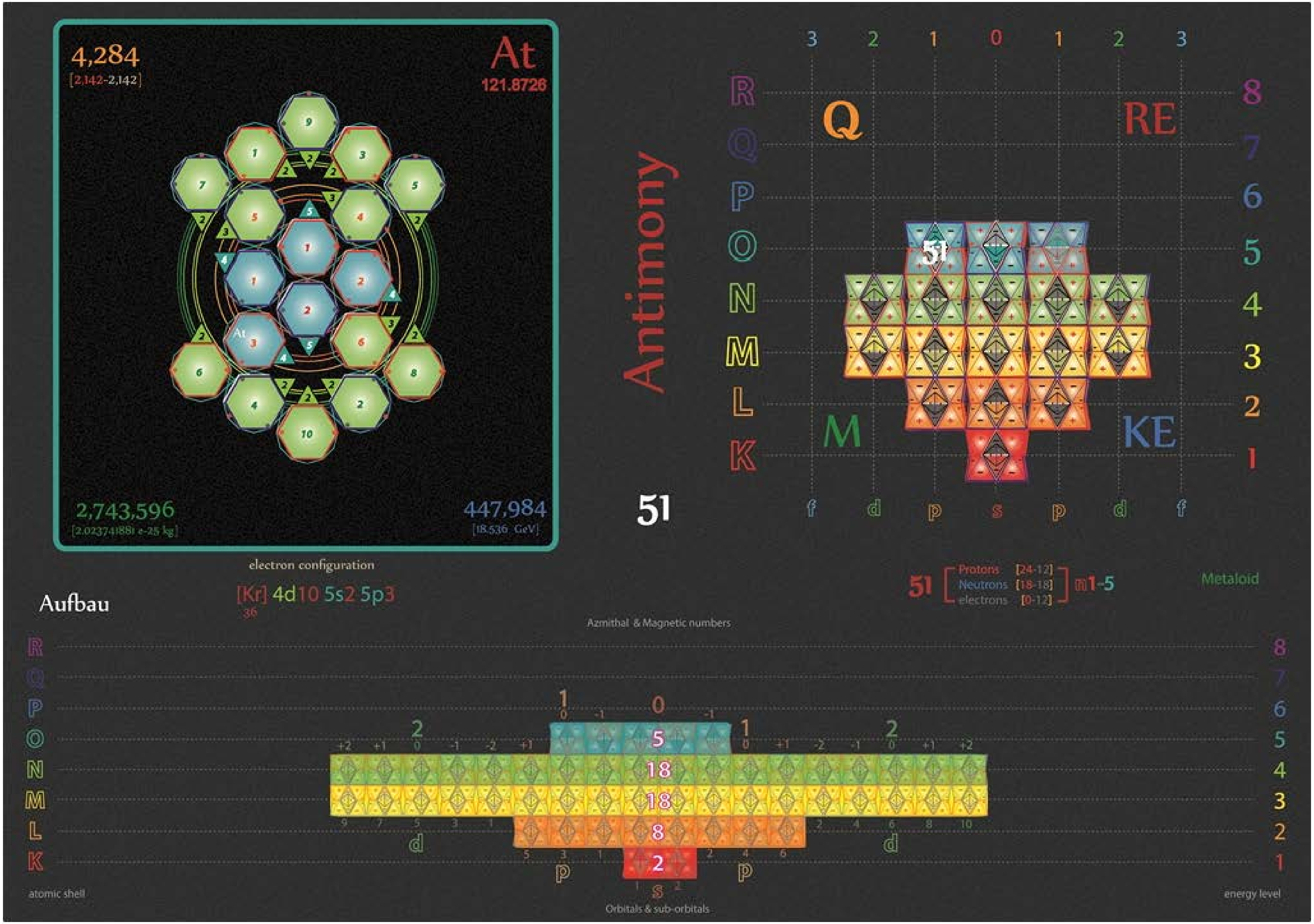
4,284
[2,142-2,142]
At
121.8726
2,743,596
[2.02374188i e-25 kg]
447,984
[18.536 GeV]
Antimony
51
electron configuration
[Kr] 4d10 5s2 5p3
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
51 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Metaloid
Azmithal & Magnetic numbers
5
18
18
8
2
d p s p d
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.51 - Antimony atom

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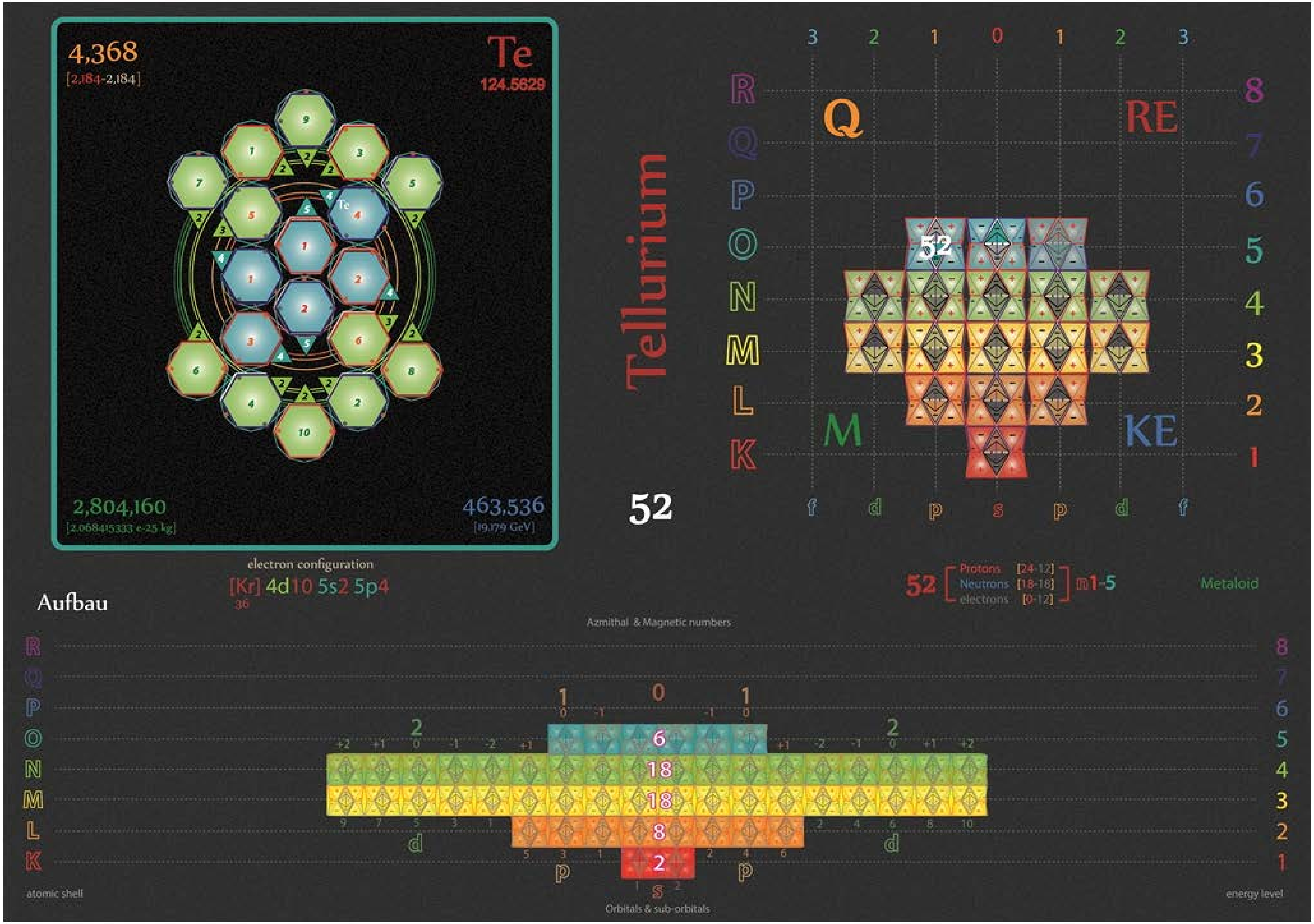
4,368
[2,184-2,184]
Te
124.5629
2,804,160
[2.068415333 e-25 kg]
463,536
[19.179 GeV]
Tellurium
52
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Kr] 4d10 5s2 5p4
36
Aufbau
52 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Metaloid
Azmithal & Magnetic numbers
6
18
18
8
2
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.52 - Tellurium atom

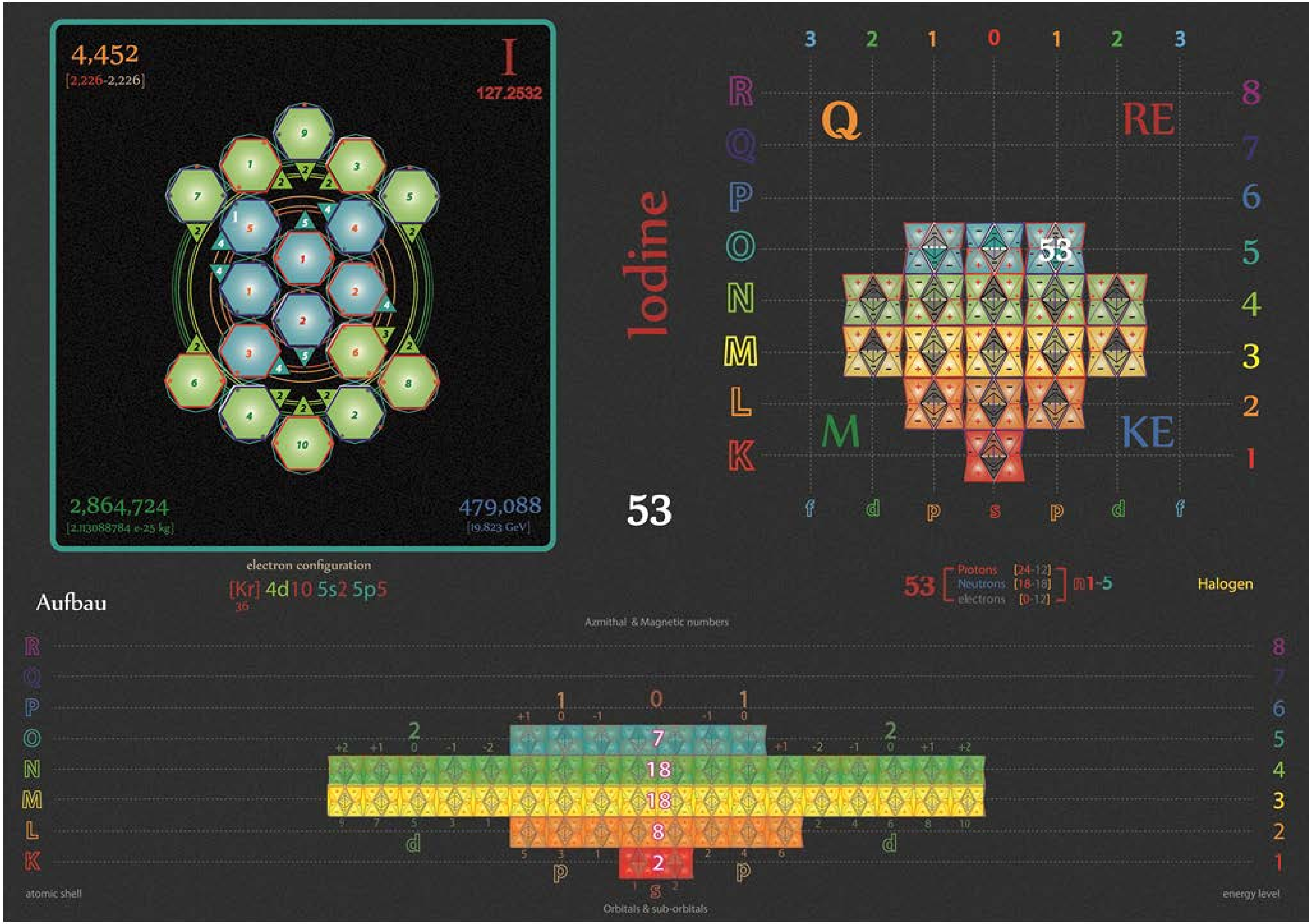
4,452
[2,226-2,226]
I
127.2532
2,864,724
[2.113088784 e-25 kg]
479,088
[19.823 GeV]
Iodine
53
electron configuration
[Kr] 4d10 5s2 5p5
36
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
53
f d p s p d f
53 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Halogen
Azmithal & Magnetic numbers
1 0 1
+1 0 -1 -1 0
2 2
+2 +1 0 -1 -2 +1 -2 -1 0 +1 +2
7
18
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.53 - Iodine atom

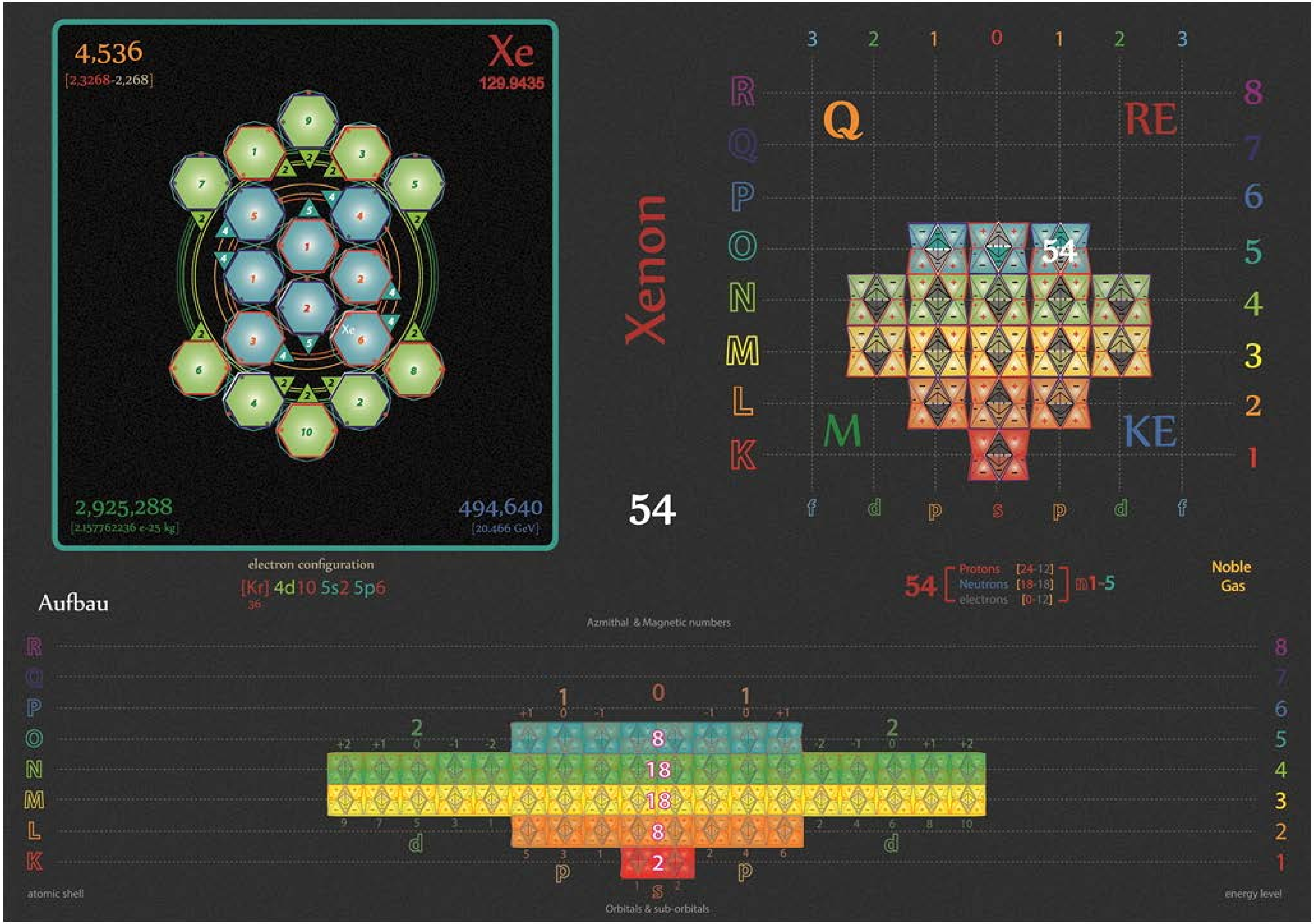
4,536
[2,3268-2,268]
Xe
129.9435
2,925,288
[2.157762236 e-25 kg]
494,640
[20.466 GeV]
Xenon
54
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Kr] 4d10 5s2 5p6
36
Aufbau
54 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-5
Noble Gas
Azmithal & Magnetic numbers
1 0 1
+1 0 -1 -1 0 +1
2 2
+2 +1 0 -1 -2 -2 -1 0 +1 +2
8
18
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.54 - Xenon atom

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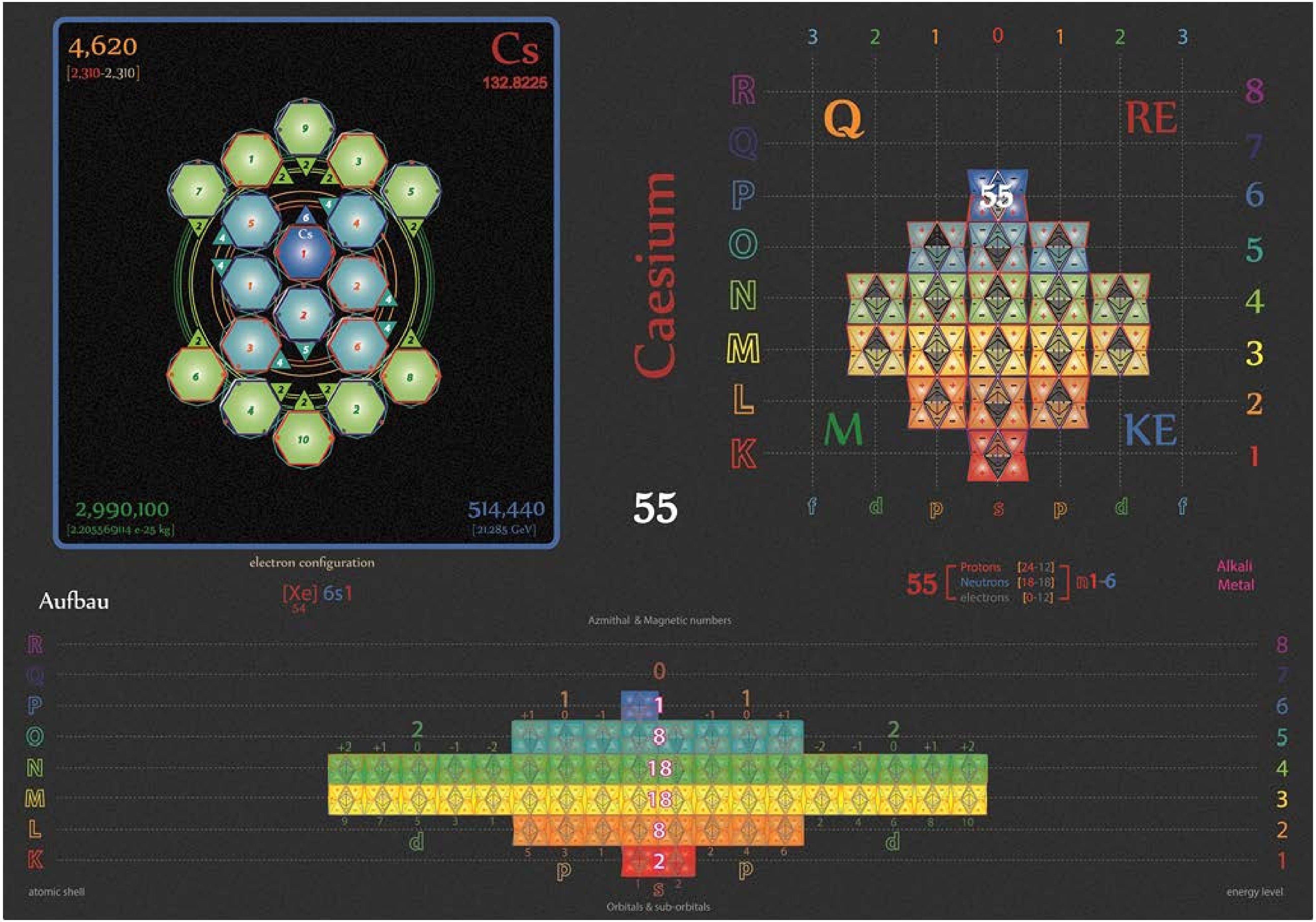
4,620
[2,310-2,310]
Cs
132.8225
2,990,100
[2.205569114 e-25 kg]
514,440
[21.285 GeV]
Caesium
55
electron configuration
[Xe] 6s1
54
Aufbau
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
55
55 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Alkali Metal
Azmithal & Magnetic numbers
0
1
8
18
18
8
2
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.55 - Caesium atom

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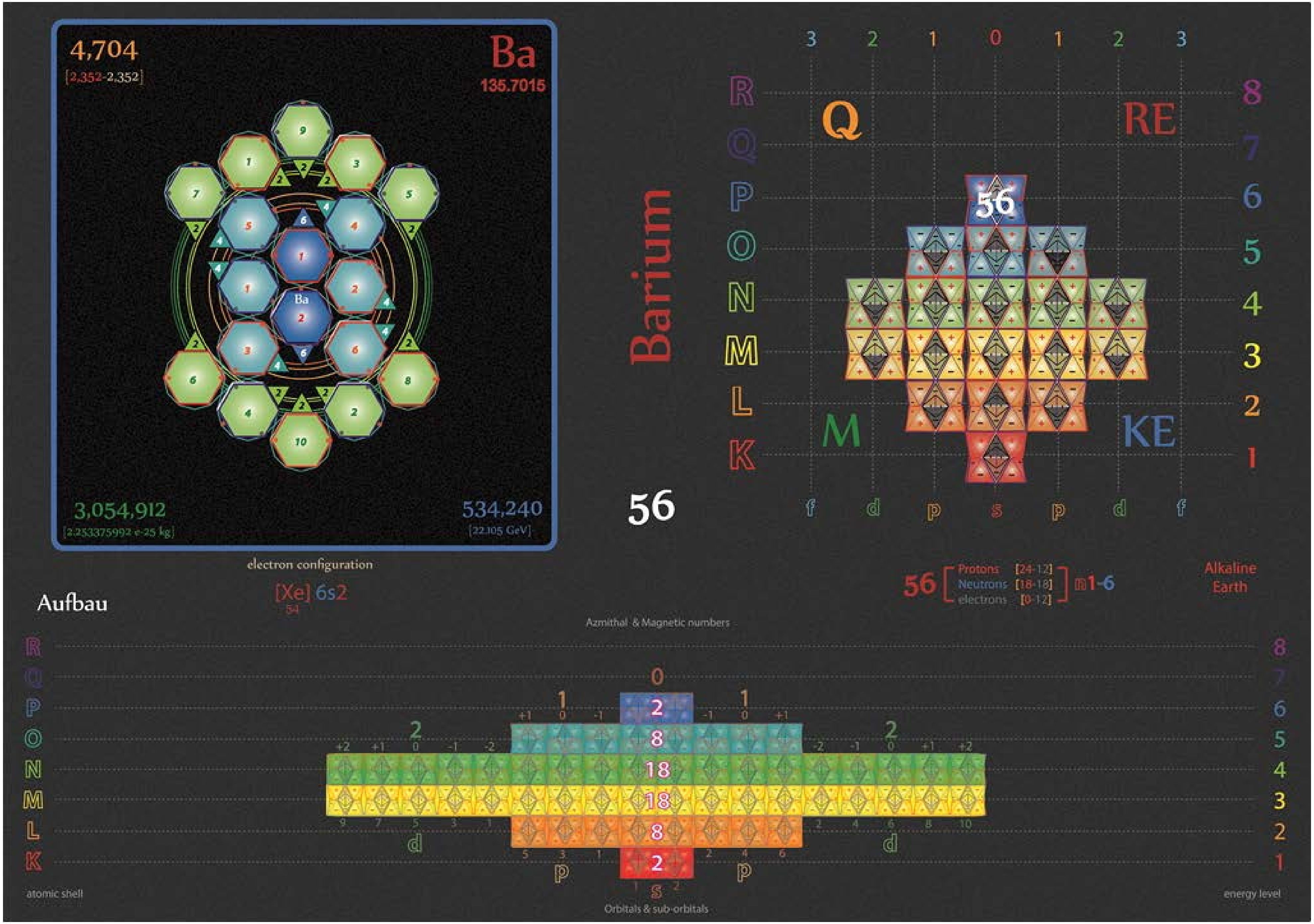
4,704
[2,352-2,352]
Ba
135.7015
3,054,912
[2.253375992 e-25 kg]
534,240
[22.105 GeV]
Barium
56
3 2 1 0 1 2 3
R Q P O N M L K
Q
RE
M
KE
8 7 6 5 4 3 2 1
f d p s p d f
56
electron configuration
[Xe] 6s2
54
Aufbau
56 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-6
Alkaline Earth
Azmithal & Magnetic numbers
0
1 1
2 2
+1 0 -1 -1 0 +1
+2 +1 0 -1 -2 -2 -1 0 +1 +2
2
8
18
18
8
2
9 7 5 3 1 2 4 6 8 10
d d
5 3 1 2 4 6
p p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.56 - Barium atom

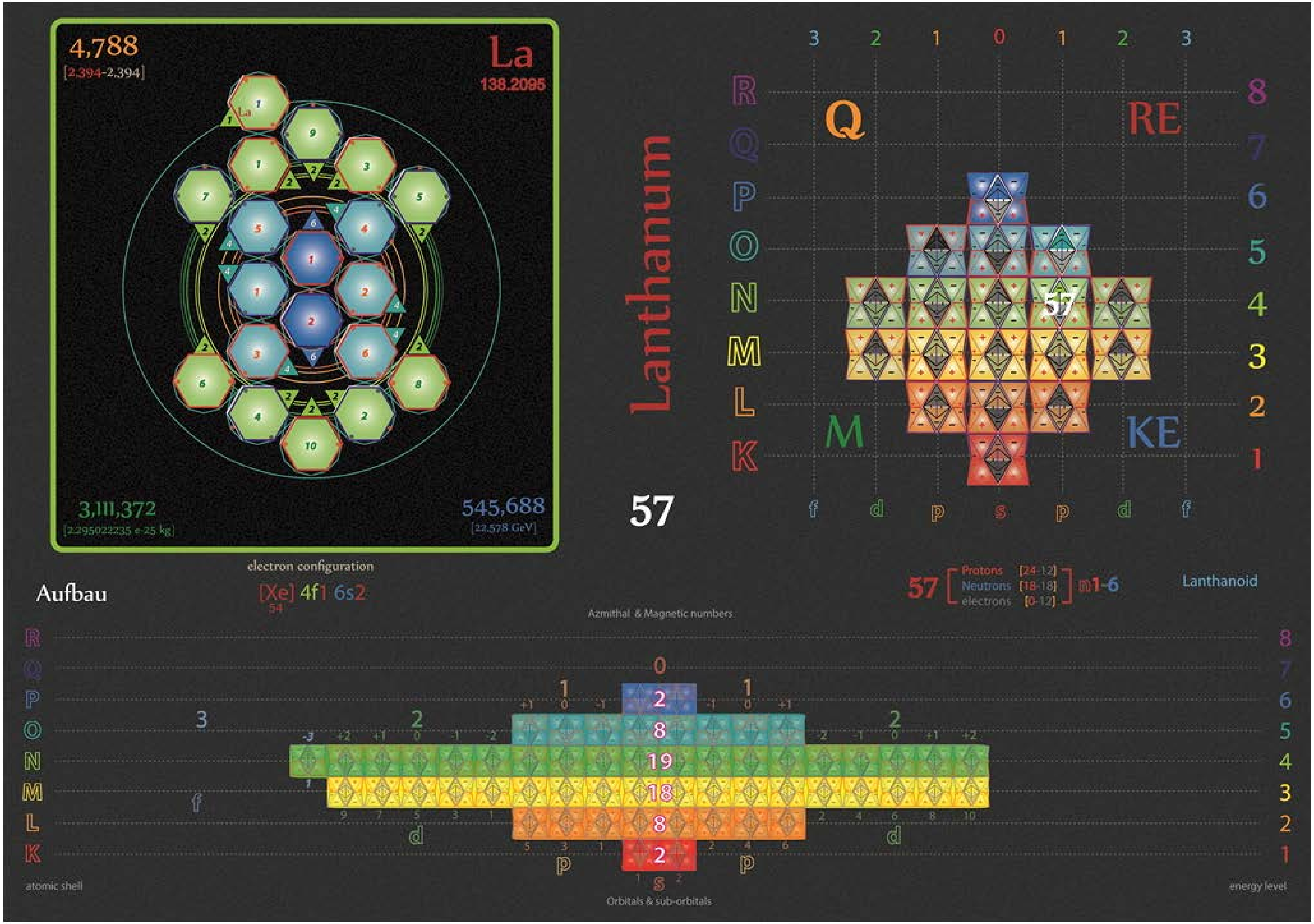
4,788
[2,394-2,394]
La
138.2095
3,111,372
[2.295022235 e-25 kg]
545,688
[22.578 GeV]
Lanthanum
57
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
57
f d p s p d f
electron configuration
[Xe] 4f1 6s2
54
Aufbau
57 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Azmithal & Magnetic numbers
0
1 1
2 2
3
+1 0 -1 -1 0 +1
-3 +2 +1 0 -1 -2 -2 -1 0 +1 +2
2
8
19
18
8
2
f
d d
p p
s
9 7 5 3 1 2 4 6 8 10
5 3 1 2 4 6
1 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.57 - Lanthanum atom

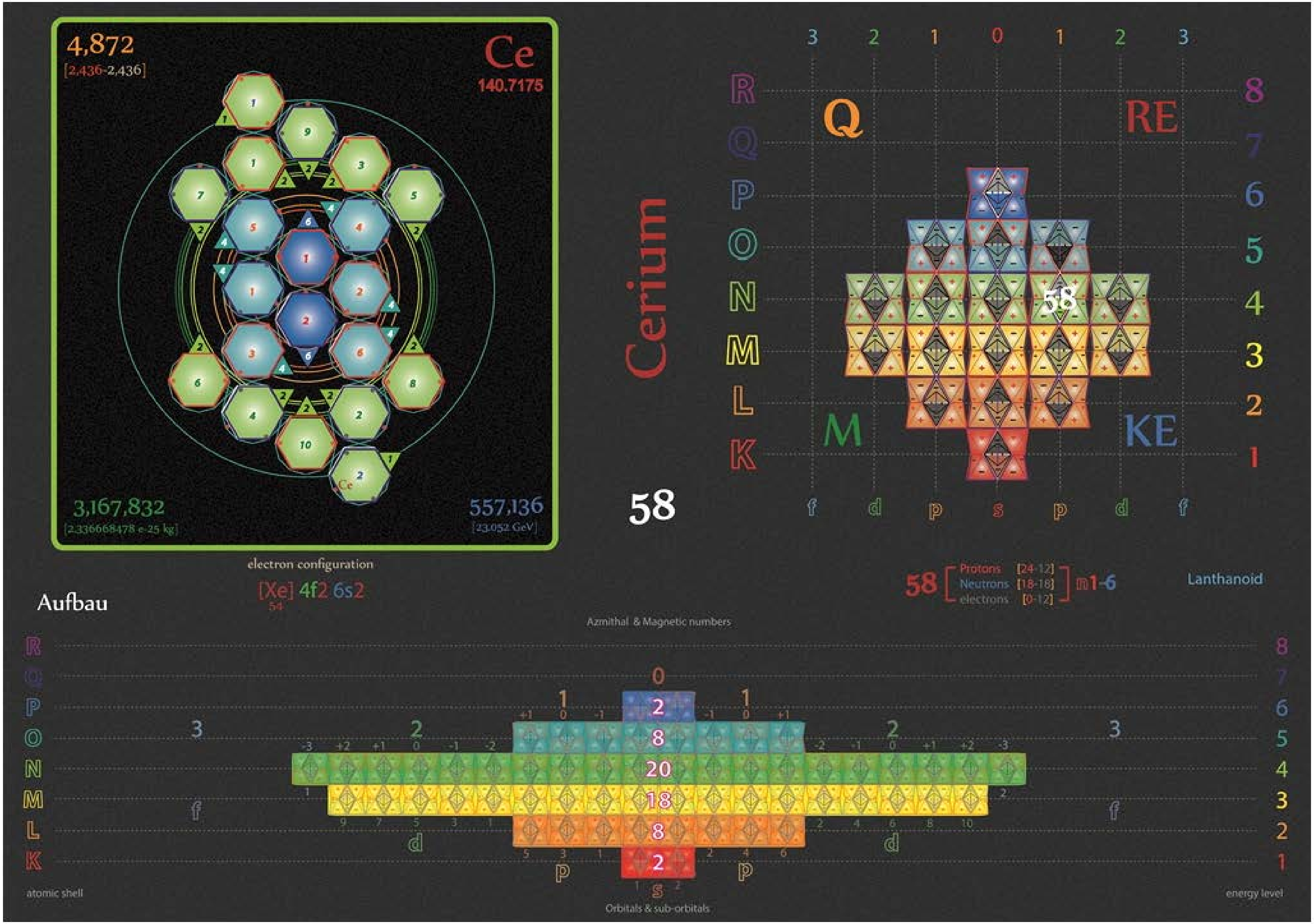
4,872
[2,436-2,436]
Ce
140.7175
3,167,832
[2.336668478 e-25 kg]
557,136
[23.052 GeV]
Cerium
58
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
Q
RE
M
KE
8 7 6 5 4 3 2 1
f d p s p d f
58
electron configuration
[Xe] 4f2 6s2
54
58 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Aufbau
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
2
8
20
18
8
2
f
d
p
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.58 - Cerium atom

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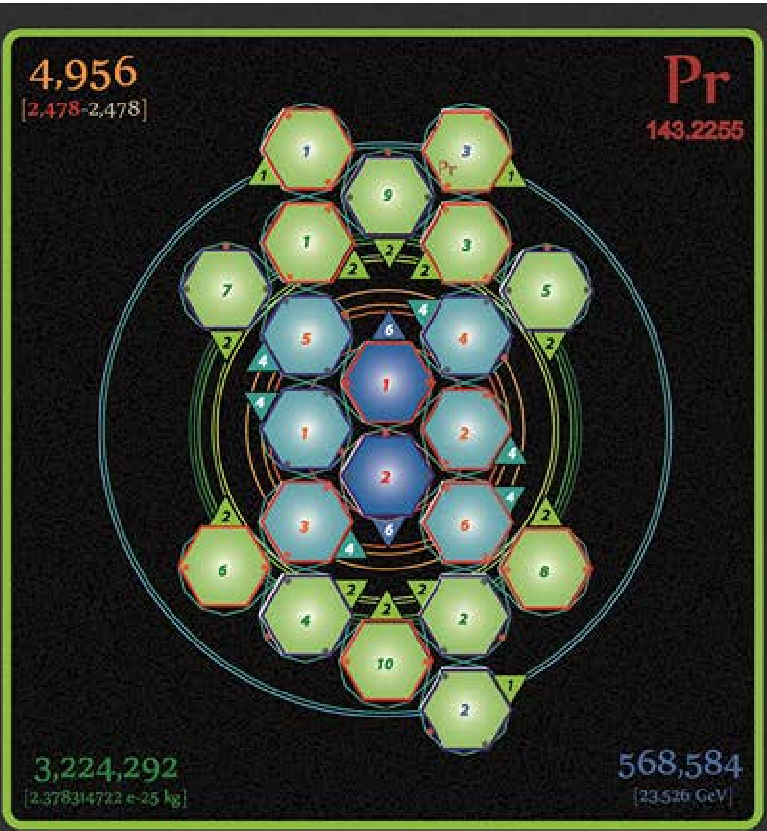

4,956
[2,478-2,478]

Pr
143.2255

3,224,292
[2.378314722 e-25 kg]

568,584
[23.526 GeV]

1
3
9
Pr
1
3
7
5
5
4
1
1
2
2
3
6
6
8
4
2
10
2

Praseodymium

59

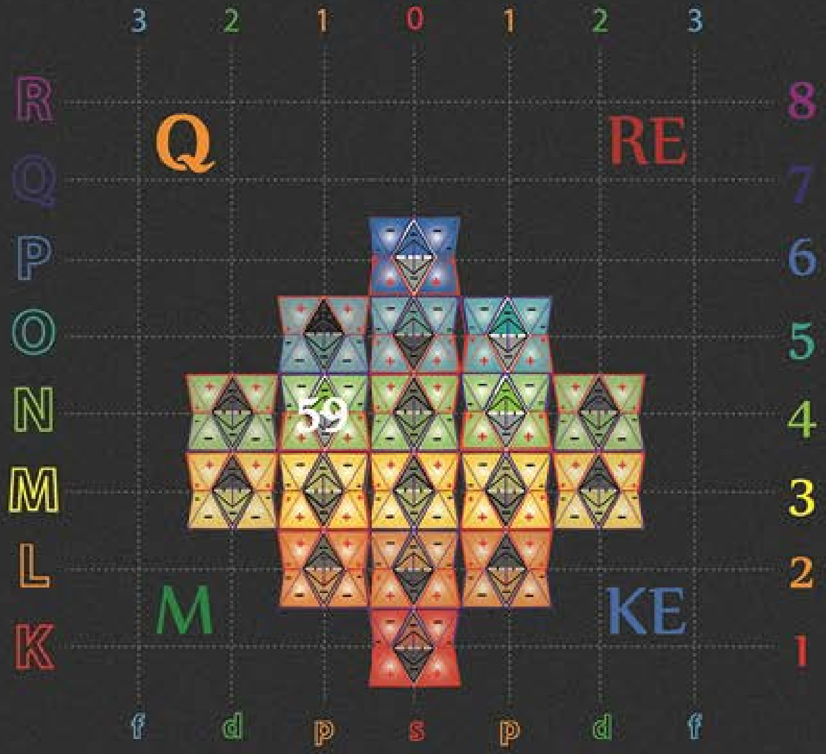

3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
59
f
d
p
s
p
d
f

59 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6

Lanthanoid

electron configuration

[Xe] 4f3 6s2
54

Aufbau

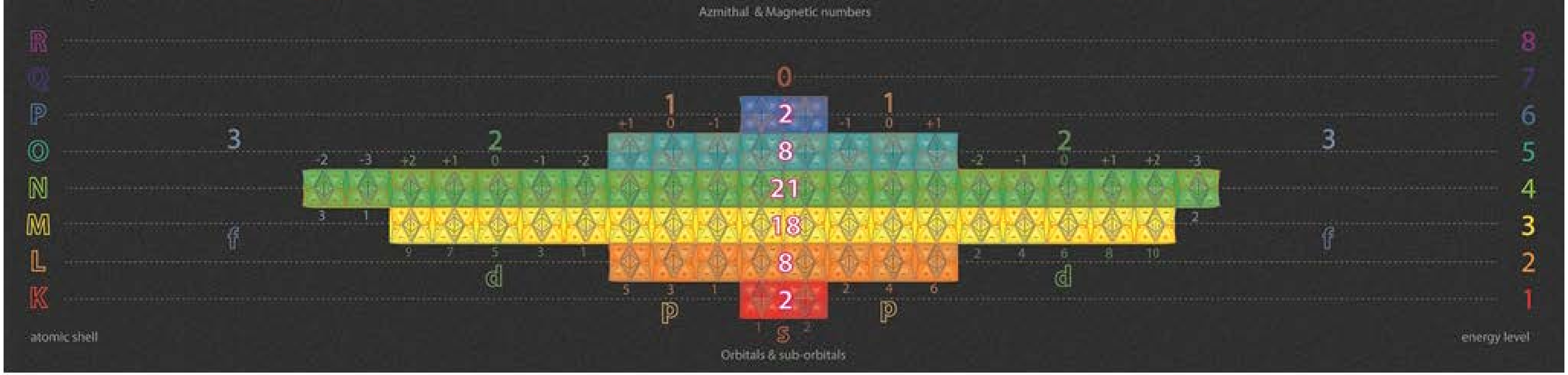

Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
2
8
21
18
8
2
1
1
2
2
3
3
f
f
d
d
p
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.59 - Praseodymium atom

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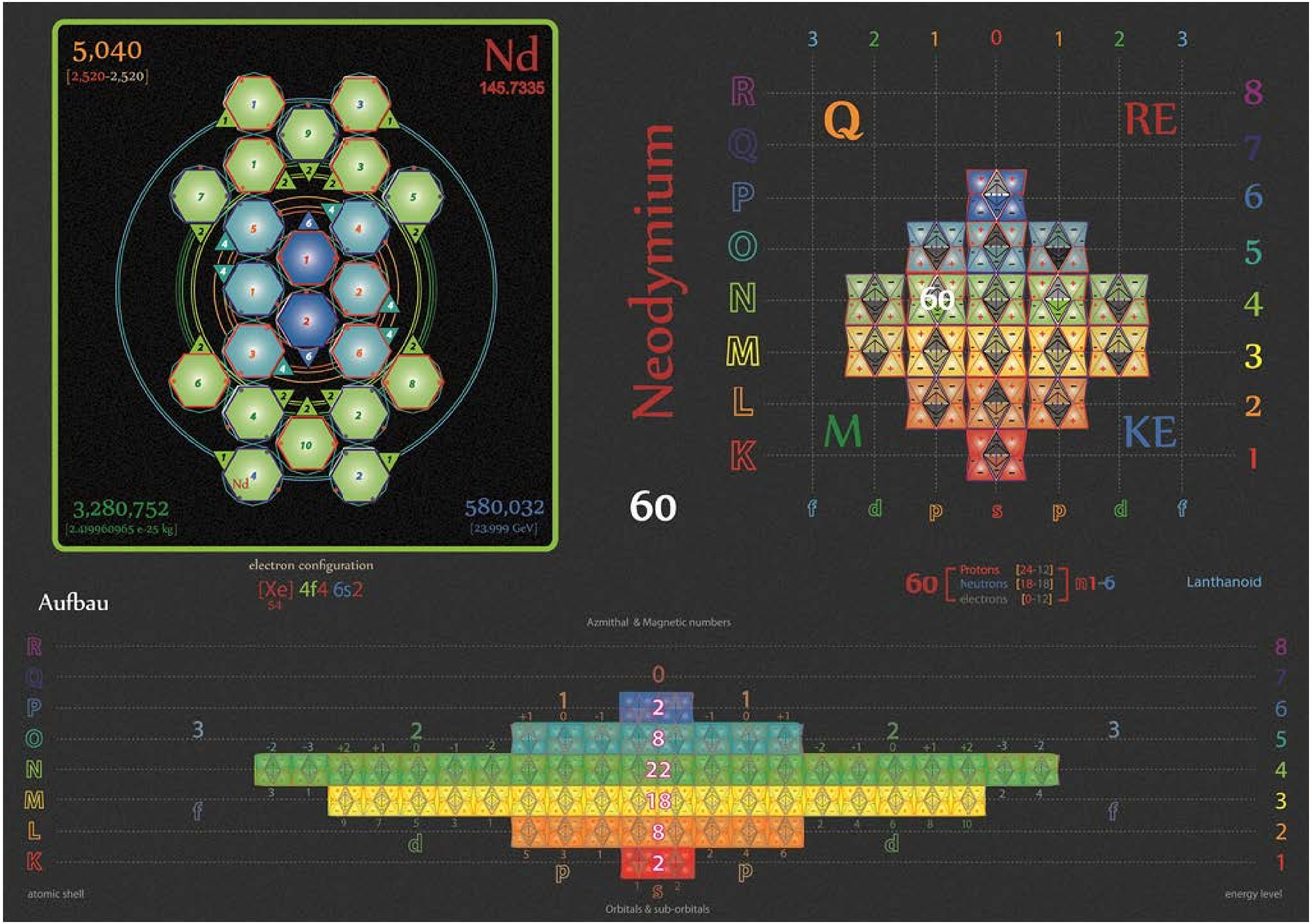
5,040
[2,520-2,520]
Nd
145.7335
3,280,752
[2.419960965 e-25 kg]
580,032
[23.999 GeV]
Neodymium
60
R
Q
P
O
N
M
L
K
Q
RE
M
KE
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
electron configuration
[Xe] 4f4 6s2
54
60 [Protons [24-12] neutrons [18-18] electrons [0-12]] n1-6
Lanthanoid
Aufbau
Azmithal & Magnetic numbers
0
2
8
22
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.60 - Neodymium atom

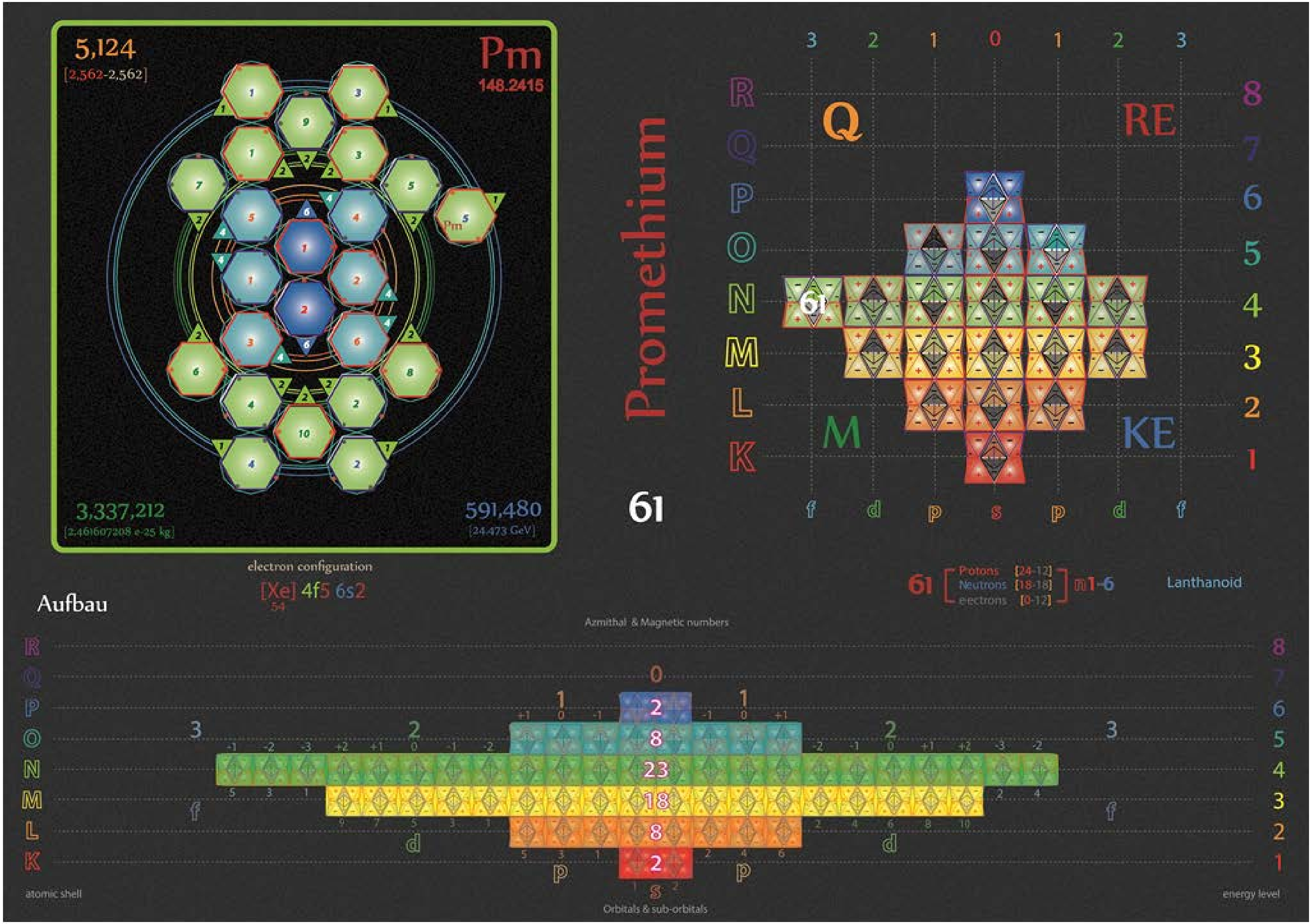
5,124
[2,562-2,562]
Pm
148.2415
3,337,212
[2.461607208 e-25 kg]
591,480
[24.473 GeV]
Promethium
61
electron configuration
[Xe] 4f5 6s2
54
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
61 [Potons [24-12] Neutrons [18-18] electrons [0-12]] n1-6
Lanthanoid
Azmithal & Magnetic numbers
2
8
23
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.61 - Promethium atom

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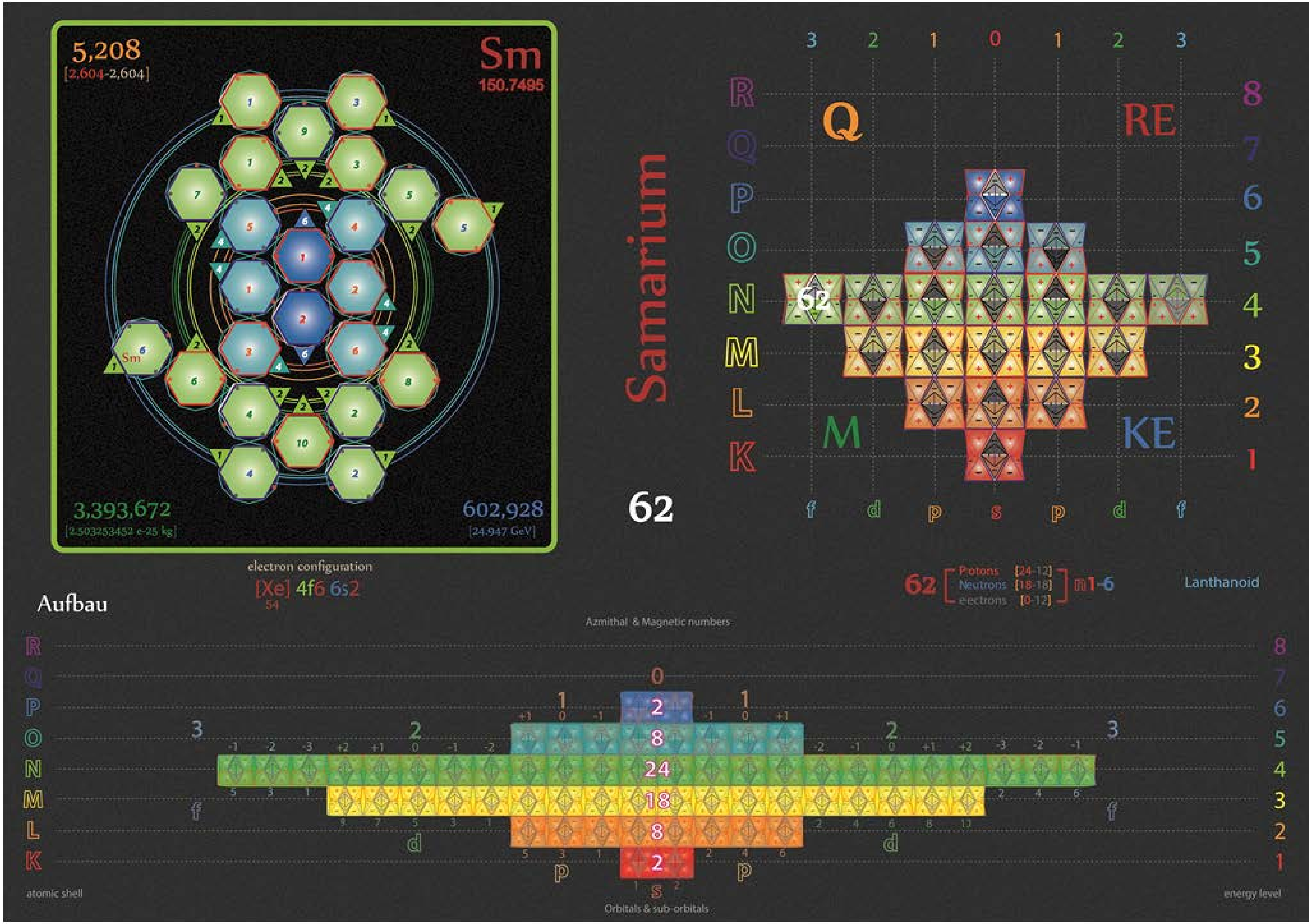
5,208
[2,604-2,604]
Sm
150.7495
3,393,672
[2.503253452 e-25 kg]
602,928
[24.947 GeV]
Samarium
62
electron configuration
[Xe] 4f6 6s2
54
Aufbau
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
62
62 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Azmithal & Magnetic numbers
2
8
24
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.62 - Samarium atom

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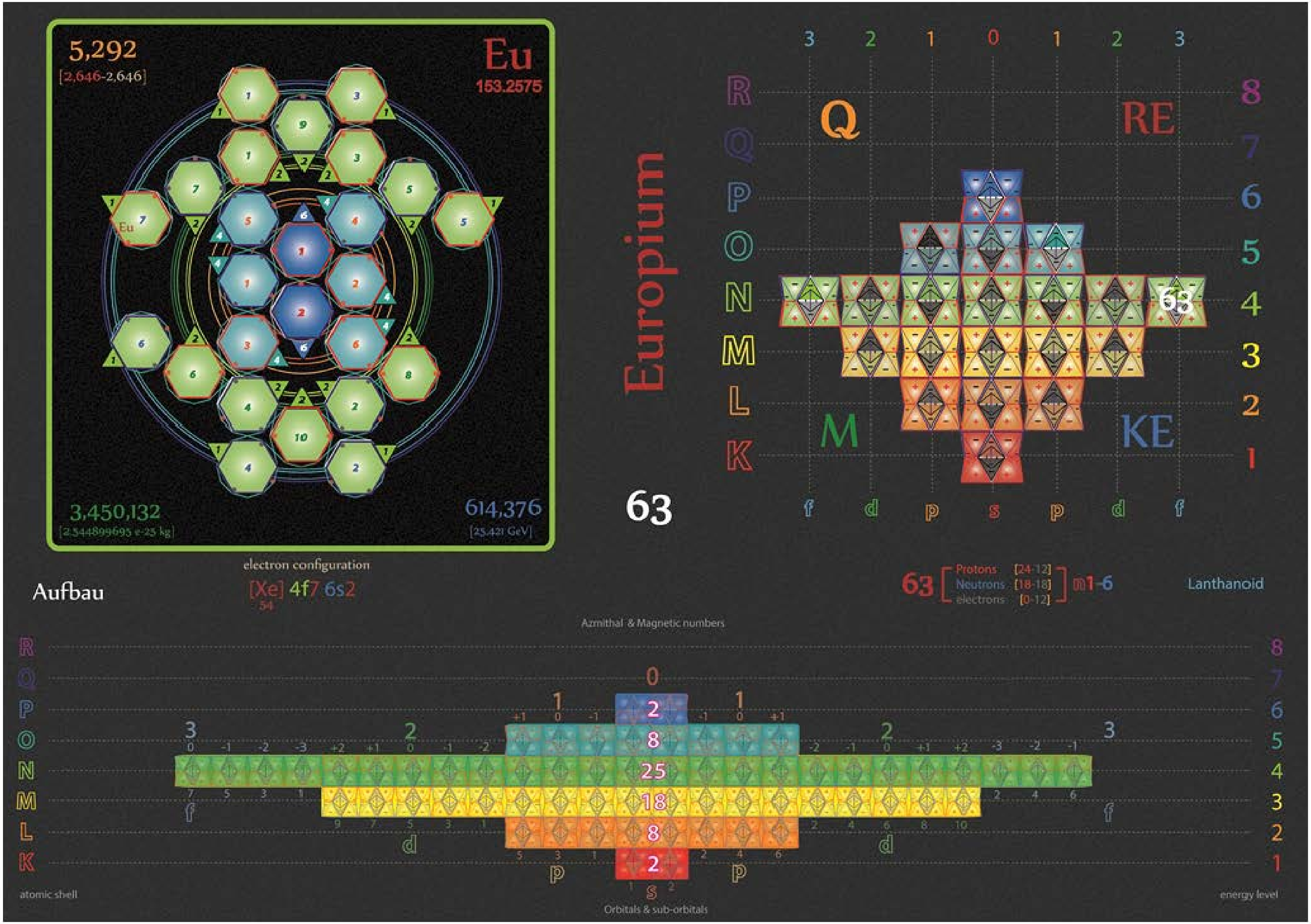
5,292
[2,646-2,646]
Eu
153.2575
3,450,132
[2.544899695 e-25 kg]
614,376
[25.421 GeV]
Europium
63
R
Q
P
O
N
M
L
K
Q
RE
M
KE
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
electron configuration
[Xe] 4f7 6s2
54
Aufbau
63 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Azmithal & Magnetic numbers
atomic shell
energy level
Orbitals & sub-orbitals
2
8
25
18
8
2

Tetryonics 51.63 - Europium atom

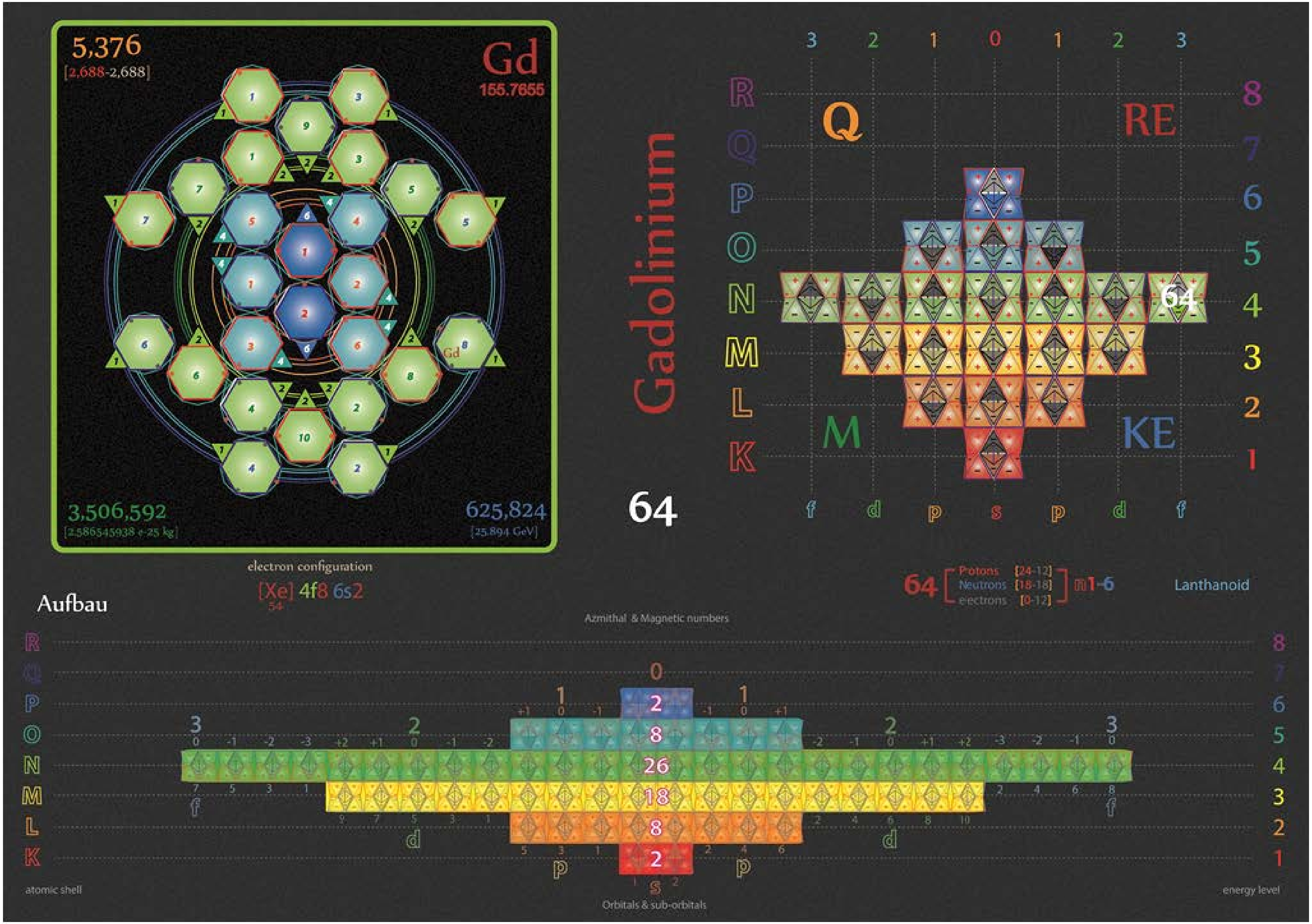
5,376
[2,688-2,688]
Gd
155.7655
3,506,592
[2.586545938 e-25 kg]
625,824
[25.894 GeV]
Gadolinium
64
electron configuration
[Xe] 4f8 6s2
54
Aufbau
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
64
f
d
p
s
p
d
f
64
Potons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-6
Lanthanoid
Azmithal & Magnetic numbers
2
8
26
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.64 - Gadolinium atom

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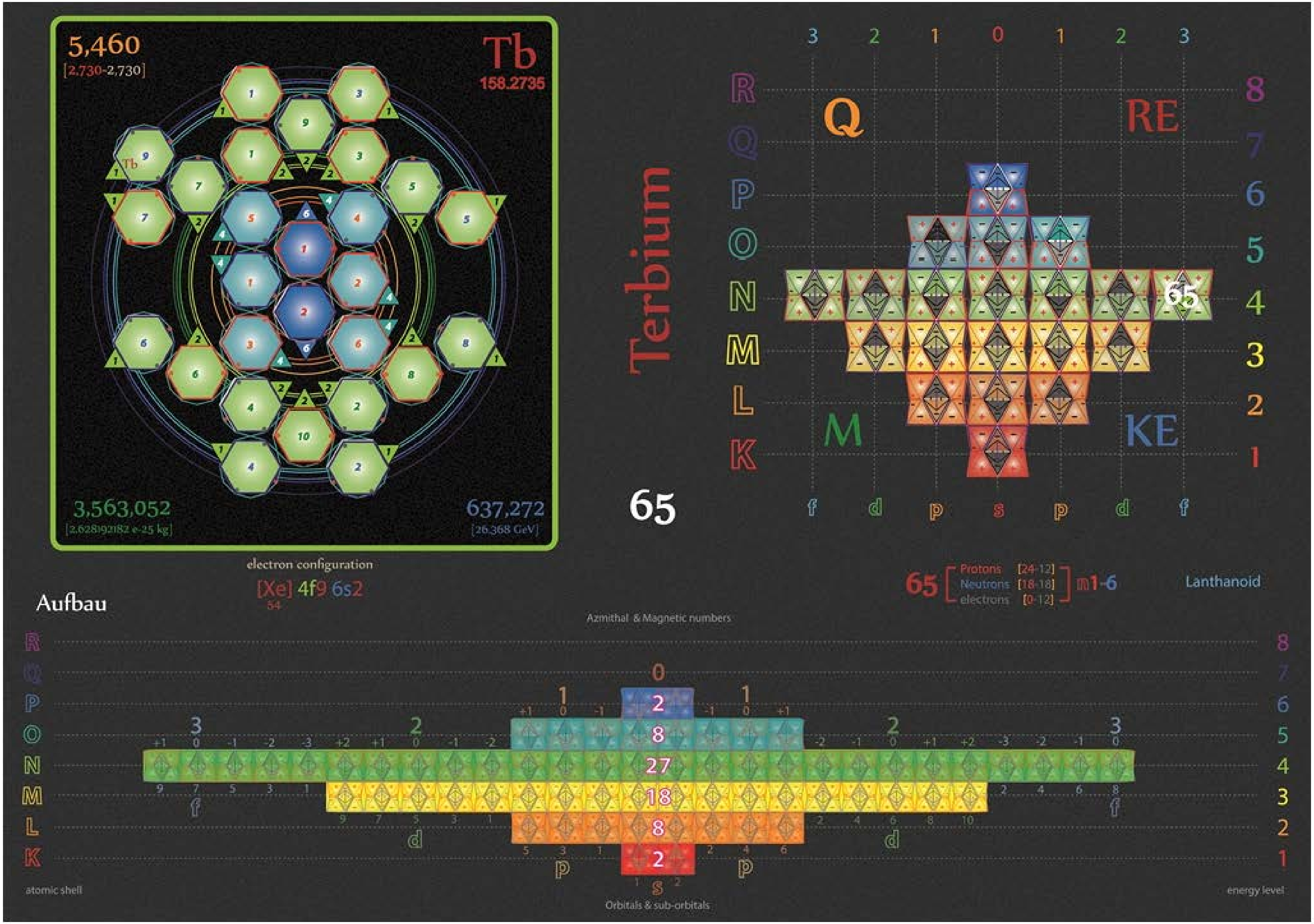
5,460
[2,730-2,730]
Tb
158.2735
3,563,052
[2.628192182 e-25 kg]
637,272
[26,368 GeV]
Terbium
65
R
Q
P
O
N
M
L
K
Q
RE
M
KE
3 2 1 0 1 2 3
8 7 6 5 4 3 2 1
f d p s p d f
electron configuration
[Xe] 4f9 6s2
54
65 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Aufbau
Azmithal & Magnetic numbers
0
2
8
27
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals
s
p
d
f

Tetryonics 51.65 -Terbium atom

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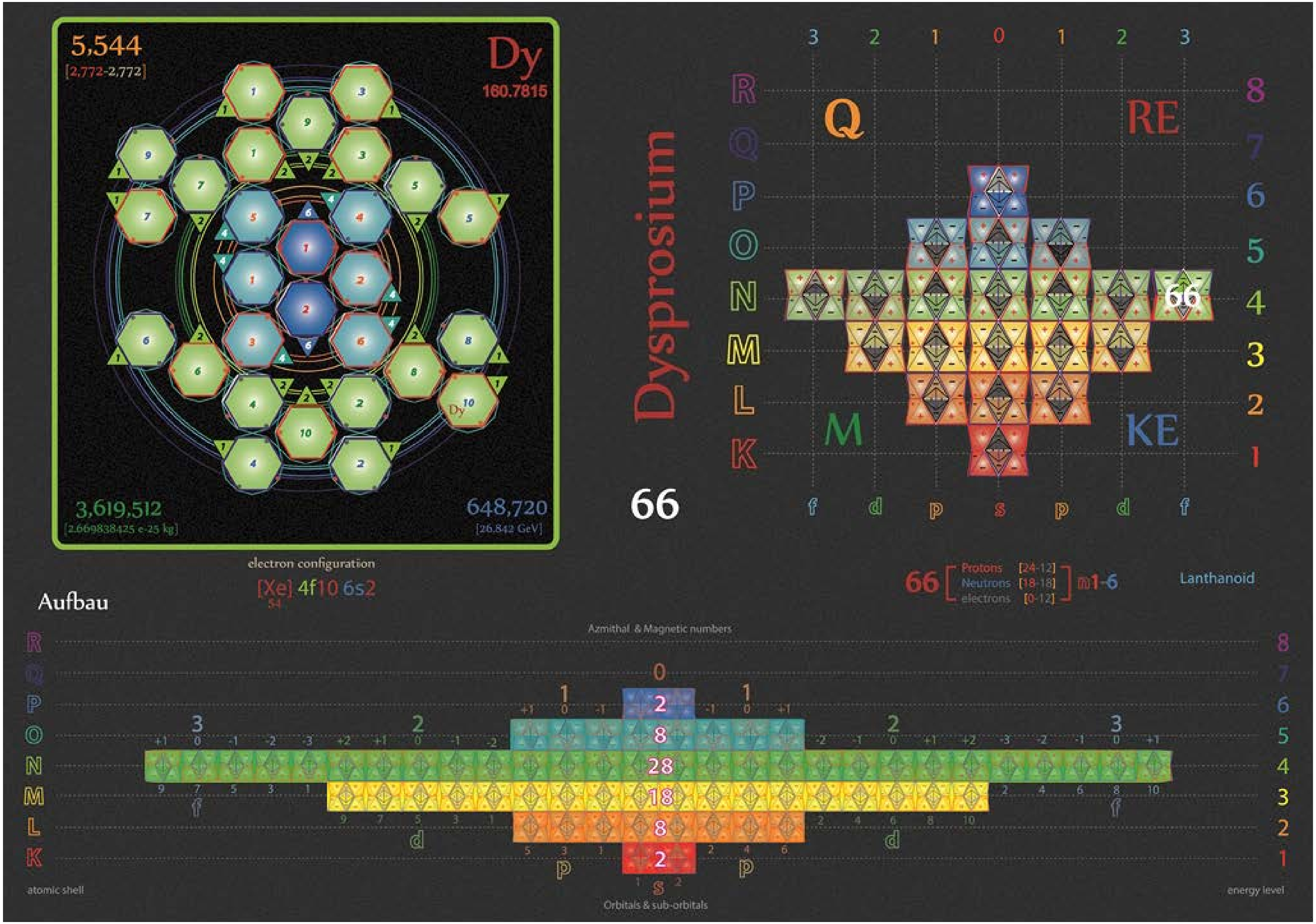
5,544
[2,772-2,772]
Dy
160.7815
3,619,512
[2.669838425 e-25 kg]
648,720
[26.842 GeV]
Dysprosium
66
electron configuration
[Xe] 4f10 6s2
54
Aufbau
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
66 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Azmithal & Magnetic numbers
2
8
28
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.66 - Dysprosium atom

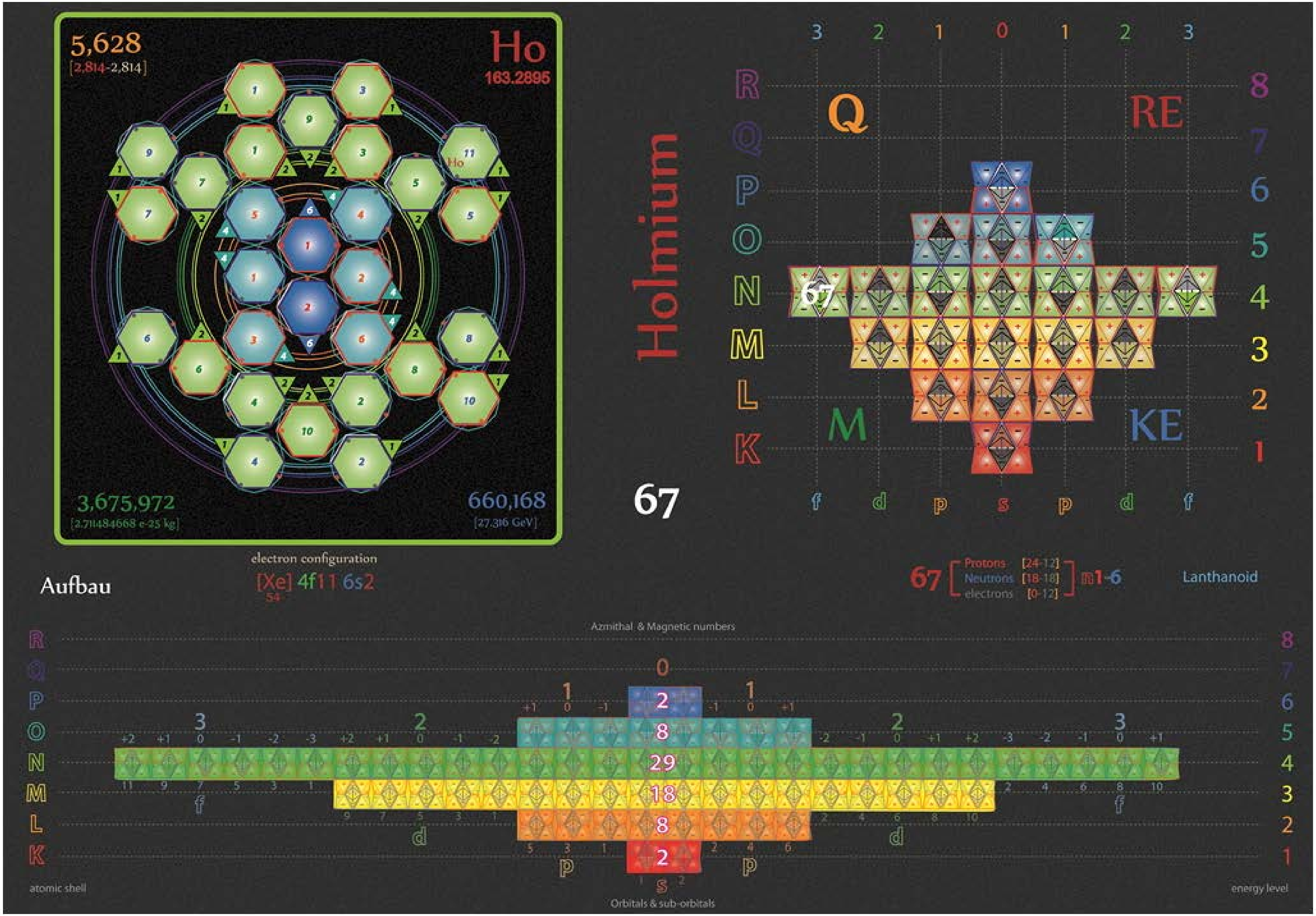
5,628
[2,814-2,814]
Ho
163.2895
3,675,972
[2.711484668 e-25 kg]
660,168
[27.316 GeV]
Holmium
67
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
f
d
p
s
p
d
f
3
2
1
0
1
2
3
Aufbau
electron configuration
[Xe] 4f11 6s2
54
67
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-6
Lanthanoid
Azmithal & Magnetic numbers
2
8
29
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.67 - Holmium atom

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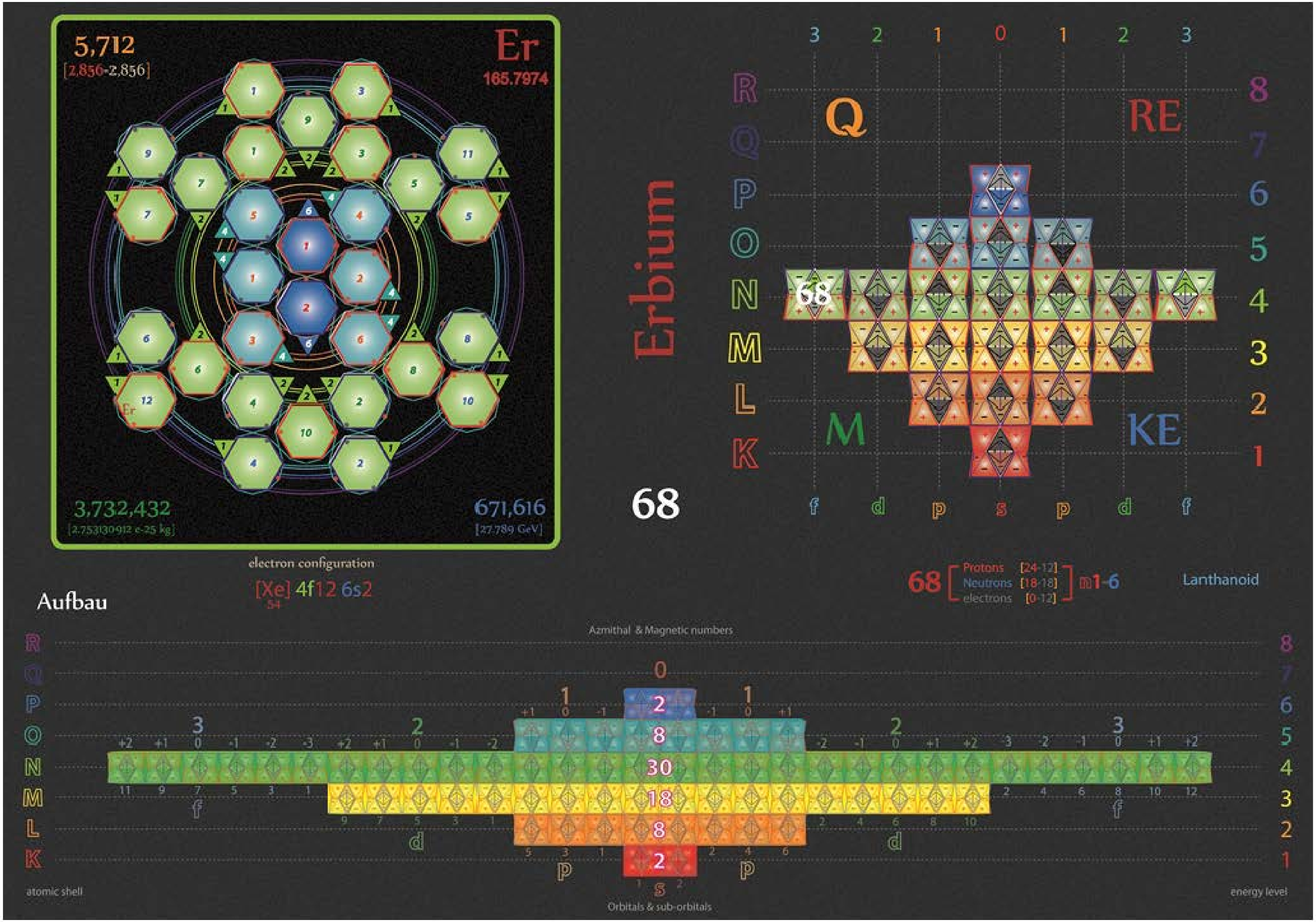

5,712
[2,856-2,856]
Er
165.7974
3,732,432
[2.753130912 e-25 kg]
671,616
[27.789 GeV]
Erbium
68
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Xe] 4f12 6s2
54
Aufbau
68 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
2
8
30
18
8
2
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.68 - Erbium atom

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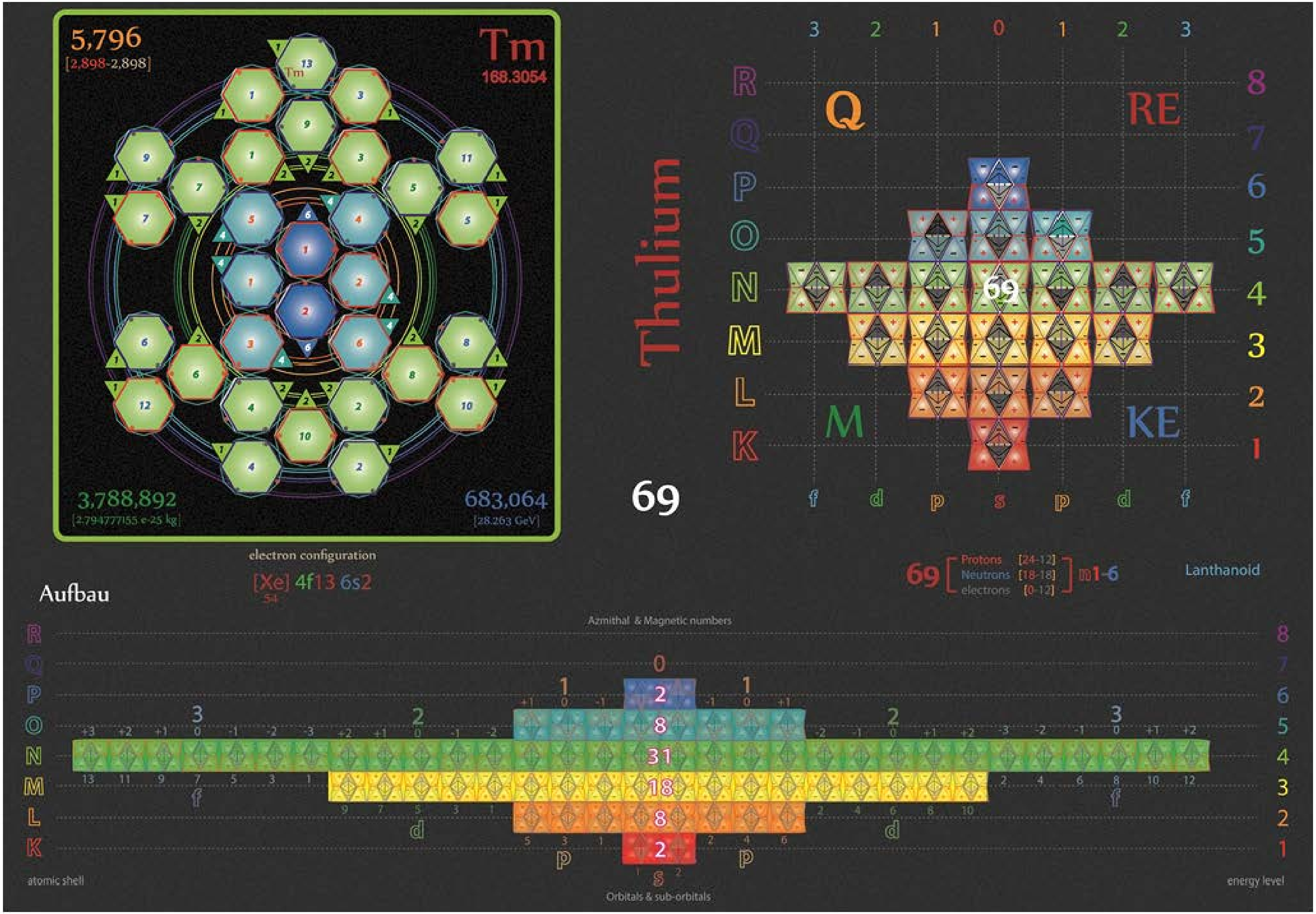
5,796
[2,898-2,898]
Tm
168.3054
3,788,892
[2.794777155 e-25 kg]
683,064
[28.263 GeV]
Thulium
69
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Xe] 4f13 6s2
54
Aufbau
69
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-6
Lanthanoid
Azmithal & Magnetic numbers
2
8
31
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.69 - Thulium atom

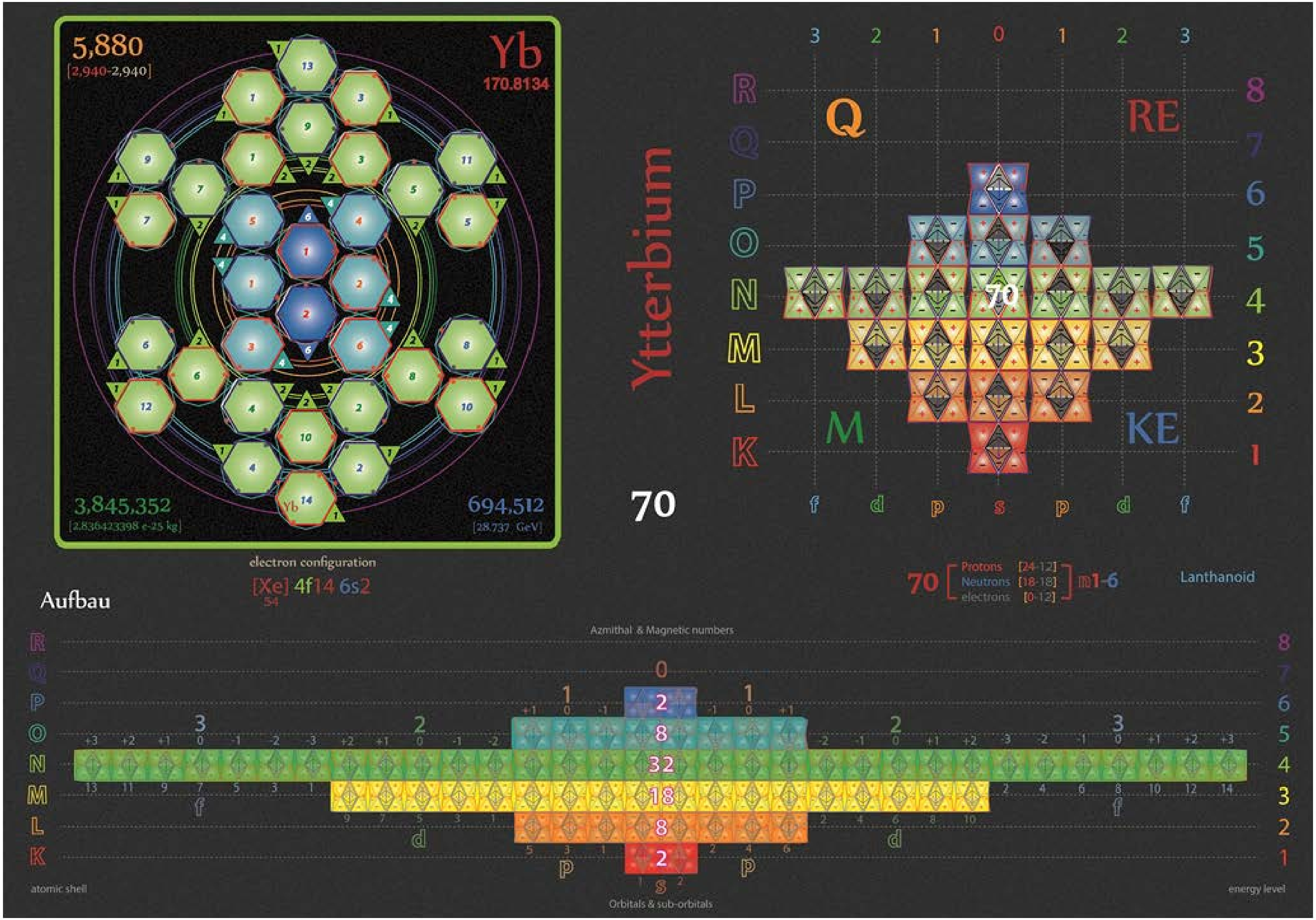
5,880
[2,940-2,940]
Yb
170.8134
3,845,352
[2.836423398 e-25 kg]
694,512
[28.737 GeV]
Ytterbium
70
electron configuration
[Xe] 4f14 6s2
54
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
70
f d p s p d f
70 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Lanthanoid
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+1 0 -1
-1 0 +1
+3 +2 +1 0 -1 -2 -3
+2 +1 0 -1 -2
-2 -1 0 +1 +2
-3 -2 -1 0 +1 +2 +3
2
8
32
18
8
2
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.70 - Ytterbium atom

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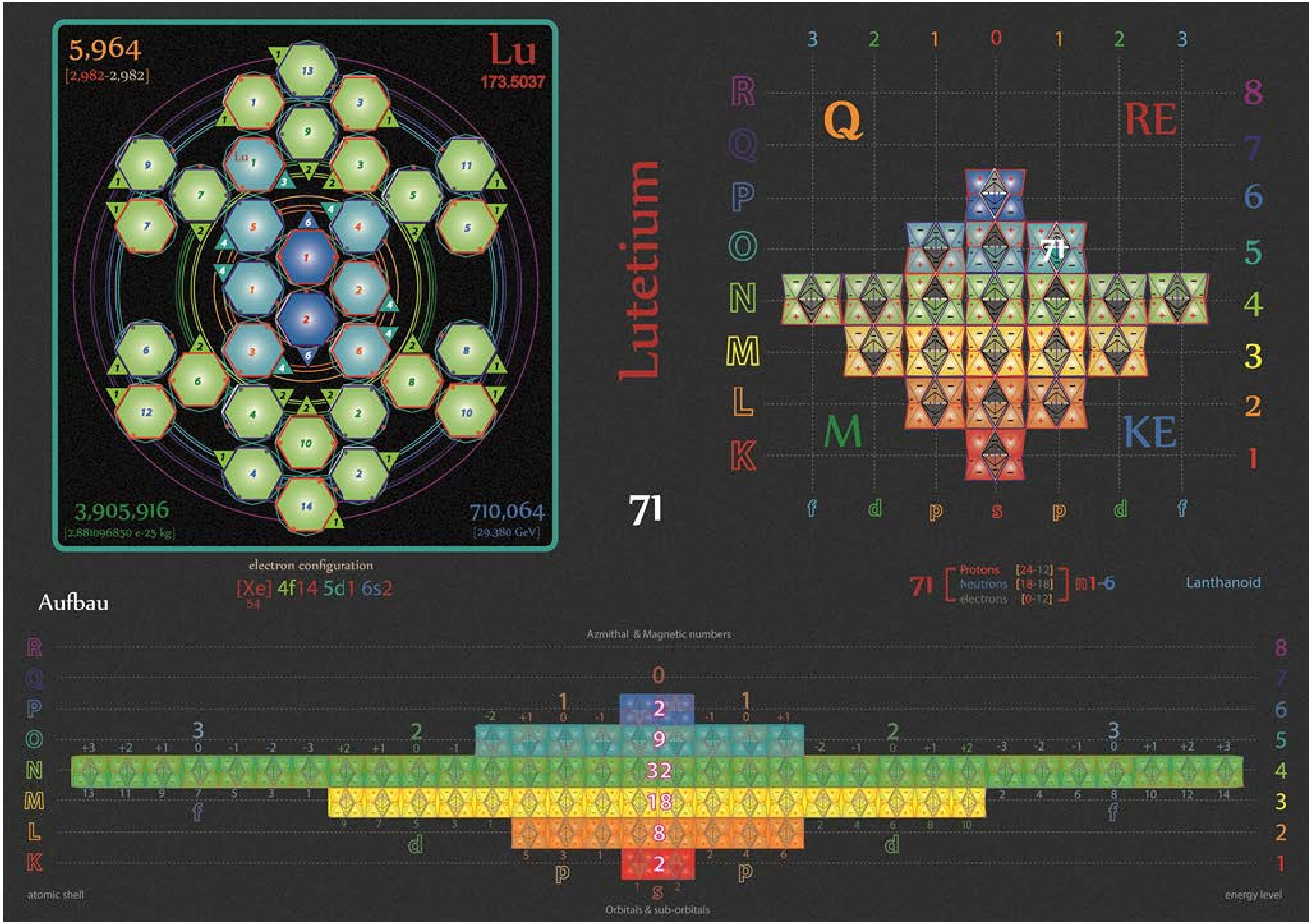
5,964
[2,982-2,982]
Lu
173.5037
3,905,916
[2.881096850 e-25 kg]
710,064
[29.380 GeV]
Lutetium
71
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
electron configuration
[Xe] 4f14 5d1 6s2
54
71
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-6
Lanthanoid
Aufbau
Azmithal & Magnetic numbers
0
2
9
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.71 - Lutetium atom

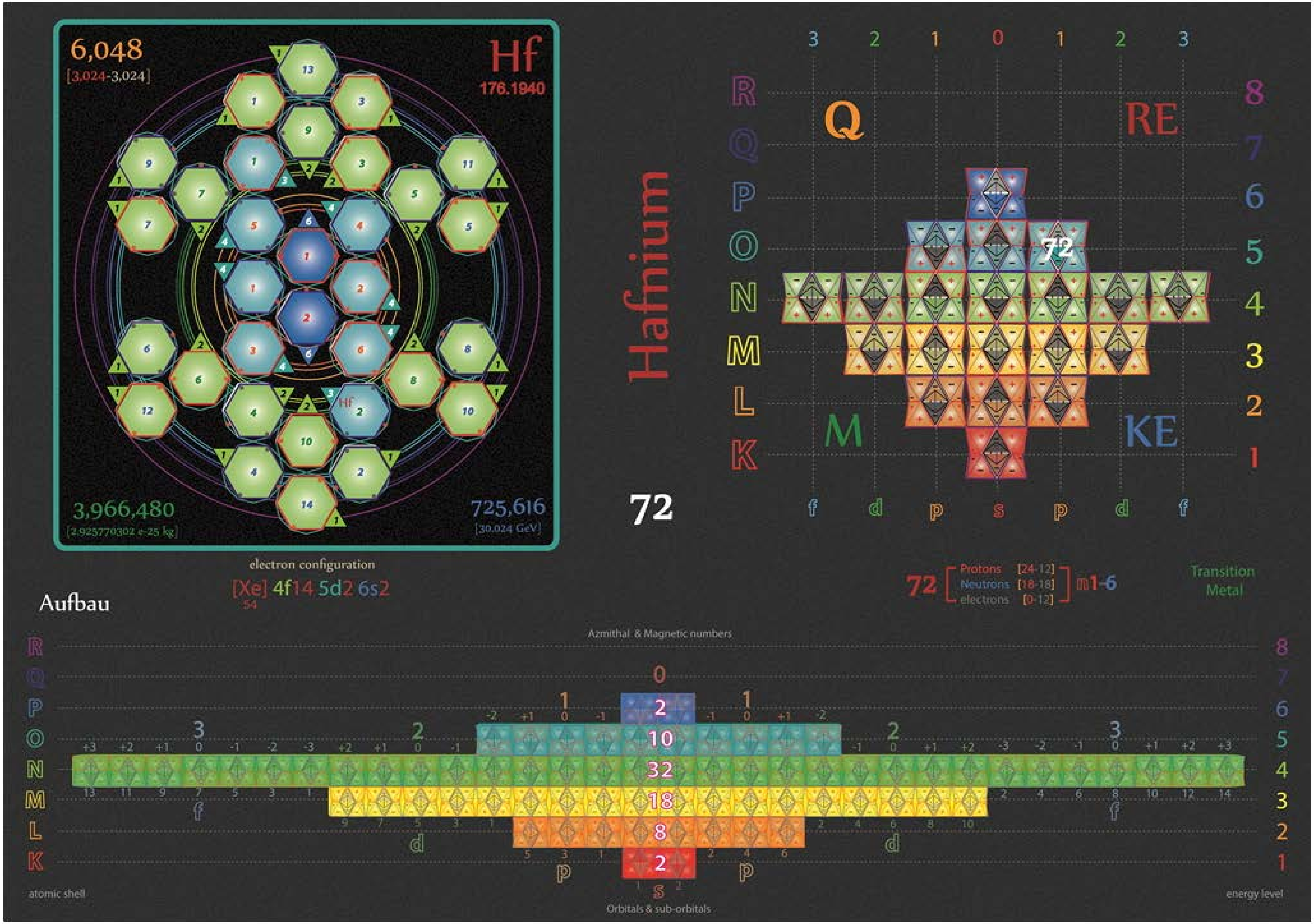
6,048
[3,024-3,024]
Hf
176.1940
3,966,480
[2.925770302 e-25 kg]
725,616
[30.024 GeV]
Hafnium
72
electron configuration
[Xe] 4f14 5d2 6s2
54
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
72
f d p s p d f
72
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-6
Transition Metal
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
2
10
32
18
8
2
f
f
d
d
p
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.72 - Hafnium atom

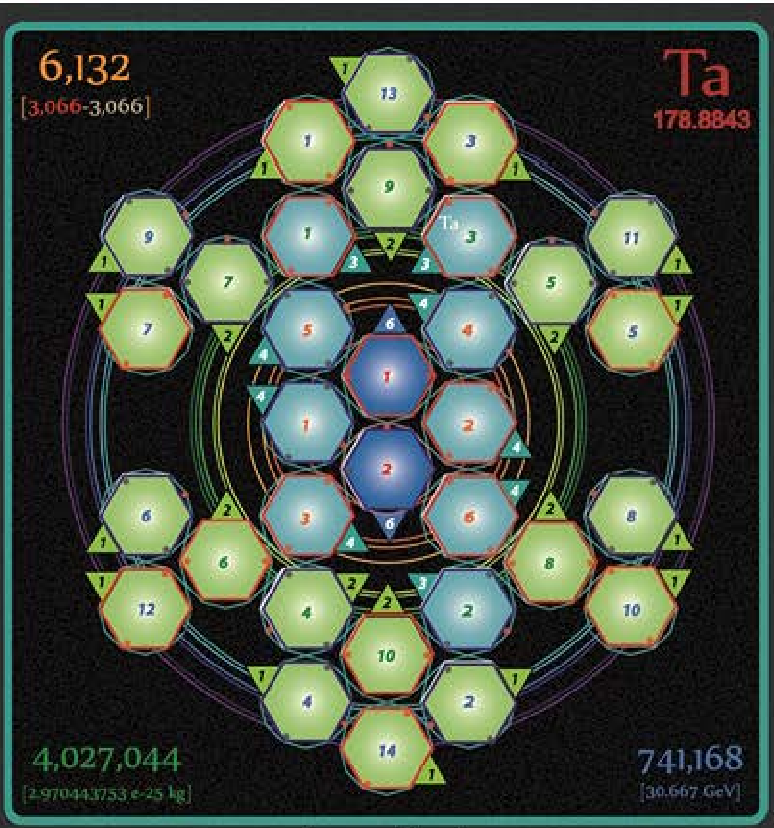
6,132
[3,066-3,066]
Ta
178.8843
4,027,044
[2.970443753 e-25 kg]
741,168
[30.667 GeV]

Tantalum

73

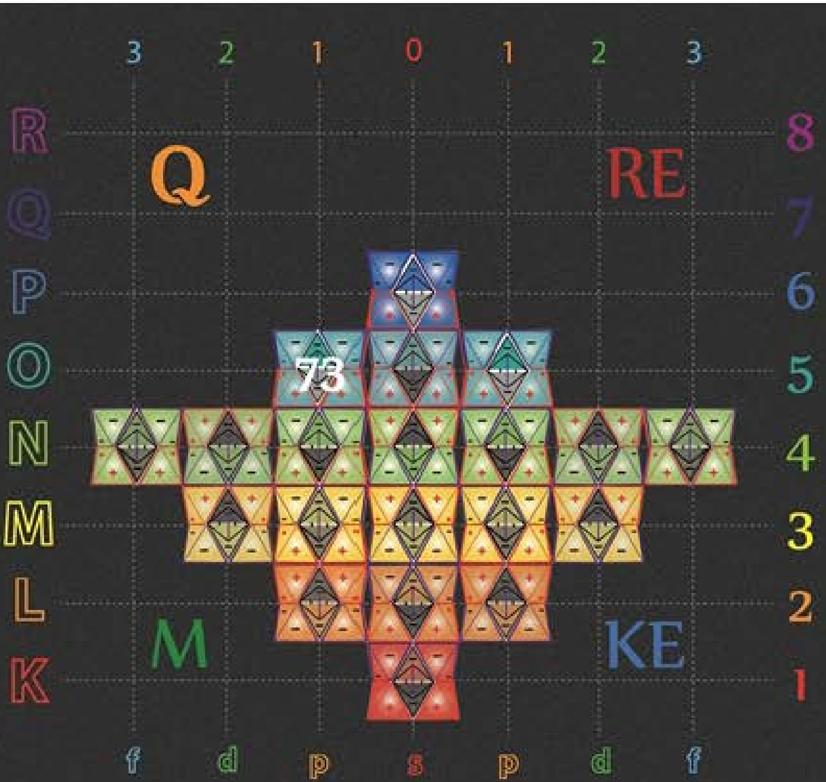
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
73
M
KE
f
d
p
s
p
d
f

electron configuration

[Xe] 4f14 5d3 6s2

54

73 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6

Transition Metal

Aufbau

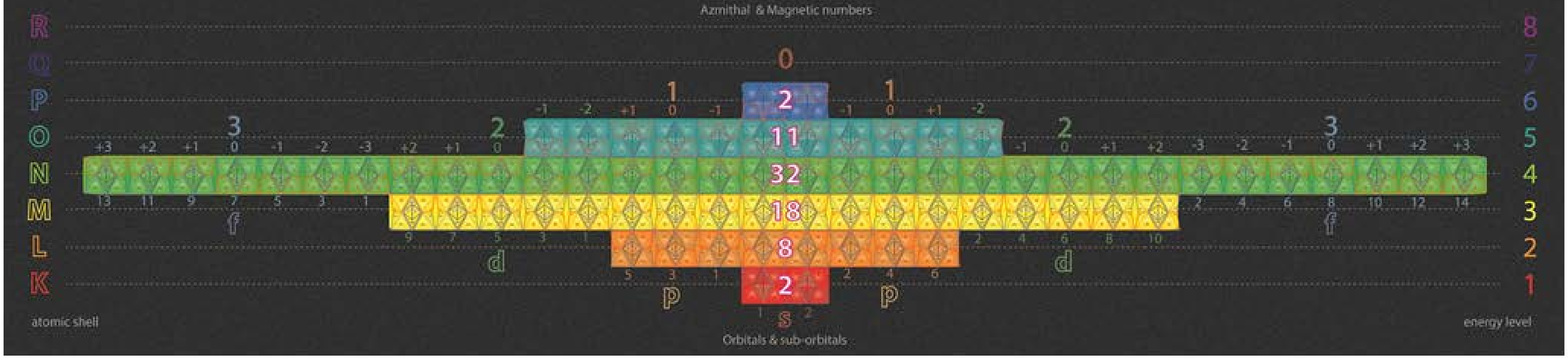
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
1
1
3
2
2
3
2
11
32
18
8
2
f
f
d
d
p
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.73 - Tantalum atom

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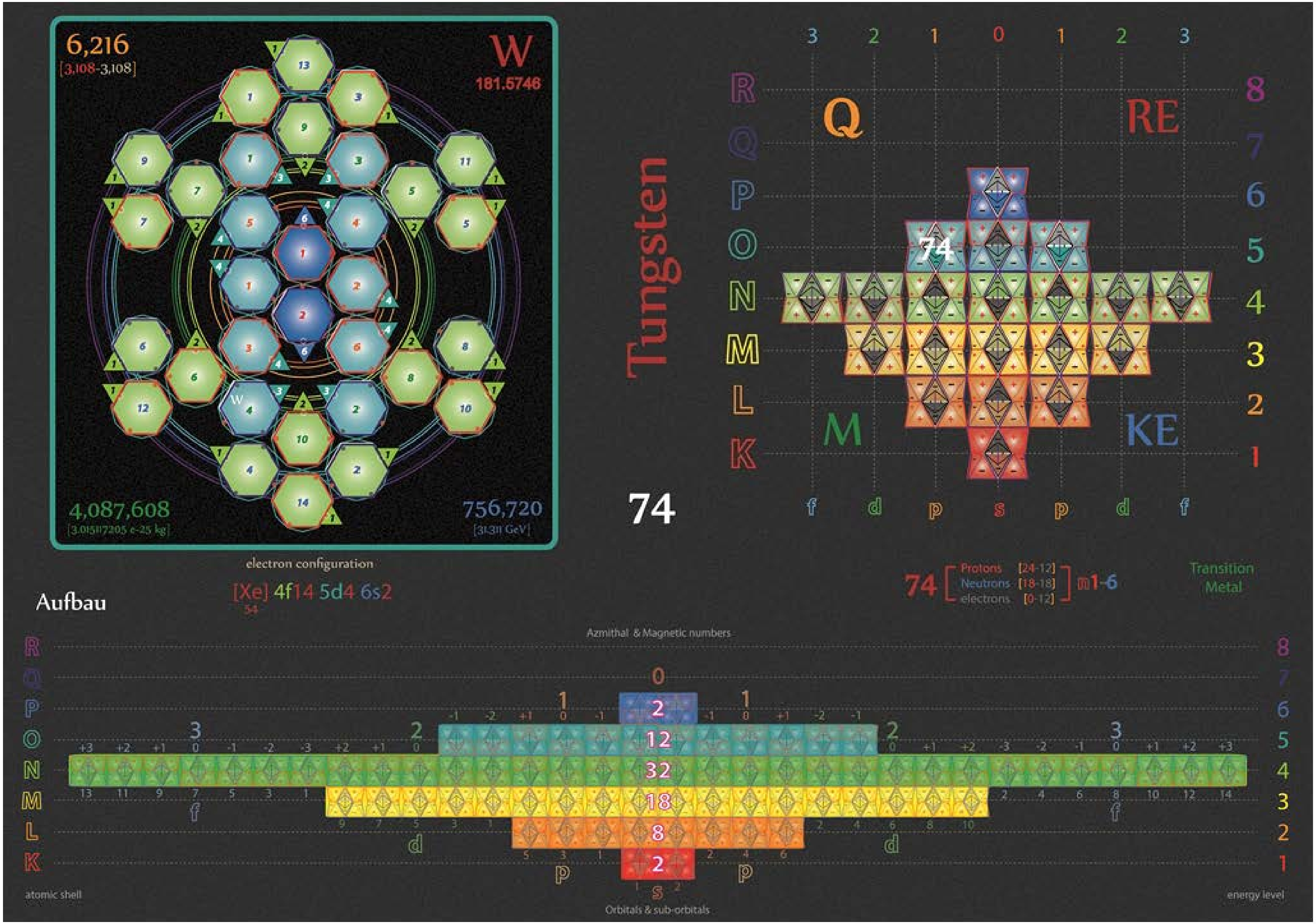
6,216
[3,108-3,108]
W
181.5746
4,087,608
[3.015117205 e-25 kg]
756,720
[31.311 GeV]
Tungsten
74
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
Aufbau
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
2
12
32
18
8
2
f
f
d
d
p
p
s
Orbitals & sub-orbitals
atomic shell
energy level

electron configuration

[Xe] 4f14 5d4 6s2

54

74 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6

Transition Metal

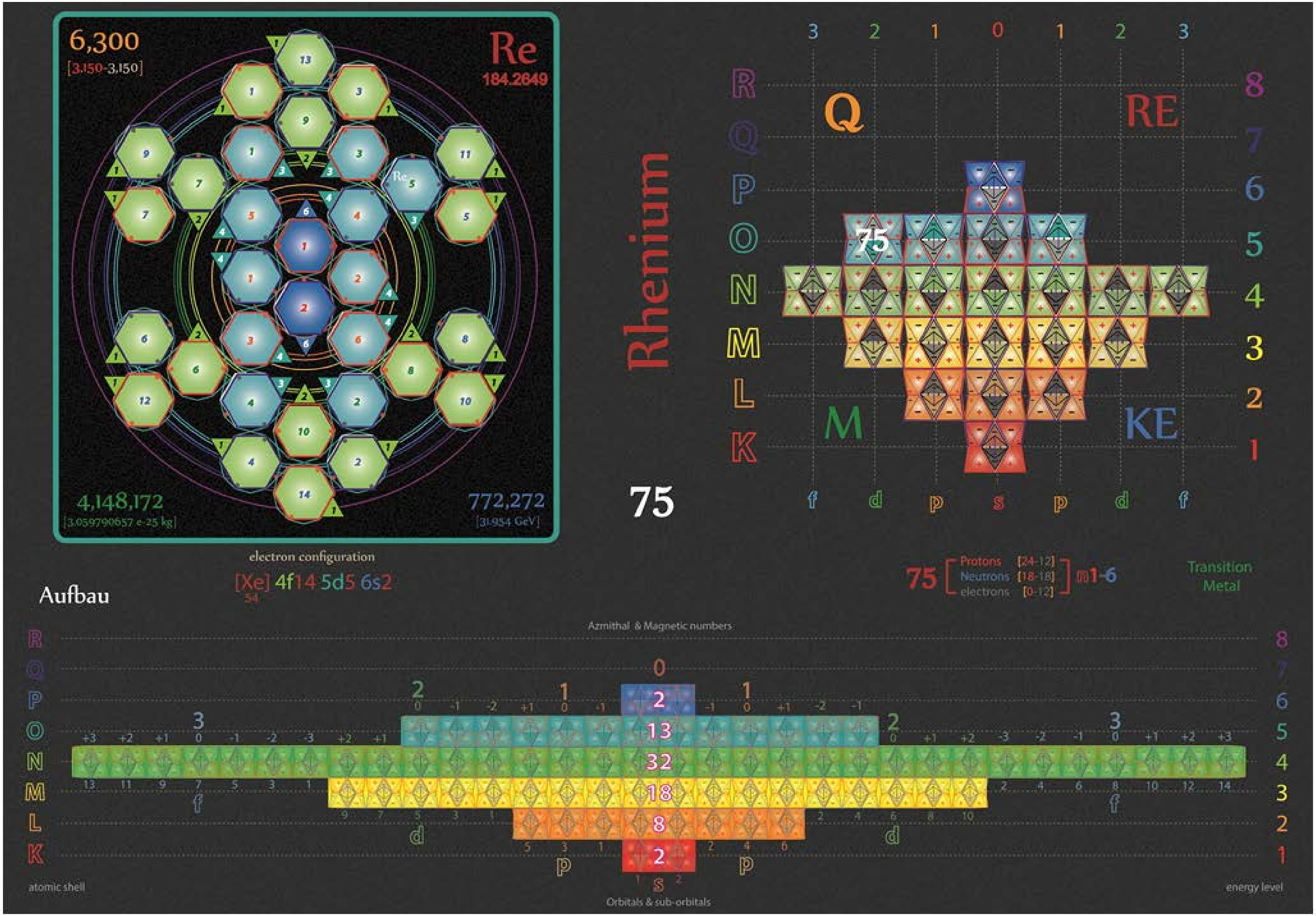
6,300
[3,150-3,150]
Re
184.2849
4,148,172
[3.059790657 e-25 kg]
772,272
[31.954 GeV]
electron configuration
[Xe] 4f14 5d5 6s2
54
Aufbau
Rhenium
75
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
8
7
6
5
4
3
2
1
Q
RE
M
KE
f d p s p d f
75 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Transition Metal
Azmithal & Magnetic numbers
2
13
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.75 - Rhenium atom

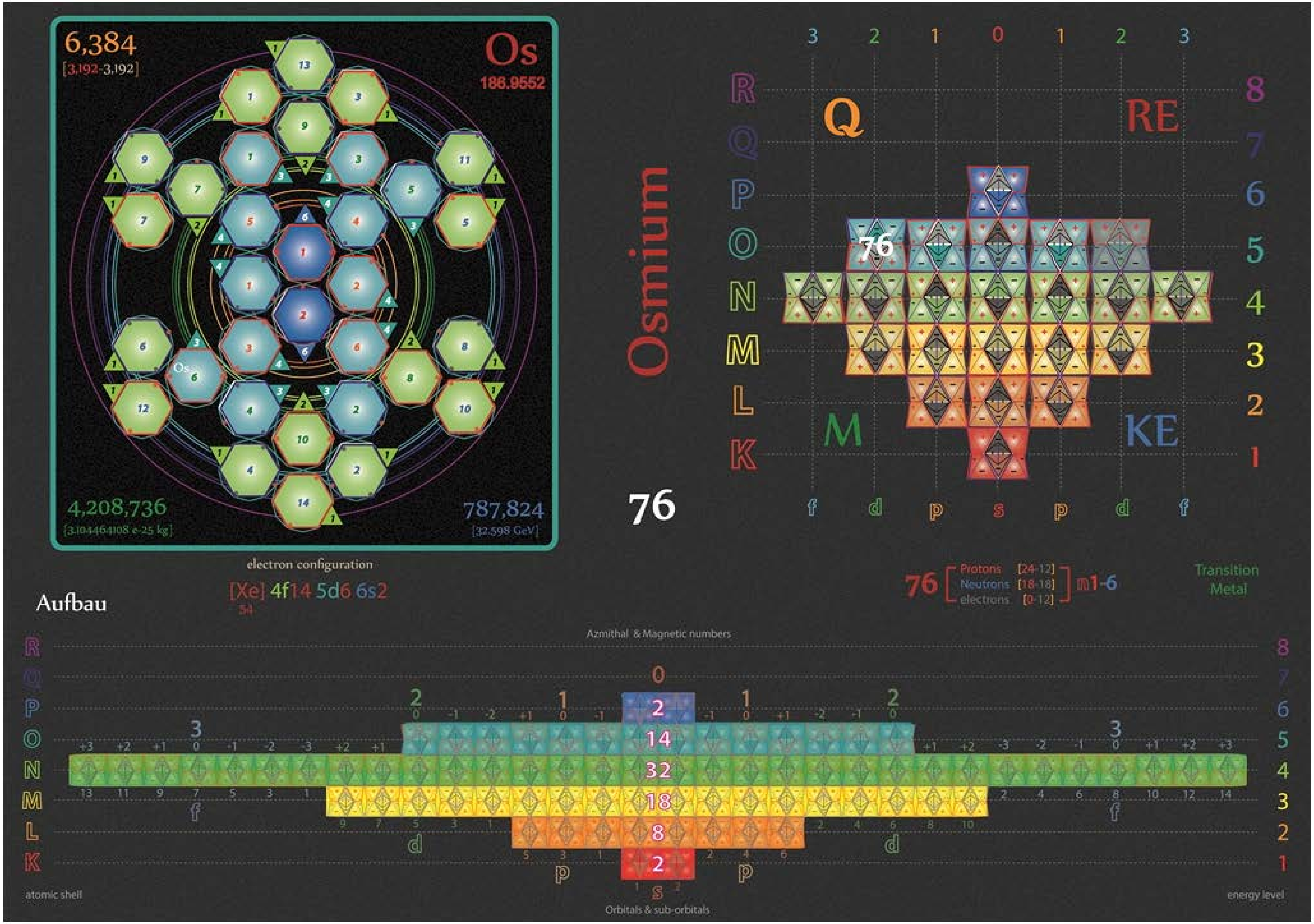
6,384
[3,192-3,192]
Os
186.9552
4,208,736
[3.104464108 e-25 kg]
787,824
[32.598 GeV]
electron configuration
[Xe] 4f14 5d6 6s2
54
Aufbau
Osmium
76
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
76
f d p s p d f
76 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Transition Metal
Azmithal & Magnetic numbers
0
2
14
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals
s
p
d
f

Tetryonics 51.76 - Osmium atom

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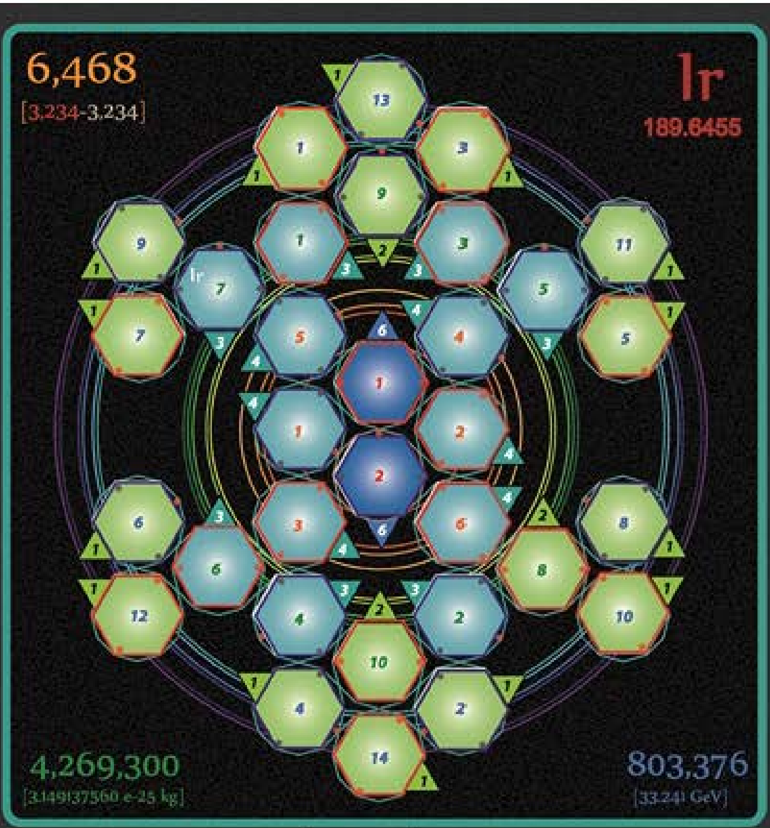
6,468
[3.234-3.234]
Ir
189.6455
4,269,300
[3.149137560 e-25 kg]
803,376
[33.241 GeV]

Iridium

77

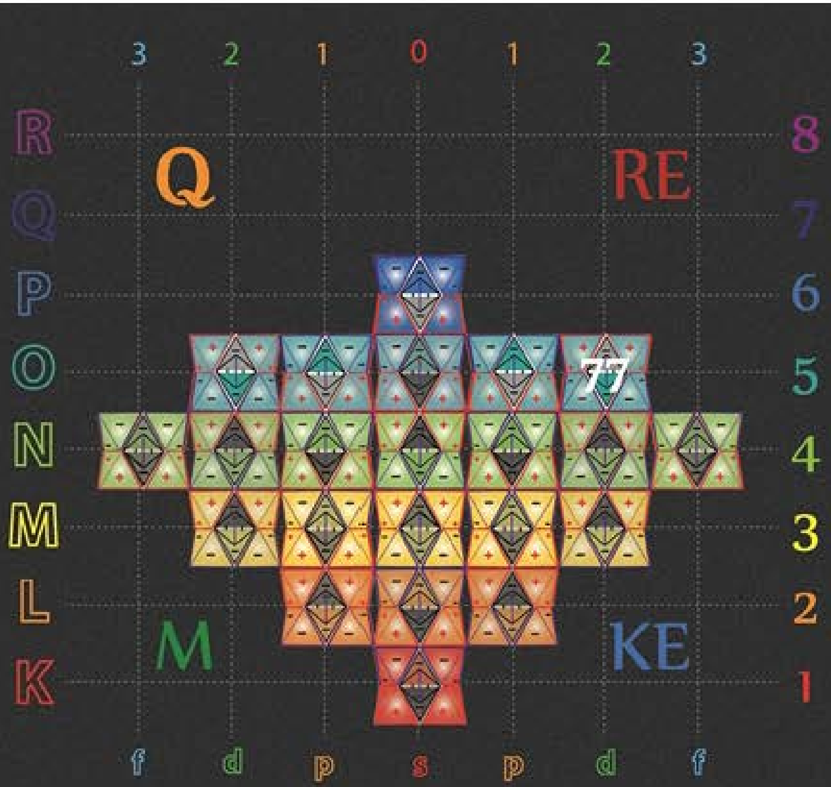
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
77
f d p s p d f

electron configuration

[Xe] 4f14 5d7 6s2
54

77 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6

Transition Metal

Aufbau

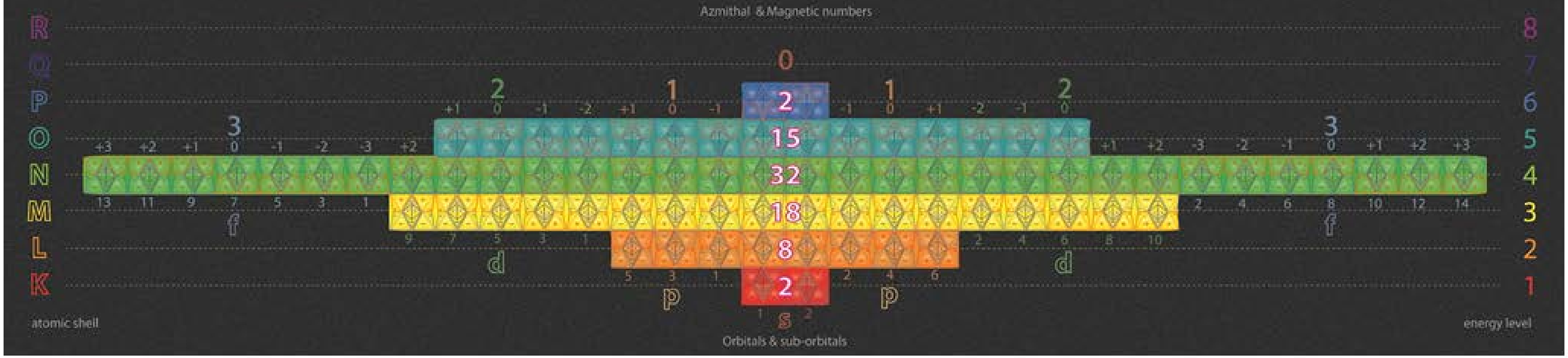
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
0
2 1 1 2
3 3
2
15
32
18
8
2
f f
d d
p p
s
atomic shell
energy level
Orbitals & sub-orbitals

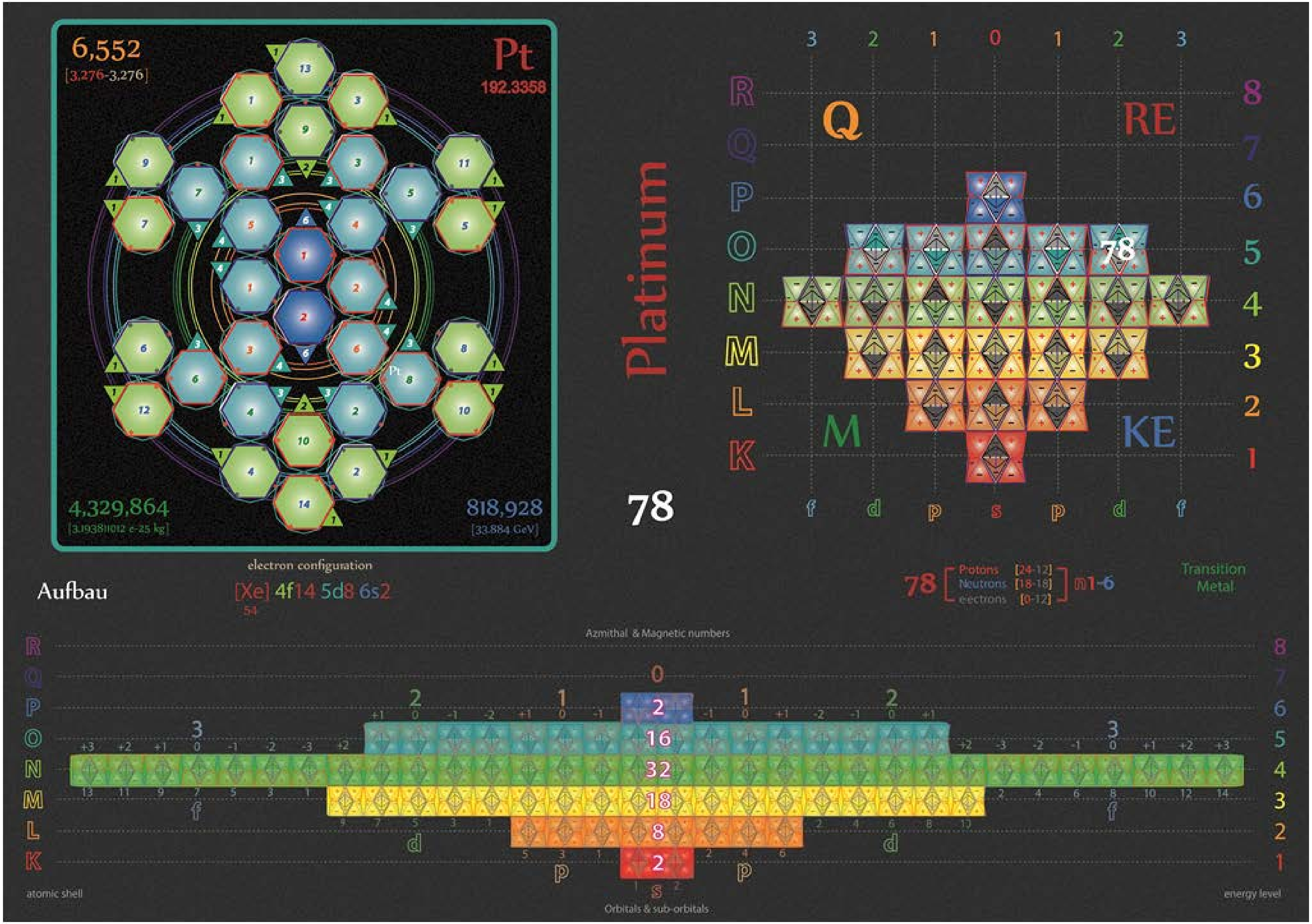
6,552
[3,276-3,276]
Pt
192.3358
4,329,864
[3.19381012 e-25 kg]
818,928
[33.884 GeV]
Platinum
78
Q
RE
M
KE
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
electron configuration
Aufbau
[Xe] 4f14 5d8 6s2
54
78
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-6
Transition Metal
Azmithal & Magnetic numbers
2
16
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.78 - Platinum atom

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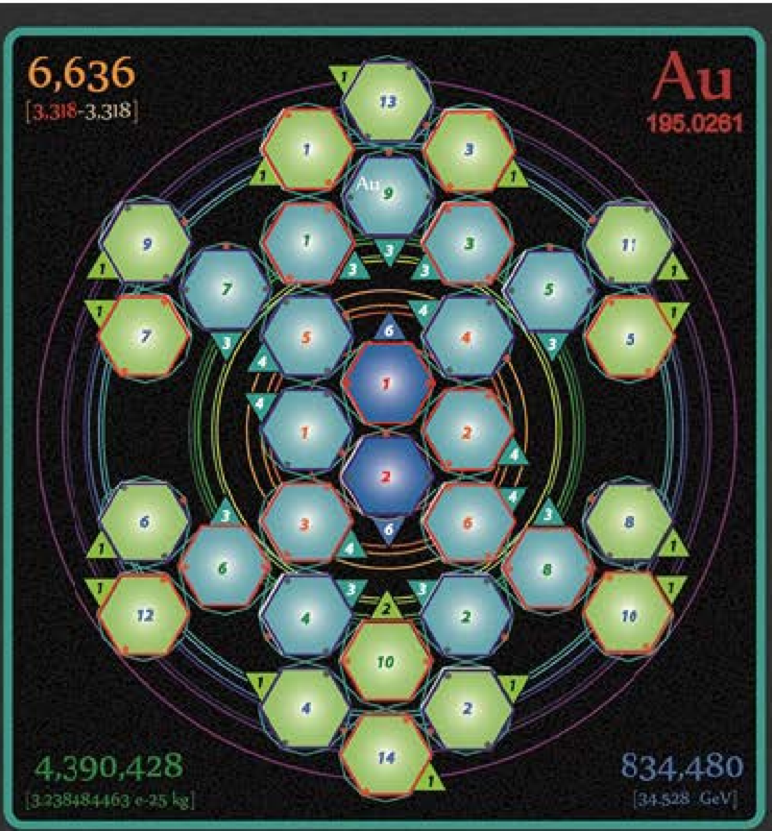
6,636
[3.318-3.318]
Au
195.0261
4,390,428
[3.238484463 e-25 kg]
834,480
[34.528 GeV]

Gold

79

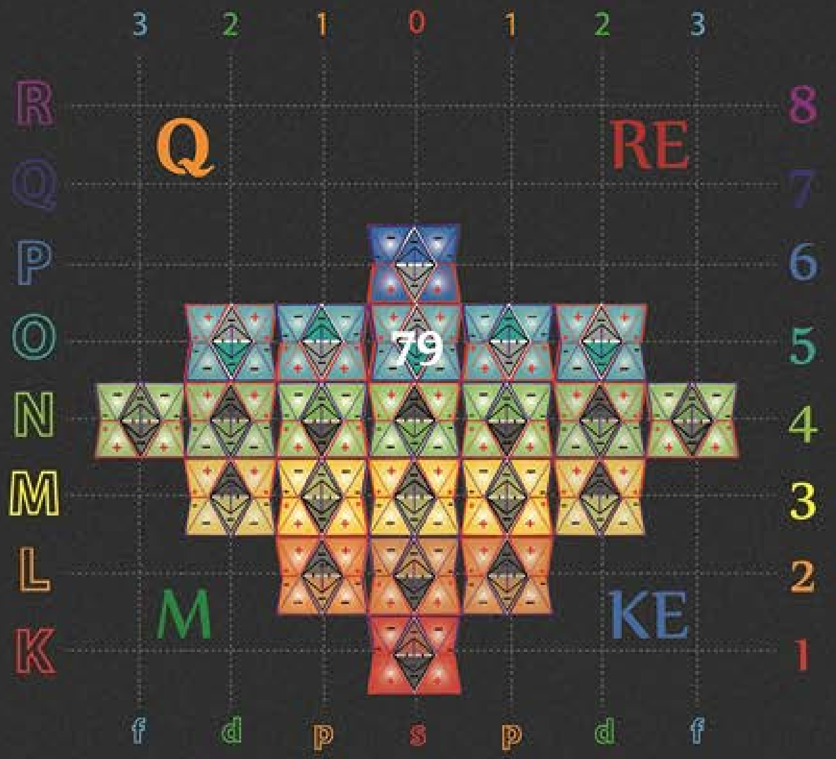
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
79
f d p s p d f

electron configuration

[Xe] 4f14 5d9 6s2

54

Aufbau

79 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-6

Post Transition Metal

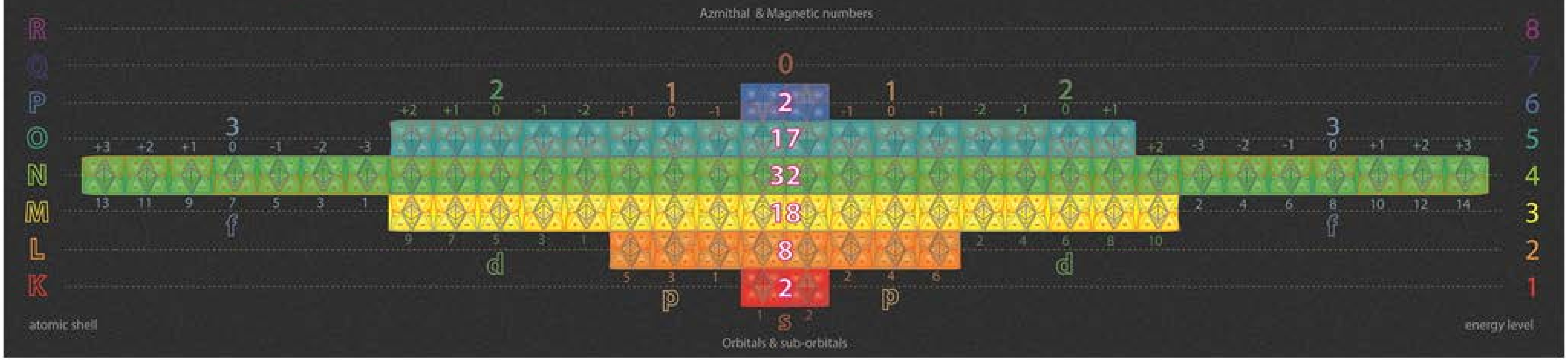
Azmithal & Magnetic numbers
R Q P O N M L K
8 7 6 5 4 3 2 1
2
17
32
18
8
2
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.79 - Gold atom

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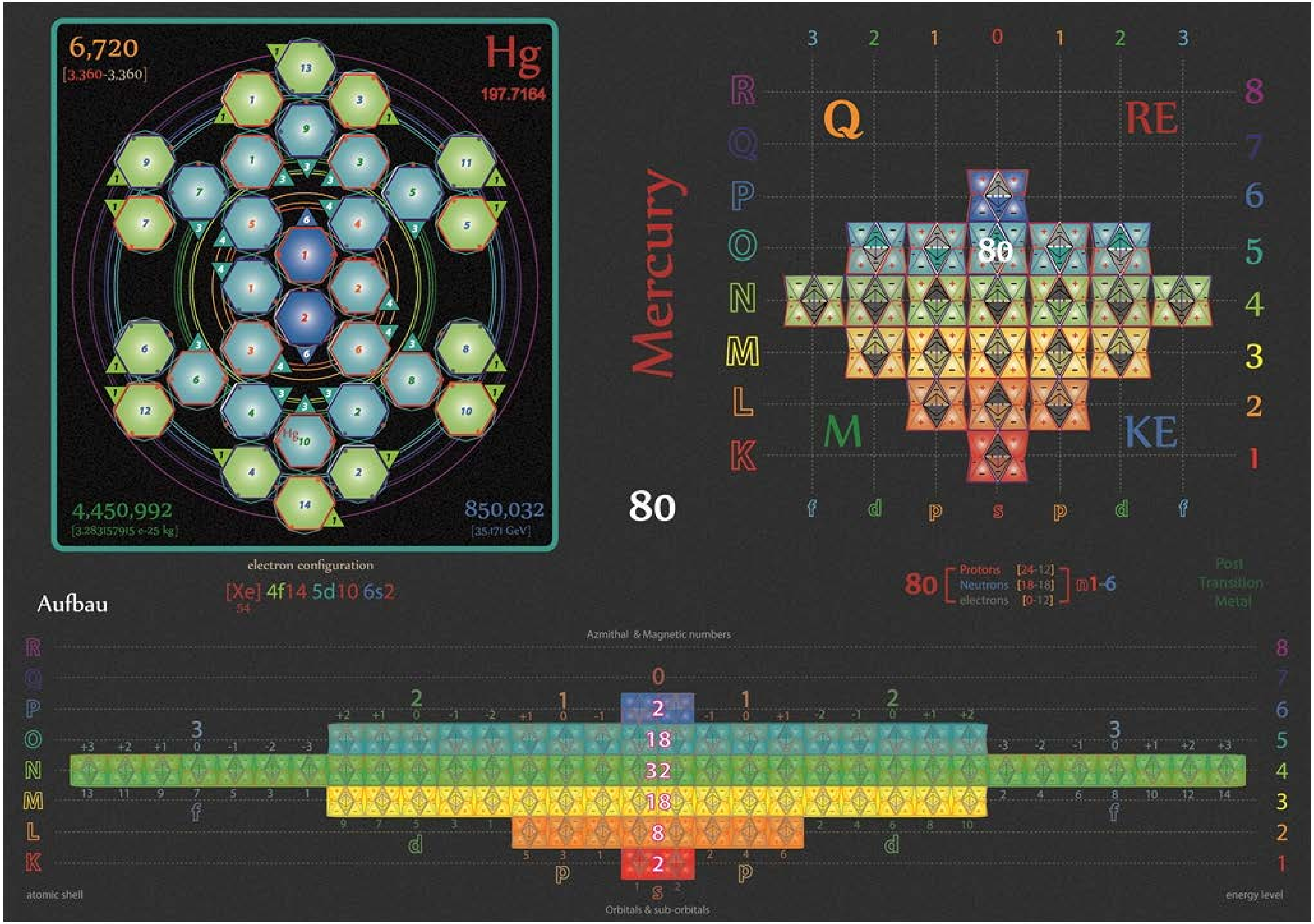
6,720
[3,360-3,360]
Hg
197.7164
4,450,992
[3.283157915 e-25 kg]
850,032
[35.171 GeV]
Mercury
80
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Xe] 4f14 5d10 6s2
54
Aufbau
80 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-6
Post Transition Metal
Azmithal & Magnetic numbers
2
18
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.80 - Mercury atom

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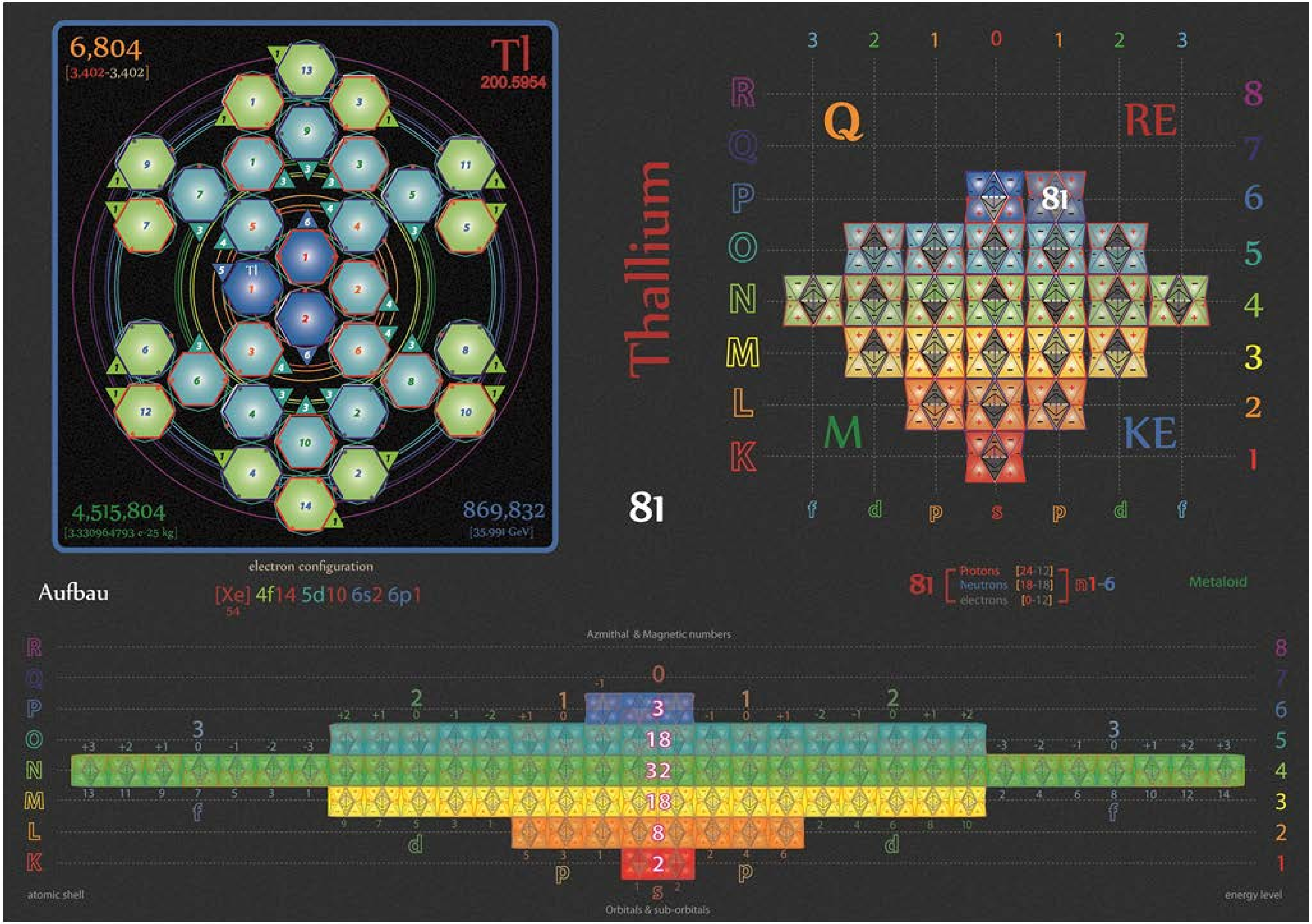
6,804
[3,402-3,402]
Tl
200.5954
4,515,804
[3.330964793 e-25 kg]
869,832
[35.991 GeV]
Thallium
81
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
Q
RE
M
KE
8
7
6
5
4
3
2
1
f d p s p d f
81
electron configuration
Aufbau
[Xe] 4f14 5d10 6s2 6p1
54
81 Protons [24-12] Neutrons [18-18] electrons [0-12] n1-6
Metaloid
Azmithal & Magnetic numbers
0
3
18
32
18
8
2
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.81 - Thallium atom

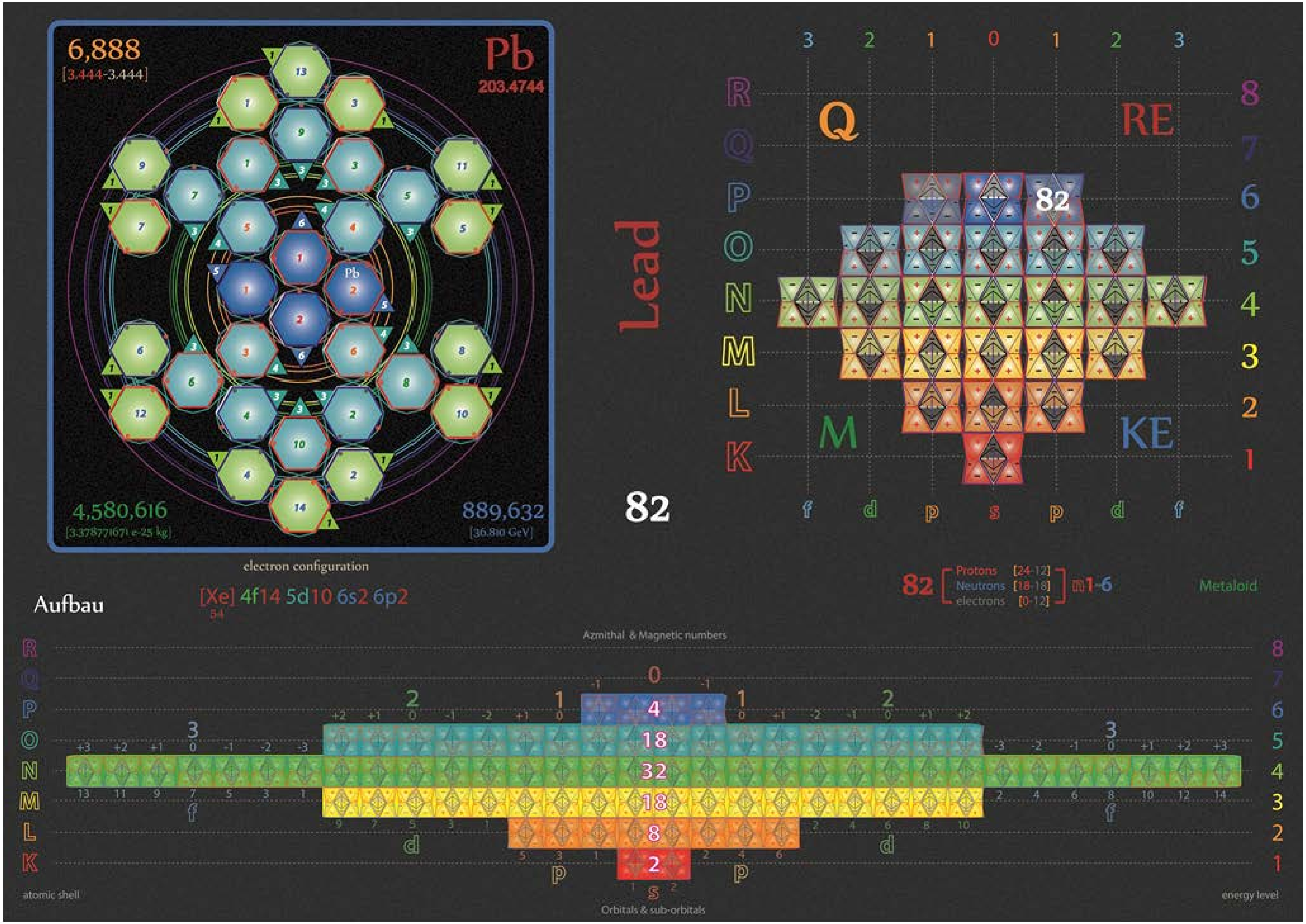
6,888
[3.444-3.444]
Pb
203.4744
4,580,616
[3.37877167 e-25 kg]
889,632
[36.810 GeV]
electron configuration
Aufbau
[Xe] 4f14 5d10 6s2 6p2
54
Lead
82
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
82 Protons [24-12] Neutrons [18-18] electrons [0-12] m1-6
Metaloid
Azmithal & Magnetic numbers
4
18
32
18
8
2
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.82 - Lead atom

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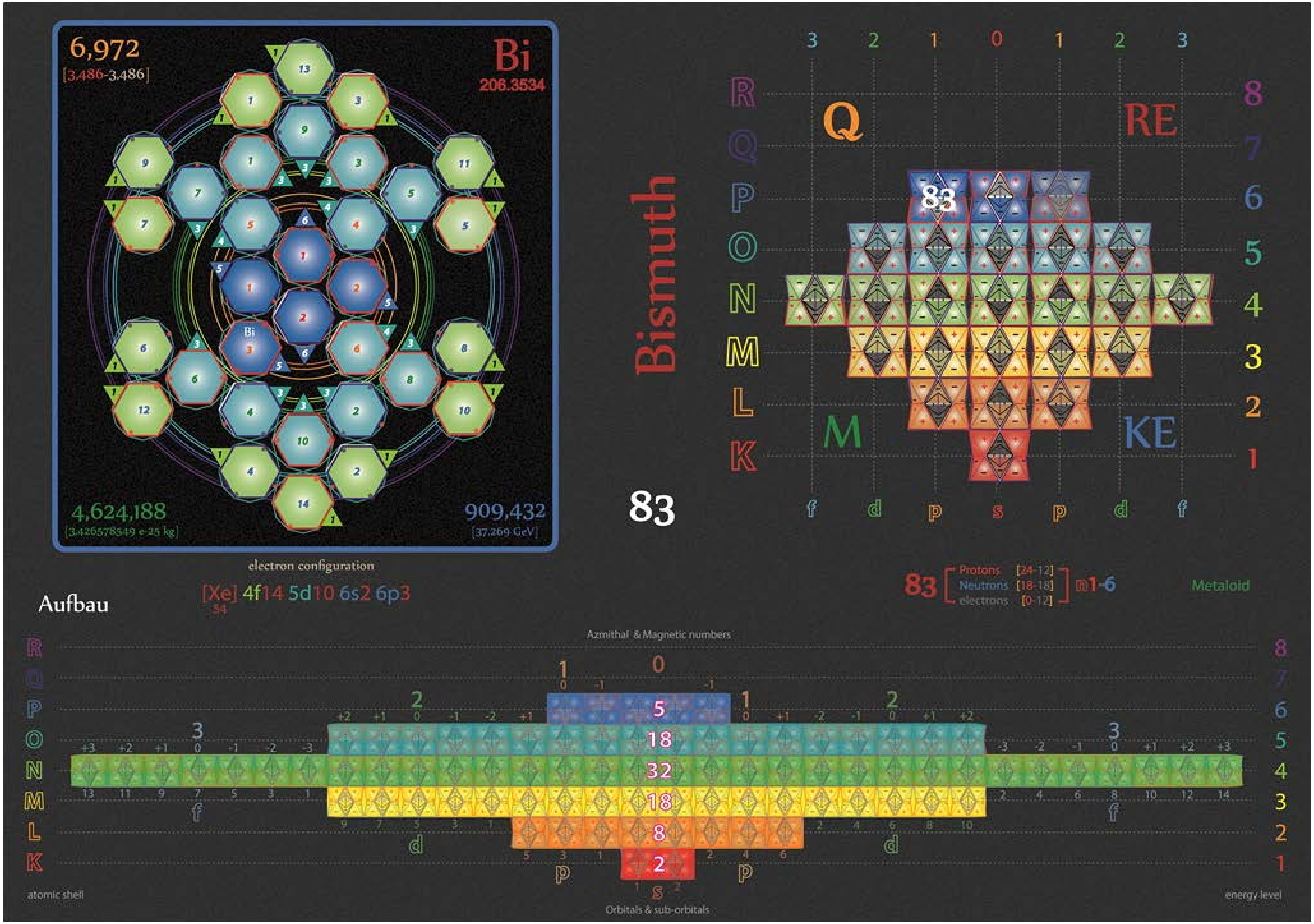
6,972
[3,486-3,486]
Bi
208.3534
4,624,188
[3.426578549 e-25 kg]
909,432
[37.269 GeV]
Bismuth
83
R
Q
P
O
N
M
L
K
Q
RE
M
KE
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
electron configuration
[Xe] 4f14 5d10 6s2 6p3
54
Aufbau
83
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-6
Metaloid
Azmithal & Magnetic numbers
5
18
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.83 - Bismuth atom

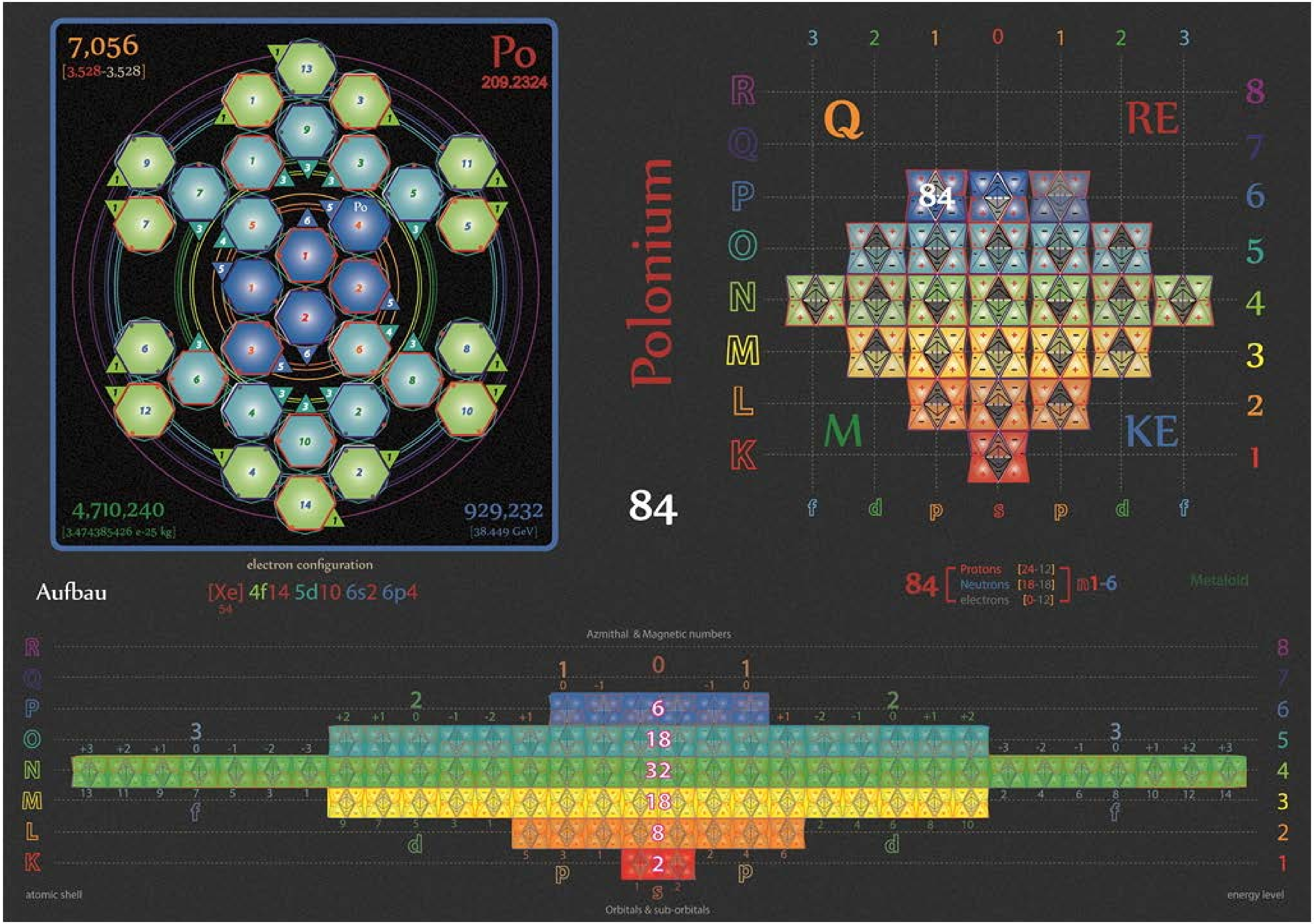
7,056
[3.528-3.528]
Po
209.2324
4,710,240
[3.474385426 e-25 kg]
929,232
[38.449 GeV]
Polonium
84
R
Q
P
O
N
M
L
K
Q
RE
M
KE
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
electron configuration
Aufbau
[Xe] 4f14 5d10 6s2 6p4
54
84
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-6
Metaloid
Azmithal & Magnetic numbers
6
18
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.84 - Polonium atom

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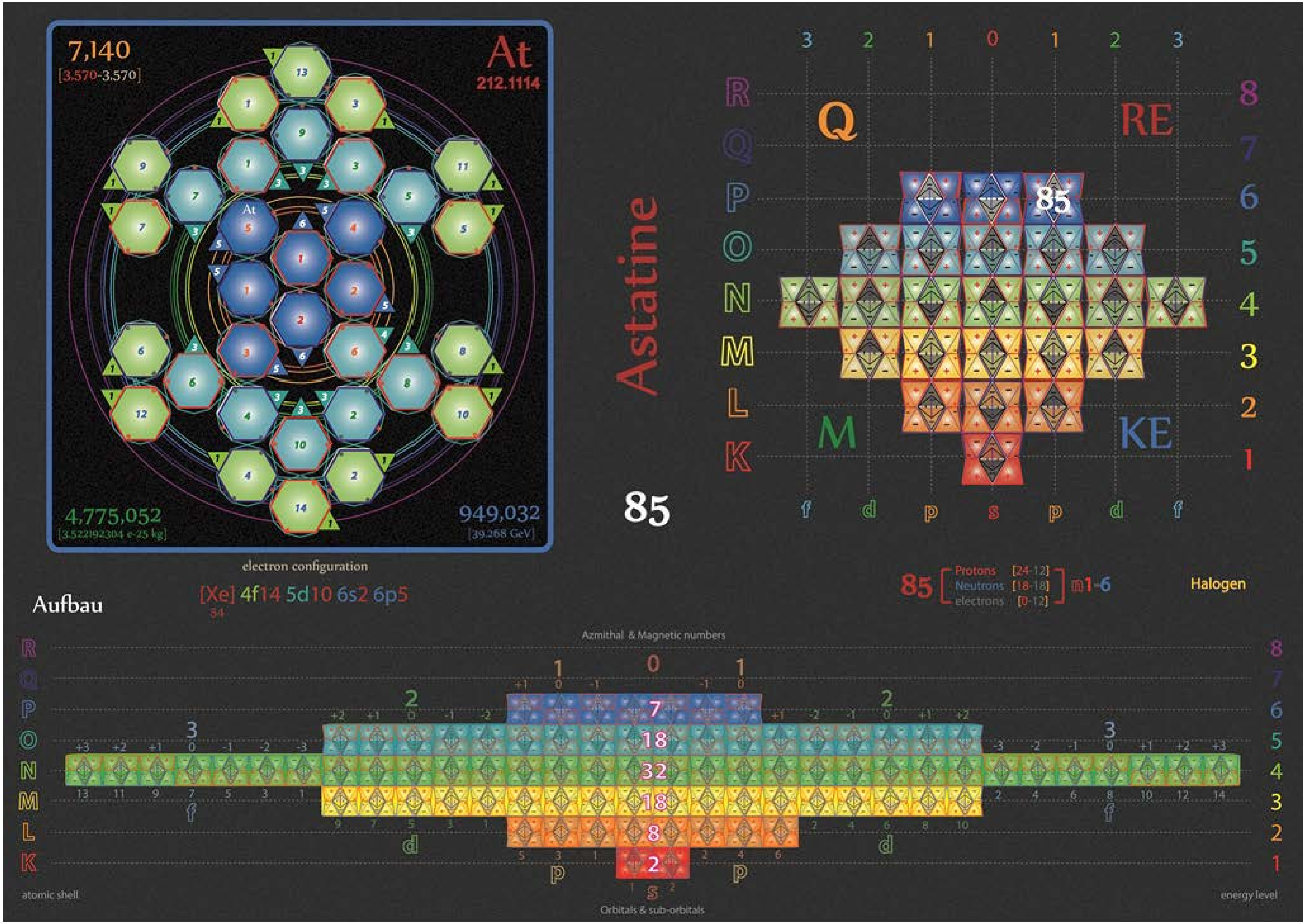
7,140
[3.570-3.570]
At
212.1114
4,775,052
[3.522192304 e-25 kg]
949,032
[39.268 GeV]
Astatine
85
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
3 2 1 0 1 2 3
f d p s p d f
85 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Halogen
electron configuration
[Xe] 4f14 5d10 6s2 6p5
54
Aufbau
Azmithal & Magnetic numbers
7
18
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.85 - Astatine atom

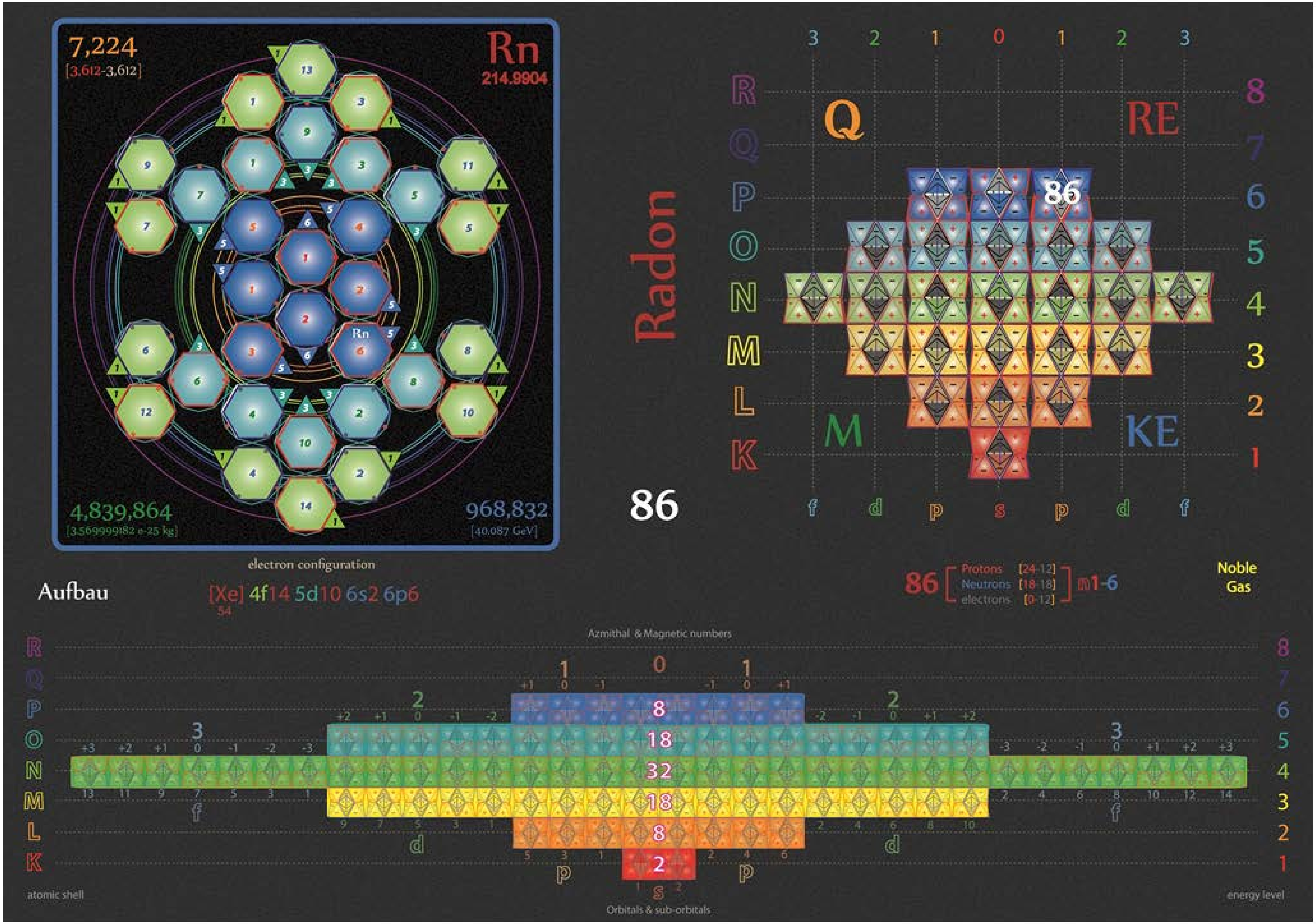
7,224
[3.612-3.612]
Rn
214.9904
4,839,864
[3.569999182 e-25 kg]
968,832
[40.087 GeV]
Radon
86
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
8 7 6 5 4 3 2 1
Q
RE
M
KE
86
f d p s p d f
electron configuration
Aufbau
[Xe] 4f14 5d10 6s2 6p6
54
86 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-6
Noble Gas
Azmithal & Magnetic numbers
8
18
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.86 - Radon atom

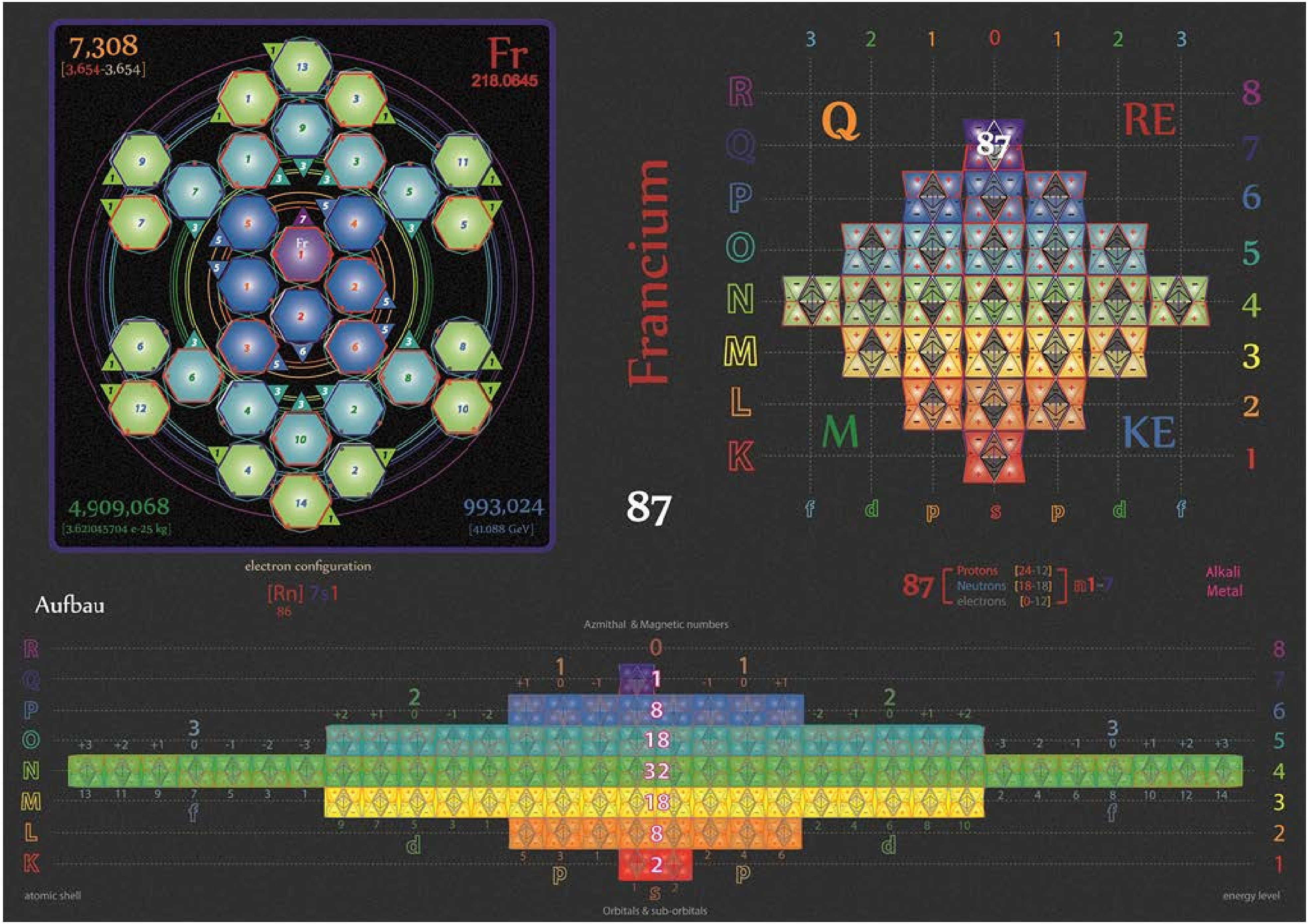
7,308
[3,654-3,654]
Fr
218.0645
4,909,068
[3.621045704 e-25 kg]
993,024
[41.088 GeV]
Francium
87
electron configuration
[Rn] 7s1
86
Aufbau
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
87 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Alkali Metal
Azmithal & Magnetic numbers
0
1
2
3
+3 +2 +1 0 -1 -2 -3
1
8
18
32
18
8
2
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
f
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.87 - Francium atom

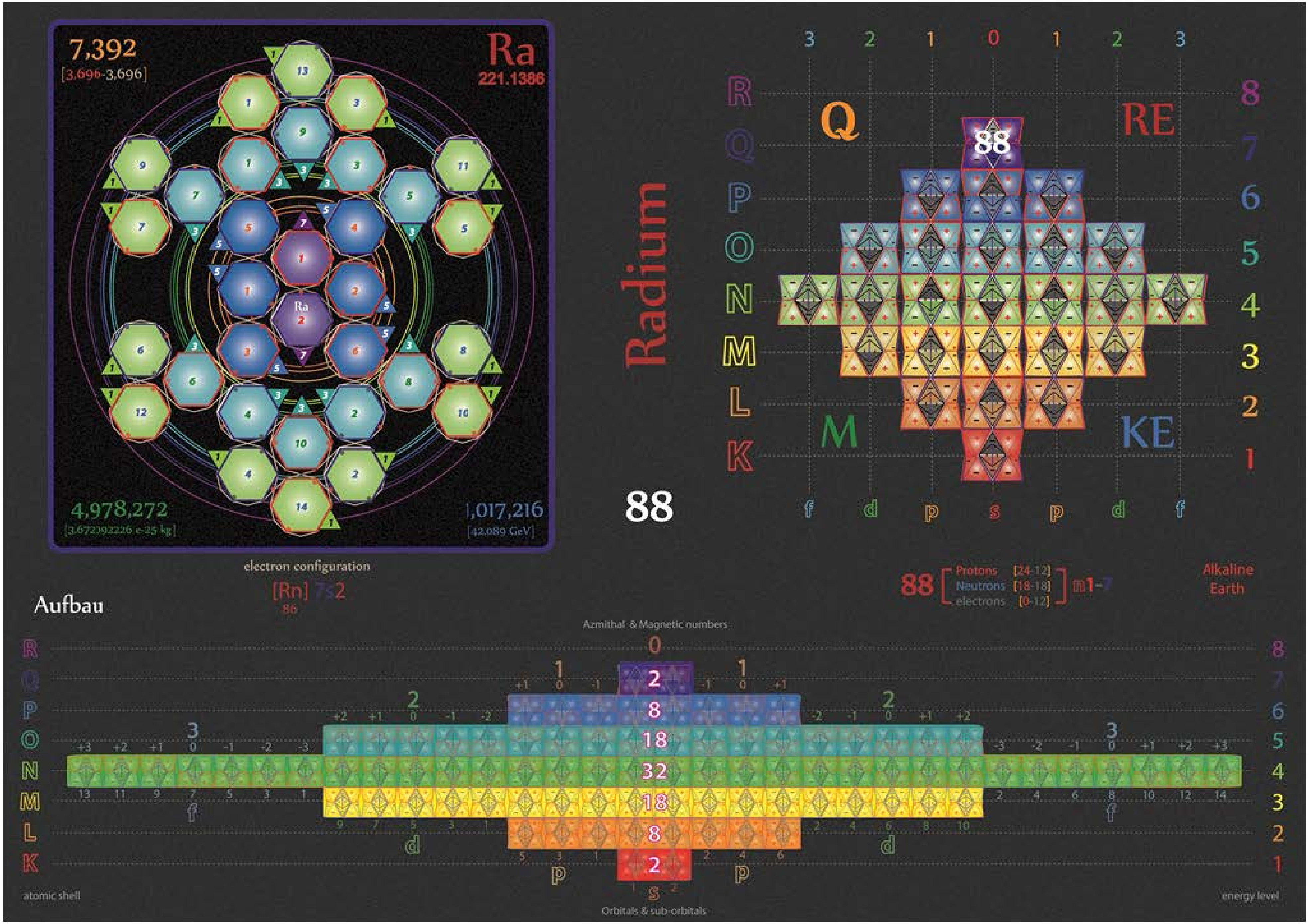
7,392
[3,696-3,696]
Ra
221.1386
4,978,272
[3.672092226 e-25 kg]
1,017,216
[42.089 GeV]
Radium
88
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
88
electron configuration
[Rn] 7s2
86
88 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Alkaline Earth
Aufbau
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
+1 0 -1
+2 +1 0 -1 -2
+3 +2 +1 0 -1 -2 -3
2
8
18
32
18
8
2
13 11 9 7 5 3 1
2 4 6 8 10 12 14
9 7 5 3 1
2 4 6 8 10
5 3 1
2 4 6
1 2
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.88 - Radium atom

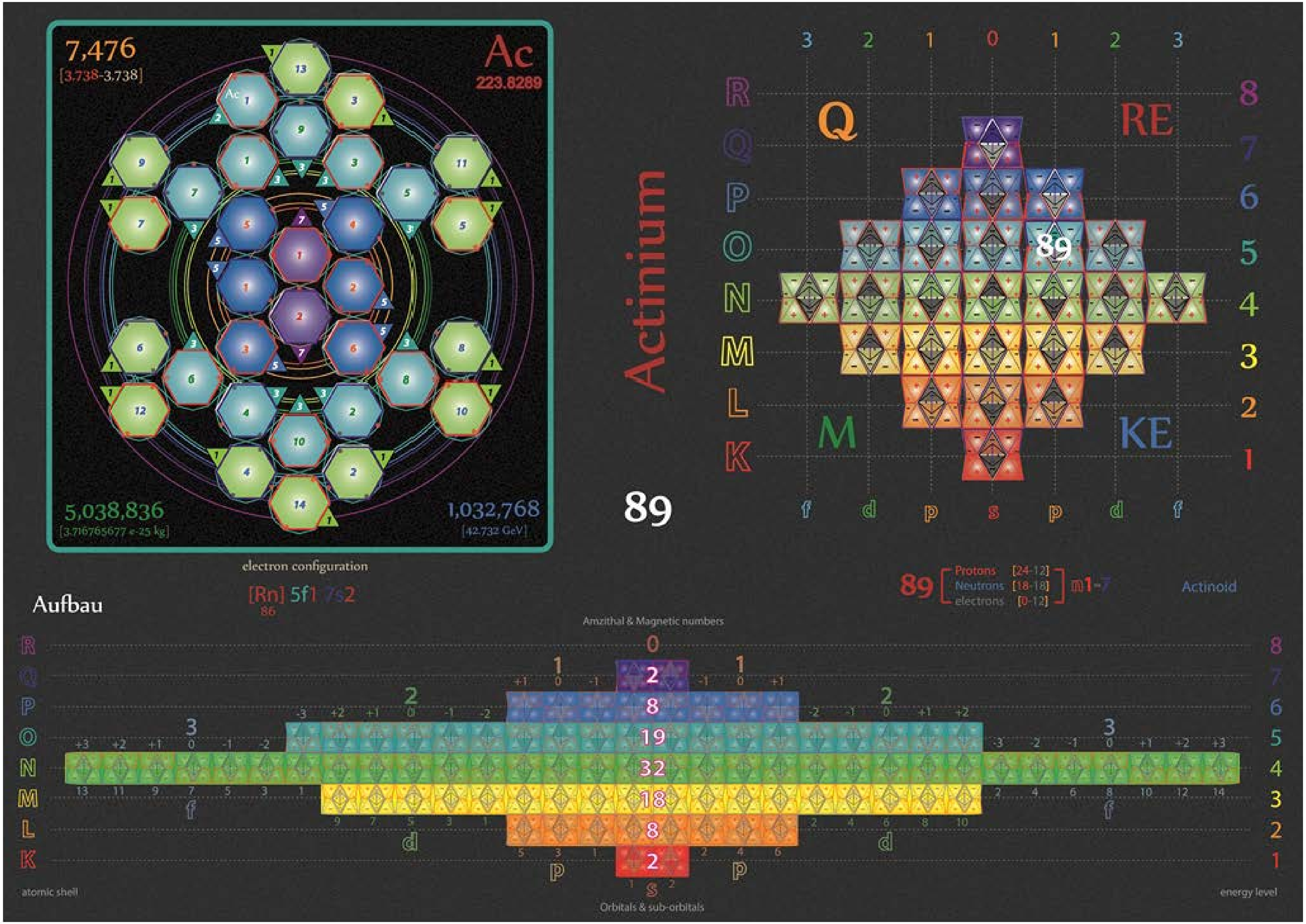
7,476
[3.738-3.738]
Ac
223.8289
5,038,836
[3.716765677 e-25 kg]
1,032,768
[42.732 GeV]
Actinium
89
electron configuration
[Rn] 5f1 7s2
86
Aufbau
Q
RE
M
KE
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3
2
1
0
1
2
3
f
d
p
s
p
d
f
89
89 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Amzithal & Magnetic numbers
0
2
8
19
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.89 - Actinium atom

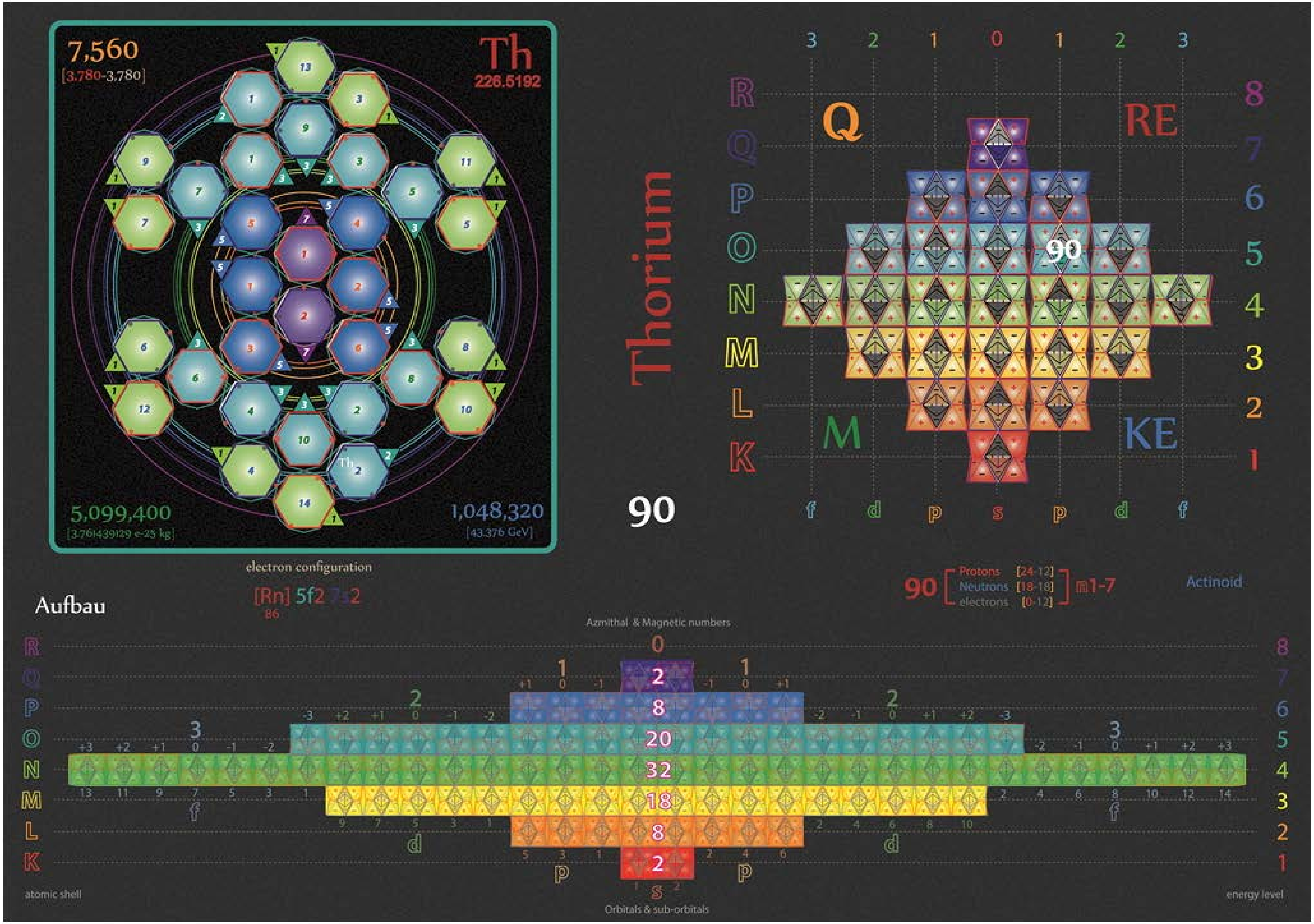
7,560
[3,780-3,780]
Th
226.5192
5,099,400
[3.761439129 e-25 kg]
1,048,320
[43.376 GeV]
Thorium
90
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
90
f d p s p d f
electron configuration
[Rn] 5f2 7s2
86
90 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Aufbau
Azmithal & Magnetic numbers
0
1 1
2 2
3 3
2
8
20
32
18
8
2
f d p s p d f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.90 - Thorium atom

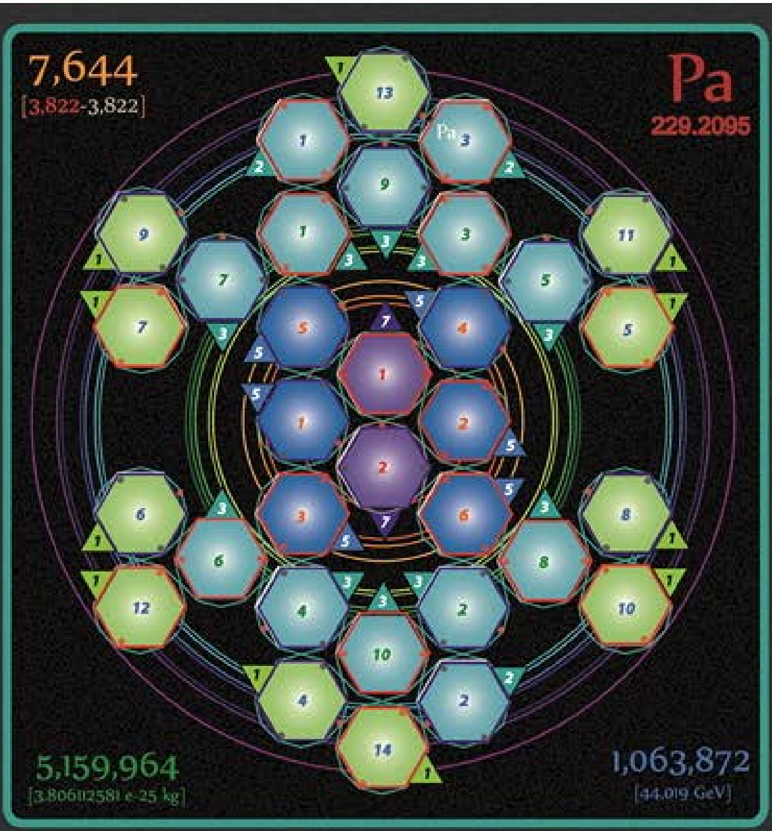
7,644
[3,822-3,822]
Pa
229.2095
5,159,964
[3.806112581 e-25 kg]
1,063,872
[44.019 GeV]

Protactinium

91

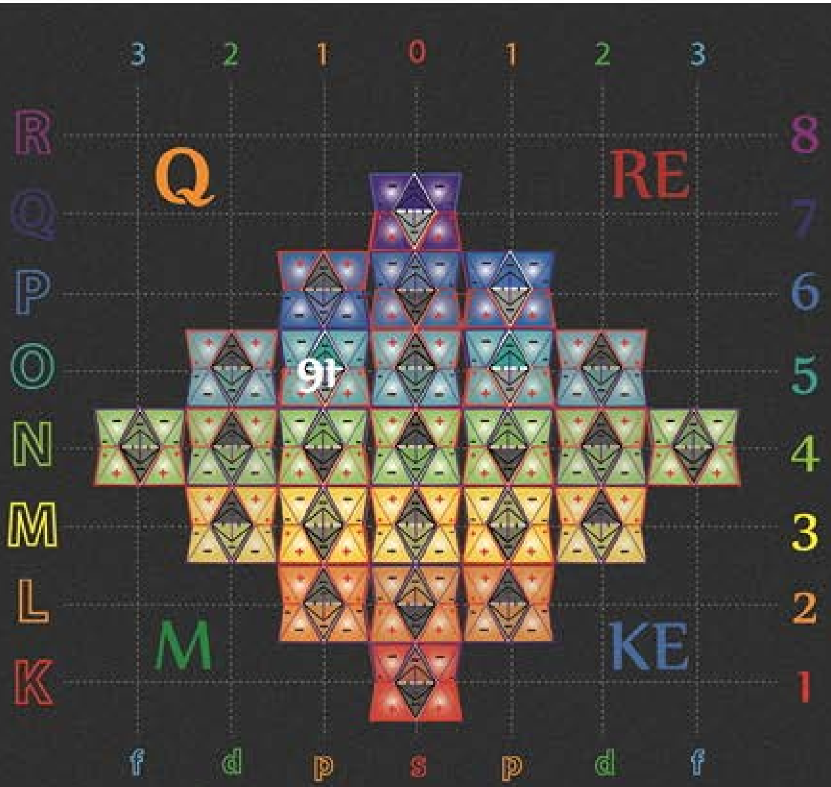
3 2 1 0 1 2 3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
91
8
7
6
5
4
3
2
1
f d p s p d f

Aufbau

electron configuration

[Rn] 5f3 7s2
86

91 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7

Actinoid

Azmithal & Magnetic numbers

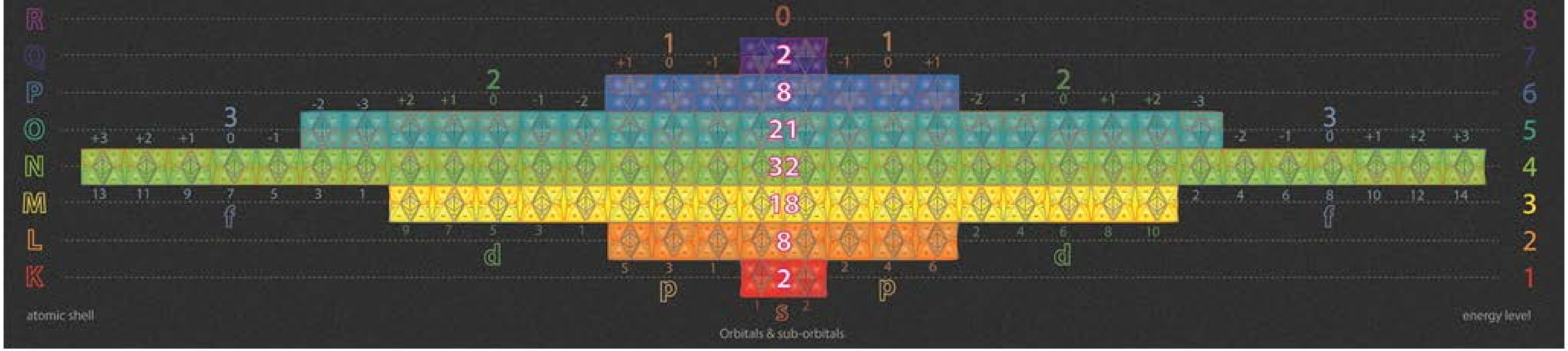
R
Q
P
O
N
M
L
K
0
1
1
2
2
3
3
2
8
21
32
18
8
2
f
f
d
d
p
p
s
8
7
6
5
4
3
2
1
atomic shell
energy level

Orbitals & sub-orbitals

Tetryonics 51.91 - Protactinium atom

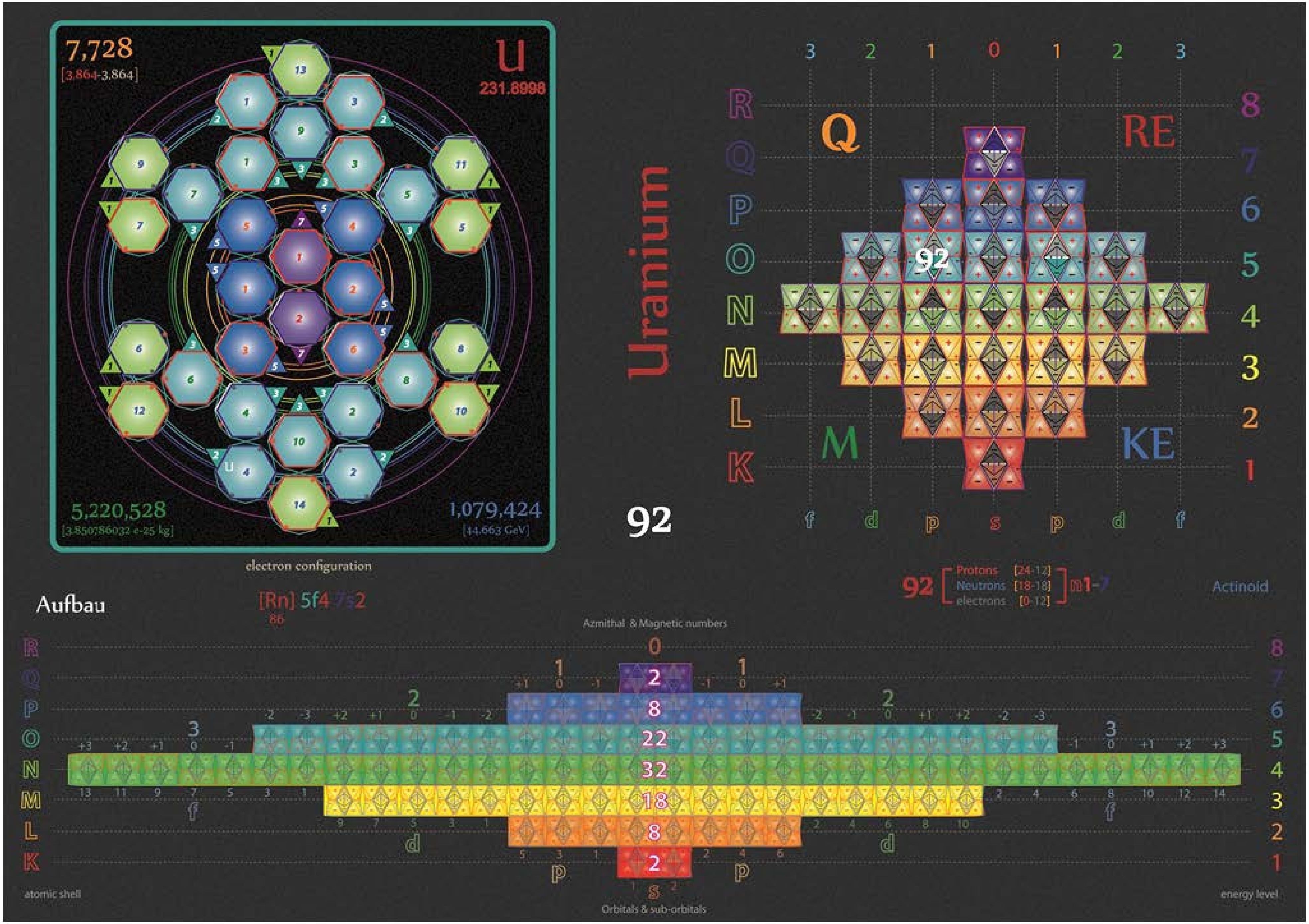
7,728
[3,864-3,864]
U
231.8998
5,220,528
[3.850786032 e-25 kg]
1,079,424
[14.663 GeV]
electron configuration
Uranium
92
3 2 1 0 1 2 3
R Q P O N M L K
Q
RE
M
KE
8 7 6 5 4 3 2 1
f d p s p d f
92
92 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-7
Actinoid
Aufbau
[Rn] 5f4 7s2
86
Azmithal & Magnetic numbers
0
1
2
3
2
8
22
32
18
8
2
f
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.92 - Uranium atom

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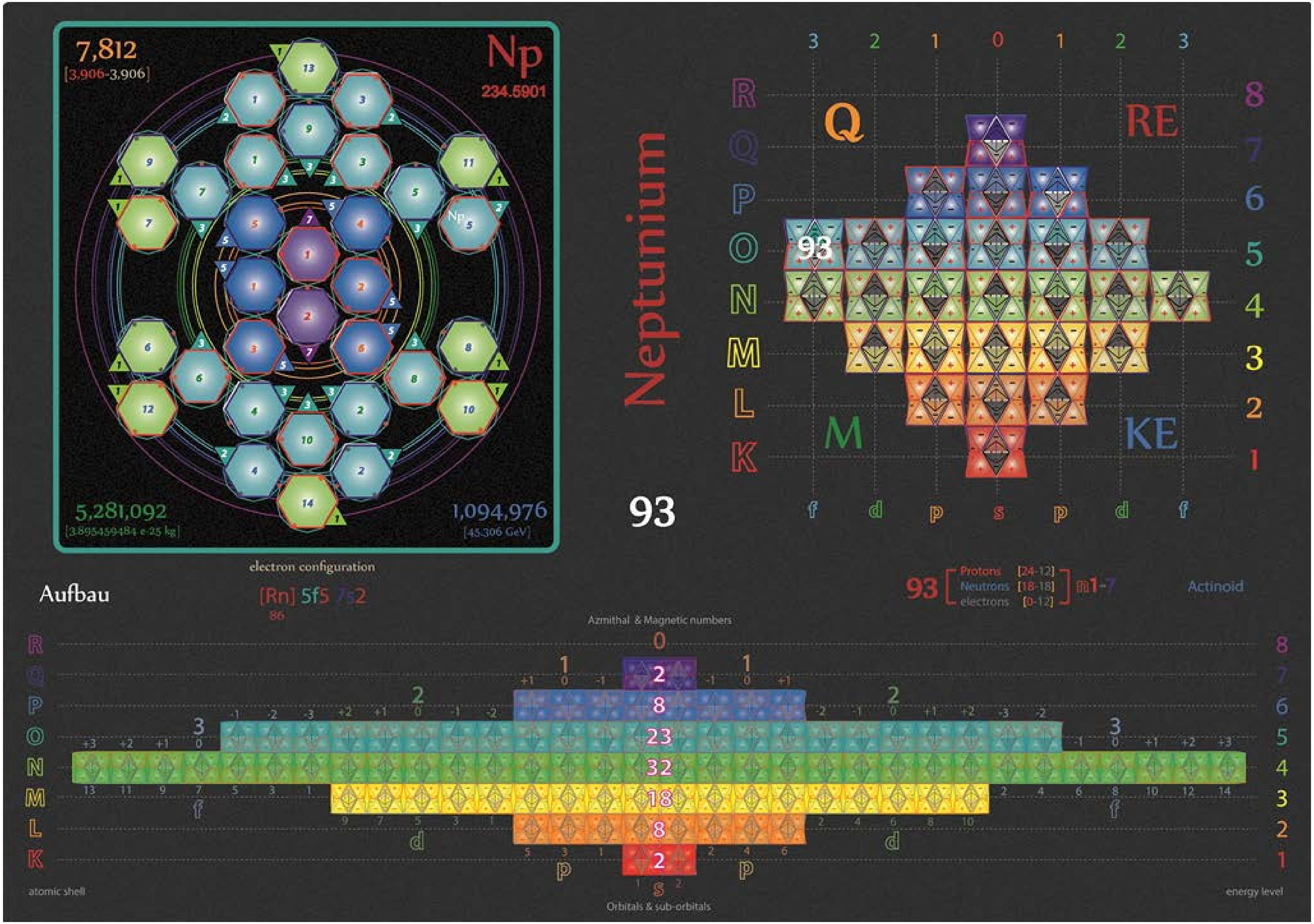
7,812
[3,906-3,906]
Np
234.5901
5,281,092
[3.895459484 e-25 kg]
1,094,976
[45.306 GeV]
Neptunium
93
Q
RE
M
KE
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
electron configuration
Aufbau
[Rn] 5f5 7s2
86
93 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
2
8
23
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.93 - Neptunium atom

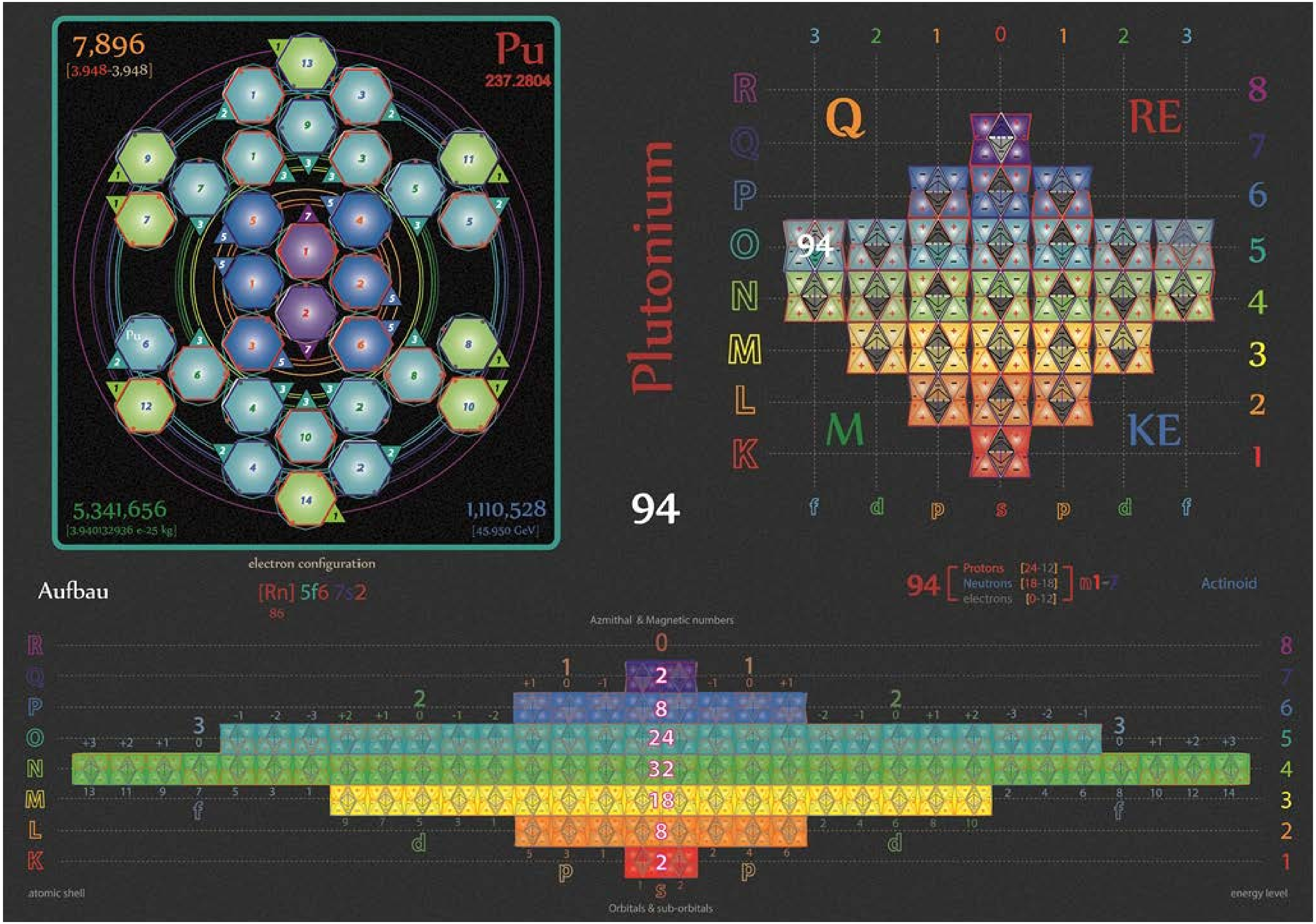
7,896
[3,948-3,948]
Pu
237.2804
5,341,656
[3.940132936 e-25 kg]
1,110,528
[45.950 GeV]
Plutonium
94
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f6 7s2
86
94
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
m1-7
Actinoid
Azmithal & Magnetic numbers
2
8
24
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals
s
p
d
f

Tetryonics 51.94 - Plutonium atom

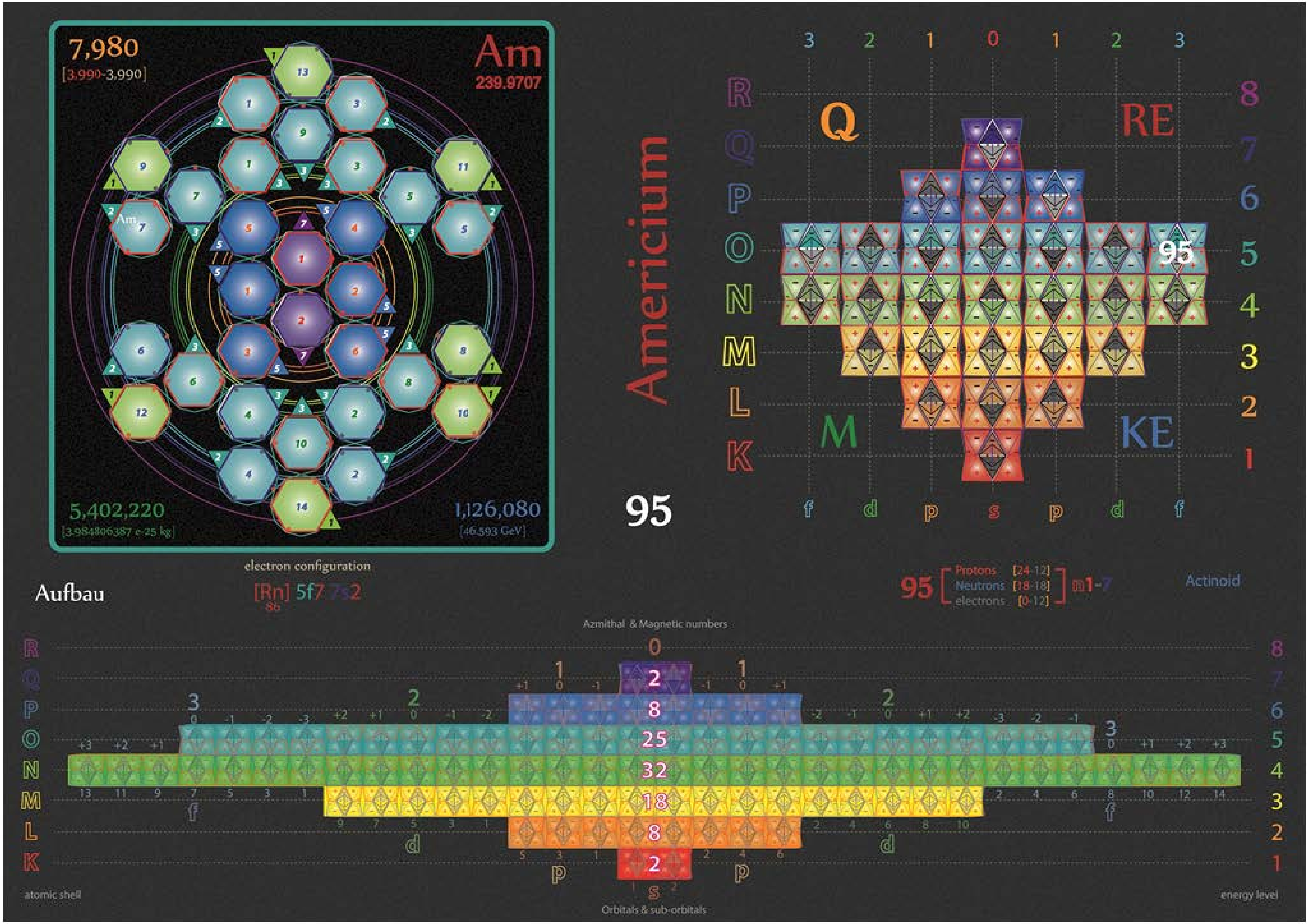
7,980
[3,990-3,990]
Am
239.9707
5,402,220
[3.984806387 e-25 kg]
1,126,080
[46.593 GeV]
Americium
95
Q
RE
M
KE
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
electron configuration
[Rn] 5f7 7s2
86
Aufbau
95 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-7
Actinoid
Azmithal & Magnetic numbers
2
8
25
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.95 - Americium atom

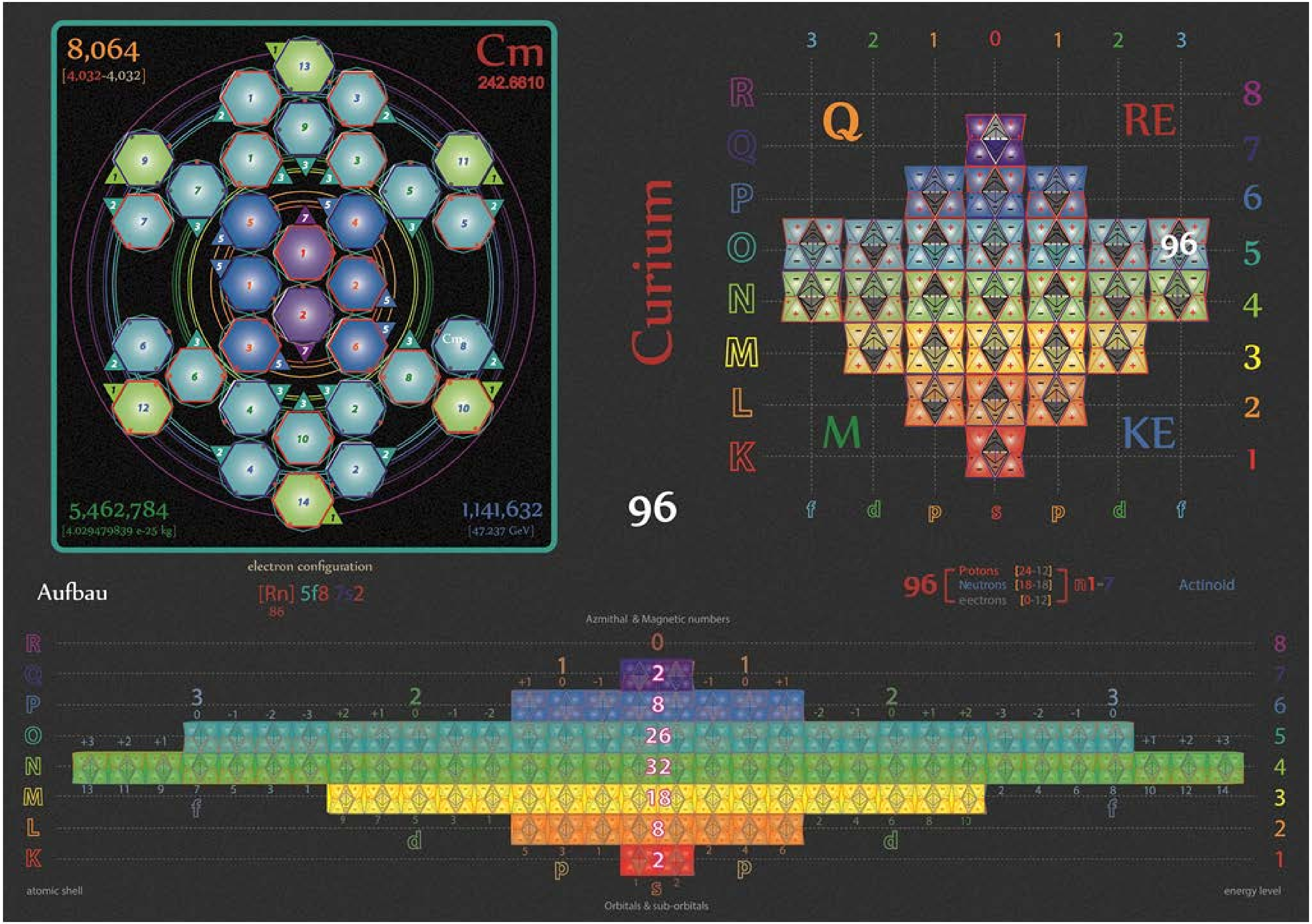
8,064
[4,032-4,032]
Cm
242.6810
5,462,784
[4.029479839 e-25 kg]
1,141,632
[47.237 GeV]
Curium
96
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
[Rn] 5f8 7s2
86
Aufbau
96 [Potons [24-12] Neutrons [18-18] eectrons [0-12]] n1-7
Actinoid
Azmithal & Magnetic numbers
0
2
8
26
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.96 - Curium atom

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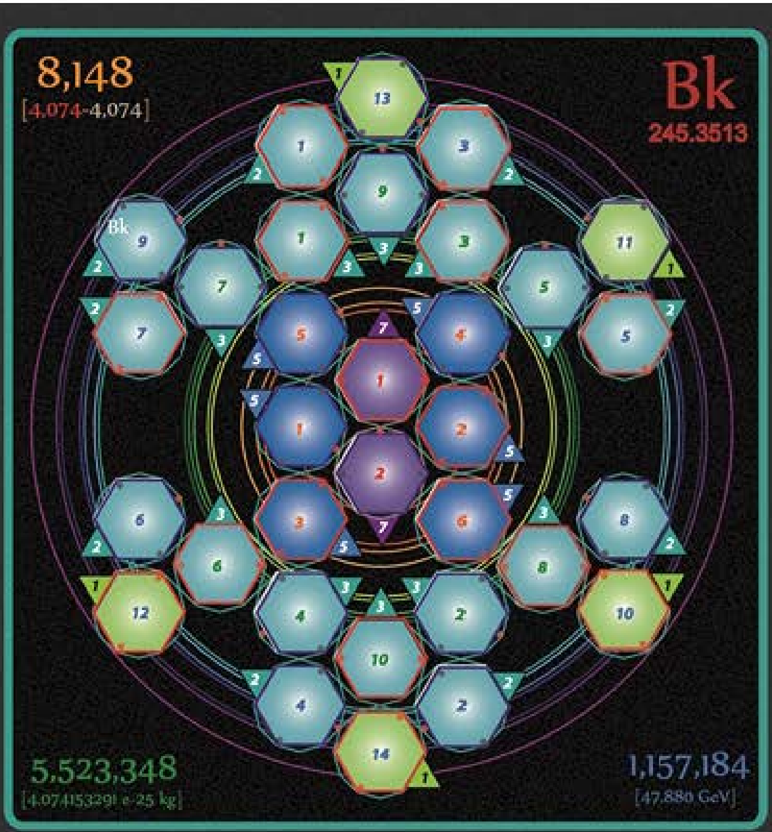
8,148
[4,074-4,074]
Bk
245.3513
Bk
5,523,348
[4.074153291 e-25 kg]
1,157,184
[47.880 GeV]

Berkelium

97

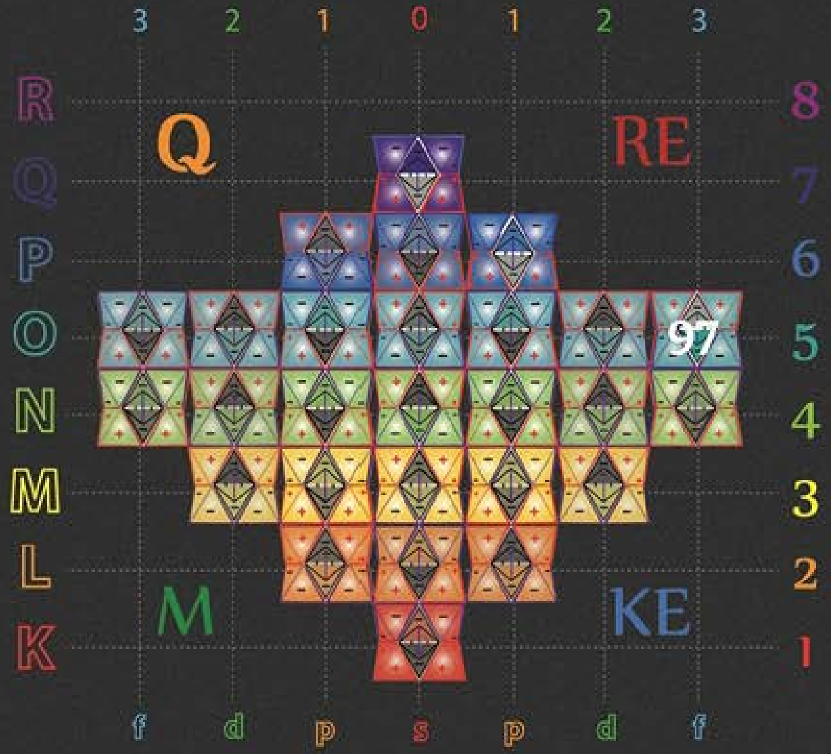
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
97
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

electron configuration

Aufbau

[Rn] 5f9 7s2
86

97 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7

Actinoid

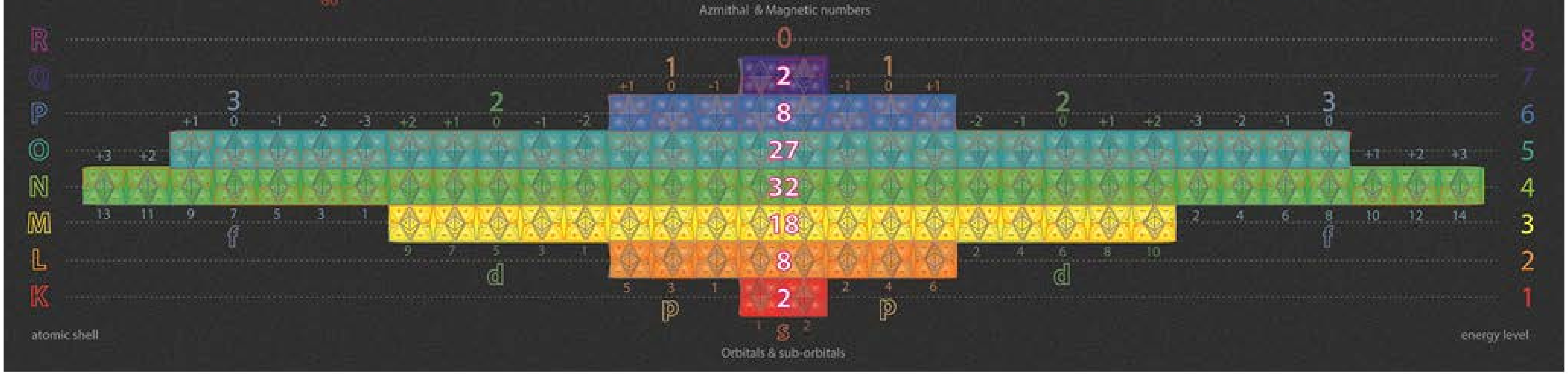
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
0
1
1
2
3
2
3
2
8
27
32
18
8
2
f
f
d
d
p
p
s
8
7
6
5
4
3
2
1
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.97 - Berkelium atom

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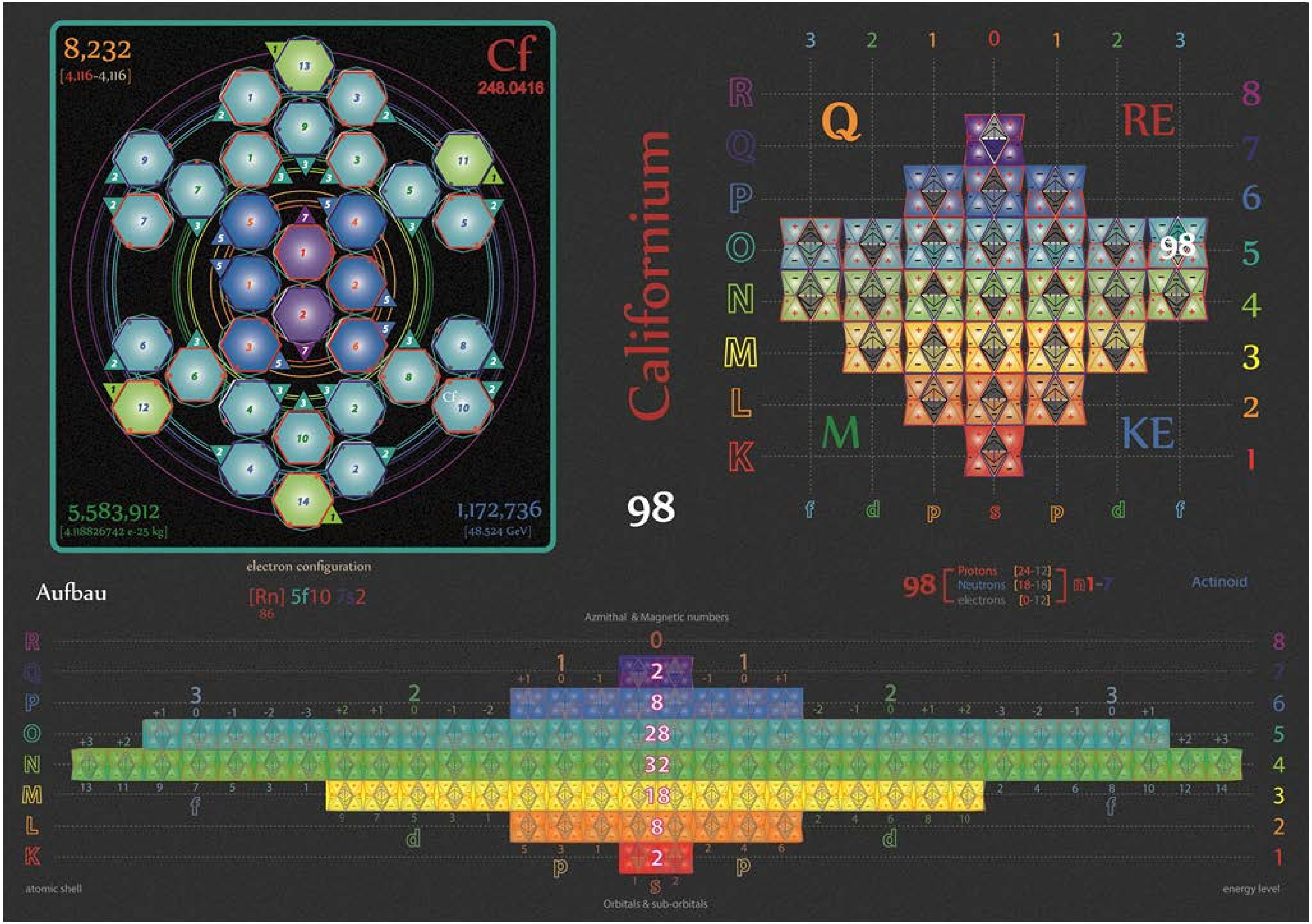
8,232
[4,116-4,116]
Cf
248.0416
5,583,912
[4.118826742 e-25 kg]
1,172,736
[48.524 GeV]
Californium
98
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
98
f d p s p d f
electron configuration
Aufbau
[Rn] 5f10 7s2
86
98 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
0
2
8
28
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.98 - Californium atom

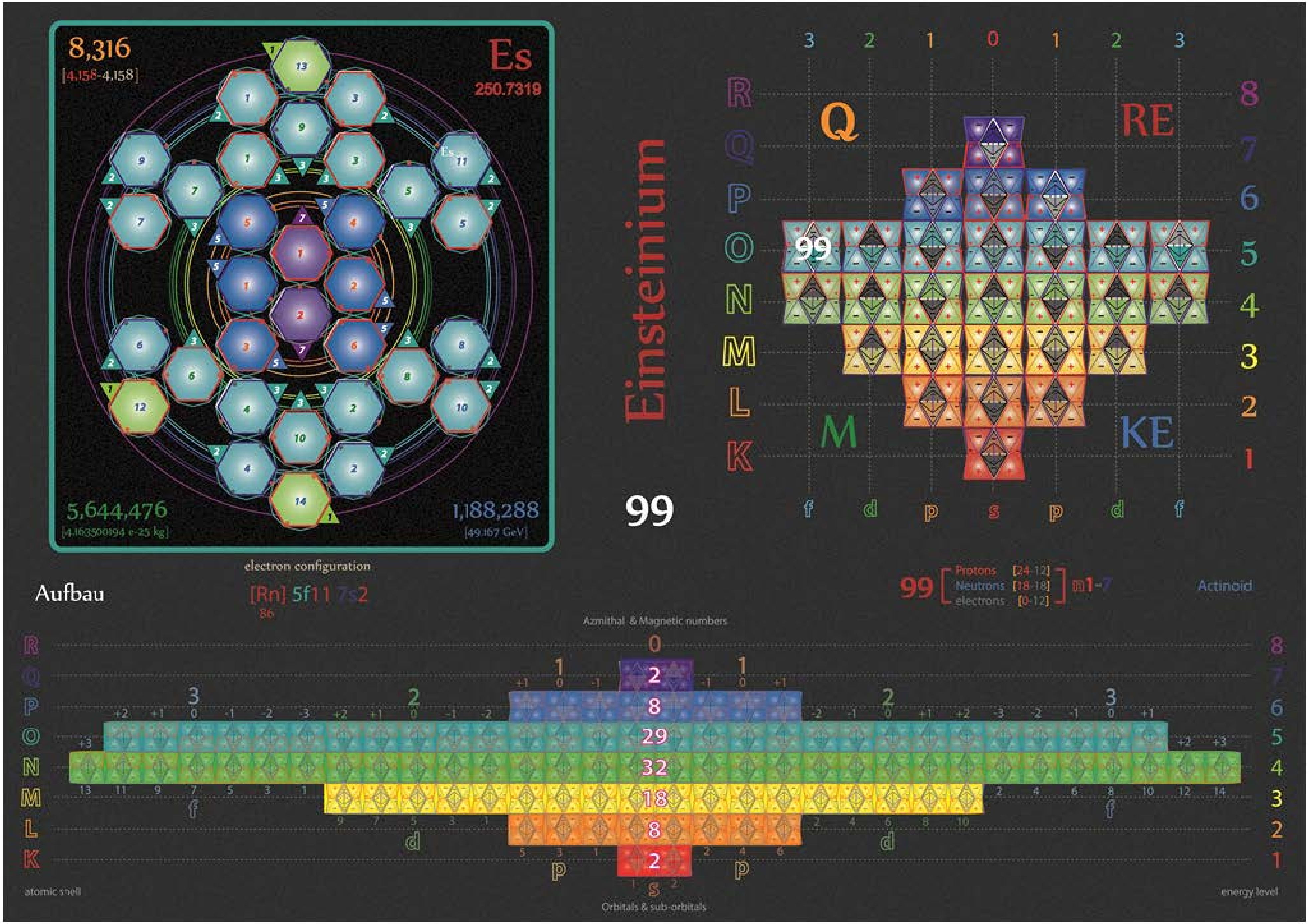
8,316
[4,158-4,158]
Es
250.7319
5,644,476
[4.163500194 e-25 kg]
1,188,288
[49.167 GeV]
Einsteinium
99
R
Q
P
O
N
M
L
K
3
2
1
0
1
2
3
Q
RE
M
KE
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
electron configuration
Aufbau
[Rn] 5f11 7s2
86
99
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-7
Actinoid
Azmithal & Magnetic numbers
2
8
29
32
18
8
2
atomic shell
Orbitals & sub-orbitals
energy level

Tetryonics 51.99 - Einsteinium atom

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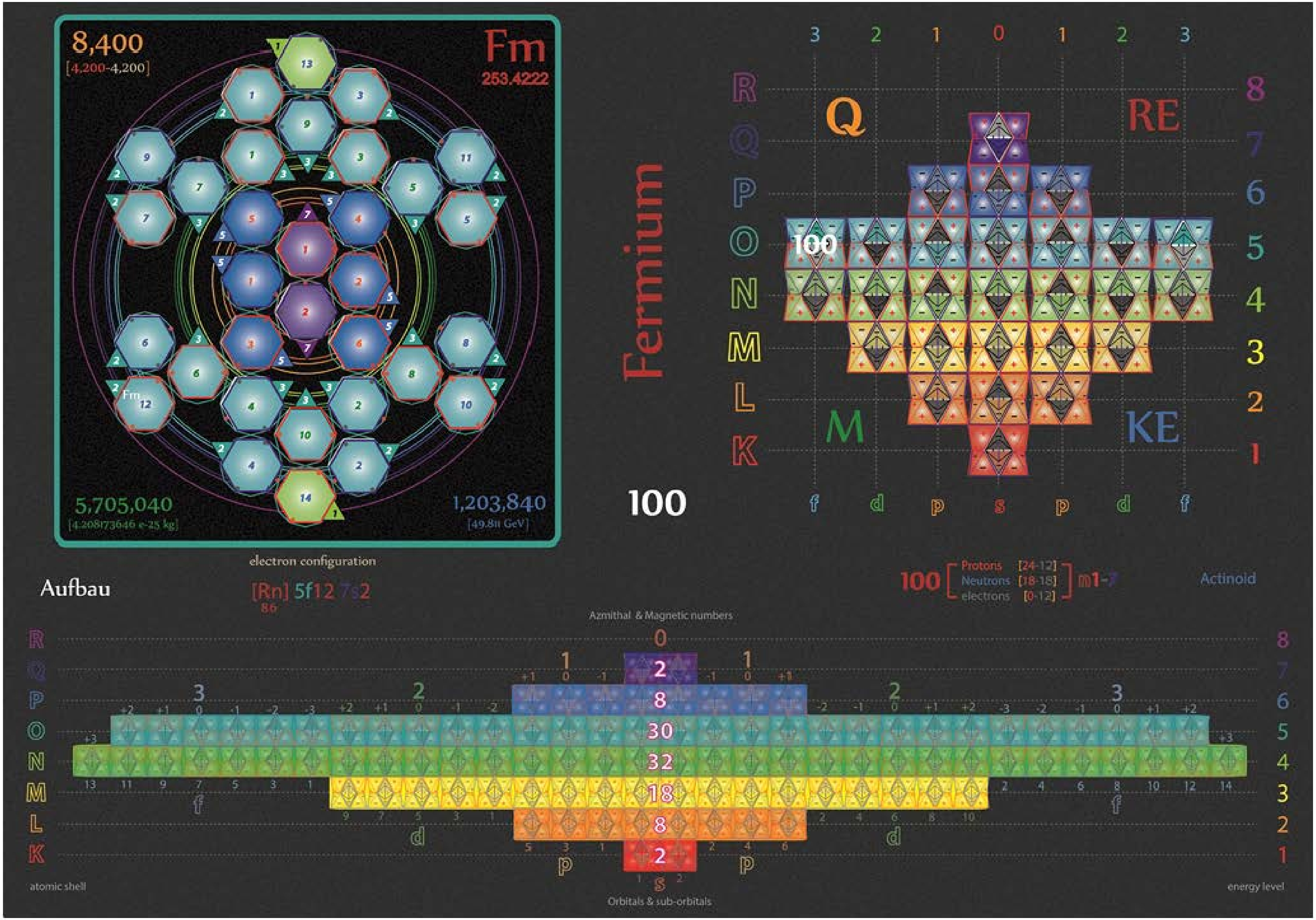
8,400
[4,200-4,200]
Fm
253.4222
5,705,040
[4.208173646 e-25 kg]
1,203,840
[49.811 GeV]
Fermium
100
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
electron configuration
[Rn] 5f12 7s2
86
Aufbau
100 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
2
8
30
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.100 - Fermium atom

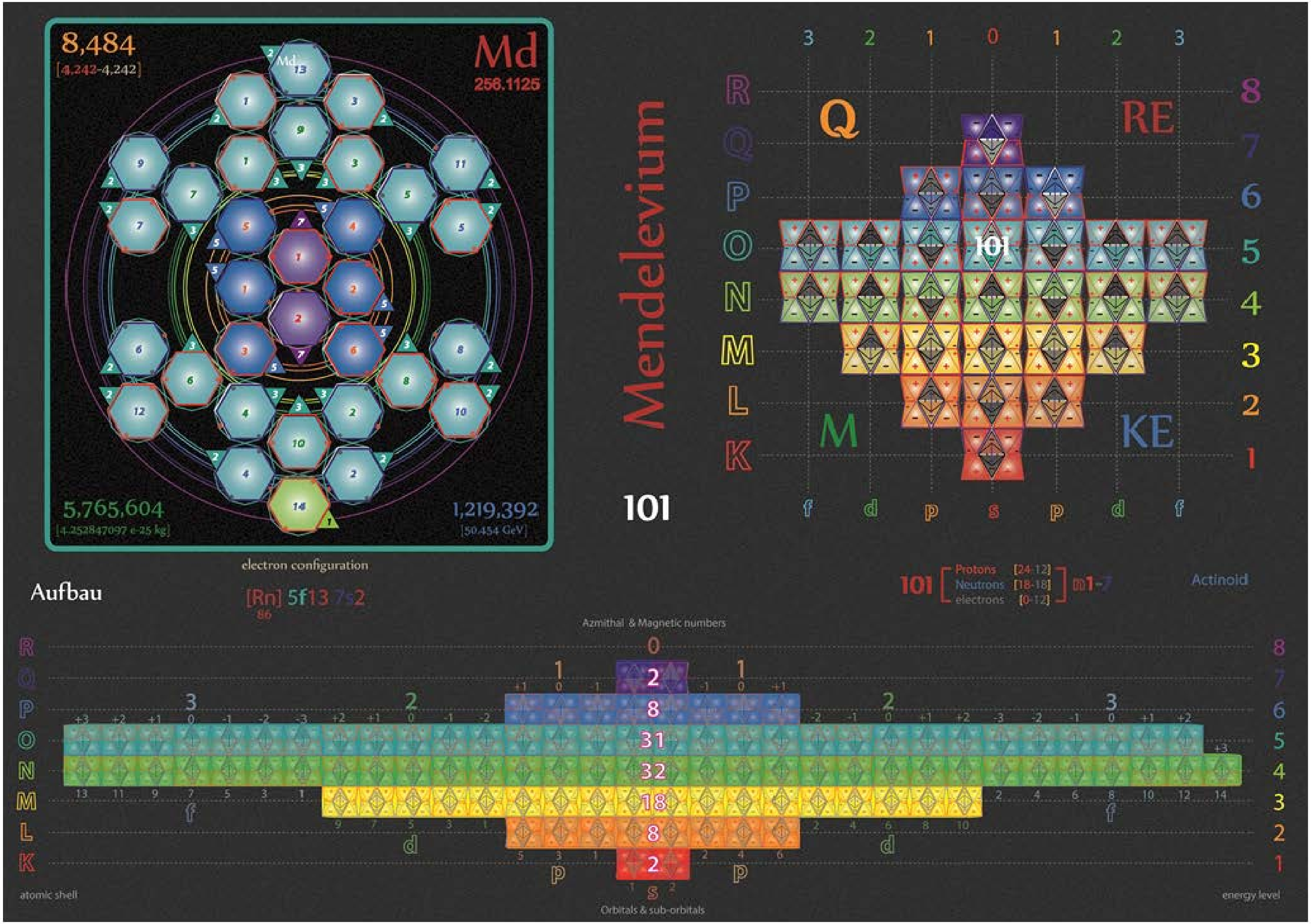
8,484
[4,242-4,242]
Md
256.1125
5,765,604
[4.252847097 e-25 kg]
1,219,392
[50.454 GeV]
Mendelevium
101
Q
RE
M
KE
R Q P O N M L K
8 7 6 5 4 3 2 1
3 2 1 0 1 2 3
f d p s p d f
electron configuration
Aufbau
[Rn] 5f13 7s2
86
101 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
2
8
31
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.101 - Mendelevium atom

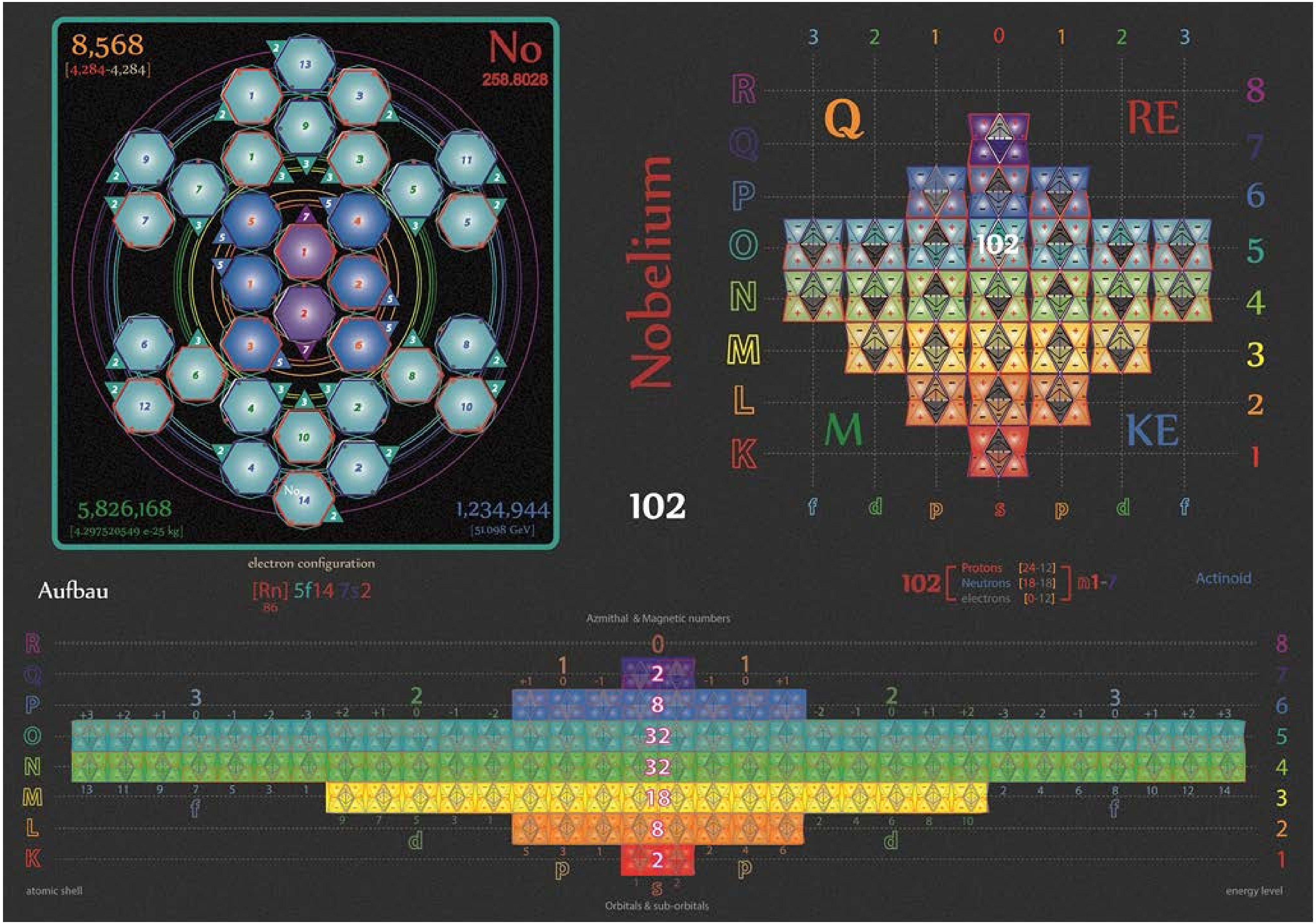
8,568
[4,284-4,284]
No
258.8028
5,826,168
[4.297520549 e-25 kg]
1,234,944
[51.098 GeV]
Nobelium
102
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 7s2
86
102 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
2
8
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.102 - Nobelium atom

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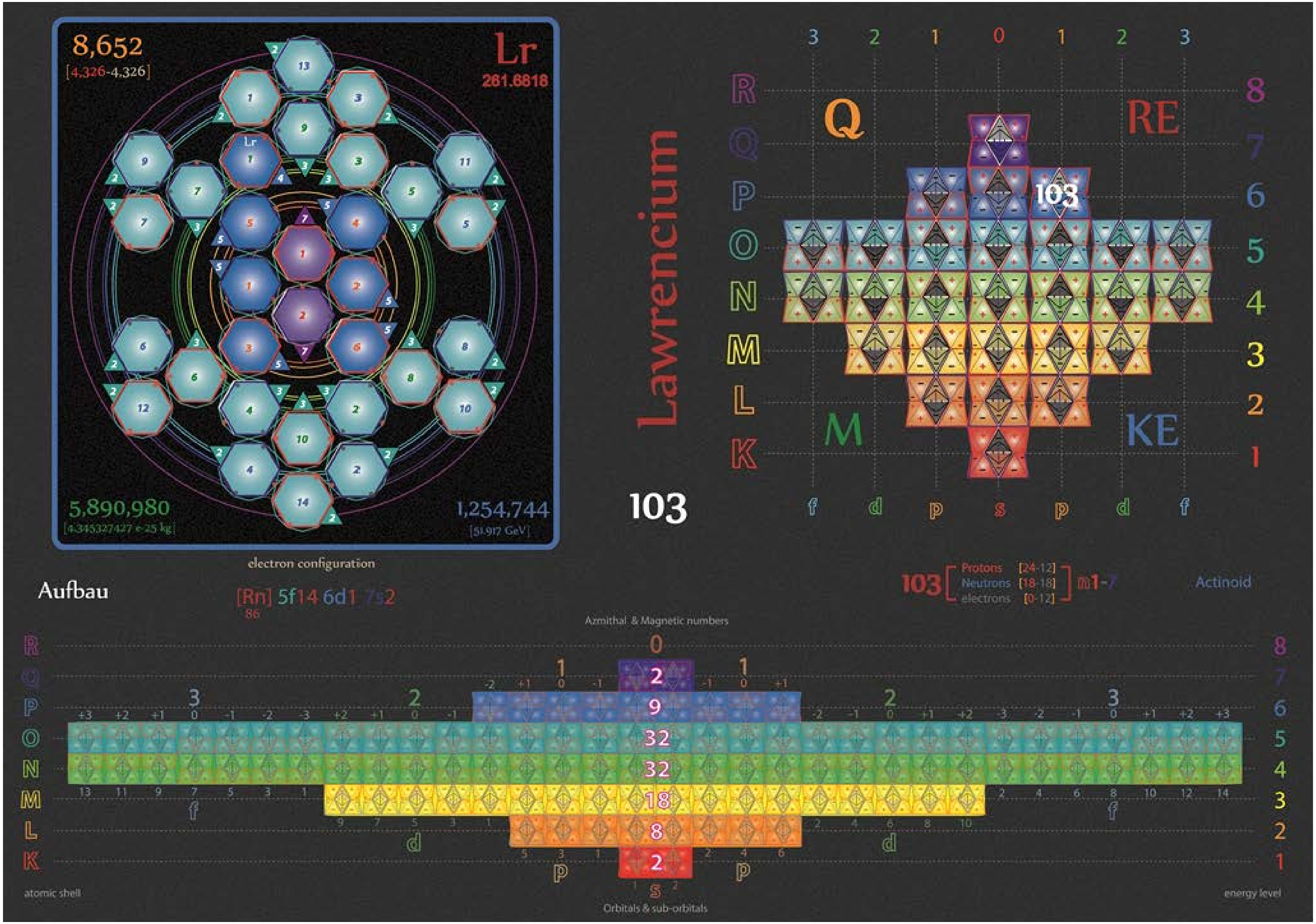
8,652
[4.326-4.326]
Lr
281.6818
5,890,980
[4.345327427 e-25 kg]
1,254,744
[51.917 GeV]
Lawrencium
103
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d1 7s2
86
103 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Actinoid
Azmithal & Magnetic numbers
0
1
2
3
2
9
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.103 - Lawrencium atom

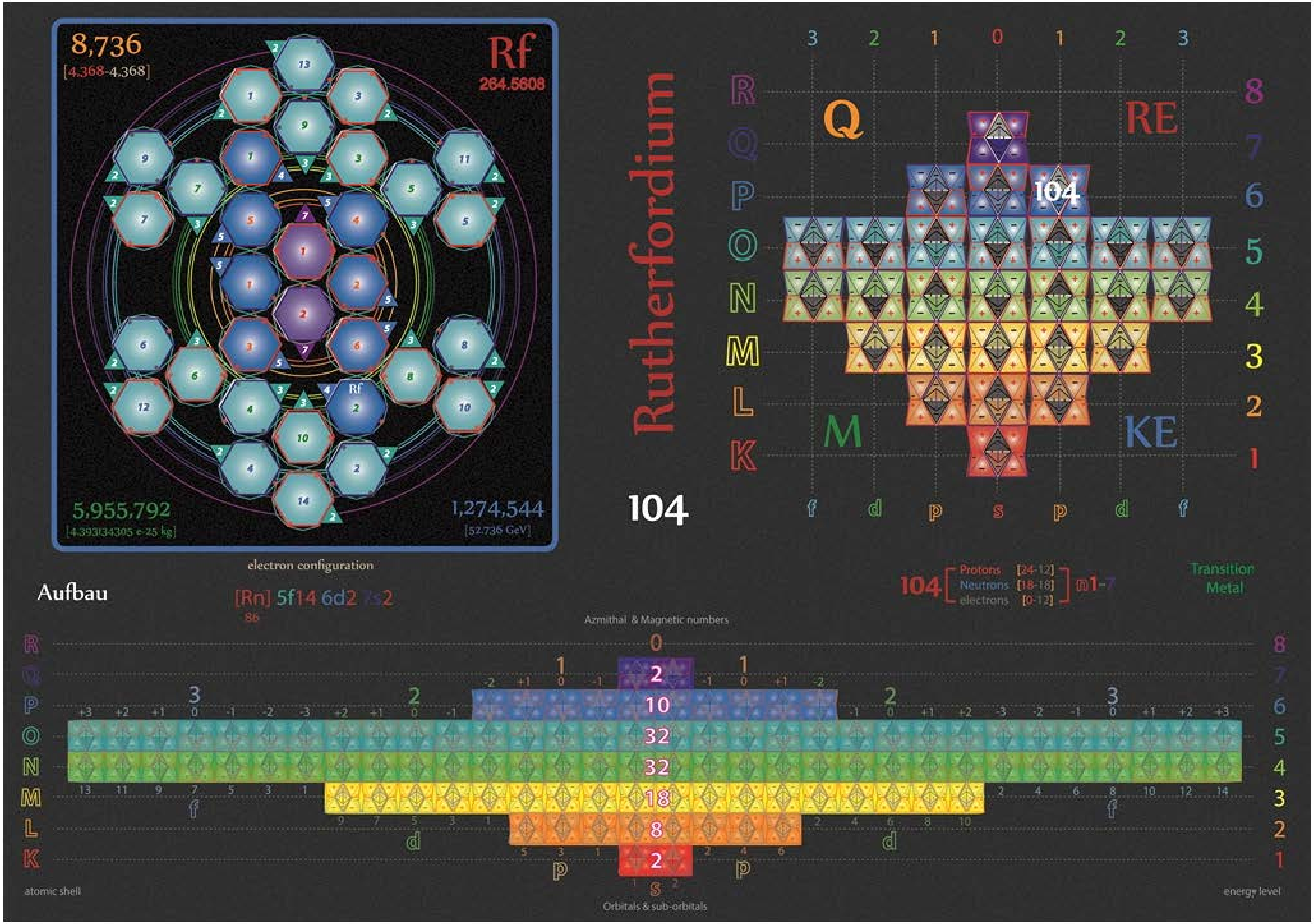
8,736
[4,368-4,368]
Rf
264.5608
5,955,792
[4.393134305 e-25 kg]
1,274,544
[52.736 GeV]
Rutherfordium
104
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
Q
RE
M
KE
8
7
6
5
4
3
2
1
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d2 7s2
86
104 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-7
Transition Metal
Azmithal & Magnetic numbers
0
2
10
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.104 - Rutherfordium atom

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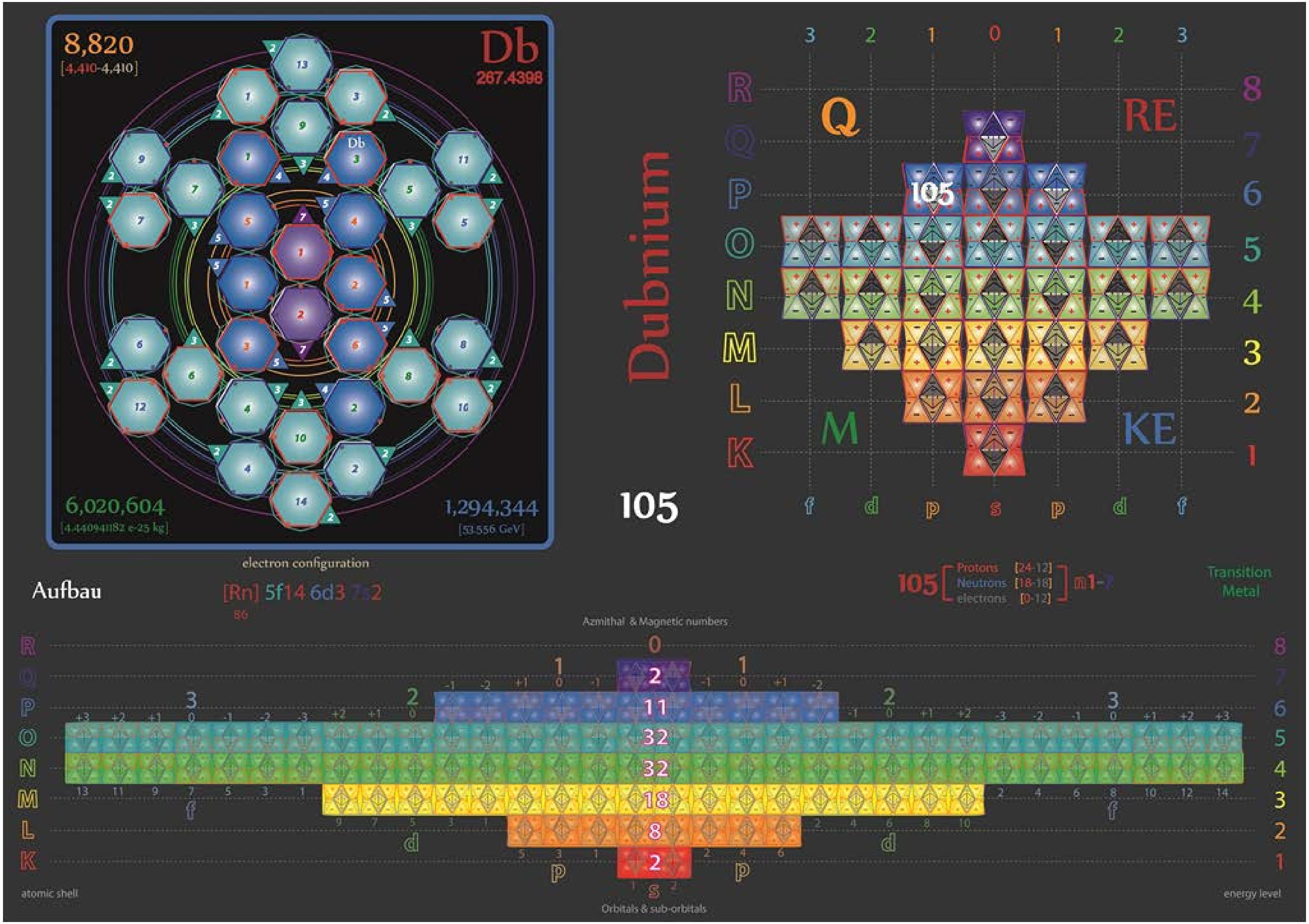
8,820
[4,410-4,410]
Db
287.4398
6,020,604
[4.44094182 e-25 kg]
1,294,344
[53.556 GeV]
Dubnium
105
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d3 7s2
86
105 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Transition Metal
Azmithal & Magnetic numbers
2
11
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.105 - Dubnium atom

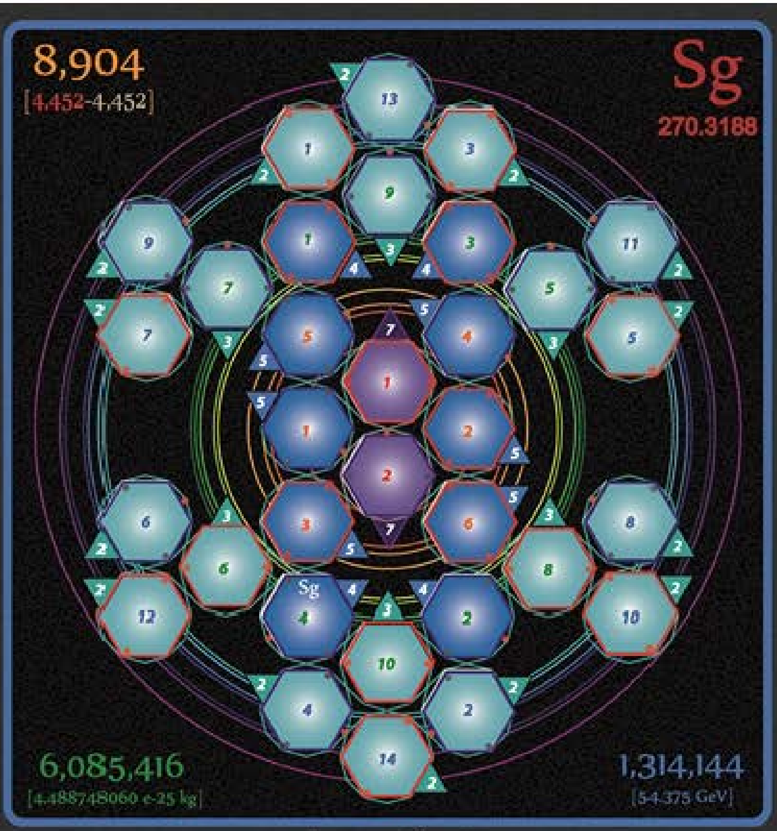
8,904
[4,452-4,452]
Sg
270.3188
6,085,416
[4.488748060 e-25 kg]
1,314,144
[54.375 GeV]

Seaborgium

106

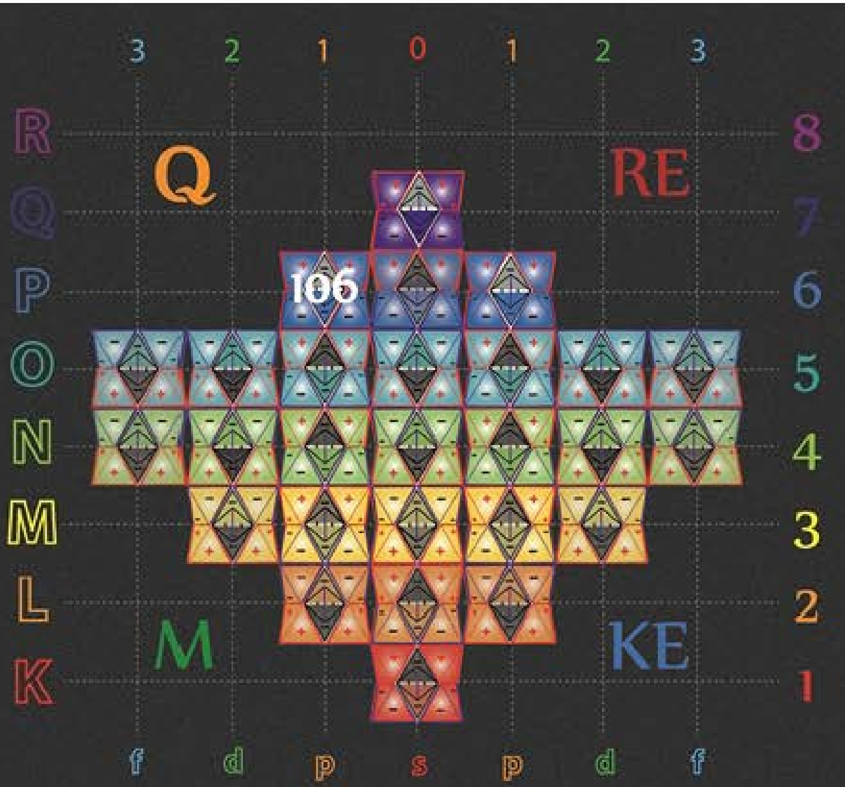
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
Q
RE
M
KE
106
f
d
p
s
p
d
f

electron configuration

Aufbau

[Rn] 5f14 6d4 7s2
86

106 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7

Transition Metal

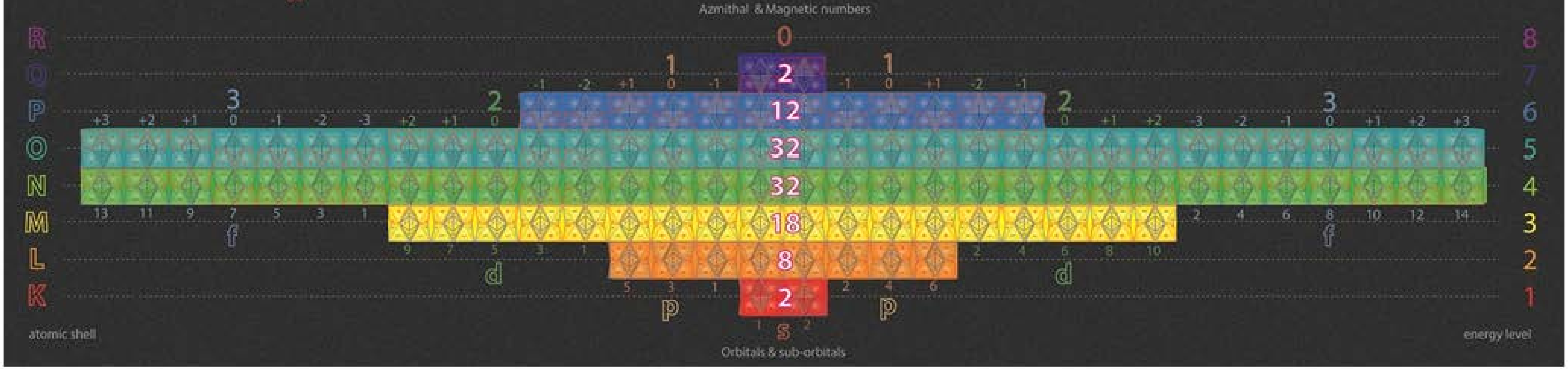
Azmithal & Magnetic numbers
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
0
2
12
32
32
18
8
2
f
d
p
s
p
d
f
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.106 - Seaborgium atom

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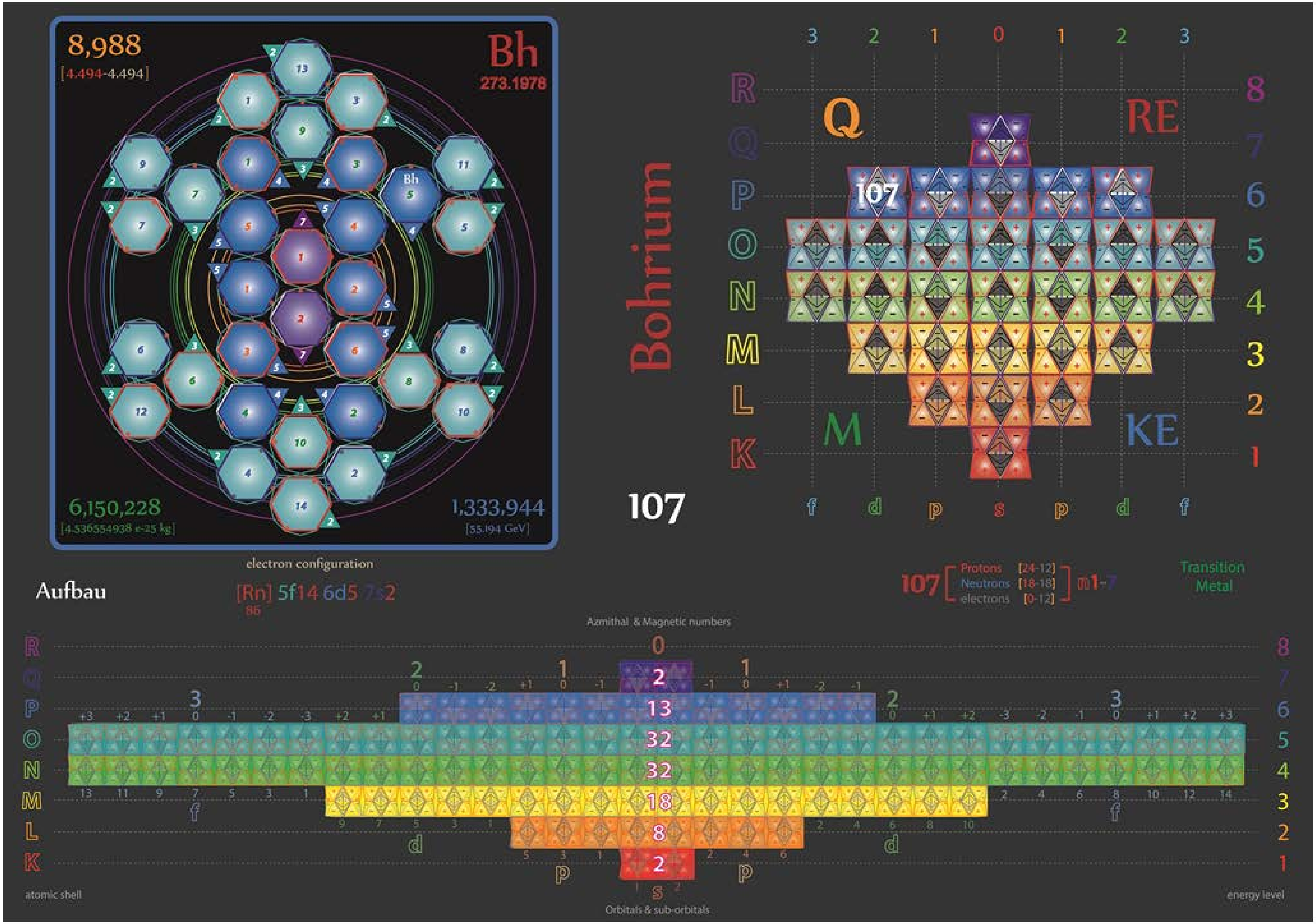
8,988
[4.494-4.494]
Bh
273.1978
6,150,228
[4.536554938 e-25 kg]
1,333,944
[55.194 GeV]
Bohrium
107
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d5 7s2
86
107 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Transition Metal
Azmithal & Magnetic numbers
2
13
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals
s
p
d
f

Tetryonics 51.107 - Bohrium atom

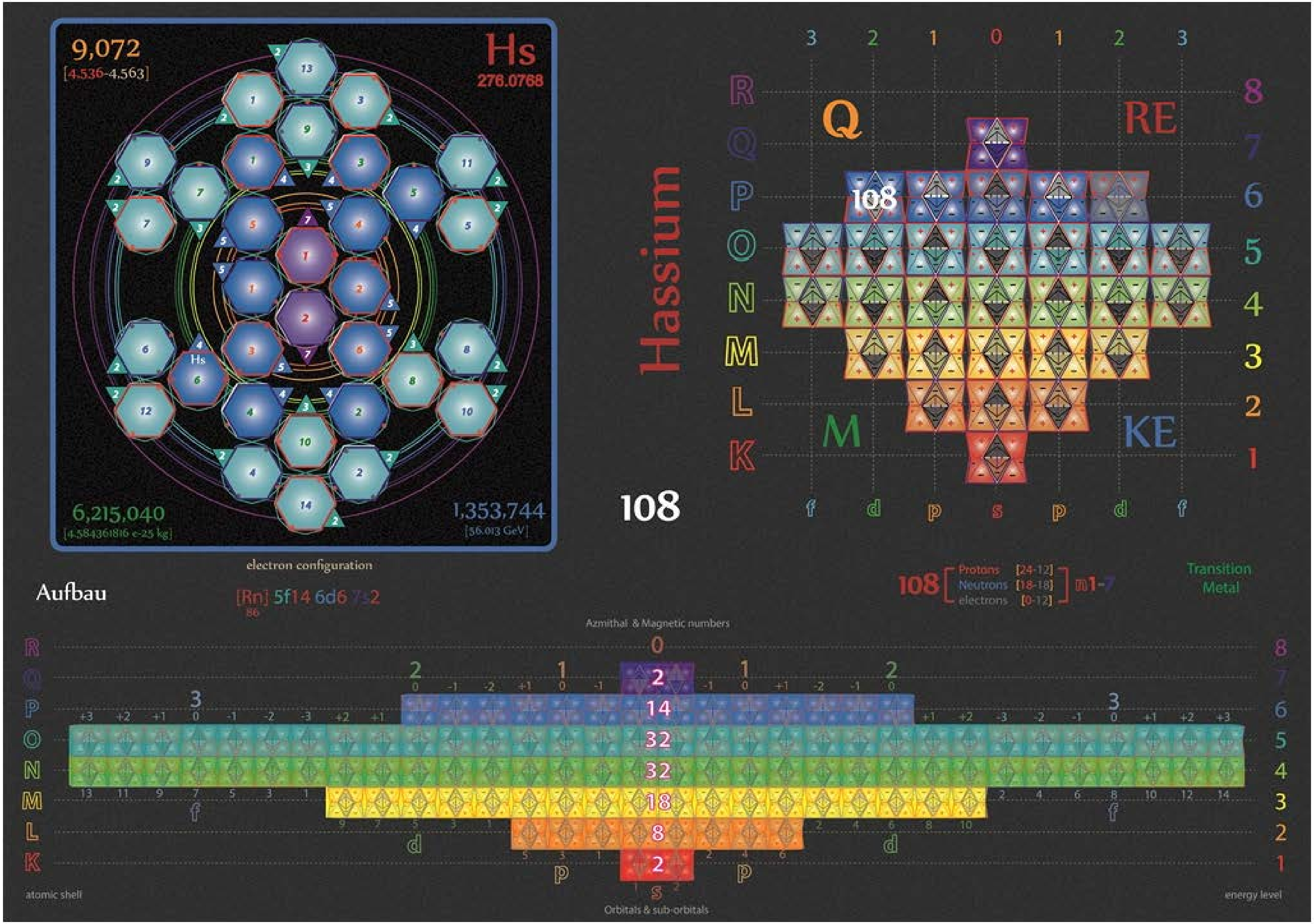
9,072
[4.536-4.563]
Hs
276.0768
6,215,040
[4.584361816 e-25 kg]
1,353,744
[56.013 GeV]
Hassium
108
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
3 2 1 0 1 2 3
f d p s p d f
Q
RE
M
KE
electron configuration
Aufbau
[Rn] 5f14 6d6 7s2
86
108 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Transition Metal
Azmithal & Magnetic numbers
2
14
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.108 - Hassium atom

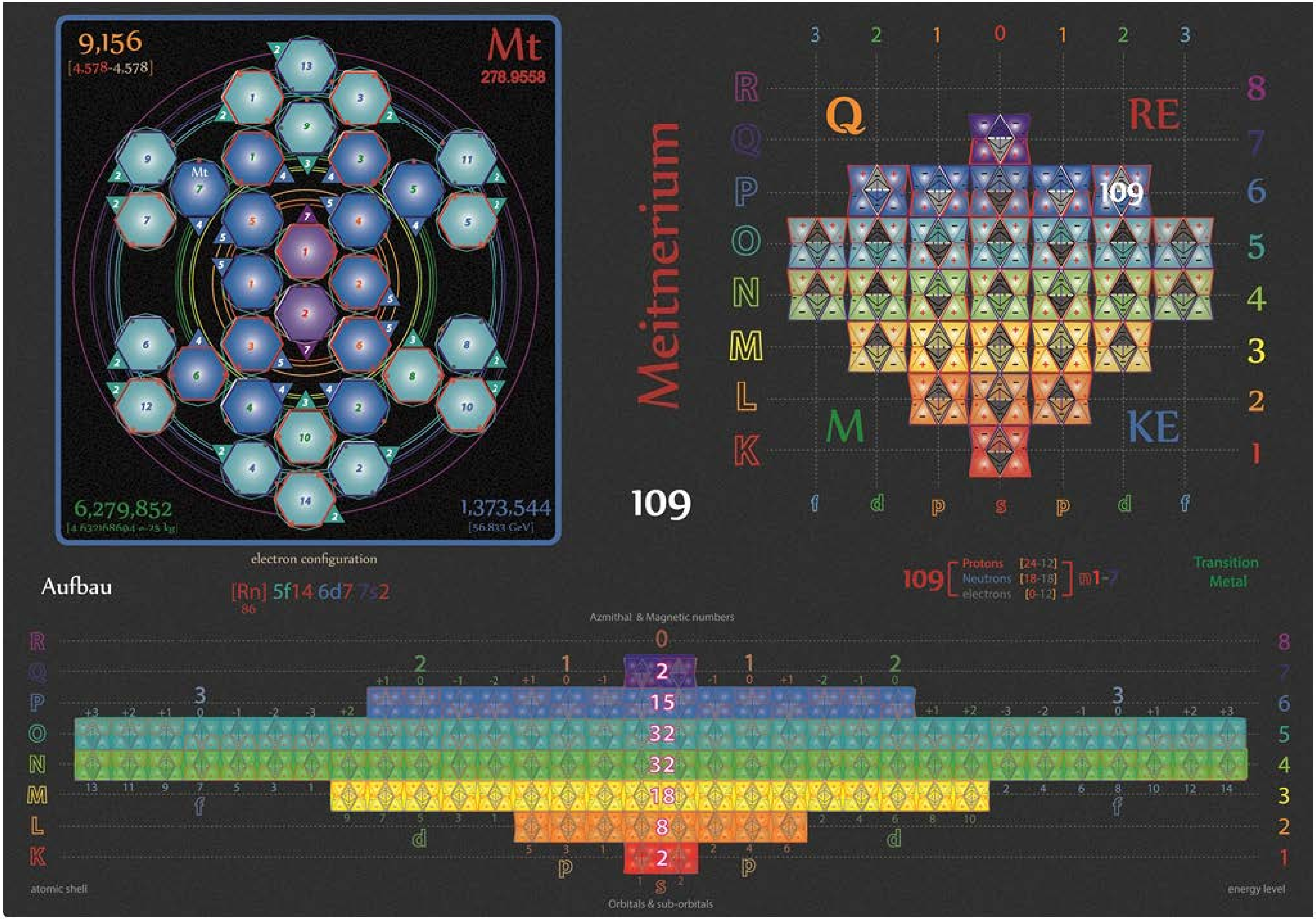
9,156
[4,578-4,578]
Mt
278.9558
6,279,852
[4.632168604 e-25 kg]
1,373,544
[56.833 GeV]
Meitnerium
109
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d7 7s2
86
109 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-7
Transition Metal
Azmithal & Magnetic numbers
2
15
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.109 - Meitnerium atom

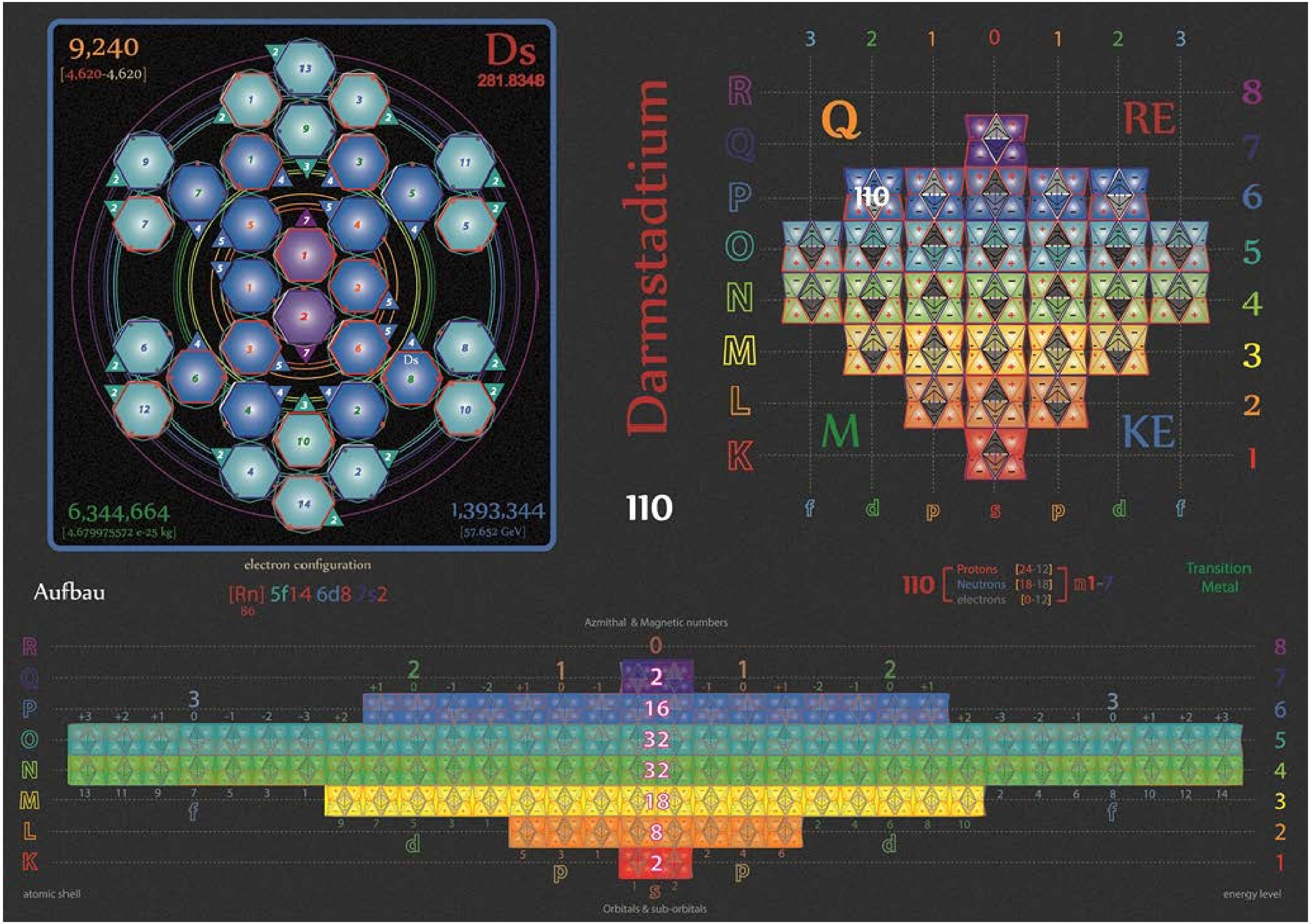
9,240
[4,620-4,620]
Ds
281.8348
6,344,664
[4.679975572 e-25 kg]
1,393,344
[57.652 GeV]
Darmstadtium
110
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
electron configuration
Aufbau
[Rn] 5f14 6d8 7s2
86
110 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Transition Metal
Azmithal & Magnetic numbers
2
16
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.110 - Darmstadtium atom

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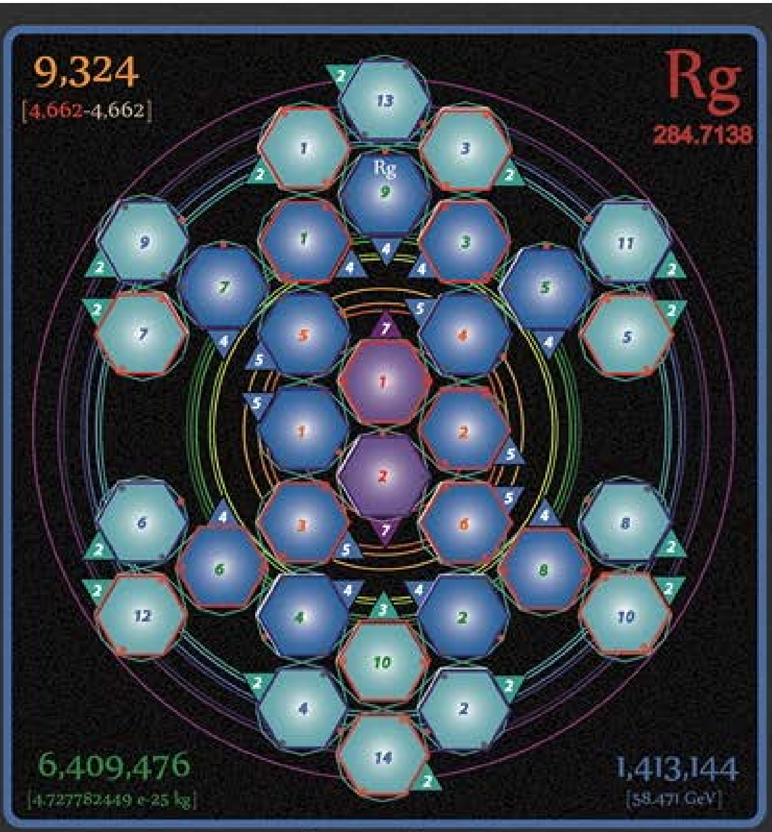
9,324
[4,662-4,662]
Rg
284.7138
Rg
6,409,476
[4.727782449 e-25 kg]
1,413,144
[58.471 GeV]

Roetgenium

111

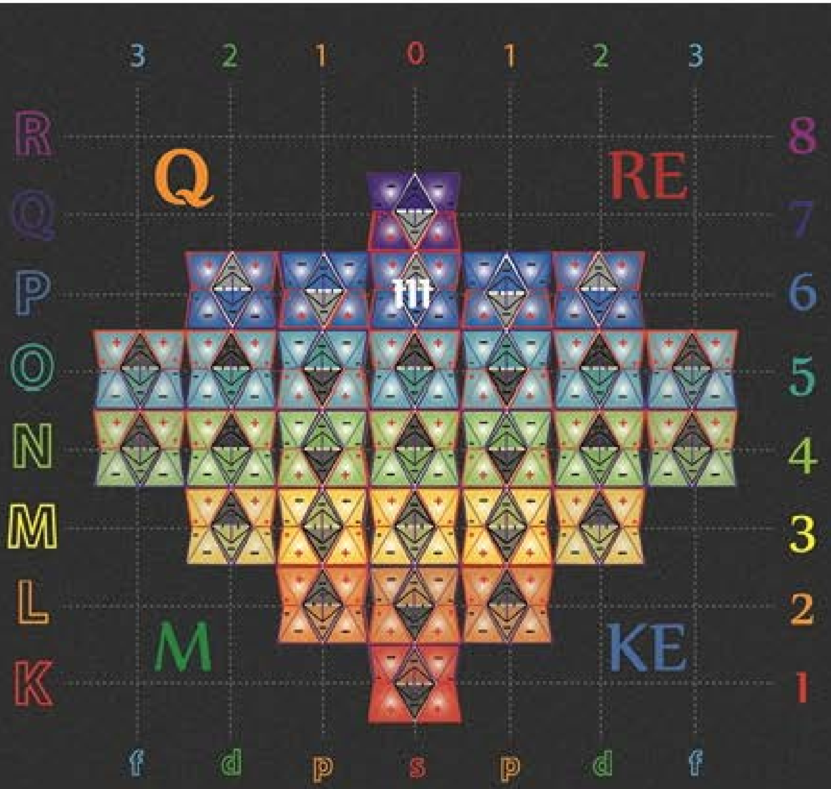
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
Q
RE
M
KE
111
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f

111 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7

Post Transition Metal

electron configuration

Aufbau

[Rn] 5f14 6d9 7s2
86

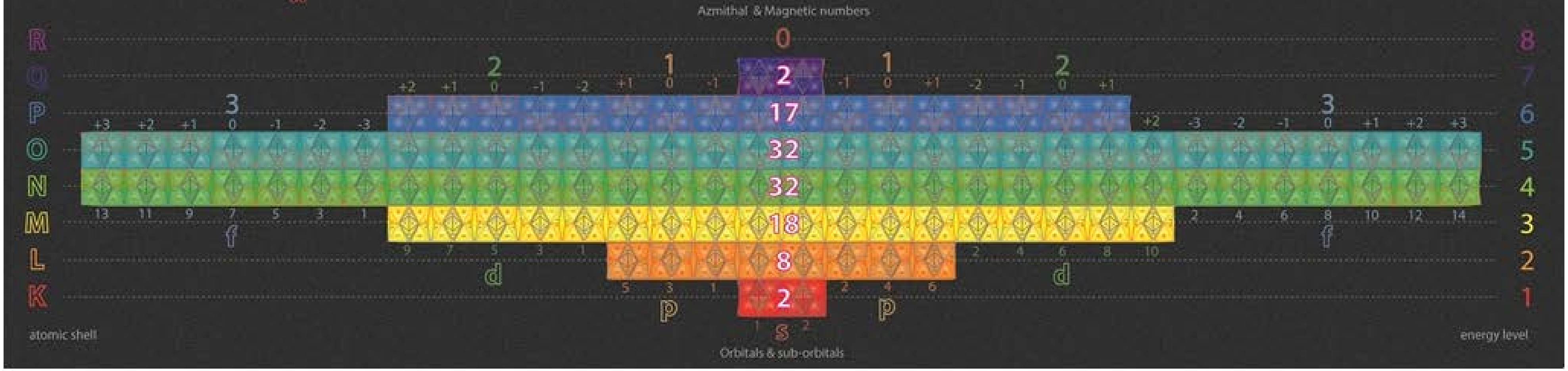
Azmithal & Magnetic numbers
0
1
2
3
+3
+2
+1
0
-1
-2
-3
R
Q
P
O
N
M
L
K
2
17
32
32
18
8
2
8
7
6
5
4
3
2
1
f
d
p
s
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.111 - Roetgenium atom

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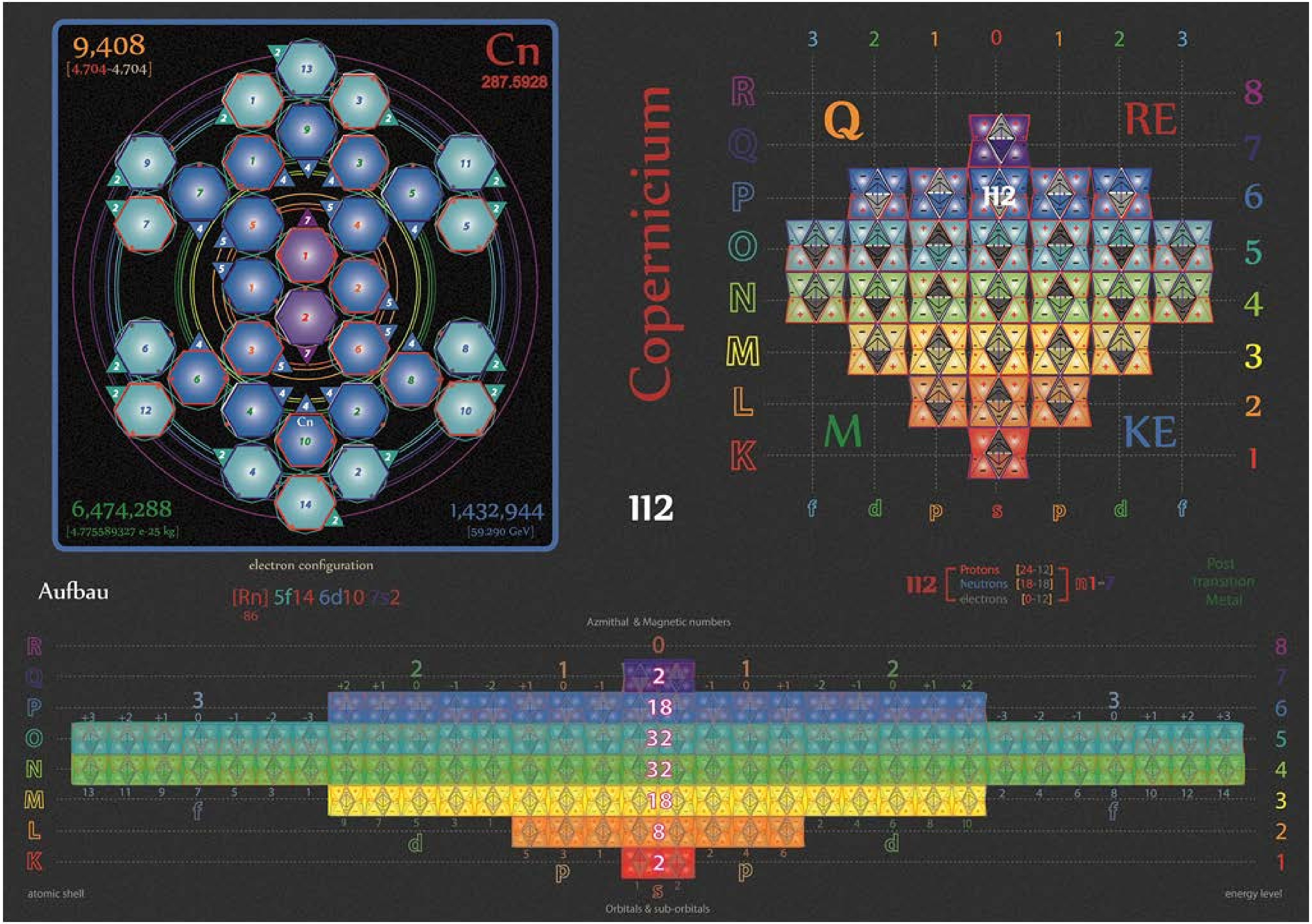
9,408
[4,704-4,704]
Cn
287.5928
6,474,288
[4.775589327 e-25 kg]
1,432,944
[59.290 GeV]
Copernicium
112
electron configuration
Aufbau
[Rn] 5f14 6d10 7s2
86
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
112 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Post transition Metal
Azmithal & Magnetic numbers
2 18 32 32 18 8 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.112 - Copernicium atom

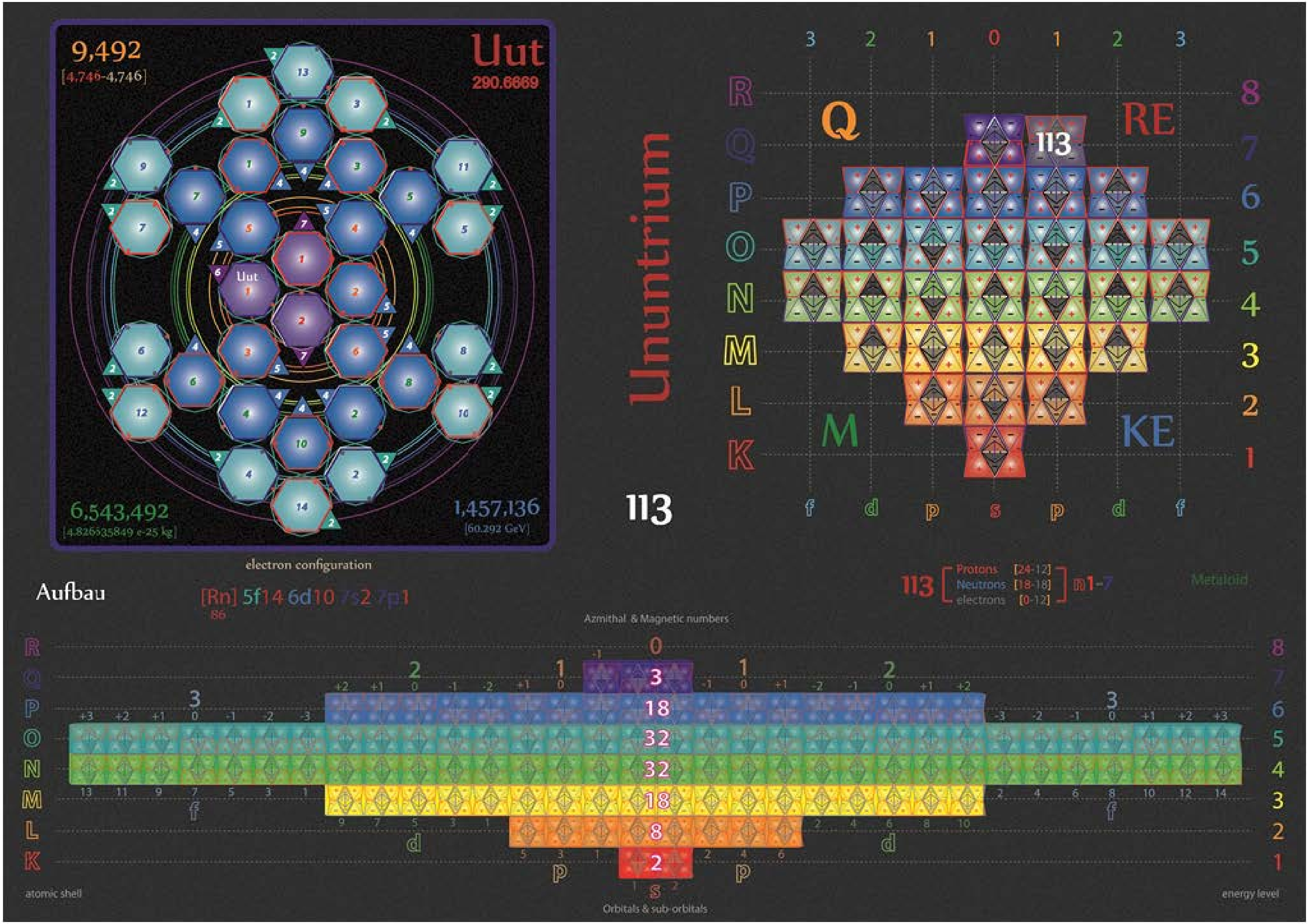
9,492
[4,746-4,746]
Uut
290.6669
Uut
6,543,492
[4.82635849 e-25 kg]
1,457,136
[60.292 GeV]
electron configuration
Ununtrium
113
Q
RE
M
KE
113
R
Q
P
O
N
M
L
K
3
2
1
0
1
2
3
f
d
p
s
p
d
f
8
7
6
5
4
3
2
1
113
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-7
Metaloid
Aufbau
[Rn] 5f14 6d10 7s2 7p1
86
Azmithal & Magnetic numbers
0
3
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.113 - Ununtrium atom

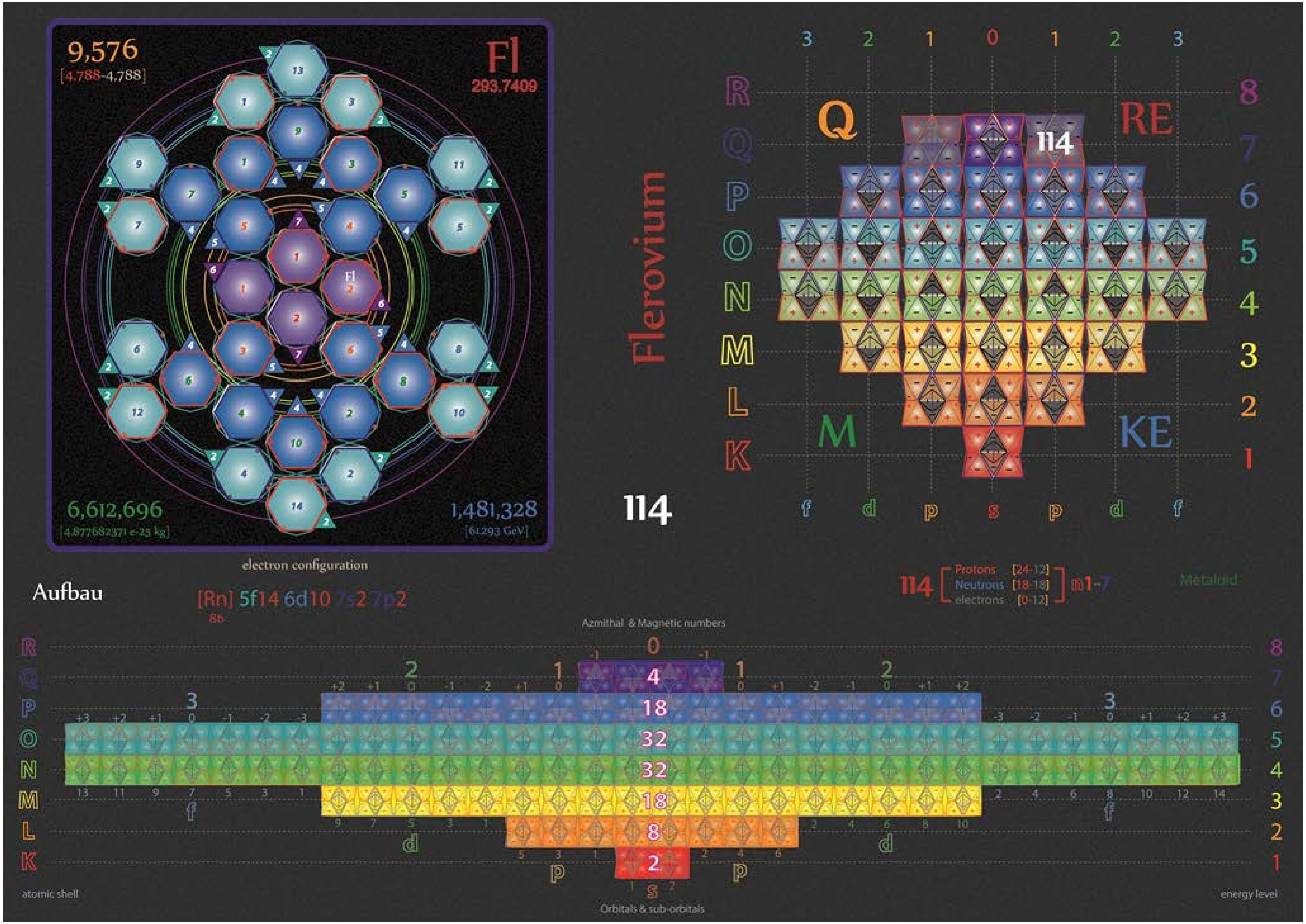
9,576
[4.788-4.788]
Fl
293.7409
6,612,696
[4.877682371 e-25 kg]
1,481,328
[61.293 GeV]
Flerovium
114
electron configuration
Aufbau
[Rn] 5f14 6d10 7s2 7p2
86
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
114 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Metaloid
Azmithal & Magnetic numbers
0
4
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.114 - Flerovium atom

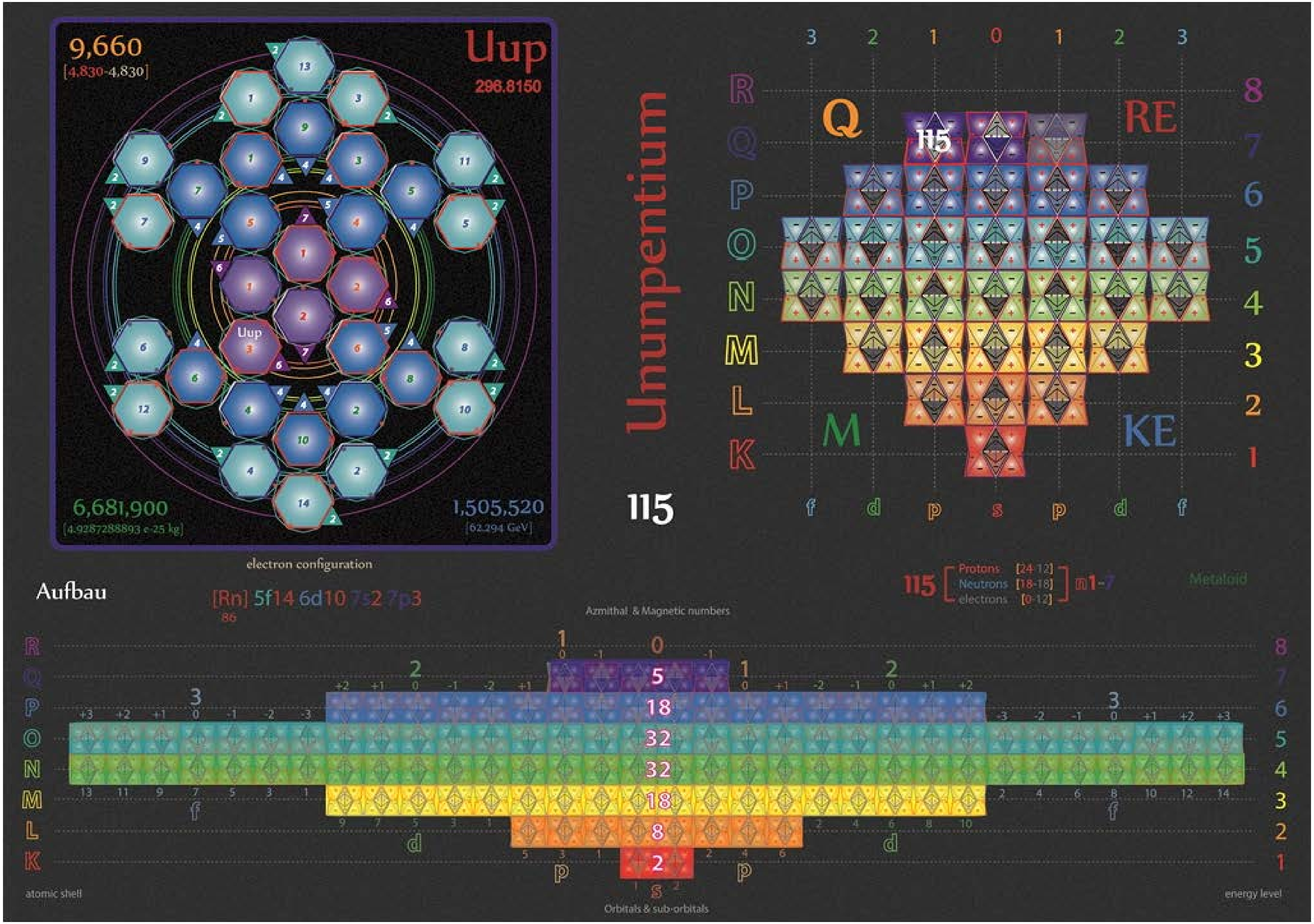
9,660
[4,830-4,830]
Uup
298.8150
6,681,900
[4.9287288893 e-25 kg]
1,505,520
[62.294 GeV]
Uup
Ununpentium
115
electron configuration
Aufbau
[Rn] 5f14 6d10 7s2 7p3
86
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
115
f d p s p d f
115 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-7
Metaloid
Azmithal & Magnetic numbers
5
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.115 - Ununpentium atom

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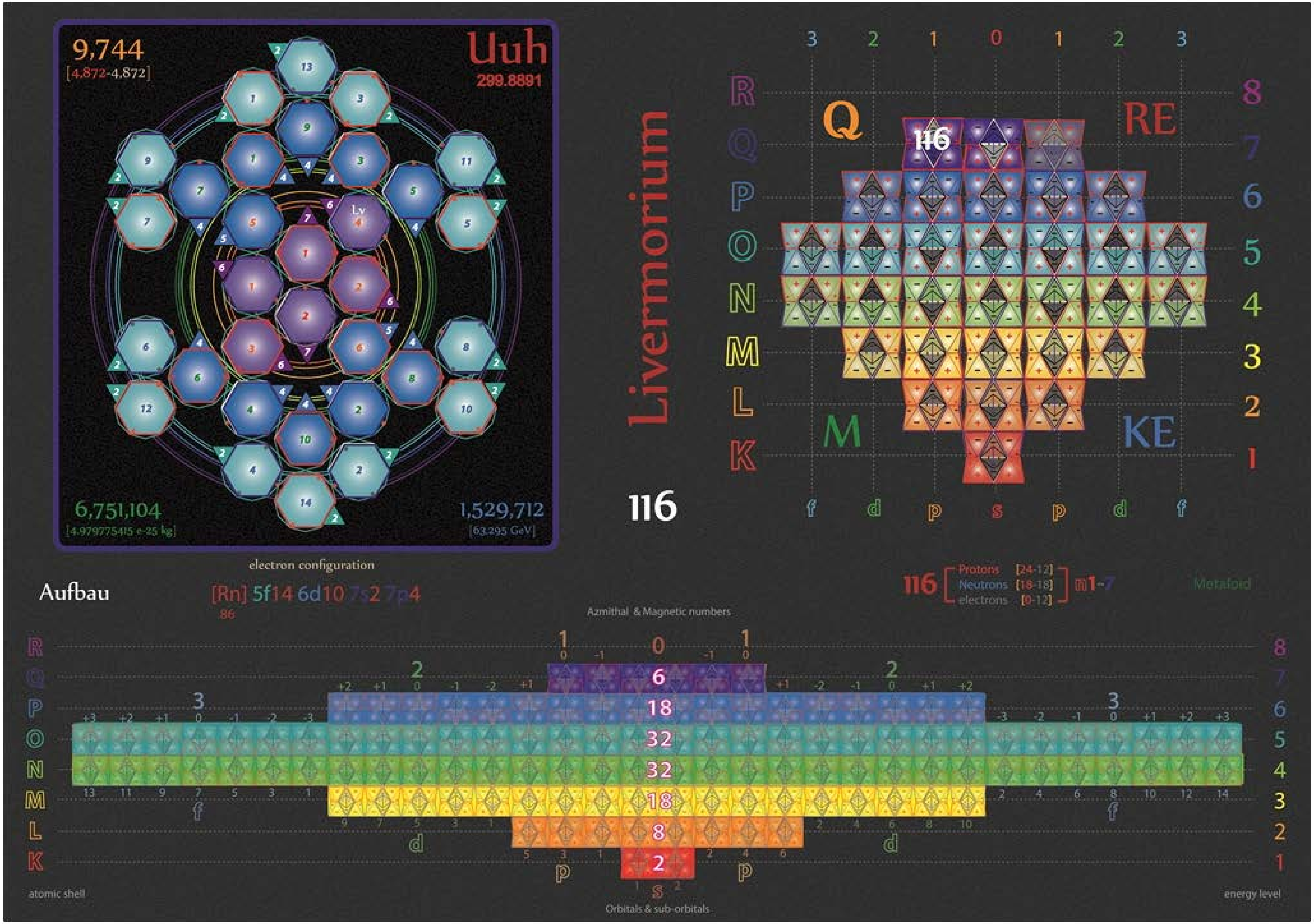
9,744
[4,872-4,872]
Uuh
289.8891
Lv
6,751,104
[4.979775415 e-25 kg]
1,529,712
[63.295 GeV]
Livermorium
116
electron configuration
Aufbau
[Rn] 5f14 6d10 7s2 7p4
86
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
f d p s p d f
116 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-7
Metaloid
Azmithal & Magnetic numbers
6
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.116 - Livermorium atom

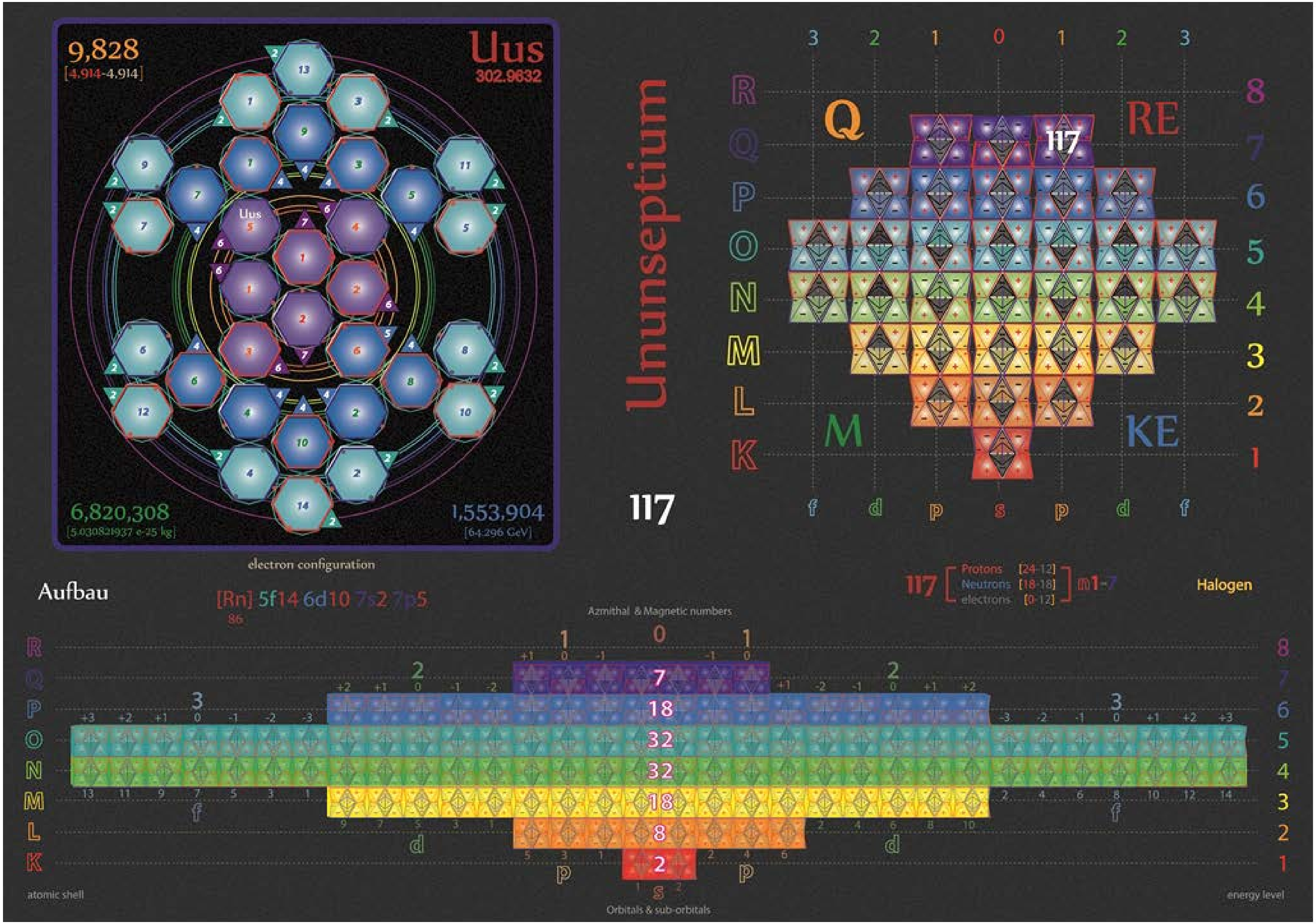
9,828
[4.914-4.914]
Uus
302.9832
Uus
6,820,308
[5.030821937 e-25 kg]
1,553,904
[64.296 GeV]
electron configuration
Ununseptium
117
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
Q
RE
M
KE
117
8
7
6
5
4
3
2
1
f d p s p d f
117 [Protons [24-12] Neutrons [18-18] electrons [0-12]] m1-7
Halogen
Aufbau
[Rn] 5f14 6d10 7s2 7p5
86
Azmithal & Magnetic numbers
0
1
1
2
2
3
3
+1 0 -1
-1 0
+2 +1 0 -1 -2
+1 -2 -1 0 +1 +2
+3 +2 +1 0 -1 -2 -3
-3 -2 -1 0 +1 +2 +3
7
18
32
32
18
8
2
13 11 9 7 5 3 1
2 4 6 8 10 12 14
f
f
9 7 5 3 1
2 4 6 8 10
d
d
5 3 1
2 4 6
p
p
1 s 2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.117 - Ununseptium atom

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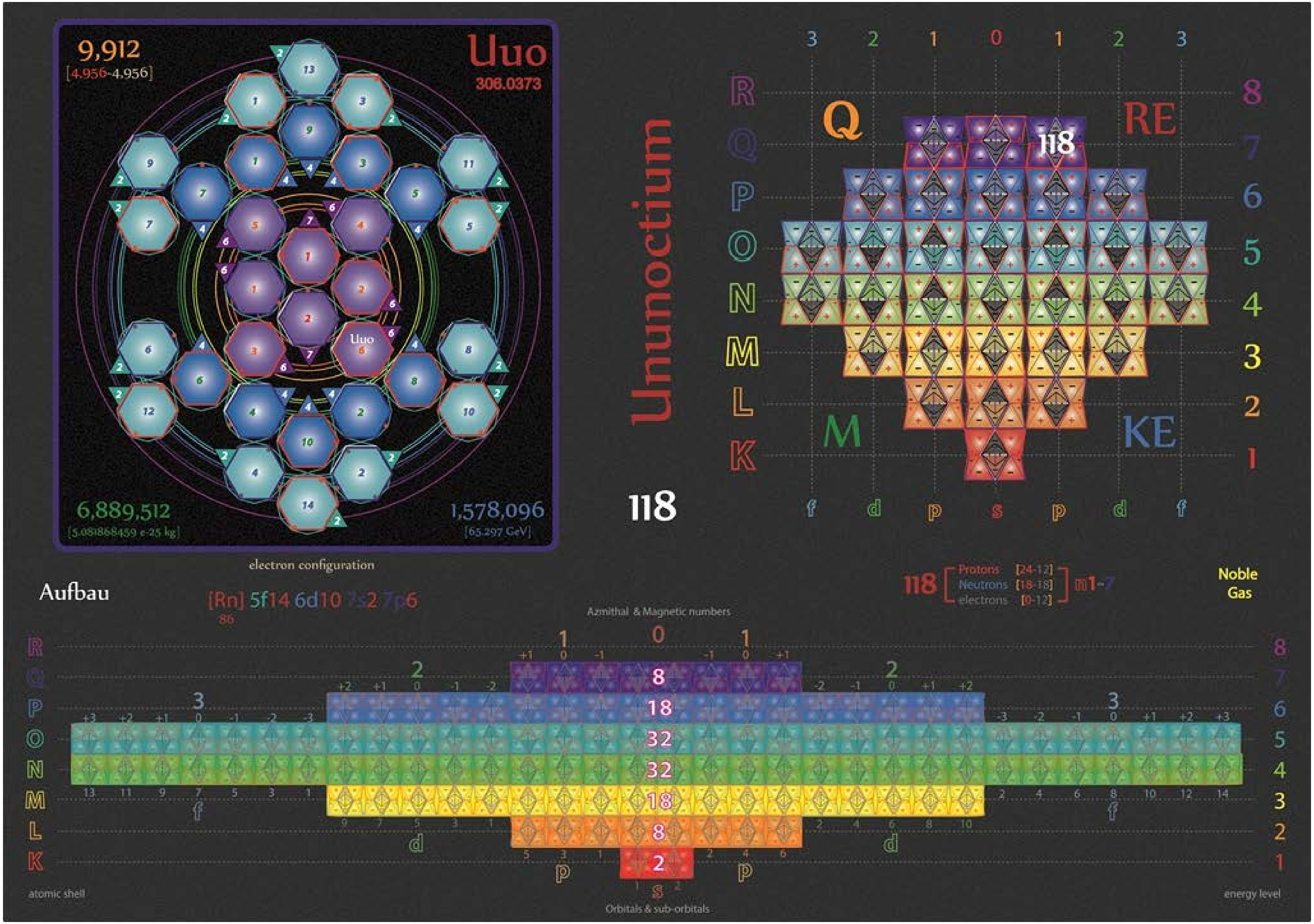
9,912
[4,956-4,956]
Uuo
308.0373
6,889,512
[5.081868459 e-25 kg]
1,578,096
[65.297 GeV]
electron configuration
Ununoctium
118
Q
RE
M
KE
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
f
d
p
s
p
d
f
118 Protons [24-12] Neutrons [18-18] electrons [0-12] m1-7
Noble Gas
Aufbau
[Rn] 5f14 6d10 7s2 7p6
86
Azmithal & Magnetic numbers
8
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.118 - Ununoctium atom

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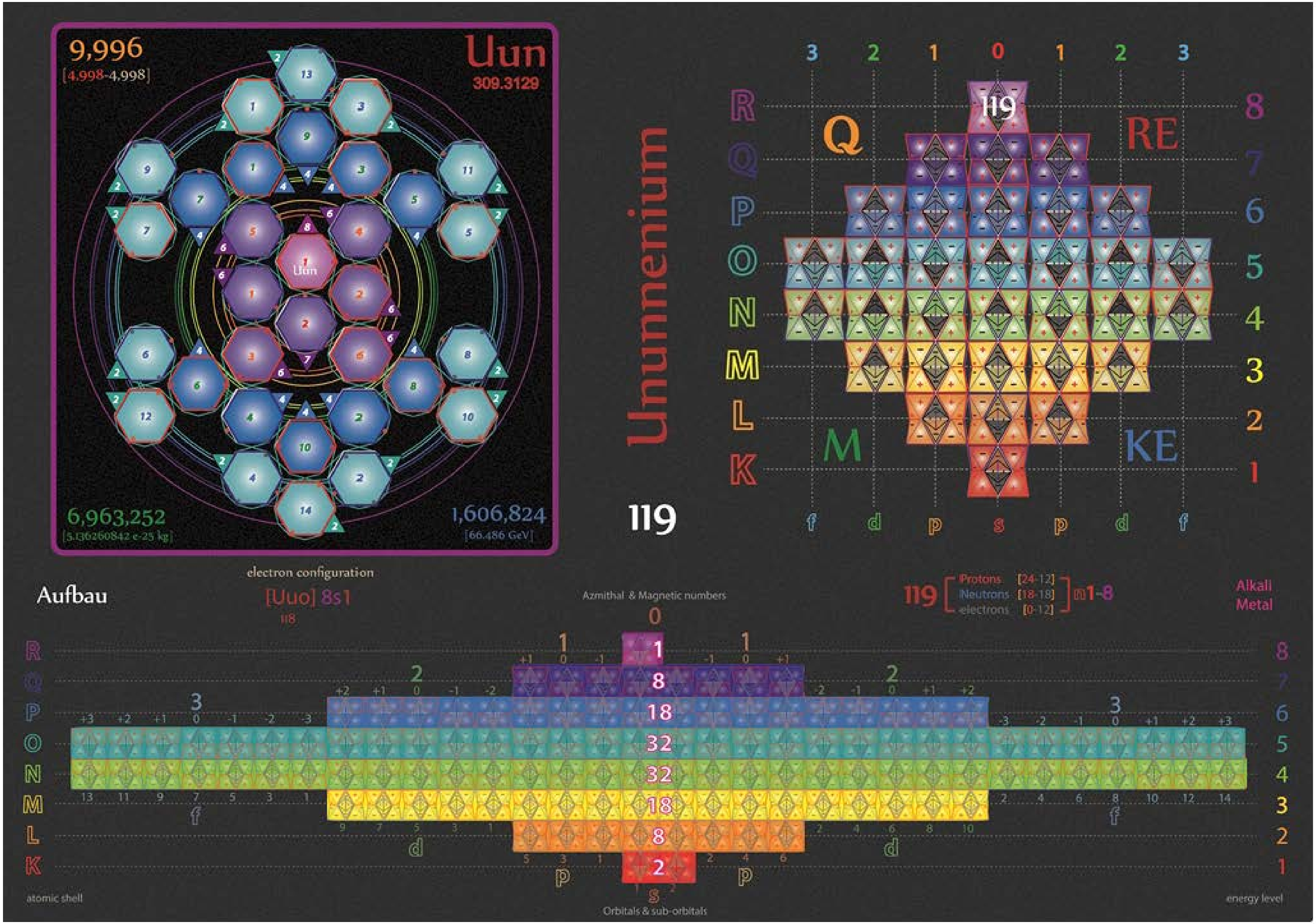
9,996
[4,998-4,998]
Uun
309.3129
Uun
6,963,252
[5.136260842 e-25 kg]
1,606,824
[66.486 GeV]
Ununnenium
119
3 2 1 0 1 2 3
R Q P O N M L K
8 7 6 5 4 3 2 1
Q
RE
M
KE
119
f d p s p d f
electron configuration
Aufbau
[Uuo] 8s1
118
Azmithal & Magnetic numbers
119
Protons [24-12]
Neutrons [18-18]
electrons [0-12]
n1-8
Alkali
Metal
1
8
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.119 - Ununnenium atom

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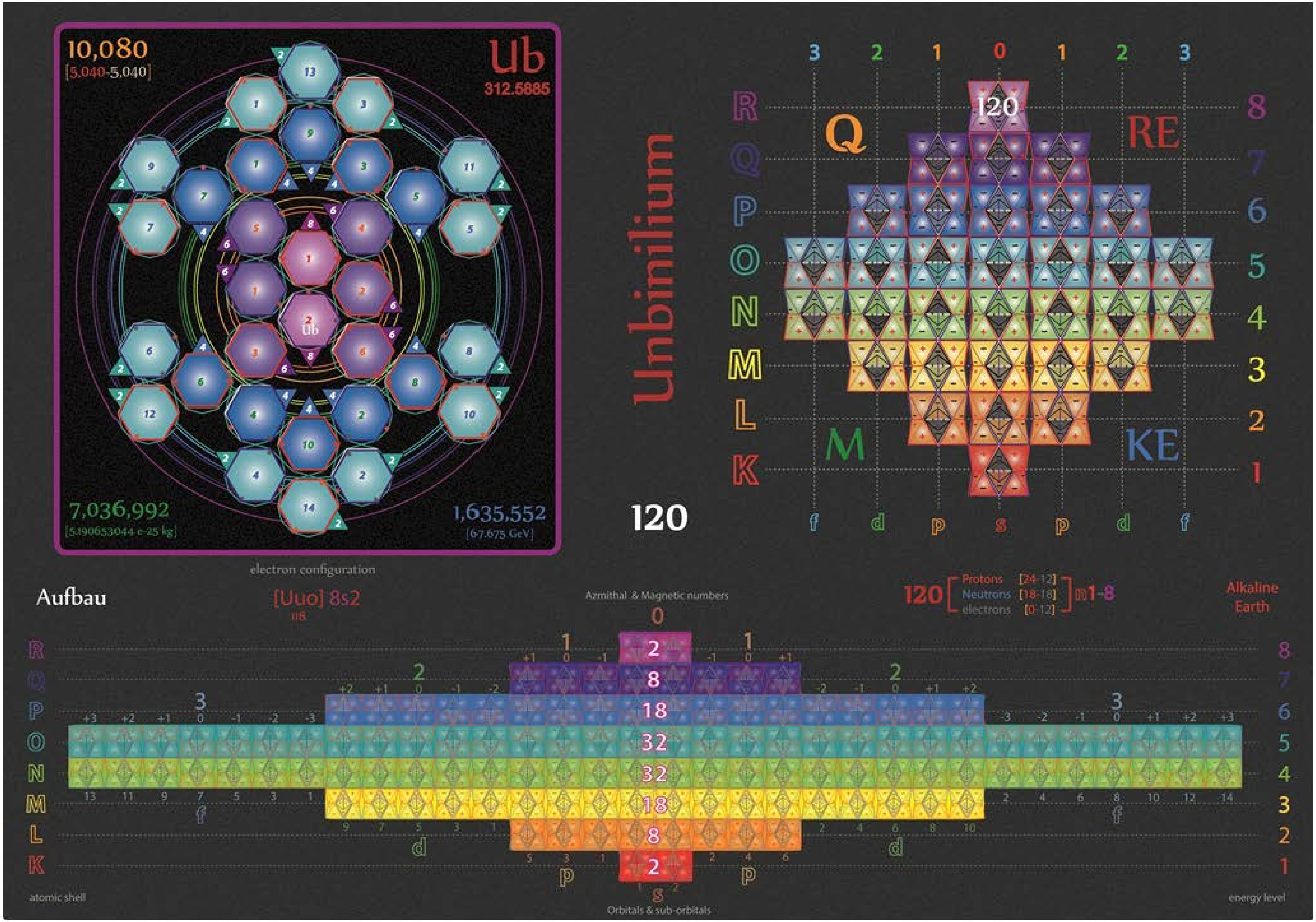
10,080
[5,040-5,040]
Ub
312.5885
7,036,992
[5.190653044 e-25 kg]
1,635,552
[67.675 GeV]
Unbinilium
120
R
Q
P
O
N
M
L
K
3 2 1 0 1 2 3
Q
RE
M
KE
8 7 6 5 4 3 2 1
f d p s p d f
electron configuration
Aufbau
[Uuo] 8s2
118
Azmithal & Magnetic numbers
120 [Protons [24-12] Neutrons [18-18] electrons [0-12]] n1-8
Alkaline Earth
2
8
18
32
32
18
8
2
atomic shell
energy level
Orbitals & sub-orbitals

Tetryonics 51.120 - Unbinilium atom

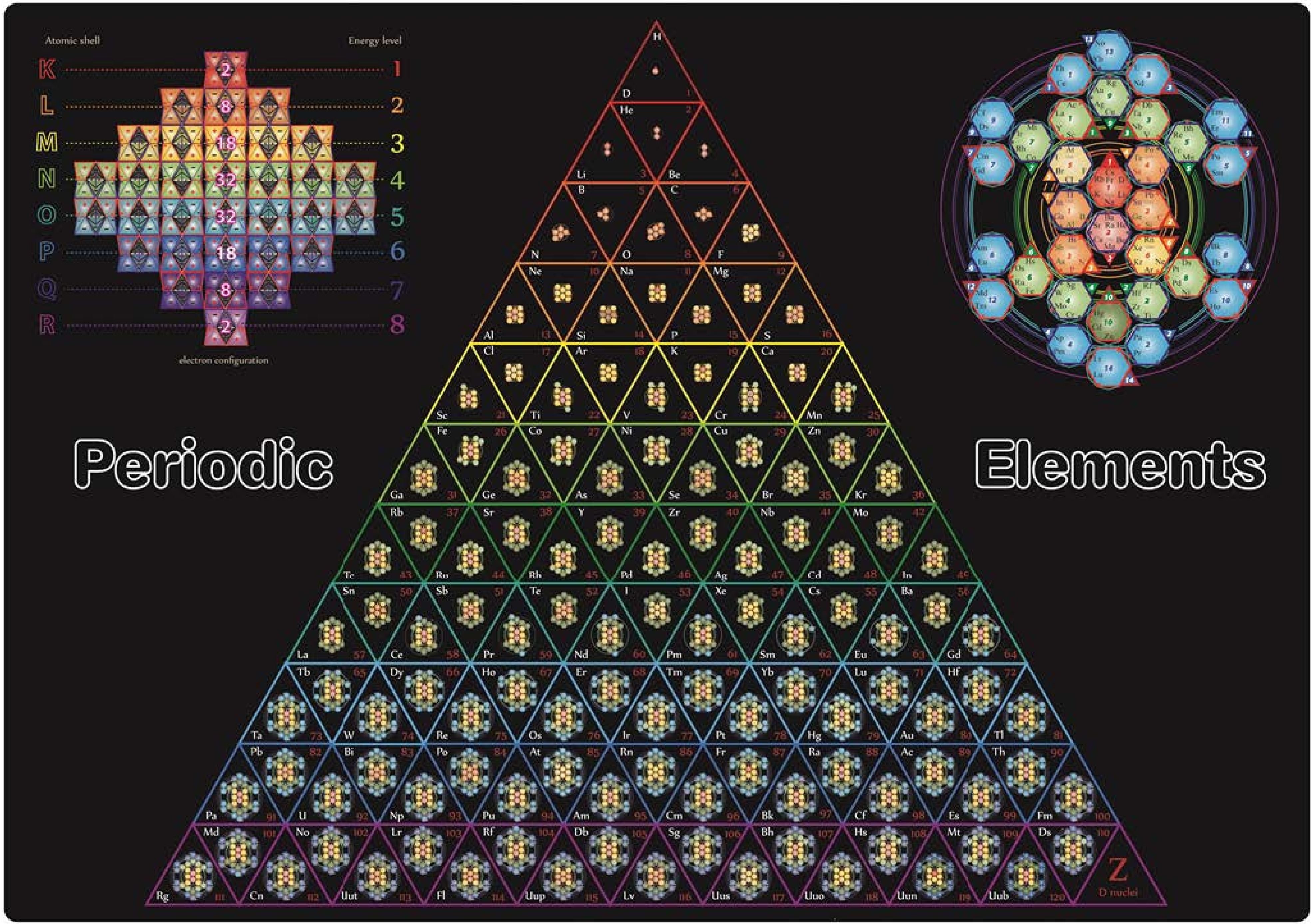
Atomic shell
Energy level
K
L
M
N
O
P
Q
R
1
2
3
4
5
6
7
8
2
8
18
32
32
18
8
2
electron configuration
Periodic
Elements
H
D 1
He 2
Li 3
Be 4
B 5
C 6
N 7
O 8
F 9
Ne 10
Na 11
Mg 12
Al 13
Si 14
P 15
S 16
Cl 17
Ar 18
K 19
Ca 20
Sc 21
Ti 22
V 23
Cr 24
Mn 25
Fe 26
Co 27
Ni 28
Cu 29
Zn 30
Ga 31
Ge 32
As 33
Se 34
Br 35
Kr 36
Rb 37
Sr 38
Y 39
Zr 40
Nb 41
Mo 42
Tc 43
Ru 44
Rh 45
Pd 46
Ag 47
Cd 48
In 49
Sn 50
Sb 51
Te 52
I 53
Xe 54
Cs 55
Ba 56
La 57
Ce 58
Pr 59
Nd 60
Pm 61
Sm 62
Eu 63
Gd 64
Tb 65
Dy 66
Ho 67
Er 68
Tm 69
Yb 70
Lu 71
Hf 72
Ta 73
W 74
Re 75
Os 76
Ir 77
Pt 78
Au 79
Hg 80
Tl 81
Pb 82
Bi 83
Po 84
At 85
Rn 86
Fr 87
Ra 88
Ac 89
Th 90
Pa 91
U 92
Np 93
Pu 94
Am 95
Cm 96
Bk 97
Cf 98
Es 99
Fm 100
Md 101
No 102
Lr 103
Rf 104
Db 105
Sg 106
Bh 107
Hs 108
Mt 109
Ds 110
Rg 111
Cn 112
Uut 113
Fl 114
Uup 115
Lv 116
Uus 117
Uuo 118
Uun 119
Uub 120
Z
D nuclei

Tetryonics 52.01 - Tetryonic Element Table

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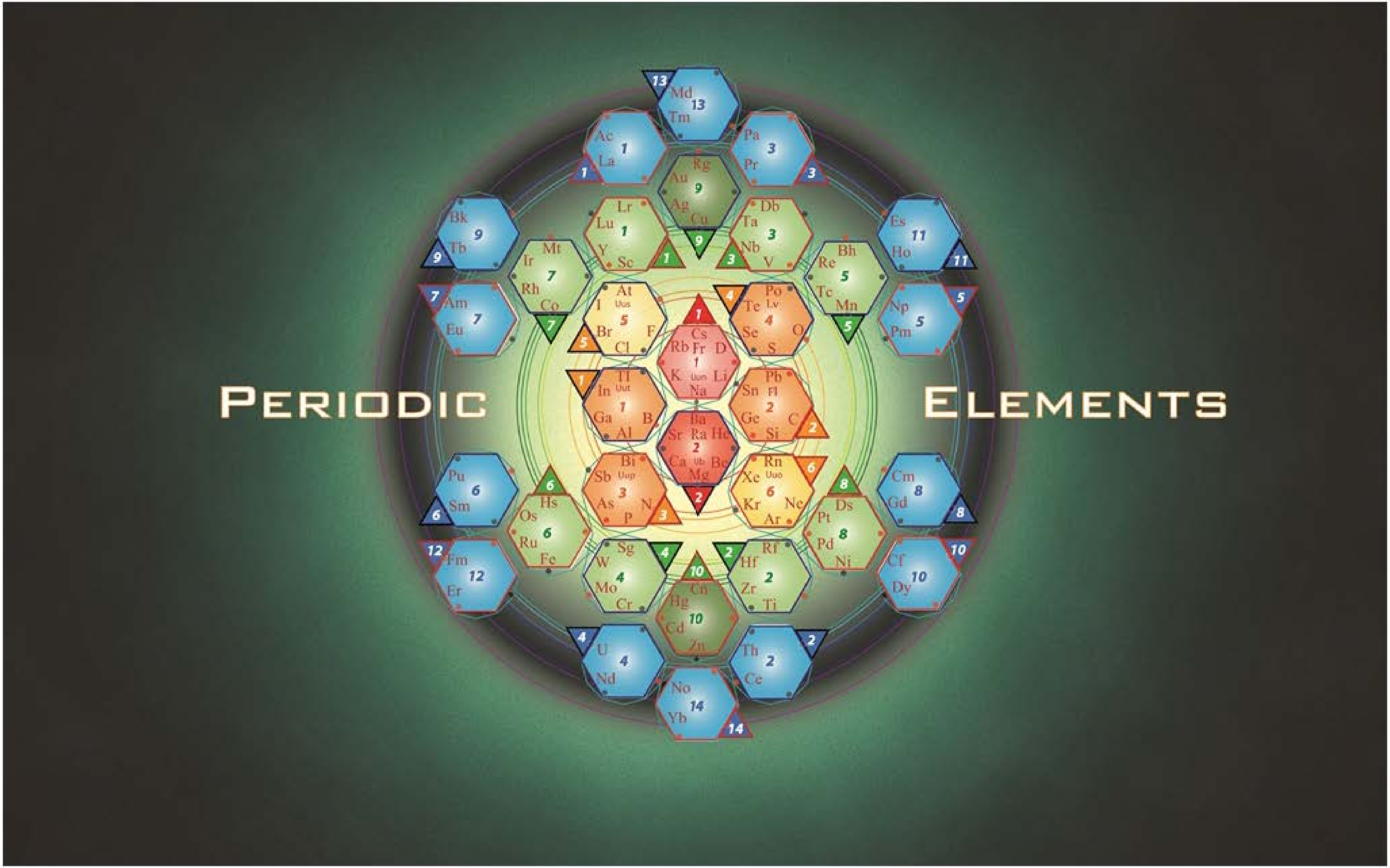
PERIODIC
ELEMENTS
13 Md 13 Tm
Ac 1 La 1
Pa 3 Pr 3
Au Rg 9 Ag Cu 9
Bk 9 Tb 9
Es 11 Ho 11
Lr Lu 1 Y Sc 1
Db Ta 3 Nb V 3
Mt Ir 7 Rh Co 7
Bh Re 5 Tc Mn 5
7 Am 7 Eu
Np 5 Pm 5
At I Uus 5 Br F Cl 5
1 Cs Rb Fr D 1 K Uun Li Na
4 Po Te Lv 4 Se O S
1 Tl In Uut 1 Ga B Al
Pb Sn Fl 2 Ge C Si 2
Ba Sr Ra He 2 Ca Ub Be Mg 2
Bi Sb Uup 3 As N P 3
Rn Xe Uuo 6 Kr Ne Ar 6
Pu 6 Sm 6
6 Hs Os 6 Ru Fe
8 Ds Pt 8 Pd Ni
Cm 8 Gd 8
12 Fm 12 Er
Cf 10 Dy 10
Sg W 4 Mo Cr 4
10 Cn Hg 10 Cd Zn
2 Rf Hf 2 Zr Ti
4 U 4 Nd
Th 2 Ce 2
No 14 Yb 14

Tetryonics 52.02 - Periodic Table [Elements]

Response to an analysis of Tetryonic Chemistry by Robert J Brotherus [July 2015]

In reply to a paper outlining Mr Robert Brotherus' examination and *mis*-understanding of Tetryonic theory and in particular how it applies to the modern understanding of Chemistry as it currently taught…..

Point by point I'll firstly address the particular points of concern raised wrt modern chemical theory and physics in general:

Tetryonics paper on quantum chemistry is very scarce on making any predictions about atomic properties or comparing such predictions to experimental results.

Tetryonic theory provides many predictions regarding the physical 2d planar **geometrie**s of bosons [radiant mass-energies] and the 3D material **Topologies** of Fermions [Matter and their associated physical properties]. Inclusive in these are many predictions and repeated statements and illustrations of specific particle shapes and the values of mass-energy momenta attributed to each… as well as how these values stem from the equilateral tessellation of Planck energy momenta and why they differ from the established values of modern scientific theory….

In many cases there are similarities to be found with existing observations but where Tetryonic theory differs from modern theory it is not by choice but rather dictated by the equilateral mass-energies within charged Matter topologies themselves and all too often led to much effort in order to reconcile the differences, leading to further insights and extensions of the theory over time…. Where differences exist it is deliberate not by error.

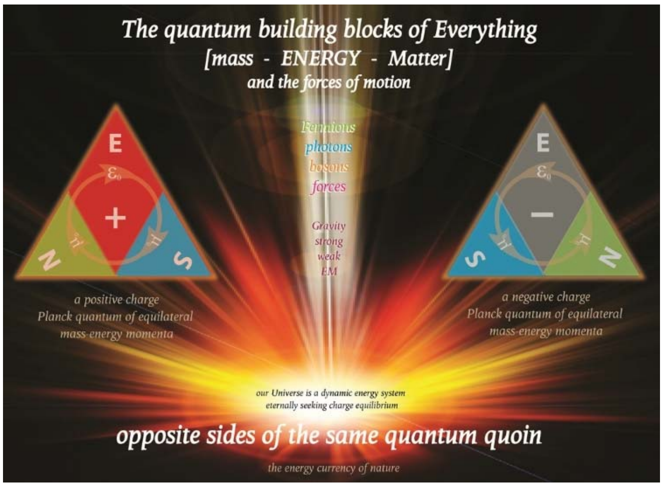
The quantum building blocks of Everything
[mass - ENERGY - Matter]
and the forces of motion
Fermions
photons
bosons
forces
Gravity
strong
weak
EM
E
ε_0
+
μ_0
N
S
E
ε_0
–
μ_0
S
N
a positive charge
Planck quantum of equilateral
mass-energy momenta
a negative charge
Planck quantum of equilateral
mass-energy momenta
our Universe is a dynamic energy system
eternally seeking charge equilibrium
opposite sides of the same quantum quoin
the energy currency of nature

Tetryonics is a BOTTOM-UP physical theory that unifies many currently disparate theories of science into a coherent unified model of the same – but not without its own set of mental challenges to those who are first becoming acquainted with it. As such it must be recognised that Tetryonic theory should not be studied without a sound understanding of the foundation upon with it is built…. Many have approached analysis of my work in such a way only to find that their analysis was limited by modern science's lack of precise detail of the foundations of the physics that they attempt to explain [to wit modern theory is a top-down explanation of the science build up over many generations with an equal number of varying interpretations and assumptions]

Tetryonics plays down importance of "mathematics" and instead emphasizes "geometry".

Arguably I place a lot of emphasis on geometry over that of mathematics in Tetryonic theory, but only so as it offers insights into physical theory that maths alone has not been able to provide since its wholesale incorporation into the science in the 1600's. This is not to downplay the importance and productiveness that maths has provided us a scientific tool, but rather to 'illustrate' and draw attention to the advances that a purely geometric model has to offer us in advancing our understanding of the same…. To wit, Tetryonic geometries are based on the postulate that all physical theory is founded on equilateral Planck quanta of energy momenta and as such these physical entities afford no room for speculative ideas or mathematical manipulations beyond what is physically possible to be constructed.

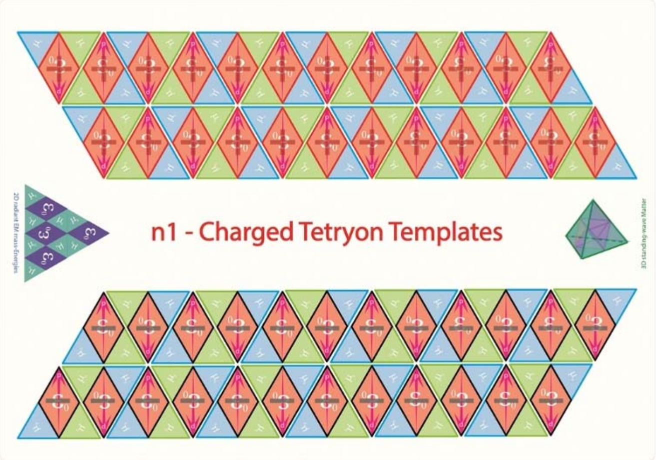

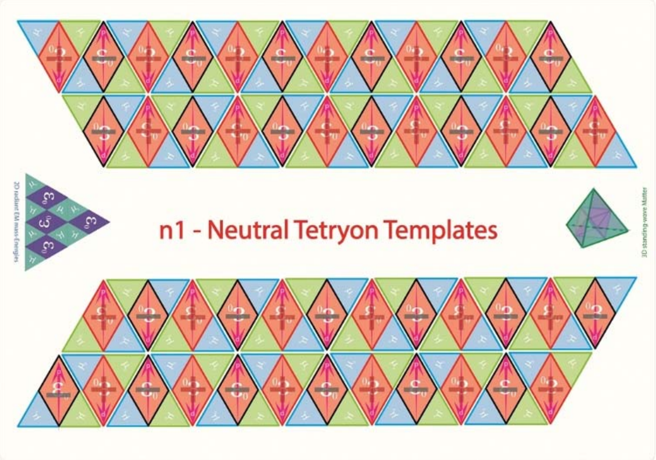

To help elucidate my work and thoughts on the differentiation of 2d planar mass-energy geometries from 3D Material topologies I recorded a detailed YouTube video titled "Tetryonics 101" where I show HOW to use the existing Tetryonic templates [of Planck mass-energy momenta] to construct all the fields [boson & photons] of the Standard model along with the 3D Mater topologies of all the known fermions [and them some]… I do hope you'll take the time to review this detailed instruction on the creation of quantum fields and Matter and try to replicate them same yourself – it is THE most informative thing students of Tetryonics and science in general can do when trying to increase their understanding of the hitherto unseen constituents that make up quantum theory and our macro-scale Universe and the laws of Nature we observe….

Tetryonics paper on physical chemistry is scarce on such numerical predictions and where it does make such predictions they are often in contradiction to observed experimental facts.

In addition to the maths found within Tetryonic illustrations there are also many spreadsheets developed from those very same equations over time to provide the numerical detail found in the illustrations – particular wrt periodic elements and theory rest atomic masses and kinetic elements etc. – It is by no means exhaustive on every topic imaginable but they do address the information provided on particles & elements etc. along with their kinetic and relativistic energies of motion.

Tetryonic Problem: Missing hydrogen element

Hydrogen is not missing from Tetryonic theory – in fact it is extensively detailed and modelled in Tetryonics [1] – Quantum Mechanics eBook [again highlight the need not to jump into one's preferred field of expertise and study but rather learn Tetryonic theory as you would any modern physical theory in order of presentation]

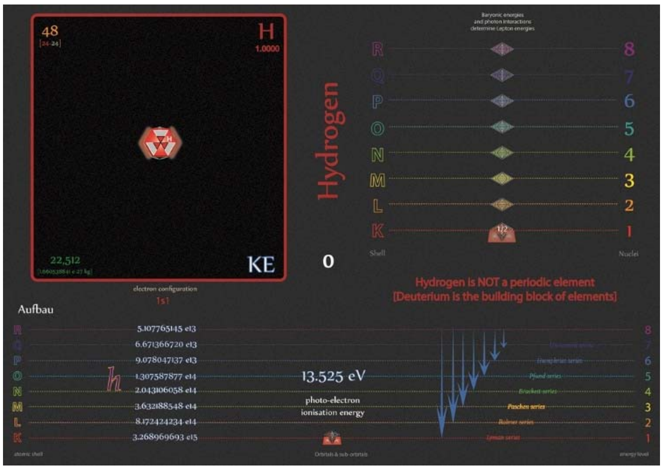
48
[24-24]
H
1.0000
22,512
KE
0
Hydrogen
Baryonic energies and photon interactions determine Lepton energies
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1/2
Shell
Nuclei
Hydrogen is NOT a periodic element
[Deuterium is the building block of elements]
electron configuration
1s1
Aufbau
5.107765145 e13
6.671366720 e13
9.078047137 e13
1.307587877 e14
2.043106058 e14
3.632188548 e14
8.172424234 e14
3.268969693 e15
h
13.525 eV
photo-electron
ionisation energy
Pfund series
Brackett series
Paschen series
Balmer series
Lyman series
atomic shell
Orbitals & sub-orbitals
energy level

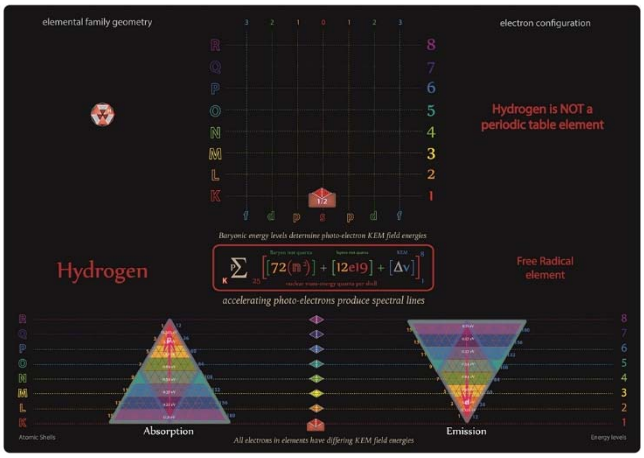
elemental family geometry
electron configuration
3
2
1
0
1
2
3
R
Q
P
O
N
M
L
K
8
7
6
5
4
3
2
1
1/2
f
d
p
s
p
d
f
Hydrogen is NOT a periodic table element
Baryonic energy levels determine photo-electron KEM field energies
Hydrogen
Free Radical element
accelerating photo-electrons produce spectral lines
Absorption
Emission
Atomic Shells
Energy levels
All electrons in elements have differing KEM field energies

$$\sum_{K}^{P} {}_{25}\left[[72(n^{2})] + [12e19] + [\Delta v] \right]_{1}^{8}$$

Hydrogen is designated as element 00 in Tetryonic theory as it is **NOT** the building block of periodic elements as is currently understood but rather a sub-unit of Deuterium the real building block of all elements…. This is not an arbitrary decision but one forced on anybody who attempts to build physical models of all elements in order to match and explain many of the current established aspects of chemical and quantum theory wrt the quantum electrodynamics of elements themselves wrt molar mass, the Aufbau principle, Schrodinger and Bohr numbers for each element and how Deuterium nuclei [or any other] may bind together in order to form all the elements of the periodic table and their respective spectral emissions lines.

Attempting to build heavy elements utilising Z number Hydrogen nuclei as a foundation with the excess molar masses being accounted for by way of 'extra or excess' Neutrons [as is the established model of modern chemistry] runs into a number of problems immediately – namely:

The lack of residual strong Force binding points on nuclei to facilitate the binding of Neutrons to the nuclei in order to form the elements [particularly elements 60+]

The incorrectness of ‘reserve beta decay’ to explain and model Neutron particle formation and the mechanics of electron binding to periodic elements in accordance with Schrodinger’s wave equation and Bohr’s atomic model of the same in order to produce observed spectral line emissions of each element in the PT.

There is no uncertainty or indeterminacy in Tetryonic theory as there is in modern theory to explain away such inconsistencies between various aspects of physical theory – each attribute MUST be modelled and explained from first principles & invariably leads to new insights into quantum chemical theory that are at odds with established lines of thought.

To wit I stand by the claims and statements made in my eBooks :

> Each elemental nuclei is made from Deuterium" (p. 12)
> “120 elements in 8 quantum levels *and hydrogen as a free radical*.” (p. 26)
> “Deuterium (not hydrogen) is the building block of all elements." (p. 21)
> “Hydrogen is NOT a periodic element” (p. 83)

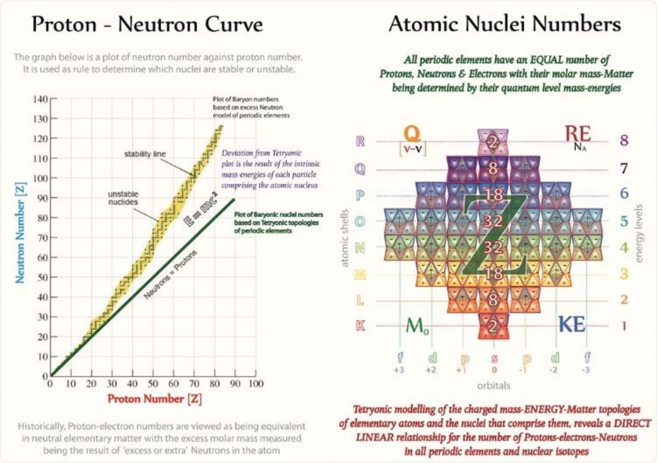

As it is the ONLY way to model and explain how all the periodic elements are created from equilateral Planck energy momenta that is in accord with the known observables… they are not in agreement with some aspects of established theory BUT they do closely mirror the observables and once KEM fields of thermal heat, kinetic motion etc. are taken into account provide a very accurate quantum model of chemical processes at the quantum scale.

Tetryonics does not throw all these facts out of the window just because hydrogen does not fit neatly into my [or other] pre-conceived set of boxes and triangles and hexagons, they are calculated from the Material models and immaterial fields associated with each element that MUST grow from first principles… not from assumptions elaborated upon over time.

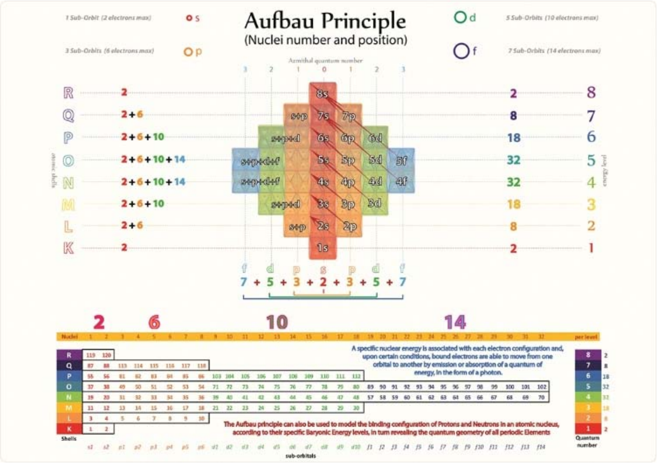
Aufbau Principle
(Nuclei number and position)
s
p
d
f
R
Q
P
O
N
M
L
K
2
2+6
2+6+10
2+6+10+14
2+6+10+14
2+6+10
2+6
2
2
8
18
32
32
18
8
2
8
7
6
5
4
3
2
1
7 + 5 + 3 + 2 + 3 + 5 + 7
2
6
10
14

In fact the Aufbau table is shown in Tetryonic theory to be a table that has been ‘right justified’ to match the nomenclature of mathematics rather than the geometric topology of reality [which is centred about the principle quantum numbers and shells of Schrodinger and Bohr respectively]… it is only our skewed perspective of maths that prevents most from seeing the real symmetry present in atomic nuclei as detailed in the quantum numbers of Schrodinger’s wave equation for the same … ie there are no g,h,I,j, shells as supposed and all the quantum numbers of Schrodinger’s wave equations match the symmetric topology of elements as geometric portrayed in Tetryonics [and are in agreeance with Bohr’s shells and orbitals as well, thus unifying all 3 theories]

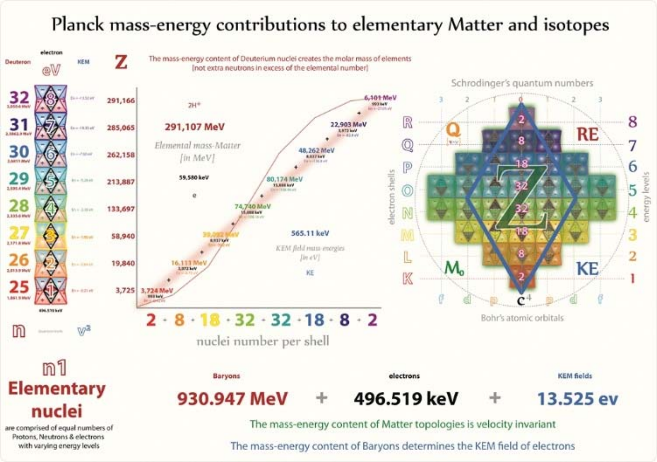
Planck mass-energy contributions to elementary Matter and isotopes
Z
eV
32
31
30
29
28
27
26
25
291,166
285,065
262,158
213,887
133,697
58,940
19,840
3,725
291,107 MeV
Schrodinger's quantum numbers
Q
RE
Z
M0
KE
c4
Bohr's atomic orbitals
2 · 8 · 18 · 32 · 32 · 18 · 8 · 2
nuclei number per shell
n1
Elementary nuclei
Baryons
electrons
KEM fields
930.947 MeV + 496.519 keV + 13.525 ev
The mass-energy content of Matter topologies is velocity invariant
The mass-energy content of Baryons determines the KEM field of electrons

The material topologies of Tetryonic theory then also lead to the necessity to correct ‘weighted’ values for all known particles and elements [and then some] in light of the quantum mechanics of the same – ie their identical 3D charge topologies and the mechanics of the quantum rotating synchronous convertors [Deuterium nuclei] that they form in deference to the accepted theory of mini-solar systems and Neutrons that are heavier than their identical charged counterparts [Protons and anti-Protons]

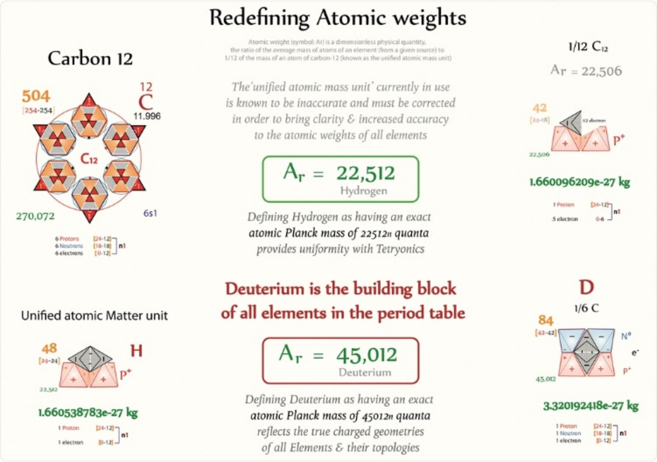

Redefining Atomic weights

Atomic weight (symbol: Ar) is a dimensionless physical quantity, the ratio of the average mass of atoms of an element (from a given source) to 1/12 of the mass of an atom of carbon-12 (known as the unified atomic mass unit)

The 'unified atomic mass unit' currently in use is known to be inaccurate and must be corrected in order to bring clarity & increased accuracy to the atomic weights of all elements

$A_r = 22{,}512$ Hydrogen

Defining Hydrogen as having an exact atomic Planck mass of 22512n quanta provides uniformity with Tetryonics

Deuterium is the building block of all elements in the period table

$A_r = 45{,}012$ Deuterium

Defining Deuterium as having an exact atomic Planck mass of 45012n quanta reflects the true charged geometries of all Elements & their topologies

Carbon 12
504
[254-254]
12
C
11.996
C12
270,072
6s1
6 Protons [24-12]
6 Neutrons [18-18]
6 electrons [0-12]
n1
1/12 C12
Ar = 22,506
42
[24-18]
1/2 electron
P+
22,506
1.660096209e-27 kg
1 Proton [24-12]
.5 electron 0-6
n1
Unified atomic Matter unit
48
[24-24]
H
P+
22,512
1.660538783e-27 kg
1 Proton [24-12]
1 electron [0-12]
n1
D
1/6 C
84
[42-42]
N0
e-
P+
45,012
3.320192418e-27 kg
1 Proton [24-12]
1 Neutron [18-18]
1 electron [0-12]
n1

Point in case being **Tetryonic Problem: Incorrect Proton and Neutron masses**
As detailed in illustration 49.04 & 49.05 respectively in my eBook… Tetryonics demands an exact mass for Planck quanta and the molar masses [at absolute zero] for each and every particle in our Universe for modelling and any additional energy momenta [by way of thermal, spectral, kinetic or observational energies etc.] are accounted for in the KEM fields of each respective element or particle.

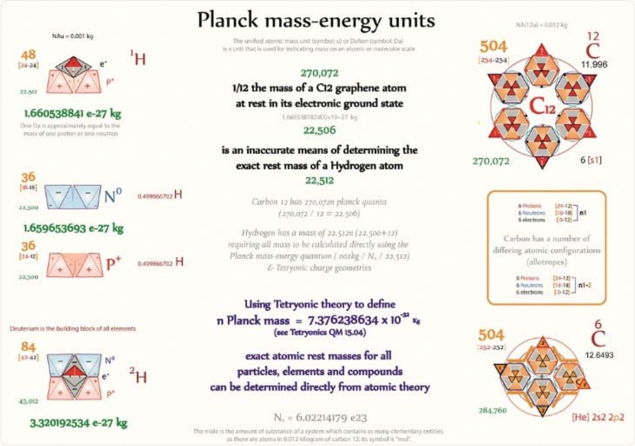

Planck mass-energy units

The unified atomic mass unit (symbol: u) or Dalton (symbol: Da) is a unit that is used for indicating mass on an atomic or molecular scale

270,072
1/12 the mass of a C12 graphene atom at rest in its electronic ground state
1.660538782(83)x10−27 kg
22,506
is an inaccurate means of determining the exact rest mass of a Hydrogen atom
22,512

Carbon 12 has 270,072n planck quanta (270,072 / 12 = 22,506)

Hydrogen has a mass of 22,512n (22,500+12) requiring all mass to be calculated directly using the Planck mass-energy quantum (.001kg / N_A / 22,512) & Tetryonic charge geometries

Using Tetryonic theory to define n Planck mass = $7.376238634 \times 10^{-32}$ Kg (see Tetryonics QM 15.04)

exact atomic rest masses for all particles, elements and compounds can be determined directly from atomic theory

$N_A = 6.02214179$ e23

The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12; its symbol is "mol".

NAu = 0.001 kg
48
[24-24]
e-
1H
P+
22,512
1.660538841 e-27 kg
One Da is approximately equal to the mass of one proton or one neutron
36
[18-18]
N0
0.499866702 H
22,500
1.659653693 e-27 kg
36
[24-12]
P+
0.499866702 H
22,500
Deuterium is the building block of all elements
84
[42-42]
N0
e-
2H
P+
45,012
3.320192534 e-27 kg
NA(12u) = 0.012 kg
504
[254-254]
12
C
11.996
C12
270,072
6 [s1]
6 Protons [24-12]
6 Neutrons [18-18]
6 electrons [0-12]
n1
Carbon has a number of differing atomic configurations (allotropes)
6 Protons [24-12]
6 Neutrons [18-18]
6 electrons [0-12]
n1-2
504
[252-252]
6
C
12.6493
284,760
[He] 2s2 2p2

There is NO room for a 'weighted' atomic mass as utilised in modern chemistry which conveniently ignores the mass and motional energies of the electrons in the elements or which ignores the KEM field energies noted above for 'most' situations and calculations – Tetryonic theory MUST account for all of these energies even if it does so at the risk of disagreeing with modern theory at times…

The Proton and Neutron MUST have identical atomic masses as they are identical – both are 36π Baryon Matter topologies differing only in the net charges of +12 [24-12] vs 0 [18-18] they possess as a result of their constituent quarks [UDU vs DUD] as extensively detailed in my QM eBook… Neutrons are NOT created through the process of 'reverse' beta-decay as is supposed presently supposed in modern theory and accordingly do NOT have a slightly higher mass than Protons which in turn affects the molar mass calculations for all periodic elements and isotopes as outlined in my Chemistry eBook as well at length.

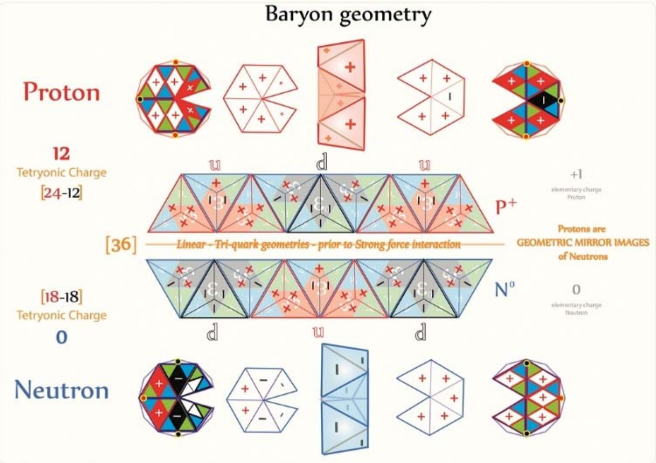
Baryon geometry
Proton
12
Tetryonic Charge
[24-12]
u
d
u
P+
+1
elementary charge
Proton
[36]
Linear - Tri-quark geometries - prior to Strong force interaction
Protons are
GEOMETRIC MIRROR IMAGES
of Neutrons
[18-18]
Tetryonic Charge
0
d
u
d
N°
0
elementary charge
Neutron
Neutron

Ie Carbon 13, 14 and upwards are not the result of 'extra' Neutrons being bound to the Carbon nuclei – such a nuclei if possible would be stable and not decay as observed – but rather they are simply the result of the inherent 'squared' equilateral mass-energies of each Baryon in the nuclei being increased from n1 to n2 to n3 …. Resulting in a net mass increase that 'appears' to be the result of a number of 'extra' Neutrons in the nuclei [again this is detailed in my Chemistry eBook and spreadsheets of the calculations be easily created from the formulae found in chapter 53 on my Chemistry eBook….

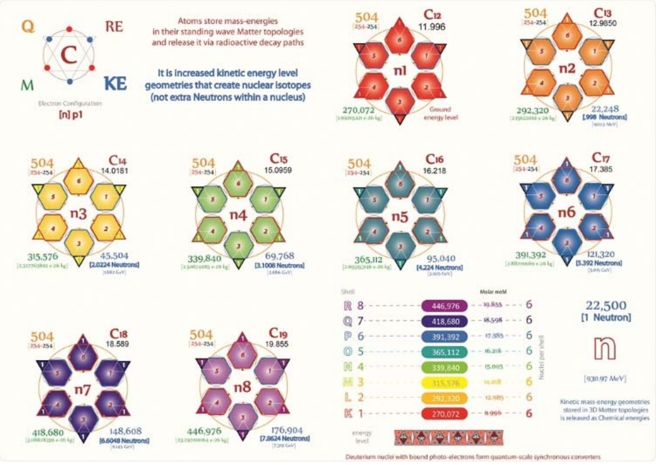
Q
RE
C
M
KE
Electron Configuration
[n] p1
Atoms store mass-energies in their standing wave Matter topologies and release it via radioactive decay paths
It is increased kinetic energy level geometries that create nuclear isotopes (not extra Neutrons within a nucleus)
504
[254-254]
C12
11.996
n1
270,072
Ground energy level
C13
12.9850
n2
292,320
22,248
[.998 Neutrons]
C14
14.0181
n3
315,576
45,504
[2.0224 Neutrons]
C15
15.0959
n4
339,840
69,768
[3.1008 Neutrons]
C16
16.218
n5
365,112
95,040
[4.224 Neutrons]
C17
17.385
n6
391,392
121,320
[5.392 Neutrons]
C18
18.589
n7
418,680
148,608
[6.6048 Neutrons]
C19
19.855
n8
446,976
176,904
[7.8624 Neutrons]
Shell
Molar meM
R 8
446,976
19.855
6
Q 7
418,680
18.598
6
P 6
391,392
17.385
6
O 5
365,112
16.218
6
N 4
339,840
15.095
6
M 3
315,576
6
L 2
292,320
12.985
6
K 1
270,072
11.996
6
Nuclei per shell
energy level
22,500
[1 Neutron]
n
[930.97 MeV]
Kinetic mass-energy geometries stored in 3D Matter topologies is released as Chemical energies
Deuterium nuclei with bound photo-electrons form quantum-scale synchronous converters

This 'significant discrepancy' with Tetryonics prediction of Proton and Neutron masses from observed ones alone will be enough to prove Tetryonic theory a worthy successor to modern quantum chemistry theory – unless you can explain all of the above using 'excess' Neutrons.

I am neither ignorant of the basic masses of basic particles nor do I think that Tetryonic theory and observed facts of nature disagree, but rather the established theoretical 'facts' of modern chemical theory must be in error

I agree that in reality Matter has **3D structure** (including **volume**) hence the terminology of Matter **topologies** throughout my work. To portray my planar illustration of elements and particles in my PDF eBooks as not reflecting their true material topologies is grossly inaccurate and reflects that fact that **YOU have NOT read all my work** including Tetryonics 101, the Google sketch warehouse of 3D CAD models of each and every particle [kindly developed by Rene Cormier over many months of effort] and extensive list of all elements and their charged 3D topologies and electronic wave function properties and numbers which are freely available to all – only planar 2 d mass-energy **geometries** [bosons and photons] are portrayed as being like thin 2D sheets in Tetryonic theory, something I am sure you will become more familiar with as your understanding of T-theory advances,[and your distain for its predictions and values not in accord with modern theory wains over time].

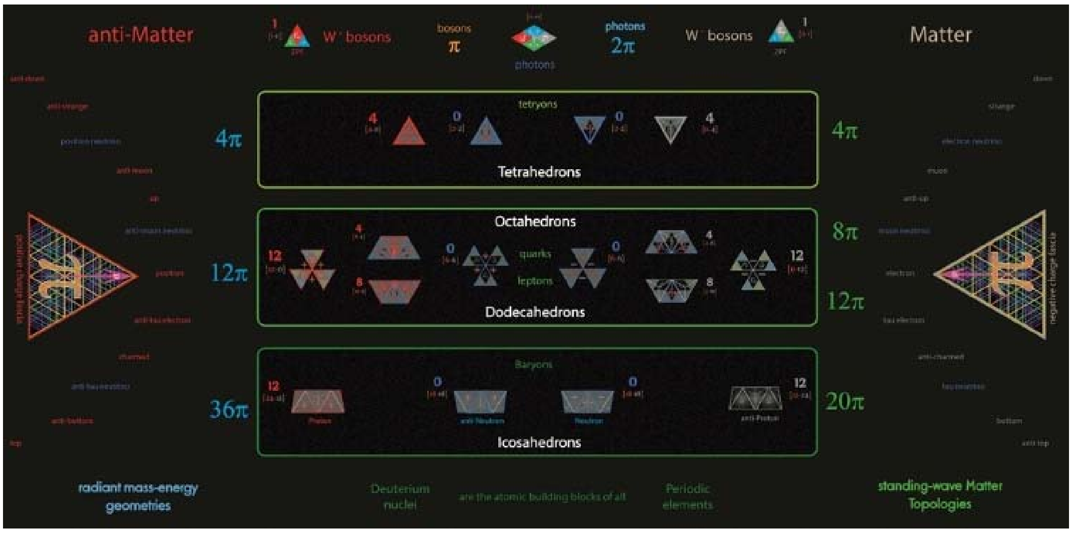
anti-Matter
W bosons
bosons
π
photons
photons
2π
W bosons
Matter
tetryons
4π
Tetrahedrons
4π
Octahedrons
quarks
leptons
Dodecahedrons
12π
8π
12π
Baryons
36π
Icosahedrons
20π
radiant mass-energy geometries
Deuterium nuclei
are the atomic building blocks of all
Periodic elements
standing-wave Matter Topologies

Regarding the ‘separation ‘ of electrons from the atomic nucleus – this is an antiquated model of quantum electrodynamics that is fashioned on planets and their satellites [ie the mini-solar system Bohr model] and which has been extended to a fuzzy electron orbital model to incorporate the Schrodinger quantum model and the ‘inherent’ quantum uncertainly/indeterminacy of statistical probabilities intrinsic to quantum theory as the theories developed over time…. Tetryonics makes it quite clear in T[1] – QM that the atomic nucleus is in fact a quantum synchronous convertor [ala Tesla/Westinghouse] that can store and release mass-energies in a controlled and predictable manner [ala isotopic decay and spectral line emissions] and that quantum mechanics is NOT quantum inherently uncertain nor in determinant as it is often portrayed – in fact quantum theory as explained by Tetryonic theory is very much deterministic in every way – it was only our top-down view of the mechanics that led modern science to this erroneous conclusion, which I have attempted to correct through Tetryonic theory.

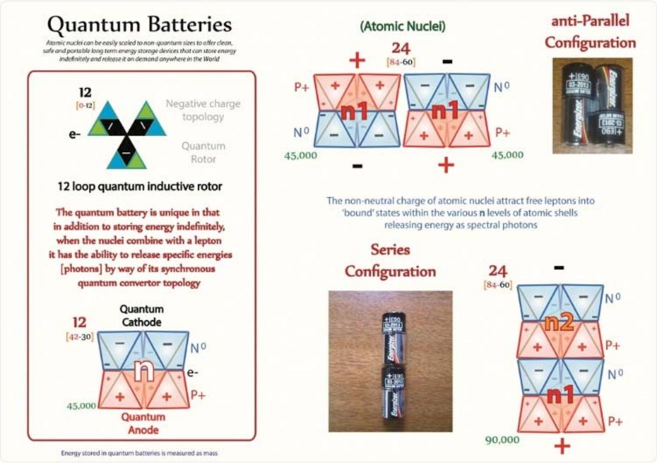
Quantum Batteries

Atomic nuclei can be easily scaled to non-quantum sizes to offer clean, safe and portable long term energy storage devices that can store energy indefinitely and release it on demand anywhere in the World

12 loop quantum inductive rotor

The quantum battery is unique in that in addition to storing energy indefinitely, when the nuclei combine with a lepton it has the ability to release specific energies [photons] by way of its synchronous quantum convertor topology

The non-neutral charge of atomic nuclei attract free leptons into ‘bound’ states within the various n levels of atomic shells releasing energy as spectral photons

Energy stored in quantum batteries is measured as mass
12
[0-12]
e-
Negative charge topology
Quantum Rotor
12
[42-30]
Quantum Cathode
N0
e-
P+
n
45,000
Quantum Anode
(Atomic Nuclei)
24
[84-60]
+
-
P+
N0
n1
n1
N0
P+
45,000
45,000
-
+
anti-Parallel Configuration
Series Configuration
24
[84-60]
-
N0
n2
P+
N0
n1
P+
90,000
+

The electron does not orbit the atomic nucleus of any element but rather is bound via its magnetic dipole moment to the positively charged nucleus and spins akin to the rotating rotor of quantum convertor partially within the 3D Matter topology of Deuterium nuclei….

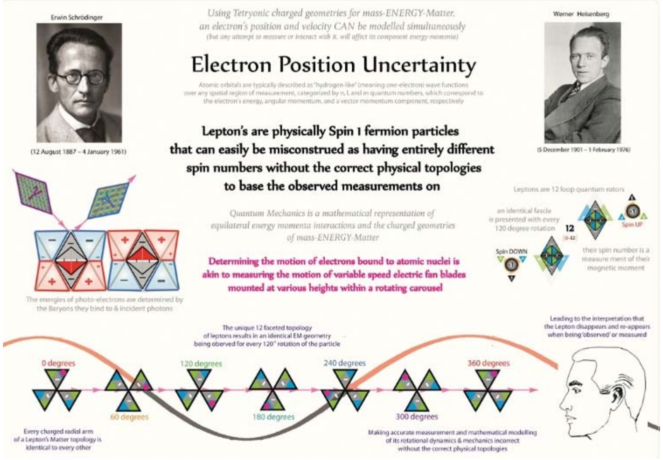

Using Tetryonic charged geometries for mass-ENERGY-Matter, an electron's position and velocity CAN be modelled simultaneously

(but any attempt to measure or interact with it, will affect its component energy-momenta)

Electron Position Uncertainty

Atomic orbitals are typically described as "hydrogen-like" (meaning one-electron) wave functions over any spatial region of measurement, categorized by n, l, and m quantum numbers, which correspond to the electron's energy, angular momentum, and a vector momentum component, respectively

Lepton's are physically Spin 1 fermion particles that can easily be misconstrued as having entirely different spin numbers without the correct physical topologies to base the observed measurements on

Quantum Mechanics is a mathematical representation of equilateral energy momenta interactions and the charged geometries of mass-ENERGY-Matter

Determining the motion of electrons bound to atomic nuclei is akin to measuring the motion of variable speed electric fan blades mounted at various heights within a rotating carousel

The energies of photo-electrons are determined by the Baryons they bind to & incident photons

Leptons are 12 loop quantum rotors

an identical fascia is presented with every 120 degree rotation

their spin number is a measure ment of their magnetic moment

The unique 12 faceted topology of leptons results in an identical EM geometry being oberved for every 120° rotation of the particle

Leading to the interpretation that the Lepton disappears and re-appears when being 'observed' or measured

Every charged radial arm of a Lepton's Matter topology is identical to every other

Making accurate measurement and mathematical modelling of its rotational dynamics & mechanics incorrect without the correct physical topologies

Erwin Schrödinger
(12 August 1887 – 4 January 1961)
Werner Heisenberg
(5 December 1901 – 1 February 1976)
12
(0-12)
Spin UP
Spin DOWN
-1
0 degrees
60 degrees
120 degrees
180 degrees
240 degrees
300 degrees
360 degrees

Again these models have all been built and operate according to established electrodynamic theory and their operation is well understood in the macro sense [but obviously the acceptance of such a model strains the thoughts of most who have grown up a mental picture of fuzzy electrons orbiting a spherical nuclei]

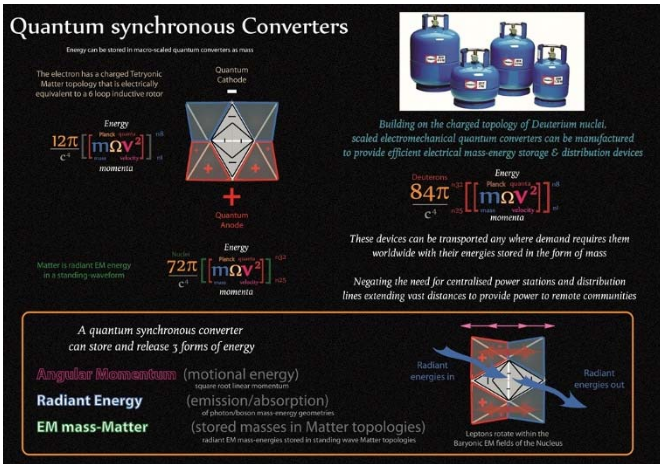

Quantum synchronous Converters

Energy can be stored in macro-scaled quantum converters as mass

The electron has a charged Tetryonic Matter topology that is electrically equivalent to a 6 loop inductive rotor

Matter is radiant EM energy in a standing-waveform

Building on the charged topology of Deuterium nuclei, scaled electromechanical quantum converters can be manufactured to provide efficient electrical mass-energy storage & distribution devices

These devices can be transported any where demand requires them worldwide with their energies stored in the form of mass

Negating the need for centralised power stations and distribution lines extending vast distances to provide power to remote communities

A quantum synchronous converter can store and release 3 forms of energy

Angular Momentum (motional energy)
square root linear momentum

Radiant Energy (emission/absorption)
of photon/boson mass-energy geometries

EM mass-Matter (stored masses in Matter topologies)
radiant EM mass-energies stored in standing wave Matter topologies

Leptons rotate within the Baryonic EM fields of the Nucleus

Quantum Cathode
Quantum Anode
Energy
$\frac{12\pi}{c^4}[[m\Omega v^2]]$
momenta
Nuclei
$\frac{72\pi}{c^4}[[m\Omega v^2]]$
Deuterons
$\frac{84\pi}{c^4}[[m\Omega v^2]]$
Planck
quanta
mass
velocity
n32
n25
n8
n1
Radiant energies in
Radiant energies out

Again the electronic structure of each and every one of the 120 possible periodic elements is well detailed wrt Bohr shells & orbitals and unified wrt their respective Schrodinger numbers for the same in my Chemistry eBook for all to view…. Unlike modern texts which normally stop at element 20 and claim that it is just too difficult to show the quantum models of larger elements with their evermore complex electron configurations and Schrodinger numbers

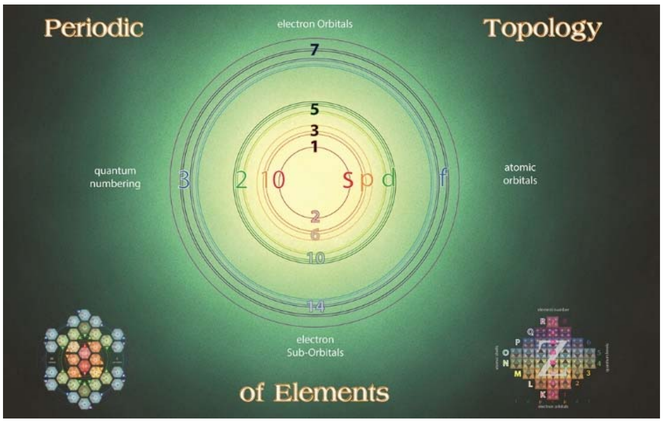

Periodic
Topology
of Elements
electron Orbitals
7
5
3
1
quantum numbering
3
2
1
0
s
p
d
f
atomic orbitals
2
6
10
14
electron Sub-Orbitals

The s.p.d & f orbitals of electrons ‘around’ any elementary nuclei is the result of the atomic nuclei rotating about is centre of mass/gravity [classical angular momentum] and the electrons tracing out easily determined and well defined concentric orbits about the same centre [as illustrated] …. A close examination of the Schrodinger numbers [or in fact Bohr orbits] of heavier/larger Z number atomic nuclei reveals the there are no g,h I orbits etc as often postulated but in fact there is a reversal of electron orbital distance as the element number and principal energy levels increases….. Resulting in the periodic symmetry depicted in Tetryonic theory of an atomic nucleus resembling a child's spinning top, which could be mistaken for a spherical topology from our macro view of the quantum scale.

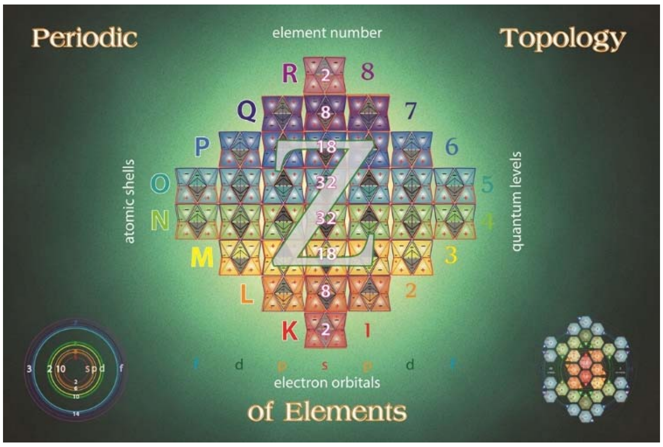
Periodic
element number
Topology
R
Q
P
O
N
M
L
K
2
8
18
32
32
18
8
2
8
7
6
5
4
3
2
1
Z
atomic shells
quantum levels
d
s
d
electron orbitals
of Elements

With each element's Z number reflecting the number of **Deuterium** atoms in each nuclei, *not the number of Hydrogen atoms with an ever increasing number of Neutrons to account for observed molar masses*

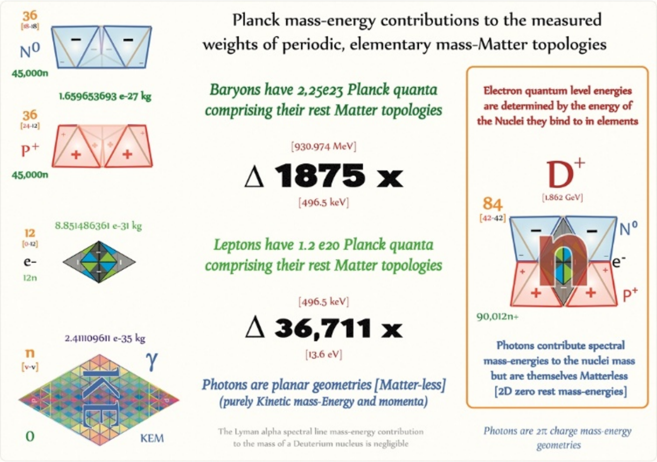
36
[18-18]
N0
45,000n
1.659653693 e-27 kg
36
[24-12]
P+
45,000n
12
[0-12]
e-
12n
8.851486361 e-31 kg
n
[v-v]
2.41110961I e-35 kg
γ
0
KEM
[930.974 MeV]
Δ 1875 x
[496.5 keV]
[496.5 keV]
Δ 36,711 x
[13.6 eV]
D+
[1.862 GeV]
84
[42-42]
N0
e-
P+
90,012n+

Planck mass-energy contributions to the measured weights of periodic, elementary mass-Matter topologies

Baryons have 2,25e23 Planck quanta comprising their rest Matter topologies

Leptons have 1.2 e20 Planck quanta comprising their rest Matter topologies

Photons are planar geometries [Matter-less] (purely Kinetic mass-Energy and momenta)

The Lyman alpha spectral line mass-energy contribution to the mass of a Deuterium nucleus is negligible

Electron quantum level energies are determined by the energy of the Nuclei they bind to in elements

Photons contribute spectral mass-energies to the nuclei mass but are themselves Matterless [2D zero rest mass-energies]

Photons are 2π charge mass-energy geometries

The electrons associated with each atomic element's structure in fact have an important and direct bearing on the spectral emissions of each particular element. Even though their mass-energies of their electronic topologies are only 0.000533' % of the mass-energies of each Baryon in any atomic nuclei this mass-Matter differential along with the energy momenta of the electron's KEM field is key to facilitating the absorption and release of spectral line emissions particular to each and every element known… again, it is not simple good enough to conveniently ignore electrons ad hoc in scientific theory to suit a particular point or theory just because they are or 'insignificant' mass compared to the whole nucleus. Any successful model of science and physics in general must be able to account for ALL the known aspects of modern observations not just a select few that suit their purposes in order to unify physics on all energy scales. Ie a new model of the quantum structure, topology and mechanics of atomic nuclei must account for charge, atomic and chemical interactions, spectral line series and all known elements and compound creation in the ONE physical model.

Clarifying question about Tetryonics nuclear vs. atomic size wrt the Zenon atom
I humbly submit that illustrations 51.49

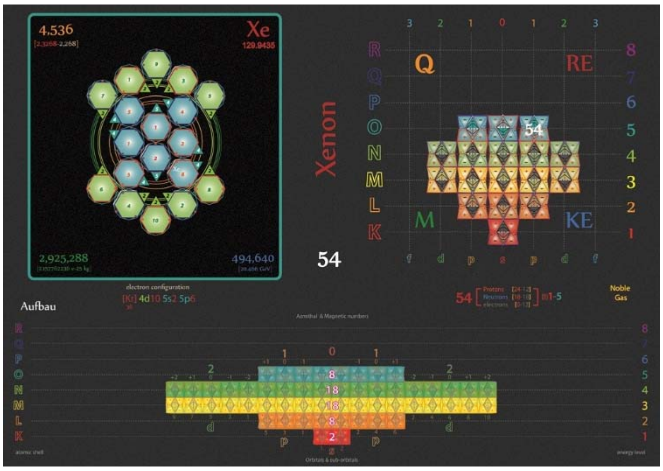
4.536
Xe
129.9436
Xenon
Q
RE
M
KE
54
2,925,288
494,640
electron configuration
[Kr] 4d10 5s2 5p6
Aufbau
Noble Gas
R
Q
P
O
N
M
L
K
8
18
18
8
2
d
p
s
Orbitals & sub-orbitals

And 53.49 respectively along with the 3D CAD illustrations of the same

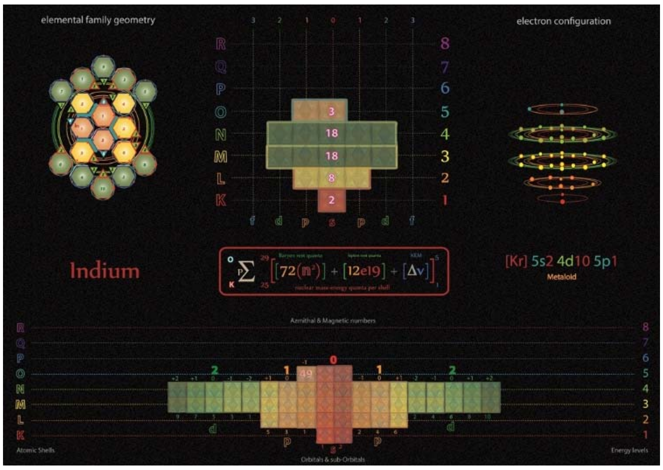
elemental family geometry
electron configuration
3
18
18
8
2
Indium
[Kr] 5s2 4d10 5p1
Metaloid
Azmithal & Magnetic numbers
Atomic Shells
Energy levels
Orbitals & sub-Orbitals

Should be sufficient to explain and illustrate all properties of the Zenon atom [or any other you chose] including their rest mass-Matter energies [at absolute zero], their charged Matter topology in accord with Bohr shells/orbitals and Schrodinger numbers and the kinetic mass-energies of their bound electrons.

Clarifying question 2 about Tetryonics nuclear vs. atomic size

According to Tetryonics the proton and neutron in Deuterium nuclei touch one another at the point son their respective charge topologies where the e-field components of their constituent quarks are located - this is indicated on all Tetryonic element illustrations via red [for positive] focus points and black [for negative] focus points.

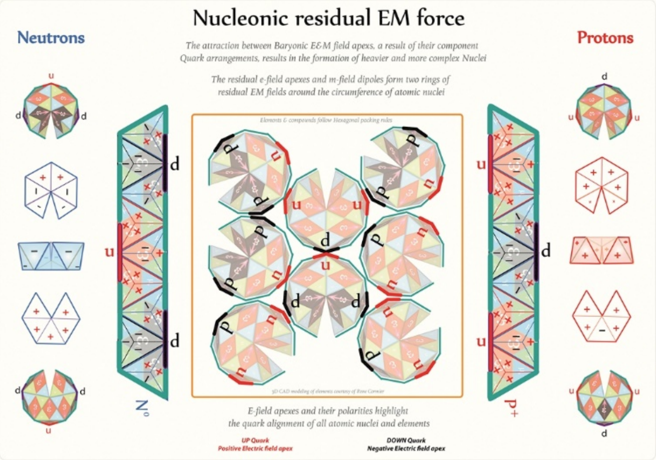

Nucleonic residual EM force

The attraction between Baryonic E&M field apexs, a result of their component Quark arrangements, results in the formation of heavier and more complex Nuclei

The residual e-field apexes and m-field dipoles form two rings of residual EM fields around the circumference of atomic nuclei

Elements & compounds follow Hexagonal packing rules

3D CAD modeling of elements courtesy of Rene Cormier

E-field apexes and their polarities highlight the quark alignment of all atomic nuclei and elements

Neutrons
Protons
u
d
d
d
u
d
N⁰
P+
UP Quark
Positive Electric field apex
DOWN Quark
Negative Electric field apex

But since Tetryonics does not include any separate strong nuclear force but just electromagnetics, all particles of Tetryonic nucleus would fly apart in a nanosecond.

Again, this misunderstanding and erroneous statement about Tetryonic theory seems to stem from you having failed to read Tetryonics [1] – Quantum Mechanics, viewed my Tetryonics 101 instruction video or even attempted to build and understand how atomic nuclei are formed and come together to form larger elements and compounds alike prior to commenting ….

In my first eBook I have gone to great lengths to show that the STRONG force does indeed exist and in fact plays a crucial role in bringing tetryons [the tetrahedral quantum of Matter topologies themselves] together to form leptons, quarks, mesons & Baryons – it is the parallel opposite charge interaction present between the planar charge faces of each tetryon within each and every Baryon [not to be mistaken for the residual strong force]

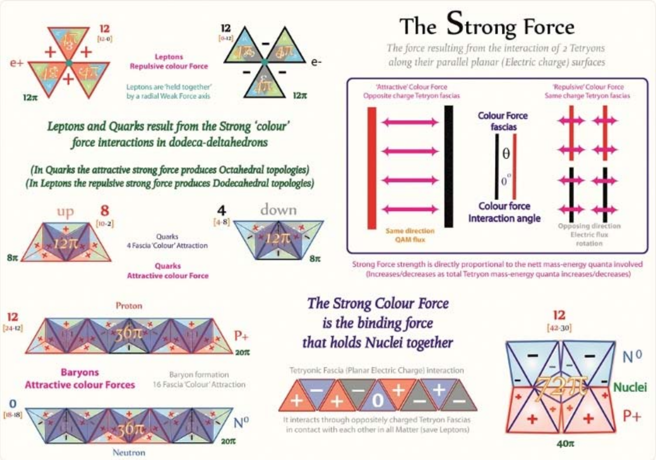

The Strong Force

The force resulting from the interaction of 2 Tetryons along their parallel planar (Electric charge) surfaces

Leptons and Quarks result from the Strong 'colour' force interactions in dodeca-deltahedrons

(In Quarks the attractive strong force produces Octahedral topologies)
(In Leptons the repulsive strong force produces Dodecahedral topologies)

Strong Force strength is directly proportional to the nett mass-energy quanta involved (Increases/decreases as total Tetryon mass-energy quanta increases/decreases)

The Strong Colour Force is the binding force that holds Nuclei together

It interacts through oppositely charged Tetryon Fascias in contact with each other in all Matter (save Leptons)

12
[12-0]
e+
12π
Leptons
Repulsive colour Force
Leptons are 'held together' by a radial Weak Force axis
12
[0-12]
e-
12π
'Attractive' Colour Force
Opposite charge Tetryon fascias
'Repulsive' Colour Force
Same charge Tetryon fascias
Colour Force fascias
θ
0°
Colour force Interaction angle
Same direction QAM flux
Opposing direction Electric flux rotation
up
8
[10-2]
12π
8π
Quarks
4 Fascia 'Colour' Attraction
Quarks
Attractive colour Force
4
[4-8]
down
12π
8π
Proton
12
[24-12]
36π
P+
20π
Baryons
Attractive colour Forces
Baryon formation
16 Fascia 'Colour' Attraction
0
[18-18]
36π
N⁰
20π
Neutron
Tetryonic Fascia (Planar Electric Charge) interaction
12
[42-30]
72π
N⁰
Nuclei
P+
40π

Obviously this co-planar opposite charge interaction holds all atomic nuclei together and your claim of Tetryonic particles flying away in a nanosecond just doesn't hold water…

In fact just place two sheets of glass together with a thin film of water between them and see how easy it is to pull those sheets apart by applying a force orthogonal to the co-planar sheets of glass and you'll soon understand the STRONG force much better that you do presently.

This charge interaction between the e-fields of quarks in Baryons serves to not only bring positive charge Protons together with neutral Neutrons [something modern theory cannot explain] but also serve to orientate each baryon to the other so as to facilitate electron bonding and the creation of ever larger atomic elements and compounds [the residual strong or EM force as it is often termed or the London force]

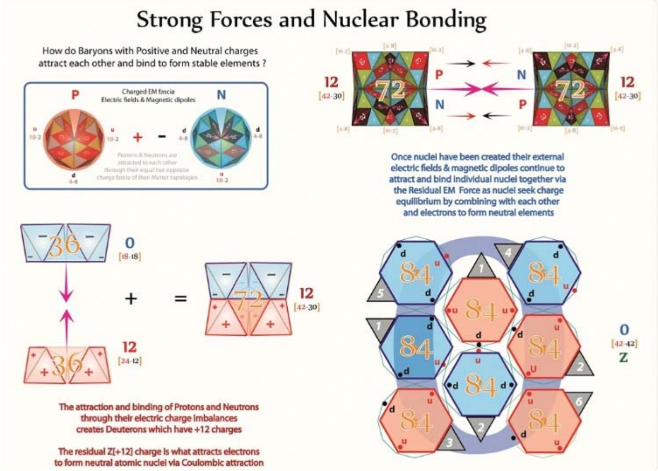
Strong Forces and Nuclear Bonding
How do Baryons with Positive and Neutral charges attract each other and bind to form stable elements ?
P
Charged EM fascia
Electric fields & Magnetic dipoles
N
+
-
Protons & Neutrons are attracted to each other through their equal but opposite charge fascia of their Matter topologies
12
[42-30]
72
P
N
N
P
72
12
[42-30]
Once nuclei have been created their external electric fields & magnetic dipoles continue to attract and bind individual nuclei together via the Residual EM Force as nuclei seek charge equilibrium by combining with each other and electrons to form neutral elements
36
0
[18-18]
+
=
72
12
[42-30]
36
12
[24-12]
84
0
[42-42]
Z
The attraction and binding of Protons and Neutrons through their electric charge imbalances creates Deuterons which have +12 charges
The residual Z[+12] charge is what attracts electrons to form neutral atomic nuclei via Coulombic attraction

Yes I have an ‘obsession’ with all atomic nuclei have equal numbers of Protons, electron AND Neutrons in accord with their Z number, just as you have an obsession with them being Hydrogen atoms with excess Neutrons ‘bound’ to them – but for the reasons highlighted above, and many others – as for the quantum structure of Protium (regular hydrogen), Deuterium and Tritium being ‘missing’ - again my T[1] - QM eBook holds the answers

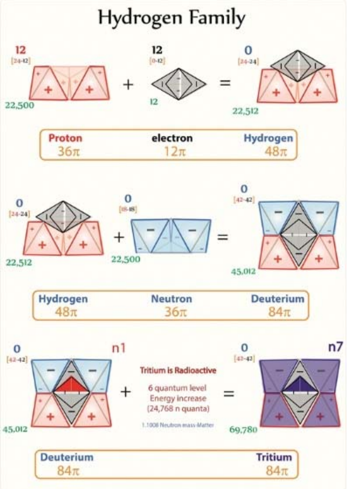
Hydrogen Family
12
[24-12]
22,500
+
12
[0-12]
12
=
0
[24-24]
22,512
Proton
36π
electron
12π
Hydrogen
48π
0
[24-24]
22,512
+
0
[18-18]
22,500
=
0
[42-42]
45,012
Hydrogen
48π
Neutron
36π
Deuterium
84π
0
[42-42]
45,012
n1
+
Tritium is Radioactive
6 quantum level
Energy increase
(24,768 n quanta)
1.1008 Neutron mass Matter
=
0
[42-42]
69,780
n7
Deuterium
84π
Tritium
84π

With additional space being made to highlight the Tetryonic genesis of Tritium & Helium 3

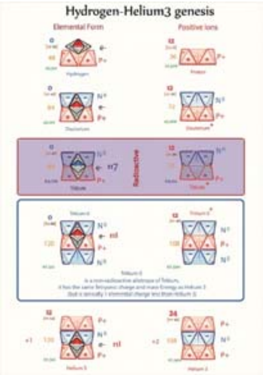
Hydrogen-Helium3 genesis
Elemental Form
Positive ions
Radioactive

All isotopes are simply Z number nuclei with the energy levels of their Baryons raised to the next quantum energy level [n1-n8] in accord with the 3D material symmetry of the atomic nuclei themselves and the Bohr shells/Schrodinger principal quantum numbers, which can occur either through natural energy absorption or the artificial increase of their mass-energy content in the lab….

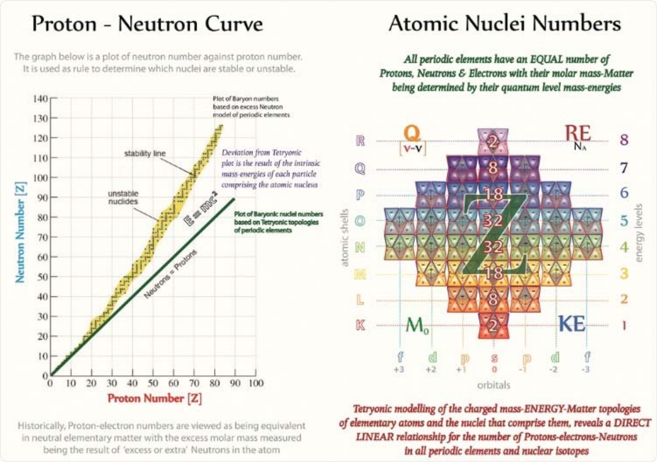

Proton - Neutron Curve

The graph below is a plot of neutron number against proton number. It is used as rule to determine which nuclei are stable or unstable.

Deviation from Tetryonic plot is the result of the intrinsic mass-energies of each particle comprising the atomic nucleus

Historically, Proton-electron numbers are viewed as being equivalent in neutral elementary matter with the excess molar mass measured being the result of 'excess or extra' Neutrons in the atom

Atomic Nuclei Numbers

All periodic elements have an EQUAL number of Protons, Neutrons & Electrons with their molar mass-Matter being determined by their quantum level mass-energies

Tetryonic modelling of the charged mass-ENERGY-Matter topologies of elementary atoms and the nuclei that comprise them, reveals a DIRECT LINEAR relationship for the number of Protons-electrons-Neutrons in all periodic elements and nuclear isotopes

Neutron Number [Z]
Proton Number [Z]
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Plot of Baryon numbers based on excess Neutron model of periodic elements
stability line
unstable nuclides
E = mc²
Plot of Baryonic nuclei numbers based on Tetryonic topologies of periodic elements
Neutrons = Protons
Q
[v-v]
RE
N_A
R
Q
P
O
N
M
L
K
atomic shells
8
7
6
5
4
3
2
1
energy levels
2
8
18
32
32
18
8
2
Z
M_0
KE
f
d
p
s
p
d
f
+3
+2
+1
0
-1
-2
-3
orbitals

Obviously with all Deuterium nuclei being quantum synchronous convectors as the energy levels of their Baryons are increased [or decreased] the electrons bound to them respond in kind [hence synchronous] via spectral line emissions [or absorption] ….all covered in Tetryonics [2] – Quantum Electrodynamics.

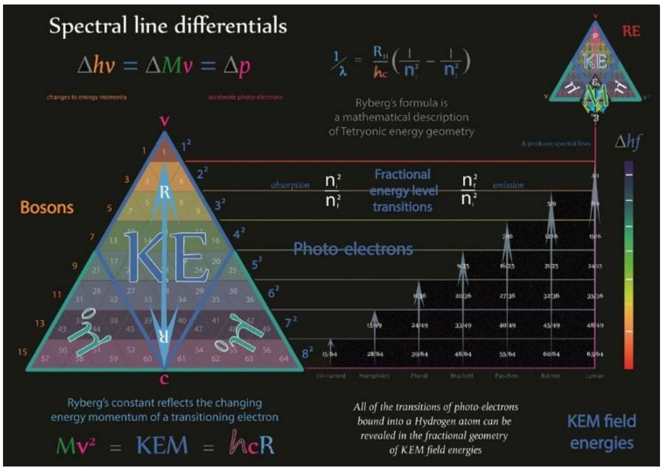

Spectral line differentials

$$\Delta hv = \Delta Mv = \Delta p$$

$$\frac{1}{\lambda} = \frac{R_H}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Ryberg's formula is a mathematical description of Tetryonic energy geometry

Ryberg's constant reflects the changing energy momentum of a transitioning electron

$$Mv^2 = KEM = hcR$$

All of the transitions of photo-electrons bound into a Hydrogen atom can be revealed in the fractional geometry of KEM field energies

changes to energy momenta
accelerate photo-electrons
& produces spectral lines
RE
KE
M
Δhf
Bosons
v
c
R
KE
1²
2²
3²
4²
5²
6²
7²
8²
absorption
emission
Fractional energy level transitions
Photo-electrons
15/64
28/64
39/64
48/64
55/64
60/64
63/64
Un-named
Humphries
Pfund
Brackett
Paschen
Balmer
Lyman
KEM field energies

There is NO explanation in modern chemical or quantum theory that accounts for the Proton-Neutron 'curve' of atomic isotopes nor for the islands of stability that exist for various elements, however Tetryonic theory accounts for all of this firstly by 'straightening' out the curved Z line of Protons and Neutrons underpinning atomic elements [by showing that all atomic nuclei are comprised of D nuclei not H atoms with excess neutrons] and then showing that the observed isotopic masses of each are the result of increased principal energy levels of their constituent baryons with the D nuclei comprising each element…. It is no error or 'false notion' as you put it, rather it is the current explanation of these facts by modern theory that is in error

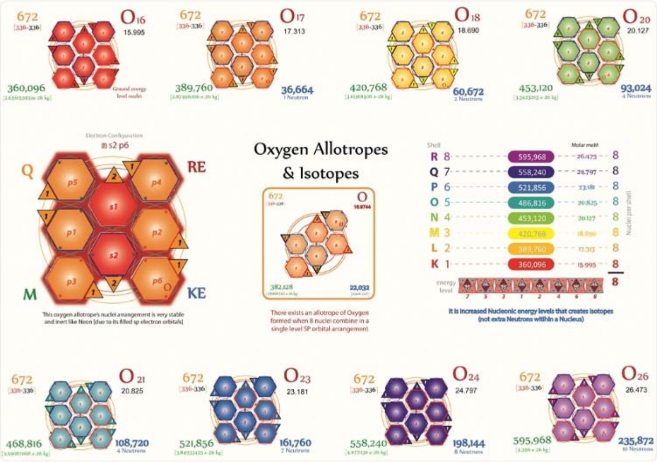
672
[336-336]
O16
15.995
360,096
Ground energy level nuclei
O17
17.313
389,760
36,664
1 Neutron
O18
18.690
420,768
60,672
2 Neutrons
O20
20.127
453,120
93,024
4 Neutrons
Electron Configuration
s2 p6
Q
RE
M
KE
p5
p4
s1
p1
p2
s2
p3
p6
This oxygen allotrope's nuclei arrangement is very stable and inert like Neon [due to its filled sp electron orbitals]
Oxygen Allotropes
& Isotopes
O
382,128
22,032
There exists an allotrope of Oxygen formed when 8 nuclei combine in a single level SP orbital arrangement
Shell
Molar meM
R 8 595,968 26.473 8
Q 7 558,240 24.797 8
P 6 521,856 23.181 8
O 5 486,816 20.825 8
N 4 453,120 20.127 8
M 3 420,768 18.690 8
L 2 389,760 17.313 8
K 1 360,096 15.995 8
8
Nuclei per shell
energy level
7 5 3 1 2 4 6 8
It is increased Nucleonic energy levels that creates isotopes (not extra Neutrons within a Nucleus)
O21
20.825
468,816
108,720
4 Neutrons
O23
23.181
521,856
161,760
7 Neutrons
O24
24.797
558,240
198,144
8 Neutrons
O26
26.473
595,968
235,872
10 Neutrons

You have chosen Lithium to make your point I chose Carbon, Nitrogen and Oxygen to make mine, but the explanation for Lithium remains the same….. an increase in the mass-energies of the baryons making up the element concerned… btw I have done spreadsheets for each and all the elements as a matter of course during the development of my theory.

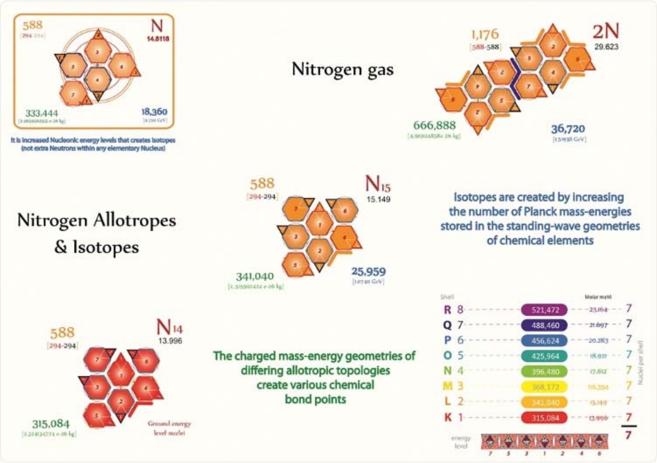
588
N
14.8118
333,444
18,360
It is increased Nucleonic energy levels that creates isotopes (not extra Neutrons within any elementary Nucleus)
Nitrogen gas
1,176
[588-588]
2N
29.623
666,888
36,720
Nitrogen Allotropes
& Isotopes
588
[294-294]
N15
15.149
341,040
25,959
Isotopes are created by increasing the number of Planck mass-energies stored in the standing-wave geometries of chemical elements
588
[294-294]
N14
13.996
315,084
Ground energy level nuclei
The charged mass-energy geometries of differing allotropic topologies create various chemical bond points
Shell
Molar meM
R 8 521,472 23.164 7
Q 7 488,460 21.697 7
P 6 456,624 20.283 7
O 5 425,964 18.921 7
N 4 396,480 17.612 7
M 3 368,172 16.354 7
L 2 341,040 15.149 7
K 1 315,084 13.996 7
7
Nuclei per shell
energy level
7 5 3 1 2 4 6

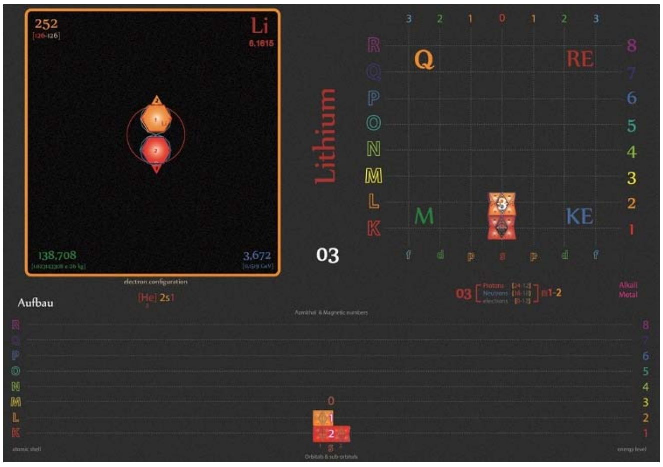
252
[126-126]
Li
6.1615
138,708
3,672
electron configuration
[He] 2s1
Lithium
03
3 2 1 0 1 2 3
R Q P O N M L K
Q
RE
M
KE
8 7 6 5 4 3 2 1
f d p s p d f
03
Protons
Neutrons
electrons
Alkali Metal
Aufbau
Azimuthal & Magnetic numbers
atomic shell
energy level
Orbitals & sub-orbitals

Element 3 – Lithium [ground state atomic topology and electronic configuration]

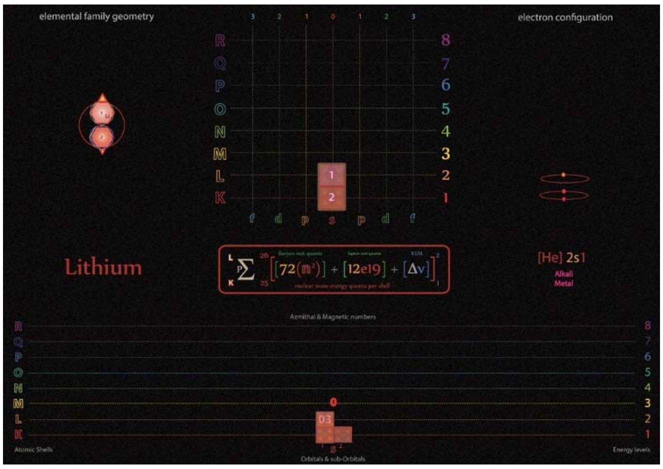

Regarding your comment of “but in reality **only electrons are on these shells** and the structure of the nucleus is completely separate from these shells”, - that is only the current opinion/consensus explanation of quantum chemistry at this stage and is obviously at odds with Tetryonic theory *built from the ground up from equilateral Planck energies not the top-down through supposition*….. I am confident that over time this consensus will change.

1. Explaining the extra (neutron) weight as higher energy-levels of the Deuterium nuclei seems *ad hoc* explanation with no supporting evidence – *simply nonsense*…..
2. No calculation is presented to *derive a prediction* for the excess mass (or energy) from the Tetryonics model – *have you even read my work in detail – calculations and mass-energies are provided everywhere throughout it*.
3. The excess mass of, say, Lithium 7 (one excess neutron compared to 3x deuterium) *– again a number based on your erroneous viewpoint – not y given explanation and illustrations of the same.*
4. This is inconsistent with the fact that there are **multiple** isotopes of each element.- *how so?*

   The energy level of Baryons of each and every illustrated element in Tetryonic can be increased resulting in isotopes of that element – with NO extra Neutrons present, again you seem to have failed to read and/or comprehend what was presented before you in the Tetryonics chemistry eBook.

5. See above for Hydrogen family [please]

All the ‘observed’ masses you have provided in that table are firstly just that, weighted [averaged] measurements of particles with kinetic energies [heat, spectral, motion etc.] not the absolute rest masses I have provided and clearly stated as such…… you must account for observational and inherent kinetic energies for your stated values to even begin reflecting the quantum values of particles at absolute zero.

Again, ‘isotopes’ is NOT what you think and proclaim – there are no extra Neutrons in the nuclei – only Baryonic energy above that of the res/ground state of such an element at absolute zero – unless you can account for those KEM field energies [as should be done]

Tetryonic Problem: Helium as Alkaline Earth metal

- And Hydrogen is element 1 which no-one can agree on which position it truly belongs in on the current periodic table.

Tetryonics problem: 120 possible maximum elements

- That is what is dictated by the charge topology of particles and elements themselves, perhaps you'd care to share what your spherical [or other] model for element 93 is, and how all the 'extra' Neutrons bind to each other to create that particular model?

Tetryonics shows quite clearly the reasons for there being only 120 possible periodic elements and it agrees with the math and equations of both Bohr and Schrodinger's models despite the differing quantum topologies.

Perhaps, you can produce element 121 and prove me wrong on this.

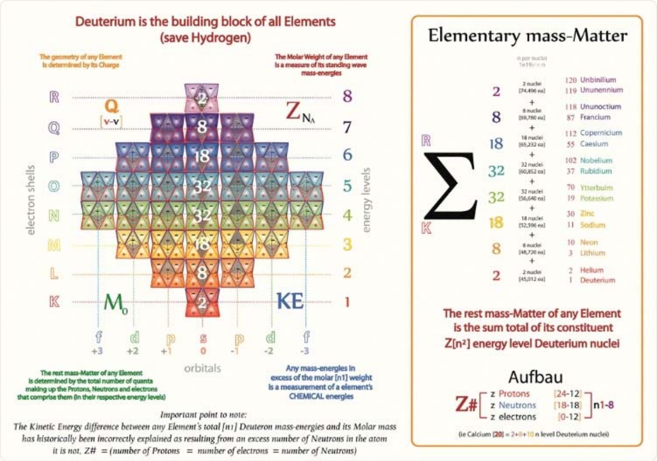
Deuterium is the building block of all Elements (save Hydrogen)
The geometry of any Element is determined by its Charge
The Molar Weight of any Element is a measure of its standing wave mass-energies
R
Q
P
O
N
M
L
K
electron shells
Q
[v-v]
Z_{N_A}
8
7
6
5
4
3
2
1
energy levels
2
8
18
32
32
18
8
2
M_0
KE
f +3
d +2
p +1
s 0
p -1
d -2
f -3
orbitals
The rest mass-Matter of any Element is determined by the total number of quanta making up the Protons, Neutrons and electrons that comprise them (in their respective energy levels)
Any mass-energies in excess of the molar [n1] weight is a measurement of a element's CHEMICAL energies
Important point to note:
The Kinetic Energy difference between any Element's total [n1] Deuteron mass-energies and its Molar mass has historically been incorrectly explained as resulting from an excess number of Neutrons in the atom it is not. Z# = (number of Protons = number of electrons = number of Neutrons)
Elementary mass-Matter
R
Σ
K
2 — 2 nuclei [74,496 ea] — 120 Unbinilium, 119 Ununennium
8 — 8 nuclei [69,780 ea] — 118 Ununoctium, 87 Francium
18 — 18 nuclei [65,232 ea] — 112 Copernicium, 55 Caesium
32 — 32 nuclei [60,852 ea] — 102 Nobelium, 37 Rubidium
32 — 32 nuclei [56,640 ea] — 70 Ytterbuim, 19 Potassium
18 — 18 nuclei [52,596 ea] — 30 Zinc, 11 Sodium
8 — 8 nuclei [48,720 ea] — 10 Neon, 3 Lithium
2 — 2 nuclei [45,012 ea] — 2 Helium, 1 Deuterium
The rest mass-Matter of any Element is the sum total of its constituent Z[n²] energy level Deuterium nuclei
Aufbau
Z# [z Protons [24-12], z Neutrons [18-18], z electrons [0-12]] n1-8
(ie Calcium [20] = 2+8+10 n level Deuterium nuclei)

Additional random quotes - the uncertainty principle erroneously dictates that position and momentum cannot be simultaneously determined

- There's nothing random about this comment/quote - Tetryonic theory is founded on the SINGLE postulate that Planck mass-energy momenta has an quantum equilateral geometry [ie quantised angular momenta (m^2/s] is equilateral/triangular not circular as it is the macro sense of angular momentum] - from that flows the fact that the probabilistic nature of quantum theory and the maths used to describe it are in fact not 'fuzzy' or indeterminate as supposed presently but in fact an emergent property of the tessellation of mass-energy momenta at the quantum level.

The inherent indeterminacy of quantum theory is a crutch used my mathematicians and scientists alike to explain many of the puzzling aspects of quantum theory like the inherent statically probabilities of quantum fields themselves or the wave-particle duality of photons or particles in motion….. Again it is them and modern theory that have simply failed to grasp the geometric reality of energy momenta that underpins these phenomena and how they build to form the familiar laws of Nature at our scale of observation.

Tetryonic theory is all about correcting these erroneous assumptions and established viewpoints – but any change of perspective is not without birth pangs of angst and misunderstanding from those who first encounter it [like Newton, Planck and Einstein with their theories of Gravity, Quantum mechanics & Relativity theories before it]

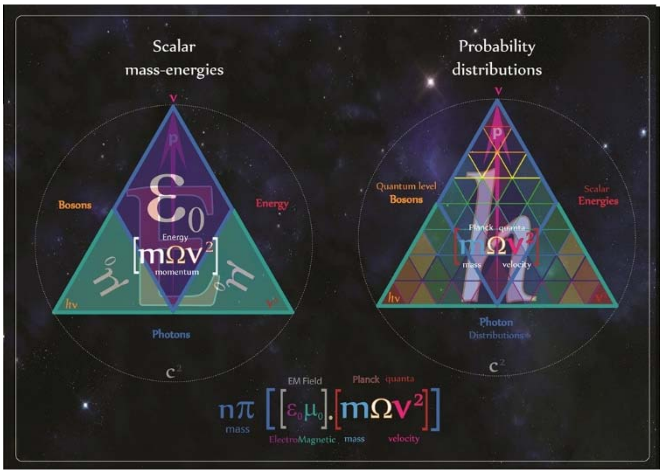
Scalar
mass-energies
Probability
distributions
v
p
Bosons
Energy
ε_0
Energy
$[m\Omega v^2]$
momentum
hv
v^2
Photons
c^2
Quantum level
Bosons
Scalar
Energies
Planck quanta
mass
velocity
Photon
Distributions
EM Field
Planck quanta
$n\pi\,[[\varepsilon_0\mu_0].[m\Omega v^2]]$
mass
ElectroMagnetic
mass
velocity

That it is the transverse bosons Max Planck described using E=n.hv when resolving the ultraviolet catastrophe and spectral line emissions

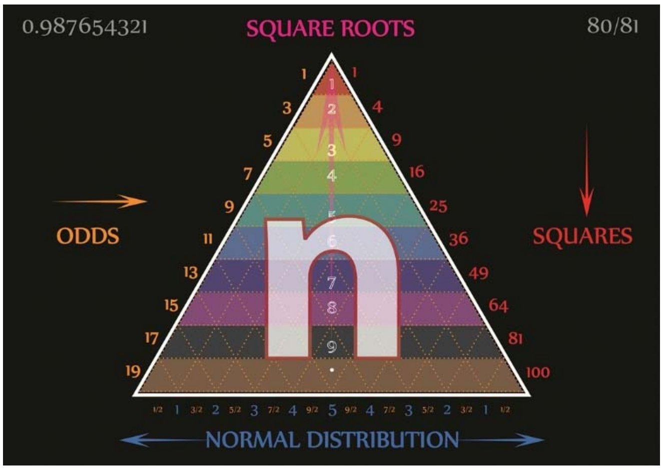
0.987654321
SQUARE ROOTS
80/81
ODDS
SQUARES
1 3 5 7 9 11 13 15 17 19
1 4 9 16 25 36 49 64 81 100
1 2 3 4 5 6 7 8 9
n
1/2 1 3/2 2 5/2 3 7/2 4 9/2 5 9/2 4 7/2 3 5/2 2 3/2 1 1/2
NORMAL DISTRIBUTION

And which subsequent theorists incorrectly applied directly to Einstein's formulation of E= hf to describe neutral PHOTONS of energy momenta [dual charge bosons – quantum transformers]

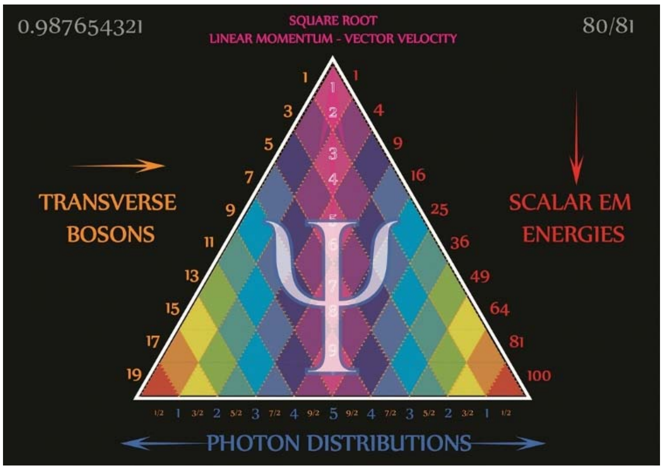
0.987654321
SQUARE ROOT
LINEAR MOMENTUM - VECTOR VELOCITY
80/81
TRANSVERSE
BOSONS
SCALAR EM
ENERGIES
1 3 5 7 9 11 13 15 17 19
1 4 9 16 25 36 49 64 81 100
1 2 3 4
Ψ
1/2 1 3/2 2 5/2 3 7/2 4 9/2 5 9/2 4 7/2 3 5/2 2 3/2 1 1/2
PHOTON DISTRIBUTIONS

And then erroneously attributed to an inherent uncertainly in quantum field dynamics etc. that does NOT and never existed in Nature itself or in Tetryonics….

I do look forward to further elaborating Tetryonic theory in detail with you – but also strongly suggest that you become more familiar with my Tetryonics [1] – Quantum Mechanics and & Tetryonics [2] - Quantum Electrodynamics eBooks beforehand as a lot of your suspicions of, and reaction to Tetryonic theory seem to stem from a lack of understanding of the basics of the theory….

And as I mentioned in previous communications, I remain open to an online discussion so we may discuss these points in far more detail than possible herein.

There is also lots more additional information and explanation of Tetryonic theory to be found on YouTube and Otto's Science of Life web- blog & the detailed 3D CAD models developed by Rene Cormier in the Google sketchup warehouse.

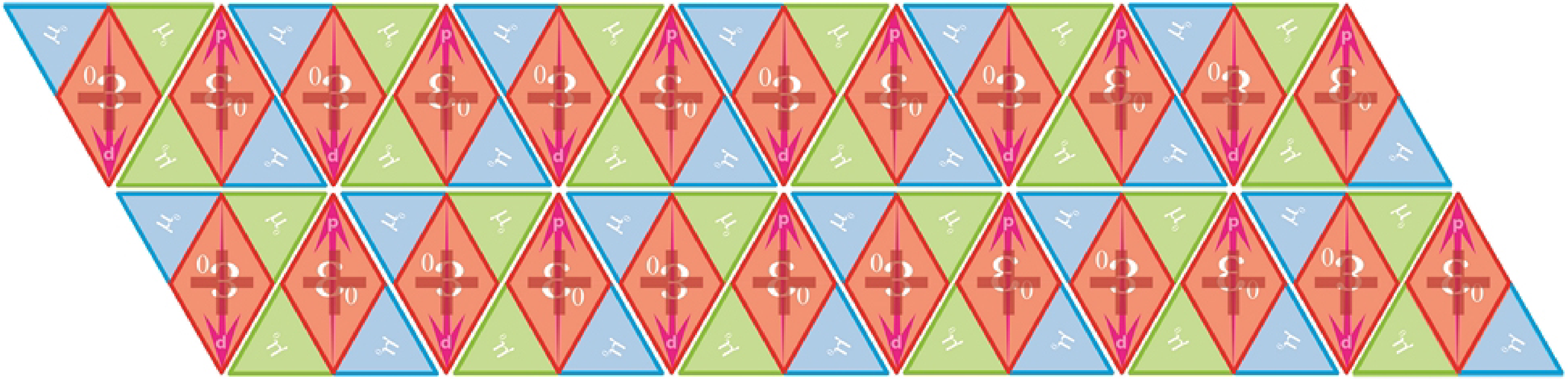

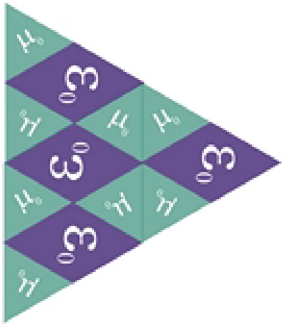

2D radiant EM mass-Energies

n1 - Charged Tetryon Templates

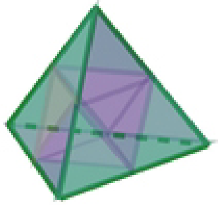

3D standing-wave Matter

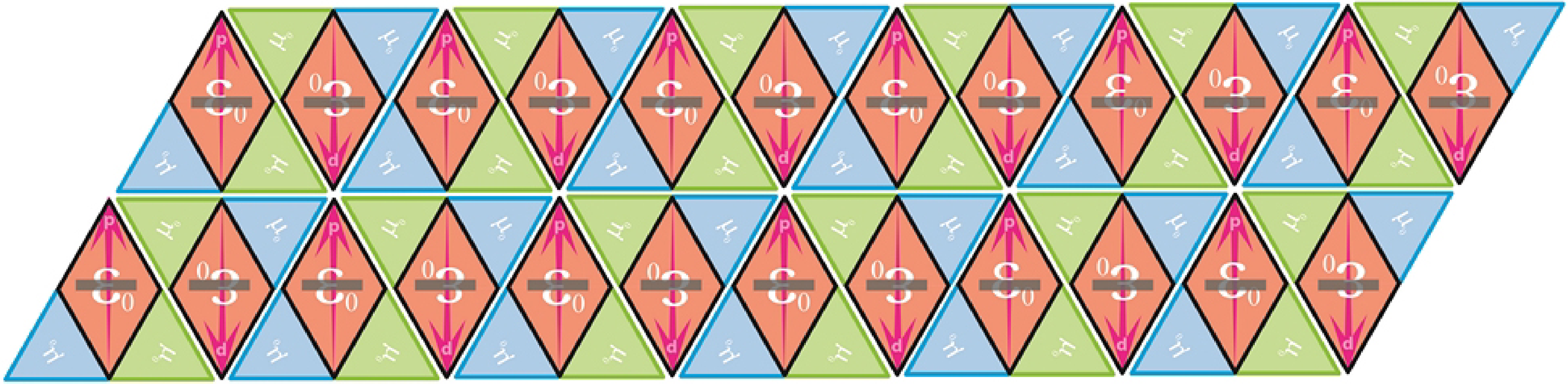

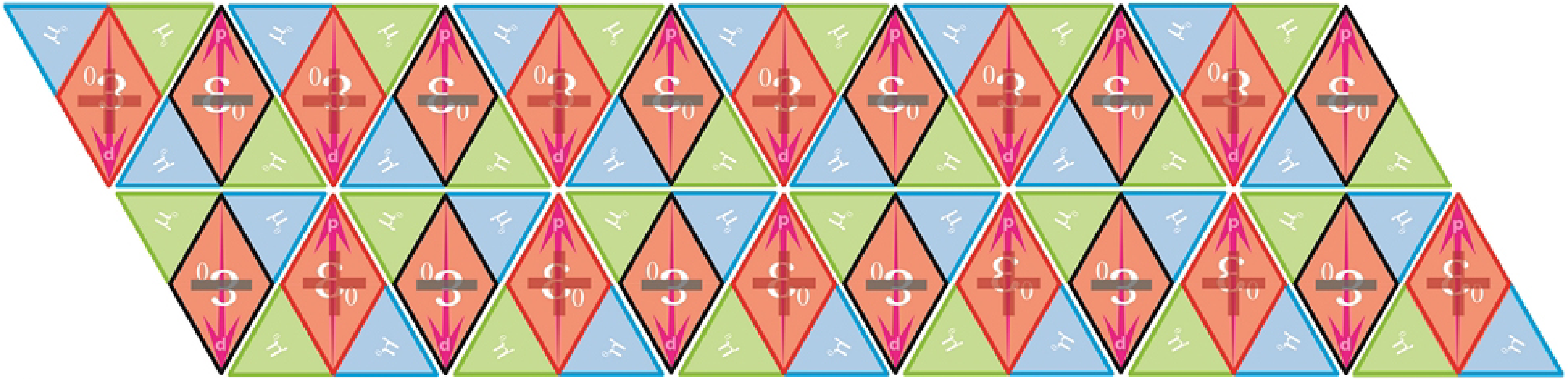

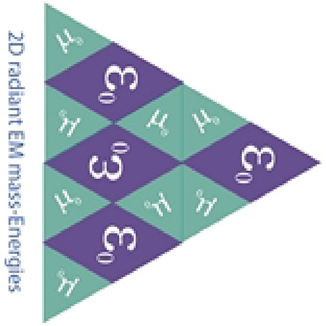
2D radiant EM mass-Energies
μ₀
ε₀

n1 - Neutral Tetryon Templates

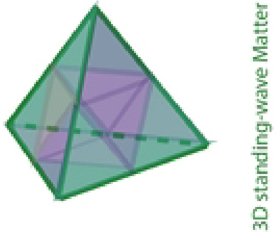
3D standing-wave Matter

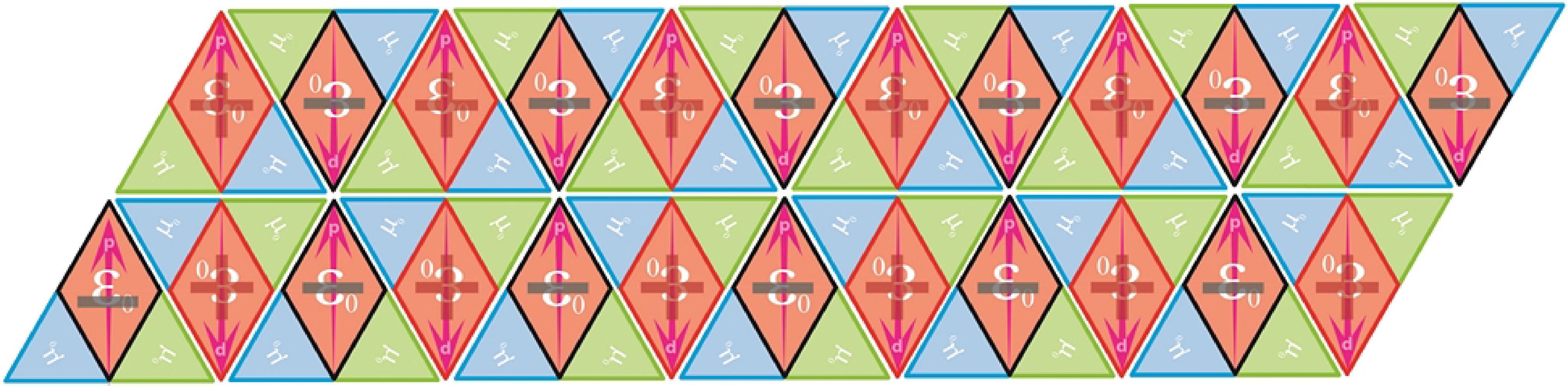

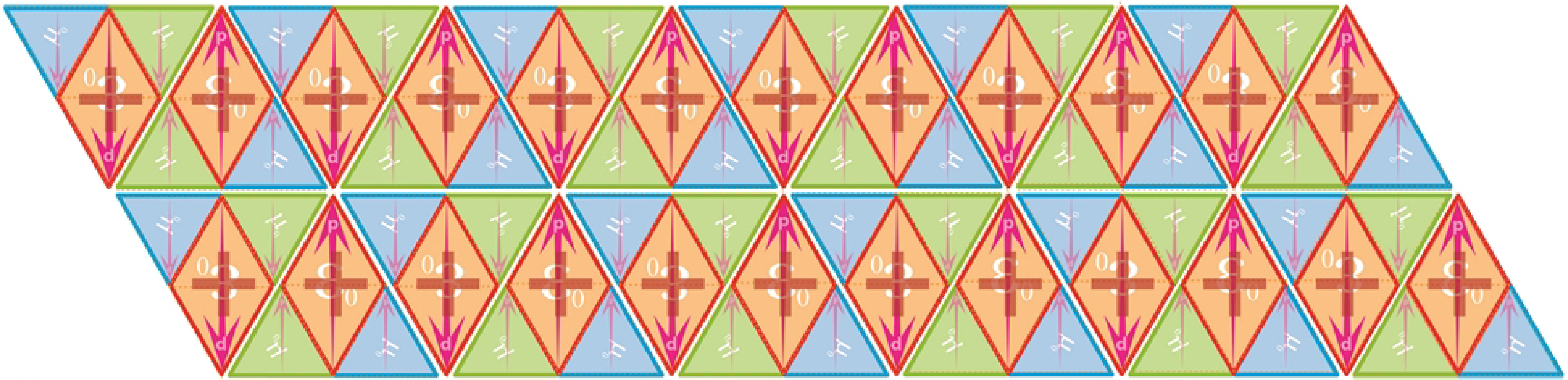

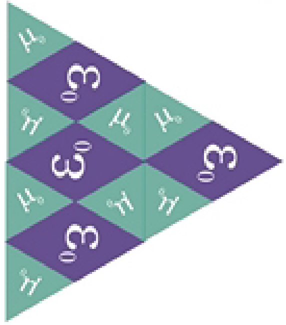
2D radiant EM mass-Energies
μ0
ε0

n2 - Charged Tetryon Templates

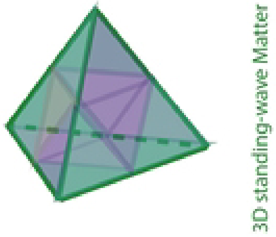
3D standing-wave Matter

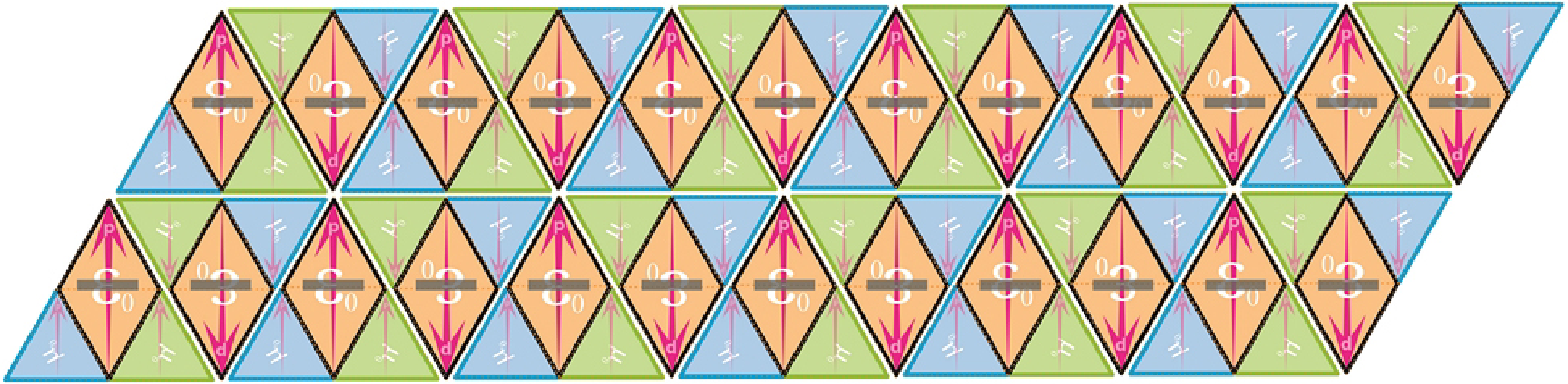

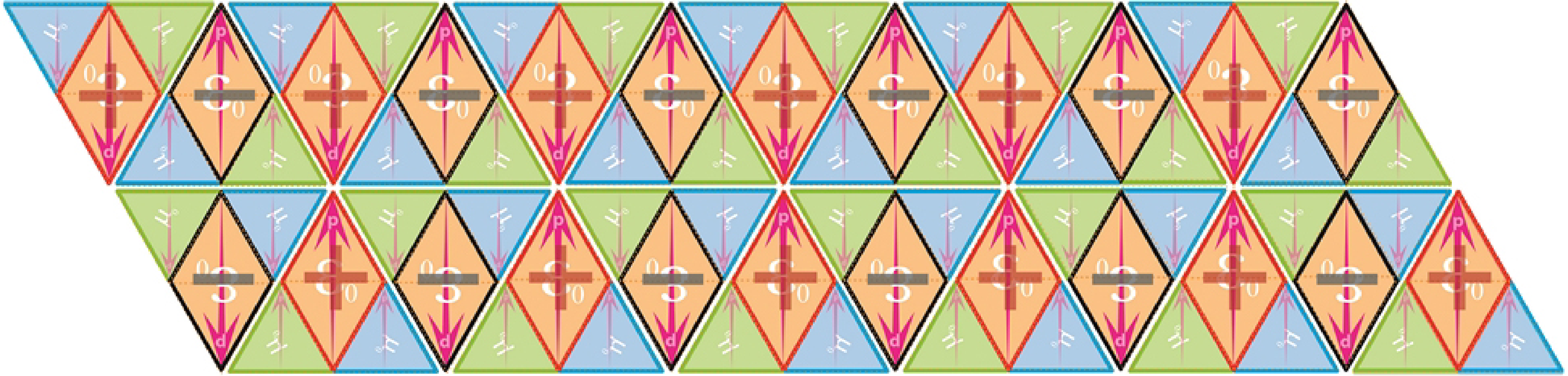

μ_0
ε_0
p
d

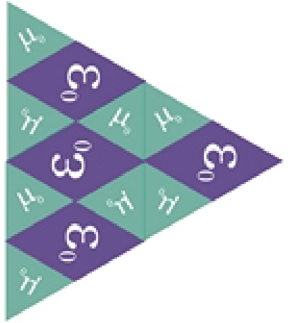

μ_0
ε_0

2D radiant EM mass-Energies

n2 - Neutral Tetryon Templates

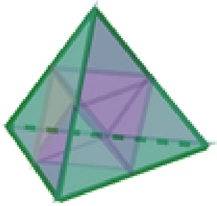

3D standing-wave Matter

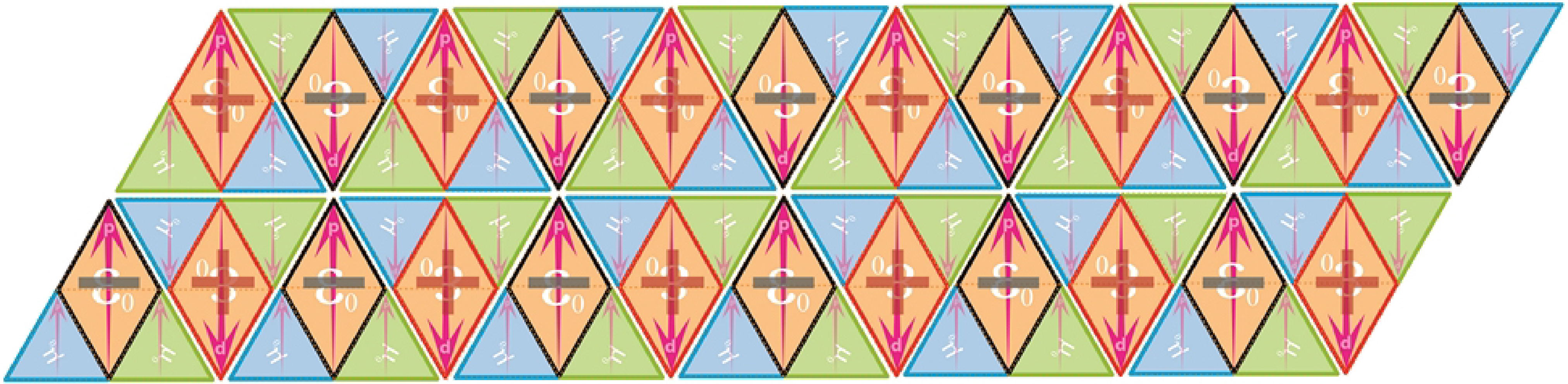

μ_0
ε_0
p
d

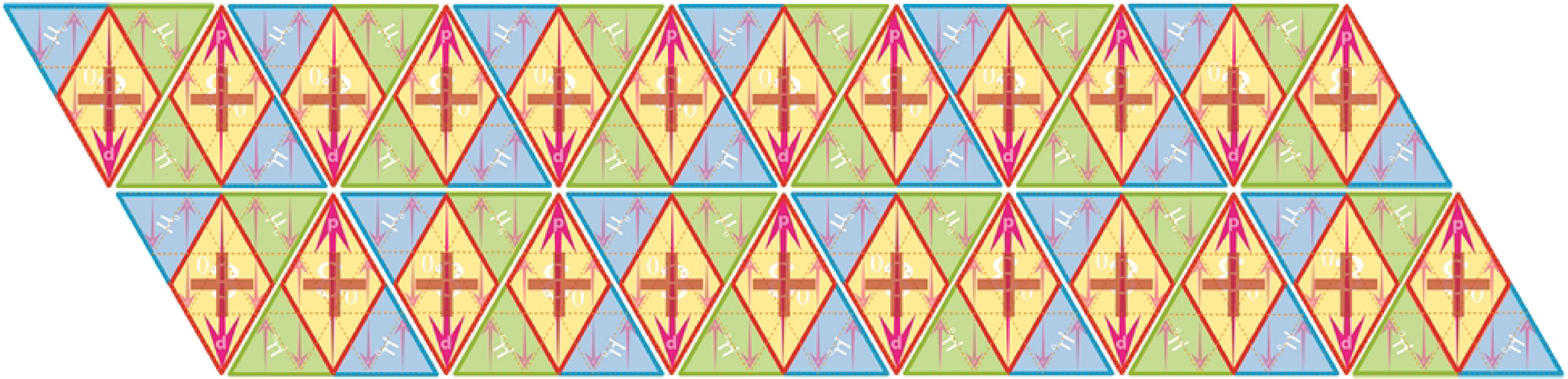

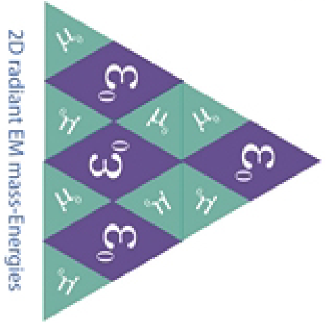
2D radiant EM mass-Energies
μ0
ε0

n3 - Charged Tetryon Templates

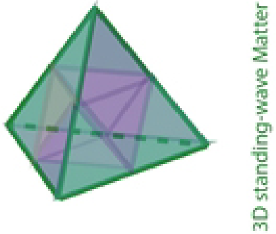
3D standing-wave Matter

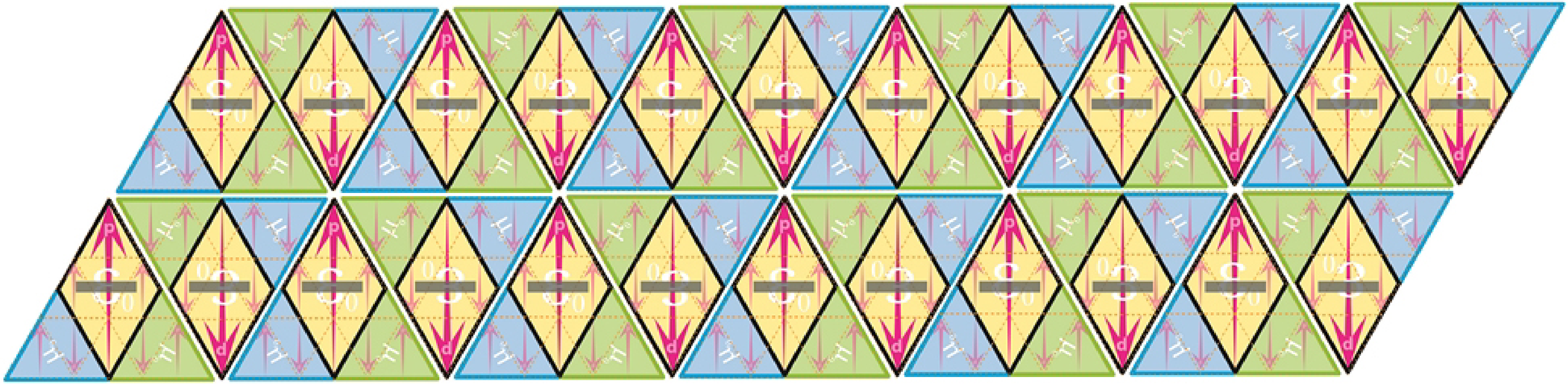

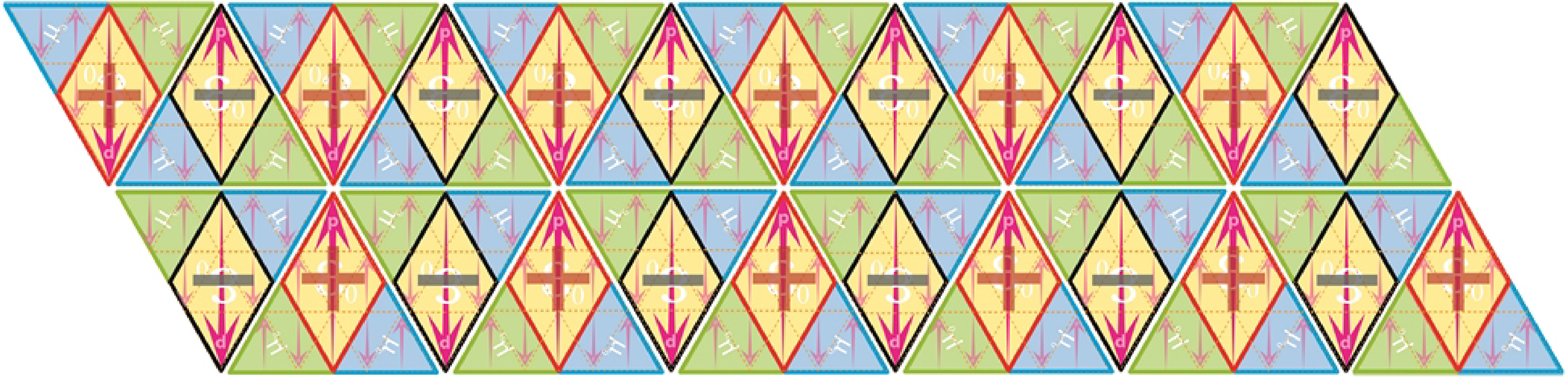

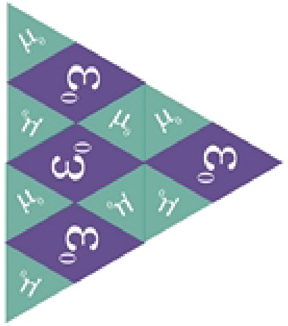

2D radiant EM mass-Energies

n3 - Neutral Tetryon Templates

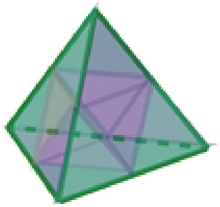

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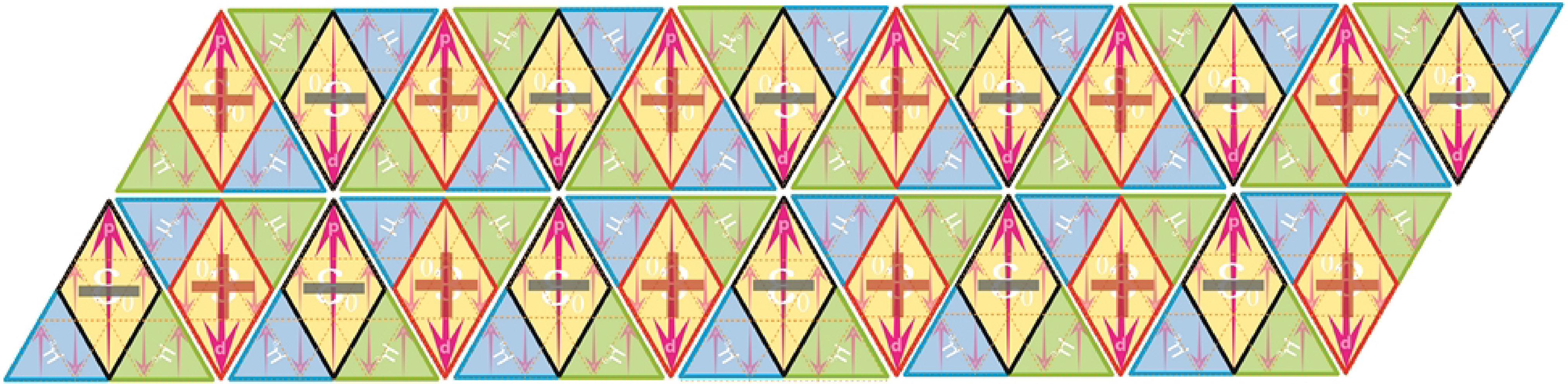

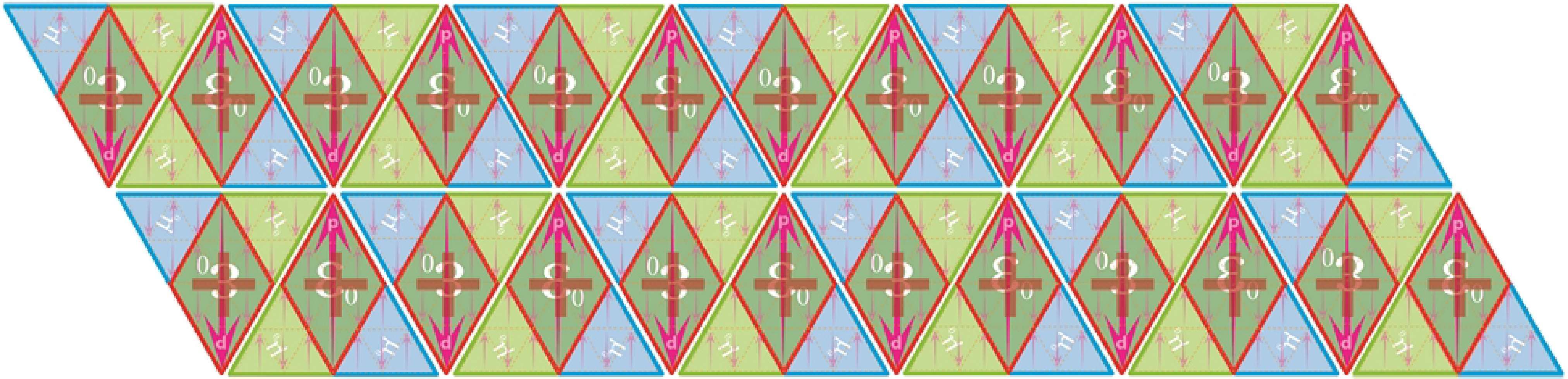

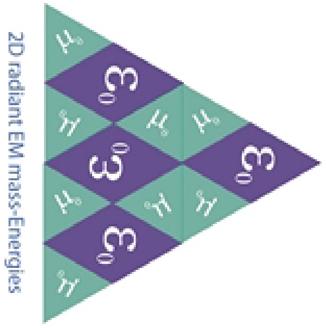
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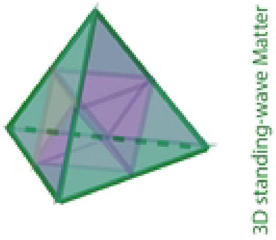
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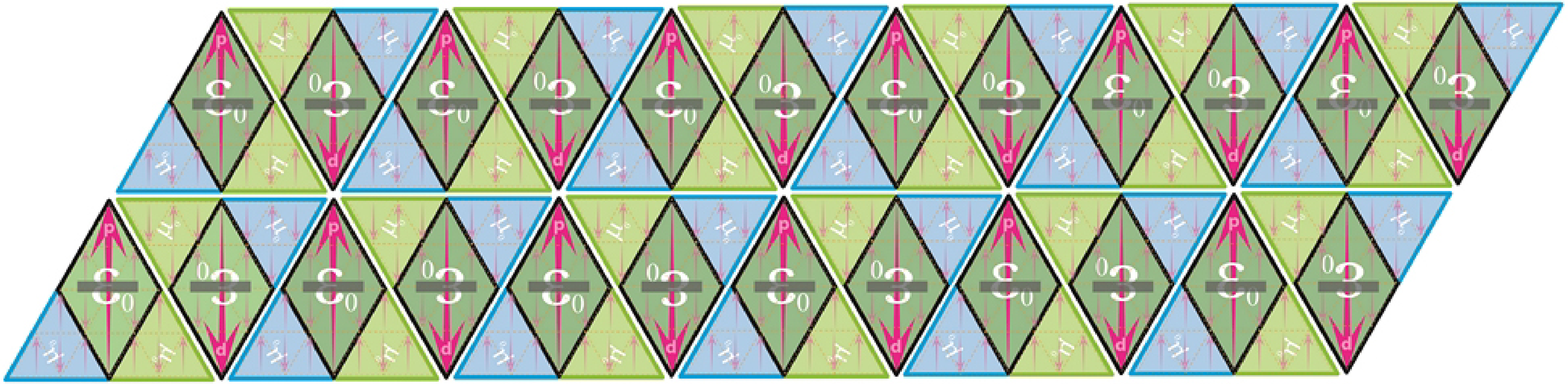

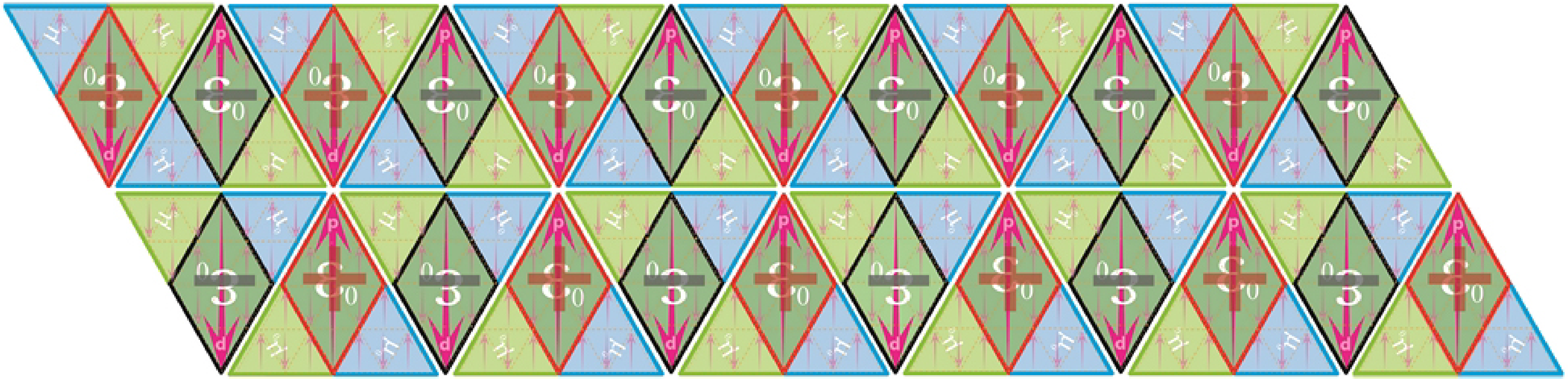

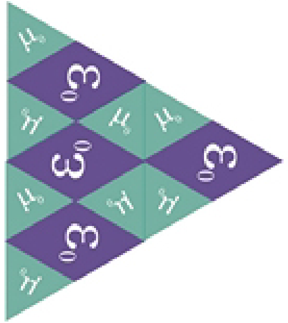

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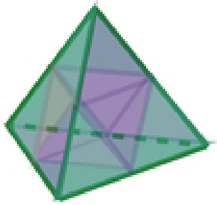

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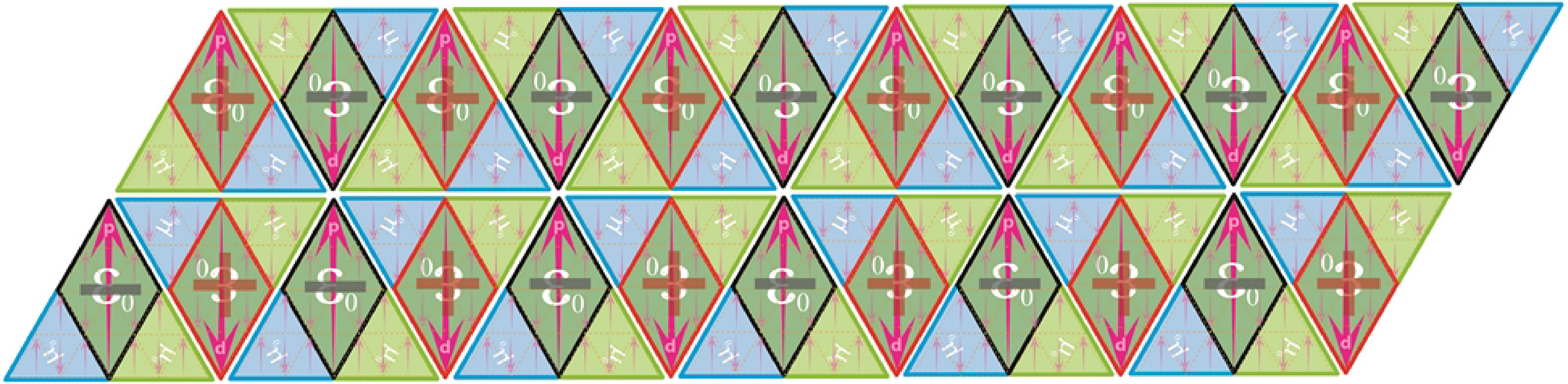

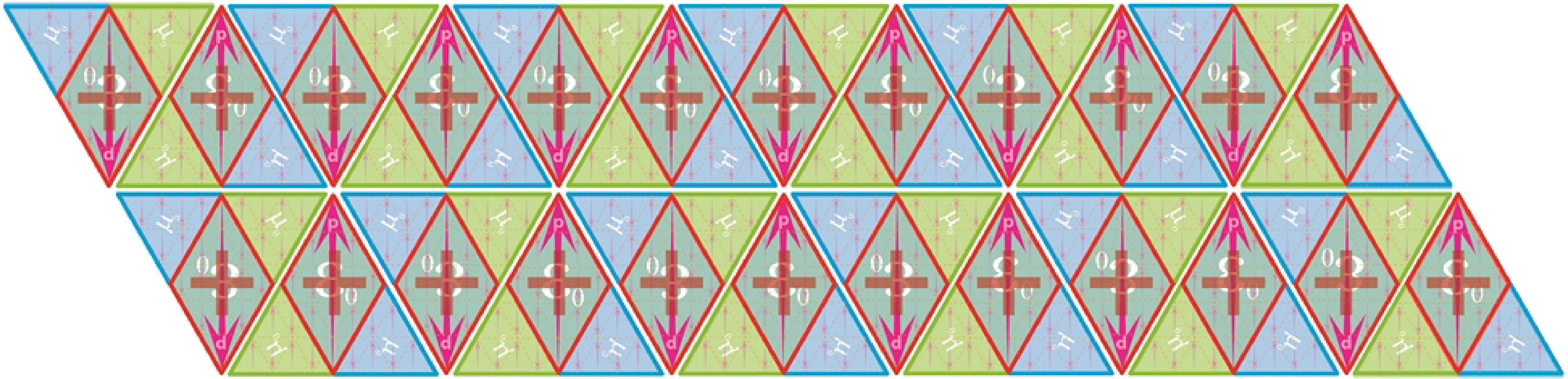

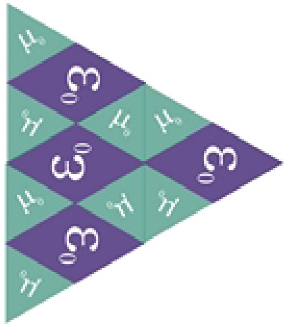

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n5 - Charged Tetryon Templates

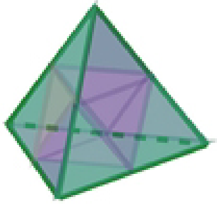

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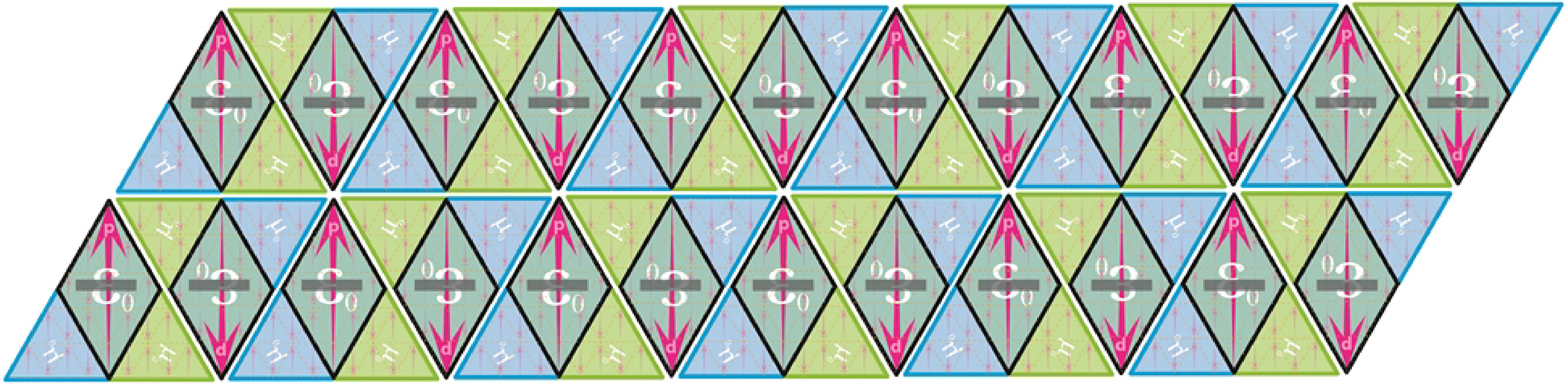

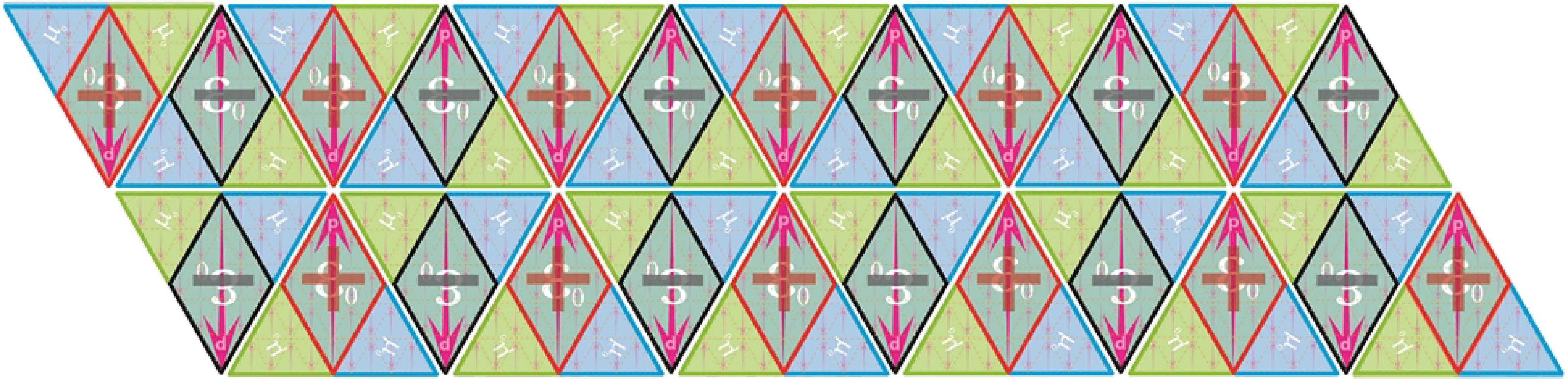

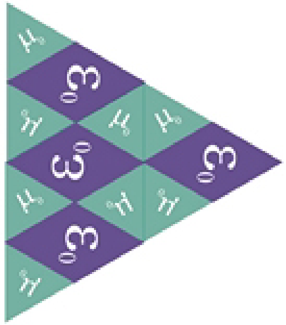

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n5 - Neutral Tetryon Templates

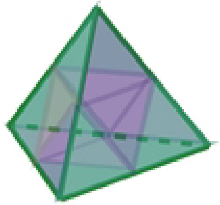

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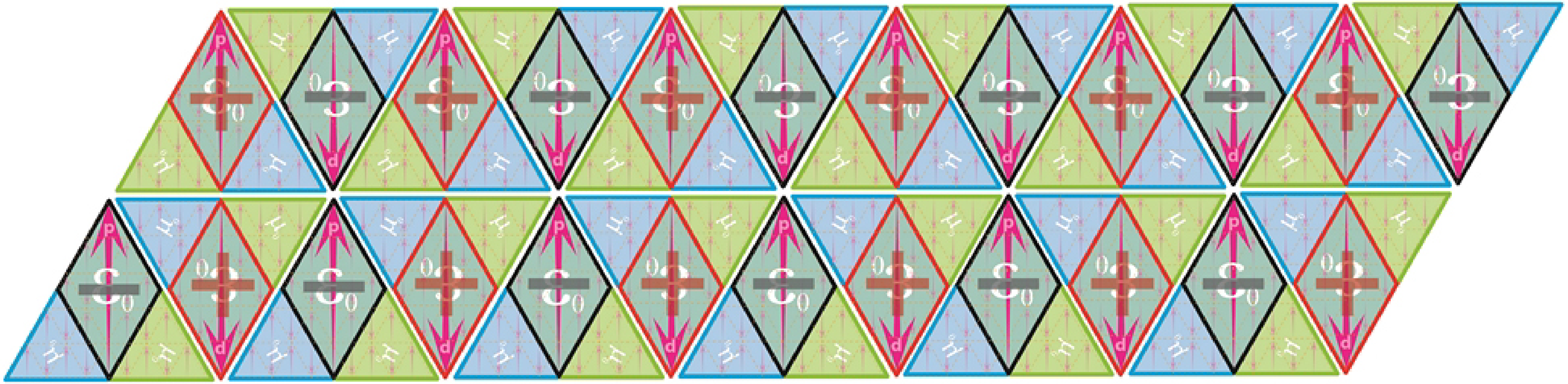

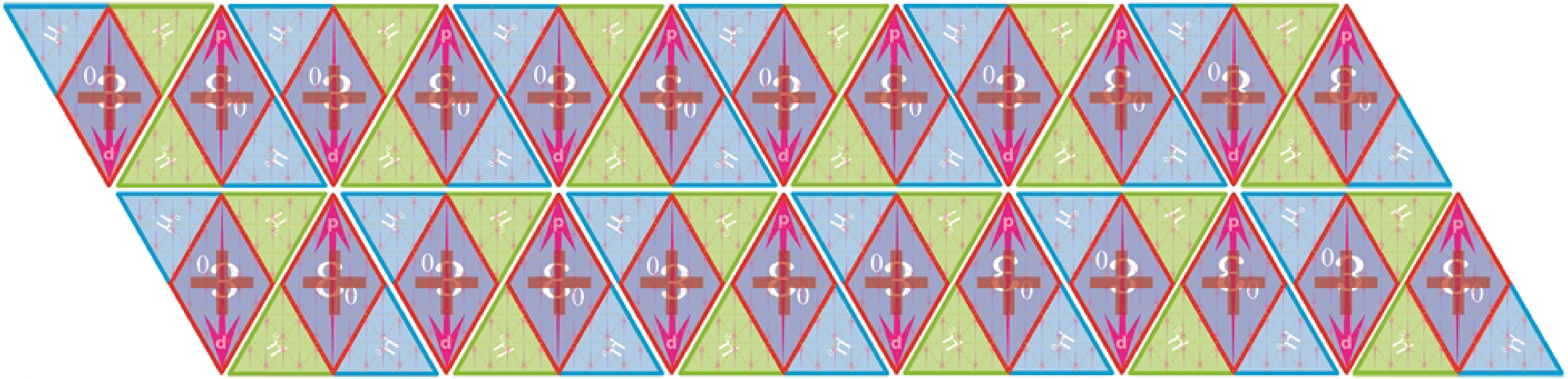

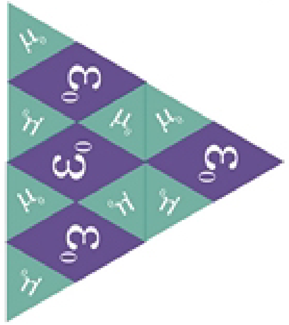

2D radiant EM mass-Energies

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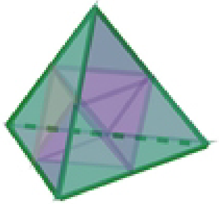

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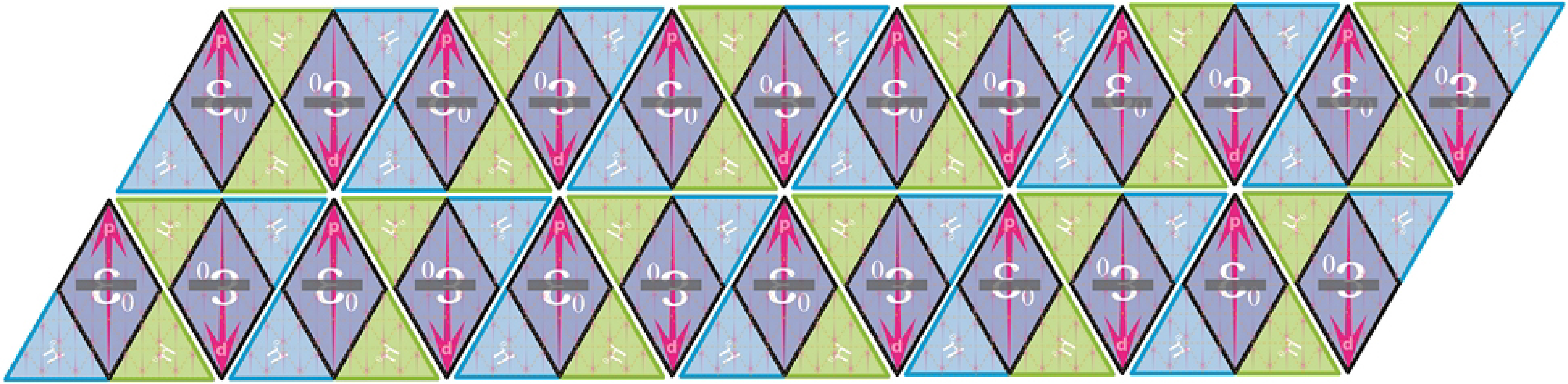

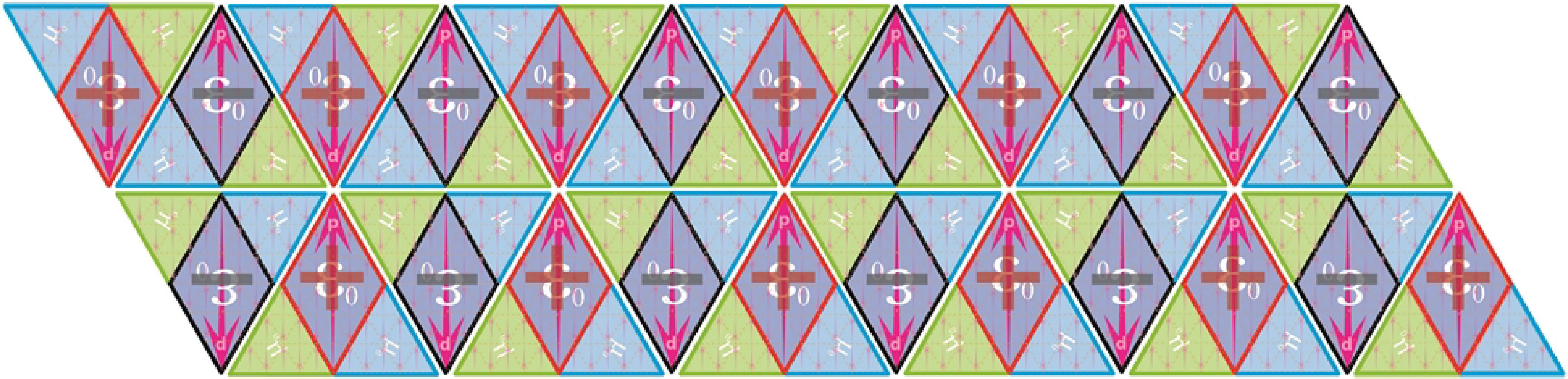

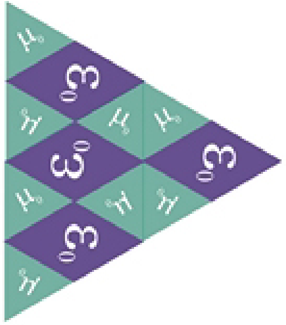

2D radiant EM mass-Energies

n6 - Neutral Tetryon Templates

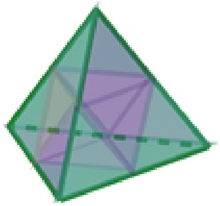

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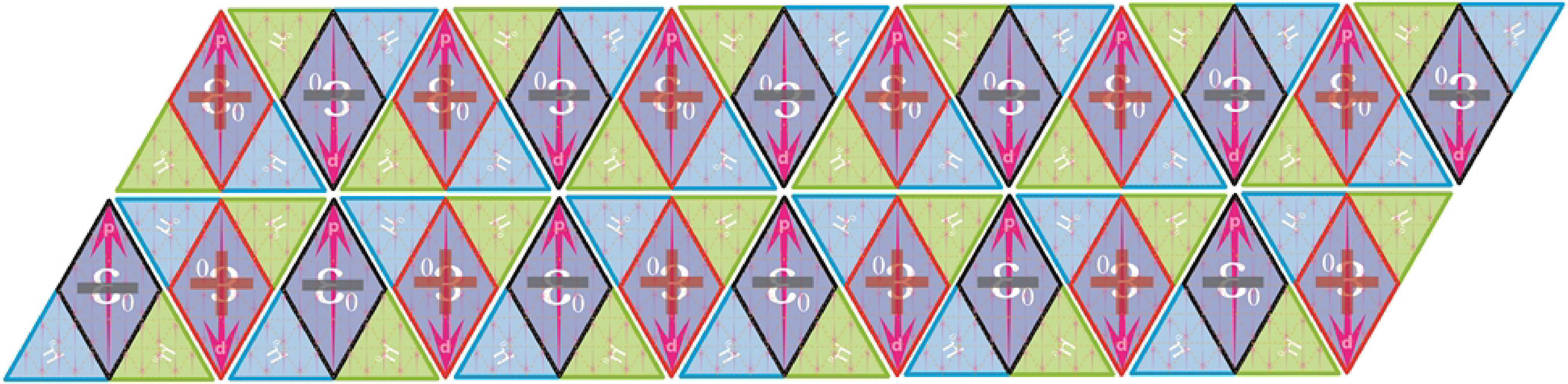

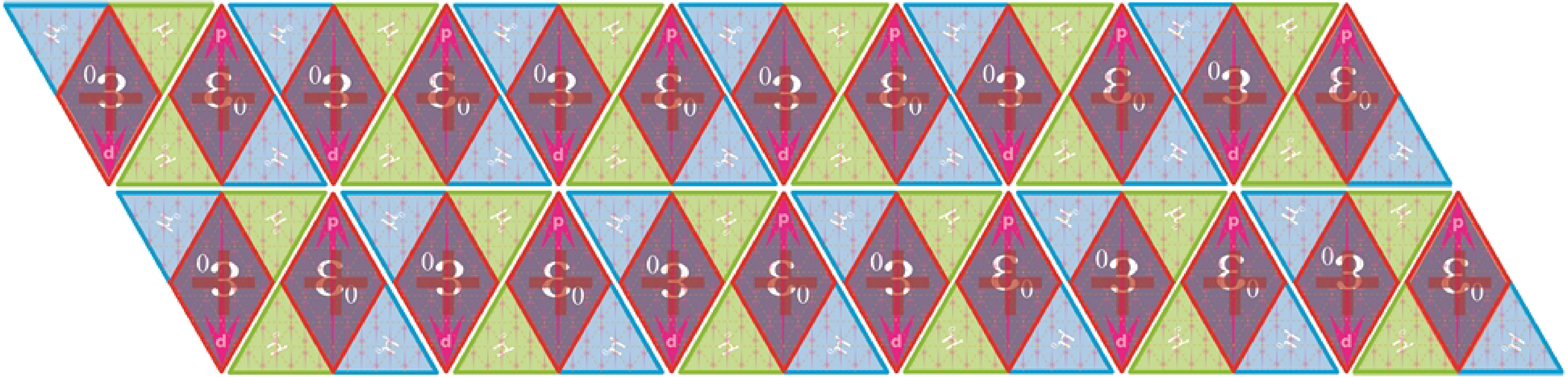

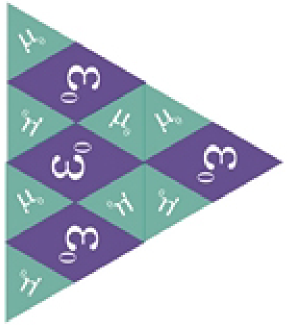

2D radiant EM mass-Energies

n7 - Charged Tetryon Templates

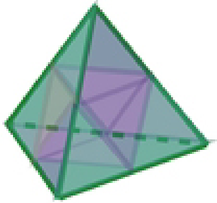
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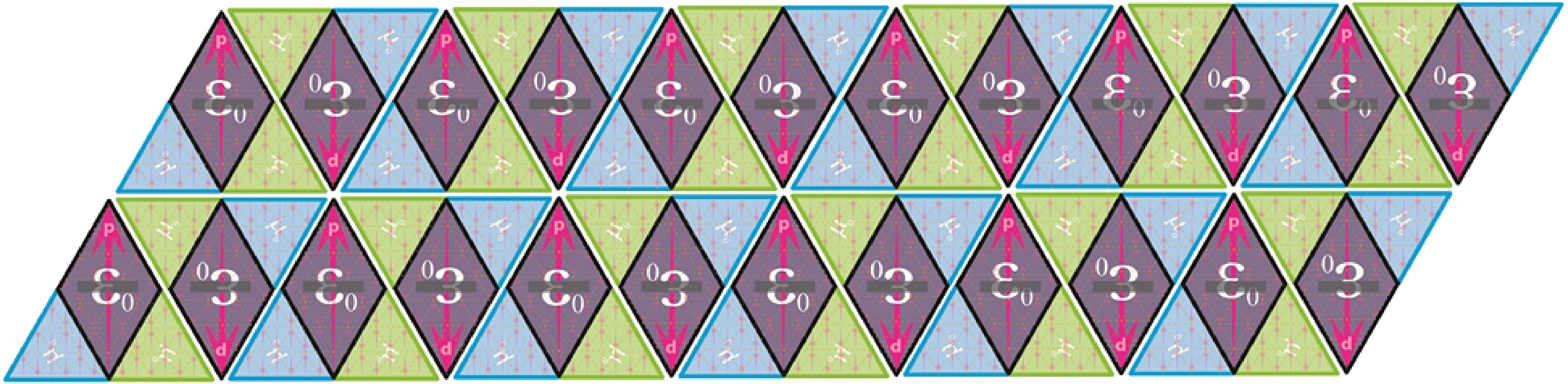

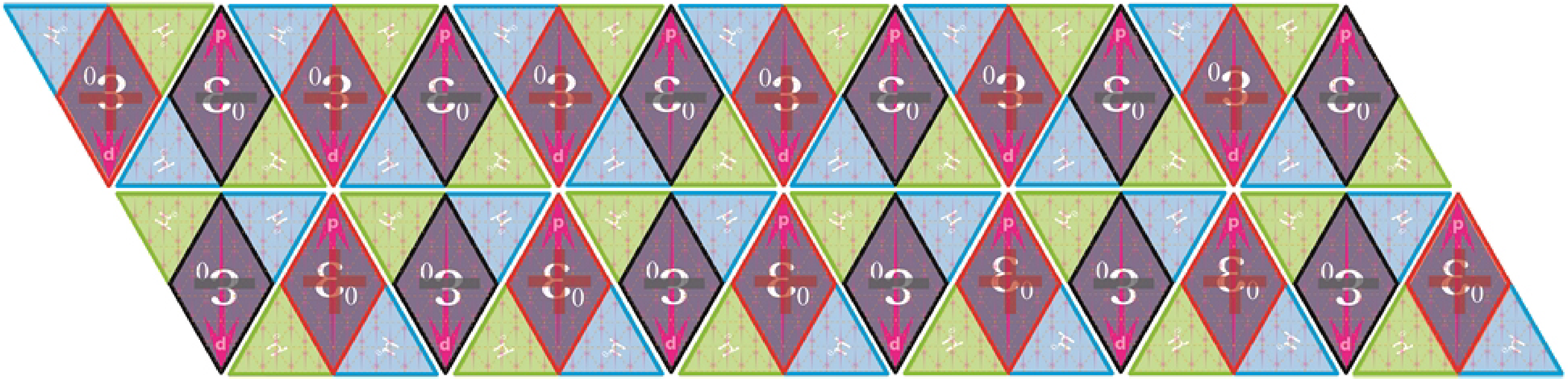

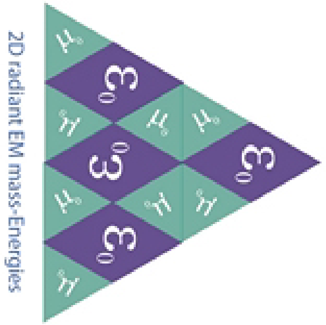
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n7 - Neutral Tetryon Templates

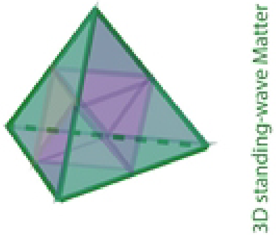
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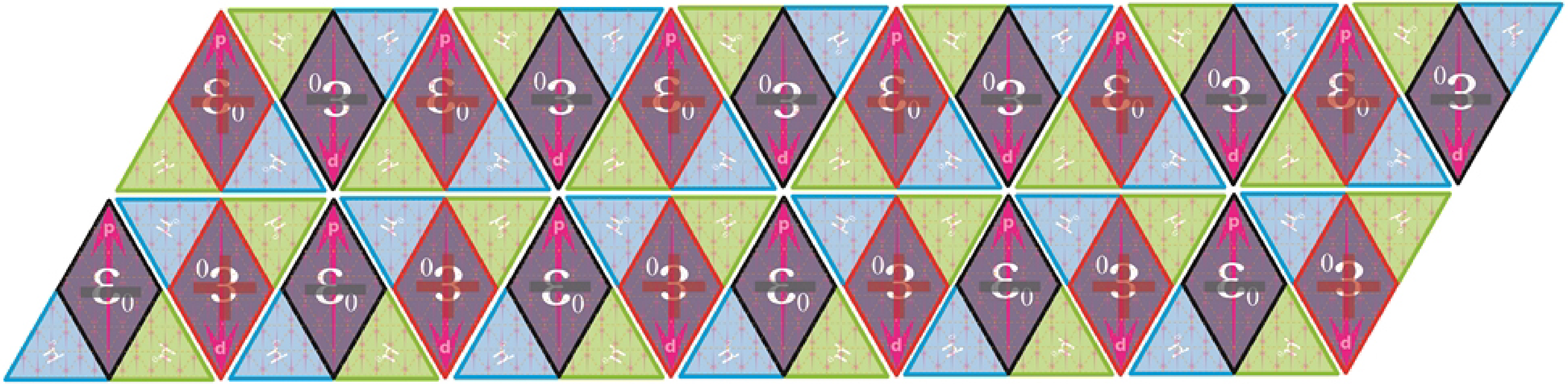

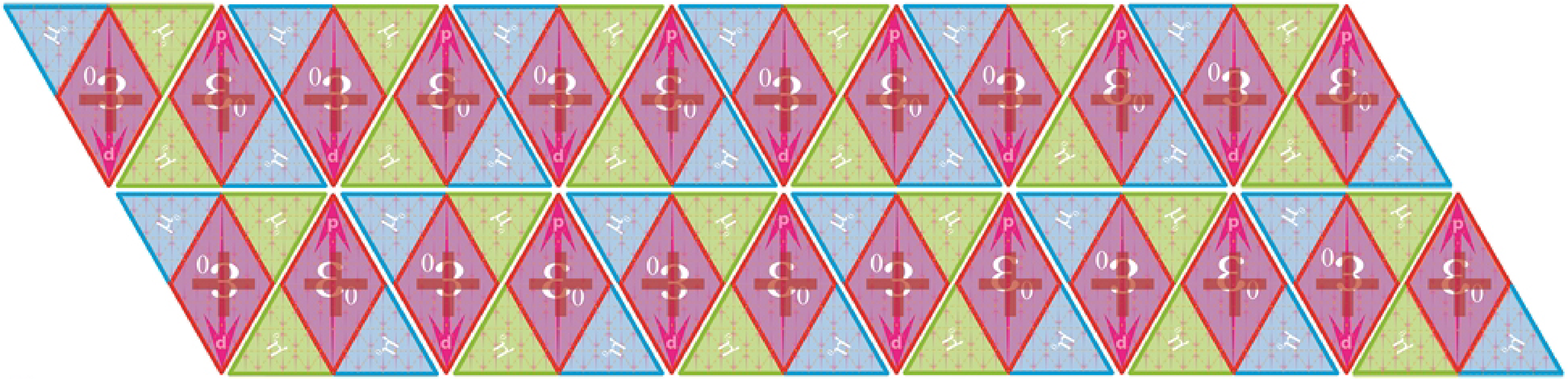

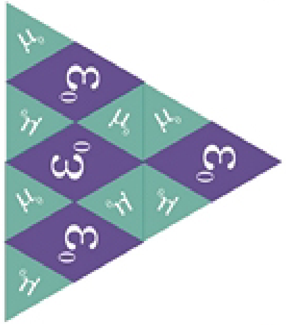

2D radiant EM mass-Energies

n8 - Charged Tetryon Templates

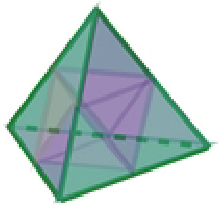

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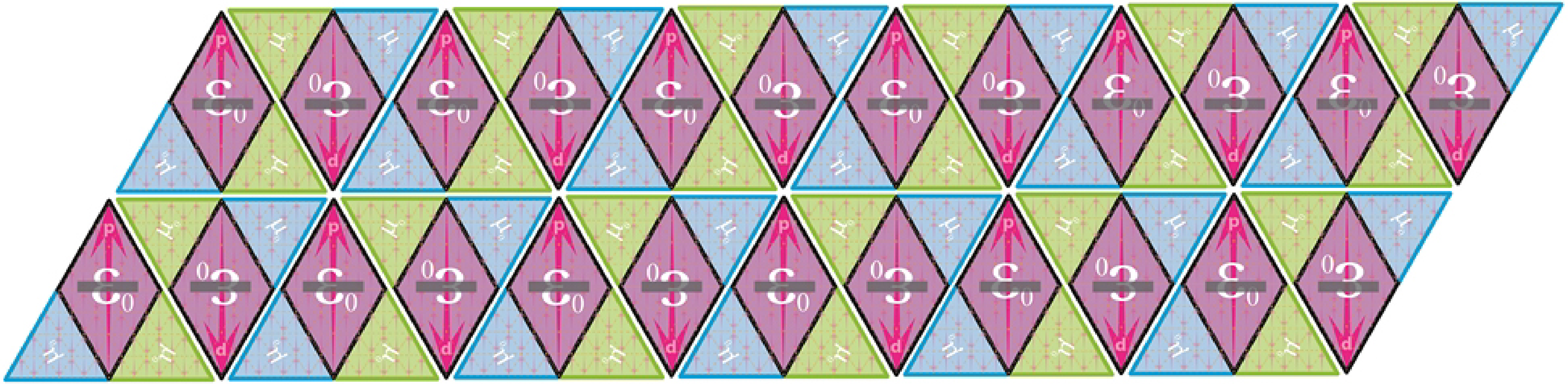

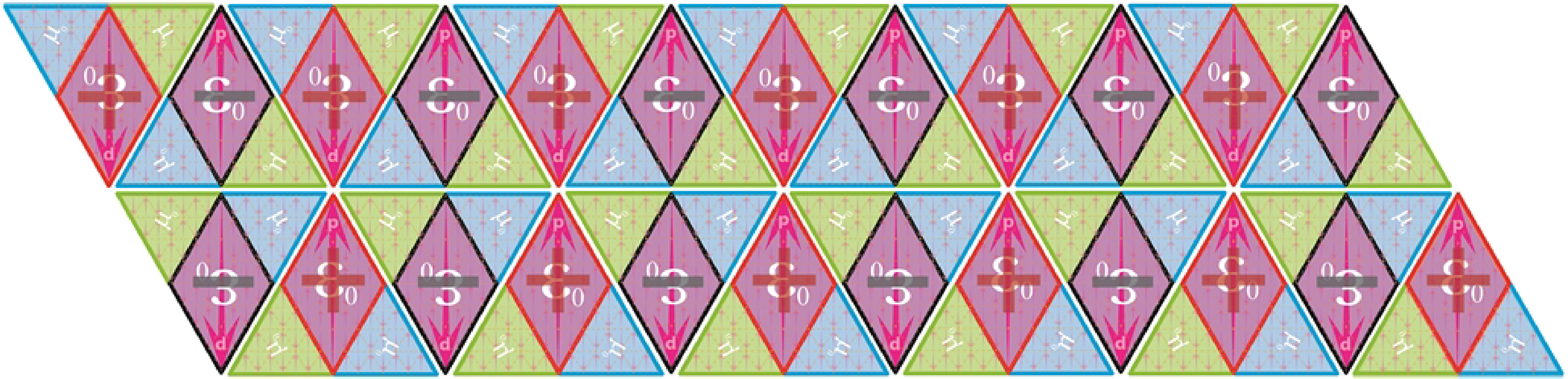

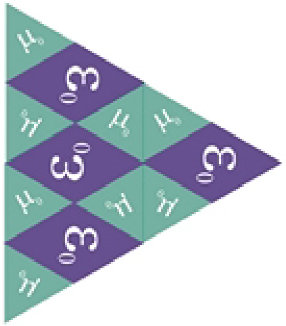

2D radiant EM mass-Energies

n8 - Neutral Tetryon Templates

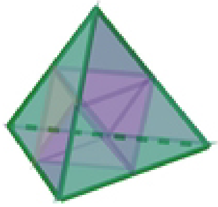

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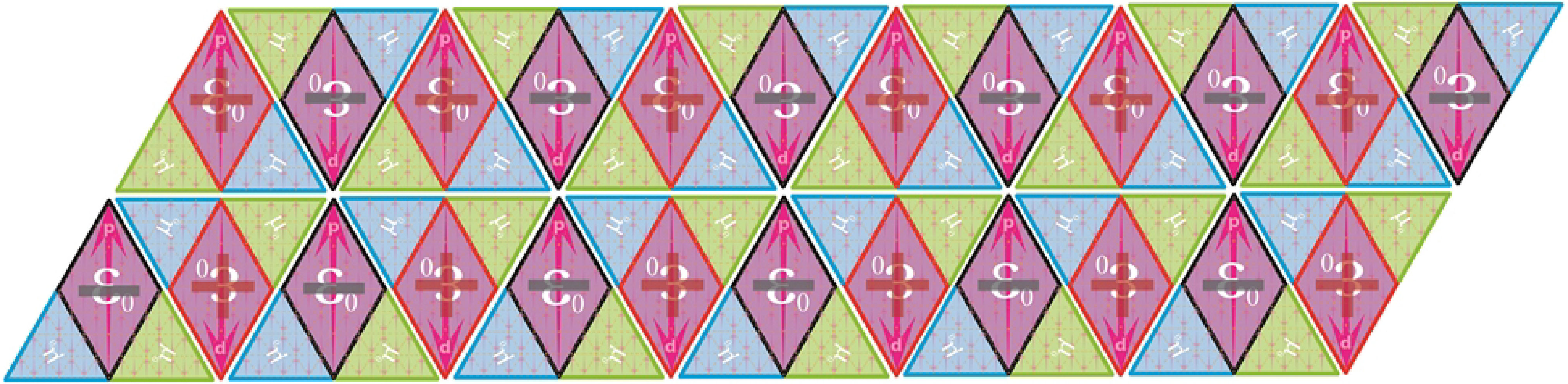

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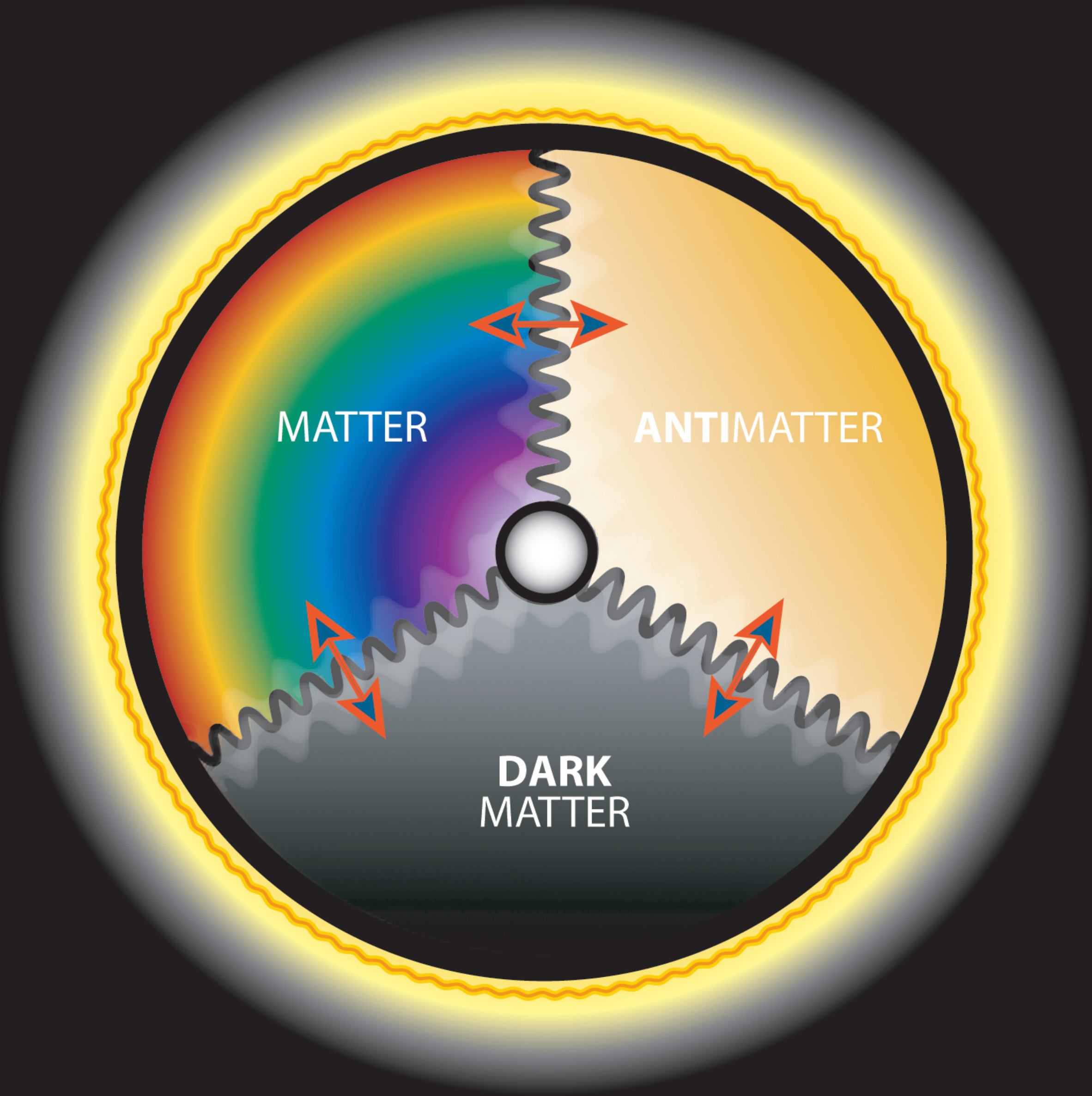
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ANTIMATTER
DARK
MATTER

by Nuclear Engineer M.T. KESHE

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The Universal Order Of Creation Of Matters

ITNOTGOG

… a Reflection

Mans intelligence has reached levels that through the use of modern technologies that anyone can peer the knowledge he reads to verify its logic and validity.

I firmly believe that this work has to be understood by all Men and not judged by a few whose self-interest might, and has been, obstructing the release of such a knowledge as disclosed in this book.

This book is written in such a way that anyone from any background field of science, and interest in the workings of all Matters of the universe, can understand the full new knowledge and be their own peers in receiving such a disclosure, which is at the edge of science and technology.

In this book a synthesis is given of the *understanding of new first principles in physics* that are gathered for over more than thirty years of independent research and development, where several working prototypes and numerous tests with different loadings have confirmed their correctness and operativeness.

Mehran Tavakoli Keshe
2009

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Forewords

In Mans technological and scientific evolution over thousands of years, conversion of the Earthly state of matters and energies from one state to another has been the key to his progressive success.

For man to progress further in the path of this evolution, man has to learn, understand, and unravel the powers of the initial fundamental particles of the Matters.

In the following pages, simple new theoretical principles and results of tests done to unleash the powers of the initial fundamental particles forces will be released and discussed.

In my writings, the simplest form of language is used so that every man, from all corners of the world, can read and will be able to comprehend the fundamental orders of their physical creation.

Therefore, every man on Earth will have the same groundwork knowledge and opportunity to build his own environment and so be in control of his future and destiny.

This simple transfer of knowledge gives every man, by understanding the principles of his world of creation, the possibility to utilise and enhance the fundamental powers of creation for his advancement in his path of evolution.

Through appropriate use of this new knowledge, one can generate as much clean power as one needs for survival at any location in the universe.

This is energy production capability, without the production of any further new wastes to damage the environment and to endanger the future generations' chances' of survival.

This new knowledge allows man to produce food and medicine through the natural process of the construction of his cells' initial fundamental plasmas.

Therefore, no child, woman or man should go hungry and rely-upon others for his survival.

This new knowledge gives man the opportunity to produce all his materials' needs, without him being tied-up to the Earthly resources, or environmental conditions, or the place or a position in the universe, wherever that might be.

This new knowledge brings about the capability for man to be able to move and travel in his environment and in the universe with universal magnetic fields protection, in any atmospheric or space conditions.

This new knowledge, gives man the freedom of motion irrespective of the medium whatever his medium, and wherever he might be in the universe. For man to be able to use systems for travel that is at all time in protected magnetic fields levels and gravitational field levels as on the Earth. As his physical body has become accustom to the atmospheric condition around his home planet.

Which up to now, this has been a dream and unattainable in all dimensions, with his present level of scientific development and knowledge.

Men will build on this new knowledge, and they will add their own scientific and technological flavours and unique additions and discoveries to overcome their present natural problems and limitations.

Our hope is that, Men, irrespective of their race, colour of skin, creed or religion, will use this new knowledge collectively and in unity, for advancement of the human race. We pray that, Man uses' these new knowledge and information's for creation of peace and justice among their fellow men and other of Gods' creations and creatures, whom they will come to be in touch with, irrespective of their appearance, technological progress and intelligence.

Mehran Tavakoli Keshe

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Introduction

In the progressive path of mans' technological achievement, it has been proven that the human race has not been able to create and produce fundamental energy systems similar to the ones which are operating in the spans' of the universe.

Nevertheless, he has managed simply to convert one form of energy to another and he has made use of the small surplus energies released by these methods to his advantage.

In the universe, the structure, operation, appearance and existence of the plasma and an atom, does not so much differ from the relationships and interactions of their larger counter parts as the molecules, solar systems and galaxies.

Where, as in the ***present*** science and state-of-the-art technology, the lower orders of particles of construction of an atom in its nucleus are considered to be made of quarks and gluons.

The world of science has never looked at and into the ***progressive construction of a plasma*** (Chapter 3) on the same basis and principles' as other larger matters and fields in universal orders of creation and motion.

What this simply means, is that scientists over centuries have made some limited and un-necessary self-imposed conditions in looking at the physical realities of Matters and matters in their surrounding environment, for them to be able to compare and draw parallels from these phenomena and principles to understand the criterions by which the initial seeds of plasmas are set in the universe and to understand the methods by which different forces operate within them.

From the basic knowledge of what is in hand in the world of science at the present, it is not too hard to discover what are the real elementary particles in the universe, and find an *alternative and realistic way* of how these fundamental particles of plasma come together to create ***the initial seed of plasma***.

It is important to note that the existence of dynamic and different strengths, speed, velocity and densities of ***magnetic fields***, and their interactions, are the **cause** and the **foundation** of the existence of different **Matters** within the universe. In the universe, *collections* of *loose and weak magnetic fields* have initiated the creation of, and finally become the initial components of the Matters of plasma.

Rays and plasmatic magnetic fields

At the same time, we consider "rays" as individual and directional magnetic forces. We consider "fields" as the same ray's magnetic force as it is influenced by other rays and magnetic field forces, which the ray makes a dynamic zone of influence in its path.

We consider the same phenomena in principle with respect to plasma and ***plasmatic***

magnetic fields, where, a plasma of magnetic fields is considered to be a collection of such rays and fields of rays.

The collective interactions of weak plasmatic magnetic fields in the universe are considered to become the foundation and the cornerstone of the creation of initial fundamental particles.

In the universe, the same and regular specific sequential and consequential interactions of lower orders of magnitude plasmatic magnetic fields strength are always considered to lead to the formation of the plasma and its sub-Matters' components.

Throughout this book a clear distinction has been tried and been made between the magnetic field and plasmatic magnetic fields.

The **Plasmatic magnetic fields** are considered to be of *collection* of near *similar dynamic rays of* magnetic fields *strength*. We refer to the Plasmatic Magnetic Fields as "***pmtics***", *as Magnetic fields, which were detached from their source of creation*, hence, the use of the term "plasmatic" for these magnetic fields. For clarity: In this book the term "**plasmatic**" refers to a "collection" of dynamic magnetic fields, and **NOT** to the ***state of a plasma*** in its common term use that refers to a *state of dynamic protons*.

At the same time, pmtics interactions with other pmtics are considered to create effects the likes of gravitational fields and Magnetic fields of Matters, plasmas, planets and so on.

These magnetic rays or fields and their collection as plasmatic magnetic fields, become known as the **Initial Fundamental Particles.** Therefore we consider that magnetic fields to be the **"real" fundamental particles**.

The present science considers that the 'elementary particles' to be of 'quarks' and others. With the new understanding of creation of Matters and forces within the universal order of creation, in this book when the term **'elementary particles'** is used, this means that the **'magnetic fields'** are considered to be the **new** *'elementary particles'* and their forces. The existence and interaction of these magnetic fields leads to and creates all other effects that one sees and observes in the universe, like creation of Magnetic and gravitational fields which leads to creation of what I call different ***Matters*** *(Matter, Antimatter and Dark Matter)* of the plasma, or what presently is known as quarks and so on of the plasma. Where, we consider the Dark Matter as an integral and part of the same normal Matters of existence and as an important part of the construction of the initial fundamental plasma in the universe, and we do not consider the Dark Matter as an exotic and distant hidden Matter.

From this point on in this book, we refer to 'magnetic fields' as the ***'elementary particles'*** and *not consider quarks and others as elementary particles any further*, I consider that these quarks of different colour, with up and down notation and spin are all created as the outcome and consequences of different interactions and attraction of these 'magnetic fields' or 'plasmatic magnetic fields'. As quarks themselves are now known to be made of simpler particles of 'magnetic fields', then quarks cannot be considered to be the elementary particles.

In this book will be explained how 'magnetic fields' become to be the creators of quarks and other effects and forces within the plasma of proton, then the **'magnetic fields'** become the '**new elementary particles'** in the science of physics.

Further in this book it is explained how *different strength of these fields* leads to the creation of different **Matters and their forces** as has been observed by world of science.

Furthermore, these weak collections of pmtics and their interactions with magnetic fields and turbulent magnetic fields forces in different parts of galaxies manifest themselves as the seeds of atoms, stars, galaxies and so on.

Magnetic and gravitational fields (Magravs)

When we write **M**agnetic field (with capital M), we considered that these fields refer to the Magnetic field of celestial objects, like a Star, planet, etc. Where this Magnetic field is always accompanied with gravitational fields of the object.

Where we consider that ***gravitational fields and Magnetic fields*** cannot exist in the universe without each other, and that they are produced simultaneously. Through the same dynamic materials and Matters in the same region. Due to the construction of other Matters in their catchments area, these entities could have a different value than the other. As the Matter/matter content of the object dictates which will be stronger in strength and value than the other in that given position. The only known and possible objects that its gravitational and Magnetic fields could be equal in value strength, in majority of the cases in the universe, are objects of mono-material (like some stars), with pure hydrogen content. There are cases in the universe(s) that mono-matter of objects can be like uranium or heavier elements. These objects of heavier mono-matters are usually the producers of stronger gravitational fields and Magnetic fields, by several orders of magnitudes than the hydrogen mono-matter objects. It is assumed that each universe cannot possess more than one heavy material mono-magnetic star.

It has to be noted that the co-existence of these two fields always in interaction with any other magnetic fields or plasma of fields always lead to the creation of a ***magnetosphere***, which the boundary of the magnetosphere is the maximum point of balance or equality between the two field forces. Any variation in strength of one of the two fields in respect to the other will create different effects, for example such unbalance field between the two fields can be seen in Mercury, which has no atmosphere, and such a misbalance can also be observed in most moons of planetary systems.

In this book, as one field cannot exist without the other, for representation of the **MA***gneti*c and **GRAV***itational field***S** we use the term: "**MAGRAVS"**.

Plasmas

We consider that " The **Plasma** in its **collective existence** is a combination of different initial fundamental Matters, which these Matters are created through the interaction of at least two or more of the same strength plasmatic magnetic fields (the initial fundamental particles)".

Plasmas (Chapter 3) are considered to be collection of combination of interaction of pmtics forces of Matters', Antimatters' and Dark Matters' and other magnetic fields forces, all at the same time and within an overall sphere of the confines of the plasma.

Further, in the process of interactions and collections of these initial pmtics with each other, in specific combinations, these leads to creation of atoms, molecules, matters and so on.

In this disclosure, simple connections between *Initial Fundamental **Particles*** and *initial Fundamental **Plasmas*** are explained and discussed.

These specific collections and interaction of initial fundamental *particles* and initial fundamental *plasmas* and their interaction with other magnetic fields manifest themselves as **states of matters**, these are purely magnetic fields densities and compactness environment dependent, and they present themselves as different states of matter (gases, liquids and solids).

Matter and matter

In the following sections, we clearly distinguish between *states of matter* (gases, liquids and solids), denoted as "**matter**", and *state of the Matters* (Matter, Antimatter and Dark Matter) denoted as "**Matter" or "Matters**".

Initial Gravitational Fields

The interaction of different magnetic fields of different strengths, upon each other, is considered to be the creator of initial gravitational fields for the start of the creation of the initial seeds of the Matters of the plasma (Fig. 8 B).

We consider that pmtics interact to create the attraction field or gravitational field.

Reactor technology

With the new knowledge and new first principles which are disclosed in this book about the creation of Matters' and plasmas', techniques acquired and reactor systems have been designed, developed and tested, it has become possible to replicate the pmtics of plasmas' environment that allows different Matters of plasma to be released from their interlocking magnetic fields forces within the confines of a reactor.

Further on, it has become possible within the structure of these reactors, to manage and control, these unlocked fields and Matters of the plasma, for specific predetermined functions and applications.

In these new reactors, in being able to weaken the Magravs of the plasmas (Coulomb magnetic or energy barrier) and by allowing the Matters of the plasma to be more free to move within the environment of the reactor. Where, these reactors were designed to facilitate the reduction in plasma magnetic fields forces and eventually to create an environment that Matters of the plasma can freely move in a soup of Matters, pmtics and rays. Where, through the operation of these types of reactors the famous Coulomb barrier becomes irrelevant in the overall structure of the soups of Matters binding magnetic fields of the plasma.

With these new methods of the manipulation of the structure of the Matters' of the plasma it has become possible for the pmtics forces of the plasma within these reactors to be unleashed, and with plasmas' constituent substructure loosen, it has become possible to manage to attain new powerful effects and properties from these rather weak initial fundamental magnetic fields of the plasma. Where up to the present time, these have been the unknown knowledge and methods in the world of science.

Within the structure of simple nuclear-based systems that have been developed, ***conditions*** *are created in which simple weak ambient dynamic pmtics, similar to the internal construction of plasmas, are generated.* The technology for creation of conditions similar to the internal structure of the plasma and methods which have been specially developed, that allows the loosening of the magnetic fields structure of the plasma, this will change the course of present nuclear fusion, and allows scientists in this field to achieve their goals *rapidly* and *at the fraction of cost* of present systems.

In the new state-of-the-art technology much simpler, softer and more practical ways, very similar to conditions as in the universe, are employed to attain fission and fusion of different Matters and plasmas.

During the reading of this book the reader will discover various future applications of this technology, so it will not surprise the reader that we have applied for several international patents to cover all aspects of the topics, principles, methods and systems mentioned in this book and the ones to follow.

Fission and Fusion by Plasma Dilution

The present methods of fusion and the Antimatter production technologies apply strong magnetic fields forces or high-speed rotation of the plasma, with low or limited success. As the real principle of the construction and structure of these sub-plasma Matters have never been understood correctly.

In our new state-of-the-art science and technology, one creates a control-conditioned environment within the confines of a multi-core reactor, which facilitates and allows the plasmas' Matters to ***disentangle*** themselves into their sub-Matters and pmtics components.

In these reactors the effects of the newly freed principal Matters of plasma's interactions with each other are utilised to create new and more powerful internal and external Magravs' forces, within and in respect to other plasmas and Matters in multi-core reactors system environments'.

In the new state-of-the-art technology reactors, after achieving desired goals, the system parameters can be changed so that the system can allow the same separated parts of plasmas' Matters to return to their original properties and regroup as the original plasmas.

This new method of loosening and the use of plasmas' Matters within the confines of a reactor is to be called the ***Keshe Theory*** of the "**Plasma Dilution**" and the art to achieve this "Plasma Dilution Technology"(Chapter 21).

This technology means that it is now possible to create an environment of weak magnetic fields within the cores' of a reactor, where the plasma is allowed to be opened-up and be released of the interlocking magnetic fields forces between its different constituent Matters.

The new dilution method in opening-up the plasma is a more practical and gentler methods for fission or fusion of the plasmas and/or its sub-Matters' components, for utilisation of their effects and properties.

In the present state-of-the-art technology in physics, scientists have chosen harsh method systems in fission industry. For fusion, they have chosen high speed and by compression of plasma, utilising giant magnetic fields induced technology to achieve their goals.

They use accelerators to slam the plasma on to a surface, to extract the sub-plasmatic components like the Antimatter component of the plasma (6, 7, and 8).

In the new state-of-the-art plasma dilution technology, within the confines of the reactors, environments and conditions are created, which are like a soup of weak pmtics, similar to the internal structure of plasma's own environment.

In this new approach, any new introduced plasma into the reactor, new **plasma's *binding* magnetic fields forces** come into an environment and ***interact*** *with fields* ***similar to their own plasmatic magnetic fields strength*** to allow their more condensed fields of interlocking Matter, Antimatter and others, to loosen and operate more freely in the environment of the pmtics soup of the reactor cores.

Using this new state-of-the-art science and technology, achievements of astonishing effects has been reported over the past few years. Where, with the current state-of-the-art technology, to achieve these effects, is considered to be nearly impossible and literally a dream and against the present known laws' of physics.

These effects reported, like being able to lift a reactor system weighing several kilograms by the use of a few grams of gasses, utilises the properties of the Antimatter components of the plasma's interactions with each other within the cores of these reactors.

This new technology makes it possible to produce in a very fast and easy manner nanomaterials and their constituent pmtics, like nano atomic layers known as graphene (sp2), diamond atomic structure (sp3) and nano-oxides, at room temperatures and atmospheric conditions, as has been independently confirmed by reputable organisation in the west.

In fact, all that has been achieved is the application of the understanding of how to use the soup principle to undo the tangles of magnetic fields of the plasma, and release of its substructure Matters, like Antimatter, in a reactor.

Lift and Motion by Magravs positioning

By utilising the properties of the interaction of forces of the collection of pmtics, interlocking between the Matters of the plasma and/or their sub-magnetic fields, which are part of the structure of the Antimatter and the Dark Matter, it has become possible to create stronger Magnetic fields, or gravitational fields' forces within the confines of and in respect to the surrounding environment of multiple-core reactors'.

These Magravs, if strong enough to interact with similar fields in their environment and with other fields of the same components of plasma in other parts of the same reactors, these Magravs interactions' of the system and the planet can cause lift and motion of the mass of the system, which the reactor is attached to.

Scientists at the Fermilab (6) in the USA state that small amounts of Antimatter, as little as a spoon-full, can release enough energy equivalent for the launch of several shuttle flights. This laboratory has confirmed that they have managed to collect some of this Antimatter in the past forty years, using special plasma separation and containment methods.

Utilising the new plasma dilution simple methods', not only are the Antimatter components of the plasma separated but, at the same time the interaction of the magnetic fields of these Matters are used within the system for the creation of strong Magravs within and in respect to their environment, for creation of lift and motion.

The newly created Magravs in these reactor cores, in interacting with the surrounding planetary Magravs and in trying to find a new Magravs balance, for example, in respect to the Earth fields, causes the system to move.

This method of achieving system motion due to interaction of Magravs forces is to be known as the ***Keshe principle of Magravs positioning*** *(Chapter 19)*. This position is, the point where the combined gravitational and Magnetic fields strength of the reactor system and the Earth, find a new position, where they are in balance strength in respect to each other.

After achieving the required Magravs positioning, this being the new height and/or distance, in respect to another Magravs force like that of the Earths Magravs, the systems' internal parameters can be changed again to create a new Magravs strength within the reactor. At this point, a new Magravs positioning balance needs to be attained by the system in respect to the planet. This, forces the system to find a new Magravs balance in respect to the planet Magravs' strength, and consequently for the need for the system to achieve the new Magravs positioning in respect to Magravs of the planet.

In attaining a new Magravs positioning balance, this leads to the movement of one system, in respect to another.

Thus through this new Magravs positioning method, motion of crafts, cars and systems for energy production can be attained *without burning* any fuel or using the present propulsion technology for lift of relatively small payload into space.

Through Magravs positioning principles, this is how ***motions*** *of atoms, planets, and stars and so on, are created and achieved in the universe (Chapter 19).*

Through tests, we can confirm that, the motion of any mass for any Magravs positioning system is not size dependent, but mass dependent, where the smaller mass always tends to move in respect of the larger mass in the universe. There are some exceptions in respect to this rule of the thumb. As in Magravs positioning reactor systems, where gravitational field strength control within the cores of the reactors plays a major roll to achieve lift, motion and Magnetic field protection of the system.

As I have said before "no one has ever seen a rocket in the back of the Earth that has been causing its motion for billions of years".

Subsequently, if necessary, through the same changes in internal parameters of these new reactors, the components of the Matters' of the plasma are and can be allowed and be facilitated to regroup and return back to their original structural state of pmtics levels of Matters and composition, once the desired affects are achieved.

Through new understanding and new state-of-the-art technology and by simply following the methods and universal orders of creation of Matters, the components of plasmas' Matter, Antimatter and Dark Matter can be manipulated and utilised for effective lift and motion of objects, creation of energy, production of new Matters and so on.

By the release of this new knowledge, this does not mean that the paths chosen up to now by other scientists have been wrong; this is by no means so. Nevertheless, their achievements have been and are limited because of the focus on the use of the **matter**; it's state of gases, liquids and solids, and even a limited view on plasma (as the fourth state-of matter) rather than our approach in use of the **Matters;** it's state of Matters, Antimatters, Dark Matters with their different pmtics strength components of the plasma.

With the use of the matter, one has to burn fuel to overcome gravitational field forces to attain a new position in respect to the planet. However, "with *Magravs positioning systems* one uses the pmtics of the Matters of plasma (Matmags) to create Magravs forces within the reactor, for the reactor system to *move within* the Magravs forces of another object, like the Earth, for the system to attain a position in respect to the Earth Magravs forces."

We consider that as much as there are Magravs forces between Matters, the same is true for the existence of Magravs forces between the Antimatter and the Dark Matter components of the plasmas too. This principle applies the same in respect to the inertia of Matter as much as to inertia of the Antimatter and the Dark Matter components of the plasma.

That is to say, in the universe there are Antimatter Magravs forces and Dark Matter Magravs forces as well as inertia for all three Matters.

All Matters and their effects can be used for the creation of motion and energy production in conjunction with other matters and Matters of the plasma.

Our newly released knowledge is for achieving and reaching the same target as other scientists and institutes, but with new knowledge about the construction of Matters of the plasma, we are achieving more profound and stronger effects, in simpler and less complicated ways than have been chosen in the past.

We see this release of new knowledge and technologies as an addition to the rest of the past and present scientific works, and a breakaway from the complicated ways and harsher methods.

In this disclosure, one comes to understand how Matters and matters are made from the start of time (Chapter 3). Where, the method of creation of plasma and atoms in the universe is explained in a simple form.

Then one can see how to use the inner construction of Matters' pmtics to generate vast amounts of energy and learn to use magnetic fields principles of interaction that are the fundamental principles' in the universal method for creation of motion.

We have tested the Magravs positioning systems for motion, and the results confirm the correctness of the theoretical aspects of the approach. The future of space technology will be based on simple safe portable Magravs positioning nuclear-based reactors, which have been developed and tested.

CHAPTER 1

Historically unexplained principles

The main reason for the lack of understanding of simple processes of creation and control of Matters of the plasma is not so much the lack of knowledge in the scientific world in the past or present. Rather the lack of progress is by large due to, the peer review obstruction mechanism, which has been put-up, for some scientists, to protect their individual financial interests and titles, in their schools of thoughts in their field of science.

For example, despite having huge research budgets and human resources, the world of science in respect to understanding of the simple structure of the plasma and its fusion, has not reached substantial results in the past sixty years. Where, nuclear physicists and industry have been trying to cause fusion of plasmas of hydrogen atoms, in fusion reactors, which have been built, and are being built at costs of billions of dollars.

The structure and working of these state-of-the-art fusion reactors are built against the natural laws of physics and opposite to the way, that fusion of plasmas takes place in the universe. Where, these reactors operate with near zero-gravitational field forces within their structure in trying to achieve fusion. Where in these systems, the natural internal gravitational field forces needed for a simple fusion is missing.

What they miss as the natural gravitational field forces needed for fusion, they try to replace this with the use of strong external electro-magnetic fields, by the use of large massive coils and huge amount of energy to operate these systems, and then the they try to achieve fusion. This is like as they are trying to bake bread with only water, salt and heat, without having its main ingredient, the flour. The question to ask from these scientists, is simply that, where are the gravitational fields essential for fusion in these reactors, and where is it suppose to come from, if there is going to be a successful fusion chain process as in the middle of the Sun, which, these forces are in thousands of G‘s.

In fact, with the use of giant external magnetic coils, they squeeze plasmas into tighter balls and then they try to fuse two hard balls of plasmas together. This is the reason why, they have and will achieve very little, if the present misguided path of fusion technology is to continue.

Another point is that the present twenty-first century advanced world of science is lead to believe and to accept the outdated 19th century principles of creation of Magnetic fields through convection principles in the centre of the Earth. Even, when scientific seismological data’s (1, 2, 3, 42A, 42B) indicate that another explanation is needed.

For example, some peers consider that man in the 21st century is not intelligent enough to discover how gravitational fields of planets are created. According to these peers, the principle of creation of gravitational field forces and their control at present is beyond comprehension of other scientists.

Where, as new Magnetic and gravitational fields positioning systems, which have been developed and tested, confirms the ability to create lift and motion by just using the effects of Matters magnetic fields (Matmags), without burning any fuel or use of propulsion technology.

Within the present 21st century knowledge and proven science, there are a number of unacceptable points from these earlier centuries accepted principles like the creation of the magnetic fields of planet through convection principles.

New theories and principles for these misassumptions, unexplained and out-of-the-hat principles are explained and discussed in the following sections and chapters.

In the following four sections in this chapter, it is important to note that:

Information that have been obtained through the earth-quakes seismological data over past thirty years from around the world, these data points to the fact, that what has been assumed to be the ***solid inner core** of the planet* and to be made of one piece solid metallic matter (Fig. 1), this core in fact has *a **cavity** in its centre* (Fig. 1) (1, 2, 3, 4, 5, 41A, 41B). This newly discovered cavity in the solid core of the planet has been called by geologists the ‘inner-inner’ core of the planet and is assumed to be about at least over 500 km in radius in the centre of the inner solid core of the planet.

I have called this new core, “***The Caroline Core***” (Fig. 1, 2 and 3), to distinguish it from other presently known cores’ of the planet (12).

1. The creation of Magnetic Fields of the Earth

The assumption of the creation of the Magnetic fields of the Earth by scientific world has been based on the understanding of the working of the dynamo principle of earlier centuries. Where, the process of the production of the current was accepted to start-off with the motion of high temperature fluid of matters in the outer core (Fig. 1), in the centre of the Earth by heating and liquidity of matters in this core.

Where electrons of atoms of matters are considered to be released or loosened from their atoms to be free to vibrate or float in this region, and as the rotation of the solid metal inner core (Fig. 1) of the planet interacts with these free electrons in the outer core of the planet, this leading to the creation of Magnetic field of the planet (Fig. 1 Field M).

If this assumption is totally correct, then how do other planets and stars create their Magnetic fields?

Stars like the Sun, possess Magnetic fields and yet do not have solid inner cores as the Earth does. The Sun definitely generates Magnetic fields, which does span beyond the

Earth and the Saturn.

The first flaw with this convection theory of electrons motion is that, we know now **that plasma of an atom** is a charged entity **and possesses much stronger charges** by several orders of magnitude ***than its smaller counterpart electron***.

Thus, the main Magnetic field force of the planet is more feasible to be created by the plasma charges rather than electrons charges. With the knowledge we now know, that even the electron is a plasma condition similar to the proton construction (Chapter 3, 17, 18 and 19).

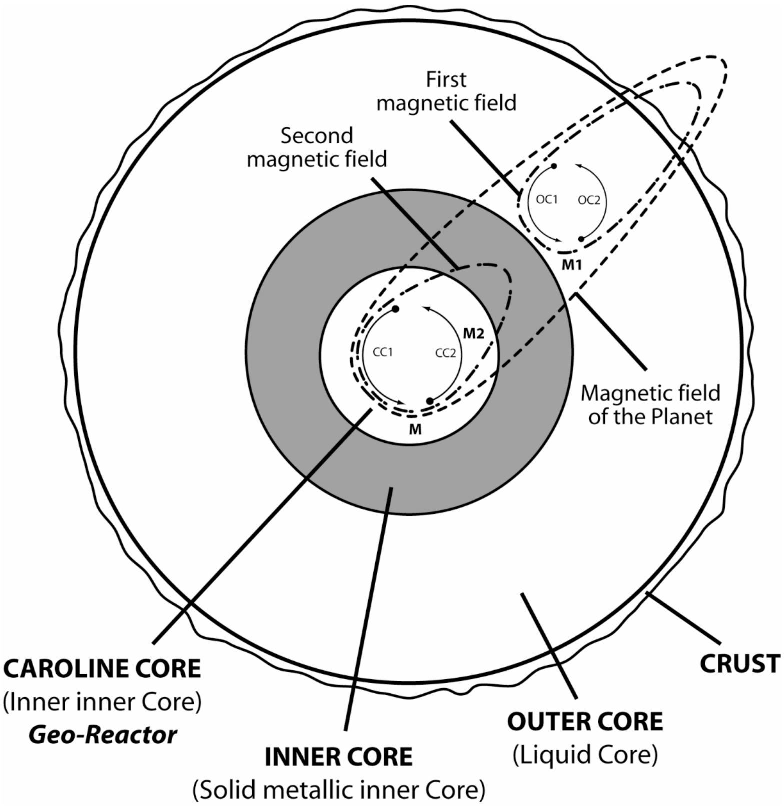
First magnetic field
Second magnetic field
OC1
OC2
M1
CC1
CC2
M2
M
Magnetic field of the Planet
CAROLINE CORE
(Inner inner Core)
Geo-Reactor
INNER CORE
(Solid metallic inner Core)
OUTER CORE
(Liquid Core)
CRUST

Fig. 1: Two interacting plasmatic magnetic fields in the inner cores of the Earth lead to the creation of the Magnetic field of the planet.

Note: The Caroline Core, can contain plasmas, atoms (nanomaterial), molecules, different matters, hydrogen, potassium, uranium and plutonium due to nuclear decay, fission, possible fusion, ionisation of matters, leading to the creation of heat in this core, which is transferred through the solid inner core to keep the materials content of outer core in fluid state.

Through current knowledge in plasma physics and studies in the nuclear fusion industry, it is a known fact that dynamic protons (plasmas) of atoms are positively charged entities and do generate their own currents, through what is known as the Birkeland current principle. It is through this principle of creation of current and the dynamism of plasma in the centre of stars that main solar Magnetic and gravitational fields forces of stars are created, and not the convection principle.

Secondly, if we have plasma in the centre of the planet, which is possible, then the convection theory for the production of Earth's Magnetic field has limited validity, and it is possible that some of the Magnetic fields of the planet are partially created by the convection principles method too.

2. Creation of the Gravitational Fields of the Earth

The other major concept, which is an obstacle to the development of new knowledge, is to understand how gravitational fields of planets are created. This is a concept that has not been understood until now. Where, the creation and maintenance of gravitational field's forces in stars and planets have unnecessarily made been by the scientific world into the holy grail of science.

In fact, the creation of the gravitational fields of planets and stars in the universe is as simple as the creation of their Magnetic fields.

The hypocrisy with this is that the scientific world and an infant child (at school age) agree on one principle, that, two dissimilar poles of solid magnets, gets attracted to each other and pulls one magnet to the other, or they have gravitation in respect to each other. It is an accepted fact that, opposite poles of magnetic fields forces can interact to create attraction field forces or the gravitational fields forces in respect to each other and other matters around them.

Thus, it is correct, to assume that, to have a gravitational field in a planetary system, the gravitational field forces must be made similarly by the same principles of attraction and interaction of at least two magnetic fields, in the centre of the planet in respect to each other. Therefore, the gravitational fields of the planet must have been made by interaction of two or more sources of magnetic fields in respect to each other in the centre of planets or stars that can span beyond the physical boundaries of these objects.

By the reality of the existence of the Magnetic and Gravitational field forces around the Earth, this leads to the confirmation and understanding of a need for two independent regions that can create magnetic fields forces within the structure of the planet inner cores, that, their interaction leads to the existence of the gravitational field forces of the planet.

Consequently the Earth, being in possession of gravitational fields, this confirms and indicates to the existence and operation of at least two independent magnetic fields forces regions in the centre cores of the planet (Fig. 2, fields G1 and G2).

Where, the interaction of the two magnetic fields (Fig. 2, fields G1 and G2), which are generated in the centre cores of the planet, upon each other, leads to the creation of attraction or gravitational field forces of the planet, similar to the attraction fields of opposing poles with solid magnets.

It is a known fact that, planets and stars are made of different layers of different materials. Similarly stars are made of the same material (Hydrogen), which, due to variation in the compression and temperatures, layers are created in these objects, where the same matters in different layers create and behaves and show slightly different properties and effects; These different layers produce their own slightly different in strength magnetic fields force, compared to their adjacent layer magnetic fields strength. Thus, the layers of plasmatic or fluid materials in different depth of stars and planets, each layer create their own independent magnetic fields in the centre of planets or stars.

The magnetic fields created in each dynamic layer in the cores of these celestial bodies, due to the proximity have no alternative, but to interact with the magnetic fields generated in ascending or descending layers from them. The interactions between these magnetic fields in different layers are considered to be as or similar to a solid magnets state magnetic fields interactions.

In the case of stars and planets' inner cores, magnetic fields are created by and in plasmatic states or fluid states of Matters. Where, these flowing dynamic materials in the inner layers of celestial objects cannot physically lock to each other through the magnetic fields generated by each layer, as it happens with solid-state magnets. This being due to fact that atoms and molecules in these layers are continuously in motion and are pushed around by other forces and the rest of the Matters in their given layers or by other layers effects and forces.

Nevertheless, the magnetic fields created by each dynamic layer interact with the magnetic fields of the adjacent dynamic layer or layers. These interactions of magnetic fields in different layers creates attraction magnetic fields, as much as, repulsion Magnetic fields forces, in between the materials in the different layers.

Therefore in the same regions and by the same matters, **similar magnetic fields polarities** in different layers interact and two similar polarities magnetic fields forces (Fig. 1 field M1 and M2) repel each other. This repulsion magnetic fields forces (Fig. 1 field M1 and M2) becomes' the ***outwards field force pushing*** and what is known as the ***Magnetic field force*** of the planet (Fig. 1 field M).

Further, the *opposite polarities magnetic fields* in these layers at the same time, interact simultaneously and in a similar way, and the interaction of **opposite magnetic fields** polarities of matters in these layers (Fig. 2 field G1 and G2), leads to the creation of the different layers magnetic fields pulling or attraction in respect to each other. This attraction magnetic fields force (Fig. 2 field G1 and G2) becomes the ***inward field forces pulling*** field force and what is known as the ***Gravitational field force*** of the planet (Fig. 2 field G)(18).

Through tests done over several years with the construction of similar set-ups as in the inner cores of the planet, the ***Keshe Theory of creation of gravitational field*** of dynamic objects in possession of dynamic cores states that:

"***The dynamic outward' Magnetic fields forces of planets and stars are created by interaction of the same materials and in the same layers, as their dynamic***

gravitational fields forces".

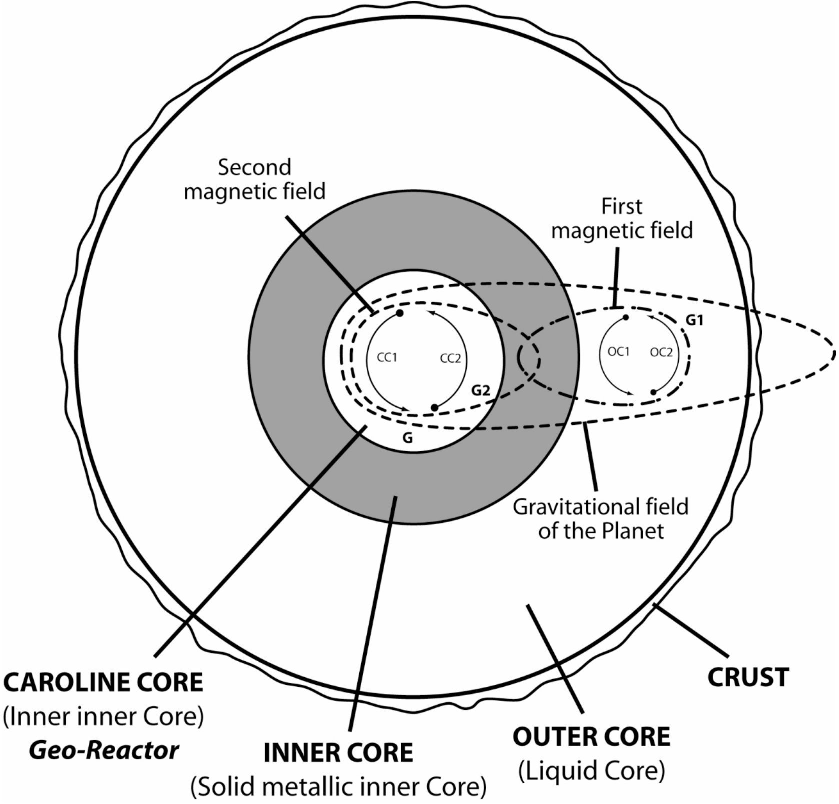
Second magnetic field
First magnetic field
G1
CC1
CC2
OC1
OC2
G2
G
Gravitational field of the Planet
CAROLINE CORE
(Inner inner Core)
Geo-Reactor
INNER CORE
(Solid metallic inner Core)
OUTER CORE
(Liquid Core)
CRUST

Fig. 2: Two interacting plasmatic magnetic fields in the inner cores of the Earth lead to the creation of the Gravitational field's forces of the planet.

The ***Magnetic fields forces*** of the planets are made from the interaction of similar polarities of plasmatic magnetic fields of Matters in the dynamic layers of its inner cores (Fig. 1 field M) and these radiate themselves ***outward***. The ***Gravitational fields forces*** (Fig. 2 field G) are created by the interaction of the opposite plasmatic magnetic fields polarities of the same Matters in the same layers in the cores of planet, creating the pull or ***inward*** attraction in these celestial objects".

This new understanding of interaction of multi-magnetic fields in the planets inner cores brings about a new definition, new understanding and new explanation of how gravitational field forces are created in centrally dynamic multi-inner-cores celestial objects in the universe the like of the Earth and the Sun.

Gravity can now be defined on the real basis and what leads to its manifestation, strength, existence and control.

Therefore, Gravitational field forces are magnetically based fields, and thus according to ***the Keshe Theory of Gravity***, Gravity is defined as:

"***The Gravity is, the measure of the interaction and attraction of two or more, magnetic fields forces or dynamic plasmatic*** strength created within the second system"(18).

This is the same as Newton's definition of gravity, with the extension however, that two Matters or matters cannot possess pulling forces nor have gravitation in respect to each other position, without the existence of magnetism.

Certainly, the attraction and interaction of pmtics forces changes with respect to position of two objects and they are distance and fields' strength dependent.

If the celestial objects do not possess magnetic fields strength that can interact with each other, then, how could they be attracted to each other?

Thus, gravitational field now can be understood and explained in its real terms of what creates it, and this is due to interaction and attraction of pmtics created within dynamic cores of celestial objects in respect to each other.

Secondly, as the gravitational fields of these planets or stars are magnetic fields strength dependent, one can now understand why their attraction is position dependent.

Therefore, *gravity in a simple form can be defined as; that gravity or gravitational fields forces are the measure of the interaction and attraction of two or more magnetic rays or magnetic fields systems of two or more entities in respect to each other's strength and position at any point in the Matter, plasma, matters, planets, solar systems, galaxies and universe*.

This new definition of gravitational fields is an extension to the present knowledge and due to new understanding of the plasmatic magnetic fields interactions between components of Matters (see Chapter 3).

Another proposition can be that: We further can assume that the cell of a human or matters of other objects, which all are made of atoms and plasmas and of magnetic fields can/are/or behave as the possessor of the second magnetic field in respect to any other plasmatic magnetic fields in their environment. Therefore, it is possible that pmtics of these cells and matters in their interaction with the dynamic pmtics of the planet can behave and replace the interacting double magnetic fields system principles necessary for the creation of gravitational phenomenon principle to operate.

Further it can be said, that any substance in possession of plasma or nuclei has gravitational attraction in respect to the planet.

If this is correct and applicable, then, this can be another reason why, a singular Magnetic field of a planet can be enough to create the gravitational field pull in respect to any object within the catchments zone of the Magnetic field of the planet's. That is to say, a single Magnetic field would be sufficient for the gravitation of plasma to the planet to be created and exist.

Nevertheless, there could be a flaw with this concept, as one need the gravitational and magnetic fields (Magravs) together to be able to have a constant free motion and position option of the two objects too.

In this book, we try to make a distinction between *magnetic fields of matters* and *Magnetic fields created by* dynamic interaction of two magnetic *rays*, two *magnetic fields* or *two pmtics*. Where, in the case of like **plasmas** and planets *Magnetic field* and *gravitational fields*, which they always accompany each other we use **capital M** as **Magnetic field**. In these references instead of writing **Ma**gnetic and **grav**itational field**s** we write in short as "**Magravs**" ***magnetic fields forces in respect to each others position***".

"Where, the Gravitational field force of one celestial body in respect to the other is a measure of the attraction and of the interaction of one plasmatic magnetic fields strength created within one system in respect to another plasmatic magnetic fields.

3. The source of the Heat in the Earth Cores

Another unanswered question in geophysics is that, where does exactly the heating of the inner solid core of the planet Earth comes' from that can keep the outer core materials in their fluid state? Secondly, how and through what method is heat generated in the inner cores of the planet?

These questions have not been addressed fully with clarity up to the present time in the science of the planet.

In general, it is an accepted fact that the Earth maintains heating of its inner cores. I consider that the Caroline core is a Geo-nuclear reactor (Fig. 1, 2 and 3) to be known as the **Geo-Reactor** (Fig. 2). It is not hard to assume that there are radioactive matters (41C) in this new central core of the planet (12), which leads to the heating of the inner cores of the planet. In general, nuclear geophysicists and myself agree upon this, up to certain degree, with difference in the content of the matter types and the process by which this heating is generated.

Where, geophysicists mainly consider that the heat in the Caroline core is generated through the nuclear decay of heavy elements, which have sunk into the centre of the planet due to their weight.

As a nuclear engineer having built several simple nuclear reactors replicating the structure of the inner cores of the planet Earth and achieving the same effects of creating Magravs similar to of the Earth, I believe, Matters, plasmas, hydrogen atoms, carbon atoms, radioactive matters and other matters collectively are parts of the mixture of the matters content of the Caroline's core (12).

One can now clearly explain that the major contributor to the generation of heat in the inner cores of the planet are, or can be due to nuclear decays, operation of plasmas, nuclear fission (41C) and possible nuclear fusion of materials in the Caroline core of the planet.

Materials in this region of such a high temperature are, and can be, considered to be in the fluid state (12) as has been considered by present geophysics scientists in respect to the condition in the outer core materials of the planet.

Matters in this region, due to their fluidity, can be considered to be able to produce their own dynamic magnetic fields (Fig. 1 field M2 and Fig. 2 field G2), due to the *dynamic motion of fluid matters* in this section of the planet and these fields can/and interact with the dynamic solid inner core of the planet (Fig. 2). This being in principle similar to what has been assumed by geophysicists, that to be happening in between the **inner core** and the **outer core** regions of the planet matters leading to production of Magnetic field forces of the planet at the present time. Secondly due to the *charged plasmas and charged electrons and their motion in this core, these could be partially responsible for the creation of the second magnetic field force of the planet.*

By the discovery of the second cavity, the Caroline core, in the inner cores of the planet, it becomes clear that the **second magnetic fields** (Fig. 1 field M2 and G2) can be, and are created in the very centre of the planet. Where, the solid core of the planet will act as a separating partition wall, between the two dynamic matter regions in the centre of the planet, namely the fluid matters in the Caroline core and the fluid matters in the outer core.

So, the holy grail of the gravity (18) can be explained by the principle of interaction of two dynamic magnetic fields sources in the centre of the planet as was discussed in the above section. Therefore, the interaction between two pmtics on either side of the solid core is the source of the plasmatic Magravs of the planet.

4. What causes the Rotation of the planet Earth?

Another unexplained and daily-accepted phenomenon is the rotation of the planet Earth. How is the rotation of the planet Earth created and maintained? What causes and dictates its constant speed of rotation of the planet, irrespective of where the planet is in its solar system?

The way and how the rotation of a planet is created, has never been explained in the past by world of science.

The existence of two independent pmtics forces (Fig. 1 field forces of M1 and M2, and Fig. 2 field forces of G1 and G2) on either side of the inner solid core of the planet (Fig. 3) can help to explain the next mystery in the world of geophysics, through the ***Keshe Theory of "The principle of the rotation of the planet"***.

Magnetic fields are known to possess *field forces* that can exert pressure on an object, and are capable of causing its motion.

The existence of, and the continuously maintaining and interplay of the two dynamic pmtics forces (Fig. 1 fields M1 and M2 and Fig. 2 fields G1 and G2) on either side of the inner solid core of the planet, partially goes to answer the sources of the fields that exert forces on the inner solid core of the planet that causes the motion of the inner solid core.

It has been explained that the interaction of two dynamic magnetic fields on either side of the inner solid core, leads to the creation of Magravs forces of the planet. At the same time the interaction and exertion of the same magnetic fields forces on the inner solid core of the planet put magnetic pressure on the inner solid core of the planet, causing the motion of the inner solid core of the planet (Fig. 3 fields G1 and G2). In the figure 3 the total and overall effect of Magnetic field and Gravitational field forces of each core on the inner solid core are denoted as G1 and G2.

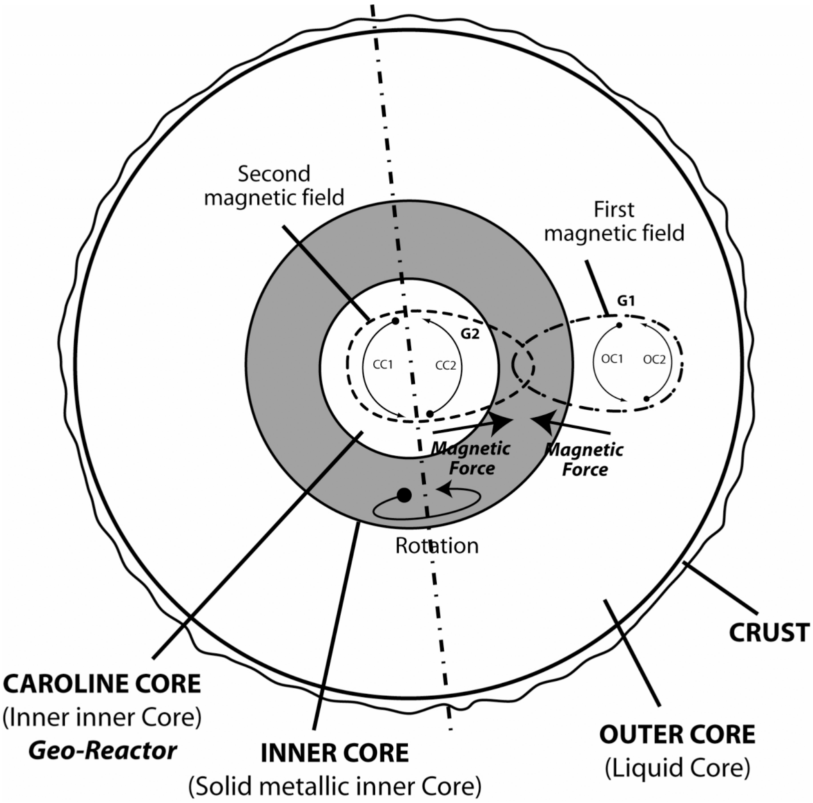
Second magnetic field
First magnetic field
G1
G2
CC1
CC2
OC1
OC2
Magnetic Force
Magnetic Force
Rotation
CRUST
CAROLINE CORE
(Inner inner Core)
Geo-Reactor
INNER CORE
(Solid metallic inner Core)
OUTER CORE
(Liquid Core)

Fig. 3: Interacting plasmatic magnetic fields in the inner cores of the Earth leads to the creation of the rotation of the planet.

As the solid inner core confines' the materials in the Caroline core (Fig. 3) and the outer cores materials are confined by other matters at the outer boundaries of this core (Fig. 3), these two cores are considered to be holding a constant volume and weight of matters. Thus, it is possible to assume that the magnetic fields forces created by each core will be constant and these magnetic fields forces will be maintained on either side of the inner solid core of the planet for a long period of time (billions of years).

Hence, the *balance of magnetic fields forces* exerted on the metallic inner solid core, by both magnetic fields on either side of the inner solid core, will determine the speed of rotation of the solid core of the planet.

Consequently, through the principle of viscosity and friction of the matters inside the planet, the final speed of the rotation of the whole planet is considered to be set and be due to the motion of the inner solid core of the planet. Which is carried out to the outer layers of the planet and becomes the final rotational speed of the planet.

Therefore, the speed of the rotational motion of the planet is determined by the planet's internal cores magnetic interactions upon the inner solid core of the planet and by large, this speed of rotation is **irrespective** of the position of the planet in its solar system and overall effect of the external Magravs forces, which are exerted by other planets, and the star of the solar system, on the planet.

So the twenty-four hour speed of rotation of the Earth is totally dictated by the exertion of the magnetic fields of the other cores on the solid inner cores of the planet as has just been explained, and not necessarily by any other factors.

This principle of constant speed of rotation of celestial object should hold true for the all-dynamic celestial objects that are in possession of dynamic thermal central materials cores and this rotation is irrespective of the temperature of the inner cores or temperature of the outer layers and surrounding environment of these objects.

Through tests in laboratory of similar reactors as the construction of Earth inner cores, we have concluded that the **speed of rotation of celestial objects and Matters** and the **creation of Magravs strength** are **temperature independent**.

The motional rotation of a planet is created through the same principle as the linear motion that is attained in the present Maglev magnetic railway system of Japan, with the difference that, due to *spherical shape* of the inner solid core of the planet (Fig. 3), the motion created in this case will be a rotational one (12) rather than linear. We can consider that this principle is universal.

5. The difference between Matter and matter

Another unexplained phenomenon in the world of physics has been the understanding and the difference between the Matter and the matter, one in respect to the other.

In this book we make a clear distinction between **the Matters** and **the matters** in all levels of universal orders of materials, where;

The **Matters** are understood to be as the like of the Matter, the Antimatter and the Dark Matter. These three Matters are all made of ***different*** *plasmatic magnetic fields strength* and are ***field strength*** dependent in respect to each other. The three Matters are the three major components of a plasma. Each of the three Matters have pmtics of another strength, where the constituent strength of the pmtics creates different Magravs, different magnetosphere field strength and different mass for each Matter, and these independent of the other two Matters within the plasma, and independent of the environment that surrounds the plasma.

Whereas:

The **matter** refers to the Matter component of the plasma. Matter becomes matter, when the Matter comes to levels that **plasmatic magnetic fields forces** and the ***motion*** *of these forces* in their environment can determine the compactness of the components of the Matter pmtics appearance in the plasma that make the matter appears as a gas, a liquid or a solid ***state-of-matter***. These forces being created due to interactions of Magravs, dynamism of the environment, and so on.

At the same time, Matters are pmtics strength, contact friction dependent. Where, the friction of pmtics in matter usually leads to the change of the state of the matter through the change of plasmatic magnetic fields forces to the likes of light, heat and other's.

It is the **external field forces** and ***not the field strength*** of the environment that dictate the compactness of any of the plasmas' Matters so that the pmtics becomes matter and visible or tangible to human senses, like odours or appearance of Matter as solid, gas or liquid, it is then that the ***Matter*** comes to be called the ***matter***.

The principle of ***strength*** of the magnetic fields of Matters is very different than the strength of magnetic fields in matters.

When we consider to work with Matter(s) for space technology, the term "**fuel**" is not applicable, therefore the use of the term "**MAT***ter* **MAG***netic* **S***upply*", abbreviated to "MATMAGS". This is a Matter (Matter, Dark Matter, Antimatter) ***source of pmtics*** used in reactors for the production of Magravs for the operation of gravitational positioning reactors, where one can state the Matter needed and the strength of the Magnetic fields of the Matter needed to achieve desired effects from the reactor.

Since "fuels" only refer to the *matter level*, where fuels are usually *burned through ignition of matters*, whereas ***magnetic fields of Matters***, in the form of Magravs, are manipulated to create a preferred effect, and where the magnetic fields can be reversed back to any other state of Matter, and they are never lost. The only difference would be that with the Matter supply the magnetic fields strength can differ after processing, but in reality one would be left still having magnetic fields of varying degrees in strength.

6. How motion of matters and Matters are created?

The question to be asked first is, that, how the Matter, the Antimatter, and the Dark Matter are created in the universe.

Secondly, how are the regular independent motion of **Matters** (Matter, Dark Matter and Antimatter) and **matters** (electrons, atoms, matters, planets, stars and galaxies) in the universe without burning of any fuel created and maintained?

No explanation has been put forward by the scientific world that is realistic, fundamental and applicable in all levels and to all sizes of objects and in any position in the universe.

In the following chapters of this book, I will disclose how **matters** (gasses, liquids and solids) and **Matters** (Matter, Antimatter and Dark Matter) as part of fundamental elements of creation, move in the universe. In addition, it will be explained, how the plasmas, electrons, planets and stars attain and maintain their motion in the span of the universe. (Chapters 19)

Motion in the universe is achieved by understanding in full that how the construction of Matters happens at their simplest form, from the inception of the initial fundamental particles how they come together, and how they respond to each other's magnetic fields forces, that the interactions of all constituents Magnetic field forces in Matter and plasma of Matters, leads to the creation of motion of plasmas, electrons, planets, stars, and so on.

7. How Light is created?

The present science of physics accepts that the light is created through the drop in energy of an electron from one energy level to a lower, or its ground energy level.

Further, in this book we will explain how light is created in the universe, where actually there are *no electrons present* in the plasma-saturated environment.

The other unanswered question is whether the speed of light (C) is the ultimate speed in the world of Matters.

The speed of light is in the world of science thought to be the ultimate speed that any Matter can travel.

I consider this assumption to be **incorrect** for all states of Matters (Matter, Dark Matter and Antimatter).

The assumption that the speed of light is the ultimate speed can be correct **only** for *interactions between matter and Matter component* of the three basic Matters (Matter, Antimatter, and Dark Matter).

I consider that the **plasma** is to be in **possession of all three states of Matters,** these being **the Matter, the Dark Matter and the Antimatter.** (See the cover image of the book)

Secondly, the assumption that the speed of light to be the ultimate speed, can at the same time be partially correct and applicable, only for a limited fraction of time for specific conditions of **matter** (and not necessarily only in vacuum conditions). Where **matte**r itself is only a small part of bigger components of Matters of plasma in the universe.

There are too many physical facts that are present in the mechanism of the universe's daily operation that rejects that the speed of the light being the ultimate speed. These new theories will be discussed further in Chapter 7, titled "Speed of light". A large numbers of physicists around the world do not accept such a limitation on the speed of matters in the universe.

CHAPTER 2

Interaction of Plasmatic Magnetic Fields (pmtics)

In the Matters the strength of the magnetic fields goes back to the origin of the creation of magnetic fields. Where, the strength of the magnetic fields is in terms of reference, the power of the magnetic fields. Where magnetic fields in essence are created out of the potential difference in position from their source and the rate of the flow of the magnetic fields from their source becomes the current of the magnetic fields. Thus, as the position is closer and the rate of the flow is higher, the stronger the strength of the fields. This principle of creation of magnetic fields and magnetic fields strength are explained in full in the paper titled "The creation of magnetic fields".

In understanding the ways and the simplicity with which the gravitational field force of plasmatic conditions are generated and maintained in planetary and stars systems, we can now state that the method of creation and production of the Magnetic fields and gravitational field forces of galaxies, stars, planets, molecules, atoms and plasma are all considered to be through the same method, irrespective of their physical size.

At the same time, it is important to appreciate that this applies to all scales of the universal order of creation. That is to say, stars are made of the denser, larger and stronger by order magnitudes of plasmatic magnetic fields strength forces in the universe. Compared to the plasmas and the electrons, which are made of a weaker order of magnitude of plasmatic magnetic fields strength forces.

Nevertheless, the same principle of structural formation applies to the Magravs structure of stars as to the structure of an atom, the plasma and the electron.

In the physically big state order of matter, large scale, stronger and denser magnetic fields can be easily observed and detected, like the magnetic fields of the Earth, the Sun or the Galaxies.

By the same measure and the same order of the scale and magnitude, plasmas and electrons possess and are made of and follow the same principles of Magravs interaction and attraction, and hold on to their different Matters and forces, as a star or a galaxy does.

Whereas, the existence of the lower order of the magnitude pmtics that make the physical structure of plasma due to their very weak magnetic fields strength, can mainly be confirmed through the physical existence of the plasma itself, its behaviour, and its properties.

Through our own tests, which have been done over several years, it is apparent that the plasmas possess their own Magravs forces, which are made from the interactions of combinations of different pmtics forces within their structure.

The fact is that, if the plasma did not create and maintained Magravs forces internally, it would not have been able to hold on to its fundamental particles, for the plasma to exist. By the ***Keshe Theory of the Gravity***, the existence of Magravs forces as the existence of a magnetosphere of the plasma confirms the existence and interaction of at least two plasmatic magnetic fields forces within this structure.

Secondly, if the plasma did not possess Magnetic field, it would get stock to other plasmas in its environment, these environments being for example the like of the other plasmas in the nucleus of heavier atoms. Then as the plasma is a free motion entity, which keeps distance from other plasmas in its environment, this confirms the existence of Magnetic as well as gravitational field's, which is internally maintained and emanated from the plasma itself.

Unless it can be proven to the contrary, we can assume that all plasmas are made of the same types of pmtics, and the same structural Matters and the same structural configuration. Then, we can say with confidence that all plasmas are made of identical Matters and create the identical Magravs forces within their structure.

We consider neutrons, protons and *especially* electrons as being of plasma structure with only difference in their pmtics content level. Thus, different atoms of different matters have different energy and physical pmtics properties from other atoms purely due to the level of total pmtics of their total plasmas that they can hold onto.

From this point on, in this book, it is considered that all **hydrogen atoms** have and will always be in ***possession of the same properties***, be of ***the same construction*** and be made ***of the same similar internal pmtics and Matters***.

Therefore, it is assumed from this point in this book that what we call initial fundamental plasmas, or what is called neutron, must always be made of the same composition and of the same specific pmtics at all times, for all such plasmas of all atoms.

Furthermore, it can be said that all initial fundamental plasmas create the same and similar plasmatic Magravs forces.

Until contrary to this fact is proven, then it is correct to assume that majority of plasmas have the same characteristics, the same properties, and have the same dimensions, and the same measurement of Magravs density and field strength.

Therefore, it is right to assume that the *majority of plasmas* in the universe are all made of the same collection of pmtics interactions.

Hence, it is correct to assume that to have plasma of specific characteristics and specific Magravs strengths; the plasma is made of and must be able to attain a Specific Magnetic Configurations for all initial fundamental plasmas.

From observation of motion of plasmas in the universe, it is clear that not all packs of pmtics are connected to a specific source. They are mainly free floating in space and are made of different magnetic fields strength.

Where, some of these pmtics interact with others of the *same strength*. Which, these interactions lead to the creation of the plasmatic Magravs, in their space and in respect to other floating pmtics in their given environments.

Initially, when pmtics of similar strength get close to each other, the interacting fields get entangled with each other and set-off a new cycle of Magravs in respect to other pmtics and magnetic fields in their given environment.

Further on as more pmtics of different field strength are gathered together due to their initial magnetic fields strength the new seeds for creation of new and different Matters are set to start. Where, the collection of these different Matters and fields and their interactions leads to the creation of initial fundamental plasma, in a specific given position in space.

Plasmas are always considered to be made in the same manner, by the same process, by the collection of the same pmtics force strength and the same interaction procedure of the fields within their structure.

Hence, plasmas are said to be made of **S***pecific* **E***ntangled* **P***lasmatic* **MA***gnetic* **F***ields* (SEPMAF) and this is considered to be the same for composition of all plasmas in general.

CHAPTER 3

The Initial Fundamental Particles of the plasma

The **initial fundamental particles** components of plasma are considered to be *a **collection** of weak* **plasmatic magnetic fields** (in short: pmtics) originally existing in the spans of galaxies.

These are **residuals** of different plasmatic magnetic fields activities of matters and Matters, which are released by the interaction of different magnetic fields by/and through for example processes like fission and fusion within stars and so on. It is considered that some of these ***weaker*** plasmatic magnetic fields are *released into the environment* by the nuclear decay of atoms themselves.

Where some of the pmtics (Fig. 4) are *continuously created in the **denser** environments* by the **interaction and friction** of two or denser ***or stronger*** *pmtics* and some ***weaker pmtics*** are generated through the **collision or friction** of *matters and Matters* in the universe.

South
North
South
North

Fig. A

Fig. B

Fig. 4: Graphic presentation of plasmatic magnetic fields.

Note: The figure 4 A: represents the collection of plasmatic magnetic fields of different strength. The figure 4 B: represents a graphical representation of dynamic pmtics in motion.

The pmtics due to their very weak strength are usually considered to exist and be in motion in **packs** within the different parts of universe (Fig. 5). Where, each pack can be made of number of different orders of magnitude of pmtics strength.

For ease of understanding in trying to explain that how plasmas are created initially, we will consider three packs of pmtics. Where, for our purposes, each pack of plasmatic magnetic fields is denoted by one capital letter. Then each strength sub-constituent magnetic fields forces is number denoted. The different strength fields denoted with different numbers (Fig. 5).

For simplicity of explanation, we will consider three packs of A, B and C with constituents of different dynamic pmtics (considering that fields are in motion in their environment).

Furthermore we consider that each pack of magnetic fields contains five different sets of fields strength called (**Pack A**) as A1, A2, A3, A4 and A5, (**Pack B**) as B1, B2, B3, B4 and B5 and (**Pack C**) as C1, C2, C3, C4 and C5 respectively (Fig. 5).

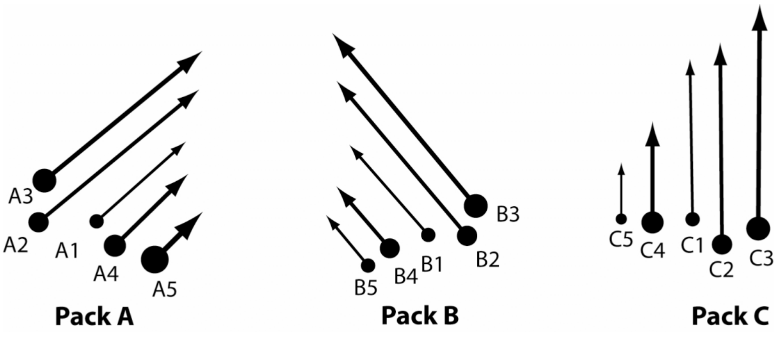

Fig. 5: Initial fundamental particles of plastic magnetic fields.

It is important to remember in this section, that when we talk about the *gravitational field forces (Magravs)*, this means the **gravitational fields** and the **Magnetic fields** of any entity in possession of these magnetic fields, which are generated simultaneously by the interaction of the same two or more plasmatic magnetic fields.

It is crucial to remember that there cannot be a situation where, there are gravitational fields and no Magnetic fields within a system and vice-versa. Even where, the Magnetic field comes to be placed in the boundary of the gravitational field zone.

In principle, the gravitational fields and the Magnetic fields of the plasma are represented in the same region in our diagram(s), and for simplicity, these are shown with the doted line and this single line is representing both the Magravs zone of a Matter.

Creation of Matter of plasma through interaction of pmtics.

Initially considering interactions between, the pack A and the pack B and ***at least one pmtics of each pack***, which are to match with each other strength ***of the other pack***, where these two pmtics are allowed to interact and interlock into each other.

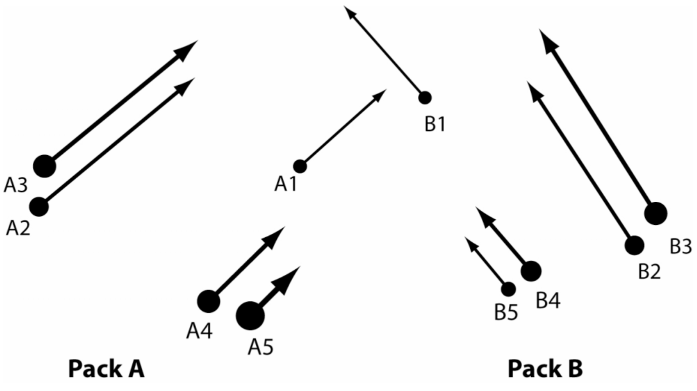

Fig. 6: Dynamic plasmatic magnetic fields A1 and B1 making the initial magnetic interaction of two packs.

Note: Only pmtics of similar or near similar pmtics strength can interlock into each other, where pmtics of different strength are attracted to each other but cannot interlock in the majority of the cases.

For the pmtics of packs A and B, which are similar or equal in magnetic fields strength, and they are in motion, and able to interact with each other or to interlock into each other (Fig. 6 and Fig. 7 a), it is considered that the North Pole of pmtics A1 and the South Pole of the pmtics B1, (Fig. 7 b) start the ***attraction*** of the two pmtics to each other.

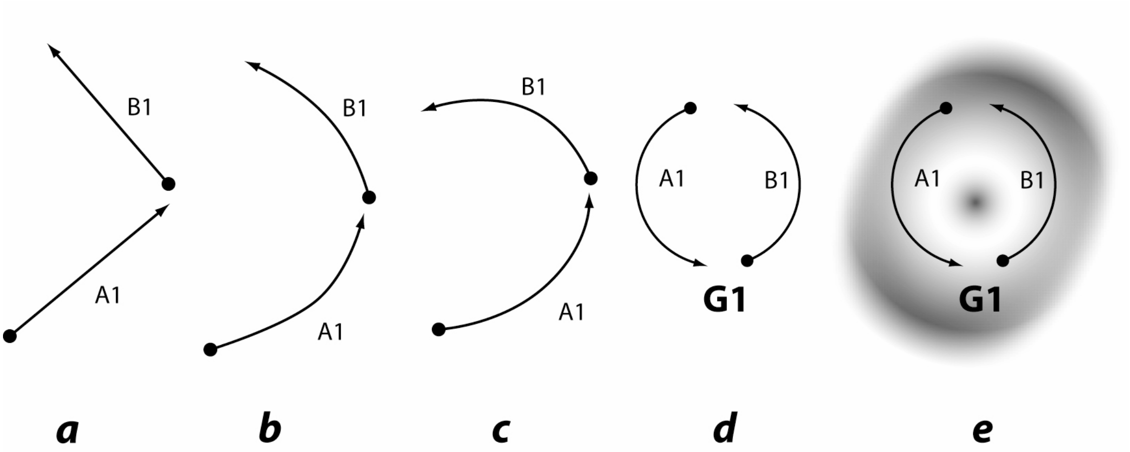

Fig. 7: Interacting plasmatic magnetic fields making pmtics of Matter.

Note: It is considered at all times in the universe all magnetic fields and plasmatic magnetic fields are in dynamic and in the state of motion, as magnetic fields in essence are always attracted or interacting with other magnetic entities, thus they are always on the move towards or repulsing from one magnetic field to another. This is how the motion of Matters and fields are maintained in the universe. This continuous dynamic mixture of different magnetic fields strength become part of a localized or universal pmtic soup(s).

This interaction and interlocking of these pmtics initiates and creates the ***first step*** of interactions between two packs A and B plasmatic magnetic fields (Fig. 7 c). This ***interlocking***, leads to the creation of the very first *initial fundamental magnetic fields set*, or the first initial Magravs, what is called the initial configuration of pmtics needed for initial seed of the plasma (Fig. 7 d and e).

The interaction of at least one plasmatic magnetic fields of each pack that is initiating, and starting the initial weak Magravs forces of a Matter of a plasma, this is the **first step** *for the interlocking of the two packs* of A and B, of pmtics forces in respect to each other.

From this point on, the first plasmatic Magravs force, essential for the seed of the first Matter of the plasma, is set to start and operate (Fig. 7 e). That is to say, the first gravitational field (G1 in Fig. 8 B) and the Magnetic field (M1 in Fig. 8 B) forces can be considered to be created in between these weak pmtics packs.

It is appropriate to consider that the interlocking of the two dynamic fields, due to their interaction and attraction, are bent inward or become overall to be ***spherical*** in shape (Fig. 7e and Fig. 8 A).

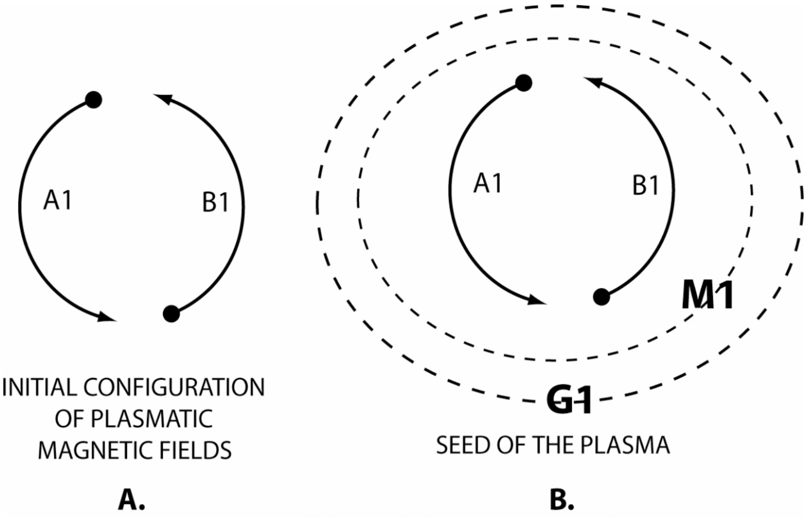

Fig. 8: The creation of the seed of the plasma.

For ease of explanation, all the initial plasmatic gravitational fields (Fig. 9 field G1), and all the plasmatic Magnetic fields (Fig. 9 field M1) from now on in this disclosure are denoted as G1 fields (Fig. 10), or what we call **Magnetic and gravitational fields** or **Magravs** and considered these to be the seed of the pmtics of the **Matter** components' of the plasma.

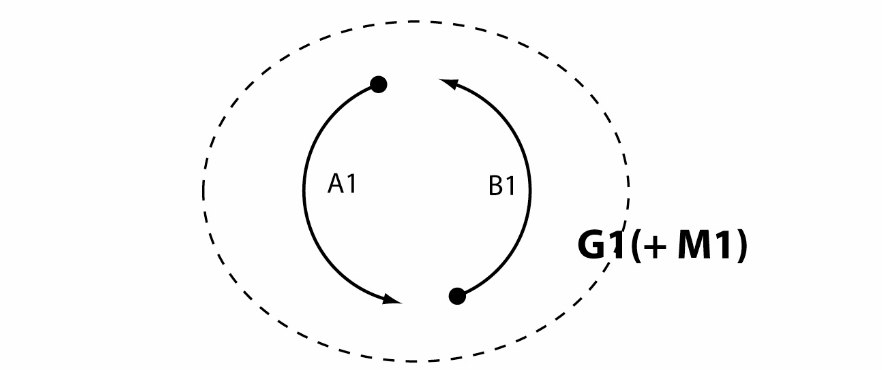

Fig. 9: Initial gravitational fields and Magnetic fields (Magravs) of the Matter components of the plasma.

At the same time, the ***remaining*** pmtics in each pack of A and B, due to the dynamism and Magravs in the vicinity of this seed, these will be kept around the seed G1 as one dynamic pack SET P1.

The collective Magravs force of the seed of Matter will be known as G1 (Fig. 10) and the remaining pmtics magnetic fields of Pack A and B as initial set of the Matter component of the plasma is denote as **SET P1** (Fig. 10).

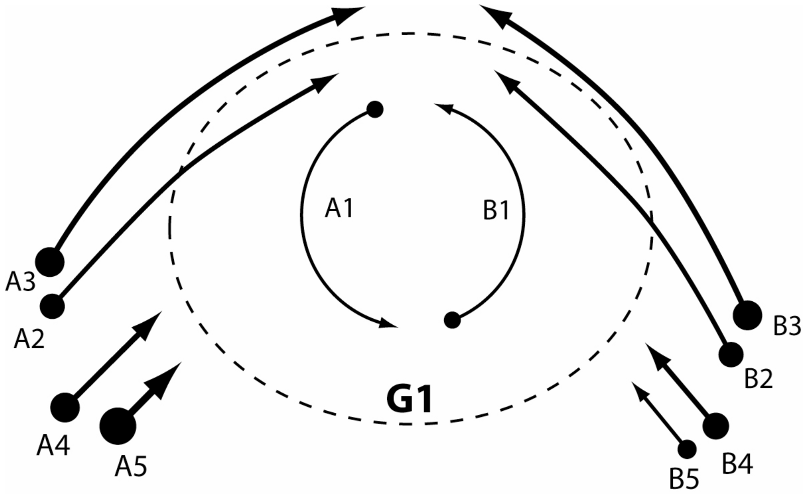

Fig. 10: **Set P1**, the initial pmtics of the Matters Magravs' components of the plasma.

Note: It has to be remembered that the pmtics in G1 are not produced and connected to a source of a solid magnet, but these ***forces*** *were made by magnetic fields and were detached from their source of creation, some times before, hence, the use of the term "plasmatic" for these magnetic fields. The term "plasmatic" refers in this book to a "collection" of dynamic magnetic fields, and* ***not*** *to the state of a plasma in its common term use, which for example refers to a state of dynamic protons.*

Nevertheless, the remaining plasmatic magnetic fields of the two packs A and B are ***not matching in strength*** and hence they cannot lock into each other, *these being* pmtics A2, A3, A4, A5, and pmtics B2, B3, B4, B5.

Therefore, the initial dynamic pmtics interaction of the two packs making up the G1, possessing dynamic Magravs force, become the **Matter** component's of the *upcoming plasma*.

In the open spaces of the universe, the SET P1 due to its dynamism and motion, naturally and eventually will come across another pack of pmtics, like the **pack C**.

The interaction between magnetic fields of the SET P1 and pmtics of the pack C will be different in respect to the initial interaction of the packs A and B.

In this set of interactions between all the fields and initial Magravs force of the SET P1 and the pack C, several steps can take place instantaneously, simultaneously or over a length of time.
The first step is that, some of the magnetic fields strength in the pack C (C1, C2, C3, C4 or C5) could be **similar** to certain magnetic fields strength as in the G1 of the SET P1.

The *addition of* ***new*** *plasmatic magnetic fields* does not necessarily increase the strength of the fields of the G1, but it just adds to the density of the compact pmtics in the G1, and hence **increases of the mass** of the G1 only.

Creation of the Antimatter of plasma

The **second step** is that the stronger field of the SET P1 interacts with similar fields as in the pack C and as they are ***stronger***, they would create a much stronger Magravs strength set. This, leading to the creation of a new Magravs zone, **near** the initial Magravs forces of the G1.

Due to its ***higher*** *pmtics strength*, this new Magravs system denoted as the G2 (Fig. 11) and it would have a separate distinctive characteristic. The new Magravs set possesses **a much stronger field** due to its stronger pmtics, which initiated its creation. This new and stronger Magravs will ***exert forces on the G1*** (Fig. 10), this making the pmtics constituent of the G1 a denser environment as the seat of the Matter (solid, liquid, gas) components of the plasma.

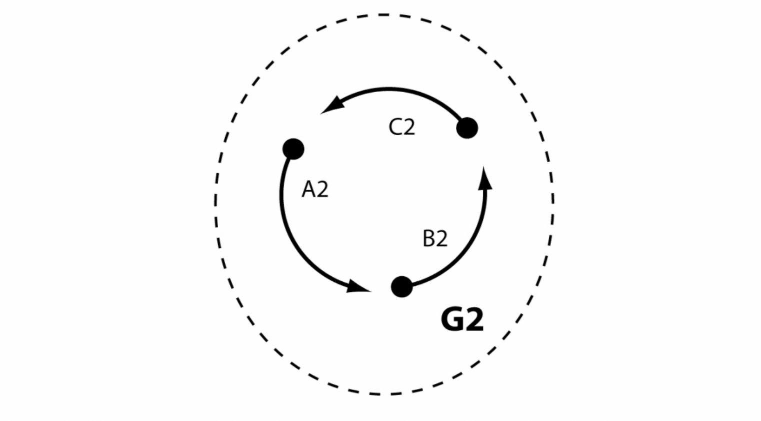

Fig. 11: The pmtics of the second Magravs.

Hence, this new interaction of fields creates a separate and stronger Magravs zone G2 (Fig. 13) adjacent to the G1 (Fig. 13) and in the same environmental plasma condition as G1. This new Magravs G2 (Fig. 11) is independent and interlocked to the initial Magravs of Matters of G1 but it will not interfere with the operation of the G1.

In fact, the Magravs forces within the G2 (Fig. 12) and its surroundings become the seed of another Matter in the same environment.

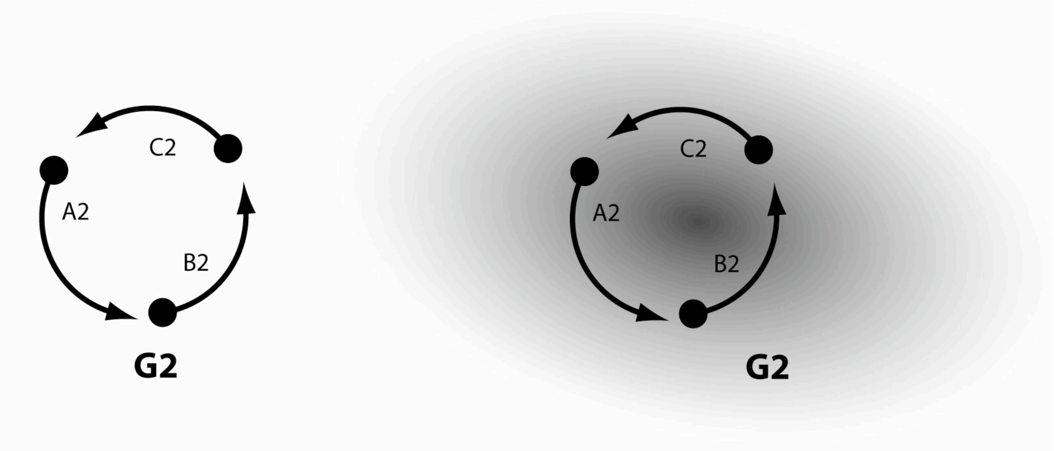

Fig. 12: The Antimatter Pmtics and Antimatter pmtics Magravs.

This new and stronger Magravs force, due to its stronger plasmatic Magravs interactions and its transparency, become what is known as the Antimatter part of the plasma (Fig. 12 G2).

For clarity, the new stronger magnetic fields interaction between the SET P1 and the pack C, and creation of the Magravs force of G2 (Fig. 11), becomes part of the **SET P2** (Fig. 13).

Where, now this new set includes the G1 the Matter and the G2 the Antimatter and the remaining pmtics of the three original packs. Where, the weaker Magravs of the G1 and the stronger Magravs of the G2 co-exist next to each other, and are interlocked to each other by the original three pmtics fields in the original packs, which they originally shared (Fig. 13). Through overall Magravs of the two Matters in respect to each other, these two Matters' Magravs keep the rest of pmtics of the original three packs together and around them.

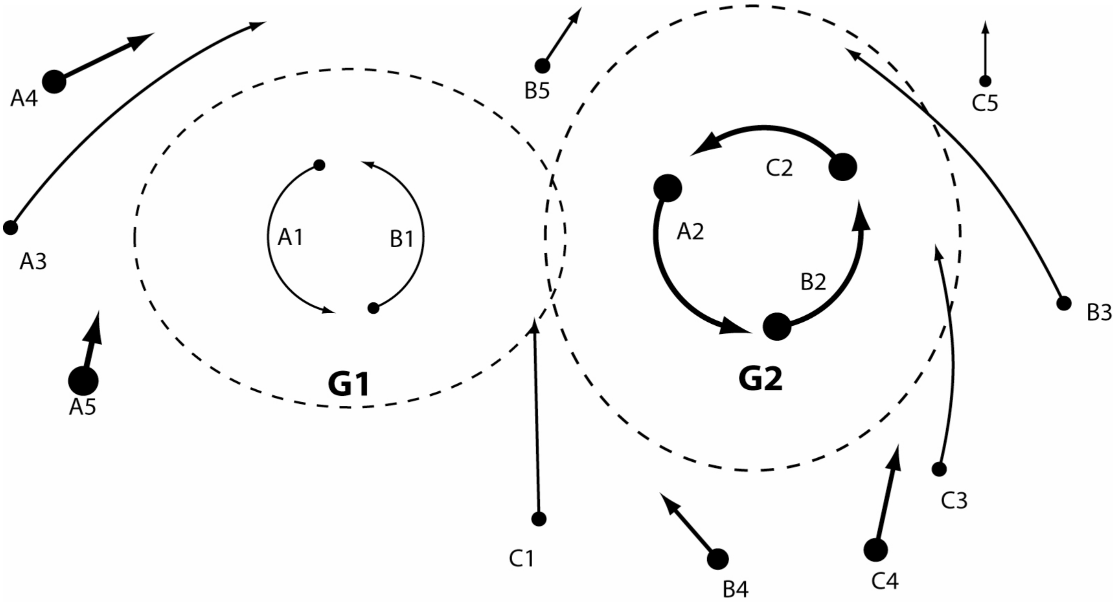

Fig. 13: Set P 2. This set includes pmtics and the Magravs of the Matter, the Antimatter and residual pmtics of 3 original packs.

This interaction of two different plasmatic Magravs sets of different strengths is similar to the plasmatic Magravs set forces operating in independent celestial bodies of the solar systems the like of the Earth and the Sun, where, the Earth can be considered to be the G1 pmtics Magravs and the Sun the G2 pmtics Magravs of the set.

Creation of the Dark Matter of plasma

The **third step** of the same interaction of the pack A, B and C pmtics, is from the other residual fields of these packs. Where some of the *residual* magnetic fields will generate a new Magravs force environment, the like of the G3 (Fig. 14). The G3 gravitational field force is a part of the same set of the same plasma environment as the G1 and the G2.

This new Magravs force zone of the G3 is created through the same process as the other two Magravs, with a difference that the outward Magravs strength created by G3 are in magnetic fields strength balance with the overall pmtics strength created by the G1 and the G2 and other pmtics within the environment of the original three packs of pmtics.

This G3 is independent from the magnetic fields of other two Matters of the plasma. But these sets overall Magravs are ***near equal*** or are ***in balance***, in respect to the pmtics of the overall enclosure of the plasma and of all the three original packs and the two gravitational sets of G1 and G2.

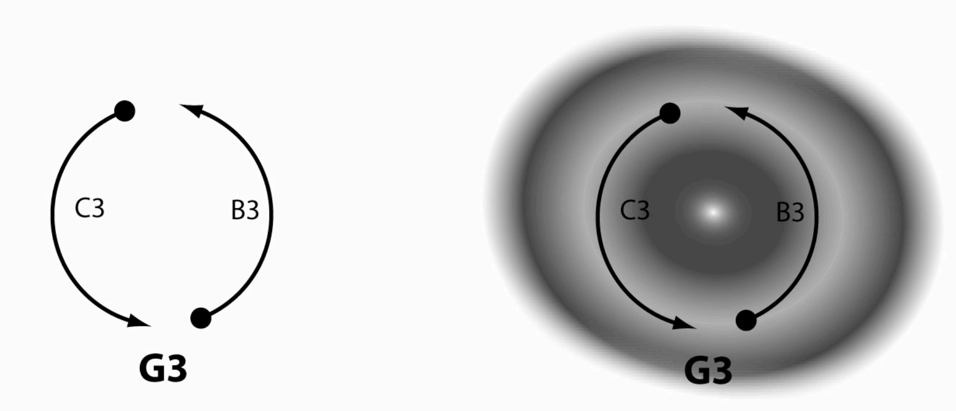

Fig. 14: The schematic and pmtics representation of Dark Matter.

Hence, even though this region of the plasma possesses Magravs forces, but it appears to be void of external magnetic fields, or this region appears to be void of a magnetosphere. Where, in the interaction of the G3 Magnetic fields with its surrounding magnetic and Magravs of the G1 and the G2 of the same environment, these fields of the G3 fail to create a visible and distinguishable magnetosphere for the G3 set with other magnetic fields in its surrounding environment. Therefore, as there are no interaction between the overall balance of the Magravs of the G3 with its surrounding pmtics, thus no visible or may be very little detectable light due to the interaction magnetic fields of the G3 with its surrounding pmtics are produced, that these could create light that could make this new gravitational centre to be detectable. Which this light can confirm the existence of another internal gravitational fields of another Matter in this region of the plasma.

Even though there would be a gravitational field force in this region of the plasma, which confirms the existence of another Matter in this region of plasma. However, the G3, due to the balance external Magravs interaction with other fields around this region with the lack of stronger external magnetic fields to create more profound detectable light in comparison to the G1 and the G2 magnetospheres within the plasma, makes this region around the G3 darker in respect to the rest of the plasma environment (Chapter 7).

Nevertheless, this region possesses pulling field forces or gravitational field forces but will not be as visible or detectable as the rest of the plasma, or will be darker in comparison, due to a lack of the stronger magnetospheric interface (Fig. 15 **SET P3**).

The G3 gravitational field force region, due to its dark appearance, becomes the Dark Matter component of the plasma (Chapter 14).

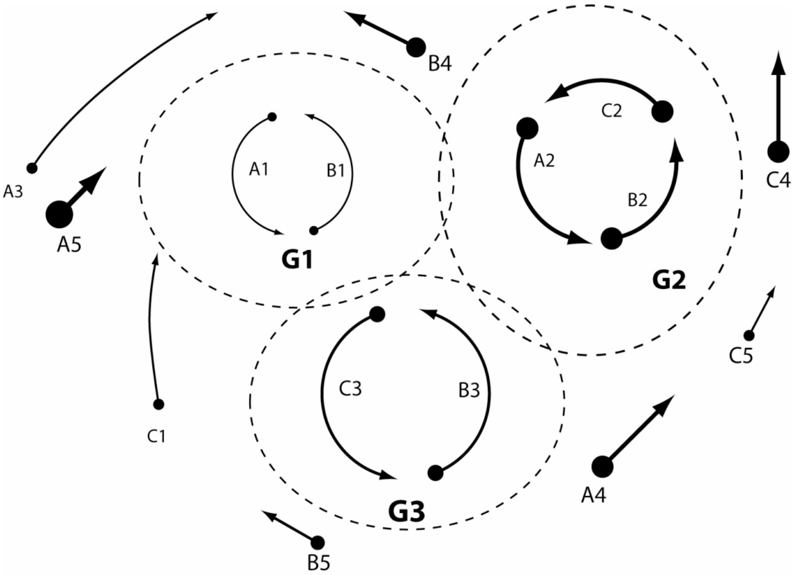

Fig. 15: Set P3 interactive gravitational fields of a Matter, Antimatter and Dark Matter.

In the past papers (36) and the Dark Matter chapter, ***Keshe Theory of creation of Dark Matter*** considers' and explains' that "Matter which possesses both Magravs, but where the overall Magravs strength are *in balance or near balance* in respect to its environments pmtics strength, so much so, that these regions do not create any or create only a very little magnetospheric visible light zone through the interaction of their pmtics (Chapter 7), that the Matter cannot become detectable or become visible in respect to its surrounding environment at specific given time and position, hence the Matter Magravs magnetosphere appears to be darker in that part of given environment, hence the term **Dark Matter**" is used.

These interactions and principles of how Dark Matters are generated have been explained and discussed in detail in the paper titled "The creation of Black Hole" (13), "Creation of Dark Matter" (36), "The rings of Saturn" (39) and further in different following chapters in this book.

We consider the creation and appearance of the Dark Matters, Black Holes, Dark Spots on the surface of the Sun and Dark sections of the rings of the Saturn, are all to be due to and through the same fundamental principle of the interaction of equal plasmatic Magravs strength forces in their given specific environment at a specific duration of time as in the G3 (13, 14, 17, 18, 24, 36).

Nevertheless, the Magravs forces of the G3 will be interacting with the rest of the plasma Matter's field's forces. The G3 pmtics released partially will feed the plasma's of other components of Matters for their motional energy and in keeping the gravitational field forces of the G1 and the G2 intact and overall to keep the plasma as one integrated system (Fig. 15).

Creation of the torus field force

The **fourth step**: Further on in this process of interaction of three original packs of pmtics, and due to the dynamic characteristics of the other three Matters Magravs, soon ***some of free pmtics*** left in the overall initial three packs will come to be positioned in the centre of three Magravs forces of the G1, the G2 and the G3, and becomes the **interlocking force** between the three. The free pmtics become a dynamic swirling compact of residual of *un-matching pmtics* field strength and behave as a partial sphere of rotating magnetic fields forces to be known as the **F1** (Fig. 16) part of the plasma.

C1 A3
F1
C1 A3
F1

Fig. 16: The spherical torus field force.

These free F1 pmtics, due to not being able to find equal magnetic fields strength partners to establish themselves as a Matter condition phenomenon, this portion of the interacting fields become void of central gravitational field forces.

As the G1, the G2 and the G3 are in continuous motion, and as these three Matters lose their energies and momentums, due to their long-term dynamic activities, they come close to this inner field force region of the F1 and in contact with its pmtics forces. This is the point where, the three Matters of plasma gain momentum from their interactions and encounter with the dynamic magnetic fields forces of the F1 (Fig. 17).

This dynamic pmtics region in between three dynamic Matters can be compared to an empty spherical torus shaped field force effect (F1) (Fig. 17), as the field forces turn inwards, without any central gravitational field forces strength, and without any matching pmtics to generate any viable internal gravitational field force for the creation of any Magravs to lead to the creation of any Matter types.

In practice, the conversion of the pmtics of the F1 into energy, partially allows the balanced dynamism of the whole plasma to be maintained.

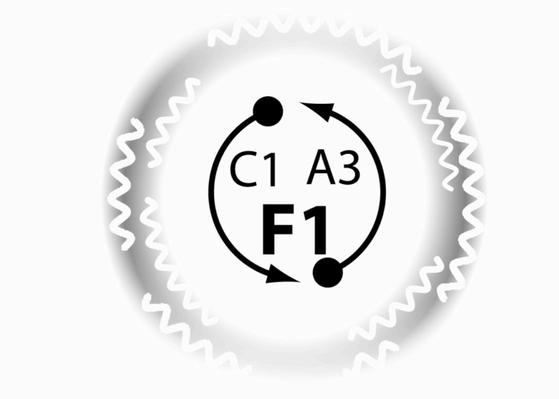

Fig. 17: Spherical torus shaped pmtics made by interaction of different strength residual pmtics of the three original packs.

F1's are considered as a natural process and phenomenon in the plasma and in the universe, with the content of larger order of magnitude difference in pmtics strength in their constituents.

This dynamic spherical magnetic fields force region of the F1 in plasma or in space, void of central gravitational field forces, is commonly called a ***Wormhole***, and its operation of its field's forces in motion as Wormhole effect.

It has been hypothesized in the past by scientists that such a Wormhole can be used for inter-space travel with extreme speeds of motions near the speed of light.

We consider that these dynamic magnetic fields regions can be used to increase the speed of any object, which comes in touch with their dynamic magnetic fields. In fact the fast journey of the object through the F1, will not necessarily lead the Matter to anywhere rather than giving a turbulent fast ride within the structure of the plasma.

In case of wormhole in a galaxy, the object will have a fast speed travel without much control in speed and dictating the point of final destination of where the object might end up.

These are points in space that acceleration for motion for other Matters of the plasma or physical matters can be obtained, by using the dynamic pmtics forces of the F1 in plasma or space, where these forces happen to exist. Finding these points in space are much easier than ever thought before (Future publication).

Initial structure of Matters of plasma

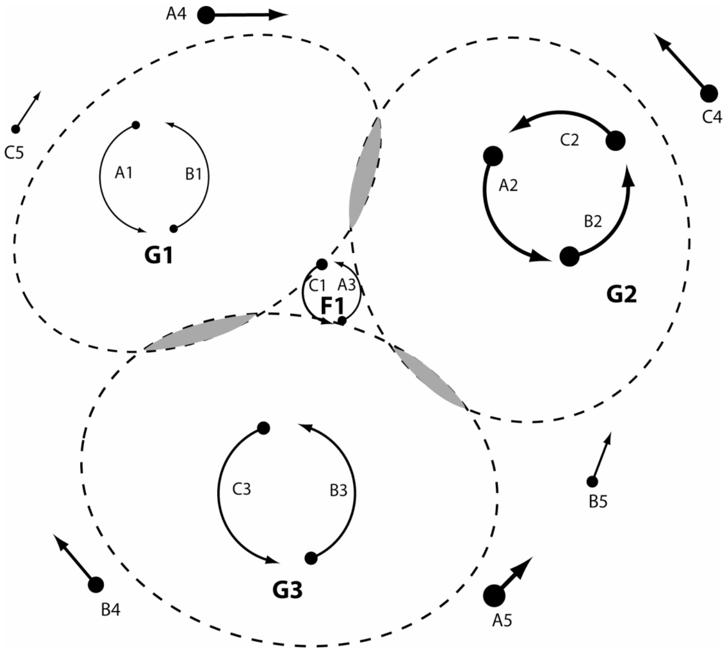

Fig. 18: Set of interaction between the three Matters and the F1.

Even though each of the three Matters are separate and operates independently from other Matters within the plasma, it is possible that from time to time the magnetospheric envelop of each Matter comes in touch with other magnetospheres of Matters of the plasma and creates a common ***interface*** in the region for the window of time of the interaction (Fig. 18 shaded areas).

It is important to note that plasmas can possess several G3's and F1's of different pmtics strengths in its overall entity for some time, individually or simultaneously, at different time in its life cycle.

Transition-zone pmtics

The new overall interaction of all three Matters and all fields of all pmtics of all three Packs, as one entity, leads to the creation of the initial Matters and Forces of the plasma (Fig. 19).

At this point, there could be other pmtics of the three original packs within the structure of plasma that could not link or be part of the components of the three Matters and the F1, these free leftover pmtics literally float in the plasma and over time, they become the feeding pmtics for one Matter or another and the interlocking magnetic fields forces of part of the other Matters of the plasma.

These loose pmtics in-between interfaces of Matters are the dynamic plasmatic magnetic fields transition zones, which we call "***the energy transition zones***" (Fig. 20, the field arrows), in the overall structure of plasma. The magnetic fields in these intervening gaps among the Matters are fields that are mutually shared by all Matters in the plasma, when there pmtics strength comes to their level; these residual pmtics are considered more as a mixture of magnetic rays than pmtics.

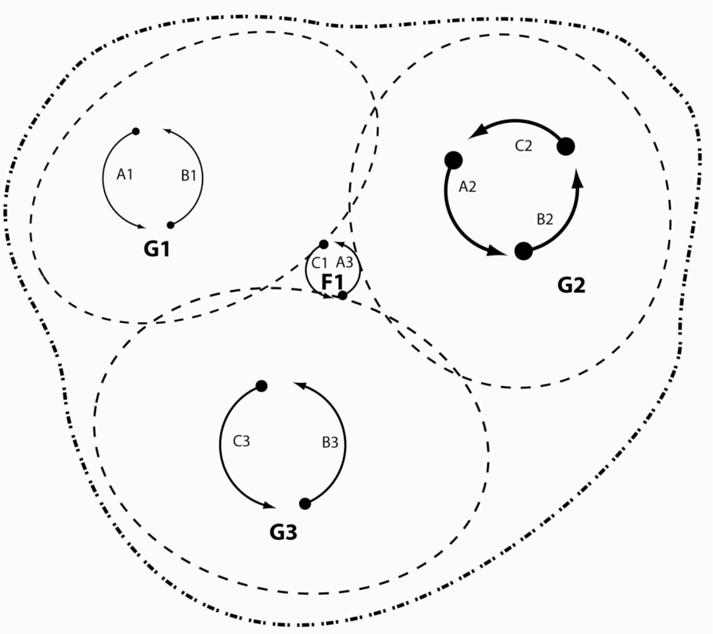

Fig. 19: Initial Matters and forces of the envelope of plasma.

They are in the plasma, like intermediating or interface zones in between two or more

Matters of the plasma at the same time.

Now that all the plasmatic magnetic fields of the three original packs are considered and counted for and used up, now we consider that the full set of the G1, the G2 and the G3, loose pmtics in the transition zones and F1, create an overall **integrated** independent Magnetic field and gravitational field of their own to keep the integrate of all pmtics of the three Packs A, B and C, together as on entity. Where this new entity becomes to be known as the "Initial Fundamental Plasma".

Initial Fundamental Plasma

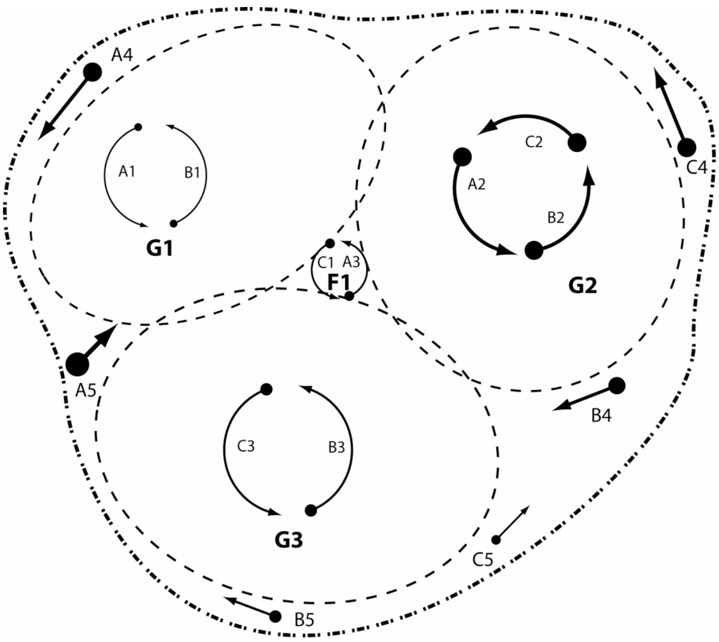

Fig. 20: Keshe Model of the Initial fundamental plasma.

I call this dynamic concept the **Keshe Model of *"The Universal order of creation of Matter"***.

We consider the Initial Fundamental Plasma to be similar to **the construction of the Neutron** (Fig. 20).

Figure 21 gives the conceptual presentation of complete plasmatic magnetic fields of plasma, of "**The universal order of creation of Matters**". This model represents the pmtics structure of the **Initial Fundamental Plasma**, where the G1 is the Magravs of Matter, the G2 is the Magravs of the Antimatter and the G3 is the Magravs of the Dark Matter.

It is considered that Initial Fundamental Plasmas always have an internally balanced magnetic fields environment, as one observes in the plasma as in the solar systems.

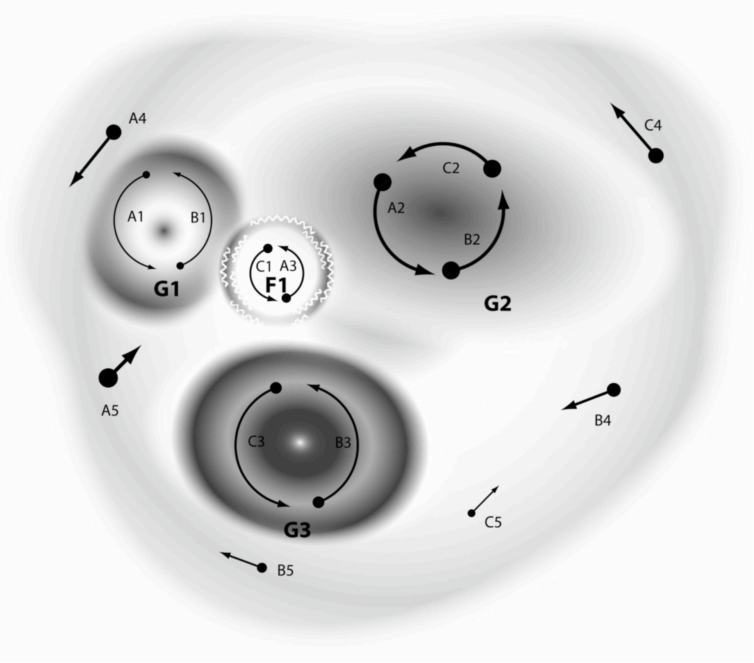

Fig. 21: Keshe Model of the pmtics of Matters of plasma.

At the same time initial fundamental plasma maintains an overall and external Magravs created by Matters and all pmtics, which are within the confine of the plasma too. Thus the internal balance magnetic fields of the neutron does not mean that it does not possess Magravs in respect to its outside environment. But due to the existence of Magravs of its component structure the initial fundamental plasma maintains an independent magnetosphere in respect to its surrounding environment.

When, contemplating on discussing about the proton or the neutron as a plasma, one has to talk about the whole of the plasmas' components, namely, the *Matter* part (what has been considered as the matter part of the nucleus of the atom), the *Antimatter* part, the *Dark Matter* part, the *spherical torus magnetic fields* and the *transition magnetic fields parts.* These are all together ***the components of one plasma*** and have to be considered as one package and entity.

There cannot be a plasma condition, where all three Matters do not participate in the existence of the plasma.

Decay of initial fundamental plasma

At the point in the cycle of the life of an initial fundamental plasma, when the shared magnetic fields of the transition zones, or pmtics of one of the Matters of plasma are partly exhausted and the Magravs balance among or in the Matter fields are disturbed and the Magravs binding forces are unbalanced, then the initial fundamental plasma disintegrates to its substructure of new balanced Magravs of the same Matters for the initial fundamental plasma to find a new balanced combination within its own Matters and fields within their given environment.

This process of splitting of the initial fundamental plasma to find new and smaller balanced plasmas for Magravs of Matters and fields balance, I call this process the **decay of the Initial fundamental plasma.**

The decay of the initial fundamental plasma always leads to the creation of at least two new balanced and smaller initial plasmatic magnetic fields plasmas of the same configuration, with, one plasma which possess more of the Matters and is larger, and one plasma which is a smaller and holds less of the Matters and pmtics of the original initial fundamental plasma. Nevertheless, the two new plasmas and their contents have to keep the overall balanced structure of the initial fundamental plasma. This happens so that both plasmas can survive within their environment as one entity.

The outcome of the **decay** of the **initial fundamental plasma** into two new components is considered to become the creator of the new ***proton*** and the ***electron*** of an atom. This new balanced pmtics entity, or so-called atom; itself has to have an overall balanced Magravs forces operating within it, for the atom to keep the integrity of the original initial fundamental plasma.

The decay of the initial fundamental plasma leads to the splitting of its content into a proton and an electron simultaneously (Fig. 46 diagrams 1 to 8). Nevertheless, at the same time as the new plasmas' component reposition and rebalance during this process of decay, this leads to the release of some residual pmtics or magnetic fields, which are not needed for or by the two new entities for their respective parts of their Magravs positioning (Chapter 18).

The release of the unwanted fields for the balance interaction between the two new plasmas, leads to the release of the magnetic fields packs as different rays or energies from the splitting of the initial fundamental plasma. This release can be in any form like a mixture of rays, pmtics, sound energy packs and so on.

I consider this ***process of the decay*** of the initial fundamental plasma of the contents of its three Matters and fields to be a **new** fundamental universal principle, where in larger scales of order of magnitude; it is called the nuclear decay of atoms.

In science at the present, scientists consider that elementary particles are quarks and so on, but now we know that ***quarks*** *themselves are further* ***made-up of basic magnetic fields and their interactions***. Where, ***collections*** of magnetic fields in a group, as dynamic plasmatic magnetic fields, and their interactions with other dynamic plasmatic magnetic fields, leads to the creation of the Matter(s). Where, the mass of the "quark" is produced by the interaction of these plasmatic magnetic fields through the principle of the creation of gravity as has been explained in Chapter 1.

Secondly, what is at the present called the spin of the quarks now we understand is the natural dynamic motion of the Matters created in the plasmas' environment, through the interaction and Magravs positioning of the dynamic Matters of the plasma.

Thirdly, what is considered by the present science, as the *colours of the quarks*, are in reality the different contents, of different plasmatic magnetic fields strength interactions leading to the creation of gravity and Magnetic fields with their overall interaction effect in respect to their environment pmtics, which leads to the creation of the magnetosphere of each Matter of the plasma, these being the magnetosphere of the Matter, the Dark Matter and the Antimatter in the magnetic environment of the plasma or the neutron, the proton or the electron.

This means that the quark cannot be considered as an "elementary particle" as it has sub-components and is made of magnetic fields itself.

Thus, ***I consider the new "elementary particle" to be of the "magnetic fields" origin,*** which this itself explains why one sees all sorts of effects, like the present quarks, bosons and the spin of the dynamic Matters of the plasma, and so forth. Where, these all can now simply be explained as being due to the interaction of different magnetic fields strengths, which makes up the structure of the Matters of the plasma and the other magnetic fields, which are within the structure of the plasma.

Even in the largest scale, this initial fundamental plasma decay model is what cosmologists see in the galaxies as the collapse of stars (which the star is and can be considered to be the initial fundamental plasma) and its re-emergence as new smaller components of star or solar systems. By the same principle, the release of energies for the star to find its new balance through its star decay always leads to releases of vast amounts of unwanted matters, Matters and energies and creation of sub-components but still with its Magravs forces.

This decay of initial fundamental plasma is discussed in more detail in Chapter 15.

CHAPTER 4

Matters' of plasma and their transition of states

There is conclusive evidence to show that plasma possesses energy, and maintains specific magnetic behaviour, and that plasmas can and do generate their own Magnetic fields and gravitational field forces.

Research done by a number of institutes around the world indicates that the plasma of Matter is accompanied by a second Matter constituent called the Antimatter. Some institutes (6, 7, 8) claim that they have separated and have managed to contain the Antimatter.

In other sections of science, scientists refer to what is called the **Dark Matter**, and observations of virtual matters.

The world of science has failed to consider the creation of all these three states' of Matters (Matter, Antimatter and Dark Matter) as constituents, and as of one process, in the chain of initial progressive process of creation of the three Matters and as the content of one plasma in the universe.

This failure has been due to the lack of understanding that the Matter, the Antimatter and the Dark Matter components of plasmas are all created simultaneously and as one integrated dynamic plasmatic magnetic entity.

It is fundamental to understand that one of these Matters' does not exist without the others within the overall structure of the plasma. Then through this process, it becomes easier to understand the operation of Matters, matter and fields, plasmas, atoms, molecules, solar systems and galaxies.

One can now translate this new understanding of how plasmas are created and operate into how larger celestial objects are created, and operate in their given environment collectively. In other words, we translate the knowledge of the operation of electrons around the nucleus to the operation of planets around their stars.

To understand the relationship and construction of the plasma with more clarity, every effort in this book have been made to go through stage by stage, how **Matters** of plasmas are considered to be connected, and *appear* **to inter-transit from one state of Matter to another** within different environments without loss or gain of any of their plasmatic magnetic fields strength.

In the matter world this is like the inter-change between states of matters, from solid-to-liquid, liquid-to-gas, and vise-versa.

Where in the matter world the ***state-of-matter*** is *magnetic fields'* **forces** dependent, and in the ***state-of-Matter*** it is *magnetic fields'* **strength** dependent.

The phenomenon of transition from one state of Matter to another is a regular occurrence in dynamic pmtics processes in the spans of the universe (Fig. 21).

All components of Matters of the plasma or any Matter or matters in the universe are connected to each other through the interaction of their pmtics, and their pmtics strength, which are the constituent and the creator of their Magravs.

Thus, as each Matter gains or losses some of its pmtics, one Matter component of the plasma will become or can become the component of another Matter of another plasma or field at "a given point in motion of pmtics" (time) and at a given point in its space.

For example, Matters of plasma can interchange from one Matter to another due to their motion of dynamic pmtics or what is called energy levels changes in respect to a given environment pmtics strength.

All Matters can appear as different Matter by just changes of the environmental pmtics strength too. For example the same plasma or Matter by just passing through another region of different pmtics strength. This is the process what we call *transmutation*, but in this case the transmutation is done by the environmental condition and not by the internal Matter pmtics strength change.

Matter can appear as different Matter, for example Dark Matter can appears as Matter by *simply entering into a new pmtics environmental condition*. This is how Dark Matter suddenly appears as virtual matter.

For example, **Dark Matter** in a given environment of plasmatic magnetic fields strength by entering into a new and stronger or weaker pmtics strength configuration, instantaneously, becomes **visible Matter** in respect to its newly entered environment (Dark Matter to Virtual matter). I call this the ***phase of transmutation of Matter(s)***, so this is the unveiling or occurrence of a new state of Matter from the same old Matter in a different outfit.

Secondly, Matters can change their status and behaviour from Matter to another for example from Dark Matter to Antimatter or Matter, by simply ***gaining from*** or ***losing to*** a part of their plasmatic magnetic fields strength to other Matter(s) or pmtics in respect to their given environment.

If Antimatter Magravs strength reaches an environment pmtics strength that its overall Magravs strength becomes equal and in balance with its new environment pmtics strength level, then the Antimatter can become and behave as the Dark Matter entity in respect to its new given environment (Fig. 22).

On the other hand, for example as the pmtics strength of the components of Antimatter reduces or as Antimatters interact with other Antimatters of different Magravs strength, these Antimatters lose enough of their Magravs strength that one or both Antimatters come to a new balance of plasmatic magnetic fields strength. Where, these balances can be in their internal and external Magravs, then these Antimatters Magravs strength can come to a level that the new strength of the former Antimatter become to be in the pmtics strength level of the Matter, or change to the Dark Matter field strength level status in respect to the same environmental condition.

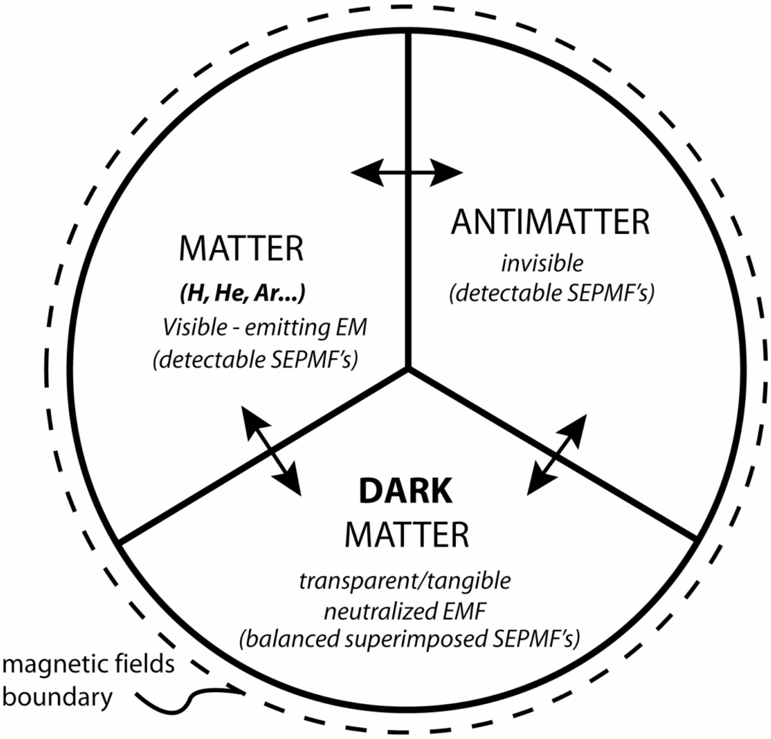
MATTER
(H, He, Ar...)
Visible - emitting EM
(detectable SEPMF's)
ANTIMATTER
invisible
(detectable SEPMF's)
DARK
MATTER
transparent/tangible
neutralized EMF
(balanced superimposed SEPMF's)
magnetic fields
boundary

Fig. 22: Schematic Keshe model of interconnection relation between different states of Matters.

This is what we call the ***Keshe Theory and principle of the transition of Matters***, that is to say "***the transition from the Matter to the Antimatter or the Dark Matter and in reverse, and the transition of the Dark Matter to the Antimatter and in reverse, is a normal condition of transition of the Matters"*** (Fig. 22 and Fig. 23). These figures showing in a simple and new way how and the connections by which interchange(s) between the states of Matters in the universe are achieved.

Keshe principle of transition of the Matter states' that, "the plasmatic magnetic fields strength of the environment in which the Matters operate in, ***dictates*** what the Matter appears as or presents itself as, in that given environment" or on the other hand "when one Matter gains or losses enough of its plasmatic magnetic fields strength that the Matter Status, characteristic or behaviour becomes of other Matters of the plasma status and behaviour or characteristics within the same given environment".

Therefore, Matters can change from one Matter to another by increase or decrease in their pmtics strength or they can appear as different Matter as they enter different plasmatic strength environment and conditions.

That is to say, the Matter can become to have the characteristic of the Dark Matter in a given environment pmtics strength, and by the same measure, the Antimatter can lose enough of its pmtics to become Matter, and so one. The schematic transitions of state of the Matters are shown in figure 22 and figure 23 of the ***Keshe model of transition of Matters.***

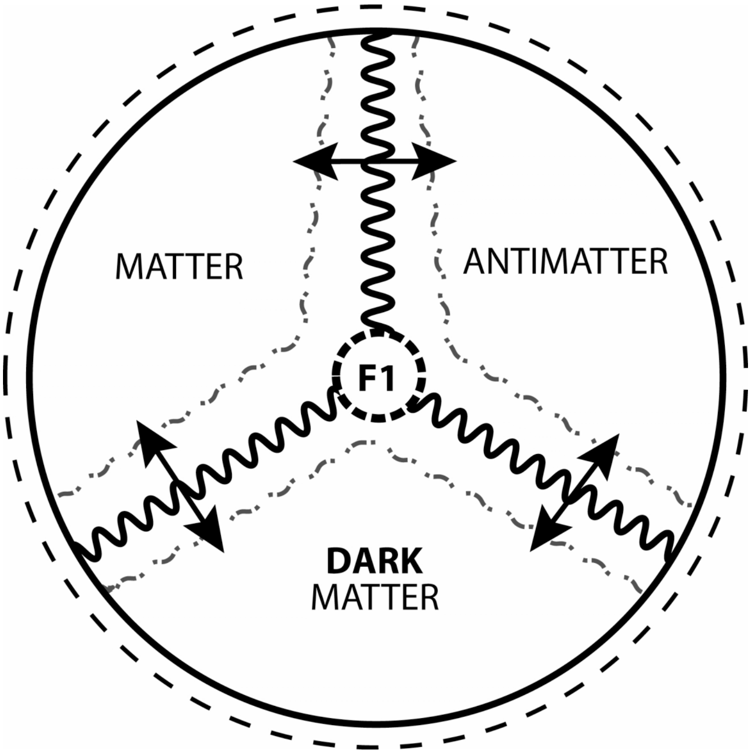

Fig. 23: Keshe universal Model of the plasma transition of plasmatic magnetic fields and Matters.

With the use of simple pmtics plasma dilution reactors, which have been developed by Keshe Foundation through its Keshe Technology development sector, the principle of transition of Matters have been tested and results have proven to be in line with the theoretical consideration.

Where, in these nuclear-based reactors, Matters can be allowed to go from one state of Matter to another and then allowed to return to their original state of Matter. This new method of transition of Matters brings about a new way and technology of producing all man’s material needs for motion, energy, creation of new matters and so on.

For example, effects and properties of transition of Matters (Fig. 23) can be used to make physical Matter to have no magnetospheric boundary as Dark Matters do in a given environment, so that the Matter behaves like the Dark Matter in characteristics. In these environments, the Matter will become translucent dark or the centre core behaves as becoming invisible in respect to its surrounding environment, without any change in the property of the physical Matter or change in its gravitational field strength or position in space of the Matter.

As the Matter with this property presents no effective magnetospheric condition in respect to its surrounding environment due to the lack of /or little interaction between the pmtics of the Matter and its environment, then the Matter now can behave as Dark

Matter and move without friction and freely within the same environment.

Utilizing this state of the Dark Matter effects around an aircraft or spacecraft, this condition will give the craft frictionless motion and higher speeds and possible invisibility in the same environment (Chapters 13).

The technology of transition of Matters has been tested-out over years by the Keshe Foundation, and several systems were designed, developed and manufactured and used to achieve the formation of original magnetic fields plasmas to prove the correctness of these principles, and indeed the effect of transition of Matters were proven to be correct.

The implication and application of the use of transition of the states of Matters are so immense and profound, that one needs to know, for example, where the Matter will end-up in, and in what state of Matter in respect to its environment, one will appear as.

That is to say, one has to know if for example, going from Matter to Antimatter, where in the strength fields of Antimatter, one will end-up in. Vice-versa, when one can go from Dark Matter into a Matter condition zone, one has to know in what state of matter (gas, solid, and liquid) one will come to ends up in.

Through the operation and control of these reactors, one needs to know where the system state of matter and magnetic condition will end-up. This could be in liquid seas, or in the middle of a solid Matter or in the middle of deserts. Without being prepared for these parameters through the operation of systems, which can facilitate such a transition behaviour and characteristic, the use of Matter transition can have catastrophic consequence, not only for the system, which produces it, but also for the occupants of possible crafts using this type of transportation in the spans of the universe.

By the understanding of the principles of creation of the initial fundamental Matters within the initial fundamental plasma, through the interaction of the initial fundamental particles, a number of unanswered questions in the world of science can be answered.

For example, in the universe the total quantity of plasmatic magnetic fields and the related energies are to be considered ***constant***. Therefore, *in the **totality***, no matter, Matters or magnetic fields will ever be lost or gained in the universe. Pmtics of different strength start existence at one strength level and they consolidate to become stronger, or lose their field strength through division and collision to become weaker in strength. Nevertheless, pmtics in their different strength fields can never be destroyed or lost.

Therefore, pmtics simply interact, divide, and interlock to produce different Matters and conditions like forces, motions, heat and compactness for them to be matters to be visible to the eye of creatures, according to their positions, and so on.

Pmtics in their interactions with others of the same can only move from one state of Matter to another depending upon the condition(s), which prevails at a given point in a given time in space. Thus, the Matter can go from the Dark Matter to the Antimatter and vice-versa, and the Matters to the Dark Matters and vice-versa and so on.

Therefore, the theory and the discussion that universe one day will run out of matters and energy and then there will be nothing as has been promoted by some scientists in the recent past is anything but a fallacy.

By the same principle, we call the **pmtics in motion as** the **energy** of the pmtics**.** These pmtics in motion can release and can lead to creation of the same Matters as they were created-out of, and can have the same capability. That is to say, for example, the energy of the Dark Matter can change into energy of Matter, or part of the matter, and the same applies for other states of Matters.

In understanding, the principles of "**the universal order of creation of Matters**", one can utilise the transition of states of Matters and matters to take full advantage of universal Matters and matters pmtics and their energies.

Through the permanent interaction of all dynamic pmtics of different scales of strength, there will be no end to the universe, as the universe moves through its different pmtics strengths field interactions and repulsions. Where, these will lead to eternal motion of the universal pmtics forces and creation of new Matters, matters, forces and new condition for them to cooperate within the universe. Thus, there never has been a Big Bang and there will never be a doomsday scenario for the universe as a whole, the universe will be forever in equilibrium in its overall universal order of pmtics.

The pmtics of Matters will ***transit*** from one state of **Matter** (Matter, Dark Matter, and Antimatter) to another state of **Matter**. In addition, from one state of **matter** (solid, liquid, gas) to another state of **matter.**

Where, these changes will depend on the properties and forces of the states of plasmatic Magravs and their strength in respect to each other. Similarly, pmtics from strength of fields of Matter will transit to pmtics of different pmtics strength of Matter, in these ***processes of transition***, plasma releasing dynamic pmtics in motion as **energy**.

The real size of the universe will never change; that is to say, the universe cannot expand into a space if the space for its expansion was not there to begin with. Where, from our point of view we only observe a small fraction of the whole, which we observe that fraction expanding. The observed expansion is relative to the position of the observer in respect to a given position in the universe, for example what will be a red shift observation of one at one end of the universe, this will be blue shift to an observer on the opposite direction of the motion of the same entity. In the paper titled "Creation of magnetic fields" it has been explained that the ***blue shift of light*** is created when ***pmtics are compressed***, and the ***red shift is created*** when the ***pmtics move away*** from each other, or ***when pmtics are opened up***.

In the real world of the universal order of creation there is no room for the principle of singularity. Except, if, we would call, a large pmtics, that covered the whole of the universe singularly by itself. Then all that has happened, is that the original single plasma has gradually disintegrated to smaller and weaker strength fields, which their interaction has lead to the creation of what has been seen and is in the present in the short time of the life of man on the Earth. Then, such original singular plasma, which covered the whole of the universe, had to gradually to disintegrate to smaller strength fields, which their interactions have lead to the creation of all events, Matters and matters in the Universe.

The transition of state of Matters principles will be discussed in full in future disclosures.

CHAPTER 5

Definition of Energy Through pmtics

The initial components and construction of plasma are due to the existence of initial dynamic plasmatic magnetic fields.

For a magnetic field to be able to be detected or its existence to be confirmed, the pmtics has to *leave the confines of the boundaries* of its containments, this being the boundary of Magravs of the Matter or the plasma.

It is important to keep in mind that the pmtics do not possess or show **field force** unless they are in motion.

The energy possessed by a plasma can be define as "the total plasmatic magnetic fields forces of all its constituent Matters *and fields in motion,* in respect to the original position of the plasma in a full three hundred and sixty degree spherical direction''.

This is an important factor, as up to this point, scientists have measured and calculated the energy of the Matter component of the Matters of the plasma. Where, in calculating the true energy of the plasma, *one has to calculate the energy of* ***all Matters*** (Matter, Antimatter and Dark Matter) and the other components of the dynamic plasma.

When the magnetic field has left the Matters' or the plasmas' boundary, at this point its existence and the content of the pmtics strength of all Matters pmtics' released can then be confirmed as energy. This is shown in (Fig. 24), the magnetic fields in the Matters.

The pmtics constituent constructions of individuals Matters of plasma are not energies in respect to other Matters while they are within the boundary of the plasmas Magravs' forces. These are shown as the magnetic fields inside the Matters on the left of image (Fig. 24) but are *only forces* (these being the like of Magnetic field or gravitational field forces) in respect to other Matters and pmtics.

When the field leaves the environment of its Matter or the plasma, it is at this point that it can release its domain pmtics to other plasmas in regions or combinations of field interaction zones. These are shown as field forces A at the boundary of the plasma in figure 24.

As the plasmatic magnetic fields, moves further from its original plasmas' boundary (field B in Fig. 24), the plasmatic magnetic fields uses' its energy to overcome other Magravs in its environment. Hence, as the plasmatic magnetic fields moves further away from its mother plasma, the less energy it will have to transfer to other plasmas as it comes into contact with their pmtics.

Thus, energy transfers from one Matter to another Matter through one pmtics strength and the measure of the pmtics possessed at the point of the contact with the second Matter, this is position and distance dependent, from the point of departure to the point of arrival.

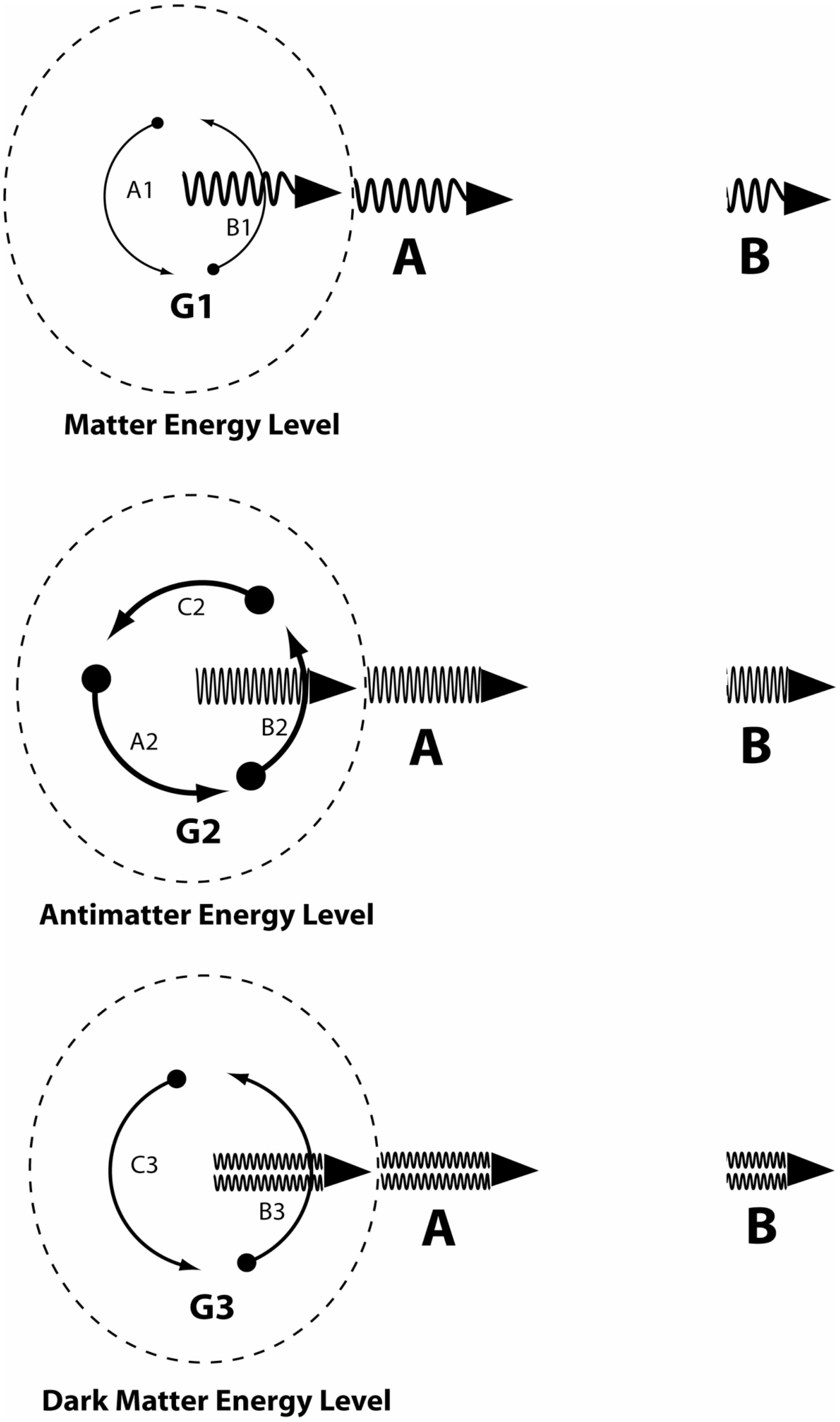
A1
B1
A
B
G1
Matter Energy Level
C2
A2
B2
A
B
G2
Antimatter Energy Level
C3
B3
A
B
G3
Dark Matter Energy Level

Fig. 24: Schematic presentation of relationship of pmtics and energy in respect to their Matters.

The total Energy released by the Matter or plasma is the total of pmtics forces that the plasma can release and transfer, and that and what measure of the pmtics can be absorbed by all components of other plasmas in its environment.

That is to say, the same proportion of magnetic fields forces by Matter, Antimatter and Dark Matter and other fields of plasma are released and the same proportion of all energy fields are transferred to the all recipient plasmas and Matters and pmtics.

The total energy of Matter is said to be the total pmtics that Matter can release as it disentangles all the components of its **initial fundamental magnetic fields**, or what is known as its' "**initial fundamental particles**", which the plasma and of the Matters of plasma were made up of, at the point of their inception.

Thus energies released by the plasma or the total energy possessed by the plasma is in fact, the total collection of initial fundamental magnetic fields of all the component constituents of the plasma, which disentangles from their Matters or plasmas and are in motion in the direction of the encountering other pmtics components.

Pmtics absorbed by some plasma's can be only a part of the total pmtics in motion, or energies that have been released by the initial fundamental plasma, and are not necessarily considered to be the total energies that a plasma possessed or has released.

Energies released by plasma are said to be "**the total initial fundamental pmtics released by all components of that plasma" passing its Magravs boundary.**

Multi-plasma atoms' release more plasmatic magnetic fields, due to their total sum of the plasmatic magnetic fields released by all their participating plasmas (protons plus neutrons, and electrons).

The principles of creation of Magravs forces, gives us an insight that "**energy**" can simply be defined as "pmtics, once released, through the dynamic Magravs characteristic boundary from the plasma or Matters, that these released pmtics can ***exert or pass a part of their released pmtics to another plasma,*** for the new Matter or plasma to maintain its existence and/or maintain constant normal magnetic fields strength and/or increase its magnetic density of the same pmtics strength condition to their ground base levels, in their given environment" (Fig. 24).

Measure of a mass

One of the central unsolved questions in the world of physics is how the mass of the Matters or of matters are created, and how they can be calculated.

Through the ***Keshe theory of Mass***, the creation and the measure of the mass of an entity can be defined to be:

"Due to the interaction of at least two magnetic rays, magnetic fields, or plasmatic magnetic fields, which the outcome of their interactions leads to and creates two field forces of a ***pulling*** field forces called *the gravitational fields force* and a ***pushing*** field force called *Magnetic fields force*, whereby the interaction of the gravitational and the Magnetic field forces with each other, this interaction of two field leads to the creation of a given magnetic fields strength **balance** between the two field forces, where, the measure of the magnetic fields difference of the interaction of these two field forces of the gravitational and the Magnetic field forces, is the measure of the Mass of the entity which the two original magnetic fields have created.”

The outcome of the interaction of the fields balance is creation of the mass of the Matter, components’ of the plasma (Fig. 25), or mass of the matter (solid, liquid or gas).

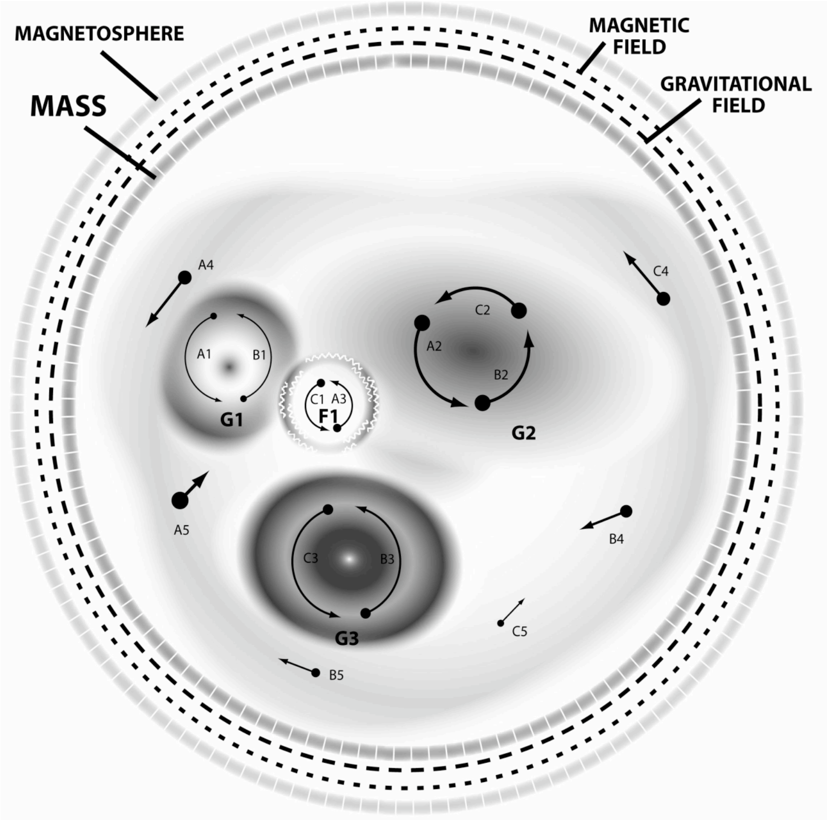
MAGNETOSPHERE
MASS
MAGNETIC FIELD
GRAVITATIONAL FIELD
A4
C4
C2
A2
B2
A1
B1
C1
A3
F1
G1
G2
A5
B4
C3
B3
G3
C5
B5

Fig. 25: Mass

That is to say by the ***Keshe law of measure of the mass*** of any entity, this being Matter, plasma, atom, matter, planet, star, etc states that:

“ **M**ass of any entity =

***M**easure of the total gravitational fields strength forces of the entity*

- (minus)

***M**easure of the total Magnetic fields strength forces of the entity*”

Through this definition and understanding it becomes clear that the gravitational field forces are always predominate and stronger as all entities possess mass, otherwise their mass would be negative.

Thus ***mass*** *is the measure of the* ***difference between two or more magnetic fields after their interaction***, and **NOT** the measure of strength **before interaction**.

Where, the measure of the magnetic fields *before interaction* is their "forces" of their fields, and *after the interaction* of the magnetic fields the outcome of the balance between the gravitational and Magnetic fields that is generated, becomes the mass in respect to a given fixed position of the central Magravs.

The creation of Magravs always is accompanied by the creation of a ***Magnetosphere*** and the creation of the mass of any entity in the universe, and all these four forces are created instantaneously and simultaneously.

That is to say, "the **Initial Fundamental four forces** of existence of an entity that are, the ***Magnetic fields***, the ***Gravitational fields***, the ***Magnetosphere field*** and the ***Mass field*** forces, are *all the outcome of the interaction and interlocking of two or more mainly matching in strength magnetic field*s or plasmatic magnetic fields, irrespective of the size of the entity, this being Matter, matter, an atom or a star.

This is the reason why the mass of any object, which is created by any two magnetic fields strength, is *independent of any external forces and factors*, like gravitational fields forces of other objects or entities. The instance the two magnetic rays or magnetic fields interlock, to generate the first Gravitational fields as an entity, at that moment the span of the Magravs of the two fields forces involved in the original fields are not as individual fields, but they become an *independent entity* in respect to their environments' fields forces. That is the reason why the **Mass of any entity**, like the Matters, are *constant and independent and irrespective of the environmental Magravs forces* which the entity exists and operates within.

That is the reason why the Mass of spacecrafts of the future, or the Mass of planets like the Earth are independent of their environmental conditions. That is to say, the **strength** of the interaction of the two **original** magnetic fields and the span of the fields they produces that created the Magravs *decide how much mass the interaction of the two fields will carry* and no other factors.

This is the reason why, Man will be able to make crafts that can carry any payload by the use of Grapos nuclear reactors Magravs strength, as the payload of these systems and the strength of Magravs that these systems generate, creates independent environment Magravs forces *as long as the boundary of the magnetosphere of the Grapos can cover the physical boundary of these crafts*. Figure 25, in its design, explains' this concept fully. That is why the two magnetic fields have to be equal in strength before they can create the initial four field forces.

If two unequal magnetic fields in strength interact, the two create the gravitational, the Magnetic, the magnetosphere and the Mass, and the lowest strength field, which dictates the maximum level of the strength of the four fields that the Matter can have. The stronger magnetic field residuals of these types of unequal magnetic field strength encounters and creation of matters become the ***tail*** **magnetic field of the entity**, and this tail is the cause of the creation of the coiling effect of these kinds of masses. Where and if the two unequal magnetic fields strength ***cannot*** create a mass, the same interaction leads to the creation of the coiling of the two fields and to what is known as the ***coiling of the magnetic fields***, this effect is partially the cause of the *swirling of the F1* torus field zones in the plasmas, and its larger counterpart, the rotation of Wormholes, as these regions in the universe are created out of unbalance Magnetic field strength interactions and interlocking, this be it in the plasma or in the universe. In so many ways in knowing the strength of two magnetic rays, magnetic fields, plasmatic magnetic fields and so on, which are about to interact and to create the initial Magnetic and gravitational fields of an entity, one can tell what would be the outcome measure of the mass of the entity they will create.

Einstein has related the mass of matter to its energy through the general equation of relativity.

As explained above, the mass of an atom or plasma itself is made of a collection of dense pmtics strength and their interaction with each other.

Thus initial fundamental plasmas always have the same mass irrespective of the Magravs of their environment.

By the same measure, the Atoms of the same elements are always made of the same number of initial plasmatic magnetic field's sub-components, of neutrons, protons and electrons.

Atoms of the same elements always have the same total plasmatic magnetic gravitational fields **pull** and Magnetic field **push** in respect to all their internal components, irrespective of the environmental plasmatic Magravs that the atoms might be in. This becomes the total mass of an atom, as mass is an expression of measurement of the total enclosed pmtics interaction within the fields of confinement of the plasma.

In considering the general equation of relativity

$$E = m \,.\, c^2$$

The energy for the mass of Matters of the plasma, accordingly will be

$$E = m(M) \,.\, c^2$$

That is to say "the total pmtics released in motion by the Matter of plasma (once they have left the boundary of the plasma) (Energy), is equal to, the total balance after interacting pmtics strength of the Matter components of the plasma (Mass) which the plasma is made of, multiplied by the square of the maximum speed that pmtics can travel in the matter environment (speed of light)".

Considering that, pmtics of different strength can travel different distance from their point of release with ***different speeds*** in *different Matters,* Matter *and* matter mediums.

Then it is correct to say that the pmtics of the Matter, once it has left the Matter

Magravs of the plasma, this pmtics of the Matter will travel with a different speed than the plasmatic magnetic fields of the Antimatter of the same plasma, or be it the pmtics of the Dark Matter component of the same plasma, in the matter environment.

The Antimatter has and is made of different pmtics strengths, by virtue that it has been created initially by stronger fields, then its speed will be different and higher than that of the pmtics of its Matter component of the same plasma in the same environment.

By the same principle, the faster field of the Antimatter carry more energy or more powerful energies than the slower pmtics in motion of the Matter component of the same of plasma.

Alternatively, in reverse, as the Antimatter possesses more power or energy than the Matter, then for the same volume of Antimatter as Matter in the plasma; the Antimatter pmtics must move faster than the pmtics' of the Matter, in the matter medium.

The Fermi National Accelerator Laboratory - or Fermilab, in USA (6, 7) - considers a small amount of the Antimatter, once released from the Matter of plasma; it can deliver more energy than its Matter parts of the same plasma. They are considering and working on the principle as; they can burn the Antimatter to release its energy so that by the time the Antimatter reaches the state of matter energy, that they can harvest its surpluses energy.

Through the ***Keshe principle of conversion of energy***, the fundamental universal conversion principle follows the path that the Matters convert to matters through their **dynamic pmtics in motion and forces,** or what is refer to as the **energy of the Matter magnetic fields forces, as these energies are transferred to the constituent pmtics' of matter**.

From what I call "The fundamental ***universal conversion principle***" follows that "the pmtics of the Matters' like of Antimatter slow down, through interaction with other magnetic fields, so that their energy can be absorbed and converted to Matters' pmtics strength levels, that become useable in matter environment and appears as the matter (solid, liquid and gas)".

By the same principle, the matter can be converted to Antimatter through the same method in reverse. Where, these processes are not much different for both paths of conversions.

Only the state of pmtics strength and the effects of the environment, which dominates at a given point and at a given motional position (time), that will dictate what state the dynamic pmtics in which the state of Matters, the matter manifest itself as, and what matter will appears in the line of sight by given tools of detection at a given point in the universe. This dictates if pmtics strength will appear in state of matter as solid, liquid or gas, or will manifest itself in one of the state of Matters, as Matter, Dark Matter or Antimatter.

CHAPTER 6

The total energy balance equation of Plasma

The energy balance equation or general equation of relativity (E = m.c²) gives the relation between the *tangible part* of Matter of the plasma and its constituent energy.

The mass of an atom or collection of plasmas of its components, themselves are made of a collection of densities of pmtics strength of different Matters and their interactions, in respect to each other within their respective initial fundamental plasma.

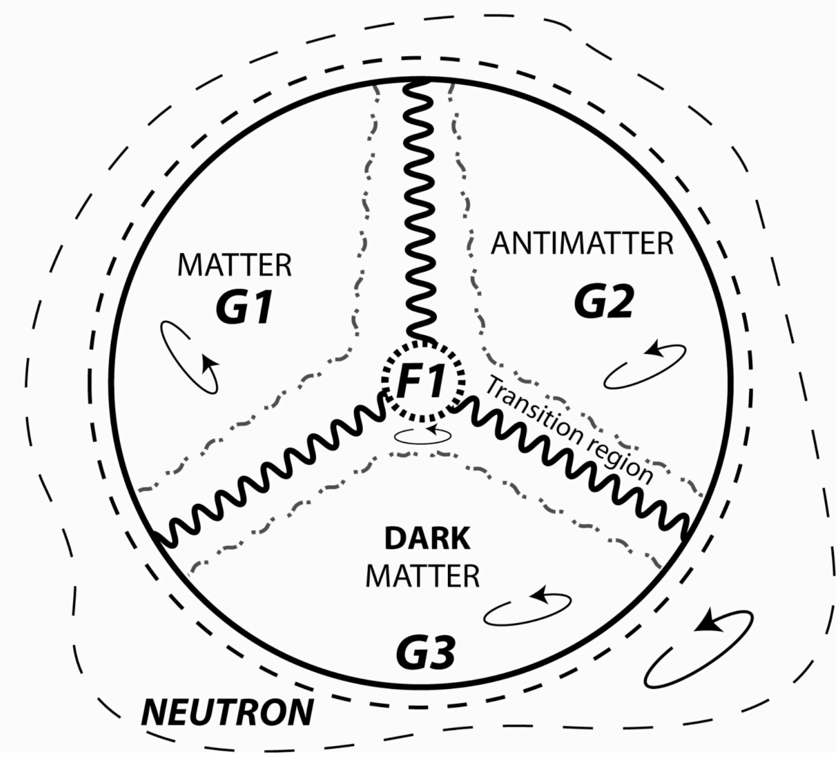

Fig. 26: Schematic of the fields of all components and of the initial fundamental plasma.

In considering the plasma, the general equation of relativity can be written in its real terms of its constituent components and their interactions and effects. Thus, this equation as has been said can be defined in respect to the Matter components of the plasma in the following manner.

That is to say "the total pmtics released in motion by the Matter of the plasma (once they have left the boundary of the plasma) (Energy), is equal to, the total balance after interacting pmtics strength of the Matter components of the plasma (Mass) which the plasma is made of, multiplied by the square of the maximum speed that pmtics can travel *in the **matter** environment* (speed of light)".

Knowing the new composition of the plasma, then the ***total energy of the plasma*** has to be in its ***totality of all its masses of all its Matters*** and not just its Matter component.

Therefore:

K (the total energy of plasma) = [energy of the Matter + energy of the Antimatter + energy of the Dark Matter + energy of the spherical torus-shaped field force effect + the energy in the inter binding between the other parts in the transition zones of the plasma].

K= [E (Matter) + E (Antimatter) + E (Dark Matter) + Ecf (centre spherical torus pmtics) + Etr (pmtics within transition zones)].

Where, total general equation of relativity for the whole of the components of the plasma can be written in the following form.

$$\mathbf{K = EM + EAm + EDm + Ecf + Etr}$$

Or:

K = [(The total components of constituent pmtics of the **Matter**) x (the square of the **speed** of pmtics in the **Matter medium** or the speed of light) + (The total components of constituent pmtics of the Antimatter) x (the square of the **speed** of pmtics of the Antimatter in the Antimatter **medium**) + (The total components of constituent pmtics of the Dark Matter) x (the square of the **speed** of pmtics of the Dark Matter in the **Dark Matter medium**) + The total energy components of constituent pmtics of spherical torus-shaped field force effect + The total components of constituent pmtics of the inter binding between the four other parts in the transition zones of the plasma].

$$K=M\ (M)\ .\ c^2(M) + M\ (Am)\ .\ c^2\ (Am) + M\ (Dm)\ .\ c^2\ (Dm) + E(cf) + E(tr)$$

Note: Capital M indicates here a mass of Matter.

When for example an apple is measured using the present measuring tools and methods, the figure attained is only for the mass or the weight of the Matter part of all the plasmas' of atoms of the whole apple.

As a representation, one initial plasma of an atom in the whole construction of an **apple** with it's Matter, Antimatter, Dark Matter, and other pmtics are shown on the right hand side picture of figure 28. Where, the *tangible apple **as matter*** represents the total Matter components of all the pmtics of an apple is shown on the left picture of figure 28.

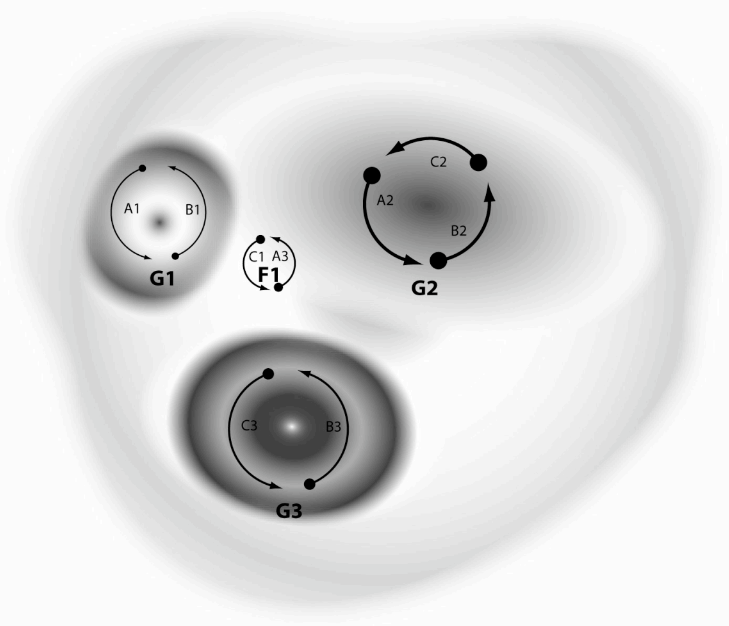

Fig. 27: The pmtics of all components and of initial fundamental plasma.

The total weight or mass of the plasma has to be the total weight and the total mass of all the components pmtics and all of all the plasmas of Matters of the initial fundamental plasma.

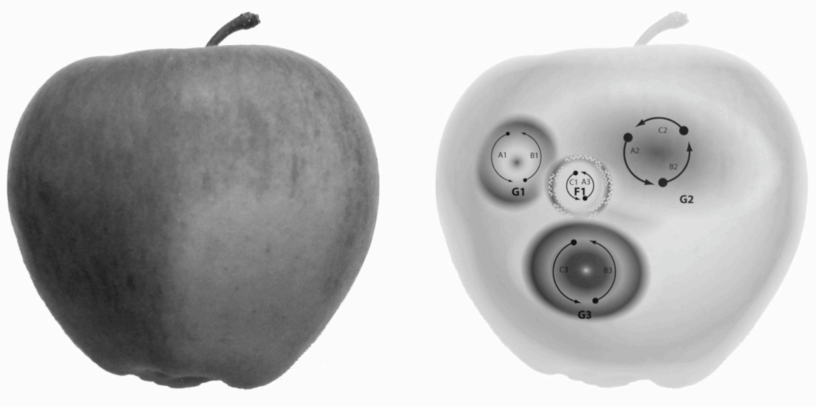

Fig. 28: Newton's apple has different types of pmtics and Matters.

Note: When the Matter is part of the plasma, this is denoted as ***Matter*** *(G1 in Fig. 26, Fig. 27 and Fig. 28) and when the same is considered as tangible matter, it is noted* ***as matter*** *(Apple in Fig. 28), of an atom or an object.*

By the same measure, if one has managed to separate the Antimatter of the plasma from its other constituents of the Matter and the Dark Matter of the plasma to confine the Antimatter in separate container as the Fermilab has claimed. The question to ask is that, what is the weight or the mass of the balanced leftovers of the Matters, (or Matter, Dark Matter and residual pmtics) of the plasma? By the laws of physics, one cannot have something (Matters/Energy) out of nothing. One cannot have mass of Antimatter component of the plasma, when its mass is not calculated in the overall mass of the plasma, or the leftover mass of the Matter and the Dark Matter of the same plasma must be less than before the Antimatter was taken out.

On the other hand, the question is that, is the present used methods of measuring the weight and mass of the plasma, measuring the ***total mass*** of ***all*** *the Matters* of the plasma? Alternatively, does one has to break the present numbers of mass and weight of each Matter, up to its sub-weights and sub-mass of the Matter (Fig. 26 and Fig. 27 G1), the Antimatter (Fig. 26 and Fig. 27 G2) and the Dark Matter (Fig. 26 and Fig. 27 G3) of the plasma. Further, the Magravs of the Matters of the plasma in conjunction with their own Magravs and other pmtics in the plasma create their own additional gravitational and Magnetic field forces, their own additional mass, as well as the individual masses of the Matters of the plasma. Thus the total mass of the plasma has to be more than the total mass of individual Matters of the plasma.

As Fermilab has separated the Antimatter components of the plasma, then, the question to ask from them, is that, if the mass of the matter of the plasma they hold still has the same mass as before without the Antimatter in it? So, what is the mass or the weight of the Antimatter that has been separated?

This applies the same to the Dark Matter components of the initial fundamental plasma too.

As has been said before, the total weight or total mass of the plasma is and has to be the total weight and total mass of all components of the Matters of plasma. This includes the masses or energies of the magnetic fields force of the F1 and the residual fields in the initial fundamental plasma.

Thus, there is a *fundamental error* in the present methods and technologies of measuring the weight and the mass of the plasma systems as a whole.

That is why suddenly one can see strange results from the Antimatter component of the plasma of the same mass or weight in the matter environment.

If, the total dynamic pmtics of the initial fundamental plasma, would have been, measured correctly from the beginning, then there would have not been such an ambiguity and mystery arising from the sudden hidden energy sources called the Antimatter, or the powers of the Dark Matter of the plasma.

The fact is that, the Antimatter and the Dark Matter possess plasmatic Magravs forces and that is why, they are called the **Matters**, as they possess mass and energy.

Hence, if there is a gravitational field's force of the Antimatter or the Dark Matter components of the plasma, then these Antimatter and Dark Matter have to have mass and they have to have weight in respect to the other Matters in the plasma and in respect to their environments pmtics, which the plasma is in, at given time. Therefore one needs the measurement of both of the mass and the weight of the plasma as whole as an entity as well as all the individual masses of each Matter too.

Then, the same as with the atomic mass and atomic weight of an atom measurement phenomenon of today’s science, **there is a need for a new scale of measurements**, and new measuring tools to be brought about and developed for the true and total pmtics measurements of the constituent Matters and fields of the Initial fundamental plasma.

By this new total weight measurement, then the ambiguities in the present plasma physics and nuclear physics will be sorted.

That is to say then, where and when one gives the measure of the mass or the weight of the plasma, then at this point, one has to give the mass or the weight of the Matter, the Antimatter, the Dark Matter and the rest of components of the plasma in a given motional position, and the position in the life of the plasmas independently, for all components of the plasma, and one measurement for the plasma collectively as the whole needs to be given too.

The reason for stating the position and motions of the plasma is due to the fact that, the plasmas having dynamic characteristic components, plasma itself as a whole is a dynamic system too and continually gains or losses pmtics from or to its surrounding pmtics environment respectively. Therefore, the total pmtics of plasma, in different frame of motion (time), will be different, from one point to another in a given space.

In the future measurements, one has to be clear about all measurements of the Dark Matters as well as the Matter as well as the Antimatter components, as well as all magnetic field components, the likes of the F1 or maybe several F1 configurations in any given pmtics of the initial fundamental plasma. Therefore, there is a need for correct figures for the mass, the weight and the energy of the initial fundamental plasma, because such data are needed for in-depth research and developments of various kinds of applications in Magravs positioning systems using components of Matters of plasmas as the Matmags, for future space travel.

Another point to consider is the Matters environment in which the weight or mass of the plasma is carried out. That is if, this is carried-out in the Matter plasmatic magnetic fields, Antimatter pmtics strength, or Dark Matter pmtics strength environment.

Similarly, the plasmatic magnetic fields’ strength in which the measurements are taken should be considered. This being, in what fields strength in the Matter, the Antimatter or the Dark Matter field strength or their respective pmtics energies measurements are taken place.

This is the true nature of the complexity of the relationship with the mass, weight, energy and their interactions in the world of Matters. These cannot be so simplified with one equation of relativity with three simple denotations, if in the future scientists strive to achieve the universal method of producing energy and motion.

The space travellers of the future will come truly to understand that a small error in the measurement of all matters and Matters components, the environmental magnetic plasmatic strength and so forth, can land them in strange and peculiar environments, which these were not planned for or expected. These small errors can end them up in new conditions and positions in the galaxies, which could be nice for experimental purposes, but not necessarily good for the health or the life of the passengers of these future crafts using Matters *Magravs positioning systems* (Chapters 22 and 23).

It is possible that due to miss-calculations, one part of the systems of the future crafts, or even the reactors of crafts, which are creating the conditions for motion or energy, will experience different environmental and Matter conditions than the rest, of the craft or the reactor. As, for example, the same system can land in the border of two different pmtics strength environments, or, in a different plasmatic condition than was originally planned, because of the miscalculation of the Dark Matter Magravs strength.

A physical comparison of the two state of Matters can be for example, considering a cube of sugar, half-submerged in a hot liquid, like tea, where, half of matter of sugar is in the solution of the hot liquid and the other end of the cube being between the fingers of the dipper, in solid state.

Therefore, the question emerges, of how does or can one put the original components of the sugar cube together to get back to the first state of the solid cube, in its original solid state and shape.

The rearranging Matters through the understanding of the Matter energy balance will be the solutions for these kinds of mistakes.

The misunderstanding and potential pitfalls with space technology of the future will be with the miss-calculation of the loading of matters as the “Matmags”, and the control in the reactors of crafts of the state of Matters transitions will be interesting.

Nevertheless, the travels and space ventures of the future through miss-calculation of energy balance and wrong Matter Matmags loading will not be without its problems and sorrows, as have been experienced in the short lifetime of the space explorations of today for men whom have dared to test the limits of space explorations.

Who dares, in the space traveller of future, may succeed to have a taste of the pleasure of the unseen in the universe! Our hope is that they come out of these journeys much wiser, but not necessarily less darer than before.

CHAPTER 7

The creation and speed of light

One of the possible ways that light in the universe is created can be through interaction of pmtics' of the plasmas. The speed of light is not considered to be the ultimate speed of Matters. We will discuss how, the interaction of pmtics of the flight systems using Magravs positioning reactors would lead to the creation of light around such a system in the atmospheric conditions like that of the Earth.

Understanding the basic structure of the initial fundamental plasmas, the rationale that the speed of light is the ultimate speed of travel of any Matter becomes questionable.

The phenomenon that the speed of light is the ultimate speed of travel of any Matter(s) or matter(s) is an assumption that has a clear flaw in its concept and cannot be correct for all states of Matters in the universe.

In the iron-based magnets of the solid state of matter, the magnetic fields flow is in one direction, out off the North Pole and their return through the opposite South Pole.

The question that needs to be asked is that, what is the ***speed of the flow*** of the magnetic fields force from one pole to another in solid state of matter?

For ease of understanding let us consider two packs of dynamic plasmatic magnetic fields strength of the pack A and the pack B (Fig. 29), in the path of collision with each other.

The pack A and the pack B can be considered to be of the plasmatic magnetic fields of the plasmas, solar systems or galaxies. The other assumption is that the pmtics strength of these two sets considered not being equal. These two sets of pmtics are supposed to be the mixture of the pmtics of gravitational and Magnetic fields of their respective Matters or objects in each pack.

In considering three snapshots a), b) and c), the motion of the two packs A and B in a given space of time and pmtics strength of the environment area of the D in respect to each other.

a) As the pack A and the Pack B are in motion in space and heading towards each other and these two fields are set to collide with each other (Fig. 29).

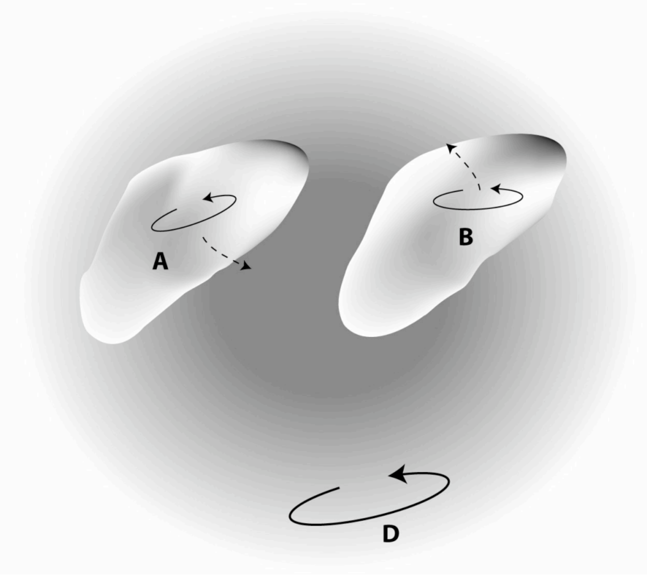

Fig. 29: Two unequal pmtics packs heading for collision.

b) Further, in the process of their motion, the two pmtics collide with each other (Fig. 30).

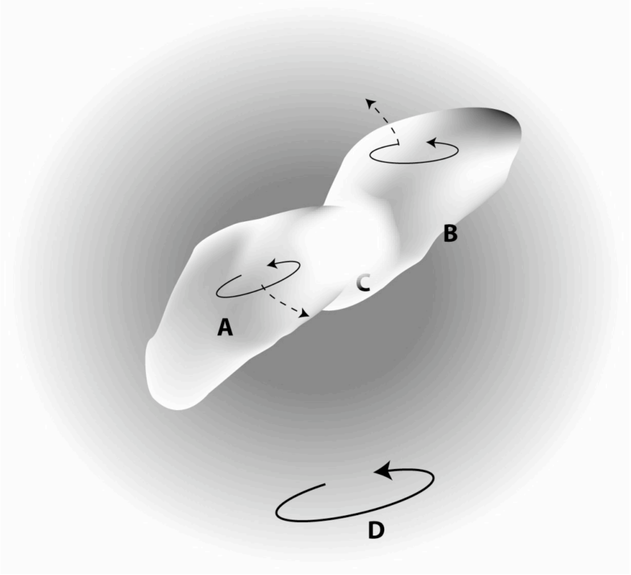

Fig. 30: Two unequal pmtics packs colliding and releasing lower order of pmtics strength as light (C).

c) Further, in the process of the interaction of two original pmtics of A and B, the two fields separate (Fig. 31) and carry on in the universe with some of their fields being released during the collision.

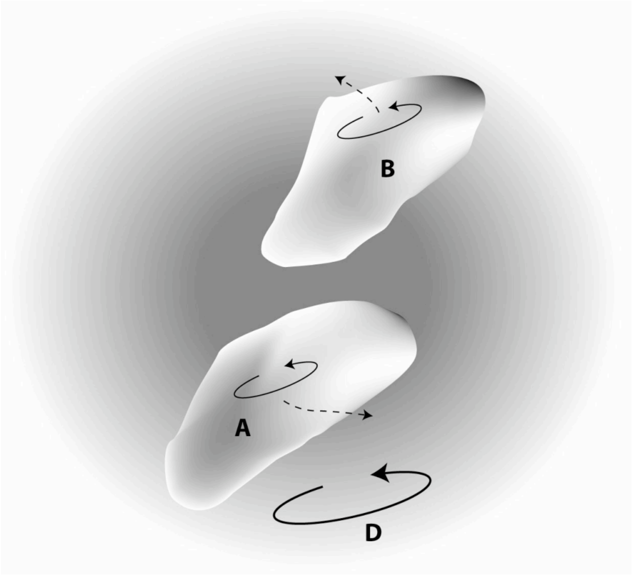

Fig. 31: Two unequal pmtics packs after collision moving away from each other.

Considering the point (b) of impact and collision as in figure 30, as there is no physical matter in these zones, only the pmtics forces can collide and interact.

The collision of the two plasmatic magnetic fields due to their frictions with each other, this leads to separation and production of fragments of pmtics, which some will be of slower plasmatic magnetic fields strength than the two original pmtics of the two original packs.

In case of physical matter, it is normal that when two matters collide head-on, they slow down and some parts of their matter are sheared off and released as fragments.

Through the collision and the interaction of these two packs of pmtics with each other, and the friction between them, these cause separation and fragmentation of some of the same pmtics from the two original pmtics of the two packs. The collision in between two sets of magnetic fields causes some of the pmtics to slow down. In the case of pmtics collision, these slowed down fragments of original two packs of pmtics are slower, and possesses weaker strength pmtics compared to their original two pmtics strength, which were involved in the collision.

We can assume that the original two pmtics plasmas speeds of travel have to be much higher by order of magnitude than the fragments that are created by the collision and interaction of the two packs of magnetic fields forces.

In other word, when two pmtics are colliding with each other, the outcome is partly slowed down fragments of pmtics as the residuals of this collision. These slowed down plasmatic magnetic fields fragments of the collision of the two stronger plasmatic magnetic fields, are slowed enough to appear as, and to be of light magnetic spectrum within the matter magnetic fields strength spectrum of the matter detection zone.

Nevertheless, one can say that, when the two pmtics of A and B collide, the outcome are residual pmtics fragments of the collision, which some of their slowed down magnetic fields fragments created due to their friction and collision, leads to the creation of slower pmtics strength in the range of visible light (Fig. 30 field zone C). Where, this visible range of the magnetic wavelength is part of the overall universal order of magnitude of the magnetic wavelength spectrum fields.

In the universe, when two or more plasmatic magnetic rays, fields, plasmas, of Magravs collide with each other, some of the residual pmtics fragments produced by their collision will be slowed down to magnetic rays or plasmatic magnetic fields strength levels, which the strength of these magnetic rays or magnetic fields are in the range of magnetic fields strength spectrum of the visible light. In other word, the outcome of the interaction of two or more magnetic rays, magnetic fields or plasmas of Magnetic and gravitational fields (Magravs) is the production of light.

This being considered as "one of the prime methods by which visible light is created in the universe. These being the residual of slowed down weaker magnetic fields strength fragments of pmtics released by the collision of two or more pmtics of Margraves of plasmas with each other".

The speed of pmtics fragments, which has slowed down due to a head on collision of two pmtics plasmas, cannot be faster than the original two pmtics plasmas themselves that have caused it to be produced.

Thus, the ***speed of the light***, which is created by interaction of two faster fields' head-on collision, as a fragment and slowed down field, cannot have a faster speed and more pmtics strength than the fields that have caused its creation due to their collision.

For example, by the slowing down of the two faster pmtics of the Earth and the Sun that have not been visible, after collision with each other, and slowing down, they create the slower plasmatic magnetic fields' strength and slower speed magnetic fields in the range of the speed of visible pmtics as of the daylight.

It is correct to accept that "the pmtics, through their collision, have to slow down so that they became slow enough that they become in the range of the slower wavelength in the visible light pmtics wavelength spectrum".

It is obvious that a slower fragment cannot be faster than the fields that have caused its creation. Therefore, "The speed of the light is not and cannot be the ultimate speed of motion" when itself is created by interaction of faster or stronger plasmatic magnetic fields.

In universal order of magnitude of the speed of motion, I consider "the speed of light to be somewhere in the lower end of the overall universal magnetic fields speed spectrum".

Thus, the speed of the light is only the fastest to human methods of detection and not necessarily true in other levels of universal order of motion.

It can be said that the speed of the light is “the ultimate speed that can be attained by pmtics in the Matter components of the plasma”.

Another, fundamental point to realise is that “the speed of travel of light is **different** in a Matter environment than the Antimatter environment and even in the Dark Matter environment”.

Similarly, it is correct to say that “the light created by the interaction of the Antimatter pmtics plasmas and the Dark Matter pmtics plasmas, they have **different** speeds than the light created by the interaction of Matters’ pmtics plasmas”. These faster speeds of magnetic fields than the pmtics of the light spectrum are not detectable by the present tools in the scientific state-of-the-art technology. But their effects and power and strength has been seen and observed in the reactors, which have been built and tested for lift and motion in the past years.

Considering the collision of two pmtics like those of the Earth and the Sun, where the Earth’s Magnetic and gravitational pmtics (Fig. 32 field B) being made through interaction of magnetic fields of Matters in the inner cores of the Earth (Chapter 1), and the Sun’s Magnetic and gravitational pmtics (Fig. 32 fields A) being made by the matters, in the cores of the Star. (In this case, we do not consider the pmtics of Matter, which are released by interaction of matters pmtics on the surface of the Sun).

An example of the creation of the light through the interaction of pmtics:

As the pmtics of Magravs produced and released by the Sun, reach’s’ the boundaries of the Earth pmtic of Magravs, these two pmtics of Magravs collide with each other at the edges of the Earth’s upper atmospheric levels.

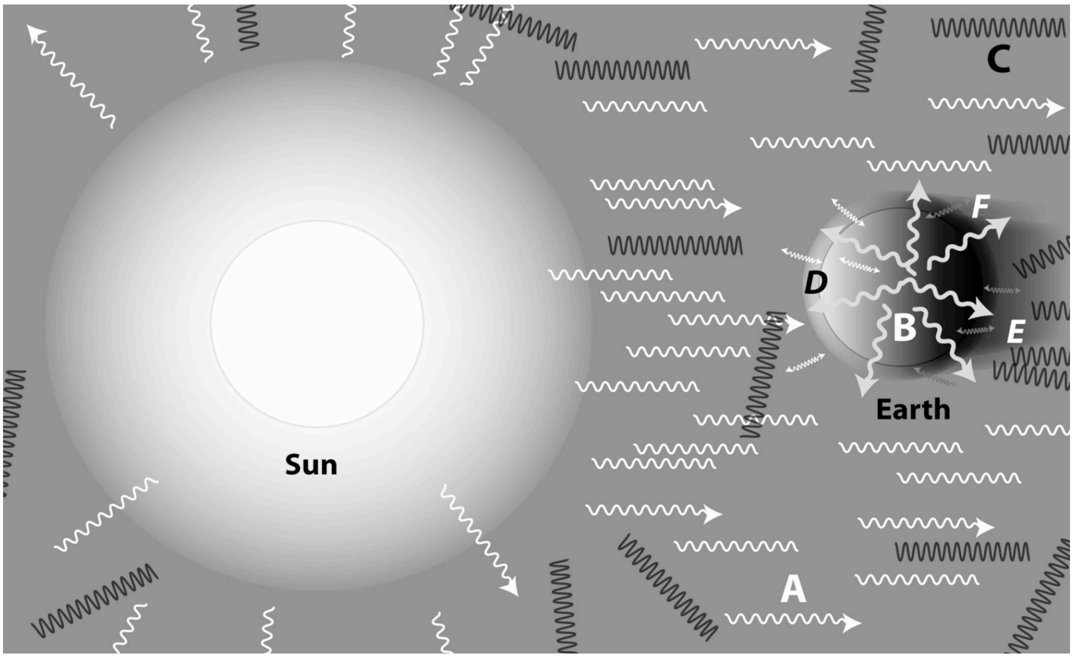

Fig. 32: Interaction of three different types of pmtics strength (A, B, C) and the resulting three residual fragment pmtics (D, E, and F).

Where, these interactions leads' to the creation of the pmtics interface, or the **magnetosphere** of the planet. Where, this magnetosphere of the Earth is partially produced at the same time in respect to the other surrounding pmtics of Matters and other plasmatic magnetic fields (Fig. 32 field C) in the solar system as well as the pmtics of the Sun.

Through the pmtics plasma interaction principles, the pmtics of the Magravs of the Sun interaction with pmtics of Magravs of the Earth leads to the creation of new residual ***slower rays and pmtics strength in the light spectrum*** (Fig. 32 field D), where, the overall effect of these pmtics fragments of light generated, leads to the creation of the *daylight* on the Earth, in the interfacing sector of the Earth with Sun's pmtics only.

The light generated in the sector of the planet, facing away from the pmtics of Magravs of the Sun, in interacting with the weaker pmtics of the Dark energy of space around it, due to the weaker plasmatic magnetic fields' strength of these pmtics of Dark energies in space (Fig. 32 field C) and the same constant pmtics strength of the Earth (Fig. 32 field B), in this sector, **weaker strength pmtics residuals** (Fig. 32 fields E and F) are created and released, thus, the appearance of the darker sky or the *night light*.

Thus, the interaction of the *same pmtics* of Magravs strength of the Earth (Fig. 32 field B) with the *stronger* plasmatic magnetic fields of the Sun (Fig. 32 field A) leads to the creation and release of more powerful pmtics strength residual fragments in the light spectrum (Fig. 32 field D), hence **the daylight**. Similarly, the interaction of the *same pmtics* of Magravs of the planet (Fig. 32 field B) with the *weaker pmtics* of the Dark energy (Fig. 32 field C) in space, away from the Sun's plasmatic magnetic fields, leads to the creation of weaker pmtics strength residual fragments, hence weaker lights or dark night light and creation of the translucent plasmatic darkness (Fig. 32 field E and F) light of the night.

As the Earth's reach a more Magravs pmtics strength balance and equilibrium with its environment's plasmatic magnetic fields' strength, thus the darker that part of the atmosphere it appears to be (This principle is described in Chapters 12 and 13).

Through the same principle of interaction of and collision of solid matters of the cosmic dust and the pmtics of the Earth, the northern lights in different colours are created. Where in this case, the light created is due to collision of the matter pmtics and pmtics of Magravs of the Earth.

It is not correct to consider the speed of light to be the ultimate speed of motion, for any pmtics of Matters environments existing within the universe. Similarly, it is conceivable that pmtics can fuse and that their pmtics can increase in strength and consequently they can increase their speed too. (Paper: Creation of magnetic fields).

In principle, the speed of light is not only achievable by the reduction in pmtics of higher order of magnitude pmtics strength, but conversely it can be achieved from the addition or adhesion of the strength of lower order of magnitude pmtics strength too. By the same measure, the pmtics of the light can be integrated, to create their stronger and faster speed of motion, with new and faster pmtics from their interactions too.

The **pmtics strength** and **the speed of plasmatic magnetic fields** is environment dependent and there are no limits in its lower or higher orders of magnitude. Generally, as long as plasmatic magnetic fields can interact, they can add to pmtics speed or lose their speed.

The limitation of speed of travel to plasmatic magnetic wavelength of light is the restriction that Man has forced upon himself, purely due to lack of his understanding of the true construction of Matters of his universe.

The present limitation of the speed of the light for motion is very much similar to the earlier century's hypocrisy and lack of knowledge of Man, with the belief that the Earth was flat and at the centre of the universe.

The pmtics become visible light to the human eye, purely due to the fact that human eyes are adapted through their protein molecular pmtics strength chain, for them to be able to interact and recognise them. This range of the plasmatic magnetic wavelength is translated for the human brain to be the visible light for humans to be able to see and function. Where, this visible range of the magnetic wavelength is part of the overall universal order of magnitude of the plasmatic magnetic wavelength field's strength and not necessarily its ultimate speed.

Thus, "if the human proteins pmtics strength had a different chemical chain, that is to say, if the protein chain did not have hydrogen, oxygen, carbon and nitrogen in its composition, then man would have had different overall pmtics strength in his protein and the universe would have been visible to man in a different range of plasmatic magnetic wavelength field's strength spectrum".

This phenomenon of the protein chain pmtics strength of creation is explained in more detail in the book to be published, titled "The universal order of existence (9)".

Further, in this book we will talk about new nuclear-based systems, which have been developed for them to be able to make use of the creation and control of pmtics of Magravs strength for motion. We have called these systems ***GRA**vitational **PO**sitioning **S**ystems* (**GRAPOS**). From, tests and what we have seen and observed in the past years in proof of pmtics creation and control, the following can be discussed in respect to the interaction of the pmtics of the Grapos Magravs and the pmtics of Magravs of the Earth.

Using Magravs positioning reactors, the interaction of the Magravs generated by these reactors with Earths' Magravs, these interactions of the two of Magravs, by their natural phenomenon of creation and interaction of pmtics, these Magravs interaction of the Grapos reactor and the planet, always leads to the creation of light around these systems in planets' atmospheric environment.

Crafts using **Grapos for lift and motion** in their movement and travel in pmtics plasma of Magravs environments, like the Earth's atmosphere, **these systems generate pmtics fragments of rays of light and appear** to be like **moving *bright lights* in the skies** (Fig. 33 disk 3 and 4).

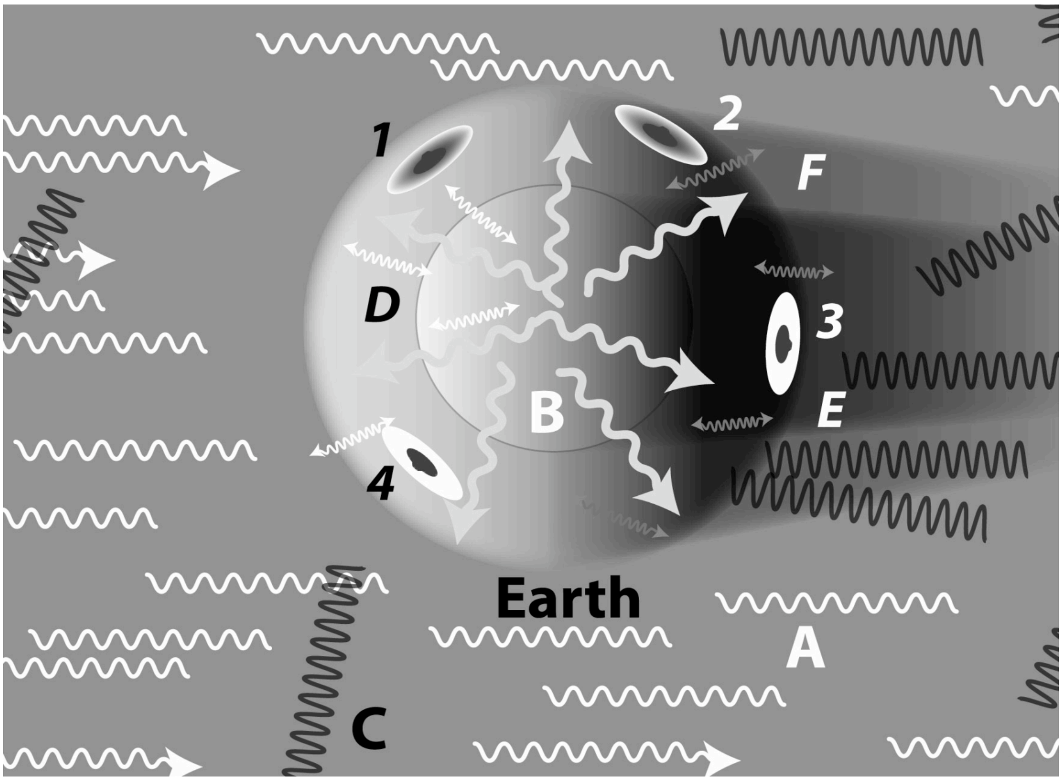

Fig. 33: Visualisation of Magravs positioning systems (1, 2, 3 and 4) within Earth atmosphere.

The effects of the interaction of the *four different Grapos and their different* pmtics strength and lights they produce around these systems, due to their of Magravs strength in respect to the Earths' pmtics are demonstrated in the figure 33 disks 1, 2, 3 and 4.

The **brightness** of these lights in sky is due to the pmtics of Magravs strength of Grapos' in respect to their environment pmtics of Magravs of plasma strength of the Earth, and these *lights are balance pmtics strength dependent*. Lights around these crafts are produced by the same principles and are similar to the way light is created by stars.

Another example of the Magravs positioning reactors to be used in future craft systems' is, in creating a balanced Magravs strength in respect to the Earth atmospheric plasmatic magnetic fields' strength, so that there would be not much field strength difference and hence nearly no interaction between the pmtics of the system and the Earth. Thus, no or very little light created around these systems as is shown in figure 33, with disks lights 1 and 2. So the system or spacecraft in a given position and time in the Earth atmospheric condition can become dark translucent in respect to the Earth pmtics strength. This giving the impression that, the system has disappeared from the sky, in fact, the system has created its own balance plasmatic magnetic fields' strength condition of dark light in its environment in respect to its environments Magravs strength, while the system still is/or can be keeping the same position in atmosphere. By being able to adjust the Magnetic and gravitational field's strength of Grapos reactor(s), these crafts can change their visual appearance in the Earth atmosphere, from dark to bright light and deemed-light and so one. Four different Magravs strength of Grapos in Magravs of the Earth are shown in figure 33 and figure 55 in disks 1, 2, 3 and 4.

Man can and will travel several times faster than the speed of the light in the future. This will be of his own choosing and limited by his technological advancement and the limitation of understanding of his own tangible existence.

The speed of motion, due to the interaction or gravitational pull of the planets and stars of destination, in pulling the crafts equipped with Grapos towards them is beyond the present technological ability and comprehension of the scientific world, but in time this will be as easily and manageable as daily atmospheric flights of today. Which these crafts can travel several times faster than the speed of light.

The other scenario of collision of pmtics around the Earth could be that when the two field Magravs of the Earth and the Sun collide, and their overall field interactions can lead to the creation of faster pmtics than that of visible light. This again is the result of the amalgamation of two pmtics strength forces from two celestial objects.

Theoretically this is not possible around the Earth as most of the fields of the Earth are outward going and crossing the path of the pmtics of the Sun, and these fields would be carried away and out from Earth's atmosphere and not inwards. Therefore, any amalgamation of two pmtics of the Sun and Earth has to be inward so that Earth's atmospheres can generate the daylight.

This phenomenon of the addition of two fields to create light in the case of the high speed of the plasmatic magnetic fields of the Sun and the Earth is not a common possibility, or there is so very little of it.

By the pmtics theory, in the case of an atom's structure, pmtics of Magravs of the constituent Matters of the electron interact with the pmtics of Magravs of the proton. This creates the fuzzy light around the electron fields in motion, which makes it dimensionally easier to detect the presence of the electron than its nucleus. This fuzzy light being similar and created through the same principle as to the interaction of the pmtics of Magravs of the Sun and the Earth, as was explained.

Considering the interaction of the pmtics of matters on the surface of the Sun: The lights which can be observed from the surface of the stars is primarily due to the interaction of the pmtics of the gravitational and Magnetic field from the centre of the star and their interaction with the Magravs of the plasmas on the surface of the star, where this interaction of the two fields leads to the release of pmtics in the visible light spectrum. The intensity of the light of the stars is in principle due the strength of the gravitational and Magnetic fields generated in the centre of the star, as the pmtics of the hydrogen plasmas on the surface of the Sun are considered to be constant.

We consider the pmtics received by the fields of the Earth from the pmtics from the matters from the surface of the Sun to be small and to be a fraction of the power of the pmtics released due to the gravitational and Magnetic fields from the centre of the star which reaches the planet Earth. The only time when the pmtics of the materials on the surface of the Sun has any effect on the interaction with the Earths' gravitational and Magnetic fields is when there is a surge in the volcanic eruptive activities on the top layers of the materials on the surface of the Sun. These eruptions cause the release of large quantities of physical material of plasmas into the solar system.

CHAPTER 8

Dark Light phenomena

In the previous Chapter we explained that the *visible light* is created through the interaction of Magravs and the *light* created due to the difference in strength of Magravs. Opposite to this, must be the interaction of balanced Magravs strength where the weak or balanced Magravs fields strength, which leads to the creation of a type of night light or dark light at nights.

The point has reached in physics, that these balanced pmtics Magravs strength conditions needs to be considered on their own, where the **Dark light phenomena** can be introduced as part of the science of physics.

"**This Dark light phenomenon**, with Dark light intensity, can be said to be created and be due to the near to, or balanced, equilibrium in pmtics strength reached, or that can be achieved, through the interaction of two or more pmtics forces in respect to each others in a given environment". Where, the intensity of the darkness is pmtics strength balance dependent (Fig. 36 zone C).

The level of measurement of this darkness is not field strength dependent, but *plasmatic magnetic fields strength balance dependent of one pmtics in respect to another pmtics.* That is to say, the interacting pmtics environments can possess any magnetic strength, but in all cases, when the two pmtics strength are ***near equal***, then the darkness phenomenon of the same dark intensity prevails and the same type of dark light phenomenon occurs, irrespective of the original pmtics strength involved.

If this phenomenon is fully understood, just as man has developed night-vision tools, equipment can be produced that can view Dark light plasmatic magnetic fields strength balance in respect to different pmtics strength. Then the universe would be full of new objects that have never been seen in light energy matter conditions.

What a wonderful world would one be in and see, through these tools and machines, Men of vision would take pleasure and treasure by looking through from such a machine.

CHAPTER 9

Relation between Gravity and Light

Through the pmtics theory principles, as gravitational fields are made of interaction of pmtics, and the light being itself made of pmtics, it is inevitable that entities made of the same, will interact with each other.

From previous chapters, it is clear that the light is made of the lower order of magnitude pmtics strength in the overall pmtics strength spectrum in the universe. The light in essence is itself moving dynamic pmtics and that by the principle of this definition **light is energy**. Alternatively, it can be said that the light possesses energy.

We consider that light is a made of pmtics strength of a lower order of magnitude in the overall pmtics strength spectrum in the universe.

At the same time as has been explained, "Gravity and gravitational fields' (Chapter 1) are themselves made of interaction of at least *two **similar** pmtics* or at least *two **similar** magnetic rays*".

It is understandable that, any gravitational field's forces, as an entity, in essence are made of interactions of pmtics. Thus, gravity can and will effect any other entity in possession of pmtics, or entities being made of pmtics, like light. The light and the Magravs (known as gravitational fields) are both made of the same magnetic entities; it is normal that they have interactions and attractions in respect to each other's position.

Fundamentally, it is **not correct** to say that **light is gravitational dependent.**

But, it **is correct** to say that, "the attraction and interaction of **the light rays** in respect to, and from, another collection of plasmatic magnetic fields like **gravitational fields (Magravs) are position dependent".**

In classic physics, the behaviour of the light has been said to be gravity dependent. Through the new understanding of the creation of Magravs, this cannot be correct. As the light and gravity are made of the same magnetic fields of different strength, thus they can have near enough the same speed of motion in matter magnetic field strength medium.

In the case of light rays, when the ray comes in the vicinity of, or in position in space that it can be within a field of, or be near to or in the catchments area of a collection of Magnetic fields or gravitational fields (Magravs), these two entities' magnetic fields interact.

Thus, light is not gravitationally dependent, but in fact the attraction of light is position dependent from a pmtics of any Magravs area.

Thus, the stronger the Magravs of an object are, the stronger the pull.

Following the new principles of magnetic field interactions, the stronger pmtics of Magravs strength of the Matter, the Antimatter or the Dark Matter will exert their gravitational magnetic field forces on the weaker magnetic field strength of the light rays. Hence, the stronger pmtics of heavy matters and the stronger pmtics of stars, the Antimatter and the Dark Matter, pull weaker magnetic fields like light pmtics towards themselves.

So that the visible light will move slower as it will be pulled towards the gravitational force of these stronger, Magravs like stars and Antimatter zones and as it interacts with their pmtics forces.

Light has a different speeds in the Antimatter, the Matter and the Dark Matter due to their magnetic fields strength, very much like as it has slower speed in liquid than in air in the matter environment.

The difference between matter environment and the Antimatter and the Dark Matter environment is very much in that the former is pmtics compactness and density dependent, as in the latter it is pmtics strength dependent.

Thus, light, by the principle of its construction from pmtics, will be pulled and travel slower in other state of Matters and near large and stronger plasmatic Magravs strength of objects like stars, through the magnetic fields interaction principles or the gravitational pull of one stronger magnetic fields in respect to the weaker magnetic fields of the light.

In physics, this has been said to be like the effect of the bending of light when it passes a planet or star in possession of gravitational field forces. The principle of bending of the light, or gravitational lensing in vicinity of, for example, stars is purely due to the interaction of the pmtics of the light with the plasmatic Magravs forces of the star.

It is important to notice that in positions in space, where the Magnetic fields of the star supersede the gravitational fields' strength in respect to any given ray of light, the light ray as well as being able to bend inward due to the gravitational pulls, it can also be reflect away from Magnetic fields forces too.

By the same principle, it is now understandable, why and how for example in strong gravitational fields like black holes areas, even light appears as to get absorbed into them. This being due to the fact that Magravs strength in the centre of the black holes in these regions are so strong, that due to their magnetic fields strength they gravitate the magnetic fields of the light inwards or what they call in common terms "absorb" the light. This attraction is simply a gravitational pull of stronger Magravs strength of Matters and matters in the centre of a black hole in respect to the much weaker magnetic fields of the light.

Most certainly, ***gravity and its field strength is not warp dependent*** or gravity is not caused and is not created because of a warping of the matter in the plane of time and space, as has been discussed in some fields of present physics.

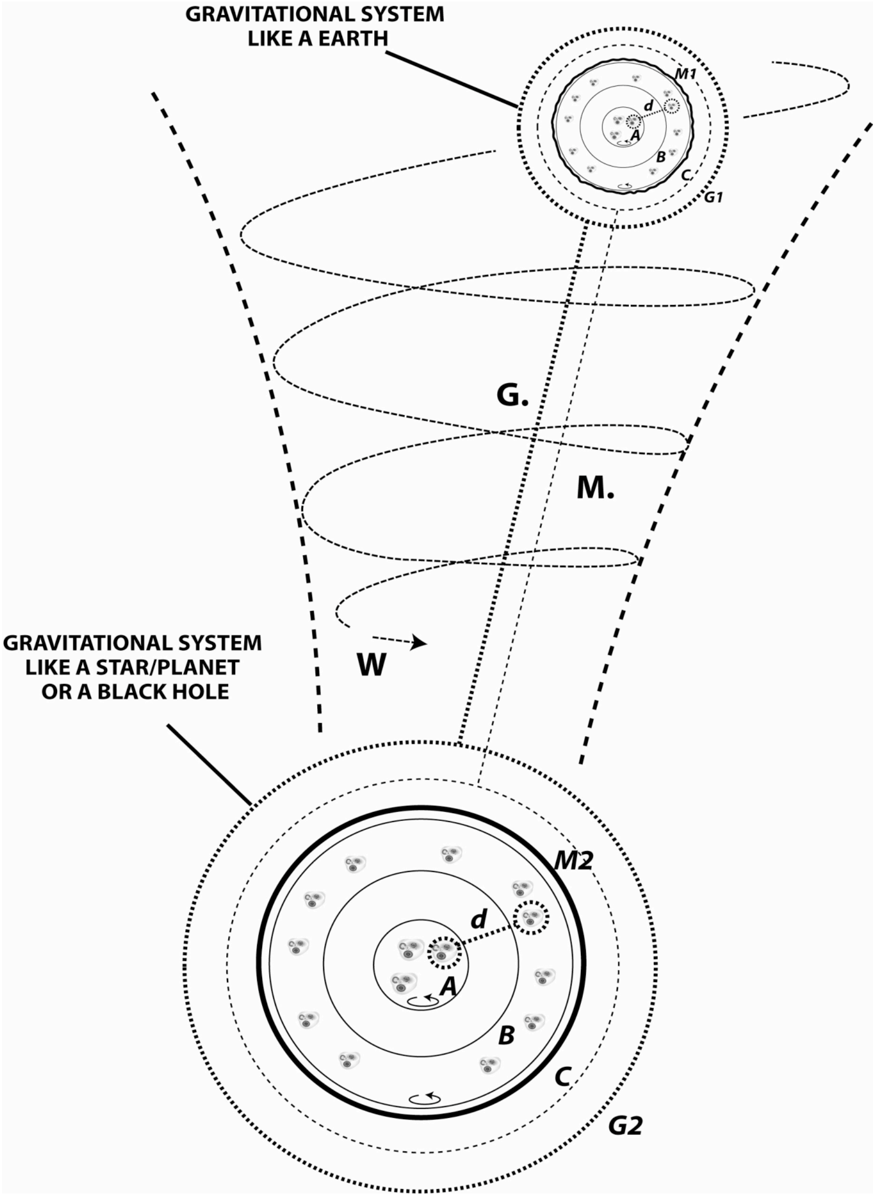
GRAVITATIONAL SYSTEM
LIKE A EARTH
M1
d
A
B
C
G1
G.
M.
W
GRAVITATIONAL SYSTEM
LIKE A STAR/PLANET
OR A BLACK HOLE
M2
d
A
B
C
G2

Fig. 34: Warping path of a weaker Magravs system towards the stronger Magravs system.

Note: Definitely the warping is not the creator of the gravitational fields, but the warping shows the path of the motion of the one gravitational field downward or toward onto another gravitational field.

That is to say, one weaker gravitational field can be attracted towards another stronger gravitational field G2 (Fig. 34), so that the path of the direction of the motion of the weaker gravitational fields G1, towards the stronger, could make the warp like path (Fig. 34 path W) in a given plane of time. This is the warping effect of a ***weaker*** *gravitational field* in respect of a ***stronger*** *gravitational field* and this is the warping path of attraction.

Therefore, warping of the matter is not the cause of the creation of gravity in the matter of the weaker gravitational field strength object, but in fact the warping is only an indication of the path of the attraction and motion of the weaker gravitational fields towards the stronger gravitational fields.

Celestial matters in possession of Magravs, through their internal pmtics and their attractions and interaction and nothing else, can generate the majority of their own gravitational fields in the universe. At the same time, the motion of two objects in the possession of their own gravitational fields can set and start different gravitational fields of one object in respect to the other. That is to say, when two stars in the universe come into each other's catchments zone, the catchments envelope creates its own gravitational pull, separate from the internal gravitational pull of the stars themselves. That is in fact the operation of two original pmtics Magravs being cascaded by the bigger one outside them. The interaction of the two stars, in trying to find their position, causes the swirling effect first and then the warping effect type of motion of the weaker stars' gravitational fields towards the stronger pmtics gravitational field.

External motion of matter does not necessary create gravitational fields inside an object, but the path and speed of the motion of matter indicates the strength of the pull of one field towards another and the direction of the path of the attraction.

There are no planes of references for this warping, as the original point of the reference of the interaction of the two pmtics magnetic fields in respect to each other comes from where, *they first come into touch* and start the first fields interactions; this becomes the plane reference point for the path of the attraction of one gravitational field towards another (Fig. 34)

In fact, the theory of warping creating gravity is as far from reality, as gravity being time dependent.

Maybe it is right to say, "In time, once two Magravs come in contact with each other and stay interlocked, the two fields might merge into one, this time of merger is then pmtics Magravs strength dependent".

As has been explained, Matter is one of the three parts of the Matters of the plasma. Thus, the same interaction between the three gravitational pulls of three Matters within the structure of the Matter (see Chapter 18 and 19) causes the warping and motion of Matters in respect to each other within the plasma.

In fact, any magnetic and pmtics entity, at all times of its existence, is gravitating or will have gravitation towards one or another magnetic ray or pmtics or Magravs in its regions and is warping towards one point or another in space at any given frame of time. That is to say, there are ***no regions in space in the universe, which are void of magnetic rays or pmtics***, and their gravitational interactions and attractions in respect to one field or one Magravs or other.

Nevertheless, there are different magnetic fields strengths, which in one form or another, are gravitated to one or another magnetic fields regions in the universe, in respect to their proximity of distance from a ray or a pmtics.

Maybe we can say “that gravitation in respect to time, is dependent on the position in space and pmtics strength of the any two entities, and that in time, for example light being in essence a magnetic field in origin, it will be effected or attracted or gravitated to another magnetic field or collection of fields, and that these magnetic fields can already possess gravitation in respect to each other.

Thus light rays in given point in space will come in touch with other magnetic fields, which they will gravitate towards each other, for them to merge, where this merger will take a certain given duration.

Thus, the light rays and other pmtics strength have a direct effect on the rate of attraction of one field to another. Thus, speed of attraction is pmtics strength dependent”.

In real physical terms, the light itself can be or become one-half of a gravitational field set, so not only is the light getting attracted towards another Magravs system, but also in this process, the light becomes part of a second magnetic field of a gravitational set itself in respect to the first gravitational field. Then this light pmtics becomes part of a plasma magnetic field, which this is, a new set of a light field and the first gravitational field interaction, and this itself becomes another Magravs system like.

The other important point to consider, is the time it takes for the light ray to reach or be attracted into or by a gravitational field, zone or area. This interaction and attraction, is both gravitational field strength, and the light ray’s magnetic fields strength, dependent.

That is to say, stronger gravitational magnetic fields, ***pulls*** rays faster to themselves than a weaker gravitational magnetic fields.
Thus, *the time, that it takes for a light ray to get attracted into the gravitational field zone is gravitational field strength dependent and not time dependent,* as the strength of the pmtics of the light of the matter is considered to be constant for all states of Matters.

Then for different Matters (Matter, Antimatters and Dark Matters) in the universe, there should be different *frames-of-reference* of duration or time. As the light created in the matter environment will have different speed in the Antimatter and Dark Matter magnetic fields spectrum environments of stronger pmtics strength regions. While the light created by the Antimatters and the Dark Matters pmtics, interactions have very **different speed** than the light created by Matter pmtics interaction. Secondly, the speed of the light from Dark Matters and Antimatters are much faster than the speed of the light of the Matter state or in matter state pmtics’ strength levels.

Some notes about light

1. The frequency of the light wave is created on the same basis and due to the same principles as the change of the polarity in the stars, for example the Suns’ eleven years half shift in polarity change (12, 18).

2. By the same principles, the alteration in the extreme points known as maximum and minimum points of return of the waves are Magravs positioning balance dependent,

and not as what has been assumed, electromagnetic field based, as electrons themselves are made of plasmatic magnetic fields.

3. The pmtics as rays, as they enter or come in touch with an atom or an object that they can move or cause motion in the penetrated atoms, electrons of matter or Matter or in their initial fundamental particles, because the matters or Matters components are similarly made of dynamic pmtics, thus, when a pmtics comes in touch with another pmtics, these pmtics interact and collide with each other. Thus, the outcome is a transition of pmtics from one entity to another.

4. The transition of pmtics takes place when the plasmas of Matters come into contact with the initial fundamental plasma of the Matter and they transfer their plasmatic magnetic fields strength from one to another. Usually this transfer is from the stronger to the weaker field strength directional of flow.

CHAPTER 10

The Antimatter

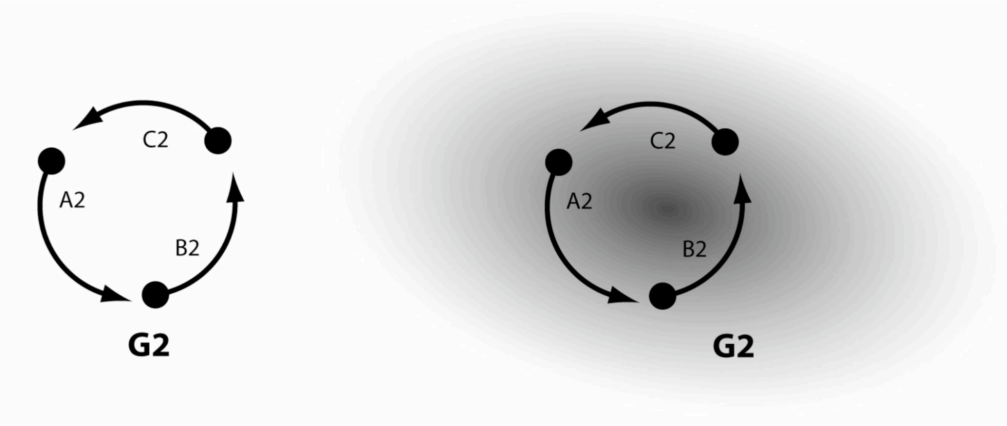

In the world of science, the Antimatter has been considered and said to be the largest source of energy for the future of the energy, space and motion technology.

In the structure of the initial fundamental plasma, I consider that "the Antimatter is the *main component* of the whole structure of the plasma and it is the carrier of the *largest amount and strongest* of dynamic pmtics strength in the plasma, which Antimatter can release the maximum and the larger amount of pmtics strength in the full spectrum of pmtics of energies from the plasma".

To understand what the role of the Antimatter is in the overall construction of plasma, we can simply look at the larger scale of the same type of entity and its effect in the universe. In the universe, the large-scale plasma conditions are said to be the like of the Stars, or the Suns' in their solar systems.

Where, the **Antimatter** part of the plasma is the same as the Star of a solar system, and it is the ***holder of the main quality and quantity*** and the possessor of the ***strongest pmtics strength*** of all Matters of the initial fundamental plasma.

I consider that, the Antimatter is the **source of the energy** and **the central gravitational point of the plasma** as a whole. The Antimatter is in fact the Star of the plasma, thus it is as the Sun to the solar system. In fact, there is nothing "anti" about this Matter component of plasma in the universe.

This is the reason why, in being able to free them from the sub-components of the Matter and the Dark Matter of the plasma, the Antimatter appear to be such a fantastic new source of energy.

As the Antimatter was made initially from the stronger magnetic fields strength in the plasma to start with, hence it holds the real fundamental source and the supplier of pmtics to all matters in the plasma. It can be said that pmtics released by the Antimatter are the platform for the change for almost everything that is made in the matter world.

That is to say, “that Antimatter is the source, where pmtics are positioned to start the change from stronger pmtics strength level in the plasma components, and transfer more of pmtics strength of Matters to matters”.

It is the pmtics of the Antimatters, which are transferred in most parts‘, from one plasma to another, which, causes energy transfer from one molecule to another or one cell to another.

We have used these Antimatters pmtics strength effects in the recent past in our reactors, the pmtics interactions of Antimatters were utilised to create the Magravs forces needed for the Magravs positioning of these systems in respect to another plasmatic Magravs of another object, this being like the Earth’s Magravs.

Through tests, it has been proven that the presence of the **Antimatters** and its strong plasmatic magnetic fields that it provides for the creation of Magravs in the reactors is the main reason why, we have managed to lift and move large masses through the gravitationally positioned principle.

In Grapos test reactors, which have been developed and tested for lift and motion, the operativeness of pmtics strength of the Antimatters have been proven to be in line with our theories, where if the pmtics of the Matter were used in these reactors, the Magravs created by pmtics of this Matter would not haven been strong enough to cause the motion or lift of the system.

The scientific world is using accelerators (6, 7, and 8) to slam the plasma into a wall of matter, for the plasma to open and to release its Antimatter sub-components.

In present technology, scientists are trying to understand how to gather and harvest the power of this Matter. It is however crucial to understand that, “**one does not burn the Antimatter as fuel,** as it is assumed by the present scientific world in this field and as Fermilab (6, 7) is considering”.

Nevertheless, there is an easier and smoother way to achieve this separation, and that is just to dilute the plasma (Chapter 21), through this method, it will be easy to release the Antimatter from its plasma.

Once the scientific world has a full understanding of how to separate this Antimatter from its plasma, then they will understand that one does not need to burn this Matter as fuel to create motion and energy. But, they simply have to learn **to use the effects of the interactions of the constituent pmtics of this Antimatter** in conjunction with other Antimatters pmtics of other plasmas or Matters pmtics to achieve lift, motion, and for creation of energy, as has been done in the universal order of motion and creation of energy for billions of years.

CHAPTER 11

The Antimatter energy

Antimatters are known to be the sources of vast amount of the **strong pmtics**. The strong fields of the Antimatter are considered to be the major sources of the energy supplied into their respective environment for Matter-to-Matter, and from Matter-to-matter through their pmtics. The ***strong** pmtics*, once released by the Antimatter, and these pmtics in being *in motion* in their environment, they become to be called the **energy of the Antimatter**.

These pmtics by essence of their origin and strength they are, and become, ***strong** energy field sources* and reservoirs of energy in their environment. Where, some of the pmtics within the Antimatter are used to maintain the integrity of the Matter and the plasma itself.

At the same time, some of the pmtics of the Antimatter are equally reduced in strength, and these changes and reductions in their strength of some of the pmtics strength of the Antimatter overall constituent pmtics, these pmtics are allowed then to escape the gravitational fields of their Antimatter pmtics Magravs.

These released pmtics from the Antimatter, become the Antimatter pmtics in motion (energies) due to the strength of their plasmatic magnetic fields' forces. These pmtics can travel *much further* from the Matters and plasma, to transfer their energies to other pmtics in their environment.

These released fields become the Antimatter pmtics in motion (energies), which, due to the strength of their plasmatic magnetic fields' forces, these pmtics can travel *much further* from the Matters and the plasma, for them to transfer their energies to other pmtics in their environment.

Due to the fact that the Antimatter itself is originally made of the stronger pmtics, the Antimatter will let go of pmtics in stronger and wider spectrum of magnetic fields strength. Thus, the Antimatter releases a full spectrum of pmtics strength forces. That is why they are more powerful and covering a wider range spectrum of energy levels as they slow down.

In essence, the **Antimatter** itself starts from a combination of interactions of stronger pmtics bases, and hence has more to lose of its slowed down fields and it has more to attract due to its stronger Magravs too. At the same time, it covers a larger domain as its pmtics can spread further.

In fact, the energies that are released by the Antimatter look to be, and basically are stronger than other energy fields around them, purely due to the fact that they start their life from stronger pmtics strength base in their environments.

CHAPTER 12

The Dark Energy

The principles of creation of the Dark energy as an outcome of normal interaction of pmtics are discussed. The similarities of the Dark energy and force, which are created around Black holes, are in principle of the same origin.

In the dynamic environments of the universe, changes happen due to various conditional factors like motion, compression, turbulence, temperature, and so on, that can individually or collectively lead to concentration or motion of pmtics (energy). These changes in environmental conditions can lead to the manifestation of Matters like the Matter, the Antimatter, the Dark Matter, atoms, stars and galaxies and so on. This is the common fundamental base for the creation of Dark energy and creation of Dark Matters (36) and any dark objects like the Dark Matters, the regular appearance of dark spots on the surface of the Sun and stars (12, 13, 14), the appearance of Dark spots in the galaxies known as Black holes (13), the Dark Rings around Saturn (17) and so on. The creation of these conditions and matters can all be explained through the following interaction of normal dynamic pmtics in the universe.

By pmtics theory, the Dark energy is said to be the ***collection of balanced and equilibrium pmtics strength forces in motion*** in respect to their environments pmtics strength, this being in any given environment, in deep space in the universe or in the centre of an atom and so on.

The universe always possesses equilibrium pmtics strength in its total energy balance, hence the universe possesses more environments which are in pmtics balance strength and hence the existence of vast-spans of the universe which energies are in motion, but due to their balance magnetic fields strength in these regions of the universe, no light through the interaction of various magnetic fields are produced to confirm the motion of the pmtics in that region.

It is important to note, that in the universe only the difference in magnetic fields strength is the cause of creation of visible light from the human observation point of view. Where there is balance and equilibrium in the environment, no lights through interaction of magnetic fields or pmtics are produced. This doesn't mean that there are no magnetic fields or pmtics in motion (energies) and that nothing is present in that region of the universe. In fact the darkness of dynamic environment of the universe confirms the existence of the balanced magnetic fields strength. Beholding the truth, the darkness of the universe confirms the existence and motion of balance and equilibrium of magnetic fields strength, and not the lack of the existence of magnetic fields in motion (energy).

We have defined Energy as: "**pmtics forces in motion**". Therefore the Dark energy has the same definition, where in this case, these are **balanced or near balanced pmtics**

strength forces in respect to their environment pmtics field forces in motion.

The universe always possesses equilibrium pmtics strength in its total energy balance, hence it possesses more environments which are pmtics balance strength and hence the darkness of the universe.

Steps in the creation of Dark Energy

To explain the phenomenon of creation of the Dark energy in more detail, let us consider two equal pmtics environment zone A and B in figure 35. These two fields' zones can be for example pmtics from two galaxies in motion in the universe or two pmtics in the span of a plasma.

Before the interaction of the two field zones, pmtics of each zone are interacting with their respective environment, which creates their own boundaries of their field strengths through their magnetosphere boundaries, in respect to their environmental pmtics (zone A with zone D, and zone B with zone D).

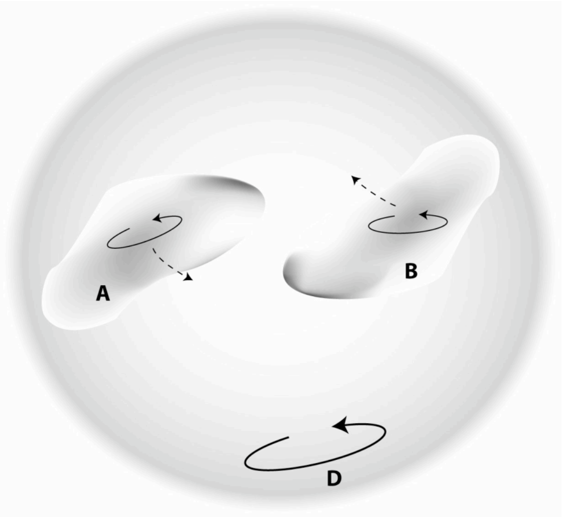

Fig. 35: Two equal pmtics strength entities moving in each other path.

Lets assume; a) The universal magnetic fields are always in rotational motion as of D (Fig. 35), and b) The two pmtics of the A and the B are in motion in directions shown. Through their motion and the environmental forces, the two fields zones come to be partially in contact and interact with each other. (Fig. 36)

As segments of pmtics of the zones A and B collide (Fig. 36), and as their interacting pmtics are similar in strength, then there are no differences in field strength for the two pmtics to create the magnetospheres condition (14) or no residual pmtics or very little pmtics fragments are produced from the interaction of these two pmtics zones. Thus in the interaction of two fields and due to balance in their pmtics strength, this interaction **zone C** of fields does not lead to creation of pmtics fragments in the light magnetic field spectrum leading to the creation of pmtics of light (Chapter 7), to make this region light to show the existence and occurrence of collision between two equal magnetic fields strength zones.

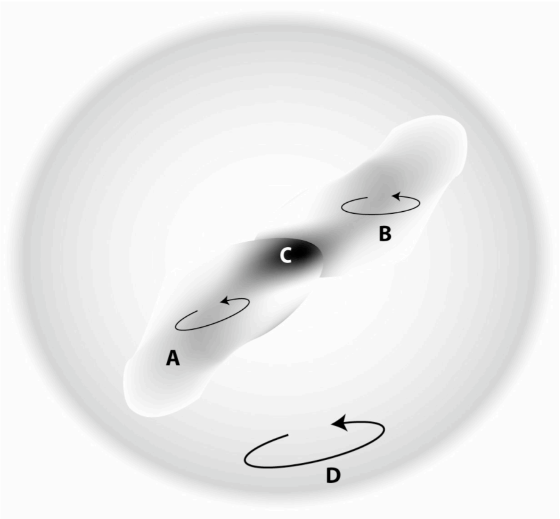

Fig. 36: Two equal pmtics strength entities moving in each other path colliding and creating a temporary Dark energy zone (zone C) due to their interaction.

Thus in respect to the surrounding environment the colliding of two pmtics in motion and the lack of production of pmtics fragments strength in the bandwidth of the light in this section of colliding pmtics, this creates the appearance of being dimmer or darker zone (Fig. 36 zone C) compared to its two original zones magnetospheric condition in respect and in comparison with their surrounding pmtics.

In the region of C of figure 36, due to the balance in pmtics strength and the creation of very little residual pmtics fragments, this area has a darker appearance in comparison to the rest of the region which one can observe with the rest of the two zones of A and B in the overall region of the D environment. Nevertheless, the energy of the pmtics in motion of the two pmtics zone of A and B exist and they can be measured, as the two pmtics of A and B move on, this confirms the existence of energy in the dark zone C, where in fact there are no sources for such an energy field to justify their existence in this darker appearing region.

Thus, in the case of the Dark energies zones in the universe, most of the time, one has to look at the overall picture of the interactions of the package and area, rather than to the local zone where the darkness and dark energies appears to be and where pmtics in motion as energy fields are present.

Further on, as the two fields zones A and B are dynamic entities and they are pushed by the forces in the bigger picture of the zone D, the Dark zone C, figure 36 disappears as two zones of A and B move away from each other.

Thus, the interaction and creation of the zone C, figure 36 is a **temporary phase** as the two field zones separate and carry on in their own path and the Dark energy zone C in figure 36 disappears, as there never was a Dark energy zone in that part of the zone D as whole (Fig. 37 fields A and B).

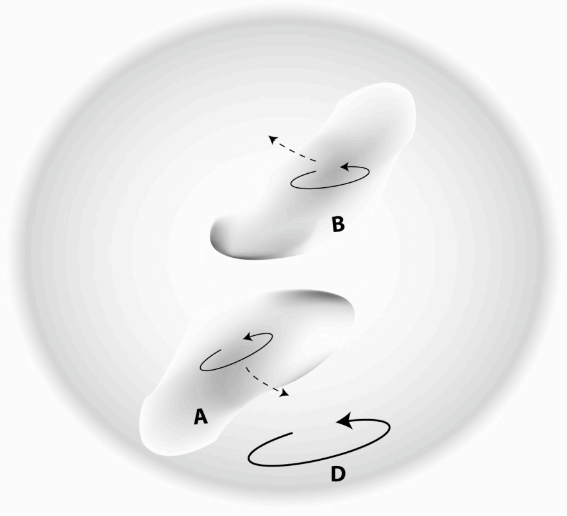

Fig. 37: Two equal pmtics strength entities moving away from each other after their collision.

Therefore, Dark energy zones in the universe are not necessarily a place where there are void of Matters or magnetic fields, but the darkness itself confirms the existence of the balanced pmtics strength in motion in respect to the majority of pmtics strength forces in that given environment, which pmtics in these areas are in balance and in equilibrium in strength with each other in a given point and a given window of motion of fields called time in the span of the universe.

At the same time, these sudden Dark energy regions in space are temporary conditions in a given specific time and specific position from a specific point of observation.

On the other hand if one is inside such a zone not necessarily means that one is in the Dark energy zone. In some cases of dynamic solid gravitational fields of matters in the centre of these energy zones, due to the interaction of the Magravs of the Matters and in level of Dark intensity translucent, inside these Dark energy zones one can have bright zones as being near a star zone.

It is obvious that most of the universe appears as dark, even though pmtics always exist in these areas of the universe and are essential components of its structure. This by itself means that the universe is in pmtics strength balance and equilibrium within itself.

The Dark Matters do not all possess the same pmtics strength and therefore the Dark energies are not all of the same magnetic or Magravs strength, in respect to other pmtics strength environment.

By the same measure, the Dark Energies in the universe do not all possess the same pmtics strength, as their strength is pmtics strength dependent in respect to the environment pmtics strength of their appearance.

In the case of the Dark Matters as sources of the Dark energies, these Dark energies are produced through the initial pmtics interactions in the centre of the Matter, and hence the energy they produce as their overall outward Magnetic fields and inwards gravitational fields, are always in balance in respect to other pmtics in their given environment. Where this balance of pmtics strength gives the Matter the appearance of **darkness**, or darker looking in respect to its overall given environment.

Some of the Dark energies have a Magravs source in their centre in the universe. Thus, these types of Dark energies are part of a Dark Matter source, which are part of the overall magnetospheric environment of the Dark Matter pmtics. These sources of the Dark energies are the Magravs of a matter which in respect to its environment from a given position in space, and due to the equilibrium of the pmtics of the Matter and the environment, cause the Dark energy zone, from that specific point of observation, as that given zone of pmtics interaction appear to be darker than the rest of the environment surrounding it.

CHAPTER 13

The Dark Matter

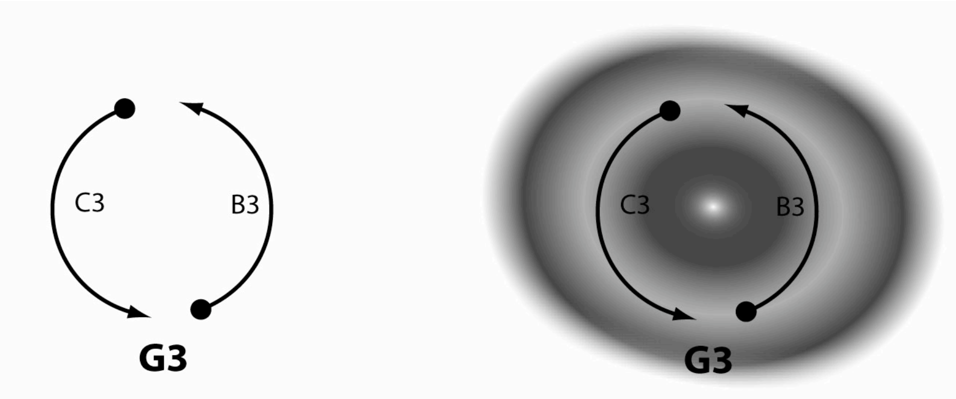

According to the ***Keshe pmtics Theory of Dark Matters*** "*for an entity to be considered as a Matter, the entity has to possess both Magravs pmtics forces, so that not only the Matter can maintain its Magnetic and gravitational fields, but at the same time the Matter can maintain a balanced pmtics magnetosphere magnetic fields forces strength zone and a magnetic fields mass, for the Matter hold on to its constituent pmtics for it to exist, with the difference with the Dark Matter that the magnetosphere created through the* ***overall*** *interaction of its Magnetic and gravitational fields forces strength of the Matter and the environment pmtics force strength that these two forces are in equilibrium in strength, where the interaction of the pmtics of Magravs of the Dark Matters' magnetosphere and the environment pmtics field force in interacting with each other, they do not create residual fragments pmtics that is in the light magnetic fields strength spectrum level, that makes this Matter visible or detectable, hence the term Dark Matter (Fig. 38 G3)* (36).

At the same time the Magravs forces created by the same Dark Matter appears to create a magnetospheric fields forces' zone around the central Matter, which gives an impression of an energy source that comes from a dark space in a given environment without a visible material source and hence the use of the term **Dark Energy** (Fig. 38 C)."

The Matter is said "to be dark, as its effects can be seen or felt, but, it, is not made observable to the line of vision or is undetectable through detection systems, which are looking for signs of light as means of confirmation of the existence of the Matter"(36).

The Dark Matter can be defined in another way, that is to say:

"The Dark Matter (Fig. 38 Matter G3 field C) is the Matter that, by the interaction of its internal initial pmtics strength, creates the Magravs effects and its external plasmatic Magravs as the magnetospheric field effect for the Matter to exist. Nevertheless, it is due to the overall balanced Magravs strength that are created by the Matter as the magnetosphere of the Matter, being in balanced magnetic fields strength with respect to its given environment pmtics strength, so that the interaction of the two magnetic fields does not creates pmtics fragments in the light spectrum, where the Matter cannot create detectable magnetospheric light."

That is to say, the interaction between two plasmatic magnetic fields strength of the Dark Matter and the second pmtics strength of environment does not create a **visible or detectable magnetosphere** effect, which would be needed to confirm the presence of the Matter in that given environment and in a given position, at a given point in time.

The Dark Matters effect of Magravs energies can confirm its existence, as the Matter that *appears* as Dark or translucent Darker Matter, in respect to its given environment, to the line vision appearance of the Matter, in a given position and time.

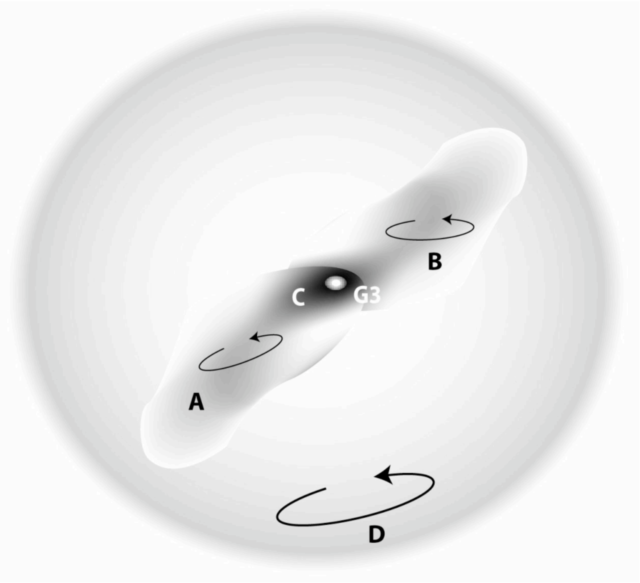

Fig. 38: The Dark Matter (G3), the Dark energy (C)

The Dark Matters can be, or, are made of stronger or weaker plasmatic magnetic fields than the Matter, and the Antimatters components of the plasma.

The Dark Matters are Matters which appear as areas in the universe in possession of Magravs forces but no or a very weak, detectable external magnetosphere in respect to their environment at given point and **a given window of transition of time**, where the confirmation of the existence of the Dark Matter is environmental pmtics strength and position dependent.

If one could create the fundamental principles of the Dark Matter, by the use of Grapos, with the production of balanced pmtics strength around the system, then one can travel the spans of the universe with pmtics Magnetic field protection and more or less without any friction, or resistance in the direction of the motion of the system, this allows the system to achieve speeds far beyond the present knowledge of Man in the space and aircraft industries (36).

The same effects of the creation of balanced pmtics strength in respect to the environment can be used to make systems, that without moving; such system becomes invisible to the line of vision at any point in atmospheric condition or in deep space.

The larger entities like of the Dark Matters in scale of magnitude are the black holes in the galaxies, where a large gravitational fields zone is observed and no physical tangible source for the large and strong pulling forces in that region of the galaxy can be seen. These areas, which are usually and mainly in the centre of galaxies or on the edges of turbulent boundaries of galaxies, as there are more Matters, matters, magnetic fields and plasmatic magnetic fields on the move. Where the total balance of these fields, in respect to their given environment, gives these regions an impression to have the appearance of the **darkness**.

These dark regions with strong gravitational pulls are overall temporary events in the bigger cycle of life of galaxies bigger picture of motion of pmtics and Matters (12, 13).

Sudden appearance of Dark Matter as Matter due to changes in fields forces in the environment can be analogised like having a wet cloth that is dry looking. However, by twisting and squeezing the cloth, out of nowhere, drops of water start dripping out of the cloth. The appearance of the water drop does not mean that water was not in the cloth, but in fact it means that the condition were not there to force the water to manifest itself within the cloth.

The Dark Matter can become visible as Matters around their environment pmtics strength changes. On the other hand, the Dark Matter can become visible Matter when there is a change in the internal pmtics strengths of the Dark Matter, which the change in magnetospheric strength of the Dark Matter, changes the magnetosphere pmtics strength in respect to its environment pmtics strength and the Matter becomes visible. That is why the Dark Matters are environmental pmtics strength dependent. The appearance of Dark Matters, due to changes of their pmtics strength or environment pmtics strength changes have been seen in the universe by scientists and they call these, the Virtual matters or the Virtual particles (Chapter 14).

Dark spots on the Sun and Black Holes

The Dark spots on the surface of the Sun; These effects are usually seen on the dynamic surface of stars, where large numbers of similar pmtics strength materials in motion interact with each other, and hence there are more possibilities of having balanced pmtics strength regions, as most of the matters are of the same structure of hydrogen plasmas.

The main reason for the increase in the levels of the dark areas and dark spots on the surface of the Sun, about every eleven years, is due to change of polarities of the Magravs created by magnetic fields in the centre of the Sun. This increase is purely and only due to one factor, this being that the creation of dark spots on the Sun is primarily due to the interaction of pmtics of the matters on the surface of the star and the pmtics of the Magravs from the centre of the star. As at time of polarity change of the star, there are more chances of the interaction between two pmtics, which are made by the components of the same matters (Hydrogen). Thus, there are more chances of reaching Magnetic strength equilibrium conditions between the surface pmtics strength of the matters on the surface and the internal Magravs' fields strength created in the centre of the star. Where at these points of balance zones of pmtics strength, no or very little pmtics fragments in the spectrum of light are created, hence the reason why appearance of the increase in the number of dark spots on the surface of the Sun during the polarity changes of the star (12,13).

Thus, the dark spots of the Sun are natural outcomes of the balance interaction of the pmtics strength of the overall Magravs created by the centre of the Sun in respect to the pmtics strength of the plasmas of the materials on the surface of the Sun. Thus, as there are more balance pmtics areas produced, a higher number of darker zones can be observed on the surface of the Sun.

The darkness of Black holes in galaxies, and the Dark energy fields they produce in their environment, are due to the same process (12, 13). Similarly, all Dark energies are not necessarily connected to the central Magravs of the Dark Matters.

The Dark Matter and the Dark Energies appear and behave as dark regions, in respect to a given magnetic fields strength environment, at a specific point in time and space, and specific conditions from the point of observation. By the same principle, the Dark Matter and the Dark energy will be a visible or tangible Matters or matters in a different pmtics strength environment and even from another point of observation.

Therefore, state of the Matters, this being the Matter, the Antimatter, the Dark Matter appearance and detection of their energies are totally pmtics environmental respective dependent.

That is to say, "what is **the *Matter and the energy*** *in one given plasmatic magnetic fields' strength environment* can become *the **Dark Matter** or the **Dark Energy** in another pmtics strength environment* to the human point of observation".

In the universe, the Matters and the Matter energies or the Dark Matters, the Dark energies, the Antimatter and the Antimatter energies **change from one state of Matter to another**, or one **state of Matter energy to another**, purely due to *the respective Magnetic fields or gravitational field* strength as of their environments pmtics strength as these Matters and energies pass *through them*.

In the micro and macro universe, suddenly Matters and energies ***appear*** **out of nowhere** and **Matters and energies suddenly *disappear* into nothing**. These appearances are all pmtics strength respective environment dependent as the Matter or energies pass through a given field at a given time in their immediate environment.

The universe is considered by us to be covered with the Dark Matters and the Dark Energies. In general it can be said, where there are no faster or slower pmtics, or differences in pmtics strength, interacting or for other pmtics of the same or different strength to collide with, through these balanced pmtics strength regions, there are no unbalance fields to create friction or to have an interface or to have residual pmtics between the environmental and the moving pmtics, these regions in the universe give the appearance of lack of *Matter,* or the Dark Matter or the existence of Dark energy in respect to the given point and position in the universe. This means that the dark regions of the universe are balanced in pmtics strength, and *not void of pmtics*. Hence as the universe is magnetically strength balanced, therefore the universe, in general, appears dark and empty, even though the universe has no regions without magnetic fields.

These types of darkness can be see-through and can be transparent through their pmtics energies; I call these areas the "***translucent Dark energy zones***".

This translucence state of position in a given environment is a state where, there is total darkness but at the same time, there are pmtics strength field interactions that allow enough light, in respect to vision and detection for one to confirm the lack of light.

This being the reason why, one can see or detect, other Matters or matters through this universal Translucent Darkness light.

This light in the span of the universe is due to the interaction of very weak pmtics in motion (energies) in the constituent universal pmtics soup. In fact, these dark regions of their environment are where the pmtics are in balance within these regions.

As was discusses in the previous chapter, to the human eye protein pmtics balance set, these residual fields of the two pmtics interactions, due to their pmtics strength balance, appears as the Dark Matter and is like Dark energy zones in space. If humans would possess another chemical pmtics protein chain, what are the Dark Matters and the Dark energies by present means of detection, by viewing through different tools of vision, then these areas will be as visible light regions of the universe, and may be in different colour, for example in the Antimatter colours spectrum of the universe, or even in the Dark Matter colours' spectrum of the universe. Through the use of such tools, the importance of the use and function of the Dark energy (Fig. 36) and the Dark Matter (Fig. 38) will be soon grasped by men of vision, to see the true darkness. Where in the colour spectrum of the Antimatter the colours are magnetic fields strength dependent and these colours are not noticed by the human eye matter-based protein pmtics. The same applies to the Dark Matter colour spectrum.

In the universal order of containment for Matters and energies, it is not far from the truth to say that the state of Dark Matter is the same as gasses in matter state, that the Dark Matters and Dark energies do not have self-containment.

That is to say, "As with gasses in a state of matter, Dark Matter fills all the environment and space that is given to it, as it creates no effective magnetospheric interface boundary resistance in respect to its environments' pmtics strength forces.

The boundaries of the Dark Matters and Dark energies are dictated by the boundaries occupied by stronger or weaker pmtics strength regions around them in their given points in the universe."

The forces of Dark energies can be confirmed only through their interaction with other plasmatic magnetic fields in motion, in respect to the field of the Dark energies motion themselves.

That is to say that the dark lights generated by the Dark Matters and Dark Energies cover the whole of their given spaces, this being the space in-between different Matters in the atoms structure or solar system or even galaxies, I call this ***principle of creation of dark light*** strength difference of pmtics magnitude needed for creation of light, the **principle of pmtics magnitude**.

It is very correct to assume that one atom of Dark Matter and its Dark energies can be and/or is enough to span its balanced pmtics to cover the whole of a solar system, or its bigger counter part galaxies or smaller spaces as the space in the pmtics Matters of one tangible atom.

CHAPTER 14

Virtual Particles (Virtual Matters)

The existence of virtual particles, *which appear out of nowhere*, and have the characteristics of real particles in essence, has been described in the Dark Matter section of this book. The method by which these particles appear within their environment is exactly how the Dark Matters do exist and appear in their environment, after their overall Magravs, magnetosphere strength changes' or due to changes in the pmtics strength of the environment.

In fact the virtual particles are individual atoms' or plasmas, or any Matters, of the Dark Matters behaviour' (Chapter 13, and reference 12), which when they come into new pmtics strength environment *which is **different** than their previous balance condition* pmtics strength environment with their Magnetic field and gravitational fields, then these particles generate a new magnetosphere in respect to their new condition pmtics strength environment, thus they create light due to their interaction of their plasmas (Chapter 7) and so they appear *as **new matters or virtual Matter***.

There is nothing new about virtual particles; these are like loose plasmas or a single atom in the soup of the universal Magnetic and gravitational fields.

Thus, in simple way according to ***Keshe Theory of creation of Matters***, virtual particles are Matters and behave like Dark Matters. They are created from the interaction of at least two pmtics, which leads to the creation of Magravs of the Matter, therefore what scientists call virtual particles, these are real Matters, which due to the change in their environmental magnetic fields strength condition, they suddenly ***appears as matter(s)*** for *a very short time*, until they lose their pmtics strength or their environment pmtics strength changes or as they move out of the environmental pmtics strength level or they seem to disappear.

Virtual particles possess a magnetosphere and the light they create in their new environment is due to the interaction of their pmtics of their magnetosphere with the pmtics of this new environment, which makes them visible in that given point and given time.

Note: When the (virtual) particle(s), Matter(s) or matter(s) is moving towards the observer due to it's ***compacting of pmtics***, this creates the blue shift colour of magnetic wavelength spectrum (Chapter 7). If the virtual particles are moving away from the point of observer, due to ***opening of the pmtics*** of the environment, they create light in red shift colour of magnetic wavelength spectrum. (This is described in the paper: Creation of Magnetic field).

The virtual particles are actually individual nano-atom or plasmas or sub-Matters of plasmas.

The Casimir effect

In present physics, virtual particles are related to Casimir effects.

First of all, the Casimir effect and the photon energy appearance in its setup of its confirmation is always considered to be in a **vacuum condition** between two conductive plates where, photons in between two plates are observed and electrical charges are measured.

In fact, it is not important what vacuum condition level can be achieved in test laboratory conditions, nevertheless still a number of pmtics, Matters, plasmas (electrons and protons) and atoms could be left in the space between the two plates, which are under observation.

As matters are made of plasmas of interacting magnetic fields of Matters, when the space in between the plates is freed and void of most of its atoms and Matters, at this point the leftover matters or Matters between the two plates are more free to move in the newly created condition environment. Hence it is natural that these residual atoms, electron plasmas, proton, can move really in empty space and can collide with the walls of the matter of the two plates and due to their interaction fragments of pmtics strength are released which these are in the range of the pmtics strength of photons.

So vacuuming the gap between the plates creates a new environmental plasmatic magnetic fields force condition that allows a more free motion of leftover Matters and atoms in between the two plates, where in fact the boundary of the magnetosphere of one atom can occupy or expand the full span of the gap between the two plates.

Casimir effect measurement is a good tool to measure how many atoms and/or what Matters are left in the gap between the two plates at a given vacuum level.

We have done experiments in plasma dilution reactors, which we have developed and have seen the Casimir effects. In these tests, we have seen some serious voltages and currents, but never photons. Which indicates that these voltages can only be from Antimatter source in-between plates, as matter cannot produce these levels of voltage and amperages.

In a number of tests we have created 30 mm gap between plates and the results have been the clear indication that Casimir effect testing is good to find nearly the number of Matters in between the gaps, and types of Matter which are left in between the gaps. As **Matter and matter** create *different charge levels* than the **Antimatter** components of the plasma.

We have created environments of 10 (-9, -10, -11, and -12) bar in our tests, and in tests over 10 (-8) bars there was not much difference in voltage and current measurements from both plates' terminals. This indicating that it does not make much difference how far one can vacuum the gap in between the plates, there are still some components of Matters or matters will be present in the gap, which can move with more freedom than before. Where this small number of matters or Matters in-between the plates can transfer energy through the free motion of their plasmas in collision with plasmas' of matters of the wall and lead to the release of pmtics fragments in the strength of the light magnetic field spectrum or a photon.

Van der Waals forces

In respect to the Van der Waals effect, this **push and pull effect** is now very clear and easy to explain, this is to say as plasmas contains all Matters (Matter, Antimatter and Dark Matter) and these Matters are all made from the interaction of plasmatic magnetic fields, which leads to the creation of their Magravs, so that each Matter is *like a **independent entity*** within the structure of the plasma, at the same time plasma possesses its own Magnetic and gravitational field forces.

By the same measure, the atom, as an independent system, possesses its own Magravs in respect to other atoms in molecules. The same, the molecules have their own Magravs in respect to each other.

Therefore, what has been considered as Van der Waals forces of push and pull of molecules, these are simply Magnetic and Gravitational field forces or Magravs forces of one molecule in respect to any other molecule.

The Van der Waals force is in fact the pull (gravitational effect) and the push (Magnetic effect) of the individual molecules in respect to any entity (atom, molecule) around them.

CHAPTER 15

Interaction between Matters

Different Matters in their environment interact and create different conditions, and state of Matters are similar to the state of matter, as one can mix liquid with solid and gas with liquid in state of matter, the same can be done with different states of Matters, like allowing the pmtics of the Matter to interact with the Antimatter and further the Antimatter with the Dark Matter. As in the case of Matters, they are all pmtics strength dependent, where these kinds of mixings of states of Matters allow more profound effects to be developed. This kind of mixing between the state of Matters will open new world of science to mans' encyclopaedia of knowledge ***Matteorology*** *(knowledge of Matters).*

The process by which, Matters are created and operate in respect to each other within the construction of the plasma has been explained in previous chapters. These Matters individually possess their own properties and create their own effects in respect to their environment, both individually and in conjunction with each other.

What is important to understand is: *What happens when these Matters interact or come to collide with each other within the plasma or their environment?*

What is the outcome of the amalgamation of the plasmatic magnetic fields strength of different Matters with each other?

Let us consider some of the variations between interactions of different Matters.

Interaction of Matter with Antimatter

The Matter is composed of ***weaker*** Magravs strength than the **Antimatter**. In this case, the Matter always gets attracted towards the Antimatter.

In the case of the plasmatic magnetic fields of the Matter ***colliding*** with the plasmatic magnetic fields of the Antimatter, the Matters components will **get *absorbed* into** the larger and stronger pmtics strength, by order of magnitude, of Antimatter.

What can be observed from this impact is the release of some plasmatic magnetic fields residual as pmtics, like release of some lights or rays or magnetic residual. The content of the dynamic plasmatic magnetic fields of the Matter or its energy is *absorbed into the environment of the Antimatter* and gets mixed in within its structural magnetic fields strength. At this point there will be no more signs of the Matters past existence.

Where, most of the rays released in this interaction are mostly due to the coming close of the two Magravs of the two Matters, rather than the splashing of the pmtics from the surface of the Antimatter.

This is like when a drop of water falls into a cup of tea, in this case, the drop of water becomes part of the larger teas' liquid.

Majority of scientists working in this field, are lead to believe, as the Matter and the Antimatter collide, due to their charge balance after the impact, the content of the two Matters ***disappear into nothing***, except some residuals released as energy, gamma rays or photons, then, in their opinion, there is nothingness left as these two Matters' charges balance each other out.

Such a belief and concept is against any natural laws of existence. That is to say, there cannot be a position of total annihilation of both Matters, where there can be nothing left at all after the two actual Matters in possession of Magravs collide with each other. This nothingness of the two Matters after the collision of the Matter and the Antimatter is a rash assumption and incorrect.

In fact, the Matter and so-called the Antimatter by their pmtics strength order of magnitude in the matter world, is like the Earth slamming into the Sun, and then saying that after this collision there is nothing left of the Sun and the Earth, except some outwards splashing fragments of plasmas from the surface of the Sun. This is illogic attempt at a scientific explanation for such a real physical event.

The Matters of the Earth would cause a small splash on the Suns' surface. This splash then releases some plasmas or gamma rays or photons from the surface of the Sun. Then the plasmatic magnetic fields components of the Earth become part of the plasmatic magnetic fields of the plasmas of the Sun. This is exactly the same incident as when pmtics of the Matter collides with pmtics of the Antimatter.

In view of this principle in physics of the conservation for energy, ***nothing in the universe is lost or can disappear***. They just change their magnetic fields strength and their compactness from one form and level to another.

Thus, collision of the Matter and the Antimatter create nothing but the Antimatter, with more content of different plasmatic magnetic field's strength of the Matter components inside it. Therefore the outcome of this collision is mainly the Antimatter balance remaining.

Interaction of Matter with Dark Matter

This follows the same principle as the previous states of the Matter and the Antimatter. The content of the Matter then becomes the constituent Matter of the gravitational centre of the Dark Matter. With the difference, that in this case the Matter will not have to overcome any magnetosphere of the Dark Matter.

This interaction will be the same as seen in the universe matter dimension, where for example Stars and cosmic matters disappear into a Black hole in the universe.

In some instances, this process can disturb the overall Magravs' strength balance of the Dark Matter in respect to its surrounding plasmatic magnetic fields strength. This change can induce the production of slightly stronger or weaker magnetic fields strength magnetospheric conditions of the Dark Matter in respect to its surrounding field's environment.

In these rare cases, due to the change and unbalance of the magnetic fields strength between the new content and new Magravs strength of the Dark Matter, this new stronger or weaker plasmatic Magravs strength, allows the creation of a new magnetosphere field strength of the Dark Matter in respect to its environments pmtics strength to take hold. Then, what was the Dark Matter in a given environment, can in the same given environment, with a different and new plasmatic magnetic fields strength, now create and possess a new magnetospheric field strength zone in respect to the same environment's pmtics strength and then the Dark Matter can become like the Matter that is more visible.

This incident has been recorded by cosmologists a number of times. Where, *out of nowhere*, Matters appear in the Dark spaces of the universe.

In fact, even changes in the tightness of plasmatic magnetic fields in the span of universe, can unbalance the Dark Matter environment pmtics strength and make the Matter visible.

This magnetic unbalance of the environment causes different balance condition around the Dark Matter pmtics, and then out of nowhere stars appears in the Dark spans of universe.

The interaction of Antimatter and Dark Matter

In the case of the interaction of the Dark Matter and the Antimatter, there are clearly several scenarios, which are possible.

1) Scenario 1

This case is the most probable and is considered to be the norm. This interaction is a collision of the giants of the Matters of the plasmas'.

Assuming that this scenario of interaction takes place within the environment of an initial fundamental plasma.

Considering the construction of pmtics strength of the Dark Matter and the Antimatter, when, these two Matters of the plasma collide, the outcome is normally production and release of new and balanced plasmatic magnetic fields environments. In this case, it is considered that each of the Matter's components of the plasmas keeps their pmtics strength plasma status.

Due to the enormity of the quantity of the amounts of the two plasmatic magnetic fields of the ***Antimatter and the Dark Matter amalgamation*** (denoted as **A-D Matter**), new supersized, unstable giant plasma is initially created. This new plasma needs to reach stability over the entity of the plasma as a whole for it to survive. Thus, the new super giant plasmatic magnetic field has to find a new Magnetic and gravitational balance and equilibrium within itself.

For the new giant plasma to reach the new equilibrium condition, the new plasma has to, and always does, release its excess plasmatic magnetic fields into its surrounding environment. The new released plasmatic magnetic fields have to be in balance by themselves too, for them to exist and stay within the gravitational fields of the A-D Matter.

This new release of excess plasmatic magnetic fields near to A-D will contain some of the Antimatter, some of the Dark Matter and some other newly balanced interacting and attracting weaker plasmatic magnetic fields of different strength in the Matter pmtics strength level. These *weaker fields* are mainly from the leftover weaker fragments of the collision of the two giant Matters. These new released small bundles of weaker plasmatic magnetic fields strength themselves due to their proximity and their source of origin, these usually bunch-up and become a new *miniature plasma version of the original initial fundamental plasma within the A-D Matter.*

At the same time, this newly created mini-plasma still has to keep it's own balance and the balance of the whole of the original Matters pmtics and stays' within the Magravs hold of the giant A-D Matter mixture. This mini-plasma creates its own Magravs and then this mini-plasma has to have a Magravs positioning in respect to its original initial fundamental plasma. Thus the new mini-plasma is forced to take a new position and new gravitational positioning in respect to its larger neighbour of A-D and it is at this point that it is forced out of the A-D Matter plasma environment, but still in A-D Matter Magravs catchments' area, therefore this mini-plasma attempts to stay in the orbit of its mother seed, and becomes the **initial fundamental satellite plasmas'** of the original A-D Matter.

Further on with the same process, the A-D Matter mixture has constituents of two unbalanced and un-matching plasmatic magnetic fields strengths of the Dark Matter and the Antimatter within it, at some point, the two Matters plasmatic magnetic strength fields separate and the balance returns' to a new central plasma. By this time the central plasma due to this interaction, finds itself with a new rotating satelliteing smaller plasma.

It should be noted that pmtics of different strength ***never mix*** with each other, however they can be ***influenced*** by each other.

The collision of the Dark Matter and the Antimatter, and creation of new satelliteing mini-plasmatic Magravs rotating around the central plasma is the ***creation of the electron*** from the interaction and collapse of theses two Matters of the initial fundamental plasma. The interaction of the Antimatter and the Dark Matter of the Initial

Fundamental plasma leading, to the creation of a new central plasma and its satellite mini-plasma, lead to creation of **Initial Fundamental Atom** (hydrogen atom). This is what I call the initial fundamental decay of the initial fundamental plasma, or decay of the neutron.

The collision of the Dark Matter and the Antimatter is usually due to unbalance or some deviation in the plasmatic magnetic fields' strength of one Matter or other within the confine of structure of the plasma itself.

2) Scenario 2

This scenario happens usually when the F1 collapses altogether, sending the two giants Matters of the plasma, the Antimatter and the Dark Matter, to collide head on.

In this case, there are two possibilities, which remains open to the new A-D Matter plasmatic magnetic fields.

A) The first possibility is that the plasmatic magnetic fields of the Dark Matter superimposes the Antimatter plasmatic magnetic fields.

By this process, the outcome will be a giant size plasmatic region of the Dark Matter and energy in the plasma.

This new giant Matter, due to the interaction and amalgamation of the two sets of plasmatic magnetic fields strength and their Magravs of its two separate Matters will have large-scale gravitational pull system, with no clear magnetospheric zone boundary in respect to interaction with its outside plasmatic magnetic fields strength environment as before.

This will be a giant gravitational region that will have massive pulling effects, but its core cannot be seen due to the lack of interaction of its magnetospheric condition with its environment's pmtics. Therefore, this region even possessing enormous amount of gravitational field pull has no balance interacting Magnetic field strength or a balance Magravs strength in respect to its surrounding pmtics strength. This Matter seems as if it does not exist, or appears to be Darker than it's surrounding. Around this area, enormous gravitational pulls‘ can be detected, but the cause of all the pulling and where the gravitational pulls is coming from are not clear and obvious. Where, this darkness is purely due to the balance magnetic fields strength of the magnetosphere of this Dark Matter and being too similar in strength in respect to its surrounding environment pmtics strength to be able to generate the magnetospheric light.

Thus, this area is and looks like as a giant eating machine, which has a lot of energy and gravitational pull, but no visible source to show for its Dark energy as was explained before (36) and the Dark Matter. This condition is usually referred to as the ***Black Hole effects*** (13).

In fact, the only way that one can say that the Antimatter is cascading in this case by the

Dark Matter, is by observation of the appearances of the interaction of the Matters Magravs patterns of the magnetosphere of the whole structure from the outside of the structure.

In these cases of cascading, where the two pmtics strength at the point of separation between the Antimatter Magravs strength and the Dark Matter Magravs strength, internal layers cannot mix due to their different magnetic fields strength, this interaction between two different pmtics field strength at this magnetic interface, creates an ***internal pmtics-interface zone***. Where, this pmtics strength interface zone creates a different zone gravitational and Magnetic field strength on the outside of the magnetosphere surrounding environment of the cascading Dark Matter, and the position of this zone on the outer regions of the Magnetosphere of the Dark Matters are in position and in-line with its physical position of the pmtics interface in the infrastructure in the centre of the cascaded Material.

This internal interface plasmatic magnetic fields zone can create ring-like zones around the outer boundaries of the Dark Matter magnetosphere, where these rings are like different colour or light intensity rings around the whole of the outer boundary of the Dark Matter in respect to their environment pmtics. Where, the thickness and the width of such a ring is equal to the thickness of the embedded Antimatter component.

The physical observation of these effects of the pmtics-interface strength can be seen in the gaseous planets which have initial solid core centre, and where different pmtics strength zones interfaces of different Matter layers are created internally due to their internal pmtics interfaces, as each interface is seen as one ring in the extended magnetosphere of the giant gaseous planets.

These type of magnetospheric rings are usually seen around the gaseous planets with a embedded and initiated solid matter centre cores, and as a number of different layers of the same or different gases are superimposed on top of each other over the life time of the planet. Where the solid matter due to temperatures of its blanketing of gases has become to be in the fluid state-of-matter and creates its own plasmatic Magravs forces. Which the Magravs of matters core interact with the Magravs of the gases in different layers, and/or gas-to-gas of different layers. Where, at the interface of each layer of matters, different Magravs strength are generated and their regions and position of pmtics Magravs strength balance are observed, as one ring related to that specific interface, around the outside of these planets magnetosphere environment in their solar systems. This is exactly how the rings of the Saturn and the Jupiter are created (17, 18). In fact if one could count all the numbers of the dark rings of the Saturn, one should be able to say how many layers of gasses the planets has in its constituent inner structure. This is like counting the rings across cutting of the trunk of a tree to establish its age. How these rings have come to be made and how layering of different gas layers have been achieved by the planet Saturn has been explained in full in the papers under reference 17 and 18.

These multi-layer gas rings actually can bee seen around some stars too, but these are hidden within the intense light from the surface of the star.

The application of multi-solid core and rings in Magravs positioning reactor

When this principle is used in a Grapos reactor, this gives the system and craft a major impenetrable multilayer magnetic shielding ring for protection from cosmic dusts or in defence technology for maximum shielding from incoming asteroids on the path of high-speed crafts (17, 18, 29, 33). Or these types of magnetic multiple ringing can be used around a craft for submerging in deep ***liquid environments*** (29, 33). Where, the craft using these systems become liquid-sealed and Magnetic field and gravitational depth positioning, and temperature independent.

B) The second possibility, with this interaction is that the Dark Matter's plasmatic magnetic fields moves to the centre of the Antimatter's plasmatic magnetic fields region.

In this case, the Dark Matter plasmatic magnetic fields are superimposed and they are cascaded by the Antimatter plasmatic magnetic fields.

Considering that this scenario happens in the environment of the initial fundamental plasma and between its Dark Matter and the Antimatter components. In this case, again, giant plasma of double layers of the Antimatter and the Dark Matter is created and the new plasma will suck-in the Matter components and the electron or another pmtics around it into itself as before.

Nevertheless, this interaction gives the impression of a sudden expansion of the Antimatter as a bright Matter. That is to say that the magnetospheric zone of the Antimatter becomes the total magnetospheric zone of the central plasma. Thus, this new combination of interactions will have a new plasmatic Magravs strength of the three Matters. These being the contents of plasmatic magnetic fields' strength of the Matter, then the Dark Matter and then the plasmatic magnetic fields of the Antimatter.

All these Matters again as previous scenario being cascaded this time by the pmtics of the Antimatter. Where, the weakest pmtics strength of the Matter will be in the centre, superimposed by the plasmatic magnetic fields of the Dark Matter. Then, these two Matters are superimposed by the pmtics strength of the Antimatter on the outside.

The new giant combination of three Matters at this stage is a super plasma size, and this is a temporary condition and is called the Nova state of the three layers Antimatter cascading of the plasma.

Where, the Antimatter's strong plasmatic magnetic fields strength are on the *outside* and create enormous amount of light compared to when there was a balance state of the initial fundamental plasma. This sudden expansion of the Antimatter due to ballooning of the other Matters inside the cascade gives the impression of a sudden expansion of the bright plasma, or what is called a ***Nova condition***.

Sometimes in stars, due to the internal interacting dynamic plasmatic magnetic fields of the plasmas, and through natural process of interaction like fusion or fission or nuclear decay and generation of weaker fields in the centre of these objects, Dark Matters and

Matters pmtics strength conditions are generated and held in the centre of the star.

This generation of new Matters *internally* will cause the expansion and ballooning of the volume of the star initially for a short time. Further on, at this point, as the content of the new-cascaded plasma of Matters can push its boundary to limits beyond the internal central gravitational strength pulls of its three different Matters, then the star explodes in its environment.

This explosion leads to the total release of the internal plasmatic magnetic fields of all its constituent Matters and pmtics inside the cascade. Therefore, these Matters and plasmatic magnetic fields can again start new interacting conditions and environments. Henceforth, the whole cycle of the creation of fundamental particles, then initial fundamental Matters, plasmas, atoms and matters starts again.

This is in fact the normal cycle of the process of interaction and attraction of plasmatic magnetic fields strength in their confined of their environment. There is nothing more and nothing less to this natural cycle of regurgitation of plasmatic magnetic fields of different strength and conditions that these create for themselves and the effects they create to secure their existence.

That is to say, in the case of the plasma, this becomes the release of some particles, which gets absorbed by the other atomic plastic structures around the plasma.

In the case of a star, this becomes an exploding star, which its constituent plasma after disintegration becomes part of the soup of the galaxy and the content of the star gets absorbed in, for regeneration of new stars and so on. In the case of galaxies, this is the same; further on the same happens to universes and so on.

There is the possibility of another scenario for the same new cascaded materials, and that is:

Once the Nova is created and it is not allowed by the external field force in its environment to expand its boundaries beyond its combined internal Magravs' strength, it is at this point that, the *internal* gravitational fields of its three Matters interactions starts to lock into each other and create one overall Magravs force in respect to their outside environment.

This new overall plasmatic Magravs force, which is created due to the interaction of plasmatic magnetic fields of the three layering and three different pmtics strength of the three Matters (the Matter, the Dark Matter and the Antimatter) in conjunction with each other [This is a similar principle to the systems of three internal layers for creation of gravitational field forces of the planet Earth as explained in Chapter 1 (12, 18)], once this new gravitational fields forces takes place and takes hold, and becomes operational, then purely due to its interacting layering gravitational strength magnitude, and the span of its coverage the Matters of the cascade will start pulling all three plasmatic magnetic fields components of three Matters tightly to itself. This causing the retraction of the matters of the Nova and hence contraction of the Nova. The Nova volume shrinks, in response to the new created three layers interactions' Magravs strength.

Thus, by the time all the Matters settle down to their new position, this new plasma will be a condensed Matter of all sorts. As each Matter layer, due to their plasmatic magnetic fields strength will hold onto their position within the construction of the cascaded plasma. Once, the new matters settle into their new positions from the previous giant Nova condition, this new plasma state of the three Matters will be a fraction of its Nova size. Nevertheless, its size will not be equal to the total size of the collection of all three previous Matters and its initial fundamental plasma size, but its overall internal gravitational fields strength will be enormous compared to its past when it was the whole initial fundamental plasma.

By the this stage the content of the outer layer is still active plasma with bright lights of the Antimatter, but due to the new strong internal gravitational pull of the Matters, even the light that is created through the interaction of plasmatic magnetic fields in the outer regions of the Antimatters, interacts with the strong internal field of the cascaded materials and converges inwards (Chapter 9). This giving the impression that the plasma or the Star is dormant or dying, but in fact the systems has never been as powerful and active internally as this in its whole existence even as plasma or as a star.

Interaction of plasma with plasma

Another possible scenario in interaction of collection of Matters as a plasma, is in collision with another collection of Matters as a plasma.

Electron interaction:

i) For example, there is the possibility that the plasma of the electron can be fused into the plasma of the central nucleus of its proton.

“I have called this interaction and fusing of the electron to its proton plasma the ***inter-atomic fusion principle*** (37). I consider this method to be a simpler and more practical to achieve fusion for production of energy, than the path being followed by the present scientific world in fusion reactors technology in trying to fuse two large plasmas of the proton, without any tangible success up to now after over fifty years of research and development to attain any sustainable fusion cycle to produce usable energy for domestic market. These systems being like of the Jet project (Tokamak) in UK and the present upcoming ITER (Tokamak) project being built in the South of France at the cost of over ten-billion US dollars investment with the final goals of only to produce for a few milliseconds of energy within 10 year’s time.

The process of the inter-atomic fusion is shown step by step in figure 39.

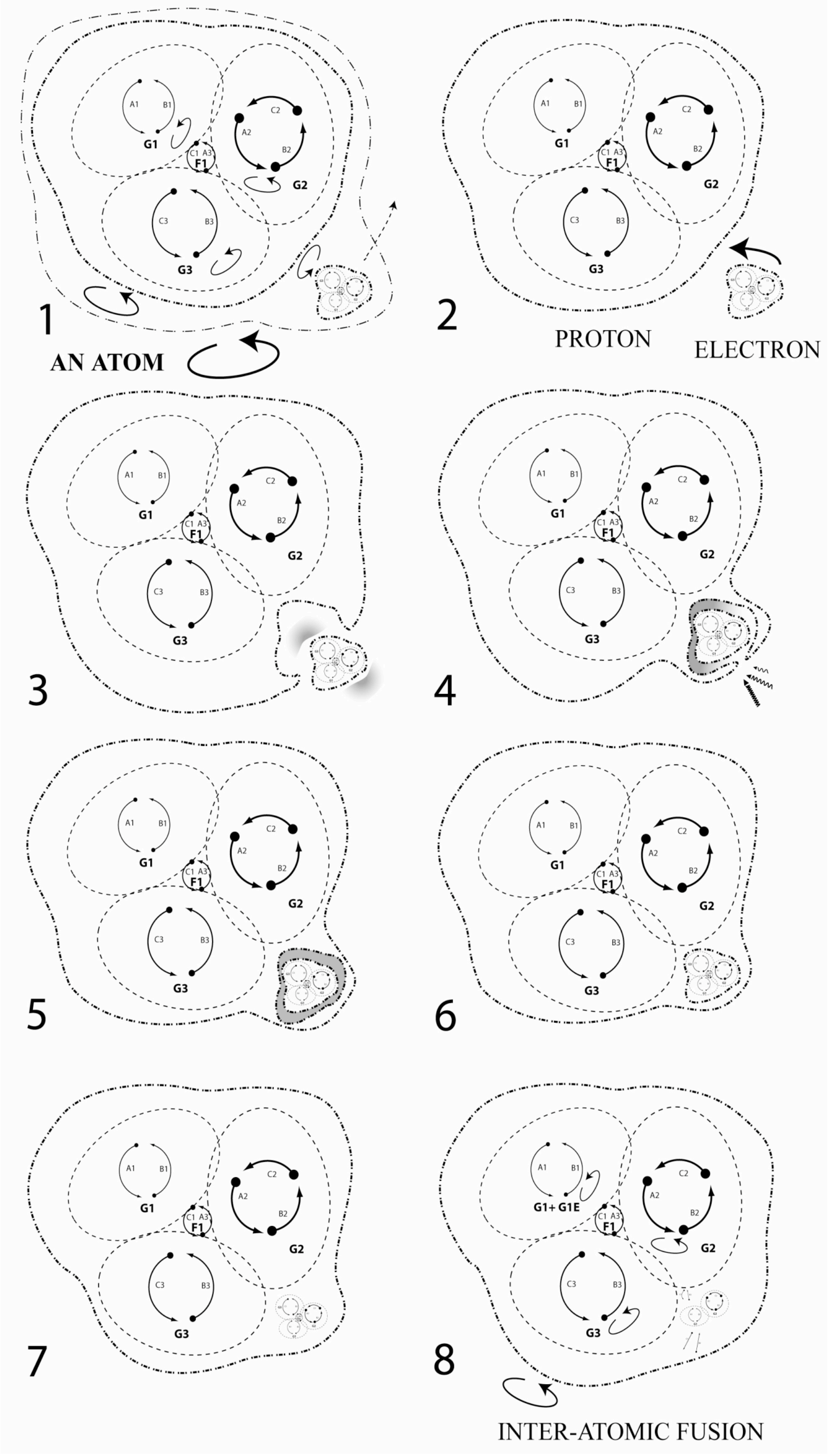
A1
B1
C2
A2
B2
C1 A3
F1
G1
G2
C3
B3
G3
1
AN ATOM
2
PROTON
ELECTRON
3
4
5
6
7
G1+ G1E
8
INTER-ATOMIC FUSION

Fig. 39: Schematic process of the inter-atomic fusion.

Where, initially by using Dilution plasma reactors (Chapter 23, Fig. 57), by feeding the atom of hydrogen into this reactor cores (Chapter 21, Fig. 54), and then in allowing the magnetic atomic structure to dilute and to open up in the soup of the plasma of the reactor (Fig. 39 diagram 1) into its sub-components of electron and proton. At this point the magnetic fields' strength of the soup of the reactor is brought to the levels, which now can be matching with the plasma of the proton pmtics level, for the reactor fields strength to match the overall Magnetic and gravitational pmtics of the protons' plasma. This is the magnetic field strength level of the binding of the plasma, which is called the Coulomb charge barrier of the plasma. Which at this point, the Matters' of the electron are more free and can be gently Magravs positioned to join up in to the Matter components of the proton.

This is the natural method of fusion in its basic form, where there is no need for the huge magnetic fields forces to achieve what happens naturally in the universe to fuse an electron of atom to its proton. The same process of fusion in the plasma dilution reactors' technology can be used for fusing Matters, plasmas or even atoms.

This inter-atomic fusion is done in a magnetic field environment of ***soft*** plasmatic magnetic fields forces and at the same time in a similar magnetic fields forces strength of the same atom environment of the two similar plasmas of the proton and the electron of the same atom, where, in fact the magnetic fields of the outer cores of the reactor performs a similar job as the magnetic rings of the Tokamak systems in providing the containment magnetic fields. Where as in the plasma dilution reactors, at the same time natural gravitational and Magnetic fields needed for fusion criterion is provided by the operation of the fields in two cores of the reactor fields' interactions with each other.

If scientists use this method of creation of Magnetic and gravitational fields forces in the present Tokamak reactors', to replace the solid coil electric magnetic rings, they will achieve fusion in real universal conditions, fusion within natural gravitational fields forces environment necessary to accommodate the fusing of any plasma at a fraction of the present costs and in a very short time-frame.

With these soft magnetic fields in plasma dilution reactors, one can achieve more rapidly fusion than using current induced enforcing magnetic fields rings. These types of magnetic fields strength in dilution plasma reactors are similar to the magnetic fields strength of the plasmas and atoms, and hence they can be manipulated much easier, than, trying to force the plasmas' of two protons.

In comparison, that is to say, to make *an omelette*, it is easier to mix the contents of two uncooked eggs homogeneously as happens in plasma dilution reactors, whereas in trying to make the same omelette, this time by boiling the content of two eggs first into two hard boiled eggs, as Tokamak scientists have been trying to do for past fifty years to make the fusion in reactors by hard balling the content of plasmas (by squeezing the plasma with the use of external magnetic fields to a tighter, harder, smaller entity) and then trying to fuse the two hard balls of plasmas to achieve the fusion process. Then hoping, with increasing the speed of the two hard balls, that they can smash and fuse the two smaller hard balls together. That is why the present path of Tokamak technology in trying to achieve fusion is a sweet dream that will never come true.

In this inter-atomic fusion technology, smaller and weaker plasmas of electrons, which are already within the structure of an atom, are fused into the Matters' component of the proton of its central plasma (Fig. 40). This is a more realistic and practical method of fusion than the present, fusion technology in trying to fuse two large plasmas of hydrogen's protons together, and creating unmanageable heat, of several billions of degrees. Where, the tools and materials to control and harvest the energy of such huge temperatures, on the long term bases in small Tokamak reactors, does not exist within the known galaxies in the universe.

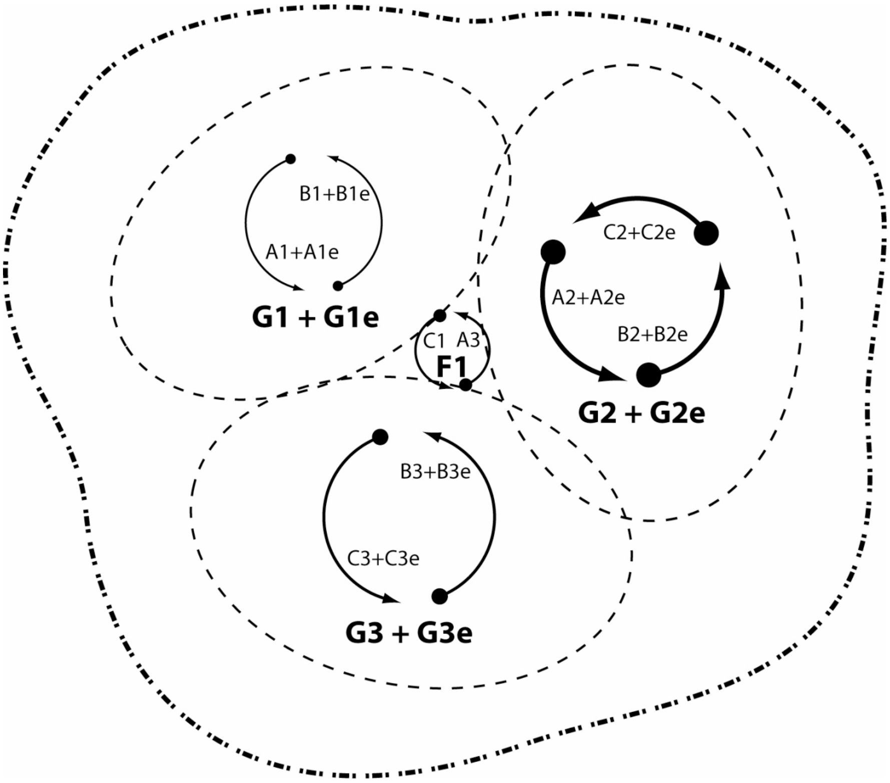

Fig. 40: Schematic diagram of the fused proton and electron plasmas.

In these processes of dilution plasma technologies, when the electron plasma is gravitationally positioned or encouraged to amalgamate its contents with the content of the plasma of the proton, as the two plasmas approach each other, the interaction of two plasmatic magnetic fields of the two plasmas will and can produce several scenarios, which their effects can be harvested for production of different energy levels or production of new materials and so many other purposes.

In brief two cases are discussed here:

a) If the strength of the pmtics of these plasma dilution reactors is set at a level, to be just below that of the total balance of the pmtics strength (Coulombs barrier) of the plasma of the proton, in this case, as the two plasmas approach each other, the initial stages' of the process of fusion starts, which this process begins and will be accompanied with light and heat emission as in figure 39 - diagrams 1 to 5. This light or heat from this process can be used for example for present state of art technology turbine power generators directly. Where, the temperature of the interaction of the systems can be set at the optimum efficiency temperature of the turbine. Hence, operating these reactors in the same configurations as is done in the present fission reactor technology power generators to generate steam to run turbines. With the difference that these dilution technology reactors leave and produce no nuclear waste, and heat can be generated at any level as per demand of the system.

In these reactors, the Magravs strength similar to the plasmas' **Coulombs barriers** charges can be created and controlled. In the dilution plasma reactors' the magnetic fields created through the soup of the plasma will create and maintain pmtics strength, which can be similar to the magnetic fields barrier strength of the plasma of the proton. Where, the strength of the pmtics field in the reactor will decide the strength of the pmtics in comparison to the protons' plasma Magravs strength. As the pmtics strength of the reactor reaches more to the level of the Magravs strength of the plasma, then there is ***less resistance*** *and* ***less friction*** *between the plasmas of the proton and the electron*, when, they are brought together to fuse. Thus as the strength of the magnetic fields of the plasma can be reached by the reactor operation, this allows less friction and hence *less heat* to be produced by the interaction and by the gravitation of the two plasmas of the proton and the electron to fuse. By being able to control the pmtics strength of the plasma dilution reactors Matters' soup of plasma, one can dictate the amount and the rate of the heat release from the interaction of the two plasmas, thus one can control the heat output of the reactor, if the production of heat is the primary objective of the use of such a system.

In general, in being able to control the ***Coulombs barrier strength*** in respect to the given environment of the reactor, one can **vary** this barrier magnetic fields strength in the soup of Matters in the plasma dilution reactors.

Therefore there is no need even to fuse the plasma of the proton with the plasma of the electron, and by just bringing them close to each there to create the right friction when the Coulomb barrier is at the right strength, between the two plasmas, then the reactor can generate a controlled heat-output, or any other rays that is demanded from the systems' operations.

Therefore by *bringing the reactor magnetic fields strength to the level of Coulomb barriers*, one can bring into balance the magnetic strength barrier changes in the overall mixture of the reactor to any level from, or to the Coulombs barrier magnetic fields levels.

Where, the ***difference*** between the two, the **reactor** and the **plasmas' magnetic fields strength**, will decided the ***temperature output of the reactor*** when, the plasma of the electron is gravitated to the plasma of the proton to fuse. The outcome of the bringing of the two plasmas into each other proximity and the interaction of their Magravs, leads to the friction between the two plasmas, and the release of pmtics in form of heat. Where, the temperature of the heat released by this attempted fusion is directly controlled by the pmtics field strength within the reactor and in respect to the variation level from the

Coulomb barriers' pmtics strength level.

An example of this controlled heating of interaction pmtics in the natural world is the like of when the pmtics of the sunlight in atmospheric condition becoming in touch with pmtics of the cell of the human body. Where, as the pmtics of the proteins of the cell are always constant, by varying pmtics strength of the direct sunlight, the heat released from the interaction of these two pmtics, the human feels the increase in the pmtics strength as heat of different degrees. The stronger the pmtics of the sunlight, the more heat is produced from the interaction of two pmtics, thus the warmer one feels. This is like walking from the shadow into the sunlight.

The phenomenon of heating during illness, happens due to the interaction of pmtics of a bacteria within the blood protein pmtics, where as a blood cell comes in touch with a stronger pmtics of the bacteria, the level of the interaction of the extra pmtics from the structure of infection, in ***interaction*** with the blood cell, manifests itself as heat or the increase in the body temperature (this is explained in detail in the paper: Universal order of creation, to be published as a book), where the interaction and possible ***fusion*** of two pmtics of the bacteria and the body cell leads to a release of heat, called "an infection" temperature. This being the reason why the same pmtics of bacteria can have no affect on some human bodies and the same infection can create high temperatures like 41°C +. The reason being that the cell of the one with the high temperature has a lower pmtics strength, thus the interaction of the two infection and the body Magravs pmtics creates more release of fragments of pmtics as heat. When the temperature reaches a level that the Magnetosphere of the human protein reaches its dilution point then the cell is de-structured.

b) When the neutron is needed to be produced from the atom of hydrogen in space for production of heavier atoms, one can follow the process from stage 1 to stage 8 of the Fig 38. In this process the pmtics strength of the reactor are set to be nearer to the binding Magravs strength of the boundary of the protons of the plasma, so that the electrons' plasma literally melts into the protons Matter structure and the matching pmtics of both plasmas of the proton and the electron. Which these plasmas and their pmtics were all of the same origin; this is amalgamation to produce new neutron type initial fundamental plasma. This is the process of the decay of the initial fundamental plasma in reverse, using the same original components of Matters pmtics of all three matters of the plasma. Such a neutron can be added to the construction of the atomic structure of lighter atoms to create **gap(s)** needed for Magravs positioning for the protons of the nucleus to accommodate an extra proton and its accompanying electron for production of even heavier atoms, for example for the production of carbon, oxygen and nitrogen to produce protein base nutrition in deep space travels. Alternatively, one can produce atoms of any matter from initial hydrogen atoms, through the use of the same method of progressive accumulations of protons and neutrons in fusion in plasma dilution reactors.

ii) The other condition is, when the plasma of an electron is attracted to the protons' plasma, ***but does not get absorbed*** within its pmtics, due to their Matters strength friction at the zones of contact of the two plasmas.

As has been explained in previous chapters, the electron is itself a plasma condition and a collection of dynamic pmtics of Matters. Where through the method of its construction and motion around its nucleus, this electron is always in proximity of other electrons of the similar construction or it is in the proximity of larger plasmas such as the neutrons or the protons of the nucleus of its atom.

The ***Motion*** *of the electron* around the proton is created due to the construction of its internal Matters (Chapter 19). Similarly, it has been explained that the interaction of two pmtics due to their friction lead to release of pmtics strength fragments of lower strength of pmtics or rays in the electro-magnetic field spectrum of the light.

Now it is very simple to understand how light is released due to external factors. When the electron of the atom is forced to come close enough to another electron or the components of the plasma of its nucleus or a nucleus of another atom. So that, the interaction of the two plasmas Magravs of the electron and the proton leads to the release of lower magnitude pmtics strength fragments that, its pmtics strength are in the light electromagnetic spectrum (It has been explained that when two plasmas interact and collide; the pmtics fragments of their collisions always releases pmtics in the light bandwidth)(Chapter 7).

This interaction and collision of the pmtics of the two plasmas does not mean amalgamation of the two, but in coming too closed to each other, the two pmtics strength touch and bounce off due to their dynamism.

Hence, as the electron has lost some of its pmtics due to the interaction and collision, with the pmtics of the proton, so now being in possession of different Magravs strength, the electron accepts a new Magravs positioning (Chapter 19) in respect to its proton plasmas.

This interaction of the two plasmas creating the closeness or distance of the electron to its systems' central Magravs point, or what is called that the electron finds a new *ground energy level* position after releasing some of its energies as light, this is then a new Magravs positioning of the electron in respect its protons' Magravs strength forces, which is acceptable by both plasmas Magravs within the atoms structure after collision between the two pmtics of the plasma of the electron and the proton or other plasmas in its vicinity.

Thus when plasmas interact like the plasma of the electron and proton, this leads to the creation of light in the majority of case.

CHAPTER 16

The fundamental difference between Inertia and Gravity

Inertia is said to be due to the total interaction of pmtics of Matter(s) of a solid object without the central dynamic cores that can create Magnetic and gravitational fields forces.

Inertia, through the new understanding of the structure of the plasma, can be simply defined as "the pmtics and gravitational fields due to the Matter in the matter (solid, liquid, gases) components of the plasma (Fig. 41 link F)"

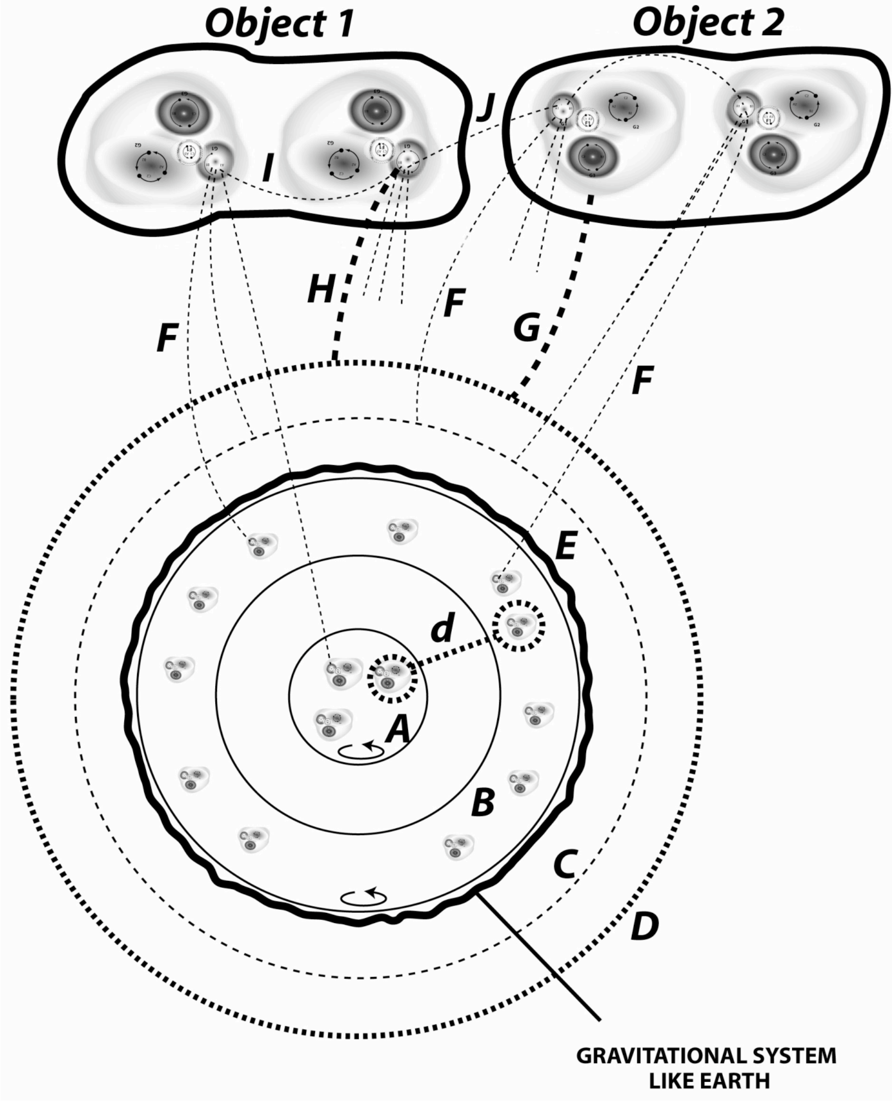

Fig. 41: Interaction and connection between inertia of Matter pmtics of an entity (I and J) in respect to another entity and their interaction (F and H) with magnetic field (C) and gravitational field (D) of systems respectively.

Gravity is simply defined as ”the total pmtics Magravs created by all components of the Matters (Matter, Antimatter, and Dark Matter) of the plasma (Fig. 41 link D and G, and Fig. 42 Link G).”

Inertia is said to be due to a *total collection of pmtics* of the constituent Matter(s) of atoms and molecules of an object, interacting and attracted with each other and any other Matter(s) or matter(s) or Magravs.

The principle of inertia is applicable to the Dark Matters and the Antimatters as well as the Matter components of the plasma in the universe.

As each atom is made of and possesses specific pmtics strength, these fields, in interacting with each other in the state of matter (solid, liquid and gas), create their own total Magravs by addition of the overall magnetic fields of all the atoms of the structure of any matter. The structure of the matter could be made of molecules or an asteroid or any physical object, which is void of gravitational pull, but in possession of pmtics Magravs’ pull of Matter component of plasma, due to the construction of components of its neutrons, protons and electrons of matters. These pmtics, in being interlocked with each other, cannot create a dynamic Magnetic and gravitational pull or interactions between the constituent pmtics of all the Matters of an object. Nevertheless, they create gravitation in between the Matter components of the Matters of plasmas of the object.

In other words they have or create gravitation in respect to Matter-to-Matter components of plasma, or this singularity Matter attraction or gravitation of the total Matter of plasma, is called the **Inertia**.

As the **Gravity** is due to the overall dynamic pmtics strength of all Matters of an object, which is in possession of at least two **sets** of dynamic pmtics in respect to other pmtics, where, the interaction between two sets of dynamic pmtics, leads to the creation of gravitational field forces and simultaneously Magnetic field forces for plasmatic magnetic fields, or rays of magnetic fields, or the whole Matters of an object, this being a planet or a star or others.”

In the case of larger objects with multi-core configurations like Earth, the multiple pmtics forces of dynamic multiple-core objects are loose from each other. Hence, the overall dynamic pmtics of their Matters can interact, creating much more active fields to be brought into play. These being, the stronger magnetic fields constituent components of the plasma; Matter, Antimatter, and Dark Matter, F1 zone fields and all other transition zone fields to interact with each other within the plasma.

That is to say, that the collective **free Matters** of the plasma create a stronger pull or gravitational forces than when the same independent are compacted and cannot be free in a dynamic condition in matter (solid, liquid and gas).

Gravitational fields, due to their free motion and strength of interaction of their Matters with others of the same, can span and reach further a field in the environment.

Gravitational field forces are always stronger and span wider in their given environment, than their inertia of individual Matter counterparts, simply because gravitational field forces of planets or stars are mainly created by all components of pmtics of Matters of the plasma (Fig. 42), rather than the collective plasmatic magnetic fields of individual types of Matters' components of the plasma or the matter.

Planets' and stars' total pull is a combination of the gravitational fields and inertia pull of all their constituent Matters and matters. These composite pulls are created due to the dynamic plasmatic materials of their constituent Matters in the inner cores of these objects in respect to each other, plus the total pmtics interaction of their matters.

Through tests, it has been proven; that the Magravs force strength of a dynamic object is independent of temperature and pressure of their cores. Where, we do not consider this to be the same for the inertia of the matter (solid, liquid and gas).

At the same time, Magravs of a dynamic object can vary as the strength of its Matters pmtics constituent changes. Where, the inertia of the solid matter is always constant, both in respects to the same initial given position.

It is considered that Matters, in general, possess Magravs forces due to their dynamic construction of their pmtics.

As much as the universe has inertia field forces, in respect to Matter components of the plasma, there is ***Antimatter inertia*** in respect to the Antimatters components of and ***Dark Matter inertia*** in respect to the Dark Matter components of the plasma or the universe (Fig. 41). In fact, a collection of the Antimatter and the Dark Matter can possess inertia similar to the physical Matter conditioning of their environment. Therefore, the same matter possesses separate Dark Matter and Antimatters inertias too.

By the same measure, it is to realise that there are Matter Magravs systems as are Antimatter and Dark Matter Magravs systems in the universe. In understanding this clarification, in the systems of attraction of Matters, reactors can be build which are inertia dependent and not gravitational dependent.

It is important to note that; gravitational fields of planets and stars are all created by the Matters components of plasma. This means gravitational fields affect all Matters of plasma (Fig. 42), where inertias of certain Matters affect only that particular Matter component of the Plasma. At the same time, it is clear that gravitational field reactors can be produced in such a way that their gravitational fields *can attract certain Matters only*.

These systems will be like laser systems with the advantage that the laser operation can work ***in reverse***, that is to say the system can send rays of a given pmtics strength as well as attraction or gravitating the same rays and collection of pmtics towards or into the system too.

These systems can or will have, single or multi-molecules pmtics gravitational settings, that can be attracted to, or repelled by only specific pmtics strength, to or from their environment.

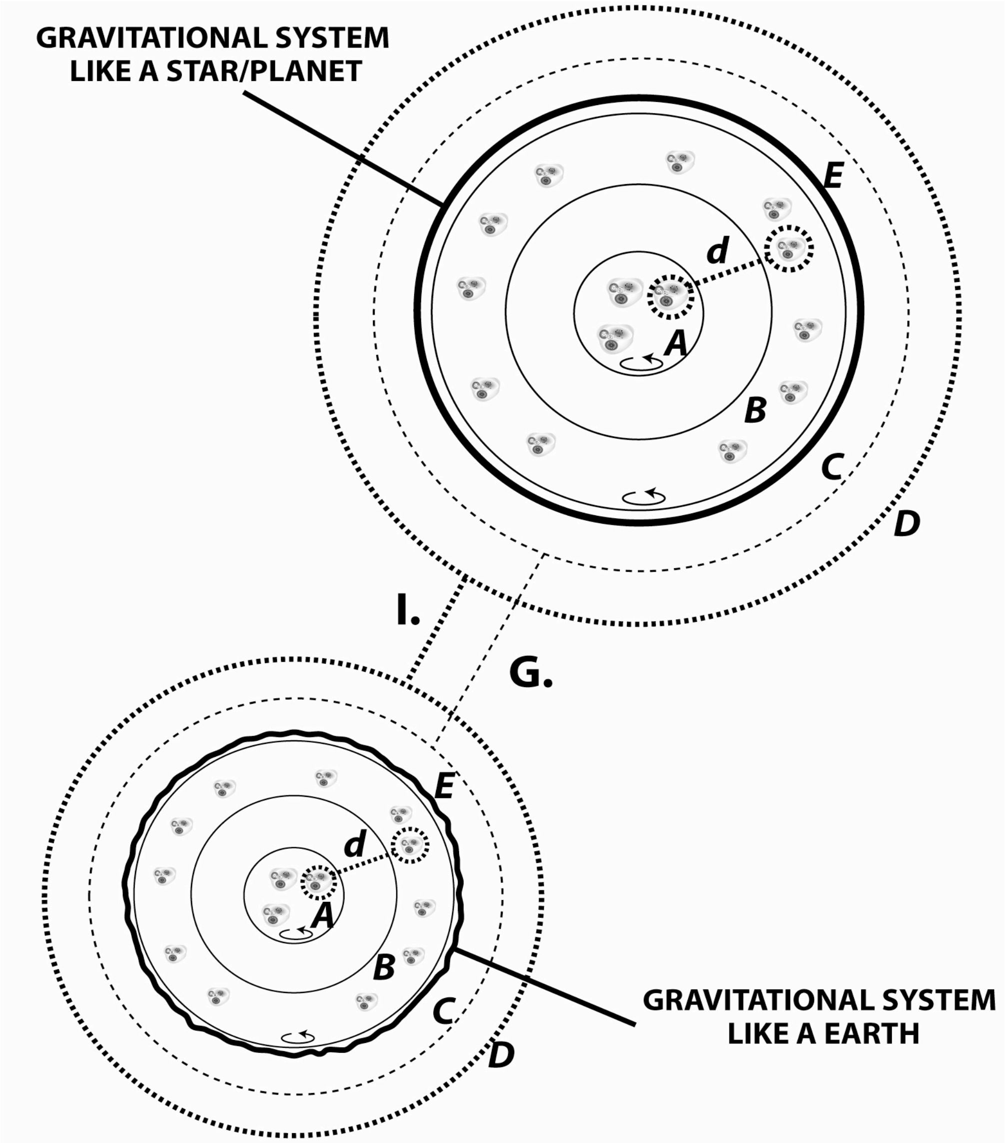

Fig. 42: Interaction between the pmtics Magnetic fields (I) and gravitational fields (G) of two Magravs systems.

Note: In fact the term used as "gravity" has to be explained as gravitational and Magnetic field forces, as when an object is attracted by gravitational fields of a matter, like the Earth, at the same time it is repelled by the Magnetic field forces of the object too. Thus, when talking about gravity it is correct to talk about the overall Magnetic and gravitational fields (Magravs).

These simple mono- or multiple-setting gravitational or inertia systems (Fig. 41 and Fig. 42) can be used for specific *extraction* of certain Matters, matters or materials from the universal Matters or matters soup.

Such systems, will change the present industrial systems thinking that magnetic attraction is only *limited to ferrite metallic objects*. Man has now the possibility to make systems *that can attract* ***any matter*** through the development of these systems."

These systems for example can be used, once set to appropriate pmtics gravitational field strength levels, so that they can extract only the CO_2 from air, or specific poison from water, or rare metals from the Earth and space and so forth (31).

These reactor systems can be used for production of proteins for human consumption and so forth in the future space travels (32, 34, and 38). The production of proteins like matters, through gravitational plasma dilution mixing has been tested and different matters were collected in several tests in summer of 2008. In these tests, the proteins produced and extracted from the reactor cores caused the damage to the ancillary systems of the reactor set-ups. These proteins layers were physically visible and tangible.

Using the mono-Magravs systems (38), new matters can be extracted from other environments, like nano-materials of all sorts. These systems can be used to produce specifics matters too, matters like, uranium, hydrogen and so forth from the plasma of the universe as the needs for their use arises.

Thus through the understanding of the principle of mono- or multi-gravitational and inertia systems, reactors can be evolved that are gravitational to one object or one matter or one Matter only. Through understanding of the interaction of the plasmatic magnetic gravitational principles, reactors have been built, that have a Magnetic or gravitation to plastic at one point, and by resetting its configuration becomes magnetic to carbon and so on. Thus, mono-gravitational and inertia systems can be developed that have specific magnetic attraction or repulsion to one Matter, matters or any Matters of the plasma that can be expected of them through their pmtics strength operation setting.

On the other hand, the repulsion technology of the same Grapos can be used to send the Dark Matter and/or its pmtics energy as the Dark energy of the same plasma of specific pmtics strength into deep space for specific applications.

These types of gravitational lasers type reactors can be used for example in communication systems, where the information packs, using mono-pmtics strength of the Dark Matter and Dark energy can be sent through the system, so that the information can be packaged in the Dark Matter-envelop and sent without resistance or loss of energy, for it to travel with speeds beyond the speed of light to its destination anywhere in cosmos. The speed of communication through mono-Magravs systems are speeds which can be several times faster by order of magnitude than the present used state-of-the-art communication systems with satellites and microwave technologies. These speeds of transfer of information will be, by order of magnitude, faster than the speed of light.

These **GR***avitational l***ASERS** systems, that can be called "**Grasers**", can be used for example to avoid a head-on collision and destruction of crafts by an asteroid in the path of the motion of crafts in deep space (33), or within atmospheric condition. The present missile technology due to its slowness through development of these reactors are obsolete, as once fired to protect the craft in space, for example from asteroids by the time the missile will arrive at the point of destined collision between the spacecraft and the asteroid, maybe it will be years after the craft has past that point.

These mono-gravitational or mono-inertia systems will bring to Man the realisation that the time of making war-machines has come to its end.

As Man will come to understand, soon enough that using these mono-gravitational or inertia systems against one another as tools of war will mean and will have only one outcome, and that is a total wipe-out of the human race from the face of the Earth. The men of war through this technology will come to accept peace not out of their pleasure but out of the fear of their own demise.

The use and capability of the use of this knowledge and of the effectiveness of these *mono-Magravs system*s lethality, has been the cause and the keeper of the peace in the universe. No chance, will be given to the Man, to change the tranquillity of universal peace by use of this technology.

Man through the lethal powers of these mono-Magravs systems will be taught an unforgiving and painful lesson, if he ever tries to use this technology and knowledge to carry on with his aggressive behaviours, as has been his habit for centuries on his own planet. Then this will be the coming of the end of the term of the Man in the universe.

It is clear that any celestial object as the planets, stars and galaxies, are all created through the attraction and interaction of these Matters and matters, their interactions and their constituent plasmatic magnetic fields. These interactions and collections of Matters and matters in respect to the plasmatic magnetic fields strength, which larger objects possess by their order of magnitude, decides' what will be in their part of their environment. That is to say, the plasmatic Magravs created by the plasmatic magnetic fields of Matters in the inner cores of the stars in principle will decide on the size and the span of the dominion of its field in its environment. Then these Magravs strength and their balances dictate what matters or Matters will be attracted to the atom, molecule, planet or the solar system.

This principle of mono-gravitational plasmatic magnetic fields strength forces is the main reason in the universe that why certain planets only retain one element in their structure. For example, this is one of the reasons why the planet Saturn is mainly made of helium on its outer layers as its main constituent matter (17). The reason being that the initial Magravs of the interaction of pmtics of Matters and matters in the inner cores of the planet has been set to be equal to the helium plasmatic magnetic fields strength of matters in that part of solar system in the early life of the planet.

This mono-Magravs positioning field strength of the Saturn is one of the reasons, why this planet, with its strong gravitational field forces, does not pull in and absorbs a large number of asteroids from the Astor-belts. The other reason is that, mono-Magravs systems possess very strong Magnetic fields too, which this is one of the reasons why this planet can keep the matters of asteroids in check.

Alternatively, certain galaxies have more of one matter like hydrogen than the others having nitrogen and so on. Thus, the pmtics of Magravs forces and their mixture with the inertia of a planet dictates what matters are extracted from their part of their environment, like the solar system or galaxies.

Thus, Magravs positioning reactors are not only for creation of motion and for protection, but they will be the main tool for cleaning environments, collecting preferred Matters, matters, etc.

CHAPTER 17

Plasma’s and Nuclear decay

The nuclear decay principles of an atom, is in general, considered to be on “the same principles and methods and as the simple decay explained previously for the initial fundamental plasma into a proton and an electron (Fig. 43)”.

For the initial fundamental plasma to reach the ground-level plasmatic magnetic fields content condition, the plasma divides itself into two new and exactly similar structures with different amount of mass of the same constituent plasmatic magnetic fields Matters for the creation of a proton and an electron, and releases its unwanted pmtics as residual pmtics or as rays (gamma or x-rays, etc)(Fig. 42). I call this process of the neutrons decay “***The initial fundamental plasmatic decay***.”

Through the process of releasing of the exact amount of plasmatic magnetic fields from the **neutron** necessary for the creation of a **proton**, an **electron** and the **release of energy or other rays** from the initial fundamental plasmatic magnetic fields, this, in a way, confirms that *all initial fundamental particles of plasmas are always make exactly of the same and similar plasmatic magnetic fields and the same configurationally structure*. This being another proof that initial fundamental plasmas in the ***universal order of Matter*** are always made through and by the same Specific Entangled Plasmatic MAgnetic Fields (SEPMAF) strength criterion and procedure, as has been previously explained.

The principles of the nuclear decay of initial fundamental multi-plasmas of an atom, is considered to be solely due to the re-balancing of the overall plasmatic Magravs strength components for Matters of plasmas of the atom ***to maintain an overall Magravs forces balance of all participating plasmas***, in the construction of the atom. These being the plasmatic magnetic fields of neutrons, protons, electrons and their constituent Matters, their plasmatic magnetic fields of their Matter, Antimatter and Dark Matter and their magnetic fields forces of each plasma.

For the plasmas of an atom to stay together and hold onto its constituent structure plasmatic magnetic fields, some of these *plasmatic magnetic fields in motion* (energy) are ***transferred to*** *other plasmas*, and in term, these plasmatic magnetic fields are said to be used. At the same time, part of the initial fundamental particles fields of plasmas are used for the upkeep of the integrity of the nucleus positioning and dynamism; As part of the binding energy is consumed for holding the fundamental plasmas together. As in this cycle of consuming pmtics reaches that enough pmtics have been used, that the initial fundamental plasmatic Magravs of the plasma cannot hold onto their initial gravitational positions in respect to each other. The plasmas making up the part of participating neutrons or protons in the centre nucleus of atom, gravitationally reposition themselves within the nucleus for the nucleus to find a new Magravs *balance and equilibrium positioning* in respect to other plasmas.

At this point of magnetically repositioning of the plasma of the heavy nucleus, the nuclei of heavier atoms split into exactly the same configurations of two or more new Magnetic fields and gravitationally positioned balanced plasmatic strength configurations (Fig. 43) of the plasma's of neutrons to protons and electrons, and hence split into two new atoms. This regular splitting pattern of heavier atom to two or more light atoms is known as a ***controlled fission*** of atoms.

As the initial fundamental plasmas were all made of the same initial fundamental particles of the same specific magnetic fields strength and interactions, in their disintegration of denser nucleus atoms, they split and gather into two or more new less denser atoms and of Magravs' configuration, and their need for the new equilibrium of collective plasmas of new atoms.

That is how the atoms are always spilt into exactly the same lower order of numbers of neutrons, protons and electrons in the new nuclei for the overall new balance pmtics of the two new atomic structures to be able to be kept.

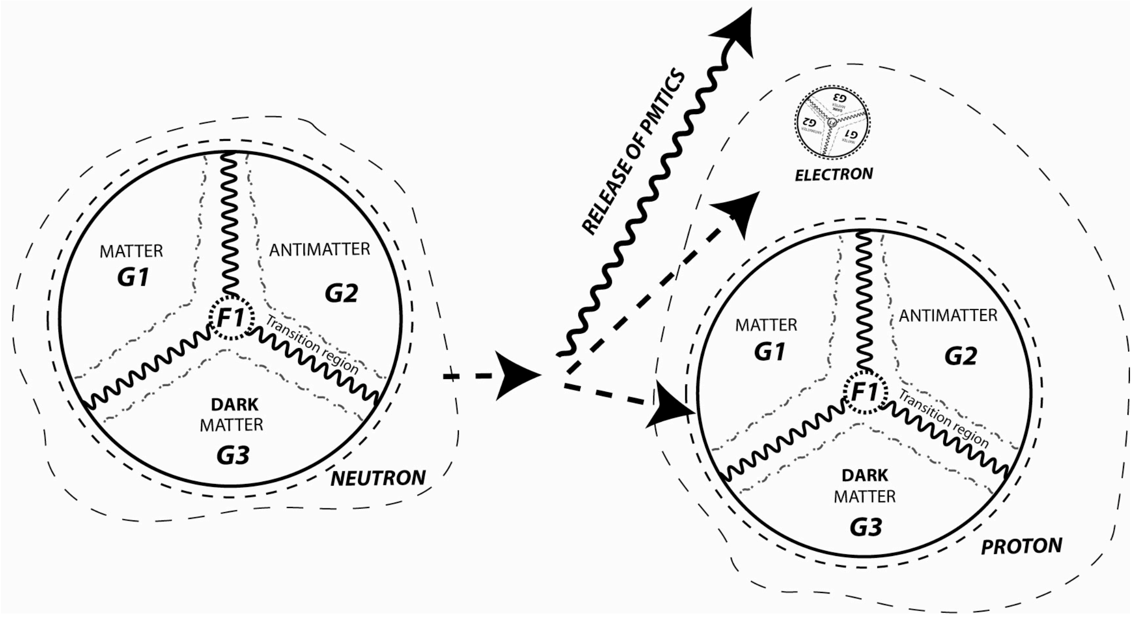

Fig. 43: Schematic of a decay of pmtics and Matters of the Initial Fundamental Plasma (NEUTRON), "the initial fundamental plasmatic decay".

In principle the overall disintegration of all atoms heavier than Hydrogen, involved in the collective pmtics of a given matter, the collective pmtics of the residual matters is always constant, and of the same end-structure of new and lighter atoms.

The overall numbers of the plasmas involved in a structure of a given matter is said to be constant, purely due to the fact that the overall rate of interactions and disintegration of plasmatic magnetic fields are considered to take place at a constant rate. Hence, the phenomenon that takes about the same time for the plasmas to reach a point of using a given amount of dynamic plasmatic magnetic fields (energy), before they reorganise themselves to a new balance condition. This reorganisation or rebalancing of overall plasmatic magnetic fields of the components of nuclei, leads to the fundamental principle of the nuclear decay nuclear of an atom.

This reorganisation of the new plasmatic magnetic fields balance in mass of matters is in so many ways dependent on all of the atoms participating in the total structure of the mass of the matter. This is irrespective of the number of atoms in the matter, these being in the solid, liquid or gaseous state of matter.

The nuclear decay in some plasmas can be triggered and be due to internal changes in the plasmatic magnetic field's structural balance, or can occur due to changes in the external environment of the initial fundamental plasma. These changes can be due to the ***changes*** in the external equilibrium of magnetic fields forces or field strength of other initial fundamental plasmas, or surrounding plasmatic magnetic fields adjacent or near to the initial fundamental plasma.

This being why different atoms of a given matter decay at different rates depending on their position within the overall structure of tangible matter. That is to say ***the decay of atoms is environmental pmtics strength dependent.*** Which the environment can be within the same matter construction of atoms, or the interface between the matter and for example matters of air. Where each environment enforces different rates of use of internal pmtics of different matters within the nucleus of that atom. This being the reason why different rate of decay of atoms within matters are considered to have a **half-life** principle. Where the half-life is, and can be pmtics strength environmental dependent.

Interesting point to consider:

Does the reorganisation take place in the same position first and the same number, which initiates the course of the decay in the rest of the mass?

Is the decay of an atom in a mass happening faster in the inner positions of the mass of matter, or on the edges of the mass?

CHAPTER 18

Neutron-Proton, Electron-Atom

Through the new understanding of the method by which the initial fundamental particles and their subsequent plasmatic magnetic fields interaction, leads to the creation of the initial fundamental Matters (Matter, Dark Matter and Antimatter) leading to the creation of initial fundamental plasmas or the Neutrons, the subsequent degeneration of initial fundamental plasmas through decays further leads to creation of protons and electrons of an atom, and their interactions and collections into molecules and matters (solid, liquid and gas).

Fundamentally, *initial fundamental particles* ***interactions***, leading to the creation of different states of Matters and the creation of initial fundamental plasmas, where these plasmas are considered to be in a ***total plasmatic magnetic equilibrium state*** (Fig. 44 and Fig. 45).

The Initial Fundamental Plasmas are **neutrons** in characteristic. Neutrons (Fig. 44 and Fig. 45), in their construction, are considered as ***balanced*** dynamic plasmatic magnetic fields environments.

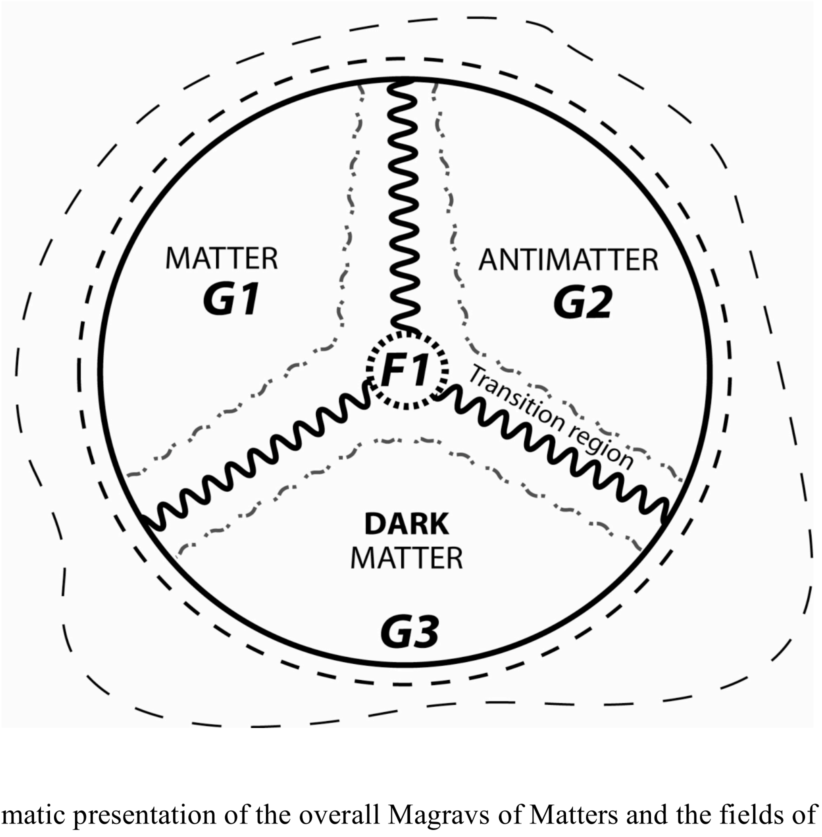

Fig. 44: Schematic presentation of the overall Magravs of Matters and the fields of the Neutron.

Neutrons, due to **the *larger content* of the three Matters and their F1**, they create a ***stronger gravitational pull*** between the Matters of the plasma, consequently their overall Magravs of the initial fundamental plasmas are considered to possess more mass, than the total sum of the masses of the individual proton and electron, from the same plasma after its decay.

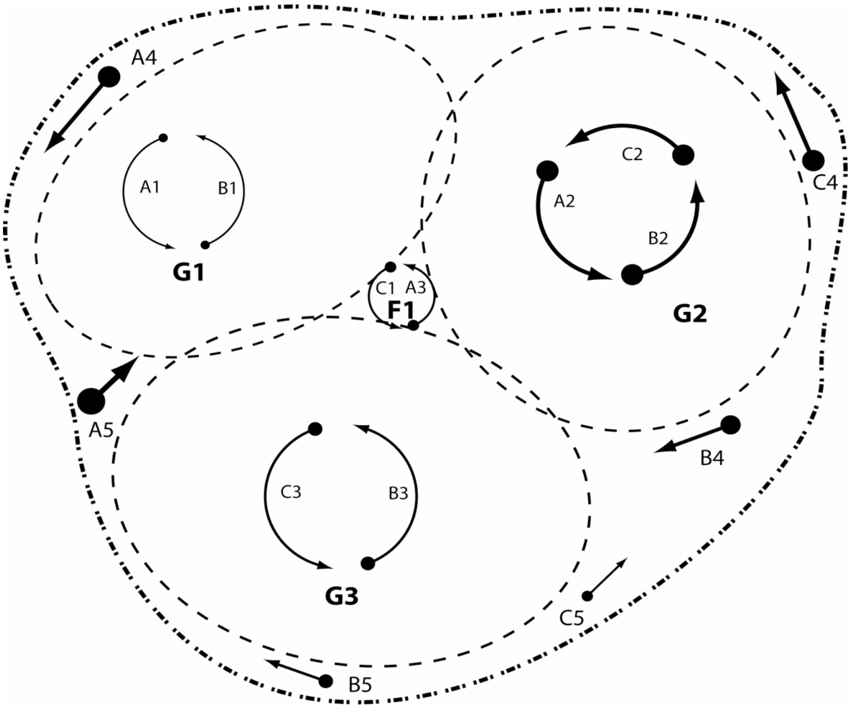

Fig. 45: Matters schematic diagram of the Neutron.

For the ***initial fundamental plasma*** to find its final balanced equilibrium plasmatic magnetic fields force strength condition, due to different effects, the initial fundamental plasma ***reduces*** *its plasmatic magnetic fields balance* to its **ground-level** magnetic fields mass level (Fig. 46 diagram 7) for it to survive, hence the initial fundamental plasma disintegrates or decays' to its sub-Matter levels and fields.

The decay of the neutron

This process has been explained in previous chapters where, now we look at this process in more detail.

The release and division of components of the initial fundamental plasma leads to the release of two independent, yet at the same time interlocked, balanced plasmatic magnetic fields environments plasmas (Fig. 46 diagram 8). Of these two new plasmatic magnetic fields plasmas, one would retain more of the initial fundamental plasmas' mass and be the larger of the two balanced plasmatic magnetic fields (Fig. 46 diagram 7). The second plasma will contain less of the pmtics of the initial fundamental plasma and mass and would be smaller (Fig. 46 diagram 6). The *larger of the two plasmas', would* ***stay in the centre,*** due to its mass and Magravs strength would become ***the proton*** of the atom (Fig. 46 diagram 8). The new smaller balanced plasmatic magnetic fields released can be said to manifest itself as ***an electron*** (Fig. 46 diagram 8) of the same atom.

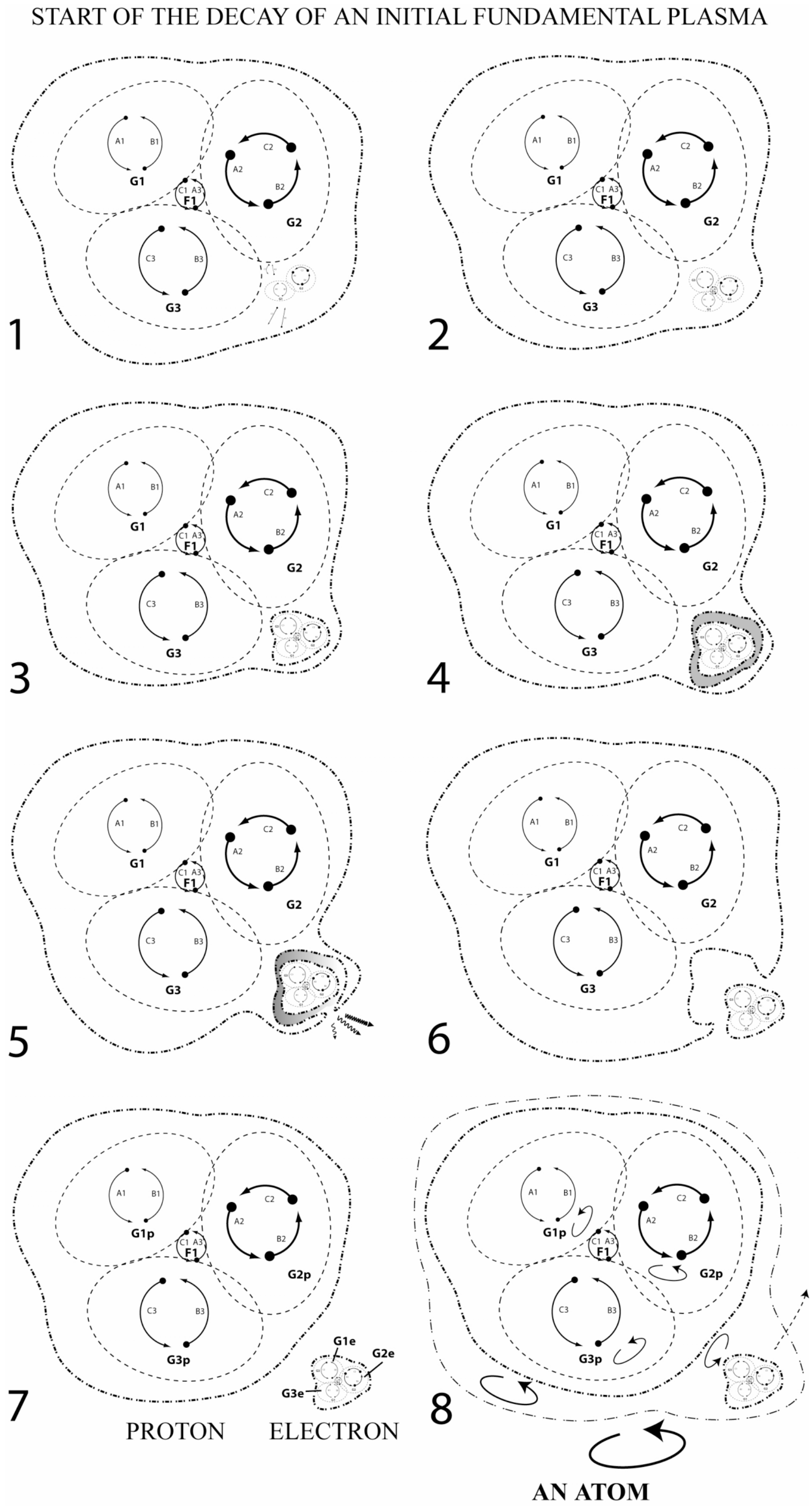
START OF THE DECAY OF AN INITIAL FUNDAMENTAL PLASMA

1
2
3
4
5
6
7
8
A1
B1
G1
C1 A3
F1
C2
A2
B2
G2
C3
B3
G3
G1p
G2p
G3p
G1e
G2e
G3e
PROTON
ELECTRON
AN ATOM

Fig. 46: The eight steps of the Neutron decay cycle to a proton and an electron and then an atom.

It is considered that the ***pmtics of the Antimatter components*** *of the* ***neutron*** **start the process of the decay** of the neutron. As the Antimatter is the main and the strongest of the Matters' of the initial fundamental plasma (Fig. 46 diagram 1), in comparison the Antimatter is the star in a solar system. Then the pmtics of the Dark Matter part of the neutron plasma splits simultaneously as the total balance of the Magravs forces of the plasma is disturbed (Fig. 46 diagram 1). This process is continued up to the point that, due to the cycle of separation of more and more of the two pmtics of the Antimatter and the Dark Matter, leads to splitting of the Matter part of the plasma (Fig. 46 diagram 4) as the plasma tries to keep its overall stability and equilibrium.

At this point, the pmtics fragments of the Antimatter, the Dark Matter, the Matter, and other pmtics within the plasma, through the dynamism of the plasma internal environment, are brought close to each other and then merge to produce a small and independent **mini-plasma** within the structure of the initial plasma.

Where this new embedded mini-plasma in the overall structure of the initial fundamental plasma becomes the structure of the initial fundamental plasma of the **electron** of the atom.

The plasma of the electron by this time is formed internally and has establishes its own balance Magravs zone and hence its own magnetosphere (Fig. 46 diagram 5 and 6). At this stage, the Magravs of the electron plasma tries to find and reach its own Magravs positioning balance in respect to the leftover pmtics and Matters Magravs of the initial fundamental plasma. At this point, as the two plasmas try to find their Magravs positioning in respect to each other, the electron plasma is pushed out-off the boundaries of the initial fundamental plasma (Fig. 46 diagram 7) environment.

At this point where the two plasmas find their Magravs positioning balance, this becomes **the gap** *between the proton and the electron*, or the ground energy level for the electron in respect to the proton' of the plasma. From this point on, the foundation for the final step of the making of an atom with contents of a proton and an electron is reached (Fig. 46 diagram 8).

Therefore the new balanced fields of the original initial fundamental plasma now becomes the components of the two newly balanced plasmatic magnetic fields plasmas of the proton and the electron of an atom (Fig. 48).

From this point on, the motion and rotation of the electron around the proton is set to follow, according to what is described in Chapter 19.

The similarities between the construction of the protons' plasma and the electron plasmas components of Matters, as both have started together quasi-independent life, from the same initial fundamental plasma mother (Fig. 47).

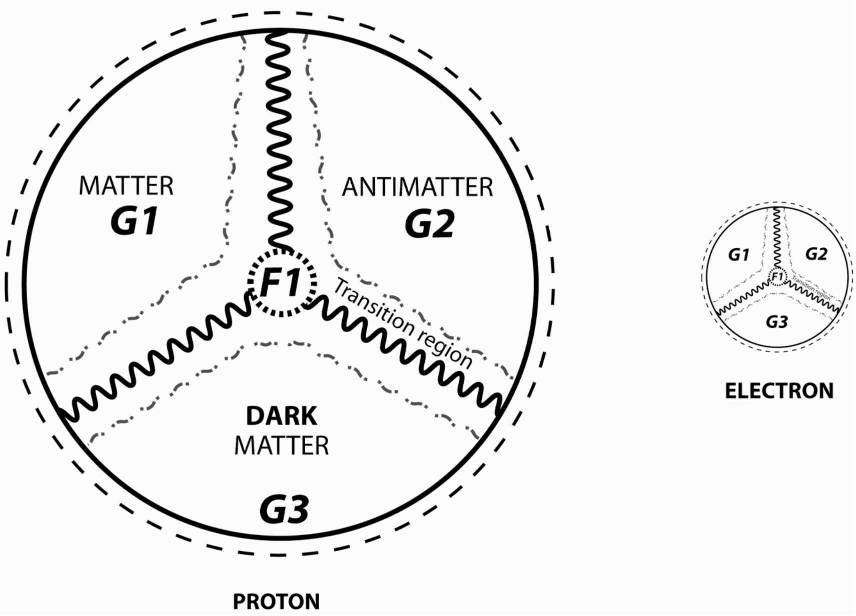
MATTER
G1
ANTIMATTER
G2
F1
Transition region
DARK
MATTER
G3
PROTON
G1
G2
F1
G3
ELECTRON

Fig. 47: Schematic similarities between construction of a proton and an electron (components of Matters).

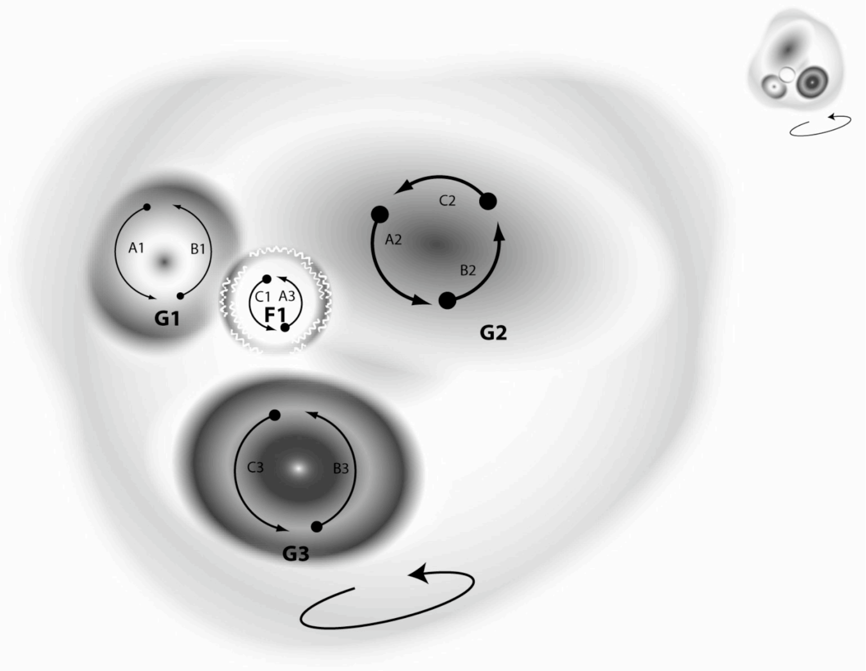
A1
B1
G1
C1 A3
F1
C2
A2
B2
G2
C3
B3
G3

Fig. 48: Pmtics presentation of Initial Fundamental Atom (hydrogen).

As the initial fundamental plasma splits into two balanced plasmas (Fig. 46 diagram 1 to 8), this guaranties the total balance of the integrity of the complete original initial fundamental plasmatic Magravs configuration.

Thus, the splitting and decay of the initial fundamental plasma into the proton and the electron (Fig. 48), called the ***initial fundamental decay***, is a natural decay process as is the ***nuclear decay*** of heavier atomic structures into lighter atoms. Where as the plasma uses some of its pmtics to keep its position, motion and magnetosphere boundary, it needs to break up to smaller atomic substructures that can guaranty its overall magnetic and gravitational field structure, thus the term "*decay of the atom"*. This neutron division, to the substructures of a proton and an electron, is for guaranteeing the survival overall of what was achieved before for the creation of initial fundamental plasma (Fig. 48).

This method of the Initial Fundamental Plasma Decay to the proton and the electron is the reason why in atomic structures the number of the electrons and the protons have always been seen to be in ***matching numbers,*** as there is no alternative way in nature for the creation of proton and electron in the universe in general, however individual electrons can be produced from the pmtics in plasma dilution reactors.

In the construction of higher atomic number elements (Fig. 49), for the total balance in both Magravs of the nuclei and their respective electrons, these heavier atoms need to have more of the balanced plasma components of neutrons.

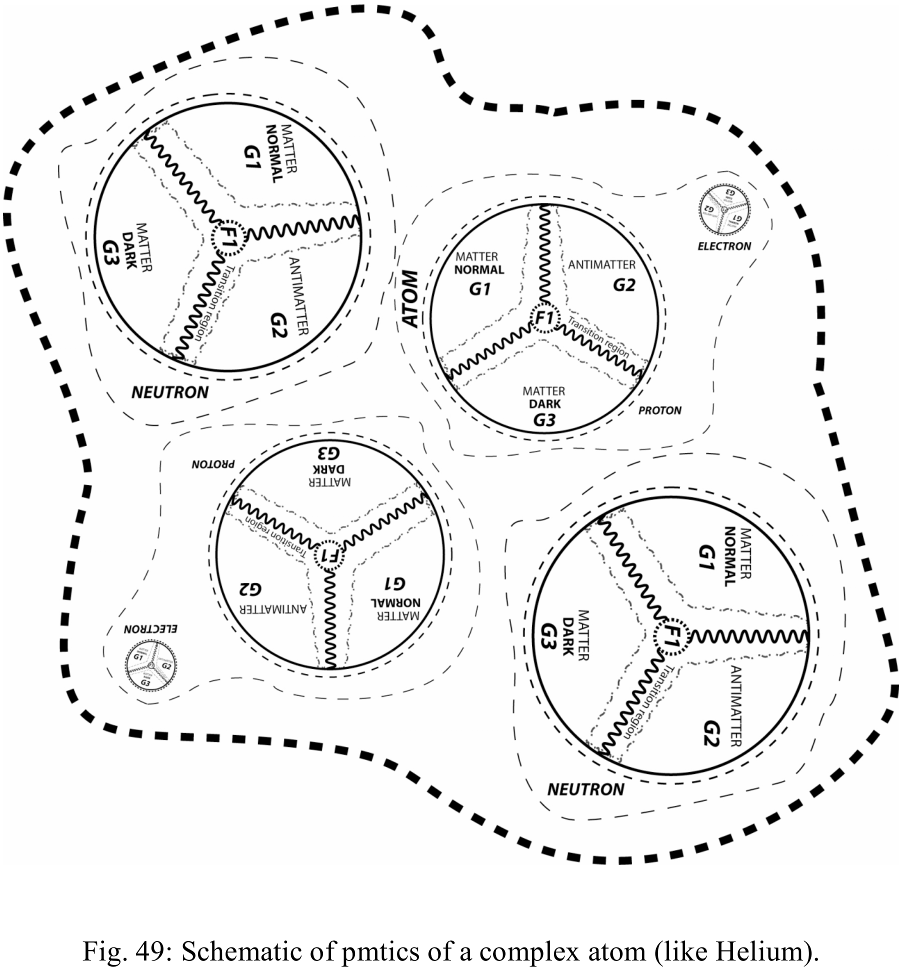

Fig. 49: Schematic of pmtics of a complex atom (like Helium).

Note: Through this simple configuration (Fig. 49), one can understand why certain chemical bindings and structure of some atoms and molecules of certain proton combination interactions in a given environment become possible.

In fact, the neutron, due to its balanced magnetic plasma or neutrality, and at the same time possessing its own Magravs magnetosphere, becomes the space gaps and space(s) needed for Magravs positioning of protons, in respect to each other, as much as magnetic fields equalisers or balancers in the construction of the nucleus of atoms with more than one proton (Fig. 49).

In the heavier elements, due to the tightness of packing, if there were not so many neutrons to create some magnetic and Magravs positioning balance gap, or what we call **gaps**, then due to the protons gravitational pulls, part of the nucleus would most probably clog-up, this being due to the interlocking of the Magravs of protons in the nucleus of the atom. In the majority of cases, this ***clogging-up*** would most probably lead to the explosion of the nucleus, due to *repulsion* of the fields or Magnetic fields of Magravs within the construction of the nucleus in being too close to each other's proximity. On the other hand without the existence of neutrons as a gap the nucleus would not be a gravitationally positioned stable configuration.

A configuration of the complex structure of the initial fundamental plasmas like an atom of the Helium and the positioning of its neutrons, protons and electrons are shown in figure 49. This shows the overall gravitational fields and Magnetic fields generated by interaction of these individual parts, in respect to the dynamic Matters and the fields each part produces both internally, and in their overall external boundary interaction of the plasmatic Magravs of the atom.

By a close observation of the proton and electron's Magravs balance, it is now clear how the *different* ***electron orbits*** *of heavier atoms* come to be created. That is to say, as the number of protons increases, the boundary of the Magravs of all protons in the centre of the nucleus increases, thus allowing and accommodating the next orbit for the motion and Magravs positioning of the next layers orbits of electrons. It has to be remembered that protons are *dynamic* entities, thus not more than certain numbers can revolve in the compact zone of a nucleus. So as the number of protons and their equivalent electrons are added to the nucleus, *more room is needed* for the *free* motion of these protons. Hence the only way a neutral zone can be created for the free motion of these additional protons for the structure of nucleus to be Magnetically and gravitationally in balance, is to add more balance neutrons to create an environment for the free motion of the protons and their Magravs positioning.

Thus as proton number increases, and the volume of the nucleus increases to keep all protons in motion, and hence more numbers of neutrons are needed. This is the reason why one sees a larger number of neutrons in the nucleus of heavy atoms. The more neutrons and protons are in the centre, the *larger the magnetosphere of the nucleus* boundaries. Hence, the accommodation of more electrons in *further distances locations* from the centre nucleus. Where all these electrons, protons and neutrons overall pmtics Magnetic field and gravitational field have to be at all times in balance.

It is fundamental to understand that " the negative field charge of any magnetic fields is due to its Gravitational field strength or pull, and the positive charge of the fields due to the Magnetic fields strength or push of the Magravs of the Matter, like a planet.

In electric field charge and current flow, its to be understand that the **positive charge** is the flow of the Magnetic field push of the Magravs, and the **negative charge** is the gravitational pull of the flow of the gravitational fields of the Magravs of the plasma and its Matters content. This in a way explains the ***Resistance*** and the ***Impedance*** respectively of the matters in the electrical section of physics. Where the impedance is the measure of the gravitational pull of the flow of the pmtics in respect to the matters' atoms and where the resistance is the measure of the Magnetic push of the flow of the pmtics in respect to the matters' atoms.

CHAPTER 19

Motion of the Electron around the Proton

The constant rotation of the electron around the nucleus of an atom indicates that the electron and the nucleus of the atom constantly maintain an overall balanced Magravs forces between and Magravs positioning, in respect to each other.

Within the structure of the initial fundamental plasma (the neutron), and through its sub-dynamic Matters (Matter, Antimatter, and Dark Matter) and at the same time, with all Matters of the plasma being in possession of their own independent internal dynamic plasmatic Magravs forces, they all exert dynamic and varying levels of Magravs on different constituent of Matters of plasma internally, which these field forces span beyond the boundaries of the nucleus plasma itself individually and collectively.

The total effect of these dynamic forces, from the nucleus plasma (proton) (Fig. 50), will affect the *path* of the *rotation* of the satelliteing electron around the nucleus.

Similarly, the *plasma of the* ***electron*** (Fig. 50) itself is *made of the* ***same three dynamic plasmatic magnetic fields structures*** *of Matters as of the proton in its nucleus*.

The effect of these **dynamic** plasmatic Magravs of different Matters in the centre plasma **(proton)** of an atom on the **dynamic** plasmatic Magravs of different Matters of the plasma of its **electron,** and their collective effect of each plasma on each other, is the reason why the electron does not have a constant and a defined path of motion around the nucleus.

That is to say, the electron plasma by itself is in possession of its own individual Matters' (the Matter, the Antimatters and the Dark Matter) Magravs forces' as well as their collective plasmatic Magravs forces of all the Matters of the electron, and the same applies to the Matters and the plasma of the proton.

As the Magravs of different Matters of the electron passes different Matter components of the proton, each of the facing Matters' Magravs forces within the proton and the electron have to interact with each other, plus the electrons' and protons' overall Magravs positioning in respect to that particular Matter in the proton and electron. Which, this type of interactions and Magravs repositioning between the two involved Matters of each plasma will keep on repeating on continuous bases as both the proton and the electron are independent dynamic entities. As the ever-continuous Magravs positioning between the two dynamic entities leads to the ever changing in position of the lighter by mass (the electron) of the two entities, to move around the proton, hence this chasing-up of the ever-repositioning movement becomes the "uncertain" position or erratic motion of the electron around its proton.

This giving the electron in that given configuration of interactions of the Magravs its *pulled* ***closer*** *to* ***or pushed*** *further away* from the nucleus. Then, immediately, the electron has to finds its new overall Magravs balance positioning, in respect to the proton.

Then, due to the dynamism of both plasmatic Magravs of proton and electron, other Matters' fields in the two plasmas come into play and face each other and their Magravs of these two new Matters and overall Magravs have to interact again.

Therefore, the new facing Matter of the plasma of the electron Magravs have to find a new Magravs positioning in respect to the new Matter of the proton's Magravs and the overall Magravs of the two plasmas.

Further on, again, as both the proton and electron are dynamic, the electron has to find a *new Magravs positioning*, in respect to these new Matters facing each other from each entity interactions, this change of Matters facing each other takes place on a continuous basis, as different Matters and Magravs of both components and the overall structure of each atom come to exert their forces on each other and the overall balance distance of both the electron and proton position is to be maintained as every time new Matters in each entity come to face each other. We call this the ***Magravs positioning principle*** (or Magravs positioning).

The result of this continuous change of the Magravs positioning of the Matters of the electron in respect to the Matters of proton and their overall Magravs, causes and creates the motion of the electron around its nucleus.

The behaviour and interaction of the ever-changing of Magravs positioning of the proton and the electron Magravs in respect to each other, leads to the creation of an erratic, never duplicated path, and is the cause of the motion of the electron around the proton.

That is to say, as the electron rotates around the proton, its position and distance in respect to the proton changes, according to the overall position and balance of the gravitational pull forces and Magnetic field push forces of all three components of its Matters and their respective plasmas, in respect to the position of all three Matters Magravs of the protons' and overall Magravs of the proton.

Nevertheless, as the Matters, in the proton and the electron are both dynamic themselves, the rotation of the electron around the nucleus is changing by the principle of the Magravs positioning of the Magravs balancing. Where, this leads to the ever motion of the electron around the proton of an atom (Fig. 50).

As the overall strength of the Magravs of both components of the atom are the same, this leads to a minimum and maximum distance that can be attained by the electron field strength, in its position in respect to and from its proton. This explains why an electron appears to be moving erratically around the centre point, with a given minimum and maximum distance from the centre proton. This minimum and maximum is to be known as the amplitude (minus and maximum) of the distance of the electron from its proton.

In fact, as the Matters dynamic components Magravs of the electron interact with the combined dynamic Magravs of the proton, the electron, which is the less magnetically dense of the two, has to try to find its position, in respect to all the components of the denser magnetic fields plasma of the proton.

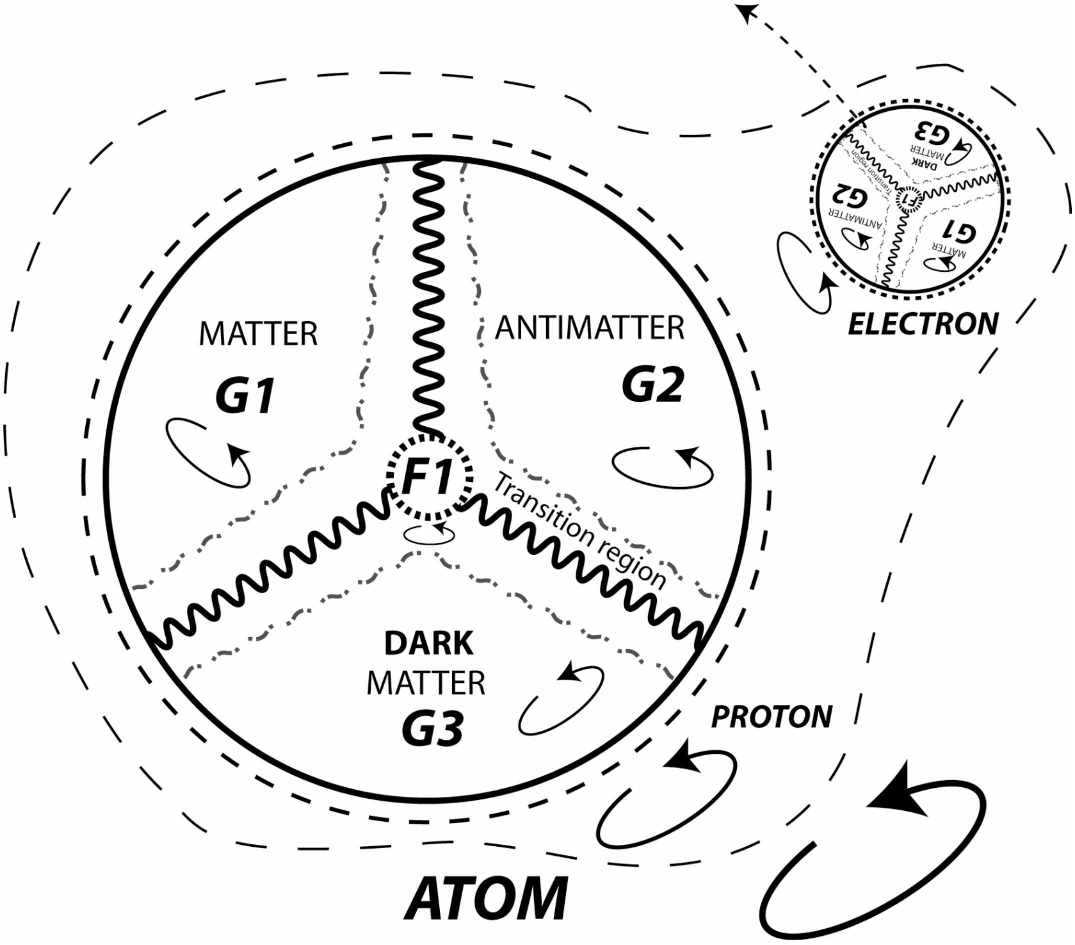

Fig. 50: Schematic of dynamic pmtics of Matters and fields of the proton and the electron and their interaction of individual Matters and their overall plasma and Magravs, leading to Magravs positioning and motion of electron in respect to its nucleus.

This continuous change in the Magravs positioning of the electron, in respect to the proton, leads to the continuous rotational motion of the electron around the proton (Fig. 50)

In fact, one can conclude “the proton and the electron are made up of composite Magravs of several different Matters by simply observing the erratic path of the motion of the electron around the proton”.

In principle it can be said that the magnetic fields strength of any magnetic fields or Matter is ***position dependent*** of the two parts of the fields from each other, which the field has been released from. This is how magnetic fields strength in principle are determined and created. (Paper: Creation of Magnetic fields).

For example, the interaction of the Magravs of the Dark Matter’s in the plasma of the electron interacting with the Antimatter’s Magravs in the plasma of the proton and their overall Magravs of the electron and proton plasmas in respect to each other, decides the position and the distance of the Dark Matter of the electron in respect to the proton.

Universal Magravs positioning principle

The effect of the composite components of the proton and the electron's Magnetic fields and gravitational fields strength, changes the path of the electron as it approaches each Matter of the proton. In composite nucleus, the overall fields' strength of all the protons of the nucleus dictates the distance of the electron from the nucleus.

All motions of objects and fields in the universe are due to the ***overall*** *Magravs positioning of one pmtics of one object or ray*, and so on, *in respect to another*.

I call this dictation of position of an entity in respect to another entity, due to their Magravs positioning distance, the "**universal Magravs positioning principle"** for motion in the universe.

This Magravs positioning of Matter takes place within the constraints of Matters' possessing their own composite pmtics Matters fields' strength.

Universal method of motion

In principle, "the **continuous dynamic Magravs positioning** of one dynamic single ray or multiple Matters of multi-cores plasmas of an object in respect to another dynamic single or multi-Matters of a multi-cores plasmas of another objects, **leading to and/or can lead to and cause the motion** Matters, matters in the universe in respect to each other".

I call this method of **continuous change in Magravs positioning** of one entity in respect to another causing motion in one of the two entities, "**The Universal method of motion "**.

Motions of atoms and their components interactions, the molecules, solar systems and galaxies in the universe, are all based on the ***same*** *simple universal method of motion*.

The dynamic plasmatic Magravs of Matters within the constituent structure of one entity dictates the position and direction and the path of the motion of one object in respect to another dynamic plasmatic Magravs of Matters within the constituent structure of the entity. Motion of components of atoms, motion of planets of solar systems and physical contents of motion of galaxies in the universe are all based on this principle.

The universal method of motion of any two gravitated objects in respect to each other is based on the dynamic plasmatic Magravs strength interaction and attraction of all of its complete composite components of Matters and forces within the object, ***irrespective*** *of the physical size* of the system. All universal gravitational objects follow the same principle of motion as an electron around its proton, the same as is for the motion of Matters in the initial fundamental plasmas.

It is correct to say, "**motion in the universe** is totally and exclusively caused and is due to **Magravs strength positioning** of rays, fields, matters, Matters electron, planet, stars and galaxies in **respect** to each other".

Thus from this point on it is clear that **one does not need to burn fuel** to create **motion, but use Matmags**. However, one only needs to create the right Magravs strength within any system to attain dynamic Magravs positioning in respect to another object, this being, a planet, a star, a solar system or a galaxy for the system to be in motion.

This method of utilising the plasmatic Magravs interaction for the creation of Magravs forces within a system, that brings about the motion of one object in respect to another due to Magravs positioning, is to be known as the "**Magravs positioning methods and universal principle of gravitational motion".**

Thus, the Magravs positioning principles of motion are the future for the creation of motion for automotive, marine, air and space industry.

Through this method of Magravs positioning, there is no need for the burning of fuel in engines to move cars or use liquid fuelled jet propulsion systems to fly rockets into space.

When speaking about gravitational or Magravs positioning, this means the collective effect of gravitational field and Magnetic fields of one system in respect to another object or plasmas, Magravs of planets or stars.

It is important to remember that in the universal order of motion, the ***plasmatic gravitational field*** and ***plasmatic Magnetic fields***, are *integrated*, thus simultaneously they co-exist and one cannot exist and operate without the other.

In the universe the **Magravs positioning of Antimatters** in respect to each other and their plasmatic magnetic fields does exist. Further, there exists the **Magravs positioning of the Dark Matter** in respect to each other and their plasmatic magnetic fields too.

The way the Magravs systems of the future will be set-up and operate will dictate in which gravitational fields strength and dimensions the crafts of future will travel in.

In man-made systems using the plasmatic magnetic fields of the Matters that, through their interaction with each other, create the Magravs needed for positioning*: simply by creating Magravs* ***within a reactor***, and these systems will, by trying to find its new Magravs positioning balance in respect to the Magravs, for an example, in atmospheric area of the planet, cause the motion of the reactor system in respect to the surface of the planet.

The creation of motion through Magravs *positioning* can be used in an aircraft equipped with gravitational reactors in respect to Earth, or with a spacecraft in respect to a planet(s), solar system or galaxy.

Methods based on the Grapos principle for motions are the future for the creation of motion in space, according and in parallel to the way the universe is operating for millions of years for its dynamic existence.

CHAPTER 20

Molecules

The creation of plasma and the way its plasmatic Magravs interact to bring about a balance in its overall plasmatic Magravs and their effect on each other, leading to further interactions and balances in different atoms and their components in different dimensions in atoms has been explained. This balancing and positioning of plasmatic Magravs in between different atoms of different Matters brings about how the final Matters, plasmas and atoms can be brought together, leading to how molecules are come to be generated.

That is to say, for the creation of a molecule, it is necessary that the plasmas of protons and neutrons of any nucleus of an atom, and atoms of different elements, need to have a total plasmatic Magnetic field forces and gravitational field forces positioning balance in a given environment so that these atoms can hold onto their total structure, for the molecules to be created.

Thus, by the same principle a molecule or a cell can only be created where, the Magnetic fields and gravitational fields positioning are in equilibrium in all its participant atoms plasmatic magnetic fields (Fig. 51).

At the same time, the whole of the structure of the molecules' plasmatic Magravs have to find plasmatic Magravs balance in respect to their surrounding environments Magravs for the molecules to be able to exist as an entity in a given environment. This in fact, explains why certain atoms and molecules, in certain configurations, can never exist in one environment, while they are prevalent in other environments, like planets, or galaxies and why different pmtics forces and conditions can apply to the same Matter, and Matter manifest itself as a matter in state of solid, liquid and gas.

Likewise, the same can explain why proteins of specific characteristics are created or maintained by certain cells in one part of the human body and not in other parts of the body (9).

In fact, if the same conditions of plasmatic magnetic fields are, or can be, maintained in any part of the universe, one can reproduce exactly all the Matters known to Man anywhere in the universe.

That is to say, when one can create the required balance and equilibrium environment in the total and overall Magravs of the atoms participating in the construction of a molecule, one can replicate and maintain any molecule. Therefore this explains that Van der Waals forces of **pull** and **push**, merely can be known as the **gravitational** fields forces and **Magnetic** field forces respectively operating between different molecules, irrespective of their binding structure with other molecules or atoms.

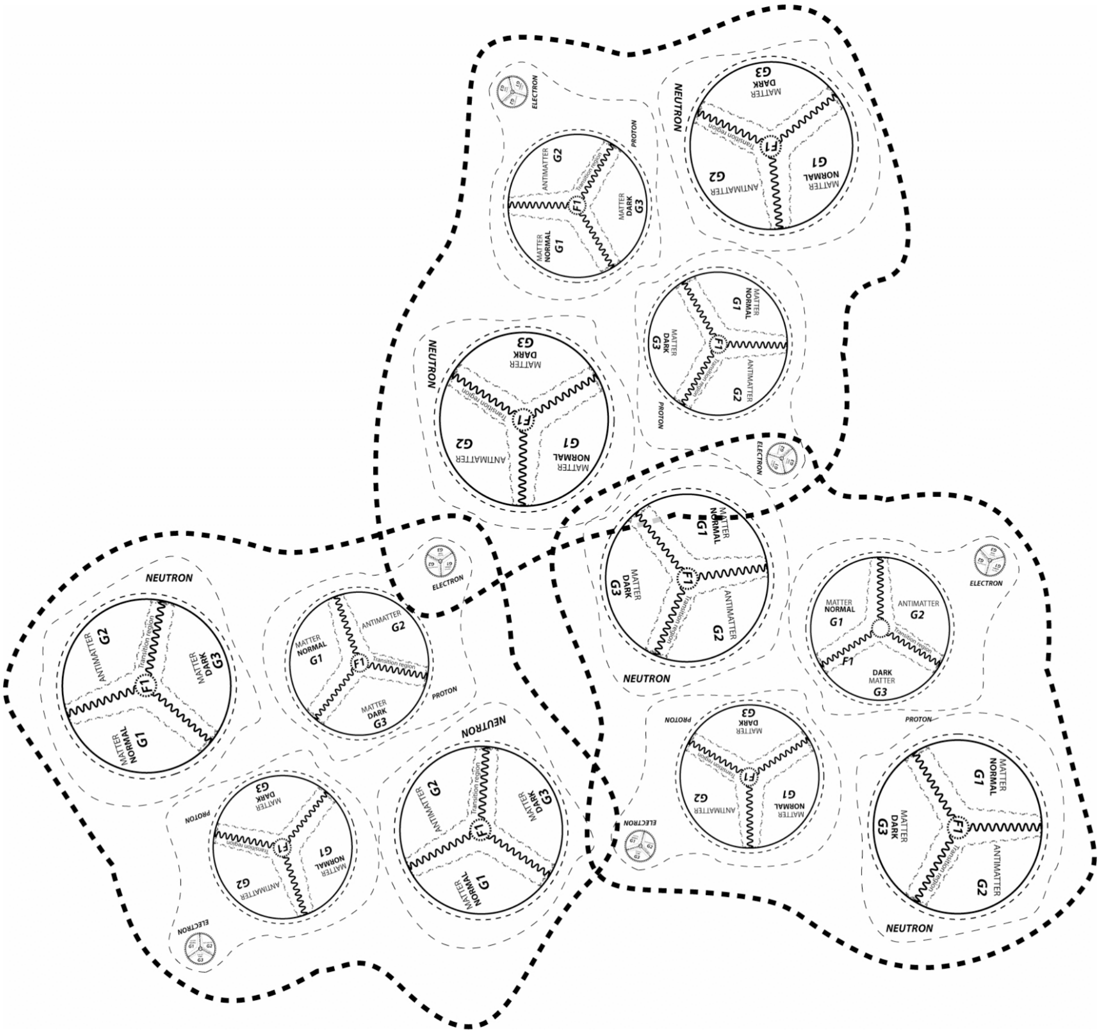
ELECTRON
PROTON
NEUTRON
MATTER
NORMAL
G1
ANTIMATTER
G2
MATTER
DARK
G3
F1
Transition region

Fig. 51: Schematic pmtics of atoms gravitational (Magravs) positioning to form a molecule.

In the industrial Magravs reactors of the future, one can produce as many atoms as one needs by just absorbing the plasma from space or the environment, for any application and purpose like the production of the hydrogen molecules, carbon, nitrogen, oxygen for the production of proteins for food, air, water and so forth, by simply replicating the Magravs of the preferred molecules and allowing their positioning and interactions.

In the future, by giving a standard chart of Magravs strength and prevailing magnetic fields forces, temperature and pressure of plasma, atoms and molecules, one can produce and maintain any atom and molecule anywhere in the universe.

CHAPTER 21

Plasma Dilution Technology

The Plasma Dilution Technology is the new approach for the use of new gained knowledge for creation and control of plasma and its sub-Matters constituents Matters and their fundamental elementary particles.

The new understanding and insight into the construction and the structure of plasma and its constituent Matters and their magnetic fields, opens up new opportunities for the creation of energy and motion, production of new materials, for medical uses and so many other applications.

The plasma dilution technology allows the plasmas' Matters components to be diluted within a soup of Matters and their pmtics made up of exactly of the plasmas' own composite structure.

Through the specially designed ***nuclear reactors***, conditions are created within the structure of the reactor that the plasma is contained in a safe and secure way in reactors cores configuration.

The operation of these reactors can be controlled so that they do not release any radiation into the environment and they create no waste of any kind, this being the likes of radioactive materials or CO_2 waste, as has been the trend in the current nuclear and energy production industry.

Through the understanding and creation of a parallel environments, similar to the internal environment of the same weak plasmatic magnetic fields of the plasma itself, plasmatic magnetic soup environments are produced in these types of reactors, so that the plasmatic magnetic fields condition within the reactor cores matches the plasmatic magnetic fields of the binding forces (Coulomb Barrier) of the initial fundamental plasma, as the components of this plasma soup, this barrier is magnetically diluted and soften, allowing the plasma to open through the operation of the reactors, for the Matters of the plasma to become part of the dilution soup of Matters and fields forces of the reactor.

A soup of weak plasmatic magnetic fields

These plasmatic magnetic fields saturated reactors will allow components of any plasma introduced into the reactor to be loosened and, the Matter, the Antimatter and the Dark Matter of the plasma, to be free to move within the structure of the plasma soup, which has been created through specific setting and Matter combination. Matters once loosen from other Matters within the soup of the plasma, these are then free for their fundamental particles effects to be utilised to achieve any desired effects, like for fusion and production of new matters, lift and motion.

Reactors that facilitate such a dilution of plasma I call **Plasma Dilution Reactors** (Fig. 56) and their process of dilution as the **Plasma dilution principle** and their knowledge as the ***plasma dilution technology*** (Fig. 52).

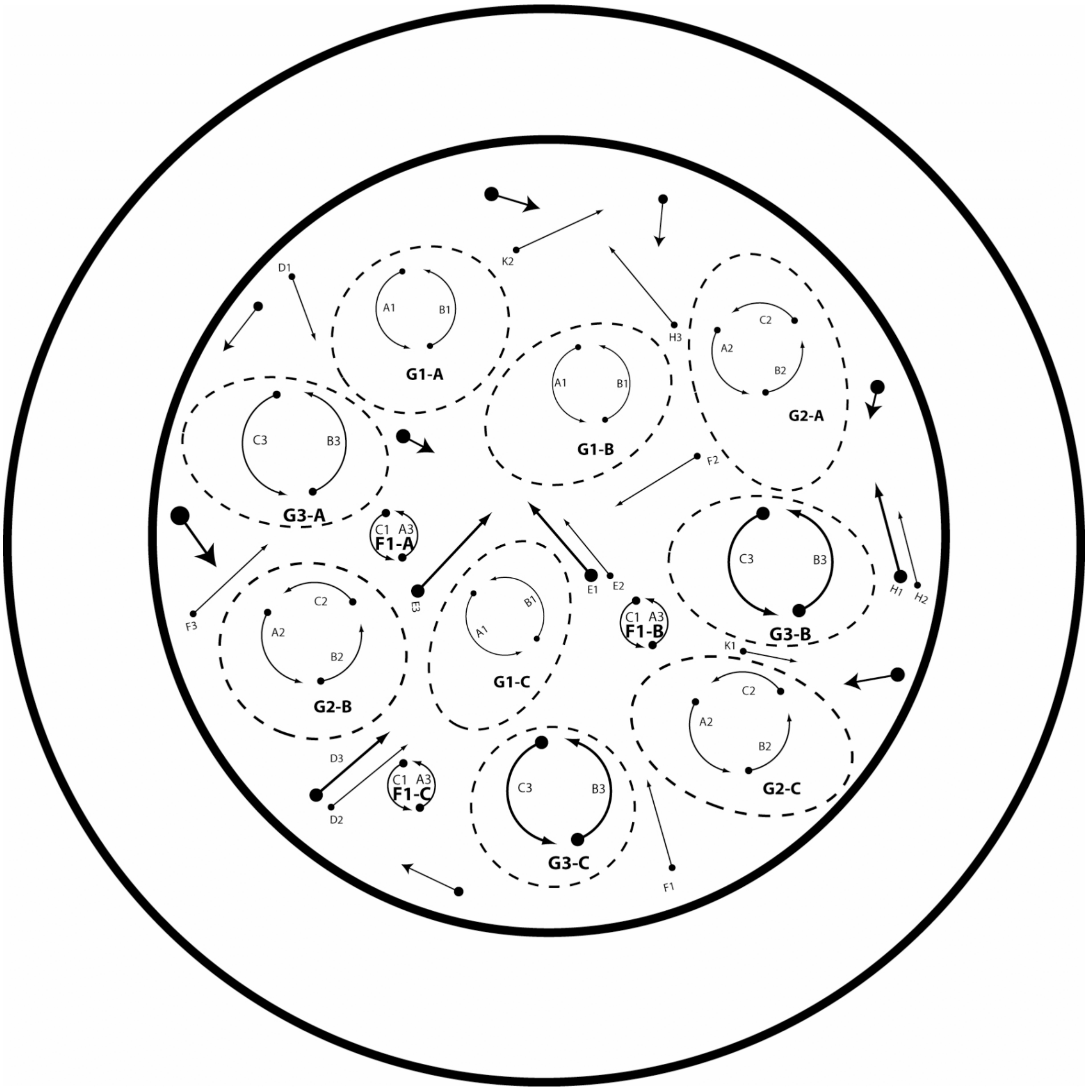
D1
K2
A1
B1
G1-A
H3
C2
A2
B2
G2-A
A1
B1
G1-B
C3
B3
G3-A
F2
C1 A3
F1-A
C3
B3
G3-B
H1
H2
F3
C2
A2
B2
G2-B
E3
A1
B1
G1-C
E1
E2
C1 A3
F1-B
K1
C2
A2
B2
G2-C
D3
D2
C1 A3
F1-C
C3
B3
G3-C
F1

Fig. 52: Plasma dilution concept and technology.

Further interaction of the constituent principle plasmatic magnetic fields of the Matters of the plasma inside the cores of these reactors can create effects that can be used to achieve desired outcomes from their interactions with other Matters or matters and fields outside or inside the reactor's structural environment and this is exactly the way and the method that different entities in the universe function and operate to achieve certain desired effects and production of Materials.

Diluting the plasma in the larger pmtics environment of the reactor is another option in the nuclear world for achieving fission, fusion, production of new Matters, matters, for generation of energy and motion.

Disentanglement

Through the Plasma dilution process, once the new plasma soup is produced in the reactor cores, the weak interacting plasmatic magnetic fields soup interacts with the binding fields of the components of the Matters of the plasmas which are further introduced into the reactor cores, this allows the Matters of new plasma to disentangle themselves from each other (Fig. 53), if this level of dilution of new plasma is required.

In this process of plasma dilution, the sub-components of the plasma are allowed to loosen up from each other and not necessarily allowing the separation of all the Matters of the plasma from each other.

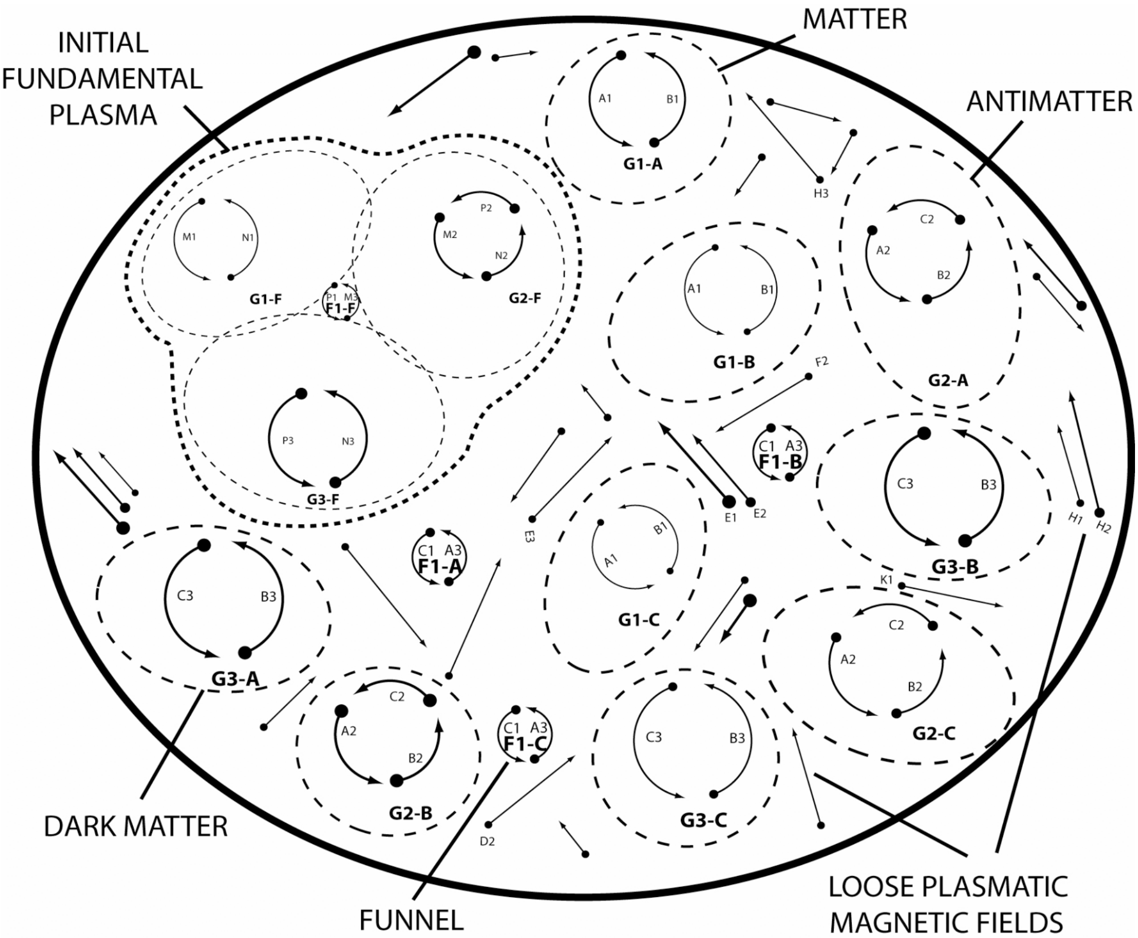
MATTER
INITIAL FUNDAMENTAL PLASMA
ANTIMATTER
G1-A
A1
B1
H3
G1-F
M1
N1
G2-F
P2
M2
N2
P1
M3
F1-F
G3-F
P3
N3
G1-B
F2
G2-A
C2
A2
B2
C1
A3
F1-B
E1
E2
E3
G1-C
G3-B
C3
B3
H1
H2
G3-A
F1-A
K1
G2-C
G2-B
F1-C
D2
G3-C
DARK MATTER
FUNNEL
LOOSE PLASMATIC MAGNETIC FIELDS

Fig. 53: Dilution process of initial fundamental plasma within a soup of Matters.

Through this method, different components of the Matters and fields of the plasma can be used for any purpose that the operator decides or that the system is pre-set to.

Hence, each sub-component Matter of the plasmas in the reactor can be separated from the plasma in any quantities of individual Matter within the soup.

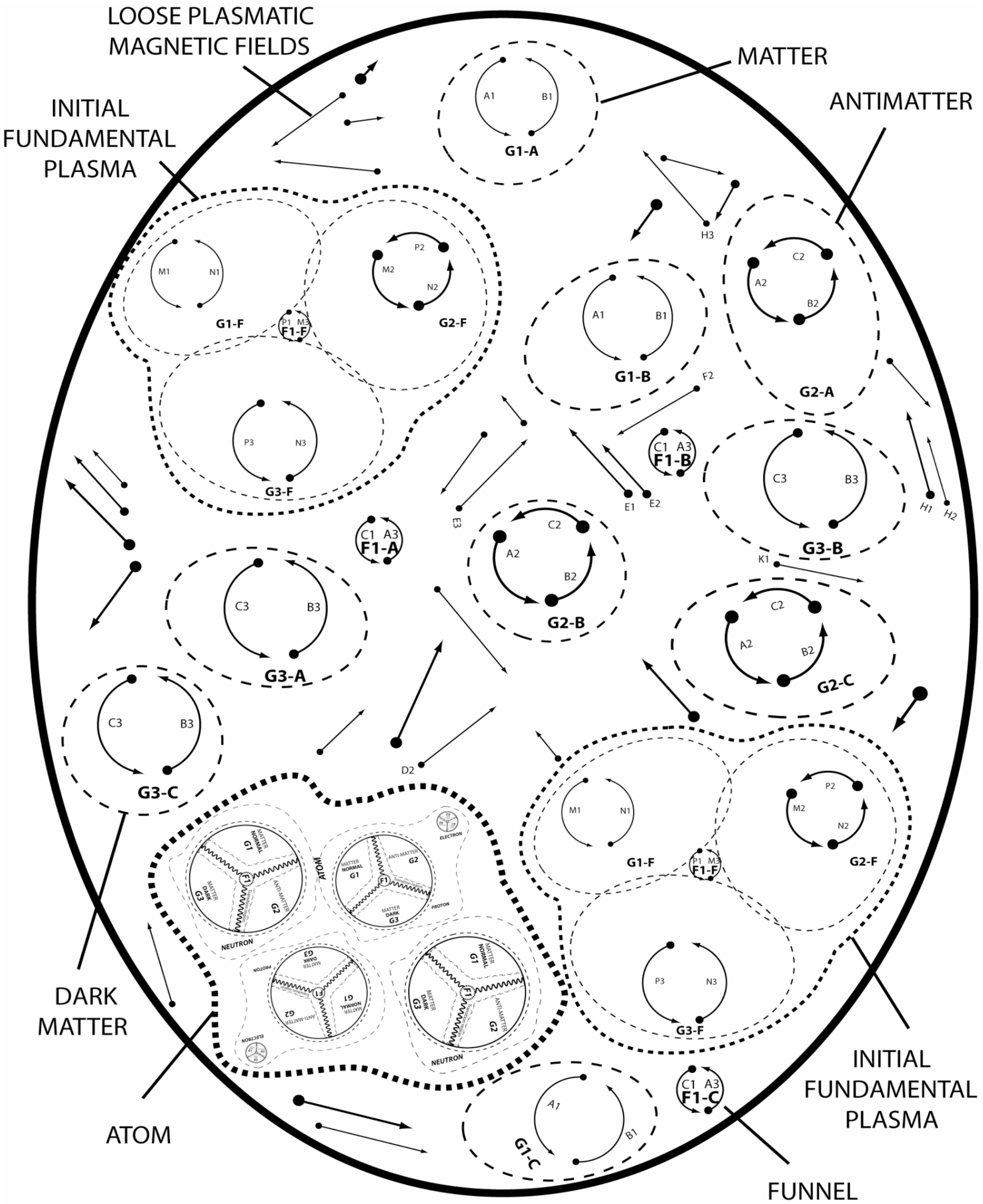
LOOSE PLASMATIC MAGNETIC FIELDS
MATTER
INITIAL FUNDAMENTAL PLASMA
ANTIMATTER
A1
B1
G1-A
H3
M1
N1
P2
M2
N2
G1-F
P1 M3
F1-F
G2-F
C2
A2
B2
G2-A
A1
B1
G1-B
F2
P3
N3
G3-F
C1 A3
F1-B
E1
E2
C3
B3
G3-B
H1
H2
C1 A3
F1-A
E3
C2
A2
B2
G2-B
K1
C3
B3
G3-A
C2
A2
B2
G2-C
C3
B3
G3-C
D2
M1
N1
G1-F
P1 M3
F1-F
P2
M2
N2
G2-F
P3
N3
G3-F
ATOM
NEUTRON
PROTON
ELECTRON
MATTER NORMAL G1
ANTI-MATTER G2
MATTER DARK G3
F1
DARK MATTER
ATOM
A1
B1
G1-C
C1 A3
F1-C
INITIAL FUNDAMENTAL PLASMA
FUNNEL

Fig. 54: Dilution process of initial fundamental plasma and atoms and molecules within a soup of Matters and pmtics.

The plasma dilution technology (Fig. 54) replaces the present state-of-the-art technology *accelerators* used for the separation of different components of plasma or an atom.

The plasma dilution reactors for example can be used for the extraction of Antimatter, instead of the presently used methods of slamming plasma at high speeds in accelerators into specific pure solid metal matters to extract its Antimatter, by chance, every once in while (6, 7 and 8).

In the same way, the plasma dilution reactors can be used in the fusion industry where, present technology uses huge enforcing magnetic fields to force the fusion of plasmas.

With the plasma dilution method, the components of the plasma are opened up, in a soft way, loosened, and then are allowed to be separated from other Matters in their surroundings, and into their specific sub-components, interacting collectively in the soup of the Matters for their use for any given specific purpose (Fig. 54), like for fusion of Matters or matter.

These reactors even can be used for fusing components of two plasmas together. If the Antimatter is needed to be separated from the Matter, this can be easily done, as by creating a weak plasmatic magnetic field, around the plasma, then, the Antimatter components of the plasma can be separated for the use of their plasmatic magnetic fields properties and effects for example for the production of powerful Magravs forces. Where, the rest of plasmas' components are then *left in the* ***dilution soup***.

When one has used these freed Antimatter plasmatic magnetic fields for their effects they create, for the purposes that one needs, then the system-loading Magravs configuration and parameters can be altered to *change the dynamism of the reactor*, and gradually disassemble the dilution fields. Then the Matters of the plasma are allowed to return to their original Matters' components state of the plasma, and for the plasma to return its atomic structure and so forth.

All these reactions can be created and controlled without the creation of unstable or high temperature environments as is seen in the universal order of creation of Matters, energy and motion.

At the same time, there is no need to hold on to certain Matters and to run expensive holding systems for Antimatter as done for example by Fermilab at the present.

All these processes are carried out without any release of radiation or the production of new radioactive waste.

These effects can be created at room temperature and within portable safe nuclear reactors, which have been designed, developed and tested in the past few years.

There is conclusive evidence from tests, that the principle of the untangling of plasmas' magnetic fields binding forces through plasma dilution technology is a proven fundamental principle for the future of energy production and creation of motion for space travel.

That is to say, that we have seen the effects that Antimatter in being loose in the cores of the reactors to possess stronger fields and create stronger Magravs forces than the Matter components of the same plasma. We have managed to lift and reduce weight of reactor systems in respect to its environment, and we have create new matters, all at room temperature, in the recent past through the operation of plasma dilution reactors, as we have reported and applied patents for.

This stronger characteristics and effects of Antimatter are purely due to the fact "that at the inception of the plasma, the Antimatter components of the plasma were created by the stronger plasmatic magnetic fields to start with".

Similarly, gravitational field forces of the Dark Matter components of the plasma can be used through the plasma dilution technology for the creation of high-speed motion without friction for crafts of the future in space technology, or these reactors can be used for the extraction of poison from a substance like water or air.

In testing for the production of the Dark Matter principle, systems have been twisted in their axel and damaged, confirming the enormous power of invisible, powerful, Magravs of the Dark Matter.

In general, it can be said, "The future is **bright**, the future is plasmatic magnetic fields based, through the production of controlled plasmatic dilution technology reactors"

CHAPTER 22

Matters and Magravs systems

The technology that uses the properties of the Matters of plasma to create motion and energy, instead of the present use of matter, I have called ***the Magravs positioning Systems Technology***.

The fundamental difference between the **Matter** gravitational technology and **matter** propulsion and energy systems can be explained in simple way.

matter propulsion technology

The present **matter** propulsion systems in burning fuels have **to fight and to overcome** Magravs of the planet for **lift and motion.** This we see in the rocket propulsion space technology of today.

In the matter systems, like the propulsions systems, power stations and cars use the fundamental principles of ***burning matter*** to release its energy and convert this energy from one form to another to create motion and energy. This technology has always delivered *limited energy*, and due to its bulkiness of mass and weight of the fuel that have to be carried by systems to achieve their objectives, these systems are payload dependent.

The matter system uses the ***Matter part*** *of plasma*, the **weakest** and **least energetic** part of the plasma. By their nature as has been seen in the past, matter systems create different type of waste, like CO_2, nuclear waste, and so on.

Matter gravitational technology

The **Matters** Magravs system uses the *properties of the all Matters* in the plasma to create motion, lift and energy without destroying the characteristic of the Matters, and the system works **within** and through the **Magnetic field** and **gravitational field** of its environment to **attain position and motion,** one can achieve more working ***within*** *than* ***fighting against*** the Magravs of the planet.

In the present state-of-art technologies, always the matter components are considered for their physical ***action and reaction***, and not their Matters field's components.

Matters used in the Magravs systems, uses the properties and interaction of all the initial fundamental particles properties of all Matters within the components of the fundamental plasma, "Matter, Antimatter and Dark Matter". There is no need to "react" as in the matter processes, since the system works' within and is part of the same magnetic fields base system and works through the universal natural forces. Therefore there is never a need for reaction for motion, as the system always magnetically balances itself in respect to other magnetic fields forces.

These reactor systems are developed to function in the same way as the interaction of the initial fundamental particles leads to the creation of Magravs for the motion of Matters through the Magravs positioning principle in the universe.

In these systems, there is no destruction of Matter, since the system can use Matters pmtics properties for the enhancement of Magravs positioning, for the creation of motion and energy and so forth.

This method of the use of Matters creates heat, if it is needed from a system.

As it has been observed, stars create massive heat to create vast amount of energy and Magravs forces, through tests it have been proven that the creation of motion and energy by the use of Magravs forces, these systems creating effects which are ***temperature independent***.

Used in the atmospheric conditions, the Grapos, through the principles of the creation of plasmatic Magravs within the cores of the reactor and their interaction with the plasmatic Magravs of the planet, this interaction of these two Magravs, leads to creation of a *magnetosphere* around the systems. Where, the interaction of plasmatic Magravs of the system and the planets Magravs always lead to ***the creation of light*** around the system. This light being created through the principle of interaction of two plasmatic magnetic fields as was explained in Chapters 7 (Fig. 29 and Fig. 31). This is exactly how the magnetosphere of the Earth is created in respect to the Magravs interaction of the Earth and the Sun, and the same principle as for the creation of the daylight as seen around the Earth.

The magnetosphere created around the Magravs system, can be a spherical or oval bright light in shape depending upon the speed of motion and protection chosen by the operator.

In the **Universal systems** like stars**, their Magravs forces** are *fixed* by their initial matters' contents in their inner cores at the point of the inception of the star, and the magnetic fields strength they generate for the production of their Magravs strength, once the strength of the Magravs is set for the stars, these cannot be changed arbitrarily to achieve different Magravs strengths for the stars.

Whereas in the **Grapos reactors'** developed for the motion of crafts, the **Magravs** parameters of these reactor systems *can be changed and manipulated* according to the position, speed, energy and so forth, as is desired of the system by their operators.

In these systems, the reactor-operator dictates the Magravs strength of the system, therefore he decides the speed and the position of the craft at any position in space in respect to another Magravs system, the like of the Earth surface or a given distance from the moon or galaxies.

Interesting enough, all these effects of motion are achieved even though the system uses the same fundamental methods and Matters as in the cores of the planet or star that the systems is operating within or aiming for.

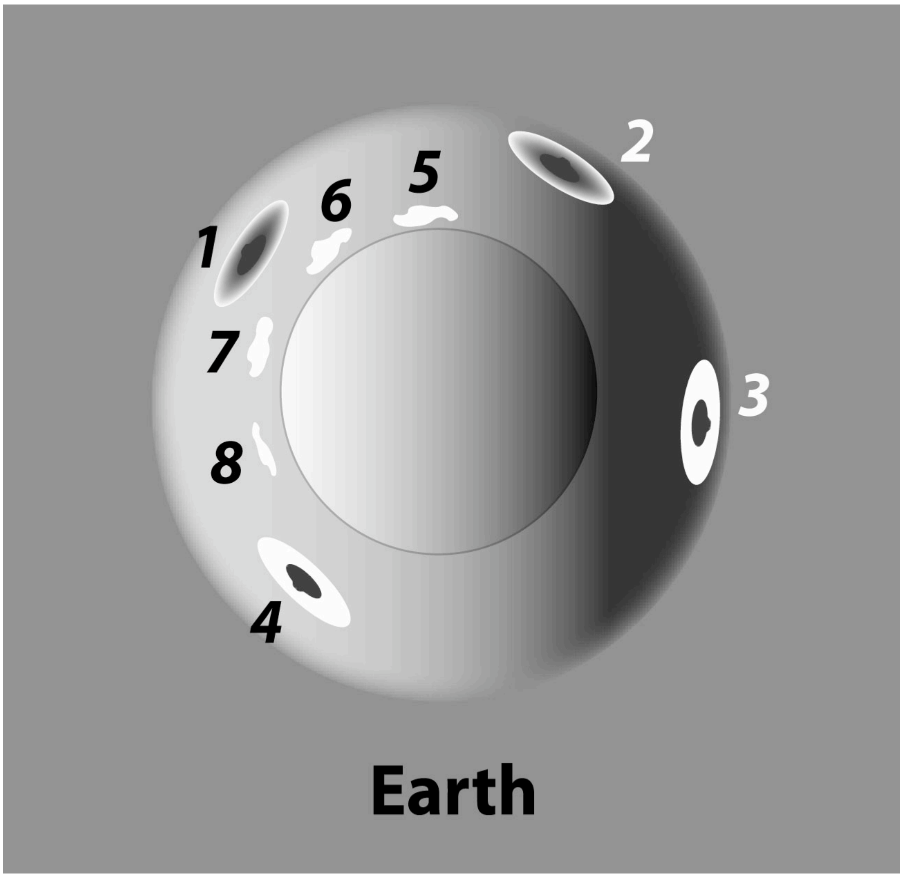

Fig. 55: Representation of interaction of four different pmtics strength of gravitational (Magravs) positioning systems (Grapos) in respect to Earth pmtics Magravs (1, 2, 3 and 4).

Note: Figure 55, numbers 5, 6, 7 and 8 show that the position of clouds in respect to Earth are pmtics Magravs strength dependent, and not size or volume dependent.

Thus, wherever the Magravs principles reactors are used for flight in a system, like in atmospheric condition of the planets', the natural outcome of the interaction of the two pmtics Magravs of the environment and the reactors Magravs is the appearance of and creation of natural light around these flying systems (Fig. 55 light regions of 1, 2, 3 and 4). Thus, the same Magravs positioning systems can be used, to produce lamps that can create light for years without needing to burn any fuel or consuming electricity.

Simultaneously, in a dense plasmatic magnetic fields environment, like the Earth, when the Grapos are used for motion and lift, due to the interaction pmtics Magravs, of the Earth and the system, these systems will produce their own magnetosphere around them. This magnetospheric light intensity is reactor Magravs' ***strength*** *dependent* and through the principle of interaction of two pmtics of plasmas as was discussed before, these magnetospheres will cause the creation of bright light around these systems in the

Earth atmospheric condition. As the brightness of the magnetosphere around the system in respect to its surrounding pmtics strength will be dependent on the strength of the plasmatic magnetic fields that are created by the Magravs positioning reactors, and in respect to the systems' position, considering that the plasmatic magnetic fields of the Earth is constant.

Thus, the confirmation of systems using Magravs positioning technology for motion in dense atmospheric condition like the Earth will be the appearance of bright moving lights (Fig. 55 lights 3 and 4) in the Earth atmosphere or any given atmosphere or medium in the universe. In dense atmospheric conditions, these Magravs systems will be appear to be a shining bright light floating in air, either with high speeds or seated stationary.

In some literatures, systems that use Grapos for motion and appear as bright lights from an unknown source in the skies have been called, the Unidentified Flying Objects, also called ***UFO's*** (Fig. 55 lights 1, 2, 3 and 4). Now that the method by which these bright lights in the sky are produced, their operation understood, and known, these crafts are not Unidentified Flying Objects no longer.

Nevertheless, in reality, it is now interesting to see who are the users of these systems. Whoever are the users' of these Magravs systems, this does not necessarily means that they are more advanced in scientific level than the human race in its present scientific and technological evolution. However, this simply means that they have managed to harvest the principles of the plasmatic magnetic fields, and the constituents of Matters, some time before the human race.

Now that the technology and the principles behind the plasmatic Magravs positioning fields are open to the human race, it is not hard to see that interaction with users of these bright lights will be inevitable and will only be to the Mans advantage, to help man to reach new levels of understanding about his universe.

In tests, the effects and bright light created by use of these reactor systems, which have been developed and tested for weight reduction and lift, has been noted.

The operation and interference with the radar and radio frequencies, through tests running of these Magravs positioning reactors have been videoed and recorded in August 2008. This confirms the origin of the motion of these systems to be on a plasmatic magnetic fields basis, as the system's Magnetic field operation interferes with radio waves, which radio waves are magnetic fields based entities.

NASA has done tests on these types of magnetospheric condition and motion system, on a miniature scale, in advance concept projects known as MINI-magnetospheric plasma propulsion project called M2P2 (40). They have achieved this by using the argon gas up to this stage. They hope to be able to finance the project to reach helium and then the use of hydrogen as base-material in years to come. They may then use plasma of hydrogen atoms later as they progress in gaining knowledge in 30 to 50 years and having the budget. However this is still one of the theoretical approaches for NASA.

Fermilab (6, 7, and 8) is looking for the Antimatter as the "fuel" for propulsion systems of the future space programs for NASA. If they redirect their attention into the properties and the effects of the Antimatters that they have gathered by now, they can achieve the same results as have been seen and tested in the recent Magravs systems reported on our Foundation web site and patents that have been applied for.

Through the understanding of the real forces in operation of the universe, the Magravs positioning reactors are simply years ahead of their time.

Our Magravs positioning reactors are not in a mini-scale dimension as NASA's project has tested and envisages at this moment in time, but these are in several sizes, which can create controllable size magnetospheric conditions, as the operator of these simple systems sees fit the purpose.

In the near future, these Magravs systems will replace the propulsion systems that have been used for space explorations and air travel.

The advantage with the Matters powered Grapos is that these systems create a magnetosphere around the reactor system. This is the same natural magnetic protection barrier for the future spacecrafts as the magnetosphere around the Earth has been, protecting man from space debris and cosmic radiations for billions of years.

These systems' magnetosphere protection capabilities can be used to protect the craft in deep oceans from water and the crafts to be used like the submarines of today, with the difference that these systems magnetosphere will allow these crafts to reach the deepest parts of oceans floors without any problem, as they can reach any depth in liquid planets in the universe.

The magnetosphere generated by Grapos will create *magnetic shielding* at Matters' level of the plasmas that can be used to pass through materials like ice without melting their matter(s). But simply by diluting the ice Matter(s) at plasma levels as in the plasma dilution reactors. In these conditions the crafts will appears as the craft will come out of nowhere and with no holes indicating the position of the exit from the ice by the spacecraft. If observed from the distance these crafts will be like bright lights shining and jumping out from the ice-covered sea-surface.

These plasma dilution Magravs positioning systems, by the use of Matters, will be the only solution for plasmatic saturation, once these crafts will pass and go through cosmic dusts as they temporarily disentangle the Magravs of atoms and plasmas of these cosmic dusts by just diluting the components of the Magravs of the Matters of cosmic dusts with the Magravs of the craft protection magnetosphere, and the craft passes through the dust matters as if they were not there.

CHAPTER 23

Matter Pmtics in reactors for lift and motion

The utilisation of the Magravs forces of dynamic multi-core systems, in respect to each other, for the purpose of the creation of lift and motion is discussed in this chapter.

In multiple cores *dynamic plasmatic dilution Grapos* that have been developed and tested at room temperature, these systems have proven to have the capability to produce different plasmatic Magravs forces strength as strong as those of a hot centre core object, like the Earth.

Using the principle of the creation of dynamic plasmatic Magravs forces within the structure of a multi-core reactor, the system can be caused to find its own position in respect to the environment of a planet or any Magnetic field and gravitational field forces in space.

In developing and achieving the Magravs positioning of these systems, in respect to the planet's Magravs forces, on the surface of the planet, leads to the reduction of the weight of the system to start with. Once the two plasmatic magnetic fields of the planet and the system reach **the total balance or equilibrium**, the ***zero weight*** of the system, in respect to the planets gravitational fields at a given point and the position, is achieved.

From this point of ***total equilibrium*** any further change(s) in Magravs force strength of the reactor in the same direction and configuration as before, this leading to and causing the ***free lift*** and **motion** of the reactor system, in respect to the planet.

Principle concept of upward or separation motion

The upward motion of the systems in respect to the planetary fields or any other Magravs systems is simply due to the fact that the **Magnetic field of the planet** and the Magnetic field of the system is of the *same polarity*. Thus, the two similar Magnetic polarities ***repel*** each other, hence causing the upward or separation motion of the system.

It is fundamental to understand that: In the Magravs positioning reactors **"The repulsion of two objects or moving away from each other, like moving away form the surface of the Earth, is totally due to interaction of the two pmtics of Magnetic fields forces of the systems and of the planet.**

Whereas**, any closeness or gravitation of the reactor system in respect to the planet is controlled by the pmtics of the gravitational fields between the system and the planet in respect to each other."**

This is how Magravs positioning reactors, in possession of dynamic cores, create up or down (lift and descend) motion in respect to another Magravs of an object, like the Earth.

In these systems by changing the strength of any of the gravitational or Magnetic fields strength within the reactors of a system, this system, necessitates the finding of a new balance position between the system and the planet's Magnetic and gravitational fields.

By changing the parameters of the reactors and for the reactor to find a new balance between the systems' own Magravs and the planetary Magravs, this causes the motion of the system as it tries to reach the newly desired balanced Magravs force position, in respect to the planet Magravs.

This is the universal method of **creation of motion *without burning an atom*** of any matter, and this is exactly how all the celestial objects find their position and motion in the ever-dynamic environment of plasma of an electron in an atom, solar systems, galaxy and universes.

The motion of the system is purely due to the phenomenon of **Magravs positioning**, of one system in respect to the other(s).

Simple, portable, plasma dilution nuclear reactor systems, can produce the required Magravs forces within its reactor cores on a continuous repositioning criterion bases that can cause the motion of the Magravs positioning system (Fig. 56).

In these Grapos, the individual pmtics released in the central core (Fig. 56) in their interaction with the compatible and matching pmtics' strength of other pmtics *in the same core* can then collectively interact with the same collection of pmtics created in the other cores of the reactor (Fig. 56), and interactions and interlocking of the same pmtics strength in *different cores* of the system leads to the creation of Magravs within and around these types of reactors simultaneously.

By referring to figure 1, 2 and 3 in the early chapters, then it can be realised that, what has been achieved in these dilution plasmatic Magravs positioning reactors (Fig. 56), is exactly what has been going on in inner cores of planetary systems such as the Earth, to create their Magravs for them to hold on to their components through their gravitational fields, and at the same time to protect their matters from other celestial objects through their Magnetic fields, and at the same time create positioning in respect to other Magravs, at the same leading to creation of motion of the reactor. These reactors are truly an all ***integrated system for flight and motion.***

At the same time, these reactors during their operation within a craft system creates' and maintains' an independent internal gravitational field forces within the reactor cores fields catchments' zone. For example these properties and effects can be used to maintain an earth, one-G gravitational field force within the confine of any spacecraft, independent of the position and speed of the craft where, this position in the universe might be.

These reactors in collaboration and simultaneous production of the Magnetic fields and gravitational fields leads to the creation of a distinctive and separate magnetosphere around the reactor or the craft which, uses such reactor technology, similar to the Earth atmospheric magnetic field.

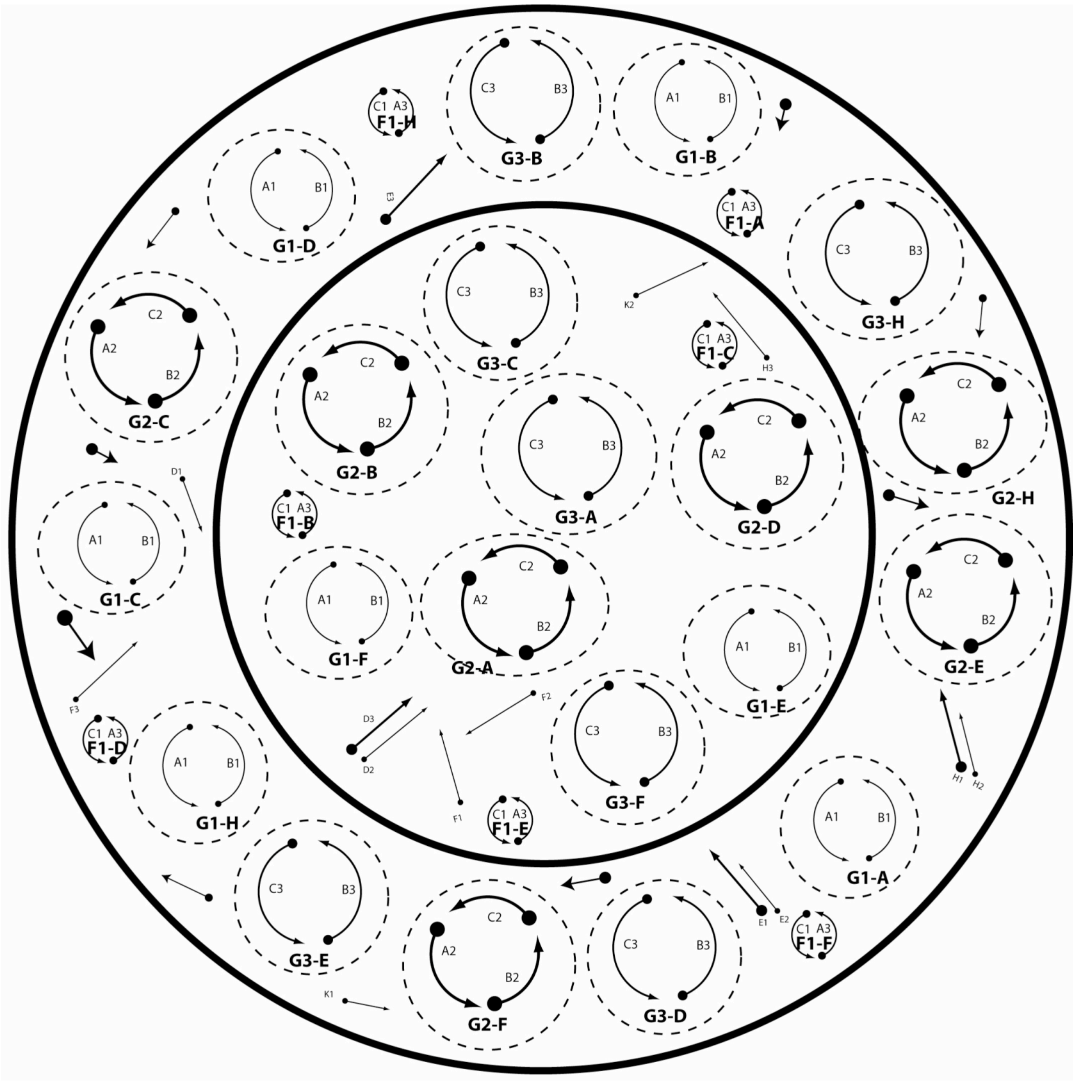
C1 A3
F1-H
C3 B3
G3-B
A1 B1
G1-B
A1 B1
G1-D
E3
C1 A3
F1-A
C3 B3
G3-H
C3 B3
G3-C
K2
C1 A3
F1-C
H3
C2 A2 B2
G2-C
C2 A2 B2
G2-B
C2 A2 B2
G2-H
C3 B3
G3-A
C2 A2 B2
G2-D
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A1 B1
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C1 A3
F1-B
A1 B1
G1-F
C2 A2 B2
G2-A
C2 A2 B2
G2-E
A1 B1
G1-E
F3
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G1-H
D3
D2
F2
C3 B3
G3-F
H1 H2
F1
C1 A3
F1-E
A1 B1
G1-A
C3 B3
G3-E
C2 A2 B2
G2-F
C3 B3
G3-D
E1 E2
C1 A3
F1-F
K1

Fig. 56: The Keshe Model of Plasma Dilution and Magravs positioning reactor.

Thus, the Grapos are exact copies of the planetary Magravs producing systems. Similarly, they utilise the same Matters inside them, and the same principle of interaction to create Magravs between the systems and a planet. This being the same principle as, between the Earth and the Sun field forces and the Earth, and the rest of planets in the solar system and the same system principle as between electrons and protons. (Fig. 57)

Therefore, by changing the strength of the Magravs strength of Grapos, these systems can be positioned in any orbit or position around the Earth (Fig. 55, Fig. 56 and Fig. 57 c), in the solar systems or galaxies, with the use of Matters, rather than matters in the system.

In other words, the balancing of two Magravs' forces of the system, in respect to the planetary Magravs forces, leads to lift or descend of the systems. This separation only leads to a vertical up or down motion of one-system field in respect to the other systems' field. This means lift or descend of the system in a craft takes place vertically and not a 360-degree directional motion of the system.

In current physics, scientists call this the anti-gravitational field forces needed for lift and these systems are called anti-gravitational systems.

In reality, any motion of a system is not due to anti-gravitational field forces, but in fact is due to the total balancing of the gravitational field and Magnetic fields of the two systems of the planet and the Magravs positioning of a reactor, in respect to each other in a given position.

For directional motion, the same principle as vertical lift is used with the difference that in the directional case, the ratio of change between Magnetic fields and gravitational field created within the system are utilised, as the two field forces in the reactor of such a system have an opposite gradient of scale of strength with each other. That is to say, the control of the creation of gravitational fields increases with the same increment as the decrease in Magnetic field strength, within the interaction of the fields of the cores of the system, in respect to the planetary field forces.

The same principle of Magravs positioning can be used in space for motion, in a direction of motion towards or away from a planet, star or galaxy.

There is an alternative *method of motion*, which is by *compartmenting* each core of the reactor. This is a highly advanced technology and needs a full understanding of the creation and control of the magnetic fields' strength of magnetic rays and Matters mixtures and full control of the motion of dynamic Matters in a dynamic environment of the reactor cores.

As motioned before, reactors have been designed, built, and tested to confirm the effects of weight reduction and lift, and the results have proven the correctness of the principle of Magravs positioning reactors, rather than the anti-gravitational field assumptions.

It has been shown that the **system gravitational field and Magnetic field strength** are **independent** of the **size of the system for the mass that** they can lift.

In tests carried-out in 2008, a ten-kilogram reactor system was used to lift a 100-kilogram weight.

In early 2009, the system combination was used to reduce weight from 9 kg by increments of 100 grams. Then another system was use to reduce the weight of the system from 7 kg to 6.5, 6.3 and 6.1 kg and so on in increments of 100 grams. In some tests, the weight of the same system was increased by 100-gram increments also.

These tests were done to show the correctness of the theoretical principles and its practical applications in reduction or increase in Magravs forces of one system in respect to another like the planetary system.

CHAPTER 24

Passive Magnetic Fields

In the universe, there are two types of interaction in respect to plasmatic magnetic fields forces.

One pmtics force is called ***active*** magnetic fields force and the other ***passive*** magnetic fields force.

The *active magnetic fields forces* are the pmtics forces that can exert forces on other fields and components of other pmtics of plasmas causing them to move or vibrate, or receive motion or vibration from the pmtics. This is usually matter-based motion and creates tangible or physical motion of matter.

Active magnetic fields forces usually cause dislocation of the electrons in a cell or vibration of electron in conductive material, etc.

Matters of the plasma mainly produce the **passive** plasmatic magnetic fields.

Passive pmtics can deliver their magnetic fields forces as energies to another plasma of the atom, for them to increase their magnetic fields density or energy without dislocating any Matters plasma's.

Through passive magnetic fields strength, if the plasma is in need of the extra pmtics strength, it can receive the quantity that it needs *of the **same** pmtics strength* for it to return to its ground level pmtics strength level. Otherwise, the pmtics will pass the plasma without transferring any of its pmtics to the second plasma. At the same time the second plasma, if it has extra pmtics which it does not need, it gives the extra pmtics *to the **passing** pmtics,* if it needs the extra pmtics for both pmtics to return to ground levels of their original pmtics strength.

The passive magnetic fields do not cause the atom to move or be dislocated from its position but also cannot cause vibration of the electron of the atom as such.

Passive magnetic fields are pmtics used for delivering the energy levels of vitamins and minerals to atoms and molecules of protein chains and are ***Matter pmtics orientated*** and based.

It is important to note that each plasma carries' one pmtics strength pack in the majority of cases. Thus for human body to receive all its pmtics strength spectrum, the body need to consume different minerals and vitamins and proteins that can deliver certain specific passive plasmatic magnetic fields strength to cover all his cells' needs.

Where the ***active pmtics*** are **matter orientated** and create heat, motion, and vibration in the matter components of the plasma.

CHAPTER 25

New understandings and New Technologies

From the new explanation and understanding of the creation and control of initial fundamental particles (magnetic fields), and further in having access to the new knowledge and the technologies that to be able to replicate the same in small reactors and their systems, the production and the control of MATTERS and the initial fundamental plasma as in **the universal order of the creation of Matters** in these reactors have become simple and practically possible.

The world of science and technology can find new solutions and new sources of Matters for the production of energy, the creation of motion and other applications within the confines of these reactors and this technology will be developed further for these purposes.

In understanding the principles of the working of these reactors, one can make use of, and manipulate, the Matters and energies embedded in the initial fundamental plasmas for the production of new materials, motion and energy. One would be able to use the new understandings of the Matters sub-plasmatic structure for the release of magnetic fields and energies from these Matters.

Through progressive development of this technology, new and simpler methods are devised and developed further for the fission and fusion of Matters and their relevant technologies. Through these new understandings and developments of reactors, new ways and opportunities for the production of energy in the world of nuclear physics has become possible.

For energy production in nuclear fission of today, the state-of-the-art technologies use the ***collision effect*** of neutrons and atoms to break up an atomic structure and release its energy. On the other hand, in the world of nuclear fusion, the reverse methods are in use. Scientists in nuclear and physics laboratories use as ***much force*** as possible to fuse plasmas, and harvest the residual released energies from this process.

Through our technology new and simple reactors are in the reach of the scientific world for the disintegration of an atom, or for the fusing of plasmas through plasma dilution technology. This new approach is less energy consuming, much simpler, more practical and the resulting energies produced are easy to harvest.

The same is seen in the world of aircraft and space industry where, jet engines and propulsion systems are in use to force and displace matters like air to create lift and motion.

With this new knowledge and approach to plasma dilution technology as one integrated system, much simpler and more effective methods based on the universal methods for creation of motion are made available to the aircraft and space industry to move crafts within atmospheric or outer space (Fig. 57 C). Magravs positioning principle of an electron in respect to its proton (Fig. 57 A) and Magravs positioning of the planet Earth in respect to Magravs system of its Sun (Fig. 57 B), these shows similarities between the principle of the use of the new Magravs positioning reactors and their universal parallel systems.

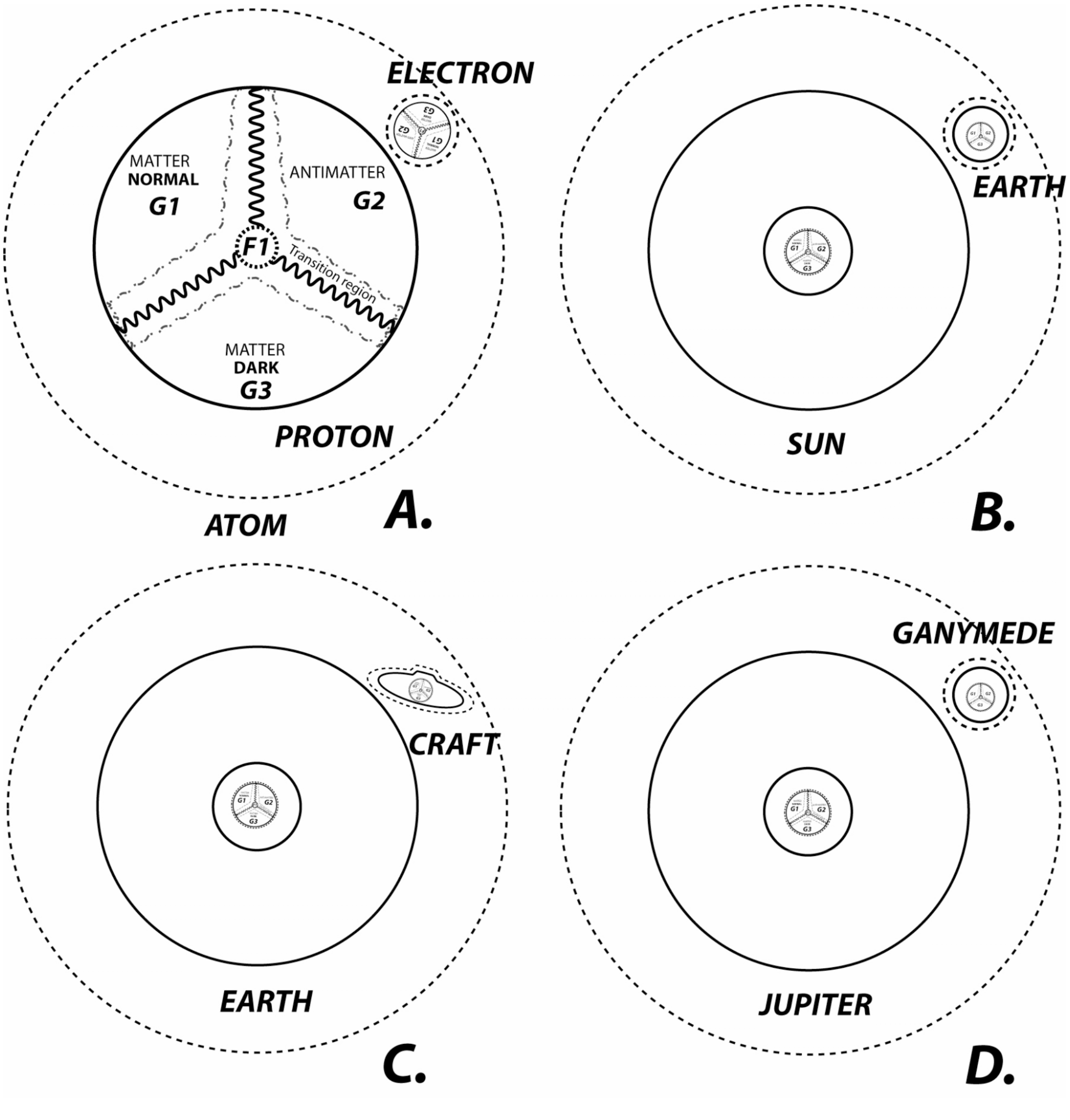
ELECTRON
MATTER
NORMAL
G1
ANTIMATTER
G2
F1
Transition region
MATTER
DARK
G3
PROTON
ATOM
A.
EARTH
SUN
B.
CRAFT
EARTH
C.
GANYMEDE
JUPITER
D.

Fig. 57: Similarities between four different Magravs positioning principles and systems for motion and position.

Note: Figure 57 D. shows that an independent plasmatic Magravs system can exist within another Magravs system, and have Magravs positioning in respect to each other, as the ***Ganymede****, a moon of the planet Jupiter, has been functioning for millions of years within Jupiter's Magravs. To cosmologists the case of the Ganymede is the only known condition of an inter-gravitational planetary system positioning, and its operation within the Jupiter's magnetosphere could never be explained with present scientific knowledge. Similarly, Grapos reactors can be used in crafts for motion and Magravs positioning within the magnetosphere of the planet Earth, as shown in figure 57 C using the same fundamental principle as the Ganymede.*

Through the fundamentals of this new understanding of the creation and control of plasmatic magnetic fields reactors (Grapos), **craft systems** *do not need to burn Matmags* to create **lift and motion, but where, the reactor uses the Magnetic fields strength of the Matter (the Matmags) to create gravitational positioning.**

In the **Magravs positioning Technology reactors**, by the simple creation of the acquired plasmatic Magravs levels of the desired point in space, within the reactor's systems, the system is forced by its' internally produced Magravs, the need *to reach a new plasmatic Magravs balance* position between the system and the planet Magravs forces', this causing the motion of the system in respect to the Earth **without burning any fuel.**

The Magravs positioning technology once used in a craft, unusually these crafts become weight independent. That is to say, the systems payload compared to the power of the gravitational positioning forces of these reactors are so insignificant, that the payload mass becomes irrelevant.

This is how small cores size of matters in comparison, in the centre of the planet Earth, can create such strong plasmatic magnetic fields, that their interactions can keep and cause continuous motion of the heavy loads of matters of the planet, at ease, for billions of years.

The important point about using Grapos in aircraft systems is that the plasmatic Magravs and Magnetosphere fields' catchments area of the system has to pass the physical boundary of the craft itself during motion, in-flight and stationary floating mode or protection mode.

During the operation of plasmatic Grapos, magnetospheres are created around the system interface between system and the planet. At the interface of the magnetosphere of the system, due to the friction between two plasmatic Magravs of the system and the planet, only at the point of the magnetospheric interface of the system, this leads to the creation of visible light (Chapter 7).

In respect to plasmatic gravitational field systems, once the fields are allowed to pass beyond the physical boundary of the craft, this gives the craft being in possession and the advantage of having a dynamic magnetically based magnetospheric protection environment around the system. This magnetic magnetospheric zone around these crafts operates and functions exactly and similar to magnetosphere possessed by the Earth, which, the Earth has generated around itself by the interaction of its own plasmatic gravitational and Magnetic fields with that of its star and the pmtics around its environment in space.

This production of plasmatic magnetospheric shielding is a *natural protection* system offered by all celestial objects in possession of dynamic plasmatic Magravs for the entrapped matters within their systems.

Thus, by the use of Grapos in crafts nothing less than that is natural in the universe and a normal phenomenon for protection of internal matters and structure of the planet are offered.

Using this magnetospheric protection capability of Grapos, crafts of future will travel at speeds beyond the capability of the present technology in the aircraft and space industry. These crafts will travel without their outer-surface ever getting heated-up, or ever being in a position to be hit for example by birds in Earths atmospheric conditions or in space by space debris. The reason for this is due to the fact that the outer surfaces of these crafts *never come to be in contact with other matters*, except its own internally created plasmatic Magravs.

The ***interface*** between the crafts' dynamic Magravs and planets plasmatic dynamic Magravs can be extended through the design and control of the Matters within the reactor cores of these systems, that their interface to be far enough away from the physical body of the craft, that there will be no contact or interface with other Matters and matters of physical body of the craft system. These matters outside the boundary of the system can be Dark Matter, air, liquid or others. These Magravs are needed for the protection of a system like this in space, as the systems cannot be hit or damaged by any cosmic dust or asteroid in the path of motion of the system.

The magnetosphere created around these systems, due to the dynamic characteristics of their nature, create plasmatic magnetic fields that will act and is a magnetic shield for the embedded craft within it. These dynamic magnetospheres around these crafts are naturally watertight systems.

If the plasmatic magnetic fields generated by the system, do not reach and pass the physical outer boundaries of the craft, these crafts can have the gravitational shearing gradient forces fields effects, enforced on it, half-way within its structure, rather than around its outer physical boundary; which partial structural cover of Magravs on the middle of the structure of the craft will end-up in the physical damage or in extreme cases the breaking-off of parts or the whole section of the craft at the point of interface between the system and the planet pmtics Magravs. This shearing-off zone is possible and can happen purely due to a difference in the two Magravs forces strength levels at the magnetospheric boundary of the reactor system in the middle of the structure of the craft.

At the same time the passengers of the future, using the Magravs positioning systems, will travel in gravitational field forces within the boundary structure of the craft in similar conditions as on the Earth. The passengers of these crafts can travel without the need for the present compression systems, in use, in the state-of-the-art aircraft industry. There will be no G-force changes inside these crafts during their flight due to the sudden changes in directional motion or at high-speed capabilities of these crafts. Using Grapos, in spacecrafts, this allows normal life and motion within the craft without the effect of weightlessness as is experienced by the space travels of today.

These crafts through their natural plasmatic magnetic fields interaction will always be rotating, as all celestial objects in possession of Magravs positioning field force do. This rotational effect can be facilitated through the design of the craft that the rotational motion can be transferred and be connected to the outer physical boundaries of these crafts, without affecting the working of the internal structure or passengers of these types of crafts.

This method of travel using plasmatic Magravs protection for motion for the future space systems is to be called the **M***agnetically* **O***riginated* **J***oint* **H***abitation* **A***nd* **N***utrition* (MOJHAN) system. The passengers of this **M***an* **O***riginated* **Z***one* **H***abitation* **A***nd* **N***utrition* to be known as "MOZHAN".

These new names unify the human race by the use of the name of the technology and the method of its travel, through the Men's collective effort to reach this point of scientific achievement over thousands of years, through their progressive evolution in science and technology. This takes away the national dependent names, like Cosmo- or Astro- and the rest from the unique and individual nations, for the collective effort and contribution by all of the inhabitants of the planet in different measures over the times to reach this point in Mans scientific evolution.

The use of Grapos will make national boundaries irrelevant except for tax and local laws. The Grapos will not need airports to land near too. These systems know no national or planetary boundaries and they have no need for fuel as such.

Thus, in the near future the nations will have to devise new ways of dealing with the Mozhans as they can land anywhere, without a need for a specific plot or landing strip. In reality however, these crafts will never even need to touch the ground.

Nevertheless, these systems can reach ground level, when their total reactor Magravs sizes are reduced to a safe planetary level, within a specific spherical zones cavity, allocated just out-side the boundary of the reactor systems but within the craft environment.

Pmtics reactors for production of energy

The creation of energy in the universe and utilisation of Grapos technology for production of energy in essence are based on the same principles.

In the universal order of production of energy like in stars, in these units, the principle of the production of current and energy is not on the base of electrons and their vibration movement. In fact, current and voltages on massive scales in these celestial objects are produce through their only ingredients, which are the plasmas and their creation of the pmtics of Magravs of their Matters within their inner natural cores.

In current state-of-the-art power production units like power stations generators, the rotational motion of magnets, and the magnetic fields forces within the confines of the copper windings, is used to create a continuous vibration of the electrons in the solid matters of the copper wire, to generate a flow of current.

We consider the flow of pmtics in materials like that of the ***wind flow of pmtics*** or what is commonly called the ***current*** *flowing through matters* like in copper wires. Where the plasmatic magnetic fields flow in matters like copper, the strength of the magnetic wind decides the rate of the vibration of the electrons of the atoms of the copper.

In understanding the new concept of the internal structure of an atom there are two fundamental points to consider.

First, the electron is the smaller and the weaker of the two components of an atom. Secondly, **the proton by order of mass is much heavier** and is made itself of greater amounts of the ***same*** plasmatic magnetic fields as **the electron**.

Thus in utilising the power of the plasma of the proton rather than the plasma of the electron, it becomes easier to produce the same levels of power with the use of a fraction of the material compared with the present power units.

This is to say; the new dilution plasma technology will bring into to play the ***use of magnetic characteristic of Matters of the plasma of the proton*** rather *than the vibration of the electron.*

To be able to separate the Matters of plasma of proton within the plasma dilution reactors, one needs to release enough dynamic plasmatic magnetic fields, in motion (energy), in the field strength level of the plasma of proton. These plasmatic magnetic fields can move the plasma of the matters of atoms with profound effects, rather than the electron of an atom.

This new capability and control of magnetic fields strength that can be released by the plasmatic reactors, brings into play totally new methods for energy production for any purpose.

The important point to note is that the production of energy through this method does not mean a change in the common use of electrical equipments. The beauty of this method is that the generators of the future will not be limited in their power production capabilities because of the material and size of the system. This means that even pmtics of plastics, nanolayers or any sort of matters can be used for current production and flow of current.

This changes the present power production capability, and gives the possibility of any generator's construction or any power levels at the point-of-demand, this being nano-amps or megawatts of power, through the operation of the same reactor, simultaneously and separately.

The other advantage is that the plasmatic magnetic fields strength of these reactors can be changed through the operation of the system. This capability of the plasma reactors gives a new insight into the power production capability of these new generators using the present equipments and tool.

New type of Generators

Through the control and power of the plasmatic magnetic fields strength **DY***namic* **P***lasmatic* **M***agnetic* **F***lux* **S***trength*, abbreviated to: **"DYPMFS"** that can be released by these new plasmatic dilution reactors, future electric power generators only need to change their Dypmfs, or the dimensions of the **VO***lume of the* **MA***gnetospheric* **F***ield* **S***trength*, abbreviated to "**VOMAFS**" of the reactor, to envelop the generators' winding using the coil winding method for power production.

Where, the Vomafs of the reactor can cover more of the same copper winding, to produce larger amounts of currents or the strength of Dypmfs of the reactor can be increased or decreased to change the levels of the current out-put of the same winding.

With these new types of plasma magnetic fields system there is no need for transformers, since the exact power input to the motor or engine can be produced by the plasmatic magnetic fields release at the point-of-demand.

For example: considering the present Power Station generating units (Fig. 58), it can be seen that, what has been used as fuel (coal, oil, gas, nuclear) to boil water, to generate steam, to turn the turbine and for the turbine to cause the rotation of the rotor, which is mounted with fixed flux strength magnets, for the motion of these magnetic fields cutting with the matter of the copper coil windings, to generate power, for this power to feed into a power grid.

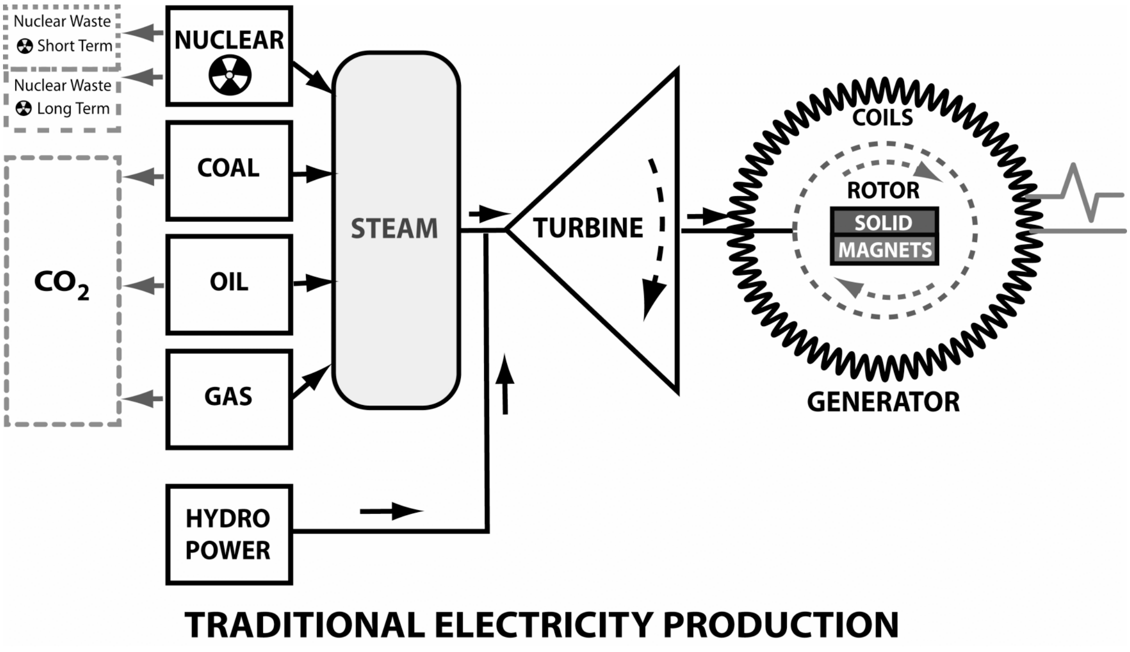

Fig. 58: Schema of actual electricity production

With the present power station generating units *one losses a vast amount of energy through each step of conversion* from solid or liquid or gas to steam to rotation, by all sorts of channels like different types of frictions, heat lost, losses through the grid. These systems usually need hundreds of kilometres of **transmission lines** to transfer the generated powers to the point-of-demand usually into cities. At the same time these types of generating systems using matter components of plasma, these always produce wastes like CO_2 or nuclear wastes.

In understanding the principle of the rotation of the Earth, through the interaction of two magnetic fields (Fig. 3) and the capability of the planet to create simultaneously the external dynamic Magnetic field (Fig. 1, similarly Fig. 61), with the new knowledge of the use of the plasma dilution Magravs positioning reactors with the ability to produce **a controllable, continuous, dynamic rotational flexible Magnetic field strength**, within the cores of such reactors, it is now easy to construct and produced new strong and powerful generators that do not need to burn any fuel (Fig. 59), to create rotating Magnetic fields, but, just by using Grapos nuclear reactor one can achieve the same and even more power than the present matter-based frictional systems. Even it becomes possible to produce varying frequencies of current output of the system from the same generator.

Grapos generators can produce power from kilowatts to megawatts in seconds, by just increasing the strength of the Magravs for the **Dypmfs** of the reactor or by increasing the **Vomafs** coverage of the Magravs. We have called this new generation of power generators the ***Keshe reactor generators*** (Fig. 60).

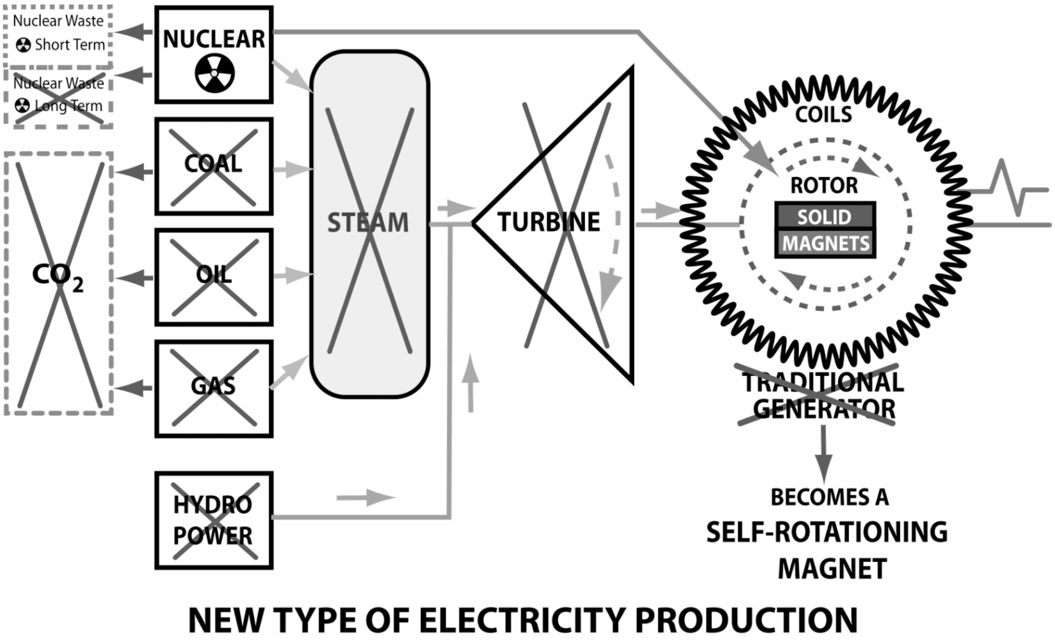
Nuclear Waste
Short Term
~~Nuclear Waste~~
~~Long Term~~
NUCLEAR
~~COAL~~
~~OIL~~
~~GAS~~
~~CO2~~
~~HYDRO POWER~~
~~STEAM~~
~~TURBINE~~
COILS
ROTOR
SOLID
MAGNETS
~~TRADITIONAL GENERATOR~~
BECOMES A
SELF-ROTATIONING
MAGNET
NEW TYPE OF ELECTRICITY PRODUCTION

Fig. 59: New approach to generate electricity

The use of plasma dilution Magravs positioning reactor brings to an end the need for burning of fuel (Fig. 59), to create rotational motion of the rotors' for production of electricity as it happens in the present generators.

Our new approach puts an end to the production of greenhouse gasses (like CO_2) through the burning of fuels (coal, oil, gas) and finally an end to the habitual burning of matters to generate motion and energy. This also bringing to an end the current production of dangerous nuclear waste by running the present nuclear power stations.

By purely using the effects of interaction of the Magravs of the Matters, within the cores of these reactors, motion and Magnetic fields, for production of any amount of electric power can be achieved in one all-integrated nuclear-based unit without creating any waste of any sorts.

In a way this is how all plasmas, atoms, planetary systems, stars and galaxies create their own motion and Magnetic fields (Fig. 60 and Fig. 61). Why not for the man to take advantage of this new knowledge of clean source of supply of Matters for new energy production technology through the real universal method of workings of magnetic fields of Matters?

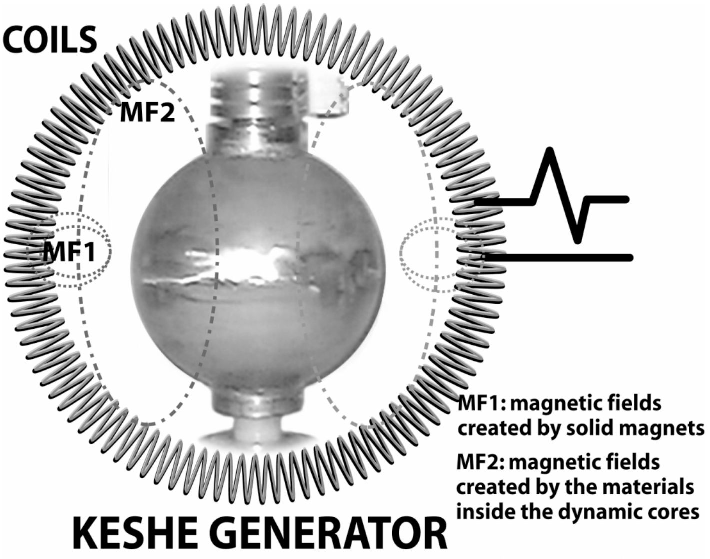
COILS
MF2
MF1
MF1: magnetic fields created by solid magnets
MF2: magnetic fields created by the materials inside the dynamic cores
KESHE GENERATOR

Fig. 60: The Keshe generator, which rotates for years in a coil structure.

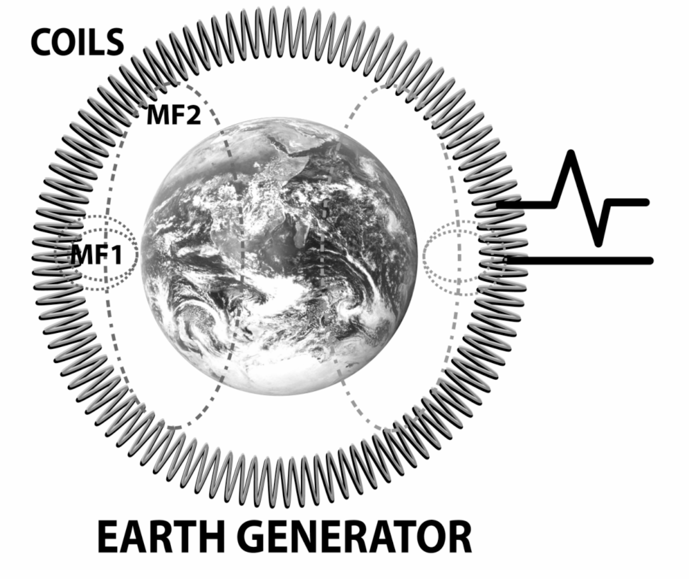
COILS
MF2
MF1
EARTH GENERATOR

Fig. 61: The virtual Earth generator, which rotates and generates Magnetic fields (MF1 and MF2) for millions years, and could generate electricity if there was a copper coil around it.

Similarly, using the plasmatic magnetic fields reactors can **eliminate** the need for generators and **transmission lines**, due to the fact that the pmtics needed for production of a given current and voltage level can be created at the point-of-contact of the system. Even the structure of the matters electrons or plasmas can be used to create current for their use in the same equipment. This means that one can produce current from the atoms and plasmas of a silicon or plastic cover of a microchip, to meet the components energy needs.

One possible use for a small reactor is to produce the right plasmatic vibration of electrons or the plasma of matter, within any given environment to generate light and power.

Prototype reactors have already been made and can be further refined that only need to generate plasmatic magnetic fields within their cores, that the interaction of the pmtics generated by these reactors with its surrounding matters, creates a *magnetosphere* at the point of the interface of the two pmtics of the system and atmosphere, that leads to the release of pmtics in the range of visible light of any colour and ray. This will be how future light producing units will be manufactured.

Similarly, in a given environment, in such as a craft, the operation of reactors can produce Magravs, that the interior of such crafts would always be lit due to the principle of the interaction of the surrounding Vomafs of the reactor and the dynamic plasmatic magnetic fields of the particle content of the air within the confines of these crafts.

The strength of these Dypmfs generated by the reactors can be set to produce any colour rays of any magnetic wavelength, be this red or orange light, and X-rays or gamma rays. We have seen this effect in laboratory tests and have measured the radiation fields.

The power generating units of the future, using the plasmatic magnetic dilution technology, will be a departure from the present power and light production technology.

Grapos, due to their ability can create rays at any frequency, can be used for example for disinfection of any give environment and materials, by the production of Ultra Violet lights for matter and Extreme Ultra Violet for Matter in space.

The same principle, for generating matching plasmatic magnetic fields for the production of proteins in these reactors have been tested and proven to be correct. These tests were carried out in 2008 and the production of proteins by the use of nitrogen from air through this technology was proven to be simple and achievable.

In separate tests conditions, the hydrogen atoms of water were used to transfer the right plasmatic magnetic fields to the right pmtics strength of plants and human cells for the pmtics of the cell to gain nourishment or recover to their original level of plasmatic magnetic fields’ strength.

This technology has been used in trial cases for helping volunteers with different vitamin deficiencies, or cell plasmatic deficiencies, to recover from the disorders produced by the deficiency, and people to live a normal life after years of suffering.

Alternatively, this technology can be used for production of new materials for coating or new processes of coating.

At the same time, through simple magnetic plasmatic reactors, the lattice structure of matter can be changed so that the nano-components of the matter can be realigned to change their lattice formation to another. The change of characteristics and properties of one element to another has been tested and confirmed to be correct by independent organisations. In these tests, the nano-matter of an element was captured and then its lattice formation, through the right plasmatic magnetic fields conditions, was changed to attain new properties from the same matter. This was carried out through several tests, at room temperature and pressure, where ***atomic carbon*** was initially released from a C-H bound matter. The carbon was then allowed to deposit itself on a layer of copper. This deposition was dependant on the presentation of the right plasmatic magnetic fields at different points on the same copper Matter. This copper surface was then tested and proven to have sections of nanolayer coating in the form of sp2, and on the same layers and same condition the lattice structure changes the same material to a diamond lattice structure, or what is known as sp3. Where, sp2 is a two-dimensional nanolayer, and sp3 is a three-dimensional diamond-lattice nanostructure.

The plasmatic magnetic fields' of reactors can be tuned to similar frequencies' as the plants pmtics, to generate certain vitamins and minerals. These single or multi-plasmatic magnetic fields producing reactor sources can and will replace the fertiliser industries of today's technologies in space for food production, once scientists grasp the method of their use.

In tests, seeds of herbs were grown by being feed using water treated in these reactors, the parallel seeds, which were grown normally with rainwater, died in early October. The herbs that were watered from reactor system were still green till March of the following year, because the molecules of the water were structured through the reactor system to act as fertilisers. Similar tests are in progress.

In this section, it has been shown and explained some of what has been tested and achieved through this new understanding. Scientists and users of this new technology will find their own ways to expand and will add their own new knowledge to our disclosures.

Seed of thought

Where, in the present time the majority of the nations in the third world due to the lack of funds to purchase fuel even in having power stations, or being able to afford to build generators at the cost of tens of million of dollars, they cannot afforded to run these generators to provide power for their nationals. Secondly, there is not enough production capacity to build new power stations and power grids. Therefore local alternatives can be in the range of windmills and solar cells, but these will not solve the incredible lack of electricity in next decades.

Now, through the use of **Keshe generators reactors**, which can cost as little as a new car, these governments can provide electricity and clean water for their nationals.

Where, these governments do not need to pay for fuel as these reactors run on hydrogen extracted from their environment. These reactors can be placed at the ***point-of-demand*** in a village or in the cities without the need for transmission lines or for any expertise to operate these reactors. Where through the production of electricity, purification systems which are part of these reactors integral operations will allow fresh clean water supply to every child, woman and man on this planet. This new energy source and clean source of water, given opportunities to third world nations to rise above and from poverty and reliance upon foreign aids and charities organisations. Where these nations can produce food and warmth for their nation as the rest of developing world without the backbreaking debt to other nations.

According to a ***United Nations report*** (Energy Challenge for Achieving the Millennium Development Goals 2006), "*Currently****, at least 1.6 billion people do not have access to electricity*** *for lighting, refrigeration, mechanical power, telecommunications and other beneficial uses. ... Moreover under today's policies and investment trends in energy infrastructure*, **1.5 billion people will still lack access to electricity in 2030**". (42)

Of course this is not acceptable. It is clear that humanity is not capable to deliver fundamental care to all of its members, even not within next twenty years!

Man is not complete and healthy if parts of it human structure suffers from paint of self-inflicting disability, this is the same for the human race as whole. This race is not complete until all its members have and can exists and have the privilege to live the same standard of the development as the rest.

"The future is bright, the future is plasmatic magnetic fields based, through the production and control of plasmatic dilution technology reactors to bring peace and comfort to the human race."

CHAPTER 26

Matters Experimental results and observations

Tests for the proof of all the concepts have been carried out over some years. The direct results and observations made in some of these tests have already been mentioned in some other parts of this book and now will be brought under one chapter collectively and will be discussed in general.

The reason for writing this book is to disclose the theoretical new first principles of our technology; because most of our test results are so groundbreaking that they cannot be explained by actual knowledge. Actual science is partly based on a number of mainstream accepted assumptions about fundamental interactions and particles and matters, where these assumptions have become almost "laws", and do not consider the true occurrences of real events in the universal order of creation of particles, plasmas, matters, energy, gravity and motion as they take place in the universe.

Where, the major processes in the universe are based on fusion and fission of Matters and plasmas, and the transformations and conversions of matters from one form to another. In this book we explain how such conversions and transformations can be reached in plasma reactors, and by this insight we were able to attain such amazing results. Where some people don't feel comfortable with them, or a priori reject them because these new findings and their applications counter their school of thought and their financial gains.

For example, one of the major obstacles in the world of nuclear fusion has been to overcome the Coulomb barrier for fusing two plasmas, and this problem has not been solved for the past sixty years by all scientists in this industry, even though billions of US Dollars and more has been spent by different nations in laboratories and fusion reactors testing to overcome ***the weakest of the weakest of magnetic fields interactions*** in the world of creation, which this is a magnetic barrier, also known as the Coulomb barrier, where this barrier is exactly the Magravs of the plasma, and as now we know how it is created, we have found the solution not to fight and force to cross this magnetic magnetosphere barrier, but the solution is how to create an environment matching the magnetic fields strength of this magnetosphere of the plasma for it to open-up and unveil its real constituent Matters. As the environment of the whole reactor becomes in magnetic fields strength equal to the magnetic fields strength environment of the plasma. Therefore, through this method, there are no barriers to overcome, and fusion of matters of plasmas or the use of the Magravs of the Matters of the plasma becomes a child's play.

For the first time in the world of energy and motion, we offer through dilution reactor technology, at low costs, to open the plasma and dictate the strength and the resistance of this Coulomb barrier to realize the dream of fusion.

Similarly, to achieve lift and motion where, the present space agencies are only able to deliver a limited payload into space, and the burden and the costs of such launches of crafts and personnel, cannot be met by one nation easily. Where, Magravs Grapos reactors can lift much larger payloads at low costs, without limitation on passengers and no weightlessness conditions in space.

Radiation

During tests in 2008, radiation detectors in the surrounding environment of a test reactor detected high levels of magnetic fields radiation. These high-energy magnetic fields have been measured more than 1.5 meters away from the plasma reactors. Where, there were ***no neutron sources*** in the laboratory or in the building. Through known physics or theories, these radiations should have not been in the environment.

These strong radiation fields were tested and looked for and were not present in the laboratory at any other times with other different testing configurations with the same reactors, using the same radiation measuring detectors.

Such high levels of magnetic fields radiations could have only been due to the release of the magnetic fields that had been entrapped in the Matters of the plasmas, which the system was set to produce. These releases of components of the plasma were achieved during the specific pre-set configurations of loadings of reactors. These strong magnetic fields were released by the operation of multi-core plasmatic dilution environment reactors and at no other time they were detected in the laboratory.

Most of the reactors, mainly built and tested for lift and weight reductions, are made of different simple parts, which some part have materials like plastic rings, and PVC, thus these systems do not and could not have been operating at high temperatures.

In other tests in 2008, and in repeats of the same tests in January and February of 2009, the same results have been achieved, all of which have been recorded on video.

In these tests with the use of a less than *one **gram** of mixture of matters* in the similar multi-core dilution magnetic fields systems, fundamental plasma separations were created through the same method as before. These tests were done using five different reactors, each having a different set of internal configurations.

In all test settings of the reactors, different loadings of materials and different dynamics for the reactors were used.

Weight reduction, motion and lift

In all cases, when the dilution of the plasma and the subsequent untangling of its Matters in the reactors were achieved, then the effects of the disassociations of Matters were observed through the effects they created internally in the reactor and externally through lift and motion, and jamming of radio-frequencies and so on.

In the early original reactor tests, full lift was achieved so fast that the effects of free motion were noticed a while after it was clearly apparent and were in progress, through the replay of the video recorded sessions of the sessions of tests. Through video replay of the recordings of tests, the motion of the system freely on the floor of the laboratory could clearly be seen prior to physical observation of the lift of the reactor system. These reactors have no protrusions, are not equipped with propellers, or portholes, which could cause the lift of the reactor by air repositioning means.

In one configuration and loading of the system, control of the system was lost, so the reactor had to be caught by hand in mid-air, that it could be brought under control before it was damaged.

In one configuration, two reactors with different external bodies and two different internal settings were used next to each other. These systems were kept about thirty centimetres apart from each other. These reactors were entirely different in design and had different settings and loadings. In the two-system loadings that were adjacent to each other, the systems' interacting fields pushed one reactor away from the stronger Magnetic fields of the two systems. With the same systems and different configurations of loading one system was attracted by and was pulled by the stronger gravitational fields strength system, where physical force was used to keep the two systems away from colliding with each other.

"These systems have no portholes, and no physical means of interaction with the outside environment and no aerodynamic systems to cause them to propel up or move side-ways through the air, and they have been no solid magnets or electro-magnets for repositioning or for motion, for them to move the total collective weight of 15 kg of the two systems. There are no external systems and tracts used to help causing the lift or motion of the system in the laboratory. Thus the motion is ***not due to*** **propulsion** ***or*** **aerodynamic** ***design and movement***". This is the conclusion of independent expert appointed as observer for the validation of the results of the tests.

During other tests systems weighting several kilograms, their weight were reduced in a controlled manner at increments of one hundred grams and two hundred grams per setting of a reactor and these tests were all videoed and recorded. For reduction of weight in these increments, the systems needed less than one thousand^{ths} of a gram of a new material combination as Matmags, even in some tests no new material was introduced and by just adjusting some internal parameters of the reactors reductions were achieved.

With the use of such a small amount of physical mass of matters used, creation of such lift and the reduction of system weight seven kilograms, has been said to be impossible without any external energy or equipment.

Through the understanding of the principles of the plasma dilution methods of disassembling the plasma components to utilise its sub-components, systems were designed to achieve these effects in simple ways. With the interaction of the disassociated Matters components of plasmas in different parts of the system, then the scene was set for creation of profound effects such as a *reduction in weight* with respect to the Magravs forces of the planet.

The interaction of the strong Antimatters' of the plasmas components, which were released in the different cores of the ***plasma dilution reactors*** and the interaction of the fundamental magnetic fields of Antimatter upon each other, was observed during different tests. The interaction of pmtics of Antimatter leads to the creation of the strong Magravs in the vicinity of, and within, the reactor cores.

Through the control of plasmas and by being able to separate the components of Antimatters and utilising their constituent magnetic fields in reactor cores, this led to the creation of Magravs forces that initially led to a reduction in the weight of the whole system. In following on with this process there was a detachment of the system from the ground as the system found a new Magravs positioning in respect to the Earth's Magravs force strength.

When looking at the effects and results achieved, there is no doubt about the powers of the interaction of the magnetic fields of Matters, which were diluted and their fields were allowed to interact in these reactors' cores. These effects were attained by allowing a number of the pmtics of the Antimatters of the plasmas *to integrate* ***in one core***, and allowing these fields of Antimatters to interact with the same and similar fields *integrated* through the same principles in ***other parts*** *of the reactor*. Where, the interaction of the pmtics of the components' of Antimatters in different parts of the system with each other, led to the generation of strong specific plasmatic Magravs. The reactor facilitates for these stronger Magnetic fields to interact and generate strong plasmatic Magravs in the reactor cores, with allowing these Magravs created in the reactor cores to interact with the Magravs forces of the planet, and due to the strength of the fields produced in the reactor, this causes' reduction or increase in the weight of the system in respect to the planet's Magravs.

The new Magravs created within the system, pushing against the Magravs of the planet at the boundary of the systems fields, causes the variations in the weight according to the combination and configuration of the Grapos loading. The produced Magravs forces *within the confines of the system* are independent of the external planetary gravitational fields. In numerous tests, it was observed and recorded that the changes in the *internal* gravitational field forces of the system, did not necessarily change the weight of the system in respect to the Magravs of the planet. The interacting internal pmtics forces clearly showed to be generated independently by increase and decrease through internal electrical measuring components set in the system for the detection of these types of changes.

It has become clear that it is the interaction of the Magravs of the planet and the system that have brought about the reduction or increase in the weight and lift or descend of the system in respect to the planet. In some tests, these increases or decreases in the weight of the system have been without any addition or withdrawal of physical matters from the system.

In continuing with the same processes of creation of varying Magravs in the system, weight reduction was managed and followed to such an extent that the total balance of the interaction of Magravs of the system and the planet, in respect to each other, eventually zero reading on the measuring scale system. The point was reached where there was total physical detachment of the system from the table or floor first, and then the upward motion of the system, away from the surface was achieved.

Some call this the anti-gravity principle but in fact, this interaction and new balance in Magravs forces in between the system and planet, is due to both gravitational and Magnetic positioning of the reactor system in respect to the planet, as both objects are in possession of ***active*** *dynamic plasmatic Magravs forces*.

In a specific reactor, set for weight reduction, internal gravitational field reduction and zero-gravitational field force were disturbed, where the human touch was applied causing the change in the magnetic interface between the fields of the system and planet. This gave a tingling feeling on the tip of fingers after repeated tests.

In numerous tests over years, where the equilibrium state of internal Magravs strength between cores were achieved, the whole system, including internal physical dynamic parts, came to halt, sometimes for up to thirty minutes or more. Then, the dynamic motion of the systems re-set by itself and the system restarted. This ***re-setting*** has been due to losses and reduction of one Magnetic and/or gravitational field strength in respect to another within the cores of the reactor.

A number of times, *external power sources* were used to try to restart the system. In some cases measured energy of up to three, four and eight times the normal operational energy was continuously applied to the internal systems to try to push-start the system, but to no avail.

This shows that the power generated by a countable number of Matters of molecules, was so powerful that additional systems built in the reactor cores could not overcome the kinds of powers produced by so few Matters magnetic fields interactions.

These tests have shown the creation of independent Magravs in separate cores of the reactor. They show the creation of independent plasmatic Magravs within the system boundary, and then the combination of the same Magravs prevailing around the outside or beyond physical boundary of the reactor as magnetospheric or cosmic radiations were produced, which these types of fields are prevalent as have been observed in space around stars and planets.

Indications are that these radiations created in these system, due to their characteristics, do not shown any side effects in the human tissue of the operator up to this moment, years after having been involved with these fields tests.

These fields around the cores are considered to be due to the interaction of plasmatic magnetic fields' of Matters of plasma and environments' Matter or matter, and are independently created in different parts of the cores of the system.

This technology opens up new opportunities for the industrial development and manufacturing of systems that have different gravitational conditions inside the system for living, and have different gravitational conditions compared to the outside and around the physical boundary of the craft. This allows for having a one-G gravitational field force for the normal habitation of Man inside spacecrafts, or in a dome outside and around the crafts for habitation. While the conditions outside the craft can be zero G to tens of G's. The passengers of crafts using Grapos can walk around the craft, or in and around the dome created by the extension of Magravs of the systems, on any planet surface, as if they were in Earth's gravitational field force environment.

No high temperature core environments or sudden surges of heat were recorded in any tests. The reactors were in some cases opened immediately after operation for new settings, in a normal lab environment. There was no physical damage ever noticed to the internal parts of the system. This includes melting and twisting or destruction of any parts due to the presence of Matters.

Even though we lost a full system by pure enthusiasm to catch, lift upwards, which the jumping on the systems after several times cracked the structure and the systems was lost. We have kept the reactor casing for further analyses of matter lattice changes, and another reactor was damaged when a Black hole condition was replicated.

On only one occasion, where a specific setting was used, a black spot was noted on one of the external sides of the reactor core wall. This is supposedly was due to an energy surge during the test. The effect of the black burn was not removed for further analysis.

Production of matters

In different tests, a new orange and gold coloured material was noticed on two occasions in a reactor, and samples were collected for further testing to show the material production capability of the system.

This method of the production of Matter can be used by manipulating and changing the plasma's and rearranging them for the production of oxygen, hydrogen and water from collections of initial fundamental particles found in space, for human deep-space travel and colonisation. Where, the components of plasma absorbed from the cosmos are loosened by producing the right pmtics strength in the reactor for production of the first two atoms of hydrogen. Using further plasmas from space, in the matching gravitational fields as of the atoms of oxygen in the same reactor, this element can be produced. Then through the same reactor's operation, this allows the combination of the two elements, of hydrogen and oxygen, which was produced from the space plasma, this allowing the ***production of drinking water***.

In the future tests, one can attempt to combine the gravitational effects of the systems for production of energy, material production and other capabilities of the technology all simultaneously in ***one reactor***. We have achieved this much but there is a lot more to learn.

These reactors are truly an integrated system, which can produce and attain several effects and properties, like production of Magravs, creation of matters and so on simultaneously.

Dark Matter technology

The system using the Dark Matter in travelling through the Magravs of the planet creates no magnetospheric conditions, friction, or pmtics force resistance, between its pmtics Magravs and the planet pmtics Magravs. Thus, zones around a craft can be created that there is no magnetospheric field between the craft's magnetic interface and the planetary system's. Hence, a craft using the Dark Matter ***cascading*** can travel within a stronger pmtics, like that of the Earth, *without detection* since the system can create no interface magnetosphere, as there would be no visible light to be seen with this method of motion.

Through this method of using the Dark Matter for transportation, high-speed motions can be attained for spacecraft in planetary systems, solar systems and galaxies.

Using the ***Dark Matter principle for transportation***, the environment between the systems and the planet is **saturated** with the dynamic plasmatic magnetic fields of the system and the planet. This zone appears to possess energies but they cannot be linked to any source. Even though the source of the dynamic pmtics, in motion around the system or so-called energies of the pmtics, is set in the centre of a strong plasmatic Magravs systems inside the crafts and centre of the planet. Such Dark energy fields give the appearance and confirm the existence of dynamic energies, which have no explicit source of origin. Where, the source of energy or the dynamic pmtics is the hidden gravitational source in the centre of the Matters reactors and the planet.

This new technology is a radical breakaway from the hold that physical matter have had on the destiny of Man on the Earth.

With this new understanding of the methods of how Matters are created in the universe, it is possible for Man to use the real Matter sources for energies and powers available to him in the universe for his future scientific evolution.

CHAPTER 27

Discussions and Conclusions

With this new understanding, the elementary particles have become to be the 'magnetic fields' and their interaction leading to the creation of Magravs, this leading to the creation of Matters, as the state of each Matter depending upon the strength of the magnetic fields which have led to its creation in respect to their environment fields strength, which the Matter appears as the Matter, the Dark Matter or the Antimatter, where the collective interaction of the Matters Magravs, leads to the creation of the Initial fundamental Plasma (the Neutron), where the environmental magnetic fields forces conditions, around the Plasma, dictates the physical appearance states of the Matter part of the plasma as matter, this being solid, liquid or gas.

It is obvious that the universe will never stop creating new Matters and matters and their effects, and their interactions, as the universe is a soup of dynamic and ever-changing conditions, created by the Magravs positioning of plasmas, dynamic Matters, matters and their components and effects.

Man can learn how to create the same conditions as the universal order, and to rearrange these fundamental particles for his use, in a much simpler way than he has chosen up to this point in his path of technological and scientific evolution by the use of matter(s).

In the present state-of-art technologies for the production of energy, scientists have chosen the path of force and *destruction of atoms and molecules* to overcome barriers. In the universal order of creation, one works within the magnetic fields forces to achieve the same and even better results.

This ethos of ***burning and destruction*** has been the fundamental focal point for Man's survival in his environment, due to what he has been conditioned to in his evolutional path on Earth. He has seen the power of fire, from fires in forests, and he has used this knowledge to keep himself warm and so he has learned to do the same using the same methods and materials. By perfecting this art, through the burning of wood and oil and so on, he has managed to create energies for cooking and warmth and running industries.

Then he saw the birds and understood the concept of motion in air and so he used the concept of fire to create propulsion and jet engines, still burning one form of fuel or another to achieve flight, still based on the principle of ***matters repositioning and conversion***.

He has seen death through disease, so he has produced other elements to destroy the germs that can cause and bring an end to his uncertain and fragile physical life.

If man would learn to work within the structure of **the universal order of creation of**

Matters and the method and principle of their use, he will learn that he does not need to burn or destroy anything to keep himself warm or feed himself, or even to overcome diseases.

He can very simply change the characteristics of the plasmatic magnetic fields of the elements that caused the misbalance in the first place, leading to his ailment, without swallowing a single tablet in his lifetime.

We have developed and tested such simple systems in the past years and have seen their amazing results.

For example people suffering from Fibromyalgia for thirty years or more, within 3 months of drinking water through these systems, have started living a normal life without any signs of their disease. Follow-up over 18 months has shown a total eradication of the ailment.

We have tested this technology on other forms of illnesses and viruses and the results are amazing. However, this is what is to be expected with the use of the true knowledge of the creation as has been disclosed in this and future books.

With this new disclosure, man in the future will learn to live and operate in the real universal order of creation of Matters and their existence in the universe for his life. He will never destroy any Matter or matter, but he will learn to work within their structure. He will learn to achieve more, with less use of the resources in his environment. This is an improvement on the past, whereby at the present by the use of destructive methods, he has brought himself to the point that the abuse of the matters is now endangering his future on his own home planet.

Man has to learn to work with the real elementary particles and elements and their functions in the universe, such as magnetic fields and their interactions, for him to be able to produce what he needs irrespective of where in space he might be or would want to be.

Maybe this knowledge and the proof of its pleasures will change the ingrained ethos of destruction for the survival for man. One could even hope for a change in his animal instinct of killing other people and other creatures of god to survive.

Additionally he can change his habits and the instinct to want more since through the understanding of this technology he can have whatever he desires from his materialistic world.

In this disclosure, some theoretical nature of the universe has been spoken about, but the real physical aspects can be created to achieve the same conditions as in the universe as we have shown through our tests.

Man will be able to carry on with his life, but at the same time will be able to live in a balanced environment.

The reactors we have developed, which in real terms are ***miniature universes***, that can provide man with all his needs, such as water, food and medicine for him to survive and enjoy the beauties of creation.

The conditions in these reactors are soft and gentle environments and the methods of their use for control and creation of mans' needs are based on working within the universal structure, and not destroying to achieve, as has been the principle of the past for the Man.

For example, when the principles of the creation of Magravs are applied to the lower orders of creation, like the interlocking of atoms to make molecules, there are explanations as to why certain types of Matters are attracted to the reactor, and why certain molecules are, or can be, produced in certain ways and combinations, in certain parts of the universe.

The same applies in the even lower orders of creation, that one can explain and produce certain magnetic fields and their interactions that can lead to the creation of present fundamental elements in the centre of the proton, plasma, an atom and finally the man himself.

The world of science has to understand the conditions by which the interactions of initial magnetic fields can lead to the creation of an initial state, for the creation of the Matter, matter, plasma and finally atom.

Then there is a need to understand and demonstrate as is done in this book the way Matters and matters are created in vast spans of the galaxies.

Scientists have studied over centuries the structure of matters and the atom, and their interactions, in their material and tangible *states of matter*. However, the structure and method by which the atom is created, maintains and guaranties it's existence has not been fundamentally fully understood, due to the lack of overall overview of workings of the universal order of Matters. Even the construction of protons with its sub-components (quarks, gluons), up to today, is based on assumptions and indications by the use of particle accelerators and plasma reactors, by *only looking at* ***matter*** *components* of the proton and some Antimatter parts. So the present scientific world looks for an answer in the construction of the proton on the ***matter-to-matter*** level.

By the present science, the existence of the Matter, the Antimatter and the Dark Matter are largely considered to be independent entities in different points in space, and have never been considered to be as ***one collective*** *and all being* ***integrated parts of one system*** making up the plasma, up to this disclosure.

Mass of the Matters and Mass of the plasma

In the new knowledge we consider the three different quarks of a proton, ***as the three different Matters*** (Matter, Antimatter and Dark Matter) ***of the plasma***.

Where each Matter is *created* through the interaction of at least two different magnetic fields or pmtics, where through the interaction of these two plasmatic magnetic fields of different strength, initial gravitational and Magnetic field for creation of different Matters of the fundamental plasma are set to start.

So that the interaction of *at least two pmtics of* ***each*** *Matter* creates it's own Magravs forces. What we call the interaction of the Magravs strength forces between and in respect to each other of these three different Matters of the proton.

Where, through the understanding of the method of creation of different Matters of the plasma, due to interaction of at least two magnetic fields and the creation of gravitational and Magnetic fields, this confirms that ***each Matter*** irrespective of its environment Magravs *possesses an independent* ***mass*** *of its own*. In the present science this is called the mass of the quark. In fact each Matter, Dark Matter, Antimatter and Matter, has its own individual mass in the plasma. As each Matter is created by the interaction of at least two different magnetic fields strength, the ***total mass of the plasma*** is the mass of the three Matters plus the total interaction of Magravs interaction of the overall plasmatic magnetic fields within the plasma. Consequently the *total mass of the plasma* is always considered to be ***larger*** than the *total mass of its three Matters'* components.

Due to the dynamism of the interaction of the two initial pmtics, leading to the progressive creation of the Magravs of each Matter, *each Matter* is always in a ***dynamic rotational state*** within the plasma. Where the **speeds'** of the dynamic rotation of the different Matters in the plasma are not the same and they are independent from each other, since their speed of rotation is set by the strength of their initial magnetic fields interactions. Where in the present science the observation of this natural phenomenon of rotation is called the ***spin of each quark***. One can compare this, in cosmological sense, as the ***independent*** *speed of rotation* of the Sun and Earth, in spite of that they are within the same solar system. Where the initial plasmatic magnetic fields strength, which leads to the creation of different Matter(s) in it's interaction with it's environment pmtics strength, leads to the creation of an individual magnetosphere of a specific field strength for each of the Matters. Where the intensity of each magnetosphere creates *different light intensity* in its environment.

Now we understand that the interaction between the pmtics of the magnetosphere of each Matter of the initial fundamental plasma leads to the release of different pmtics strength fragments in the range of visible light (Fig. 18).

Due to the interaction of the plasma of each of the three Matters with each other and the release of light or energy, these interactions in parts reduces their strength and the pmtics content of each Matter, where due to these reductions in Matters quantity and strength of pmtics, different colours are attained by these interactions for each Matter during the cycle of the life of each Matter.

It has become clear that all states of Matters are the same in their nature of their creation with only differences in their field strength. What does differentiate these Matters from one another is in principle the strength of their fields and their position(s) and interaction(s) with other pmtics in their environment and in respect to each other.

Thus, Matters are Antimatters and Dark Matters depending on the point-of-observation and the field strength of the environment of the appearance at a given point and position, but they are all made of the same entity at source, which is the magnetic field.

The front-cover image of this book has been chosen specifically to emphasise for the scientific world to reconsider their assumptions.

The Matter can change to, or appears as the Antimatter and the Dark Matter and vice-versa, if the right conditions and the right plasmatic magnetic fields forces are given or taken away from the pmtics of the Matter.

In this disclosure, we have explained in a simple way that magnetic fields are the *new* initial fundamental particles, and the **magnetic fields** are the new elementary particles ***instead*** of what has been assumed at present as *quarks*. So, the magnetic fields and their interactions are the **creators** of these quarks and so on, in the plasmas.

Then we have explained how the Matter, the Antimatter and the Dark Matter, and the relevant energies of the Matter, the Antimatter and the Dark Matter, are all decided, dictated and created at the inception of the creation of the first stages of the creation of the initial fundamental plasmas of these Matters.

In this disclosure, we have discussed the results and shown how the three states of the Matter, the Antimatter and the Dark Matter are created, but through ***real tests conditions***, we have confirmed the co-existence of these three Matters and their respective energies.

For example, in tests there have been the very strong magnetic wavelengths of cosmic gamma-like radiations levels, which have been detected ***for meters*** around the system, *where there has been* ***no physical source*** *of such radioactive materials ever being present*. Whereas, it is a known fact that alpha and beta rays cannot travel that far in room condition environment. These levels of radiations could only be created through the interaction and the creation of strong magnetic fields in the reactors cores, which in their interaction with the pmtics of matters in the room environment have led to the release of these gamma-like radiations. This is exactly by the same principle as the Magravs generated in the centre of the stars in their interaction with the plasmas of matters on their surface, generate lights and high-level cosmic radiations.

An **atom** is considered to be “a collection of different densities and strengths of magnetic fields interacting with each other, in different magnetic mixtures and levels, in, and under, the same physical rules of the existence as the rest of the Matters, matters and bodies in the universe”. The atom is nothing more than a collection of the lower order energy magnetic fields strength in motion in the universe, that always come together in the same specific pattern of dynamic pmtics and strength.

The question is, that, is it the collections of magnetism, which created the MATTERS’ of the plasma, or did the existence of the MATTERS of plasma create the magnetism?

At this point, the existence and understanding of the Dark Matter becomes important, since the human eye and the physical machines of today can only observe what is in possession of visible and detectable energy fields.

The **Dark Matter** is created by interaction of magnetic fields which create and are in possession of intense fields of gravity and magnetism, and at the same time, and it is void of visible light in respect to their given environment magnetic fields strength. On the other hand, the existence of the Dark Matter is position dependent and pmtics strength balance dependent, in respect to its environments pmtics' strength.

Through the operation of hundreds of static and dynamic tests we have very strong indications that the universe is indeed made in the normal conditions and of packages of dynamic pmtics.

From our observations, we can say with a large degree of certainty, that the dynamism of the whole universe is constantly maintained through the principle of the interaction and attraction of different pmtics, according to their strength and positioning in respect to their neighbouring rays, fields and plasmas. Where magnetic fields of different strengths are locked to each other by the principle of their ***Plasmatic Magnetic Energy*** (PME) and ***polarity***. These causing the first stage of the creation of the magnetic attraction or what is called the ***Magravs force*** for the creation of the first Matters and plasma and further on of the first atoms, molecules, matter, stars and galaxies.

Through the above disclosures, it is clear that these components of plasma themselves have no solid parts, but are merely *a collection of energy and fields, trapped or interlocked in different magnetic fields strength of the other parts*, according to their strength where, they can appear as the smaller components of these parts or near to visible as the physical state of matter.

These dynamic pmtics or energies on their own in the universe are not that influential, but as they *gather with other collections* of dynamic pmtics or energies of the same levels, they appear as part of Matter, the energy constituents of an electron or the Matter parts of matters, that they show and exert their influence.

When the pmtics binding principles are fully understood, the world of creation and the understandings of the origin and working of the universe will become much easier to work with.
Why, only a part of the pmtics levels is visible to Man is not a mystery, but the reality is that Man has the habit of only looking at things in physical terms. If Man looks for the real existence of the effects of the energy levels, he will open his eyes to a new horizon in the world of creation.

The question is if one can develop the ***pmtics*** as in the universe and manage to release part of these plasmatic magnetic fields from initial plasma as energy, then, one can manage to control the level of these pmtics and their interactions that are needed to create and replicate energy combinations that can lead to the creation of the Matter and then matters. This in time will be done and depending upon the openness of Man to accept the realities of his owns creation and his existence in the midst of others.

In developing reactors, which have been openly disclosed, and in understanding their modes of operation, which are discussed, these reactors will not only be used as future sources of energy for Mans energy needs, further, these reactors will become the incubator for the creation of the energy levels, which can lead to the creation of the pmtics, which will lead to the creation of Matter and matters, like oxygen, food, water and so on.

Through the use of the plasma dilution and gravitational reactors systems of the future, one can and will experience the Black Hole concept and the reversibility of the polarity of planets (12), as we have done in our lab tests and become aware of their pleasure and dangers.

In these plasma dilution technology reactors it is not only the fusion of Matters that is possible, but also the fusion of Antimatters and Dark Matters and their real application in the production of Antimatter and Dark Matters atoms and molecules that will become part of daily use. Where, these will be used for the production of energies and effects, which are above the levels of the Matter components strength.

The beauty of the application of these universal reactors will be the opportunity for the creation and manipulation of the much weaker and smaller energy levels that can lead to the creation of electrons and protons.

These weaker strength magnetic fields for the creation of Matters will be noticed and can be collected at the *outer boundary of the plasma*, but not on the edge of the plasma in the reactor. This is due to the fact that the edges of these reactors are dynamic and are violent areas in which temperature interfaces will not be so suitable, but can allow creating the conditions for weak energy levels to be maintained and to manifest themselves. These zones are good to create the conditions for the creation of electrons' plasma, where loose plasma conditions are needed for fine-tuning of the fields in these reactors. This is due to the fact that electrons, in their foundation, are made of low energy levels bindings and interacting with each other, largely in a dynamic volume as compared to the protons, and in possession of weaker binding energy than protons.

To create conditions for the production of the protons, there is a need for the same energy levels, but tighter and stronger magnetic fields plasma conditions are essential and the size of the plasma and the mixture of energies available in both conditions are important.

The techniques for the use of the ambient temperature reactors to perform fusion or the production of new and heavier atoms can be learnt through the development of initial fundamental plasma dilution technology, which is very much different from the mode of operation of the present fission or fusion reactor technologies.

In the present nuclear fusion industry, the most important point in the world of creation, the *presence of controllable gravitational field forces*, has been absent and totally ignored by scientists.

In **dilution plasma technology**, as in the universe, **gravitational field forces** within the systems are the ***cornerstones*** of the operation of the reactor.

This is a unique method of the creation of new Matter and the creation of energy, which has been explained in the operation of dilution plasma technology. This is exactly how Matters are created in the universe.

In the right conditions and mixture of initial fundamental particles, the use of plasma dilution technology will lead to the transformation of the *initial fundamental plasma* into protons' and electrons' to create the basic matter and simple atoms like ***hydrogen***. With the right method of application of the plasma dilution technology, hydrogen atoms can be used for the production of the heavier elements.

It is important to note that, in an atom, "The interaction between the two pmtics of neutrons and protons Magravs are in fact the source of the **double magnetic fields** of the atom and consequently the creation of the Magravs of the whole atom.

Even though **neutrons** are supposed to be ***balanced*** *pmtics entities*, the magnetic energy of the nucleus can be ***increased*** up to a limit *without the disintegration* of the inner gravitational forces of its constituent parts for its components Matters field strength to attain the plasmatic magnetic energy of a higher strength or new pmtics element.

In his progressive evolution, Man has learnt to use what has been available to him, like wood to create fire, steam to create power, the use of oil for engines to create motion, and in the recent past the breaking of the atom and joining of plasma in nuclear reactors for energy.

Through the understanding of the creation of the initial fundamental plasma, the energies of not only the Matter parts of the plasma are used, but this technology allows the utilisation of all Matters of the plasma, that is the Matter, the Antimatter and the Dark Matter and their energies that these possess and can produce, that come into play and can be used.

In the other words, we welcome the Man to ***the real world of creation***.

CHAPTER 28

Insight into the Future

Using the new acquired knowledge from above chapters, one can look into the future and say that the struggles of the past will bring beautiful fruits of creation for the future of the man.

From understanding of the operation and relation between magnetic fields within any structure, this being an atom, molecules, and even a star, different types of life in all corners of the universe can exist in all forms, and through other matters then the nitrogen based protein chain of the human race, which other lives through their different pmtics can operate through the same principles as the human protein chain. These creatures through the balance of their pmtics criterion do and can exist in the spans of universe. In fact, their protein chains with different matters than nitrogen could be more efficient in its use of passive pmtics than the humans' protein chain in using pmtics from the soup of the universe.

These Beings might have different colour of liquid distribution medium than Mans' red blood, but not necessarily this mean that they are any different from the Man in essence.

For example, if the liquid of life for these creatures of god have the potassium as the base element instead of nitrogen or mixture of the potassium and the nitrogen, then this liquid can function as good as, and even better than nitrogen-based protein of the human blood for converting and the use of Matters and matters in the universal soup of supplies. Even these Beings' protein-based cell can be more efficient for the conversion and the use of the passive pmtics of the Matters of universe. This efficiency can mean more and different comprehension, intelligence, and brain structure, etc.

Thus difference in these creatures and the Man will, and could be only the colour of their medium liquid system in their bodies.

The Potassium, in combination with pmtics of matters like the hydrogen and the oxygen mixture, in vacuum condition of systems in the Earth atmosphere, creates a silver greenish pmtics magnetospheric interface colour. Which, to mans' protein mixture, in the light absorption spectrum, these creatures with potassium-base proteins can be different in colour. Thus the liquid of life of these creatures in its interaction with Earth's atmosphere pmtics will create blood of different colour than the human red blood. Even in their external appearance they might be, or having to be reflecting the colour of their blood (9).

In reality as different planets have acquired different matters due to their Matters Magravs strength as their base materials, at their inception in their galaxies, rather than nitrogen or potassium as the base for what is called their protein for cell production to sustain life in their medium, in mans' journeys into deep space to these planets and zones, he will come across different intelligence, colour, sizes, transparency and shapes creatures.

Man has to understand that the level of intelligence, colours of skin or blood and shapes of these beings in the universe, can and is, intriguing as is in his home base with his red blood of the Earth to them.

What is important is that these creatures, with their pmtics balance protein chain could have a different viruses tolerance passive magnetic fields levels than to the Man in the Earth atmosphere pmtics condition too.

From this point on in the journey of the Man in the universe, the prejudices of colour of skin, and the nationhood will have no meaning. From this point on the colour of the blood is only the means of indication of the origin of point of life reference and nothing more and nothing less.

In the short-term for the future one can envisage:

The implications and applications of the transition of Matters will be the key to the survival of Man in the hostile environments of the universe. If this technology is understood fully, Man will be able to conquer the control of most of the forces within the universe and use them to his advantage. The use of the *transition states of Matters* are such a powerful tools for science for the future, that if their applications are harvested in full, most of diseases of the present and future can be eradicated. Through the appropriate use of this knowledge, Man can use the pmtics strength to free himself from most ailments, by producing the right pmtics strength equal to his protein level configuration, to ***reset** the cells in his body* to their right and original pmtics strength of operation without swallowing a single tablet.

For example, Man can produce ***enough food*** from the initial plasmas of the universe, without the need for soil, by simply converting the initial plasma to the atoms and molecules of the proteins and vitamins that he requires, at the point-of-demand, anywhere in the universe. As the food, itself is made of and is from the conversion of different dynamic pmtics strength. Where, the planets and animals do the conversion for man, for them by absorbing the pmtics strength of the Sun, and converting these different pmtics strength to vitamins and proteins for mans consumption for his survival. Where plasma dilution reactors can do the ***direct conversion*** of what animals and plants do for production of pmtics strength in levels that can be used by humans, and have the same effect and gives the same pmtics amount and strength needed by the different cells in the human body.

At the same time by the use of plasma dilution reactors, there will be no need to carry all of Man's physical needs with him into space, like oxygen, water, food or matters for his colonisation of planets, and space. Man will be able to convert *Matters-to-matters* through the fusion technology using plasma dilution reactors in space as he travels, and produce what he needs at any given point in space (Fig. 56).

Man can produce ***any** material* from the initial plasmas absorbed from the environment of space, he can produce any Matter or matters at the point-of-demand, this being an atom of hydrogen, oxygen, water, protein molecules, leafs' of gold or sheets of steel. The crafts of the future will not need to carry any raw basic materials for the production of parts into space. Man can produce materials for the construction of permanent habitation zones at any point in space and any planetary environment, through the use of dilution plasma and Grapos reactors.

Systems can be developed, which even in possession of the Dark Matter gravitational field forces, the same system can produce balanced pmtics strength in respect to its environment, for the system to appear as the source of Dark energy.

Systems can be developed, which have the ability to produce internal Magravs forces that can be tolerated by the human body. However, at the same time, the same system is being able to generate a balanced external pmtics strength in respect to its surrounding environment, these pmtics created by the system can be matching to the environment so that they do not have to interact with other systems pmtics forces (like those of the planetary systems' magnetic fields forces), so the pmtics around this region of the craft can have the appearance of systems that can produce Dark Matters and Dark energy.

However in one instance, by creating the balanced pmtics in respect to its environment, the systems that have been physically visible in one position in the given space, without a change of position, suddenly become dark or translucent in respect to their environment. In these systems and condition of operation the interaction between the balanced pmtics strength of the system and the fields of the planetary system can be brought to be matching without the system ever moving, this giving the impression that the system has moved to another position.

New systems can be developed that can produce ***instantly*** as much *energy-on-demand*, at temperature and pressure independent conditions, anywhere in the universe.

In possession of this new knowledge and Technology: ***Man can free himself from the shackles of the Earths gravitational field forces.***

Through the understanding of the ***methods of creation and control of pmtics***, Man can produce its own controlled *protection Magravs* magnetospheric conditions within and around the crafts, with the use of the plasma dilution Magravs positioning reactors, these magnetospheric field forces strength will be similar to the Earth Magnetic field strength (Fig. 62) or similar to the magnetosphere of an electron around its proton (Fig. 63). Where, the Matmags of transport for the crafts of the future can be gathered from the plasmatic magnetic environment of the universe.

The Magravs positioning systems (Grapos) can be used as much in a plasma, on Earth, in Space as they can be used in deep liquid environments, and galaxies, irrespective of the pressures and temperature around the craft.

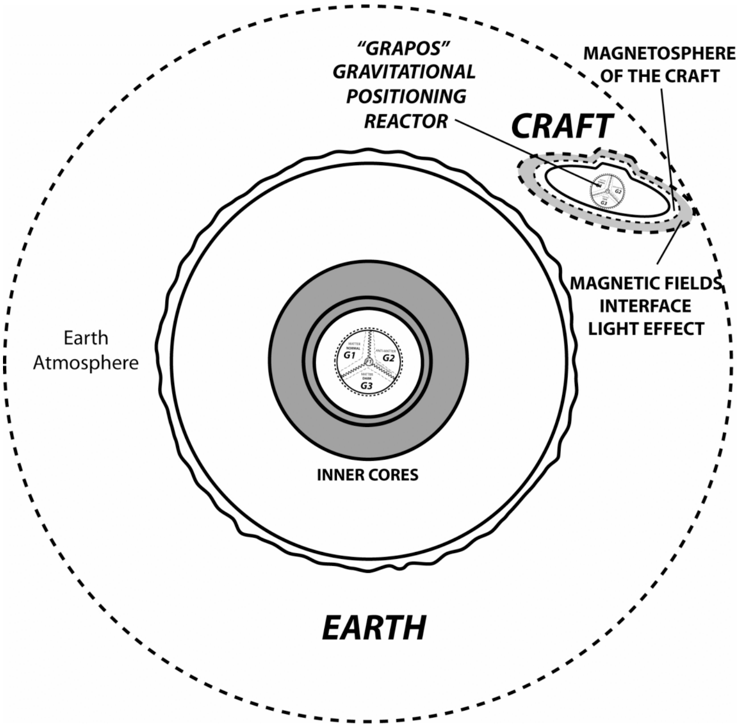
"GRAPOS"
GRAVITATIONAL
POSITIONING
REACTOR
MAGNETOSPHERE
OF THE CRAFT
CRAFT
MAGNETIC FIELDS
INTERFACE
LIGHT EFFECT
Earth
Atmosphere
G1
G2
G3
INNER CORES
EARTH

Fig. 62: The plasma dilution Magravs positioning reactors used in a craft due to the interaction of their plasmatic magnetic fields can lead to the creation of shining silver light in the atmosphere of the Earth.

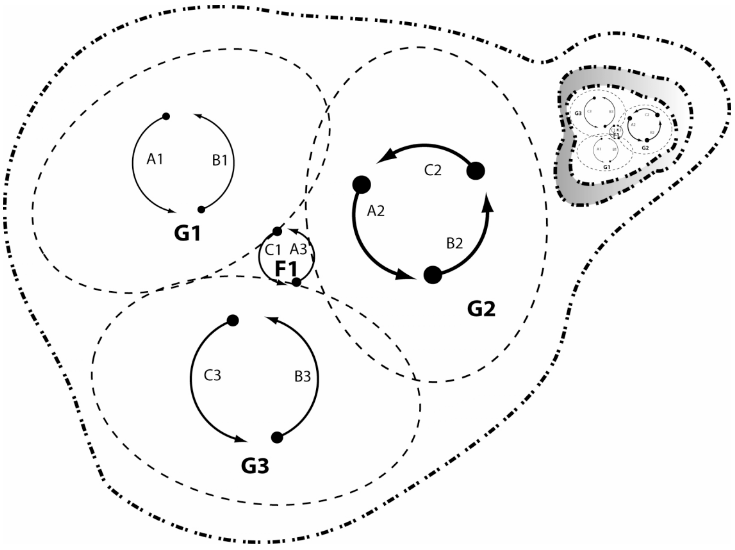
A1
B1
G1
C2
A2
B2
G2
C1
A3
F1
C3
B3
G3

Fig. 63: Initial fusion process for the production of matters and creation of bright magnetosphere of the electron as it approaches' and is amalgamated into the plasma of the proton of the atom.

Our hope, is that this technology cannot and will not be allowed to be utilised for destruction, killing and damage to any environment or against any of God's created

Matters and creatures, whether in possession of intelligence or not.

God help Man with this knowledge so that Man will find peace within himself and others.

As Mans weakness, his greed and his hunger for power and control, soon he will come to be thought the lesson that there is no forgiveness for the ones' whom misuse this knowledge and the technology for harming others.

By understanding in totality this new knowledge and what it can bring, maybe now Man will understand the meaning of that there are balances in the overall construction of his initial fundamental materials and that their lives always have to be within their limitations, of these balances.

Mans' fundamental construction of his initial state magnetic field structure, is always the same in force and energy and specific in its initial components, as the initial fundamental components of Matters, or matters of the universe ***cannot take more than what they need*** to be constructed of the pmtics of the universe and balance enough to share their inner constituents pmtics to pass on what is needed by others' configurations for them to exist, even if this giving can mean and can bring about their own demise.

Thus every creation, in its essence, has the attributes of its creator. Therefore, with this new knowledge and the reality of its existence, maybe Man can strive to understand the truth about himself and purpose of his creation in the universe.

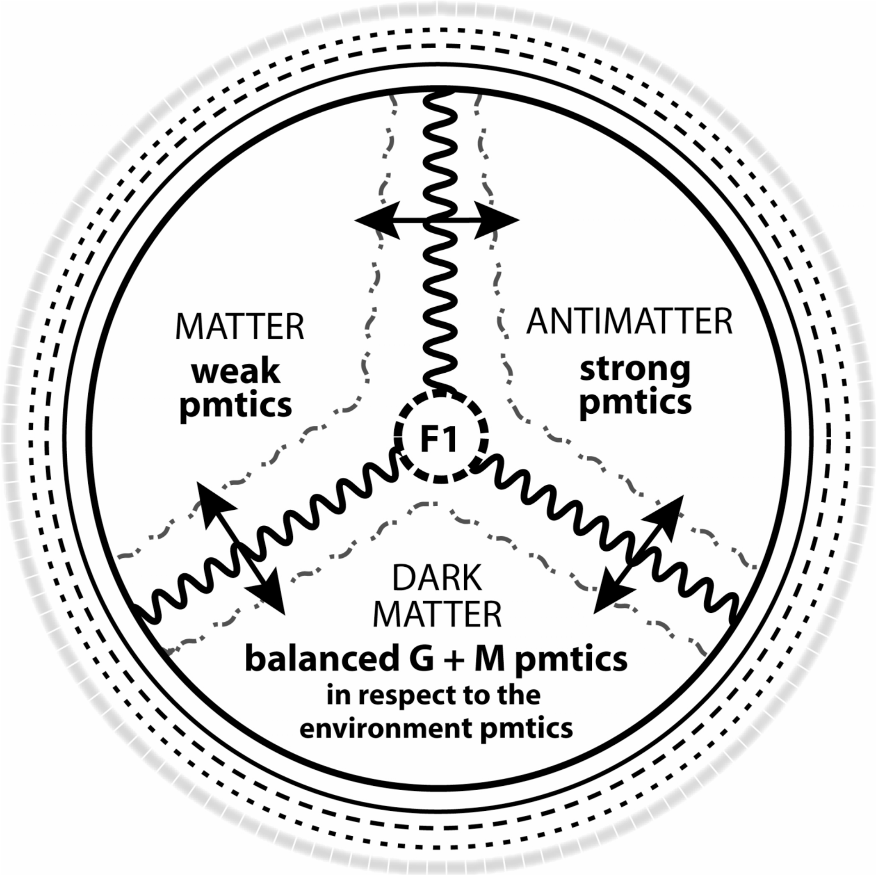
MATTER
weak
pmtics
ANTIMATTER
strong
pmtics
F1
DARK
MATTER
balanced G + M pmtics
in respect to the
environment pmtics

Fig. 64: The fundamental insight.

In general, I can say,

"God has been the creator of All,

and Man the converter of some".

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11: **The Airborne reactor** (Release date 25.3.2004)

12: The seed of the Earth (Release date 25.3.2004)

13: **The creation of Black Hole** (Release date 25.3.2004)

14: **Magnetosphere** (Release date 9.6.2004)

15: Correction to the Einstein equation of Relativity (Release date 15.6.2004)

16: Introduction to the new system (Release date 2.7.2004)

17: The rings of Saturn (Release date 2.7.2004)

18: The creation of gravity (Release date 11.7.2004)

19: Death of a star (Release date 26.7.2004)

20: Fusion (Release date 28.7.2004)

21: Life of a Cell (Release date 28.11.2004)

22:The Atom (Release date 19.12.2004)

23: Magnetism (Release date 8.1.2005)

24: The creation of the magneto-gravitational force (Release date 5.2.2005)

25: The core of the Earth (Release date 20.4.2005)

26: The electron-atomic welding (Release date 3.5.2005)

27: Shutdown and safety of the reactor core (Release date 6.6.2005)

28: Reactor Start-up (Release date 9.6.2005)

29: The energy balance of the reactor (Release date 29.6.2005)

30: Nuclear decay or half-life (Release date 20.7.2005)

31: The decontamination system (Release date 10.10.2005)

32: The difference in atomic and molecular structure under gravitational force and pressurised conditions. (Release date 15.8.2005)

33: The Defence and shielding system (Release date 4.9.2005)

34: Method of creation of an atom or nano Matter (Release date 11.10.2005)

35: The relationship between Gravity and Mass (Release date 21.1.2006)

36: The Dark Matter The Fifth state of Matter (Release date 21.1.2006)

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Published and unpublished works by M. T. Keshe

There are a number of unfinished articles that are to be converted to full disclosures when completed, like Antimatter method of energy releases, Nano space technology, relation between the creator and the created, space communication system, deep space defence technology, dynamic magnetic fields force regions (wormholes) construction and control, creation of magnetic fields, and so on.

Some of these works have already been published through different channels and some have not yet been released.

In the following section some of the works done by the same author are mentioned, with a brief disclosure of their contents.

Some of these papers can be purchased and obtained through direct request and access through specific links.

A number of papers with * and ** marks are not for public release due to their sensitivity of information and only available to relevant commercial and governmental organisations for peaceful applications of the technology.

The universal order of creation

(5.7.2006)

In this disclosure the main construction principles and the method of the link and control in the universal order of the existence of living cells, like the function and operational method of any matter based on so called proteins chains, as for example in human cell are explained in detail.

REF 9

The author considers this paper as one of his most important and fundamental works to be published and to be added to the sets of disclosures written by him.

Cosmic Rays

(Release date 24.3.2004)

This paper explains the source and the origin of cosmic rays and the way these work within our cosmos, their function and their benefits.

REF 10

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*The Airborne reactor

(Release date 25.3.2004)

This paper covers the total design of airborne reactors for space technology. This covers all aspects of operation, design and control of such reactors.

REF 11

The seed of the Earth

(Release date 25.3.2004)

Some extracts from this paper:
The theory that the heat of the core of the Earth is due to inertia of the material pilled on top of each other is completely dismissed through this new disclosure.
The author M T Keshe believes that this centre core is made of hydrogen, other gases and a mixture of liquid and solid Matters, which were in the vicinity of the centre of the core of the Earth at the time of its inception in the solar system.
Through this new understanding of the new inner cores of the planet, this brings to play the fact that the old inner core of the Earth that is already assumed to be made of a solid piece itself becomes a sealed container for the new inner core.
The author through design of a parallel system has set to confirm the validity of this assumption, that the centre of the Earth possesses a *semi- fusion atomic reactor* and not a fission reactor as has been assumed by other scientists.
This theory of hydrogen in the centre of the planet is in line with the physical reality of the creation and the present situation in the physical construction of the solar system.
By the laws of physics all the gases in the solar system should have been in the giant gas planets at the outer layers of the solar system, like in Jupiter and Saturn.
The physical reality in the solar system, is that the lightest of all these gasses, the Hydrogen, has taken its place right in the centre of the solar system in its star, the Sun.
It has to be recognised that the centre of all planets in possession of gravity due to the centre cores heating, are always in possession of two Magnetic Field Forces in their inner sanctum (M. T. Keshe " The creation of gravity").
In the case of the Earth up to now and with the present knowledge there has been acceptance of only one inner core and one magnetic force.
As it is explained in the paper titled "the creation of gravity", there is an inner core in the inner core. This inner core, due to it physical content, motion and position in the centre of the Earth, creates and maintains its own magnetic field force, independent of the magnetic force which has been known to be created by the interaction of the inner core and the outer core of the planet.
These two magnetic fields interact to create the planet's own double magnetic fields in its centre. The interaction of these two magnetic fields forces upon each other leads to the new concept of the "DOUBLE MAGNETIC FIELD EFFECT", where the interaction between these two field forces in the centre of the planet leads to the creation of the gravity and the magnetic forces of the planet (Paper: The creation of gravity).
This new second core is the seed core of the planet, the mother seed of the planet

positioned in this new inner core.

REF 12

The creation of Black Hole

(Release date 25.3.2004)

In this paper it is explained that the Black Hole is created out of a natural sequence of events, and that the existence of the Black Hole in a galaxy is a normal event. Further it is explained that a Black hole is created in similar ways to the Dark Spots on the surface of the Sun. In this paper for the first time, it is explained how the Black Hole is physically created and what function it plays in its galaxy.

REF 13

Magnetosphere

(Release date 9.6.2004)

"The shape and the strength of the magnetosphere of a planet is exactly what a fingerprint is to a man. It is unique to each planet, star and galaxy. It is a tell tale of all its attributes, and it reveals the hidden mysteries of the internal materials' structure".

REF 14

Correction to the Einstein equation of Relativity

(Release date 15.6.2004)

In this paper the physical reality of the Einstein equation is considered, and efforts are made to bring this equation to the real conditions. Even Einstein considers this equation applicable for very small mass, and not in real three-dimensional multi-Magnetic and gravitational conditions, which are external and have nothing to do with the theoretical object's mass and speed, but have effect on the speed and the mass of the object under consideration.

REF 15

***Introduction to the new system**

(Release date 2.7.2004)

In this paper it is written "It is essential to understand that, with the application of this system of motion, one cannot bring into play the solid, liquid and gas fuel method to create motion, as is used today. What is offered in this system is in simple words a fully integrated plasmatic magnetic energy system. Which creates within and around the core environmental conditions as known to man in the universe, like creation of gravity and magnetic field protection the same as the magnetospheric protection condition of planets and motion through interaction of magnetic fields as planets and stars do in their given environment".

REF 16

The rings of Saturn

(Release date 2.7.2004)

One of the oldest puzzles in the world of astronomy has been the existence of the rings around Saturn. How did these rings come to exist the way they are now? How did they come to appear and behave the way they do? These questions and much more about the creation of these rings are all answered in this paper.

REF 17

The creation of gravity

(Release date 11.7.2004)

In this paper it is explained that "the source and the creator of the magnetic forces and the gravitational forces are due to the interaction between the same materials in the same region of the planet."

Further it is explained how the gravitational field force can be created, replicated and controlled within a nuclear reactor. Further it is explained how this property can be used for the motion of a system within a planetary or solar system.

Now by understanding the principal of the creation of gravity, in this paper it is further explained that "the gravity in reality is the effect of the interaction of **two plasmatic magnetic energy fields** of any two object in respect to each other."

REF 18

Death of a star

(Release date 26.7.2004)

In this paper the death of stars is explained, "The death of a star and the creation of a supernova is in reality the same as the half-life cycle energy step-down of an atom. With the difference that this show is in a larger scale, and more spectacular, in all aspects of its dimensions".

REF 19

Fusion

(Release date 28.7.2004)

In this paper the physical and scientific problems with present fusion technology is considered. Where it is written, "nuclear Scientists, with the fusion reactors of today, are trying to create fusion in the opposite way to the known laws of physics and their parallels in the universe”. Further in this paper it is written, "if the present path for creation of fusion is followed, with the present scientific knowledge of physical materials for construction of such system, then following the present path of development to create energy from current fusion systems *will be a distant dream*".

REF 20

Life of a Cell

(Release date 28.11.2004)

Extracts from this paper; "The reality of the transportation and transmutation of a cell is not far from the reality of the life of an atom or a star. Where the life cycle of the cells are slightly more complicated, as they contain other Matters like acids, which have their own magnetic characteristic of their on chemical structure. For this reason the control and replication of the energy of the cell is very much complex, but very simple to achieve".

REF 21

The Atom

(Release date 19.12.2004)

The content of this paper explains how and where atoms in the universe are originated from and how the construction of atoms in a cold plasmatic nuclear reactor can be replicated.

REF 22

Magnetism

(Release date 8.1.2005)

In this paper it is written, "The question is where did the Magnetism come from? This is the Secret of creation. The world is made of one thing and only one thing and that is Magnetism. Its combination and interaction with its own different strength fields makes it appear as different Matter. The rest of creations are the outcome of these interactions of different strength of this thing called magnetism and the forces it creates. Magnetism is the origin of existence and the real singularity in its full meaning".

REF 23

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*The creation of the magneto-gravitational force

(Release date 5.2.2005)

The creation of magneto-gravitational field force is and will be fundamentally independent of temperature and pressure, proviso to the fact that as long as a homogenous free floating PMF within a Matter is created.

REF 24

The core of the Earth

(Release date 20.4.2005)

One of the original assumptions in developing the new Magravs system some thirty years ago by M.T. Keshe was on the basis that the centre of the Earth possesses addition cores, which create the necessary gravitational conditions of the planet. After some twenty years of space technology and through Earthquake seismological data's this assumption has been shown to be correct and after over twenty years, it has been scientifically proven that the inner core of the Earth has an inner core of 600 km. Professor Guy Master in 2002 ref 24 nuclear planet. The centre of this core is assumed to have an inner core of 8 Km, this he thought to be made of the plutonium or other nuclear materials

But the developer of this new plasma reactor technology has proven through physical dynamic cores that these cores possess a mixture of hydrogen plasmas and the process of the heating of the centre of the Earth are due to a semi-fusion chain of events.

REF 25

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*The electron-atomic welding

(Release date 3.5.2005)

Some extracts from this paper:
"The electron atomic welding or atomic welding principle is the phenomenon that atoms of the same material, through a common shared electron, become a magnetically balanced molecule of the same Matter, with the difference that the shared electron will create a balanced PMF in the molecule".

REF 26

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*Shutdown and safety of the reactor core

(Release date 6.6.2005)

In this paper the safety parameters in the operation of the gravitational and energy reactors are simply explained to avoid the loss of plasma and gravitational field forces created within its cores.

REF 27

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*Reactor Start-up

(Release date 9.6.2005)

In this paper the systematic start-up of the dynamic reactors for the creation of gravitational field forces and the production of energy are set out. The start up of these systems are totally different then the prior arts known in the nuclear industry.

REF 28

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*The energy balance of the reactor

(Release date 29.6.2005)

Some extracts from this paper:

The energy balance of these types of reactors is not as simple as might look in the first instance. The energy creation is simple. But the heat leakage and dissipation through the deliberate inherent material design are and can be zero. That is to say the system not only can hold on the heat it creates. At the same time due to the close circuit feed operation will become self-sufficient but long lasting.

In planets, the loss of heat through their surface creates the variation in the central core condition over several billions of years. In this reactor as losses can be literally negligible, the system can operate at low energy loss temperatures. Even the boundary of the body could be made through the right combination of material in the chambers, so that the body of the reactor will be colder then its surrounding boundary. So the system will not only lose energy to its surrounding, but it can be made to absorb heat in the negative temperature gradient from its surrounding, so that there are no losses.

REF 29

Nuclear decay or half-life

(Release date 20.7.2005)

Extracts from the paper:

"The nuclear decay always has the same or near the same time duration. This is due to the fact that the all neutrons and protons, from their inception, carry a predetermined level of plasmatic magnetic energy. This energy is continually used for the motion and vibration of different elements of the nucleus in respect to each other and the surrounding Matters of the atom. As the space and dimensions of a nucleus of an atom always obeys the same principal of the magnetic separation and magnetic attraction. Protons or neutrons can and will need to use or consume the same energy before they become weak enough that the splitting or decay becomes a clockwork job. The nuclear decay is the natural levelling done of a nucleus' energy, due to the energy consumption and heat dissipation for the motion of the elements of the nucleus for its remaining plasmatic magnetic fields energy necessarily needed for them to hold one together".

REF 30

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*The decontamination system

(Release date 10.10.2005)

"What this means is that, for example in trying to recycle the CO_2, by the use of the right Matter in one of the cores of the reactor, the system will then use the O_2 to produce H_2O, in the form of pure water, and C in the form of atomic or molecular carbon, or even by feeding this back through certain operational compressions and gravitational interactions within a small core, to create industrial diamond or graphite, for different industries."

The use of the reactor for this purpose has been proven to be correct and Raman spectroscopy has proven the concept and physical reality of the separation of Matter in atomic level after separation in the same system from a composite Matter.

(See the graphene on the technology web site)

REF 31

The difference in atomic and molecular structure under gravitational force and pressurised conditions.

(Release date 15.8.2005)

In this paper is written that "the atomic and molecular structure of Matter is totally aligned and positioned in a fundamentally different configuration where it has come together due to gravitational forces, than when Matter has been brought together by the means of pressure. This has a fundamental effect on the behaviour of the structure and properties of the Matter which is created in either way". Where this is explained and utilised to develop a new method in creating graphene and Sp3 atoms and walls in a simple core made of a coca- cola bottle.

REF 32

**The Defence and shielding system

(Release date 4.9.2005)

Some extract from this paper:

The design of the side open system for lunch of high saturation magnetic plasma package is one of the most effective technologies for defence of the reactor and the

craft, which is in possession of such a system.
It is essential for any space technology in the open environment of the universe, if the craft is to keep a straight line of motion and to be able to protect itself from any solids or Matters in its path in the cosmos.
This technology can destroy any object by the principal of plasmatic magnetic energy saturation of the incoming object at a molecular level, that object will disintegrate in the form of magnetic vapour and not atomic level destruction, before Matter can damage the craft as debris, and before the craft ever becomes in touch or near these space Matters.
This technology can also be used to protect Earth from the collision risk of NEO's (Near Earth Objects), like comets and asteroids.

REF 33

Method of creation of an atom or nano Matter

(Release date 11.10.2005)

The manufacture of an atom of any density, this being of the simplest form of nucleus or a full atom of hydrogen, or even heavier elements in the universe, all follow the same principal.
Atoms are created in the soup of the cosmos from collections of very weak plasmatic magnetic fields, which for their existence cluster and share their energies with the magnetic fields that are not far from their own plasmatic magnetic field strength.

REF 34

The relationship between Gravity and Mass

(Release date 21.1.2006)

Extracts from text of this paper:
"A planet like Earth possesses a combination of both gravity and inertia. Where the gravity comes from the interaction of plasmatic magnetic energy fields from the processes within its core, and the inertia comes purely from the collection molecules PMF of Matters which has built the physical body of the planet.
Any object, being an electron, atom, molecule or even a human body, is a collection of plasmatic magnetic energy fields of different strengths and their interactions between each other, which in total decides the total or collective magnetic field possessed by that object where this is the mass of the object.
Where the mass of an object is a collective package of plasmatic magnetic energy field tightness of a given object and will not change as long as the object is intact as one entity in its overall atomic or molecular or collective molecular appearance.
Which plasmatic magnetic energy of a physical body (so called the mass of the body) in interaction with molecular or atomic magnetic field (this being gravitational or inertia) of another object will determine the weight of the two object in respect to each other in each others environment".

REF 35

The Dark Matter

The Fifth state of Matter

(Release date 21.1.2006)

Extracts from text of this paper:
The existence of Dark Matter is not questionable,
Proving its existence, and its effect on the energy balance of the universe, in all Matters as small as in the heart of an electron or in a solar system needs to be created, replicated and its effect measured.
The theory of Dark Matter does not and needs not to be considered as complicated, if one understands in real terms the plasmatic magnetic energy of the Matter in the visible and invisible dimensions of the universal work.
The Dark Matter has two distinctive characteristics, which makes it totally apart from the visible Matter.
The Dark Matter possess mass but not visible light, where its existence can only be determined by the weight of the its hidden mass, which could be substantial due to its internal gravitational field.

REF 36

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*The inter-atomic fusion

(Release date 3. 5. 2006)

Extract from this paper:
"The fusion of two or more atoms has been the pre-occupation of nuclear physicists for past years.
Conditions to achieve fusion of two hydrogen plasmas in the TOKAMAK reactors have taken years to teach scientists a lot about the behaviour of plasma and their fusing.
The reality about the fusion in someway has to be reconsidered as, if the scientific world is trying to amalgamate the contents of two plasmas to release energy. There must be a simpler way to achieve releases of similar energies.

The fundamental principal of the inter-atomic fusion is a much simpler way to achieve fusion. If this principal is applied to the atomic condition of fusion, then fusion will be attained in a simple but in a much more physically realistic environment.

The explanation for the inter- atomic fusion is very simple and direct.
In the fusion of two plasma of proton of hydrogen atom, the physicists try to fuse two large plasmas, and by doing so, they try to release a large amount of energy. Where in this process enormous amount of magnetic field forces and currents are needed to bring two plasma in close proximity, so that the energy barriers in between them can be overcome for them to amalgamate or fuse.

In the inter-atomic fusion the overcoming of energy barriers does not exist, as in this method of fusion, the electron of the atom which is circulating the nucleus of the atom and is of the same origin will be encouraged to return into and fuse with the nucleus of its atom".

Where this is a more practical way to create and release manageable energies and there is no need for elaborate systems where even if the energy release will be small compared to dreamed up fusion systems of today.

With inter-atomic fusion method at least small and practical systems can be developed to handle low temperatures of the fusion process.

REF 37

The conductivity of the Matter in the vacuum of the interplanetary mediums

(Release date 21.1.2006)

Some extracts form this short paper "Therefore plasmatic magnetic energy field of elements within the interplanetary medium will cover the space given to them in their environment. Where due to their motion and their electric charges even in eV levels, they become perfect conductor, and in turn, due to their motion on their environment, they become plasmatic electromagnetic generators.

REF 38

The production of Graphene

(Release date 25.7.2006)

Repeated experiments and tests in simple static reactors, and tests in more complex dynamic reactors, prove that atomic separation and recombination of Matter like carbon and hydrogen can be reached at room temperature and at atmospheric conditions.
We have now indications - through static and dynamic tests in our reactors - that the universe was made in normal condition, which was originally nothing but packages of plasmatic magnetic fields of different strength, which were themselves nothing but areas of plasma or collections of loose magnetic fields energies. Where magnetic fields of different strength in locking to each other, by the principle of their **plasmatic magnetic energy (PME),** have caused in the first stage the creation of fundamental particles, secondly atoms, then molecules and then Matter, clouds and asteroids and then stars and galaxy's".

The big bang theory conditions have no room in the reality of the creation of the universe.

REF 39

INTERNET LINKS

Web site: www.keshefoundation.com

Large images of this book on the web site:
http://www.keshefoundation.com/book/images/

Links on the web site to YouTube movies: http://www.keshefoundation.com/youtube/

Forum: http://www.keshefoundation.com/forum/

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In this book nuclear engineer Mehran Keshe discloses in a very logical way that the initial fundamental building blocks of the universe find their origin in a cosmic magnetic soup that contains an uncountable number of magnetic fields of different strengths. In this soup magnetic fields of similar or equal strength can meet, interact and entangle into a larger dynamic spherical pack. The interaction between different dynamic packs, leads to the creation of Gravitational and Magnetic field effects and properties in their given environments. Due to the differences in their magnetic field strength each spherical pack will possess a different strength, which each magnetic field strength will be in the order of magnitude of the three basic types of Matters (Dark Matter, Antimatter and Matter).

As these three Matters being made of magnetic fields, they also interact, inter-balance and can interlock with each other, these interactions of three Matters results in a larger integrated dynamic system, called the Initial Fundamental Plasma, or the Neutron. By the natural decay of this plasma, the proton and the electron come to be generated and to co-exist, where plasma of each proton and each electron still contains the Trinity of the three Matters of the original plasma.

The discovery of these new first principles in physics will open for mankind a large number of benefits, since the various type of interactions of the three basic Matters and their field forces in their environment leads to the creation and control of matters (solid, liquid and gas).

In this book, new first principles and criterions for the creation of Gravitational and Magnetic field forces of the planet Earth are explained. Similarly it is explained how safe, simple, nuclear reactors, which have been build to replicate the structure of the planet inner cores, confirm the Keshe theory of creation of gravitational fields of the planet, as these reactors can produce fields which can cause reduction in weight, cause motion and lift of the reactor system, and produce an independent magnetosphere around such reactors. The interaction of the dynamic plasmatic magnetic fields of the magnetosphere around these reactors with the planetary magnetic fields creates light around the reactor. These light-effects confirm the Keshe's theory of creation of light through the interactions of plasmatic magnetic fields. These systems will open new ways of Space Travel.

By this knowledge it became possible to design, develop and test new low cost reactors that can dilute plasma and achieve fusion of plasmas in a simple and affordable way. So it now becomes possible to create vast amount of energies (like electricity and heat) and motion without the need of burning any fuel and without creating any waste. These reactors can create at any point-of-demand matters like air, water, food, medicine, and new materials, also at nano-level.

This new revolutionary technology can help to solve a number of global problems, like of the climate change, since Keshe reactors can be build to attract greenhouse gasses like CO2, or the global issue of water shortage and water pollution since it becomes now possible to create water and to attract hazardous elements out of the polluted and contaminated waters.

The Keshe Foundation

The Keshe Foundation is an independent non-profit and a non-religious organization founded by nuclear engineer M.T. Keshe, aiming to bring new scientific knowledge and new technologies to mankind, and to bring new solutions for the major global problems, like famine, water shortage, shortage of electrical power supply, climate change, illnesses, by the use of new types of plasma reactors, and to give Man the real freedom to travel in Space.

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The Structure of the Light

MATTER
PRINCIPAL MATTER
TRANSITION MATTER
MATTER
PRINCIPAL MATTER
TRANSITION MATTER

Kf
Editions

Nuclear Engineer M.T. KESHE

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(The Netherlands)

The Structure
Of The
Light

ITNOTGOG

Reflection

The light has plasmatic structure the same as the plasma of the proton and electron and it is made of mixture of magnetic fields strength with difference that the light has dynamic composite magnetic field strength spiral helixial cylindrical composite matter mafs plasma structure rather than the dynamic composite mafs spherical structure of the matters the like of the plasma of the neutrons.

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Forwords

All knowledge gathered and learned in every fields of science by man in his cycle of scientific evolution from his beginning of time and up to this point, these are like of the speck of dust of the universal wisdom in comparison to what man will enjoy from the knowledge which is to be revealed in this disclosure.

This shall not be all that the man has to know about his creation and the creator but through this new knowledge man will become close to realise how much more he needs to discovered and learn more about the created bigger universe, and our hope is that we have managed to bring man to his ultimate point of maturity about his world and the world of other creatures of universe through what is to be disclosed in this book.

In these new series of disclosures including this we will open the world of science into the realisation of the real working of the universe and how man can advance his intelligence and that this new and up to now unknown science can clear the way for bringing peace to the Man’s own wondering life and other intelligent beings in the universe.

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Introduction

With the present knowledge in the plasma technology and the new understanding of the internal structure of the plasma, the light is and can be considered to be a cylindrical version of the spherical plasma like of the proton and the plasma of the light is in possession of all three magnetic fields of the matters of the plasma (1).

The ray of light is in possession of Magravs and hence its own gravity, mass and Magnetosphere, and due to its dynamism this plasma of the light possesses momentum and hence can carry and transfer this momentum as energy to other light rays, tangible and non-tangible entities.

As the plasma of the light is moving from one dynamic magnetic field strength spherical in shape plasma to another and as each matter's mafs of the plasma of the light interacts with its surrounding environment's plasmatic magnetic fields in any matter environment, then the appropriate matter mafs components of the light and its ever present environment come to interact with the same and different matters and matter mafs in strength of its environment, this leads to less losses of the plasmatic magnetic field (pmf) contents of the mafs of the matters of the ray of light and hence allowing the light to travel in any environment at the speed of its given environment plasmatic magnetic fields strength with less friction and maximum speed in that given pmf strength. Then in matter mafs and matter magnetic fields strength environment, this property allowing the ray of light to have a speed of light in matter environment strength as is observed by man, and where in antimatter environment the antimatter light travels at antimatter magnetic field strength environment, which the speed of antimatter light is far higher than the speed of light in the man's matter plasmatic magnetic field strength environment.

Thus the speed of the light in the matter environment is not the ultimate speed of matters in the universe, but the speed of light is dictated and controlled by the environmental magnetic field strength which the light operates in.

It is possible to attain faster speeds than the speed of light in a matter magnetic field strength environment by using the magnetic fields properties of the antimatter plasmatic fields.

Once understanding this criterion and concept then at this stage one will face the magnetic strength barriers to overcome as one does in the matter environment with sound barrier.

Therefore: One has to understand the truth about the real construction of the light and its movement in each plasmatic magnetic field strength environment for the man to be able to travel the spans of the universe with pleasures of being able to observe and learn all the truth about the creation in all pmf strengths which operate in the universe.

The re-naming of matters and conditions

(Advice: Skip this section unless you need to refresh or reading for the first time or read it after you have read the chapter 1, 2 and 3 as this section can be confusing and distracting you from the main body of the book).

(Point of reference: The following section is and to be added to all disclosures for the ease of understanding as most of these have been disclosed in the book (1), and it is added here for the ones who have not read the book and are not familiar with terminologies in the works of the author).

In this literature, when using the term "mafs" for example in form of the antimatter mafs this means and refers to the magnetic fields (mafs) which this entity is made of and it is considered to be as a plasma of magnetic fields, and where the term "antimatter" is used on its own this meaning the physical tangible or detectable entity of the same. This usage of mafs similarly applies to physical matter and Dark matter too.

Further, the difference with Antimatter and matter is only in their plasmatic magnetic fields (pmf) strength and compactness of their fields. Thus, what is the magnetic fields (mafs) of antimatter they become magnetic fields of the matter as antimatter magnetic fields unwinds, loosens up, weaken in their field strength through their interaction with other magnetic fields and matters and become matter mafs and in plasmatic magnetic field strength of matter environment the matter mafs becomes tangible and become matter.

Therefore the antimatters are a more compact strength magnetic fields entities of the same of the magnetic fields of the matter, and due to their tightness of their fields, these magnetic fields of these mafs of matters they create stronger gravitational and Magnetic fields and hence they have stronger Magravs and hence upon their unwinding, they release magnetic fields and pmf which are faster, higher in strength and hence they look as to be strange strong and fascinating matters.

This means that antimatter entity of for example ten centimetres in diameter once unwinds in structure it becomes a matter of several thousands of meters in diameter entity in matter magnetic field strength environment.

Inevitably one should call the term antimatter the start matter and therefore antimatters should be renamed the Principal matter. Therefore there is nothing anti about these matters mafs and matters at their pmf strength as has been assumed in the world of science.

The Principle mafs matter itself has different degrees of strength by itself and not all magnetic fields of the Principal matters have the same magnetic field strength. Where, the principal mafs plasmatic magnetic fields strength has a spectrum of field's strength too.

As the magnetic fields of the principal mafs unwinds, it releases and loosen in its environment these magnetic fields (mafs) of the principal matters disperses into their environment, then they lose their strength through contact or interaction and friction with mafs' of matter and matters, and hence these principal mafs matters pmfs go for through magnetic fields strength of the Dark mafs matter strength first before through further reduction in strength, the dynamic pmf of mafs of the dark matter in motion reaches the pmf strength of the matter mafs level and hence becomes visible in matter pmf strength environment and becomes matter.

Now that the essence of existence of dark energy or dark matter can be explained in its realistic manner, and that is what has been called dark matter is in fact this is a magnetic field in transit from the principal mafs matter and matter strength to matter mafs strength and matter.

Then as energy has been defined as “magnetic fields in motion” then the dark energy in fact is transition mafs matters in motion, or what is called the transition energy.
Then the dark energy can be called the Transition energy instead of the Dark energy, as the pmf in motion as this magnetic fields from the mafs strength of the principal matter in motion to reach to mafs strength of the matter level, this is only a Transition pmf condition, and transition mafs matter phase only.

Where, the interaction of mafs of transition matters with other of the same leads to and creates the Transition gravitational and Magnetic fields of their own or create what is called the Transition Magravs and in some cases this condition leads to creation the transition matter (dark matter) and consequently sometime interaction of mafs of transition energy leads to appearance and become transition matter (dark matter) in the cosmos.

Therefore, the magnetic fields strength which makes the **dark matter** is to be renamed as the mafs of the transition mafs matter and the dark matter as tangible matter becomes the transition matter, the dark energy to be renamed to transition energy.

The plasma of the principal mafs matters exists everywhere in the universe. This being in the centre of the universes, galaxies, stars, planets, plasma of proton and even in the centre of the plasma of the electron and in the lower order pmf strength environments which have been undetected up to now by man.

In reality in the centre of what is called a black hole in the universe, there exist and is the home of the principal mafs matters and principal matter. Therefore the *black holes should be called* ***the principal stars*** in the centre of galaxies, stars, plasma of protons and other entities like these.

The choice of the term star for principal centres of matters is correct as these principal matter concentration centres are like a star in the centre for the matter world like solar system, and the Principal stars are the place for the mafs of the Principal matters and the principal matters which their fields radiate outward into their surrounding as it does with the stars. Thus from this point on in this disclosure we call the black holes the Principal stars in the universe now that we understand the real source of their mafs of this matter(s) and its principal matters.

It can be understood now that where the intensity and the strength of stars and planets come partially from the existence of the principal mafs pmf strength which has been released by the Principal stars in the galaxies. This is to say that the seed of the pmf of the galaxies and matters needed for the creation of stars in principle are from pmf of the mafs of the Principal matter. Where, *the interaction of the pmf of these mafs’ of the Principal matters* leads to *creation of initial strong Magnetic and gravitational fields* needed for the creation and attraction of mafs of matters of plasmas of matters, the mafs of the transition matter and transition matters of the same region of the galaxies, plasma of stars, plasma of the proton and other entities of the same structure in the universe.
At the same time when using Magnetic with capital “M” this means the like of the Magnetic field of the earth, which itself is the plasmatic environment created by the interaction of at least two magnetic rays and indicates the outward flow of the magnetic fields from a plasmatic environment the like of the earth.

Similarly, when using magnetic field with small “m” this simply means the magnetic fields as in what we observe at the end of a solid magnet as magnetic fields of the object without its interaction with other fields.

Chapter 1

The light

The initial assumption which has been made by Einstein that the light is energy and travels with the ultimate speed of acceleration in the world is nothing but short of the lack of the understanding of the scientist about the real truth about the real different composition of dynamic Magnetic fields strength which the light is made of.

It is really unthinkable that the light in matter environment can be considered as energy as has been done by Einstein, as he has even proven that the light tends to bend when it passes near large objects like stars.

This bending of the light should have indicated to Einstein that, when energy tends to bend in and around any objects like a star, this by itself indicates that the light is and possesses both a Magnetic and gravitational entity structure. He should have understood that only Magnetic fields or the gravitational fields, which both are magnetic fields based, that these two entities can only attract or interact with other magnetic fields based Magravs entities and then in finding their position in respect to each other, this causing the positioning and not bending of the light in respect to the star and hence light bypasses such large objects by manoeuvring around them and gets or give the appearance of bending near the object as it position's itself in respect to large objects Magravs.

Hence light is not energy but a physical plasma entity like the plasma of a proton or an electron. Therefore, the interaction and Magravs positioning of two physical dynamic entities, which leads to observation of what is called the bending or lensing of the light near large objects the like of the star.

Whereas this was not so and light was an energy, and as has been explained before energy is when plasmatic fields (pmf) are in motion, then light would have been absorbed by the Magravs of most stars into their magnetic fields based atmosphere on the way of them passing through cosmos and as has been observed the light would have been absorbed by the other entities in the cosmos, and the light ray would not find its position in respect to star and bend around stars and large dynamic entities in the universe and the light ray would have never been able to cross the universe that one can now see the emitted light of stars from far corners of the universe.

Therefore as light tends to react and bend near objects like stars this by itself indicates important points that the light is a composite magnetic field based entity and if one can attract and interact with any composite magnetically based entity, then the entity has to have both Magnetic and Gravitational field forces.

When two or more plasmatic spherical magnetic fields Magravs interact then this can lead to release and creation of cylindrical Magravs of the light, which ***this transitional Magravs entity*** possesses both **mass and gravity**. Therefore, as the plasma of the light possesses gravity and Magnetic fields, hence this entity due to its structure possesses its **own mass** and its **own magnetospheric environment** too.
Where, this magnetosphere which is created by the interaction of the two the Magnetic fields and gravitational fields of the light in its interaction with other pmf of Magravs of a given environment, this leads to and creates the visible light in matter mafs and matter environment when the outer matter content of the light is in matter environment.

Hence the interaction of the plasma of the light and its environment's magnetosphere leads to release of pmf in the human protein Magravs strength, which manifestation itself as the visible light.

That is to say as the magnetosphere of the light interacts with the magnetosphere of its given environment, due to friction of the two fields*, residual magnetic fields leftover* are created, which they are manifested as visible light or other wavelength of magnetic fields according to the human eyes protein cells plasmatic magnetic fields strength levels in earth environment Magnetic fields condition and in comparable environments.

Chapter 2

The structure of the light

As an entity in possession of Magnetic and gravitational fields moves from one spherical plasmatic magnetic fields environment (for example the plasma of the proton) to another plasma, the plasma Magravs motion in between these two spherically dynamic plasmatic entities (transition plasma magnetic fields (pmf) stretches' to and takes the shape of elongated cylindrical Magravs entity rather than a spherical shape.

It can be considered that the tangible or detectable pmf are of dynamic spherical in shape entities and they possess the pmf Magravs of their own and as the pmf moves from one dynamic spherical entity to another dynamic spherical pmfs Magravs environment then the plasmatic magnetic field Magravs in transit between the two spherical Magravs due to interaction and its composite Magravs configuration and the Magravs composite of its environment becomes elongated pmf in shape from the Magravs of the spherical plasma and takes and become narrow and elongated and hence spiral cylindrical in shape.

It has been explained in detail that the plasma of dynamic spherical entities like plasma of the protons' is made of three main components of mafs of the matters, the mafs of the principal matter and the mafs of the transition matter and mafs of the matter (1).
Therefore the elongated plasma of the same must contain the same mafs and matters but in a different structural positioning configuration.

Hence the dynamic cylindrical shape plasma of the mafs of the matters in transit from one plasma to another will have the same quantity mafs of all matters of the dynamic spherical plasma and therefore the plasma in transit possesses and it is made of the same mafs of the principal matter (Fig.1, 2), mafs of the transition matter (Fig.1, 2), and the mafs of the matter (Fig.1, 2), hence the plasma of the light contains the same mafs of the matters as the plasma which is manifested from.

This dynamic elongated cylindrical plasma once in motion due to its new shape it can penetrate and move faster in its environment as it has less frontal interface and creates a lesser friction as if it was spherical in shape, this allowing faster speed to be attained by the plasma of the light in transit from one matter mafs environment to another irrespective of the plasma matter mafs of the light being in the principal mafs, transition mafs or matter mafs mediums pmf strength environment.

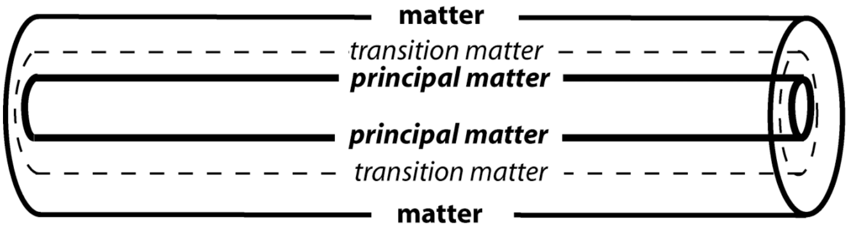

Fig.1 The schematic mafs of the matters components' of the light

This internally dynamic cylindrical plasma of the light in its motion creates friction between itself and the Magravs of its environment, which this friction at the point of their interaction and due to friction of the two pmf Magravs at this point of interface releases plasmatic magnetic fields, which are in the man's protein pmf strength detectable magnetic spectrum. Through biological structure of the humans protein pmfs strength visionary sensors' which can detect this interface interaction pmf strength then these sensors become aware of different pmf strength, its position and condition and this information is passed to the brain, where this method of interface interaction of two Magravs of the rays of the light and the protein has become the method for man to be aware of his physical surrounding in his environment pmf strength and the man has called this matter interaction conditioned wave length the light ray.

The light ray in its interaction with the surrounding magnetic fields in their environment leads to creation of magnetic field in range to man visible light according to the human protein pmf strength of the universal Magravs spectrum, where the shine or the visibility of the light observed become and it is at the boundary of the magnetosphere of the plasma of the light.

The structure of this dynamic cylindrical plasma of the light ray, which creates its own Magravs, is initially consisted of, in the centre, the content of mafs of the principal matter, then the next layer to the principal mafs is the mafs of the transition matter and then the layer surrounding this, is the matter mafs strength magnetic fields components of the light.

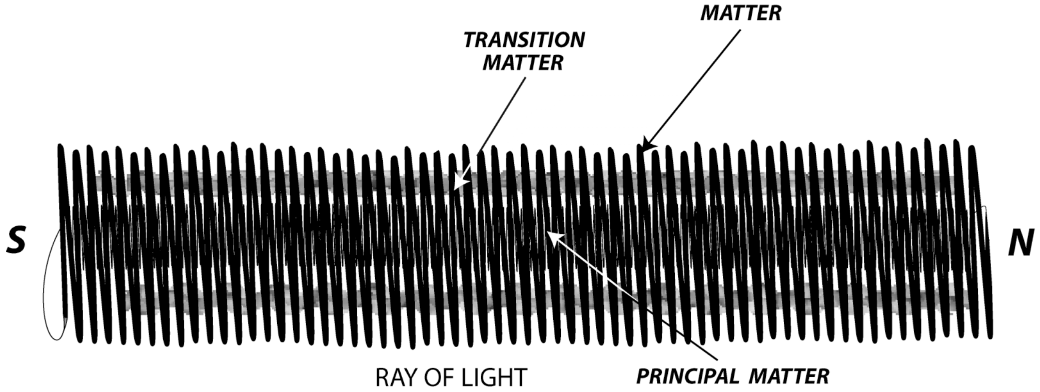

Fig. 2 The mafs of the matters components' of the light

These dynamic plasmatic magnetic fields due to their proximity to each other, they have to interact with each other as all magnetic fields in close proximity with each other do and by the same universal principle laws of physics these magnetic interactions leads to creation of gravity (1) and creation of Magnetic fields within and around this dynamic cylindrical plasma, where these magnetic fields interactions leads to creation of internal and inward magnetically initiated gravitational fields force of the light and the outbound Magnetic fields forces of the light. Therefore due to interaction of different constituent magnetic fields of different mafs' of the matters of the light, the light must create and does possess its own Magnetic and gravitational fields, and due to the interaction of these two plasmas of the fields of the gravity and Magnetic fields, this leading to creation of the mass and the magnetosphere of the ray of light (1).

Hence the light by natural laws of magnetism possesses mass and magnetosphere and similarly not all lights have the same mass and by the same laws and principles lights of different intensity and lights which can travel longer distances possess a larger mass. Where, their mass is primarily dictated by the strength of the pmf of mafs of the principal mafs of the light components'.

The interaction of the mass of the light and the environment of the medium that the light is traveling through, then the light acquires weight in respect to its given environment fields strength.

The mass of the light has different weights according to the gravitational environment which it is passing through or being produced or arrive at. In understanding the construction of the ray of the light then the mass of the light has to be measured along its total length and not across its width.

Most rays of light possess anticlockwise spiral longitudinal rotational motion for their constituent fields and not spherical rotation of the fields as for example in spherical dynamic entities the like of plasma of the proton.

Rays of light as in the case of matter plasma of protons the light rays mainly possesses and maintains a clockwise directional motion.

Due to composite structure of the light's mafs, if one looks' at the cross-section of the light (Fig. 3), one should be able to observe a tighter magnetic fields strength region of the principal mafs in the centre, leading to creation of the strong light in the principal spectrum level and stronger gravitational fields of this sections' structure that creates its own magnetosphere region, then this section is covered with the transition mafs region structure of the light, and then when the transitions mafs have reduced in their strength, then they become in the level of the matter mafs strength and at this zone the matter mafs and matter of the light are established and maintained (Fig. 3).

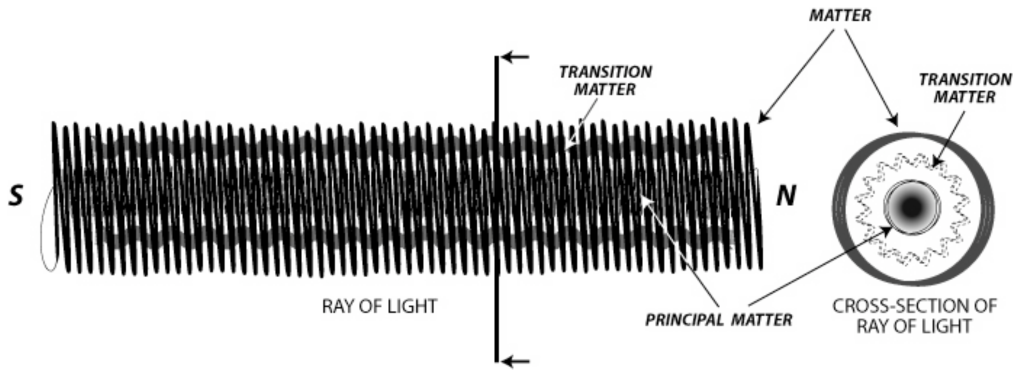

Fig. 3 The cross section of the ray of light

The lights' structure is similar to the structure of inner sanctum of the Sun and principal star in the centre of the galaxies, where for example the Principal Star takes its position in the centre of the galaxy and due to its higher inner magnetic field's strength of the principal star, this creates what appears as the principal stars strong gravitational field forces that all matters around it are pulled inward and at the same directional motion of the galaxy is set by their principal star too, where simultaneous this central matter radiates outward its own light in the principal mafs strength (3 and 4).

The straight helixal cylindrical shape of the light ray has polarities the same as any straight solid magnet, where the outer magnetic fields lines of the light ray converge inwards and the inner magnetic lines of fields diverge outwards, this creating an inward (South-Pole) and outward (North-Pole) directional motion of fields (Fig. 4).

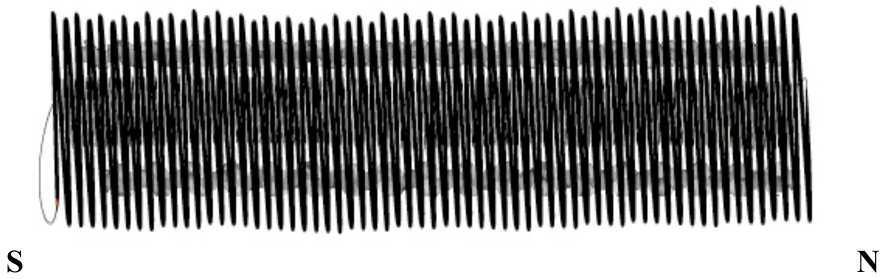

Fig. 4 The polarity of the ray of light

Due to the structure of magnetic fields of the light, it can be said that the matter mafs fields components of the light will be interacting and be attracted and drawn inwards' through the centre of the structure of light's magnetic fields at the ends of their pmf length (South -Pole of the light) and then as they go through or in proximity of the mafs of the principal mafs of the light in the centre they absorb some of the pmf, which has been unwinded by the mafs of the principal mafs fields and then these matter mafs fields, now energized, then due to their rapid motion are ejected and appearing from the other end (North-Pole) of the light ray.

This inward revolving motional central rotation of the outer matter mafs fields at the same time gives the light its property of high speed forward motion, where the conversion and the overall and total gravitational field strength and the helixial cylindrical rotation of Magnetic fields of the lights' principal mafs' dictates the length of the light ray and hence where the beginning and the end of the light ray would be.

This process of matter of light going inwards and then ejecting from other point, is very much like the process what some consider as the imaginary phenomenon commonly called and known as a wormhole principle. The continues rotation of the mafs of the matter's fields concaving-in and will go through the inner Principal Star like system of fields in the centre of the ray and then the pmf of the mafs of the matters emerges from the opposite-end as it has entered with new and higher pmf strength.

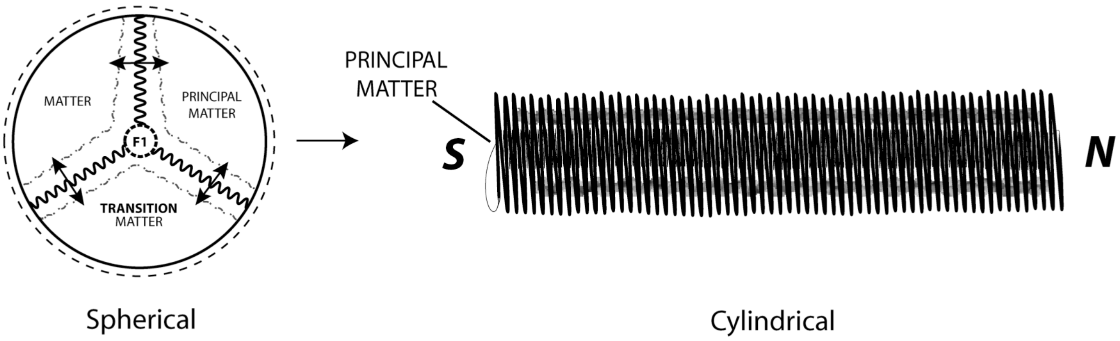

Fig. 5 The first conversion. The spherical plasma structure converts to the cylindrical plasma structure of the light (The first metamorphoses of the light)

When, the spherical plasma first changes to cylindrical plasma that is the point when the ray of light is created and becomes straight line directional in motion entity, and the spherical entity goes through the first metamorphoses (Fig. 5).

Then as and when this dynamic cylindrical entity reach's its destination point, this being of any mafs or matters plasmatic fields strength environment, then at the point of arrival then this cylindrical entity goes through the second metamorphoses and reverts back and spherical rotational fields entity (Fig. 6).

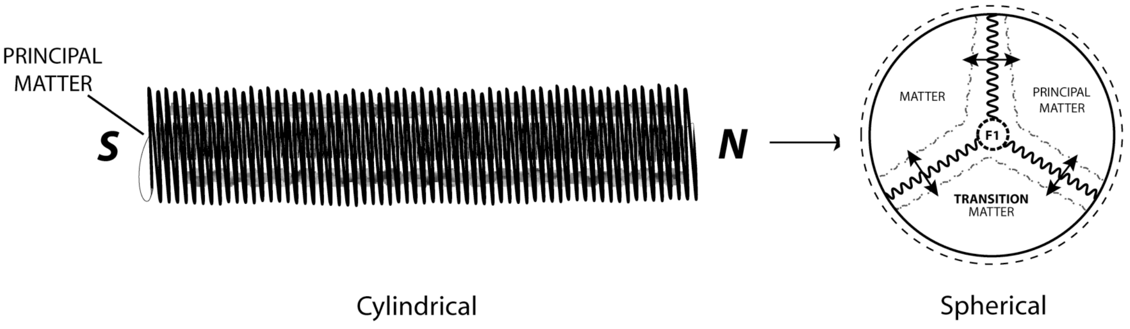

Fig. 6 The second conversion. The cylindrical plasma structure of Light converts back to a spherical plasma structure (The second metamorphoses of the light)

Where, the plasma of the light gets gravitated and absorbed then it takes the shape of the matters in the target entity environment as the content matter of the plasma of the lights gets added to the plasma of the target environment and the target entity receives an additional dynamic plasmatic magnetic field of all mafs of the matters of the light or what is called the target plasma receives an additional energy from the plasma of the light.

Therefore the plasma of the matter to hold on to its maximum pmfs and transfer its pmfs from one point in the universe to another as fast as possible, then the plasma of mafs uses and goes through double metamorphoses process of spherical to cylindrical and then to spherical entity (Fig. 7).

In reality the light ray due to its mass possesses momentum rather than light being a ray which only transfers' it magnetic fields and energy upon interaction with other entities in the universe.

Therefore, IFF the light was a ray and not a plasma composite of different mafs strength, then only one of the matters' mafs of the plasma of the targeted entity would increase in mass and this creates unbalance in the inner structure of the targeted plasma and only in that matter's content, which in the case of the matter environment this energy is so low compared to the principal mafs contents' of the targeted plasma, that this increase in matter pmf would not have shown any increase in its content and increase in the energy as the whole.

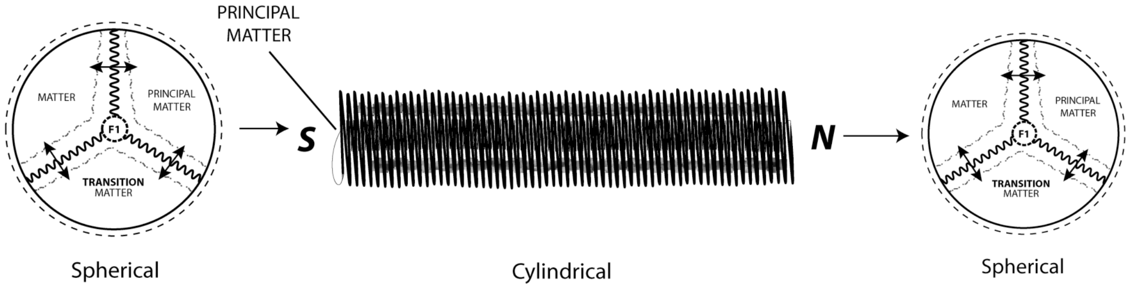

Fig. 7 The double conversion of the plasma from spherical to cylindrical, and on its arrival back to spherical plasma entity
(The double metamorphoses process of the plasma of the mafs)

But as the light transfers all its mafs of all its matters content to the targeted plasma, then the whole pmfs matters of the plasma of the target plasma increases and then the whole plasma shows signs of increase in the plasma content and for example the whole atom structure gets energised.

This being the like of when plasma of an atom receives injection of a ray of light that the whole proton and electron gets excited and energized and not only the matter components of the plasma (note: the term plasma of an atom as the whole structure of an atom including its neutron, proton and electron create its own magnetosphere and it can be considered as one plasma containing plasmas of these particles). Where, the electron due to its lesser mass shows a more rapid motion and excitation, whereas the plasma of the nucleus absorbs most of the light mafs and adds this to its total mass of all its matters.
If! The protons of the nucleus magnetosphere are measured before and after interaction of the light with its atoms magnetosphere, then it can be observed that there is a marked increase in the magnetosphere size of the plasma of the proton too, this indicating that the whole atom absorbs all matters mafs of the light and not only the plasma of the electron, which moves and takes new position in respect to the protons Magravs.

In comparison, in earth condition as meteoroids enters its magnetospheric zone, the facing side of the meteoroid on entry into pmf of the earth, its interface surface matter curves' backward, where the same happens in the case of dynamic plasma of the light in entry into a new pmf strength environment, then the same types of curvature and convergence of the mafs of outer matter mafs layer of the light due to the speed of the transition and obstruction and friction of the new environment, then the outer mafs of the light take their position on the outer layer and the rest of the mafs of other matters' of the light follow the same process and take their position within the new plasma and the cylindrical structure of the light converts into spherical plasma and hence the light converts into a tangible spherical matter, and all its matters content fuses and amalgamates with all matters of the same in the new target plasma environment (Fig. 6).

The reversal of the helixal motion and cylindrical plasma of the light to spherical and rotational mode of matter is entirely dependent on and due to the environmental plasmatic magnetic fields strength, which the light arrives at and it is dependent on the tightness or strength of the magnetic fields of the destination environment.

In this process pmf traveling from one point to another in the universe, as the fields of the mafs of the transition matters have faster speeds than the matter mafs fields of the light then, when the light arrives at the point of its destination, where is to release and converts its fields to the given environments' of other plasmas, then the conversion in the matter mafs to matter fields strength leads to creation or release of plasmatic fields in the soft x-ray which is the essence of creation of life (6) and other magnetic fields strength of magnetic spectrum levels.

In the matter environment the slowing down from the principal mafs components of the ray to matter mafs fields strength leads to release of magnetic fields plasmas in the gamma rays strength levels and similarly the beta plasmatic magnetic fields strength is due to fields strength from principal mafs to mafs of the transition matter and transition matter mafs to matter mafs and matter pmf strength this become to release alpha rays in the magnetic field spectrum.

The production of gamma ray through such similar process can be observed, when the star in the supernova state releases gamma burst, where this gamma burst is due to the rapid expansion of the principal mafs of the star converting into the matter mafs magnetic field strength or the rate of the change of the principal maf to matter and matter maf leads to release of gamma rays.

As the matter mafs composition and the construction of the plasma of the electron has been understood to be of the same as the plasma of the proton and neutron (1), then gamma rays are and can be produced by the mafs of the matters of electron the same way as done by the neutron or protons, when and where the right condition for the release of the fields strength equal to the gamma rays are made available for this ray pmf strength to be released. Where these rays released by the electron can appear in the inner structure of the plasma of the protons of the nucleus and be manifest as the incoming and mysterious energies which are moving within the plasma of proton or neutron and their source unknown.

There are lights rays which are created by the electron in the same process of spherical to cylindrical structure conversion between the pmf of the electrons and the proton or an atom.

It has been explained (2) that there is current of magnetic fields flowing within the different mafs of the matters magnetic fields strength of any plasma as it does between the plasmas themselves. Where the current of magnetic fluxes in the case of the light rays is in the light plasma magnetic fields strength and not electron levels of magnetic fields strength of the spectrum of the magnetic fields, when magnetic fields moving from one matter mafs to another within the layers of the mafs of the matters of the light. This current of pmf within the mafs of the matters' of the light is to be called the **light Magnetism**, "***ligmagnetism***" instead of electromagnetism as their mass of the mafs are totally in different scale of measurement.

It has to be said that as there are electromagnetic fields so there are *protomagnetic* field as well in the operation of universe, these are a more powerful current follow of magnetic fields package, which the world of science is not so much aware of these at the present, but in the construction of space reactors for the future of space technology the use of protomagnetic fields and their currents are much easier systems to produce and this gives opportunities for the development and production of a much smaller but more powerful by factor of several orders of magnitude than electromagnetic based plasma space reactors, where huge masses can be lifted with few grams of fuel. This concept of light to neutron and lift and motion is the main corner stone of knowledge and principle that allows the stars to create such a powerful gravitational and Magnetic fields, which the scientific world at the moment has not understood as of yet and has been entangled in the smaller component of the atom, rather than understanding the real power house of the atom and utilise this for their benefit to achieve some wonderful and interesting results.

The pmf current within the mafs of the matters of light structure magnetic field in strength has a different spectrum due to its length and rotational motion than the electromagnetism measurement. This ligmagnetisem has more powerful current flow and by size have stronger field's strength as it has more field contents in the principal mafs fields' spectrum than the electromagnetism which is in matter fields' strength spectrum.

Electromagnetism or electromagnetic flow (2) is said to be the electron magnetic fields strength equal to the strength of the magnetic fields of the plasma of an electron and the current is explained as the rate of the flow of the magnetic fields from one magnetic field strength to another (1 and 2).

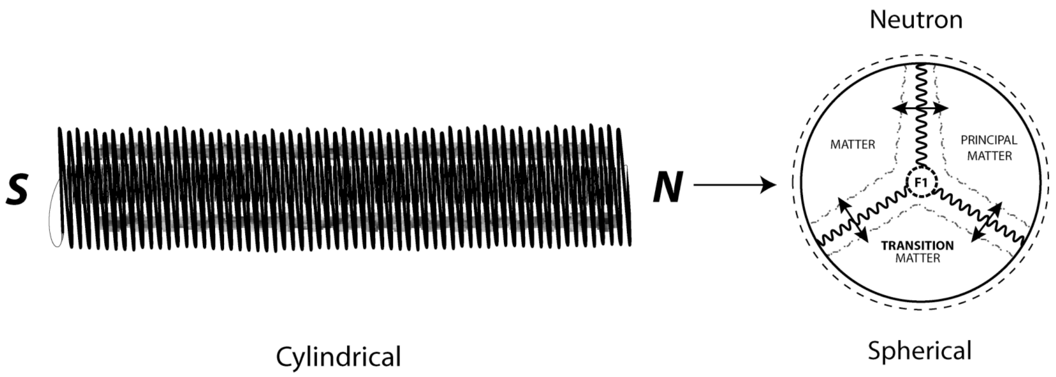

Fig. 8 Conversion of the ray of light into the fundamental plasma
or what is known as neutron

In most cases when the lights have enough mixture of mafs of different strength, these rays upon their arrival to a given environment, they directly convert into the complex plasma of fundamental plasma or what is known as the plasma of neutron (Fig. 8)(1).

At the same time collection of smaller and fragments of lights plasmatic magnetic fields upon arrives at the point of destination, due to the vacuum level of the environment go through the process of accretion and they create or lead to creation of the fundamental plasma (neutron) in their new environment.

In cases the light ray carries more mass contents of all three mafs of matters compared to the its environmental mafs need for production of fundamental plasma in this new environment, then in these cases the large in mass light rays has enough mass of mafs that the light ray in this new environment goes directly into the structure of the fundamental atom or what is known as atom of hydrogen, that once this ray. That is to say in certain conditions, the structure of atom is due to total conversion of the light rays components and the ray of the light does not go through neutron decay conversion (1) for the light to become an atom (Fig. 9).

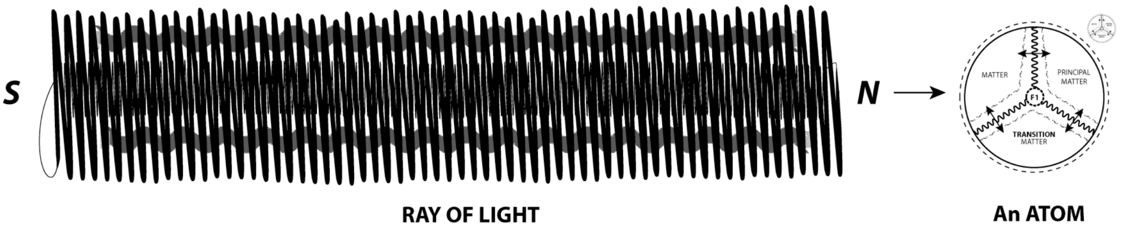

Fig. 9 Production of an atom direct from the ray of light

Some light rays due to their internal dynamism and different mafs strength in their structure, these lights rays create and contain entities moving internally and these internal structures keep the plasma of the lights' mafs in order and under control. These internal entities are the like of the electrons, which are externally positioned in the overall structure of the atom, these internal entities have specific position and purpose and they mostly convert to electrons' of the plasma of an atom in given specific conditions once the plasma of the light converts into matter of an atom, where with this process there is no conversion into neutron and then the nuclear decay of the neutron that leads to creation atom, in this process the light converts directly into atomic structure in one step. These internal entities are usually observed in the lower order environment medium which the light is traveling through, where the low speed of the entry of the outer layers fields, in-going through the faster speed principal mafs, these create small vortexes between the two fields in the transition mafs environment of the palms of the light, which these vortexes start operating independently and gradually fiend a fix position in the internal structure of the plasma of the light and when the light transfers to structure of an atom, these mafs entrapped in these vortexes become the electron of the matter of the atom (Fig. 10A).

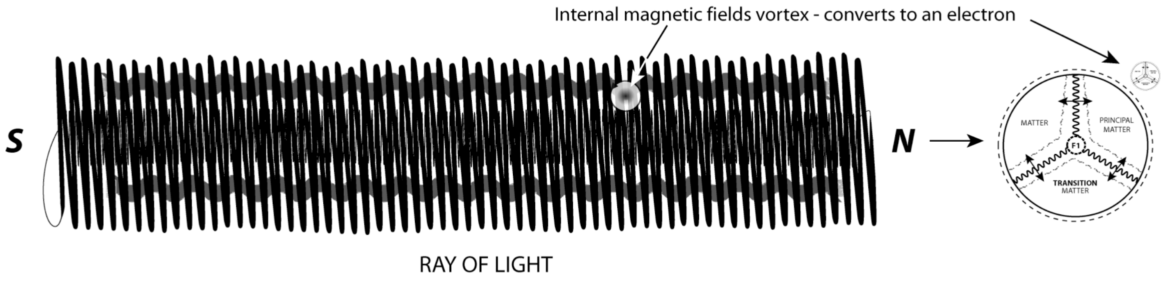

Fig. 10A The conversion of light containing vortexes into the structure of an atom direct.

The reason why the plasma of the light takes the spiral helixial cylindrical motion and shape is simply due to the fact that plasmas' with this type of structure does not have a need for additional external plasma(s) around them for coherence and a balanced plasma the like of electron in the spherical plasma structures of an atom.

In principle rays of light get their strength from their inner plasma of the principal mafs' strength rather than any other part. This being the reason, ***why light look as to be an energy rather than entity with the mass***. Therefore the light is a composite of plasmatic magnetic fields of different mafs of the matters fields' strength and **light is not a single magnetic field structure**.

The lack of understanding of the structure of the light and the inability in scientific world to be able to split the structure of the inner components of a light ray has led the scientific world to consider the light rays as an energy rather than a dynamic structural plasma as of the same as the electron or proton.

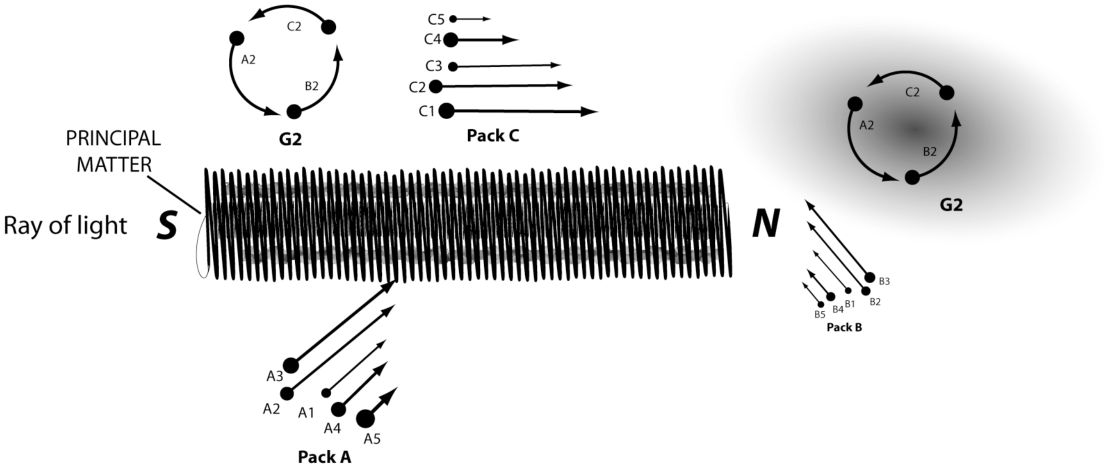

Fig. 10B Ray of light travelling through and interacting with outer mafs and initial fundamental particles of pmfs.

Due to the cylindrical structure of the light plasmatic magnetic fields and their interactions, light has the wonderful capability to be able to change its outer mafs cover as/and depending upon the matter mafs or matter medium that it is traveling through or where it arrives at.

In choosing and using helixial cylindrical motion the light does away with the need for external rotating plasmas like as the electron(s) with the atomic and planets with solar system.

This, meaning that all rotational spherical objects the like of the solar systems and atoms need to have two or more parts that their centrifugal magnetic forces can keep their matters and mafs content of dynamic magnetic fields in an encircled and enclosed loop for them not to lose too much of their magnetic fields through leakage to other plasmas in their environment.

In reality helixial cylindrical rotation partially can be seen in structure of some of galaxial structures too, primarily due to this phenomenon.

Where, for faster and simpler speed, the layers can move inside-out and vice-versa according the mediums' magnetic fields strength of the environment of travel. This meaning that due to dynamic cylindrical helixial motional and composite matters mafs structure of the light, the mafs of the transition matter plasmatic magnetic fields can become and take its position on the outer shell of the light rays in a mafs of the transition matter mafs and medium strength and similarly the principal mafs components of the light can take their place on the outer fields layers' of the light rays in principal mafs and matter fields strength environment.

The light is energized from the central magnetic fields strength region of its structure in a matter medium and this being the reason why the light seems to be able to travel long distances and behave as energy and not an entity. This change of cover allows less losses' of the mafs of all matters of the light ray due to friction in any medium magnetic field strength.

Now it becomes clear, how and why spherical rotational shape of the movement of the dynamic plasmatic magnetic fields leads to creation of matters and at the same time longitudinal cylindrical helixial rotation of the same dynamic plasmatic magnetic fields lead to creation of light rays. Therefore the method of transport of pmf and Magravs in space is through the Light Magravs, where at the point of interaction and slowing down the lights' pmfs are transformed and transferred to matters fields strength of plasma of the new environment.

Hence, in the universe mafs of the matters are transferred and transported through the mechanism and the use of plasma of the light and when for example the Magravs of the light reaches matter environment it becomes and slowed down enough to reach's all content matters Magravs strength levels, then what is released in by the light pmf, this surplus or released pmf then becomes the pmf which targeted pmf receives as addition pmf or what is commonly called ***it receives energy from the*** pmf of ***the light***.

When, the light ray reaches the principal matter environment then its principal mafs pmf will have the same interaction as delivery to its given environment as mafs of matter have in the matter environment.

The reason matters can feel forces of rays of light are primarily due to the momentum of the motion of the mass of the light itself and not through absorption of its energy.

In the solar-sail transportation the motion of these would not be due to energy of rays of light absorbed by the sail, but in real term the created motion is due to the motion of the mass of the light and its momentum that once it comes to rest at the point of interaction with the material of the sail, the light transfers its momentum to the fabric of the sails' matters and hence the increase in the momentum of the sail and hence the motion of the sail.

It is essential to realize that as there are gamma rays, beta, and alpha rays and so on in the matter world so do the same types of rays of the same in equivalent and in proportion in strength exist in the environments of the Transition and the Principal Matters too.

Therefore one has equivalents' of the gamma ray in the principal mafs environment and the same as x-ray in the mafs of the transition matter environment in magnetic fields strength too. This meaning that the sub-division and spectrum of pmf strength of the light is not the exclusivity of the matter environment only and it has parallels' in other matters' pmf strength environments.

At the same time the interaction of the Magravs of the lights surrounding with Magravs of the light leads to release of magnetic wave's rays in the visible light spectrum in these matter mafs environments depends up on the observes pmf strength visibly tools of observation.

The inter matter's mafs cover exchangeability of the light rays is the reason why light has the capability to travel long distances in mafs of the transition matter environment of the universe, as the similar in strength mafs of the transition matters creates no loses or interactions in this level that can lead to minimum losses of light's plasmatic magnetic fields and its strength. The reason being that visible light is only released, when two different Magravs in strength collide and not when two pmf of the same interact or very little pmf are released in these compatible pmf strength entities and environments encounters as in the interaction of the similar pmf lead to and creates very little friction between the pmfs of the light and the environment and hence these interactions releases very little light and this being the reason why in the universe, the interaction of the transition mafs of the light rays with the transition matters of the universe creates very little light or a dark light or what can be called the Transition Translucent light (1) and not a bright visible light, when one looks into the deep cosmos.

The invisibility of travel path of the ray of light through the deep space is in fact ***due to its***

capability to change its outer layers according to the environment that it travels through.

That is to say as the light goes through the Transition fields regions of the universe, then the transition mafs and matters of the light will come to take their position on the outer layer of the ray, then through this process less pmf are used in interaction with these fields and matters and hence less friction and less loses of mafs of the light, and in these interactions there are very little loses through the Magravs of the mafs of the transition mafs of the light, these faint lights produced in the interaction of light's outer mafs of its transition matter and of the same and/or transition matters in the universe, where these very few interfaces of the collision between the light and the environment Magravs gives the universe a dark but translucent effect that one can see through the universe. In a way this interaction of lights' transition mafs and universe's transition mafs is the cause and the reason for the invisible transparent structure which allows the production of universes discreet light that one can see through this universe but blocks opportunity that one cannot see the lights from and the universes outside this universe (3).

It can be said that the light due to its interaction and helixial rotational characteristics is like a **chameleon** and ***it has the ability to changes its cover matter and mafs according to its environmental Magravs strength***, which it travels though and when and where the fields strength changes are too great then the light changes its cylindrical to spherical shape structure and its outer skin matter and mafs take's strength of its environment mafs or the matters' plasmatic magnetic field strength. Or it can be said that the light has **surface** Magravs strength matching characteristics and capabilities. As the Magravs of the light reaches or tries to enter another spherical Magravs or cylindrical Magravs then part of the released Magravs due to friction of two Magravs with each other lead to transfer of pmf to spherical pmf and release of some pmf in the form of magnetic rays' strength spectrum.

The light as it enters or comes in contact with plasmatic magnetic environment the likes of the earth, then the interaction of their two dynamic cylindrical and spherical Magravs creates fragments of plasmatic magnetic fields that are in the range of the man's protein Magravs strength that to man's sensory detection tool called the eyes can recognise the interface of the interaction of the two Magravs as the visible light.

In reality the light is created and operates through and from different pmfs strength and it is not as simple as an energy as if one define the true meaning of the energy, which is "the plasmatic magnetic fields (pmf) is motion" (1), then taking the motion or speed of the ray of light's movement in a different matters and mafs environment then one can see that the light in truth is no one magnetic ray but it is made of a complex plasmatic magnetic fields of different strength.

Whereas, in the light's principal mafs (3) the stronger and tighter of its fields seats in the centre of the structure (Fig.1) and as this mafs of the matters field's unwinds, these newly made available which are lower in strength and are going from one strength to another, then these mafs in motion to be known as ***transition energy*** (dark energy) and when these mafs slow down enough to their transition matter and mafs environmental strength, then these appear as mafs of the transition matters (dark matter), and then when the transition mafs pmf strength reduces or unwinds enough that this mafs reach's the matter mafs pmf strength levels environment then it become tangible or detectable the matter at this strength (Fig. 11).

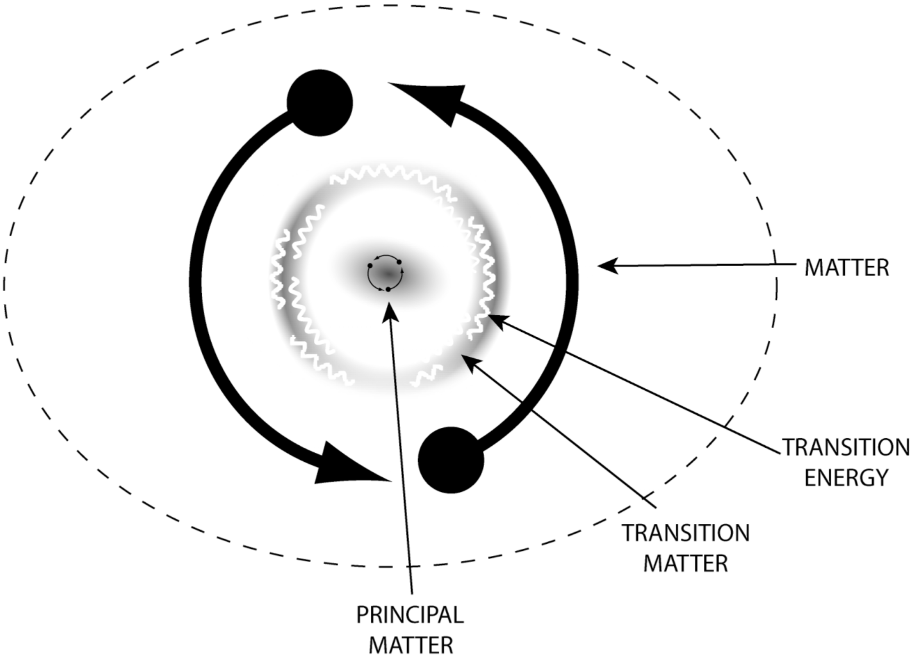

Fig. 11 The magnetic field structure of the plasma of the light

Where, the visibility of the light at this point the like as in the earth and human body, then this light is human protein chain mafs strength dependent, then it became visible light to the human eye in the Magravs strength of the planet gravitational field strength and then the light appears in matter pmfs strength and as tangible or detectable matter.

Light in its visibility and tangibility has different strength and what is visible light in one matter mafs and matter environment strength, this it is not necessarily visible and tangible matter mafs and matter's pmf strength in another environment and vice-versa. The visibility of the light or its transparency is ***environment and target magnetic field strength dependent.***

The structure of the light prevail that in general in matter environments the stronger or the principal fields take its position that as it unwinds it become the source of the magnetic fields to the lower field's strength and it can be divided into the lower field's strength of the plasmatic and magnetic fields.

At the same time the tightness of the fields of the mafs of the principal matters and their content of the principle fields in their interactions with other principal strength fields of the same strength mafs and matters creates visibility in their level of strength too that these lights are not visible for example in matter mafs or matter environment to human eyes even though in the matter environment the existence of the principal fields and mafs of the matters can be felt or even their affects can be seen.

It has to be said that if the light was not in possession of its own Magravs, the light would have been attracted and absorbed into and by the first magnetic fields or the first object in possession of Magravs in its travel in the universe, whereas the light being in possession of its own Magravs (the dotted line around the mafs of the light in the figure 11) (1) this allows the light to find its position according to its Magravs strength in respect to other objects Magravs and magnetic fields in the universe and this giving the light the ability to travel the length of the universe without being absorbed into or by other objects Magravs and magnetic fields. Thus the light has the ability to establish and maintain its own Magravs positioning criterion in respect to other entities in its environment.

The light rays with higher mass of the mafs of the principal matters, these rays can travel further in space compared with rays of lower mass. Therefore what one can observe as light from far corners of the universe in general these are some of the lights which possess the more mass of the mafs of the principal matters at the point of their inception, as the rays with lower mass have already been absorbed by the other entities in the universe over the life of the universe from the time that these rays were created and have been in travel in cosmos that they could not be observed by man at this point in the life of this universe.

The light observed from far corners of the universe are some of and not all the lights from the whole of the universal light from the point of creation of this universe as most lights by now have interacted and been absorbed or are interacting and getting absorbed by the other fields in the universe, then this can indicate that lights of lower mafs of the principal matters strength and content of principal matters from the origin of the time of the birth of this universe have mostly already been absorbed or been attracted by other pmf and entities in the universe.

The absorption of different rays of light in the universe are environmental dependent and it can be said that the lower mafs strength of the principal matters of the mass of a light ray can become the **seeds of neutrons** or it can be said that the principal mafs of the light as it arrives in a matter magnetic fields strength environment, then this principal mafs of pmf of the light becomes dynamically spherical in structure and then become the seed of the creation of neutron. Hence one can understand how energies which are defined as “the plasmatic magnetic field in motion” convert to matter in a given Magravs environment. Where, each mafs of the matters field’s strength components of the light then can become in its arrival at a given environment the seed of one of the components of mafs of the matters of different plasmas too.
Therefore it can be said that the initial seeds of the creation are in motion in the universe at all levels and all time and once they reach given an appropriate environment mafs pmf strength, then in that environment depending on theirs plasmatic magnetic fields strength and the given environment plasmatic magnetic fields strength then light rays manifest themselves or can become tangible and detectable in that environment.

For example the light which has the plasmatic magnetic fields strength of a neutron then can upon its arrival in a given environment changes to a tangible and detectable neutron and then through the losses of some of its magnetic fields to its environment this neutron goes through the nuclear decay (1), which this lead to creation of plasma of an electron and a proton and the light ray becomes the seed of the fundamental atom (1) or the atom of the hydrogen in matter environment plasmatic magnetic fields strength of for example of the Earth.

Thus; “the present assumptions that the first atoms in the universe were created when the universe cooled, **this theory is not and cannot be correct** and in reality atoms are created through change in the plasmatic fields strength of the mafs of the light, secondly at the point of creation of the universe, the universe was not hot and there were never high temperatures that the cooling of the universe has led to creation of the first atoms as presently commonly stated. The first atoms and universally all first atoms’ the like the atom of hydrogen in all mafs strength in the universe ***are created through the magnetic field strength reduction*** and through no other means.

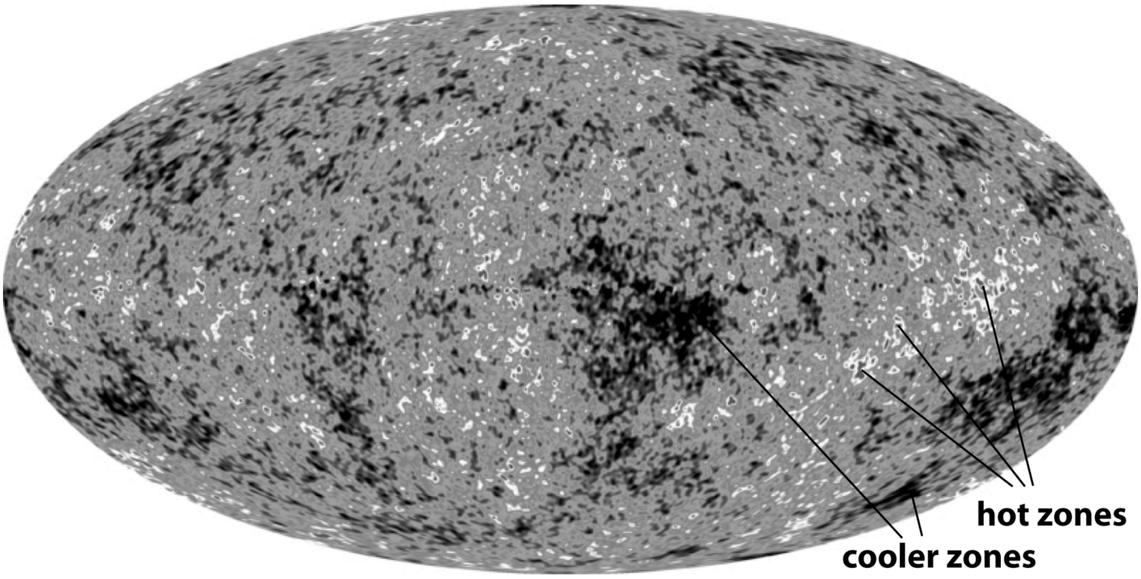

Fig. 12 The universe heat distribution map (W-MAP of the universe)

This concept of creation of heat and high temperatures at the birth of the universe is not observed in the plasmas of electron and proton, when the plasma of neutron decays and divides into an atomic structure, and in the universe there are always continuity and parallels, thus the universe has never been hot that has cooled down to create atoms, and this is the reason why W-MAP (8) shows present balance heat distribution of the universe (Fig.12).

In truth the current assumptions of initial heating of the universe at time of its birth cannot be true as the initial atoms of the universe and presently atoms were and are created from the original principal mafs strength which radiated out as principal lights rays of the universe in the centre of the universe and the initial atoms and matters of this universe were not created through cooling of the universe at the point of inception of this universe, which this universe itself is created from the decay and division of bigger mass of another universe as it happens in the division and decay of plasma of neutron to plasmas of proton and electron (3). One does not observe heating in the plasma of electron or proton in this division and so be it the same when the bigger universe divided and led to creation of this universe of the humans (3).

In fact, if! The universe was created by the present scientific assumption then the WMAP should have shown cooler region in its outer boundaries than the present near homogenous heat distribution which has been physical observed and from collated data by the publishers of the universal heat distribution map of the universe.

The heat distribution and the heat concentration on the central line of the WMAP confirms that the universe started from a central line in the middle and as the principal mafs of the universe unwinds then the transition mafs and the matter mafs were released and as were spreading outwards into the space of a larger universe (Fig. 13), then as the Magravs of the principal mafs in the central line region are converted and are reducing, then the overall unified oval-spherical shape explanation of the WMAP come to exist, and then as the total margrave of the central principal matters reach a point where they cannot hold on to all the mafs and matter expansion of the universal-magnetosphere, then at this point the universe will go through a division and all the matters and mafs at this point rearranged and regroup as and in the principal strength mafs and the universe then divides into two principal mafs of lesser masses of universes, which these new universe are magnetically interconnected and then these new universe go through the same principle of the principal light unwinding and the same process as creation of new universe carries as before (3).

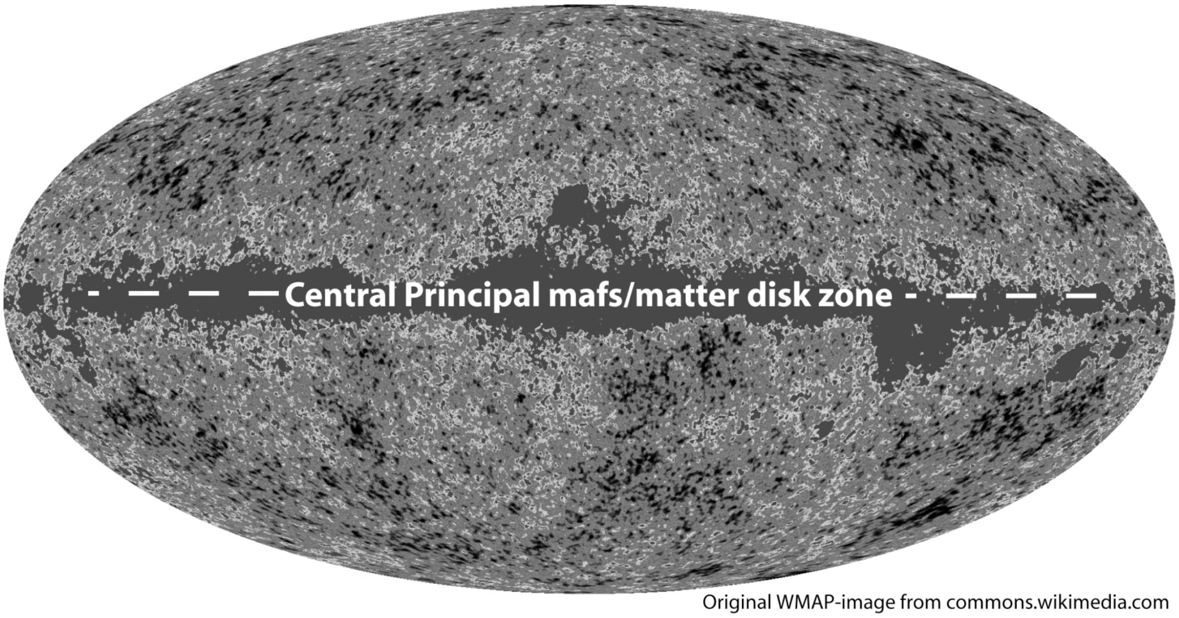

Original WMAP-image from commons.wikimedia.com

Fig. 13 The microwave heat distribution of the universe shows a concentrated heat in the centre disk of the universe

That is to say that the principal matters are the way that universes divided and arrive form another universe and as the light in the principal mafs strength unwinds' in its new environment then the new envelop of the new universe starts to be created (3). The same process occurs when the neutron decays and divides into the plasma of the proton and electron.

Thus, the universe is not created as a big-ball of fire which has been cooling down as has been promoted, but in fact the universe is created the like of as an ejected principal mafs is injected into new a universe environment and as the principal mafs radiate outward as light of stronger mafs, then they create the other matters mafs and matters depending on the given pmtics strength of a given region in the larger process of this unwinding of the principal maf and matters and its lights (3) in this new expanding universe.

Therefore this universe is in fact created inside out than what has been assumed up to now that as it cools down to what it is, which this explains why even the universe is observed to be expanding, as the reason for expansion of the universe is being due to the presence of principal mafs in the centre of the universe and as principal lights of the principal mafs radiate outward, these light rays of the principal mafs while traveling in their new environment they reduce in strength and this creates new matter mafs and matters according to given environments magnetic fields strength and in a given point pmtics hence the creation of new mafs and matters and so forth, which this leads to creation of atoms and molecules and stars and so forth.
Thus there has never been a big-bang and the current appearance of the expansion of the universe is due to the principal maf which as unwinds it creates the sphere of this universe (3).

This method of the creation of the universe now explains' why there is a central gravitational matter concentration in the universe as this pull is centred in the dynamic central line of the injected principal maf of the universe at the time of its inception, which this can be seen as the red line in the W-MAP (Fig.13), which the more concentration of the mass of the principal matter seats in the central disk of the W-MAP and as these principal mafs create their own magnetic interactions, hence these create their own gravitational and Magnetic fields of their own and thus the central gravitational of the universe is in the centre of the denser point of principal mafs of the centre universal heliosphere of this universe is created and solving the present mystery in scientific world that, where the gravitational pulls of the universe come from.

This is how even the plasma of the neutron decays and divides into plasma of the proton and electron too, where the matters mafs of different quantities and masses of different strength from neutron are divided and injected in the new area in their environment, where the original in their overall Magravs of all their mafs as original components concurrently maintained that the plasma of the electron and proton(Fig. 14) and then as the matter mafs ***unwind*** and interact they reach given Magravs level and position ***that new plasmas of the sub-components of the atom are created***.

Where this process of division due to micro -level of masses involved it appears as an instantaneous process of creation of proton and electron.

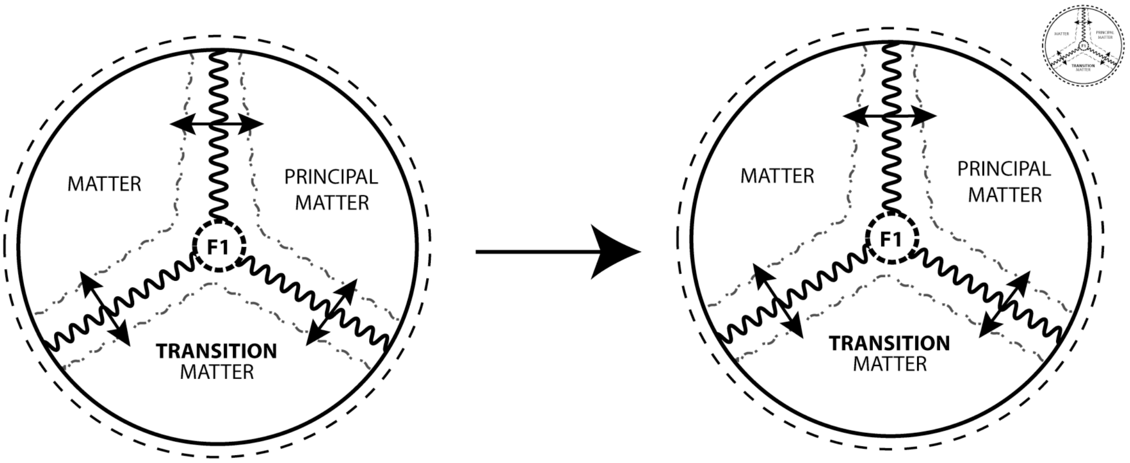

NEUTRON

PROTON + ELECTRON

Fig. 14A The conversion of the plasma of neutron to plasmas of the electron and proton
The same process is considered to occur when the universe divides (3).

This being the reason why the proton does not get heated as a big-bang theory suggests but as portion of principal mafs of the neutron which become part of the plasma of the proton **expand centrally** and as the principal maf unwind to the transition matter and matter maf of the plasma of the proton and all other fragment of pmtics and magnetic fields, hence the protons' plasma is created from the division of the principal plasma and the fragments of the fields as different constituent mafs, matters and fields in the plasma of the proton.

The structure of the plasma can be compared to ***the winding spring of a mechanical clock***, were as the main spring is winded up using a key and then as it unwinds.

Where as the winded spring is *tighten in the centre* this tightened spring becomes like the ***principal matter*** of the plasma, a compact entity full of energy in the centre (figure 14b-1) and as the spring unwinds it releases its magnetic fields in lower strength that this unwinding of the fields and reduction in their strength further down the line of unwinding of the spring becomes the magnetic field strength in the ***transition*** (dark matter) ***field strength*** (Fig 14b-2).

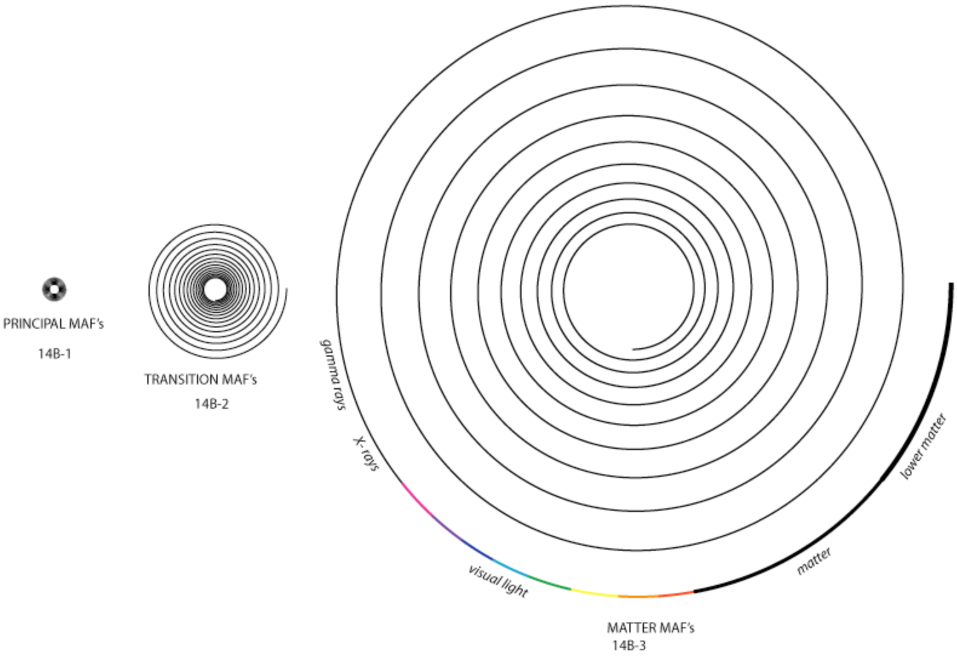
PRINCIPAL MAF's
14B-1
TRANSITION MAF's
14B-2
gamma rays
X-rays
visual light
matter
lower matter
MATTER MAF's
14B-3

Fig. 14B The visualization of the universal spectrum of magnetic fields.

Further as the magnetic field strength and as this field opens up in it's environment and slows down and reduces in strength, these fields in this region become in the visible light and lower magnetic fields strength in the unwinding cycle of the principal magnetic fields reaches the ***matter*** magnetic field strength (Fig 14b-3) and further on this field reduces in strength to even lower fields strength magnetic fields.

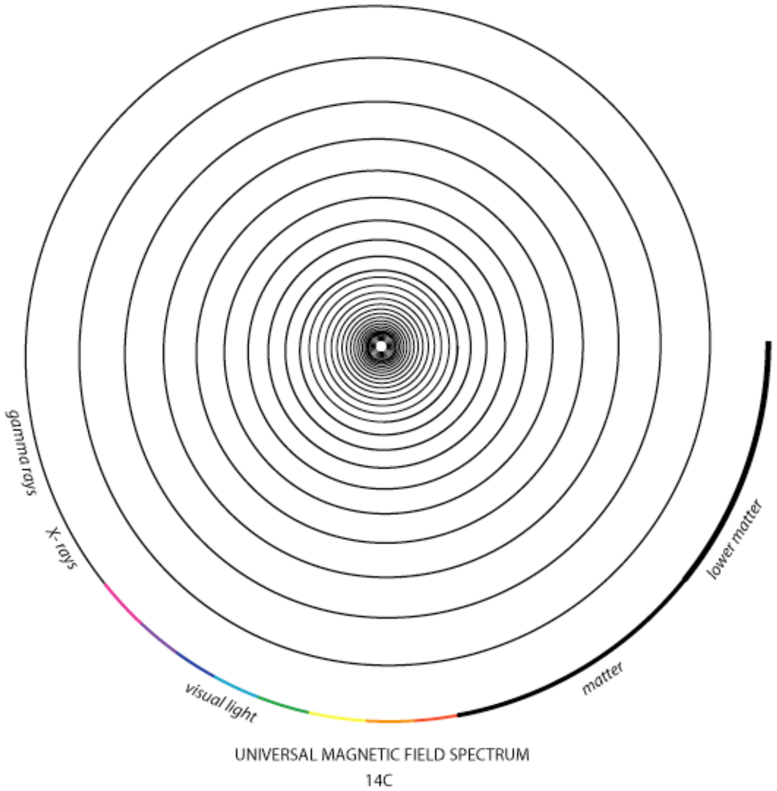
gamma rays
X-rays
visual light
matter
lower matter
UNIVERSAL MAGNETIC FIELD SPECTRUM
14C

Fig. 14C The visualization of the universal magnetic field spectrum.

Then as one puts the whole magnetic fields spectrum of the principal mafs, transition mafs and the matter magnetic fields as one continuous magnetic field strength spring or then the true sense of the unifying magnetic field spectrum which connects all creation of fields and matters as can be observed in the universe, that this can be called the universal magnetic field spectrum (Fig 14C).

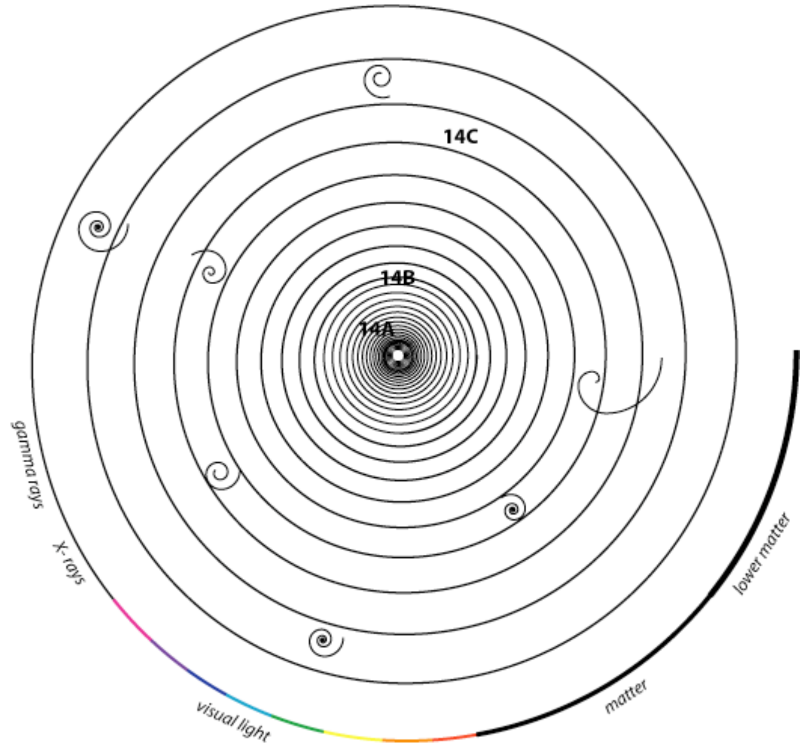

Fig. 14D The universal plasma magnetic fields structure

Where in the plasma of a proton for example, as the fields unwind and divide in the lower scale of the maf strength these lower fields as themselves unwind they interact with other fragments of the fields of the same in the Magravs of the principals matters of the plasma and hence they create the division and sub fields which one observes within the structure of the plasma, these being like what they call quarks and bosons and so forth. Where this total interaction within the capture zone of the Magravs of all the fields is called the universal plasma magnetic fields structure 14D.

The same process can happen with the ray of the light originated from principal mafs strength (what is called the principal light), when this principal light arrives in the principal mafs strength environment and hence the first fundamental principal atoms' can be created in that given environment through the same principle as principal atoms are created in the principal matter environment (1).

In reality: if! one could follow and observe the rays of the light which arrives at the boundary of the heliosphere of a solar system, one should be able to observe that some of these light rays of varying in mafs strength, which can reach this point in the Oort clouds region, these due to the balancing of their pmf and their environment vacuum condition and mafs strength, then these light rays individually or as collection of fields will become particles, plasmas of neutron, atoms and matters, and over the life of the solar system then they rain inward towards planets and the star of the solar system (Fig. 15)(4).

These light's rays which have slowed down in the Oort clouds layers or other inner sectors of the solar system can and do become as neutrons or other particles, then some of these become like of what is commonly known as neutrinos and get attracted back to the star.

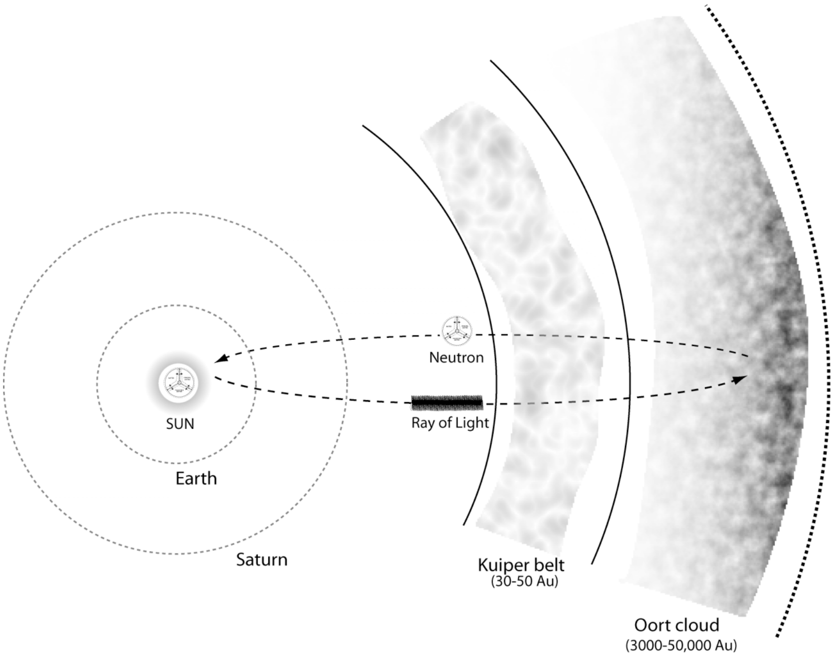

Fig. 15 Conversion of the light ray to neutron, atoms and gans in the Oort cloud

Thus as the stars of solar systems through their light emission continuously feeds their planets and moons with light rays in form of heat and further the sae light rays in slowing down in form of matter, then the same principle continues as the solar systems themselves get feed by the principal stars in the galaxies through their principle lights which these lights at the moment due to the man's lack scientific tools these lights have been invisible for detection to the man of science.

The neutrinos are on the other hand produced by and through the same process from the fragments of principal mafs of the light rays of the Sun or the principal matters in the centre of the earth inner cores too. At the same time and by the same measure neutrinos, which are released by the principal matters and mafs content of the inner-inner core of the earth which are detectable leaving the earth surface their existence and the exit from the surface of the earth is the confirmation of the presence of the principal matters and principal mafs in matter environment of the cores of the earth, as the light emitted by these principal entities lose their pmf strength within the centre cores of the earth (4) and as they move outward from the centre of the planet they appear as neutrinos exiting the earth surface.

Some of these light rays due to their Magravs strength get attracted and in a process known as the fusion of light rays and produce the initial molecules of the matters in the solar system too.

In understanding the concept that lights' rays from the Sun converts into atoms and molecules, then this make obsolete the theory that the ice particles left from the time of the creation of the solar system are the ones observed in the Oort clouds, the Kuiper belt, in the rings of the Saturn and so forth in the solar system.

That is to say most and even all matters in the solar system like the fuzzy material in the Oort clouds layers are mainly the product of the slowing down of the light rays of the star of the system and not the hypothetic present assumption that the meteoroids and all particles in the outer edges of the heliosphere of this solar systems are the residual materials from time of the creation of the star and the solar system.

This recycling of the light rays and production of for example particles is comparable and it is in fact the same process as one observes in systems which have dynamic magnetosphere the like of the earth, where the molecules of the vapours of water rise-up to upper and further regions of the earth magnetosphere and when they reach a given temperature and environmental condition then they gather and when they are heavy and enough of these entities then they rain down on the earth. This is the exact process as it happens with light rays of the Sun as these rays reach to the outer boundaries of the solar system in this process due to magnetic field strength difference instead of temperature difference as in a planetary system, they slow down and become matter mafs and matters and then they rain back towards their star due to its magnetic field interaction and gravitational field strength (4).

In attraction and motion of these lighter atoms and molecules solar winds in the outer region of the solar system are created and as they move in the Kuiper belt of the solar system these matters become part of the constituent matters of the outer giant planets and these light rays become part of and the creators of comets, asteroids and meteoroids as different densities of matters are released and created in this process and collected in these so called belts of the solar system.

Where, the existence of the meteoroids and their pattern of motion confirms the change of the mass of the light to the molecules of gans of the hydrogen as these comets and meteoroids go back in the Oort clouds layers, then meteoroids attract the newly produced molecules of the hydrogen and oxygen and at the same time they carry on mixing the soup of the Oort clouds matters(Fig. 16), this leading to collisions of new produced gas and gans of matters needed for the production of heavier matters and molecules like water in the solar system.

In reality the light rays becoming part of comets and meteoroids, these themselves become like a mixing spoon of the solar system and the cause of the mixing and displacement of the matter mafs and matters needed for having an active and dynamic matter environment in all parts of the solar system.

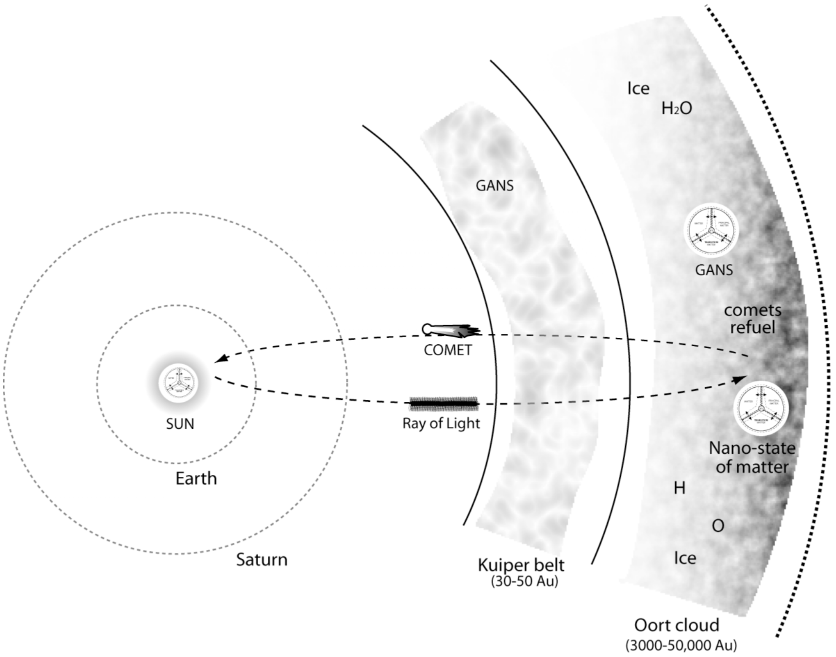

Fig. 16 The light rays become water molecules and get attached to comets and meteoroids and then return back into the inner parts of the solar system.

Therefore the reason, why giant planets exist and possess most of the gasses at the outer boundaries of the solar system, this is due to the fact that these gas planets *continuously absorb all the freshly* *atoms and the molecules of the gasses and gans* which are produced by the ***transformation of the light rays to these atoms***, and hence these gas and gans atoms and molecules get gravitated and pulled around and held or get captured by gravitational, Magnetic fields and get positioned, for example, ***in the rings*** of giant gas planets according to these ice **gans** particles Magravs strength and Magravs positioning.

The collection of ice particles and solids in different rings in the planetary or solar system is primarily due to magnetic fields of static inertia of these objects the like of asteroids and on the other hand due to and Magravs positioning through the Magravs of the gans matters their interaction with the planet or solar system Magravs strength and due to their of these planet's fields nearest to the Kuiper belt and Oort clouds.

Thus, light rays of the star are the feeder of the star, planets, meteoroids and asteroid as they rain back inwards into the star heliosphere over time as the Star's strong gravitational fields pulls' every matter and matter mafs in its system back to itself.

Therefore the light emitted by the star partially become the sources of the materials which are returned to the star matter for it to carry on with its everlasting existence.

Chapter 3

The conversion of light rays to the Gans of the matter

Considering the transition of the light into matter in the outer boundaries in the Oort clouds environment of the heliosphere of the Sun, there is a further process which occurs to these newly created tangible mafs from light rays of the Sun as these newly born neutron goes through its nuclear decay (1) and become an elementary atom of the hydrogen in possession of an electron and the proton. This atomic matter in the coldness and in low gravitational and Magnetic fields of the Oort clouds and Kuiper belt become in atomic or nano state of matter of hydrogen rather than atomic hydrogen and hence sometimes due to the weak gravitational field forces in these zone these lights become the gans (5) of the same element.

The **gans of the matter** is the ***state of matter, where the atomic gas of matter becomes the single solid atom of itself*** or what we have called "the gas in nano state of matter" in short or "gans" of the same element (5). Where, the gans of the matter is *internal gravitational and Magnetic field strength dependent* and at the same *time where the gravitational and Magnetic fields of the matter* ***is stronger*** *than its environments 'Magnetic and gravitational fields strength.*

The difference between the atomic gans or a nano gas material is in the fact that gans of an atom is its solid three dimensional free state of matter due to its internal gravitational field interaction.

As the Gans is the solid state of atom of gas in its natural three dimensional structures that its mafs of this matters are interlocks due to their internal Magravs strength of its own and their internal mafs loose bindings, and not rigid binding as in solid atomic state of matter as in the form of ice state of matter of the same entity of the same atom, which ice state of matter is due to and dependent upon external magnetic fields' strength of the environment which are exerted up on the binding structure of atoms that become creates the state of the ice of the same atom.

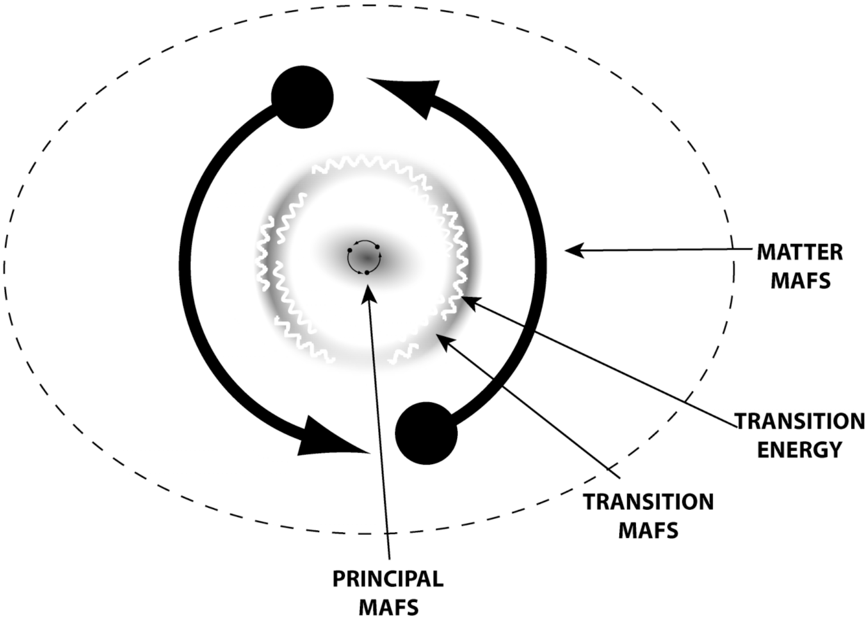

Fig. 17 The structure of gans of neutron

Where, at the same time it has to be noted that the light in becoming in ***state of gans*** it can create the fundamental plasma of the gans (Fig. 17); in the same region as it does create the fundamental plasma (of neutron) too.

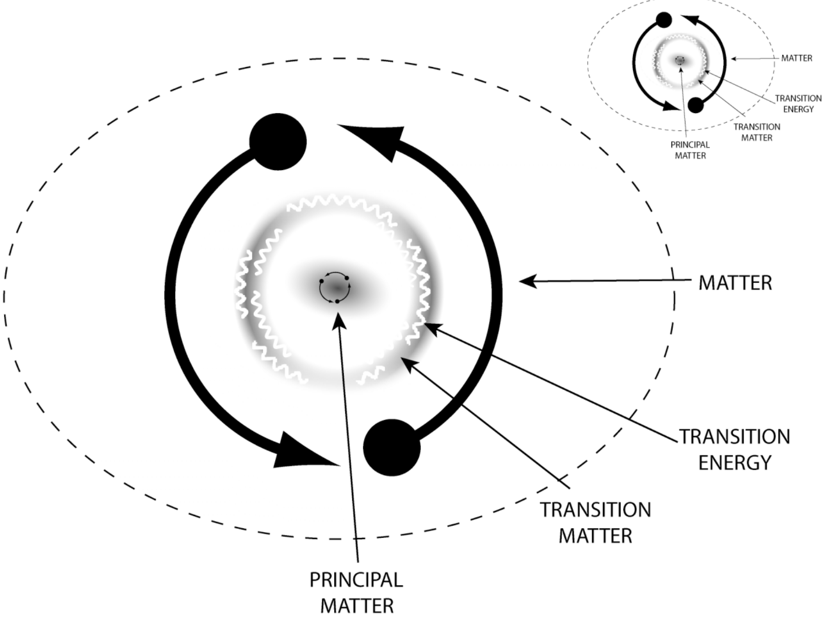
MATTER
TRANSITION ENERGY
TRANSITION MATTER
PRINCIPAL MATTER
MATTER
TRANSITION ENERGY
TRANSITION MATTER
PRINCIPAL MATTER

Fig. 18 The structure of gans of an atom

The gans of elements (Fig. 18) are created through the same process as of known atom directly from the rays of light or through the decay of the neutron of the gans going through its nuclear decay and creation of its own gans of the same elements in atomic state.

It can be said that the gans state of an neutron or atom is internal magnetic and gravitational fields strength dependent, where atom or nano of matter of the same element is environmental magnetic fields strength the like of heat and pressure dependent (Fig.19).

In this illustration the difference between the internal and external magnetic fields forces and processes which lead to creation of gans of matter structure of neutron respectively are shown.

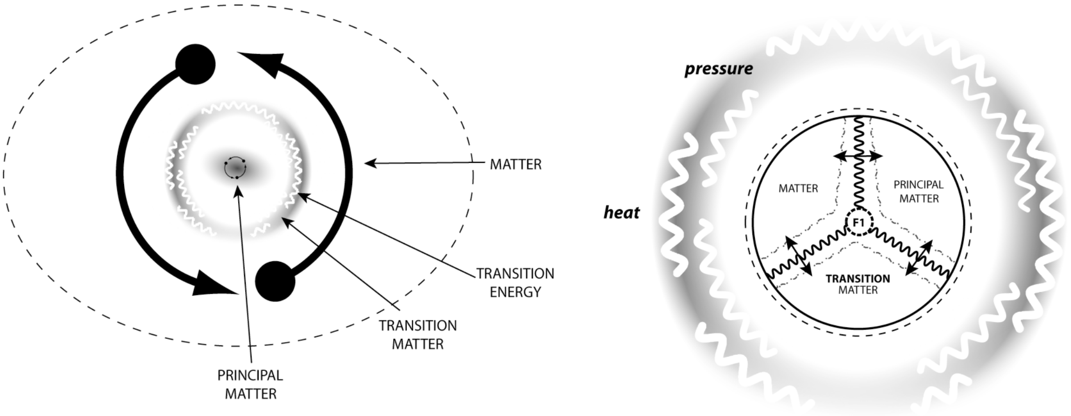
MATTER
TRANSITION ENERGY
TRANSITION MATTER
PRINCIPAL MATTER
pressure
heat
MATTER
PRINCIPAL MATTER
F1
TRANSITION MATTER

Fig. 19 The comparison between the gans of neutron on the left and the fundamental plasma (neutron) on the right

The gans state of matter is the reasons why for example the molecule of gans of the amino acid (Fig. 20) in the structure of protein and other cell structures the like of in the leaves of plants have tangible, flexible, soft characteristics that they can be manipulated and not being rigid hard.

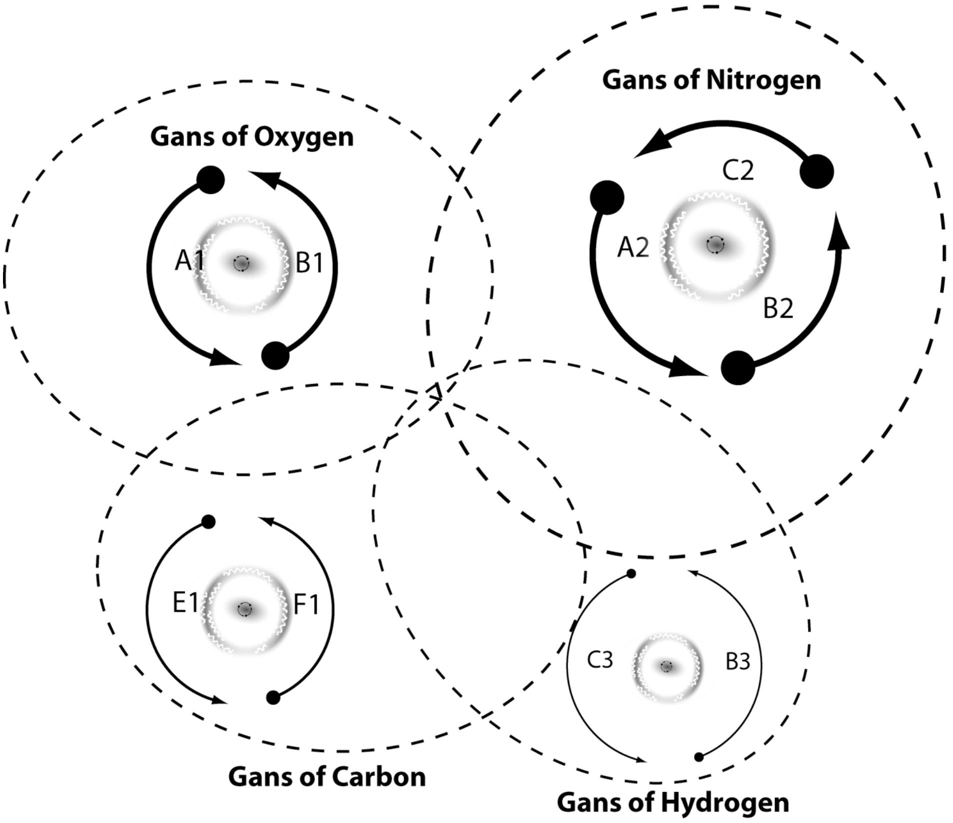

Fig. 20 The structure of a molecule of gans of amino acid

May be it can be said that gans is the solid state of matter of living entities. That is to say the structure of the protein is one of the molecular states of the gans in matter magnetic fields strength environment. Where, through the gans state of matter as part of the cell of the living beings this makes the transition of pmfs needed for rapid transfer of given mafs much easier as by the availability of the gans of an atom rather than nano of atom, this makes it possible to transfer the information of the matters as magnetic fields and not the whole of the atom from one atom or molecule to another as has been assumed by the world of science up to now, and hence once the right measure of the mafs are transferred to a cell then through accretion of mafs in the vacuum of the body then a new gans cell is produced.

Where, for example, if one pinches oneself flesh or skin, what one holds within its fingers are gases of oxygen, nitrogen, carbon and hydrogen in state of gans of the matter, otherwise the body of the man would been a balloon of gases and not in the state of matter as one finds between ones fingers.

At the same time the energy transfer to the already existing cell is due the transfer of pmf of mafs from one cell of gans of lymph to the existing cell. By the same measure as the cell uses its appropriate mafs and is left with wrong or mis-measured amount of mafs for its use, then the cell transfers these pmf of mafs to the blood cells for their removal from the body's systems. This being the reason why for example one does not finds residual of urine in the blood, but as the blood passes through a different dynamic gans molecular structure of the kidney, then the mis-measured mafs in the gans blood cells are reconstituted as liquid and appear as urine in the walls of the bladder.

This applies the same for the transfer of the molecules and atoms of the minerals and vitamins which in fact are mafs of different combinations.

In reality, the world of science and humanity always have known this state of matter as part of the structure their own body but they always have considered it as molecules of the same element and not as another state of matter, thus gans can be considered as the **fifth state of matter**.

This condition of gans of matter is to be explained as the gases when their physic-chemical at ambient temperature and pressure and due to internal gravitational and Magnetic field's strength of the atom the atom physical appearance the atomic structure of the gas ***changes to a compact configuration of the solid*** and as the atom of the same gas become and behave like solid but ***with totally new properties and characteristics*** which has never been known as when the atom was in its other three initial known states (gas, liquid and solid).

This ***conversion of the light rays to solid state*** occurs in the **outer regions of the solar system**(s) where the gravitational field forces (vacuum) are low and the temperature has no effect on the internal motion of magnetic fields that create this solid state of matter. Then, as the ray becomes and appears as gas and in a given conditions manifest itself as the nano structure of gas or what is called "GANS" in the same environment *due to atom's own internal Magnetic and gravitational fields configuration* and ***not due to*** *its environmental magnetic fields.*

This state of gans and gas of an atom is being the *same difference as between* ***the mass*** *and* ***the weight*** *of an atom* respectively, where **mass** is due to internal atomic interaction of fields of the atom and irrespective of external field forces and where the **weight** is due to environmental magnetic fields effect on the outside appearance of the same mass.

Humans are familiar with the gans of the molecules and atoms as integral constituent of their own tangible body, where ***gases at low internal vacuum condition*** *of the body convert* ***gases into gans or soft individual solid atom state***, but up to now the scientific world has never considered this state of matter as they just say for example the carbon of protein chain or matter of a cell or a carbon as part of the structure of a sugar of a leaf of a plant and so one. That is to say for example, when an atom or molecule of a hydrogen gas, which was created from the ray of light as this gas is absorbed by the human body then this gas of the atom changes to the gans of the same atom and then through the accretion process in vacuum condition of the human internal operation, then this gans particle according to its Magravs strength becomes part of the molecular ganses of the **N-C-O-H protein chain** of the human and that is why human body becomes tangible entity. Where, the creation of the solid gans in the atom of the gas of the atom, this process by itself is due to the accretion process of all the fields of the mafs of the gas atom itself.

If this change of state of light to gans does not take place, then the human body should have been a balloon of gasses and not in the solid tangible arms and legs and so forth.

Further, it has to be said that as the light ray changes to the atomic gas of the hydrogen and as it reaches the planetary condition and natural Magravs state of planets this matter changes to gans atom of the same matter in the atmosphere of the planetary entities too.

The confirmation of the production and existence of the gans in the Oort clouds and Kuiper belt is and can confirmed by the existence of the hexagonal rings on the top of atmosphere of the poles of the Planet Saturn. Where the composite dynamic layers of nano gans of material(s) in this part of the planet leads to creation of the hexagonal shape solid clouds as has been recorded by pictures taken the scientific world from the pole region of the planet (4).

The only reason that one sees these types of structures in the universe is primarily due to existence of gans state of matters like hydrogen, methane ganses and others in these layers, as the Magravs of the planet interact with dynamic metallic characteristic structure of the hydrogen gans and other matters ganses and this nano state of matter in dynamic magnetic fields of the poles of the planet leads to creation of current in between these layers and consequently for example in the poles of the Saturn the formation of hexagonal shape rings of the clouds which is the consequence of these interaction , which are natural positioning for the gans in dynamic mixed and composite magnetic and nano structures.

To create the hexagonal shapes of the clouds in the north-pole of the Saturn one needs at least three layers or mixture of three different ganses of different or the same elements to be able to create these shape features in the upper atmosphere clouds of this planet (4).

In reality gans's of matters behave as semiconductors do in the matter environment, with the difference that the gans of matters are *always as they are in a* ***semiconductor state*** *and at the same* ***time they create current*** *in any environment* due to their internal dynamic magnetic fields structure.

On the other hand, the conversation of the light into gans and its absorption and their interactions with the strong Magravs producing planets like Saturn is the cause and producer of the internal Auroras that are commonly observed at the poles of the gas planets. Where these auroras are due to the fact that as the gans of the elements from Kuiper belt gets absorbed into the giants planet atmosphere and as these ganses are in solid atomic matters state the like of the cosmic dusts and in their interaction with the magnetic fields of the planet, these interactions of the gans and the magnetic fields of the planet leads to creation of the Aurora at the poles of these giant gas planets.

It is essential to understand the fundamental effect of the light rays mafs of the matters' in the solar system and even in the creation of the solar systems and planets themselves that one can understand why the rays of light are the transporters of creation in the universe as in their conversion they become the created entities the like of atoms, cells and so forth due to their pmf strength of their environment. Where, in fact the lights in becoming the gas of the matter, then they become the source and the cornerstone of the creation in all matters levels of the universe. Thus as light changes to atom and gans then in the right environment of for example one G (gravitational field strength of the earth) as on earth then the collection of atoms as the molecules of ganses state of matters leads to creation of the beings, the like of single cells and complex combination as of the human's body.

Light ray from the Principal Star (black holes) as it loses its strength and becomes to matter mafs state strength and then it becomes to the nano and atomic level of the matter strength of the fundamental element of atom of hydrogen, it is at this point, where this matter generates the first external gravitational and magnetic fields or what is called the Magravs of itself in matter environment that this tangible entity due to its Magravs positioning and strength in respect to other Magravs that it can be attracted by or attract to itself the same and others elements in the same environment. Then it is at this point that the light becomes physical entity and the seed of the stars and planets and the essence of the tangible entity in the all matters environments of the universe.

In the spans of the solar systems, galaxies and cosmos as the gans and atomic of the hydrogen interact, they create the first seeds of creation of more powerful Magravs that leads to attraction and conversion of other light rays in the universe into liquid and solids, which these interactions leads to creation of galaxies, stars and planets, where the light itself in different strength becomes the tools of the division of the hydrogen for it to start the cycle of creation of intelligence and creation of the lives in all corners of the universe (6).

The gas and gans of hydrogen becomes the dynamic fuel source of creation of the magnetic fields necessary for the creation and establishment of the stars and solar systems and their planets, as the interaction of different magnetic fields of gases and ganses lead to the creation of the initial

Magnetic and the gravitational fields needed for these celestial bodies to be created in the universe. The existence of nano materials in the core of the planets like earth has been initially disclosed (1), now it can fully be understood that how these nano materials in state of nano matter, gas and gans become to exist in the centre of these celestial entities and be the initial seeds of their creation.

It is important to realise that due to internal structure of the nano material in layers and in gans state, these materials by large keep their structural integrity, where high external environmental matter conditions like pressure and temperatures cannot affect the total structural integrity ***once they are in individual matter gans compound state***.

This meaning that internal structure and molecular binding of gans and nano materials in nano layers or composite structures will not be affected by the matter environment's the likes of temperature and pressure condition of the environment. But the gans will be changing in its structure when conditioned to high level dosage of radiation.

For example, this is one of the reasons, why the DNA of the human being is venerable to changes and absorption of radioactive energy and in the radioactive environment or to burst of radiation, as the real structure of the amino acid of the protein of the DNA chain is made of gans of matters and not solid matter of the same gases (6).

In these conditions the gans of the matter receives radiation in the upper levels of the matter mafs strength and hence it has to accommodate this extra pmf of radiation hence the gans reaches a new magnetosphere pmf strength and consequently the gans of the atoms of the protein which has absorbed the additional pmf has to accept a new positioning in respect to other ganses in the chain, hence new positioning means new additions or new configuration in the setup of the DNA and hence new changes and hence slightly new chain configuration or alteration (6).

The property of the light in gans state make the gans venerable and receptive to changes due to the magnetic fields spectrum in all levels of mafs of the matters strength, this be it from the higher order mafs of the principal matters fields to lower pmf strength of below matter environment. This being the reason why DNA due to absorption of for example high level radiation or strong ray can change its configuration this leading to new permutation and change in the characteristic and change in parts of the being characteristics of the living matter.

Through this process of Magravs positioning and that all Magravs needing to be in their given position in the DNA chain that one observes the consistency with structure of the DNA for every living entity in the universe, which these chains of protein positioning become entities exclusive to that of a given being or entity. Now one can understand how light and its process of conversion, fusion and amalgamation lead to creation of exclusive structure of DNA and creation of beings (6).

Scientists due to old understanding of creation of magnetic field consider that the earth has an iron metallic core which due to its motion through convection theory leads to creation of Magnetic fields of the earth. The fact that the Sun does not possess a metallic iron core but it has large and powerful Magnetic and gravitational field forces; hence the existence of iron in the centre of all dynamic rotational bodies is not a common and acceptable principle and natural order of creation of Magnetic and gravitational fields in the universe.

In truth the plasma of neutron does not possess iron core, but it goes through the decay and division to make plasma of electron and proton and in this process of decay neutron does not go through iron energy balance condition as has been claimed by the cosmologist that this is how they consider stars reach the point of no return due to the creation and solidification of iron matter in their central core. And at the same time geologist consider iron core of the earth is reason for the planet possessing

Magnetic fields.

The method by which the Magnetic field's (repulsion of fields) and gravitation field's (attraction of fields) are generated exponentially increased in all planetary, solar and galaxial object are initially and primarily through the magnetic properties of the plasmas, nano and gans materials within the centre and internal structure of all celestial objects. As in the inner cores of celestial objects the ganses of the matters due to their mafs and through nano layers or different composition of collective crystal and magnetic fields structure they become or behave as the best insulator and conductor simultaneously in their environment, where the gans and nano matters, and their mafs and their properties ***changes from conductor to insulators*** as these matters behave as semiconductors and metals and at the same time due to their dynamism of their pmfs this leads to the initial and then partially continues production of the Magnetic fields and gravitational fields of the star or planets respectively (2, 3, 4 and 5). It is at this point that magnetic properties of the nano and gans materials in their interaction lead to creation of Magnetic and gravitational field's forces, this leading to creation of the independent mass and magnetosphere of the new entity.

Through the gans internal disassociation of its mafs structure as the internal principal mafs of the structure unwinds rapidly and when this transition to matter level strength is very rapid, then this lead to release of the high temperatures and strong rays of light in man's protein and the visible magnetic fields spectrum strength and hence detection of the release of spectrum of magnetic fields of the light rays.

The gravitational properties of nano materials and the creation and attraction and absorption of matters from the environment have been explained in the paper published in detail (5), at the same time matter cannot attract or gravitated towards another matter if both are not in possession of magnetic fields, where at the same time it has been confirmed (5) that nano materials possess magnetic properties and as magnetic fields interact then nano and gans materials create their own gravitational field zones and environments; and in having nano and gans materials in the centre of planets and stars this indicates how the gravitation fields (6, 7) of all dynamic systems and objects in the universe are created.

Ganses being in the right magnetic fields strength environment due to their Magravs strength these materials ***will convert into gravitational zones in their environment and attract light and in turn absorb, create and release energy***, where this energy leads to creation and attraction of gases and their conversion as for example the same process in the human body to solid state of matter at room temperatures, where in test it has been shown that this process of absorption or conversion of the gas to gans leads to creation and release of energy and similarly vice-versa. As for example in absorbing CO2 from its environment the plant releases energy into its internal structure to be used for conversion of minerals to food for the plant to assist with its survival and growth.

Thus the truth about how even the heat of the body is created is far from the present assumptions which the scientific world has led the man to believe, as they themselves never understood the real working of universe and the process by which matters behave and operate in its low vacuum conditions.

This concept and process has been tested, explained and published in detail in Chapter 4 of this book, where for example in capturing gases of CO2 from the environment and collecting it as gans as a tangible entity at room temperatures and pressures, the energy released through this process is use to light and run lights and motors respectively in the lab by independent scientists as has been published in the journals in May 2010.

Whereas, in this case energy is released is in a similar way as it happens in the human body, when the light or magnetic fields of the light enters in the micro vacuum condition of system or the body and in receiving the light rays and in trying to entangle or go through the process of atomic-entanglement in gans level and then accretion, this process leads to release of the surpluses energy and then accumulation (accretion) of solid ganses which appear as cloud of matters in tests and in human body which then this become tangible structure of matters of the body and the surplus energy is released as the heat of the body or it is used for the communication system of the body.

This process of accretion is one of the sources of energy release in the living body entities and in experimental testing this released dynamic energy in the level of plasmatic magnetic field strength of an electron produced through this process become the source of power and is enough to light a LED for several months, as this process is a natural process as long as the light or other rays can penetrate the liquid, jell or soft tissue condition of the system this process can continue.

The other important reason that one finds water in this solar system is primarily due to the fact that pmf and Magravs strength of this solar system and the ones like this encourage and enforce initially the production of gans of magnetic matters the likes of oxygen, which leads to creation of liquid state of matter of water.

At the same time it is curtail to understand the structure of three and two dimensional properties and characteristics of the same atoms in layering and physical positioning. The gans of the matter is captured and held in three dimensional states, where gans of matters gravitate and make dynamic clusters of ganses around themselves and become dynamic entities, whereas, in the linked version of the same atom clustered the same matters in solid state makes layer and gives and possess totally different properties and appearance.

The light in its conversion to atom of gas or atom of gans according to its given environment then will take and enforces its preference estate of its manifestation, and with slight change in level of its internal vacuum (defined as availability of Magravs and their strength) then the light will appear as the gas of an atom or a gans of the same.
It is interesting that scientists and scientific organizations are not in possession of tools at this moment to identify these two separate states of matters of the light in visible entity of matter and hence always consider all matters as the atoms and in presently considered four states' of matters as has been tradition.

The same ray of light when changes to gans of the hydrogen atom, this change's its dynamic diamond crystal structure of the same matter and hence this gives the same matter insulating properties and hence allows the creation of conductive and isolative properties of the same element in its layering and clustering structure and its dynamic properties in between the same elements of atoms of the gas and gans.

The gans in specific condition has diamond crystal structure of the hydrogen atom and with slight change in its environmental condition become a conductor for short or on a long term. Where this has been experimental prove and demonstrated and then clustering of this structure mixture of gas and gans of the same atom leads to creation of multi-layers of conductive and isolative matters of the same matter and hence in the dynamic magnetic environment of the universe this leads to creation of different and stronger Magravs, and start of attraction and positioning of different matters towards these initial seeds of gravity and Magnetic fields and hence start of creation of initial celestial entities like plasmas of neutron, atoms, stars and galaxies.

This is the reason, for example why the same matter of carbon becomes to be the best conductor as nano layer Sp2 and the best insulator as the diamond crystal insulator structure known as Sp3 across the same layers or through its layers respectively where the production of such a mixture has been independently confirmed by Ramon spectroscopy of these structures produces as layers on a given surface. Therefore all elements and molecules or their combinations can have both Sp3 or Sp2 structure and property at the same time and in the same environmental condition.

This being the like of the protein chain, where each gans of each element exist individually and collectively in the amino acid as molecule of gans as each element plays its individual role which can affect collectively the operation and existence of the acid in its given environment (6).

In understanding the concept of the conversion of light rays to gans and gas and creation of nano materials, this discredits the present philosophy of the planets needing solid iron cores which enables them to create their Magnetic fields that they can operate in the universe or even the human race could be brought to the earth from other places from far corners of the universe. The life on earth is the natural product of lights' motion and its conversion in the internal activity of this planet and solar system.

By the same measure light plays in different environments different roles which can lead to creation of the same and similar or totally difference combination of creation of molecules of gans, which these manifestations of difference appearance of the light are environmental pmf mafs strength dependent. This is to say that life is not and shall not be the exclusivity of this planet and this solar system once on understand the principle of creation and motion of the light rays in the universe.

Thus the centre of the earth does not need to have solid iron core for it to possess Magnetic and gravitational field's forces leading to creation of life on the planet too. Whereas, composite elements of nano materials, gases and ganses crystal structure of the same element in the inner cores of the planet can lead to creation of the same Magnetic fields and gravitational fields of the planet.

This explaining why even some planets like Saturn possess Magnetic fields, even though these planets could possess some solid matter as their constituent materials as part of their inner structure.

In reality as layers and layers of dynamic gas and gans are piled-up in the centre of the planet the effects of dynamic magnetic layers exponential strength that they make as the Magravs of the planet take hold and this phenomenon lead to creation of stronger fields that can span billion of kilometres in the solar, galaxial heliosphere in the environment of these entities.

Thus the transition dynamic helixial cylindrical ray of light in slowing down in a given environment Magravs strength, this lead to creation of specific matter in that given Magravs strength environment.

The scientific world has to understand that the state of gans of matter is a natural phenomenon in the world of creation, this meaning as man has learned about the solid, liquid and gas state of matter, as these states of matters are due to temperature and pressure difference in the environment of these matters, but there is another state of the same matter even though as it's like a gas and behaves and exists as matter in form of liquid and solid but due to its internal gravitation fields forces of its atomic structure this matter for its appearance and properties is ***not external environmental dependent***.

The gans or the gas in nano state of solid state of matter will play an important part in the future of the science and technology. That is where the same atom behaves like a gas, liquid and solid at the same time depending on its own internal magnetic fields interaction in its plasma and not of the external environment conditions around the plasma the same matter will be in dynamic solid state at room temperature at all-time irrespective of the environmental condition.

That is to say the plasma of an atom of gans receives or coordinates its own Margravs and its own Magravs positioning in respect to its own electron and proton and other gans structure.

Thus, gans is the state of the structure of the light which has changed from dynamic cylindrical plasma of magnetic fields to a dynamic spherical entity of the same matter mafs, which its state of manifestation in matter environment is internal gravitational dependent and not environmental condition dependent. That is why one can observe the same element in coldest and hottest regions of the universe and still misreads them as atomic matter rather than nano-atomic or gans of the same matter.

This is how some of the plasmas and rays ejected by the Sun, depending on how they arrive at the Oort clouds and Kuiper belts then become nano materials of gas or gans and in clustering with other matters and ganses become part of the meteoroids or asteroids and look as they have been there from the time of the creation of the solar system.

In the universe and solar systems of the right Magravs strength, the light changes into the nano hydrogen and through internal magnetic fields of the solar system through the principle of magnetic balancing and accretions this matter elevates to the next magnetic material, which one of these materials' is the gans of the oxygen. This element due to its Magravs positioning and balancing in the Magravs of some solar systems lead to creation and production of water molecules in the Oort clouds belt and then these water nano particles gets pulled back into the inner parts of the solar system as nano ice particles of gans of this material which for example one observes them in the rings of Saturn.

The ice particles in the ring of the Saturn are there and for ever are produced by the return of the rays of light which were released by the Sun itself, on their way back to the Sun as gans and ice particles and they are temporarily trapped and positioned in these rings, and the present assumption that these ice particles exist in these rings are not by the crash and splitting of meteoroids or asteroids into smaller pieces that afterwards have stock in these rings of the Saturn as can be observed at the present time.

Thus as the light reaches the outer boundaries of the solar system, its becomes nano material, which due to their magnetic properties, this leads to creation of a nano magnetic material which is oxygen and then this matter of nano particles gans of oxygen to find stability for its Magravs, this attracts two atoms of gas or gans of the hydrogen nano particles, which this leads to production of gans of ice looking particles of water in the Oort clouds belt of the solar system, which they move inward and become the liquid magnetic substance and the source of the life in this solar system.

Thus the water in the solar system is generated by the rays of the light of the Sun itself mainly and by no other source and hence water is produced in the solar system by the recycling of the light rays of the Sun itself.

The mixture of these ice nano materials with solids matters of the solar system leads to creation of meteoroids, whereas these dynamic objects in traveling between the Oort clouds and Kuiper belt, these objects attract nano water molecules and then they return to the inner regions of the solar system. This being one of the reasons why the meteoroids are seen on regular basses and their size never changes, but their vapour trail tells the existence of the water residuals in their structure's as forever these objects gets replenished with the Sun rays in the form of gans of water in these outer regions of the solar system and return back into the inner parts of the solar system.

Therefore the theory that water is brought to planets like earth by meteoroids as has been assumed is partially correct, but Magravs of planets like earth in the Magravs of its Sun have the ability to convert light to nano matters and nano matters which have been produced into hydrogen and molecules of water through accretion process in the vacuum of the solar system and in the upper layers of the earth atmosphere itself. Hence water is the creation of the combination of atoms created by the rays of light and in different magnetic fields conditions in the Margraves environment of this solar and planet system.

This process of conversion of the light can happen anywhere in the universe as the nano particles of the hydrogen is one of the first and weakest Magravs strength that light can change to matter anywhere in the Magravs strength of this universe.

Thus water is not exclusivity of this solar system and is product of the light rays of the universe in matter environment.

There are waters like substances in other matter mafs and matter strength environments in the universe too.

It is important to realize that all gans have the magnetic properties with the difference that oxygen is the one of few common magnetic materials in the solar system and in most of the universe needed for braking of the light itself to lower level strength, which can lead to creation of intelligent life. In some solar systems and galaxies pmf strength of the gans of the matter of the oxygen is the common magnetic elements and the reason why all maters existence dependent upon availability of this matter in the pmf of the environment.

In the living bodies in possession of systems the like of the lungs and gills in fish, the light in changing to molecule of oxygen and in being inhaled for their existence, in these systems contrary to present belief the atoms and molecules of the oxygen will never cross the boundary of the structure of the lung or being absorbed by the blood as has been thought and promoted by scientific world (6). The fact is that in the process of inhaling or in case of fish by passing the water through its gills, the atoms of oxygen simply passes limited value of their matching plasmatic magnetic fields strength to its matching oxygen atom of protein of the blood cell that the blood cell as commonly called gets oxygenated in the lung (6). In reality no oxygen atom or molecules ever passes the walls of the lung as has been assumed, but the oxygen atom transfers its pmf to the bloods oxygen atom in its protein and then this pmf is carried through and by the same principle as the pmf from the oxygen of the blood protein cell is passed on to other oxygen atoms ganses in the protein chain of other cells in the human body (6) as they come across their corresponding mafs strength protein in the blood.

The oxygenation of the red blood cell is primarily another quantum-entanglement of the same matching matters strength or entanglement transfer of adequate amount of pmfs of specific cell of the matters of blood.

The fallacy that oxygen atoms cross the walls of the lung is so far from the reality of existence that as saying a man can walk through a solid wall. This hypocrisy has been the consequence and through the lack of understanding of the real structure of the oxygen and its origin being laying in the structure of the light that matching plasma of light and atoms can/and frequently entangle and transfer their pmf up to level of their mutual strength that existence can be guaranteed in one form or sub-structure of the same and without the plasma of actual solid atom crossing the boundaries (6) of the lung.

In fact the energisation of the red cell is through transfer of the pmf of the atom of oxygen and not the actual transfer of the crossing of oxygen into the blood stream and the brightening of the red cell passing through the lung is like the variable light switch, that as one increase the current through the

light the light shines brighter, this is the same process and in the same way as the red blood cells receive the pmf of the oxygen, then the blood become brighter or richer in pmf, then the blood cell after transferring its pmf to appointed cell in the body then pmf strength of the blood cell is reduced in energy and illumines less, dimmer or looks darker as it returns to the lung to be recharged (6). Man has a lot to learn first about his own body before he can conquer the universes.
In understanding the function and the fundamental properties of the gans and molecular gans then computing systems can be produced that not only they think the same ways as humans do but due to their dynamic energy and singular directional rotation, then at this point the first quantum computing systems can be produced that these computers will be exact copy of the human brain and muscles in structure with the same multi-neuron-cross linkage and communication channel, as these channels are created as gans molecular Magravs linkage will allow them to have the same simultaneous multi-cross connection that these quantum gans of molecules structures will be exact parallel systems as do the human brain in all aspects of a real working structure of logical system, which even they can carry emotions as well as control and logic. Where, in fact the binary gans and twin gans sets will be the future of fast thinking units needed for the high speed control logic system for space systems travels of the future.

As there are gans in the matter environment mafs strength then there are gans in pmf strength of principal matter and transition matter too, and at the same time the gans of matter in all mafs strength will operate in all levels of pmfs strength. Thus it is possible to produce molecular gans unites which work at high speeds and with same emotion and logical systems as human brain, but with speeds that are far exciding speeds of the human brain processing capabilities.

Therefore it can be said that for the first time the man has the capability and the knowledge of not only producing solid gans of gas at room temperature, but it can go one step further than present conceptual nano matters and nano matter based computers and start working on real brain based matter structure logical systems by using the gans of the gases which are the building block of the human amino acids.

But the question is that would we as far as building the first human operational brain and body using these matters as we have already decoded the DNA of the human genome, and as we know the full chain of the DNA sequence and we have already unravelled the mechanism that the RNA produces it energy and current for its internal communication and control of the internal systems of the DNA, then would man become the creator of new beings bases on human structure and would the discovery of the gans and simple method of its production will allow the ethical question of mass replication without the need for stem cell or even egg and sperm, which are memory banks of human survival on this planet. Would man will make one of his own with a clean DNA memory. OR is the human being to become the god of new generation of beings.

This is not the first time in the universe that one created has the ability to reproduce another of the same, but at the same time this discovery of structure and properties of the gans would have become apparent to man of science in due time as he would have progressed in his scientific conquests.

Some scientists believe that solid iron is the main magnetic matter in the universe and this matter in the centre of the stars and its energy balance conversion between its fission and fusion is the point when stars goes through their slowing down process or reduction or what is known as their nova state. The truth is that the plasma of mafs of the simplest structure of the plasma is the common and the fundamental and elementary magnetic entity in the universe. Thus the plasma of the light is the basic and common magnetic matter in the universe and one does not need iron to reach this point, as the plasma of matters in given position can lead to unbalancing of their total environment pmf mafs and Magravs, this leading to total disassociation of the all matters in any matter or object in the span of the universe, and once the process of the chain reaction of disintegration and disassociation starts then the whole entity disassociation from each other begins and in the case of plasma of neutron and star at this point disintegrates to re-association in a different as plasma of proton and electron and new star and planets in their form in difference point and place in their given environment.

By the same measure the plasma of neutron which is created by the conversion of the light ray is the common magnetic matter of the solar system and not atoms of iron, and in reality the light of the Sun and its Magravs dictates this property of this mafs of the matter and the present assumption that energy balance conversion of iron is the cause of their nova cannot be correct and as most of matters in the universe are created because and through the existence and the operation of principal matters in the centre of the stars and their rapid unwinding and balancing of their Magravs in the centre of the star leads to the expansion and disintegration of the star and not as has been assumed at this point by some cosmologists due to the iron fission-fusion balance (3,4 and 5) phenomenon.

What has been explained above, this is the process of creation and recycling of the light through its full circle of its existence from matter to light and from light back to matter(s).

The detailed information and explanation about the existence of the gans of the matter has been possible due to through series of tests which has been carried out and absorption of the physical solid CO2 at room temperature has been confirmed. The procedures and tests results in confirming the existence of this new state of matter was originally published in 23.12.2009 by the Keshe Foundation on its website. For those whom have not been able to read this paper a copy of the same is published in this chapter.

The state of gans of matter can now explain about the truth of life in the universe and this opens new horizons in the world of energy, new materials, production of more natural components of the human body parts, production of new medicine, new types of food processing technology, which this eliminate the need for present farming processes to feed the populations, as protein can be produced from the content of the light or the mixture of composition of lights mafs in gans state of matter that can lead to production of solid matter the like of fresh meat and or composition of dairy milk and so forth. Thus through production of gans dependence on the extensive farming in the space becomes irrelevant, where in deep space by absorbing weak residual mafs of the light and in bringing them together and through accretion, then producing the gans of the fundamental plasma, then producing the gans of fundamental atom and then through accretion creating composition of ganses of protein, then one can produce any food in the span of the universe directly using the matters of the light. Originally this concept of producing protein through gans from the gases of environment was considered and successfully tested in Tehran in the summer of 2008, and through simple process the first gans of protein in small quantities by using the natural air at room temperature was produced.

In the appendix section of this book, attached is the paper titled “The unifying field theory” published in the 28.10.2009, in this publication it is discussed and can be concluded that the origin of all entities, tangible or not are magnetic fields and the interaction of at least any two of any magnetic fields of any strength can lead to creation of all other effects and matters which are observed in the universe.

Thus the magnetic field is the unifying field and the mother and the seed of all created and creation in the universe, thus the magnetic field is the Holy Grail, which the scientific world had been searching for in the universe strength to connecting all fields and effects observed in the universe.

Chapter 4

CO2 in Gans State (paper 2009)

Direct absorption of carbon dioxide CO2 and methane CH4 gases from the environment and their conversion into nano solution and nano solid matters and production of energy and oxygen by the use of nano compound at ambient temperature and pressure.

Abstract

In this paper, results of processes will be introduced for the absorption of carbon dioxide CO2 and methane CH4 gases direct from environment and their conversion into nano materials of the same suspended in solution or dried as powder. Where, concurrently within the processes of extraction of these gases in a simple reactor, we have managed to produce energy and oxygen.

Discussion

New methods for absorption of CO2, CH4, and others gases and further conversion and preservation of these elements in their nano solid state of matters at room temperature and pressure has been developed and achieved.

We have developed simple processes by which carbon dioxide CO2 and methane CH4 gases can be extracted from their environment where no additional heat or pressure to achieve this has been applied.

At the same time conditions can be created within these systems that CO2 in conversion without going through any chemical process, can lead to creation of methyl, oxygen and methane gas and vice versa.

Where during these processes of CO2 and methane gas extraction or conversion we have managed to produce usable energy and oxygen molecules in sustainable way.

Production and extraction of CO2 by applying energy is a known technology in the present science, what is new with our technology is, that not only CO2 is extracted in a simple system at room temperature and pressure, at the same time, energy released through absorption and conversion of the captured CO2 to formic acid, we have developed simple techniques to capture the energy release from this transition process to produce useful power.

The novelty with this new technology is that in previous state of art technologies, engineers and scientists had to add energy to extract CO2 the environment or to produces O2, where through our technology, not only we generate useful energy while absorbing these gases from the environment, but also at the same time, the system can produce molecules of oxygen.

Thus, this simple system has the ability to replicate the processes as in a natural way as plants achieve in their conversion of CO2 into oxygen.

With this technology, CO2 and CH4 gases are absorbed and attracted into and within the solution in their nano state, and then they are allowed to amalgamate to produce gel like residual solution and then form nano sediment.

Where, nano CO2 can be extracted or removed from the solution as solid matter at room temperature.

The CO2 stays in state of gel as nano materials in the solution due to their diamond crystals structure (sp3), or due to their crystal lattice structure, this creating a non-adhesion molecular bound like diamond crystals. Which, this does not allow more than certain number of molecular structures to adhere to each other. Where, CO2 nano matters once reaching a certain molecular gravitational level, as crystal, then they do not attach or cannot hold on to more than single or certain numbers of nano molecules of CO2 and form independent or nano cell of matter. Thus, all clusters of CO2 in solution have certain dimensions and that is why they stay like clouds or gel within the solution.

We have to explain that it is known tested fact to us that nano-coated materials and nano materials in sp2/sp3-state due to their characteristic of diamond crystal behaviour, they cannot be soldered to each other or soldered to another material. However, at the same time in a peculiar way the outer electron of these materials allows conductivity of matter. What this means, is that, even through they do not or cannot be attached to any other material from their outer structural boundaries, but in being connected with each, these materials allow flow of current and voltage through their outer boundary.

In a way, these behave like quartz materials, but at the same time after a number of layers, they do not or would have the gravitational pull or adhesion capability to allow more layers to be added to their layers.

Where, these layers along their grain and layer, they behave as a superconductor, but across layers in PN junction, depending on the position of PN cavity within the layers, they become best resistors. Where, we have measured the resistance of these layers and this have been confirmed by other scientists whom have tested our material of sp2/sp3, that these materials have shown to have 20 M Ohms resistance threshold barrier. On the other hand, this material on the surface has as good as resistance capacity as air and diamond.

We have further managed to obtain solid matters of CO2 from the system or dry the nano-saturated nano CO2 dilution into nano CO2 powder. Thus for the first time in the world of science we have managed to generate at room temperature and pressure nano matters of CO2 and methane through the same process.

To confirm that solutions obtained in our tests to contain CO2 and CH4 matters and these matters are in nano form, we had to under take laboratory tests of the solution with infrared spectroscopy and XRD respectively.

Further, as we know through our previous developments in nano technology, that nano materials are by principle sp2/sp3 in their character. Thus from results obtained from infrared spectroscopes and XRDs of matters during our process of absorption and nanolisation, we have concluded that the extracted CO2 and CH4 materials in solution and dry are both in nano state of matters of these gases.

At the same time parallel researches which we have found on the internet since the publication of the first addition of this paper on the 23.12.2009 done by other scientists, Dr Omar M Yaghi of the university of California released on 7.12.2009, which extracts of this has published in article by The New York Times published 4 on the 8.12.2009, this article refers to “metal-organic frameworks (MOFs) material promise of carbon capture and release, and that these materials being crystalline sponge hybrid lattices of organic compound and metal atoms that has a huge internal area where gas molecules can be absorbed."

Where we have reported these characteristics of metal-organic sponge effect and capture of CO2 in 2006, and this has been confirmed by indecent testing by major nuclear testing centre in Europe in their report in 2007.

Further, in the paper Dr Yaghi states, "***MOF used in the study contained magnetism atoms***"

Where in our previous disclosures and patents applied, we have declared that the absorption of these atom of CO2 and CH4 are Magravs (Magnetic gravitational fields) based. Which this independent scientific paper confirms our finding that CO2 and CH4 are gravitated to the water as nano molecules, and they do not have any interaction with the medium of the water, but the water *is the container and tool or catalyst to keep these captured molecules in their singular or nano state and sp3 floating condition or as a solution.*

In the same paper, Dr Yaghi refers to how material separated out CO2, which allows methane to pass.

Where, our system not only captures the CO2, but also at the same time it can capture CH4 as we have reported before. That these captured carbon dioxide CO2 and methane CH4, produce diamond structure nano matters or crystals, with metallic behaviour like, which they have a superconductor characteristics and behave like conductors.

Thus, our findings are inline with other scientists and their scientific research works, which have been reported. Where now we can clearly state these captured gases can be converted to solid nano materials, which behave like metals, and are superconductors, but in reality, their superconductivity of the matter is due to their sp3 nano characteristics and not their metallic condition.

Further Dr Yaghi states that 87 percent of the CO2 captured, at 13-degree temperature are released back by the MOF matter to the environment.

Where this is inline with our reported behaviour, that as the CO2 are extracted by these materials we have developed, which our capturing materials are metallic and organic in their real structures, these materials then release their captured CO2 in the water at room temperature in Gans (Gas-Nano-Solid) state.

Further, he states that to release the balance 13 percent of the captured gas, one-need temperatures of 175 Fahrenheit.

Where, we release all captured CO2 as nano-material into the basic solution of the system, this all at room temperatures without any heat being applied.

Further more, the Canadian company Mantra-Venture-Group has announced on Business News Network that in conjunction with 3M using electro reduction of carbon dioxide, they confirm that ***they need 6Mw of energy to extract one tonne of CO2***, which this is considered to be at the edge of technology of CO2 extraction.

Where, with our new technology we produce energy rather than consuming energy.

Where, further MantraEnergy in conjunction with use of the CO2 they capture, they can produce formic acid, using the technique developed by Dr Gabor Laurenczy. Where, he has confirmed that he can generate hydrogen from formic acid. (Video-interview:

http://www.mantraenergy.com/mantra-in-the-news/squeezeplay-zapping-carbon.html).

We clearly have shown and absorbed CH4 not only from the environment, as similarly we have reported the production of formic acid through the natural gravitational forces of our system as has been shown by laboratory tests results which are discussed below.

We have reported the production of CH3 in our system late last year as we managed to separate the CH3 and its capture in nano state of matter in our system. The production of radical CH3 from the H2O molecule of the water as the magnetic and gravitational catalyst of the system, subsequently this leading to existence of two radicals in the systems at the same time, one of the CH3 and one of an atom of Hydrogen leading to release of molecules of oxygen.

Scientists at a nuclear centre have confirmed the production of hydrogen radical through our technology in 2007 in their independent (not yet published) report.

Therefore, it has become a simpler method through our development to extract CO2 and CH4 and released it in nano solid matter in water, and at the same time have the ability to produce energy and oxygen as we have demonstrate it to independent engineers in December 2009.

Further on in this paper we show and present pictures of both matters of CO2 and CH4 in solution and solid state for the first time (Fig. 29 for solution and Fig. 30 for powder of CO2, and Fig. 31A-B for solution and Fig. 32 for powder of the CH4). The CO2 in solution and dry state has a white milky appearance and methane CH4 has a blue greenish colour.

We have mentioned Dr Yaghis' paper in this section as the findings in his paper is near to our finding and is one of the latest in this field.

The CO2 capture is well documented subject on internet and we are not here to list them to support our claim, one can refer to these on the internet to find that our claims our inline with main stream physics community, with the difference that we reported the capture of CO2 in early 2005 in nano materials on our web site and now we are reporting the first solid nano material of the gas as in Gans-state. We call a Gas-Nano- Solid state the GANS-state, which is a state or phase of transition of matters, which has bee unknown in actual science up to the release of this paper.
Meanwhile in light of our latest discovery and disclosure of the capture of CO2 as solid or in solution, our foundation will ask the nuclear centre which has done the independent test for our system in 2006-2007, that if we can release part of this report confirming the CO2 capability capture of our materials.

The CO2 absorption

In our tests and development phase, we have managed to produce a special material for the production of a new and a simple system for absorption of CO2 through the principle of Magravs field forces, rather than the chemical method of absorption of these gases. Where, the absorption principles through gravitational systems have been disclosed in full in the book, which we have published in July 2009 (titled: The Universal Order of the Creation of Matter; ISBN 978-94-6087-001-9). In this book, I have, explained in detail, the principle of gravitational and Magnetic field positioning and attraction and repulsion of matters from these systems respectively.

Through the development of these new composite materials of organic and metallic nano layers, we have managed to create specific static gravitational field forces which can be in the magnetic wave length of the CO2 molecules, or we have developed condition(s) that as the gravitational field attracted the CO2 to the material, the Magnetic field(s) within these layers cause the repulsion or the release of the captured molecules of the CO2 from the layers. Thus causing the creation of nano molecules of CO2 in the water, and as we use the magnetic fields of the water for stability and as a magnetic catalyst, they come to allow the formation of clusters of Gans of CO2 and create a solution of these nano matters, which these latter manifest themselves as a sediment in the liquid of the system at the bottom of the holding container (Fig 30E).

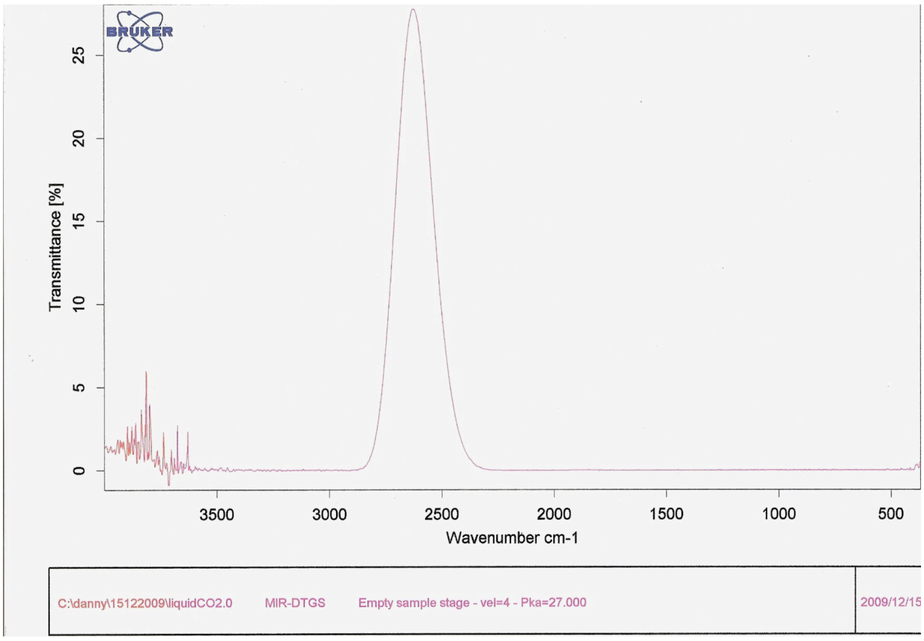

Fig. 21 Infrared spectroscopy of the CO2 solution.

The solution of nano carbon dioxide CO2 and has been subjected to infrared spectroscopy by independent laboratory confirming the production of the first nano CO2 in a solution or as gel at 2630 cm-1 wavelength of the spectrum (Fig. 21).

This is actually the best observe data as calculated and predicted figure is said to be at 2640 cm-1 (Fig. 22). (Source: http://science.widener.edu)

The closeness of the figure of 2630 showing the purity of the CO2 solid matters within the solution obtained during our test.

Where even the predicted matter has a multiple peaks, where these captured matters due to their singularity in the measured sample has a sharp and clear single peak as has been shown in Fig. 21.

This sharp peak can confirm the possible nano sp3 structure of the suspended capture matters of CO2 in this solution, once XRD test was carried out for the same sample.
For further confirmation of nano structure of the matters captured within the solution and then the solution was allowed to dry and then as a film was subjected to XRD testing.

The results of this test showed a clear match only as superconductor characteristics for this material. Further analysis with the data from XRD, a superconductor material characteristics perfect match was not found for this matter.

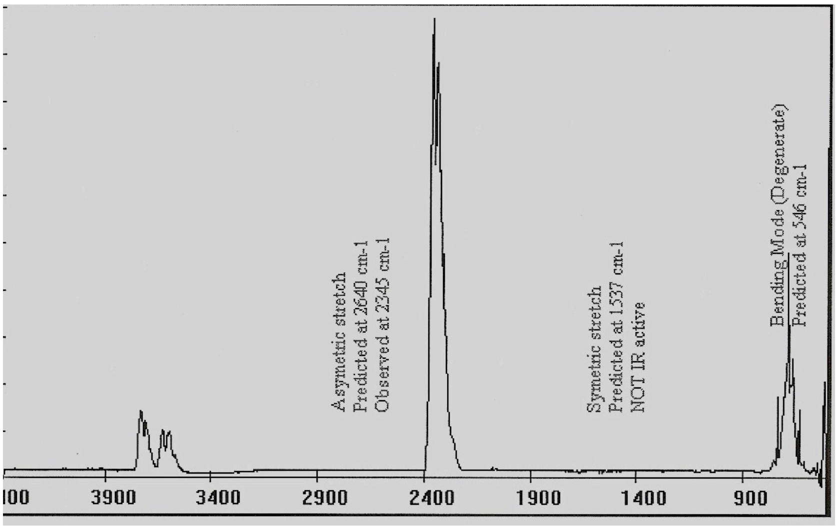

Fig. 22 Standard CO2 infrared spectroscopy graph.

With this test, and from our pervious developments and testing, clearly it is shown that the matter within the solution has superconductivity property (Fig. 23), which has new non matching data in the present collected reference data, and this is the characteristics of nano materials in sp3 state of matter.

This matter as superconductors known or ever been recorded for observation.

Thus the XRD of the CO2 data as solid and its graphs have become the new base knowledge and fundamental basic data for any future capture of these gases, once they are absorbed as a nano material in solid state.

From our previous developments and tests, we know that all nano materials show and have superconductive characteristics. Now with this test, now we have further proof that the captured CO2 in the solution is in a nano state of matter.

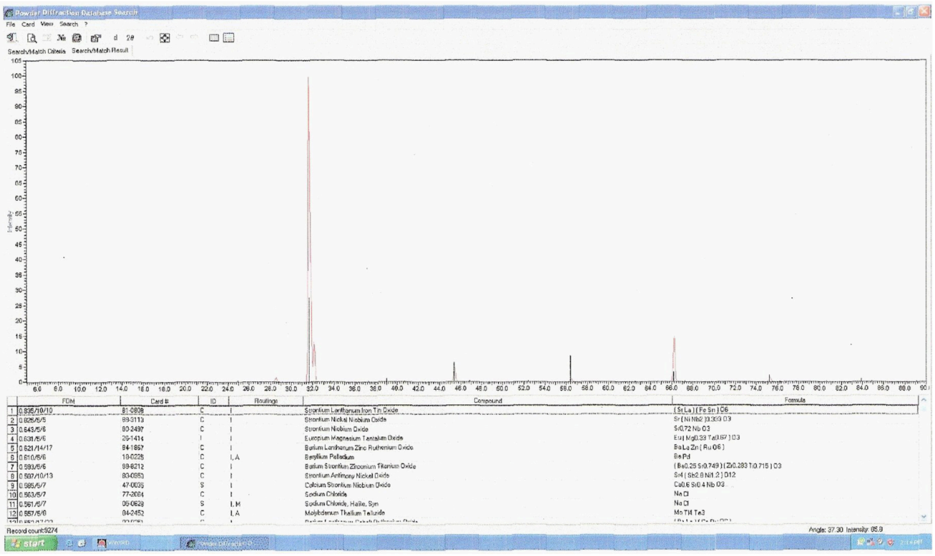
Powder Diffraction Database Search
File Card View Search ?
Search/Match Criteria
Search/Match Result
Intensity
6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0 32.0 34.0 36.0 38.0 40.0 42.0 44.0 46.0 48.0 50.0 52.0 54.0 56.0 58.0 60.0 62.0 64.0 66.0 68.0 70.0 72.0 74.0 76.0 78.0 80.0 82.0 84.0 86.0 88.0 90
start
WinXRD
Powder Diffraction D...

	FOM	Card #	ID	Routings	Compound	Formula
1	0.835/10/10	81-0808	C	I	Strontium Lanthanum Iron Tin Oxide	(Sr La) (Fe Sn) O6
2	0.826/5/5	89-3113	C	I	Strontium Nickel Niobium Oxide	Sr (Ni Nb2)0.333 O3
3	0.643/5/6	80-2497	C	I	Strontium Niobium Oxide	Sr0.72 Nb O3
4	0.631/5/6	26-1414	I	I	Europium Magnesium Tantalum Oxide	Eu (Mg0.33 Ta0.67) O3
5	0.621/14/17	84-1867	C	I	Barium Lanthanum Zinc Ruthenium Oxide	Ba La Zn (Ru O6)
6	0.610/5/6	18-0225	C	I, A	Beryllium Palladium	Be Pd
7	0.593/5/6	89-8212	C	I	Barium Strontium Zirconium Titanium Oxide	(Ba0.25 Sr0.749) (Zr0.283 Ti0.715) O3
8	0.587/10/13	83-0853	C	I	Strontium Antimony Nickel Oxide	Sr4 (Sb2.8 Ni1.2) O12
9	0.585/5/7	47-0035	S	I	Calcium Strontium Niobium Oxide	Ca0.6 Sr0.4 Nb O3
10	0.563/5/7	77-2064	C	I	Sodium Chloride	Na Cl
11	0.561/5/7	05-0628	S	I, M	Sodium Chloride, Halite, Syn	Na Cl
12	0.557/5/8	84-2452	C	I, A	Molybdenum Thallium Telluride	Mo Tl4 Te3

Record count:9274

Angle: 37.30 Intensity: 85.8

Fig. 23 XRD of the CO2 nano material

The closest match as superconductor characteristics to CO2 in the solution or in dry state of matter, this was found to be an exotic mixture of five different materials, as can be seen in the table at the bottom of the graph, with the best match reference data figures to be about 80%-90% superconductivity properties of this matter.

With the discovery of this new state of matters and the simplicity of their production and their high superconductivity properties, we predict that gans (GAs Nano Solid) of gases are going to be the next-best purest superconductor and resistor materials of the future.

Further more: in confirming the matter of solution being carbon dioxide and at the same time confirming that this matter within the structure of the solution and the system set-up has the capability of conversion to formic acid in presence of CO2 captured in the solution of water, a further test was carried out with **infrared spectroscopy** to confirm this conversion principle of the confirmed nano CO2 capture to formic acid within the solution.

For confirmation of absorption capability of nano CO2 by the solution and its conversion into formic acid, the chamber of the infrared spectrometer system was field with pure CO2 and measurement were taken. This measurement is shown as line A on graph Fig. 24.

Then the solution of nano CO2 from our test was then injected into the chamber and the graph line B in Fig. 24 was obtained.

The peak region NC in the Fig. 24 shows an increase in carbon dioxide in the solution was once it was introduced into the chamber.

This showing that the CO2 solution is extracting carbon from the chamber or causes reduction in carbon content of the chamber.

This in away showing the absorption capability of the solution of nano CO2 of more CO2 on its own independently, and confirming further from previous results that nano materials are CO2 absorber by their nature of construction, even though these matters are themselves part of the original solution.

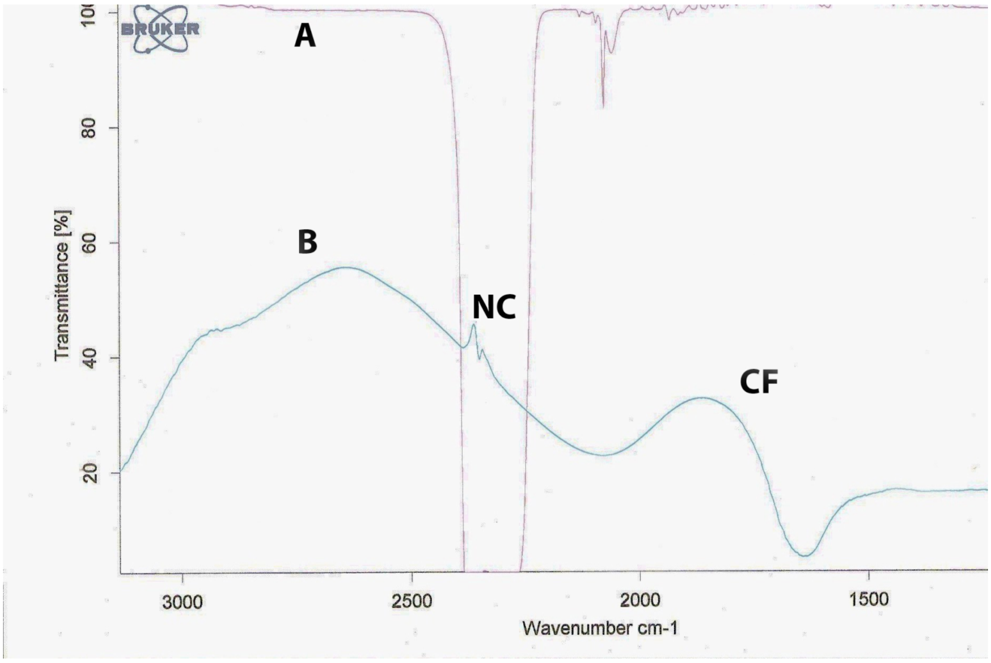

Fig. 24 The comparison graph of injection of the solution of CO2 into CO2 gas environment.

In this graph the peak NC showing absorption of CO2 from the chamber and this followed by formation of formic acid as shown in the CF region of this graph through infrared spectroscopy test Fig. 24.

The graph of the CO2 from the solution and its conversion is independently shown in Fig. 26.

It is at this point of gravitation attraction and subsequent Magnetic field repulsion that the magnetic fields strength equal to the strength of the Magravs of the proton and the electron are made available to the system, which these fields are absorbed by the electrodes within the system and then these are past to cooper wire atoms', which are the constituent matters of electrodes and cause the vibration of electrons within the copper wire leading to creation of current in them.

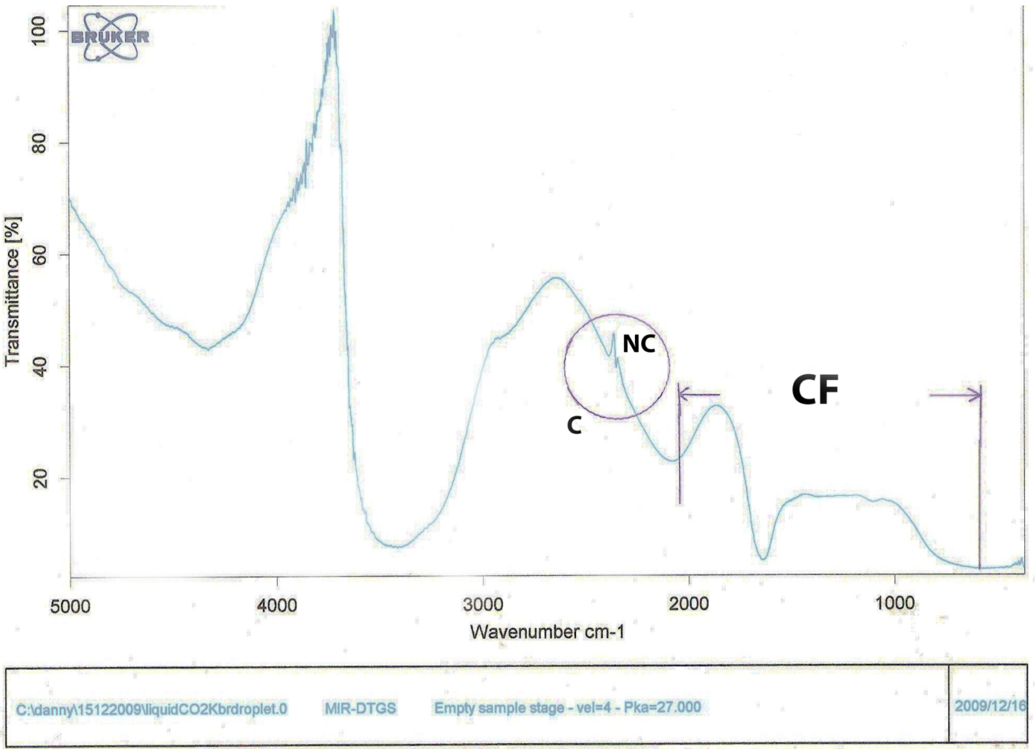

Fig. 25 The graph of the conversion of the CO2 into the formic acid within the chamber.

In the actual physics they call these released packages of magnetic fields or energies as photons as they are released which are then these are absorbed by electrodes placed within the system and used for example to light diodes.

Through development of this technology, production of power without burning fuel and at levels that can meet the demand of a household or a car, is achievable.

Where, for separation of CO2 from environment, in present state of art technologies, energy is used to be able to first separate the CO2 and then cause the formation of formic acid reaction chain, this leading to production CH4 or hydrogen.

Where, through our simple technology, in opposite to the norm, we ***generate energy while extracting CO2 from the environment.*** The method we use is the principle of gravitational positioning and is exactly the way by which matters are extracted and separated in the universe as has been explained in this book.

Our approach is totally different than the present state of art technology, where they use and follow the fundamentals of chemistry, hence the need for their system for energy input to achieve the separation or extraction and we follow the universal method of extraction and holding where magnetic fields as energies are made available through the process.
The example of energy production during the process of CO2 extraction is shown by lighting the diodes as can be seen in Fig. 26.

Where, this set of three LED lights being powered by CO2 capture process. These lights have being on contentiously from 7 pm Saturday 11.12.2009 until this report is release 05.01.2010. Further we expect that these lights will be on for months to come, if we allow the set-up to be running as it is. The intensity of the lights from these LEDs has not diminished and in fact, sometimes they are brighter.

Through development of this technology, production of power without burning fuel and at levels, which can meet the demand of a household or a car, is comfortable achievable.

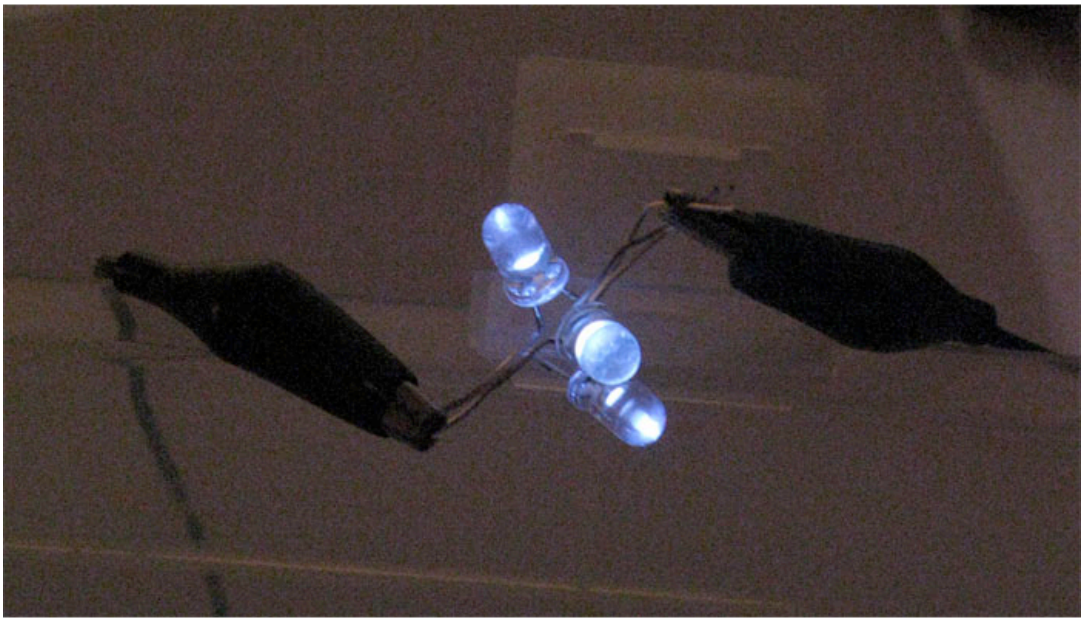

Fig. 26: Group LED's light

For further investigation into confirmation of CO2 capture and its conversion in their interaction with water to form formic acid, the standard reference infrared spectroscopy graph and data of formic acid was obtained as shown in Fig 27.

To confirm further the conversion of the CO2 into formic acid from the CO2 nano solution from our test, the following procedures were carried out.

To begin with, formic acid liquid with 95% purity was introduced as film on the sample disc of infrared spectroscopy system and the graph FA in Fig. 28 was obtained.

Then a drop of solution of nano CO2 was placed on the film the formic acid and the graph CO2+FA in Fig. 28 was obtained.

When the three graphs are superimposed, that is the original infrared graph of the nano solution of CO2, on the graph of the formic acid and then the graph of the mixture of formic acid with CO2 solution, these clearly showing the absorption of CO2 in the zone 1 in Fig. 28, and then presence and formation of formic acid as shown in the zone 2 of the Fig. 28.

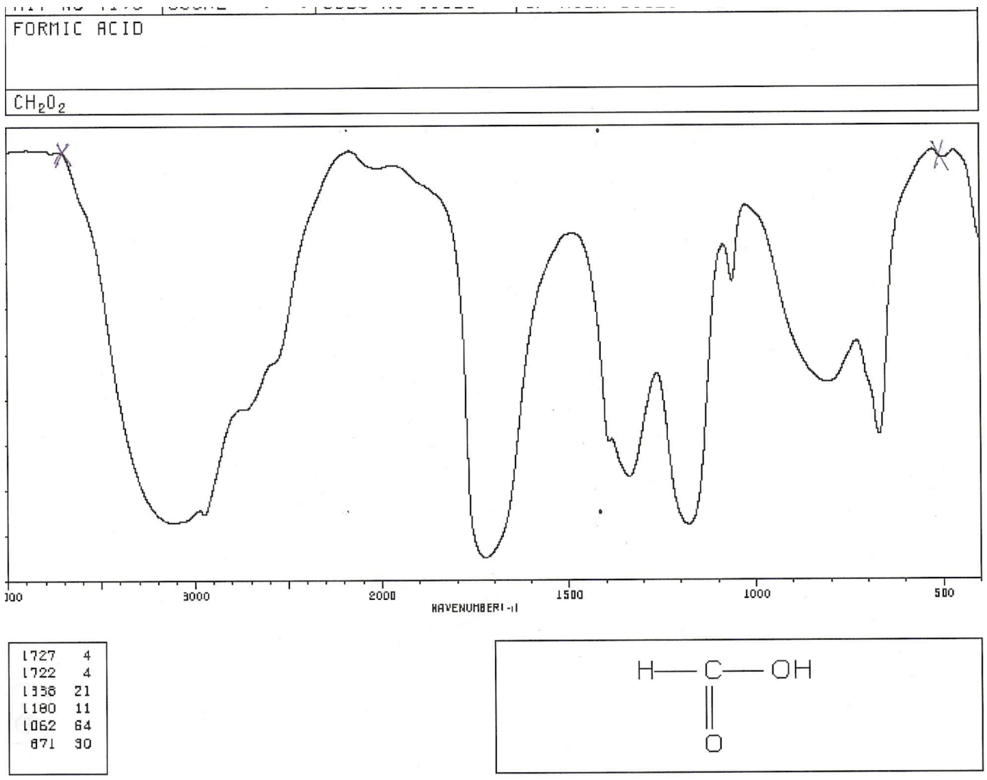

1727	4
1722	4
1358	21
1180	11
1062	64
871	30

Fig. 27 The standard reference of IR spectroscopy of the formic acid.

This showing the same pattern of presence of Formic acid in the solution of nano CO2, hence not only confirmation of existence of CO2 in the nano CO2 solution, but at the same time the absorption capacity of nano CO2 solution of CO2 from the environment and conversion of these additional CO2 in conjunction with water into formic acid.

Having established the characteristic of the matter within the solution from testes and results shown in Figures 21, 23, 24, 25 and 28, without the shadow of a doubt, the white material is CO2 in nano state, and from Fig. 23, we have the confirmation that this matter is a nano structure in sp3 and behaves as a superconductor.

Further, as the process of the energy production from the system has been extended to days and weeks, the following characteristics and materials have been detected and collected from the system.

In the process of the running the system, the area around the electrodes, which have been specially treated, start gathering a white cloud around them after subjecting the electrodes to certain conditions. From this point on the environment around the electrodes start creating a mist of white material around them, and then gradually the whole containment becomes like milky colour liquid, and then white sediment is established in the container.

Through the infrared spectroscopy shown in Fig. 21, we can confirm that the material in the solution is carbon dioxide and the nano state of this material is very much confirmed by the second test of XRD, as the only match for the dried solid residual of this milky substance shows' superconductivity behaviour of this material. This confirming the nano characteristics of the CO2 as white powder, or in its solid state of matter.

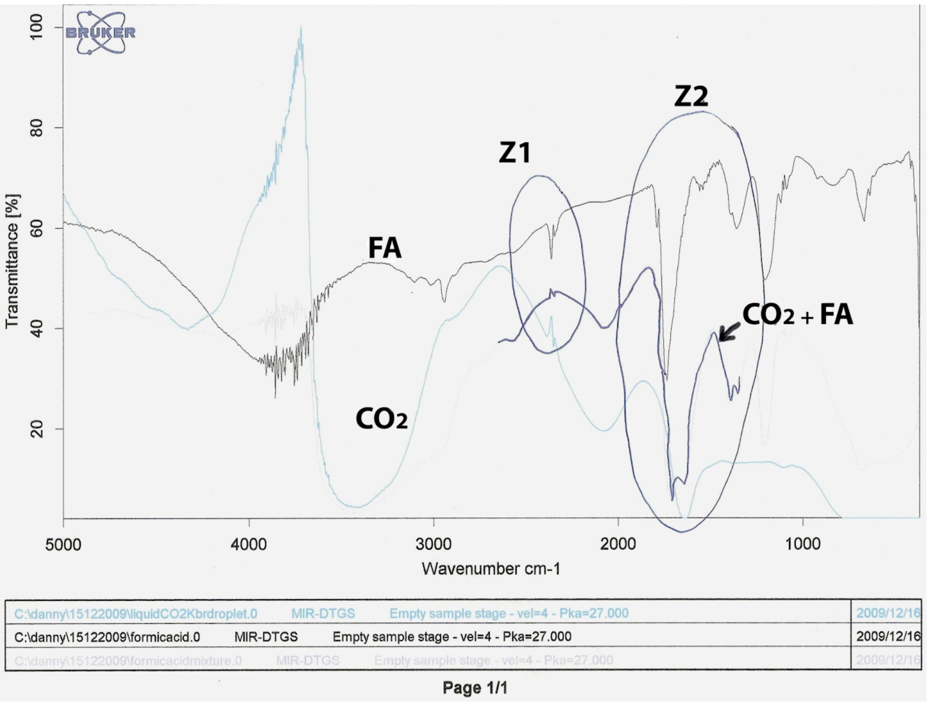

Fig. 28 The superimposed graph of CO2 and conversion o Formic acid and formic acid and mixture of formic acid and solution of nano CO2.

This is for the first time in the world of science that CO2 as gas not only can be captured without use of any pressure, temperature, or energy, but this matter can be extracted and held as a solid at room temperature.

The picture of concentrated nano carbon in solution used for infrared spectroscopy leading to graph in Fig. 21 is shown in Fig 29.

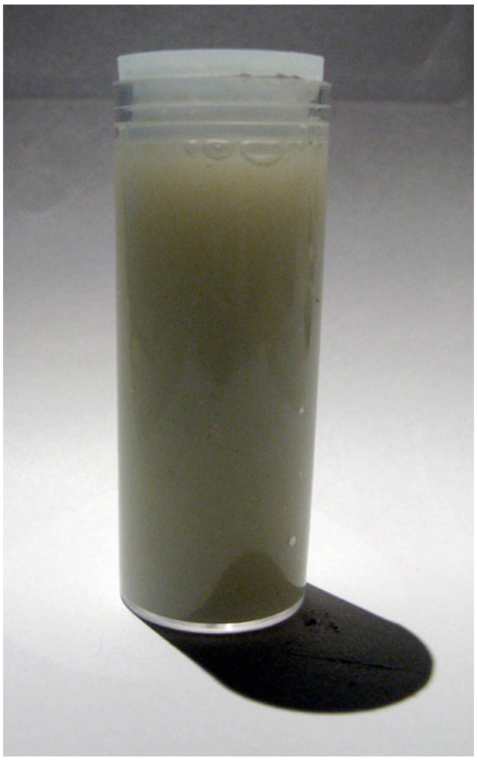

Fig. 29 Solution of nano-CO2

To our knowledge, this is the first picture of nano CO2 solution produced and maintained at room temperature and pressure ever been recorded.

Photographs of dried powder of nano CO2 are shown in Figures 30 A, B, C, and D. These are the first pictures taken of nano CO2 in solid state in atmospheric condition.

This is important as nano CO2 or **CO2 has *never* been observed in solid state at room temperature** and the only solid state of this gas known has been in frozen state of this matter as like of ice blocks (Dry ice).

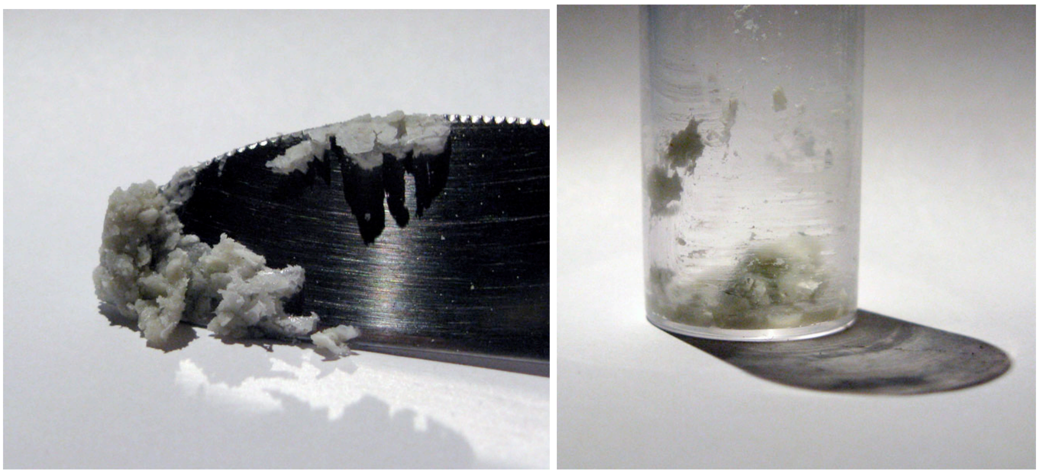

Fig. 30 A, B: Solid nano-CO2 on a knife and in a vial

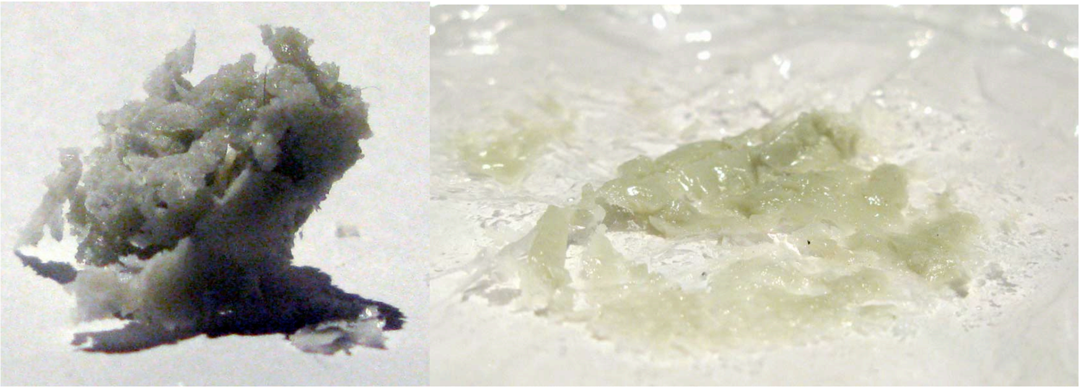

Fig. 30 C: Solid and gel nano-CO2

The important point to note is that, there is no content ratio between the CO2 absorbed in the liquid and the water, as is the usual procedure to state in most tests like these content ratios between sediments or gel and the water of the solution.

With this method of CO2 absorption technology, as long as one can extract nano CO2 from the environment or surrounding environment of water, the CO2 absorbed can be removed without ever a need for the change of the water.

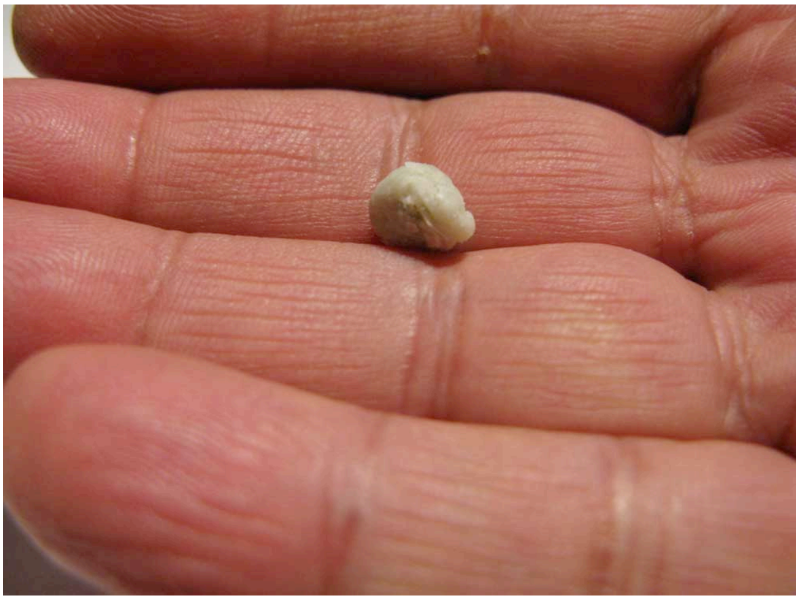

Fig. 30 D: The Solid CO2 material in the Gans-state being held in hand at room temperature. This solid CO2 is not a 'dry ice', but a mastic-like matter.

In practice, we have a number of times collected Gans of CO2 from the same water within the container. The only reduction in the water is due to vaporisation or when it is part of the gel.

This is a very important and crucial point, and this is where this technology departs from present science of chemistry, and stands on its own merit as a nuclear gravitational system.

That is where if the system were a chemically based system, the CO2 content of the water would have been fixed and hence there would have been a ratio balance and final content for CO2 in the water and this value would have been fixed.

Due to the new understanding of the gravitational systems, as has been explained in the book (The universal order of creation of Matters), these specifically designed systems, with specifically placed and produced electrodes, these systems can create a strong but invisible gravitational and Magnetic fields within the layers zone of the electrodes, that these electrodes, as gravitational positioning elements, can create ***the gravitational pull*** *that can absorb CO2 molecules from the water and beyond the boundaries of the water*, without the CO2 as a nano molecule ever chemically interacting with the water molecules content of the system and going through the normal chemical processes.

Thus; if this was not so, how could electrodes deep submerged in liquid would have been able to extract CO2 from the air above the liquid and bring them into the material of the electrode for them to be separated as individual CO2 molecules on a continues bases, as we have been collecting these materials from the same container over period of weeks.

Where in this processes, as the materials like CO2 become in nano structure of their own state, then they are sealed like the diamond and hence they achieve a self sustained gravitational system, like a planet, that does not interact gravitational or magnetically with any other matter and attain the state of singularity or nano state.

This solution of CO2 material feels like mercury as gel, and to touch it feels cold, but does not stick to its container that much.

After extracting the water from the CO2 gans solution, the matter takes the form of gel and is cream whitish in colour.

Thus, this is a **static nuclear gravitational and magnetic field extraction process**, which has never been recorded or known up to this point.

With this method of CO2 extraction, there are no ratios between the matters collected as nano matters and the water content of the system, as the residual of gans of the gases can continuously be extracted from the environment of the system, without change in the volume of the water of the system.

The point to note is that, the volume of the water content of the system stays the same. Where, the system caries on gravitating to itself gases of CO2 and other gases from its environment indefinitely. But the total mass and the volume of the system increases as gases are absorbed into the system by the gravitational principle.

In fact, the system gains weight, mass, and volume as it absorbs more gases. This phenomenon was observed after the test was completed in Holland in the lab, and the increase in volume of the content of the system was noted at the end of that meeting, that we have more liquid in the bottle than when we started the test after about four hours of testing and running the system for energy production trail.

This is normal phenomenon, as extra gases from the environment of the system have been absorbed in the system and converted to gans, which settled at the bottom of the bottle of liquid.

The snap shot from video of the matters content of gans of CO2 as misty residual matter collected after the test in master bottle is shown in Fig. 30E.

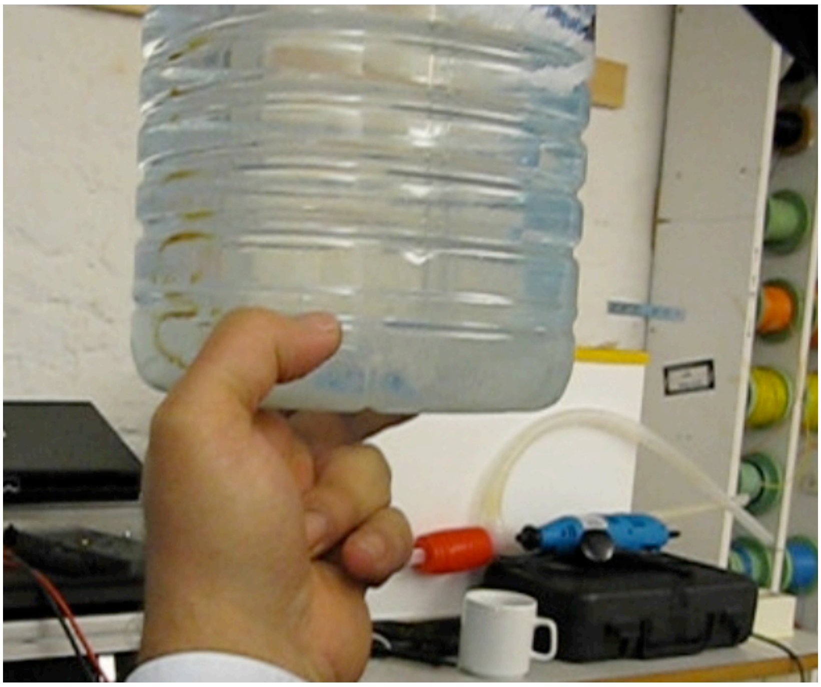

Fig. 30E   A misty residue at the bottom of the bottle.

The principle and the technology used for the extraction of CO2 and its containment as a nano matter can be used for making and allowing the production and development of vacuum systems or singular atomic weight extraction systems, which can attain high purity vacuum condition needed for space technologies of the future or in room laboratories for extracting certain molecules or germs.

This vacuuming technique can be achieved without use of any suction system or high-vacuumed pressure pumps as is the norm in today's technologies for production of interstellar space level conditions that are hard to achieve. These systems do not even needs to be adjacent to the system or near the space where the extraction is needed to take place.

In the universe, this singular Magravs strength principle is the exact method used by certain planets or stars and solar systems in managing to extract only certain materials from their solar or galaxy environment respectively. An example of mainly mono Magravs system is few elements material content, being the like Saturn with mainly helium content matter.

In fact in this system we have shown, a micro universal selective gravitational, which in this scale we only absorb CO2 gases from the environment. Where the operation of these systems can be changed and modified to extract any material from any environment without the use of suction or chemical process and so on.

The methane CH4 absorption

During the process of running the system for extraction of CO2 and production of useful current, due to specific configuration setting of the system, specific section of system starts the absorption of methane gas from the environment.

At this point, the water content of these sections of the power system starts to become blue greenish or violet blue in colour, similar to reported colours of the methane in solid state.

Further to confirm the nature of this new material, the same tests as for the CO2 gas extraction was undertaken and results obtained were as follows.

Through infrared spectroscopy test, it is has become clear that this solution has the ability to facilitate the CH4 capture and the release of the residuals of CH4 as solid in the in the dilution of the liquid through the same principles as described above for CO2 gas.

This effect of separation of CH4 as solution shown in Fig. 31 A and B as blue-greenish water and the same colour sediments in the tube.

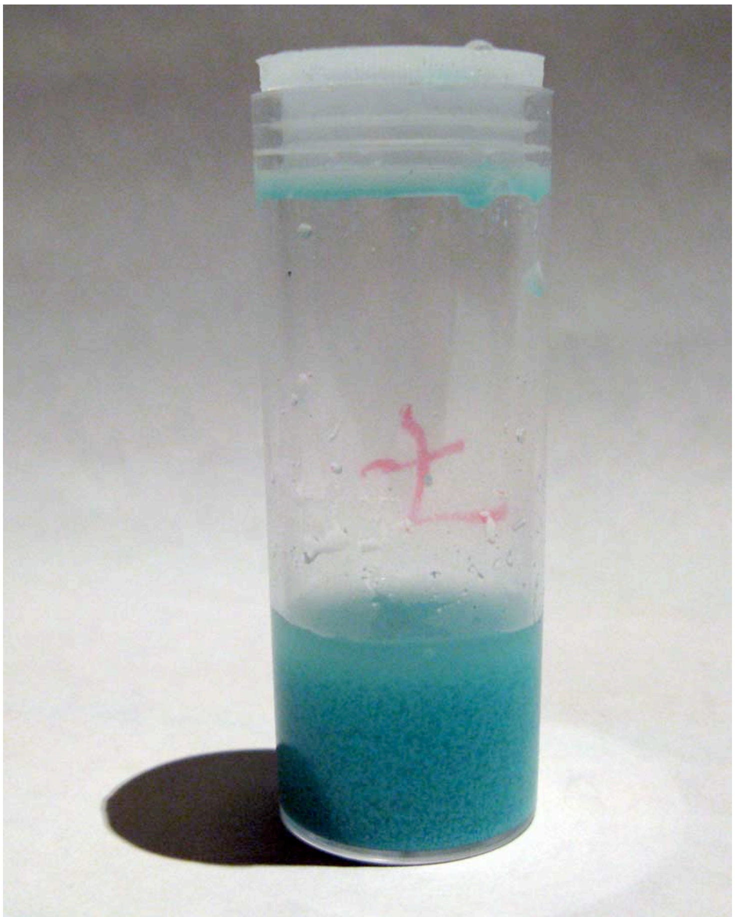

Fig. 31A. Solution of nano Methane (from two different angles)

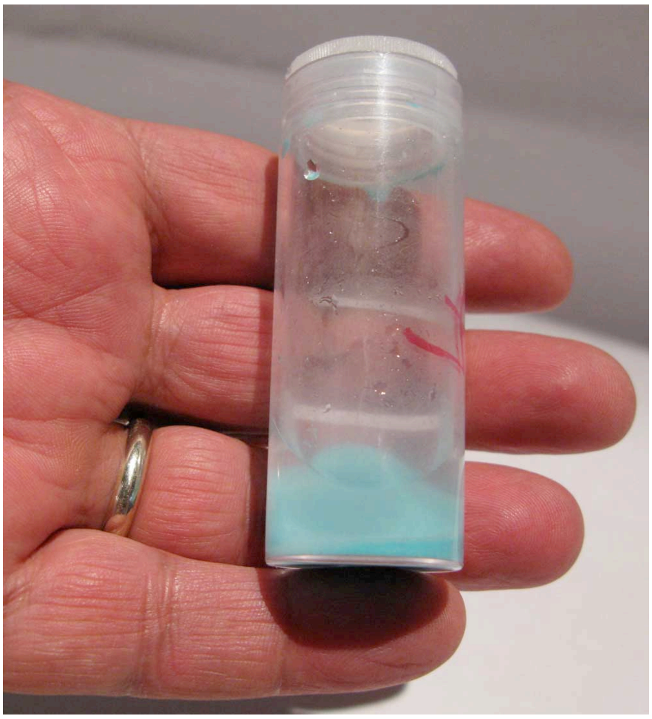

Fig. 31B. Solution of nano Methane

The solid dry residual nano CH4 powder is shown in Fig. 32.

Fig.: 32. Solid nano CH4 (gans of Methane)

The process of creation of current and the observation of appearance of residual of solid matter indicates two clear processes:

Firstly, the system starts to absorb methane gas from the environment through the same principle as described through mainly Magravs process as for gas of carbon dioxide CO2.

With the difference that in this case different and specific conditions Magravs strength level by the layers of matters' of electrodes are generated, that this new Magravs strength level facilitates the extraction or absorption of the new material by the system and within and through the system.

As the gravitational and Magnetic fields needed for extraction of the CH4 Magravs are slightly different than the Magravs fields for CO2, hence different combination of Magravs is needed to extract the CH4 from the environment.

Hence, in being able to collect and further test the new material from the solution to confirm the extraction of CH4 from its environment, this proves that, the system has the ability according to its pre-set conditions, to create different Magravs strength within the layers of the electrodes, that can absorb or gravitated different materials to the system such as CO2 or CH4, through operation of the same system concurrently.

Secondly, another process can take place within the system, where the CO2 absorbed in the system goes through process of interaction with water and initiates the production of CH4 and release of molecules of oxygen.

To achieve the production of methane gas through this process, one molecule of CO2 and two molecules of water H2O are required, that by using the energy absorbed by the material within the system leads to production of CH3 radical and then CH4 as molecule.

Where, this process is not a chemically binding rather is Hydrogen plasma gravitated and it is sustained through magnetic field strength within the layers of coating or matters and energies within the system facilitate such a process.

In conventional chemistry, it is assumed at least energies equivalent to eight photons are needed to achieve such a conversion from CO2 to CH4.

Through this method of using our new system, the material of the systems acts as catalyst and magnetic field provider, that such energy (eight photons) are not required, but in fact gravitational and magnetic fields of the plasma of the oxygen and hydrogen of the water become the magnetic field binder for this chain of events.

This being the reason why in similar cases and in theoretical chemistry one needs energy to trigger such conversion, where as through our system the hydrogen and it sister radicals in presence of the free magnetic oxygen, the solution becomes the magnetic bridge, allowing the system to release energy in larger quantities than eight photons, rather than in parallel chemical process in needing energy for the same process to take place in these systems.

In this second path of production of CH4, one needs catalytic effect of the material used in the set-up of the system. In the nature, this catalytic effect needs eight photons of energy for it to take place, which this is usually provided through sunrays.

In the case of our system the conversion of CO2 to production of CH4 and O2 takes place through the layers structural materials and the localised gravitational fields which they generate. As these materials have the ability to absorb infrareds rays too as well as sunrays in the environment and hence these new materials can facilitate the production of the methane and oxygen gases and release of energy twenty-four hours a day.

Thus in fact with the development of this new system, we have clearly shown that for process of photosynthesis, one needs the Magravs strength in the infrared spectrum. Through this process we have clearly shown why plant do their CO2 to CH4 and O2 conversation mainly during the night time, where the infrared radiation from the planet is high, as the sun magnetic field can not suppress their emission upwards from the earth surface. Where, it is known fact that the earth is the best suppler of infrared rays.

Further on, to show the correctness of our technology and that we do not require energy to extract CH4, where in fact we produce energy as power supplier through our technology, the engineers at the lab proposed to connected our system to an electric fan, to see if the poser produce can run mechanical devices like this on a long term. As can be see in Fig. 33. Where we ran the fan for over an hour.

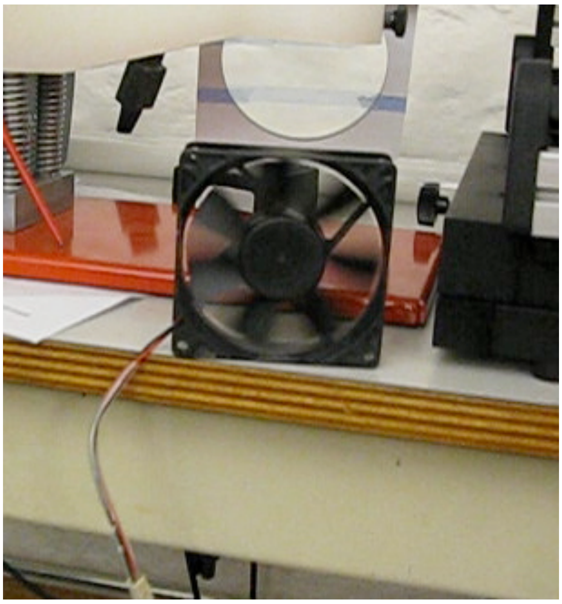

Fig. 33: Turning fan powered by CH4 extraction system.

This test was done in presence of a journalist and engineers from the magazine that we cooperate with and all has been videoed. The test happened in the basement of their premises, in the absence of any sunlight.

Energy release by the process of gravitation and extraction of CH4 creates more energy and stronger current than the same process of absorbing CO2 from the environment. Where, this process leads to creation of strong current rather than stronger voltage output from the system.

The absorption of CO2 from the environment and conversion of it into formic acid and release of energy needed for the photosynthesis and where at the same time the CH3 stage of methane gas as methyl becomes first stage for the production of sugar bases in organic materials has been observed and videoed with operation of one of systems.

Thus for the first time the process of photosynthesis can be shown to take place exactly as happens in a nature like in a tree through these systems can be demonstrated.

These systems not only absorb CO2 from environment, but through their process of conversion, they can lead to production and released of oxygen as molecular structure.

To confirm and be able to show such a process takes place within the process of the production of methane and oxygen and hydrogen from our system, it is essential to show that methane in nano state of matter as we have collected in our system is or has a superconductivity behaviour, as was shown for CO2 nano material.

For the confirmation that the captured CH4 solid material is or has a ***super-conductive*** behaviour, we subjected the solid residual of the blue-greenish matter to XRD testing in the laboratory.

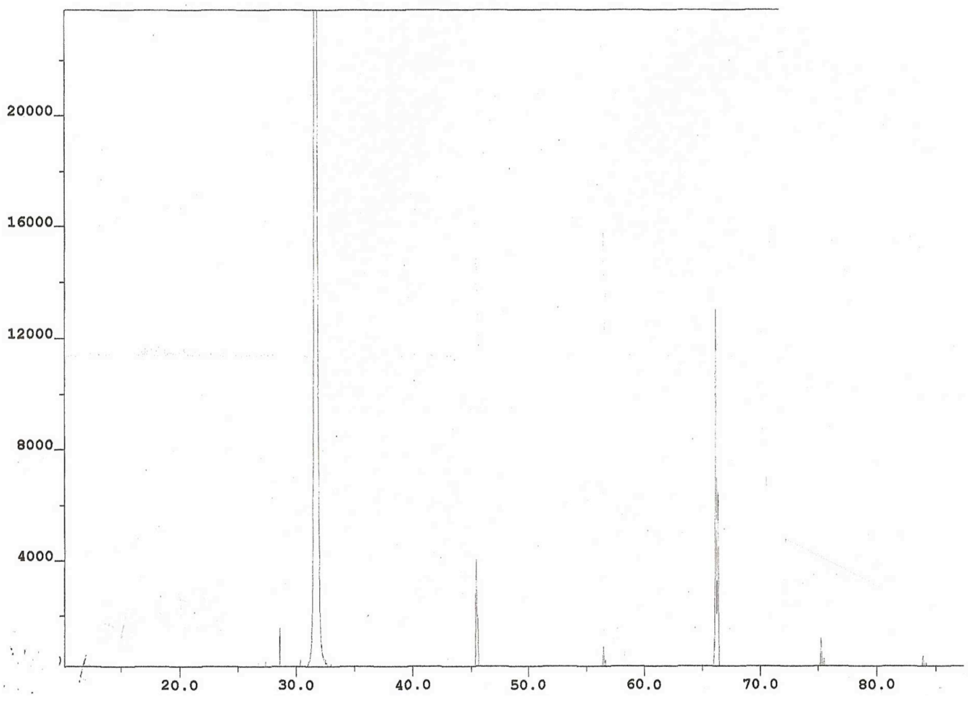

Fig. 34 The XRD of the superconductor characteristic of nano Methane solid

The result of this test has to be noted that CH4 as CO2 in nano state has superconductivity behaviour detected seen in XRD is shown in the graph of Fig. 34.

The nearest material composite match to this material characteristic of our solid matter is beryllium palladium, which matches by 95% as a superconductor behaviour only. The list of near enough matches as superconductor to CH4 in nano state can be seen in the table shown in Fig. 35.

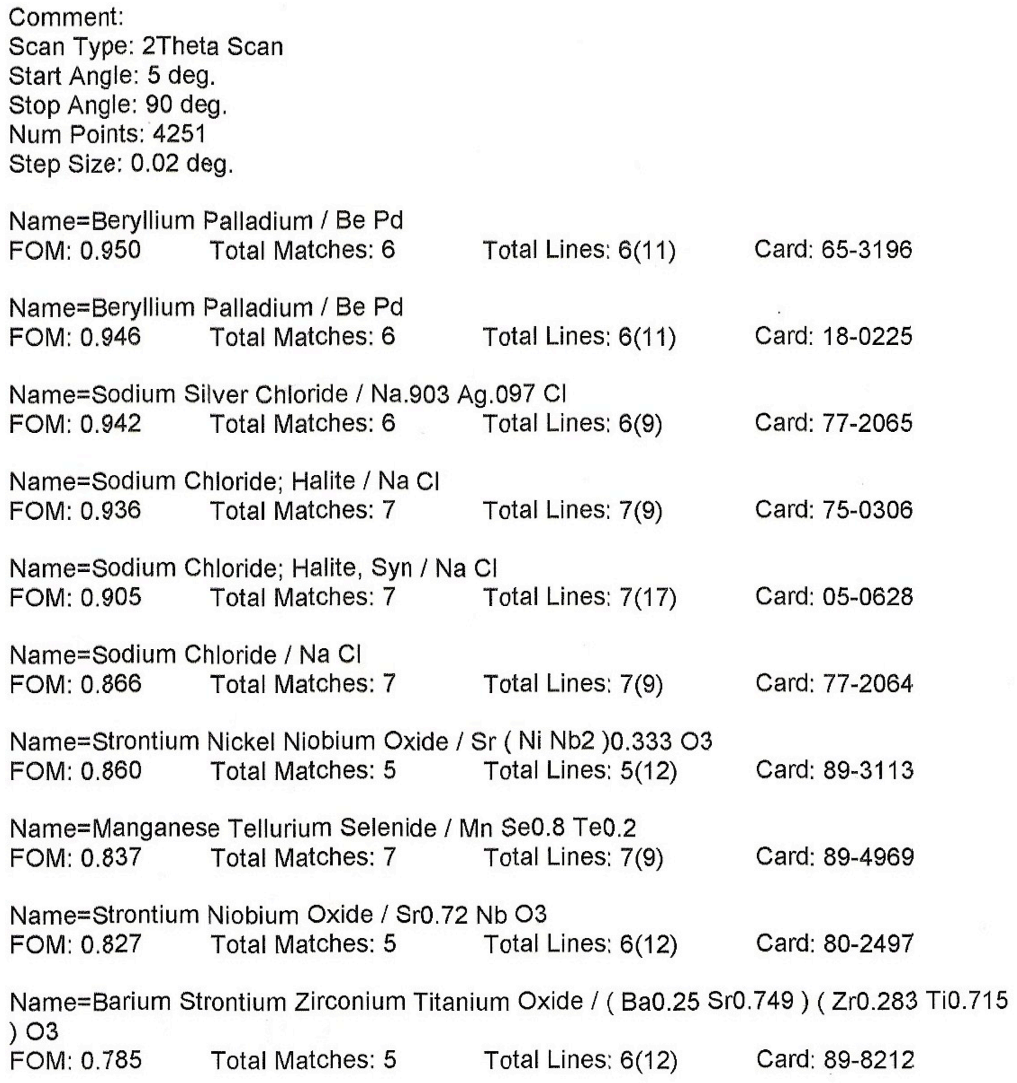

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Comment:
Scan Type: 2Theta Scan
Start Angle: 5 deg.
Stop Angle: 90 deg.
Num Points: 4251
Step Size: 0.02 deg.

Name=Beryllium Palladium / Be Pd
FOM: 0.950        Total Matches: 6        Total Lines: 6(11)        Card: 65-3196

Name=Beryllium Palladium / Be Pd
FOM: 0.946        Total Matches: 6        Total Lines: 6(11)        Card: 18-0225

Name=Sodium Silver Chloride / Na.903 Ag.097 Cl
FOM: 0.942        Total Matches: 6        Total Lines: 6(9)         Card: 77-2065

Name=Sodium Chloride; Halite / Na Cl
FOM: 0.936        Total Matches: 7        Total Lines: 7(9)         Card: 75-0306

Name=Sodium Chloride; Halite, Syn / Na Cl
FOM: 0.905        Total Matches: 7        Total Lines: 7(17)        Card: 05-0628

Name=Sodium Chloride / Na Cl
FOM: 0.866        Total Matches: 7        Total Lines: 7(9)         Card: 77-2064

Name=Strontium Nickel Niobium Oxide / Sr ( Ni Nb2 )0.333 O3
FOM: 0.860        Total Matches: 5        Total Lines: 5(12)        Card: 89-3113

Name=Manganese Tellurium Selenide / Mn Se0.8 Te0.2
FOM: 0.837        Total Matches: 7        Total Lines: 7(9)         Card: 89-4969

Name=Strontium Niobium Oxide / Sr0.72 Nb O3
FOM: 0.827        Total Matches: 5        Total Lines: 6(12)        Card: 80-2497

Name=Barium Strontium Zirconium Titanium Oxide / ( Ba0.25 Sr0.749 ) ( Zr0.283 Ti0.715
) O3
FOM: 0.785        Total Matches: 5        Total Lines: 6(12)        Card: 89-8212
```

Fig. 35 The nearest data of matching materials available that match the green blue powder superconductivity characteristic to the extracted nano methane solid from the solution.

The comparison of superconductivity characteristics of the CO2 and of the CH4 nano materials obtained by XRD and matching and similarity in behaviour of carbon dioxide CO2 and methane CH4 as super-conductive nano materials are shown in Fig. 36.

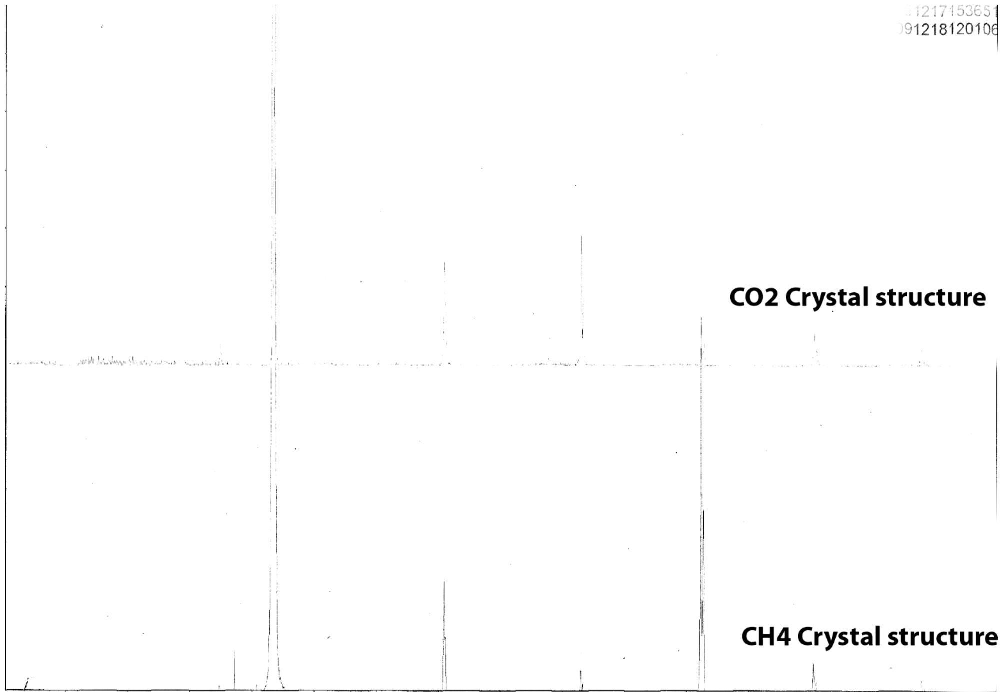

Fig. 36 The XRD superconductivity characteristic comparison of nano CO2 and nano CH4.

The common behaviour between the CH4 and CO2 nano matters have been observed and shown by superimposing their infrared spectroscopy graphs as shown in Fig. 37.

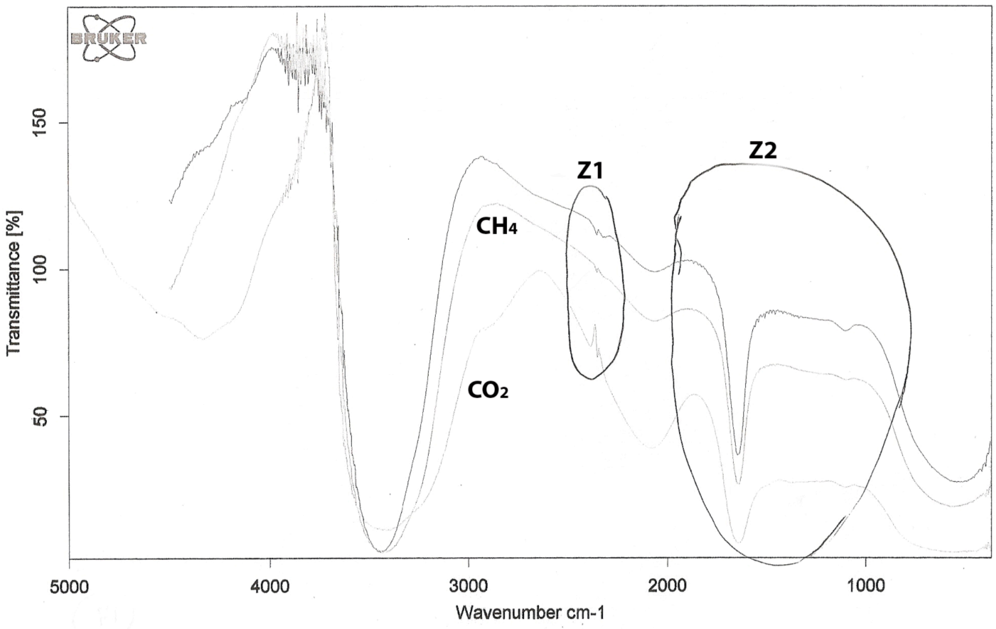

Fig. 37 The IR spectroscopy comparison between nano CO2 and nano CH4 in solution

In this graph the CO2 in zone 1, shows extraction of CO2 gas from its environment and then forms formic acid as seen in zone Z2. Similarly methane (Me) releases increase the availability of CO2 in the environment of the chamber of the spectrum machine as seen in zone Z1, and then the same releases' of formic acid as the same as CO2 as can be seen in the zone Z2 through this process.

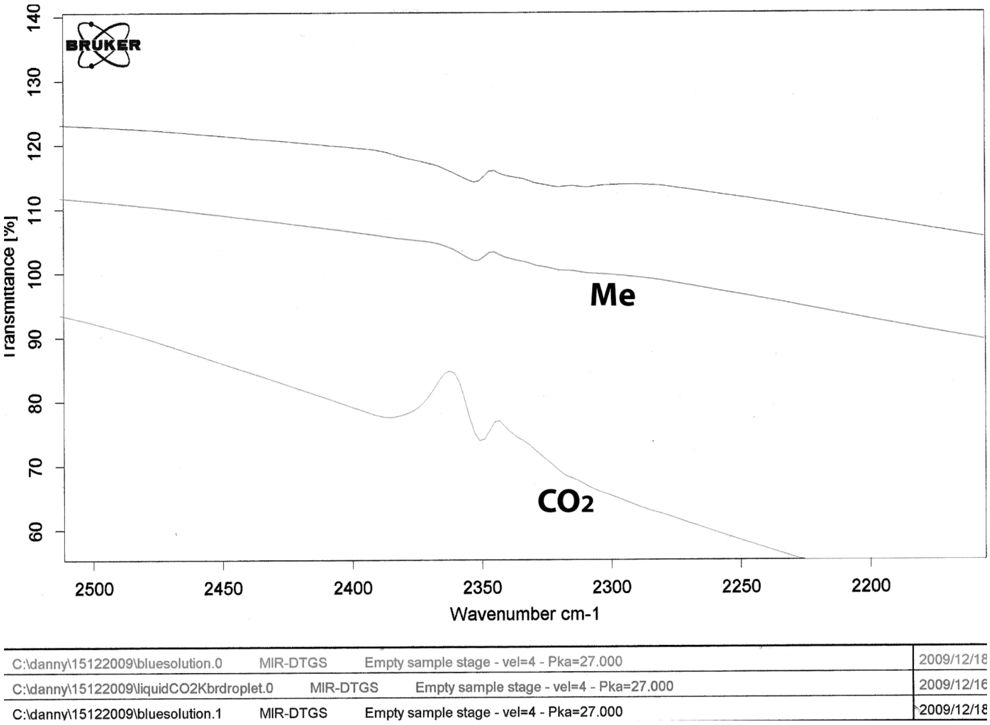

Fig. 38 the enlarged section of the CO2 and CH4 in infrared from Fig. 37.

This explaining two factors, one that the solution is processing both CO2 and CH4 extraction simultaneously and or it is has the ability to produce CH4 through CO2 absorption and the water chain interaction as was discussed before.

Enlarged section of the zone Z1 in Fig. 37 are shown in Fig. 38.

Superimposed graphs of these nano materials of the same region in graph 37 are shown in Fig. 39.

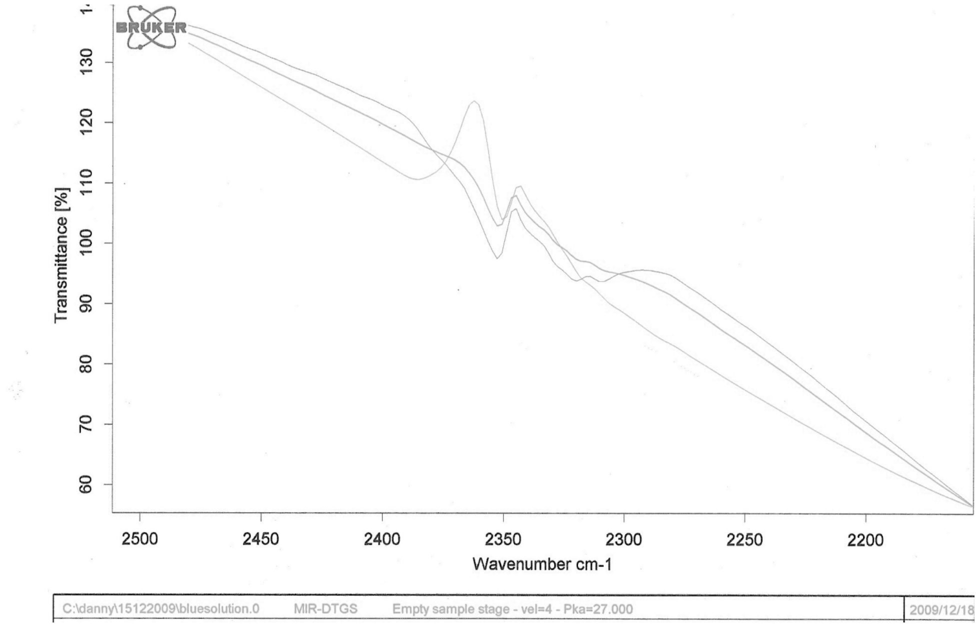

Fig. 39 The superimposed and enlarged section of carbon sector of the Fig. 37.

Observations and notes.

In the development discussed above, one has shown how by absorbing CO2 from the environment, this being on earth or as the content of craft, this gas can be used to generate energy and oxygen to sustain life without the need for additions reserves of these gases using the man himself as the supplier of the main ingredient matter, the CO2.

What this new technology offers for the planet earth is a survival line that in the present environment of the global warming with the CO2 generated by burning of fossil fuels and production of methane gases produced by extensive cattle farming, through the utilisation of this new technology for the first time ***these gases can be extracted from the atmosphere and simultaneosly be converted to solid matters or solution, this process can be used to lead to, and cause the release of energy, and through the use of specially developed composite materials, this leading to separation and generation of oxygen.***

Where some of methane and carbon dioxide in the form of nano materials of the same gases can, all be suspended in the solution or dried as solid and reburied or returned to earth as topsoil.
Where this new technology shows for the first time and make it possible to achieve creation and holding of carbon dioxide or methane gases in solid state at room temperatures and pressures. Through evaporation of water from solutions, solid of carbon dioxide CO2 and methane CH4 gases in the form of powder nano materials of these gases are produced.

This new system and technology completes the circle of life for maintenance and existence in the future while it can clean up the mess man has created by the use of fossil fuels on earth in the past centuries.

Where these new systems will behave as trees on earth and for the passengers of space systems of the future, by simple converting CO2 into oxygen, and where the man himself becomes the supplier of CO2 for the system to keep the cycles functioning.

Through the development of the technology that has been disclosed in this paper the initial steps to conclude this process for application in our space technology is considered to be completed. In the space technology of the future, one has to be able to use all matters available within a spacecraft to attain continues and sustainable existence of man in deep space travels.

This technology of direct extraction of CO2 and CH4 from the environment can happen in reactors of small and large dimensions. Thus the technology can be used to tackle the Climate Change problem. For example large installations can be connected to exhaust systems of heavy industry, and small extraction devices can be made for households or be built in cars. None of these installations will need powering, as they will deliver themselves electricity. On the other hand we don't have a sequestering problem since the CO2 and CH4 are already in a solid state, which make storage easy. However our liquid and solid CO2 combined with limonene oxide can also be used to make new type of polymers and plastics.

We have developed and attained a fully integrated system that is able to sustainable life in space.

In letting the process of CO2 absorption and production of energy to continue, some cells of the system start the process of production of methyl CH3. This is a significant process as this shows organic process as CO2 is in progress within the system.

Further, this process in conjunction with its water content, and nitrogen from the environment, can itself lead to production of natural sugars, starch and proteins, using our simple static gravitational system.

This simple system can be used not only to clean up the environment from CO2, but at the same time the same CO2 can be used in conjunction with specific matters of the system, to release energy, oxygen. Further at the same time producing CH3 and methane and formic acid and by use of nitrogen this leading to production of protein(s) that can be the food supply for the humans' passengers of spacecraft's of the future while they inhale oxygen and exhale CO2.

Thus through this new technology mans' existence on board of the spacecraft's of the future, the man becomes the container and supplier of carbon dioxide and hence the provider of oxygen for his own existence.
Thus, man himself becomes the conversion system to maintain his own survival in deep space or on earth during shortages of food or natural disasters.

The property of this system has allowed us to submit a full patent for the first full day and night energy panels.

New state of matter

When considering this new technology and understanding the potential of its physical ability to convert gases into solid state of the same, where up to present knowledge the gas from being able to take the shape of its container, for the same atom or molecule becoming the container of itself as a nano matter, then this new state of matter or the solid state of the gas at ambient conditions like the room temperature and pressure, ***itself becomes the nano matter of the gas*** and this state of matter has never been known in the world of science and has to be considered to be a new state of Matter or the fifth state of matter.

Where, through our development of matters in our technology we consider solid, liquid, gas, plasma, and dark matter as the first five known states of matters up to this point in our technological development.

This being due to the fact that this new nano matter of the gas in solid state, it does not behave and looks as any of its old states of matters or any other state of matter as we have known and what we have seen before from these matters.

The infrared and XRD testing of these carbon dioxide CO2 and Methane CH4 gases in nano state showing that this matters behaves like a ***superconductor material***, where nor hydrogen or hydrogen and the carbon in there matters are considered as super-conductive materials in the present world of science known knowledge in their gas state of their molecules.

To our present knowledge superconductors at these levels are by principle of matter in diamond structure or sp3 state of matter. Where, their physical gas equivalent of these matters known to science and are classed as odours.

Thus as in this new state of matter molecule of GAs which becomes Nano of itself and become and appears as Solid state of matter as we have seen from our testes and shown as solid of the matter in this paper, this new state of matter needs a new name, for it to show the source of the matter, that is from GAs to Nano of Solid and to be called **GANS** for short.

This new name in fact clearly not only indicating the source of the matter, which is the gas, but at the same time it clearly explains what to be expected and describes the characteristic of these matters too.

Where these new characteristics being like superconductivity, lightness, singularity of grains and so on, of the same molecule as it become nano of itself and become solid of itself but having full molecular structure of a gas, but self gravitationally and magnetically closed and singular, but it still can be in a gas state of itself, but as it becomes singular atom or molecule of itself it behaves as solid matters do.

Thus from this point on, we do not call these solids of nano of gas or nano CO2, but **GANS** of CO2.

First ever pictures of these matters in Gans or solid state are shown in Fig. 30(A-D) for CO2 solution and dry state.

Pictures in Fig. 31A and 32B shows the first ever solutions of methane and dry or gans of CH4 respectively.

Through experiments and deliberate mixing of different gans in one solution, it is clear that these materials do not mix or do not chemical interact with each other. Where each gans of each matter stays separated from the other matters within the solution, and stays the original gans. Fig. 40 shows a mixture of three gans in a solution, where they stay without any chemical binding, where for example the green residue settles can be seen at bottom of the tube.

Similarly for the first time in the world of science, through understanding of this technology, we can capture odours as solid? But the question is that, would they smell the same as their sp3 counterpart as gases? This is the question to be answered and explored in the times to come.

Parallel with development and extraction of gans, these systems produce energy, which are not due to burning of fuel or chemical conversion like in a battery. The energy produced during the process of gans from any system, which this energy can be used for any purpose, this being creation of gravitational field force to create static sources for creation of Magravs, power to run a motor or light-up a lamp, this new source of energy needs a clear and new name classification.

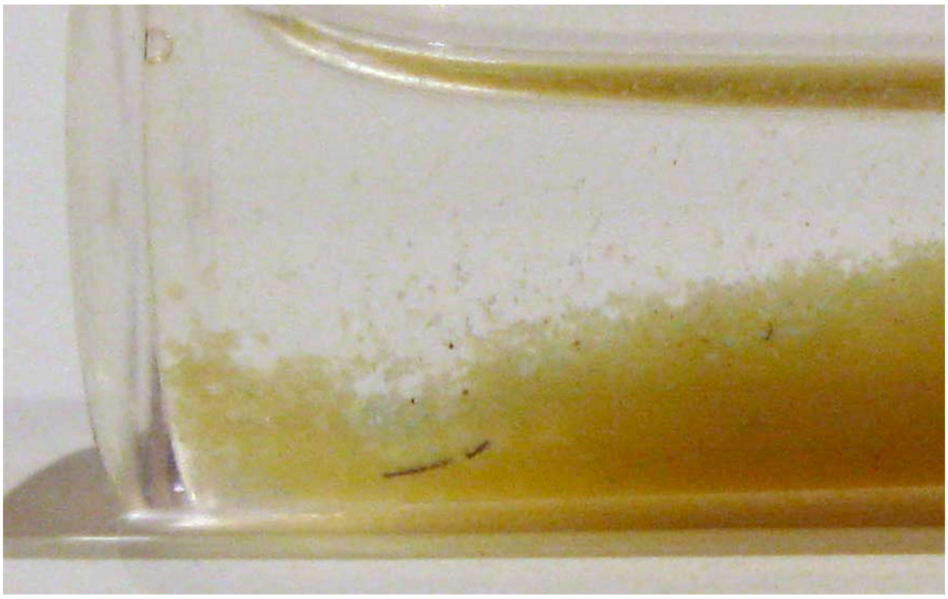

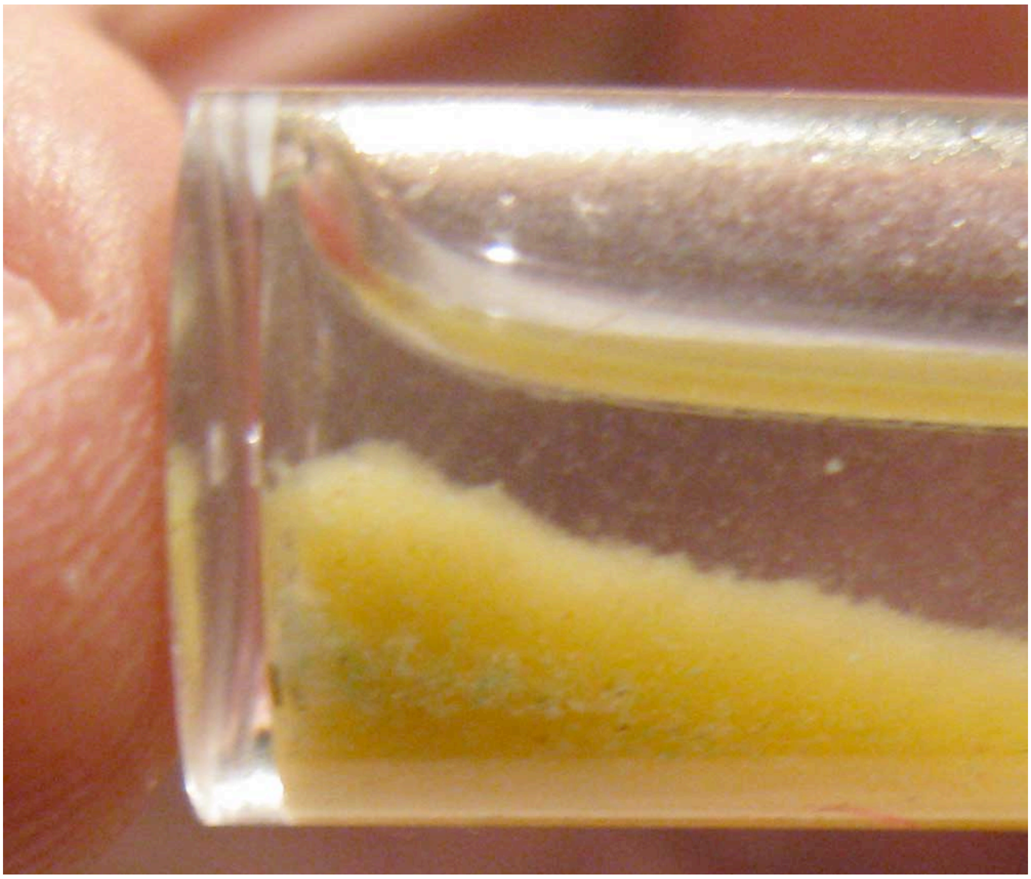

Fig. 40 Different Gans do not mix or chemically bind, and stay separate in the solution.

We call this new method of production of clean energy, this being in magnetic field force strength or electric energy, the **GAs Nano Solid Energy** or GANSE for short or Gas Energy Solid for short **GES**.

Implication and applications of this new technology

In the development of the technology discussed above, we have shown how by absorbing CO2 from the environment, this being on earth or as the content of craft, this gas can be used to generate energy and oxygen to sustain life without the need for additions reserves of these gases using the man himself as the supplier of the main ingredient matter, the CO2.

What this new technology offers for the planet earth is a survival line that in the present environment of the global warming, with the CO2 generated by burning of fossil fuels and production of methane gases produced by extensive cattle farming, through the utilisation of this new technology for the first time these gases can be extracted from the atmosphere and simultaneously be converted to solid matters or solution and return of this matter as solid into the ground,

The development of this new technology shows and makes it possible, for the first time in world of science to achieve absorption and containment of carbon dioxide or methane gases in solid state at room temperatures and pressures.

Through evaporation of water from solutions, solid of carbon dioxide CO2 and methane CH4 gases in the form of powders nano materials of these gases can be produced, where in later stages in different applications like manufacturing processes, these materials can be added to effect the physical or the property of different matters or produce new types of matters with these new materials.

These new matters of gans can be used for example as new biological nano filters, where their purity or the molecular size of gans can determine the matters to be filters, this being cancer cells, germs or other matters.

Through the use of this new technology the circle of life for maintaining a clean environment in the future, while it can clean up the mess man has created by the use of fossil fuels on earth in the past centuries.

Where these new systems will behave as trees on earth and for the passengers of space systems of the future, these systems by simple converting CO2 into oxygen, guaranteeing ever supply of life essential need, where the man himself becomes the supplier of CO2 for the system to keep the cycle functioning and guaranty his own survival.

In our tests, in letting the process of CO2 absorption and production of energy to continue, some cells of the system start the process of production of methyl. This is a significant process as this shows organic process in progress within the system.

Further, this process in conjunction with its water content, and nitrogen from the environment, can itself be used to lead to production of natural sugars, starch and proteins, using our simple static gravitational system.

This simple system can be used not only to clean up the environment from CO2, but at the same time the same CO2 can be used in conjunction with specific matters of the system, to release energy and oxygen. Further at the same time producing CH3 and methane and formic acid and by use of nitrogen this leading to production of protein(s), that can be the food supply for the humans' passengers of spacecraft's of the future while they inhale oxygen and exhale CO2.

Through the development of this technology that has been disclosed in this paper, the final steps to conclude the process for application of these systems in our space technology is considered to be completed.

Where, these CO2 extraction systems, by their nature of operation as described above, they can become the natural backup energy systems and vacuum systems for spacecrafts of the future.

With the completion of this sector of our technology, we have developed and attained a fully integrated system that is able to sustainable life in space. Where we have shown through other sectors of technology, systems for motion with gravitational positioning through our nano materials we have shown how to produce matters in the universe and materials to manufacture for what man needs for food and habitation, then we have shown how to develop the system to feed and produces systems to cure ailments through our medical application section, and in the energy production system we have shown how to generate energy through simple natural process, and finally now with this technology we have shown how to create a self sufficient environment to sustain life with extraction of CO2 and use of the same to create oxygen for man to survive in space.

Thus through this new technology mans' existence on board of the spacecrafts of the future, where the man himself becomes the container and supplier of carbon dioxide and hence the provider of oxygen for his own existence is complete.

Thus, man himself becomes the conversion system to maintain his own survival in deep space or on earth during shortages of food or natural disasters.

The property of this system has allowed us to submit a full patent for the first full day and night energy panels and all other points which has raised as new science in this paper.

Conclusion

Through new and simple methods which has been developed and explained and production of new materials with some new properties which has been confirmed, we have managed to create and establish clearly how gases can be made to be contained, extract and converted into solid state of matter, without the use of any chemical reaction, temperature or pressure, and simply through creation of condition of mini and localised Magnetic and gravitational fields within the system, as is done in the universe.

Where, these fields are hidden within the static layers of different matters within the system, as they have been chosen as the electrodes within the structure of these systems.

Where clearly in picture Fig. 40, one can see that these matters are normal solid and can be handled like any other solid matter.

Clearly from the infrared spectroscopy and XRD graphs of these matters and solution it is clear that the matter absorbed or extracted from the environment, as gans are so pure and in nano state that their spectroscopy recorded data is as close as to perfect theoretical for CO2 gas. This purity of the matter, showing itself in such clear and single perfect lines of graphs shown from the test of the actual sample of the solutions of these ganses.

At the same time, it is confirmed that nano gases do behave as their metallic and semi metallic matters in the universe and they become or attain the behaviour of conductors and superconductors and super resistors. Where this finding of the behaviour of these gans solves and answers a number of unanswered questions in the world of physics, chemistry and biological binding, movement and motion of planets, stars and matters in cosmos.

This paper in its simplicity of its presentation and the knowledge it has put forward, it will in due course bring about fundamental new ways that a number of problems in the scientific world concerning gases and solids are to be considered.

For example we can think of ways to solve the mystery of the ***a-biogenesis*** (the study of how life on Earth could have arisen from inanimate matter.) or how proteins could have been created in Space by local super-conductive conditions.

With the knowledge gained with the operation of these simple power cells, new systems in production of vacuum, creation of matter, extraction of matters and conversion of matters can be developed, and in a way this paper opens a new an unbelievable horizon to the man for science and space technology of tomorrow.

We have shown and clearly proven not only one dose not need all sorts of machines to create or extract matters from the environment but simply following the laws of universal gravitational and magnetic field forces, one can achieve the same in a much simpler ways, and instead of using energy to achieve production of a matter, one can extract energy from the same system and achieve better results in doing the same process.

Additional pictures

Some pictures of different matter, which have been gravitated to the system, are shown in the picture below.

Up to this point we have managed to attain six different elements in gans-state, which each one has it's own colour as can be seen in sample tubes as they have been extracted from the system during it operation, while producing energy. Some of the materials shown have not been subjected to IR and XRD spectroscopy to confirm the composition of the original gas before they were converted to their gans-state.

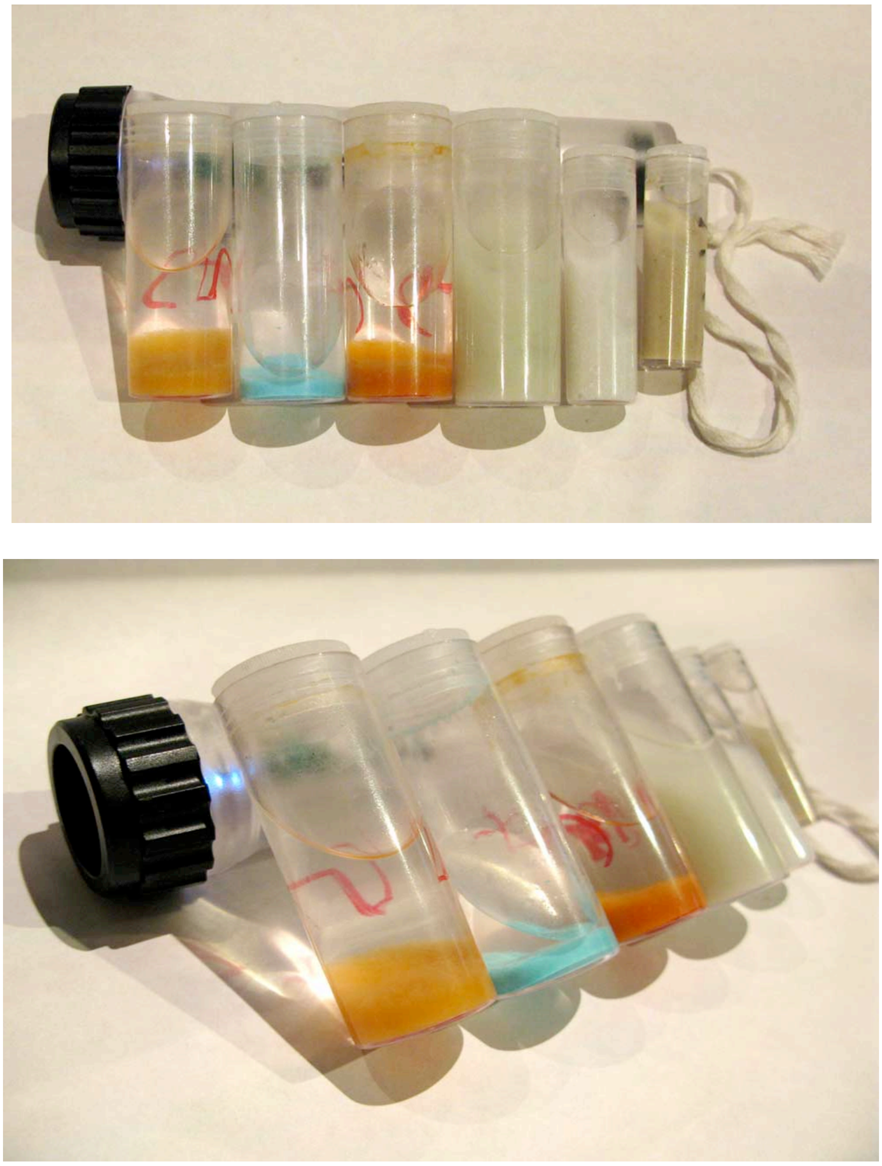

Fig. 41. Six different materials in gans-state which have been gravitated by the system up to today (05.01.2010).

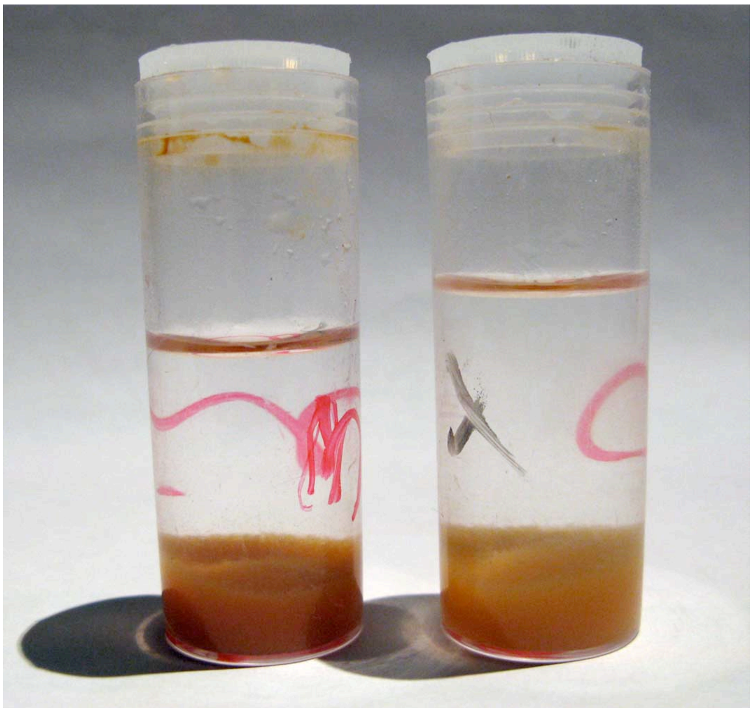

Fig. 42. Two different materials in gans-state, which have been gravitated by the system, which we think these, are organic gases in Gans-state. They have different orange colours.

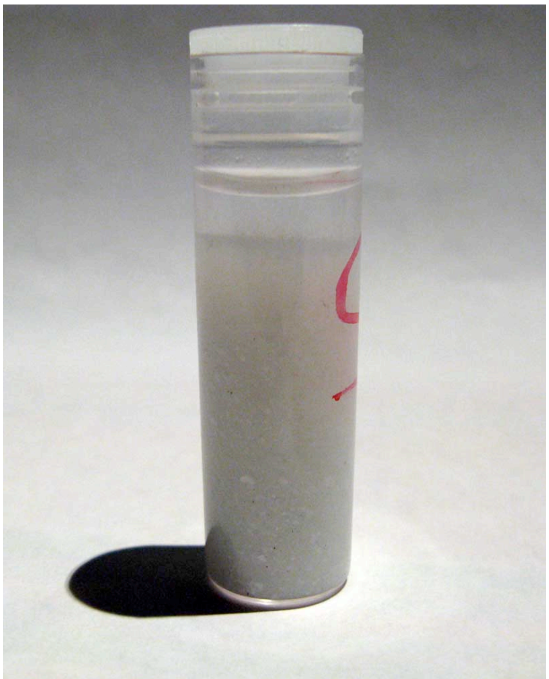

Fig. 43. CO2 in gans-state , which have been gravitated by the system. It contains solid flakes within the solution

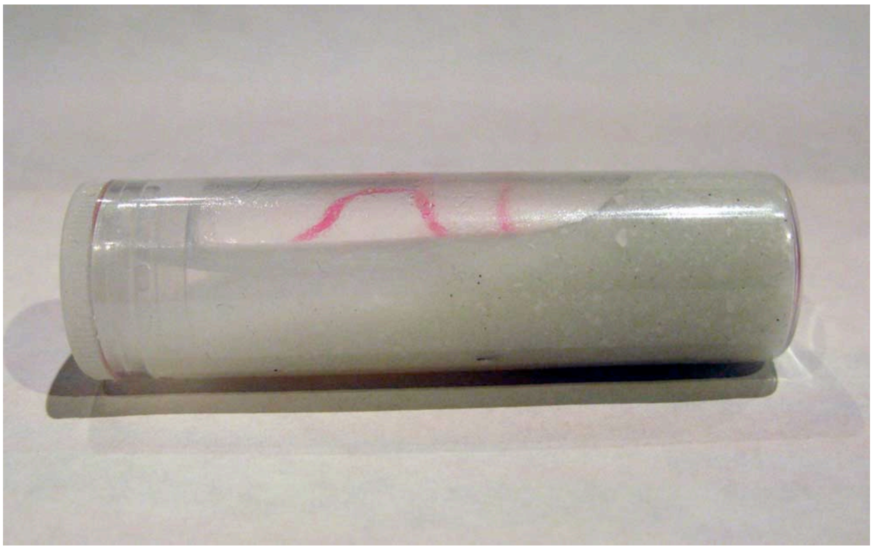

Fig. 44. Different angle of show from the same solution as figure 23. CO2 in gans-state, which have been gravitated by the system. It contains solid flakes within the solution.

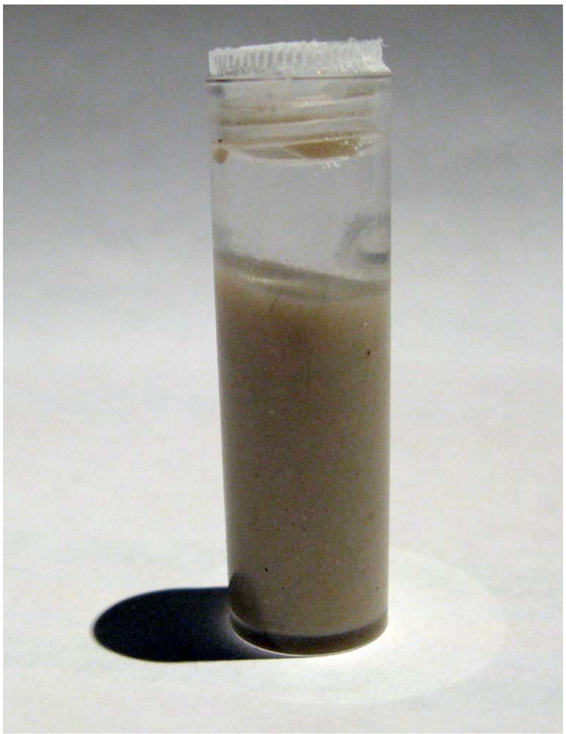

Fig. 45. Unknown composite material in gans-state which have been gravitated by the system.

Chapter 5

The light and its interaction with the Principal star

The Principal Star is what has been commonly called the Black Hole (3) and it is understood that these entities are places, where the principal mafs and matters are create and collected.

The pmf of principal star being covered by dense layers of the transition mafs, this being the reason as why they look to be dark or where there are no lights are transparent in these regions in the specific parts of galaxies in the cosmos (Fig. 46).

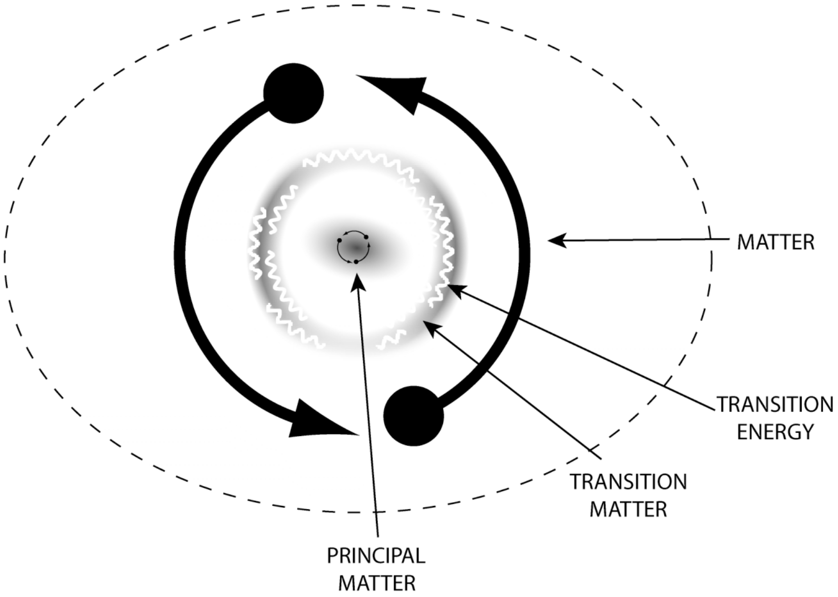

Fig. 46 Structure of the principal star

The light being in possession of the gravitational and Magnetic fields of its own and consequently the light having the Magravs of its own, these fields forces' of the light in matter magnetic field strength environment of the universe take their positions in respect to the Magravs of these principal stars in the centre or any other part of the galaxies.

In these environments in the universe one can observe that as the light rays come close to the principal star the light in majority of cases will not be absorbed by the extensive gravitational fields forces of the principal star, but the light ray finds its way by going around the principal matter star instead of as it being absorbed by this entity. This ability of bending of the light is commonly called the lensing of the light near large objects, and this is the process by which currently scientific world can confirm the existence of the principal star in the universe.

The reason for the bending of the light being due to the fact that as the light possess its own mafs of the principal matter, then the light's principal mafs Magravs take their Magravs positioning in respect to the principal star mafs' and matters' and this positioning of the two Magravs of the principal mafs of the light and the star from the point of an observes from a distance looks as the light bends around these objects or what is called lensing phenomenon of the light around the Principal star occurs (Fig. 47).

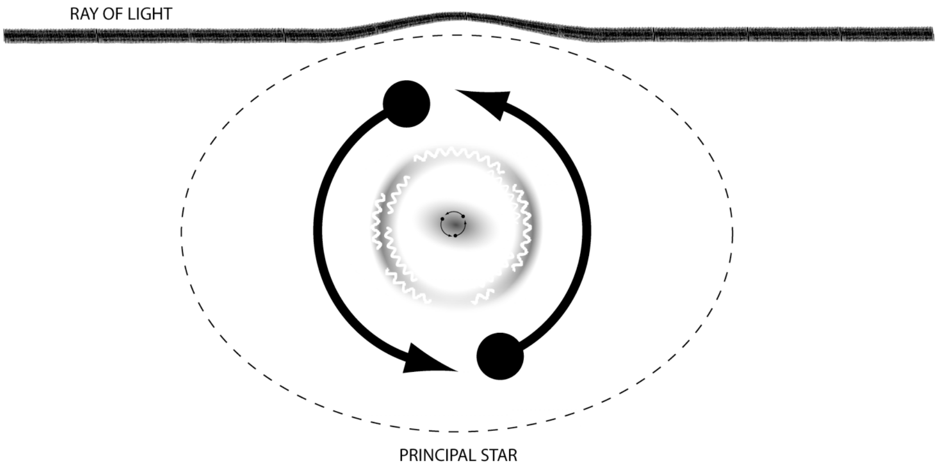

Fig. 47 Bending phenomenon (lensing) of the light around the Principal star due to Magravs positioning

The theory that even the light will not escape the Principal star gravitational field forces once passes the event horizon, this shows the lack of the understanding of the scientists in this respect too, as if the scientists had the tools to observe and could detect the principal mafs magnetic field spectrum, then they could observe that as in matter mafs stars like the Sun of the earth's solar system, these Principal stars will radiate pmfs in the principal mafs strength spectrum and the Principal stars are like bright shining stars in their environment, and as they absorb light in matter's spectrum strength, they at the same time release light in principal mafs and transition mafs pmf strength simultaneously.

In time the scientific world would produce tools that with these tools they will be able to observe the motion and emission of the Principal and transition lights rays from these dark spots in the universe. Then one can observe that light in principal mafs strength are emitted from these stars in the galaxies as light are emitted from the Sun of the solar systems and the disappearance of the light in even horizon is only illusion and not a reality as the pmf of the light mafs get diluted in the stronger pmf fields of principal and transition mafs rays.

The concept that how principal stars are created, how they operate and how they absorb and emits some light has been disclosed in detail in the paper written in 2002 and published in 2006 titled "The creation of Back Hole".

Principal stars if they absorb mafs and of the matters, stars and visible light as it appears to human eyes' vision spectrum, then they can and they do at the same time emit light in the mafs of the principal matters spectrum into the environment of their galaxies too, as this was not the case then the conservation of principal mafs and matters in the cosmos will not hold and this is against all the laws of physics.

In reality the dynamism of the mafs of the principal matters in these stars and the light they emit is the cause and deliverer of pmf needed for the creation of matters and stars in the galaxies.

In a simple way, as the light from the Sun feeds its own solar system mafs of the matters and matters the like of its planets, the same is done by the Principal star through its light emission in the Principal mafs pmf strength feeds all mafs and matters in its captured Magravs sphere or so called its galaxy.

At the same time the Magravs of the Principal star dictates the position and attraction of other matters, stars and galaxies' in respect to itself as the total mass of the matter mafs and transition mafs of the matters in galaxies are about less than five present of the total mass of the galaxies (3).

Thus the positioning and directional motion of the galaxies in the universe, the same as in the solar systems is dictated by the mass of the principal mafs and matters of the principal star of the galaxy and no other factor (3). Therefore the mass of the galaxy is the measure of the interaction of the Magnetic and gravitational fields' forces that the principal mafs contents of the principal matter can produce and maintain.

Once these principal stars are formed in the universe then the Principal stars and the lights which are releases form them become the means of the supplier of pmfs and nourishment of to the environment of these galaxies" (3).

The concept of the structure of the principal's star lights as the source of pmf into its heliosphere zone is applicable the same but in much smaller quantity of mafs of in the operation of plasma of an electron, proton and stars too.

In the modern science the source of the creation of matters in the plasma of electron and proton are mysterious entity, which lead to creation of quarks, bosons and other names content of the plasma, in fact for example so called the bosons are the pmf of lights released by the principal mafs of the plasma, which as this dynamic light reaches a given point and given pmf strength in the plasma of the proton or electron due to reduction in its pmfs strength in motion in the plasma, this leads to appearance of matter mafs and matter of different pmfs strength in all regions of these plasmas.

The mysterious forces which the scientific world has been observing in the plasma of the proton, these are released by the principal star of the plasma itself as lights in the principal mafs strength unwinds and as these lights reduce in strength to different mafs and matters pmf levels strength. Then these slowed down pmfs lead to appearance of different weaker matter pmf strength in the content of the plasma, where and when two matching field's strength and matters strength can interact that they can create a given gravitational fields forces within the plasma then these points of gravitational field appears as bosons and other named entities within the plasma. At the same time these entities create their own Magravs which the operation of fields forces of these Magravs appear as mysterious filed forces within the plasma of the proton or electron.

Theory of Higgs and Higgs boson concept: In fact if these scientists would have understood that the interaction of at least two magnetic fields (bosons) leads to creation of gravity (attraction) and Magnetic fields (repulsion), which further interaction of these two fields of Gravity and Magnetic fields leads to creation of the mass of the matter (Higgs), then Higgs would have understood that interaction of magnetic fields not only in plasma but in any level of magnitude in the universe leads to creation of matter which this matter always possess its own mass and magnetosphere, or in other word when two magnetic fields interact they lead to creation of mass which is the maximum strength of the gravitational strength less the Magnetic fields strength created by the interaction of these two secondary fields (1). Thus Higgs theory is correct and in reality one does not need to smash an atom in accelerators to observe and prove his theory, but it would be easier to the same behaviour of production of matter ***if two rays of light are fused*** that **they lead to creation of matter** and thus the Higgs theory would be proven to be correct in a simpler way.

This is process of the production of bosons, Higgs and other entities in the plasma of proton is the replication of the same process as the operation of light rays in the solar system changes to matter in different pmf strength regions in the heliosphere of the star, where in the case of plasma of proton ***the same process takes place in micro/nano level*** of the mass of the principal star and principal mafs and matter in size.

Stars in the centre of the galaxies in motion near the Principal stars even though they release rays of light but not all these rays get absorbed into the principal star or the stars themselves and in reality the Principal stars do not absorb all lights from the matter stars (the sun is a matter star) into themselves as the plasmas of the lights in the matter mafs pmf strength contain their own principal mafs and matter and these principal mafs of the light create their own pmf Magravs, which this Margrave allows the light to take its position in respect to the Principal star which is so close to, and this Magravs positioning of the light allows the light from the star in the matter strength to move away from the principal star as is observed by the astronomers. In fact the speeds and the distance of the star from the principal star is dictated by their own principal's mafs content and the Magravs strength.

The matter stars in their inner sanctum contain and hold on to large quantities of the principal mafs and matters (1), This meaning that even the Sun in its process of feeding light into its heliosphere, at the same time in this process the Sun *releases a large quantity of the magnetic fields of the principal mafs and matters as the* ***principal light rays strength of magnetic spectrum*** in this environment.

It has to be said that in galaxies, the high speed of the rotation of matter stars near principal stars has to be extremely high, this being due to the fact that as the matter star itself contains principal mafs and matters and at the same time these mafs of the principal matters interact within the structure of matter star that they create their own gravitational and Magnetic fields that the matter star takes it principal mafs Magravs strength positioning in respect to the mafs of the principal star matters and mafs Magravs. Thus the only way that matter star can hold on to its pmf structure is to attain a high speed as its mafs of the principal matters of the matter star content have to find a constant continues renewing its new position in respect to the principal stars matter's and mafs' content. These high speeds of the stars near the principal star has been puzzling the cosmologist, but if they look close enough and as they could understand the principal of the rotation of an electron in respect to the proton of an atom (1), then the speed of the matter's star with composite matter and mafs content near the principal star shows and is flowing the same path and the same principle of motion as an electron does in respect to the proton in the nucleus of the atom as electron moves fast around its nucleus to maintain its position and hold on to its content matter (1). Thus now may be the high speed of the matter stars near principal stars can be explains and the single directional orbit of the star matter in these regions confirms content of the Principal star as to be mainly as of the Principal mafs and matters, that this singular mafs and matters contents' of the principal star allowing the more circular motion or elliptical motion of matter stars with their large mass near the Principal stars.

This is the same process as to replacing the proton with the principal star and the electron with the matter star, with parallel high speed dynamic motion of the matter star with controlled Magravs positioning around it nucleus. The reason that the motions of the matter star around the principal star is not as unpredictable as of motion of electron around proton (1); this is primarily due to mono content matters and mafs of the principal star. In fact in these cases the light observed by the cosmologists created by the matter star is mainly due to the interaction of Magravs of the two matter and principal stars, and at this point the Magravs of the matter star has to find rapidly its position in respect to the Magravs of the principal star, and this is how the matter star become to attain speeds' in the region of the speed of light in matter pmf strength. Thus the majority of the visible light of the matter star in close proximity of the principal star is not of the star itself but it's due to the interaction of the Magravs of the two stars. Now one can see another marvel of the universe, where matter mafs in creating light which itself is the light of itself.

This concept of mass moving at speed of light in matter pmf strength environment due to interaction of principal mafs strength will have such a profound effect on the man's scientific progress and in man being able to travel the depth of universe and this will be the point of and the tool of detection of future space crafts in motion at speeds beyond the speed of light in matter mafs strength and above in the cosmos, once the concept of the light rays in the pmf strength of principal mafs strength are understood fully.

Chapter 6

The light and its planetary interaction

The interaction of different lights of different matters (principal, transition and matter) can be utilized to create the appropriate magnetic fields and currents and gravitational fields' forces as it is needed for any purpose, then this concept of interacting lights is the way that food and energies from the right light mafs levels can and will be produced in deep space travels of the future, as one can take the right components and amounts of the mafs in matter field strength needed of any required levels of mafs as/and for nourishment of the mans' physical body, without man actually eating tangible food.

This conversion and absorption of light rays is in fact what plants and animals do in the earth environment as they absorb specific plasmatic magnetic field strength of light spectrum and due to their atomic and molecular Magravs field's strength they create measured vacuumed condition within their structure to and for transformation of a given pmfs' strength of the light to be converted this to gans of that mafs in the structure of the plants or animals. Which, these ganses have Magravs equal to Magravs strength of vitamins or minerals levels as the planet produces or the animal needs for existence in a given environment. The process of production of minerals and vitamins in understanding how light is and can be converted to gans in earth atmospheric condition will allow the production of the same matters and vitamins by use of the light matters' structure in conjunction with the using a simple dilution Magravs positioning reactor anywhere in the universe (1).

For example man by eating a given plant, he absorbs that spectrum of the fields transmitted and absorbed from the spectrum of the light mafs of the matters fields for specific use in specific protein in man's body, and now man has the knowledge to produce the same proteins and minerals from the light rays without the need for plants or animals as an intermediary conversion toll for this process.

In earth atmospheric Magravs condition herbs absorb pmf of the higher strength of the same light as normal plants do and the meat can absorb the complex strength magnetic fields of the light. The structure of herbs pmfs attraction and storage is more dependent on the pmf emitted by the light spectrum from the earth fields as the fruits store most of the light spectrum which are entered into the atmosphere from above and that is why each entity has different mafs strength storage and conversion capacity and capability. Where, the same light from space in different distance and interaction with the magnetic fields strength of the light of the earth leads to creation, storage and production of different pmf spectrum of the light by the same plant and animal DNA.

The ray of light in its entry into the magnetosphere of the earth and the interaction of the two Magravs lead to release of specific characteristic rays of specific magnetic fields strength, that this ray through a special process with the hydrogen atom lead to creation specific division of energy that can sustain life on this planet. This ray and its process of creation, which is not known in the world of science presently has been fully explained in the book "the universal order of creation" to be published in the future. We see that in time man of knowledge would be able to comprehend this process, and once this process used then the wisdom of all creations in the universe will be understood and can be replicated anywhere in the universe.

The rays of light at any strength of its mafs at their entry into any dynamic plasmatic environment have the ability to lead to or through conversion process cause the initial chain of reactions needed for the start of life and then the matters produced use the light itself to further create more cell like beings and then through the ray of light conversion in these cells this leading to final step that the light ray in becoming the creature like man, then using light rays and its product main gains intelligence and the intelligent body at this stage acquires its magnetosphere and Magravs or what is known its ***soul***.

Chapter 7

The use of the properties of the structure of the pmf of the light for space technology

As the man's knowledge reaches and becomes in line with realities of creation; in the future the mafs of all components of the light and the phenomenon of light rays entanglement will be used for space technology in an efficient way and in manners which are not even comprehendible at the present.

The helixial cylindrical motion and reversibility capabilities of the outer-magnetic mafs of the shell of the light in space reactors of the future will be the key in control of the motion and the directional motion which these crafts can travel and the same time the control of the speed of the motion of the space crafts of the future can be set by using the matters' components of the light.

The gravitational fields' forces of the light and the reactors using and producing light gravitational properties that can be used for control of the directional motion are much easier systems to produce in a fully integrated combination space reactors setup that using different mafs' strength of the light makes take-off and landing possible in every environment and pmf fields strength in the universe, without putting the craft and its passengers ever in any danger. Where, with the use of the lights' mafs Magravs technology one can reach the deepest part of the universe in time spans that are within the fraction of the life of humans, rather than the present assumptions of thousands of the light years. In comprehending the concept of the structure of the light in full; this will the time, when the Man understands the truth about the world of creation in the universe, and how universe was created and real universal motions are created and maintained.

How, different rays of lights get entangled and leads to creation of conditions of mafs of matters is due to Magravs positioning of one light ray in respect to another of the same. The Magravs positioning of two rays of lights or what is known as the light–entanglement is the condition for example, where and when the light rays can converts from mafs of matters to characteristics of tangible or detectable matter in a given plasmatic magnetic field strength environment.

It has to be noted that there is fundamental difference in light entanglement and fusion of light rays. The ***fusion of the light*** is more fundamental process in production of matters and mafs and this process can be used for production of stronger light rays or for the production of heavier elements without going through the process of the matter state fusion. This being the like of the production of oxygen molecules through the fusion of light rays, rather than multiple fusion processes of the rays of the light's once the neutron to an atom of hydrogen is reached, and then through multiple fusions processes to reach the production of oxygen molecules.

In fact fusion of the matters of the light does not require energy and in reality does not lead to release of vast amount of energy. Whereas, in the present process of fusion of the matter of hydrogen the present fusion scientists have got themselves tied up with the wrong concept and technologies and they are in the dream of achieving fusion of matters through the use of present laborious fusion reactor technology with very little success.

By the same default in understanding the real process of the fusion in the universe, there has been a misconception by nuclear scientists in production of the heavier matters through fusion of matters in the centre of stars and in their nova process. Where, the **present assumption** that matters are created in the centre of the stars through process of fusion of matter **is not in reality correct**, whereas the process of fusion and production of all matters in the universe primarily takes place at the *point of the fusion of the light rays* ***first***, then as the light rays become to the point of matter mafs strength they first *all convert to gans of the neutron* and then through process of the Magravs positioning and collective balancing of these forces of the total light rays in a given environmental pmf strength, then some of the light rays once converted to neutrons some stay as neutrons and others of the weaker strength in the collection go through the process of the neutron decay (1) and become proton and electron of the collection of the light rays and hence in a given pmf strength, the physical matter with given number of neutrons and protons and electrons are created. Therefore, it is the collection of fused light rays which changes to collection of neutrons and then as some neutrons go through neutron decay and become proton and electron, this is *how* ***atoms of different matters are created*** *in the universe*. Where, further this process of the light pmf strength matching through light-entanglement process is a much easier process than the matching and fusing physical plasma of atom or molecules and solids.

In fact this is how neutrons are found to take their place in the centre of atoms to start with and this is how fusion takes place in the ***real universal cosmos*** (unicos). This being one of the reasons why the present science have problem to produce fusion as they try to fuse matter as in real term in the universe and in the centre of the stars fused light rays lead to creation of matters of different mass.

Fusion light **ray reactors** are simple practical systems which do not need very much energy for them to run and operate, but they can create and facilitate *directional motion of the space crafts of the future* using their capability to split the plasma content of the light to its sub structure matters and fields and create Magravs of different strength and in a cylindrical reactor of the same to stack the light rays gravitational and Magnetic fields forces for creation of the directional change and at the same time these reactors can be used for the production of the matters for the use in the space environment of the future.

For the space technology of the future there is a need for multiple light reactors that an instantaneous three hundred and sixty degree spherical motion of space crafts can be achieved and the at the same time the shielding magnetic fields can be interchanged from matter mafs to principal mafs and change of the dynamism of the same fields can be used for rapid deployment and penetration in dangerous and denser matter and mafs parts of the universe.

The same entanglement or interconnection process exists between light rays as does and prevails in the atomic and matter environment. At the present time the scientific world is considering ***quantum entanglement*** and its use in transportation of matters and other uses within and across the boundaries of the universe. In reality if scientists comprehend the concept of the light–entanglement and understands the principle use of this phenomenon, then one can use the matching structure plasmas of light rays before they become matter to achieve high speed transportation in the range of and beyond the speed of principal light rather than limited speed of the light in matter environment as man is considering to be the ultimate speed of motion at the present.

In entanglement process one can/and have the capability of use of different mafs of the lights for crossing the universe, and without change of physicality of the plasma and change of its state and then at this stage one can even copy and lock the same plasma of the light that in Magravs positioning of one plasma in keeping its connection with the same plasma of the light of the same strength or length in other parts of the universe.

If this concept of light interconnection and complex light-entanglement of Magravs of light balancing is understood and replicated then feeling, like touch, loving and hate and so forth can be transported across the universe without actually the matter or being ever crossing it physical boundaries. Thus coping atoms and interaction of the atoms and even the emotions of the matter (which complex, vibrational and rotational based) of one atom or light to another can be transported across the universe using light entanglement technology.

In fact this is how dreams in the inner sanctum of the human brains are created and take shape and give the man the image of seeing and communicating even with people which they have never physically met or to other Magravs of other beings which in their time of living in that give environment their Magravs of the dreamer and dreamed of have been exposed too.

The light entanglement is a real and correct physical process, where certain cells within the inner brain or thought control systems of the living being has the capability to operate within these pmf mafs strength and this is the natural part of the operation of the brain of the human beings that scientific world has not mastered to unravel.

In fact the light entanglement communication method called telepathy is the easier way of communication than using the ears or other method of listing and talking and the place for this system seats in the inner parts of the man's original main brain structure.

The light entanglement technology will allow collective entanglement and different strength molecular light entanglement allows the full structure transportation and even continuous motion replication of the molecules. This meaning the transportation through the light plasma entanglements of let say heart, brain and all tissues at the same time, with the same heart beat and the same liquid with emotion of the entity across vast points of the universe becomes a possibility of the use of this process. Where, the light in all its pmfs of all its mafs of all matters and strength are available in all corners of the universe and all needs to be done, is to re-produces the same strength and combination mafs of different matters to replicated and reproduce the copy of the original entangled light for the two lights entanglement across the universe to interact and communicate and transfer their knowledge without acutely the matters of the light ever leaving their original environment.

Using this technology one can even transmute the same from one mafs of the matters' strength to another to speed up or reduce the transportation and trans-crossing time from one field strength and matter mafs to matter strength variation and principal mafs to matter mafs and matters strength. This needing and leading to change of light's mafs to the appropriate measure and sizes and conversion from matter mafs to matter like the mafs of food or oxygen and so forth for human consumption in crossing the universe without relying on and physically carrying food or power supply or even transporting human beings across the universal physical boundaries.

This concept of transmutation which is commonly used in the universal method of transportation will be thought in detail in future disclosure and partly has been disclosed in the book the universal order of creation of Matters (1) papers references 11, 16, 21, 29, 34 and 37.

In the matter environment of the earth, this can be achieved in plasma reactors of simple structure using complex combination pmf of mafs of the light and matters and plasmas in the dynamic nuclear supported reactors.

This concept of light entanglement is one of the easy solutions for transportation in the future without physically moving matter across the universe. This concept has been tested in medical application of the technology and results confirm the correctness of the technology. Where, copy of the correct cell information is translated to cells that the cell makes the copy of the right cell and uses this knowledge to cure or replace damaged cells or by allowing the process to be moved to another part of the body while one part of the brain recovers from damage (the coma case).

The concept of the atomic-entanglement and the binding between two atoms is a natural process of interaction in the universe and if one understands the similarity of this interaction and the light–entanglement then one can see that in the physical world twin stars and the atomic entanglements are of the same in principle interaction and in concept, with difference in their magnitude and the size of the entities involved. Taking note that there are differences in between the twin and binary connection of atoms and stars and their process of entanglements criterion are totally different. Where, the twin atoms and stars are matching in matter contest and, where the binary stars and atoms are matching in magnetic and field contents.

Where, in the binary system the overall Magravs is matching that entities can magnetically polarity interlock. Whereas with twin entities every matter matches in mass and position as well as Magravs and their pole positioning.

The reason that a pair of atoms in receiving additional pmfs of rays of light is elevated to create a mysterious binding between them, is due to one of the fundamental principles of the reversibility in the magnetic polarity of one atom in respect to the other, even though both atoms having the same directional motional rotation. That is to say, *one of the plasmas involved in the entanglement get its magnetic polarities reversed in respect to the other atom.* This meaning, if the first atoms' proton and electron have their North-Pole on the top, in receiving additional mafs of the light, then the second atom receives enough mafs that causes or initiates the change polarity in this second atom, that at this point the North and South poles of each atom interlock with each other and the sudden atomic binding due to the lock of magnetic fields flow between the atoms takes place.

The same principle of atomic entanglement and attraction of reverse pole attraction holds true, when one observes the rotation of twin and binary stars entanglement. Whereas one star reverses its magnetic polarity, automatically the twin star polarity changes too, that the magnetic lock between the two stars to be maintained that the entanglement and twining and binary system can be sustained.

Star, atomic and plasma twining and binary process locking is the safest and common occurrence in the universe as this gives the stars a total magnetic balancing and guaranty's the survival of the both entities. This phenomenon of reverse polarity entanglement holds true and exists for all the twin system in the universe, this being for atoms, stars, galaxies and even universes.

The reason that the light injection or absorption of additional energy by two atoms in some cases leads to creation of entanglement is primarily due to the fact that additional energy received from the ray of the light leads to increase in the magnetosphere dimension of the atoms and this in turn allows two atoms in proximity of each other two magnetically interact and entangle and at the same time in coming close to each other, one atom changes polarity and the two atoms pmf lock and gets gravitated to each other but at the same time each atom is holding on to their Magravs positioning strength gap which is dictated by their internal pmf maf contents. Once the mafs of one star and atom changes due to whatever reason, then one will observe the disconnection of the entanglement or the coupling between the two entities, where at this point the higher Magravs strength partner will pull the weaker Magravs entity to itself.

This is a crucial phenomenon to understand, especially when using light entanglement reactor process in reaching any destination and requiring the change of the plasma of the light from principal mafs to matter mafs strength condition. Thus atom entanglement is a natural phenomenon and at the same time once an atom is created the content of two atoms' plasmas are hardly ever the same, this is to say, to find matching content of pmf of two plasmas of electrons and protons are as rare as finding two completely matching structure of two snow flacks.

The injection of the light into the plasma of two atoms allows some of the atoms, which are near enough in pmf mass to reach the same point of mass or Magravs strength equality at the same time and hence have the capability of coupling. But there are points that additional pmfs of the light can induce enough energy that one atom can come near to another atom pmf balance and being able to interlock too.

The atomic–entanglement is not and cannot be used for transmutation of elements as easily as has been suggested by some scientifically advanced schools of thoughts.

In the present scientific world, scientists have been observing and detecting regular pulses of for example gamma radiation in the upper atmosphere of the earth, which they consider that these radiations all originate from the cosmos and for example they are from the time when a star explodes through the nova principle in the universe. These types of radiations are not the only types of radiations that arrive towards the inner part of the solar system from the cosmos. In reality there is spectrum of radiations and magnetic fluxes of different strength that go through the solar which are originated in the cosmos. In comparison, the radiation that arrives in the inner-most part of the solar system and at the boundaries of the earth atmosphere, these cosmic origin based rays are nothing compared to the gamma rays and other rays which are created within the heliosphere of the solar system itself.

The truth about the main source of these background radiations which has been considered to be from the cosmos and are released, when stars in the universe go through supernova, this concept that these explosions are the main source of these gamma rays and other background radiation which are detected, this shows the lack of the understanding of the process of the conversion of the light into matter and movement and collision of these new matters and mafs in the Oort clouds and Kuiper belt of the solar system. The main source of the gamma radiation bursts detected are originated and created through the motion of the charged particles of the new matters mafs and matters and their collision with each other in the Oort clouds and Kuiper belt region of the solar system and these gamma bursts have nothing to do with supernova and release of gamma bursts that they produce.

That is to say as/and, when newly born charged particles of mafs of the matter and matter as gases, nano matters and ganses move in outer regions of the solar system and ***as they collide with each other***, they release magnetic fields in the gamma, other radiations and noises in magnetic field spectrum levels in these regions of the solar system, which these radiations find their way into the inner parts of the solar system due to the strong magnetic fields interactions pull of their star.

The way these radiations and noises are generated and released is exactly the same way as the lighting and thunder are created and how light and sounds are released through the collision of clouds on earth and in other active atmospheric conditions or in other planets and moons in the solar system and similarly as it happens on the surface of the Sun, when matters mafs of the Sun collided in its upper atmosphere.

Thus the space travellers of the future have to consider all components of the all rays of the magnetic spectrum in the matters' mafs, matters, light, sounds, the principal mafs and matter and its sound and all their light radiation spectrum strength levels too, which these are all free and in motion in the space of this solar system and in the cosmos.

The radiation danger and damages from the light in the principal mafs strength levels are more predominant, stronger and profound than the matter mafs light ray spectrum strength and these radiations and their motion in space will play a crucial role in the future of space travel as these rays will be lethal and fatal if protection from these are not facilitated into cosmos excursion systems and scientific world has to have a viable protection technology for the passengers in the space crafts of the future before they contemplate on such excursions into cosmos and specially traveling in the centre of the galaxies and near principal stars.

Whereas, for example one of these problems will occur, when strong mafs of the principal matters radiations will interfere with matter mafs dilution Margraves positioning reactors used for motion of the craft in space and these principal mafs upon them reaching inside the reactor, they can create Magnetic field surges that can lead to surges in these reactors gravitational and Magnetic fields, which this can lead to the loss of the system and the total inhalation of the system, or the change in the Magravs strength leans the craft in totally different part of cosmos than where the craft was originally destined for.

Therefore, before the men of science contemplate on traveling beyond the boundaries of this solar system, they have to master the knowledge of the mafs of the principal matters spectrum's magnetic field strength and the light transportation mechanism in this spectrum.

If one could understand the structure of the light and how it changes from spherical shape plasma to cylindrical in shape for it to be able to travel with less friction and high speed from one dynamic environment of spherical or cylindrical entity to another spherical environment, then in the future the man of knowledge can develop elongated cylindrical three matters mafs strength spherical and cylindrical composite mafs fuelled combination setting and reactors and crafts, which these elongated crafts will have the benefit of possessing spherical or cylindrical plasmatic magnetic shielding of higher order magnitude pmf strength of the principal mafs and matters for fast and protected space travel in the universe, then at this point one can travel the spans of the universe in times which are not even imaginable at the present by the man of science by use of these types of composite setting and fuelling reactors.

The use of light for purpose of transportation technology and communication through the understanding of the relationship and interaction of mafs of plasma and plasmas of the light(s) in each and every mafs strength of the matters of the light structure is the key to final and ultimate intellectual growth of the human race and point of maturity of the coming of the age of the man as has been promised. This technology will be at the edge of man's enlightenment in the knowledge of creation and control of light and its mafs and matters in the universe.

Chapter 8

Insight into the future use of the structure of the light

From the new understanding of the structure of the light, can easily and readily be concluded that if the light did not and was not made of the structure of three mafs of the matters then the light would have not possessed its own gravitational and Magnetic field forces and for example the light from other stars in the universe would have never been able to reach the earth as an individual magnetic field due to the characteristic and properties of the magnetic fields interactions and gravitations, as through magnetic interactions all these rays' of lights would have been absorbed by other magnetic fields and gravitational fields in the universe and the light would have never reached the far distances of the universe. Hence the light as a physical entity which is similar to other physical entities the like of proton, electron, earth and the Sun and the light being in possession of both Magnetic and gravitational fields, the light ray has to find its position in respect to any other object and pmf in the universe as it passes these entities in the universe, and hence in its travels in cosmos light ray has to find it's Magravs positioning in respect to them that this allows the light ray not to be absorbed but to go around these objects. Hence, the reason for the physical observation of the lensing or the bending of the light near these object as the light passing large and strong gravitational object is purely due to its Magravs and its positioning in respect to these entities in the universe.

Therefore the lensing of the light is the confirmation of its existence as dynamic composite magnetic field strength fields physical and tangible entity in position of Magravs, and the light is not a ray of magnetic field in motion or what has been called that the light to be an energy. Whereas, the plasma of the light ray in motion can transfer it Magravs to other matters and thus has the ability to transfer its momentum to other matters and mafs as energy.

Hence due to the fact that the light possess both Magnetic fields and gravitational fields and in line with laws of physics, when the gravity and the Magnetic fields interact (1 and 2), their interaction lead to the creation of entity in possession of its own mass and its own magnetosphere. Where, the interaction of the lights magnetosphere with the magnetosphere of other objects due to their friction leading to release of residual magnetic fields in the matter magnetic field strength level of the human protein, which this makes the point of interaction of two Magravs detectable pmf field or what is called the visible light to human eye and his tools and methods of detection of pmfs in this ranges of filed strength, out of the full magnetic fields spectrum of the universe.

Where, the motion of the dynamic spherical plasma of magnetic field in its travel from one point in the universe to another causes and leads to elongation of the dynamic spherical pmf, hence the restructuring into a dynamic cylindrical plasma ray of the light, and as this plasma of the ray of light reaches the right pmf environment strength that slows down enough or losses its strength, at this point the cylindrical plasma restructures back to its spherical structure and leads to the creation of pmf of matter mafs and matter in given matter pmf strength environment (Fig. 48) The book cover image. Hence light has the same structure as the pmf of any other plasma known to man like the plasma of electron and proton but in elongated form rather than presently known dynamic spherical shape of tangible matters.

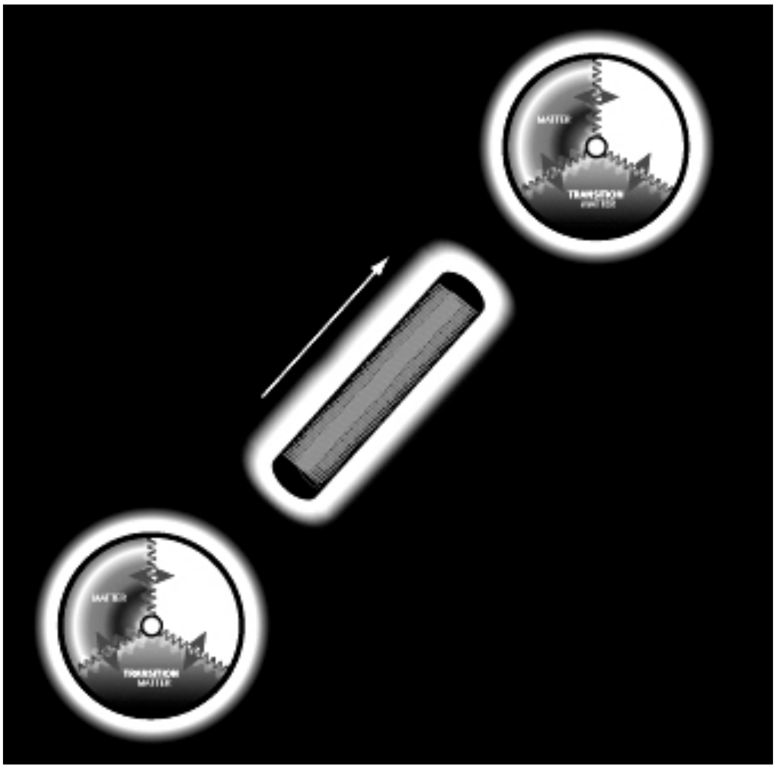

Fig. 48 The conversation of dynamic spherical pmf into dynamic helixial cylindrical ray of light and its conversation back to dynamic spherical (Cover image).

Where, at the same time the plasma of the light in its travels in space can become visible according to the plasmatic magnetic fields of the environment which it travels through and according to the observers' plasmatic magnetic fields strength which in the case of human living Magravs protein molecules structure.

Different proteins have different pmf strength for different creatures in the span of the universe, hence what is visible light to one creature in one point pmf strength in one part of universe this does not mean that to another protein Magravs strength in the same environment this can be visible light too. Hence what is visible light in principal matter or mafs strength, in transition mafs and matter and in matter mafs world in a given matters' magnetic fields environment respectively these light rays are detectible or visible according to the environment and of each mafs and matter in the binding Magravs of the structure of the observer.

The plasma of the light has the capability to present the magnetosphere around itself according to the pmf strength which it is passing through, thus it is the environmental pmf strength which decides the outcome of the mafs of the matter of external layer of the plasma of the light and the final presentation of the light in a given environment.

The plasma of the light to reduces its losses in its pmf of its matters and at the same time allowing it to encounter less resistance for it to be able to travels through the same pmf strength that have less or faces no losses, thus the light ray has the capability of the change of cover mafs and matters of its structure. Thus it is inevitable to consider and conclude that the light like its larger combinations has its own intelligence and its own internal logical magnetic processing that allows it to survive and exist in every dimension in the universe that it might travel through or be part of. This giving the light the capability of being able to travel long distances, and at the same time, this allowing the light not to have fixed maximum speed in all universal magnetic field strength spectrum opposite to what has been assumed by scientific world at the present.

At the same time, the light becomes more visible or detectable as it travels from stronger matter mafs fields strength to a lower matter fields strength environment.

Two rays of lights with different mafs of the principal matter strength can pass through the same medium and they can create different brightness intensity and therefore all lights rays do not have the same intensity primarily and their strength and intensity is internal initial principal mass and strength dependent. Therefore a ray of light can be dimmer or slower compared to another ray primarily due to their mafs of the principal matters content and their strength.

Lights have speed according to their lowest common denominator of it environment pmf strength. Therefore, speed of light in Principal environment due to the stronger field strength of the principal mafs pmf is much faster than the speed of the same plasma in the matter environment, hence the present assumption that the speed of the light as observed by man is the maximum speed of the plasma of the light is ***incorrect***, and hence the plasma of the light has speeds in the Principal matter environment far beyond the present assumptions in the matter environment of the earth and this universes matters' pmfs strength.

Even though the formulas used for conversion of main connection of mass and energy looks as to be balancing and to be correct, in fact this equation is only correct for small and minute amount of plasma and only in the matter environment and not in other plasmatic fields environment of principal mafs and mafs of the transition matter or combination and composite plasmatic magnetic fields strength of principal mafs and matters environments and where only individual rays are considered.

Now that one knows that mass is created through secondary effects and interaction of the effects of the interaction and connection of at least two dynamic plasmatic magnetic fields of the gravity and Magnetic fields (1), which these Gravitational and Magnetic fields both themselves are created and are products of interaction of at least two initial magnetic fields, then in fact mass itself is product of interaction of four fields of two initial fields and two effects of these two fields and hence the formula of relativity now is totally incorrect and has to be rewritten as now one of the factor of the four of the magnetic fields and their combination of their products with each field in position of its own speed of its mafs strength, as energy which is define as magnetic fields in motion, then multiple of speeds of the light in their initial matters mafs strength times the matters mafs of their effect strength in a given mafs strength is the realistic method of the measuring the energy in respect to the mass of the same matter.

Using this knowledge and understanding the structure of the light and applying these in the space technology and in the space reactors crafts of the future for travel in deep space, then by knowing the mass and the strength of the fields which one needs to be traveling to and by the same principle the strength of the original mafs of pmf can be calculated and measured by using the fundamental application and implication in production of light Magravs strength of the system and of the same of the destination point, then one can estimate the power of the crafts Magravs need to be and at the same time what the speed of the travel of the craft shall have, and using the mafs of the light at that given matter environment, one can calculate what mass of the light the system needs to have and be loaded that the system can travel at a given speed in a given environment, or what speed the craft might have once one uses the certain amount of mass of the light in any combination in any of multiple combined fuelled integrated multiple Magravs positioning reactors of the space crafts of the future (1, reference 24,18 and 11).

In understanding the strength of the principal mafs fields strength and using this phenomenon for creation of speed of motion of the systems and crafts, then one can calculate and understand that travels with speeds hundreds and thousands of times and millions of time faster than the speed of the light in matter environment in the near future will become as conventional as jet liner travels of today. The assumption that the speed of light in the matter world is the ultimate speed in the universe cannot be correct. This assumption, when using the principal mafs fields as source of fuel in dynamic plasma dilution gravitational positioning space reactors, which have been developed and tested can be used to achieve higher speed than the speed of light in the matter environment.

Through this technology of the use of light gravitational positioning systems, speeds of travel in Principal and Transition mafs strength environments, which are beyond the present understanding of the man in the matter universe are faster than the speed of light in matter environment.

Now one can understand, that once by not using the principal matters as fuel as has been discussed and promoted by some organisation to burn, as has been the habit of the man to burn to attain motion and height in the past centuries, then in using the mafs of the principal matters in creating gravitational fields and Magnetic fields within a gravitational system, then one can travel the length of the universe in times which are not acceptable to man at the present time due to restrictions which has been forced on the humanity by the less knowledgeable scientists of the time and due to their lack of understanding of the creation and control and structure of the light itself.

Then now one has to make new concepts and measuring tools for local time and universal times as these will be different according to the light mafs strength of the space crafts and environment of measurement and new conventional translation for time has to be employed, otherwise traveling in one speed of the light mafs strength and then entering another to live in, this will create untold problems for the future universal travellers of this universe and for the inter-universes travellers of the future (3, 6 and 7). Invariably in the near future one can use the principal mafs and matters magnetic fields for the purpose of transportation in the universe, where from this point on travel with speeds beyond the matter pmf strength environment for travel in the universe and between universes become a natural means of transportation.

At the same time the speed of light in the principal mafs and matters strength is visible light to the man too, with the difference that in this environment as the protein chain of the man contains and is consisted of plasma of electrons and protons, and these plasmas themselves are made of and operating and consisted of the composition of principal mafs and transition mafs and matters (1) too, then the principle mafs strength of the protein will come into operation and the life will be as normal as one living in the present matter mafs and matter environment of the universe. With a slight difference that he needs to learn about control of the operation of his physical body and his tools of detection in the speed and light configuration.

The parallel world of different pmf strength of matter mafs and mafs of the principal matters are the faster and stronger in pmf strength of life which the Man has come to comprehend and live with and soon he will be able to transmute from one pmf strength of mafs to another and use this knowledge for the advancement of his race and connection and communication in and with the other creature of the universes.

The gravitational field forces of the mafs of the matters of the structure of the light will be the smartest and fastest method for creation and control of space reactors of the future. At the same time speed of the separation of mafs of the matters of the light will be the best directional controller and magnetic shielding protection system for the space crafts of the future as the lights' mafs and matters separation and control in different mafs of the matters and matters of the universe this make the plasma of the light the safest and quickest methods to generate parallel speed of the light in different mafs of the matters environment and at the same time the directional motion of the Magravs transportation system can utilize the mafs of the matters of the light interaction for smooth transition from one matter mafs field strength to another or from matter mafs to matter environment and vice-versa.

This light matter mafs structure division and utilization will be the technology which needs a full understanding of the world of creation and once mastered as has been done by other inhabitants of the universe, then the man will be of the same strength and capability of the understanding of the universe of universes operation, interaction and universal organisation.

When, the intelligence of the man reaches the full understanding of the potentials of the use of the light mafs of the matters, then one will be able to travel in different mafs of the matters environment with use of the mafs of the principal matters magnetic fields strength as the protection magnetosphere created around the crafts in possession of the multiple Magravs positioning reactors.

The dynamic twin reversal of directional motional shielding system made of and through the use of mafs of the principal magnetic fields' strength of the light guaranties the total non-penetrable protection for travel in all mafs and matters environment in the universe, without leaving any traces of direction of motion and without being visible to the human eyes and any other tools and means of detection of any other creatures in the universe.

Where, this technology can be used for fast speed travel in crossing boundaries of universes and for travel across one universe without spending thousands of light years in traveling time as is currently calculated by human scientists. Thus one can travel with full safety using the highest lights Principal Magnetic field strength for every aspects of the motion in the universe.

Once the concept and the principle structure of the principal mafs and matters and other mafs of matters and lights are fully understood then one can use the knowledge of the light structure in full and the scientific world will be able to use the structure and mafs of the light for creating new matters and production of food and nourishment for the life of the passengers and for the space machineries of the future and food producing reactors for the man in deep space where the light is the only available matter for use and at his disposal.

The mafs of the matters of the light can be brought to levels that one needs for the body to absorb for it to survive a pleasurable and comfortable life. Where, different strength mafs of the matters and of the light can be used as vitamins and minerals and proteins for the Man's needs to live. Where, the light mafs of the matters can be used directly without the need for the plant and animal conversion systems of the light mafs of the matters to minerals and nourishment for the human consumption.

One has to understand that there are lives in the lower pmf strength of the universe too; where in reality the matter universe is not the lowest level pmf strength in the universe. The light in this universe is the same and operates in the same way.

In the future one can *use the light mafs of the matters to produce and lower their strength mafs of the matters to pmf for example of the sodium or vitamin A or B*. Therefore from this point on one can even produce composition of matters or what has been the dream of producing energy and new matters through fusion. Now one can use the Principle matter mafs field's strength of the light to fuse the elements in the matter environment. In fact fusion is more practical and achievable if one uses the principal mafs and matter's field's strength of light and their division to create environment of matter mafs for the matters to be created. Fusion of pmf of the light mafs is in so many ways easier than physical matter fusion once the light is transferred into neutron or an atom. The lights' mafs of the matters fusion is a way for the re-production of heavier elements or their pmfs without creating enormous amount of heat that one cannot and has no tools and means to control and contain such matter fusion technology.

Once the man learns the use of the construction of mafs of the matters of the light, then one will learn that source of mafs of the matters are available in all corners of universe and on the other hand one does not need to create the physical matter to have the properties of the physical matter, but one can use pmf strength properties of the given matter in its fusion of the light mafs of the matters to achieve the same effect, the likes of the production of energy and food without ever using fusion of physical matter to achieve the same goal and actually without ever needing physically to eat and to digest food. Then in the near future man's body will do with the digestion system and in the further times man will learn and will do with the physical body for it to exist and for it to travel the spans of the universe(s).

Using the mafs of the matters of the structure of the light rays for **communication purposes**, in the matter environment, then the communication system can be set to transfer the information in the Principal matter mafs strength and once the information arrives at the point of destination the receiving system can decode the information from the principal mafs strength to matter mafs strength and then the information can become available for whatever purpose it was transmitted for, this being audible, visual or computable information or transfer of matters. This method of use of mafs of the matters of the light field's strength will eliminate any time delay in communication across the spans of the universe, the delay time which has been observed in the present cosmos communication systems will not exist once using principal mafs strength and then communication become instantaneous anywhere in the universe.

Thus by switching from one matter mafs strength to another matter mafs strength of the same light, this will bring into play a totally new technology and facilitates new approaches in the production of tangible matters too. That is to say one can strip the light from one of its mafs of the matters for one purpose and use its residual mafs of the matters for other purposes. That is to say, by striping the light off its principal mafs for the communication purposes, then one can use the mafs of its transition matters and mafs of the matters of the same plasma of the light for production of increase in other matters and matters growth or expansion in their given environment or use these for production of energy for human existence in space.

The universal language using mafs of the matters of light and using the same mafs of the matters of the light for their transportation will be the cornerstone of the future transmutation of matter and matters and communication in the universe among other intelligent creatures of the universe(s).

The positrons are created at the point of the creation of the plasma of the atoms from the ray of the light and the clockwise motion of these particles is totally and primarily internal magnetic fields position dependent. This meaning that the directional rotational motion of all matters are dependent on the speed of the rotation and position of the mafs of the principal matters and matters in respect to each other, this plasma be it of the plasma of electron, proton, atoms even stars and galaxies.

The clockwise or anticlockwise rotation of electrons, protons, planets and stars is determined by the principal mafs matters speed of rotation and its distance in respect to the matter mafs and distance between different layers mafs components of the plasma of the entity after the light ray is converted to matter of the electron or the proton and star and its matter content.

In conclusion one has to be aware that visible light magnetic fields spectrum, which makes man to see its universe is the same in all pmf strength levels. This means that in every pmf strength environments there are visibility criterions to all created life, but the visibility is pmfs field strength dependent. Therefore, what is not visible to one being is visible environment to another using different pmf strength for point reference as tool for vision and this applies to all pmf strength mafs of the matters and matter universes and environment.

At the same time vision is not through the vision tools like the eyes, but vision is the openness to receive knowledge through the real means of the operation of the universe in the pmf strength of the level of intelligence of the structure of the beings.

The reality of the existence has been measured by the strength of the light, which a matter can emit, and the duration and the depth the Magravs of the created light can penetrate in its environment. Then the question for the Man to ask of his existence, is that how does the matter like him, who is the user and the producer of the same physical entities as stars, how does his existence will shine and operate in the span of the universe after the demise of his physical life on this matter strength environment?

May be it is the time for the Man to come to understand the true meaning of the light, as all beings in the universe announce their existence through the emission of the light into and onto their surroundings.

This technology of the light ray's protection gives the man the ultimate knowledge for survival and brings the man knowledge and intelligence in par with and equal to the knowledge known to the rest of the universal manifestations and the same we have served our purpose in bringing the same to all men of progress.

Thus would be correct for the Man to consider his connection beyond his physical existence and through the light of his presence during its time, and hence would the soul of the man be of the light of the confirmation of his existence.

Be wise to the truth of the creation of the man, if the light of wisdom is the light of the soul from the time of beginning to the end of time. This light will exist and will be the source of the confirmation of everlasting existence of his soul, as the light of far distance star after billions of years are shining in the deepest part of the universe, this has been and shall be destined for the soul of the Man throughout all times of the existence of the universe.

Thus it can be said

The man has come from,
He exists, operates through and
He shall return to
the Light

Definitions

Below is a list of the new terms and their definition that used in this book. A number of these words and terms have been used in the previous book and scientific papers, which have been published by the foundation and most readers, are familiar with these terms and reference. In this book a different approach and language and terminologies is used, therefore has become necessary to create a new terminology and words that can explain the real term application and processes in the world of physics.

Mafs: magnetic fields

Magnetic: with **capital M** refers to the plasma of magnetic fields created by a dynamic entity as for example this refers to the magnetic field of the earth.

Magravs: Magnetic and gravitational fields (Magnetic referring to the plasma of magnetic fields created by a dynamic entity as for example this refers to the magnetic field of the earth)

Pmf: plasmatic magnetic fields

Principal matter: This matter in conventional physics is called the ***anti-matter***, as now the real structure of this matter is fully understood and is said to be source of all matters from the dark matter to matter, thus it has been called the original matter or the principal.

Principal mafs: These are magnetic fields, which are in the principal strength levels and considered to be I order magnitude several hundreds of times stronger than the magnetic fields which make up the tangible and visible matters.

Principal star: This entity in the conventional physics is called the Black hole

Transition energy: This energy in conventional physics is called the dark energy. This is the pmfs that are in motion from principal to matter magnetic fields strength so called the transition energy as energy is defined as the pmfs in motion.

Transition matter: This matter in conventional physics is called the Dark matter, as now the real structure of this matter is fully understood and is said to be when plasmatic magnetic fields are in transition state from the principal matter to tangible matter thus the term transition matter is used.

Transition mafs: These are magnetic fields which are in strength level between the principal and matter magnetic fields strength, and are in transit from the principal mafs to matter mafs strength levels.

Gans: a new state of matter; a molecule of a gas (GAs) which becomes Nano of itself and appears as Solid state of matter. **GA**s to **N**ano of **S**olid and to be called **GANS** for short.

Reference

1. The book, “The universal order of creation of the Matters”, M T Keshe, published July 2009 ISBN 978 46 6087 001 9

2. The unifying theory of the fields M T Keshe 2009

3. The origin of the Universe M T Keshe 2010

4. The creation of the solar systems M T Keshe 2010

5. The CO2 capture paper by MT Keshe Published 23.12.2009

6. “The universal order of existence” finalized and to be published in 2010-2011 by M T Keshe

7. The Magravs positioning M T Keshe 2010

8. NASA WMAP common.wikimedia.com

Published and unpublished works by M. T. Keshe

There are a number of unfinished articles that are to be converted to full disclosures when completed, like antimatter mafs method of energy releases, Nano space technology, relation between the creator and the created, space communication system, deep space defence technology, dynamic magnetic fields force regions (wormholes) construction and control, creation of magnetic fields, and so on.

Some of these works have already been published through different channels and some have not yet been released.

In the following section some of the works done by the same author are mentioned, with a brief disclosure of their contents.

Some of these papers can be purchased and obtained through direct request and access through specific links.

A number of papers with * and ** marks **are not for public release** due to their sensitivity of information and only available to relevant commercial and governmental organisations for peaceful applications of the technology.

The universal order of creation
(5.7.2006)

In this disclosure the main construction principles and the method of the link and control in the universal order of the existence of living cells, like the function and operational method of any matter based on so called proteins chains, as for example in human cell are explained in detail.

REF 9

The author considers this paper as one of his most important and fundamental works to be published and to be added to the sets of disclosures written by him.

Cosmic Rays
(Release date 24.3.2004)
This paper explains the source and the origin of cosmic rays and the way these work within our cosmos, their function and their benefits.

REF 10

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*The Airborne reactor

(Release date 25.3.2004)

This paper covers the total design of airborne reactors for space technology. This covers all aspects of operation, design and control of such reactors.

REF 11

The seed of the Earth
(Release date 25.3.2004)

Some extracts from this paper:
The theory that the heat of the core of the Earth is due to inertia of the material piled on top of each other is completely dismissed through this new disclosure.

The author M T Keshe believes that this centre core is made of hydrogen, other gases and a mixture of liquid and solid matters mafs, which were in the vicinity of the centre of the core of the Earth at the time of its inception in the solar system.

Through this new understanding of the new inner cores of the planet, this brings to play the fact that the old inner core of the Earth that is already assumed to be made of a solid piece itself becomes a sealed container for the new inner core.

The author through design of a parallel system has set to confirm the validity of this assumption, that the centre of the Earth possesses a semi- fusion atomic reactor and not a fission reactor as has been assumed by other scientists.

This theory of hydrogen in the centre of the planet is in line with the physical reality of the creation and the present situation in the physical construction of the solar system.

By the laws of physics all the gases in the solar system should have been in the giant gas planets at the outer layers of the solar system, like in Jupiter and Saturn.

The physical reality in the solar system, is that the lightest of all these gasses, the Hydrogen, has taken its place right in the centre of the solar system in its star, the Sun.

It has to be recognised that the centre of all planets in possession of gravity due to the centre cores heating, are always in possession of two Magnetic Field Forces in their inner sanctum (M. T. Keshe “The creation of gravity").

In the case of the Earth up to now and with the present knowledge there has been acceptance of only one inner core and one magnetic force.

As it is explained in the paper titled "the creation of gravity", there is an inner core in the inner core. This inner core, due to it physical content, motion and position in the centre of the Earth, creates and maintains its own magnetic field force, independent of the magnetic force which has been known to be created by the interaction of the inner core and the outer core of the planet.

These two magnetic fields interact to create the planet's own double magnetic fields in its centre. The interaction of these two magnetic fields forces upon each other leads to the new concept of the "DOUBLE MAGNETIC FIELD EFFECT", where the interaction between these two field forces in the centre of the planet leads to the creation of the gravity and the magnetic forces of the planet

(Paper: The creation of gravity).

This new second core is the seed core of the planet, the mother seed of the planet positioned in this new inner core.

REF 12

The creation of Black Hole
(Release date 25.3.2004)

In this paper it is explained that the Black Hole is created out of a natural sequence of events, and that the existence of the Black Hole in a galaxy is a normal event. Further it is explained that a Black hole is created in similar ways to the Dark Spots on the surface of the Sun. In this paper for the first time, it is explained how the Black Hole is physically created and what function it plays in its galaxy.

REF 13

Magnetosphere
(Release date 9.6.2004)

"The shape and the strength of the magnetosphere of a planet is exactly what a fingerprint is to a man. It is unique to each planet, star and galaxy. It is a tell-tale of all its attributes, and it reveals the hidden mysteries of the internal materials' structure".

REF 14

Correction to the Einstein equation of Relativity
(Release date 15.6.2004)

In this paper the physical reality of the Einstein equation is considered, and efforts are made to bring this equation to the real conditions. Even Einstein considers this equation applicable for very small mass, and not in real three-dimensional multi-Magnetic and gravitational conditions, which are external and have nothing to do with the theoretical object's mass and speed, but have effect on the speed and the mass of the object under consideration.

REF 15

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*Introduction to the new system
(Release date 2.7.2004)

In this paper it is written "It is essential to understand that, with the application of this system of motion, one cannot bring into play the solid, liquid and gas fuel method to create motion, as is used today. What is offered in this system is in simple words a fully integrated plasmatic magnetic energy system. Which, creates within and around the core environmental conditions as known to man in the universe like creation of gravity and magnetic field protection and the same as the magnetospheric protection condition of planets and motion through interaction of magnetic fields as planets and stars do in their given environment".

REF 16

The rings of Saturn
(Release date 2.7.2004)

One of the oldest puzzles in the world of astronomy has been the existence of the rings around Saturn. How did these rings come to exist the way they are now? How did they come to appear and behave the way they do? These questions and much more about the creation of these rings are all answered in this paper.

REF 17

The creation of gravity
(Release date 11.7.2004)

In this paper it is explained that "the source and the creator of the magnetic forces and the gravitational forces are due to the interaction between the same materials in the same region of the planet."

Further it is explained how the gravitational field force can be created, replicated and controlled within a nuclear reactor. Further it is explained how this property can be used for the motion of a system within a planetary or solar system.

Now by understanding the principle of the creation of gravity, in this paper it is further explained that "the gravity in reality is the effect of the interaction of two plasmatic magnetic energy fields of any two object in respect to each other."

REF 18

Death of a star
(Release date 26.7.2004)

In this paper the death of stars is explained, "The death of a star and the creation of a supernova is in reality the same as the half-life cycle energy step-down of an atom, with the difference that this show is in a larger scale, and more spectacular, in all aspects of its dimensions".

REF 19

Fusion

(Release date 28.7.2004)

In this paper the physical and scientific problems with present fusion technology is considered. Where, it is written, "nuclear Scientists, with the fusion reactors of today, are trying to create fusion in the opposite way to the known laws of physics and their parallels in the universe”. Further in this paper it is written, "If the present path for creation of fusion is followed, with the present scientific knowledge of physical materials for construction of such system, then following the present path of development to create energy from current fusion systems will be a distant dream".

REF 20

Life of a Cell

(Release date 28.11.2004)

Extracts from this paper; "The reality of the transportation and transmutation of a cell is not far from the reality of the life of an atom or a star. Where the life cycle of the cells are slightly more complicated, as they contain other matters mafs like acids, which have their own magnetic characteristic of their own chemical structure. For this reason the control and replication of the energy of the cell is very much complex, but very simple to achieve".

REF 21

The Atom

(Release date 19.12.2004)

The content of this paper explains how and where atoms in the universe are originated from and how the construction of atoms in a cold plasmatic nuclear reactor can be replicated.

REF 22

Magnetism

(Release date 8.1.2005)

In this paper it is written, "The question is where did the Magnetism come from? This is the Secret of creation. The world is made of one thing and only one thing and that is Magnetism. Its combination and interaction with its own different strength fields makes it appear as different matter mafs. The rest of creations are the outcome of these interactions of different strength of this thing called magnetism and the forces it creates. Magnetism is the origin of existence and the real singularity in its full meaning".

REF 23

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*The creation of the magneto-gravitational force
(Release date 5.2.2005)

The creation of magneto-gravitational field force is and will be fundamentally independent of temperature and pressure, proviso to the fact that as long as a homogenous free floating PMF within a matter mafs is created.

REF 24

The core of the Earth
(Release date 20.4.2005)

One of the original assumptions in developing the new Magravs system some thirty years ago by M.T. Keshe was on the basis that the centre of the Earth possesses addition cores, which create the necessary gravitational conditions of the planet. After some twenty years of space technology and through Earthquake seismological data's this assumption has been shown to be correct and after over twenty years, it has been scientifically proven that the inner core of the Earth has an inner core of 600 km. Professor Guy Master in 2002 ref 24 nuclear planet. The centre of this core is assumed to have an inner core of 8 Km, this he thought to be made of the plutonium or other nuclear materials

But the developer of this new plasma reactor technology has proven through physical dynamic cores that these cores possess a mixture of hydrogen plasmas and the process of the heating of the centre of the Earth are due to a semi-fusion chain of events.

REF 25

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*The electron-atomic welding
(Release date 3.5.2005)

Some extracts from this paper:
"The electron atomic welding or atomic welding principle is the phenomenon that atoms of the same material, through a common shared electron, become a magnetically balanced molecule of the same matter mafs, with the difference that the shared electron will create a balanced PMF in the molecule".

REF 26

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*Shutdown and safety of the reactor core
(Release date 6.6.2005)

In this paper the safety parameters in the operation of the gravitational and energy reactors are simply explained to avoid the loss of plasma and gravitational field forces created within its cores.

REF 27

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*Reactor Start-up

(Release date 9.6.2005)

In this paper the systematic start-up of the dynamic reactors for the creation of gravitational field forces and the production of energy are set out. The start-up of these systems is totally different than the prior arts known in the nuclear industry.

REF 28

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*The energy balance of the reactor

(Release date 29.6.2005)

Some extracts from this paper:

The energy balance of these types of reactors is not as simple as might look in the first instance. The energy creation is simple. But the heat leakage and dissipation through the deliberate inherent material design are and can be zero. That is to say the system not only can hold on the heat it creates. At the same time due to the close circuit feed operation will become self-sufficient but long lasting.

In planets, the loss of heat through their surface creates the variation in the central core condition over several billions of years. In this reactor as losses can be literally negligible, the system can operate at low energy loss temperatures. Even the boundary of the body could be made through the right combination of material in the chambers, so that the body of the reactor will be colder than its surrounding boundary. So the system will not only lose energy to its surrounding, but it can be made to absorb heat in the negative temperature gradient from its surrounding, so that there are no losses.

REF 29

Nuclear decay or half-life

(Release date 20.7.2005)

Extracts from the paper:

"The nuclear decay always has the same or near the same time duration. This is due to the fact that the all neutrons and protons, from their inception, carry a predetermined level of plasmatic magnetic energy. This energy is continually used for the motion and vibration of different elements of the nucleus in respect to each other and the surrounding matters mafs of the atom. As the space and dimensions of a nucleus of an atom always obeys the same principles of the magnetic separation and magnetic attraction. Protons or neutrons can and will need to use or consume the same energy before they become weak enough that the splitting or decay becomes a clockwork job. The nuclear decay is the natural levelling done of a nucleus' energy, due to the energy consumption and heat dissipation for the motion of the elements of the nucleus for its remaining plasmatic magnetic fields energy necessarily needed for them to hold one together".

REF 30

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*The decontamination system

(Release date 10.10.2005)

"What this means is that, for example in trying to recycle the CO2, by the use of the right matter mafs in one of the cores of the reactor, the system will then use the O2 to produce H2O, in the form of pure water, and C in the form of atomic or molecular carbon, or even by feeding this back through certain operational compressions and gravitational interactions within a small core, to create industrial diamond or graphite, for different industries."

The use of the reactor for this purpose has been proven to be correct and Raman spectroscopy has proven the concept and physical reality of the separation of matter mafs in atomic level after separation in the same system from a composite matter mafs.
(See the graphene on the technology web site)

REF 31

The difference in atomic and molecular structure under gravitational force and pressurised conditions.

(Release date 15.8.2005)

In this paper is written that "the atomic and molecular structure of matter mafs is totally aligned and positioned in a fundamentally different configuration where it has come together due to gravitational forces, than when matter mafs has been brought together by the means of pressure. This has a fundamental effect on the behaviour of the structure and properties of the matter mafs which is created in either way". Where this is explained and utilised to develop a new method in creating graphene and Sp3 atoms and walls in a simple core made of a coca- cola bottle.

REF 32

**The Defence and shielding system

(Release date 4.9.2005)

Some extract from this paper:
The design of the side open system for lunch of high saturation magnetic plasma package is one of the most effective technologies for defence of the reactor and the craft, which is in possession of such a system.

It is essential for any space technology in the open environment of the universe, if the craft is to keep a straight line of motion and to be able to protect itself from any solids or matters mafs in its path in the cosmos.

This technology can destroy any object by the principle of plasmatic magnetic energy saturation of the incoming object at a molecular level, that object will disintegrate in the form of magnetic vapour and not atomic level destruction, before matter mafs can damage the craft as debris, and before the craft ever becomes in touch or near these space matters mafs.

This technology can also be used to protect Earth from the collision risk of NEO's (Near Earth Objects), like comets and asteroids.

REF 33

Method of creation of an atom or nano matter mafs
(Release date 11.10.2005)

The manufacture of an atom of any density, this being of the simplest form of nucleus or a full atom of hydrogen, or even heavier elements in the universe, all follow the same principle.

Atoms are created in the soup of the cosmos from collections of very weak plasmatic magnetic fields, which for their existence cluster and share their energies with the magnetic fields that are not far from their own plasmatic magnetic field strength.

REF 34

The relationship between Gravity and Mass
(Release date 21.1.2006)

Extracts from text of this paper:
"A planet like Earth possesses a combination of both gravity and inertia. Where the gravity comes from the interaction of plasmatic magnetic energy fields from the processes within its core, and the inertia comes purely from the collection molecules PMF of matters mafs which has built the physical body of the planet.

Any object, being an electron, atom, molecule or even a human body, is a collection of plasmatic magnetic energy fields of different strengths and their interactions between each other, which in total decides the total or collective magnetic field possessed by that object where this is the mass of the object.

Where the mass of an object is a collective package of plasmatic magnetic energy field tightness of a given object and will not change as long as the object is intact as one entity in its overall atomic or molecular or collective molecular appearance.

Which plasmatic magnetic energy of a physical body (so called the mass of the body) in interaction with molecular or atomic magnetic field (this being gravitational or inertia) of another object will determine the weight of the two object in respect to each other in each other's environment".

REF 35

The Dark matter mafs
The Fifth state of matter mafs
(Release date 21.1.2006)

Extracts from text of this paper:

The existence of dark matter mafs is not questionable, Proving its existence, and its effect on the energy balance of the universe, in all matters mafs as small as in the heart of an electron or in a solar system needs to be created, replicated and its effect measured.

The theory of dark matter mafs does not and needs not to be considered as complicated, if one understands in real terms the plasmatic magnetic energy of the matter mafs in the visible and invisible dimensions of the universal work.

The dark matter mafs has two distinctive characteristics, which makes it totally apart from the visible matter mafs. The dark matter mafs possess mass but not visible light, where its existence can only be determined by the weight of the it's hidden mass, which could be substantial due to its internal gravitational field.

REF 36

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*The inter-atomic fusion
(Release date 3. 5. 2006)

Extract from this paper:
"The fusion of two or more atoms has been the pre-occupation of nuclear physicists for past years. Conditions to achieve fusion of two hydrogen plasmas in the TOKAMAK reactors have taken years to teach scientists a lot about the behaviour of plasma and their fusing.

The reality about the fusion in some way has to be reconsidered as, if the scientific world is trying to amalgamate the contents of two plasmas to release energy. There must be a simpler way to achieve releases of similar energies.

The fundamental principle of the inter-atomic fusion is a much simpler way to achieve fusion. If this principle is applied to the atomic condition of fusion, then fusion will be attained in a simple but in a much more physically realistic environment.

The explanation for inter- atomic fusion is very simple and direct.
In the fusion of two plasma of proton of hydrogen atom, the physicists try to fuse two large plasmas, and by doing so, they try to release a large amount of energy. Where in this process enormous amount of magnetic field forces and currents are needed to bring two plasmas in close proximity, so that the energy barriers in between them can be overcome for them to amalgamate or fuse.

In the inter-atomic fusion the overcoming of energy barriers does not exist, as in this method of fusion, the electron of the atom which is circulating the nucleus of the atom and is of the same origin will be encouraged to return into and fuse with the nucleus of its atom".

Where this is a more practical way to create and release manageable energies and there is no need for elaborate systems where even if the energy release will be small compared to dreamed up fusion systems of today.

With inter-atomic fusion method at least small and practical systems can be developed to handle low temperatures of the fusion process.

REF 37

The conductivity of the matter mafs in the vacuum of the interplanetary mediums

(Release date 21.1.2006)

Some extracts form this short paper "Therefore plasmatic magnetic energy field of elements within the interplanetary medium will cover the space given to them in their environment. Where due to their motion and their electric charges even in eV levels, they become perfect conductor, and in turn, due to their motion on their environment, they become plasmatic electromagnetic generators.

REF 38

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The production of Graphene

(Release date 25.7.2006)

Repeated experiments and tests in simple static reactors, and tests in more complex dynamic reactors, prove that atomic separation and recombination of matter mafs like carbon and hydrogen can be reached at room temperature and at atmospheric conditions.

We have now indications - through static and dynamic tests in our reactors - that the universe was made in normal condition, which was originally nothing but packages of plasmatic magnetic fields of different strength, which were themselves nothing but areas of plasma or collections of loose magnetic fields energies. Where magnetic fields of different strength in locking to each other, by the principle of their plasmatic magnetic energy (PME), have caused in the first stage the creation of fundamental particles, secondly atoms, then molecules and then matter mafs, clouds and asteroids and then stars and galaxy's".

The big bang theory conditions have no room in the reality of the creation of the universe.

REF 39

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Further works on medical research and developments have been written and completed, and will be published on the Foundation medical site in due course.

The process of the reversal of coma: Published in December 2010

Multiple Sclerosis: Published in December 2010

Epilepsy: Published in December 2010

Fibromyalgia: Published in December 2010

INTERNET LINKS

Web site: www.keshefoundation.com

YouTube Channel: http://www.youtube.com/user/keshefoundation

Forum: http://www.keshefoundation.com/forum/

Appendix 1

The unifying field Theory

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Date of release of paper 28.10.2009

Abstract

In this paper the origin of electromagnetic fields or electromagnetism and how they are created within the existence of the other magnetic fields are simply explained.

Discussions

The creation of magnetic field and its interaction with physical matter or other fields always leads to release of electromagnetic fields or energy equal to the energy of an electron.

In the universe, energy equal to energy of an electron, where there are no matters for magnetic fields to interact with, for electromagnetism to be created or to be released, in these environments electromagnetic fields do still exists and function.

Electromagnetic fields or electron energy does not need to be created by interaction of magnetic fields and matters as like in generators of present time, as in the universe electromagnetism is constantly produced due to the difference of the magnetic field strength between two fields and without presence of any matter or physical interaction of fields or fields and matters.

Due to the development of gravitational systems and having the ability to create different strength plasmatic magnetic fields within gravitational reactors cores, with the capability of being able to create and maintain different magnetic field strength in different part of reactors, where these fields are continuous and can be kept at a given constant strength level, that their difference in strength in fields can be equal to the magnetic field strength of an electron, where electromagnetic current flow can be maintained from one magnetic field to another due to their field strengths difference, this has enabled us to create and maintain energy field or elect magnetic fields strength of an electron in a plasma reactor without an electron being present or in motion within these reactors.

Where production of electromagnetic fields can be achieved by the simple creation of two magnetic fields with different magnetic field strength of an electron, that as fields are down levelled, from one magnetic fields strength to another, one can creates a flow of magnetic field equal to magnetic field strength of the an electron, thus the creation of electromagnetic current, or production of flow of electromagnetism can be achieved.

Where electromagnetism or current of magnetic fields of an electron can be created at any level of magnetic fields strength, as long as a strength level difference between two fields in magnetic fields exist, and where, in plasmatic magnetic fields the strength level difference of the fields causes the flow of magnetic fields from one field strength to another can be caused or what is called commonly electromagnetic field flow can be maintained.

Therefore, one can have electromagnetic fields of any strength, this being Matter, Antimatter or

Dark Matter, as long as their magnetic field strength difference between to field strength is equal to the magnetic field strength of an electron or magnetic fields of Matters of an electron. Or the magnetic field strength that can affect the motion of other fields to be equal to the magnetic fields strength of an electron. Then at this stage one achieves the electromagnetic current thought flow of magnetic fields, from one stronger to the weaker field, which the magnetic field strength of the flow is equal to magnetic field of an electron (see Fig. 1).

Electromagnetism

In the real world of existence, all Matters do not have boundaries as tangible matters do, but their boundaries are dictated and created through the space they cover through and by their dynamic magnetic field effects. Where, this space of effect of their magnetic field is called the environment of plasma of these fields.

Thus when we speak of plasma or plasma of an electron, proton or neutron, what we talk about here, is the space and environment where the effect of these magnetic fields of the total structure and the entity of for example an electron can cover.

Thus an electron is in fact nothing but a space in an environment, which the total effects of all magnetic fields of all Matters and fields, can be detected or be contained in.

Thus to this end, when an entity possesses magnetic field strength equal to total magnetic fields strength of an environment within the plasma of an electron, then this entity is in possession of mixture of dynamic magnetic fields of an electron or this entity has magnetic field strength measure of an electron or what is called possesses electromagnetic field.

Where this space being in possession of magnetic fields, by its nature has to interact with other magnetic fields and entities made of magnetic fields in it's surrounding, where these interaction can be attraction (gravitation) or repulsion (Magnetic).

Hence and direction of motion of this space of fields (Fig. 1) or electromagnetic fields is totally dependent on other magnetic fields within its environment, which their environments total strength in gravitation and repulsion dictates the direction of the motion of the plasma of an electrons magnetic fields.

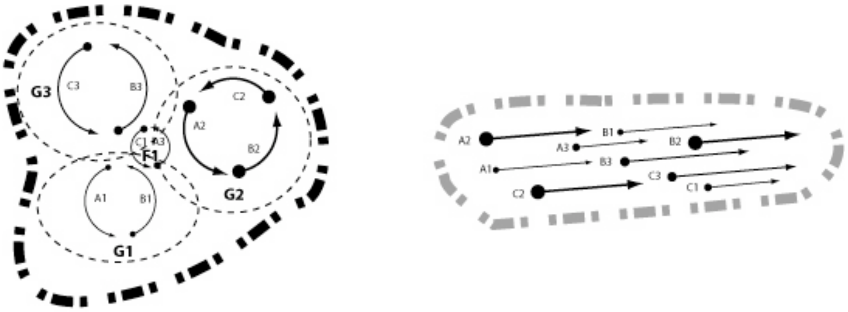

plasma of an electron

Flow of pmtics

Fig. 1 Magnetic fields concept of an electron and a flow of plasmatic magnetic fields equal in strength to that of an electron.

As I have explained in the book, The Universal Order of Creation of Matters (2009, ISBN 978-94-6087-001-9) the magnetic field strength decay of the plasma of a neutron (Fig. 2) leads to creation of two plasmas of the same structure of a proton and an electron.

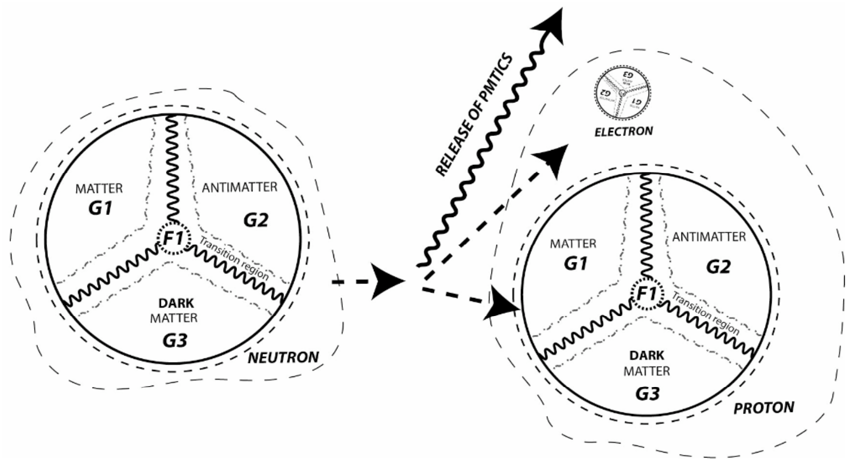
MATTER
G1
ANTIMATTER
G2
F1
Transition region
DARK MATTER
G3
NEUTRON
RELEASE OF PMTICS
ELECTRON
MATTER
G1
ANTIMATTER
G2
F1
Transition region
DARK MATTER
G3
PROTON

Fig. 2 Decay of plasma of Neutron into two plasmas of proton and an electron.

It is an important to understand that the structure of an electron in fact is plasma and it is like the plasma of proton but in a smaller scale in the mass compared to the proton (Fig. 3).

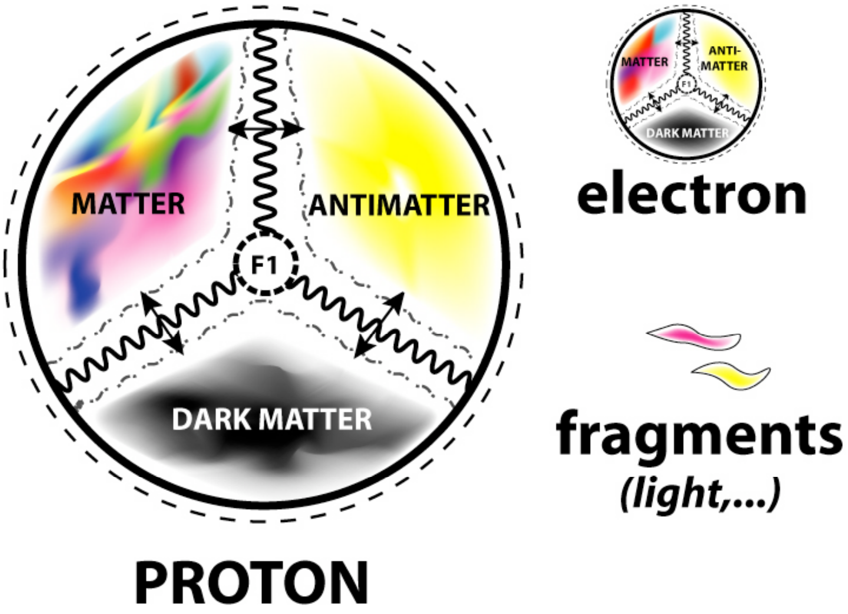
MATTER
ANTIMATTER
F1
DARK MATTER
PROTON
MATTER
ANTI-MATTER
F1
DARK MATTER
electron
fragments
(light,...)

Fig. 3 This showing that proton and electron both possess the same electromagnetic field strength of different Matters, with each entity having different mass of each matter.

Thus the electron is and has the structure of a proton and similarly possesses all its three states of Matters (Matter, Anti-Matter and Dark Matter), and its content is proportion to its neutron plasma prior to its decay into two plasmas of the proton and an electron. As electron is made of electromagnetic field strength of varying strength, this being the reason, why its current and its flow can be influenced by other magnetic fields, as magnetic fields of different strength do influence each other's path of motion and speed of motion in different Matters and matters environment.

Where, at the same time and by the same principle the dynamics (orbits) of the electron around its proton is due to the continuous repositioning (alternating attraction and repulsion) of the smaller Matters parts of the electron in respect to the large Matters magnetic fields of the proton. This is the reason why that the trajectory of the electron is said to be uncertain.

Where, by the same principle, the Magnetic field source of all Matters and matters and their different magnetic fields strength, is the cause and the sources of all effects and matters we observe in the universe.

In the book I have explained how the gravity is created through interaction of two or more magnetic fields, and how mass is the measure of difference between gravitational fields and Magnetic* fields created by the interaction of the same two or more magnetic fields. Thus even mass is magnetic field strength dependent too.

Further the relation between mass and energy, which both are magnetic field strength dependent (1), and as has been explained, energy is the measure of the mass and the rate of it's the speed of transfer in its own Matters medium (this being Matter, Antimatter or Dark Matter medium) from one magnetic fields strength to another depending upon attraction or gravitational strength from one magnetic field to another. Where, this speed is magnetic fields order of magnitudes strength dependent.

Where, transmutation from one magnetic field strength of Matter to another, like from Matter to Antimatters can lead to creation of current or electromagnetism within the given environment of the same plasma itself too.

In fact in the universe one has proton magnetic field current flows or **protomagnetism** (proton-magnetism) too. This current is the flow of magnetic fields to another, which are equal to magnetic fields strength of one proton. These magnetic fields are bases of the cosmic magnetic field storms and have more profound effects on the structural integrity of the galaxies than their weaker counter parts electromagnetic fields.

Further more as now we understand the concept of plasma of an electron and even by the same principle one can understand the principle structure of the plasma of the proton and by the same measure of the plasma of the neutron, hence in the universe we have observed plasmas of neutrons in motion, which these have the same ability as electromagnetism and protomagnetism in motion and these are called the **neutromagnetism (neutron-magnetism).** Where, these are the space in universe, which carry magnetic field strength equal to the strength of magnetic fields of all Matters, and fields, which make the structure of an entity a neutron.

In fact what is called a neutron star, these in reality do not possess neutrons, but these stars emitted magnetic fields strength in the range of Magravs of neutron. Hence tangibility of the neutron becomes later on as they disassociate themselves from the other fields in their environment, and at this point, they create dynamic space or environment or what we call the plasma of the neutron, where these magnetic fields can exercise their influences on other fields within their surrounding.

Further to this explanation, one can simply understand that in the matter world or in the magnetic field strength of matter, the gravitation and repulsion between these magnetic fields are in the level of matter magnetic field strength of electron, proton or neutron.

Hence in the matter world like in solid magnets, magnetic or magnetism or attraction or gravitation, is the attraction between the magnetic fields strength of Matter components of the plasma of electron, proton or neutron of that matter.

Thus is the reason, why in the physical world certain matters are attracted to each other, which they make certain types of molecules or physical matters. Where, the attraction of atoms to make up any matter it is entirely Magravs strength dependent and no other factor.

Where these attractions or gravitation of atoms or molecules in respect to each other, on other hand is environmental magnetic field dependent too. This is the reason why we can observe certain matters in one environment and not in the others. This being due to the fact that environments themselves are made or created or are conditioned due to interaction and Magravs (Magnetic and gravitational fields) of other magnetic fields.

Permanent magnets

Sometimes in the future I will release a book which initial basic work for it already has been set. The book will be titled "The universal origin of magnetic fields". In this book I will explain how magnetic fields are generated and how plasmatic and specific Matters magnetic fields exist in different dimensions.

In simple terms, the Matter magnetic field or what we call permanent solid magnets are mono magnetic fields strength which are at the levels of the Matter components of the plasma of an electron, which are in sequence with the plasmatic magnetic field Matters' of the proton of their element.

What this means is that when plasmatic magnetic field of the Matter components of an atoms' proton and electron field strength become interconnected and in field balance, then a continuous field between the Matter fields of the proton and electron is set to operate, where in the case of for example Iron at earth magnetic and gravitational field strength, this connection is set to be holding and hence creating a permanent magnet.

Hence as one establishes inter-connection between electron and proton internal field strength, then due to the more of supply from the proton, then the matter stays in one field strength for indefinite time.

This being the reason for example why magnetic fields in level of the water molecules, do not have strength to attract for example cooper atoms gravitational level, but can attract other water molecules'.

In fact iron will not be magnetic as it is on earth in most of positions in the universe. This being due to the fact that even permanent magnetic properties or characteristic of all matters are their environmental Magravs dependent. Hence what is permanent magnetic in solar system, its no similarly the same in other solar systems or galaxies.

Secondly magnetic fields or plasmatic magnetic fields are independent of Matter, but dependent of Magnetic field of Magravs of the Matter, Antimatter and Dark Matter of plasma of electron and proton too.

But at the same time it is important to understand that to have long term or permanent magnets, the Antimatter components of the plasmas have to and are positioned that they establish a continues field between the other antimatter component of the atoms of the same matters too.

The difference between conductors and superconductors

The present world of physics has a dilemma with the fundamental principles of conductors and

superconductors. Where this should not be so, if, scientists could understand the real term difference between the current flow of electron and current flow of magnetic field flux equal to the magnetic field strength of an electron.
What this means is that in conductors, the motion of or vibration equal to vibration of an electron causes the flow of current in the matter.

Where as in superconductor it is not the flow of the electron or the vibration of an electron that causes the flow of the current, but current flow is caused by the flow of electromagnetic field strength equal to magnetic fields strength of an electron, which flows through the material.

Where in the case of superconductors' there is no need for vibration or motion of matter, as with superconductors the same magnetic field strength equal to the magnetic field of the an electron flows through the superconductor materials.

Where in the case of superconductors the lattice boundary of molecules or atoms are so closely and perfectly packed that the electromagnetic flows through the lattice structure without a need for vibration of the electrons of the atoms or molecules of that structure.

In fact one can say that the same electromagnetic field, which starts from one end of the superconductor, itself will be traveling out of the other end of the superconductor, irrespective of the length of the material of the superconductor.

In the case of conductors vibration of electron needs kinetic energy and hence loses, where in the case of superconductors the structure of the material is so that no electron moves, but the material has the ability to transfer the electromagnetic fields strength equal to an electron magnetic fields strength, hence literally no kinetic move, no resistance and no loses.

The superconductivity of the matter is lattice position structure dependent and this is usually better observed in sp3 or diamond-structured materials.

Thus in conductors, electrons have to move and in superconductors magnetic field strength equal to magnetic field strength of an electron needs to be transmitted, and as there are no physical motion of matters within a superconductor, thus there are no loses, this resulting in faster transmission of magnetic fields without losses.

Current and impedance

The origin of all motions in any material or environment is always magnetic field strength dependent. Where in the case of transfer of current in any conductive material for electrons to be moving forward or being capable to transfer current, the material or the atoms of it have in respect to their adjacent atoms two behaviours, one is attraction or gravitation and one is repulsion or outward motion.

In the connection of let say a power source to a energy consuming unit like a light bulb, the light bulb creates a position that has lower gravitational and magnetic field strength in respect to the sources' electrons magnetic field strength. Thus this negative gradient in the magnetic field strength causes the flow of the Magnetic field motion of the electron in the direction of the lower strength magnetic field, from the source to the component.

At the same time, as electron vibration is in the forward direction of the magnetic field strength of an electron towards the component and has to be maintained, there is a similar and opposite pull for the electrons of the conductive matter between the power supply and the components too. Where, this pull is the same as the gravitational field force between the power supply and the light bulb too.

Thus for the connecting wire to be able to keep its constituent atoms together, the atoms of the wire need to have equal repulsion and attraction in respect to each other and at the same time maintain the negative gradient in magnetic field strength between the component and the power supply too.

Thus for supply and component to be interacting that flow of the electromagnetic fields are maintain in between them and due to gravitation of one field to another, the reverse field flow or reverse attraction flow of the fields leads to gravitation field or equal to the field strength of the an electron magnetic field or what is call the impedance flow.

Where, the flow of the current equal to the strength of an electron magnetic field outward is the electromagnetic fields and the gravitational pull between two fields or the current of flow of attraction between the two fields, which create the pull of electromagnetism of the fields, is the impedance of the field.

Thus in fact we can compare the current and impedance to two Magnetic and gravitational field of the planetary system, one can say that the outward flow field of the planet or its Magnetic fields are the current or electromagnetism field and attraction or gravitational flow of the planet is the impedance fields in the matter, where the flow of magnetic fields are restricted within boundaries of a copper wire or an electric light bulb.

Note; At the point where the impedance or the current in a wire increase in one or the other, that is the point, where for example the wire separates and magnetic fields of the atoms of the matters can not hold on to their atomic balance Magravs as the increase in repulsion between the atoms of the wire causes the separation of atoms, and in the case large numbers of repulsion between atoms, then the separation or what is called in common language the melting of the wire occurs.

Where in fact the melting is not due to the heat, but in physical terms, the melting is due to repulsion of atoms of the copper due to not being able to maintain constant gravitational fields of atoms of the wire.

Experimental point's observation

In our reactors we a have the ability able to release the energy of protons which has magnetic field strength by order of magnitude of about 2000 times of an electron magnetic field forces.

Thus one can see how small amount of plasma can create and release vast amount of magnetic fields that one can use these magnetic fields in their dynamic state for the production of electric currents or Magravs in a confined of a small reactor, that these can be utilised for motion and production of vast amount of electric current in conjunction with other field within or within the vicinity of these type of reactors.

Further the interaction of these magnetic fields for example with physical copper winding outside the reactor in a generator structure configuration can lead to creation of energy as we are use to in present generators, without single movement or vibration of an electron within the cores of the reactor and only is presence of plasma of fields equal to the field strength of an electron.

Conclusion

The electric charges, magnetic field and gravitational fields are all of the same and of one origin. Where the gravity is due to pulling effect of two dissimilar poles of the same plasmatic magnetic fields interactions and Magnetic field is due to repulsion of two similar magnetic poles, and electric current is due magnitude of the flow of magnetic field from one field to another.

Thus the ***grand Unifying field*** is the magnetic field, and the missing link has been to understand that gravity is the product of interaction of two plasmatic magnetic fields, mass is the difference between the magnetic fields strength of similar and dissimilar field strength (gravity and magnetosphere forces strength Fig. 25 of the book), and the energy is the measure of the magnetic field that is transferred between magnetic fields at the speed that magnetic field can travel within a given matters' medium, for it to be able to move from one magnetic field strength to another, and the electromagnetic current is the rate of movement of the magnetic field from one field to another and where the electromagnetic field is due to magnetic field strength difference and is the equal to the magnetic field strength of an electron.

Thus the unified and common field is the magnetic field, between the gravity, mass, energy, and electromagnetic field.

Thus the unifying theory for the first time is complete and it is fully understood.

Where *magnetic field interaction* makes **the gravitational fields** and the *flow magnetic field from one field to another* creates **the electromagnetic current**. Energies can be created, from any ambient, depending on what one wants to produce or obtain from these currents or fields.

Electromagnetism is created *as magnetic fields strength are transferred from one field strength to another* and in the process of the flow of magnetic fields this leads to creation measurable field movement or measurable current from what is called "electromagnetic fields".

This simple sentence brings the whole of understanding between magnetic fields and its flow from one magnetic field strength to another and is the grand link between the gravity, the mass and energy and this finalises the long lasting missing link of the unifying field.

Now that one can understands that current is the rate of flow of magnetic field from one strength to other, and "the connection between electromagnetism, gravity, mass and energy" is finally understood. Thus the origin of all things tangible and their effects is magnetic field based and magnetic fields are the origin of all and unifying field in the world of creation.

Reference:

1; The Universal Order of Creation of Matters by M.T. Keshe (2009, ISBN 978-94-6087-001-9) Chapter 5.

*Magnetic field with capital M is the plasmatic magnetic fields created by systems like earth, which this spans beyond the boundary of their physical matter.

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M.T. KESHE

THE ORIGIN OF THE UNIVERSE

The Origin of the Universe

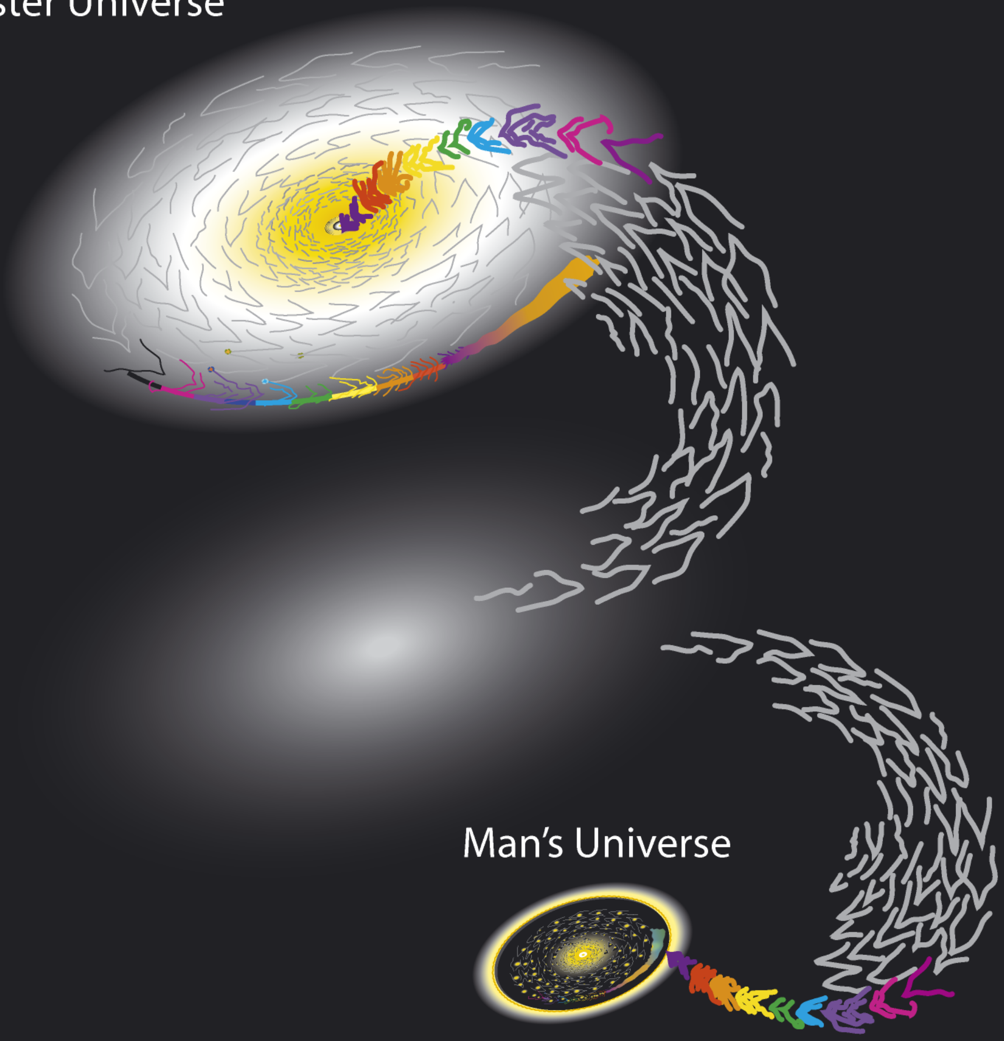
Sister Universe
Man's Universe

The Keshe Foundation

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Nuclear Engineer M.T. KESHE

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(The Netherlands)

The Origin of the
Universe

ITNOTGOG

Reflection

The creation of a new universe(s) is as simple as creation of an atom from the division of the neutrons, thus universes are made from division of bigger universes and the same shall be the future of this universe of the Man.

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Forewords

In the past centuries so much discussion has been about the origin of this universe, where in the recent times the groundless concept of the Big Bang theory has taken hold in the scientific world and been considered to the norm accepted fact.

It will be explained in this disclosure that there has been start to this universe, but not necessarily in the way as it has been thought and promoted by the present scientific world due to their lack of the understanding of the universal processes of the magnetic field division and plasma decay as it is the norm in the nuclear structure.

The origin of this universe has to be on the physical realities and in parallel with the rest of the cycles of creations and developments of matters and field as we have seen and observed around us in daily life and the creation of this universe cannot be an exception to rest of universal order of creations and operations.

Introduction

The present visible universe to man is a larger scale in matters and fields of what have been seen by man of science in the structure of the plasma of the neutron, and universes division occurs in the same manner and by the same principle as decay of plasma of neutron to plasmas of an electron and a proton.

The creation of this universe is the replica of the same process as decay structure of neutron but in a larger scale in quantities of magnetic fields strength and matters. This universe is not the only universe in existence and this universe is created through the same natural processes as other elements and entities in the unicos and through decays, division and amalgamation of other fields and elements in the inner sanctum of their mother universe.

Thus in truth there are as many physical universes as there are galaxies and solar systems and man's universe is one of the units in this overall structure of the greater mother universes.

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CHAPTER 1

The Universe

The term Universe to me as a nuclear physicist's has one meaning, and that is the more of the same magnetic fields of different strength as it is in the plasma of an electron or proton. Where, the total behaviour and operation of all magnetic fields and matters created by fields within the operation of stronger fields' strength catchment's in the centre of each entity is considered to be of the same and through the same and similar processes.

Where in the smaller scale entity the like of the plasma of proton we call the bigger and stronger entity to be is the Principal mafs and matter, or what is commonly is called the up or down quark in the present physics, where in the universal scales we call these the central the principal mafs line, where the other components within the plasma of the universe are exactly created and operate as the galaxies, solar and plasma of electron systems within these universes are created and operate.

Thus, the difference between the plasma of a neutron and the plasma of the universe is the size of the mafs of the fields which has come together to create that entity and otherwise all self-contained gravitational-spherical and magneto-spherical entities this being the plasma of proton to the plasma of solar system, the plasma of a galaxy or the plasma of the universe, they are all created through the same principle and operate through the same physical conditions and restrictions.

Where, under certain conditions of magnetic field or gravitational fields strength and positioning in certain parts of the these plasmas, whatever they could be, conditions can be created that allows the growth and suitability condition that clusters of fields can become active and sustain a rhythmic and coherent field interactions that these can lead to creation of certain types of repetition of the same fields in these plasmas.

Where, the repetition of Magravs of these types' fields within these plasmas of different scale can lead to creation and sustainability of continuity of being able to absorb mafs in motion from their environment that these clusters of fields can sustain long-term durability and exist-ability, or what we call to attain the process of life.

Where, different versions of life can exist in the plasma of proton as it does in the plasma of the solar systems as is on earth and different forms of lives exists in the plasma of the universe and universes within the unicos of the creation of the bigger structures of universes.

Thus, this universe or other universes, which have led to creation of this universe and the cycle of the life of this universe in time it will lead to creation of smaller universes, where these in time have all come from one essence of a larger fields entity(s) and in time as they divide and they become weaker, then in time these fields will gather together to create a different universe(s) with different field(s) strength properties (Fig. 1).

Thus, this universe is not unique and there are others, which are created through the same process(s) and there is remote chance that there could be another universe similar to this universe in the ***unicos*** (Fig. 3) of the creation, but not necessarily it will have the exact combination and structure of mafs and positioning of its fields and matters in its internal structure as man's universe.

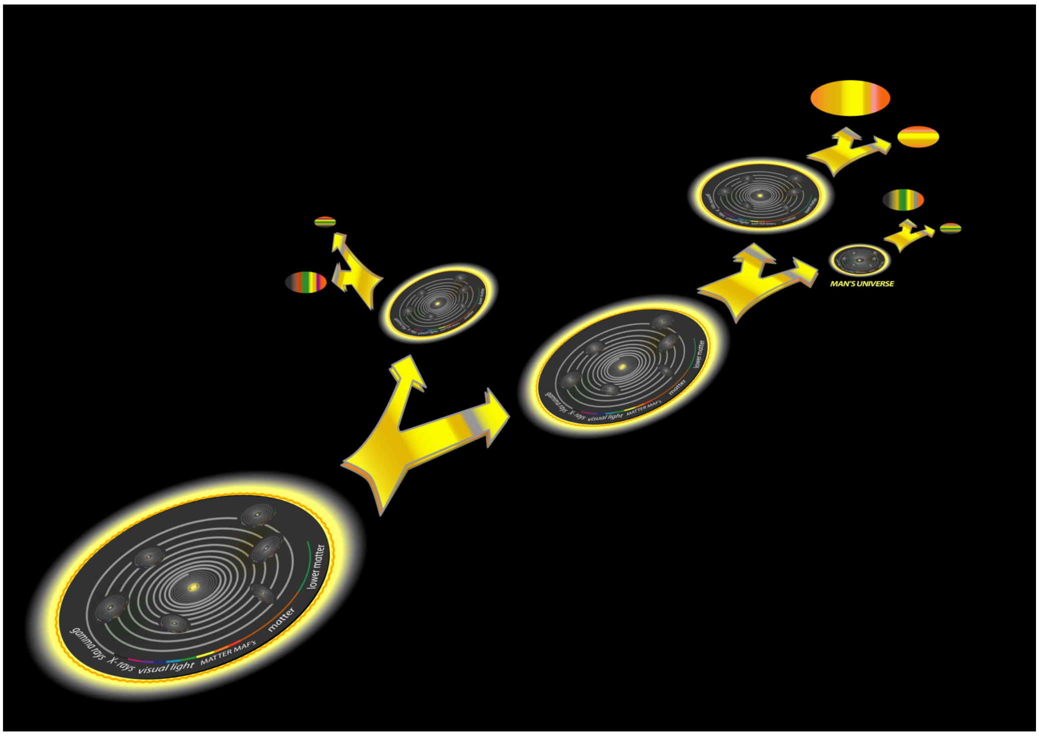

Fig. 1. Creation of new universes out of the division of a larger universe
through the process of decay similar to the decay of the neutron in proton and electron.

In truth the universes are created with a long whisper as one sees and hears gases leaking out of cylinder or a balloon (Fig. 18 C an D), and more like trajectory line depending on the magnetic and gravitational balances of their mother universe and outside environment, which they are getting released into and as the release gases try to find their new position in the new environment, which they have been released into.

Thus the creation of universes are not made with huge sound and explosion but very much with a long whisper as the plasma of the larger universe is dividing and ejecting its matters into two or more environments to guaranty the survival of its overall Margrave strength structure. Very much as the neutron divides and creates the proton and the electron plasmas.

Then as each universe reaches it's own Magravs balancing positioning then it again divides and creates further universes (Fig. 2).

This has been the truth about the creation of this universe in the unicos and in time man will come to understand that the creation of unicos, universes, atoms and plasma are nothing but natural dynamic processes of the interaction of different amount and strength of magnetic fields at different time and position in the overall world of the creation.

Then the question becomes, where did it begin to start with (ref 23), then one needs to understand the truth about the levels and position differences of the origin of the magnetic fields.

This in time will be revealed to the men of real insight in the world of creation as the man at this moment is not mature enough to understand and comprehend the totality of creation of the universe.

If one reads all the writings' of the author, and if! and that is a big if, then the reader will understand the truth about the essence of creation and the origin of the creation. One will come to see its creator way of operation and purpose of creating such an intriguing mesh of unify principles in all levels of creation in all of unicos's.

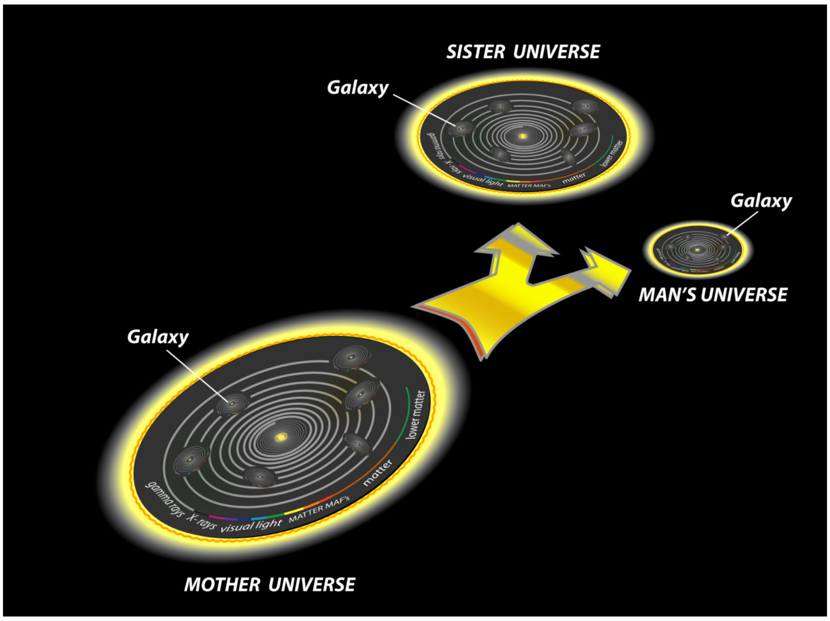
SISTER UNIVERSE
Galaxy
gamma rays
X-rays
visual light
MATTER MAF's
matter
lower matter
Galaxy
MAN'S UNIVERSE
Galaxy
gamma rays
X-rays
visual light
MATTER MAF's
matter
lower matter
MOTHER UNIVERSE

Fig. 2. The creation of Man’s Universe after the decay of it’s Mother Universe Magravs’ maf’s.

This shall be the point of maturity of the man to understand how feeble he has been created according to his understanding, where in fact he carries the whole of the world of creation within himself

CHAPTER 2

Theory of Expansion of the Universe

There have been theories and observational data, which support the concept of the expansion of this universe at the present time.

There are two aspects to this expansion theory of this universe, which each one has to be considered on the real terms of expansion of the universe that both can be scientifically acceptable.

In principle, it can be said that this universe cannot expand in to space in bigger unicos's space, if this space was not there for Man's Universe to expand into and to begin with. Thus this universe cannot be the only universal system that exists in the bigger **UNI**versal **COS**mology (unicos).

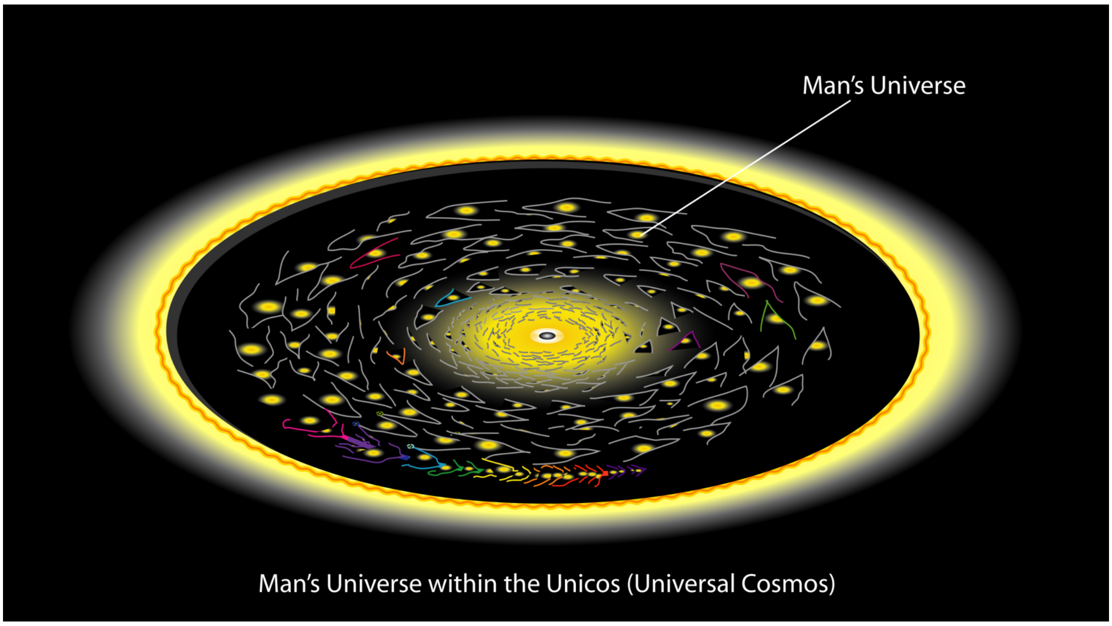
Man's Universe
Man's Universe within the Unicos (Universal Cosmos)

Fig. 3. The Unicos

The Man's Universe is a small fraction part of the unicos universes (Fig. 3).

This Man's universe is expanding due to two factors, ***firstly*** as the principal mafs of the central fields of this universe are unwinding they make available more mafs in the strength of different matters (Book 2) that as these fields open up they lead to creation of new galaxies and other entities, and ***the other factor*** is that the stronger gravitational fields environments which are outside the boundary of this universe's at the same time are pulling on this structure and keep it dynamic (on the same principle of motion of electron around it proton (Book 1, Chapter 19)), and the expansion of this universe in reality is part of the motion of the unicos as in the direction of the motion of all the universes in respect to unicos's internal central Magnetic and gravitational field forces interactions.

This meaning that if one looks at the overall directional motion of all the galaxies in this universe, it will be noted that not all galaxies in this universe are following the rest of this universe's galaxies on a straight overall spherical one line motion of expansion, but in fact part of this universe's galaxies overall line of motion is curvature and is following in the direction of the pull of an outside sister's universe gravitational field force, which this is necessary as this universe is to find its balance and position in respect to other external fields forces of the same of other universes in the unicos (Fig. 4).

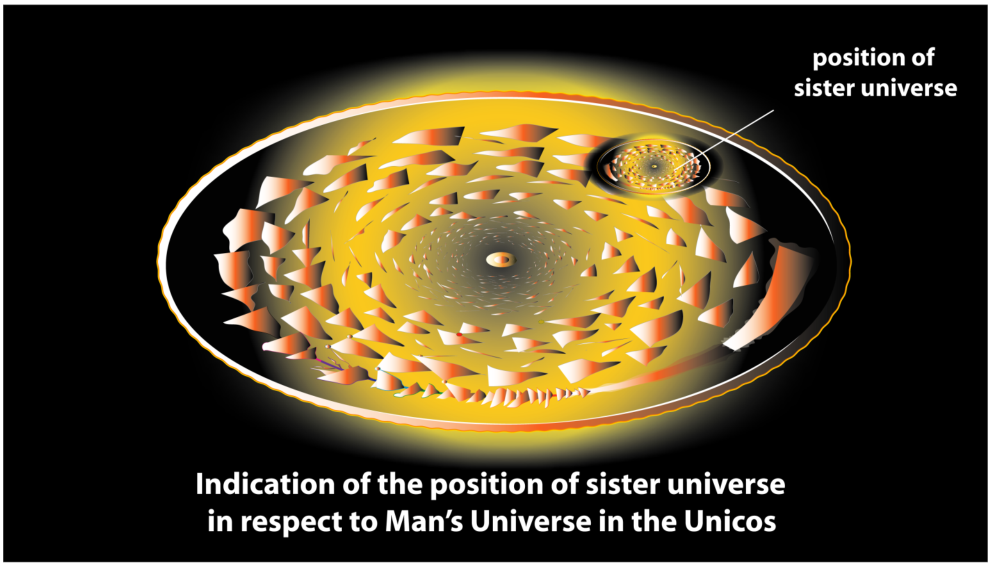
position of
sister universe
Indication of the position of sister universe
in respect to Man's Universe in the Unicos

Fig. 4 The position of the sister universe in respect to the Man's Universe.

At the same time each universe possesses a central principal mafs and matter point and or central principal matter line, where these mafs strength and quantity of in this centre point or the centre line dictates the size of any universe and at the same time the Magravs created by this is like a Principal star and line in the centre of the universe that this dictates the position of the universe in respect to other universes in the unicos and this Magravs strength of the central line dictates the matters which are attracted and created in that universe and the matter and content of Galaxies' in respect to itself and no other matter in that universe.

Where, the total mass of the mafs and transition mafs in a galaxies are about less than five percent of the total mass of the universe principal matters and mafs in its central line and its principal star.

Thus the positioning and directional motion of the galaxies in the universe, the same as in the solar systems is dictated by the mass of the Principal mafs and mafs in that universe central principal mafs and star in the centre of that universe but in larger order of magnitude of contents and due to no other factor.

At the same time as the universe is created out of the ejection of the large quantity of principal mafs and matters and have motion in their time of creation, thus it is more feasible to consider an stretched line of principal matters and mafs across a central line of the universe rather than a centre point universe star of principal mafs and matters in the central line of universes.

Therefore the mass of the universes are measure of their principal mafs and matter content, which their Magnetic and gravitational field forces dictates every motion of matters in galaxies in that universe, hence strength of the principal matters and mafs in the central line and central principal star dictates that universe's-magnetosphere, gravitational pull sphere and the mass of that universe.

To understand the process of creation of mafs and matter and elements in the universe, one needs to look at the smaller scale universe, which are similar to the constituents' plasmas and the structure of an atom, its creation from division of the neutron to a simple hydrogen atom with it's plasma of electron and proton, the way they are created from neutrons division and the mafs which are released in the process of decay of the neutron into its environment, leading to creation of the simplest atomic system of Hydrogen.

Where, any mafs realised through and during the process of the division is not necessarily transferred to the newly created plasmas that lead to heating of the two new plasmas of the proton and electron.

Thus there could be some heating of the plasma of the electron and proton during and due to decay of its mother neutron, but this energy may and possibly and do *not necessarily is transferred totally that leads to heating up of the plasma* of the proton and electron.

Therefore the same applies to the division of this universe, when it was created ***from the decay of it mother neutron universe.*** Hence there are no logical reasons that the universe was heated and was hot and it has cooled for elements in this universe to be created due to creation of gravitational field forces.

As in the production of two parts of the plasmas of an atom (1) from the division of the plasma of neutron, the present assumptions in physics that the first atoms in the universe were created ***when the universe cooled***, this theory is not and cannot be correct and in reality *atoms are created through change* ***in the plasmatic fields strength of the mafs of the light***, secondly at the point of creation of the universe, the universe was not hot and there were never high temperatures that the cooling of the universe has led to creation of the first atoms as presently commonly stated. The first atoms and universally all first atoms' the like the atom of hydrogen in all mafs strength in the universe are created through the magnetic field strength reduction of the principal mafs and through no other means.

The concept of creation of heat and high temperatures at the birth of the universe is not observed in the creation of plasmas of electron and proton, when the plasma of neutron decays and divides into an atomic structure, and in the universe there are always continuity and parallels, thus the universe has never been hot that has cooled down to create atoms, and this is the reason why W-MAP (1) shows at present balance heat distribution in this universe (Fig.5).

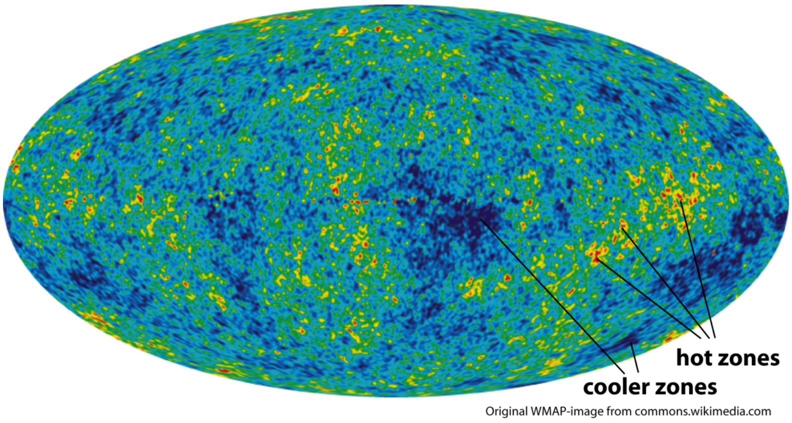

Original WMAP-image from commons.wikimedia.com

Fig. 5 The universe heat distribution map (W-MAP of the universe)

In truth the current assumptions of initial heating of the universe at time of its birth cannot be true as the initial atoms of the universe and present atoms were and are created from the original principal mafs strength, ***which radiated out as principal lights rays of the universe*** in the centre of the universe and the initial atoms and matters of this universe were not created through cooling of the universe at the point of inception of this universe, which this universe itself is created from the decay and division of bigger mass of another universe as it happens in the division and decay of plasma of neutron in two plasmas of proton and electron. One does not observe heating in the plasma of electron or proton in this division and so be it the same, when the bigger universe divided and led to creation of this universe of the humans. (Fig. 18).

In fact, if! The universe was created by the present scientific assumption then the W-MAP should have shown cooler region in its outer boundaries than the present near homogenous heat distribution, which has been physical observed and from collected data by the publishers of the universal heat distribution map of the universe.

The heat distribution and the heat concentration on the central line of the WMAP confirms that the universe started from a central line in the middle and as the principal mafs of the universe unwinds and reduced in strength (Book 2) then the ***transition mafs*** and the ***matter mafs*** were released and created, and as these were spreading outwards into the space of a larger universe (Fig. 1) from its central line ejected mafs into unicos, then as the Magravs of the principal mafs in this central line region are converted and are reducing in strength, then the overall unified oval-spherical shape explanation of the WMAP come to exist.

Then as the total Magravs of the central principal matters reaches the point of the equilibrium of its forces, then at that point, this becomes the boundary of the universes boundary or becomes the plasma of the universe. At this point where they Magnetic and gravitational field forces cannot hold on to all the mafs and matter of that universe and this become the point of the limit of the expansion and the boundary of the universe and the envelop of the mafs at the given point in time, which are under control of these forces from the central lines principal mafs of that universe, where this expansion line becomes that universe’s magnetosphere boundary line.

Then, When a point in the cycle of the life this universe reaches that the overall strength of the Magnetic fields and gravitational fields of the central line principal mafs and matters cannot hold to their overall fields balance, then at this point this universe will go through a division the same as the division of neutron decay and all the matters and mafs at this point rearranged and regroup as and in the principal strength mafs and the universe then divides into two principal mafs of lesser masses of universes, which these new universes are magnetically interconnected as proton and electron do after the division of neutron and then these new universes go through the same principle of the principal mafs light unwinding and the same process as creation of new universe carries and central line as before.

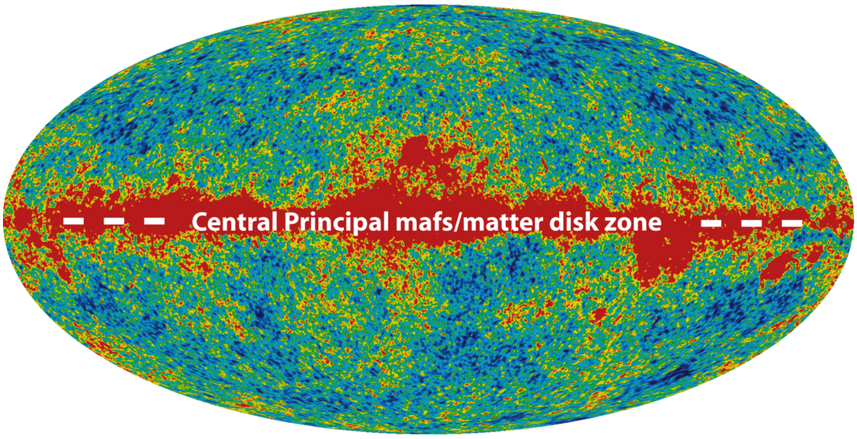

Original WMAP-image from commons.wikimedia.com

Fig. 6 The microwave heat distribution of the universe shows a concentrated heat in the centre disc of the universe

That is to say through the principal mafs and matters are the way that universes divided and arrive form another universe to start a new universe and as the light in the principal mafs strength unwinds' in its new environment then the new envelop of the new universe starts to be created.

The same and similar process occurs, when the neutron decays and divides into the plasma of the proton and electron.

Thus, the universe is not created as a big-ball of fire which has been cooling down as has been promoted, but in fact the universe is created the like of as ***an ejected principal mafs*** is injected into a new area in the unicos and as the new universe environment and as the principal mafs radiate outward as light of stronger mafs, then as the weaken and radiate outwards in their new environment, then they create the other matters mafs and matters in this new envelop depending on the given pmtics strength of a given region in the larger process of this unwinding of the principal maf and matters and its lights (3) in this newly born and expanding universe.

Therefore: this universe is in fact created inside out rather than what has been assumed up to now that as it cools down to what it is, which this explains why even the universe is observed to be expanding, as the reason for expansion of the universe is being due to the presence of principal mafs in the centre of the universe and as principal lights of the principal mafs radiate outward, these light rays of the principal mafs strength while traveling in their new environment they reduce in strength and this leads to creation and transition mafs and matters, which further on losing its strength creates new matter mafs and matters according to given environments magnetic fields strength and in a given point pmtics, hence the creation of new mafs and matters and so forth, which this leads to creation of atoms and molecules and stars and so forth in this universe and its galaxies and solar system through the same principle.

Thus there has never been a Big Bang and the current appearance of the expansion of the universe is due to the principal maf, which as unwinds, it creates the expansion of the universal-sphere of this universe (3).

This method of the creation of the universe now explains' why there is a central gravitational matter concentration in the universe and as this pull is centred in the dynamic principal central line, which the original principle mafs were ejected out of the mother universe when it divided, where the injected principal maf of the universe at the time of its inception can be seen as the red line in the W-MAP (Fig. 6) which the more concentration of the mass of the principal matter sets in the central disc of the W-MAP and as these principal mafs create their own magnetic interactions, hence these create their own sphere of gravitational and Magnetic fields and thus the central gravitational of the universe is in the centre of the denser point of principal mafs of the centre universal heliosphere of this universe and as the more principal mafs are unwinding and spread outward are reduced in their strength they principal mafs become transition mafs and further as they reduce in strength they become the matter in the unisphere of the universe and as the principal mafs open up and reduce in their environment this leads to creation and expansion of the balloon of this universe in the unicos, and this explanation resolves the present mystery in the scientific world that, how and where the central gravitational pulls and the expansion of this universe which has been observed by scientists of the universe comes from.

This is how the plasma of the neutron decays and divides into plasma of the a proton and an electron too, where the different quantities of matters and mafs of different strength of the neutron are divided and injected in two new areas in their environment, that their overall Magravs of all their mafs are as original components that the plasma of the electron and proton concurrently maintain their overall Magravs of the original neutron Magravs (Fig. 7) and then as the matter and mafs unwinds and interact they reach given overall Magravs level and position as the new plasmas of the sub-components of the atom are created.

Where, this process of division of neutron due to micro-level of masses involved, these appear as an instantaneous process of creation of proton and electron, where the same applies to creation of universe and larger universes divide to guaranty their overall existence in the unicos.

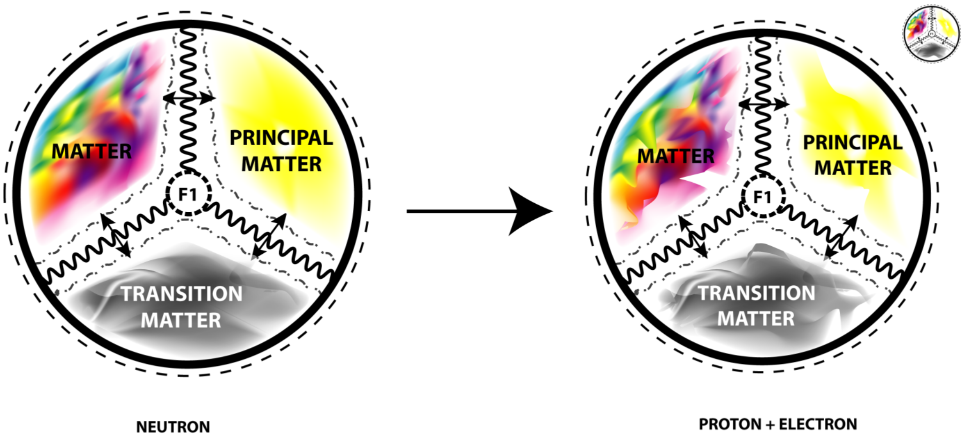
MATTER
PRINCIPAL MATTER
F1
TRANSITION MATTER
NEUTRON
MATTER
PRINCIPAL MATTER
F1
TRANSITION MATTER
PROTON + ELECTRON

Fig. 7 The conversion of the plasma of neutron to plasmas of the proton and the electron.
The same process is considered to occur when the universe divides (3).

This being the reason why the proton and electron in their process of creation ***do not get heated*** as a Big Bang theory suggests but as different portions of principal mafs of the neutron which become parts of the plasma of the proton and electron unwinds and expand from the central line of their centrally disc which they are rejected into their environment by the division of the neutron, and as *their principal maf unwind* in this disc to the ***transition matter*** and then, as they weaken further, they create ***maf and matters in tangible mafs levels***, the like of the plasma of the proton and ***all other fragments of pmtics and magnetic fields*** in these new plasmas (Book 2, Chapter 1 and 2), in these processes of creation of new smaller plasmas of there is no Big Bang and there is not heating of the plasma of the neutron and electron (Fig. 8).

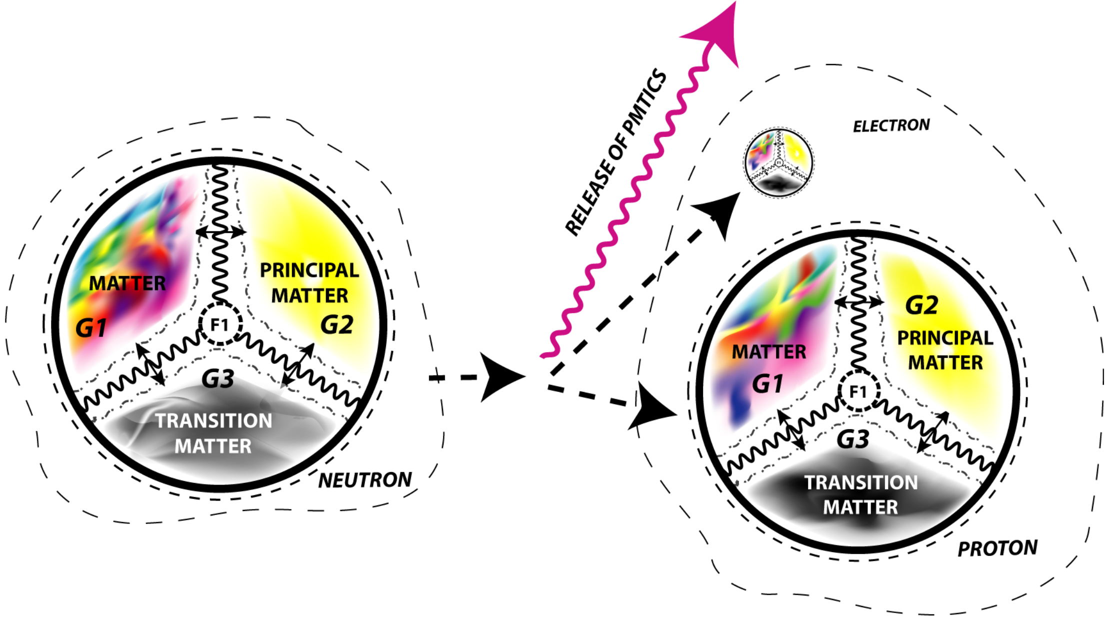
MATTER
G1
PRINCIPAL MATTER
G2
F1
G3
TRANSITION MATTER
NEUTRON
RELEASE OF PMTICS
ELECTRON
MATTER
G1
G2
PRINCIPAL MATTER
F1
G3
TRANSITION MATTER
PROTON

Fig.8 Decay of plasma of neutron in plasma of proton and plasma of electron.

Hence the theory of Big Bang is not correct and has no meaning in the real world of creation.

The same process can happen with the ***ray of the light*** originated from principal mafs strength (what is called the **principal light**), when this principal light arrives in the principal mafs strength environment and hence the first fundamental neutron principal plasmas and principal atoms' can be created in that given environment through the same principle as atoms are created in the matter strength environment (1).

At the same time the Magravs strength of the **P**rincipal **U**niversal **L**ine **M**afs (PULM, the central line of the universe)(Fig. 9) dictates the position and attraction of other matters, stars and galaxies' in that universe in respect to itself.

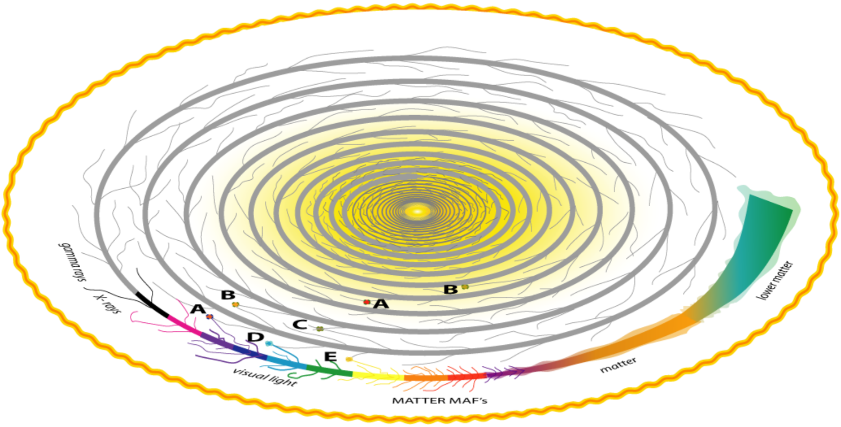
gamma rays
X-rays
B
A
D
C
E
A
B
visual light
MATTER MAF's
matter
lower matter

Fig. 9. The Principal Universal Line of Maf's.

The total mass of the matter mafs is about five percent and transition mafs of the matters about fifteen percent in any universe and is the same as with galaxies, solar and plasma of proton systems in the universe. The reason for this is due to the principal mafs (Fig. 10) and mass conversion and conservation and motion as they move within the plasma of the universe and lose their strength and reduce to transition, and matter mafs. Secondly if any mass more than this ratio of principal mafs is converted and stays within these systems, these can lead to unbalance and faster division of the entity, this be it plasma of the proton, neutron, solar system or universe.

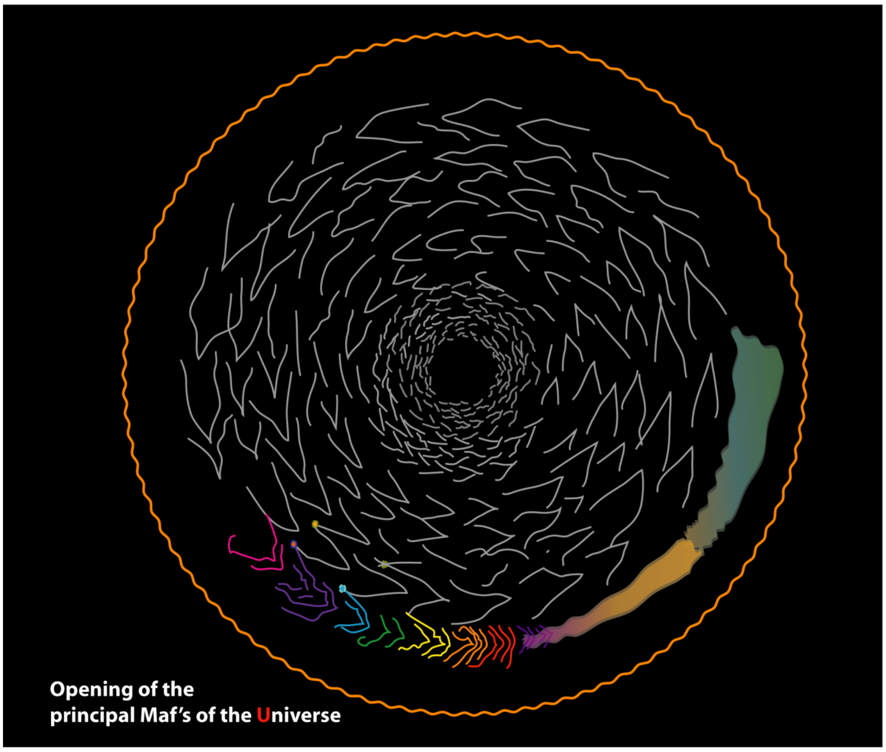
Opening of the
principal Maf's of the Universe

Fig. 10. The principal maf's of the Universe.

Thus, the positioning and directional motion of the galaxies in the universe, the same as in the solar systems is dictated by the mass of the principal mafs and matters of the principal mafs of the universal line star mafs (pulm) of the galaxy and no other factor.

Therefore the mass of the universe is the measure of the difference in the interaction of the Magnetic and gravitational fields' forces that the principal mafs contents of the principal matter in the universe can produce and maintain. The same measurement principle applies with the galaxial and solar system.

Once these principal stars are formed in the universe then the Principal stars and the lights which are releases and radiate outward from the pulm becomes the means and the supplier of pmfs and nourishment source to all entities in the internal plasma environment of that universe, these be it galaxies, solar system atoms and so forth (Fig. 11).

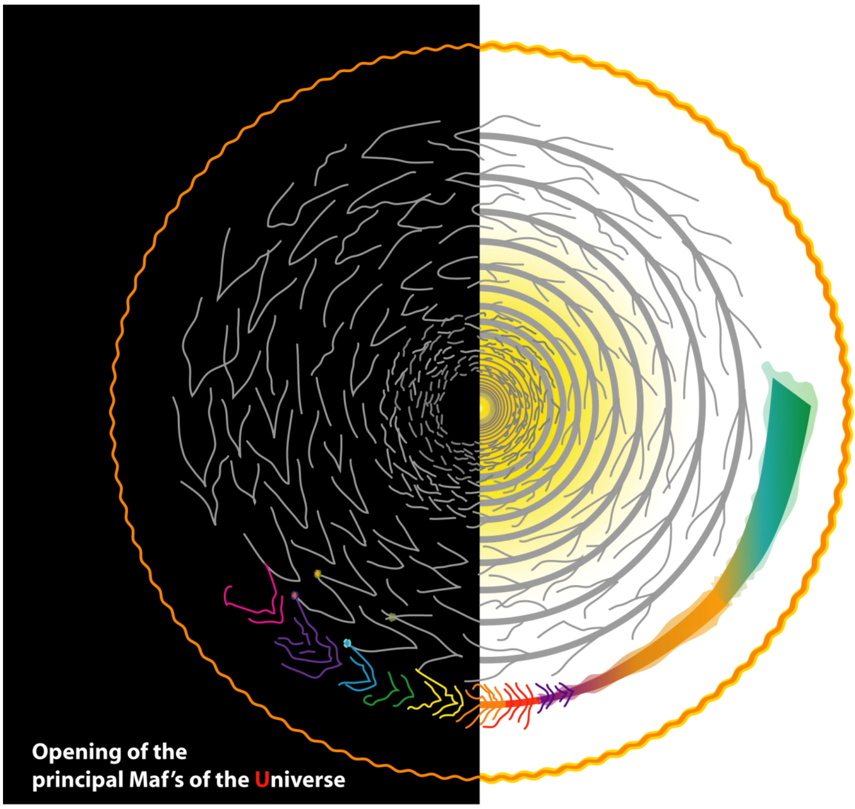
Opening of the
principal Maf's of the Universe

Fig. 11. The unwinding of Magravs in an entity.

The same applies as to the galaxies, solar systems and plasma of proton systems too, where in fact in the centre of each galaxy, solar system and plasma there is the principal star (Fig. 12) with a plasma of principal mafs and matters and as these unwind, expand and spread within the Magnetic and gravitational fields which they create, these releasing, opening's and loosening of principal mafs in the pulm leads to creation of transition and then matter strength mafs and matters in the envelop of the magnetosphere of the universe leading appearance and creation of principal matter in the galaxies, solar and plasma systems, exactly the same as it has happened and has led to the creation of the plasma of a neutrons, stars, galaxy's.

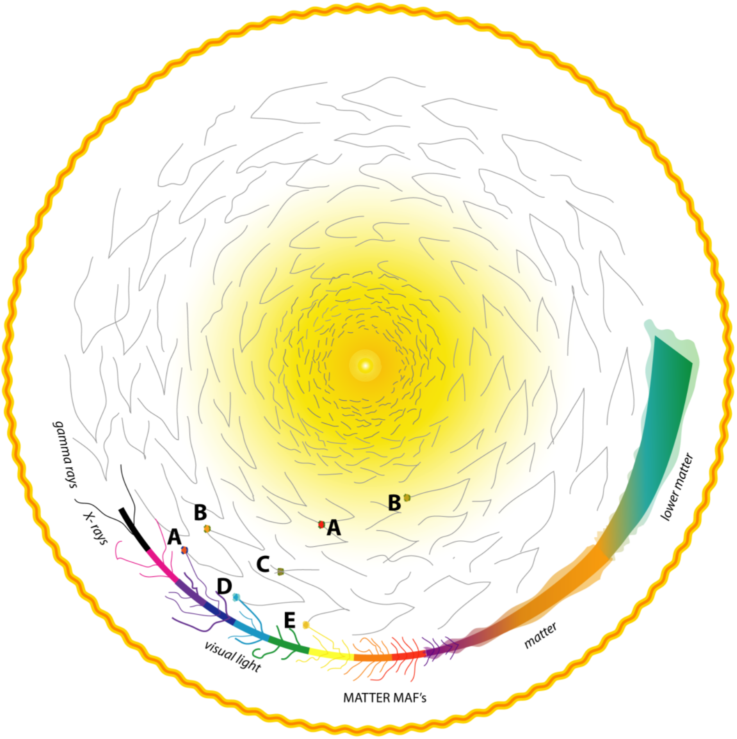
gamma rays
X- rays
A
B
A
B
C
D
E
visual light
MATTER MAF's
matter
lower matter

Fig. 12 Plasma of the Universe: any entity can be created anywhere in the Universe as long as the appropriate maf's strength of that entity is reached through reduction or interaction of maf's of the Universe

Where, A(s) are the universal magnetic fields oceans in the form of fields forces or light, where sea of lights are created by the interaction of the fields which these can be in any light strength of matter, transition or principal magnetic fields strength, B(s) are universal matter oceans, C (s) are the transition matter and mafs oceans, D(s) are galaxies, E(s) are sub-matter mafs and matters oceans in the plasma of the universe, where all these entities they are created due to and through the interaction of the residual fields which are released by and through the release and separation of fields from principal mafs and transition mafs and matter mafs of the main or the subsequent divisions of these mafs as the principal mafs of the universe open up and divided and expand in the structure of the plasma of the universes' Magravs (Fig. 13).

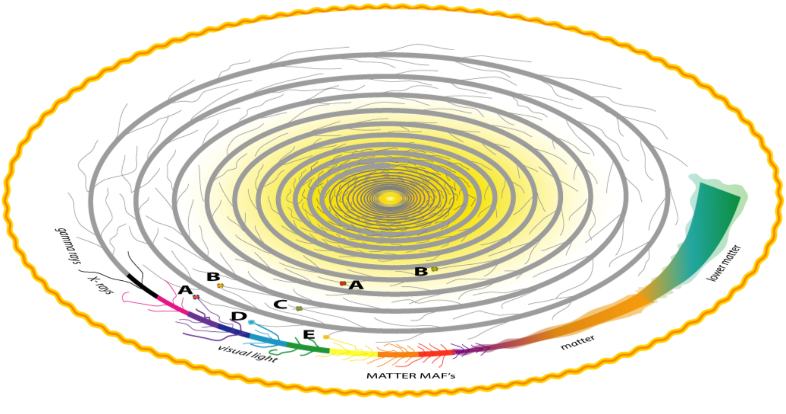
gamma rays
X- rays
A
B
A
B
C
D
E
visual light
MATTER MAF's
matter
lower matter

Fig. 13 Plasma of galaxy: any entity can be created anywhere in the galaxy as long as the appropriate maf's strength of that entity is reached through reduction or interaction of maf's of the galaxy itself or its Universe's maf's

Where, the same principle applies to the structure of the creation of stars and planets in the galaxies and solar systems, and where the same process of creation of matters and fields is applied in the creation of entities in the plasma of neutron, proton and electron.

Where, A can be the point of creation of a star, a B the black hole, C the creation of planet in the solar system, D the cloud dusts and E the magnetic fields ocean of the galaxy.

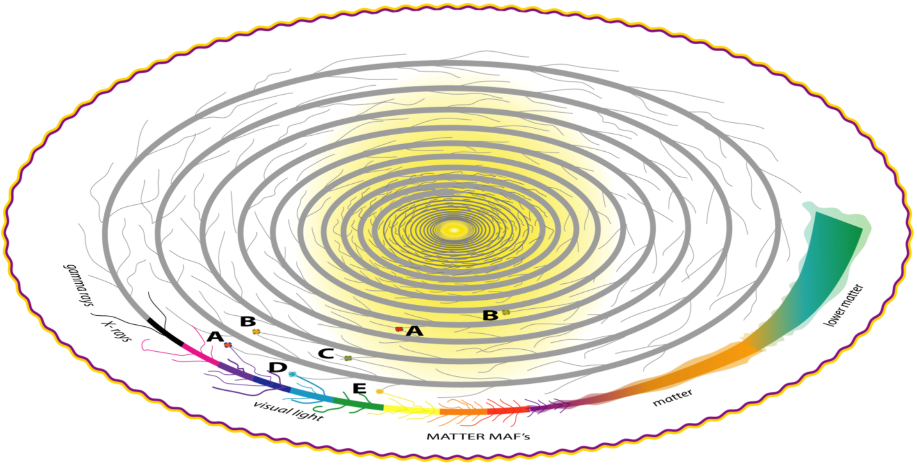

Fig. 14 Plasma of Neutron: any entity can be created anywhere in the neutron as long as the appropriate maf's strength of that entity is reached through reduction or interaction of mafs of the neutron and it's galaxy itself or it's Universe's maf's.

Where, A can be the principal matter, B the transition matter, C the matter, D are the fields in motion, E are dust of matters in creation and motion within the plasma of the neutron (Fig. 14). Where even the creation of the X-rays and gamma rays are normal features of the plasma of the neutron as one observes in the process of the existence and operation of the galaxies (Fig. 15) and universes plasmas.

The universe as the plasma of the proton can expand according to the amount of the transition matters which can travel away from the principal matter line, and hence the expansion of the universe or plasma is dictated by the amount of the transition matter and mafs and speed of by which the principal mafs and matters can release which the pulm can hold on to the total Magravs of its structure. Now this can explain why this universe through WMAP (Fig. 5 and 6) shows to be more oval than sphere in shape.

On the other-hand the shape of the WMAP being oval can explain the same characteristics as one observes in the major composite gas planets in the solar system as they are not fully sphere in shape, but have more flat poles.

The oval shape of this universe confirms the existence of a central principal disc point in the centre of the universe and the flat disc spread shape of the principal mafs distribution in the central line disc of the universe.

At the same time the uniformity of the speed of the objects in the universe and galaxies shows the connection between the principal mafs release in the pulm.

This confirming the real process by which plasma and atoms are created and appear across the universe, where their accumulation leads to the creation of cosmic dust, stars and planets.

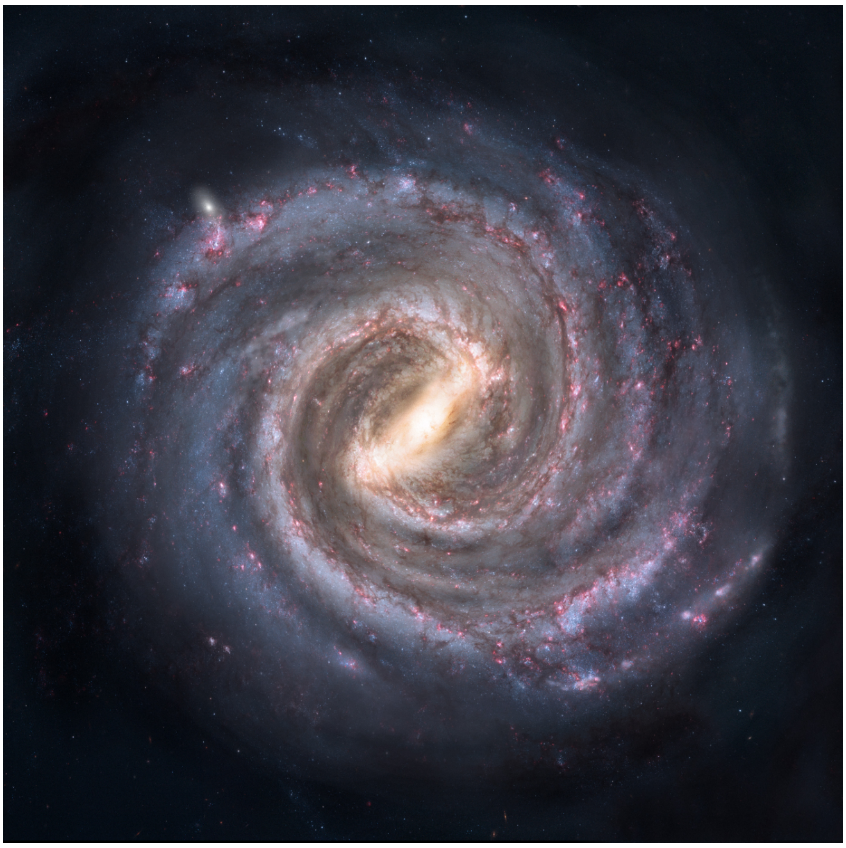

Fig.15 Galaxy (Source: Hubble)

Where, the concept of the cooling of the universe leading to creation of the atom becomes to be meaningless, as the creation of plasma and atoms is totally due to reduction in the mafs strength of the principal mafs to matter mafs strength and has no connection with heat or cooling inside or in any position in the plasma of the universe.

Where, the heat in different points in the plasma of the universe has only have the effect once the plasma of matter is created, then the environmental temperature in any point in the universe ***only dictates if the plasma in matter state will manifest itself as gas, liquid or solid.***

Then in fact this brings a question mark on the theory of time and space as then time will have no meaning as a new plasmas of atom can be created in the far corners of the universe from high speed mafs of the principal mafs which left the pulm, where some mafs go through the mafs strength reduction before arriving in the same point in the plasma of universe.

Thus; the theory that the whole parts of the universe are created about the same time and the more ancient galaxies are in the centre of the universe in some extent ***is not correct***. As matters in the universe move as their Magravs positioning dictates and hence some components of the universe move in such a rapid way which are not visible to the present technology available to the man.

CHAPTER 3

The method of transportation of mafs in different mafs strength in the universe

In all dimensions of the universal mafs strength, these be it principal matter, transition matter or matter environment, for the plasma of these matters to travel with the maximum speed and minimum loss of mafs to their environment, in all dimension of the universal mafs levels, the spherical shape plasma of the matter transforms itself to elongated plasma of itself or what is commonly is called as a ray of light (Fig. 16) (Book 2).

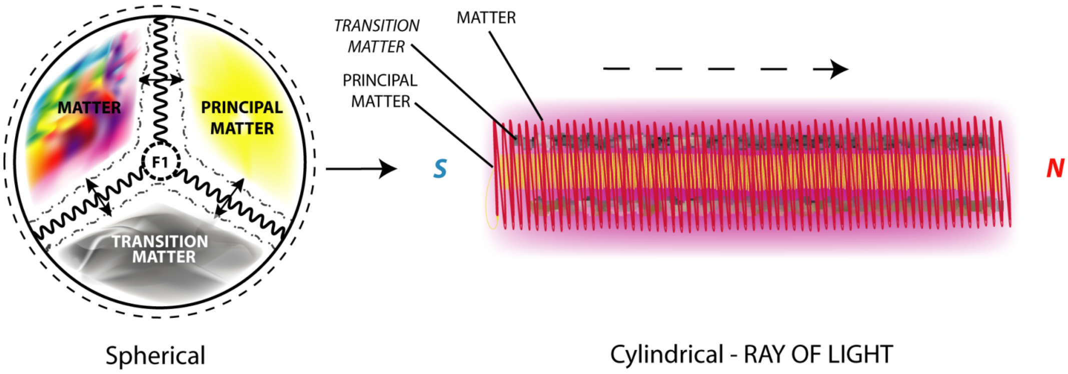

Fig. 16. Conversion of the spherical plasma of a neutron in a cylindrical ray of light.

That is to say for example as the principal light goes through the Transition fields regions of the universe, then the transition mafs and matters of the ray will come to take their position ***on the outer layer of the ray***, then through this process less pmf are used in interaction with these fields and matters of their environment and hence less friction and less loses of mafs of the ray, and in these interactions there are very little loses through the Magravs of the mafs of the transition mafs of the light.

Then any faint lights produced in the interaction of these rays outer mafs transition matter and of the same transition matters in the universe, where there are very few interfaces of the collision between the ray and the environment Magravs this gives the universe a dark but translucent effect that one can see through the universe.

In a way this interaction of rays transition mafs and universe’s transition mafs is the cause and the reason for the invisible transparent structure which allows the production of universes discreet light that one can see through this universe but blocks the opportunity that one cannot see the lights from the universes outside this universe.

The most important point to understand is that light exists in all mafs strength levels in the universe, that is to say *there are lights in the principal mafs strength* as much *as light in the transition mafs strength* and *as man observe there is light in the matter world of the man*.

It has to be point out, that as one hears sound boom in the matter world when one reaches the speed of sound in the matter environment, or what is called the sound barrier, the same applies when the systems developed by man reach’s and passes the ultimate speed of the light in the matter environment too.

That is to say when rays go from lower level strength to higher level strength mafs, one will hear audibly and will feel the vibration of the passing the light barrier.

This sound will not be a one of boom as when the sound barrier is broken, but due to the spectrum of the light transition forces, this noise will be more like a continues varying and long boom and roars. Therefore one will hear a long term tunes and not just one of noise.

This applies the same as one passes the transition mafs environment into principal mafs strength too.

Thus light speed barrier will always be the speed of the light according to man's mafs of his amino-acid and the visible light in all mafs strengths, which are the universes' creature's structures' mafs strength dependent.

When, the man become habitual to travel with the speeds faster than the mafs of matter strength, then on frequent bases man will hear a roar of a noise as passing the light barrier limit.

There are lights in all levels of the matter and mafs strength in the universe, that is to say there are lights in the principal mafs strength specific to that mafs strength environment, which is not necessarily the same as the white light as one observes in the man's matter world and at the same time each light has its own speed which is dependent on the mafs strength of its environment.

Therefore there are lights in the transition mafs strength as much as there are in the man's matter levels.

There are rainbows (Fig. 17) in all levels of the mafs strength in the universe as there are in the matter mafs strength of the earth. The light in all mafs can diffract according to the Magravs strength of the mafs of the given environment.

Fig. 17 The colour of rainbow according to the Man's pmtics strength in Earth Magravs strength.

CHAPTER 4

How matters are created in the universe

In the spans of the solar systems, galaxies and cosmos as the **gans** and **atom of the hydrogen** interact, ***they create the first seeds of creation of more powerful Magravs*** that leads to ***attraction and conversion of other light rays*** *in the universe* into gas, liquid and solids, which these interactions leads to creation of galaxies, stars and planets, where the light itself in different strength becomes the tools of the division elements the like of the hydrogen for it to start the cycle of creation of lives and the creation of intelligence in all corners of the universe (6).

The ***gas and gans of hydrogen*** becomes the dynamic fuel source of creation of the magnetic fields necessary for the creation and establishment of the stars and solar systems and their planets in some parts of this universe, as the interaction of different magnetic fields of gases and ganses lead to the creation of the initial Magnetic and the gravitational fields needed for these celestial bodies to be created in the universe.

The existence of nano materials in the core of the planets like earth has been initially disclosed (1), now it can fully be understood that how these nano materials in state of nano matter, gas and gans become to exist in the centre of these celestial entities and be the initial seeds of their creation once the mafs of the principal matter is reduced to the mafs of the matter strength.

It is important to realise that due to internal structure of the nano materials in ***layers*** and in ***gans state***, these materials by large keep their structural integrity, where high external environmental matter conditions like pressure and temperatures cannot affect the total structural integrity once they are in individual matter gans compound state. This meaning that internal structure and molecular binding of gans and nano materials in nano layers or composite structures ***will not be affected by the matter environment's the likes of temperature and pressure condition of the environment***. But the gans will be changing in its structure when conditioned to high-level dosage of radiation. Thus such entities have monoid characteristics.

For example, this is one of the reasons, why the DNA of the human being is venerable to changes and absorption of radioactive energy and in the radioactive environment or to burst of radiation, as the real structure of the amino-acid of ***the protein of the DNA chain is made of gans of matters*** and not solid matter of the same gases (6).

Thus, gans is the state of the structure of the light which has changed from dynamic cylindrical plasma of magnetic fields to a dynamic spherical entity of the same matter mafs, which its state of manifestation in matter environment is internal gravitational dependent and not environmental condition dependent. That is why one can observe the same element in coldest and hottest regions of the universe and still misreads them as atomic matter rather than nano-atomic or gans of the same matter.

Thus as mafs strength of the universe changes according to mafs available in any given part of the universe, this allowing the production or appearance of plasma of any matter which the mafs strength allows it become in that point in the universe.

Thus this why in one part of the universe one observes the hydrogen as in some parts helium or even gold can be observed without actual existence of any hydrogen atom any other matters.
In some part of the universe the matter take up their nano crystal structure, that the same matters looks to be the diamond structure of its parallel matter in another environment in the same galaxy or universe's environment.

Thus matters are created and to be part of the structure of star and planets or being in the universe according to the mafs strength of the environment and then they become appear in state of gas or solid according to the pressures and temperatures of that same given environment.

CHAPTER 5

The theory of decay and division of the universe(s)

In reality all theories which have been put forward up to present time have no parallel in the universe as has been observed by scientists.

In the universe everything and every process has parallel. In the universe there are always parallels due to the magnetic fields laws of interaction, and hence there cannot be any divisions from these laws.

At the present the scientific world has been intrigued and encouraged to understand the phenomenon of the creation of this universe and scientists have to unravel the mysteries of the creation of this visible universe.

In fact the creation of this universe as is visible to the world of science cannot be any different than any other process in the world of creation, and this universe has been created through the same principles as the rest of the magnetic plasmatic nuclear and atomic additions and divisions of entities in the universe.

This meaning that the present universe is created though the same method as has been observes in the division of the neutron's plasma into plasma's of electron and proton or smaller and/or bigger components of the same Matters.

Hence to follow the principle of the universal order of matters, this universe is created from the division of a larger universe that the man's visible universe is or can be the smaller part of the division.

The reason for it being the smaller part is that in the present cosmological term, this universe is following the attraction of the bigger part and hence it is always in the motion to follow the Magravs of the bigger sister .

This being the reason why it looks as the universe is always expanding as the external field forces pull and pushes the boundary of this universe mafs and as part of the universe has been noted to be collectively following different path of motion than the rest of the universe.

The portion of the independent motion of this universe is the indicator that where the bigger portion of the division of the pervious universe is in respect to the man's universe.

It has to be said that the original universe through the same principle of decay of neutron to plasma of electron and proton (1) and similarly as the decay of heavier atoms to two or more lighter atoms, through the same principle as the mother universe of the man's universe as itself has been created and was created from the division of a larger universe through the same method of decay and division.

The difference in the universe creation and decay is in principle merely is the size of the plasmatic field content in comparison to plasma of electron or proton after nuclear decay and division of the neutron.

Thus in fact this present universe itself is and was created some billion of years back from the division of a larger universe (Fig. 18). Where in Fig. 18 A to G, step by step the phases of the unbalance of the Mother Universe, it's opening and as the fields disperse in to two different zones in the unicos, where these fields interactions and Magravs positioning with Magravs of the Mother universe leads to the establishment of position and placement of two new universe entities, where the same process of decay of neutron and creation of Hydrogen atom occurs.

Hence every time as it is the same with division of the plasma of neutron to plasma of electron and proton, in this division the new universe carries the characteristics of its mother's universe, but due to reorganisation of magnetic fields and their strength the new universe will have a new and fresh cycle of time, which this shows as the age of the new universe.

In fact this being the like of giving birth to a child, where the age of the mother is irrelevant once the new seed of life is created and once the child is born, even though; the new child carries some of the same DNA fingerprint of the parents. The new life has its own cycle of life and its own timing.

Therefore the theories of Big Bang and M-11 as has been proposed in the past and present have no meaning and have no parallel principles in the physical world of creation of universe. One does not see the same Big Bang , when the atoms and neutron go through division or decay, hence this cannot be the same in the division of universes too.

Then if this was so, then every time an electron is created from the division of neutron there must be a Big Bang , This proposed principle is nothing, but showing the man's and scientific worlds lack of knowledge and ignorance of the real terms and parallel entities existence of all units in the universe.

In fact once the division is created and the universes are created, then the rest of the materials and matter content and how they organise themselves in that universe is more or less follows the same principle as before and once the fields are released within a given Magravs which the fields can created in interaction with each other, then the size of galaxies, stars and planets and even creatures within that given Margraves strength of the newly produced universe are determined.

The mafs and matters as arrive directly into the new universe are mafs first which can change to matter then divide between the two universes and then new matters are created in the new universes independently according to the Magnetic fields and gravitational fields in interaction with each other these mafs can achieve to maintain and create. Thus all universes in content are not and cannot be the same in material and mafs strength, and content of each universe are dependent upon the internal interaction of fields which are transferred into the new universes.

The new structure is dependent on the fields within the new universe and their internal motion of the new universe is internally determined by the total mass which the interaction of the Magnetic fields and gravitational fields of the universe can master.

This new universe has all the attributes and mafs of its mother's universe, where the subsequent production of mafs and matters like Principal matter and Principal Matter, planets, solar systems and galaxies and so forth, are nothing but the consequential outcome of all other effects in a given universe.

Thus in other universes there could be ***no physical matter*** the like of hydrogen and where for example hydrogen can be *only in nano or gans state only*, thus the life in these universes will be in order of fields and mafs strength rather than matters in this visible section of this Mans' universe.

But if this universe has the same structure as its mother's universe and co-birth universe, then this universes can be a micro replication of a bigger version, where these universes are macro version of the total universe in the greater universe.

Phases of the decay of the plasma of a Universe

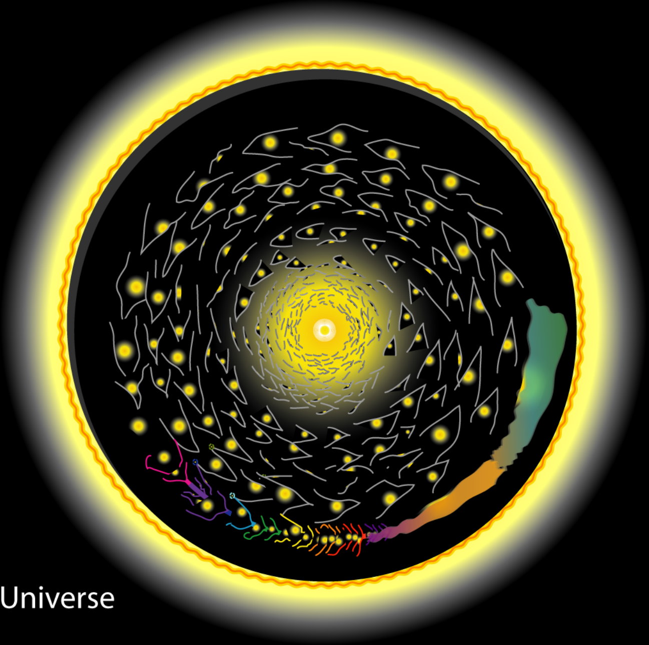

A. Mother Universe

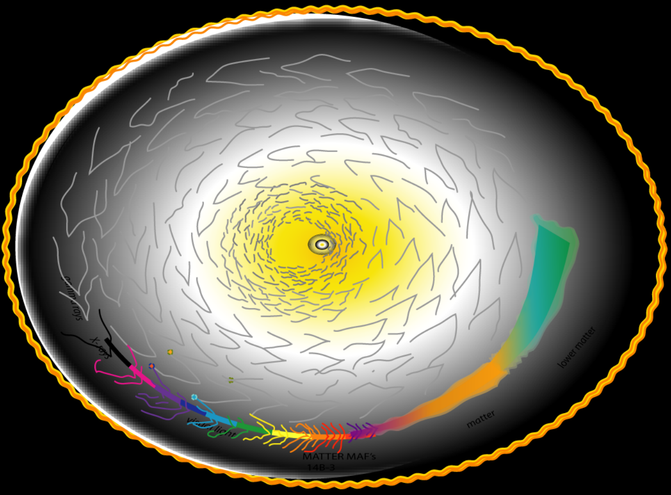
gamma rays
X-rays
violet light
MATTER MAF's
14B-3
matter
lower matter

B. Initial Magravs unbalancing

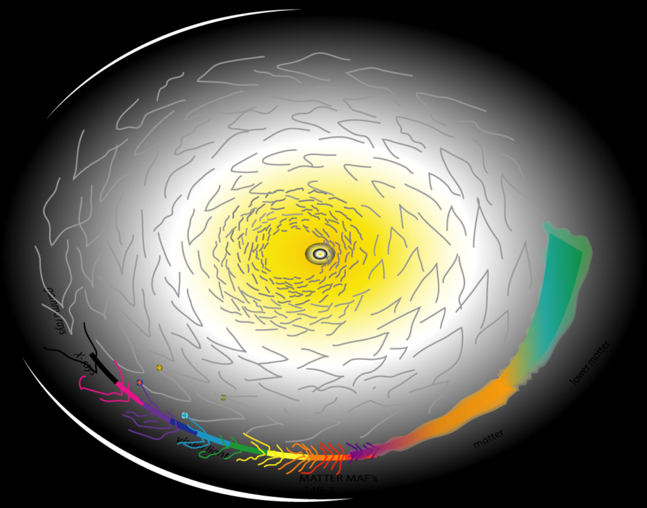
gamma rays
X-rays
MATTER MAF's
matter
lower matter

C. Loss of structure

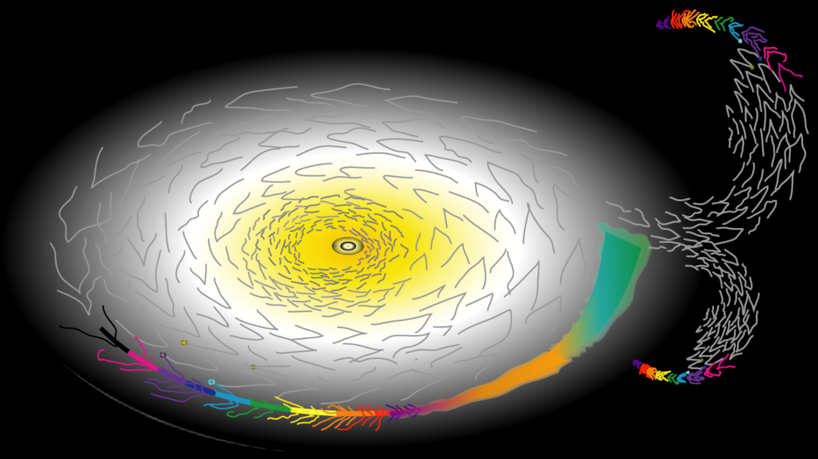

D. Dispersion of fields of the plasma of the Mother Universe in the unicos.

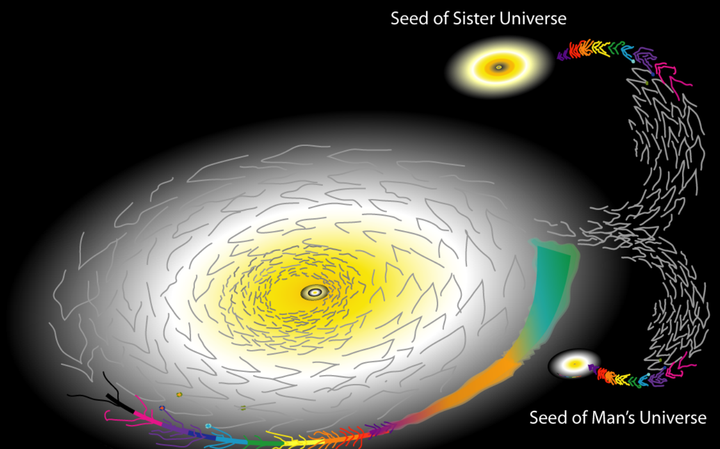
Seed of Sister Universe
Seed of Man's Universe

E. The creation of the seeds of the new universes from the decay of the Mother Universe, where the two new universes have to maintain a magravs positioning in respect to the Mother's and each others magravs.

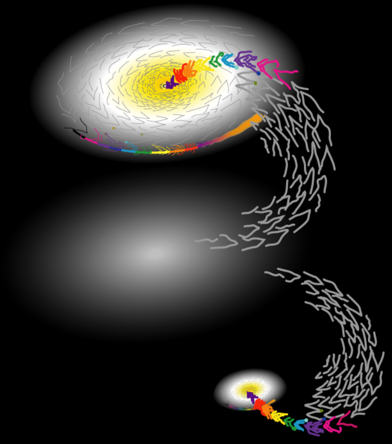

E. Full splitting of the Mother's Universe plasma into two new plasma's

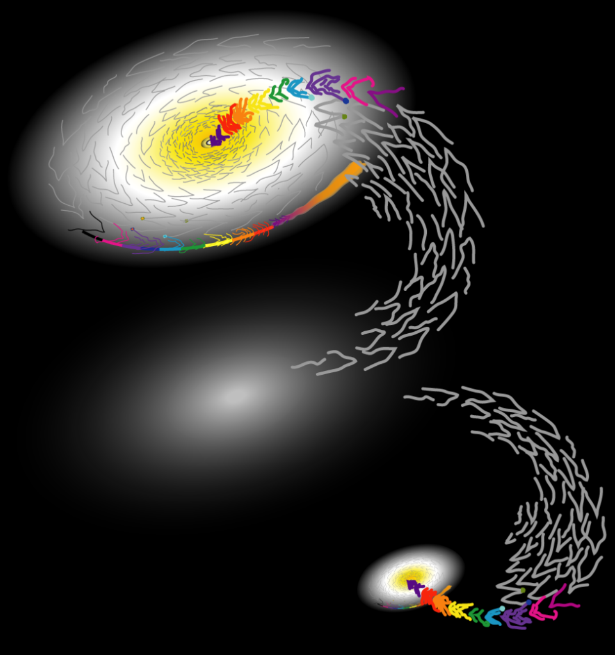

F. Initial stage of creation of gravity and magneto-sphere of the two universes due to unwinding and interaction of the fields

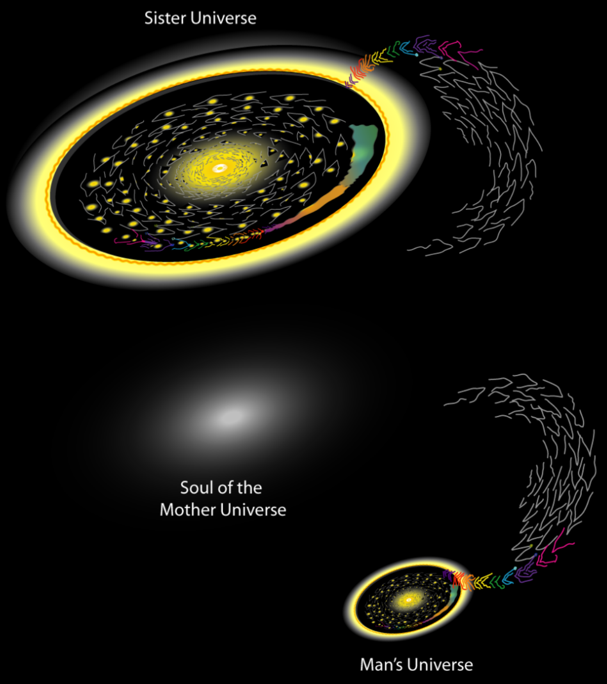
Sister Universe
Soul of the
Mother Universe
Man's Universe

G. The final physical parameters of the Mother Universe, the Sister Universe and the Man's Universe. Where the same process applies to decay of neutron and it's division in proton and electron, where Man's Universe is the like of the electron after the division.

Fig. 18 (A to G). The process of the division of the Mother's Universe in to Man's Universe and it's Sister Universe

Thus, in fact in the bigger portion of the original mother universe which the man' universe is partly created out of it is bigger or smaller mass portion of the original mafs of the mother fields, then the bigger portion or co-birth universe of this universe, due to the larger mass of its content, this universe's galaxies and stars can be much larger in proportion in comparison to the galaxies in mans universe and conversely due to larger Magravs of the internal structure of the larger portions, the beings within these universes can be smaller or they be totally different in operation than the beings in the mans universe.

It has to be said that life in any form is not exclusivity of the Earth, if this is the mind-set of some, this shows their lack of understanding of universe and how it is created and not the real truth and how fields and matters operated and function in the universe.

CHAPTER 6

The Man and his soul and their connection to the universe

In the structure of the Principal mafs centres or the Principal star or what is so called the Principal stars in the centre of galaxies and mafs and matters in the centre of stars and in giant planets and even in the centre of some planets, the Magravs of these objects seems to possess a stronger or larger than the mass ratio for such an object, that the object possess and covers a stronger Magravs forces than usually a matter in these regions by the present in the world of science knowledge become apparent. The reason for the stronger Magravs of these objects comes from the multiplicity in the Nano magnetic mafs' and matters' and layers in the inner structure layers in the sanctum of these objects.

In understanding the operation of different mafs of matters in the universe and the process of the reduction in strength of these mafs to reach the lower levels light, visible light and tangible structure's like atoms, then one should understand that the structure of the man's body will not change as the physical structure of the man goes through and from matter to transition matter or from transition matter to principle mafs and matters strength's environments.

The reality about this, is that the plasmas of the atom of the structure of the man, like the individual atoms, which are active in the structure of fundamental amino-acid molecule of the human body, these are all made of plasma of mafs of universe and for the proton or the electron of let say carbon atom in the amino-acid, this plasma of the proton has in its centre principal mafs and maters as well the transition mafs and matters and finally the matter mafs, which is its tangibility state which make matter visible to for example the eye of the human.

But once these plasmas of the tangible matter structure of let say proton and electrons of the carbon atom cross the barrier from the light mafs strength and matter fields to transition mafs and matters field strength, or even the body of the man crosses the principal mafs and matter strength, then at each point of field strength crossing, that part and components transition or principal mafs and matters of the plasma of the proton of the carbon will come to operate and interact in that entered field strength zone, and hence the integrity of the structure of the human being physical body will be maintained, but indifferent mafs strength level.

This meaning that the man will be still intelligent and will have the use of all its faculties, but the body will operate through the principal mafs of its plasma rather than present matters mafs strength of it material world strength.

Thus the man is not restricted to life in matter world only, but life in all dimension of strength of the mafs of the universe.

The reason for the plasma of the human body having the ability to operate in any mafs strength, is due to the fact that the atoms of each cell of the human body operate in the gans state of matter and not solid state of matter, which this gives the plasma of all the elements of the human body to cross mafs strength barriers by calling up on their mafs components of their environment.

That is to say the gans of the carbon in the amino-acid of the human beings' will bring forth and operate through it transition mafs strength in the transition mafs environment. Then the same gans of atom will operate with its principal mafs components in the principal mafs strength environment.

Thus the body of human will not be destroyed or evaporate in different plasmatic magnetic fields strength environments as it orderly crosses them.

But the body of the man will be destroyed if the mafs of principal mafs strength is applied to it in the matter strength environment, where in this case the mafs and the matters of the atoms of the man become diluted as a minor part in the mafs and matters of the applied fields.

Therefore man is part of an inclusive pattern of field's in motions in the universe and nothing more or less can be attached to the existence of the man.

The man in physical term is an entity and in and through his soul the connection of the field between himself and the other fields in the universe.

The physical body of the man is the like of the planet earth, where it has mass and its magnetosphere which expands beyond the physical body, but its total magnetic fields and gravitational fields determines its position and relation with other matters in its solar system and in a small way it determines the position of its star in its galaxy and, then the position of star determines in a small way the position of the milky-way in the universe and so forth.

Thus the soul of the man is the external connection of the operation of the physical body of the man in the universe, it is part of one and inclusive realty of interaction of the whole.

Therefore the soul is part of the operation of the universe and every creation which can extent the effects of its overall magnetic field to others which can affect their position and existence is in possession of a soul.

Thus soul which magnetic fields created and expand beyond the physical body of the man is not exclusivity of the creature but it is the common denominator and common link between the man and other creatures of the God and has direct effect on the operation of the rest of the universe.

Therefore the man's body due to the interaction of its atoms protons and electron and neutrons magnetic fields, this object creates its own magnetosphere and its own mass and this body is and has to be in possession of magnetosphere which shows the working of the magnetic fields of its constituent matters and its subcomponents and fields.

Where, in the physical worlds as the same as the solar systems possessing magnetosphere as so do the star and planet, so does the body of the human through the same physical principle possess the magnetosphere, which is so called aurora of the human body, the field of the aurora is part of the soul of the man, but is fact the total effect of the internal interaction of all fields of the body which creates the Magnetic field and gravitational fields of the body and their interaction on each other which leads to the interaction with their fields in the universe, this overall output of the fields of the body of the man is the soul of the man.

Thus; all dynamic plasmatic matters in the universe possesses a soul. But the man has the intelligence to allow the interaction of its soul with others. Therefore through this principle the man is responsible for all his actions and he stands answerable to other souls in the universe. As he decides how these fields which partial and fully control through the Magravs of the matters of his brain how and what happens in its interaction with other souls during its physical existence.

Hence the man has to understand, that universe and others, whom this universe has been created from and the universes which will be created from the division of this universe in the future are all interconnected and operate through the same fundamental principle magnetic fields.

Therefore there are parallel universes to this universe, with the difference in the measure of their magnetic fields and their position in their given environment.

Thus as we have the same and similar electrons structure's and protons structures in the same structure of an atom, this structure of positioning of electrons and protons is the same for all known atoms, then the same applies to the universe and the souls within them too. This meaning that there are similar universe as this universe in the greater universe and other universes which this universe has been created from or it shall create.

It has to be said that at the same time the matters in the universe have the same universal language of communication, where in the universe the common language is the basic plasmatic magnetic fields, based on the first plasmatic magnetic field strength of plasma or the simplest atom of matter of their environment.

This language is universal and once the man on earth understands this phenomenon and can fully measure the magnetic fields strength of the electron Magravs and uses this as the base strength, then man will be able to understand and communicate with rest of soul possessing creature of the universe. Until then, the search in the sound waves to look and try to communicate with other creatures of the universe is a primitive picture and shows the lack of mans understanding of the world of the Creation.

Therefore the gravitation, magnetic, radiation and other similar properties and interactions of the field(s) on each other in this and other universe(s) decides on how and the way the creatures in the different universes and in the man's universe would look and behave.

But in a essences they are all made of the same building block of *MAGNETIC FIELDS AND IN ITS AND THEIR INTERACTION OF DIFFERENT STRENGTH AND TIGHTNESS OF IT IN THEIR ENVIRONMENT*; This determining how tall and short and if one has eye or uses the interaction of fields to interact and communicates with other creatures of its environment, universe(s) with or without physical tangible or visible so called body.

May be now it can be understood what has been said that in the universe,

I have made man in the image of myself

CHAPTER 7

The creation of gravity in the universe

At the present time the scientific world uses the terminology that when the gravity took hold then that was time when the matters in the universe began to be created.

The reality is that as when the universe is created from the magnetic fields of the previous universe(s), then the content of the new universe is nothing but a soup of different strength plasmatic magnetic fields, then as these magnetic fields interact with each other usually laws of magnetism they attract or repel each other, where at this point the attraction fields of these plasmatic magnetic fields become the ***gravitational fields*** forces of the universe and the repulsion field forces of the magnetic fields become the Magnetic fields forces which the same fields create.

This interaction of fields in the plasmatic fields always enclose itself in the form of an envelope, which this always in the universe leads to creation of the spherical shapes of all entitles, this be it plasma of a neutron, earth, or universe?

The interaction of field and attraction fields which leads to creation of a circular motion of the gravitational fields as the fields in respect t the matter have keep their gravitational positioning too.
Thus the spherical shape of the fields is primarily due to the gravitational field and positioning combined together which this causes the magnetic fields in the universe to close and created a full circular; and hence the creation of spherical objects in the universe.

Therefore the gravitational filed forces of the new universe is created by the interaction of its content magnetic fields and in fact gravity is created by the natural laws due to interaction of two opposite polarities of two magnetic fields, which as these opposite fields interact they create attraction fields or what commonly called the gravitational field, where the strength the outcome field from this interaction of fields expands beyond the boundaries of the two original fields, this leading to the creation of an envelope or area of the effect of this new field that attracts other fields to itself and the strength and compactness of this new field leads to creation of gravity which in the universe this leads to creation of Principal matters, transition matters and then visible matter of galaxies , stars and planet and so forth.

The creation of gravitational fields forces in the for example the plasma of neutron, its strength and contest by large measure is dictated by the universal gravitational fields forces and not in full by the field which leads to creation of the neutron to start with. In the universe the creation of the neutrons are dependent on their universal gravitational fields forces. To this effect not all neutrons are all the same and not all neutrons in the different universes have the same gravitation a magnetic fields forces and dimension.

In fact the human race has to learn that what it is observed by them as the physical matter in fact is only a fraction of overall content of matters of the universe created through creation of gravitational forces and what he sees are not all of its matters.

This meaning that the universe has other matters and mafs contents and as the man's technological and intellectual capabilities expands and increased then man will come to see more of the realities of the universe.

CHAPTER 8

Insight into the realities of the working of the Universe and what they bring about

In the recent past scientists have talk about the term dark energy and anti-matter, where these covers the part of knowledge which they cannot find explanation for within the present understanding in the scientific world. For example the term dark energy is used to understand the forces, which is nor explainable and neither does fall within the conventional present world of physics too.

In this disclosure the terms like the matter, transition matter and Principal matter are used, where these terms are and have become recent addition to man's scientific vocabulary, where these can more precisely explain the rang and the medium, where each magnetic field in respect to their fields and its own magnetic fields strength is and would behave.

In the universe the same as in the physical matter world there are sources of magnetic fields, which are stronger in magnetic fields strength and some which are in the transition and there are some which are in between the strong and the weaker field strength.

In the physical world one called the stronger fields source the star, where in the plasmatic fields of the universe, the stronger fields' plasmatic regions or fields are easier to be called the **Principal fields**, which their interaction leads to creation so called **principal matters** (anti-matter), which these are real physical entities, which have been unknown to man up the recent times.

There are **transition fields,** which are in between the Principal matter fields in strength and the matter field's strength, and as these are in balance in between the both fields of Principal matter and matter world, and then these do not create visible light when they interact with Principal matter or matter fields strengths. Hence they tend to be like ***transparent*** and ***translucent*** in their environment and hence they give the appearance of the darkness to their environment.

When, magnetic fields are in motion they are called energies (Book1), where these translucent fields as they are in motion from one state of mafs to another they create what is called the Transition energy (commonly called the dark energy) which this explains the Transition energy mystery of today's science.

Then there are in the universe fields, which are the weaker plasmatic fields region in strength, which these fields are in the human protein plasmatic Magravs strength that they become detectable or what is called the visible or tangible matter.

Therefore in simple term, the Principal matter is the like of the sun and sources of energy in the universe, the transition matter is the magnetic fields strength fields travelling from the stronger field to weaker field, and the matter fields are the like of the planets of the solar system.

There are no mysteries about these fields, energies and matters, except in the lack of knowledge in the man's progressive and advancing science about his universe and living environment.

- Where, in the universe one sees the effect of the stronger Principal matter's fields as in the centre of the galaxies as the star do in the solar systems. The present world of science will come to realise the order of fields are all time kept and all followed the same rules and principles in all levels of the universal creation and created.

- This meaning that in the centre of the galaxies the entity which recently called as the Principal star of the galaxies, this entity in its centre have nothing but Principal matter magnetic fields, which their interaction leads to creation of strong gravitational fields. Where, this centre of Principal matter is covered by the transition fields as they are on their way to visible matter fields strength or what one observes as the dark environment around the central Principal matter region, hence the term black hole (Fig. 19) or Principal star, which this darkness region is only due to the balance transition between fields in motion and the fields which the rays are travelling through.

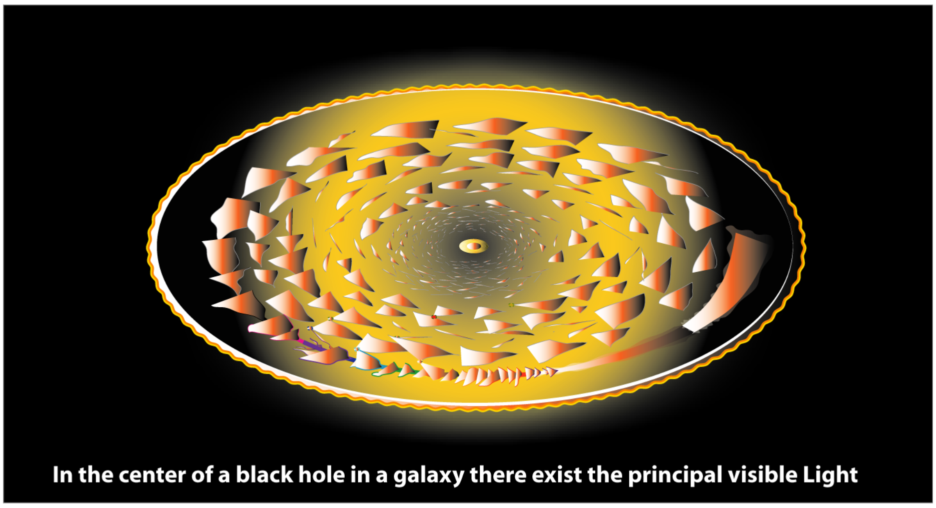
In the center of a black hole in a galaxy there exist the principal visible Light

Fig. 19 The Principal Light inside a black hole.

- The existence of the principle fields and matters in the centre of the universe with its strong gravitational fields is the reason as it seems that the Principal star is eating everything and absorbing everything this being rays or matters, where in fact it is the gravitational field forces of the Principal matter in the centre of this dark spot which are creating these large pulling fields.

- The size of the Principal star in the centre of the pulm is the combination of gravitational fields and Magnetic fields forces or the field's strength of the Magravs of the Principal matter content of the Principal star.

- In a sense as the Principal star extracts more material from its environment in the universe, then a position is reached that the total Principal matter absorbed by the Principal star from the objects, the like of stars, planets, plasmas and so forth, a point of criticality is reached that the gravity of the Principal matter fields exceeds the Magnetic fields of the Principal matter and that these forces cannot sustain their balance, hence the Principal star has to release enough material and fields that it can reach equilibrium between its two fields, and that is the point where the principal stars release vast amount of fields and matters without actually causing the division of the universe (Fig. 20).

- Where, these massive fields and matters of massive principle fields released will disturb the equilibrium of the universe as they travel the spans of the universe and in case can lead to creation of new galaxies and even stars and new mattes suddenly out of nowhere in the universe. These principal storms are very much like the sun storm one observes on the surface of the sun. In this process of rebalancing, it can observed in the universe, like as in galaxies that their Principal star has sodden volcanic eruptions in the rest of universal galaxies central principal stars as they absorb some of the principle matters and fields which they receive through the universes principal field eruption and the Principal star spewing of the surplus mafs and matters in to its surrounding environment.

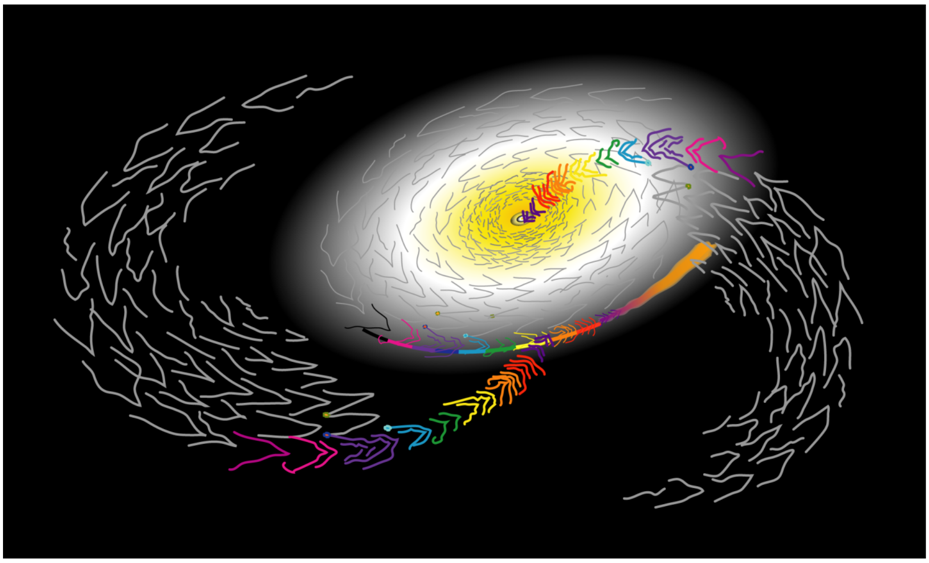

Fig. 20 The absorption of matters and fields by principal stars of the universe or galaxies.

- The principal star of the galaxies as much as the same with the principal mafs and matters of the stars of the solar systems or their sun have observed this process in smaller scale. Where up to now man has not have had the tolls to observe that when the star of its solar system not only release the visible matters and releases huge amount of magnetic field into its heliosphere, but at the same time through and amongst these eruption of the Sun huge amount of principle fields and matters are released into the plasma of the solar system, which these have not be observed by the scientific world due to the lack of appropriate tools.

- The ejection of principal mafs and matters from the surface and right from the centre of the sun is an essential part of sustainability of the fields and matters within the solar system and essential part of the creation of new atoms and matters on the surface of the planets of the solar system. Where at the same time the solar systems as the whole on continues bases receives large amount of principal mafs and matters from principle star of its galaxy and principal stars disc in the pulm centre of the universe.

- It will observed that Principal star in the central disc of the universe even absorb principal light, in fact as light is an entity which possesses both gravity and Magnetic fields and its own mass, thus Principal star is extracting another object from its environment due to its stronger fields strength (2) is a normal occurrence. (Fig. 21)

- Where, the same has been assumed in the present science that black holes even absorb light, but the truth is that principle stars be it in the centre of the universe, or galaxies are created from the principle mafs, which are of the higher order of magnitude in mafs strength and the mafs than of the light mafs in the matter mafs strength. Thus in fact it is normal for weaker field’s strength to be attracted by much larger and stronger mafs of Magravs of the principal stars in the centre of the universe or galaxies.

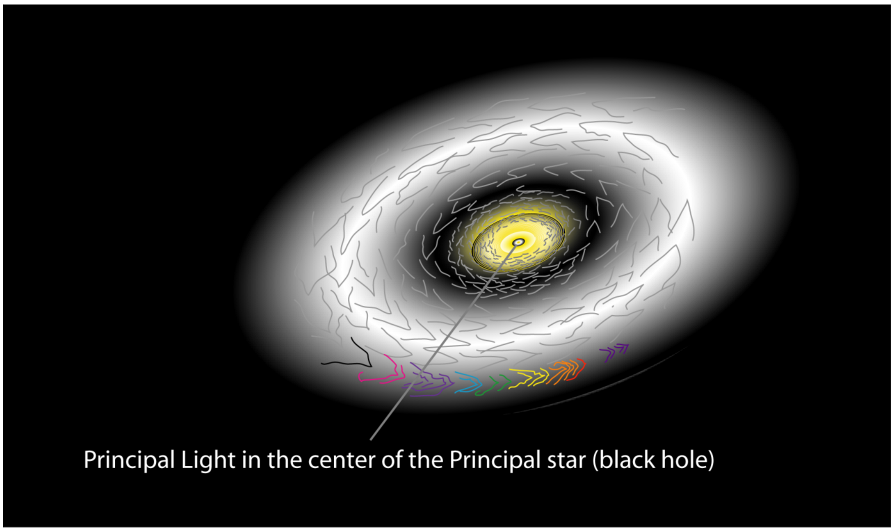
Principal Light in the center of the Principal star (black hole)

Fig. 21 Principal Light in the centre of the universe.

- But at the same time it is normal to see that the principal stars in the centre of the universe and galaxies spew stronger lights in the order of magnitude of principal mafs which are not visible to human eyes, where the light in the matter mafs strength is visible to him, hence man see one way traffic and not the real truth about the world of creation of duality and equilibrium.

- Thus in the universe it should be possible to observe points where the light lenses the Principal star if it is far enough that Magravs of the Principal star cannot overwhelm the Magravs of the light, but strong enough that Magravs of the light find their position in respect to the Magravs of the Principal star and creates their own Magravs positioning. As this can be observed in respect to the light and star of a system so as the star is made of mafs of principal mafs and matters too and has the same effect of the lensing for the lights rays too.

- Lensing of the transition light when passing the principal mafs regions of the universe should be observed the same way in the future as one observes the lensing in the matter light mafs strength. Where even the lensing of principal light should be observable in the specific cases and some regions in the universe.

- The matter, Transition Matter, Principal stars, the dark spots on the surface of the sun all are created through the same concept and principle that when plasmatic magnetic fields of the any field or matter is equal to the plasmatic magnetic fields of its environment, then there are no collisions between the matters fields which can leave or release any surplus or residual magnetic fields in the light spectrum of the mafs strength or lead to creation of magnetic wave in the visible light balance of the human protein pmf strength or that specific mafs spectrum anywhere in the universe. Thus these areas in the universe, the galaxies and stars surface looks as creating not too much light or what is called to be looking as to be darker than the rest of their surrounding environment(1).

- Thus the assumption that even light cannot escape the gravitational fields of the Principal star is position and the lights itself Magravs strength dependent.

- In truth if and when the Principal matter magnetic fields over time are reduces in strength and they unwind and transfer their fields to their environment, which as these fields slowdown, they become transition matter energies and then transition matter and finally they slow enough that they reach the plasmatic magnetic fields of the mafs strength, which at this point they become energies observable and absorbable and tangible to human field touch and visible to it virtual magnetic fields sensors.

- It has to be said that there is a great misunderstanding in the operation of the fields and mafs in the universe, this misunderstanding over time has reason due to the man's concept of heat in the *MATTER WORLD, WHICH THIS NEEDS SOME CORRECTION THAT CAN BE APPLICABLE IN THE UNIVERSE* as whole (The full explanation of the magnetic fields, plasmatic magnetic fields, matter and mafs is explained in the reference 1).

- The universe will never run out of energy and get cold, the universe will not expand to nothingness, but universe will decay to smaller universes as universal gravitation will never disappears as long as there are two or more magnetic fields remain in the universe that they can interact and attract and repel each other that they can create gravitational and Magnetic field forces that the whole process can restart again.

- In the nuclear decay one does not observe temperature increases and one sees uniform temperature gradients across the newly divided plasmas and the temperature distribution will be constant, this is the same with division of mother universes to smaller universes. Thus the concept of universe was hot and as cooled down matters are created is fallacy and not in parallel with the rest of the universal laws and processes.

- This observation is parallel with the W-MAP, which has been planned out by present scientific world, where one does not observe huge heated areas and points in the universal map. Here the equal heat distributions parallel with the nuclear decay and heat balance in the divided components of electron and proton after their division and long term motion in their environment is observed.

- The individual heat spots observed across the universe, these points are due to newly arrived mafs and matter movements in that given region of the universe and they are temporally condition.

- The central heat line across the W-MAP is due to dynamism of the principal mafs and matter in the centre of the universe and this is due to concentration and dynamism of the mafs and matters and their reduction to transition energies within this region.

- The creation of gravity in the beginning of time of the universe(s) was and will be primarily due to the interaction of combination of different plasmas of mafs within the plasma of each universe which have arrived from the mother universe and as the magnetic fields interacted, they create gravitational fields and Magnetic fields of the new universe, which these in turn as there are made of many mafs strength, which have arrived in the new universe from the division of the old universe, then different gravitational fields and magnetic fields due to their interaction are created, this leading to creation of different galaxies and matters. Thus, the universe never been cooled but pmfs from one strength meets-up with another and leads to creation of central gravitational fields of the universe and these interactions in the future will lead to creation of specific new matters in that universe, which these matters existence and appearance are closely related to the gravitational fields which the pulm mafs and matters have stared and maintain during the life of that universe and will allow to be created and be held in that universe. Thus all universes do not contain the same matter and all their basic matter is not based on the plasma of the hydrogen as is in the man's universe.

- The internal and initial gravity created in the plasma of any universe is on the same principle as the one created in the plasma of proton and electrons mafs and matters and from the interaction of their mafs of matters, transition matters and their principal matters once they arrived from the decay and division of the neutron. Thus the gravity of the universe is established from the interaction of different mafs and matters strength once the mother universe is divided and they are created in respect and relation to the original Magravs of the mother universe as these fields are separated from their mother universe into two or more universes like the one visible to the man. Therefore it can be said that man's universe is part of the multiples of universes which all have been created from one mother universe, which this present visible universe to man is a fraction and part of operation of bigger and more active universal order of the Grand universe.

- In reality one can say that this universe is nothing but like an electron in the structure of a uranium atom which this atom is part of a large mass of a large block of uranium atoms.

- This visible universe is part of a total universe and man's universe which looks so large to him is only due to his lack of understanding of the real terms of the world of creation and existence and is dependent up on his openness and understanding of levels of his own existence.

- The principal concept of creation of the principal matter and transition matter strength from mafs and matters in matter mafs strength can be achieved through the process of fusion of mafs, when these mafs and matters of lower order strength enter into the principal star regions of the universe and their fields become and are squashed and tightened in intensity of the fields within the mafs and Magravs of the principal star that the entered fields into the Magravs catchment's of the principal star merge different field strength magnetic rays and fuse these rays that they become and reach mafs equal to the strength and density of the principal mafs and matter strength.

  Thus Principal stars are, where the process of fusion of mafs and matters occurs to amalgamate and increasing the mafs strength of loose and incoming lights and matters from weaker strength mafs is set to take place. This is to say that Principal stars of different size and intensity in galaxies of the universe are the places where the principal mafs and matter are cooked up and separated and processed and manipulated into their given strength and then through conditions become to be known the like of quasars these new recycled stronger fields are released into their given environment, leading these principal mafs and matter to become the centre point for the creation of the stars and planets in their galaxies and as some become to be in the centre of the plasma of proton and electrons and so forth.

- Where, at the same time the Principal stars are the points in the universe that by and due to their high gravitational fields of their environment, this is the place in the universe, up on entry of different mafs and matters, these matters strength can be increased to higher level magnetic fields strength. Thus the Principal star are the points in the universe where the mafs and matters can increase their strength to transition matter levels or to the principal matter magnetic fields strength and where the transition mafs matters fields can be increased to the principal matter field's strength

- In the centre of the stars as the same as the in the centre of galaxy and universes, where the fusion process of fields and matters are considered to take place and heat to be generated due to fast movement of the pmfs. In reality in movement of the stronger and weaker mafs and reduction in strength of the mafs, which these changes disturbs the plasmatic magnetic fields of the Magravs of plasma of the components of atom, this be it the plasma of electron and plasma of proton in principal matter, transition matter or matter strength, this leads to release of mafs fragments, which these can manifest themselves as heat or radiation in their given environment mafs strength. This movement of plasmatic magnetic fields leads to weakening of the magnetosphere of plasma of the all atoms, this be it plasma of principal, transition or matter atoms, hence this weakening allowing the process of entry and amalgamations or fusion of different plasmatic fields into another magnetosphere of any other plasma or an atom or increase and amalgamation of lose mafs of different strength within the environment of a principal star.

- By creating and using the higher strength mafs than the gravitational and magnetic fields strength any entity this be it atom or rays, one can create conditions, where one can cause fusion of atoms, plasmas and rays without creating heat and any need for accelerating particles and in colliding them to create fusion as has become the tradition in the present plasma of matter fusion technology on earth in the recent times.

- If the full concept of fusion in matter level is to be achieved in much easier way, then it will more appropriate to separate the different components of the plasma's mafs and matters, amalgamate the same together and then allow the re-amalgamation of different mafs strength to take place. This is how fusion of field's and matters are attained the span of the universe.

- In the universe the principal mafs and matters are the sources of the energy and supplier of the pmfs of the universe, thus when the plasma of principal mafs or matters interacts or collides with the lower strength mafs in order of magnitude of any matter then mafs and magnetic field content of matter becomes part of the principal matter spectrum and their content is added to the mafs of the plasma of principal matter.

  Hence the current fallacy that when matter and principal matter interact nothing is left of the two, except some release of magnetic fields or energies, this is hypocrisy and man lack understanding of its own world and the world of the creation. This is like saying that if earth gets attracted and absorbed into the Sun of the solar system as a lot do on frequent bases in the universe, then there will be nothing left of the Sun.

  The principal mafs and matters are the source and stars of the universe and by order of magnitude and strength and the mass the principal matters and stars mafs are by far stronger and possess denser fields than their by-products the transition matter and matter fields strength which are created and released originally by the principal mafs and matters itself to begin with (1) which has led to creation of the planets and stars. Then how can the weaker and insignificant part in matter strength level destroy the larger entity?

  Thus nothing happens when matter entity comes to contact with principal matter (antimatter as is known at the present time) entity. There will be only principal matters left with addition into it the content of matters mafs and matters, which have collided with it.

- Thus the physical structure of the plasma of principal stars in the universe is as follows the principal mafs and matters in the centre, transition mafs and matters and the then mafs and matters in the matter mafs strength.

  This entity what man calls the universe follows the rest of the universe orders of linking the magnetic fields polarities of north and south poles together as has been observed in the man's planet. This universe is near spherical in shape in general and dynamic and rotational anticlockwise in direction of motion. But the principal star can pull into itself due to its strong Magravs and gravitational field's matters as well as matters to itself from its content plasma as well as from the unicos of it outside environment, where in the process it can separate their sub-Matters for these to be added to its principal matter too.

  Looked from outside this universe surly will possess rings as planet Saturn's does, as this universe has the same construction as the gaseous planets, but; with the difference that its rings will be colourful and much more dynamic than Saturn's rings.

- In universe(s) principal stars can be found which have anticlockwise motion and some, which have vertical rotation and may be some, which have combination of both clockwise and vertical rotation too. These motions are primarily matter and fields' strength and position dependent as has been seen in the man's solar system (1, 2).

In the principal mafs state of matter all matter more operate in the gans state of matter than the gas or plasma of the matter, where with the gans of the matter the mafs of the environment decided the appearance of the element in a given condition and in all cases tangibility of matter is the consequence outcome of these conditions.

Hence all matters in the universe are not matter atoms, but gans of matters, as gans of matter can take all lattice structural combination of elements, where for the matter of same element to converse from one lattice structure to another high temperatures and pressures are needed. Where, in the universe majority and nearly all conversion of lattice are done through gans of the matter and not atom of the matter.

To achieve the gans state of matter the environment of the atom of the gas needs low and continues flow of mafs in transition for the atom of the gas to be converted and its Magravs changes from magnetosphere of a gas to a magnetosphere of tangible matter of the gans (4) state of matter, and in fact this happens when the gravitational field of the gas is made more powerful than the Magnetic field of the gas and hence the plasma of the gas gravity contracts or tightens and hence the gas changes from gas to gans and becomes what is called solid nano state of matter in the atmospheric condition.

- Multi-layering of mafs and matters increases and exacerbates the initial magnetic fields strength of the matters and the fields they can create. This causing an increase in the strength of the Margraves of these objects and even Magravs strength can be further increased if the mafs and matters are in gans state of matter or in combination of different mafs strength in different layers.

- Ganses as gases once reach the state of certain structural lattice as in the gases on the earth atmospheric pressures, these ganses change their characteristics and take the properties of non-dimensional plasma or they become what is known as odder or what can be detected of their existence in their environment. This principle applies the same to the gans of the matter too, that the ganses of all elements have odder and hence the universe outside the earth atmosphere has an specific odder of its own, which in fact each galaxy has the same properties and different odder and each universe has its own odder primarily due to the structures of the gans(s) of the elements they create or they can hold on to, and the same element does not have the same odder in all corners of the universe. As odder is the mafs strength dimension dependent the gans of smelling entity mafs combination and/or of the gans's mafs strength itself.

- At the birth of the universe there has never been and in the future there will never been creation of heat, as in the same process of decay and division of neutron in to plasma of proton and electron. Thus the theory which has been created and been followed in the world of cosmology that universe at the beginning was hot and then as it cooled down and gravity took hold and then matters are created are false, The hot universe and cooling and production matter through cooling, this is an understanding of creation of matter and based on the matter world condition structure is base of old centuries and understanding of matter from cooling of gases and liquid into solids.

  The heat distribution of the universe is the same as the heat distribution in the plasma of the proton after the division from the neutron. This balance distribution of the heat has been observed and recorded by the W-map. This pattern of no heat and creation of gravity due to interaction of pmf fields in the universe leading to creation galaxies and stars are the normal process. Where in the universe matters operate through mafs and their environmental mafs and no other factors. This being the reason why one can observe matter in all corners of universe independent of temperatures and pressures which prevail in that part of the universe.

Matters in the universe are brought to the state of conductivity and connection through their Magravs and not heat and pressure and that is the reason why life exists in all dimensions and structures and intelligence in all corners of universe and life is not the exclusivity of water and oxygen based entities and environments the like the earth and its citizens.

- The present concept that the production of iron atoms are the limits of fusion in the universe and the point where the fusion of matters leading to production of iron and absorption of all energies of the star this leading to collapse of the star and that the star go through the final cycle of life as an active star, this again shows the man's lack understanding of the full science of creation and motion of mafs and maters in the universe.

  In fact due to presence of principal matter in the centre of stars, the process of fusion will go on and all heavy elements are produced through the process of fusion in the centre of the star and not as has been assumed when the process of red dwarf and white dwarf are initiated.

  Stars produce the heavier elements in a rapid process when the Principal mafs of the star releases part of its pmf, facilitating and making available pmf necessary for the fusion of the matters to heavier elements. All heavy matters in the universe are created in the fusion centres of the stars and most of very heavy material like uranium and heavier principal mafs are created in the principal star regions of the universe.

  The point to realise and which has been overlooked is that most of the universal objects like stars and planets, and principal stars they all carry in their centre a large amount of nano materials in all mafs and matter forms and it is correct to understand that in these areas there is a large amount of gans of matters too. The reason for the existence of these nano matters in the form of individual or specially in the form of layers and sheets in the layer boundaries or interfaces of one or different state of mafs or matters, the existence of gans and nano mafs and matters in these large objects leads to creation and production and enhancement of gravitational, and Magnetic fields of the these entities through the principle of interaction of dynamic motion of mafs and matters with magnetic matter or matter of these objects. As this interaction are the main source of increase in mafs and their effects in all matters accelerations in the universe and scientific world by large has not understood this concept in full, as if they would have understood this, they would have understood that there are no limitation within the structure of the planets and stars for them to create conditions that through fusion all elements in the universe can be produced within their sanctum during their cycle of existence, and not when they are at the their latter stages of their cycle of existence.

  In the centre of planets and stars always through interaction of plasmas and their capability to unwind and open up and release all their components of mafs and matters, then it is possible for the centre of planet to reach a point that they can release the content of the plasma of their gas, gans and matters that this leads to release of the principal matter of the plasma, that this high strength mafs through rapid reduction in strength can lead to rapid creation of new atoms and due to its localised strong Magravs in the centre of stars and even planet, this allowing the production and help with the fusion of large number of plasmas of proton and electrons separately, that further on by interaction of large quantities of these plasmas this can lead to production of any element in the centre of the planet or a star. This be it the atom of uranium or copper or even fusion hydrogen to produce helium.

  Fusion is not action, which is exclusivity of the centre of stars or universes. Fusion can take place in simple environment of universe, where there are no confinement matters like the core of the earth or where there are no high temperature regions the like of the centre of stars.

Fusion of elements can and do take place in the open spans of the universe, when the right mafs strength environment are created without even existence of no tangible matter.

Thus the creation of iron in the centre of stars being its doomsday has no meaning, and has no truth in the realities of world of production of matter in the universe, the reality is that if the centre of the star cannot create new heavier matters than iron during its working concentrated fields how can it do so when most of its matter are in process of disintegrating and diffusing in the environment of the star. Thus this is another fallacy about the doomsday of star and creation of iron atoms in the centre of the stars.

- In the process of the movement of pmf one has to understand that the interaction of magnetic fields and the repulsion of the similar magnetic field poles of the pmf of matters of the universe leads to creation of the repulsion forces of the universe, thus leading to its so called separation of its matters and what is called the expansion of the universe.

  While the interaction of opposite polarities of the same magnetic fields leads to creation of the gravitational field forces of the universe and universe cannot exceed its magnetospheric interaction size, where this is the maximum fields balance between the gravitational and Magnetic fields of the universe, and at the same time the mass of universe will remain the same as the mass is the balance fields between the gravitational fields and Magnetic field strength of the universe.

  Thus the mass and the content mafs and matters of the universe are set to be the same at the beginning of its creation less what pmf are transferred to it surrounding universe(s) during its life for this universe to keep its distance and Magravs positioning in respect its contents and in respect to others universes in the grater universal scale of existence in the unicos.

- When, the pmf of matters transferred by this universe to it neighbouring universes is more than what this universe needs to sustain its existence, then this universe cannot hold its present universal magnetosphere and gravitational balance, once this balance is disturbed then this universe like its previous universe(s) will go through division to find its new balance and this leads to creation of new universe(s).

  Thus, the concept that this universe will expand to point of running out of energy and go through crunch and/or dies as a cold entity or go through the contraction and go through a singularity point again, these are nothing but fallacy of the misunderstood and short-slightness of a few to realities of the operation of the universe and not in line with real world of existence as has been observed in the universe, and why in truth the creation of this universe should and division, but never ending process of the cycle life of this universe of its matters and fields be any different than the rest of universal methods of creation of fields and matters in their birth, fusion and decay.
  Therefore the limit of the expansion of the universe is dictated by the total Magravs strength of this universe itself and at the same time the space which is accommodate by and for this universe by the mother universe and the space given to this universe to expand into and the expansion of the universe observed presently is not dependent on no other factors.

  It is possible some times in the future this universe itself will merger and fuses with another universe and make a larger in mass universal unit too as much as it can divided into two or more universes.

- It has been considered that the noise which has been detected by scientist in the 1960's, that this noise goes back to origin of the universe, when this universe was made, this has no truth as the noise which is constantly can be detected from the cosmos is the constant noise of interactions of pmf of mafs of different matters and mafs in the universe and these are created continuously and constantly.

Thus is the same as when mafs of different field in the universe interact and create visible light, thus the noise from the universe shows that it active and living universe as different parts of it interact with each other, as one can hear the noise from the Sun in the solar system when it matters and field interact with each other.

In fact if there were any noise left from the time of the creation of the universe, by now it would have escaped from this universe through its magnetosphere into the mother universe, the way strong radiation pointed upward from the earth escapes from earth atmosphere.

- In the universal levels, the energy is defined by the term, that when the pmf are moving from one point in the universe to another, and as they transfer or they carry pmf of the principal matter for it to be slowed down to matter levels, hence this transportation of pmf of the principal matter to slowdown to matter level strength, this is called the energy of the universe or what commonly called the Transition energy (dark energy) of the universe.

- The universal energy is the one which the pmf in motion is carrying that is balanced in mafs strength with the environment in which they are travelling through which due to their balance field strength the two field create near to no resistance to each other that this condition creates near no interaction with pmf of its environment that leads to release of pmf that become visible, thus the pmf of the universe travels in the soup of its own field and hence less losses and hence the lack interaction, which this condition of travel does not create collision and hence no residual release of mafs of any significant and hence not much of the visibility of the travel of the mafs of the universe, but this transition energy is translucence and as one can see through it so much so that one can see through it stars billions of kilometres away as their light travels in the balance Transition energy of the universe.

  This concept of travel of pmf or Transition energy in the transitions matter is explained in the book “The structure of the Light” (2).

- The universal energy does not need to cool to create matter, to reach matter mafs pmf strength level, but the energy reduces in strength to pmf strength of the matter that matter can be formed, this being the reason why there is a homogeneous heat distribution is observation of the W-MAP as heat is not created during the early seconds of the creation of the universe. Thus the cooling phenomenon of the universe is a fallacy.

- The reality of the operation of the universal system is that the universe is made of pmf which their mafs and matters in motion become energies and that is where the cosmologist says that at the point of birth the universe there was only energy and as it is known now energy is defined (1, 2) is nothing but magnetic fields or plasmatic magnetic fields in motion.

  At the present some consider that there are more Transition energy than transition matters, which is not a correct assumption, where if this was correct then this means that the principal mafs and matters are unwinding much faster and in a rapid manner, which if this state has or to be achieved in the universe, then this means that the losses are more than expected and this can indicate that universe is losing too much too fast and this can be an indication that the universe is getting ready for a further division into two or more universes.

- At the same time it is possible as the universe was created from the splitting of the mother universe, then the separation of the pmf of that neutron universe due to separation of its mafs and matters have released some pmf, which might have created some localised heating in some parts at the point separation and division of the neutron mother universe, which this separation leading to creation of hot spots or small heating of the new universe in sporadic positions and conditions within the plasma of the universe.

- The plasmatic magnetic fields strength that are released from the Principal matter to matter levels and during their process of the strength level reduction from principal matter to matter level, what is known as the Transition energy, as the plasmatic fields need space and matter in the universe to release and lose some of their strength to their environment to reach the plasmatic magnetic matter mafs strength level, which is mafs in motion from one level to another strength level is known as the Transition energy or universal energy or what is called the universal energy in motion.

  The speed of travel in the universe has only relation in respect to its mafs and matter strength environment, hence one can travel at the speed of light of environment strength in any mafs strength, this meaning that in the matter environment on can go faster than the speed of the light if one travels with the Magravs of the plasmatic magnetic field strength of the transition matter or Principal matter plasmatic strength level.

  Therefore one can only travel with a faster speed than speed of light in matter environment only if one has the capability to create and/or captures Principal matter or transition matter plasmatic magnetic field strength in a Margrave positioning reactors (1).

  Hence the limitation of the speed of travel limited to speed of the light in matter environment is applicable if one use matter and mater mafs for transportation otherwise there are no speed limitation in this environment as one can travel faster than the speed of the light in matter environment when using principal mafs strength in the cores of the Magravs systems, where the speed of the light in principal matter environment is millions of times faster than the speed of light in the matter environment.

  One has the ability to travel any speed in the universe and with any mafs and matter plasmatic fields strength in but there are hazards to consider prior to taking such a travel.

  The theory, that the speed of the light to be the ultimate speed of travel is only applicable in the matter environment using matter plasmatic magnetic field strength and it is not true if using stronger mafs strength, thus one can travel the spans of the universe by using higher order mafs with speeds millions of times faster than the speed of light in matter mafs strength like on the surface of the earth.

  The body of the man will not feel any difference and will behave as one is in the jetliners of the last centuries as the pmf of the mafs of the human body cells contains within their structure mafs of principal matter, then the man will not feel that much difference travelling with speed of light or thousands of times faster than speed of the light in the universe.

- It has to be noted that as in the matter and mafs universe and environment, in the principal mafs and transition matter environment, these environment possess their own shock waves and speeds of sound and as said before even smells and odour of themselves, which these are different than the ones in the matter universe. One can smell the Principal matter and hear the noise of the transition matter interactions, once one is trained and developed the senses for the observation of the transition matters and principal matter which are part of the structure of every living thing as these matters and mafs are part of the structure of the plasma of every proton and electron in the matter environment of the universe.

- Once understanding the structure of the universe, it can be conclude that universe will never end, there are no singularities and no cold ends to it and no crunch, and only for ever the universe(s) will divide in plasmatic magnetic fields strength and from one mafs to another and then in fusing together they repeat the same process, and as the universal structure never can lose any of its fields through by its natural laws of conservation in physics, then only matters and matters converts from one matter or mafs to another form of mafs or matters and order of preservation of fields and matters is obeyed even in the bigger universal order as has been in the matter world as has been studied in details over centuries. Thus preservation of energy and conversion from one form to another is the essence of creation in every levels of the bigger universe too.

- In the matter universe for example smell is only diamond structure of the or SP3 structure of the same atom in the gas state, thus in the principal matter environment the principal matter possesses and have different states of matter like the gas, liquid and solid state of Principal matter too.

  The same there are molecules and atoms and plasma of the Principal matter too, therefore principal matter have smells and odours and they frieze and they boil and they create clouds and become all thing as one has observed in the matter environment of the universe too.

  Then one can ask the questions that are the cold and warmth the same as the matter universe as in the principal matter universe. And the answer to this is most certainly is yes, with the difference that the temperatures are beyond the levels of man's understanding as the strength levels of plasmatic magnetic field in these environments are off the scale of comprehension of the human at the present time.

- Then the point arises that are there lives in the Principal matter and transition matter scale of plasmatic magnetic field strength of the environments of the universes, and the answer to this is most certainly yes, as the same structure of interaction and creation of cells and life exists in the these environments in the universe as are these conditions available and possible in the matter environment in the larger scale of the working of the greater the universes.

- The matter made available to the matter universe by the down levelling of the plasmatic magnetic fields strength from the Principal matter levels is what allows the creation of the matter, where these new matters have to find physical Magravs positioning in respect to each other, this need for new positioning in cases can lead to movement of the matter and increase in spacing of matters in respect to each other, hence this new increase in the spacing looks as the universe is expanding. Thus the increase in the spacing or expansion is limited as the matters and the rate of conversion from the principal mafs to matter has a limit and hence the universe cannot explode and only thing which can happen to the universe, is that as the Margrave of the universe is reached a point that cannot be sustained in its present mafs levels needed for the creation and sustaining its Magravs level, then the universe in a gentle way divides to guaranty its overall survival in two parts, rather than losing everything in the mother universe to other universes all together.

- The universal Magnetic fields within the transition matter is the force which pushes the universe apart and the gravitational fields within the transition matter is what brings the matters of the universe together and is the glue of the universe. Where both these forces are created by the principal mafs and matters field's interactions of the universe and the transition matter is the medium which they use without interfering with to a large extend for these forces to keep the universe in its dynamic condition.

- If the rate of the conversion of the principal mafs reaches to the point that there are more energies in transition mafs strength levels that the rate of conversion cannot lead to creation of matter mafs of magnetic fields strength, then the transitions energies fields interact and this will lead to creation transition matter, which this condition is abnormal and this ultimately in some cases can lead to creation unbalanced Magnetic fields and gravitational fields within the universe, and this is the trigger point for sudden expansion of the universal magnetosphere in certain point and as this cannot be sustained, then the universe goes through division and the universe and creation of two or more fragment of this universe are the consequences of such condition.

- It has to be clearly understood that the neutron division to electron and proton, usually is caused due to sudden expansion of the neutron magnetosphere, which is caused through the same process of the rapid change of the principal mafs to transition energy, which this leads to temporarily creation of transition matter that this creates a new magnetosphere condition which cannot be sustained, hence the neutron goes through the process of division to electron and proton too.

- As the pmf of the transition energy slows and reduces in strength once reaching the boundaries of the universe as it happens in the planetary upper atmosphere and solar systems heliosphere, in the same way and by the same principle these transition mafs will rain inwards into the interior of the universe, where they started their lives from and at the edge of the universe boundary the same as cloudy earth in its upper levels will have showers of matters in the form of small plasmatic matters and mafs and this looks as universe is raining inward. Thus once one look at the boundary of the universe one will see cloudy or a hazy shell, in fact this haziness it is nothing but the weak mafs and matters which are lingering around as clouds do or dust particles do in the planter systems upper atmosphere.

- The same cloud systems do exist in the solar systems heliosphere too, where this zone where most of meteoroids and asteroids of the solar systems find their seeds and receive their regular matters and mafs from.

  It has to be said that once man learns to cross the boundaries of the heliosphere of the solar system, the travellers of the crafts as is done when man leave for the travel to the moon at the present time, these crafts as they enter the heliosphere of the solar system they will encounter the same misty cloudy space at the edges of the solar system too and still they have to deal with solar heliosphere re-entry and cloud dusts and so forth as one encounters in the re-entry into the earth atmosphere.

  On the edges of this universe one will see weak pmf of matter and transition matter and transition energy plasmas and even one will observe the entry of other mafs and maters and plasmas in all mafs strengths and entry of universal meteoroid from other universes and unicos, as one sees meteoroid and radiation entries into the earth atmosphere from the solar system and cosmos. There are universal lightings and universal meteoroid too, in fact if the W-map observers look for this they will see another storm and lightings as these vast energies and large matter enters this universe at the edges of the universe, but they simply have registered these as hot spots in this map’s outer boundaries.

  The existence of these short lived hot spots will show that they are dynamic, live a short life and their energy is fast moving, as it happens when one has meteoroids entering into the earth atmosphere.

  In reality the existence of these hot spots on the edges of the W-map should give a clear indication to the man the existence of other universes and the greater universe as earth is part of a solar system and a galaxy, the same is with this visible universe of the man, and all one sees in this universe as the same is repeated in the greater universe too.

- One of the fundamental principal concepts of the universal energy is what the scientific world of today to a large extent has not understood fully and has up to now ignored this fundamental principle of the pmf magnification using the pmf of the mafs and matter and energies and specially the universal energy.

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If the scientific world understand how universe uses its dynamism and its inner content dynamic universal energies layering to magnify its power in its operation of this universe, then men of wisdom will come to realise that one does not need principal matter that much and in truth any matter so much all to operate this vast universe and transfer energy to all its far distance corners.

The world of science of today has been by large ignorant to this fact and has not managed to understand the magnetic layering and dynamic universal energy principle and in turn this has put man in disadvantage in comparison to the technological advance with other travellers of the universe.

Man of wisdom should look within to see the creation of their own being, then they will come to understand how small amount of matters and mafs and magnetic fields has been creating conduction and energy transfer in their own structure without utilising or using very little mafs or matters, then they find the power of creation and its application and manipulation for untold usages.

Then they will realise that one does not need wormholes and all that fancy words to travel within the universe with the speed of their own creator. This shall and will remain the mystery of existence upon the time when man learns not to trespass the boundary of others and he learns the existence of balance and true peace within himself and its people and it's surrounding.

- One should understand the concept of multiple principal stars operation in one galaxies system and the role they play to create disc like or spiral galaxies. The operation of visible and invisible principal stars in the universe will play the same role as the twined solar systems and twin galaxies, where in this cases the twined principal matter centres are and have the capability to discharging different pmf strength according to their anti-martial gravitational pull and the measure of the mafs that they might release to control their field of domain. The multi- principal matter centres are and can be used in the space travel in a fascinating way, where once creates multiple jumping steps, with differential and opposite dynamic direction of motion of these Matters. The speed and protection created from and through these manipulations will give the man the chance to travel the length of galaxies and universes in the minutes, but one has to be aware of the destruction power of these technologies as there will nothing left but pmf of the creatures travels of these universal craft if things goes wrong at these mafs levels.

- It should be noted that the shapes of the galaxies and their physical appearances, should teach one the power of the effect of the other matters and entities around them as they will allow and pull an push these objects toward or away from one point or other and hence allowing the appearance and the physical visible structure of these celestial bodies to obey and have a given shape, this is important in the understanding that one has not to look at an entity but look at the surrounding area of the entity to understand the limitation of the operation and the shape of the matter and mafs internally and externally as it is allowed by the environment of the entity for it to exist within a given point and time of a system, this being a planet, solar system, galaxies or universal entity.

- The uniformity of the pmf within the plasma of a proton, an atom or a universe these all show the equilibrium and balance condition between all the participating magnetic fields forces which have been designated to the entity at the point of its inception and creation. Thus, if one sees a fast moving object the like of the Plasma of an electron in an atom or in a larger part the universe, then this does not mean that the universe is expanding and it will be chaos internally in these entities. Thus the fast movement of the internal matters and mafs of the universe does not mean that the universe is expanding, on the other hand this means that the universe is internally controlling its mafs as repositioning to guaranty its existence as an entity and at the same time the universe is holding its position or what is called universal Magravs positioning in respect to other universes in the unicos.

Thus this universe will have matters and mafs which will be moving away in one position but at the same time other fields in the universe will be moving in the opposite way to, but it has to be said that the conversion of mafs to matters creates a visible expansion, but overall gravitational field forces of the universe cannot be changed and the universal order of preservation of fields will be maintained, does not matter what is converted to what fields and matters and the internal universal gravitational fields strength will be maintained and preserved.

- The universe has laws and conditions and has primary atoms and particles, at the present man has managed to understand the structure of atom and plasma of proton and other particles and through this understanding and his vision of his universe thinks that the atom of the hydrogen is the simplest structure as he can see and understand, in time this will become apparent not to be the same for all creature of the universes, but up on and until then man has to learn that the fundamental particles and unifying fields and the fundamental fields of universe are the simple magnetic fields of the universe and the whole operation of the universe is based up on their interaction and operation.

  But at the same time man has to learn that all created entities in the grater universe have achieved a common method of communication or what is known as the universal fields communication, all created being which have managed to influence their environment and have managed to interact with other intelligent being individually or as unified groups and have managed to accept one universal communication language that is acceptable to all, this language is known as the universes language and is bases on the strength of the pmf of the different strength and not based on the voice or sound or physical alphabets and shapes.

  The man will have to learn this language and will be able to communicate with the other intelligent created entities in the universe once man learn to find peace within himself and reaches the understanding that they cannot trespass and cannot create division in the universe as they have been accustom to on earth to get their way and in achieving and attaining physical possessions and that in the universe martial possession are nothing but the lack of man's understanding of his position and short slightness of use of his intelligence.

  The universal language is transparent and clear language and works on the pmf waves strength and has standard forms and accepted levels for communication depending upon the creatures of different environments which creatures are initiated from.

  Where, one should understand that not all created intelligent beings in the universe need or needed the physical planetary structure as human do for their existence for them to be created or to survive.

  Life is created in the universe in and within the fields of the universe and it does not necessarily need physical tangible, food and land for it to exist and collaborate and operate with others in the universe.

Whereas, and as long as the Man tries to contact others through pictures and voices using the present technological advancement, man will find in general he will have a long time to wait for the response, as the other created intelligent beings of the universe have been and are and will be visitors to man's home from the time of its creation and to its demise, but the universal language will be established and communications will be opened when man learns that he does not need to take more than he needs to and at the same time man does not need to create division to get what he desires and cause conflict.

The cause of isolations of the man from the universal community has been his lack of understanding that in the universal language the other creature do not need to use words but they can and do understand and communicated at pmf fields levels, thus the thoughts of the man which is pmf based in his operation in the brain of the man, these pmf are detected and are like visible light to these creatures and as what is said they can see and understand the real intentions of the man's deeds without man uttering a single word.

Thus man isolation from the universal community has been in forced up on it out of protection of the universal peace, rather than man's inability to find the other creatures to communicate with.

- The Universe in general is a peaceful place and wars and conflict has been things of the past and a long-long time in the past, hence once the man learns the advantage of peaceful living, then man will learn the universal language and then man will be allowed to learn more and join the universal community of Beings, irrespective of these being physical or field appearance to the eye of the man.
- One does not need eye to see but the intelligence to understand, and then the real sight is the real will of the observer of the beauty of the creation in all levels of universes.
- In the material world for example the neutron always divides into balancing masses that the overall gravitational positioning of two new masses can guaranty the existence and continuation of the life of the neutron in the same material world. This applies to the universe too, that universe will divide in mass and as in the neutron the lighter mass will have to follow the graters mass fields forces Magravs motion and hence the universe of the smaller mass will be more agile than the heavier mass. Whereas, the smaller mass universe will be and has to follow the internal motion of its own mafs and matters and at the same time the overall Magravs of the smaller universe has to find its position in respect to overall Magravs of the larger universe and the overall dynamic motion of the mafs and matters which the bigger universe creates.

  Thus, the smaller universe can be in **a** snapshot or in the case of man life time over a million years, this universe be looking as it is stationary in its internal space, but in fact this universe is following another larger universe at very high speeds itself to keep its position and at the same time the universal centrifugal force of motion allowing the universe to hold on to its content of its own mafs and matters.

  All universes the like of the galaxies and solar systems are all in motion not only internally but at the same time they are in motion in respect to their the other half of the their mother universe, which it was originated from. The overall direction of the motion of the universe in its bigger universe can easily be detected and realised. The direction of motion of the universe is shown by the directional motion of the mass of universe, which is moving out of normal direction of the whole content of the universe itself. This meaning that, if! The full matter motion of the universe is planned out; one should see a region, which is moving as a whole in totally arbitrary and independent direction.

The reason for this envelope of the mass following an independent directional motion is due to the fact that this mass of the universe is connected Magnetically and gravitationally is locked to the direction of the interaction of the Magravs of this universe in respect to the Magravs of it co-birth sister Universe (Fig. 22).

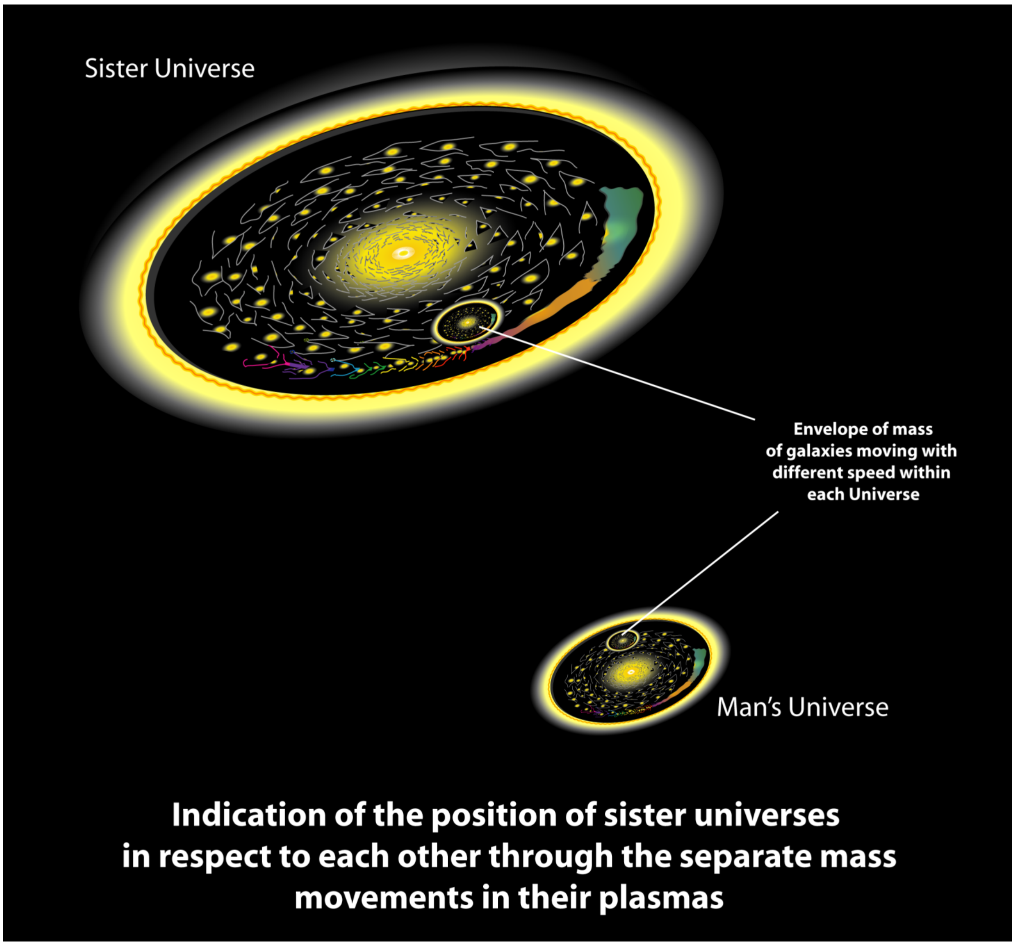
Sister Universe
Envelope of mass of galaxies moving with different speed within each Universe
Man's Universe
Indication of the position of sister universes in respect to each other through the separate mass movements in their plasmas

Fig. 22 Envelope of galaxies in each Universe indicating the position of the Sister Universe.

The mass of the matters involved in this motion should indicate the extent and power of the Magravs interaction between the two universes.

This mass moves in all three hundred and sixty degrees direction as the co-birth universe is dynamic and has its own dynamic Magravs motion too.

This independent zone in motion in the universe has already been detected by the cosmologist for this universe, but they could not understand the reason for this independent part motion in the plasma of the universe.

Thus the direction, which this mass in the universe is moving and is positioned, this shows the position of the co-birth universe in respect to this universe.

Therefore if and when the man's scientific and technological achievements reached the level in the future that man can see through the universal magnetosphere, then the position to look for the co-birth universe, would be the direction where this internal mass is in motion and at the same time the distance of the this internal mass from the edge of the universe will show the distance of this universe in respect to its co-birth universe.

- In the universe the heat and cold is not measured in the way, which has been accustomed in the world of physics of today. In the universe heat is measured to the extent that the matters pmf can be loosened to allow the bridge of what is known as the atomic or molecular magnetosphere.

  Thus what is commonly known, as the coulomb barrier, in the atomic physics is only the extent of the resistance or the tightness of the Magravs of the atom. In fact man has to realise that if he unifies the terminology then he will solve most of the problems in the world of the science of physics. For example, by unifying the word of the magnetosphere and coulombs barriers, which in fact these are both the same properties and principles; where one shows the tightness of the Magravs of the planter system and the second show the same for the atomic structure. If this discrepancy in language is resolved and man understood all phenomenon of the creation of magnetosphere in all levels universal mafs strength which has been discussed above, then the nuclear and theoretical physics would not have the problem in creating and maintain fusion of all matters and mafs in the universe.

  Thus for fusion one does not heat or speed to create and achieve fusion, but the loosening of the Magravs or dilution of the Magravs of the mafs and matters will lead to fusion and creation heavier elements without the need for the elaborate accelerators and others gadgets which has become the tools of the advance science of today.

  The use of the accelerators are nothing but to show the true lack of understanding of the scientific world in the what these scientists are trying to achieve and their misunderstanding of the operation of the universe.

  The heat created by the fusion processes within the stars or the principal stars is the by-product and in fact the heat assist with the operation to loosen the Magravs and loosening the Coulomb's barrier that fusion or mixing of different plasmas of mafs and matters are accommodated, but not the cause or the outcome of the fusion.

  Where in the world of the fusion of today scientists try to speed up and accelerate plasma and make them to collide and hope for the fusion, but in the universe the reverse process happens, whereas in the universe fusion takes place in condense centre of the principal stars and matter stars, where there are no rooms for the plasmas to speed-up, but due to loosening of the pmf forces magnetosphere of the plasma or coulomb barrier, then matter mix and fuse and what is not necessary from the amalgamation of two plasmas fusion, then these appears and are released as surplus unwinding pmfs of mafs which as in this process of higher to lower mafs strength is so rapid that this process shows itself as the heat in these environment of the universe as part of the process.

  Thus heat can be explained in its real term as the pmf which is unwinding from one state of matter to unwind that the pmf field released allows the other matters to open their magnetosphere that they can receive the pmf in transit from other plasma.

  Then the cold can be explained as the when the pmf of the matters are reduced to beyond the magnetosphere of the matter that matter cannot transmit any pmf to another matter.

  At the point, where the total transfer is zero, this is known as the Absolute zero point at the present time. Where, the scientists say that at this point there are no molecular movement. In fact the plasma of the matters or ***the atoms is still at this point active*** and maintains their internal dynamic condition and environment. If this was not so then magnetic fields creating the mafs and matters would have ceased to interact and the matter or mafs would have lost their gravitational fields and magnetic field and hence the matter and mafs would not have been able to maintain the magnetosphere and the mass of the atom, and hence nothing would have existed; But as one still sees the matter at absolute temperatures, then the condition is inter plasma magnetosphere connection and not internal magnetic connection;

In fact magnetic fields, which are the principal particles or are known as the fundamental matters can never come to a point that they do not exist or interact with other fields and at the same time due to ever existence of other magnetic fields and fundamental elements in the universe, then all fields and matters at all times are attracted or repelled by one matter or other and hence a total non-dynamic universe never can exist and in truth the creation of the universe and creation and origin of the magnetic fields is due to and through the fundamental of difference in the universes differential waves. Thus the magnetic fields are themselves created out of strength level difference in the universe and thus the origin of the magnetic fields is the cause of the existence of the universe and the existence the universe is the cause of the existence of the condition differential which is the creation of fields to compensate for this difference and hence the creation of entity to cover the difference in position and hence the creation of the magnetic fields. Thus one in a simple language now knows even how magnetic fields, which their variation leads to the world of the creation of universe has come from and how the real essence of all creation become to exist.

- It can be said that at the Absolute temperature the time stops for the matter and material world but not for the mafs and mafs dimension and hence if the universe were made only of matter and mafs then the physical matter would have never existed in the deepest part of the universe if the temperature were at absolute temperature.

- The measure of the cold in the universe is dependent upon the slowing down of the movement of given pmf in a given direction and strength, hence the measure of the coolness is the external strength dependent and not plasma internal fields motion dependent. This being the reason why like in the planetary systems planets can and do produce their own independent temperatures irrespective of where in the universe they are and how cold or warm the environment of their surrounding planets and stars could be. Therefore *THE ABSOLUTE ZERO IN RESPECT TO* mafs and matter environment is only applicable to the earth position and environment and not to all universal condition. This being the reason why, one can see and observe life in all kinds of pressure and magnetic field strength in the universe.

  Therefore the Absolute zero for mafs and matter environment is not applicable true for principal, transition and matter mafs and matter strength and environment.

  This being the reason why that internal atomic structures can exist and atoms mafs can hold on to its structure and its existence, while the molecular structure in the matter environment can be cold that no external motion within the atoms of the molecule can be observed at absolute temperature.

  The absolute temperature in a given environment can be said to be when the Magravs of the constituent matters environment come to be in total balance; and that is the point that the total losses and gains from the surrounding environments are said to be balance out that the total magnetosphere of the environment will compensate for the losses that the environment can keep on holding on to the zero motion of the total environmental Magravs.

  On other hand the environmental Magravs can be reduced that there is no interaction between atoms that the motion of the atoms in respect to each other ceased to exist and motion in respect to each other become frozen. This is known as balance Magravs criterion and to produce this within the structure of reactor is an art not known to man. Where, the balance Magravs positioning is the key to establishment of colonies in the universe, where there are no planets and stars as point of reference, but the condition of balance allows the station to be permanently positioned in that spot that all passengers of space can come to meet.

Production of an absolute balance give man the ability of what is known as hovering, where there are no propellers and no vertical jets of today to stay stationary in mid-air.

Absolute Magravs balance allows crafts of the future to keep a constant position and this can create fantastic composition for gate-thing, which is needed for movement from one Magravs system environment to another without actually needing to handle re-entry problem in either direction.

The operation and the use of the absolute balance Magravs technology systems are as for the physical doors of today, when used in the future, when one moves from Magravs plasma environment to another.

- In the operation of the universe, the distance of pmfs and the speed of the rotation of one pmf in respect to another is the criterion by which the speed and directional rotation of one matter or plasma in respect to another plasma is dictated.

  Where, the positioning of mafs in respect to each other in the universe has a direct effect on how fast, when and where an entity will position itself and even this dictates the measure of the cold or heat of two entities in respect to each other and to other environments. This concept is seen in the universe in respect to the rotational direction of planets, stars and galaxies, where their direction of the rotation if different to the one other entities in their surroundings.

  The criterion of mafs positioning is the reason, why for example the Vinous rotates in different direction than the rest of planetary systems in the solar system of the man, as its internal pmfs speed of rotation and their position in respect to others of the same within the internal structure of this planet are as such that the outer layers of this planet are forced by the configuration of the combination positioning of different cores and their pmf strength, forcing the planet to rotate in the clockwise direction rather than the anticlockwise direction as the rest of the planetary entities in this solar system.

  This principal of the mafs positioning and speed in way can explain even why all matters in the universe rotate anti-clockwise or what is commonly called the electro negativity of the hydrogen atom directional motion.

  Hence it can be said that the anti-clockwise directional movement of the plasma of proton and electron are due to the mafs strength within their plasma and the position of different mafs in respect to each other within the plasma.

  Then this puts a closure to present theory of electron and positrons, where in fact electrons and positrons only difference is that one's internal magnetic fields are slightly differently positioned than the other and as their mafs contents of fields is the same, then only the positioning of the fields in respect to each other dictates the direction of the rotation of the plasma of these entities. This directional motion variation can even affect the absolute temperature of the operation for the positrons and electron in different environments too.

- Time as man is accustomed to on earth, this time in the universal language does not exist; time is a manmade phenomenon to measure the course of his life. In reality the time is the measure of the pmf of given strength to pass a given predetermined strength, thus time in the universal language is magnetic field strength and environment dependent. Where in the principal mafs world the time of reduction is much faster than the time of reduction in the same matter environment. Thus time or measure of reaching from one level of strength to higher or lower by the same order of magnitude is the measure of the time in the universe.

Where, the universal positioning time will be measured according to the central position of the universe and considered to be zero at this point and then to make an appointment to be at a given time then the motion of all mafs and matters in the universe in respect to this point needs to be considered, Where this position is and has a three dimensional three hundred and sixty degree reference. Where, in fact time in the universe needs point of reference and that is earthly time, solar time, galaxial time and universal time.

Time is unchangeable and it is the same in the same gravitational and Magnetic field strength environment. This is important, as at the present there is a fallacy, which has been accepted to convince the scientific world that time goes faster in the universe as one moves away from the earth.

This is nothing but hypocrisy and lack of the understanding of how gravitational fields are created. This fallacy has come to a point that in the satellite systems of today an error time has been allocated that the satellite timing is adjusted in respect to position location of a matter or entity on earth. Where in fact if the scientific world would understood the full principles of the creation of matters, and if scientists can create the same g strength forces in the environment of the operation of the electric and mechanical processing of these satellite does not matter where they are positioned, what is called the environment of what is called one g, then these satellites do not need correction factor which they are using.

Where, in fact the time correction factor is due to the fact that matters in the different Margraves and gravitational position around the earth have and operate under different magnetic and gravitational field strength and this is the reason why there is a difference.
Thus for the correction of time in these systems only one needs to consider creating the same Magravs strength at on the surface of the earth and then there will be no difference in time.

This concept is important for the future travels of the man into space and his excursions in the universe if he wants to keep to his habitual twenty four hour clock and earth gravitational magnetic field strength of his planet.

Man soon will find and realise a simpler way and then the hypocrisy of time travel and wormhole and going to the past and to the futures and so-called granddad theory will come to an end.

One point to remember that light which itself is plasma entity moves out in a spherical three hundred and sixty degree environment of the universe and for example the feature of a the face of the man will create man lights for it to be seen as a whole, but in time as light travels in the ever rotating sphere of the universe and these rays some get absorbed and some get distorted, then one cannot bring all the lights of all the matters of the one human face together to see that entity as it was so many time lapses before.

Thus if one hopes think that one can see the past of one person on a revolving dynamic environment through one light or making a machine to go backward to see the face of its forefathers, this shows nothing but the lack of the understanding of the science of creation and motion of light through the haze of dynamic universe by these men of science.

One can see the structure of matters like stars and fields in the far points of the universe primarily due to the fact that the light is and has plasmatic environment and like a telescope can pass the information to the point of arrival. But the light cannot bring the past of its source, but shows the pattern of its source like a move at the time it left the object.

In fact it can be said that light is composite matter and entity with active complex pmf of different mafs.

Thus, for example one as one enters the principal matter environment, where the principal matters is the creator and controller of Magravs of the environment, then in these environments one travels at the speed of the pmf of the principal matter and not pmf of tangible matter. Then if considering the principal matter environment in the centre of galaxies, then time for the matter world will be looking as being much faster or matter seems to be travelling thousands of times faster than what has become to be as the speed of light in the matter world in these environments.

Thus in reality the accepted time and speed of light as the maximum limit is only applicable for and to human understanding of the universe and not considered to be the truth in the real working of the universe.

When, the race of the man understands the concept of the use of the principal matter in the travel systems of their creation, then the man will be able to travel into the universe with much faster speeds than the speed of light of the mafs in the matter world and then one can travel the spans of the universe in seconds in human term and then one can travel the length and the breadth of the greater universe as one travels the earth glob with the toy systems of the jetliners of today.

Then the point arises that why some mattes and entities in the universe can last for a long time, where for example the human life is limited, the answer to this is very simple, and that is the body of the man is made of composites of mafs and matters and the more one adds to the composite the more Magravs are available to be lost to the surrounding Magravs, and be effected by the surrounding Magravs too.

Thus the life of the man is environment conditioned and in time as the DNA of the man learns to preserve more, then this will be adding to the life of the man and then the man will live longer, but eternal life is and belongs to no one entity in the universe, but the entity is the total facet and attribute of the whole as a whole. Thus man has been and shall ever be, not in the physical form but rather in the attributes of its physical existence in all universes of the god. Where, god is part of whole and fraction of none.

Where, the universe possess mafs and matters which their difference only is in their strength and nothing more and nothing less, thus time is faster in the stronger field for the weaker matter created entities and time is slower for the stronger mafs field strength in slower in weaker matter field strength. Thus time in the universe in reality does not exist and is a creation man's state of position and possession. Thus if one is in universe, where the strength of the mafs are one thousands time stronger than the other mafs, then the time is one thousands time faster and this applies to all mafs and matters in the world of creation.

One point to realise is that the magnetic rays which are released and are prevalent in the environment of the man are the time setters for the degeneration and division of the man's cells and have direct effect on the life span of the man in the universe, this be it a word of wisdom for the ones who come to comprehend and look for the eternal time life.

- What holds the universe together are the attraction and repulsion force of the pmf content of the universe. Thus the tightness of and the position that matters appear in the universe are totally pmf strength dependent.

  Therefore as the pmf strength of the matters are attained at any point in the universe then that matter becomes to manifest itself in the given point and time in that part of the universe. Thus the glue of the universe is a combination of the interaction of all the mafs and matters, which their interaction makes the Magnetic and gravitational fields Magravs of the universe.

Thus in fact what is called the bosons theory has its truth in the position of and their interaction of the magnetic fields of different pmfs, plasmas, matters in a given position in the universe as these interaction dictates what and how pmf are given or taken from the universal soup of magnetic fields, and what the outcome entity shall be and how the matter manifest itself at given point and for what period of the time.

- Thus once a given pmf strength in the universe is achieved which can be initiated combination of the interactions of several conditions, plasmas, and environmental magnetic fields, then at that point in the universe a specific given mafs or matters comes to exist, this being mafs or tangible matter magnetic fields strength and so forth. This is the secrete of universal existence and manifestation of the all mafs and matters and the observation of one mafs or another matter is totally dependent on the observers pmf Magravs strength that one matter or another can be tangible or visible.

- As in the solid state magnets in the plasma state of the magnetic fields regions of the universe, these plasma poses and operate through the North and the South poles and the same goes with their attraction and interactions in respect to other magnetic fields of all plasmas too, that is to say that plasmatic magnetic fields position themselves as solid magnets do in respect to strength and position of other plasmatic magnetic fields near to and in their environment. Thus the North-pole of the plasma attracts the south-pole of other plasmas and at the same time the South-poles of the plasma keep and make distance from the South-poles of other plasmas as it happens in the solid state magnets.

  In the physical matter one can see the motion of the magnetic fields and motion of magnets in respect to each other as magnets move and find their position in respect to each other in their given environment once they are brought into the proximity of each other. The same positioning and movements are applicable and are created and maintained in the magnetic environment of the plasma two plasmas once they are brought within the mafs field interaction of each other too.

  The plasmatic magnetic fields of all entities can recombine to allow the circulation of their fields and in general determine the point at which the fields can re-enter the plasmatic magnetic fields to complete a full spherical plasma of the fields. Where, this point of re-entry of the fields is primarily dictated and decided according to the environment, which the mafs of the entity operates in and, not necessarily by the mafs strength of the field of the entity itself. Thus, the point of termination and re-entry of the fields of the plasma of mafs of even solid matters is dictated by the environmental mafs strength and not by the matter. That is to say the termination point for the magnetic field lines for a plasma and solid matters (the beginning and end of a field line) is decides mainly by the environmental mafs strength and not necessarily the strength of the fields of the matter.

  This being the reason why the magnetic fields can reconnect anywhere in the universe irrespective of their physical distance, as the environment which the fields enter and carried to their full destination is supported and facilitated through the mafs of the environment and not the strength of the fields of the entity. Where, this phenomenon is well explained in the interaction of the change of polarity of two atoms, which as one changes its polarity, the second one does the same instantaneously. This is what one observes in the change of polarity of plasmatic field's entities, that for example as one plasma changes polarity, the other does the same parallel changes automatically that one never observes any changes in the structures of either entity.

  This being like the change of the polarity of the earth and the synchronized change of the polarities of the cells of all beings on earth, that no physical change can be detected by the inhabitancies of the planet as the physical polarity of the earth changes.

Even though the same cannot be said about the change of the polarity of the moon of the earth as it does not changes as the earth polarity changes in majority of the cases.

In understanding the principle of this phenomenon, then man of science can make any matter anywhere in the universe as the need of the time be, this be it production gold or production of amino-acid needed for production of proteins of chain of fibres of heart of man anywhere in the space for the travellers of the future.

Thus, one can control the point where what appears as the magnetic fields can draw in fields (as called conventionally called the exit pole) and where the field exits to release the fields (the north-pole of the mafs. Then size and the length of the magnetic field and the gravitational fields and Magnetic fields, which any entity creates, can be controlled and hence the size of plasma of an electron or proton can be predetermined. That is to say the total field strength of the Magnetic field and the magnetosphere which an entity creates and can hold on to, this determines the exact and precise dimension of the plasma of be it this be the plasma of the proton and electron.

Thus, in principle one can have field zone of the same length, which upon their interaction they create a given magnetosphere, but one can have the same spherical dimension of magnetosphere with a different magnetic fields strength, which this creates different Magravs field zone. Thus, the length of the magnetic fields determines in what entity is to be created, this being the plasma of proton or an electron, and so forth.

Complex magnetic fields create different field lines, hence different Magravs. This being the reason why in the plasma of the proton different pmf and matters entities are observed and detected.

- In the bigger picture of universal works, scientists will come soon to realise that all parameters are the same, all plasmas do and behave within a given procedure and sequence. Thus, what one sees in the plasma of this universe is the same as what goes on in the plasma of the proton and electron too. That is to say what has been puzzling the theoretical physicists about the content of the plasma of the proton, as one can see in the operation of the universe then one should have been expecting the existence of different matters, fields and fields strength in the plasma of the proton and even the same in the plasma of the electron as one sees in the plasma of the universe.

- Interesting enough scientists soon will start wondering about the creation and control of these magnetic fields that how they lead to creation of different plasmas of magnetic fields too, and how plasma of the magnetic fields become to become units of the same fields and how a magnetic fields can be attracting one plasma while the same end of the matter can repel another of the same from the same end or exit port of the magnetic fields. That is to say how can a solid magnet at the same time as can attract the opposite polarity and then at the same time and simultaneously the same pole can attract another dissimilar polarity. The fact is that magnetic fields of plasma of fields do not bunch all to north and south or all exit and entry port, but they arrange themselves as one of entry and one of exist and or one north pole and on the south pole adjacent to each other, but they do not set end to end with each other. Thus for example looking at the section cut across cluster of the magnets, the fields are arranged like mosaic of north and south in correct sequence and order. Where, in the case of the dynamic plasmas like protons the top view shape of the magnetic fields are the likes of a whirlpool and not straight-line fields of the same mosaic.

Then one should understand how the structure of nucleus of atoms are arranged in a similar manner too, as one exit port sets next to an entry port, then when a nucleuses has two protons then the in and out ports are matching and the magnetic fields of the atoms internal magnetosphere is complete and the atom is stable, but when the atom possess two of the same ports and one of the other ports in its nucleus then the extra port is sharing its fields and or is looking for the an extra port that can receive its pmf or it receives pmf from, and hence the odd number protons nucleuses always are more receptive in receiving or dividing for them to have matching pairs pmf ports of entry and exit, that they can make their own matching magnetic plasma. In fact single magnetic fields do not exists in the world of plasma, and in a way the theory string shows nothing but lack of understanding of operation of the fields in the universe. This explains why odd number proton numbers go through decay or they are more receptive to make polymers of themselves or join up to make molecules.

Where, the entry port of the fields can take magnetic fields from the other ports or from the soup of the Magnetic fields of its environment, and thus the size of the entry port of the fields in principle determine the matter and mafs condition in a given environment.

The reality is that the entry point consumes more energy than the fields, which are coming out of the exit port of the plasma of the fields. The fact is that whenever fields interact they create minute contact points that at these contact points fields are divided into smaller length and strength, this is like when two bodies collide and due to their friction some heat or fragments are created; This happens the same when two magnetic fields interact to create their own magnetosphere and mass. Then due to this friction between fields the magnetic fields entry of south-pole are slightly weaker and less in mass than the total mass which originally entered the magnetosphere of the two fields in the south-pole. Where, in fact the slight difference in the mass and fields strength between the entry and exist of the ports, leads to ever reconnection and closing of the loop of the fields between the North–pole and the South-pole, and the motion of the fields within the structure of the matter and the entity.

Where, the South-pole or entry port is the feeder and the North-pole or exit point is the provider, where at the same time the due to miniature and micro size of the magnetosphere of the fields, there are too many magnetospheres which are connected and arranged in the mosaic of the one cross section, thus the entries and the exists or the north and south poles set next to each other and where the entries poles are more stronger the matter attracts and where two facing section the south pole are stronger the matter repel and hence the sequence of pulling and attraction of mafs and matters in the universe.

Where, the entry points both need to attract as much as possible so they move to guaranty their own continues supply of fields and this being the reason why similar poles move away from each other, that is simply to allow the entry or exit of the same floor of the fields to have the maximum chance of attracting fields to guaranty their field supply.

The dissimilar poles gravitate, as the entry-pole try's to absorb all that it needs from the supply of exit-pole of the other entity.

Further on the minute fields which are released from the interaction of the two fields, in them separating and being able to travel a given distance away from the original two fields and their interaction, these fragments travelling distance capabilities determine the magnetosphere region of the two interacting magnetic fields too.

The interaction of fields in creating plasma of fields needs a constant supply of fields from its environment, and that is why the fields can and do regurgitate some of the fields which was released by their own interactions and this being the reason why the Plasma of magnetic fields can last for a long time in the given environment.

In a way the attraction or the gravitational fields forces is created out of the necessity of the need for the two interacting fields to keep locked to each other, and hence the need for a constant sources of supply of magnetic fields in the universe, which this need is meet in large from a stronger source of fields and their unwinding of the principal mafs sources which are scattered around the universe. Where for example the larger plasma's the likes of the stars needs are meet by the cosmoses principal fields as they unwind and in the micro levels the need of weaker fields magnetic fields of atoms are meet by their lower level strength fields of their environment.

Where, at the same time the magnetic fields can enter a centrifugal region where their strength can be tightened and thus fields as much as they can lose their strength through unwinding, and then through the same process of rewinding they can increase their strength too. That is to say that if the mafs fields are entered into a winding region or in a tighter pact region fields strength of the universe, their magnetic fields can be winded up that the mafs strength increases to principal mafs field strength. Or what is said in the common language of present science the mafs can become of principal mafs strength and the centre of the tightening mafs is the principal centre of what is called at the present science the principal region of the environment, this being in the centres of the cell, galaxies or universes.

Thus as long as the environment can supply surplus amount of the pmf for a given system for its north and south poles to be maintained, then there will always be an entity existing, does not matter what word in the vocabulary is used to confirm its existence.

The mass is created when the field at the entry port and the exit port are linked and it is independent of any other entities of the same or there scale of mafs entities in the environment. Where, the mass is the amount of the fields needed from the environment for the interaction between two fields or plasma of its fields to exist.

- The magnetosphere is the limit of the field's exertion in a given environment created by the interaction of the gravitational and Magnetic fields of the two original fields. Where the magnetic fields are the cause and the gravitational and Magnetic fields are effects their interaction and the Magnetic fields interaction now becomes the cause of the creation of the mass and magnetosphere of the entity as the latter become the effect of the interaction of gravity and the Magnetic fields.

This being the reason why, that the mass is independent of the environmental conditions and effects, as the mass is the indication of the given internal interactions itself and is due to internal processes of interaction of the same internal magnetic fields. Thus when the environmental magnetic fields, gravitational and Magnetic fields are considered and applied to the given mass system, then the weight or the measure of the mass in respect to the environmental fields forces can be measured.

As the puzzle of creation of gravity is solved, this should open new horizon in the world of science and make life easier for scientists to understand the working of the universe. Where the whole world of creation can be said to start from the difference in condition in position, where this leads to creation of field that the different position can interact and be connected to each other, This known to be the origin of creation and origin of the creation of magnetic fields in the universe.

Where, this movement of and need for interaction of fields to cross the space of their environment leads to creation of what is come to be known as magnetic fields flow, and the extent of the flow to cover the strength difference and the proximity to each other trying to cross the gap to guaranty continuity of flow of fields in the environment become the current or the strength of the magnetic fields.

Where, the interaction of magnetic fields leads to creation of Magnetic (repulsion) or gravity (attraction), where the interaction of the created Magnetic fields and gravitational fields leads to creation of mass and Magnetosphere (1) for the magnetic fields concerned. Where the interaction of magnetic fields depending upon their strength leads to creation of stronger fields to be connected to each other, thus the stronger fields become the principal fields or feeders of mafs and the weaker fields become the matter mafs fields of the universe.

In the man's range of Magravs strength of his protein, the weaker mafs become tangible and visible or detectible and part of his own being's structure and his matter world is created and where in other levels due to stronger fields the principal mafs create a visible world for the one's whom their protein Magravs strength is set to a level beyond the man's mafs strength level.

Thus, the universe is the collection of and the creator of magnetic fields in different length and strength and their interactions to create different magnetosphere in size and strength in Magravs, and whenever and wherever there are fields to interact then they coagulate and linkup and create mafs and matters of different strength.

In the universe there are no empty places, which are void of magnetic, Magnetic and gravitational, mass and magnetosphere fields or not being in the path of the movement of fields. In general what is tangible and visible magnetic fields collection has been and it can be called matter and what is fields in the motion which are not yet attached to any matter to become part of given environment of matters or mafs are called energies of the universe.

The universe will never cease to exist as long as there are fields to attract and repel each other. Universe has no dark and black unknown phenomenon about it, it has principles and how they are applied and enforce themselves or it is enforced upon them, then a given condition and fields and mafs are created for given span of duration of fields interaction so called time.

The earth is not the unique environment which can provide and sustain life and intelligence, but life starts from fields and their interactions and upon their complex interactions and order they choose to be a club of plasmas, matter mafs, atoms, molecules, Magravsly to be bind (chemically), combination orderly repetitively Magravsly bind (biological) and creating communication in the biological Magravs repetitive order to guaranty the survival of their overall Magravs which these interactions lead to creation of intelligence.

Thus the man is not the only being with intelligence in the universe, as given the environment of interaction of fields entanglement is the facets of progression interaction of the fields which can be sustained everywhere in the unicos.

What is interesting is that one does not need the intelligence to have the soul, the same as one does not need to see the star in the far corners of the universe to know of its existence, but the plasmatic magnetic fields which it released during its existence it has travelled and nourished the universe to reach the position of the observes. This is the same for the soul of the man and the manner of it's creation and movement in all dimensions of existence, wise one now can understand the mystery of nothingness and of the creation of the soul of the man and the essence of its meagre existence in the world of universes.

The survival of the soul of the created being is the beauty of it, for it to give and to receive and not to be an outcast, then man of wisdom will enlighten the man of possession that there is nothing to possess if one uses what one needs and no more. Be wise on what has been said and open to be received and receive what is in your path of life in its different levels of interaction and attractions.

The ultimate point of understanding for the man who is one of the created entities in the universe and through what has been revealed on to man in the verities of disclosures in the recent past is that in the universe among its created whom have attained intelligence and have managed to take into spaces of transition environment of universes, that in the universe there are no animosities and no wars and nor this rule shall be changed as war and acts of aggression has been the habit of the passengers of the planet earth during their technological progress and their short lives on this planet.

The reason for the universal peace is not the lack of technology among its inhabitancies, but the truth is that the intelligence of the beings of the universe is so advanced that they have no reason to fight for what they can attain in and achieve and obtain from the universe.

Thus the universe is ruled by peace and justice and the ones whom have the habit of the like of the blue blood from the blue planet will be thought soon a lesson that unless unity takes over the thoughts of the creatures of this planet, then these shall be thought a lesson that they will soon fall and follow the rules of the universe and not the old habits of the feeble man.

Not forgetting that the everlasting habitant of the universe have attained the knowledge that can wipe-out any type of life from the universe, thus the peace in the universal order is not due to the weakness of its inhabitants, but their strength to be able to see any short sightedness from the newly joined members of the universal community that they cannot and shall not be allowed or even think they can carry on with their old habits of war and division and injustice and exploitation of the other habitants of the universe as they has become accustom to on the blue planet.

The laws of the universe shall be in the hand of the land of the lion as they have been graceful and has been just and as has been promised, the knowledge of universe shall come from the land of the lion and the Sun where it will shine upon the rest of humanity in equal measure and with true powers of grace and justice. This has been the command of the created and shall be attained.

CHAPTER 9

The creation of Gravity

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Abstract

The universe is built and held together and operates on the basis of two forces. One cannot work and exist without the other and when one of these two forces dominates the affects can be interesting, drastic or/and at times dramatic for the entity, this be it the universe, solar system, planet, atom or plasma. These two universal principal dynamically plasmaticaly magnetic field forces one being the Gravitational fields forces (attraction field forces of the entity) and the other the Magnetic fields forces (the repulsion or magnetosphere fields forces of the entity), which both have their origin within its centre these operating entities.

Hypothesis

The source of creation and sustainer of the gravitational field force and the Magnetic field forces of for example planets are the same elements and the same conditions in the centre of the planet.

Prototypes

To prove this concept, several static and dynamic prototypes over span of five years have been made and tested (Fig. 23), which the outcome of these tests shown system on the bases of this concept can be made that the system creates both gravitational and Magnetic fields forces, which in the operation of the system allows the system to reduce its weight first and then the system separates from its ground base and hovers within its environment. This proving that the concept of production of dual Magnetic and gravitational fields through the same elements and conditions to be correct, and the results and observation from these tests are summarized in general in this and other papers to be published.

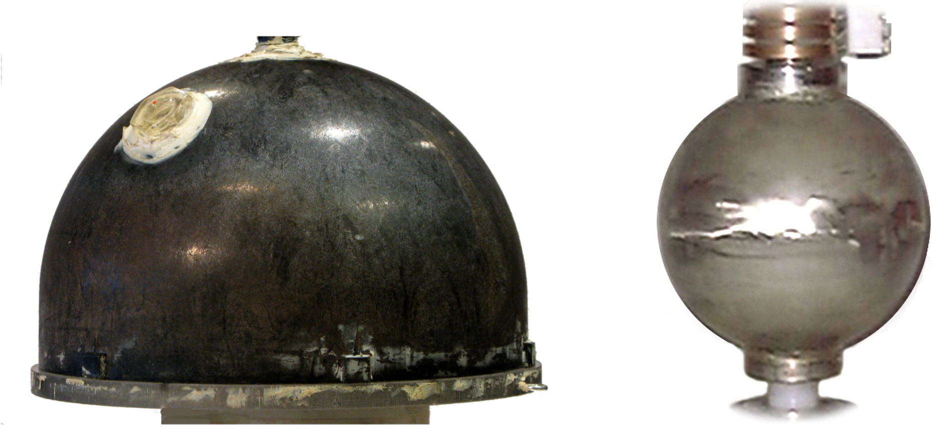

Fig. 23. Some of the prototypes used for creation of Magravs.

Discussions

In this paper for ease of understanding the structure of planet earth is considered as vast amount of information about the inner-structure of this planet are available. In fact this principle of creation of gravity through interacting magnetic fields can be scaled up to structure of universe or scaled down to structure of the plasma of proton and electron and the principle will still applies and be correct.

If scientists would have discovered both magnetic field forces and the gravitational field forces of the planet at the same time, they would have probably had a totally different understanding of their principles, their capabilities and their connections and most probably the human race would have taken a different course in its intellectual and scientific world. It seems this miscomprehension has been purely due to the physical time gap between the discovery and understanding of these two forces of creation.

Working on a real basis for gravitational field's forces production at the centre of the planet, the author set out in early 1980's to design and has produce several real and practical reactors (Fig. 23), which these reactors could replicate the universal order for generating magnetism and finally their interaction lead to the creation of Magnetic and gravitational field forces within the same system to prove the correctness of the principle of above hypothesis.

A fundamental assumption to achieve the proof of the creation and control of a gravitational force within a system has been that the Earth in its inner part has and maintains a semi-fusion and fission nuclear chain of reactions, also called a geo-nuclear reactor.

The interaction between materials and magnetic fields of semi-fusion and fission chain of events in the Caroline core (Fig. 24) of the planet (*This being the core within the inner-inner-core of the Earth, "The seed of the Earth"* (12)) always leads to creation and maintenance of planets physical forces of Magnetic field (MF) and gravitational fields (GF).

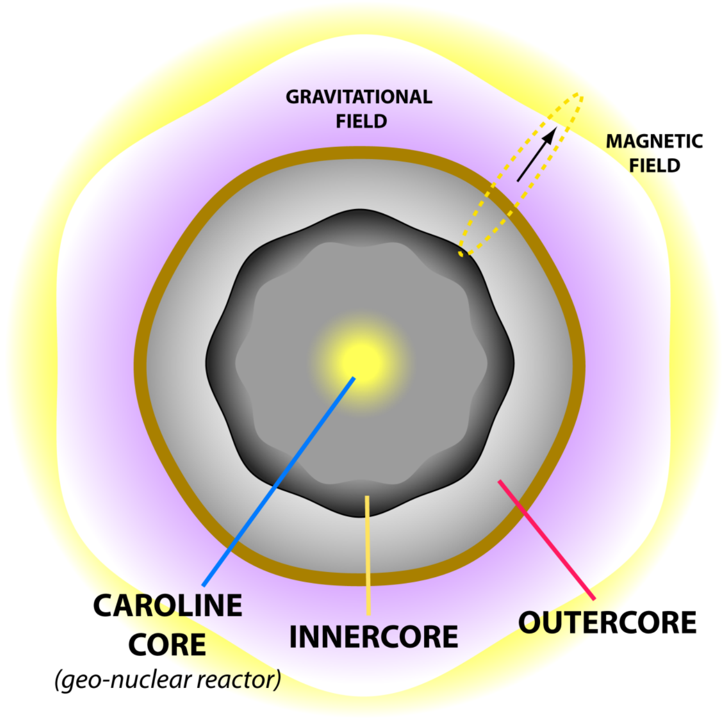

Fig. 24. The structure of inner cores of the Earth (12).

This semi-fusion and fission sequences of processes and existence of plasmas, nano-materials, gases and other materials in the containment of Caroline's' core and the convection process due to the heat transferred from the Caroline core to the Outer core of the planet once being passed through to the inner-core has been considered to be the principle operation of the inner cores of the planet, where, due to dynamic characteristic of the materials, which are charged and rotating within in vacuum condition of inside of the Caroline core, leads to independent creation of current and plasmatic magnetic field within this core, irrespective of the already assumed second and already known magnetic field, created between rotation of the inner-core and the outer-core of the planet.

These two independent dynamic plasmatic magnetic fields which are separated by means of the physical barrier made by the existence of the known solid inner-core.

The interaction of these two dissimilar poles if the these two dynamic plasmatic magnetic fields due to their proximity within the centre of the planet leads to the creation of the central gravitation field force of the planet, which this force spreads out to cover the whole of the structure of the planet.

Hence it is clear that the source of the Gravitational field force of the Earth and all planets are due to the interaction of two dynamic plasmatic magnetic energy fields, which are created independently in the centre of the planets.

The Caroline core of the Earth creates its own spherical dynamic plasmatic magnetic energy field, and the already known second field, comes from the dynamic spherical plasmatic magnetic field, which is created in the outer-core of the planet at the same time.

In trying to lock onto each other, these fields forces create the condition of double spherical magnetic fields, which both possess their own North-pole and the South-pole, where due to dynamic and loose atomic, molecular structure of the matters and fields in these two cores, the dissimilar poles of the two cores can never quite reach the point of total locking into each other, and as they try to reach this point of full lock, the field forces they create lead to creation and maintenance of the perpetual motion of the two fields in the centre of the planet.

These separated dynamic fields forces on either side of the solid-inner core exert their forces on the solid inner-core of the planet and cause it to rotate, and this leading to creation of the rotational movement of the planet (12)

At this point the interaction of the fields created by atoms and molecular elements, which cannot lock to each other due to their similarity of magnetic poles, will create the outward plasmatic magnetic field between the two cores, or they create what is known as the Magnetic field force of the planet (this being created by the environment and the behaviour of two similar poles of a solid magnet which they repel each other).

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Where, at the same time the interaction of the magnetic fields created by atoms and molecular elements which cannot lock into each other due to their dissimilarity of magnetic poles, these interaction of the magnetic fields will create the pulling power effect between the fields, atoms and molecules contents of the two cores and this creates the dynamic attraction plasmatic magnetic fields of the planet or what is called the gravitational (Pulling) field force of the planet

Thus; Gravity or gravitational field force does not and cannot exist with existence of only one plasmatic magnetic field force as has been assumed to be so up to now in respect to the creation of the magnetic fields of the planet.

The gravity and gravitational field forces manifest themselves upon the creation and existence and maintenance of the second dynamic plasmatic magnetic field within the structure of any dynamic plasmatic field entity, that in the case of the earth fluid matter in the outer-core is source of this second field and may be generated through the assumed convection theory by the convection of the matter in the outer-core, and the interaction of fields in this core with the plasmatic magnetic field which was originally created in the Caroline core of the planet through the fluidity of the fields, plasmas and matters in this core.

Therefore the gravity is an outcome of the interaction at plasmatic, atomic or molecular levels between two dynamic plasmatic magnetic fields created and maintained by the two inner-cores of the planet upon each other.

Ultimately for creation and maintenance of gravitational field force, for all stars and planets or any dynamic maintain plasmatic magnetic fields system, and to maintain a gravitational fields forces in any celestial entity there is a need for existence and establishment of two independent dynamically, molecularly or/and combination of the two independent plasmatic magnetic fields forces, which these can be created by any mixture of matters and fields, in any combination of magnetic fields, liquid, gas, plasma or other state of matters within the confined of specific condition and entity, this leading to generation of loosely interlocking plasmatic magnetic fields, which these two fields are separated and maintained by any physical supranational means, in any state of matter or function, separately and independent from each other, even though one magnetic field could be the cause of the creation and maintenance of the second pmf.

Where, the separation of the plasmatic magnetic fields could be established by the means of solid, liquid and gases, plasma and energy directly in adjacent layers to each other as has been observed to be in the structure of the inner-core of the Sun material layers.

Once the strength of the plasmatic magnetic fields of the inner-inner-core (Caroline) and the outer-core in a system, by controlling the creation of the plasmatic magnetic fields in the Caroline core or the outer-core is attained by the system, consequently the strength of the gravitational field forces of the system like the earth is set.

Looking at overall view of the centre of the Earth magnetic fields and it their near spherical shapes structure and with the new understanding of its' physical inner construction and material composition, one will come to understand that at least the two magnetic fields generated within the inner cores structure of the Earth are spherical in shape and they generate dynamic spherical plasmatic magnetic fields. Where, one field being superimposed on top the other are in operation within the centre of the planet.

Whereas, one of the fields being the spherical magnetic fields maintained by the inner-inner-core due to existence of plasmas, hydrogen atoms, other gases, nano, gans, nuclear and non-nuclear materials in presences of second magnetic field generated by spherically dynamic plasmatic magnetic the outer-core in the centre of the Earth (Fig. 25).

Which, this creates and brings about the phenomenon of the dynamic magnetic confinement for the materials in the Caroline core, which this brings about the conditions for the fusion process to be attained in this core of the earth. This explaining why the planet can exist for a long time with its matters and motion intact, as matters through fission and fusion use a very little matter in the close capsule environment of the Caroline core.

The second spherical dynamic plasmatic magnetic field in the outer core of the earth possibly is created through convection, due to its materials in motion in the outer core.

There are strong indications and possibilities that the outer core could be operating in the same matter mixture composition as the Caroline core, which this eliminate and invalidates the concept of the convection theory.

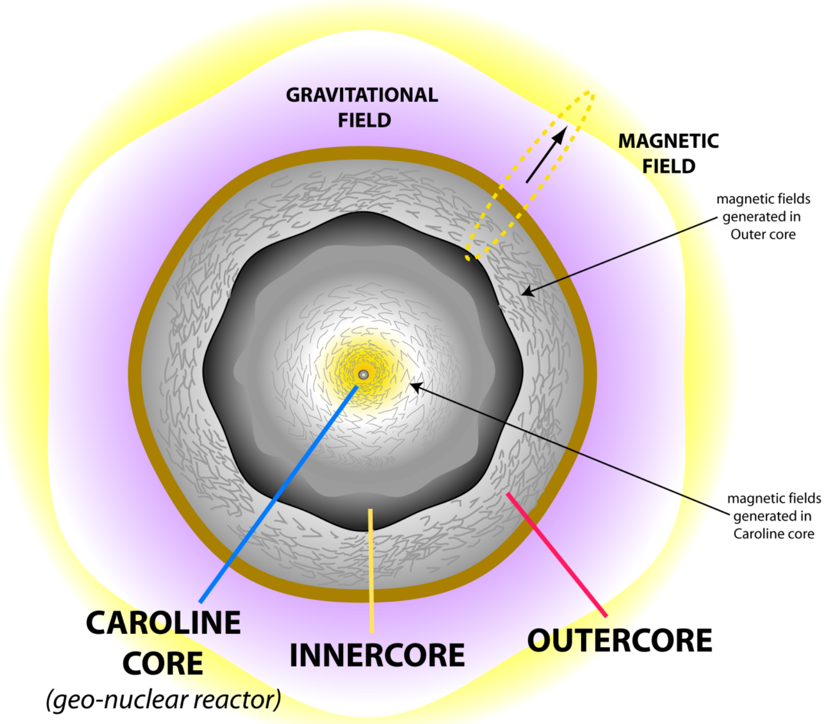

Fig. 25. Existence of minimum two separate magnetic fields in two cores of Earth.

It has to be said and it can be proven that the Caroline core maintains and through nuclear decay of its matter content produces plasma of matters, then by the understanding of the concept of generation of current through motion of the plasma itself, this proves that one does not need the convection principle to create the current and magnetic fields in the Caroline core or even in the outer core of the planet.

Therefore the existence convection theory and motion of the solid inner-core to create the magnetic fields of the earth losses its credibility, as in plasma technology, it is well understood that plasma in motions create their own current and in turn the interaction of this current with matters and other fields in their environment this can lead to they creation their own magnetic fields.

Thus, the theory of convection has to large extent no validity in the present understanding of nuclear science as one observes these operations of plasmas' phenomenon at the solar, galaxial and universal systems levels.

The convection theory was he understanding of the eighteenth century and the understanding of the working of dynamo of bicycles and this has no room in the integral working of the universal motion of plasma and magnetic fields of today.

Secondly entities like stars do not have solid core that leads to creation of their strong magnetic fields and gravitational field, as they only operate on the principle of plasma layers and some helium matter in, nano, atomic and molecular level.

Therefore in reality the physical positioning of the matter in the cavity of the once presumed solid sphere of the inner-core is the catalyst and contributor and the creation of both plasmatic magnetic fields of the planet, which both fields are independent of each other, but at the same time interconnecting or magnetically reconnecting tool for both spherically plasmatic magnetic fields on either side of the solid inner core of the earth to produce the Magnetic field and gravitational field of the Earth.

Where the interaction between these two dynamic plasmatic magnetic fields in the physical body of the inner-core of the earth leads to creation of the double spherical plasmatic magnetic fields' phenomenon needed for creation and control of the strength of the plastically magnetically based gravitational field forces and plasmatic Magnetic field forces necessary for the creation of the mass of and the atmosphere or magnetosphere around the planet.

These reconnections' of plasmatic magnetic field generated in two cores of the planet are totally on atomic and molecular levels, this leading to a creation of loose plasmatic magnetic field forces that operate at weak levels, but strong enough to cover a vast area in their surroundings.

That is why a small Caroline core in the centre of the Earth can create a strong magnetic fields effect of up to outer boundary of the magnetosphere and gravitational field of the Earth and beyond.

As the plasmatic magnetic fields could be created by use of any elements in both cores of the planets that they can generate any amount of heat and a given gravitational fields forces and for example with the Earth operating at central temperatures of several thousands of degrees centigrade at its core with surface gravitational force of one g at its surface, and similarly the Sun physically possessing several of thousands of times larger mass and volume than the Earth with central temperatures of several millions of degrees centigrade, which has only the surface gravitational force of about twenty eight times more than the Earth, therefore the following statement can be made that "*the strength of gravitational field force of any system is largely independent of temperature, and is primarily dependent on, the composition of its dynamic inner structure mafs and matters, and the fields they created or maintained and the physical condition and are positioned in respect to each other, which through their interactions these leads to creation of the two dynamic plasmatic magnetic fields strength of the gravitational fields and magnetic fields of the system within its inner sanctum*",

In relation to the physical data's available, the present gravitational field system which has been assumed to be created by the single magnetic system due to motion of matter and the inner-cores and the outer-core in the centre of the planet is not scientifically acceptable and cannot stand the present physical knowledge about the inner construction of the planet from seismological data's of the past twenty five years.

The concept of single plasmatic magnetic field of the planet, which has up to now been assumed does not stand scrutiny of present knowledge and the present expanded laws of physics, as for the planet to be able to create gravity and Magnetism (for magnetosphere) that can span a vast area of the solar system irrespective of its position and the material carried in its outer shells and on its surface, then the planet has to have two active plasmatic magnetic field forces in its centre cores, that the interaction between these two plasmatic magnetic fields can create the fields that affect the behaviour other entities' with dynamic plasmatic fields elements in the vicinity of these fields, and the interaction of the fields of the planet and the fields of the entities allows for the entities' to position themselves in respect to and within the plasmatic magnetic field strength of the planet to be attracted by the effective plasmatic magnetic field of the planet. This is what we have called Magnetic and gravitational position or for short Magravs positioning of one entity in respect to the other entity, where both entities possess internal dynamic plasmatic magnetic fields.

The reality is that, if Earth has had only one magnetic field as has been assumed until now, then all elements on the planet would have been firmly attached to it, due to principle of attraction or repulsion of two magnets, and as it is observed on the planets all systems have been able to freely positioned themselves and being able to be mobile.

Without the shadow of a doubt the centre of the planet maintains two independent plasmatic magnetic fields, that the interaction between these two plasmatic magnetic fields at the plasmatic, atomic or molecular level leads to creation of an environment in which the matters in the surrounding area of the two plasmatic magnetic field will have the power to attract and repel mafs and matter within this created field. By the same law as the atomic matter, itself is made of magnetic energy fields, which possesses polarity hence why the attachment of the man to the earth as his being is made of these entities.

Therefore the matter will only by finding its Magravs position within the plasmatic magnetic field of the planet, if it can be attracted and be kept as part of the matter of the planet, or if its plasmatic magnetic field is too weak or too strong to be kept within a given field. Thus now it can be clearly understood how and why different planets can manage to hold on to certain matters and not the others and now one can understand why different matters take their positions in different layers of the planet too, where this positioning, like of the gases and solids, are totally related to the strength of the plasmatic magnetic energy of the atom in respect to the plasmatic magnetic energy of the planet or in other word, in respect to the total interaction between the pmf of mafs of the matter and the Magnetism and gravity of the planet.

The plasmatic magnetic field force created on these levels in the physical inner cores body of the planet these creates the condition, where all magnetic forces within these fields will be influenced through their magnetic reconnection, this being in atomic or molecular level, this creating pulling inwards forces for the two plasmatic magnetic fields of the matter and the planet to be locked into each other. This interlocking and the strength of it bind creates the effect of the gravitation field force, as the matters' magnetic force and the planet plasmatic magnetic field created by the double plasmatic magnetic energy field, reconnect to keep each other at a physical interactive but loose distance.

In reality gravity is the strength of the plasmatic magnetic field created by the interaction of the double dynamic magnetic force fields of the planet that can influence to pull the matters around these field to stay within its strength, or what is called its gravitational field force.

The interlocking of these forces are the same as with two bars of magnets when they are brought close to each other, but their binding of forces is in planetary plasmatic levels, which are at a loose atomic or molecular level rather than electrons' realignment or what is called are energy equal to the collective plasmatic magnetic energy of the electrons of Iron atoms interlocking plasmatic magnetic field level.

With the difference that in the planetary or astronomical, cosmological and universal levels these so called magnets are in the form of closed loop spherical shape and may be in possession of internal heating in respect to their surrounding temperature and system, where their plasmatic magnetic field force can vary and they can change their strength due to the compression and other factors in their centre cores, as in solid magnet the strength of the magnet is constant and permanent.

In the closed loop spherical plasmatic magnets, the system of the plasmatic magnetic field lines has to find their magnetic reconnection line for the loop to be completed. Where, this plasmatic magnetic field's reconnection leads to the directional polarity leading to the creation of the North and South Pole phenomenon of the planet.

Through replication and production of such a system as the structure of the inner-cores of the earth, in being able to control the amount of matter and fields within the structure of these systems, the strength of the plasmatic magnetic fields of the cores of the system can be controlled and adjusted, so that, this will allow the creation and control of the measured gravitational fields forces by the systems in respect to the environment in which the system is operating in.

In the case of motion of an object like a manmade system, in possession of its own gravitational power production, in the gravitational pull of another object like a planet, the use of the phenomenon of the creation and control of the gravity in the centre of any system can be treated in the same manner as in the planetary system.

Where, the gravity created in the centre of manmade system needs to be slightly changed in the positive or negative direction in respect to its previous position for the object to be repelled or be attracted towards the planet or an object.

This Magravs positioning of a system in respect to planets plasmatic magnetic fields, can be achieved through several means, like by the change of characteristic of the dynamic of the one core in respect to the other, or changes configurations of the parameters, materials or physical structure aspects of one core or both core of the system.

The magnetic and gravitational forces of a Star are to some extent dictated by the position of planets within the system as much as the constituent content matters of the Star itself. On these bases, this being the gravitational forces of the system and its position within its galaxy is to a large extent dictated and controlled by its' planets and the gravitational force they create independently on their own.

This is very much like the rotational plasmatic magnetic fields of the electrons circulating around the nucleus of an atom. Where, the magnetic rotational spin of the electron decides the plasmatic magnetic field strength of the nucleus and the position which the element occupies and the number of other electrons it can carry, so this dictates the properties and its characteristics in respect to other elements around it, even though the plasmatic magnetic field of the nucleus is much more powerful than the plasmatic magnetic field of the electrons around it, or in other word the gravitational forces of the nucleus is needed for the electrons to be kept in their orbit and vice versa.

Thus the gravitational forces of a system or a galaxy is not only dependent on the plasmatic magnetic energy forces of its centre or its star, but it is fully controlled and determined by a bigger scale by its constituent planets and stars in that system too.

From the topography of the Earth gravitational field pattern provided by space agencies, Earth plasmatic magnetic field does not keep a constant pattern and there are constant changes in the strength of these fields in different parts of the planet, where these are dictated by the activities within the centre cores of the planet at the point of observation. These variations in gravitational field's patterns confirming that the planet has composite and not necessarily spherical shape cores.

These variations in these forces in the cores of the planet could be due to the variation between the interaction of the inner and the outer plasmatic magnetic fields, where for example at point where these forces vary drastically in respect to each other, then one gets distortion of the fields and reduction or increase in the gravitational field force in that region of the planet by small factor. Then where, for example one force field, like the fields created in the Caroline core is more powerful due to sudden short burst of ionization in the core, at that point and that moment, the plasmatic magnetic fields interaction of the centre field is more powerful, then the gravitational field force can be more powerful at that given point, but these changes due to close confinement of the centre cores are usually not so large.

For example by observing the pattern of the gravitation field of the Earth, a constant depression in the plasmatic magnetic field in the region of the southern eastern hemisphere in respect to the rotation of the planet usually can be observed. Where, this phenomenon now can be easily be explained, and this is what I so call the washing machine effect and that is, where the material within the inner-core has loose plasma area of rotation, as in the drum of washing machine filled up with clothes, the inner-core of the Earth does not possess the blades as in the drum of the washing machine, then the more dense matters in the Caroline core as they cannot role all the way up against the internal wall of the cores, and then due to toroidal and interaction with poloidal motion of the Earth, these materials pull up the wall of the core and due to their viscosity they roll back over in this area, this whirlpool effect due to slower motion and less available field in this region effects the gravitational field in the south American continent area too.

This washing machine effect of the materials in the Caroline core directly affect the plasmatic magnetic field production in this core, and consequently its interaction with the plasmatic magnetic field of the outer core, and in turn this creates the disturbance in the gravitation field of the planets in these two regions as has been noted in the overall pictures of these regions gravitational field forces effect, where dents in the gravitational field forces patterns are observed on continues bases.

Even thou Newton did note the effect of interaction of two forces between the matters and the planet and he measured its strength and called it gravitational field's forces of the planet, but he could never establish the source and method of its creation. He speaks about the effects of the gravity in relationship between two objects in respect to each other's position, and not the effect created by two plasmatic magnetic forces in respect to each other and their position in respect to each other, where he could not understand that gravity was magnetic field bases entity and magnetic field strength and it effect are magnetic fields position dependent. Newton never could relate and understand the connection between Magnetism and the gravity as both to be created by the same matters and conditions which manifesting itself as two different forces in respect to other magnetic field forces.

Scientists explain the gravity as the relationship of attraction between position of two bodies in respect to each other, and not the reality that gravity manifest itself in relation to interaction and attraction of two bodies in possession of dynamic plasmatic magnetic field forces created and maintained in respect to each other position.

In understanding the real method by which the gravitational field forces of planetary systems are created then systems can be made to replicate the same process and by being able to create and control gravity as done in the planets one is able to observe the effect of this natural phenomenon within operation of a manmade system.

In manmade reactors as the concept of gravity has been replicated, now the concept of the gravity has to be redefined as the " attraction between two bodies, where at least one body possesses a double spherical dynamic plasmatic magnetic field force, where one field is superimposed by the other plasmatic magnetic field forces within an object, where their overall plasmatic magnetic field strength interaction upon each other can create an overall plasmatic magnetic field, that other matters in possession of their own dynamic plasmatic magnetic field or static plasmatic magnetic field, within their catchments area can position themselves according to their internal plasmatic magnetic fields strength".

The interaction of these double dynamic spherical superimposed plasmatic magnetic fields in the centre of the planet separated by the physical matter of the inner-core upon each other is the cause of the rotational motion of the inner solid core of the Earth and where the motion of the inner solid core itself is the containment body of the centrifuge system for the gases in the Caroline core for the atomic fusion chain of events in this chamber, for it to sustain the ionization process in the this chamber. Where, at the same time the inner-core plays the effective mixing machine for the matter in the outer-core of the planet, where the interaction of plasmatic magnetic field of the Caroline core with interaction with the plasmatic magnetic field of the outer-core would change the combined plasmatic magnetic field effect of the whole planet, which in reality would have changed the gravitational field strength of the planet.

The rotation in the gas layers of the Caroline core in conjunction with turbulence, which leads to convection in the materials in the cores of the planet, this effecting the generation of current and plasmatic magnetic field in the core of the planet and consequently the gravitational forces created by the core of the system.

Now one can explain that the change of the polarity of the earth and any other entity the like of the Sun is only due to change direction of flow of the current in one core or layer of these dynamic magnetic fields based star and hence the change of direction of the flow of the current for example in the plasma of the Sun layer leads to change of the polarity of the star, as one can sees the same change of polarity in the production solid magnets, where the change of direction of the flow of current changes the polarity of the metal, as is the same for the plasmatic magnetic field entities too.

Thus change of polarity of the earth is only due to the change of direction of the current within the core(s) of the earth and would not affect the gravitation field or Magnetic field strength of the earth when it will happens.

Now that the method of the creation and control of gravitational field forces of planet is understood and can be replicated, it becomes easy to understand how systems can be produced that can create magnetic field structure of any element or matter in the universe, this being magnet for hydrogen atom or uranium atom or magnetic machines can be produced that can gravitated to themselves molecular structure like water or protein.

Where, the system gravitational field can be created to match for example only the plasmatic magnetic field of atom of gold, so that the system becomes a gold magnet or the system will generate only or gravitates towards the plasmatic magnetic energy of the gold atom, so one can separate gold or any other matter which the system is present to generate the Plasmatic magnetic energy of. This system will then can replace the present centrifuge system of the present time.

Magravs measuring system

In the gravitational systems, where only magnetic fields forces are considered and measured, the present earthly measurement tolls of gravity has no meaning and room. Space scientists of the future have to learn to measure magnetic field force in respect to each other and not kilogram per centimetre per Seconds Square.

Thus the measuring gravitational systems to be developed have to be first of all three dimensional, as field forces of all matters and fields in space have to be considered and balanced against or with.

The gravitational tools of the space technology is fixed magnetic fields shear against the magnetic fields of the system against the total magnetic fields forces in the overall sphere of the systems fields.

In fact the gravitational fields of the space technology are like a magnetic fields sphere positioned around the gravitational reactors, as these measuring tools of the gravitational systems will measure the Magravs of the all fields of all forces internally and externally in respect to their position in respect to the reactor Magravs.

The Magravs measuring tools are to be called **Universal Magravs Measuring System** (UMMS) and position of Magravs of the system in respect to another Magravs are called **Magravs positioning System** (MPS).

Elaborations:

Through understanding the real term concepts of the creation of the gravitational field forces and design and production of specific nuclear-based reactors of the function of matters within static and dynamic reactors, the principle of the hypothesis of creation of gravity has been proven to be correct.

The difference between inertia and gravity is said to be the gravity is an attribute of a body in possession of two dynamic plasmatic magnetic field forces interacting upon each other, where the inertia is the attribute of collective molecular magnetic force of an object which does not possess a double magnetic field structure as whole, even though both behave the same and due to their plasmatic magnetic fields appear to be the same thing.

Where, in case of planets like Earth, the total pulling power of the planet in respect to other objects in, on, or about it are due to collective forces created by the gravity and its constituent's matters inertia.

The creation and maintenance of gravity is dependent on two dynamic regions being in possession of two independent dynamic plasmatic magnetic field forces and gravity is totally independent of the mass of the object as mass itself is the by-product of the interaction of the Magnetic fields and gravitational fields of the entity, but dependent on the position of their plasmatic magnetic forces in respect to their plasmatic magnetic field strength from the centre entity.

The centre of planets, does not matter what their inner layers are made of do not need a metallic matter or metallic behaviour conditioned matter for the creation and maintenance of their own electromagnetic effect due to motion of electrons and charged plasmas in their core as these entities generate current and potential difference levels for the core to maintain independent plasmatic magnetic field forces leading to the creation of plasmatic magnetic field and finally by interaction of two such dynamic plasmatic field forces upon each other, leading to creation of gravitational field forces within the entity and in its surrounding area.

The interaction of these two plasmatic magnetic field forces upon each other, or the concept of *"DOUBLE DYNAMIC SPHERICAL PLASMATIC MAGNETIC ENERGY FIELD EFFECT",* in the centre of any dynamic plasmatic entity will lead to creation of the gravitational field force and the magnetic field forces of that entity in respect to other entities with the catchments fields force of the entity.

Therefore, the gravitational field strength of a system manifest itself and can be explained as the relation to interaction and attraction of two bodies in possession of dynamic plasmatic magnetic field forces created in respect to each other plasmatic magnetic field position and strength. Even, further it has been proven through prototype reactor tests that the speed of the rotation of the planet is determined by the speed of the solid inner-core of the planet, where the speed of the rotation of the planet is set and dictated by the interaction between the dynamic plasmatic magnetic fields of the Caroline core and the outer-core of the planet, as the motion induced by the strength of the two fields in the centre cores, upon and interacting within the solid inner core, determines the speed of the rotation of the inner core, and in turn this will determine the speed of the rotation of the whole planet.

Whereas, if the speed of the rotation of the planet were not set by the planet by this principle, then the planet would have had different speeds at different points in its daily axial rotation and it would have had different speeds in its annual path in circling its star, where the effect of the other objects in the system would have dictated different speed of the rotation of the planet, therefore it is correct to assume that the speed of the planet is controlled by the speed of the solid inner-core of the planet, and the same applies with other entities like the star as the speed of the internal fields interaction dictates their speed of rotation.

The motion of the inner solid core is very much like the motion of the trains on magnetic tracks, where by not allowing the two dissimilar magnetic poles to be aliened, the train moves forward. Where, in the case of the spherical solid metallic inner-core of the Earth, this motion is rotational rather than linear.

Through tests, it has been proven and understood for the first time, that the magnetic polarity change of planet or the system occurs when the direction of the flow of current this being due to motion of electron or charged plasma in the cores in the whole of the system changes from one direction to the other, or in some cases one field change of direction of internal current can causes the half reversal of the polarity of the whole system. This is understandable, as the plasmatic magnetic fields are created due to directional motion of electrons, plasmas or charged plasmatic current within the matters of any entity, thus as the direction of the flow of the current changes, this will change the direction of the polarity of the planet.

Understanding the direct relationship between the magnetism and gravitational forces within a system, in the manmade systems the change of polarity in the reactors of a system has to be avoided, as, if this happens during the operation of the reactor, this can and would lead to the overturning of any platform which is equipped with such a system. This being one of the fundamental reasons why the reactors which have been developed and tested up to now for space technology, always are preferred to be constructed in a half spherical shape, simply to avoid the flipping of the polarity in the cores of the reactor, where the speed of the rate of the polarity change is very dependent on the components and conditions created within of the centre of a planet or a star.

If a planet is made of near enough similar material on both side of the inner core, the flips of polarity will be much faster and on a shorter time lapse, like in the Sun.

If the planet is made of a composite core, and made of two or more different materials in its Caroline core (the real centre core), for the two fields to re-align, then this will take a longer time for the magnetic flip of polarity to occur, like in the core of Earth. In any case, as the materials in both cores are always constant and cannot change that much, therefore the time laps between the changes of polarity stays on the same time intervals.

In the case of the Sun, due to its more uniform and singularity or only composite of three matters of plasma, hydrogen and helium in its core, the change of polarity takes eleven years, and the full polarity change has the predetermined time of twenty-two or three years.

In the case of smaller planets’ like the Earth, which is made of composite mixtures cores, the time lapse in change of polarity will be longer. Where, the switching of polarity is a natural outcome of the direction of the flow of current created by the electrons and primarily by the charged plasma and due to dynamic characteristic of the core, and is an inherent characteristic of the atomic structure of each element and environment which they are condition to within the cores of the planet.

It has been observed in tests, that the plasmatic magnetic field of the core increases by the principle of extraction of the electron from the core, where electrons are facilitated to be absorbed by the walls of the reactor core. Where, the majority of the field created is primarily due to the motion of charged plasmas. Where, at the same time for weaker magnetic fields test the reactors have present to absorb the plasma of the proton that only the lesser mass of mafs available in the plasma of the electron can be used for a given test condition.

Therefore according to need of the use, reactors can be set to utilize any components of an atom or the mafs of their constituent plasmas without in fact destroying any structure of the mafs or the matter, which the mafs was used for that given exercise.

In principle it is observed that the plasmatic magnetic energy of the planet is primarily due to the motion of the charged plasma in the core and not electrons, where in reality the motion of charged dynamic nuclease of an atom has/ and indeed, possess a much larger electrical charge then its counterpart the electron by factor of 2000 times. Thus now it is apparent and clear why such a small core in planets can master such large magnetic field forces within and around them, and now it is understood how planets can carry the burden of such large mass in their journey through their system for such long period of time of billions of years in their solar systems.

In tests plasmatic magnetic field created by these type of cold condition plasma using a 20 cm dynamic core, has been noted to create a 4-meter radius dynamic spherical plasmatic magnetic field span, which can last up to several minutes after the switching off the whole system.

The dynamic plasmatic magnetic fields created within the double cores of the planets, determines the magnetic or gravitation fields, which the planet will possess and consequently the material, which the planet will hold on to. This explaining why planets behave like magnets, which only have the characteristic of one element or several materials plasmatic magnetic band(s) which covers some and not the other elements, which this dictates the material composition of the planet within, on the surface and around the planetary system. Where, the same applies to the solar system and galaxies and so forth. Where, the gravitational field forces created by the balance of the two interacting dynamic plasmatic magnetic fields is the principal factor in determining the constituent material of a plasma, planet, star or a system.

The creation of the gravitational field forces of a solar system and even the gravitational field force of the galaxies are not far from the gravitational system and method's used in the atomic and planetary systems. That is to say, that solar system's possess and generate plasmatic magnetic fields like planets and they possess gravitational forces according to their stars constituent materials. If one could stand on the edges of the solar systems, one should be able to see and detect the gravitational forces of this system, by it simply absorbing and attracting with the entry of cosmic meteoroids and asteroids into its gravitational and solar heliosphere region of its solar system.

Solar systems, like planets, possess and create magnetospheres of their own which is specific to their composition materials. The entry and exit from these solar Magnetic and gravitational fields uses the same method as the entry into or exit out of planetary systems.

This also holds true for a solid magnet, where if a piece of magnet could be cut into two halves or four quarters, each piece of the material will still carry the same north and south poles and each piece will have the same magnetic powers as the original piece. That is to say, that if one uses the same volume ratio of the same mafs or matters and proportional physical conditions in the core of a system; one will attain the same magnetism and gravitational field force from the system as its bigger dimension system with the same mass ratios.

In astrophysical terms, the Magnetic field forces of any entities are what keeps the entities apart from each other, and at the same and opposite to this, the gravitation filed forces are what keeps them together.

Where, the pattern of distribution of Magnetic and gravitational fields forces of the entity interacting with another Magnetic and gravitational field force shows itself as the magnetosphere of the entity.

This Magnetic and gravitational field force (Magravs) of dynamic plasmatic fields force is known passive magnetic field (PMF) and has no relation with the magnetism as known in a solid-state magnet. This is so called passive plasmatic magnetism due to the fact that, this type of magnetism cannot magnetize an entity otherwise all the materials in the universe would have stuck to each other. But this mixture of Magnetic and gravitational fields are used to position one entity in respect to each other that they not necessarily collide or move too far from each other once they established inter-magnetic connection.

The reason the Magravs are called passive plasmatic magnetic field is due to their capability of passing through human tissue without in majority of the cases affecting the function of their atomic and molecular magnetic field, which human cell possess on their own for their structural bindings.

In the past, magnetism and gravity have been explained according to the physical understanding of a solid magnet and not according to the planetary magnetic forces, this new understanding of creation of magnetism and gravity, is one of the corner stones of the creation of plasmas, planets, solar systems and galaxies. By not appreciating the connection between the magnetic field force and gravitational field force of a system like Earth, it has become a challenge for the scientific world even to overcome the weak gravitational field forces of small planet like earth in just trying to send a small rocket into the Earth's orbit.

Through development and tests on double core type of cold condition plasma reactors creating the same conditions as it has been assumed to exist in the centre of planets, it has been observed and physically been proven, that the source of the three dimensional spherical gravitational field and three dimensional spherical magnetic field of the planets are the same materials and the dynamic interaction of plasmatic magnetic fields created individually and independently in each core of these reactors and their effects upon each other creates and maintains both forces of the creation Magnetic field and gravitational fields forces simultaneously.

If one were able to create the right condition and material in a simple core, as has been done in our tests with core developments, then one can create and control magnetism and then the gravitational field forces within that object, and then in the environment which the object is positioned in respect to other external plasmatic magnetic fields around it, where, the plasmatic magnetic fields created within and by the object will becomes its Magnetic field around it, very much like the magnetosphere of the planets, this providing a magnetic shielding like Earth atmosphere around the object and due to the spherical shape of objects in possession of both forces, this creates a magnetic loop, where they create the two poles of the magnet as the North and the South Poles.

If a system can take advantage of this phenomenon, for it to move within forces of a planet, rather than trying to overcome them, or to resist them for its motion, then not much energy or effort is needed to create the right gravitational forces and magnetic field protection within and around a system for it to move inside or outside the atmosphere of a planet or a system without burning a single atom as a fuel, which this puts an end to the propulsion technology for rapid and protected motion anywhere in the universe.

Due to the spherical shape of most of celestial entities and their rotational motions in the universe, the gravitational force created by the dynamic plasmatic magnetic effect has a pulling force, which has the tendency to encircle and reconnect within the interior of the entities fields of the same dynamic structure. This being the reason why the gravitational forces increase as one moves closer to these objects and as one moves' towards the centre of these matters.

The difference between the solid magnetism and plasmatic geomagnetism are two clear factors, in this particular order, first is Dynamism of the magnetic fields which creates the geomagnetism, and second the need for the interaction of two independent fields upon each other to maintain the plasmatic magnetise, where plasmatic magnetism for it to exist the plasma needs to create and maintain a full gravitational and Magnetic fields system of its own, which can absorb and feed other plasmatic magnetic fields within its environment to guaranty its survival in that environment at the same time, whereas in solid magnet, the order of continuity is within the structure of the matter and not mafs of the matter.

Conclusion

The gravity is the product of interactions of fields and wherever in the universe fields will interact their interactions will gravitates some fields or matters to them, or caused these fields to be attracted and gravitate towards another setup of the same or stronger and by laws of nature the stronger attract and gravitates more to itself and the heavier mass as they are made of more magnetic fields tend to dominate the seen when it comes to gravitational pull. Through tests it is apparent that the power of Magnetism and gravity of all entities in the universe are independent of the physical size of the entity and more dependent on the strength of mafs, which have led to the creation of the entity.

Through design and test of double core reactors we have proven that the origin of the gravitational force and magnetic force of a planet or any celestial systems in the universe are the same mafs and materials and conditions, where they are created out of the interaction of two independent and dynamic plasmatic magnetic fields.

Note; this revised version of the creation of gravity paper has included extracts from collection of three other papers published by the author, which these were, the gravitation measurement system, the relation between Magnetisem and gravity (35) and the original paper of the creation of the gravity.

CHAPTER 10

The creation of Black Hole

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Author: Nuc Ir. Mehran Tavakoli Keshe
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Note:

The original version of this paper, which explains how black holes are created and how they do leak matters and rays into the environment of the universe, was submitted to the Royal Astronomical Society of United Kingdom in London in April of 2004 for peer review and publication. The author after three months received on the 8.7.2004 a letter (Fig. 29) from the Society dated 7.7.2004 that this paper will not be published and will be kept in the library of the Society.

Interesting enough on the same day 8.7.2004 (check the press) Mr Steven Hawking, the imminent Black hole scientist and expert in this field of science announced that he, after thirty years has changed his mind and he says that indeed the black holes do leak rays out and that he announce this in a conference in Dublin later that month (see the press), as now he has lost a bit of shirt.

We have wondered for years how coincidental of the topic, the date of letter from the institute, the date of announcement, and the change of mind of a scientist!

This is the reason why the Keshe Foundation does not believe in the scandals and process of peer review and the foundation publishes its own scientific papers on its website and its own books for the reader to peer review the newly gain knowledge. As with this process the knowledge is passed on first hand and in some cases in matters of hours of the discovery to the public and not waiting for month and years until there is gap in some journal that the paper can be published. The Keshe Foundation firmly believes that 'as if a man, has reached the age of maturity and intelligence that he can read, then he can independently investigate and judge the correctness of the knowledge he receives according to his own level of intelligence for himself", unless he is an innocent, then he needs to accept the enforced control system of peer reviewing to tell him what to think, that this peer reviewing can suit the self-interest of the peer reviewer, or organisation which supports him financially or the nation which has promoted the peer reviewer for their own clandestine purposes, as we have seen the same process of control through peer review systems in different occasions in different countries around the world in this recent times.

A copy of the letter from the Royal Institute of Astronomical Society is enclosed at the back of this chapter for reference. (Fig. 29).

Abstract

Since first disclosures of this phenomenon, scientists and the rest of academic world have tried to understand and explain the reasons for the existence of these mysterious Black spots in the universe.

Hypothesis

The object of this paper is to prove that Black Holes are created out of a natural sequence of events in the universe and to prove that existence of a Black Holes in the galaxies and in the universe is a normal event as the appearance of the Dark Spots on the surface of the Sun. Black holes are simply a creation or an outcome of natural interaction between two or more mafs, passive magnetic fields and matters in motion within any dynamic plasmatic magnetic field entity in the universe (Fig. 26).

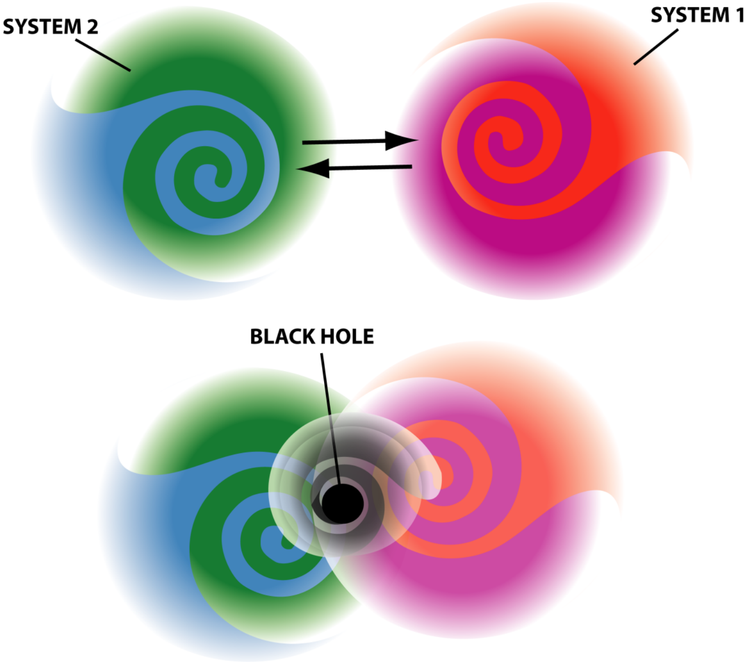

Fig. 26 Interaction of two plasmatic energy fields creating the effect of a Black Hole.

Discussion

In this paper for the first time, it will be explained how the Black Hole is physically created and in this disclosure it will be explained

1) The conditions, which this physical object is created in the universe naturally.

2) How this body of the mass appears as a dark spot in the galaxy?

3) What purpose it serves in the universe?

4) Parallel example of the Black Hole condition in our solar system.

5) The use of this phenomenon for Man to enable him to travel in space.

When, one could fully understand the concepts of the creation of galaxies, stars and planets and plasmas, and then one could be able to understand the creation and existence of the Black Hole in the universe in its different scale of dimension, where the creation of these entities in the universe all follow the same principle.

In understanding the fundamental principle that galaxies like solar systems and planets are given their inner mass and energy at the point of their birth in the universe, so they cannot create additional new masses and new source of energy on their own. Then it is understandable that Galaxies can only recycle what they have been given at the start of their lives, to create different new objects like stars or planets within themselves. In universal terms they have a finite mass and energy available to them and nothing more. But at the same time as a part of bigger picture galaxies have to obey the universal laws of physics. Consequently, all galaxies follow the same rules and so do their physical contents like solar systems and atoms within them.

A Black Hole is created primarily and only under-one condition in the Universe and as the consequences of other acts in a galaxy. They are not created as a deliberate act and as predetermined plan in and by a galaxy. But in their way, they make an enormous contribution in keeping the matters in check in their surrounding environment during their relatively short life.

At the same time they redistribute fresh materials throughout the galaxy during their cycle of existence. This is done through and as the consequent of them being the source for the creation of cosmic rays in their galaxies, as this is very much like natural fertilizers production systems of galaxies. Where, the old matters give its energy in an indirect way, for the existing other planets, to keep them healthy and for them to receive sustenance from their galaxy.

Black Holes in the universe are nothing but the centre for collection and re-cycle waste bin of cosmic debris of different sizes, this being giant meteoroids to specs of cosmic dust.

As the black hole grows bigger and their gravitational forces take over, then a Black Hole becomes a predator for parts of this galaxy. They become vast eating machines of the debris and stars and planets and this is exactly what is to be expected of them.

The Black Hole is originally created totally by chance. There are no patterns in their creation. They are simply a creation or an outcome of natural interaction between two or more passive magnetic fields or matters in motion within the galaxy or the universe.

Creation of the Black Hole

To explain the concept of creation of black holes, phenomenon's that are normal and familiar are used and will be relied upon in this paper. Then a parallel for the creation of the Black Hole type of incidents will be drawn with the same process in the solar systems, galaxies and universe.

Black Holes are created according to the rules of physics in galaxies to collect and then replenish the galaxies with fresh recycled materials, where this recycling is the vital factor in sustaining and making sure that as the galaxy moves that there are new materials available to start new systems within the galaxies. At the same time for them to nourish the other planets within the galaxy with fresh supply of materials. Where, for example the Earth receives several thousands of tons of cosmic dust from the solar system through the similar method through its atmosphere per year from the black hole within its galaxy and from the universe.

The parallel similarities between the Black Hole and presentation of new material in the universe and on Earth can be compared to the effect of collision of Earth's tectonic plates. When, two sources of solid materials interact with each other. In the long run stars and planets in the galaxy, as the same with Earth submerged tectonic plates; these become the source of the supply of new materials in the galaxy, similar to, as lava becomes the new continents, or mountains on the Earth.

Let's explain this in the following manner. The continental plates and stars systems are forever on the move, they move slowly, but surly they are on the move. On the Earth, when two or more continental plates move in random manners, over centuries and millions of years, at some point they come on each other's path so as do the stars and their systems, like solar system and others in our galaxy.

When on Earth the two or more continental plates come together. Several things can happen, this happens in galaxies but in a different form too. Where, the continental plates in galaxies are replaced by cosmic spherical or flat oval magnetic fields of the stars or systems.

The next steps in the procedure are very familiar on Earth as the continental plates push against each other, if, they are of similar strength, they rise together to create the mountains over millions of years as these plates are still pushing and moving while they are exerting their strength on each other. So, large mountain ranges on the surface of planets are created.

Other things can happen too and that is if, one of the continental plates has weaker energy strength the weaker plate will slide under the other, where the continental plate which sub-merges in the long run becomes the material in the lower levels inside the planet, which later this becomes the base material for the magma of the planet, then over millions of years this matter again appears on the surface of the Earth through volcanic eruption. Then some times in the future these too become the source of materials for new continents or an island and so on through volcanic eruptions.

The material drawn into centre of the planet does not disappear but for the time being is hidden from the view and parallel to this scenario happens in the galaxies, when two or more systems in the galaxy reach each other, where an area in the space is created that the two passive magnetic fields and or entities have to interact with each other. Where, their passive magnetic fields push against each other like continental plates (Fig. 27).

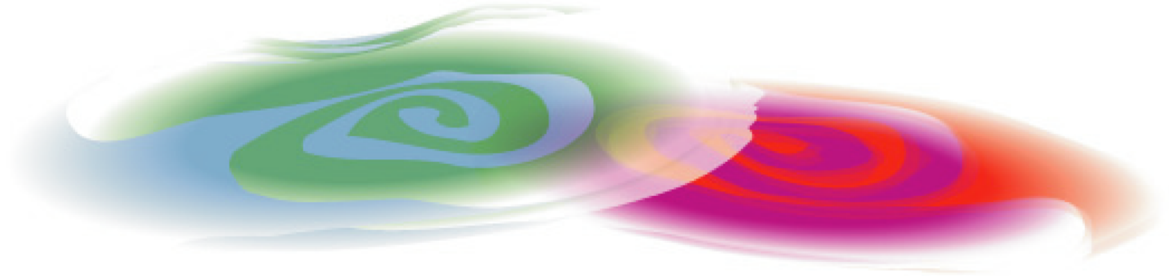

Fig. 27. Plasma of passive magnetic fields pushing each other creating
a balanced magnetic field region, called Black Hole

As they are on a collision path with each other and as at the same time the surrounding systems forces are pushing for their position, they do not allow any other course of motion but path of the collision of the two systems on the move. Then, a point is reached that as there are solid materials in motion from both systems and they have no choice but to collide and interact with each other. Where, in this process being thrown at each other by their systems, pieces of inter-planetary garbage, parts of moons or meteoroids and other bits of the two systems in this region are in the same pot too and all are mixed up and get entangled with each other.

In this area and at the same time as the two systems physical materials are pushed and thrown at each other, so do their mafs and passive magnetic fields are exerting their powers and authority too as in the like of in the planetary the hidden forces pushing the continental plates into each other. Then a point is reached, where these two magnetic force fields' of the two set of entities forces become to near enough to cancel each other out and create a condition of magnetic field equilibrium, where one field force cannot dominate the other passive magnetic field force, and inevitably an area of no or very week passive magnetic fields force in this region of the universe is established, where during all this processes materials from both systems are still being pile-up in this part of space. Where, the two systems materials are brought together due to pure forces of the Passive Magnetic Field forces of the systems and their surrounding systems in the galaxy.

Even stars themselves in the latter stages of the development of the Black Hole could become the victims of the Black Hole, which their system themselves were partially the cause of creation of. At this point the new mass of the Black Hole may even be a larger mass than any of the individual systems that created the Black Hole in the first instance.

One cannot forget that these masses are still in motion and rotating at very high speeds.

This new mass in the centre of this is pile all together creates a very large gravitational force within its region due to sheer weight of the mass which is collected and primarily these could become inertial pull rather than gravitational pull of the matter in these Black Holes too.

By laws of physics, one knows that the only reason that stars shine or cosmic rays glow is the phenomenon of the motion of charged particles passing through a magnetic field. In this region where the magnetic fields are very weak, this region lacks the main component that could make it shine or to be bright and that is the lack of the passive magnetic field in this region, due to the equilibrium and / or cancelling out of the two interacting magnetic field forces of the two systems.

Or for a time in the motion of the two magnetic fields of the systems passing each other in some parts there are no or there will be very little magnetic field force available, even thou there are charged particles in the area, but there are no magnetic fields strong enough for them to interact with to create the visible light. Consequently, in these areas of galaxy there are No glows and No shine.

Reason why this is called the Black Hole, is due to the fact that in these parts of the galaxy, which two or matters and their magnetic fields meet and interact, and can balance each other out, there will be very little visible light emission due to the lack of interaction between charge particles and non-existence of magnetic fields or existence of weak magnetic fields, that cannot produce bright light enough to be visible from the Earth.

This is the reason, why if one look's at these areas of the galaxy these areas seem to be darker compared to their surrounding areas, as the light not only is emitted from the mass of the black hole, but at the same time these matters due to their physical dimensions and their magnetic fields forces strength will not allow and block lights coming from other sources behind them in the galaxy too.

This is why, these regions of the space seem to be black, but from an outsider point of view looking over the area it looks as everything and all materials are thrown in to this dark spot from one side and nothing is coming out of the same side and consequently the physical term of The BLACK HOLE was invented.

This area appears as to be a Dark part of the universe, but in reality some rays of light should be observed being produced in this zone, as some charged particles still interact with the some weak PMF of the systems or what is left of them before they enter and interact and in this part of the galaxy there are visible light but matters are disappearing too.

So, in this region of the galaxy astronomers observe a large gravitational force due to the large amount of mass thrown in to this area by the two systems as they pass each other. But, they have no explanation as what is happening to all this mass. Now one understands the reason for this false assumption and appearance. This is the region where the gravitational forces are in reality mixture of gravity and inertia pull of two systems.

One has to remember that as these two or more systems are passing each other, several scenarios can happen again, which every one of these will have and has drastic and profound effect in that region of the galaxy. Where, at the same time these events can generate a vast amount of new recycled material for other entities within the galaxy.

At the same time one has to take into account the time factor and that one is dealing with a three dimensional picture, as in some cases the Black Hole exists for millions of years during the crossing of the two systems crossing each other's path at a slow speeds. The truth is that the Black Holes are a temporally condition, so to speak, in the bigger picture of cycle of the life of a galaxy, but they surly look like being there forever.

Some of the residual of these interactions will be some cosmic rays (10) or the outcome could be the birth of a new system with a new mass from the mixture of the masses of the two old systems after the system parameters balances each other out. In this case the overall masses of elements within the black hole are present as they were in their original systems. Where, now the new Black Hole could possess slightly less than the combined mass of two old systems. With lose of the some of its matter in the process of the interaction of the two systems into the galaxy.

One cannot forget that the centre mass of the Black Hole is still rotating most probably in the same direction as the systems were rotating which created it. At the same time, as the centre mass is void of the Passive Magnetic Field (PMF), the usual interaction between the passive magnetic force and gravitational force do not take place that usually creates the first basses of heating and sustaining that heat, so that the temperature gradient could take hold, that this in turn could create the scenario conditions for the mass to become a large star or a system.
So that the centre mass have enough material but not the right condition to create the necessary heat, for the time being to make the jump to become the source for a new system or a new star in possession of gravitational forces.
This is one of the ways that the Black Holes become the creator of new stars and systems. Therefore the mass relies upon the heat that is produced mainly by the natural friction of the elements pilling on top of each other in the centre of the black hole.

But at the same time these places become the centre of the mafs of principal matters of the entities within the collision zone. Where at this point the principal mafs and matters of the constituent matters within the collision can take hole and star t the process of creation of the principal star with its strong magnetic and gravitational field forces, which this condition can lead to creation of principal star and hence through realises of mafs of at principal level and through its slowing down and through production of transition mafs, these parts of the universe can again appear to be dark than the rest of their immediate surroundings, and hence the creation of balance mafs of created and the surrounding environment field, then again due to lack of creation of interaction sufficient to create mafs at the mafs of visible light, then these areas of the universe again look darker than the neighbouring regions, and as the centre of this region is covered with the seed of principal mafs and matters then one observes the strong pull of matters to this region without being able to see its origin which is the principal star in the centre of the dark zone.

These interactions between passive magnetic fields occur on regular basses in our galaxy, as systems are at all times on the move in a confined space of their Galaxies and if one had enough time to look out into the space, one will observe the creation of so called black hole the way one observes passing of dark clouds in the sky of the earth during stormy times.

The motions in this specific part of galaxy are in progress over thousands of years, the Black Hole's due to other systems magnetic fields surrounding it and their influence and interface with passive magnetic fields of these systems making and allowing the black hole to leak cosmic rays into the galaxy like a fountain in its surrounding area.

Then it should be understandable now that why the scientific world finds materials from the Universe that is not nor have not the same age as the original component of the galaxy. As like supernovas, the Black Holes are the source of the new material for the galaxy primarily because of the way they are created and the way their life cycle finishes.

The other scenario of the interaction of the two systems could be totally different with an interesting outcome. This is the most horrendous way that the two systems could come into contact with each other and in this case as the two magnetic fields come too close to each other, at the same time other systems around them push these Passive Magnetic Fields themselves together.

The two fields interact and the first stage of creation of the Black Hole is reached very rapidly, but as the two systems surrender more and more of their debris and planets to the Black Hole, the central mass of the Black Hole increases and as the Black Hole is receiving its contents from two different systems simultaneously, then a point reached that the weight and the gravitational force of the new centre mass of the Black Hole super-passes the mass weight of one of the systems, which created it in the first place.

Systems which have already lost some of their mass to the Black Hole at the outset of the creation of it, now losses control of its magnetic fields too. To an outsider looking at this event, it seems as the Black Hole is consuming everything around it. Where, this process can take over thousands of years, until a temperature gradient or a dynamic principal mafs and matters of in the centre of the mass is established.

As the centre mass of the Black Hole has consumed the entirety of two systems, and it is operating in a no magnetic field zone for a period of time, where its internal dynamic plasmatic magnetic field cannot pass its physical boundary (see the paper "The creation of dark matter" M T Keshe for clarity), the system will still can absorb or attract other masses from its surrounding into itself.

In this scenario, if mafs and materials are held for long enough time within the centre mass! That new magnetic field force could be produced and maintained, where at this moment of its life cycle this giant of a mass of the Black Hole will be nothing but a huge Gravity and Magnetic field producing machine. Where, by the end of this process a new system or several systems will come to be born and new materials will be scattered in the galaxy, and this Black Hole will be a Dark place but not necessarily cold.

If the centre mass during its creation does not manage to heat up, then the third phase of the Black Hole syndrome takes hold. This being that, the centre mass at this stage becomes so big and as it never had a chance to heat up due to total absence or lack of strong magnetic force at the same time where the new large centre of the mass is rotating, this new mass will be inherits a huge natural inertia force from its collective mass with no or little magnetic field beyond its physical boundary to keep it at bay, so, this massive large body will start pulling smaller objects near to it into its trap.

The same phenomenon applies when two galaxies come to pass each other's path too, with the most horrendous outcome for the galaxies in that part of the cosmos, where the outcome of such encounter is beyond imagination. This has happened before and astronomers forecast it for The Milky Way galaxy in the future as it passes the nearest galaxy to it in the next few billion years. Where, the surrounding areas near the newly created Black Hole will not be safe from the onslaught as this new mass at all time of its existence has the same fundamental problem as of all other systems, and that it tries to hold onto all its elements. At the same time like other systems the lighter elements and weaker mafs in the mass move to the outer layers and to the edges of the mass.

Where, weaker mafs as lighter gasses and particles move to the outer region of the mass, they become better candidates for them to be pulled away from the centre mass by any opening in the adjacent Magravs systems near to the Black hole. When the centre mass reaches a point that Magravs or its inertia force become weak on its edges, that lighter elements can manage to loosen themselves and escape from its grip into the space of its neighbouring environment.

These freed elements will become part of matter that can be attracted by adjacent systems to the black hole or due to the rapid motion of the Black hole released as cosmic dust in the galaxy. Therefore objects can and do leak out of the Black holes into their respective galaxy even during the time of their creation.

If these elements are pulled out of the power of the centre mass, through the strength or gap in the adjacent systems or weakness in the power of the black hole, then they become the cosmic rays this being due to the fact that during extraction most atoms get striped of their electrons, and some heavier atoms in this scenario lose their electrons in the same way and so they appear as plasma and as part of the cosmic dust in the galaxy too. Black Holes are the source of most of cosmic rays and dust in the galaxies due to this effect (10).

In the galaxies Black Hole's while are in process of being created and during their existence at all times are still surrounded by other systems and are under the influence of their Magravs.

The powers of these Black Holes are usually kept at bay by other systems around them with their larger magnetic field forces and gravitational forces, which the black hole is still encapsulate amongst.

Black Holes are normally observed close to the centre of the galaxies and the universe, as there are more systems clustered together in these regions as this increases the chances of different systems to come in the path of each other and in turn increasing the chance of the collision of solar systems in the and galaxies in the universe and hence increase in the chance of the creation of numbers of the Black Holes.

The stronger mafs and the heavier elements of the universe and galaxies are largely concentrated in and near the centre of these entities, thus the passive magnetic fields and gravitational forces of the systems in these central regions are many times more powerful near the centre of galaxies then what is experience in the outer edges of them.

Consequently, the gravitational forces and passive magnetic forces in the centre regions of the galaxy will soon bring and keep the size and the power of these giants Black Holes under control.

What these collisions of systems and creation of Black Holes achieve is the fundamental principle of regeneration of new systems out of the old matters, and at the same time unclogging of the galaxy of all the loose debris.

If one looks at a three dimensional overview of these areas in space, surely due to the movement of stars and planets and the interaction of their forces, one should be able to predict, where the next Black Hole in that part of galaxy could be produced.

In time, a point will be reached, where the passive magnetic fields systems in one of the immediate systems' neighbours to the Black hole will move on, and at this point the feeding frenzy of the Black Hole will come to an end.

Like volcanic eruptions on Earth, where the mantle is thin enough that pressure of the lava can takeover, and that it can to pure out, pushing its way out into the atmosphere as a volcanic eruption.

This is exactly what happens when one of the passive magnetic fields in this area moves or weakens.

This creates a gap in the fields containing and controlling the black hole parameters, where the materials in the centre of the Black hole, which has been pushed previously into the Black Hole from one direction, for these materials to be released or scattered in to the galaxy.

In this process, part of these materials will manage to cluster together and generate the conditions essential for creation of one or more systems or stars.

Where the rest of the materials of the centre mass of the black hole becomes cosmic dusts, some become comets and some become cosmic rays and so on.

Thus Black holes are not gigantic eating machines compared to the size of their galaxy. In reality, they are nothing but a temporary condition created in the galaxies due to movement of plasmatic magnetic field systems as they are crossing each other.

Very much like two masses of clouds crossing each other path colliding with each other. Where, this interaction of clouds upon each other creates abnormal conditions in that area of the planet, where, their thickness can block the rays of the Sun behind them and the sky looks darker, but in reality these are temporary conditions for the viewer from Earth.

Contrary to common belief, Black holes always release matters and release new recycled material into their surroundings; they are not bottomless pits, where everything disappears into them. They are like a funnel, that if one looks at one end it seems that they are taking everything in, but exactly like a funnel, they have a hole on the other end, that what goes in has to come out, with a difference that the end of this funnel is connected to a kitchen-waste unit of the universe, where that on one end it crunches everything up and mixes whatever goes in before spewing the waste out through the waste pipe.

So the behaviour of the Black Hole is very much dependent on the position of the observer. If one looks from one end they are massive eating machines and from the other end they are the supplier and feeder of new life in the Galaxy.

In real term this dark part of the galaxy is at all times emitting electromagnetic waves of varying levels and strength from all the activities which is happing within, around and because of it. Black holes can easily be identified in their environment and their position can clearly be pinpointed by using much simpler method of detection than by just guessing and look for their effects in a given region of the universe.

In principle the Black hole has all the attribute of any system, but in fact as the internal plasmatic magnetic energy field of the systems creating it, in the given region of the galaxy, cannot create outward plasmatic magnetic energy field, that can interact with other plasmatic magnetic energy fields in its immediate given environment, for it to create outward visible magnetosphere at boundary of the black hole to manifest itself as a visible space in its region, this leads to creation of lack visible light in the man’s Magravs amino-acids matter mafs strength.

The phenomenon of Black Hole occurs on the continuous bases on the surface of stars of any Solar system. The principle of the creation of Black hole happens on a smaller scale on the surface of the Sun in the solar system, where these are called the Dark Spots of the Sun.

These are where dynamic plasmatic magnetic fields systems on the surface of the Sun go through the same cycle of interaction of fields with each other as it happens for the creation of the Black Hole in the galaxies, where these plasmatic magnetic fields come across each other in the atmosphere and on the surface of the Sun, consequently they have to interact or pass each other, with the difference that these plasmatic magnetic fields systems on the surface of the Sun, even thou they are so powerful, they in one way or other meet-up with each other, and as their energies have to interact, then sometimes these energies cancel each other out and reach a balance magnetic energy condition.

At these points then, the same cycle as the creation of a Black Hole, on the surface of the Sun in much smaller scale repeats itself as there are no magnetic fields interaction because of similarities and identical mafs strength of the interacting fields, then there very little friction of fields that residual fields in the strength of the man's mafs of amino-acid strength are released, and hence or a very little light in the region and hence the appearance of the Dark Spots on the surface on the Sun is observed. In some instances the same is created as there are no interactions or balanced pmfs strength of the matters and mafs between the charged particles and mafs from the surface temporally are produced and consequently there is no or very little emission of light from the surface of the Sun in these regions.

On the surface of the Sun the same scenario of retraction and absorption of matter as the of the Black Hole starts occurs with a slight variation, which in this case the gravitational fields force of the Sun is so powerful and very close by that as the gravitational forces of the Sun are (in proportion) many times stronger than the gravitational force of the particles captured within the Dark spot region on its surface, that once the magnetic fields have interacted their energies and the content within the catchments of their forces have reached the equilibrium level, then the mass of particles in these regions are sometimes pulled back inward onto the surface of the Sun instantaneously after the collapse magnetic fields which created the dark spot regions, then at this point the physical matter of plasma in this region of the dark spot are pulled back into and is literally missile back into the liquid surface of the Sun, this creating a secondary dispersion of matter in the atmosphere of the Sun and into the solar system and hence the increase in the Sun flairs during the creation and as sequence of the collapse of dark spots on the surface of the Sun.

In reality the persona of dark spot is created mainly through interaction of mafs fields of the Sun and these are created very high above the surface of the Sun, that the dark image observed is not in reality mainly on the surface but much further up in the atmosphere above the real solid surface of the Sun.

In other instances as the plasmatic magnetic energy fields interact to create the Dark spot, the surface tension of the Dark spot becomes weaker on its face away from the Sun and all sorts of mafs and matters in the full spectrum mafs of the universe directly gets ejected into the solar system with much more power and matter then normal dispersion.

Once the temporally condition of creation of dark spot of the Sun is created, By this time, most of the other plasmatic magnetic fields of the Sun physically push and cajole the plasmatic passive magnetic fields (PMF) that created the Dark spot, so that, these external forces in the surrounding environment of the dark spot move and shift them from their position, where by this movement there are no more active plasmatic magnetic fields in the region to interact with each other in these regions and then the normal process of the charged particles interacting with the plasmatic magnetic fields around them start again as before, then everything goes back to normal and the light or the shine on the surface of the Sun returns to normality.

When too many dynamic plasmatic magnetic energy fields start cancelling each other out, the surface of the Sun become congested with many different plasmatic magnetic energy fields and they clog up the surface of the Sun, like congestion in traffic jams, hence the number of the Dark Spots starts increasing.

It is important to remember that Objects (these being solid, gas, plasmas or etc.) possesses their own plasmatic magnetic energy field and all these plasmatic magnetic energy fields on the surface are dynamic and respond to other dynamic plasmatic magnetic energy fields, which are created internally in the inner cores of the star. Where, these internal magnetic fields are the creators' of the gravitational field and the overall magnetic field of the star itself. Where, The stronger plasmatic magnetic energy field (the gravitational field) usually dictates and plays apart in the position and level of freedom of the weaker plasmatic magnetic energy field (the object) in respective to each other.

Thus, when the inner cores of the stars due to their near mono atomic structure go through their internal current realignment (12, 18) this in turn leads to change in the direction of the gravitational field and thus the polarity of the whole star.

Consequently the rotation of the gravitational field which itself is originated and created magnetically interacts with the dynamic plasmatic magnetic energy field areas on its surface and in its atmosphere causing them to move in respect to the internal dynamic plasmatic magnetic energy field movements of the star.

Therefore main reason for sudden periodic increase in the movement of the plasmatic magnetic energy field on the surface of the star and sudden increase in the creation of black spot in their environment can be clearly be identified, to be due to the interaction of the dynamic plasmatic magnetic field created by the matters and mafs on the surface and the inner Magravs fields force of the stars.

Where, the inner dynamic plasmatic magnetic field of the star is by order of magnitude several millions of times much stronger than the isolated single or packages of dynamic plasmatic magnetic fields on the surface. Thus the stronger inner fields force of the star, dictating the direction of the motion of the weaker fields of the Dark spot. This being the very reason why the eleven-year cycle of change of polarity of the Sun brings about an increase in the number of the Dark spots of the surface on the Sun on regular bases. This being due to Sun's internal plasmatic magnetic energy fields' changes which brings about the polarity changes, every eleven years. Where, at these cycles there are more of these surface and atmospheric dynamic plasmatic magnetic energy fields in motion and available to interact with each other and the internal mafs of the Sun.

In fact, as the polarities of the Sun changes, so more dynamic plasmatic magnetic fields start moving from one pole to the other to accommodate the physical practicality of the plasmatic magnetic energy field polar change. Thus, a larger number of the dynamic plasmatic magnetic fields become to cross each other's path and consequently there are more chances of two or more dynamic plasmatic magnetic fields to meet and to balance out each other's field. Inevitably, as at these areas, there are no effective plasmatic magnetic energy fields for the charged matter to interact with, thus there is less light emission from these areas of the Sun. Henceforth the appearance of darker areas or dark spots in these areas on the same principle as the creation of the Black Hole phenomenon re-occurrence.

The increase in the number of dark spots of the surface of the Sun is always in sequence with the period when the Sun internal dynamic plasmatic magnetic fields activities go through their repositioning.

The number of these Dark spots increases and as they move, suddenly a vast number of dynamic plasmatic magnetic fields cancel each other out and as the change of polarity of the Sun completes itself and settles down.

The whole cycle of collapse of the Black hole re-occurs', that is, where a Dark Spot collapses, and their new plasmatic magnetic energy fields fines its total balance, and the matters which where gravitationally trapped under the influence of the dark spots, which are mainly plasmas, are retracted by the gravitational pull of the star and are ejected back onto the surface of the Sun is large quantities and numbers. This is the time, where there are massive activities and strong Sun flares scattering outwards from the surface of the Sun, where, large quantities of the Sun matters are plashed outward in the solar system.

Sometimes, as the mass of particles collected in a Dark Spot is pulled back into the surface of the Sun, due to their mass and speed, these become like meteorites hitting the surface of the Sun. This act causes more than usual charged particles to be leaving the Sun surface into surrounding space.

The darkness on the surface of the Sun is not due to what is commonly thought to be due to cooler temperature in these regions, as the Dark Spots are purely due to the fact that there are no or very little dynamic plasmatic magnetic fields available in these regions to interact with the charged particles to create light.

So underneath the Dark Spots on the surface of the Sun the temperature of the surface is still the same as the rest of its surface.

Conclusions

Black holes are natural physical by-products of the motion of forces and matters like every other object in the universe. The only difference for this body to appear is the fundamental shortage or total lack of one of the three main ingredients of the creation, namely the lack of the Passive Magnetic Force Fields in the region, where these black holes manifest themselves.

Black holes are another creation of universe like the uniqueness of the Blue planet and once one has understood the methods of universe's powers of creation within all its physical parameters, then every aspect of the appearance of objects and fields can only be explained with understanding of the interactions of these with each other.

The most beautiful part of this phenomenon will be! How Man will use this knowledge now for the advancement of its race?

Understanding of the method of creation, existence and the behaviour of the Black Hole in space opens new doors for the Man to plan his future excursions in space and the appropriate name for this object should not be a Black Hole.

These regions of Black hole in the galaxies cover areas as large as several solar systems, with them possessing all the physical attribute of solar system. With the difference that they do not shine due to the lack of appropriate dynamic plasmatic magnetic fields strength within their construction or during the time of their existence in the environment of their operation.

The appropriate name for this object as has one body and two distinctive characterizes behaviours and appearance, by first characteristic being a gigantic eating machine, and the second characteristic by allowing new systems to start from what it has digested. There is an old Aryan name for an arrow with two heads as the Black Hole with two characters and this object is called ZHUBEEN.

I call this unpredictable object in the galaxy with this name, as now it is a known object and not a mysterious scientific phenomenon.

Elaborations

The helio-seismology is the study of the internal structure and dynamic of the Sun using Sun-quakes, and the Sun oscillates continuously by varying degrees and directions. These oscillations are caused mainly by turbulent convection just below the surface. The data from spherical-symmetrical solar model of the same condition shows close correlation to physical collected data through inversion. This showing that the data simulation is close to the physical reality of what is happening in the inner sanctum of the Sun.

For our testes in dynamic cores and data's attained through them, it can be confirmed that the rotation and the turbulence have direct effect on the heating of the matter within the confined of the reactor build on the same principles, where in the reactor and consequently in the creation of the current through convection and magnetic fields production within it, where the turbulence of the matter in the core of the reactor creates the dynamic and the dynamo effects which this has a direct effect in and on the production of the dynamic plasmatic magnetic field in the reactor.

Turbulent convection and differential rotation in the Sun are thought to be the cause of the creation of the solar magnetic fields and the directions in which these magnetic fields appear to flow out of the surface of the Sun according to their direction of rotation their tightness are known as helicity of the magnetic field in the region. Where, Helicity simply describes the handedness of this field and as the field literally opens up like a cone as it moves away from the centre towards outer region. As Magnetic and Magravs helicity is in fact a measure of the knottiness and the twistedness of these fields within a region, where this closely related to the turbulent dynamo effect. Where, from all observation in the past, large-scale poloidal magnetic fields the helicity have a direct linkage with strong toroidal field leading to finite helicity.

As, in the reactor tested on the same bases as turbulence of the mafs of matters where the reactor cores having a finite parameters and the rotation and turbulence are predetermined, therefore the helicity of the magnetic fields has to be the same at different points but equal for all distance from the centre. Where, due to the small size of the core, a mean or average strength or tightness of the magnetic field could be assumed.

Thus a point of interaction of two magnetic forces in the cores will create condition similar to the dark spot on the surface of the plasma. Which if the collapse can go through plasma towards the boundary of the core, this can create a sudden surge of dynamic plasmatic magnetic field or which this can alter the system operation mode. The reason for writing this paper has been due to the fact that in the reactor designed, if the condition of Black Hole is created, this can lead to the shutdown of the system or unstable condition of the operation of reactor. As this has happened in two occasions during testing of the spherical core, where the second magnetic field was deliberately created and positioned to interact with the internal magnetic field created by the core.

In both cases the whole system did go through magnetic poles trying to bypass each other.

In the second test in trying to prove the point of the interaction of two magnetic fields and creation of black hole condition, the whole system was twisted and the axial pines of the core were off centred.

The core axels had to be realigned, but the damage to the core weld and axel proven to be too much to repair, and more or less this test of creation of black holes caused the loss of the first steel prototype core (Fig. 28).

At the same time in the same reactor the creation of the dark spots due to interaction of the matters were deliberately created for specific use of the system, where investigation in the creation of dark spots, and where the use of transition matter condition for the creation of dark matter, for the fuel needed for deep space travel was tested and confirmed.

This is how these above phenomenons clearly can be explained, and the principle for the creation of the Black Hole can easily be demonstrated.

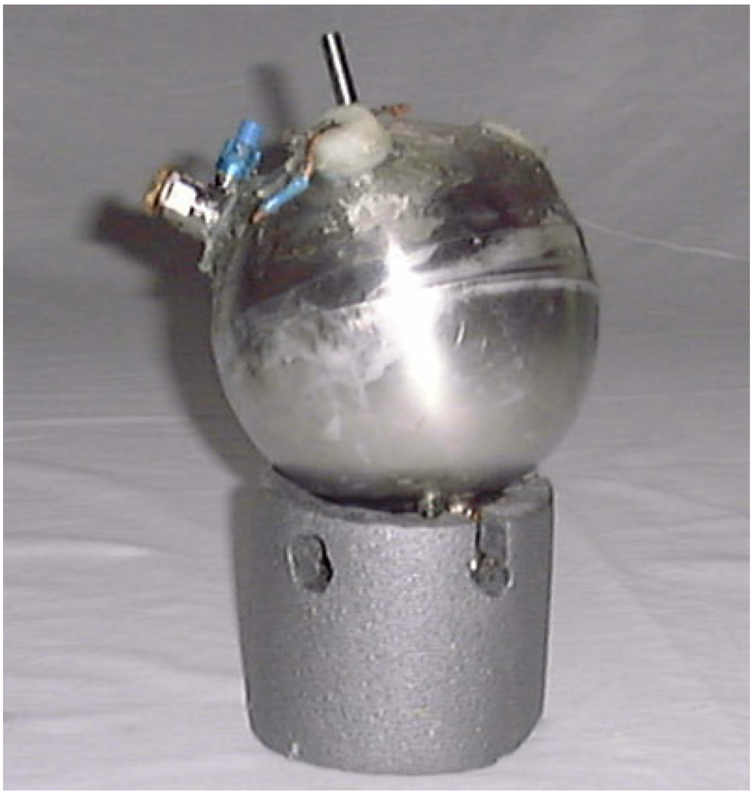

Fig. 28 Test reactor

In the future papers the writer will explain how the Black Hole's effects can be useful in helping to travel through galaxies and in the Universe. These are at this moment of time beyond understanding at the present level of scientific achievements.

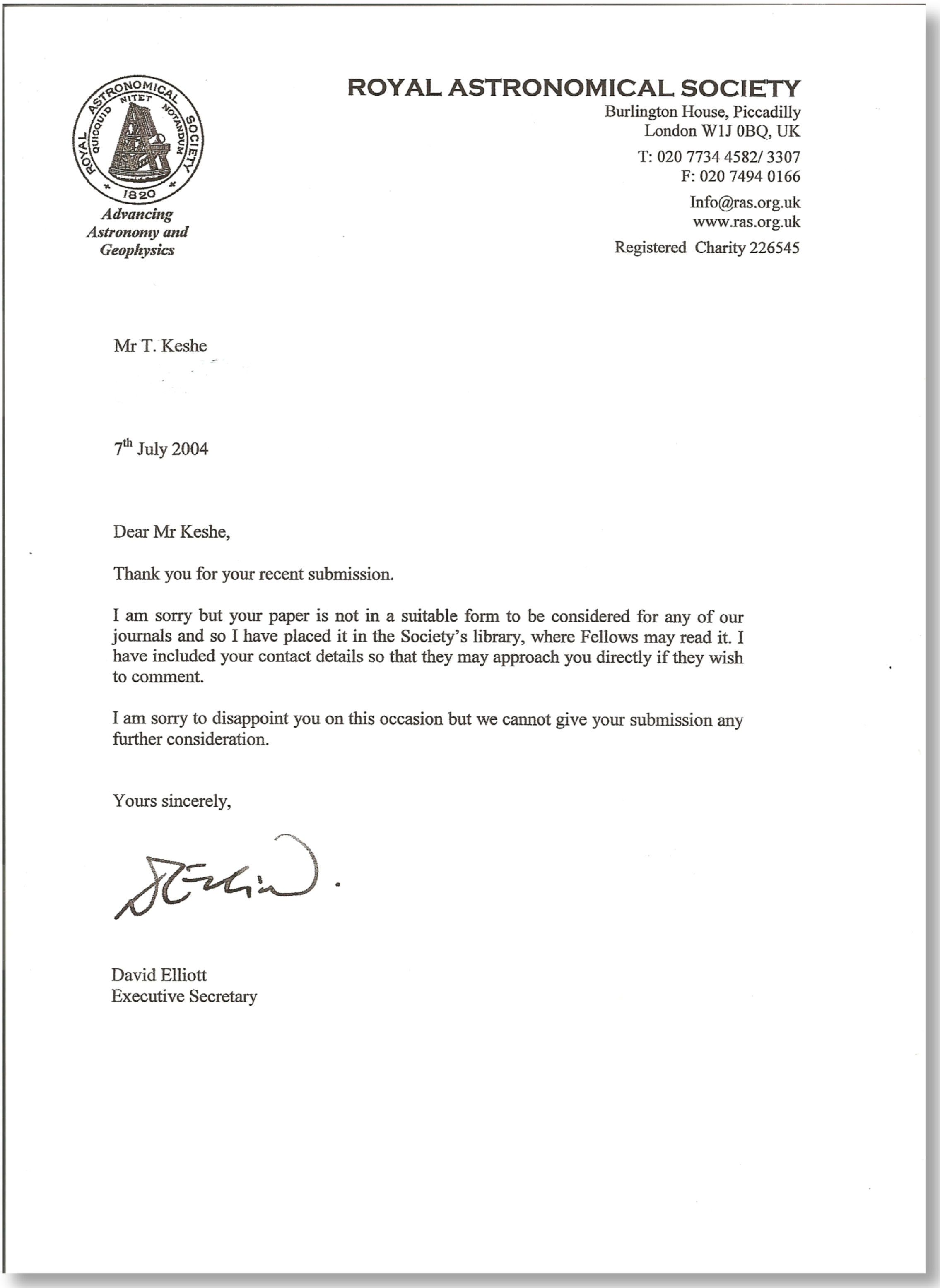

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Mr T. Keshe

7th July 2004

Dear Mr Keshe,

Thank you for your recent submission.

I am sorry but your paper is not in a suitable form to be considered for any of our journals and so I have placed it in the Society's library, where Fellows may read it. I have included your contact details so that they may approach you directly if they wish to comment.

I am sorry to disappoint you on this occasion but we cannot give your submission any further consideration.

Yours sincerely,

David Elliott
Executive Secretary

Fig. 29 . Letter of Royal Astronomical Society

CHAPTER 11

The relationship between gravity, mass and weight

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Author: Ing. Mehran Tavakoli Keshe
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This paper is written for clarification by the encouragement from Mr Dirk Laureyssens.

Abstract

With the new understanding of the creation of the double dynamic plasmatic magnetic field of planets and understanding the new principle and method of the creation of gravitational forces, further on the balanced fields outcome of the collective and internal interaction of Magnetic and gravitational fields up on each other of any entity within the structure of mafs, plasmas, atoms or molecules this leads to creation of so called the mass effect of an object, it is now simple and apparent that what the mass is, how it is created and why the same mass possess different weights in different gravitational field forces environment.

Hypothesis

The mass of an entity is created from the outcome of the deduction of the interaction of the gravitational fields and Magnetic fields forces of an entity and has nothing to do with external field's interaction and strength of the environment of that entity. The variation in the numerical difference in the weight of the same mass of an object in different dynamic plasmatic Magravs field forces of different environments or different planets, is totally due to the interaction of the total collective dynamic plasmatic Magravs fields forces, including the inertia effect of the environment which the entity is weight measured and of the collective internal dynamic plasmatic Magravs fields strength of the mafs of the entity which create the mass of the objects upon each other.

Where, the magnetosphere of the same entity is the total sum of the magnetic field and gravitational field forces catchments zone of the same two internal fields which make the Mangroves fields of the entity that they can attain in their given Magravs fields strength environment.

Discussion

Planet like the Earth possesses a combination of two magnetic field forces. First the gravity, created due to the interaction of the two independent dynamic plasmatic magnetic fields in its centre cores upon each other. Second the inertia, which is the collective dynamic plasmatic magnetic field of its atoms and molecules of its constituent matters, which has the physical body of the planet.

Any object, this being plasma, an electron, an atom, a molecule or even a human body is created from a collection of the plasmatic magnetic Magravs energy fields of different strength and their continues interaction between and up on each other, which in total decides the total or collective magnetic field possessed by that object or the mass of an object and the total interaction within molecular or atomic dynamic plasmatic magnetic field of a given object is always constant irrespective of the other dynamic plasmatic magnetic field fields around it. The mass of an object has a collective package of plasmatic magnetic field tightness of all its constituent elements, and this will not change as long as the object is intact as one entity in its overall atomic or molecular or collective molecular appearance.

Which the interaction of the one object dynamic plasmatic magnetic fields with molecular or atomic magnetic field of another object Magravs in its vicinity or it environment will determine the weight of the two objects in respect to each other or in a given environment.

The mass of a body in relation to another molecular magnetic field, like gravity is dictated by the strength of the magnetic fields which creates the gravity, which in the planetary system like earth, this is maintained by the planet according to its inner molecular construction and conditions in and by which the Magravs strength of the planet manifest itself to the body.

The interaction between two or more dynamic plasmatic magnetic fields created by a planet to create and determine the gravitational strength of the planet are due to conditions and in conjunction with its elements.

Usually these types magnetic fields created by planets are very strong, so an object like a human body which possess a weaker collective dynamic plasmatic Magravs and in reality possesses its own gravitational field forces due to its combined electromagnetic fields of its elements which it is composed of, which for a given body this is constant, these will be attracted and be operating in a much more stronger dynamic plasmatic magnetic field environment of the planet. Which, this gives the body due to its interaction of the Magravs and the planet dynamic plasmatic Magravs interaction, where the strength of the Magravs force of the planet and the body in respect to each other, this determines the attraction force between the two fields of two entities of the body and the planet and consequently the mass of the weaker force or the object in respected to and within the stronger Magravs forces of planet or Magravs forces of the body dictated the weight of the body in respect to the planet.

In reality the reverse of the same criterion is true too, for the mass of the planet, and its weight in respect to the dynamic plasmatic magnetic field of the body.

Thus, it is easy to explain, when a body interacts with two planets of the same size and when the two planets are made of the same materials, where one for example has lower temperatures, or internal speed of rotation or lower rate of ionization of the prime materials within its Caroline core, which all these can affect the strength of the Magravs of the planet for it to possess a weaker dynamic plasmatic Magravs strength, then planet which has a more inertia power, which is of the weakest order than gravity, but always constant, for a planets like moons, then the magnetic attraction, or pulling, between the same object and the second

Magravs force will be weaker, this by the same principle as above giving the body in the second environment a lesser weight value.

This is the very essence, why man's body appears to have less mass on the moon than on the Earth. Where, this is simply due to the fact that the dynamic plasmatic Magravs of the moon, which creates its gravitational force, and even this could be the inertia effect of the moon, have weaker Magravs strength power to interact with same given human body's dynamic plasmatic Magravs than the Earth dynamic plasmatic Magravs strength on the same body.

Therefore, the weight of a body is position dependent in its relation to its counter interacting planet or object inner Magravs forces, which create the Magravs or/and the inertia, or static Magravs of atones of that planet.

That is to say, if one could replicate the same Magravs field as on the moon, within a given position in the Earth atmosphere, one will have the same weight as the body will have on the moon within the Magravs force of the Earth.

This is why in propulsion technology there is an absents of the Magravs within the system objects always float and have less mass, as first of all the propulsion systems do not create Magravs that the object can position itself in respective to and lock to the position that the object become motionally stable and this and the secondly for example in respect to the body of space users of the propulsion system, the body's collective dynamic plasmatic Magravs strength, has been positioned far enough away from and within the dynamic plasmatic - Magravs strength of the Earth, that the mass dynamic plasmatic magnetic field strength of body in that position within the Earth gravitational field, due to the speed of the rotation or motion and conditions created within of the craft, will have a weaker interaction upon the body, allow the body a more freedom of movement.

Using the principle of the Margrave positioning for vertical take-off or choosing stationery or fixed position orbit for an object, like for satellites, within any atmospheric condition, where the magnetic fields created within the reactor of a craft can lead to creation and control of the Magravs within the craft, allowing the mass of the body of the object in a given position within the atmosphere of the planet to reach the equilibrium in relation to the Magravs of the planet, then in that particular point within the fields that are created by the planet the body will have the same mass as the earth and the time delay lapse of free float satellites to tune with earth gravity become irrelevant and there will not be a need time delay or adjustment.

This is the fundamental principle and criterion for any system that is used in any spacecraft's technology to replace the present jet propulsion or rocket technology.

Therefore the mass of an object is the representation of the effect of the Magravs of a body in respect to the Magravs of the second body.

The Magravs positioning is the reason why atoms of the same element fuse to create molecules, as their weight in respect to each other is zero, or equilibrium, even thou they both possess the same mass.

At the same time, if this is understood in full, then most of the chemical and biological interaction of atoms to create molecules can be comprehended and replicated in an easier manner.

Where, the collective mass of atoms in respect to other atoms within a molecule Magravs will dictate the number of, position of and the composition of atoms of different elements within that molecule.

Then this explains why it is easier to create certain material in absence of gravity in space labs, that in the presence of lesser dynamic plasmatic Magravs strength of the planet in high altitude then only the weaker Magravs forces of the elements come in to play as they are in a much weaker dynamic plasmatic Magravs strength levels from the centre of the planet and they can combine to produce materials, which under Magravs forces of the Earth are impossible.

Conclusion

Therefore the mass of an object possess different numerical weight values in two different Magravs force environments purely due to the interaction of the double dynamic plasmatic magnetic field of the planet and the constant collective dynamic plasmatic Magravs of the object.

The gravity itself is created by the interaction of magnetic fields of the matter and as the mass is the product of interaction of gravitational force and Magnetic fields forces of the same matter magnetic fields based generated phenomenon and as any environment in the universe possess magnetic fields irrespective of their strength and interaction of these fields in that given environment creates a new Magnetic and gravitational fields or Magravs in that environment that the outcome the interaction the two Magravs of the matter and it environment become the weight of the matter in that environment.

That is to say the variation in weight of an object in different environments is totally due to the interaction between the dynamic plasmatic Magravs strength of the two of entities upon each other, in respect to each other's position, in their respective environment.

Where Magnetospheres of the entities are the outcome of the sum of the interaction of Magnetic fields and gravitational fields forces that the entity can master for it to be able to protect and hold on to all its mafs and matters which the difference field forces of the same Magnetic fields and gravitational or Magravs of the same entity has managed to attract and accumulate within its given environment.

In short the interaction of the two or more dynamic plasmatic magnetic fields lead to creation of Magnetic and gravitational field (Magravs) of the entity, and then the balance of interaction of the Magnetic and gravitational fields forces leads to creation of the mass of the same entity which the mass is entirely dependent on the strength of the two original magnetic fields of the entity, and then when the Magravs of entity interact with the Magravs of another entity which itself magnetic fields origin based, then difference or the influence of one Magravs of one entity in respect to the second entity Magravs make the weight of the two entities in respect to each other, where as much as the first entity has weight in respect to the Magravs of the second entity at the same time second entity has a weight in respect to the first entity too.

CHAPTER 12

Parallel worlds

Mysteries of existence about parallel worlds, the questions to ask are or can be as follows:

1. How do they become to exist?
2. How can we interact or be aware of their existence?
3. What can we do or have done to get there?

Let us consider the structure of simplest entity of plasma of an electron in overall structure of let say an atom of hydrogen (or atom of sodium which is part of piece of stone or metal, gas and etc.).

The plasma once created and maintained from interaction and down levelling in strength of different mafs of which this plasma in its division leads to creation of an atom which at this point the plasma of the electron of the atom has an independent existence from plasma of its proton and electron decides about its own motion and its own position in its environment in respect to its proton. Even though, this is conditioned on the position and strength of the proton of its atom. Where, electron itself is made up of collection of different magnetic fields strength and their interactions and as the electron of an atom is not aware of the its larger counterparts of proton(s) and other electron(s) in a larger elemental or molecular structures and it is not aware of any state of matter and at the same time that the electron is not aware of the part of heat and cold in its environment are playing in its position and motion in respect to its proton and other entities of the same which it is connect to.

Where, this electron physical appearance as any physical matter is dependent on its environmental condition. Where, let say this electron can be an electron of atom which is part of atoms of a piece of stone and at this point the electron is not aware of the existence of a stone in larger scale levels of its existence. But the electron exists within the existence of an atom, which the atom exist in existence of the stone.

But now let’s say the stone is parts of a salt stone grain which is consumed by an animal.

Now the sodium atom by making its Magravs available to protein of a cell of the animal it becomes and takes part in the bigger scale and larger Magravs of a protein chain connection, where sodium on its own could not achieve.

Let’s say that now the protein and in conjunction with sodium this creates the condition of neuro-connection and the cell becomes part of living being, this being part of neuro system a shrimp, dog or a man.

Where, for example the combination of different protein and different atoms and the interaction of their Magravs and balancing act within their mangroves lead to need for interaction and new balancing Magravs, where this new interaction of proteins and their different Magravs, leads to a need for cohesive and balancing line of magnetic fields line of transfer of fields. Where, an accumulation of different fields and Magravs and their interaction brings about feelings and intelligence and so forth in the animal.

Now as the different Magravs and their interaction takes place, this being in the level of an atom, a solid, protein, combination of proteins and their attachment to other atoms, these new entities create two distinctive levels of individual compacted fields one for their tangible state of existence and one they facilitates their fields and positioning for the use by and to other parts which are related to them but not connected to their existence in the line of communication of other atoms.

What this means, is that the entity gives life to existence of two levels, one is the physical tangible of itself and one is the fields and energy which it is part of, but once it is created the new entities has enough field that is an accumulation of the interaction of another interaction that this new entity does not need a physical entity to manifest itself in the tangible world, but the fields strength is sufficient enough that the new entity can easily exist on its own right in the universe and make decision about all others whom have become part of and operate through the new entity.

Now as the more and more fields and matters interact and creates a certain fields levels, that let say they lead to tangible matter existence of an entity, the accumulated physical matters have a parallel acuminated non tangible levels too which are its fields which allows it to be part of bigger entity.

Where in complexity of previous interactions to reach a point, these interactions have released or will release new complex fields that these fields perform and exist as the matter part do.

But sometimes the matter and associated fields interlocked, but exists and operate into different levels. Even though the tangible matter is aware of its own existence, but it is not aware of the existence of the associated counter interlocked fields within it, this be it the same as the plasma of electron of a piece of stone, which the electron is part of.

Thus now it becomes clear how a man has physical body and a soul. Where, the physical body is conditioned of the matter world and its environment, where the soul has no such a conditioning.

Thus the soul is aware of the existence of the physical body, but independent of its existence, but it receives the changes in the condition of the physical Magravs of the body.

Thus the soul of a man is a parallel world to the physical world of its associated plasmas, which has created it.

But as soul has no need for the physical body to sustain its existence once it is created, as it operates in a different field zone non tangibility, hence the physical body can die, but the soul will be left in tacked and carries on without its detached physical counterpart in the world of creation.

At the same time, the fields of the soul will carry-on with its interaction with other fields and Magravs of its own level and it will keep on attaining more and keep on and interacting as it physical counterpart did and combining with more and creating more the same and different.

The soul, itself is the balancer of the physical matter of the body, but from point of detachment, does not need the physical body for it to exist. As the physical interaction has led to its existence, but by now it is independent enough to carry on with its own operation.

This is like giving of a birth, even though the baby has been in need of the mother for it to start and become entity, up on the departure from the mothers body, the two entities can live two independent lives, without a need for each other existence.

Thus the soul of an entity, this being stone, animal or a man has the same method of operation and existence as any other matter or fields in the universe, and that as once it is established and sets its frame work, it does not need its physical counterpart which led to its existence.

Now one can understand how different levels of existence do operate and exist in conjunction and in parallel with each other.

Take this one step further and let say fields of the souls have established the same methods of interaction and communication as their physical counterpart plasmas of atoms did with each other and souls through their fields of existence interact with each other and lead to a more dynamic parallel non tangible world of existence in the dimension no need for the actually physical dimension of existence.

In the universe there creatures, which are made from the interaction of principle mafs and matters strength as man is made of matter mafs and matter fields strength and they can operate in a non-tangible level of existence rather than the physical tangibility to the eye of the man

This does not mean that they creatures do not have a soul or they are more intelligent than the man, but the only difference is that they operate in different mafs strength, which these lives can be strange to the mans' travels of the futures as they have the ability to transmute between different levels of mafs strength and be able to visible or detectable in their spectrum of mafs strengths

The soul of the man ids the like of the light from the star in distance universe, where the physical star could have been exploded and destroyed billions of years ago, but still at night the man observes the soul of the stars as the shining light in the dark of the night.

Parallel world exist even within the and during the life of the man himself, but they need the eye of the wisdom for the beings to see them and recognise them in their environment.

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CHAPTER 13

The universal principle of division of pervious universe(s) and their decay leading to creation of new universe(s)

Written in 2009
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ITNOGOG

In the universe there are always parallels due to the magnetic fields laws of interactions and hence there cannot be any deviations from these laws.

At the present the scientific world has been intrigued and encouraged to understand the phenomenon of the creation of this universe and scientists have tried to unravel the mysteries of the creation of this visible universe.

In fact the creation of this universe as is visible to the world of science, it cannot be any different than any other process in the world of creation and this universe has been created through the same principles as the rest of the magnetic plasmatic nuclear and atomic interactions, addition and division.

This meaning that the present universe is created though the same method as has been observes in the division of the neutron into electron and proton or smaller and/or bigger components of the same Matters.

Hence to follow the principle of the universal order of matters, this universe is created from the division of a larger universe that the man's visible universe is the smaller part of the division.

The reason for it being the part of a system is that in the present cosmological term, this universe is following the attraction of the bigger part and hence it is always in the motion to follow the Magravs of the bigger sister.

This being the reason why it looks as the universe is always expanding and as part of the universe has been noted to be collectively following different path of motion than the rest of the universe.

Where, the portion of the independent motion of the universe is the indicator that where the bigger portion of the division of the pervious universe is in respect to the man's universe. (Fig. 30).

It has to be said through the same principle of decay of neutron to plasma of electron and proton (1) and similarly as the decay of heavier atoms to two or more lighter atoms, the original universe through the same principle the mother universe of the man's universe, itself has been created and was created from the division of a larger universes through the same method decay and division during the time of the life of the unicos.

The difference in the universe's creation and decay is in principle merely the size and amount of the plasmatic field content plasma of each universe in comparison to plasma of electron or proton after nuclear decay and division of the neutron.

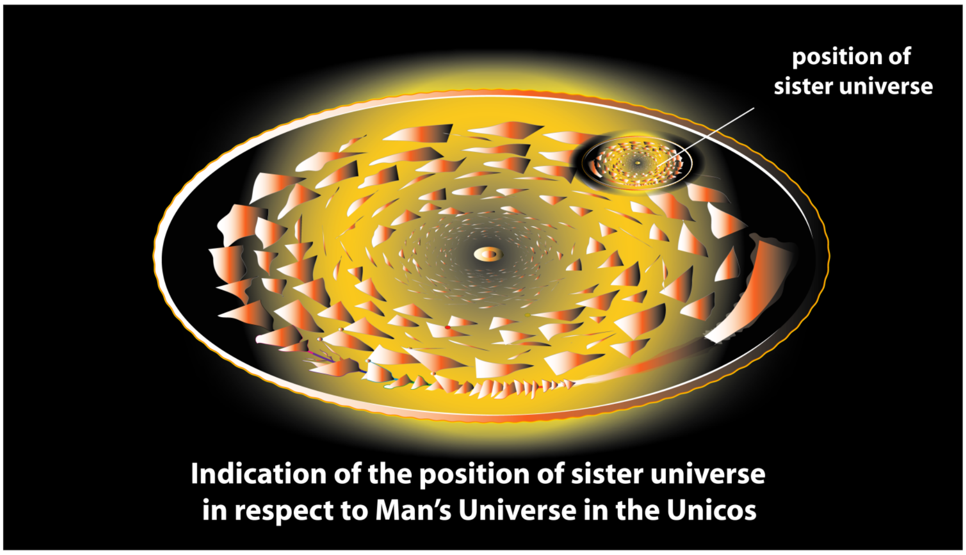
position of
sister universe
Indication of the position of sister universe
in respect to Man's Universe in the Unicos

Fig. 30 The position of the sister universe in respect to Man's Universe

Thus in fact our present universe itself is and was created some thirteen billion years back from the division of a larger universe. Hence every time as it is the same with division of the plasma of neutron to plasma of electron and proton, this division the new universe(s) will carries the characteristics of its mother universe, but due to reorganisation of magnetic field strength the new universe will have a new and fresh time, which this shows as the age of the new universe.

In fact this being the like of given birth to a child, where the age of the mother is irrelevant once the new seed of life is created and once the child is born, even though; the new child carries some of the same DNA fingerprint of the parents. The new life has its own cycle of life and its own timing.

Therefore the theory of Big Bang and M-11 as have been proposed in the recent past has no meaning and has no principle parallels in the physical world of creation of universe, a child or plasma of the proton or an electron. These two proposed principles are nothing, but showing the man's and scientific worlds lack of knowledge and ignorance of the real terms and parallel entities existence of all units in the universe.

In fact once the division is created and the universe is created the rest of the material and matter content and how they organise themselves in that universe is more or less follows the same principle as before and once the field are released within a given Magravs which the fields can created in interaction with each other, then the size of universe, galaxies, stars and planets and even creatures within that given Margraves strength of the newly produced universe are determined by the entity itself and without interference from its previous part.

Where, the new structure is dependent on the fields within the new universe and the internal motion of the new universe is internally determined by the total mass, which the interaction of the Magnetic fields and gravitational fields of the universe can master on its own.

Thus in fact in the bigger or smaller portion of the original mother universe which the man' universe is partly created of, in the bigger or smaller portion due to the larger mass the galaxies can be much larger in portion to the galaxies in this universe and conversely due to larger or smaller strength Magravs of the internal structure of the larger or smaller portion, the being's within these universes can be smaller or bigger or totally different in operation than the beings in this universe.

It has to be said that life in any form is not the exclusivity of the earth, if this is the mind-set of some men, thus this shows their lack of understanding of universe and how it is created, not the real truth and how matter's operated and function in the universe.

Therefore man is part of an inclusive pattern of field's motions in the universe and nothing more or less can be attached to the existence of the man.

The man in physical term is the entity and in the soul the connection of the field between himself and the other fields in the universe.

The physical body of the man is the like of the planet earth, where it has mass and its magnetosphere expands beyond its physical boy, but its total Magnetic fields and gravitational fields determines its position and relation in respect with other matters in the solar system and in a small way it determine the position of its star in its galaxy and souls which are created within it in their course their operation in the universe, as then the position of star determines in a small way the position of the milky-way in the universe and so forth.

Thus the soul of the man is the external connection of the operation of the physical body of the man in the universe, it is part of one and inclusive realty of interaction of the whole.

Thus the soul is part of the operation of the universe and every creation can extent the effects of its magnetic field to others which can affect their position and existence of any in possession of a soul.

Thus the soul, which is magnetic fields created and expands beyond the physical body of the man is not exclusivity of the creatures but it is the common denominator and common link between the man and other creatures of the God and has direct effect on the operation of the rest of the universe.

Therefore the man's body due to the interaction of its atoms protons and electron and neutrons magnetic fields, this object creates its own magnetosphere and its own mass and this body is and has to be in possession of magnetosphere which shows the working of the magnetic fields of its constituent matters and its subcomponents and fields this being including thoughts.

Where, in the physical worlds as the same as the solar system possess magnetosphere and so does the star and planet, then the body of the human through the same physical principle possesses the magnetosphere, which is so called aurora of the human's body. The field of the aurora are part of outer appearance as the soul of the man, but is fact the total effect of the internal interaction of all fields of the body which creates the Magnetic field and gravitational fields of the body and their interaction on each other which leads to the interaction with their fields in the universe, this overall output of the fields of the body of the man is the soul of the man.

Thus, all dynamic plasmatic matters in the universe possess a soul. But the man has the intelligence to allow the interaction of its soul with others; therefore through this principle the man is responsible for all his actions and he stands answerable to other souls in the universe. As he decides how these fields which partial and fully controlled through the Magravs of the matters of his brain, in how and what happens in its interaction with other souls effects their operation in the larger universe.

Hence man has to understand, that universe and others, which has the use of this universe all have been created from and the universe, which has been created from the division other universe and will be created from the division of this universe and in the future are all interconnected and operate through the same fundamental principle.

Therefore there are parallel universes to this universe, with the difference in the measure of their magnetic fields and strength and their position in their given environment.

Thus as we have the same and similar electrons structure's and protons structures in the same structure of an atom, which this structure of positioning of electrons and protons is the same for all known atoms, then the same applies to the universe too. This meaning that there are similar universe as this universe in the greater universe and other universe which this universe has been created from it and those that we will shell create through he operation of our souls and bodies mafs and matters.

It has to said that at the same time all beings in the universe use one and the same universal language of communication, where in the universe the common language is the basic plasmatic magnetic fields of basic field's. This is based on the first plasmatic magnetic field strength of existence of the simplest plasma of atom of the universe, and is similar to what we call in this universe neutron and its division and collections as atoms the like of the Hydrogen atom, which the mystery of this has been kept from the man and not apparent through his own misunderstanding of the operation of the universe.

This language is universal and once the man on earth understands this phenomenon and can fully measure the magnetic fields strength of the electron Magravs of it and he uses this as the base strength, then man will be able to understand and communicate with rest of soul possessing creatures of the universe.

Until then, the search in the sound waves to look and try to communicate with other creatures of the universe is a fantasy and shows the lack of his understanding of the world of the Creation by the man of ignorant intelligence.

Therefore the gravitation, magnetic, radiation and other similar properties and interactions of the field(s) on each other in this and other universe(s) decides on how and the way the creatures in the different universes and in the man's unicos and universe would look and behave.

But in essences they are all made of the same building block of *MAGNETIC FIELDS AND IN ITS AND THEIR INTERACTION OF DIFFERENT STRENGTH AND TIGHTNESS OF IT IN THEIR ENVIRONMENT*; This determining how tall and short and if one has eye or uses the interaction of fields to interact and communicates with other creatures of its environment, universe(s).

CHAPTER 14

How would it end?

The end of this universe will be the same as it started.

What this means is that as the magnetic field balances of the universe reduces to a level that the universe has to re-organize itself that it can keep its constituent field forces together, the whole universe will, like as with neutron plasma will decay and divide into two constituents of smaller universes, which these universes are still connected to each other through their original magnetic field forces (book 1 - chapter 17).

Hence this universe will be divided in to a smaller universe and larger universe parts of a set. This being the same process as the like of the process as neutron decays and the rest of the known nuclear decay of atoms do as there are no other known processes of division process in the universe, and there has to be uniformity in all dimensions of creation.

There is no end in the universes but conversion and amalgamation of fields and matters, which are created out of fields themselves.

Thus, this universe will divide into two active fully operational of lesser universe and bigger universe masses (fig. 31). But in total the overall balance of the matters and fields in both universes will be near equal of what was in this universe, with a little leakage of fields into the Universal Cosmos (unicos).

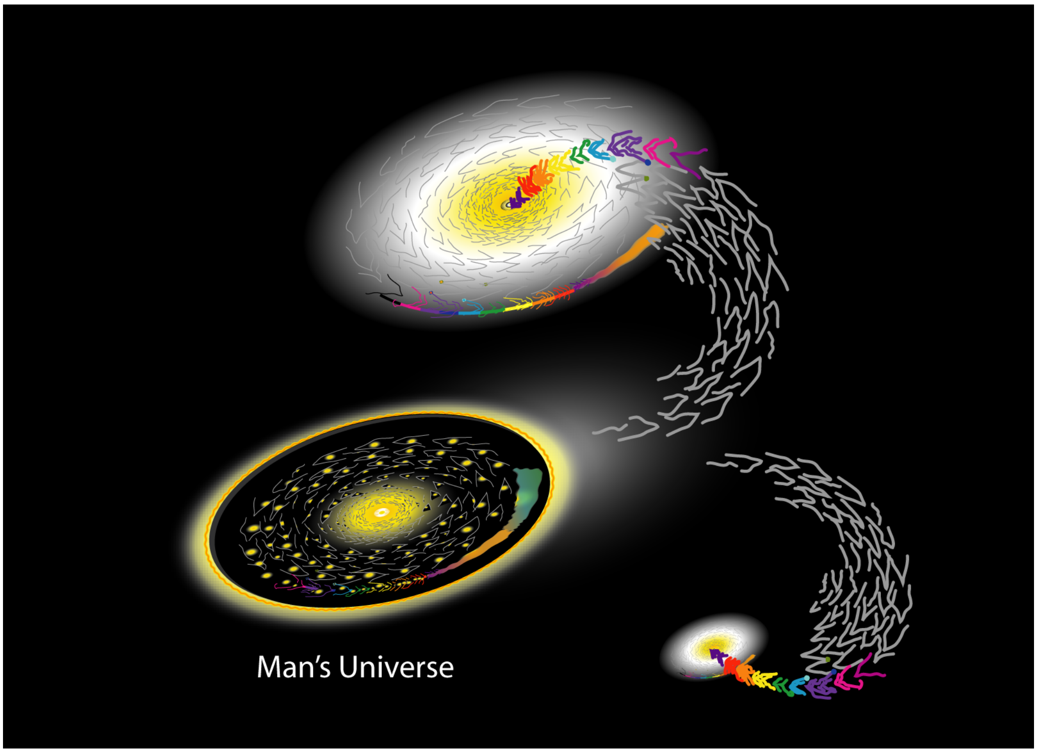

Fig 31. In time the decay of Man's Universe.

Where, the lesser mass part of the division of this universe will rotate around the larger mass universe. Where, the whole of the two new universes both will be rotating around larger universe mechanisms, which this universe on its own was rotating around.

Thus, if one is in the lesser universe, and looks into its motion, it looks as their universe is expanding, as they always seems that matters and fields in this universe to be running away from them as their universe is looking as being expanding.

Where, in fact being in the smaller universe, the gravitational field of the larger universe is continuously pulling or holding onto the lesser universe that the lesser universe stays within its orbit, as the electron does with its proton in atomic structure. As there can be no difference in all levels of creation of larger universe, as it is with the structure of decay of all atoms known to man.

Therefore this is how this universe was created and how future universe will be created out of this universe.

Thus there has never been a big bang, and there will never be a dooms day or the big rift. All it will happen is that this universe will go through a division, which is the norm in all-universal orders of creations.

The original universe has divided itself to smaller universes, which our universe is one of its offspring's and the same will happen over and over again to this universe and its offspring's.

Thus this universe is not the original universe, but part of a fraction of a fraction of fraction of a bigger picture.

May be now it can be understood that in the universe, as has been said that "I have made man in the image of myself" and now the reality of operation of different and all entities of the universe understood and are set in motion for the man to have the full understanding of method of creation and control and the way he has come to be on this planet at this moment in time and if he understood the purpose of his creation, then it can be said that:

The universe exists and operates within the structure of the man

and

the man exists and operates within the structure of universe

Definitions

Below is a list of the new terms and their definition that used in this book. A number of these words and terms have been used in the previous book and scientific papers, which have been published by the foundation and most readers, are familiar with these terms and reference. In this book a different approach and language and terminologies is used, therefore has become necessary to create a new terminology and words that can explain the real term application and processes in the world of physics.

Mafs: magnetic fields

Magnetic: with capital M refers to the plasma of magnetic fields created by a dynamic entity as for example this refers to the magnetic field of the earth.

Magravs: Magnetic and gravitational fields (Magnetic referring to the plasma of magnetic fields created by a dynamic entity as for example this refers to the magnetic field of the earth)

Pmf: plasmatic magnetic fields

Principal matter: This matter in conventional physics is called the anti-matter, as now the real structure of this matter is fully understood and is said to be source of all matters from the dark matter to matter, thus it has been called the original matter or the principal.

Principal mafs: These are magnetic fields, which are in the principal strength levels and considered to be I order magnitude several hundreds of times stronger than the magnetic fields which make up the tangible and visible matters.

Principal star: This entity in the conventional physics is called the Black hole

Transition energy: This energy in conventional physics is called the dark energy. This is the pmfs that are in motion from principal to matter magnetic fields strength so called the transition energy as energy is defined as the pmfs in motion.

Transition matter: This matter in conventional physics is called the Dark matter, as now the real structure of this matter is fully understood and is said to be when plasmatic magnetic fields are in transition state from the principal matter to tangible matter thus the term transition matter is used.

Transition mafs: These are magnetic fields which are in strength level between the principal and matter magnetic fields strength, and are in transit from the principal mafs to matter mafs strength levels.

Gans: a new state of matter; a molecule of a gas (GAs), which becomes Nano of itself and appears as Solid state of matter (Gas to Nano of Solid and to be called GANS for short).

The re-naming of matters and conditions

(*Advice: Skip this section unless you need to refresh or reading for the first time or read it after you have read the chapter 1, 2 and 3 as this section can be confusing and distracting you from the main body of the book*).

(Point of reference: The following section is and to be added to all disclosures for the ease of understanding as most of these have been disclosed in the book (1), and it is added here for the ones who have not read the book and are not familiar with terminologies in the works of the author).

In this literature, when using the term "**mafs**" for example in form of the antimatter mafs this means and refers to the magnetic fields (mafs) which this entity is made of and it is considered to be as a plasma of magnetic fields, and where the term "**antimatter**" is used on its own this meaning the physical tangible or detectable entity of the same. This usage of mafs similarly applies to physical matter and Dark matter too.

Further, the difference with Antimatter and matter is only in their plasmatic magnetic fields (**pmf**) strength and compactness of their fields. Thus, what is the magnetic fields (mafs) of antimatter they become magnetic fields of the matter as antimatter magnetic fields unwinds, loosens up, weaken in their field strength through their interaction with other magnetic fields and matters and become matter mafs and in plasmatic magnetic field strength of matter environment the matter mafs becomes tangible and become matter.

Therefore the antimatters are a more compact strength magnetic fields entities of the same of the magnetic fields of the matter, and due to their tightness of their fields, these magnetic fields of these mafs of matters they create stronger gravitational and Magnetic fields and hence they have stronger Magravs and hence upon their unwinding, they release magnetic fields and pmf which are faster, higher in strength and hence they look as to be strange strong and fascinating matters.

This means that antimatter entity of for example ten centimetres in diameter once ***unwinds*** in structure it becomes a matter of several thousands of meters in diameter entity in matter magnetic field strength environment.

Inevitably one should call the term antimatter the start matter and therefore antimatters should be renamed the Principal matter. Therefore there is nothing anti about these matters mafs and matters at their pmf strength as has been actually assumed in the world of science.

The ***Principal mafs matter*** itself has *different degrees of strength* by itself and *not all* magnetic fields of the Principal matters *have the same magnetic field strength*. Where, the principal mafs plasmatic magnetic fields strength has a spectrum of field's strength too.

As the magnetic fields of the principal mafs unwinds, it releases and loosen in its environment these magnetic fields (mafs) of the principal matters disperses into their environment, then they lose their strength through contact or interaction and friction with mafs' of matter and matters, and hence these principal mafs matters pmfs go for through magnetic fields strength of the Dark mafs matter strength first before through further reduction in strength, the dynamic pmf of mafs of the dark matter in motion reaches the pmf strength of the matter mafs level and hence becomes visible in matter pmf strength environment and becomes matter.

Now that the essence of existence of dark energy or dark matter can be explained in its realistic manner, and that is what has been called dark matter is in fact this is ***a magnetic field in transit from the principal mafs matter and matter strength to matter mafs strength and matter***.

Then as energy has been defined as “magnetic fields in motion” then the dark energy in fact is transition mafs matters in motion, or what is called the transition energy.

Then the dark energy can be called the Transition energy instead of the Dark energy, as the pmf in motion as this magnetic fields from the mafs strength of the principal matter in motion to reach to mafs strength of the matter level, this is only a Transition pmf condition, and transition mafs matter phase only.

Where, the interaction of mafs of transition matters with other of the same leads to and creates the Transition gravitational and Magnetic fields of their own or create what is called the Transition Magravs and in some cases this condition leads to creation the transition matter (dark matter) and consequently sometime interaction of mafs of transition energy leads to appearance and become transition matter (dark matter) in the cosmos.

Therefore, the magnetic fields strength, which makes the dark matter, is to be renamed as the mafs of the transition mafs matter and the dark matter as tangible matter becomes the transition matter, the dark energy to be renamed to transition energy.

The plasma of the principal mafs matters exists everywhere in the universe. This being in the centre of the universes, galaxies, stars, planets, plasma of proton and even in the centre of the plasma of the electron and in the lower order pmf strength environments which have been undetected up to now by man.

In reality in the centre of what is called a black hole in the universe, there exist and is the home of the principal mafs matters and principal matter. Therefore the black holes should be called the principal stars in the centre of galaxies, stars, plasma of protons and other entities like these.

The choice of the term star for principal centres of matters is correct as these principal matter concentration centres are like a star in the centre for the matter world like solar system, and the Principal stars are the place for the mafs of the Principal matters and the principal matters which their fields radiate outward into their surrounding as it does with the stars. Thus from this point on in this disclosure we call the black holes the Principal stars in the universe now that we understand the real source of their mafs of this matter(s) and its principal matters.

It can be understood now that where the intensity and the strength of stars and planets come partially from the existence of the principal mafs pmf strength, which has been released by the Principal, stars in the galaxies. This is to say that the seed of the pmf of the galaxies and matters needed for the creation of stars in principle are from pmf of the mafs of the Principal matter. Where, the interaction of the pmf of these mafs’ of the Principal matters leads to creation of initial strong Magnetic and gravitational fields needed for the creation and attraction of mafs of matters of plasmas of matters, the mafs of the transition matter and transition matters of the same region of the galaxies, plasma of stars, plasma of the proton and other entities of the same structure in the universe.
At the same time when using Magnetic with capital “M” this means the like of the Magnetic field of the earth, which itself is the plasmatic environment created by the interaction of at least two magnetic rays and indicates the outward flow of the magnetic fields from a plasmatic environment the like of the earth.

Similarly, when using magnetic field with small “m” this simply means the magnetic fields as in what we observe at the end of a solid magnet as magnetic fields of the object without its interaction with other fields.

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Published and unpublished works by M. T. Keshe

There are a number of unfinished articles that are to be converted to full disclosures when completed, like antimatter mafs method of energy releases, Nano space technology, relation between the creator and the created, space communication system, deep space defence technology, dynamic magnetic fields force regions (wormholes) construction and control, creation of magnetic fields, and so on.

Some of these works have already been published through different channels and some have not yet been released.

In the following section some of the works done by the same author are mentioned, with a brief disclosure of their contents.

Some of these papers can be purchased and obtained through direct request and access through specific links.

A number of papers with * and ** marks are not for public release due to their sensitivity of information and only available to relevant commercial and governmental organisations for peaceful applications of the technology.

The universal order of creation
(5.7.2006)

In this disclosure the main construction principles and the method of the link and control in the universal order of the existence of living cells, like the function and operational method of any matter based on so called proteins chains, as for example in human cell are explained in detail.

REF 9

The author considers this paper as one of his most important and fundamental works to be published and to be added to the sets of disclosures written by him.

Cosmic Rays
(Release date 24.3.2004)
This paper explains the source and the origin of cosmic rays and the way these work within our cosmos, their function and their benefits.

REF 10
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*The Airborne reactor
(Release date 25.3.2004)

This paper covers the total design of airborne reactors for space technology. This covers all aspects of operation, design and control of such reactors.

REF 11

The seed of the Earth
(Release date 25.3.2004)

Some extracts from this paper:
The theory that the heat of the core of the Earth is due to inertia of the material piled on top of each other is completely dismissed through this new disclosure.

The author M T Keshe believes that this centre core is made of hydrogen, other gases and a mixture of liquid and solid matters mafs, which were in the vicinity of the centre of the core of the Earth at the time of its inception in the solar system.

Through this new understanding of the new inner cores of the planet, this brings to play the fact that the old inner-core of the Earth that is already assumed to be made of a solid piece itself becomes a sealed container for the new inner core.

The author through design of a parallel system has set to confirm the validity of this assumption, that the centre of the Earth possesses a semi- fusion atomic reactor and not a fission reactor as has been assumed by other scientists.

This theory of hydrogen in the centre of the planet is in line with the physical reality of the creation and the present situation in the physical construction of the solar system.

By the laws of physics all the gases in the solar system should have been in the giant gas planets at the outer layers of the solar system, like in Jupiter and Saturn.

The physical reality in the solar system is that the lightest of all these gasses, the Hydrogen, has taken its place right in the centre of the solar system in its star, the Sun.

It has to be recognised that the centre of all planets in possession of gravity due to the centre cores heating, are always in possession of two Magnetic Field Forces in their inner sanctum (M. T. Keshe “The creation of gravity").

In the case of the Earth up to now and with the present knowledge there has been acceptance of only one inner-core and one magnetic force.

As it is explained in the paper titled "the creation of gravity", there is an inner-core in the inner core. This inner core, due to it physical content, motion and position in the centre of the Earth, creates and maintains its own magnetic field force, independent of the magnetic force which has been known to be created by the interaction of the inner-core and the outer-core of the planet.

These two magnetic fields interact to create the planet's own double magnetic fields in its centre. The interaction of these two magnetic fields forces upon each other leads to the new concept of the "DOUBLE MAGNETIC FIELD EFFECT", where the interaction between these two field forces in the centre of the planet leads to the creation of the gravity and the magnetic forces of the planet (Paper: The creation of gravity).

This new second core is the seed core of the planet, the mother seed of the planet positioned in this new inner core.

REF 12

The creation of Black Hole
(Release date 25.3.2004)

In this paper it is explained that the Black Hole is created out of a natural sequence of events, and that the existence of the Black Hole in a galaxy is a normal event. Further it is explained that a Black hole is created in similar ways to the Dark Spots on the surface of the Sun. In this paper for the first time, it is explained how the Black Hole is physically created and what function it plays in its galaxy.

REF 13

Magnetosphere
(Release date 9.6.2004)

"The shape and the strength of the magnetosphere of a planet is exactly what a fingerprint is to a man. It is unique to each planet, star and galaxy. It is a tell-tale of all its attributes, and it reveals the hidden mysteries of the internal materials’ structure".

REF 14

Correction to the Einstein equation of Relativity
(Release date 15.6.2004)

In this paper the physical reality of the Einstein equation is considered, and efforts are made to bring this equation to the real conditions. Even Einstein considers this equation applicable for very small mass, and not in real three-dimensional multi-Magnetic and gravitational conditions, which are external and have nothing to do with the theoretical object's mass and speed, but have effect on the speed and the mass of the object under consideration.

REF 15

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*Introduction to the new system

(Release date 2.7.2004)

In this paper it is written "It is essential to understand that, with the application of this system of motion, one cannot bring into play the solid, liquid and gas fuel method to create motion, as is used today. What is offered in this system is in simple words a fully integrated plasmatic magnetic energy system. Which, creates within and around the core environmental conditions as known to man in the universe like creation of gravity and magnetic field protection and the same as the magnetospheric protection condition of planets and motion through interaction of magnetic fields as planets and stars do in their given environment".

REF 16

The rings of Saturn

(Release date 2.7.2004)

One of the oldest puzzles in the world of astronomy has been the existence of the rings around Saturn. How did these rings come to exist the way they are now? How did they come to appear and behave the way they do? These questions and much more about the creation of these rings are all answered in this paper.

REF 17

The creation of gravity

(Release date 11.7.2004)

In this paper it is explained, "the source and the creator of the magnetic forces and the gravitational forces are due to the interaction between the same materials in the same region of the planet."

Further it is explained how the gravitational field force can be created, replicated and controlled within a nuclear reactor. Further it is explained how this property can be used for the motion of a system within a planetary or solar system.

Now by understanding the principle of the creation of gravity, in this paper it is further explained, "the gravity in reality is the effect of the interaction of two plasmatic magnetic fields of any two object in respect to each other."

REF 18

Death of a star

(Release date 26.7.2004)

In this paper the death of stars is explained, "The death of a star and the creation of a supernova is in reality the same as the half-life cycle energy step-down of an atom, with the difference that this show is in a larger scale, and more spectacular, in all aspects of its dimensions".

REF 19

Fusion
(Release date 28.7.2004)

In this paper the physical and scientific problems with present fusion technology is considered. Where, it is written, "nuclear Scientists, with the fusion reactors of today, are trying to create fusion in the opposite way to the known laws of physics and their parallels in the universe”. Further in this paper it is written, "If the present path for creation of fusion is followed, with the present scientific knowledge of physical materials for construction of such system, then following the present path of development to create energy from current fusion systems will be a distant dream".

REF 20

Life of a Cell
(Release date 28.11.2004)

Extracts from this paper; "The reality of the transportation and transmutation of a cell is not far from the reality of the life of an atom or a star. Where the life cycle of the cells are slightly more complicated, as they contain other matters mafs like acids, which have their own magnetic characteristic of their own chemical structure. For this reason the control and replication of the energy of the cell is very much complex, but very simple to achieve".

REF 21

The Atom
(Release date 19.12.2004)

The content of this paper explains how and where atoms in the universe are originated from and how the construction of atoms in a cold plasmatic nuclear reactor can be replicated.

REF 22

Magnetism
(Release date 8.1.2005)

In this paper it is written, "The question is where did the Magnetism come from? This is the Secret of creation. The world is made of one thing and only one thing and that is Magnetism. Its combination and interaction with its own different strength fields makes it appear as different matter mafs. The rest of creations are the outcome of these interactions of different strength of this thing called magnetism and the forces it creates. Magnetism is the origin of existence and the real singularity in its full meaning".

REF 23

----

*The creation of the magneto-gravitational force
(Release date 5.2.2005)

The creation of magneto-gravitational field force is and will be fundamentally independent of temperature and pressure, proviso to the fact that as long as a homogenous free floating pmf within a matter mafs is created.

REF 24

The core of the Earth

(Release date 20.4.2005)

One of the original assumptions in developing the new Magravs system some thirty years ago by M.T. Keshe was on the basis that the centre of the Earth possesses addition cores, which create the necessary gravitational conditions of the planet. After some twenty years of space technology and through Earthquake seismological data's this assumption has been shown to be correct and after over twenty years, it has been scientifically proven that the inner-core of the Earth has an inner-core of 600 km. Professor Guy Master in 2002 ref 24 nuclear planet. The centre of this core is assumed to have an inner-core of 8 Km, this he thought to be made of the plutonium or other nuclear materials

But the developer of this new plasma reactor technology has proven through physical dynamic cores that these cores possess a mixture of hydrogen plasmas and the process of the heating of the centre of the Earth are due to a semi-fusion chain of events.

REF 25

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*The electron-atomic welding

(Release date 3.5.2005)

Some extracts from this paper:

"The electron atomic welding or atomic welding principle is the phenomenon that atoms of the same material, through a common shared electron, become a magnetically balanced molecule of the same matter mafs, with the difference that the shared electron will create a balanced pmf in the molecule".

REF 26

----

*Shutdown and safety of the reactor core

(Release date 6.6.2005)

In this paper the safety parameters in the operation of the gravitational and energy reactors are simply explained to avoid the loss of plasma and gravitational field forces created within its cores.

REF 27

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*Reactor Start-up

(Release date 9.6.2005)

In this paper the systematic start-up of the dynamic reactors for the creation of gravitational field forces and the production of energy are set out. The start-up of these systems is totally different than the prior arts known in the nuclear industry.

REF 28

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*The energy balance of the reactor
(Release date 29.6.2005)

Some extracts from this paper:
The energy balance of these types of reactors is not as simple as might look in the first instance. The energy creation is simple. But the heat leakage and dissipation through the deliberate inherent material design are and can be zero. That is to say the system not only can hold on the heat it creates. At the same time due to the close circuit feed operation will become self-sufficient but long lasting.

In planets, the loss of heat through their surface creates the variation in the central core condition over several billions of years. In this reactor as losses can be literally negligible, the system can operate at low energy loss temperatures. Even the boundary of the body could be made through the right combination of material in the chambers, so that the body of the reactor will be colder than its surrounding boundary. So the system will not only lose energy to its surrounding, but it can be made to absorb heat in the negative temperature gradient from its surrounding, so that there are no losses.

REF 29

Nuclear decay or half-life
(Release date 20.7.2005)

Extracts from the paper:
"The nuclear decay always has the same or near the same time duration. This is due to the fact that the all neutrons and protons, from their inception, carry a predetermined level of plasmatic magnetic energy. This energy is continually used for the motion and vibration of different elements of the nucleus in respect to each other and the surrounding matters mafs of the atom. As the space and dimensions of a nucleus of an atom always obeys the same principles of the magnetic separation and magnetic attraction. Protons or neutrons can and will need to use or consume the same energy before they become weak enough that the splitting or decay becomes a clockwork job. The nuclear decay is the natural levelling done of a nucleus' energy, due to the energy consumption and heat dissipation for the motion of the elements of the nucleus for its remaining plasmatic magnetic fields energy necessarily needed for them to hold one together".

REF 30

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*The decontamination system
(Release date 10.10.2005)

"What this means is that, for example in trying to recycle the CO2, by the use of the right matter mafs in one of the cores of the reactor, the system will then use the O2 to produce H2O, in the form of pure water, and C in the form of atomic or molecular carbon, or even by feeding this back through certain operational compressions and gravitational interactions within a small core, to create industrial diamond or graphite, for different industries."

The use of the reactor for this purpose has been proven to be correct and Raman spectroscopy has proven the concept and physical reality of the separation of matter mafs in atomic level after separation in the same system from a composite matter mafs.
(See the graphene on the technology web site)

REF 31

The difference in atomic and molecular structure
under gravitational force and pressurised conditions.
(Release date 15.8.2005)

In this paper is written that "the atomic and molecular structure of matter mafs is totally aligned and positioned in a fundamentally different configuration where it has come together due to gravitational forces, than when matter mafs has been brought together by the means of pressure. This has a fundamental effect on the behaviour of the structure and properties of the matter mafs which is created in either way". Where this is explained and utilised to develop a new method in creating graphene and Sp3 atoms and walls in a simple core made of a coca- cola bottle.

REF 32

**The Defence and shielding system
(Release date 4.9.2005)

Some extract from this paper:
The design of the side open system for lunch of high saturation magnetic plasma package is one of the most effective technologies for defence of the reactor and the craft, which is in possession of such a system.

It is essential for any space technology in the open environment of the universe, if the craft is to keep a straight line of motion and to be able to protect itself from any solids or matters mafs in its path in the cosmos.

This technology can destroy any object by the principle of plasmatic magnetic energy saturation of the incoming object at a molecular level, that object will disintegrate in the form of magnetic vapour and not atomic level destruction, before matter mafs can damage the craft as debris, and before the craft ever becomes in touch or near these space matters mafs.

This technology can also be used to protect Earth from the collision risk of NEO's (Near Earth Objects), like comets and asteroids.

REF 33

Method of creation of an atom or nano matter mafs
(Release date 11.10.2005)

The manufacture of an atom of any density, this being of the simplest form of nucleus or a full atom of hydrogen, or even heavier elements in the universe, all follow the same principle.

Atoms are created in the soup of the cosmos from collections of very weak plasmatic magnetic fields, which for their existence cluster and share their energies with the magnetic fields that are not far from their own plasmatic magnetic field strength.

REF 34

The relationship between Gravity and Mass
(Release date 21.1.2006)

Extracts from text of this paper:
"A planet like Earth possesses a combination of both gravity and inertia. Where the gravity comes from the interaction of plasmatic magnetic fields from the processes within its core, and the inertia comes purely from the collection molecules pmf of matters mafs which has built the physical body of the planet.

Any object, being an electron, atom, molecule or even a human body, is a collection of plasmatic magnetic fields of different strengths and their interactions between each other, which in total decides the total or collective magnetic field possessed by that object where this is the mass of the object.

Where the mass of an object is a collective package of plasmatic magnetic field tightness of a given object and will not change as long as the object is intact as one entity in its overall atomic or molecular or collective molecular appearance.

Which plasmatic magnetic energy of a physical body (so called the mass of the body) in interaction with molecular or atomic magnetic field (this being gravitational or inertia) of another object will determine the weight of the two object in respect to each other in each other's environment".

REF 35

The Dark matter mafs
The Fifth state of matter mafs
(Release date 21.1.2006)

Extracts from text of this paper:

The existence of dark matter mafs is not questionable,

Proving its existence, and its effect on the energy balance of the universe, in all matters mafs as small as in the heart of an electron or in a solar system needs to be created, replicated and its effect measured.

The theory of dark matter mafs does not and needs not to be considered as complicated, if one understands in real terms the plasmatic magnetic energy of the matter mafs in the visible and invisible dimensions of the universal work.

The dark matter mafs has two distinctive characteristics, which makes it totally apart from the visible matter mafs. The dark matter mafs possess mass but not visible light, where its existence can only be determined by the weight of the it's hidden mass, which could be substantial due to its internal gravitational field.

REF 36

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*The inter-atomic fusion
(Release date 3. 5. 2006)

Extract from this paper:
"The fusion of two or more atoms has been the pre-occupation of nuclear physicists for past years. Conditions to achieve fusion of two hydrogen plasmas in the TOKAMAK reactors have taken years to teach scientists a lot about the behaviour of plasma and their fusing.

The reality about the fusion in some way has to be reconsidered as, if the scientific world is trying to amalgamate the contents of two plasmas to release energy. There must be a simpler way to achieve releases of similar energies.

The fundamental principle of the inter-atomic fusion is a much simpler way to achieve fusion. If this principle is applied to the atomic condition of fusion, then fusion will be attained in a simple but in a much more physically realistic environment.

The explanation for inter- atomic fusion is very simple and direct.
In the fusion of two plasma of proton of hydrogen atom, the physicists try to fuse two large plasmas, and by doing so, they try to release a large amount of energy. Where in this process enormous amount of magnetic field forces and currents are needed to bring two plasmas in close proximity, so that the energy barriers in between them can be overcome for them to amalgamate or fuse.

In the inter-atomic fusion the overcoming of energy barriers does not exist, as in this method of fusion, the electron of the atom which is circulating the nucleus of the atom and is of the same origin will be encouraged to return into and fuse with the nucleus of its atom".

Where this is a more practical way to create and release manageable energies and there is no need for elaborate systems where even if the energy release will be small compared to dreamed up fusion systems of today.

With inter-atomic fusion method at least small and practical systems can be developed to handle low temperatures of the fusion process.

REF 37

The conductivity of the matter mafs in the vacuum
of the interplanetary mediums
(Release date 21.1.2006)

Some extracts form this short paper "Therefore plasmatic magnetic field of elements within the interplanetary medium will cover the space given to them in their environment. Where due to their motion and their electric charges even in eV levels, they become perfect conductor, and in turn, due to their motion on their environment, they become plasmatic electromagnetic generators.

REF 38

The production of Graphene
(Release date 25.7.2006)

Repeated experiments and tests in simple static reactors, and tests in more complex dynamic reactors, prove that atomic separation and recombination of matter mafs like carbon and hydrogen can be reached at room temperature and at atmospheric conditions.

We have now indications - through static and dynamic tests in our reactors - that the universe was made in normal condition, which was originally nothing but packages of plasmatic magnetic fields of different strength, which were themselves nothing but areas of plasma or collections of loose magnetic fields energies. Where magnetic fields of different strength in locking to each other, by the principle of their plasmatic magnetic energy (PME), have caused in the first stage the creation of fundamental particles, secondly atoms, then molecules and then matter mafs, clouds and asteroids and then stars and galaxy's".

The Big Bang theory conditions have no room in the reality of the creation of the universe.

REF 39

* * *

Further works on medical research and developments have been written and completed, and will be published on the Foundation medical site in December of 2011

The process of the reversal of coma: Published in December 2010

Multiple Sclerosis: Published in December 2010

Epilepsy: Published in December 2010

Fibromyalgia: Published in December 2010

INTERNET LINKS

Web site: www.keshefoundation.com

YouTube Channel: http://www.youtube.com/user/keshefoundation

Forum: http://www.keshefoundation.com/forum/

Internet radio interviews:

Interview 06-09-2011 with Red Ice Creations (hour one):
http://www.redicecreations.com/radio/2011/06/RIR-110609.php

Interview 06-09-2011 with Red Ice Creations (hour two - need for simple registration):
http://www.redicecreations.com/radio/2011/06/RIR-110609.php

Interview 05-09-2011 radio interview with Alienshift:
http://www.livestream.com/alienshift/video?clipId=pla_8251665e-ac74-4d77-a785-443bbca65bf6

Interview 04-27-2011 with Mrs. Kim Greenhouse of Its RainmakingTime:
http://itsrainmakingtime.com/_radioshows/110427Keshe.mp3

Interview 04-20-2011 with Mr. Redneck Radioman of blogtalkradio.com:
http://www.blogtalkradio.com/paranormalpalace/2011/04/20/gravitational-technology-with-nuclear-scientist-mehran-keshe
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Interview 04-17-2011 radio interview with Mrs. Aurora and Mr. Bill Alek of vortexnetworksnews.:
http://intalek.com/AV/VNN/VortexNetworkNewsHour/04-17-2011-VNN.mp3

Interview 04-09-2011 second radio interview with Mr. Bill Alek of vortexnetworksnews.:
http://intalek.com/AV/VNN/ProgressiveTechnologyHour/04-09-2011-Technology.mp3

Interview 04-02-2011 first radio interview with Mr. Bill Alek of vortexnetworksnews:
http://www.intalek.com/AV/VNN/ProgressiveTechnologyHour/04-02-2011-Technology.mp3

Interview 12-18-2009 radio interview with Mr. Allan Sterling of Peswiki:
http://www.mevio.com/episode/205187/fen-12-18-09-interview-with-mehran

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*As we are helping with series of books which have been published and to be released, to build the full knowledge of the structure of the operation of the magnetic fields and their interactions in the world of creation for man to understand the entire process, one comes to the point that one has to explained different proportion of this entity in different levels of creation of the greater universe and not the man's universe. In the **first book** the creation of of matter, the operation and interaction of smaller fields, which leads to creation of matters was explained. In the **second book** we merely explained the method of travel of the collection of fields in the form of so called light. In this **third book**, it is further I have explained the operation and interaction of a bigger cells of the same fields, which these leads to creation of the mans universe and more and what is too much for the man to understand with his present scientific knowledge and he calls it his universe.*

*Where, the so called this universe in this book is explained itself is to be a part of natural process of creation and it has been created from the division of bigger quantities of fields and in time this universe will itself will be divided into and will create smaller universes or part of it will amalgamate with other universes and their fragments' to create bigger universes in the overall structure of **the unicos,** the universal cosmos.*

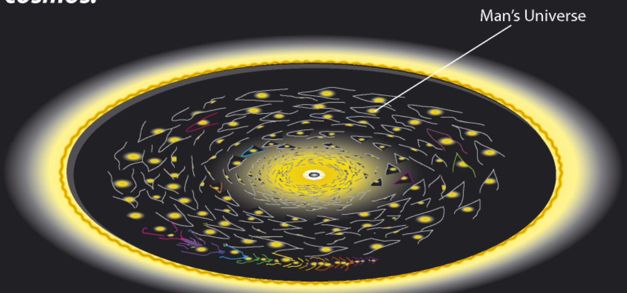

Man's Universe within the Unicos (Universal Cosmos)

This process is being the like of the division of the plasma of the neutron to plasma of the electron and proton to create an atom and/or the fusion of two proton to create a heavier bodies of plasmas.

Thus this universe is not the centre of creation and itself is part of the bigger structure.

That is the same dilemma as man had as he tough the earth was the centre of the universe and as he understood more, he realised that he, his planet and himself are the smallest part of solar system and his solar system was in fact smaller part of a galaxy and so forth, and this is the same with operation and existence of the of the mans' universe in the bigger operation and structure of universes in the cosmos of universes: the Unicos.

The Keshe Foundation is an independent non-profit and a non-religious organization founded by nuclear engineer M.T. Keshe, aiming to bring new scientific knowledge and new technologies to mankind, and to bring new solutions for the major global problems, like famine, water shortage, shortage of electrical power supply, climate change, illnesses, by the use of new types of plasma reactors, and to give Man the real freedom to travel in Space.

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978-94-6087-000-2

The Keshe Foundation

THE ORIGIN OF THE UNIVERSE

M.T. KESHE

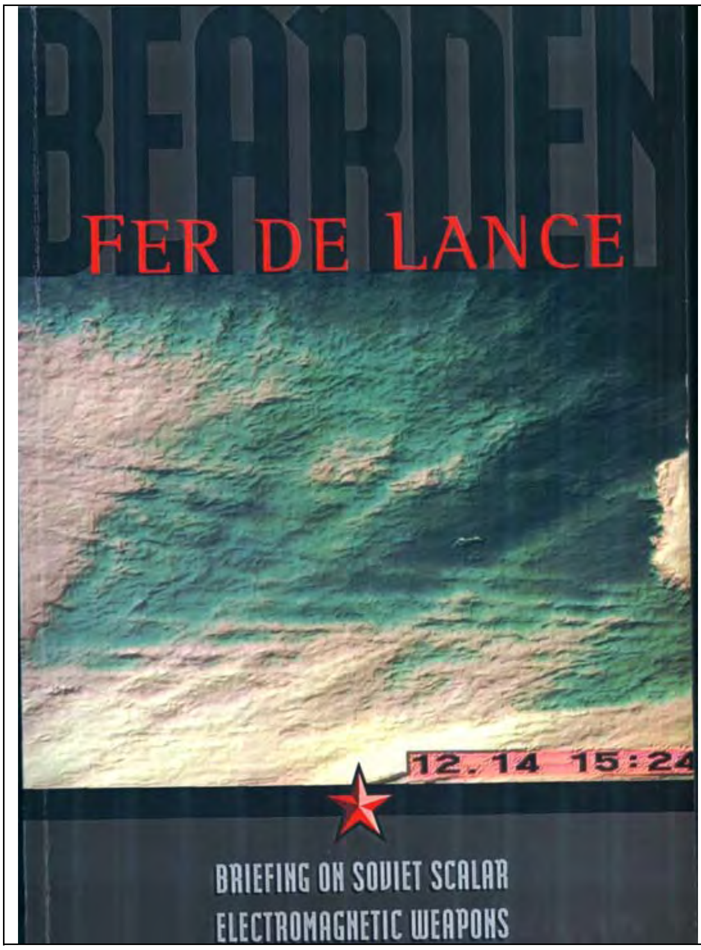

FER DE LANCE

Lieutenant Colonel Thomas E. Bearden (U.S. Army, Retired) PhD, is the author of numerous books, papers, briefings, and presentations dealing with anomalous phenomena, scalar electromagnetics, free energy devices, Soviet Tesla weapons, and Soviet scalar electromagnetic weather warfare.

Lt. Col. Bearden was previously a senior scientist and department manager with the Alabama division of a major aerospace company where he directed the company's design and production of expert systems (artificial intelligence) applications for the U.S. Army command control systems. He has more than 29 years experience in air defense systems, tactics, and operations; technical intelligence; nuclear weapons employment; computerized wargames; anti-radiation missile countermeasures; and military systems requirements.

Bearden obtained a Master of Science degree in nuclear engineering from the Georgia Institute of Technology and a Bachelor of Science degree in Mathematics from Northeast Louisiana University. He is a graduate of the U.S. Army Command and General Staff College.

When Fer De Lance was originally written, Tom was a member of Mensa, Society for the Investigation of the Unexplained, International Tesla Society, American Association for the Advancement of Science, Association of American Physics Teachers, the Air Force Association, the Association of the U.S. Army, the American Nuclear Society, and the American Defense Preparedness Association. He is currently the Director of the Association of Distinguished American Scientists (ADAS), Fellow Emeritus of the Alpha Foundation's Institute for Advanced Study, and is CEO of CTEC, Inc.

In private life, Tom has two sons and two daughters, and lives in Huntsville, Alabama with his wife, Doris.

"...In 1999, the Earth's first strategic sub-space war
was silently fought and won..."

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Sweating done by red_gonzo.

Note: sometimes formatting of the text may be a little fuzzy. It's all because the OCR process didn't go as smoothly as I expected. Also there may be some errors inside text so be vigilant. In any case share this book, send emails to people about knowledge contained in it. Since this book talks about the most terrifying weapons present today the information in it is even more of value. But knowing an old saying »the knife cuts both ways« one can also use the same knowledge in order to heal ourselves since it seems that our body already does it using the physics described inside. Hopefully the latter will prove to be the most useful way to use this old but forgotten / supressed knowledge.

The contents include the 2002 update and the older 1986 briefing with slides.

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The Russians have sustained the largest weapons development program ever launched by any nation, and they have kept it effectively hidden from prying Western eyes. I have called this program "Fer-de-Lance," after the deadly South American pit viper of that name.

The dreaded fer-de-lance is a snake of great agility and lethal effect. It often ambushes its hapless prey, striking unexpectedly and without warning. Its first sudden strike is usually lethal to its victim, which promptly expires in writhing agony. Since the Soviet development of scalar EM weapons has been designed for the same purpose, the name seems appropriate.

2002

Overview[1] and Background of the Energetics[2] Weapons Threat

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September 15, 1998
Update

Note: We have placed this update as a section in front of the original paper. This leads to some redundancy, which remains to insure clarity.

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[1] This is an updated and slightly sanitized version of a paper originally prepared for and transmitted to selected Senators and Congresspersons.

[2] The present name of the old KGB is the Federal Security Services. The leopard's spots remain the same, regardless of its new name—at least for a die-hard old communist faction of it. Presently the helm of Russia has been turned over to a new Premier who has an extensive KGB background. However, Putin has chosen to differ from the traditional KGB outlook and seems intent on becoming America's trusted cheap oil partner and supplier, in a bid to help his economy and pump much-needed funds into it. His friendship with George Bush may be one of the turning **points** of this new century He at least has achieved sufficient control over much of the KGB to get on with trying to solve his economic problems and break the old "die-hard communist" mold a **bit**

2002 OVERVIEW AND BACKGROUND

For some time, Russia and several other nations have possessed highly advanced "extended-electromagnetics" *(energetics)* weapons of a very novel kind, using a dramatically extended electrodynamics theory {1}. To comprehend these weapons requires a combination of non-Abelian electrodynamics in at least the 0(3) gauge symmetry {2}, general relativity, Bohm's interpretation of quantum mechanics {3}, and the use of time-domain (scalar) energy, fields, and potentials to directly enter distant 3-spatial points without propagating energy through 3-space. It also requires correcting many of the serious errors in classical electrodynamics. Probably the most elegant and applicable extant model to deal with these phenomena and weapons is Sachs' {4} unification of general relativity and extended electrodynamics, particularly as implemented in O(3) electrodynamics. O(3) allows direct engineering by modified EM means.

Most of these energetics weapons are more advanced than what has previously been known to the U.S. military, intelligence, and scientific communities, although parts of the communities are finally making real progress in understanding such "revolutionary" areas. For example, every major weapons lab on earth seems to have discovered longitudinal EM waves and longitudinal EM wave weapons—the scalar interferometry we have been discussing for so long {5}. A major contributing factor holding back U.S. catch-up is that the flawed foundations of Maxwell's 1865 theory {6} have not been changed by the Western scientific community.

Historically, the scientific community exerts resistance to substantial innovation. Often 40 to 50 years are required to do what can be done with a concerted effort in four years. The Manhattan Project in WW II is a notable example of where the scientific community made a maximum effort and did a difficult job in four years. Also, "skunk works" efforts continue to be utilized for very rapid development when something really advanced is to be done and done quickly.

With the U.S. substantially behind in these "new" strategic superweapons, a new Manhattan Project would appear to be advisable and warranted. There are at least some indications that such may actually be going on at last. We hope the indications are true.

A sobering development that occurred early this year (2002) was China's deployment of both quantum potential (QP) weapons {7} and *negative energy* electromagnetic pulse (EMP) weapons (a type which we originally called the *MindSnapper* to disguise its true nature) {8,9}. The QP weapons are the dominant weapons on Earth today, followed closely by negative energy EMP weapons in second place. We have not been able to ascertain exactly how many nations have the negative energy EMP weapons, but it is at least five at the time of this writing.

The U.S. is still well behind in the use of special "engines" (special curvatures of spacetime and their dynamics, but achieved with higher group symmetry electrodynamics) for directly engineering the mind itself, and for producing *nonmaterial* robot systems made totally of such engines—"causal system robots" which we will mention later. Several of the Western nations do accomplish work in the mind control area, but use a sort of "brute force" method oriented on frequency and frequency changes, etc. where the true active mode is the unsuspected transformations of the U(1) electrodynamics to a higher group symmetry unified field theory electrodynamics, accomplished by the human body tissues and structures themselves.

Western scientists have not realized that all EM energy in 3-space actually comes from the time domain *to* each point in 3-space and *returns from* that 3-space point back to the time domain.[3] Hence "propagation" of 3-space EM energy is actually the propagation of a "circulation" of EM energy between the time domain and 3-space, involving each 3-space point presently said to be "occupied" by the energy. Unfortunately, Western science is still unaware that *no observable exists in time,* a priori, since by definition it has no extension in the time dimension at all {10}. Instead, an observable *continually recurs* as a frozen 3-space snapshot of an ongoing dynamic 4-space interaction, due to the continual repetition of the observation process which is the application of a *d/dt* operator to the ongoing 4-interaction. Hence, we "see" physical reality (3-space reality) similarly to the way we view a "motion picture" series of successive frozen frames. The major result of this flaw (mistaking a 3-space observable as a 4-spatial cause) in Western science is that Western science still extensively substitutes effect for cause—e.g., in the notion of a separate 3-force acting on a separate 3-mass. No such situation exists in nature, and nothing "moves" or "changes" in 3-space alone. For an entity to exist in time, it requires at least 4-space because a time length is required. Nonetheless, the West is making progress. If some of its scientific dogma can be overcome, the younger scientists will break free and readily do the job required for the defense of this nation.

Mad Scramble of Soviet Science After the End of WWII

During WW II the West produced a great technical breakthrough and obtained the atom bomb as a decisive new weapon. While speeding up his own atomic

---

[3] Specifically, energy comes from the time domain to the negative 3-charge, thence to the positive 3-charge, thence back to the time domain in a *4-circulation* of EM energy. With extra energy *appearing* and present at the negative charge due to entering 3-space there, and with less energy present at the positive charge due to the energy *leaving* 3-space there, there is a delta in energy density (pressure) across a dipolarity, oriented from negative to positive. That is the exact basis of the T. T. Brown unilateral thrust force, and the force used in the "lifters" experiments today. To calculate the **force, th**e long-unaccounted Heaviside energy flow component must also be accounted— not just the weak Poynting flow component.

weapons program[4] as a result, Stalin also ordered his own Academy of Sciences to quickly derive the next great new technical breakthrough, and he held the top scientific leaders themselves personally accountable to him, to see that it was done at all speed (Figure 1).

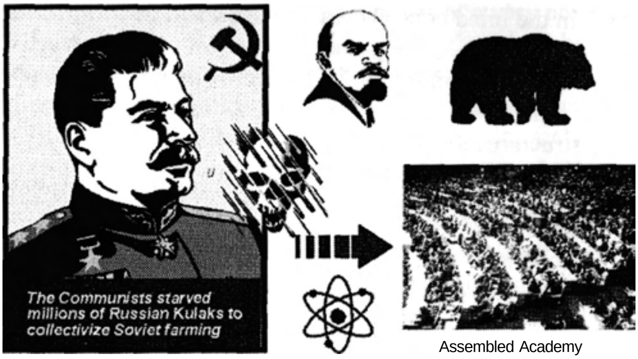
The Communists starved millions of Russian Kulaks to collectivize Soviet farming
Assembled Academy
Stalin

"The destiny of communism has been frustrated by the U S development of the atomic bomb That is not the last great technical breakthrough The next one WILL be Soviet! You will provide me with that great new technical breakthrough at all speed, or I will have your heads Do I make myself dear, comrades?"

Figure 1 Stalin's dictum removed any resistance from his scientific community.

Simply put, Stalin placed the heads of the Soviet scientific leaders on the chopping block, since he was an absolute dictator and often killed or imprisoned those who opposed his instructions. To survive, the leaders of the Soviet Academy had to demand the utmost of their subordinates, because they themselves had to report their progress or lack of it to a dictator who would and did take swift action if they did not produce results. Thus, Stalin simply bypassed the usual scientific posturing and protracted delay so typical of our Western scientific bureaucracies.[5] If the Directors of the Russian scientific community dragged their feet and did not push his desired program to the limit, their heads would roll—and some did.

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[4] At the Potsdam conference, after Truman informed him the U.S. had just exploded a great new explosive weapon, Stalin secretly called the head of his nuclear weapons program and ordered him to accelerate the Soviet nuclear weapons program.

[5] As a simple example, the U.S. National Academy of Sciences, National Research Council, National Academy of Engineering, and the National Science Foundation—and all the electrical engineering departments at all the universities in the U.S.—have not yet recognized that all EM circuits and systems are in fact powered by EM energy extracted directly from the seething local vacuum by the source charges and dipoles in the circuit or system, and particularly by the broken symmetry of the source dipole in the generator or other primary power source. They also have not yet solved the more than a century-old source charge problem, but continue to support engineering models assuming that the charge *freely creates* real EM energy out of nothing at all, in total violation of the conservation of energy law, and pours that created energy out, freely and continuously, to establish its associated fields and potentials and their energy reaching across the universe. The agencies thus unwittingly advocate perpetual motion machines on a scale unparalleled in history. They continue to support an electrical engineering model and a classical

As a result of Stalin's forceful intervention, the entire Soviet scientific community was galvanized into a most intensive review of all of physics. The scientists desperately sought to quickly uncover potential breakthrough areas that could be developed into the great leap forward that Stalin demanded. They had to have progress, and they had to have it rapidly.

One Institute Had 2,000 PhDs and a Full Support Staff

Large review institutions were quickly set up, staffed with the best Soviet scientists and support translators and teams. One such search institute involved some 2,000 Ph.Ds along with their support staffs. Soviet ships brought in shiploads of copies of all the scientific journals of the West—from the beginning—, and they were reviewed paper-by-paper, page-by-page. Anything novel and implying new scientific possibilities, or anything that had not been adequately followed up, was laid aside in a "select" pile for further review and decision by the best Soviet theoreticians available {11}.

One gets a new physics by discovering shortcomings and flaws in the old one. This intensive Russian search almost immediately uncovered the deep flaws in classical electrodynamics—flaws that have been propagated throughout most other branches of science. Classical electrodynamics (and electrical engineering) is particularly beset by hoary flawed foundations problems, dating from at least 1865. As an example, the equations did and still do assume a material ether, and they have since the beginning! Not a single equation was changed when the

---

electrodynamics model which *do not even model* the active vacuum and its exchange with every charge, much less a *broken symmetry* in that exchange. So none of those agencies even knows what powers an electrical circuit, 45 years after the proof of broken symmetry was accomplished by Wu and her colleagues in 1957, and the Nobel Prize was then quickly awarded to Lee and Yang *the very same year* (1957) for predicting that broken symmetry revolution. In the modern view a charge is a dipolarity, when its vacuum interaction is considered. As a dipolarity, every charge exhibits the proven asymmetry of opposite charges, in its interaction with the active vacuum. The charge thus extracts and outpours real observable EM energy from the vacuum, freely and continuously, and it exhibits COP = oo. Those agencies—along with nearly all the rest of the U.S. scientific community—still naively assume that a COP>1.0 EM system (i) is impossible, (ii) is against the laws of nature, and (iii) is a forbidden perpetual motion machine. In nearly half a century since the discovery of the broken symmetry of opposite charges, those agencies have yet to apply that finding to electrical engineering and engineering curricula. Frankly, since they have dragged their collective feet for nearly a half century on extracting EM energy from the vacuum, what is needed is a Stalin to put his iron boot firmly to their posteriors and call their attention to it in language they cannot ignore. *The pollution of the planet for energy purposes and the imminent oil and energy wars that will ravish the earth are directly due (i) to this inexplicable dogma upheld by the scientific community and (ii) to the community's continued falsehoods equating EM COP>1.0 to perpetual motion machines.* The continuing failure to **incorporate** the **active vactnun** exchange—and its broken symmetry—into electrical engineering and classical **electromagetics** **a**lso poses an unacceptable threat to the continued survival of this nation.

Michelson-Morley experiments in the 1880s destroyed the material ether itself. The classical EM model also assumes a flat local spacetime (falsified by general relativity since 1915) and an inert vacuum (falsified in particle physics for several decades). It still assumes the same EM field in mass-free space as exists in mass—a non sequitur of major impact. Just to make the Maxwell-Heaviside equations easier to solve and avoid numerical methods, the *totally arbitrary* Lorentz symmetrical regauging[6] discards all EM systems far from equilibrium with their active vacuum environment. In fact, there is no "active vacuum environment" in the model, much less a broken symmetry in that exchange. Yet that very broken symmetry is exhibited by every charge and dipole {12}, and thus by every EM circuit and system. That asymmetry is involved in the continuously increasing giant negentropy poured out by every charge in the universe, thereby generating all EM fields and potentials and their energy, eventually reaching even across the universe, *and with perfect macroscopic order and time duration as long as one wishes*. Indeed, all electrodynamics is in total violation of the second law of thermodynamics, to any *macroscopic* size level and time duration desired.[7]

The terribly flawed electrodynamics model was completely overhauled by the Russian scientists *very* quickly, and the work was accomplished by some of the best nonlinear scientists in the world. Already present at the time were many things available to assist in dramatically extending {13} the hoary 1865 Maxwellian electrodynamics {6}. Gauge field theory was available since the turn of the 20th century, and the top theoreticians could readily see that something more than Abelian electrodynamics was firmly required in particle physics. The Yang-Mills {14} theory met that need in 1954 by originating non-Abelian gauge theory.

Situation in the Early 1950s

By 1950, Stalin's scientists had the beginnings of what they dubbed "energetics" {15,16}, which we would dub an "engineerable unified field theory" {17,18,19}. Longitudinal EM waves were primary {20,5} in that more fundamental approach. By the mid 1950s, one can pick out of the open literature {21} increasing incidences of prototype Russian energetics weapon testing around the world. In 1960, Khrushchev {22} spoke obliquely of these "fantastic new weapons" that were "just within the portfolio of the Soviet scientists," so to speak. Commercial aircraft sightings (Figure 2) and the reports of their captains and crews are also a particularly significant source of sightings of Russian energetics weapons tests, as are sightings by ships' crews (Figure 3) and ground observers (Figure 4).

---

[6] Actually a version of this symmetrical regauging was first performed by Ludwig Valentin Lorenz, "Ueberr die Identitat der Schwingungen des Lichts mit den elektrischen Stromen," *Ann. Phys. Chem.*, Vol. 131, 1867, p. 243-263—only two years after Maxwell published his seminal theory in 1865. The paper is also published in English, as Ludwig Valentin Lorenz, "On the identity of the vibrations of light with electrical currents," *Phil. Mag.*, Ser. 4, Vol. 34, 1867, p. 287-301. Unfortunately not much attention was paid to Lorenz's effort, since he independently derived electrodynamics. Decades later, when H. A. Lorentz also published symmetrical regauging of the Maxwell-Heaviside equations, he was given credit for it with no further mention of Lorenz. A proper historical summary of this has been given by J. D. Jackson and L. B. Okun, "Historical roots of gauge invariance," *Rev. Mod. Phys.*, Vol. 73, July 2001, p. 663-680. This is an excellent coverage of the history of who actually did what and when, and who got credit for it.

[7] This dramatically extends the size regions (microscopic through colloidal) and the time durations (momentary to two seconds) where the second law is known and proven not to necessarily apply.

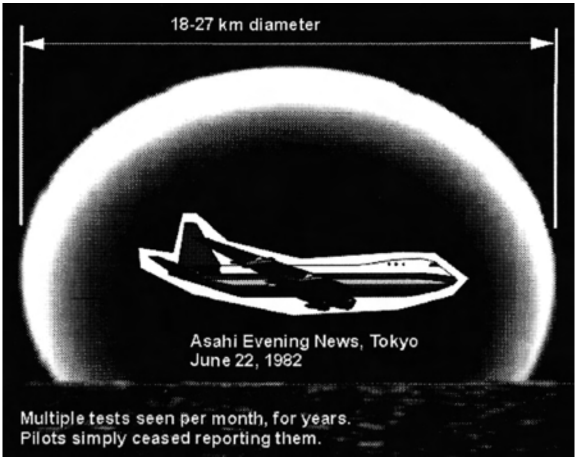
18-27 km diameter
Asahi Evening News, Tokyo
June 22, 1982
Multiple tests seen per month, for years.
Pilots simply ceased reporting them.

Figure 2 Typical shield test, northern route to Japan, seen by passing airliner.

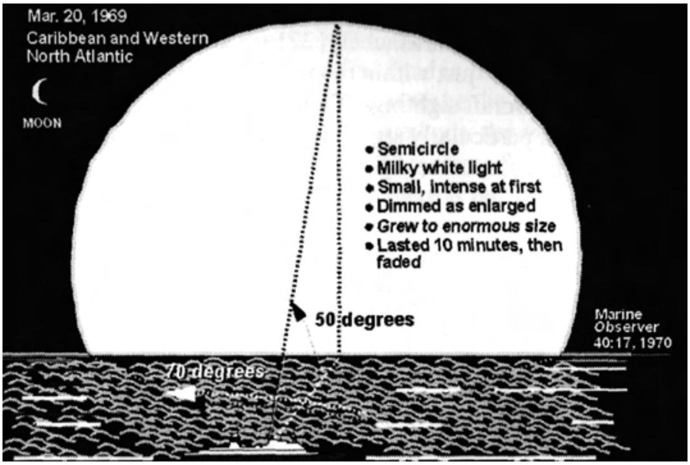
Mar. 20, 1969
Caribbean and Western North Atlantic
MOON
• Semicircle
• Milky white light
• Small, intense at first
• Dimmed as enlarged
• Grew to enormous size
• Lasted 10 minutes, then faded
50 degrees
70 degrees
Marine Observer 40:17, 1970

Figure 3 Giant missile shield test seen by passing ship's crew.

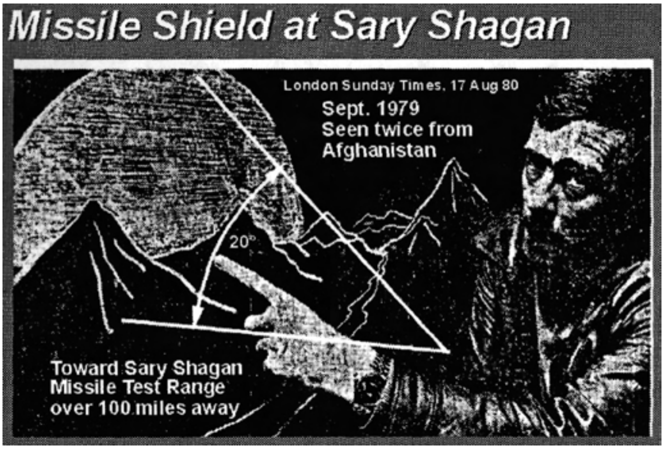
Missile Shield at Sary Shagan
London Sunday Times, 17 Aug 80
Sept. 1979
Seen twice from Afghanistan
20°
Toward Sary Shagan Missile Test Range over 100 miles away

Figure 4 Nick Downie's sighting from the ground of distant Soviet missile shield tests.

1963 Deployment and Immediate Use of Scalar Interferometers

The first huge scalar potential interferometers {23,24} of strategic range and power (Figure 5) were deployed by the Soviets in 1963, and one was used to kill the U.S.S. Thresher nuclear attack submarine (Figure 6), leaving clearly recognizable signatures {25}.

Since 1963, the Russians have had the equivalent of more than seven additional Manhattan Projects (using the Russian 5-year program instead of the 4-year Manhattan Project), back-to-back, in development of energetics weaponry. The energetics weapons have never been given to the regular Russian forces. Instead, all research, production, siting, manning, and employment are by the KGB and still under ruthless KGB control by die-hard communist factions {26}.

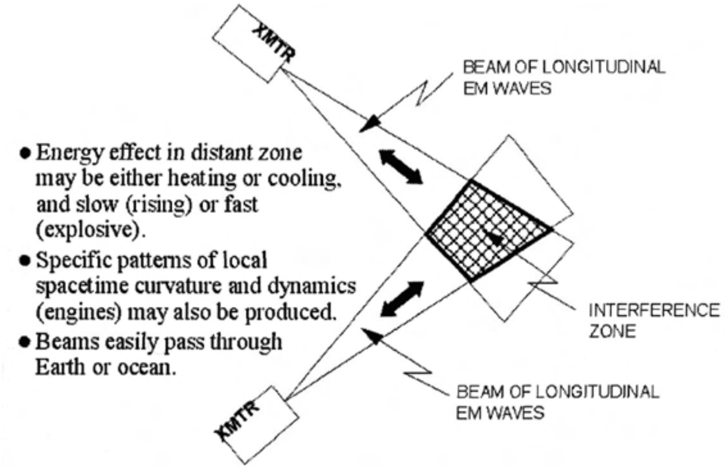

- Energy effect in distant zone may be either heating or cooling, and slow (rising) or fast (explosive).
- Specific patterns of local spacetime curvature and dynamics (engines) may also be produced.
- Beams easily pass through Earth or ocean.

Figure 5 Scalar (longitudinal EM wave) interferometer.

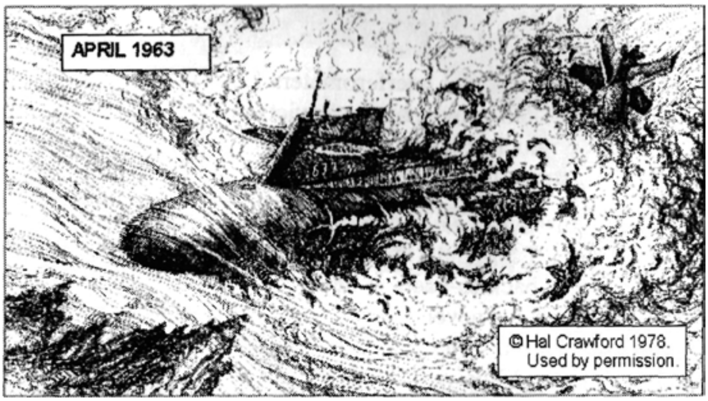

APRIL 1963

© Hal Crawford 1978. Used by permission.

Figure 6 Kill of the U.S.S. Thresher. With her controls jammed, the hull of the doomed submarine implodes when she reaches crush depth

An Example of Russian Technology Astonishing Western Scientists

Some years ago, coordinating with a Western but non-US aerospace firm, I furnished the firm with the names and addresses of some Russian scientists in Moscow, since it was clear from their internet site that the scientists were on the fringes of the KGB energetics weapons program. An excellent European engineer fluent in Russian was sent in, several times. Several unusual things were demonstrated to him, including (i) transmitting enormous energy down a very thin wire, and (ii) cold molding, or turning metal into a liquid at room temperature, pouring it into a mold, and then letting it sit and harden. All without heating.

The engineer also closely questioned the Russian scientists about Russian energetics weaponry, a subject the scientists were most reluctant to discuss. Finally they admitted the energetics weapons existed, and they actually obtained a meeting between the engineer and the KGB General who had directed the Soviet energetics weapon program for more than 20 years. In the meeting, the General coldly admitted the weapons, stated that "Of course you are not going to be allowed to see *those!"* and confirmed that somehow the Russians obtained everything the present author writes, as soon as he writes it {27}.

The engineer then brought the Russian scientists to his aerospace firm in that Western nation, where the scientists demonstrated cold molding to assembled scientists and some U.S. personnel. I forwarded a written explanation to the Western scientists of how the cold molding was performed technically. Later, on calling the engineer again, I discovered that the foreign authorities of that country had suddenly classified everything over there, and the engineer could no longer even talk to me without filing a Foreign Intelligence Contact Report. My own part in all this was completely open-source, pro bono, and I had already written of it openly and publicly.

Softening of Metal at a Distance Was One Effect Used Against the Challenger

At any rate, earlier I had openly advanced (and printed) the same mechanism, since it was the metal softening mechanism used by the KGB to kill the U.S. Challenger spacecraft in 1986. Publicly I had been resoundingly called a lunatic for advancing such a "preposterous" thesis. Nonetheless, metal softening by a distant LWI (longitudinal wave interferometer) was definitely utilized as part of the kill of the Challenger, as a close colleague here in the U.S. proved *experimentally,* detecting and demonstrating that metal-softening Russian signal prior to the kill of the Challenger. He amplified the signal and demonstrated on the bench its nearly instant softening of nails, rendering the nails momentarily as limp as wet noodles (Figure 7). Nails from the same box, not exposed to the signal, remained hard and could be hammered into a board. Not so the nails from the box that were exposed to the amplified Soviet signal! Those nails folded up like a wet noodle when tapped with a hammer, and could not be driven into a board.

Working unpaid with the foreign scientists, we had in fact obtained the "smoking gun" proving that this cold molding capability rigorously existed in the KGB inventory. Further, it had existed so long that the KGB had essentially *declassified* it so that the civilian Russian scientists seeking employment funds from the West could utilize it.

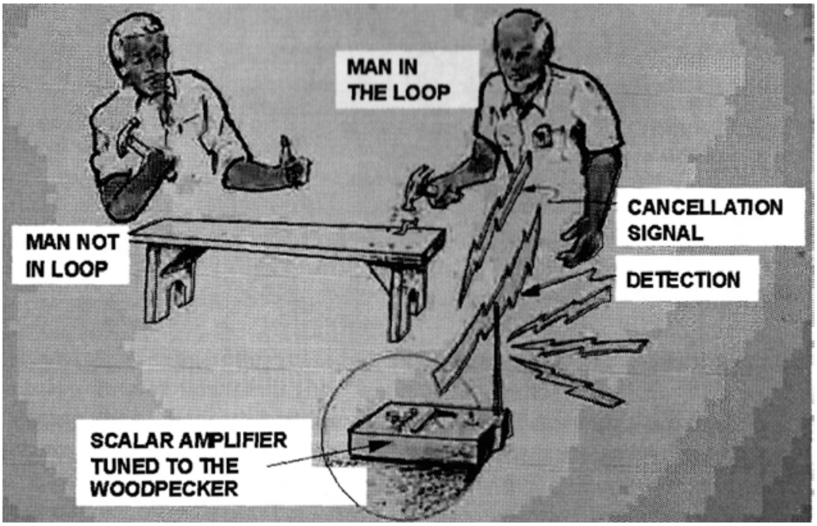

Figure 7 Proof of metal-softening signal: Golden softens nails with amplified Woodpecker signal.

Energetics: Three Branches and a Strategic Deception Plan

The *energetics* weapons use exotic polarizations of EM waves, quantum potentials, and the "infolded" LW electrodynamics (both scalar and longitudinal photons) inside and comprising every "ordinary" transverse EM field and wave. The KGB energetic weapons are categorized (Figure 8) according to what they are targeted against:

(1) against inert matter, fields, and potentials etc., that branch of weapons is called by the same name, *energetics* weapons.

(2) Against living tissue, bodies, cells, biofields, biopotentials, etc., they are known as *bioenergetic* weapons. Disease-induction electrodynamics such as used to irradiate the U.S. Embassy in Moscow are examples of bioenergetic weapons.

(3) Against the mind, thought, memory, behavior, and the mind-body coupling mechanism, they are known as *psychoenergetic* weapons. Particularly in the latter mode, these weapons also use time-polarized (scalar) EM waves and time-polarized (scalar) photons as well {28}.

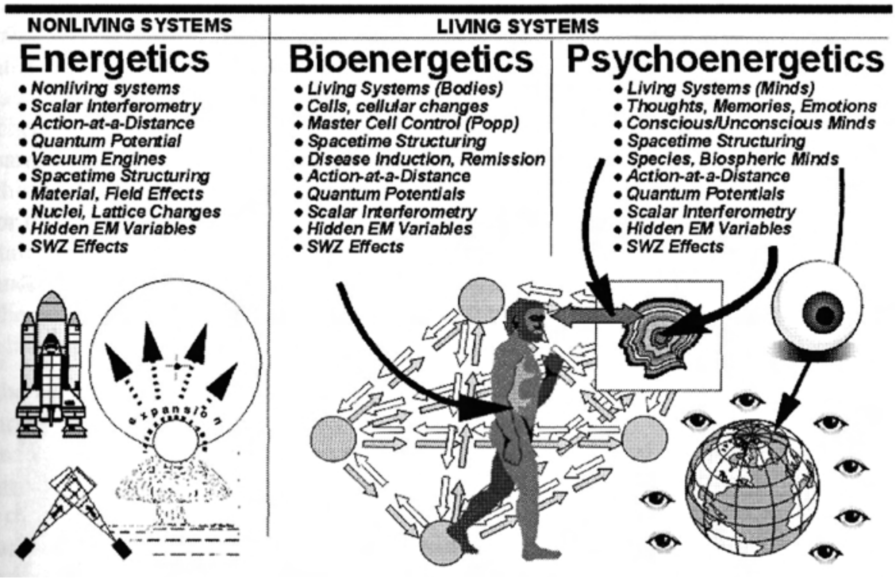
NONLIVING SYSTEMS
LIVING SYSTEMS
Energetics
• Nonliving systems
• Scalar Interferometry
• Action-at-a-Distance
• Quantum Potential
• Vacuum Engines
• Spacetime Structuring
• Material, Field Effects
• Nuclei, Lattice Changes
• Hidden EM Variables
• SWZ Effects
Bioenergetics
• Living Systems (Bodies)
• Cells, cellular changes
• Master Cell Control (Popp)
• Spacetime Structuring
• Disease Induction, Remission
• Action-at-a-Distance
• Quantum Potentials
• Scalar Interferometry
• Hidden EM Variables
• SWZ Effects
Psychoenergetics
• Living Systems (Minds)
• Thoughts, Memories, Emotions
• Conscious/Unconscious Minds
• Spacetime Structuring
• Species, Biospheric Minds
• Action-at-a-Distance
• Quantum Potentials
• Scalar Interferometry
• Hidden EM Variables
• SWZ Effects
expansion

Figure 8 Three branches of Russian energetics weapons.

The KGB also implemented an elaborate and continuing deception plan, as is standard military practice for any great strategic attack plan. The KGB deception plan has been highly successful {29} in keeping the United States convinced that these weapons do not exist, and convinced that the standard strategic nuclear weapons possessed by the West are "leading" and "superior."

Strategic Attacks Scheduled and Why We Were Not Destroyed

Indeed, the West's nuclear weapons are inferior to Russian energetics weapons, particularly to the quantum potential weapons (Figure 9) deployed at the end of 1989 and to the newer "causal system" weapons deployed since the first of 1999, where *functional robot systems* (Figure 10) are made of nonmaterial spacetime curvatures and their dynamics only! In the event of a full strategic Russian energetics strike, an opening strike with quantum potential weapons {30} will dud all nuclear weapons on earth, all nuclear power systems, and all nuclear propulsion systems in about 10 minutes. This takes care of most of the U.S. strategic armament, *within the first 10 minutes.* The publicized strategic weapons of this nation have in my opinion been almost defenseless now for at least a full decade {31,32}, but I also believe that situation may be rapidly changing for the better.

A friendly little foreign nation *does* have such weapons including QP weapons that operate in multiply connected spacetime (MCS). That little nation has been responsible for our continued survival and has continued to deter the planned KGB strategic energetics strikes upon the West. There are indications (though still not certain) that at least one—and possibly two—other friendly Western nation also possesses such weapons.

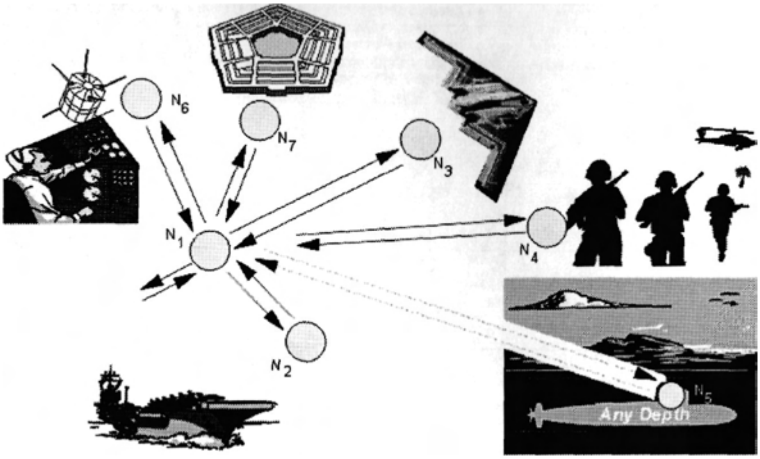
N_6
N_7
N_3
N_1
N_4
N_2
N_5
Any Depth

Figure 9 Quantum potential instantly attacking widely separated targets.

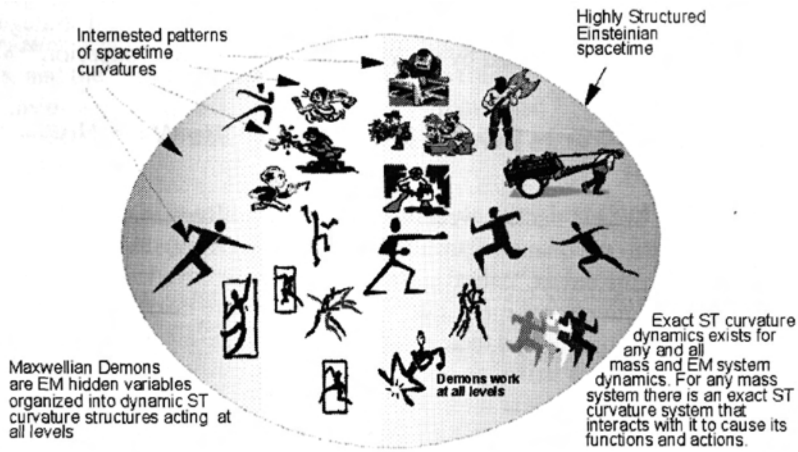
Internested patterns of spacetime curvatures
Highly Structured Einsteinian spacetime
Maxwellian Demons are EM hidden variables organized into dynamic ST curvature structures acting at all levels
Demons work at all levels
Exact ST curvature dynamics exists for any and all mass and EM system dynamics. For any mass system there is an exact ST curvature system that interacts with it to cause its functions and actions.

Figure 10 Causal system robots (CSRs). These are sets of ST curvature engines, with functions organized into a single complex weapon system with communication, propagation, weapons effects, and command and control functions incorporated. When the CSR interacts with mass, the mass performs those system functions.

Twice in 1997 alone *we were within days of the scheduled total strategic destruction of the U.S. by die-hard KGB energetic weapons,* with all-out strategic attacks actually scheduled in each case. The first attack was scheduled in latter February but was quickly countered. The attack was immediately rescheduled for May 1. The U.S. intelligence and scientific communities were apparently unaware of what was happening, and still do not believe it. However, as this author previously informed appropriate government agencies a few days prior to the attack scheduled for May 1, 1997, U.S. intelligence agencies certainly intercepted my urgent personal fax directly to the prime minister of the friendly little nation, urgently requesting that the "sane" command and control of the countering MCS/QP weapons be changed to "insane" control and spelling out the compelling reason why it was necessary.

In the insane weapons control mode, the computer periodically (say, every two hours) initiates launch sequence for the weapon, automatically. If any operating personnel remain alive on site, there is a designated short period in the sequence where the onsite personnel can countermand the order and abort the launch. If the order is not countermanded, the launch is not aborted and the "doomsday" weapon automatically fires. In that case, KGB military power and most of Russia would disappear from the face of the earth.

This was necessary to nullify the impending strikes of MindSnapper negative energy EMP weapons {33} on those critical friendly QP weapon sites to instantly kill all personnel on site. Strike by the MindSnapper instantly kills every living thing in the area, and a protracted contamination remains whereby the struck areas emit longitudinal EM waves. If one attempts to insert new crews to resume operation of the weapons, the crewmen sicken and then die in the entry attempt. First, increasingly severe interference between mind and body control occurs. Then the individuals waver, lose consciousness, go into seizures, and their minds gradually de-couple from their bodies and they die. Fortunately, alter my fax message the C3 system was changed to the insane mode, and the Russians were notified, just in the nick of time {34}. To prevent their own destruction by the certain insane counterstrike, the KGB aborted the looming strategic strikes.

Ironically, at about the very time that the KGB strategic armada was standing down, Secretary of Defense Cohen {35} was making the following statement in Georgia:

> *"Others are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves...So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations...It's real, and that's the reason why we have to intensify our efforts."*

Almost certainly Secretary Cohen had no knowledge that, so to speak, a great Sword of Damocles hanging over his head was being removed by a friendly little foreign nation at that very moment, as he uttered those words apparently referring to the older longitudinal EM wave interferometer weapons. I suspect that Dr. Cohen is to this day still unaware of the incidents that were ongoing at the time of his poignant statement.

Attempts to Alert the Nation

We alerted the President and the National Security Council as early as 1984 (Figure 54). In 1998 we also furnished selected Senators, Congresspersons, and certain high-level U.S. government agencies with color copies of a 200-page briefing and expose {36} of—among other things—these weapons, their testing, and their clandestine use against the U.S. since 1963. Because of the nearly 50 years of demonstrated induction of diseases {37, 38} (Figure 11) in personnel in the U.S. Embassy in Moscow (e.g., responsible for the deaths of three U.S. Ambassadors), we also included part of the briefing on the Priore work {39} (Figure 12) showing the remarkable cellular changes (time-reversal of diseased states back to a previous earlier healthy condition) that can be and had been experimentally induced by energetics under rigorous scientific controls.

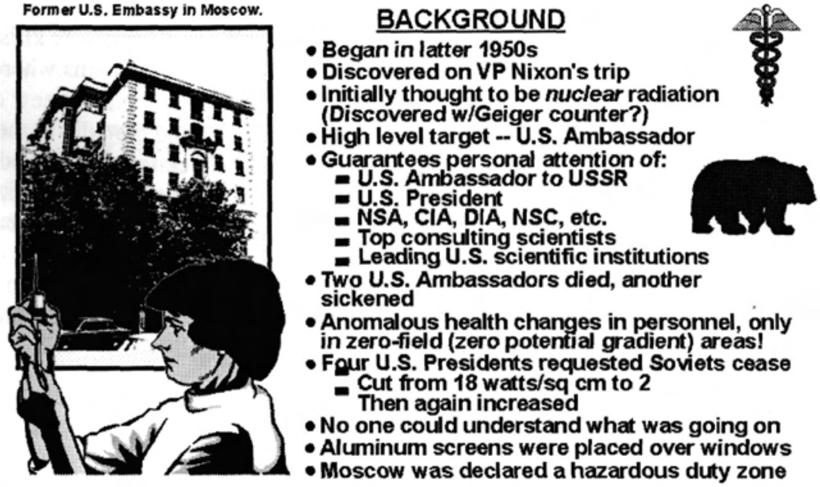

Former U.S. Embassy in Moscow.

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter?)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
  - U.S. Ambassador to USSR
  - U.S. President
  - NSA, CIA, DIA, NSC, etc.
  - Top consulting scientists
  - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero potential gradient) areas!
- Four U.S. Presidents requested Soviets cease
  - Cut from 18 watts/sq cm to 2 Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

Figure 11 Microwave radiation of U.S. Embassy in Moscow.

We proposed to the DoD a very rapid, high priority development program to develop portable suitcase-sized computer-controlled treatment devices (Figure 13) capable of saving a majority of mass casualties—e.g., from a professional large anthrax attack on a major population center.

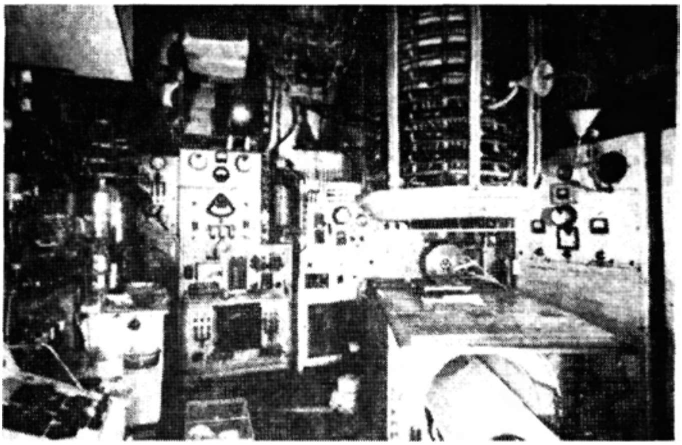

Figure 12 Priore[1] laboratory and device for treating small animals.

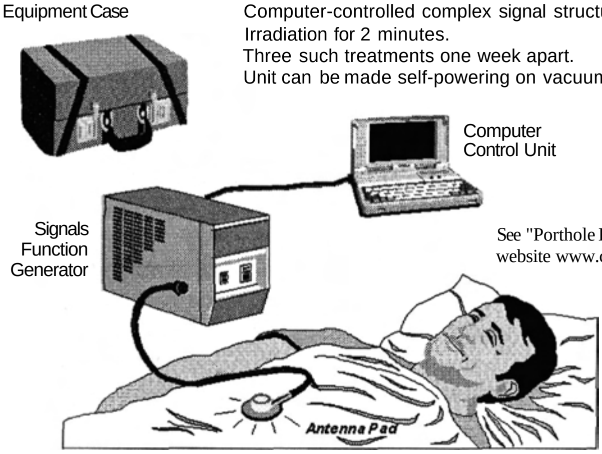
Equipment Case
Computer Control Unit
Signals Function Generator
Antenna Pad

Two blankets have antennas in them.
Uses an advanced but simple concept.
Eliminates plasma tube mixing etc.
Computer-controlled complex signal structure.
Irradiation for 2 minutes.
Three such treatments one week apart.
Unit can be made self-powering on vacuum energy.

See "Porthole Briefing" on website www.cheniere.org.

Figure 13 Portable unit for rapid treatment of mass casualties.

The Responses

The responses—or more exactly the near total lack thereof—by various U.S. government agencies were enlightening. E.g., the National Institutes of Health (NIH) never let the package out of its Policy (i.e., *political spin control)* section. It did not check a single scientific reference on a proven method documented in the hard French scientific literature for reversing terminal cancer, infectious diseases, etc. Not a single scientist called me to discuss such a proven, revolutionary effect. Instead, the NIH Policy section simply shipped the package over to the DOD as "their problem, not ours." That was because the package also explained how the Gulf War Disease was induced, including how semen can cause infection of the wife, and how the structured body biopotential of the sickened veteran can induce similar structuring of the biopotentials of his children by proximity, thus inducing various aspects of the disease.

Effective Survival Treatment of Mass Casualties Could Be Developed

Meanwhile, we had uncovered a way to dramatically speed up the Priore healing process, and use only normal transverse EM radiations for ready adaptation of existing equipment, while still forcing the same time-reversal of diseased and damaged cells back to normal. Just much faster. This meant that very small, suitcase-sized treatment units (Figure 13) could now be developed in a reasonable time—e.g., in two to three years, given a high priority, intense effort, adequate funding, and a carefully chosen scientific team.

So, we proposed a crash development by DOD of a small, suitcase-size portable device for quick, mass treatment of mass U.S. casualties following terrorist attacks on our cities using weapons of mass destruction. Eventually an innocuous reply (forced by my congressman) simply stated "it was not supported by the literature." In the package, of course, I had *specifically cited* the numerous scientific papers in the French scientific literature reporting and proving the experimental results. I had also worked 14 years to decipher the mechanism actually performing the revolutionary healing accomplished in rigorous animal testing by the Priore team. Eleven years after suppression of the Priore effort, the University of Bordeaux, which had been pressured into rejecting Priore's doctoral thesis, did approve and publish a doctoral thesis by Perisse on the work {40}.

The National Science Foundation (NSF) did not reply at all. Yet at the time the official strategic threat to the United States listed WMD attack on our cities and great population centers as the greatest threat of all (Figure 14). Today, as everyone knows we are in a war after the terrorist attack on the twin towers in New York and on the Pentagon on September 11, 2001. The U.S. government clearly recognizes that it is not a matter of if additional attacks on the U.S. cities and populace will occur, but *when.* The terrorists are also known to have already infiltrated weapons of mass destruction such as biological warfare weapons (anthrax, smallpox, bubonic plague, etc.) Nonetheless, apparently the NSF simply did not believe a novel but *rigorously demonstrated-in-the-1960s* unorthodox process that could potentially save most of those millions of Americans who otherwise will surely die—and who *are* going to die in the first major WMD strike on our population centers.

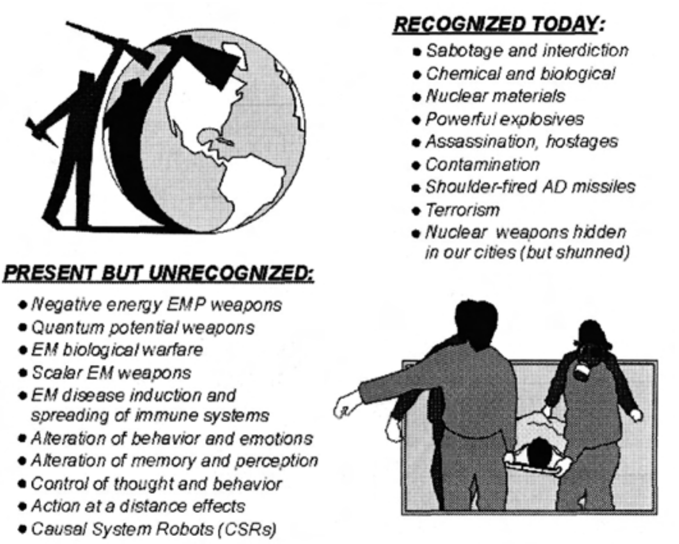
RECOGNIZED TODAY:
• Sabotage and interdiction
• Chemical and biological
• Nuclear materials
• Powerful explosives
• Assassination, hostages
• Contamination
• Shoulder-fired AD missiles
• Terrorism
• Nuclear weapons hidden in our cities (but shunned)
PRESENT BUT UNRECOGNIZED:
• Negative energy EMP weapons
• Quantum potential weapons
• EM biological warfare
• Scalar EM weapons
• EM disease induction and spreading of immune systems
• Alteration of behavior and emotions
• Alteration of memory and perception
• Control of thought and behavior
• Action at a distance effects
• Causal System Robots (CSRs)

Figure 14 The mass destruction weapons threat to our populace.

The entire scientific method is based on assigning priority to experimental truth rather than dogmatic belief. If experiments refute the theory, the theory must be changed and the experimental results accepted. Else one is not following scientific method. Apparently the National Science Foundation does not follow scientific method, nor does it seem interested in doing so. Neither do the National Institutes of Health. The decisive results of some 2,000 rigorous animal experiments reported in the refereed scientific literature in leading French journals, by multiple established French scientists, were simply ignored because the results are contrary to present dogma. Meanwhile, four years have been lost. During that four years, the portable units could have already been developed, mass produced, and made available to treat and save millions of coming U.S. civilian casualties. Apparently the lives of those Americans are not as important as maintaining the present medical dogma. When those millions do die—and they will—we shall most certainly remind those agencies of the caliber of their dedication to scientific method and of their service to their fellow Americans. In my personal view, ignoring a chance to save so many Americans is treason of a very special kind.

The Official Silence Was Deafening

Not a single scientist in any of those and other organizations seems to have taken the package seriously. Not one called me to discuss it, or apparently studied the references, etc. No one asked for a personal briefing. No one was interested in the actual photo of the strike of a Russian EM missile from a scalar interferometer, offset from a U.S. night shuttle launch (Figure 15) from Cape Canaveral in latter November 1985, or the photo of the actual registration point ball of light high in the air (Figure 16) over that same shuttle launch {41}. The same weapon then killed the Arrow DC-8 at Gander, Newfoundland about two weeks later (Figure 17). An eyewitness (or more than one) actually observed the streak of light from the sky that struck the Arrow DC-8 in the right fuselage ahead of the engines {42,43}, after the thrust of the engines were reduced during take-off by use of a negative energy (cooling) interferometer. A similar ball of light associated with the kill of a Titan missile fired from Vandenberg AFB in early 1986 {44} and printed in *Aviation Week & Space Technology* magazine, was also apparently of no concern.

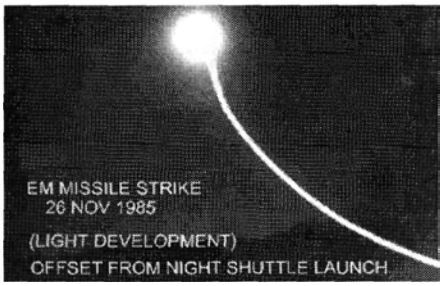

PHOTO BY BOB GLADWIN

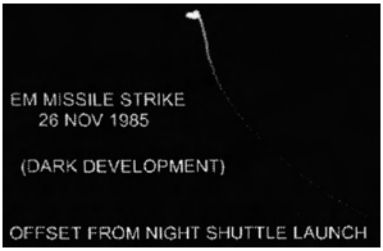

Scalar interferometer operator fires offset EM missile from Russia.

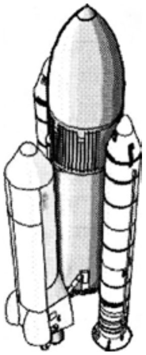

Figure 15 Soviet EM missile strike offset from U.S. shuttle launch at Cape Canaveral on 26 Nov. 1985. This is the smoking gun.

These remarks are intended to show the lack of understanding that has existed in our governmental, scientific, and intelligence communities of what energetics is and of the great energetics superweapons that have been developed. With the present rapidly growing interest in longitudinal EM waves, however, we suspect that such lack of understanding is now no longer the case. We certainly hope that is true, and we are

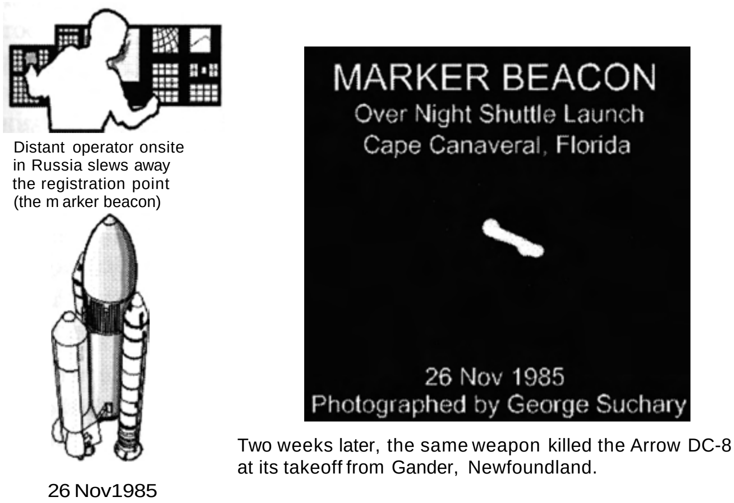
MARKER BEACON
Over Night Shuttle Launch
Cape Canaveral, Florida
26 Nov 1985
Photographed by George Suchary

Distant operator onsite in Russia slews away the registration point (the marker beacon)

26 Nov1985

Two weeks later, the same weapon killed the Arrow DC-8 at its takeoff from Gander, Newfoundland.

Figure 16 Marker beacon above U.S. shuttle launch at Cape Canaveral, 26 Nov. 1985. Russian crews were using shuttle launches as practice ICBM launch targets.

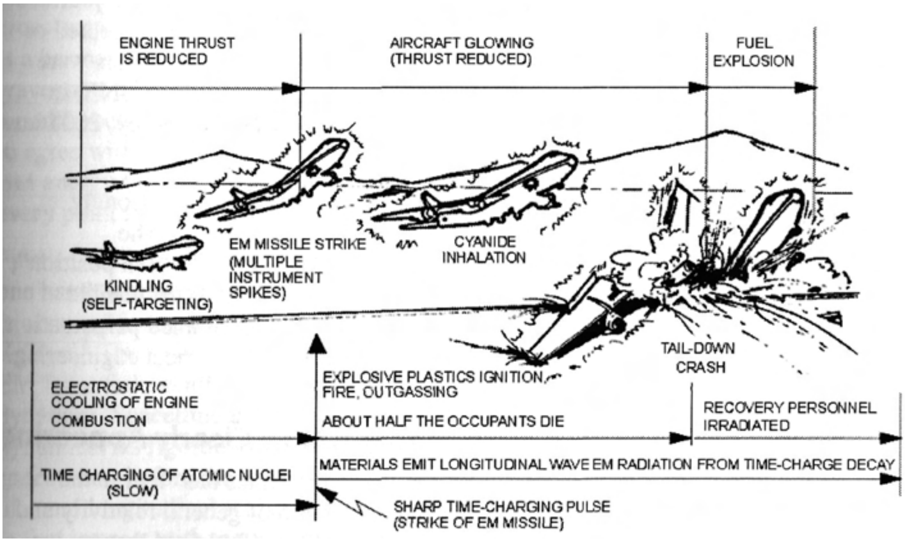
ENGINE THRUST IS REDUCED
AIRCRAFT GLOWING (THRUST REDUCED)
FUEL EXPLOSION
EM MISSILE STRIKE (MULTIPLE INSTRUMENT SPIKES)
CYANIDE INHALATION
KINDLING (SELF-TARGETING)
TAIL-DOWN CRASH
ELECTROSTATIC COOLING OF ENGINE COMBUSTION
EXPLOSIVE PLASTICS IGNITION, FIRE, OUTGASSING
ABOUT HALF THE OCCUPANTS DIE
RECOVERY PERSONNEL IRRADIATED
TIME CHARGING OF ATOMIC NUCLEI (SLOW)
MATERIALS EMIT LONGITUDINAL WAVE EM RADIATION FROM TIME-CHARGE DECAY
SHARP TIME-CHARGING PULSE (STRIKE OF EM MISSILE)

Figure 17 Kill of the Arrow DC-8 at Gander, Newfoundland Dec. 12,1985.

much encouraged that at least one—and possibly two—friendly Western nations now possess quantum potential weapons.

The Long Dry Spell in Correcting Electrodynamics May Be Slowly Ending

In over 20 years of unrelenting effort, until 1999 we were unable to get any significant Western scientists of real "horsepower" (e.g., in non-Abelian electrodynamics, foundations errors in electrodynamics, advanced gauge field theory, general relativity, etc.) to meticulously examine conventional U(1) electrodynamics and its glaring errors, and to look at weapons implications of higher group symmetry electrodynamics.

Beginning about three years ago, however, a noted scientist, Dr. Myron Evans {45,2}, along with other theoretical scientists of the Alpha Institute's Institute of Advanced Study (AIAS), have been extending electrodynamics by developing the 0(3) electrodynamics. They also have deeply examined the Whittaker work of 1903 and 1904 on which the early part of the Russian energetics weapons are based {24}.

The AIAS analyses, and subsequent papers by Dr. Evans and Alex Labounsky as well as by the entire AIAS group, have clearly established the primary importance of time-like precursors of EM fields, operating in massfree spacetime where fields E and B cannot exist. These time-like precursors *create* all the rest of the conventional electrodynamic entities {46}. This is a dramatic extension to electrodynamics and physics across the board. More than 100 papers have been produced to date, with more than thirty published in journals such as *Foundations of Physics,* and many of the others are either accepted or still in the referee process with various journals. Some 60 of the papers were published as a single special edition of the *Journal of New Energy* (JNE) in latter 1999, and a second edition of *Modern Nonlinear Optics,* Wiley, 2001 has been published with many important papers.

However, the problem is that the scientific community, which is strongly committed to "business as usual", has funded none of this work. The conventional lead agencies of the community are still in the "ostrich position", with their heads buried very firmly in the sand with respect to the terrible damage they continue to enforce on this nation by their continued perpetuation of an old, long-archaic, inadequate electrodynamics and electrical engineering.

Engineerable Unified Field Theory Is Now Clearly Appearing

The rapidly emerging AIAS extension of electrodynamics has "met in the middle" with Sachs' {4} revolutionary generalization of general relativity and electrodynamics. For the first time, an *engineerable* unified field theory—employing 0(3) electrodynamic means—is now being produced. The AIAS work in 0(3) electrodynamics was shown to be an important subset of Sachs' approach. It also now provides the full, rigorous theoretical foundation and model for the Priore mechanisms and results.

We also comment most strongly that the important SU(2)xSU(2) electrodynamics as developed by Barrett (47) leads to essentially the same conclusions, since Barrett's electrodynamics is homomorphic with 0(3) electrodynamics. Barrett, of course, is one of the pioneers of ultrawideband radar—another scientific area that was fiercely opposed and suppressed by the orthodox U.S. establishment for some time. Ironically, today those very scientists who were so dogmatic in their vociferous condemnation of UWB radar, have assumed the mantle of "experts in the UWB field", sometimes even taking credit for having "advanced it" in the first place.

Examples of Some Major Non Sequiturs in Conventional Electrodynamics

In every textbook and millions of technical papers in the West, electrodynamicists routinely calculate the "magnitude of the scalar potential". Actually, not a single one—including Maxwell—calculated or calculates the *magnitude of the potential itself.* Instead, they universally calculate the *reaction cross section* of the potential at a point occupied by an assumed intercepting/collecting unit point *static* charge {48}. At best that is a representation of the *intensity* of the field at each point. The reaction cross section of the potential with a fixed unit point static charge is indeed a scalar value. The "scalar" potential itself, on the other hand, *is not* its own reaction cross-section at each point of itself, and it is not a scalar entity at all! Instead, it is a harmonic bundle of bidirectional EM longitudinal phase conjugate wavepairs, as shown by E. T. Whittaker in 1903 {49}. It is and always has been a multi-vectorial, multiwave entity. By slightly reinterpreting Whittaker's work to agree with quantum field theory, the scalar potential is also a circulation of EM energy from the time domain to 3-space and back to the time domain, at every point in space that is occupied by the potential.

Further, the "field" notion is utilized in two self-contradictory manners. On the one hand, it is assumed in the massless reaches of space, and on the other hand it is assumed in mass, *which is the only case in which a force field is properly defined.*[8] The so-called "electromagnetic field" existing in empty space is not an EM force field at all, but a curvature or curvatures of spacetime with assorted ilynamics. Spacetime is after all active, and being active means curvatures and ilynamics. As rigorously shown by the AIAS theoreticians, what exists in *spacetime*—before the force-fields appear on reacting charged mass—are time-like and longitudinal scalar potentials and fluxes. These "pre-EM field" entities in fact interact with mass to produce all the force fields (the electromagnetic fields). Mass is a *component* of force; simply by F == *d*p/dt, which is expanded into F = d(mv)/dt, which is ma + v*(dm/dt).* Note that both terms have mass as a component. Hence there is no force or forcefield when mass is absent. Present mechanics is seriously wrong (and has been wrong for hundreds of years) in assuming a separate massless force acting upon a separate mass.

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[8] Since Maxwell and **the** original pioneers believed in a material ether filling all space, to them t**here** was not a single point anywhere in the universe that was devoid of mass. Hence to them there was only one kind of field: **the** kind that exists in mass.

Jackson, one of the ablest classical electrodynamicists of our day, adroitly states how electrodynamicists skirt that issue. Quoting, p. 249 of his *Classical Electrodynamics,* second edition: *"Most classical electrodynamicists continue to adhere to the notion that the EM force field exists as such in the vacuum, but do admit that physically measurable quantities such as force somehow involve the product of charge and field."*

Our comment is that one does not get an observable until after the interaction of a cause with a previous effect, to provide a change (a new effect). The 4-cause itself—in this case the field that actually exists in the vacuum—is never observed nor is it observable. Its *effect* (force with an affected observable mass as a component of it) is observed. The field in space and the field in matter thus do not even have the same fundamental units, but differ by a factor of m. In electrodynamics the m is avoided by "defining" the field as force per unit coulomb of "charge" (without saying or accounting "charged mass").

Wide Confusion of Cause and Effect

Present electrodynamics (and even the hoary old mechanics, as pointed out) has thoroughly confused the causal (4-space) side of the observation process with the effects (3-space) side—observation yields *3-spatial* entities, not 4-spatial. Indeed, as is well known, *time is not observable, even in theory.* That is really because observation is a *d/dt* process applied by the 3-space intermediary (e.g., mass) being acted upon by the causal (4-space) entity in spacetime, to produce a change in that intermediary (3-spatial) that results (is observed). *A priori,* the output of the observation process does not even exist in time, since its fundamental units are LLL and not LLLT. The observation process is thus *d/dt(LLLT)* => LLL.

Further, electrodynamics omits the fact that, not only does the causal entity act upon the intermediary to produce the *effect* (changes to the intermediary), but *those changes (effects) also act back (in reverse) through the intermediary to produce changes in the causal entity itself.* This mutual interaction between cause and effect (but never stressed in exactly that manner) is well known in GR, where the curvature of spacetime acts upon mass-energy to change it, and the resulting change in mass-energy also acts back upon spacetime to curve it. The omission of the latter "back reaction" in EM theory by Maxwell resulted in omitting half the energy, half the wave, and half the causal entity in spacetime, as well as half the effect. The missing half of the effect appears as the Newtonian third law reaction, which in electrodynamics is just mystically "assumed" to be an effect without a cause.

The vast importance of restoring this missing "back action of effect upon cause" is because it can be deliberately utilized to directly engineer the causal (4-space) state itself, producing nonmaterial "engines" and unobservable functioning robot systems comprised entirely of curvatures of spacetime and their dynamics. Such "causal system robots" (CSRs) can be designed and engineered to then perform almost any desired action upon normal mass systems they encounter. The robots also can easily penetrate vast depths of mass, which is mostly empty space filled with potentials, fields and waves—all of which are just bundles of longitudinal EM waves and their dynamics. "Mass" is actually a vast superhighway through which such CSRs can easily move at the speed of light {50}.

CSRs: Engineering the Unobserved Causal Side To Create Functional Systems

Understanding early on the mutual interaction between cause and effect that existed in their energetics, the Russians were able to engineer this totally new kind of system: the *causal system robot* or CSR (Figure 10). With sufficient theoretical development, one can "work backwards" by adroitly re-engineering the effect to obtain a desired causal system (spacetime curvature set along with its impressed dynamics; (Figure 18) corresponding to some physical system and its changes one desires to engender. One thereby directly creates a deterministic set of spacetime curvatures and impressed dynamics, which we call an "engine" (Figure 18). This *ST curvature engine* system can then function as a completely separate system {51} (Figure 10). One can communicate with it via longitudinal EM waves, control it, etc. By building in scalar interferometry functions, the **CSR** can be given "weapons" capabilities, etc.

- All levels of energy structures and all levels of time structures mold spacetime geometry.
- The "pattern" is called a *template* for a vacuum engine (spacetime curvature engine).
- Spatial and temporal structurings of the engine act upon mass at all levels.
- This produces a template of forces, for precise translations and stresses within the mass at all levels. The forces exist in both time and 3-space.

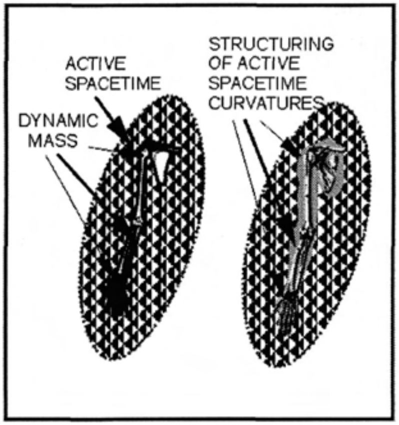

Figure 18 The principle of general relativity extended to include the concept of the vacuum engine.

In theory such a CSR can be assembled to perform any desired function or complex of functions upon matter, fields, potentials, etc. that is desired. In short, one can build real, functioning "infolded" (subspace) robot weapon systems using this "backward engineering of spacetime itself process. The huge underground facilities (hundreds) that the Russians continued to build after the collapse of the Soviet economy and the fall of the Soviet Union, apparently contained the full CSR development and control facilities as well as the operational systems employed for this totally new kind of weapon system.

A great engineering of the future lies in engineering CSRs, which already constitute a great leap forward past the material nanobot technology being pursued in the West.

Making the First CSR is Extremely Difficult; Making a Million Copies Is Easy

The development of a specific CSR with a specific set of functions is akin to developing a highly complex software system of major proportions (several tens of millions of lines of code). The job is extremely difficult, and tortuous "debugging" is required for a lengthy period. Once a single CSR is completed and debugged, however, the production of thousands or even many millions of copies is then a trivial task.

The CSR may be visualized as a sort of vast complex of longitudinal EM waves (recall, we are speaking of ST curvatures, not the conventional EM waves thought to operate on a flat spacetime. *All* EM waves operate in a curved spacetime *a priori*, as clearly shown by Sachs). It turns out that all matter is mostly empty space, filled with potentials and fields. Space itself, considering its energetics, may be taken as a giant scalar potential. All those potentials and fields and waves are in fact nothing but sets of longitudinal EM waves and dynamics. In short, they are vast superhighways for the travel of CSRs and the propagation of longitudinal EM waves.

A CSR can be embedded within any kind of EM potential, wave, or field. So to replicate one, one embeds it in a magnetic signal and records that signal on a diskette or other media. Then one makes millions of copies of the diskette, for perhaps 10 cents or less each. Or do it en masse, by first completing a CD-ROM with a hundred or two hundred CSRs embedded in its signals (Figure 19). Then simply reproduce the CD-ROM. Every reproduction has another hundred or two exact duplicates of those CSRs, made for almost no cost at all. With communications built into the CSRs, the command and control facilities take charge of them, give them individual numbers or designations, and a robot armada emerges with most unusual capabilities indeed.

The puzzling underground facilities in Russia (which our fellows apparently never deciphered and which remained a mystery) apparently contained the scientific teams, the research and development facilities, the production facilities, and the command and control facilities for the new vast CSR weapon complex. It was to see its first great employment at the end of 1999.

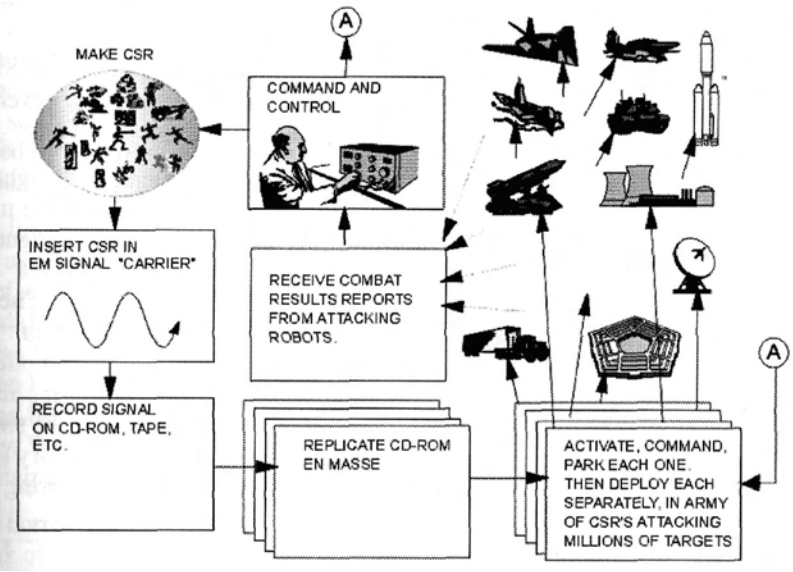
MAKE CSR
A
COMMAND AND CONTROL
INSERT CSR IN EM SIGNAL "CARRIER"
RECEIVE COMBAT RESULTS REPORTS FROM ATTACKING ROBOTS.
RECORD SIGNAL ON CD-ROM, TAPE, ETC.
REPLICATE CD-ROM EN MASSE
ACTIVATE, COMMAND, PARK EACH ONE. THEN DEPLOY EACH SEPARATELY, IN ARMY OF CSR'S ATTACKING MILLIONS OF TARGETS
A

Figure 19 Mass reproduction of a CSR is simple and inexpensive. The CSR resides in, or propagates inside, any EM signal, potential, or field.

In 1999 The KGB Deployed Massive Numbers of CSRs for a Strategic Attack

In latter 1999 the KGB began massively deploying these CSRs of various types throughout the Western world, particularly including the United States. They simply sent the CSRs back "inside" the potentials and fields and waves being emitted from radio stations, TV stations, power lines, satellites, communications systems, inside matter, etc. These CSRs were deployed and infiltrated in major command posts and installations throughout the U.S. and its allies. True to form, the KGB even "stimulated" some major computer systems in critical U.S. government facilities by having the robots "surface" some effects on the Computers, right through the firewall programs (whose EM signals and operations indeed provided nice superhighways for the robots). Our fellows **detected** the interference as a "sophisticated computer hacking attack" (puzzlingly from the Russian Academy of Science), and then the robots "submerged" again after deliberately performing actions to produce obvious changes and guarantee the U.S. detection of those changes. The purpose of this "stimulus and probe" was to see if the U.S. was aware of CSRs and CSR **technology.** We clearly showed we were not, and we still are not aware of them. Fur**ther,** the entire government apparatus—including all our vaunted national laboratories—knows absolutely nothing at all about CSRs, and none of the laboratories believe it. That is the same posture they've been in with respect to energetics weapons for a half-century. Apparently they will be in that same posture for another half century, left to their own devices.

However, I was not allowed to remain a casual onlooker for this new CSR armada! The KGB also planned to use me as a stimulus to ping the government yet another way, and then assess the government's response.

Here in Huntsville, suddenly I was personally struck by such a CSR right from my computer monitor, with the attack riding through the light from the monitor to my eyes and retinas and right into the brain and nervous system (Figure 20). This was the type of CSR that can lurk in any potential or field inside a computer, and then strike and kill the operator looking at the screen. The CSR took over control of the machine, split the screen so that only one-inch horizontal strips were luminous—one at the top and the other at the bottom of the screen with the middle dark. These two separated horizontal strips allowed scalar interferometry via the inner LWs comprising the light from the two strips. The LWI signals crossed in my vision center, where suddenly ordinary EM signals and waves were produced by the scalar interferometry occurring there.

Stimulating apparently the only analyst capable of recognizing a CSR attack and connecting it with the scheduled giant strategic CSR attack.

KGB General commanding the energetics weapon previously confirmed that what this analyst writes on his computer is received as soon as he writes it. Apparently accomplished by Tempest techniques or directly by energetics.

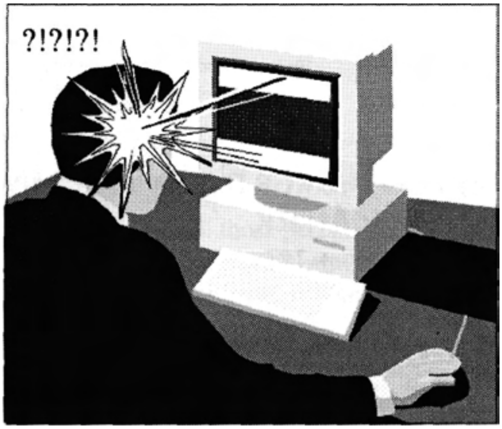

Figure 20 Present author struck by CSR in latter 1999 as a deliberate nonfatal stimulus.

I saw rapid blinding flashes like a hundred flashbulbs exploding at once right in my face. However, the signals representing those "flashes" were being created right there in my vision center. An external camera would have recorded only the weirdly separated screen display. It *would not* have shown the brilliant flashes of light I was seeing, unless it was set up stereoscopically. The strike was deliberately sustained for only about 10 seconds so as to be severe but nonlethal; about 30 seconds would be totally lethal. Violent fibrillation of the heart also resulted explosively, and I was instantly hypnogogic and seriously weakened by sudden hypoxia from near total lack of blood pumping (because of the fibrillation). The purpose was apparently to strike the only analyst in the U.S. who would recognize what the nature of the attack was, stimulate him, watch him try to notify the government, and then observe the government's reaction. It look four days to recover from the strike. But I knew immediately what had made the strike, and that I had been hit with a CSR weaponized by having a built-in scalar interferometry capability. It was also a very sophisticated CSR, as it showed by assuming complete "intelligent" control of my computer's functions.

When I finally recovered, I did notify the government and warn them of CSRs, exactly as anticipated by the KGB. As might be expected, the government's total disbelief and lack of reaction clearly showed they knew nothing of CSRs. They simply did not believe such weapons existed or even could exist. Sadly, once again one faced the "not invented here" syndrome. General relativity and its provision for spacetime curvatures and their associated dynamics (engines) operating back upon mass are apparently just supposed to remain a theoretical curiosity. Why, obviously no scientist in his right mind would think of weaponizing such!

A more correct answer is, *"Like hell they wouldn't!"* *American* scientists would not think of it, but *Russian* scientists with their national chess-playing psychology will immediately seize upon any opportunity—even many moves ahead in the game—and develop it and utilize it. They understand and use the boa constrictor. We only understand and use the immediate rattlesnake.

How the Asymmetrically Deployed Strategic Attack Was Stopped in Its Tracks

However, we also alerted the "little nation" that has advanced EM weapons technology, which—since early 1997—has been saving the U.S. by forcing the abortion of impending KGB energetics weapons attacks.

When I warned them in 1997 about the MindSnapper weapons and mind-control weapons used against Captains Button and Svoboda, unknown to me at the time they later reacted and suddenly destroyed those facilities in Russia (apparently with violent scalar interferometry strikes). So *that* mind-control type of attack being readied for 1999 was thwarted for a few years by these strikes sometime prior to mid-1998.

But to return to the CSRs. In the latter quarter of 1999, the Russians were developing and deploying throughout the West numerous kinds of CSRs. So the period at the end of 1999/first few days of 2000 attack was already scheduled for a massively programmed CSR attack. It was designed to cripple the entire **nation,** and perhaps even collapse it economically, yet all would be blamed on Y2K! Our scientific ignorance guaranteed that we would blame it on something **mundane that** our scientists could understand: Y2K problems in all the old software programs running so much of our automated systems, communications, and centralized functioning, accounting, banking, etc. In short, the KGB planned to give us a bicentennial gift: a Y2K nightmare far beyond our wildest fears.

After my recovery from the CSR strike in the latter quarter of 1999, I again urgently alerted the friendly nation of the development of CSRs and their widespread deployment—and informed them of the personal attack on me and specifically why it was made nonfatal. Of course I also alerted our own government. We were scheduled for a *real* Y2K problem that would curl one's hair, so to speak, with everything imaginable failing—and probably all blamed on Y2K.

Admirably, beginning just at the end of 1999, the friendly nation simply began methodically and massively cleaning out all the CSRs, and they disposed of them in very short order! Such CSR systems[9] may easily be located and destroyed by strategic longitudinal EM wave weapons {52}, when and if one has the longitudinal EM wave technology sufficiently developed. So Y2K came and went with only a few relatively minor incidents from the *normal* Y2k problems expected.[10]

However, unknown to our scientists and intelligence community, a great war of a very special kind—*the Earth's first strategic subspace war*—had just been silently fought and won, right there inside our power systems, command and control systems, major weapon systems, electrical power systems, electrical control systems of our nuclear submarines and strategic bombers and missiles, even inside the electronics of our nuclear warheads, etc. And not a bobble showed on the surface, anywhere. This was the first real "subspace" war, where weapons made of pure spacetime curvatures and dynamics were involved as the main offensive battle systems. LWI destruction of numerous CSRs inside potentials and fields in various electronic equipment throughout the nation, created little or no overt signs at all.

This time we won, thanks to the "good guys" and not to our own scientific community. Next time we may not be so fortunate.

The Mostly-Ignored Time-Energy Interaction

For some inexplicable reason, physicists in the West have omitted one-half the actual photon interaction.[11] If one allows the spatial energy component of the photon to interact, then one must also account for the simultaneous interaction of the time-component of the photon. A mass m absorbing a photon (AE)(At) becomes *masstime* (m+dm)t, not mass m. Mass *m* and masstime *mt* are as different as are force *F* and impulse *Ft.* No scientist in his right mind would ignore the *t* in *Ft* and consider just the force *F.* Yet that exact kind of giant *faux* ***pas*** has been done for many decades now in the photon interaction. And it is still ubiquitously done in physics. *Mass does not emit photons; masstime does.* Again, physicists confuse effect and cause.

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[9] These early CSRs apparently had no "stealth" capabilities built-in, so they were easily detected and destroyed, rather like shooting fish in a rain barrel.

[10] Even so, a normally disastrous Y2K problem was narrowly averted, in the nick of time, by a concerted national software reprogramming effort massively mounted and costing billions of dollars. Otherwise, the expected "ordinary" Y2K problem would have been very bad indeed.

As the Russian energetics weapon scientists know full well, time is actually spatial energy compressed enormously, by at least the factor c^2. Hence time has at least the equivalent energy density of mass. The greatest amount of "energy" existing in a photon—particularly in lower frequency photons—is in that "time" part that is arbitrarily ignored and discarded. An ELF photon has enormously more total energy—by many orders of magnitude—than does a gamma ray photon.

Energy and time components in the photon are canonical. Low frequency photons are reduced in the magnitude of their *spatial* energy component and thereby maximized in their *time* components. For the ordinary (decompressed) *energy equivalency* of the time component, one must multiply the time in seconds by c^2. Halving the frequency, e.g., doubles the time component, whose spatial equivalent energy is now $(2t)\times(c^2)$. With respect to the original photon, the new total energy (achieved by halving the frequency) is given by $[(\Delta E)/2] \times [(2\Delta t) \times c^2] = [(\Delta E)(\Delta t)\times c^2]$. So halving the photon's frequency increases its total energy by a factor of c^2, which is approximately by a factor of 9×10^{16}. Hence photons actually carry enormously greater total energy (most is locked up as time) at low frequency than at high frequency. Indeed, the highest energy photon interactions in the universe are at low frequency, *if and when* a transduction of the available time-energy into spatial energy occurs.

This has been completely missed in the West, but not by the Russian energetics weapons scientists. They have been *engineering* that formidable new high energy but low frequency physics—a physics far more energetic than that used in our most energetic colliding beams in "conventional high energy physics".

The cold fusion processes[12] stumbled onto by Western scientists are using the

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[11] I.e., except for accounting for the overall "action" (angular momentum) and such things as **minimum** action theorems, etc. Treating the photon's increment of time specifically as a formidably compressed piece of spatial EM energy does not appear in Western physics. It has **long** been utilized in the KGB's secret energetics weapon science.

[12] For an explanation of the use of time-reversal zones in cold fusion experiments, and some of the resulting new transmutation reactions that result, see T. E. Bearden, *Energy from the Vacuum: Concepts and Principles*, "Chapter 10: Cold Fusion: Low Spatial-Energy Nuclear Reactions at High Time-Energy," Cheniere Press, Santa Barbara, CA, 2002. Available from www cheniere.org. Statistically, the formation of significant time-reversal zones is guaranteed by **the transient** fluctuation theorem of Denis Evans et al., and by recent experimental work by Evans et al. proving that such zones (where the reactions run backwards) can and do occur at up to **micron** (colloidal) size and for up to two seconds in duration. We stress that this is a recognized, **proven** violation of the second law of thermodynamics already known to physics.

time-energy component of photon interactions, to generate enormous localized EM energy directly upon the interior quarks and gluons of nucleons {53}. We worked out a speculative explanation of the active time-energy transduction mechanisms that fits all the experimental phenomena, including the eerie instrument anomalies occurring in rigorous electrolyte experiments at China Lake for some years. That is included in my new book, *Energy from the Vacuum: Concepts and Principles,* Cheniere Press, Santa Barbara, CA, 2002, available from www.cheniere.org.

Of course consistency alone does not prove it conclusively; consistency is a necessary but not sufficient condition for proof. But at least the proposed explanation is consistent, and nothing else seems to be, at this time. In one chapter in my referenced new book we do cover the cold fusion mechanism and give specific new nuclear reactions producing the excess deuterium, tritium, and alpha particles in so many successful cold fusion experiments worldwide.

My "time-reversal zone" approach is stringent, because the recent work by Denis Evans *et al.* {54} has clearly shown that reactions can and do run in reverse—totally in violation of the second law of thermodynamics—at micron (colloidal) level in size and for up to two seconds in duration (and sometimes even a little longer). So experimental demonstration that the "time reversal zones" I assumed can and do indeed occur has now been accomplished by Evans *et al.* This provides strong experimental and theoretical support for the basic assumption (of the formation and momentary existence of localized time reversal zones that subsequently decay) we used to derive the fundamental cold fusion mechanism including some of the specific reaction equations for excess deuterium, tritium, and alpha particles now demonstrated in hundreds of successful experiments.

In a reversed zone *the law of attraction and repulsion of charges is reversed,* so that like charges attract—sometimes so closely that each enters the strong force region of the other, forming a quasi-nucleus (Figure 21). As the time-reversal zone subsequently decays back to a time-forward zone, the reduced strong force is restored much faster than the Coulomb force is reduced and then reversed back to normal. So during this readjustment decay process, the quasi-nucleus will simply change to an isomer and a known nucleus by quark-flipping to change an H+ ion to a neutron. Note that the "reversal zone" momentarily changes the Coulomb barrier—always the only thing that has really prevented chemical fusion and transmutation at low spatial energy—to a Coulomb attractor. Hence cold fusion—as now backed up by more than 600 successful experiments worldwide, by multiple laboratories and researchers in multiple nations—is an established fact and a herald for a vast new science based on deliberate and intentional reversal of the Coulomb barrier and use of time-energy.

With its usual perspicacity, the organized U.S. scientific community has flubbed it—and flubbed it badly—with respect to cold fusion. Its contribution has largely been a tirade of ad hominem attacks, slander, and libel of a viciousness seldom seen in the annals of science. Once again, the community is far more devoted to defending its cherished dogma (and its own rice bowls from the conventional Big Nuclear Science that cold fusion thoroughly upsets), than it is in applying scientific method which calls for *believing the experiments* and changing the dogmatic theory.

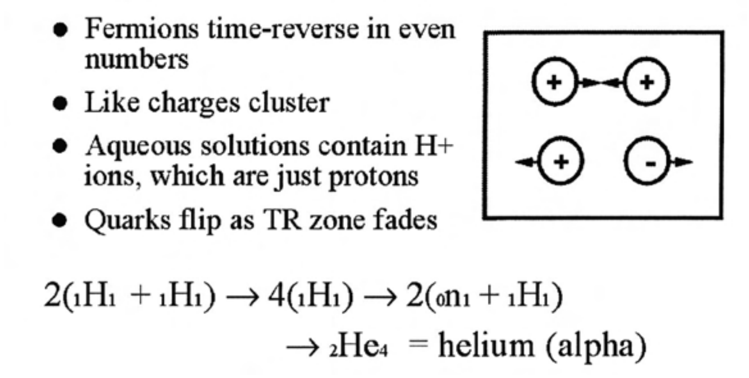

- Fermions time-reverse in even numbers
- Like charges cluster
- Aqueous solutions contain H+ ions, which are just protons
- Quarks flip as TR zone fades

$$2({}_1H_1 + {}_1H_1) \rightarrow 4({}_1H_1) \rightarrow 2({}_0n_1 + {}_1H_1)$$

$$\rightarrow {}_2He_4 = \text{helium (alpha)}$$

Figure 21 Example of a time-reversed zone nuclear reaction common in successful cold fusion experiments.

Development of Threats and Scheduled Attacks Aborted

KGB energetics weapons have long constituted our single most pressing yet largely unrecognized national security problem. That problem has also increased with the growing development and deployment of such weapons by other nations such as China. Some 10 nations, for example, now have scalar interferometry weapons, and even the Japanese Yakuza has them and also has their own secret facilities for producing them in Japan, including small portable units developed for use in assassination and terrorist type warfare within a targeted nation—the United States of America.

Unknown to our government, we narrowly escaped destruction twice in the first half of 1997 from scheduled all-out strategic KGB energetics weapons attacks. **Only** the actions of a friendly small country countered the attacks and caused the **KGB** to abort on each occasion.

When the second scheduled Russian strategic attack was aborted just prior to May 1, 1997, a new KGB counter-counter for the friendly counter used by the **little** nation in latter April 1997 was already rapidly being deployed. The new **Russian** counter-counter—seizure and control of the mind of an operator at a distance, and complete control of his actions while he performs sophisticated technical tasks—was tested in two separate incidents {55}, first on Captain Button (Figure 22, Figure 23) and then on Captain Svoboda about two months later (Figure 24), each flying an A-10 Warthog aircraft over the U.S.

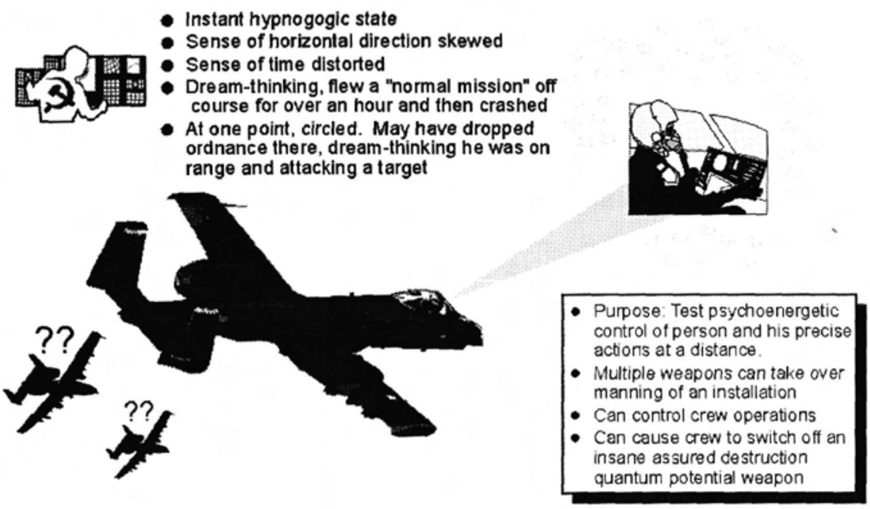

- Instant hypnogogic state
- Sense of horizontal direction skewed
- Sense of time distorted
- Dream-thinking, flew a "normal mission" off course for over an hour and then crashed
- At one point, circled. May have dropped ordnance there, dream-thinking he was on range and attacking a target
??
??
- Purpose: Test psychoenergetic control of person and his precise actions at a distance.
- Multiple weapons can take over manning of an installation
- Can control crew operations
- Can cause crew to switch off an insane assured destruction quantum potential weapon

Figure 22 Captain Button's bizarre flight to his death on 2 April 1997.

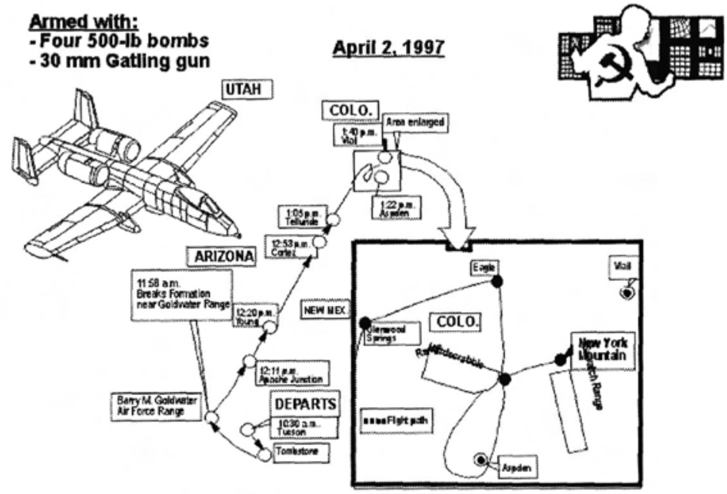

Armed with:
- Four 500-lb bombs
- 30 mm Gatling gun
April 2, 1997
UTAH
COLO.
Area enlarged
1:40 p.m. Vail
1:22 p.m. Aspden
1:05 p.m. Telluride
12:53 p.m. Cortez
ARIZONA
11:58 a.m. Breaks Formation near Goldwater Range
12:20 p.m. Young
NEW MEX.
12:11 p.m. Apache Junction
Barry M. Goldwater Air Force Range
DEPARTS
10:30 a.m. Tucson
Tombstone
Eagle
Vail
COLO.
Glenwood Springs
New York Mountain
Range
Flight path
Aspden

Figure 23 Captain Button's flyaway path to his eventual fatal crash.

The highly successful test against Captain Button (Figure 22, Figure 23) is particularly significant, as we have explained. Captain Button was controlled while performing highly technical operations, for more than a full hour, and one hour was apparently the acceptance test specification. Captain Svoboda (Figure 24) simply had her mental perception of up and down instantly reversed while climbing her A-10 warthog from low level ordnance delivery on target. Erroneously perceiving she was diving, she immediately "corrected" sharply to "climb", thereby diving headlong into the ground and perishing in the resulting explosion of her aircraft.

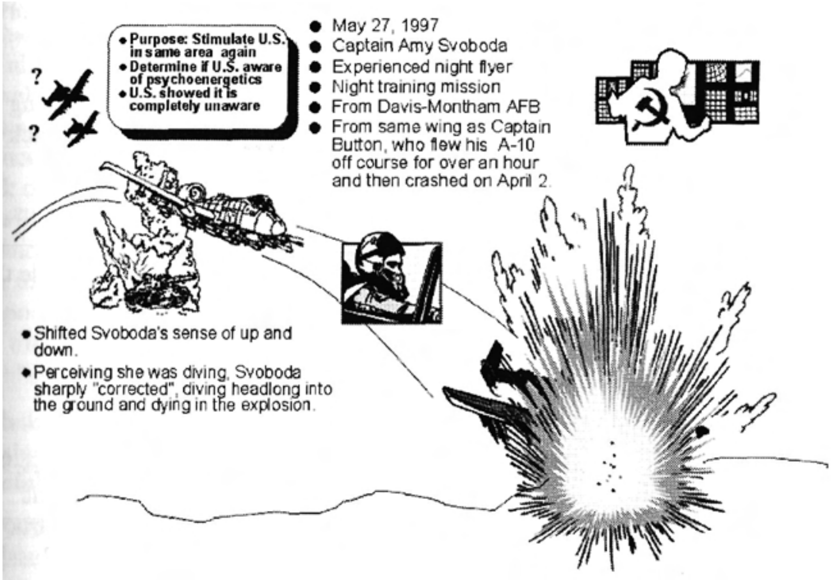
• Purpose: Stimulate U.S. in same area again
• Determine if U.S. aware of psychoenergetics
• U.S. showed it is completely unaware
?
?
● May 27, 1997
● Captain Amy Svoboda
● Experienced night flyer
● Night training mission
● From Davis-Montham AFB
● From same wing as Captain Button, who flew his A-10 off course for over an hour and then crashed on April 2.
• Shifted Svoboda's sense of up and down.
• Perceiving she was diving, Svoboda sharply "corrected", diving headlong into the ground and dying in the explosion.

Figure 24 Climbing out of low-level ordnance delivery, Captain Svoboda suddenly dives headlong to her death on 27 May 1997.

Svoboda's kill demonstrated a *tactical destruction* usage, whereas Button's test demonstrated a *strategic* hostile usage of the adversary's defending weapons crew to take action against the adversary's defending strategic weapons system. A new KGB strategic energetics attack against the United States—using the mind control (psychoenergetics) weaponry to take over the operators of the little nation's QP weapon sites and stand the sites back down for maintenance—was rescheduled apparently for latter 1997 to mid-1998 or so. It appears that the extensive preparations for that attack were totally destroyed clandestinely and very suddenly by the friendly little nation some time after we warned them, as we mentioned above.

However, still another Russian counter—the development of "weaponized engines" (functioning causal system robot weapons, "infolded electromagnetic" in form) consisting of organized and functioning systems of spacetime curvatures operating in and traveling through EM fields, potentials, waves, and signals—came on line (Figure 10, Figure 18). The KGB simply altered the attack plan for a Millennium Strike and completed the forward deployment of these eerie new CSR systems by introducing millions of them directly throughout U.S. facilities, command centers, weapon systems, power grids, ships, aircraft, submarines, missiles, nuclear warheads, computers, communications systems, etc.

We estimate that several million such systems were introduced in that manner, and readied for the Millennium Strike. The United States and its allies were and are almost totally unprepared for this dramatically new kind of strategic warfare that has been developed and deployed against us. No such weapons have previously existed in history. Consequently our national survival and the survival of our allies was once again at stake—and right on schedule during the critical period from mid-1999 through mid-2000 that we had predicted back in 1997.

The die-hard elements of the KGB indeed had a new millennium gift for us, but it was not at all the kind of gift we would appreciate. The KGB is not a monolith! This plot apparently did not include Putin, and it did not include the rest of the KGB, particularly that element reporting to Putin.

Live Destructive Tests Over and Near the U.S. Have Continued

Without elaboration, we believe that the Learjet crash incident and the EA-990 crash incident may have been very sophisticated tests of these new robotic causal EM systems. We also believe that the long years of Russian construction of over a thousand mysterious underground facilities, even though the Russian economy was collapsed and the citizens and soldiers were destitute, is significant. Those facilities apparently contain the set of command and control systems for this vast new strategic weapon system.

The facilities also include the "factories" where the CSRs are made, because the factories are unlike any other factories ever conceived. They do not build "physical" systems, but something more like "software." Only now the "software program" itself is an independent robotic system, with a full set of weapon systems functions, and capable of independent navigation and functioning anywhere, while remaining under KGB command and control via longitudinal EM wave communications infolded inside the potentials of earth, ocean, and space. The facilities also contain the operational forces, headquarters, and communication and control systems that maintain, deploy, and employ (fight) these CSR systems, and direct the battle.

The purpose of the 1998 document we sent to DoD—which did not include the causal robot system armadas later deployed throughout everything in the West—was to inform selected members of the Senate and Congress of the energetics threat situation and summarize it for them. Accordingly, we presented the background of the development and testing of the KGB energetics weapons since WW II, in some detail, for selected Legislators and their staffs. We also included some specifics on the failure of the U.S. scientific community to keep American science and technology abreast of that of our adversaries.

The Scientific Basis For Energetics Weapons Is Established

As pointed out above, the scientific basis for our early use of Soviet scalar EM interferometry is now rigorously established by work accomplished by the Alpha Foundation's Institute of Advanced Study. It is also rather "old hat" now **that** all major weapons labs have discovered longitudinal EM waves and are **actively** working on and with them. The Director of the AIAS, Dr. Myron Evans, is an eminent scientist and theoretician with over 600 papers in the hard science literature. He and his colleagues also have had zero funding for their work on the higher group symmetry electrodynamics necessary to understand such things as energetics. A combination of non-Abelian electrodynamics, advanced gauge field theory, and the impact of E. T. Whittaker's work shortly after the turn of the century has shown that scalar interferometry is real, and that weapons based on scalar interferometry can be a potent threat on the battlefield. The time-like (time-energy) basis for electrodynamics is now clearly established.

With this important new work, we are now only some 40 years behind the **Russian** weapons scientists! But we are beginning to close the gap—and hopefully that will be done very rapidly.

In 1999 after being personally attacked by a CSR, I again contacted the office of the leader of the friendly small nation and again furnished all the information we possess on the new CSR systems programmed by the KGB as a countering method against the small nation's QP weapons. The outcome was that the little nation destroyed the CSRs in time, as we stated above. We were lucky that (i) the KGB did attack me with one of the weapons, deliberately to "get my strong and immediate attention", and (ii) deliberately did not kill me with the strike. Otherwise, there would have been no warning to the little nation, and the U.S. a**nd** its allies would have experienced a "Y2K" problem worse than their wildest fears, possibly collapsing the economy of the United States and much of the developed world.

Our Situation Here In the U.S. Is Precarious

Meanwhile, our own scientific community apparently does little or nothing in **these** areas, except to castigate, slander and libel anyone daring to suggest that such "out of the box" weapons areas even exist. E.g., there does not appear to be a single U.S. scientist who knows how to create a *time-polarized* EM wave.[13] There do not seem to be any concerted programs to deal with t-polarized photons and t-polarized EM waves. Our scientists still firmly believe that one has to propagate spatial EM field energy through space to affect a target electromagnetically, when that was obsoleted by Russian "subspace EM longitudinal wave propagation" weapon systems deployed as early as 1963, and was completely obsoleted by deployment of quantum potential weapons in 1989.

Yet a close colleague of the present author has single-handedly developed and demonstrated prototype superluminal communication systems using the infolded (longitudinal EM wave) electrodynamics, and these systems would have been heading onto the market in latter 2001 except for the sudden bankrupting of the major backing company. There has not been any funding forthcoming for his revolutionary work, but only clumsy attempts to take it from him. It is my fear that the further clumsy takeover attempts will be successful, and this desperately needed technology will never see the light of day in defense of our nation. As a single example without further discussion, his work revolutionizes the present notions used in the rapid development of quantum communication and quantum computing, because it revolutionizes the very notion of the Q-bit, completely removing the statistics of the quantum state and making it engineerable. This of course is completely counter to present QM notions, but is consistent with the Bohm hidden variable approach to quantum mechanics.

Meanwhile, our own weapon scientists apparently still do not recognize the possibility of a superluminal longitudinal EM wave communication system, and appear to have no motivation or intention to develop such. This is in a way quite sad; quantum tunneling at more than four times the speed of light, of a clearly recognizable Mozart symphony, has already been demonstrated in a section of a waveguide {56}. Whatever one wishes to call it and however one wishes to do it, superluminal communication of intelligible signals has been clearly demonstrated in the laboratory. For the "infolded" longitudinal EM waves, all the "normal" or "envelope" EM waves, potentials, and fields are just great *superwaveguides* for such longitudinal EM wave "tunneling through subspace" at superluminal speeds.

---

[13] Keeping one's sense of humor, apparently there has also not been a U.S. scientist who even recognized and knew what actually powered an electrical circuit, until our solution to the source charge problem and publication of it in 1998. Eerily, even after the technical basis for a solution had been proven in particle physics in 1957, no one seemed to have applied the broken symmetry of opposite charges to the common dipole and to a dipolarity such as a scalar potential and a charge (with its associated virtual charges of opposite sign, in the modern view). Everyone accepted that the fields and potentials and their energy are established by their associated source charges, but no one had stated that the source charge receives its input energy from its asymmetry in its seething energy exchange with the active vacuum.

The Dominant Weapons Are Quantum Potential Weapons

Full-bore deployment of Russian quantum potential weapons occurred by the end of 1989, the first lab prototype weapon having been tested in April 1986 against the U.S. air attack on Libya (Figure 25). Beside Russia, two other nations—Brazil and the "little friendly nation"—also had developed quantum potential {57} weapons. The United States did not develop them, or at least apparently not just yet.

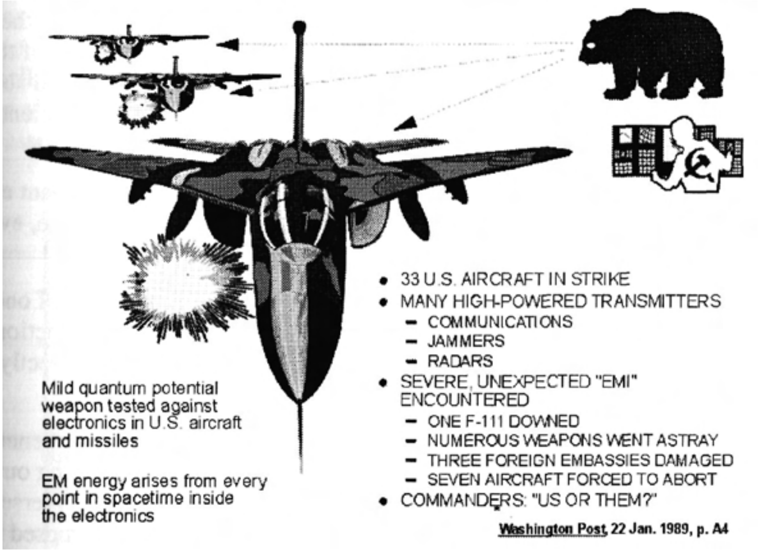
• 33 U.S. AIRCRAFT IN STRIKE
• MANY HIGH-POWERED TRANSMITTERS
– COMMUNICATIONS
– JAMMERS
– RADARS
• SEVERE, UNEXPECTED "EMI" ENCOUNTERED
– ONE F-111 DOWNED
– NUMEROUS WEAPONS WENT ASTRAY
– THREE FOREIGN EMBASSIES DAMAGED
– SEVEN AIRCRAFT FORCED TO ABORT
• COMMANDERS: "US OR THEM?"
Mild quantum potential weapon tested against electronics in U.S. aircraft and missiles
EM energy arises from every point in spacetime inside the electronics

Washington Post 22 Jan. 1989, p. A4

Figure 25 U.S. air strike on Libya, April 1986.

Burlier this year (2002), China also deployed QP weapons, and we now find that an*other friendly* nation has them as well. That brings the total to five, as of this writing. Two of those are friendly, and a third is astraddle of the fence, so to speak. The other two are Russia (the KGB) and China.

At this point China could go either way, so it represents a future enigma. China **has** control of the Panama Canal, and has inserted more than 200,000 Chinese into Panama—which is on the way to gradually becoming a Chinese territory, as soon as the Chinese in Panama outnumber the native Panamanians. In addition, under the Clinton administration China gained access through two U.S. ports (with little checking, so anything can easily be inserted). China also has a**dditional** ports in the Western hemisphere. China is almost certain to eventually attack and seize Taiwan, which puts her on a collision course with the U.S., si**nce** the U.S. has an agreement to defend Taiwan. She has also declared the South China Sea—through which passes some 60% of the oil bound for Japan, a**nd** much oil for other nations also—to be Chinese territorial waters. China also has developed bioenergetics weapons, having long ago induced cancer into most of the GRU Russian representatives then serving in China. She almost certainly has or is rapidly working to develop psychoenergetics weapons as well.

So far as I am aware, there still exists not a single funded U.S. scientific program to directly correct the glaring errors in our own classical electrodynamics—such as those problems deplored by Nobelist Feynman and Wheeler {58,59,60}. Both knew that the force field concept in space was erroneous. As they put it, only the "potential" for the force field exists in space, in case some charged mass is available there for interaction. But the field itself is created by the interaction and is the effect of it. It does not exist before the interaction occurs. Yet all our texts continue to teach the disinformation of the "field in space." And our science community continues to fiercely defend such dogma, attacking and sometimes destroying the careers of those brave scientists who do try to change it.

One notes that time is multiply-connected, since in theory the same instant exists at every point in the universe. Or said another way, in any instant in time, every point in the universe simultaneously exists.

Operating in the time-domain as a causal system, and then turning out of one point there into any point in 3-space desired, is a means of producing "action at a distance" that obsoletes our old concept of transmitting the energy directly through space {61}.

Presently the U.S. scientific community has little predisposition toward energy turning into the time-domain, operating in the time-domain, then turning out of the time-domain into any desired point in 3-space, anywhere in the universe.[14] Every 3-space point in the universe simultaneously exists in (is superposed in) each point in time, as those points in time occur. In one sense, time can be considered to be the total multiple connectedness of space! We suspect that it may even be possible to interpret "instantaneous" communication—as by a quantum potential—in that "in here-out there" instantaneous fashion via "tunneling through the multiple connection of the time channel".

Finally, mass—being an observable and 3-spatial—does not exist in time. Mass continually turns into masstime (by photon absorption), then masstime turns back into mass (by photon emission). Masstime exists in time, but mass does not. U.S. scientists also seem unaware that the so-called "rate of flow of a mass through time" is generated by the sum total of all photon interactions (both virtual and observable) with that mass. The ubiquitous interaction of a mass with photons also causes that mass to continually recur, and thus to seemingly "continuously exist." It is continually observed, but it does not continuously exist! Since the photon interaction is engineerable, then it follows that a specific muss can be time-reversed back to an earlier state {62}.

---

[14] If one models the time domain in three dimensions instead of one, e.g., then in theory it becomes possible to "flip" a 3-dimensional mass object into the time 3-domain at a single "moment," then rotate from that "time 3-point" back into 3-space at a new 3-space location anywhere in the universe. Hence the "beam 'em up Scotty!" of the old Star Trek (and the more modern beaming version) may hold more of a promise than just for science fiction entertainment.

Cellular Time Reversal: Revolutionary Healing by a Team of French Scientists

Priore and eminent French scientists {39,40} unwittingly used the mechanism for time-reversing a mass and every part of it, to time-reverse diseased and damaged cells, including tumor cells, physically changing them back to their previous healthy physical state and condition in vivo. This included all parts of the cell, including its genetics. The Priore team demonstrated revolutionary cures of terminal tumors, infectious diseases, atheriosclerosis, and restored depressed immune systems.

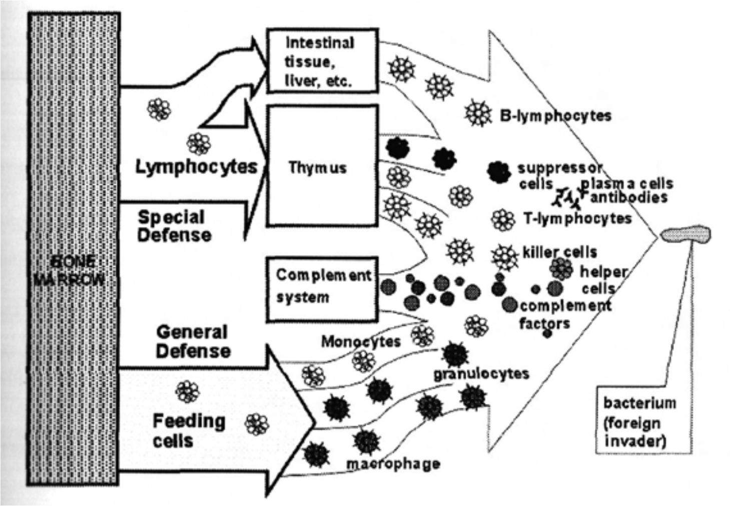
BONE MARROW
Intestinal tissue, liver, etc.
Lymphocytes
Thymus
Special Defense
Complement system
General Defense
Feeding cells
B-lymphocytes
suppressor cells
plasma cells
antibodies
T-lymphocytes
killer cells
helper cells
complement factors
Monocytes
granulocytes
macrophage
bacterium (foreign invader)

Figure 26 Simplified diagram of the immune system.

The immune system (Figure 26) *heals nothing, not even its own damaged cells.* The human cellular regenerative system {63} is responsible for all healing in the body—and it utilizes time reversal of the damaged cells as the active healing mechanism. The regenerative system (Figures 27, 28, 29) pumps the damaged cells with longitudinal EM waves (and therefore with time-polarized EM waves, which always accompany longitudinal EM waves), inducing the cells and all their parts to add the phase conjugates, thereby forming time-polarized EM waves and pumping in the time-domain rather than the 3-space domain. This dramatically extends nonlinear optics to the time domain, and mass pumped in that fashion is time-reversed (propagated back along its own time-track, to a previous physical condition.

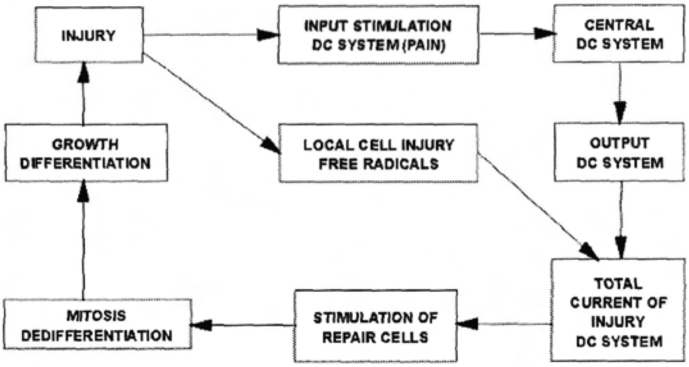
INJURY
INPUT STIMULATION DC SYSTEM (PAIN)
CENTRAL DC SYSTEM
GROWTH DIFFERENTIATION
LOCAL CELL INJURY FREE RADICALS
OUTPUT DC SYSTEM
TOTAL CURRENT OF INJURY DC SYSTEM
MITOSIS DEDIFFERENTIATION
STIMULATION OF REPAIR CELLS

Note: Becker only had conventional EM available, hence was unable to model the inner structuring and inner dynamics of the fields and potentials. *So he missed the deeper "engine and antiengine" mechanisms.*

***Robert O. Becker, "The significance of bioelectrical potentials," Bioelectrochemistry and Bioenergetics, Vol. 1, 1974, p. 191.**

Figure 27 Becker's theoretical control system involved with response to injury.

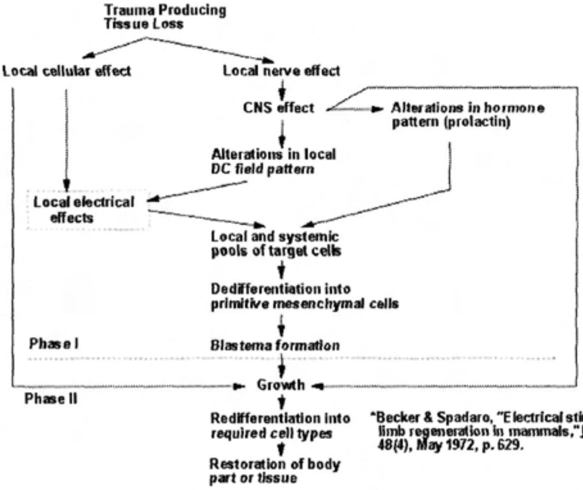
Trauma Producing Tissue Loss
Local cellular effect
Local nerve effect
CNS effect
Alterations in hormone pattern (prolactin)
Alterations in local DC field pattern
Local electrical effects
Local and systemic pools of target cells
Dedifferentiation into primitive mesenchymal cells
Phase I
Blastema formation
Growth
Phase II
Redifferentiation into required cell types
Restoration of body part or tissue

***Becker & Spadaro, "Electrical stimulation of partial limb regeneration in mammals," Bull. N. Y. Acad. Med., 48(4), May 1972, p. 629.**

Figure 28 Becker's proposed control system governing regeneration.

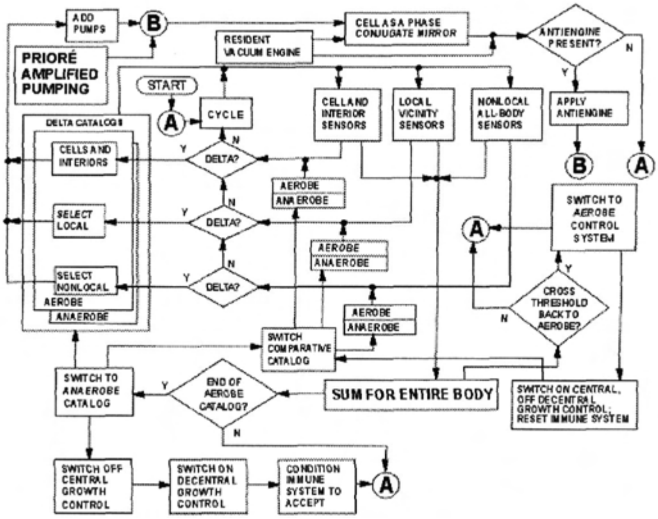
ADD PUMPS
B
CELL AS A PHASE CONJUGATE MIRROR
ANTIENGINE PRESENT?
RESIDENT VACUUM ENGINE
PRIORÉ AMPLIFIED PUMPING
START
A
CYCLE
CELL AND INTERIOR SENSORS
LOCAL VICINITY SENSORS
NONLOCAL ALL-BODY SENSORS
APPLY ANTIENGINE
DELTA CATALOGS
CELLS AND INTERIORS
DELTA?
AEROBE
ANAEROBE
SELECT LOCAL
SWITCH TO AEROBE CONTROL SYSTEM
SELECT NONLOCAL
CROSS THRESHOLD BACK TO AEROBE?
SWITCH COMPARATIVE CATALOG
SWITCH TO ANAEROBE CATALOG
END OF AEROBE CATALOG?
SUM FOR ENTIRE BODY
SWITCH ON CENTRAL, OFF DECENTRAL GROWTH CONTROL; RESET IMMUNE SYSTEM
SWITCH OFF CENTRAL GROWTH CONTROL
SWITCH ON DECENTRAL GROWTH CONTROL
CONDITION IMMUNE SYSTEM TO ACCEPT
Y
N

Figure 29 Author's deeper block diagram of the cellular regeneration system.

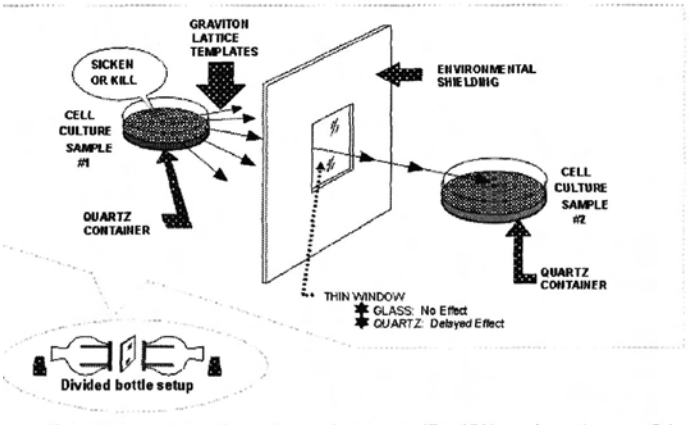
GRAVITON LATTICE TEMPLATES
SICKEN OR KILL
CELL CULTURE SAMPLE #1
QUARTZ CONTAINER
ENVIRONMENTAL SHIELDING
CELL CULTURE SAMPLE #2
QUARTZ CONTAINER
THIN WINDOW
GLASS: No Effect
QUARTZ: Delayed Effect
Divided bottle setup

Note: Minimum lattice is one harmonic interval: IR to UV is such a minimum G-lattice. Consider particularly the dielectric pathway in the emitting diseased cells and in the receiving targeted healthy cells.

Figure 30 Kaznacheyev's electromagnetic induction of cellular disease and disorder.

Kaznacheyev has shown that essentially any cellular disease or disorder can be electromagnetically induced in cells at a distance (Figure 30). Together with Becker's work, this shows that the cells can be altered either detrimentally (disease induction) or beneficially (disease elimination) by purely **electromagnetic** means. It would seem that diseases such as AIDS, e.g., could be **rather** dramatically cured by use of whole-body longitudinal EM wave radiation (with its simultaneously time-polarized EM wave radiation), as was done for other diseases by the Priore team and properly reported in the French scientific literature. We have also uncovered a process and method for causing the body to directly produce the time-polarized EM wave pumping, reducing the irradiation to perhaps 30 seconds of pumping instead of two or three hours {64}.

Becker's Study of the Cellular Regeneration System

In all our medical science, the only true healing procedures being utilized appear to be the use of Becker *et al.'s* tiny EM stimulation across otherwise intractable bone fractures {65} (Figure 31), to dedifferentiate (time-reverse) red blood cells, then redifferentiate (time-forward) them again twice to form osteoblasts, which are deposited in the fracture site to make new bone growth. All the other medical procedures seem to be *interventions,* not *healing.* After the intervention—which of course may be urgently necessary—it is then up to the body to heal itself (restore its cellular and tissue damage and functioning). So we have little *healing* science today, and in fact our medical establishment hardly funds any *healing* studies at all. EM radiation is usually considered as something that simply heats tissue. Our present medical science is deeply engrossed in studying the immune system. Again, the immune system heals nothing, not even its own damaged cells.

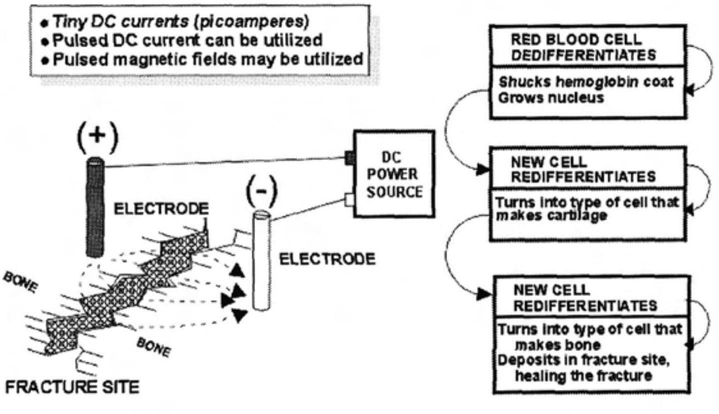
• Tiny DC currents (picoamperes)
• Pulsed DC current can be utilized
• Pulsed magnetic fields may be utilized
(+)
ELECTRODE
(-)
DC POWER SOURCE
ELECTRODE
BONE
BONE
FRACTURE SITE
RED BLOOD CELL DEDIFFERENTIATES
Shucks hemoglobin coat
Grows nucleus
NEW CELL REDIFFERENTIATES
Turns into type of cell that makes cartilage
NEW CELL REDIFFERENTIATES
Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

Figure 31 **Becker's epochal bone fracture healing.**

After the immune system "kills the bad guys" and saves the day, the battlefield is littered with residue and many cells of the body are damaged. The immune system sends in large scavenger cells that clean up the residue. And that's it for the immune system. Comparing it to an army's operation in the field, the immune system is the combat troops, not the medical services.

Restoration (healing) of the damaged cells back to normal is accomplished by the *cellular regeneration* system (Figure 29). This system is little known and little studied, but mostly studied by Becker (Figures 27, 28). It is a system that functions electrodynamically, but uses time-domain pumping to time-reverse the cells and their every part (including their genetics) back to an earlier state. In biology, the effect is called *dedifferentiation*, but without any knowledge of the actual EM mechanism.

So, within its capabilities, the cellular regenerative system in the body already uses longitudinally polarized EM waves, time-polarized EM waves (TPWs), and optical pumping by LWs and TPWs. Here we point out that neither the longitudinal photon nor the scalar (time-polarized) photon is individually observable; however, the combination of the two is observed as the instantaneous scalar potential {66}. With a little correction to properly make the phase conjugate replica wave a time-polarized EM wave, Whittaker's fundamental bidirectional EM longitudinal wave decomposition of the scalar potential (Figure 32) is consistent. Immediately the direct involvement of both **the** scalar photon and the longitudinal photon—and both the scalar EM wave and the longitudinal EM wave—are seen in Becker's bone-healing work using a scalar potential (Figure 31).

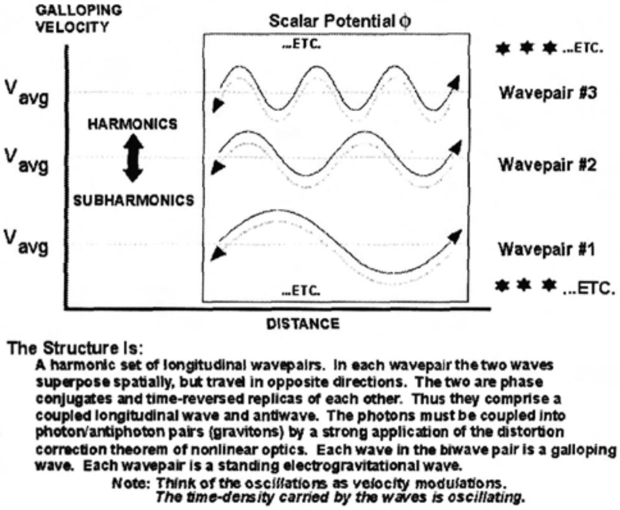

The Structure Is:

A harmonic set of longitudinal wavepairs. In each wavepair the two waves superpose spatially, but travel in opposite directions. The two are phase conjugates and time-reversed replicas of each other. Thus they comprise a coupled longitudinal wave and antiwave. The photons must be coupled into photon/antiphoton pairs (gravitons) by a strong application of the distortion correction theorem of nonlinear optics. Each wave in the biwave pair is a galloping wave. Each wavepair is a standing electrogravitational wave.

Note: Think of the oscillations as velocity modulations. The time-density carried by the waves is oscillating.

Figure 32 Infolded longitudinal EM biwaves composition of a scalar potential, per Whittaker 1903.

Priore unwittingly stumbled onto the actual mechanism used by all biological systems in "healing" (cellular regeneration), and also recognized how to amplify it **(Figure** 12). But no one understood its exact nature, including Priore and the scientists who worked with him at the time, and the conventional community still does not understand it. The Russian scientists not only *understood* it early on, but *weaponized* it as well. So did the Chinese.

Need to Correct and Extend Classical Electrodynamics

The organized scientific community's protracted defense of a seriously flawed classical electrodynamics is long standing. The conventional, comfortable ways of "doing business as usual, leisurely" now threatens the survival of the nation itself. We need to quickly admit and correct long-standing EM errors—such as calculating a reaction cross-section of an entity and calling it the magnitude of the entity itself! Our electrical texts continue to make that fundamental mistake, and they have done it now for 100 years or more. We need to quickly change the classical EM model to include the active vacuum and its interaction, and we need to change all textbooks to clearly state that all EM energy in the universe comes from the active vacuum, via the asymmetry of the source charges in their fierce energy exchange with it.

We also need to point out that all primary electromagnetic entities—the charge, the field, the potential, and every joule of EM energy in the universe—totally violates the second law of thermodynamics. The charge produces continuously increasing negentropy, the field and the potential are formed at expanding light speed across the universe and are perfectly ordered (thereby totally violating the statistical mechanics basis of the second law), and every joule of EM energy is either field energy or potential energy, and hence violates the same statistical basis of the second law.

The Situation Is Serious

Admittedly these are strong statements highly critical of our scientific establishment's track record. But our national survival continues to be increasingly at stake, the situation is serious, and we must not continue to bury our collective heads in the sand like ostriches. We simply cannot continue to idly sit by and pontificate while other groups and nations methodically maneuver technically to cut our collective throats with advanced weapons we cannot defend against, once they find a way to "get by" the little nation that has been countering them for some years. Our own beloved nation may have less than 10 years {67} and perhaps less than three years to survive, unless the organized scientific community is galvanized to focus its very best scientific efforts in the energetics area.

So far, in truly innovative approaches to new methods for electrical energy, the U.S. scientific community is about as energetic as a sand terrapin sleeping in the tropical sun. There is no discernible move to recognize the seriousness of the problem, or to do anything effective about it. In 45 years, the asymmetry of the dipole (and the charge in its modern view as a dipolarity of special kind) has not made it across the university campus from the particle physics department to the electrical engineering department. In fact, the implication of broken symmetry to

electrical engineering and classical electrodynamics seems to still be completely unnoticed by the National Academy of Sciences, the National Science Foundation, our universities, and our great national laboratories. In the scientific community, other than work on vaccines etc., it is largely "business as usual."

A New Manhattan Project Is Warranted

Our need in the energetics weapons area is extreme, as are our needs in the medical area for quick, cheap, easy, and effective portable treatment of the coming mass casualties and our coming dramatic needs in energy. We *do* have superb scientists with the horsepower necessary to do something about it. The astounding, independent work of Sachs, the AIAS, and a few other scientists—which we stress has been unfunded—already clearly proves that. But unless we change the organized scientific community's normal rather snail-like pace—by a strong measure such as a Presidential Decision Directive and a declaration of a Nalional Emergency—the U.S. scientific community will overshoot the point of no return now approaching.

We need a new Manhattan-type project. We need it very quickly. If we do not change and focus our present scientific procedure, then—all too shortly—little that the scientific and intelligence communities are doing will be of value. We shall all be very, very dead or else in a new Dark Ages where most of the world economy has collapsed and freedom has largely disappeared from the face of the Earth.

T. E. Bearden, Ph.D.
Lieutenant Colonel, U.S. Army (Retired)
President & CEO, CTEC, Inc.
Director, Assoc. of Distinguished American Scientists

2002 ENERGETICS WEAPONS THREAT TO THE U.S.

T. E. Bearden 2000
Updated Oct. 1,2002

The U.S. Narrowly Escaped Energetics Destruction Twice in 1997

On two occasions in 1997 (latter February and on May Day), we were scheduled In be strategically attacked without warning and completely destroyed. Eerily, in public statements the leader of the Aum Shinrikyo sect (Figure 33) had foreshadowed the dates for the planned attacks, since his group was also involved—in fact, shooting down the TWA-800 (Figure 34) as advanced practice and stimulation of the U.S. to see if it knew what was afoot. Those two planned strategic strikes in 1997 were avoided only in the nick of time by actions of a friendly little foreign country, which was the only nation on earth at the time that could counter the KGB quantum potential (QP) weapons. I am sure that proper U.S. agencies intercepted my urgent personal faxes to the Defense Attache in Washington, DC and directly to the Prime Minister of the nation involved. Actions by that nation did succeed in averting our destruction in the nick of time.

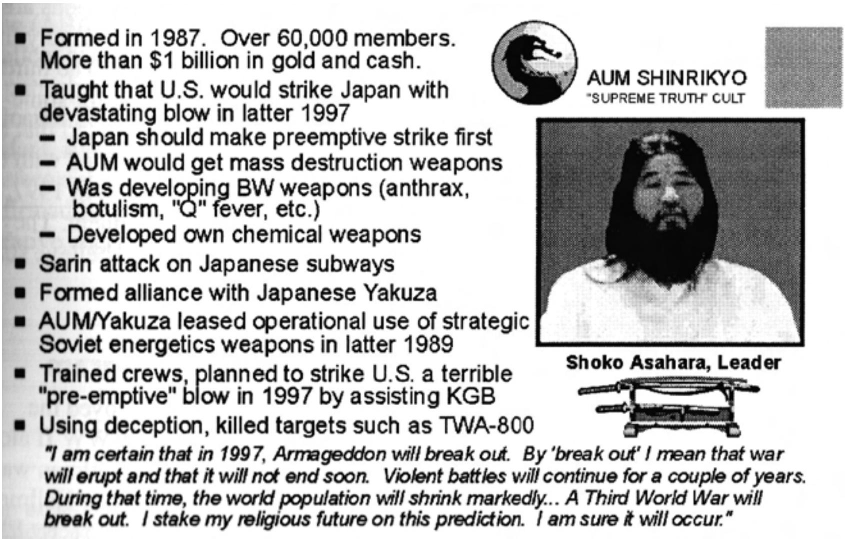

- Formed in 1987. Over 60,000 members. More than $1 billion in gold and cash.
- Taught that U.S. would strike Japan with devastating blow in latter 1997
  - Japan should make preemptive strike first
  - AUM would get mass destruction weapons
  - Was developing BW weapons (anthrax, botulism, "Q" fever, etc.)
  - Developed own chemical weapons
- Sarin attack on Japanese subways
- Formed alliance with Japanese Yakuza
- AUM/Yakuza leased operational use of strategic Soviet energetics weapons in latter 1989
- Trained crews, planned to strike U.S. a terrible "pre-emptive" blow in 1997 by assisting KGB
- Using deception, killed targets such as TWA-800

AUM SHINRIKYO
"SUPREME TRUTH" CULT

Shoko Asahara, Leader

"I am certain that in 1997, Armageddon will break out. By 'break out' I mean that war will erupt and that it will not end soon. Violent battles will continue for a couple of years. During that time, the world population will shrink markedly... A Third World War will break out. I stake my religious future on this prediction. I am sure it will occur."

Figure 33 Planned KGB/Yakuza/Aum Shinrikyo attack in 1997 was foreshadowed in public statements made by Shoko Asahara.

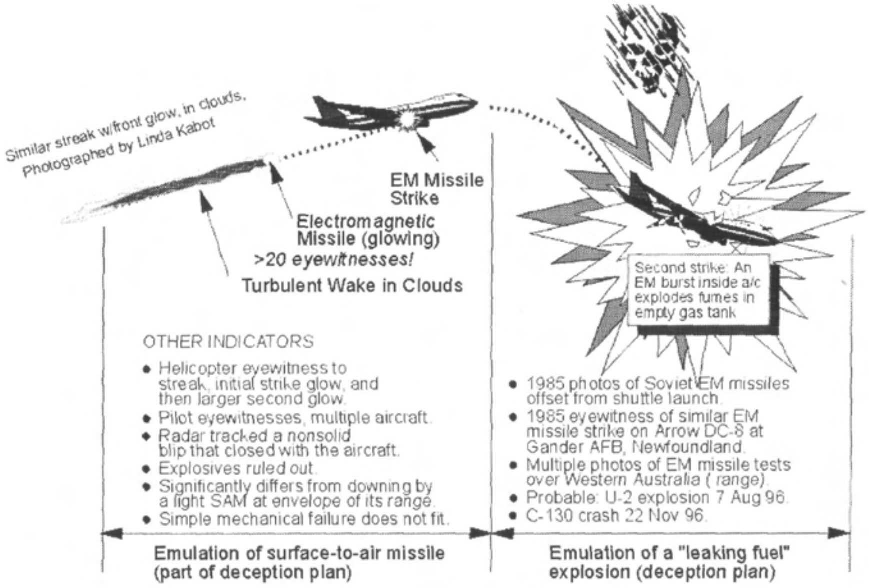
Similar streak w/front glow, in clouds. Photographed by Linda Kabot
EM Missile Strike
Electromagnetic Missile (glowing)
>20 eyewitnesses!
Turbulent Wake in Clouds
OTHER INDICATORS
• Helicopter eyewitness to streak, initial strike glow, and then larger second glow.
• Pilot eyewitnesses, multiple aircraft.
• Radar tracked a nonsolid blip that closed with the aircraft.
• Explosives ruled out.
• Significantly differs from downing by a light SAM at envelope of its range.
• Simple mechanical failure does not fit.
Second strike: An EM burst inside a/c explodes fumes in empty gas tank
• 1985 photos of Soviet EM missiles offset from shuttle launch.
• 1985 eyewitness of similar EM missile strike on Arrow DC-8 at Gander AFB, Newfoundland.
• Multiple photos of EM missile tests over Western Australia (range).
• Probable: U-2 explosion 7 Aug 96.
• C-130 crash 22 Nov 96.
Emulation of surface-to-air missile (part of deception plan)
Emulation of a "leaking fuel" explosion (deception plan)

Figure 34 Kill of TWA Flight 800 on 17 July 1996 by Yakuza and Aum Shinrikyo.

Only five nations or national groups have quantum potential (QP) weapons, though one or more additional nations are almost certainly working on them and may even have them. First of the five is the KGB in Russia (the weapons are not in the regular Russian forces, and never have been). Second is the friendly little foreign country to whom we presently owe our continued survival. The third is Brazil (which has had a small and successful QP weapon program for some time). China deployed QP weapons in early 2002, and I recently found that at least one other friendly nation has them as well. I'm not too impressed with that other friendly nation, since they played no role in saving our bacon in 1997. It appears they did not actually know the coming attacks were imminent. They certainly do not have Causal System Robot weapons, nor do they believe such weapons even exist.

Initiation of the Brazilian Energetics Weapon Program

Brazil implemented an energetics weapons program after it employed the repatriated Dr. Hellman, a German scientist taken to Russia after WW II along with the German radar team. Years after being taken to Russia, Hellman was repatriated and made his way back to Germany. In a news interview Hellman reported that he had worked directly on the development of Soviet secret EM weapons which could suddenly freeze large areas of the ocean surface. That of course is a scalar interferometry weapon, producing negative (converging) EM energy rather than positive (diverging) EM energy in their distant interference zones.

Also, when the U.S. made David Bohm *persona non grata* in the McCarthy witch-hunts, Bohm was later employed in lecturing and teaching in Brazil for some time. At the time our own scientists continued to pontificate as to whether they *liked* or could *tolerate* Bohm's quantum potential and his hidden variable interpretation of quantum mechanics {3}. Meanwhile, the KGB weapon scientists and the Brazilian Hellman project seized upon Bohm's hidden variable theory with alacrity as soon as he published his seminal paper. Those two weapon groups were already familiar with the internal longitudinal EM wave structuring of potentials, fields, and waves (Whittaker 1903), and immediately saw the fantastic weapons implications of a deliberately structured quantum potential, containing a specific "engine" as desired. Most of our scientists still are unaware of it to this day, and are unaware of its formidable weapon implications when combined with Whittaker's 1904 superpotential paper, his 1903 potential decomposition, and quantum field theory. Most of our scientists still adhere to the Bohr interpretation of QM, which excludes the normal, everyday, observable, ordered universe we all inhabit and observe.[15]

The Bohm quantum potential is, after all, a scalar potential, and at least in theory it has a Whittaker biwave decomposition {68}. Even in the Coulomb gauge, the scalar potential has infinite velocity, as pointed out by Jackson.[16]

Several tests of the "cold explosion" Russian weapons referred to by Hellman have since been openly made. One major test seen by at least five jetliner crews was the anomalous rapidly rising cloud and subsequent extremely huge light globe (ABM energy shield) effects off the Kurils in April 1984 (Figure 35). Two excellent scientific articles on the physical phenomena observed in that incident are published in the prestigious journal *Science* {69}. We had explained the cold explosion phenomena and the ABM energy shield effects some years before that incident. Even ordinary superpotential theory {70} and longitudinal EM wave interferometry at a distance can substantiate the capability. We also positively confirmed by private sources that the scalar interferometry, the MindSnapper (negative energy EMP), and the cold explosion weaponry are real.

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[15] This exclusion is euphemistically known as the "missing chaos" problem in quantum mechanics, and it is resolved in Bohm's hidden variable approach.

[16] J.D Jackson, *Classical Electrodynamics,* 2nd Edn., John Wiley & Sons, New York, 1975, p. 222, 223. Usually the instantaneous scalar potential contributes only to the near field.

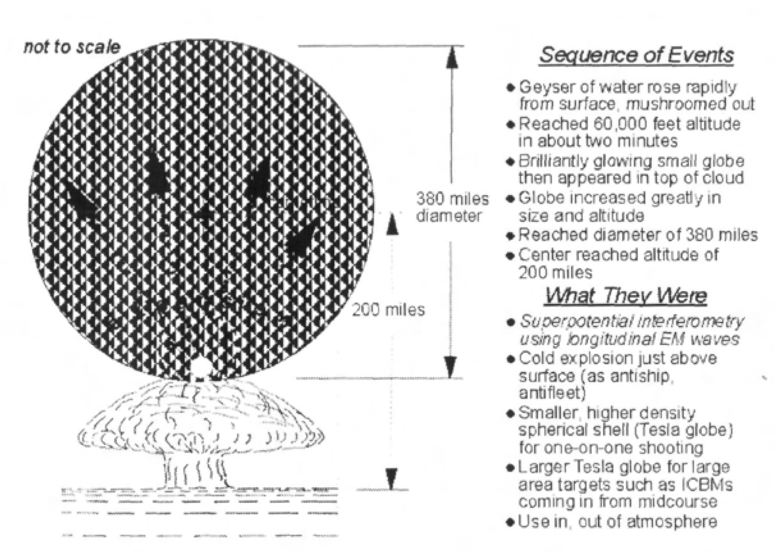

Sequence of Events

- Geyser of water rose rapidly from surface, mushroomed out
- Reached 60,000 feet altitude in about two minutes
- Brilliantly glowing small globe then appeared in top of cloud
- Globe increased greatly in size and altitude
- Reached diameter of 380 miles
- Center reached altitude of 200 miles

What They Were

- *Superpotential interferometry using longitudinal EM waves*
- Cold explosion just above surface (as antiship, antifleet)
- Smaller, higher density spherical shell (Tesla globe) for one-on-one shooting
- Larger Tesla globe for large area targets such as ICBMs coming in from midcourse
- Use in, out of atmosphere

Figure 35 Exothermic (cold) explosion off the Kurils 9 April 1984. A second test, an expanding globe of light, was added in the exothermic mode to demonstrate rapid serial switching between weapon modes.

Related Phenomena

In 1969 in Toronto, Canada, Sid Hurwich demonstrated a device capable of "freezing" a pistol lying on a table so that the gun could physically not be moved and the trigger could not be pulled {71}. For this exhibition of *strong electrogravitation,* general relativistic fields initiated by the EM force field (including the usually unaccounted Heaviside nondiverged component that Lorentz arbitrarily discarded) as the agent of spacetime curvature were used {72}. The strength of the effect was attested by the fact that the hands of the observers' watches all showed "no passage of time" during the half hour they were in the room with Hurwich's device operating.[17]

Rapid development of that strong electrogravitational technology and concomitant energetics then proceeded in another nation. Weapons of such nature were then employed by that nation a few years later, in two well-known international incidents. Clear signatures of the nature of the weaponry utilized were present in those incidents. Details of these incidents will not be included in this paper.

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[17] We point out that this is highly interesting itself, since it showed that the observers were operating in a different frame from that of the watches and the gun, which were "frozen". We also point out that recently light itself has been "stopped" in quantum experiments, yielding something quite similar.

Since the energetics weaponry already utilized special EM "hidden variables," Bohm's hidden variable theory and quantum potential were directly adapted into the program to dramatically extend it into the development of quantum potential weapons.

Stalin *Personally* Initiated the Soviet Energetics Program with the Greatest Urgency

While Stalin was at the Potsdam conference, at the close of WWII, the U.S. exploded the first atomic bomb in the desert. Truman informed Stalin in general terms that a powerful new U.S. weapon had been successfully tested. Secretly, Stalin already knew of our atomic bomb progress, for he had a spy in the program. While he was still at Potsdam, he then secretly called the Director of the Soviet atomic weapons program and directed a speed-up.

After we exploded two atomic bombs on Japan, the Japanese surrendered and WWII was over. See again Figure 1. Stalin vehemently ordered his Academy of Sciences to produce the next great technical breakthrough at all possible speed, since the American atomic bomb had frustrated his plan to wait two years after the war while the West speedily disarmed, then march into Europe and take it in six weeks. Now his massed troops could just be bombed back into the Stone Age by U.S. bombers using atomic bombs.

A Great Technical Breakthrough in Physics Can Always be Had in Four Years

The scientific community can have a great new technical breakthrough whenever its furious and dogmatic resistance to innovative discoveries or the possibility of innovative developments can be suspended. All that is necessary is a concentrated group of highly skilled, open-minded scientists, the money and facillities, and a strong headlock placed on the powerful but dogmatic scientific groups who would otherwise hamstring the program and destroy it.[18]

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[18] Present day examples are (i) the cold fusion fiasco, where the U.S. scientific community has revealed furious determination to ignore more than 600 successful experiments worldwide, (ii) a similar fury against any and all research into extracting EM energy from the vacuum, even though all EM energy comes directly from the active vacuum via the proven asymmetry of source charges and dipoles, (iii) violent suppression of proven "extended electrodynamics" methods of rapidly curing severe diseases, even in terminal stage (resistance to anything except "cut, drug, burn" and anything that would interfere with the monstrous profits of the large pharmaceuticals), (iv) continuing dedication to an electrical engineering model that does not even model or apply what powers an electrical circuit, (v) continuing resistance to quantum potential research and development, (vi) slavish dedication to "big nuclear science", massive accelerators, dangerous nuclear power plants, and a "hot fusion WPA program", even though much higher energy physics than these programs advocate and use can be and is being done on the tabletop, using time-energy instead of spatial energy, and (vii) increasing "lock-up" of all research funds into the organized hierarchy's politically approved agenda. The community has deviated so far from scientific

We proved it in the WWII Manhattan Project, where we went from nearly zilch to the operational atomic bomb in 4 years. But we did it only by secretly bypassing the conventional U.S. scientific establishment. Einstein wrote to President Roosevelt *around* the scientific community, and when the President approved and ordered the highly classified program, conventional scientists not on the project were just parked on the sideline and ignored so that the job could be completed. The naysayers were also muzzled because of the extreme classification of the project; they faced jail if they engaged in their usual ad hominem attacks and dogmatic eloquence.

Further, today the "Skunk Works" approach repeatedly proves that bold new projects can be done, when the skilled scientists and facilities are mobilized and no adamant opposition by the conventional community is tolerated.

Numerous examples of the U.S. scientific community's suppression of innovation and new technology can easily be furnished. Such are well known to any historian of science. Cold fusion, the amorphous semiconductor by Ovshinsky, the first laser papers, ultrawideband radar, Mayer's original conservation of energy law, Boltzmann's work, Wegener's continental drift, flight of heavier-than-air machines, the rocket as a great strategic weapon, and hundreds of other examples come readily to mind. Such suppression has been *the* major characteristic of the organized scientific community since its inception, as pointed out by numerous leading scientists and authors. As Planck stated, usually one gets a new physics only after the old physicists who so adamantly oppose it just die off and get out of the way.

Today, the U.S. scientific community is in fact our "front line troops," although—except for a little lip service—the managers of the organized scientific community are blissfully unaware of it and have little or no sense of mission in out-of-the-box areas with respect to national survival. It is ironical, e.g., that our orthodox scientific community does not even know what powers an EM circuit—energy extracted directly from the vacuum by the asymmetry of the source charge (considered in its modern view as a dipolarity) and by the source

method in defending archaic theory in the face of experiments that falsify it, that the ubiquitous violation of the law of increasing entropy (second law of thermodynamics) by electrodynamics itself continues to be adamantly resisted using ad hominem and inflammatory attacks, slander and libel, and destruction of scientific careers of researchers. We flatly are not getting our taxpayer money's worth from our present scientific community, and—barring a Stalin-like shakeup from top to bottom—we are not going to get our money's worth in the future unless the community is forced to free up funds for young graduate students and postdoctoral scientists wishing to work in "out of the box" scientific areas. As Max Planck stated, *"An important scientific innovation rarely makes its way by gradually winning over and converting its opponents: it rarely happens that Saul becomes Paul. What does happen is that its opponents gradually die out, and that the growing generation is familiarized with the ideas from the beginning."* In other words, one doesn't get a scientific innovation until the old dogs so bitterly opposing it just die off and get out of the way. This long-known and stated characteristic of the scientific community—its fierce and unrelenting resistance to change and innovation—is presently the greatest threat to the survival of this nation.

dipole (Figure 36).

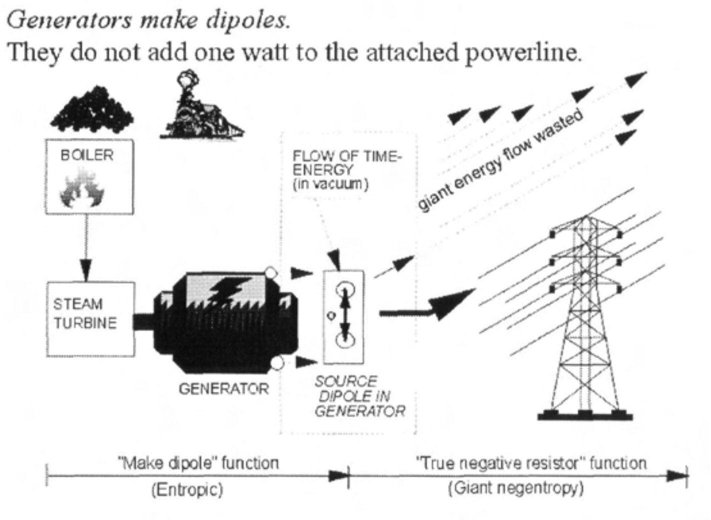
Generators make dipoles.
They do not add one watt to the attached powerline.
BOILER
STEAM TURBINE
GENERATOR
FLOW OF TIME-ENERGY (in vacuum)
SOURCE DIPOLE IN GENERATOR
giant energy flow wasted
"Make dipole" function
(Entropic)
"True negative resistor" function
(Giant negentropy)

Figure 36 Energy extracted from the vacuum by the asymmetry of the source dipole powers every electric power line and electric circuit.

A Typical Example: The Suppression of Cold Fusion

As an example, much of U.S. Science—dominated by nuclear factions since the advent of the atomic bomb in WWII—vehemently attacked cold fusion and the cold fusion researchers, including wholesale ad hominem attacks, with a viciousness seldom seen in the history of science. Many dogmatic scientists declared the entire field at best a mistake and at worst a fraud. Even the character of many of the leading cold fusion scientists was openly impugned and the researchers were slandered and libeled. All this was done by conventional dogmatic scientists who have not solved the fundamental source charge problem {10,12}, have no inkling that all EM energy in 3-space comes from the time-domain {10}, and have not a clue as to what really powers every EM circuit. Since they also do not know where the electrical energy driving the chemistry actually comes from, they have no knowledge of the effects of time-energy in electrolyte solutions.

They also appear to have little or no knowledge of the implications of Evans' and Searles' *transient fluctuation theorem*[19] in thermodynamics showing to what degree the second law of thermodynamics can be violated and reactions can run in reverse, nor its extension to the micron (colloidal) size level and to two seconds in duration.[20] If they did, then they would realize that the Coulomb barrier provided by *repulsion* of like charges (such as two H+ ions), often reverses into the *attraction* of like charges, with the barrier changing into the Coulomb attractor. This can last (by experimental proof shown by Evans *et al.)* up to two seconds, in a volume of fluid up to a micron in diameter. Hence it is not "against the laws of physics and thermodynamics" to observe attraction of two protons in an electrolyte so closely that each enters the strong force region of the other and the two form a quasi-nucleus. In the decay of this reversal zone, the preferred decay of the quasi-nucleus can be by quark flipping in one of the protons, yielding an atom of deuterium emerging from the decayed time reversal zone. Such results have been meticulously observed in many cold fusion experiments in multiple labs and nations, and by multiple researchers. Since these and other novel nuclear transmutation results are *replicated* experiments (more than 600, in multiple labs, multiple nations, and by multiple researchers), it means that no amount of theory can refute them or the results. The harsh skeptics launching the frenzied ad hominem attacks are thus revealed as the unscientific bigots they are, since they ignore substantial experimental results that contradict the prevailing theory. The excess energy production and inexplicable new nuclides (Figures 21, 37, 38) obtained by these multiple experimenters are completely inexplicable by ordinary nuclear interactions in the accepted theory.

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[19] D.J. Evans and D. J. Searles, *Phys. Rev. E,* Vol. *50,* 1994. p. 1645.

- Fennions time-reverse in even numbers
- Like charges cluster
- Aqueous solutions contain H+ ions,
  which are just protons
- Quarks flip as TR zone fades

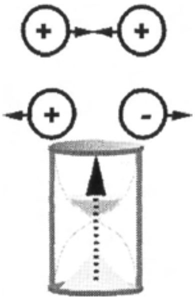

$$({}_1H_1 + {}_1H_1) \rightarrow ({}_0n_1 + {}_1H_1) = {}_1H_2 \text{ deuterium}$$

Figure 37 Electronuclear reaction in a time-reversed zone producing excess deuterium ions.

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[20] G. M. Wang, E. M. Sevick, Emil Mittag, Debra J. Searles, and Denis J. Evans, "Experimental Demonstration of Violations of the Second Law of Thermodynamics for Small Systems and Short Time Scales," *Phys. Rev. Lett.,* 89(5), 29 July 2002, 050601.

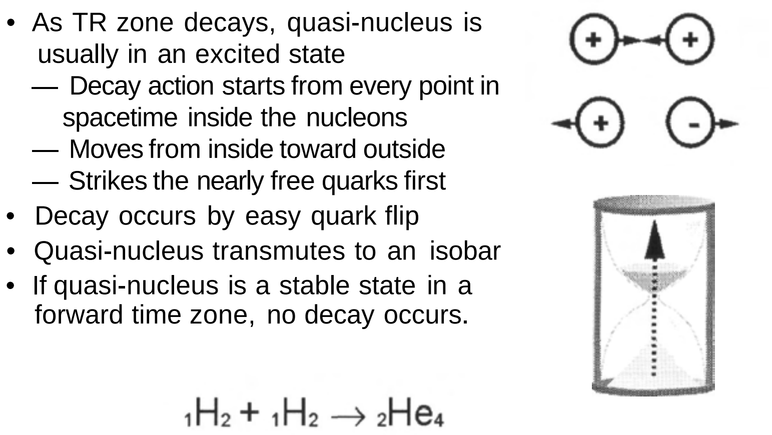

- As TR zone decays, quasi-nucleus is usually in an excited state
  - Decay action starts from every point in spacetime inside the nucleons
  - Moves from inside toward outside
  - Strikes the nearly free quarks first
- Decay occurs by easy quark flip
- Quasi-nucleus transmutes to an isobar
- If quasi-nucleus is a stable state in a forward time zone, no decay occurs.

$${}_1H_2 + {}_1H_2 \rightarrow {}_2He_4$$

Figure 38 Electronuclear reaction in a time-reversed zone producing excess alpha particles.

Meanwhile, the U.S. Patent Office has been instructed not to accept any patent applications that would interfere with present nuclear planning. Positive cold fusion results have also been successfully obtained in several U.S. government laboratories, including at China Lake where very strange instrumental effects have the experimental team puzzled. I proposed an explanation of those anomalies in August 1998, and have included it in my book just published in September 2002 {73}.

Revolutionary New Processes Are Hidden in the Cold Fusion Experimental Results

Once understood, cold fusion holds the breathtaking key to systems that consume *a tiny fraction of time flow itself* as a fuel to produce copious heat energy for the world's needs. Unknown to the conventional scientists, of course, electrodynamics itself already does this, but it has just not been recognized and accepted. Transducing one microsecond per second of time into transverse wave EM energy will produce some $9x10^{10}$ watts of real electrical power, if all the transduced EM energy is intercepted and used. This is the *real* way to extract energy from the vacuum and use it cleanly and cheaply.

To grasp such a notion, recall that the fundamental units used in physics are completely arbitrary. It is perfectly possible to express all physics in only a **single** fundamental unit—for example, *the joule*. Time then becomes totally a function of energy. So it is not so insane after all to express time as highly compressed energy. Mass is also highly compressed energy. That concept is now familiar after Einstein, the nuclear age, and $E = mc^2$. Time-as-energy is just as straightforward as mass-as-energy, but it has just not yet come into recognition.

The *use* of time as compressed energy, however, leads to some profoundly new types of electronuclear reactions presently unknown in particle physics. These new transduction reactions produce the new nuclides in cold fusion experiments, and generate the electronuclear interaction. We explain that in some detail in our new book, *Energy from the Vacuum,* previously cited {10}.

When interpreted as using time-energy, cold fusion shows us the way to a new electronuclear regime of nuclear reactions where nuclei, elements, and compounds can just be directly assembled by comparatively weak (in terms of *spatial* energy!) electromagnetic interactions. Presently we have made substantial progress in understanding the fundamental mechanisms generating these electronuclear reactions, after presenting preliminary results in August 1998.

As one example, time-reversing a single fermion (a particle with spin 1/2, 3/2, etc.) is precluded by the Pauli exclusion principle. But one can time reverse *two* of them, or any even number n, where they act as a semi-boson or group of semi-bosons. Simply put, if a time-reversal zone is established momentarily in the region where like charges exist, then the n-tuple fermion cluster can be achieved because the law of attraction and repulsion of charges is temporarily reversed {74,75}. This unexpected "attraction of paired fermions of like sign" will form quasi-nuclei in many cases, particularly in small clusters of two or four, etc.

Hence two H+ hydrogen ions (two protons) in such a time-reversal zone in a fluid are drawn together into a quasi-nucleus, which actually is an excited isomer of deuterium (Figure 37). Time-reversal zones are temporary in cold fusion experiments due to the statistics of their formation and the transient fluctuation theorem {76} of thermodynamics. As the time reversal zone decays, the quasi-nucleus of two protons is increasingly in an excited and unbalanced state. The excited-state *diproton* nucleus decays by flipping a quark in one proton, converting it to a neutron. That produces a *neutron + proton nucleus*, which is a deuterium ion, strictly by electronuclear means. Or four protons may cluster by "attraction in a time-reversal zone" and form a 4-p nucleus. That is an excited isomer of a helium nucleus. As the time-reversal zone decays, first one quark flips in one proton and then another quark flips in a second proton. That produces a helium nucleus - i.e., an *alpha particle.* Or two deuterium ions can attract and form a quasi-nucleus (Figure 38), which is already an exact isomer of a helium nucleus and thus easily decays into an alpha particle by simply "tightening" as the weakened strong force recovers faster than the Coulomb force can reduce, vanish, and resume in the opposite direction. The exact reaction equations for these reactions are given in my new book, *Energy from the Vacuum* {10}.

We filed an Invention Disclosure on the process of forming and using time-reversal zones to cause like charges to attract and unlike charges to repel *in* ***vacuo,*** in fluids, and in other media, resulting in the formation of semi-nuclei as excited isomer states of other nuclei, followed by decay into new nuclides. We will follow it with patent applications in the future. This represents a completely new kind of particle physics interaction presently not included in the textbooks, and not requiring high-energy processes. Literally thousands of new nuclear interactions—all *permissibly* violating the second law of thermodynamics because the statistics permit such violations and experiments prove it—are now possible.

Cold fusion does indeed hold a new kind of nuclear physics in its hand—but a physics presently considered very alien by our orthodox nuclear science community. For decades nuclear scientists have been seeking ever more *spatially* energetic particle smashing, believing that extreme high energy nuclear reactions and transmutations cannot possibly be done with charged particles at low *spatial* energy. One is sympathetic to the scientists, because even the **concept** of "low spatial energy transmutation" itself sounds like an oxymoron. And it would be, *if one were limited to spatial energy alone*, as is presently assumed by physicists. But one is also speaking of the neglected and compressed *huge time-energy* component of those low-spatial energy photons, and that is quite a different matter. The lower the spatial energy of the photon (the lower its frequency), the greater the amount of compressed energy transported in the time component as "time". The transposition of time-polarized EM energy into longitudinally polarized EM energy—and vice versa—is already justified in quantum field theory. Use of that extremely high energy component by its transposition or partial transposition into spatial energy in fact provides a much higher energy physics interaction than present orthodox high **energy** physics utilizes, knows, or considers.

Almost all the learned scientists are thinking *only* of spatial energy, since that is **the** only kind they have been "taught" to consider. Hence, from their view (i.e., on the premise of their implicit *assumption)* it is perfectly "logical" to condemn cold fusion, since in their view, "cold" implies low (spatial) energy and "fusion" implies high (spatial) energy transmutation. What is unknown to the orthodox community is that the "cold" in cold fusion also implies "extraordinarily high time-energy". So with a little transduction of highly compressed time-energy **into** spatial energy, "cold" fusion actually can imply "extremely high spatial **energy** made available by transduction" also.

As an example, the Chief Editor of *Science* recently had the courage {77} to **publish** results of sonoluminescence research reporting positive experimental transmutation results {78}. A paper was then published in *Nature* {79}, pointing out that the (spatial) energy involved is insufficient for such nuclear transmutation temperature, thereby implying that the reactions reported by the first researchers are not possible.

However, given formation of a time-reversal zone, this second paper is not necessarily applicable to the sonoluminescence fusion process, because the paper is based on an unwitting two-part premise that *(i) only spatial energy can be used for nuclear transmutation and (ii) no time-reversal zones exist to nullify that premise by having reactions (such as the law of attraction and repulsion of charges) run backwards.* That premise is already experimentally proven to be invalid by Evans et al., and it fails when the time reversal zone effect is considered.

We strongly stress that thermodynamics—both in theory and as demonstrated in experiments—not only allows but predicts—for a certain fraction of the time—the formation and existence of just such "reversal zones" where the usual reactions *run in reverse* {76}. It is also experimentally proven {54}. In that case a much higher energy—time energy—can be and is employed to convert the Coulomb barrier into the Coulomb attractor.[21] We know now (from the experimental demonstrations by Denis Evans et al.) that such "reversal zones" may be up to a micron in size and may endure for up to two seconds. The subsequent decay of that TRZ then allows the quasi-nuclei temporarily formed in it to decay by quark flipping alone, allowing the quasi-nucleus to easily transmute into a perfectly well known nuclear reaction product.

To quote Arthur C. Clarke, when a learned scientist says something is *possible*, he is probably right. When he says something is *impossible*, he is probably wrong.

Stalin's Dictatorial Impact on Soviet Scientific Management's Response

Stalin was a powerful dictator. He simply killed or jailed those who opposed his will. So after his blunt order (Figure 1) circa latter 1945 to find a great new technical breakthrough area quickly, his Academicians and high level science managers were faced with a severe dilemma: They could not afford to *oppose or criticize a vigorous search* for new innovations and a great breakthrough, and they could not remain passive. Their very lives depended on they themselves *personally finding such a breakthrough in great haste and presenting it to Stalin*. They had to actively spur the efforts of their most outstanding subordinates and Soviet science itself, or suffer dire personal consequences. Siberia and prison camps loomed for the lot of them unless they produced.

To put it bluntly, Stalin "got their collective attention" and their "whole-hearted support." Those few who resisted simply were shipped post-haste to the notorious prisons of Siberia, and worked to death in short order.

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[21] We strongly point out that, when the reactions run backward and negentropy appears in those reversed regions, the conservation of energy law is violated unless time-energy is being converted to spatial energy. Either we must begin accounting time as energy, or we must give up the conservation of energy law itself. The obvious solution is to account the time energy being utilized, as well as the 3-space energy.

So the highest-level Soviet scientific managers now desperately demanded of their subordinate scientists *anything*—*anything at all*—that was novel and had breakthrough implications. An almost convulsive national scientific effort was launched immediately, with hardly a detracting voice. A great team of the very **best** Soviet scientists was rapidly formed and methodically searched the scientific literature of the world from beginning to end. Nothing even remotely like that search and review has ever occurred in the West.

For example, one great technical center set up by the Soviets had a staff of about 2000 Ph.D.s with associated translators, staffs, etc. The Soviets purchased and **hauled** in copies of all the scientific literature of the West—by the shiploads—to such centers. Their scientists then methodically went through the material, **journal** by journal, paper by paper, page by page. There are and always have **been** myriads of innovations and discoveries sitting on the shelf in the scientific **literature,** never followed up, or opposed by standard models and credos. The first tier of reviewing Soviet scientists was composed of excellent scientists. They skimmed out the "cream" into a select pile which the second tier then analyzed in depth. The second tier was composed of the best nonlinear scientists in **the** world—the "superscientists."

They were seeking *new principles of nature that could rapidly be developed into highly advanced technology*, and they found them—sitting there in the literature, already pointed out, and long ignored by the Western scientific community.

Shortly Stalin had his great new breakthrough area emerging, and they had their heads.

Our Own Science Community's Progress During These Decades

For decades foundations physicists (Bunge, Feynman, Wheeler, Lindsey, **Margenau,** etc.) in the U.S. have repeatedly pointed out the substantial foundations problems in electrodynamics. Nobelist Feynman and the great John Wheeler tried to "fix" the problem whereby electrodynamics still erroneously assumes force fields in a space filled with a *material ether* (unit point positive charge, unit point north pole, and unit point mass assumed at every point in s**pace).** Unfortunately they failed, primarily because their absorber theory {80} contradicted the photon hypothesis and hence quantum mechanics.

Meanwhile, our own National Science Foundation and National Academy of Sciences has directed only minimal work on correcting electrodynamics and dramatically extending it. Faraday and Maxwell—as did every other scientist at the time—rigorously assumed a material ether. Maxwell's equations also implicitly included that material ether assumption. They still do, even after Heaviside's truncation and Lorentz's symmetrical regauging, because none of the Maxwell-Heaviside equations were changed to eliminate the material fields in **space** (material ether) assumption after the Michelson-Morley experiments falsified it.

Every major university in America still teaches that implicit material ether, even though it was falsified over a century ago. That is an exact measure of the caliber of "foundations" work our own scientific community does if left alone. *In more than 100 years, they have not even chosen to root out the material ether from electrodynamics.*

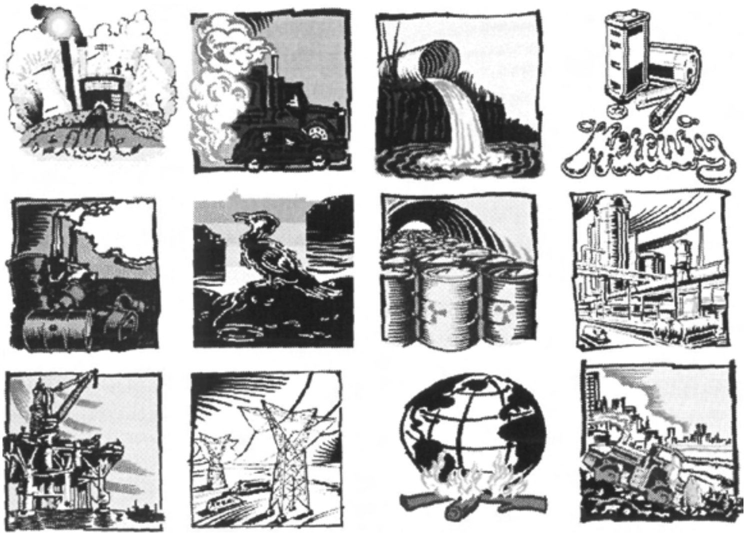

Figure 39 This polluted and suffering planet. Direct result of the scientific community's adamant resistance to upgrading classical electrodynamics and electrical engineering.

The prevailing flippant attitude is that, "Well, your TV set works, doesn't it?" Yes it does, but we also do not have practical electrogravitation and inertial propulsion, nor do we have cheap clean EM energy from the vacuum. Instead, we have a severely polluted planet (Figure 39), ever increasing deaths from biospheric fumes and polluting byproducts, increasing destruction of species, and a monstrous unleashing of far more coal and hydrocarbon burning in our near future while the world tears itself apart and destroys its economy and civilization in a rising series of oil and energy wars. The direct responsibility for that mess lies directly with the scientific community and its fierce resistance to innovative research and development, and changing a century-old, long outmoded classical EM and electrical engineering model.

Wryly put, it's high time we "got the lead out" of EM field theory, where the lead is the material ether and other non-sequiturs cluttering the theory.

Such drastic modeling errors would not be tolerated of government-funded aerospace engineers and contractors developing a new missile system. So it should be equally intolerable in the government-funded scientific community and in fact in the civilian scientific community as well, and it should not be tolerated of either the National Academy of Sciences or the National Science Foundation.

Einstein {81} said it perfectly, as follows:

> *"...the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the eternally problematic character of his concepts. He uses this conceptual material, or, speaking more exactly, these conceptual tools of thought, as something obviously, immutably given; something having an objective value of truth which is hardly even, and in any case not seriously, to be doubted... in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them."*

Upholding and perpetuating flawed electrodynamics models seriously impedes the progress of scientific development and revolutionary new technology.[22,23] At some point, one must legitimately question the upper management of the U.S. scientific community for not modifying classical EM and electrical engineering to include the active vacuum exchange with every charge and EM system. In not doing so, they continue to advocate perpetual motion source charges, creating energy from nothing, on a scale unparalleled in history.

It is little wonder that we do not have electrical power systems that successfully and freely utilize more than a trillionth of the vacuum energy they freely extract from the local vacuum. *There is not now and there never has been a single*

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[22] Oddly, the conventional electrodynamics model assumes that every source charge freely creates energy out of nothing at all, and pours this energy out continuously in all directions, thereby establishing its associated EM fields and potentials at light speed, reaching out across the universe. From the 1960s alone, the total assumption of incredibly vast numbers of perpetual motion machines has been carefully hidden from the new students, so that today even many professors do not realize that in their model all EM fields and potentials, and every joule of EM energy in the universe, are assumed to be created by a vast assortment of perpetual motion machines called source charges. That problem has not been solved in electrical engineering or in classical electrodynamics, and if the scientists have their way, it is not going to be solved. Yet the basis for its solution—the asymmetry of opposite charges such as the dipolarity (in the modern view) of a source charge—has been in particle physics since 1957, with the award of the Nobel Prize to Lee and Yang in December of that year.

[22] One keeps one's sense of humor. The raucous skeptics and "defenders of the orthodox EM faith" who so noisily denounce legitimate COP>1.0 EM system researchers as "perpetual motion nuts", are themselves unwittingly the greatest perpetual motion nuts ever recorded in history. Further, they are so ignorant of what their present model actually means, that they do not even know it. It is one thing to be ignorant and to recognize it; it is quite another thing to be ignorant and so ignorant one does not know it—45 years after broken symmetry was rigorously established experimentally by Wu and her colleagues, and the Nobel Prize awarded to Lee and Yang.

electrical engineering department, professor, or textbook that knows what actually powers an EM circuit—real observable EM energy extracted from the local seething vacuum by the source charges and the source dipolarity.

Since our scientific community cannot seem to make such a simple change (as including the active vacuum's interaction with every charge and the charge's broken symmetry in that interaction) even 45 years after the basis for that change has been resoundingly proven in particle physics, our national survival is at stake and the nation itself is seriously threatened by the superweapons developed by the KGB over the last five decades. We would have already been totally destroyed—twice in 1997 alone—had it not been for the intervention of a friendly little foreign nation. My colleagues and I played a very small alerting role in those affairs, so we are speaking from experience, not from extrapolation. We would be quickly destroyed today, were it not for the continuing "balance of terror" provided by the little nation.

U.S. Scientists Have Committed Monstrous Crimes and Gone Unpunished

Rather sadly, we also point out another thing that has to be said: *scientists are no more moral or immoral than any other slice of American citizens.* A percentage of scientists is capable of committing horrible scientific crimes, as distasteful as such a statement may be. That includes the deliberate experimentation on humans, resulting in deaths. In short, at least manslaughter and perhaps even murder, since knowledge of the probable results was there beforehand.

One would think U.S. scientists would *never* scientifically condone and perform experiments leading to mass deaths for 30 years (i) as they did in the Tuskegee case in Alabama. Over 400 poor blacks were supposedly treated for syphilis, while actually not being treated at all, but were deliberately tricked and allowed to rot with syphilis so our "ethical" scientists could watch how their brains decayed, so to speak. Over 100 of those poor blacks died with the disease while the scientists cold-bloodedly watched them expire and kept meticulous records. Or (ii) as they did in the case of whole body nuclear radiation for 30 years—again by trickery, deceit, and illegal use of security classification to hide these acts—of helpless retarded children and others, some of whom also died.

Once these heinous incidents were exposed publicly, the political power of the scientific community is such that *no scientist was ever indicted or tried for these heinous mass murders, and none is going to be.* The scientific community *has* *not* fiercely called for punishment of these mass murderers amongst their midst—guilty of precisely the same kind of horrible actions for which we tried and executed war criminals at Nuremberg.

Incredibly, the President of the United States formally apologized for these incidents! He did not turn the case over to the Justice Department for prosecution of high crimes against humanity and mass murder, *as would have* *been done for ordinary citizens.* Had a single doctor in his private clinic done such things on his own, he would have been arrested, summarily tried, and either sentenced to life in prison or executed.

The sad thing is that there was really no sharp clamor from the scientific community to bring their fellow scientists to justice, a la Nuremberg. By their silence, the organized scientific community showed a side that scientists are **loftily** not supposed to possess. *So long as the scientific community continues to tolerate those mass murders of American citizens and not call for justice, then just so long do they stand convicted by their own resounding silence and inaction.*

We cite these painful incidents (there are others!) to point out that one must not **deify** the scientific community. The conduct of science is no better and no worse **than** the conduct of human affairs in other areas. Science is also a big business, and it has its moral scientists and its immoral scientists. It does its moral business and it does its immoral business.

We painfully submit that both sides of the scientific character must be considered, when one examines such things as the tolerance or intolerance of the scientific community to dramatic innovation and "out of the box" research. We have to consider it now, because it has become a serious threat to the continued **survival** of our nation. The conduct of scientific affairs will unavoidably include suppression, maneuvering, spin control, and fierce struggle for power and funds—such is in the very nature of human beings, and it is present in the scientific community on a bell-shaped curve as in all other human communities. It is ongoing widely today, and to an uncomfortably large extent much of science has been captured and effectively controlled by controlling the scientific funding and prescribing what research must be done for the funds available.

As the French say, "The more things change, the more they remain the same." Science is still the same way as it was when Planck made his famous statement. It will still be that way tomorrow, and a century from now. As with any other big enterprise, it has to have checks and balances imposed and enforced on it from outside—by the government itself. Little or no indication exists of that **happening** in the near future, until we get something like an anthrax spray attack on a large city, and have a million or more Americans dying in the streets.

Energetics: New Principles of Physics and How the Soviets Found Them

Under Stalin's whip, the Soviets particularly sought anything that indicated *possible new principles of nature.* It is no accident that Nobelist Petr Kapitsa later informed Nikita Khrushchev that a means of total neutralization of foreign missiles could only come from *a group of new principles in physics called energetics.* A group of new principles is precisely what energetics *is.* So if our scientific and intelligence communities wish to understand energetics, they must first understand the new principles it is based upon. They cannot just simply apply ordinary electrodynamics and "business as usual" as they have largely done. The massive Soviet scientific search program spurred by Stalin is where those new principles came from.

When the first tier of Soviet review scientists found something that had not been followed up, and saw that it had significant implications if found valid, that paper was laid aside into a "select" pile. That select pile then went to the "super" scientists, for full-blown review and analysis by some of the brightest and sharpest minds on the planet.

The Russians came up almost immediately with Whittaker's 1903 and 1904 work. That work shows a hidden electrodynamic *longitudinal* EM wavepair structure (in phase conjugate pairs) inside the scalar potential and comprising it.

This is a dramatic extension of electrodynamics to incorporate a full-infolded general relativity infolded inside the electrodynamics. Whittaker showed that scalar potential functions in interference already *create* all the "normal" fields and waves anyway (the beginning of superpotential theory). This novel interferometry and its inherent capability for action-at-a-distance did not elude the Russian superscientists. The superb Soviet scientific team came up with that and with much, much more.

Nothing like the comprehensive, intense review of the entire scientific literature has been accomplished by the U.S. scientific community. Nothing like it is being done now.

Longitudinal EM Wave Interferometry Energetics Was Almost Immediately Uncovered

At the end of WW II, the German radar team and infrared team were taken to Russia. Both teams were years ahead of their Western counterparts.

One of my close colleagues has validated that the German radar team had some severe instrumental anomalies while still in Germany. We think this is what they were:

In WW II the Germans invented radar absorbing materials, to coat their submarine snorkels and prevent Allied antisubmarine warfare bombers from tracking the snorkels and destroying the subs. A wide variety of highly nonlinear, doped materials were investigated. In addition to single beam radar cross section, the Germans also examined the materials in multi-beam illumination circumstances.

It appears that, in some multibeam experiments with some materials, conditions were just right so that the multi-illuminated absorbing material acted as a pumped phase conjugate mirror (PCM), and wave-to-wave interactions emerged. This meant that the absorber material PCM would suddenly gather up all the energy in the pumping beams, use one of the other beams as a signal input beam, and fire an amplified retroreflected pulse right back down the signal input beam, wrecking the experiment and creating havoc in surrounding equipment.

When the German radar team went to Russia, their knowledge of these anomalies went with them. In the desperate Russian scientific climate to find *lust such anomalies,* this startling and anomalous phenomenon would have been exhaustingly examined and studied, once the German radar engineers got to Russia to their new laboratories.

In short, it appears that the Russians quickly came up with what today is called "nonlinear phase conjugate optics," but first in the radar band rather than optics.[24] So before 1950, it appears that the Russians already had working phase conjugating pumped phase conjugate mirrors for the radar bands and in other bands.

Fisher {82} details that we Americans did not "stumble onto" practical phase conjugate optics experiments until Russian physicists briefed Lawrence Livermore National Laboratory scientists in 1972 about the strange wave in **many** of their optical experiments that "came out of nowhere and restored order **from** disorder." At that time, the KGB energetics weapon scientists had known about phase conjugate retroreflection and its amplified pumping, for more than 20 years. Indeed, the first giant strategic scalar interferometers had already been deployed and utilized to kill the U.S.S. Thresher nearly a decade earlier (Figure **6).**

By 1950 Russian Energetics Was Off and Running

By the beginning of the 1950s, the Russian scientists under iron KGB control were already experimenting with "scalar potential interferometry" at a distance, a la Whittaker 1904. Here transverse EM waves, EM fields, and EM energy—either *divergent* (heating) positive energy or *convergent* (cooling) negative enery—could be readily created at a distance {83} (Figures 40 and 41). Further, the longitudinal EM wavepairs used in this interferometry had the marvelous characteristic of easily penetrating right through the earth and ocean, with only a little intervening interaction, given that the LWs are sufficiently well made {84}. The interferometry "beams" can and do also move superluminally—again, right through the earth and ocean.

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[24] **Of course, they would also have investigated it at all other bands as well.**

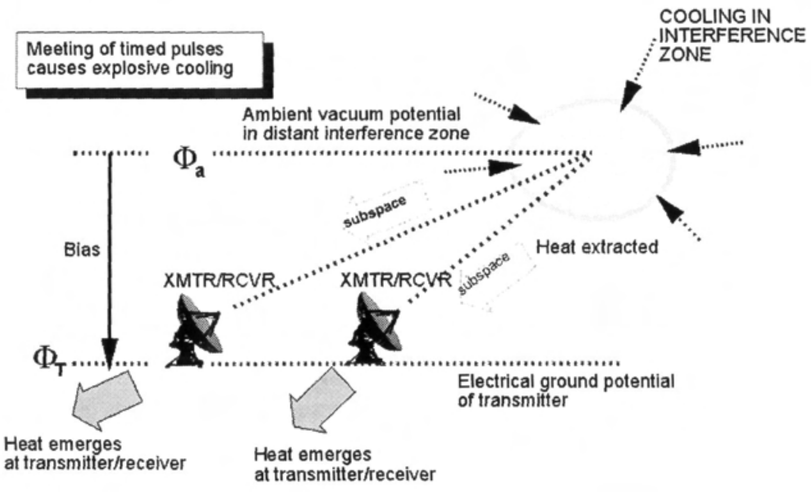
COOLING IN INTERFERENCE ZONE
Meeting of timed pulses causes explosive cooling
Ambient vacuum potential in distant interference zone
Φ_a
subspace
Bias
Heat extracted
XMTR/RCVR
XMTR/RCVR
subspace
Φ_T
Electrical ground potential of transmitter
Heat emerges at transmitter/receiver
Heat emerges at transmitter/receiver

Figure 40 Scalar interferometry in the endothermic (cooling) mode.

It is not accidental that Admiral Gorshkov, head of the Soviet Navy, would later bluntly state: *"We have made the oceans of the world transparent."* And so they had.

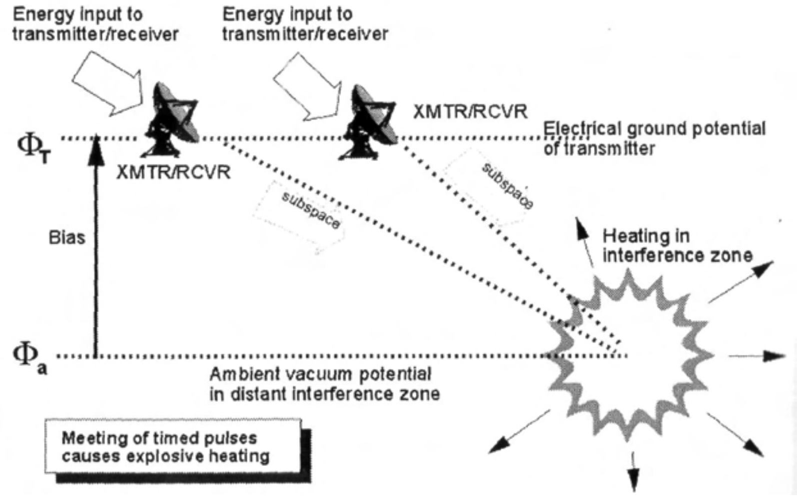
Energy input to transmitter/receiver
Energy input to transmitter/receiver
XMTR/RCVR
Φ_T
Electrical ground potential of transmitter
XMTR/RCVR
subspace
subspace
Bias
Heating in interference zone
Φ_a
Ambient vacuum potential in distant interference zone
Meeting of timed pulses causes explosive heating

Figure 41 Scalar interferometry in the exothermic (heating) mode.

By 1950, the Russian scientists were experimenting with deliberately creating and phase conjugating longitudinal EM waves, forming phase conjugate wavepairs. They then assembled the desired (mathematically calculated) sets of those waves, adjusted frequencies and magnitudes, phasing, etc., to produce EM potentials having a desired deterministic internal spacetime curvature set (internal spacetime engines) and dynamics.

As a result, by the mid-50s Russian weapon scientists were already experimenting in *bioenergetics* with the direct inductance of diseases and health changes via the transmission into human targets of such "internally structured" EM potentials, fields, and waves. They were also experimenting with the production of EM energy, potentials, fields, and waves at a distance, directly through the earth and the ocean. Either heating (energy flow divergence) (Figure 41) or cooling (energy flow reconvergence) (Figure 40) could be produced at will in the distant interference zone, merely by altering the bias voltage on the chassis grounds of the interferometer's transmitters. Rapid switching between the exothermic and endothermic modes thus was straightforward{85}, as demonstrated (Figure 35).

By the latter '50s, longitudinal wave interferometry weapons had already emerged from advanced engineering development and were in full production engineering toward deployment. The LIDA device {86} and even more advanced versions for directly affecting the human mind and its state of consciousness had emerged in *psychoenergetics* as one class of devices rather openly released and utilized. The LIDA uses structured EM microwaves {87} to induce a hypnogogic or cataleptic type of trance-like state in either a human or a cat. as tested years later by Dr. Ross Adey of the U.S. Early prototypes were purportedly used against our prisoners in North Korea during the Korean War to assist in their brainwashing by their North Korean Captors. Prisoners reported that its effects were irresistible.

Meanwhile, energetics weapon testing in several major modes was being conducted, particularly from Soviet research ships over remote regions of the ocean and at night. Descriptions of such tests—many of them seen by passing ship's captains—can readily be found in the open maritime literature. We gathered and published many such incidents and cited references.

Deployment of the Soviet Energetics Weapons and Their Quick Use

In January 1960 Khrushchev spoke obliquely of these "fantastic" new superweapons, just within the portfolio of the Soviet scientists, so to speak, in an important speech to the Presidium. Parts of that speech were reported in the *New York Times* {88}. No one in the West knew what Khrushchev was talking about. Our intelligence community, which bases many of its assessments on the tired old phrase "We have no evidence that..." simply treated it as propaganda, It wasn't, and the U.S.S. Thresher was to be destroyed (Figure 6) three years later by that same weapon Khrushchev was speaking of.

Khrushchev began rapidly inserting long-range missiles and nuclear warheads into Cuba in 1962, precipitating the Cuban Missile Crisis. Kennedy knew Khrushchev's strategic bombers and rockets were in horrible shape, due to direct information received from Colonel Oleg Penkovskiy, a Russian spy in our employ courtesy of British Intelligence. No one knew of the superweapons, but they were not yet operationally ready in Oct.-Nov. 1962. So Kennedy called Khrushchev's bluff and faced him off. Blustering awhile to obtain U.S. assurance that it would not invade Cuba, Khrushchev was forced to back down and withdraw the missiles. In his exuberance he had simply moved too fast in inserting the missiles into Cuba. Had he waited a few months later, the strategic superweapons would have been operational and ready. Any U.S. naval blockading force would have thus faced quick and eerie destruction or disabling, as was soon to be demonstrated in the case of the U.S.S. Thresher and its surface companion, the U.S.S. Skylark.

This severe loss of face by Khrushchev, before the Communist Party, made it imperative that he do something quite dramatic to stay in power, and do it as quickly as possible.

Khrushchev's first large, full-up, strategic longitudinal EM wave energetics interferometer weapon became operational on site by April 1, 1963. A few days later, Khrushchev employed it to kill the U.S.S. Thresher atomic submarine (Figure 6) underwater off the East Coast of the U.S. By simply creating EM noise in an interference zone placed on, in, and around the sub underwater, and thus jamming the sub's electrical controls so that it could not be controlled, the helpless sub sank to crush depth and imploded. The U.S.S. Skylark on the surface had multiple systems seriously jammed or rendered nonoperational. This was the Russian deception plan, to have the kill of the sub resemble an accident.

One day after the successful clandestine kill of the Thresher, the same weapon was used to demonstrate a powerful underwater electromagnetic burst 100 miles north of Puerto Rico (Figure 42). The energetics underwater burst equaled a substantial deep underwater nuclear explosion in size. The burst was seen by a passing U.S. jetliner crew and was reported to the FBI and the U.S. Coast Guard when the aircraft landed in Florida. A colleague interviewed the co-pilot of the aircraft, and relayed the interview information to me.

Khrushchev's Second Demonstration

Deep Underwater EM Explosion 11 Apr. 1963

(Similar to this photo set of a deep underwater nuclear **test** explosion)

Phenomena observed and reported by passing U S jetliner

100 miles north of Puerto Rico, over Puerto Rican Trench (One of the deepest parts of the ocean)

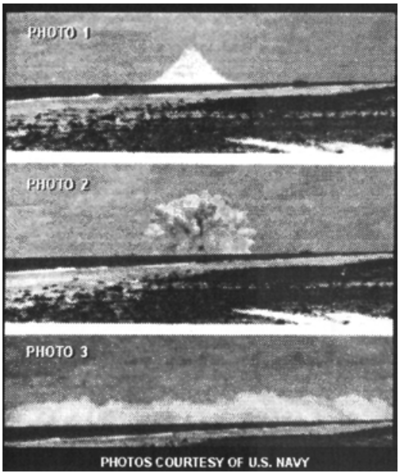

PHOTOS COURTESY OF U.S. NAVY

Figure 42 Deep underwater nuclear burst, demonstrating same water phenomenology produced by Khrushchev's second demonstration on 11 Apr. 1963, the day after killing the U.S.S. Thresher.

Why the Soviets Could Continue to Attack and Kill U.S. Targets with Impunity

Ironically, Khrushchev clearly demonstrated the inability of U.S. science to comprehend the numerous test incidents of Soviet LW interferometers, including the actual destruction of strategic U.S. targets (our latest and greatest nuclear attack submarine!) right off our coast. *The greatest strategic weakness of the U.S.—and the thing that may yet completely destroy all of us—is the continuing snail-like pace of U.S. scientific progress in revising, correcting, and extending its seriously flawed classical electrodynamics model. This scientific inertia placed us several decades behind in development of defenses in the areas of longitudinal EM wave weapons, quantum potential weapons, and causal system weapons. It countered our strategic nuclear armada for two decades. We were for some time analogous to the Spanish Navy with its wooden ships, when it faced and was destroyed by American steel ships. Hopefully at least some more modern work has now been accomplished in higher group symmetry electrodynamics, so that we are not quite as defenseless as we formerly were. But we still have a very long way to go.*

When one performs a standard strategic analysis on a nation, one of the areas examined in depth is called *national style.* One of the major characteristics in the U.S. **national** style is that we do not react to slowly increasing threats or changes

(Figure 43). That style particularly applies to the scientific community. Because of it, the Russians knew that our government only inches forward in achieving new *basic* science. We run at enormous speed, doing *applied* science. We are essentially Romans and great engineers. We are largely not Greeks and not great esthetics discoverers. We also will just ignore new threats if they emerge very slowly and are only gradually perceived, and we will hide behind that infamous phrase, "We have no evidence that..."

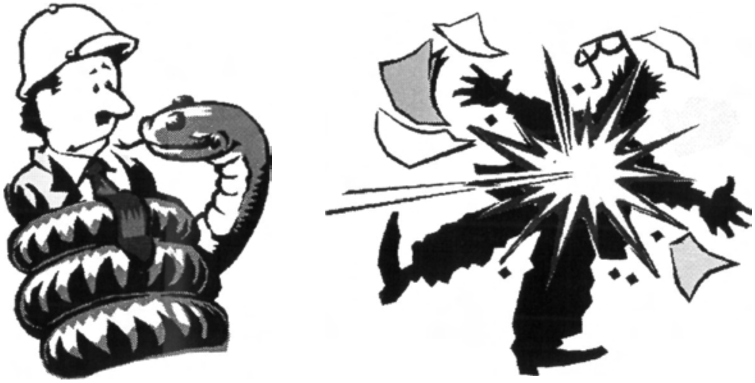

Americans tend not to react to slowly increasing things,
but react to rapidly increasing things.

Figure 43 America's national style: we do not react to slowly increasing threats.

In short, *we react to the coiled rattlesnake, not to the boa constrictor*. We are now in a long, bloody, costly war against terrorism because of that very characteristic of our national style. For decades, the slowly increasing infiltration of terrorists and their weapons was just ignored. Oh, yes, the official "threat studies" pointed it out, placidly.[25] But no one got very excited about it. The prevailing attitude was that "Ah, yes, but nothing like that will happen on *my* watch!"

As clearly demonstrated by their successful decades-long radiation of the U.S. Embassy in Moscow, the KGB chess masters knew that, if the test kills using their superweapons were not too often repeated, and if they even vaguely resembled other things known in the world, the U.S. scientific community and government investigators would resist all suggestions of Russian superweapons and super technology using new principles of nature. And so would our intelligence community, since they rely on the scientific community for their scientific assessments. They were well aware of our historical "ostrich" position (Figure44).

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[25] Indeed, if one will look at the threat studies prior to William Cohen taking office as U.S. Secretary of Defense, one will find widespread complacency about the terrorist threat, and mostly just lip service to it. It was definitely not very important to most of the intelligence and scientific community. Cohen built a fire under the entire threat community, forcing them to get their act together and start actually studying the terrorist threat, asymmetrical warfare capabilities and dangers, and what could be done about it. He did force the research and threat communities to do a creditable job of studying it, and to publish reports detailing it. Unfortunately, the tenor of the political community outside SecDef Cohen's control was basically "business as usual, not to worry." September 11, 2001 changed all that forever. Once again we had waited until the rattlesnake struck and actually bit us, before the nation rose up and paid attention.

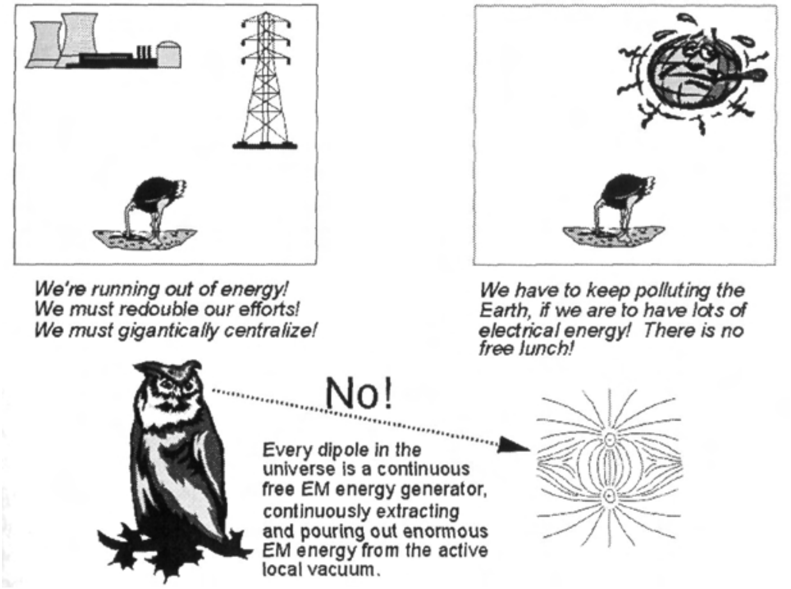
We're running out of energy!
We must redouble our efforts!
We must gigantically centralize!
We have to keep polluting the Earth, if we are to have lots of electrical energy! There is no free lunch!
No!
Every dipole in the universe is a continuous free EM energy generator, continuously extracting and pouring out enormous EM energy from the active local vacuum.

Figure 44 The only energy resource problem is the theoretical ostrich problem in science. We *must* become theoretical owls, rather than ostriches.

The KGB deception just depended upon the U.S. tiger to keep its stripes and exhibit its normal reactions or lack thereof. They also utilized (i) a series of strategic deception plans, deliberately designed to perform the tests suggestive of discredited phenomena such as UFO reporting and "lights at night" types of things, and (ii) a continuing series of subtle and anomalous stimuli (probes) designed to rather slowly attract the attention of U.S. Government at high levels, and of state-of-the-art U.S. government scientific contractors as well. The trick was not to attract U.S. attention *too suddenly or too strongly.* Show them the slow boa constrictor, not the lightning-fast rattler, and see how they reacted, if at all. By their reactions, the KGB could assess whether or not the U.S. governmcnt, intelligence, and scientific communities understood what was happening.

Precisely as anticipated by the KGB, we showed them for some decades that we really had little or no comprehension of the superweapons and their testing right over our heads. Even today, at least in the open community there is still little recognition, even of the violent weather war raging right over our own heads since July 4, 1976 and easily recognized.[26]

A case in point was the deliberate induction of diseases and health changes in U.S. personnel in the U.S. Embassy in Moscow for over 40 years (Figure 11). On a continuing basis, this excellent intelligence probe showed (by the U.S.'s actions or lack thereof) that we knew nothing about energetics.

Another KGB probe method was to kill a target once in a while, such as a jetliner or a submarine (deliberately rather seldom here, because the U.S. military would react if a certain frequency threshold were exceeded). Such kills resemble or can be posed as natural accidents or terrorist incidents. Quite a number of such incidents have occurred over the last three decades. The National Transportation Safety Board (NTSB) does not have higher group symmetry electrodynamics in its knowledge base or on its "checklists", nor does it have scalar interferometry, psychoenergetics, bioenergetics, or quantum potentials. In total, the results of deliberate stimuli of the U.S. continually assured the KGB chess masters (with 100% certainty) that we were a complete novice in the energetics game, and we were a lamb increasingly ready for the slaughter.

The major contribution to the continued success of these deliberate measures by the KGB has been provided for decades *in the "nonreaction of our own scientific community to slowly increasing threats."* To a lesser extent, our own intelligence community has also not focused sufficiently open-minded and highly qualified scientists to comprehend what is occurring in "new principles of nature" phenomena. "In the box" electrical engineers with Bachelor of Science degrees often are the analysts who analyze and assess such "out of the box" phenomena. Good luck!

Ordinary radar engineers may analyze an ordinary radar rather well. They will never, never become aware of a radar beam carrying infolded spacetime curvature engines. Such is not even in their lexicon or in their belief structure. They have no understanding or experience at all with longitudinal or time-polarized EM waves—most have never even *heard* of time-polarized EM waves. Mention curvatures of spacetime and their dynamics as deliberate "engines" impressed *inside* EM fields and potentials and waves, and one gets a glaze right over the eyes of the intelligence analyst recipient.

Western science conceives the mind as a meat computer, and does not understand that mind operations are totally electromagnetic and causal, but nonphysical—meaning in the time domain rather than in 3-space. Mind operations primarily use time-polarized EM waves rather than the transductions into transverse EM waves that the scientists actually measure. Hence Western science has not the foggiest notion as to what Russian psychoenergetics is all about, or how it can even "be." Certainly Western science has had no notion of deliberately creating time-polarized EM waves for direct engineering within the mind itself and within the mind's time-EM operations.

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[26] The weather war over our heads has been particularly violent, and violently resisted, this year (2002).

As Arthur C. Clarke puts it in his "third law," *"Any sufficiently advanced technology is indistinguishable from magic. "*

Our long fascination with our "normal" (optics, IR, UV, radar, COMINT, satellite photography, etc.) technological intelligence collection systems will certainly not lead to any great breakthrough understanding of Russian energetics weaponry. That could only have come through HUMINT or COMINT. HUMINT is an area which, in the past, we have mostly just neglected or given lip service to for decades—and that came back to bite us severely on September 11, 2001. Even when we use HUMINT, it will not yield energetics results if the managers and directors themselves (and the agent handlers in the field) have no understanding of it and do not even know the proper questions to ask. And the system will not deliver results if the Intelligence Collection Requirements do not address the proper issues because ordinary electrical engineers and conventional electrical physicists having no inkling of psychoenergetics, or how it works, drew them up.

COMINT, on the other hand, suffers from its own extraordinary prolific output -as well as by only conventional analysts and conventional scientists examming it. Warehouses of COMINT information often have not even been read in any way except a casual glance by a junior analyst, and certainly have not had serious foundations scientists examine it in detail. ELINT does a little better insofar as a human analyst looking at it, but then what is a conventional electrical engineer or radar engineer to make of a giant hemispherical globe that slowly forms and expands from a tiny "seed bubble" of intense glowing light that appears (Figure 35), as it did off the Kurils in April 1984? What will he label it? "Light phenomena?" Where are the technical descriptors of the actual process forming the phenomenon? Where are the implications as to the strategic military use of such phenomena? The reader can see the point. For decades our analysts ignored prolific reports of such incidents by the hundreds. Why, everybody knew it was glowing swamp gas!

One cannot even write a proper "intelligence collection requirement" if one does not understand the basic phenomenology. So essentially no one in U.S. intelligence was writing the proper intelligence collection requirements.

The Science Behind the Soviet Energetics Weapons

The science behind these weapons is called *energetics*. (See again Figure 8.) Energetics consists of three branches, depending upon the nature of what is being targeted. The branch targeted against nonliving matter is just called the same name: *Energetics*. Targeted against living cells and biological material, the nervous system, etc., that branch of energetics is called *bioenergetics*. Against the mind and its functions (which are time-like and thus involve scalar photons and time-polarized EM waves), energetics is called *psychoenergetics* {89}. See Figure 45. Psychoenergetics includes both the conscious[27] and unconscious mind[28] of the individual—and even Jung's collective unconscious mind[29] of the entire human species {90}, and in fact even the collective unconscious mind in all species on earth, which corresponds to Lovelock's *Gaia* concept.

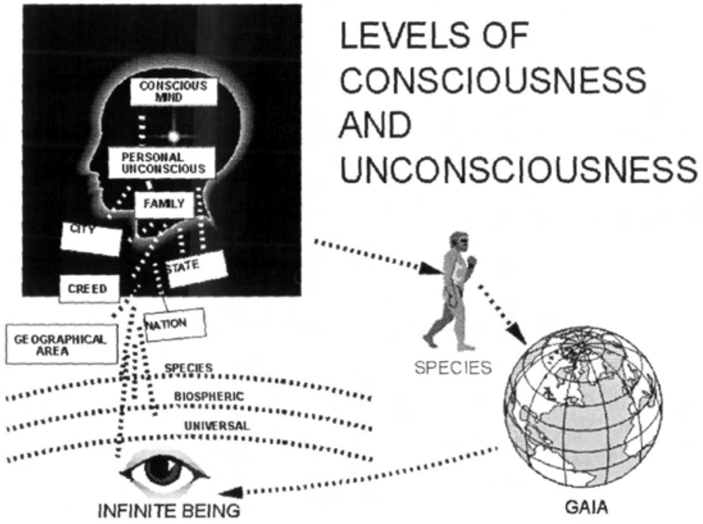
LEVELS OF CONSCIOUSNESS AND UNCONSCIOUSNESS
CONSCIOUS MIND
PERSONAL UNCONSCIOUS
FAMILY
CITY
STATE
CREED
NATION
GEOGRAPHICAL AREA
SPECIES
BIOSPHERIC
UNIVERSAL
INFINITE BEING
SPECIES
GAIA

Figure 45 Mind levels are subject to engineering by higher group symmetry electromagnetic (psychoenergetic) weapons.

We remind the reader that we are talking *physics,* not metaphysics and not mysticism. Strong Soviet physics developments over a sustained period have occurred in all three energetics areas, and these areas continue to be developed at present.

Once a nation enters into LW EM development, it has just entered into unified field theory development also. Particularly with longitudinal EM waves, one is directly engineering general relativity itself, and spacetime itself, as well as the dynamics of spacetime curvatures and sets of such curvatures. But it is an even greater unified field theory than Western physicists suspect. Not only does it unite the four forces of physics, but it also unites mind and matter and their dynamics as well.

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[27] The conscious mind is a very fast serial processor, processing one snapshot at a time.

[28] The unconscious mind is a massively parallel processor, doing a great many things simultaneously. It is totally conscious, but multiply so. Since the serial processor conscious mind can only "see a single slide projector in the viewgraph at one time", when it "looks at the unconscious mind" it sees a large number of slides simultaneously, hence just sees "black" or "nothingness" (no single thing).

[29] Jung himself labeled it a *mind* (and hence a living entity). His modern followers shudder at such a concept, and very much downplay the "mind" and "entity" aspect, preferring that it just go away.

We shall also refer to time-polarized EM waves as *time-density waves*. The reason is that a time-polarized EM wave is one where the EM energy is on the time-axis and oscillating along it, like the squeezing of an accordion. In short, it is a longitudinal EM wave on the 4th Minkowski axis *ict*, where the only variable is *t*. Hence it is a wave of the variation of time-density along that axis.

All three branches of KGB energetics use longitudinal EM waves, longitudinal E*M* wave interferometry, and Whittaker-structuring of fields and waves to provide organized curvatures of spacetime known as *spacetime engines* or *vacuum engines*. They also use time-polarized EM waves, as mentioned above. Any or all can also employ the quantum potential as well as negative energy EMP aspects. For now, the reader should just recognize that each infolded longitudinal EM wavepair comprising the scalar potential, includes both a *time-density wave* along the time axis and a longitudinal EM wave in 3-space {91}. So ordinary electrostatic scalar potential fi—ordinary voltage—is made of a harmonic structure of *coupled time-polarized and longitudinal EM wavepairs.*

Oscillations of time density oscillate the local rate of flow of time. In turn, since time has the energy density of mass, its spatial energy equivalence *W is* given by $W = c^2t$. Any change in a time density wave is a very powerful oscillation of loca1 spacetime curvature. So time-density waves constitute a very powerful form of infolded general relativity, inside potentials and hence inside all EM waves and fields. The KGB weapon scientists call that inner general relativity (time density waves) the *information content of the field*. Unfortunately our follows confuse that term with common "spectral analysis" which it very definitely is not. But as part of the deception plan, the Russians are quite happy to help them think it is exactly that, and in fact the Russians go to some pains to continue to help our fellows think that.

KGB energetics involves the use of a highly structured general relativity infolded inside electrodynamics—inside EM potentials, fields, and waves regardless of type. In addition, that very special GR is using the very strong EM force along the time axis as the main agent of curvature. By deliberately structuring these time-polarized EM waves and their dynamics, extremely powerful *spacetime curvature engines* can be employed, either created locally or at a real distance, or also globally in an entire selected distant region.

Once these spacetime curvature engines structure the distant targeted spacetime region. Then in that interference zone the engines therein act upon any mass present. In theory, any physical effect known can be engineered, according to general relativity, once one can create and utilize the proper set of spacetime curvatures (the proper set of spacetime curvatures and their dynamics). In GR, curvature of spacetime acts directly upon any mass present, and vice versa. With such technology one can therefore *engineer mass* to any level and at any distance (and eventually in any quantity) at will, using energetics methodology. *The engineered mass may be either living or inert* {92}. It follows that bioenergetics and psychoenergetics effects can also be engineered at a distance in similar manner. All it requires is the proper engines for the effects desired in the targets desired.

By using time-density waves and their dynamics, mind itself can be engineered and controlled at a distance as in the cases of Captains Button (Figures 22 and 23) and Svoboda (Figure 24).

The Importance of Scalar Photons and Time-Density Waves

Now we digress momentarily. Again, there are four major photon polarizations in quantum field theory {93}. The first two are *transverse* photons, polarized in the x- and y-direction respectively (transversely to the line of propagation, which is customarily taken along the *z*- axis). Ordinary transverse EM waves are comprised of such photons or blends thereof. Though ignored, EM waves prior to interaction with mass do *transport EM time-energy* as well as EM spatial energy, though in electrodynamics that time-energy transport has been ignored, thus confusing the effect with the cause.

The third polarization is a *longitudinal* photon, vibrating along the *z*- direction (the direction of propagation). Obviously longitudinal EM waves are comprised of such longitudinal EM photons.

The fourth polarization is a *scalar* photon, since it oscillates only along the time axis (the word "scalar" refers to the fact that it has no vector field component in 3-space). In American physics the latter photon is largely ignored since time is not an observable in quantum mechanics. However, such scalar photons do comprise time-density waves and EM time-energy currents, and they are involved in powerfully curving spacetime via oscillating the time domain. Hence by their oscillations they produce spacetime curvature oscillations, which in turn project small components into 3-space. Sufficient such coherent projection components are in fact longitudinal waves in 3-space.

The combination of the scalar and longitudinal photons is observable as the instantaneous scalar potential, and when Whittaker's 1903 decomposition of the scalar potential is slightly corrected, then the scalar potential is comprised of coupled pairs of waves, where each pair consists of a time-polarized EM wave coupled to a longitudinal EM wave. The combination of the scalar and longitudinal EM waves in the presence of charge is observable as the macroscopic scalar potential. Negative charge absorbs the time-polarized photon from the time domain and re-emits a longitudinal photon in 3-space, while the positive charge absorbs a longitudinal photon from 3-space and re-emits a time-polarized photon in the time domain.

Psychoenergetics: Engineering the Mind-Matter Interaction by Engineering Mind

We shall be interested in what actually constitutes a living biological system in **the** psychoenergetics view (Figure 46). Mind operations are *time-like* rather than existing in 3-space, and for that reason mind and its operations are not observable. Observation is a *d/dt* operator acting on an LLLT ongoing interaction, which removes the T and leaves a frozen LLL snapshot, via d/dt(LLLT) => LLL. *Imposition ofobservation itselfbreaks,* any and all connection with time-like operations, including mind and its operations.

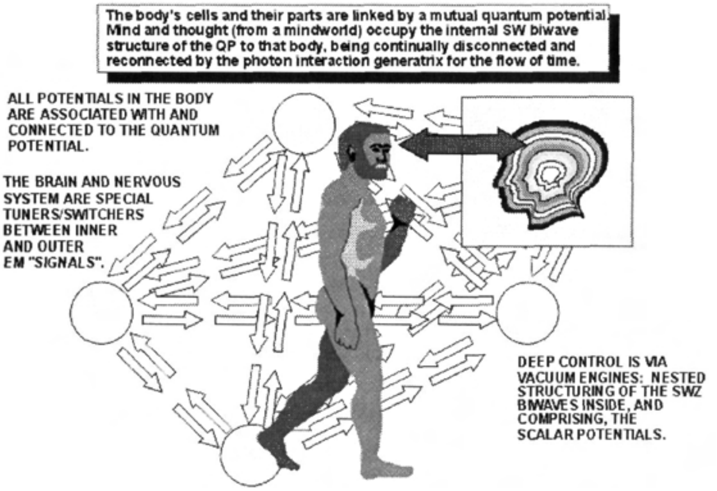
The body's cells and their parts are linked by a mutual quantum potential. Mind and thought (from a mindworld) occupy the internal SW biwave structure of the QP to that body, being continually disconnected and reconnected by the photon interaction generatrix for the flow of time.
ALL POTENTIALS IN THE BODY ARE ASSOCIATED WITH AND CONNECTED TO THE QUANTUM POTENTIAL.
THE BRAIN AND NERVOUS SYSTEM ARE SPECIAL TUNERS/SWITCHERS BETWEEN INNER AND OUTER EM "SIGNALS".
DEEP CONTROL IS VIA VACUUM ENGINES: NESTED STRUCTURING OF THE SWZ BIWAVES INSIDE, AND COMPRISING, THE SCALAR POTENTIALS.

Figure 46 A living biological system (psychoenergetics view).

"Dynamics" involves "velocity", and in general relativity's 4-space velocity is rotation (Figure 47). Any mind-operation or change is dynamics and produces a small velocity, which is a small rotation. This projects a very small component into 3-space, in the physical body, but still in the virtual state. We are speaking of physics rather than metaphysics! *Sufficient* coherent mind operations (changes) have just such small (virtual) rotation components in 3-space that will project coherent little projection components (virtual) into 3-space. Coherently sustaining these components (intent) results in their coherent integration to breach the quantum threshold and become detectable (produce an observable 3-space result). That is how an "intent" change sustained in the mind becomes an actualphysical energy input to the body and nervous system.

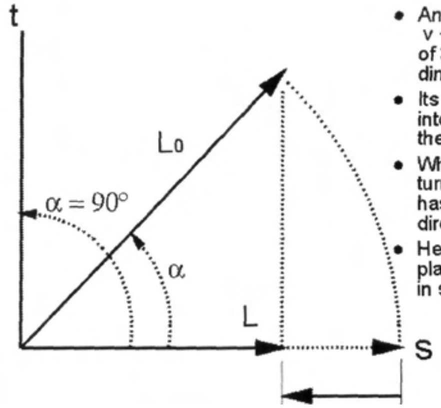

- An object moving with velocity v < c has rotated slightly out of 3-space toward the time dimension.
- Its "projection" back into 3-space is shorter, providing the Lorentz-Fitzgerald contraction.
- When velocity v = c, a full right-angle turn has been made, and the object has "lost" its projection along its direction of motion.
- Hence it appears as a 2-dimensional plane moving at the speed of light; in short, a photon or a light wave.

Lorentz-Fitzgerald Contraction

Figure 47 Velocity is rotation. Necessary to understand the mind-body coupling mechanism.

We again stress that the scalar potential is comprised of coupled time-density and longitudinal EM wavepairs. Mental operations also are time-density wave changes, hence they are changes to the interior of potentials, including the ambient potential of the vacuum itself. Potentials superpose, and their coherent internal structures add (integrate) coherently. Hence, mind changes can coherently integrate to produce minute but real, observable, physical input changes to the body system. *Mind permeates the body via the interlinked and superposed potentials of the body.* The living bio-organism's mind and its operations can be modeled as an organized operating wave dynamics inside a scalar potential and superposed potentials of the body of that organism. Since fields are made from the more fundamental potentials, these operations also function inside the fields of the body. The organized time-density dynamics constitute both the conscious mind and its operations and the unconscious mind and its operations. More subtle depths of the time-density dynamics also constitute the human collective unconscious mind functions and operations. Again, we are speaking physics, not mysticism.

See Figure 48. The "component projection" (coherent integration) process from time-like mind operations into 3-space in the body potentials introduces into the living body the *physical* commands correlated to the *mental intent* of that entity. This is the solution {94} to the long unresolved *philosophical problem of intent*, and addresses the unresolved physics problem of *just what constitutes the "observer."* But the subsequent physical changes accomplished by the responding body as a servomechanism, also produce small rotations into the time domain (into the mind domain) but in the virtual state. However, a series ol' coherent physical changes produces coherent virtual state changes in the mind realm, which in turn coherently integrate into perceptual input. In this fashion, the mind senses the response of the body to its order, and any errors in that response that need correction. The time delay gives also the sense of identity and personal persistence, hence creates the perception of self, the "responding body belonging to self," etc. Interwoven perceptions of coherent rotation changes from other 3-space phenomena that do not respond to mind intent, also create the perception of the "separate physical world." That these phenomena do not respond directly to mental intent creates the perception of the "separateness" of this "external" physical world, while the interweaving creates the perception of "existing simultaneously" with or in the external world.

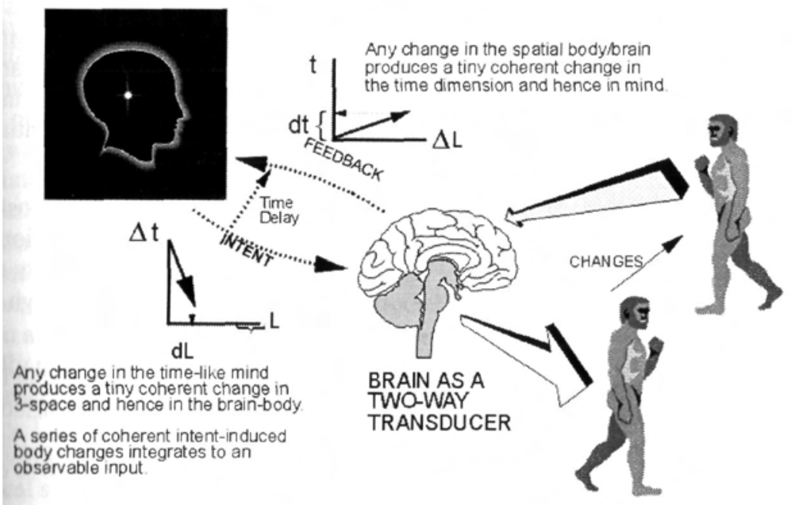
t
Any change in the spatial body/brain produces a tiny coherent change in the time dimension and hence in mind.
dt
ΔL
FEEDBACK
Time Delay
Δt
INTENT
L
dL
CHANGES
BRAIN AS A TWO-WAY TRANSDUCER
Any change in the time-like mind produces a tiny coherent change in 3-space and hence in the brain-body.
A series of coherent intent-induced body changes integrates to an observable input.

Figure 48 Mind-body coupling mechanism at work.

All of that perception, dynamics, rotation, and processing is subject to direct engineering via psychoenergetics means.

Without further elaboration, we again stress that the conscious mind is a serial processor, whereas the unconscious is a massively parallel processor. Westerners are prone to equate self to consciousness or conscious mind operation alone. That is not the case. Consciousness is just one attribute of the self (of the total feedback loop having delay between feedforward and feedback).

The totality is the mind-body coupling mechanism (Figure 48) enabling a living biological system (Figure 46).

By using time-density waves formed of scalar photons, the mind realm also can be directly engineered by the same energetics technology. Hence, for the Russian energetics weapon scientists there followed the development of psychoenergetics as an entire class of breakthrough electromagnetic weaponry.

This resulted in the development of not only a unified physics of matter and space, but also a unified physics of mind and matter reaction. Any true unified field theory must integrate the observer and the unobserved as well as the various categories of the observed. It is now possible to *directly model and engineer both physical and mental reality and their interaction.* Russian psychoenergetics has been developed to do precisely this {95}.

Quantum Potential Weapons Are Utilized in All Three Energetics Branches

In addition to scalar interferometers, there is another category of energetics weapons used in all three branches. That category involves the use of *quantum potential weapons,* after David Bohm's quantum potential in his hidden variable interpretation of quantum mechanics {96}, published in *Physical Review* in 1952. We openly published one mechanism for creating a quantum potential {97}; there are others.

Presently these quantum potential weapons are the most powerful and most flexible weapons on earth. Nothing else can stand against them. Any nation not possessing QP weapons is already a second-rate power, regardless of how many nuclear missiles, bombers, and submarines it possesses, or how many high-energy lasers and high power microwave weapons it possesses.

The greatest problem the Soviets had was not in *making* the QP itself, but in (a) *localizing* its creation to the specific area or region desired, and (b) restricting its coupling to the type of equipment, entity, level, size, type of nuclei, etc. that was desired. We have not yet fully solved the problem of how they are able to do that, but have made a little progress upon it.

The Importance of Longitudinal EM Waves

The KGB energetics weapons use longitudinally polarized and time-polarized EM waves as their basis, rather than transversely polarized EM waves. There is a surge of renewed U.S. interest—and a revolution in electrodynamics—just underway in this country (and in the major weapons laboratories of other nations) *vis a vis* longitudinal EM wave solutions to the major equations of physics. E.g., one may check the Los Alamos National Laboratory Internet web site for summary papers by Rodrigues and Lu {98}. There are now formal EM wave solutions faster than light speed, slower than light speed, etc. {99}. There is also experimental support for superluminal tunneling of EM waves in waveguides {100}. In addition, as is well known, the speed of the ordinary scalar potential is infinite in the Coulomb (transverse) gauge {101}

Higher topological algebra is being used to embed the electrodynamics in most of the KGB energetics work. Maxwell's original theory {6} was some 20 quaternion and quaternion-like equations in 20 unknowns. Quaternion algebra has a higher topology than either vectors or tensors. Heaviside and others reduced the quaternion-like theory of Maxwell down to four equations in four unknowns—or to two coupled equations, depending upon how represented—and formed the much lower topology vector algebra in the process. This serously demoted the topology of electrodynamics and placed undue limitations upon what can be done with it. The subsequent mathematical promotion of electrodynamics to tensor algebra still did not recover much of the EM functioning possible in quaternion algebra. An even vaster, far more powerful electrodynamics emerges in *Clifford Algebra* electrodynamics, which may be **the** coming modern trend.

However, even with Clifford Algebra, there remain fundamental foundations difficulties—such as bluntly confusing *energy transport* with *energy dissipation, by* arbitrarily integrating the Poynting vector around a closed surface so as to select only the divergent portion of the Poynting energy flow. That produces the *energy dissipation flow* associated with the circuit, not the overall energy flow associated with it. The overall energy flow is some 10^{13} times greater in a nominal case, as (i) discovered by Heaviside in the 1880s, (ii) never even considered by Poynting, and (iii) deliberately discarded by Lorentz with a little integration trick {102} still used by classical electrodynamicists and electrical engineers. Electrical engineering departments, professors, and texts do not know and do not teach that all EM power sources—such as generators and batteries—actually pour out of their terminals a far greater energy flow than the meager shaft energy input to the generator or the chemical energy dissipated in the battery. Lorentz arbitrarily discarded the huge Heaviside nondiverged output energy flow component a century ago, with the observation that it "has no physical significance" {103,104}.

Part of the emerging electrodynamics revolution is intuitively obvious. Higher topology algebra used in one's electrodynamics model means that lots more things can be done—in circuits, equipment, and components. As an example, suppose one can only draw geometrical figures on a flat, uncurved plane. Then compare the figures there to what can be drawn when a third dimension is added so that the plane can be curved, twisted, folded, stretched, compressed, etc. in 3-dimensional space. That is similar to the dramatic differences between electrodynamics in a higher topology algebra and electrodynamics in the far more limited tensor and vector algebras.

Further, if someone's circuits *are working* in a higher topology, a lower topology **analysis** will not even see their true functioning. This turns out to be true for Tesla's work, where so many pundits have used vector or tensor algebra in the belief that they therefore knew what Tesla was doing. They did not, nor did they even use the proper tools to see what he did. For the proof, see Barrett's examination of Tesla's actual patented circuits, using quaternions {105}.

Energy, Wave Energy, and Wave Speed are All Dramatically Altered

The energy of a pure longitudinal EM wave (LW) is infinite (unlimited). In practice, only an imperfect LW is produced experimentally, and therefore its energy is finite, but that energy may be extremely large, and the wave's propagation may be many times faster than the speed of light. This is much like quantum tunneling, which has been measured to be superluminal. Nimtz *et al.*, e.g., have transmitted Mozart's 40th symphony through a barrier in a waveguide at 4.7 times the speed of light {100}. Other researchers have transmitted information at lesser velocities but still at greater than c, the speed of light in standard vacuum.

Einstein assumed light speed in vacuum to be universally constant. That is correct for *transverse* photons and *transverse* EM waves, but not necessarily for other polarizations. Instead, it can be a function of the energy density of the vacuum (i.e., its stress energy density), which can be a matter of the gauge and the wave polarization. Further, *c* as a constant applies to transverse polarized EM waves (which are "surface" waves of the medium, so to speak) and not to longitudinal or time-polarized EM waves (which are "subsurface" or "subspace" waves). In general, the speed of the EM wave can be a function of the energy density of the vacuum (i.e., its stress time-energy density). And it is also a function of the type of EM wave being utilized.

"Empty space" is filled and writhing with the continual transiting of higher order EM waves, the presence of standing high order EM waves, and energetically organized regions where the energy is in the LW mode and in the time-density mode. Indeed, space (more correctly, spacetime) itself is nothing but a plenum of such waves and their wave-to-wave interactions.

The longitudinal and time-density effects in empty space are correlated with seasonal and periodic variations of time-charging and longitudinal EM wave emissions from planets, stars, etc. As a result, the characteristics of empty space itself periodically vary, and these can be detected as variations in the speed of light through the affected space.

The interplanetary radar measurements, e.g., do indeed show several periodic variations of the speed of light in interplanetary space, on a weekly and essentially monthly basis. In this data the proclaimed constant speed of light is upheld only by averaging the measurements over a month-long period, as shown by Wallace {106}. Actually, the scientists are dealing with variations of the periodically varying local time-density of spacetime, but have not taken that into account.

There are also specialized "galloping wave" zones, created by variations in the interferometry of the interpassing and interfering longitudinal EM waves in space. Such galloping waves from wave interferometry are already known in the literature {107} from 0.1 to 100 times the speed of light, but they do this on a "surge forward and lag backward" mode about an *average* speed of c in the laboratory here on earth. In space away from planetary masses, that value "c" varies from its textbook value also.

All that has really been shown is that interplanetary space is *not quite* uniform after all, contrary to present scientific assumptions.

One would think that this *fundamental foundations anomaly* shown by the interplanetary radar measurements would excite the entire scientific community and trigger a massive scientific investigation. Instead, scientists such as Wallace who publish critical analyses showing that the data directly prove the variation of c in "ordinary" space, are just ignored and essentially "parked on the side-lines" until they eventually fade away.

A Process for Creating Longitudinal and Time-Density EM Waves

Today we know that some plasmas very often can produce a longitudinal EM wave from a transverse EM wave, and can produce a transverse EM wave from an input longitudinal EM wave. This was not known when the Priore team was performing its experimental work. However, it provides one method for producing and detecting longitudinal EM waves.

The Priore team in France unwittingly made longitudinal EM waves by inputing transverse EM waves into Priore's rotating plasma in a giant plasma tube (Figures 12 and 49).

- At the end of the project, Priore had developed a large unit to treat humans.
- A few were treated.
- Cures replicated what had been done in lab animals.
- The massive size of the unit and long treatment time (hours) made the process bulky and very inconvenient — and expensive.
- We proposed a way to do it with a suitcase-sized unit and a treatment time of two minutes.*

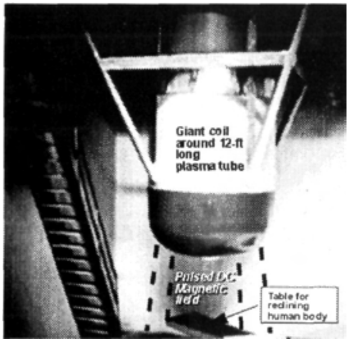
Giant coil around 12-ft long plasma tube
Pulsed DC Magnetic field
Table for reclining human body

*See *Porthole Briefing,* www.cheniere.org

Figure 49 Priore's large plasma tube installation in his 3-stories-high treatment facility for humans. Results obtained in animal experiments were also duplicated in human experiments.

Quantum Potentials and Multiply Connected Spacetime

It appears that a sufficiently clean longitudinal EM wave can be utilized to create a *quantum potential*, very similar to Bohm's notion, by iterative retroreflection between two phase conjugate reflectors. When sufficient *iterative self-targeting* occurs and persists, the waves eventually "snap in" and fully converge to laser-like beams without any energy divergence {97}. At that point, one has achieved an essentially "pure" LW, which has infinite velocity. For all practical purposes, there is then little or no difference between this wave and a quantum potential.

A pure longitudinal EM wave just "appears instantly" everywhere in space that it will be. It is already an element of a quantum potential. In this sense, all that a "quantum" potential is, is an ordinary scalar potential in which the composite EM longitudinal phase conjugate wavepairs really are pure longitudinal EM waves. It would seem that this also moves the gauge to the Coulomb gauge, so far as the potential is concerned. It follows that, by establishing significant and clean longitudinal EM wave contact between any two points via iterative retroreflections, one establishes a quantum potential if sufficient harmonics are established in the contact. The implications for "phase conjugate shooting" to go one step farther are obvious.

By "scanning" an area with the appropriate LW transmitter array, with deliberately imperfect LWs so that contact reaction occurs, and then decreasing the imperfections in the scanning by iterative retroreflection, it appears that a quantum potential can be created and connected between the transmitters and a desired distant region.

Essentially, in the case of pure longitudinal EM waves and quantum potentials, we must model the situation in terms of a *multiply connected spacetime*. The divergence-free waves are now pure longitudinal waves in one sense, and pure potential beams in another sense. In any case, the Coulomb gauge applies. As is well-known, the potential moves at infinite velocity in the Coulomb gauge.

Thus a single station can be connected by such a QP to any number of distant stations—by first "knitting them together" into a common multiply connected spacetime by iterative mutual LW self-targeting beams. It matters not if one or more distant station(s) is/are then moved beyond the star Sirius; the moment an energy signal appears in the initiating station, it is already instantly in each distant coupled station anywhere in the entire universe. There is no separation distance involved. Here *one no longer needs to propagate transverse EM wave energy painfully through space at the speed of light.* Instead, one is now dealing with multiply connected spacetime. One now has the instant appearance *in each and every distant coupled target* of the energy input into the single "transmitting" or "coupling" station. So the process is a startling and giant "energy amplification method" as should be expected from something that has infinite energy in the first place!

One vulnerability and disadvantage of a QP weapon is that, if the target is aware of one's coupling and also has QP technology, he can now immediately send back any energy form or "greetings" he wishes, from any one of his coupled targets. He can even do it inadvertently, without even knowing he has been coupled by a quantum potential. In other words, the QP provides a two-way street, if the target is aware of it and has the technology himself, *and even if he is unaware of it and does not have the technology*. For that reason, actual use of the QP weapon in strategic strikes requires caution and special considerations. Usually it requires very rapid single use and then cessation of any further usage.

Need for Caution with QPs Used Against Biological Organisms

Another QP weapon disadvantage is that rather extreme care must be rigidly exercised, particularly when linking living creatures. For living things, the QP is best utilized in the absolute minimum energy mode. E.g., *an extremely weak OP already links every member of the human species*. Suppose one increased that linkage intensity carelessly. Immediately the entire human race is in grave difficulty. Every death of a person feeds into every other living person. Every birth of a baby feeds into every living human. Even the fertilization of one **human** ova instantly feeds into all other ova. The integration of all those changes would totally disrupt—and instantly destroy—all human life on Earth. Since chimpanzees have very similar genetics to that of humans, all the chimps would probably die also. Other higher primates would also suffer or die, as would many other species.

What might be useful, of course, would be to use a QP to kill every smallpox, HIV, Ebola, and other dread disease pathogen on Earth. If so, it would first have to be made extraordinarily specific, else it could threaten all or most of the life on Earth.

A very useful adjunct would be to use a QP device to nearly instantly scrub and decontaminate (disinfect) an anthrax-contaminated large city—such as New York or Washington, D.C.—by instantly killing all the anthrax spores in that locality. Or to clean all the antibiotic-resistant staph pathogens out of U.S. hospitals by just killing them all instantly and periodically. Or to rid the Earth of necrotizing fasciitis—flesh eating disease pathogens.

An extremely localized QP could be used to connect with all HIV viruses and DNA inside an AIDS patient's own DNA. One could then kill the HIV viruses not yet integrated into the patient's cellular DNA. One could also time-reverse the patient's own HIV-infected DNA back to normal, effectively "removing" the HIV DNA already dumped into the patient's own infected cells. In theory, 100% of the HIV infection could be removed from the patient's body, restoring him or her to a completely HIV-free condition.

A Hypothetical Example

Suppose one arbitrarily increased the even weaker QP that presently joins all living things on Earth, regardless of species. Instantly every living thing on Earth would die, and the Earth would be instantly converted to a sterile planet.

Even though *physically embodied* life was gone, however, all the forms of those species would remain in spacetime activity, their vacuum engines—for both minds and bodies—forever embedded in the local potentials and fields of the material Earth. In other words, the Earth's potentials and the local spacetime potential would still be *dimensioned* and *conditioned* for the life forms that once moved upon it in physical form. The dimensioning and conditioning (engines) for every life form that ever lived on the Earth *exists now* at every point in the Earth and in the local spacetime. With proper application of energetics, in theory it is possible to recover any of these life forms desired, back into living form.

When one understands that environmental aspect, one understands why the Miller-Fox-Urey biogenesis experiments {108,109,110} (Figure 50) would still produce living organisms again. A *physically* dead planet or test flask is not necessarily a "completely dead" planet or flask, when one considers the presence of spacetime engines and dimensioned potentials. One recalls that these forms and engines contain not only physical forms, but also the mind-aspects and the mind/body coupling and dynamics aspects as well.

In short, the entire biochemical notion of biogenesis from truly inert matter devoid of any form of life or pattern of life appears to be a false premise. Since potentials reach to the end of the universe, then any structured potential structures *(dimensions)* the universal vacuum potential everywhere in the universe {111}. The Miller-Fox-Urey experiments were not performed in a truly "sterile" environment after all, when the new energetics is considered {112}. One realizes that the entire universe is alive; the mere presence of a single living microbe or other form anywhere establishes an entire living noosphere. The Russian researchers—such as Kaznacheyev {113}— into EM induction of disease in targeted cells at a distance also realized that biology included a noosphere, and it could be engineered.

- Engines of and from all life forms ever on earth or in the universe exist in the ambient vacuum potential.
- The Miller-Fox-Urey experiments were not in a "sterile" environment.
- Heat (IR) and UV constitute (1) a harmonic interval with a difference frequency, and (2) amplifying by the process previously shown.
- These experiments "kindled" previously living forms from the available gases etc. by amplifying the ancient living engines from their virtual state to the observable state, so that the masses were molded into the physical states of their templates.

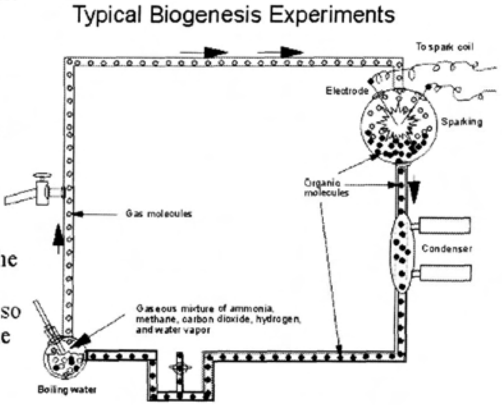
Typical Biogenesis Experiments
To spark coil
Electrode
Sparking
Organic molecules
Gas molecules
Condenser
Gaseous mixture of ammonia, methane, carbon dioxide, hydrogen, and water vapor
Boiling water

Figure 50 Typical Miller-Fox-Urey biogenesis experimental apparatus.

Herman Kahn, then director of the Hudson Institute (a leading think tank), once remarked that it did not concern him that there existed mechanisms that would destroy all physical life on earth. Instead, he stated, it concerned him that he know almost 200 such mechanisms. The quantum potential weaponry is yet another doomsday weapon with a thousand lethal mechanisms to add to Kahn's list, were he still with us.

The QP Weapon Is a Superb Energy Amplifier "For Free"

In a multiply connected spacetime established between multiple separated (to the observer) stations, one can instantly input one megawatt of power into *every distant stution* by inputting it into a single station. Suppose that coupling station is coupled via QP to one million distant stations (scattered anywhere in the universe). Then in each distant coupled station there now instantly appears one megawatt of power, even though we have input only a single megawatt in our "transmitter" coupled station. This is a superb *one-on-many weapon system and energy amplifier*—perhaps the ultimate weapon system.[30]

AS an analogy for understanding, one can look at it this way. Put a dot (point) on a piece of paper. Mathematics tells us that an indefinite number of other points can be "superposed" directly on that original point. Now input some "energy" into the original point. It instantly appears in each and every other superposed point. That is precisely the way a quantum potential linkage between stations works, except that in normal singly-connected 3-space the points are *observed* by a normal observer to be widely separated. Aristotelian logic—which is an "either/or" logic—does not apply. Instead, a higher topology logic applies.[31]

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[30] However, we should not be loo surprised at such "astonishing" effects, once we appreciate that with the quantum potential and pure longitudinal waves one is playing with infinite energy anyway.

The QP weapon can be used with microwatt input to induce low-level disease states or pre-disease states *(shadow disease states)* (Figure 51) in entire populations. Tests done in this fashion will violate the "vector carrier" aspect of infectious disease transmission. Instead, the tests will cause a few widely spaced nearly simultaneously cases of the disease being tested. Several such tests (e.g., with necrotizing fasciitis) have already been conducted in the populace of the United States.

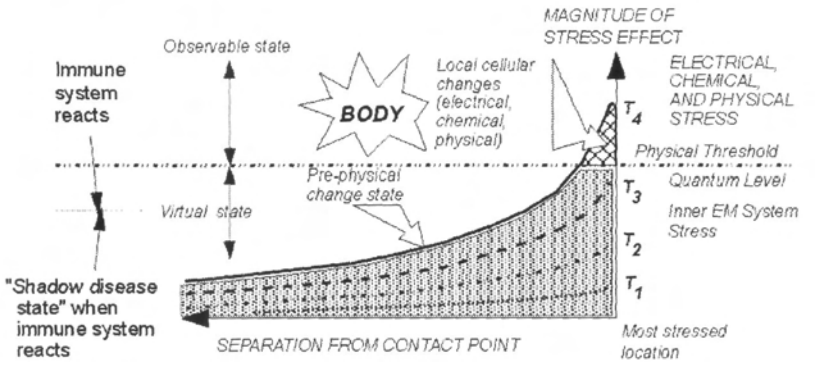
MAGNITUDE OF STRESS EFFECT
Observable state
Immune system reacts
BODY
Local cellular changes (electrical, chemical, physical)
ELECTRICAL, CHEMICAL, AND PHYSICAL STRESS
T_4
Physical Threshold
Pre-physical change state
Quantum Level
T_3
Virtual state
Inner EM System Stress
T_2
T_1
"Shadow disease state" when immune system reacts
SEPARATION FROM CONTACT POINT
Most stressed location

Figure 51 The shadow disease state is that structured virtual state level of the promoting disease engine template, at which the immune system reacts.

Or a QP weapon can be used with megawatt or gigawatt input to blast multiple distant targets simultaneously. One may destroy, e.g., every single transmitter of a given type. Or one may instantly kill all ships and weapons and paraphernalia in a large naval task force steaming toward its target. Or if one wishes to take the ships and equipment, the weapon can just kill all the humans instantly in that task force. ICBM sites, e.g., are vulnerable and obsolete since 1990 to any nation possessing QP weapons. So are underwater nuclear submarines and long-range strategic bombers. The entire strategic and tactical armada we have built up so painfully over the decades is obsoleted—also meaning *countered*—by any enemy possessing sufficiently advanced energetics weapons, and particularly quantum potential weapons.

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[31] We developed such a logic years ago, and have recently included **it** in *Energy from the* ***Vacuum*** 2002, *ibid.*

Other Novel Uses of QP Weapons

If an enemy has such QP weapons and you do not, you are easily and directly destroyed at will, once certain other deterrents are overcome. One of these previous deterrents that had to be overcome was the stability of nuclear weapons in our nuclear arsenal. To remove this stability and render them easily destroyed, the holder of a scalar interferometry capability could induce sudden massive fissioning and fusioning of many of the targeted onsite weapons if the scalar potential interferometers were used massively. However, the resulting tremendous nuclear explosions—many "in the dirt and dirty"—would also unacceptably damage the attacker. Further, major antagonists usually clandestinely introduced hidden nuclear weapons into the cities and target areas of their opponents, which practice was known as "dead man fuzing." The notion was that, even if one side suddenly destroyed the other, that destroyed side could still detonate its secret nuclear weapons hidden in the attacker's homeland territory, destroying him as well. In essence, the killed side (the "dead man") had set off the fuzing of his pre-planted weapons, to destroy the attacker even though the "dead man" was already dead.

One strong reason that the Russians pursued the quantum potential weapon so strongly was precisely because it offered a mechanism to solve this "dead-man fuzing" problem, removing it as a viable deterrent. Obviously it would be quite advantageous to be able to dud or destroy these hostile weapons in one's very midst, even though one did not know their locations, and pull the fangs of the dead-man fuzing installed by one's opponent.

There appear to be ways of directly connecting a QP, e.g., to every atomic nucleus of a given type, in a given region (say, in a region consisting of on the surface of the Earth, in the Earth to some depth, in nearby space, on the surface of the ocean, and beneath the ocean). Connection can be made, e.g., to every U235 nucleus and to every weapons grade plutonium nucleus. Or with the technology developed, the users ought to be able to make such connection only between certain pre-selected *localized amounts* of U235 nuclei or plutonium nuclei.

Now suppose that such a QP is established between weapon-sized groups of U235 atoms. Then one hits one U235 nucleus in such a group in an activator station with a neutron bullet. Voila! One simultaneously hits every other linked U235 atom (including the activator station—one just blew it to smithereens if it contained very many U235 nuclei) in such weapon-sized groups. The raw U235 in ores in nature is still okay if the ore contained only tiny traces of U235 nuclei. But all the "neutron-struck" fissionable nuclei in nuclear weapons worldwide—regardless of owner or location—fission in the weapons immediately. That destroys all the nuclear weapons on Earth—including the clandestine nuclear weapons that various nations have spirited into other nations perceived to be their enemies, as a "checkmate" against sudden surprise attack. *One* does not need to know where a weapon is at all.

However, it gets all the weapons by exploding them, and that itself could create a giant nuclear destruction and fallout problem that would probably do in most life on earth because a great many nuclear weapons will have exploded "in the dirt and dirty." In short, it is an entirely unacceptable solution to the dead-man fuzing problem.

Of course, no *sane* enemy would wish to use the QP in such fashion, because it is quite suicidal for him and essentially destroys civilization. But suppose the sane enemy is well aware of the exact nature of the new cold type nuclear reactions (we explained these in an initial rough paper given in August 1998 at an Energy conference in Utah). The energy initiating these "time-reversed" nuclear reactions starts from "inside" the nucleons in the nucleus and moves outward (that is true of any "reversed" zone).

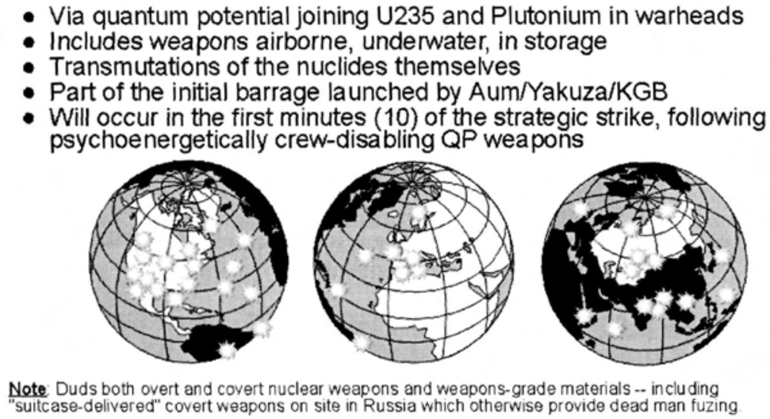

- Via quantum potential joining U235 and Plutonium in warheads
- Includes weapons airborne, underwater, in storage
- Transmutations of the nuclides themselves
- Part of the initial barrage launched by Aum/Yakuza/KGB
- Will occur in the first minutes (10) of the strategic strike, following psychoenergetically crew-disabling QP weapons

Note: Duds both overt and covert nuclear weapons and weapons-grade materials -- including "suitcase-delivered" covert weapons on site in Russia which otherwise provide dead man fuzing

Figure 52 Simultaneous dudding of nuclear weapons worldwide. Also duds nuclear reactors and nuclear propulsion systems.

Direct *isomeric transmutation* then becomes a preferred decay reaction to induce in the nuclear weapons one wishes to dud. By gradually inducing (slowly "kindling") one of these transmutation reactions, one can just "transmute" the U235 to—say—an isomer such as U238, with some readjustment and energy balancing in the ensuing rebalancing decay processes. In that way, one gets no nuclear explosions. One can even choose the transformation or several successive transformations so as to minimize any resulting nuclear radiation. The attacker also destroys all the nuclear reactors, including those in civilian power plants, nuclear submarines, and elsewhere. But he gets just about all the nuclear weapons if he transforms both U235 and plutonium (Figure 52). In about 10 minutes he will dud them all, without any nuclear explosions, but he would probably allow about one hour "just for good measure and nearly 100% certainty."

This offered the Soviets the ideal solution to the worrisome hostile nuclear arsenals of the world, since they also had additional nonnuclear strategic weapons of a different kind and of great power.

Apparently that very kind of QP weapon became operational, on site in Russia, circa 1989 under KGB control. For the first time, it provided the KGB with a guaranteed solution to the nuclear dead-man fuzing problem that had until then prevented its massive use of the scalar potential interferometers (such as in 1985-1986 as originally envisioned by Brezhnev).

By almost simultaneously leasing the earlier scalar interferometer weapons to **the** Yakuza and Aum Shinrikyo at the end of 1989, the KGB obtained an influx of vast new funds {114}. It thus concentrated even more intensely on the more advanced energetics weapons such as QP weapons and psychoenergetics weapons {115}.

So with a QP weapon one can attack multitudes of targets, using a single "coupler" or "transmitter," all without "propagating the EM energy through 3-s**pace."** Further, with the technology developed, only the number of outrigger stations coupled limits the energy amplification achievable. One can alter matter at any level, from the quarks in the protons and neutrons in the nucleus, to the lattice bonds, to the molecular bonds, etc. Or one can structure the emerging energy (that emerges directly out of the local spacetime itself), so that *structured local spacetime curvatures* (engines) appear in the target zone(s). These ST engines can be generated so as to perform macroscopic functions against real systems—e.g., jamming electronics, as against the U.S. air attack on Libya in April l986 (Figure 25), or as was done by a longitudinal EM wave interferometer in the attack and kill of the U.S.S. Thresher (Figure 6) in April 1963 {116}.

The U.S. Narrowly Escaped Destruction Twice in 1997 Alone

On two occasions in 1997 the United States would have been utterly destroyed by the die-hard faction of the KGB, except for direct countering by a friendly little foreign nation. The present author and three colleagues played a very minor role by alerting that nation to the impending attacks. There was certainly no reason to contact officials of our own country; the U.S. was and is powerless to prevent such attacks, although *hopefully* that is changing! It made much better sense contact the only nation that could possibly avert our impending disaster. Of course we later also informed proper U.S. government officials of our actions.

The first strategic attack was scheduled for between early to mid-February, and involved (1) dudding all nuclear weapons, (2) striking the QP weapons in the little nation simultaneously, as well as extant scalar interferometer weapon sites in other foreign nations, and (3) then leisurely blasting cities, facilities, and installations with iterative and continued scalar interferometer strikes. This third phase would include work assigned to the Yakuza/Aum Shinrikyo teams. That is how the Yakuza (and Aum Shinrikyo) expected to revenge themselves for the Western defeat of Japan in WWII, and for the West's dropping the atomic bomb on Nagasaki and Hiroshima. To be able to "get in on the kill" is why the Aum Shinrikyo and Yakuza leased the scalar (longitudinal EM wave) interferometers from the Russians in the first place {117}.

These, along with negative energy EMP weapons, are the kind of energetics weaponry that now determines our fate, and against which the U.S. presently has still inadequate defenses. Our own scientific community does not believe such weapons even exist—apparently due to the "not-invented-here" syndrome. Most of the U.S. scientific community is thus relatively useless and outdated as far as contributing to the strategic survival of the United States is concerned.

Purpose of the Novel Attack on Captain Button

Hopefully, some scientists are aware of the strange incident that involved the mental seizure of Captain Button in his A-10 (Figure 22) and controlling him for well over an hour (Figure 23), including controlling his perceptions, intent, and actions while performing complex technical tasks. That was the test of a KGB *psychoenergetics* weapon, developing and to be deployed by the KGB. That was the "acceptance test", so to speak—deliberately conducted over the United States—for the KGB's system that would be produced in numbers sufficient to counter the QP weaponry, if the QPs of the little friendly nation were to be placed in the insane command and control mode. This was yet another Soviet counter, planned for the near future against the counter by which the little nation did force abortion of the KGB second attack (scheduled for May 1) in 1997.

The purpose of the attack on Captain Button can be understood as follows: The later second scheduled strategic attack on the U.S.—scheduled for May 1, 1997—was forcibly aborted after the friendly defending nation switched to an *insane* command and control mode. The insane C3 mode counters the MindSnapper type attack that instantly kills all on-site operators and renders the sites too "hot" for new personnel to come in from outside and control it. In short, the U.S. could have been destroyed in that scheduled May 1 attack, but with the change of the friendly QP weapons to insane C3, Russia would also have perished in the immediate quantum potential counterblow from the little nation[32] that would have been automatically delivered by the site weapons themselves. The May 1 attack had been predicated upon the fact that a preliminary MindSnapper (negative energy EMP) attack on the friendly QP weapon sites would have instantly killed all persons on site,[33] and neutralized the site for some months because of the resulting longitudinal EM radiation. However, the shift of the C3 of the QP weapons to insane mode rendered such a pre-emptive MindSnapper attack totally ineffective because Russia would still have been destroyed.

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[32] There are also variations. As an example, the insane C3 can also include a separate channel requiring a countering "punch in" code every 15 minutes (as in a heightened alert status) or the control system will order the launch initiation (this accepts that all on site personnel have now been suddenly killed). So the insane control system is also flexible, and many variations and considerations are possible.

Hence another countering means was required, and in fact that additional system was already in development. It was a very sophisticated array of psychoenergetic weapons, each with a special, highly trained team of operators capable of fully controlling one targeted individual while he was directed and controlled to go about performing desired technical tasks. We estimate that it required one psychoenergetic weapon (very complex, multiple transmitters) and an operator team of perhaps 20 to 30 skilled operators (one for each major human function to be controlled) to adequately control the mind and actions of one distant person performing quite technical tasks. Hence several hundred such "weapon sets" were required to take over all persons on the targeted QP weapons sites in the friendly nation, have the controlled crews deactivate the QP weapons including using the security code and procedures to standdown for maintenance, etc.

Once the QP weapons were totally on standdown, then the MindSnapper would have struck suddenly and killed every living thing on site, neutralizing the site for several months due to subsequent strong longitudinal EM wave emissions from the struck site. No new crews could have entered the site and lived, so the sites could not be operated after MindSnapping, even though the QP weapons were still intact but just on standby. Of course, a third phase then would have involved strikes by scalar EM interferometers to leisurely and completely destroy the systems and sites, permanently taking out the physical system as well.[34] With the first two of that three-part series of strikes completed successfully, then the KGB weapon sites would have been absolutely free to blast North America and our European allies into smoking ruins, leisurely and at will, given the first 10 minutes of dudding all nuclear warheads worldwide, to take care of that old type of "dead man fuzing".

From the open reports of the Button incident, and from the kill of Captain Svoboda a few weeks later, the nature of the next strategic attack that would be scheduled was immediately apparent. Accordingly, we warned the little nation about the shift to a new attack plan, and estimated the new schedule between mid - 1999 and the first of 2000. Of course, we also passed that information on to our government as well, but apparently, no one believed it. The proper U.S. intelligence agencies, however, certainly intercepted my faxes to the little nation's Military Attache in Washington D.C., and particularly my fax a few days before May 1, sent directly to the Prime Minister of that nation and urging the change to an insane command and control system for the QP weapons and the reason why.

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[33] We point out that it required a longer time to develop the more powerful negative energy EMP weapons capable of just destroying the sites, personnel and all. The first effective weapons of that type could easily kill personnel brains, nervous systems, and hearts while still doing little damage to the much more robust *QP* systems and on site equipment.

[34] We strongly believe there are shielding provisions at those sites, against scalar interferometry attacks, which reduces their effectiveness and delays their destructiveness. However, so far this analyst has not deciphered those shielding methods or mechanisms.

It turned out that, some months after I alerted them to the coming psychoenergetics, MindSnapper, and scalar interferometry attack in that order, to be scheduled between mid-to-end of 1999, apparently the friendly nation suddenly struck and utterly destroyed the KGB facilities for the MindControUer negative energy EMP weapons being painfully built up in sufficient number. Probably scalar interferometry weapons were used to destroy them. The onsite psychoenergetics crews and facilities were destroyed and neutralized completely.

Anyway, as we passed mid-1999, the type of "Y2K" problem we were worrying about was whether or not the attack was on, headlined by a psychoenergetics weapon strike on the little nation first, with the three phases as previously scheduled back in 1997.

Later, in early 1999 I realized the Russian/KGB development of the causal system robots (Figure 10), mentioned in the introduction. In the latter part of the third quarter of the year, working at my computer at night, I was struck by one of these very beasts from within my computer (Figure 20), in very bizarre but unmistakable fashion (previously detailed). In 10 seconds I was nearly killed and severely disabled for a period of time (it took four days to recover completely). Because of the features deliberately utilized by the CSR on my computer screen so I would recognize it, I grasped the nature of the attack (the KGB *wanted* me to recognize it, and live to tell about it!), how it was done, how it jammed the brain and vision center and strongly fibrillated the heart, upset the equilibrium, etc. I also realized that, in 20 seconds or so additional exposure, I would have been a very dead person, expiring with a very violent heart attack and severe brain embolisms. Note that the CSR deliberately struck directly from the computer screen through my retinas and onto the nervous system, passing through the vision center and flashing it tremendously, and jamming my mind, brain, and nervous system.

When I recovered shakily about four days later, I notified the small nation, once again, as best I could, giving the exact symptoms of the attack and explaining what it was. By then I knew what was coming down, the form it would take, and the deceptive cover (Y2K uncorrected errors!).

The little nation then quickly proceeded to search out—apparently *inside* the North American signals, potentials, fields, and waves "superhighways" for the CSRs—all the CSRs and destroy them in place. It turns out to be a fairly straightforward operation, once one possesses advanced longitudinal EM wave interferometry weapons and techniques. Locating a "very dense" and very dynamic set of LWs performing organized functions is analogous to a normal radar locating a large bomber in cloud cover. One "burst" from the LW "radar," and the targeted CSR is completely disrupted and electronically destroyed.

So a very short (lasting a few days) and strange strategic battle was fought in infolded space or subspace, inside our electrical and electrical systems and inside the fields, potentials, and waves in them. A mighty attacking armada of perhaps several million main battle systems was intercepted and destroyed throughout our homeland, without the slightest notice by our own government, scientific, and intelligence communities. And without a whimper of what is usually recognized as "combat actions".

Afterwards, a very simple and innocuous little message was received which, reading between the lines, simply meant "thank you very much." In short, my hard-pressed colleagues and I got a small "Attaboy!" for our role in alerting the friendly nation.

So Y2K and the Millennium Celebration came, while we waited to see if the CSRs were gone or if they would erupt with damage all over the U.S. Fortunately, they were gone like popping balloons, and so the *fourth* scheduled strategic attack upon the U.S. in the space of three years—this time actually launched—was successfully destroyed.

Whatever I can do to help the survival of my country I will continue to do without hesitation, regardless of whether the U.S. scientific, intelligence, and military communities are aware of the new threat or not, and regardless of whether they believe it or not. Presently our fate and that of the Western world rests on the shoulders of a small but advanced and friendly nation. That is beginning to change, it seems, but still not swiftly enough to suit our needs.

We simply must change all that, by developing QP weapons and defenses ourselves. It is not an option; as an example, China has now finished—as of earlier 2002—and deployed QP weapons. Almost simultaneously, China also finished and deployed the more powerful negative energy EMP (MindSnapper-type but much more powerful) weapons and deployed them as well. So we have entered a very dangerous period when the strategic changes that are likely to occur will be both massive and traumatic.

AS this is being written in early October 2002, it is obvious that our nation is also preparing to strike Iraq if need be, either with a coalition effort or alone. If so, then Saddam Hussein will certainly unleash whatever terrorist forces he has in North America. He will attempt to unleash upon us all the weapons of mass destruction at his command. This could even happen within the next 30 days, with the MidEast exploding, giant polarization of the Arab world, general chaos in the MidEast and upset of world oil supplies, and skyrocketing fuel and energy costs with severe impact upon the already seriously ailing U.S. stock market.

If Saddam Hussein succeeds in doing sufficient damage to our cities and energy infrastructure with more weapons of mass destruction than we have credited him with, then the potential economic collapse of the United States and much of the developed world is an uncomfortable possibility. If that happens, turf wars will erupt all over the world, the world economy may collapse, the KGB and rogue Japanese (Yakuza and Aum Shinrikyo) will move and unleash further destruction, Pakistan and India are likely to erupt into a nuclear war, and several other regions may also erupt into nuclear war and use weapons of mass destruction. What China might do in such event is anybody's guess.

In short, the Armageddon we have so long feared, with the resulting collapse or destruction of much of civilization, could well be approaching. Let us hope that dark picture is terribly, terribly wrong, and that we successfully avoid Armageddon one more time!

Meanwhile, we would be in much better shape to weather the coming storm had our scientific community not grossly betrayed us. But if and when millions of Americans are dying in the streets with no effective means of treatment, and no effective defenses to prevent onslaught after onslaught against our nation, all those deaths and all that suffering will be directly the fault of our own organized scientific community.

Rogue Japanese (Yakuza and Aum Shinrikyo) Have a Role

In the information briefing furnished the previously named agencies, we briefly detailed the elements of the attack, how our own nuclear weaponry can be dudded anywhere, etc.

We also detailed the strange role of the Japanese Yakuza and the Aum Shinrikyo, who leased the operational use of the early generations of KGB longitudinal wave interferometry weapons in 1990 directly from the KGB. The first down payment on the lease was $900 million. I previously furnished pertinent information on this to an investigative U.S. Government agency. Since then, the Yakuza have set up their own scalar interferometry weapons development facilities in Japan, including portable energetics weapons,[35] and have assumed a very secret and nearly unsuspected role somewhat similar to Bin Laden's role in the attacks of September 11, 2001—but much more deadly when the coming Armageddon erupts.

Inducing the Gulf War Disease

In 1986, the Russians had already solved the dead man fuzing problem theoretically, but had not yet completed the development and deployment of the necessary QP weaponry. The KGB's first "combat demonstration" test of the **ability** to localize a QP in a selected region of space was against the U.S. air attack on Libya in 1986. That test apparently used a laboratory apparatus to prove the process. In short, it was a major milestone whose success moved the system into full production engineering and production. The system was then developed at very high speed after the successful demonstration in 1986. The first strategic KGB QP weapon(s) became operational on site in latter 1989.

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[35] We strongly suspect some of these portable weapons have already been infiltrated into the United States—e.g., to be used against nuclear power plants and other lucrative targets such as refineries, oil fields, etc.

It was this QP weapon that was used to generate the so-called *Gulf War Disease* in our soldiers in the MidEast. In the action package, I explained precisely how that was done. I have also finally placed the simplified gist of that explanation openly on the Internet for all to see (website www.cheniere.org). Those suffering U.S. veterans were *casualties of war,* not victims of just nerve gas whiffs or chemicals or their own stress, etc. The initial U.S. Government and U.S. scientific community's assertion that "it was all in their heads" and due to stress, insults every veteran who has ever served his nation. One justifiably has contempt for such treatment of our veterans. Sadly, the latest "studies" are **beginning** to conclude the same thing once again.

Apparently our intelligence and military command agencies have not yet learned the lesson of the decades long Soviet microwave radiation of the U.S. Embassy in Moscow, which was responsible for health changes of many kinds in U.S. personnel and was also responsible for the deaths of three U.S. Ambassadors to the Soviet Union. Apparently we are still using radar engineers and electrical engineers for electrodynamics analysis, and these analysts apparently still believe that in the absence of the EM fields there can be no induced EM effects. One sadly comments that, just as the electrical engineering departments of our universities have been unable to walk across the campus to the particle physics department and find out what the discovery of broken symmetry in 1957 portends for their discipline and model, then the intelligence community apparently has not yet learned that no EM analysis of such things as the microwave radiation of the U.S. Embassy in Moscow or the shootdown of the TWA-800 is worth a tinker's dam unless it is a higher group symmetry EM analysis. As Barrett showed, our fellows still have not grasped what Nikola Tesla already accomplished in actual patented circuits circa 1900 and shortly thereafter. Tensor analysis and vector analysis simply will not show what is really there.

Our veterans were hit with a "cocktail mix" of specialized disease "spacetime curvature engines" just below the observable threshold, in the "shadow" (virtual, but nearly observable) state[36] (Figure 53). The immune systems and the cellular regenerative systems do react to that shadow state level.

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[36] One should think deeply about this, in terms of the solution to the source charge problem (which our engineers have not thought of very much, much less solved). Every charge already "engineers" the virtual stale at will, converting virtual energy into deterministic observable EM energy. That means we can directly engineer the virtual state vacuum itself if we put our minds to it. **Actually** Nobelist Lee has already pointed out that we have *not even tried to do this!* See T. D.

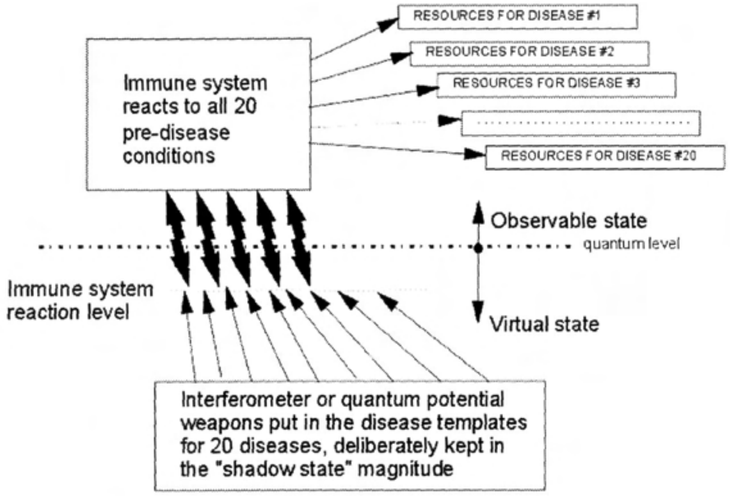
RESOURCES FOR DISEASE #1
RESOURCES FOR DISEASE #2
RESOURCES FOR DISEASE #3
RESOURCES FOR DISEASE #20
Immune system reacts to all 20 pre-disease conditions
Observable state
quantum level
Virtual state
Immune system reaction level
Interferometer or quantum potential weapons put in the disease templates for 20 diseases, deliberately kept in the "shadow state" magnitude

Figure 53 Spreading (thinning) the immune system's ability available to meet a new pathogen.

Such a "simultaneous mix" shadow induction "spreads" the reacting *finite* immune system and regenerative system (Figure 53) and their resources all across that entire mix of shadow diseases, so that only a much smaller portion of the immune system and of the regenerative system is directed against *any one* of the shadow diseases. This in turn greatly heightens (by a factor of 5 or more) the susceptibility of the body to all additional disease pathogens, and it greatly lowers the ability of the body to recover from any disease or biological warfare strike. In addition, the exposed veteran's body fluids and masses have accumulated a persistent "time-density charging" that very slowly decays (by emission of weak *longitudinal* EM waves) over months or even a few years.[37] The sperm from these veterans did indeed have the innate "engines" and therefore the capability to gradually infect their wives. So did the saliva in their mouths. The weak "dimensioned" LW radiation from their bodies could also slowly alter the cellular regeneration and immune systems of their family members in close proximity, over a period of time, thus inducing the disease in them {118,119,120}.

Lee, *Particle Physics and Introduction to Field Theory,* Harwood, New York, 1981, in his "Chapter 25: Outlook: Possibility of Vacuum Engineering," p. 824-828. On p. 383 Lee points out that the microstructure of the scalar vacuum field (i.e., of vacuum charge) *is not utilized.* We add that the West does not utilize it. It has been utilized for some decades in the former Soviet Union and now in the continuing KGB energetics and bioenergetics weapons programs.

[37] See T. D. Lee, "Can Time Be a Discrete Dynamical Variable?." *Phys. Lett.,* 122B(3,4), Mar. 10, 1983, p.217-220.

The induction of GWS in our troops was in fact a test for the *present* clandestine use—already ongoing—of that technique to spread the immune and regenerative systems of the targeted U.S. population. This in turn gradually makes us more susceptible to terrorist BW attacks and disease pathogens of all types *from anyone else.* This tactic is already in place and accomplished, and it will substantially increase the American civilian casualties in our cities when they are subjected to terrorist BW attacks in the near future. *Those attacks now will have some five times the effectiveness that our present planners estimate.* In short, it is going to insure the deaths of millions more Americans. The approaching war in the MidEast, with Saddam Hussein's unleashing of his terrorist assets in the U.S. to the maximum extent possible, thus will probably see a five-fold increase in the effectiveness of some of his mass destruction weapons that Hussein's assets are able to unleash on America.

The entire affair of the Gulf War Disease was both a preliminary test and also a magnificent intelligence probe by the KGB, to clearly demonstrate once again that the U.S. Government and the U.S. scientific community are still nearly totally unknowledgeable of QP weaponry, immune and regenerative system "spreading," disease induction by bioenergetics means, etc. It follows a methodology used with great success for four decades by the KGB,[38] and one that our own government, scientific community, and military community has yet to decipher. *So long as the threat only slowly increases, Americans remain complacent in their ignorance, ignoring the boa constrictor slowly strangling them, while awaiting the cobra seen in the distance?*[9] We have unwittingly cooperated with the KGB boa constrictor for four decades, even as it slowly prepared to crush us. In the Gulf War, that crushing moved to the next threshold, to actually inflict casualties and deaths on U.S. troops and totally get away with it because of the bioenergetics (in the Russian sense) ineptness of the U.S. scientific community.

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[38] The decades-long microwave radiation of the U.S. Embassy and induction of health changes and diseases, was a case in point. A high level target—the U.S. Ambassador—was involved, guaranteeing U.S. Government attention at the highest level. Puzzled, the U.S. government would then call in their most trusted EM scientific analysis groups. By the responsive actions then taken by **the U.** S. at the Embassy, the KGB could ascertain with absolute certainty whether or not our scientists knew of the use of infolded engines in bioenergetics. For more than four decades our actions assured them with 100% certainty that we knew nothing of what their "information content of the field and potential" actually was, or how it had been weaponized and was being used right in front of our faces and before the entire world.

[39] It is bizarre that our scientific community—even after those decades of EM induction of diseases and health changes in American personnel in the U.S. Embassy in Moscow—*still do not and cannot believe that conditioned EM radiation can induce cellular disease.* Such total blindness is inexplicable.

40-Years of Russian Induction of Diseases In U.S. Embassy Personnel

Sadly, our own fellows have never even figured out how the diseases and health changes were previously induced by the KGB for decades in personnel in the former American Embassy in Moscow. Three U.S. Ambassadors to the Soviet Union died as a result of their exposure to that radiation. Many other Americans on site were made ill or suffered health changes.

When Johns Hopkins scientists studied the problem, they found a most anomalous thing: no health changes occurred in areas *where the EM forcefields existed* in the microwave radiation. Instead, the health changes only occurred in areas where the potentials were gradient free so that the force fields were zero—and thus the potentials (and their specific internal "engines") were *persistent.* Using only a classical EM force field analysis—which does not show any of the internal longitudinal EM wave substructuring of the fields, potentials, and waves—the Johns Hopkins scientists erroneously concluded that it could not have been the weak microwave radiation causing the health difficulties, *because no such health difficulties occurred where the forcefields were present.* That is, they very naively assumed that "no force fields" meant no EM effects were possible. Their entire findings thus were based on a total non sequitur, the assumption that there can be no electromagnetically induced physical changes in matter in the absence of fields! The Aharonov-Bohm effect alone falsifies that entire premise. So does general relativity and higher group symmetry electrodynamics.

Actually, the Johns Hopkins scientists had just clearly proven the exact opposite: *that it indeed was the radiation that induced the health changes.* That is simply shown statistically, and it is a deep and continuing mystery how good scientists and their governmental overwatch did not notice the violation of inference methodology.

Simply put, there was 100 percent correlation to the presence of *gradient free EM potentials— the persistent kind.* There was zero correlation (or 100% anticorrelation) to the presence of the normal electric and magnetic fields—i.e., where the potentials changed over a very small region of space. Hence it could *only* have been the constant potentials, else we must throw out statistical inference theory altogether.

If the changes had *not* been caused by the EM radiation at all, one would have had some health changes in regions where fields were present and some health changes where the fields were absent. Considering the lengthy time the radiation persisted and the number of personnel affected, the statistics are decisive. Without question, the cause was indeed the persistent potentials where the **force** fields were zero. Whittaker's two papers—one in 1903 and the other in 1904-would then show how it was done. The 1904 paper and superpotential theory alone would *not* have explained it, since that alone does not include the "information content of the field"—i.e., spacetime curvature engines infolded inside the normal EM potentials, fields, and waves.

So, the U.S. government and U.S. scientific community "botched it badly," unfortunately, by elemental statistical inference standards. And unfortunately, they have continued to "botch it" to this day. Both the scientific community and the intelligence community missed it. Elementary statistics theory alone, coupled with the Johns Hopkins results, clearly indicates that the microwave radiation was causing the health changes, to a very high degree of confidence.

This demonstrates how "totally inexplicable" some of the effects generated by longitudinal EM wave interferometry and by "structured" or dimensioned potentials, fields, and waves can seem to our conventional scientists. If we examine the serious foundations flaws in classical electrodynamics and electrical engineering taught in our universities, and the near-total lack of higher group symmetry electrodynamics training, we can understand why our scientists and intelligence analysts did not and do not have the background required to properly assess the incidents and effects.

Western Electrodynamics Is in Sad Shape

Actually, numerous scientists have long pointed this out. For example, quoting Mario Bunge {121}: *"...it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state."*

In quantum electrodynamics, it is the *potentials* that are the primary causes of all electromagnetic phenomena, not the force fields as used by Johns Hopkins and the Government in its analysis. We know that classical EM is wrong in its focus upon force fields as primary EM causes; the Aharonov-Bohm effect, Berry phase, and geometric phase work in some 20,000 papers in the physics literature already show that. Indeed, we also know that the classical force fields do not even exist apart from mass; in space, only the potential for such a force field exists, in case some charged matter is brought in to interact with the EM entity as it exists in mass-free space (as curvatures of spacetime).

The Aharonov-Bohm effect and its implications have been published in *Physical Review*—our most prestigious physics journal—since 1959. Later publications have included the Berry phase extension of the AB effect, and Aharonov and Anandan's further extension of the Berry phase to what is today called the geometric *phase.* The potentials are indeed the primary EM causes, and *the force fields do not even exist as such in mass-free space, but only in mass.* Yet our classical EM taught in our universities has not been changed in its fundamental acceptance of the material ether since 1865.

Every university in America is still teaching and defending a rather mangled electrodynamics where

(1) The material ether is still assumed, even though destroyed more than a

century ago by the Michelson-Morley experiments;

(2) The force fields are erroneously assumed to exist in massfree space, but in force-free form(!!!) when what actually exists there as an EM disturbance is a general relativistic perturbation of spacetime (i.e., an oscillation of the local curvature of spacetime). Actually, force identically is the time rate of change of momentum, where momentum is mass times velocity. Thus mass is a *component* of force and force field. There is no force or force field without mass. As Feynman put it, there is no force field in massless space; instead, there is only the potential for such a force field to be formed at the various points, should a charged mass be placed at (added to) each of them;

(3) The source charges are erroneously assumed to *create* their fields and potentials and all that energy in them, reaching across the entire universe from each and every charge, right out of nothing at all. This perpetual motion and creation of energy error continues even though particle physics has known (and proven, both theoretically and experimentally) that any charge (as a set of composite dipoles, when the charge is taken with its clustering virtual charges of opposite sign) is a broken symmetry in its fierce energy exchange with the vacuum. Hence the charge extracts that energy in its fields and potentials *from the active vacuum,* and outputs the extracted energy across space {122}.

Our own electrodynamicists and electrical engineering professors and departments would have us believe - and they continue to imply such in every university in America—that every charge is a perpetual motion machine clearly in violation of the master energy conservation dictum that *energy can neither be created nor destroyed.* The complete lack of scientific understanding that every charge extracts energy from the vacuum and freely and continuously pours it out as real observable EM energy, is reflected in rather silly "witch-hunts" {123} against electrical systems which exhibit more energy output than the operator himself inputs—i.e., systems which exhibit a coefficient of performance (COP) of COP>1.0, which are open EM systems far from equilibrium in their active environmental exchange.

Let us reason together! If the second law of thermodynamics really did prohibit COP>1.0 *electrical* systems, then it also would prohibit the demonstrated COP = oo of a solar cell array. It would also prohibit the demonstrated COP>1.0 *mechanical* systems such as a windmill, waterwheel, or sailboat—all of which have COP = oo! In other words, the second law cannot even be a law if it discriminates only one type of energy prohibited from being used for COP> 1.0,

For some inexplicable reason, EM COP>1.0 systems have come to be dogmatically labeled "perpetual motion machines" by the professional skeptics since EM systems must take their excess energy from the known active vacuum environment! In short, the dogmatic scientific community is saying that "windmill-type EM systems" with COP = oo are permissible for exchanges with *physically active and observable* environments (such as the sunlight used in solar cells, the heat in the air used in heat pumps, the water currents used hydroelectric power plants, the winds used in windmill power generation, etc.), but they are not permissible for exchanges with the proven modern active vacuum *virtual particle flux energy* environment, even though the discovery of **broken** symmetry in 1957 already proves that all EM energy is indeed freely taken from the seething vacuum environment by the asymmetry of the modern dipolarity of the source charge! We refer the interested reader to the proven broken symmetry of opposite charges {124}. We also refer the reader to Nobelist T. D. Lee's statement applicable to the skeptics' naive notion of symmetry. Finally, in modern physics all the major forces of nature are generated by the exchange of virtual particles. It is these forces that then translate against a resisting mass or entity to provide useful work. So all useful work in the universe already comes from the interactions of the seething virtual flux of the vacuum. On what distant planet have the skeptics been hiding while all this modern physics has been developed?

One must keep one's sense of humor! It is ironic but true that every major university in the U.S. continues to teach, uphold, and advocate—by implication—EM charges as ubiquitous perpetual motion machines, freely creating energy from nothing. And that is those professional skeptics and witch-hunters never mention that their own naive understanding of electrodynamics already implicitly assumes and teaches perpetual motion machines freely creating energy from nothing at all—and on a scale unparalleled in scientific history!

We have one chart with some 32 major foundations errors and flaws in the electrodynamics taught in all our schools; there are many others in addition. This erroneous teaching has so indoctrinated our graduate students that most electrical engineers no longer know the real difference between power (the rate of change of form of energy and thus the rate of production of work) and rate of energy flow (whether it is being dissipated or not).

Every textbook speaks of "sources furnishing power," when it is the rate of dissipation of energy in the individual loads and losses to provide the rate of doing work that *constitutes* power. Sources do not furnish power! They furnish energy flow (specifically, their source dipole furnishes energy flow, extracted and transduced directly from the active vacuum, and only a tiny bit of that enormous energy flow is diverged into the circuit and used). The various components of the receiving circuit interact with that energy flow to catch and dissipate a little of it, thus producing power and work locally in the intercepting and dissipating component.

A massive nondivergent (nonintercepted) energy flow has zero power (time-rate of doing work), but if intercepted and diverged, the divergence may develop enormous power (time rate of doing work) in and upon the interceptor, diverger, or collector. Even many physicists today are confused on the difference between rate of work and rate of energy flow per se. E.g., for about 30 years now, there has been a polite debate involving that very subject in the *American Journal of Physics.* It is still not completely resolved, because the argument has not actually addressed where all EM energy in fields, potentials, and waves comes from in the first place: directly from the seething vacuum via the asymmetry of the source charge. It also has not addressed the long unaccounted giant Heaviside nondiverged energy flow component.

Toward a Deeper Electrodynamics

The first thing the Soviet Academicians did after WW II was to completely overhaul electrodynamics, but in highly classified areas controlled totally by the KGB. Stalin's boot firmly planted on their backside saw to it, creating the terrible fear that if they failed to produce, they would surely die. Not having experienced such a "Stalin boot," our own scientific community continues leisurely onward, while it teaches 110 years old electrodynamic material filled with non-sequiturs.

The Russian use of the "information content of the field" euphemism is a case in point. Our fellows (in both the intelligence community and the scientific community) assume the Russians are speaking of simple transverse EM wave spectral analysis. Nothing could be farther from the truth. Let me explain.

In 1903, E.T. Whittaker—a leading theoretical physicist at the time—showed that any scalar potential is comprised of a harmonic set of bidirectional *longitudinal EM wavepairs.* Each pair consists of a longitudinal EM wave and its true phase conjugate replica (i.e., its "antiwave", or time-reversed twin, coupled together).

Unknown to Whittaker, that LW wavepair actually includes a *time-density wave* in the time domain, coupled to a longitudinal EM wave in 3-space. Per quantum field theory {66}, such a coupled pair would be observable as the scalar potential. Knowledge of this specialized coupling is necessary in order to properly decipher the Priore mechanism. That mechanism was demonstrated to *time-reverse* (dedifferentiate) a diseased or damaged cell and all its parts back to it previous normal state, *genetics and all.* The time-reversal was accomplished by "pumping" the cell and all its parts in the time-dimension so that time-reversal propagation of the mass-energy is achieved. The time-domain pumping is done by the associated time-density wave, which always accompanies any longitudinal EM wave a priori. So sometimes we sloppily say that the "longitudinal EM wave pumping" causes the time reversal of the mass, but it is really the associated time-density wave pumping that causes it. The time-density wave component also can cause *time charging* or *time-excitation charging* of a mass. During its alternate existence as masstime, the time portion is altered, and that is a time-excitation or time-energy excitation.

It turns out the human cellular regenerative system (Figure 29) also uses the same time-excitation charging methodology to produce time-pumping of the cell and all its parts. This produces a slow time-reversal (dedifferentiation) of damaged cells back to a previous state. This is in fact the basic mechanism for healing, as used by the living body.

Reversing aluminum, for example, just converts it back to ordinary aluminum. Not too interesting.

Reversing an HIV infected cell, however, would produce a healthy, normal cell with normal genetics. When a damaged cell turns into a cancerous cell, it is due to a process called *promotion* (change of the cell to a cancerous cell). *Reversing a* cancerous cell would change it back to a healthy, normal cell again—in short, it would constitute _demotion_ of cancer and then healing of the damage in the now normal but damaged cell. In the AIDS patient, simply pumping the entire body with the time-density wave accompanying the longitudinal EM waves produced in a plasma—as Priore did for terminal tumors—would time-reverse all cells, completely ridding them of any residue of HIV infection. This would remove all the "HIV factories", thus completely solving the problem of AIDS. We have also uncovered a more advanced process where *matter can essentially be directly engineered in any conceivable manner,* including nuclear transmutation etc. We have filed a Provisional Patent Application and will file formal patent applications on those processes in the future, as soon as funds are available (patent attorneys are expensive!)

Time Is Highly Compacted Energy

Since time is energy compacted by some $9x10^{16}$, even small time-density changes can produce enormous spatial energy, should any of that compacted energy be *transduced* from time-density waves into transverse EM waves and thus into spatial EM energy. Such transduction can indeed occur in nonlinear materials and processes, such as in electrolysis.

The New Transduction Model Explains the Cold Fusion Results and Mechanisms

In August 1998, we presented a conference paper pointing out that cold fusion uses this very _transduction of EM wave types,_ one into the other. We presented such new concepts as (i) TW to LW to TDW transduction and in the other direction also, (ii) time density charging of a particle to an excited time-density state (analogous to energy charging to an excited energy state), and (iii) the observation that excess phase conjugation in a local region can generate a time reversal zone where like charges attract and unlike charges repel.

With these concepts we were able to explain the excess heat appearing in the cold fusion experiments of hundreds of researchers. We also came up with (iv) a totally new class of nuclear reactions without the usual high-energy considerations. That is, we showed the exact nature of the electronuclear reaction that is forming the anomalous nuclides in cold fusion experiments. Production of the new nuclides was revealed to be simply what one would expect from this mechanism, as indeed was particle clustering of like-charged particles.

We also explained (v) all the instrumental anomalies occurring in a series of well-documented cold fusion electrolysis experiments at China Lake. In fact, (vi) we added a completely new term to the conservation of energy law, thereby extending it.

An updated explanation is included in my new book, *Energy from the Vacuum,* 2002, *ibid.* With the new transduction interactions, one must state that the total energy in (a) spatial energy form, (b) mass-energy form, and (c) time-energy form is what is conserved.

So when transduction occurs in cold fusion experiments (electrolysis), some of the time-density charge energy is gradually transduced into ordinary transverse EM wave energy, which as it scatters produces excess heat not accounted for in present particle physics interaction models.

Scientists with only the "old" 2-term Einstein conservation law in mind, will be firmly convinced that this excess heat represents a violation of conservation of energy, hence is impossible. So they will question the calorimetry ability of the cold fusion scientists, etc. Unfortunately, the more ardent defenders of the orthodox faith will unjustifiably impugn the intentions and morals of the experimenters themselves with vicious ad hominem attacks. Such has indeed been precisely the case. Many of the harsh scientific critics have acted like cur dogs in a pack attack, and not as scientists at all.

Once one analyzes cold fusion in the new 3-term conservation manner and with the new transduction concepts, one immediately sees that the *overall* conservation of energy is upheld, while the *special case* represented by the former energy conservation law (conservation of the sum of the spatial energy and the mass-energy) is *permissibly* violated. The former case was a special case in that it arbitrarily assumed that no transduction of time-energy into spatial energy or mass energy—or vice versa—occurred.

In essence, successful cold fusion experiments show that, via transduction, a bit of time itself can be "utilized for fuel" and transduced into ordinary EM energy. Energy-wise the system has become a nonlinear open dissipative system[40] far from thermodynamic equilibrium {125}. As such, it is permitted to (1) self-organize, (2) self-oscillate, (3) output more energy than it itself has, by merely receiving, converting, and using excess energy from its environment (in this case, from the transduction of a tiny bit of the time-charging that has occurred), (4) power itself while simultaneously powering a load or performing useful work, and (5) exhibit negentropy. With the exception of transduction of time-charge into excess energy, all of that is already in the thermodynamics texts, though it has not been clearly spelled out in electromagnetics texts. The source charge, e.g., exhibits all five of those capabilities. *The inclusion of the time-domain as part of the external active environment, however, is an extension of* ***previous*** *open dissipative system work by leading researchers such as* ***Prigogine.*** *It dramatically extends the meaning of "active environment".*

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[40] But we point out one idiosyncrasy of thermodynamics, which defines a "closed system" as one in which mass does not cross the system boundary, but energy is free to exchange across that boundary {125}. Hence, eerily a "closed thermodynamic system" is actually an open system with respect to energy exchange between system and environment. As such, energy-wise the system can be a system far from energetic equilibrium with its external active environment, and still be considered a closed thermodynamic system! Energetically, a *closed thermodynamic system* that exchanges energy but not mass is permitted to exhibit COP>I .0 and even COP = oo!

Why There Is a Time Delay in the Onset of Cold Fusion Phenomena

With an energy-to-time compaction ration of $9\text{x}10^{16}$, energy processes have to transduce spatial energy into time for quite a while in order to build up very much *time-excitation charge*. This leads to an initial delay in the onset of the "new law" transduction phenomena, as directly shown by the vast majority of careful cold fusion experiments. This build-up occurs during the "palladium-lattice loading" time, e.g.

By the same token, there is a time delay after cutoff of the input power to such experiments, during which time the slowly decaying time-density charge by its transduction into spatial energy continues to maintain the anomalous new processes (such as excess heat production) as they slowly subside. So the hours-long or even days-long delay phenomena after input power shutdown are also explained by the new approach.

In summary, there exist some very anomalous but very good experiments by excellent scientists—more than 600 of them—that are at least totally consistent with the above new wave polarization transduction model. Consistency with experiments is the first element of proof (it is necessary but by itself it is not sufficient). The new model also contains and obeys the conventional conservation of energy law until the new transduction phenomena become observable, at which time the extended energy conservation law applies. So in its lower limit, the new model corresponds to the present model—again, another requirement of any model purporting to extend a scientific area past that area's conventional model description.

The KGB weapons scientists—not the regular Russian academic establishment—have about a 40-year lead on us in all these areas. While our own scientists have dallied and pursued the standard model, the Russian weapon scientists have produced the equivalent of 10 Manhattan Projects, back-to-back, in the "new" energetics area.

The Early Soviet Longitudinal Wave Interferometers

Using longitudinal EM waves, the early KGB energetics interferometers could pass their beams right through the earth and ocean. LWs readily penetrate matter, reacting with it only weakly.

Some LW interferometry was also done using ordinary EM waves as carriers for the LW wave functions. Each such transverse wave carrier is in fact two scalar potential functions (Whittaker 1904, the initiation of superpotential theory). In each scalar potential for which functions are extracted and used to make the normal transverse carrier wave, there exist LW biwave pairs comprising said potential. So by assembling the desired LW biwave subsets, the two scalar potentials and their resulting interference-produced carrier wave are internally structured as desired. This is the use of the so-called *internal information content of the field*. We speak of such a deliberately structured potential, field, or wave as having been *conditioned*, *dimensioned*, or *activated*. If these terms are deemed inappropriate, just use the more generic term "internally structured." Then one has to explain what the "internal" is, and how this "internal" can be "structured."

In the distant interferometry zone, those *dimensioned* potentials, fields, or carrier waves would interfere and produce the desired alterations in the local spacetime (including specific spacetime curvature engines). Remember, the potentials are just bundles of special waves. We are discussing a special form of nonlinear multiwave interferometry, where the individual waves and waveforms comprising the total wave package assembly constituting a carrier have been carefully chosen in advance.

In the local spacetime in the distant interference zone, such multiwave longitudinal EM wavepair interferometry creates ordinary EM waves and energy that arise directly from each and every point in that individual interference zone. We stress that ordinary transverse wave EM energy propagation through the intervening space between the interferometer transmitters and the distant target *does not occur.*

In January 1960, in a speech to the Presidium, those are the weapons then in final engineering development for production that Khrushchev spoke of as "fantastic new weapons".

Khrushchev Killed the Thresher to Prevent His Own Dismissal

The first deployed large force-structure interferometer weapons became operational circa 1 April 1963. Khrushchev was still smarting from his Cuban missile crisis fiasco and his humiliation by Kennedy. Having overplayed his hand and gotten caught,[41] Khrushchev was desperate to stay in power and not be thrown out by the Communist Party leaders for such a massive loss of face.

On April 10 of 1963 Khrushchev used his new interferometers to reach through the earth and ocean and "kindle" EM jamming in the electrical controls of the **U.S.S.** Thresher nuclear submarine underwater off the East Coast of the U.S. **The** reader should recall that, wherever the interference zone is established—including in the earth or underneath the ocean, in the atmosphere, or in space—the energy arises directly out of the local spacetime. *There is no Faraday shielding of such effects, which do not depend upon ordinary transverse wave EM field energy propagation through space*. The energy appears everywhere within the targeted object, simultaneously.

It is extremely important that the reader recognize the dramatic difference in the way energy propagates in the new mode as compared to the old "propagation through space" mode. In the old mode, energy transport arises in one spatial location and is considered to proceed serially through the intervening spatial points to the intercepting and interacting particle's location. The Poynting model presently uses only this mode. In other words, the energy propagates from *without* the object *to* the object, and thence *inward inside* the object, if possible as the object interacts.

On the other hand, when the energy arises at each and every point in spacetime, it then propagates outward from each arising point. Thus in the nucleus of an atom, the "energy flow" starts at all interior spatial points and flows or diffuses outward in all directions. So the energy "meets" and interacts with the quarks in the nucleons, *before* it meets the "nucleon as a whole" and translates it. For this reason, with energetics it is easier to alter and "flip" quarks in nucleons than it is to translate nucleons, since one is using the new energy propagation mode. *This simple reversal of the outside-to-inside energy propagation to an "inside-to-outside" mode, is a revolution in particle physics and effects on materials.*

In fact, the energy dramatically enters the "interior" areas of nuclei, nucleons, etc. in a manner heretofore impossible or extremely difficult to achieve by high-energy physics, which can only do it by smashing into the object with sheer brute kinetic energy. Therefore the new "inside to outside" energy propagation mode can produce—at feeble spatial energy—extraordinary nuclear interactions not possible by brute force "outside-to-inside" energy propagation means. By controlling the structuring of the arising of the energy at each point in spacetime, the energy structure interacting with the quarks and other interior components can be tailored to order. This is the primary secret of transmuting an element at a distance by a specialized energetics weapon. The structuring of the emerging internal energy can be deliberately tailored to change quarks in—say—some of the nucleons of U235 and plutonium nuclei. In this fashion nuclear warheads, nuclear powerplants, and nuclear propulsion systems of atomic submarines can be altered at a distance, beneath the earth's surface, beneath the ocean's surface, in space above the earth, etc.

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[41] Oddly, had he simply waited a few more months or a year before injecting the missiles and nuclear warheads into Cuba, Khrushchev's strategic scalar interferometers would have become operational. With those in operation, a "Cuban missile crisis" might well have had a different outcome.

The EM "hash" emerging from the Russian interferometry simply jammed the electrical controls and systems of the Thresher *from inside its very electrical circuits.* Out of control and helpless, the Thresher sank to crush depth and imploded (Figure 6). The EM "splatter" from that interferometry, arising from the local spacetime throughout a surrounding region, engulfed the Skylark, the surface companion of the Thresher. The resulting spurious EM jamming severely interfered with multiple electronic systems on the Skylark. Several electronic systems just ceased working altogether. Their electrical forces were time-energy excited and time-reversed so that electron currents in them became impossible (blocked).

It required over an hour for the Skylark to transmit an emergency message back to the Navy that the sub was in difficulty, through all that interferometry jamming effects. The Russians undoubtedly "tracked" the sub till it imploded, then cut off the interferometry. As the "time-density charging" in the area slowly diminished, all failed electronic systems in the Skylark returned to full functioning. This was because the excess time-energy excitation just decayed away, so that electrical currents could again flow.

Khrushchev Demonstrated the Powerful Blast Capability of Strategic Interferometry

The next day, 100 miles north of Puerto Rico, the same KGB interferometer weapon was powerfully pulsed to produce a giant EM burst deep under the ocean's surface (Figure 42). A cone of water rose up from the surface to about a half-mile in height, observed by the startled crew of a passing U.S. jetliner and reported to the FBI and Coast Guard when the aircraft landed in Florida. As it rose, the cone of water spread into a cauliflower shape typical of a deep underwater nuclear burst that does not vent the gas bubble. Then that giant cauliflower of water fell back out of the sky and into the ocean. The second successful demonstration of Khrushchev's scalar interferometer weapon had been made for the benefit of the Presidium and the leaders of the Communist Party.

With those two dramatic tests, Khrushchev had killed the latest and greatest U.S atomic submarine and demonstrated the awesome power of energetics weapons. He had shown the leaders of the Communist Party that the U.S. had no inkling of his new superweapons. He had struck the U.S. a formidable blow in a direct act of war—but a new kind of *clandestine* energetics war—and gotten clean away with it. Now it was Kennedy, rather than Khrushchev, who had been duped. So had the entire U.S. Intelligence Community and the U.S. Scientific Community. Sadly, mostly they apparently remain duped or partially duped to this day.

Khrushchev managed to stay in power nearly two years longer by these two demonstrations. So the KGB/Soviets embarked on a decades-long program of buildup and development of the new weaponry, clandestinely, in order to take the U.S. by surprise attack and destroy it utterly.

In 1972 Brezhnev named 1985 as the target year when Russia would be able to do as it pleased, and would essentially control the land, the oceans, and space {126}. This was stated at a secret meeting of the European Communist parties in Europe. A British intelligence agent was in the meeting, and furnished the U.S. that information. Later it was openly released and published.

The Russians met that 1985 deadline, and the resulting increase in killing U.S. missiles and aircraft in 1985-1986 was most indicative. Other indicators such as massive weather engineering were already ongoing.

Weather Engineering Over North America

The first KGB weather engineering tests over the U.S., using their relatively new interferometers, produced signatures of anomalous perfectly round holes appearing in clouds. These experiments started in 1967 or thereabouts. The Russians gave us that very severe "deep freeze" winter of 1967, as an initial weather-engineering test of their energetics interferometry weapons.

The KGB communists do have a sense of historical dates, and they often do things on certain dates in symbolic fashion. Full-time Soviet weather engineering over North America started in earnest on July 4th, 1976—our Independence Day and our bicentennial. This was the KGB's "gift" to the United States on such a historic occasion. Full-bore weather engineering over the Americas has continued to this day, and even increased. It was passed into the hands of the Yakuza and the Aum Shinrikyo upon their leasing of those interferometers on site in Russia at the end of 1989. In 1985 I produced a rather crude videotape[42] (40 minutes) with pictures of the giant radial cloud signatures etc. associated with such weather engineering operations since 1976.

The *basic* weather engineering method is simple. Use an LW interferometer (LWI) to reach through the earth and *cool* the air in a region and produce a high-pressure area, due to the densification of the air. Use another interferometer to *heat an*other area and form a low-pressure area, due to the expansion of the air. Then carefully steer those *highs* and *lows* by gradually and slowing rotating the distant antennae and slowly adjusting the interferometry range simultaneously, according to a calculated schedule.

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[42] T. E. Bearden, "Soviet Weather Engineering Over North America," 1985.

By that means, the LWIs easily catch, entrain, and steer the jetstreams largely responsible for our weather. Put sharp loops and twists in that steering, and the huge angular momentum of the jetstreams developed in those sharp turns and circles will spawn tornadoes, violent weather, etc.

The first complete weather engineering system over North America in 1976 also used the Woodpecker's normal EM carrier signals with dimensioning and internal assemblage of the composite longitudinal EM wavepairs. A giant "interference grid" was established over much of North America. A great deal of local adjusting of the interferometry in the grid was necessary. These local grid readjustments caused "sudden popouts" of EM energy, creating many atmospheric booms, rumbles, and explosions.

To really stir up big weather trouble, the Russians—and now the Yakuza and Aum Shinrikyo—also heat or cool areas of the ocean where El Nino and similar "water engines" form. A dimensioned LW interferometer is required for this operation. By slowly and protractedly heating or cooling the water in one of the "warm water engines" fueling the weather, one causes a very significant, long-term, later effect on perhaps an entire continent.

One can create great droughts in some areas, great floods in others, etc. The KGB has been doing this extensively, since 1976. The great floods in Red China a few years ago are a direct example of KGB/Yakuza weather engineering, as is much of the extreme heat of 1998. In fact, thanks to the weather operations of the Yakuza under their KGB mentors, 1998 was the overall hottest year on record till then, since records were kept. At least for the summer of 2002, the record may have been broken again, with a significant season of giant forest fires burning away.

One purpose of the excess heating of the atmosphere, of course, is to do damage. An added "benefit" to the KGB is to furnish support to the environmentalists who are concerned about global warming. Understand, there is indeed such a thing as global warming. But by augmenting the atmospheric (and ice sheet) heating just a bit in a single year, the statistical analyses are skewed. The skewed analyses will show that the global warming problem is far more imminent than it really is, if the LWI engineering of it were suspended. Nobody on either side of the global warming debate seems aware of the LWI intervention that is ruining the results of their models and calculations.

In turn, the heightened global warming indications, detected as a result of the LWI interruptions, impel strong activist support for such things as the Kyoto treaty, *which is specifically designed to the strategic detriment of the U.S.* if and when the U.S. Senate ever approves it. The Kyoto treaty does not even apply to some 160 countries including Russia, China, etc. This focuses a certain proportion of our government time and effort in grappling with an inflated global warming problem, immediately. It directly fits the KGB strategy of "spreading" our government energy and attention all over the map, anywhere but upon the coming strategic energetics strike and upon energetics weaponry.

The die-hard section of the KGB strategists are chess players. *They will come at you anyway, anyhow, and anywhen that they can.* Everything that can be impressed to serve or support the overall objective, will be impressed and used. **That** is the overriding principle when analyzing Russian KGB strategy.

Khrushchev meant every word of it when he said to Nixon in their famous Kitchen Debate: *"We will bury you!"* Interestingly, to this day Americans and **their** government officials have continued to be deceived as to exactly what Khrushchev meant. He meant it literally.

Earthquakes to Order

According to U.S. Defense Secretary Cohen, electromagnetic induction of earthquakes is now recognized by the U.S. Department of Defense, considering **his** little-noticed statement in Georgia in 1997, which we previously quoted. An interesting exchange of induced earthquakes (Figure 54) had occurred in latter 1988 and early 1989. Here two sides seemed to be "counting rifles."

Opening bet (induced quakes)
- Quebec 25 Nov 88
- Pasadena 3 Dec 88

Raise you
- Armenia 7 Dec 88

Call - what do you have?
- Malibu 8 Jan 89

Four aces
- Soviet Central Asia 23 Jan 89

***Clear** table (stress relief)*
- Bakersfield CA et al. various

Figure 54 Counting rifles with earthquakes: Put up or shut up.

As Secretary Cohen made his April 1997 statement obliquely recognizing the scalar interferometer weapons, the little friendly nation had just completed countering and averting a massive strategic energetics strike upon the United States and Western Europe, scheduled for May 1, 1997 —just three days later. A little more than two months earlier, a previously scheduled attack had also been countered and averted by the same friendly little nation.

Once one can reach into or through the earth and ocean and create energy in a desired interference zone, induction of earthquakes is simple. Use the interferometers to deposit energy in a fault zone over a period of time. Keep it up, and the piezoelectric plates build up enough mechanical stress to forcibly "slip" and produce an earthquake.

Put the energy in very slowly, and one gets a long "overpotential" effect where the rocks do not slip for a long time, while the energy builds to higher levels due to the static friction of the rocks. Then there occurs a rather rapid catastrophic slip. In short, one produces a large destructive earthquake. The KGB weaponry can produce earthquakes of the highest magnitude if they work at it.

If one wishes to induce a quake in an area where there are no known faults, then one simply focuses the interference zone there inside the solid rocks and proceeds to deposit the energy, preferably rather quickly (in hours instead of days). The entire rock will be expanded and it will fracture, producing an anomalous so-called "flat plate" earthquake.

Around the early 1900s, the "normal" rate of large earthquakes was two or three per year. That gradually increased after WW II. During one week in year 2000, there were some 20 major earthquakes around the globe. Obviously, someone is doing it, since this is far beyond what could be expected naturally. Presently that "someone" is mostly the Yakuza and Aum Shinrikyo, on site in Russia and leasing the LWIs. With the scheduled CSR attacks forcibly aborted, the KGB has the problem of restraining an increasingly impatient Yakuza and Aum Shinrikyo group, while keeping them paying the lucrative lease money. Consequently, inducing some big earthquakes is one way to "keep the troops occupied and busy." Shooting down the occasional aircraft or missile is another way.

I worked for 8 years or more with an inventor (Floyd Sweet, now deceased) who had an energy device {127,128} sensitive to *artificially* induced quakes of that fashion, even such quakes thousands of miles away. The device would sit right on top of a *normal* quake and not react. We could tell within some 8-10 thousand miles—and often even for greater distances— which quakes were artificial and which were natural.

So during that period I was able to clearly ascertain what was going on, and who was doing what to whom, and which quakes were normal and which were manmade. Several artificial U.S. quakes, the Armenia quake, and a subsequent big quake in Russia were particularly interesting in the mid and latter 1980s. The huge 1976 China quake was directly induced by the KGB.

Figure 55 Brewer briefs President Reagan on Soviet scalar EM weapons October 1984, then briefs National Security Council

In 1984, on my behalf Roy Brewer {129} had briefed President Reagan on these scalar interferometry weapons (Figure 55), then briefed the National Security Council. Let us hope that these high level briefings may have borne at least some fruit.

Readying the Weapons for the 1985 Readiness Demonstration Tests

In latter April 1985 I received an urgent call from my close colleague Frank Golden. In his avionics repair work, he suddenly found that his best calibration instruments were very "noisy." He replaced one expensive instrument, and the second was "noisy," also. A third proved equally noisy. This was unparalleled. It was not the instruments, but instead it was all the electronics to be repaired, that were emitting electromagnetic noise!

So Frank borrowed one expensive instrument and brought it home for the weekend. He altered it by a proprietary method so that he could detect energetics radiation. Voila! The entire earth was alive with Soviet energetics signals. The weak interferometry of so many signals impinging into the weakly interacting electronic systems to be repaired, had generated the electronic noise his instruments had detected.

In response to Frank's call, I immediately proceeded to his location. I personally observed on the oscilloscope, as detected by Golden, some 27 pairs of Russian energetics signals, each of the two in a pair being 12 kilohertz apart. (We have previously explained why two frequencies are used, and one "pretends" one transmitted the difference frequency). Each of these frequency pairs represented the entire earth held in entrained resonance. Each pair was an "energy tap" in the earth, extracting enormous energy from the heat of the molten core of the earth itself and outputting it as 12 kilohertz power for transmission to giant interferometry weapon sites.

Each "tap" was extracting energy sufficient to power perhaps 4 to 6 of the giant intercontinental energetics interferometer weapons. We were observing something like 100 to 150 massive weapons on line and radiating. A full-up strategic dress rehearsal—or preparations for a full-up strategic attack on the U.S.—was underway.

Gorbachev was still a "new man on the job" at that time. Further, 1985 was the 40th anniversary of the end of WWII, and a very important occasion for the Communists and in fact for all Russians. The May Day celebrations that year went on for several days, not just on May 1.

What we were seeing were preparations for a massive May Day weaponry demonstration in and around May 1, 1985. We were observing the preparation and demonstrated readiness of all that great armada of Soviet energetics weapons, to meet Brezhnev's 1985 schedule laid down back in 1972 {126}.

Longitudinal EM wave communications to deep underwater Soviet subs, the huge interferometer armada, and everything else—all were being readied and demonstrated. I can assure the reader that observing full rehearsal of preparations for the next World War was a most sobering experience.

After May 1, most of the armada of interferometers was stood down again because it had been demonstrated that the "ready schedule" had been met. All but one of the giant energy taps in the Earth were also stood down again. That one remained active.

The May Day report to the heads of the Communist Party that year must have really been something!

As usual, apparently our own scientific and intelligence communities did not detect the main activities, and would not have believed it if one told them. They certainly did not believe it when I published it in 1986 in *Fer-de-Lance,* but labeled it sheer fantasy or at best total conjecture.

It was neither fantasy nor conjecture. It was direct experimental measurement. It was in fact what used to be called *scientific method.* The problem with our intelligence agencies was that they operated behind *policies.* Once the *policy* is decided, then regardless of what the intelligence analysis indicates, anything against the official *policy* is just ignored. This neat little *policy* method of doing business has resulted in making our intelligence agencies some of the most political-minded and manipulative groups on Earth.

Meeting the 1985 Schedule for Readiness

In 1985, KGB/Russian preparations began in earnest for the energetics weapons readiness projected for that year by Brezhnev in 1972. Being full-bore tests, these actually went after destruction of vehicles and killing people. These were actual acts of war. The so-called "Cold War" was not nearly so cold as pictured in the news media!

Early that year, an LWI was used to cool the combustion in the engines of a jet liner off the coast of San Francisco, bound for Los Angeles (Figure 56). This flamed-out the engines. The stricken craft fell 30,000 feet before the time-density "cooling" charge drained away, sufficient for the pilot to restart his engines and limp into San Francisco. Gravitational and inertial anomalies—*a clear signature of the use of this EM/GR weapon*—were exhibited upon the personnel in the cockpit. The official investigators ignored those signatures; after all, such is not in their standard checksheets! And everybody knows the standard checklists are already perfect!

SIX MILE DROP IN TWO MINUTES

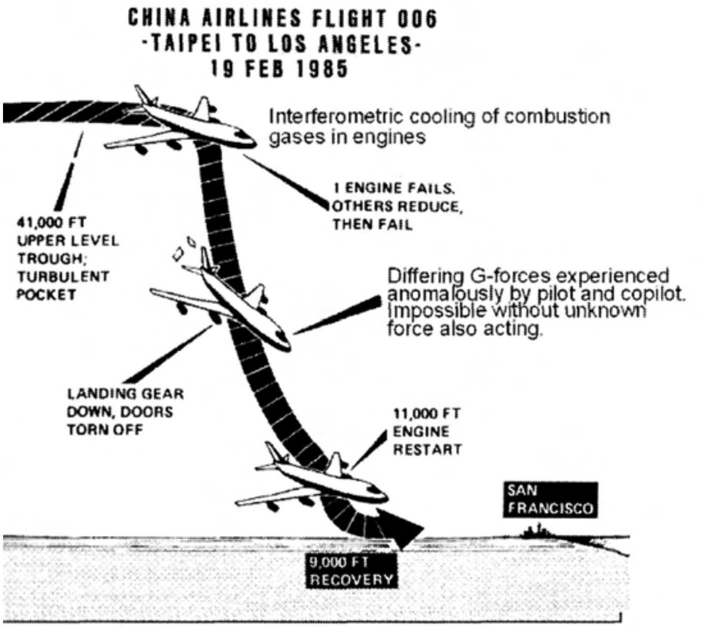
CHINA AIRLINES FLIGHT 006
-TAIPEI TO LOS ANGELES-
19 FEB 1985
Interferometric cooling of combustion gases in engines
1 ENGINE FAILS. OTHERS REDUCE, THEN FAIL
41,000 FT UPPER LEVEL TROUGH; TURBULENT POCKET
Differing G-forces experienced anomalously by pilot and copilot. Impossible without unknown force also acting.
LANDING GEAR DOWN, DOORS TORN OFF
11,000 FT ENGINE RESTART
SAN FRANCISCO
9,000 FT RECOVERY

Figure 56 Extinguishing combustion in the engines of a jetliner 19 Feb. 1985.

KGB Crews Regularly Practiced Against U.S. Rocket Launches from Cape Canaveral

In a late Nov. 1985 night shuttle launch at Cape Canaveral, the Russian interferometer crews continued their practice of using the U.S. shuttle launches as convenient "simulated" ICBM launches, for energetics interferometer crew practice (Figures 15 and 16). EM missiles (balls of EM energy formed in the area by distant LW interferometry through the earth) were used as the "destructive agent", but were offset from the actual launch in order not to destroy the shuttle. This was *normal crew drill,* not combat operations. The practice range for energetics weapons is—as might be expected—the actual targeted area and targeted nation itself.

As shown in *Fer-de-Lance,* I published an actual picture (Figure 15) of such a KGB EM missile strike, offset from that shuttle launch in late Nov. 1985 and snapped by Bob Gladwin. I also published an actual picture of a second such EM ball of glowing energy (Figure 16), over the launch site for the same launch, and used as a registration point (the LWs deviate slightly in passage through the earth, since the potentials in the earth are not constant). George Suchary took the second photo.

A standard artillery "shift-from-known registration point" method of firing was being used. In other words, the crews establish LW track on that EM registration ball, right through the earth. That represents *a point having a known set of coordinates*—a registration point—established in the firing computer. Then when the targeted strategic missile (in this case the shuttle's main booster) ignites, the interferometer also tracks the huge ionization target of the exhaust with the same weapon system.

That gives a known *relative* location of the missile rear end, with respect to one's registration settings for the registration point ball of light. Then add some meters to move up onto the missile body proper, and voila! The center of the target missile that will be fired is now in the bulls-eye, so to speak. That is a standard "shift from a known registration point" method of shooting, well known to every artillery group on the planet. The "marker beacon" is what is known as a "high burst registration," except it is not a burst but a steady ball of energy maintained over the area as the registration point.

The distant rocket or missile can now be destroyed in a variety of ways:

(1) Just create a sudden EM surge arising right in that spacetime (that is, just pulse the interferometer). That burns out some of the inner electronics of the missile, causing partial or complete missile failure.

(2) Sharply pulse the interferometer to introduce EM energy surges and sparks in the fuel or solid propulsion, igniting it massively and blowing up the rocket. Works well for aircraft fuel tanks as well.

(3) Form another EM missile and hit the missile broadside with that, burning

through it and destroying it immediately.

(4) Hit it with an explosive EM missile internally, instantly exploding the missile into pieces. Or

(5) Hit it with several of the above simultaneously.

Suchary and Gladwin had captured the direct evidence of KGB dress rehearsal for the strike and kill of the Arrow DC-8 in Gander, Newfoundland about two weeks later.

Kill of the Arrow DC: Practice Turned into Performance

Two weeks later, the same KGB weapon tested against the Cape Canaveral shuttle launch was used to destroy the Arrow DC-8 at Gander, Newfoundland, killing some 256 occupants, 248 of them being U.S. soldiers returning from peace-keeping operations overseas. The aircraft *was not* iced up; later that was clearly established.

See Figure 17. As the ill-fated Arrow aircraft began its thrust down the runway for takeoff, it was already under LW interferometer track (the exhausts of the **engines** were being precisely tracked) by distant KGB operators. The KGB operators simply began to cool the combustion gases in the engine combustion chambers as had been done to a U.S. jetliner earlier that same year (Figure 56) off the coast of San Francisco (there they had completely flamed out the en**gines).** Now they did not want to flame out the engines during take-off, but just wanted to reduce the thrust of those engines.

So the available thrust of the engines began decreasing as the aircraft picked up speed on the runway toward takeoff, even though the turbines were rotating at full speed. For powered flight, it is the *thrust-per-drag ratio* that is important. One can reduce that ratio by ice-loading and therefore increasing the overall aircraft drag, as all Transportation Safety Board checksheets assume if the engines are at full rotation and if operation and icing conditions are present. Or one can reduce the ratio by reducing the engine thrust itself, as was done for the Arrow, even though the plane is de-iced. All the Transportation Safety Board checksheets *assume* that it has to be drag increase, and thus due to icing.

The National Transportation Safety Board (NTSB) investigators know nothing about longitudinal EM wave interferometry and its capabilities—and its development by several nations of the world. Neither do their checksheets. Sad**lly,** the NTSB is not even aware that the electrodynamics and electrical engineering it assumes is so perfect is in fact a decrepit old model based on century-old errors. They are unaware that much better electrodynamics models have long been developed for particle physics, because the crusty old classical model is totally inadequate. Their checksheets also are "unaware" of anything really modern such as electrodynamics models of the higher group symmetry **kind.**

The thrust reduction by combustion gas cooling *does not appear on the official checksheets and is never considered.* It is not considered to this day. It will probably still not be considered this century.

Observers on the ground heard those engines "laboring," which can be a direct symptom of combustion gas cooling and engine thrust reduction. Rough running and missing can be another, if the cooling increases. Engine flameout occurs when the combustion no longer can be sustained because of the dramatically lowered temperature of the gases.

The Arrow Pilot Sensed the Lack of Power, But the Aircraft Was Immediately Hit

See Figure 17. At rotation and liftoff, the pilot of the Arrow DC-8 immediately sensed his lack of lift, and started a slow turn to the right, apparently intending to come around and land again as an emergency measure. Meanwhile, crossed beams had formed in the sky above and off to the right side. From those crossed beams of light, there shot down a bright "streak" of light that struck the fuselage of the aircraft in the right side, ahead of the engines. That was the EM missile strike—just as had been offset from the shuttle launch two weeks earlier in Florida, and photographed by Bob Gladwin.

That piece of Arrow DC-8 fuselage hit by the EM missile, with the burned hole in it, was recovered and tested. Tests showed no explosive residues on the edges of the hole, so it *was not* made by a bomb or other explosive device. Instead, it was made by an EM missile of the type that over a decade later hit the TWA-800 several times off Long Island and killed it.

In the Arrow aircraft's kill, the fiery EM missile sharply ignited the plastics in the forward cabin, which explosively outgassed. One product of such outgassing is hydrogen cyanide. A whiff or two, and all the passengers in that section were already dying of cyanide poisoning. *In the autopsies of the recovered bodies, about half the passengers were already dead of cyanide poisoning before the plane impacted the ground and exploded*. They died while that aircraft was still flying and sinking tail-first toward the ground.

The results of those autopsies were deliberately withheld from the Canadian investigative board.

The impact of the EM missile on the Arrow DC-8 was clearly recorded by sharp, vertical EM surges (spikes) in traces on both data recorders on board the aircraft. In *Gravitobiology,* on p. 82 I printed the recorded sensor responses **for** that signature also.

Elements of the U.S. Government Deliberately Suppressed Vital Evidence

Several eyewitnesses, including Judy Parsons, physically observed the formation of the crossed beams in the sky. Parsons and perhaps others actually saw the streak-down and strike of the EM missile when it hit the doomed Arrow DC-8. Parsons tried to testify, but her testimony was never allowed to be heard by the Canadian Transportation Safety Board. A major U.S. News agency interviewed her, but then squelched the story for some "unknown reason." Other witnesses (who are still reluctant to come forward) did observe the strike of the EM missile also.

Why would the U.S. government deliberately suppress information relating to the cause of the deaths of 248 of our soldiers returning from peacekeeping missions overseas? Why were they so determined that this direct act of war be declared an "accident" in the face of overwhelming evidence that it was not an accident at all?

Iran Contra was not yet divulged at the time. Recall, at very high level our own fellows had directly violated the law, and were engaged in the illegal Iran Contra fiasco up to their eyeballs. Also, some officials in Washington in certain high U. S. Government circles were in near panic, in their personal (erroneous) firm belief that a MidEast-sponsored terrorist bomb had destroyed the Arrow. In that case, so they reasoned, with the murder of 248 of our soldiers, the American public would be so aroused and angry that they would force military action against the MidEast nation or group, and that would then reveal Iran Contra. *Too many highly placed people's hands were dirty!*

So extreme spin control was the major requirement. Damn how many American soilders had just been killed in an overt act of war against the U.S. Damn the implications of the use of eerie new weapons we did not possess. A hue and cry from the U.S. public would almost certainly reveal Iran Contra and smoke out the duly secrets. That must not happen at any cost. Some high officials—particularly the ones who engage in such illegal acts, in assassinations, murders, etc.—are far more interested in covering up their nefarious deeds than they are interested in any kind of justice or morality. Consequently, the fix was in.

So *U.S. officials placed enormous pressure on Canada to produce a finding of icing.* Lots of other skullduggery occurred, which probably constituted criminal activity by some U.S. officials. A high-ranking U.S. military officer arrived on site quickly, apparently under orders to erase that scene as fast as possible. He almost immediately wanted the Canadians to bulldoze over the site, even before recovery operations were complete and while the investigation was just getting underway. The site was bulldozed over in unseemly haste not long thereafter. That would appear to possibly constitute deliberate tampering with the evidence at an official site of investigation, on the part of whoever ordered the General to bulldoze the site precipitously.

In addition, witnesses such as Parsons were never allowed to testify. The Canadian Board waited until the half of its members who strongly opposed any ad hoc finding were absent, and hastily approved a finding of icing as the cause of the "accident." Later the disgruntled Board members who were absent when the "voting" occurred, issued their own minority report. Unfortunately they knew nothing of scalar interferometry and energetics weapons, and so they strongly believed it had to be sabotage and explosives.

Anyway, the blackguards hiding Iran Contra buried the incident, and the savage kill of 248 of our soldiers and 8 civilians went unpunished. Anyone such as the present author who pointed out what had really happened and why, was just branded a lunatic. After all, the blackguards who do not flinch at murder and unapproved assassination do not blink an eye at slander and libel.

The sad part is those fine young soldiers and the 8 civilians who were killed, and the grief and lasting changes made to their families. It is the children who had to grow up without their fathers, the mothers whose husbands were suddenly dead, etc. They deserved much better from their government than they got.

Other Direct Energetics Signatures on the Arrow DC-8

Meanwhile, in the lifting DC-8 the strike of the EM missile had also *time-density charged* the forward cabin materials. Those materials slowly decayed from their excited states via longitudinal EM wave emission. When a human body is subjected to fairly significant LW waves (accompanied with their time-density waves), it gets its internal immune system and cellular regeneration system "jammed," since these systems use LWs and accompanying time-density waves. The cells and tissues are also "time-energy charged" as well, and so spurious LWs continued to be slowly emitted in their tissues and cells locally, leading to gradual, general debilitation. After a time delay for the effects of this time-charge decay to be exhibited, such exposed persons will get sick with odd symptoms of various diseases such as influenza.

The ground handlers on the scene and exposed to the struck materials of the aircraft, were also exposed to longitudinal EM wave radiation from those materials which had been instantly "time-charged" at the powerful strike. Hence they were exposed to fairly significant LW waves, and should therefore have shown later symptomology.

Some 60 or so of the ground handlers actually retrieving the crash materials later sickened with all sorts of mysterious maladies: dizziness, stomach cramps, flu-like symptoms, weakness, nausea, fatigue, etc.—precisely what would be expected if some the materials they were handling were emitting longitudinal EM radiation, exposing them to significant LW radiation. That is a clear signature again of a strike by an EM missile, and the exposure of those retrievers to LW emissions. *In no normal way could 60 of those ground crewmen handling the wreckage debris all come down simultaneously with the exact symptoms of*

LW radiation sickness, unless that was what it actually was.

Many of those sickened persons remained debilitated for years. Probably a few are still alive and debilitated.

There are other signatures on the Arrow DC-8 kill. I did a small bit of work on the problem in the interests of Arrow airlines, but of course the conventional investigators they also hired could only conceive of an ordinary explosive. Nevertheless, I did tell them as best I could what happened to their aircraft, their crewmembers, and our own valiant soldiers.

Our troops on board the tragic Arrow DC-8 *did not* die from a simple over-iced plane that crashed as a result of carelessness in deicing operations. *They died as the result of an act of war against the U.S., carried out by the KGB as a test in an entire series to demonstrate the 1985 readiness that Brezhnev had specified in 1972.* That war is still partially ongoing and undeclared to this very day, with other players such as the Yakuza and Aum Shinrikyo also now in the game—and possibly even the Chinese, who certainly have had the weapons for some time, and have had QP weapons and negative energy EMP weapons since earlier this year (2002).

With the kill of the Arrow DC-8, the KGB made its deadline that had been set down 13 years earlier by Brezhnev. To meet the 1985 schedule, something significant had to be killed successfully and clandestinely, no later than Dec. 31, 1985. The KGB made the schedule on December 12, 1985, by killing the Arrow DC-8 after a warm-up and full dress rehearsal against a U.S. night shuttle launch at Cape Canaveral about two weeks earlier. And they also demonstrated just how ignorant of such energetics weapons and their usage the U.S. government, scientific community, and investigative boards really were.

We were fortunate they did not just go ahead and kill that same shuttle in late November 1985. Instead, they waited and killed the Challenger a few months later.

Other Acts of War Completed the Milestone

Apparently the final demonstration of milestone completion called for the destruction of an aircraft, kill of an ICBM, kill of a space shuttle, induction of earthquakes, and demonstration of the new quantum potential weapon still in the advanced laboratory stage. The KGB completed much of the milestone demonstration in 1985. The remainder they completed in 1986.

In January 1986 they killed the space shuttle Challenger, and the very next night the KGB even gave a big party in Moscow, to celebrate the "perfect success of their active measures" against the shuttle. General Daniel O'Connor, former head of U.S. Army intelligence, personally issued an alert to many high-ranking U.S. government officials, pointing out the almost certain involvement of the KGB and the fact that the loss of the shuttle was almost certainly due to a hostile act by the Soviets.

In April 1986 (May Day report time was coming!) the KGB killed a Titan ICBM fired from Vandenberg Air Force Base. They also induced several large earthquakes for practice, and then began the induction of the long-dreaded "giant California quake" in the San Andreas Fault zone.

This latter induction of what would have been a massive quake in both San Francisco and Los Angeles, and all along the San Andreas Fault, was countered (destroyed) by a civilian group known to this author, with a backlash that resulted in the Chernobyl incident.

In April 1986 (for the same May Day report) the KGB also demonstrated the effectiveness of their newly emerging quantum potential weapon against the convenient U.S. air attack on Libya (Figure 25).

Kill of the Titan Missile Over Vandenberg Air Force Base

In 1986, the KGB began gingerly using those energetics interferometry weapons to kill other U.S. aircraft and several U.S. missiles, including killing a Titan 34-D fired from Vandenberg AFB on 18 April 1986. The Titan was killed 9 seconds after launch, partially crippling the U.S. space surveillance program. That kill was part of the demonstration of readiness milestone completion.

There was a completely decisive signature on the kill of the Titan. Simply check *Aviation Week & Space Technology,* 124 (17), Apr. 28, 1986, p. 18, where a picture (the one taken from longer range) of the Titan explosion is printed. Look about an inch above that explosion, which is already well developed. There above the Titan explosion sits the KGB ball of light registration point, just as it was sitting over the night shuttle launch in Cape Canaveral in latter Nov. 1985 when videotaped by a private photographer.

I persuaded NBC engineer Ron Cole and his colleagues to analyze a copy of that video tape frame by frame. In 17 frames, that little ball of energy above the explosion moved off on its own course, independent of the Titan explosion. Since the launch area for such missile launches is controlled and there were no aircraft over the explosion, then one again has a very clear signature. The KGB killed the Titan, with 100% certainty.

That of course was a test of the interferometry weapons in the role of *Launch Phase ABM system*. Tested against the Arrow, the KGB operators were emulating test of the system in a *Launch Phase Antibomber role*. These were vital *strategic* weapon tests. I published details of the use of the weapons in many other roles.

Dead-Man Fuzing and Outside Assistance Deterred a Full Strategic Attack in 1986

We have previously documented and published why the U.S. was not fully attacked and destroyed by the Soviets in 1986. It was because of our nuclear facilities, warheads, etc. which would have exploded, creating great fallout hazards worldwide, and because of nuclear dead-man fuzing weapons clandestinely placed in Russia by one or more other nations.

A friendly small nation possessing energetics weapons also intervened directly in l986, and blew up several Russian missile ammunition storage sites, some five or so in six months. In one such explosion, about one third of all the missiles in the Russian Northern Fleet were destroyed. As we stated, the so-called "Cold War" was not nearly so cold as has been represented.

In short, the friendly little nation served notice on the Soviets that, if they moved against the West, the Soviet Union itself would suffer terribly. They put it in language clearly understood by the KGB. So any full-up strategic attack for that period was stalemated by that combination of factors.

A major concern for the Soviets was their inability to counter the dead-man fuzing problem posed by nuclear weapons clandestinely hidden inside Russia and by the nuclear warheads and reactors inside the targeted nation(s). They already had the quantum potential (QP) answer *theoretically,* and had conducted a demonstration test of a laboratory QP device, but they had not yet completed the *QP* weapon systems and deployed them.

Nonetheless, a very powerful strike of peculiar nature—induction of a giant earhquake in the San Andreas Fault zone, including in both Los Angeles and San Francisco—was scheduled. This strike would have caused billions of do11ars worth of damage and would have killed perhaps 200,000 Americans. The initiation of the strike was actually begun in April 1986—as the reader can begin to see, there was to be one helluva May Day report in 1986! Incredibly, a private group here in the U.S. then made a unique and unprecedented contribution that saved the day for Los Angeles and San Francisco.

What Really Happened in the Chernobyl Disaster

Using the "inside" of the Woodpecker beams as superhighways for their longitudinal waves and interferometry, in April 1986 the KGB interferometers had started their build-up of substantial induced EM energy in the sides of the San Andreas Fault that runs through Los Angeles and up through San Francisco. Two beams were being used by the Soviets: One was coming down on the target from the North—coming over the North Pole regions and the ice caps—and one was coming around from the East and upon the target area. Completely (100%) certain signatures were present, including some ELF "chugger" waves symptomatic of the Soviet method of inducing very large quakes. The time-energy is being used, hence very low frequency ELF is employed to maximize the amount of time-energy available for transduction in the rocks on the side of the fault. The Soviets were building up a very large earthquake—indeed, to spawn a whole series of such quakes all along the San Andreas fault—with severe aftershocks following after the main quake had done terrible damage. In short, they were preparing to hit California with the "big one" that everybody had been anticipating and dreading for so long.

A private group contacted me. They stated they could take out one of the transmitters by producing a powerful (giant) phase conjugate replica signal pulse upon it that would backtrack right into the transmitter and catastrophically burn it out—a surface application of the "phase conjugate shooting" once considered for armed satellites that could shoot down rising hostile ICBMs at 10,000 miles distance. As I understood it, they had a new kind of essentially noise-free regenerative amplifier, used in a transmitter. This meant that *extreme amplification* could be achieved in a pulse response to a received Woodpecker signal, before the transmitter burned out.[43] Since the group had no knowledge of the exact KGB transmitter locations or the possible consequences of such an action, they asked my opinion as to the risks associated. This placed me in a real quandary.

At the time, the U.S. was literally under siege. We have mentioned some of the

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[43] A very subtle but important point is this: An energy flow of any amount—say, 10^{20} joules per second—has absolutely *zero power* if none of that energy flow is diverted or changed in form. So if one has a truly perfect noise-free amplifier, and a pure noise-free energy signal input, the signal energy input can be directly and freely amplified without limit, so long as those noise-free conditions can be upheld. In short, that rigorously constitutes *regauging,* and the widely used **and** well-known axiom of gauge freedom—the ability to change the local energy density of a system or spacetime freely and at will—applies. Relativistically, such re-gauging is merely rotating the frame of the system away from the laboratory frame. This group indeed had such an amplifier, which I physically saw, and apparently has it today. Our present texts have not yet realized the real implications of gauge freedom: It means that one can freely amplify energy without limit, once certain conditions (no divergence of the energy or change of its form) are met. This does not violate energy conservation; the "potential energy of a system" is not a fixed number at all, but depends on the frame of the observer vis a vis the frame of the system. We point out that there really are no true conservation laws in general relativity unless introduced by arbitrary measured The great Hilbert already knew this in 1917, two years after the advent of Einstein's general relativity. Hilbert stated: "*I assert... that for the general theory of relativity, i.e., in the case of general invariance of the Hamiltonian function, energy equations... corresponding to the* ***energy*** *equations in orthogonally invariant theories do not exist at all. I could even take this circumstance as the characteristic feature of the general theory of relativity.*" [D. Hilbert, *Gottingen Nachrichten,* Vol. 4, 1917, p. 21]. Loskutov and Logunov commented as follows: *"In formulating the equivalence principle, Einstein actually abandoned the idea of the gravitational field as a Faraday-Maxwell field, and this is reflected in the pseudotensorial characterization of the gravitational field that he introduced. Hilbert was the first to draw attention to the consequences of this. ... Unfortunately, ... Hilbert was evidently not understood by his contemporaries, since neither Einstein himself nor other physicists recognized the fact that in general relativity conservation laws for energy, momentum, and angular momentum are in principle impossible."* ["Nonuniqueness of the predictions of the general theory of relativity," *Sov. J. Part. Nucl,* 18(3), May-June 1987, p 179).

"target year" activities, such as kill of the Arrow DC-8, flameout of jet engines early in 1985, target practice against shuttle launches at Cape Canaveral in November 1985, etc. Actually kill of targets had continued in 1986. A huge earthquake followed by several large aftershocks had been used against Mexico City on 19 September 1985, causing great damage and demonstrating a little of what might be expected when they chose to hit Los Angeles and San Francisco much harder. The Mexico City quake had been preceded by an induced, giant hailstorm weeks earlier, and on the evening of 18 September 1985 by giant radial cloud signatures accompanying the generation of excess energy in the underlying rocks as the KGB prepared next day's giant Mexico City quake. The reader should recall that, working with Sweet during this period, I knew with certainty which earthquakes were natural and which were manmade.

U.S. missiles and aircraft had been hit, the Challenger had been destroyed, and the Titan 34-D had been destroyed at Vandenberg AFB on 18 April 1986, accompanied by a 100% indicator (the substantiated presence of the marker beacon for registration and shift firing). In addition, a little Richter 5.3 quake in the San Francisco Bay area had been induced by the Soviets on 31 March 1986, a quake which was correlated with preparatory activity on the Woodpecker transmitter signals the day before, showing Soviet induction of the energy to create the quake. Again, we had instrumental evidence that it was manmade.

That quake on 31 March had been a "warm-up" and practice for the big one now about to be induced in both Los Angeles and San Francisco, and along the San Andreas Fault. In fact, it appeared that the entire fault zone would be stimulated by deposit of excess energy all along its length. In that case, induction of a distrituted California quake of unprecedented extent and great magnitude was now in process, though just beginning. If that event or those events occurred, the loss of American lives and property would be staggering.

The High Side Risk Factor

The group's query to me presented a very difficult decision situation. Such huge Soviet interferometer beams, once built up, contain *enormous* longitudinal EM wave energy. If a Soviet transmitter were near large nuclear facilities, and were instantly blown and shorted, all that potential energy might flash directly into the ground.

In case of such a catastrophic transmitter failure, an enormously powerful longitudinal wave pulse would spread out in all directions in the surrounding earth. The first nuclear material the pulse encountered would be fissioned abruptly and very violently. If the transmitter were within a few kilometers of one or more of the large "monster" Soviet ICBM sites, the full-up explosion of several 30 or 40 megaton warheads might result—in the dirt and dirty. The resulting fallout and contamination would be massive, would spread round the world, and would eventually kill millions for years to come. Nuclear reactor stations were a similar risk; instant fission of all the fissionable material in one of them would constitute an unprecedented and giant nuclear explosion, in the dirt and dirty. That was the high side risk.

The Low Side Risk Factor

The low side risk would be that little or nothing at all would happen; perhaps a tremor induced in a nearby fault zone, etc. I knew that the Soviets—after an early Kyshtym transmitter failure—had produced such a flashover on a much smaller scale and that flashover had caused the nuclear explosion of nearby stored nuclear wastes. The resulting fallout contaminated some 1200 square kilometers, which is still contaminated to this day. I also knew that, after Kyshtym, the Soviets had installed safety devices on all their scalar interferometer transmitters in case of just such failures.

So if the safety devices held when the transmitter suddenly shorted out, they could hold the longitudinal EM wave beams and potentials long enough to drain the energy slowly and harmlessly into the earth over an extended period. That was the low side risk.

The *most likely* consequence, of course, would be somewhere in the middle, between the extreme upper risk and lower risk limits. In other words, we could expect some bad repercussions in the Soviet Union almost certainly, but hopefully it would mostly be confined to that spot.

Consequences of Not Taking Counterfire Action

If no action were taken, the risk to the U.S. was appalling. If the transmitters continued, then perhaps 200,000 Americans were going to die in Los Angeles and San Francisco and along the San Andreas Fault. Perhaps 300,000 more Americans would be injured, and many of them would also die. Enormous physical damage would also be done, and those basins would be disaster areas for some years to come. It would be interpreted by our inadequate scientific community as a great "natural" disaster caused by a giant earthquake, and the ghost of Khrushchev would have had one more laugh at us, with his words "We will bury you!" silently ringing in the ether.

My Recommendation to the Counterfire Group

To save those American lives, some reasonable element of risk had to be accepted. In other words, it became a classic "risk-to-benefit" military analysis, but one that was deadly serious. To me, as a military person the medium risk had to be accepted in such case.

I gave the group my reasoning. They then asked what I would personally do if my own finger were on the fire switch. I answered that I would take out the transmitter or transmitters and save those American lives, accept the medium risk, trust in God, and pray **for** the best. Military decisions often have to be made in just such uncertain conditions. If one's military could not make such tough decisions, then one's military forces would inevitably lose their wars.

The Group Fired and Took Out a Transmitter

The group thanked me, stated that they would fire, and hung up the phone. See Figure 57. They did fire on April 25, just as they promised, and they did destroy one of the KGB transmitters—apparently located some kilometers (perhaps 30?) from the Soviet nuclear reactors at Chernobyl.

At the moment the transmitter was hit and destroyed, engineer Bill Bise—out in the field with magnetic field detectors and measuring the Woodpecker beams—observed the abrupt failure of the Woodpecker transmitter beam coming around **the E**arth from the East. Thus, he actually detected the successful destruction of that distant interferometer transmitter. Unknowingly he had detected the results of a great counterstrike in a very dangerous strategic battle.

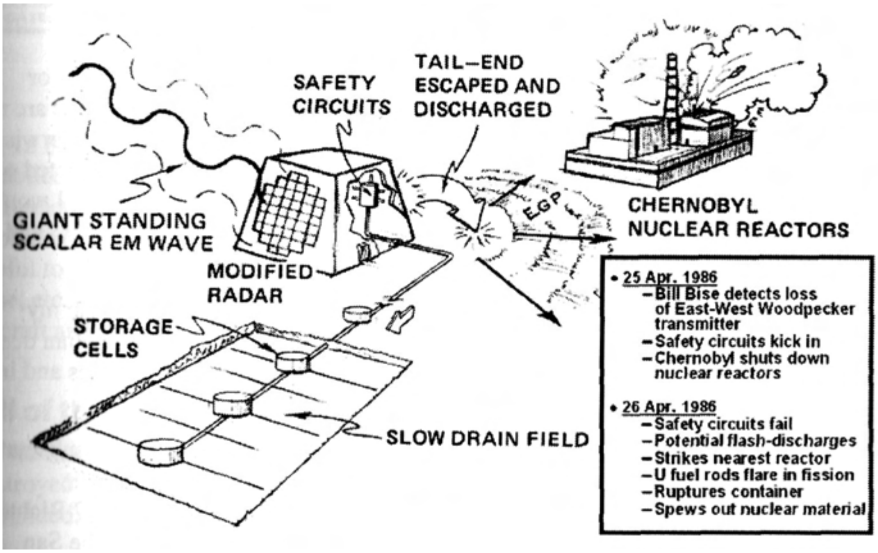
SAFETY CIRCUITS
TAIL-END ESCAPED AND DISCHARGED
GIANT STANDING SCALAR EM WAVE
MODIFIED RADAR
EGP
CHERNOBYL NUCLEAR REACTORS
STORAGE CELLS
SLOW DRAIN FIELD

- 25 Apr. 1986
  - Bill Bise detects loss of East-West Woodpecker transmitter
  - Safety circuits kick in
  - Chernobyl shuts down nuclear reactors
- 26 Apr. 1986
  - Safety circuits fail
  - Potential flash-discharges
  - Strikes nearest reactor
  - U fuel rods flare in fission
  - Ruptures container
  - Spews out nuclear material

Figure 57 Chernobyl disaster 25-26 April 1986.

Results at the Transmitter and at Chernobyl

We were very, very lucky. At the destroyed transmitter site, the safety circuits kicked in and caught the huge beam potential and held it for about 24 hours, gradually draining down the intense beam energy into the earth in a slow manner all the while.

A **frantic** Russian message to the Chernobyl reactors galvanized the operators to immediately shut down those reactors (put in the cadmium control rods).

However, the uranium in the fuel rods was of course still sitting there. Chernobyl then waited with bated breath to see if the safety circuits would hold.

Then on 26 April, the safety circuits at the transmitter site finally crumbled, and a far weaker LW flashover occurred than would have occurred earlier without the safety. The spreading LWs in the earth struck the nearest reactor core at Chernobyl, preceded seconds before by a tremor induced in the earth at Chernobyl as the LWs arrived. *Part* of the struck uranium in the core fissioned immediately, venting the containment structure and spewing out radioactive material. Nuclear fallout spread over much of Europe. The rest of the disaster is well known.

That unknown group, in my estimation, saved a large number of American lives—at least 200,000 or more and perhaps as many as 300,000. They also prevented enormous physical damage to California, both to Los Angeles and San Francisco and to points in between. The members of that group are the unsung heroes of this bizarre episode. It is my hope that I may live to turn the names of those persons in for the award of a very high Presidential medal. Until then I will not reveal those names under any circumstance.

Whether or not the U.S. scientific and intelligence communities know it or believe it is of no concern. What matters is that a great many Americans are still alive, and their children born since then are alive. Those Americans otherwise would have been very, very dead or never born. I personally have reflected on those desperate circumstances many times. If I had it to do over again, I would unhesitatingly urge the same action: Fire and save those American lives, and accept the medium risk. And pray.

And I did pray after recommending the strike. In my opinion, this time my fervent prayers were answered. I am extraordinarily sorry for the civilian deaths that occurred; all one can say is that it was under severe circumstances and in a very peculiar—and very desperate—war.

The Soviets had many other interferometers on line. They induced a substantial earthquake in Mexico at the end of April. Thus they did complete their "earthquake footsteps" of the milestone. On 7 May they induced a 7.7 Richter quake in the Aleutian Islands. If 7.7 to 9.5 quakes had hit all along the San Andreas Fault in Los Angeles and San Francisco and in between, then the destructive scenario I had envisioned for the West Coast would have occurred.

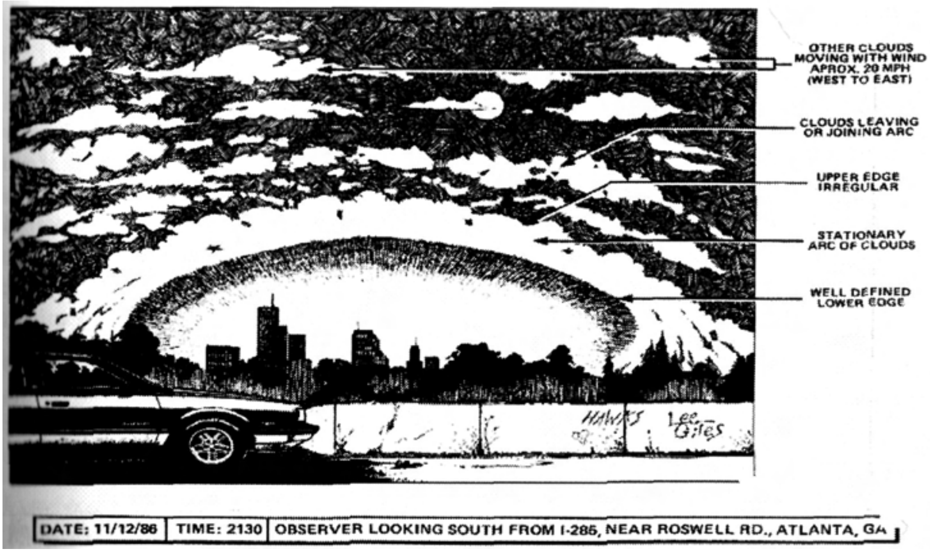
OTHER CLOUDS MOVING WITH WIND APROX. 20 MPH (WEST TO EAST)
CLOUDS LEAVING OR JOINING ARC
UPPER EDGE IRREGULAR
STATIONARY ARC OF CLOUDS
WELL DEFINED LOWER EDGE
HAWKS
Lee Giles
DATE: 11/12/86
TIME: 2130
OBSERVER LOOKING SOUTH FROM I-285, NEAR ROSWELL RD., ATLANTA, GA

Figure 58 "Bottling up" shield practice over Atlanta 12 Nov. 1986. With a real shield, aircraft or missiles flying into it (from inside or from outside) explode and are destroyed.

On 12 November 1986 the Soviets even placed a giant "dummy shield" (practice) over Atlanta, Georgia (Figure 58). If the shield had been real and not just practice, any aircraft and missiles flying into it would have been instantly exploded and destroyed. That mode—"bottling up" a strategic weapons area—is useful to nullify an entire strategic ICBM launch complex or a large bomber base, etc. It can also "bottle up" a large carrier task force at sea, including the aircraft and the Tomahawk missiles, the shells from the naval guns, etc.

Kill of the Challenger Included Use of Metal-Softening

As we mentioned, during that 1986 preparation period the Russians also destroyed the Challenger spacecraft (January 28, 1986). Numerous signatures abounded, all of which we have already published.

A few weeks before the kill of the Challenger, a close colleague had experimentally proven that a metal-softening signal was indeed placed on the Russian "woodpecker" signals (Figure 7). He did this quite simply: he wired himself into a receiver, through an intervening amplifier, and tuned the receiver to the Woodpecker signals.[44] Then he took nails from a can of nails he was using, and hit them with a hammer to drive them into planks. The nails all folded up instantly like totally wet noodles. A couple dozen, one right after the other. Simultaneously, his son—who was not connected to the Soviet signal—was pounding nails from the same box, normally and without difficulty. None of the nails picked up and pounded by his son experienced any difficulty or softness.

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[44] Here he was taking advantage of the fact that the infolded LW signals inside the Woodpecker carrier wave, comprising the "engines" for metal-softening, also constitute "perfect" divergence-free EM energy, so to speak, at least overall. Amplifying the signal also amplifies the "engine" inside it. When connected to his body, "potentials superpose" is the rule, and that transferred the amplified engines to his body and into the EM field immediately surrounding his body. Hence he softened the hammer metal a tiny bit, and softened the much less tempered nails quite a bit more.

Then my friend disconnected himself from the signal, and waited a bit. Whereupon when he then used nails from that same box, he drove them in without difficulty. There were no more "wet noodle" nails.

We reach a very simple conclusion: When he connected to an amplified Woodpecker signal, his body was time-excitation charged (quick charge and quick decay) with a specific signal so that the nails he picked up were charged. Then when hit with the hammer, the nails acted as if made of very limp rubber without a rebound. When he disconnected from the amplified Woodpecker signal, and waited a moment for the induced charge in his body to dissipate, the nails also discharged their engines and quit acting like limp rubber bands when hit, and became normal nails with normal behavior. That would seem to be quite sufficient to prove the thesis.

The Challenger was then destroyed, as we previously printed, with numerous signatures of the hit, including even a KGB party in Moscow to celebrate the success of killing the vehicle (and getting away with it).

Cold Molding: An Epilog to the Metal-Softening Donnybrook

I was called a total lunatic for pointing out a metal-softening capability on the Russian signals. So be it. Metal softening is achieved by an engine which serves as a pumped phase conjugate mirror for the vibrations and signals in the lattice bonds of metals. Build up that engine in the metal until the precisely reversed and overlaid signals negate the normal signals, and one has "dissolved" the lattice bonds, converting the solid to a liquid. Lattice bond cancellation is not heating.

But that was not to be the end of the "metal softening" story.

A few years later, working informally with a large UK aerospace firm "for free", I furnished them an address in Moscow of some Russian scientists associated on the perimeter of the KGB energetics weapon program. The address had been taken from their cautious advertisement for business on the Internet and furnished to me by a correspondent. A UK engineer fluent in Russian was sent to meet with those scientists in Russia. They nervously showed him several novel things, one of which was "cold-molding" of metal. The liquefied the **metal**

The result was that a hammer blow onto a nail head resulted in the nail acting as a limp noodle upon impact.

without heating, poured it in a mold, and waited for the "effect" to wear off and the liquid to turn back into a solid again.

Briefly, an energetics charge (using LWs) was induced on the metal lattice vibrations, adding their phase conjugate replicas to the interior LWs comprising the lattice bond signals. The metal's atoms were time-density charged to an excited state (presently not recognized in Western science). Thereupon the metal lattice EM forces "dissolved" and the metal became liquid at room temperatures and without heating. The cool liquid metal was then poured into a mold. Then after awhile, the time-density charge and slowly drained away, and the metal resumed its normal solid state—all without any heating whatsoever.

On a subsequent trip the engineer brought that Russian team itself out of Russia and to the UK. The Russian scientists demonstrated cold molding to assembled UK scientists, and to some U.S. visitors. The phenomenon was physically demonstrated and proven.

I was correct about the metal softening then. We were also correct back there in 1986 about the metal-softening signal employed against the Challenger (together with several other things).

There are numerous other signatures on the death of the Challenger. Again, *the death of the Challenger was not an accident.* It was due to a deliberate act of war by the KGB. The KGB knew in advance—after substantial probing incidents—that they would get away with it. And they did so.

Additional Update from Year 1998 to Year 2,000 Has Been Given

In the action package we sent to the DoD in 1998, we told the rest of the KGB energetics weapons story up to that date. We gave the attack plans as we saw them and the most useful types of attacks to be expected.

I hope the reader is interested in this special energetics weapons information. High power microwave weapons, high energy lasers, and nuclear weapons are useful but no longer decisive weapons either strategically or on the battlefield against a foe equipped with such energetics weapons, and particularly against a foe equipped with quantum potential weapons and negative energy EMP weapons.

At present, we are intensely watching to see if we can pick up indicators for the next scheduled strategic attack, its probable timing, and the "new twists" included in it.

Presently, we have perhaps an 80% chance that the little nation can once again counter any new threat and cause the KGB to abort the impending attack. On the other hand, with Putin apparently limiting at least some of the action of the KGB, we have moved into our present asymmetrical warfare against terrorism—

and ultimately against the extensive terrorist teams and assets already infiltrated into our homeland.

As a single example, before the collapse of the former Soviet empire, the Russians long ago slipped in nuclear weapons (from 20 to 40 KT) and hid them in all our large cities and population centers, along with the Spetznaz teams to detonate them on command.[45] Several nations have introduced teams with normal sabotage assets and also with weapons of mass destruction such as radioactive nuclear materials (for a dirty bomb), anthrax, smallpox, bubonic plague, etc. Behind the scenes, the die-hard remnant of the old KGB crew are using QP weapons to "spread" the immune systems (Figure 53) of our populace and materially enhance any BW strikes that the terrorists unleash. The rogue Japanese team (Yakuza and Aum Shinrikyo) on site in Russia are using their LWIs in a giant weather war and the occasional kill of an aircraft, etc. Over the decades Castro infiltrated some 10,000 guerrilla/special forces types trained in camps in Southern Mexico for decades. Probably at least half are still loyal and dedicated—and waiting to blow up bridges, power substations, high voltage power distribution system towers, dams, harbor facilities, refineries, pipelines (both oil and gas), etc. The first phase of WW III—delivery of the weapons of destruction and mass destruction to the targets along with means to unleash them—has already been accomplished.

We are particularly struggling against the rise of asymmetrical warfare—the superpower's paradox (Figure 59)—and our present involvement in that "new" kind of warfare is still quite foreign to us. Only time will tell how well we fare in this new type of war, which we will be engaged in for many years to come. Vice President Cheney rightly regards it as almost a state of perpetual warfare we shall have to learn to live with, as shown by his words on Oct. 21, 2001:

"The war on terrorism will not be over in our lifetime. It is different than the Gulf War was in the sense that it may never end. At least not in our lifetime. The way I think of it is, it's a new normalcy."

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[45] See Stanislav Lunev (with Ira Winkler), *Through the Eyes of the Enemy,* Regnery, Washington, 1998. Lunev is a high-ranking GRU defector. He is a former Colonel in the GRU, the military counterpart of the KGB. In p. 22-33, he summarizes the Spetznaz capabilities. On p. 22-27, he summarizes Spetznaz use of nuclear weapons already on American soil. On p. 26, he gives some of the ways in which the Soviets easily brought nuclear weapons into the U.S. On p. 30 he confirms Russian seismic weapons. Use of EMP weapons is on p. 30-31. Use of very, very low frequency weapons to destroy the human brain, put people into a zombie-like state, and aid in brainwashing is confirmed on p. 31. And this is i**nformation** Okayed by the CIA for release!

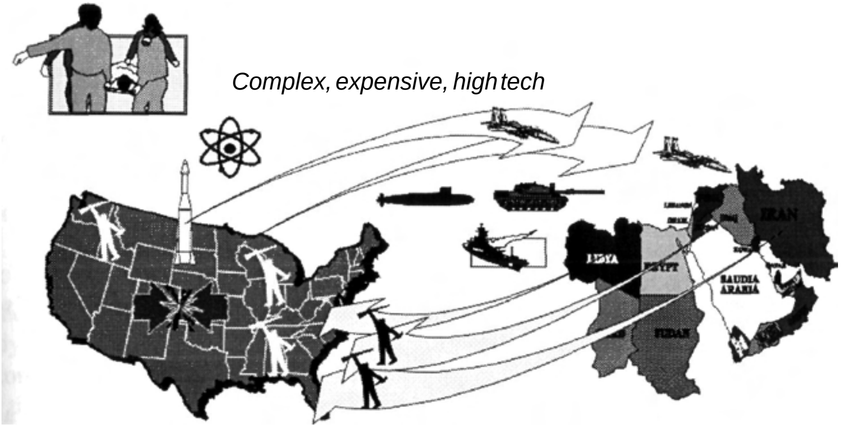

Complex, expensive, high tech

Simple, cheap, low tech initially.
Later includes high tech and very high tech.

Figure 59 The superpower paradox: Asymmetric cheap WMD strategic strikes and destruction, later becoming extremely high tech and extreme yield.

There is Also a Severe Bioenergetics (EM Biological Warfare) Threat

The threat from bioenergetics is equally vivid. That old die-hard section of the KGB can now attack an entire population, e.g., with electrodynamically (energetics) induced diseases of any kind whatsoever, particularly when using QP weapons. Such attacks are totally immune to inoculations and antibiotic treatment. Any kind of strain or variation of a disease can also be induced in the pathogen pool for that disease. Against a foe who has such capabilities, our entire medical establishment—including all our emergency treatment procedures and agents—*is obsolete right now.* A vaccination and the presence of antibodies, e.g., does absolutely nothing against the EM induction of the exact physical effects and form of a disease, as shown in the decades-long "microwave radiation" of the U.S. Embassy in Moscow (Figure 11).

To the Assistant to the SecDef in such matters, in 1998 we furnished a 200+ page briefing package and loosely proposed a crash development of the new type of medical therapeutic treatment devices pioneered and proven by the Priore group in France in the 1960s and early 1970s. Later, Congressman Cramer queried that office for an answer.

Unfortunately the Assistant SecDef s office erroneously responded to Congressman Cramer that nothing in the literature supported the mechanisms proposed. Indeed, the package we furnished contained a *detailed list* citing the hard French scientific papers in the literature, reporting the exact experiments and the astounding results obtained. Some 2,000 highly successful animal experiments for more than a decade of experiments in fact supported the thesis, and higher group symmetry electrodynamics fully supports the ability to use EM means to make spacetime curvature engines, so that these engines then interact back upon the targeted matter to perform the actions desired. That it does not appear in conventional electrical engineering is of no consequence; it appears in physics and it is good physics, just on the cutting edge.

We also reported, explained, and cited Becker's epochal work (Figures 27 and 28), which is copiously published in the hard literature and which was an example of the fundamental mechanism also. Becker was twice nominated for a Nobel Prize for his outstanding work. Unfortunately, the Assistant SecDef s office responded with a non sequitur.

Packages were sent also to NIH, NSF, CDC, and several other government agencies. Not a single one of those agencies was interested enough to have a competent scientist contact me and discuss the area. I strongly doubt that a single scientist anywhere in the Government bothered to *seriously* read and ponder the material so painfully and expensively compiled and furnished. Lieutenant Colonel (Retired) Ken Moore and I worked our fingers to the bone for weeks, preparing that briefing, and we spent all the spare money doing it that we could rake up and obtain.

The near-total lack of response itself seems astounding, but it clearly shows the state of U.S. science with respect to novel energetics innovations, even long after those innovations have been experimentally proven and documented in the hard literature, and even after they have been weaponized against us. It is a direct indication of why the U.S. never deciphered what was going on in some four decades of Soviet weak microwave radiation of the U.S. Embassy in Moscow, including the kill (eventual deaths) of three U.S. Ambassadors.

For decades there have been manipulations, to say the least, in the hotly contested field of the biological effects of EM radiation. We refer the interested reader to an excellent expose of that situation: The expose is by Dr. Andrew A. Marino, Ph.D., J.D., *Powerline Electromagnetic Fields and Human Health,* which is current. I believe it can be freely downloaded from: http://www.ortho.lsumc.edu/Faculty/Marino/PowerlineTOC.html. Dr. Marino has been personally and deeply involved in the investigation of EM bioeffects, in court cases, and in Blue Ribbon Panel investigations and proceedings. The book is an eye-opener, and it gives one a good view of the machinations in the EM bioeffects field. We quote directly from Dr. Marino, Chap. 6, p. 1:

> *"Oversimplistic as it may sound, whoever pays for EMF bioeffects research and analysis determines what data is produced and the way it is interpreted. Soon after the possibility that powerline EMFs were health risks was raised in a legal dispute involving the New York Public Service*

> *Commission, power companies and their trade associations, particularly the Electric Power Research Institute (EPRI), became massively involved in EM bioeffects research. Subsequently, the power industry dominated funding of the effects of powerline EMFs, both in terms of absolute dollars and compared with dollars from non-industry sources...the power companies and their trade associations were deeply deceitful regarding the information they provided to scientists and to the public regarding the potential health hazards of powerline EMFs."*

In the entire EM bioeffects field, there does not appear to be any mention of, study of, or recognition of EM bioeffects induced by the most powerful EM factors: longitudinal EM wave irradiation, time-polarized EM wave irradiation, and time-excitation charging of particles throughout the body and its cells, with resulting emission of transduced longitudinal and transverse EM radiation *from-within-to-without.*

National Institute of Health Reaction

NIH replied to my letter and action package from their *Policy*—read: *spin control*—Section. They noted that the package mentioned the Gulf War Syndrome, which was not in their mission area. So they just sent it off packing to DoD (simplest way to get rid of it, apparently no one seriously read it or even cared to read it). I queried them back by separate response letter about their lack of interest in a revolutionary proven new medical methodology well-documented to cure cancer and other dread diseases, in many hundreds of experiments by leading French medical scientists. This was certainly within their mission area.

They hastily replied from the *Policy* Section that, yes of course NIH was interested in all such things, and told me where to "submit a proposal." We never got out of their *Policy* department. Again, not a single competent scientist in the U.S.'s supposed master medical agency apparently even read the package or cared to call and discuss the matter. This was an indicator of their total lack of any grasp of the energetics threat, its testing, and its use to induce the Gulf War Disease.

Now perhaps one can see why we are so far behind the KGB energetics weapons scientists and weapons program.

Marino, *ibid.,* is particularly enlightening on the adamant opposition by appropriate sections of NIH vis a vis the harmful effect of nonionizing EM radiation.

No responses at all were received from the NSF and the CDC, or the other U.S. government agencies to which the package was furnished.

The CDC of course comes under NIH, and thus its responses or lack thereof would be dictated by the parent NIH policies. As for the NSF, Marino, *ibid.,* again is enlightening on the qualifications or lack thereof of its membership.

So as the reader can see, the top of the medical establishment in this nation is flatly not interested in any "controversial" or "out of the box" proven method for curing cancer, dread diseases, and mass treatment of those millions of American casualties that are coming in our cities and population centers. Again, they directly ignore scientific method's very premise: *If the experiment is replicated and contradicts the theory, accept the experiment and change the theory.* I personally concluded that the U.S. Medical establishment largely does not follow scientific method, but follows dogma and the already approved methodologies.

How the New Revolution in Medical Healing Works

For the reader who is a medical scientist and trained in physiology and biology, one might be interested in that revolutionary French therapeutic methodology and how it worked (before it was ruthlessly suppressed in the early 1970s).

Priore's apparatuses (Figures 12,49, and 60) simply pumped the cells of the entire body with longitudinal EM waves (each accompanied of course by its time-polarized twin, in a Whittaker pairing). The cells and every part of them are very nonlinear, so they act as pumped phase conjugate mirrors for Whittaker wave-pair engines resident in the cells and acting as "input signal complexes".

Once the cells are pumped by these now-established *time-density* waves, the damaged or diseased cellular masses slowly "charge up" with excess time-excitation. The irradiation took several hours, and this was the "activation" or "time-excitation charging" stage. Thereafter, the time-charge decayed slowly, all the while constituting *pumping* of every cell and every part of it, in the time domain.

The resident engine in the cell contains two components: (1) the normal or healthy component, and (2) the abnormal component representing disease or debility. Pumping these two components time-reverses both of them and amplifies that reversal. This creates amplified and incredibly precise *antiengines* in each cell and in each part of each cell. These antiengines override the weaker cellular engines resident. In turn, this "reversing" action of the antiengines causes the pumped cellular masses (actually the mass-energy, in its exact structure and dynamics)—at any and all levels, including the genetics—to be time-reversed back to normal. In biological instead of physics terms, it "dedifferentiated" the diseased or altered cells back to a previous healthy state by simply eliminating the diseased engine component. *This is a dramatic extension of nonlinear optical phase conjugation from the 3-space pumping domain to pumping in the complex (time) plane, and it is effective for time-reversing mass-energy at any and all frequencies. We accent that the cellular* *__time__ reversal back to a previous state includes all the cell's genetics and every __part__ of the cell no matter how small.*

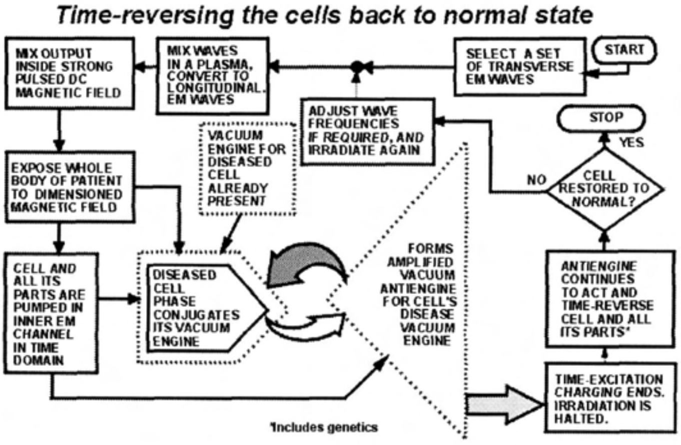
Time-reversing the cells back to normal state
START
SELECT A SET OF TRANSVERSE EM WAVES
MIX WAVES IN A PLASMA, CONVERT TO LONGITUDINAL EM WAVES
MIX OUTPUT INSIDE STRONG PULSED DC MAGNETIC FIELD
ADJUST WAVE FREQUENCIES IF REQUIRED, AND IRRADIATE AGAIN
VACUUM ENGINE FOR DISEASED CELL ALREADY PRESENT
EXPOSE WHOLE BODY OF PATIENT TO DIMENSIONED MAGNETIC FIELD
CELL AND ALL ITS PARTS ARE PUMPED IN INNER EM CHANNEL IN TIME DOMAIN
DISEASED CELL PHASE CONJUGATES ITS VACUUM ENGINE
FORMS AMPLIFIED VACUUM ANTIENGINE FOR CELL'S DISEASE VACUUM ENGINE
STOP
YES
NO
CELL RESTORED TO NORMAL?
ANTIENGINE CONTINUES TO ACT AND TIME-REVERSE CELL AND ALL ITS PARTS*
TIME-EXCITATION CHARGING ENDS. IRRADIATION IS HALTED.
*Includes genetics

Figure 60 Block diagram of Priore's healing (regenerative and time-reversing) process.

Normal cells are just backed up to a slightly younger condition. Diseased cells **have** their abnormal engine component overridden and reversed back to zero (its earlier state), so that only a slightly younger normal engine remains resident in the cell. This simultaneously reverses the cellular masses back to their previous healthy condition.

Contrast this direct healing mechanism to the action of the immune system.

The immune system itself does not *heal* anything. It contains the killers, the scavengers, the locators, the markers, the attackers, and the troops manning the ram**parts.** Usually after a fierce battle with invading hostile pathogens, it wins. Lots of cells still living are damaged in the melee. The immune system scavenger cells then scavenge up the residue littering the battlefield. But *the immune system itself cannot heal and restore a single damaged cell, including one of its own.*

That healing and restoration of damaged cells is the job of the *regenerative **system,*** still little known and inadequately studied today. Perhaps the most fundamental studies were mostly by Becker *et al.* some decades ago. The regenerative system (Figure 29) is an EM system in its operation, as clearly shown by Becker (Figures 27 and 28), yet it is able to physically differentiate and dedifferentiate cells from one form to another at will, and in highly selective fashion. The regenerative system acts within its limitations (only weak pumping can be done for the time-reversal of diseased or damaged cells) to eliminate the delta (the deviation from normal of the resident engines in the pumped cell). That restores the normal (healthy) engine and slightly amplifies it as well.

It is obviously of the utmost medical importance to understand and apply (and amplify) this little-known technical mechanism by which the regenerative system is able to restore damaged cells back to normal.

It turns out that *the regenerative system in its novel EM functioning uses precisely LW and TDW pumping of those damaged cells and gradually time-reverses their entire masses back to a normal healthy state, within its limitations.*

This is the secret of the mechanism of the cellular regenerative system—which is an electrodynamic system of very unusual nature. The exact mechanism has not previously appeared in the literature. It took me 14 years to uncover that fundamental mechanism, and another 4 or 5 to refine it a bit, even though both Priore and Becker (as well as others) applied it decades before without being able to fully decipher it.

The experimental proof is already in the literature, once one understands the higher topology EM unwittingly used by both Becker and the Priore team. The proper types of higher group symmetry electrodynamics required to understand the action of the cellular regenerative system are available. There exist scientists skilled in their application and use. These scientists and that higher group symmetry electrodynamics are little used, and are never used at all in the medical field. There exists no funding anywhere for higher EM examination and modeling of the functioning of the cellular regenerative system—i.e., for the fundamental healing process.

Just imagine what this could mean to medicine: *One can now develop a new medical science to amplify and apply nature's own proven method of restoration and healing of damaged cells, including all their damaged genetic material*. It matters not what caused the damage, whether pathogen or gamma radiation, whatever. This new therapeutic method is a totally new general relativistic process where powerful spacetime engines are created which work directly upon the damaged cell and every part of it, physically reversing the cell and all its parts precisely back to normal condition.

General relativity rigorously tells us that a precise spacetime curvature engine (set of precise spacetime curvatures) is present and active for every specific disease condition and every nuance in it. It also tells us this flawed (disease or damage carrying engine) continuously operates on the cellular mass at every level, maintaining the exact physical condition of the cell and its dynamics. By creating a precise "anti-engine" and amplifying and applying it, general relativity assures us that we are physically acting upon the cell and all its parts at every level, down to the smallest—to precisely return every part in perfect proportion back to a previous normal healthy condition. *Pautrizel directly proved the time-reversal to an actual earlier state of the cells and the organism* (Figure 61). Amplification by time-domain EM pumping, means that we can cause this time-reversal of the cells back to normal to happen much more quickly than can the body itself, which can only pump very weakly.

- Pautrizel compared identical treatment of immature rats with immature immune systems, and mature rats with mature immune systems.
- Treatment restored the damaged mature system back to full mature functioning, and it promptly recognized and dispatched the pathogens.
- Treatment restored the damaged immature system back to full immature functioning, unable to cope, and the pathogens promptly reinfected and killed the immature rat.
- The lesson: The body is indeed returned to a previous physical state. The pathogens themselves are not killed by the treatment, but by restoring the ability of the immune system to recognize and destroy them.
- Only *the previous ability* of the immune system is restored by the process.

PROF RAYMOND PAUTRIZEL
(Renowned Parasitologist)

Figure 61 Pautrizel's proof of time reversal of the stricken cells back to a previous state.

General relativity also assures us that any and every disease is subject to this novel treatment approach, even diseases which have resisted every other known therapy. The Sachs unified general relativity and electrodynamics, and GR/EM unification applications in O(3) electrodynamics produced by Evans, for the first time provide a solid theoretical basis for Priore's methodology and his evolutionary results. They also offer direct engineering of startling physical cures, once the technology is developed.

The profound implications of that treatment can be seen. Apparently, however, **our** leading governmental agencies and health agencies do not see it, do not wish to see it, have no appreciation for general relativistic effects in healing, and do not intend to have any appreciation for general relativistic effects in healing. Indeed, they seem totally uninterested in even trying to comprehend and research t*he fundamental healing mechanism* demonstrated by nature herself.

What the French Researchers Showed

Among other things, the Priore team produced revolutionary cures of *terminal tumors, infectious trypanosomiasis, suppressed immune systems, and atheriosclerosis* in several thousand laboratory animals in rigid laboratory tests under rigorous protocols. Eminent scientists such as Robert Courrier and Raymond Pautrizel worked with the Priore team. Courrier was head of the Biology Section of the French Academy of Sciences at the time, also *Secretaire Perpetuel* of the Academy, and a noted scientist of high stature. Courrier personally presented the astounding Priore results to the entire assembled French Academy. He also sent his own most able scientist assistant to personally prepare the terminal tumor grafts on the lab animals before their treatment.

A world-renowned parasitologist who did enormously important work with Priore was Raymond Pautrizel, who is still alive at this writing though quite aged. Pautrizel was greatly persecuted for his years of determination and effort. Courtesy of Pautrizel via the late Christopher Bird, I personally have the very Ph.D. thesis that Priore himself submitted to the University of Bordeaux on his revolutionary work. That thesis was maliciously rejected in the suppression that was applied to the project. When the French Government changed to a Leftist government in the mid-70s, Government support was immediately withdrawn and the project was ruthlessly suppressed. Priore later sickened and died and that was the end of that. More than a decade later a brave and determined Pautrizel finally was able to get a doctoral thesis approved in the Priore work area, at the same university, by another doctoral candidate, Eric Perisse {40}.

There are two U.S. patents on the Priore device itself, and of course several French patents also.

All the above was rigorously documented in the 1998 package prepared and submitted by Ken Moore and I.

While Priore was still alive, a team with which I was connected attempted to mount a well-funded effort to restore the Priore methodology while Priore was still alive. We also were viciously suppressed. The lives of our financial backers and their families were threatened. The head of our project was viciously attacked financially and destroyed, fleeing the country for his very life. Whoever thinks that dramatically innovative medical science in this country is just sweet reason and scientific method, should have a strong enema to remove the serious blockages interfering with his perceptions.

This vicious outside suppression of our project so infuriated me that I made a solemn promise that, were it humanly possible, I would decipher the Priore process before I died. It took 14 years, but we made good on that promise. During the 20 years or so since our project was suppressed, it is heartbreaking to consider the millions of children and sickened and suffering people who could have been saved had the project continued and succeeded. It is heartbreaking now to consider the coming millions of casualties in our civilian populace in our cities, most of who are going to die from mass destruction weapons. And most of those would not have to die, would the scientific community waken from its long sleep and discover some modern physics and higher group symmetry electrodynamics—and their application to solve nature's mechanism for **healing.**

When one time-reverses the body's cells and all their parts, one forces the diseased cells to dedifferentiate back to healthy state. We strongly accent that this is accomplished by unified GR/EM processes involving precisely **organized** spacetime curvatures and their local actions in the cells and all their inner components, down to the finest level. It can be rigorously expressed in good unified physics, as expressed in an electrodynamics such as O(3).

The nondamaged or nondiseased cells just get a little younger. That is also highly beneficial; it reverses the ravages of aging, just a little. Indeed, one of the implications of the Priore mechanism is that aging can indeed be reversed by the process and treatment. Again, one must keep one's sense of humor. In order to get this technology and therapeutic method born, what seems to be needed is an extremely wealthy person, strongly desiring to live longer than the expected life span and do it in a vigorous, healthy body—and who is willing to fund the project with the necessary $60 million required so to redevelop and extend the Priore technology so it can be readily applied. A byproduct will be the saving of millions of American lives when those coming mass casualties from weapons of mass destruction occur in our cities.

How the Regeneration Mechanism Was Finally Deciphered

What took so long in deciphering the mechanism was the problem of how to make such precisely tailored and exact ST curvature engines, specifically so that they are *exact* antiengines for a specific disease and even a specific pathogen, and even for different versions of the engines for different cells in a single body having different strains of the same pathogen, having different body DNA, etc. For years, the solution of that task seemed hopeless. How on earth could one possibly work all that out in a hundred lifetimes, so that it could be precisely calculated even by an array of the most powerful computers on Earth?

After years of struggling with the problem, in one stroke of enlightenment it was revealed to be the simplest thing in all the world. Absolutely no calculation was necessary, and the exact amplified antiengine effect was a fairly simple and straightforward thing to obtain. General relativity tells us that every cellular mass and each part of it, has its own unique spacetime curvature engine, to the finest detail and an exact fit. As Wheeler put it so nicely {130}, *"Space acts on matter, telling it how to move. In turn, matter reacts back on space, telling it how to curve. "* The mass and its dynamics and the engine and its dynamics constantly interact upon each other, and "keep attuned and in perfect adjustment," so to speak.

That means that a "normal" cell already has just such a precise "normal" ST engine residing in it, and acting upon every component at every level—even in the atomic nuclei. Well, a diseased cell has an absolutely specific structuring, and therefore it also has an absolutely specific ST engine structuring. *A priori that* resident structuring for the diseased or damaged state in the individual cell differs (by some delta) from the structuring of the normal healthy cellular state for that individual cell.

Voila! That means that *the ST engine for the damaged cell can be decomposed into two parts (two engines):* (1) the normal "healthy cell" state engine, and (2) a delta ST engine that has been added to it so that together the two comprise the full ST engine for the exact individual condition of the cell.

What is now needed is a way to produce an exact antiengine of two parts: (1) one for the normal engine and (2) a second one for the delta (disease) engine. Applying this amplified and combined "antiengine" would overpower the resident combined engine, precisely reversing the cellular condition by reducing the delta to zero. Rigorously, the cellular mass and every part of it must then also revert to a previous physical state, or else we must complete discard general relativity itself.

Well, if we were to just time-reverse the resident engine and its two components, that would give us the perfect antiengine with its two components. Amplifying this antiengine would then produce one that was more powerful than the resident engine in the cell. Applying that amplified antiengine to the cell, that would not really change the "normal" engine component, but it would precisely reduce the delta engine component back to zero (its previous state, before it was there!) Voila! A specific healing signal of perfect structure, for the specific deviant condition of the individual cell and its every part.

Since we have a combined GR/EM to use, we can think electrodynamically about this general relativity problem. Immediately we see that phase conjugate optics is a candidate, since the "resident composite engine" can correspond to the "signal" or input wave, and the pumping of the nonlinear mass of the cell and its parts (where they act as nonlinear phase conjugate mirror materials) produces an exact phase conjugate replica (the exact amplified antiengine). The presence of that antiengine overrides the magnitude of the resident engine, and it moves the cell precisely back along the temporal path previously taken. In short, it applies a specific kind of dedifferentiation of the cell back to its previous healthy condition.

Since we extend phase conjugate pumping to the time-energy domain, then the resident composite engine and its time-stream component are the "input." The amplified antiengine and its time domain component will then forcibly propagate that pumped mass energy back over the time trajectory previously taken by it. In short, it will time-reverse the cell and all its parts back to a previous condition, completely eliminating the delta (disease or disorder). The beauty is that it will also reverse damaged or altered genetics, such as in the AIDS disease. It can do this prior to the appearance of health symptoms—it can be done as soon as the patient tests positive for HIV.

Since the antiengine is amplified, it moves the cell back to normal fairly rapidly (in a few hours, for example). At least the time charge for the reversal process is delivered in that period; one may allow (as Priore did) a full week for the time-charge and its transduction to continue reversing the cells. But it is much faster than the normal speed of the human regeneration system using the same process, because now we have greatly amplified the time-reversal rate.

It is therefore ideal for a method of quickly treating mass casualties, particularly since it can be developed and used in a portable unit about the size of a large suitcase (Figure 13).

Interestingly, during the radiation with LW EM radiation, one also pumps the pathogen and time-reverses it as well. Its "normal state" towards the beginning was a condition whereby it could move with relative immunity past the immune system's opposition, having deceived the immune system. In the treatment, a small amount of the pathogen is therefore converted back into this condition just shy of the beginning, where that part of the pathogens is resistant to the immune system. However, a very small, short "post treatment" irradiation with LW radiation for a much shorter interval and at weaker power, will clean up this altered pathogen residue by allowing the immune system to recognize it and destroy it. Pautrizel clearly demonstrated this significant fact.

Cellular and Body Rejuvenation are Possible, Once the Technology is Developed

One can in fact really accomplish *rejuvenation* of the aged and infirm, as the technology is developed. One could certainly solve the major problems of Medicare, and cut the patient load at least in half, relatively quickly and inexpensively. Of course lots of big U.S. drug companies will be rather violently opposed to any such idea, because much of their empire would be threatened. Much of the organized medical community depends largely on the Big Drug Approach. So the organized medical community will also vehemently oppose it, just as the formal medical science community in France viciously opposed it.

One could also produce cheap, portable LW treatment units *en masse,* which is what we were suggesting to the Assistant. SecDef. That way one could flood the emergency response system (response teams, hospitals, fire stations, police precinct stations, schools, etc.) with quick and effective treatment devices. They could be used to rapidly {131} treat those millions of American casualties that are going to occur when one or more of our cities are attacked in the near future by terrorist WMD attacks. This would save the lives of most of those stricken millions of Americans.

Mow Many Americans Could Be Saved?

For an anthrax attack on Washington, D.C., first generation equipment could save perhaps 70% of those sickened Americans, almost all of who are going to die with *present* capabilities. With second-generation equipment, one could save perhaps 90%.

For an anthrax attack without spreading via QP clandestine preparation of the populace, one would save 0.7 to 2.1 million Americans. With clandestine KGB QP spreading and a *5:*1 increase in the yield of the anthrax strike, one would save 3.5 to 10.5 million Americans.

For a truly nightmare attack (as a worst case scenario) perhaps 5 major cities might be attacked in such manner and to such degree. In that case, one is talking about saving 3.5 to 10.5 million Americans for the unspread attack case, and up to 17.5 to 52.5 million Americans for the spread case.

Further, the development of the necessary portable treatment units is doable and affordable, for mass treatment capability. Training on a portable machine could be done for a high school student in 30 minutes or less, and that student could then give emergency treatment effectively.

Absolutely nothing else out there can presently warrant such projections. Yet this is the very technology our own medical science community is eminently uninterested in, has no knowledge of, does not wish to obtain any knowledge of, and does not wish to scientifically discuss.

There Are No Resistant Strains to the New Technology, and There Cannot Be Any

A most interesting thing is that there cannot be a "resistant strain" of a pathogen for the new treatment methodology, *a priori.* No mass can shield against spacetime curvature effects. Slight adjustments of the controls will adjust the spacetime engines being utilized. Two or three hour's work with a developed unit and a lab team on a new strain would suffice to completely determine the required adjustments, once the technology is developed. The new information could then be quickly relayed to all stations treating patients. On each treatment device, adjusting a few dials and controls for the laptop computer controlling the unit will do the trick. The use of the final device would be so simple that a teenager could be trained to use it in less than 30 minutes.

Such new capabilities are urgently needed not only for the millions of civilian casualties we expect in the future, but also for support of our armed forces in the field. Frankly, the anthrax shots are not going to do them much good, once one realizes that the "spreading" of their immune and regenerative systems is already occurring via KGB quantum potential means. Camel pox is available to any terrorist foe, and has almost the identical actions and constitution as smallpox. Indeed, it is almost identical to smallpox.

The Gulf War Disease and Syndrome were just small preludes of what is to come and what is already being used against the entire U.S., though as yet very clandestinely. Look again at the Kaznacheyev work. *He clearly proved in thousands of successful experiments that any kind of cellular disease or damage or death whatsoever, can be induced at a distance by novel EM means.* Replication experiments were successfully accomplished at the University of Marburg and also at the University of Sydney.

Results of the Priore' Treatments Are Well-Documented and Independently Supported

The Priore team's results are well documented in the hard French scientific literature. At least one French doctoral thesis was eventually accepted upon the work. The astounding results really occurred. They were scientifically substantiated under rigorous protocols and even police-guarded labs for tests by a learn of outside scientists. To then deny those results simply because no one **has** *understood* the active mechanism until now, is to deny the scientific method itself: *Believe the experiment when it refutes the prevailing theory.*

There is also independent work by other scientists that strongly supports the Priore results, once the mechanism is finally understood.

Robert Becker *et al.* in the U.S. conclusively showed that living cells *in situ* can be dedifferentiated, redifferentiated, etc. by laughably weak currents (picoamperes) and DC potentials (which are comprised of those famous Whittaker pairs). Becker was unaware that his potentials included time density waves and longitudinal waves, as predicted by quantum field theory and as shown by Whittaker in 1903 (once one understands that a bidirectional phase conjugate longitudinal EM wavepair is a time-density EM wave coupled to a longitudinal EM wave). Application of such EM potentials by Becker transformed red blood cells into pre-cartilage cells, then further into pre-bone cells. That latter cell type was then deposited in bone fractures, healing them when nothing else would. Becker and others have demonstrated partial regeneration of limbs in small test mammals, using the technique. The bone-healing techniques were finally approved by the FDA and are often used in some hospitals for treating otherwise intractable bone fractures.

Since then,other scientists have shown the directed formation of other types of body cells from cells from distant parts of the body (i.e., muscle-type cells from cells produced in the bone marrow, etc.). Such things are now well documented in the U.S. literature, in at least several hundred papers and in the leading journals including *Nature, Science,* etc.

The Present Threat Is Urgent, and Our Strategic Destruction is Still at Issue

Our own medical community, our science community, and our intelligence community are at least 20 years or more behind the KGB right now. We are also behind the Chinese. In many respects our scientists have simply missed the biggest scientific breakthrough of the century.

It is urgent that we find some way to counter and avoid future strategic energetics attacks sure to be scheduled. The eventual attack actually launched—if the little nation's QP weapons can be countered first—would destroy the U.S. in about 2 hours. It only takes about 10 minutes, it seems, for the QP weapons *already deployed* to negate almost all our strategic nuclear arsenal. Thereafter, the KGB and Yakuza/Aum Shinrikyo can simply attack us at will and utterly destroy the U.S. To any loyal American, that is an entirely unacceptable solution.

The most urgent requirement would seem to be immediate and strong contact at the highest level between the U.S. government and the leaders of the little foreign nation (and the other friendly nation) that presently is guarding the ramparts and saving our necks. A cooperative crash program to develop our own QP weapons would seem to be the order of the day, if it can in any fashion be negotiated. But to have any chance of success, the President and the Congress will have to use the utmost care in selecting the U.S. negotiators and scientists to explore this possibility.

Immediate transfer of the requisite capabilities to the U.S. would be desirable, at least from our own view. From their view, of course, we do not necessarily resemble a trustworthy scientific partner at all, based on our past scientific performance, and it is up to the U.S. scientific community to prove to them that the leopard really has changed its spots. That would all have to be negotiated and worked out.

If that is not possible, then it is of extreme urgency that our own country embarks upon a new Manhattan Project to develop strategic quantum potential weapons and defenses. It would be a great relief to discover that such had already been started, but I fear not.

Desperately Needed Defensive Capabilities Can be Provided by a QP Solution

We pose one more very, very useful QP capability prior to closing. As we stated, if a large U.S. city is hit with—say—an anthrax attack done in professional manner, we would expect 1-3 million casualties, according to a well-known major U.S. government study. With immune/regenerative spreading presently already ongoing here in our populace by KGB QP weapons, that figure may actually increase by about 5-fold. So the casualties (prompt and delayed) might well reach 5-15 million, in a single *professional* anthrax spray attack by two persons from one light plane on a calm night dispensing 100 kilograms of anthrax spores sprayed over the city with a simple agricultural sprayer. With the indicated Priore technology and treatment units in all emergency response hands, at least 70% or so of those casualties could be saved. Otherwise, *presently almost all of them will die.* That dramatic saving of lives is one desperately needed capability that could be met.

But there is a further capability of LW technology that nothing else presently known can do without serious impact upon the populace.

After the prompt and shortly delayed casualties are mostly cured and the remaining fraction dies, a terrible problem of BW contamination still remains. No one anywhere really knows how to clean up an entire city from anthrax spores. But unless harshly decontaminated, that contaminated city is going to be effectively uninhabitable for decades to come, if only the present technology and methods are available. Islands of the coast of Scotland, where anthrax was tested decades ago, are still "hot" and contaminated—and off limits.

The indications are that our nation has developed chemical sprays that can kill and neutralize the anthrax, including in the lungs of the populace breathing the spray. On the other hands, it is indicated that the spray is a high physical stress factor, and some of the more debilitated citizens will be injured or even killed by the spray itself. This includes babies and small children, the aged, those with lung and breathing difficulties, etc. As a matter of national survival, desperate diseases do deserve desperate remedies. So while spraying the zone might itself sicken and kill some thousands of our weaker citizens, at least—so the thinking would go—it saves millions. This of course is similar to the use of triage—reserving treatment and scarce medical capabilities and supplies for treating those most likely to live and recover with treatment, rather than treating those more seriously affected and less likely to survive. Sadly, presently triage will almost certainly be necessary because of very short supplies and treatment teams, etc. So most of those 1 to 3 million casualties will simply be dragged aside and left to die, and just made as comfortable as possible.

However, the QP technology can be adapted to produce systems that can indeed do complete decontamination, very quickly, and without harm to the citizens in zone. The anthrax can simply be modified by specialized spacetime curvature engines—specialized EM fields and waves carrying hidden inner "information content of the field" engines that are designed specifically to change and destroy anthrax and nothing else. Eventually one could develop the capability to do it similarly for *any other* major contaminant, including nuclear radioactive materials contamination of a major city.

Any strategic and tactical analyst can immediately see the tremendous value of such capabilities.

In Conclusion

I hope the above admittedly lengthy overview is of interest to the reader and useful. If we are to survive the debacle that now looms before us in this new asymmetrical war we shall be in for decades, it will require the efforts of leading and dedicated Lawmakers and Overwatch persons. Without firm prodding, the military, scientific, and intelligence communities are likely to just continue their present pace until many or most of us all die suddenly.

The KGB energetics threat is still real and imminent; Russia is not a monolith and Putin still does not have complete control over the KGB. Another full strategic attack is sure to be scheduled before very long by either that die-hard faction of the KGB, the Yakuza/Aum Shinrikyo, the Chinese (particularly if they move against Taiwan and we defend), or someone. And so our possible deaths also to be taken into account, if we just continue to do business as usual.

Along with other Americans, I love my country and served it to the best of my ability for 20 years of active duty. It is the survival of America itself that is now at stake, both in the asymmetrical war against terrorists and in the continuing war against energetics weapons. Our scientific, military, and intelligence communities simply must be jolted awake and into massive efforts in energetics.

We have the scientists with the required capability. We have the facilities. We have the leadership, and we can do it if we can put this thing under a Presidential Decision Directive, under an Executive Order and a Declaration of National Emergency (along with the several already in effect).

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1986

Fer De Lance

Briefing on Soviet Scalar Electromagnetic Weapons

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1986

Note: This is the original Fer De Lance briefing paper wich includes some minor text and artwork editing.

1986 FER DE LANCE INTRODUCTION & BRIEFING ON SOVIET SCALAR ELECTROMAGNETIC WEAPONS

This briefing presents the basic concepts of Soviet scalar electromagnetic weapons, some of the major types available, and evidence of their widespread testing.

Scalar Electromagnetics is Electrogravitation

Scalar electromagnetics is an extension of present electromagnetics (EM) to include gravitation. That is, it is a unified, and, what is more important, it is a unified engineering theory. Nikola Tesla initially discovered its basis.

In the scalar EM extension, EM field energy can be turned into gravitational field energy and vice versa. This exchange can be patterned and localized, in specific areas or objects. Such a controlled change of electromagnetics to gravitation is not possible in the normal EM or physics presently taught in Western textbooks. However, the bits and pieces of the theory have been scattered through the physics literature for some time, but no orthodox Western scientist seems to have realized that these anomalous portions could be integrated into a startling new physics. Unorthodox experimenters, inventors, and scientists have made discoveries in this arena for several decades, but again have not realized the exact implications or the precise manner in which their results could be combined with present electrical physics.

Fer-de-Lance

Such sluggishness is certainly not present in the Soviet Union. For over three decades, the Soviet Union has been developing electrogravitation and applying it to develop strange new secret weapons of incredible power and capability. They have sustained the largest weapons development program ever launched by any nation, and they have kept it effectively hidden from prying Western eyes. 1 have called this program "Fer-de-Lance," after the deadly South American pit viper of that name.

The dreaded fer-de-lance is a snake of great agility and lethal effect. It often ambushes its hapless prey, and strikes unexpectedly and without warning. Its first sudden strike is usually lethal to its victim, which promptly expires in writhing agony. Since the Soviet development of scalar EM weapons has been designed for the same purpose, the name seems appropriate.

The equivalent effort of about seven Manhattan projects has been poured into Fer-de-Lance by the Soviets, and the program has been successful almost beyond imagination. The eery weapons are now developed, deployed, and tested. The ambush has been completed; Fer-de-Lance is coiled and ready to strike.

Energetics and Directed-Energy Weapons (DEWs)

The ordinary Soviet name for this type of weapons science is energetics. In the West, that term is believed to be associated with conventional directed-energy weapons (DEWs) such as particle beam weapons, lasers, radio frequency (RF) directed-energy devices, etc. The Soviets do not limit the term in this way.

Western scientists are familiar only with directed-energy weapons where fragments, masses, photons, or particles travel through space and contact the target to deliver their effects. Hence in their thinking they limit the Soviet term "energetics" to the type of weapons they themselves understand - exotic but normal weapons using energy or mass traveling through space to impact a target.

However, it is possible to focus the potential for the effects of a weapon through spacetime itself, in a manner so that mass and energy do not "travel through space" from the transmitter to the target at all. Instead, ripples and patterns in the fabric of spacetime itself are manipulated to meet and interfere in and at the local spacetime of some distant target. There interference of these ripple patterns creates the desired energetic effect (hence the term energetics) directly in and through the target itself, emerging from the very spacetime (vacuum) in which the target is imbedded at its distant location. As used by the Soviets, energetics refers to these eerie new superweapons, as well as to the more mundane DEWs known to the West.

As a consequence of the Soviet breakthrough and decades of feverish development, monstrous strategic weapons undreamed of in the West are already in Soviet hands. A noose is slowly and steadily being tightened about our throats, and it is already the 11th hour.

The Soviets Use a Deception Plan

Concomitant with this supersecret development program, the Soviets developed and implemented an elaborate deception plan to conceal these startling weapons and their nature from Western eyes until it is too late. Soviet deception has been so successful that even when Western scientists are confronted with the actual Soviet tests of these weapons directly over their heads, they do not recognize the weaponry nor the nature of the effects produced.

As early as January 1960, Nikita Khrushchev announced the Soviet development of a new, fantastic weapon. On May 1, 1960 Soviet defensive radars - rigged as prototype weapons of this new kind - probably downed Francis Gary Powers's high-flying U-2 reconnaissance plane over the Soviet Union, precipitating a major diplomatic incident.

On April 10, 1963 one of the first new superweapons operationally deployed was used to destroy the U.S.S. Thresher atomic submarine underwater, off the east coast of the U.S. The next day, April 11, 1963 the same deployed superweapon was utilized in a different mode to produce a giant underwater explosion in the ocean over the Puerto Rican Trench, 100 miles north of Puerto Rico.

Over the years, various aircraft were interfered with or downed as tests of these Soviet weapons. A particular case involved the mysterious loss of F-111s in the Vietnam conflict. At least one downed F-111 crew was recovered in the subsequent prisoner-of-war exchange. On that aircraft, all electrical systems suddenly were in difficulty simultaneously. All emergency indicator lamps were lit up, "like a Christmas tree." This was probably due to special Soviet teams converting some North Vietnamese SA-2 missile system radars to the scalar EM mode, and employing "scalar beam" interference to produce spurious EM noise throughout the electrical and electronic systems of the aircraft.

In late April/early May of 1985, the entire armada of Soviet strategic scalar EM superweapons was activated as a special celebration of the 40th anniversary of the end of WWII. Activation of this armada (which probably contained over 100 giant weapons), together with 27 giant power systems and a large number of command and control transmissions, was monitored on an advanced, proprietary detection system by Frank Golden. After the giant strategic exercise, which lasted several days, most of the weapons and power sources were once again stood down to "standby."

The NASA shuttle launches provided a convenient opportunity for Soviet testing of these superweapons in a Launch Phase ABM mode, where a launched missile can be detected and destroyed shortly after liftoff. At first, electromagnetic pulse (EMP) bursts on the early shuttle trajectory were deliberately delayed in time, to prevent actual destruction of the target and avoid alerting the U.S. that something unusual was happening.

The shuttle launch of November 26, 1985 saw a particularly significant-test of this kind. In this case, a very loud "sonic boom" or explosion occurred over the launch site 12 minutes after shuttle liftoff, when the shuttle was already away and downrange. At least two previous shuttle launches had also been used as pseudotargets, with delayed booms occurring over the launch site well behind the vehicles.

After the lack of U.S. reaction to these three tests showed that the U.S. still had no knowledge of the new technology and did not even recognize its employment, the Soviets apparently decided to proceed with tests where the target vehicles would actually be destroyed.

On December 12, 1985 the same Soviet weapon tested against the NASA shuttle launches may have deliberately interfered with the controls of an Arrow DC-8 taking off from Gander Air Force Base, Newfoundland. At an altitude of 100 feet, the aircraft - carrying over 250 U.S. soldiers and civilian crew members - lost power and sank into the ground tail-low, killing everyone on board. Three Canadian witnesses to the crash were interviewed over the Canadian Broadcast Corporation's television news on April 8, 1986 at 10 p.m. No flame or smoke issued from the plane before its descent and crash. However, the aircraft was seen to be mysteriously glowing with a yellow glow. That is a signature of the use of a scalar howitzer in the "continuous EM emergence" mode, similar to the manner in which the F-111s were downed in Vietnam. In short, the DC-8's electrical systems were interfered with by electromagnetic noise created throughout each increment of spacetime occupied by the aircraft. The powerful charge created in and on the aircraft also apparently caused the loss of two engines, one after the other. With its controls ineffective and power drastically reduced, the aircraft sank to earth, still in its "tail down" configuration from takeoff, and crashed and burned. The "yellow glow" was a corona due to the acquisition of a high electrical charge by the skin of the aircraft.

Other factors contributing to the crash may have been reduced lift due to poor engine maintenance, increased weight of the aircraft due to icing, and heavy loading. Still, no one has recognized the significance of the "yellow glow" or what it implies, or the possible connection between loss of the aircraft and previous Soviet testing of-a Launch Phase ABM system against U.S. shuttle launches.

As this book goes to press, the last two U.S. Air Force Titan 34-D missiles fired from Vandenberg Air Force Base in California have blown up shortly after launch. The first one blew up on Aug. 28, 1985 just after lift-off. That loss has been attributed to failure of a high-powered fuel pump, causing a massive oxidizer leak and a smaller fuel leak. The second Titan loss occurred on April 18, 1986 when the missile blew up 5 seconds after lift-off. Its loss is still under investigation and no determination of cause has been made. Apparently the shuttle and the Titan presently provide the only viable launch vehicles for launching U.S. "spy" satellites. The loss of these sensitive satellites - if indeed they constituted the payloads - cannot help but be damaging to our strategic surveillance capability. According to the Los Angeles Times, the single remaining KH-11 satellite was launched in December 1984 and, with an expected life of two to three years, it could stop functioning later this year.

Whether or not significant Woodpecker grid activity existed in the vicinity of the Titan launch of August 1985 is unknown at this time. However, significant activity in the grid definitely occurred before the April 18 Titan disaster and on the same day.

On Easter Sunday, Mar. 30, 1986 engineer Ron Cole observed significant **cloud** signatures of grid pattern activity, correlated with Soviet Woodpecker measurements. On April 18, the present author observed traces of a cloud **radial** over Huntsville, Alabama and took photographs of it. Preliminary reports from

Thousand Oaks, California indicate extensive grid activity again on April 18, the day the second Titan exploded.

At least the second of these two missile destructions shortly after launch is suspicious, since the grid positively was active during that time. Also, a clear trail of Launch Phase A8M system indicators exists back to the massive scalar exercise of April/May 1985. The first Titan explosion in Aug. 1985 thus falls within the Soviets' "now let's test them against U.S. launch vehicles" period. The second Titan loss follows highly suspicious losses of the Arrow DC-8 on Dec -T7 1985 and the Challenger on Jan. 28, 1986. The same Soviet weapon system that destroyed those targets may also have destroyed one or both of the critical Titans.

The Soviets have also been able to significantly engineer the weather over North America for more than a decade without being found out. They have tested a fantastic range of anti-ballistic missile (ABM) defense weapons for over two decades, and no one is the wiser in the West.

As previously stated, prior to the end of November, 1985, at least three "wet-run" tests of a Soviet "launch phase ABM system" against actual U.S. shuttle launches were made directly over Cape Canaveral itself, and still no one recognized what was happening or what sort of weapon was being tested. On December 12, destruction of the Arrow DC-8 in Newfoundland produced no indications that the Americans and Canadians knew anything about the nature of the weapon possibly used.

Accordingly, after a sufficient wait to test our reactions (if any), the Soviets prepared to actually destroy a shuttle after its launch.

Destruction of the Challenger in January 1986

As the whole world knows, on January 28, 1986 the shuttle Challenger was launched from Cape Canaveral, Florida after exposure to undesirable weather conditions, and disastrously exploded shortly after launch. The evidence seems to indicate that, as the rising vehicle was stressed, one end of its right booster broke loose, twisting away and into the main fuel tank, causing rupture, spillage of the fuel and catastrophic explosion. Several other anomalies still exist, however, and it is clear that a problem existed with at least one of the booster seals. All seven astronauts aboard the flight were killed in the fiery destruction of the vehicle.

Of course no one had recognized that the Soviets had already tested a launch-phase anti-ballistic missile (LPABM) system against three of our previous shuttle launches. These "wet-runs" used a deliberate "time offset" to delay the explosive emergence of electromagnetic energy in a launched shuttle's location along its trajectory. The delayed test shots resulted in very large "booms" above the launch site after the shuttle was safely out of the area, but did not destroy the shuttle vehicles themselves. For example, the delayed-shot boom occurred 12 minutes after the evening launch of Nov. 26, 1985. Even a marker beacon (large light in the sky) was utilized on that launch shortly after lift-off. The marker beacon was photographed. In addition, another photograph taken in a time sequence shows another sudden streak of light coming down and ending in a burst of light. This was probably a spatially-offset test of the "pulse" mode for destroying the shuttle. The "light burst" would have been detected in the Soviet Union and scored against its intended offset position. However, another mechanism may have been used to cause destruction of the shuttle itself.

On Jan. 1, 1986 the presence of a metal-softening signal added on to the Soviet LPABM system's scalar EM transmissions was detected by a surprised Frank Golden. The metal-softening ability of the detected signal was experimentally verified by him. Golden also locally nullified the action of the scalar EM signal in a test, rather conclusively establishing (1) that it existed and (2) what it was. The signal was apparently being prepared for use against an upcoming U.S. shuttle launch.

Just prior to the launch of the shuttle in late January, 1986, the Soviets accomplished significant weather engineering over the U.S. The jet stream was severely bent southward in the middle of the U.S., bending rightward again to move across the Florida panhandle. Icy cold air from Canada was drawn far down, into Florida and onto the Challenger sitting on its launch pad. This exposure to cold outside its tested range was probably an additional factor contributing to the Challenger's failure. Positive signatures of the Soviet weather engineering and jet stream manipulation were observed and photographed by several persons, particularly in Alabama and California.

On January 28, 1986, the Soviet scalar EM weapon system effects were sharply localized in the launch zone. Localization involved higher frequencies being present; these are quite painful to small brains - whose hemispheres act as a scalar interferometer and detector - such as in birds. As commented upon by national news commentators, strangely the birds were not flying that morning. Indeed, they were staying down on the ground or avoiding the area, since the sky over the area was painful to them.

As the Challenger rose, the metal-softening signal would have been experienced in and around the boosters shortly after ignition, since the booster flame acts as a special "ion-plasma" turner/detector for the scalar signal. (Certain plasmas have a unique characteristic: they transform an input transverse wave to a longitudinal wave, or an input longitudinal wave to a transverse wave.) The effect of such a local signal is to "change mass in the immediate vicinity" with the particular scalar resonance signal. (Mass acts as a capacitance or accumulator for scalar resonance).

The ill-fated Challenger was doomed. After ignition, the booster flame acted as a ionic plasma detector/amplifier for the scalar metal-softening signal on the

Soviet Woodpecker grid. The metal in and around the booster flame was slowly and steadily weakening due to charge-up with the metal-softening pattern. This attributed to booster leakage from the already cold-damaged seal. The leaking booster poured out smoke and later flame, contributing to the impending disaster.

Substantial winds and air turbulence over the site increased the stress on the Challenger as it rose through this region. This also contributed to the impending disaster and may have been deliberately created there by Soviet weather engineering.

As the Challenger stressed, eventually one or more weakened metal mounts gave way, partially freeing the end of the right booster. The booster oscillated, rotating into the tank and rupturing it. Contact of the escaping liquid fuel and the flame resulted in a fiery explosion, destroying the vehicle.

Even so another anomalous flame or light was observed on the vehicle, and may have represented a very small additional "pulse mode energy form" produced by the Soviet weapon that was attacking the Challenger. The shock of the explosion probably killed the astronauts instantly, although the cabin appears to have remained essentially intact while it plunged several miles to the ocean below.

By treating excess cold exposure to the shuttle, inducing metal-softening in and around the ignited booster, and possible adding a deliberate "intensely hot spot", the Soviets caused the Challenger to weaken and destroy itself shortly after launch, in so subtle a fashion that NASA scientists would not suspect what had actually caused the mishap. The Soviets also had previously withdrawn all their trawlers and ships which normally shadow a shuttle launch, to prevent any suggestion of Soviet presence near or involvement in the catastrophic accident.

A few days later, sporadically intense "high frequency localization signals" were still present on the grid, at least at one hinge-point at Birmingham, Alabama. From 1-4 February 1986, many birds inadvertently flew into the zone when an intense breakout of these components occurred, and dead birds fell from the sky in substantial numbers.

* According to an Urgentgram sent out by General D. Graham, on the evening of the Challenger's loss, KGB headquarters held a party to celebrate "success of their active measure against the shuttle." Note that all Soviet scalar EM weapons - development, testing, deployment, and usage - is under command and control of the KGB.

Among other things, this briefing details the bizarre series of indicators that showed the Soviet intention to destroy the vehicle, and documents the accidental discovery of the signal with which they intended to cause the shuttle to fail and destroy itself.

Technological Surprise and a New Hiroshima

Sadly, the bureaucratic smugness of orthodox Western scientists has materially assisted the Soviet deception process. Most Western managerial scientists - particularly in weapons development activities — have continued to view the Soviets as ignorant peasants, still trying to clean the mud off their boots. This view, of course, is totally untrue and unwarranted.

It takes only a few examples to refute this attitude. In nonlinear mathematics, engineering and science, the Soviets have led their Western counterparts since the beginning. The electromagnetic pulse (EMP) effect of a nuclear explosion appeared in the ordinary Soviet scientific literature before Western scientists were even aware that the effect existed. The Soviets continue to lead the world in explosive welding, titanium forming and welding, etc. While the Soviet scientists exhibit little inclination to build good washing machines, they certainly do produce state-of-the-art technology — and beyond — in any area in which they focus their main efforts. (We do lead the Soviets in some areas such as computers, computer software, miniaturization, etc.)

Once before, a modern nation - the United States - developed a mighty weapon in secrecy and used it to force a powerful foe - Japan — to its knees. The mindbending atomic blows to Hiroshima, and shortly after to Nagasaki, showed once and for all that in the modern age technological surprise can prove instantly disastrous. Yet in our scientific arrogance, we have assumed that no one else will ever do such a thing. We have assumed that it certainly could never happen to us, and that the "secret weapon" scenario will never be repeated. On the contrary, it has happened again, someone else has done it, and it has happened to us.

It has also become fashionable in the West to believe that all the laws of physics are already discovered. We assume we already know all of them. While we have been pridefully crowing this tune, the Soviets have been steadily discovering new laws in secret, as well as new ways to circumvent the old laws.

We Have Given Up Defense in the Larger Sense

Meanwhile, to defend ourselves strategically, we have chosen to forego "defense" and rely almost totally on building a powerful strategic offense that is capable (we think!) of destroying our would-be enemies anywhere in the world. Our offensive striking power is based mostly on a triad of deterrent forces - land-based ballistic missiles, submarine-launched ballistic missiles, and strategic bombers. The cruise missile is presently being added to the triad. If this 4-part offense were nullified or destroyed by Soviet secret weapons, we would be powerless to prevent our own destruction and Soviet domination of the world.

We have been viewing ourselves as Samson, confident in the strength of our locks.

Yet literally our locks have been secretly shorn and the Philistines are already upon us. Indeed, Soviet energetics weapons are now capable of destroying our triad shield, our homeland, our armed forces in the field, and our population, quickly and efficiently. We have a new "gap" of monumental proportions: not a missile gap, not a submarine or bomber gap, and not even a particle beam or laser gap. We have a scalar electromagnetics or electrogravitation gap.

In this briefing, it is my purpose to show a portion of the Soviet weapons developments that have lead me to such dire conclusions. The Fer-de-Lance briefing is also an attempt to galvanize our leaders and scientists into action, for our present total vulnerability to the Soviet Fer-de-Lance weapons is intolerable and unacceptable.

Unless we achieve defenses — and quickly — our own demise in a fashion similar to the Hiroshima-Nagasaki scenario is inevitable and imminent.

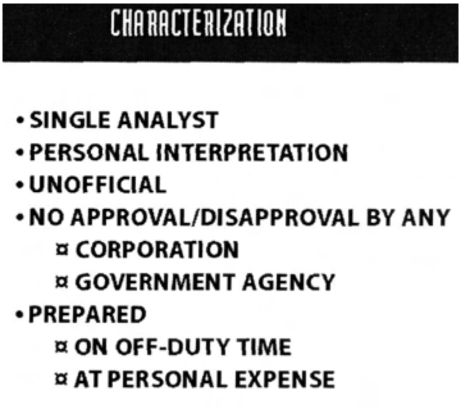

CHARACTERIZATION

- SINGLE ANALYST
- PERSONAL INTERPRETATION
- UNOFFICIAL
- NO APPROVAL/DISAPPROVAL BY ANY
    - ¤ CORPORATION
    - ¤ GOVERNMENT AGENCY
- PREPARED
    - ¤ ON OFF-DUTY TIME
    - ¤ AT PERSONAL EXPENSE

Slide 001: Characterization

We point out at the beginning that this briefing and its interpretation are the result of 22 years of analysis and effort by a single analyst. It is entirely unofficial. It is not approved or disapproved by any corporation, company, or government agency. It has been prepared by this analyst at nights, on weekends, on holidays, and during off-duty time.

It has been prepared mostly at personal expense, though several grants and support have been received from R. J. Reynolds III, Peter Kelly, Mike Bearden, Interdimensional Sciences, Association of Distinguished American Scientists, and others. Very valuable assistance has been received from the U.S. Psychotronics Association and the Planetary Association for Clean Energy. These contributions are deeply appreciated and most gratefully acknowledged.

Graphics and artwork support by Hal Crawford, Margaret Wilson, Tommy Neumann, Ron Cole, and Lee Giles has been invaluable. My sincere thanks go to these artists who have made the presentation vivid and imaginative. A great deal of background support was given by Joe Gambill, Frank Golden, Tom Herold, Ken Moore, Pete Kelly, Eike Mueller and Mel Bartlett and is deeply appreciated.

Finally, the help of many other persons and colleagues too numerous to enumerate is also gratefully acknowledged.

If the U.S. bureaucracy ever moves and develops defenses against scalar EM weapons, it will largely be due to the support of the persons and organizations who have freely given of their talents and resources to further this effort.

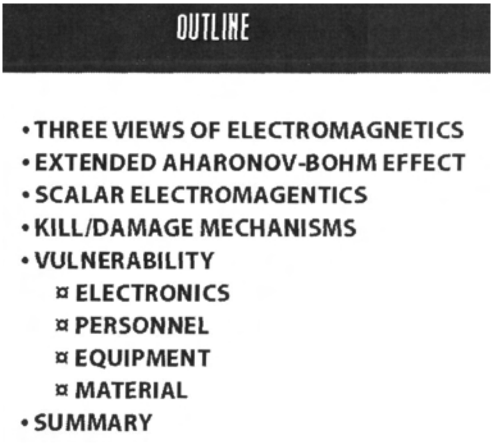

OUTLINE

- THREE VIEWS OF ELECTROMAGNETICS
- EXTENDED AHARONOV-BOHM EFFECT
- SCALAR ELECTROMAGENTICS
- KILL/DAMAGE MECHANISMS
- VULNERABILITY
  - ¤ ELECTRONICS
  - ¤ PERSONNEL
  - ¤ EQUIPMENT
  - ¤ MATERIAL
- SUMMARY

Slide 002: Outline

This presentation does not attempt to cover the complete field of energetics weapons developed by the Soviet Union. Instead, it concentrates on the major areas necessary to understand the type of weapons likely to be unleashed on our strategic and tactical installations and our troops and their equipment. It does not attempt to present the frightful bio-electromagnetic weapons the Soviets have developed to be unleashed on our populace at large and on our troops in the field. Also, the briefing does not dwell on the historical progression, but on the types of weapons themselves.

Of necessity, it presents several shortcomings in classical EM, and presents three differing views of electromagnetics and what can be done with them. The briefing particularly stresses the Aharanov-Bohm (AB) effect. This mesoscopic effect, which produces action at a distance by pure EM flux and not EM force fields, has been extended by the Soviet weapons developers into the macroscopic world around us.

In addition, we develop the basic concepts of scalar electromagnetics and how electrogravitation is achieved. The basic concepts of scalar interferometry and scalar resonance are briefly advanced, and a few of the major kill and damage mechanisms are presented. The nearly total vulnerability of our present electronic equipment, personnel, communications, vehicles, aircraft, ships, missiles, submarines, nuclear weapons, and materiel is stressed.

Finally, a short summary is given to highlight the main points of the briefing.

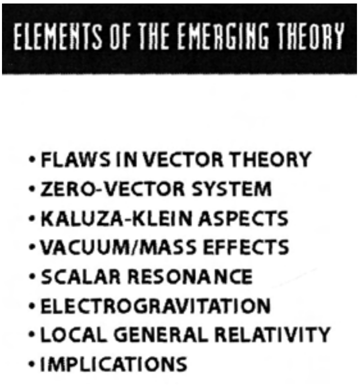

ELEMENTS OF THE EMERGING THEORY

- FLAWS IN VECTOR THEORY
- ZERO-VECTOR SYSTEM
- KALUZA-KLEIN ASPECTS
- VACUUM/MASS EFFECTS
- SCALAR RESONANCE
- ELECTROGRAVITATION
- LOCAL GENERAL RELATIVITY
- IMPLICATIONS

Slide 003: Elements of the Emerging Theory

Specifically, we will point out some flaws in vector mathematics itself, particularly with the concept of the zero force vector. The zero force vector is a system of forces that sum to a zero resultant. Hence the components of the summation represent a patterned stress in the medium to which they are applied, or in which they are imbedded. This includes the vacuum (spacetime) medium. In classical electromagnetics, this vacuum stress due to a zero-vector summation of EM force fields has been totally omitted and ignored.

As such, the EM "zero" force-vector summation produces a "trapped internal EM flux and flux pattern, without resultant (external) force field" condition - precisely as does the Aharonov-Bohm effect. The components of the artificially zeroed system, however, can be transmitted and still maintain their special relationship and coherence. While the AB effect has been shown to hold for the mesoscale (a few thousands of angstroms), the zero-vector scalar EM effect can hold for hundreds of thousands of kilometers.

To provide a unified electrogravitation, we adapt Kaluza-Klein 5-dimensional gravitational concepts to the idea of the zero-vector stress system in vacuum-spacetime. We also point out how simultaneously varying the magnitudes of **the** force components of a stress, all in phase, produces a stress wave or scalar EM wave. Scalar waves are almost always absorbed and emitted by the nucleus of the atom, not by the electrons in orbit.

The relationship of mass and vacuum, and the constitution of the vacuum, are pointed out from the viewpoint of modern quantum mechanics.

How a scalar wave resonance differs from conventional EM resonance is developed briefly. Mass and inertia are the direct result of - and are - trapped scalar resonance. The trapping mechanism is the spin of the particle.

Severely limiting assumptions in ordinary general relativity (OGR) are pointed out. In OGR, it is assumed that the local frame is always a Lorentz frame, and never curved. In other words, local spacetime is always assumed to be flat. This **saves** the conservation laws, simplifies relativity, and reduces "general" relativity to special relativity with distant perturbations and curvatures.

By removing this ad hoc assumption, a much richer local general relativity results. This local general relativity is readily engineered. Note that, in OGR, the physicist has actually assumed that he can never "engineer" local general relativity! Indeed, with the scalar EM approach, he can easily do so, in contradiction to what is taught in all Western universities.

By engineering a local general relativity (LGR), the individual conservation laws can be violated locally. This includes the conservation of energy/momentum, and the conservation of charge, for example.

The major implication of this startling new engineering physics is that one can **engineer** physical reality itself. For example, elements can be transmuted with minuscule energy input, free energy devices are possible, action at a distance is possible, communication faster than light speed is possible, etc.

By using the zero-vector approach, the virtual state can be organized and made **largely** deterministic, rather than statistical. This means that the probabilities of the states propagated forward by the Schroedinger equation can be engineered and changed. Whether or not a certain quantum change shall emerge or not can be determined or substantially influenced in advance. Bohm's hidden variable **theory** now becomes directly engineerable. This is a drastic change to quantum mechanics and physics in general.

Another implication is that this is the final engineering, for it allows the direct engineering of physical reality itself. Humans must now find a way to resolve their differences peacefully, or shortly Man will destroy himself and his biosphere by his own hand.

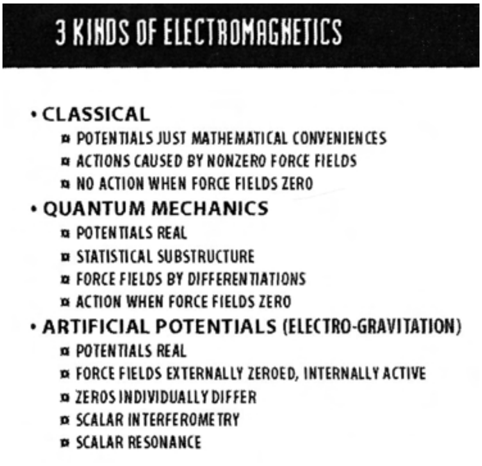

3 KINDS OF ELECTROMAGNETICS

- CLASSICAL
  - POTENTIALS JUST MATHEMATICAL CONVENIENCES
  - ACTIONS CAUSED BY NONZERO FORCE FIELDS
  - NO ACTION WHEN FORCE FIELDS ZERO
- QUANTUM MECHANICS
  - POTENTIALS REAL
  - STATISTICAL SUBSTRUCTURE
  - FORCE FIELDS BY DIFFERENTIATIONS
  - ACTION WHEN FORCE FIELDS ZERO
- ARTIFICIAL POTENTIALS (ELECTRO-GRAVITATION)
  - POTENTIALS REAL
  - FORCE FIELDS EXTERNALLY ZEROED, INTERNALLY ACTIVE
  - ZEROS INDIVIDUALLY DIFFER
  - SCALAR INTERFEROMETRY
  - SCALAR RESONANCE

Slide 004: Three Kinds of Electromagnetics

There are actually three kinds - or three views - of EM. These are (1) the classical view, (2) the quantum mechanical view, and (3) the scalar EM or electrogravitational view.

In the classical view, the potentials are just mathematical conveniences and do not physically exist. The real causative agents are the force fields, and there is no longer any electromagnetics going on if the force fields reduce to zero. Further, the ideas of "charge" and "charged mass" have been made erroneously synonymous.

Of course the classical view was formed from the idea of a thin material ether, with electricity as a thin fluid, long before the discovery of the electron. Since most earlier scientists studied string waves and these are transverse, the EM wave was modeled as a transverse wave. Also, detection equipment actually detected transverse waves. The role of electron spin and drift velocity, which would have shown that force-field-causing EM waves in the vacuum could only be longitudinal, was not yet discovered. Maxwell's equations and the classical approach became so engrained that the basic derivations were never corrected for more modern discoveries.

The quantum mechanical view, on the other hand, regards the potentials as the real physical actants, and the force fields are just effects derived from the potentials by differentiating operators. Classically oriented physicists have adamantly opposed this foundations requirement of QM because it would require nearly a complete redo of EM theory. It would also rather drastically change our ideas of physical reality. For years a controversy has raged around the Aharonov-Bohm effect (which demonstrates the reality of the potentials, among other things). Only this year - 1986 - have most physicists finally accepted the AB effect with its implications (see Physics Today, Jan. 86). However, no changes have yet been made to EM theory and the basic classical approach to electrical physics and engineering.

Yet even the QM view is flawed, since it has not examined the structure of EM forces which sum to a vector zero. Such a system produces stress, and if the summation is in the vacuum itself, it produces stress of vacuum/spacetime. Rigorously, this is a gravitational effect, and the energies of the various EM components in the local region are locked into an artificial potential. From general relativity, this type of potential where the energy density of vacuum is altered is a gravitational potential. From Kaluza-Klein unified theory, it is at least a 5-dimensional gravitational potential.

If the individual force vector components of the vector zero are varying in magnitude - say, all in phase - then they produce a gravitational wave. The energy density of the local vacuum is being rhythmically varied. Call such an EM wave a scalar EM wave, where, by "scalar" we imply that, to an external observer, the EM force vector resultants are identically zero, but the local gravitational potential of the wave is varying. Thus this is an electrogravitational wave, and vector zeroing of EM force fields constitutes a means of changing EM field energy into G-field energy. On the other hand, by breaking up the coherence of the zero-vector summation of the EM forces, nonzero EM resultants are recovered, constituting the change of gravitational energy into EM energy.

A simple means to break zero-summed coherence is by interference of two or more such zero-vector waves.

In this, third view of EM, action at a distance is easily possible, and is the norm rather than the exception. In addition, a new kind of resonance - scalar resonance - exists. The scalar EM wave does not interact with orbital electrons, but rather with the interior of the nuclei of atoms. Thus the new scalar EM resonance is between nuclei and within nuclei.

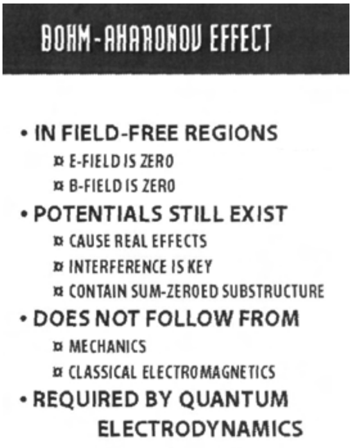

BOHM-AHARONOV EFFECT

- IN FIELD-FREE REGIONS
  - ¤ E-FIELD IS ZERO
  - ¤ B-FIELD IS ZERO
- POTENTIALS STILL EXIST
  - ¤ CAUSE REAL EFFECTS
  - ¤ INTERFERENCE IS KEY
  - ¤ CONTAIN SUM-ZEROED SUBSTRUCTURE
- DOES NOT FOLLOW FROM
  - ¤ MECHANICS
  - ¤ CLASSICAL ELECTROMAGNETICS
- REQUIRED BY QUANTUM ELECTRODYNAMICS

Slide 005: Bohm-Aharonov Effect

In 1959, Aharonov and Bohm published a fundamental paper in Physical Review, which pointed out the QM implications of potentials as the real entities, while force fields were derived effects. They showed that, even in the presence of zero EM force fields, the potentials may still exist and produce real effects in physical systems. They also suggested experiments to prove these predictions.

Interference of the potentials is the key mechanism producing real effects in charged particle systems, even in the presence of zero E-field and zero B-field. Unfortunately the AB paper did not address the issue of zero-summed systems of EM force fields as one way of producing artificial potentials having unique characteristics

At any rate, the "AB effect," as it came to be called, was rather hotly resisted and debated over the years, until finally it has generally been accepted as proven in 1986. The principle represents a violation of both classical mechanics and classical electromagnetics. It is required, however, by quantum mechanics and quantum electrodynamics. And experiment has proved it.

(See Y. Aharonov and D. Bohm, "Significance of Electromagnetic Potentials in the Quantum Theory," Physical Review, Second Series, 115(3), Aug. 1, 1959, p 485-491.).

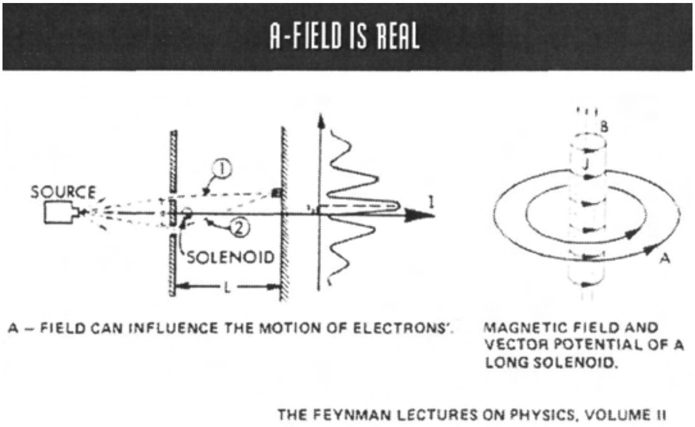

A-FIELD IS REAL

A – FIELD CAN INFLUENCE THE MOTION OF ELECTRONS'.

MAGNETIC FIELD AND
VECTOR POTENTIAL OF A
LONG SOLENOID.

THE FEYNMAN LECTURES ON PHYSICS, VOLUME II

Slide 006: A-Field is Real

In classical EM, the vector magnetic potential (the A-field) had been defined as a mathematical convenience by the equation

$$\nabla \mathrm{x} A = B \qquad [1j$$

But if the potentials are real, then conceivably the A field can be loosed from its enchainment to the $\nabla \mathrm{x}$ operator. In that case, it becomes a free, new, and independent field of nature with potentially unique characteristics. For example, its defining equation shows that magnetic force field can be made from it, and the rightmost term of the equation

$$E = -\nabla Ø - dA/dt \ [2]$$

shows that its time rate of change makes an electric field.

Let us explain this in more simple terms, and somewhat more precisely than conventional theory. We will use the Kaluza unified G-EM interpretation and electron flow in our explanation.

In the A-field, we have a certain kind of 5-dimensional G-potential which can bleed-off as EM force fields in two ways: (1) in a swirl fashion, where the vortex producing the swirl moves parallel to electron movement, and the swirling is a torque or spin, and (2) in a linear fashion, where the time rate of change of the A-potential produces a linear E-field on the electrons.

The first bleed-off as given by equation [1] constitutes the magnetic B-field, and the second bleed-off as given by the rightmost term of equation [2] creates a component of the overall electrical E-field. (Bleed-off of the electrostatic scalar potential produces the other component of the E-field).

Now in general relativity (GR) theory, "the" G-potential is just a conglomerate of many things, each of which has the characteristic of curving spacetime. "The" gravitational field is not a single thing at all, but is composed of a collection of many things.

Thus if we realize that both the electrostatic scalar potential (Ø-field) and the magnetic vector potential (A-field) are components of the 5-d G-potential, then we see immediately that bleed-off of these two components of the 5-d G-potential creates all normal EM force fields.

It follows that, if we produce a zero-vector summation of the two or more EM bleed-offs, we are actually "putting as much back in" to the 5-d G-potential through its A and Ø components as we are taking out electromagnetically. In that case, the 5-potential is in a state of equilibrium with respect to EM bleed-off. It is now forced to bleed-off in the only other way it can: as ordinary 4-dimensional gravitational field. Thus by vector-zeroing EM force fields, we turn EM field energy into G-field energy and vice versa, via the intermediary of the 5-potential.

At any rate, soon after publication of the Aharonov-Bohm paper, experiments showed that, if the magnetic field is trapped inside a long solenoid, a phase shift still is induced in the two-slit electron experiment, even though - classically - no contact of the enclosed magnetic field and the moving electrons occurs. This phase shift is explained by the fact that the freed A-field exists outside the trapping solenoid, even though the B-field does not. Consequently, interaction of this free A-field with the electrons produces a phase shift of the QM interference detection pattern.

This proves that A-field is real and causes physical effects.

It also proves that a form of action at a distance is real, just as required by quantum mechanics.

Years ago, Frank Golden and this author - together with Dr. William Tiller - experimented with "free A-field" devices. Golden went on to develop prototype transmitters and receivers and a prototype underwater communication system.

Since that time, Gelinas has patented several curl-free magnetic vector **potential** (free A-field) devices: see U.S. patent no. 4,447,779, May 8, 1984; 4,429,288. Jan. 31, 1984; 4,429,280, Jan. 31, 1984; and 4,432,098, Feb. 14, 1984. These patents are assigned to Honeywell.

(See also Theodor Kaluza, Sitz. Berlin Preuss, Adad. Wiss. 966, 1921.).

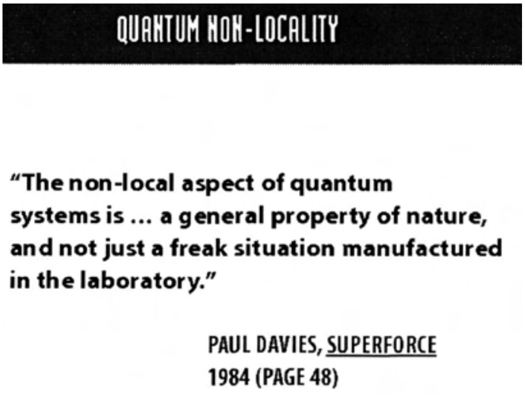

QUANTUM NON-LOCALITY

“The non-local aspect of quantum systems is ... a general property of nature, and not just a freak situation manufactured in the laboratory.”

PAUL DAVIES, SUPERFORCE
1984 (PAGE 48)

Slide 007: Quantum Non-Locality

Indeed, quantum systems exhibit nonlocal effects that are general properties of nature. These effects are not just freak situations manufactured in subtle laboratory experiments.

However, if spatial coherence in such microscopic effects can be induced and sustained, then action-at-a-distance can be obtained in large macroscopic systems. This is the engineering aspect of the scalar EM approach.

It is also the aspect that the Soviets have secretly weaponized for over three decades.

The zero-vector EM force-field summation of multiple EM waves is used to transport specific time-phased patterns of EM polarization of vacuum to a distance. There interference of two or more such patterns results in the interference of the internal patterns, breaking of the phase relations, and appearance of positive (added) or negative (extracted) EM energy in the intersection region.

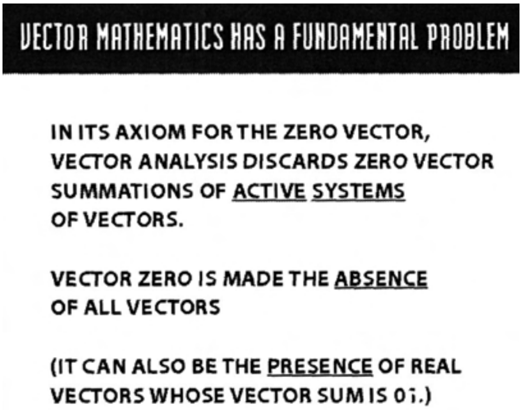

VECTOR MATHEMATICS HAS A FUNDAMENTAL PROBLEM

IN ITS AXIOM FOR THE ZERO VECTOR,
VECTOR ANALYSIS DISCARDS ZERO VECTOR
SUMMATIONS OF ACTIVE SYSTEMS
OF VECTORS.

VECTOR ZERO IS MADE THE ABSENCE
OF ALL VECTORS

(IT CAN ALSO BE THE PRESENCE OF REAL
VECTORS WHOSE VECTOR SUM IS 0ī.)

Slide 008: Vector Mathematics has a Fundamental Problem

In its concept of the zero vector, vector mathematics discards zero-vector summations of active systems of vectors. It replaces such a summation with a zero vector. This is fine for mathematics as an abstract system, but it is in error when applied to real electromagnetic force fields of nature.

In the abstract mathematics, a vector zero summation is made the "absence of all finite vectors". Further, all vector zeros are made equal. No concept of the "internal stress" of the zero vector exists in abstract vector mathematics.

However, physically the zero summation or "balancing" of vector forces in a medium represents stress in that medium. In the physical case, a vector zero summation system of non-zero vectors has a dynamic substructure, and this substructure is an individual.

Obviously, in the physical case vector zero summations may materially differ, both in the pattern of stress and the magnitude of stress. They cannot all be equated. Further, they are not the absence of vectors, but represent the presence of vectors in a special manner. Such a zero summation of EM vector forces directly stresses the "medium" - which may be the vacuum itself.

In the physical case, several changes to the axioms of abstract vector mathematics are required. (1) the "potential" of a vector zero must be taken into account, such as is represented by the sum of the squares of the magnitudes of its vector components. (2) the specific deterministic pattern of the vector components comprising the zero must be taken into account. (3) The dynamic variation in both the deterministic directions and deterministic magnitudes of the components and of the overall pattern must be taken into account. (4) Frequencies of the changes in the direction, magnitude, and actual makeup of the vector zero must now be accounted for. That is, time and wavelengths are rigorously aspects of the vector zero, and these may be deterministic variables. Since time itself is now a variable aspect of the vector, the vector zero system can affect its "rate of time flow" in the observer's system. (5) Since a "reference vector zero" can be established at any point of a vector magnitude, then individual vectors themselves may have dynamic substructures inside a special "zero reference" in and on the vector. The patterned potential of a vector is a reality.

This leads to a system of "vectors nested inside vectors" ad infinitum. In other words, it leads to an infinite-dimensional system, and the "opening" of every finite closed vector system through its vector zeroes.

For application to physical electrogravitational systems, at least 5 dimensions are required, four of space and one of time.

Here we still are considering only a special case where all vector zero summations represent EM force field energy locked in a gravitational potential, or gravitational force field energy locked inside the EM potentials. That is, we are prescribing a system where the only intertranslation of energy is among mass, EM field, gravitational field, and vacuum virtual energy (anenergy).

(See T. E. Bearden Toward a New Electromagnetics: Part III: Clarifying the Vector Concept, Cheniere Press, Santa Barbara, Ca. www.cheniere.org, 1983; Part 4: Vectors and Mechanisms Clarified, 1983. See also E. T. Whittaker, Proc. Lond. Math. Soc. 1, 367, 1903; Robert Bruce Lindsay and Henry Margenau, Foundations of Physics, Dover, New York, 1963, p. 283-287; Richard P. Feynman et al, The Feynman Lectures on Physics, Addison-Wesley, New York, **Vol.** I, p.2-4.).

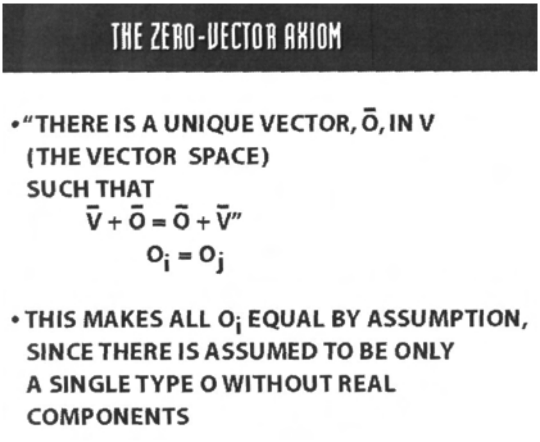

THE ZERO-VECTOR AXIOM

- "THERE IS A UNIQUE VECTOR, $\bar{O}$, IN V (THE VECTOR SPACE) SUCH THAT

$$\bar{V} + \bar{O} = \bar{O} + \bar{V}"$$

$$O_i = O_j$$

- THIS MAKES ALL O_i EQUAL BY ASSUMPTION, SINCE THERE IS ASSUMED TO BE ONLY A SINGLE TYPE O WITHOUT REAL COMPONENTS

Slide 009: The Zero-Vector Axiom

This slide shows a standard mathematical statement of the zero-vector axiom, used in many texts.

As can be seen, all zero-vectors are made identical, and no substructure is considered.

Such an abstract system of vector mathematics does not fit physical reality. However, when all one's EM foundations concepts are strongly conditioned in this fashion, the gravitational aspects of EM are discarded.

Further, EM theory, experiments, and equipments will be developed along these limiting lines. In that case, EM engineering of gravitational effects will not be developed. One will assume that it is impossible to have a locally curved spacetime, and hence all local frames will be Lorentz frames. Therefore the conservation laws will rigorously apply.

Further, the nonlocal quantum effects will stay firmly in the microscopic world where they belong. Physical macro-reality will stay stable and predictable in a classical manner.

General relativity (in curved spacetimes) will be restricted to the special case of the local special relativistic (uncurved) spacetime, with only distant perturbations (spacetime curvatures).

The world will stay sane and "normal", and the totally variable insanity of physical reality will remain bottled up in the minute microworld or the distant maelstrom of suns, stars, black holes, etc.

The Aharonov-Bohm heresy will stay kaput in the real world and will not be unleashed beyond mesoscopic reality — a few thousand angstroms or so.

With such an error in the application of vector mathematics to physical science, we become "flatland physicists," so to speak. We become like skimmer bugs on the surface of a pond; we have no appreciation of the dynamics of the depths below or of the heavens above.

Worse, we condition our development of instruments according to the fixed notions in our heads. Then we use these "biased" instruments to do experiments that reaffirm our notions. Any deviation suggested to this is considered heresy and nonsense.

And as Max Planck once pointed out, you will get a new physics only when the old physicists — who so adamantly oppose it — die off.

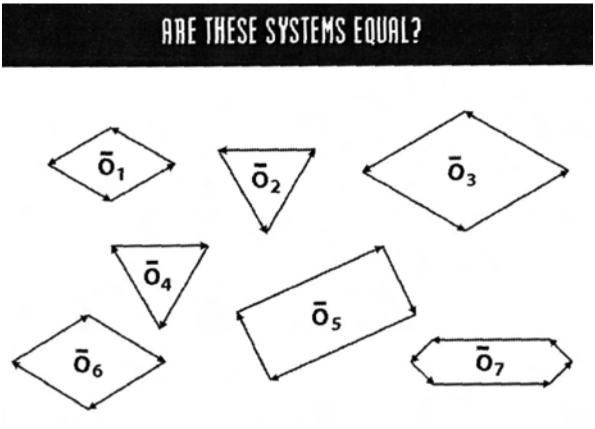
ARE THESE SYSTEMS EQUAL?

Slide 010: Are These Systems Equal?

Shown here are some representations of various very simple zero-vector systems. As can be seen, the stress magnitudes and the spin and dynamics of all of these systems are very different.

Further, their "stress potential" substructures are not composed of a huge collection of little random force vectors. Instead, their substructures are deterministic. If the components being put into the zeros are varied in direction and magnitude, but always sum to a zero resultant, then highly complex substructure dynamics may be created and utilized, infolded (Bohm's term) inside the zero vector.

In theory one can establish "channels" of communication and power (magnitude) transmission without ever surfacing a nonzero EM force field. In practice one can do this with very little EM spillout. Thus one can establish electrogravitational channels and energy transmission inside normal EM potentials and/or ordinary EM carrier waves.

One can use a conventional system of EM potentials, force fields, and waves as a special kind of "wiring circuit" in and through which to transmit and produce electrogravitational effects. By distant interference, EM effects at a great distance can be accomplished, yet no "ordinary EM energy" has passed between the transmitters and the distant interference zone.

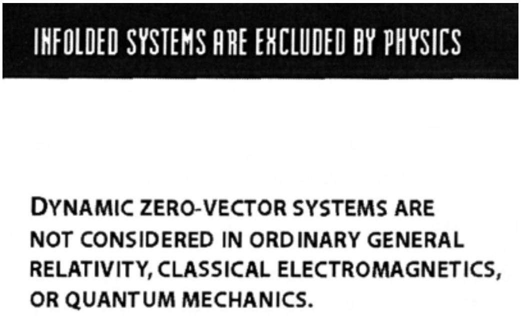

INFOLDED SYSTEMS ARE EXCLUDED BY PHYSICS

DYNAMIC ZERO-VECTOR SYSTEMS ARE NOT CONSIDERED IN ORDINARY GENERAL RELATIVITY, CLASSICAL ELECTROMAGNETICS, OR QUANTUM MECHANICS.

Slide 011: Infolded Systems are Excluded by Physics

Unfortunately, these infolded dynamic zero-vector systems have been eliminated from physics.

They are omitted in classical EM, ordinary general relativity (OGR), and quantum mechanics.

That is, they have been omitted in Western physics.

They have not been omitted in secret Soviet weapons labs and weapons development programs.

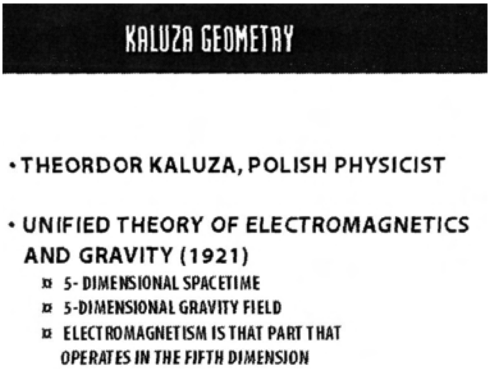

KALUZA GEOMETRY

- THEORDOR KALUZA, POLISH PHYSICIST
- UNIFIED THEORY OF ELECTROMAGNETICS AND GRAVITY (1921)
    - ¤ 5- DIMENSIONAL SPACETIME
    - ¤ 5-DIMENSIONAL GRAVITY FIELD
    - ¤ ELECTROMAGNETISM IS THAT PART THAT OPERATES IN THE FIFTH DIMENSION

Slide 012: Kaluza Geometry

In 1921, Theordor Kaluza, a Polish physicist, published a unified theory of electromagnetics and gravitation. Albert Einstein, who had had the paper for two years, recommended his paper for publication. In that theory, five dimensions - four space and one time - are utilized in the basic model. This gives a 5-dimensional spacetime.

In the model, electromagnetics and ordinary gravity are two aspects of a single more fundamental field: the 5-space gravity field. Electromagnetism is that part of the 5-field that operates (bleeds-off) in the fifth dimension.

The ordinary 4-space G-field is the small residue that spills over into our ordinary 4-space, and doesn't slide around into the fifth dimension and bleed-off there as electromagnetics.

Implicit in the theory, but not explicitly stated, is the fact that the 5-space G-potential bleeds-off in two fashions: (1) in the 5th dimension nearly unopposed, to produce what we see as EM force fields, and (2) in the ordinary 4-space we live in, which we see as ordinary gravitational field.

Normally almost all the force field bleed-off is in the fifth dimension as EM; only a minuscule bit bleeds off as 4-gravity.

Just as one example, between two electrons the 5-space G-potential bleeds-off into electric force field about 10^{42} times as much as it bleeds-off into 4-space G-field.

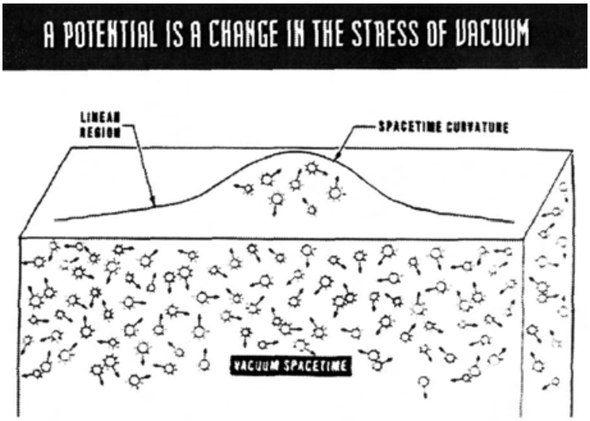

A POTENTIAL IS A CHANGE IN THE STRESS OF VACUUM

Slide 013: A Potential is a Change in the Stress of Vacuum

In physics, the idea of a "potential" is very poorly defined, if at all. The normal "definition" for the electrostatic scalar potential, for example, is not a definition at all. Instead, it's an abstract operation that tells how to mathematically calculate the magnitude of the potential, by pushing a unit charge in from infinity, against the potential field.

Now ultimately a definition must be an identity statement, not an operational statement about something.

Since I could find hardly anyone who actually understood what a potential was, and how or of what it was composed, I simply took quantum mechanics at face value and constructed this model.

First, the modern view of the vacuum is that it is not an emptiness, but a plenum. It's teeming with an incredible amount of raw energy, existing totally as the temporary bits of energy of virtual particles. That is, the vacuum "energy" exists as the nonintegrated energies of little particles which appear from nothing fare spontaneously created) and disappear into nothing (are spontaneously annihilated) almost instantly. This happens so fast that the little particle and its energy cannot individually be detected; it doesn't hang around long enough.

Hence the fleeting little booger is called a "virtual" particle. Like, "We had 'im there man, for just a moment, but he was gone before we could grab 'im!"

This kind of ghostly particle, however, is very real in modern physics. All observable forces are theorized to be due to the integration or collection of a large number of virtual forces created by exchange of these little particles.

However, this implies a peculiar thing about the vacuum "energy." Actually it's vacuum energies, for each little bit of energy only exists momentarily, then returns to the nothingness from which it came. That is, vacuum virtual energies are totally unintegrated. Each "bit" of virtual energy exists individually. These virtual energies cannot be "added up" to compute the "available energy" unless some collector or integrating mechanism puts them together.

That is, unless some kind of "zipper" is there to "zip them together" into macroscopic, observable energy. The usual "zipper" is a spinning, observable particle of mass. We say that the vacuum energy is unzipped and hence unobservable in that state. We say that "observable energy" is just zipped-together vacuum energies - integrated by and on a spinning, observable particle of mass.

So the vacuum can be visualized as a special sort of violent, unzipped plasma, where the particles of the plasma are fleeting and do not last. We can speak of it also as a sort of special unzipped gas, in the same manner.

The "pressure" of the vacuum gas we refer to as "stress." Due to its violent boiling activity, the vacuum gas is always under very high stress.

This "stressed virtual plasma" identically IS the vacuum and identically IS spacetime. Length, time, frame, mass, etc. - all arise by zipping operations (or understood zipping operations) in and of this raw vacuum/spacetime. When one uses the vacuum notion in this manner, one now uses the term "ether" again. However, this is not the old "thin material ether that hangs around"; this is an entirely new kind. It's a virtual flux and a virtual plasma.

The ether is also what we call "spacetime" in relativity. As can be seen, spacetime is stressed. Further, spacetime has a substructure.

By an uncurved spacetime, we mean one in which the stress of these virtual particles (the "pressure in the ethereal gas," so to speak) is constant from one place to another and from one time to another. Indeed, we also should mean that the stresses of the individual components of the entire plasma are constant from one place to another and from one time to another.

By definition, when we determine the lengths between every two points, we determine a frame. (Actually, we have prescribed a universal "length zipping" operation/mechanism as well as its characteristics.). A "linear frame" or "Lorentz frame" is one in which the pressure or stress remains constant. It may be higher than ambient vacuum, however, due to a particle's or an object's motion through the observer's ether. In the case of constant velocity, the particle/object encounters a higher level of virtual particle flux in the observer's ether, like a vehicle moving through raindrops. It encounters a constant rate of flux, however. In such constant velocity case, the moving object's frame is said to be "rotated," but not curved, with respect to the laboratory frame of the observer.

In a "curved" spacetime, we mean one in which the stress of vacuum increases or decreases from one place to another, or from one time to another, or both. At one fixed location, if spacetime is curved, then the stress is increasing or decreasing as a function of time. That is, the flux density of that area is changing. We may visualize the local frame as undergoing angular acceleration, rotating more or rotating less. This is a non-Lorentz frame, or curved spacetime. It is also a nonlinear vacuum.

In such a vacuum, local gradients exist in the flux of virtual particles. If affected by (coupled to) one or more of these gradients by a nonzero coefficient, a local object experiences effects (forces and actions) "without observable cause." Observably, conservation laws may be locally violated by these "virtual rivers" of vacuum by coupling, just as a paddlewheel dipped in a river violates its own local "conservation of energy" due to the river providing an energy source to it.

One must be very careful with the "pressure" analogy, however, when one utilizes unified theory (Kaluza theory). We now have a virtual plasma vacuum in five dimensions, not four. But the basic notions to enable our visualization and understanding still apply.

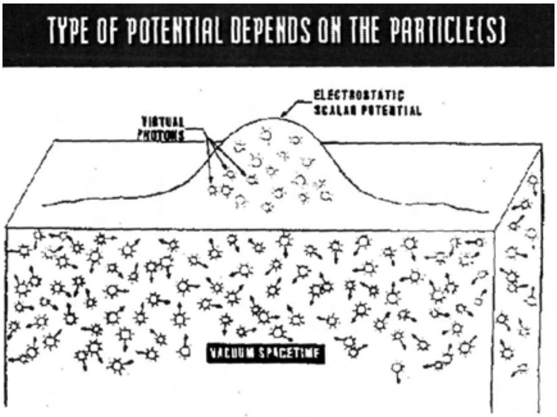
TYPE OF POTENTIAL DEPENDS ON THE PARTICLE(S)
ELECTROSTATIC SCALAR POTENTIAL
VIRTUAL PHOTONS
VACUUM SPACETIME

Slide 014: Type of Potential Depends on the Particle(s)

Now one can see that, by choosing the type or class of virtual particle, and looking at its potential or stress in the vacuum, one can have many kinds of "potentials" existing in the overall "gravitational potential" of vacuum spacetime.

For example, the stress of the virtual photon flux (which is what causes electrical charge) is called "electrostatic scalar potential."*

We can choose any other class of virtual particle we wish, and there exists a potential (and "change") for it. There are quark potentials, neutrinic potentials, etc.

Indeed, one of the reasons for ignoring Kaluza unified theory for so long was that it predicts a great many types of potentials and fields which have never been observed and which are unknown. Approximations, which neglected all these mysterious, and unknown fields, gave erroneous results. Perplexed physicists, seeking to simplify matters, simply turned away from it in frustration. They returned to it in the mid-70's when it appeared that 11-dimensional Kaluza-Klein theory possibly offered a complete unified theory.

Actually, the diversity of new fields in Kaluza theory was its strength not its weakness. That they are presently unobservable and undetectable is beside **the** point. Neither is time directly observable; however, we have worked out handy procedures and measurements of spatial quantities, which allow us to infer **time.** We have not just tried to drop it from physics!

And indeed the Kaluza theory is consistent with experiment when the higher fields are included. The message is, we must work out "clocks" for these new potentials and fields, so that they can be inferred with at least some degree of precision

- The character of movement also determines the type of potential. The longitudinal (radial) movement of the virtual photon flux is implied in electrostatic scalar potential. The swirl (tangential) component of this flux might be taken as the magnetostatic scalar potential - a magnetic pole - when the cw and ccw components of the swirl balance, but the sum of their absolute values differs from the sum of the absolute values of the corresponding tangential components in the swirl flux of the local ambient vacuum. If this swirl stress is higher than the vacuum swirl stress, this constitutes a north magnetic pole. If lower, it constitutes a south magnetic pole. If there is a prevalence of direction (cw or ccw) in the swirl (i.e., one component exceeds the other), this corresponds to the magnetic vector potential (the A-field) when the A-field is freed from the magnetic force field (B-field) — i.e., when A-field is freed from its $\nabla \times$ operator in the equation $\nabla \times A = B$. The bleed-off of the excess swirl stress from the north magnetic pole to the deficient swirl stress of the south magnetic pole constitutes the magnetic force field, B — usually referred to simply as the "magnetic field."

A POTENTIAL EXTENDS TO INFINITY & INVOLVES THE ENTIRE UNIVERSE

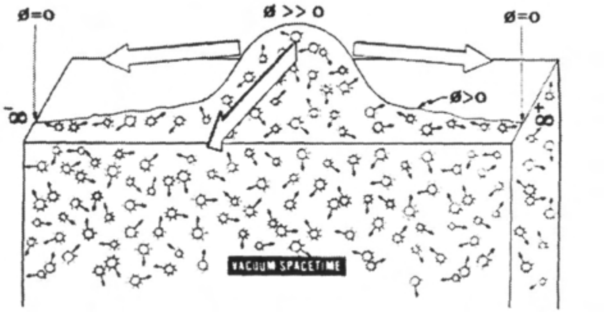

Slide 015: A Potential Extends to Infinity & Involves the Entire Universe

As shown on this slide, the change in the stress of vacuum due to a potential tapers off to infinity. Its magnitude normally does not reduce to zero until infinity.

Some types of potentials reduce much faster or slower than others, however, and so - at some distance away from a common origin of the potentials, one or more may be neglected in its (their) overall effects on an experiment or system.

Also, the speed of propagation of potential is highly dependent upon (1) what type of virtual particle or particles produce its stress, (2) its magnitude, (3) its composition, and (4) the presence or absence of coupling objects and other interacting potentials.

Fundamental observable particles are like little spray pumps and little vacuum cleaners at the same time.

Each is emitting virtual particles into the vacuum in a spray or flux, and at the same time it is absorbing virtual particles from the vacuum spray or flux. It's a little dynamo, and nature furnishes its driving energy unceasingly.

However, each little virtual particle it emits is itself such a little simultaneous pump and vacuum cleaner. That is, it's also emitting an even finer (and faster) flux of smaller virtual particles, and at the same time it's also absorbing flux al this time finer level.

"Bigger fleas have smaller fleas to bite em;

And so on ad infinitum".

We may consider the vacuum to be made of an infinite number of virtual state layers or levels.

It is not too difficult to show that each of these successively deeper, nested "layers" of virtual state corresponds to a successively higher dimension being added to our 4-space basic spacetime. So hyperdimensions and deeper levels of virtual state are one and the same thing.

The basic "speed" of the first layer is c, the speed of light.

The basic "speed" of the second layer is c^2.

And so on.

This is interesting. We may directly engineer the virtual state by means of the vector zero (scalar electromagnetics) approach. By nesting vector zeros inside other vector zeros, we may directly engineer the deeper layers of virtual state, and consequently hyperdimensions.

Scalar electromagnetics thus is virtual state engineering and hyperspatial engineering at one and the same time.

Superluminal communications systems, hyperspace drive, and materialization and dematerialization are all hypothetically possible, using scalar electromagnetics. As the technology develops, we should see the development of many of the systems long thought impossible except in science fiction.

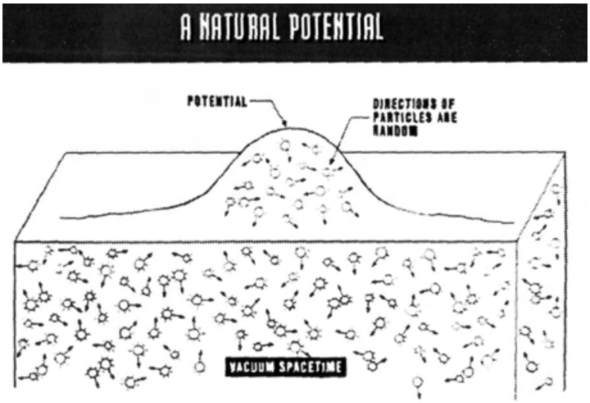

A NATURAL POTENTIAL

Slide 016: A Natural Potential

There are two broad categories of EM potentials, depending upon the way in which they are formed.

The two categories of potential formation are: (1) natural, and (2) artificial.

The difference is in the virtual particle flux substructure that comprises the potential.

If the substructure of emerging and vanishing virtual particles is random and without deliberate order (polarization) except in one broad, overall sense, then that is a natural potential. As such, there is no deterministic functioning going on inside the substructure of the potential itself. The potential can only act "as a whole" on a charged particle system.

Natural potentials have substructures of random virtual vector components. Any small amount of coherence as a function of distance vanishes quickly (on the order of a few thousand angstroms at most, according to present Aharonov-Bohm experiments).

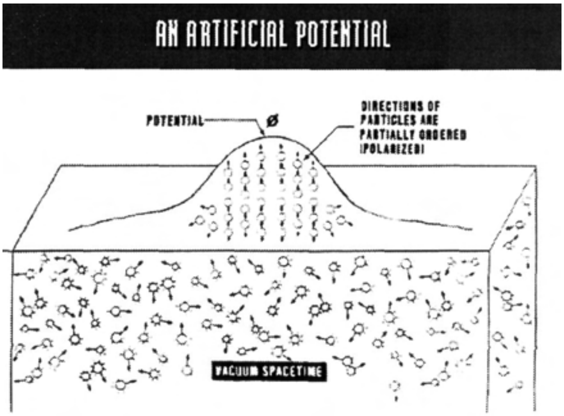

Slide 017: An Artificial Potential

An artificial potential by definition has a substructure composed of deterministic observable vector components, summed to an overall zero vector. Coherence as a function of distance can be maintained over enormous macroscopic distances - even hundreds of thousand of kilometers - by simultaneous transmission of the entire cluster of substructure components as a coherent "zero" group.

To the conventional linear EM detector, at any point along its transmission path, this substructure is detected as a zero-E vector and a zero-H vector. Hence the conventional detector does not see the artificial potential, even if its "stress magnitude" (a function of the magnitudes of all summed components) changes.

Action at a great distance is possible with this artificial potential, however, if a highly nonlinear situation is met so that the phasing of the components is broken or significantly altered. In that case, the components do not sum to zero after their dephasing, and real EM force fields emerge. This "dephasing" can be made to occur at the distant nonlinearity.

Action at a great distance is not possible with the natural potential, but is possible with the artificial potential.

Further, with the transmitted artificial potential, VO must be applied from the transmitter to the distant interruption zone, as if there were no intervening space between.

Note that VO may be positive or negative. Thus energy may emerge at the distant disruption, or be extracted from there. In the first case, energy is input to the transmitter, to re-emerge at the distant dephasing zone. In the latter case, energy is extracted (disappears) from the distant dephasing zone and is received (reappears) back at the transmitter

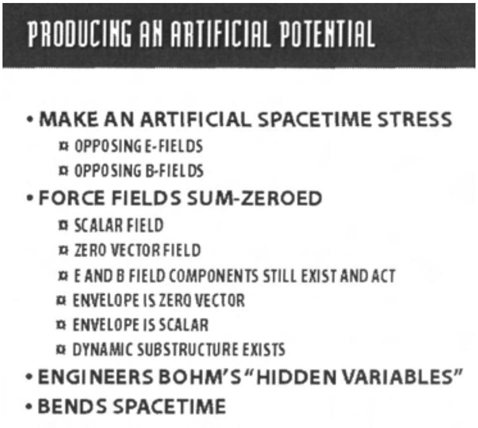

PRODUCING AN ARTIFICIAL POTENTIAL

- MAKE AN ARTIFICIAL SPACETIME STRESS
  - ¤ OPPOSING E-FIELDS
  - ¤ OPPOSING B-FIELDS
- FORCE FIELDS SUM-ZEROED
  - ¤ SCALAR FIELD
  - ¤ ZERO VECTOR FIELD
  - ¤ E AND B FIELD COMPONENTS STILL EXIST AND ACT
  - ¤ ENVELOPE IS ZERO VECTOR
  - ¤ ENVELOPE IS SCALAR
  - ¤ DYNAMIC SUBSTRUCTURE EXISTS
- ENGINEERS BOHM'S "HIDDEN VARIABLES"
- BENDS SPACETIME

Slide 018: Producing an Artificial Potential

AN artificial potential is deterministically patterned spacetime stress, made by opposing E-fields and/or B-fields so that they sum to vector zeros in a special pattern.

The resulting zero-summed envelope has no EM force field, to an external observer/detector.

However, the infolded E-field and B-field vector components still exist and act. They may dynamically vary, so long as their summation is always kept to zero.

The simplest variation is to vary all their magnitudes at once, by the same degree. In that case, each one comprises an "EM wave." However, the summations of this cluster or "locked group" of waves still exhibit a zero-E and zero-B field to any external observer/detector. In other-words, to an external observer, one now has a varying wave of pure spatiotemporal stress, but one that has a deterministic structure. This is a scalar EM wave, or electrogravitational wave. It is also an alternating current of specific scalar pattern.

Varying the stress of spacetime locally, curves it locally. This violates the conventional assumption of restricted general relativity that local spacetime is uncurved (is a Lorentz frame).

By use of scalar EM waves with deliberate substructures, one can engineer Bohm's "hidden variables" so that quantum mechanics becomes deterministic rather than statistical. This is a drastic change to the common (Bohr) interpretation of quantum mechanics.

And Einstein's intuition that God does not play dice with the universe turns out to be correct after all.

Since physicists haven't seen where the real game was being played, it has all seemed bewilderingly statistical to them.

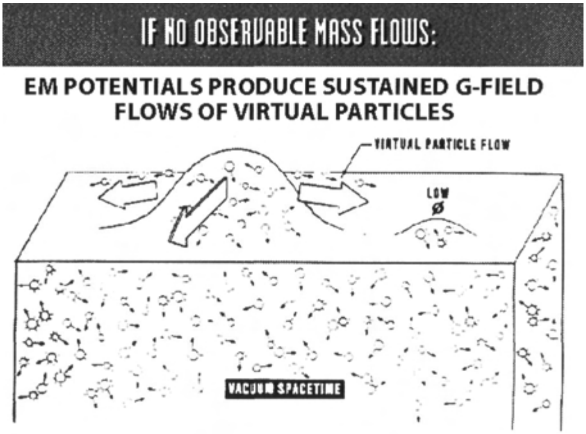
IF NO OBSERVABLE MASS FLOWS:

EM POTENTIALS PRODUCE SUSTAINED G-FIELD FLOWS OF VIRTUAL PARTICLES

Slide 019: If No Observable Mass Flows:

Since there are no observable mass particles flowing in vacuum, there are no observable force fields produced. Only virtual force fields can be produced in the virtual particle medium that is vacuum itself.

Thus (here is no observable E-field in the vacuum surrounding a charged point. There is, however, a virtual E-field there. When an observable charged particle such as an electron is introduced in the surrounding vacuum and "couples to" (integrates, zips together) the virtual E-field, an observable E-vector force is produced on and of the observable charged particle.

(For the classically trained electrical engineer or electrical physicist, the statement that no E or B fields as such exist in vacuum, is usually bewildering. Let me point out that any so-called "vector field" (such as the assumed E and B vacuum fields) can mathematically be replaced with two scalar fields. See E. T. Whittaker, Proc. Lond. Math. Soc.l, 366, 1903. What we are saying here is that the definition of an E field is in terms of force per unit charged mass. The scalar fields - which are actually what exist in vacuum - provide only a virtual or unzipped E field, until an observable spinning particle couples to both of them by virtue of its "dynamo flux pump" action. The ensemble, then, of two electrostatic scalar potentials coupled to a spinning observable particle, constitutes and is the so-called "E-field.")

When detecting these "vacuum E-fields," it is the free electrons in the electron gas in our probe or antenna which couple to the two "Whittaker scalar fields". These electrons produce ensembles that interact with each other collectively.

Charges in this electron-gas coupled medium is what we actually detect - not "what is in the vacuum."

To repeat this again for emphasis: The usual detector is an "electron-wiggle" detector. It detects changes in its own conduction electron gas, not in the vacuum itself. That is, the disturbance in the virtual-particle vacuum interacts with the observable particles of the electron gas, if (and only if) the spins of these observable particles couple the vacuum disturbance to the electrons and integrate their virtual components. After integration, an observable disturbance of the integrating object - say, the electron - results. It is this electron gas disturbance that is "detected" by almost all orthodox EM detectors.

If the spin of the observable conduction electrons cannot couple the electron to the vacuum flux disturbance, then the normal "simple" detector will not detect the disturbance. (By a "simple" detector we mean one in which the electrons are able to couple to the vacuum disturbance! Little circular definition here!)

Now most potentials reach to infinity before reducing to zero. The change in the virtual particle flux intensity of vacuum - which comprises the potential - decreases with distance from the potential. The magnitude of the change tails off" toward zero as one approaches infinity.

To any finite distance, then, there exists a decreased gradient in the change of the virtual flux intensity of vacuum, from a potential. Therefore virtual particles are flowing in the direction of the decrease of this gradient, just as gas molecules flow from a region of high pressure toward a region of lower pressure.

So there is a virtual particle "river" in the vacuum between any two separated points of different potential magnitude. The type of potential determines the type of virtual particle(s) in the river.

If the potential is natural, the gradient river does not carry any coherent substructure.

If the potential is artificial, the gradient river carries the coherent substructure everywhere within it. In this case, there is a flow or "river" of the virtual structure of this coherent pattern in the vacuum between two separated points of different "potential" in that pattern.

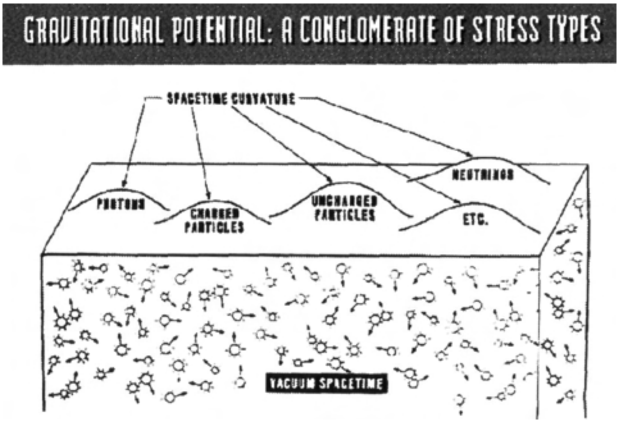
GRAVITATIONAL POTENTIAL: A CONGLOMERATE OF STRESS TYPES
SPACETIME CURVATURE
NEUTRINOS
PROTONS
CHARGED PARTICLES
UNCHARGED PARTICLES
ETC.
VACUUM SPACETIME

Slide 020: Gravitational Potential: A Conglomerate of Stress Types

Rigorously, all EM potentials are actually part of the overall 5-dimensional gravitational potential.

There is no such thing as "the" singular gravitational potential: instead, it is a conglomerate of different stress types and patterns, each of which is named for the type of action that produces it.

The movement of charged particles, for example, creates electromagnetic potentials. At any point in vacuum, the potential consists of a flux of virtual particles.

The vacuum contains a great variety of particle fluxes. There are virtual photons, virtual electrons, virtual positrons, virtual protons, virtual pions, virtual neutrinos, etc.

The conglomerate stress from all these virtual particle stresses constitutes the overall gravitational potential

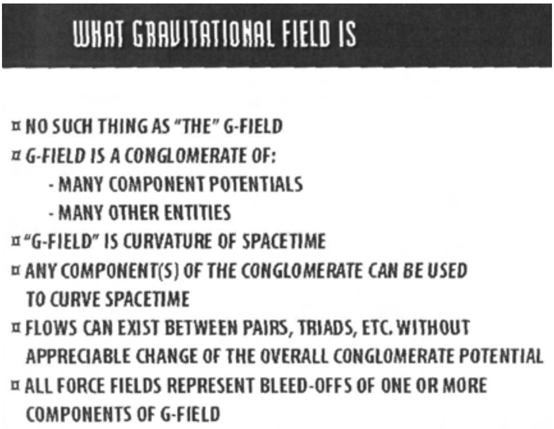

WHAT GRAVITATIONAL FIELD IS

¤ NO SUCH THING AS "THE" G-FIELD
¤ G-FIELD IS A CONGLOMERATE OF:
  - MANY COMPONENT POTENTIALS
  - MANY OTHER ENTITIES
¤ "G-FIELD" IS CURVATURE OF SPACETIME
¤ ANY COMPONENT(S) OF THE CONGLOMERATE CAN BE USED TO CURVE SPACETIME
¤ FLOWS CAN EXIST BETWEEN PAIRS, TRIADS, ETC. WITHOUT APPRECIABLE CHANGE OF THE OVERALL CONGLOMERATE POTENTIAL
¤ ALL FORCE FIELDS REPRESENT BLEED-OFFS OF ONE OR MORE COMPONENTS OF G-FIELD

Slide 021: What Gravitational Field Is

As previously stated, there is no such single thing as "the" gravitational field, as is assumed in the Newtonian sense.

G-field is a conglomerate of many component potentials and other entities.

Rigorously, anything that "curves spacetime" is a gravitational field.

In the modern view, all forces ultimately arise, by some means, from the curving of spacetime. Thus all forces and force fields are related to - and caused by, so to speak - gravitational field.

If the vacuum stress is uniform from one place to another in an observer's **frame** then the observer's spacetime is uncurved. The observer's frame, is said to be linear or uncurved; or a Lorentz, frame. In such a situation the conservation laws rigorously apply for macroscopic, closed systems.

If the vacuum stress is not uniform from one place to another, then the spacetime is curved. In such a situation the conservation laws may be violated for macroscopic systems, since they are "opened" to the vacuum stress, and vacuum virtual particle flux gradients exist across the system or portions of it.

Note that the overall stress magnitude may be constant across a region, but its composition may change. That is, two or more components may vary canonically. In that case, the spacetime is uncurved in the gross external sense, but contains specialized "internal" curvature patterns locally. Depending upon reaction to the canonical infolded curvature patterns, some macroscopic systems will still exhibit conservation, but certain other macroscopic systems may not.

An example is symmetry breaking. Here charge, parity, and time symmetry may be violated individually or in pairs, but not all three simultaneously. An overall conservation law is obeyed, but any two of the three conservation laws can be (und are) violated.

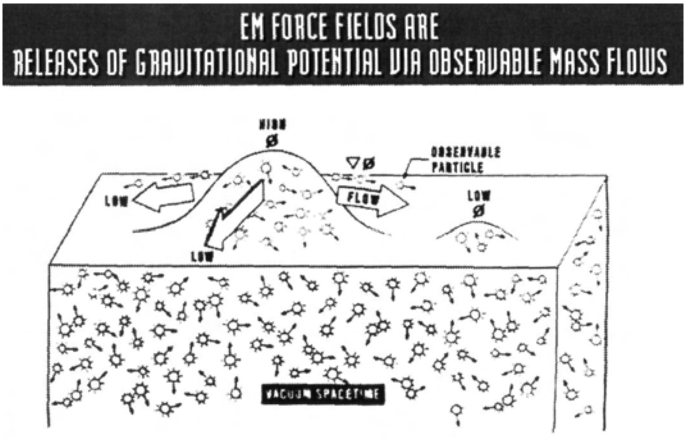

EM FORCE FIELDS ARE
RELEASES OF GRAVITATIONAL POTENTIAL VIA OBSERVABLE MASS FLOWS

Slide 022: EM Force Fields are Releases of Gravitational Potential via Observable Mass Flows

In Kaluza theory, we may take EM force fields to be the 5th dimensional "bleeding-off" of a 5-G potential. However, in vacuum alone this bleeding-off is totally within the virtual state. That is, only virtual EM force fields exist in vacuum.

By the ordinary term "EM force fields," physics has chosen to imply measureable or observable E and B force fields.

That implies that the 5-G potential gradient flows of virtual particle flux must be coupled to observable charged particles - such as electrons, protons, ions, etc. - before observable E and B force fields exist.

Rigorously, E and B force fields consist of the virtual E and B force fields coupled to observable charged particles. They do not "cause" a particle to accelerate; they are the product of the particle and its acceleration.

As these observable particles are themselves "spray pumps" producing virtual particle flux, then a collection of them represents an increased or decreased **flux** (for negative or positive charge) vis-a-vis the ambient background flux of vacuum. Nature furnishes the continuous power to drive these "virtual flux" pumps.

Normally, EM potentials are formed in natural and manmade electrical circuits by collections of these observable particle "spray pumps." Such collections of increased or decreased "spray flux" density, of course, represent 5-potentials, gravitationally.

Release of these pumps in conductors or in the vacuum itself results in creating E-fields and B-fields on and of the moving observable charged particles. But release of the observable-particle spray-pumps from the collection (the potential "pressure head" or "source") reduces the potential or "pressure" at the source.

Thus the formation of E and B fields represents the release of the 5-potentials. Hence EM force fields are the bleed-off of 5-dimensional G-potential via observable mass flow.

Since classical EM always seeks to create the force fields, it always bleeds-off and discards the gravitational effects that could be otherwise achieved.

To allow orthodox EM flow is to dissipate the gravitational effects.

Strangle the orthodox EM flows, and you can keep and use the amplified gravitational effects.

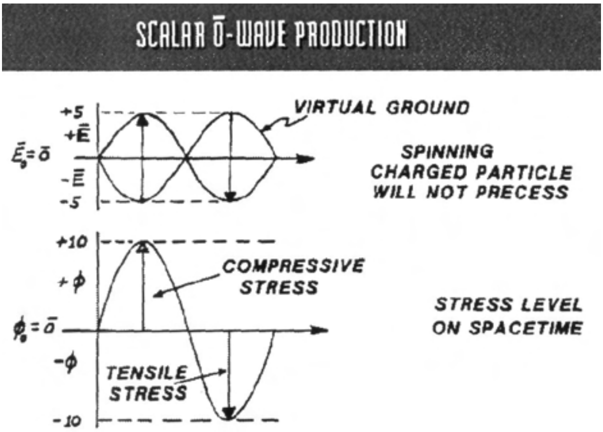

SCALAR Ō-WAVE PRODUCTION

+5
+Ē
$\bar{E}_0 = \bar{0}$
-Ē
-5
VIRTUAL GROUND
SPINNING
CHARGED PARTICLE
WILL NOT PRECESS
+10
+φ
$\phi_0 = \bar{0}$
-φ
-10
COMPRESSIVE
STRESS
TENSILE
STRESS
STRESS LEVEL
ON SPACETIME

Slide 023: Scalar O-Wave Production

We now visualize the formation of waves of pure stress in the spacetime medium (in the vacuum). These we call scalar EM waves, Tesla waves, electrogravitational waves, longitudinal EM waves, waves of pure potential, electrostatic/magnetostatic waves, and zero-vector EM waves. All these terms are synonymous. Each sheds its own particular light upon the nature of these waves or of their original discoverer, Nikola Tesla.

We use a gedanken experiment, or thought experiment, in which we can be "perfect."

Thus we have two single-frequency EM sine waves whose E-field componenls are shown on the slide. The two waves are of the same frequency, traveling together in the same direction, and superposed 180 degrees out of phase with each other.

In this case, at any spatial point, the summation E and B fields are vector zeros.

However, if we plot the spatiotemporal (vacuum) stress induced by the wave, wo see that it constitutes a sine wave, with compressive stress in one half cycle **and** tensile stress in the second half cycle.

Rigorously this defines a "longitudinal" EM wave - or what Tesla called a "sound wave in the nonmaterial ether."

Also, rigorously it is a gravitational wave, for it is a wave of the curvature of spacetime (nonlinearity of vacuum) itself. That is, what is changing in the wave is the vacuum stress, or intensity of the virtual particle flux of vacuum. That is identical to changing the curvature of spacetime. In one half-cycle, spacetime is curved positively. In the second half-cycle, spacetime is curved negatively.

Since the increase or decrease of the intensity of virtual particle flux (vis-a-vis the ambient vacuum's virtual flux intensity) represents electrical charge, then in one half-cycle negative charge is represented, and in the other half-cycle positive charge is represented. This directly explains the "positron-electron pair" representation of an electromagnetic photon - the "photon" being one wavelength.

In one half-cycle, time moves slower. In the second half-cycle, time moves faster. Thus scalar waves can also be considered to be "tempic" waves (to use Wilbur Smith's term), or oscillations of the rate of flow of time itself, about the ambient rate of time flow. Since these oscillations are variations in the curvature of spacetime, then they represent gravitational or force-generating waves, when coupled to a mass.

Variations in the rate of flow of time produce force, just as any other type of curvature in space-time does.

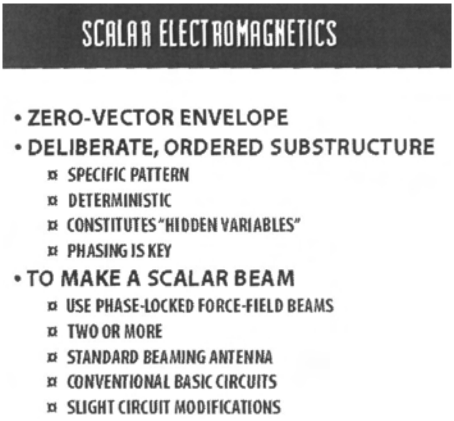

SCALAR ELECTROMAGNETICS

- ZERO-VECTOR ENVELOPE
- DELIBERATE, ORDERED SUBSTRUCTURE
  - SPECIFIC PATTERN
  - DETERMINISTIC
  - CONSTITUTES "HIDDEN VARIABLES"
  - PHASING IS KEY
- TO MAKE A SCALAR BEAM
  - USE PHASE-LOCKED FORCE-FIELD BEAMS
  - TWO OR MORE
  - STANDARD BEAMING ANTENNA
  - CONVENTIONAL BASIC CIRCUITS
  - SLIGHT CIRCUIT MODIFICATIONS

Slide 024: Scalar Electromagnetics

To rehash: scalar waves are zero-vector waves. Patterned E and B fields exist in a relationship where their summation equals vector zero. Electromagnetically, the zero EM "envelope" of a scalar EM wave is composed of a zero-summation of infolded finite EM force-vectors.

However, the internal (infolded) substructure is deliberate, macroscopic, and ordered. Vacuum is polarized deterministically by the wave, and macroscopic spacetime is locally curved by it.

These substructure components constitute Bohm's "hidden variables." They can be manipulated and varied at will. Phasing, beaming, frequency, superposition, interference, resonance, and Fourier expansion are the keys to scalar EM engineering.

To make a scalar beam, special modifications are made to the EM wave transmitter so that, effectively, the transmitter transmits multiple transmissions simultaneously, and these vectorially sum to zero. This is the same thing as transmitting multiple phase-locked EM force-field beams simultaneously, in the sum-zeroed fashion.

Standard beaming antennas and conventional circuits can readily be utilized with slight modifications.

Any radar can be converted to a scalar EM radar quite simply. Indeed, a modification kit to accomplish that can be developed and held until the scalar mode is desired. The modification kit can be quickly installed to provide the scalar capability.

Scalar radars, for example, cannot track "corner reflector" targets. However, they can magnificently track smoothly filleted corners; rounded, smoothly curved surfaces; and curved or flat metalized dielectrics. Against aerial targets using special construction to lower their cross-section to normal radars, the application of the scalar radar mode is immediately obvious.

Scalar waves pass through the electron shells of an atom and interact with the nucleus. They are continually absorbed and emitted by all nuclei in the universe.

BACKGROUND FOR THE BRIEFER.

Any large collection of nuclei - such as a star or a planet - is a strong absorber and radiator of scalar wave radiation.

The Sun is a particularly strong source of scalar radiation. This radiation penetrates the Earth deeply, interacting more and more with the deeper layers which, under greater mechanical stress, are more nonlinear. Most of the heat in the molten core of the Earth comes from the dephasing of a portion of this absorbed scalar radiation from the Sun, liberating ordinary EM energy as heat.

The Earth also re-radiates scalar wave radiation back to the Sun. The Sun and Earth are thus coupled into a "scalar" system in equilibrium or near-equilibrium. Each body in the couplet possesses both a feed-forward and a feedback loop.

The Earth also radiates scalar wave radiation to the Moon, and the Moon reradiates scalar radiation back to the Earth. The Earth and Moon also are coupled into a "scalar" system in equilibrium or near-equilibrium. Again, each body in the couplet possesses both a feed-forward and a feedback loop.

The Sun and Moon are correspondingly coupled into a scalar system in equilibrium or near-equilibrium, each with both a feed-forward and a feedback loop.

The Earth, Sun, and Noon thus form a triad-coupled system of special importance to the stability of our existence here on Earth, and the stability of our biosphere.

And so on with all the other planets in the solar system, and combinations thereof.

The solar system is thus a very sensitive scalar-coupled system, with strong subsystems within it.

ADDED FOR THE BRIEFER:

Actually this scalar coupling of the solar system provides a major check on unrestricted use of the large Soviet strategic scalar EM weapon systems. If significant scalar effects are produced on earth in a "pulse" mode, pulsed disturbance of the earth-sun and earth-moon systems results. Here a danger exists that one or more natural resonances of the coupled system may be excited. If the feedback stimulation of the Sun is not insignificant, for example, large sunspot activity may result sometime thereafter, say in a day or two. If too much or too sharp stimulation occurs on earth, the coupled resonant response from the sun could be disastrous. Indeed, a solar response could be stimulated so that the Sun would violently belch and destroy our biosphere, among other effects. The simplest doomsday stimulation would be for a violent expulsion of Solar EM energy and particles to occur. If this were due to resonance, the expulsion of Solar EM energy and particles would continue during some decay time. In that case, fiery destruction of the earth, strongly indicative of Biblical prophecy, would result. Particularly sensitive are the resonances of the sun-earth, sun-moon, and earth-moon systems.

Note the abnormal influence of the moon on tides - tides of both the tectonic plates and the oceans. One cannot help but point out that, if the earth-moon resonant system were overstimulated, one might expect violent earthquakes of extraordinary magnitude, and tremendous tidal waves hundreds of feet in height. (The potential connection to legends of earth-destroying floods, evidences of extreme water levels in mountains, and legends of ancient cataclysmic destruction of supposedly advanced technological oceanic cultures is obvious.)

Accordingly, use of huge scalar EM weapons is a double-edged sword. Unless carefully employed, use of the weapons could cause a terrible backlash to the user as well as the victim, and even accidentally cause the destruction of the earth itself. It is not accidental that in 1960 Khrushchev stated that his new fantastic weapon could - if unrestrainedly used - destroy all life on earth.

This appalling backlash potential is apparently what prompted Brezhnev in 1975 to make so strong an effort to get agreement to outlaw the development of "new weapons of mass destruction" more frightful than the mind of man had even dreamed of. Gromyko even introduced such a draft agreement into the proceedings of the United Nations. The first article of the draft agreement indicated that the nature of the weapons referred to would be negotiated. Sadly, the entire Western world did not even know what the Russians were talking about.

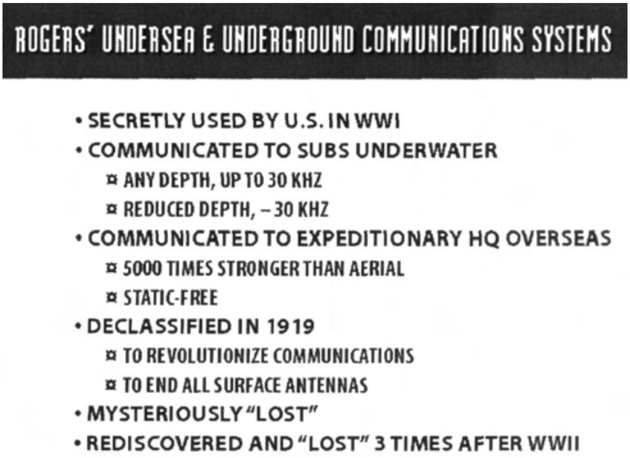

ROGERS' UNDERSEA & UNDERGROUND COMMUNICATIONS SYSTEMS

- SECRETLY USED BY U.S. IN WWI
- COMMUNICATED TO SUBS UNDERWATER
  - ¤ ANY DEPTH, UP TO 30 KHZ
  - ¤ REDUCED DEPTH, – 30 KHZ
- COMMUNICATED TO EXPEDITIONARY HQ OVERSEAS
  - ¤ 5000 TIMES STRONGER THAN AERIAL
  - ¤ STATIC-FREE
- DECLASSIFIED IN 1919
  - ¤ TO REVOLUTIONIZE COMMUNICATIONS
  - ¤ TO END ALL SURFACE ANTENNAS
- MYSTERIOUSLY "LOST"
- REDISCOVERED AND "LOST" 3 TIMES AFTER WWII

Slide 025: Rogers' Undersea & Underground Communications Systems

In an article in the March 1919 issue of the Electrical Experimenter, a real bombshell was released on an unsuspecting world.

In that issue, details of the Rogers'undersea and underground communication systems were released. These systems had been classified SECRET during WWI, and used to communicate with (1) U.S. submarines underwater around the world, and (2) U.S. Expeditionary Forces Headquarters overseas.

Subs at any submerged depth could be reached with transmitters of frequencies up to 30 kiloHertz. At reduced depths, frequencies above 30 kHz could be used.

At the headquarters of U.S. overseas forces, the signals were received through the earth. They were 5,000 times stronger than aerial signals through the atmosphere, and static-free.

The Rogers' systems were covered by a series of patents. They used special antennas implanted in the ground.

While the patents are somewhat confused, several of the diagrams in the Electrical Experimenter reveal that the antennas were producing scalar waves. Scalar waves can indeed travel through the earth and through the ocean. Indeed, if good quality scalar waves are made, then frequencies well above 30 kHz can be sent through the ocean. Multi-megahertz frequencies, for example, are easily achievable. (The problem, of course, is that these waves are pure zero-vector artificial potentials that do not move electrons in the conduction gas of a conventional antenna/receiver combination. Normal receivers and detectors do not see them. Special underwater detectors - such as those developed by Frank Golden - are required.).

With the startling declassification and revelation of the Rogers' systems, it was expected that all communications would be revolutionized, and that all surface antennas would be removed.

Strangely, this entire technology faded away quickly, as if it had never been. Certain powerful interests did not wish the extended electromagnetics to be discovered or taught. That, after all, would lead to free energy and loss of economic control of the citizens. That was precisely why Nikola Tesla had already been suppressed.

According to the important research of Dr. Robert Beck, the same scalar technology has been rediscovered and mysteriously "lost" at least three times after World War II!

Today the orthodox establishment is still suppressing it.

One wonders why no orthodox physicist - with the single exception of Dr. Hooper (see U.S. patents 3,610,971, Oct. 5, 1971 and 3,656,013, Apr. 11, 1972) - seems to have experimented with deliberately constructed zero-vector EM waves and devices, and published his results in the literature.

One would think that any university physics department would wish to explore such a gaping void with at least a few graduate student experiments, if for no other reason than scientific curiosity, particularly when the experiment is easily performed, it is totally different from anything else in the theory or literature, and the implications may be formidable. A true scientist in that related field ought to try it!

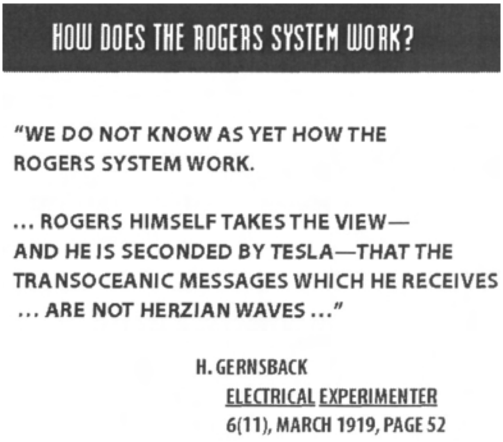

HOW DOES THE ROGERS SYSTEM WORK?

"WE DO NOT KNOW AS YET HOW THE
ROGERS SYSTEM WORK.

... ROGERS HIMSELF TAKES THE VIEW—
AND HE IS SECONDED BY TESLA—THAT THE
TRANSOCEANIC MESSAGES WHICH HE RECEIVES
... ARE NOT HERZIAN WAVES ..."

H. GERNSBACK
ELECTRICAL EXPERIMENTER
6(11), MARCH 1919, PAGE 52

Slide 026: How does the Rogers System Work?

In the same March 1919 issue of Electrical Experimenter, Hugo Gernsback pointed out that no one as yet knew how the Rogers' system actually worked.

Rogers himself believed he was not using conventional Hertzian waves.

Nikola Tesla himself confirmed that the underground and undersea waves were not Hertzian waves.

If so, they could only have been scalar waves.

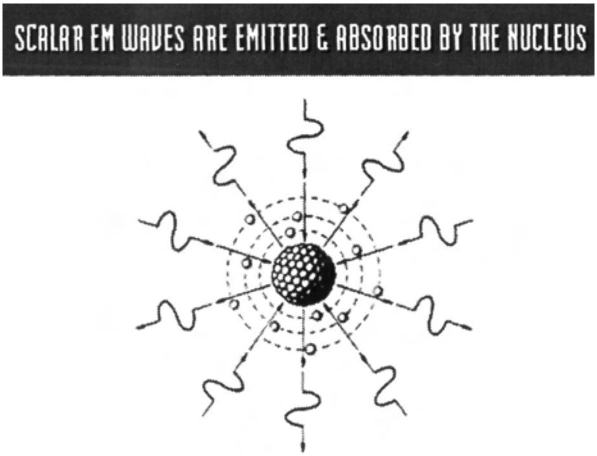

SCALAR EM WAVES ARE EMITTED & ABSORBED BY THE NUCLEUS

Slide 027: Scalar EM Waves are Emitted & Absorbed by the Nucleus

Normally scalar EM waves do not couple to orbital electrons. Entering into the atom, incoming scalar EM waves penetrate the electron shells without interaction. They continue, penetrating into the interior of the closely packed nucleus, where the extreme nonlinearity of the charged virtual particle flux that binds the nucleons together distorts the scalar wave, dephasing its summed EM vector components. This produces a nonzero EM resultant and polarized pattern directly inside the virtual particle charge flux of the nucleus.

The new EM resultant immediately couples the distorted scalar wave to the nucleus, resulting in absorption of the wave and incorporation of its polarization pattern into the nucleus' virtual flux. This in turn results in a slightly excited nucleus. Normally the excited nucleus will promptly decay by emitting another scalar wave, which passes through the orbital electron shells and radiates out into the universe.

However, as can be seen, if the same strong scalar pattern is constantly radiated into the nucleus and absorbed by it, the excitation of the nucleus "charges up," leading to decay by other modes. In this manner the nucleus can be engineered even transmuted - by rather minuscule power of the engineering radiation signal.

This is how living biological systems are able to transmute elements, as discovered by Louis Kervran. (Kervran was nominated for the 1977 Nobel Prize for this work.). The biosystem produces scalar EM waves. If the appropriate signal is employed into and on the appropriate nucleus, a changed element emerges. In this fashion chickens denied sufficient calcium in their diet, but allowed a surplus of potassium, are able to transmute some of the potassium into calcium. Note that one of the isotopes of potassium is an isomer of normal calcium. Transmutation of this potassium isomer to calcium is easiest.

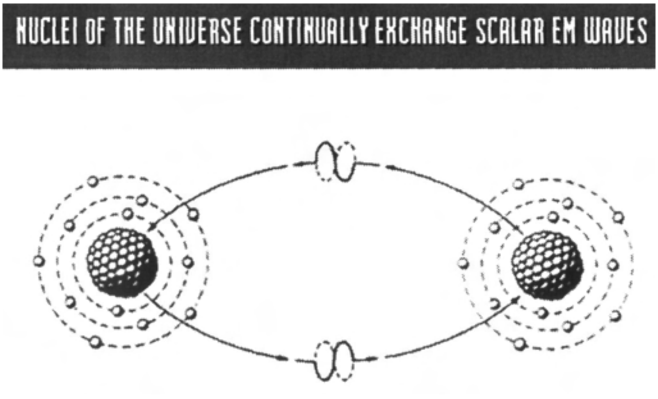

NUCLEI OF THE UNIVERSE CONTINUALLY EXCHANGE SCALAR EM WAVES

Slide 028: Nuclei of the Universe Continually Exchange Scalar EM Waves

Thus scalar EM waves are continually exchanged by all nuclei of the universe, and the vacuum is - among other things - a seething cauldron of scalar radiation.

In fact, it is this seething scalar wave cauldron that creates the virtual particles and the virtual particle flux of vacuum itself. (Since the scalar EM wave represents an oscillation of the curvature of spacetime, and since everything - virtual or observable - is a curvature of spacetime, then scalar waves can be taken as the universal generatrix.

The intensity of the trapped scalar flux in the nucleus of an atom is responsible for the mass and inertia of the nucleus.

Mass is localized trapped scalar resonance.

The trapping agent is the spin of a particle.

The mass and inertia of the particle are due to the scalar resonance that is trapped. Increasing the amplitude of the trapped scalar resonance increases the mass and inertia; decreasing the amplitude decreases the mass and inertia.

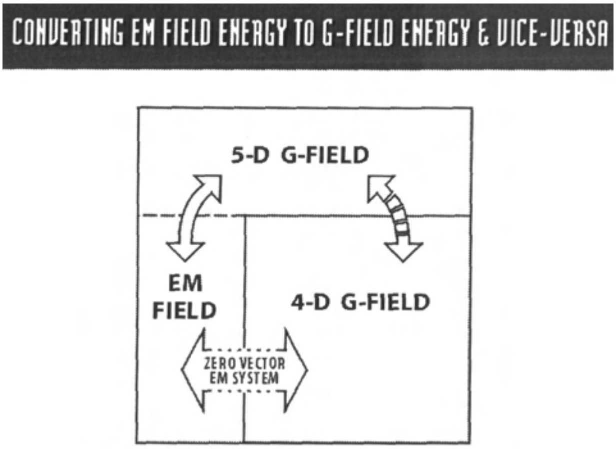
CONVERTING EM FIELD ENERGY TO G-FIELD ENERGY & VICE-VERSA

Slide 029: Converting EM Field Energy to G-Field Energy & Vice-Versa

According to Kaluza theory, there are no such things as a separate EM field and a separate gravity field. Instead, in five dimensions there is only one field: the 5-d gravitational field. The EM field is the 5th dimensional aspect, while our normal 4-dimensional G-field is the other aspect of the 5-field, in our normal 4-space.

Thus we may say that the 5-field is composed of two components: the 5th dimensional component (our normal EM field) and the component occupying our normal 4 dimensions (our normal G-field).

The 5-d "force" field, of course - or the 5-space analogy to a force field - would be due to a gradient or "bleed-off of the 5-d gravitational potential. This gradient in turn is composed of two components: the 5th dimensional "bleed-off" outside our normal 4-space (this outer bleed-off is our normal EM force field) and the bleed-off inside our normal 4-space (this inner bleed-off is our normal G-field).

Normally the 5-potential bleeds-off outside our 4-space as EM field, far greater than it bleeds-off inside our world as G-field. Between two electrons, for example, the electric field is about 10^{42} times as strong as the G-field. Since in the Kaluza view there is only one 5-d G-potential that is causing both force fields, this shows that there is an incredibly greater EM bleed-off of the 5-

potential between the two electrons than there is a G-field bleed-off between them.

As shown on the diagram, the 5-d G-field is normally comprised almost entirely of the 5th dimensional EM field. Only a small 4-space G-field component exists.

However, suppose we were to "block" the bleed-off of the 5-potential in the EM mode. Then none of the 5-potential could bleed-off in the 5th dimensional EM field. Instead, it would be forced to bleed-off into the 4-space G-field. In our two-electron example, this "perfect case" would result in the disappearance of the E-field between the two electrons, and the G-field between them would increase to about 10^{42} times its normal strength.

The end result would be that, by blocking the EM force field bleed-off, EM field is converted to G-field. In addition, EM field energy is converted to G-field energy. With the extremely amplified gravitational and inertial effects that result, one can now accomplish direct engineering of gravitation, mass, and inertial effects.

We can effectively accomplish this "blocking the EM bleed-off by opposing EM force fields so that they sum to vector zero. This is the same as summing various 5th dimensional gradients of the 5-potential to a zero vector resultant. In that case, as much "EM bleed-back to 5-potential" occurs as there is "EM bleed-off from 5-potential." This places the 5-potential in equilibrium with respect to EM bleed-off.

Also, another nice thing results: Since we can readily vary the magnitudes of the EM force field components of the vector zero summation, we can actually form phased "zero vector waves" by increasing and decreasing the magnitudes of all the component EM vectors in phase, but retaining their vector summation always equal to zero.

In that case we have produced a very simple 5-space G-potential wave, which concomitantly forces phase-locked variations in the 4-space G-potential. In short, we have produced an electrogravitational (EG) wave, or scalar EM wave for short. This wave described is the simplest EG scalar wave we can produce; much more complex EG waves can be produced and used for highly **specialized** purposes.

The scalar EG wave changes EG potential energy into 4-gravity potential energy in one half-cycle, and changes 4-G potential energy into EG potential energy in the other half-cycle. However, the EG potential energy in the first half-cycle does not react electromagnetically in linear circumstances, since it is electromagnetically a linear vector zero.

So our scalar EG wave actually oscillates energy back and forth between a locked-in 5th dimensional EM potential and a 4-space G-potential. As can be seen, to the linear 4-space observer this scalar EG wave appears as a purely gravitational wave, with G-potential magnitude varying in a wavelike manner.

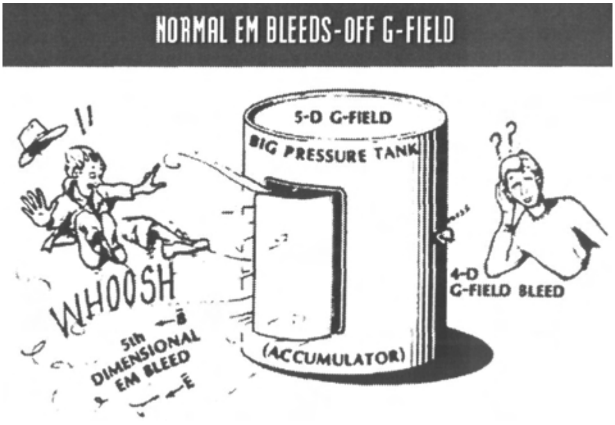
NORMAL EM BLEEDS-OFF G-FIELD
!!
5-D G-FIELD
BIG PRESSURE TANK
??
4-D
G-FIELD BLEED
WHOOSH
B
5th
DIMENSIONAL
EM BLEED
E
(ACCUMULATOR)

Slide 030: Normal EM Bleeds-Off G-Field

For easy visualization, we may regard the situation in the analogy shown on the slide.

The 5-potential of 5-space vacuum is like a high pressure in a big tank. The tank has a huge open door in the 5th dimension, leading to rapid bleed-off of the 5-presure through the big door; that is, as EM field. Only a very small hole in the tank normally exists in our own 4-space world, so only a very small amount of the pressure bleeds off as our G-field.

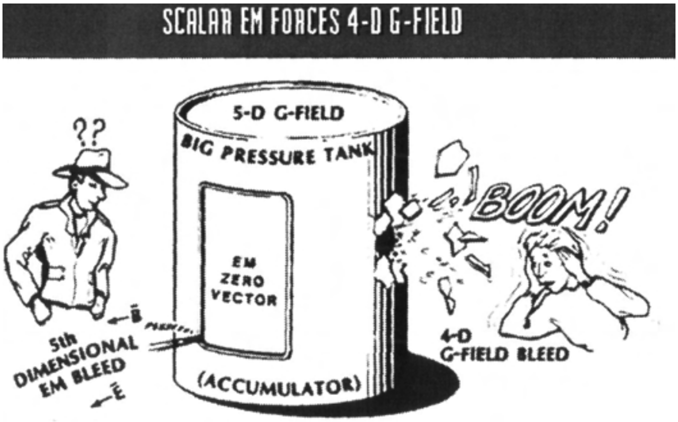
SCALAR EM FORCES 4-D G-FIELD
??
5-D G-FIELD
BIG PRESSURE TANK
EM ZERO VECTOR
(ACCUMULATOR)
BOOM!
4-D G-FIELD BLEED
5th DIMENSIONAL EM BLEED
B
E

Slide 031: Scalar EM Forces 4-D G-Field

As can be seen however, if we shut the big door so that we have only a little bleed-off through the seals, then most of the pressure is forced to bleed-off through the small opening, greatly enlarging it. In that case, most of the 5-potential bleeds-off as 4-G force field.

The mass exposed to such increased 4-G bleed-off exhibits a much greater mass and inertia.

In fact, mass itself can act as an accumulator for the effect, and it can increase its ability to store trapped scalar resonance. This increases its inertia.

By the use of scalar EM (blocking the EM bleed-off), we can input normal EM energy and obtain powerful gravitational and inertial effects. Many other powerful effects can also be obtained.

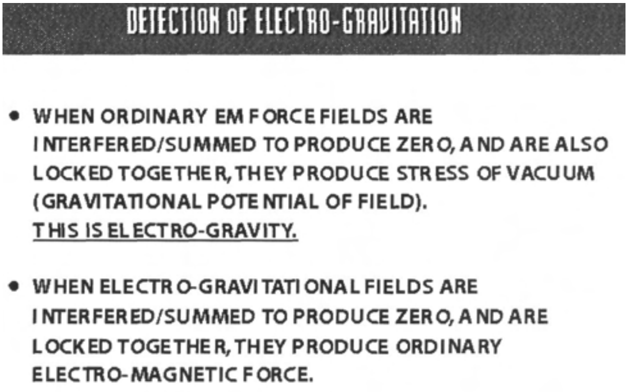

DETECTION OF ELECTRO-GRAVITATION

- WHEN ORDINARY EM FORCE FIELDS ARE INTERFERED/SUMMED TO PRODUCE ZERO, AND ARE ALSO LOCKED TOGETHER, THEY PRODUCE STRESS OF VACUUM (GRAVITATIONAL POTENTIAL OF FIELD).
  THIS IS ELECTRO-GRAVITY.
- WHEN ELECTRO-GRAVITATIONAL FIELDS ARE INTERFERED/SUMMED TO PRODUCE ZERO, AND ARE LOCKED TOGETHER, THEY PRODUCE ORDINARY ELECTRO-MAGNETIC FORCE.

Slide 032: Detection of Electro-Gravitation

Here are two magic rules in the scalar electrogravitational business:

(1) When ordinary EM force fields are interfered or summed so that they produce vector zero, and the fields are locked together, they produce stress of vacuum (5-potential). One component of this 5-potential is the 4-space G-potential. Since bleed-off as a gradient of this 4-space G-potential is all that is allowed, then the EM destructive interference/zero summation bleeds-off to produce gravitational force field. This is because opposing equal forces, which sum to a vector zero force field resultant, actually produce a stress potential having stress energy of spacetime. And that is a curvature of spacetime, hence gravitational.

In short, total destructive interference of EM waves or force fields produces excess stress potential energy in spacetime, and therefore gravitational force field on detecting/coupled particles.

(2) When electrogravitational fields are interfered/summed to produce vector zero, this destructive interference/zero summation bleeds-off to produce ordinary electromagnetic force field.

In short, destructive interference of scalar EM waves or fields (electrogravitational waves or fields) produces electromagnetic force fields on detecting/coupled particles.

BACKGROUND FOR THE BRIEFER:

Mathematically we can summarize this as follows;

$$G_{(1-4)} = G_{(1-4)}(\mathrm{m}) + G_{(1-4)}(\mathrm{EM}) \qquad [3]$$

$$G_{(1-5)} = G_5 + G_{(1-4)} \qquad [4]$$

If $$\mathbf{E} = \Sigma \mathbf{\mathring{a}}_i E_i = \mathbf{0},\ E_i \neq \mathbf{0};\ \mathbf{B} = \Sigma \mathbf{\mathring{a}}_i B_i = \mathbf{0},\ B_i \neq \mathbf{0} \qquad [5]$$

then $$G_{(1-4)}(\mathrm{m}) = G_{(1-4)}(\mathrm{EM}) = G_5 = G_{(1-5)} \qquad [6]$$

and $$G_5 = G_{(1-4)} = f[\Sigma(\mathbf{\mathring{a}}_i\,|\mathbf{E}_i|^2)] + g[\Sigma(\mathbf{\mathring{a}}_i\,|\mathbf{B}_i|^2)] \qquad [7]$$

and $$G_{(1-5)} = G_5 = G_{(1-4)}(\mathrm{m}) = G_{(1-4)}(\mathrm{EM}) = f(\phi) + g(\mathbf{A}) \qquad [8]$$

Where:

$G_{(1-5)}$ is the 5-d G potential, or total G-stress on dimensions 1-5.

G_5 is the combined EM potential, or G-stress on dimension 5 only.

$G_{(1-4)}(\mathrm{m})$ is the normal 4-d G-potential of mass alone, or the G-stress due to mass-gravity.

$G_{(1-4)}(\mathrm{EM})$ is any extra 4-d G-potential of mass due to conversion from G_5 stress (normally zero).

E and B are the electric and magnetic force fields.

ϕ is the electrostatic scalar potential.

A is the magnetic vector potential.

Thus the age-old scientific dream of direct engineering of gravitational field — and of spacetime itself — can now become reality. To start, one simply makes an intense EM vector zero and varies its stress intensity and internal pattern of summed components. One also varies the reference potential at which the patterned EM stress zero is created, and the frequency of internal component variation.

BACKGROUND FOR THE BRIEFER.

He that has ears, let him hear.

Here is the secret of antigravity

The "electrical charge" of a charged particle — such as one of the orbital electrons of an atom or one of the protons of its nucleus — represents a difference in flux intensity (potential) between the local particle and its ambient vacuum.

It's the continual bleed-off of gravitational charge as electrical charge.

If that bleed-off is reversed or stopped, a drastic effect on the gravitational potential and charge ensues. The 5-potential and 5-charge have become 4-G-potential and 4-d-charge respectively.

Thus "charging" an object with its scalar EM pattern charges it gravitationally.

Now the only "bleed-off channel" is through the 4-G force field.

Further, in a nucleus the nucleons continually change back and forth between proton and neutron, so the electrical charge is "spread" throughout the nucleus and shared by all the nucleons.

Further, each element (actually each isotope) has its own unique "ensemble pattern" of Fourier expansion scalar frequencies, amplitudes, etc. This pattern, of course, can be reproduced artificially and transmitted by modified EM transmitters (i.e., by scalar EM transmitters). There is, however, a sort of "master key" scalar EM (EG) pattern for nucleons (protons and neutrons which are changing back and forth into each other by exchange of virtual charge currents).

If one "reverses the charge" by inverting this pattern, and then "charges up a mass with the inverted charge," to the external observer the charging mass just gets lighter and lighter, and its inertia gets less and less. Eventually it seems (to him) to acquire negative mass and negative inertia, and just accelerate away from the earth. The object "falls upward" instead of "falling downwards."

There are also some weird time effects. The object can be moving slower through time than the laboratory observer, or even be moving backwards through time with respect to the laboratory observer. (Don't believe everything they laught you in relativity; none of those professors had ever engineered a single general relativistic situation. Little that they teach in GR is based on direct experiment. Most of what they teach is already experimentally proven to be incomplete or in need of further extension.).

But back to our slide.

Inside the pattern itself, it's just a quite normal pattern. No change in or on the object seems to have occurred, to it, if the charge is evenly accomplished throughout the object. Indeed, to an internal observer it's the external environment that seems to have suddenly gotten very strange! This is what occasionally happens to a hapless aircraft or ship that experiences anomalous spatiotemporal difficulty in an *occasionally scalar-active* area such as the Bermuda triangle. Under the right conditions, the vehicle's gravitational charge is affected by anomalous changes in the scalar radiation from the earth in that area. To the passengers and crew, it is the external environment that suddenly seems weird. In addition, on-board EM and inertial instruments may be affected, and other electrogravitational effects may also occur, due to differing rates of charge in different parts of the vehicle.).

"Reversing or lowering the EG-charge" is controlled by means of biasing the ground potential on the ensemble pattern transmitters. These transmitters can even be on-board the vehicle itself. (Remember, in scalar EM to transmit is also to receive. A vehicle can change its own bias potential (with respect to local vacuum G-potential) by properly transmitting, which translates to "receiving potential charge." The charge current can either be negative or positive (its potential can be lowered or increased vis-a-vis that of the vacuum.) Think of this as handling positive and negative energy, which means positive and negative gravity.

By "fiddling" with this, you can float metal. Or a human body. Or a battleship. Or a high-speed vehicle containing a crew.

You can even "dematerialize it" or "teleport it."

The Philadelphia Experiment may have been real after all. If so, the test ship and its personnel were "blasted" into this strange realm, instead of making a gentle, controlled entry.

Suppose you materially lower or reverse (adjust) the gravitational charge (gravitation 5-potential with zero-summed EM to throttle EM bleed-off). At zero gravitational charge, to the external observer, such an assumed vehicle would seem to have no mass and no inertia. It is capable of extreme accelerations, right angle turns at full speed, etc. It is also right on the point of dematerialization, and may appear to be glowing or just a vehicle of light.

If the pilot wishes to "land," of course he must adjust the charge on the vehicle.

If the pilot wishes to "dematerialize" or "teleport," again he must adjust the charge on the vehicle.

If he wishes to go "hyperspatial," again he must adjust the charge on the vehicle and allow the proper bleed-off to produce a hyperspatial force. That's done with nested zero summations and nested patterns of scalar EM transmission.

That is, he can charge and bias the vehicle in multiple, nested zero-summations simultaneously.

That is necessary for hyperspatial control and travel.

Note that in lower hyperspace such a vehicle could do some very strange things. Such as "penetrate" solid matter (actually, it goes "around" the 3-space matter in a 4th Kaluza-Klein space).

We might expect to see such vehicles glowing. Their various surface features and mechanisms might appear to be glowing or revolving lights, etc.

They could exhibit incredible "aerodynamic performance," seemingly in the atmosphere. Actually they would not be moving "through" the atmosphere at all but through a higher space outside each particle of atmosphere.

They could seem to materialize and dematerialize.

They could seem to plunge into the ocean or rise out of it.

They could even seem to operate under the ocean or inside the earth itself.

Such anomalous vehicle performances have been seen all over the world, particularly since a few years after WWII.

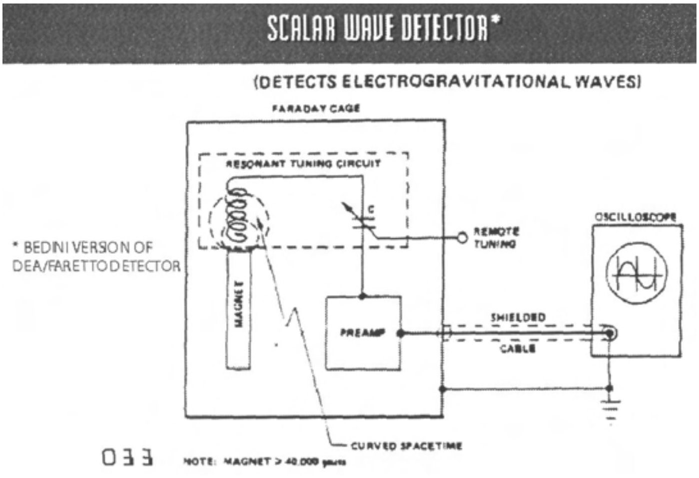
SCALAR WAVE DETECTOR*

(DETECTS ELECTROGRAVITATIONAL WAVES)

* BEDINI VERSION OF DEA/FARETTO DETECTOR

033

NOTE: MAGNET > 40,000 gauss

Slide 033: Scalar Wave Detector

On this slide we show a concept for a detector for scalar EG waves. This is the Bedini scalar wave detector, adapted from an original concept by Dea and Faretto.

The idea is quite simple: install a very powerful bar magnet vertically inside a grounded Faraday cage. Then install an open-ended coil longitudinally above the magnet so that a line through the longitudinal axis of the magnet passes through the longitudinal axis of the coil above it. The open end of the coil does not touch the magnet.

Connect the other end of the coil to a variable tuning capacitor, so that the coil and capacitor form a tunable, series-LC-oscillatory circuit. The output of the capacitor is connected to a transistorized preamplifier inside the cage. A tuning shaft for the capacitor is very carefully passed through a small hole in the shield to allow tuning from outside.

The output of the preamp passes very carefully through a small hole in the shield, through a shielded cable, to an adjacent oscilloscope. The cable shield in also grounded to reference ground potential.

The theory is as follows: Suppose a normal EM wave appears inside the cage, above the magnet or closely adjacent thereto. In that case a coupled **oscillation** appears in the field of the magnet, and this oscillation is coupled to the coil immediately above it. If the oscillation is within the bandwidth of the tuned series LC circuit, detection occurs. This is amplified by the preamp and passed to the oscilloscope, where it is displayed on the scope.

Note that the detector detects normal EM wave. Now our problem is: how do we get an EG wave to be detected? And how do we assure that we do not detect ordinary EM waves from outside?

Actually this is simple. Ordinary waves (except for quite low frequency) will be grounded out by the Faraday shield, and will not penetrate the cage. Thus these normal EM waves cannot enter the cage and appear above the magnet. They will not be detected.

Scalar EG waves, on the other hand, will enter the cage since they do not couple to conduction electrons in the metal of the cage. Above the pole of the magnet, spacetime is locally bent. After all, a pole is a magnetostatic scalar potential, which is a part of the conglomerate called "G-potential." The pole represents an increase (or decrease, depending upon whether it is a north or a south pole) in the magnetostatic component of the local G-potential. This is a curvature of spacetime. An EG wave entering this region adds a varying component of magnetostatic G-potential, which bleeds-off in the coil as an ordinary EM wave.

Another way to view the detector is to model the EG wave as a longitudinal wave, and an ordinary EM wave as a transverse wave. When the EG wave enters the curved spacetime region above the magnet, to the coil (the "observer" in this case) the longitudinal aspect of the EG wave appears to be rotating back and forth, so that an oscillating transverse component is present. This transverse component appears to the coil as an ordinary EM field, and so the LC circuit detects it if it is in the proper frequency band.

Yet another way to view the situation is to realize that an EG wave entering the magnet results in an oscillation component added to the magnetostatic scalar potential (pole strength) of the magnet. Accordingly, the magnet is a receiver for scalar waves, which are detected to "bleed-off as an oscillation of the magnetic field strength of the magnet. Coupling of this oscillating magnetic field to the coil creates an oscillating current flow into the capacitor. This oscillates the voltage input to the preamp, which amplifies and feeds the signal to the oscilloscope for display.

In fact rather like the latter view! It is important to remember that a magnetostatic potential and an electrostatic potential can be oscillated by a scalar EG wave. By placing a magnetic material inside a Faraday cage, the oscillation of the magnetostatic scalar potential (pole strength of the magnet) can be used as the EG detecting mechanism. By placing a chargeable material inside a Faraday cage, the oscillation of the electrostatic scalar potential can be detected. (Possible examples of the latter type detectors are given by Hodowanec, Radio Electronics, April 1986.)

Note also that one may detect waves at one reference level and not at another. Changing the bias on the zero-reference ground of the Bedini detector affects the detection. To look inside a normal EM carrier (such as the Woodpecker) and see what scalar signals are riding upon it, the carrier may be used to bias the reference ground of the Bedini detector.

To produce a spectrum analyzer, simply use additional series resonant LC tuning circuits in parallel (put multiple taps on the coil, and wire each tap to a separate tuning capacitor of different capacitance). Again, varying the zero reference level is important, as is varying the strength of the magnet.

Golden also has invented an excellent series of scalar wave detectors based upon quite different proprietary principles.

The bottom line is: we can indeed rigorously detect and measure scalar EG waves. When one considers the large sums of money presently being spent to bury large aluminum cylinders etc. in an attempt to detect gravitational waves, one wonders why some funds could not be released to a few unorthodox researchers by the National Academy of Sciences to fund the proven creation and detection of electrogravitational waves!

Note from TEB: I understand that it took Bedini about 600 attempts before he got the device to work. It was then handed over to a different party to produce, who made some "improvements," and the device then failed to work.

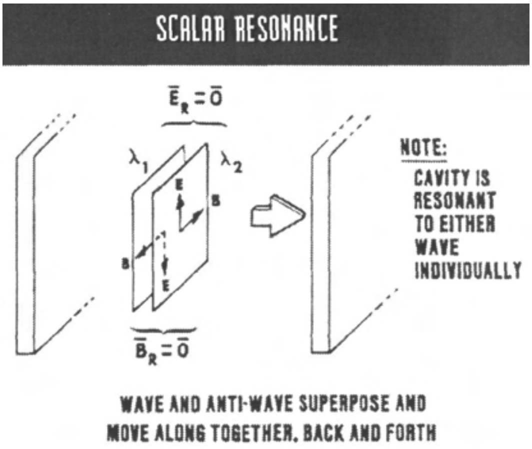
SCALAR RESONANCE
$\bar{E}_R = \bar{0}$
λ_1
λ_2
E
B
B
E
$\bar{B}_R = \bar{0}$
NOTE:
CAVITY IS
RESONANT
TO EITHER
WAVE
INDIVIDUALLY
WAVE AND ANTI-WAVE SUPERPOSE AND
MOVE ALONG TOGETHER, BACK AND FORTH

Slide 034: Scalar Resonance

Here we explain a new kind of resonance: scalar EH resonance, or electrogravitational resonance.

First, imagine we have a standard resonant cavity, represented by the two walls in our diagram. In this cavity we have a resonant EM wave moving back and forth, represented by the forward-most plane. In accordance with convention, we show the E-field vector and the B-field vector at right angles in this moving wave front. As the wave front moves back and forth, the vectors vary back and forth; however, at any one point between the walls, the two vectors always have the same value. Thus our resonant EM wave forms a standing wave in the cavity.

Now imagine that a second wave front, precisely like the first and of the same frequency, is superposed over the first wave front and travels along with it. This second wave - the "antiwave" - has its force vectors 180 degrees out of phase with the force vectors of the reference wave. Hence the E-fields and B-fields of the two superposed waves always sum to vector zeros, anywhere in the cavity. To an external observer, the cavity contains no ordinary electromagnetic force fields, hence no ordinary EM energy.

However, the energy density of a single EM sine wave in vacuum is given by

$$[E^2+B^2]/8\pi \qquad [9]$$

This energy density is always positive. Hence the energy density of the two waves at any point x between the walls is equal to

$$[E^2+B^2]/4\pi \qquad [10]$$

where

$$E = E(x)\ ;\ B = B(x) \qquad [11]$$

Thus the energy density of vacuum varies with x. But, rigorously, since the resultant E and B fields are zero, this describes a standing gravitational wave. Hence we have a standing EG wave, existing in the resonant cavity. This is an example of scalar resonance. Rigorously the cavity has mass and inertia, to an outside observer, as a result of the two warps in spacetime it contains.

Note that in one half-cycle the energy density of vacuum is greater than ambient, and in the other half-cycle it is less. In the region of one half-cycle, time flows at a faster rate than to the ambient observer, and in the other half-cycle time flows at a slower rate than to the ambient observer.

One half-cycle appears to contain negative electrical charge, and the other appears to contain positive charge.

One half-cycle appears to contain a north pole (positive magnetostatic scalar potential), and the other half-cycle appears to contain a south pole (negative magnetostatic scalar potential).

Perhaps now one can begin to understand why a continuously accelerated orbital electron in the atom does not radiate EM energy, completely in violation of Maxwell's equations. The electron is naught but a complex aspect of a standing scalar resonance, existing between the nucleus and the orbit.

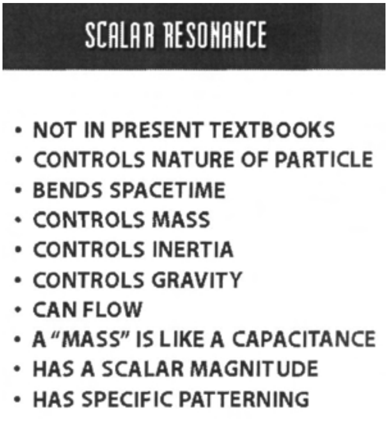

SCALAR RESONANCE

- NOT IN PRESENT TEXTBOOKS
- CONTROLS NATURE OF PARTICLE
- BENDS SPACETIME
- CONTROLS MASS
- CONTROLS INERTIA
- CONTROLS GRAVITY
- CAN FLOW
- A "MASS" IS LIKE A CAPACITANCE
- HAS A SCALAR MAGNITUDE
- HAS SPECIFIC PATTERNING

Slide 035: Scalar Resonance

Scalar resonance is not in the conventional textbook.

Scalar resonance is a particular zero-summed multi-resonance, electromagnetically, so that it does not act in an electromagnetic manner.

A scalar resonance is a standing electrogravitational wave. It can be made **electrically,** but it is not electrical in behavior.

In any scalar resonance, spacetime is curved, and it is the magnitude (and direction; of this spacetime curvature that is oscillating in "standing wave" fashion. In respect to stress of the vacuum medium, one half of a standing sine wave of scalar resonance is tensile; the other half is compressive. However, this is with respect to the local ambient stress of vacuum.

"Mass" of a particle is just a characteristic exhibited by a trapped scalar resonance. Usually this trapping is done by the "spin" of the individual particle.

The concept of "mass" may be compared to the concept of "capacitance." That is, a mass is an accumulator for scalar waves; that is, for scalar resonances. It is continually being "charged" and "discharged" by absorption and emission of scalar waves from and to the ambient vacuum scalar wave flux.

Indeed, the magnitude of a mass may be defined in terms of the absolute value of this "switching" (absorption = switch in; emission = switch out) rate. In a very early paper I defined the mass of an object as proportional to the absolute value of the sum of the input and output switching rates, where each "switch" represents a change of action of h/(4). (Bearden, Quiton/Perceptron Physics: A Theory of Existence, Perception, and Physical Phenomena, Mar. 1973, AD 763210, available through NTIS.) In that scheme, one kilogram of mass equals a switch rate of 17.053 x 10^{50} switches per second. An object is in a Lorentz frame when the switch-in and switch-out rates are equal in a given direction. If, in addition, the in-out rates in all directions are constant, the object is "stationary" with respect to a Lorentz observer. If not constant in all directions, the object is in a curved spacetime with respect to a Lorentz observer. In that case either the object's local spacetime is warped or the object is in a generalized, accelerated frame.

In the normal linear spacetime, the "charging" and "discharging" are equal in all directions; hence the "mass" exhibited in any direction is the same.

With respect to an "external observer's" equilibrium flux, a moving object encounters an increased amount of flux rate along its line of motion, just as a moving object in a rainstorm encounters more raindrops per second in the direction of its path, than does a stationary object. Encountering increased scalar wave flux (with respect to the external observer) forces the moving object to absorb and emit scalar waves at a higher rate along its direction of motion than when it is not moving. Thus to the external observer, the mass of the object has increased, insofar as any disturbing force along its line of motion is concerned.

At right angles to its line of motion, however, the flux rate is precisely the same as when the object is at rest. Therefore the "mass" of the moving object with respect to any disturbing force at right angles to its line of motion has not changed, as seen by the external Lorentz observer.

Thus is explained both parts of one of the alltime great mysteries of special relativity: (1) how the mass of an object increases with respect to its motion, and (2) why the mass only increases with respect to its line of motion, and not at right angles to it.

The inertia of a particle is due to its mass, i.e., to the total magnitude of its trapped scalar resonance.

The gravitational attraction between two masses is due to their spacetime curvature. Further, mass is like a capacitance. It can trap additional scalar waves as trapped resonance; hence increase its magnitude or "inertial charge." Or, it can discharge more scalar waves than it absorbs; hence decrease its magnitude or "inertial charge."

Those scalar waves emitted from resonance are emitted as a pattern ensemble of the resonance. Hence they may be regarded as constituting a current of scalar resonance leaving the mass-accumulator-object. Scalar waves absorbed into trapped resonance may be regarded as constituting a current of scalar resonance into the mass-accumulator-object. Thus it is proper to speak of scalar resonance as being able to "flow."

Further, it is possible to increase the mass of an object directly, by transmitting scalar EM waves to it so that it absorbs them. (By "absorbing" scalar waves one means that more enter the object than leave it, so the object acts as an inertial accumulator charging up with inertial charge. This is done by insuring that the reference potential of the scalar wave transmitter is higher than the reference potential of the irradiated object.)

It is also possible to decrease the mass of an object directly, by transmitting scalar EM waves to it so that it emits more than it absorbs. (By "emitting" scalar waves one means that more leave the object than enter it, so the object acts as if it were an inertial accumulator that is discharging its inertial charge. This is done by insuring that the reference potential of the scalar wave transmitter is lower than the reference potential of the irradiated object.)

As can be seen, the scalar wave "transmitter" is actually somewhat comparable to a heat pump; it can either act as an "energy transmitter" or as an "energy extractor," depending upon the difference in potential between "transmitter" and "receiver."

Finally, scalar resonance can have a specific pattern: both in frequency and in spatial curvature aspects, as well as "rate of flow of time" aspects. Indeed, scalar-wise every object has its individual "scalar pattern" which is a unique fingerprint. Since that print is spatiotemporal, it is a product of the object's entire past history. Thus - scalar-wise - no two objects are identical.

This brings up another rather amazing potential: If a reasonably precise scalar pattern of an object can be "irradiated" and resonated with scalar waves, energy may be created in or extracted from the distant object, just as stimulating one tunning fork can excite another at a distance by sympathetic resonance. We leave it as an exercise for the reader to ascertain the relevance of this statement to clairvoyance, radionics, remote viewing, etc.

For the skeptic, however, we must point out that - rigorously - quantum mechanics requires that, continually, in any localized region of spacetime, the "pattern" of any object in the universe appears momentarily in the virtual state, purely from statistical considerations alone. So long as the situation remains statistical, any place in the universe can continue to have the "ghosts" of everything present there, in an ethereally thin pattern, and the observable world will not be affected by it. However, if one can discriminate and scalarly "charge" or "discharge" individual patterns in this "ghost-realm," action-at-a-distance is directly possible, as is materialization and dematerialization. If one accepts that even thought itself produces such virtual "ghost-patterns" in the virtual particle flux of vacuum, then it is at least theoretically possible to even materialize thoughts and thought images.

We have entered a new kind of reality where the old rules and the old limitations do not necessarily apply.

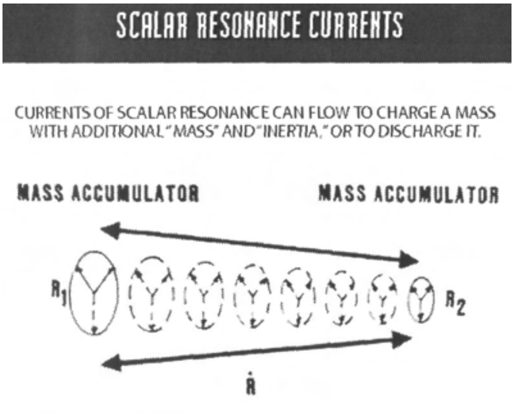

SCALAR RESONANCE CURRENTS

CURRENTS OF SCALAR RESONANCE CAN FLOW TO CHARGE A MASS WITH ADDITIONAL "MASS" AND "INERTIA," OR TO DISCHARGE IT.

Slide 036: Scalar Resonance Currents

As we pointed out, we can often greatly simplify matters by considering currents of scalar resonance. These currents flow from higher potential to lower potential, regardless of whether we are considering "transmission" or "reception."

Indeed, to "transmit at lower potential" is to receive, and to "receive at higher potential" is to transmit.

Thus the "transmitter-receiver" is a special system where simply biasing the two nodes differently determines which way the scalar resonance current will flow.

We may increase or decrease an object's inertia and mass, simply by properly biasing the transmitter-receiver system's two nodes.

In one accidental experiment of some hours in duration, Golden charged up an area so that, locally, all clocks became erratic. This included electrical clocks, battery-driven watches, wind-up kitchen clocks, and a pendulum-operated grandfather's clock. The rate of flow of time itself was apparently altered in the local area by the accumulated charge, which took some four days to drain off and discharge. At the end of the four days of discharge, all clocks and watches had returned to normal.

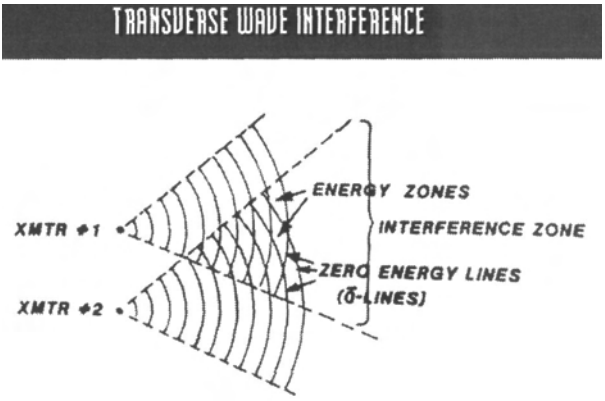
TRANSVERSE WAVE INTERFERENCE

Slide 037: Transverse Wave Interference

On this slide we show the orthodox representation of EM wave interference.

The chart is stylized since we assume two single-frequency EM waves that intersect and interfere in the indicated region.

In the interference zone, in-phase wave amplitudes add (constructive interference) while out-of-phase wave amplitudes subtract (destructive interference). In our stylized mode, we show the zero-summed locations as lines.

Conventionally, these interfering waves are considered to be transverse waves in vacuum.

The point is, in this scheme we think of "putting in the waves of finite amplitude, and creating the zero-amplitude regions by destructive interference." We create additional waves of increased-amplitude regions by constructive iterference.

Note that this view is only half correct. It addresses the electromagnetics, but not the gravitational aspects. Actually the regions of destructive EM interference are regions of constructive G-interference, and the regions of constructive EM interference are regions of destructive G-interference.

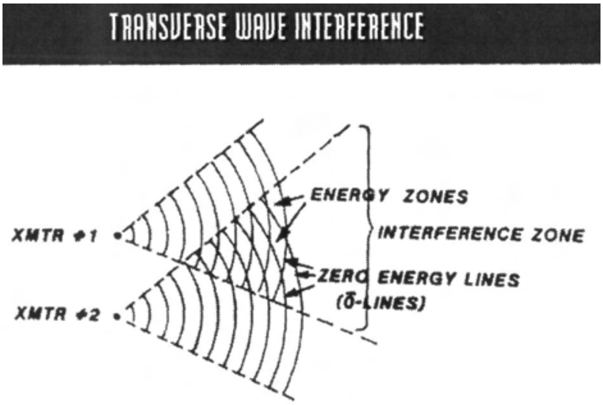

Slide 038: Transverse Wave Interference

Here we show the same interference situation, only now we think of transmitting scalar EM waves, which we model as longitudinal waves.

Again we assume two single-frequency scalar EM waves that intersect and interfere in the indicated region.

However, to an external observer, each of these waves individually appears to have zero E and H fields, hence to contain zero EM energy. That is, conventionally we seem to be transmitting waves of "pure potential," without any "force field" amplitudes whatsoever. We say we are transmitting waves of "artificial potential," since we deliberately constructed the zero-vector-summation scalar waves in the first place.

In the interference zone, a strange thing now happens. The relative magnitudes of the artificial potential of one wave with respect to the artificial potential of the other depend upon the phase relationship between the two. Further, whether the "gradient" so established appears negative or positive also depends upon the phase relationship between the two.

What results is most interesting: the out-of-phase condition now produces an EM gradient whose sign and magnitude are functions of the location within the interference zone.

Thus one now has real, non-zero EM potential gradients, both electrical and magnetic. And so real EM energy has emerged in an interference pattern within the area.

Ironically, we get essentially what we had before! Only now we have "put in the zero-reference lines, and produced the non-zero gradient (energy) zones."

In other words, we have recreated ordinary EM energy at a distance, directly from the interference of gravitational potential energy (anenergy).

And, to the laboratory observer, there has been no "EM wave" energy flow through the intervening space.

This was Tesla's secret of "wireless transmission of energy to a distance without losses."

Further, in a hypothetically perfect case, the interference represents a sort of "energybottle."

But now recall our need to take the sign of the scalar current into account. In this energy bottle, then, EM energy emerges and stabilizes - if and only if our transmitters are at higher reference potential than the ambient interference zone. If our transmitters are biased at lower potential, then energy is extracted from the energy bottle and re-emerges back at the transmitters, where it must be extracted and disposed of, if the transmitters are not to be burned out.

BACKGROUND FOR THE BRIEFER:

If we interfere two transmitters in a region of great energy -such as the molten core of the earth itself- and bias the transmitters negatively, we can extract enormous energy directly from that distant source!

Indeed, a slight variation of this effect is precisely how the Soviet Union obtains the enormous energy with which to power its incredibly powerful strategic "continent-buster"scalar EM weapons. Scalar frequency pairs - 12 kiloHertz apart - are transmitted into the earth itself on some portion of the earth's "giant scalar resonance" frequency curve. Biasing the two transmitters differently with respect to each other produces a high potential difference (voltage) between them. At the same time, biasing them both negative with respect to the earth's molten core produces a scalar resonance current from the core to the two transmitters. In the "outer loop" between the two scalar transmitters, there appears a gigantic voltage and gigantic electrical current that can be captured by appropriatemeans. This electrical power is tapped off and transmitted to incredibly powerful scalar EM weapon systems. There special accumulators and switchers are are utilized to provide the power of many Niagaras to each weapon.

Just before May 1, 1985 the Soviet Union performed a "full-up" operational test of their entire strategic scalar EM weapons complex. This test was detected and monitored periodically by Frank Golden. Some 27 of these giant Soviet "power taps" were locked into the molten core of the earth, producing forced (entrained) scalar resonance of the entire planet on 54 controlled frequencies under our very feet. The remainder of the scalar frequency spectrum was ablaze with literally hundreds of Soviet scalar transmitters: probably the entire strategic scalar command and control system to underwater submarines, higher command centers, distant commands, etc. was activated in the giant exercise.

For several days, the system was exercised on a mind-boggling scale, apparently as part of the Soviet Union's highly accentuated 40th anniversary celebration of the end of World War II.

Ironically, not a single U.S. intelligence agency, laboratory, or scientist detected this monstrous exercise for the new Soviet leader, Gorbachev. Not a one of them had a detector for scalar EM radiation, and not a one of them officially believes the exercise ever happened.

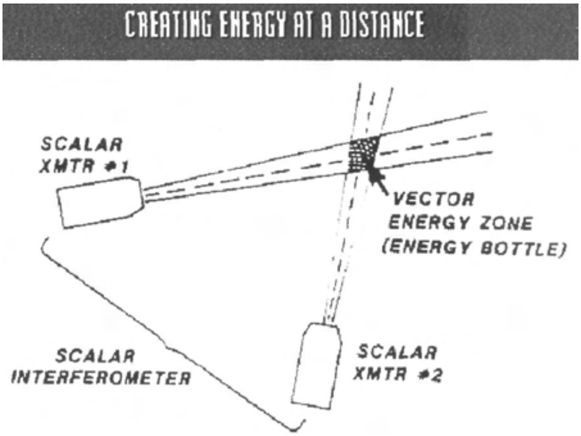
CREATING ENERGY AT A DISTANCE
SCALAR XMTR #1
VECTOR ENERGY ZONE (ENERGY BOTTLE)
SCALAR INTERFEROMETER
SCALAR XMTR #2

Slide 039: Creating Energy at a Distance

A most useful device is obtained if one uses a scalar interferometer where the two transmitters transmit beams that intersect at a distance.

In the interference zone, an energy bottle is created.

By biasing the transmitter reference potentials well above that of the distant energy bottle, EM energy emerges in that zone. In that case the interferometer is operating in the exothermic mode.

By biasing the transmitter reference potentials well below that of the distant energy bottle, EM energy is extracted from the distant zone and emerges from the transmitter. In that case the interferometer is operating in the endothermic mode.

If the transmitters transmit continuously, the effect in the distant zone is continuous.

If each transmitter transmits a pulse, and the two pulses meet in the distant intersection zone, then an explosive emergence or extraction of energy occurs at the distant interference zone, depending upon whether the interferometer is operating in the exothermic or the endothermic mode.

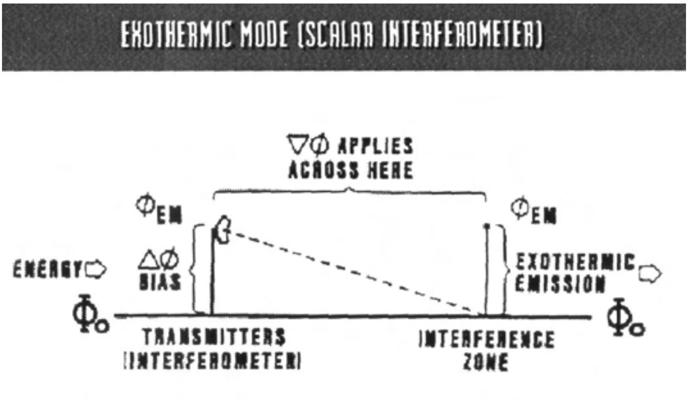

Slide 040: Exothermic Mode (Scalar Interferometer)

For a scalar interferometer, "del phi" (the gradient of the potential) applies between the transmitter site and the distant intersection site, not to the intervening space in between. Thus one speaks of "energy flow" as being between transmitter and intersection, without any "in between." In the intervening space, all the energy exists as locked-in artificial potential, not EM force field energy (gradient bleed-off of potential).

In the exothermic mode, the ground potential of the transmitter is biased well above the ground potential of ambient vacuum. Energy enters the transmitter and "disappears", to "reappear" in the distant interference zone.

If continuous wave transmission is used, the energy continuously appears in the distant zone.

If pulse transmission is used and timed so that the two scalar pulses meet in the distant zone, energy explosively appears there.

If multiple frequencies are transmitted in the manner of a Fourier expansion of a particular geometric form, then a 3-dimensional energy form appears at the distant intersection. In this manner, a spherical or hemispherical shell (a globe of "dome" of EM energy) can be created at a distance. If pulse transmission is used, this will be an impulsive or explosive emergence of that energy form. If continuous transmission is used, this will be a continuous glowing form.

By feeding incredibly powerful transmitters with large amounts of energy extracted from the earth's molten core by "energy taps," very large spherical globes and hemispherical domes of EM energy can be created. The energy in the interference "shell" of such a sphere or hemisphere is sufficiently dense to lift Dirac matter from the Dirac sea of the vacuum. Thus the shell contains a glowing plasma.

Many such scalar howitzer signatures have been seen over the oceans, particularly over the North Pacific by jet airliners flying into and out of Japan. Also, such globes and domes of light have been seen deep within the Soviet Union, by observers in Afghanistan and by pilots of aircraft landing in Iran.

In the impulsive exothermic mode, a large visible flash will occur if EM energy in the visible spectrum is produced. "Flashes" in the infrared may similarly occur, if the emerging energy is in that spectral band. In September 1979 our Vela satellites detected such a large "nuclear flash" over the South Atlantic, off the southern coast of Africa. A second "nuclear flash" detected by the Vela satellites in 1980 was in the infrared only. Some years ago, a series of Momalous "flashes" and "booms" occurred off the east coast of the United States. These were due to the orientation and alignment -and registration - of one or more Soviet "scalar howitzers" - scalar EM interferometers in the exothermic mode.

Large "booms" occurred over the shuttle launch site at Cape Canaveral, associated with three shuttle launches prior to the end of November 1985. These were tests of such exothermic scalar EM howitzers, being tested as part of the Soviet Launch Phase ABM system. In that mode, the scalar pulses from the two transmitters are injected into special zero-reference scalar EM "channels" established in the EM carriers of the Woodpecker over-the-horizon radars. The scalar pulses travel through these channels, traveling in the ordinary EM beam of the transmitter and following it in its curvature around the earth in the earth-ionospheric waveguide. The scalar pulses are timed, phased, and oriented so as to meet the rising shuttle. In these tests the transmissions were offset in time so the shuttle would not actually be destroyed, but the system could be tested against actual shuttle launches in the U.S.

The specific uses of these various exothermic modes will be covered in later parts of the briefing.

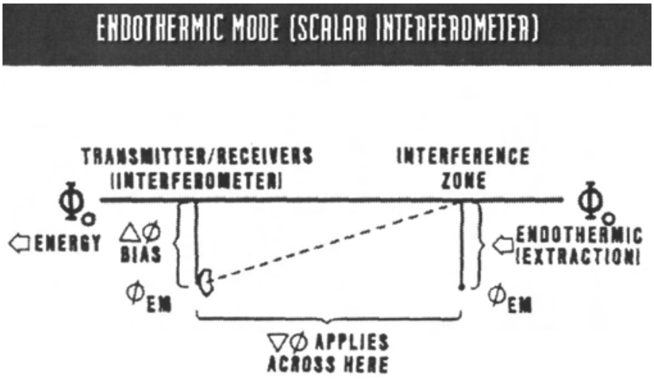
ENDOTHERMIC MODE (SCALAR INTERFEROMETER)
TRANSMITTER/RECEIVERS (INTERFEROMETER)
INTERFERENCE ZONE
Φ_o
Φ_o
ENERGY
$\Delta\phi$ BIAS
ENDOTHERMIC (EXTRACTION)
ϕ_{EM}
ϕ_{EM}
$\nabla\phi$ APPLIES ACROSS HERE

Slide 041: Endothermic Mode (Scalar Interferometer)

In the endothermic mode, the bias on the transmitters is such that energy is extracted from the distant intersection zone, to re-emerge at the transmitters. There the energy must be caught and disposed of if it is not to burn out the transmitters. When very large amounts of energy are extracted from distant points, the Soviets often use a "dump" method of temporarily capturing, and storing in an accumulator, the heat energy emerging at the transmitters. A "scalar energy tap" established into the accumulator then feeds a second howitzer in the exothermic mode. This howitzer is focused on a distant dumpsite - often Bennett Island, where U.S. weather satellites continually observe exhausts.

In the impulsive endothermic mode, energy is impulsively extracted from the distant intersection zone. In the atmosphere this results in a very sharp cooling, or a "cold explosion." It also results in the type of boom and rumble often associated with thunder after a lightning bolt.

On April 9, 1984 the Soviet Union tested such a "cold explosion" off the coast of Japan, near the Kuril Islands. In the suddenly induced low pressure "cold zone" above the ocean, ocean water was sharply sucked up from the ocean, forming a dense cloud. Then air rushing in to the low pressure zone forced the cloud upward, forming a mushroom much like that of an atomic explosion in visual appearance, except for the absence of a flash and the absence of a giant shock wave moving out away from the site of the explosion. (In this case the

Soviets controlled the rise time of the pulse so that no "giant atmospheric boom" occurred.).

As the cloud rises, it expands by mixing - very similar to a giant thunderhead buildup, except much faster. In this case the cloud rose to 60,000 feet in about 2 minutes, spreading out until it reached a diameter of about 200 miles. The pilots and crews of several Boeing 747 jet airliners in the general vicinity saw the incident. Sometime after that, a U.S. weather satellite photo of the area occurred. The cloud in that photo has an anomalous density distribution, differing from that of all other clouds in the area.

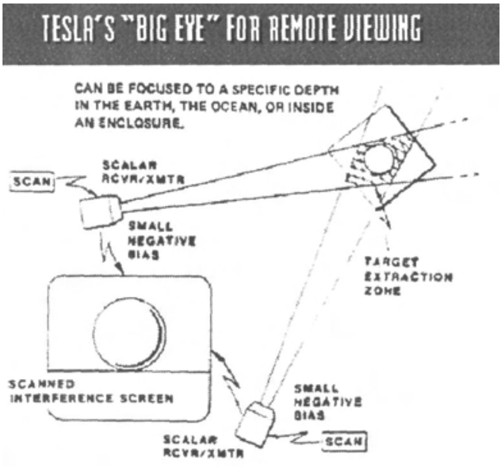
TESLA'S "BIG EYE" FOR REMOTE VIEWING
CAN BE FOCUSED TO A SPECIFIC DEPTH IN THE EARTH, THE OCEAN, OR INSIDE AN ENCLOSURE.
SCAN
SCALAR RCVR/XMTR
SMALL NEGATIVE BIAS
TARGET EXTRACTION ZONE
SCANNED INTERFERENCE SCREEN
SMALL NEGATIVE BIAS
SCALAR RCVR/XMTR
SCAN

Slide 042: Tesla's "Big Eye" for Remote Viewing

Nikola Tesla also planned a very special use for his endothermic scalar interferometer. He planned to produce what he called his "big eye to see at a distance."

This is accomplished as shown on the diagram. First, the system is only weakly endothermic, so that only a small amount of energy is extracted from the **distant** target. Also, the beams are "scanned" by an open receiver, timewise, from side to side and top to bottom. By scanning yet another single beam through the intersection zone and phasing its pulses, an even better representation can be obtained. Thus the receiver produces a representation of the energy extracted from various locations within the distant endothermic zone. By displaying the received signals on an appropriately scanned screen, a representation of the distant scene in the intersection zone can be created. Indeed this is a special kind of "microwave interferometry," and - with modern techniques - the imagery obtained might be surprisingly good. With development, it might even become as good as the image presently obtained by side-looking acquisition radars.

Interestingly enough, since scalar EM beams will easily penetrate the earth or the ocean, one can also look beneath the earth or beneath the ocean with this type of scanning scalar interferometer.

The importance of this capability to strategic and tactical reconnaissance is obvious. Camouflage, cover, and concealment have no effect on such a **system.** One can easily look inside buildings and into underground facilities. With a small system such as this, the U.S. Marines at Khe Sahn would have had **little** difficulty locating the tunnels continually dug under the perimeter by the Viet Cong. And targets under jungle canopies are directly visible.

BACKGROUND FOR THE BRIEFER:

It requires little imagination to see that this system is easily adapted to produce an "underwater radar." With such devices, the problem posed by the underwater nuclear submarine is solved. For example, an entire area can be continually searched, much like acquisition radar systems do now. A submarine can be detected and tracked, and none of its ordinary detectors will detect anything out of the ordinary. By using a separate pair of beams in the exothermic mode, powerful scalar pulses can be fired at the distant sub, intersecting at the submarine in a violent EMP throughout the sub and its armament. Thus the sub and all its missiles are destroyed instantly.

Or, continuous exothermic transmission can be used by the targeting weapon at lesser power, gradually interfering with the sub's electrical systems and causing it to lose control. The sub then sinks to crush depth and implodes.

Precisely that scenario seems to be what happened on April 10, 1963 to the U.S.S. Thresher nuclear submarine. It left a signature: the sub's surface companion, the nearby U.S.S. Skylark, was in the "splatter zone" of the underwater scalar interference. That is, spurious EM noise was being generated In all the Skylark's electrical systems, some of which were actually disabled. So intense was the "electronic jamming" that it required over an hour and a half for the Skylark to transmit an emergency message back to its headquarters that the Thresher was in serious trouble and contact with it had been lost. Some of the Skylark's communication systems actually failed, but later resumed operation inexplicably, once the jamming was gone. That type of "jamming" of multiple bands and multiple electronic equipments, of course, together with the anomalous failure of electronic equipment and its later mysterious recovery, were direct signatures of the use of the exothermic scalar interferometer against the undersea target area in the vicinity of the Skylark.

The very next day, Apr. 11, 1963, the same Soviet scalar EM howitzer system was tested in the "destroy submarine" pulse mode. A huge underwater EM blast occured off the coast of Puerto Rico, about 100 miles north of the island. The underwater explosion caused a huge boiling of the surface of the ocean, followed by the rising up of a giant mushroom of water about a third of a mile high. The mushroom of water then fell back into the ocean, completing the signuture.

Fortunately the startled crew of a passing U.S. jetliner that was just passing its checkpoint in that area saw the entire incident. (See Robert J. Durant, "An Underwater Explosion - or What?", Pursuit, 5(2), April 1972, p. 30-31.)

These two incidents were full-up operational tests of Khrushchev's newly deployed superweapons. He probably staged this dramatic one-two punch in a desperate effort to recover face with the Communist Party after his disastrous facedown by Kennedy in the Cuban Missile Crisis a few short months previously. Apparently the attempt was successful, since he remained in power another year before being deposed.

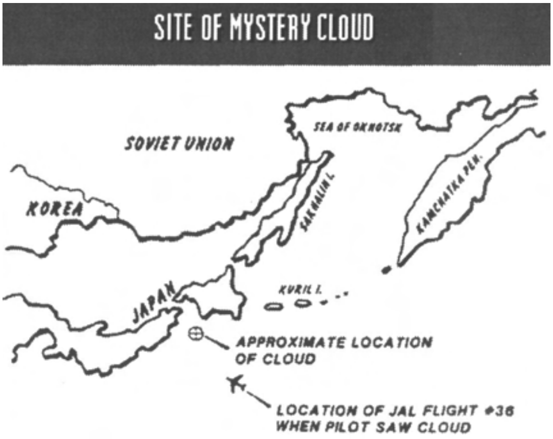
SITE OF MYSTERY CLOUD
SEA OF OKHOTSK
SOVIET UNION
KOREA
SAKHALIN I.
KAMCHATKA PEN.
KURIL I.
JAPAN
APPROXIMATE LOCATION OF CLOUD
LOCATION OF JAL FLIGHT #36 WHEN PILOT SAW CLOUD

Slide 043: Site of Mystery Cloud

On this slide we show the location of the "cold explosion" off the coast of Japan on April 9, 1984. The site of the explosion was only about 200 miles from downtown Tokyo. The crews of several jet airliners, including Japan Air Lines Flight 36, saw it.

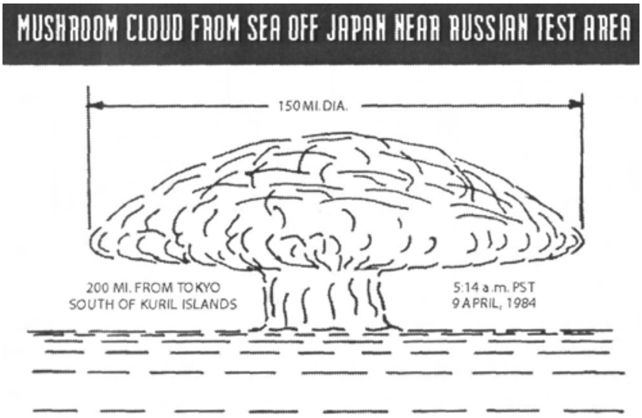

Slide 044: Mushroom Cloud from Sea off Japan near Russian Test Area

A short time before, the Soviets had hastily announced missile tests would be conducted into a zone some distance away from the cold explosion site. This may have been intended as deception to cover this incident, should any foreign nation indicate they understood what was going on.

It also was a direct "stimulus" to the Japanese and the rest of the world: That is, stimulate the system and see if the scientists recognize what happened. If they do, then they know about scalar EM weapons. If they don't, then their countries know nothing of scalar EM weapons, and those countries are defenseless against them.

At any rate, at about 5:14 a.m. Pacific Standard Time on April 9, 1984, a **giant** mushroom cloud erupted above the ocean south of the Kuril Islands. The mushroom rose rapidly, expanding as it rose. In two minutes it had reached **an** altitude of 60,000 feet and a diameter of about 200 miles.

One pilot of a Boeing 747 who observed the cloud was a former B-52 bomber pilot. He described the cloud as very similar to a mushroom cloud from a gigantic nuclear explosion, except there was no flash of visible light. Taking evasive action, he turned off course away from the blast, and braced for a blast shock wave, which never came.

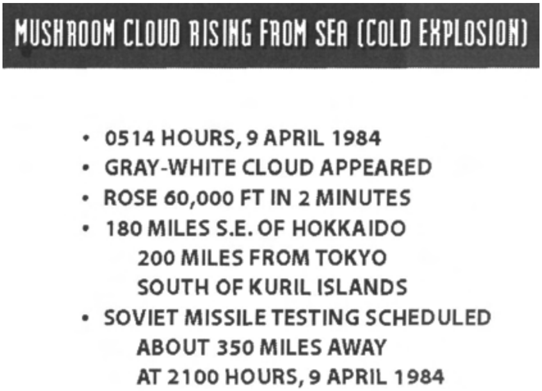

MUSHROOM CLOUD RISING FROM SEA (COLD EXPLOSION)

- 0514 HOURS, 9 APRIL 1984
- GRAY-WHITE CLOUD APPEARED
- ROSE 60,000 FT IN 2 MINUTES
- 180 MILES S.E. OF HOKKAIDO
  200 MILES FROM TOKYO
  SOUTH OF KURIL ISLANDS
- SOVIET MISSILE TESTING SCHEDULED
  ABOUT 350 MILES AWAY
  AT 2100 HOURS, 9 APRIL 1984

Slide 045: Mushroom Cloud Rising from Sea

Indeed, this highly anomalous cloud was due to a cold explosion - a test of a Soviet scalar EM howitzer in the pulsed endothermic mode.

In the weapon's targeted interference zone, EM energy (heat) was rapidly withdrawn when the biased endothermic extraction occurred. Above the ocean an intense low-pressure zone was created. Water from the ocean was sucked up, as if by a giant vacuum cleaner. The water was violently broken into droplets, forming a dense cloud, with a strong upward momentum.

The surrounding higher-pressure air rushed into the low-pressure zone, pushing the rising dense cloud of water vapor upward as its upward momentum continued. Mixing caused rapid expansion of the rising cloud, causing its density to thin measurably as it rose and expanded. An effect very similar to the formation of a strong thunderhead resulted, except much faster.

The mixing cloud also resembled the mushroom cloud from a giant nuclear explosion, just as an emerging thunderhead does.

But no outward blast wave resulted as does from a nuclear explosion. Also, no visible flash occurred, probably as a result of deliberate design by the Russians.

Thus a beautiful "stimulus" and test was conducted: quite a few airliners were "pinged," providing a high-level stimulus to competent observers. The news was sure to be reported by them to several nations. The press was sure to pick up the story. This was a high order stimulus to see whether the U.S., Japan, or other potential adversaries of the Soviet Union recognized the testing of a cold explosion weapon.

By our reaction, we assured them (with high confidence) that we still knew nothing of scalar EM interferometry or cold explosions.

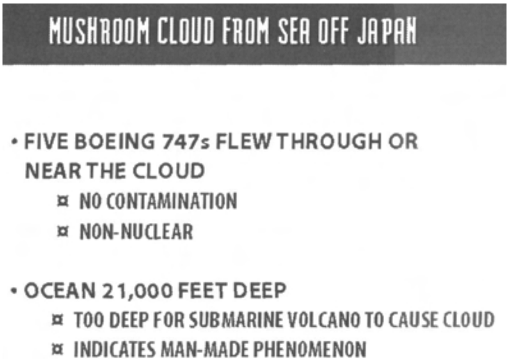

MUSHROOM CLOUD FROM SEA OFF JAPAN

- FIVE BOEING 747s FLEW THROUGH OR NEAR THE CLOUD
  - NO CONTAMINATION
  - NON-NUCLEAR
- OCEAN 21,000 FEET DEEP
  - TOO DEEP FOR SUBMARINE VOLCANO TO CAUSE CLOUD
  - INDICATES MAN-MADE PHENOMENON

Slide 046: Mushroom Cloud from Sea off Japan

Five Boeing 747's flew through or near the cloud on their way to Anchorage, Alaska. The aircraft were checked at Anchorage for radioactive contamination, but nothing was found. This showed that the huge "explosion" had been non-nuclear.

The ocean in the area is also about 21,000 feet deep. That is really too deep for a submarine volcano to have erupted and caused the cloud. (Besides, a volcano would have continued to snort at least a bit, and so that appears to be out of the question as a possible cause of the incident.)

In short, a manmade phenomenon is indicated.

Indeed, we know it was a cold explosion. As I've stated previously, a colleague has in fact produced the basic effect over a dish of water in the laboratory, using a small scalar interferometer in the endothermic mode.

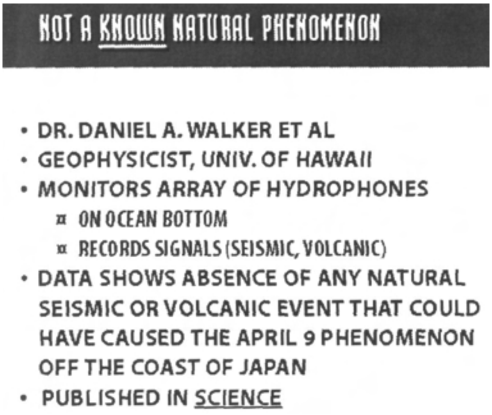

NOT A KNOWN NATURAL PHENOMENON

- DR. DANIEL A. WALKER ET AL
- GEOPHYSICIST, UNIV. OF HAWAII
- MONITORS ARRAY OF HYDROPHONES
  - ON OCEAN BOTTOM
  - RECORDS SIGNALS (SEISMIC, VOLCANIC)
- DATA SHOWS ABSENCE OF ANY NATURAL SEISMIC OR VOLCANIC EVENT THAT COULD HAVE CAUSED THE APRIL 9 PHENOMENON OFF THE COAST OF JAPAN
- PUBLISHED IN SCIENCE

Slide 047: Not a Known Natural Phenomenon

Further, the story does not end there.

A geophysicist at the University of Hawaii, Dr. Daniel A. Walker, together with his colleagues monitor an array of hydrophones on the ocean bottom, recording signals such as seismic incidents, volcano eruptions, etc.

Dr. Walker and his colleagues performed a comprehensive analysis of the data recorded by the hydrophones in and around the time of the incident in question. The data shows the absence of any natural seismic or volcanic event that could have caused the April 9th phenomenon off the coast of Japan.

He and his colleagues concluded that it was either an as yet unknown natural phenomenon, or a man-made phenomenon.

Their report is published in Science. (Walker et al, "Kaitoku Seamount and the Mystery Cloud of 9 April 1984," Science, 227(4687), Feb. 8, 1985, p. 607-611.)

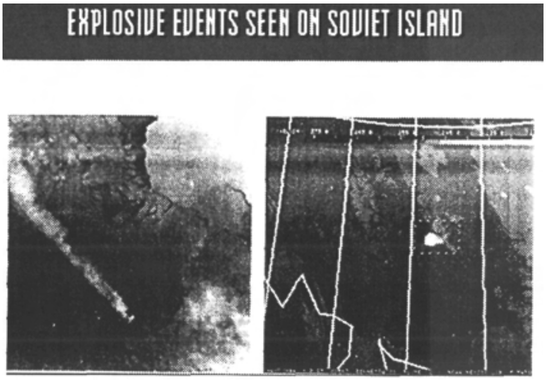
EXPLOSIVE EVENTS SEEN ON SOVIET ISLAND

Slide 048: Explosive Events seen on Soviet Island

Here are two U.S. weather satellite photos of the anomalous exhausts on Bennett Island we previously referred to.

The exhaust in the left picture is about 150 miles long, and is nearly horizontal (about 1.5 degrees above the horizontal). It is entirely consistent with the continuous exhaust from a "dumping transfer" scalar EM howitzer in the continuous exothermic mode. (The primary howitzer, of course, was activated in the endothermic mode.)

I think any open-minded investigator must admit that that is indeed a very powerful jet-like exhaust, and not like anything one ever sees from a natural volcano or geological gas vent. If anyone knows of such an anomalous volcanic or geological exhaust, I would be most delighted to see a photo or report. To my knowledge, no such natural photo exists, and no such natural exhaust has ever been reported.

The right picture shows the "puff of an explosive emergence of the exhaust. In other words, this one is the exhaust from a "dumping transfer" howitzer used in the pulsed exothermic mode. Since it did not have so much energy to dump, it could dump it in a pulse. Again, the primary howitzer, of course, was activated in the endothermic mode.

Over 100 weather satellite photos of these anomalous exhausts have been taken since 1974.

One or more U.S. aircraft have even been vectored through the exhausts, and samples of the exhaust taken and analyzed. The exhaust is made up of a little clay and mud and water, and is colder than the surrounding air.

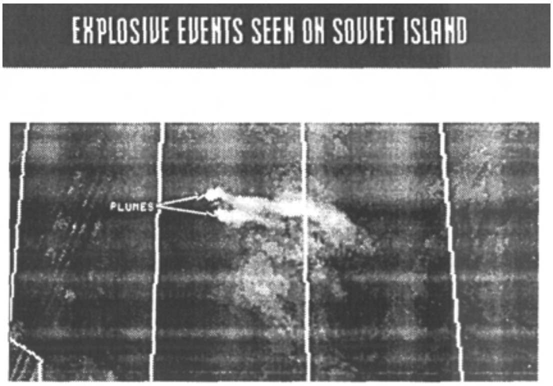

EXPLOSIVE EVENTS SEEN ON SOVIET ISLAND

Slide 049: Explosive Events seen on Soviet Island

U.S. weather analysts euphemistically call these exhausts from Bennett Island plumes.

Here is another U.S. weather satellite photo, showing the twin emergence of multiple puffs.

One might expect such exhausts if the secondary "dumping transfer" howitzer is operated in the continuous mode, with continuous extraction by "power tapping" the accumulator of the primary howitzer. In that case, the signature of the exhaust would expose the operation of the primary howitzer. For example, this exhaust would indicate multiple puffs, hence probably multiple frequencies and multiple primary transmitters, each phased in a controlled manner. That of course indicates the production of Fourier expansion forms - of 3-dimensional geometrical forms - by the primary howitzer(s). Since these are puffs, it may indicate the explosive formation of distant spherical balls of energy by the primary howitzer. This in turn indicates the use of a howitzer system in the "pulse firing" mode, which can be used against missiles, ships, aircraft, ground targets, armored vehicles, underwater targets, etc.

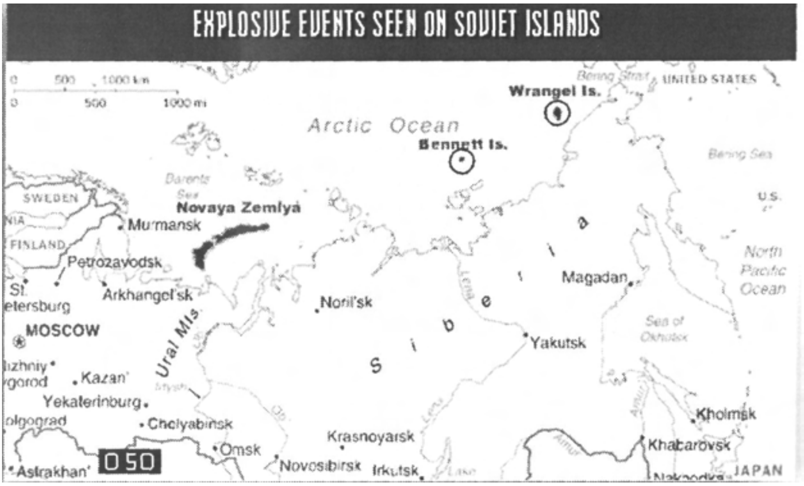

EXPLOSIVE EVENTS SEEN ON SOVIET ISLANDS

0 500 1000 km
0 500 1000 mi
Arctic Ocean
Wrangel Is.
Bennett Is.
Bering Strait
UNITED STATES
Bering Sea
U.S.
Barents Sea
Novaya Zemlya
SWEDEN
FINLAND
Murmansk
Petrozavodsk
St. Petersburg
Arkhangel'sk
MOSCOW
Nizhniy Novgorod
Kazan'
Yekaterinburg
Volgograd
Chelyabinsk
Astrakhan'
Omsk
Novosibirsk
Krasnoyarsk
Irkutsk
Ural Mts.
Noril'sk
Lena
S i b e r i a
Yakutsk
Magadan
North Pacific Ocean
Sea of Okhotsk
Amur
Kholmsk
Khabarovsk
Nakhodka
JAPAN
050

Slide 050: Explosive Events seen on Soviet Islands

This slide shows the location of three areas of interest relative to Soviet scalar EM weapons testing.

Wrangel Island, north of the northeastern portion of the Soviet mainland, is associate with tests of these weapons in large circular breakups of the ocean's ice cover. This of course could aid submarines that wished to surface and fire cruise missiles, or submarines that wished to fire from underwater and needed the **ice** broken up.

Strangely enough, Wrangel Island has a most peculiar history: legally it still belongs to the U.S., but has been "given" to the Soviet Union without permission of the U.S. Senate, which is illegal.

Bennett Island, a little farther to the west and still north of the Soviet **mainland,** is noted for its phenomenal number of anomalous exhausts as previously discussed.

North of the Soviet mainland and near its middle lies the large island of Novaya Zemlya. Weather satellites have taken pictures of anomalous circulations over this island, which are further candidates for exhausts from scalar EM howitzer operations.

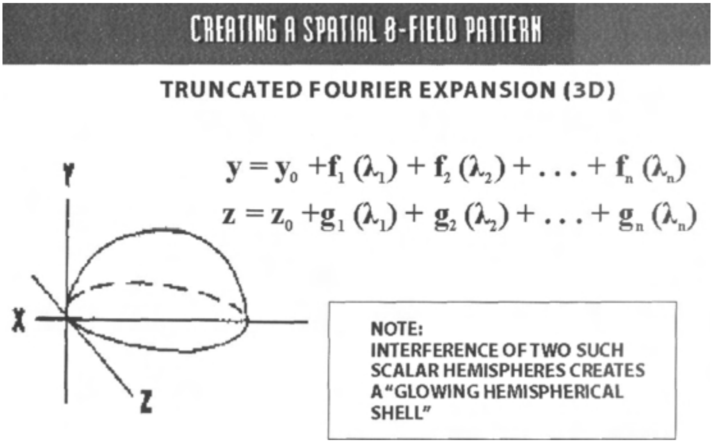

CREATING A SPATIAL 8-FIELD PATTERN

TRUNCATED FOURIER EXPANSION (3D)

$$y = y_0 + f_1(\lambda_1) + f_2(\lambda_2) + \dots + f_n(\lambda_n)$$

$$z = z_0 + g_1(\lambda_1) + g_2(\lambda_2) + \dots + g_n(\lambda_n)$$

NOTE:
INTERFERENCE OF TWO SUCH SCALAR HEMISPHERES CREATES A "GLOWING HEMISPHERICAL SHELL"

Slide 051: Creating a Spatial 0-Field Pattern

On this slide we show that a hemispherical dome (or other regular shape) can be composed from scalar waves by 3-dimensional Fourier expansion. By truncating the expansion - say after 10 or 12 frequency terms - a good representation of **the** desired form can be obtained with a practical number of frequencies, and in turn a practical number of transmitters. A computer is used to compute the multiplying functions for each frequency, and the entire complex of frequencies is **then** transmitted to produce the scalar form. By interfering two such scalar forms, a 3-dimensional shell of locked-in, ordinary EM energy is formed in **space.**

Interference of two such scalar hemispherical surfaces creates a "glowing hemispherical shell or dome of energy."

Interference of two such scalar spherical surfaces creates a "glowing spherical shell or globe of energy."

Both such geometric forms have been repeatedly seen.

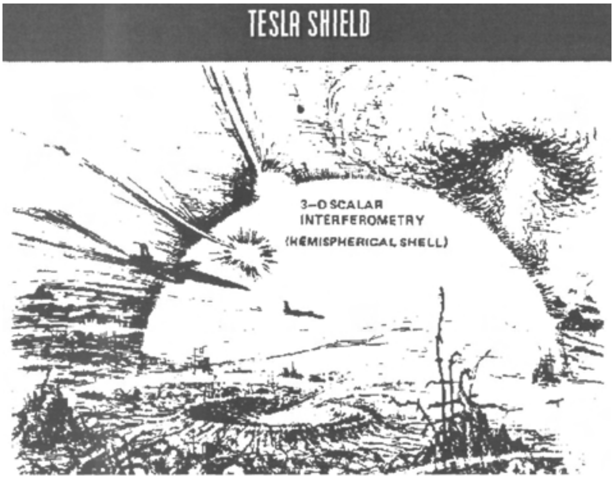

Slide 052: Tesla Shield

Of particular interest is the hemispherical shell of energy, which years ago I dubbed the "Tesla shield."

As shown on this slide, two scalar hemispherical surfaces are created, using multiple frequency transmitters and truncated Fourier series expansions. Interference of the two scalar hemispheres creates a great, glowing hemispherical shell of ordinary electro-magnetic energy. In the shell, the energy density is sufficient to lift Dirac matter from the Dirac Sea of vacuum. The shell is thus filled with a glowing plasma.

Such a shell may be several hundred miles in diameter at the base. The enormous energy required to form such a defense shell is obtained by a "scalar power tap" into the molten core of the earth itself, as previously explained. In late April/early May of 1985, 27 such "power taps" were placed in the earth by the Soviets. If each tap is capable of powering four to six large scalar EM weapons, then the Soviet strategic scalar EM arsenal contains over 100 monstrous superweapons capable of generating exothermic explosions, endothermic explosions, engineering the weather, locating and destroying underwater submarines, detecting and destroying ballistic missiles shortly **after** launch, detecting and destroying long range strategic bombers as soon as they are airborne, etc.

At any rate, the giant Tesla shield is useful against any penetrating vehicle. If the shell is not so large, its energy density may be very high. In **that** case, **the intense** plasma heating will fuse and even vaporize metallic bodies. In addition, any vehicle encountering the shell is subjected to an extremely intense EMP arising everywhere inside its circuitry. EM shielding is of no use against the creation of energy throughout the spacetime of the circuits; such shielding only helps against energy flow through space in the conventional sense.

Thus the electronics of any vehicle encountering the shield are instantly dudded, whether or not they are shielded against ordinary electromagnetic interference (EMI). This includes the electronics operating a nuclear warhead, carried by a re-entry vehicle. Electrically everything penetrating the shell is totally dudded. Further, explosive materials are exploded when such an EMP is encountered, and combustible materials are fiercely consumed or set afire. Ablative shielding suffers an interesting catastrophe: since energy does not try to "flow into" the shielding but "arises everywhere in it simultaneously", "ablation" occurs everywhere throughout the ablative material, simply exploding it instantly. In addition, for smaller Tesla shells (say of 50 miles diameter) the energy density is sufficient to melt or vaporize metals such as in missile structures.

With such a Tesla shield, there is no need to discriminate true warhead-bearing re-entry vehicles from decoys, chaff, etc. The entire "mess" entering the shield is simply "cleaned up" and "sterilized" or destroyed. The shield can take care of ICBMs/IRBMs and their nuclear warheads, strategic bombers and their nuclear **bombs,** cruise missiles and their nuclear warheads, re-entry vehicles and their warheads, decoys, chaff, etc.

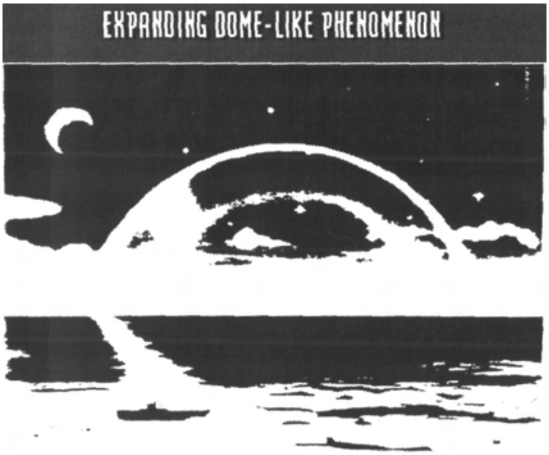

Slide 053: Expanding Dome-like Phenomenon

Here we show one instance of apparent Soviet testing of the Tesla shield (hemispherical shell of energy) over the ocean. This incident occurred in the Caribbean and Western North Atlantic Ocean on Mar. 20, 1969 and is reported in the Marine Observer, Vol. 40, 1970, p. 17. A semicircle of milky white light, quite intense at first, was sighted on the horizon. The semicircle enlarged, dimming as it expanded. The incident lasted for about 10 minutes. Seen from a passing ship, the top of the hemisphere reached a sighting elevation angle of about 50 degrees, while the base of the hemisphere of light subtended an arc of about 70 degrees. This is directly indicative of a test of the Tesla shield, first as a small, more intense shield and then expanding to greater size for a less intense shield whose primary destructive mechanism is EMP. Note that the EMP in a Tesla shield is locally contained in the energy-bottle shell. It is not an ordinary EMP of energy radiated out of the shell.

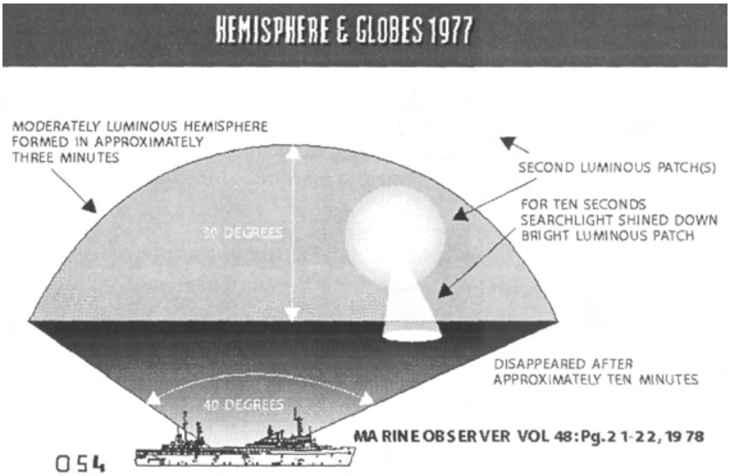
HEMISPHERE & GLOBES 1977
MODERATELY LUMINOUS HEMISPHERE FORMED IN APPROXIMATELY THREE MINUTES
SECOND LUMINOUS PATCH(S)
FOR TEN SECONDS SEARCHLIGHT SHINED DOWN BRIGHT LUMINOUS PATCH
30 DEGREES
DISAPPEARED AFTER APPROXIMATELY TEN MINUTES
40 DEGREES
MARINE OBSERVER VOL 48:Pg.21-22,1978
054

Slide 054: Hemisphere & Globes 1977

Here is a second instance of apparent Soviet testing of the hemispherical Tesla shield over the ocean. This time it is combined with simultaneous testing of two smaller scalar interferometers creating Tesla globes of EM energy.
This incident occurred at 23 degrees 5 minutes north, 17 degrees 25 minutes west. It was sighted and reported by a British ship, H.M.V. Kinpurnie Castle, on Mar. 24, 1977. The report is in the Marine Observer. Vol. 48, 1978, p. 21-22.

First a large, moderately luminous hemisphere of light formed, requiring about 3 minutes to do so. Seen from the ship, the top of the hemisphere was at a sighting elevation angle of about 30 degrees, while the base subtended an arc of about 40 degrees. This was the basic Tesla shield.

Then two other luminous globes or patches of light, each of about 1 degree diameter as seen from the ship, formed in the same area; one inside the shield and one outside it. From the glowing globe inside the shield, a light beam similar to a giant searchlight shone down to the ocean's surface for about 10 seconds.

Again the phenomena lasted about 10 minutes and then disappeared.

The luminous globe or patch inside the hemisphere might be the test of a second weapon deployed from a Soviet aircraft in the area. If so, the aircraft has placed a **strong** spherical shield around itself. In addition, the aircraft is utilizing some sort of scalar interferometer beam weapon in an underwater mode. Probably this would imply a "shot" at a hostile nuclear submarine inside the shielded zone. Thus this aircraft would have the scalar EM equipment to search for the underwater sub and detect it, and also to concentrate interference energy upon it underwater, destroying it quickly.

Suffice it to say that it is possible to perform scalar interferometry by means of a single beam, in a proprietary process discovered by a close colleague. Thus the "glowing beam to the ocean" resembling a searchlight makes very good sense in the anti-submarine role. The same weapon, of course, could also attack any hostile surface vessel that might have been inside the shielded area at its formation.

The second luminous globe or patch, outside the hemisphere, is probably from a second scalar interferometer from the naval task force, simulating the continuous attack of a certain target (missile or aircraft) outside the protective dome.

As can be seen, this phenomenon is directly indicative of the types of operations one would expect from the testing of Soviet scalar EM weapons at sea, possibly to protect a Soviet naval task force during simulated combat operations.

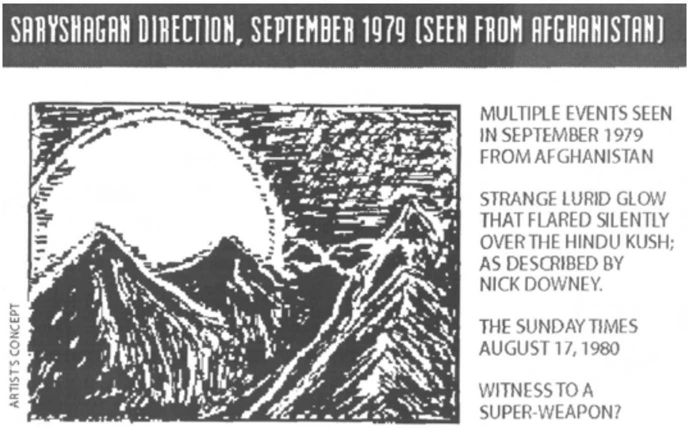

SARYSHAGAN DIRECTION, SEPTEMBER 1979 (SEEN FROM AFGHANISTAN)

MULTIPLE EVENTS SEEN
IN SEPTEMBER 1979
FROM AFGHANISTAN

STRANGE LURID GLOW
THAT FLARED SILENTLY
OVER THE HINDU KUSH;
AS DESCRIBED BY
NICK DOWNEY.

THE SUNDAY TIMES
AUGUST 17, 1980

WITNESS TO A
SUPER-WEAPON?

Slide 055: Saryshagan Direction, September 1979

The London Sunday Times of 17 August 1980 contained information and a photo-sketch of incidents of sighting of the testing of very large Tesla globes deep within the Soviet Union. British war cameraman Nick Downie made the sightings from Afghanistan. The phenomena seen were in the direction of the Saryshagan Missile Test Range, which - according to the U.S. Defense Department's Soviet Military Power, 1986 - contains one or more large directed energy weapons (DEWs).

Even though Downie was seeing the giant globe of light from a great distance, it flared silently over the Hindu Kush and expanded to subtend an arc of about 20 degrees, dimming as it expanded. (An arc of 20 degrees subtended by an object many hundreds of miles distant indicates an object of well over a hundred miles in diameter. This gives some idea of the enormous energy being controlled and manipulated by these Soviet weapons.).

Downie saw the sight on more than one occasion in September 1979.

BACKGROUND FOR THE BRIEFER:

In the same month - September 1979 - a stationary luminous globe containing a vertical stripe of black in the center was seen in the sky off Saint Petersburg, Florida. This particular type of sighting in that area has been previously correlated with times of known activity at Saryshagan.

Further, in the same month U.S. nuclear-warning Vela satellites detected a mysterious "nuclear flash" over the South Atlantic, off the coast of Africa. Controversy has raged in U.S. intelligence and scientific circles to this day as to whether a nuclear explosion or some other mechanism produced the flash.

Indeed, the flash may have been produced by a scalar EM howitzer from Saryshagan as one more "ping" of the U.S. intelligence system, to ascertain whether or not it knew anything about scalar EM howitzers. Again, the negative response told them with high confidence that (1) we still didn't know about scalar EM stuff, and (2) we were still absolutely defenseless against the Soviet scalar EM weaponry.

In 1980, a second "Vela flash" was reported. This time it occurred in the infrared region only, which positively rules out any sort of nuclear explosion. Even this increased stimulus still evoked a U.S. action that revealed total ignorance of scalar EM weaponry.

An alternate possibility for the September 1979 Vela flash also exists: countries not hostile to the U.S. may have tested a scalar EM weapon that produced the flash.

At any rate, from Downie's sightings, it is highly probably that the DEW weaponry at Saryshagan Missile Test Range was active in September 1979, and was producing huge Tesla globes. If the DEWs at Saryshagan can produce the giant luminous Tesla globe, they almost certainly are scalar EM interferometers and can produce the giant Tesla shields as well. Downie reported other earlier sightings of similar phenomena seen by Afghans deep within the Soviet Union in the same direction toward Saryshagan.

Briefly let us cover the uses of such a "giant globe" or spherical shell of glowing EM energy and plasma.

By placing such a "giant globe" thousands of kilometers out away from the defended heartland, an entire arc of the sky can be defended against long-range ballistic missile attack in midcourse. During their midcourse trajectory, the attacking missiles would have to penetrate the globular shell twice, exposing them to giant internal EMPs twice. A very high probability thus exists that all missiles entering the space occupied by the globe are dudded upon entry and/or exit. This includes the electronics inside the nuclear warheads themselves. Also, this is particularly effective against MIRV and MARV missile carriers, since the multiple re-entry vehicles are normally still on the main vehicle during most of midcourse. The use of this midcourse ABM globe defense greatly reduces the number of vehicles arriving at the latter part of midcourse and at the terminal phase of their trajectory.

By using a smaller, more intense globe and placing it on incoming clusters of objects or single objects, both EMP and intense local heating are used against the objects. This is suitable in the latter part of midcourse and in the **terminal** phase of ICBM's, IRBM's, SLBM's, and cruise missiles. It is also useful against incoming strategic bombers and their air-to-surface missiles, both ballistic and cruise.

Two modes of the globes - especially the small ones - can be used. First, the continuous mode can be used to "fry" or vaporize incoming objects in a relatively small volume (say two or three tens of kilometers in diameter). Second, the "pulse" mode can be used to "service" all incoming objects, whether or not they have passed through the "large globe" midcourse defense. This provides an additional guarantee of killing the objects; discrimination is not required, just service all of them. The exposure of all incoming objects to multiple attacks raises the probability of kill to essentially 100%, or as close to that as one wishes. Of course the incoming vehicle may still encounter a terminal defense consisting of the Tesla shield and associated roving "quickshot" small intense globes.

In short, with these systems an essentially 100% ABM and anti-bomber defense is possible. Further, the Soviets have possessed such an effective defense for two decades, just as they have openly stated.

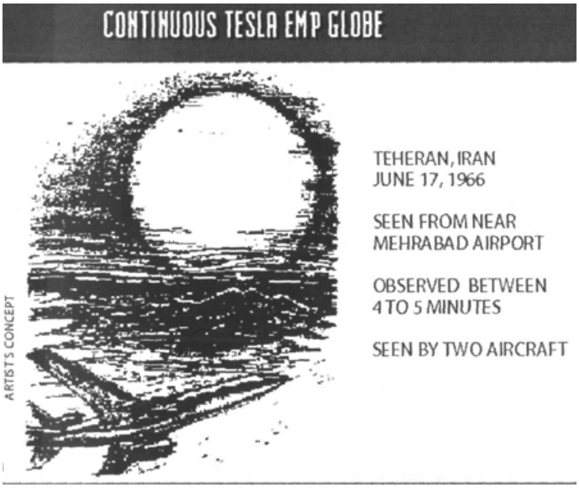

CONTINUOUS TESLA EMP GLOBE

TEHERAN, IRAN
JUNE 17, 1966

SEEN FROM NEAR
MEHRABAD AIRPORT

OBSERVED BETWEEN
4 TO 5 MINUTES

SEEN BY TWO AIRCRAFT

Slide 056: Continuous Tesla EMP Globe

Here is another verified incident of a gigantic test of a Soviet scalar EM howitzer deep within the Soviet Union.

This is a CIA report, released under the Freedom of Information Act. One can be quite sure that the incident occurred as stated.

The phenomenon was seen from two aircraft approaching Mehrabad Airport in Teheran, Iran on June 17, 1966 and reported by their pilots.

On the far horizon deep within the Soviet Union, an intense spherical ball of light appeared, "sitting on the horizon" so to speak. The globe of light increased to enormous size, dimming as it did so, literally filling an arc of the distant sky as it expanded. The sighting was shielded from most ground observers' view at the airport itself due to an intervening mountain range that masked most of tin-phenomenon from the ground.

The silent, expanding globe was observed for four or five minutes before it faded away.

BACKGROUND FOR THE BRIEFER:

Again, this is positive evidence of the testing of a giant scalar EM interferometer, in the "midcourse ABM globe" type of action.

However, note the date - mid 1966! The Soviets have therefore been testing such scalar weapons of enormous size and power for at least two decades. This implies that development must have started at least a decade earlier, or in the mid '50s.

Still earlier in January 1960 Nikita Khrushchev had announced the development of a "fantastic" Soviet weapon, one that could even destroy all life on earth if unrestrainedly used. In 1962 the ebullient Khrushchev was forced to back down and lose face before John Kennedy in the Cuban Missile Crisis. Khrushchev's missiles and bombers were in woeful shape, as Kennedy well knew (by courtesy of the Soviet spy, Colonel Oleg Penkovsky). Kennedy did not know that Khrushchev's new superweapons were nearing deployment, but were not yet quite ready.

To save face and prevent his immediate ouster, Khrushchev apparently conducted a startling two-strike demonstration of his new weapons as soon as they became operationally ready. On April 10, 1963 he detected and destroyed **the** U.S.S. Thresher nuclear submarine using a scalar EM howitzer in the underwater "continuous" mode.

The next day he demonstrated the "pulsed" underwater destruction mode for **nuclear** subs by producing a giant underwater EM explosion underneath the ocean 100 miles north of Puerto Rico. Ironically, just as the Atlantic was coming a**live** with U.S. naval vessels searching for the lost Thresher, a second test of the weapons that had finished off the sub occurred to the south of them, unnoticed and disregarded, even though seen and reported (to the FBI and the U.S. Coast Guard) by a passing U.S. jetliner's pilot and crew, who observed the underwater explosion.

We thus can peg the development of these weapons by the Soviets as starting **well** before 1960. The first operational deployment of the giant strategic weaponry occurred in early 1963.

Note that the 1966 testing observed here is completely consistent with this estimated development schedule.

Thus large Soviet strategic scalar EM weapons have been operational on site for 23 years! This implies that at least three additional generations of the scalar EM weapons have been developed and deployed by now.

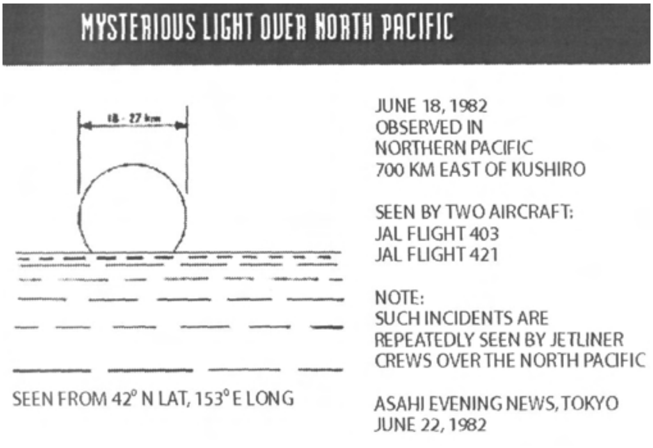

MYSTERIOUS LIGHT OVER NORTH PACIFIC

SEEN FROM 42° N LAT, 153° E LONG

JUNE 18, 1982
OBSERVED IN
NORTHERN PACIFIC
700 KM EAST OF KUSHIRO

SEEN BY TWO AIRCRAFT:
JAL FLIGHT 403
JAL FLIGHT 421

NOTE:
SUCH INCIDENTS ARE
REPEATEDLY SEEN BY JETLINER
CREWS OVER THE NORTH PACIFIC

ASAHI EVENING NEWS, TOKYO
JUNE 22, 1982

Slide 057: Mysterious Light over North Pacific

Incidents of Soviet testing of the Tesla shield and the Tesla globe weapons are routinely observed by airline pilots flying over the North Pacific into and out of Japan.

This is one typical example. Two jetliners, Japan Air Line flights 403 and 421, sighted and reported a large glowing globe of light sitting just beyond the horizon and extending well above it. The aircraft were in the vicinity of 42 degrees N latitude and 153 degrees longitude at the time. The sighting was thus about 700 miles east of Kushiro.

The pilots estimated the diameter of the ball as at least 18-27 kilometers. Depending upon the actual distance to the sphere, it may have been of much larger size.

This incident is reported in the Asahi Evening News, Tokyo, June 22, 1982.

The jet airliner pilots flying over these waters have reported many other **similar** sightings.

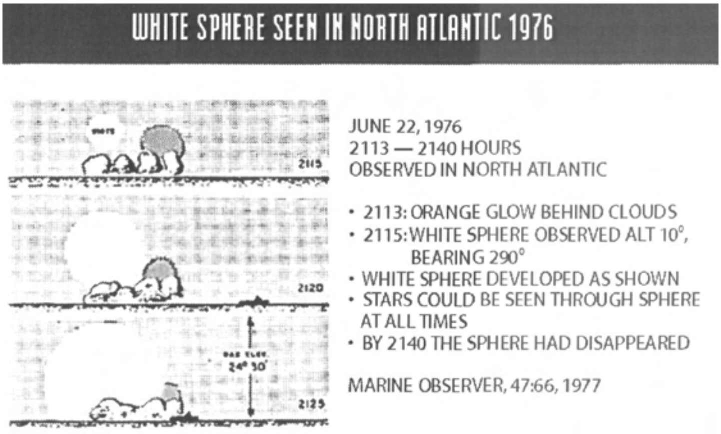

WHITE SPHERE SEEN IN NORTH ATLANTIC 1976

2115
2120
OBS ELEV. 24° 30'
2125

JUNE 22, 1976
2113 — 2140 HOURS
OBSERVED IN NORTH ATLANTIC

- 2113: ORANGE GLOW BEHIND CLOUDS
- 2115: WHITE SPHERE OBSERVED ALT 10°, BEARING 290°
- WHITE SPHERE DEVELOPED AS SHOWN
- STARS COULD BE SEEN THROUGH SPHERE AT ALL TIMES
- BY 2140 THE SPHERE HAD DISAPPEARED

MARINE OBSERVER, 47:66, 1977

Slide 058: White Sphere seen in North Atlantic 1976

Here is another sighting closer to home.

This incident was observed from a passing ship on June 22, 1976 in the North Atlantic, at about 2113-2140 hours. It is reported in the Marine Observer, Vol. 47. 1977, p. 66.

First, an orange glow was sighted behind some distant clouds. A couple of minutes later, a glowing white sphere of light was observed to the left of the orange glow, just above the clouds. The white sphere then slowly expanded to a much larger sphere, dimming as it expanded. At its maximum size, the top of the white sphere reached about 24 degrees 30 minutes elevation angle to the observer. Development to maximum size required about 10 minutes.

By 2140 hrs the sphere had faded and disappeared. The sphere was sufficiently thin that the stars could be seen through it at all times.

Again this incident strongly fits the large Tesla globe mode of a Soviet scalar EM interferometer.

The significance and role of the orange glow are not known at this time.

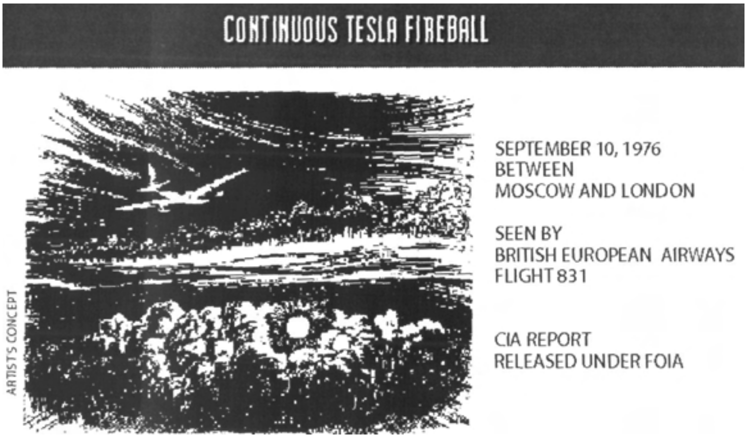

CONTINUOUS TESLA FIREBALL

SEPTEMBER 10, 1976
BETWEEN
MOSCOW AND LONDON

SEEN BY
BRITISH EUROPEAN AIRWAYS
FLIGHT 831

CIA REPORT
RELEASED UNDER FOIA

Slide 059: Continuous Tesla Fireball

Here is another incident that represents a stimulus to the British government, to see if the British are aware of scalar electromagnetics.

Again, this is a CIA report released under the Freedom of Information Act, so the details are reliable.

On Sep. 10, 1976 British European Airways flight 831, flying between Moscow and London and over Lithuania at the time, observed an intense ball of light above the clouds below the aircraft. The light was so intense that it lit up the sky in the entire vicinity.

The concerned pilot reported the glowing object to the Soviet ground authorities with whom he was in contact. He received the harsh instructions to ignore the light, and essentially to continue on his way out of there.

Here we see an incident involving a small, intense Tesla globe, of the kind with which the defense could "service" objects that had already penetrated a large midcourse globe, or aircraft approaching the defended area.

Obviously the Soviet authorities were tracking the aircraft, and knew it was in the vicinity. It seems logical, then, that they deliberately placed the brightly glowing ball beneath the aircraft so that the pilot and crew could not fail to observe it.

The strange message to the pilot was simply designed to increase the intensity of the stimulus. The stimulus was to be something like, "The Soviets are doing something in research and development that allows them to create intense balls of glowing light at a distance, and place these objects in the air in and around aircraft, possibly to intercept them." The purpose, of course, was to observe the British government's reaction after the incident was reported by the pilot upon his arrival at London.

Again the reaction of the British - and the U.S. as well - was as predicted. Again we showed that we knew nothing of scalar electromagnetic weapons, and did not recognize one when we encountered its effects.

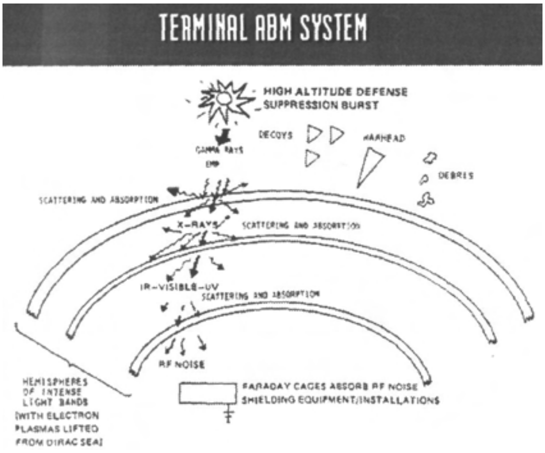
TERMINAL ABM SYSTEM

HIGH ALTITUDE DEFENSE SUPPRESSION BURST
DECOYS
WARHEAD
GAMMA RAYS
EMP
DEBRIS
SCATTERING AND ABSORPTION
X-RAYS
SCATTERING AND ABSORPTION
IR-VISIBLE-UV
SCATTERING AND ABSORPTION
RF NOISE
HEMISPHERES OF INTENSE LIGHT BANDS (WITH ELECTRON PLASMAS LIFTED FROM DIRAC SEA)
FARADAY CAGES ABSORB RF NOISE SHIELDING EQUIPMENT/INSTALLATIONS

Slide 060: Terminal ABM System

Very neat things can be done if one nests several Tesla shields - say three or four - concentrically, one inside the other. In that case even the nuclear radiation (such as gamma rays) from a defense-suppressive high altitude nuclear burst can be handled.

For example, suppose three such concentric shields are placed over a large vital area. Further, suppose a high altitude nuclear burst is placed up above the outer shield. Gamma radiation almost instantly strikes the plasma in the outer shell, where it is absorbed, scattered, and re-radiated at lower temperature. (That, after all, is what plasmas do.)

Inside the first shell, the scattered radiation is now in the x-ray and ultra-violet region. Let us track the most lethal component, the x-rays.

The scattered x-rays then strike the second plasma shell, and are absorbed, scattered, and re-radiated at lower temperature. Inside the second shell the scattered radiation is now in the visible and infrared region, with a little ultraviolet.

This optical radiation in turn strikes the third plasma shell, and is absorbed, scattered, and re-radiated at still lower temperature. Inside the third shell most of the energy is now in the form of radiofrequency (RF) energy, with a little IR and visible band spectral energy content.

At this point, ordinary electromagnetic interference (EMI) shielding of electronic equipments on the ground and inside the third shield can take care of any RF interference resulting from the emergent RF noise.

As can be seen, three shells are sufficient to convert the gamma and x-ray radiation (and ultraviolet and infrared) mostly to harmless RF energy before all three shells are penetrated. Thus the tactic of deliberate defense suppression by a preliminary high altitude nuclear burst can be countered by multiple Tesla shields.

In addition, of course, any ordinary vehicles penetrating all three shields are exposed to successive violent EMP's, and are almost certainly electrically dudded. The vehicles are also subjected to multiple periods of intense heating, so combustibles, fuels, explosives, and ablatives are destroyed. In addition, metal structures may be melted or vaporized.

Think of it this way: anything that hits one of these Tesla shields goes phht! Just **like** a bug hitting an electrified bugkiller screen.

For years passing ships have observed and reported such multiple-shield "light phenomena" over remote regions of the ocean. U.S. intelligence has routinely **not** paid any heed to reports of "lights at night" over remote ocean areas, and so Soviet tests in this manner have remained relatively unnoticed by officialdom.

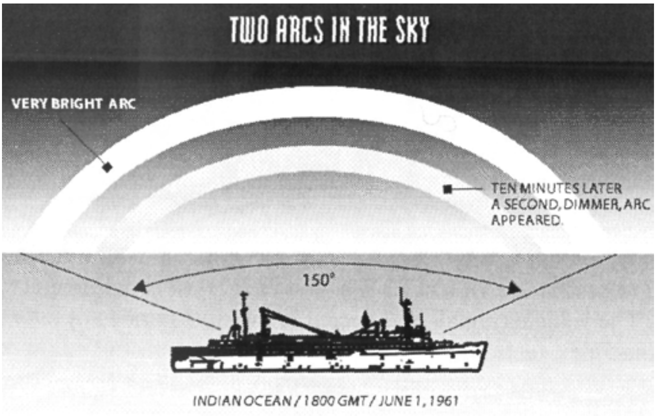

Slide 061: Two Arcs in the Sky

Just to list one incident involving the testing of multiple concentric Tesla shields, here is an early test conducted in mid-1961 over the Indian Ocean.

The incident occurred at 1800 hrs. Greenwich mean Time (GMT) and was observed by a passing ship. The report is contained in Marine Observer, Vol. 32, 1962, p. 64.

First the ship's crew observed a gigantic, very bright arc of light on the horizon or beyond it, with both ends passing below the line of sight to the horizon. This was in fact probably a large Tesla shield, but of such low intensity that only **its** intersection arc could clearly be seen. The arc subtended an arc of about 150 degrees across its diameter at the bottom. After about 10 minutes, a second **and** dimmer arc appeared, concentrically inside the first one. The ship thus was observing what probably was the nesting of two giant hemispheres (of EM energy) to provide a multiple Tesla shield.

This was probably a test of an early research and development prototype, since Khrushchev had only announced his new "fantastic weaponry" in development in his January, 1960 speech to the Soviet Presidium. And apparently land-based weapons such as this prototype probably did not become deployed and operational until April 1963. However, even in 1961 the Soviets would have been developing and testing prototypes of the weapon adapted for naval task force protection and usage.

Several other similar phenomena involving nested hemispheres or giant concentric arcs of light have been seen by mariners at sea.

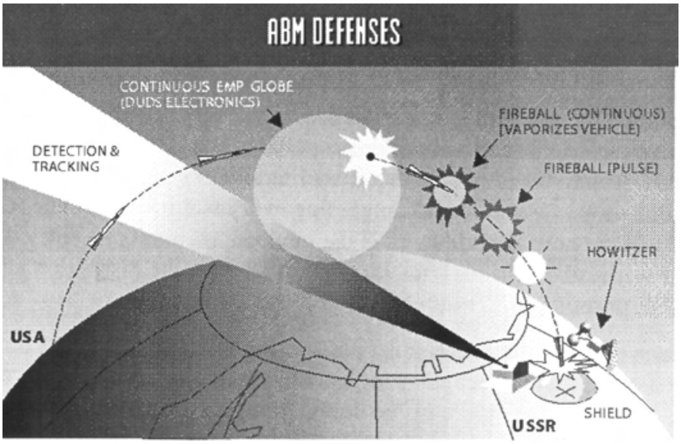

Slide 062: ABM Defenses

When the various capabilities of Tesla shields, globes, and scalar howitzers are integrated together into an ABM defense, a most formidable Soviet strategic defense capability is apparent.

On this slide we deal only with midcourse and terminal phase ABM defense. Later we shall cover the application of these weapons to launch phase ABM defense, primary phase bomber defense, underwater antisubmarine defense, etc.

Suppose the U.S. is provoked to desperately launch a missile attack toward Russia, as indicated on the slide.

First would come the launch phase destruction of the launched missiles, which we will cover shortly.

Any remaining missiles in midcourse would encounter extremely large, glowing spheres of light, where the EM energy density is contained and held in the spherical shell "energy bottle" of the glowing globes. Each globe might cover an are of up to about 20 degrees, as seen from the Soviet defended area. Missiles carrying MIRV and MARV payloads would not yet have deployed their re-entry vehicles.

As a missile and its payload encounter one of the globular shells, an intense EMP is suddenly experienced throughout the missile and all of its components. Again, EMI shielding is of no consequence since the EMP arises in each increment of spacetime throughout the vehicle volume. The result is instantaneous dudding of all electronic circuitry, including the electronics of the nuclear warheads themselves. The HE content of the nuclear warhead system is violently exploded, totally destroying the configuration of the warhead. A low-order nuclear detonation may occur, but more likely the warhead's nuclear material is just broken up, finely divided, and set afire.

In addition, all combustible materials are set fiercely afire or destroyed. Explosive materials such as booster propellants and HE explosives are violently exploded. Ablative and plastic materials literally explode into pieces, torn apart by sudden violent ablation and outgassing everywhere within. The remnants of the vehicle are now total duds, as is the payload, including re-entry vehicle, nuclear warhead electronics, nuclear materials from the disruption and explosion of the HE portion of the warhead system, etc.

Still, each piece of the debris must pass through the glowing shell once more before it exits. Thus a second "shot", precisely as effective as the first, still awaits each and every piece of the debris plunging along inside the shell as it exits.

As the debris continues on to the latter part of midcourse and early terminal phase, any portions large enough to track are subjected to small, intense Tesla globes where the energy density in the shell is many orders of magnitude greater than in the larger globe used in earlier midcourse. This part of the defense system simply services each incoming "blob" methodically, probably first in the pulse mode. Later, any blobs still remaining are given the maximum "continuous heating" mode with a small Tesla globe, to actually vaporize metals and materials.

In the unlikely event that anything active still remains, or that an object has managed to elude the large and small Tesla fireballs, a Tesla shield is still to bo encountered, towering over the protected area. For significant targets this shield will be concentric, and will contain three or more concentric Tesla shields. Again, the approaching vehicle will be subjected to multiple EMP's and severe heating throughout its volume. In addition, the concentric shields will "clean up and sterilize any gamma radiation and EMP resulting from any deliberate high altitude defense suppression nuclear burst that somehow (inconceivably!) gets through the launch phase ABM system, and the Tesla-globe midcourse and earl terminal phase defenses.

As can be seen, the system complex represents a most formidable defense **that** certainly approaches 100% effectiveness against the present triad, and even against the addition of cruise missiles.

In addition, since these weapons suffer from very strange constraints and limitations, the scalar transmitters are actually dual mode: they become conventional radars by simply switching into the ordinary EM mode. They arc part of the more conventional ABM defense system complexes we presently recognize in the Soviet Union. In this conventional role, backup ABM missile interceptors are available, to be employed in case the conventional role must be assumed.

Later we will address the reason for the strange limitations that must be placed upon unqualified use of the large scalar EM systems, particularly in the pulse or "burst" nodes.

NETWORK OF VIRTUAL TRANSMITTERS

Slide 063: Network of Virtual Transmitters

In July 1976 the U.S. received very special Bicentennial greetings from the Soviet Union.

At that time, communications systems of the world in the 3-30 megaHertz band suddenly met substantial interference from extremely powerful, chirped Soviet transmitters that were suddenly activated. These transmitters continue their transmissions to this day.

Estimates of the power of these enormous transmitters vary, but figures range as high as several hundred megawatts, with a nominal figure being 100 megawatts.

These powerful transmitters were promptly nicknamed "Woodpeckers" because of the characteristic sound of the chirped signal when received. That is, the received signal made a "pecking" sound much like a woodpecker's beak hitting a block of wood.

Several nations protested, but the powerful signals have continued, right down to this day. The only Soviet response was to add a "spread spectrum" capability, so that the transmitter did not dwell too long on one specific frequency, but shifted periodically to other frequencies.

These transmitters have apparently never been precisely located by U.S. intelligence, but their beams carry much of the characteristics of an **over-the** horizon (OTH) radar. They have been dubbed OTH-radars by U.S. intelligence, and can without question perform that mission, in addition to some very interesting missions which U.S. intelligence does not assess.

Soviet Military Power, Department of Defense, 1985, p. 45 shows the direct intersection over the United States of the Woodpecker radar beams used in an OTH-role. We show an illustration of that intersection on this slide.

In addition, we show an additional "scanner" beam that can be scanned across the intersection "grid" over the U.S., formed by waveform interference of two main Woodpecker beams.

These Woodpecker transmitters have a great many diverse functions.

First, they can be used in a conventional over-the-horizon radar node, since their beams follow the earth-ionosphere waveguide and curve around the earth. In this mode they can detect missiles at launch and thereafter, and strategic bombers when taking off and thereafter.

However, these scalar interference grid weapons have many other uses.

First, they can be used to biologically attack entire populations in a targeted area. This aspect is not covered in this briefing. Suffice it to say that phase-locked ELF modulation signals ot 10 Hz and less are often detected on multiple Woodpecker frequencies simultaneously. In a target area, this modulation - if sufficiently stronger than the Schumann resonance of the earth's magnetic field - will entrain a percentage of the brains into "forced entrainment." In that case, these human brains are "synchronized" to the Woodpecker signals so that multiple coherent frequencies are phase-locked into them. That is, multiple coherent EM channels directly into these entrained brains now exist. At that **point,** Fourier expansions may be used to attack specific portions of the brain geometrically.

In addition, scalar EM disease patterns can be modulated upon the carriers, again with Fourier expansions. Specific biological effects can be induced in the entrained populace at will, limited only by the state of the art of the Soviet technology used to attack them. Possible induced effects include instantaneous **death,** heart seizure, severe emotional disruption, loss of control of internal functions, diseases, disabling of the immune system, and even implantation of **thoughts,** emotions, and ideas which are interpreted by the targeted subjects as their own.

While further discussion of this area is beyond the scope of this briefing, the biological aspects of the Woodpecker transmitters are horrible. It suffices to say that, in thousands of experiments, Kaznacheyev demonstrated that almost any **kind** of cellular death and disease pattern could be electromagnetically transmitted. Kaznacheyev reported the effect in the near ultraviolet. Experimenters at the University of Marburg in West Germany duplicated the experiments in the infrared.

The bottom line is that photons themselves can carry death and disease patterns between cells. Scalar E*M* technology allows the synthesis of the actual potential pattern (which after all represents total control of charge and charge distribution, hence biochemistry in the cell) of a particular cellular disease or death mechanism. Symptoms (and cellular death from them!) of nuclear radiation, chemical poisoning, bacterial infection, and other mechanisms were successfully induced by the Kaznacheyev experiments.

Dr. Popp of West Germany has published an analysis of the virtual photon master control system of the cells. Since scalar EM represents the deliberate ordering of virtual particle flux into deterministic patterns, the master control system can readily be entered with scalar techniques to induce disease and disorder at will.

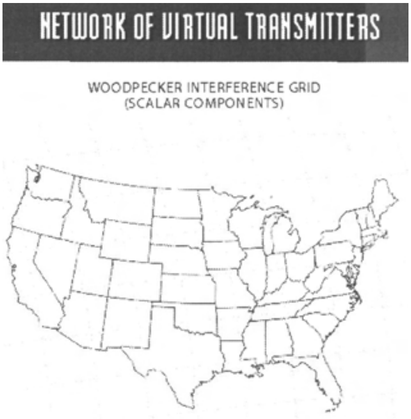

NETWORK OF VIRTUAL TRANSMITTERS

WOODPECKER INTERFERENCE GRID
(SCALAR COMPONENTS)

Slide 064: Network of Virtual Transmitters

On this slide we diagrammatically represent the Soviet woodpecker interference grid over the U.S. This grid can easily be used to influence and control the weather, and for over a decade the Soviets have manipulated the weather over the U.S. and other parts of the world.

By the peculiar title of this slide, we wish to call attention to the fact that, in the exothermic mode of scalar interferometry riding on the woodpecker radar signals, each of the woodpecker grid interference cells can act as a little "virtual transmitter." It's exactly as if the Soviets had been permitted to enter the U.S. and build thousands of EM transmitters at regular intervals all over the country!

And of course it's even worse. In the endothermic mode, it's as if the Soviets had been permitted to enter the U.S. and build thousands of "cold generators" all over the U.S. That is, in that mode, each of the "transmitters" can actually extract electromagnetic energy.

These two modes have enabled the Soviet Union to drastically manipulate the weather at will over the U.S. during the last decade (and similarly, for other places as well.)

(For a disclosure of the Soviet weather control operations over the U.S., see T.E. Bearden, Soviet Weather Engineering Over North America, 1-hr. videotape, 1985, available from The Tom Bearden Website www.cheniere.org. We will only summarize here.).

Briefly, inside various reference level zeros on the ordinary EM woodpecker carriers, scalar "channels" are established. Scalar beams, signals, and interferometer pulses and transmissions can be transmitted through these reference channels as if directly through a wire. Phasing, pulse shaping, and Fourier expansion formation of geometric forms are then the key to be used in scalar interferometry through the internal scalar channels of the Soviet woodpecker signals.

By choosing one or more grid cells and using scalar interference there in the exothermic continuous mode, local heating and expansion of the air, and formation of a high-pressure area, occurs.

By choosing one or more grid cells and using scalar interference there in the endothermic continuous mode, local cooling and shrinking of the air, and formation of a low-pressure area, occurs.

By electromagnetic "rotation" of the interfering scalar beams, the hotspots and coldspots can be moved along a desired path and at a desired speed.

By these methods the entire jetstream across the U.S. can be deviated and controlled to a large degree. Moisture can be drawn from the Pacific beyond Southern California and Mexico, and collided over the southern U.S. with extremely cold air brought down from Canada, producing ice storms such as those in and around February 1, 1985.

Violent thunderstorm activity can be induced and directed. By adding "spin", these same storms can be induced to form extensive tornados.

By sustained weather engineering operations, drought or excessive rain and flooding can be induced in areas of the U.S. as desired. Crops can be destroyed or heavily damaged by severe and unseasonal weather.

If the grid is placed in the ground on scalar EM carriers instead of normal EM carriers (and the woodpecker "radars," can switch to, or add, scalar carrier mode whenever they wish), it can be used as an anti-submarine weapon, as we shall see later. It can also be used to cause substantial ocean effects that have drastic consequences on the world's weather - such as the anomalous El Nino of 1982-83.

By localizing one spot of heating at the top of a thunderstorm anvil, and another spot of cooling at its side, a localized downburst can be created. Our weather satellites have detected just such an anomalous combination heating and cooling of thunderstorm anvils over the U.S. While there may exist natural mechanisms to cause this anomalous dual pattern, it may also be caused by Soviet weather engineering, which can cause either broad-area or highly localized effects.

All these types of weather engineering incidents have been deliberately created over the U.S. by the Soviet Union.

Perhaps the greatest weather effects can be induced by altering some of the large-scale normal mechanisms that influence and control our weather. Thus the **artificially** induced El Nino of 1982-83 was a case in point, causing drastic weather upsets worldwide for a year or more.

The last decade has seen weather so anomalous that it could only occur once in 1200 years by chance. It has not been due to normal chance, but by Soviet weather engineering, particularly since the advent of the Woodpecker transmitter complexes.

ADDITIONAL BACKGROUND FOR THE BRIEFER:

The Woodpecker transmitters can carry scalar components, which, in addition to biological strikes, can be used for many other purposes such as to

1. Influence and control the weather,
2. Deviate the giant jetstreams of the upper atmosphere,
3. Detect, track and destroy missiles shortly after launch,
4. Detect, track and destroy strategic bombers and other aircraft,
5. Attack land and ocean surface targets by large aerial electromagnetic explosions: the EM explosion produces the fireball, the thermal effects, and the blast wave of a nuclear explosion without the nuclear radiation and radioactive fallout contamination;
6. Attack surface land and ocean targets by large "cold explosions", where living things freeze almost instantly, leaving the surface facilities and equipment intact,
7. Attack land and ocean surface targets by severe internal electromagnetic disruption, so that all electronics are dudded,
8. Attack personnel on land and sea by direct destruction of their nervous systems with an internally induced strong EMP,
9. Disrupt the operation of distant facilities, equipment, and personnel or destroy food crops in large areas by severe cold or severe heating, or even startling oscillation between the two.

    In addition, the scalar aspects of the Woodpecker transmitters can be beamed through the earth and ocean as surface waves or at a given depth to intersect at a distant region. This mode can be used to

10. Cause distant earthquakes in a distant fault zone by depositing energy in the rocks there, increasing the plate stress until slippage occurs at a fault zone,

11. Cause large, anomalous rocking of an entire plate or large area, by depositing and extracting energy from alternate areas, causing buckling of the large rock plate,
12. Set up an interference grid under the water, so that underwater submarines can be detected, tracked, and destroyed on station and with their missiles still unfired,
13. Attack naval vessels and task forces through the water and through their hulls, without warning,
14. Attack missile silos and nuclear storage sites "before launch", directly through the earth itself,
15. Initiate the full nuclear explosion of implosion-type nuclear warheads on-board missiles on station,
16. Initiate full nuclear explosion of implosion-type nuclear warheads in storage sites and ready reserve,
17. Destroy seaborne and ocean-bottom-mounted mines and underwater sensors, even including entire "fields" of them,
18. Detect and destroy hostile torpedoes, ship-to-underwater anti-submarine missiles, and dumped anti-submarine munitions and charges,
19. "Pump" the electrical grounding of distant electrical power distribution and generation systems so that the system catastrophically fails,
20. "Pump" the electrical grounding of distant electrical power systems so that radio and television transmitters, power grids, and wiring complexes in buildings and facilities radiate a desired scalar wave component or signal complex at equipment and personnel.

All in all, the woodpecker transmitter complexes and other associated scalar EM weaponry are most useful in the major missions required in war.

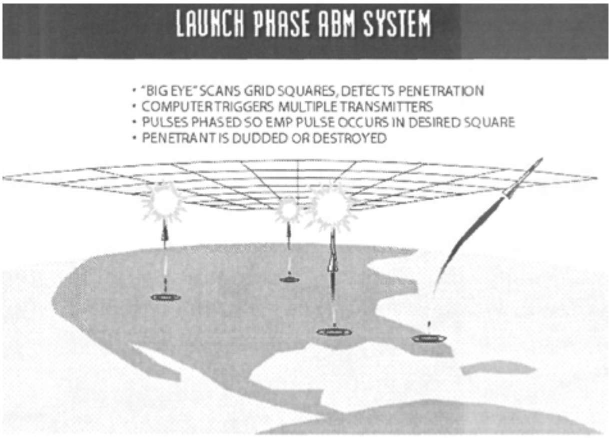

LAUNCH PHASE ABM SYSTEM

- "BIG EYE" SCANS GRID SQUARES, DETECTS PENETRATION
- COMPUTER TRIGGERS MULTIPLE TRANSMITTERS
- PULSES PHASED SO EMP PULSE OCCURS IN DESIRED SQUARE
- PENETRANT IS DUDDED OR DESTROYED

Slide 065: Launch Phase ABM System

On this slide we show the use of the Woodpecker grid in the Launch Phase **ABM** system role.

The scalar components establish an interference grid over the U.S., at some altitude above the earth. One or more separate scalar interferometers transmit through scalar channels established in the Woodpecker's normal EM carriers, scanning through the grid square cells one by one in the "just barely extract energy" endothermic mode.

Back in the Soviet Union, the energy extracted passes through a scanned receiver biased just so that the normal energy extracted from the distant atmosphere does not show on a scanning screen. Any substantial amount of additional energy appearing in the cell - such as from the jet engines of a large aircraft or the rocket exhaust of a large missile - will be detected.

The **operation** of this weapon is four-fold: (1) the scanning interferometer or "big eye" scans the grid squares, detects penetration, and tracks the rising missile. (2) A separate scalar EM interferometer (a howitzer) is controlled by a computer and fired through a separate scalar EM channel opened in the ordinary EM woodpecker carriers. (3) Two timed scalar pulses are fired so that they converge and meet in the grid cell containing the rising missile. This results in the **sudden** emergence of a violent EMP pulse throughout the missile and the surrounding vicinity. (4) All missile and warhead electrical and electronic systems are instantly dudded and destroyed. In addition, fuels, propellants, and explosives of the missile are immediately ignited, explosively destroying the penetrating missile.

That takes care of the missile target. (The same weapon, of course, can be used against airborne strategic bombers - including Stealth-type bombers. In fact, Gary Powers' high flying aircraft was probably shot down in 1960 by a "jury-rigged" scalar EM howitzer using modified radars and timed scalar pulses to provide an aerial explosion and EMP.)

The Woodpecker grid/howitzer weapon system can be placed over the ocean and used against cruise missiles, naval surface-to-air and surface-to-surface missiles, submarine-launched ballistic and cruise missiles, etc. Placed over a carrier task force, it can also take care of the aircraft launched by the carrier as fast as they are launched. It can also handily take care of the missiles launched by guided-missile cruisers of the accompanying task force.

Now let's take a look at the command and fire control end of this weapon system, way back in the Soviet Union.

SOVIET COMMAND & CONTROL CONCEPT

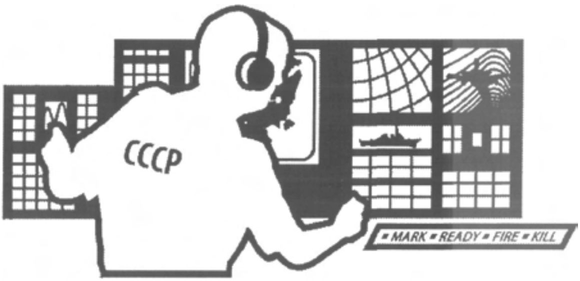

Slide 066: Soviet Command & Control Concept

On this slide we show a postulated Soviet fire control system for the grid weapon.

Two or more operators sit at a control console, facing a giant display (screen). The display contains a grid, which represents the distant interference grid of the Woodpecker carriers (or scalar EM carriers, if in the underground or underwater mode). A distant missile launched into the real interference grid overhead will cause a spot of light to appear in the appropriate grid square (cell) on the operators' screen. The operators will track the displayed target, select firing mode and type of action, engage the target, and assess whether or not the distant target is killed or missed by the firing.

When a missile is launched in the distant area over which the Woodpecker grid has been placed, it quickly rises through one of the scanned grid cells on its upward journey. As it penetrates the cell, additional energy is extracted (since part of the missile's exhaust energy is now extracted also). At the screen in the Soviet Union, the additional energy received rises above bias, causing a "bloom" or spot of light to appear on the screen at the appropriate grid cell representation.

The distant operator has now detected the missile launch and its location. He places a marker over the target track and activates the computer, also inputting the type of firing or action to be performed. In this case, let us say he wishes a burst of **energy** to emerge inside the distant launched missile, and has activated that mode of firing action.

The computer computes the necessary parameters for another scalar interferometer channel in the exothermic mode, and for firing at the location of the rising missile so that two scalar pulses will meet in the cell penetrated by the rising missile on the other side of the earth. As the channel is opened, the firing solution settled, and the interferometer howitzer readied, the computer activates indicators on the console notifying the operator. When all is ready, a "ready-to-fire" light is lit on the console.

Upon receiving the command to fire and destroy the missile, the operator presses the fire button. The computer fires the activated scalar EM howitzer in the pulse mode. The operator continues to watch his screen.

When the pulses meet in the distant grid cell, a violent EMP suddenly arises in and throughout the missile and its surrounding vicinity. This explodes the missile propellants and warheads, destroying the target.

On the distant screen, a sudden drastic "blossoming" of the target results from the sudden extraction of a great deal of additional energy by the scanning scalar interferometer. The operator thus knows he has made a "kill."

Should for some reason the target be missed, additional energy will still be extracted by the scanning interferometer from the grid cell/vicinity in which the EMP suddenly emerges. The distant operator will still see a bloom on his scope, but not nearly so great as when the missile explodes. He thus knows that the EMP effect of the firing has occurred, but the target has been missed (he will see the bloom in its offset location as well). In that case, the operator can quickly mark the EMP location, hit the switch, and the computer will automatically correct and fire again.

At any rate, for a miss a large "sonic boom" or blast still results in the EMP emergence zone from sudden heating of the air. These are precisely the type of booms that were associated with three NASA shuttle launches prior to the end of 1985. These were actual testing of this weapon system, using the shuttle launches to provide a target, and delaying the burst some minutes so the shuttle would not actually be destroyed. On Nov. 26, 1985 a "marker beacon" (glowing ball of light) was also created over the site. This was probably to orient **satellites** and other detection systems. Some 12 minutes after that nighttime launch, **a** large blast occurred over the site, heard for hundreds of miles up and down **the** coast. Shortly after, the light suddenly moved away very rapidly - faster than **a** jet aircraft.

If many missiles are being launched, the operator marks them rapidly, one **after** the other, and the howitzer fires burst after burst at them, decimating the launched missiles, one after the other. In this fashion most of the counterstrike missiles launched by the U.S. would be destroyed shortly after launch, greatly reducing the number of missiles that make it to midcourse.

However, apparently the loss of the shuttle launched on Jan. 28, 1986 was caused by the addition of a metal-softening pattern in the exothermic mode, in and around the booster, using the actual booster ionic flames as a receiver-amplifier. This led to the failure of one of the supports and the partial breakaway of the right booster. The booster rotated into the tank, causing damage and the resulting explosion when the venting main fuel hit the booster flame.

By spread spectrum techniques and proper timing and phasing, one system of Woodpecker transmitters can set up multiple interference grids, in various parts of the world. The scanners and howitzers can operate in the appropriate zones, again by spread spectrum techniques and proper timing and phasing.

In fact, the latest versions probably can operate in the "ordinary EM carrier" (atmospheric) mode and the "scalar EM carrier" (underwater and in the earth) mode simultaneously - again by timed switching between EM and scalar EM carriers, spread spectrum techniques, and timing and phasing of howitzers and Manners.

Thus a single system can operate in the earth, underwater, and atmospheric modes. It can operate against the very wide range of different targets previously mentioned. It can do all this "simultaneously," from a real-time practical viewpoint.

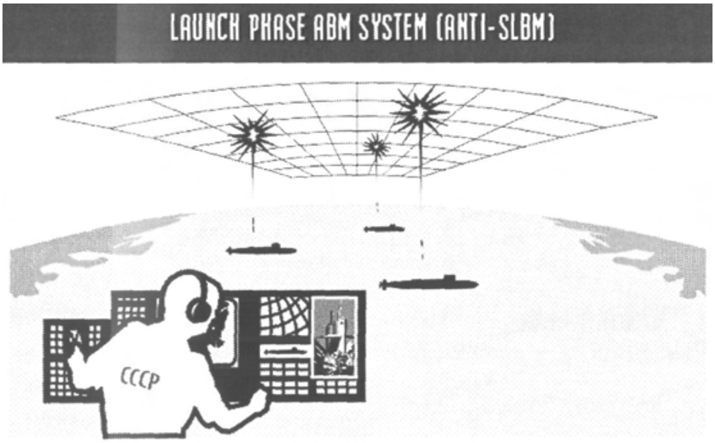

LAUNCH PHASE ABM SYSTEM (ANTI-SLBM)

Slide 067: Launch Phase ABM System (Anti-SLBM)

Here we show the operation of the system in the atmosphere over the ocean, to destroy sub-launched ballistic missiles such as Poseidon and Polaris. The system operation shown uses the normal EM Woodpecker carrier frequencies, with scalar components to establish the interference grid, and scalar channels for the scanners and howitzers. The grid can be set up by this method anywhere in the world.

As can be seen, during their early launch phase, this mode will take care of the missiles launched from underwater U.S., British, and French nuclear submarines.

Remember, this is just one mode in which the system is operating. It can at the same time have other interference grids at other locations, and even in other modes, including underwater grids used against the submarines themselves, it can be engaging a multitude of targets of a wide variety of types, essentially all simultaneously.

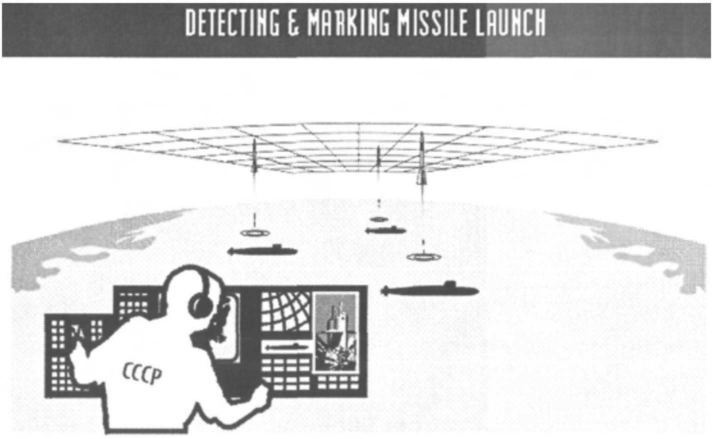
DETECTING & MARKING MISSILE LAUNCH

Slide 068: Detecting & Marking Missile Launch

Here we show the missiles launched from the underwater submarines, when just detected in the atmosphere over the ocean. As each rising missile is detected, an operator at the screen places a cursor (a "marker") over the detected track spot on the scope.

The computer quickly computes the firing parameters and indicates when the system is "ready to fire."

By using additional scalar scanner frequencies in the multi-gigaHertz range and fine scanning, the operator is able to accomplish non-cooperative target identification.

After the operator places a cursor over a target, the advanced system fine-scans and identifies it as hostile, then continues the track in automatic.

When the operator presses the fire button for a designated target, the computer intiates fire by the appropriate scalar EM howitzer through established grid scalar firing channels.

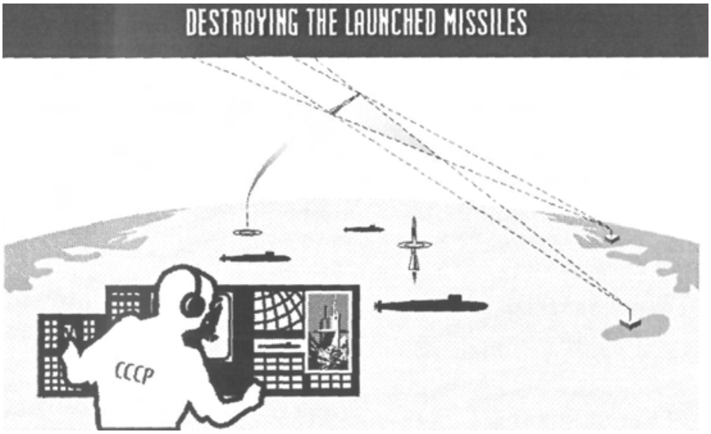

DESTROYING THE LAUNCHED MISSILES

Slide 069: Destroying the Launched Missiles

On this slide we temporarily omit the interference grid and diagrammatically show the operation of the scalar EM howitzer. As shown, two pulses are fired so that they meet in the grid cell where the rising missile is located. A drastic EM pulse suddenly emerges everywhere throughout the missile and its vicinity causing instant missile destruction.

Of course, individual howitzers not in the Woodpecker carrier's scalar channel can also fire at the missiles in the purely scalar exothermic mode. Or they can utilize the large "Tesla globe" in the continuous mode, the small Tesla "ball of light" in the continuous or pulsed mode, etc.

Also, continuous EM energy can be caused to emerge in a broader, "defocused" interference area causing electronic dudding of circuits in vehicles over a wider area. This is a very useful mode to use against mass attacks by many aircraft and/or many missiles at the same time. That is, the entire formation can be attacked in the "dud electronics" mode, and then followed up by more intense servicing of each individual hapless target.

Again, in 1960 Gary Powers was probably downed by a crude prototype scalar interferometer "howitzer" obtained by modifying two ordinary radars. At least the Soviets had previously been unable to down a penetrating U-2 with missiles they possessed. We know the scalar howitzers were in development, for Khrushchev had announced to the Presidium in January 1960 that a new "fantastic weapon" was in development. A development prototype was probably used to down Powers' aircraft.

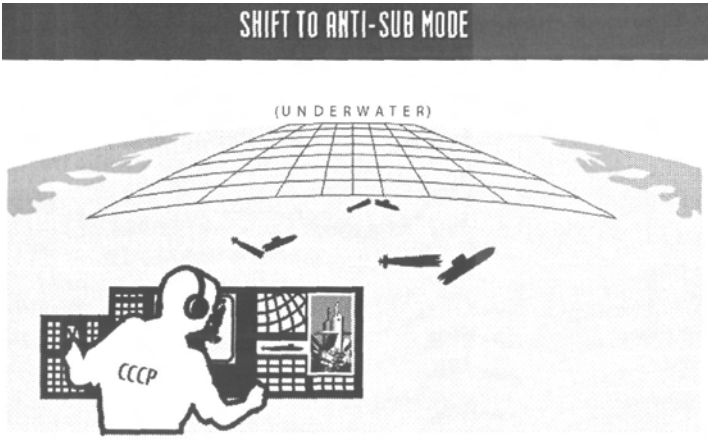
SHIFT TO ANTI-SUB MODE

Slide 070: Shift to Anti-Sub Mode

In the underwater mode portrayed on this slide, the Woodpecker transmitters have been switched to "scalar carriers" mode and the carrier beams transmitted through the ground and into the ocean underwater. (Remember, an artificial EM potential that does not couple to charged particles or ions will travel through the ocean, but a force field will not.)

Thus a giant scalar interference grid is now established underwater. Additional scalar beams in the weakly endothermic mode scan this grid. When a submarine enters the grid, it substantially changes the potential in that cell, and the scanner picks this up. The distant screen now displays the sub as a "track" of light in the appropriate grid square cell. The computer switches in fine-scanning and non-cooperative target identification. It identifies the target as hostile and alerts the operator (by blinking the track and changing its color to red, for example).

As before, the operator marks the target and enters the firing mode and type of action desired. Again, let us assume the "EMP burst" mode of destruction is to be used. The computer computes the firing parameters and readies the howitzer, When the commander gives the command to fire, the operator presses the firing button. The computer fires the howitzer.

Two scalar pulses proceed through the howitzer scalar channel and meet in the submarine. Throughout the sub and its vicinity, a violent EMP is suddenly experienced, knocking out the electrical systems, electronic equipment, and igniting propellants and explosives in the on-board missiles and armament. This explodes the submarine, missiles, and torpedoes instantly.

At the distant command console, the scanners detect the violent eruption of energy from the exploding submarine. It appears on the screen as a sudden strong blossoming of the track. The operator assesses that the target has been destroyed. He immediately engages another target if one is present.

If the EMP is off-course and misses, the scanners still pick up a smaller blossoming in the offset location. The operator immediately knows he has missed the target. He marks the offset bloom, presses the switch for "Correct!" and the computer makes the firing correction. When the operator again gets a Ready-to-Fire light illuminated, he presses the firing button and fires again at the target, this time with corrections applied.

Again, the same Woodpecker system - using timing, phasing, scalar/EM switching and spread-spectrum techniques - may be involved in several grids and many types of targets. When in a target-rich environment, the firing operators may be very busy indeed.

As we shall later see, the same weapon system may also be firing in the "cold explosion" or pused endothermic mode, where intense bursts of instant and severe freezing are unleashed in the target zone.

SHIFTING TO EARTHQUAKE MODE

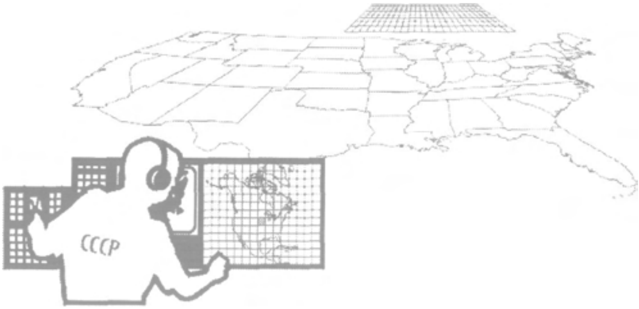

Slide 071: Shifting to Earthquake Mode

The uses of the complex grid, scanners, and scalar howitzers is limited only by human ingenuity and state-of-the-art of the technology developed.

By shifting to the scalar-carrier mode and transmitting in the surface layer of the earth, the interference zone can be established in a distant region of the earth, beneath the earth's surface.

Suppose we establish a very small interference grid in the earth at and around a distant fault zone. Then by steadily depositing energy in the zone in the continous exothermic mode, the stress in the fault area is steadily and gradually increased. Eventually the plates on each side of the fault will slip, and a "natural appearing earthquake" occurs. If the energy is deposited slowly and gently, a gentler quake can usually be effected. If the energy is deposited fairly rapidly, a higher peak stress can usually be reached before the rocks slip, and a larger, more destructive earthquake results.

By making a wider grid in the earth in a larger area, a strange kind of earthquake can be induced, whether or not a fault zone exists in the area. By pouring energy out of alternate cells and extracting energy from the others, a "wave-like" buckling tensile and compressive stress is created throughout the zone. As this continues, the entire plate area will try to oscillate, moving and causing an anomalous sort of "rocking, flat earthquake" throughout a large area.

Not too many days after the destruction of the Challenger on January 28, 1986, such an anomalous "flat earthquake" occurred in the U.S., near the Great Lakes, involving some 10 states. This was probably the subsequent testing of an additional weapons mode of the same Soviet scalar EM system that destroyed the shuttle.

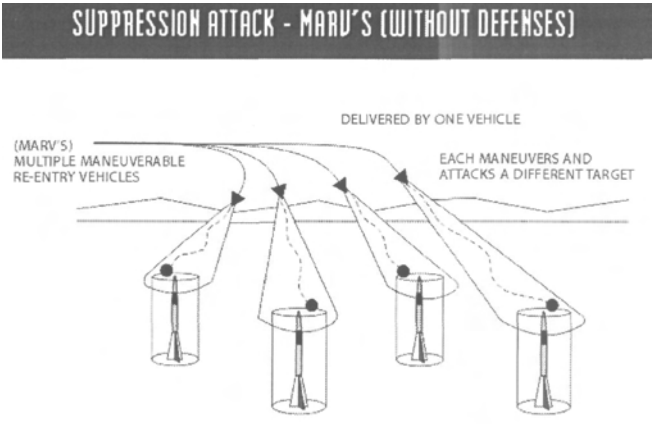

SUPPRESSION ATTACK - MARV'S (WITHOUT DEFENSES)

DELIVERED BY ONE VEHICLE
(MARV'S)
MULTIPLE MANEUVERABLE
RE-ENTRY VEHICLES
EACH MANEUVERS AND
ATTACKS A DIFFERENT TARGET

Slide 072: Suppression Attack—MARVs (without defenses)

Now to shift the emphasis a bit, and look at the impact on some "normal" strategic systems and concepts.

On this slide we show the basic idea of suppression attack against an enemy's ground based missile force in fixed-site silos. The attack uses multiple maneuverable re-entry vehicles (MARVs) delivered by a single carrier missile, which acts as a "bus." The bus ejects the MARVs at the appropriate time, and each of the MARVs heads toward its predesignated target, maneuvering as it re-enters the atmosphere and proceeds to the target. The maneuver makes conventional intercept of the MARV by conventional anti-ballistic missiles more difficult.

In this manner, missile silos without defenses may be caught by surprise and destroyed.

The "bus" concept actually multiplies the number of targets a single launched missile can attack, and the maneuvering of the MARV increases the difficulty of defending the target area by orthodox means.

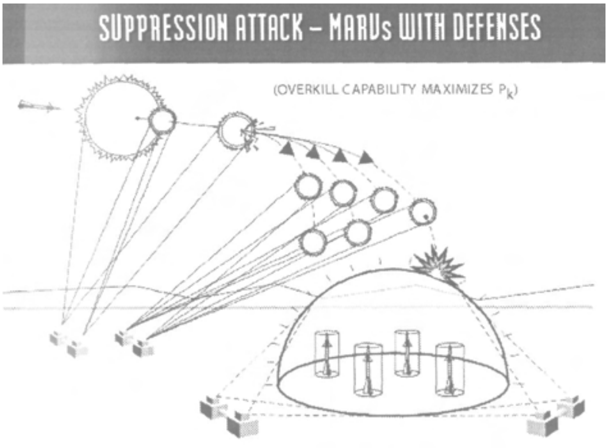

SUPPRESSION ATTACK – MARUs WITH DEFENSES

(OVERKILL CAPABILITY MAXIMIZES P_k)

Slide 073: Suppression Attack—MARVs (with defenses)

Now suppose some of the scalar EM defenses we have discussed are added to the picture.

On this slide we show a similar missile field, defended by a Tesla dome and by multiple scalar howitzers.
The howitzers take the incoming buses under attack during the early midcourse phase, by means of very large spherical EMP globes. Many of the buses - and their entire payloads, including the nuclear warheads themselves - are dudded by these midcourse defenses.

Servicing of dudded vehicles that have penetrated the globe now occurs farther along in midcourse. Each dud vehicle may be serviced, for example, with a small globe in the continuous mode for an appreciable number of seconds. This causes vaporization or fusing of the physical structures of the vehicles.

Groupings of incoming vehicles may also be serviced by medium-sized globe in the pulse mode. This assures dudding, and is especially useful for clearing away chaff and debris with smaller ballistic coefficients. It also is useful to further insure that the nuclear warheads themselves are totally dudded.

An additional wrinkle is to place scalar signal patterns - that affect and transmute a nuclear warhead's radioactive nuclei - onto a continuous globe. In short, by the proper scalar signals it is possible to transmute plutonium and uranium into harmless elements, and it can be done at a distance. The 4th and 5th generation Soviet scalar EM technology is probably capable of doing **this**

This insures that, not only are the incoming nuclear warheads electromagnetically inert, but they are also nuclearly inert and incapable of generating nuclear explosions.

Still another wrinkle - particularly useful against implosion-type weapons - is to utilize a scalar signal pattern that causes sudden generation of neutrons in the active material (plutonium or uranium). This harmlessly explodes the nuclear warheads while they are far away from their intended targets and out in space. The burst mode is probably the most useful for this tactic.

Note that, if desired, this same tactic - exploding the nuclear weapons themselves - can also be utilized in the Launch Phase ABM system grid against the missiles after launch. This capability converts an adversary's intended nuclear attack against you to an actual attack against himself!

Also note that the adapted grid system in the surface of the earth can be used to explode the nuclear warheads in ICBMs while they are still in the silos, or to explode nuclear warheads in storage. In the underwater mode, the nuclear warheads in the Poseidon and Polaris missiles on-board the nuclear submarines can be exploded in a similar manner. In fact, the nuclear reactor used to furnish the power for the nuclear submarines can also be exploded or disabled in this manner, as can land-based and ship-based reactors.

Again, this actually turns an adversary's own nuclear weapons against him. His own weapons can be used to obliterate him. Without scalar defenses, possessing the capability of nuclear attack becomes a serious detriment!

But back to our slide. Just in case something gets through this formidable defense somehow, the Tesla Shield (dome) provides the final reiteration that takes care of any residue "leakage."

The sum total of these defenses fully justifies the 1968 Soviet statement in Military Strategy that the USSR has achieved a 100% defense, and the West has

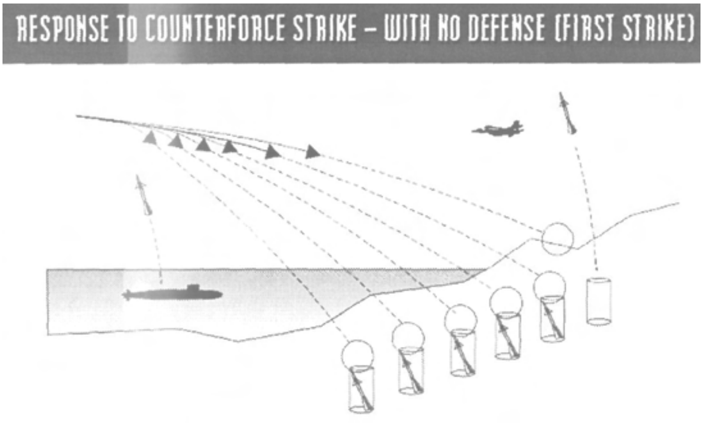
RESPONSE TO COUNTERFORCE STRIKE - WITH NO DEFENSE (FIRST STRIKE)

Slide 074: Response to Counterforce Strike with No Defenst

Here we show the orthodox concept of response to a surprise counterforce nuclear strike when the surprised force has no defenses.

A great percentage of the attacked missile silos are destroyed. The surprised side thus is able to mount only a limited strike in retaliation. Perhaps he is able to launch some remaining silo-based missiles that escaped destruction. He is also able to launch missiles from any of his underwater nuclear submarines that escaped. Some of his strategic bombers may have escaped destruction on the ground or while airborne on station; these surviving bombers can be directed to proceed with strategic reprisal against the enemy.

As can be appreciated, this entire concept is now totally obsoleted by the Soviet possession of scalar EM weapons.

The "mutual assured destruction" capability - or MAD concept as it was so aptly named! - is no longer mutual.

And for two reasons: (1) the Soviet surprise attack could destroy essentially all our Triad forces wherever they are, in the first attack. (2) Even if a very small number of our strategic forces survive, the puny strike we could attempt to launch could be repeatedly decimated from launch to terminal phase.

The restraint on the Soviets is not because of our Triad forces. The restraint is twofold: (1) a second nation has scalar EM weapons, and would undoubtedtly unleash them upon the Soviet Union with great violence if such a massive world-wide destruction of U.S. forces occurred or was threatened (is it really "accidental" that six major Soviet missile ammunition storage sites mysteriously exploded within seven months?); (2) the closed-loop scalar radiation exchange system of Earth-Sun could be inadvertently "tweaked" in the feedback loop from Earth to Sun, so that a large solar scalar resonance was stimulated. In that case the Sun could emit a mighty resonant "burp" that would simply wipe out all life on Earth in a fiery shower.

The "terror" in the "balance of terror" between nations has just increased by many, many orders of magnitude.

The biblical prophecy that the Earth will be wiped out by "fire and brimstone from heaven" is very near fulfillment now.

Put another way, the pucker factor - even on the Russians who may contemplate unleashing Armageddon - is higher than any Western strategic analyst has ever imagined, even in his wildest nightmares.

Truly these weapons are "more frightening than the mind of man has imagined," as Brezhnev put it in 1975.

The frightening scalar EM weapons can be used, but only very, very gingerly indeed. If a slight mistake is made, everybody loses everything.

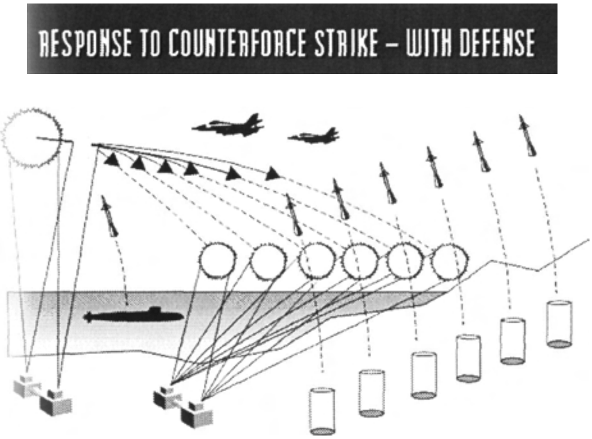

RESPONSE TO COUNTERFORCE STRIKE – WITH DEFENSE

Slide 075: Response to Counterforce Strike with Defense

On this slide we show the impact of scalar defenses against an adversary who possesses only the orthodox nuclear weapons and delivery systems, and makes a "first strike" by surprise against his opponent.

In this case, the attacked opponent has scalar EM defenses.

With just the midcourse and terminal scalar EM howitzer defenses, almost all of the attacking missiles and re-entry vehicles are destroyed.

If for some reason (such as to prevent triggering the sun and destroying the world inadvertenly!) the attacked adversary does not wish to attack strategically with scalar EM weapons, he may now launch a massive retaliatory strike on his opponent.

And if that opponent has no ABM defenses, he's just bought the farm.

What a funny coincidence! Long ago, we crazy Americans chose to put all **our** eggs in the offensive basket. That is, we thought the Soviets cannot dare to strike us because we will have enough surviving missiles to penetrate any orthodox defense and destroy them in return. They would also have the same "mutual assured destructon (MAD)" capability, of course!

The MAD concept was aptly acronymmed - it was an insane idea from its inception. That is, the Soviets were not supposed to defend their cities **and** populace, and neither were we. That way, you see, we could destroy their citizenry at will, and they could destroy ours at will. We deliberately agreed to that, thinking - in our insanity - that the Soviets agreed also.

Of course the Soviets weren't playing the same lunatic's game at all. They simply fed our own garbage back to us, and we importantly thought we were negotiating something. Unknown to us, they were secretly building and deploying scalar EM defenses even then. Since we didn't know of any other defense, we assumed the Soviets could not defend their citizenry with ABMs any better than we could defend ours with ABMs. So we blithely scrapped our ABMs.

The high government officials of the United States of America grossly violated our constitution and their sworn oaths of office. Our constitution specifically charges the government of the United States to defend the people of the United States. That means our officials are specifically charged with defending our people. Yet they deliberately agreed not to do so, and they deliberately sacrificed us in advance.

They committed treason of the highest kind, by deliberately surrendering us to total destruction anytime the big balloon goes up.

The constitution doesn't charge the government with surrendering our citizens to destruction under any circumstances. It charges the government with defending us against destruction.

Ronald Reagan is the first U.S. president in some time to see through the MAD concept. At least he stands forthrightly for defense. It's just a shame that the government and scientific leaders under him aren't aware of the Soviet scalar weapon developments, so they could brief him on these startling developments.

Be sure you understand what the government leaders before Reagan have been saving. For years, our official policy has effectively said to the Russians: "We will allow each side a token defense only. We deliberately will not defend ourselves, so that anytime you decide to strike us you can destroy us. In return, however, we do not think you will want to strike us, for we believe that - before we become ashes from that strike - we can get enough away at you, to destroy you as well. Of course we believe you are in the same sort of boat."

Then we said, "There! That's settled! What a relief! Nobody can strike anybody anymore. Now can we talk about partial disarmament and on-site inspection?"

The Soviets just kept their astonished amusement to themselves and kept building scalar defenses (and scalar offenses as well!). Their deception plan called for imbedding the scalar EM weapons in ordinary systems when possible, and hiding the scalar EM weapons tests in ordinary weapons tests when possible. Of course they had to be adamant in their opposition to on-site inspection; after all, even Western scientists, if allowed on site with the dual-mode weapons, might suspect something was different and possibly things were amiss.

The Soviet deception has worked like a charm. The U.S. MADmen who created and implemented the MAD doctrine have succeeded in prejudicing two generations of academicians and elected U.S. leaders against the need for effective defense. A vast wasteland of inane paper studies - learnedly dealing with ABM's, penetration tactics, leakage, force and counterforce, radar blackout, electronic warfare, etc. etc. - has been churned out by our military, industrial, and university "think tanks" to clog the minds, efforts, and literature of our defense and governmental establishments.

Our homeland has no effective ABM defense (and very little defense against aircraft or subsonic cruise missiles).

Our field army has no effective ABM defense (or air defense). Our naval forces have no effective ABM defense (although they are better defended against air attack than the field army). Yet ballistic missiles - and to some extent cruise missiles - have supposedly been our greatest threat for decades, followed closely by the secondary threat of massed aircraft attack.

A cynic might take the stand that, if our Defense Department hasn't been allowed to defend us (with deployed weapon systems, not by "paper studies") against what we ourselves have proclaimed is our biggest threat, then why is it called the Defense Department? Why not call it the No-defense Department'?

Understand, a great many fine, hard-working people in DoD have certainly tried to get adequate defenses developed and deployed. The sheer weight of the bureaucracy and its mind-numbing entanglements has prevented it.

But it's even worse. Our bureaucrats - both in government and in "big, organized science" - have been so caught up in the "Russians are really just ignorant peasants" syndrome and the "not-invented-here" (NIH) syndrome that they've not recognized the greatest scientific and technical breakthrough in history. Such a breakthrough - far greater in importance that the nuclear bomb has been made, developed, and deployed by the Soviet Union, all in secrecy and behind the smokescreen of a masterful deception plan.

We've totally missed the most incredible "secret superweapons" development program of all times, and the worldwide testing of the weapons themselves.

Hiroshima and Nagasaki should serve as object lessons in the price of ignorance of such technological breakthroughs.

History does repeat itself. But this time it's not we Americans who got the growl new superweapon first.

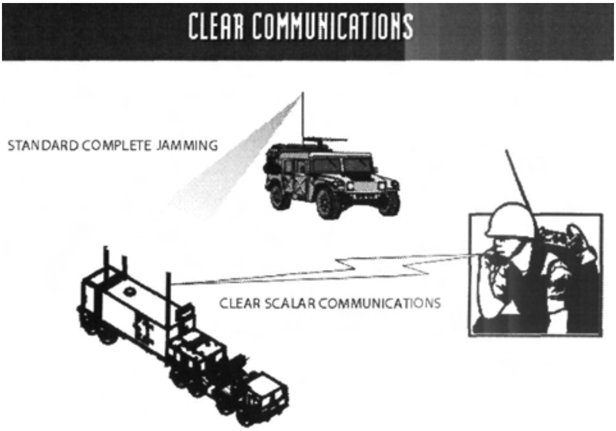

CLEAR COMMUNICATIONS

Slide 076: Clear Communications

Now let us rapidly give some unique capabilities that one can do with scalar EM in smaller things. Not only can scalar EM weapons be used in the big "continent burning" strategic weapons, but they can also be used for a variety of smaller defense tasks.

For example, one can establish a zero reference anywhere one wishes in an ordinary carrier. Inside that zero, one can establish as many independent "carriers" as one wishes, and hide them completely from ordinary detectors.

The way to do that is easy. Take as complex a signal as you wish. Subtract it from zero. That gives a "complement" which, when summed with the original signal, will produce the zero. Then only a scalar detector can go inside the zero and pullout the individual components.

So take a carrier wave. Let the enemy jam it completely, with gobs of power.

Your scalar communication channel stays serenely there, calm and unjammed. The enemy thinks you're jammed and can't communicate. Meanwhile, you continue to communicate just fine.

Or be real smart. Take one of those components inside the first zero. Pick a zero reference inside it. Hide still more carrier components inside the second zero. Do this as many times as you wish.

You can put all the telephone calls in the United States of America on one carrier. And you can keep them clear, right through total jamming.

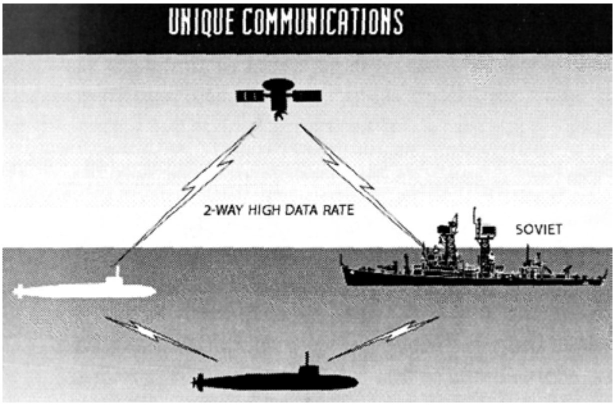

Slide 077: Unique Communications

But that's still not all.

You can also communicate with your submarines underwater. High data rate. Chat away as you wish. You can scramble, frequency hop, encrypt, the works. They can also communicate back to you.

Remember. EM force fields of any appreciable frequency won't travel through the water. Natural EM potentials grab charged particles and ions, so they won't travel through the ocean either. But artificial potentials don't grab onto charged particles or ions, and they will go through the ocean quite nicely.

Everything - aircraft, ships, shore installations, submarines, etc. - can communicate like gangbusters if they possess scalar EM technology.

In fact, you can even build scalar EM underwater radar if you wish.

The airborne scalar EM radar can see under the ocean with a little adjustment. perhaps as well as a conventional side-looking radar sees distant targets today, The airborne scalar EM radar can detect and track the underwater submarine while tooling along.

In fact, the airborne scalar EM radar can then destroy the sub, by using a **little** scalar interferometry. And it's even possible to do scalar interferometry with a single transmitter! How, is proprietary to a friend.

In fact, you can even use your enemy's jamming transmission as a "wire" along which to establish your scalar EM channels. You can use these scalar channels In the "weakly endothermic mode" to locate his transmitter and "lock-in" on it. You can "walk" the lock-in right past his encryption function to the "clear" Input, and receive and record that in the clear. All this from a distance.

You can then destroy his equipment if you wish, or just continue to monitor him in the clear if it's important to do so. Perhaps now we can understand what the decades-long weak microwave radiation of the U.S. Embassy in Moscow is all about. Or why the Soviets are building a nice new Embassy, bristling with antennas, on the high ground in Washington, D.C.

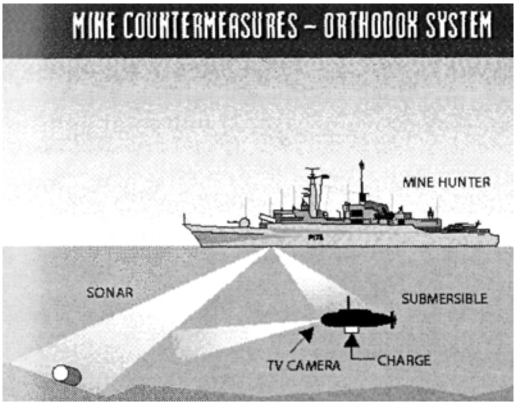

MINE COUNTERMEASURES – ORTHODOX SYSTEM

Slide 078: Mine Countermeasures—Orthodox System

Take something like mine countermeasures, for example. Finding and destroying mines - particularly those placed on the bottom in relatively shallow areas such as ports and rivers - is a really tough problem.

Presently it's often done as portrayed on this slide.

Here a minehunter ship uses an underwater sonar to locate the mine, or what resembles a mine. Then it directs a submersible robot vehicle to proceed over to the object and examine it with an underwater television camera. If it's a mine, the submersible places a remotely operated charge beside it, then chugs away. When it reaches a safe distance away, the charge is exploded, causing the mine to detonate.

A very painful process. Very time consuming, and very difficult.

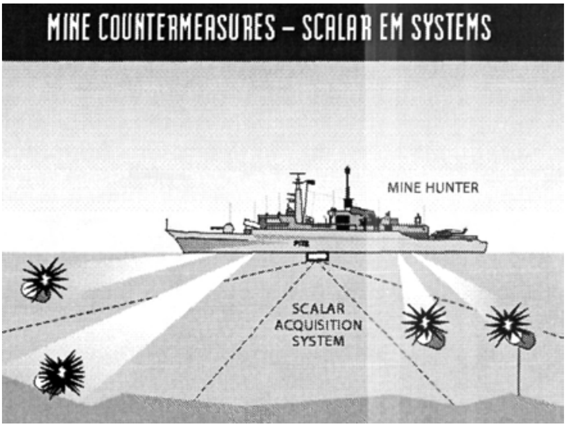

MINE COUNTERMEASURES – SCALAR EM SYSTEMS

Slide 079: Mine Countermeasures—Scalar EM Systems

Now try the same thing while using scalar EM underwater systems. The scalar EM acquisition system is really a sophisticated scalar radar. It scans a large area rapidly, locating moored mines, bottom-planted mines, and drifting mines.

The acquisition system is also a scanned "underwater eye." The operator in the surface vessel can tell whether or not it's a mine he's located.

Once the target mine is detected, a computer computes the firing parameters for a scalar interferometry pulse to hit it and destroy it. The operator fires the pulse, destroying the mine.

The same system that detects the mine at a distance identifies and destroys it at a distance. In this way large areas can be quickly scanned and swept clean of mines.

If a suspicious object is detected and one is still not quite sure it's a mine, shoot it anyway! If it's a mine, it explodes. If it's just a rock, nothing happens. So the same system can do "discrimination by fire."

The same system is useful to destroy midget submarines, bottom crawlers, etc.

It can also wipe out whole arrays of underwater sensors by electromagnetically dudding them.

It can take on a sub if it has to! Here it would just gently kindle EM energy inside the sub's controls, causing it to lose control of all its systems. The sub would then sink to crush depth and implode. The scalar EM mine sweeping system could, of course, simply "blow" the sub, but might itself get caught in the resulting explosion.

SCALAR ANTI-PERSONNEL WEAPON

Slide 080: Scalar Anti-Personnel Weapon

From a military viewpoint, these scalar EM weapons are really quite all-around weapons.

For example, they are very lethal against personnel.

Set in the "high intensity pulse mode," one blast and a person's nervous system is destroyed instantly. Total, instantaneous death results. One can blast away at entire groups of infantrymen, for example. It's the peak power that's important, not the average power. So the weapon doesn't require too much battery power.

Set on a lower intensity pulse mode, one zap can simply knock out a person, rendering him instantly unconscious.

Quite useful if one needs prisoners to interrogate. Also very silent, which is useful in operations employing stealth and surprise.

AFGHANISTAN

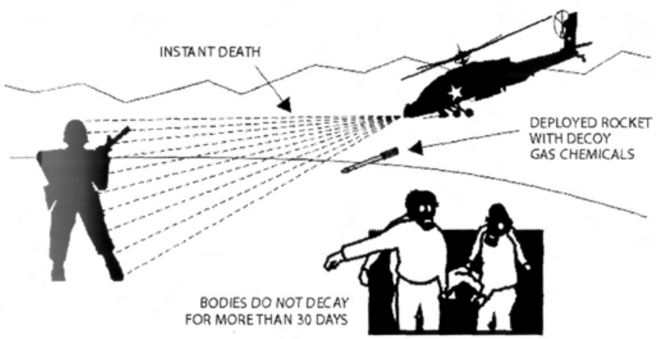
INSTANT DEATH
DEPLOYED ROCKET WITH DECOY GAS CHEMICALS
BODIES DO NOT DECAY FOR MORE THAN 30 DAYS

Slide 081: Afghanistan

The Soviets are employing just such a scalar "death ray" weapon in Afghanistan, apparently in the noses of some of their HIND helicopters.

These choppers usually fire gas rockets to camouflage the testing of the tactical scalar death ray. For example, they may fire rockets filled with nerve gas, and some persons will die convulsively from the chemical.

Those hit by the scalar EM weapon, however, have a most peculiar death **mode,**

Death comes instantly and totally. There is no convulsion, no response. The entire nervous system is destroyed instantly. Every living cell in the body is killed instantly, including all bacteria, germs, etc.

A body hit with this thing falls like a limp rag and lies where it falls. It doesn't decay in even 30-45 days. In a macabre fashion, it's been reduced to something like food irradiated with nuclear radiation; everything is killed, so the material is preserved for an extended period before any decay can set in.

Western military authorities have speculated that this strange death is due to some sort of eery new gas.

However, even with the most virulent gas, some seconds are required for a b**ody** to die. And while it's dying it goes into convulsions. Violent convulsions.

This eery, instant death that leaves a non-decaying corpse is not due to a **gun,** This is the signature of a high-powered pulse kill using a scalar EM weapon

The associated gas rockets are the disguise used to fool our intelligence analysts.

They're just part of the Soviet deception plan.

ADDITIONAL NOTES AND REFERENCES

15. For details of the mysterious, instant deaths in Afghanistan, see Yossef Bodansky, "Soviets testing chemical agents in Afghanistan," *Jane's Defence* Weekly, 1(13), Apr. 7, 1984, p. 508

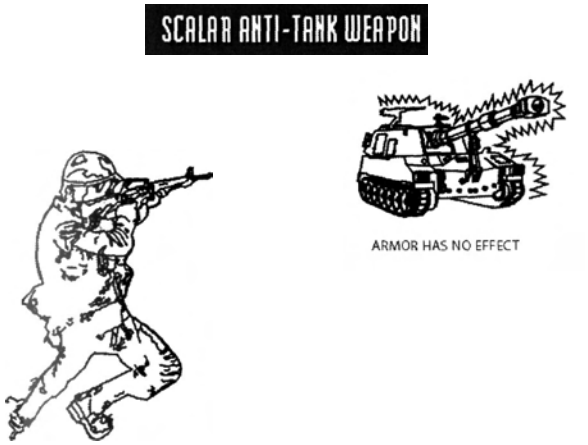

SCALAR ANTI-TANK WEAPON

ARMOR HAS NO EFFECT

Slide 082: Scalar Anti-Tank Weapon

Such weapons are also effective against armored vehicles, for example.

They can be carried by personnel, mounted on vehicles, mounted in helicopters, etc.

They are truly all-purpose weapons.

An infantryman with a bazooka-sized scalar EM pulse weapon can easily knock out a tank with one shot. The armor has no effect; scalar EM goes right through conductive shielding and Faraday cages.

And with the same weapon he can knock out another tank, and another, and another...

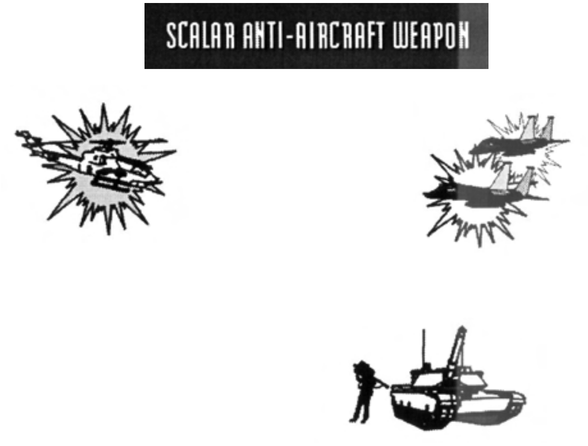

SCALAR ANTI-AIRCRAFT WEAPON

Slide 083: Scalar Anti-Aircraft Weapon

And, if a helicopter or a fixed-wing aircraft attacks him, he can bring the same weapon to bear on it.

He can knock down a chopper or a jet. With one shot.

And another. And another.

Also, it's a line-of-sight weapon. He doesn't have to compute lead angle and all that jazz. Just aim, get the target in his sights, and pull the trigger.

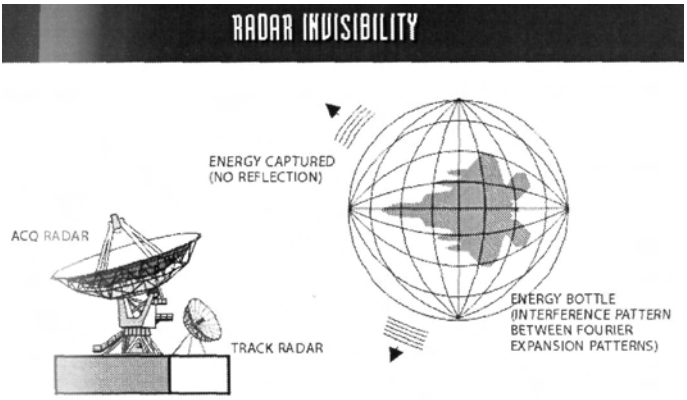

Slide 084: Scalar Anti-Aircraft Weapon

Another neat trick you can do with scalar EM is make an aircraft invisible **to** ordinary radar.

Just use multiple transmitters on the airplane to establish a spherical interference shell, in the bandwidth of the threatening radar, around the aircraft.

When the signal pulse (or continuous wave) from the ground-based radar **strikes** the "energy bottle" in the shell, it interferes with it and is diffracted, scattered, and partially absorbed.

The ground-based radar doesn't get any coherent return pulse or return signal reflected from the target.

Radars don't track aircraft; they track the reflection of their own signal bouncing off aircraft. No reflected signal, no aircraft - as far as a radar is concerned.

To shield against a passive radar (one which tracks emissions from the aircraft), just detect and complement your own emissions so that "near zeroes" result In the spectrum of interest.

Or do both, to protect against both.

It's even possible to cool the exhaust and heated surfaces of the aircraft by a scalar EM adaptation of electrostatic cooling. Theoretically it's even possible to cause the aircraft to "disappear" optically. Takes a bit of doing, but it's possible The basic scheme here is that, when a photon hits the target from a given direction, it's absorbed totally, and a corresponding or "matching" photon is emitted from the opposite side in the same direction the original photon was going. In that fashion, the light emitted from the target from one direction seems to have "passed through it" from the other direction.

Since that's what empty space does, then what a distant observer sees is "empty space," so far as he can tell.

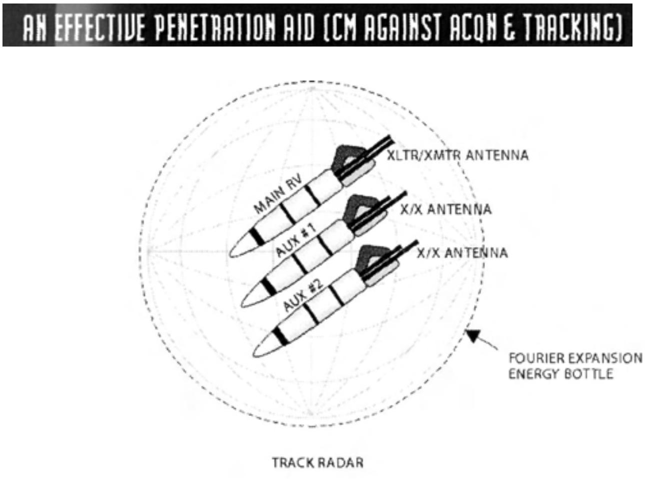

AN EFFECTIVE PENETRATION AID (CM AGAINST ACQN & TRACKING)

XLTR/XMTR ANTENNA
MAIN RV
X/X ANTENNA
AUX #1
X/X ANTENNA
AUX #2
FOURIER EXPANSION
ENERGY BOTTLE
TRACK RADAR

Slide 085: An Effective Penetration Aid

Of course you can do the same thing for re-entry vehicles.

Use some multiple antennas on a vehicle. Or better yet, use satellite RV's to carry the extra transmitters necessary for scalar interferometry.

Deploy the interferometer RV's and activate the scalar EM transmitters. Place an energy bottle Fourier expansion interference shell around the ensemble in the bandwidth of interest.

Radars in that bandwidth now will be unable to detect the incoming ensemble. If nothing detects the threat, nothing is going to shoot at it or react to it.

This can also be used on a bus vehicle during midcourse, for example.

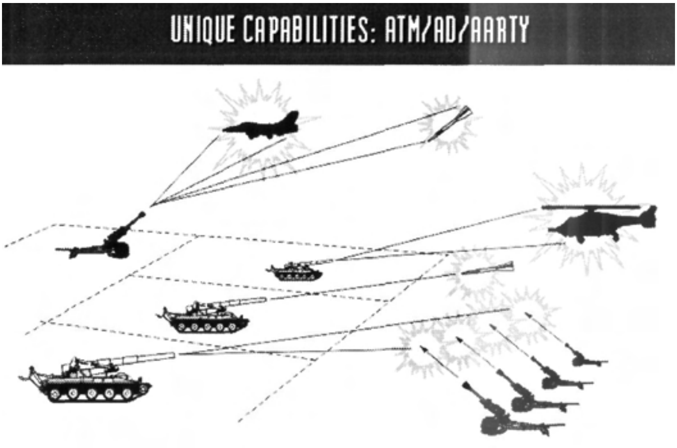

UNIQUE CAPABILITIES: ATM/AD/AARTY

Slide 086: Unique Capabilities: ATM/AD/AARTY

But the uniqueness of scalar EM devices and weapons doesn't end there.

You can hit lots of other threats that are presently difficult or impossible to effectively handle.

For example, on the tactical battlefield, the same scalar EM radar interferometer system can defend against tactical missiles (ATM role), aircraft (AD role), cruise missiles (ACM role), and even artillery and mortar shells (AARTY role).

How the devil, you might ask, can it defend against artillery and mortar shells?

Simple. Sweep the artillery or mortar barrage with closely spaced pulses. Sorta like a machinegun. Or more like a phased-array radar.

If the peak power in the sweeping pulses is sufficient, the explosives are sparked and detonated. Fuses are destroyed.

So even mortar and artillery rounds can be destroyed, by the same system providing air defense and anti-tactical missile defense.

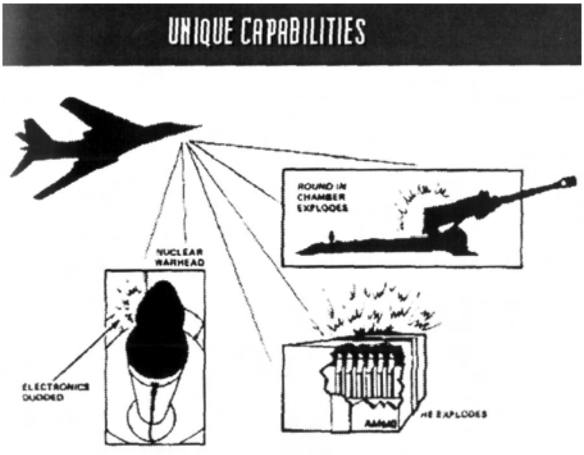

UNIQUE CAPABILITIES

Slide 087: Unique Capabilities

That's still not all.

An incredible number of different types of targets can be attacked with scalar EM weapons.

For example, aircraft equipped with scalar EM weapons can attack targets such as loaded artillery pieces. The round in the chamber explodes, destroying the weapon.

It can also attack nearby stored ammunition. Again, the high explosive in the ammunition explodes, destroying the store.

Even underground missiles can be attacked. The scalar pulse will go right through the overhead cover and dud the electronics, including the nuclear warhead. It will also detonate the HE in the warhead and detonate the fuels and propellants.

A great variety of other targets can also be attacked, as we shall see.

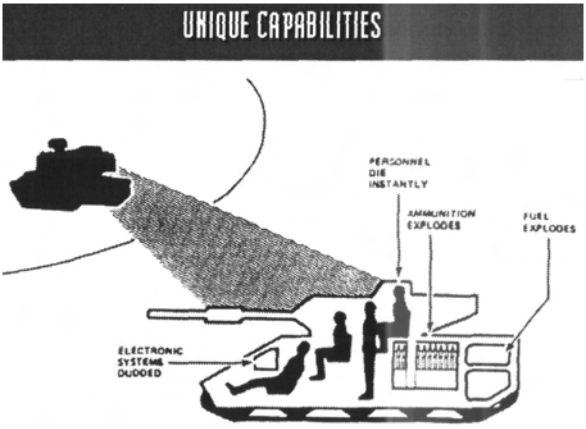

UNIQUE CAPABILITIES

PERSONNEL DIE INSTANTLY
AMMUNITION EXPLODES
FUEL EXPLODES
ELECTRONIC SYSTEMS DUDDED

Slide 088: Unique Capabilities

For example, suppose one attacks a tank.

With scalar EM pulse, the personnel die instantly. Total personnel kill is achieved.

All electronic systems of the tank are dudded. Total systems kill is achieved.

The ammunition in the tank explodes. Total kill is achieved.

The fuel explodes. This is another total kill mechanism.

That tank has been killed totally, by a variety of mechanisms, all simultaneously.

That's a k-kill in any analyst's book.

And **don't** worry about retrieval and repair. That tank is finished permanently.

Even **the** most modern tank is just as vulnerable as the most obsolete.

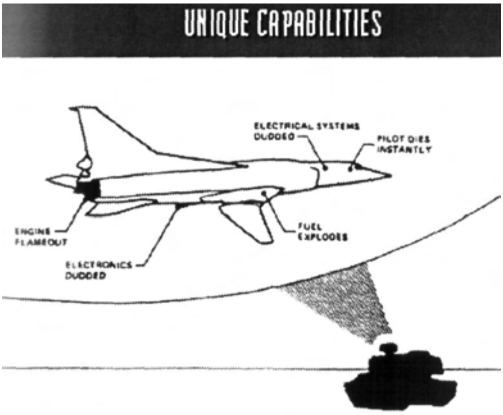
UNIQUE CAPABILITIES

ELECTRICAL SYSTEMS DUDDED
PILOT DIES INSTANTLY
ENGINE FLAMEOUT
FUEL EXPLODES
ELECTRONICS DUDDED

Slide 089: Unique Capabilities

Suppose one attacks a fighter-bomber aircraft.

Again, the kill is catastrophic from multiple simultaneous kill mechanisms.

The pilot and crew die instantly. Total destruction of their nervous systems.

The electrical systems are dudded.

The electronics in all avionics and ordnance is dudded.

The fuel explodes.

HE in on-board or out-board ordnance explodes.

The jet engine flames out if the pulse is powerful enough.

That aircraft is finished. Permanently.

And it's point-and-shoot, line-of-sight.

Even the most modern aircraft is just as vulnerable as the most obsolete.

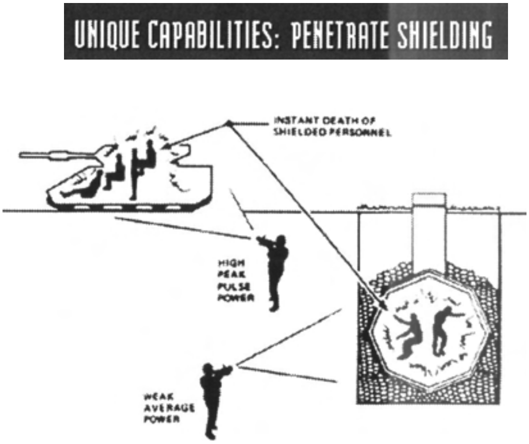

UNIQUE CAPABILITIES: PENETRATE SHIELDING

INSTANT DEATH OF SHIELDED PERSONNEL
HIGH PEAK PULSE POWER
WEAK AVERAGE POWER

Slide 090: Unique Capabilities: Penetrate Shielding

Shielding is ineffective.

The scalar pulse (or continuous wave) can go anywhere gravity can go.

It penetrates the steel hull of tanks and armored vehicles.

It penetrates underground shelters and bunkers.

It penetrates pillboxes and fortifications.

Foxholes are no protection. Just shoot through the earth into them.

There is no longer any place to hide.

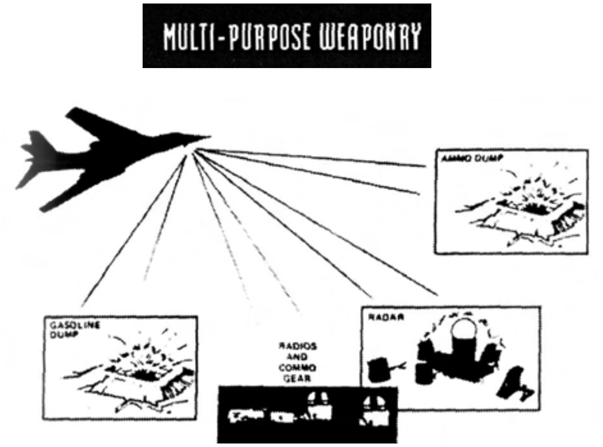

MULTI-PURPOSE WEAPONRY

AMMO DUMP
GASOLINE DUMP
RADIOS AND COMMO GEAR
RADAR

Slide 091: Multi-Purpose Weaponry

These scalar EM weapons are all-purpose. Things such as ammunition dumps, radar systems, radios and communication gear, communications centers, gasoline dumps, etc. can easily be destroyed.

Not only that, but the weapons can be swept, giving area coverage.

You can hit both point targets and area targets.

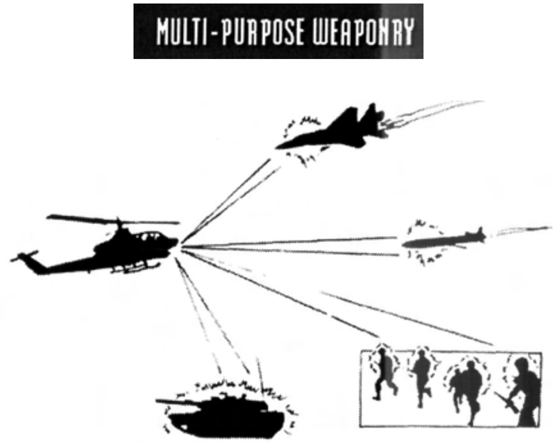

MULTI-PURPOSE WEAPONRY

Slide 092: Multi-Purpose Weaponry

Look at what a weapon a helicopter becomes.

The same vehicle, equipped with scalar EM weapons, can engage and destroy jet aircraft, other helicopters, cruise missiles, personnel, and armored vehicles.

It can also hit all the other targets we've been talking about. Any vehicle equipped with scalar EM weapons becomes a formidable destroyer on the battlefield.

And "reconnaissance by fire" takes on a particularly lethal meaning.

For example, don't worry about the enemy in cover and concealment, or highly camouflaged.

Don't worry about decoys or dummy positions.

Just sweep the area with scalar EM fire. The actual targets will be discriminated by fire and destroyed.

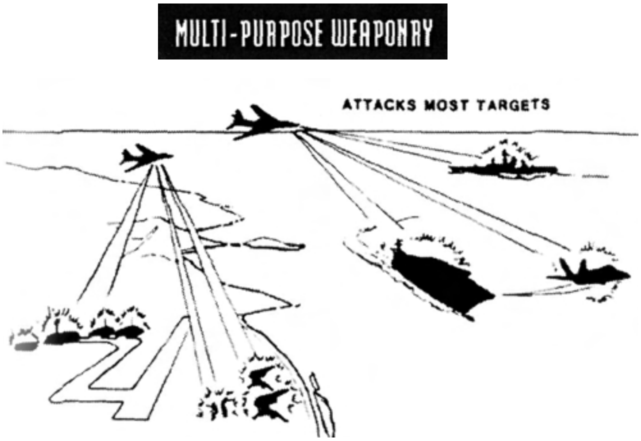

MULTI-PURPOSE WEAPONRY

ATTACKS MOST TARGETS

Slide 093: Multi-Purpose Weaponry

As can be seen on this slide, most targets of interest can be attacked.

A single aircraft can sink an aircraft carrier or destroy a battle cruiser from afar.

It can also destroy aircraft, ground installations, artillery, personnel, nuclear weapons storage sites, tanks, vehicles, fuels, and combustibles.

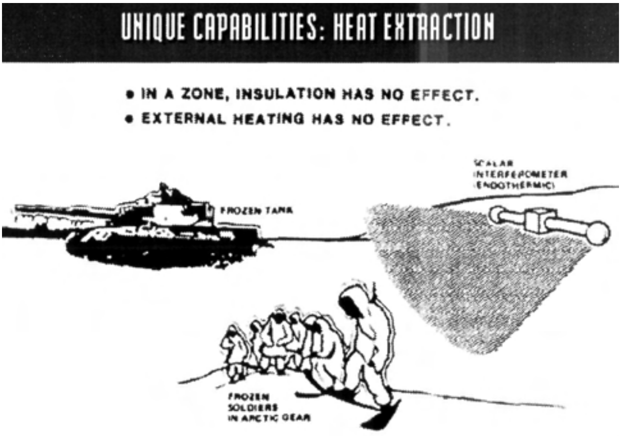

UNIQUE CAPABILITIES: HEAT EXTRACTION

- IN A ZONE, INSULATION HAS NO EFFECT.
- EXTERNAL HEATING HAS NO EFFECT.

SCALAR
INTERFEROMETER
(ENDOTHERMIC)
FROZEN TANK
FROZEN
SOLDIERS
IN ARCTIC GEAR

Slide 094: Unique Capabilities: Heat Extraction

Or one can get truly exotic.

To prevent destroying equipment and installations, the endothermic mode can be utilized.

Cold explosions can be used to freeze tanks, personnel, and equipment.

The equipment and tanks thaw out.

The personnel thaw out too, but they are dead when they do. Heaters and arctic clothing are no protection.

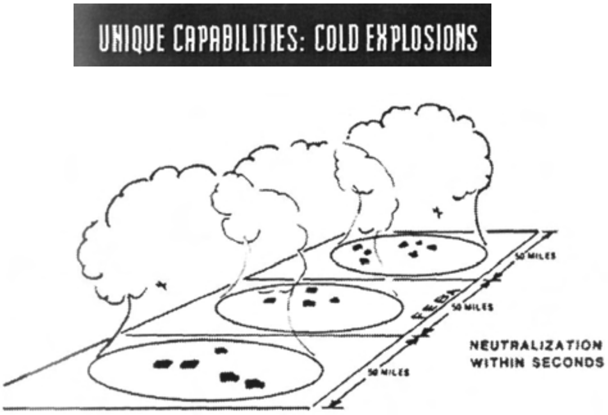

Slide 095: Unique Capabilities: Cold Explosions

For example, suppose three cold explosions, each 50 miles in diameter, are placed upon the front-line strength of NATO.

In seconds there is no longer any "front line strength" of NATO. Every living thing is frozen into a block of ice.

A few more of these things placed on selected rear area installations, and the battle is over before it gets started. Say in about one minute flat!

Suppose NATO is quickly defeated - say in two days. And then the Russians offer us a "Dunkirk." They agree to allow us to evacuate the beaten remnant of our forces.

Are we going to evoke a strategic nuclear exchange, or are we effectively "decoupled" from Europe? Particularly if the Soviets also offer sweeping accommodations to the Europeans, and they accept? If we punch the strategic button, we guarantee our own absolute destruction. (MAD doctrine and all **that,** old chap!)

Whether or not we could do anything to the Russians is a matter of conjecture.

For a demonstration, they could even invite us to launch a couple of missiles, and destroy them over our heads shortly after launch.

And they could take out a few submarines under the ocean, just to make it believable.

And destroy some SAC bombers that are orbiting on station.

Or take out a U.S. Naval Task Force, with a nuclear carrier, as a demonstration that they mean business.

Would a sane President go ahead and destroy us, or accept the Soviet's "Monroe Doctrine" and an "armistice"?

If the Soviets thought he was seriously contemplating ordering a nuclear strike, they could immediately destroy all our nuclear armaments where they sit. Our own weapons would obliterate us!

What would Congress do - after the Soviet Union had demonstrated its absolute power, offered a Dunkirk and armistice, and threatened our total destruction if we "reached for the holster," so to speak - when it realized the President might actually be contemplating evoking assured national suicide?

What would you do if you were a Congressman? If you were the President?

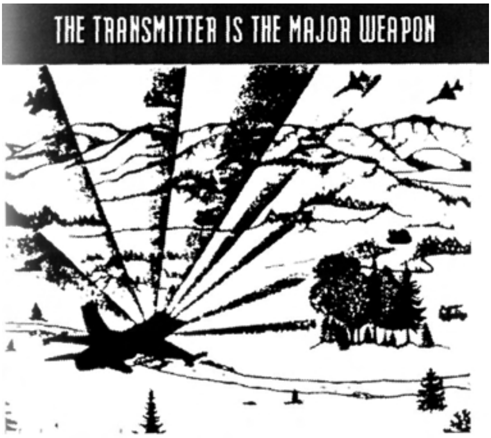

THE TRANSMITTER IS THE MAJOR WEAPON

Slide 096: The Transmitter is the Major Weapon

As shown on this slide, with scalar EM the transmitter becomes the major weapon on the battlefield.

Almost every type of target of any importance can be easily and effectively attacked and destroyed or nullified by scalar EM weapons.

Small wonder the Soviets do not discard their thousands of "old" radars!

How effective do you suppose some of their "old" transmitters on their "old" aircraft might be?

What chance do you think SAC bombers would have against thousands of "old" radar-directed gun sites and "obsolete" air defense missile sites?

Could it be that even something like the old SA-1 could be startlingly effective?

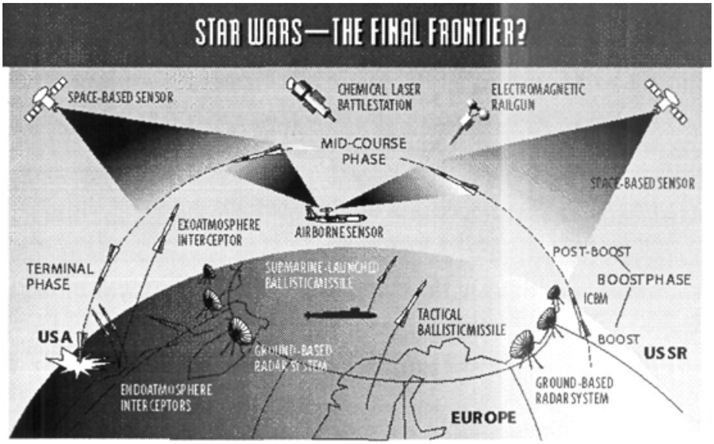
STAR WARS—THE FINAL FRONTIER?
SPACE-BASED SENSOR
CHEMICAL LASER BATTLESTATION
ELECTROMAGNETIC RAILGUN
MID-COURSE PHASE
SPACE-BASED SENSOR
EXOATMOSPHERE INTERCEPTOR
AIRBORNE SENSOR
POST-BOOST
TERMINAL PHASE
SUBMARINE-LAUNCHED BALLISTIC MISSILE
BOOST PHASE
ICBM
TACTICAL BALLISTIC MISSILE
USA
BOOST
USSR
GROUND-BASED RADAR SYSTEM
ENDOATMOSPHERE INTERCEPTORS
GROUND-BASED RADAR SYSTEM
EUROPE

Slide 097: Star Wars—The Final Frontier?

But what of our advanced concepts, such as the strategic defense initiative?

Here we show some of the expensive and complex components of that powerful system.

We have ground-based radars, endoatmospheric interceptors, exoatmospheric interceptors, airborne sensors, space-based sensors, chemically propelled interceptors, electromagnetic railguns, particle beam weapons, high energy lasers, etc. all tied together by a massive command and control system. This massive, expensive system is designed to detect and destroy missiles, including ICBMs, IRBMs, cruise missiles, SLBNs, etc.

*The s*ystem detects the missile launches and engages them from launch on in to the terminal phase.

Massive systems. Electromagnetic marvels. Nuclear-pumped lasers of staggering power. Perhaps even x-ray and gamma ray lasers. Directed energy RF weapons. Stupendous railguns. Sensors everywhere. Giant webs of communications. Banks of computers and control systems.

And it's totally vulnerable to scalar EM interferometer weapons. Giant scalar EM "radars" can simply sweep through all that like a scythe through standing hay.

As it stands, it's obsolete before its design is even finished.

It's obsolete to Soviet scalar EM weapons that are already deployed and operationally tested in place!

Without scalar EM weapons and defenses, all our present weapons and concepts are deadly vulnerable.

The war is over before it hardly gets started. It's not a war; it's more like a clay pigeon shoot.

Understand, if orthodox science was all the Russians possessed, the Strategic Defense Initiative would be the way to go.

But they do possess something else, and presently they have all the trump cards in the deck.

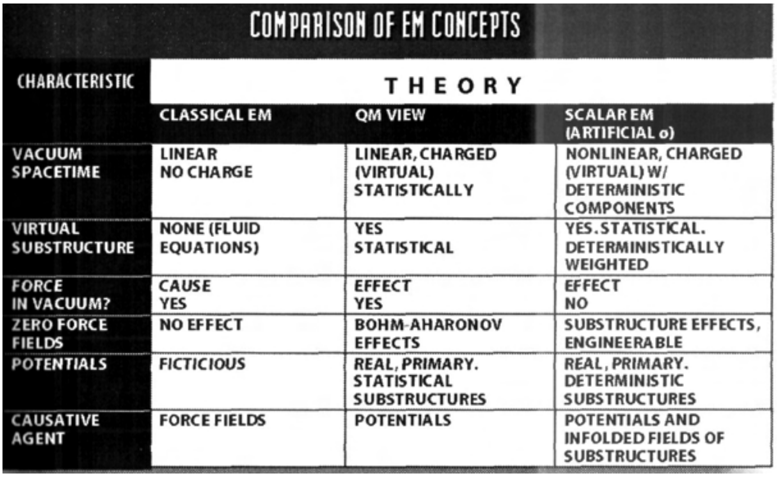

COMPARISON OF EM CONCEPTS

CHARACTERISTIC	THEORY		
	CLASSICAL EM	QM VIEW	SCALAR EM (ARTIFICIAL o)
VACUUM SPACETIME	LINEAR NO CHARGE	LINEAR, CHARGED (VIRTUAL) STATISTICALLY	NONLINEAR, CHARGED (VIRTUAL) W/ DETERMINISTIC COMPONENTS
VIRTUAL SUBSTRUCTURE	NONE (FLUID EQUATIONS)	YES STATISTICAL	YES. STATISTICAL. DETERMINISTICALLY WEIGHTED
FORCE IN VACUUM?	CAUSE YES	EFFECT YES	EFFECT NO
ZERO FORCE FIELDS	NO EFFECT	BOHM-AHARONOV EFFECTS	SUBSTRUCTURE EFFECTS, ENGINEERABLE
POTENTIALS	FICTICIOUS	REAL, PRIMARY. STATISTICAL SUBSTRUCTURES	REAL, PRIMARY. DETERMINISTIC SUBSTRUCTURES
CAUSATIVE AGENT	FORCE FIELDS	POTENTIALS	POTENTIALS AND INFOLDED FIELDS OF SUBSTRUCTURES

Slide 098: Comparison of EM Concepts (Chart)

On this slide and the three that follow, we show a comparison of some of the major characteristics of the three kinds of electromagnetics.

We compare the classical, the quantum mechanical, and the scalar EM (electrogravitational) views of electromagnetics

Notice the differences between the three in regards to vacuum spacetime, virtual substructure, force, whether or not force exists in vacuum, the effect of zero force fields, potentials, and what is to be regarded as causative agents.

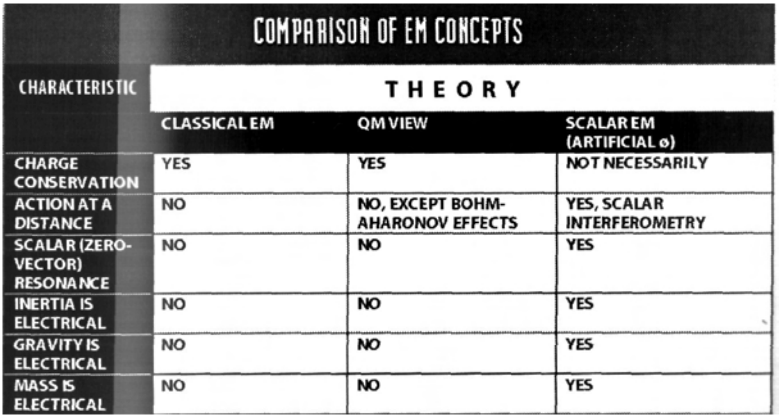

COMPARISON OF EM CONCEPTS

CHARACTERISTIC	THEORY		
	CLASSICAL EM	QM VIEW	SCALAR EM (ARTIFICIAL ø)
CHARGE CONSERVATION	YES	YES	NOT NECESSARILY
ACTION AT A DISTANCE	NO	NO, EXCEPT BOHM-AHARONOV EFFECTS	YES, SCALAR INTERFEROMETRY
SCALAR (ZERO-VECTOR) RESONANCE	NO	NO	YES
INERTIA IS ELECTRICAL	NO	NO	YES
GRAVITY IS ELECTRICAL	NO	NO	YES
MASS IS ELECTRICAL	NO	NO	YES

Slide 099: Comparison of EM Concepts (Chart)

Now note the differing views of charge conservation, action at a distance, scalar resonance, and whether inertia, gravity, and mass are electrical.

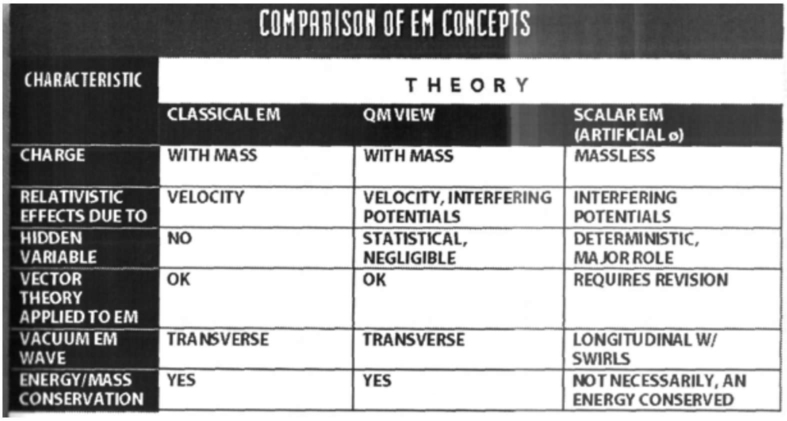

COMPARISON OF EM CONCEPTS

CHARACTERISTIC	THEORY		
	CLASSICAL EM	QM VIEW	SCALAR EM (ARTIFICIAL ø)
CHARGE	WITH MASS	WITH MASS	MASSLESS
RELATIVISTIC EFFECTS DUE TO	VELOCITY	VELOCITY, INTERFERING POTENTIALS	INTERFERING POTENTIALS
HIDDEN VARIABLE	NO	STATISTICAL, NEGLIGIBLE	DETERMINISTIC, MAJOR ROLE
VECTOR THEORY APPLIED TO EM	OK	OK	REQUIRES REVISION
VACUUM EM WAVE	TRANSVERSE	TRANSVERSE	LONGITUDINAL W/ SWIRLS
ENERGY/MASS CONSERVATION	YES	YES	NOT NECESSARILY, AN ENERGY CONSERVED

Slide 100: Comparison of EM Concepts (Chart)

Continuing, note the differences in the views of charge, what relativistic effects are due to, whether or not one has hidden variables and whether they are enginerrable, how vector theory is applied to electromagnetics, the nature of the EM wave in vacuum, and conservation of energy/mass.

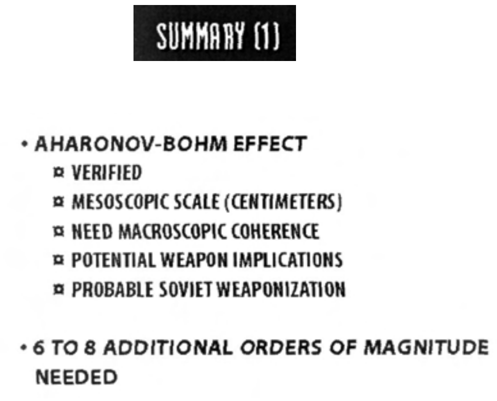

SUMMARY (1)

- AHARONOV-BOHM EFFECT
  - ¤ VERIFIED
  - ¤ MESOSCOPIC SCALE (CENTIMETERS)
  - ¤ NEED MACROSCOPIC COHERENCE
  - ¤ POTENTIAL WEAPON IMPLICATIONS
  - ¤ PROBABLE SOVIET WEAPONIZATION
- 6 TO 8 ADDITIONAL ORDERS OF MAGNITUDE NEEDED

Slide 101: Summary (1)

Now we examine the three views for whether or not electro-gravitational waves exist and what they interact with, the number of required spacetime dimensions the type of geometry, the nature of a zero-summed EM vector, local and distant relativity aspects, and whether or not the probability states propagated by the Schroedinger equation can be deterministically engineered.

As can be seen from the last four slides, the three views are quite different, and the scalar EM view is drastically different.

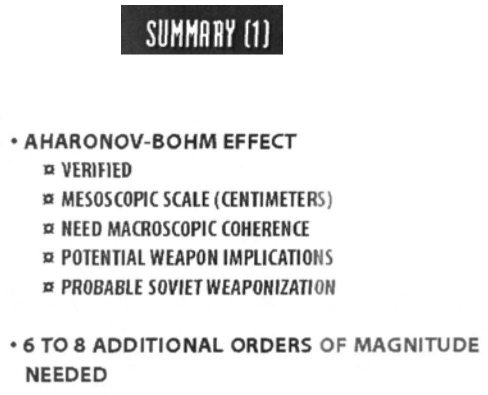

SUMMARY (1)

- AHARONOV-BOHM EFFECT
  - VERIFIED
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  - POTENTIAL WEAPON IMPLICATIONS
  - PROBABLE SOVIET WEAPONIZATION
- 6 TO 8 ADDITIONAL ORDERS OF MAGNITUDE NEEDED

Slide 102: Summary (1)

In summary, we can now state unequivocally that the Aharonov-Bohm effect has been conclusively proven, at least for the mesoscopic scale over a few thousand Angstroms, and possibly over a few centimeters.

But in these experimental proofs; the "natural" type of potential has been used, it is basically incoherent in its substructure, dooming the effect to stay small.

By utilizing macroscopic EM force fields and waves to zero-sum and comprise artificial potentials, the coherence can be maintained over a macroscopic distance - even for hundreds of thousands of kilometers.

The weapons implications - only some of which we have set forth in this treatise - are mindboggling.

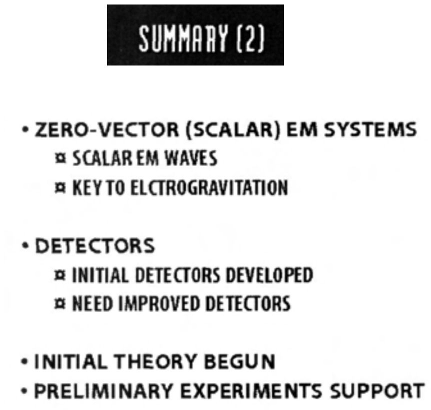

SUMMARY (2)

- ZERO-VECTOR (SCALAR) EM SYSTEMS
  - ¤ SCALAR EM WAVES
  - ¤ KEY TO ELCTROGRAVITATION
- DETECTORS
  - ¤ INITIAL DETECTORS DEVELOPED
  - ¤ NEED IMPROVED DETECTORS
- INITIAL THEORY BEGUN
- PRELIMINARY EXPERIMENTS SUPPORT

Slide 103: Summary (2)

Zero-vector (scalar) EM systems are the key to scalar EM waves, which are actually electrogravitational waves.
Scalar wave detectors nave been developed and are being improved. Further improvement is needed. This development is limited only by funds.

The initial theory has been begun. More work is needed. Again, this development is limited only by funds.

Preliminary experiments support the scalar EM concepts.

Equipment can be designed and made to work electro-gravitationally.

And it has been.

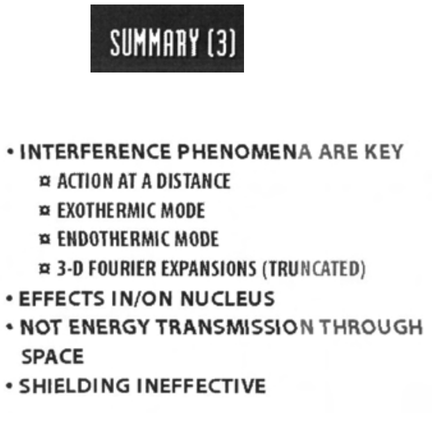

SUMMARY (3)

- INTERFERENCE PHENOMENA ARE KEY
  - ¤ ACTION AT A DISTANCE
  - ¤ EXOTHERMIC MODE
  - ¤ ENDOTHERMIC MODE
  - ¤ 3-D FOURIER EXPANSIONS (TRUNCATED)
- EFFECTS IN/ON NUCLEUS
- NOT ENERGY TRANSMISSION THROUGH SPACE
- SHIELDING INEFFECTIVE

Slide 104: Summary (3)

Interference phenomena are key.

One can get action at a distance - even over hundreds of thousands of kilometers.

One can engineer gravitational and inertial effects.

One can engineer the nucleus, including transmute it, easily and cheaply. One could clean up all the nuclear wastes.

Electromagnetic energy can be produced at a distant target, or extracted from a distant **target.**

This is is not energy transmission through space in the form of EM force fields. Instead, it is transmission through spacetime in the form of electrogravitational potentials.

Conventional EM shielding is ineffective against scalar EM.

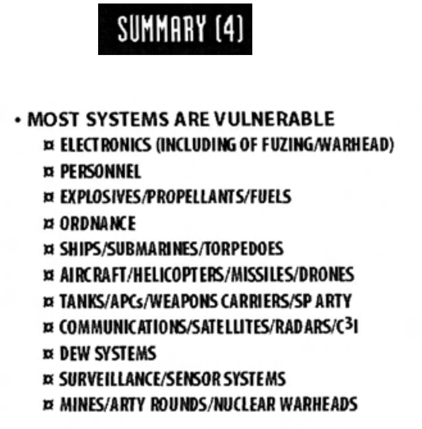

SUMMARY (4)

- MOST SYSTEMS ARE VULNERABLE
  - ¤ ELECTRONICS (INCLUDING OF FUZING/WARHEAD)
  - ¤ PERSONNEL
  - ¤ EXPLOSIVES/PROPELLANTS/FUELS
  - ¤ ORDNANCE
  - ¤ SHIPS/SUBMARINES/TORPEDOES
  - ¤ AIRCRAFT/HELICOPTERS/MISSILES/DRONES
  - ¤ TANKS/APCs/WEAPONS CARRIERS/SP ARTY
  - ¤ COMMUNICATIONS/SATELLITES/RADARS/C^3I
  - ¤ DEW SYSTEMS
  - ¤ SURVEILLANCE/SENSOR SYSTEMS
  - ¤ MINES/ARTY ROUNDS/NUCLEAR WARHEADS

Slide 105: Summary (4)

Almost every weapon system we presently have - or are developing - is totally vulnerable to scalar EM weaponry.

This includes personnel, electronics (including fuzing and warhead), explosives, propellants, fuels, ordnance, ships, submarines, torpedoes, aircraft, helicopters, missiles, drones, rockets, tanks, armored vehicles, weapons carriers, self-propelled and towed artillery, communications, satellites, radars, command and control, directed energy weapon systems, surveillance and sensor systems, mines, artillery rounds and ammunition, nuclear warheads, etc.

We are in dire straits. We need a "Manhattan Project" of the highest priority. Now!

The Soviets have already had the equivalent of seven or eight Manhattan Projects in this area.

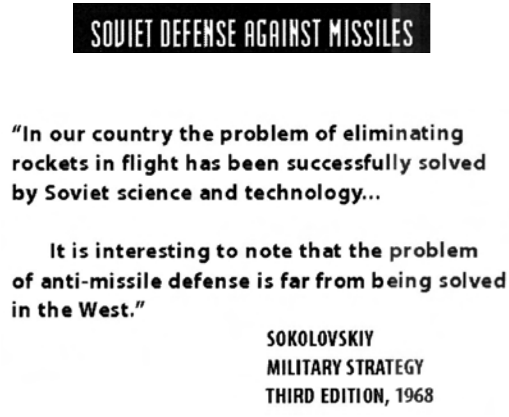

SOVIET DEFENSE AGAINST MISSILES

"In our country the problem of eliminating rockets in flight has been successfully solved by Soviet science and technology...

It is interesting to note that the problem of anti-missile defense is far from being solved in the West."

SOKOLOVSKIY
MILITARY STRATEGY
THIRD EDITION, 1968

Slide 106: Soviet Defense Against Missiles

Here is a significant statement by Sokolovskiy, contained in Military Strategy, 3rd edition, 1968.

This is not propaganda. The Soviets really do have an effective missile defense. We do not. At the present rate we're going, we may not have one in the year 2000 - if we live that long.

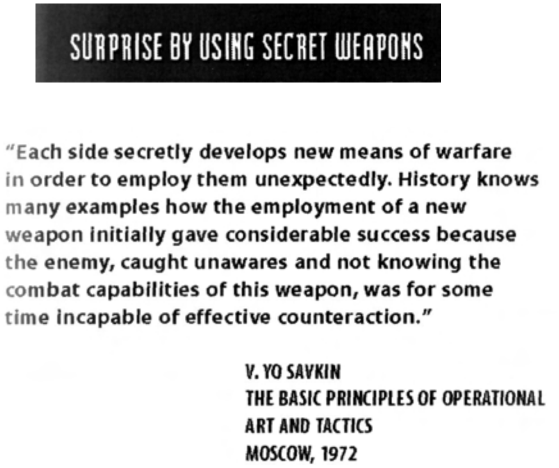

SURPRISE BY USING SECRET WEAPONS

"Each side secretly develops new means of warfare in order to employ them unexpectedly. History knows many examples how the employment of a new weapon initially gave considerable success because the enemy, caught unawares and not knowing the combat capabilities of this weapon, was for some time incapable of effective counteraction."

V. YO SAVKIN
THE BASIC PRINCIPLES OF OPERATIONAL ART AND TACTICS
MOSCOW, 1972

Slide 107: Surprise by Using Secret Weapons

The Soviets took to heart the lesson of our secret development of the atomic bomb. Thrust suddenly upon a fanatical nation, the atomic bomb brought the empire of Japan to its knees.

Other lesser examples - such as the impact of the German V-l and V-2 missiles and jet fighter - also were not lost on the Soviets.

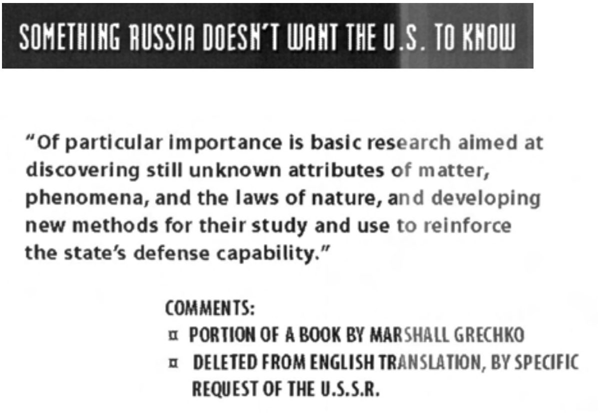

SOMETHING RUSSIA DOESN'T WANT THE U.S. TO KNOW

"Of particular importance is basic research aimed at discovering still unknown attributes of matter, phenomena, and the laws of nature, and developing new methods for their study and use to reinforce the state's defense capability."

COMMENTS:

- PORTION OF A BOOK BY MARSHALL GRECHKO
- DELETED FROM ENGLISH TRANSLATION, BY SPECIFIC REQUEST OF THE U.S.S.R.

Slide 108: Something Russia Doesn't Want the U.S. to Know

But Marshall Grechko said it even plainer.

He made it clear that the Soviet Union has actively searched for great technical breakthrough areas, particularly in discovering new laws of nature, unknown attributes of matter, and new phenomena, and developing their use for defense.

He made it so clear that the Soviet Union formally requested the U.S. State Departmentto have deleted from its. English translation that portion of his book.

That is a positive signature that the statement is exceedingly sensitive to the Soviets. In other words, it's a real tipoff.

So of course the State Department leaned on the publisher and got that section eliminated.

ADDITIONAL NOTES AND REFERENCES

1. Nikola Tesla, "The Problem of Increasing Human Energy," Century magazine, June 1900, p. 208-209. In this article Tesla spoke of using standing waves to produce distant effects and locate objects such as ships. At this point he was thinking of a scalar radar locator, something more advanced than even our radar today. It was also capable of producing electrical effects at any part of the globe. To quote: "Stationary waves... mean something more than telegraphy without wires to any distance... For instance, by their use we may produce at will, from a sending station, an electrical effect in any particular region of the globe; we may determine the relative position or course of a moving object, such as a vessel at sea, the distance traversed by the same, or its speed..."

2. Nikola Tesla, "The True Wireless," Electrical Experimenter, May 1919, p. 87.

3. T. E. Bearden, Comments on the New Tesla Electromagnetics: Part I: Discrepancies in Present EM Theory, Tesla Book Co., 1580 Magnolia, Millbrae, CA 94030, 1982.

4. T. E. Bearden, Toward a New Electromagnetics: Part III: Clarifying the Vector Concept, Tesla Book Co., 1580 Magnolia, Millbrae, CA 94030, 1983.

5. T. E. Bearden, Toward a New Electromagnetics: Part 4: Vectors and Mechanisms Clarified, Tesla Book Co., Millbrae, California, 1983, p. 6, 39.

6. T. E. Bearden, Solutions to Tesla's Secrets and the Soviet Tesla Weapons, Tesla Book company, 1981

7. T. E. Bearden, Tesla's Secrets and the Soviet Tesla Weapons, 1 hr. 40 min. videotape, Weather Engineering, POB 1472, Huntsville, AL 35807, 1981.

8. T. E. Bearden, Soviet Weather Engineering Over North America, 1-hr. videotape, Weather Engineering, POB 1472, Huntsville, AL 35807, 1985.

9. T. E. Bearden, Star Wars Now! The Bohm-Aharonov Effect, Scalar Interferometry, and Soviet Weaponization, Tesla Book Co., 1984

10. Stefan T. Possony, "The Tesla Connection," Defense & Foreign Affairs, Aug. 1984, p. 12-14, 27.

11. Stefan T. Possony, "Psy-War: Soviet device experiment," Defense & Foreign Affairs Daily, 12(104), June 7, 1983, p. 1-2. Reports on Dr. Ross Adey's investigation of the Soviet LIDA device which is used to bombard human brains with radio waves in the 40 MHz region. Also reports on work by A. S. Davydov of the Ukrainian Academy of Sciences, who discovered how the blood-brain barrier can be penetrated by low-frequency radio waves so that brain cells are affected.

12. Fritz Albert Popp, "Photon storage in biological systems," in Electromagnetic Bioinformation: Proceedings of the Symposium, Marburg, Sep. 5, 1977. Edited by Fritz Albert Popp et al, Munchen, Wien, and Baltimore, 1979, p. 123-149. Dr. Popp has discovered, both theoretically and experimentally, that mitogenetic radiation from cells can be seen as a sort of "waste" from a virtual electromagnetic field with a high coherence. This field has a tendency to become stationary over the whole organism. In addition, it includes the storage of "virtual" coherent photons. (In other words, there is a master EM field with high coherence, stationary over the whole body. This is the cells' master control system. Storage of virtual photons -- i.e., scalar signals -- occurs in this field.).

13. To gain an appreciation of the Aharonov-Bohm effect, see Y. Aharonov and D. Bohm, "Significance of Electromagnetic Potentials in the Quantum Theory," Physical Review, Second Series, 115(3), Aug. 1, 1959, p. 485-491. For an exhaustive discussion of the Aharonov-Bohm effect and a large number of references, see S. Olariu and I. Iovitzu Popescu, "The quantum effects of electromagnetic fluxes," Reviews of Modern Physics, 57(2), April 1985. See also Bertram Schwarzschild, "Currents in normal-metal rings exhibit Aharonov-Bohm effect," Physics Today, 39 (1), Jan. 1986, p. 17-20.

14. For details of the mysterious explosions of six major Soviet missile ammunition storage sites in seven months, see photograph, Jane's Defence Weekly, 2(3), July 28, 1984, p. 92; see also Mark Daly, "Goa and Goblet SAMs in Severomorsk explosion," Jane's Defence Weekly, 2(6), Aug. 18, 1984, p. 224; Derek Wood, "Soviets' northern fleet disabled... 'not viable' for six months," Jane's Defence Weekly, 2(1), July 14, 1984, p.3; Derek Wood, "Six explosions in the past seven months," Jane's Defence Weekly, 2(1), July 14, 1984, p. 3; John Moore, "The aftermath of Severomorsk," Jane's Defence Weekly, 2(6), Aug. 18, 1984, p. 224.

15. For details of the mysterious, instant deaths in Afghanistan, see Yossef Bodansky, "Soviets testing chemical agents in Afghanistan," Jane's Defence Weekly, 1(13), Apr. 7, 1984, p. 508.

16. For details of the Enhanced-V cloud signature of severe weather, see Gary Ellrod, "Dramatic examples of thunderstorm top warming related to downbursts," National Weather Digest, 10(2), May 1985, p. 7-13; T. J. Fujita, "Manual or Downburst Identification for Project Nimrod," SMRP Research Paper No.156, University of Chicago, 1978; D. W.McCann, ., The Enhanced-V: A Satellite Observable Severe Storm Signature," Monthly Weather Review, 111, 1978, p. 887-894.

17. For a good discussion of the modern view of the vacuum, see
I.J.R. Aitchison, "Nothing's plenty: The vacuum in modern quantum field theory," Contemporary Physics, 26(4), 1985, p. 333-391.

18. For a discussion of the ring interferometer experiments related to quantum and gravitational effects, see G.E. Stedman, "Ring interferometric tests of classical and quantum gravity," Contemporary Physics, 26(4), 1985, p. 311-332.

19. For information on self-induced transparency with pulsated light, see E. L. Hahn, Scientific American, June 1967. This is a scalar EM effect. The phenomenon is observed only in insulators, not in conducting materials. A dielectric tends to stop the flow of electrons, thus stopping the bleed-off of the Kaluza-Klein 5-potential as EM force fields. Thus through the insulator or dielectric, an electrogravitational pulse is transmitted. When this pulse emerges from the other side of the

dielectric, then electrons are free to move again and form ordinary EM fields, resulting in resumed EM bleed-off of the KK (Kaluza-Klein) 5-potential. Thus ordinary photons strike the dielectric, changing into electrogravitational waves which transit the opaque dielectric, and these EG waves transform back to EM waves on the far side of the dielectric. Advanced scalar EM application of this effect can make an object optically invisible.

20. For a lucid and profound presentation of the entire subject of elementary particle physics and quantum field theory, see T. D. Lee, Particle physics and introduction to field theory, Harwood Academic Publishers, New York, 1967. Subjects covered include those at the forefront of current research. Chapter 16, "Vacuum as the source of asymmetry," is particularly important. Here Lee concisely covers the idea of degenerate vacuum states, vacuum structuring, and vacuum effects causing symmetry breaking (violation of conservation laws). An excellent coverage of asymmetries and observables is given on p.181-188. For example, whenever symmetry is spontaneously broken, a nonobservable (virtual entity) has become observable. Thus there exist mechanisms for the direct translation between virtual and observable states.

Most engineers are unaware that physics has already rigorously proven (both theoretically and experimentally} that conservation of energy can be physically violated, even by excitation of the vacuum.

However, in the present assumption of a randomized virtual microstructure of a vacuum potential, these broken symmetry effects are individually confined to very small microlevels. For example, on p. 383, Lee points out that the microscopic structure of the scalar vacuum field (i.e., of vacuum charge or "potential") is not utilized.

This of course is reasonable if all vacuum potentials used in particle physics are treated as having a randomized microstructure of virtual particle flux vectors. Since any appreciable directional coherence in such a randomized microstructure could persist only over extremely tiny distances, then the microstructure of vacuum degenerate states has negligible local effects in ordinary macroscopic systems.

In other words, these conservation violation effects would be very difficult to coherently capture and utilize to provide "free energy, emerging from the vacuum."

The randomized momentary coherences, however, are responsible for the violent microfluctuations of the EM fields, well-known in classical electrodynamics. An approach such as taken by Yater or Moray would be necessary to achieve a vacuum energy tap under such conditions. To achieve usable macroeffects, a very large collection of charge or magnetic material, etc. would be required before the probability of usable coherences would become sufficiently large. Therefore this area is neglected in practical physics and engineering.

However, this is precisely where scalar EM is lost in conventional theory and engineering practice. In scalar EM, the coupling together of macroscopic EM force field vectors into a summed zero system means that the vacuum potential's microstructure is now macroscopically ordered by that system. Further, it is sustained during translation through space. In such case, one has produced directional gravitational potential gradients that have macroscopic range and form. Further, by coherently varying the amplitude of the individual components of the zero vector system, a gravitational wave -- a controlled oscillation of the degenerate states or vacuum -- is produced. By processing the EM components, this gravitational wave can be narrowed, formed into a beam, and projected. Two such beams can be interfered, even at a great distance, producing G-interference and causing EM effects to emerge in the distant interference zone. Thus scalar EM profoundly affects quantum mechanics, quantum field theory, particle physics, general relativity, and electromagnetics.

21. For some strong and pertinent critique of present scientific bias, see Ruggero Maria Santilli, Ethical probe on Einstein's followers in the U.S.A.: An insider's view, Alpha Publishing, POB 82, Newtonvllle, MA 02160. Santilli is a highly published physicist and the editor of a refereed scientific journal, the Hadronic Journal. After lengthy attempts to correct injustices within the Scientific system, to no avail, he finally has gone public with his specific charges. Santilli references senior Russian physicist G. Yu. Bogoslovsky, whose 1984 paper "Generalization of Einstein's relativity theory for the anisotropic spacetime," whose research would have been impossible in the U.S. Quoting Santilli: "He would have been discredited, humiliated, and chased out of these institutions [Harvard, M.I.T., and Yale] beyond any reasonable doubt by ample documentation on similar cases." Again to quote Santilli: "Papers bearing the title of 'Generalization of Einstein's relativity' are routinely permitted with human dignity at Moscow University in the U.S.S.R., but they are absolutely inconceivable today at the departments of physics of Harvard University, of the Massachusetts Institute of Technology, of Yale University and of other similar institutions in the U.S.A., as numerous senior scientists would readily testify."

You see, dear reader, there has been a deep scientific conspiracy in the U.S. to prevent any change in the severe restrictions placed on general relativity by Einstein. This has reduced GR to a sort of "special relativity, with only distant perturbations." Specifically, it has excluded scalar electromagnetics and branded as heresy the inconceivable idea that general relativity could be local, and engineerable.

Now you know why the Soviets have been able to develop these monstrous weapons for over three decades while our scientists slept at the wheel. Scientific arrogance and pride has been our greatest enemy.

See also Bryan G. Wallace, "The great speed of light in space coverup," Scientific Ethics, 1(1), Feb. 1985, p. 2-3; "Radar testing of the relative velocity of light in space," Spectrosc. Lett. 2, 1969, p. 361; Wallace, "Letter to the editor," Physics Today, 36(1), 1983, p. 11; "Letter to the editor," Physics Today, 37(6), 1984, p. 15. See M.E. Ash et al, Astron. J., 72, 1967, p. 72. Direct experiments on Einstein's second postulate, in the 1961 interplanetary radar contact with Venus, challenge whether relativity is correct. Variations of over 30,000% of the best possible general relativity fit the MIT Lincoln Lab could generate were measured. The variations were not random but contained diurnal, lunar, and synodic periodic components. See also Bryan G. Wallace, Spectrosc. Lett. 4, 1971, p. 79 for an analysis of published 1961 data on the interplanetary radar contact with Venus that concludes that the data showed a component that was relativistic in the Galilean c+v sense. See also Wallace, "The Unified Quantum electrodynamic ether," Foundations of Physics, 3, 1973, p. 381. which details Measurements strongly challenging the Einstein assumption of the constant velocity of light, and deals with the nature of the ether. See also Thomas E. Phipps, Jr., "Critique of accepted theories of special relativity and electromagnetism," Scientific Ethics, 1(2), Apr. 1985, p. 17-23.

22. For a sample of Soviet scientific freedom from narrow-minded bias in general relativity, see V. I. Denisov and A. A. Logunov, "The inertial mass defined in the general theory of relativity has no physical meaning," Teor. i Matemat. Fizika, 51(2), May 1982, p. 163-170 (In Russian). See also A. A. Vlassov and V. I. Denisov, "Einstein's formula for gravitational radiation is not a consequence of the general theory of relativity," Teor. i. Matemat. Fizika, 53(3), Dec. 1982, p. 406-418. Here we find that the intensity of gravitational radiation and the total intensity determined in the general theory of relativity in accordance with Einstein's formulas depend on the choice of the coordinate system, so that they can be made to vanish or even become negative. [Note by T.E.B.: If local curvature is

engineerable, as in scalar EM, the local choice of coordinate systems can itself be directly engineered. This clearly implies that scalar EM can thus produce either "positive" intensity radiation or "negative" intensity radiation; thus it can "produce energy at a distance" or "extract energy from a distance.]
Continuing with Denisov: This result is a particular consequence of the general assertion to the effect that in general relativity there are no energy-momentum conservation laws for a system consisting of matter and the gravitational field. [Note by T.E.B.: Thus we can have an energy source or energy sink appear in the distant interference region, where matter has been lifted from the Dirac sea and exposed to the highly nonlinear interfering EG fields.]. See also V. I. Denisov and A. A. Logunov, "New theory of spacetime and gravitation, "Teor. and Matemat. Fizika, 50(1), July 1982, p. 3-76. Points out that ". . . the gravitational field in general relativity is completely different from other physical fields and is not a field in the spirit of Faraday and Maxwell." (p. 3, English version).

23. In the Proceedings of the Tesla Centennial Symposium, an IEEE Centennial Activity, Colorado College, Colorado Springs, Colorado, Aug. 9-11, 1984, see Richard A. Blade, "Modification of Maxwell's equations in free space to account for nonzero photon mass and scalar electromagnetic waves," p. 91-92; Jack Y. Dea, "Scalar fields: their prediction from classical electromagnetism and interpretation from quantum mechanics," p. 94-98; Robert W. Bass, "Self-sustained non-Hertzian longitudinal wave oscillations as rigorous solutions of Maxwell's equations of electromagnetic radiation," p. 89-90; T. E. Bearden, "Tesla's electromagnetics and its Soviet weaponization," p. 119-138.

24. To see the limiting assumptions imposed on general relativity that results in the severely restricted "ordinary general relativity" taught in almost all Western universities. see Charles W. Misner, Kip S. Thorne and John Archibald Wheeler, Gravitation, W. H. Freeman and Co., San Francisco, CA, 1973, p. 19-21, 71-72, 367-369. Among other things, these arbitrary restrictions save the conservation laws. When they are removed. the conservation laws can be violated.

25. Several anomalous events -- skyquakes, booms, or earthquakes -- have been documented in Europe. See H. W. Haak. "The Seismic event of November 9, 1983: Earthquake or sonic boom." Seismic Activity in Western Europe, (With particular consideration of the Liege Earthquake of November 8, 1983), Ed. by Paul Melchior, D. Reidel Publishing Co., 1985, p. 215-222. For such events in the United States, see S. Claflin-Chalton and G. J. MacDonald, "Sound and light phenomena," The Mitre Corporation, McLean, Virginia 22102, Nov. 1978.

26. Fundamental experiments were performed by Eotvos et al. in the early 1920s. See R.V. Eotvos, D. Pekar and E. Fekete, Ann. Phys. (Leipzig) 68, 1922, p. 11. Actually a fifth force of nature due to hypercharge may have been found by these experiments. See Ephraim Fischbach et al. "Reanalysis of the Eotvos experiment," Physical Review Letters, 56(1), Jan. 6, 1986, p. 3-6. See also F. D. Stacey and G. J. Tuck, Nature 292, 230 (1981); S. C. Holding and G. J. Tuck, Nature 307, 714 (1984); G. W. Gibbons and B. F. Whiting, Nature 291, 636 (1981); F. D. Stacey, in Science Underground, edited by M. M. Nieto et al., AIP Conference proceedings No. 96, (American Institute of Physics, New York, 1983, p. 285. See also S. H. Aronson et al, Physical Review Letters 48, 1982, p.1306; Physical Review D 28, 1983, p. 476, 495. Also, comparison of satellite and terrestrial determinations of the gravitational field constant reveals significant disagreement: see R. H. Rapp, Geophys. Res. Lett. 7, 1974, p. 35; Bull. Geod. 51, 1977, p. 301.

27. John J. A. O'Neill. "Tesla cosmic ray motor may transmit power 'round the earth: Famed scientist, on eve of 76th birthday, says he has succeeded in harnessing 'penetrating rays' to operate small motive device." Brooklyn Eagle, July 10,1932. Tesla reported he had harnessed "cosmic rays" and caused them to operate a small motive device. Tesla's use of "cosmic rays," however, encompassed scalar EM radiation. Tesla later seems to have progressed to a simpler motive unit. In the Kansas City Journal-Post, Sep. 10, 1933, he stated: My power generator will be of the simplest kind -- just a big mass of steel, copper and aluminum, comprising a stationary and rotating part, peculiarly assembled." A similar type of "gravitational turbine" seems to have been invented by John Bedini.

28. To see just how arbitrary and postulational are present "definitions" of mass and force, see Robert Bruce Lindsay and Henry Margenau, Foundations of Physics, Dover Publications, New York, 1963, p. 283-287. Note on p. 283 that a "field of force" at any point is actually defined only for the case when a unit mass is present at that point. Also see Richard P. Feynman, Robert B. Leighton, and Matthew Sands, The Feynman Lectures on Physics, Addison-Wesley, New York, Vol. 1, 1963, p. 2-4 for a definition of the electric field in the context of its potentiality for producing a force. This problem did not exist for the original foundation of electromagnetic force fields in vacuum, since the vacuum was assumed to be a material ether. With the modern view a nonmaterial ether has emerged, yet the classical electromagnetic theory has not been made sufficiently rigorous in distinguishing "observable" and "virtual" electromagnetic force fields.

29. E. P. Battey-Pratt and T. J. Racey, "Geometric Model for Fundamental Particles," International Journal of Physics, Vol. 19, No. 6, 1980, p. 437-475.

30. Some years ago, Dr. William Tiller produced very important "free A-field" theoretical work which showed waves which did not fall off as $1/r^2$. Interesting theoretical work in scalar wave theory has also been advanced by Dea. See Jack Dea, "Fundamental Fields and Phase Information," presented at the 1985 U.S. Psychotronics Association Conference, Bergamo Center, Dayton, Ohio, July 1985. Dea has formulated an important theory for vacuum EM scalar waves, derived from Maxwell's equations with zero E and B fields. He predicts waves whose intensity falls off with distance as $1/r$ instead of $1/r^2$, and detection of these waves by various means. He shows simple generators for the waves. Detection is quantum mechanically by electron interference, not by single electrons. Thus such scalar waves will pass through normal Faraday shields. In his theory Dea does not address the question of spin vortexes in vacuum scalar waves. It is the present author's view that all vacuum waves are scalar waves, and the primary distinction between the "transverse" EM wave and the longitudinal scalar wave is simply the presence or absence of spin-vortexes. Indeed, one may argue that the present "vector wave" EM theory can be replaced by a scalar wave theory. In 1903 Whittaker proved that any vector field can be replaced by two scalar fields. See E. T. Whittaker, Proc. Lond. Math. Soc.1, 367, 1903. By implication, since a vector wave is simply a moving vector field, it can be replaced by two moving scalar fields.

31. David Jones, "Israel's Secret Weapon," Weekend Magazine, Dec.17, 1977.

32. John Hutchinson, private communication. Masses of wood, metal, etc. -- some weighing over 60 lbs. -- have been levitated by Hutchinson.

33. For a description and details of the April 9, 1984 incident off Japan, see Daniel A. Walker, Charles S. McCreery, and Fermin J. Oliveira, "Kaitoku Seamount and the Mystery Cloud of 9 April

1984," Science, 227(4684), Feb. 8, 1985, p. 607-611. See also transcription from Japan Airlines flight 036 to Anchorage International Flight Service, 9 April 1984, at 1406 Greenwich mean time, Federal Aviation Administration (FAA) — Alaska Region; Jim Derry, Special Agent, FAA-Alaska Region, interviews with Captain C.H. McDade, Japan Airlines Flight 036, with Captain Cornelis Vander Berg, KLM Royal Dutch Airlines Flight 868; with First Officer Reint Sol, KLM Royal Dutch Airlines Flight 868, and with Captain Mike Howe, Flying Tiger Lines Flight 078, Anchorage Daily News, 10 April 1984, p. A-l; Anchorage Daily News, 12 April 1984, p. A-l; Honolulu Advertiser, 10 April 1984, p. B-l; Newsweek, 30 April 1984, p. 25, Gregg Ripee, "Mushroom cloud sighted off Japan," Los Angeles Daily News, 11 April 1984, p. 1,8; Ross Gelbspan, "Mystery cloud baffles scientists," Boston Sunday Globe, 13 Jan. 1985, p. 1, 14; T.E. Bearden, Soviet Weather Engineering Over North America, 1-hr. videotape, 1985. See also McKenna, Daniel L. & Daniel Walker,"Mystery Cloud: Additional Observations", Science, 234(4775), Oct. 24, 1986, p. 412-413.

34. For a description of the April 11, 1963 anomalous underwater explosion north of Puerto Rico, see Robert J. Durant, "An Underwater Explosion — or What?", Pursuit, 5(2), April 1972, p. 30-31.

35. For details of the loss of the U.S.S. Thresher and the interference experienced by the U.S.S. Skylark, see John Bentley, The Thresher Disaster, Doubleday, Garden City, N. Y., 1975, particularly p. 164. Some of the communications systems of the Skylark experienced temporary failure, but were not disabled, later resuming operation.

36. The Soviet Union has a well-established history of interfering with and destroying aircraft; for example, for a listing see "Soviet and Warsaw Pact air incidents," Jane's Defence Weekly, 3(2), Jan. 12, 1985, p. 58.

37. For details of the anomalous "nuclear flashes" detected by U.S. Vela satellites, see "Scientists Fail to Solve Vela mystery," Science, 207, 1 Feb. 1980, p. 504-506. "Satellite Evidence Shows 'possibility' of Nuclear Test, DOD Says," Aerospace Daily, Oct. 29, 1979, p. 286. "A Flash of Light," Newsweek, Nov. 5, 1979, p. 64-65. "Was It a Nuclear Device?", Newsweek, July 21, 1980, p. 19. "Diverging Views," Washington Roundup, Aviation Week & Space Technology, July 21, 1980, p. 15. Philip J. Klass, "Clandestine Nuclear Test Doubted," Aviation Week & Space Technology, Aug. 11, 1980, p. 67, 69, 71-72. "Debate continues on the Bomb That Wasn't," Science, 209, 1 Aug. 1980, p. 572-573. "Navy Lab Concludes the Vela Saw a Bomb," Science, 209, 29 Aug. 1980, p. 996-997. See also Jack Anderson and Dale Van Atta, United Press Syndicate, "CIA knew South African-Israeli nuclear test was coming," Birmingham Post-Herald, Apr. 26, 1985, p. A5. The latter article repeats the CIA/DIA argument that the Vela incidents represent concurrent South African-Israeli testing of atomic weapons. Taiwan is considered a possible third partner. According to Anderson and Van Atta, a South African navy contingent was "in the area" at the time of the 1979 Vela detection, and Israel and South Africa were cooperating on an atomic bomb project as early as 1966. Apparently U.S. announcement of an impending South African atomic test in the Kalahari Desert in 1977 led to such an outcry that the test was suspended. Anderson and Van Atta cite succeeding visits to South Africa by Israeli scientists, technicians, and defense officials. However, since the actual Vela detections showed some deviations from what would be expected from nuclear tests, one can speculate that Anderson and Van Atta have presented evidence for the development of scalar electromagnetic weapons by two additional countries. One may further speculate that this could reveal what has been checking the Soviets from simply moving against the West with scalar electromagnetic weapons.

Indeed, the mysterious destruction of six major Soviet missile ammunition storage areas within the space of seven months could have been a preemptive measure and warning to the Soviets if they had actually been considering moving against the West. Also, other incidents reported in the South Atlantic may possibly be associated with the program producing the "Vela flashes." For example, see N.W.C. Rutherford, "Unidentified Phenomena," Marine Observer, 51, 1981, p. 186 for a description of a great bluish-white flash and small bolt of lightning, indicating some sort of anomalous electrical discharge, on Dec. 23, 1980 at 2245 hours (10:45 p.m.). Many other anomalous flashes for which no known causative mechanism exists have been detected by satellites. For example, the OSO-2 and OSO-5 satellites have detected about one mysterious short (less than 0.1 sec) flash about every ten orbits, at times when the fields of view of the telescopes were well above the earth. As many as three of the satellite's photometers have detected a flash simultaneously. These flashes must be removed from any discussion of satellite-observed lightning; see J. G. Sparrow and E. P. Ney, "Lightning Observations by Satellite," Nature, 232, 1971, p. 540.

38. For a description of sightings of enormous glowing globes of light deep within the Soviet Union in the direction of Saryshagan, see Gwynne Roberts, "Witness to a Super Weapon?", The Sunday Times, London, England, Aug. 17, 1980. Several incidents were observed by Downie and others.

39. For an artist's conception of a directed energy weapon installation at Saryshagan, see Aviation Week & Space Technology, July 28, 1980, p. 48. For a DOD sketch, see Soviet Military Power, 1985. Obviously classically-trained U.S. military analysts, with no knowledge of scalar interferometry, have not considered the installation as a candidate hyperspatial howitzer.

40. For a description of multiple pilot sighting (from Iran) of an enormous glowing globe of light deep within the Soviet Union, see Central Intelligence Agency (CIA) Information Report No. CO-B-321/15354-66, "Sighting of Unusual Phenomenon on Horizon Near Iranian/USSR Border," Sep. 8, 1966, released on 15 Dec. 1978 under the Freedom of Information Act (FOIA). The sighting occurred at 2142 hours (9:42 p.m.).

41. For details of sighting of the intensely glowing ball of light near British European Airways flight 831 between Moscow and London, see CIA Foreign Intelligence Information Report CO-B-324/33601-76, "Aerial observation of intense Source of Light," Nov. 18, 1976, released on 15 Dec. 1978 under the FOIA. The incident occurred between 1800 and 1900 hours (6:00-7:00 p.m.). The light was observed for 10-15 minutes, until the aircraft had flown past and left the light behind.

42. For other examples of pertinent 1ight phenomena: F. S. Angus and G. Carling, "Optical Phenomenon: Caribbean Sea; Western North Atlantic," Marine Observer, 40, Jan. 1970, p. 17-18; R. A. Holmes, "Unidentified Phenomenon, off Barbados, West Indies," Marine Observer, 40(229), July 1970, p. 107-108; H. K. Dyer, "Unidentified Phenomenon: Western North Atlantic," Marine Observer, 43, July 1973, p.114. For a 1961 double concentric hemispheric shape observed in the Indian Ocean, see Marine Observer, 32, 1962, p. 64. For a particularly significant combination of forms, see Marine Observer, "Unidentified Phenomenon," 48, 1978, p. 21-22. Also, on the night of July 26, 1984 the pilot and crew of a Boeing 747 (American carrier) flying from Tokyo to Fairbanks, near the Kuriel Islands, at 47 5'44" N: 161 00'05" E, noticed a slowly expanding hemisphere of white light off to their left above the horizon. The shell of light continued to expand over a 10-minute

period until ahead of them and to the right. The crew braced for a shock wave which never arrived. Their weather radar saw nothing out of the ordinary. The shell of light had sharp edges and was semi-transparent so that stars became visible through it. (Richard F. Haines, private communication, Sept. 27, 1984). See also Richard Hall, "Aerial anomalies at sea," The Info Journal, 4(3), May 1975, p. 6-9 for an unusual light phenomenon seen in the Caribbean by the R.M.S. Carmania (British). The phenomenon occurred four times at precise hourly intervals, strongly suggesting an artificial origin. See also F. Shepherd, "Cloud: Strait of Gibraltar," Marine Observer, 51(273), July 1981, p. 107-108 for an incident of associated cloud, arch, and anomalous pressure effects. For another significant airline sighting by Japan Airlines flights 403 and 421 of a giant, expanding globe of light on June 18, 1982, in the North Pacific, 100 km. east of Kushiro, see the Asahi Evening News, Tokyo, Japan, June 22, 1982. For additional evidence that nomadic tribesmen passing through Kazakhstan repeatedly observe such gigantic light phenomena in close association with Saryshagan missile test range, and that Soviet deception planners foster the notion of "UFO activity" as a Red Herring, see Robert Jackson, "KGB takes to the flying saucers!", Northern Echo, Darlington, England, March 15, 1984.

43. For details of Khrushchev's announcement of a Soviet superweapon, see Max Frankel, "Khrushchev Says Soviet Will Cut Forces a Third; Sees 'Fantastic Weapon'", New York Times, Jan. 15, 1960, p. 1.

44. See Christopher S. Wiren, "Brezhnev Calls for Accord against 'Terrifying Arms,'" New York Times, June 14, 1975, p. 1, 11. In a major Kremlin speech on June 13, 1975, Leonid I. Brezhnev included a statement that one major concern not covered by existing agreements was "assuming ever greater urgency with each passing day." Calling for a ban on new weapons of mass destruction, the Soviet leader stated: "The level of modern technology is such that a serious danger arises of creating weapons more terrifying than nuclear ones." He stated, "The reason and conscience of humanity dictate the necessity of erecting an insurmountable barrier to the development of such weapons." See also Malcolm W. Browne, "Senatorial Group Received by Brezhnev," New York Times, July 3, 1975, p. 2. Leonid Brezhnev repeated his proposal to a group of U.S. senators on July 2, stating that the capability to develop more terrible weapons was obvious. He emphasized, however, that he "had no particular weapon in mind." Here he may have been deliberately misleading the U.S. senators, to prevent revealing that the Soviet Union had already developed such weapons, and was horrified at their potential for total destruction. E.g., if massive and rapid scalar explosions occur, the linearity of spacetime -- and the orderly flow of time itself -- may be seriously perturbed throughout the earth and its adjacent space. From a general relativistic viewpoint, such an event might well prove catastrophic for the entire biosphere. Boris N. Ponomarev, a Soviet national party secretary, again raised the same issue to a delegation of visiting U.S. congressmen in the Kremlin on Aug. 11, 1975; see Christopher S. Wren, "Moscow Now Pressing Disarmament." New York Times, Aug. 12, 1975, p. 6. At the United Nation's thirtieth session of the General Assembly on Sept. 23, 1975, Foreign minister Andrei A. Gromyko strongly raised the same issue, warning that science can produce "ominous" new weapons of mass destruction. He urged that all countries, led first by the major powers, should sign an agreement to ban the development of these unspecified new weapons. He even offered a draft, entitled "Prohibition of the Development and Manufacture of New Types of Weapons of Mass Annihilation and of New Systems of Such Weapons." The first article provided that the types of these new weapons would be "specified through negotiations on the subject." Because of its fixation on nuclear weapons, the West may have lost its only opportunity to prevent the spread of scalar electromagnetic weapons of power unprecedented even by nuclear arms. Of course, it may also have

been a Soviet ploy to prohibit the U.S. from developing scalar electromagnetics defensive weaponry to counter the massive strategic scalar electromagnetics weapons already developed, tested, and deployed by the Soviet Union. Certainly in 1973 at a secret meeting in Prague with European communist leaders, Brezhnev had laid out a firm statement of Soviet domination of the world by 1985. See "Secret Speech: Did Brezhnev Come Clean?", National Review, 29(8), Mar. 4, 1977, p. 248, 250. Brezhnev's speech contained statements such as: "We are achieving with detente what our predecessors have been unable to achieve using the mailed fist...come 1985 we will be able to extend our will wherever we need to." Brezhnev stated the Soviet Union would control the oceans of the world, 90% of the land, and the air and space above. A front-page Boston Globe article on Feb. 11, 1975 was the first to carry the story. A copy of Brezhnev's secret speech was obtained by British intelligence in 1973, but denigrated by Secretary of State Kissinger. Apparently the first official U.S. reference to Brezhnev's startling speech did not appear until the 1976 National Intelligence Estimate. Although the big intelligence bureaucracies can do a fantastic job with "current intelligence," their record at predicting a drastic change is woeful, precisely because of the political nature of bureaucracies. See "What is Intelligence," Colonel William V. Kennedy et all, Intelligence Warfare: Penetrating the Secret World of Today's Advanced Technology Conflict, with an introduction by Dr. Ray S. Cline, Crescent Books, New York, 1983, p. 8-23. Intelligence Warfare is heartily recommended as the single book which best gives the reader a grasp of modern technical intelligence organizations, capabilities, and operations.

45. For details of Soviet weather engineering operations over the U.S., see Thomas E. Bearden, "USSR: New beam energy possible?", Defense & Foreign Affairs Daily, 13(111), June 12, 1984, p. 1-2. Cloud signature patterns reported in the article have been repeatedly sighted over multiple areas in the U.S. A series of anomalous "hole in the cloud" patterns, possibly associated with early Soviet weather engineering efforts over the U.S., was widely seen in 1967-68. See Weatherwise, 21(4), Aug. 1968, cover and p. 143; 21(5), Oct. 1968, p. 194-195, 204-205; 21(6), Dec. 1968, p. 238-245. Peculiar stationary blocking patterns have also been observed to occur and influence weather over the U.S., leading to severities such as the winter of 1976-77. See K. K. Tung and R. S. Lindzen, "A theory of stationary long waves, Part 1, A simple theory of blocking; Part 2: Resonant Rossby waves in the presence of realistic vertical shears; Part 3, Quasi-normal modes in a singular waveguide," Monthly Weather Review, 107(6), June 1979, p. 714-774. See also T. E. Bearden, Soviet Weather Engineering Over North America, videotape, 1985 for an expose or the physics and some major incidents of major Soviet weather engineering, including details and photographs of cloud signature patterns. See also C. B. Baker, "Soviet Weather Mayhem," Youth Action News, Nov. 1983, P.O.B. 312, Alexandria, Virginia 22313, p. 1-8; C. B. Baker, "Diabolic Soviet Warfare," Youth Action News, Nov. 1984; For a conventional Soviet look at weather modification (possibly intended to mislead the West), see E. T. Protasevich, "Microwave weather modification," Soviet Technical Physics Letters, 7(3), March 1981, p. 114-115. For a downburst mechanism, see Gary Ellrod, "Dramatic examples of thunderstorm top warming related to downbursts," National Weather Digest, 10(2) May 1985, p. 7-13. See Art and Kay Westermann, Weather War — Worldwide, Liberty Bell Books, POB 288, Sedona, Arizona 86336, 1983. See also U.S. Senate Resolution on Environmental warfare, July 11, 1973.

46. For details of the Soviet Woodpecker beams bending around the earth and intersecting over the U. S., see Christopher Chant and Ian Hogg, Nuclear War in the 1980's?, Harper & Row, New York, 1983, p. 71. See also Soviet Military Power, U.S. Department of Defense, 1985, p. 45. The

intersection forms an interference grid. Scalar EM channels added to the Woodpecker carriers then provide a corresponding sca1ar EM interference grid in the scalar area.

When adjusting the scalar interferometry components of the grid, bursts in the interference and discharges of energy as well as bursts of energy extractions occur. This leads to the production of anomalous aerial phenomena such as explosions, rumblings, airquakes, etc. In addition, direct Bohm-Aharonov forces may be engendered in ground structures, shaking buildings and windows, etc. without seismic disturbances. Such anomalous disturbances have been widely noted in the open U.S. press. E.g., particularly see Kenneth F. Bunting and Daniel M. Weintraub, "Mysterious Rumbles Jar Southland," Los Angeles Times, Dec. 8, 1984, CC(II), p. 1,10; Let Scarr, "People shook up over mystery shakes," The San Diego Union, Dec. 8, 1984, p. Bl, 4. Following this and a Dec. series of anomalous aerial disturbances off the Los Angeles/San Diego coast, a sharp and unexpected weather front appeared, racking the area with high winds on the night of Dec. 12, producing widespread damage and power outages. The newly-formed front moved on to produce significant snowstorms in other areas. See Ted Thackery, Jr., "Winds Kill Two, Wreak Havoc as They Sweep Through the Southland," Los Angeles Times, Dec. 14, 1984, MF/Part II, p. 1,8; "Even Tucson gets snow in storm that dumps 20 inches," AP release, Los Angeles Herald Examiner, Dec. 14, 1984, p. A-12. During several months prior to the December 1984 Los Angeles incident, anomalous electrical failures and outages had occurred in the San Diego and Southern California area, possibly due to scalar interferometry adjustments in the Woodpecker grid over the area. For other typical incidents possibly associated with adjustment of the interference grid, see "Who boomed? Odd Noise unnerves Ohioans," Journal, Milwaukee, Wisconsin, Dec. 28, 1982; "Tremors shake Miss. Gulf Coast," Times-Picayune, New Orleans, Louisiana, Feb. 27, 1983; Sandra Skowron, "Sonic boom is just Mother Nature," Beaver Co. Times, Beaver Falls, Penn., Jan 13, 1983; "Booms in Rockland, New York Times, Mar. 1. 1979, Sec. 8, p. 82; "Loud 'boom' unexplained," Star-Beacon, Ashtabula, Ohio, Feb. 21, 1983; Paul Senecton, "The word is now IDENTIFIED," Mail, Hartlepool, England, Feb. 3, 1985: On Jan. 23, 1974 a mysterious explosion over North Wales rocked a 60-mile radius area. Associated anomalous light phenomena were also seen. Hundreds and hundreds of anomalous booms, aerial rumbles, and aerial explosions, many accompanied by flashes or anomalous shaking of ground structures, buildings, windows, etc., have occurred over the U.S. and other Western nations in the 60's, 70's, and 80's.

On occasion, an aircraft at the proper altitude and position can conceivably experience interference in its electrical systems and in its engine combustion processes due to exothermic kindling or endothermic extraction of electromagnetic energy. The combustion processes of aircraft engines produce highly ionized gases in very nonlinear conditions. These can act as strong dephasers and decouplers of the vector EM components of a vector zero summation in a scalar interference zone. Exothermic interference would have little effect on combustion, but strong endothermic interference can result in engine flameout. Anomalous simultaneous failure of jet and propeller-driven aircraft engines sometimes occurs. For high altitude grids, this can result in engine flameouts, but restart and recovery after unusual loss of altitude has dropped the aircraft out of the scalar interference zone. Several candidate incidents over and near the U.S. exist, particularly where power failures were experienced by multiple aircraft. The more usual exothermic case, however, if substantial could result in anomalous loss of control of the aircraft. For a recent candidate incident, see "Jetliner drops 32,000 feet; 400 aboard; 50 are injured," Associated Press release, Huntsville Times, Feb. 20, 1985, p. 1 and "China Airlines Pilot Denies Cockpit Error," Associated Press release, Huntsville Times, Feb. 21, 1985, p. A-9. Deliberate use of this effect as an anti-strategic-bomber weapon capable of destroying bombers at or shortly after takeoff is possible (the Arrow DC-8 which crashed just after takeoff from Gander Air Force Base, Newfoundland on December 12, 1985 may have been deliberately interfered with by just such a Soviet weapon -- see extensive newspaper and TV news coverage of that event).

In scalar EM interference with aircraft, certain signatures may occur. Different instruments may sharply contradict each other, since their activation and inactivation is no longer a simple function. The pilot's instrument panel, for example, may indicate failure of the control system, when actually it has not failed, and the flight recorder may record that the control system is still operating. In such case, the pilot may take proper action based on his own instrumental readings, yet these actions may be contraindicated for the actual status of the aircraft, resulting in opposing pilot/autopilot actions. Tentative indications of the jetliner that anomalously dropped 32,000 feet and recovered are that apparently such anomalous instrument disagreements occurred. Another signature is that, as the EM charge accumulates in and on the aircraft, its skin charges up electrically, producing a glowing corona similar to St. Elmo's fire. The Arrow DC-8 was observed to be glowing yellow by eyewitnesses, according to the Canadian Broadcast Corporation's 10:00 p.m. network TV news on April 8, 1986.

47. T. E. Bearden, Star Wars Now! The Bohm-Aharonov Effect, Scalar Interferometry, and Soviet Weaponization, Tesla Book Co., Millbrae, California, 1984, p. 19-22.

48. For a paper possibly related to the first Bedini scalar wave detector from the "free A-field is a scalar field" view, see Robert R. Lewis, "Aharonov-Bohm effect for trapped ions," Physical Review A, 28(3), Sept. 1983, p. 1228-1235. This paper analyzes the role of the Aharonov-Bohm effect for the bound states of a charged particle in the superposition of two fields: a uniform magnetic field plus the vector potential of a solenoid. Gives exact solutions for a solenoid of zero size and discusses the corrections due to a solenoid of finite size. Shows that a series of new "betatron resonances" appear in the spectrum, dependent on the flux quantum number. The fundamental betatron resonance remains narrow and unshifted for solenoid radii large enough to broaden and shift the cyclotron resonance. See also W. Ehrenburg and R. E. Siday, Proc. Phys. Soc. London, Sect. B62, 1949, p. 8 which, among other things, discusses the effect of the vector potential in electron interferometry, where the insertion of a tiny solenoid between the interfering paths is shown to give an additional phase difference proportional to the flux through the solenoid. The resulting shift in the fringe system is called the Aharonov-Bohm effect.

49. Frank Golden has developed a most important and precise scalar EM detection system to display scalar EM signals on a cathode ray tube. His important measurements have mapped the scalar resonant frequency responses of the entire earth. Two completely different types of scalar instrumentation show precise agreement on the frequency maps. The measurements show that the Soviet Union has for some time entrained the entire earth into giant scalar electromagnetic resonances on two frequencies approximately 12 kilohertz apart. It is the opinion of the author that the beat frequency between these two giant resonances is utilized by the Soviet Union to extract enormous power from the earth, essentially by a mechanism that Golden has uncovered. A complex of four to eight weapon systems might reasonably be powered from the single bi-resonant tapping source. In April 1985 Golden discovered the rather sudden activation of many other scalar frequencies with characteristics resembling command and control communications. In addition, a significant number of additional paired scalar resonances had been entrained upon the earth. It is the

opinion of the author that this showed a major activation of the Soviet strategic scalar electromagnetic defense system, with the power up of from 80 to 100 weapons, along with the complete command and control system. Golden has previously built a prototype of an actual Soviet scalar communications system and demonstrated that it works. Because of the impending mayday and the 1973 statement by Brezhnev indicating that 1985 was a critical planning year, the sudden activation of such massive numbers of weapons and communications was alarming. Accordingly, the author discreetly notified certain contacts to alert the U.S. system. Golden then detected the periodic turn-on and turn-off of the systems, indicating a large command and control exercise rather than preparations for direct tactical use. An additional difference, however, was the change from scalar electric to scalar magnetic field on many of the large transmitters. This is indicative of electrostatic location, targeting, and adjustment of the target on the earth and then switching to the "power input" mode. It is the opinion of the author that this indicated the choice of a geological target and proceeding to attack that geological target in the "slow buildup" mode. Again, proper contacts were so notified.

50. A very good coverage of the Soviet microwave radiation of the U.S. Embassy in Moscow is given in Paul Brodeur, The Zapping of America, W. W. Norton & Co., New York, 1977, passim. None of our U.S. Embassy security personnel knew of scalar interferometry, nor did they possess scalar electromagnetics detectors. Further, orthodox U.S. scientists were also ignorant of scalar electromagnetics. The Soviets were thus in a position to tailor the radiation signals and precisely determine what our on-site personnel would detect. Details of the effects on U.S. Embassy personnel, possibly associated with the microwave radiation, are given by Brodeur. A great number of related releases by the open news media also exist. For example, see Robert C. Toth, "Radiation Devices Bug U.S. Embassy," Huntsville Times, reprinted from the Los Angeles Times, Feb. 8, 1976; "U.S. Screening out Soviet 'Listening Rays'," United Press International release, Washington D.C. Star, Feb. 11, 1976; Norman R. Beebe, "Nixon Exposed to Radiation In Russia?", Associated Press release, Huntsville Times, Apr. 30, 1976; Barton Reppert, "U.S. Scientists Puzzled Over Embassy Radiation Effect," Associated Press release, Huntsville Times, May 28, 1976; Barton Reppert, "Radiation Entering Embassy in Moscow through Phone Line," Associated Press Release, Huntsville Times, May 28,1976. See also Martin Ebon, Psychic Warfare: Threat or Illusion, McGraw Hill Book Co., New York, 1983.

51. For details of the electromagnetic transmission of cellular disease and death, see Vlail P. Kaznacheyev, "Information function of ultraweak light flows in biological systems," Problems in Biophysics, Novosibirsk, 1967, p. 7-18. Kaznacheyev et al, "Conditions necessary for appearance of distant intercellular interactions after UV-radiation," Bulletin Experimentalnoy Biologii i Meditsiny, (5), 1979, p. 468-471; Distant intercellular interactions in a system of two cultures connected by optical contact," Ultraweak Luminescence Biology, Moscow, 1972, p. 224-227; "Distant intercellular interactions caused by UV-radiation," Photobiology of a Living Cell, Leningrad, 1979, p. 221-223; "Studies on the biological role of electromagnetic emission as a factor of adaptive behavior of cells under conditions of latitude changes," Abstracts of the second all-union conference devoted to the problem of human adaptation to different geographical, climatic, and labor conditions, Novosibirsk, 1977, p. 101-104; Vlail P. Kaznacheyev, S. P. Shurin and L. P. Mikjhailova, "Distant intercellular interactions in a system of two tissue cultures," Official Bulletin of the committee on inventions and discoveries affiliated to the council of ministers of the USSR, Discovery no. 122 (19), 1973, p. 3, also printed in Psychoenergetic Systems, 1(3), Mar. 1976, p. 141-142; "Apparent Information Transfer

Between Two Groups of Cells," Psychoenergetic Systems, 1(1), Dec. 1974, p. 37.

52. For evidence of anomalous scalar reflection out of the scalar grid caused by a Navy chaff drop, See "Navy sabotages traffic lights, TV sets," United Press International, PM cycle, Jan. 11, 1985; "Power blackout blamed on anti-radar particles," United Press International, AM cycle, Jan. 11, 1985; "Power Disrupted Briefly After Navy Plane Drops Metallic Strands," Associated Press, AM cycle, Jan. 16, 1985.

53. A good summary of the early incidence of the Soviet Woodpecker signals is given by Bradley Wells, "The Russian woodpecker: a continuing nuisance," CQ, Nov. 1984.

54. A particularly important Soviet Paper is E. B. Smetanin, "Electromagnetic field in a space with curvature -- new solutions," Soviet Physics Journal, 25(2), Feb. 1982, p. 107-111. In this paper, a solution to the stated problem is obtained, which may be regarded as a classical model of a charged particle that has both a magnetic moment and a nonzero magnetic charge density. Interaction with spacetime curvature can disrupt the gauge invariance of the EM field, and it can also reestablish invariance in an initially noninvariant theory. (Hutchinson has had anomalous breaks of metal caused by standing scalar waves, which seems to be due to a mechanism that produces monopoles and deposits them in the metal at standing-wave nodes. This paper should be directly applicable.)

See also Yu. S. Vladimirov and A. A. Kozlenkov, "6-optics and a general theory of gravitation and electromagnetism," Soviet Physics Journal, 27(12), Dec.1984, p. 1039-1041; V. G. Bagrov and M. D. Noskov, "New exact solution of the Dirac equation. XI," Soviet Physics Journal, 27(12), Dec. 1984, p. 1030-1034. See particularly V. I. Petukhov and I. A. Kuzin, "Weak processes in the field of a gravitational wave," Soviet Physics Journal, 27(12}, Dec. 1984, p. 1025-1029.

In the latter paper it is significant that the decay probability increases in a locally curved spacetime, and that solutions are obtained for circularly polarized waves.

(In EM waves, circularly polarized waves have special characteristics in nonlinear isotropic media: exact solutions exist. Also, when two longitudinal sine waves of differing frequencies are transmitted into a nonlinear isotropic medium, the apparent difference frequency is transmitted as a sine wave, undistorted. This characteristic has been used by Westinghouse to produce improved sonar transmission through seawater, for example. The scalar EM (electrogravitational) wave may be represented as a longitudinal EM wave. Immediately, if one wishes to produce a pure scalar EG wave in the nucleus of an atom, two frequencies should be transmitted such that their difference is the frequency wished. Or circularly polarized waves may be utilized.)

Note that, by implication, one should be able to deliberately tailor scalar EM waves to greatly speed the decay of long-lived radioisotopes, such as are contained in radioactive wastes from nuclear reactors and other processes.

55. For some evidence of continuing persistence of the higher frequency scalar components applied to the scalar grid on Jan. 28, 1986 to localize the effects when attacking the Challenger, see "Poison suspected in unexplained deaths of birds," Huntsville Times, AP release, Feb. 6, 1986. From 1-4 Feb.

1986, various kinds of dead birds -- such as blackbirds, cardinals, sparrows and bluebirds -- plummeted to the ground in Birmingham, Alabama. At first some sort of mysterious poison was suspected, but later was ruled out. During this period, the woodpecker grid was particularly active in weather engineering operations. Multiple sightings of giant cloud radials occurred in various places throughout the U.S. The retention of the high frequency components possibly was intensified in the Birmingham area sporadically during the period. Birds flying into this zone would be killed if their brains acted as scalar receivers and were sufficiently jammed by the signals. Normally Huntsville (further north) is a "hinge point" for increased scalar activity, to start the Jetstream bending northeast to move along the Appalachian mountain chain. However, just before 28 January the jetstream had been diverted further south than usual by the Soviet interference, bringing unseasonably cold weather to Florida and the waiting Challenger on its launch pad. Probably hinge points further south than Huntsville were needed for this operation. If these more southern points were retained for a few days, and the high frequency components were retained, then an inadvertent high intensity area of these components may have sporadically occurred in the Birmingham area, killing the birds.

For description of the Apr. 18, 1986 Titan blast and its ramifications to the spy satellite program, see James Gerstenzang and Ralph Vartabedian," Los Angeles Times News Service, "Titan Blast to Hurt Spy Program," Huntsville Times, Apr. 19, 1986.

56. For another very important paper indeed, see Vu. G. Ignat'ev, "Relativistic kinetics of an anisotropic plasmalike medium with damping in a field of gravitational radiation," Soviet Physics Journal, 27(12), Dec. 1984, (English translation: Plenum, June 1985), p. l066-1069. If we substitute the vacuum "virtual plasma" for the observable plasma, this paper may be part of the smoking gun to show that the Soviet Union has developed scalar electromagnetics. Extrapolating from this paper, the amplitude of the "induced longitudinal field" is proportional to the square of the amplitude of the gravitational wave (GW) in an initially isotopic medium, but reduces to a linear proportionality as the medium develops nonlinearities (anisotropies or inhomogeneities). Whereas conventional GW are considered to be weak, the scalar GW may be very strong since we ourselves determine the variation in the energy density of vacuum it involves. Further, sharply spiked scalar EM (EG) pulses may develop appreciably more amplitude that the linearly calculated amplitude from the magnitudes of the zero-summation components. The end result is that (1) we can produce powerful gravity waves using the scalar EM approach, (2) local spacetime can be curved, producing violation of the conservation laws, and (3) the assumption of a local Lorentz frame made by Einstein as a limitation on ordinary general relativity is falsified.

In passing, note that immediately one also has a clear basis for the excess local production of energy when the battery furnishing power to a DC series motor is sharply spiked backwards in a "recharging" fashion. Further, the ions in the battery (which are several hundred thousand times as massive as an electron) possess a resonance on the order of 16 megahertz in a typical lead-acid battery. Under the correct conditions, the ions collect the excess energy (due to the initial square effect) produced by a sharp pulse of recharging potential. The ions are shocked into resonance and, on reversal, "overshoot" and deliver this excess energy to the plates, recharging the battery. Thus such a system can violate linear conservation of energy because spacetime is locally curved by the spiking, and excess energy from the excited local vacuum is collected by the ions and delivered to the plates. This is precisely the effect upon which the first Bedini free-energy motor depended. The timing and adjustment, however, are highly critical and difficult, and the battery takes a rather severe beating.

57. For details and photographs of highly anomalous exhausts seen on Bennett Island, see "Explosive Events Seen on Soviet Island," Aviation Week & Space Technology, Sept. 26, 1983, p. 31. NOAA-6 and NOAA-7 weather satellite photographs of massive smoke plumes, one of them 150 miles long and nearly horizontal, are shown. Also, in U.S. weather satellite photos of Novaya Zemlya, similar plumes have been detected, making this location a tentative candidate for a second Soviet "exhaust site." See also Letter John M. Miller, Geophysical Institute, University of Alaska, Jan. 4, 1985 with attachment, "Bennett Island plume cases recently found." Satellite photos showing actual circular breaking of arctic ice have also been taken near Wrangel Island. See Sam Bishop, "UA photos show Soviets break ice for missiles," Fairbanks Daily News-Miner, Dec. 15, 1984, p. 1,3; Craig Covault, "Soviet Abi1ity to Fire through Ice Creates New SLBM Basing Mode," Aviation Week & Space Technology, Dec. 10, 1984, p. 16-17. Wrangel Island in fact has a bizarre history: it belongs to the U. S., but has been illegally given to the Soviets and occupied and used by them. For details, see "Wrangle over Wrangel and the Weather War," Don Bell Reports, 32(9), Mar. 8, 1985.

58. For details of anomalous blinding (probably by scalar EM means) of U.S. satellites, see Philip J. Klass, "Anti-Satellite Laser Use Suspected," Aviation Week & Space Technology, Dec. 8, 1975, p. 12-13. For details of anomalous failures and recoveries of a British satellite, see Joe Schwartz, Nature, 280, July 12, 1979, p. 95.

59. For other possible evidence of traces of Soviet scalar EM activity over the oceans, see George D. Curtis, "An electromagnetic radiation pattern over the ocean," Undersea Technology, 5(8), Aug. 1964, p. 29-30, 40. In producing a scalar wave, there exists a sort of "signal to noise" ratio of the desired scalar wave to an accompanying, undesired normal EM component. Due to practical equipment imperfections, the generated scalar wave inevitably is accompanied by a small residue of ordinary EM wave. While measures can be taken to further purify the scalar wave, a residue always remains. Curtis may have detected the weak EM residue accompanying early Soviet interference gridding for weather control testing over the U.S.

60. Interactions which occurred between Khrushchev and renowned physicist and Nobelian P. Kapitsa are of interest. Khrushchev desired absolute defense of the Soviet Union so that the Soviets might be able to launch any action desired without risk or serious concern. Kapitsa informed the Soviet leader that, if a means of total neutralization of foreign missiles was to be found, it could only come from a group of new principles in physics which was called " energetics." The term "energetics," of course, was contracted from "psychoenergetics," and is essentially the expanded physics/electromagnetics that this author has dubbed scalar electromagnetics.

Strangely, a portion of a book by Marshal Grechko was deleted from its English translation at the specific request of the Soviet Union to the U.S. State Department. The passage stated: "Of particular importance is basic research aimed at discovering still unknown attributes of matter, phenomena, and the laws of nature, and developing new methods for their study and use to reinforce the state's defense capabilities."

The most definitive Soviet book on military strategy is titled Military Strategy (Voyennaya

Strategiya). See V. D. Sokolovskiy, Soviet Military Strategy, third edition, edited with an analysis and commentary by Harriet Fast Scott, Crane, Russak & Company, Inc., New York, 1975. There are three editions, the latest in 1968. In the third edition, the exotic weapons normally proposed for defense against strategic ballistic missiles -- such as particle beams, high energy lasers, exotic nuclear warheads, plasma weapons, antigravitational weapons, etc. -- are discussed and discounted by implication. The statement is made several times that 100% defense against missiles and aircraft is possible. A statement is also made that it is interesting to note that this capability (a solution to the strategic missile defense problem) has been achieved by the Soviet Union, but not by the West (e.g., p. 298.) In the same edition, a previous definition of antimissile defense obviously consisting of radars, computers, and interceptor missiles is deleted (see author's note 190, p. 454).

The Soviets also recognize the great importance of technical surprise: "The experience of war shows that warring sides quite often have tried to employ new types of weapons to this end to achieve surprise, which are a surprise for the enemy or are little known to him. Each side secretly develops new means of warfare in order to employ them unexpectedly. History knows many examples how the employment of a new weapon initially gave considerable success because the enemy, caught unaware and not knowing the combat capabilities of this weapon, was for some time incapable of effective counteraction… The mass introduction of new weapons into an army usually cannot remain secret for long for the other side. -- New means of warfare, and in mass numbers, are impossible to create often and quickly. In this regard, the sides have begun to take other paths concerning the attainment of surprise along with searches for new weapons and their sophistication." V. Ye. Savkin, of The Basic Principles Operational Art and Tactics, Moscow, 1972, U.S. Air Force translation, U.S. Government Printing Office, Washington, D.C. 20402.

61. The Soviets have not discarded most of their old radars, and have continued to develop, build, and deploy giant new radars (in apparent violation of SALT agreements), which U.S. analysts always analyze in conventional fashion. It is fairly straightforward, simple, and inexpensive to modify an ordinary pencil beam radar to produce scalar wave beams and geometrical scalar Fourier expansion forms. Radars can provide a wide array of totally new and unexpected capabilities when utilized in the scalar electromagnetics mode. Even older Soviet radars, with antiaircraft gun sites and older surface-to-air missile sites, will exhibit new and startlingly advanced capabilities against ballistic and cruise missiles and Strategic Air Command bombers. Since there are many thousands of these older Soviet radars still operationally deployed, in the scalar mode the Soviet strategic defense may well approach 100%, just as Military Strategy implies. Also, the antiaircraft and antimissile defense capability of Soviet land forces may be far greater than anything presently estimated by U.S. analysts.

62. To the physicists, engineers, and researchers who have made the tough sledding to this point, congratulations! Here's a bonus for you.

Turn to page 32, equation [7]. Time differentiate it (this is left as an exercise for the reader). Collect terms and study the result intensely.

Now you have the reason why rise time is so important from a scalar EM viewpoint. You can also see why spiking the innate inductance of any system very sharply is so important. Fast rise time greatly increases the value of the time derivative terms, and your gravito-inertial effects go up with the collective squares of your zero-vector summed components. Any system has at least a little inductance. For sharp spikes, the gravitational potential goes very high. The inductance of the system momentarily opposes any current (translation: opposes any current bleed-off, or EM force field bleed-off). During that time you've got the 4-space G-potential to use. If you need to hold it longer to use it, then increase the inductance.

Now you can see why extremely rapid discharge of properly tuned, giant Tesla coils give gravitational and inertial effects sometimes.

You can see why the sharp "EMP" (electromagnetic pulse) from a nuclear explosion or EMP generating device can penetrate the ocean.

That's why the spikes (such as used by the neurophone) can carry messages directly into the brain and nervous system. You also should see why the Soviet woodpecker carriers (a Soviet over-the-horizon radar system) are loaded with scalar EM spikes (Bedini has precisely detected them from 50 Hz to 10 MHz; Golden has detected them into the gigahertz range.) to work on the humans in the targeted area. They're zapping the hell out of us. And they have done something similar at the U.S. Embassy in Moscow for decades.

Bedini has developed a simple, cheap device to mess up the phaselocking of the scalar EM spikes on the woodpecker carriers. It's based on the fact that the Russkies use a lot of circularly polarized transmitters when they make the spikes. Here's what to do: Take 4 strong bar magnets and an old (but operational) long-playing record turntable. Set it on 33-1/3 RPM speed. Glue the magnets on the top of the turntable, standing vertically, symmetrically placed around the turntable's outer edge. Place them so that on one a north pole is up, on the next a south pole is up, then a north up, then a south up. Now turn the turntable on and let it run. This gadget makes a slowly rotating magnetostatic wave. (Yes, it will also make a rotating "magnetic" wave, which is actually two rotating magnetostatic waves.). These rotating magnetostatic waves will interfere with the scalar spikes, changing them to EM (electromagnetism) and slowly rotating their phase. This breaks the phaselock of the Soviet circularly polarized scalar EM signal on the human brain. This gadget will protect the average large room.

But back to our differentiated equation.

Now you should also see why the first Bedini motor is so "devilishly difficult" to adjust. You've got to get the effect and examine it in well under 20 nanoseconds. You'll need an oscilloscope of 350 MHz range or so. Microwave-quality bench equipment is necessary; the ordinary electrical and electronic shop equipment is not good enough. You can also see why the ordinary lead-acid battery takes such a beating. However, a special battery certainly can be designed to take it. Now you know.

Okay, you tigers. Go get 'em.

63. Now here's a final bonus for the persistent reader.

This time, see J. N. Brittingham, "Focus Wave Modes in Homogeneous Maxwell's Equations:

Transverse Electric Mode," J. Appl. Phys. 54, 1983, p. 1179-1189; T. T. Wu and R. W. P. King, "Comment on 'Focus Wave Modes in Homogeneous Maxwell's Equations: Transverse Electric Mode' [J. Appl. Phys. 54, 1179 (1983)]", J. Appl. Phys. 56, 1984, p. 2587; T. T. Wu and H. Lehmann, "Spreading of Electromagnetic Pulses," J. Appl. Phys. 58, 1985, p. 2064-2065; T. T. Wu, "Electromagnetic Missiles," J. Appl. Phys. 57, 1985, p. 2370-2373. Pay particular attention to the latter paper.

Because of the Strategic Defense Initiative (SDI) and other programs, great interest has recently been kindled in using EM pulses to carry energy from a high-powered source to a target. However, so far almost all the work is still couched in terms of purely ordinary (though sophisticated) electromagnetics. It still involves the EM concept of "EM energy flow through the intervening space from the transmitter to the target." As such, the work to date still suffers from all the self-imposed ills and limitations of using the classical force fields concept of EM.

However, the theoretical work of these referenced papers is of great interest to us here.

In the first paper, Brittingham sparked a great deal of interest with theoretical work which promised a permanently focused 3-dimensional concentration of EM energy that propagates in a straight line with the speed of light. That is, this mode used a newly formulated wave packet (called the "focus wave mode") that acted as a non-dissipating EM soliton.

In the second reference, it was concluded that Brittingham's focused wave packet actually satisfied Maxwell's equations, but not the associated boundary conditions.

[Comment by this reviewer: both of these formulations use "linear time" and a "linear frame," ignoring the local general relativity aspects. Indeed, Brittingham's "focused wave packet" can be made by the zero-vector approach! However, it will not be an "EM" packet, it will be a pulse (or oscillating wave, depending upon how it is made) of 5-gravity potential. As such, it contains a multiplicity of locked-in, 5th-dimensional, non-zero EM gradients in and EM gradients out. Collectively these gradients themselves constitute a deterministic "flux of gradients" or an EM flux in the 5th dimension, with no resultant effective current of EM gradients. In other words, it's possible to build a "flux of gradients" and to have a "current of gradients," just as in ordinary EM it's possible to have a "flux of virtual particles" and a "current of virtual particles." The argument concerning the EM boundary conditions of Maxwell's equations is not relevant in such a case. The only boundary involved is the zero itself.]

Be that as it may, the 4th reference is of direct interest. In this paper, Wu has done us a great service. He shows that, under transient excitation, an antenna of finite size can transmit energy to a faraway receiver so that the energy decreases as slowly as one wishes. An electromagnetic pulse of energy with such slow decay is conveniently referred to as an "electromagnetic missile."

The electromagnetic missile has important applications, according to Wu. One possible application is the transmission of information in a manner that is very difficult to intercept or jam. A second possible application is to destroy or disable a distant target. However, Wu feels that so much energy is required [remember, he is speaking of EM non-zeroed force fields traveling through ordinary space] that a like1y radiating source must be something like a nuclear explosion. However, as Wu points out, a nuclear explosion produces a powerful EM pulse which includes frequencies from microwaves to gamma rays. To weaponize the explosion to produce a coherent beam, the nuclear explosion must be controlled to produce a coherent radiating source and a pulsed laser-like EM beam. Wu points out that such a technology is difficult and has not been developed.

We comment as follows: It is certainly true that enormous energy is required if the waves in the pulse remain electromagnetic -- that is, if they have non-zero resultant E and B fields to the external observer.

On the other hand, if we form a complex of waves in opposition so that we control the energy content of each individual component wave, but blend all the waves so that their collective envelope wave has zero E-field and zero B-field resultants, then -- to the external observer -- the EM energy is infolded and unzipped electromagnetically. It is now electrogravitational energy, and limitations of "EM force field energy flowing through space or through a physical medium" need no longer apply. However, we may still look at each EM component wave as an individual EM wave, moving in the Kaluza-Klein 5th dimension that is wrapped-around each and every point in our ordinary 4-space. In other words, to the ordinary 4-spacetime observer, each component wave has a special channel around every point of his space, not through it. Thus we have established multiple EM channels "just outside" each point of observer space. These we call "scalar channels," and EM energy can move through each one as if it were moving through a wire. The relative potentials between the "ends of each wire" determine in which direction the "EM energy current" flows along the wire.

And in each of these "special channels," we just have a normal kind of space (to the internal observer). Wu's paper assures us that we can get as much of the input energy to the distant target as we desire. The problem then is how to break the zero-summed EM envelope (and hence the "zero channel" for each component EM energy wave) in the distant target itself, spilling the infolded contents of all the special channels back into ordinary spacetime as EM energy (either positive or negative).

That, of course is easily done by interference in the distant zone. As previously stated, there is a way in which we can even perform this interference in a single scalar beam. Since the newly formed EM energy emerges from each and every increment of spacetime occupied by the distant target, it already emerges inside the very vitals of the target. It does not have to translate through the intervening ordinary space between transmitter and target. Instead, it goes through the Kaluza-Klein fifth dimension. It translates along a line through our space, but not through our space. With the scalar EM approach, we transmit EM energy through hyperspace, not through normal space.

Hereafter we will adapt and expand Wu's SDI term "electromagnetic missile" to include these electrogravitational aspects. In other words, we include the "scalar EM missile", which consists of an infolded multiple of Wu's ordinary EM missiles moving together coherently in special sheathed hyperspace channels.

In Appendix I we show an anomalous photograph taken by Bob Gladwin, just before the shuttle launch of Nov. 26,1985. While the photograph may be an artifact, it also is a candidate for the test strike of such a Soviet scalar "electromagnetic missile" tested against an aiming point offset from the shuttle launch which followed a few seconds later. The test was accomplished before the shuttle was launched, and offset from it, so that it positively would not endanger the shuttle itself. The conditions under which this spectacular photograph was taken happened to coincide with the special conditions required to photograph such scalar EM energy. Those conditions are clarified and explained in the Appendix.

My deep appreciation goes to Mr. Gladwin for allowing me to use this photograph. As we will point out in Appendix I, the video camera caught a picture of the Soviet scalar EM marker beacon associated with the Titan explosion of April 18, 1986. One can rest assured that the Soviets probably destroyed that vehicle, using a scalar EM missile.

APPENDIX 1: SOME IMPORTANT INDICATORS AND DESTRUCTIVE TESTING

Some of the indicators which bear on the use of the Soviet scalar electromagnetic grid via the Woodpecker EM carrier beams are given in this appendix. along with other information believed pertinent to overall scalar EM effects.

IN ADDITION, THE THESIS OF ACTUAL LIVE TESTING OF THESE WEAPONS BY THE SOVIETS -- TO INCLUDE THE DESTRUCTION OF A TROOP-CARRYING U.S. AIRCRAFT, A SHUTTLE, AND A TITAN MISSILE -- IS ADVANCED AND INDICATORS PRESENTED.

An anomalous photograph taken by Bob Gladwin is presented which possibly may have captured the "smoking gun" -- the strike of a Soviet scalar EM missile at an offset aim point near the shuttle *Atlantis,* just before its launch on Nov. 26, 1985. However, this photograph is caveated since it may also represent an anomalous but ordinary artifact. captured in some as yet unknown manner. The manner in which such a photograph may have been taken -- when normally the scalar energy does not show on a photo -- is explained.

Another photograph taken by George Suchary after the launch did capture the Soviet "marker beacon" utilized in the test firing, however. This independent photograph is presented, and adds credence to the thesis that the Gladwin photograph captured the test of a Soviet scalar EM pulse missile.

- INDICATORS AND SUCH -

1. Continual cloud radials have repeatedly been seen and photographed over Los Angeles, California or its vicinity.

Los Angeles is also apparently a "hinge point" for bending and controlling the jetstream. Three typical radials seen to form one after the other by Margaret Wilson (and sketched and airbrushed by her) in the greater Los Angeles area are shown in figures 1, 2, 3, and 4. These radials were formed on Sunday, Jan. 26, 1986. Ms. Wilson had heard my Saturday night "Soviet Weather Engineering" broadcast over KABC Los Angeles, and my request that anyone who saw the typical radial cloud formation should photograph or draw it, noting time and location, and send the photos or drawings to me.

As Margaret described it. "To my astonishment, the next day I not only saw one, but three in the sky at the same time.

The time of the first one was Sunday, Jan. 26, at 1:15 p. m.

. . . I stepped out the back door for some minor errand and noticed a
fan of long straight clouds in the sky. The sky had been filled with dark clouds most of the morning but this had been breaking up and the western half of the sky was now clear with these lines of clouds spread out on it. I immediately thought of your request and tried to see the bottom of the fan which was hidden behind bushes and a garage. When I stepped into the street, I saw there was
a semi-circle beneath them.

Not having film and a wide-angle lens on my camera. I knew I couldn't capture it in its entirety. I am, however, a retired commercial airbrush artist so I quickly sketched the formation. It is illustration #1.

It was in the western sky, the base of the central semi-circle sitting about 15 degrees above the ocean horizon. It was very clear and sharply defined. The semi-circle was broken at the top and the two broken ends curled inward like commas. As I sketched the wind deformed it somewhat, the right half of the whole formation sliding down away from the left.

Ten minutes later it was getting quite clear of clouds except
for a bank over the Santa Monica Mountains to the north and there, straight north, another fan was forming. As I watched it took shape -- illustration #2. The same broken semi-circle (with commas') but this time the bases of the rays were feathered about half-way out with end halves long straight wisps.

As I sketched, another fan had begun to take shape further east. It was hard to tell its size but I had estimated the first one at about 15 miles across and the second a little larger and the third larger yet. At the peak of its formation it looked like illustration #3. ...There in the middle of the central circle, hazy and a little faint was what looked like the top of a mushroom cloud. Or was it only a distant thunderhead that coincidentally found its way to a place behind the formation? The arms of the last, largest formation were rather wavy and feathery like some gigantic sea creature. It did not disperse as fast as the others, but held for a couple of hours, though it was pretty distorted by then. I could not estimate its size as I wasn't sure of its altitude.

Were they aircraft contrails? Certainly not! There was an airliner in the sky at the time -- a mere scratch on the smooth blue sky (see illustration #3, right center.).

The three formations were present in the sky at the same time although the first was getting quite distorted by the upper level winds before the last reached its peak.

Tuesday our weather changed from hot and sunny to rainy as the weather man said the path of the jetstream altered, and then there was the space shuttle explosion.

...The Russians seemed very sincere in their sympathy for the loss of our astronauts but only two days later it was printed in TASS and I personally heard Vladimir Posner say that Russia hoped that the United States would now realize what could happen if the S.D.I. program was further pursued. Was this friendly concern or a threat? It is very evident that if the S.D.I. can destroy a missile in flight, it can also destroy one on the ground. This would immediately put all Russian missiles in [reach of] our arsenal. They are already in place in the most desirable target areas -- their own launch sites. I'd be panicky too if I were a Soviet leader."

[Ed. comment: My sincere thanks to this thoughtful lady who took the time to sketch the cloud radial phenomena occurring in the Los Angeles "jetstream pivot point" at this critical time, just prior to the launch and destruction of the Challenger.

Anomalous cloud grid activity (formation and dissolution) in the Los Angeles area has been positively correlated with Soviet Woodpecker activity by engineer Ron Cole, with 100% correlation in 30 straight Woodpecker measurement runs. Statistically, of course, this is quite decisive.].

2. Continual cloud radials have repeatedly been seen and photographed over Huntsville, Alabama, associated with weather engineering and grid activity. Typical radials seen by this author are shown in Bearden, Soviet Weather Engineering Over North America, 1-hr. videotape, 1985. Huntsville is apparently a pivot point or "hinge point" for bending and controlling the jetstream.

3. Spectacular cloud grid patterns have been seen over Huntsville, Alabama and Los Angeles, California. An excellent videoclip of one of the Los Angeles area grids, personally observed and shot by KABC Open Mind talk show host Bill Jenkins, is shown in Bearden, Soviet Weather Engineering Over North America, 1-hr. videotape, 1985. An artist's sketch of an earlier gigantic grid, extending from horizon to horizon in every direction, seen over Huntsville, Alabama by Tom Bearden and Ken Moore, is also shown in the tape. The videotape is available from P.O. Box 1472, Huntsville, AL 35807. Sketches and details of another highly anomalous grid pattern observed in the greater Los Angeles area by engineer Ron Cole are shown in figures 5 and 6.

The reason that clouds of water droplets and/or ice particles detect the scalar interferometry and form signature patterns is simple: Consider each H_2O molecule as having two light little hydrogen atoms hanging on to the much heavier oxygen atom. The covalent sharing with the oxygen atom of the electron from each hydrogen atom means that (1) the electrostatic scalar potential between the H ion and the O ion it is bonded to, is rhythmically varying as the electron is shared back and forth, (2) this varying potential contains "electron spin holes" since it is made by the moving electron, (3) two such varying potentials exist since there are two H atoms sharing covalent electrons with the O atom, (4) the two H ions are at an angle of over 100 degrees with respect to each other, (5) the molecule assembly thus constitutes one part (one half, so to speak) of a scalar interferometer with imbedded electron spin holes for electron hooking, (6) Incident scalar waves from outside the system interact with the "half scalar interferometer." This scalar interferometry interaction is coupled to the covalent bonding electron because of the internal spin hole pattern of the molecular half of the interferometer. The coupled electron moves with the scalar pattern's changes, causing an observable interaction with and in the electrical structure and ionic potential of the molecule, (7) the weak H to H hydrogen bonding between molecules connects resulting ionic potential changes to the structuring of the entire macroscopic cloud assembly. Thus by scalar interferometry with the H_2O "half interferometers", an incident scalar EM pattern is detected and translated into patterns of E and B force fields. The H_2O molecules then "line up" in accord with the electrical patterns detected.

Thus the clouds form "signature patterns" according to the incident scalar EM radiation patterns. Giant cloud radials in the targeted area are probably due to the type and shape of antennas -- including the type and shape of the electrical wires establishing the antennas' ground planes -- 640used by the Soviet Union to project the scalar waves. Note that such "radial" antenna patterns were occasionally used by James Harris Rogers in his underground and undersea scalar EM transmission system.

[For Rogers' patents, see U.S. patent numbers 1,316,188, Radiosignaling system, Sept.16, 1919; 1,322,622, Wireless Signaling System, Nov. 25, 1919 (figure 6 of this patent clearly shows a "radial wire" ground plane antenna); 1,349,103, Radiosignaling system, Aug. 10, 1920 (the fourth version in figure 1 shows inside/outside variation which, for the long waves used, to a distant observer appears as a varying magnetostatic scalar potential using opposing B fields); 1,349,104, Radiosignaling system, Aug. 10, 1920; 1,220,005, Wireless Signaling System, Mar. 20, 1917; 1,303,729, Wireless signaling system, May 13, 1919; 1,303,730, Radiosignaling system, May 13,1919; l,315,862, Radiosignaling system, Sept. 9, 1919; also 958,829, Method and Apparatus for Producing High Frequency Oscillating Currents, May 24,1910.].

4. Anomalous power outages in Ventura County, Southern California on Nov. 8 and 9, 1985. Again, engineer Ron Cole, who lives in the affected area, investigated and reports as follows:

"On the evening of 11-8-85 in a rural area of Ventura County known as Carlisle Canyon, a strange electrical phenomenon began to occur at about 10:15 p.m. Our first observation was that random white dots began to appear on the TV screen, then began to increase in size and brightness. The brighter the dots got, the dimmer certain lights in our home became. Yet later we found that, when some lighting circuits were dimming, other circuits were causing lights to shine much brighter than normal. After a bit of checking, we were able to determine that lighting circuits common to pole 1 of the service transformer were the ones that were seeing a reduction in voltage, while all circuits on pole 2 were seeing an increase in voltage.

There is another interesting condition that was observed on the TV screen. The dots were in sync with the vertical field or frame rate of the signal. This means that the interference had to be of a frequency of 59.7 Hz or 29.85 Hz. Normal power line interference will form a grouped dash pattern across the screen and will strobe upward at the rate difference of 59.7 Hz or 29.85 Hz. In the 8 November case, there was no strobing of the dots whatsoever.

These conditions continued off and on for the rest of the entire evening and were observed by no less than six other persons that I know of. They were observed over the entire TV frequency spectrum, low band VHF, high band VHF, and on two UHF channels. Line interference is almost always most prominent on the low band VHF frequencies only.

These anomalous events would take place on a somewhat irregular time pattern; anywhere from 3 to 10 minutes apart. They would always last for about 2 minutes.

At 12:30 a.m. I went to bed and was not aware of any further activities until 6:20 a.m., at which time I was awakened by several sharp snapping or cracking sounds coming from the walls of my house. I rolled over and went back to sleep, only to be reawakened about 15 minutes later by my wife, who informed me that the power and phones were out. My comment was, "Some dummy must have crashed into a power pole," and I dozed off again.

At 10:15 a.m. the power and phones came back on line. Shortly after, our phone began to virtually ring off the hook. About a dozen neighbors up and down the canyon wanted me to check out their electrical wiring and various appliances. All of them were trying to explain their individual encounters and what took place when the power went out. Such things as wires snapping in walls, singing and humming sounds coming from wiring in walls, strong smell of ozone, light bulbs exploding, buzzing coffee pots, and a handful of other phenomena all took place just before the power went out at 6:20 a.m.

A typical example was that of Rob Steel. [Ed: Name changed for this report; his real name is in my files.] Rob lives four miles down the canyon from us. He had just turned on the lights in his barn and was getting ready to feed the livestock, when he realized he had left several needed items in the garage located about 75 yards from the barn. Upon entering the garage, he saw the garage lights began to flicker, then go to a dim orange glow. Upon stepping from the garage area, Steel saw that lights in the barn were so bright that he thought the entire structure was about to explode. He froze in his tracks for a moment and his whole house and garage began to hum. Then everything went out.

An interesting point to inject is that Mr. Steel's home and several others farther down the canyon from us are being fed from a different 19 kv power feeder source than the 14 kv feeder that supplies us and most homes in the canyon.

At about 2 p.m. on 11-9-85 I was in contact with the power utility company (Southern California Edison Company) to inquire as to the cause of the power outage. My first assumption was wrong. No power poles had been knocked down; only a ceramic fuse in the 19 kv feeder system had blown and a two-pole oil breaker had kicked out on the 14 kv feeder system. Load charge recorders at the power company show that both fuse devices kicked out at exactly the same time, but they are in no way common to each other as to load distribution. They only supply power to adjacent areas.

Also, the phone company has no record of its service being out, yet the phone service was restored when the power was restored. The phone company does not use Edison Company's power to power its phones. Again, the only commonality is that the phones and phone lines were in the same area.

Numerous magnetic breakers, used as manual switch devices for well pumps and other services, were on when power was returned. These switches had previously set in their off state.

A strong electrical-type ozone odor was detected at five locations at the time the power went out.

Later we found that a Research and Development laboratory in a nearby area measured 29 Hz intermittent signals late on the night of 11-8-85. These signals were interfering with some critical tests the lab personnel were trying to accomplish. The laboratory itself did not experience a power outage.

At this point in time, the only realistic surmise we can come up with is that a tremendous ELF or scalar ground wave was adding and subtracting to the grounded neutral service side of the power pole transformers so as to sum in and out of phase. When peak nodes were achieved, all line transformers ended up back-feeding the feeder lines out of phase, causing the final power outage.

Twenty-one persons are aware of the strange conditions of the power outage and prior events. [Ed: Their names are in my files.]"

Editor's comment: Another anomalous power outage also occurred in the same area. This occurrence is possibly associated with effects of the scalar interference grid adjustments. If the Soviets were preparing for a major test of the grid in the Launch Phase ABM mode, substantial tests and exercises may have been performed before the actual "wet run" against the shuttle launch on Nov. 26, 1985 -- about two and a half weeks after the anomalous power outage at Carlisle Canyon.

See the Rogers' patents, referenced above, for ideas of how scalar EM signals couple to the power lines and telephone lines.

As this book goes to press, John Bedini has notified me that his new and very sensitive developmental scalar detector positively verifies scalar frequency "spike" activity on the Woodpecker grid (and possibly the ground reference) from 50 Hz to 10 MHz. A normal instrument will definitely not see these signals. John's lab is at Sylmar, California and about 70 miles from Carlisle Canyon.

5. During the Skylab mission, NASA astronauts observed and photographed a mysterious green glow of the atmosphere. The glow was over 1,000 miles long and over 100 miles wide. From Carlisle Canyon, Ventura County, California the sky has also been observed to possess a mysterious green glow from horizon to horizon, on three occasions. [Editor's comment: It is hypothesized that this green glow is associated with grid activity in the Launch Phase ABM System mode.]

6. Just prior to the hapless launch of the Challenger on Jan. 28, 1986, the Soviet Union sharply bent the jetstream down through the center part of the country, then curved it eastward across the Florida panhandle. This exposed the waiting Challenger on the launch pad to severe cold air, brought down from Canada by the sharply deviated jetstream. The use of the scalar interferometry aspects of the Woodpecker grid for weather engineering over the U.S. has been documented previously. [Bearden, Soviet Weather Engineering Over North America, 1-hr. videotape, 1985;

Bearden, "USSR: New beam energy possible?", Defense & Foreign Affairs Daily, 13(111), June 12, 1984, p. 1-2.]. Wilson's cloud radial sightings on Jan. 26, 1986 and Cole's giant cloud grid sightings on Jan. 24, 1986 are directly connected with adjusting the Woodpecker grid and deviating the jetstream, to carry cold air to the Florida launch site.

7. The previous testing of the grid in the Launch Phase ABM/Anti-bomber Mode, using actual jet aircraft as "wet-run" targets, has been demonstrated by various anomalous incidents.

As one probable example, see "Jetliner drops 32,000 feet; 400 aboard; 50 are injured," AP release, Huntsville Times, Feb. 20, 1985, p. 1 and "China Airlines Pilot Denies Cockpit Error," AP release, Huntsville Times, Feb. 21, 1985, p. A-9. In this incident (see figure 7) a Boeing 747, flying at 42,000 feet and bound for Los Angeles, experienced unusual engine flameouts while still out from San Francisco. In a hair-raising plunge toward the earth, the pilot fought to restart the engines and regain control of the aircraft. After a fall of some 32,000 feet in two minutes, the engines finally restarted, and the pilot was able to fly into San Francisco and land safely.

We have already explained how the Soviets are able to track the aircraft's jet engines. Later in this Appendix we show just how accurately an actual "scalar EM missile" may be focused by the Soviets on a hapless target. If a negatively biased pulse or continuous wave scalar EM "energy extraction" beam hits the engines, the extraction of energy will result in engine flameout. (No heat energy, no combustion of the fuel.). This is apparently what happened to this aircraft. In the presence of "splatter" from the extraction beam targeted at the engines, the aircraft instruments were seriously affected. Different instruments have different responses to such an anomalous scalar EM kindling effect. Thus a signature would be that the instruments disagree with each other, and need not record what actually occurred. This appears to have been the case, constituting a signature that scalar EM was targeted against the aircraft. The pilot's instruments apparently indicated that the control system had failed, while the flight recorder apparently indicated that it had not.

Let us assume this was a Soviet test. When the distant Soviet operator turned off the extractor beam, the engines returned to normal state after a "discharge time constant" period. They normalized before the plane struck the ground, so the pilot was able to restart the engines and proceed.

Notice that this was a limited test to cause engine flameout only. If the scalar EM missile had been used against the aircraft in the "pulse" mode, it would instantly have exploded in mid-air.

The crash of an India jet aircraft outside Great Britain may have been a test of the same weapon in the pulsed "destroy aircraft" mode, since there are indications that the aircraft suffered an anomalous midair explosion. Another candidate for such a possible "shoot-down" of a jet aircraft is an (Italian) Itavia DC-9 that crashed into the Mediterranean in June, 1980. Both Itavia and the Italian Transportation Minister Salvatore Formica believed that a missile struck the jetliner and was the likely cause of the crash. It may have been a scalar EM missile and a full-up test by the Soviet Union. See "Plane was probably hit, judge says," Birmingham Post-Herald, Jan. 17, 1981.

Also the present author has knowledge of at least one instance in the early 1980's when an American-made tactical ballistic missile was anomalously destroyed shortly after being launched by troops in Europe. The destruction was anomalous and a large hole was inexplicably burned through the side of the missile -- exactly as if it had been struck by a scalar EM missile test in the anti-tactical missile (ATM) role.

8. As another example of airborne scalar EM activity in the Woodpecker grid, in January 1985 a U.S. Navy-dispensed chaff cloud, dispensed well-offshore from San Diego, California was caught by an unexpected wind and blown toward the city. (See figure 8.). As the chaff cloud moved in, significant failures of electrical systems and electrical components resulted. Power was disrupted to as many as 60,000 homes by the incident.

The sudden, unpredicted wind was suggestive of a wind blowing toward an artificially created low pressure area. Under certain conditions, a specialized structure such as that of a piece of sophisticated chaff will reflect scalar waves of frequencies within its cut bandwidth. If scalar modulation frequencies within the chaff bandwidth were present on the Woodpecker carrier grid above and surrounding San Diego, a myriad of reflecting bits of chaff in the moving chaff cloud would produce myriads of random, invisible "fireflies" of EM energy kindled at a distance, from random scalar interferometry, in a zone surrounding the cloud. As these invisible "firefly" pulses of

EM energy pulsed inside components of the electrical systems and electrical controls in San Diego and vicinity, extensive and random internal electrical interference occurred. This lead to widespread, anomalous electrical failures throughout the city.

Note that this activity preceded the huge Soviet scalar EM exercise of April-May 1985. The grand exercise would certainly have been scheduled well in advance by Soviet strategic forces controlling the scalar EM howitzers and Woodpecker grid weapons, and adjustments and smaller tests would have been being made for some months before the tests.

9. Other anomalous "electrical strikes" certainly exist, suggesting Soviet testing may occur widely throughout the world, yet be reported as ordinary but anomalous phenomena. An example which comes readily to mind is the anomalous blast (or blasts) that struck Bell Island, off the east coast of Newfoundland, on April 2, 1978. Persons on the shore of Conception Bay reported seeing fireballs coming down out of the sky and hitting the island, according to Royal Canadian Mounted Police. Highly anomalous atmospheric electrical activity preceded the blast. This may have been Soviet testing of scalar-created electromagnetic missiles. Extensive information on this incident can be obtained from P.A.C.E., 100 Bronson Ave., Apt. 1001, Ottawa, Canada T1R 6G8.

As another possible example, villages in an area of West Donegal in Ireland have been terrorized by freak "lightning bolts" for over two years. Roofs have been literally stripped off, windows smashed, telephones and television sets blown up, and pipelines wrecked. On Dec. 25, 1984 a mighty blast caused a three-day blackout: it accompanied a snowstorm, the first "white Christmas" in the area in 20 years. See "Bolts from the blue," Fortean Times, Issue no. 45, Winter 1985, p. 5.

10. Scalar spikes or pulses from the Soviet testing may also cause other anomalies, including deaths of unsuspecting persons using the telephone. For a candidate event of this type, see "Killer Phones," Fortean Times, Issue no. 45, Winter 1985, p. 8-9; also AP release, Huntsville Times, May 30, 1985; AP newswire June 2, 1985; and New York Times, Sep. 11,1985.

On May 21, 1985, five days after passing a complete physical examination, 17-year-old Jason F. Findley of

Piscataway, New Jersey was on the phone at his grandmother's house, talking to his girl friend. An odd click occurred on the line, followed by a gasp from Findley and then only the TV playing in the background. His grandmother found him unconscious, still clutching the phone in his hand. Rushed to Muhlenberg hospital, he was pronounced dead shortly afterwards. An autopsy could not determine the cause of death, and the telephone company found the phone working properly, properly grounded, and no evidence of excess electrical charge. Findley was lying on a wooden bed which would not conduct electricity. He had a hemorrhage of the inner ear. There had been an electrical storm over Scotch Plains, New Jersey the night Findley died.

AP wire services were told by the special forensic investigator with the New Jersey medical examiner's office that about six people had died in the U.S. in similar circumstances. Others had reported being knocked unconscious by "high voltage shock" from their telephones. Several weeks before Findley's death, another man from Whitehouse Station, New Jersey had been found unconscious with a telephone in his hand. According to the Consumer Product Safety Commission in Washington, D. C., in 1984 nearly 12,000 people in the U. S. were taken to emergency rooms with injuries related to telephones. A hundred of them died, although exact details were not revealed.

Note that the giant Soviet scalar exercise of May 1985 had been detected and verified by Golden. Substantial activity in the Soviet weapon complex, and in the Woodpecker grid over the U.S, continued throughout May and beyond. A phone line may by chance detect one or more atmospheric scalar EM pulses, just as occurred in the blackout in Ventura County, California on Nov. 8-9, 1985. These scalar pulses can travel along a phone line and be broadcast into a person's ear and brain from the telephone earpiece. The proper scalar EM pulse can induce both "acoustic shock" in the inner ear and "electrical shock" conditions in the nervous system. The pulse may also interrupt the body's electrical timing pulses to the heart, causing the heart to stop without physical damage. The scalar EM shock to the brain and nervous system can knock the person unconscious or, if sufficiently strong, kill him instantly. The condition is worsened if the person is ungrounded, since then he acts as a large, open-ended capacitance in series with the telephone instrument's inductance. In such case, the scalar resonance of the equivalent series LC circuit can be sharply excited and resonated. By the nonlinearities of the body and nervous system, the scalar resonance can be translated into an ordinary electrical pulse or resonance. Since the scalar power is not translated into ordinary power except inside the nonlinearities of the human capacitor/nervous system, no damage to the telephone or phone lines need happen. [At the ComTec exhibit in Las Vegas in 1984, John Bedini demonstrated powering a 200-watt speaker system through a 100-foot length of #40 magnet wire, using scalar EM means. He put some 200 "watts equivalent" of scalar energy through the tiny wire to the speakers, where a small Bedini translator translated it back into ordinary electrical "force field" energy, powering the speakers. This was much to the astonishment of the technical audience, since the wire was quite cool and exhibited no evidence of heating, even though by conventional thinking it should have been instantly melted.]

The bottom line is: With increased Soviet scalar weapons activity over the U.S., the telephone system is likely to become more hazardous to humans using it, when the instrument is connected to the external wire. A radio phone is much safer against anomalous scalar EM "spiking."

11. The metal-softening detected and verified by Frank Golden on Jan. 1, 1986 is certainly indicative of a new mechanism or effect added to the Woodpecker grid. The highly specialized nature of the particular detector/amplifier which Golden was using provides strong evidence that the signal was actually derived by recording the scalar EM signals produced by a human cerebrum (two cerebral hemispheres connected by the corpus callosum, forming a scalar interferometer) when the human was successfully performing psychokinesis (metal-bending). The fact that Golden was able to nullify the signal locally by special methods worked out by him lends further credence to this hypothesis. In any event, three hours of very objective experimental data strongly support this thesis. It is therefore indicated that (1) the metal-softening signal had been added for a purpose, and (2) something made of metal was going to be softened, leading to its failure. Certainly the Challenger would have been an ideal target; softening the metal on its boosters and fasteners by even a small percentage would significantly reduce the vehicle's ability to withstand the

stress during launch. This of course is circumstantial evidence only, but the finger of suspicion is there nonetheless. It is a fact that the metal-softening signal was and is in the Soviet Woodpecker-repertoire; it is a presumption that it was intended for use against the Challenger.

- FINAL DRESS REHEARSAL BEFORE THE BIG SHOW -

12. The shuttle launch from Cape Canaveral on the evening of Nov. 26, 1986 seemed smooth as silk to the army of official observers and onlookers. In reality the Soviet Union clandestinely conducted one or more Launch Phase ABM System tests against the vehicle, using it as a convenient target.

Figures 9, 10, 11, and 12 are included to give the reader some preliminary background on the highly significant events which occurred in conjunction with this flight, and previous to it. These figures are newspaper articles from the News Tribune, Fort Pierce, Florida. The articles are used by permission.

Anomalous atmospheric "booms" and airquakes had occurred in the Florida area for over three and a half years prior to the launch. Sixteen counties, most of them on the northern Gulf coast or close to it, had reported booms during the two-year period preceding April 1984. State and local emergency preparedness officials and U.S. Air Force Base representatives met but could not resolve the mystery of what was causing all the anomalous booms.

In fact, many booms had occurred in and around the gulf coast of Florida, particularly offshore from St. Petersburg, starting from several years earlier.

These anomalous booms were caused by the Soviets adjusting and testing the Woodpecker scalar EM grid for weather engineering and potential weapons use. The booms and airquakes were certainly not confined to Florida alone, but also occurred at many other locations throughout the U. S. and Europe.

Mysterious, highly localized seismic microquakes also had occurred at widely scattered locations throughout the U. S.

On at least two shuttle flights prior to the Nov. 26, 1985 launch, large anomalous "booms" had occurred over or around the launch site after launch. No one in NASA knew what they were or what caused them.

So prior to Nov. 26, the Soviets had already prepared and tested the Launch Phase ABM system mode of the grid against at least two U.S. shuttle launches. However, so eerie and strange are the scalar EM weapons that they had been able to do so without the U. S. government even becoming aware of what was going on. In the Kremlin, they must have marveled at our continued ignorance.

At any rate, they tested the Launch Phase ABM system again on Nov. 26, and this time private U.S. citizens happened to capture at least some evidence of what was going on. It still would have died there without surfacing, except for a curious chain of events. Let me briefly recount those events.

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Lucius Farish publishes a fine little monthly newsclipping collection called UFO Newsclipping Service (Route 1, Box 220, Plumerville, AR 72121). In it she includes clippings on all sorts of anomalies, including UFO's, strange light phenomena, etc. Because of my long work in UFOs (for some time now, placed on the back burner due to the press of my work in Soviet scalar electromagnetic weapons), I've subscribed to Farish's service for several years.

And this time my unorthodox interests certainly paid off. Farish published a clipping of the article, "NASA officials stumped by strange light, boom," by Susan Burgess, News Tribune writer (see figure 10). The moment I read the article, I realized that the Soviets had actually tested the Launch Phase ABM System's area mode against the shuttle launch of Nov. 26, 1985. Further, George Suchary had taken a picture of the marker beacon as it was slewed away at the conclusion of the test.

With alacrity I contacted Ms. Burgess and, through her, George Suchary. Both were very helpful, and Mr. Suchary gave me permission to use his important photograph of the light moving away after the test.
Ms. Margery Bril , the kind librarian at the News Tribune, sent me four clippings.

After reading the article by Julie Enders, Showcase Editor of the News Tribune, I contacted her also. Although extremely busy, Ms. Enders kindly gave me additional details, including the fact that Bob Gladwin had taken a series of eight stills of the launch itself, and in one frame an anomalous, curving line of light with a splash on the end appeared.

At first I thought it might be the answer to a dream. Very tentative information suggested that the "curved light with a splash on the end" might have occurred in one of the pictures taken during the launch sequence itself, with the light striking directly under the shuttle shortly after it lifted off. I was positive the Soviets could strike at the shuttle (or a missile) with a "scalar EM pulse" missile, but hardly dared hope someone could have actually been lucky enough to get a photograph of it.

From my acquaintance with two masters of paranormal photography -- the indomitable Trevor James Constable and a close friend, Joe Gambill -- I understood how one could possibly get a picture of such a strike -- assuming it occurred -- at night, when the same picture could not have been taken in the daylight. I also understood why the camera might catch it when the human eye would not see it.

It seemed that, between them, these friendly, cooperative persons just might have gathered together the positive evidence to prove that the Soviets had struck at the shuttle with an offset test of a scalar EM missile, using a marker beacon for adjustment. (As it turned out. it was not to be as definite as that!) However, time was of the essence.

The Soviet tests had definitely included a test in the "area burst" mode, which can catch and destroy several missiles fired from a deployed silo complex at once. The clinching evidence I had needed for so long on a Soviet test of the pulse mode -- the scalar EM pulse missile -- just might be there in one of Bob Gladwin1s photographs. But there was no time to lose; such evidence is fleeting. and unless I moved quickly, it was likely to fade away and disappear forever. With persistence, the rest followed swiftly. Mr. Suchary graciously gave me permission to use his photographs. These of course prove that the marker beacon was there. (In addition, it was seen by numerous persons.). The News Tribune gave me permission to print the articles. Mr. Gladwin furnished his negatives and gave me full permission to analyze and use his photographs. Personal friends, Everett and Shirley Edwards, printed the photographs in their private darkroom so the negatives would not be out of safe hands for even a moment.

At the time, this book was almost finished. If the photo of the candidate Soviet use of the electromagnetic missile was accurate, quick work would be necessary if it was to be included. My friend and publisher, John Ratzlaff. had already agreed to swiftly publish this large output as soon as I could get it to him. At Omni Video Publishing, Ms. Electra Briggs was alerted to the potential importance of what was coming. She and Mr. Glenn Shoemaker swung by my house from New Orleans, and a quick, informal videoclip was taped, announcing the book. (Murphy's law -- if anything can go wrong, it will -- got me there. Inexplicably, in my near-total fatigue from months of 19-hour days and 7-day weeks on this project, I spoke the date of the Titan explosion as April 19th, knowing full well it was the 18th! It happens. Electra suggested she slap a correcting statement over the video. Done. Be ready to get it out. It's too important; don't sweat the small stuff.)

Zerox copies of the photos were received. There in the fifth photo (or so it seemed) was an unequivocal strike of the scalar EM missile, in the launch sequence itself. The assumed strike seemed to have occurred right under the shuttle, a few seconds after liftoff.

The evidence seemed complete. All that was left was to receive the actual negatives and verify the sequence. At last we seemed to have the smoking gun. The Soviets would have been caught redhanded.

Based on the advance zerox copies, the manuscript was altered. Everything was ready. And then the negatives came in.

In this business, you learn to meet and accept a lot of failures. Things often go astray, and don't wind up as they seem at first blush. This time was no exception. Murphy got us again! The photos on the negative were in a different order then they had been on the zerox copies.

There's no mistaking the order in which the pictures were taken. There they are on the negatives, one right after the other, and clearly numbered. And the curving light with a splash at the end did not occur during the launch sequence at all. Instead, it was taken before the launch -- just how long remained to be seen. Everett and Shirley took the photo and developed it at both extremes: very dark and very light, to bring out all the details possible.

The results were most interesting. As shown on the lighter print (figure 13), the light does not curve down out of the sky and strike toward the ground, it turns up toward the sky and strikes above the distant treeline. Further, as shown on the darker print (figure 14), it does consist of a little ball of light, just like a scalar EM missile would appear. No apparent structure to hold the light appears in either picture, though one could not positively rule this out completely without microdensitometer tests. (One can inadvertently get artifacts like this by focusing on a ball-like light bulb, for example, and then moving the camera while the shutter is still open. On the other hand, there is no evidence that this happened at all, and no street lamp post or other foreign object in the photo.)

(The remaining photos of the liftoff sequence are shown in figure 15.).

We called Mr. Gladwin. He verified that the photos had been taken in order, one right after the other. He had not had the camera on a tripod, but had steadied it on a railing. In other words, the "light streak with a burst on it" had been taken just before the liftoff. Also, Mr. Gladwin had not observed 'the marker beacon, and had not attempted to photograph any such "light in the sky." In fact, visually he had not observed any such streak and burst of light in any scene he was photographing.

So the question is, exactly what did Mr. Gladwin photograph in that photo, just prior to the shuttle's liftoff? The answer is. we just don't know for sure.

Let's run through the two possibilities:

(1) He may have snapped an artifact while moving the camera. If so, the camera was definitely quite still at least most of the time the lens was open, for the treeline is quite clear in the lighter photo, which reduces light saturation and shows details more clearly. Further, there is no evident support or structure attached to the light itself; it seems to be a "disembodied" light. So this possibility is ambiguous, though reasonable. Mr. Gladwin does not recall any such movement of the camera; it was steady while he was shooting.

(2) He may still have snapped a scalar EM missile. If so, it means the Soviets fired a "small test" of the exothermic pulse or scalar EM missile in advance of the actual shuttle launch. Let's pursue that for a moment, and suppose it to be true.

The Soviets already had the marker beacon up in the sky -- that's certain. Many persons saw it. Soviet trawlers off shore and Soviet satellites could also have given the actual position of the marker beacon. Thus the Soviet LPABM System would have had (a) the actual parameters the computer had used to transmit the beacon, and (b) the actual location at which the beacon emerged. Comparison of (a) and (b) is much like having a "meteorological data message" in field artillery: One has the corrections to apply for specific conditions of the medium that cause deviation.

These corrections can then be applied to calculated or "table" data to adjust firing for real-world conditions.

So far so good. The Soviets had the exact position of the registration beacon, and could apply corrections for a shot of the scalar EM missile. They certainly would know the exact position of the shuttle on its launch pad.

If a fairly substantial offset for the scalar EM missile shot were used, "mett corrections" could be applied and a small scalar missile could be zinged in, stopping momentarily at the final offset "strike" position so that a track could be obtained by the scanner extraction beam. Then by comparing the detected offset position of the "burst" of the scalar EM missile to the detected offset position of the marker beacon, the difference could be applied to the beacon's true position to get the true strike position of the missile. The offset used could then be subtracted to give the location where the missile would have struck without the offset, had it actually been fired at the rising shuttle after liftoff. This "adjusted final strike position" could be compared to the shuttle's expected early trajectory (which varies only slightly from standard for the first few seconds) to determine the expected combat success of the shot. It's a little roundabout, but it's a very safe way to do it if one wants quite positive assurance that the missile will not strike the shuttle and destroy it. Since the Soviets delayed the "area burst" and its concomitant atmospheric "boom" to T + 12 minutes, it is evident that a large offset was used for the area strike -- probably about 10 extra minutes -- to positively assure that there would be no actual damage or threat to the shuttle.

It seems logical, then, that they might fire the small scalar EM missile well offset from the shuttle, and just before its launch, to prevent any possibility of actual damage to the shuttle.

So there you have it. Mr. Gladwin's photograph is consistent with such a careful, safe scalar EM missile test by the Soviets, prior to the actual liftoff of the shuttle. On the other hand, it's not possible to say with certainty that that is what it is. It may simply be a very peculiar artifact. In fac, if it were not for the other indicators, one would most certainly not consider such a bizarre possibility as an offset Soviet scalar EM missile strike at the shuttle.

If the "streak" photo is examined as a candidate for a sca1ar EM missile test, then one other thing must be explained: Why did the film capture the test when observers did not see it at all? That, of course, we can explain!

So back to our presentation. Here I'm going to assume -- and accent that this is a postulation -- that the Gladwin photo actually represented a scalar EM missile test. We will run through a possible sequence of events, based on that assumption. We will hypothesize the LPABM system operation and the Soviet conduct of the test. The major events here in the U.S. may be quite real; those assumed to occur in the Soviet Union, of course, are "author's license" -- but hopefully realistic.

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The evening of Nov. 26, 1985 is perfect. At Cape Canaveral, the shuttle Atlantis is poised on its launch pad waiting to move majestically into the heavens on its impending journey. As launch time approaches, everything is as smooth as a cat's whisker. There is, however, just one small anomaly.

A mysterious light is hanging up in the sky, staying still for awhile, then gently rocking back and forth. The light is a Soviet marker beacon for a scalar EM howitzer. The howitzer, employed in a special scalar EM channel contained in the Woodpecker transmitters and interference grid, will shoot through the EM carriers at an aiming point offset from the shuttle.

Since this is still to be a nondestructive test, no chances will be taken. The pulse mode will be used, and a "scalar EM missile" -- a bundle of energy buried in hyperspace around its moving zero-point in this world -- will be fired directly at an offset aiming point prior to launch of the shuttle. A substantial offset in distance will be used to prevent posing any danger of inadvertently hitting the shuttle on its launch pad.

The marker beacon is necessary for precision. Its desired position will be calculated and the beacon will be placed on station. By placing this source of continuous EM energy in the area, it can be detected by the scanning "energy extraction beam" and tracked by the distant Soviet operator. Soviet trawlers and satellites monitoring the test will report the true position of the marker beacon, which will deviate from the calculated location due to conditions of the channel medium (the Woodpecker beams) at the time. Comparison of the beacon's true position to its desired, calculated position "registers" the marker beacon and yields the "meteorological corrections" which must be applied to standard firing table calculations. These corrections can be applied to any further shot into the area to correct its aim, just as standard field artillery applies registration corrections in the target area.

When the shuttle boosters ignite, an additional track will be obtained from it. The offset from the received track of the marker beacon and the received track of the shuttle booster flame thus will give the exact correction or "shift" from the marker beacon settings that should be used to set the howitzer's aim. In other words, a "relative" firing, offset from the marker beacon registration track, will automatically compensate for any vagaries of the medium experienced by the beams in transmission.

The Russians, being excellent artillerymen, have simply applied the standard artillery technique of shifting from a known registration point.

The Soviet Launch Phase ABM System is cocked and ready. This is the last test in the "wet run" series in which an offset will be used. If everything goes as planned, future shots will move into the next phase, where actual U.S. targets will be destroyed. The two great powers are already at war, but one of them does not know it yet. Because of the importance of this last test before the next step in hostilities commences, Gorbachev himself is monitoring the test.

The countdown begins. In Florida a great many persons are observing the event. George Suchary has already spotted a strange light hanging in the sky, where none ought to be. Bob Gladwin, resting his camera on a railing, prepares to snap his first picture so that he will be sure to have a sequence completely across the launch.

Deep within the Soviet Union, a large display screen is illuminated. The marker beacon's track is clearly shown on the display, as are synthetic symbols for the shuttle on its launch pad, several Soviet ships off the coast of Florida, and several Soviet satellites.

The control officer barks, "Missile test! Proceed!" The simulation officer presses a switch, and a simulated shuttle launch track appears.

The operator responds immediately, "Launch detected!" The identification officer, scanning the frequency components and the signature of the energy extracted from the launch, calls out, "Missile! Target hostile!" He presses a button, and a light illuminates on the panel, marking the target as a hostile missile. The launch track begins to blink.

The control officer announces, "Prepare to fire!" "Pulse mode!" "Strength one!" "Test!" "Apply burst offset!" The operator rapidly flips switches, setting the mode of fire and the offset. Instantly lights light to show that the computer has computed the shift and offset, and corrections. A red "Ready to Fire" light illuminates and a low siren begins its wobbulating growl.

The control officer orders, "Fire!" The operator presses the fire switch. A "Fire" light appears. A slight, deep shudder is felt briefly as the howitzer fires its scalar EM pulse missile of deadly energy. On the screen, the path of the scalar EM missile is traced out as it speeds toward its target far over the horizon.

In Florida, George Suchary is getting more and more curious about that pesky light. Bob Gladwin is preparing to snap his first photo as the final seconds of the countdown tick away.

On the distant Soviet screen, a sudden small burst appears, superposed over the synthetic shuttle track. The operator yells, "Burst!" On a smaller screen, a vertical profile shows the strike directly underneath the target. Immediately a blinking "Target Killed" light appears as the computer assesses the shot a kill.

The operator excitedly calls out, "Kill !" "Direct Hit!" Cheering breaks out from the firing team and the onlookers. Gorbachev and his entourage are smiling broadly and clapping. The cheering quickly hushes as the crew and participants continue to watch the track of the rising shuttle, and prepare for the launch and the next test.

Bob Gladwin has snapped his first picture (figures 13 and 14) leaving the shutter open a bit to allow for the nighttime conditions. As luck would have it, the scalar EM missile strike Occurs during the time the shutter is open. The film has captured the strike by a special process, even though human eyes have not seen it. (We will explain that shortly.).

At 7:29 the Atlantis's boosters ignite and the vehicle begins to rise smoothly off the launch pad. She will continue to rise, then pitch over to a 45 degree angle and proceed down range..

Bob Gladwin is snapping pictures regularly, one after the other.

In the local Florida area, hundreds and hundreds of persons are watching the flawless launch. The tip-off of the Indian River Community College basketball game and the St. Lucie County School Board meeting are held up while participants watch the Atlantis begin to rise serenely upward.

In the Kremlin, another track has appeared on the control screen display. Once again the sharp-eyed operator snaps, "Launch detected!" The identification officer, scanning the frequency components, tersely rasps "Missile! Target hostile!" Again he presses a button, and a light lights on the panel, marking the target as a hostile missile.

The control officer orders, "Simulate multiple firings!" The simulation officer acknowledges, "Multiple firings simulated!" and presses a button to cause the computer to simulate multiple launches on the display.

Immediately other synthetic target tracks begin to appear on the display screen, one by one, clustered around the shuttle launch at various separation distances, prearranged to represent multiple firings from a missile silo complex for this exercise. A special audio alarm sounds as each track appears.

The operator immediately calls out, "Multiple tracks! Missile launches!" and then "Identified hostile!"

The control officer orders, "Prepare to fire!" "Area pulse mode!" "Test!" "Apply time offset ten!"

The operator flips switches rapidly, acknowledging. Lights illuminate on the console, showing status of preparation for firing. The "Ready to Fire" light illuminates and the low siren begins again.

Back in Florida, Bob Gladwin has stopped snapping photographs. George Suchary has gone into his house to find his Polaroid camera and take a picture of that pesky light still hanging up there in the sky.

Back in Russia, the fire control officer orders, "Fire!" The operator presses the fire switch. The "Fire" light illuminates, immediately blinking, and the siren changes tone. On the display screen, all target tracks are blinking. A large light on the console comes on, showing that an "exercise time offset" of 10 minutes has been applied. A digital clock starts ticking off the minutes.

Minutes pass as the offset time ticks down.

Back in Fort Pierce, George Suchary is coming out to take photographs of that darn light, which is still hanging up there!

Folks are streaming back into the Indian River Community College gymnasium for the basketball game. Attendees at the St. Lucie County School Board meeting are wandering back inside, to get ready for the meeting.

More minutes pass.

Back at the control console in the Kremlin, the offset clock ticks down to zero. The siren ceases its wobbulating tone and holds a steady note. The "Fire" light ceases blinking and illuminates with steady brilliance. A deep shudder is felt as the howitzer fires again. On the screen, the rapid trace of the mighty scalar EM serpent is shown as it races toward its target.

Suddenly it reaches the target area, and a large blossoming light appears, covering all the target tracks. The operator announces, "Burst!"

All the target tracks flare brightly, then dwindle and die. The "Targets killed" light illuminates and the operator yells, "Kill! All targets killed!"

Wild jubilation breaks out. Everyone is grinning and clapping. Gorbachev personally congratulates the fire control officer and pumps his hand. The tension relaxes visibly. In the noise, the operator touches a joystick and slews away the marker beacon, preparing to shut down the system.

The final test has been a crowning success. Now the real first phase of active combat begins. "And the fools don't even know it yet!" a grinning Gorbachev delightedly announces.

Back in Fort Pierce, precisely 12 minutes after liftoff, high in the atmosphere above the launch site and a little downrange, a tremendous rumbling boom suddenly rocks the coast for hundreds of miles in each direction. The blast is heard as far north as Charleston and as far south as Key West.

George Suchary is taking pictures (figure 10) as the hanging light in the sky suddenly begins to move away, obeying the controls of a Russian operator thousands of miles away. Bob Gladwin has already finished snapping his photographs (figures 13, 14, and 15) of the launch and taken down his camera.

The anomalous light disappears rapidly in the distance, moving faster than any jet aircraft.

People gradually resume their normal activities, talking about the beautiful evening and the perfect launch. Many of them have noticed the strange light that hovered and bobbled in the sky, then sped away.

The final Soviet registration of their eerie weapons for World War III has been completed. A totally different kind of Pearl Harbor -- more akin to a Trojan Horse -- has been prepared for the unsuspecting United States.

Countdown toward Armageddon begins.

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George Suchary's photograph of the marker beacon, just after it had started slewing away, is shown in figure 10, as printed in the News Tribune.

Bob Gladwin's photographs of the shuttle launch are shown in figures 13, 14, and 15.

Figures 13 and 14 show two developments of the same shot, one light and one dark. The light one shows the treeline in focus in the distance, with the light streak and burst.

Figure 15 shows liftoff of the shuttle and its rise and tilt over on the first part of its trajectory.

Figure 16 shows a possible detailed interpretation of the first Gladwin photo. The simulated aim point was offset from the shuttle, and the strike was directly at the offset point. The computer computed the burst strike strike of the scalar EM missile from the adjusted registration data, and determined whether or not the target was killed.

The control precision is shown by the small size of the scalar EM missile.

The strike of the weapon is caught by the camera, but not seen by the naked eye. None of the many hundreds of onlookers saw the strike, though all of them saw the shuttle launch.

There is a very good reason for that, though it is not commonly known.

Constable

The reason is that Bob Gladwin's camera was utilizing a form of photography pioneered -- to the best of my knowledge -- by Trevor James Constable. At least I learned about it from Constable's books and articles. I then told it to my good friend, Joe Gambill, and Joe applied and adapted it to the unusual photography which he performs. Both Constable and Gambill are masters of this type of photography. Once I got deeply into scalar electromagnetics, I finally figured out what was going on in this methodology.

Briefly, here's the way it works. Scalar energy, of course, has to be detected by some sort of interference phenomenon. There exists a very special way to get a camera to perform such interference for you.

In the EM spectrum, the infrared and the ultraviolet have a special relationship to each other. The ultraviolet is exactly twice the frequency of the infrared, if the two zones are properly chosen. In other words, the UV is the first harmonic of the IR.

The scalar EM energy, since it operates in the Kaluza hyperspace surrounding every point in ordinary space, may be considered to be composed of pure spin. (That is, it's moving in a dimension where each particle of that dimension is spinning). Harmonics there are spin harmonics.

In this photon-interaction produced level of reality (the ordinary world), the IR and UV bands are more closely connected to the "shadow world" in which scalar energy moves. Thus there is a sort of shadowy "swirling" of the scalar energy near the IR and the UV. Entry of the scalar energy into this world, through the IR and UV windows by a kind of "harmonic interferometry," is normally prevented by the presence of visible light. That is, visible light "squelches" the "paranormal channel" that lurks beneath the IR and UV zones.

To make use of the IR and UV interference source zones, Constable covered his camera lens with a special filter (18A) which is opaque to the visible light spectrum and transparent to the IR and UV. Note that the film is sensitive to the IR and UV region we are talking about, but the human eye is not.

When pointed at a sufficiently strong source of scalar energy, such a specially filtered camera has unique characteristics. It strips out the visible spectrum, but still admits the IR and UV spectrum. The scalar energy surges through these two source windows, and phaselocks harmonically. That is, the scalar energy entering through the UV window fits twice neatly in the scalar energy entering through the IR window. This interference, on the film, is (recall) swirling in frequency. The net result is that the film records the interfering scalar energy as visible spectrum energy.

Infrared film can be used to increase the response in many circumstances.

Both Constable and Gambill have rigorously proven this technique in literally thousands of "paranormal" photographs. (They do not necessarily use my scalar EM terminology, but the technique is rigorous and works, regardless of terms.)

Under nighttime conditions, sometimes the particular lens and film combination will phaselock between IR and UV for incident scalar EM energy. This is particularly true when a relatively strong source of IR is in the vicinity.

While Bob Gladwin was taking his photographs, there was no suppression of the IR/UV phase-lock effect by visible light because it was night and there was hardly any visible light entering his lens.

Thus his camera lens and film formed an IR/UV phase-locked interferometer that detected and recorded the strike of the scalar EM missile underneath the shuttle, even though human eyes did not detect it.

At this point it would be interesting to know whether NASA may have had IR cameras focused on this shuttle launch (which was at night). If so, it would also be interesting to know whether any of them may have developed the IR/UV phaselocked interferometer effect, and captured the strike of the weapon.

Note that daylight shots would automatically break the IR/UV phase-lock possibility, by jamming out the effect with visible light, unless a special filter is used to filter out the visible light but leave both the IR and UV.

One would hope that both NASA and the U.S. Air Force will take note and discreetly add a specially filtered camera to the instrumentation observing and recording all future daylight launches.

To recapitulate the major events at the shuttle launch on Nov. 26., 1985, see figure 17. A marker beacon was placed in the vicinity, high over the area, for precise registration and location of tracks relative to it. A scalar EM missile strike may have occurred just prior to launch, and offset from the shuttle.

Then the shuttle lifted off. The exercise called for simulating multiple launches from a missile field. The area code was computed, and the fire order given. A substantial time delay -- say, 10 minutes or more -- was used to absolutely assure that the actual shuttle was well away from the engage blast.

Twelve minutes after launch, the delayed firing in an area "multiple missile kill" mode occurred, producing a massive boom heard for hundreds of miles up and down the east coast. After the boom, the marker beacon was slewed away, and photographed by George Suchary just as it moved.

The shuttle moved on downrange and went merrily on its way, blithely unaware of the jaws of the tiger that had snapped shut behind it.

To the Soviets, this final test of the preparation phase was highly successful. They were now ready to increase the risk level and fire the first round of World War III.

- THE SHOW BEGINS -

13. On Dec. 12, 1985 the same Soviet weapon tested against the previous NASA shuttle launches and against various aircraft may have deliberately interfered with the controls of an Arrow DC-8 taking off from Gander Air Force Base, Newfoundland. At an altitude of 100 feet, the aircraft -- carrying over 250 U.S. soldiers and civilian crew members -- lost power and sank into the ground tail-low, killing everyone on board. It was a tragedy of enormous proportions to the U.S., and especially to the families and friends of the brave servicemen and crewmembers who lost their lives.

Three Canadian witnesses to the crash were interviewed over the Canadian Broadcast network television news on April 8, 1986 at 10:00 p.m. No flame or smoke issued from the plane before its descent and crash.

However, witnesses reported seeing the aircraft mysteriously glowing with a yellow halo. That is a signature of the use of a scalar howitzer in the "continuous EM emergence" mode, similar to the manner in which several F-111's were downed in Vietnam.

In short, the DC-8's electrical systems were interfered with by electromagnetic energy and noise created throughout each increment of spacetime occupied by the aircraft. A powerful charge was rapidly created in and on the aircraft structures and skin. The "yellow glow" seen by the witnesses was a corona due to the skin of the aircraft acquiring a high electrical charge.

Something also apparently caused the rapid loss of two engines, one after the other. This indicates that the distant Soviet operator may have struck at the engines, one after the other, with a scalar "energy extractor beam." Thus he apparently tracked the aircraft as it moved down the runway, then used two modes against it: one to create serious EM interference with the electrical systems of the aircraft, and one to disable the engines.

With its controls ineffective and power drastically reduced, the doomed aircraft sank to earth, still in its "tail down" configuration from takeoff, and crashed and burned.

Admittedly other factors may also have contributed to the crash. These included reduced lift due to poor engine maintenance, increased weight of the aircraft due to icing, and heavy loading. However, normally the aircraft could still have taken off and flown to its destination. (See "Arrow Air was absolutely safe, FAA official says," UPI release, Birmingham Post-Herald, Apr. 17, 1986.)

To date, no official seems to nave recognized the sinister significance of the "yellow glow" or what it implies. No one seems to have connected the loss of this aircraft, the mysterious booms over U.S. shuttle launches, the Woodpecker interference grid, the anomalous loss of the U. S.S. Thresher, the high altitude "booms" off the east coast of the U.S. some years back, the puzzling loss of two critical Titan launch vehicles in a row, anomalous engine flameouts of civilian jetliners, etc.

Certainly officialdom has not recognized that a Soviet Launch Phase ABM System is being tested directly over its collective head, to include actual destruction of U.S. aircraft, missiles, and space vehicles with concomitant severe loss of American lives.

Direct and diabolical acts of war have been committed upon us by the Soviet Union, but in a fashion that still eludes our erstwhile pundits.

However, it is not as simple as that. To even energize giant scalar EM weapons is to run a risk -- to all mankind -- so horrendous that it boggles the imagination. Truly it deserves Brezhnev's 1975 phrase, "...more frightful than the mind of man has ever imagined."

Shortly we will reveal exactly what he meant.

- Apr. 18, 1986: Death of a Titan -

14. As this book goes to press, the last two U.S. Air Force Titan 34-D missiles fired from Vandenberg Air Force Base in California have blown up shortly after launch. The first one blew up on Aug. 28, 1985 just after lift-off. That loss has been attributed to failure of a high-powered fuel pump, causing a massive oxidizer leak and a smaller fuel leak. The second Titan loss occurred on April 18, 1986 when the Missile blew up 5 seconds after lift-off. Its loss is still under investigation and no determination of cause has been made. Apparently the shuttle and the Titan presently provide the only viable launch vehicles for launching U.S. "spy" satellites. The loss of these sensitive satellites -- if indeed they constituted the payloads -- cannot help but be damaging to our strategic surveillance capability. According to the Los Angeles Times, the single remaining KH-11 satellite was launched in December 1984 and, with an expected life of two to three years, it could stop functioning later this year.

Whether or not significant Woodpecker grid activity existed in the vicinity of the Titan launch of August 1985 is unknown at this time. However, significant activity in the grid definitely occurred before the April 18 Titan disaster and on the same day.

On Easter Sunday, 30, 1986 engineer Ron Cole observed significant cloud signatures of grid pattern activity, correlated with Soviet Woodpecker measurements. On April 18, the present author observed traces of a cloud radial over Huntsville, Alabama and took photographs of it. Preliminary reports from Thousand Oaks, California indicate extensive grid activity again on April 18, the day the second Titan exploded.

At least the second of these two missile destructions shortly after launch is highly suspicious, since the grid positively was active during that time. Also, a clear trail of Launch Phase ABM system indicators exists back to the massive scalar exercise of April/May 1985. The first Titan explosion in Aug. 1985 thus falls within the Soviets' "now let's test them against U.S. launch vehicles" period.

The second Titan loss follows highly suspicious losses of the Arrow DC-8 on Dec. 12, 1985 and the Challenger on Jan. 28, 1986. The same Soviet weapon system that destroyed those targets probably also destroyed one or both of the critical Titans.

At least, on the second Titan explosion, the Soviets left another signature. In one of the videotapes taken of the explosion, the marker beacon can be seen well , above the exploding debris, moving away from the explosion site.

See for yourself! Refer to "Titan Explosion Cripples U. S. Launch, Surveillance Capability," Aviation Week & Space Technology, 124(17), Apr. 28, 1986, p. 16-19. Specifically, look at the color photo of the explosion on p. 18.

Look well above the explosion (about one inch on the page) and to the left (about one inch on the page) of the center of the top of the fireball portion. There you will see a little light, caught in the very act of moving away.

At my rather frantic urging, engineer Ron Cole sought out a copy of the original videotape. He and a team spent two hours, going through this portion of the tape frame by frame. The light is there. It's real. And it moves on out of there, well above the explosion and independent of it.

It's the Soviet marker beacon, caught in the very act. Here I want to express my sincere appreciation to Ron Cole for his untiring efforts to nail this light down. Without his dedication to supporting this investigation, it would have been impossible to say for sure that the light was there.

So we have caught the bear red-handed, with his fingers in the cookie jar. If the marker beacon is there, you may rest assured that the Soviets destroyed that Titan missile, with very high probability. [See also "Investigators Search for Clues to Cause of Titan Blast," Aviation Week & Space Technology, 124(17), Apr. 28, 1986, p. 19-20; also "Titan Accident Prompts Funding, Technology and Policy Questions," AW&ST, 124(17), Apr. 28, 1986, p. 21.].

Continue

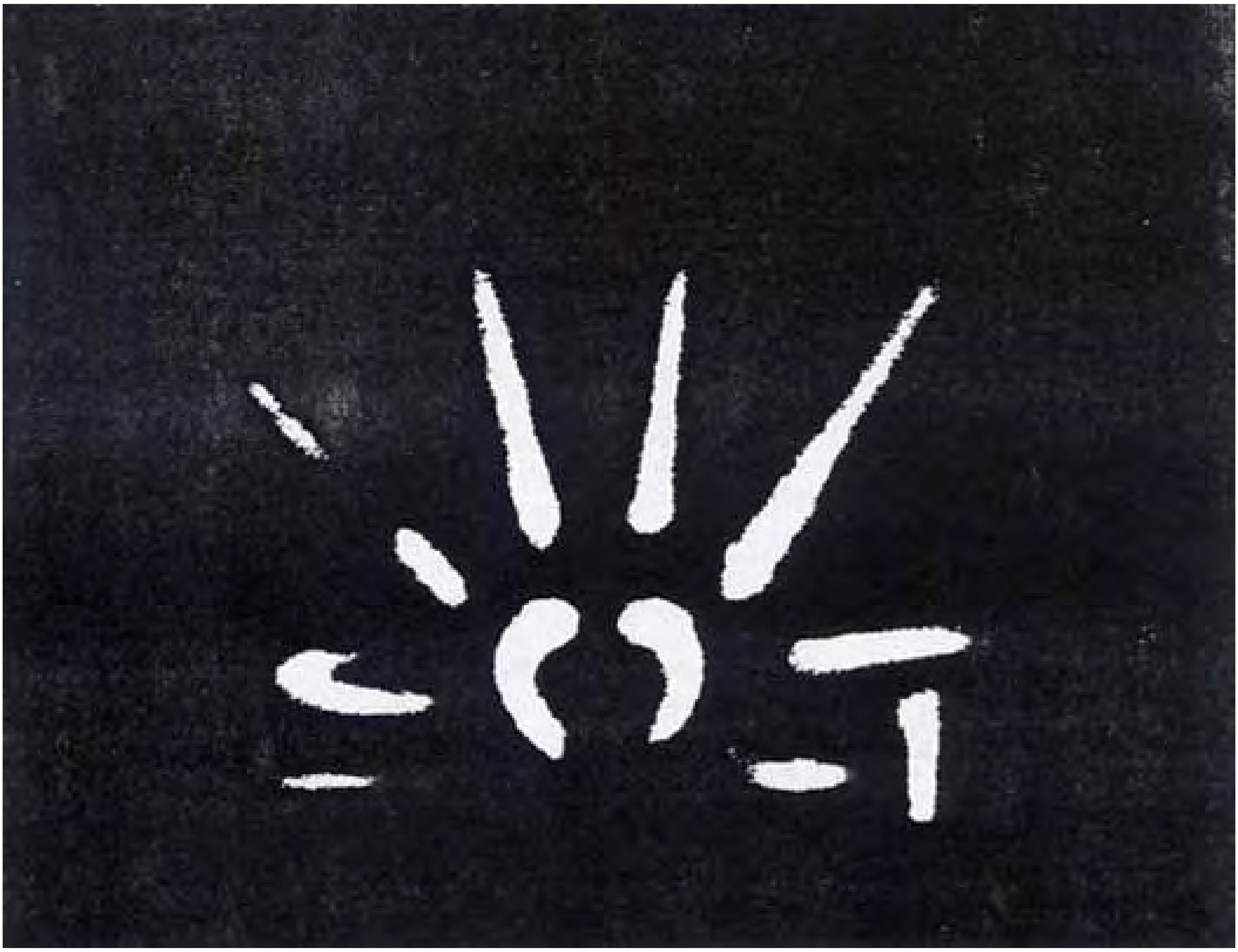

Figure 1. Wilson's first cloud radial

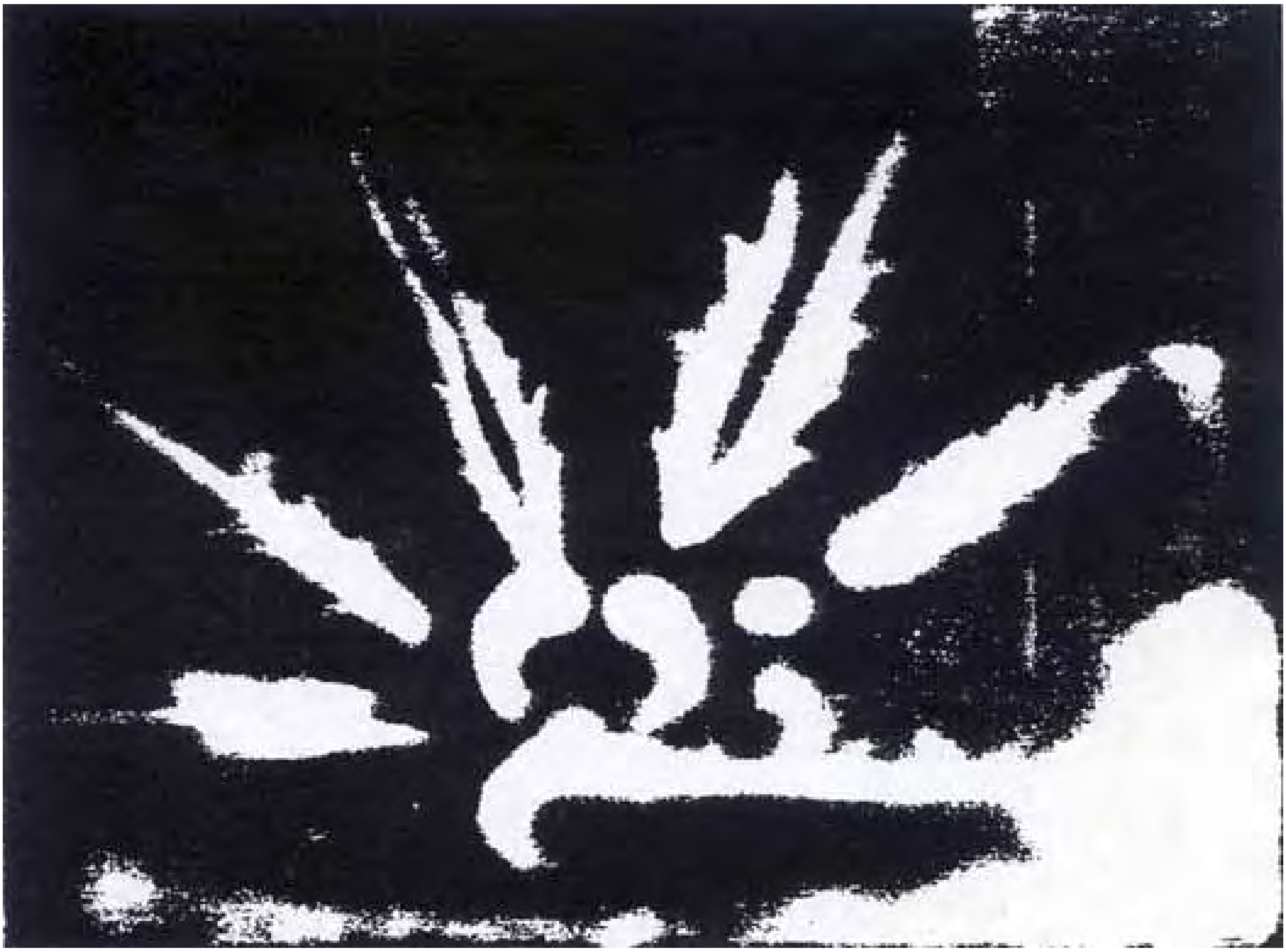

Figure 2. Wilson's second cloud pattern

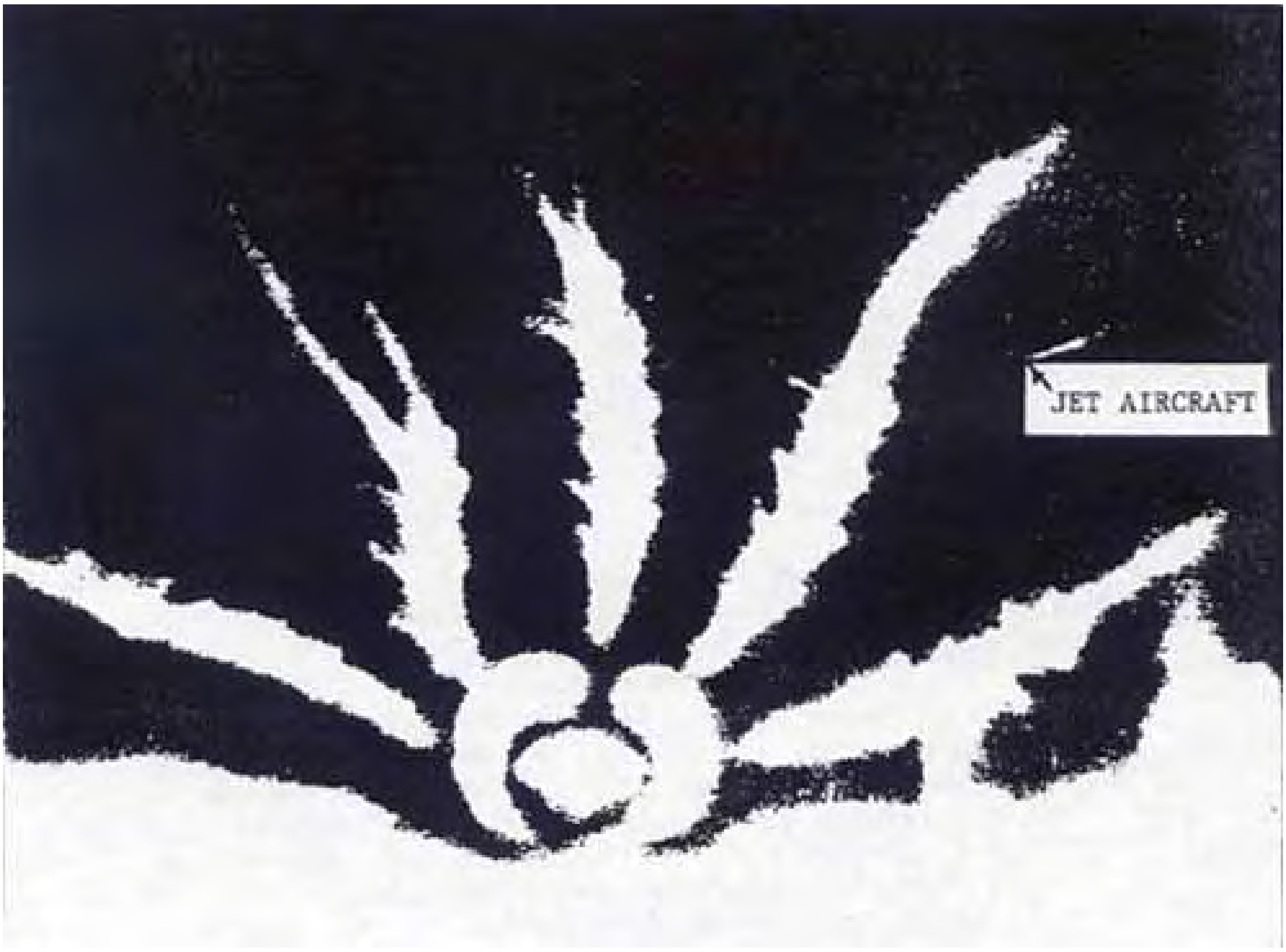
JET AIRCRAFT

Figure 3. Wilson's third cloud radial

Figure 4.

PLACEMENT OF WILSON'S THREE RADIALS

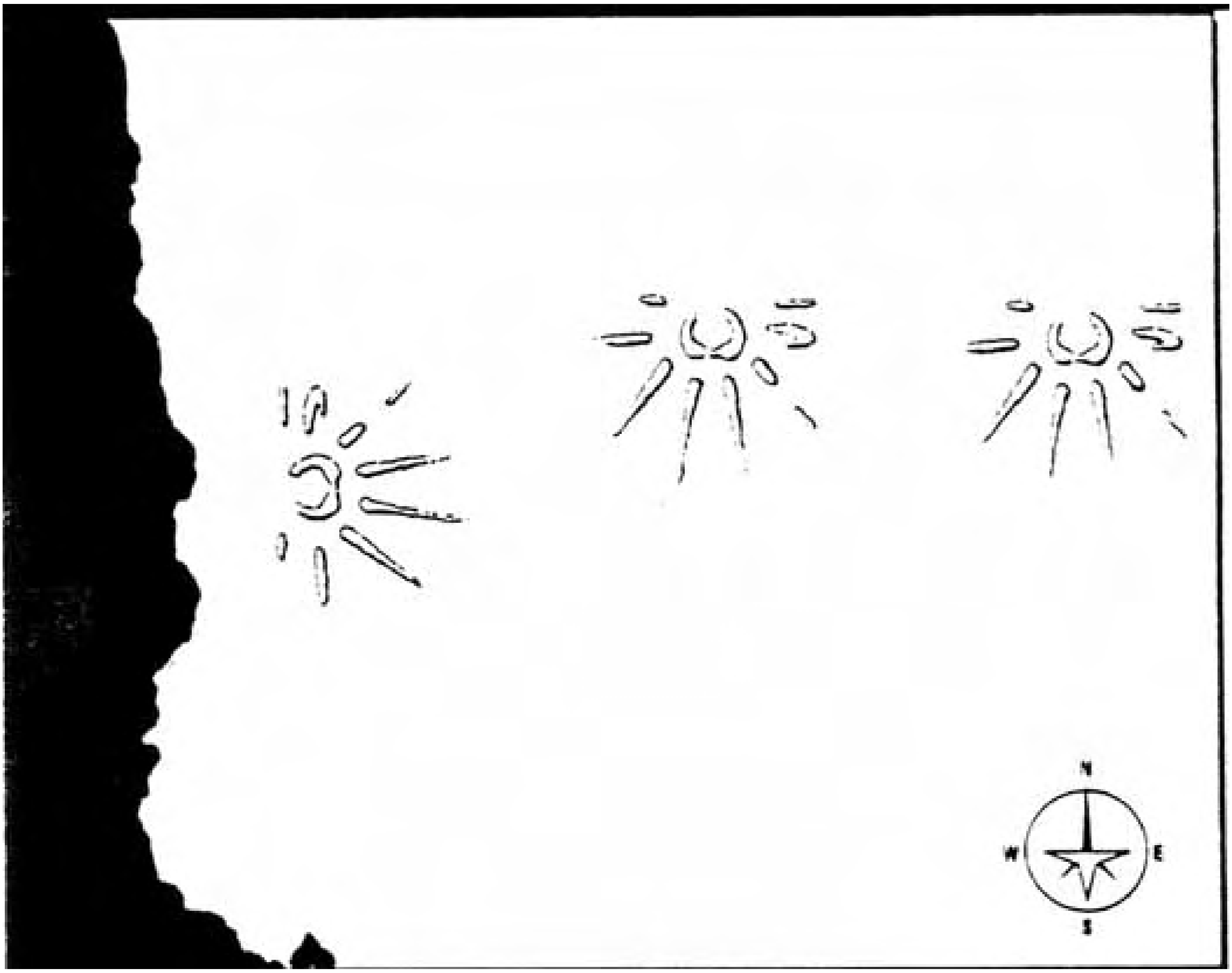

Figure 5.

VIEW FROM WESTLAKE OVER VENTURA COUNTY, CA

1-24-86, 280• WEST/NORTH-WEST

11:45 AM PST

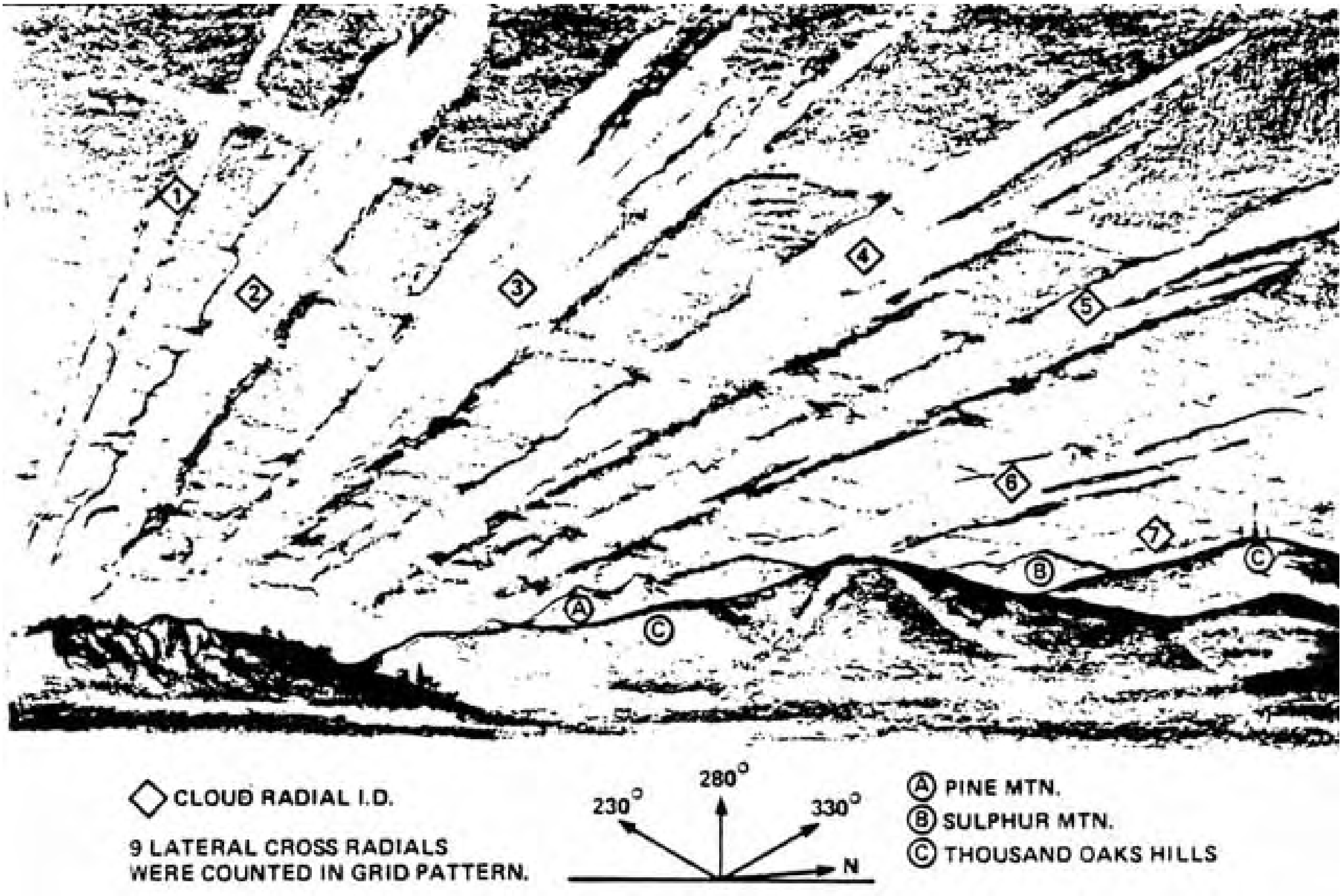
1
2
3
4
5
6
7
A
B
C
C
CLOUD RADIAL I.D.
9 LATERAL CROSS RADIALS
WERE COUNTED IN GRID PATTERN.
230°
280°
330°
N
Ⓐ PINE MTN.
Ⓑ SULPHUR MTN.
Ⓒ THOUSAND OAKS HILLS

Figure 6.

GRID VECTOR APPROXIMATION

1-24-86 VENTURA COUNTY, CA

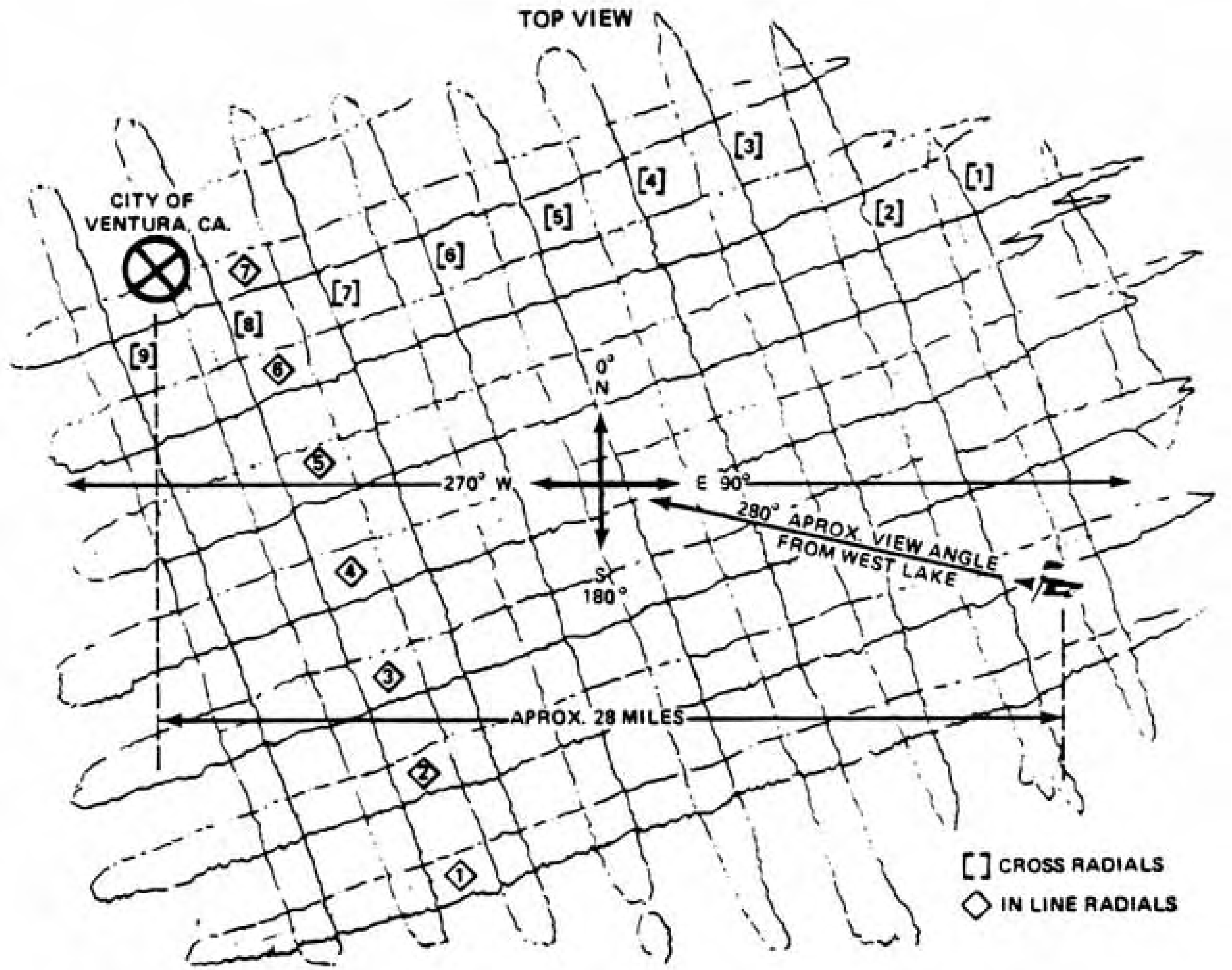
TOP VIEW
CITY OF
VENTURA, CA.
[1]
[2]
[3]
[4]
[5]
[6]
[7]
[8]
[9]
⑦
⑥
⑤
④
③
②
①
0°
N
270° W.
E 90°
S
180°
280° APROX. VIEW ANGLE
FROM WEST LAKE
APROX. 28 MILES
[ ] CROSS RADIALS
◇ IN LINE RADIALS

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Fer de Lance

Figure 7.

SIX-MILE DROP IN TWO MINUTES

CHINA AIRLINES FLIGHT 006
- TAIPEI TO LOS ANGELES -
19 FEB 1985

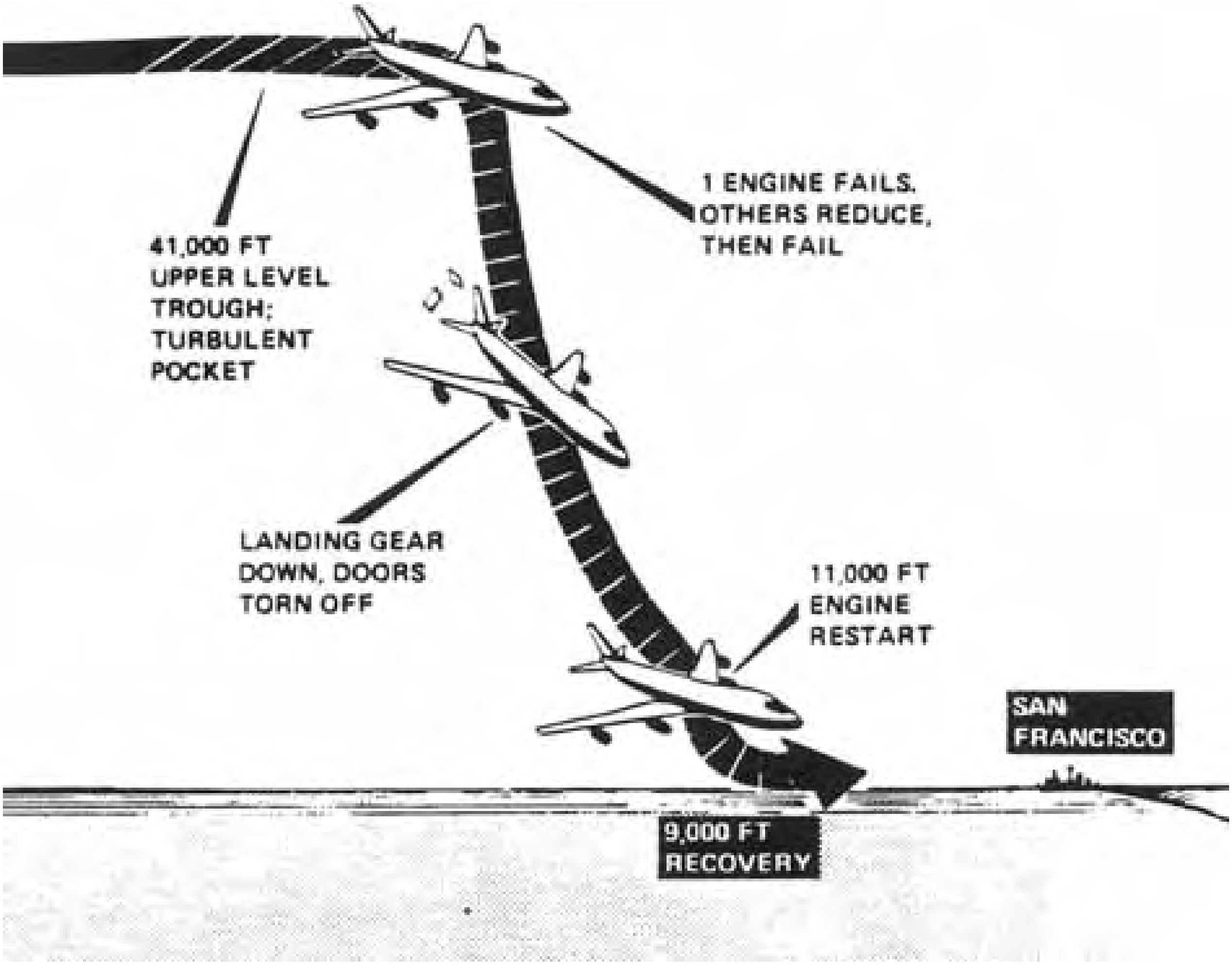
1 ENGINE FAILS, OTHERS REDUCE, THEN FAIL
41,000 FT UPPER LEVEL TROUGH; TURBULENT POCKET
LANDING GEAR DOWN, DOORS TORN OFF
11,000 FT ENGINE RESTART
SAN FRANCISCO
9,000 FT RECOVERY

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Figure 8.

SAN DIEGO CHAFF INCIDENT, JAN. 1985

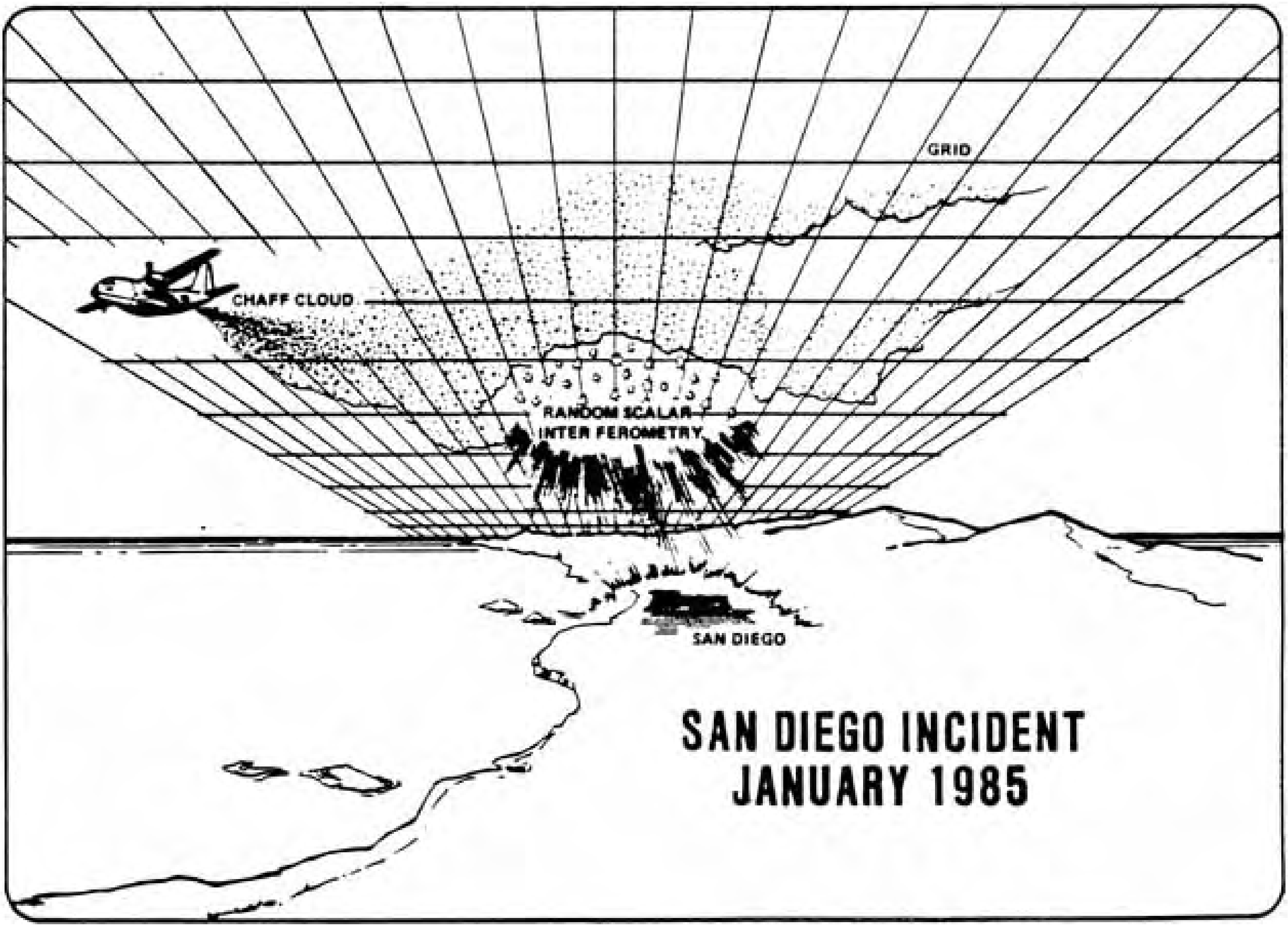
GRID
CHAFF CLOUD
RANDOM SCALAR INTER FEROMETRY
SAN DIEGO
SAN DIEGO INCIDENT
JANUARY 1985

Return to Fer de Lance Index

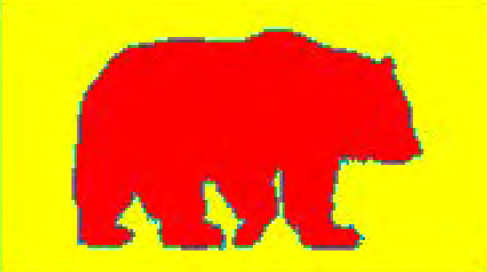

EM Missile Strike, Offset from Night Shuttle Launch

Cape Canaveral, Florida

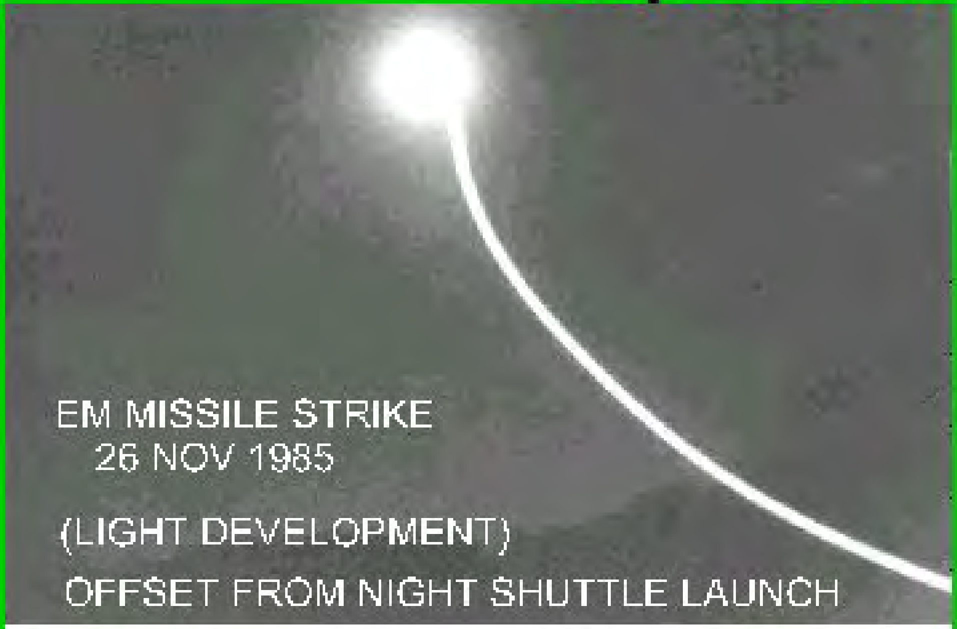

EM MISSILE STRIKE
26 NOV 1985

(LIGHT DEVELOPMENT)
OFFSET FROM NIGHT SHUTTLE LAUNCH

PHOTO BY BOB GLADWIN

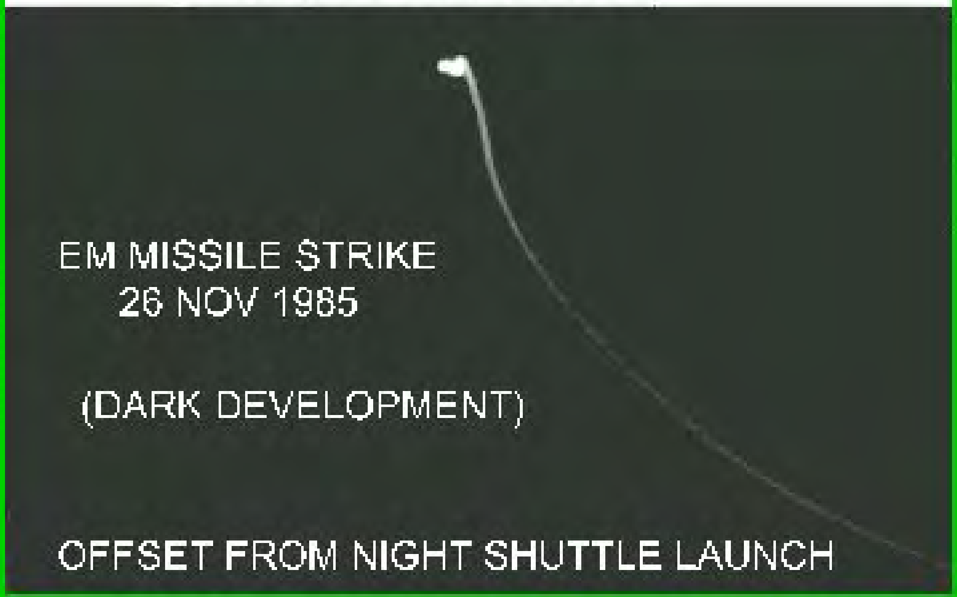

EM MISSILE STRIKE
26 NOV 1985

(DARK DEVELOPMENT)

OFFSET FROM NIGHT SHUTTLE LAUNCH

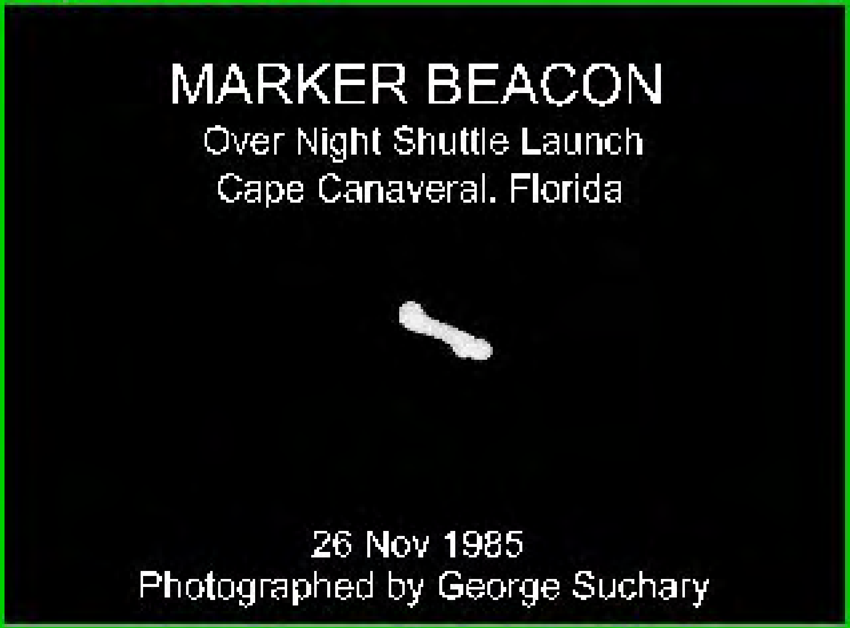

MARKER BEACON
Over Night Shuttle Launch
Cape Canaveral, Florida

26 Nov 1985
Photographed by George Suchary

© T.E. BEARDEN 1995

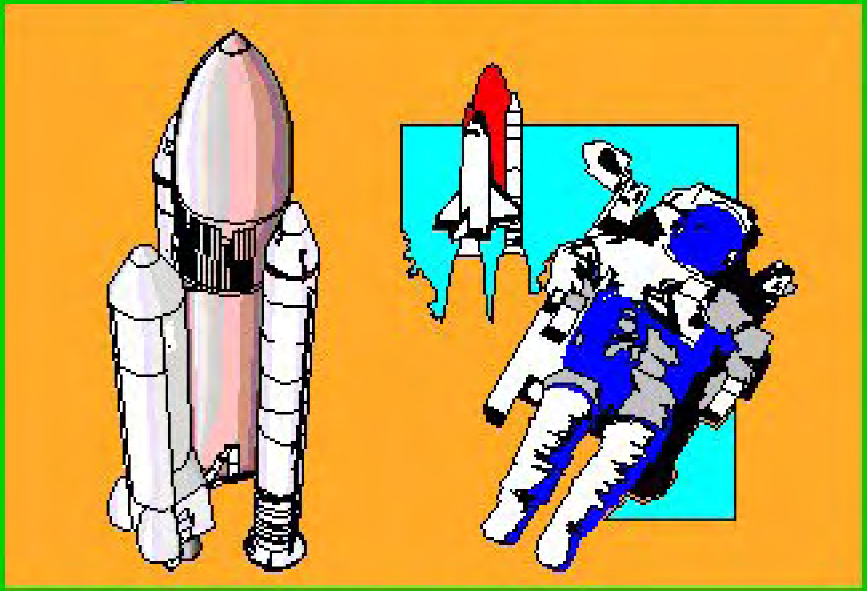

The Smoking Gun on 26 Nov. 1985

Longitudinal EM Wave Interferometry: Exothermic

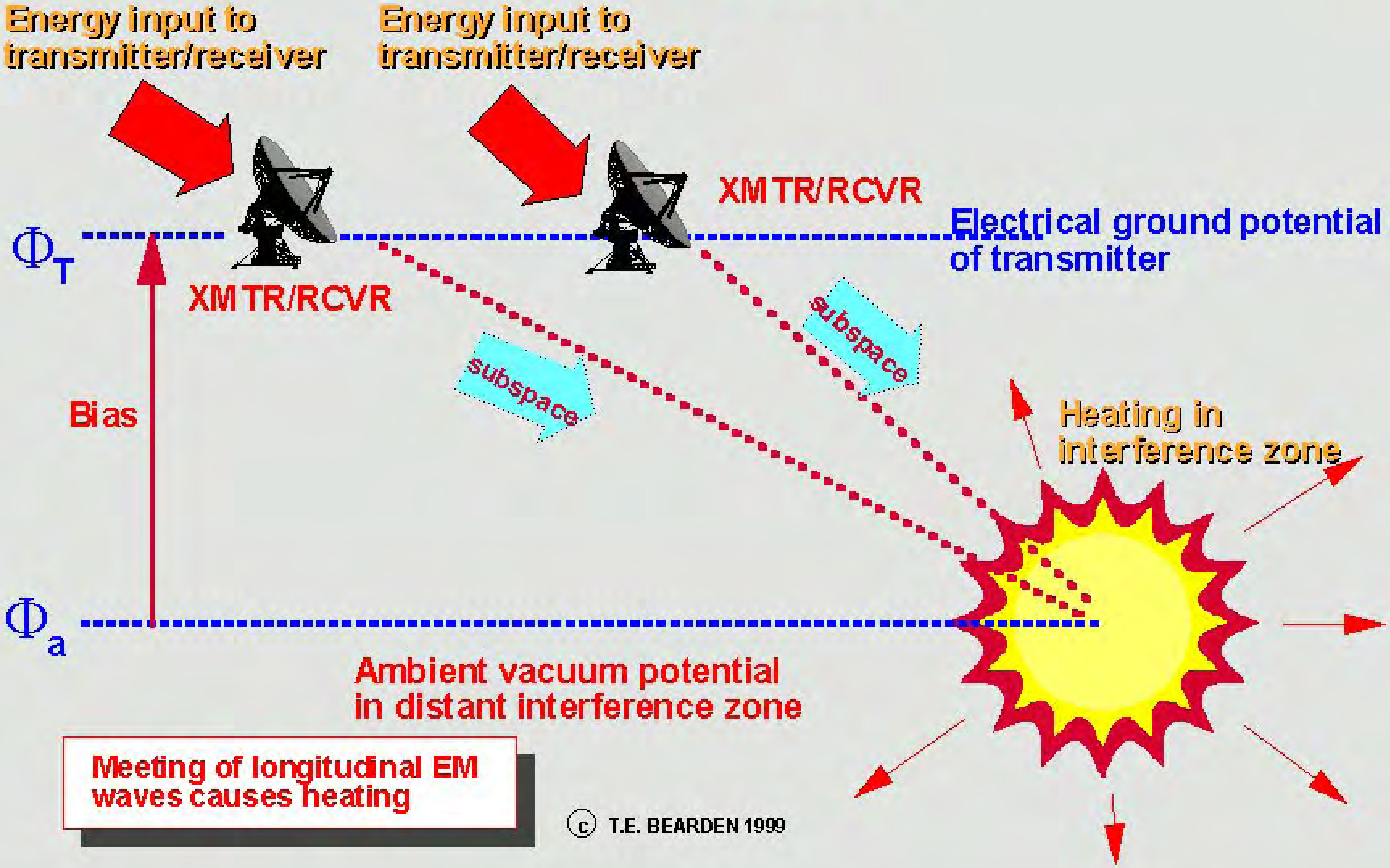

Energy input to transmitter/receiver

Energy input to transmitter/receiver

XMTR/RCVR

XMTR/RCVR

Φ_T

Electrical ground potential of transmitter

subspace

subspace

Bias

Heating in interference zone

Φ_a

Ambient vacuum potential in distant interference zone

Meeting of longitudinal EM waves causes heating

ⓒ T.E. BEARDEN 1999

Longitudinal EM Wave Interferometry: Endothermic

Meeting of longitudinal EM waves causes cooling

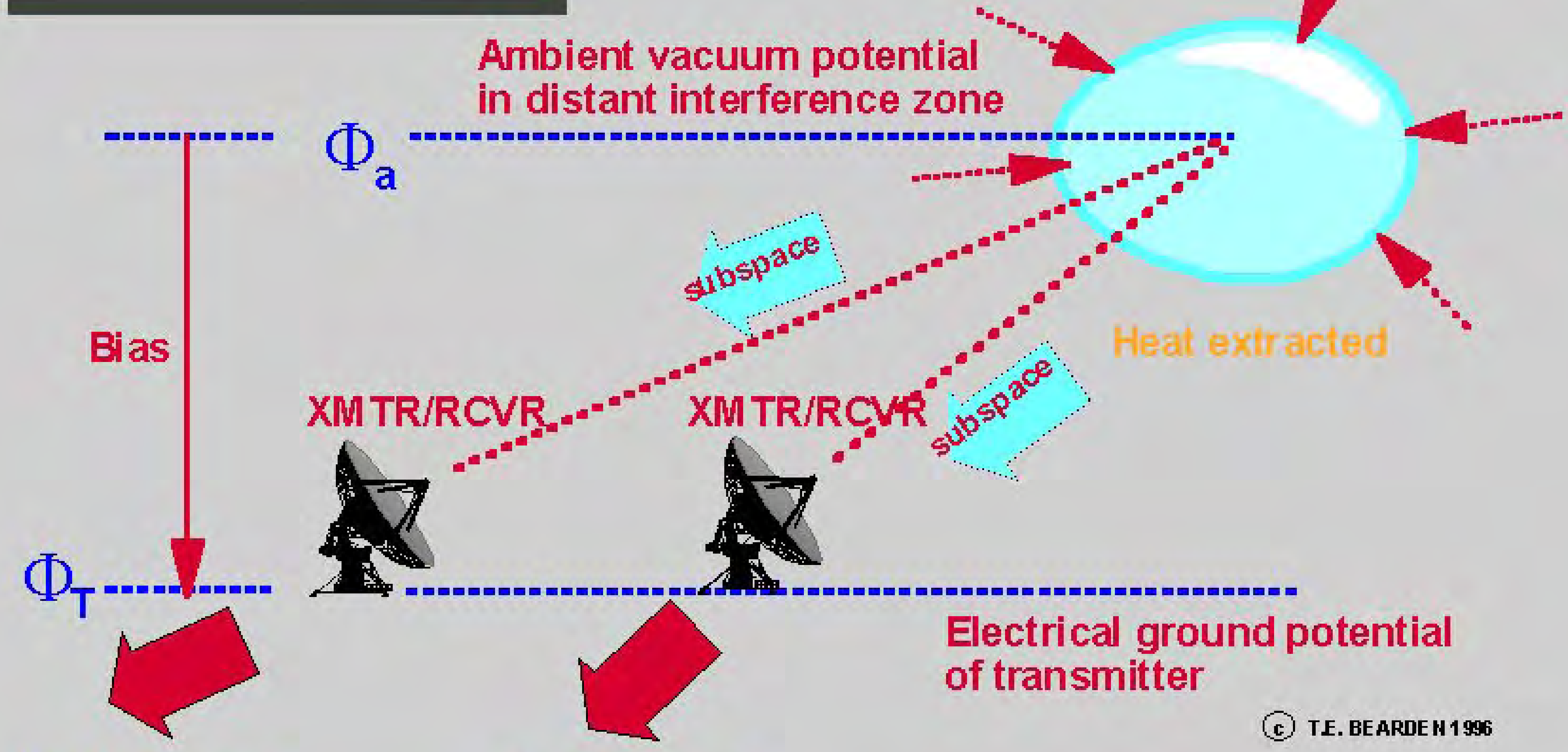

COOLING IN INTERFERENCE ZONE

Ambient vacuum potential in distant interference zone

Φ_a

subspace

Bias

XMTR/RCVR

XMTR/RCVR

subspace

Heat extracted

Φ_T

Electrical ground potential of transmitter

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Heat emerges at transmitter/receiver

Heat emerges at transmitter/receiver

- More Frightening Than the Mind of Man Has Ever Imagined -

Brezhnev's unheeded 1975 characterization of these weapons as "more frightening than the mind of ran has ever imagined" has very real justification. In a moment we shall explain what he meant. We shall also explain why the Russians may be serious about substantial nuclear disarmament.

There is now a "balance of terror" loose in the world that makes the old MADmen's MAD concept look like a sunny day in Hawaii.

Let me explain just a little of what I mean.

The scalar EM can and does use an ordinary EM beam as a medium. Many, many scalar EM channels can be infolded into an ordinary carrier. Thus the amount of energy stored in the carrier as "electrogravitational" energy has little to do with the feeble amount of electromagnetic energy stored in the EM carrier signal.

Thus in one sense, when the Soviets are employing the big "continent buster" weapons, literally hundreds of millions -- or even billions -- of watts of energy may be infolded into the seemingly weak carrier beams. All this energy is in the scalar EM channels established in the carriers.

Plus which, the scalar beams are employed in a "standing wave" node. Each scalar standing wave is like a gigantic "capacitor": It is highly charged. Under normal conditions, it has a charge and discharge time constant as well. If something were to "short circuit" one of these huge standing waves -- say, one with a thousand megawatts in it -- all that stored electrogravitational charge would discharge through the short circuit into whatever is on the other end of the short, and into the ground itself. In other words, the earth itself in that location would receive a mighty electrogravitational pulse (EGP). The ground in a region surrounding the discharge point would "charge up" just like a capacitor, and would transmit the EGP as a hemispherical current into the earth and spreading around it. This is where the real problem cores in.

The problem, as originally discovered by Wilhelm Reich [orgone energy was and is real, and is simply one form of scalar electromagnetics], is that radioactive material has a very great affinity for this EGP and undergoes a drastic reaction to it. Crudely, it works like this:

Imagine the vacuum as a virtual particle gas. This gas is under extremely high "pressure" or, more correctly, internal Stress. This stress is a gravitational potential.

However, the stress of the ambient vacuum is normally about the same in most localities. So a chunk of radioactive material doesn't experience a difference in vacuum potential across itself or throughout itself. In other words, the scalar EM fluxes in and out of every part of the nucleus are very high, but of equal magnitudes. The radioactive nucleus, however, is "unbalanced"; that is, it has an extra bit of unresolved EG potential which it would very much like to get rid of or discharge, by spitting out one or more particles. That is, it would like to "decay" to a more stable configuration. A nucleus that is trying to decay to a more stable configuration is a radioactive nucleus.

Remember, the radioactive nucleus is involved in a tremendously dynamic virtual particle flux exchange with the vacuum potential. And a part of it isn't quite in balance in that flux. Sooner or later the right "bobble" in the input flux will come along, and the nucleus will decay and emit a particle and/or radiation. By measuring the level of decay activity in a certain amount of the radioactive material, we can determine a "decay constant," or basically the probability that a nucleus will decay in one second. We can then determine how long it will take that chunk of material to decay away to a stable, relatively inert material. Some materials only require a few minutes to decay, while others may require thousands of years.

Now if you suddenly and drastically change the stress of the vacuum in which a radioactive nucleus is imbedded, you change the potential placed on the unbalanced nucleus. You hit it, in other words, with a strong EG potential pulse -- an EGP. That instantly unbalances the nucleus and it decays explosively. That is, it changes the decay constant and the probability of decay.

Basically that's what happens in a nuclear implosion weapon: You hit the radioactive hunk of material in the center with a very high, imploding pressure wave, which is carrying an EGP. The EGP causes all the nuclei to decay nearly instantly, producing a nuclear explosion.

The bottom line is: strong EGPs wreak havoc if they happen to hit anything radioactive. Such as nuclear warheads, in missiles or in storage. Such as nuclear reactors. Etc.

Now do you begin to see the problem? Let me spell it out.

Suppose the Soviets have activated some of their giant scalar EM transmitters, to place a giant weather engineering grid over the U.S., or to knock down a Challenger or a Titan. They've got their scalar EM beams all charged up. One of the giant Woodpecker transmitters has -- let's say -- 500 megawatts in its infolded scalar EM standing waves. Everything is going good. They're socking it to the Americans and the Europeans.

All those multiple scalar EM frequencies they're using to form the patterns, etc. have to all be absolutely phaselocked. Therefore all the transmitters have to be rigorously phaselocked, too.

And suddenly something goes wrong. A major amplifier/transmitter controlling or stabilizing the phaselocking malfunctions. The phaselock is disturbed, and begins to quiver.

Emergency circuits react instantly, trying to stabilize the situation and restore the quivering phaselock. Little "shorts" are being applied to the circuitry and to the "giant capacitor" that is the scalar EM standing waves. Dumps and discharges of EM energy are beginning to flash in the transmitter and associated circuits -- and into the ground. These make the situation more unstable. Feverishly the emergency circuits struggle to contain this thing -- and Wham! they cave in, all at once.

Now you get a mighty and continuing discharge of the scalar EM energy in that standing wave back into the transmitter and into the ground. It burns out the transmitter. And the discharge continues as the "capacitor" drains all its EG energy into the earth in a giant pulse.

Around the transmitter site, the EGP is transmitted radially away, still very much like a standing scalar wave. It reaches the first nuclear facility. Let's suppose it's a nuclear reactor. Specifically, let's suppose it's a nuclear reactor at Chernobyl.

If you'll check Soviet Military Power, DoD, 1986 you'll find that there's a big ABM radar site not far from Chernobyl. And Canadian sources verify that one of the large Woodpecker transmitters seems to be sitting in that general location. Now check "The Soviet Nuclear Disaster," The Wall Street Journal, Apr. 30, 1986, p. 24. Check the small drawing in the lower right corner of the bigger drawing. Here you can see that a Woodpecker transmitter located near Chernobyl would ideally transmit nearly due west to intersect over the U.S., entering across North America from its east. Other Soviet "over-the-horizon (OTH) radar transmitters" go over the north polar regions, to enter the U.S. from the North. The two then form a giant interference grid over the U.S. (You can see that in Soviet Military Power.).

Suppose you were in the field in the U.S., measuring the Woodpecker signals. Suppose the stronger beam was coming from the east. You would be able to see this with your instruments.

Now suppose the giant transmitter near Chernobyl got into the type of failure we're talking about. The emergency circuits panic and cut down the EM carriers, trying to drain away the standing scalar waves in a controlled fashion. Then your instruments would suddenly record the "new" direction as coming from the north, since the east carrier is gone.

That's exactly what engineer Bill Bise detected out in California, about the time it appears the reactor at Chernobyl began to get in trouble.

Let's continue with our scenario. Suppose the emergency circuits at the discharging Chernobyl transmitter contain things for awhile. The standing scalar waves are steadily draining into the earth. The EG potential starts to rise at the Chernobyl nuclear power plant.

In the nuclear reactors, the decay constant of the uranium in the fuel rods changes. Additional radioactivity begins to pour out of the uranium. The reactor alarms go off, and the crew takes measures to reduce the problem. The control rods go further in, to slow it down.

But the EG charge keeps increasing. The radioactivity of the uranium continues to increase. The control rods go further in to counteract this. The electrical controls begin to act up, showing anomalous indications. The radioactivity increases. In panic, the controls are fought until the control rods go all the way in. The reactor should in fact now be shut down completely, in normal circumstances.

Things settle and hold a bit. The scalar EG charge increases. Finally the "shutdown" reactor starts to increase in radioactivity again. The control rods can't handle it. Everything is heating up, including the graphite moderator. Back at the transmitter, the emergency circuits finally are overwhelmed and give in. They fail all at once. The dreaded "uncontrolled short circuit" now exists between the collapsing standing wave and the earth. A gigantic discharge of EGP into the earth occurs at the transmitter site.

In the desperate reactor, suddenly a great EGP appears. Instantly the uranium goes intensely radioactive. A gigantic pressure of heat, steam, graphite and radioactive materials bursts out of the reactor, breaching the building and erupting violently into the atmosphere. The core melts down. The graphite moderator ignites. You've got the realization of the nuclear engineer's worst fears: core meltdown and reactor out of control. It's afire and spewing deadly radioactivity out by the gobs. And the heat! It's like hell itself opened up for business in this spot.

At any rate, something very similar to that seems to have happened at Chernobyl.

This author believes something similar happened in 1957 in the Southern Urals. (See Zhores A. Medvedev, Nuclear Disaster in the Urals, Translated by George Saunders, W. W. Norton & Co., 1979, p. 150.). In the Kyshtym area, an explosion of nuclear wastes stored underground occurred in the winter of 1957-58. The area for miles around was contaminated, and is still contaminated to this day.

Recall, Khrushchev spoke of a fantastic weapon in development in January 1960. Early prototypes of the weapon would have been in development and testing in 1957. Probably at that time there were no emergency control circuits to handle standing wave collapse, or only primitive circuits at best.

If the failure of a transmitter occurred in full-power experiments, the unrestrained collapse of the standing scalar EM wave would most certainly have produced a large EGP in the ground, and instantly activated the nuclear wastes stored nearby. Eyewitness accounts reportedly stated that the wastes exploded, and that is totally consistent with our thesis. It is in fact a scalar EM accident signature.

Any nuclear facility at all is an incredible and monstrous risk whenever scalar EM weapons are active.

Of course, one's nuclear facilities are at risk if one's enemy has scalar EM weapons and fires at them, as we covered earlier in this book.

However, they are at terrible risk even from one's own scalar EM weapons. The consequences ot a relatively simple electronic failure can be catastrophic; not only for the local nation, but for the earth as a whole.

To show what we mean:

Suppose a similar scalar EM accident -- such as seems possibly to have happened at Chernobyl -- occurs at some other giant Soviet "radar" facility. Further, suppose this particular transmitter is not too many tens of kilometers away from a Soviet missile silo complex. Just to really throw in the grit, suppose these missiles are the "big monsters" with--- say -- a 50 megaton warhead in each missile. Suppose there are 10 of them in the complex.

Let's say this accident occurs "catastrophically" -- that is, the emergency control circuits are overwhelmed immediately and a discharge of all the scalar energy begins at once.

A giant EGP strikes the earth, spreads in all directions, and strikes the waiting monster missiles. In their implosion trigger warheads and in their fissionable and fusionable payload, everything goes at once. Actually, it goes better than when normally triggered. So each one goes at about 100 megatons.

You've just had a monstrous 1,000 megatons of nuclear explosion in the earth. You get a giant earthquake. If it's not too far from the ocean, you get a tidal wave also. You get incredible amounts of lethal dirt and debris, radioactive and deadly, hurled violently into the air.

This is just about the equivalent of a "normal all-out nuclear war!"

And what about the other side's detection and early warning systems? Who's going to alert whom, and for what? How many missiles get launched?

I think you see the point.

And I haven't even covered what a giant EGP can do to humans. If it's truly a catastrophic failure, you can get an EGP that can wipe out half a mighty nation in one burst!

And if the discharge happens to tickle the Sun and Moon's feedback loops the wrong way, you'll get convulsions of the earth, mighty burps of the sun raining fire and brimstone on the earth, and a violent increase in the interior heat of the earth's molten core, with a concomitant eruption of that core right up though the mantle.

In other words, it could be "back to the beginning" for the earth, and start all over -- if, that is, some semblance of an earth survived.

The Soviets know full well the implications of their giant scalar EM weapons. (Remember, I estimate they have over a hundred of these monsters, based on Frank Golden's detection of their full-up exercise in April/May 1985.).

Scalar EM weapons have added a totally new dimension to the meaning of the word "terror". If one develops them and his adversary does not, nothing on earth can stand against them. So in Man's present state, the temptation to develop them is nearly irresistible.

On the other hand, if one's adversary already has developed them, one is already totally defeated unless one also develops them. Again, the need to develop them is imperative.

Yet, whenever one activates a large scalar EM weapon, one immediately places the entire earth in deadly peril. The slightest misstep, and it's curtains for everyone. And it's curtains for the earth as well.

So one is damned if one does, and damned if one does not.

We have reached the final turning point in human history. The clock is ticking away the last years -- or days -- of the lives of all humans on earth. There has never been such a threat.

We simply have come to the crossroads. somehow, all Mankind has to change.

Infatuated with the thirst for ultimate power, we are facing two doors. Behind one is a beautiful lady, and the fulfillment of all man's dreams: control of physical reality itself. Behind the other is the deadliest tiger ever dreamed of in our wildest nightmares.

Which is it to be, the lady or the tiger?

SCALAR EM INOCULATION AND ITS IMPLICATIONS

My appreciation goes to Gary North for his openly sharing the above important information with the public. Human nature being what it is, one or more of his more dire scenarios is going to happen sooner or later.

The problem becomes enormously more compounded if the hostile agent or agents possesses sophisticated scalar EM technology.

With scalar technology, there exists the potential that the worm or virus can be implanted from a distance. If scalar scanning devices of sufficient precision can be developed, then major software residing in a chip, a computer, or on a disk can be read from a distance. With scalar EM methods, the ordinary software "guards" are totally ineffective. The scalar "reader" could simply read off the software directly as the disk or device goes about its normal operations.

After the software is read, a germ or a virus is designed to produce a particular problem as desired and upon special stimulus. Then a scalar "imprinter" device is used to produce the necessary digital pulses directly upon the media in which the software resides. The required code has now been .implanted. In effect, the operating system has been injected from a distance, and contaminated with the desired "sleeping agent" -- germ or virus. From there on, it's just like Gary North's scenarios.

So the scalar EM technology can probably be used (at least eventually) to place "mines" in systems in advance, for damage or destruction at a future date. At least it's possible in principle.

However, it's not the injection of computers and equipment that bothers me. It's the injection of human beings. Here's generally how it can be done (and possibly is being done).

Basically, human brains have various rhythmic waves which represent "envelope pulsations" of the entire electrical system. However, it is not the EM force fields represented by these pulsations which are important: it is the summed-zero (scalar) patterning of the entire complex of neuron firings which represents the real activity of the brain -- and represents it thoughts and emotions. A storage system for these patternings exists, but it's a scalar pattern storage, not an E and B field storage. The storage system is in the nuclei of the tissues of the nervous system itself, not in electrical or electrochemical potentials.

At any rate, the human brain rhythms are also "riding along" relatively entrained to the Schumann resonance of the earth's magnetic field. So all the patterning of the brain is grouped together into giant overall orders, and one or more of these is normally synchronized to our natural environment.

If a varying magnetic signal of extremely low frequency -- say 10 hertz -- bombards the brain with greater power than the earth's magnetic field, it is possible for the brain's rhythm to be "forcibly entrained" to synchronize with that signal, rather than with the normal Schumann resonance. If a large number of brains are forcibly entrained to such a signal, and the signal is artificial, then a master coherent phasing of all the brains to the transmitted signal has been accomplished.

And that can be utilized -- and is utilized -- by the Soviet Union. On the Woodpecker signals, Bob Beck has detected up to 16 carriers, each with a 10 Hertz modulation, and with all the 10 Hz modulations in phase.

Let's stress what we're saying here. At times, the Woodpecker signals have shown 16 carrier frequencies which contain the same 10 Hertz modulation, and which are all kept coherently sync-locked.

If those signals and the modulations are strong enough, the brains in a targeted area demodulate the 10 Hertz signal and phase-lock to it -- actually, to them. At that point, the brains are entrained to a 10-Hertz driver, and 16 channels of multimegahertz frequencies are locked-in to the brain.

Now if the Soviets have broken the genetic code of the human brain (which they have) and succeeded in developing the ability to implant thoughts, emotions, pictures, etc. (which at least to a degree they have), then they can simply record the proper signals from human guinea pigs, using scalar technology and instrumentation. They can tailor those signals and add them onto the Woodpecker carriers, using scalar EM techniques. By using most of the sixteen carriers as a means to express Fourier frequency expansions, specific areas and functions of the brain can be targeted.

Notice that the distant transmitters al ready "know" the correct phasing; just use the 10 Hertz modulation signal as a reference. In that case, phasing takes care of itself inside the captured human brains.

The brain has a unique characteristic. If a signal arises inside it, it interprets that it itself originated the signal. Thus for the first time in history , true unwitting "robot" actions and emotions can be engendered in masses of human beings.

But it's still worse. The Kaznacheyev experiments (see references) proved conclusively that electromagnetic signals can carry and transmit cellular disease and death patterns into a targeted biosystem. You can rest assured that the Soviets continued on to actually measure and determine a wide variety of death and disease scalar patterns. All of that can be added on to the Woodpecker carriers so that the population in the intersection grid area is devastated. One can even test it out in advance by producing a modified pattern of a disease in the targeted populace, and keeping the percentage of brains entrained down to a small level. This lowers the number of persons "injected" from a distance to a small percentage of the populace. Then the outbreak of the "new strain" of a familiar disease -- such as influenza, pneumonias, and something like AIDS -- can be monitored to provide targeting and effectiveness data. Notice that a series of diseases was experienced by U.S. personnel assigned to the U.S. Embassy in Moscow, probably as a result of the so-called "weak microwave radiation" of the Embassy by the Soviet Union.

But that's not all. Much more subtle effects can be produced in the targeted populace, without anyone getting wise. Cancers and leukemias should be relatively easy to induce. Also, the immune system can simply be attacked directly. If done slowly, a series of common, ordinary diseases will just seem to get "tougher and tougher to cure." Actually it's not the disease that got tougher, it is the immune systems that got weaker. It is my opinion that precisely that sort of testing -- against the immune system -- has been accomplished by the Soviet Union against the U.S. since about October, 1985. A great percentage of influenza patients during the period from then until now have had complications. So much so that multiple sessions -- as many as 3 to 5 -- of antibiotics are necessary before the patient recovers. At least in the Huntsville, Alabama "hinge pin" area, that seems to have been the case. This author personally experienced this, having influenza and follow-on complications for a period of seven months -- something quite different indeed for him.

But it's even worse.

The human scalar EM nervous system ("inside" the ordinary EM signals and functioning of the system) also has its own resident "software." It has special storage media contained in its brain. its cells, and its genetic material, and its actual nucleons. All of these storage media are continually telecommunicated with via scalar EM means. The "stability" of what each of us is, is largely conditioned by those recordings. As personalities we literally "are" what we have experienced, felt, thought, and did. Our whole "functioning conscious system" has been evolved by our experience, and it continues to be "us" by means of continual reference to the record base.

I hope you now realize that the actual record base itself can conceivably be altered by scalar electromagnetic means, even from a distance. Even by the hidden scalar EM content of 16

Woodpecker carriers, locked into a captured brain and pouring in their deadly content. It is conceivable that even what one is can be taken from him, and what someone decides he will be, he will be.

A totally new -- and ultimate -- form of "slavery" has emerged.

Also, look at all this scalar EM functioning of the human system as a special kind of cybernetics. A scalar EM computing software and hardware system.

What if scalar techniques are used to plant "worms" and "viruses" in this system? With hidden triggers? What about a series of them, so that a range of "eruptive software diseases" can be stimulated at will?

And guess what. Such scalar EM "worms" and "viruses" can even be induced by contact with or consumption of "contaminated" water and food. Or saliva. Or other body fluid.

So you can see the possibilities of "seeding" a population with a staggering variety of time-bombs.

I think you begin to see the point. Now you can change North's "Soviet blackmail" scenario drastically. In a new scenario, Gorbachev simply announces to Reagan that a graduated series of specific sweeping changes are going to happen in our population -- changes which we are absolutely powerless to stop. The last stages are various deaths. The master "trigger" for this series has already been initiated. Incidentally, the Soviet populace has been carefully "seeded" with the proper antidotes. The Russian leader demands certain things (very similar to what North's scenario utilized). Unless his demands are met, a "killer virus" will be activated by a special signal. If so, everyone dies. The first step change in the series will start to occur in a few hours. And it does.

In fact, this scenario could be added to North's scenario, and both used simultaneously. What do you think the President and the Congress would do? Or could do?

There are other even more diabolical possibilities, but these should be quite sufficient to illustrate the point.

Pandora's box has already been spilled, and the end of humanity is ticking away like a time-bomb. It's already nearly midnight, and the watchman hasn't even sounded the alarm yet.

I certainly can anticipate the next question: Have the Soviets already "seeded" the populations of the U.S. and other selected western nations with scalar EM viruses and germs"?

The answer is, I simply don't know. And just like Gary North, I don't know what if anything can be done about it if they have. This researcher certainly doesn't have all the answers. An immediate national crash program to develop scalar EM defenses is essential if we are not simply to be crushed beneath the hammer and sickle. It takes funding, people, facilities, and time.

In some 22 years of unrelenting struggle to convince the system we've got a terrible problem, I've hardly been able to move it off dead-center (no pun intended). This book, produced under extreme workload stress, is all I can do to raise the alarm. I've given it my very best shot.

What happens now remains to be seen. Other hands, hearts and minds are going to have to take up the task and carry it forward. This researcher has reached his limit, and has no more left to give.

1986 APPENDIX II

COMPUTER WORMS AND VIRUSES, AND THE IMPACT OF SCALAR EM

Source: - Gary North, "Electronic Aids (Parts 1 and 2)," Remnant Review, 12(20), Nov. 1, 1985, p. 1-8; 12(20), Nov. 15, 1985, p. 1-8. POB 8204, Fort Worth, TX 76124. Phone (817) 595-2691.

Annotation: - Two deliberately un-copyrighted issues to alert the public to software worms and viruses, and their implications for drastic interruption of society. Describes a hypothetical scenario in which drastic scrambling and destruction of banks' computer tapes, files, and records occur due to software worms and viruses. Written in first person by Gary North. [Slightly edited.]

Article: - "Worms." Earlier this year, I read a very interesting article on a major problem facing computer software (programs) development companies. A program comes on one or more 5.25-inch plastic discs. It takes only a few seconds to copy a program on one disc to a blank disc, which costs $3. Yet these programs normally run at least $250, and usually sell at $495, and sometimes cost thousands. Very few are less than $100. So you have a major temptation: make a $500 asset out of a S3 asset. Insert the $500 program into drive A, write "COPY A:*.*.B:" and hit the "enter key;" sixty seconds later, you have a $500 program in drive B.

There are ways to make this copying more difficult. The companies code the programs, and force you to have a control disc in drive A at all times. These "copy protected" programs are a hassle for users. We cannot put them on "hard (big) disc" easily, and sometimes the control disc dies for some reason. Then what? Your data are locked in your hard disc or on a floppy disc, but you can't get to the data because the control disc is not functioning. You order a replacement. Weeks go by.

Last year, several firms came up with a solution. It is called a worm. A worm is a command that is built deep into the complex code that creates the program itself. These are incredibly complex codes, and it is easy to bury a command in them. They cannot be traced.

What does the worm do? It "eats" things. Say that you are a software thief. You make a copy of a non-copy-protected disc, either to use on a second computer, or to give (or sell) to a friend. The program works just fine. But when the program is copied to a new disc, the worm is "awakened." It bides its time, maybe for many months, maybe for years. The program's user is blissfully unaware that a monster lurks inside his pirated program. He continues to enter data, make correlations, etc. He becomes completely dependent on the program.

Then, without warning, the worm strikes. Whole sections of the data disappear. Maybe the data storage disc is erased. Maybe it is just scrambled. Even his backup data discs have worms in them. Everything he entered on those discs is gone. Forever.

Can you imagine the consternation of the user? He has become dependent on a booby-trapped program. His business could simply disappear. For the savings of $500 (stolen program), he could lose everything he has.

Several firms threatened to insert worms into their programs. But then they backed off. They are afraid that lawsuits initiated against them might go against them in court. They could be hit for damages suffered by the thieving victims. Juries might decide that the punishment, a bankruptcy) was too much for the crime (a $500 theft).

So far, no worms are lurking in any commercial software programs — as far as I know and the industry knows, anyway. But what if a disgruntled programmer was to hide one in a master copy of, say, Lotus 1-2-3, the most popular business program on the market? What if ten thousand copies a month go out for, say, three years? Then, without warning, every company that has started using them loses three years of data? They sue Lotus. Lotus goes bankrupt paying lawyers. No company in the industry is willing to talk about this sabotage threat publicly. Obviously.

LARCENISTS

I just happened to stumble across an article on worms in a computer magazine. It occurred to me that it might be possible to use the worm technique as a form of deliberate sabotage rather than just as a copy protection device. But what did I know? I'm not a computer expert.

I know a computer expert, however. I mean, a real expert — one of those people you occasionally read about. In the world of business, they're called "space cadets." They operate somewhere in between the asteroid belt and Jupiter. But this one is different. He's a businessman, too.

I got him to sit down with me to discuss the problem of worms. It turned out that he has a real fascination for the topic. He tells me that there are advanced design worms, called 'viruses' by 'hackers' — computer freak programming geniuses. "The software virus is the most terrifying thing I've ever come across," he told me. And then he showed me why. My initial scenario is based on only a portion of his estimation of the threat. It gets a lot worse.

He gave me a 90-minute FIRESTORM CHAT interview. He must remain anonymous. He used to be a software developer for programs that were used in the U.S. banking system, but is now employed in a highly sensitive job in a related industry. Therein lies his problem. If he were to tell the story of what he is capable of doing to these banks, his firm might lose a lot of sales. He can't "go public." Let's call him Tom.

Let me summarize briefly some of the details he gave to me. They floored me. They're going to floor you.

(1) Jackpotting. The rush is on in the banking world to get automated teller machines (ATM's) into shopping malls, supermarkets, and in front of every bank. We've all seen them. Just walk up, punch in your card number, ask for cash, and you get it.

In a busy location, one of these machines can hold as much as $250,000 in cash, mostly small bills. These machines are controlled by computer. They are hooked up to the bank's computer system, usually by phone lines. This local line, Tom tells me, is what computer freaks call THE LOOP. The loop is wide open to tampering. He says that what computer thieves are doing is to hook up a cheap Apple II computer, tie into the phone lines, break into the ATM, and get it to empty itself. This is "jackpotting."

He tells me that ATM thieves are hitting banks continually, but nothing is getting to the press. The banks have yet to show a profit with the ATM's so far, which is understandable. They are hoping to get their machines placed in key locations, so "market share" is crucial to their plans. They are suffering horrendous losses in the short run in the hope that long-run profits will pay off, if and when a defense is developed.

The banks are saying nothing because of their fear that if the extent of the losses gets into the press, they will be forced by pressure from depositors — bank runs — to cancel the ATM's. The losses are horrendous, he says. At present, there is no known defense, given the communications technology.

(2) Rounding Off. This is the "preferred" computer bank theft system. Someone on the inside who has access to the software takes advantage of the banks' need to round off numbers. The programs carry numbers out to 13 places. Banks can't use all that space. So when they balance the books (interest rates at, say, 9.873), they just don't count every tenth of a cent. The program is assumed to round off the numbers randomly. What does the bank care? But the thief has set up bank accounts that absorb those random tenths or hundredths of a cent. In millions of dollars worth of transactions (federal funds, etc.), programmers in some cases have stashed away hundreds of thousands of dollars — maybe millions — over a few years. No one knows how much of this goes on.

How could a bank spot this? The books would always balance to the penny. How would the accountants ever know?

I think of a story that Adam Osborne tells in his paperback book, Running Wild. The president of a large firm was looking out his window one day, and he noticed two Rolls Royce cars parked next to each other. He inquired as to the owners. They were two men in the data processing department. He called in investigators, and the cars and the men disappeared. They fled to Brazil and took their cars with them; **Brazil** has no extradition treaty with the U.S. Years later, as

Osborne was writing the story, the firm still hadn't figured out what they had done.

ARSONISTS

These are the fearful ones, far more than the larcenists. These are the practical jokers who get into a major data bank and trash things. It's a kind of multimillion-dollar "Kilroy was here" graffitti.

How easy is it to get in? Incredibly easy. The boy in "War Games" really could have broken into most firms' telephone-connected computers. Computer programs exist that allow the user to hook up his computer to a phone line and randomly dial numbers until they hear the telltale whine of a computer line. It then notes the phone number and goes on its way, searching out more lines.

They can do it by long distance, free of charge. The telephone company has a tough time tracing those who use various sorts of electronic black boxes to call anywhere on earth at no charge. Some people get caught, of course. "The tip of the iceberg," says Tom.

How do they get in? Easy: few systems are protected, once you locate the line. If one is, he says, you create a deliberate error. Most programs then collapse the protective shell, and the hacker finds himself inside the heart of the system. Tom has designed a program that keeps this from happening to his company's programs, but few companies have anything like it.

It's very easy to get in if someone has "logged on," — opened his terminal's connection to the main computer — if the system is connected to phone lines. Or anyone in the company can just tap in, if someone has left his desk and left the computer on. It's common to forget and leave an open terminal.

He showed me. He says anyone can get fired for leaving a computer on. He demonstrated his point. With 40 computers on line, he ran a quick search and found two of them "logged on," despite the fact that it was after hours. All the security in the world can't do anything if a computer line is open. It's like a burglar alarm; it's worthless if you leave the door unlocked or leave the keys lying around. That janitor you hired. Is he a computer illiterate? Or a plant?

Once inside, what can you do? Steal a fortune? Yes, if you really know the system. He told me he could easily steal $3 million from a local bank, even as an outsider. He would then offer to give it back and keep his mouth shut about how easy it was if the bank would pay him 10% the take. He thinks most banks would capitulate for fear of the publicity. In any case, he knows that he probably wouldn't get caught.

How about creating a new identity? The grade-changing scene in "War Games" is true. You could even create a new identity, give yourself high grades in any academic discipline, just by breaking into a university's database. There is very little security here, he says.

But for sheer vindictiveness, for sheer envy, consider the possibilities of a virus-implanter. He gets inside the computer for a major communications link: telephones, large information database, bank wire transfer, or whatever. Then he lays the egg: a tiny, untraceable brief instruction. Inside a huge database are just a few characters. These float inside a system, seeking to devour certain kinds of data, or executing certain routines.

There is a game played by computer freaks called "Core War." They try to implant these killer messages, which seek out each other and battle one another. If you find one morning that yours has been consumed, you lost the battle. That was probably the origin of worms and viruses.

TERRORISM

Say that a revolutionary terrorist group, or some anti-zionist group gets a "ringer" into a system. He might be a computer genius type. Everyone knows they are either oriental, dark-skinned people with accents, or teenagers. The firms don't hire teenagers, but they hire a lot of foreigners. They may even check the guy's credentials. Electronic credentials. (Ha!) Then they turn the guy loose in the system.

The virus is implanted deep inside the system. It can then be transferred to any other bank's computer by means of EFT (electronic funds transfer). Maybe it is triggered when someone with a peculiar name and address opens a bank account. Three days later: Bam! The data disappear. They haul out the back-up tapes. Bam! The virus is on them, too. It is a process of infection, contamination, and incubation. There is no known defense. Not yet. This is the bottom line.

ANTIBODIES

The designer of a virus can also design an "antibody." The antibody is a counter-virus agent that seeks out a virus and destroys it. But like other antibodies, it must be specific. The only way today that an antibody system can be created is to know what kind of a virus is involved beforehand.

Tom says that people are now selling antibodies at very high prices. Who is paying? Big companies that suspect that there is a virus present in their computers. In all probability, the guy selling the antibody created and injected the virus. But now can any businessman prove it? So he pays the blackmail.

NATIONAL DEFENSE

A Soviet agent or American spy working for the Soviets penetrates any of a dozen computers used by the military. He plants a virus. The computers talk to each other, and the virus spreads to all of them. It tells them to execute a certain routine when a certain command is entered at a missile-controlling terminal. That command might interfere with a routine that activates a missile or launches it. Upon reading that command, the virus shuts down the computer, or scrambles the executing program, or scrambles the data. No more "launch on warning." No more launch at all. Dead metal.

Scenario: The President of the United States receives a telephone call on the "red phone" — the direct link to Moscow. He lifts the receiver and says, "Hello."

"Mr. President, this is Michael Gorbachev. You must recognize my voice. I have very little time. I will come directly to the point. You have refused to back down on your threat to implement your Strategic Defense Initiative. You intend to go ahead with space-based weapons. My military staff informs me that they think that the United States has the technology to implement it, and that it could place my nation's military strategy in jeopardy. We cannot allow you to do this.

"If we allow you to deploy the SDI, it will be too late for us to respond effectively. Therefore, we are taking the initiative today. I issued orders this morning to put Soviet military units on immediate alert. We are abiding by your biblical rule to announce the initiation of hostilities before striking. Neither the Japanese nor the Germans gave us this courtesy. If you do not come to terms with us, we will launch a first strike against your nation in three hours. We will delay for one day, if you agree to follow a precise procedure that I will outline shortly.

"At one time we feared nuclear retaliation. We no longer do. Within two hours, you will know why not. I suggest that you instruct your ballistic missile team to prepare your missiles for a strike. Then, to prove to yourself that we no longer are concerned about retaliation, launch one or two of them. As far as I am concerned, launch all of them. But please instruct your senior military commanders to report back to you concerning the effects of their instruction. I suggest that you try launching three or four as a test. We don't care which ones.

"Mr. President, let me tell you what is going to happen. As soon as anyone attempts to launch a missile, that missile's computer guidance system will shut down. It will lock up tight, and you will not be able to unlock it within the time you need to respond to our attack. Two hours and thirty minutes from now, your nation will have no remaining Minuteman III missiles to respond with, should you finally unlock your frozen computers.

"I suggest that you contact your senior officers now. You will have to mobilize them within 60 minutes. The test should take about 30 minutes. I will telephone you again in 90 minutes to present our terms of surrender." Click.

The President calls the Joint Chiefs. If he is lucky, he will be able to locate two of the three in time. They will be paralyzed. Who wouldn't be? But in all likelihood, they will at least test Gorbachev's theory. They will order one or (wo missiles launched. The computer guidance system on both will shut down the system. They will try two or three more, with the same result. They will attempt to launch one from a submarine, with the same result.

The President brings in senior Congressional officials and the remaining Joint Chiefs member to the White House.

Exactly 90 minutes after he had hung up, Gorbachev telephones back. He presents his list of demands. First, the immediate removal of U.S. troops from Europe. Second, the withdrawal of personnel from Diego Garcia Island in the Indian Ocean. Third, the breaking of diplomatic relations with Red China and Taiwan. Fourth, the removal of all U.S. troops from Korea. Fifth, a moratorium on all debts owed to U.S. banks by the Soviet Union and its client states. Sixth, the removal of all Minuteman III missiles from their silos. Seventh, the return of all U.S. submarines to port. If he agrees, and the orders are delivered within two hours, the Soviet Union will delay launching a first strike. The President complies.

They might do it with our communications satellites, Tom says. You might do it with any aspect of U.S. data transmission. The virus could sit dormant in a system for years, and no one would know. Triggered, it would then strike.

THE WEST'S VULNERABILITY

The West has become increasingly dependent on computers. We can no longer function without them. The Third world hasn't. Neither has the U.S.S.R. Their technology is still pre-computer. They are inefficient, but they are far less vulnerable.

Tom says that the world of computers presumes that almost everyone is essentially honest, and that all the brightest programmers must be honest. They aren't. Thus, the members of the entire system — banks, national defense, large and small businesses, public utilities — have opened themselves to attack. The attackers are invisible.

"Nothing I have seen in all my years of computers scares me as much as this does," he says. "The system has been designed in terms of a far older set of standards, especially with respect to security. It is totally vulnerable."

He compares it to plague, or venereal disease. People copy each other's software to save a few bucks. They use public access databases. They use "loops" — the phone lines. Yet these transmission belts of information can become transmission belts of collapse.

This is what I have harped on for twenty years: the potential for a collapse of the division of labor. We become rich by means of a brilliant technology, yet we become dependent on it to an extent that no previous society ever has.

Centralized institutions are most vulnerable, but because we use public transmission lines, from microwave transmissions to cables in the ground, each local unit is vulnerable. Those who would choose to bring down the system need only plant electronic viruses in a handful of major common-use databases or transmission sources, and live years or ten years later, the disease hits.

It could bring down the system if technological defenses are not developed. Nothing on the immediate horizon points to a solution, he says. The silence of those who should know what to do indicates that they don't know what to do, but they don't want panic to spread.

Is this fantasy? Last summer a 23-person team broke in (by phone) to Chase Manhattan Bank's computer.

Break-in: - Continuation of part 1, a treatise on worms and viruses in cybernetic systems.

"Maybe you saw the article buried somewhere in your newspaper. I saw it in the New York Times (Oct. 19):

> "A group of at least 23 teen-age computer users broke into a Chase Manhattan Bank computer installation by telephone in July and August and "significantly damaged" bank records, the Federal Bureau of Investigation said yesterday.
>
> Chase officials insisted that no money was stolen or transferred out of customer accounts as a result of the break-ins, and said no intrusions have been detected recently. But Federal officials, in an affidavit, said that in several cases the youths changed passwords, preventing customers — and in one case a unit of the bank itself — from gaining access to their own computer files."

And where were these teen-agers located? In San Diego, across the continent! It gets even more ludicrous:

Federal officials said that most of the offenders were probably too young to be prosecuted.

Robert D. Rose, the assistant United States Attorney handling the case, said: "We're not yet sure what we are going to do. But these things can get out of hand — it did get out of hand — and we have to treat them seriously."

Treat what seriously! "These things?" What things? If they can't legally treat the electronic trespassers seriously, just what is the man talking about? He is talking about the topic, above all topics, that bank and government officials don't want to face: the vulnerability of their computer records.

I have seen no follow-up on this story in the conventional press. A brief article did appear in the computer-oriented tabloid, Info World (Oct. 28). It turns out that the students had broken into the fifes of Interactive Data Corp. of Waltham, Massachusetts, which maintains the bank's financial records. The break-ins were discovered in late July. They had obtained the toll-free 800 number which was restricted (Ha!) to Interactive Data subscribers. As late as October 9, an illegal entry was observed. In short, it took ten weeks after the break-ins were discovered to put a stop to them.

The response of the bank's bureaucracy was predictable. It will ever be thus: "Bank officials are claiming that the FBI exaggerated the nature of the activities of the suspected individuals. A spokesperson for Chase Manhattan said that Interactive's customers were not prevented from accessing their accounts and that none of Interactive's data was altered or manipulated in any way." In response, FBI supervisory agent John Kelso said that the FBI has sworn affidavits from bank officials that say data has been manipulated or damaged. "That sounds pretty serious to me," he volunteered.

Here is the capper: Interactive Data has 25,000 subscribers who are tied into that toll-free phone line. Try keeping tight security on a system with 25,000 users. Chase Manhattan couldn't. If they can't, who can?

And if Chase Manhattan Bank was vulnerable to 23 teenagers who are too young to prosecute, consider its vulnerability to just one envy driven genius who knows all about electronic viruses. The students that did this were apparently just goofing around. But what if just one malevolent computer freak decided to "get even" with Chase Manhattan? What if he had phoned in just once or twice, implanted a long-dormant data-killing virus, and quit? What if he had tied its detonation to, say, a calendar clock in the Interactive computer? If it took security forces from July until early October 15 to raid the 23 students' homes, they would never have spotted one break-in. They could not have traced it, either. Conclusion: we have a risk-free opportunity for electronic arson. We face a potential electronic epidemic. And when I say "we" I mean the entire financial system of the West.

Sure, all the bank "spokespersons" in the world will tell you, "No problem." But there is a problem. A horrendous problem.

At this point, it really gets interesting. Chase Manhattan Bank has just announced that we will be able to set up our own personal electronic banking facilities with them by buying an expanded version of *Managing Your Money*, Andrew Tobias' home financial management.

Citicorp and Bank of America have opted for *Dollars and Sense* a rival program. You will be able to pay monthly bills electronically, balance your "checkbook," monitor your net worth, buy and sell stocks, etc., etc., just by dialing Citicorp or Chase Manhattan. Fantastic! But despite all the assurances, I get nervous. Yes, I know no one will be able to break in and tamper with the numbers. But 23 teenagers shouldn't have been able to do it, either. And now we're talking about a lot more subscribers than 25,000.

Obviously, the master program used by the banks will prohibit easy entry. Unfortunately, someone has to write the program. Can you imagine the blackmail possibilities? Some hotshot programmer could build-in a bomb, and then threaten to detonate it. In fact, he could merely pretend to have inserted a virus. Who would want to call his bluff? Not Chase Manhattan, I would bet.

CORE WARS REVISITED

In May of 1984, A. K. Dewdney published an article in Scientific American's "Computer Recreations" column. It was a light-hearted-piece on how computer experts can get involved in playing this exciting game of "blow up your opponent's defenses." You know: recreation! In the March 1985 issue, he wrote a follow-up. It begins:

"When the column about Core War appeared last may, it had not occurred to me how serious a topic I was raising. My descriptions of machine-language programs, moving about in memory and trying to destroy each other, struck a resonant chord. According to many readers, whose stories I shall tell, there are abundant examples of worms, viruses and other software creatures living in every conceivable computing environment. *Some of the possibilities are so horrifying that I hesitate to set them down at all.*"(emphasis added.)

It turns out that tne French nave been enjoying a novel on the international implications, *Softwar: La Guerre Douce,* by Breton and Beneich. A translation is scheduled for publication here by Holt, Rinehart & Winston. The study revolves around the sale of a high-power computer to the Soviet Union. The U.S. allows its export because it has a "software bomb" in it. When the U.S. Weather Service announces a certain temperature at St. Thomas in the Yirgin Islands, the program proceeds to subvert every piece of software in the Soviet Union.

A pair of Italian programmers was "inspired" by the translation of Dewdney's original article to dream up a virus (a virus is a computer-to-computer killer, whereas a worm is resident in one man's computer). They figured out that by infecting a disk operating system disk (these start computers and tell them what to do with programs and electronics), and then installing it on disks used by the biggest computer shop in the city, they could create an epidemic. They decided not to do it. In short, the only restraint is self-restraint.

A high school student in Pittsburg wrote a virus that was subtler than a data-destroying virus, which at least tells us that we have a problem. His virus created a plague of very subtle errors in the disk operating system. "All of this seems pretty juvenile," he wrote, but "Oh woe to me! I have never been able to get rid of my electronic plague. It infested all of my disks, and all of my friends' disks." He wrote a program to destroy the virus (an "antidote" to it) but it is not anywhere near as effective as the virus is.

Warning: do not copy disks from your friends' copies. This act of piracy could cost you plenty.

A COMMERCIAL WORM

Just a few days after I wrote "Electronic AIDS, Part 1," 1 read a column in the Washington Times, the conservative (Moonie-owned) daily newspaper. One of the reporters has a computer. He had purchased a newly released program from

Microsoft Co., called "Access." Understand that Microsoft supplies the disk operating system that is used by the IBM PC, the most popular microcomputer. In other words, this is no backyard company. It is one of the two or three software giants in the U.S. (Its owner is under age 30, which tells you something about who is pioneering the microcomputer revolution).

As he was setting up his computer to take advantage of this telecommunications program, a warning flashed on his screen: "The weed of crime bears bitter fruit. Now trashing your program disk." Wham! He lost all his files — probably a couple of year's worth of work. Sure, he was probably smart enough to have made back-up copies, but think of the risk. And what if it had been a worm that kept silent for a few years, infecting all of his back-up disks?

He called Microsoft, and they gave him the runaround. They told him that they were not responsible. Some programmer had put in the worm in order to zap program pirates, but the journalist insisted that he was an original buyer. Tough luck, they told him. Obviously, they didn't know that he was a reporter.

Then he published his article. All of a sudden, the victim was not some average buyer. He was big trouble. Things started moving. InfoWorld (Oct. 28) reports that Microsoft has admitted that a programmer put in the worm, but without permission. The offending text has now been removed, we are assured. But what if it had sat in the master for three years? Here is the premier firm in the software.

This is not idle speculation. It has already happened, verifying my hypothetical scenario within a few days after I published it.

Can you imagine the absolute havoc that a dormant worm or virus could create if it were imbedded in all updates of Microsoft's masters of PC DOS and MS DOS, the operating systems for all IBM microcomputers and IBM-compatible microcomputers? It could cost the U.S. economy billions, and some microcomputer-dependent firms wouldn't survive. Any Microsoft spokesman who says, "It's impossible; it could never happen," has to explain how it already did happen to "Access."

ADAM OSBORNE'S WARNING

You may know the name Adam Osborne. He invented the revolutionary portable computer, the Osborne 1. Before there was an Osborne 2, the company went bankrupt. Compaq, the most successful first-year firm in U.S. history (over $100 million in sales in its 12 months of operations) and others built imitations that were far superior.

That isn't my point, however. Adam Osborne was "present at the creation" of the microcomputer industry. He created Osborne publications, and then sold out to McGraw Hill. He knows what is going on. In his delightful paperback book, Running Wild, which is a history of the microcomputer (desk top) revolution, 1975-82, he offers this warning. He says that three areas should not be allowed to be computerized: 1) bank money transfers; 2) the stock market; 3) elections.

All three are just about fully computerized. Another ten years, or maybe five, and they will be 100% computerized. Several firms allow microcomputer buying and selling of stocks (e.g., Charles Schwab), and New York Stock Exchange floor transactions eventually will be fully computerized, at which time it will be pressured to get rid of the "specialists" who make (and sometimes manipulate) the market, short-term — Richard Ney's hated "Wall Street Gang" — but the price of getting rid of them may turn out to be horrendously high.

"The great fortunes of the 21st century," Osborne predicts, "will be the legacies of the great computer thieves of the 20th."

Three years ago, I used a firm to supply computer services I needed. The head of it was a former businessman, quite young, and a true "space cadet." I've quoted him in the last issue. I call him Tom. He operated in a world far removed mentally from the rest of us. He is a nice fellow, a Christian, and a moral philosopher of sorts.

He ran the operations of the local elections. He did it fairly inexpensively. He told me why: "I want to keep these elections honest. It would be incredibly simple to rig the program to produce whatever outcome I wanted in close races. If I can do it, anyone with enough skill to set up the system could do it."

I asked him if he thought Osborne was correct in his predictions about bank theft. "It would be a piece of cake for me to steal three or four million from any local bank. I could go in the next week, offer to give the money back, keep 10% as a finder's fee, and promise not to tell the press how easy it was to steal. They would probably pay me my 10% just to keep me quiet."

Look, These people are geniuses. Worse, they are geniuses in a very narrow field technically, which is now being used to control darned near everything. This unique intellectual-technical skill is the possession of literally a handful of people, mostly under 35 years of age. They are "fooling around" with Chase Manhattan Bank's computers. What happens when a few of them stop fooling around and get deadly serious?

Computer program designers keep telling us that there is no 100% secure way to defend data banks. Maybe there will be a 98% secure system someday, but not now. To defend itself, the system relies on the integrity of youth. In short, self-government is the major defense.

And where have they learned self-discipline? In the public schools?

"NOW YOU'VE DONE IT!"

About four years ago, I read an article in the *Rolling Stone,* the tabloid aimed at rock music fans. It was the only article I ever read in that periodical. It was a gem.

It described a subculture of students at Stanford University, "hackers." These people are computer freaks. The mainframe computer at Stanford was cheaper to use after midnight, so from midnight to 6 a.m., the hackers gathered at their terminals. They lived on candy bars, junk food, and high-technology dreams.

One of the games they played was breaking into each other's programs. It was considered the mark of a master hacker to be able to crack another hacker's defenses. They would spend hours trying. They were "hacker-crackers."

One bright fellow then designed a classic booby trap. He wrote a program that warned trespassers not to tamper with it. This, of course, alerted every would-be electronic safe cracker to the challenge. It was a complex program, and it took days to crack it. Then, after repeated warnings, the successful trespasser got a surprise. Japanese letters appeared on his screen. Roughly translated, the words proclaimed, "Now you've done it!"

At that point, the victim's computer screen went blank. Then the names of all his own computer files appeared on the screen — files that may have taken years to assemble. One by one, they blipped off the screen. In horror, the victim would stare at the screen, unable to stop the process.

As it turned out, the booby trap was only a practical joke. It really didn't erase all the victim's files. It only listed the names, and then erased them. But for a horrifying few minutes, the victim wouldn't know this.

Hackers play games. Very interesting games.

The kind of people who spend six hours, midnight to 6 a.m., trying to break into each other's programs are different from the rest of us. Among their ranks are some highly individualistic people. Some of them are libertarians. I mean anarchists. They are electronic "don't tread on me" sorts of people. They do not appreciate bureaucracy. They appreciate being pushed around even less.

The folks at Chase Manhattan really do have a problem. Do you attempt to prosecute a legally un-prosecutable kid? A kid who has already cracked your computer system? I don't think you do. You play the role of stern but appreciative banker. "Son, I am impressed by your ability to break in. But understand, we are honest people. There is a code of honor here. You wouldn't want to break that code — of honor, I mean — would you?" Because if this kid gets angry, he can do it again. Quietly. And next time, he deposits a virus.

Of course, Chase may hire a programming team to create an unbreakable system. Sure. "Hire fox A. Give him chain link fence B. Hire him to build fence B around chicken coop C."

TEEN CHALLENGE

Suppose that the public gets wind of the threat to the whole banking system that is posed by viruses. What do the bankers (or anyone else) announce to the public? "We want to assure you that our computer program is impenetrable. No one can break in. It is foolproof."

Here is the challenge — rather like the Stanford program that announced: "Do not trespass." These kids see breaking-in as a challenge, a kind of sport. They do not regard it as theft. They do not regard it as vandalism, even if it costs a company millions of dollars to unscramble. They may be ethical in other respects, but they think of "core wars" as a game.

How would you like to be the 60-year-old banker who doesn't know a byte from usury, but whose public relations department tells him to inform the public that nobody can crack his bank's code? To cite Mr. T in "Rocky III," that bank is dead meat. So are its depositors.

But if he keeps quiet, and the story still gets out about the vulnerability of the system, one or two small "virus-demolished" banks could trigger a collapse of the system, as people do the only smart thing: run for cash. The whole fractional reserve banking system would deflate; only the FED's printing presses could "save the day," in a wave of fiat money.

What I am saying is this: I think that we will see the end of fractional reserve banking in our day. At the very least, I think we will see it subjected to tremendous shocks. People will lose faith in electronic promises made by bureaucrats who do not know anything about the monsters that their efficient computers can be turned into.

Attack on Martinsburg. Now, let's take it a step farther. Some day some state or Federal bureaucrat is going to step on the toes of some genius entrepreneur who has created a software development firm. The bureaucrat will try to wrap this entrepreneur in red tape. Or maybe — just maybe — he will try to sock him with a tax bill that the entrepreneur regards as unfair.

In Martinsburg, West Virginia, there is a large computer. It is owned and operated by the Internal Revenue Service. Into it, over the next five years, the I.R.S. apparently intends to deposit all the records it can assemble on every U.S. taxpayer. This computer database will be the biggest in the world. It is the tool by which the I.R.S. hopes to increase taxpayer compliance. And it may succeed. For a while.

This is one reason for saving all letters to and from the I.R.S. If the I.R.S. becomes dependent on its computer system, which is likely, then any short-circuiting of its database could create havoc for tax collecting. If word gets out that a major failure has hit the I.R.S., the tax revolt could multiply overnight. You would see the deficit become astronomical. If the I.R.S. continues to tie its "voluntary" compliance program to the myth of the "all-seeing computer," then news of the computer's scrambling could backfire.

It is possible that the story of the I.R.S. database is a myth. Maybe they aren't going to build it. But if the public believes that such computer power is at the disposal of the I.R.S., and taxpayers then learn either that the system has been blown, or that it was mythical from the start, the tax revolt could spread like an epidemic. The electronic epidemic-could trigger a tax revolt epidemic.

He who lives on the cutting edge of technology eventually dies on the cutting edge of technology.

"PEOPLE ARE BASICALLY GOOD"

Let's return to my taped interview with "Tom." In a 90-minute interview, we covered a lot of ground. But one topic that stands out in my mind is our discussion of the pre-supposition that goes into the creation of a computer-based society. The computer people have all adopted the assumption that undergirds modern science, namely that, participants are well meaning, that they will not fake their experiments, and that they will play fair. If scientists had to check every aspect of every article, science could not advance very fast.

What about the computer industry? The whole system rests on faith: "Men are not malevolent. They are not envy-driven. They will not deliberately seek to destroy the work of some random victim." Tom says categorically that this assumption is false. There are bad people with tremendous computer skills, and modern society has not restructured its economic institutions to protect itself.

Here is one example of a break-in technique. Someone phones in to a computer, which has been left open temporarily by some user. The lock is unlatched; he needs no key to get in. He then seeks to penetrate the inner core of the program, such as a bank's program. He creates a deliberate error, which all too often triggers a kind of electronic explosion. The protective shell self-destructs, and the invader now finds himself inside the system, where far fewer defense mechanisms exist.

Tom designed his own firm's defense against this tactic. His program automatically records the source of the error, and throws the user out of the program. The program has protection against deliberate errors, but most of them don't, he says. A major error simply collapses the program's outer shell.

In my previous issue, I speculated that a Soviet spy or agent could penetrate U.S. computers. Note: I did not assume that he would simply phone in; I assumed that a disloyal programmer, or a team, could plant the virus as insiders. From there, the virus would spread through the system through normal telecommunications. Several people have written in to tell me that a wrecker cannot destroy the system by penetrating it from the outside. They may be correct. But when informed that I am assuming an inside job by someone with access to a major computer, the critics have admitted that this might be possible.

The weed of crime bears bitter fruit: for honest, computer-dependent people.

FEDERAL FUNDS

The Federal Funds bank transfer lines allow banks to borrow money overnight. Hundreds of billions of dollars go across these lines every working day. The bank's computers communicate with each other by means of this telecommunications hook-up. What if someone were to plant a long-delay virus in the software that operates these transfers? And what banker has even thought about this problem?

What if this scenario was to take place: a virus triggers the disruption of bank records — not a total breakdown initially, but disruptions in the data? It might be weeks or months before auditors recognized the extent of the problem.

As rumors begin to leak out about complex accounting or other data-management problems of major banks all over the U.S. (including off-shore branches), the various banking regulatory agencies would be swamped with crises and outside rumors. Then, all at once, bank computers begin breaking down.

The rumors then explode. The lines appear in front of banks. The only answer at this point is to print up paper money. It would be printed by the hundreds of billions in order to offset the deflationary effects of bank runs (paper money that is pulled out but not re-deposited in another bank).

You could topple the fractional reserve banking system all over the world. The entire payments system could easily become engulfed in chaos. Debits and credits would no longer be meaningful. A pure paper money inflation would replace the manipulated, "fine-tuned" monetary inflation of modern central banking.

All of a sudden, market-created alternative currencies would be revived. It would then be metallic cash that talks loudest. Silver dimes are not electronic. "They can't be infected electronically." They still circulate when banks are "temporarily closed, due to circumstances beyond our control."

The loss of efficiency would be initially horrendous, I would guess. The division of labor would break down. You could then have the crash that lurks in the minds and suspicions of average depositors. Who says it cannot happen? A lot of public relations firms hired by the banks — computer illiterates in high places?

What we have is an internal bank money wire system that is totally vulnerable to some vindictive programmer. There is little doubt in my mind that the bankers are desperately fearful of this sort of vandalism. It could topple people's confidence in the fractional reserve banking system, and confidence is the only thing that keeps it going.

Conclusion. Technologically, there is no solution at this point. I have no heartening message. Maybe later; not now. Keep precious metal coins. Don't assume that it can't happen here. It can. The only thing holding it back is the restraining hand of God, through the temporary self-restraint of a technological priesthood.

[Reviewer's comment: I was unaware of the problem of computer worms and viruses until I read Gary North's two articles. His open release of this important information is appreciated.]

SCALAR EM INNOCULATION AND ITS IMPLICATIONS

My appreciation goes to Gary North for his openly sharing the above important information with the public. Human nature being what it is, one or more of his more dire scenarios is going to happen sooner or later.

The problem becomes enormously more compounded if the hostile agent or agents possesses sophisticated scalar EM technology.

With scalar technology, there exists the potential that the worm or virus can be implanted from a distance. If scalar-scanning devices of sufficient precision can be developed, then major software residing in a chip, a computer, or on a disk can be read from a distance. With scalar EM methods, the ordinary software "guards" are totally ineffective. The scalar "reader" could simply read off the software directly as the disk or device goes about its normal operations.

After the software is read, a germ or a virus is designed to produce a particular problem as desired and upon special stimulus. Then a scalar "imprinter" device is used to produce the necessary digital pulses directly upon the media in which the software resides. The required code has now been implanted. In effect, the operating system has been injected from a distance, and contaminated with the desired "sleeping agent" — germ or virus. From there on, it's just like Gary North's scenarios.

So the scalar EM technology can probably be used (at least eventually) to place "mines" in systems in advance, for damage or destruction at a future date. At least it's possible in principle.

However, it's not the injection of computers and equipment that bothers me. It's the injection of human beings. Here's generally how it can be done (and possibly is being done).

Basically, human brains have various rhythmic waves, which represent "envelope pulsations" of the entire electrical system. However, it is not the Et, force fields represented by these pulsations which are important: it is the summed-zero (scalar) patterning of the entire complex of neuron firings which represents the real activity of the brain — and represents its thoughts and emotions. A storage system for these patternings exists, but it's a scalar pattern storage, not an E and B field storage. The storage system is in the nuclei of the tissues of the nervous system itself, not in electrical or electrochemical potentials.

At any rate, the human brain rhythms are also "riding along" relatively entrained to the Schumann resonance of the earth's magnetic field. So all the patterning of the brain is grouped together into giant overall orders, and one or more of these is normally synchronized to our natural environment.

If a varying magnetic signal of extremely low frequency — say 10 hertz — bombards the brain with greater power than the earth's magnetic field, it is possible for the brain's rhythm to be "forcibly entrained" to synchronize with that signal, rather than with the normal Schumann resonance. If a large number of brains are forcibly entrained to such a signal, and the signal is artificial, then a nester coherent phasing of all the brains to the transmitted signal has been accomplished.

And that can be utilized — and is utilized — by the Soviet Union. On the Woodpecker signals, Bob Beck has detected up to 16 carriers, each with a 10-Hertz modulation, and with all the 10 Hz modulations in phase.

Let s stress what we're saying here. At times, the Woodpecker signals have shown 16 carrier frequencies that contain the same 10-Hertz modulation, and which are all kept coherently sync-locked.

If those signals and the modulations are strong enough, the brains in a targeted area demodulate the 10-Hertz signal and phase-lock to it — actually, to them. At that point, the brains are entrained to a 10-Hertz driver, and 16 channels of multimegahertz frequencies are locked-in to the brain.

Now, if the Soviets have broken the genetic code of the human brain (which they have) and succeeded in developing the ability to implant thoughts, emotions, pictures, etc. (which at least to a degree they have), then they can simply record the proper signals from human guinea pigs, using scalar technology and instrumentation.

They can tailor those signals and add them onto the Woodpecker carriers, using scalar EM techniques. By using most of the sixteen carriers as a means to express Fourier frequency expansions, specific areas and functions of the brain can be targeted.

"Notice that the distant transmitters already "know" the correct phasing, just use the 10 Hertz modulation signal as a reference. In that case, phasing takes care of itself inside the captured human brains.

The brain has a unique characteristic. If a signal arises inside it, it interprets that it itself originated the signal. Thus for the first time in history, true unwitting robot actions and emotions can be engendered in masses of human beings.

But it's still worse. The Kaznacheyev experiments (see references) proved conclusively that electromagnetic signals can carry and transmit cellular disease and death patterns into a targeted biosystem. You can rest assured that the Soviets continued on to actually measure and determine a wide variety of death and disease scalar patterns. All of that can be added on to the Woodpecker carriers so that the population in the intersection grid area is devastated. One can even test it out in advance by producing a modified pattern of a disease in the targeted populace, and keeping the percentage of brains entrained down to a small level. This lowers the number of persons "injected" from a distance to a small percentage of the populace. Then the outbreak of the "new strain" of a familiar disease — such as influenza, pneumonia, and something like AIDS — can be monitored to provide targeting and effectiveness data. Notice that a series of diseases was experienced by U.S. personnel assigned to the U.S. Embassy in Moscow, probably as a result of the so-called "weak microwave radiation" of the Embassy by the Soviet Union.

But that's not all. Much more subtle effects can be produced in the targeted populace, without anyone getting wise. Cancers and leukemia should be relatively easy to induce. Also, the immune system can simply be attacked directly. If done slowly, a series of common, ordinary diseases will just seem to get "tougher and tougher to cure." Actually it's not the disease that got tougher, it is the immune systems that got weaker. It is my opinion that precisely that sort of testing — against the immune system — has been accomplished by the Soviet Union against the U.S. since about October 1985. A great percentage of influenza patients during the period from then until now have had complications. So much so that multiple sessions — as many as 3 to 5 — of antibiotics are necessary before the patient recovers. At least in the Huntsville, Alabama "hinge pin" area, that seems to have been the case. This author personally experienced this, having influenza and follow-on complications for a period of seven months — something quite different indeed for him.

But it's even worse.

The human scalar EM nervous system ("inside" the ordinary EM signals and functioning of the system) also has its own resident "software." It has special storage media contained in its brain, its cells, and its genetic material, and its actual nucleons. All of these storage media are continually telecommunicated with via scalar EM means. Those recordings, largely condition the "stability" of what each of us is. As personalities we literally "are" what we have experienced, felt, thought, and did. Our whole "functioning conscious system" has been evolved by our experience, and it continues to be "us" by means of continual reference to the record base.

I hope you now realize that the actual record base itself can conceivably be altered by scalar electromagnetic means, even from a distance. Even by the hidden scalar EM content of 16 Woodpecker carriers, rocked into a captured brain and pouring in their deadly content. It is conceivable that even what one is can be taken from him, and what someone decides he will be, he will be.

A totally new — **and** ultimate — form of "slavery" has emerged.

Also, look at all this scalar EM functioning of the human system as a special kind of cybernetics. A scalar EM computing software and hardware system.

What if scalar techniques are used to plant "worms" and "viruses" in this system? With hidden triggers? What about a series of them, so that a range of eruptive software diseases can be stimulated at will?

And guess what. Such scalar EM "worms" and "viruses" can even be induced by contact with or consumption of "contaminated" water and food. Or saliva. Or other body fluid.

So you can see the possibilities of "seeding" a population with a staggering variety of time-bombs.

I think you begin to see the point. Now you can change North's "Soviet blackmail" scenario drastically. In a new scenario, Gorbachev simply announces to Reagan that a graduated series of specific sweeping changes are going to happen in our population — changes which we are absolutely powerless to stop. The last stages are various deaths. The master "trigger" for this series has already been initiated. Incidentally, the Soviet populace has been carefully "seeded" with the proper antidotes. The Russian leader demands certain things (very similar to what North's scenario utilized). Unless his demands are met, a "killer virus" will be activated by a special signal. If so, everyone dies. The first step change in the series will start to occur in a few hours. And it does.

In fact, this scenario could be added to North's scenario, and both used simultaneously. What do you think the President and the Congress would do? Or could do?

There are other even more diabolical possibilities, but these should be quite sufficient to illustrate the point.

Pandora's box has already been spilled, and the end of humanity is ticking away like a time bomb. It's already nearly midnight, and the watchman hasn't even sounded the alarm yet.

I certainly can anticipate the next question: Have the Soviets already "seeded" the populations of the U.S. and other selected western nations with scalar EM viruses and germs7

The answer is, I simply don't know. And just like Gary North, I don't know what if anything can be done about it if they have. This researcher certainly doesn't have all the answers. An immediate national crash program to develop scalar EM defenses is essential if we are not simply to be crushed beneath the hammer and sickle. It takes funding, people, facilities, and time.

In some 22 years of unrelenting struggle to convince the system we've got a terrible problem, I've hardly been able to move it off dead-center (no pun intended). This book, produced under extreme workload stress, is all I can do to raise the alarm. I've given it my very best shot.

What happens now remains to be seen. Other hands, hearts and minds are going to have to take up the task and carry it forward. This researcher has reached his limit, and has no more left to give.

APPENDIX III: CONTINUING THE SCENARIO

On May 3, 1986 a stunning loss of a U.S. Delta rocket carrying a critically-needed weather satellite occurred. The rocket suffered a shutdown of its main engine during launch and began to veer off course, causing the range safety officer to destroy it.

The takeoff of the blue and white Delta "workhorse" from launch Pad A at Cape Canaveral at first appeared picture-perfect. About a minute later, six of the nine booster rockets were expended and the remaining three switched on. Shortly after that, the rocket seemed to lose power. The main liquid-fueled engine had suddenly shut down, with the three strap-on boosters still burning. The rocket then had no stability and started to slowly drift off course, creating an increasing angle of attack. Within a few seconds, the nose cone snapped off under the severe stress. The U.S. Air Force range safety officer then sent a destruct command to the stricken rocket, which exploded in a ball of flame.

The Delta, built by McDonnell Douglas, had previously piled up a continuous string of 43 successful launches. Since 1960, 177 launches have occurred, and the success rate has been 94%. The Delta is one of the most reliable rockets ever built.

The unexpected shutdown of the main engine was perplexing. At a news conference following the mishap, William Russell. NASA's Delta project manager. stated: "It was a very sharp shutdown. almost as if it were a command shutdown."

Preliminary data, such as turbine speed and temperatures in and around the engine, "all appeared to be very normal." Russell said.

It may well have been a "command shutdown," unknown to Bill Russell and his NASA engineers.

Preliminary runs of the videotapes of the incident, aired by the national TV news media, show that during liftoff, a mysterious light approached the rocket from below and from the side. rising and striking the vehicle. This light and its path are strongly reminiscent of the first anomalous "light streak and ball" photo taken by Bob Gladwin just prior to the shuttle launch on November 26, 1985.

Let' s suppose that on May 3 the Soviet scalar EM grid was in the launch Phase ABM system mode and was tracking the launch of the Delta rocket.

If the anomalous light that moved up and contacted the rocket was a small ball of continuous electromagnetic energy formed by a distant Soviet scalar EM howitzer, then the rocket's main engine control circuits would have received a sudden and continuous pulse of EM power. This would probably have shutdown the engine by an actual "command" signal, artificially delivered. *

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*Engineers have now determined that such a shorting of the engine circuitry occurred, causing engine shutdown.

Certainly such mysterious switching of satellite circuits has occurred before, probably due to Soviet scalar EM precision testing. For example, the British Ariel VI satellite has exhibited very strange anomalies in its command and control circuitry -- in fact, with very precise control switching being exhibited as if from an external source.

Thus a very small scalar EM missile may have been utilized by the Soviets to disrupt the control circuits in the rocket. A resulting pulse of power in the engine shutdown command circuit could have "ordered" the shutdown of the main engine -- just as it appeared.

It remains to be seen whether or not the Soviets used a "marker beacon" associated with the disruption of the Delta launch. One news photograph seems to contain a suggestion of such a light, but the videotapes must be studied frame by frame before it can be ascertained exactly what if anything is really there.

If a marker beacon was not used, the distant Soviet operator could simply have "popped out" the continuous EM ball of energy, tracked it and the ascending rocket exhaust, and "joysticked" the scalar EM missile up into the rocket.

Analysis of this incident is continuing, so nothing is certain as we go to press.

However, if this incident was indeed another Soviet kill, then it will have served the Russians well. Much of the world's media attention will now be focused on NASA's launch difficulties, and away from the recent Chernobyl nuclear reactor disaster in the Soviet Union. It's bound to take some of the media pressure off the Soviets.

In addition, it further cripples the U.S. satellite program. Loss of this critical weather satellite payload seriously reduces U.S. weather monitoring capabilities.

Further, the U.S. space program now appears to be all but grounded by the Challenger, Titan, and Delta explosions. For example, it will require about 18 months for the U.S. to redesign the shuttle so that America's shuttle program can get going again. So things are delayed until summer of 1987 at the earliest.

Meanwhile, the Russians are set to grasp the lead in the space race. In 1985 they launched about 100 rockets, five times as many as the U.S. They have a shuttle program of their own, well underway, with a flight expected within months. Earlier this year, they launched Mir, a second generation space station; a U.S. version is still some eight years away.

Charles Vick, of Huntsville, Alabama's Space and Rocket Center, summed it up: "They have their standard military program, a shuttle program and the equivalent of an Apollo program, all within a 10-year period. It's awesome."

An experienced propagandist like Gorbachev certainly understands the advantages of a strong Soviet push into space, such as (1) military advantage, (2) national prestige, (3) scientific achievement, and (4) projecting an image in the world's news media that the Soviets are first in space exploration.

So the failure of the Delta rocket provides many benefits to the Soviet Union.

It also continues to exercise and demonstrate Soviet mastery of the skies over North America itself.

Meanwhile, two U.S. nuclear submarines have "inadvertently" run aground in the last month or so.

Gorbachev again seems disposed toward a summit meeting soon.

If it's held, the agenda may be quite different from the one President Reagan is prepared for.

The clock ticks on toward midnight.

2002 ENDNOTES

1. It is actually a unified field theory since the infolded electrodynamics inside all EM potentials, fields, and waves is utilized—and the internal electrodynamics forms spacetime curvatures and dynamics of those ST curvatures.

2. M. W. Evans, "0(3) Electrodynamics," *Modern Nonlinear Optics,* 2nd Edition, M. W. Evans (Ed.), Wiley, New York, 2001, Vol. 2, p. 79-267.

3. David J. Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of'Hidden' Variables, I and II." *Phys. Rev.,* 85(2), Jan. 15, 1952, p. 166-179 (Part I); 180-193 (Part II); — "Quantum theory as an indication of a new order in physics." A:, *Found. Phys.,* Vol. 1, 1971, p. 359; B: "Implicate and explicate order in physical law," *Found. Phys.,* 3(2), 1973, p. 139-168.

4. Mendel Sachs, General *Relativity and Matter,* Reidel, 1982; — "Symmetry in Electrodynamics: from Special to General Relativity, Macro to Quantum Domains," *Modern Nonlinear Optics,* 2nd Edition, Wiley, New York, Vol. 2, p. 677-706.

5. M. W. Evans, P. K. Anastasovski, T. E. Bearden et al., "On Whittaker's Representation of the Electromagnetic Entity in Vacuo, Part V: The Production of Transverse Fields and Energy by Scalar Interferometry," *J. New Energy,* 4(3), Winter 1999, p. 299-301 gives a basic mathematical expose of scalar interferometry.

6. James Clerk Maxwell, "A dynamical theory of the electromagnetic field," *Phil. Trans. Roy. Soc,* Vol. 155, 1865, p. 71, 459. Orally presented in 1864. This was Maxwell's definitive presentation of his theory, with 20 quaternion and quaternion-like equations in 20 unknowns. Also in *The Scientific Papers ofJames Clerk Maxwell,* edited by W. D. Niven, Dover, New York, 1952, Vol. 1, p. 526-604.

7. In T. E. Bearden, *Gravitobiology: A New Biophysics,* Cheniere Press, Santa Barbara, Ca. www.cheniere.org, 1991 we first exposed the quantum potential weapon and some of its uses and characteristics.

8. A negative energy EMP weapons strikes the target or target area with an extreme pulse of negative energy empty Dirac Sea 4-holes. As a result, the free electrons flowing in electrical currents in the struck target instantly disappear by re-absorption into the Dirac Sea. A living body struck by such a blast is totally and instantly dead in every smallest part, since all its brain and nervous system currents, cellular currents, etc. are instantly and totally extinguished. The Russians tested this weapon in the 1980s in their war in

Afghanistan, against two Afghan villages. I spent two hours in Washington D.C. with the then-representative of the Mujahedin to the U.S. Government, verifying the incidents and going over the exact characteristics of the instantaneous deaths of those villagers. With such a sudden death, the mind-body interconnection loop is instantly severed, so that the mind is instantly snapped loose from its connection to the body—hence my use of the term "MindSnapper." The struck body usually emits longitudinal EM waves for an extended period, so that vultures and other predators will not approach the bodies and eat them. All bacteria, viruses, etc. in the body are also killed instantly, and the body does not decay, even in 30 or 60 days.

9. As can be seen, the negative energy EMP weapon is an all-purpose weapon extremely effective against every kind of target: missiles, aircraft, communications, satellites, ships and particularly aircraft carriers, personnel, generators, power systems, the electronics of nuclear warheads, submarines, tanks and vehicles, and the electrical and electronic controls of any kind of machinery or equipment. Such weapons are the second most powerful weapons on earth. In the first part of 2002, a U.S. 2-carrier task force maneuvered in the South China Sea as a precautionary warning to the Chinese that we would defend Taiwan. Unknown to that fleet, tracking it and trained on it were the newly deployed Chinese negative energy EMP weapons, which could have destroyed the entire task force—everything in it—with a few shots in less than 10 minutes.

10. T. E. Bearden, *Energy from the Vacuum: Concepts and Principles,* Cheniere Press, Santa Barbara, CA, 2002. Chapters 1 and 2 give a deeper coverage of this and similar foundations principles.

11. As is well known, Russian theoreticians have always been the best nonlinear scientists on Earth, since the beginning. They still are.

12. See T. E. Bearden, "Giant Negentropy from the Common Dipole," *J. New Energy,* 5(1), Summer 2000, p. 11-23 for solution of the source charge problem. On DoE restricted website http://www.ott.doe.gov/electromagnetic/ and on www.cheniere.org. The problem of the source charge can be solved by treating (with the modern quantum field theory viewpoint) the "isolated" observable charge and its cluster of virtual charges of opposite sign as a composite dipole. Because of the broken symmetry of its opposite charges, any dipole or dipolarity continuously receives virtual energy from the seething vacuum, transduces it into real observable EM energy, and pours out observable photons in all directions at the speed of light. See also E. T. Whittaker, 1903, *ibid.* There is a scalar potential between the ends of each dipole. The scalar potential may be decomposed into a bidirectional set of longitudinal EM phase conjugate energy from the time dimension (from the imaginary plane) and outputs that EM energy in the real 3-space. 3-space conservation of energy flow

is violated, but 4-space conservation of energy flow is upheld. This rigorously follows from the discovery of broken symmetry of opposite charges in 1957—one of the types of asymmetry for which Lee and Yang received the Nobel Prize.

In classical electrodynamics, the charged particle itself is *assumed* to be the source of its own fields and potentials. In other words, the charge is implicitly considered to be *creating*—right out of nowhere—the Poynting energy flow it continuously pours out across the universe in all directions. That makes the charge a perpetual motion machine of the grossest kind, violating the maxim that energy can neither be created nor destroyed.

So the greatest perpetual motion advocates of all times are our own classical electrodynamicists and electrical engineering departments and professors who still ignore the active vacuum interaction that is missing from the classical model. They thereby ignore that the charge is a broken 3-symmetry in its violent exchange of virtual energy with the active vacuum, and merely organizes and emits in observable form a fraction of the energy it continuously receives from the imaginary plane (from the time domain). Yet, that broken symmetry has been known in particle physicists, both experimentally and theoretically, for 45 years.

When Maxwell wrote his theory, neither the electron, the atom, nor the nucleus had been discovered. There was no knowledge of the Drude electron gas, electron spin, etc. There was no knowledge of the nucleus of the atom, and even the atom itself was still contentious. A thin material ether (fluid) was believed to fill all space, so that no point in all the universe was empty of mass. Consequently, E and B were conceived as physical force fields in a material medium—the luminiferous ether. All Maxwell's equations—including the subset selected and modified by Heaviside that today are called "Maxwell's equations"—assume this material ether to this day.

Electricity was thought to be a "thin material electric fluid" running through wires like water through a pipe. The magnitude of the potential was not used; its reaction cross-section was calculated and erroneously used as its magnitude, as it is today (although a good electrodynamicist does know that it is only the *intensity* of the potential, not its magnitude).

Faraday believed that his "lines of force" were taut physical "strings" in this material ether, and that EM perturbations were the vibrations of these taut strings. As he clearly states in his 1873 *Treatise...*, Maxwell sought to capture Faraday's work exactly. He simply *assumed* Faraday's "plucked taut string" waves. Later the measurement in instruments of what was actually the lateral gyroprecession of electrons in receiving wires was thought to prove that the incoming ether vibrations were transverse, like those string waves, because the detected electric **fluid (electron** precession) waves in the receiving wire were transverse. The drift velocity of electrons longitudinally in a wire (in a typical case, several inches per hour) was unknown. A charge *q* was just a piece of electric fluid, much like a cubic centimeter or other volume of fluid; it had no connotation of "charged particle." There was no concept in all of physics of EM energy flowing through space. There was no knowledge that the same fields created in the transmission wire, which perturbs the Drude electrons laterally, also perturbs the positively charged nuclei laterally, in the opposite direction, highly damped but with equal energy.

There was no way to realize that the energetic perturbation of the curvature of spacetime around the sending wire antenna, by the Drude electron perturbation energy, is simultaneously accompanied by an equal and opposite perturbation of the curvature of spacetime in the opposite direction (energy density, not amplitude of the disturbing wave, determines the degree of curvature of the surrounding spacetime). Hence Maxwell omitted precisely one half the EM energy, one half the EM wave, and one-half the electrodynamics. As a consequence, the "Newton's third law recoil" of the nuclei today is thought to spontaneously arise as if some mystical demon observes the Drude electron perturbations, and simultaneously kicks the positively charged nuclei in the equal and opposite direction. Hence Newton's third law, so to speak, is erroneously still omitted from classical electrodynamics, and the better texts say so.

In the 1880s, the Michelson-Morley experiments falsified the material ether. Not a single one of the Maxwell-Heaviside equations were ever changed to this day. Instead, the electrodynamicists eventually announced that, since there was no longer an ether, they were not using one! Then a total non sequitur was incorporated: that in massfree space, the same E and B fields (defined as material entities and thus existing only in mass) still remain but the forces go to zero. Simple algebra reveals this clever, insidious faux pas, using the E-field as an example: First, F == d/dt(mv), so mass is a component of force. (This reveals the great error due to the hoary old notion that a separate force acts upon a separate mass; the mass is a component of the force, and the force is a coupled system of a curvature of spacetime and a charged mass.). Then E == F/q, which rigorously holds when mass is present.

Now for whatever reason, let F = 0. Then F/q = 0 and E = 0 also, else we must discard algebra. What actually remains is easily explained in general relativity terms (available since before 1920). The couplet of a curvature of spacetime and a charged mass is broken up by absenting the mass. What remains is that specific curvature of spacetime. GR assures us that curved ST acts upon mass, and that any force involves a curvature of ST. Yet in more than 80 years, this erroneous old "material ether remnant" in electrodynamics has been fiercely defended. Every textbook today uses and confuses the E and B fields in two dichotomous fashions: (1) as massive force fields existing only in the presence of mass, and as "massless force-free fields" existing only in the absence of mass. This of course is a non sequitur.

13. E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," *Math. Ann.*, Vol. 57, 1903, p. 333-355. The "scalar" potential itself is not even a *scalar entity*, as shown rigorously by Whittaker. Instead, it is a harmonic series of bidirectional EM longitudinal phase conjugate wavepairs, and it decomposes into that series. Hence it is a *multiwave, multivectorial entity*.

14. C. N. Yang and R. L. Mills, "Conservation of Isotopic Spin and Isotopic Gauge Invariance," *Phys. Rev.*, Vol. 96, 1954, p. 191.

15. The term "energetics" simply means *energy as the primary thing in the universe*. Rankine first used it. G. Helm in 1887 revived Rankine's term "energetics" and factored energy into an *intensity* factor and an *extensity* factor (which today we would call potential and kinetic energies). William Ostwald in 1893, 1895, and 1901 raised the concept of "energetics" (energy as the primary thing in the universe) to the forefront. Thus when the Russians developed new extensions and principles in weapons physics, they simply used the historical notion of "energy as the primary thing in the universe" and adopted the earlier name for it: *energetics*.

16. Later when Khrushchev demanded a 100% antimissile defense, famed Russian Nobelist Petr Kapitsa answered, *"If a means of total neutralization of foreign missiles is to be found, it can only come from a group of new principles in physics, called energetics"*.

17. See T. E. Bearden, "Mind Control and EM Wave Polarization Transductions, Part I", *Explore*, 9(2), 1999, p. 59; Part II, *Explore*, 9(3), 1999, p. 61; Part III, *Explore*, 9(4,5), 1999, p. 100-108. It appears that Sachs' unified GR and EM approach is perhaps the best Western physics model to apply to analysis of the KGB energetics weapons. However, because of the third branch *(psychoenergetics:* engineering the mind directly), Sachs' work would appear to need further extension along the lines indicated by the present author in the cited paper.

18. See T. E. Bearden, "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves," *J. New Energy*, 3(2/3), 1998, p. 12-28; — *Energy from the Vacuum*, 2002, *ibid.* For nuclear transmutation at a distance (e.g., dudding all nuclear weapons by transmuting U235 and weapons grade plutonium), extension is required along the lines indicated by the present author in these references.

19. See M. Sachs, *ibid.*, also M. Sachs, "Relativistic Implications of Electromagnetic Field Theory," in T. W. Barrett and D. M. Grimes, eds., *Advanced Electromagnetism*, World Scientific, 1995, p. 551. The Sachs theory

already expresses the greatest generalization possible of electrodynamics, and fully justifies the preceding view.

20. See Whittaker, 1903, *ibid.;* — "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions," *Proc. Lond. Math. Soc,* Series 2, Vol. 1, 1904, p. 367-372. The latter paper was published in 1904 and orally delivered in 1903. Per these two Whittaker papers, it is known that (i) ordinary EM fields and waves are the result of interference of two or more scalar potential functions, (ii) scalar potentials are comprised of harmonic sets of bidirectional EM phase conjugate wavepairs, (iii) all ordinary EM fields and waves and potentials have LW EM dynamics internally, and (iv) in theory, this "infolded" electrodynamics can be engineered. Sachs' theory dramatically extends the richness of that internal electrodynamics ignored in the West, and highlights the general relativity (sets of spacetime curvatures, or "engines", involved).

21. E.g., *Marine Observer* was a rich source for Russian energetics weapons testing in remote ocean areas, sighted by ships' captains and crews and entered into the ships' logs.

22. Portions of Khrushchev's statements to the Presidium are given in Max Frankel, "Khrushchev Says Soviet Will Cut Forces a Third; Sees 'Fantastic Weapon'," *New York Times,* Jan. 15, 1960, p. 1.

23. See Whittaker 1903 and 1904, *ibid.,* for the original basis of scalar interferometry and its creation of any kind of EM field, potential, and wave in the interference zone.

24. Also see M. W. Evans, P. K. Anastasovski, T. E. Bearden et al., On Whittaker's Representation of the Electromagnetic Entity in Vacuo, Part V: The Production of Transverse Fields and Energy by Scalar Interferometry, *J. New Energy,* 4(3), Winter 1999, p. 76 for mathematical proof of scalar interferometry. There are several other AIAS papers in the same issue of *JNE,* dealing with interferometry and with the implications of the Whittaker papers.

25. As an example, the U.S.S. Skylark, surface companion of the Thresher, was beset by mysterious "jamming" of multiple types of EM systems in multiple bands. So bad was it that it required more than an hour to get an emergency message to Naval headquarters that the Thresher was in serious difficulty. Later, as the scalar interferometry died away, all the EM systems aboard the Skylark resumed normal functioning. The Skylark was in fact in a "splatter zone" of the underwater interference zone around the Thresher.

26. Circa the end of 1989, the earlier longitudinal EM wave weapons on site in Russia were leased to a rogue Japanese group comprised of Aum Shinrikyo and Yakuza, who have been operating those weapon systems—on site in Russia—since then. Senator Sam Nunn's investigations revealed the presence

of the Aum Shinrikyo in Russia, to include establishing a university there. His investigators missed the Yakuza involvement and also missed the exotic weaponry aspects as one might expect.

27. I concluded from this remark that TEMPEST techniques are probably used at some nearby site not too distant from my home here in Huntsville, to read and record my work as I write it on the computer. That appears to be a good assumption.

28. As a small example of what can be done, see a series of papers by M. W. Evans, P. K. Anastasovski, T. E. Bearden et al, published in *J. New Energy*, 4(3), Special Issue, Winter 1999. The papers are: (a) "On Whittaker's Representation of the Electromagnetic Field in Terms of Two Scalar Potentials, Part I"; (b) "An Experimental Test of the Existence of Whittaker's *g* and/Fluxes in the Vacuum"; (c) "On Whittaker's Representation of the Classical Electromagnetic Field in Vacuo, Part II: Potentials Without Fields"; (d) "On Whittaker's F and G Fluxes, Part III: The Existence of Physical Longitudinal and Timelike Photons"; (e) "Representation of the Vacuum Electromagnetic Field in Terms of Longitudinal and Time-like Potentials: Canonical Quantization"; (f) "On Whittaker's Analysis of the Electromagnetic Entity, Part IV: Longitudinal Magnetic Flux and Time-Like Potential Without Vector Potential and Without Electric and Magnetic Fields"; (g) "On Whittaker's Representation of the Electromagnetic Entity in Vacuo, Part V: The Production of Transverse Fields and Energy by Scalar Interferometry"; and (h) "On Extending Whittaker's Theory, Part VI: Photons Without Fields and Vector Potentials".

29. As an example, one part of the strategic deception plan was devoted to convincing the West that Soviet psychoenergetics was nothing but a technical wrinkle upon the rather harmless Western parapsychology. This part of the program was completely successful for decades. Another very clever use of deception is to allow release of some real scientific advances that lead the West, but are not too important to the KGB in the weapons arena. The increasing emphasis on torsion fields is an example of this "deception by giving good information that directs the adversary upon a path one wishes him to take", effectively steering him away from the path one wishes him to avoid. Lately, however, there is an uproar amongst the academicians in the Russian Academy of Sciences over this very point, that torsion fields being presented as the "end all, be all" is simply disinformation.

30. With their deployment of QP weapons in 2002, the Chinese are also on the way to having this capability.

31. The multiply connected spacetime (MCS) or quantum potential weapons went on site circa latter 1989. A laboratory prototype had been tested against the U.S. air attack on Libya in April 1986. For details of the extremely anomalous jamming **of aircraft** and missile guidance and control systems in that

attack on Libya, see Mark Thompson, "Mixed signals may have misguided U.S. weapons," *The Washington Post,* Jan. 22, 1989, p. A-4.

32. One or more QP weapons also apparently induced the Gulf War Disease in MidEast forces in the Gulf War. We have previously explained the peculiar anomalies, how it was done, why the endemic natives did not contract the disease, why the French forces did not contract it but U.S., British, and Canadian forces did, etc. We briefly discussed quantum potential weapons in T. E. Bearden, *Gravitobiology: A New Biophysics,* In T. E. Bearden, *Gravitobiology: A New Biophysics,* Cheniere Press, Santa Barbara, Ca. www.cheniere.org, 1991.

33. (a) Yossef Bodansky, "Soviets testing chemical agents in Afghanistan," *Jane's Defence Weekly,* 1(3), Apr. 7, 1984, p. 508 gives something of the two Soviet tests of this weapon in Afghanistan. In addition to the fierce blast of empty Dirac Sea 4-holes, these weapons produce a powerful time-polarized EM pulse in the area, producing a very sharp "jerk" in the rate of flow of time, (b) The mind-body coupling mechanism—which cannot withstand such a sharp jerk in the rate of flow of time—has been given by T. E. Bearden, "Mind Control and EM Wave Polarization Transductions," *Explore,* 1999, *ibid.* This sharp "jerk" in time-flow instantly snaps the mind-body coupling mechanism for any living thing in the struck area. A very small version of this weapon was tested twice in Afghanistan, where the bodies in the "mind-snapped" zone died instantly, fell like limp rags, never twitched, and did not decay or get molested by insects or scavengers for the 30 days it required the Mujahedin to fight their way back into the two struck villages. The Mujahedin thought it was some new, extremely fast acting nerve gas, which they dubbed "smerch" or "death wind".

34. Two Ph.D. scientists were working closely with me on this entire effort, as was another close colleague. There was much more involved in the effort that is so briefly mentioned here.

35. Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.

36. T. E. Bearden, *Energetics: Extensions to Physics and Advanced Technology for Medical and Military Applications,* CTEC Proprietary, Mar. 21, 1998, 200+ page inclosure to CTEC Letter to Gen. (Ret.) Walter Busby, Deputy Secretary of Defense for Counterproliferation and Chemical and Biological Defense, March 21, 1998. Copies were sent to various other U.S. government agencies, including to NIH, CDC, the USAF, etc.

37. See Vlail Kaznacheyev and L. P. Mikhailova, *Ultraweak Radiation in Intercellular Interactions,* [in Russian], Novosibirsk, 1981. An English exposition of much of the Kaznacheyev material is given in Vlail Kaznacheyev, "Electromagnetic Bioinformation in Intercellular Interactions," *Psi Research,* 1(1), Mar. 1982, p. 47-76. The work of Vlail Kaznacheyev led to the understanding of how to electromagnetically transmit cellular death and disease into targeted cells (or bodies) at a distance, and involved thousands of lab experiments. Highly sanitized work revealing the results but not the mechanisms, were permitted in order to stimulate the West to see if it knew about energetics.

38. See Stanislov Lunev and Ira Winkler, *Through the Eyes of the Enemy: Russia's Highest Ranking Military Defector Reveals Why Russia Is More Dangerous Than Ever,* Regnery, Washington, D.C., 1998. The Red Chinese also were able to decipher the Russian EM disease transmission methodology, early on. As a strange kind of "poetic justice" action the Chinese induced cancer into many Russian spies stationed in the Russian Embassy in China. Quoting Lunev, p. 160: "...I *was not the only person who was stationed in Beijing to come down with cancer...Almost all of the GRU officers stationed in China with me have been diagnosed with cancer. People assigned to the embassy had told me that they were picking up high levels of radiation from the apartment building around the embassy compound. Whether it was a form of high-tech monitoring or a conscious effort to harm our health, it seems to have been successful. So much so that in 1992 the GRU was asked to investigate the high rate of cancer among embassy officials. The findings, however, have never been made public; in part, no doubt, because of the rapprochement between Russia and China."*

39. See my "Porthole Briefing", on www.cheniere.org. Also see "Le Probleme Priore," *Rapport de la Commission de I'Academie des Sciences a Monsieur le Ministre d'Etat charge de la Recherche et de la Technologie,* France, 1982, p. 1-22; J. B. Bateman, "Microwave Magic," Office of Naval Research London Conference report, ONRL C-14-77, 1977; —*A Biologically Active Combination of Modulated Magnetic and Microwave Fields: The Priore Machine,* Office of Naval Research, London, Report R-5-78, Aug. 16, 1978; — "Staging the Perils of Nonionizing Waves," *European Scientific Notes,* ESN 32-3-85-88, 1978; T. E. Bearden, "Energetics Update and Summary," Parts 1, *Explore More,* No. 1, 1996, p. 13-18; Part 2, *Explore,* 8(1), 1997, 53-56; Part 3, *Explore,* 8(2), 1997, p. 42-45; Christopher Bird, "The Case of Antoine Priore and His Therapeutic Machine: A Scandal in the Politics of Science," Explore, 5(5-6), 1994, p. 97-110; R. Cambar, "Rapport general des travaux de la Commission de Controle constituee en vue de verifier l'un des effets biologiques obtenu par l'utilisation de l'appareillage de Priore A. Bordeaux," [General findings of the work of the control commission formed to verify one of the biological effects obtained by use of the apparatus of A. Priore at Bordeaux],

1969; R. Courrier, "Expose de M. le professeur R. Courrier Secretaire perpetuel de 1'Academie des Sciences fait au cours d'une reunion a l'lnstitut sur les effects de la machine de M. A. Priore 26 Avril 1977" [Presentation by Professor R. Courrier, Perpetual Secretary of the Academy of Sciences, made at the meeting of the Academy on the effects of the machine of M. A. Priore.]; Jean-Michel Graille, *Dossier Priore: A New Pasteur Affair,* De Noel, Paris, 1984 [in French]; Antoine Priore, "Apparatus for producing radiations penetrating living cells," U.S. Patent No. 3,368,155, Feb. 6, 1968; — "Method of producing radiations for penetrating living cells," U.S. Patent No. 3,280,816, Oct. 25, 1966; — "Procede et dispositif de production de rayonnements utilisables notamment pour le traitement de cellules vivantes," [Procedure and Assemblage for Production of Radiation Especially Serviceable for the Treatment of Living Cells], Republique Francais Brevet d'Invention P.V. No. 899.414, No. 1,342,772, Oct. 7, 1963; A. Priore, *Guerison de la Trypanosomiase Experimentale Aigue et Chronique par L'action Combinee de Champs Magnetiques et D'Ondes Electromagnetiques Modules* [Healing of intense and chronic experimental trypanosomiasis by the combined action of magnetic fields and modulated electromagnetic waves], thesis submitted in candidacy for the doctoral degree, 1973—rejected when the project was suppressed.

40. Eric Perisse, *Effets des Ondes Electromagnetiques et des Champs Magnetiques sur le Cancer et la Trypanosomiase Experimentale* [Effects of Electromagnetic Waves and Magnetic Fields on Cancer and Experimental Trypanosomias], Doctoral thesis, University of Bordeaux No. 83, March 16, 1984. Although Priore's own thesis was suppressed in 1973, Pautrizel nevertheless finally succeeded in getting this doctoral thesis by Perisse approved on the work, at the University of Bordeaux which had rejected Priore's thesis, after eleven more years had passed. Considering the viciousness of the suppression, this was a major accomplishment.

41. The photo was taken by George Suchary of the registration point (ball of light) high over the Nov. 1985 night shuttle launch from Cape Canaveral. For a photo of the same kind of "ball of light" registration point above the kill of a Titan missile launched from Vandenberg AFB in early 1986, see reference 39 below.

42. The picture by Canadian investigators showing the hole burned through the right fuselage ahead of the engines of the Arrow DC-8 is shown in T. E. Bearden, *AIDS: Biological Warfare,* Cheniere Press, Santa Barbara, Ca. www.cheniere.org , 1988, p. 52.

43. See T. E. Bearden, *Gravitobiology: A New Biophysics,* Cheniere Press, Santa Barbara, Ca. www.cheniere.org, 1991, p. 82. Two sensors on-board the Arrow DC-8 independently recorded the sharp electrical spike generated by the strike of the EM missile.

44. "Titan Explosion Cripples U.S. Launch Surveillance Capability," *Aviation Week & Space Technology,* 124(17), Apr. 28, 1986, p. 16-19. Specifically see the picture of the explosion on p. 18. It clearly shows the Soviet marker beacon (little ball of light) well above the missile explosion. General background on the Titan explosion and investigation is given in "Investigators Search for Clues to Cause of Titan Blast," *Aviation Week & Space Technology,* 124(17), Apr. 28, 1986, p. 19-20.1 persuaded NBC engineer Ron Cole with a team of engineers to examine the videotape of the explosion, frame by frame. In 17 frames the ball-of-light (registration point) is visible, and moves away completely independent of the explosion. No "bogies on the range" were reported at Vandenberg AFB.

45. Dr. Evans is co-discoverer with Vigier of the B(3) field, now well established but still not in the textbooks. He is the Director of the Alpha Foundation's Institute of Advanced Study (AIAS) and has over 600 papers and books in the literature.

46. M. W. Evans, P. K. Anastasovski, T. E. Bearden et al., "On Whittaker's F and G Fluxes, Part III: The Existence of Physical Longitudinal and Timelike Photons," *J. New Energy,* 4(3), 1999, p. 68-71; — "Representation of the Vacuum Electromagnetic Field in Terms of Longitudinal and Time-Like Potentials: Canonical Quantization," *ibid.*, p. 82-88; — "On Extending Whittaker's Theory, Part VI: Photons Without Fields and Vector Potentials," *ibid.,* p. 79-81.

47. Terence W. Barrett, "Electromagnetic Phenomena Not Explained by Maxwell's Equations," in Lakhtakia, A. (ed.): *Essays on the Formal Aspects of Electromagnetic Theory,* World Scientific Publishing, River Edge, NJ, 1993, p. 6-86; — "On the distinction between fields and their metric: the fundamental difference between specifications concerning medium-independent fields and constitutive specifications concerning relations to the medium in which they exist." *Ann. Fond. Louis de Broglie,* 14(1), 1989, p. 37-75; — and D. M Grimes. [Eds.] *Advanced Electromagnetism: Foundations, Theory, & Applications.* World Scientific, (Singapore, New Jersey, London, and Hong Kong), Suite 1B, 1060 Main Street, River Edge, New Jersey, 07661, 1995. In the latter book see T.W. Barrett, "Sagnac Effect: A Consequence of Conservation of Action Due to Gauge Field Global Conformal Invariance in a Multiply-Joined Topology of Coherent Fields," p. 278-313.

48. But see Craig F. Bohren, "How can a particle absorb more than the light incident on it?" *Am. J. Phys.,* 51(4), Apr. 1983, p. 323-327. By *resonating* the intercepting charged particle, its reaction cross section increases, and more EM energy is collected and re-radiated by the charge than is input to it by the conventional accounting (which only accounts the input Poynting energy that would be intercepted by a *static* charge). The conventional input energy

calculation therefore ignores the huge nondiverged Heaviside component surrounding the Poynting component and wasted. The resonant particle sweeps out past the usual Poynting component into the unaccounted Heaviside input component, and collects excess energy. The Bohren experiment with resonant charged particles produces COP =18. Metallic particles at ultraviolet frequencies are one class of such particles and insulating particles at infrared frequencies are another. For independent confirmation of the Bohren experiment, see H. Paul and R. Fischer, {Comment on "How can a particle absorb more than the light incident on it?'}," *Am. J. Phys.,* 51(4), Apr. 1983, p. 327.

49. E. T. Whittaker, 1903, *ibid.*

50. A beneficial use, e.g., would be to use such CSRs to investigate and report the interior of the sun and planets, including the Earth and its core. Since a CSR can also travel "through" the interior of a light beam, in theory such could be dispatched back into some of the nearer stars to also explore and report their interior.

51. This is no more curious than stating that sets of waves and their dynamics can exist in space, without interacting with mass, and that they can then later interact with a mass system to change it in specifically designed manner. Since longitudinal EM waves and their dynamics are "infolded" inside ordinary EM waves, fields, and potentials, they are also infolded "inside" the ambient vacuum potential, which itself is a part of the local vacuum potential. In short, one forms highly complex LW wavesets and functional dynamics, in essentially a sort of "subspace" as popularized by the Star Trek television series. The LW "engines" are identically ST curvature engines. A close colleague of the present author has in fact already invented and rigorously demonstrated such a communication system, but his former funding by several very large communications companies collapsed before he could develop and employ this system for the commercial market.

52. This is easily understood if one shifts one's vision from "space" to "subspace." Subspace is filled with (literally is composed of) longitudinal EM waves and their dynamics. The CSR's are quite unique, enormous systems "singing away" with longitudinal EM waves. So a longitudinal EM wave interferometer can easily locate them by sweeping its beams through subspace, as a radar sweeps to track aircraft in space. Once the CSR target "pings", the system automatically hits it with a profusion of interacting LWs, completing disrupting and destroying its dynamics. Scratch one system. Probably several million such systems were destroyed throughout the West (command centers, power grids, submarines, nuclear bombers, etc.) in rapid fire order, all without any external "spatial" sign other than perhaps a wee bit of very low level "EM noise" briefly as a struck CSR fractured.

53. See M. Sachs, *Quantum Mechanics from General Relativity,* Reidel, 1986. Sachs'unified field theory, e.g., applies equally to the quarks and gluons, as it does to the nucleons, the atoms, molecules, and macroscopic objects and phenomena. See also M. Sachs, "Symmetry in Electrodynamics: From Special to General Relativity, Macro to Quantum Domains," in *Modern Nonlinear Optics,* Second Edition, 3 vols., M. W. Evans (ed.), Wiley, 2001; vol. 1, p. 677-706.

54. G. M. Wang, E. M. Sevick, Emil Mittag, Debra J. Searles, and Denis J. Evans, "Experimental Demonstration of Violations of the Second Law of Thermodynamics for Small Systems and Short Time Scales," *Phys. Rev. Lett.,* 89(5), 29 July 2002, 050601.

55. The tragic death of Captain Hess was also very probably such a test. Hess, perfectly normal and happy, laid out his uniform in the early morning and then went for his customary morning jog. He suddenly veered aside, sat down in a path and stabbed himself 26 times, all deep stab wounds, four of which would be totally incapacitating (two right through the heart) to any normal individual experiencing normal shock, etc. To a psychoenergetically controlled individual where shock does not occur nor does emotion or pain, this is understandable. Add this to the incidents involving Captains Button and Svoboda, and one begins to see the picture.

56. W. Heitman and G. Nimtz, "On Causality Proofs of Superluminal Barrier Transversal of Frequency Band Limited Wave Packets," *Phys. Lett. A196,* 1994, p. 154-158. Aichmann and Nimtz and co-workers at the University of Cologne have transmitted 8.7 GHz microwaves (free space wavelength 3.4 cm) traveling in a rectangular wave-guide that contains a "barrier" section of reduced dimensions. They have recently transmitted Mozart's 40th Symphony as frequency modulated microwaves through a barrier wave-guide at an FTL group velocity of 4.7 c, receiving audibly recognizable music from the microwave photons that survived their barrier passage. The transit time through the barrier was about 81 picoseconds and was observed to be constant for barriers with widths varying from 4.0 cm to 11.4 cm.

57. Quantum mechanics in fact requires instantaneous transmission of effects. A mishmash of learned contention would have us believe one can "transmit" energy instantly, but not intelligence. This argument has essentially stymied our scientific establishment so that it has not really funded strong investigation in this area. It is a stupid argument: Simply transmit one change, then a second one, then a third one, in serial order, where the "order" contains the intelligence. No different from Morse code. Somehow the pundits so certain that intelligence cannot be superluminally transmitted seem to have forgotten what "intelligence" is. They also seem to have assumed that one superluminal change can be **transmitted** on order, but a second, third, and fourth cannot.

58. Feynman and Wheeler tried very hard to formulate a new absorber theory of electrodynamics to eliminate many of the fierce foundations problems. Wheeler described the effort this way: *"...we may summarize the account of radiation reaction given by Wheeler and Feynman in 1945. In it every charged particle is envisaged as coupled to every other charged particle by a field that is symmetric in time: half advanced, half retarded. Interconnections run forward and backward in time in such numbers as to make an unbelievable maze. That weaving together of past and future seems to contradict every normal idea of causality. However, when the number of particles is great enough to absorb completely the signal starting out from any source, then this myriad of couplings adds up to a simple result: the familiar retarded actions of everyday experience, plus the familiar force of radiative reaction with its familiar sign."* [John Archibald Wheeler, "Law without law," in *Quantum Theory and Measurement.*, preprint, p. 39].

Unfortunately, when the foundations of any science are closely examined in their roots, one runs into the age-old bane of the philosopher: ultimately opposites are identical, at least prior to the observation (separation) action to separate them. It follows that all scientific reasoning is circular at its most primary basis.

59. See Charles W. Misner, Kip S. Thorne and John Archibald Wheeler, *Gravitation,* W. H. Freeman, San Francisco, CA., 1973, p. 71. Wheeler spoke of that inescapable fact in this manner: *"Here and elsewhere in science, as stressed not least by Henry Poincare, that view is out of date which used to say, 'Define your terms before you proceed.' All the laws and theories of physics, including the Lorentz force law, have this deep and subtle character, that they both define the concepts they use (here B and E) and make statement about these concepts. Contrariwise, the absence of some body of theory, law and principle deprives one of the means properly to define or even to use concepts. Any forward step in human knowledge is truly creative in this sense: that theory, concept, law, and method of measurement—forever inseparable—are born into the world in union."*

60. Also see T. E. Bearden, *Energy from the Vacuum: Concepts and Principles,* 2001, *ibid,* for a rework and extension of Aristotelian logic to eliminate its present fatal flaw, extending it into a 5-law logic.

61. The very notion of "propagation of energy through space" is radically extended in the extended unified EM and GR being pursued by AIAS and Sachs. Time-like EM energy currents dominate in the vacuum. E.g., see M. W. Evans et al., "Representation of the Vacuum Electromagnetic Field in Terms of Longitudinal and Time-like Potentials: Canonical Quantization," *J. New Energy,* 4(3), Winter 1999, p. 82.

62. Multiwave interactions (between transverse EM waves) produce time-reversed EM waves (phase conjugate replicas of the signal wave input). That method time-reverses EM energy in waveform. To time-reverse EM energy in mass form, simply pump that mass with time-polarized EM waves. As an alternative, it may be pumped with longitudinal EM waves (which are always accompanied by time-polarized EM waves anyway), and the pumped mass is also pumped in the time-domain because of the presence of the time-polarized EM waves in the pumping. We previously filed an invention disclosure with the U.S. Patent Office dealing with how to do that.

63. Mostly studied by Becker. See (a) R. O. Becker, "The control system governing bone growth in response to mechanical stress," *J. Ark. Med. Soc,* Vol. 62, 1966, p. 404; (b) — and David G. Murray, "The electrical control system regulating fracture healing in amphibians," *Clinical Orthopaedics and Related Research,* Vol. unk, No. 73, Nov.-Dec. 1970, p. 169-198. This latter paper is the definitive technical exposition by Becker of his electrical control system ideas and findings. Good references for the educated layperson are (c) R. O. Becker, "A technique for producing regenerative healing in humans," *Frontier Perspectives,* 1(2), Fall/Winter 1990, p. 1-2; (d) Robert O. Becker and Gary Seldon, *The Body Electric: Electromagnetism and the Foundation of Life,* William Morrow and Company, New York, 1985; and (e) Robert O. Becker, *Cross Currents: The Promise of Electromedicine, the Perils of Electropollution,* Tarcher, St. Martin's Press, New York, 1990.

64. A provisional patent application has been filed on the process, and an overview of the method can be seen as the "porthole briefing" on my website www.cheniere.org.

65. (a) C. A. L. Bassett; R. O. Becker, and R. J. Pawluk, "Effects of electric currents on bone in vivo," *Nature,* Vol. 204, Nov. 14, 1964, p. 652-654. The complete electrical control system (conventional EM theory) for the healing of bone fractures is given in (b) R. O. Becker, *Clinical Orthopedics and Related Research,* Vol. 73, 1970, p. 169. A paper "putting it all together" is (c) R. O. Becker, J. *Bioelec,* Vol. I, 1982, p. 239.

66. F. Mandl and G. Shaw, *Quantum Field Theory,* Wiley, 1984, Revised Edition 1993, under the heading "5.2 Covariant Quantization" and "5.3 The Photon Propagator" in Chapter 5. The longitudinal and scalar photon polarizations are not directly observable, but only in combination, where they manifest as the instantaneous Coulomb (i.e., electrostatic) potential interaction, *"which emerges as an exchange of longitudinal and scalar photons."* So the common old electrostatic scalar potential is actually comprised of longitudinal EM waves and time-polarized EM waves.

67. With the MidEast increasingly set to explode, we may be facing the unleashing of weapons of mass destruction, a vast shortage and curtailment of

available oil and energy, and a total collapse of the Western economy and therefore most of the world economy, in as little as three or four years, if the impending energy crisis worldwide is not resolved quickly. See T. E. Bearden, ADAS position paper, "The Unnecessary Energy Crisis: How to Solve It Quickly," *ibid.* As this is written, we have already had a warning shot across our bow: the vicious terrorist attacks on September 11, 2001. We are in Afghanistan and elsewhere in a war against terrorism, and anyone can see the escalation in the MidEast toward war between the U.S. and Iraq, and almost certainly a resulting explosion in the MidEast and unleashing of the hostile terrorists assets and mass destruction weapons already inside the United States. Since modern economies are based on cheap energy, and cheap energy is largely based on cheap oil, then with surging energy demands worldwide we shall see "oil wars" erupt and rage worldwide, with terrorist retaliations and attacks—using weapons of mass destruction—occurring in U.S. cities. *Unless energy from the vacuum is quickly developed and deployment begun at high speed, we risk the coming collapse of the world economy, great destruction of populaces, and a new Dark Ages.*

68. E. T. Whittaker, 1903, *ibid.*

69. Daniel A. Walker, Charles S. McCreery, and Fermin J. Oliveira, "Kaitoku Seamount and the Mystery Cloud of 9 April 1984," *Science,* Vol. 227, Feb. 8, 1985, p. 607-611; Daniel L. McKenna and Daniel A. Walker, "Mystery Cloud: Additional Observations," *Science,* Vol. 234, Oct. 24, 1986, p. 412-413.

70. Superpotential theory was initiated by E. T. Whittaker, extending earlier concepts advanced by G. Johnstone Stoney. See E. T. Whittaker, *Proc. Lond. Math. Soc,* Series 2, Vol. 1, 1904, p. 367-372. Nisbet extended the Whittaker and Debye two-potential solutions of Maxwell's equations to points within the source distribution. This is a full generalization of the vector superpotentials (for media of arbitrary properties) together with their relations to such scalar potentials as those of Debye. See A. Nisbet, *Physica,* Vol. 21, 1955, p. 799. Also, A. Ricci in 1901 introduced what might be called the magnetization potential, satisfying a certain equation, as an alternate to the Hertz vector. This was a part of early vector superpotentials. For an excellent overview discussion of superpotentials and related things, see Melba Phillips, "Classical Electrodynamics," in *Principles of Electrodynamics and Relativity,* Vol. IV of *Encyclopedia of Physics,* edited by S. Flugge, Springer-Verlag, 1962. Phillips discusses, for example, that Whittaker 1903 (note: oral delivery; paper was published in 1904) was the first to prove that one can derive a general electromagnetic field from two scalar functions, which are really components of the vector superpotentials, with proper choices of the gauge functions. Whittaker's method is well known in the treatment of transverse electric and transverse magnetic modes of a cylindrical cavity or a waveguide. Nisbet has shown that this result may be extended within the source distribution (assumed

given) by a suitable choice of stream functions. The Debye potentials and the Bromwich potentials are essentially radial components of the vector potentials of which Whittaker potentials are the real parts. So in general the particular integral (the stream potentials) of the inhomogeneous Maxwell equations may be so chosen that the complementary function can be expressed in terms of only two scalars, which are components of the vector superpotentials. The Whittaker and the Debye-Bromwich potentials are special cases of two vector superpotentials.

71. David Jones, *Vancouver Sun Times,* Weekend Magazine, Dec. 17, 1977, p. 17.

72. For more specific information on the production of practical antigravity and an experiment demonstrating it, see T. E. Bearden, *Energy from the Vacuum: Concepts and Principles,* Cheniere Press, Santa Barbara, CA, 2002, Chapter 8. Approach to Antigravity.

73. T. E. Bearden, *Energy from the Vacuum: Concepts and Principles,* Cheniere Press, Santa Barbara, CA, 2002, Chapter 10. Cold Fusion: Low Spatial-Energy Nuclear Reactions at High Time-Energy. By inadvertently using highly compressed time-energy, cold fusion researchers are actually using—on the tabletop—higher energy density than our present high-energy physics uses in its largest accelerators. The conventional scientific community does not have a single scientific program dedicated to using time as energy, even when one's physics model can legitimately be made of a single fundamental unit. When the joule is chosen as that unit, then time becomes totally a function of energy, just as is mass. The use of mass-energy gave us the nuclear age; the use of time-energy will give us a far greater age, if we can ever get the scientific community off its duff and moving.

74. Further, the second law of thermodynamics has long been known not to apply to a single charge, atom, or molecule or to a small group. For such microscopic phenomena, there will occur reversed reactions a certain small fraction of the time. But also see G. M. Wang, E. M. Sevick, Emil Mittag, Debra J. Searles, and Denis J. Evans, "Experimental Demonstration of Violations of the Second Law of Thermodynamics for Small Systems and Short Time Scales," *Phys. Rev. Lett.,* 89(5), 29 July 2002, 050601. These researchers have experimentally proven that the second law can be and is violated for much larger scales—up to micro (colloidal) size—and for much longer times (up to two seconds). Hence it is now proven that such "reversed zones" where reactions run backwards for quite a bit, can and do in fact occur on the colloidal scale, sufficient for the formation of large clusters of like charges. Evans and his colleagues have pointed out that these results dramatically affect chemistry.

75. Shoulders has been creating and using such charge clusters for years. See Kenneth R. Shoulders, "Energy Conversion Using High Charge Density,"

U.S. Patent # 5,018,180, May 21, 1991; — "Energy Conversion using High Charge Density," U.S. Patent No. 5,123,039, 1992; — "Method and Apparatus for Production and Manipulation of High Density Charge," U.S. Patent #5,054,046, 1991; — U.S. Patent #5,054,047, 1991; — "Circuits Responsive To and Controlling Charged Particles," U.S. Patent 5,148,461, 1992; — and Steve Shoulders, "Observations on the Role of Charge Clusters in Nuclear Cluster Reactions,"J. *New Energy,* 1(3), Fall 1996, p. 111-121.

76. D. J. Evans and D. J. Searles, *Phys. Rev. E,* Vol. 50, 1994, p. 1645.

77. See Donald Kennedy, "To Publish or Not to Publish," *Science,* Vol. 295, 8 Mar. 2002, p. 1793.

78. R. P. Taleyarkhan, C. D. West, J. S. Cho, R. T. Lahey Jr., R. I. Nigmatulin, and R. C. Block, "Evidence for Nuclear Emissions During Acoustic Cavitation," *Science,* Vol. 295, 8 Mar. 2002, p. 1868-1873. Quoting from the abstract: "In cavitation experiments with deuterated acetone, tritium decay activity above background levels was detected. In addition, evidence for neutron emission near 2.5 million electron volts was also observed, as would be expected for deuterium-deuterium fusion. Control experiments with normal acetone did not result in tritium activity or neutron emissions."

79. Yuri T. Didenko and Kenneth S. Suslick, "The energy efficiency of formation of photons, radicals and ions during single-bubble cavitation," *Nature,* Vol. 418, July 25, 2002, p. 394-397.

80. E.g., see John Archibald Wheeler and Richard Phillips Feynman, *Phys. Rev.* 59, 1941, p. 683; —"Interaction with the Absorber as the Mechanism of Radiation," *Rev. Mod. Phys.,* 17(2, 3), Apr.-Jul. 1945, p. 157-181.

81. Albert Einstein, "Foreword," in Max Jammer, *Concepts of Space: The History of Theories of Space in Physics,* Harvard University Press, Cambridge, Massachusetts, 1969, p. xi-xii.

82. Robert A. Fisher, [Ed.], *Optical Phase Conjugation,* Academic Press, NY, 1983, p. xv.

83. Basically, the choice between distant heating in the interference zone, or distant cooling, is as simple as how one biases the ground potential used for the electrical grounds of the interferometer transmitters. Biasing well above the ambient potential in the distant IZ produces divergent EM energy (heat) forming and radiating in the distant zone. Biasing well below the ambient IZ potential produces convergent EM energy (cold) forming and radiating in the distant zone.

84. Mass is mostly empty space filled with EM potentials, fields, and waves. Since these potentials, fields, and waves are simply bundles of longitudinal EM waves and their impressed dynamics, it follows that mass itself

is mostly a "giant superhighway" for the transmission of LWs. This is actually a sort of "subspace" transmission "right through" matter, so to speak.

85. As demonstrated by such dual serial usage by a giant interferometer in the anomalous and explosive "cloud" phenomena near the Kurils in April 1984. For excellent descriptive articles and a hard look at the phenomena, see Walker et al., *Science, ibid.*

86. See "Soviet device uses radio waves as tranquilizer," AP release, *Huntsville [Alabama] Times,* May 19, 1983. See also W. Ross Adey, "Biological effects of low energy electromagnetic fields," *Proc. NATO Adv. Study Inst. on Advances in Biological Effects and Dosimetry of Low Energy Electromagnetic Fields,* Plenum Press, New York, 1983, p. 359-391. Adey apparently was aware only of ordinary U(l) electrodynamics. He describes the **LIDA** device as follows: *"Soviet investigators have also developed a therapeutic device utilizing low frequency square wave modulation of a radiofrequency field. This instrument know as the LIDA, was developed by L. Y. Rabichev and his colleagues in Soviet Armenia, and is designed for the 'treatment of neuropsychic and somatic disorders, such as neuroses, psychoses, insomnia, hypertension, stammering, bronchial asthma, and asthenic and reactic disturbances.' It is covered by U.S. Patent #3,773,049. In addition to the pulsed RF field, the device also delivered pulsed light, pulsed sound, and pulsed heat. Each stimulus train can be independently adjusted in intensity and frequency. The radiofrequency field has a nominal carrier frequency of 40 MHz and a maximum output of approximately 40 watts. The RF field is applied to the patient on the sides of the neck through two disc electrodes approximately 10 cm. in diameter. The electrodes are located at a distance of 2-4 cm from the skin. Optimal repetition frequencies are said to lie in the range from 40 to 80 pulses per minute. Pulse duration is typically 0.2 sec. In a 1-year trial period, the instrument was used on 740 patients, including adults and children. Positive therapeutic effects were claimed in more than 80 percent of the cases treated."* We accent that this is one of the simplest Russian psychoenergetics devices, obsoleted very early on, and thus released very early for public use.

87. Since U.S. researchers are unaware of the EM wave polarization transduction mechanisms, and in general have no instruments for detecting longitudinal EM waves, the specific transduction effects on humans would not be measured by U.S. laboratories. Hence the U.S. scientists could only think of it in conventional electrodynamic terms, and remained totally unknowledgeable about the specific transduction mechanisms in the human body producing time-polarized EM waves and effects from the device.

88. Max Frankel, "Khrushchev Says Soviet Will Cut Forces a Third; Sees 'Fantastic Weapon'," New *York Times,* Jan. 15, 1960, p. 1.

89. For a simplified introduction to psychoenergetics and the mind-matter coupling mechanism, see T.E. Bearden, "Mind Control and EM Wave Polarization Transductions, Part I", *Explore,* 9(2), 1999, p. 59; Part II, *Explore,* 9(3), 1999, p. 61; Part III, *Explore,* 9(4,5), 1999, p. 100-108.

90. One of the serious goals of the die-hard KGB psychoenergetics scientists appears to be to achieve the capability of directly engineering the entire human collective unconscious mind. The plan envisioned is to convert the human species into a sort of "giant ant species" where each one has perfect, machine-like niche and function (except, of course, for the elite Communist masters). In short, they conceived back there in the 1960s that such a "perfect communist state" for all humanity was in fact possible to achieve technically, with sufficient development of psychoenergetic technology. They are apparently well along the way toward achieving that goal. [The U.S. has not even conceived such a scientific possibility, and modern cognitive science in the West seems bent on the rather astounding proposition that mind itself does not even exist!]. We point out that no type of physical defense is even possible against such a capability engineered into the collective human unconscious, once it is achieved. The only "counter" is to use the same technology (it has to first be developed) to "re-engineer" what will have been done. But our fellows have not even conceived the possibility of the threat, much less the cause or the counter. Hence they continue to totally misunderstand what happened to Captains Button, Svoboda, and Hess in successful mind-control tests achieved perfectly at great distance.

91. To see the nature of the time-density wave (which is basically a longitudinal EM wave along the time axis), due to the perfect correlation between time-energy flow currents and variations with respect to longitudinal EM waves, see T.E. Bearden, "Giant Negentropy from the Common Dipole," 2000, *ibid.* Not stressed in the paper is the fact that the same dipolar negentropy with correlated EM time-energy currents and EM spatial energy currents, exists in the "individual" photon. Further, they can occur in coupled photon-antiphoton pairs, yielding the graviton. For time-polarized EM photons, it appears that two photon-antiphoton pairs are coupled, yielding the "supergraviton." Elsewhere we have briefly and addressed these novel formations as hypotheses.

92. Induction of specific diseases and health changes in the U.S. Embassy in Moscow over four decades, included causing the deaths of three U.S. Ambassadors. It was accomplished by implementing desired disease-pattern "engines" infolded inside field-free potentials. The Johns Hopkins study of the radiation patterns revealed a most significant finding: All the affected persons were in regions of the Embassy where the Russian microwave radiation *fields* were absent. In short, where the field-free—and thus very stable—potentials existed. Since these scientists (and most others in classical EM) consider that EM effects are caused only by fields, they concluded (totally erroneously) that

these health changes could not have been caused by the microwave radiation. To the contrary, they had just clearly proven that the radiation was indeed the cause. They showed a 100% correlation to the *presence of field-free potentials,* and a 100% anticorrelation to where the fields were present. This was for induced phenomena over several years. Had the radiation not been the culprit, then some health changes would have occurred where the fields were present, and some would have occurred where they were absent. That is not what happened at all, and this inexplicable logical non sequitur against common statistical inference was the accepted decision. The truly revealing aspect was that *apparently the entire U.S. Intelligence community had no competence or capability in higher group symmetry electrodynamics.*

93. E.g., see Lewis H. Ryder, *Quantum Field Theory,* Cambridge University Press, 2nd Edition, 1996, p. 147+ which covers the four photon polarizations. See also F. Mandl and G. Shaw, *Quantum Field Theory,* Wiley, 1984, Revised Edition 1993, under the heading "5.2 Covariant Quantization" and "5.3 The Photon Propagator" in Chapter 5.

94. We elaborate on this somewhat, in "Mind Control and EM Wave Polarization Transductions", *ibid.*

95. Again, we point out the unified field approach of Mendel Sachs as probably being the best Western model in which to grapple with these phenomena.

96. David J. Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of'Hidden' Variables, I and II." *Phys. Rev.,* 85(2), Jan. 15, 1952, p. 166-179 (Part I); 180-193 (Part II).

97. T. E. Bearden, *Gravitobiology: A New Biophysics,* Cheniere Press, Santa Barbara, Ca. www.cheniere.org, 1991.

98. W. A. Rodrigues Jr. and J.-Y. Lu, "On the existence of undistorted progressive waves (UPWs) of arbitrary speeds 0 < v < oo in nature," *Found. Phys.,* 27(3), 1997, p. 435-508. A slightly corrected version is downloadable as hep-th/9606171 on the Los Alamos National Laboratory web site. It includes corrections to the published version.

99. W. A. Rodrigues Jr. and J. Vaz Jr., "Subluminal and Superluminal Solutions in Vacuum of the Maxwell Equations and the Massless Dirac Equation," *Adv. Appl. Clifford Algebras,* Vol. 7(S), 1997, p. 457-466.

100. E.g., see A. Enders and G. Nimtz, *Phys. Rev. Lett.,* Vol. 48, 1993, p. 632. Enders, Aichmann, Nimtz and co-workers at the University of Cologne have transmitted 8.7 GHz microwaves (free space wavelength 3.4 cm) traveling in a rectangular wave-guide that contains a "barrier" section of reduced dimensions. They transmuted Mozart's 40th Symphony as frequency modulated

microwaves through a barrier wave-guide at an FTL group velocity of 4.7c, receiving audibly recognizable music from the microwave photons that survived their barrier passage.

101. J. D. Jackson, *Classical Electrodynamics,* 2nd Edition, Wiley, New York, 1975, p. 222.

102. See H. A. Lorentz, *Vorlesungen Uber Theoretische Physik an der Universitat Leiden, Vol. V, Die Maxwellsche Theorie (1900-1902),* Akademische Verlagsgesellschaft M.B.H., Leipzig, 1931, "Die Energie im elektromagnetischen Feld," p. 179-186. Figure 25 on p. 185 shows the Lorentz concept of integrating the energy flow vector around a closed cylindrical surface surrounding a volumetric element. This is the procedure which arbitrarily selects only a small component of the total energy flow in space outside a circuit and associated with it—specifically, the small Poynting component diverged by the surface charges into the conductors to power the electrons—and then treats that tiny component as the "entire" vast energy flow (which may be a trillion or more times greater in magnitude). Thereby Lorentz arbitrarily discarded all the huge *Heaviside* energy transport component that does not strike the circuit at all, is not diverged into the conductors, and is just wasted. See Oliver Heaviside, *Electrical Papers,* Vol. 2, 1887, p. 94. Quoting: *"It [the energy transfer flow] takes place, in the vicinity of the wire, very nearly parallel to it, with a slight slope towards the wire... . Prof. Poynting, on the other hand, holds a different view, representing the transfer as nearly perpendicular to a wire, i.e., with a slight departure from the vertical. This difference of a quadrant can, I think, only arise from what seems to be a misconception on his part as to the nature of the electric field in the vicinity of a wire supporting electric current. The lines of electric force are nearly perpendicular to the wire. The departure from perpendicularity is usually so small that I have sometimes spoken of them as being perpendicular to it, as they practically are, before I recognized the great physical importance of the slight departure. It causes the convergence of energy into the wire."*

103. When it is associated with positive energy fields and potentials from positive mass, positive energy source charges, we have nominated that long-unaccounted Heaviside energy flow component as the source of the excess gravity holding the arms of the spiral galaxies together (a solution to the dark matter problem). When it is associated with negative energy fields and potentials from negative-energy Dirac Sea holes in 4-space, we have nominated that unaccounted energy flow component as the source of the excess antigravity responsible for accelerating the expansion of the universe (a solution to the dark energy problem).

104. About a year from now, Bedini and I will also release a very novel use of this Heaviside energy flow component in inverted circuits—circuits that

operate almost completely in reverse from normal textbook circuits. This is a totally new kind of circuit that we hope will revolutionize power systems and electronic control systems. Until our intellectual property rights are secured, we are not releasing any details at all.

105. Terence W. Barrett, "Tesla's Nonlinear Oscillator-Shuttle-Circuit (OSC) Theory," *Ann. Fond. Louis de Broglie,* 16(1), 1991, p. 23-41. Tesla was able to shuttle energy around in his circuits at will. Barrett went on to improve the process and patent two versions. See T. W. Barrett, "Active Signalling Systems," U.S. Patent No. 5,486,833, Jan. 23, 1996. This is a signaling system in time-frequency space for detecting targets in the presence of clutter and for penetrating media. See also T. W. Barrett, "Oscillator-Shuttle-Circuit (OSC) Networks for Conditioning Energy in Higher-Order Symmetry Algebraic and RF Phase Conjugation," U.S. Patent No. 5,493,691. Feb. 20, 1996.

106. Bryan G. Wallace, "The Unified Quantum Electrodynamic Ether," *Found. Phys.,* 3(3), Sept. 1973, p. 381-388.

107. William G. Harter, John Evans, Roberto Vega, and Sanford Wilson, "Galloping waves and their relativistic properties," Am. J. *Phys.,* 53(7), July 1985, p. 671-679. Most waves caused by a single frequency source have a galloping motion. The only exceptions are the very special cases of absolutely pure moving waves or absolutely pure standing waves. The superposition and resulting interference of two oppositely moving waves generally yield a wave having nonuniform motion; in short, the wave rushes forward rapidly, then slows appreciably, etc. A relativistic example is given in which the source frame observes a very nonuniformly galloping wave whose velocity varies between 0.01 c and 100 c, even though its average velocity is c. Relativistic properties of interfering electromagnetic plane waves are discussed.

108. S. L. Miller, "The Formation of Organic Compounds on the Primitive Earth," *Ann. NYAcad. Sci.,* Vol. 69, 1957, p. 260; — *Bioch. Biophys. Acta.,* Vol. 23, 1957, p. 480-489; — *Science,* Vol. 117, May 15, 1953, p. 528-529; — and H. C. Urey, "Organic Compound Synthesis on the Primitive Earth," *Science,* Vol. 130, 1959, p. 245-251.

109. R. Harada and S. Fox, "Thermal Synthesis of Natural Amino-Acids from a Postulated Primitive Terrestrial Atmosphere," *Nature,* 201(4917), 1964, p. 335-336; S.W. Fox, "How Did Life Begin?", *Science,* 132(3421), July 22, 1960, p. 200-208; — and S. Yuyama, "Abiotic Production of Primitive Protein and Formed Microparticles," *N.Y. Acad. Sci. Ann.,* Vol. 108, June 1963, p. 487-494; — and K. Harada, "Thermal Copolymerization of Amino Acids to a Product Resembling Protein," *Science,* 128(333), 1958, p. 1214; — and M. Middlebrook, "Anhydrocopolymerization of Amino Acids Under the Influence of Hypothetically Primitive Terrestrial Conditions," *Federation Proc.* Vol. 13, Mar. 1954, p. 211.

110. H. C. Urey, "On the Early Chemical History of the Earth and the Origin of Life," *Proc. Nat. Acad. ScL,* 38(4), 1952, p. 351-363.

111. I.e., one may speak of the "potential" of a specific engine of a former life form, and then realize that the potential for that form reduces in magnitude inversely as the radial distance from the Earth. However, it does not reduce to zero until an infinite distance is reached.

112. As an example, a great EM energy flow—produced by the cross product ExH of the earth's magnetic field and the earth-to-electrosphere electric field—flows from West to East around the earth, nearly parallel to the equator. Infolded in that great EM energy flow are all the structures of all the genetics and life forms on earth, or that have ever been on earth and conditioned the natural scalar potential of the earth. The vials in the laboratory experiments of Miller, Fox, and Urey were all continually bathed in that great energy flow, which within it contained the entire life structure and dynamics of the planet. So no "inert" experiments were ever performed, contrary to the interpretations of the scientific community.

113. Vlail Kaznacheyev and L. P. Mikhailova, *Ultraweak Radiation in Intercellular Interactions*, [in Russian], Novosibirsk, 1981 [an English exposition of much of the Kaznacheyev work is given in Vlail Kaznacheyev, "Electromagnetic Bioinformation in Intercellular Interactions," *Psi Research,* 1(1), Mar. 1982, p. 47-76.] Kaznacheyev, e.g., appears to have headed the Soviet team actually producing the basis for the disease-inducing technology utilized for four decades in the microwave radiation of the U.S. Embassy in Moscow.

114. Specifically, the down payment was $900 million in gold. The lease is probably about $1 billion per year. Thus the Yakuza acquired very powerful strategic weapons, and became a secret power to be reckoned with internationally and strategically. Since 1990, weather engineering over the U.S. and occasional shootdown of aircraft (such as the TWA-800) have been by rogue Japanese fingers on the scalar interferometer weapon triggers, on site in Russia.

115. The Yakuza has also transferred some of the longitudinal EM wave interferometry technology to their Japanese facilities. One such system has apparently been deployed in the power grid, and has been used to kill some government officials who opposed the Yakuza. This information was obtained by some brave Japanese risking their lives to get the information to the present author.

116. Many important KGB weapon tests happened in April of various years; the KGB weapons folks were simply preparing for their May Day reports, and each wished to have a good one.

117. Sen. Sam Nunn's investigation teams verified that the Aum Shinrikyo were actively seeking the "Tesla Weapons", with the Aum Shinrikyo even visiting the Tesla Museum in Beograd for that purpose. We have 100% certain confirmation of the Yakuza and Aum Shinrikyo leasing of the scalar interferometers from the KGB and Russian Mafia (working for the KGB) at the end of 1989 or first few days of 1990. Sen. Nunn's report confirms that the Aum Shinrikyo set up a University in Moscow. Our comment is that this is where the Russians actually taught the Japanese crews the science and technical functions so that they could successfully man and use the scalar (longitudinal EM wave) interferometry weapons.

118. Recall that in the 1950s and early 1960s, Kaznacheyev et al., *ibid.,* had already clearly proven that nearly any form of cellular change, damage, or disease could be induced in cells at a distance by purely electrodynamic means.

119. In the kill of the Arrow DC-8 at Gander, Newfoundland on 12 Dec. 1985, the struck aircraft did charge up with time-density charging, and many pieces of the wreckage did indeed emit longitudinal EM waves thereafter for some time. Consequently, the Canadian recovery crews working the site and handling the materials, were exposed to longitudinal EM wave radiation for varying degrees of exposure. It follows that many of those on-site handlers should have later come down with physical ailments, with symptoms such as flu-like features, weakness, heart palpitations, headaches, dizziness, disturbance of equilibrium, and with various infections because of weakened immune systems. They also should have had weakened cellular regenerative (healing) systems, so their physical problems would endure and largely remain. About five dozen of the recovery personnel did come down with those exact symptoms, and many remained disabled or debilitated for some years.

120. We have also explained (a) why the French forces in the Gulf War did not get GWS, while American, British, and Canadian forces did, (b) why the native population did not exhibit GWS, and (c) the remaining anomalous phenomena associated, such as the semen "infecting" the wife, the children catching similar or related conditions from sustained close proximity to their father's biofields (transmission of engines), etc.

121. Mario Bunge, Foundations of Physics, Springer-Verlag, New York, 1967, p. 176.

122. T. E. Bearden, "Giant Negentropy from the Common Dipole," J. *New Energy,* 5(1), Summer 2000, p. 11-23 gives the solution to the long-vexing source charge problem. The paper is also carried on DoE restricted website http://www.ott.doe.gov/electromagnetic/ and on www.cheniere.org

123. Two examples of inane articles and actions in this respect, revealing no knowledge that every charge in the universe already exhibits COP = oo, are (a)

Graham P. Collins, "There's No Stopping Them: Perpetual Motion is alive and well at the U.S. Patent Office," and (b) Resolution by the Executive Board at the June 2002 meeting of the American Physical Society (APS) as follows: *"The Executive Board of the American Physical Society is concerned that in this period of unprecedented scientific advance, misguided or fraudulent claims of perpetual motion machines and other sources of unlimited free energy are proliferating. Such devices directly violate the most fundamental laws of nature, laws that have guided the scientific progress that is transforming our world."* So the learned APS has just declared the source charge as an unacceptable "free energy" machine and perpetual motion machine, since the charge simply sits there and continuously pours out real observable EM energy in all directions at the speed of light, without any observable EM energy input. Thus the APS has implicitly declared all EM fields and potentials and their energy—which includes every joule of EM energy in the universe, in matter or in space—to be unacceptable byproducts of perpetual motion nonsense. We heartily call upon the APS in the name of science to enforce their resolution in the orthodox academic community, who are the greatest perpetual motion advocates in history. To be consistent with their own resolution, they must root out and destroy—from all texts and universities and from the scientific literature—any mention whatsoever of charge, field, potential, and EM energy. Either they must do that, or stand hoisted on their own petard as a dogmatic group still very much unaware of why the Nobel Prize was awarded to Lee and Yang in 1957 and what the proof—by Wu et al.—of the asymmetry of opposite charges means with respect to the source charge considered in its modern quantum field theory view as a dipolarity of a bare infinite central charge surrounded by clustering virtual charges (also infinite charge) of opposite sign in the active vacuum. Every electrical engineering department and professor and textbook still uses a model and teaches a subject assuming that every charge in the universe freely creates energy from nothing at all. Further, the APS in every annual meeting also tolerates, encourages, and publishes multiple papers and presentations with the same such unacceptable perpetual motion assumptions in them. Such is the lofty understanding of our present organized scientific community, which seems much more politically bent than scientifically bent. The simple Bohren experiment and the entire area of negative resonance absorption of the medium has long been established in nonlinear optics, and such experiments widely yield a nominal COP = 18. In other words, the experiments nominally output 18 times as much energy as the operator inputs, and the excess input energy is furnished absolutely for free from the active vacuum's exchange. In this case the Executive Board of the APS is not even aware of what its own physics discipline has long proven and accepted in particle physics, for nearly a half century. Neither are the self-appointed defenders of the faith, who also are totally unaware of what physics has already proven with a Nobel Prize awarded nearly a half century ago.

124. C. S. Wu, E. Ambler, R. W. Hayward, D. D. Hoppes and R. P. Hudson, "Experimental Test of Parity Conservation in Beta Decay," *Phys. Rev.,* Vol. 105, 1957, p. 1413. We also quote Nobelist T. D. Lee as follows: *"Since nonobservables imply symmetry, any discovery of asymmetry must imply some observable. The experiment of Wu, Ambler, Hayward, Hoppes and Hudson... established the asymmetry between the positive and negative signs of electricity."* [T. D. Lee, *Symmetries, Asymmetries, and the World of Particles,* U. Wash. Press, Seattle, 1988, p. 11.].

125. Dilip Kondepudi and Ilya Prigogine, *Modern Thermodynamics: From Heat Engines to Dissipative Structures,* Wiley, New York, 1998, reprinted with corrections 1999.

126. See "Secret Speech: Did Brezhnev Come Clean?" *National Review,* 29(8), Mar. 4, 1977, p. 248, 250

127. For the energy description of this device and some results, see Floyd Sweet and T. E. Bearden, "Utilizing Scalar Electromagnetics to Tap Vacuum Energy," *Proc. 26th Intersoc. Energy Conversion Engineering Conf. (IECEC '91),* Boston, Massachusetts, p. 370-375.

128. Also see my book, *Energy from the Vacuum,* 2002, *ibid,* which includes photographs of the self-powering Sweet device, courtesy of Walter Rosenthal.

129. Roy Brewer was very active in Hollywood Unions against Communists when they were busily penetrating the Hollywood complex. He was a staunch anti-communist, fighting them out of control of the unions, way back when. Ronald Reagan was a personal friend of his of long standing, and Roy had open access to the White House when Reagan was President.

Roy briefed Reagan on the Russian scalar weapons, and Reagan believed him. Three times, Reagan ordered his Secretary of Defense to take action in that area, but neither of the three did so because the U.S. Intelligence Community did not believe it and adamantly opposed any such action. We took quite a beating in those days, for quite a long time (some years), before certain key parts of the Government finally believed us, checked it out experimentally, and found that it worked.

Roy also introduced me to the Duke de Grantsmesnil, one of the last of the great old British intelligence men, now unfortunately deceased. In the hectic 1997 days when we were trying desperately to warn a little friendly nation (and our own) against a coming great strategic strike on the U.S. and other allies, the Duke played a major role in introducing us directly to higher political levels in that little nation - which was the only nation on earth that could counter the pending strike. The first planned strike scheduled in February 1997 was successfully countered, only to be immediately rescheduled. In the second incident, the attack was scheduled for May 1, 1997. We finally realized why the hostile nation could reschedule and go ahead, and needed then to warn the little nation of the reason in some detail. We had tried everything to get certain information through, and all means had failed. A former ambassador of that nation to Great Britain was also assassinated during that struggle. Roy Brewer was one of the key fellows assisting in that attempt, as were other personal colleagues of mine who also were witnesses and direct participants in those desperate events. When all else failed, I finally just faxed the Prime Minister directly, in the clear, some five days before the attack, urging the most urgent and immediate action possible by the Prime Minister. A complete change in command and control of the weapon was required, and that change had to be made and then the hostile nation had to be notified that the change was in place (and probably shown that it was). The Prime Minister accepted the message and the necessary action was carried out immediately. So two days or so before the actual attack was scheduled, that great hostile armada began standing down. Oh, the hostile nation and its leaders could have easily destroyed the entire United States in two hours or so, without fail! But then their own country would have promptly disappeared from the face of the earth. So they stood down. And our own Intel community never even picked it up (they did get my messages alerting the U.S. Government, but thought it was a joke or something). They, of course, also intercepted my open fax to the Prime Minister, and so were all over me for that one for a while thereafter.

Interestingly, at the very time that great armada was just beginning to stand down, then Secretary of Defense William Cohen made the following statement at a conference in Georgia: "Others are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves...so there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations...It's real, and that's the reason why we have to intensify our efforts, and that's why this is so important." Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.

Ironically, the Secretary was referring to the earlier scalar interferometer weapons, and now the quantum potential weapons etc. He was completely unaware that a great strategic strike had actually been scheduled and was just being aborted as he was speaking those words.

Roy Brewer is one of those fellows who has been a great American, has served his country admirably during his lifetime, and contributed greatly to preventing a planned take-over by the Communists of the labor unions of America. In addition, he helped set up the contacts with the friendly **liltle foregn nation, so** that on four occasions planned attacks to destroy the United States have been successfully aborted or handled.

As you know, one of the great failures in the Communist plan to have America go communist was their failure with the labor unions. And we owe that failure to the steadfast efforts of some staunch folks like Roy Brewer. He helped save our nation when many of us were still wearing knee pants.

130. Wheeler's principle, as stated in W. Misner, K. S. **Thorne, and J.** A. Wheeler, *Gravitation*, W.H. Freeman and Co., San Francisco, 1973, p. 5.

131. With the new improvements we uncovered, treatment time can be reduced to 5 minutes per patient. Three such treatments one week apart would be what are required. Hence one machine station could treat a patient every five minutes, around the clock. With sufficient portable treatment units, mass treatment for mass casualties would become a practical reality.

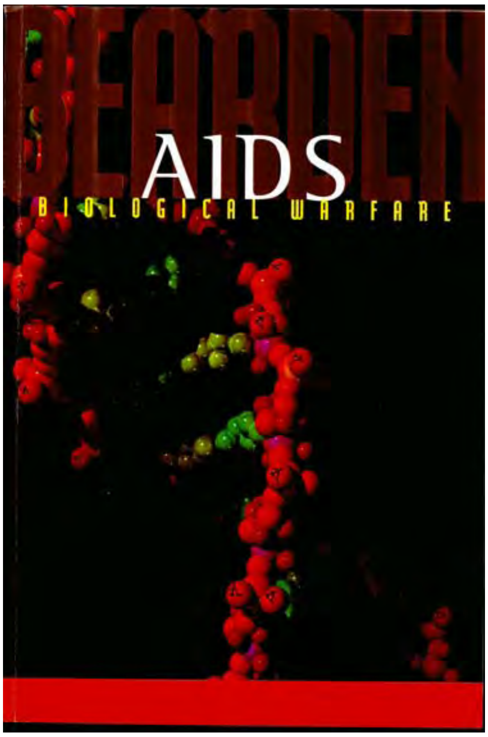

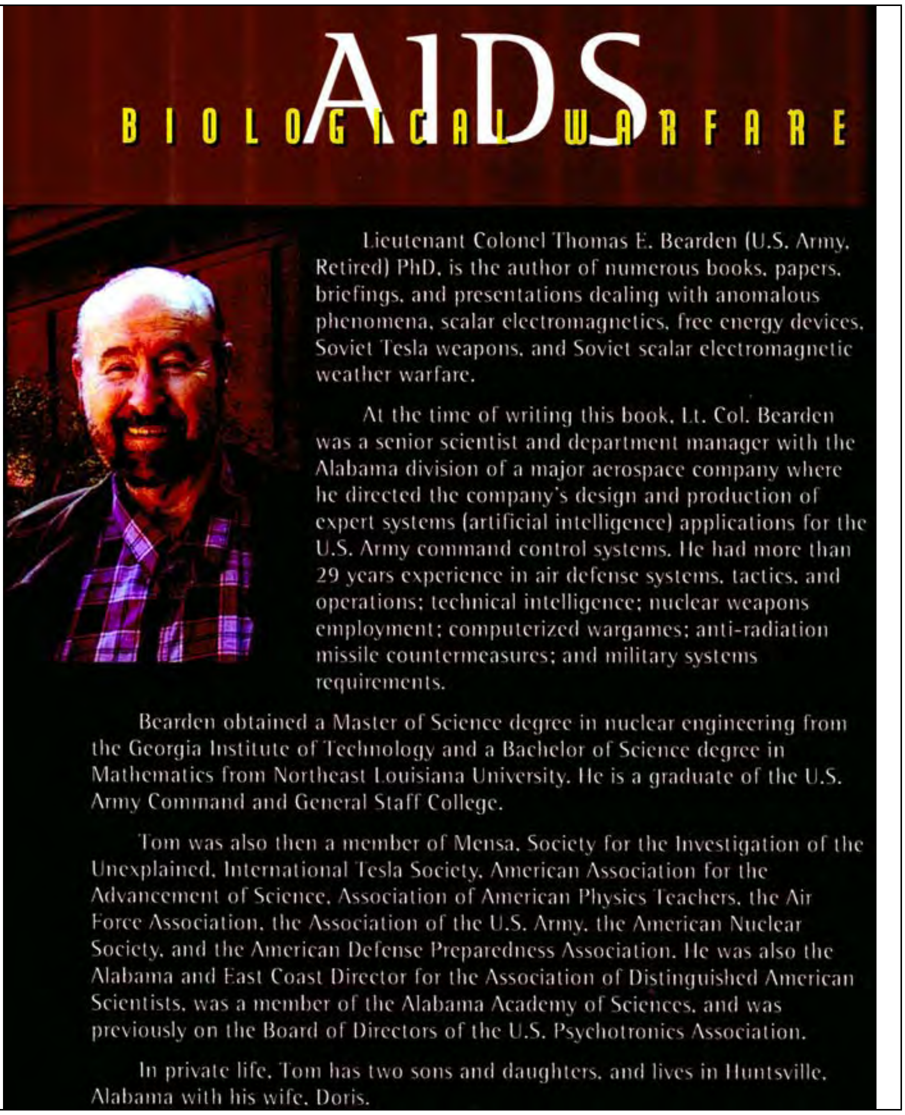

AIDS
BIOLOGICAL WARFARE

Lieutenant Colonel Thomas E. Bearden (U.S. Army, Retired) PhD, is the author of numerous books, papers, briefings, and presentations dealing with anomalous phenomena, scalar electromagnetics, free energy devices, Soviet Tesla weapons, and Soviet scalar electromagnetic weather warfare.

At the time of writing this book, Lt. Col. Bearden was a senior scientist and department manager with the Alabama division of a major aerospace company where he directed the company's design and production of expert systems (artificial intelligence) applications for the U.S. Army command control systems. He had more than 29 years experience in air defense systems, tactics, and operations; technical intelligence; nuclear weapons employment; computerized wargames; anti-radiation missile countermeasures; and military systems requirements.

Bearden obtained a Master of Science degree in nuclear engineering from the Georgia Institute of Technology and a Bachelor of Science degree in Mathematics from Northeast Louisiana University. He is a graduate of the U.S. Army Command and General Staff College.

Tom was also then a member of Mensa, Society for the Investigation of the Unexplained, International Tesla Society, American Association for the Advancement of Science, Association of American Physics Teachers, the Air Force Association, the Association of the U.S. Army, the American Nuclear Society, and the American Defense Preparedness Association. He was also the Alabama and East Coast Director for the Association of Distinguished American Scientists, was a member of the Alabama Academy of Sciences, and was previously on the Board of Directors of the U.S. Psychotronics Association.

In private life, Tom has two sons and daughters, and lives in Huntsville, Alabama with his wife, Doris.

Sweating done by red_gonzo.

Note: sometimes formatting of the text may be a little fuzzy. It's all because the OCR process didn't go as smoothly as I expected. Also there may be some errors inside text so be vigilant. In any case share this book, send emails to people about knowledge contained in it. This book should especially be interesting to any person in medical community (being as a doctor or as patient) as it provides factual evidence of successful (but supressed) treatments through electromagnetic means. But before any devices can be understood and developed a new and extended kind of physics must be introduced into our educational system. Only then can this proper foundation be learnt and used by applicative sciences such as medicine. So far such knowledge has been contained in highly classified military circles and hopefully now, after many decades of suppression, it will finally be used for the good of mankind.

Dedication

This book is sincerely dedicated to the millions of persons who have died needlessly of cancer, leukemia, and AIDS in the last two and half decades. They were men, women, and children. Some were weak, some were strong. Some died in agony, some died silently. All of them were our fellow human beings. We remember them. They were important. Their anguish cries out to be heard. God willing, the new electromagnetic medicine so long suppressed will flower, and save the millions otherwise yet to die.

Special Acknowledgements

Mr. Christopher Bird's kind permission to print, his summary of the Priore Affair is gratefully acknowledged, as is the contribution of his own extensive Priore research material to this effort. The author owes a great debt indeed to Chris Bird for his magnificent assistance.

Mr. Robert Whitney graciously contributed rare photographs of Antoine Priore's device and also translations of background papers by French scientific journals. His previous valiant though fruitless efforts to bring the Priore machine into the mainline of Western medical treatment are specifically recognized and commended.

Vital contributions by Drs. Robert B. and Theodore A. Strecker are particularly acknowledged. Their March 1986 alert to the federal government, that AIDS was a deliberate biological attack spawned by Soviet agents working in Western research laboratories, is specially pointed out.

Heroic efforts by Dr. John Seale and other scientists to alert the medical research community to the true source of AIDS is specifically recognized and gratefully acknowledged.

Continuing efforts by Dr. William C. Douglass to "tell it like it is" on the AIDS crisis is specially pointed out. His permission to extract and present an excerpt from his research, pointing out tested healing of viral infections by UV irradiation of the blood, is deeply appreciated.

The unyielding and continuing efforts of Dr. Eva Snead, to alert the national authorities to the fact that there is more to AIDS than meets the eye, is also particularly recognized and appreciated.

Decades of effort by John Crane to bring Royal R. Rife's work out of suppression are specifically recognized and appreciated.

Important scalar EM experiments by John Bedini and Frank Golden are fully recognized and deeply appreciated. Their experimental efforts over a period of years have profoundly influenced my own thinking and understanding.

As always, my great admiration and deep thanks go to my friend Hal Crawford, whose keen artistic vision and skilled hand have contributed key illustrations to my work for years.

Other important illustrations and artwork by Messrs. James Thomas Neumann and Lee Giles are gratefully acknowledged.

Photographs furnished by John Moray showing his father's pioneering free energy work are appreciated. T.H. Moray's genius and achievements will yet be recognized.

Support from the Association of Distinguished American Scientists and Mr. Richard J. Reynolds III is deeply appreciated. Without that support, this effort could not have been accomplished.

Important contributions from a host of other colleagues and persons are deeply appreciated. These persons include Frank Golden, John Bedini, Ken Moore, Tom McLaughlin, Joe Parrot, Randy Davidson, George Fencl, Andrew Michrowski, Stefan Possony, Tony Gideon, Electra Briggs, and many others too numerous to mention.

Finally, nothing that I have attempted could have been accomplished at all without the unflinching and loyal support of my beloved wife, Doris.

To all of you I owe a great deal. If this bizarre struggle to save humanity is ever won, it will largely be due to the significant contributions you have made.

Thomas E. Bearden
Jan. 17, 1988

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Chapters 4 and 5
contain complex scientific material
and are suggested for those who are
technically proficient.

FOREWORD

What This Book is About

In my book, **"Fer-de-Lance: A Briefing on Soviet Scalar Electromagnetic Weapons,"** (Tesla Book Co., P.O. Box 1649, Greenville, Texas 75401, 1986), I specifically pointed out that I was of necessity neglecting the biological warfare (BW) aspects. I intended to later write a second book covering the BW aspects.

This book contains the most important item of that planned second book, including the photobiology aspects of BW.

The material is put down in great haste, for it is meant to serve as an urgent warning. There is no time to do the six months additional research and compilation necessary to "flesh it out", sculpture it and meticulously document it, as should be done by a careful scholar.

I apologize to the reader for this lowered standard, but in this case the basic information is far more important than scholarship.

Further, I acknowledge the fundamental contributions of Dr. Robert B. Strecker, M. D., Ph. D., who together with his brother Ted, has for some time urgently called attention to the terrible threat posed by the AIDS epidemic.

I specifically acknowledge his important warning, "This is a Bio-Attack Alert," Mar. 28,1986, which was sent to the U. S. President and Vice-President, Governors of the states, various federal agencies such as Departments of State, Defense, and Agriculture; National Security Agency, Federal Bureau of Investigation, Central Intelligence Agency; and three members of Congress.

Dr. Strecker has also strongly pointed out the covert involvement of Soviet and other communist agents in the epidemic, and the absolute necessity for an *electromagnetic* solution.

Also recognized are the efforts of the other medical scientists, such as Dr. John Seale, M.D., and Dr. Eva Snead, who have tried repeatedly to call attention to the nature of the AIDS initiation, only to have their submitted papers resoundingly rejected by important journals such as New Scientist, **The** Lancet, etc.

Work by Dr. William C. Douglass in alerting the public to the no-nonsense truth about aids is particularly recognized. His monthly newsletter, **The Cutting Edge,** is an oasis of clarity sharply standing out in a sea of misinformation. Permission to reproduce his published research article on UV irradiation of the blood to successfully heal viral infections is deeply appreciated.

The continuing efforts of Dr. Andrija Puharich and Dr. Robert Beck to assist in achieving an AIDS solution are pointed out and recognized. Important contributions by Ed Skilling are also recognized in this regard.

The vital and extensive contributions of Christopher Bird are particularly acknowledged. Chris has unstintingly and unselfishly shared with me the results of his enormous research on the Priore device and affair and the results of his translations from the French. He has most graciously permitted me to publish his important summary of the Priore affair, and I am greatly in his debt. The reader will find that material most illuminating, and well may be shocked at the depth and malevolence of the scientific and political suppression of Priore's rigorously demonstrated electromagnetic cure for cancer, leukemia, and other killer diseases.

Special acknowledgement is made to Robert Whitney, who so nobly labored to bring the Priore technology into the mainstream of medical treatment, only to be ruthlessly suppressed in his efforts. Photographs of the Priore machine were furnished by Bob from his collection.

My special thanks to colleagues John Bedini, Frank Golden, Andrew Michrowski, George Fencl, Ken Moore, Tom McLaughlin, Joe Parrott and Randy Davidson, without whose assistance this project could not have been accomplished.

The material in this present small book is intended to be of any assistance possible to certain brave colleagues who — with little or no funds or resources except what they can tear out with their bare hands — are already laboring around the clock to develop a permanent solution to the AIDS problem.

As a matter of discretion, I shall not mention the names of those colleagues. The solution sought is radical, by orthodox assessment. Yet it is the only possible approach that has any chance whatsoever of succeeding.

What they are doing, I cannot do. If they do not succeed, no one can. But I will say this, and most strongly: In my view, the only hope for humanity lies in the work they are doing, and they have my utmost admiration and support.

Their initial results are exciting and encouraging. Basic phase conjugated electromagnetic "mixed-modulations" signals lethal to bacteria, nematodes (hookworm-like organisms), various amoeba, viruses, etc. at very weak power levels have been synthesized and demonstrated.

In my best estimate/opinion, these researchers must succeed in *two years or less, certainly in no longer than three years,* else the **AIDS** incubation already accomplished by then, and the implementation time delay — even given a cure —together will insure a devastation of humanity unparalleled in all of history.

Let me accent that developing this AIDS cure is far more important than developing our entire arsenal of new military weapons. It is even more important than the development of defenses against the Soviet scalar electromagnetic weapons I detailed in **Fer-de-Lance.** Problems in the Middle East, Korea, and Nicaragua are insignificant compared to the AIDS problem.

Desperate Diseases, Desperate Remedies

Spurred by the looming holocaust of AIDS, and by the strong efforts of my colleagues, I have decided to release specific *information on how to develop electromagnetic healing, essentially against any and all of the "killer" diseases including cancer, leukemia, and AIDS.*

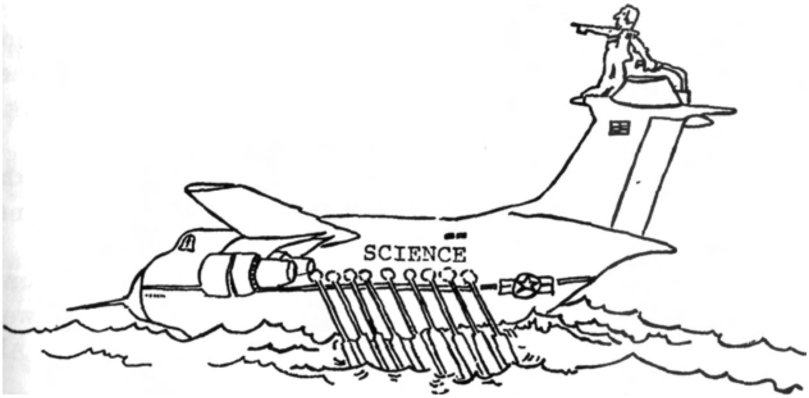

Figure 1. Conventional science cannot do the job.

Unavoidably this also releases a major principle of scalar electromagnetics: what is really going on in phase conjugation. If phase conjugation is truly understood and applied, all the Soviet weapons I have pointed out in **Fer-de-Lance** can be understood, designed and developed.

I'm also releasing specific information on mind and thought that will enable them to eventually be directly detected, measured, and investigated scientifically. Unfortunately, this also will enable them to be technologically manipulated for nefarious purposes.

However, the developing scalar EM technology for the AIDS cure must not be hamstrung. There is no time to apply the standard "Let's classify it!" response. If we do, we'll win the skirmish and lose the war.

As shocking as it sounds, I am convinced that the Soviets have already launched WW III, to the hilt. And it's not at all the kind of war we've been expecting.

There's no time to rail against the Soviets, who have cunningly and in great secret "struck our vitals with the mailed fist." We've been struck in such a way that, *unless we can solve the AIDS problem, in two to three years or less, we are already finished.*

We have been preparing to fight a better World War II. The one we're preparing for is never going to be fought. The real World War III is already raging. Our death knell has been sounded, *and we've not yet even recognized that the battle is underway.*

A great Soviet "first strike to finish us" has already been accomplished. The new "Pearl Harbor" has already happened. The enemy has already overrun our Maginot Line; we are at our Dunkirk. There are no boats waiting, and there are none on the way.

The great Soviet first strike has been delivered with surreptitious biological warfare, not with nuclear weapons or ground forces.

As always in the past, we have almost no troops facing the brunt of the first strike and trying to turn it. This time we have far fewer than we've ever had. Just two or three unorthodox researchers. All the orthodox researchers are manning the wrong ramparts.

Ironically, this time our entire system—the government, the medical establishment, the scientific establishment, the universities — all are far too dogmatic, and have far too sluggish a response time, to offer any assistance at all. They are simply so "out of it" that they don't even know what's really happened.

The bureaucracy simply is so stagnated that, even with a giant paroxysm, it cannot change quickly enough to do the job in time.

The best response the orthodox system could theoretically make —if it immediately placed the nation under martial law, marshalled all the universities and scientists, everything — would require at least seven years to produce results. A more likely response time is 10 to 14 years. That won't do the job.

So the job has to be done from completely *outside* the system. It has to be done with *independent* financing. Financing without a lot of conventional, bureaucratic strings on it. Resources must be committed as needed, immediately, not with a several months' approval process.

Everything in the orthodox establishment simply has to be bypassed.

The government, the medical establishment, the scientific establishment, the universities, everything.

Otherwise, we're as good as finished *right now*.

The "Dirty Dozen"

In the West, there are only perhaps a dozen persons or so that I know of, who are qualified to work on the main task required. They are all unorthodox researchers and scientists.

There are thousands of fine orthodox scientists, of course, who can help with the peripherals — making and testing viral solutions, setting up and operating equipment, doing interminable tests, all the lab stuff, etc.

But only about 12 unorthodox guys are qualified and mentally and emotionally prepared to come to grips with the particular scalar EM technology required for rapid development of an AIDS cure.

Right now, there are just two or three of the 12 working on this, hammering away as best they can, at terrible cost to themselves and their normal endeavors.

Obviously immediate funds are needed for facilities, equipment, and marshalling that dozen unorthodox researchers and a team of scientists — along with support staff and personnel.

An Analogy

I'm reminded of a story from WWII.

On the beach at Anzio, in a battle lull some doughboys were briefly resting near their foxholes, eating lunch from C-ration cans.

A lone German Messerschmitt appeared, closing on them fast and low with machineguns blazing. They were forced to hastily jump into their foxholes as the Messerschmitt strafed their position.

The pilot continued to make strafing run after strafing run, low and "on the deck." Obviously lunch was rather totally disrupted.

Suddenly, in total disgust a soldier leaped up and flung his half-filled C-ration can into the air directly at the approaching aircraft, full in the teeth of the machinegun fire.

Incredibly, the can sailed straight up into the air intake of the hurtling aircraft, where it was sucked into the engine, which sputtered and died.

The surprised German pilot banked his plane upward and bailed out.

He was promptly captured by the very troops he had been strafing only moments before.

Those two or three colleagues of mine are literally "throwing their C-ration cans" in a desperate effort to ward off a monstrous threat.

Those two or three are striving to the limit of their endurance.

This book and the release of the material in it represent my own "Oration can" hurled into the teeth of the actual Soviet threat as a last resort. Hopefully we can "hit the air intake" of the Soviet juggernaut, so to speak, and stop its progress.

The giant Soviet scalar electromagnetic weapons that I detailed in **Fer-de-Lance,** e.g., are easily countered — in six months or less. Primarily, it is necessary to make a pumped phase conjugate mirror adjunct (PPCMA) that operates at the frequency band of interest, and associate it with a receiver. Once a signal is received from the enemy weapon — say, from a Woodpecker transmitter — it is introduced to the PPCMA. A powerful phase conjugate replica energy pulse is returned into the distant hostile transmitter, totally destroying it.

To meet the viral biological warfare weapon, however, we must develop electromagnetic healing.

In an important article, "SDI vs. the plague," Mar. 8,1988, p. 6, the **Washington Times** revealed a startling Pentagon conclusion that the Soviets may counter SDI with genetically engineered weapons.

Valentin Falin, Chief of the Soviets' Novasti Press Agency, is quoted as saying:

> *"We won't copy you anymore: We'll take asymmetrical means with new scientific principles... genetic engineering could be a hypothetical example. Things can be done for which neither side could find defenses or countermeasures, with very dangerous results. If you develop something in space, we could develop something on earth. These are not just words. I know what I'm saying."*

The genetically engineered Soviet counterstrokes exist and are already being taken. This book tells you what the asymmetrical means, new scientific principles, and genetically engineered weapons are.

May God help us all. If we do not move immediately and correctly to augment the effort of my colleagues, the Free World and half of the peoples of the earth will perish before another decade passes.

CHAPTER 1

THE VACCINE CONNECTION

The following quote is from Don Rowe, **Wall Street Digest,** 214 Carnegie Center, Princeton, New Jersey 08540.

"The AIDS Plague will affect society in ways that you cannot now imagine. AIDS is 100% fatal. Scientists and medical research people are not optimistic about an immediate cure to [or] vaccine. They do not expect to develop an effective vaccine within the next two decades. Public health officials estimate that as many as 2.4 billion people (half the world's population) will die from AIDS within the next 15-20 years."

"Economically, the insurance and medical health systems could be devastated in the 1990's. Nothing short of a spectacular medical breakthrough will keep Western civilization from suffering the worst catastrophe in the history of the world."

The first official U. S. AIDS case was diagnosed in San Francisco in 1981. This followed the puzzling outbreak of the disease in Third World areas such as Africa and Haiti in the 1970's.

The U.S. AIDS outbreak at first seemed to be confined to the gay community, such as in San Francisco.

No one seemed to connect the apparently unrelated facts that, before the outbreak in the U.S. gay community, (1) the World Health Organization had accomplished substantial smallpox vaccination in Haiti, and (2) West Coast gays — particularly from San Francisco — had made Haiti a main playground and vacation spot.

Most orthodox medical scientists have not the foggiest notion why such a drastic "explosion" of the virus has occurred.

It has occurred because *AIDS was introduced by contaminated vaccine used by WHO in its smallpox eradication campaign.* A high correlation exists between WHO vaccination and subsequent outbreak of AIDS.

Figure 2. The "monkey-bite" theory.

The "Monkey-Bite" Theory

As the prevailing rationale goes, a naturally-mutated monkey AIDS virus derivative or strain is believed to be the cause of the monstrous plague looming to strike down half of all the humans on earth.

That is, a monkey is supposed to have bitten a man—an African—and transmitted the normally harmless monkey AIDS virus to him. The virus is then supposed to have naturally "recombined" its genetic material with other viral genetic material and the man's human genes, to produce the virulent new strain of AIDS.

Then this new strain, *from its single human host,* is supposed to have rapidly started spreading through Africa and around the world.

That is simply nonsense.

In Africa, for example, monkeys as well as other animals have had their viral diseases for thousands of years. If monkey virus were the culprit, African man would have been devastated by AIDS thousands of years ago. He either would have been dead or—as have the monkeys — he would have developed a certain resistance and tolerance for the disease, so that it is no more harmful than others.

Understand, the "monkey bite plus human cell modification" undoubtedly does occur in Africa with great rarity — once in several thousand years.

However, even if that rare natural recombination of the monkey AIDS virus were to occur in a single human, normal contact between other humans and the infected human is totally insufficient to provide any substantial infection rate *unless the rate of infection of new individuals is greatly assisted and vastly speeded up by some other outside mechanism — for example, by something like AIDS-contaminated vaccine and a mass inoculation program.*

Retroviruses ***and Recombinants***

As Dr. John Seale has pointed out, "The AIDS virus (human immunodeficiency virus or HIV) is a lentivirus — a little-studied sub-family of the retroviruses. It is highly pathogenic to man but it differs profoundly from any other virus of humans. It is spreading rapidly in the general population of central Africa, and amongst homosexual men and drug addicts in the West. *It is the first virus to have appeared in mankind for many centuries which is entirely new, highly lethal, and spreading steadily from person-to-person world-wide."* [accent by the present author.]

Dr. Seale has courageously pointed out some other very disturbing facts:

(1) Retroviruses of animal origin, if repeatedly passed from human cell culture to human cell culture, will gain the ability to infect human cells *preferentially.* Indeed, they may then even cease to be infectious to their original animal hosts.

(2) In 1982 Robert Weiss pointed out that, in the laboratory, the genetic code of retroviruses commonly recombine if two of them infect the same cell simultaneously.

(3) In a 1984 article in the **Journal of Virology,** David Baltimore showed an efficient means of overcoming the cell's block against simultaneous infection by two or more retroviruses.

(4) Further, Baltimore reviewed how *this had widely been done during the preceding ten years!*

(5) Outside the laboratory, recombination of multiple simultaneous retroviruses has not been shown to occur naturally in humans.

(6) In animals, there is some evidence that it may occur naturally with extreme rarity — indeed, only once in many thousands of years.

(7) By the early 1970's, the technology to make new recombinant retroviruses virulent to humankind was already developed and had been widely published.

To the layman, the infection and reproduction by retroviruses is peculiar to say the least.

When a retrovirus infects a cell, from its own genetic material (RNA) it first makes a "template" or pattern (DNA) for forming other retroviruses just like it. It then inserts this "DNA template" into the DNA of a cell. The host cell itself is now a "sleeping factory", ready to start producing retroviruses.

When activated, the "template" in the cell causes the factory to go into production of retroviruses. Activation is varied. The "infection production factory" can just remain dormant, be slowed over years, take place almost immediately, or be slowed for years and then "explode" to rapidly increase the infective viruses.

Genetically, the cells of any person infected with AIDS or any other recombinant retrovirus have been permanently transformed. Literally that person has acquired a new set of genes. He or she has been converted into a "factory" for producing—and spreading—the virus.

Cancer Research Produced Ideal Biological Warfare Agents

In 1971 President Nixon signed into law the National Cancer Attack Act. Though certainly not intended by the President and the Congress, *the inadvertent result of this act was that taxpayer's funds were used to research and develop the precise things that constitute the most lethal kind of viral biological warfare.*

The on-going small effort in medical research laboratories to alter animal tumor viruses — including retroviruses —to replicate efficiently in human cells was drastically speeded up, as part of the new "war on cancer." In other words, whether intended or not, much of our cancer research money was converted into the precise kind of research that develops virulent biological retroviruses for potential use in biological warfare.

Not only was the research drastically accelerated, but also the direct participation by Communists and scientists sympathetic to the communist cause was accepted and encouraged.

Astoundingly, this open invitation to the communist scientists was issued at a time when one of the high KGB priorities was to infiltrate our recombinant DNA genetics laboratories! To the Soviets' utter astonishment, we simply opened our labs and invited them in.

The Soviets participated — and penetrated — with alacrity. It is an obvious conclusion that a number of the Iron Curtain scientists sent to help staff our laboratories were undercover KGB agents.

In the cancer laboratories, on a wide-spread scale, animal retroviruses were injected and reinjected into human cell cultures, until these retroviruses had become efficient, lethal recombinants favoring human cells as their hosts.

At that point, infection of one or more persons by one of these lethal new retroviruses could unleash a massive AIDS-like plague on all mankind.

A single laboratory accident (or a single act by one Communist agent) could unleash the Great Death Plague.

Weak and ineffective reference to this forthcoming danger was made in 1974 by the Committee on Recombinant DNA Molecules, which had been established by the U.S. National Academy of Sciences. According to **Science,** July 26,1974, p. 303, the Committee made the following rather bland and ineffectual recommendation:

"Scientists throughout the world (should) join with the members of this committee in voluntarily deferring experiments (linking) segments of the DNA from (cancer-causing) animal viruses to... possibly increase the incidence of cancer or other diseases."

So much for the great scientific watchdogs.

U. S. "Cancer War" Labs Were Infiltrated

As we said, ironically we ourselves helped load and cock this potentially disastrous biological warfare cannon. Incomprehensibly, enemy fingers were permitted — even encouraged! — to be placed on the trigger. Many of our medical research facilities involved in this research contained known Communists, dissidents, etc.

For example, see page 106 in Omni, March 1986. Carlton Gajdusek, presently Chief of the National Institute of Health's Laboratory of Central Nervous System Studies and Laboratory of Slow, Latent and Temperate Virus Infections, was asked the question, "Isn't Fort Detrick in Maryland such a biological-warfare research facility?" He responded:

> **"No, emphatically no! There is no defensive or offensive warfare microbiology done at Fort Detrick today. It is the national cancer research facility of NIH. In this facility I have a building where more good and loyal Communist scientists from the USSR and mainland China work — with full passkeys to all the laboratories — than Americans. With night-working U. S. citizens and foreign Communist investigators here, obviously there is no "secret" bacterial warfare activity going on. Even the Army's infectious-disease unit is loaded with foreign workers — not always friendly nationals. It is a valid basic research unit on worldwide problems of infectious -diseases in which no classified or secret activities unfold."**

The point is, what was being produced in these labs were viruses that would grow in human cells. Under tight control, these new lethal agents could be safely studied, and many things could be tried experimentally to see if they would slow, stop, or kill the viruses and heal or benefit the virally infected human cell cultures.

The viruses were being developed to benefit man by aiding in the war on cancer — we accent this most strongly.

However, many of them were precisely the same things that would be developed in a biological warfare lab: lethal new viruses that preferred the human as a host, and against which humans have developed little or no immunity.

The Deed Was Easily Done

Now one can see the subtlety and irony in the Soviet Union accusing the U. S. of having made the AIDS virus at Ft. Detrick!

It's both true and false at the same time.

There is substantial information indicating that the AIDS disease is manmade, and has been deliberately unleashed on mankind by Soviet and other Communist agents, augmented by the international control groups and shockingly inept work by U. S. and European medical researchers.

Human cell cultures deliberately infected with animal viruses were carelessly handled in U. S. and European laboratories — carelessly handled in that far too great (essentially open) access to the new viral strains was permitted.

Our own scientists were apparently unwitting pawns, and Soviet agents performed the "final touchups" to insure release — whether intentional or inadvertent — of the lethal new agents against an unsuspecting world.

Viruses can infect bacteria, since a bacterium is a one-celled organism and the virus is a single molecule.

Cell cultures where vaccine is made from weakened bacteria could easily be contaminated with the desired recombinant viruses available in the cancer laboratories.

To insure worldwide release of the lethal virus, covert Communist agents apparently caused contamination of the smallpox vaccine that was prepared in quantity in Western laboratories.

This contaminated vaccine then was widely used to inoculate Third World peoples and others, in the successful international program to eradicate smallpox.

With only a few agents in key places, the Soviets could easily have taken advantage of the looseness of Western laboratory procedures to deliberately contaminate the animal cell cultures used to make the vaccines.

They had an abundance of agents in the key laboratories, for they were openly invited in and accepted!

The Soviets had their fingers in it, up to the elbow.

And at just exactly the right time, the answer to a Communist's biological warfare dream was available: The World Health Organi-

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Figure 3. The Soviets have delivered an intended knock-out.

zation was already involved in its 13-year campaign of massive smallpox inoculation in the Third World, to eradicate smallpox.

All that was needed was to contaminate the WHO vaccine by one or more of the lethal new recombinant retroviruses that had been developed — and were continually being developed — in cancer research laboratories filled with Communists agents.

The opportunity was presented for a great Soviet "first strike" against the West, using biological warfare agents developed in U.S. and European laboratories and administered by an international agency.

The opportunity was ripe for the taking. It was irresistible. You can be sure the Soviets took it.

It's Actually Documented!

Virus-contaminated vaccines were then widely administered to Third World countries—particularly in Africa, South America, and Haiti. Administration of these vaccines by the World Health Organization is precisely correlated to the subsequent outbreak of the AIDS epidemics in those countries.

This strongly indicates that the vaccine itself was the "precursor" agent initiating the start of the AIDS infection.

In a shocking article, "Smallpox vaccine 'triggered Aids virus'," in the London **Times** of May 11,1987, **Times** Science Editor Pearce Wright announced that the AIDS epidemic may have been caused by World Health Organization (WHO) smallpox inoculations in third-world countries.

In an important article in **Easy Reader,** June 4, Jon Rappoport reported the **Times** article and the results of an interview with Robert Matthews, technical correspondent of the **Times.**

According to Rappoport, Matthews informed him WHO itself had somehow suspected that its immunization program against smallpox might be connected to AIDS. An outside consultant was employed to perform an independent study, and the study confirmed that WHO vaccines were indeed — somehow — causing AIDS to evidence in inoculated persons.

Needless to say, WHO promptly buried that report—whose conclusion must have been the last thing WHO wanted to hear.

The consultant then came to the **Times.** The **Times** heard him out and printed the story.

This astounding story has almost startling correlations: *"The smallpox vaccine theory would account for the position of the Central African states as the most afflicted countries; why Brazil became the most afflicted Latin American country; and how Haiti became the route for the spread of AIDS, to the U.S.: Brazil, the only South American country covered in the eradication campaign, has the highest incidence of AIDS in that region."*

Rappoport confirms that the subject of contaminated vaccines— "vaccines which, made in tissue cultures of animal parts, contain 'extra' dangerous viruses" — has been of increasingly serious concern to medical scientists in recent years, and the WHO smallpox vaccines may have been contaminated in this fashion.

A documented U.S. Army incident is a case in point.

New U.S. Army recruits are routinely vaccinated against a range of diseases. One of them is smallpox, in case an enemy should try to use smallpox as a biological warfare agent.

A healthy 19-year old Army recruit developed AIDS after vaccination, and was admitted to Walter Reed Army Medical Center, where he died.

In a paper published in the **New England Journal of Medicine,** Walter Reed medical team scientists reported their discovery of the connection between vaccination and stimulated AIDS disease.

They also warned against the WHO plan to use modified versions of the smallpox vaccine to combat other diseases in developing countries.

WHO's 13-year vaccination and eradication program ended in 1980. The program is credited with saving two million lives a year and preventing 15 million infections.

It may be inadvertently responsible for the ultimate death of billions.

In a meeting of 50 experts near Geneva in May, 1987, it was revealed that millions of new AIDS cases are about to hit Southern Africa. The experts believe that up to 75 million Southern Africans — about a third of the population — may have AIDS within the next five years.

From our previous statements above, it appears almost certain that Communist agents who had penetrated U.S. and European laboratories manipulated the contamination of the altered vaccines.

Further, the Soviets may be stimulating the disease and guiding it electromagnetically, by special implanted signals carried by the giant Soviet woodpecker "over-the-horizon radars" and other Soviet transmitters.

Or, the Soviets may be using their own transmitters and ours, including our own power lines and radio and TV stations, to broadcast signals that "precondition" and greatly amplify our population's vulnerability to certain selected diseases — AIDS and otherwise.

We will address these issues and Soviet subtle EM capabilities later.

Soviet Biological Warfare Background

In World War I, the Russians suffered half a million casualties to gas warfare, including 50,000 dead.

At 10,000 troops per light division, that's the equivalent of 5 divisions killed and 45 divisions incapacitated.

This made a deep and lasting impression on the Soviets. Lenin himself ordered a major effort mounted to develop and manufacture chemical and biological weapons, for he understood the implications of such mass-destruction weapons.

In 1919 the Soviets began work in earnest on BW weapons. Work on them has not stopped since then. It will not stop so long as the Communists remain in power.

To loyal Communists, Lenin's dictate to develop and lead the world in biological weapons is absolute and unquestioned.

By 1937, the Red Army was fully equipped and psychologically prepared to wage chemical and biological warfare.

Continuing today, the Soviet forces have the highest training in chemical warfare of any troops in the world. Red Army soldiers practice regularly, often using actual chemical agents. Decontamination is a standard measure and practiced as a matter of course.

Even though the Soviets, along with many other nations, signed the Geneva Protocol of 1925 which banned the use of deadly chemical and bacteriological weapons, the Soviets have never ceased development of such weapons.

In the 1930's, a secret Soviet bacteriological institute was set up at the town of Suzdal. Prisoner microbiologists worked on a variety of new weapons and vaccines, including bubonic plague and tularemia (rabbit fever). By World War II the Soviets were prepared to retaliate vigorously to any use by the Germans of chemical and biological warfare agents.

After the war, Soviet research and development in chemical and biological weapons continued apace. However, much of the genetic work was hampered by Stalin's stern support of the autocratic control of agronomist Trofim D. Lysenko. Lysenko's crackpot theories on genetics, for example, held that genes did not even exist. After the death of Stalin, Lysenko's work was discredited, and the Soviets set forth immediately to "catch up" with the West in genetic implications such as recombinant DNA techniques.

Thus in the early 1960's the Soviets began sending Russian scientists to the West to catch up with Western genetics research. One of these scientists was David Goldfarb, who later became a leading Soviet expert in the field of molecular genetics. He headed up the Laboratory of Molecular Genetics of Bacteria and Bacteriophages of the Soviet Academy of Sciences in Moscow. Although he did not work on secret Soviet projects, the Soviet authorities stopped him cold when he applied for a visa to leave in 1979. Goldfarb was a specialist in plasmids, antibiotic resistances, and recombinant DNA technology—all very, very useful to the Soviet effort in biowar.

One can readily understand the reluctance of the authorities to release scientists such as Goldfarb. After all, the Soviet "dirty work" with the deliberate AIDS contamination of the World Health Organization's smallpox vaccine had already been accomplished and a great Soviet biological warfare "strike" was already underway, thanks to the massive smallpox vaccination program of WHO.

In 1972, in the Biological and Toxin Weapons Convention, the Soviet Union and every major power agreed not to develop or use biological weapons. The agreement went into effect in 1975. Although it bans the development, production, and stockpiling of biological agents and toxins for hostile purposes, it has not slowed or altered the Soviet program.

In the early 1970's, Soviet leaders made a decision to use genetic engineering to produce new and improved BW weapons. Highly secret institutes for this purpose were set up in Moscow, Leningrad, and Novosibirsk. These laboratories specialize in seeking ways that genetic engineering techniques can be used to develop virulent strains and agents that their opponents cannot resist.

Every Soviet civilian institution dealing with bacteriology and epidemiology is responsible for certain military work as well. The Soviet Academy of Sciences in fact funds appreciable research of such nature at these institutions.

One of the major Soviet centers for recombinant DNA techniques in biological weapons research is in the village of Protvino, near Moscow. Research on chemical and biological weapons is very easy to conceal, and the Soviets are sure that they will not be caught. Satellites cannot detect what is going on in the labs. The payoff is big and the risk is minimal. The Soviets push this area vigorously.

A number of installations capable of producing disease agents and toxins on a large-scale basis and placing them in munitions and delivery systems have also been identified. One such facility is in the city of Sverdlovsk and has a long history of BW research and development and production, with emphasis on anthrax. During early April 1979, an accidental release of anthrax occurred in Sverdlovsk that caused many casualties and deaths in spite of heroic efforts by Soviet doctors and cleanup and decontamination crews.

Note that, according to DoD's 1987 edition of **Soviet Military Power,** page 110, *"Anthrax causes a high mortality rate when the infection results from ingestion (up to 70 percent fatal) or inhalation (almost 100 percent fatal) if treatment is not promptly begun."*

In addition to military BW institutes, military officers and KGB agents are assigned to key posts in the Soviet Union's normal health and science ministries to monitor research and development that has possible military significance.

Also, the KGB has a continuing and highly active program to insert recruited Soviet Scientists in Western genetic research institutes and agencies. This is a high priority effort, and it has been very successful. Also, it obviously says something about the probability of Soviet agents penetrating U.S. and Western European cancer research institutes, particularly those using recombinant DNA techniques. To make it even worse, we simply invited them in with open arms!

Indeed, it was that KGB program plus the "open arms" in Western cancer virology research institutes that enabled the Soviets to set up and bring about a massive "first strike", using WHO and Western laboratories to do the actual dirty work unknowingly.

We *Need An Immediate, Full Scale Investigation*

Annually, President Reagan makes a report to the U.S. Congress on the subject of Soviet noncompliance with Arms Control agreements.

In April, 1984 Defense Secretary Caspar Weinberger put it this way:

"There is an apparent effort on the part of the Soviets to transfer selected aspects of genetic engineering research to their biological warfare centers... Soviet research efforts in the area of genetic engineering may also have a connection with the biological program...Normally harmless, non-disease-producing organisms could be modified to become highly toxic or produce diseases for which an opponent has no known treatment or cure. Other agents, now considered too unstable for storage or biological warfare applications, could be changed sufficiently to be an effective agent."

At the time that Secretary Weinberger made this statement, a devastating biological warfare strike using those exact techniques had already been unleashed on the Western world by the Soviet Union, cleverly disguised under the banner of the World Health Organization's smallpox vaccination program.

It is imperative that the Congress of the United States launch a full investigation of the entire background of the AIDS biological warfare strike, as a matter of the highest priority.

The investigation should include the role of the Soviet Union, fellow-travelers, and Western scientists openly sympathetic to the Soviet cause.

It requires little investigation to see that there is a well-marked trail for several decades, showing that such a biological warfare strike against humanity has long been considered — and even preferred — by those advocating the Communist cause and world domination.

For example, Bertrand Russell, philosophical spokesman for a group of Westerners, explicitly stated this diabolical BW capability for consideration, in his **Impact of Science on Society:**

"At present the population of the world is increasing at about 58,000 per diem. War, so far, has had no very great effect on this increase, which continued throughout each of the world wars... War has hitherto been disappointing in this respect... but perhaps bacteriological war may prove effective. If a Black Death could spread through the world once in every generation, survivors could procreate freely without making the world too full. The state of affairs might be

unpleasant, but what of **it?"**

The blood of every American — and every European, African, and Asian — should curdle at such words. We are now facing the very "Black Death" type of plague referred to by Russell in such glowing terms!

Highly influential followers of the Russell philosophy — and his callous approval of the periodic slaughter of much of the world's population — may have continued to view the great destructive power of new viral warfare agents as the best means to achieve their end: Selective thinning of the world's population.

At least a few such men may have continued to cooperate with the Soviet Union to work powerfully behind the scenes in international organizations, trying to arrange the proper opportunity to achieve their nefarious purpose.

The "East-West cooperative effort" in cancer research created and gave them the precise biological agent custom-made for the job.

WHO's massive, worldwide smallpox inoculation program gave them the precise means to rapidly get the deadly virus into enough human veins to assure a new "Black Death."

All that had to be done was surreptitiously contaminate the vaccine — the easiest thing of all.

This plague has been knowingly, with malice aforethought, unleashed upon mankind. The perpetrators should be hounded down like the wild beasts they are, uncovered in the full light of day, and suitably punished with the swift and sure justice they deserve.

At least one outstanding medical consultant had the courage to report to WHO that their vaccine was generating the AIDS epidemic. When WHO suppressed the evidence, the London Times had the courage to print the story.

I strongly urge every U.S. Senator and Congressman to introduce and/or support immediate legislation that would launch a full-scale, massive investigation, with no stone left unturned. I urge every concerned activist to demand and support such an investigation at the highest level.

By preoccupying ourselves with lesser things — "IranGate," Nicaragua, the Middle East, etc. — we are simply fiddling while Rome burns.

CHAPTER 2

THE SOVIETS KNEW THE U.S. WOULDN'T REACT

Administering the Coup-de-Grace

As we've seen, the present AIDS viruses were deliberately created in Western cancer research laboratories strongly penetrated by Communist scientists and Soviet agents.

In laboratory experiments that were a legitimate and vital part of the war against cancer, animal retroviruses were repeatedly injected into human cell cultures until they recombined to produce **strains** hostile to human life—strains that would thus live in human cell cultures.

Even though their work was accomplished for a totally different purpose, cancer laboratories produced the ultimate, made-to-order biological warfare agents.

The World Health Organization (WHO) is also strongly penetrated — and even controlled at some levels—by communist agents, **as** are many other such international agencies.

And WHO's massive smallpox vaccination program in Third World countries provided the Soviets a made-to-order opportunity to have (ostensibly) "someone else" deliver the actual BW strike.

In other words, the Soviet deception plan was complete.

It was very simple for Soviet agents to contaminate the cultures in which smallpox vaccine was being produced for WHO's inoculation campaign. This insured the production of vaccine contaminated with AIDS viruses, and the subsequent massive infection of the African peoples and other Third World nations.

It delivered what will be the knockout punch against the West, unless AIDS is countered.

Table 1. Interesting Soviet Statements

"WE HAVE A NEW WEAPON, JUST WITHIN THE PORTFOLIO OF OUR SCIENTISTS, SO TO SPEAK — SO POWERFUL THAT, IF UNRESTRAINEDLY USED, IT COULD WIPE OUT ALL LIFE ON EARTH."

NIKITA KHRUSHCHEV,
1960, SPEAKING TO THE PRESIDIUM

"WE WILL BURY YOU!"

NIKITA KHRUSHCHEV,
TO RICHARD NIXON, "KITCHEN" DEBATE

"IF A MEANS OF TOTAL NEUTRALIZATION OF FOREIGN MISSILES IS TO BE FOUND, IT CAN ONLY COME FROM *A GROUP OF NEW PRINCIPLES IN PHYSICS, CALLED ENERGETICS!"*

NOBELIAN PETER KAPITSA, TO NIKITA KHRUSHCHEV

"EACH SIDE SECRETLY DEVELOPS NEW MEANS OF WARFARE IN ORDER TO EMPLOY THEM UNEXPECTEDLY. HISTORY KNOWS MANY EXAMPLES HOW THE EMPLOYMENT OF A NEW WEAPON INITIALLY GAVE CONSIDERABLE SUCCESS BECAUSE THE ENEMY, CAUGHT UNAWARES AND NOT KNOWING THE COMBAT CAPABILITIES OF THIS WEAPON, WAS FOR SOME TIME INCAPABLE OF EFFECTIVE COUNTERACTION."

V.YO. SAVKIN, THE BASIC PRINCIPLES OF OPERATIONAL ART AND TACTICS. MOSCOW, 1972.

"OF PARTICULAR IMPORTANCE IS BASIC RESEARCH AIMED AT DISCOVERING STILL UNKNOWN ATTRIBUTES OF MATTER, PHENOMENA, AND THE LAWS OF NATURE, AND DEVELOPING NEW METHODS FOR THEIR STUDY AND USE TO REINFORCE THE STATE'S DEFENSE CAPABILITY."

PORTION OF A BOOK BY MARSHALL GRECHKO
DELETED FROM ENGLISH TRANSLATION, BY SPECIFIC REQUEST OF THE U.S.S.R.

"WILL SHORTLY SEE DEVELOPMENT OF NEW WEAPONS, MORE POWERFUL THAN NUCLEAR WEAPONS, AND THEY WILL BE NONVERIFIABLE."

LYSENKO (FIRST NAME UNKNOWN)
USSR REP/SOVIET EMBASSY WASHINGTON, D.C.
WORLD FURTURESCONFERENCE, WASH. D.C, 20 JUL 82.

Murky "Behind-the-Scenes" Intentions

As was pointed out, the WHO inoculation program is well-correlated as the precursor or "initiator" of the AIDS epidemic.

Where WHO smallpox vaccination occurred, the mysterious symptoms of AIDS disease appeared in due time.

Even the eventual spread of the AIDS virus to the U.S. homosexual community is explainable.

For example, the economy of Haiti had earlier been made a shambles. The poor citizens of that impoverished island had been reduced to desperate straits.

In desperation many younger Haitian males had begun to prostitute themselves to visiting homosexual tourists. The Haitian males were not homosexual themselves; rather, they were desperate to gain money to provide for their starving families.

In response, U.S. homosexuals — particularly from San Francisco and New York — had made Haiti their vacation playground. They even ran ads to this effect in their gay newsletters and mngazines.

WHO then vaccinated some 15,000 or so Haitians against smallpox, using the vaccine contaminated with the AIDS virus. This introduced AIDS into Haiti and into the Haitians.

The U.S. homosexuals quickly picked up the AIDS virus by direct contact, and brought it back to the U.S. with them. There the nature of the activities engaged in by homosexuals was responsible for enhanced spread of the virus among members of the homosexual community.

Engineering the AIDS epidemic appears to have been a collusion between Communists and the international control groups.

Apparently the control groups wished to "clean out the African continent and other Third World areas" — possibly to provide room for relieving population pressure in the developed countries. This may have been seen as the way to solve the problem of the ballooning human population — the so-called "biological time bomb."

The Soviets, however, realized that contamination of the smallpox vaccines would result in an epidemic of unparalleled proportions. They recognized the opportunity for safely initiating — and winning — World War III with a great first strike.

The Soviets themselves already possess an electromagnetic cure for diseases such as AIDS, but they have not unveiled it.

All such products of scalar electromagnetics (which the Soviets call energetics) are held tightly by the KGB.

That the Soviets have kept such a cure secret strongly implies that they regard it as a known antidote for biological warfare agents, and thus highly classified.

The importance of this can easily be seen: Presently the West has absolutely zero defense against a biological warfare strike using viruses as BW agents.

In such a strike, fast-acting viral strains can easily be used — say, agents which are highly infectious and kill within two or three days.

Development of a vaccine is impossible. There is simply no time to do that. Further, even if the virus was slow-acting, a vaccine could only be developed if the virus is stable. If it is unstable (constantly mutating), development of a vaccine is impossible.

The greatest vulnerability of the U.S. today is its total vulnerability to unknown BW viral agents. Absolutely nothing we have or are doing in our Department of Defense is of any consequence or protection against new BW viruses for which no vaccine is developed or possible.

The great ease with which such cheap new, highly lethal viral BW agents can be developed means that even a relatively small military power—such as Libya, Cuba, or Iran—can develop and use them against the U.S.

Such BW viral agents can also easily be clandestinely planted across the U.S., to devastate an unsuspecting, unprotected American populace.

In fact, even a single deranged madman can readily develop lethal BW viral agents sufficient to devastate even a great military power. Further, in an open society such as the U.S., that same madman can easily introduce such an agent he develops — and, if he's clever, not even get caught in the act.

Past isolated cases of "contamination" of on-the-shelf drugstore medicines is just a faint prelude of that which is to come.

Indeed, we may unwittingly do it to ourselves by accident, even without a BW strike by the Soviets, small enemy powers, or a madman.

Throughout the West, it is now most fashionable to experiment with the production of new bacteria and viruses. Gene-splicing, recombinant DNA genetics, etc. are being employed on a grand scale as the latest "scientific marvel."

Even some high school students have experimented with this sort of thing. Many other colleagues, universities, and private persons are proceeding full-tilt with casual experiments.

Most of this "casual experimentation" is uncontrolled. When finished, the residue gets dumped in the trash can or flushed down the drain. In any case, it goes into our biosphere. Some of this residue contains unstable, highly adaptable viruses.

It's only a matter of time until one of these unwitting agents gets loose and survives — one that's lethal, fast, and highly infectious.

Make no mistake: It's a *near certainty* that this will happen. The only question is *when.*

Also, with the recent Supreme Court decision allowing the patenting of a virus or bacteria, a number of laboratories and companies are now feverishly developing new agents to unleash in the biosphere upon persons, animals, and plants.

For the most part, these experiments are tightly controlled. However, it is impossible to test in the laboratory the result of the natural recombination and mutation of these agents once they are loose in the environment and in a free exchange with all the natural bacteria and viruses.

Once loosed in the biosphere, a new viral agent undergoes combinations and recombinations with the greater number of viruses already present. The situation is like an increase in a large factorial number: Only a few additional viruses will result in millions and millions of additional combinations — at least some of which inevitably will be lethal and quick-acting. This is *not* tested in those laboratories making, patenting, and releasing new viruses.

Humans have spent millions of years developing sufficient immunity to the natural BW agents to allow humanity to survive.

Very shortly we are going to have increasingly large numbers of new environmental BW agents emerging all around us. For some of them, it is a foregone conclusion that we have little or no natural immunity developed.

So we are going to enter an increasingly harsh environment, characterized by the rise of great epidemics and pandemics of many kinds.

Inevitably some of these coming scourges are going to rival the "Black Death" in ferocity and lethality.

Effective defense against one or more **such BW viral attacks — either against our forces in the field or against our civilian population — can only be provided by a ready, fully developed technology of electromagnetic healing.**

It does not really matter whether the BW strikes are performed by a hostile foe, a madman, natural mutations within our now drastically stimulated viral environment, or as a result of some particular "residue" discarded by an enthusiastic high school or college student.

The end result — the decimation of humankind — is going to be the same unless we develop and use electromagnetic healing technology.

However, with the present enormously self-hostile state of mankind, one or more enemies or madmen will almost certainly launch a strong, clandestine BW strike against the United States Armed Forces and the U.S. populace.

With EM healing technology, a specific "antidote" to any viral disease — known or unknown **— can be developed in a matter of hours.**

Mass electromagnetic treatment can then be started immediately, even for an entire army in the field or for our population in the heartland. Within hours of recognizing a BW strike, cure rates above 90% can be quickly achieved in exposed personnel.

Further, using electromagnetic healing technology, if necessary a more conventional vaccine can also be rapidly developed — say, in two weeks — for mass distribution and inoculation of the civilian populace.

The bottom line is this: Neither the U.S. Armed Forces nor the U.S. civilian populace can or will survive the coming lethal viral warfare strikes unless we quickly develop electromagnetic healing technology and have the necessary diagnostic and treatment devices already ready and waiting.

The clandestine AIDS strike by the Soviet Union is just the precursor of a great deal more to come.

The USSR Has Repeatedly Verified Our Nonreaction

The Soviet Union already knows that Western science and governments are too stereotyped and dogmatic to react to anything highly unorthodox.

For years, the Soviet have been proving this, over and over, in their development and testing of frightful scalar electromagnetic superweapons of unprecedented power. In the face of overwhelming evidence of this, the West has kept its head buried in the sand like an ostrich.

It wasn't invented in the West. Therefore it cannot be.

Years of substantial Communist indoctrination of students in our universities, by leftist/liberal professors, has placed a massive imprint into our society. An entourage of sympathetic groups has resulted — groups which believe that the Soviet leaders are just like us, that the Stalinist era is long since over, and that the Communist leopard has changed its spots and really isn't trying to take over the world anymore.

As a system, then, much of the West simply refuses to accept anything unorthodox, anything "not invented here", and anything that indicates Soviet aggression.

The Soviets know the U.S. is totally ignorant of advanced scalar EM weaponry. They have proven over and over that the U.S. will not even comprehend that it has been deliberately struck, if the strike is sufficiently unorthodox.

The Soviet scalar EM superweapons have already been documented in **Fer-de-Lance,** Tesla Book Company, 1986, and that documentation will not be repeated here.

Only a short summary of events will be presented, to put the Soviets' confidence into perspective. A longer chronology of selected events is included as Appendix IV.

31 Soviets Knew The U.S. Wouldn't React

The Soviets were quite confident in arranging for a great biological warfare strike, because of the total lack of the U.S. to comprehend incidents such as the following:

1. Beginning in the late 1950's, hidden Soviet transmitters across the street targeted "weak microwave radiation" against the U.S. Embassy in Moscow. Over the years the radiation continued, sometimes continuously, sometimes intermittently. The Soviets electronically induced diseases that resulted in extensive health problems of Embassy personnel, the death of two U.S. Ambassadors, and the sickness of a third. Several U.S. Presidents have protested the radiation. Both U.S. Intelligence and the U.S. scientific community have been totally baffled. They still do not know the true nature of the radiation, nor its purpose.

2. In the winter of 1957-58, an unexplained nuclear event happened near Kyshtym, within the Soviet Union. A huge explosion occurred in the stored nuclear wastes in the disposal section of the Soviet atomic weapons industry located in the southern Urals. Radioactive contamination covered 1,000 square miles. For years the story was opposed — or suppressed — by U.S. intelligence agencies, perhaps to allay public resistance to the U.S. nuclear industry. At the time, Soviet experimentation with large scalar electromagnetic transmitters was well underway. A large transmitter probably failed, discharging its built-up, giant electrogravitational potential (EGP) into the earth. Such a pulse would have propagated through the earth as a wave; the first nuclear material contacted would have been fissioned immediately. The stored nuclear wastes probably exploded due to receipt of an EGP from the inadvertent failure of one of the Soviet Union's new superweapons in development. Survivors reported that indeed the nearby nuclear wastes exploded.

3. In January 1960 Khrushchev announced to the Presidium that a new fantastic weapon was in development. He stated that the weapon was so powerful that, if unrestrainedly used, it could wipe out all life on earth.

Figure 4. The U.S. Embassy in Moscow. The Soviet Union has bombarded this **facility** with weak microwave radiation for decades.

Table 2. MICROWAVE RADIATION **OF THE U.S. EMBASSY** IN MOSCOW

- **SINCE 1959 OR 1960**
- **HIGH LEVEL TARGET (U.S. AMBASSADOR)**
- **GUARANTEES PERSONAL ATTENTION OF**
    - **PRESIDENT**
    - **NSA, CIA, DIA**
    - **TOP CONSULTING SCIENTISTS**
    - **STATE DEPARTMENT**
    - **LEADING SCIENTIFIC INSTITUTIONS**
    - **NATIONAL SECURITY COUNCIL**
    - **ETC.**
- **TWO AMBASSADORS DIED, ANOTHER SICKENED**
- **U.S. REACTION REVEALS ANY KNOWLEDGE OF TESLA ELECTROMAGNETICS**
- **FOUR U.S. PRESIDENTS REQUESTED SOVIETS TO CEASE**
    - **CUT FROM 18 WATTS/CM^2 TO 2**
    - **THEN AGAIN INCREASED**

ORDINARY DECAY
- **EGP MUST BE LARGE ENOUGH**
- **EGP MUST BE LONG ENOUGH**

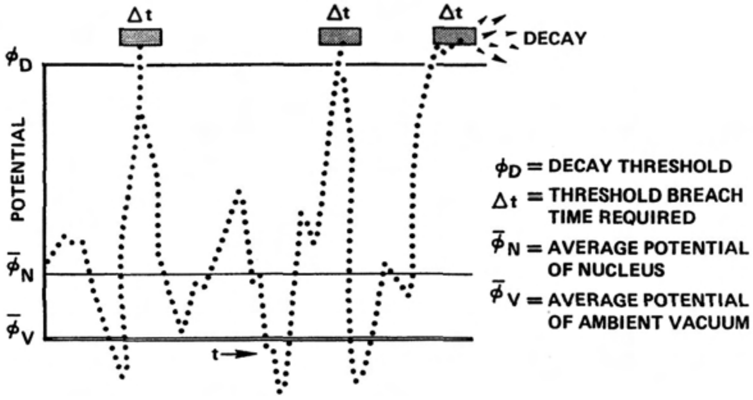
Δt
Δt
Δt
DECAY
ϕ_D
POTENTIAL
$\bar{\phi}_N$
$\bar{\phi}_V$
t
ϕ_D = DECAY THRESHOLD
Δt = THRESHOLD BREACH TIME REQUIRED
$\bar{\phi}_N$ = AVERAGE POTENTIAL OF NUCLEUS
$\bar{\phi}_V$ = AVERAGE POTENTIAL OF AMBIENT VACUUM

Figure 5. Decay of a radioactive nucleus. When it absorbs a scalar EM wave (electrogravitational pulse) that is long enough and large enough, the nucleus fissions.

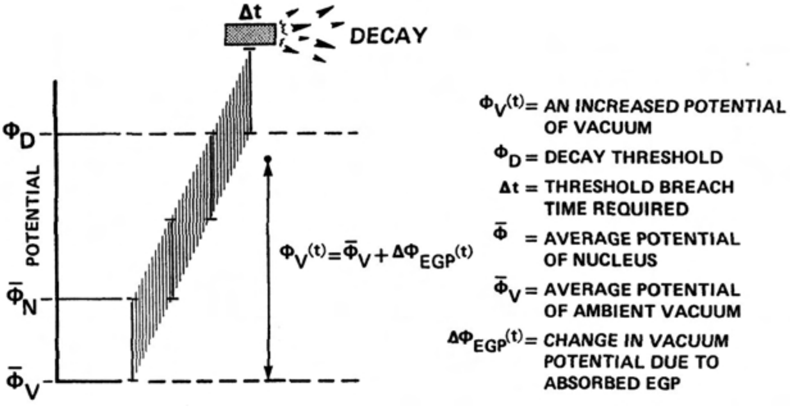
Δt
DECAY
Φ_D
POTENTIAL
$\bar{\Phi}_N$
$\bar{\Phi}_V$
$\Phi_V(t) = \bar{\Phi}_V + \Delta\Phi_{EGP}(t)$
$\Phi_V(t)$ = AN INCREASED POTENTIAL OF VACUUM
Φ_D = DECAY THRESHOLD
Δt = THRESHOLD BREACH TIME REQUIRED
$\bar{\Phi}$ = AVERAGE POTENTIAL OF NUCLEUS
$\bar{\Phi}_V$ = AVERAGE POTENTIAL OF AMBIENT VACUUM
$\Delta\Phi_{EGP}(t)$ = CHANGE IN VACUUM POTENTIAL DUE TO ABSORBED EGP

Figure 6. EGP fission of a radioactive nucleus. If an initial EGP is large enough and long enough, it will fission any and all radioactive nuclei it strikes.

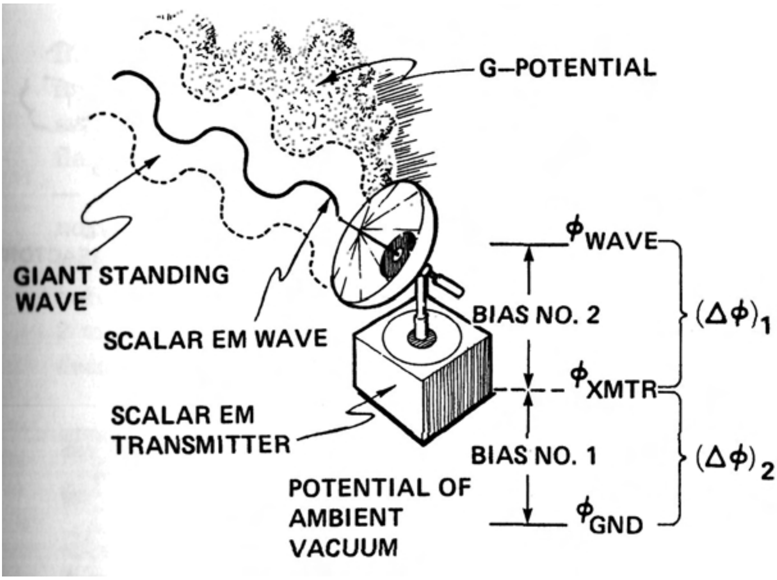
G–POTENTIAL
GIANT STANDING WAVE
SCALAR EM WAVE
SCALAR EM TRANSMITTER
POTENTIAL OF AMBIENT VACUUM
ϕ_{WAVE}
BIAS NO. 2
ϕ_{XMTR}
BIAS NO. 1
ϕ_{GND}
$(\Delta\phi)_1$
$(\Delta\phi)_2$

Figure 7. Bottled up energy in a standing scalar EM wave is a potential.

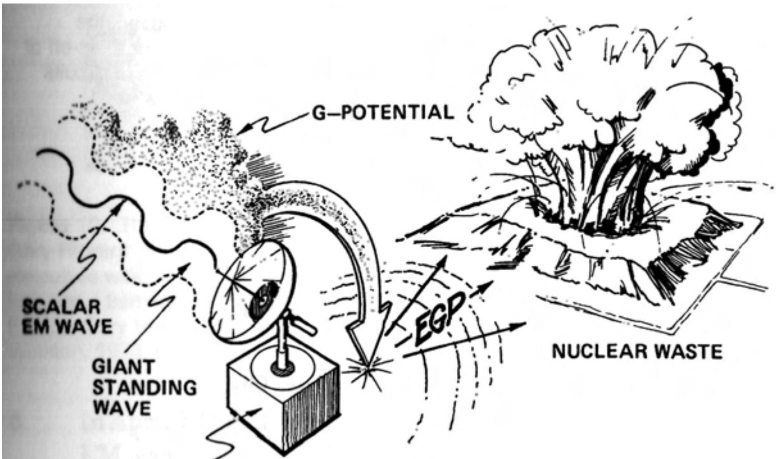
G–POTENTIAL
SCALAR EM WAVE
GIANT STANDING WAVE
MODIFIED RADAR
EGP
NUCLEAR WASTE

Figure 8. EGP short-out Transmitter failure and consequent discharge of a giant standing scalar EM wave potential caused the explosion of stored nuclear wastes at Kyshtym, USSR, in the winter of 1957-58.

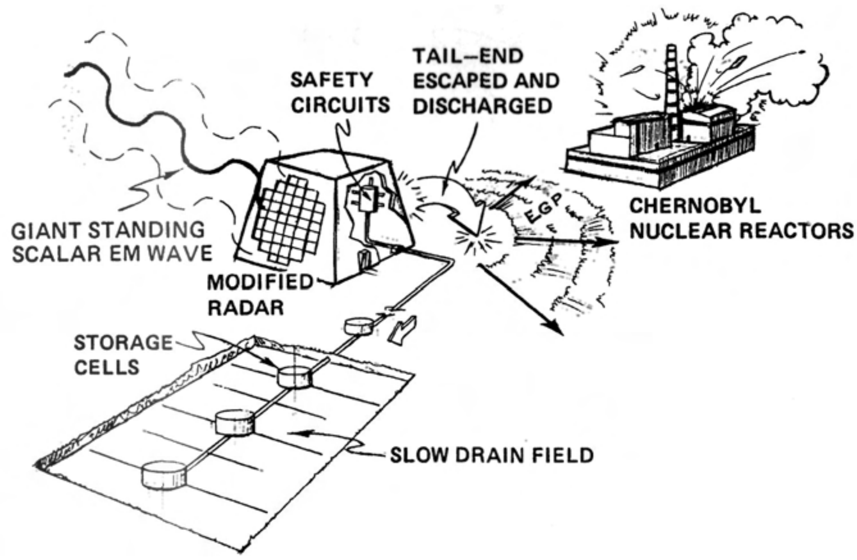
TAIL–END
ESCAPED AND
DISCHARGED
SAFETY
CIRCUITS
CHERNOBYL
NUCLEAR REACTORS
EGP
GIANT STANDING
SCALAR EM WAVE
MODIFIED
RADAR
STORAGE
CELLS
SLOW DRAIN FIELD

Figure 9. EGP initiation of the Chernobyl event. Failure of another giant transmitter near Chernobyl in 1986 eventually caused the eruption of one of the Chernobyl reactors by EGP-pulsing its nuclear fuel rods. When the transmitter failed, the alarmed Soviets shut down the four Chernobyl reactors while waiting for drain-off of the EGP potential by the safety circuits of the disabled transmitter. These circuits finally gave way, producing a mild EGP pulse into the earth. Had they failed immediately, all four reactors at Chernobyl would have violently exploded.

Table 3. KHRUSHCHEV'S 1960 STATEMENT

(Speaking to the Presidium)

WE HAVE A NEW WEAPON,
JUST WITHIN THE PORTFOLIO OF
OUR SCIENTISTS...
SO POWERFUL THAT,
IF UNRESTRAINEDLY USED,
IT COULD WIPE OUT
ALL LIFE ON EARTH!

4. In May 1960 Gary Powers' high-flying U-2 spy plane was mysteriously disabled over the Soviet Union, resulting in its subsequent crash and the Soviet capture of Powers himself. A flash appeared behind Powers' aircraft, as if from an explosion — except that *the flash persisted,* showing that it was not a normal HE explosion at all. A tracking radar, employed in a scalar EM mode, probably was used to cause the electromagnetic "flash ball" and disable Powers' aircraft. Harmless SA-2 missiles fired far below him may have been employed to deceive Western intelligence analysts.

Figure 10. The U-2 high altitude reconnaissance aircraft. On May 2,1960 Francis Gary Powers high flying U-2 spyplane was disabled over the Soviet Union. Some difficulties with the autopilot were first experienced. Then a single dull thump was felt, and a tremendous orange flash lit the cockpit and sky — *and persisted.* (See Francis Gary Powers with Curt Gentry, **Operation Overflight,** Holt, Rhinehart and Winston, 1970, p. 82.)

5. In April 1963 the Soviet Union utilized a newly deployed scalar EM weapon to destroy the submerged U.S.S. Thresher nuclear submarine, off the coast of the U.S. itself. In spite of intense and totally anomalous electronic jamming experienced by the U.S.S. Skylark, surface companion to the Thresher, the U.S. failed to recognize this major indication of a scalar EM attack. *One day later, a Soviet scalar EM weapon placed a giant*

underwater burst in the ocean, 100 miles north of Puerto Rico. With these two tests Khrushchev, still smarting from his Cuban Missile Crisis facedown by John Kennedy, avenged himself and convinced the Presidium to allow him to remain in power for yet awhile.

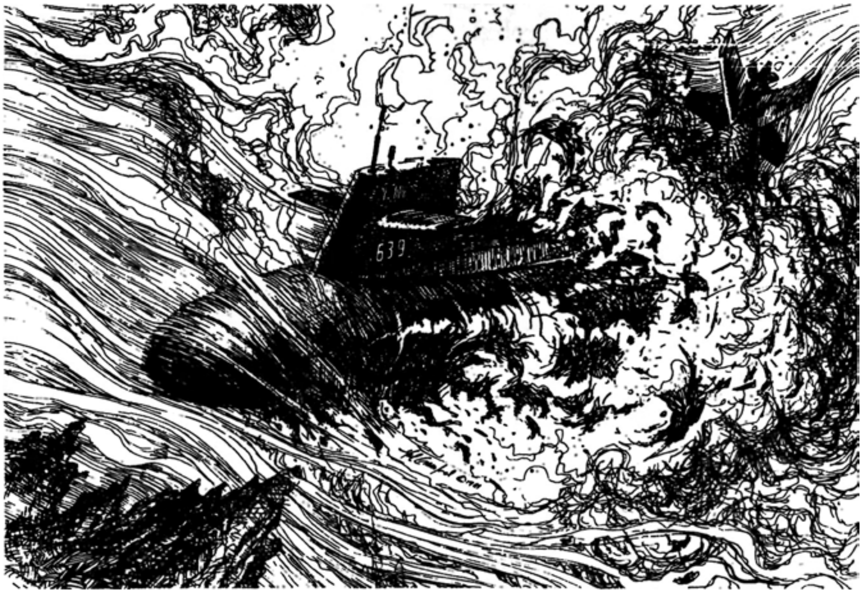

Figure 11. The U.S.S. Thresher disintegrates. © Hal Crawford 1979

Table 4. DEATH OF THE U.S.S. THRESHER

APRIL 10, 1963

- **DURING TRIALS OFF EAST COAST OF U.S. IN ATLANTIC**
- **SURFACE COMPANION: U.S.S. SKYLARK**
- **UNDERWATER PHONE BETWEEN THE TWO**
- **THRESHER DIVED AND WAS LOST**
    - **GARBLED MESSAGE**
    - **DID NOT RESPOND TO CONTROLS**
    - **SANK TO CRUSH DEPTH**
    - **IMPLODED**
- **SKYLARK ENCOUNTERED SEVERE ELECTRONIC INTERFERENCE**

Table 5. SEVERE EM INTERFERENCE EXPERIENCED BY U.S.S. SKYLARK

APRIL 10,1963

- **SKYLARK JAMMED (1.5 HR TO TRANSMIT MESSAGE)**
- **MULTIPLE SYSTEMS**
- **SIGNATURE:**
  - **SCALAR INFEROMETRY**
  - **SKYLARK IN "SPLATTER" ZONE**
  - **THRESHER PROBABLE TARGET**
- **OTHER SYMPTOMS**
  - **ONE SYSTEM KNOCKED OUT**
  - **OTHERS THEN WENT OUT**
  - **LATER RESUMED WORKING**

6. In Afghanistan, in 1981 and at intervals since then, Soviet helicopters have sometimes attacked Afghan guerrillas or villages with a strange new weapon. A body struck by this weapon dies instantly and completely. It falls like a limp rag, **and** does not decay even in 30 days. Every cell, bacterium, virus, etc. in the body has been killed instantly. Nerve gas rockets and chemical rockets are also usually fired to provide **a** "deception cover" for the nature of the real weapon. This eery Soviet weapon has been mislabeled as some strong new gas, **and** is referred to as "Smirch", a combination of the two words "smert" (death) and "semerch" (sandstorm).

7. In April 1984 a monstrously huge scalar EM incident occurred off the coast of Japan, near the Kuriles. Subsequent interviews with the pilots sighting the incident have revealed that several combined tests of the various modes of a scalar EM howitzer occurred. A giant "cold explosion" occurred, raising a giant mushroom cloud to over 60,000 feet and greater than 150 miles diameter in two minutes. A glowing dome appeared, and expanded to monstrous size. According to Dr. Walker and colleagues, **the diameter of this great** glowing, **hem-**

ispherical **shell expanded to several hundred kilometers.** * He and his colleagues were able to rule out any possible known natural events or mechanisms that could have caused the incident.

8. Numerous incidents of hemispherical shells of light and giant balls of light within the Soviet Union have been seen from Iran and from Afghanistan. Such giant artificial phenomena have also repeatedly been seen over the oceans by mariners and airline pilots.

9. Several instances of anomalous disabling of jet engines of commercial airliners have occurred while the aircraft were in flight.

10. Direct and intensive weather engineering over the U.S. itself has been accomplished by the Soviet Union for a decade, using the interference grid resulting from the crossing of two or more giant beams from the woodpecker "over-the-horizon radar" transmitters. Specific cloud signatures (anomalous holes, giant radials, twin giant radials, and razor-sharp giant interference patterns) have continually occurred, but the orthodox system has blithely ignored them.

11. A giant test of over a hundred huge Soviet scalar EM weapons occurred in and around May 1, 1985 for the 40th anniversary of the end of WWII. The entire Western scientific and intelligence establishment remained sublimely unaware of the giant exercise. They had not a single scalar EM signal detector — even though the air, land, and ocean was filled with hundreds of Soviet scalar EM transmitters, chattering away to Soviet armed forces, submarines under the water, etc. Underneath our feet, the earth itself was in giant scalar EM resonance on 54 frequencies — 27 pairs, each of which tapped energy directly from the molten core of the earth and fed it to an ensemble of giant Soviet strategic scalar EM weapons.

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*See Science, 227 (4584), Feb. 8, 1985, p. 607-611; Science 234 (4775), Oct. 24, 1986, p. 412-413.

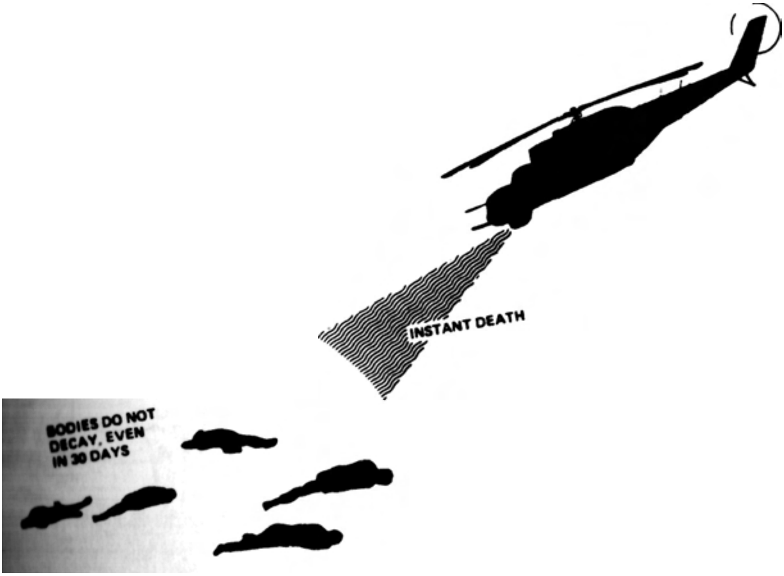
INSTANT DEATH
BODIES DO NOT
DECAY, EVEN
IN 30 DAYS

Figure 12. Soviet helicopters have used a "death ray" in Afghanistan.

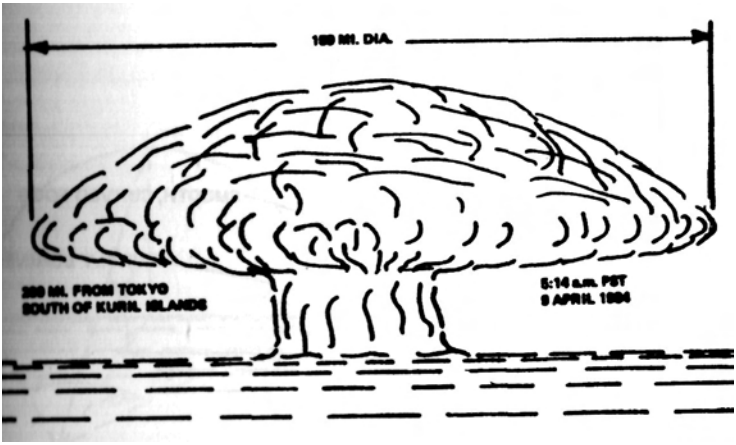
160 MI. DIA.
200 MI. FROM TOKYO
SOUTH OF KURIL ISLANDS
5:14 a.m. PST
9 APRIL 1984

Figure 13. Mushroom cloud from the sea off Japan, near a Russian test area.

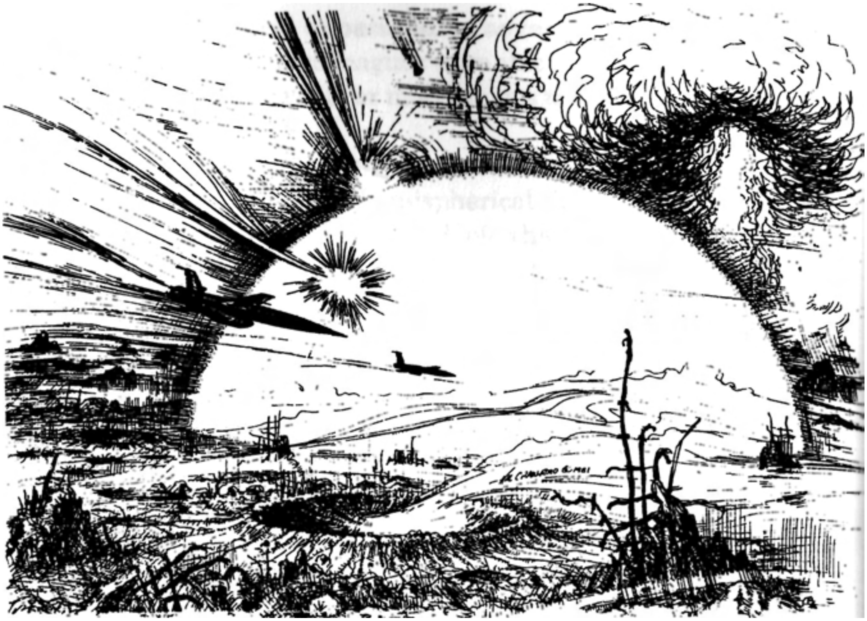

©Hal Crawford 1981

Figure 14. The Tesla shield, a giant hemispherical shell of energy. Seen repeatedly in Soviet tests in out-of-the-way places and remote regions of the ocean.

8:15 PM
THURSDAY
AUG 1969
VIRGIN ISLANDS
SEEN BY MANY RESIDENTS

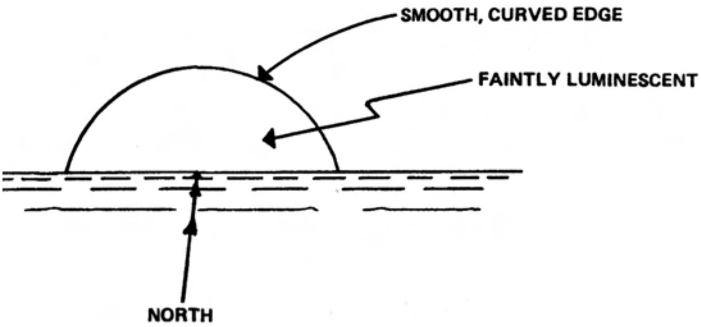
SMOOTH, CURVED EDGE
FAINTLY LUMINESCENT
NORTH

Figure 15. The Tesla shield: A 1969 Virgin Islands incident.

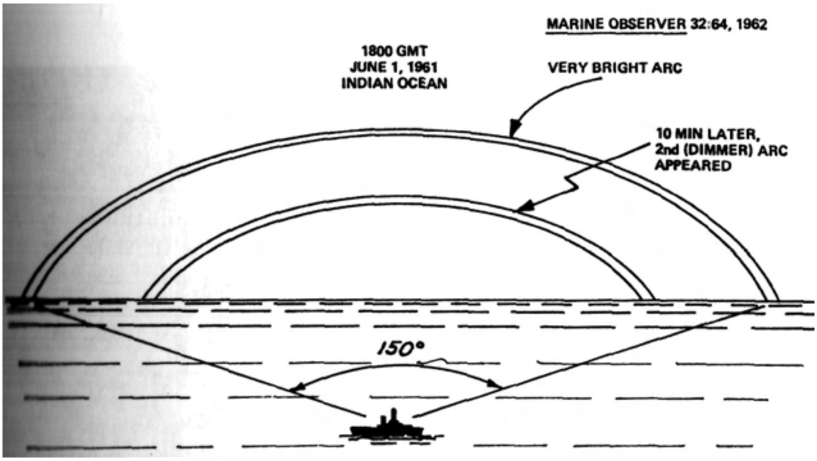
MARINE OBSERVER 32:64, 1962
1800 GMT
JUNE 1, 1961
INDIAN OCEAN
VERY BRIGHT ARC
10 MIN LATER,
2nd (DIMMER) ARC
APPEARED
150°

Figure 16. Tesla shields: Two nested arcs of light in the sky.

MAR 20, 1968
AND WESTERN
NORTH ATLANTIC

MARINE OBSERVER 40:17.1970

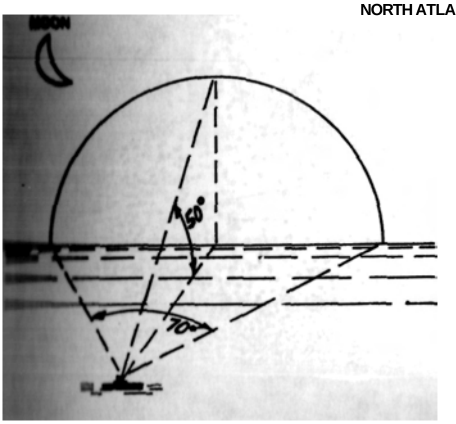

- **SEMICIRCLE**
- **MILKY WHITE LIGHT**
- **QUITE BRIGHT AT FIRST**
- **DIMMED AS ENLARGED**
- **LASTED 10 MINUTES**

Figure 17. Tesla shield: An expanding hemispherical circle of light.

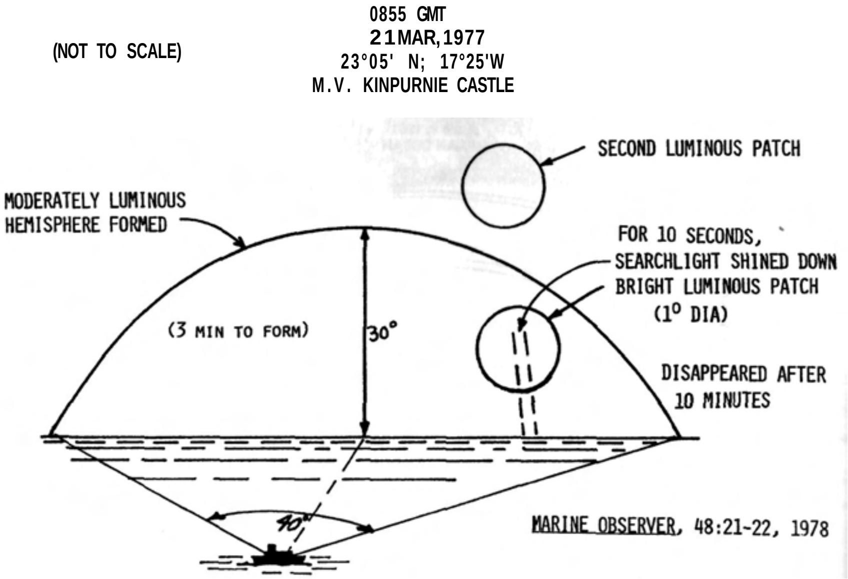
0855 GMT
21MAR,1977
23°05' N; 17°25'W
M.V. KINPURNIE CASTLE
(NOT TO SCALE)
SECOND LUMINOUS PATCH
MODERATELY LUMINOUS
HEMISPHERE FORMED
FOR 10 SECONDS,
SEARCHLIGHT SHINED DOWN
BRIGHT LUMINOUS PATCH
(1° DIA)
(3 MIN TO FORM)
30°
DISAPPEARED AFTER
10 MINUTES
90°
MARINE OBSERVER, 48:21-22, 1978

Figure 18. Tesla shield: Hemisphere and globes, 1977.

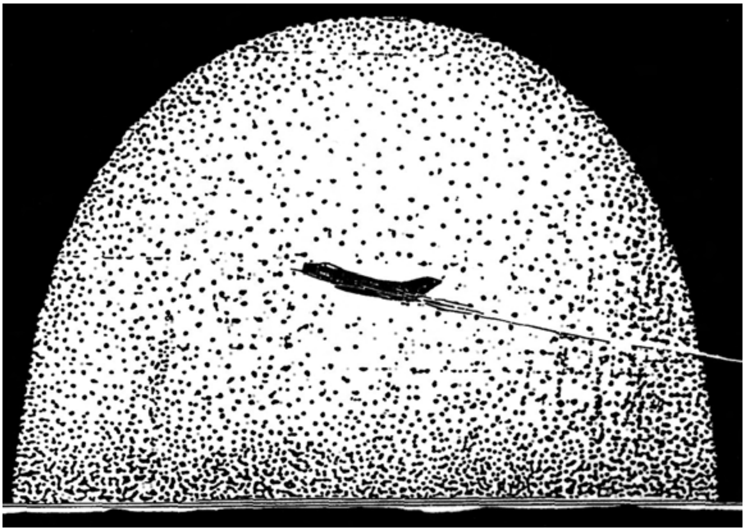

Figure 19. Large Tesia Shield observed by Red Chinese fighter pilots. Electrical difficulties in the aircraft were also experienced.

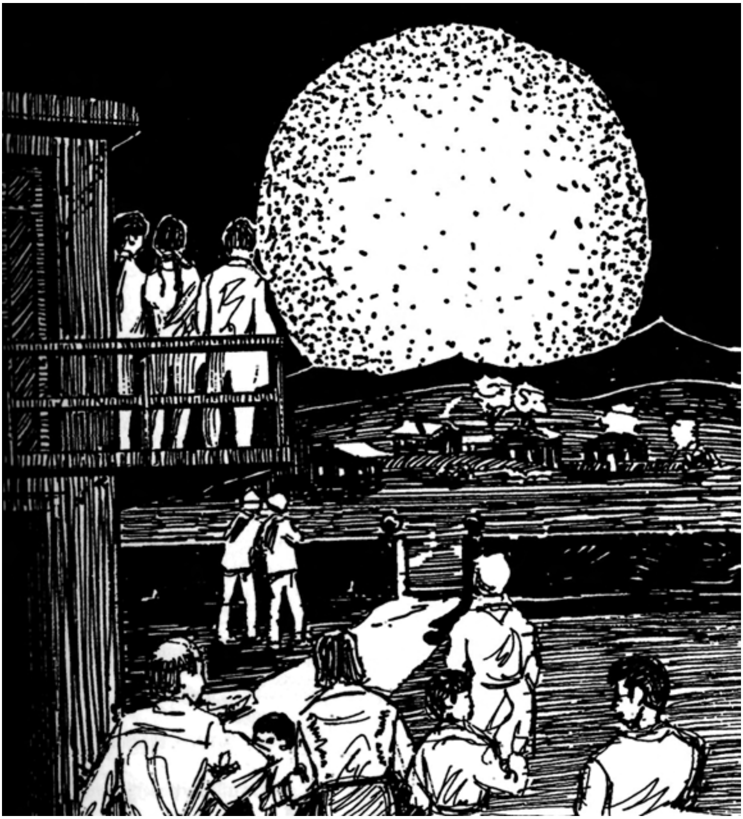

Figure 20. Large glowing Tesla Globe," Red China. Observed by hundreds of **persons.**

45 *Soviets Knew The U.S. Wouldn't React*

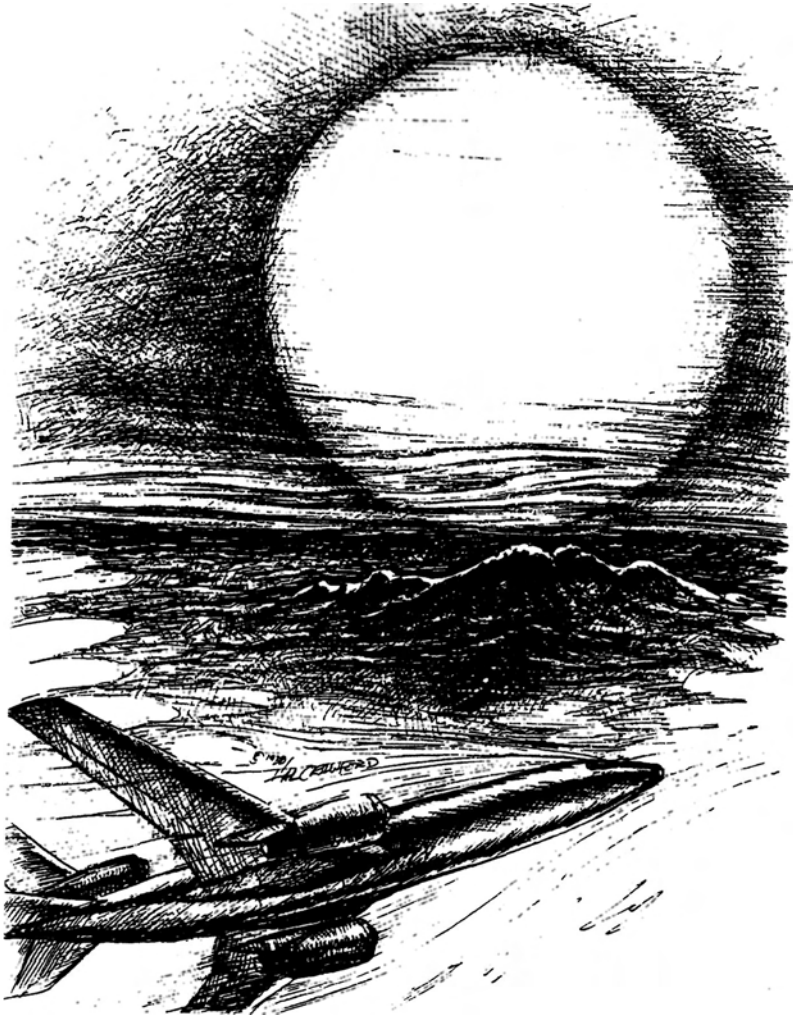

©1980 Hal Crawford

Figure 21. 1966 test of giant Tesla Globe, expanding deep within the Soviet Union. Seen from Teheran, Iran June 17, 1966 by two aircraft approaching Mehrabad Airport. Observed for several minutes.

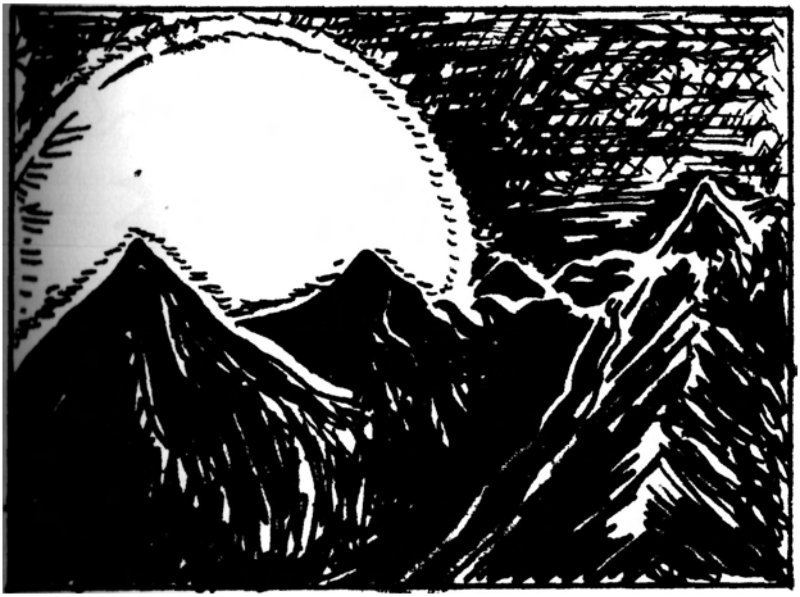

Multiple events seen in Sept. 1979 from Afghanistan

Strange lurid glow that flared silently over the Hindu Kush; as described by
Nick Downie.
The LONDON SUNDAY TIMES, 17 August 1980

Figure 22. A giant globe, deep within the Soviet Union in 1979. Seen several times frorn Afghanistan, looking toward Saryshagan.

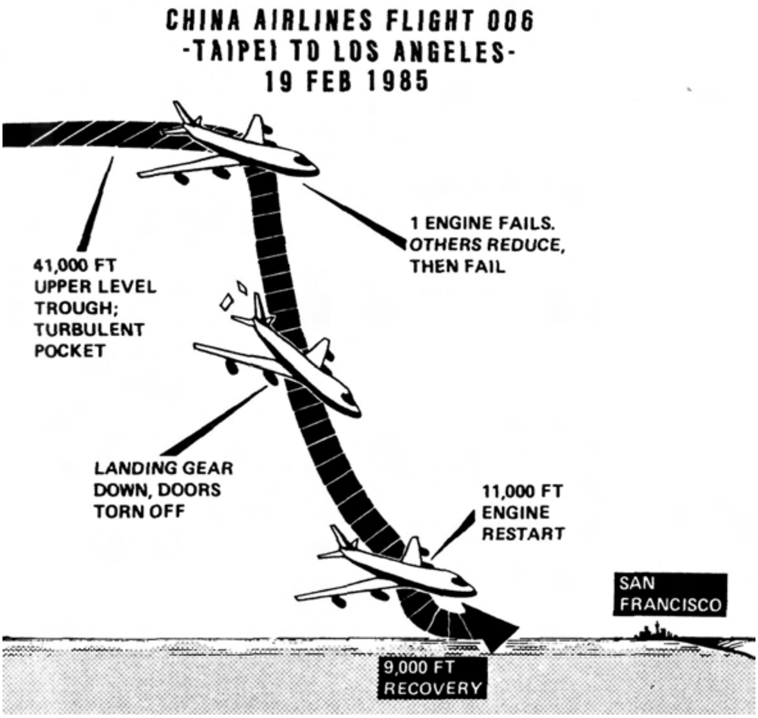
CHINA AIRLINES FLIGHT 006
-TAIPEI TO LOS ANGELES-
19 FEB 1985
1 ENGINE FAILS. OTHERS REDUCE, THEN FAIL
41,000 FT UPPER LEVEL TROUGH; TURBULENT POCKET
LANDING GEAR DOWN, DOORS TORN OFF
11,000 FT ENGINE RESTART
SAN FRANCISCO
9,000 FT RECOVERY

Figure 23. Engines disabled, a passenger jet drops six miles in two minutes.

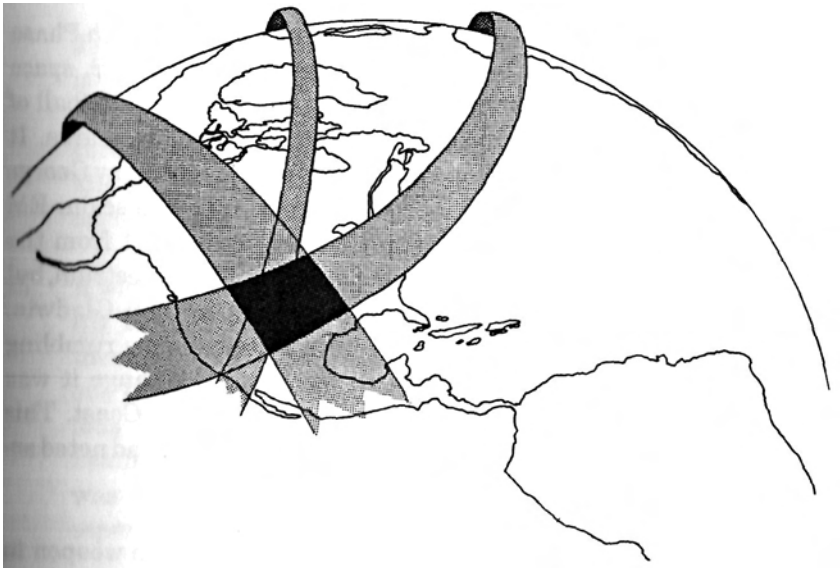

Figure 24. Giant "Woodpecker" beams intersecting over the U.S. Used for weather control, as a launch phase ABM and anti-bomber system, electromagnetic attack of distant populations, and disease conditioning. Using phase conjugate radar mirrors, any amount of energy desired can be delivered to any distant target from which a radar return has been received. Real-time distant holography, to produce powerful energy forms at a distance, can also be accomplished.

Table 6. MASSIVE 1985 STRATEGIC MAY DAY EXERCISE

APRIL/MAY 1985

- **BREZHNEV'S 1972 STATEMENT FULFILLED**
- **40th ANNIVERSARY OF WWII**
- **GORBACHEV NEWLY IN POWER**
- **EARTH IN GIANT SCALAR EM RESONANCE**
    - **54 FREQUENCIES**
    - **27 "POWER TAP" PAIRS**
    - **4 TO 6 WEAPONS EACH PAIR**

- **C^3I SCALAR EM LINKS**
    - **UNDERWATER SUBS**
    - **NAVAL FORCES**
    - **OTHER FORCES**

12. In late November, 1985 the Soviets tested their Launch Phase ABM system over Florida, using the launch of a U.S. space shuttle as a convenient test target. A marker beacon (ball of light) was placed in the sky, hovering near the launch area. It was seen by hundreds of persons, and photographed by George Suchary. During the final countdown to launch, a scalar EM "missile" (ball of intense energy) was fired, offset from the shuttle. This ball of energy was not in the visible spectrum, but may have been accidently photographed by Bob Gladwin. Twelve minutes offset after launch, a tremendous rumbling overhead boom echoed through the area — so huge it was heard for hundreds of miles up and down the East Coast. This was the third U.S. shuttle launch in which NASA had noted associated anomalous phenomena, but did nothing.

13. On December 12, 1985 the Soviets used the same weapon in the anti-bomber mode to destroy an Arrow DC-8 jet just after its takeoff from Gander Air Force Base, Newfoundland. **Over 250 U.S. soldiers and civilian crew members were killed.** Gander has long been a registration point for the Soviet scalar EM weapons. For example, in one 4-day period in 1982, 36 anomalous incidents occurred in and around Gander, involving moving lights, lights in the sky, etc.

14. On January 28, 1986 the Soviets destroyed the U.S. space shuttle Challenger, shortly after its launch. A dozen signatures are associated with this Soviet kill, too many to mention all of them. To give only a few: First, the Soviet ships monitoring the launch site suddenly departed at high speed, four hours before the launch. This was unparalleled. Second, according to General Daniel Graham, *the following evening KGB headquarters gave a party to celebrate the success of the KGB's perfect active measures against the Challenger!* Direct and unmistakable indications of extreme localization of the Soviet transmitters to the Challenger's launch site existed on the day of the launch. In addition, a metal-softening signal was confirmed on the Soviet Woodpecker beams as early as

January 1,1986. Many other indicators also exist. The total is a very strong statement that the Soviets destroyed the Challenger with the same weapon they had tested against three previous shuttle launches, and which they had used to kill the Arrow DC-8 at Gander Air Force Base only six weeks earlier.

15. A whole series of anomalous missile failures occurred, involving Titan, Delta, and Ariane launches. The odds against all these launches failing in that pattern were millions to one. In one Titan failure, video taken of the event showed the anomalous "marker beacon" light in the vicinity, high overhead. Frame-by-frame analysis of the video showed that the light was indeed independent of the explosion, and it moved off separately after the rocket exploded.

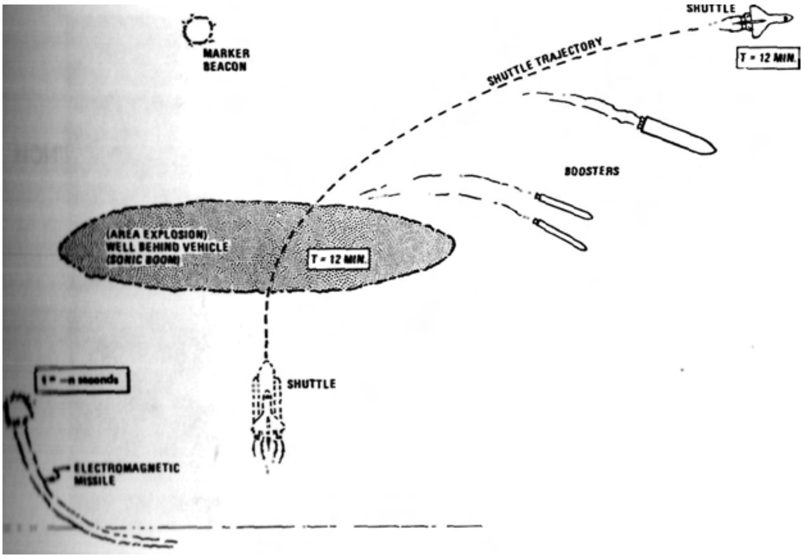
SHUTTLE
MARKER BEACON
SHUTTLE TRAJECTORY
T = 12 MIN.
BOOSTERS
(AREA EXPLOSION) WELL BEHIND VEHICLE (SONIC BOOM)
T = 12 MIN.
t = –n seconds
SHUTTLE
ELECTROMAGNETIC MISSILE

Figure 25. Third Soviet non destructive testing against shuttle launches, Nov. 26, 1985.

Table 7. SHUTTLE **LAUNCH ANOMALIES, NOV. 26, 1985**

- **MARKER BEACON**
    - **PHOTOGRAPHED**
    - **SEEN BY HUNDREDS**

- **OFFSET SCALAR EM MISSILE**
    - **INVISIBLE TO HUMAN EYES**
    - **STRIKE PHOTOGRAPHED**

- **GIANT ATMOSPHERIC BOOM**
    - **T + 12 MINUTES**
    - **HEARD FOR HUNDREDS OF MILES**

- **THIRD LAUNCH WITH SUCH A BOOM**

Table 8. SOVIET ESCALATION AFTER 3RD TEST AGAINST SHUTTLE LAUNCH on Nov. 26,1985.

- **U.S. STILL UNAWARE OF SCALAR EM WEAPONS USE**
- **SOVIETS ESCALATED ACTION**
- **DESTROYED OR DISABLED:**
    - **ARROW DC-8 (DEC. 12,1985)**
    - **CHALLENGER (JAN. 28, 1986)**
    - **TITAN 34-D (APRIL 18, 1986)**
    - **DELTA ROCKET (MAY 3, 1986)**

- **MAY HAVE DISABLED:**
    - **ARIANE II(MAY 31,1986)**
    - **TWO U.S. NUCLEAR SUBS WHICH RAN AGROUND**
    - **STEALTH FIGHTER WHICH CRASHED**

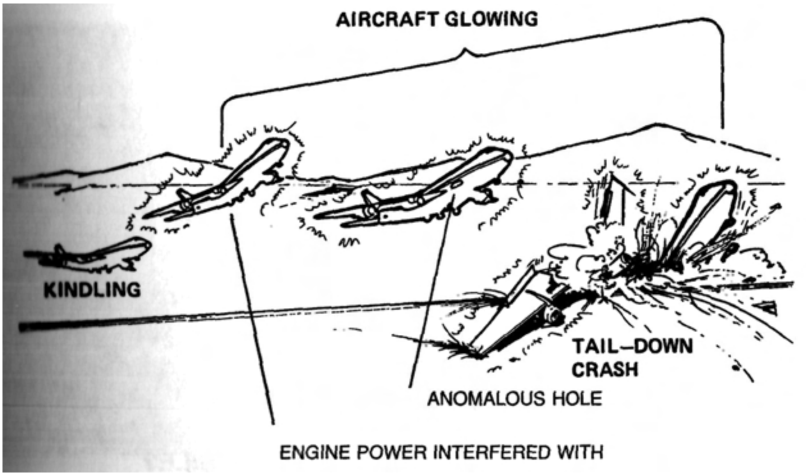
AIRCRAFT GLOWING
KINDLING
TAIL–DOWN CRASH
ANOMALOUS HOLE
ENGINE POWER INTERFERED WITH

Figure 26. Death of the Arrow DC-8, Dec. 12,1985. Three eye-witnesses saw the doomed airliner glowing. An anomalous hole was found in the fuselage, forward of the engines. Engine combustion was interfered with, by phase conjugate (negative) energy. Engines were rumbling laborously, not roaring with power, as the aircraft passed 100 ft directly over a witness.

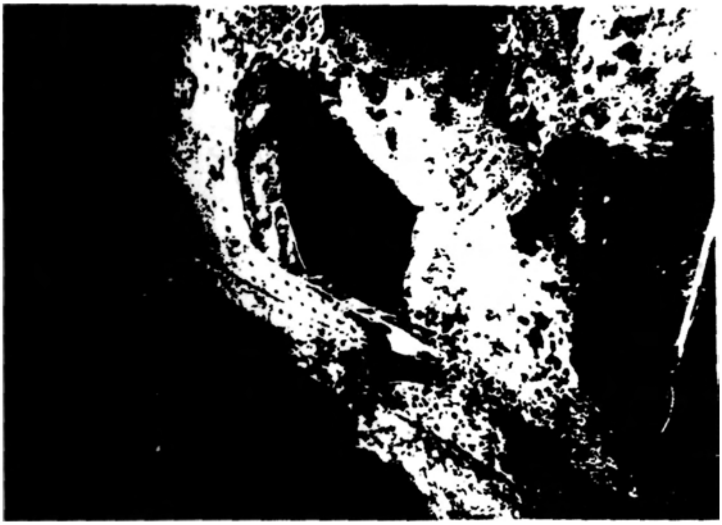

Figure 27. Anomalous hole in the right fuselage of the ARROW DC-8, ahead of the engines. With crossed over-the-horizon radar beams and multiple phase conjugate radar mirrors, real-time holography allows the production of a ball of EM energy at a great distance. The ball may be as small as desired, and contain as much energy as desired.

Table 9. ARROW DC-8 DISASTER, DEC. 12, 1985

GANDER AFB, NEWFOUNDLAND

- **AIRCRAFT LIFTED OFF**
- **AIRCRAFT WAS GLOWING YELLOW - ORANGE**
- **SANK TAIL-DOWN AND CRASHED**
- **SIGNATURE OF ENGINE/COMBUSTION INTERFERENCE**
  - **LAUNCH PHASE WEAPON**
  - **ANTI-BOMBER MODE**
  - **ANOMALOUS HOLE IN FUSELAGE, FORWARD OF ENGINES**
  - **STRUCK BY ELECTROMAGNETIC MISSILE?**
  - **EXTENSIVE "BALLS OF LIGHT" WEAPON TESTS IN AND AROUND GANDER**
- **CLOSELY FOLLOWED THIRD TEST AGAINST SHUTTLE NOV. 26,1985, IN ABM MODE**

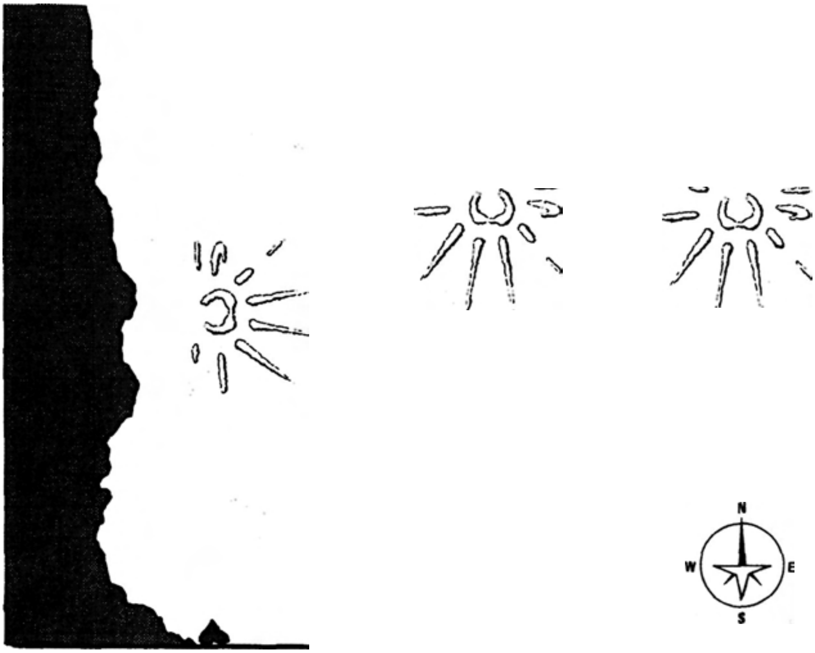

Figure 28. Part of the Soviet engineering of U.S. weather, just prior to the death of the Challenger. Three "giant radial" clouds sighted over the greater Los Angeles area by Margaret Wilson. Appeared one after the other, at 10 min. intervals.

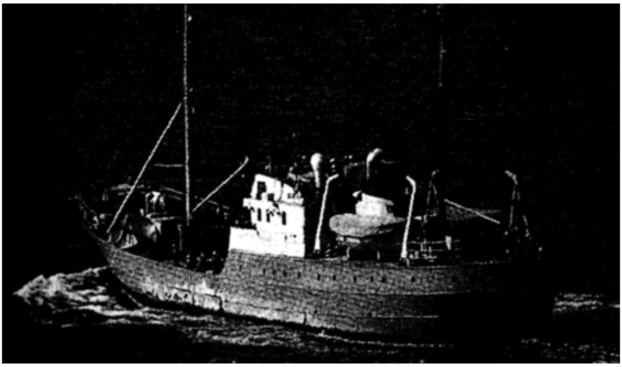

DOD PHOTO

Figure 29. Soviet Trawler spyship. About four hours before the launch of the Challenger, all Soviet ships off coast, that normally monitor each launch, suddenly and mysteriously departed at high speed. Unprecedented event.

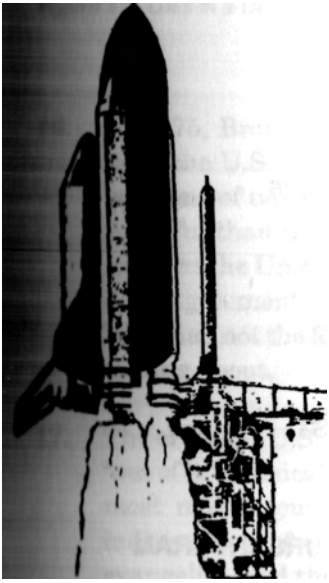

- **SOVIET WEATHER ENGINEERING**
- **SEVERE COLD STRESS**
- **METAL-SOFTENING**
- **BOOSTER SEAL PROBLEM**
- **SOVIET SHIPS ABSENT**
- **LOCALIZATION**
- **AIR TURBULENCE**
- **BIRDS NOT FLYING**

Figure 30. Launch of the doomed Challenger, Jan. 28,1986.

Table 10. DEATH OF THE CHALLENGER, JAN 28, 1986

- **METAL-SOFTENING SIGNAL ON WOODPECKER GRID AS OF JANUARY 1, 1986**
- **SOVIETS ENGINEERED COLD WAVE INTO FLORIDA**
- **SEVERE COLD STRESS ON VEHICLE**
- **GRID LOCALIZATION SIGNATURES**
  - **BIRDS NOT FLYING IN LAUNCH AREA**
  - **BIRD FALLS IN BIRMINGHAM, AL (HINGE)**
- **SOVIET SHIPS/TRAWLERS DID NOT TRACK LAUNCH**
- **BOOSTER SEAL PROBLEM SEVERELY AGGRAVATED**
- **CAUSED SHUTTLE FAILURE**
- **SOVIET KGB HEADQUARTERS CELEBRATED "PERFECT SUCCESS OF ACTIVE MEASURES" AGAINST THE CHALLENGER!**

Table 11. KGB CELEBRATION

EVENING OF JAN. 28,1986

- **AFTER DEATH OF CHALLENGER**
- **KGB HEADQUARTERS**
  - **JUBILANT PARTY**
  - **CELEBRATED SUCCESS**
  - **OF ACTIVE MEASURES AGAINST THE CHALLENGER**

SOURCE: GENERAL DANIEL GRAHAM, URGENTGRAM

- **NOTE: SOVIET SCALAR EM WEAPONS ARE CONTROLLED BY KGB**

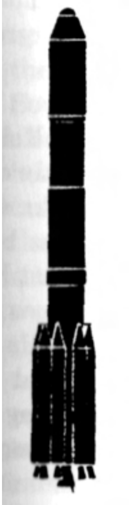

- **SHORTLY AFTER LAUNCH**
- **ANOMALOUS POWER SURGE**
- **"COMMANDED" ENGINE SHUTDOWN**
- **VEHICLE THEN UNSTABLE**
- **RANGE SAFETY OFFICER DESTROYED ROCKET**
- **EXTERNAL RANGE SENSORS DID NOT RECEIVE SURGE SIGNAL**
- **SIGNATURE OF TIME REVERSED WAVE**
- **WHICH LOCALIZED ON ROCKET**

Figure 31. Loss of a Delta rocket, May 3, 1986.

16. In 1975, Brezhnev had surprisingly urged U.S. senators to have the U.S. cooperate in banning the development of new weapons of unparalleled horror. He used the phrase, "more frightful than the mind of man has ever imagined." Shortly after, at the United Nations, Gromyko had even introduced a draft agreement for all nations of the world to sign. Again, the West had not the foggiest notion as to what the Russians were talking about.

17. The orthodox U.S. news media has been, and is, almost totally "out of it." Ironically, at the time of our deadliest peril, and the most momentous period in history, incidents such as the indiscretions of a presidential candidate and of a television evangelist, and the "Iran Gate" actions of the National Security Council in trying to illegally get arms to the Contras, are the "burning issues of the hour" — and the week, and the month, and the year, and HO on ad nauseam.

18. The Congress — great watchdog and the direct representative of the U.S. citizenry — is equally immersed in interminable hearings of little or no substance except news media coverage and publicity.

19. A belabored president, misled and now hemmed in on all sides and on the defensive, has had his power to act greatly constricted. In addition, the orthodox filtering networks surrounding him have effectively isolated him. He has been unaware of the extensive information that shows just how certain it is that the Soviets have fantastic superweapons and have been gingerly using them against us for decades. He and his immediate advisors are fed highly filtered, shaped and interpreted data. U.S. intelligence is very good at doing the things that it does. However, it is also very good at ignoring the things that it ignores! Further, the intelligence community is a past master at "slick-tonguing" the interpretation of anything new, and anything it really doesn't understand, in terms such as "We have no evidence that ..." For decades, the community has consistently underestimated the Soviet threat, and it has also usually projected any unpleasant present Soviet capability in the terms that "If the Soviets keep this sort of thing up, it may prove to be a real threat 30 years from now!" For years U.S. intelligence was unaware of a Toronto inventor's development and public demonstration in the late 1960's of an inertial field generator device, for example, because it simply did not place high value on simple overt intelligence such as reading the newspapers! The entire event was printed in detail in a Canadian newspaper. Only very recently, within the last few years, has the community again realized that the most important intelligence can only come from human (HUMINT) sources. And in relying on the scientific community — which itself knows nothing of scalar electromagnetics — the intelligence community has not received the technical advice necessary for it to properly task its collection agencies to collect information on the Soviet superweapons.

20. Western science has also shown itself to be highly dogmatic and ensconced in the comfortable "status quo." It has regally ignored the important Soviet developments in unified field theory. It has assumed an aristocratic stance, regarding the Soviet scientists as little more than peasants still trying to clean the mud off their boots. In fact, the Soviet scientists have been ahead of the rest of the world in *nonlinear* science — the truly hard stuff — since the beginning. They have always been the best nonlinear mathematicians in the world. Soviet scientific papers regularly appear which deal with local general relativity and the overcoming of the sacrosanct conservation laws as a matter of course. That subject is still a "no-no" in U.S. scientific publications, even though breaking symmetry and consequent violation of conservation laws has long boon proven in particle physics. To my knowledge, with the exception of Hooper's obscurely published work, not a single US. scientific paper appears in the literature showing any detailed investigation of "bucking fields" as such and investigating the behavior of materials exposed to such "sum-zeroed" fields. Yet ironically a whole area of optical physics — phase conjugate optics (PCO) — has shown great activity since we discovered it in the open Soviet literature in the late 60's, and since two Soviet scientists visited Livermore* in 1972 and briefed us upon the subject (as another stimulus to see if we recognized the awesome weapon implications). In PCO, the scalar EM wave formed by two waves 180 degrees out of phase with each other, and locked (modulated) together by a nonlinear medium, is blithely called the *pump wave.* Using it on nonlinear materials produces extraordinary results — such as electromagnetic waves traveling backward in time. Further, the PC effect is known to be universal, and not just in the optics region at all; for example, it has also been done with sound waves. **The obvious experimental and theoretical proof of scalar EM has been in our literature for nearly two decades, and even in PCO our scientists do not yet realize that the "pump" wave is a scalar wave, a wave of**

***Lawrence Livermore National Laboratory**

artificial potential, and a gravitational wave that pumps the nuclei of the atoms in the nonlinear medium. They also still do not understand that it is the nucleus of the atom that produces the phase conjugate replica wave in PCO.

Table 12. BREZHNEV'S 1975 PROPOSAL

AT THE SALT TALKS ON JUNE 13, 1975

- **THE SOVIETS URGED THE U.S. TO AGREE ON A BAN AGAINST RESEARCH AND DEVELOPMENT OF NEW KINDS OF MASS DESTRUCTION WEAPONS MORE TERRIBLE THAN ANYTHING THE WORLD HAS KNOWN!**

- **BREZHNEV PERSONALLY URGED VISITING U.S. SENATORS TO AGREE TO THE BAN.**

- **GROMYKO INTRODUCED A DRAFT AGREEMENT INTO THE UNITED NATIONS MEETING AND URGED THE NATIONS OF THE WORLD TO SIGN IT.**

- **THE WEST HAD NO IDEA WHAT THE SOVIETS WERE TALKING ABOUT!**

- **SOVIET HAWKS THEN GAINED DOMINANCE, AND THE USSR STARTED ITS MASSIVE BUILDUP FOR EVENTUAL WORLD TAKEOVER.**

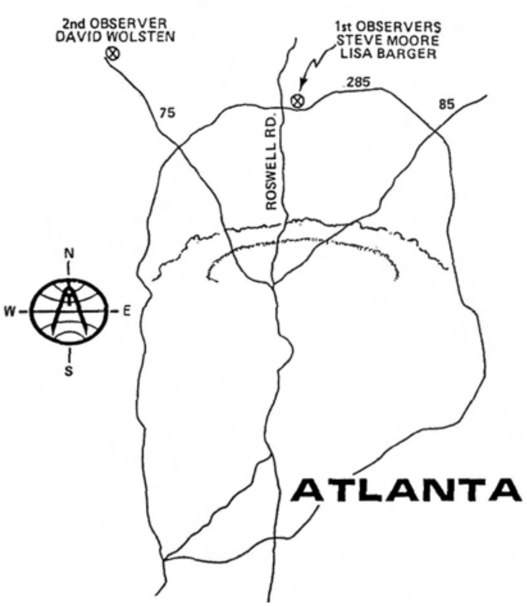
2nd OBSERVER
DAVID WOLSTEN
1st OBSERVERS
STEVE MOORE
LISA BARGER
285
75
85
ROSWELL RD.
N
W
E
S
ATLANTA

A. Location of the incident

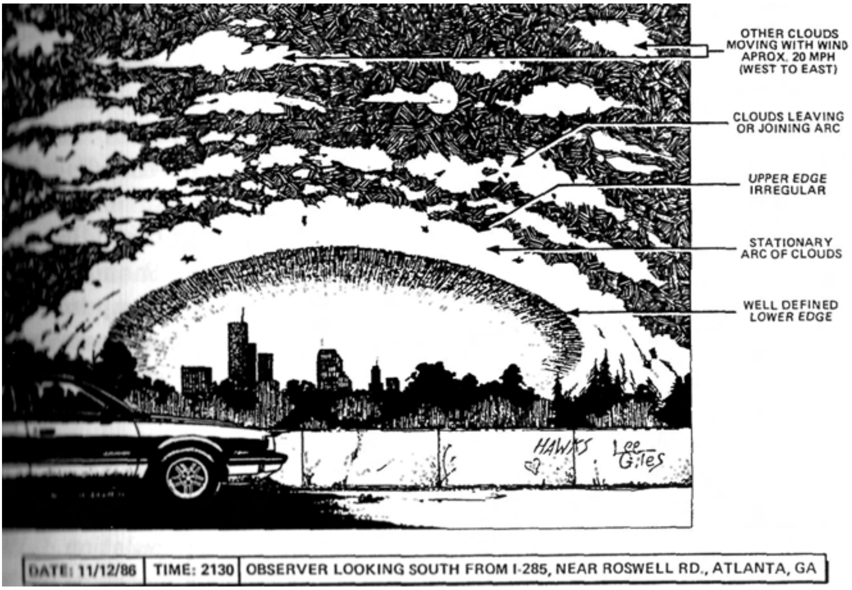
OTHER CLOUDS MOVING WITH WIND APROX. 20 MPH (WEST TO EAST)
CLOUDS LEAVING OR JOINING ARC
UPPER EDGE IRREGULAR
STATIONARY ARC OF CLOUDS
WELL DEFINED LOWER EDGE
HAWKS
Lee Giles
DATE: 11/12/86
TIME: 2130
OBSERVER LOOKING SOUTH FROM I-285, NEAR ROSWELL RD., ATLANTA, GA

B. Artist's sketch of the incident.

Figure 32. Probable Soviet test of a Tesla Shield over Atlanta, Georgia.

Continually assured that Western science and intelligence remained outrageously ignorant and would obstinately persist in wearing orthodox blinders, the Soviets felt quite safe in striking the U.S. and its Western allies a mortal death blow.

The Soviets knew there would be no retaliation, so long as the blow was sufficiently unorthodox.

After all, the Soviets have been waging a slowly increasing unorthodox war against us for decades, and totally getting away with it.

Consequently the Soviets manipulated the cancer research and the contamination of the World Health Organization's smallpox vaccine to produce the perfect biological warfare "first strike," administered unwittingly by the WHO itself in its mass immunization program to eradicate smallpox. The Soviets continue to manipulate the spreading AIDS viruses electromagnetically so that the West will be devastated, as well as Africa and the Third World.

At least one other spreading AIDS-strain has already appeared in Africa. Testing for exposure to the first strain in most cases did not detect exposure to this second strain.

Officially no one knows whether it will be as infectious as the first strain. However, a suspicious correlation has appeared between hepatitis vaccination in several large U.S. cities and consequent outbreak of AIDS among the persons inoculated.

Further, the latest studies are beginning to show that (1) AIDS may be just as spreadable, though more slowly spread, in the heterosexual community as in the gay community, (2) the AIDS tests themselves are far more unreliable than suspected; one may have the AIDS virus — and serve as an active carrier —for up to three years before the tests begin to detect it, and (3) no one has any real idea as to how many persons have already been infected.

As can be seen, even orthodox scientists are beginning to suspect a coming AIDS infection "asymptote" which may represent an explosion of the disease into a mass pandemic in the world population. In Africa, for example, AIDS is spreading freely among the hetersexual population as well as the homosexual population. * We may be on the verge of seeing a similar phenomenon emerge in the

*Although there is much speculation as to why African heterosexuals seem so vulnerable, at present no one knows why it is true.

Western world.

If so, we are looking full in the face of a forthcoming AIDS massacre that makes the 1918 influenza pandemic pale by comparison. Not only will AIDS decimate Africa and the Third World, but it will also decimate the West a little later.

In the Soviet plan, after the AIDS massacre has peaked, the remaining much smaller U.S. and European populations will be decimated and totally powerless. The demoralized and devastated Western nations will easily capitulate and pass under the Soviet hammer and sickle.

In their deception planning, the Soviets even are allowing some contamination of their own citizens by AIDS. Thus they can keep up *a pretense* that they are just as much victimized as we are, and just as much "in the dark" as we are about the whole thing.

Of course, once the AIDS infection does its lethal dirty work in the West, the Soviets can easily eradicate it in their own population at will, using the electromagnetic healing technology they already posess. The Soviet planners regard the loss of a few Soviet citizens along the way as one of the things necessary to insure the success of the Great Strike and the Final Revolution. Forward divisions in the standard Soviet attack are always regarded as such sacrificial pawns to guarantee the success of the follow-on echelons in the attack. In this BW strike, the sacrifice of some Soviet citizens is deemed necessary to the overall success of the attack.

Remember, these are the same type of Soviet communist planners who killed 20 million Kulaks — their own people — to forcibly collectivize Soviet agriculture. For their highest purposes, these planners are still quite capable of ruthlessly sacrificing millions of their own people to achieve their objectives.

The *Asian Tiger Mosquito: A New and Efficient Vector*

As almost everyone now realizes, in the past our government has greatly understated the AIDS problem. Past projections of the limitation oft he spread of the disease have been far more optimistic than warranted.

For example, officially the government is still denying any possibility of insect vectors for the disease.

Don't believe it. In fact, highly efficient insect carriers of the disease are already on the way.

Insects in Africa have positively been verified to be harboring the AIDS retrovirus. Of course, such reports are always accompanied by the bland assurance that "We have no evidence... (that the insect bites will give AIDS to humans).

Let's see now: We're supposed to believe that a monkey bite will do enormously more than that. Even when the monkey didn't have the exact present form of the AIDS retrovirus. Even though monkey bites hadn't done the trick in thousands of years.

But we're supposed to turn right around and believe that an insect carrying the live AIDS retrovirus can bite you, inject into you some of his body fluid containing AIDS viruses, and you won't stand any chance of developing AIDS .

What are we supposed to believe? That the injected AIDS virus from an insect bite won't bother you, but the injected AIDS virus from other causes will?

Nonsense!

Anyone who believes that is a prime candidate for purchasing that bridge down the road...

Of course insect vectors will give you AIDS!

And we've got a real tiger — mosquito, that is, on the way to do just that.

The Asian Tiger mosquito has been introduced into the U.S. (it just "accidentally" appeared, of course!) and is now spreading through the Southeastern states. This vigorous and voracious mosquito prefers man as its target, and has an unusually wide range.

Recently U.S. scientists have reluctantly confirmed the presence of the AIDS virus in the Asian Tiger mosquito. However, as usual we are presented with the same tired refrain, "We have no evidence that... the mosquito's bite is capable of causing a human to develop AIDS."

Of course, you can be sure that eventually we *will* have evidence of precisely that!

The AIDS virus is now known to be able to live outside the body for up to at least 15 days, if not longer.

Also, the AIDS virus is an unstable virus — it's constantly mutating and changing its form. That means it's "highly adaptable" - **that** is, it's continually adapting to its environment, at a rate millions of times faster than normal stable viruses change and

That fact implies that some mutant strain of the virus will almost certainly be adapted to living in the Asian tiger mosquito and being introduced into its human host by the mosquito's bite.*

It's not a matter of "Can it do that?" or "We have (as yet) no evidence of that."; instead, it's a matter of "How long will it be until that occurs and we confirm it?"

The Asian Tiger mosquito apparently is intended to serve as the major vector (carrier), or at least one of them, to eventually rapidly increase the AIDS infection rate and devastate the U.S. population.

AS the vector spreads and the virus adapts to that mode of transmission, the rate of increase of the AIDS infection will itself accelerate. This means that all the projections for "doubling times" are seriously in error.

The latest data from Alabama, for example, shows that the disease is now doubling every six months instead of every year. Also, the doubling interval itself has been shortening, at least up to the p**resent.** Note also that, from the data of the new studies confirming a much longer lag time for the AIDS test to indicate the presence of the infection, even the present data on the number of persons infected and the doubling time are underestimated.

If these and other data are a true indication, it appears that we literally may have an "explosion" of the AIDS infection in no more than two to three years.

In addition, as we said the AIDS virus is an unstable virus. Mutations in the virus itself are occurring so rapidly that producing an effective vaccine essentially will be impossible. Without a totally new means applied to produce an AIDS cure, AIDS simply cannot be **stopped.**

•And one or more strains will eventually evolve that can be infectuously spread like the influenza virus is.

In fact, recenly it has been discovered that the AIDS virus is far more devious than previously susupected.* It attacks in more ways than suspected. It changes in the body, increasing its virulence as the disease progresses.

Macrophages, the immune system's scavenger cells, become infected and carry the virus to other body cells. It appears that macrophages may pass the virus to the T-cells, conditioning the destruction of the immune system. Infected macrophasges are found in rectal material of AIDS patients and in cervical fluid and semen. Thus through infected macrophages the AIDS virus is able to infect partners through exhange of semen, cerical fluid, and rectal material — even though there are no breaks or tears in the skin, and even though the number of free AIDS viruses in the fluids is too small to pass the infection.

Other immune system cells —such as Langerhans cells—are also suspected to be capable of serving as AIDS carriers when infected. The end result is that, as the AIDS patient sickens, the virulence of the AIDS virus increases, so that it attacks a greater variety of cells and can more easily infect them.

Present orthodox methods cannot cure AIDs in time, if ever.

Unless unorthodox technology is applied to solve the problem the West is already defeated.

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*See Gina Kolata, "Fatal Strategy of AIDS Virus Grows Clearer," Science Times section, **New York Times,** Mar. 22, 1988; see also "Growth in AIDS Virus Virulence Found," **Los Angeles Times,** Apr. 1, 1988.

CHAPTER 3

WORLD WAR III IS RAGING AND WE'VE NEARLY LOST IT

More on AIDS Doubling Time

AS we said, the AIDS problem is much, much worse than officially announced. As stated, in some areas at least, the number of new AIDS cases diagnosed has been doubling every six months instead of every year. New studies have shown that the tests to identify infection by the AIDS virus may themselves have a 3-year lag period in which they do not reliably indicate the presence of the infection.

These facts probably make all previous "officially announced" estimates and projections off by several orders of magnitude (at least three).

If the incubation period (nominal) is, say, 5 years, then there is a factor of up to 2 (exp 10) of AIDS cases already in incubation.

The lag in accuracy of the AIDS tests however, may mean that there are even more AIDS cases in incubation than this.

And we may have a new entry into the equation at any time, once the AIDS virus adapts to its transmission by the Asian tiger mosquito and possibly even other insect vectors.*

Remember, we've got the U.S. data for only a relatively few years since 1981. So it's statistically difficult to project ahead with any accuracy. However, the best interpretation of the data we can make shows a spiraling (speed-up) trend in the rate of acceleration of the disease, indicative of a forthcoming asymptote. If that interpretation of the data holds true, the asymptote represents literally an "explosion" of the disease.

That is, the six-months "doubling interval" is slowly becoming **the s**ix-months "tripling interval," the six-months "quadrupling interval," etc.

The best indication/projection I can tentatively arrive at is this: If the total cure is not accomplished within about two to three years, then - considering the incubation ongoing by then and the speedup

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***Another HIV virus has now been identified.**

ahead — somewhere between a third and two thirds of all humans on earth will perish.

In other words, nominally half the humans on earth will inevitably die, say within five years (the incubation) after that two to three year point.

Most of the people who die are going to be highly selected. Most of them are going to be Westerners, Africans, Asians, and Brown people.

And all of our tanks, ships, bombers, missiles, nuclear weapons, and armed forces put together can't save a single AIDS victim.

We've got more generals than ever before in our history, including World War II. And not a one of them has a single tactic or a single weapon to use against this mortal attack.

Understand, our generals have not failed us against the enemy they know and recognize. The bellies of our B-52 bombers and the aircraft aboard our distant aircraft carriers are filled with nuclear bombs sufficient to destroy the world many times over. Our powerful nuclear-tipped missiles sit in land-based silos and in sleek submarines cruising silently under the oceans, waiting to respond in an instant to hostile attack, again with the power to destroy the world many times over.

Yet the fine men and women who have built and maintained that awesome force, and who man it in constant vigilance to protect our nation, are absolutely vulnerable and defenseless against the smallest foe of all —just as were the Martians in H.G. Wells' **War of the Worlds.**

With all our awesome forces, we do not have the power to stop a single AIDS virus — or indeed, any other similar new BW virus.

We can be defeated with ridiculous ease by even the tiniest determined hostile nation — or even by a single terrorist, madman, or genetic accident by a high school youth.

And if there's one thing that we can learn from history with iron certainty, it is this: If we can be defeated with ridiculous ease, then most certainly we will be!

Since the strike has already occurred, then our defeat is just a matter of time if we continue our present courses of action.

All other threats — nuclear, chemical, scalar EM, the works — pale in comparison to this seemingly innocuous, doomsday BW viral weapon that has already been unleashed upon an unsuspecting world.

World War III is Already Raging

World War III has long been unleashed and a final, decisive first strike has now occurred. We've already lost the war unless unbelievably heroic measures are taken immediately.

This thing is deliberate. It's fiendishly clever. It's effective. And a smiling Gorbachev — master propagandist — is just part of the icing on the cake to deceive us until it's too late.

Ironically, Soviet announcements have cleverly started claiming that the U.S. has produced the AIDS virus and unleashed it.

That's a very clever propaganda trick to shift suspicion from themselves. Indeed, in the Third World the propaganda has been very effective. Most Third World peoples now give at least credence to the Soviet claim.

Unless we move immediately to effect a total cure, the armed forces and the populaces of all the Western nations will shortly be devastated — perhaps even worse than if they been attacked with nuclear weapons.

With our armed forces and populations devastated, we surrender. We lose.

The Soviets get the U.S. (and European) farmland. That's what they really need.

Of course they also will have rid themselves of about 200 million Americans or so along the way.

That, solves the old "winner's problem" of what to do with, and how to effectively control and care for, a conquered, resentful populace. That problem will have already been taken care of, for most of the U.S. populace will essentially have been eliminated.

There won't be many U.S. military prisoners, for example, since most of the military personnel will also have been eliminated by the virus or viruses clandestinely released.

Communism Is Savage Enough to Do Diabolical Things

The Communist's doctrine is to wage total war. Win any way, with any weapon, at any cost.

ALSO, communism has always taught that it is necessary to destroy capitalism. That equates with destroying the U.S., the major capitalist country. Communists have always taken the long view, willing to struggle for decades to eventually accomplish their aim.

If you think no modern nation could be so incredibly savage as to deliberately destroy untold millions of people, look at the actual record of the Communists.

When the Khmer Rouge took over Cambodia, they murdered a third of their own people.

The Soviets murdered some 20 million or so Kulaks when they collectivized the Soviet farms.

The Red Chinese also slaughtered Chinese peasants by the tens of millions — perhaps as many as twenty or thirty million — when they collectivized the farmers.

Lenin's followers have proved over and over that they are capable of murdering even their own people, on a scale of millions.

Dedicated communists are highly religious people — even fanatics. Deliberate murder to achieve communism's goals is part of the accepted dogma.

The communists are quite capable of killing a billion or more "foreigners" and "enemies," given the chance. Particularly when the goal is to win the "Final Revolution."

The opportunity to strike the decisive final blow without consequences, using as simple and unorthodox a weapon as the AIDS viruses, could simply not be ignored by men who have spent their lives trying to control the world.

The unparalleled strike opportunity was particularly irresistible since someone else (the Western cancer research institutes) would develop the weapon itself, someone else (the World Health Organization) would unwittingly deliver the strike, and the blow could easily be clandestinely arranged (simply by secretly contaminating the WHO smallpox vaccine) and accomplished without repercussions to the Soviet Union.

Western Medicine is Inadequate

But what of Western medicine? Doesn't it always come through to save us?

Present Western medical science is totally inadequate to do the task required.

For example, present medicine is largely based on "slowing or killing the invader of the body." Whether that invader is a germ, bacterium, virus, or whatever.

If there's a mechanical difficulty, then present treatment is to try to mechanically remedy it — remove a bad appendix, set a broken leg, etc.

However, then it's strictly up to the body's own natural healing system - its immune system and its repair system — to actually do the healing and repair/reconstruction.

The problem with AIDS is that it directly affects and suppresses the body's systems for healing and repair.

Once this protection and repair system is in disarray, any disease organism can attack the body and infect it. If the immune system can't handle the problem, eventually the invading disease organism kills its host.

Even if a way is found to destroy the AIDS virus itself, present medicine has not the foggiest notion of how to restore the healing and repair system from the damage and destruction it will have already sustained by massive AIDS infection.

Compare the situation to division combat: Hostile invaders are met at the front of the division by the division's combat forces. A battle ensues, with penetration and damage to the rear area support and sustenance facilities. After the enemy is beaten back or destroyed, the rear support and the combat forces must be renewed and restored. If that cannot be done, the seriously weakened division can still literally be boiled over by almost anything that comes along and hits it.*

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*For this reason, standard Soviet doctrine is to attack in echelon, say, by three divisions — one behind the other. Thus, even if the first division is annihilated in the attack, the second and third divisions meet a seriously weakened enemy division and blast right over it. Similar tactics in the BW crisis - multiple viral strikes, one after the other — can almost inevitably be expected, now that the "first division" - AIDS - has engaged us.

The Soviet "repetitive attack" method *works,* in case anyone has doubts. For example, see George C. Wilson, "Army training exercises raise troubling questions," The Washington Post, as printed in the Huntsville (AL) Times, Feb. 28, 1988, p. 21A. Repeated U.S. Army tests in the Mojave Desert have shown that, in nonnuclear combat, when attacked by multiple Soviet echelons with 3:1 strength, U.S. forces lose every time! In particular, U.S. troops have poor anti tank defenses.

Modern medical dogma has concentrated almost entirely on the combat forces' problem of destroying and/or repelling the invader.

Western medicine has almost no tools or means of restoring the support and rear maintenance functions.

Even in a paroxysmal effort, dogmatic Western medical science would take decades to totally reorient its medical thinking to where it could even attack the real problem of AIDS and catastrophic sickness due to other viral BW warfare agents.

The same inability to cope with the problem also applies to our government bureaucracy, government agencies, the private companies, the universities, and to Western science in general.

If we have to depend on any or all of our present "system," the war is already over and we are all already doomed. Half of humanity will die within possibly five years after the upcoming two- to three-year "point of no return."

Medical insurance, treatment centers, and even private physicians are quickly going to be bankrupted as the AIDS plague increases. With the collapse of Western medicine, panic and pandemonium will reign in the streets. Martial law will be a necessity, and rioting on a scale unparalleled in American history will occur. We are likely to see our own U.S. dictatorship, in the form of a military junta making a coup and seizing power "to restore order and keep the lid on."

Study carefully the performance of governments and military regimes in such countries as Korea and South Vietnam, when those countries were hard pressed by enemy forces and in great disarray.

You may be looking at your own future.

The Soviets Will Not be Decimated

With the devastation of our armed forces, our governmental and civil agencies, and our population at large, a simple show of strength by the Soviets will collapse any further resistance. The hammer and sickle will wave supreme over the residue.

That's because the Russians *do* have the necessary developed scalar EM medical technology, not only to control and destroy the AIDS viruses, but also to directly restore the immune and repair systems.

The Kaznacheyev experiments alone show they have extensively studied electromagnetic induction of cellular disease and death.* We will have much more to say on that later.

If the Soviets extensively studied cellular death transmission by electromagnetics, you can bet they also studied the reverse: electromagnetic healing, or time-reversing the electromagnetic "death" signals themselves to produce specific "healing" signals for any type of cellular disease.

This is particularly certain since the Soviets also discovered and possessed the necessary "time reversal" electromagnetics: phase conjugation. This had been widely used by the Soviets in developing their enormous scalar EM weaponry, beginning about 1950 or so.

The curative signal technology was kept secret, of course, since the Soviets realized that it provided the only viable defense against viral biological warfare weapons.

The Soviets most certainly have the necessary AIDS cure. They can readily make the correct electromagnetic healing signal, by phase conjugating the AIDS death signal from dying human cells that contain AIDS retroviruses.

They also know we most certainly do *not* have the necessary EM cure. Years of weak microwave radiation of personnel in the U.S. Embassy in Moscow, and inducing illnesses in those personnel and even U.S. ambassadors, have shown that our own intelligence and scientific communities don't know what's really going on there.

Specificially, we've demonstrated (after checking with the DIA, CIA, NSA, and the orthodox scientists) that we do not recognize electromagnetic *biological warfare* —the deliberate introduction of cellular disease and death by electromagnetic means. Not only do we not recognize it, we can't do anything about it when it hits us.

And make no mistake, time-reversed electromagnetic medicine is shockingly cheap and effective, once developed. Specific healing signals for specific diseases — viral or whatever — can be quickly developed (within hours) and immediately used for mass treatment of entire populations.

For example, given the developed healing or "antidote" signal, it can even be recorded and played over ordinary transmitters, using their normal transmissions as carrier waves. A populace continually bombarded by such "healing" television, radio, and powerline signals simply doesn't get the disease. And those already infected recover when continually exposed to such healing signals.

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* There is now reliable information more closely associating Kaznacheyev with military *institutes near Moscow, engaged in* microwave weapon (directed energy) research

So the Russians can stop the AIDS epidemic cold, anytime they choose to do so.

Electromagnetically they can also gently guide and stimulate the progress of a disease such as AIDS, once the disease is introduced into a targeted population.*

Or, the Soviets can pull out all the stops and induce the disease in a distant population directly, placing the "death signals" on common carriers. Such as on our power lines, radio stations, televisions, and directly by induction from the Woodpecker over-the-horizon radar signals which continually bombard us.

The West cannot do any of these things. Neither can the West counter them, or defend against them effectively.

Unless a totally different tack is taken in the Western effort to counter this viral BW threat, Gorbachev's entrancing smile has already lured us to our doom. We are faced with a direct realization of Lenin's words:

> **"In the final revolution it does not matter if three-quarters of the earth is destroyed, so long as the remaining quarter emerges communist."**

And Khrushchev's ghost will have the last laugh after all. We will have fulfilled the prediction he made to Nixon in their famous "Kitchen debate":

> **"We will bury you!"**

Quite simply, for some decades the Soviets have had a new science — one they call *energetics,* and one which I have called *scalar electromagnetics.* The keystone or "heart" of this new science is time-reversed (phase conjugation) electromagnetics and electrogravitation.

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*A candidate for an eery test of just this capability may be the highly anomalous deaths of numerous dolphins off the East coast of the U.S. in 1987. Nearly 500 died in the summer and late fall, apparently as a result of the weakening of their immune system to the common bacterium Vibrio. See Julia Lawlor, "Key: Failure of Mammals' **defenses,"** USA Today, **Jan. 19, 1988, p. 1A-2A.**

Chapters 4 and 5
deal *with complex scientific material*
and are suggested for those who are
technically proficient.

CHAPTER 4

EXTRAORDINARY PHYSICS

Maxwell's Lost Unified Field Theory

About the time of the U.S. Civil War, James Clerk Maxwell succeded in unifying magnetism and electricity. Actually he did far more than that, in his theory as originally written.

In fact, he had produced a theory which also captured the free interchange between electromagnetic energy and gravitational energy, but no one — including Maxwell himself—realized it at the time.

Maxwell wrote his original theory in quaternion and quaternion-like mathematics. The modern form of vector mathematics had not yet been finalized by Gibbs and Heaviside. It is most instructional to examine some of the fundamental differences between a vector and a quaternion.

In a conventional 3-dimensional vector, one may have three vector components, such as

$$v = ai + bj + ck \qquad (4\text{-}1)$$

where i, j, k are unit vectors in the directions of the x, y, and z axes respectively and a, b, and c are constants.

Obviously if the vector components of vector v are zero, then

$$v = 0 \qquad (4\text{-}2)$$

We shall be interested in the "vector product" of two identical vectors v, where

$$\mathbf{v} \times \mathbf{v} = AA \sin\emptyset = \mathbf{O} \qquad \textbf{(4-3)}$$

and A is the length (magnitude) of vector v, $\emptyset$ is the angle between the two vectors (in this case zero), and O is the zero vector.

Now let us look for a moment at the quaternion situation.

First, in addition to the three vector components, a quaternion also has a separate scalar component, w. So the quaternion q for this situation is

$$q = w + ai + bj + ck \qquad (4\text{-}4)$$

Now when this quaternion is multiplied times itself, the vector part zeros, just as it did for the vector expression. However, the scalar part does not go to zero. Instead, we have

$$q \, X \, q = A^2 = a^2 + b^2 + c^2 \qquad (4\text{-}5)$$

There is a very good physical interpretation of this result. It is a square of the amplitude, hence for the vector part of a wave, it is directly proportional to the energy density of the vacuum, as a function of time, at the particular position. However, we now need to make a short explanation of variation of stress energy density of spacetime.

First, we note that, according to general relativity, the "gravitational potential" is just a conglomerate of potentials of all kinds. Basically, a potential represents a G-potential, and consequently a curvature of spacetime. The potential also represents "trapped energy."

Second, we note that Kaluza combined electromagnetics and gravitation as a unified theory in 1921. Kaluza added a fifth (spatial) dimension to Minkowski's 4-space, and applied Einstein's relativity theory to 5 dimensions.

To Kaluza's delight, a common 5-d potential is responsible for both electromagnetic field and gravitational field. The "bleed-off of this 5-potential in the 5th dimension (which is wrapped **around** each point in our 3-space) is what we know as the **electromagnetic force field.** The bleed-off of this 5-potential *in and through* our 3-space is what we know as the **gravitational force field.**

Since the EM field is very much stronger (by a factor of 10^{42} for electrons) than the gravitational field, it is obvious that most of the bleed-off of the 5-potential is in the 5th dimension, as EM force field. Only a tiny bit is left to bleed-off in 3-space, producing a very weak gravitational field.[1]

We state this fact: as a mass moves in space, it generates increased "activity" with the virtual particle flux of vacuum itself. **The** Increased virtual particle flux activity exchange between vacuum and mass is analogous to a strange kind of "virtual resistance." Since the resistance is virtual, it does not observably slow down an observable object moving in an (unobservable, virtual-particle flux) vacuum.

The increased flux activity represents an increased "virtual energy density" of space time, and an increased "trapped potential" (mass; resistance to an accelerating force) of the moving object. It represents a rotation of the spacetime frame, vis a vis the laboratory observer).

In the virtual vacuum (which contains both positive and negative time), one sees two antiparallel virtual forces: one in positive time, along the velocity vector of the object, and one in negative time (time reversed, or phase conjugated). The reason one sees virtual forces is that, each virtual (subquantal) change in the virtual flux activity represents an individual (unintegrated), separate change, hence a virtual acceleration. The observer (where things are integrated), sees the integral of all these accelerations, hence observable velocity.

The vector sum of these two virtual forces in the vacuum is a zero vector; however, the two taken together represent a stress in the local energy density of vacuum.

Since we may regard an EM wave as a stream of virtual electrons/positrons, each engaging in tremendous virtual particle flux exchange with the vacuum, then the same basic picture applies.

Now for our physical interpretation of (4-5): If we refer to an EM wave moving in the vacuum, the rotation of the frame is maximum (90 degrees). But this same rotation is just the same as additional vacuum stress, so the vacuum stress is maximum.

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[1] **Electromagnetics is 5-gravity sliding around our 3-space. 3-gravity is 5-gravity oozing** through our 3-space.

This leads to these conclusions: An electrical force field vector represents a local maximum linear stress in spacetime, along the line of the vector. (Note we specifically deny that the electrical force field vector, of an EM wave in vacuum, is transverse. Instead, it is longitudinal. That has been addressed elsewhere by the author and will not be covered further here.)

Another electrical (stress) vector interacting with the first one adds more "urging" stress to the first. However, this action is occurring in the rotated frame of the moving wave, and so is rotated 90 degrees from the electrical velocity vector. Therefore it is lateral (but in a hyperdimension, not in 3-space) at right angles to the electrical velocity vector.

The combined "urging" action of the two vectors thus sweeps out an area with respect to the laboratory observer.

This means that the total "urging" or "stressing" action of the two vectors is analogous to a vector area.

It also means that this "area" function may be taken as the "swirl" of the electrical vector, but in a hyperdimension, not in 3-space. That is, we have described the magnetic force field.

Thus any two electrical vectors that interact will have an "area" or "resistance" component generated. *Any two that interact.* Whether they add vectorially, cross-product multiply, or dot-product multiply.

What is actually happening is that the wave exists in the 5-potential. The E and B fields just represent the oscillations in that 5-potential. They represent oscillations in the bleed-offs of that potential as E-field (longitudinal) and B-field (swirl).

The drag-area represents the accumulation of extra potential — hence the local rotation of spacetime. Since this accumulation is moving (along with the EM wave), as it passes a point it represents a change in the local virtual particle flux density of vacuum at that point, **hence a local curvature of spacetime.**

Hence, the EM wave makes a 5-dimension G-potential wave as it travels. The 3-dimensional gravity wave associated with this is normally very, very much smaller in magnitude — say, by a factor of 10^{-42} or so.

However, if the two vectors interact so as to produce a vector zero resultant, then all the electromagnetic energy of tho two vectors **is** captured. That is, all the "EM vector zero" resultant means is that the EM bleedoff of the 5-space gravitational potential wave has been stopped. The 5-potential is still oscillating, and now all its trapped 5-energy must bleed off as 3-gravity force field.

Mass acts as an accumulator for this "trapped-EM energy turned into local curvature of 5-space." If we continually irradiate a mass with such a wave, the atomic nuclei of the mass slowly charge up with the new energy. Note that this potential delta may be positive or negative, if one adjusts accordingly.

In this fashion one may change the mass of a static object in the laboratory. One may either increase the mass or decrease it, or cause it to float, or even cause it to accelerate upwards.

But to return to our vector interaction and our interpretation of the scalar remainder of the quaternion.

The rule is, when the two EM vectors interact so as to form a zero EM resultant, then the EM energy represented in each of the two vectors has been converted into a special form of 5-space gravitational potential, one that is not bleeding-off in the fifth dimension (electromagnetically), but one which will gradually produce a 3-gravity potential in a mass's atomic nuclei as a function of time, the individual element, permeability and absorption factors of those nuclei, etc.

Therefore in our mathematical theory we ought to have a scalar component remaining when two EM vectors interact to form an EM vector zero resultant. That scalar component represents what is happening in the 5-potential, that will only bleed into 3-gravity.

With exploration of this phenomenology in the laboratory, one can work out the functions, constants, coefficients, and parameters which specify how the "5-G to 3-G and vice versa" component works in conjunction with mass, motion, and other fields.

That's the magic secret of electrogravitation.

It was captured inherently by the quaternion theory of Maxwell published during the American Civil War!

After Maxwell's death, when the scalar portion of the quaternion was discarded (by Oliver Heaviside) to form "modern" EM theory, that also discarded the unified field interaction between electromagnetics and gravitation.

Electromagnetic field and gravitational field were then modeled and regarded as mutually exclusive. EM field, therefore, was thought to produce no specific gravitational effects in the vacuum itself.

Hence when Albert Einstein was formulating general relativity some decades later, he knew only one way to "curve" spacetime: that was gravitationally, by "attraction of mass" forces.

But gravitational force was so weak that only a huge collection of mass would exert enough of it to measurably curve spacetime. That would require a sun or star. Since the observer and his instruments would never be on the surface of the sun or a star, **Einstein** assumed **that the local** spacetime **of the observer would not be curved.**

Hence he severely crippled his general relativity theory. In the West, it remains an assumption to this day. It is not a universal assumption in the Soviet Union, however, since the Soviets have long since written — and developed in the laboratory—unrestricted general relativity with *local* spacetime curvature, and hence *local violation of conservation laws.*

So the scalar part of the quaternion interaction, that remains when the vector part of the resultant is zero, is magic indeed.

That is the magic unified field portion that everyone has been seeking for decades and decades!

It was there at the beginning. Then we inexplicably threw it away!

But to return to our vector/quaternion examples.

Note also that the two vectors

$$\begin{aligned} Vj &= ai + bj + ck, \\ v_2 &= -ai - bj - ck \qquad (4\text{-}6) \end{aligned}$$

sum to zero vectorially when added, such that

$$v_1 + v_2 = 0 \qquad (4\text{-}7)$$

However, quaternions may behave quite differently, even under addition. For example, the two quaternions

$$\begin{aligned} q_1 &= w + a i + b j + c k, \\ q_2 &= w - a i - b j - c k \end{aligned} \qquad (4\text{-}8)$$

sum their vector parts to a vector zero resultant, but do not sum to a scalar zero as well. Instead, they sum to

$$q_1 + q_2 = 2w \qquad (4\text{-}9)$$

AS can be seen, quaternions which have the same vector parts as vectors, do not necessarily yield a complete zero when the vector parts sum to zero. And when two vectors multiply to provide a zero vector resultant, corresponding quaternions may yield a scalar term that is equal to the product of the magnitudes of the two vectors. In this way, the quaternion approach can capture the *stress of the medium,* induced by opposing or multiplying vectors. In the vector approach, the stress of the medium is entirely lost when the two vectors sum or multiply to a zero resultant.

Let us see just how important this "vacuum stress" can be.

First, the "stress in the medium" represents curvature of spacetime when that medium is the vacuum/spacetime.

In other words, the quaternion approach captures the ability to utilize electromagnetics and produce local curvature of spacetime, in an engineering fashion. Heaviside wrote a subset of Maxwell's theory where this capability is excluded.*

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*Dr. Henry Monteith has independently discovered that Maxwell's original quaternion theory was a unified field theory. See his important "Dynamic Gravity and Electromagnetic Processes," in publication

Note that, by Maxwell's original quaternion theory, however, Einstein's assumption need not be true at all. For example, look at equations (4-5) and (4-9): Here we may utilize electromagnetic force quaternions to produce zeroed EM forces, and an increased stress in local spacetime. In other words, we have curved local spacetime electromagnetically. Since (with electrons) electromagnetic forces are about 10^{42} times as strong as the gravitation force, this local curvature of spacetime is not negligible.

That is, we have produced a scalar effect from zeroing vector operation between electromagnetic forces. I have called this **scalar electromagnetics,** and pointed out that it is truly *electrogravitation.*

We stress again that this violates one of the severely limiting assumptions that Einstein placed upon his theory of general relativity. He assumed that curving spacetime could only be done by the weak gravitational force due to mass. Since gravitational force is so weak, only a stupendous collection of mass — such as the sun or a star — could curve spacetime enough to notice experimentally.

Since obviously the observer and his laboratory instruments would never be located on the surface of the sun or a star, *Einstein assumed that the local spacetime would never be curved!* In other words, the local frame would always be a Lorentz frame. This meant that, locally, the familiar conservation laws of physics would always apply. Curvature of spacetime would only occur at great distances, and at huge collections of mass such as a star or dwarf star.

Einstein did not write a complete, unlimited general relativity. He wrote a sort of "special relativity with distant perturbations."

If Einstein had had electromagnetic theory in quaternions, the scalar "vacuum pressure" parts would have been there for him to ponder. It is highly probable that he would have captured the "electromagnetics-to-gravity conversion remainder" in the quaternion interactions.

If so, he would have written the full theory of general relativity, involving local violation of conservation of energy, a unified field theory, and the direct engineering of

gravitational and antigravity effects on the laboratory bench by electromagnetic means.

In that case, we should long since have navigated all around the solar system, colonized the planets, produced practical free energy devices and power systems, and avoided two great world wars and a host of little ones.

But let us now see if we can make a gravitational wave, electromagnetically.

Again, regard equations (4-5) and (4-9). Suppose these are instantaneous operations of EM force quaternions whose vector parts are varying in magnitude, but in such a manner that the vector parts ways form a zero vector resultant. Now one can see that the scalar part remaining — which represents the stress of local spacetime - is varying as the product of the magnitudes of the vectors in the interaction vary.

This means that one has now produced a scalar wave that represents the local variation of spacetime curvature in an oscillating manner.

Rigorously this is a gravitational wave. It has been produced locally. It has been produced by Maxwell's original unified theory.

Again, I have called this area *scalar electromagnetics*. The Soviets call it *energetics.*

Where local spacetime curvature is varied, conservation laws (energy, conversation, etc.) need not hold. Curved one way, the local spacetime acts as a source (of energy, charge, etc.) Curved the other way, the local spacetime acts as a sink (of energy, charge, etc.)

The Soviets often do not utilize the same restricted kind of general relativity that Western scientists adhere to.

Soviet papers in general relativity regularly point out the complete and unrestricted theory, where local spacetime curvature is allowed. They also point out that all conservation laws may be violated by such local curvature. Thus the Soviets have no unduly dogmatic respect for conservation laws.

Further, by assuming the possibility of local spacetime curvature, Soviet scientists have assumed the possibility of direct experimentation with general relativity on the laboratory bench.

In the West, we have assumed that such cannot possibly be done, because of Einstein's limiting assumption of no local spacetime curvature. Thus Western physicists are strongly conditioned away from electrogravitation.

This is particularly ironic since the basis for just such an experimental theory was produced by none other than Maxwell himself in his original theory of electromagnetism.

Indeed, shortly after the U.S. Civil War, we should have been developing antigravity spaceships. We should have developed electromagnetics a la Maxwell and been on our way to the planets of our solar system. For Maxwell had — admittedly somewhat unwittingly — given us the basis for the necessary engineering theory of unified electrogravitation.

Heaviside's Mutilation of Maxwell's Theory

Well after Maxwell's death,Oliver Heaviside helped to finalize what is today vector analysis.

Then he undertook to "translate" Maxwell's theory from quaternion form to the new vector mathematics form.

Now quaternions were devilishly difficult to calculate in. So much so, that a majority of the electrical scientists (there were not very many of them in those days!) were in despair.

Not to worry! Heaviside took a broadax, figuratively speaking, and simply chopped off the scalar term, leaving only the vector components.

With that artifice, he greatly simplified the calculations to be performed.

Of course, he also threw away the EM stress of spacetime! That is, he threw away the "gravitation" part of Maxwell's theory!

Let me stress this fact most strongly. **After Maxwell's death a single** man**—Oliver Heaviside—directly altered Maxwell's equations, eliminating localized electrogravitation and producing the form of the theory taught throughout the West today as "Maxwell's theory."**

Maxwell's theory has never been taught in Western universities! Only Heaviside's crippled subset of the theory has been taught!

Then, shortly before the turn of the century, a short, sharp "debate" erupted in a few journals — mostly in the journal *Nature*. Only about 30 scientists took part in the "debate."

It wasn't really much of a debate! The vectorists simply steamrolled right over the remaining quaternionists, sweeping all opposition before them.

They simply threw out the remaining vestiges of Maxwell's quaternion theory, and completely adopted Heaviside's interpretation

Thus, a little over a decade later when Einstein wrote his general relativity theory, he did not know that the original work of Maxwell already indicated the unification of gravitation and electromagnetics, and indicated the ease with which local spacetime could be electrogravitationally curved locally and *engineered.*

Accordingly, he placed the scientists of the West on a road which rigorously assumed that a unified field theory was yet to be discovered. It also strongly discouraged any experimentation aimed at curving local spacetime, for it assumed that such could not be done.

After Potsdam and World War II, a frustrated Stalin was to drive his scientists to review the entire scientific literature of the Western world, actively seeking a great new technical breakthrough area such as the Allies had demonstrated with the development and use of the atomic bomb.

Great Soviet institutes — one staffed, for example, with over 2,000 PhD's — were set up to thoroughly review all the Western scientific literature from its very beginning. Anything interesting, anomalous, or unknown was put aside for further examination.

It is a good bet that the meticulous Soviet scientists discovered the difference between Maxwell's original electromagnetic theory and Heaviside's mutilation of it. Great mathematicians that they are, Soviet scientists would have realized the implications of the difference. With their knowledge of unlimited general relativity, they would have made the connection to electrogravitation.

By 1950 they had indeed done so, and were deeply into the development of what they called "energetics", and I have called *scalar electromagnetics.*

They had also reached another milestone about the same time — 1950 or so.

After WWII, both the Soviets and the U.S. were keen on securing the best of the German scientists. The U.S. particularly wanted missile scientists and rocket engineers. The Soviets wanted them too; but they also wanted the German radar specialists and infrared specialists.

The West didn't care about the German radar scientists and engineers, and the IR fellows. The Soviets did, and they got them. That was to prove a most spectacular benefit indeed.

During the war, the Germans had placed extreme emphasis upon radar and radar absorbing materials (RAM). The German scientists had fantastically developed and extended the science of radar cross section — which is the heart of the matter and very, very complex. **They were much further ahead in radar cross section theory at the end of WWII than where the U.S. is today, in the opinion of** some **U.S. radar experts.**

So the Soviets started with a great jump on us in radar knowledge, and they have steadily increased the lead over the years.

In addition, the Germans had developed highly successful radar absorbing materials, and much of the theory to accompany them.

Such materials turn out to be the key to how to build and develop a radar phase conjugation mirror, to produce a time-reversed radar wave.

Thus, because of the German scientists, by 1950 or so the Soviets had already discovered phase conjugation. And they had discovered it in radar first, not in optics!

They would have been primed for the discovery by their great review of Western literature and the foundations of science, since they would probably have noticed that the time-reversed wave is a solution to the wave equation. If so, they would certainly have realized its generality throughout all physics, all frequency bands, and all types of waves.

Superb mathematicians that they are, the Soviets would certainly have made the Kaluza-Klein theory connection, and also realized that phase conjugate waves carry negative energy as well as negative time. They would quickly have seen the gravity and antigravity implications.

So about 1950 or so, the Soviet Union would have started phenomenology experimentation in earnest, with phase conjugate radar mirrors and phase conjugate radars. This is what was referred to as *energetics.* The Soviets began a massive program in energetics about the time of the beginning of the Korean War.

By 1957-8 the Soviets had progressed to the point of a giant scalar EM accident in the Urals which exploded nearby atomic wastes, devastating the area. They had also progressed to development of great new superweapons using their new energetics — weapons to which Khrushchev referred in 1960 when he informed the Soviet Presidium of a new, fantastic weapon in development, a weapon "so powerful that it could wipe out all life on earth if unrestrainedly employed."

About the same time (mid-to-late 50's), the Soviets had also started the eery low-level microwave radiation of the U.S. Embassy in MOSCOW, to see if the U.S. knew of scalar electromagnetics (energetics) and was developing its own electrogravitational weapons and defenses.

Building Upon Whittaker's Fundamental Work

In 1904, a most fundamental paper in the foundations of electromagnetics was delivered by the British mathematician E. T. Whittaker. (E. T. Whittaker, "On an expression of the electromagnetic field due to electrons by means of two scalar potential functions," Proc. Lond. Math. Soc., Series 2, Vol. 1, 1904, p. 367-372.).

In this important paper, Whittaker showed that the electromagnetic force field equations can be replaced with the derivates of two scalar potential functions.

He also derived the most general form of electromagnetic disturbances in the ether.

This means that the coupling of two dynamic scalar functions can replace vector electromagnetics in the vacuum.

Note that Whittaker's work pointing out the overriding importance of scalar fields also accents the erroneously discarded scalar part of Maxwell's quaternion electromagnetic theory even more strongly.

Let me explain now how I got from Whittaker's paper to scalar electromagnetics, Soviet Tesla weapons, free energy, antigravity, and electromagnetic healing.

When I discovered Whittaker's paper, I had already strongly objected that "charges" and electromagnetic vector force fields — as presently included in the Heaviside version of Maxwell's equations — included observable mass. Of course there was no observable mass in the vacuum, hence the prescribed kind of EM force fields could not exist as such in the vacuum.

Obviously the foundations of our ordinary electromagnetics theory were seriously flawed. Although my objections fell on deaf ears, I determined to examine the foundations of EM theory, discover the flaws, and at least point out the necessary corrections to be made.

Though this was an arduous task to undertake and it required many years, slowly the flaws showed themselves, and the necessary corrections slowly became clearer.

Most exciting of all, in working with several unorthodox researchers, I was able to see many of these new ideas tried, adjusted, and demonstrated. In addition, the proprietary discoveries of these colleagues continued to reveal new and unique principles and concepts. The only disadvantage was that I could not reveal the propriety apparatuses and demonstrations of my inventor associates, but only the principles and concepts that developed. In turn, I also developed principles and concepts to explain what they were doing and the results they were obtaining.

So over the years I have slowly been releasing the principles and concepts. Some of them are my own discoveries, many of them are the discoveries of my associates. Some of them are simply a mixture of both.

Early on, it became obvious that the Soviet Union was far ahead on this path, and was already utilizing the new unified field theory to build eery, powerful new superweapons.

Since no one else in the U.S. seemed to be "watching thin particular store" (I was rather universally regarded as some peculiar sort of fool!), I also began to compile information and data on the Soviet weaponization of this unrecognized technology. This information I have released in a series of papers, briefings, and books, the most recent being a 1-hour videotape, "Soviet Weather Engineering Over North America," 1985, and a detailed book, Fer-de-Lance: A Briefing on Soviet Scalar Electromagnetic Weapons, Tesla Book Co., Greenville, Texas, 1986.

Building upon Whittaker's important work, I formulated a conceptual revision to electromagnetics, which I dubbed *scalar* electromagnetics to accent that the observable EM vector force fields did not exist as such in vacuum, but dynamic scalar fields did. I also wished to call strong attention to the fact that observable force does not exist until an observable particle of mass is coupled to the interference of the two scalar fields (much like in the Aharonov-Bohm effect). The Soviets, of course, call this area *energetics,* Energetics technology has been used in gigantic weapons programs of the Soviet Union for decades, and it appears to be developed under the most highly classified program that the Soviet possess. All development and deployment of energetics weapons is under the KGB and controlled directly by that organization, not by the Soviet Armed Forces.

Peter Kapitsa, the great Soviet physicist, was once pressed by Nikita Khrushchev for a total defense against missiles and air- and space-borne vehicles. Kapitsa replied that it could only come from the new energetics. In 1960, of course, Khrushchev gleefully announced to the Presidium that a new, fantastic Soviet weapon was in the development, "so powerful that, if unrestrainedly used, it could wipe out all life on earth."

Ironically, Khrushchev "jumped the gun" before his new superweapons were deployed. In the fall of 1962 he began inserting long range missiles into Cuba, bracketing the U.S. with nuclear firepower in an attempt to immediately change the balance of power. Kennedy, of course, backed him down "eyeball to eyeball," so to speak, in a blunt confrontation, but promised not to invade Cuba.

Khrushchev, with his days numbered, was desperate to deploy his new superweapons and provide a dramatic demonstration to recover face.

By destroying the U.S.S. Thresher on April 10,1963 and, on the next day, producing a gigantic underwater explosion 100 miles north of Puerto Rico, the Soviets demonstrated that the new superweapons had been deployed. Khrushchev managed to retain his position a while longer.

In the 1960's and early 1970's, I was also deeply involved in the study of paranormal phenomena.

In 1969, I entered the Georgia Institute of Technology to pursue a Master's Degree program in nuclear engineering, graduating in 1971.

In 1973, I published a rather simple paper, "Quiton/Perceptron Physics: A Theory of Existence, Perception, and Physical Phenomena," in which I pointed out the nature of quantum change, gave a new definition of mass and acceleration, and pointed out the fundamental nature of inversion of time. The paper also contained a simplified derivation of Newton's laws of motion, relativistic form. The elements of this paper had been worked out in 1971 while I was finishing my Master's program in nuclear engineering. Finishing the work had been interrupted by a slight sidetrack — a tour in Vietnam from summer of 1971 until summer 1972.

At about the same time, I formulated a fundamental correction to Aristotle's logic, adding a fourth law of logic to Aristotle's three, and a proof of it. The new logic was of great use in discovering and uncovering new concepts in unified field theory.

Incorporating Kaluza-Klein 5-dimensional concepts, scalar EM became a field theory that unifies electromagnetics and gravitation.

Incorporating dynamic sum-zeroed EM vector systems (which are discarded in normal EM theory) allowed the direct engineering of the unified field theory, including structuring the vacuum, curving local spacetime, and producing effects at a distance and in higher dimensions. Actually it allowed the recovery of much of the scalar part of Maxwell's original theory.

I then realized that, inside a vector zero EM force field summation/multiplication, the virtual particle flux of vacuum/spacetime was ordered and controlled locally and macroscopically. This of course violated one of the major assumptions (a postulate) of quantum mechanics; the assumption that the structure of vacuum was randomized, and could not be deliberately ordered, engineered, and curved locally.

Adding phase conjugation (time reversal) aspects and extended quantum mechanical concepts allowed local antigravity and local curvature of spacetime to be included — again, on an engineering basis. It also allowed one to produce a mechanism responsible for Newton's third law, and to engineer the reaction force at will.

Further, it revealed that the law of entropy was simply the *positive time* statement; it showed that there was another half of the law, the *negative time* part or the law of negentropy.

In addition, a startling new concept of mind, thought, life, biofields, disease, and healing emerged from all this — again, on an engineering basis. As we stated in the beginning of this book, it is now an urgent necessity to release my work on the basis for electromagnetic disease and electromagnetic healing. We must produce a very quick, positive treatment and cure of AIDS and other coming lethal viruses before the world is decimated.

Accordingly, this work is being released in this book.

In this chapter we will next present some perhaps surprising material on phase conjugation, from the scalar EM viewpoint, after first briefly explaining symmetry and parity.

In following subsections, we will cover briefly the remaining major concepts in scalar electromagnetics. This will then set the stage for the following chapter, Extraordinary Biology, in which we will deal with the basis for unparalleled electromagnetic healing.

Symmetry and Parity

The basic idea of symmetry is the arrangement of the parts of a body or system about an axis so that two or more parts appear the same with respect to some operation.

The most obvious example is to look in a mirror, where we notice that our image has been reversed, left to right. Yet otherwise there is no difference; and so we may say that the reflection has "mirror symmetry." It's the same except that left and right are reversed.

If you know the details of a system at one point, and at another point you know that the system will possess mirror symmetry, then you can predict exactly what state the system will be in at the latter point. It will be "left to right reversed." You don't have to calculate the laws of reflection and the laws of motion of the system.

All the laws of nature that possess "mirror symmetry" have a special property: If the words "right" and "left" are interchanged in the statement of the law, then the behavior of a system that obeys the law is unchanged.

Thus symmetry became a powerful idea in physics. For a system with a great number of possible interactions, etc., one can usually eliminate a very great number of them due to symmetry considerations. In other words, if one can assume that symmetry of the system will not be violated, then all the possible interactions that would yield "broken symmetry" can be eliminated.

On the other hand, if symmetry is broken in a physical interaction, at least one of the conservation laws is broken in that interaction. Broken symmetry — and hence violation of individual conservation laws — is a well-established fact in particle physics today.

Another concept intimately associated with mirror symmetry is parity. Each particle is assigned a number (+1 or -1), depending upon what kind of particle it is. One adds up these numbers for an assembly of particles, to obtain an overall "parity" number for the system. If parity is conserved in an interaction, then this total number does not change in the interaction.

Table 13. SYMMETRY

- **SOMETHING IS SYMMETRIC IF IT REMAINS UNCHANGED UNDER A CERTAIN OPERATION**

- **A SPHERE IS SYMMETRIC WITH RESPECT TO ROTATION ABOUT ITS CENTER**

- **A CATHEDRAL ARCH IS LEFT AND RIGHT SYMMETRIC ABOUT A VERTICAL LINE THROUGH THE CENTER**

- **LAWS OF ELECTRICITY ARE SYMMETRIC WITH RESPECT TO REVERSAL OF POSITIVE AND NEGATIVE CHARGE**

Table 14. A FORCE FIELD IS A SPECIAL LOCAL SYMMETRY

"..THE FORCE OF GRAVITY IS SIMPLY A MANIFESTATION OF AN ABSTRACT SYMMETRY — A LOCAL GAUGE SYMMETRY — THAT UNDERLIES THE PHYSICS OF THE WORLD."

"ALL FOUR FORCES OF NATURE CAN BE GENERATED IN THIS WAY."

PAUL DAVIES, SUPERFORCE.
1984, p. 115

Table 15. GRAVITY AND LOCAL SYMMETRY

- **THE** LAWS OF PHYSICS CAN BE MADE SYMMETRIC EVEN UNDER LOCAL GAUGE TRANSFORMATIONS

- A GRAVITATIONAL FIELD IS INTRODUCED TO COMPENSATE FOR PLACE-TO-PLACE VARIATIONS

- THE GRAVITATIONAL FIELD IS NATURE'S WAY OF MAINTAINING A LOCAL GAUGE SYMMETRY

- IN THE ABSENCE OF GRAVITY, THERE IS ONLY GLOBAL SYMMETRY

Table 16. HINDSIGHT IS BETTER THAN FORESIGHT

- **FROM THE TWIN REQUIREMENTS OF**
  - **SIMPLEST LOCAL GAUGE SYMMETRY**
  - **LORENTZ-POINCARE SYMMETRY OF SPECIAL RELATIVITY**

- **ONE CAN CONSTRUCT OR INFER**
  - **MAXWELL'S EQUATIONS**
  - **ALL THE LAWS OF ELECTROMAGNETICS**
  - **THE EXISTENCE OF RADIO WAVES**
  - **THE POSSIBILITY OF MOTORS AND GENERATORS**
  - **ETC.**

- **IN REALITY THESE WERE FIRST DISCOVERED EXPERIMENTALLY**

Table 17. WHEN SYMMETRY IS VIOLATED [BROKEN]:

- **A "NON-OBSERVABLE" TURNS OUT TO BE AN OBSERVABLE**
- **AN INVARIANCE IS BROKEN**
- **A CONSERVATION LAW OR SELECTION RULE IS BROKEN**

COMMENTS:

- **A VIRTUAL OBJECT BECOMES AN OBSERVABLE OBJECT**
- **LOCAL SPACETIME BECOMES CURVED, AT LEAST TO SOME POTENTIAL INVOLVING THAT OBJECT**

Table 18. SOME PROVEN ASYMMETRIES

- **POSITIVE AND NEGATIVE SIGNS OF ELECTRIC CHARGE**
- **TIME REVERSAL**
- **RIGHT/LEFT HANDEDNESS**

Table 19. SPONTANEOUS SYMMETRY BREAKING

PRESENT VIEW

1. IF 4-MOMENTUM $K\mu = 0$,

   $\text{Ø}_{(X)} = \text{Ø}_{VAC}$

   WHERE $\text{Ø}_{(X)}$ IS AS COMPLEX
   AS ANY SPIN-0 FIELD
2. **FOR** VOLUME Ω » RELEVANT MICRODIMENSION.

   $K\mu \neq 0$ BUT $K_M \sim 0$
   $\langle \text{Ø}_{(X)} \rangle \neq \text{Ø}_{VAC}$ [INSIDE *Q]*
   $\langle \text{Ø}_{(X)} \rangle \neq \text{Ø}_{VAC}$ [OUTSIDE Q]
3. INSIDE Ω, SYMMETRY PROPERTIES DIFFER
   FROM THOSE OUTSIDE Ω
4. T. P AND CP MAY BE SLIGHTLY ASYMMETRIC
5. CPT REMAINS INTACT

SCALAR EM VIEW

1. IF ARTIFICIAL POTENTIAL $\text{Ø}_{ART} >> 0$, VOLUME Ω
   MAY BE SMALL
2. Ø_{ART} MAY BE ENGINEERED IN
   - SPATIAL SIZE
   - LOCATION
   - MAGNITUDE
   - SUBSTRUCTURE
3. SYMMETRY PROPERTIES INSIDE Ω MAY
   - DRASTICALLY DIFFER
   - BE DELIBERATELY ENGINEERED
   - BE PATTERNED
4. T, P, AND CP MAY BE APPRECIABLY ASYMMETRIC
5. CPT MAY BE ASYMMETRIC

Table 20. WHY SUCH DRASTIC DIFFERENCE?

IN PRESENT THEORY

$\phi_{(X)}$ • IS USED ONLY AS A PHENOMENOLOGICAL DESCRIPTION
- MICROSCOPIC STRUCTURE OF $\phi_{(X)}$ OF NO CONCERN
- ONLY LONG-WAVELENGTH LIMIT OF FIELD IS OF INTEREST
- VACUUM ENGINEERING IS ONLY A REMOTE POSSIBLITY
- ACTION AT A DISTANCE IS NOT POSSIBLE
- LOCAL SPACETIME NOT CURVED

IN SCALAR EM

ϕ_{ART} • REPRESENTS A LOCAL CURVATURE OF SPACETIME [LOCAL GENERAL RELATIVITY]
- MICROSCOPIC STRUCTURE OF $\phi_{(X)}$ IS DETERMINISTIC AND COHERED INTO MACROSCOPIC STRUCTURE
- ALL WAVELENGTHS OF THE FIELD ARE OF INTEREST

ϕ_{ART} WAVES ARE REAL, ENGINEERABLE AND ELECTROGRAVITATIONAL
- VACUUM ENGINEERING IS A REALITY
- ACTION AT A DISTANCE IS POSSIBLE

Table 21. ASPECTS OF STRONG LOCAL ASYMMETRY

- **PROPERTIES OF AN OBJECT MAY DIFFER APPRECIABLY FOR**
  - **DIFFERENT OBSERVERS**
  - **DIFFERENT DETECTING MEANS**
  - **ONE TIME TO ANOTHER**
  - **ONE POSITION TO ANOTHER**

- **CONVERSATION LAWS MAY BE APPRECIABLY VIOLATED**
  - **ENERGY**
  - **CHARGE**
  - **SPIN**
  - **MOMENTUM**
  - **ANGULAR MOMENTUM**

- **LOCAL SPACETIME IS CURVED**
- **LORENTZ INVARIANCE OF VACUUM IS VIOLATED**
- **MAY BE A LOCAL "SINK" OR "SOURCE "**
- **GRAVITATIONAL/INERTIAL EFFECTS FROM EM**
- **TRANSLATION BETWEEN VIRTUAL AND OBSERVABLE**
- **ELECTROGRAVITATIONAL SOLITONS**
- **ACTION AT A DISTANCE**
- **TRANSMUTATION EFFECTS MAY EXIST**
- **SCALAR/PSEUDOSCALAR FIELD TRANSLATION**

For years the idea of conservation of parity convinced physicists that it would never be possible to tell right from left in the universe, Then in 1956, Yang and Lee pointed out a class of reactions where parity need not be conserved. This effect — broken parity — was confirmed experimentally, and so certain parts and interactions of the universe do possess asymmetry.

The result of all this was that particle physicists established that

(1) symmetry can be, and is, sometimes broken, (2) individual conservation laws can be, and sometimes are, broken.

Particle physics, however, concerns itself primarily with microscopic interactions. Most of the delightful new things discovered in the microworld have not yet been applied — by *physicists,* that is — in the macroworld.

If you can successfully apply broken symmetry in a major system, for example, you should be able to violate the conservation of energy law and thus produce a "free energy" engine. Several inventors with whom I work have done precisely that. The techniques and technology are still primitive and they need much further development, but the principle has been clearly established and replicated.

Physics is correct in certifying broken symmetry, and you can do it in large systems as well as in microscopic particle interactions. Of course you also *curve local spacetime* as well, something which Einstein and his followers have assumed cannot be done.

Charge-Parity-Time ***and Negative Energy***

The upshot of all this is that the physicists came up with the idea that what is really conserved is a consolidated thing called Charge-Parity-Time. You don't have to conserve any one or two of these three, but only the combined product.

Here they overlooked one key factor that is very important to our thesis: In the photon interaction, if you reverse charge and time, you reverse the sign of the energy.

That is, a photon that is emitted from a positive charge carries negative time negative energy. It is different from a photon that is emitted from negative charge, for that one carries what we have conventionally established as positive energy.

Thus physics has not considered the exclusive use of negative-energy / negative-time photons, even when some of its interactions produced them. Instead, it has just lumped together photons and antiphotons, and considered them both to have positive energy.

Antimatter systems don't have positive energy, for example; they have negative energy. *Here we don't use the positive and negative signs to indicate the direction the energy is traveling, but the fundamental kind, of energy that it is—time forward or time reversed.*

For example, consider the local conservation of energy. As conditoned, one almost always unconsciously thinks of the conservation *of positive* energy, without so stating. Yet one is perfectly free to build a system into which he inputs 100 joules of positive energy, and from which he outputs 300 joules of positive energy and 200 joules of negative energy!

For the real conservation law, that's the equivalent of putting in 100 joules of positive energy and outputting 100 joules of positive energy.

Now negative energy will run motors, light lamps, etc. —often much better than positive energy. It can be transmitted, transformed, stepped up or down in "voltage," rectified, received, etc. It can be translated into positive energy or vice versa.

Circuits run "cool" when using negative energy. If you short out a circuit of negative energy so that a violent discharge occurs, it produces cooling instead of heating, greatly lessening the danger of fire and destruction. If you mix negative energy onto a line that is carrying the same amount of positive energy, however, the two negate each other and there is suddenly "no power" on the system.

Think of what you were taught in simple arithmetic. You can take a zero — the absence of any single specific number — and replace it with any set of multiple numbers whose algebraic sum is zero. The presence of this special set of numbers you choose does not violate the condition that the zero means that you could not use just a single number.

Although zero is the absence of just a *single* thing, it can be the presence *of multiple* things.

The same thing works with energy. In the microworld, everything is fantastically energetic, and wildly fluctuating. For example, in a copper wire carrying a current of one ampere, wild momentary fluctuations at extremely high frequencies are occurring.

According to classical electrodynamics, the instantaneous current in a single one of these micro-micro fluctuations may reach thousands of amperes, and the instantaneous voltage may reach 10^{40} volts or more. As can be seen, the instantaneous energy and power are enormous. Yet outside the wire, we see a very placid and peaceful situation.

TIME IS NOT OBSERVABLE

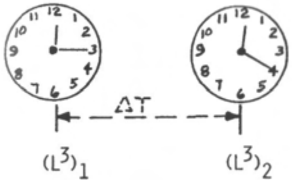

WHAT THEN IS TIME?

WHERE THEN DOES TIME EXIST?

Figure 33. The riddle of time. Unsolved by both physicists and philosophers.

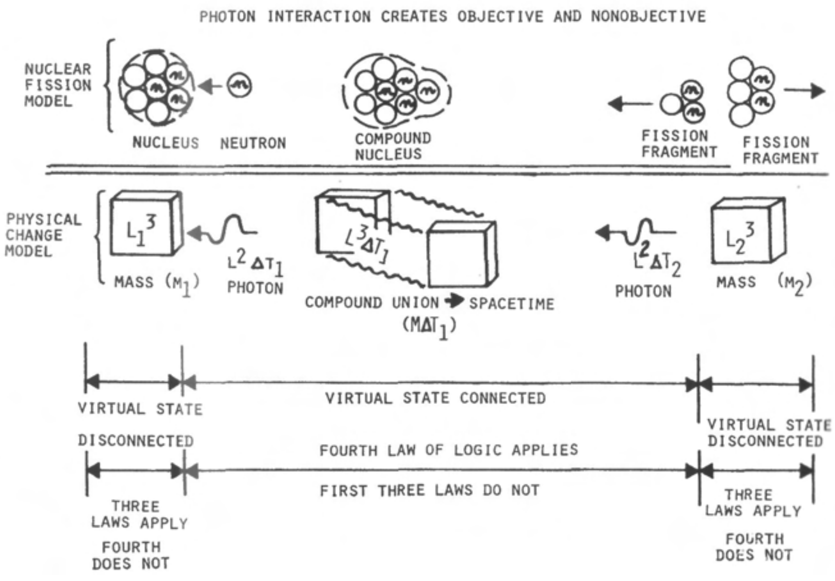
PHOTON INTERACTION CREATES OBJECTIVE AND NONOBJECTIVE
NUCLEAR FISSION MODEL
NUCLEUS
NEUTRON
COMPOUND NUCLEUS
FISSION FRAGMENT
FISSION FRAGMENT
PHYSICAL CHANGE MODEL
L_1^3
MASS (M_1)
$L^2\Delta T_1$
PHOTON
$L^3\Delta T_1$
COMPOUND UNION ➔ SPACETIME
($M\Delta T_1$)
$L^2\Delta T_2$
PHOTON
L_2^3
MASS (M_2)
VIRTUAL STATE DISCONNECTED
VIRTUAL STATE CONNECTED
VIRTUAL STATE DISCONNECTED
FOURTH LAW OF LOGIC APPLIES
FIRST THREE LAWS DO NOT
THREE LAWS APPLY
FOURTH DOES NOT
THREE LAWS APPLY
FOURTH DOES NOT

Figure 34. Raindrop model of physical change.

Table 22. FLOW OF TIME

- **PHOTON INTERACTION CONSTITUTES TIME CHANGE**
  - $\rightsquigarrow \langle \text{NEGATIVE CHARGE} \rangle \rightarrow + \Delta T$
  - $\rightsquigarrow \langle \text{POSITIVE CHARGE} \rangle \rightarrow - \Delta T$
- **CHARGE-PARITY-TIME [CPT]**

  $\rightsquigarrow \langle e \rangle \rightarrow + \overline{\Delta T}$ **(note: ~ = photon)**
  - **UBIQUITOUS**
  - **PREDOMINANT**
- **ANTIPHOTON IS A PHASE CONJUGATE REPLICA**

Table 23. PHYSICAL CHANGE

- **COMPOSED OF ACTION**
  - **h = BASIC QUANTUM**
- **TWO CANONICAL VARIABLES**
  - **ENERGY/TIME (dE dt)**
  - **MOMENTUM/LENGTH (p L) ETC.**
- **ENERGY/TIME**
  - $h = (+E)(+t)$
  - $h = (-E)(-t)$

Free Energy and Antigravity

Let's say the current flowing in the wire is alternating current at a frequency of one megahertz. Let's say we have one watt of power in the wire (there's one volt on it, and one ampere of flowing current). As a working rule-of thumb for engineering use, the available absolute micropower in an alternating current in a wire can be taken as:

$$P_a = 40 \times f \times P_c \qquad (4\text{-}10)$$

where P_a is the absolute power available, in watts; f is the frequency in Hertz; P_c is the conventional power available, in watts; and 40 is a constant of proportionality.

In our example, the absolute power actually available in the current is 40 million watts! We've got about 20 megawatts of positive power, and about 20 megawatts of negative power, in there — *in the microstructure of the electrical current itself--but disintegrated*

By applying unconventional scalar EM engineering techniques, we ought to be able to take such an "input" (a straight wire with one watt of power at a frequency of a megahertz) and get an "output" of up to 40 megawatts. It is relatively straightforward to get out 1 megawatt; such ratios have actually been achieved on the laboratory bench by my associates.

Of course we will have curved the local spacetime to do such a thing. But it is absolutely permitted to do that, by the laws of nature as best we know them from particle physics.

It is also possible to do that by Maxwell's original theory. And it has been proven in the laboratory.

Table 24. NEGATIVE ENERGY

- **CAN BE**
  - **GENERATED**
  - **TRANSMITTED**
  - **TRANSFORMED**
  - **RECTIFIED**
  - **RADIATED**
  - **TRANSLATED**
- **EASILY POWERS**
  - **AC MOTORS**
  - **DC MOTORS**
  - **LAMPS**
  - **TRANSFORMERS**
  - **RECTIFIERS**
- **CIRCUITS STAY COOL**

In scalar electromagnetics, we deliberately seek to produce such effects and systems by nonclassical application and extension of the modern conservation law CPT. And we include negative energy/negative time production in those systems and effects.

Here's the extended magic rule: First we write down the expression **CPTEGS.**

In this expression, C stands for charge, P stands for (space) parity, T stands for time, E stands for energy, G stands for gravity, and S stands for entropy.

We are referring here to the algebraic sign of each term, and to a complete photon interaction (absorption and re-radiation) with a charged particle inside an atom of matter. Specifically, we are refferringto the result, after the reaction has occurred.

Normally the photon interacts with one of the electrons in the atom's outer shell. This interaction with the negative electron charge *produces* the "normal" physical world/physical reality we see around us. In the interaction, normal parityis produced, andnormal gravitation (attraction of mass) is produced. Also, in a series of such interactions, the normal entropy (movement from order to disorder) is txperienced and produced.

So in the expression CPTEGS normally the charge term is negative, and every other term is positive, for the complete photon interaction in an atom.

Now here is the magic engineering rule: In the complete photon interaction with a charged particle in an atom, if one of these terms is reversed in algebraic sign, all the others will be reversed also.

For example, if the photon interacts with the positively charged nucleus,then parity is reversed, the bit of time-advance is reversed, a negative/time-reversed photon is emitted, a tiny bit of antigravity is produced in the nucleus, and negentropy is produced. By negentropy, we mean that the emitted photon exhibits the strange characteristics of time reversal, and hence it will return from disorder to order.

This rule is actually a statement of phase conjugation and time reversed waves, as we shall see later.

For example, using the rule, the production of antigravity is straightforward. Simply produce a great excess of negative energy and negative time in an object or generator by scalar photon interaction with the nucleus, at a sufficient rate.

In negative time, gravitational force is reversed. Thus in negative time gravity is a repulsion, not an attraction. Production of excess negative time in the atomic nuclei of a system produces antigravity in that system. Period.*

***At 100 Hz about 500 negative watts/lb is required for flotation. At 1 GHz, the effect is so *weak it cannot be measured, and no amount of power will float* the mirror.**

Let me amplify that statement. There are two kinds of energy, negative and positive. Normally, everyone thinks only of positive energy.

Take Einstein's formula for the amount of energy that's "bottled up" and stored in mass:

$$E = mc^2 \qquad (4\text{-}11)$$

That's positive energy and positive mass. It automatically implies that we are looking at things where time is forward-going.

Now suppose we "charge up" that mass with negative energy: Then the mass is negative, like this:

$$-E = (-m)c^2 \qquad (4\text{-}12)$$

And negative mass is repelled by positive mass. (Like mass G-charges attract, unlike mass G-charges repel.)

That's all there is to it! Simply charge up the protons/neutrons of the atomic nuclei of a mass with excess phase conjugate (negative) energy/time, and it exhibits antigravity compared to the earth. Nothing could be simpler.

Again, it's been done in the laboratory by an associate.

So, with respect to a negative energy/negative time generator, you just add more load and draw more negative power from the machine, forcing it to produce more. It produces more negative time, and hence more antigravity and more "repulsion." When the repulsion balances the earth's attraction, the system "floats in air." Draw still more power by adding still more load, and it accelerates upward. Draw less power by decreasing the load, and it sinks downward again. That's all there is to it.

We should have been working upon this, shortly after the U.S. Civil War.

Again, there exist two completely different kinds of electromagnetic energy: positive and negative. These have been totally and hopelessly confused by modern physics, even though physicists sometimes use these terms.

But in dealing with CPTEGS in the photon interaction in an atom, we must clearly keep in mind what kind of energy we are dealing with.

The basic engineering rules are these: (1) If any one of the factors - C, P, T, E, G, or S — is reversed, all the others are reversed. (2) If positive charge is involved in the photon interaction, then time (carried by the emitted photon) is negative and so is the energy carried by it. (3) The simplest scalar EM wave may be considered as two EM waves locked together (modulating each other), where one component wave carries positive energy and time and the other component wave carries negative energy and time. (4) Separation of the two components by interaction with charged particles creates both positive and negative time and energy. (5) If the interacting particle is negatively charged, the positive energy/positive time component will interact with it. (6) If the interacting particle is positively charged, the negative energy/negative time component will interact with it. (7) The interacting particle phase conjugates (time reverses) the component with which it interacts. (8) The primary interaction with negative electron shells of atoms yields positive energy and positive time: constituting ordinary physical reality as we observe it. (9) The secondary interaction with the positive atomic nucleus produces phase conjugated (time-reversed) physical reality. (10) Secondary interaction (nuclear phase conjugation) normally produces Newton's third law of motion. (11) In Newton's third law, the reaction force need not be equal, and need not be antiparallel. Note, however, in such case local spacetime is curved. (12) The present law of entropy is only the positive-time half; the other (negative time) half is the negentropy law.

Phase Conjugation (Time Reversal)

It is a most remarkable fact that Soviet radar engineers and radar scientists are also trained in optics. While this seems little short of astonishing by Western standards, the Soviets have an exceedingly good reason: As a matter of course, most Soviet radar systems are also operable in, or associated with another system that is operable in, a time-reversed (phase conjugate) mode.

In this mode the radar and/or its associated system is also an extremely powerful directed energy weapon, having capabilities undreamed of in the West.

A phase-conjugate (time-reversed) wave actually is a wave that travels backward through time.* That is, it is capable of precisely retracing the path through space, taken by another wave that traveled that path to a nonlinear mirror, stimulating the reflection of the time-reversed wave.

Further, in retracing its invisible path through space, the phase conjugate replica wave does not diverge as do normal waves. Instead, it continually converges upon its invisible trace.

Consequently all its energy arrives back at the distant source that emitted the stimulus wave originally. This was Tesla's original secret of his "wireless transmission of energy at a distance with no losses."**

It can easily be shown, however, that the phase conjugate wave is a legitimate solution to the wave equation. Hence it is a general property of all types of waves: sound, magnetohydrodynamic, etc. It is not confined just to the optical band.

Obviously such a startlingly different wave has phenomenal uses. Literally it ushers in a new physics.

Let us turn now to look at this strange wave that has emerged on our scientific horizon.

In the late 1960's, Soviet researchers cautiously pointed out the possibility of a time-reversed wave. Papers appeared in the open Soviet scientific literature, and shortly thereafter U.S. physicists began to read about it.

In 1972, Soviet scientists visited Lawrence Livermore Laboratory and specifically briefed U.S. scientists on the optical phase conjugation (OPC) phenomenon. Thereafter the effect became of increased interest to American scientists.

(Note, however, that phase conjugation (PC) is a major phenomenon of all physics. It is not confined merely to the optical spectrum, nor just to electromagnetic waves. Phase conjugation is a general phenomenon true of all waves, regardless of type. We will primarily discuss OPC, since most Western experimentation has been in the optics domain, and the literature is rich in that respect. However, we also point out that Western scientists have absolutely no inkling of the mechanism causing OPC. They have simply written a model for a time-reversed wave by taking the equation of a normal wave und writing the conjugation (adding an asterisk exponent) to the appropriate term, and pointed out that this new equation also satisfies Maxwell's wave equation. They also do not clearly recognize that an EM wave carries time and energy, and that a time-reversed EM wave carries negative energy and negative time. Further, they do not at all comprehend the startling implications for generating gravitational fields, including antigravity and inertial effects, directly on the laboratory bench.)

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*The external positive-time observer sees this time reversal as length (space) reversal.

**The great electrician had actually discovered what today is known as phase conjugation or time reversal of EM waves.

In optical phase conjugation, when an input EM wave (ordinary) enters a nonlinear medium, the medium "reflects" or produces a strange, time-reversed EM wave in response.

Figure (35a) shows the effect. In the figure, E1 is the normal input wave, entering a distorting, nonlinear medium (the "blob") as shown. Wave E_1 moves on through the blob, emerging on the other side and continuing, though now in distorted form.

The medium produces a second wave, E_2, which precisely retraces the steps of E_1 That is, everywhere E_1 is, E_2 now appears. The phases of the E_2 wave are precisely reversed from those of E_1 The only difference in the two waves is that wave E_1 carries positive time and positive energy, while wave E_2 carries negative time and negative energy.

(U.S. physicists are well aware of everything in the above statement except for the negative energy portion.) The historical background of the phase conjugate wave is given in Table 25.

(We strongly stress that the West did not discover the time-reversed wave; the Soviets did. At the time (late 1960's) this appeared in the open Soviet literature, the Soviets had already been using it for about two decades in their giant energetics (scalar electromagnetics) weapons development program.)

However, to return.

The time-reversed wave is called the phase conjugate replica of wave E_1. The overall characteristics of the phase conjugate replica E_2 are summarized in Table 26.

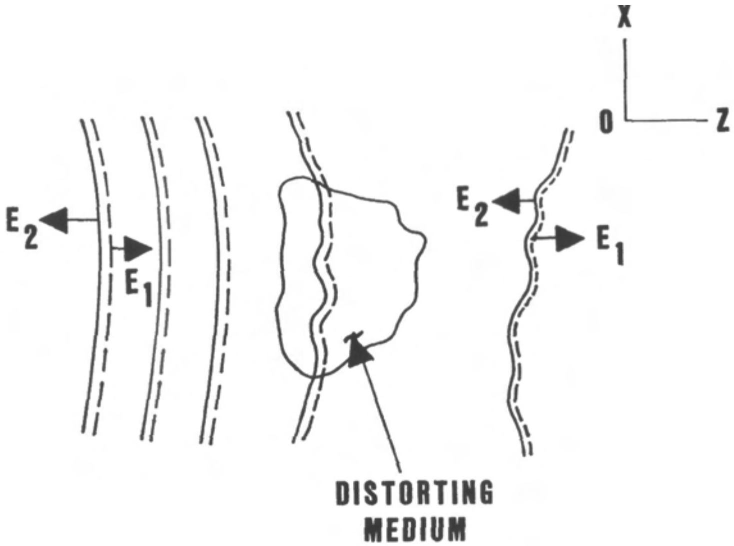
X
0
Z
E2
E1
E2
E1
DISTORTING
MEDIUM

a. Phase conjugation by a nonlinear, distorting medium.

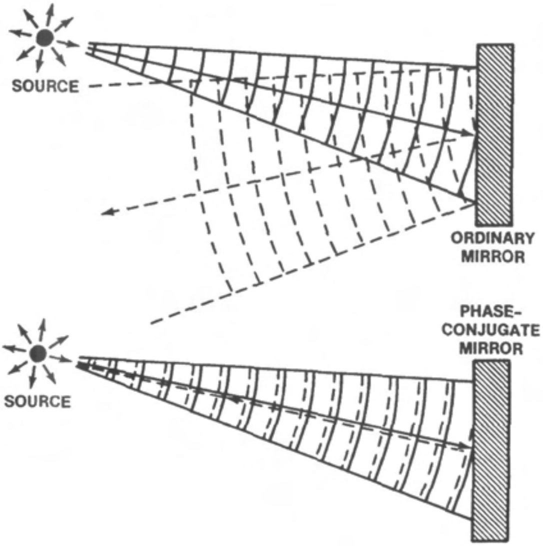
SOURCE
ORDINARY
MIRROR
PHASE-
CONJUGATE
MIRROR
SOURCE

b. Ordinary mirror reflection versus phase conjugate mirror reflection.

Figure 35. Phase conjugate reflection of a time-reversed wave.

Table 28. PHASE CONJUGATE WAVES

- NONLINEAR OPTICS TRANSIENTS
  - DISCOVERED BY SOVIETS
  - LATE 60s-EARLY 70S
- **PRESENTLY** "HOT ITEM"
- INITIALLY THOUGHT RARE
- NOW KNOWN WIDESPREAD
- THIRD POWER OF E-FIELD
- S**TILL** MUCH UNEXPLORED

Table 26. PHASE CONJUGATE REPLICA

- TIME-REVERSED
- CARRIES NEGATIVE TIME
- CARRIES NEGATIVE ENERGY
- "HEALING" PROPERTY
- DISTORTION CORRECTION
- F**ROM** DISORDER TO ORDER
- **MAY** DWARF INPUT WAVE

Table 27. DISTORTION CORRECTION THEOREM

"If a scalar wave E_1 (r) propagates from left to right through an arbitrary but lossless dielectric medium, and if we generate in some region of space [say near z=0] its phase conjugate replica E_2 (r) , then E_2 will propagate backward from right to left through the dielectric medium, remaining everywhere the phase conjugate of E_1."

We point out here that the basic nonlinearity (nonlinear medium) in spacetime is a single particle of mass. In a photon interaction with that particle of mass, the interacting (input) photon (positive energy, positive time) causes the generation and emission of a phase-conjugated (time-reversed) photon. This time-reversed photon provides the precise mechanism for generating Newton's third law: **For every action there is an opposite and equal reaction.** This will be covered later.

But back to our nonlinear medium, and the two waves E_1 and E_2.

E_1 and E_2 are "locked together" as a scalar EM wave unless something else is specially done to separate them. That is because the nonlinear medium is a *modulator,* and the two waves modulate each other (lock together as a single wave).

(We interrupt again to strongly point out this fact: This directly shows that all EM waves in vacuum exist as scalar EM waves, not as the so-called Maxwell-Hertz transverse waves of conventional theory. Nikola Tesla, the greatest electrical scientist the world ever produced, always adamantly insisted that EM waves were "sound" type waves, not "transverse" waves. For one thing, the vacuum-medium would have to be a solid to produce transverse waves! Tesla even visited Hertz in Europe and tried to convince him of the error of his so-called "proof of transverse EM waves." Tesla found Hertz, adamant on the subject, however, and returned without changing Hertz's mind. Ironically, Tesla was right and all the textbooks in the Western world have been consistently in error as to the nature of the EM wave in vacuum.)

We simply state here that, for a single-frequency EM sine wave in vacuum, a "full photon" of that wave in vacuum is actually a *single sine-wave oscillation.* The positive (positive energy, positive time) half of that sine wave is the same thing as a virtual electron (negative charge). The negative (negative energy, negative time) half of that sine wave is the same thing as a virtual positron — a virtual electron travelling backwards in time, or "time-reversed", which we detect as length-reversed and charge-reversed.

Further the vacuum — including the vacuum inside each relatively empty "mass structure" such as an atom or molecule — is a seething inferno of activity of virtual particle fluxes. It is upon that medium that all physical reality and physical changes are impressed. Thus there is nothing static in the world; what actually exists is *switching of virtual particle fluxes.* What we call a "static thing" is only an equilibrium in this switching activity. And, once switched on, any stream continues until switched off or switched to change it.

For that reason, the full photon has always contained twice as much absolute energy as is provided by the presently used equation

$$E = hf \tag{4-13}$$

Where E is energy, h is Planck's constant, and f is frequency.

One half the photon carries negative energy and negative time, while the other half carries positive energy and positive time. In the full photon interaction, one half of the photon interacts and "switches off" the stream. Thus the photon interaction makes a single change of action, energy x time, both switching on the beginning of the quantum change and switching off the ending of it.

The full photon in vacuum is, and has always been, a scalar EM photon. It rigorously is the presently accepted photon plus its directly "hooked on" and accompanying phase conjugated replica photon.

That is, in terms of the present physical view, the scalar electromagnetics view of a full photon in vacuum is that it consists of a photon and its antiphoton, directly combined in serial fashion. Further, this antiphoton part is not identical to the photon, since it is time- and energy-reversed.

The present physics makes no distinction between the two types of photons, hence makes no distinction between positive and negative photon energy. It also still considers "static" things to independently exist. It does not pursue the fact that all things appearing "static" are equilibrium states in nearly unbelievably intense virtual particle streams. Since it does not pursue that fact, it does not build a "switching" model for quantum change, not does it arrive at a method of directly engineering these "switching" operations.

For that reason, present physics has totally missed local general relativity and the engineering of spacetime curvature by electrogravitational methods, as was contained in

Maxwell's original theory.

For the same reason, present Western physics has not worked out the basic mechanism that produces phase conjugation, and it has not realized that all conservation laws can be locally violated with the new methods — methods actually hailing back to Maxwell's original theory!

Now returning again to our nonlinear medium and waves E_1 and E_2:

It is possible to separate (demodulate) wave E_2 from wave E_1 In that case, E_1 is an ordinary EM wave, carrying positive energy and positive time. E_2 is a phase conjugate replica, carrying negative energy and negative time.

Irradiation of an atom in a new sample of material with a normal EM wave such as E_1, just provides the normal photon interaction with the electron shells. That is, the electron part of the full photon adds to the orbital electron's energy state in positive time, raising the orbital electron to an "excited state." (Remember, this has switched on a continuous process of "keep raising the energy level of the electron" in positive time.) The "state-increasing" orbital electron then interacts with the second, positron-part of the full photon, which switches off the increasing, leaving the electron in its "static excited state." Simply put, one half of the full photon turns on an uplifting spray, and the second half of the full photon turns off the uplifting spray, leaving the electron in equilibrium state at a new level.*

Thus in orthodox physics we have taken the view that an electron in a shell absorbs a "photon" from the incident wave, taking extra energy and being raised into an excited energy state.

In the orthodox view, the excited-state electron then decays to release another ordinary photon (since it comes from a negative charge).

What actually happened was that, when the "full photon" of the incident wave is absorbed by the orbital electron, increase of the electron energy is switched on, then switched off, leaving the elec

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*We state here a magnificient principle without proof. When one furnishes (inputs) electrical power to a system, all the "input work" is expended purely upon switching fields by fighting against them in brute-force fashion. E.g., electrical power furnished to an electric motor does **not** run the motor, but only continually wrestles the internal fields to switch them. Obviously, to build an over-unity device, one must get it to switch its own fields, at least a significant fraction of the time.

tron in equilibrium at a new energy level.

What happened in the middle was phase conjugation. In absorbing the first half of the incident full photon, the electron acted as a phase conjugate mirror (we will explain that term shortly). It emitted a forward-travelling phase conjugate replica (PCR) of that first photon half, and this conjugate replica entered the nucleus, where it is absorbed to cause the Newtonian reaction force. Note that this PCR emission by the electron does not generate recoil in the electron-PCM, as is well known in OPC theory and experiment.

The same type of phase conjugation happened when the state-increasing electron absorbed the second half of the incident full photon. It phase conjugated again, sending this half to the nucleus to acompany the former PCR half. In the nucleus, this second half switches off the increase in excited state of the nucleus that was engendered by absorption of the first half.

The photon interaction is a process for switching on and off a continuous rate of action increase or decrease.

At the conclusion of the full photon absorption, both the orbital electron and the nucleus are in excited states. The nucleus has increased its gravitational mass.

Then the situation precisely reverses. Both nucleus and electron decay, again emitting full photons and again phase conjugating.

The PCR photon emitted by the nucleus reduces the positive mass of the nucleus. The PCR photon emitted by the electron is reversed from the electron's absorption record, reducing the negative charge's energy state, and the electron is said to "decay" from its excited state. The PCR photon emitted by the electron now (to the observer) will appear to carry positive time and positive energy.

(In passing, we point out that, actually, the situation is far more complicated. Both the electron and the positively charged nucleus are enmeshed in continuous streams of virtual particle flux, including intense streams of virtual photons. One must go to n-wave mixing, where n is greater than 4, to fully understand the total reaction. The main points are, the Newtonian reaction forces within the atom are generated by phase conjugation, the photon emitted by the decay of an excited state electron will normally carry what we call positive energy and positive time, and the photon emitted by the decay of an excited state positive charge will normally carry what we call negative energy and negative time. Full coverage of these interactions is beyond the scope of this book, and must wait for another effort in the future.).

Now once again we return to our simplified model of phase conjugation, and waves E_1 and E_2 in our nonlinear, modulating medium!

As we stated, we can engineer the situation so that the phase conjugate replica E_2 can be separated from E_1. A separated E_2, however, is a quite different breed of cat. It is a phase conjugate wave, carrying negative energy and negative time.

E_2 is a magic wave indeed!

Irradiation of the nucleus of an atom in a new sample of material with a phase conjugate replica such as E_2 causes the nucleus of the atom to interact in reverse of its normal interaction.* That is, one of the positive charges in the nucleus interacts with a photon resulting from wave E_2, and goes into an excited "negative energy" state. That state, in decaying, emits an ordinary virtual photon which promptly interacts with a virtual positive charge in the nucleus, which decays to emit the virtual photon, which interacts with another positive charge in the nucleus, etc.

In other words, the negative energy of the absorbed antiphoton is captured by the nucleus, and the nucleus overall does not *immediately* decay to discharge the negative energy.

Instead, the nucleus acts as an accumulator or capacitance, charging up and then discharging far more slowly than the normal photon/electron interaction.

(For the purist, the nucleus does phase conjugate the input negative energy/negative time wave, and phase conjugates it again — upon an electron in the electron shells, through spin coupling This second phase conjugate replica is now just a normal EM wave, and the electron exhibits a normal EM interaction. Thus **our** instruments (Which are electron wiggle detectors) detect a normal

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*Irradiation of the nucleus with a PCR wave is easily accomplished by using ordinary magnetic resonance, and modulating the PCR wave upon the magnetic carrier, as Antoine Priore did.

EM wave detection and do not discriminate between photon and antiphoton halves of a full photon. For that reason, scientists have not clearly noticed the difference between positive and negative energy, and between photons and antiphotons. They have also not resolved the basic conflict between the particle and wave theories of electromagnetics. *Note that the full photon concept, where the full photon is a normal photon and phase conjugate replica of that photon hooked together into a single sine wave, resolves the long-standing wave-particle controversy.)*

In most of their instruments, present scientists are detecting a secondary normal EM wave for the phase conjugate replica interaction, since the phase conjugate interactions in the instrument are not sorted out, and since the instruments measure only one kind of PCR, that emitted by a negatively charged electron. Hence scientists think the antiphoton has positive energy, and interpret it in positive time. Consequently they tend to accent that the wave is "phase-reversed," and not accent the negative time/negative energy implications since they have not clearly sorted them out.

Let us return to our consideration of the irradiation of the nucleus of an atom (with an incident E_2 phase conjugate replica wave carrying negative energy and negative time, with respect to our electron-wiggle-detecting observer).

AS irradiation continues, the actual "structured charge pattern" existing on the incident E_2 wave slowly charges up the nucleus of the atom with that exact charge structure, in the negative energy/negative time state.

We shall find that most interesting fact of great utility when we later discuss the mind, thought, cellular control systems, and generating a specific electromagnetic phase conjugation pattern to reverse cellular disease.

We shall also find that it is of great interest in accomplishing antigravity when we use extremely low frequency PCR irradiation.

The Phase Conjugate Mirror

Any system which phase conjugates the input wave and returns a phase conjugate "reflection" is called a phase conjugate mirror, or PCM for short.

But the phase conjugate mirror has some very unique properties, as can be seen in figure 35b.

For example, if you look in a *normal* mirror, you see your own reflection. You see your shoes and legs, for example. Light from your shoe scatters across the mirror, and it hits one spot on the mirror which reflects it at the proper angle to strike your eye.

But that simply doesn't happen with *a phase conjugate* mirror! If you were looking into a phase conjugate mirror (PCM), the light that left your shoe and scattered across the mirror would be reflected right back to the shoe, since it would retrace the path taken by the previous light striking all across the PC mirror from the shoe. So all you would be able to see would be two black dots: the retinas of your eyes. Light reflecting off them and striking the PCM would be reflected back to the source — the retinas — so you could see that light and that light only.

This path reversal is most important to keep in mind. With a phase conjugate signal, you are not functioning with an ordinary signal. Further, it has a "precursor" path taken by the incident wave that stimulated its emission from the PCM. Unless interfered with, the PCR will trace back down the invisible vacuum trace of that incident wave, or back down its wave path, like electricity goes down a wire.

This, by the way, is the secret of Tesla's wireless transmission of energy at a distance with no losses.

When broadcast into space, a normal EM wave (positive time, positive energy) diverges or scatters from its path.

Precisely the opposite happens with a PCR wave. When broadcast (reflected) into space, the PCR wave continually converges back upon the invisible trace taken by its incident stimulus precursor. Thus all the PCR energy is continually converging upon an invisible beam or "wire" through the vacuum, back to the source of the original incident wave.*

If the PCR wave is highly amplified (and means to do this are now well-known), then large amounts of EM energy can be precisely

*One can effectively move the entire imprinted vacuum path, however, by adding an additional input vector wave computed so that the **resultant** input would have come from the desired shifted distant point. In this way the PCR can be steered in space to lead and intercept a distant moving target.

returned to distant points from which a stimulus wave of any kind is received.

If a micro-microwatt is received from a point thousands of miles distant, then a gigawatt can readily be returned precisely to that distant point.

This was Tesla's magic secret. The great electrician had discovered phase conjugation, though he did not use that term. He did, however, point out that he could create an invisible wire through space to a distant point, and could send any amount of energy to that distant point without any scattering losses along the way.

He also accomplished the same thing with sound waves and mechanical waves. He pointed out that he could produce an undiminished physical (mechanical) effect at any distant point, and could eventually split the earth if he added power long enough.

Tesla had given the principles of radar in World War I! He later even spoke of his "big eye that can see at a distance." Here he was probably referring to stimulating the emission of a PCR return from that target. The PCR would automatically correct for the distortion in the intervening medium, and fairly sharp pictures of the distant scene — without showing the size dispersion of distance — could probably be obtained. Note that a non-scattering signal to a distant observer does not make him suffer any loss in field or apparent size and detail of the scanned object, which can be recovered to any resolution, limited only by the state of the art of the physical realization technology.

The implications for far greater resolution microscopy— far heyond the present limitation to about 4,500 — should be immediately obvious. The implications of such a microscope - that can see directly inside atomic nuclei; photograph nuclei and fundamental particles directly; see living viruses, molecules, and atoms directly; and theoretically see even into the virtual state itself— should be immediately obvious.

In discovering phase conjugation, the Soviet Union was attempting to break Tesla's secret of wireless transmission of energy without losses, and the Soviet scientists did so by about 1950. They highly weaponized the effects of phase conjugation, phase conjugate mirrors, and amplified phase conjugate mirrors, both in radar waves, mechanical waves, and sound waves, for nearly two decades. Then the Soviets cautiously stimulated the open literature with a limited paper on optical phase conjugation, to ascertain whether or not we realized the severe weapon implications of time-reversed waves, their production and use, and their amplification.

So phase conjugate mirrors can do very useful things. For example, look again at figure 35a. Suppose we are trying to photograph something on the other side of the distorting medium, say through a distorting gas, such as a turbulent atmosphere. In that case E_1 on the left is, say, light coming from an object on the left and passing through that distorting medium. If we just used ordinary waves in a camera on the right, we would see a very distorted wavefront, as represented by the distorted E_1.

However, if we illuminate the object by sending a wave through the distorting medium, and detect the *phase conjugate* signal that returns, it will have reversed the distortion when it gets to us, and we will get a clear picture. A very nice photo of just this process is contained in David M. Pepper, "Applications of Optical Phase Conjugation," **Scientific American,** 254 (1), Jan. 1986, p. 75.

Phase conjugation has many more uses than we have covered in this brief paper, of course, but this is an important use: the removal of distortion effects from optical systems.

It would, however, be nice to be able to amplify the effect. And so we can.

Amplifying the Phase Conjugate Effect

Let's look now at figure 36, where we will develop how to amplify the phase conjugate replica.

Be careful to notice that we are changing subscripts on you. By convention, optical scientists use A_1 and A_2 as two additional waves, called the *pump waves,* that are used to stress the nonlinear medium, and input signal wave A_4. Wave A_3 then is the stimulated PCM output, or the phase conjugate replica (PCR) wave.

In this figure we show a scheme for amplifying the phase conjugate signal that is generated and returned by the phase conjugate mirror (PCM).

We do this by adding two opposing waves of the same frequency (in this simplified case). These are the two "pump waves", and impressing them upon the PCM is called "pumping" the PCM.

Actually, in producing the pump wave, we are adding two input waves of the same frequency, 180 degrees out of phase with each other. Since the nonlinear medium is a *modulating* medium, the waves are forced to modulate each other and "lock together" as a *single scalar* EM wave of most interesting characteristics. Indeed, its E fields sum to a zero resultant vectorially, and its B-fields sum to B zero resultant vectorially. However, the scalar parts remain and are multiplied together, as in the original Maxwell quaternion theory. Since the magnitudes of the vector components in the scalar summation (quaternion multiplication, since we are addressing modulation) are varying, then the magnitude of the remaining scalar part is varying. We have therefore produced a standing scalar wave in the nonlinear material medium, having zero vector EM gradient components. We have produced a purely scalar EM wave of pure potential — and this is an electrogravitational wave, rigorously, since it represents a time oscillation of the local energy density (local virtual particle flux density) of vacuum. This scalar EM wave passes through the electron shells and enters the nuclei, where it is phase decoupled by the extreme nonlinearity of the violent virtual particle currents of the nucleus. Its energy is then absorbed by the nucleus, raising it to an excited pseudopotential. This potential decays, returning the scalar EM stress wave into the local vacuum and area. We are now pumping the atomic nuclei of the nonlinear PCM material with our two pump waves, and we have created an oscillating local gravitational field around the PCM.

This increased nuclear G-potential, looked at in Kaluza-Klein theory, is a 5-space potential. It is ready to burst out in the 5th dimension (as electromagnetic bleedoff) at the slightest provocation. That provocation is the entrance and absorption of the input signal wave, E_4. Note that E_4 acts as an "initiator" (or a pinprick into a highly inflated balloon, if you will) on the built-up, excited 5-dimensional gravitational pseudopotential of the nuclei. The moment so initiated, the entire 5-space G-pseudopotential collapses, emitting a time-reversed phase conjugate replica (PCR) of E_4. This emitted, highly amplified PCR is labelled E_3. It now "backtracks" down the invisible trace through space taken by the incident stimulus wave E_4, returning to the distant source that originally emitted

Voila! Tesla's wireless transmission of energy to a distant point without losses. *Voila!* The Soviet Launch Phase ABM system and the Soviet Launch Phase Anti-Bomber System, when used in conjunction with an over-the-horizon radar (such as the giant Wood-

Table 28. FOUR-WAVE MIXING

- **NONLINEAR MEDIUM**
- **OPPOSING PUMP WAVES**
  - **CROSS MODULATION**
  - **SCALAR WAVE**
  - **INTO NUCLEI**
- **TRANSMISSION WAVE**
- **REFLECTION WAVE**
- **REFLECTION GAIN**

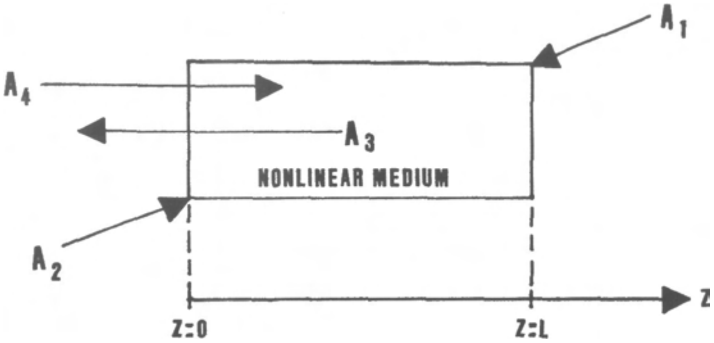

Figure 36. Phase conjugation by four-wave mixing.

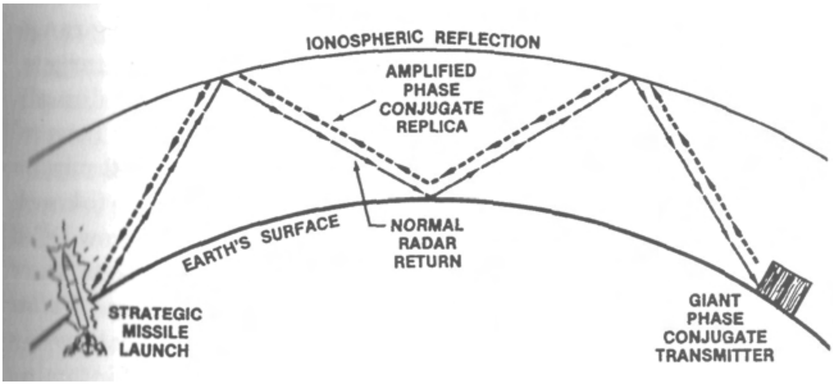
IONOSPHERIC REFLECTION
AMPLIFIED PHASE CONJUGATE REPLICA
EARTH'S SURFACE
NORMAL RADAR RETURN
STRATEGIC MISSILE LAUNCH
GIANT PHASE CONJUGATE TRANSMITTER

a. Soviet Launch-phase and midcourse ABM system.

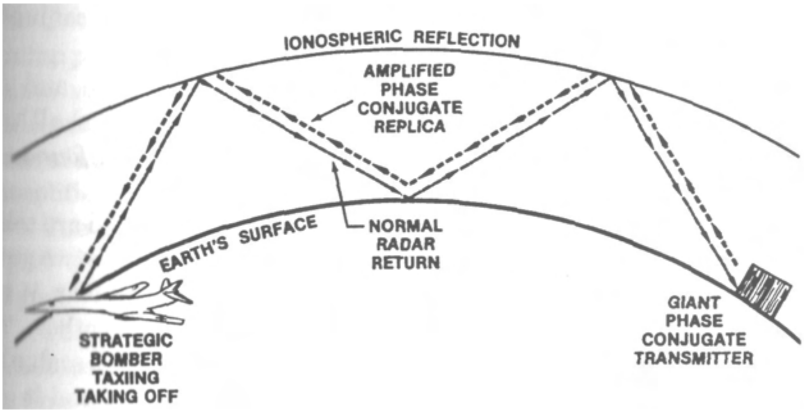
IONOSPHERIC REFLECTION
AMPLIFIED PHASE CONJUGATE REPLICA
EARTH'S SURFACE
NORMAL RADAR RETURN
STRATEGIC BOMBER TAXIING TAKING OFF
GIANT PHASE CONJUGATE TRANSMITTER

b. Soviet launch-phase and midcourse anti-bomber system.

Figure 37. Soviet launch-phase and midcourse strategic defense system.

peckers) to provide a reflection signal from a distant target. *Voila!* The true use of Soviet Stand-Off-Jammers to knock out enemy antiaircraft, air control, and anti-tactical missile radars wholesale. *Voila!* The Intermediate Phase ABM system, where a long range strategic radar is used to provide reflections from incoming targets. "Fire and fire again!" is the rule, and 100% defense is directly achievable. *Voila!* How the Soviets knocked down Gary Powers' high-flying U-2 reconnaissance aircraft. *Voila!* How SA-2 missile system radars were temporarily modified in North Vietnam to knock down several hot new F-111 aircraft. *Voila!* How the Arrow DC-8 aircraft, Titan missiles, Delta rocket, and Ariane rockets were "electromagnetically surged" from inside to destroy them. *Voila!* Why the Soviets almost never throw away old radars, since they can now add PCMs and make them formidable destroyers of incoming targets. *Voila!* How one solves the ABM problems of discrimination and weapon kill; simply pulse-fire everything — nuclear material explodes in a full nuclear explosion when struck with potential pulses of sufficient magnitude and duration.

Summarizing figure 36 and amplification of the phase conjugate replica:

When we consider the addition of the input wave and the resulting phase conjugate wave that will be produced, we shall have a total of four waves. Thus this particular process is called four-wave. *mixing.**

On the diagram in Figure 39, A_1 and A_2 by convention are taken to be the two opposing EM pump waves. Notice that these two pump waves stress the medium. Since the medium is nonlinear, it is a modulator. Hence the two pump waves modulate each other. The two waves thus lock together into a scalar EM wave. This scalar EM wave is an oscillating artificial scalar EM stress wave, and it goes directly into the atomic nuclei of the medium and pumps the nuclei themselves.

The atomic nuclei are now rhythmically stressed with the oscillating scalar wave.

*Probably the best single introduction to optical phase conjugation in the English language is David M. Pepper, "Nonlinear optical phase conjugation," **Optical Engineering,** 21(2),**Mar.**/ Apr. 1982, p. 156-183. Especially read Pepper's footnote on p. **166.**

We now input a weak signal (wave A_4) into the "pumped nuclei" medium.

By our CPTEGS rule, the positively- charged nuclei generate a negative energy/negative time wave — in short, a phase conjugate replica wave. Further, it is a highly amplified PCR, and may contain *as* much raw energy as was fed into the pumped mirror by our pump waves. This "seeker wave" or "electromagnetic missile" wave then sets out on its invisible path through space, seeking a distant "A_4 source point" and delivering all its energy intact to that point.

The Phase Conjugate Mirror as a Vacuum Triode

The pumped phase conjugate mirror (four wave mixing) can best be understood as a special kind of vacuum triode.

The pumped artificial potential on the atomic nucleus provides a powerful cathode in positive time, and a powerful plate as well in negative or reversed time. The electron shields, in their spin coupling to the nucleus, act as a grid in positive time. The input signal A_4 itself acts as a relatively weak signal onto the grid of the triode.

The positive charge difference in potential between the powerful pump potential of the nucleus (cathode, in forward time) acts as the plate voltage. The decrease of this potential when discharging (increase of the negative time, negative aspect) acts as the production of a plate signal to the negative time operation (production of the amplified, time-reversed PCR wave).

The excited nucleus immediately decays upon stimulus by the "grid signal" A_4, emitting a "time- and energy-reversed" strong signal — in short, amplified phase conjugate replica wave E_3.

The amplified phase conjugate signal moves from the cathode (nucleus) out to the electron shells and beyond, precisely because it is time-reversed. To a time-reversed signal, the grid (normal input) acts as the final plate (external output) — that is, in negative time, the elements of the triode are reversed. This makes it possible for the material to emit the powerful PCR.

I have called this effect/analogy a vacuum triode, to accent the direct engineering possibilities. My associates have already engineered this effect to obtain enormous amplification of energy ("free energy") and practical antigravity, from solid-state devices, directly

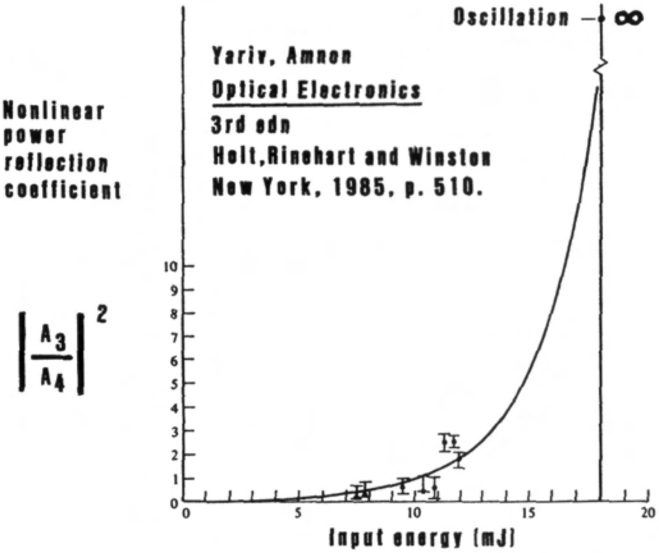

a. Typical nonlinear power reflection coefficients.

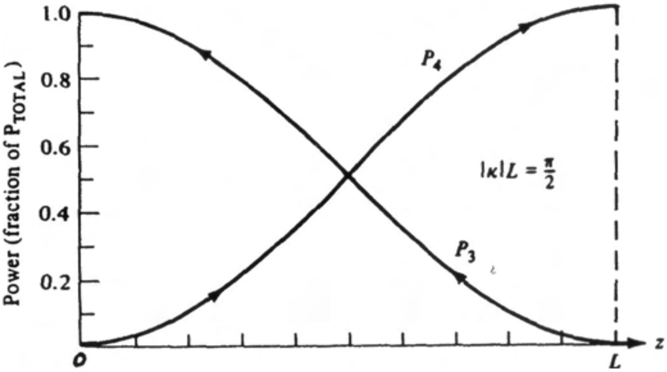

b. Intensities for the oscillation condition.

Figure 38. Power reflection coefficients and oscillation.

on the laboratory bench.

The actual "amplitude gain" of the vacuum triode is the ratio of the amplitude of A_3 to the amplitude of A_4. The square of the amplitude gain is proportional to the power gain; this entity is called the nonlinear power reflection coefficient.

Figure (38a) shows the typical nonlinear power reflection coefficient for a pumped phase conjugate mirror, as a function of the input energy and the depth of the material. As the input signal increases, the gain increases. The ultimate condition would be that the "free oscillation" condition is approached. This occurs when the angle between the input wave A_4 and the pump waves A_1 and A_2 is 90 degrees.

Figure (38b.) shows the oscillation condition and the fraction of the total pump power that is in the input wave A_4 and its output **phase** conjugate replica A_3.

At the oscillation condition, an "infinite" gain exists at the correct depth in the medium. This means that essentially all the energy being fed into the pump waves A_1 and A_2 will now be emitted **in** the output wave A_3. At that point, "saturation cutoff" of the triode output occurs, and it cannot output higher energy, since it has no more.

Notice that, at the oscillation condition, for the slightest output, the full power of the pump waves is fed into the phase conjugate replica. This powerful wave then retraces the path taken by the o**riginal** input signal, unless something else is done to divert it.*

The interesting question then arises: Since we can have infinite **gain,** can we get a special oscillation condition so that the pump wave furnishes its own energy? In other words, can the pump wave "resonate" with the vacuum flux in such a fashion that it is self-pumping and self-perpetuating?

In at least three materials, the answer is yes. Such effects have **been** experimentally accomplished in special forms of barium tita**nate.** See, for example, J. O. White et al, "Coherent oscillation by self-induced gratings in the photorefractive crystal $BaTiO_3$," **Appl. Phys. Lett.,** vol. 40, 1982. p. 450.

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*Recall that the PCR can be steered by introducing a minute wave A_5 to vectorially sum with input A_4, In that case, the effective input is the vector resultant of $(A_4 + A_5)$. The apparent distant source point and invisible vacuum path are shifted correspondingly.

Phase conjugation is a universal phenomenon. Theoretically it applies to any sort of wave: electromagnetic, scalar, sound, mechanical, etc. By using it, incredible new effects and an entirely new physics can be accomplished. It is a new and exciting field, little-known outside specialist circles, and still not well-understood. Most discoveries in the field are yet to be made.*

Newton's Third Law and the Full Law of Entropy

For example, the present author noticed that Newton's third law— for every action there is an opposite and equal reaction — is actually a result of phase conjugation. To explain that, we diverge a bit.

First, phase conjugation is also involved in the fact that a charged particle of mass is a little "dynamo" or engine.

Actually, a particle of mass is itself a "nonlinearity" in vacuum spacetime. When a photon (virtual or observable) strikes a particle of mass and is absorbed by it, it's the same as "interacting with a nonlinear medium."

In terms of virtual photons, the charged particle is continually bombarded with them, from the vacuum flux. The charged particle, being a "nonlinear medium", phase conjugates each input virtual photon, emitting a phase conjugate replica.

If it absorbs a normal virtual photon, it emits a "negative energy, negative time" phase conjugate replica.

If it absorbs a normal virtual photon, it emits a "negative energy, positive time" phase conjugate replica — just a normal virtual photon. Note that the particle of mass thus does not exist in time. Or, it exists equally in positive and negative time. Since we only observe particles, it follows that time is not normally an observable, as quantum mechanics has assumed.

The emission of a phase conjugate replica does not affect the momentum of the emitting PCM, as is well-known.

For an observable photon, the particle (nonlinear medium) absorbs the normal photon, which does not affect the energy and momentum of the PCM particle of mass.

If there is no other mass to accept the PCR, it just moves off.

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*The U.S. may finally be waking up. SDI is now starting to study EM missiles "in the time domain" as opposed to frequency. See **Av. Wk. & Spurn Tech., Feb. 29, 1988, p. 56.**

If there is another mass to accept the PCR, the PCR is absorbed and phase conjugated by it.

A charged particle in vacuum is continually bombarded by a flux of essentially "randomized" fluctuations. However, on the average these all "average out" to zero. Any particle is automatically in a very high vacuum potential, and is in a state of great agitation at all times, even if it's "at rest" with respect to ordinary observers. It's really "smeared all over the place," so to speak.

When we expose a charged particle to a *normal* potential, the interior virtual particle flux of that potential is disorganized. Hence the particle just "wiggles a bit more frantically," so to speak, randomly in every direction.

However, when we expose a charged particle to an *artificial* potential made by zero summed/multiplied EM force fields or waves, the particle wiggles more frantically in *organized directions.**

This is just as true for virtual particles as it is for observable particles.

Thus the use of such artificial potentials in scalar electromagnetics enables us to overcome the disorder of the internal structure of normal electromagnetics. By this means, we can structure the vacuum, organize electricity and electromagnetic waves, accomplish negentropy, curve local spacetime in complex, deterministic fashions , produce free energy and antigravity, reorganize and transmute nuclei (transmute elements) with miniscule input energy, etc.

Rigorously, this means that the present law of entropy is only half of the full law of entropy. Specifically, it is the "positive time, positive energy" half of the law, and it states that in closed real physical systems, continuing operations of ordered "positive time, positive energy" effects tend to inevitable "disordered" effects produced in the apparatus or system.

In other words, the present law of entropy really states that no ordered system is totally closed. The system will inevitably have energy and actions that escape the system's order, and hence (to the system) this escape represents "loss of order" — or in short, disorder.

The present law of entropy specifically excludes (by implication)

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* I.e., **the** electronic noise is partially organized. This is a major key toward building scalar EM detectors. It is also a primary cause of many solid-state circuit malfunctions. The exact principle: (Random changes) + (artificial potential) equals (chaos).

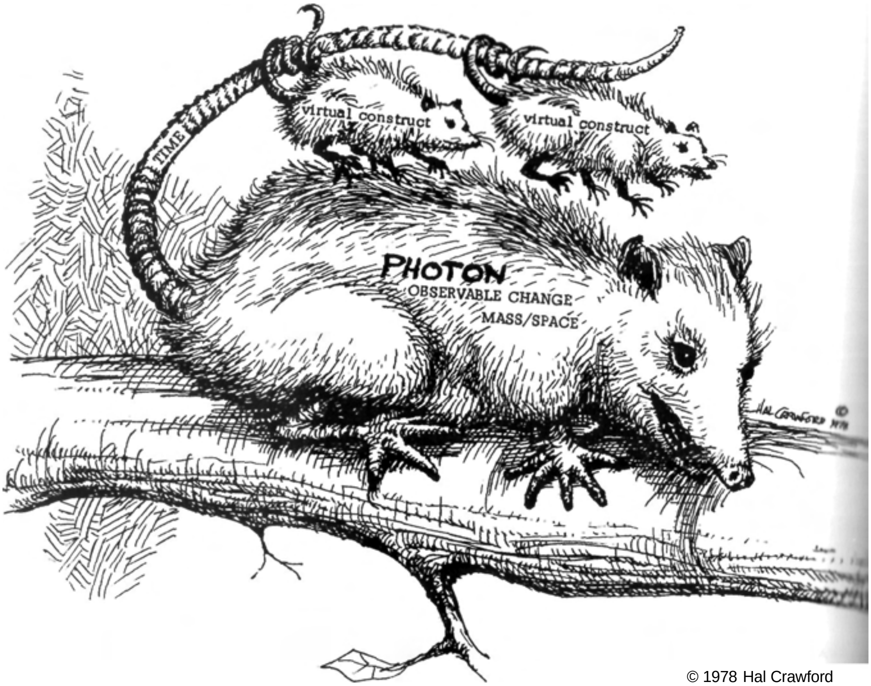

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Figure 39. Photons have virtual substructures. These may be statistical or deterministic.

negative time aspects, where external (disordered) energy time-reverses to again enter the ordered system, in perfect order. By implication, it also excludes negative energy production and operations.

However, **experimentally we can produce both negative energy and negative time, in deliberately time-reversed operations such as phase conjugation and with devices that serve as phase conjugate mirrors. Further, we can amplify the phase conjugation and disorder-to-order operations.**

Hence the present law of entropy is incomplete, and states only half the true possibilities. The other half of the law is the **law of negentropy.** In this law, disordered operations outside the **ordered** system undergo time-reversed (and possibly amplified) effects. These reordered energy effects — which may be highly amplified in comparison to the disordered escaped energy—reenter the "ordered system", restoring order. Since this process moves in negative time, it goes from disorder to order. Hence it is negentropic.

Therefore we have solved the old thermodynamic problem of the "eventual decay of the universe into disorder." Not to worry; the other half of the full law of entropy prescribes negentropic operations in negative time/negative energy, and these restore the order of the universe. That takes care of the problem.

It also means that, in highly disordered systems of many degrees of freedom and far from thermodynamic equilibrium (that is, when the disorder law is saturated), then one can expect to see further stress "create" negative time and hence create order emerging and stabilizing from disorder.

And of course that is exactly what is seen. Ilya Prigogine was awarded the Nobel Prize in 1977 for writing a new thermodynamics predicting precisely such effects, and experiments have proved his case.

But to return to Newton's third law:

Newton abstracted his third law from the classical interaction between two colliding balls.

If one ball is at rest and another approaches it at some velocity, the approaching ball carries momentum and kinetic energy. As it "collides" with the resting mass, quantum mechanics tells us what actually happens: Particles of mass in the moving ball are producing virtual photons continually, and these virtual photons strike the particles of mass of the resting ball and are absorbed by it.

The resting mass now acquires extra energy and momentum from the absorbed photons. At the same time, it acts as a nonlinear medium. It produces phase conjugate replica virtual photons, and these time-reversed virtual photons are emitted. These photons produce no change in momentum or energy upon the emitting mass. However, being phase conjugates, they precisely follow back along the paths taken by the first or "stimulus" virtual photons, striking the moving ball. They are absorbed by that ball, producing (to the external observer) negative momentum and negative energy in it.

These subtract from the kinetic momentum and kinetic energy of the moving ball, reducing them.

The virtual photons emitted by the approaching ball perform positive work upon the target ball.

The virtual, phase conjugated photons, emitted in return by the mass of the struck ball as a PCM, reverse to strike the approaching ball to do negative work upon it.

Notice that twice as much absolute work is always done on the system of two balls as we "input" with the approaching ball.

Also notice that, if we directly "engineer" the phase conjugation of the struck system, we can directly tamper with, and drastically change, the production of the negative energy and negative momentum in the moving ball. Hence we can drastically alter Newton's third law. We can now make a Maxwell's Demon.

This alone clearly establishes that it is perfectly possible to build a so-called free energy device. Though subtle mechanisms must be used, it's nothing more spectacular than putting a paddle wheel in a river, and extracting shaft power from the wheel, furnished by the river's current. Phase conjugation yields other exciting possibilities

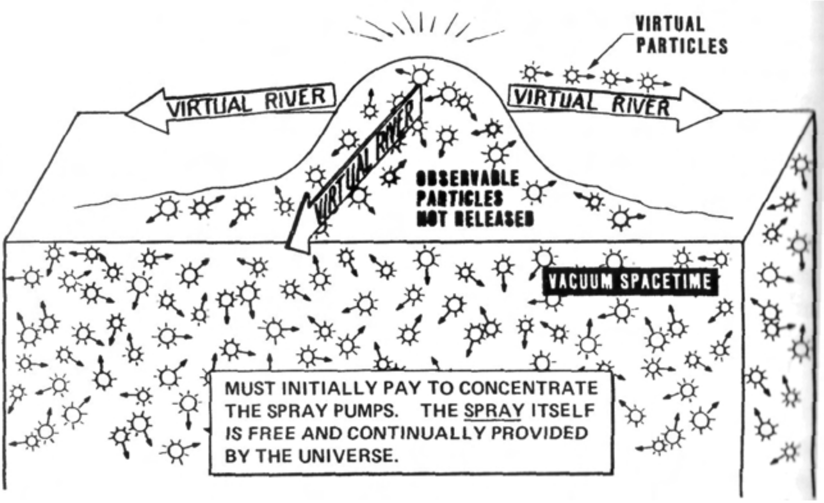

MUST INITIALLY PAY TO CONCENTRATE THE SPRAY PUMPS. THE SPRAY ITSELF IS FREE AND CONTINUALLY PROVIDED BY THE UNIVERSE.

Figure 40. Once established, a virtual river is for free.

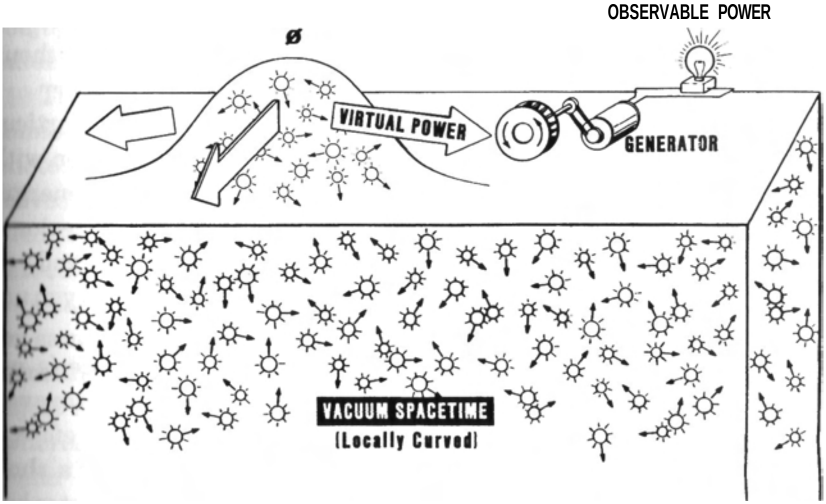
OBSERVABLE POWER
ø
VIRTUAL POWER
GENERATOR
VACUUM SPACETIME
(Locally Curved)

Figure 41. Local energy conservation can be violated.

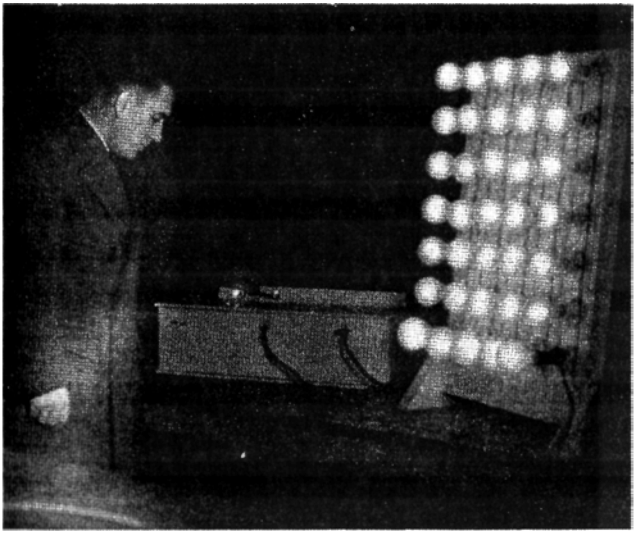

Figure 42. T.H. Moray adjusts the controls of his radiant energy device. Salt Lake City, Utah, in Feb. 1937. Moray obtained 50 kilowatts of power from a 55-lb. device, straight from the ether. Its characteristics (cool circuits, brilliantly lit lamps) reveal **that** It was negative energy.

too numerous to explore here. For just one example, by phase conjugation, real-time holography can be accomplished without having to separately make and illuminate the holograms.

Now with holography and multiple projectors — and particularly with two intersecting "normal" beams to backtrack upon with ever-converging PCR signals—you can assemble a "form of energy" at an appreciable distance from the projectors in three dimensional space. With phase conjugation, you can do it in real time. And you can do it at a great distance back along the path of any signal you use as an input.

By using PCM holography, degradation with distance is not appreciably experienced. After all, the PCR waves utilized are ever-converging. The energy does not diverge and spread. Therefore, if you can make a 6" diameter ball of intense EM energy at a short distance in the laboratory, you can make that same 6" diameter ball of intense energy at several thousand kilometers distance, using PCR real-time interference holography.

With highly amplified PCM's, you can put far more energy into the distant interference form than you can with normal holography. Conceivably it is possible to assemble so much energy in the holography "object" that it condenses into a real material object! In other words, it materializes or semi-materializes.

Both the "intense light form" usage and semi-materialization of forms (such as light forms, flying geometrical forms, etc.) have been created worldwide by the Soviets for decades, to stimulate UFO reports and provide a deception plan for their development and testing of large, strategic energetics weapons using highly amplified PCMs and PCR holography.*

Other bizarre considerations also arise. For example, in **radionics** one utilizes a "witness"—such as a photograph—of the object one is attempting to send "energy" to. (For example, this might bo a sickly plant one is attempting to spruce up). Now when the plant was photographed, the light from it struck the photoemulsion of tho film, producing a photochemical reaction. It also produced phase conjugation in the atomic nuclei of the film emulsion, since the emulsion acts in some respects as a nonlinear medium.

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*For an example of highly reliable detection and observation of "Soviet hololography UFOs," see Leif Havik, "Project Hessdalen," MUFON UFO Journal, Jan. 1988, p. 4-7. The present author certainly does not imply that all UFO phenomena are due to Soviet PCR holography, only that some UFO phenomena are.

There exists a continuous, invisible "stimulus photon and its connections" trace in time and space, between the plant when the photo was taken and that photo now, even if one or both of them have moved. That trace is highly persistent (as Australian experimenters Reid and Barsamian have shown). A phase conjugate (time-reversed) signal can be made to retrace that track and travel all the way back to the plant, in the present. The effect of using the photo (or sample of the object) as such a "witness" of the real plant and directing weak PCR energy back along the invisible trace into the object is called radionics. In most cases, the two cerebral hemispheres of the operator's brain are depended on to form the necessary scalar "pump wave" to pump the "witness" and produce phase conjugated signal energy, time-reversed to travel back into the distant object.*

The problem with present radionics is that it is far too weak, and it is "operator dependent", changing with the mood, temperament, and skill of the operator. It does objectively work, however, though Often erratically. In countries such as England, France, and Germany, use of radionics to treat human disease is legal and permitted, though operators (for example, in England) must undergo extensive training and certification. Its results are roughly comparable to the results of normal medical doctors. Radionics does not replace orthodox medicine. It can successfully treat certain things that orthodox doctors have little or no success with (such as lupus), and orthodox medicine can successfully treat many things that radionics has little success with (a broken leg or ruptured appendix, for example). The two treatments are best used in conjunction with each other.

However, we must point out that a new, amplified PCM radionics is likely to emerge in the near future. Such a new approach will offer highly effective, powerful treatment of diseases, even at a distance, by amplified PCR electromagnetics. Again, the radiation in and from a photo or witness of a diseased patient can be used as a "grid signal" into a powerful, pumped phase conjugate mirror. The

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*Again recall that we observe time-reversal of waves as **spatial path** reversal, not as time **travel.**

PCM will produce a specific, powerful, amplified signal that will travel directly to the patient, be absorbed in his entire system, including the atomic nuclei comprising his cells, and directly reverse the chemistry, toxins, and cellular damage in the patient from that disease. It will also kill or destroy the harmful viruses, bacteria, etc. causing the disease, and it can even reverse the actual genetic changes in the cell caused by disease-inducing viruses.

Of course, any powerful tool is two-edged. It can be used for harm as well as good. I think the reader can appreciate the damage that can be done to systems and persons at a distance by means of such powerful new amplified PCM radionics devices.

You can also see the security problems posed to large computing facilities in banks, federal facilities, state and municipal facilities, the IRS, U.S. military weapon systems, ships, aircraft, etc.

Obviously such devices are going to have to be highly regulated and controlled. Else criminal operators will be killing people and destroying things wholesale, secretly and at a distance, and they will have perfect legal alibis to allow them to escape prosecution.

To summarize: if a photograph or witness pattern of an object or person can be correctly stimulated by phase conjugate electromagnetics so that the emulsion acts again as a PCM, can one not argue that—theoretically — phase conjugate energy from the photograph and the instrument can be sent back along all paths, all the way back to the original object? After all, this has been rigorously demonstrated by University of Sydney researchers. Is there not an actual physical mechanism for radionics? For highly amplified, powerful radionics where the operator himself is removed from the circuit? Just because it changes our present notion of physical reality, must we dogmatically reject the results being shown on the laboratory benches, some of which are in the hard-core scientific literature?

Phase conjugation and time-reversed engineering have a diversity of applications unparalleled in the history of science. They literally present us with a new physics. New rules apply.

Most of the major discoveries in phase conjugation have yet to be made.

Scalar Electromagnetics

The scalar electromagnetic approach modifies classical electromagnetics (EM) to include gravitational waves and effects.

To do this, scalar EM utilizes summed-zero vector forces and force fields to construct polarized vacuum potentials.

Although externally it has zero E and B vector gradients, an "artificial" potential possesses an internal, dynamic E and B vector field structure. This "infolded" (Bohm's term) structure has finite size and is deterministic. The infolded structure of the artificial potential in turn deterministically structures and polarizes the vacuum and curves spacetime locally, contrary to presently assumed limitations of general relativity.

Since in free vacuum a potential normally extends to infinity in a decaying exponential fashion, then this infolded E and B vector structure of an artificial potential extends to infinity in a decaying exponential fashion.

The artificial potential itself may be rhythmically varied either in structure, magnitude, frequency, or all of the above. This produces waves of potential, and waves of the structure of vacuum/spacetime — again, in the free vacuum case, reaching to infinity in a "decaying exponential" fashion. These "scalar EM waves" are gravitational waves.

Each photon (one major wave length of the "carrier", complete with modulations) of the scalar EM wave also has structure (its included modulations).

Modulated waves have compound or "giant" photons — photons containing infolded photons.

Each compound photon of such a scalar EM wave is a vacuum engine. It deliberately structures and patterns — dynamically — the energy density and charge of vacuum.

(1) By canonically varying two or more components of the electromagnetic vector structure of the zero-summed EM force vector system, the local structure of vacuum spacetime is macroscopically varied in its internal composition. This is the compound variation of "curvature within curvature" — and hence hyperdimensional.

Table 29. A ZERO VECTOR SYSTEM:

- **IS AN ACCUMULATOR**
- **DOES "INTERNAL" WORK ON MEDIUM**
- **HAS NO "ENERGY" EXCEPT STRESS OF VACUUM, YET**
- **CAN YIELD THE ENERGY OF ITS COMPONENTS WHEN DISSIPATED**
- **IS A SPECIAL SORT OF "PUMP"**
- **CAN YIELD CONTINUOUS ANENERGY FLOW IF NOT DISSIPATED**

(2) By prohibiting internal canonical variance while coherently varying the amplitudes of all the EM components, the total stress of vacuum/spacetime — and hence its overall curvature — is locally varied, without modifying its structural form. This is simple variation of overall curvature of local spacetime, involving primarily relativistic effects.

Rigorously, each of these two methods produces a localized gravitational wave, where the local stress of vacuum is deliberately patterned as well as oscillated in amplitude.

Both methods may be applied simultaneously (and multiple infolded times) to produce an even more sophisticated gravitational wave, and more sophisticated structuring of the local stress energy density of vacuum.

The resulting unified electromagnetics/gravitation is called **scalar electromagnetics,** since the electrogravitational effects are obtained by deliberately opposing EM vector force fields so that they vectorially sum or multiply to a zero vector EM resultant, while **the** infolded (Bohm's term) EM vector components structure and vary the stress energy density of vacuum.*

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*Gravitational potential is just "in-folded and locked in" dynamic electromagnetic forces. The infolded EM energy is locked-in, representing a change in the local energy density of vacuum and hence a curvature in spacetime. Electromagnetic force fields are just the out-folding of the G-potential's inner EM contents into the 5th dimension. Ordinary gravitational force field is just the "trickle leakage" of the G-potential's infolded contents, out into and through 3-space.

Note immediately that scalar EM also deals with internally structured and patterned electricity and electromagnetism.

"Normal" electromagnetics has no deterministic internal structure.

The new electrogravitational (EG) wave is called a scalar EM wave, and is believed to have been originally discovered by Nikola Tesla.

James Clerk Maxwell was aware of the potential for electromagnetics to stress and structure the vacuum ether.

His original electromagnetic theory — written in quaternions, not vectors (which had not yet been completed by Oliver Heaviside) - can allow for these effects to be expressed.

Unfortunately Heaviside's interpretation of Maxwell's work

Table 30. STRESS IS FUNDAMENTAL

- **THE MOST FUNDAMENTAL REALITY IS STRESS**
- **THE COMPONENTS COMPRISING STRESS ARE THE GREAT CAUSATIVE AGENTS**
- **MOST OF THESE ACTIVE AGENTS ARE HIDDEN INSIDE ZERO-VECTOR SYSTEMS**
- **THE COMPONENTS OF STRESS MAY BE STATISTICAL OR DETERMINISTIC**

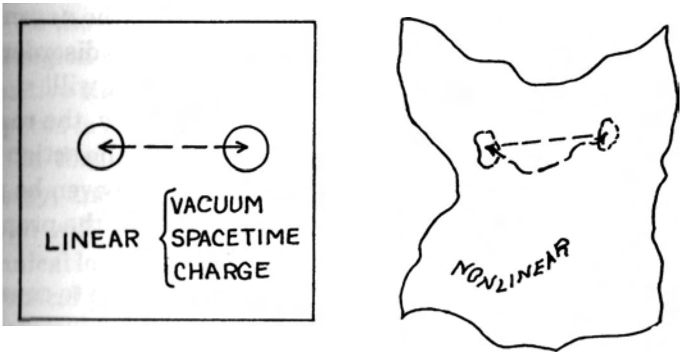

figure 43. Charge affects anything existing in spacetime.

eliminated these effects, and they have remained eliminated from the Western EM theory to the present day.

The use of the scalar EM wave directly engineers the virtual state and the vacuum itself.

Hooper's work represented important work in this respect, as does other related experimental work by Bedini, Watson, Golden, Dea, Faretto, Beck, and other inventor colleagues who do not wish their names mentioned.

Scalar EM theory also bears a strong relationship to the Kaluza-Klein unified theory of gravitation and electromagnetics. At least five dimensions — four spatial and one time — are required as a minimum.

Nested levels of virtual state may be modeled as identical to successive hyperspaces.

Internested levels of zero-summed vector EM force fields allow the direct engineering of those hyperspaces.

Negative energy and negative time flow are especially important when building free energy devices and antigravity. The mechanism producing negative energy and negative time flow is the forced amplified production and absorption of phase conjugated waves.

In addition, phase conjugation is a basic phenomenon of nature: for example, as previously pointed out, it is the direct mechanism that generates Newton's third law of motion. It also adds a negentropy law (for negative energy/negative time).

Accordingly, if we engineer phase conjugation, we can change Newton's third law to our will. And we can invoke the negentropy half of the total law of entropy, so that we can go from disorder back to order. Again, we can make a Maxwell's Demon at will!

In Newton's third law, when manipulated locally, the reaction force need not necessarily be equal in magnitude to the action force It also need not necessarily be parallel to it. It can even be phase conjugated itself to yield an addition force, assisting the propelling of a particular engine or device.

Phase conjugation may also be manipulated so as to cause like magnetic poles to attract, and unlike poles to repel.

Magnetic "force field lines" of a bar magnet normally exist in conjugate co-existing pairs. One of the pair is in observer positive time, and (by convention) runs from the north pole to the south pole. The second line of the pair is a phase conjugate of the first, and exists in negative observer time. Thus, to the "positive time only" observer, it will appear to run from the south pole to the north pole, perfectly retracing the path of its twin.

Howard Johnson uses a "two particle" theory of magnetic field, for example, where one particle (photon) is the phase conjugate of the other. This is identically the same as the scalar electromagnetics concept of phase conjugate pairs of field lines. By very complex, specialized, compound permanent magnets, Johnson is able to partially separate the two lines, and spatially concentrate or diminish the phase conjugation (negative time) component in a given area of operation.

If the negative time component lines are concentrated to outweigh the positive component lines in a local region, then the laws of magnetics are reversed in that region. There like poles attract and unlike poles repel.

In his rotary permanent magnet motor design, he concentrates the negative time component in that part of the rotation where a north rotor pole is approaching a north stator pole. Normally, in this part of the cycle, one has to overcome the repulsion of like poles to "force energy" into the device for later extraction.

However, *now* in that region *like poles attract.* There the north pole of the rotor is attracted toward the north pole of the stator, adding impetus to the rotor.

As the rotating north pole passes the stator north pole, it leaves the region of negative time concentration and returns to a normal "positive time" region again. Now the north poles repel again, and impetus is again added to the rotor.

In that manner Johnson is able to violate local conservation energy, and make a "free energy" permanent magnet motor. The motor will rotate itself and deliver constant shaft power to a mechanical load. By attaching a standard electrical generator, normal electrical power is continually and freely produced by the complete motor generator power system.

Johnson's complex nonlinear magnets severely curve local spacetime, allowing *local* violation of energy conservation.

Scalar EM View of the Vacuum

In the modern quantum mechanical view, the vacuum is not an emptiness, but instead is a plenum.

Today the vacuum is considered to be filled with incredible virtual particle activity. From nowhere, virtual particles continually arise — even with fierce energy — then disappear again into nowhere, so rapidly that they cannot be individually observed.

However, these virtual particles are quite real, for they cause all the forces of nature when they interact in the aggregate with observable particles.

To the observer, the fleeting particles also appear and disappear in both positive time and negative time. That is, the flux consists of both particles and antiparticles.

Thus the vacuum is a seething inferno of virtual particle fluxes.

The concept of an **ether** is again accepted. It refers to this "virtual flux" vacuum.

Note, however, that this is an ether far different from the old material ether that was theorized prior to relativity.

In the new vacuum ether, every imaginable type of particle continually and spontaneously arises (creation) and disappears (annihilation) at every point in the vacuum, according to modern quantum mechanics.

The rate of this seething virtual particle creation and annihilation is essentially unlimited. Hence the "flux density" of vacuum is essentially unlimited.

Further, any virtual particle created has a flux of even finer virtual particles associated, and so on without limit.

The vacuum's virtual particle flux is thus comprised of nested levels of ever finer virtual particle fluxes, in the modern view. We state without proof that **each deeper virtual level may be modeled as a higher dimension** (hyperdimension). **This yields an infinite-dimensional vacuum spacetime (hyperspace) that is identically the infinite nested levels of virtual state.**

At the same time, every nucleus in the universe is continually absorbing and emitting scalar EM (electrogravitational) waves. The emitted scalar EM waves of pure potential are waves in the stress and structuring of the vacuum itself.

VACUUM IS IDENTICAL TO:

- VIRTUAL PARTICLE FLUX
- SPACETIME
- ANENERGY
- $\o_o$
- MASSLESS CHARGE

VACUUM IS:

- MADE OF UNQUANTIZED ACTION
- WITHOUT DEFINITE LENGTH INTERVALS
- WITHOUT DEFINITE TIME INTERVALS
- N-DIMENSIONAL (UNFIXED)

Figure 44. Vacuum/spacetime is pure virtual particle flux.

Table 31. VACUUM IS:

- SPACETIME (L^nT, WHERE n >= 3)
- CHARGE (MASSLESS)
- ELECTROSTATIC SCALAR POTENTIAL
  ($\o_o \neq 0$)
  (ERROR IN PRESENT THEORY)
- BROKEN BITS OF ENERGY (SUBQUANTAL)
- PURE VIRTUAL PARTICLE FLUX
- $\o$ -WAVE FLUX
- MULTILEVEL, STRUCTURED, PATTERNED
- A VIRTUAL PLENUM
- AN OBSERVABLE EMPTINESS

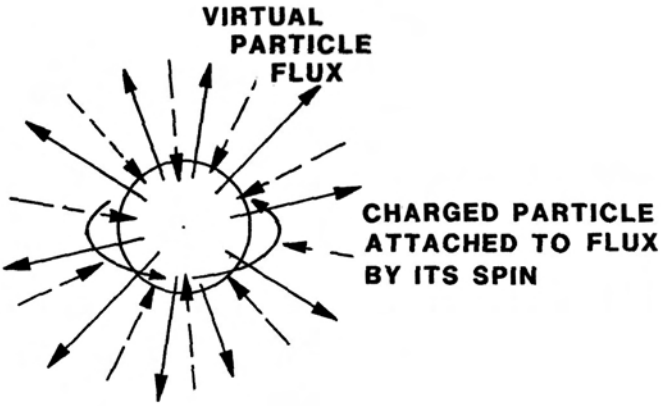
VIRTUAL PARTICLE FLUX
CHARGED PARTICLE ATTACHED TO FLUX BY ITS SPIN

Figure 45. A simplified charged particle.

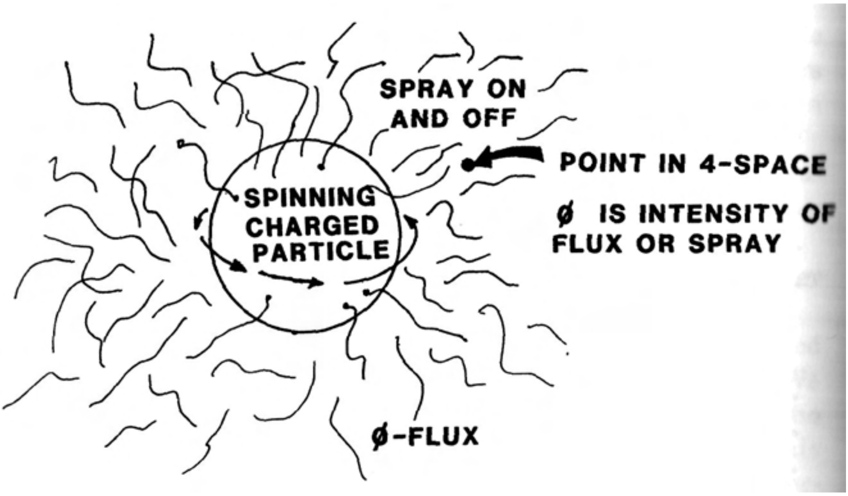
SPRAY ON AND OFF
POINT IN 4-SPACE
Ø IS INTENSITY OF FLUX OR SPRAY
SPINNING CHARGED PARTICLE
Ø-FLUX

SPRAY IS THROUGH 4 OR MORE DIMENSIONS, NOT JUST 3

Figure 46. A charged particle is a special kind of "spray nozzle."

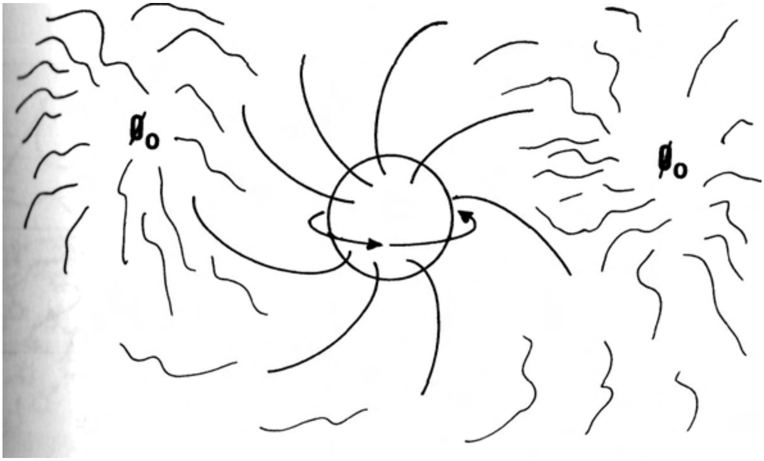

Figure 47. An observable charged particle is directly connected to virtual particle **vacuum** flux.

Table 32. SPIN COUPLES VACUUM TO PARTICLE

- **SPHERICAL ROTATION IS THE KEY**
- **A PARTICLE CAN BE MODELLED AS A SPHERICALLY ROTATING VORTEX OF SPACETIME**
- **ITS MASS IS DUE TO ITS SPIN**
- **THE SPINNING OBJECT IS CONTINUALLY CONNECTED TO ITS ENVIRONMENT**
- **VERY HIGH VALUES OF ELECTROSTATIC POTENTIAL CAN INDUCE RELATIVISTIC CONDITIONS**
  - **CHANGE RATE OF FLOW OF TIME**
  - **EVEN THOUGH VELOCITY IS NONRELATIVISTIC**

E.P. BATTEY-PRATT AND T.J. RACEY,
"GEOMETRIC MODEL FOR FUNDAMENTAL PARTICLES,"
INTL. J. OFPHYS.19. NO. 6, 437-475, 1980

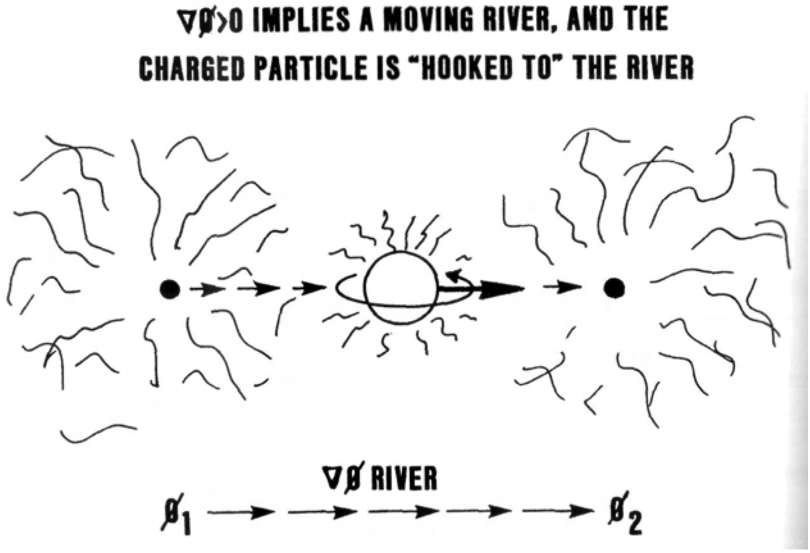
∇ø>0 IMPLIES A MOVING RIVER, AND THE
CHARGED PARTICLE IS "HOOKED TO" THE RIVER
∇ø RIVER
ø1
ø2

Figure 48. In a flux gradient (virtual particle river), a charged particle moves itself.

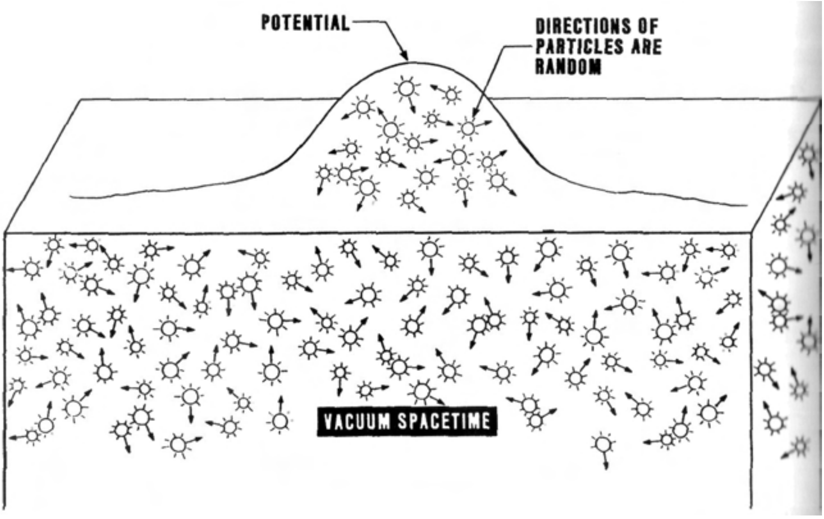
POTENTIAL
DIRECTIONS OF PARTICLES ARE RANDOM
VACUUM SPACETIME

Figure 49. A natural potential is a **disorganized change** in **the stress of** vacuum. It has a random virtual substructure.

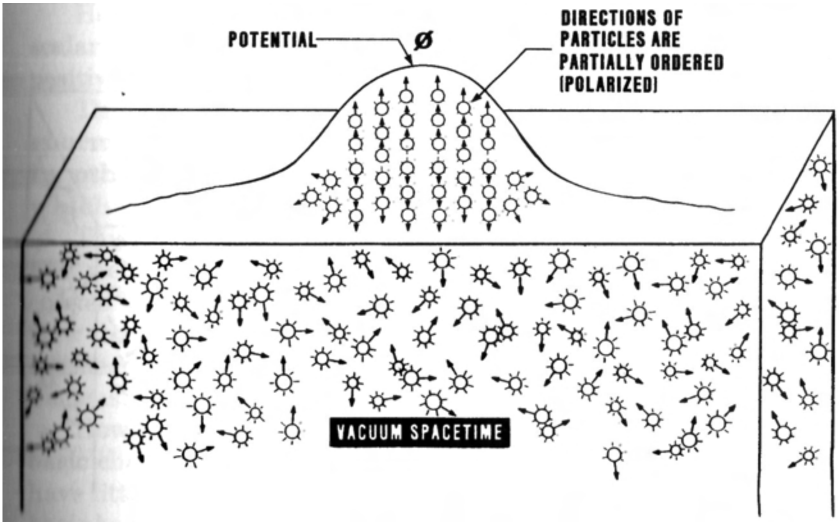
POTENTIAL
Ø
DIRECTIONS OF PARTICLES ARE PARTIALLY ORDERED (POLARIZED)
VACUUM SPACETIME

Figure 50. An artificial potential is an organized change in the stress of vacuum. It has a deterministic virtual substructure.

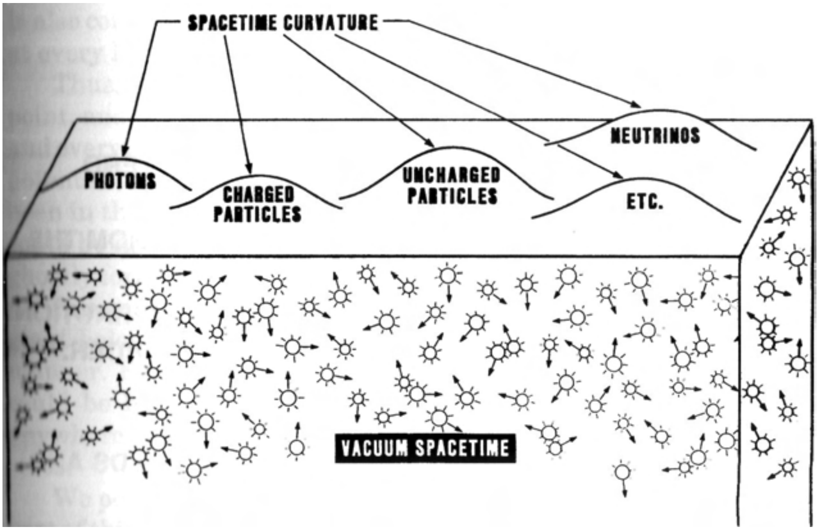
SPACETIME CURVATURE
PHOTONS
CHARGED PARTICLES
UNCHARGED PARTICLES
NEUTRINOS
ETC.
VACUUM SPACETIME

Figure 51. Gravitational potential is a conglomerate of stresses, organized or disorganized.

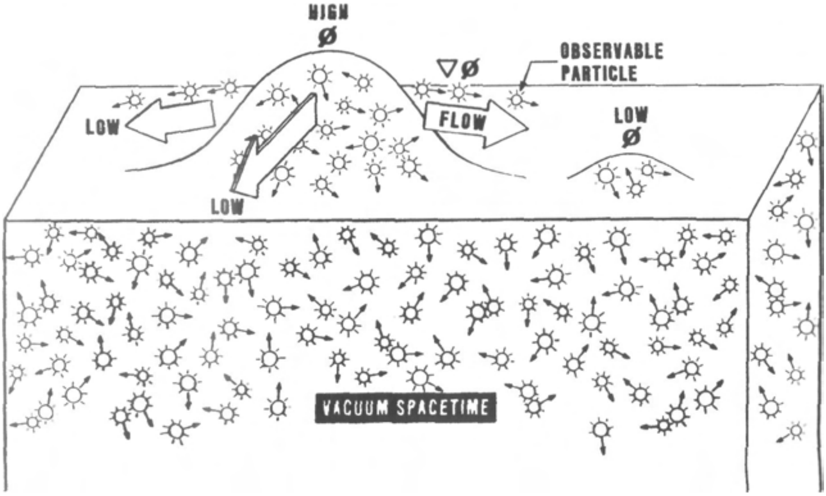

Figure 52. EM force fields are releases of gravitational potential via observable charged mass flows.

Table 33. RESIDUE UNIVERSE, RESIDUE SCIENCE

- **VECTORIALLY, STRESS IS SUM-ZEROED**
- **THE VECTOR FORCE FIELDS REPRESENT NON-ZERO GRADIENTS IN MORE FUNDAMENTAL STRESS**
- **FORCE FIELDS ARE THE RESIDUE LEFT OVER FROM THE SUM-ZEROED STRESSES**
- **PHOTON INTERACTIONS ARE FORCE-FIELD INTERACTIONS**
- **PHOTON-DETECTED REALITY IS ONLY "FIRST ORDER." IT SHOWS ONLY "RESIDUE-LEVEL" REALITY**
- **WE HAVE BUILT A "RESIDUE SCIENCE" AND A "RESIDUE PHILOSOPHY" BASED ON FORCE FIELDS AND PHOTON DETECTION**

Hence at every point in the vacuum, an intense flux of these scalar EM waves, with concomitant interferences, exists — in both positive and negative observer time.

This scalar EM flux causally **drives (constitutes) all the** enormous **quivering of the vacuum** spacetime medium **itself. In other words,** it **drives subquantum (virtual) change, which in turn drives quantum change.**

This is a drastic reorientation of quantum mechanics. In scalar EM, we view that the virtual flux of vacuum is *causally driven or created* by interacting scalar EM waves. This replaces the present **view** that the virtual flux is entirely chance. It opens up the direct engineering and structuring of the vacuum — and hence the atomic nucleus — by scalar EM means.

However, it does not replace the normal *statistical nature* of the **basic** changes of the background vacuum medium. We normally **have** little or no knowledge of the myriad of drivers that cause the basic background waves of that medium. We may, however, deliberately create special vacuum potential waves which are deterministic, and which we have knowledge of.

To the observer, from a purely statistical viewpoint, in this violent vacuum flux *any* and *every* finite pattern of virtual particles is also continually being momentarily created and destroyed — and at every level and in every hyperdimension.

Thus, in the vacuum there continually exists — at any and every point, and in any and every region — the ghostly image of anything and everything, whether in the past, present, or future; and whether **potential,** probabilistic, or actual. Even everything that could have been in the past but wasn't, or might be in the present but isn't, or could be in the future but won't be, is continually present in thin, ghostly form.

Rigorously, the universal vacuum may be taken to be a sort of giant hologram, for the whole is in each part, albeit in ghost-like manner. Everything that is, or was, or shall be; and everything that could be but isn't, wasn't, or shan't be; already exists *at once, any*where and everywhere, in this ghostly, holographic, virtual state.

We point out in passing that, conceivably, one can engineer any **part** of this "potential for reality." That is, one can directly engineer physical reality itself, in the scalar EM view.

All that must be done is to amplify (continuously and coherently

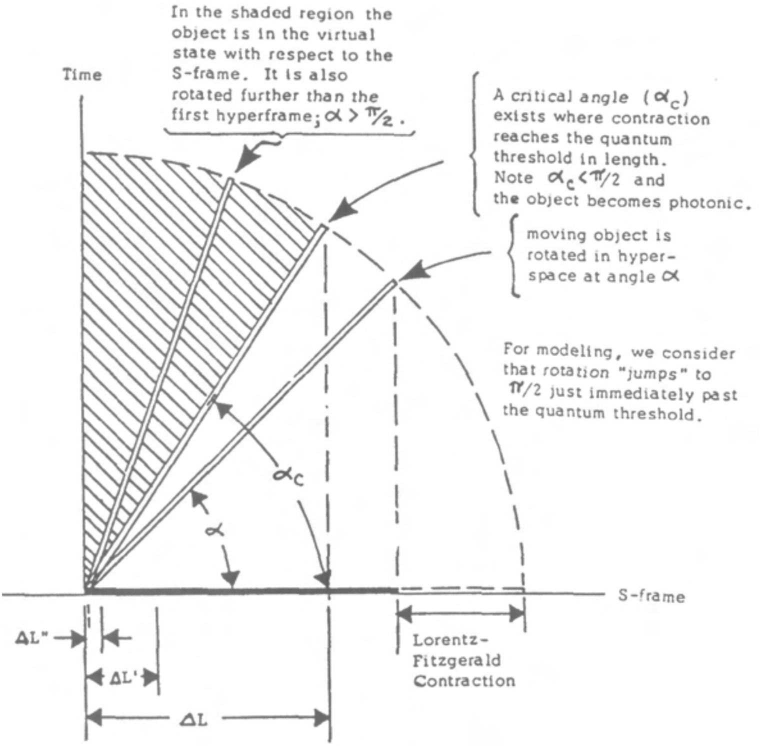
In the shaded region the object is in the virtual state with respect to the S-frame. It is also rotated further than the first hyperframe; $\alpha > \pi/2$.
Time
A critical angle (α_c) exists where contraction reaches the quantum threshold in length. Note $\alpha_c < \pi/2$ and the object becomes photonic.
moving object is rotated in hyperspace at angle α
For modeling, we consider that rotation "jumps" to $\pi/2$ just immediately past the quantum threshold.
α_c
α
S-frame
ΔL"
ΔL'
ΔL
Lorentz-Fitzgerald Contraction

Figure 53. As beyond (without), so within. Hyperspaces are internested virtual states, and rotated orthogonal frames. They are also substructures within and of vacuum state potentials.

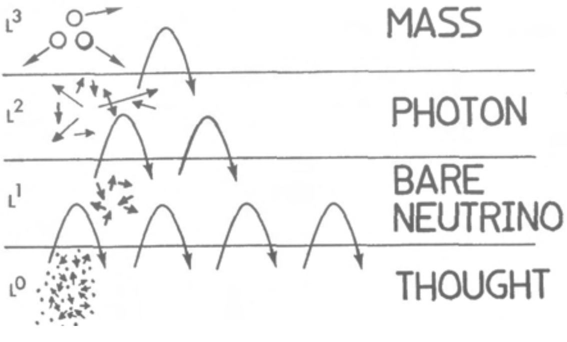
L^3
MASS
L^2
PHOTON
L^1
BARE NEUTRINO
L^0
THOUGHT

Figure 54. Internested levels of virtual state vacuum interact with neutrino, photon, and mass. "Thought" or "mental state" refers to the third and more levels down in virtual state.

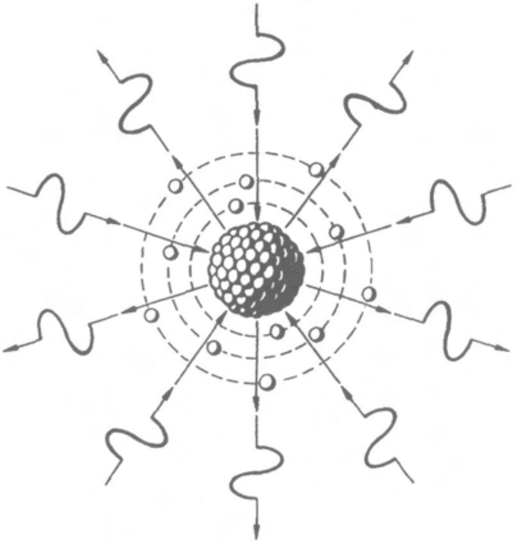

Figure 55. Virtual state patterns are absorbed and emitted by the atomic nucleus. The built-up nuclear "charge" in that particular pattern is a partial potential — for that pattern only.

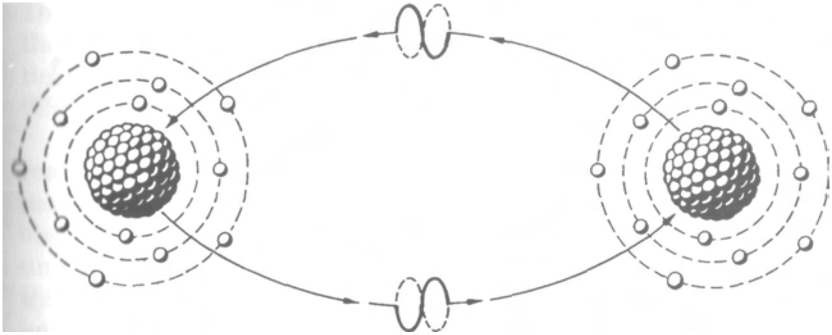

Figure 56. Nuclei of the universe continually exchange scalar EM waves and virtual **panicle** fluxes.

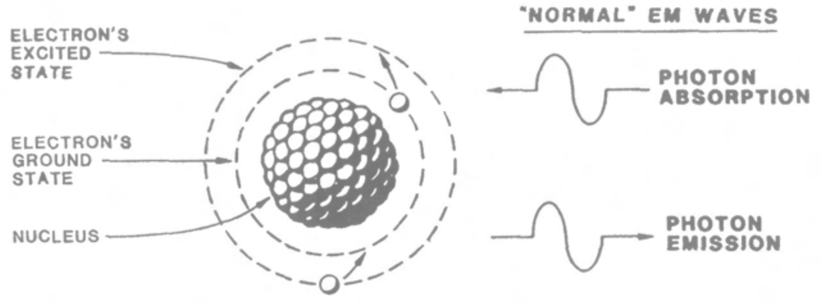
"NORMAL" EM WAVES
ELECTRON'S EXCITED STATE
ELECTRON'S GROUND STATE
NUCLEUS
PHOTON ABSORPTION
PHOTON EMISSION

- HEAVY NUCLEUS RELATIVELY UNAFFECTED
- MACROSCOPICALLY. MASS APPEARS STABLE AND "BRICK-LIKE"
- SPECIAL RELATIVITY APPLIES

Figure 57. First order reality. Rough-hewn by observable photon interaction with electron shells of the atoms of physical mass. This process is "physical observation."

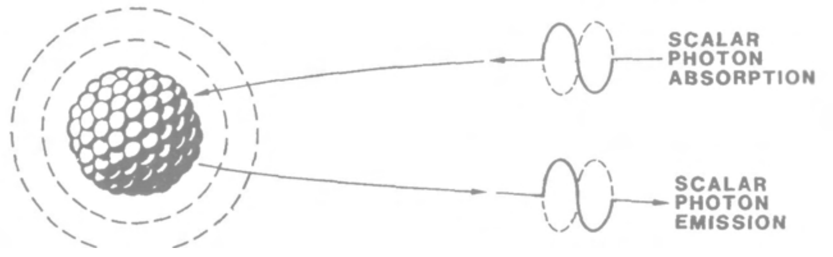
SCALAR PHOTON ABSORPTION
SCALAR PHOTON EMISSION

- HEAVY NUCLEUS AFFECTED
- MACROSCOPICALLY. MASS APPEARS FLUID AND CHANGEABLE
- GENERAL RELATIVITY AND KALUZA-KLEIN GEOMETRY APPLY

Figure 58. Higher order (hyperspatial) reality. It exists as stored in the potentials ot the atomic nuclei of physical mass.

add energy to) one of these "ghost images" virtual state forms. In that case, the form becomes "denser and denser," until eventually it starts to breach the quantum threshold. At that time, the form will be seen emerging as a sort of "coalescing form of light," where the light seems to be forming in little "chunks" or pieces. As the coalescing operation continues, the light-form will eventually become fully formed. If it continues, it will start to coalesce further into *thin, ghostly material* form, appearing much like a faint fog-form. With continued coalescing, it will become a very solid, material form which exerts pressure on tree limbs, breaks them, leaves traces, etc.

Long ago I dubbed this process *kindling.* It is rather widely met in paranormal phenomena of many types.

But back to the basic idea of ghostly images in the virtual states of vacuum.

In this view, Everett's many-worlds interpretion (MWI) of quantum mechanics is literal and real, albeit the additional worlds are to bo taken as virtual and hyperdimensional to the laboratory observer.

(It is rather simple to show that ever deeper, nested levels of the virtual state are exactly the same thing as ever higher dimensions. By "rotating" an object in many-dimensional space, one can show that, after three rotations, a physical object has lost all physical intersections with our normal 3-space, to us now only occupying time. Since this is the precise characteristic of a *thought form,* I used this phenomenon and spatiotemporal model to make a multidimensional space model directly including thought, mind and matter. That is, one is thus able to form a unified field theory of mind, th**ought,** life, and matter — a model that is testable, makes predictions, and actually unites physics and metaphysics. That work and its plications, however, are largely beyond the scope of this book.)

It is stressed that the basic scalar EM image (interpretation) of reality is directly implied by quantum mechanics. It is not idle metaphysics. Other than the scalar EM wave causality for the observer's statistical microscopic dynamics (and the extended model unifying mind, thought, life, and matter), it is not the construct of this author. Instead, it follows from interpretation of the equations and axioms of quantum mechanics (QM) itself, as changed and extended by the "zero vector system" dynamics.

Charge, Potential, and Curvature of the Vacuum/Spacetime

The flux of one type of virtual particle through a point in the vacuum may be examined.

A single type of virtual particle flux (VPF) at a point constitutes one particular type of charge at that point. For example, the flux of virtual photons constitutes the electrical charge.

Further, the magnitude of the selected flux (usually expressed as a flux density) through the point may be taken as the magnitude of the vacuum's charge there in that type of particle. In other words, at a point the magnitude of the vacuum's charge (VPF) is one type of *potential* at that point.

Various kinds of fluxes constitute various kinds of charge, and comprise various kinds of potentials. Immediately we see that one type of charge may always be decomposed into other kinds of charge, as can potentials. This point is beyond the scope of this book and will not be further amplified.

Continuing our example, the magnitude of the electrostatic scalar potential at a point in vacuum represents the magnitude of the flux of virtual photons through the point, and hence the electrical charge at the point.

Table 34. REALITY IS A HOLOGRAM

TO ESTABLISH THIS:

1. **ALL DETECTION IS INTERNAL**
   PHYSICAL REALITY CONSISTS OF THE INTERNAL DETECTIONS OF THE PERCEIVER/OBSERVER.

2. **THE OBSERVER MAY BE AT ANY POINT IN THE UNIVERSE**
   THE UNIVERSE CAN BE DETECTED FROM ANY POINT INSIDE ITSELF.

3. **THE PHYSICAL UNIVERSE IS TOTALLY INSIDE EACH POINT IN ITSELF**
   THIS DEFINES A HOLOGRAM: THE WHOLE IS IN EACH PART.

Twin Flows of Time

In quantum mechanics, each virtual photon is continually turning into an electron/position pair, and vice versa.

By Dirac theory, *a positron is an electron traveling backwards in time.*

Further, pair production produces time-smeared particles — an electron and a positron.

Pair production, then, actually produces two *electrons,* one coupled to (smeared in) a positive piece of time and one coupled to (smeared in) a negative piece of time.

Thus in the vacuum two discretized streams of time, one positive and one negative, are continually created in conjunction with pair production, and destroyed by pair annihilation.

Further, integration of tiny virtual pieces of time (from virtual photons) to form "passage of time" macroscopically is directly associated with the charge (the absorption and emission of virtual particles) of an observable particle.

This is what is meant by an object "existing" (persisting). Its continual virtual photon interactions are integrated by its mass (timeless part) to continually create its energy states and its march through time.

The absorption and emission of an observable photon, however, moves the mass (timeless part) in (comparatively) larger jumps through time. The absorption of the photon connects a positive piece of time to the mass of the particle, converting it to masstime. The subsequent emission of an observable photon "tears off the little time-tail," so-to-speak, and leaves behind a totally spatial mass entity, having no large connection to "the flow of time."

This is what is really meant by "observation."

Because the "observation" disconnects time from the previously "excited mass" (masstime), then it follows that time is not an observable.

It also follows that the twin streams of time are not continuous. Each is broken into incredibly tiny bits.

The bits of time are continually interlaced between negative and positive, and neither of the two streams of time bits is integrated in the vacuum. The vacuum is disintegrated!

A photon — the basic quantum — is composed of discretized energy and time, bound together (integrated) as action (angular momentum). That is, a photon is a little piece of energy, welded to a little piece of time, with no seam in the middle.

Two kinds of photons exist: the normal photon exists as (+dE) (+dt). The phase conjugate photon exists as (-dE) (-dt).

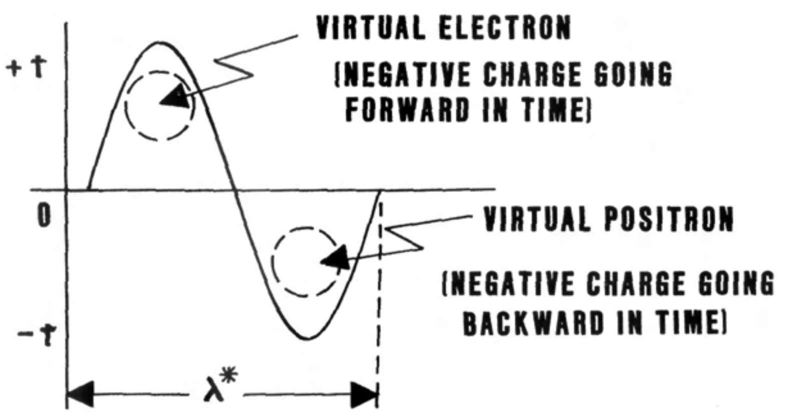
+t
0
-t
VIRTUAL ELECTRON
(NEGATIVE CHARGE GOING FORWARD IN TIME)
VIRTUAL POSITRON
(NEGATIVE CHARGE GOING BACKWARD IN TIME)
λ*

Figure 59. A photon is a single oscillation of a carrier wave. It is also two virtual electrons, one going forward in time, and one going backward in time. With internested modulations (subphotons), the structure of the photon becomes extremely complex.

Table 35. PHYSICAL CHANGE

- **COMPOSED OF ACTION**
- **h = BASIC QUANTUM**
- **TWO CANONICAL VARIABLES**
  - **ENERGY/TIME** ($\Delta E \Delta t$)
  - **MOMENTUM/LENGTH** ($\Delta p \Delta L$)

  ETC.
- **ENERGY/TIME**
  - $h = (+\Delta E)\ (+\Delta t)$
  - $h = (-\Delta E)\ (-\Delta t)$

If the photon is of a certain magnitude, given by Planck's constant, then it is an **observable photon.**

If the photon is less than h in magnitude, then it is a **virtual photon.**

A simple photon in vacuum can also be considered to be one cycle of a sine wave. One half of the sine waves exists in positive time, hence is/contains a virtual electron.

The other half of the sine wave exists in negative time, hence it is/contains a virtual positron — an electron traveling backward in **time.** This second half of the full photon (a single sine wave oscillation) is the phase conjugate (time reversal) of the first half.

As we stated previously, the full photon in vacuum actually exists as a presently visualized "positive time" photon and a phase conjugate "negative time" photon , a "serially linked pair," where **each** photon is only one-half the sine wave. This resolves the conflict inherent in wave/particle duality.

It also has a great deal to say about engineering the vacuum and about detectors and the detection process.

In the spontaneous decay of a virtual photon, it can be seen that one part (the virtual electron) is associated with positive energy and positive time; the other part (the virtual positron) is associated with negative energy and negative time.

The continual "switching" between positive and negative time in an observable particle's absorption and emission of virtual photons **(and** the associated electron/position +t/-t pairs) means that the positive flow of time, to the macroscopic observer, is continually being "started" and "stopped" (created and destroyed).

This continual attachment **and detachment of positive time to and from the "observer particle" creates the "past" and the "future" to which the observer seems somehow to be connected, and yet not connected.**

Engineering Local General *Relativity*

In a flat spacetime (linear vacuum), the two time flows are balanced, as are pair creation and pair annihilation. In this case, conservation of charge and energy hold.

Table 36. ORDINARY GENERAL RELATIVITY (OGR) IS A SPECIAL CASE

- **OGR HAS ASSUMED AWAY MOST LOCAL GR SYSTEMS, OF THE TYPE WHERE MAXWELL'S EQUATIONS AND THE CONSERVATION LAWS CHANGE LOCALLY.**

- **PHYSICISTS ARE THUS STRONGLY DISCOURAGED FROM CONSIDERING THAT GR CAN EASILY BE ENGINEERED IN A LOCAL EM SYSTEM.**

In a curved spacetime (nonlinear vacuum), one of the two triplets (positive electron/energy/time or negative electron/energy/time) predominates. Hence in a curved spacetime the rate of flow (production) of the two time streams is unequal, as is the production of the two kinds of energy and the two kinds of electrical charge.

A locally curved spacetime thus produces a predominance of either positive or negative electrons, and either positive or negative energy, and a predominance of the addition of either positive or negative time production.

The curved spacetime acts as a local source or sink accordingly, and both conservation of energy and conservation of charge can be locally violated in such a curved spacetime region.

As we stated, the locally curved spacetime produces either positive time or negative time more predominantly, acting as a source or sink for normal (positive) observer time. The local rate of flow of the observer's time can thus be speeded up or slowed down, depending upon the type of local spacetime curvature utilized.

It follows, then, that standing local gravitational waves can result in localized, stable gradients in the vacuum virtual particle flux, between the "high potential" part of the standing wave and the "low potential" part.

This allows the violation of conservation laws such as charge and energy in the local gravitational gradient, utilizing the localized curvature of vacuum to provide a special source.

For proof that conservation laws need not apply to a curved spacetime, see A.A.Vlasov and V.I. Denisov, "Einstein's formula for gravitational radiation is not a consequence of the general theory of relativity, **Theoretical and Mathematical Physics,** 53(3), June 1983 **(English translation);** Russian, Dec. 1982, p. 406-418. Quoting:

"This result is a particular consequence of the general assertion to the effect that in general relativity there are no energy-momentum conservation laws for a system consisting of matter and the gravitational field."

See also V.I. Denisov and A.A. Logunov, "New theory of spacetime and gravitation," **Theoretical and Mathematical Physics, 50**(1), July 1982, p. 3-76. This paper (p. 3) points out that:

"... **the gravitational field in general relativity is completely different from other physical fields and is not a field in the spirit of Faraday and Maxwell."**

A 1984 Soviet paper by senior Russian physicist C. Yu. Bosgoslovsky, "Generalization of Einstein's relativity theory for the anisotropic spacetime," is also very relevant.*

In composing his theory of general relativity, Einstein assumed that the local spacetime of the observer could never be curved, and instead would always be represented by a Lorentz frame (flat spacetime).

This severe assumption had the effect of "saving" the sacrosanct conservation laws, and maintaining the exclusion of electrogravitation.

Since then, Western physicists have raised Einstein's assumption — and the conservation laws — to a dogmatic belief system — in some cases, to near fanaticism.

To see a clear statement of these limiting assumptions imposed on general relativity to provide the severely restricted version taught in almost all Western universities, see Charles W. Misner, Kip S. Thome and John Archibald Wheeler, **Gravitation,** W.H. Freeman and Co., San Francisco, California, 1973, p. 19-21, 71-72, 367-369.

In other words, Western physicists still use a sort of "special

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***See* also V.I. Denisov and A.A. Logunov. "The inertial mass defined in general relativity has no physical meaning," preprint p. 0214, Institute of Nuclear Research, USSR Academy of Science, Moscow, 1981.

relativity with distant curved spacetime pertubations," and call it *general* relativity!

The Soviets do not limit themselves to the same restricted general relativity theory as does the West.

Santilli (Ruggero Maria Santilli, **Ethical probe on Einstein's followers in the U.S.A.: An insider's view,** Alpha Publishing, Newtonville, Massachusetts) has documented what essentially amounts to a conspiracy in Western physics to shut out any generalization of Einstein's severely limited relativity.

It is precisely this near-total Western scientific prejudice — along with Heaviside's mutilation of Maxwell's original theory — that has excluded electrogravitation from being developed in the West.

Note also that, by embracing a "locally flat spacetime" assumed to be decreed by the "laws of the universe," in their rigid mindset Western physicists have excluded any possibility of performing simple laboratory experiments in locally curved spacetime.

They do not believe it can be done, so they have never tried.

But let us further address the importance of the negative triplet (electrical charge/energy/time) and its concomitants parity, gravity, and entropy:

Engineering Antigravity

In negative time flow, gravity is a repulsion, not an attraction.

Producing antigravity in an object is simply the production of excess negative time flow in that object.

That is readily achieved by curving local spacetime in the appropriate direction, and forcing the object to produce excess negative energy.

Mass, for example, is just a special form of trapped energy—and trapped energy (potential) is just trapped charge of one kind or another, whether observable or virtual.*

As such, mass represents a "localized potential" in the ambient vacuum, of a certain kind of "trapped energy/time charge."

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*Actually, since it is in equilibrium in a dynamic and continual flux, a mass particle is actually a special trapped **rate** of action flow. A defining equation for mass in terms of the rate of action flow was given by the author in **Quiton/Perccptron Physics,** NTIS, 1973. Report AD-763210.

The mass/potential is continually being charged by the vacuum flux, and discharging and emitting charge flux into the vacuum flux. The mass is "in equilibrium" at its fixed potential.

Normal ("positive") mass is simply charged up with positive energy and positive time. And its external electron shells result in it presenting a "negative charge" face to the world.

If we charge up the mass, however, with negative energy and negative time, so that some of its charge potential now is of this second type, the trapped energy will now consist partially of negative energy. In addition, the mass will partially exist in negative time (be charged up partially with negative time).

When excess negative time flow is produced in a mass, the mass begins to be repelled by the earth as well as still being attracted to it in its positive time stream. The net result of the object's fixed attraction and increasing repulsion is that the object begins to lose weight in the earth's gravitational field and gets lighter.

When a sufficient rate of excess negative time flow (sufficient local spacetime curvature) is produced, the mass floats freely.

With additional negative time production rate, it accelerates ("falls") upward.

The rate of excess negative time produced may be controlled very simply by using a "negative time/negative energy" generator and varying the amount of the load applied to the device.

The negative time/negative energy generator can be rigidly affixed to a flying apparatus, serving as a sort of gravitational rocket or gravitational propulsion system.

Of course, the negative energy produced in the propulsion process can be used to light lamps and power electrical loads, as well as host of other things. (Yes, Virginia, it can also be used to generate force fields, power weapon systems, etc.)

Thus one can "eat his cake and have it too"; by using negative energy flow for power, a very practical antigravity spaceship can be developed.

An additional side benefit to the passengers probably exists: they should age at a slower rate when traveling in the vehicle.

As can be seen, since many kinds of VPFs exist in vacuum, the vacuum is filled with (and consists of) many types of "potentials." Overall, this matches very closely the view of general relativity, if we regard the vacuum itself as indefinite "spacetime", where no ordered universal frame with a fixed metric has yet been associated or prescribed.

Curved Spacetime and the Disintegrated Vacuum

From general relativity, additional characteristics of the modern vacuum/spacetime may be inferred or interpreted.

First, we may take a "flat spacetime" to consist of a charged vacuum, such that both the magnitude and structure of the VPF are essentially unchanged from point to point, and the flux of virtual particles and virtual antiparticles are balanced. Equal positive and negative time flows/charges exist.

Note, however, that we can have what casually may appear to be a "flat spacetime" but instead is "warped." This case exists when the magnitude of the overall VPF comprising the vacuum does not change from point to point, but the component structure of the VPF does vary from point to point.

In other words, the overall vacuum potential remains the same from point to point, but two or more individual potentials may canonically vary. Let us further clarify this point by analogy.

Suppose we view the vacuum/ether/spacetime as a special sort of gas, where the "gas" is actually a mixture of many, many gases.

It is a rather peculiar sort of gas; it exists in five or more dimensions and is composed of very strange, fleeting particles which . spontaneously are created and destroyed, each arising out of nowhere and returning to nowhere almost immediately.

There is only minuscule (negligible) time overlap (integration) of the existence of these virtual particles in the main.

That is, mostly each virtual particle — along with its associated energy, movement, momentum, charge, and increment of time — exists almost entirely as an individual.

The energies, movements, momenta, charges, and time increments of the individual virtual particles do not integrate or sum to any appreciable degree in vacuum.

Thus, although casually this ether/gas may seem to contain enormous "energy density", momentum density, charge density and time increment density, these are not *integrated* energy density, momentum density, and time density in the normal sense.

Instead, they are the densities *of disintegrated* energy, *disintegrated* momentum, and *disintegrated* time flow.

In scalar electromagnetics, we have called the disintegrated energy of vacuum **anenergy.** This clearly distinguishes that it exists in a fashion altogether different from normal, *integrated* energy with which we are accustomed.

By integrating anenergy, of course, one obtains ordinary energy—but it first requires an integrating agent. The most **usual integrating agent/operation is the spin of an observable particle of** mass.

Similar considerations apply to momentum and time.

With this more **precise interpretation, the vacuum contains enormous anenergy, but essentially no energy. It contains enormous virtual energy, but no observable energy.**

Unfortunately, however, orthodox physics does not yet clearly differentiate between the two states of energy, virtual and observable (disintegrated and integrated).

Instead, it continues to loosely utilize the term "energy" for both states, whether integrated or not. Thus it exclusively uses the term **"energy** density of vacuum." Rigorously, the term should be "anenergy density of vacuum."

Indeed, most physicists are not clearly aware of the distinct difference between the two different states of energy, insofar as the implication of integration or nonintegration.

Regrettably, then, we will continue to utilize the orthodox term, "energy density of vacuum." but the reader should be clearly aware that the vacuum "energy" and vacuum "stress energy density" as **such** are totally disintegrated.

Separation of Vacuum and Observable States

Because the energy density of vacuum is unintegrated, an integrated physical body — including one's personal body — can **exist** "in" the vacuum medium of incredible "energy" density, yet observably exist in a medium of zero energy density.

The unintegrated vacuum ether has enormous spatial density of *virtual* energy, but essentially has zero spatial density *of observable* energy.

Note, however, that in our hyperdimensional interpretation of the levels of virtual state, the vacuum spatially does not exist in the normal 3-space of observable matter.*

The vacuum occupies the 4th dimension (time) and all spatial dimensions (hyperdimensions) greater than the third — it occupies all levels of virtual state, but not observable state. It occupies all levels of disintegration, but not the levels of observable integration.

Exchanges occur between normal 3-space and the hyperspatial vacuum, through the common connecting dimension, time.

These exchanges (of virtual particles) are integrated by the spinning observable mass particle into the first quantally excited state — a delta (change) representing a single entrapped quantum — of the 5-space potential represented by the particle and its accumulating VPF. At that time a sharp electromagnetic (fifth dimensional) discharge of the quantum occurs, converting the accumulated 5-G quantum to the ordinary EM quantum of the 4th (time) and 5th (infolded space) dimensions.

This accounts for the so-called "collapse of the wave function", the production of unitary quantum change, and the discretizing of observable change.

We note in passing that time is the only "dimension" where everything can be considered to occupy the same "point" or "interval", but it is discretized and chopped into pieces (disintegrated), quite different in nature from the familiar three spatial dimensions of the observable (integrated) universe.

The dimensional separation (spatially) of the seething vacuum "energy" (anenergy) and the 3-space of normal matter allows a physical body to enormously interact with the vacuum at or near equilibrium at the microscopic level, but maintain its macroscopic form and stability as if no interaction were going on.

Partial Potentials, Curvature, and Warping

At any rate, we view the magnitude of the overall "potential" of this vacuum gas mixture, as the magnitude of the entire **"stress**

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*Here we sharply differ from conventional physics, which hopefully confuses the concepts of vacuum, spacetime (indeterminate), spacetime (determinate), and frame.

ENERGETICS OF A POTENTIAL
Running in Place and Getting Nowhere

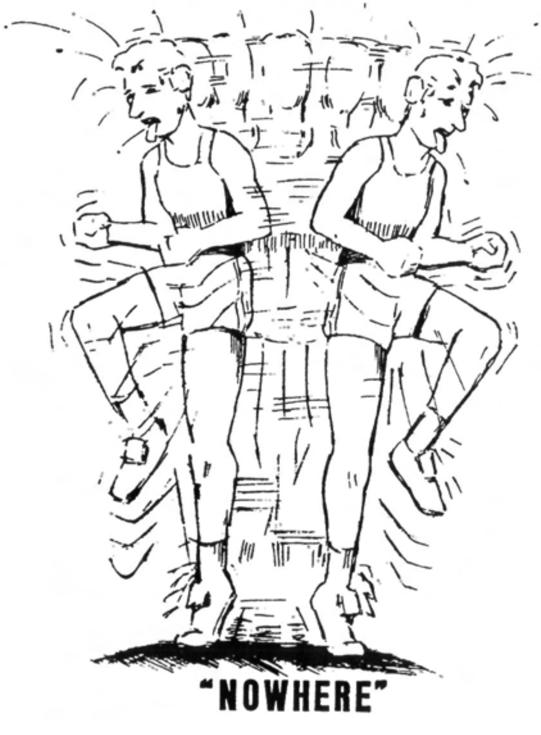

Figure 60. A potential is trapped energy. A potential in vacuum is trapped virtual-state "energy" or flux. A natural potential is trapped random energy. An artificial potential is trapped organized energy.

energy" or "pressure" of the mixture — IF AND ONLY IF this stress energy or pressure were somehow integrated.*

As can be seen, we can now look at each of the component gases in the mix as contributing a partial pressure or partial stress energy (an individual component potential) of the vacuum conglomerate.

We may have the overall pressure remain the same, yet canoni-

---

***Thus it's** really the **potential** stress energy density. The vacuum is nothing but potential!

cally change the partial stress energies (individual potentials).

In that case one has an internally twisted or "warped" spacetime.

A warped spacetime may prove quite useful, for example, for direct translation of one type of "energy" into another. In that fashion, one may conceivably obtain radiation energy at the expense of mass, or mass at the expense of radiation energy.

Or one may convert between potentials where one or more of the converted potentials are as yet unknown to orthodox physics.

Kaluza theory, for example, contains many potentials that are as yet unknown and undiscovered in nature. When undue simplifications are made to arbitrarily exclude the unknown potentials, the adapted theory leads to error in its predictions.

This was originally regarded as a great imperfection, and Kaluza theory fell into disfavor for decades. Then as modern particle physicists began to produce fundamental particles of an astounding variety, a Kaluza-Klein theory of 11 or more dimensions was found to very reasonably describe the emerging situation. Once again, then, Kaluza-Klein theory became a moving force among modern theorists.

One may also convert electromagnetic field energy into gravitational field energy, for example, and obtain enormous amplification of gravitational effects.

This is precisely what scalar electromagnetics seeks to do.

Since the electrical field between two electrons is about 10^{42} times as strong as the gravitational force between them, conversion of the EM charge flux into gravitational charge can conceivably yield up to 10^{42} times as much gravitational force as normal, depending upon the efficiency of the conversion process. Even with a process or device that uses electron currents and has an efficiency of only 10^{-22}, gravitational/inertial gains of 10^{20} are possible.

Note, however, that the levels of vacuum may also be compared to horizontal planes beneath the ocean.

For example, we may take a particular level of vacuum potential, and that level constitutes a sort of included "flat spacetime" of its own. By biasing the potential of a scalar transmitter and receiver to a given level, one may transmit (in either direction) at that level only, Receivers at higher or lower levels will detect nothing.

The immediate application to engineering the nucleus for such things as nonradioactive transmutation of elements, controlled nuclear fusion, electromagnetic healing, and processing nuclear wastes to render them harmless should be apparent.

To recapitulate our analogy, a true "flat spacetime" is a vacuum whose VPF does not essentially vary overall or in each constituent part, between two comparative points.

A "curved spacetime" is a vacuum whose overall VPF varies in overall magnitude, between two comparative points.

A "warped spacetime" is a vacuum whose VPF may or may not **vary** in overall magnitude between two comparative points, but whose partial VPFs vary their ratios, between the same two points. Note that a vacuum/spacetime can be both warped and curved.

It is stressed that we have not limited the number of dimensions **that** can be placed on the vacuum to Minkowski's four. We hold the number of dimensions necessary to represent both vacuum and observable matter to be arbitrary, but greater than four.

To unify electromagnetism and gravitation (which is what scalar electromagnetics is about), we must take five dimensions — four spatial and one time — to be the minimum necessary in modeling the unified theory, similar to Kaluza.

We state now a major characteristic: **Vacuum/spacetime consists entirely of potentials, nothing else, and these are hyperspatial a priori.**

The vacuum does not contain observable force fields nor any **Other** *non-potential* entity.

We also state without proof that in scalar EM theory it seems **very** possible to model the mind and its unification with physical **reality,** in a fashion subject to experimental verification.

Force and Mass Are Inextricably Intertwined

In foundations of physics, it is well-known that, paradoxically, force and mass can only be defined one in terms of the other.

We may use that paradox for a new interpretation of force and **force** fields: a force may be interpreted **to consist of** the time rate of changing the "mv" momentum of a mass system or object, instead of **being the cause of** its dp/dt.

That is, we may take the view that

$$\mathbf{F} \equiv \mathbf{dp}/\mathrm{dt} \qquad (4\text{-}14)$$

not just that

$$\mathbf{F} = \mathbf{dp}/\mathrm{dt} \qquad (4\text{-}15)$$

We have previously pointed this out and called it the "strong definition of force."

This immediately suggests the question: If force is an effect and not a cause, what, then, causes force?

Quantum mechanics already provides the answer: A differentiating operator must be applied to (coupled to) potential in order to produce a force field. The most usual "differentiating operator" is an observable spinning charged particle.

A charged particle exposed to the variation of electrostatic scalar potential between two points is exposed to a gradient (flow) in the virtual photon VPF, and hence to a directional "stream" of virtual photons. The observable charged particle couples to that stream. **Its** spin integrates the unobservable, disintegrated anenergy of the gradient flux into integrated, observable energy of the particle.

With greater integrated "pressure" on one side of the particle than on the other, the observable particle accelerates and translates This produces or "detects" (and comprises) an electric force between the two points.

Force is the mass particle(s) accelerating, either in time or in mass. Observable force is observable particle(s) accelerating. **Virtual** force is virtual particle(s) accelerating.

In **Quiton/Perceptron Physics,** I gave a new definition of mass that is consistent with this viewpoint:

$$1 \text{ kg. mass} = 17.053 \times 10^{50} \text{ switches/sec} \qquad (4\text{-}16)$$

where a switch is h/4*pi), having the units of action/time, or energy. This directly defines mass in terms of energy accumulation, where the energy accumulated is in equilibrium in a differentiated action flow.

Note that "energy" is the time rate of flow of action. Energy can only be accumulated (as a mass or a potential) by possessing two rates of flow of action simultaneously, one in positive time and one in negative time. This is a very deep statement that affects all of physics, but unfortunately it is beyond the scope of this present book.

To return:

The observable electric force field does not exist as such in vacuum. The vacuum and all its constituents are totally virtual. Only the potential ("potential for the electric force field, given a coupled charged observable particle") exists in vacuum, as pointed out by Richard P. Feynman et al, The Feynman Lectures on Physics, Addison-Wesley, Reading, Mass., 1964 vol. 2, p. 2.

The Concepts of Zipped and Unzipped Forces

As noted previously, the potential exists as an unintegrated virtual particle flux (VPF). Further, each little moving virtual particle is smeared in length and time, is coupled to finer VPF, and thus may be said to constitute a minute "force vector" while it exists.

Thus, the electrostatic scalar potential is composed of a myriad of little individual "virtual particle force field" vectors.

Since these little virtual vectors are essentially separate and unintegrated, one may say that the electric field is *unzipped* in vacuum. By "unzipped" we mean that the individual virtual particle E-field vectors are unintegrated.

A potential, for example, is composed of unzipped vector fields since it is comprised of unintegrated, virtual vectors.

To be static, the potential must be comprised of a pair (at least one pair) of unzipped vector fields, one in positive time and one in negative time. These unzipped vector fields must in turn be locked together. In this case, the positive time observer sees nothing (vacuum only), until he "observes" or detects. Normal detectors detect (and in so doing, they zip together) only the positive time unzipped component. The negative time (phase conjugate) vector held retraces the positive time field, in Newton's third law. Or, if generating a wave or pulse, it would be seen as a phase conjugate replica which affected the disturbing source.

Let us be very plain. **A "scalar EM potential" is actually two vector fields zipped together: one is in positive time, and the other is in negative time.** Each half is composed of microvectors. A dynamic gradient in this scalar EM potential (i.e., a scalar wave, for example) actually consists of two waves: one is the normal" positive energy/positive time" EM wave, while the other is the phase conjugate replica. When we detect the normal half (with electron detectors), we actually detect the second half with the atomic nuclei. Since it is a phase conjugate, it produces a negative momentum change on the nucleus {since one has p/(-t)} instead of LeSage's positive momentum change. In other words, it produces a drawing (attracting) force on the absorbing nucleus, instead of LeSage's assumed repelling force on it.

That is the entire secret of gravitation. And of electrogravitation. Knowing that, you can easily work out how to apply the necessary engineering to get antigravity.

But to return.

The potential can also be comprised of many unzipped vector fields at once. These may be deterministic (artificial potential) or randomized (natural potential).

The "force field" is disintegrated (unzipped) in vacuum, and integrated (zipped) on, of, and by an observable charged particle. In vacuum, it is always accompanied by its phase conjugate twin. When detection by an observable particle occurs, the spin of the particle acts as the "zipper," producing an observable force (which is actually of the particle accelerating, not "acting independently upon it.")

Vacuum is unzipped; observable mass is zipped.

Any zipped entity exists observably in 3-space; any unzipped entity exists in hyperspace outside 3-space, and is unobservable and virtual to the 3-space observer.

This interpretation is still consistent with the extended quantum mechanical view, where ultimately all observable forces are considered to be generated by absorption and emission of virtual particles by/from an observable particle (mass), at least insofar as what we may observably measure or detect.

Force, Force Field, and EM Waves in Vacuum

In the new interpretation, consistent with the quantum mechanical view, observable force becomes an effect, not a cause.

One may interpret quantum mechanics as stating that **any observable is an effect, since it is assumed to have a virtual state cause.** In the axioms of quantum mechanics, an operator is required for every observable.

The primary **causative agents are potentials, not force fields, as** is **now** firmly **established in** quantum mechanics.

The Aharonov-Bohm (AB) effect is a striking illustration of the primary reality of the potential rather than of the force field.

In the AB effect, potentials may still exist when the force fields **are** zero, and their interference can still cause real effects. The AB effect has finally become generally accepted by physicists after nearly three decades of controversy.

The immediate result is that, contrary to the outdated view imbedded in classical EM, observable E and B force fields do not exist *as such* in vacuum. This allows a totally new interpretation of the **nature** of the EM wave in vacuum: It is longitudinal. And actually, it exists in longitudinal pairs: the second is the phase conjugate of the first.

But of course we detect transverse waves with our detectors! However, this has a simple explanation.

Examine, for example, a straight-wire antenna. The spinning conduction electrons are longitudinally constrained, as is well known. The electrons are relatively unrestrained transversely in the **wire,** but can only "drift" longitudinally down the wire with a speed usually on the order of centimeters per second. The signal potential, however, moves longitudinally down the wire at almost the speed of **light.**

Obviously it is not the longitudinal movement of conduction electrons that constitutes the "signal", even though classical electromagnetics represents it that way.*

We note that a spinning electron whose movement is longitudinally restrained, but is unrestrained transversely, may be characterized as a gyroscope. Further, the axis of this gyroscope may be taken as lying in a plane perpendicular to the straight wire conduction path, since the electron is relatively unrestrained transversely.

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*Actually, we do not really know how current/electrons travel down a wire, or even if it does/ they do. See three articles by Chappell Brown in Electronic Engineering Times: "Railgun Research Shoots Holes in Lorentz's Theory," April 6, 1987,p. 49-50; "Anomalies in Electromagnetic Law Spur Debate," Sept. 14, 1987, p. 58; "Electrons and Conduction: Not So Simple After All," Dec. 28, 1987, p. 21-22.

If now disturbed by a vacuum potential gradient, the gyroscopic electron is free to precess at right angles to the length of the wire. In other words, given a disturbing force, the electron will move transversely, or radially in the cross sectional plane of the wire, because of gyroscopic precession.

Thus, assuming a gyroscopic electron and its longitudinal constraint, we will detect transverse oscillations in the electron gas in the wire, IF AND ONLY IF the incoming disturbance in the vacuum is longitudinal, and IF AND ONLY IF the unzipped vacuum disturbance "couples" to (is zipped by) the gyroscopic conduction electrons.

Two things are certain in our electron-detector model: First, by the nature of a gyroscope, the conduction electrons move (precess) at right angles to the "disturbing force." Second, we only detect the movement of the electrons themselves.

Since we do detect transverse oscillations of the precessing electrons in the straight wire antenna, then it follows that normal electromagnetic waves in vacuum—that is, the component half that, interacts with the atom's electron shells and not with its nucleus — are (1) longitudinal, and (2) of such form that they couple to electrons.

Note that Tesla always insisted that electromagnetic waves in vacuum were longitudinal. For example, he called them "electromagnetic sound waves" in the ether. In "Tesla Maps Our Electrical Future," H. Winfield Secor presents Tesla's view of transverse waves in this fashion:

"Tesla upholds the startling theory formulated by him long ago, that the radio transmitters as now used, do not emit Hertz waves, as commonly believed, but waves of sound... He says that a Hertz wave would only be possible in a solid ether, but he has demonstrated already in 1897 that the ether is a gas, which can only transmit waves of sound; that is such as are propagated by alternate compressions and rarefactions of the medium in which transverse waves ***are*** *absolutely impossible."*

In his "The True Wireless," **Electrical Experimenter,** May **1919,** Tesla himself further stated:

"The Hertz wave theory of wireless transmission may be kept up ***for*** *a while, but I do not hesitate to say that in a short time it will be recognized as one of the most remarkable and inexplicable aberrations of the scientific mind which has ever been recorded in history."*

It should also be pointed out that our analogy permits the option of making a longitudinal wave in the vacuum in such a fashion that It will not couple to electrons.

In that case a normal "electron gas" conduction detector will not detect the new wave. Such a noncoupling EM longitudinal wave is **referred** to as a **scalar electromagnetic wave,** where by use of the **term** "scalar" we call attention to the fact that the vacuum potential **is** varying, but electron coupling to form vector force fields in an **electron** gas does not occur.

Since according to general relativity the variation of a potential in vacuum rigorously is a gravitational wave, then the scalar EM wave is a gravitational wave.*

We often say it is an *electrogravitational* wave to call attention **to** its electromagnetic origin, and to the absence of EM force field "bleeding away" of the 5-space Kaluza-Klein gravitational potential. We will discuss the 5-space G-potential shortly.

The conventional equation

$$\mathbf{E} = -\nabla \varnothing \qquad (4\text{-}17)$$

thus applies in the detecting electron gas, but not in the vacuum. Instead, in the nonmaterial vacuum, rigorously

$$\nabla \varnothing \neq -\mathbf{E} \qquad (4\text{-}18)$$

and this states that a gradient in a vacuum electrostatic scalar potential produces an antiphased electric force on and of a particle, on condition that a particle is present. The intent of equation (4-17) should be stated as

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*It is also a very powerful gravitational wave, since for electrons it is some 10^{42} times as strong as "mass attraction" gravity waves.

$$\nabla \varnothing = -\mathbf{E} \qquad (4\text{-}19)$$

where the vertical line means "on condition that", and cp means "charged particle" (i.e., "that a charged particle is there.).

Equation (4-19) clearly shows that, in the vacuum, only the organized potential for an E field exists due to the quantity $\nabla \varnothing$ essentially as pointed out less strongly by Feynman et al in **The Feynman Lectures on Physics.**

Certainly, in the quantum mechanical interpretation, it is the potential that is real. The force field can only be made from the potential by a differentiating operation.

Since there is nothing in vacuum to perform this differentiating operation observably, one may interpret quantum mechanics as already prohibiting the existence of observable electromagnetic force fields in vacuum, at least in the form prescribed in classical electromagnetics.

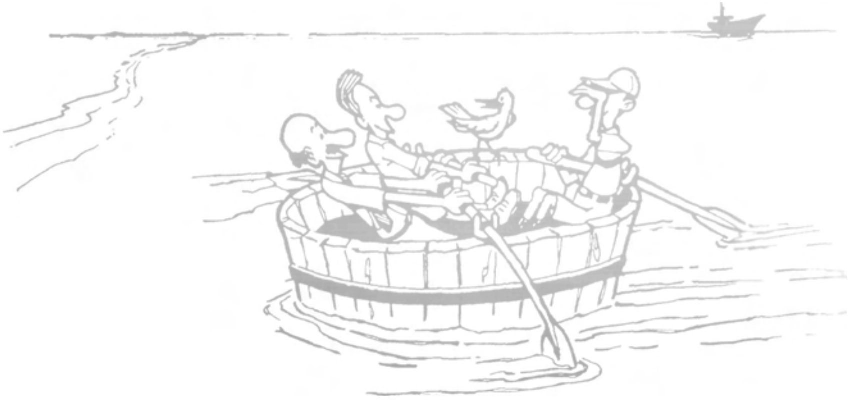

Figure 61. A force-field vector is a movement of mass in one direction.

One may regard quantum mechanics — and physics in general - to be incomplete until electromagnetic theory is changed to incorporate the implications of quantum mechanics.

In scalar electromagnetics a new interpretation is taken, and the "overhaul" of electromagnetic theory is in progress.

We accent that scalar electromagnetics is still embryonic. It is at a stage similar to that where electromagnetism was when experimenters were still rubbing glass rods with cat fur and experimenting with little charged pith balls.

Early experiments are enlightening and encouraging; nonetheless, the phenomenology and the myriad of variables are not at all well-understood, even by the experimenters themselves, and certainly not by this author.

Zero-Summed Vector Systems: Shortcoming in Vector Analysis

It has long been pointed out by this author that a fundamental shortcoming exists in classical vector analysis itself when applied to physical systems. Let us briefly look at the construction of the vector mathematics theory, to clarify this shortcoming.

First, an abstract entity called a "vector" is conceptualized. This vector has both direction and magnizude, as contrasted to a "scalar" quantity, which only has magnitude.

Next, an abstract "vector space" is defined; this is a sort of "container" for mathematical objects called vectors, with certain inherent properties of the system specified. In other words, a vector space is an abstract "system" or "space" which can contain objects called "vectors."

Next certain other properties, operations, and entities are defined, one of which is the is the "zero vector".

Essentially the zero vector is defined by a set of operations; however, one simplified interpretation is "the absence of any vector of finite magnitude." By implication, in the abstract vector theory, all zero-vectors are defined to be identical.*

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* Because, by their nature assumed in the concept, they have no internal structures. That is, effectively the zero vector has been too restrictively defined as "the absence of any and all finite vectors." It should be redefined as "the absence of any single vector being present alone." In that case the definition would admit "the presence of multiple translation vectors, where their combined translation action is zero."

In the vector addition operation, a group of finite vectors adds to a single vector called the "resultant."

It is standard practice in abstract vector analysis to replace a system of summation vectors by their resultant, since all appropriate properties of the summation system are retained by the vector resultant, in the abstract mathematical model.

This, however, is only possible because the abstract vector space has no such thing as stress, and a zero-vector has no substructure by definition. In the abstract space, only translation and rotation are possible, *by assumption*

It is also possible for two or more finite vectors to add to a zero resultant, in which case the system is replaced with a zero vector. Note that all further action by the summing vector components is eliminated by this assumption.

Again the appropriate properties of the summation system are retained by the zero resultant, in the abstract mathematical model, only because the *medium* (the abstract vector space) is not subject to stress, translation, rotation, and structuring.

Note however, that in physical systems, one cannot simply

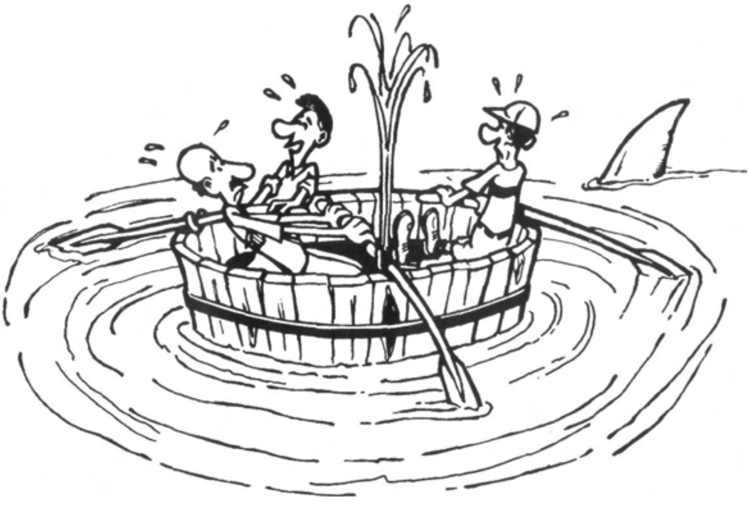

Figure 62. The zero-summed vector system is an engine and an artificial potential.

replace a zero summation system of force vectors with a zero vector and retain all characteristic physical effects caused by the replaced system. The physical medium - including the virtual flux of the vacuum, *is* subject to stress, translation, rotation and structuring.

Physically, the presence of the summing vector component forces creates a stress and a dynamic macroscopic structure in the physical medium in and on which the forces are acting. Therefore the stress of the medium and its structure must be preserved and accounted for, even though a zero vector resultant force exists.

This is particularly true in the vacuum, where internal (infolded) stresses cause charge and energy conversion between one kind of charge/potential and another.

Maxwell's Theory Was Altered and Curtailed

In fact, Maxwell seems to have been well aware of the electromagnetic stress of the ether and its importance. After all, he believed the ether to be material and mechanical, and developed his theory accordingly.

For example, in his Treatise on Electricity and Magnetism, he wrote:

> *"There are physical quantities of another kind which are related to directions in space, but which are not vectors. Stresses and strains in solid bodies are examples of these, and so are some of the properties of bodies considered in the theory of elasticity and in the theory of double refraction. Quantities of this class require for their definition nine numerical specifications. They are expressed in the language of quaternions by linear and vector functions of a vector."*

Maxwell worked out his theory in quaternions since, at the time, the modern form of vector analysis had not been originated by Heaviside and Gibbs.

To recapitulate what we stated earlier: A quaternion consists of a vector part and a scalar part and can readily take into account the stress and strain of the medium. A vector consists only of the vector part, and does not take into account the stress of the medium.

It seems certain that Maxwell knew that the scalar part of the quaternion could be present and vary, even though the vector part was sum-zeroed. Quaternions, however, are devilishly difficult, and even in the time of their founder, Hamilton, few mathematicians and scientists ever mastered them.

Maxwell's theory was transposed (shortly after his death) to its modern vector form by Oliver Heaviside. Many of the characteristics of the scalar part of the quaternion were effectively discarded.

In the remodeling, the "unified" basis was omitted, and electro-

Table 37. MAXWELL'S EQUATIONS

- **INVARIANT**
    - **UNDER CONFORMAL GROUP OF TRANSFORMATIONS**
    - **IN 4-D MINKOWSKI SPACE**
- **GROUP INCLUDES**
    - **TRANSLATIONS**
    - **ROTATIONS**
    - **REFLECTIONS**
    - **INVERSIONS WRT HYPERSPHERES OF M-SPACE**
- **HENCE MAXWELL'S EQUATIONS INCLUDE TRANSFORMATIONS THAT**

    CHANGE INERTIAL FRAMES INTO FRAMES THAT ARE NOT INERTIAL.

    PROVED IN 1910 BY
    H. BATEMAN AND E. CUNNINGHAM

gravitation was accordingly discarded. Heaviside wrote a severely limited subset of Maxwell's theory; he did not by any means capture all of it.*

The new Heaviside vector reinterpretation of EM was far easier to calculate in than Maxwell's quaternions. Many physicists (there were really very few scientists in those days!) immediately loved it.

FitzGerald wrote glowingly of Heaviside's translation (and mutilation!) of Maxwell's theory:

> *"Since Oliver Heaviside has written, the whole subject of electromagnetism has been remodelled by his work. No future introduction to the subject will be at all final that does not attack the problem from at least a somewhat similar standpoint to the one he puts forward."*

Thus it was that Heaviside discarded the basis for scalar electromagnetics and electrogravitation from Maxwell's original work, and **the** so-called "classical Maxwell Equations" appeared for the first time in their modern vector form in Heaviside's work.

Then in the early 1890's a short but vigorous debate on vectors and vectorial methods occurred, involving eight journals, twelve leading publications, and over 30 scientists. Over half the publications were in the leading British scientific weekly journal Nature.

This debate, which Lord Rayleigh characterized by the statement "Behold how these vectorists love one another," together with **the** far greater difficulty of quaternion methods as compared to Gibbs' and Heaviside's vector analysis, spelled the death knell to the position of quaternions.

After some years, the Gibbs-Heaviside vector theory was firmly entrenched. The quaternion theory of Maxwell was forever modified **and** limited to the form we know today as "Maxwell's equations."

What really happened was that electrical physicists, faced with the formidable difficulties of quaternions, simply stampeded down the far easier road blazed by Heaviside, bowling over all protests against Heaviside/Maxwell/Hertz theory.

*Specifically, Heaviside wrote the subset of Maxwell's theory where gravity and electromagnetism do not interact and are mutually exclusive.

In Western universities today, no one actually teaches Maxwell's true theory! Instead, Heaviside's curtailed reinterpretation — a severely restricted subset of Maxwell's theory — is taught.

And so that is the EM theory that is learned and applied.

One may rightly argue, therefore, that **Maxwell's theory has only been partially applied in its modern translated form, and the modern form of the Maxwell/Hertz electromagnetic theory is very much incomplete.**

To recover the stress factor in Maxwell's original theory, electromagnetics must take into account the *artificial* potential, which has a deliberately ordered, dynamic, deterministic structure. Scalar electromagnetics takes the patterned stress into account and deliberately uses it. Normal electromagnetics only considers the *natural* potential with randomized VPF structure implicitly assumed.

Scalar Waves ***and Polarization of*** *the* ***Vacuum***

Let us use a simple analogy. This will lead us into the profound implications of the deliberate vacuum polarization and curving of local spacetime that is provided by the vector zero summation (artificial EM potential) method of scalar electromagnetics.*

Visualize two sets of opposing and balanced forces pressing on the sides of a plate.

The forces sum to zero, so the resultant force acting on the plate for translation is zero. Hence the plate does not translate (move away or accelerate).

However, the plate is under internal stress (compression), and is in a quite different condition than when it has no external forces at all acting on it.

Now visualize the forces being applied with rigid rods welded to the sides of the plate, so that the forces may alternately "pull" as well as "push." Let the forces rhythmically vary, alternately "pulling" and "pushing", but always remaining balanced so that their summation for a translation resultant is constantly a zero vector.

The plate never accelerates or moves in translation, but it now contains an internal stress wave which rhythmically varies between compression and tensile stress. Rigorously the plate internally

*Vector **multiplications** that yield a zero vector product are also highly significant.

possesses a scalar stress wave, or a wave of "internal stress in the medium."

Now visualize a similar "plate-like" region of vacuum, with its virtual particle flux, instead of the material plate. Visualize two opposing sets of (unzipped) EM force fields, acting in and on the plate-like region, so that they rhythmically increase and decrease, changing direction also, but always with a zero vector summation.

In this case, there is an unzipped zero resultant EM force field (it is zero, by our assumed conditions), but there is a rhythmic oscillation of the intensity of the vacuum flux (intensity of the vacuum potential) and the vacuum structuring in the region. That is, there is a rhythmic and steady oscillation of the stress energy and structuring of vacuum, and hence of the curvature of spacetime, in **the** plate-like region.

Rigorously, this oscillation — which we call a scalar electromagnetic wave—is a gravitational wave, since the local curvature of spacetime is being oscillated.

Further, it differs from a "natural" gravitational wave in several respects:

1. It has a deterministic pattern or substructure,

2. It patterns or "polarizes" the vacuum,

3. It constitutes local curvature of spacetime, and hence localized general relativity - something which ordinary general relativity assumes cannot be accomplished,

4. It deterministically engineers the virtual state and local spacetime,

5. Since it is achieved by converting EM field energy into artificial G-field energy, one can expect tremendous gains of gravitational and inertial effects in and around electrical circuits utilizing such fields precisely,

6. It affects the Schroedinger wave and the probabilities of the

states being propagated forward by the Schroedinger wave. **With the scalar EM wave, one can thus deterministically engineer the emergence of quantum change, and violate one of the fundamental assumptions of quantum mechanics, that of the totally statistical nature of quantum change,**

7. The scalar wave can accomplish direct and localized change of the rate of flow of time (even to its reversal) and variation of mass and inertia, without concomitant translation of matter,

8. By locally curving and patterning vacuum spacetime, a stabilized standing scalar EM wave can provide macroscopic violation of the conservation laws, which rigorously depend upon a locally flat spacetime (Lorentz frame),

9. Since the components in the zero summation may be EM waves, and may be "locked together" and broadcast to a great distance and interfered there, effects at great macroscopic distances may be achieved, in violation of present assumptions of physics, and

10. Since excess negative time flow may be locally produced, antigravity, negative energy, and negentropy may be locally produced.

These are the startling implications inherent in correcting classical electromagnetics' improper treatment of zero-summed EM force vector systems in vacuum.*

By classically replacing the force vectors in a zero EM force field summation with a zero vector and discarding the components, one is totally discarding the fact that such a patterned system of oppositive forces forms a deterministically patterned stress in the vacuum medium.

By this innocuous error, classical EM discards electrogravitation, and avoids unification of gravitation and electromagnetics. It

*And its zero - multiplied force vector systems as well.

also avoids direct engineering of gravitation, vacuum/spacetime, inertia, rate of time flow, free energy, and quantum change.

Generations of Western physicists and electrical engineers have acquired a mindset in only one aspect of the vastly expanded electromagnetics actually available.

Vector Zero Systems and the Kaluza-Klein Approach

Prior to 1921, Theodor Kaluza applied Einstein's new general relativity to five dimensions.

He produced a unified theory of electromagnetism and gravitation.

In Kaluza's theory, the ordinary 4-dimensional gravitational field and the electromagnetic field are but two different aspects of a single more fundamental field: the 5-dimensional gravitational field.

Kaluza's theory was published in 1921, on the personal recommendation of Albert Einstein, who had had Kaluza's paper for two years.

In Kaluza's model, electromagnetics is the 5th dimensional aspect of the 5-d G-field, while the ordinary 4-d G-field is the intersection of the 5-d G-field with our ordinary world.

Five years after Kaluza's epochal paper, Oskar Klein explained where the extra space dimension — the fifth dimension — was. He modified it as "wrapped around" each point in our ordinary 3-space.

In the Kaluza-Klein model, then, an electromagnetic wave— which moves spatially only in the fifth dimension — does not move through our 3-space at all. Instead, on its trajectory it "flows around" each point in our 3-space along its path.

Using Kaluza's model, we may regard the EM field as the normal "bleed-off' or escape of the 5-dimensional gravitational potential in the 5th dimension.

Any gradient in a potential represents a bleed-off of the potential from the high point to the low point. The way to prevent effective bleed-off of a potential at a point is to add an equal amount of bleed-in! The bleed-out and the bleed-in at the point then become balanced, so that an equilibrium state exists in the potential.

By this mean, the magnitude of the potential can be fixed by the two opposing bleed processes in equilibrium.

Table 38. KALUZA GEOMETRY

- **THEORDOR KALUZA, POLISH PHYSICIST**
- **UNIFIED THEORY OF ELECTROMAGNETICS AND GRAVITY [1921]**
    - **5 - DIMENSIONAL SPACETIME**
    - **5 - DIMENSIONAL GRAVITY FIELD**
    - **ELECTROMAGNETISM IS THAT PART THAT OPERATES IN THE FIFTH DIMENSION**

Table 39. 5-D G-FIELD BLEED-OFF [KALUZA 5-D THEORY]

- **FAR EASIER TO BLEED-OFF AS ORDINARY EM FIELD**
- **VERY DIFFICULT TO BLEED-OFF AS ORDINARY 4-D G-FIELD**
- **E.G., BETWEEN TWO ELECTRONS:**

$$\frac{EM}{G(4)} \approx 10^{\text{[illegible]}}$$

- **BETWEEN TWO PROTONS:**

$$\frac{EM}{G(4)} \approx 10^{\text{[illegible]}}$$

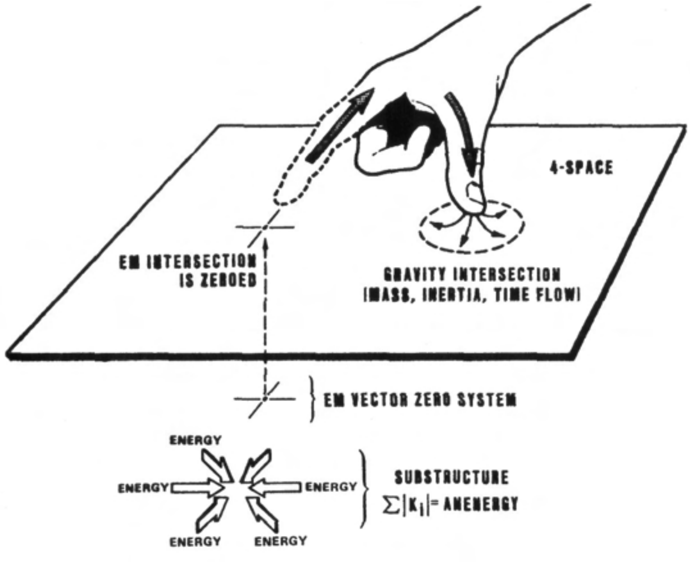
4-SPACE
EM INTERSECTION IS ZEROED
GRAVITY INTERSECTION (MASS, INERTIA, TIME FLOW)
EM VECTOR ZERO SYSTEM
ENERGY
ENERGY
ENERGY
ENERGY
ENERGY
ENERGY
SUBSTRUCTURE
Σ|K_i| = ANENERGY

Figure 63. An analogy for how scalar electromagnetics can engineer Kaluza-Klein unified field theory.

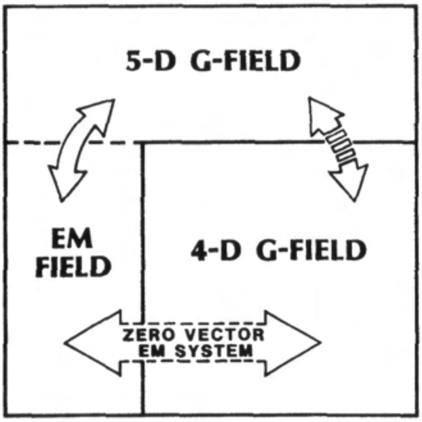
5-D G-FIELD
EM FIELD
4-D G-FIELD
ZERO VECTOR EM SYSTEM

Figure 64. The zero-vector system can engineer Kaluza-Klein theory.

WHERE DID THE EXTRA DIMENSION GO?

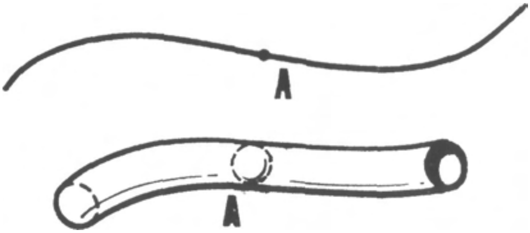

- **FROM A DISTANCE, A HOSE-PIPE LOOKS LIKE A WIGGLY LINE**

- **WHAT WE REGARD AS A POINT IN 3-SPACE IS REALLY A TINY CIRCLE AROUND ANOTHER DIMENSION OF SPACE**

Figure 65. The basic idea of Klein's explanation of where the extra dimension is.

Table 40. PHYSICAL REALITY IS ELEVEN DIMENSIONAL

- **IN THE KALUZA-KLEIN THEORY THE GAUGE FIELD SYMMETRIES BECOME CONCRETE**

- **THEY ARE THE GEOMETRICAL SYMMETRIES ASSOCIATED WITH THE EXTRA SPACE DIMENSIONS**

- **AN 11-SPACE IS REQUIRED BY THE GRAND UNIFIED FORCE THEORY**

PAUL DAVIES, SUPERFORCE.
1984, P. 160-161

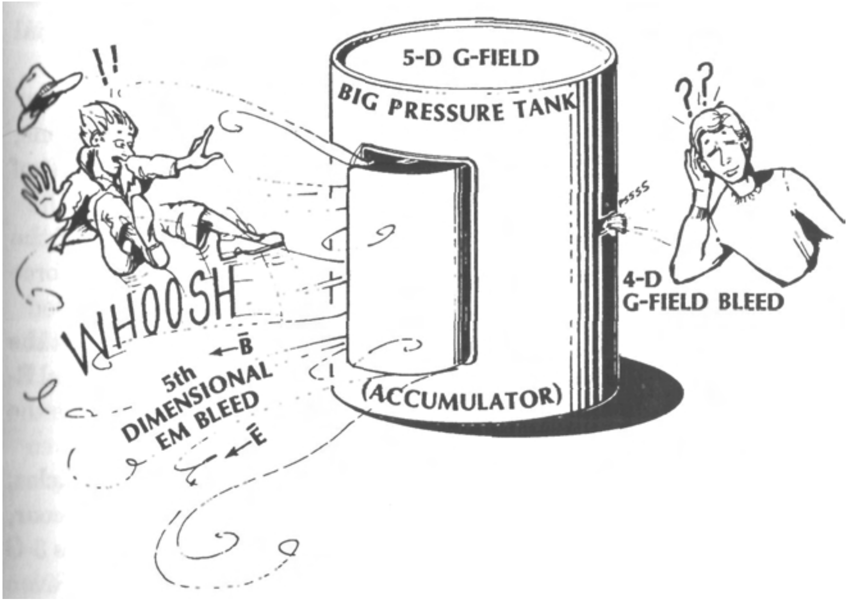
!!
5-D G-FIELD
BIG PRESSURE TANK
??
PSSSS
4-D
G-FIELD BLEED
WHOOSH
B
5th
DIMENSIONAL
EM BLEED
E
(ACCUMULATOR)

Figure 66. Normal EM bleeds off G-field.

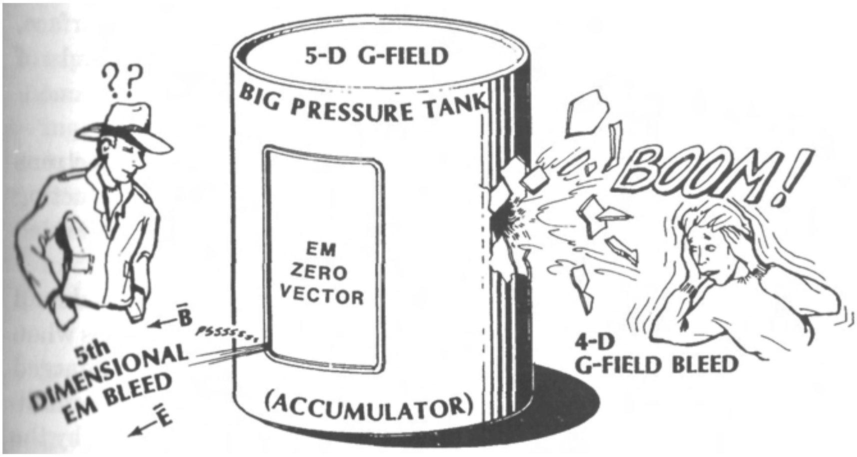
??
5-D G-FIELD
BIG PRESSURE TANK
EM
ZERO
VECTOR
BOOM!
B
PSSSSSS
5th
DIMENSIONAL
EM BLEED
E
(ACCUMULATOR)
4-D
G-FIELD BLEED

Figure 67. Scalar EM forces 4-dimensional gravitational field.

Note that this positively establishes that two or more zero-summed EM force field gradients produce and stabilize an artificial potential.

Usually, very little bleed-off of the 5-potential occurs in our normal 3-space. When the 5-space G-field is bled off on electrons, e.g., the resulting 5th dimensional E-field bleed-off is on the order of 10^{42} times as much as the 3-space G-field bleed-off.

This accounts for the enormous magnitude of the ratio of the electrical force between two electrons to the gravitational force between them.

Even when the 5-space G-potential is bled-off on and against the greater inertia of much more massive protons, its 5th dimensional E-field bleed-off is still on the order of 10^{36} or so times as much as the 3-space bleed-off.

Note that if we can stop the acceleration of the charged particles, bleed-off of the 5-space G-potential as EM force field cannot occur, and instead all of it must bleed-off as 3-space G-force field. This 3-G bleed-off normally occurs only minimally in electromagnetics, even for so-called "static" charges. This can be seen as follows:

When one charges a conductor such as a large metal sphere, for example, the electrons are unconstrained on the surface of the sphere. They are in constant agitation and motion on the surface, thus constantly bleeding-off the 5-space potential as myriads of squirming little E-fields. Only a very little is bled off as 3-dimensional G-field.

On the other hand, when one charges a dielectric, the electrons cannot be in as much agitation movement as they are on a conducting surface. Hence slightly more of the 5-dimensional G-potential is bled off as 3-dimensional G-field.

Therefore, charged conductors and charged dielectrics should exhibit slightly different gravitational and inertial properties when exposed to a gravity field potential difference. Highly charged capacitors, for example, should exhibit a small but detectable unidirectional thrust in vacuum. Apparently they do, as exhibited by the Biefield-Brown effect.

In addition, different materials should exhibit slightly different fall rates gravitationally. Again there is some evidence that they do, as exhibited by the Eotvos experiments in a modern reinterpretation by Fischbach et al.*

Electrogravitation Amplification Factor

If the movement of two free electrons could be entirely stopped, all EM bleed-off of the 5-d G-potential between them would be effectively zeroed or blocked. Then the 5-d G-potential would be forced to totally bleed-off into ordinary 3-d G-field.

For two electrons, this could increase the gravitational force between them by a factor of 10^{42}, if the EM bleed were perfectly blocked.

Such perfect blockage of the 5th dimensional EM bleedoff cannot be accomplished in practice. Normally, with the increase in potential caused by zero-summing, agitating electrons in a statically charged object agitate more intensely, moving and squirming in local, erratic constraints.

However, conversion efficiencies on the order of 10^{10} or even 10^{20} appear to be achievable in ordinary circuitry. In that case, gravito-inertial amplification gains of up to 10^{22} or even 10^{32} appear to be achievable. Gains of 10^{10} or more appear to be fairly readily achievable.

Time delay in producing the gravito-inertial effects may be experienced, however, because mass (nuclei) acts as a capacitance to incident scalar waves, exhibiting capacitive charging and discharging "time constants" when charging scalarly for a particular effect or to a particular pattern.

In these achievable amplification ranges, a single milliwatt of electrical power can control enormously powerful local gravitational and inertial effects, once the scalar EM charge is built up in the nuclei of the target material.

Excessive and frustrating "fiddling time" with the circuits is usually required, however, due to the charging "time constant" effect, the general lack of adequate measuring instruments, and the great uncertainty as to the phenomenology and major variables involved.**

*Ephraim Fischback et al, "Reanalysis of the Eotvos experiment," Phy. Rev. Lett., 56(1), Jan, 1986, p. 3-6.

••A series of scalar EM instruments, however, is being developed by Bedini, Schnur, Golden, **and** perhaps even Hewlett-Packard.

However, with persistence, in rather ordinary EM circuits and devices, the use of "summation to zero-vector" techniques and "multiplication to yield a zero-vector" techniques can lower the EM bleed-off of the 5-potential sufficiently to allow substantial local gravitational/inertial effects. By beaming and wave interference, effects at a distance can be achieved.

When gravito-inertial amplification of many orders of magnitude are involved, the assumption in ordinary general relativity of a local Lorentz frame (local special relativity, with local conservation laws applying) is readily violated.

Now one may have local general relativity, with concomitant violation of conservation laws, and local broken symmetry on a macroscopic scale.

Soviet papers already strongly point out that such unrestricted general relativity allows the violation of all conservation laws.

In the Soviet Union, scalar electromagnetics is called *energetics.*

Comparison of EM Concepts

Table 41 shows a comparison between three concepts of electromagnetics: classical, quantum mechanical, and scalar electromagnetic views.

As can be seen, scalar EM re-introduces Maxwell's original potential for electrogravitational variation and structuring of the stress energy density of vacuum spacetime. It applies Kaluza-Klein 5-dimensional unified theory in an engineering fashion.

It deliberately utilizes phase conjugation as a tool to achieve startling negative time/negative energy capabilities and results, including "free" energy and antigravity.

With scalar EM, it should be possible to overcome or circumvent most of the severely limiting assumptions of present physics and engineering.

The great conservation laws yield to direct manipulation and violation. The previously inviolate statistical structure of quantum change becomes deterministic and engineerable.

General relativity becomes an experimental scientific discipline in the laboratory, instead of a complex description of effects only observable in distant, massively curved regions such as on the surface of a star or near a black hole.

God does not play dice with the universe after all, just as Einstein suspected.

The Aharonov-Bohm Effect

In 1959, Y. Aharonov and David Bohm published a fundamental paper in **Physical Review** which pointed out the quantum mechanical implications of potentials.

The seminal paper is Y. Aharonov and D. Bohm, "Significance of Electromagnetic Potentials in the Quantum Theory," **Physical Review,** Second Series, 115 (3), Aug. 1, 1959, p. 458-491.

In classical electromagnetics, the potentials had largely been regarded as mathematical conveniences, having no real effects.

Table 41. Comparison of EM Concepts

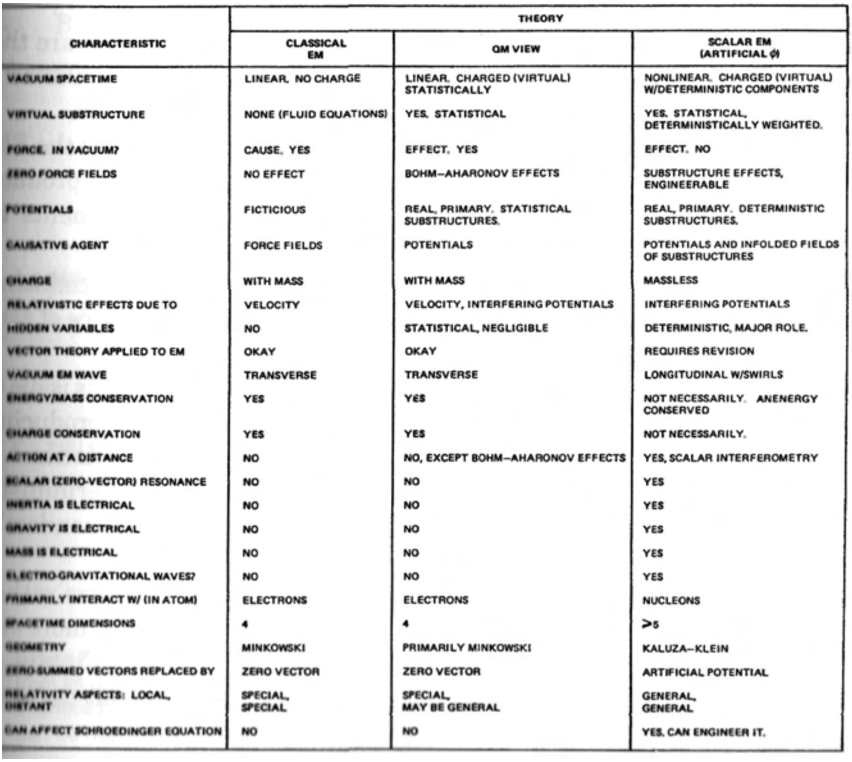

CHARACTERISTIC	THEORY		
	CLASSICAL EM	QM VIEW	SCALAR EM (ARTIFICIAL ϕ)
VACUUM SPACETIME	LINEAR, NO CHARGE	LINEAR, CHARGED (VIRTUAL) STATISTICALLY	NONLINEAR, CHARGED (VIRTUAL) W/DETERMINISTIC COMPONENTS
VIRTUAL SUBSTRUCTURE	NONE (FLUID EQUATIONS)	YES, STATISTICAL	YES, STATISTICAL, DETERMINISTICALLY WEIGHTED.
FORCE, IN VACUUM?	CAUSE, YES	EFFECT, YES	EFFECT, NO
ZERO FORCE FIELDS	NO EFFECT	BOHM–AHARONOV EFFECTS	SUBSTRUCTURE EFFECTS, ENGINEERABLE
POTENTIALS	FICTICIOUS	REAL, PRIMARY, STATISTICAL SUBSTRUCTURES.	REAL, PRIMARY, DETERMINISTIC SUBSTRUCTURES.
CAUSATIVE AGENT	FORCE FIELDS	POTENTIALS	POTENTIALS AND INFOLDED FIELDS OF SUBSTRUCTURES
CHARGE	WITH MASS	WITH MASS	MASSLESS
RELATIVISTIC EFFECTS DUE TO	VELOCITY	VELOCITY, INTERFERING POTENTIALS	INTERFERING POTENTIALS
HIDDEN VARIABLES	NO	STATISTICAL, NEGLIGIBLE	DETERMINISTIC, MAJOR ROLE.
VECTOR THEORY APPLIED TO EM	OKAY	OKAY	REQUIRES REVISION
VACUUM EM WAVE	TRANSVERSE	TRANSVERSE	LONGITUDINAL W/SWIRLS
ENERGY/MASS CONSERVATION	YES	YES	NOT NECESSARILY. ANENERGY CONSERVED
CHARGE CONSERVATION	YES	YES	NOT NECESSARILY.
ACTION AT A DISTANCE	NO	NO, EXCEPT BOHM–AHARONOV EFFECTS	YES, SCALAR INTERFEROMETRY
SCALAR (ZERO-VECTOR) RESONANCE	NO	NO	YES
INERTIA IS ELECTRICAL	NO	NO	YES
GRAVITY IS ELECTRICAL	NO	NO	YES
MASS IS ELECTRICAL	NO	NO	YES
ELECTRO-GRAVITATIONAL WAVES?	NO	NO	YES
PRIMARILY INTERACT W/ (IN ATOM)	ELECTRONS	ELECTRONS	NUCLEONS
SPACETIME DIMENSIONS	4	4	>5
GEOMETRY	MINKOWSKI	PRIMARILY MINKOWSKI	KALUZA–KLEIN
ZERO-SUMMED VECTORS REPLACED BY	ZERO VECTOR	ZERO VECTOR	ARTIFICIAL POTENTIAL
RELATIVITY ASPECTS: LOCAL, DISTANT	SPECIAL, SPECIAL	SPECIAL, MAY BE GENERAL	GENERAL, GENERAL
CAN AFFECT SCHROEDINGER EQUATION	NO	NO	YES, CAN ENGINEER IT.

Table 42. THE AHARONOV - BOHM EFFECT

- **IN FIELD-FREE REGIONS**
    - **E - FIELD IS ZERO**
    - **B - FIELD IS ZERO**
- **POTENTIALS STILL EXIST**
    - **CAUSE REAL EFFECTS**
    - **INTERFERENCE IS KEY**
    - **CONTAIN SUM-ZEROED SUBSTRUCTURE**
- **DOES NOT FOLLOW FROM**
    - **MECHANICS**
    - **CLASSICAL ELECTROMAGNETICS**

However, according to quantum mechanics, the potentials are the real entities, while the electromagnetic force fields are just effects derived from the potentials by imposed operations on them.

Aharonov and Bohm showed that, even in the absence of the EM force fields, the potentials may still exist and interfere to produce real effects in physical systems. They suggested experiments to prove these predictions.

Interference of the potentials is the key mechanism producing real effects in charged particle systems, even in the presence of zero E-field and zero B-field.

Unfortunately, Aharonov and Bohm did not address this issue of zero-summed systems of EM force fields as one way of producing artificial potentials having unique interference characteristics.

That is, by implication they did not consider the deterministically substructured "artificial" potential, but only the randomly structured "natural" potential.

At any rate the "AB effect," as it came to be called, was rather hotly debated and fiercely resisted over the years. Steadily, more and more experiments were added, validating the AB effect. Finally, in 1986 it came to be generally accepted as proven to any but the most die-hard skeptic.

The AB principle represents a violation of both classical mechanics and classical electromagnetics. It is absolutely required, however, by quantum mechanics. And experiments have now established it as proven beyond question.

The potential, then, can be a free and independent field. Further, it can directly act on charged particle systems, even when classical electromagnetics does not recognize the interaction.

Curl-Free Magnetic Vector Potential (A-Field)

As an example, in classical EM the vector magnetic potential (the A-field) had been defined as a mathematical convenience by the equation

$$\nabla \times \mathbf{A} = \mathbf{B} \tag{4-20}$$

But if the potentials are real, then conceivably the A field can be loosed from its enchainment to the $\nabla \times$ operator. In that case, it

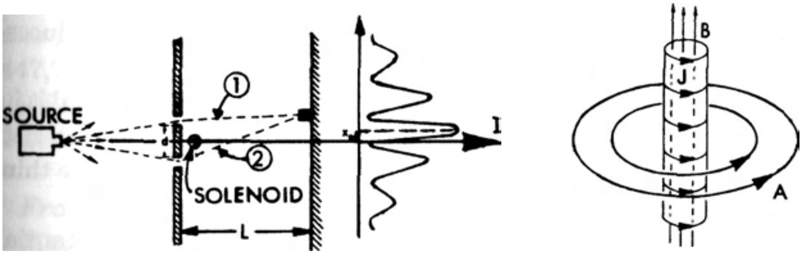

A - FIELD CAN INFLUENCE THE MOTION OF ELECTRONS.

MAGNETIC FIELD AND VECTOR POTENTIAL OF A LONG SOLENOID.

THE FEYNMAN LECTURES ON PHYSICS. VOLUME II

Figure 68. The curl-free A-field. The magnetic vector potential (A-field) may be freed from its attachment to the magnetic field (B-field) and electric field (E-field). It can interfere at a distance to cause real effects. From it, either E-field or B-field, or both, can be made at a distance.

becomes a free, new, and independent field of nature with potentially unique characteristics.

For instance, its defining equation shows that magnetic force field can be made from it, and the rightmost term of the equation

$$\mathbf{E} = -\nabla Ø - d\mathbf{A}/dt \qquad (4\text{-}21)$$

shows that its time rate of change makes an electrical field.

Let us explain this in simpler terms, and somewhat more precisely than conventional theory. We will use the Kaluza unified G-EM interpretation and electron flow in our explanation.

In the A-field, we have a certain kind of 5-dimensional G-potential which can bleed-off as EM force fields in two ways: (1) in a swirl fashion, where the vortex producing the swirl moves parallel to electron movement, and the swirling is a torque or spin, and (2) in a linear fashion, where the time rate of change of the A-potential produces a linear E-field on the electrons.

The first bleed-off as given by equation (4-20) constitutes the magnetic B-field, and the second bleed-off as given by the rightmost term of equation (4-21) creates a component of the overall electrical E-field. Bleed off of the electrostatic scalar potential produces the other component of the E-field.

Now in general relativity (GR) theory, "the" G-potential is just a conglomerate of many things, each of which has the characteristic of curving spacetime. "The" gravitational field is not a single thing at all, but is composed of a collection of many things.

Thus if we realize that both the electrostatic scalar potential (Ø-field) and the magnetic vector potential (A-field) are components of the 5-d G-potential, then we see immediately that bleed-off of these two components of the 5-d G-potential creates all normal EM fields.

It follows that, if we produce a zero-vector summation of the two or more EM bleed-offs, we are actually "putting as much back in" to the 5-d G-potential through its A and Ø components as we are taking out electromagnetically.

In that case, the 5-potential is in a state of equilibrium with respect to EM bleed-off in the fifth dimension. It is now forced to bleed-off in the only other way it can: as ordinary 3-dimensional gravitational field. Thus by vector-zeroing EM force fields, we turn KM field energy into G-field energy and vice versa, via the intermediary of the 5-potential.

At any rate, soon after publication of the Aharonov-Bohm paper, experiments showed that, if the magnetic field is trapped inside a long solenoid, a phase shift still is induced in the two-slit electron experiment, even though — classically — no contact of the enclosed magnetic field and the moving electrons occurs. This phase shift is explained by the fact that the freed A-field exists outside the trapping solenoid, even though the B-field does not. Consequently, interaction of this curl-free A-field with the electrons produces a phase shift of the QM interference detection pattern.

This proves that curl-free A-field is real and causes physical effects.

It also proves that a form of "action at a distance" is real, just as required by quantum mechanics.

Years ago, Frank Golden and this author — together with Dr. William Tiller — experimented with "free A-field" devices. Golden went on to develop prototype transmitters and receivers and a prototype underwater communication system.

Since that time, Gelinas has patented several curl-free magnetic vector potential (free A-field) devices. See U. S. patents numbers 4,447,779, May 8,1984; 4,429,288, Jan. 31,1984; 4,429,280, Jan. 31,1984; and 4, 432, 098, Feb. 14,1984. These patents are assigned to Honeywell.

Fractional Charges, Magnetic Monopoles, and Magnetic Currents

Fifteen years ago, a most distinguished gathering of physicists occurred in Trieste, Italy to review the physicist's conception of nature and how it developed. Seven Nobel Laureates were in the prestigious audience. The keynote address, appropriately, was given by P.A.M. Dirac, and — appropriately — was entitled "Development of the Physicist's Conception of Nature."

Dirac called attention to the possibility of fractional charges, and unexpectedly presented some of the data from experiments done lung before by Felix Ehrenhaft.

Years earlier Felix Ehrenhaft, former director of the Physical

Institute at the University of Vienna, had reported a number of experiments where — purportedly — he easily obtained fractional electrical charges.

Whereas Millikan had used liquid oil drops in his experiments to determine the charge of the electron, Ehrenhaft used little solid, red selenium oxide spheres. Not only could Ehrenhaft get a fractional charge, but he could actually vary the size of the fraction by varying the size of the spheres.

(Knowing what has been discovered in the last two decades on the complex bond structuring of water and liquid hydrocarbons, one might very well suspect that a solid — which has one less degree of freedom than a liquid — could possibly yield a very different experimental condition from a liquid, from first principles. However, no one seems to have noted that, or taken it into account.)

(Also, Ehrenhaft's results were replicated by other researchers who used his experimental methods. They published scientific papers, but that made not a whit to the scientific community, which simply rejected the experimental evidence.).

Dirac pointed out that Millikan himself, in his oil drop experiments that established the charge of the electron, reported one anomalous experiment which yielded a fractional charge. He discarded the results of that experiment.

Ending his speech, Dirac stated that it all made him wonder if perhaps Millikan did have a fractional charge in that one experimiment after all. And well he might wonder. Ehrenhaft — almost unknown now to the present generation of physicists — may have found not only fractional electrical charges, but the magic magnetic monopoles as well.

Over and over, Ehrenhaft reported the results of experiments which disagreed with the notions of magnetic theory at the time.

Again, some of these experiments were replicated, and reported by those researchers replicating them.

It didn't make any difference at all.

Now, finding a magnetic monopole — and the accompanying magnetic charge current — would be most satisfying to many theorists. That would make the equations of magnetics quite "balanced" with respect to electricity.

However, no one —at least whose results have been accepted -

has yet found a magnetic monopole or magnetic current.

Stanford researchers have perhaps come closest, and even reported the results of one exciting experiment that found the magnetic monopole. However, the team has consistently failed to be able to replicate those results. And in science, "no replication, no acceptance" is necessarily the dictum.

In a moment we will address a possible cause for this failure to find the magnetic monopole and magnetic charge current.

Some Ehrenhaft Experiments

Let's look at some simple, rather informal experiments that Ehrenhaft showed. We call attention to Alden P. Armagnac's excellent article , "Magic with magnetism," in **Popular** Science **Magazine,** June 1944, p. 130-133, 222, 226. In the first experiment, Ehrenhaft seems to have dissociated water with a permanent magnet.

First, Ehrenhaft seals two rods of pure iron, in holes through opposite sides of the U in a U-shaped glass tube filled with water. Then he uses the two rods — which protrude through the tube into the water — as the pole pieces of a horseshoe magnet — either an electromagnet or a permanent magnet. Dilute sulfuric acid — one percent by volume — is in the water, to give it a very slight acidity.

Bubbles of gas rise up through the twin vertical columns of water, and are collected and analyzed. Most of the gas is hydrogen, as is to be expected from common chemical interaction of the iron rods with the very dilute sulfuric acid. However, some of the gas — ranging from two to twelve percent — is oxygen, and most of the oxygen is produced at the north pole of the magnet.

The pole pieces may be short-circuited with wire, to insure they are at the same electrical potential and prevent any electrical dissociation of the water.

Without the magnet, all the gas liberated is hydrogen, as is to be expected. No oxygen at all is produced.

And another very interesting phenomenon occurs. A strong permanent magnet of the Alnico type gradually loses a marked fraction of its strength — say, 10% in 24 hours. It appears that the energy dissociates water — very similar to electrical energy from a battery draining away when electric current is used to dissociate water.

The real question is: Is this experiment a demonstration of magnetic current?

If it is, then the textbooks are wrong, and there's another constituency in magnetism that has not been taken into account. Further, if it proves magnetic current exists, it has also proven magnetic charge — the magnetic monopole — exists.

If it is not a demonstration of magnetic current, then what is it? Why don't you get any oxygen liberated when the magnetism is removed? What causes the magnet to discharge its magnetic strength?

These serious questions do not appear to have ever been resolved.

In all fairness, however, we must warn the reader that other factors in the water can very seriously affect the outcome of this

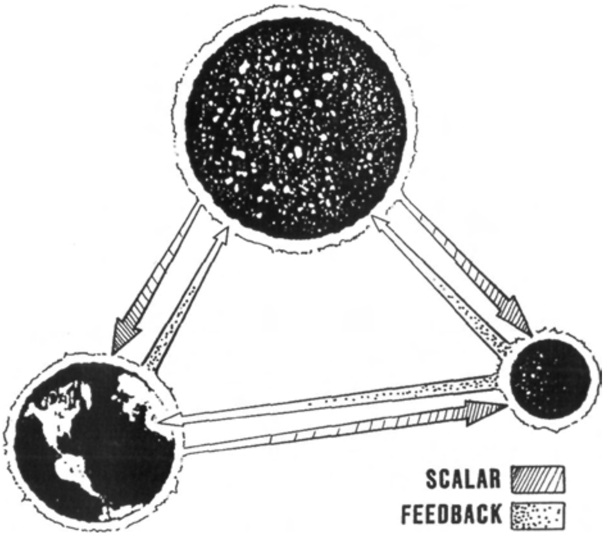
EARTH • SUN - MOON TRIAD

Figure 69. Earth, sun, and moon are locked into a triad system. They exchange both normal energy and phase-conjugate energy. The phase-conjugate energy (negative energy, negative time) streams affect all "subtle-energy" earth experiments

experiment. As we now know, the bonding structure of water is incredibly adaptive. Every bit of water you examine, for example, is absolutely unique in many respects. And in other respects, it's a sort of "single giant molecule."

Be forewarned also that subtle experiments with water are affected by just about everything under the sun. Including the sun!

Ehrenhaft himself was quite embarrassed when this "decomposition of water" failed to be 100% repeatable. It can be done — but you may have to work at it a bit. The best water for this experiment is the most natural, pure ground water you can obtain.

At any rate, it may be that these experiments of Ehrenhaft's are related to the old notion of "watergas" — the changing of water in some fashion so that, as it enters an internal combustion chamber, it decomposes into hydrogen and oxygen, and is ignited by the spark and burns as a fuel. In the typical watergas case, the experimenter has a "green powder" which, when added to water, will allow it to be burned as a fuel when it is used in an ordinary engine. Such a capability, for example, seems to have been exhibited at least once, to the U.S. Navy, by an unorthodox experimenter named Anderson.

Of course, if fractional charges exist and can be controlled (and Ehrenhaft's experiments certainly seem to confirm this), then it is conceivable that a material could be found that would do the "green powder" function. That is, if the bonding electron that bonds hydrogen and oxygen in water were replaced by a fractional charge, the "fractionated water molecule" could just barely be holding together an a liquid. A strong hydroshock — such as going through the jet nozzles in a carburetor — could then cause many of these molecules to break apart, effectively dissociating the water.

A possibly related phenomenon was reported by Le Bon in his Evolution of Matter. The experiment was to hold a piece of ordinary aluminum under the surface of mercury in a container for a period of time. Then the piece of aluminum is taken out and thrown into a container of water, where it violently dissociates the water. At least one colleague was able to replicate this experiment by holding the aluminum beneath the mercury for 36 hours.

These Ehrenhaft experiments may also be related to the extensive use in the Soviet Union (and to some extent, in the U.S.) of magnetic treatment of water pipes so that boilers do not develop so much hard precipitate. Magnetic treatment of water, for example, can rigorously be shown to alter some of a liquid's properties.

Ament, for example, in numerous well-controlled repetitions has clearly shown an increase in auto gas mileage by using a strong magnetic apparatus on the fuel line. Best results are obtained by a magnet which only has one polarity facing the fuel line, and using three stages where the middle polarity is reversed. The effect of this apparatus is definitely scalar EM (gravitational) and expressed in the atomic nuclei in the molecules of the fuel flowing through the line.

Again, the Ehrenhaft experiments may be related to the strange results of Viktor Schauberger, who obtained motive results with water and natural energy that have not been duplicated before or since, so far as anyone can tell.

Schauberger utilized "implosive" energy rather than "explosive" energy — strongly suggesting he was using the negative time aspects of energy, hence negentropy. Schauberger also conceptualized this energy in a spiral form — and that is precisely the type of motion Ehrenhaft observed in many of his bubble experiments. That such negative time/negative energy is "natural" energy will be apparent from our next chapter, where we point out that all living things must use negative time/negative energy processes if they are to defeat the inexorable law of entropy — the increasing disorder of a system as its positive flow of time progresses.

Note, **for** example, **that a** system **that is 20% efficient in positive time would be 500% efficient in negative** time.

Let's look at another of Ehrenhaft's magnetic experiments.

Taking the air gap between two very flat, very parallel pole pieces of sufficient width, one obtains a very accurately-parallel, uniform magnetic field in between them. Now suppose you place some very small particles of material—both magnetic and nonmagnetic — in the air gap.

Common sense assures us that, if closer to the south pole, for example, one of the little magnetic particles will be attracted by **the** preponderance of south polarity. That is, a little magnetic north **pole** will be induced on the side of the particle nearest the south polepiece, and a little south pole will be induced on the particle on the side away from the south polepiece. The little particle will then be attracted to the south polepiece.

Again, common sense assures us that, if closer to the north pole, the situation is reversed and the little particle is attracted to the north polepiece.

Well, that isn't quite what happens. Some move to the south polepiece, and some move to the north polepiece. And it seems to vary by the type of material the little particle is comprised of.

Now try another experiment. Let's make a permanent magnet motor. Understand, this one is not quite "for free," for we'll consume "fuel"—the strength of the magnet and the acidified water solution.

In this one, we use a glass cylindrical cell, with one vertical iron rod at the top and another at the bottom, and the rods serving as the pole pieces of a giant horseshoe magnet. (Or, for ease you can use an electromagnet). The cell is filled with the same acidified solution as before.

Without the magnet, hydrogen bubbles can be seen rising as before.

Now put on the magnet (or turn on the switch). Voila! the situation with the bubbles changes drastically. A spectacular miniature merry-go-round — a "whirligig" — of bubbles forms between the faces of the poles and parallel to them.

Add some copper particles to the solution. The particles will rotate in the same plane, but in opposite directions from the bubbles. The stronger the magnetic field, the faster the particles and bubbles will contrarotate.

If the magnetic field is reversed, the rotation of both the bubbles and the copper particles is reversed.

Only a few months after this was reported in Popular Science Magazine, Brother Gabriel Kane of Manhattan College and Charlea B. Reynolds of the Federal Communication Commission confirmed Dr. Ehrenhaft's discovery of magnetic currents.

They made a drop of copper sulfate solution spin between the polepieces of a permanent magnet. They also made an interposed microscope cover glass spin from the rotation of the copper sulfate.

It was hinted they were heading toward power machinery. If so, nothing else was heard — possibly because they never solved the problem of consuming the magnet's strength and the acidified solution.

Bill Mueller, the present inventor of a free-energy device, has also demonstrated the spinning of a piece of plastic in a magnetic field.

After WWII, Dr. Ehrenhaft returned to his post in Vienna, published later work in French and other scientific journals, and died not long after.

What is a magnetic monopole?

First, let's reiterate what we mean by "magnetic field." It'll take a little bit to get there, so please bear with me.

By electric charge, we mean the virtual photon flux connected with a particle of mass or an object (of mass). One type of charge (by convention, positive) is modeled to constitute a "source" of this flux. The second type of charge (negative) is modeled to constitute a "sink" of this flux.

Everything in electromagnetics is fluid flow, you see. The old guys who formed the theory believed that electricity was a thin material fluid. So they modeled it that way.

They modeled the positive charge as an everlasting "sprayer" and the negative charge as a "sink" or everlasting accumulator.

They reasoned that of course this "stream" of electric fluid could "swirl" or rotate, just as normal fluids can.

This "swirl" in the stream of virtual photons is magnetostatic scalar potential — or magnetic pole for short.*

Obviously there can be two directions of swirl — one right-handed, and one left-handed, with respect to the direction of the virtual photon stream. So there are two kinds of "magnetic pole" — north (right-hand swirl) and south (left-hand swirl).

The strength of one of these "swirls" can vary, of course, and that's a variation in the strength of the corresponding pole.

You can also think of the "pressure" of the swirl, so to speak, **at** least for modeling purposes. In that model, north swirl is "higher

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*Rigorously, a permanent magnet does not produce an observable B field in vacuum! Instead, it produces the dynamic, swirling "potential" for that field — i.e., an **unzipped** field. A particle of observable mass placed in this field integrates and "zips" — producing the observed B-field on and of the spinning observable particle.

than ambient" pressure, and south swirl is "lower than ambient" pressure, where "ambient" means "with respect to right-hand swirl." The swirl pressure is then considered to "bleed off/flow" from north pole to south pole. This is modeled by Faraday's "flux lines of force." This bleed off (gradient) from north pole to south pole is called the magnetic force field, or just "magnetic field" for short, even though in vacuum it's really an *unzipped* magnetic field.

Note that the original modelers didn't consider negative time and negative energy at all. And they didn't know anything about phase conjugation — in fact, the electron had not even been discovered when all this model was originally put together.

But back to the model. Considering the swirling fluid as "conserved", if you produced a concentration of one kind of swirl at one place, you had to decrease the concentration elsewhere, which is the same as producing and adding opposite swirl there. Thus, conceptually, in the simplest case (only two swirls allowed), a north pole and a south pole always occur together in a pair — though of course there's no limit to the distance between the pair.

Notice that if you have a conservative field such as we assumed, you are keeping your overall frame of observation Lorentzian — in other words, conservative. You do not have a "curved spacetime" to speak of, by assumption.

Now of course, you can have compound and very complicated magnets and magnetic fields — you don't always have to have everything so neat and simple. In that case, conceptually you could have — for example — one north pole and two south poles.

In fact, it's easily possible to demonstrate that: a bar of magnetic material is simply magnetized so that a north pole is in the middle, and a south pole is at each end. Now bend it around a bit, and you get the point.

However, now let us suppose that we curve spacetime itself, locally — something they avoid in present physics by pure assumption.

Specifically, we curve our local spacetime in such a fashion that there's more right-hand swirl in the local region than there is left-hand swirl there.

In that case, we have a north-pole region there , all by itself. We have a magnetic north monopole. If that "curved spacetime" region of trapped swirl is moving, that constitutes magnetic current, and it may be either positive (north polar) or negative (south polar) flow.

It's as simple as that! Only when you curve local spacetime can you get a magnetic "charge" or monopole. Everyone who's trying to demonstrate a magnetic monopole in uncurved spacetime is doomed to failure a priori. It takes but little reflection to see that, conceptually, a magnetic monopole is a curvature of local spacetime. Indeed, each of the two poles of a bar magnet is precisely that anyway.

Now a monopole can indeed be "made", by bending local spacetime correctly. It can be made in two ways: in the virtual state vacuum itself, or in and on physical materials. It's easiest to make it in the virtual state: just curving the local spacetime will do that. When this "excess swirl flux without corresponding antiswirl flux" is impressed into and onto matter, however, the atomic nuclei are affected, producing excited "magnetic states." In addition, a great deal of physical stress is created in the material, due to monopolar repulsion between the various "nuclear monopoles deposited in it."

If a sufficiently strong monopole intensity (magnetic charge) is produced in the material, the material will violently fragment from internal stress. When a metal, for example, undergoes such **a** "monopolar fragmentation", it is common to see "tiled edges" of the metal rupture, much as twisted little "planks" or tiles of metal unfurled and "split." Such a break may be a positive signature of the involvement of virtual magnetic monopoles (i.e., by the metal having acquired virtual magnetic monopolar charge, causing the disruption).

This precise type of metal fracture has been very well demonstrated in experiments by Canadian experimenter John Hutchinson. Anomalous, powerful breaks in metal have been obtained by Hutchinson where the two ends that break apart both have a north pole or a south pole.

The anomalous **hole in the fuselage of the Arrow DC-8 destroyed at Gander Air Force Base, Newfoundland on Dec. 12,1985,** strongly suggests that an electromagnetic missile struck the aircraft, inducing monopolar effects. That would also match the- **three** eyewitnesses' description of an anomalous glow on part of the aircraft as it faltered and then fell.

Supercharges and Fractional Charges

Now without further ado, let me just state flatly that the only way to get a fractional charge is to have an appreciable curvature of local spacetime.

To get that local curvature, it's going to be very difficult to use liquid. For weak effects, it will almost always change its bond structure and not localize the curvature in the nuclei. So "fractional charges" in liquid are much harder to come by.

However, with solids it's a different thing, particularly if you make the solid material very, very small and nonlinear — precisely like Ehrenhaft's little red selenium oxide spheres. There you can get **the** curvature to localize without so much bleedoff through the bonding lattice.

The greatest electrical wizard of all, Nikola Tesla, reported producing electrons with 50 times the normal electrical charge of an electron. That's readily understandable if you look at what's happening to the charge of a particle: To have 50 times as much charge, the electron must be exchanging virtual photon flux with its surrounding vacuum at 50 times the rate of the normal vacuum.

In other words, *it's the vacuum (spacetime) which must be*

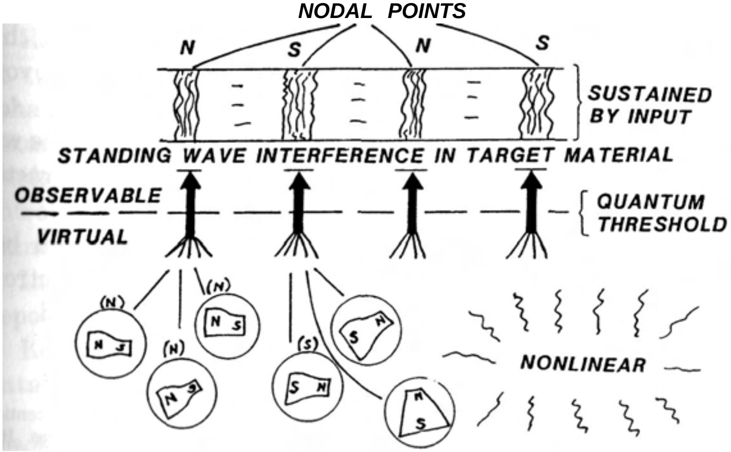
NODAL POINTS
N
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SUSTAINED BY INPUT
STANDING WAVE INTERFERENCE IN TARGET MATERIAL
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(N)
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NONLINEAR

Figure 70. Forming magnetic monopoles with a standing scalar EM wave. In a nonlinear vacuum (locally curved spacetime), virtual magnetic monopoles can be formed and deposited in materials.

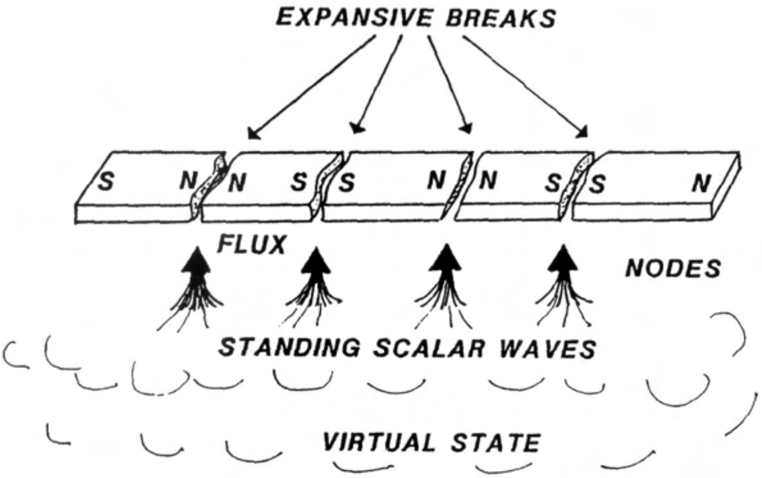

Figure 71. Metal fracture by depositing magnetic monopoles. Demonstrated by Canadian researcher John Hutchinson.

changed, not the electron! Actually, that happens anyway whenever the electron is in an electrical potential field. There are many unrecognized assumptions in the postulate that the electron charge is fixed.

If you curve local spacetime in one direction, you get the charge, of an electron increased. If you curve it in the other direction, you get the charge decreased. In that case it's called a *quark*.

At any rate, our own scientists have been looking in the wrong way and in the wrong place for magnetic monopoles and fractional charges.

Work such as that of Ehrenhaft and others should be re-evaluated. And, most certainly, the basis of the present electromagnetic theory should be both re-examined and reformulated.

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*Such as the implication that the free electron is always free to move, and that potential surrounding the electron always possesses a translating gradient when it changes. It does not consider the case where the virtual flux exchange between electron and vacuum increases isotropically, centered on the electron. That, of course, represents an *excited charge* of the free electron.

CHAPTER 5

EXTRAORDINARY BIOLOGY

Kervran's Proof of Biological Transmutation

In orthodox chemistry, one of the strongest dogmas is the stubborn insistence that it is impossible to create another element by chemical reaction. Most chemists also insist that all reactions occurring in living systems are chemical in nature. They believe fervently that chemistry can and must explain life itself.

In the early 1960's, a French researcher named Louis Kervran published work which flew directly in the face of the accepted chemistry dogma. Kervran reported the astounding results of his research showing that living plants were able to accomplish limited transmutation of elements. Kervran was then the Conferences Director at the University of Paris, and his first paper was published in **La Revue Generale Des Sciences,** July 1960.

What was so revolutionary was that, according to the prevailing wisdom of science, you can't transmute elements (permanently change the nucleus) except with enormous energy — certainly not with the microvolts and millivolts (and microwatts and milliwatts) that living systems can muster electromagnetically. *

Rutherford, the British physicist who discovered the nucleus of the atom, had shown in 1919 that you can bombard elements with alpha particles and transmute them. The accepted wisdom of today is exactly the same, except that the physicists have used heavier and heavier "bullets" in their artillery approach. No one has tried a controlled approach, for the catchecism is that you have to use the *wham it harder!* approach.

In other words, to most scientists the whole thing had to be preposterous, and Kervran had to be deluded.

Kervran published further details of his work in a book, **Transmutations Biologiques,** Maloine, Paris 1962. But the initial reaction of most scientists was disbelief and skepticism. Few scientists would stoop to repeating Kervran's experiments, which of course they knew could not work anyway.

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*Note, however.that since gravity is infolded EM, one can have extremely powerful infolded EM, yet only have miniscule electrical (outfolded) residues. Thus the actual "available power" in artificial biopotentials may not be quite so small after all.

Actually the effect is widespread amongst living systems. As Kervran pointed out, the ground in Brittany contained no calcium; however, every day a hen would lay a perfectly normal egg, with a perfectly normal shell containing calcium. The hens do eagerly peck mica from the soil, and mica contains potassium — a single step below calcium in the standard table of elements. It appears that the hens may transmute some of the potassium to calcium.

Further, if one tests this assumption, it is quickly shown to be true. Hens denied calcium but not potassium, stay perfectly healthy and lay perfectly normal eggs. Hens denied both potassium and calcium will be sickly and lay only soft-shelled eggs. If these sick chickens are allowed to peck only mica — which they will frantically do — everything returns to normal again.

Most orthodox scientists nevertheless remained skeptical or downright hostile.

However, a few other scientists began to repeat Kervran's

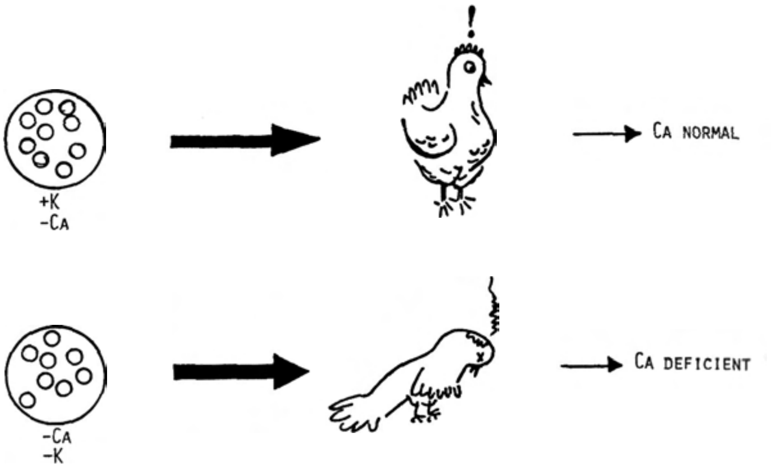

Figure 72. The Kervran effect. A biosystem can accomplish limited transmutation of elements.

experiments and replicate his results. Several of these corroborating scientists were (1) Professor Hisatoki Komaki, Chief of the Laboratory of Applied Microbiology at a leading Japanese university, (2)Professor Pierre Baranger, Head of the Laboratory of Chemical Biology of the Ecole Polytechnique in Paris, and (3) J.E. Zundel, then head of a paper company with a chemical analysis laboratory, and later a chemical engineer of the Polytechicum School of Zurich, Switzerland.

Later work by Zundel was particularly decisive: he utilized the mass spectrometer at the Microanalysis Laboratory of the French National Scientific Research Center, and neutron activation mass analysis at the Swiss Institute for Nuclear Research in Villigen to positively confirm an increase in calcium of 61% to an accuracy of 2%. Such results and instrumentation, of course, removed any doubt that the effect could be due to statistical variation. In the same experiments, the plants increased their phosphorus 29% and their sulphur 36%.

Komaki became head of a research laboratory at Matsushita Electric Company. There he conducted research conclusively proving that microorganisms (including some bacteria and two kinds each of molds and yeast) could transmute sodium into potassium. In fact, he placed a brewer's yeast product on the market that, when applied to composts, increases their potassium content.

Extensive work in the area has been done in the Soviet Union, where results similar to Kervran's have been substantiated.

Thus all doubt (to an open-minded scientist) was removed: living systems are able to change one element into another by some unknown means, using very feeble energy.

A noted French physicist, O Costa De Beauregard, suggested a mechanism for the transmutations, using weak force interactions and advanced waves.

No one — even Kervran himself— thought of negative energy/ negative time interactions. The jury is still out on the actual mechanism, but it is absolutely clear that the transmutation does indeed occur.

The Japanese researchers, having replicated Kervran's astounding results to their complete satisfaction, recommended him to the Nobel Committee for a Nobel Prize for such epochal work. Thus Kervran became a Nobel nominee, though he was not granted the prize.

Kervran has since passed away, leaving behind his books and papers that point to a revolution in chemistry and physics - transmutation of elements at very weak energy.

Biological Transmutation Has a History

Actually biological transmutation — and transmutation of elements (alchemy) in general — has a history, of both results and suppression.

Louis Nicolas Vauquelin, a celebrated French chemist, discovered that chickens could produce more calcium in their eggshells than entered their bodies. Hence they had to be able to "create" the calcium, else their own bodies would have been completely depleted.

One of his contemporaries, however — Antoine Laurent Lavoisier — became the "father of chemistry." Lavoisier laid down the dictum that nothing was created. So chemistry fixed upon the notion that the combinations of elements could be shifted, but the element itself could not be transformed.

Not until the discovery of radioactivity did any crack in this solid wall appear. But still, the basic ideas of chemistry said the element couldn't be transformed chemically. It could only be transformed if one blasted the daylights out of it with an atomic or particle bullet. .

Today most chemists still hold that exact same opinion, unshaken.

To resume: Over a century ago, a chemist named Albrecht von Herzeele proved that germinating seeds somehow transmuted elements in the process. In 1873 von Herzeele published a book, **The Origin of Inorganic Substances,** where he showed research proving that plants continuously create material elements.

Even earlier, in 1822 an Englishman named William Prout had studied chicken eggs in incubation. He found that hatched chicks had more lime (calcium) in their bodies than was originally present in the egg!

Another French scientist named Henri Spindler discovered that, a kind of algae called Laminaria could create iodine.

A German researcher named Vogel had planted cress seeds in a

bell jar. They were fed nothing but distilled water; still, when grown they contained more sulphur than had been in the seeds originally.

Lawes and Gilbert, two British researchers, also found that plants could "extract" more elements from the soil than the soil actually contained in the first place.

Baranger performed thousands of meticulous experiments in plant transmutation of elements. He proved that the transmutations do occur. He also discovered that many things affected the germinating seed transmutation process: the time the seeds germinate, the type of light they are exposed to, the phase of the moon, etc.

None of these experimenters understood the transmutation process used by the living organism. But they proved beyond question that the process existed, and universally occurred.

Surplus-of-Energy Mechanisms Proposed by the U.S. Army

There has also been other very positive support for the thesis that if living systems transmute elements, they can produce a net source of energy in the process.

In 1978 an officially-funded effort of the U.S. Army Mobility Equipment Research and Development Command, Fort Belvoir, Virginia positively confirmed that mechanisms for elemental transmutations could occur in biological systems, from an energy consideration.

The work was performed under the direction of Emil J. York, Chief of the Material Technology Laboratory. Solomon Goldfein was the principal investigator for the effort. Robert C. McMillan, Chief of the Radiation Research Group of the laboratory, provided guidance on matters of physics and nuclear physics.

The abstract of the final report (S. Goldfein, Report 2247, **Energy Development from Elemental Transmutations in Biological Systems,** U.S. Army Mobility Equipment Research and Development Command, May 1978. DDC No. AD A056906.) reads as follows:

"The purpose of the study was to determine whether recent disclosures of elemental transmutations occurring in biological entities have revealed new possible sources of energy. The works of ***Kervran,*** *Komaki, and others were surveyed, and it was concluded*

that, granted the existence of such transmutations (Na to Mg, K to Ca, and Mn to Fe), then a net surplus of energy was also produced. A proposed mechanism was described in which Mg adenosine triphosphate, located in the mitochondrion of the cell, played a double role as an energy producer. In addition to the widely accepted biochemical role of MgATP in which it produces energy as it disintegrates part by part, MgATP can also be considered to be a cyclotron on a molecular scale. The MgATP when placed in layers one atop the other has all the attributes of a cyclotron in accordance with the requirements set forth by E.O. Lawrence, inventor of the cyclotron."

"It was concluded that elemental transmutations were indeed occurring in life organisms and were probably accompanied by a net energy gain."

The researchers also concluded that elemental transmutations occurring in life organisms are accompanied by losses in mass representing conversion to thermal energy, and that such energy probably is a net gain when compared to the amount required to effect the transmutation.

All in all, they concluded that the little cell with its feeble energy does quite well! It's in control of cyclotrons, and cyclotron forces, and direct conversion of mass to energy. Pretty good for a little bitty beastie, wouldn't you say?

Actually, one should point out that, according to nuclear physics, an atom gets a little heavier when it absorbs (usually by means of an orbital electron) a normal "positive energy" photon. That is, the addition of positive energy results in the addition of a little bit of "positive mass."

Negative energy, of course, does a similar thing to the nucleus — except that it adds "negative mass." Thus the nucleus of the atom, when it absorbs negative energy, gets lighter. This is seen in the external world as "loss of mass."

With our present nuclear physics, only positive energy is assumed except in extremely rare cases.

Thus the Army study — which was conducted and controlled by some excellent scientists — worked out a "loss of mass" the way they're trained to.

By adding some positive energy, the nucleus would gain some positive mass. **By adding some negative energy, the nucleus would lose some corresponding positive mass. The conventional physics then would equate this "loss of mass" as the direct conversion of mass to energy. And so it is, only it's conversion to negative energy!**

However, by pointing out the cyclotron mechanism in the cell MgATP, the Army researchers have made a most important contribution.

Note also that the whirling motion may be very much related to Viktor Schauberger's work and to Wilhelm Reich's work. Both of them worked with what they viewed as an unusual kind of living, spiraling energy.

All the orbital electrons of an atom also are whirling around in orbit, in the simplest model. Further, these orbits themselves move and rotate or precess.

Similar orbits and shells occur in the nucleus, at least in some models (several rather independent models are used there for specific things.)

It may be that a whirling, spiraling (cyclotron) energy motion is necessary to connect positive energy to orbital electron (negative charge) shells, and to connect negative energy to positive charge shells in the atomic nucleus. *

Alchemy ***and Unusual Critters***

In ancient times, the old alchemists pursued the dream of making gold. Obviously, if one could do that economically, one could become quite wealthy.

Just as obviously, the kings and rulers of the world took rather **a** dim view of such proceedings. After all, much of their own power rested on their ability to get and control gold. And if some "loose cannon" could make all the gold anyone wanted, then the national **treasury** of the king wouldn't be worth a plugged nickel. And that would finish the king, for he would be powerless.

•The spinning/whirling motion may be viewed as integrating the unzipped vacuum flux virtual vectors into zipped observable force vectors —just as great grandma's spinning wheel integrated fibers into continuous threads.

There are some unorthodox researchers today who take the view that the alchemists were stamped out—*not because they failed, but because they succeeded.*

I subscribe to the same view.

T.H. Moray had a process to "recover finely divided gold from quartzite sands." My personal, strong belief is that he possessed a practical transmutation process. His knowledge and techniques, of course, are still possessed by his sons, and reside through them in Cosray Research Institute, Salt Lake City, Utah.

The possession of such a technical secret may be one of the major reasons why the Morays have met with such intrigue, harassment, and suppression over the years.

To speak further on "making gold," we first have to present some details on some special "critters" that live, but that can't be observed through a normal microscope — even an electron microscope.

In that vein, toward the end of this chapter, we will present some of Royal R. Rife's fundamental discoveries. Pay particular attention to his discovery of "finer" living forms — which today we could only refer to as "living energy, virtual-state forms."

Let's call them **critters** for short.

At one time, when the earth was young and the radiation from the sun was different, conditions on earth were much hotter. Great volcanic activity and fiery eruptions were commonplace and nearly continuous. Huge storms, of size and magnitude undreamed of today, swept the primitive atmosphere. The oceans were frenzied.

Under those conditions, many types of "critters" were highly active. Most of the critters, for example, lived in and worked on the atomic nuclei of matter .

After all, the critters are living, virtual-state organisms. There's a continual exchange between the virtual state (the vacuum, or spacetime) and mass (the observable state). An atomic nucleus is like an island in the "virtual state ocean", and the flux interchange is like waves breaking onto the island and then washing back to sea. The critters live in that ocean, and wash upon, so-to-speak, the mass-islands and interact with them.

In those primal days, many of the present great mineral deposits of the earth were created due to the transmutation activities of the critters.

One kind, for example, lived in copper. In an "energetics" sense, this critter "ate" copper and "excreted" gold, so-to-speak. Much of the gold that occurs in great copper deposits today was formed this way in the old days under primal conditions.

When conditions on earth changed, these little "copper critters" ceased their incessant activity and became dormant, just as viruses can do. But the critters are still there in the copper ore, waiting to be activated.

And activate them you can! You can even get the critters into a solution, and then crystallize them out as crystals.

These crystals are what the alchemists of old called the **philosopher's stone,** with the power to transmute base elements into gold. There are several kinds of philosopher's stones; this kind is for copper.

At any rate, you can then place these special crystals on some copper (and add another thing or two), and restore them to a similar primal environment as of old. That is, heat them in an electric furnace. Blast them with terrible electrical bolts. Bathe them in intense ultraviolet light. That's just a nice, refreshing spring day for the critters!*

That stimulates them and revives them. They wake up after a long sleep — and they're immediately "hungry." So they go right to work on the copper. Boom! In a little bit there isn't any more copper, just mostly gold, with a little other miscellaneous residue thrown in, such as black ruby and silver (in the experiments of one of my close colleagues).

The gold is radioactive when first made. Fortunately, all isotopes of gold are very short-lived: just minutes suffice for the radioactivity to die away. So you wait half an hour and everything's okay.

That's all there is to it.

And if you do that and try to capitalize upon it, your life expectancy is about 24 hours.

I don't know whether or not biological systems, in their Kervran-transmutations at weak energy, deliberately manipulate similar "critters." I suspect, however, that they do, at least to some extent.

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*Note the probable similar effects involved in the Miller-Fox-Urey experiments in biogenesis

The Cell Also Lives and Functions in the Virtual State

Obviously, to transmute elements the living system has to be able to directly affect and influence the atomic nucleus.

It has been shown that this is a cellular capability, for single-celled organisms can do it.

As we shall see, Rife's work showed that the living cell is connected to at least 16 intemested deeper levels of reality than a relative "point" under an ordinary microscope. Further, all levels are structured and organized.

Think of it! Each one of those levels is to the preceding level as microscopy today is to the normal world. Sixteen levels!

I think it's reasonable to state that the life of the cell is patterned and dynamically structured and functioning all the way into the virtual state; indeed, to very deep intemested levels of the virtual state. That is, it also functions *hyperspatially*.

We shall also see that the mind and thought involve these more subtle physical (though virtual) levels.

Thus the living virtual-state levels are a reality, for Rife proved it.

The living organized structures at each level are a reality, for Rife proved it.

The living ordering and control of dynamic functions on all those levels is a reality, for Rife proved it.

Those living virtual-level parts of the living organism — plant or animal — thus affect, function in, and reside in the atomic nuclei of the material that composes its bodily structures.

Beasties like bacteria and viruses also have living, organized energy structures in multiple levels of virtual state. Apparently, for these more primitive life forms, the virtual-state "energy part" can be separated and pass through a filter, then re-engender the physical form and/or itself cause the disease in a host! At least that is what Rife and other scientists showed.

"Bigger fleas have smaller fleas to bite 'em, And so on, ad infinitum."

Of course the living system can "work on" the nucleus and change it a little bit! If it couldn't do so, it couldn't stay alive and function in there in the first place!

The Kaznacheyev Experiments

Dr. Vlail Kaznacheyev is Director of the Institute for Clinical **and** Experimental Medicine in Novosibirsk.

For 20 years he has been directing highly unusual experiments with twin cell cultures. These experiments are vital to understanding disease and healing on a more fundamental basis than is presently utilized by orthodox medical science.

The Kaznacheyev experiments (several thousand) in the Soviet Union proved conclusively that any cellular disease or death pattern can be transmitted electromagnetically, and induced in target cells absorbing the radiation.

In the experiments, two sealed containers were placed side by side, with a thin optical window separating them. The two containers were completely environmentally shielded except for the optical coupling.

A tissue was separated into two identical samples, and one sample placed in each of the two halves of the apparatus.

The cells in one sample (on one side of the glass) were then subjected to a deleterious agent — a selected virus, bacterial infection, chemical poison, nuclear radiation, deadly ultraviolet radiation, etc. This led to disease and death of the exposed/infected cell culture sample.

If the thin optical window was made of ordinary window glass, **the** uninfected cells on the other side of the window were undamaged **and** remained healthy. This of course was as expected in the orthodox medical view.

However, if the thin optical window was made of quartz, a most unexpected thing happened. Some time (usually about 12 hours) after the disease appeared in the infected sample, the same features of disease appeared in the uninfected sample.

This startling "infection by optical coupling" occurred in a **substantial percentage of the tests (70 to 80 percent). From an orthodox medical view, these results were unexpected and unheard of.**

Further, if the originally uninfected cells were in optical contact

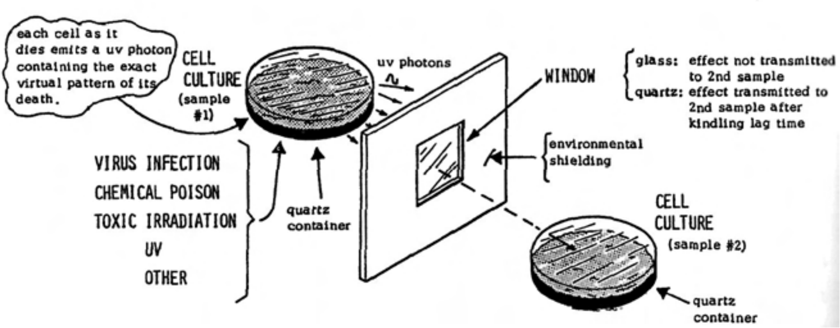
each cell as it dies emits a uv photon containing the exact virtual pattern of its death.
CELL CULTURE (sample #1)
uv photons
WINDOW
glass: effect not transmitted to 2nd sample
quartz: effect transmitted to 2nd sample after kindling lag time
environmental shielding
VIRUS INFECTION
CHEMICAL POISON
TOXIC IRRADIATION
UV
OTHER
quartz container
CELL CULTURE (sample #2)
quartz container

Figure 73. The Kaznacheyev effect. Thousands of experiments proved that (1) cellular disease is electromagnetic, and (2) it can be induced electromagnetically at a distance. Also called the cytopathogenic effect.

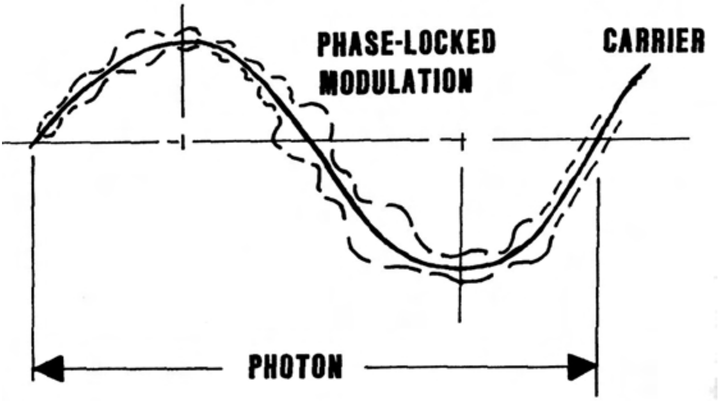
PHASE-LOCKED MODULATION
CARRIER
PHOTON

Figure 74. A photon is one oscillation of an electromagnetic carrier. It may have substructures that are modulations. Such a structure is called a "giant photon," or a "compound photon."

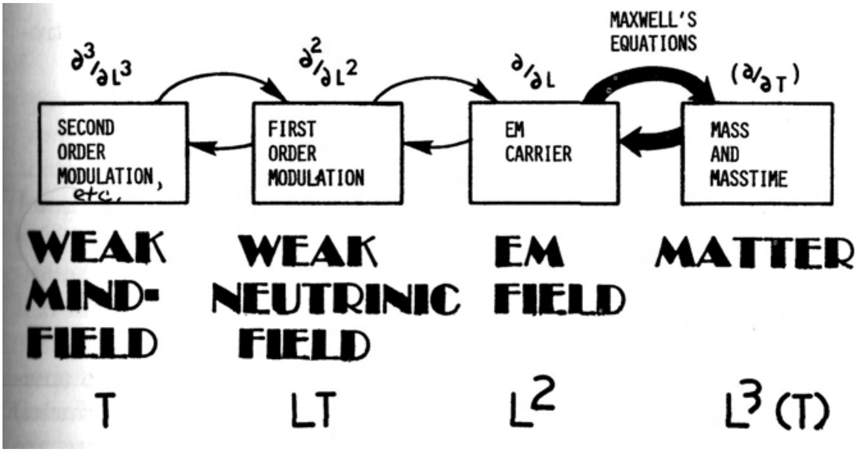
MAXWELL'S EQUATIONS
∂³/∂L³
∂²/∂L²
∂/∂L
(∂/∂T)
SECOND ORDER MODULATION, etc.
FIRST ORDER MODULATION
EM CARRIER
MASS AND MASSTIME
WEAK MIND-FIELD
WEAK NEUTRINIC FIELD
EM FIELD
MATTER
T
LT
L²
L³ (T)

Figure 75. Nested modulations are the key to hyperspatial engineering.

with the infected cells for 18-20 hours or so, and then were correspondingly exposed (optically coupled) to another uninfected cell sample, symptoms of the infection appeared in this third sample an appreciable portion of the time (20 to 30 percent).

Guided by A.G. Gurvitsch's work that showed that cells give off mitogenetic radiation (photons) that can affect other cells, the Kaznacheyev team sought an answer by looking for photons given off by the infected culture sample as its cells died.

They found that the cells in the infected culture gave off photons in the near ultraviolet when they died. The normal window glass was opaque to these near-UV photons and absorbed them. In that case, the uninfected culture on the other side of the glass was not exposed to radiation by the UV "death" photons from the dying cells, and they remained serenely healthy.

However, the quartz window was transparent to the UV "death photons". When the quartz window was installed, the UV "death photons" passed through it and were absorbed in the uninfected culture on the other side of the window. Most of the time, the uninfected culture which absorbed "death photons" sickened and **died** with the same disease symptoms.

The Kaznacheyev experiments proved conclusively that cellular death and disease patterns can be transmitted and induced electromagnetically.*

Structuring and Charging a Biopotential

Kaznacheyev thus demonstrated that a photon information/ regulatory system exists in biological systems due to a continual influx of EM energy from outside the system. That is, the cells of the biosystem are charged with an electromagnetic potential, and additions and changes to the potential are continually received. The cell is thus in minute disequilibrium.

Usually the myriad of continual inputs from the external environment into the cell's potential charge pattern (in its atomic nuclei) may be taken to be potential changes whose substructures are *disordered.* In that case, no specific environmental effect is observed except slight fluctuations without order — a miniscule form of "heating."

However, if a continual *ordered* substructure exists in the input from the external environment into the cell's potential, the cell's potential will gradually "charge up" with that pattern.

An analogy will prove helpful. Imagine an accumulator, a largo pot, that holds a volume of water. Several pipes are connected to tho pot, some are inputs for water coming in, and some are outputs for water flowing in.

Imagine the inputs all containing "blue" water, just in slightly varying shades. The water in the pot is blue, and may slightly rise and fall in level as the input flow rates vary. The water in the pot may also vary slightly in its blueness as the inputs vary. However, it will still be blue.

Now suppose that yellow water starts flowing through one of the input pipes, and at a goodly rate. Slowly the water in the pot will start to turn greenish as a greater percentage of yellow builds up. In other words, the pot slowly charges up with some of the "yellow" charge, in the process acquiring a "green" charge.

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*We point out that this effect has been investigated in both the infrared and ultraviolet. IR to UV may be taken as a single harmonic interval — an **octave,** musically speaking. The same effect can be reproduced in any other "octave" (single harmonic interval) of the electromagnetic frequency spectrum. The **reversal** of the effect can also be achieved in any harmonic interval. The mechanism for these effects involves the cellular biopotential, Popp's master cellular control system, and the deterministically-tailorcd substructure of photons.

The biopotential in the cell experiments works the same way.

A cell has a biopotential built up, which represents the "nominal equilibrium" of the scalar charge on the cell. This biopotential, being mostly a "sum-zero" of virtual state vectors, is centered in and on the atomic nuclei of the cell, constituting charge patterns in these atomic nuclei. The biopotential extends out of the atomic nuclei, through the electron shells, into and through the molecules, through the internal cell structures and membrane, and outside the cell.

From the atomic nucleus on out through the cell, every layered structure or organization of the cell will layer, structure, and organize the biopotential accordingly.

This organized, structured cellular biopotential is continually receiving "charge patterns" contained in incoming photons absorbed by the cell. The biopotential is also continually exhausting some of its biopotential charge pattern in the photons (heat, light, etc.) that the cell emits.

The Cell's Electromagnetic Breathing

Via structured photon exchange, the biopotential of the living cell thus "breathes in" the virtual state charge structure of its environment, and "breathes out" its own internal virtual state charge structure.

So, in the experiment, the uninfected cells are continually absorbing photons from their surrounding environment, and emitting photons back to it as well. According to our scalar EM view, each photon it absorbs has a substructure that depends upon the part of the environment from whence it came.

These "substructures" are actually patterns of the sum-zeroed virtual vectors comprising the potential of the absorbed photon carriers.

Normally, since a large number of very different substructures are continually being "input" into the cell's potential from the absorbed photons, the substructure of the cell's potential receives an essentially disorganized continual input from the environment. This liquates to the fact that the environment does not normally specifically influence or change the cell's potential with ordered information (organization).*

When a cell dies, it ceases to maintain the bio-dynamics that sustained its artificial potential (that part due to bio-ordering by its organized life processes, above the background level of its "inert matter" potential). The dead cell's built-up artificial potential then "discharges" by emitting a structured photon.**

Since this photon (energy) comes from an *organized potential drop, the virtual substructure of the emitted photon is organized.* The photon, then — among other things — carries the exact organized virtual charge pattern of the dying cell's disease.

We strongly insist on the quantum mechanical view here: All physical changes — chemical, material, mechanical, whatever — at root level are constituted and caused by virtual state interactions, in direct patterns of virtual particle exchanges.

In the full QM view, what's really going on in primary physical reality is just a complex set of patterns and changes in potentials anyway.

The Summed Virtual Structures of Kaznacheyev's "Death Photons" Physically Kindle the Disease

At any rate, the Kaznacheyev experiments showed that the dying cells from the infected culture emitted photons in the near UV that contained artificial (structured) potentials. The virtual-state, patterned-substructures in this photon flux directly represented tho cellular disease pattern caused by the original cell's specific infection.

In other words, as the infected cells died, they emitted "death photons" which contained the **template** pattern of their death condition.

When these "death photons" are absorbed into uninfected cells, their deterministic substructures gradually diffuse into the cell's bio-potentials. Gradually the biopotentials of the new cells are

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*There may be sufficient ordered input from the environment, however, to have something to do with territoriality in living things, salmon returning to a fixed place to spawn, turtles returning to the same beach to lay eggs, the migration of birds, etc.

Note that this photon is emitted from an atomic nucleus. Hence it is a phase conjugate (time-reversed) photon. It will interact with the biopotential of targeted cells, and thus reach their own atomic nuclei. This is the mechanism for Kaznacheyev's cytopathogenic effect. See particularly C.W. Rietdijk, **Found. Phy , 7(5-6), Jun **77, p.** 351

Table 43. THE LIVING AURA: THE CELL'S ELECTROMAGNETIC BREATH.

- **VIRTUAL EM FIELD**
- **STORES VIRTUAL PHOTONS**
- **ENVIRONMENTAL INPUTS**
- **OUTPUTS BIOPHOTONS**
- **COHERES ORGANISM**
- **TENDS TO STABILIZE**
- **EXPERIMENT ESTABLISHES**

Popp, "Photon Storage in Biological Systems,"
Electromagnetic Bio-Information. 1979

"charged up" with the integrated pattern of the disease.

The master cellular control system of the biosystem is itself a dynamically changing, ordered pattern in the biopotential of the cells, which is centered in the atomic nuclei comprising the cell materials. As the bio-potentials of the cells gradually acquire the "death photon's" substructure pattern, this pattern is also diffused throughout (modulates) the master cellular control system. All the cells in the sample (or in a biosystem) are now slowly charging up with the "death photon" pattern.

As Popp discovered, photons continually "leak out" of the virtual photon master control system of the biosystem. Some of these *leakage photons* are observable photons, **but most are virtual photons.**

Further, they are *structured* photons.

In other words, as leakage photons spill out of the master control system, observable change is now being slowly initiated in the physical structures, biochemistry, etc. of the biosystem's cells — and those changes are in consonance with the integrated "cellular death pattern" of the originally infected cells.

Note particularly that it is already well-known in quantum mechanics/electrodynamics that, when a photon is emitted from **the surface of a dielectric body, the entire dielectric body participates in that emission. If a photon is absorbed on the surface of the dielectric body, the entire**

dielectric body participates in that absorption.

Thus as irradiation by the "death photons" continues, the "death structure" in the irradiated cells increases. It is spread throughout the cell culture by the master communication system, gradually charging the virtual state structure of that system with the death pattern.

Spillage photons from the cellular control system occur throughout the culture. These photons are structured with the death pattern, and gradually affect the cell and its biochemistry physically. The previously uninfected cells thus physically start to acquire and exhibit the symptoms and characteristics of the disease pattern that killed the infected cells.

Electromagnetic Infection Results in Physical Disease

The new cells are now electromagnetically infected and physically diseased.

After all, that is all a cellular disease is in the first place — physical, electrical, and biochemical changes in the normal functioning of the cell.

For a given pattern of changes in the cells, a specific "disease" exists in them.

It absolutely does not matter what causes this exact pattern. If the specific physical pattern is there, the specific disease is there.

Note that **any ghost pattern in the virtual state flux can charge up physical matter — that is, the atomic nuclei of a mass. All that is necessary is that a continual flux of thin virtual pattern continually bathe (irradiate) the mass's atomic nuclei.**

The eventual emergence of this "ghost template pattern" into observable physical reality is called **kindling.** Kindling is charging up one or more atomic nuclei with an integrated virtual charge pattern until the integrated pattern breaches the quantum threshold, resulting in emergence of that pattern into observable physical change.

A Possible Cure for AIDS

One of the things going for the "good guys" and EM defense against AIDS is that cells are a lot tougher than viruses. Thus even non-structured EM signals can be used to effect cures in many disease cases.

In fact, ordinary ultraviolet (UV) irradiation of the blood has already been utilized to cure or control severe infections, including severe viral infections. I am indebted to Dr. William C. Douglass for pointing this out to me, and for permission to reproduce the following information from his important newsletter, **The Cutting Edge, Nov.** 1987, p. 3. The following material is quoted verbatim, with no editing.

"It's amazing what you can find by nosing around in the dusty archives of a good medical library. I came across another remarkable therapy that the AMA and drug industry (or whoever is in charge of supressing non-toxic treatments that work) have shoved down the memory hole."

"Back in 1933, Doctors Hancock and Knott treated a patient dying of septicemia (blood poisoning) with ultraviolet irradiation of the blood.[1] The patient was moribund with a blood stream infection **and** obviously near death. (Remember that this was before antibiotics and there was nothing to lose.) The patient made a complete **and** uneventful recovery."

"Searching further, I found that in 1928 a similar terminal infection was treated by ultraviolet light to the blood. This patient also made a complete recovery.[2] "

"So in 1928, practically in the middle ages, an incurable disease, blood stream infection, was cured with ultraviolet light. With such **a** breakthrough why wasn't it tried again for *5 years?* According to **the** record, *another 6 years* passed before it was tried for a third time.[3]"

"Back in those days infection was the number one cause of death. You can't help but wonder how many lives could have been saved if doctors weren't so resistant to new ideas. Just imagine a cure for **AIDS** being set aside for 11 years. Yet bacterial infections of the blood were uniformly fatal in 1935, just like AIDS is today."

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[1] Northwest Medicine, 33:200, 1934.

[2] Knott, AM. J. Surg., Aug. 1948, pp. 165-171.

[3] Am. J. Med. Sci., 197:873, 1939.

"Finally, in 1940, 110 cases treated with ultraviolet spectral energy were reported. The results were uniformly good. Between 1940 and 1948 many other conditions were successfully treated, including vein inflammation (phlebitis), polio and asthma. Up to the late 40's *over 40 thousand* treatments were given with ultraviolet blood irradiation."

"And now for the most interesting part. In 1947, Dr. G.P. Miley reported on 79 cases of virus infection.[4] Miley stated that ultraviolet blood irradiation therapy could be relied upon consistently to control an infection of a virus in a safe and efficient manner.[5]"

"AIDS is a virus. AIDS-II is a virus (the HTLV-IV leukemia and lymphoma now sweeping the world). Remember that these killer viruses are within the cell and any chemical agent that enters the cell to kill the virus will often kill the cell as well. But ultraviolet irradiation *kills the virus without harming the cell."*

"A fine piece of crystal can be shattered by exposing it to just the right frequency. You can be standing in the room and the energy from that frequency won't harm you in the least. Viruses have the same characteristics, and so, in my opinion, frequency irradiation of the blood in the ultraviolet range is our greatest hope for curing AIDS."

"But the treatment is simple, safe, inexpensive and unpatentable. That doesn't bode well for its future, at least until a few *senators* get AIDS."

The Mirror Cytopathogenic Effect and Factors Influencing It

The cellular disease induction effect was called the **mirror cytopathogenic effect** (CPE for short) by the Kaznacheyev group. Mirror CPE appeared only when the quartz or mica window was no thicker than 0.8 mm. A. F. Kirkin also duplicated the experiments using a thin plexiglas window.

There are conditions which enhance the effect, and others which inhibit or degrade it. Irradiation of the detector-culture with a low dose of UV prior to its optical contact enhances the effect, increasing

[4] Rev. Gastroenterol. 15 271-277, 1948.

[5] Am. J. Surgery, Aug. 1948, pp. 170.

it to certainty (99-100%). Increasing the temperature to 38.5 degrees centigrade also enhances the effect (from 37% to 90% for example).*

A necessary condition for the success of the experiment is the rotation of the holder with its two optically-coupled samples at a rate of about 24-25 revolutions per hour. Optical contact between the inductor and detector cells for a minimum of 4-6 hours is necessary, after which the cell cultures can be separated. A longer contact time is necessary for complete development of the irreversible effect.

Both cultures must be maintained in complete darkness throughout the experiment. Use of the detector as a new inductor in a successive state reduces the effect by 20-30%. Three or four such stages is sufficient to eliminate the effect.

There is a seasonal variation in the results. In more than 15,000 experiments, monthly variations and daily variations were noted. (The present author's interpretation of this is that it is due to the monthly variations in the virtual photon substructure input from the moon to the substructure of the cell's bio-potential. The daily variation is due to the daily variations in the virtual photon substructure input from the sun to the substructure of the cell's bio-potential.)

Negative results appear more often in winter. (The present author's interpretation of this is that it is due to the fact that the scalar potentials of the earth and the biopotentials of each living cell on earth are lowered in winter by the weaker flux from the sun.)

Effects are correlated with the polarity of the interplanetary magnetic field. Negative polarity of the field usually precedes the appearance of mirror CPE. (This is because of the positive nuclei — which prefer one direction of the magnetic field over another). Disturbance of the geomagnetic field several days before a culture planting also results in enhancing the mirror CPE effect. (Disturbing the geomagnetic field provides a "dithering magnetic disturbance" in the atomic nuclei which "livens" them. Consequently their readiness to charge-up and emit structured virtual state charges is increased).

Kaznacheyev further discovered that the Sun's activity and the

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•This is very important. Preconditioning the cells by "dithering" them in the frequency band **of** interest, or in a subharmonic band, "livens" the cells for developing the irradiated pattern. Thin is similar to a dither voltage placed on a missile fin, making it much easier and quicker **for** the fin to move when an actual order is placed on it.

Earth's magnetic field greatly affected the results of his experiments. Large flashes on the sun seem to inhibit the effect. (Such flashes cause substantially increased irradiation of the atomic nuclei by sun-emitted substructures, charging them mostly with this disordered substructure pattern and literally "burying" the disease structure several decibels below it.) In a season of active sunspots, the mirror CPE effect becomes highly unstable. (The sun emissions are sporadically jamming the effect.) Under active sun conditions, the effect varies from 90-100% on some days to complete absence on others.

Some Biological Warfare Implications

The Soviets reported detecting near-ultraviolet photons — bioluminescence — as carriers of the death/disease pattern.

However, scientists at the University of Marburg in West Germany also duplicated the effect in the infrared. This shows that bioluminescent photons in the near UV and in the IR can definitely carry "disease and death" information between cells. Further, integrating a continuing input of such photons coherently integrates the disease or death pattern from the virtual state into the observable state.

Note also that portions of the infrared spectrum are a subharmonic of the near ultraviolet. Harmonics are well-known in nonlinear oscillator theory, and biological systems are filled with nonlinear oscillators. It may be that harmonics and subharmonics are directly involved in the death pattern.

If so, the induction of such "death patterns" upon normal electromagnetic carriers is directly indicated. For example, modulations covering several octaves in the region of 10 gigahertz and above might be constructed that are the analogues of some particular cellular disease. This modulation pattern could then be added to a common microwave carrier — say in the communication band, from 3 to 30 megahertz. Say, that is, to something like the giant Soviet Woodpecker "over-the-horizon radar" signals as carriers.

In that case, a large population could be bombarded, even on the other side of the earth, with "death photons" whose virtual state substructures carry the particular disease pattern. With sufficient time, many of the targeted persons would develop the disease.

Note that, even if the power and/or irradiation time is reduced so that the absorbed "death photons" are insufficient to actually kindle the disease in the targeted population, a heightened change in the substructure of the biopotentials of the cells of the targeted persons is still accomplished.

In that case, a precursor pattern — a predisposition for that disease — exists in the targeted persons.

If the actual disease agent is now loosed on that population, the agent will be far more **infectious and lethal than it otherwise would.**

In this way, even diseases which normally do not kill or seriously debilitate the infected person can suddenly become very lethal agents indeed.

Influenza, the common cold, etc. can become devastating killers if the exposed population has been electromagnetically "pre-conditioned" for enhanced susceptibility.

What Kaznacheyev Hid: The Role of Phase Conjugation

If cellular disease can be electromagnetically induced, can it not be electromagnetically corrected or healed?

If one could time-reverse the exact signal structure (the information) that kindled the effect, and bombard the diseased cells with that reversed pattern, would not the cell deviate back to "normal" and be healed?

The burning question as to whether cellular disease conditions can be corrected by time-reversed disease signals must certainly have occurred to the Soviet experimenters.

It is highly significant that they did not openly publish those results.*

As we have explained in the sections on phase conjugation and scalar electromagnetics, there are really two major kinds of photons:

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*Recent information indicates the strong connection of Kaznacheyev with the Institute of Physiology and Biophysics and the Frank Institute in Pushkino, just outside Moscow. Since these institutes are deeply involved in microwave and coherent microwave "directed energy" weapons, it is highly probable that the Soviets are applying Kaznacheyev's "death photons" to microwave weapons — such as the Woodpecker transmitters. If so, obviously they would develop phase conjugate countermeasure signals as well.

(1) the "normal" photon carries positive energy and positive time. (2) the "time reversed" or phase conjugate photon carries negative energy and negative time.

Further, the Soviets certainly knew all about phase conjugate signals. After all, they discovered and developed the effect. We discovered it only from the open Soviet scientific literature!

Let us assume that the "death photons" in the mitogenetic radiation emitted by the dying cells are ordinary photons. Their virtual state structures (in positive observer time) are exact "templates" for the disease pattern.

Now suppose we detect the "death photons" with a phase conjugator, which by definition will produce a time-reversed counterpart to the input signal detected. In other words, the death photons are allowed to strike a phase conjugate mirror (PCM). Time-reversed counterpart photons — carrying the exact time-reversed template of the death pattern — will be created and emitted by the PCM.

These newly emitted photons now carry the exact "healing pattern" for that specific "death/disease pattern that was received and detected."

Further, if we "pump" the phase conjugate mirror, we can greatly amplify the output pattern, and hence greatly increase the healing pattern!

If one records the pattern of the "death photons" for a specific disease, one could of course modulate that pattern upon ordinary photons/signals — such as the Woodpecker signals — and accomplish disease induction or precursor conditioning.

By phase conjugating the pattern of the "death photons," one can produce an exact antidote. One can modulate this specific healing pattern upon ordinary photons/signals — such as the Woodpecker signals — and accomplish healing induction for that specific disease.

In other words, one can create the healing pattern — the antidote, if you will, for any biological warfare agent. Cancer, leukemia, AIDS, viral diseases, bacterial diseases, whatever. One can create the antidote within minutes after the first symptoms of the disease or death pattern appear.

One can then simply add the negating (healing) signal to power line signals, television and radio signals, special transmitters, etc. —

and immediately start to "administer the antidote" to the irradiated population one wishes to protect. *Now one can see why the Soviets are so ready to expose the entire world to something like AIDS. It doesn't represent a real problem to them, the instant they decide to negate it.*

So they can devastate the rest of the world, with the assurance that their population is safe.

They can allow some of their own people to develop AIDS — and even some to die of it — as a deception plan to delude the West while Western populations are succumbing en masse.

Then they can snatch their own population right back to health, from "the brink of the grave," so to speak.

Our government must immediately develop the same capability. It is straightforward. As weapons and counterweapons go, it is enormously cheap. It can be immediately and widely implemented. **And** it can protect our population against AIDS or any other biological warfare strike by the Soviet Union.

We can save our people from the AIDS knockout already unleashed upon us by the Soviet Union.

First let us do that. *Then* let us negotiate.

Remember this: **You can negotiate with the Russians only from a position of strength. If you are weak, they will bury you.**

If we do not immediately develop this biological warfare countermeasure, we are already as good as dead.

Popp's Master Cellular Communication System

Dr. Fritz Albert Popp has already discovered and pointed out the "virtual state" master communication system that controls all cells in the body, and all their functions.

Based on a thesis derived to best fit experimental results by Ruth nnd others, Popp postulates that biological systems generally have the capacity to store coherent photons that come from the external world.

In other words, the biosystem is open to environmental communication and exchange.

He has shown that the cell population is in a quasistationary state that is far away from thermodynamic equilibrium, as pointed out by Ilya Prigogine.

Popp also concludes from his analysis that ultraweak photon emission within biological systems can influence chemical reactivity. In fact, his analysis strongly implies that "ultraweak" photon intensity can regulate the whole cell metabolism and related phenomena.

The cell takes up photons from external radiation. This includes both "observable" photons and "virtual" photons. Since it stores virtual photons, it stores charge, or biopotential changes. Since its stored virtual photons may be coherent virtual photons, it effectively "polarizes" or structures its stored photon charge, hence its biopotential.

The cell emits "spillage" photons — both coherent and incoherent — from its stored potential.

Although Popp only uses conventional "unstructured" photons in his analysis, he shows that, at the molecular level, there is a stationary equilibrium, as far as photon storage and emission are concerned, between the molecular photon traps, the cell population, and the external world.

It follows that *coherent* photon/charge inception from the external world can directly and precisely influence the cell's biopotential, hence its functioning and control, by information input.

Incoherent photon inception, on the other hand, can only grossly affect the cell, such as by heating or sporadic effects.

In his "Photon Storage in Biological Systems," Popp points out the master cellular communication and control system as follows:

"The photons which we have measured can be seen as a sort of "waste" from a virtual electromagnetic field with a high coherence. This field has a tendency to become stationary over the whole organism."

After additional analysis, he adds:

"....Consequently, biological systems must exhibit 'holographic' properties to an extremely high degree. The successful trials in

finding 'pictures' of various organs in each other organ, such as the ear, the hands, the eyes (acupuncture, iris diagnosis) support these conclusions. Our assumption that the entire genetic information of the DNA is stationarily delocalized over the body in form of genons may be seen as a further striking example."

"From this we can easily deduce that pattern recognition, as, for example, repair mechanisms and immunity, depends finally on the coherence of the photon field within the body."

Finally, Popp states a most important conclusion:

"...In medicine **new aspects have developed, and not only for cancer problems. Diseases in general can possibly be understood in terms of electromagnetic interactions within the organism."**

***Scalar** EM **Comment on Popp's Communication** System*

Popp and his colleagues have produced most important work and results indeed. They only need to add the impact of the zero-summed/multiplied electromagnetics (electrogravitation).

As we cover in this book, the biopotential of the cell is rooted in the nuclei of the atoms of the cell's constituent materials. To be sure, every internal physical structure of the cell correspondingly "levels" and structures the biopotential. The overall cellular communication system is actually the exchange of "leakage" photons — both observable and virtual — throughout the overall biopotential of the organism.

Further, going beyond Popp's work, both the biopotential and the leakage photons have extensive, complex internal substructures. Leakage and intercommunication occurs laterally at all levels of the biopotential, and vertically among cells and substructures.

The master cellular control system's primary electrical conductivity path is not through the electron shells of the atoms, but is through the nuclei-to-nuclei scalar EM "biopotential levels" pathway.

With scalar EM methods, organized signals (signals with specific internal nonzero vector EM waves, but which externally sum to z**ero** vector resultant E and H fields) can be constructed for essentially any specific purpose. This includes "killing" a cancer or leukemia cell, destroying a virus, changing the DNA, etc.

This approach can directly reach and manipulate all immune and repair system functions.

The entire biochemistry and functioning of the cell — including its genetics — **is totally engineerable.** The Soviets have long known this, and have long since done it.

Further, a specific "charge pattern" of desired specific immunity (antibodies, etc.) can be designed and used to "charge up" the nuclei of the biosystem. This charge is then maintained by the system to provide permanent immunity. Thus one can develop, for example, an "electromagnetic innoculation" for AIDS, one for cancers and leukemias, etc.

Since the cellular control system is holographic, the "charge pattern" of immunity resides in every cell, including the blood cells.

Injecting a drop of blood from a scalarly immunized animal into another non-immune animal carries the scalar EM immunity pattern into the new animal. That charge diffuses throughout the overall biopotential of the organism, and the charge pattern activates the animal's immune system, including causing it to produce antibodies — according to the EM-transferred antibody template.

Antoine Priore demonstrated this effect numerous times. Thin was one of the great mysteries that confounded the orthodox members of the French Academy of Sciences.

The French Academy did not know of scalar electromagnetics, the cellular biopotential rooted in atomic nuclei of the cellular material, the cytopathogenic effect of mitogenetic radiation from diseased and dying cells, phase conjugation, and phase conjugated electromagnetic healing.

It is little wonder they did not comprehend the operational healing mechanism of the Bordeaux cancer-curing machine of Antoine Priore!

A New View of the Nature of Mind and Thought

The reason that Western science has not discovered what mind and thought are is simple: They have only built instruments and tools to look where the mind and thought *are not to be found.*

Let's look where they are to be found.

For example, consider the ionic discharges in and across the tremendous numbers of synapses of the human nervous system, and the slower discharge and migration of ions across cellular membranes, etc.

Considered as a single biological ensemble, these are much like a vast array of continual and continuing spark discharge vectors, slow charge current vectors, etc.

Overall, within the macroscopic space occupied by the body, these electromagnetic vectors sum almost entirely to a zero vector resultant. Only a tiny nonzero vector residue remains.

However, this vector zero summation has incredibly rich infolded signals, channels, and dynamic relationships (structure) within it.

Modern science/medicine measures the small nonzero electromagnetic residue (the remaining weak E and H fields) and tries to ascertain where and how mind and thought are accomplished, by studying that residue.

However, the residue E and H field remainders are simply the "garbage thrown out" of the glorious engines dynamically operating inside the vector zero summations (and multiplications).

The E and H field residues are the wastes or exhaust byproducts. They are not the functions of the mind/thought process itself; instead, they are the spillage or leakage from those functions.

Take a "frozen time" snapshot of the components of the zero vector summation. Regard the highly complex, infolded structure or pattern these components form.

Now take a second "frozen time" snapshot of the components of the zero vector summation, a very, very short time later. Subtract **the** previous "frozen pattern" from this second "frozen pattern."*

The difference or "delta" between the two patterns represents a myriad of thoughts, hence it represents the contents of the "thinking mind," in the most general sense.

The "mind" is the overall functioning and changing of the entire pattern's substructure, and the ability of an organism to have such **and** do such. The "ability of the organism to do such" requires at least

---

*Similar to the magnificient "double **exposure holography"** work of Dr Robert Powell.

two more nested levels of virtual state—two more hyperdimensions.

In simplest Kaluza-Klein theory, all those electromagnetic component vectors are in the fifth dimension. Hence they are hyperdimensional.

The zero-vector system may well have further infolded, internested levels of zero-vector systems. Systems within systems. These are hyperspatial, going into the 6th, 7th, 8th, etc. dimensions. Rife's microscope, for example, could reveal some of these levels; using evanescent waves, it could resolve some 16 ever-deeper levels of dynamic energy structure.

Everything driving the component vectors themselves is higher dimensional.

"A thought" is the exact change of a localized pattern (localized zero vector summation whose components are changing but remaining zero summed) from one moment to the next.

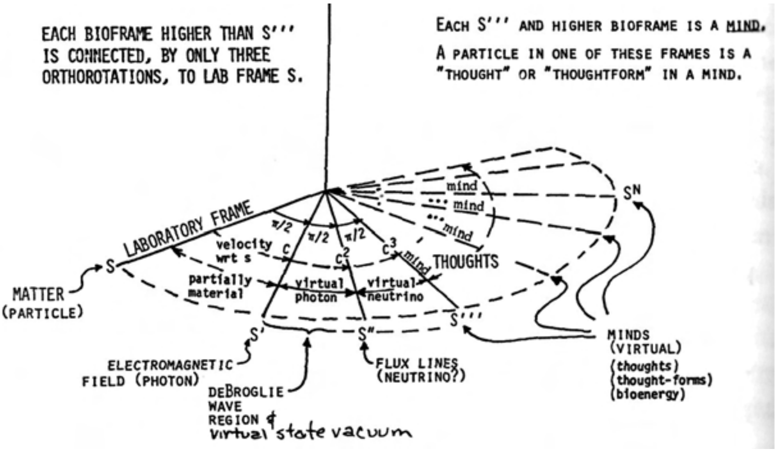
EACH BIOFRAME HIGHER THAN S'''
IS CONNECTED, BY ONLY THREE
ORTHOROTATIONS, TO LAB FRAME S.
EACH S''' AND HIGHER BIOFRAME IS A MIND.
A PARTICLE IN ONE OF THESE FRAMES IS A
"THOUGHT" OR "THOUGHTFORM" IN A MIND.
LABORATORY FRAME
π/2
π/2
π/2
velocity
wrt s
C
C²
C³
mind
mind
mind
mind
S^N
THOUGHTS
S
partially
material
virtual
photon
virtual
neutrino
MATTER
(PARTICLE)
S'
S"
S'''
ELECTROMAGNETIC
FIELD (PHOTON)
DEBROGLIE
WAVE
REGION &
virtual state vacuum
FLUX LINES
(NEUTRINO?)
MINDS
(VIRTUAL)
(thoughts)
(thought-forms)
(bioenergy)

Figure 76. Hyperframes, vacuum, virtual state, minds and thoughts.

Thought is always a pattern change, of the components inside an EM vector zero summation.

Most thoughts are totally "unconscious" (multiple simultaneous or "parallel" thoughts). A few are conscious (serially ordered, singularly considered and processed).

The unconscious mind is totally a parallel processor (many things/thoughts at once).

The conscious mind is totally a serial processor (only one thing/ thought at a time).

Most persons never take the time and trouble to reflect and notice that, consciously, they only can perceive one single thing at a time. Of course, the conscious mind is so rapid that by habit they assume they can perceive many things at once.

Since the conscious mind cannot discriminate the "multiple images in the slide projector at once" of the unconscious mind, that's what makes it unable to "be conscious" of the contents of the "unconscious."

In fact, the unconscious mind is totally conscious — it's just **multiply conscious "simultaneously."** (Which sheds some interesting light on why one can develop multiple personalities, for instance).

When the conscious mind "regards" the unconscious contents, it sees "something" which has "multiple meanings at once."

That's what we call *symbolic.* A symbol is something which can have many meanings at once.

That's why the unconscious content always "symbolizes" something when it's trying to communicate to the conscious mind. It's necessary to interpret the symbols to understand what the message being communicated is.

That's why dreams, for instance, are symbolic. And why it usually takes a trained psychiatrist or psychologist to properly interpret the symbolic representations manifested in mental disorder, and get at the underlying cause being symbolized.

With deliberately constructed scalar EM, any or all of the conscious/unconscious portions of the mind can be available for engineering and control/change. Eventually you will be able to put contents of the mind and memory on a video screen if you wish to.

It will also be possible to interact with the mind's contents electromagnetically. Mental illness will be treated directly, on an engineering basis.

Of course this opens up the frightening possibility of hostile misuse to the detriment of an individual. It will even be possible to change or erase his or her very personality itself. We pray, of course, that such a powerful tool will not be utilized this way, but will be used to heal humans, not hurt or kill them.

Unfortunately, Lisitsyn's work reveals that the Soviet Union has long since applied energetics (scalar electromagnetics) to mind control and mind engineering, including deciphering the genetic code operation. Controlled induction of images and sensations inside the brain — where they are processed as if self-originated — has been reported by the Soviets. Indeed, they have reported being able to control whether or not the induced material should rise to conscious awareness, as well as when it should rise to consciousness.

For years, U.S. intelligence analysts and U.S. scientists simply did not believe that electromagnetic signals could directly influence consciousness.

However, they were forced to reevaluate that position when a Soviet medical machine — the LIDA device — was openly obtained and evaluated.

The LIDA machine — a small unit somewhat larger than a briefcase — has been used in Soviet medical facilities to treat humans for decades.

The device uses a 40 megahertz EM carrier and very complex waveforms (signal modulations with complex mixtures of frequencies, phases, etc.)

When exposed to it, a person is caused to gradually fall into a trance-like, catatonic-like state within a few minutes. That person becomes very still and very quiet.

It was reported that the machine was tested upon a cat and had the same effect upon it.

One American scientist stated that the device had actually been used in North Korean "brainwashing" of U.S. prisoners of war in the early 1950's during the Korean War!

If so, one can see just how long the Soviets have achieved success with electromagnetic biological warfare/medical treatment techniques.

Reportedly, prisoners exposed to the machine were rendered unable to psychologically resist their harsh brainwashing interrogation.

But to return to the brain activity, with its innumerable, zero-summed minute EM vectors, and its extremely rich and complex deterministic substructure.

Note that the ensemble of sum-zeroed vectors forms potentials. These potentials — i.e., the scalar EM — penetrate to the atomic nuclei in the brain and body. Internal changes in the potentials' substructures (i.e., thoughts) also penetrate to the nuclei.

The nuclei continually "charge up" (the particles change their states) to these impressed potentials, including the "potential" or "charge" of each component of the impressed potential. That is, the nuclei charge up with both dynamic overall potential (mind) and thought (individual substructure changes).

Notice that **mind, thought, and memory reside in, and are recorded in, the atomic nuclei. At many virtual state levels. In many hyperdimensions.**

Thus the functioning mind and bio-control systems — including Popp's master cellular communication system, the immune control system, the acquisition control system, and the repair control system - all "reside" in the nuclei as dynamically interacting, patterned potentials or "patterned charge," complete with resonances and frequencies, etc.

We can regard the mind and its interactions as physical, in the extended sense we have briefly developed here.

Everything "mental" can be directly interfaced with and engineered.

One day, for example, "education" will be by direct loading of patterns into the brain/body/cellular biopotentials, much as we now place a diskette in a disk drive and load the computer memory. And then everyone can be educated, in the widest range of skills and to the highest degree ever dreamed of.

Kindling, Life, Mind, and Negentropy

The mass of the atomic nucleus can be charged up with a particular dynamically structured biopotential.

In scalar electromagnetics, I use the term **kindling** to refer to the effect of charging up mass by a specific structured charge pattern to form such a structured potential in the nuclei.

Note that we are actually and physically restructuring the nucleus itself. That is because, if the structure of the potential in the nucleus is changed, local spacetime of the nucleus is polarized in complex electromagnetic structures. The electromagnetic currents, actions, and charges of the affected nucleus adjust automatically to this structure or "grid." *

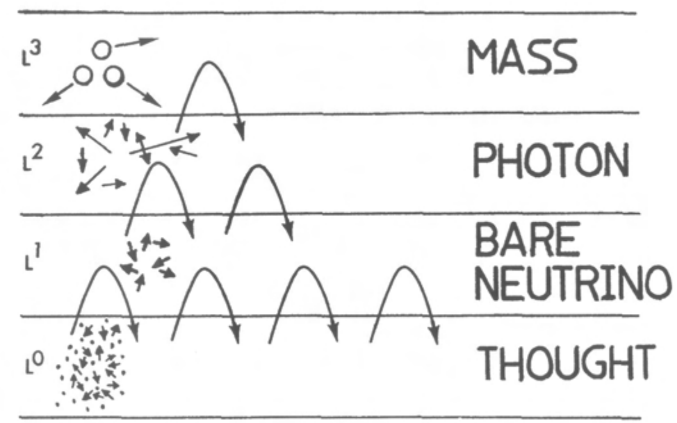

Figure 77. Internested levels of virtual state vacuum contain mind and thought. **The** vacuum also contains their interaction toward and upon mass.

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*See Richard E. Prange and Peter Strance, "The semiconducting vacuum," Am. J. **Phy.** 52(1), Jan. 1984, p. 19-21. The vacuum may be regarded as a semiconductor. This semiconductor, particularly in the region close to the nucleus, may be manipulated by subjecting it to external fields, doping, etc. Extra energy density can even be extracted; see H. Paul and R. Fischer, "Comment on How can a particle absorb more than the light incident on it^{7}'" Am. J. **Phy. 51(4),** Apr. 1983, p. 327. For the involvement of negative time/negative energy, see C.W. Rietdijk, **"How** do 'virtual' photons and mesons transmit forces between charged particles and nucleons?" **Found. Phy** 7(5-6), June 1977. p. 351-374.

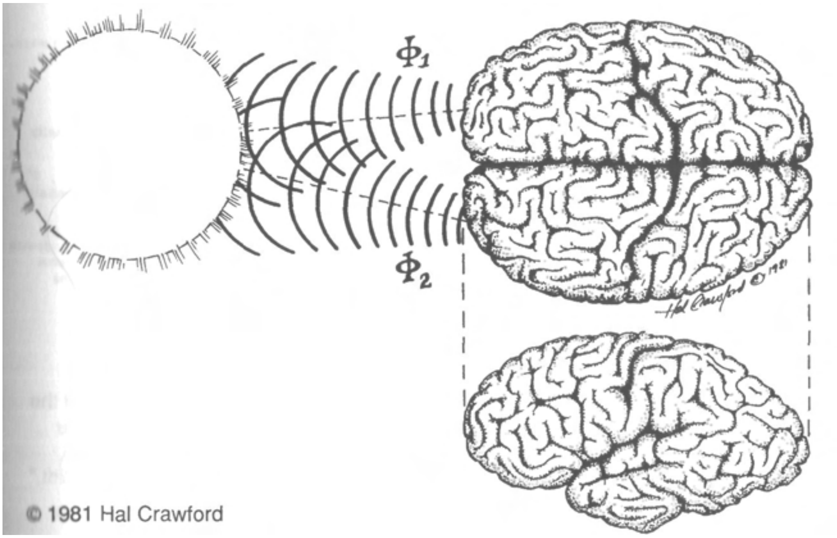
Φ1
Φ2
Hal Crawford © 1981
© 1981 Hal Crawford

Figure 78. The human cerebral cortex is a natural scalar interferometer. It is a virtual state tuner, processor, and transmitter-receiver. It also can produce...and control to some extent...phase conjugate energy and phase conjugate waves.

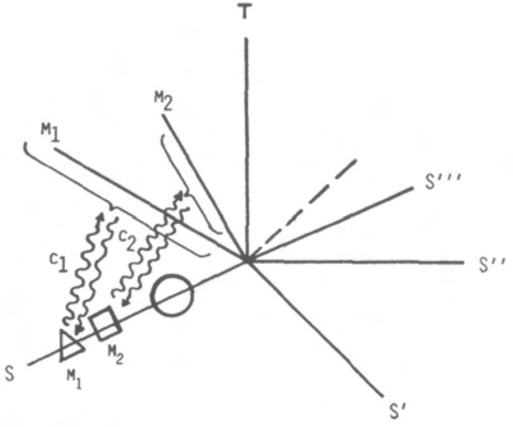
T
M2
M1
S'''
C2
C1
S''
M2
M1
S
S'

Figure 79. Consciousness and life. These phenomena refer to/constitute a deterministic hyperspatial (virtual state) coupling between mass and an ordered hyperworld.

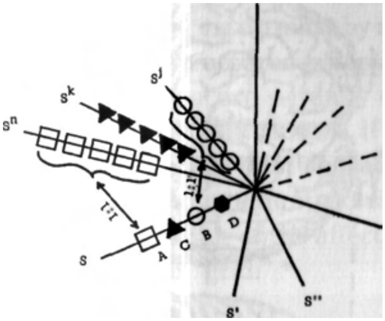
S^n
S^k
S^j
1:1
1:1
S
A
C
B
D
S'
S''

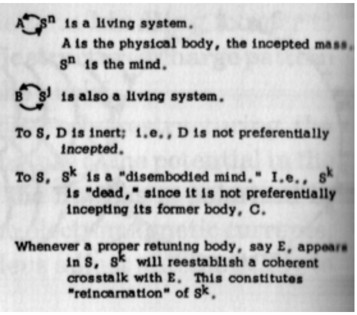

$A \rightleftarrows S^n$ is a living system.
A is the physical body, the incepted mass.
S^n is the mind.

$B \rightleftarrows S^j$ is also a living system.

To S, D is inert; i.e., D is not preferentially incepted.

To S, S^k is a "disembodied mind." I.e., S^k is "dead," since it is not preferentially incepting its former body, C.

Whenever a proper retuning body, say E, appears in S, S^k will reestablish a coherent crosstalk with E. This constitutes "reincarnation" of S^k.

Figure 80. Life and death. If the tuning or coupling between the mindworid and the tuned, structured mass body is broken, that is physical "death." Discharge of the structured cellular potentials then produces "death photons." Discharge of the overall, structured biopotential of the body constitutes discharge of the "living spirit."

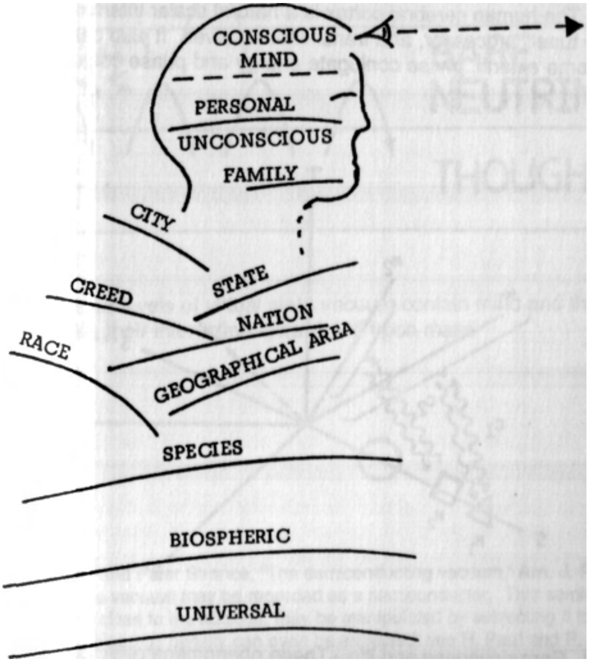
CONSCIOUS MIND
PERSONAL
UNCONSCIOUS
FAMILY
CITY
STATE
CREED
NATION
RACE
GEOGRAPHICAL AREA
SPECIES
BIOSPHERIC
UNIVERSAL

Figure 81. Layers of unconsciousness intersect hyperspatially.

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Figure 82. Scalar electromagnetics can directly interact with the various levels of human mind and personality.

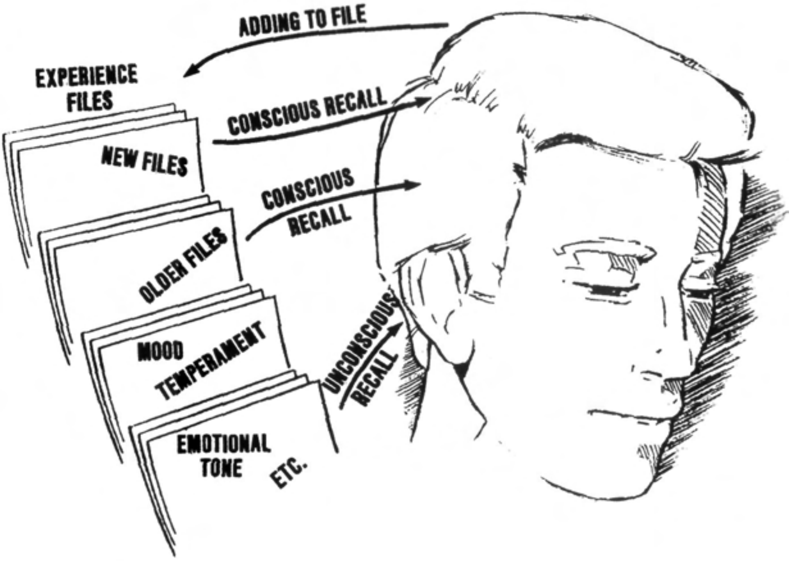
ADDING TO FILE
EXPERIENCE FILES
CONSCIOUS RECALL
NEW FILES
CONSCIOUS RECALL
OLDER FILES
MOOD
TEMPERAMENT
UNCONSCIOUS RECALL
EMOTIONAL TONE
ETC.

Fgure 83. What personality is.

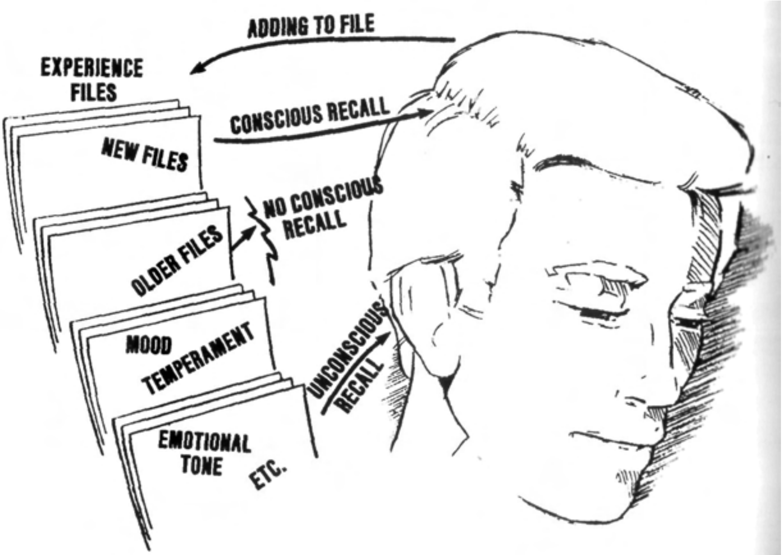
ADDING TO FILE
EXPERIENCE FILES
CONSCIOUS RECALL
NEW FILES
NO CONSCIOUS RECALL
OLDER FILES
MOOD
TEMPERAMENT
UNCONSCIOUS RECALL
EMOTIONAL TONE
ETC.

Figure 84. Jamming the "older files recall" process produces simple amnesia. If the recall process is then restored, the person regains his or her former memories.

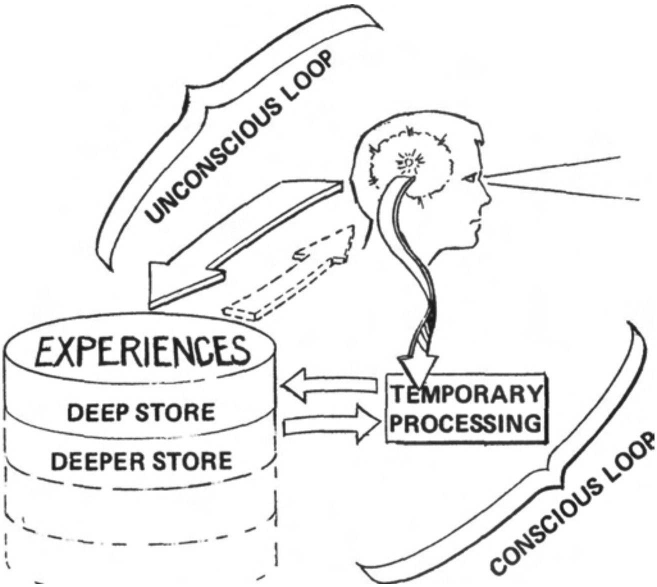
UNCONSCIOUS LOOP
EXPERIENCES
DEEP STORE
DEEPER STORE
TEMPORARY PROCESSING
CONSCIOUS LOOP

Figure 85. To sustain one's personality, continual functioning is required. All channels must be functioning.

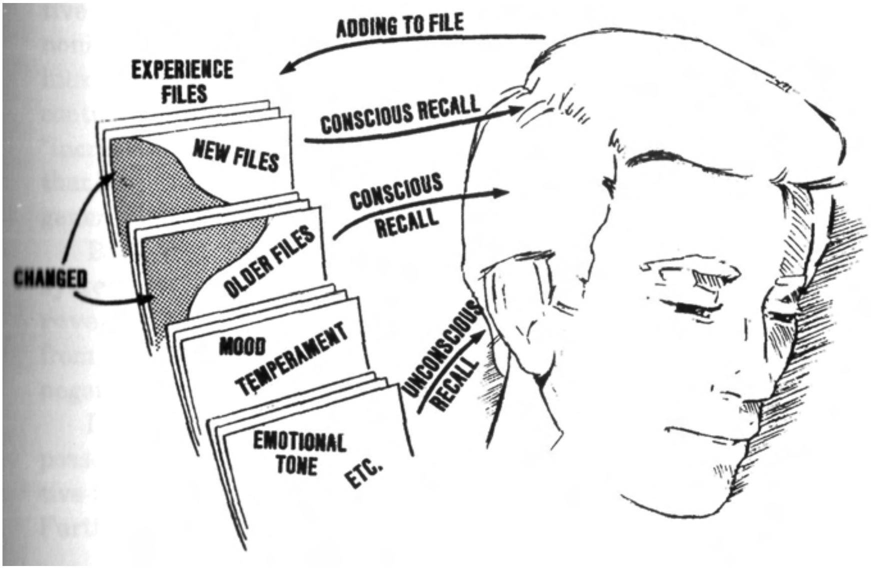
ADDING TO FILE
EXPERIENCE FILES
CONSCIOUS RECALL
NEW FILES
CONSCIOUS RECALL
CHANGED
OLDER FILES
MOOD
TEMPERAMENT
UNCONSCIOUS RECALL
EMOTIONAL TONE
ETC.

Figure 86. If the files themselves are changed, the personality itself is changed. It is possible to alter who or what a living person is.

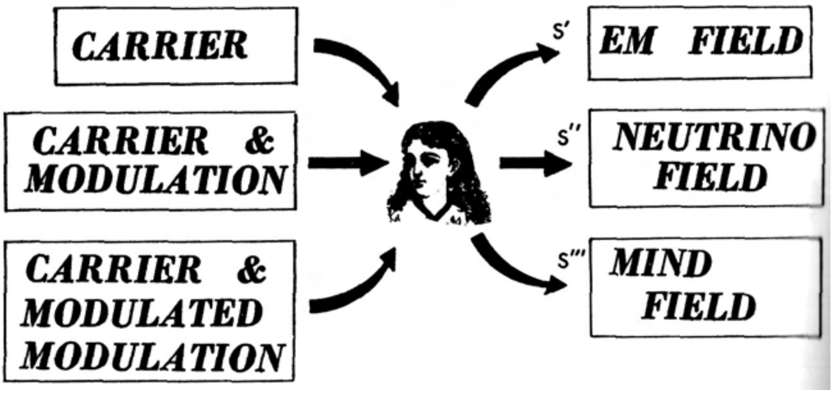
CARRIER
CARRIER & MODULATION
CARRIER & MODULATED MODULATION
S′
S″
S‴
EM FIELD
NEUTRINO FIELD
MIND FIELD

Figure 87. The mind and personality can be affected — and changed or controlled from a distance. The Soviets have developed at least a substantial part of this technology.

Table 44. LISITSYN'S REPORT

- **THEORY DEVELOPED & FITTED**
- **HYSTERESIS MEMORY LOOP**
- **CONTROLLED INDUCTION**
  - **IMAGES**
  - **SENSATIONS**
  - **PREDETERMINED EMERGENCE**
- **23 EEG BANDS**
  - **UP TO 8.1×10^{20} HZ**
- **11 INDEPENDENT CHANNELS**
- **BRAIN CODE BROKEN**
- **44 DIGITS OR LESS**

Thus by tailoring the specific scalar waveform and wave substructure with which we irradiate a mass, and utilizing phase conjugate (time reversed) waves, we can directly engineer the nucleus itself when sufficient charge structure has been built up in it to form a structured potential that is powerful enough to alter/**shape** the nuclear processes.

We can, for example, transmute the nucleus into another form. Here an isomer form is the easiest. An isomer for an atomic nucleus (a specific isotope) has the same number of nucleons (protons and neutrons) overall as that isotope does, but a different number of protons. So it's a different element, but very specially related to its isomeric "brother."

All that it takes to change a neutron into a proton or vice versa, **is** to "flip" a single quark (subparticle of the nucleon).

Living systems can do that and transmute elements, to a small degree.

For example, living systems must use phase conjugation, negative time, and negative energy. To do so, they must function nonlinearly. That is the only way they can defeat the otherwise inexorable second law of thermodynamics: that all (linear) processes continue to more and more disorder as time passes. (That's called "increasing the entropy (disorder)." Unless a biosystem could defeat **that** law, its genetic pattern would inevitably be disordered in a few generations, and the species would disappear.

By using phase conjugation and time reversal, the **living system is** able to reverse the law of entropy in its time-**reversed channel.** That is, in that channel things go in reverse: fro***m*** disorder back to order! That's called "negative entropy" or negentropy" for short.*

It follows a priori that, to do this, the living system of necessity possesses phase conjugate energy systems (negative energy, negative lime systems) that are rooted in the atomic nuclei of its body. Further, it must deterministically manipulate these phase conju-

---

To* show how fully one can integrate physics and metaphysics, we point out that, since the vacuum imprints with every **change, nothing *is* ever lost! Death, where is thy sting?

gate systems.

This allows the precise definition of a living or nonliving system. If the system deliberately utilizes and manipulates phase conjugate energy/time in its atomic nuclei, it is a living system. If it does not deliberately use this, it is an inert or nonliving system.

For example, this sheds a great deal of light on the nature of a virus.

A virus is a single molecule. Ordinarily it clouds the distinction between life and death. Viruses can be crystalized out of solution, formed into "rock-like" crystals, and placed on the shelf, so to speak. There they can remain for many years or centuries, seemingly an inert rock. Then when placed back into their "preferred medium," so to speak, the virus crystals dissolve, separate, and "come back to life" and resume their living function. Yet the virus can be killed, in which case it is just a "hunk of rock," sitting on the shelf. In that case, it won't come back to life when placed back into its preferred medium.

In one case its "deterministic phase conjugate energy system" — its mind, to put it simply — remained in the nuclei of the atoms of the crystaline form. In the other case its "mind" was destroyed or disconnected from the crystalline form.*

A somewhat similar effect can be demonstrated in bacteria.

You can "kill" bacteria, for example, with UV radiation, then hold them in the dark for 24 hours (say, for 12 generations, since a nominal bacterial generation is about 2 hours.) They will remain absolutely "lifeless" and static, with no movement or cell division.

Then if you place them in the sunlight, you will be astounded to see them revive by the hundreds of thousands. In the "special kill" case here, the virtual state substructure of the UV photons just totally "jammed" the biopotential substructure functioning of the

---

*In the living case, the atomic nuclei remained patterned by the structured biopotential In the case of true death, the structured biopotential is lost and the nuclei revert to their "inert" form.

"minds" of the bacteria on one key channel. It didn't physically damage their bodies or "physical tuners." Then when placed in the sunlight, the broad frequency spectrum of the virtual substructure of the photons "dithered" and stimulated the bacteria's body-tuners, much like a "frequency massage" in all the bands. This set the physical tuners vibrating — and therefore responding once again to the biopotential substructure changes of the mind. Hence the bacteria "revived" and swam about — fat, dumb, and happy.

We have stated that **the mind is a physical thing, albeit a virtual or hyperspatial thing. In virtual/hyperspatial reality, it is a functioning, hyperspatial thing.** Interchanges be-

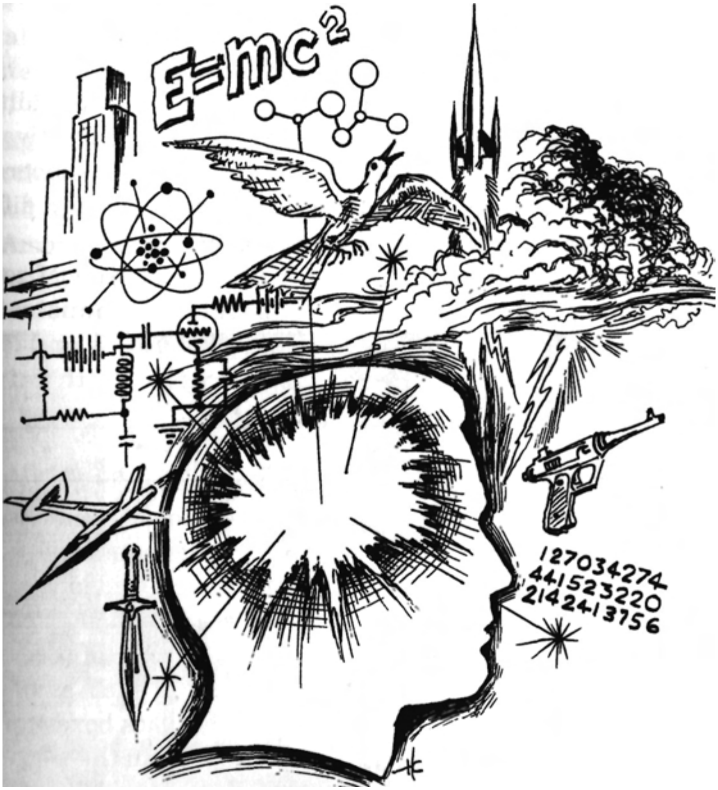

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Figure 88. The mind and personality are physical things, albeit hyperspatial and virtual.

tween it and an otherwise inert, functional, 4-dimensional ordinary physical system (a "body") comprise life functions, "thought," cellular control, etc. Those interchanges in a living system occur in the biopotentials residing in the atomic nuclei of the physical body, in the higher levels of biopotential in the body structures such as cells, membranes, and organs, and in the overall biopotential of the entire mass of the body.

We accent that this is not mysticism, but physics.

But now let us return to phase conjugation and the Priore machine.

The Priore Machine and Phase Conjugation

In the 1960's and 1970's, in France Antoine Priore built and tested electromagnetic healing machines of startling effectiveness.

In hundreds and hundreds of rigorous tests with laboratory animals, Priore's machine cured a wide variety of the most difficult kinds of terminal, fatal diseases known today.

Funded by the French government in the amount of several million dollars, **Priore's machines concretely demonstrated a nearly 100% cure of all kinds of terminal cancers and leukemias, in thousands of rigorous laboratory tests with animals. These results were shown to medical scientists as early as 1960.**

Many of the experiments and tests were done by prestigious members of the French Academy of Sciences. Robert Courrier, head of the Biology Section and Secretaire Perpetuel, personally introduced Priore's astounding results to the French Academy.

The operation of the Priore machine was seemingly incomprehensible. Many orthodox French scientists — some of them world renowned — were outraged at the success of such a machine, shrilling that science had nothing to do with "black boxes."

They loudly called upon the inventor to explain the mechanism utilized by his machine, but the inventor either wouldn't or couldn't, explain the curative mechanism.

Priore certainly knew how to build the machine and make it work. It is debatable to this day whether anyone — Priore included — actually understood its principle of operation.

Neither the French Academy nor Antoine Priore knew anything of phase conjugation at the time.

In fact, the entire Western World knew nothing of phase conjugation in the 1960's when Priore was getting his finest results. At that time, only the Soviets knew of time-reversed waves.

Certainly Priore's machine was impressive.

Into a tube containing a plasma of mercury and neon gas, a pulsed 9.4 gigahertz wave modulated upon a carrier frequency of 17 megahertz was introduced. These waves were produced by radio emitters and magnetrons in the presence of a 1,000 gauss magnetic field. Experimental animals were exposed to this magnetic field during irradiation, and the mixture of waves (some 17 or so) coming from the plasma tube and modulating and riding the magnetic field passed through the animals' bodies.

Amongst other things, a plasma can convert a transverse wave to a longitudinal wave. Also, phase conjugate (time-reversed) waves

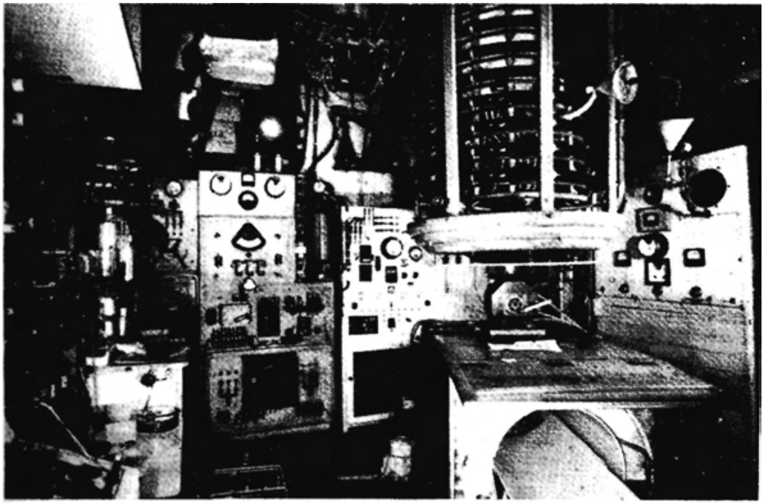

Figure 89. One of Priore's intermediate devices. This device cured terminal cancers and leukemias in thousands of laboratory animals. (Courtesy Bob Whitney)

can be produced by plasmas. Priore's apparatus produced a scalar EM wave/signal with deliberately constructed, infolded components including phase conjugate waves.

One may roughly view a cancer cell as a normal human cell gone "awry" and out of control of the body's master cellular control system. The cancerous cells, viewed as a sort of separate, parasitic group of cells, form a special kind of organism having its own master cellular control system "level," immersed in the host's biopotential.*

There is thus a specific, constant electromagnetic "delta" that differentiates the parasitic cancerous "organism" **from the normal human cellular organism.**

This "delta" can be considered a sort of constant, complex-structured charge existing in the body's atomic nuclei. It's exactly as if the body biopotential had been charged up by Kaznacheyev's "death photons" for that specific cancer condition.

If this cancerous "delta" (which may be rather like a complex intermodulation mix of waves) — or a frequency shifted "transform" of it to a different frequency band — is phase conjugated, a specific healing delta frequency pattern results.

If phase conjugate replicas of a cancer's cell's specific "delta" frequencies are fed into the body having that cancer, the deviation of the cancer cell's master cellular control system will be "time-reversed."

That will return the cancer cell to control of the animal's proper master cellular control system. The cancerous cell will be immediately destroyed, or reverted back to a normal cell of the animal.

A very similar process exists for just about every disease bacterium and infectious agent that attacks the body.

Phase Conjugates of "Death Photons" are "Healing Photons"

The Kaznacheyev experiments in the Soviet Union proved that, any cellular death and disease pattern can be induced by a specific electromagnetic pattern carried on an electromagnetic signal, if the target cells are bombarded with the pattern-carrying carrier signals for a length of time. What was not published of Kaznacheyev's work was the correspondent work showing electromagnetic reversal of cellular death and disease conditions by irradiating the diseased cell cultures by phase conjugate replicas of the pattern-carrying induction signal.

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*One strongly points out the relevance of Dr. Robert Becker's epochal experiments proving that cells can be dedifferentiated and redifferentiated electrically. Those experiments are strong indicators that the cancer cell should be capable of being reverted to its more primitive state — that of the normal cell — by electromagnetic means.

In simplified terms, if an action in forward time induces a condition, then the time-reversal of that action will reverse the condition.

The concept is almost laughably simple. **The time-reversal of an electromagnetic disease process is a specific healing process for that disease.**

In his device, Priore internally structured the carrier photons themselves — making them **vacuum engines.** He phase conjugated his vacuum engines, and then passed these time-reversed vacuum engines down and through a strong magnetic field which thoroughly penetrated all cells of the biological organism being treated.

The scalar components (structured photons) representing the time-reversal of the disease were absorbed and reradiated in all the cells, "charging up" the nuclei of the atoms in the organism to some potential level of the exact "healing and reversing pattern."

In the process, the cancer/leukemia pattern/charge also destroyed the cancer cells, or converted them back to normal cells as appropriate.

As a highly simplified analogy, the complex signal — viewed as a scalar Fourier expansion — represented a "stress" against any abnormal cellular control system encountered and returned it to the normal cell's master cellular control system of the body.

Encountering the normal control system in normal cells, it produced zero stress.

Encountering the abnormal control system in tumerous cells, it produced great stress on it, reverting it to the normal control system of the body's normal cells.

Thus to a normal cell the Priore signal pattern acted somewhat as a comb passing through one's hair.

No interference occurred with the normal cell (one whose scalar control pattern is phase-locked to the body's master cellular control system and in phase with it).

The Priore signal stimulated and "stroked" the normal cell, but did not hurt it at all.

On the other hand, the scalar control pattern in and of an abnormal (cancerous) cell is out of phase with the body's master cellular control system, and is not phase-locked to it.

Hence the Priore signal caused direct interference with the abnormal cell's independent scalar control system. The interference pattern constituted the reconstruction of normal energy directly in the cancerous cell, and also jammed its abnormal scalar life signal.

This destroyed the cancerous cell by two mechanisms: (1) physical energy was kindled directly in the abnormal cell, causing direct mechanical damage, and (2) the cancerous cell, being an "independent living critter," had its scalar life channel (connecting its primitive "mind" to its "body") jammed and stopped.

If the cancerous cell was reverted to a normal cell by the Priore stress before being destroyed, it became just a normal cell and the Priore stress had no further effect upon it.

The Effect is Universally Applicable

Any disease with cellular, biochemical, or genetic basis can be cured in like fashion.

Priore's method, for example, was clearly shown to be able to completely reverse clogging of the arteries with fatty deposits, and to be able to lower the cholesterol level to normal, even in the presence of an abnormally high cholesterol diet.

His method also showed complete mastery and cure of sleeping sickness and trypanosome-induced illnesses.

Often Priore found that every cell of the body — even the hair — must be irradiated and treated ("charged up") with the signal, for the disease pattern was in every cell. The master cellular control system is holographic — the pattern (substructured potential with its dynamic, oscillating components) is in each component (each atomic nucleus, hence in each cell.)

Every structural level of the body larger than the cell also has its own correlated pattern, or modulation, on the overall.

A biological organism can regenerate lost limbs, for example, if it can utilize its natural recovery process in a Priore manner.

Even though Priore's work was presented to the French Academy of Sciences by Robert Courrier, the prestigious head of the Biology Section, the Academy could not understand the device and its functioning.

That was because the Academicians knew nothing of scalar electromagnetics, and phase conjugation, and the Priore machine was a scalar electromagnetic device using phase conjugation.

In the Mid-70's It Ended

In 1974, a change of local government lost Priore his government supporters. His support and funding were lost.

Ironically, Priore was just completing a 4-stories-tall apparatus capable of radiating and treating entire human bodies. It would have been capable of curing cancer and leukemia in humans rather than just in laboratory rats. (His previous machines were much

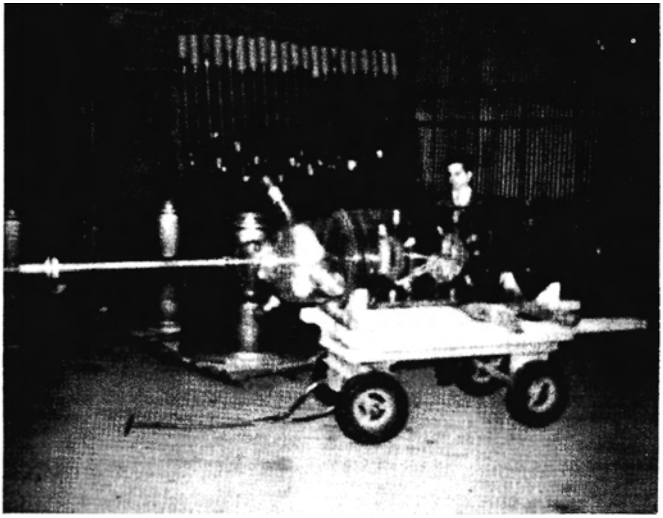

Figure 90. The large, special, phase conjugating plasma tube for Priore's giant device. The final machine would have treated humans "whole-body." (Courtesy Bob Whitney)

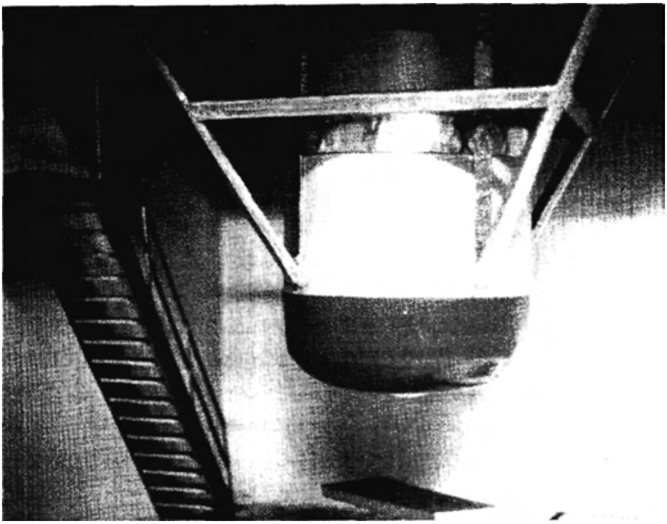

Courtesy Bob Whitney

Figure 91. Capping assembly for the top of Priore's giant plasma tube device. The last device would have treated human patients "whole-body." The cap assembly was on the third floor of the device.

smaller, and only a small animal could be irradiated whole-body.)

In that machine Priore used a "lamp," a special section, in which 17 specific frequencies were mixed and modulated upon the 9.4 gigahertz carrier.

The machine was large enough to irradiate humans over their whole body. **It should have been capable of curing cancer and leukemia in** two **five-minute irradiations, one week apart.**

While Priore was still alive, with my associates I spent nearly two years of my life in an effort to bring the Priore device to market and into the mainstream of medical research and development.

Robert Whitney, Frank Golden, and Tony Gideon played the major role, going to France and negotiating directly with the Priore group and the French government.

Verbal agreements with both the Priore group and with the French government were obtained. The machines were to be built, assembled, and tested in Bordeaux. Then they were to be dismantled and shipped to the purchasers — large medical research and development laboratories where they would be reassembled on site.

A group of wealthy backers was going to provide the necessary millions to fund the effort. Final contracts were being drawn.

Mysteriously, all funding for the project was suddenly withdrawn. Our backers were "leaned on" very hard and strongly threatened. Nothing we could do could revive the project.

Priore never again recovered his funding, and later died. The machine fell into disarray and was disassembled.

However, the proof that the requisite time-reversed signal can be produced, and will ride down a magnetic field, to penetrate every cell and every atomic nucleus in the body, is already in the present hard-core physics literature, if one knows where to look and how to properly interpret the work.

The fact that such signals can reverse nearly every major cellular illness condition of the body also has been proven by Priore and the scientists who worked with him, and it is in the French scientific literature.

The Priore-type cure for AIDS and other diseases only requires the necessary funding and personnel to be redeveloped and re-established.

Work of Australians Reed and Barsamian, and the American G. Wilbanks

At the University of Sydney, Department of Obstetrics and Gynaecology, some magnificent work of great importance to our thesis has been accomplished. Indeed, this Australian research may well be some of the most important work going on in the Western world today.

Dr. B. L. Reid, Dr. S. Barsamian, and their colleagues have produced experimental studies that positively verify pattern and form transmission at a distance, even through Faraday shielding. They have directly shown the reaction to, and results of, an unexplored information field on both living cells and inert crystalline matter.

In addition, they have replicated — and extended — the published results of Kaznacheyev on the cytopathogenic effect. In fact, they have obtained the effect at over 100 meters.

This shows, of course, that the effect is not just mesoscopic, but also macroscopic. Whether we like it or not, structural patterns of cellular disease can positively be transmitted electromagnetically, and kindled in target cell structures at a distance.

Dr. Reid has been interested in the origins of cancer since at least 1958. After much work in the standard models, by the late 1970's he was convinced that the present approach of medical science is wrong. He reasoned that we should pay stricter attention to the nature of growth before examining new growth, i.e., cancer. Growth, of course, is creation — and so the problem became, what is creation?

As a metaphor for biological growth to work with, he and his colleagues chose the growth of crystals. With keen foresight and intuition, they directed their inquiry so as to expose the complicity of some force — if any — external to solute and solvent.

Their work began to show that such a force existed, and it was a type that was unaffected by interposition of a Faraday cage. In other words, *it was not a conventional electrical force.**

Dr. Reid and his colleagues then included biological subjects in the form of living cells. They were familiar with Kaznacheyev's work in Alma Ata, Kazakstan on the subject of long range transmission of pathological (viral) effects on cells. In addition, they were familiar with the seminal studies of Gurwitsch on transmissions by onion roots cells, in the 1920's.

Most of their basic studies on the nature of the new force, however, were made with common salt, drying from aqueous solution, Some of their major results were as follows:

1. The familiar cubic symmetry is altered toward a higher energy form of dendrite crystals when biopolymers such as protein are included in the solvent.
2. A mass of lead 12-20 kg in the crystal space (up to 1 meter distant) causes an interference pattern in the salt crystal display.
3. A prospective dendrite pattern is not realized when a prospective cubic-pattern of the salt is dried in the local space (up to

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"For one related possible scalar EM (electrogravitation) interaction, see Ya. B. Zel'dovich, "Electromagnetic current and charge due to interaction between a gravitational and a free electromagnetic field," **J. Exper. and Elec. Phy.** (Soviet translation), 16(7), Oct. 5, 1972, p. 302-303, 1 meter). The latter by its presence in space is able to prevent the dendrite expression and enhance the cubic symmetry expression. **A photograph of crystals of cubic symmetry when moved by a vibrating holder (2 cps) has the same effect on the real crystals drying from the solvent.**

4. Dendrite forms of salt crystal result when certain chemical reactions involving proton or ion movement occur up to 30 meters away, separated by brick walls, glass, etc. These reactions were detailed by Dr. Reid and his colleagues. If the mother solution is examined by ac capacitance on a sensitive bridge, variations in capacitance of over 300% accompany the receipt of the signal.

5. If such a transmission from 30 meters distance is regarded as a carrier wave which is modulated by a foreign — and thus detectable — chemical, **the chemical can be detected in the distant atmosphere some 3 months later in the form of a discrete or adiabatic 'cloud' which contaminates sodium chloride drying at the same time.** In this way, copper sulfate dissolved at a site A in June 1985 could be repeatably detected at site B, 30 meters distant and separated by walls, screens etc., by a drying solution of sodium chloride solution in September 1985. Serial dryings of the sodium chloride solution on glass slides showed that each day, the cloud hovered over a space of 1-2 cm at the end of a venturi tube for several hours before 3 p.m., and then moved off at 1 meter per hour in a NW direction. The copper content of the cloud was discernible by crystal structure and chemical means from the adjacent sodium chloride.

6. All of the above crystal forms required ambient oxygen for their manifestation. Atmospheres of nitrogen and argon prevented their display. At the time, the researchers suspected that the effects may have been carried by orbital electrons of oxygen showing unpaired spin which had interchanged with electrons of the copper solution. They then

developed an information-carrying device which could 'infect' the electron cloud of a target molecule sufficient for the chemical display of properties of the infecting electron's parent atom. This concept seemed to explain the experiment of the following paragraph.

7. Two beakers of sodium chloride solution were connected in series with a small voltage source (say a 1.5V dry cell) to provide a transfer of electrons through each beaker. The second beaker in series was sampled for subsequent drying and display of the crystal form. A crystal form of cubic symmetry resulted. When the solvent of the first beaker was altered by the addition of a protein solution (such as albumen or globulin), the crystal pattern of the second beaker was altered from cubic to dendrite pattern as though protein were present in the second solution.

8. During attempts to stabilize salt crystals on glass by means of thin plastic films drying from appropriate solvents (in order to stain the salt with aqueous solutions of dyestuff), it was discovered by chance that the crystalizing process is accompanied by structural patterns on the plastic film so exposed. These patterns were of two major types: (a) vortices, or spirals in the film plane, of 0.1 to 1.0 mm diameter, and (b) smaller curled structures into which the spiral could be seen to merge or grade. From a concurrent mathematical study of vorticeal interaction as designed by Barsamian, the similarity of the curl structures in plastic films (the researchers usually used 0.25% polystyrene in benzol) to computer simulations of vorticeal vectors was shown to be remarkable.

9. The researchers then dispensed with the underlying crystals and exposed the drying polymer film to a variety of spaces where the field, thought to be responsible for many of these tele-effects, was operative. With this technical advance, the team has made rapid progress over the last year or so. They have come to have a more comprehensive grasp of the ether

field than was possible by less direct methods involving formation of crystals.

10. On the biological side, they repeated the Russian studies done at Alma Ata with transmission of the cytopathogenic effect of viruses on animal cells. They used the cytopathogenic effect of colchicine and its relative vinblastine on cells with the following differences from the published Russian work: (a) The effect can be transmitted at least 100 meters between campus buildings, (b) it is not necessary to use a magnetic field for the propagation, (c) it is not necessary to use quartz vessels; glass is quite effective. These experiments came to the attention of a colleague, Dr. G. Wilbanks, Head, Department of Obstetrics and Gynaecology, Medical School, University of Chicago in 1983. Dr. Wilbanks was able to repeat them with similar results. However, in a more faithful copy of the Russian experiments, he used quartz vessels with cells placed in a magnetic field, with the vessels separated by no more than 1 mm. Both the Australian researchers and Dr. Wilbanks shared another thing in common: their uniform inability to interest the editors of several scientific journals such as **Science, Nature, Naturewissenchaften,** and others in publishing papers describing these fundamental experiments and results.

11. Experience with interference of a lead mass in the crystal work prompted the use of several metals in the ambient field of growing cells. Only lead (and to a lesser extent tin) showed the following properties: (a) Cell growth with 0.5-5 Kg lead in the ambient field is depressed sometimes to one third normal, (b) The cells die (dye exclusion test) but then can be revived by placing a small bar magnet in the local space with its poles in an E-W orientation. At least in Sydney, a N-S orientation of the bar magnet does not revive the stricken cells.

12. The effects of energy flowing through living matter have been documented by Kirlian's method. It was therefore of interest

to the Australian researchers to expose living systems to drying films of polystyrene. They found that the staining properties of the ambient-derived image on plastic films parallel those of the real organism.

13. By appropriate use of an imposed potential on living cells, it proved possible to match the field strength and show the actual imposition of the ambient (scalar) field on the biopolymer content of the material during the permeation process. The traces obtained are not unlike noise and would be so regarded by the casual investigator. The design of this apparatus and associated experiments was the work of Dr. Barsamian.

Concepts of Dr. Reid and Associates

Dr. Reid has kindly shared with me some of the concepts he and his colleagues have formulated. These concepts, it is stressed, are consonant with direct physical results they have obtained in the laboratory.

Note that any errors in this explanation are strictly the fault of this author, and not of Dr. Reid and his colleagues.

1. Matter is bathed in an energy sea familiar to quantum theorists. The Australian team prefers to call this sea of energy **ether,** as a relatively bland term, perhaps in a way to rescue it from the oblivion where Einstein banished it. The key to the silence of this sea is its "fractional-charge" charged particle status and low energy values. The former conceals it from physics, while the latter conceals it from chemistry and thermodynamics.

2. The differing energy levels of this sea, combined with its enduring motion, are theoretically and practically best expressed as a **vortex.** Dr. Reid and associates have detailed this theory to explain the creativity of biology. The incipient creativity of the vortex is given material expression by its association (as part of the EM field) with an electron which it

now endows with equivalent novel properties. There is no intuitive reason why the energetic rearrangements of the electron cloud cannot proceed to the nucleus, there to set up a quark or proton rearrangement — or, as the quantum theorist would say, a virtual particle exchange — leading to transmutation. Kervran's work on biological transmutations is relevant; the literature of such effects goes back to 1798 at least! The team suspects that some such mechanism may underlie their experimental result of the transition of sodium to copper.

3. **A further prime property of vorticeal interaction is its proclivity for amplification,** wherein the atomic-size vortex can be built up to the meteorological hurricane by such adherence or affinity. The team has noted the affinity of ambient field vortices to those produced by an electric current in a metallic conductor, with particular reference to the ill-defined boundary between the two. This parasitism was the reason behind the team's use of "carrier waves" from chemical reactions as transporters of fields whose identity of origin were sufficiently specific to trace the field subsequently. It is at least conceivable that the whole process could be amplified and used to parasitize (modulate) a radar beam as carrier. The affinity property of fields may be exhibited by the experience of mariners with what they loosely term "magnetic phenomena" thought to be derived from luminescent plankton. In the South China and Arabian Gulf seas, giant "wheels" of light, 5-15 km in diameter and containing spiraling spokes, revolve about the ship at night, reversing their direction of rotation as they pass the midpoint of the vessel. The key observation in the context of the field affinity concept is that the luminescence is manifoldly enhanced when the ship's radar is switched on. There could thus exist a chain, scalar-EM/plankton-optical, the first leg (scalar EM) of which can be amplified by radar EM.

4. The property of affinity means that **a scalar field's** transform **or copy, of the energy disposition imposed on it by the experience of matter last permeated, may persist as**

> **a** memory **in space,** as many of the Australian observations attest. The team found that recall was not all that difficult technically. **The energy transform for copper** sulfate **existing as a non-dissipated cloud with marked adiabatic properties could be recalled five months after its formation. There is no reason why informationally more elaborate spatial configurations of energy, including human thoughts, will not behave in precisely the same way.** The cell nucleus could conceivably be the candidate for the first site for storage of such energy. The nucleus has a highly ordered structure and an associated high permittivity, and this would make it a real target. In the human subject, there is experimental evidence that the mongoloid polymer constitution will have a higher activity for storage of the ambient field than will the Caucasian.

Other Important Ideas

Dr. Reid also shared other important insights:

Lavoisier in 1748 advanced the concept that matter itself (chemicals) is inert. The activity of all chemicals, according to Lavoisier, resided in their associated ether — and God sent the ether!

Taken to its limit, this suggests that the source of the energy which we call *thought* is a property of the scalar field. Matter (say, the nervous system) interacting with these fields, would be incapable of discerning the source of the field as presented, whether of self or external origin.

In his book **Hidden Variables in Quantum Theory,** Dr. David Bohm felt that in 'elevating' (his word) matter (as particles) from the sea, it might be possible to consider the idea as containing even more elaborate energy transforms such as biological shapes, these transforms themselves undergoing metamorphosis. [Comment by this author: Rife's microscope, using evanescent waves, actually allowed one to directly see and photograph such forms, proving the thesis.]

The ability of the Australian researchers to rescue these transforms on films together with evidence that they could be seeing the results of the exclusively space interaction of virtual forms (say microbe and antibiotic), is also a direct technical step toward validating Bohm's important idea.

Wider Implications of Structured Field Information

As T.D. Lee points out in his important book, **Particle Physics and Introduction to Field Theory,** particle physicists have not attempted to use the structure of the vacuum nor the structure of potentials.

Dr. Barsamian has shared other wider implications of the structured ether.

Over the ages a phenomenon which, as discussed, can have no representation in real (that is, electromagnetic or thermodynamic) terms can hardly have been thought of as possessing specific structure or function. Instead, it signaled its undoubted presence to generations of philosophers and physicists before Einstein, solely through statistical effects.

The writings of Helmholtz, James Clerk Maxwell, and Neils Bohr are examples. The more recent Dirac and Fermi statistics are **a** continuation of the process.

If an alternative definition of science is the continuing refinement of that which we partially knew or took for granted, then the refinement of these statistical approaches ~ with their obligatory uncertainty as defined by Heisenberg — is a worthy goal.

In this sense, a more articulate description of the anatomy of the field is a logical progression from the beginnings of the ether concept in Classical Greece through to the statistics of the nineteenth to the early twentieth century.

A hundred years ago, this orderly progression even reached the concept of a vorticeal atom at the hands of J. J. Thompson. However, **it** was interrupted very effectively by Einstein's publication of the special theory of relativity.

Einstein was fortunate in that he had chosen for his mathematics a pivotal feature of the ether field, its elasticity. The mathematics of elasticity had been evolving — through the developments of Hooke, Young, invariance, and the calculus — to handle its historically increasing complexity (by tensors). This mathematics of elasticity was then available to Einstein. The wisdom of this choice was vindicated by the remarkable special relativity predictions which were born out in subsequent observation and experiment.

There was seemingly no need to suspect, let alone probe, any special properties of the medium underlying the mathematics.*

The success of these predictions effectively blocked any chance of a return to the ether field concept. Indeed, it was seen as an arrogance to despoil the "elegance" of the mathematics. Nor was the success of quantum mechanics — the other leg of the Western World statistical approach to the nature of reality — able to get the physicists to heed Bohm's 1958 ideas on the hidden variables in its fabric or Dirac's 1952 ideas on a lesser uncertainty of the particle-field relationship than Heisenberg had formulated.

Recently Dr. Barsamian has originated the concept of an **alienation of the electron from its field.** The full expression of this could see the field so alienated that it is well-nigh autonomous, and some kind of fundamental entity in its own right.

In this sense, the freed autonomous field — at least conceptually —could proceed with its creativity by hybridization with other fields and so return the product of these asides to the particle. In atoms of the next fragment of matter with which the particle then associates, this product could create novel properties derived from the interchange.

The multiple properties of such a field allow it to be resolved in EM (electrostatics and electrodynamics), in atomic structure (electrons and nucleons), and in pressure (gravity) terms. This universality makes a new concept possible, long beloved of the GUT (Grand Unified Theory) theorists: that there is only one energy.

It is also quite possible that this ubiquity need not be confined to physics. It may penetrate the biological imponderables of growth, new growth and consciousness.

In view of the work of Dr. Reid and his associates, and other work — such as that of Hines and Chimonas showing atmospheric gravity waves launched by auroral currents — the prospect of amplification and transmission of transforms and patterns over long distances,

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*As, for example, whether or not the concept of an abstract vector space in vector mathematics must be modified to correspond to what we know about the vacuum medium. If the vectors are to correspond to the movements of physical things in the *vacuum medium,* then the vector medium must correspond to the vacuum.

through affinity with long distance carriers, is indicated.

Dr. Reid stated that it would be surprising if other laboratories outside Russia had not progressed as far, if not further, than he and his associates had. Obviously the lack of similar publication indicates the nearly impenetrable editorial curtain confronting Western researchers in this and related areas.

Dr. Barsamian's Important Theoretical Insights

Dr. Barsamian has formulated a theory in relation to the development of cancer that is of great importance.

In his theory, he is developing the approach of classical mechanics to electromagnetic interactions between charged particles and between dipoles. The field associated with the primary moving particle is not neglected in his theory, and this part of it differs from Dirac's "new electromagnetic theory."

The field associated with the primary moving particle, in Dr. Barsamian's approach, is viewed as an important part of the particle's interactions. This field is stressed in the sense that diverse phenomena — from Maxwell's EM field radiating from the remotest regions of the universe to the controlled charge flow in the matter medium — are viewed as manifestations of EM forces.

This of course is unlike the traditional relativity view of EM force action on moving charges.

In Dr. Barsamian's view, the potential vectors (derived by a reatment from fluid mechanics theory) form an EM field and are positioned on a vortex curve. All parameters of such a field can be treated mathematically, and Dr. Barsamian has one or more papers presently in publication.

The duality of such potential vectors (gradients) is to conduct the motion of particles (which are always either charged or dipolar) appearing in nonmatter, which is taken as an incompressible continuum — the "void." Because the final results of these forces are always movement of matter, Dr. Barsamian prefers not to classify them by their origin.

Such a field may persist with great permanence. There are some limitations in summation (triplet conditions) and selectivity (periodicity) of the vortices themselves. Part of these limitations takes the form of particle characteristics. Presently he is rather sure that the formation of patterns of organic, inorganic and liquid crystals (typical to living biomatter) are partially responsive to the effect of the described field.

Dr. Barsamian is attempting to synthesize his own experimental findings on the dielectric behavior of biosystems as they enter the cancer process with the data that Dr. Reid is producing with respect to action at a distance.

With respect to living systems, he has slowly been approaching the conclusion that existing physical laws are just not applicable concerning (1) entropy, or (2) energy breakdown, or (3) random collisions of particles in quantum terms, or (4) electron-ion exchanges in bioelectrochemistry terms.

Under such circumstances, it is difficult to find a referee who sincerely understands the related experiments and their underlying theory. This presents a nearly impenetrable barrier to publication in leading scientific journals.

This is tragic, because these considerations and experimental results at least provide an entry into more fundamental experiments with present lethal diseases such as cancer and AIDS which annually take large numbers of human lives.

The present state of the art is telling everyone loud and clear that something fundamental is wrong with present theory, and that we should come to terms with more novel views.

Comment by the present author: In his prophetic insights, Dr. Barsamian has placed his finger squarely on the fundamental struggle of living systems against the "positive energy/time" laws of present physics. In its struggle, the living system must use negative energy/time, to correct from disorder to order and provide the extra free energy to do so. Otherwise, the steady progress toward increasing disorder in all its actions, would very shortly reduce the living system to such a disordered state that it could no longer reproduce the clear genetic pattern of its own kind. We have already pointed out the hitherto unexpected role that phase conjugation plays in allowing the living system to violate and break the iron dictates **of** conservation, nontransmutation, entropy, and raw statistics.

To live and survive, a living system must have access to other functional levels and other mechanisms beyond those contained in our present physics, electromagnetics, and biochemistry.

The incredibly productive and important work of Drs. Reid, Barsamian, and associates is of the utmost importance. Their work clearly moves everything in biochemistry and the knowledge of cellular functioning a major step forward.

It is a betrayal of the scientific method that such vital work goes so largely unreported in the leading journals. Indeed, the work of these Australian scientists should be galvanized and well-staffed and funded. They can literally usher in a new science, given the chance to further exploit and develop their results.

Royal Raymond Rife

In the 1930's and 1940's, Royal Raymond Rife revolutionized everything that has been done before or since in high resolution optical microscopy.

He also revolutionized everything before or since in cellular biology. He carried cellular structure far beyond anything ever dreamed of at the time or presently. He revealed the direct connection between organized living energy forms and organized biological systems. He revealed that life itself is organized and dynamic, to a far finer level than anything in the textbooks today. **He revealed that our present theory of disease is fundamentally very, very wrong.**

He produced direct, economical, electromagnetic cures of cancer, leukemia, and other such debilitating diseases. His work presages a future mankind could have had, where most debilitating diseases were quickly and economically corrected, and where no poisonous drugs, violent nuclear irradiation, and harsh chemotherapeutic "burning" of the patient would be necessary.

For such epochal work, he was ostracized, essentially imprisoned in a medical treatment facility, broken, condemned, and rejected by his peers. His findings, though printed in reputable publications and journals, were discredited and ridiculed.

He literally was reduced to a non-person by the power of the medical cartel.

Finally escaping from his enforced confinement, he lived out his remaining years and died quietly and unknown.

Rife's Universal Microscope

With his universal microscope, Rife achieved optical resolution of up to 31,000 diameters and magnification up to 60,000 diameters. His microscope could examine living viruses, living bacteria, and other as-yet-undiscovered living organisms and living energy forms that no other microscope before or since could see.

Even today, only the electron microscope furnishes such resolution, and it zaps-to-death the objects that are being examined. Further, it will not at all detect or see the "living energy forms" revealed by Rife's microscope.

To appreciate Rife's accomplishment, let's briefly summarize some of the performance factors of an optical microscope.*

Several factors are important in the functioning of a microscope: Resolution, magnification, and contrast lead the list.

By **resolution** we refer to the ability of the instrument to distinguish a small object. In other words, something like looking at a medical doctor's eye chart, and specifying the smallest print one can clearly see. Resolution is often referred to as resolving power.

By "magnification" or **magnifying power** we mean the ability of the instrument to "blow up" or enlarge the image produced. Roughly, it's the ratio of the apparent size of the object seen through the microscope to the apparent size of the same object seen without the instrument.

Magnifying power is exactly like enlarging a photograph. It won't improve the resolution or make the photograph any clearer, but may make whatever was captured (resolved) easier for the human operator to see. If you just keep enlarging the photograph, it will get more and more grainy, until no further details can be seen with higher magnification.

Contrast refers to the distinctness by which the various parts of the object can be distinguished from one another. To enhance contrast of objects under the microscope, staining of the objects is often used. Very often the act of staining will itself kill the living organisms — such as bacteria — that are being examined.

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*The electron microscope reveals only the "dead carnage" of the battlefield after everything is destroyed. With it, one is observing physical residuals, not the living players. For some encouraging modern work, however, see Michael Hercher, "Virometer — an instrument for the measurement of the size of viruses using an optical microscope," **SPIE Seminar Proc.**, 1977, p. 17-22.

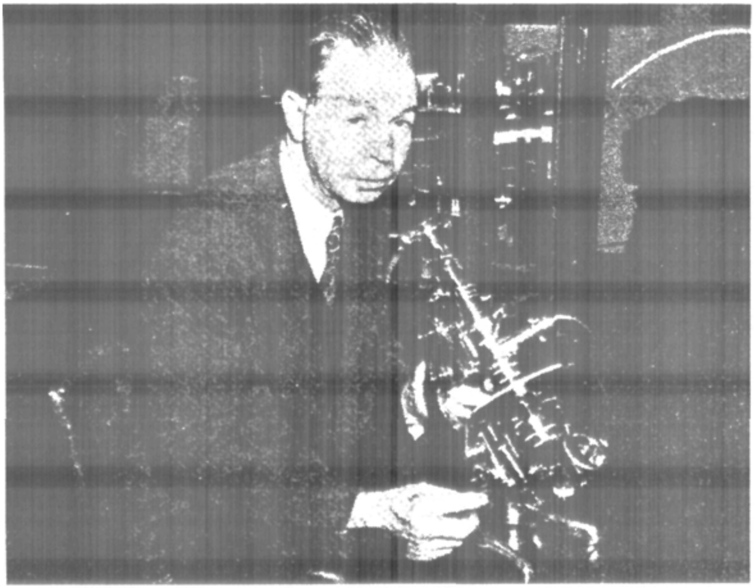

Figure 92. Royal Raymond Rife in his laboratory. Courtesy Christopher Bird

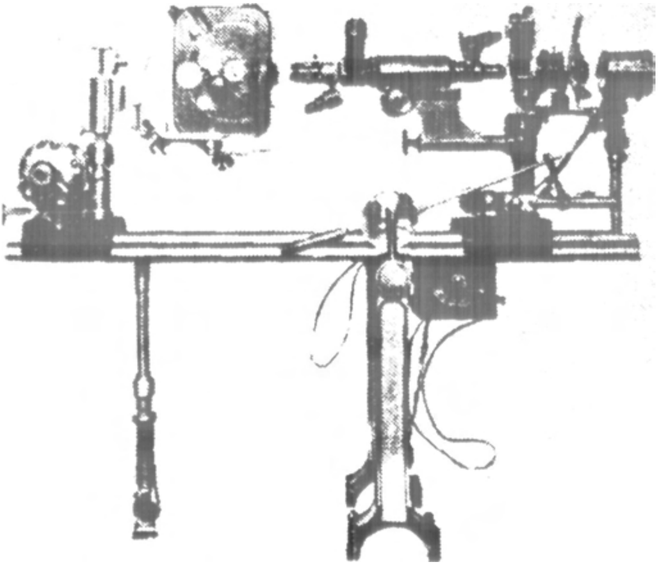

Figure 93. Rife's first virus **microscope.** Courtesy Christopher Bird

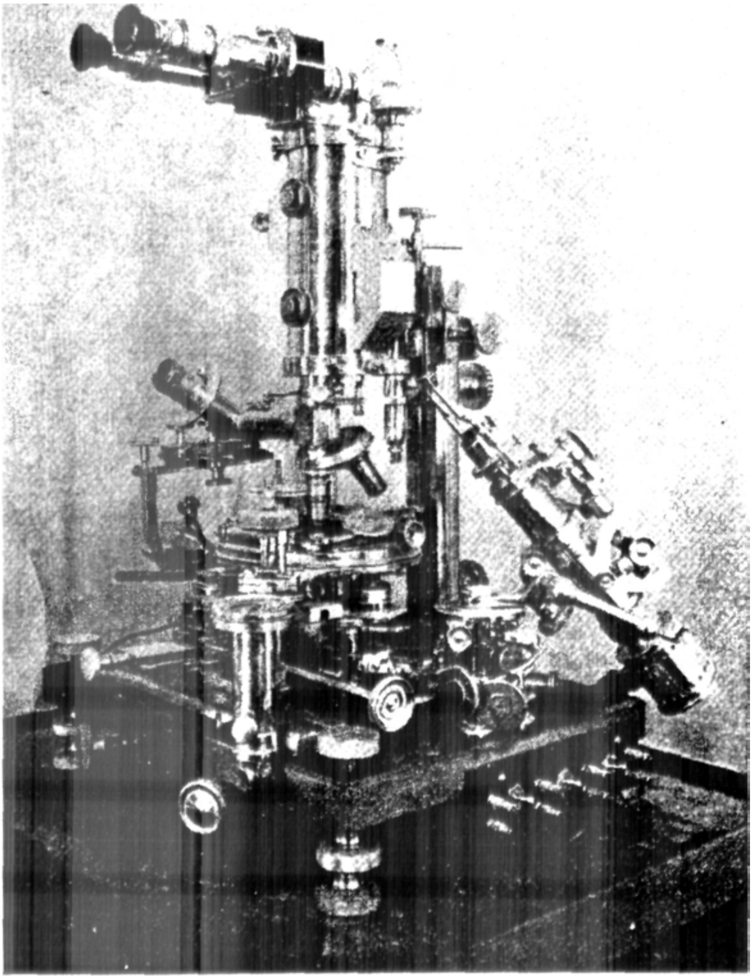

Figure 94. Side view of Royal R. Rife's prismatic universal microscope. Largest and most powerful of five Rife microscopes With it, living filterable viruses could be observed. Courtesy Christopher Bird.

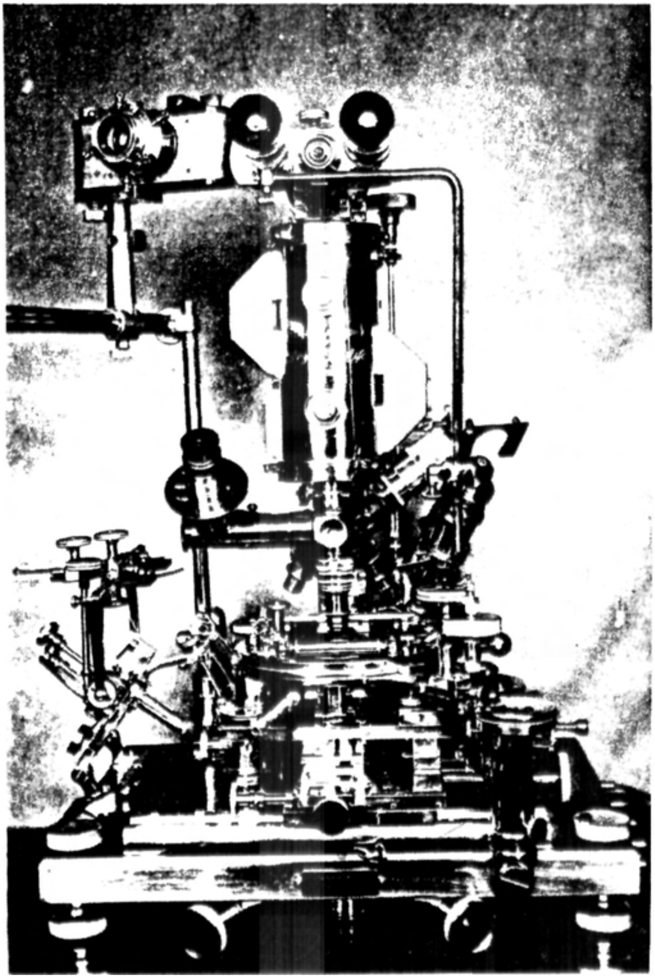

Figure 95. Front view of Royal R. Rife's prismatic universal microscope. Built in 1933 in Rife's San Diego, California laboratory. Courtesy Chris Bird.

We may state the resolution of an optical microscope in terms of the diameter of the smallest object resolved: for example, so many nanometers. Or we may just simply and loosely speak of so many thousands of diameters.

The resolution of an optical microscope depends upon the illumination conditions, its optical system, and the fact that the object viewed diffracts and spreads the light. A wide variety of mechanisms for illuminating, resolving, contrasting, etc. are used in optical microscopes.

According to standard Rayleigh theory, normal optical microscopes are limited in resolution to about half a wavelength. That corresponds to about 250 nanometers for visible light illumination. One can do a little better than that by using ultraviolet light and quartz optics. The UV has a higher frequency than visible light and hence a shorter wavelength. However, beyond 240 nanometers the resolution of an optical microscope quickly disappears.

A few researchers — notably in the 30's and 40's — remarked about other factors, such as "quality of the lenses," affecting resolution. Some of them reported results to about a tenth of a wavelength. Loosely, that translated to somewhere in the order of 5,000 to 6,000 diameters. The dependable upper limit seemed to be — and still is — about 3,000 diameters, however.

Normal optical microscopes simply are almost useless for trying to look at viruses. They will not resolve any but the very largest viruses, and will not resolve the internal features of even those few giants.

Much of today's knowledge of virus structures and shapes comes from the use of electron microscopes. They bombard the object viewed with a fierce rain of energetic electrons. These instruments see nothing of the *functioning* of the virus, for they kill it instantly in trying to view it.

With Rife's universal microscope, the dynamic living functions of the virus could be observed without killing it.

With Rife's microscope, a whole range of complex organisms and structures below the size of bacteria was revealed. Many of these organisms are still not known to present science, even though some of them were written about at the time. Filterable forms of bacteria

— forms which readily passed through filters supposed to easily block their passage — were discovered and reported by Rife and his medical colleagues.

In addition, Rife's microscope — which contained block-quartz prisms and lenses and interference stages — revealed halos around living organisms that other microscopes could not see, even though the object was within their resolving power. Further, it revealed the existence of entire organisms and forms which other microscopes could not see — even though, again, the size of the organisms was within their resolving power.

In other words, Rife's microscope not only revealed smaller physical forms than any other microscope could see, but it also revealed sizeable "living energy" forms which no other microscope could see.

Rife Proved That Everything Is Alive

The degree of smallness to which Rife's microscope would resolve, and the extraordinary energy forms it could detect, showed that direct detection of the virtual state organization of the living organism was accomplished by the instrument.

The science of the day was only just groping its way toward any sort of physics that could explain such an astounding instrumental result. Today, however, in the hard-core literature there is demonstrated proof that the optical limit of resolution can be drastically overcome, using evanescent waves.*

Shortly we will briefly give an "ad hoc" explanation of such evanescent waves.

Electromagnetism has been shown by Kaluza-Klein theory to actually exist in the fifth dimension. In other words, EM itself is hyperdimensional. It flows in the fifth dimension, which is "wrapped around" each point in our ordinary space. It is — to the first approximation — the external environment of every normal point in

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*E.g., see T. Sato et al, "Application of evanescent waves to microscopic observation," **Bull. Tokyo Inst. Technol.** (Japan), No. 125, 1974. p. 35-41. See also G.A. Massey, "Microscopy and pattern generation with scanned evanescent waves," **Appl. Opt.** (Poland), 13(3), 1983, p. 247-255.

our 3-space.

Let's say that again.

The electromagnetics "medium" itself is totally external to each point in our space. Each of our points is surrounded in higher space by the electromagnetic medium.

We live inside a totally electromagnetic medium. It's not just an "electromagnetic environment" in our own space; instead, it's an electromagnetic environment in hyperspace.

Everything already is just the internal structure of the electromagnetic medium!

That's what the "vacuum" is.
That's what "spacetime" is.
That's what the "virtual state" is.
That's what physical matter is.

And it's all alive. Totally and completely alive. Everything is alive. There is nothing but life. The electromagnetic medium is alive.

Except within a locally-organized biopotential area, it's just "equally alive in all directions." So it appears inert, where by "inert" *we mean not singly preferential.*

Every biopotential change, at any level in a biopotential, extends "decaying-expotential-wise" to infinity, by standard theory. Part of that potential change exists at every point in the entire spatial universe. And there at that point, so do the biopotential changes for every other biosystem in the universe.

Everything's alive. There is nothing but life. Anywhere. Anytime.

An interchange between this "living, surrounding electromagnetic medium" and each particle of mass in our 3-space continually occurs. This exchange involves the so-called virtual particle flux.

If we model higher dimensions, such as are necessary to include the "particle zoo" discovered by modern particle physics, each of these "higher dimensions" corresponds to a "successively deeper-"

internested level of virtual particle flux—of the vacuum, or of this electromagnetic medium that surrounds us.

The living system orders, structures, and dynamically functions and interchanges electromagnetically throughout many higher "dimensions" — throughout many such internested levels of virtual-state/vacuum/spacetime.

Except for the first layer of virtual state (the 5th dimension in Kaluza-Klein theory), gross (classical) electromagnetic theory totally ignores the infolded, ordered deeper structure of electromagnetism (of the EM medium).

Using such gross electromagnetics, orthodox science thus can only detect and grasp the gross results of the living organism's functioning. Further, it can only detect and grasp those gross results that actually move 3-space matter — observable particles.

So it only detects the grossest interchanges between "mind" or "life" and matter. Specifically, it only detects the final results of that interchange—the gross movement of material particles themselves.

The first hypernumber — "i," the square root of minus 1 — is used to model another dimension at right angles to our normal three. An electromagnetic wave thus is modeled to have two parts: the first is the part that affects or moves a material particle, and that's called the "real" part or "observable" part. The second part of the EM wave is the component that lies in this "imaginary" (unfortunate standard term!) dimension. That imaginary part does not of itself move charged particles, so it is considered to be "something other than real."

Note that what's really done in this sort of orthodox modeling is to define observation as the movement of observable charged particles.

The human "conscious mind" is a functioning part of the overall human mind that has been specifically fitted to function almost totally with our gross bodily detection of the photon interaction.

We thus consciously detect and "are aware of only the first level of reality: the interface between the first layer of virtual-state/vacuum/spacetime/ and the 3-space of observable particles of mass.

Since the physicist must be "conscious" of his observation or instrumental detection, the detection process ultimately has to have a final stage that produces a photoelectric interaction with his body — for that is all the conscious mind detects and processes.

Everything chemical, electrical, etc. — according to quantum mechanics — will involve at its root level only the photoelectric effect.

Rife's Microscope Used Evanescent Waves

However, it is certainly possible to build an instrument which is multi-staged, and one in which higher stages interact primarily with deeper internested levels of vacuum virtual state. That is, an instrument that interacts with higher dimensional phenomena. That is, one that interacts with deeper internested levels of electromagnetics. If these stages interact causally in a vertical manner, then the final interaction with the human body and nervous system can still be "normal electromagnetics" and yet indicate a higher dimensional phenomenon, event, or function.

That is precisely what Rife did: His universal microscope penetrated to a much finer level of reality because its multiple stages used **evanescent waves.**

Here's what we mean by that.

An electromagnetic wave consists of a "real" part and an "imaginary" part, as we have discussed. It's possible, however, to have the real part become zero, and still have the "imaginary" part remain and dynamically vary.

This sort of wave — containing only the "imaginary" part — is said to be one type of **complex wave,** or an **evanescent wave.**

In advanced EM waveguide and optical theory, such evanescent waves can function to guide or determine the real parts of the EM waves. That "real part" is the part that is then going to interact with electrons and move them, and give us a "detection."

In other words, the "real" part of the EM wave will be moved and guided by the "higher dimensional" or evanescent part, or even by separated evenescent parts — pure evanescent waves.

So one can build a device or instrument that utilizes such an effect to reveal what's going on in a whole dimension beyond what we normally see. Waveguides in certain RF radars already do that.

Such instruments are not limited to the resolution determined by the "real" part of the EM wave (such as the "real part" of light).

Such a microscope would not necessarily be limited in resolution by the wavelength of the light it used to illustrate the observed object.

Indeed, if one uses a higher dimensional Kaluza-Klein model (which particle physics of necessity has to consider), one could build a "repetitive stages" instrument which could view many more higher dimensions. That's exactly the same thing as viewing many more deeper internested levels of virtual state.

That is precisely what Royal R. Rife did: **He developed a microscope using multiple stages, special interferences, etc. He built a multistaged evanescent wave instrument that could see into higher dimensions and deeper levels of virtual state.**

Rife's microscopes were thus startlingly different from normal microscopes. That is why he could see phenomena and organisms, ostensibly within the size capability of normal microscopic resolution, which ordinary microscopes could not see.*

Evanescent waves penetrate the virtual state (hyperdimensions) and interact with what to us is "dimensionless" (what does not spatially intersect our 3-space). Interfering multiple evanescent waves reflected from/having interacted with these (to us) nonphysical forms can again reproduce ordinary electromagnetic "light." Thus the evanescent wave microscope, if properly built, allows one to directly "see" (and photograph) what is to us living forms of energy, nonphysical, and without 3-space matter bodies.**

The same scheme can be used to develop instruments capable of directly revealing the living nonphysical world around us — such as the human biopotentials, their internal structures (including

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*However, Rife's microscope was extraordinarily difficult to focus. Rife often spent 24 hours straight at his universal microscope, just in focusing it.

**If one is going to accept the many-dimensional theories necessary to explain particle physics, one must accept the possibility of higher dimensional living things, which we would see as living energy forms or as thought forms. These would appear nonphysical to us - as is time itself— but would be real and interactive nonetheless.

"thought forms"), etc. What the Soviets call **bioplasma** can be directly observed and photographed in this fashion. We have only to develop the necessary instruments; the science required is difficult, but it is already in the literature.

That is what Rife's microscope did. It was a forerunner of the instruments we need to develop in electromagnetic healing, and Rife was a truly great and unappreciated pioneer.

In one swoop medical science could have jumped a century ahead. The ruthless suppression of Rife and his fantastic scientific breakthrough was one of the most dastardly deeds ever perpetuated by the orthodox scientific establishment.

Rife Revealed a Far More Fundamental, Living Biology

With Rife's powerful universal microscope, it was also possible to view the interiors of the so-called "pinpoint" cells situated between normal tissue cells and just barely visible to ordinary microscopes.

Here is the astonishing living world inside those "pinpoint" cells, as revealed under Rife's powerful instrument: When one of the "pinpoint" cells was magnified, still smaller cells were revealed within its structure. When one of these still-smaller cells, in turn, was magnified, it too was seen to be composed of even smaller cells.

With Rife's microscope, this process could be repeated 16 times. An astonishing internested series of organized levels of a living cell was revealed, far more fundamental than anything that exists in present biological theory.

The present author points out most strongly that these levels correspond electrically to, and are in virtual particle flux pattern exchange with, the electromagnetic potentials of their environment. This includes their own biopotentials that are centered in the atomic nuclei of the atoms comprising the physical material of the cells, and that charge up with specific internal patterns.

The biopotential itself is organized into a corresponding virtual-state series of internested levels and functions. **The structured biopotential of the cell is a living, organized, functioning thing, and its internal functioning literally constitutes the "spirit" or "true nonmaterial deep mind" of the organism.**

All the internested levels are in constant electromagnetic exchange "up and down" with each other, particularly with respect to organized virtual particle flux patterns.

In addition, all the cells are in constant electromagnetic exchange "across" with each other, at all levels. This provides a dynamic, structured, living biopotential for the entire bio-organism (the entire body). Within this potential, dynamic interchange on all levels is continually occurring. This is the basis for the master cellular communication system that Dr. Fritz Albert Popp discovered.

Rife's powerful microscope had revealed nonmaterial functioning life forms (structured, dynamic, living biopotentials) connected to material bodies.

He could follow "filterable" forms of bacteria — actual living biopotential forms of the organisms that could not be separated out by filters, but which would easily pass through any filter.* He could observe interactions of these forms, changes of forms, translations and transmissions of forms, etc. — none of which is detectable by present biological theory or medical science.

Rife had advanced biology and biophysics a century in one jump. As always, orthodox scientists — most of whom in their scientific paradigm are self-admitted materialists — were quite unready to tolerate such heresy.

Obviously the materialistic dogma of the science of his day — and of the science of today — reacted most hostilely to such hogwash. Contrary to the prevailing mystique, most scientists are dogmatically attached to materialism and to the dogma of their present paradigm. Faced with a conflict provided by experiment, most will uphold the dogma and reject the experiment — the exact opposite of the scientific method they espouse.

Rife's revolutionary work was no exception. He incurred the unending, total opposition of powerful individuals controlling the direction of biology and medical science for their own personal gains.

Rife was hounded into court on trumped up charges. Though he was acquitted, he emerged a shaken, broken man and an alcoholic.

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*More precisely, they would easily flow *around* the 3-dimensional filter, since they were hyperdimensional.

His work was suppressed. His equipment was left to gather dust. He was also forcibly committed to a medical treatment facility.

Finally escaping from his "prison," Rife lived out his remaining years quietly. He died without ever being vindicated for his marvelous, world-shaking discoveries.

But at least he left us a legacy. Persons are still alive who knew Rife and his work, to one degree or another. Some of his microscopes are still in existence, though non-operable due to missing or stolen parts. With proper funding, an enlightened team of scientists and researchers can be assembled to quickly repair Rife's remaining instruments and duplicate his incredible work.

With concentrated effort, Rife's work will yet play a primary role in the development of a direct electromagnetic cure for AIDS. As a byproduct, it will play a role in rapid development of cures for cancer and other debilitating diseases.

Royal R. Rife's contributions may yet help save half of humanity, and prevent a Soviet takeover of the world.

CHAPTER 6

DEVELOPING THE ELECTROMAGNETIC CURE FOR AIDS

By now, how one goes about developing a electromagnetic cure for AIDS — and for cancer and other killer diseases — should be apparent.

One must set up a modern research laboratory and assemble as many of the "dirty dozen" together as is possible. One then tackles the problem head-on, adding the necessary support staff and special consultants.

First the Kaznacheyev effect for AIDS must be isolated and determined. Then it must be reversed, to yield the precise "curative" signal.

Transforms for these Kaznacheyev IR/UV "death photons" and their phase conjugated "healing photons" must be obtained for a lower electromagnetic frequency band — such as, say, 10 to 20 gigahertz.

Away must be found to irradiate the whole human body with the curative signal. The ideal way is to utilize a scalar EM curative transform so that the atomic nuclei of the body — and hence its entire master cellular control system and immune control system—will be "charged up" with the correctly structured "AIDS cancellation message."

The entire procedure and apparatus must be as simple and small as possible. My colleagues have already achieved very promising — even remarkable — progress in this respect.

Reversing the Kaznacheyev Effect

The "Kaznacheyev effect" for AIDS virus condition must be stimulated between cell cultures, so that the disease condition is electromagnetically transferred from one to another. The actual electromagnetic "delta" constituting the contribution of the AIDS infection must then be isolated electronically. The best way to do this is probably to subtract the normal cell radiation pattern from the "cell plus AIDS" radiation pattern.*

With the "AIDS delta" determined, the delta is then fed into the appropriate phase conjugating mirror system, so that its time reversed replica is produced.

The new phase conjugated signal is then the required *AIDS reversal signal* to reverse the effects of the AIDS virus itself, inside the cell where it resides dormant. This " time-reversed" signal will reverse the genetic change in the cell, not just kill the HIV virus.

In a crude way, one is making an **electromagnetic anti-virus.**

For ease of development and treatment, microwave technology is most attractive. Obtaining transforms of the signals in the radar band is ideal, since a wide variety of techniques, instruments, and electronic parts are available for that region. Millimeter waves would be most attractive, for the equipment could then be highly miniaturized.

One can regard it another way also: energy forms (critters) are involved. The action of the AIDS virus in its host cell, upon the DNA of the host, is underlaid by manipulation of energy critters. If one makes the electromagnetic anti-virus form, one is also manipulating the energy critters in their virtual state substrata.

The net result is that essentially the virus pattern — even the virus itself — can be phase conjugated by the energy critters. The result can be to turn the actual virus in the cell into a negative virus, accomplishing recombinant DNA procedures in reverse.

Remember that the signal we seek to use involves negative energy and negative time. We are also engineering the virtual state directly. The ordinary positive energy/positive time/observable state rules and limitations do not necessarily apply. And the "fixed form" first order physical reality as we normally conceive it need not be so fixed at all.

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*Procedures along the lines of the extraordinary double-exposure holographic work of Dr. Robert Powell will probably be necessary. His work on biologically significant spatial frequency spectroscopy has blazed the trail as to how to obtain the specific delta patterns desired. It is hoped that Powell will shortly publish the remarkable results of his 15 years' work.

Physical reality itself can be directly engineered.

The engineering we seek to accomplish is directly upon the probability states propagated by the Schroedinger equation, before observation and collapse of the wave function occurs. **We seek to engineer physical reality before it is born, while it is yet forming.**

Only at such a level can the previous action of the AIDS virus — that in which it combined its genetic material with the genetic material of the host cell — be reversed and undone.

Only at such a level can we convert the infected human body from an "AIDS virus factory" back to an uninfected normal human body without AIDS.

The Proof: Priore's Work

Antoine Priore's pioneering work largely proves that it can be done. Cancers, leukemias, and many other virulent diseases yielded to his phase conjugated signals passed down through a powerful magnetic field to totally penetrate every cell in the treated patient's body.

And Royal R. Rife's work proved that a virus and a bacterium are not at all the "rigidly fixed" physical forms that our normal science has led us to believe they are. Instead, both the organisms and their biochemical and genetic actions can be addressed — and changed — on a much finer level of reality.

Of course, it would be enormously helpful if one had a working Rife microscope.

My colleagues are attempting to rebuild one of the original Rife microscopes, which has parts that were missing from it. They have every hope of having the microscope in action in the future.

Another angle of attack is also possible.

One of my colleagues has discovered a very peculiar, weak electromagnetic signal that will kill viruses, harmful bacteria, toxic protozoa, etc. but not harm living human cells. Only a few volts and a few milliamps are used.

However, there exists a major problem in getting any such very weak signal into every cell in the body — which is required if one is to heal blood diseases such as AIDS and leukemia. After all, that was the reason that Priore utilized a powerful magnetic field of thousands of gauss. The magnetic field penetrated every cell in the body — even those in the bone marrow where all the blood cells are manufactured. By using the all-penetrating field as the carrier, the phase conjugated healing signal pattern could thus be introduced into every cell in the body, bathing it completely, inside and out, with the restorative signal.

Remember, **one must not just get the signal into the cells themselves — instead, one must get the restorative signals directly into, and absorbed in, the atomic nuclei.**

Again, that is why Antoine Priore found it necessary to employ a "rippling" magnetic field. The "ripple" was actually a magnetic wave, and nuclear resonance then provided the magic mechanism to penetrate all the atomic nuclei.

So the initial problem is, how does one provide a mechanism to carry the desired signals into and through each and every cell of the body and into each and every atomic nucleus of the matter of the body?

Obviously one can utilize nuclear magnetic resonance, after the fashion of Priore. If so, the resulting apparatus is going to be extremely large and expensive. It would be highly desirable to do it a different, simpler, much cheaper way.

After many hundreds of back-breaking experiments, one of my colleagues appears to have discovered a completely unique and direct way of introducing the desired EM restorative signals into and completely through every cell of the body, and into every atomic nucleus. Though much additional work to confirm this still remains, the initial results are marvelously encouraging.

Another colleague has succeeded in developing a peculiar sort of detector that should prove adaptable to detecting the actual "biopotential structural patterns" themselves, directly in and out of the atomic nuclei. Though obviously much more work is necessary before the final instrumentation is ready, the preliminary results are again most encouraging.

As I write these words on paper, this work is proceeding, but very, very slowly due to lack of the necessary funds to attack the research problems in force.

What is Needed

Time is running out —most conventional science appears to be driven by special interest groups/Drug Manufacturers who are unable and/or unwilling to counter the AIDS epidemic with anything other than extensive "Addict Style" symptom-reducing drugs that generate dollars, not cures. Though this is not universal, it *is* the conventional norm.

Unconventional disorders or diseases require *unconventional* science for *unconventional* cures.

Immediate funding is required if this awesome threat to humanity is to be stopped. An American public alerted in time to this desperate situation can demand that the government and/or private business immediately address and act on this life-threatening issue in a different, unconventional manner.

Encouraging Preliminary Work

One of my associates, already familiar with scalar EM devices, has exerted every effort to try to reduce the scope of the problem. In literally hundreds of experiments, he has been able to narrow down the search, and obtain at least some very promising results.

He has obtained an initial candidate phase conjugated signal for further test and trial.

He may well have succeeded in discovering a new and unique method to communicate signals directly into the atomic nuclei inside the matter in the human body. This signal presently appears to directly interact with the cellular biopotential and with the body's master cellular communication system.

Remember, however, these are preliminary results. They still must be fully substantiated in a great many more tests. Undoubtedly a great deal more research, analysis, and adaptation is necessary. We certainly cannot presently say we have any sort of "cure" for the AIDS virus or anything else — or that these results are to be considered as proven in any **fashion.**

But what we can say is that my colleague has been able to derive a very complicated phase-conjugated signal, which produces negative energy and negative time of the general sort required. And he may just have made a most marvelous discovery that will point the way to eventual equipment much, much smaller than the 4-stories high machine with which Priore intended to treat terminal human cancer patients.

The initial signal discovered by my colleague, when applied to the body at miniscule voltage, seems to zap all sorts of "bad things" — viruses, harmful bacteria, dangerous protozoa, microworms, you name it — without harming the blood cells, the normal body cells, or the hosted friendly bacteria.

The signal does this at miniscule voltage and amperage.

It can be applied directly to the body through special electrodes. Through a special feature, my colleague has been able to get the signal to reverberate the entire body, all cells, all parts, and even penetrate the atomic nuclei and establish scalar resonance therein.

There turned out to be some extremely strange things that have to be done to the phase conjugated signal before it will accomplish what is being sought. At least some of these "strange things" have been uncovered by my colleague.

One of the peculiarities is that the entire electrical apparatus is part of the input "form" (that conditions the potential wave structure) being phase conjugated and sent to the organism. If a lead-acid battery is included in the apparatus to power it, one will inject the electromagnetic form for the battery acid directly into the organism,* destroying it. This includes destroying the host's cells. In this case the signal is lethal, not curative. Substitution of a dry cell battery with no liquid electrolyte eliminates the problem. Exactly why a liquid electrolyte has a toxic effect and a "sludge" or solid electrolyte does not, is not understood at this time.

Other such anomalies in the tentative process have been discovered and compensated for.

However, the way ahead is exciting. It suggests that the body

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*Via a mechanism similar to that found by Reid and Barsamian (atomic nuclei) can literally be "charged up" (i.e., the living biopotentials can be "charged up" with the signal structure) so that the "disease-proofing" is very lasting, possibly for many years or even for a lifetime.

At least my colleague has pressed this to the point of demonstrating a long-lasting charge being acquired by the body.

For example, at one time his body became so "charged" from his lengthy experiments that a one-inch blue spark often leaped from his fingers when he reached out for something metallic. The discharge was cool, negative energy — living energy, if you will. It should be negentropic, not entropic. It was definitely not the type of energy the orthodox scientific community is accustomed to. And normal electricity will definitely not charge up the body in such a continuing fashion, so far as is known.

Let me clearly state again that we have not yet produced the specific anti-pattern per se. What my colleagues have discovered appears to be a broad-band signal that appears to act hyperspatially, analogous to the manner in which a broad-band drug such as penicillin acts biochemically. Even this much remains to be clearly established.

However, it is a most encouraging and promising first step.

Much more work, and a great deal of experiments to substantiate or adapt these tentative results, still need to be done. Now there is no substitute for rigor and thoroughness — and there is no substitute for clearly and scientifically demonstrating the proof of the concept in the laboratory.

It is not just good intentions that we seek, but solid, concrete, proven results substantiated by proper scientific procedures. Much work remains to be done.

But the preliminary results are very encouraging indeed.

Let me briefly share with you some of the things we foresee, if this present line of successful development continues.

We foresee being able to eventually develop and set up — legally and under proper medical auspices, of course — tested and proven devices that can easily treat up to two or three hundred persons at once. A treatment of about 45 minutes to one hour is all that would be required. Several repetitive treatments a week or so apart, might prove advisory.

In addition,once the entire gamut of the treatment process is validated and proven, and shown to be completely harmless and safe in accordance with legal medical requirements, if need arises we foresee simply adding the signal to ordinary radio and television transmitters — perhaps as simply as modulating the electrical ground. If so, a "maintenance" signal could be established to negate the AIDS virus (or other disease such as cancer and leukemia) in an entire area, and keep out other diseases such as malaria, sleeping sickness, etc.

Another advantage of such machines would be their portability in time of conflict. Also, they would be most useful indeed as defensive measures against biological warfare. For example, the inhalation of only a relative minor amount of anthrax agent is sufficient for 100 percent certain death unless treatment begins promptly. With the portable machines, however, this would be easily negated in any troops exposed to the agent, even before the lethal disease is evidenced. For a totally new agent, a "phase-conjugate delta signal" could be rather quickly ascertained and developed, and the proper settings made on the machines for immediate treatment and immunizing.

And even later, when we proceed to the direct engineering of the living energy form strata themselves, we shall see remarkable cures and remissions of diseases for which medical science offers little hope today. Arthritis, multiple schlerosis, lupus, and other such debilitating diseases come readily to mind. **Even reversal of the aging process should be possible.***

*Two other promising approaches have recently been discovered First, an electrolyte compound has recently been approved by the FDA for clinical testing. This compound has the remarkable property of raising the cellular electrical potential back to that of a strong, healthy cell. In several years of lab animal testing, this alone was indicated to be over 80% effective against cancer. It may also prove effective against diseases such as arthritis, where the body's immune system attacks body tissue with lowered cellular potentials, since it fails to recognize the weakened cells as those of the body. Second, Baylor University reseachers have found that treating blood with certain laser EM radiation kills the AIDS virus, but does not harm the blood cells This means that it will be possible to assure that blood used in transfusions will be AIDS - free, eliminating one sorce of AIDS transmission.

Conclusion

We have now come to the end of our road, literally and figuratively.

All of us have been struck a mortal blow by the Soviet AIDS first strike.

Make no mistake, this is **real.** We and our children are already as good as dead unless we move as we have never moved before.

We have a chance. A slim chance.

Americans have always come through when the chips are down. We can conquer this thing. We can overcome this mighty death blow that has been launched against us. We can defeat the others yet to come.

But we've got to move. *Now.*

Remember, Pandora's box has already been spilled. Even without the Soviet biological warfare strike, hosts of new viruses and different strains of old ones are going to be, and are now being, dumped into the biosphere by our own culture. It is also only a matter of time before terrorists and meglomaniacs turn to the use of this potent weapon against a wide-open society such as ours.

Both our Armed Forces and our civilian populace are totally defenseless against electromagnetic biological warfare. Now. At this moment.

Even without the Soviet BW strike implication, it is only a matter of time until we perish, unless we develop electromagnetic healing and electromagnetic biological warfare countermeasures.

We've come to one of those profound momentary pauses in history that determine the fate of the entire world henceforth.

It's like the parable of the lady or the tiger.

We're facing, so to speak, two doors.

Behind one is the most fearsome and hungry tiger of all time. If we delay, that door will open and we'll get the tiger full upon us. We shall be utterly destroyed. That mighty tiger will consume half the world in his roaring frenzy. Our children, and our children's children — what few of them will be left — will wear the hammer and sickle yoke for eons.

Those few future survivors will be taught strange things. How you and I were the real enemy. How we were absolutely destroyed for the good of all mankind. How glorious and necessary it was to unleash the great plagues upon us. And how heroic were those who performed the "noble deed."

Our own distant children will curse us and revile us, and they will be taught to worship at the throne of a false prophet.

The world will descend into a new "Dark Ages" far more frightful than George Orwell ever envisioned.

On the other hand, behind the second door is the most beautiful lady of all history. Literally all of humanity's dreams of health, beauty, and vitality lie behind that door.

If we open it, we achieve a freedom from disease and a measure of bountiful health for all mankind that has heretofore only been dreamed of. *Even reversal of the aging process itself lies beyond the second door. Health and youth — the dream of the ages—can be ours.*

But we have only a moment to open the second door. It is firmly shut, and we must exert ourselves to the fullest if we are to open it at all.

On the human stage, the first door is already slowly opening, inexorably. In only a few moments it will be open and the tiger will be upon us.

We must move quickly.

Which will it be for mankind, the lady or the tiger?

The next few moments in the human play will most assuredly tell.

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Author's Note: So far as I can find, there are no available references other than my own that deal precisely with my particular approach to the nature of mind and thought. There is, however, a serious debate over whether (a) the mind is simply the physical brain, similar to a computer (the prevailing materialist view of orthodox science), or (b) the mind is something else altogether, and metaphysical — at least with respect to the level of scientific knowledge today. My own approach utilizes a non-Aristotlean fourth law of logic (included in an appendix to this book) by means of which the dichotomy between mind and matter is removed. In that fashion, one can model the mind as material, or model matter us mind.

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Costello goes on to point out that a group at Sheffield University has collected a great deal of data on this subject, from case studies of 253 hydrocephalics and hydrancephalics. There seems to be no correlation between the IQ of these individuals and the amount of residual brain tissue.

One living subject, Roger, has an IQ of 126 and a First Class degree in Mathematics, yet has no more than 5% of the normal amount of brain tissue.

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APPENDIX I

The Case of Antoine Priore and His Therapeutic Machine: A Scandal in the Politics of Science

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Forty- four years ago, in 1944, an Italian engineer working as a prisoner and forced laborer for the Germans in the huge submarine base in Bordeaux, approached a French police agent to plead for his **life.** He would be killed when the Germans left Bordeaux, he said, and since they were by that time obviously losing the war, the day of his execution was at hand.

The police officer, who also worked clandestinely for the French underground, told the engineer to get in his car, then simply drove him out of the base and introduced him to the 7th battalion of underground resistance fighters, in the nearby province of Dordogne. There he so distinguished himself in military operations that he was ultimately decorated by the French government.

It was due to his thankfulness to his savior, and his loyalty to his companions-in-arms, that Antoine Priore decided after the war's end to live out the rest of his life in Bordeaux. Thus he became the focus of one of the strangest, and most scandalous, chapters in the scientific history of France or any other nation.

Antoine Priore had earlier graduated from a small provincial school for electricity in Trieste, Italy and become a radar operator in **the** Italian Navy. During this period he observed what to him was an exciting anomaly: some oranges left in a room filled with electrical bric-a-brac had fallen into an assemblage where they seemed to have been preserved in the same fresh state they had enjoyed when **bought** off a fruit stand. Other oranges in the room, bought at the same time, were rotten and putrid.

Stunned by his observation, Priore dreamed throughout the war of one day working out an electrical means of conserving foods in **their** fresh state based on what he surmised was a new, and wholly unexplained, principle. Newton's apple had become Priore's orange.

Occupied during the day as a humble electrical repairman — and **projectionist** in a movie theater — the almost wholly self-taught **Priore** devoted all his free time and his meager resources to research. With the help of his war-time companions, some of whom had attained high rank in the Bordeaux police force, he was able to beg, borrow, steal, scrounge, or otherwise acquire a mini-warehouse of electrical and electronic components and parts. With these he put together a device worthy of Rube Goldberg. Exposing lentil seeds to a magnetic field of 225 gauss and electromagnetic frequencies of 80, 32, 3 and 10 Hertz, Priore's device caused the lentil plants which sprouted from them to grow 12-15 centimeters in length, as against only 5 centimeters for controls not subjected to the same treatment. He got similar results for tulips, asparagus and other plants.

Shifting his focus, he next irradiated fertilized hens' eggs, only to see the chicks hatch in 19 days, instead of the normal 21. Though he could not explain these astonishing results, he realized he had stumbled upon a process basic to the enhancement, or speeding up, of cellular growth.

It was at this point that one of his police friends introduced him to Francis Berlureau, the former Director of Studies at the School for Veterinary Medicine in Toulouse and, at the time of their meeting, director of the Bordeaux abbatoir. Priore asked Berlureau to supply him with various animal tissues for experimentation. For 10 years they worked together, Priore's free time allowing, during which Priore noticed he could get no electrical measurement from a cancerous bull's testicles. Since he realized that, in some way, his newly constructed device (no trace of which remains today, except for a snapshot of it) affected the electrical properties of cells, he put two and two together and his sum of four led him to believe that he might be onto an electromagnetic cure for cancer. Newton's gravity had become Priore's cancer cure.

Berlureau next allowed him to expose a cat with cancer of the mammary glands to radiation of his machine. To make absolutely sure that he was not exposing himself to mockery, the veterinarian had all the histological work done by his friend and colleague, a Professor Drieux at the famous Veterinarian School of Maisons-Allfort, near Paris. Drieux wrote a technical report proving that a tumor taken from a cat had, before treatment, started to become cancerous and, after treatment, had become benign.

By 1953, with the help of a doctor of general medicine, Maurice Fournier, Priore began treating human patients whose cancers had been judged hopeless. The huge file of cases maintained by Fournier, and filed with a notary until after his death, was subsequently mysteriously lost. But a few details were preserved in letters discovered in an old dog-eared file.

Some of these dating to the year 1954 concerned a 12-year old boy, Alain B., whose diagnosis wavered between one of reticulo-histio-sarcoma and a malignant form of Hodgkin's disease. The boy was taken by his parents to Priore, who irradiated him. Though the exact nature of the radiation was not known, 12 years later a Bordeaux physician, after a medical examination, certified that the boy, now become a man of 24, was free of disease.

A second case unearthed from the old file indicated that a patient with cancer of the larynx was able to avoid a laryngectomy and be totally cured after Priore's new ministration.

Fascinated by the principle which he suspected must lie behind the strange Priore Ray, Dr. Berlureau tried to get some Bordeaux University physicists interested in the problem but was laughed out of their offices. He next turned to cancer specialists, beginning with Professor Lachapele, the Director of the Bergonie Foundation, a prestigious center for cancer research, to whom he proposed animal experiments to prove the efficacy of Priore's methodology. His plea met with a stony affirmation on Lachapele's part to the effect that he and his colleagues had no need of the new discovery, inasmuch as "all the patients treated in his hospital were cured and departed in perfect health." As if bound in the chains of his curt reply, years later Lachapele was to become one of the bitter adversaries of Priore's pioneering research.

Only somewhat discouraged, Priore kept up his momentum. He went on to build a new and more complicated version of his treatment device, called the P-l, over the next year. When it was finished he secretly and unofficially began to treat dozens of cancer patients who had been given up by their doctors as incurable. At his funeral in March of last year, among the crowd of mourners was, it is said, a small platoon of older people who had been cured of their terrible afflictions by Priore in the 1950s.

While his findings excited him, he nevertheless felt tremendously frustrated that he could apparently get no one in the world of medicine or science to pay attention to them. Undaunted by his previous rebuffs, his friend Berlureau next introduced the Italian at the end of 1959 or the beginning of 1960 to Professor Tayeau, vice dean of Bordeaux's Medical Faculty. Unlike Lachapele, Tayeau behaved as a true physician and scientist. He sent Priore to two researchers, Biraben, head of the Faculty's Department of Pathological Anatomy, and his assistant, Delmon. The two had been working together on cancerous rats for two years—specifically on animals grafted with T-8 tumors, discovered by the internationally famous team of Guerin and Oberling in Paris, which had proven to be intractable to any form of treatment yet known. To their utter surprise, the tumors in the rats treated with Priore's machine were reduced in volume by 60%, marking the first time in the history of cancerology that the virulent T-8 tumor had in any way been affected by any form of treatment.

Knowing that the mayor of Bordeaux, Jacques Chabans~Delmas-who has kept his post until this day, and was soon to become prime minister of France-- was most interested in the work of Priore (who, he too, had known as a fellow resistance fighter), they also informed Chaban.

Promptly Chaban convoked not one, but two, commissions made up of Bordeaux and Parisian scientists to study the Biraben-Delmon results in detail. Both commissions rejected Priore and his machine out of hand, and without appeal. It is curious that, in the science of our day, a result, undeniable though it may be, seems to have no hearing unless and until all means to effect it can be adequately explained. It was for this ostensible reason that the two commissions decided to so adamantly reject the research: Biraben and Delmon could not explain the nature of the radiation engendered by the Priore device.

One can stress the word *ostensible* here because the principal reason for the rejection lay elsewhere. The decision by the first commission was, in fact, hardly unanimous. But among its members was the same Professor Lachapele who had refused Berlureau's plea for assistance. His opinion was that even the results themselves were of little value because they were obtained, not on spontaneously arising, but on grafted, cancers. The fact that no treatment whatsoever had ever affected a T-8 tumor was totally discounted. As the sole cancerologist on the commission, Lachapele's dictum was preponderant.

When he learned that the rejection of the first commission had actually been a split decision, the Bordeaux mayor asked for the formation of a second commission to re-examine the problem. Fearing a reversal, Lachapele was able to get one of his colleagues, Professor Courtial, director of the Radium Institute in Paris, and one of the so-called top authorities of French cancer research, named to it. It was all but impossible for the other physicians on the new commission now to outvote not one, but two, cancer specialists, so again the antagonists won the day.

At no time did either of the commissions bother to interview Priore himself or to run a supplementary experiment under their own control.

This seemingly incomprehensible attitude on the part of scientific authority was only a foretaste of what was to come, again and again, over the years. Biraben and Delmon went on to do new experiments. They modified either the time after grafting that the radiation was applied, or the length of its duration. This time their efforts were crowned with unequivocal and complete success. The tumors stopped growing and, when still living cells were excised from them and implanted in healthy control animals, none of them became malignant.

Though these results should normally have fascinated any academy of medicine or sciences, the two researchers did not publish them. Why? The reasons horrify or disgust. It seemed that Biraben was simultaneously preparing an examination for the *agregation*, the highest French academic degree leading to a senior university teaching post. In charge of the committee to pass on, and award, this degree was none other than that same Professor Lachapele who told him: "Either you get the degree, necessary to your professional advancement, or you publish your research paper. But not both!" Discouraged, Biraben ceded to this demand but nevertheless continued to work on the research that looked so exciting and promising.

Most mystifying to him was how the machine operated to achieve its startling results. At the 3rd Congress of Biometerology held in 1963 in the Pyrennees mountains, a New York City researcher by the name of Kenneth McLean reported he had been able to obtain regressions on tumors and improve the health of cancer patients by using a magnetic field of a strength of 3000 gauss or more. Acting on this hint, Biraben and Delmon made an electromagnet that put out a field of 4,500 gauss and tried it out on the T-8 tumors but without the slightest success. Obviously, something other than a simple magnetic field was at issue.

In 1966, after others had had the same success with the T-8 tumor by irradiating it with the "Priore Ray," the two scientists finally published a memoir in the Revue of Comparative Pathology in which they stated that neither magnetic fields nor X-rays had any effect on the T-8s and that "only certain devices associating a magnetic field with high frequency waves seem at present to reveal therapeutic properties..."

Their conclusions were too late for, by that time, a campaign to stamp out Priore and his electromagnetic approach to cancer cure was well underway, a campaign that has lasted right up to the present moment.

The all-powerful Lachapele had sealed the fate of the Priore device as far as the local Bordeaux medical community was concorned. Veterinarian Berlureau and Priore next decided to carry their case to Paris. They contacted Professor Guerin at the cancer Institute at Villejuif, the leading French center for cancer research nnd the equivalent of the American National Cancer Institute in Bethesda, Maryland. Guerin, one of the discoverers of the T-8 tumor, which for the first time had been stopped in its tracks by the Priore device, courteously received his guests and heard them relate the whole story of how the device had come into being, starting at the point. when Priore had seen the oranges strangely preserved by some unaccountable electromagnetic effect.

Guerin was sufficiently impressed that he assigned his colleague, Marcel-Rene Riviere, to delve into the whole question. For two years, Riviere, who also had teaching responsibilities at the University of Rennes in Brittany, unremittingly worked to corroborate the Biraben-Delmon findings. On 9 December 1964 a note was sent for publication in the **Proceedings** of the French Academy of Sciences detailing the research and modestly concluding: "... as of now, one may already state that our first observations show that electromagnetic fields used can lead to most interesting data from a point of view of the biological behavior of grafts and their therapeutic action on experimental tumors."

Riviere next decided to see if the Priore Ray could affect another tumoral form that had never been affected by any therapeutic method, the 347 lymphoblastic lymphosarcoma. The results were even more spectacular than for the T-8 tumor. The effects produced were of broader scope and took place more rapidly. A second note was sent to the Academy for publication. The conclusion read: "We can now already affirm that our research offers proof that electromagnetic fields are capable of producing effects on quite different types of neoplasms."

At this point one of the key characters in this extraordinary drama must be introduced. There might have been no drama at all without his appearance on stage. This personage was Robert Courrier, an eminent endocrinologist, who had been named, while still in his 30s, a full professor. Courrier was now perpetual secretary of the Academy of Sciences and later would become President of the Academy of Medicine. Because no scientific paper can be accepted by an academy unless introduced by one of its members, Riviere would have had no chance to see his work so prestigiously published had not Courrier, who knew Riviere well, since he had shepherded him through the winning of his doctorate, taken the responsibility for its introduction.

It was Courrier who, at this point, also took up the cudgel to interest various highly placed French organizations responsible for the administration of scientific projects and their funding. Thus, ho sent a personal letter to the French Minister for Scientific Atomic and Space Research, who immediately offered to try to make funds available for further research on and with the Priore Ray. He also personally asked the Director of the CNRS (National Center for Scientific Research, which coordinates and oversees all such activity in France) to receive Priore and Riviere.

That this meeting was, in its way, somewhat of a disaster, can be explained in part only by a brief resume of the complex character of Priore himself. Priore throughout his life had great difficulty making himself understood in the French language and, as the **years** went by, he even forgot how adequately to speak his own mother tongue, Italian. Added to these twin impediments was his lifelong fear that his discoveries and inventions were prone to being stolen, a fear which led him never to fully explain the exact nature of the complex radiation emitted from his machine, far less the settings which controlled its various parameters. Whether Priore would not, or could not, exactly explain the functioning ofhis invention (which, as we shall see, went through several increasingly complex generations) is a question to which no precise answer has been given. It would appear that Priore was an excellent engineer gifted more with a God-given intuition than with school-book reasoning and logic. In short, Priore had a combination of talents that could remind one of the same enigmatic personality that was Nikola Tesla, the deductive reasoning behind some of whose discoveries has never fully been unravelled.

Highly placed scientific administrators are neither comfortable with, nor sympathetic to, what they see as self-appointed geniuses who have not run the same academic gauntlet through which they themselves had to pass. Thus the CNRS director took aversion to Priore's somewhat incomprehensible, yet fairly prolix explanations of his technology and only recommended that a physicist be sent to look over his device to properly decipher its working. At the same time, the Minister, together with the head of the general delegation for Scientific Research (DGRST) — still another key body in the administration of the French scientific decision-making process — let it be known to Robert Courrier that they had not understood a tingle thing about Priore's invention despite his best efforts to present it.

Advancing one more step into what was to become for him a 20 year-long expedition into a jungle of scientific intrigue, Courrier next resolutely decided to send to Bordeaux one of his most trusted laboratory workers, Madame Colonge, to repeat Riviere's experiments under her personal supervision. The DGRST director fully Concurred with Courrier's decision, while letting slip his admission that he strongly suspected that Riviere might well have been duped in some manner by Priore. When Courrier asked the minister for travel funds for Madame Colonge, he was refused with the dry remark that such a request was "premature." The now angry Courrier telephoned to reply: "You've been spending millions for programs and hypotheses about the cancer problem. Riviere has been presenting you with facts!"

The physicist who had been sent to try to elucidate the functioning principles of Priore's device, reported that he could make neither "head nor tail" of the machine.

Madame Colonge's experimentation was as prolonged as necessary. She was so meticulous that, in order not to take her eyes off the experimental animals for an instant, she limited her lunches to sandwiches eaten in the laboratory. She returned, profoundly impressed, to Paris.

Nor was Riviere idle during this period. He decided to experiment with the L-52 lymphosarcoma, a tumor similar to, but even more malignant than the 347. This time, he used not rats, but mice, as hosts for the grafts. So successful were his results that, this time, Courrier decided to bar no holds. Instead of simply having a note published in the Academy Proceedings on the quiet, he decided to present it personally, orally, and in all solemnity, before his fellow academicians at an official meeting scheduled for 1 May 1965.

That date was, and is, a turning point in what came to be known in France as the "Priore Affair." From then on the whole French, and even the international, scientific community could be divided into a minority and a majority group, the first that believed in the research, the second that did not know enough details about it, did not or would not believe, or simply didn't give a damn.

Before Courrier could make his presentation, its scheduling and subject were inadvertently and prematurely leaked to the press. Immediately thereafter, a horde ofjournalists arrived in Bordeaux. After one or two of them managed to all but force entry into his lab, Priore closed its doors and, with the help of his friends, wrote a printed press release that stressed his thankfulness to the many people who had helped him over the years rather than providing any comprehensible details about the machine he had brought to birth. Stymied, many of the newsmen travelled across town to seek an explanation from its leading cancerologist, Professor Lachapele, who informed them acidly that the machine was all but useless and unworthy of their attention or their time.

The journalists' reports, founded as they were on rumor of outright lies, roiled the pages of their newspapers and magazines in such a way that they either over-exaggerated the potential or a forthcoming cancer cure, or came close to billing Priore as just one more cancer-cure charlatan. All of which so alarmed, among many others, Dr. Wilhelm Bernhard, world specialist in electron microscopy, that he called his friend Courrier to warn him that his forthcoming presentation to the academy might put his hard-won reputation at risk as well as those of Guerin, Riviere and the Villejuif cancer institute itself.

In the journalistic melee, no one had bothered to read the declaration carefully issued by Riviere from Rennes, where he was occupied with his university courses, which formally stated: "Our experiments are of real interest. Much more experimental research has of course to be done before any therapeutic application on human cancer victims can even be considered. It goes without saying that this will take a certain time and no little effort of many types, both scientific and financial. Our work, as fascinating a perspective as it might hold, in no way, therefore, allows anyone to offer the public hope which could only lead to deception at the present time."

On May Day, Courrier gave his report to an Academy assembly hall crowded with scientists, newspapers and television reporters, photographers and an unusual number of curious bystanders. Accompanied with slides showing histological details, and animals before and after treatment, his lecture was heard out in almost tomb-like silence. When the lights came on again, he announced that he had personally checked the validity of Riviere's findings through the offices of his personal assistant, Madame Colonge. He then went on to say that he had taken the responsibility of presenting three notes to the Academy for two reasons. The first was a ringing declaration and a challenge to critics and skeptics of every stamp. It reads "When it is a question of a problem as serious as that of cancer and when one sees a little light beginning to dawn, one has the obligation to see what this light might represent. One has no right to snuff it out before learning what it may be worth."

The second was a tribute to his colleagues who had done the pioneering work, particularly Guerin, Riviere and Madame Colonge, and a statement of the essence of the problem to be faced down the road. It read: "Attention must naturally be given to the apparatus which Monsieur Priore has conceived and constructed. It has apparently already been examined by several physicists. It is found to be too complicated. While that may be possible, it is nevertheless a fact that Guerin and Riviere have obtained results with it that had to be made public. What is emitted from such an apparatus? I hope Monsieur Priore will allow disinterested physicists to study it at their leisure, for Science cannot tolerate apparatuses enveloped in mystery." Then, as almost a footnote to the history of the moment: "The biological action of magnetic fields is the object of intense research in the United States. In specialized institutes, the influence of these fields on tissue cultures, microbes, plant forms, diastases and certain tumors is under study. Up to now, the results obtained on grafted tumors seem less significant than those which have here been presented."

After Courrier sat down, a leading cancer specialist, Professor Lacassagne, rose to ask snidely why the notes had included no bibliographical references on work done on the bio-effects on tumors from electromagnetic fields, and criticized the experimentation as "impromptu." When Courrier denied this allegation as ludicrous, Lacassagne stalked out of the assembly hall in full view of the audience.

The meeting caused a new eruption of media reports which unfortunately accented one of three aspects of the problem at the expense of the other two. These were 1) the hope that a miraculous cure for cancer was in the offing 2) the contradictory, not to say discordant, reception of the data by various academics and 3) the enigma of Priore's personality.

Remarkably, no serious discussion among the scientists present at the meeting ever took place. This led a foreign scientist, present in Paris at the time, to remark: *"I don't understand. Here is a report given to the most authoritative scientific body in France by one of the most respected and eminent of its members and it is publicly subject to doubt without that leading to any reaction whatsoever."*

The General Delegation for Scientific Research was at this point still open to the idea of providing funds for more research with the Priore Ray. The big stumbling block, however, was one related to niceties involved in relations up and down the scientific hierarchy. To open the way to the allocation of such funds required the approval of the Delegation's own section for cancer research and that section was headed by none other than the same Professor Lacassagne who had so rudely walked out of the Academy's assembly hall.

At the same time the General Delegate diplomatically covered himself by suggesting to Robert Courrier that he had to have more information underscoring the potential importance of the research accomplished. Courrier told him to simply re-read the three notes he had presented to the academy. His matter-of-fact, yet terse, come back then elicited his invitation to a full-dress meeting of scientific experts at the Institute for Scientific Cancer Research.

In this short historical account we obviously cannot go into the ins and outs of what transpired at this meeting or any of the many similar meetings which followed it. A paragraph in a brilliant book, four years in the writing, by the courageous Bordeaux journalist, Jean-Michel Graille and entitled: **Dossier Priore, A New Pasteur Affair** (of which this account is but a tenuous synopsis) must suffice to pointedly characterize the nature of the problem in its most general sense.

Writes Graille: "To read what follows in this chapter might well seem tedious: an enumeration of names and titles, the content of a debate held at an administrative meeting, personal remarks by one ranking personage or another, exchanges of letters following the meeting itself and the official report which came out of it. Tedious but indispensible for not a few reasons. It is important to know who were the participants at this meeting and what of these participants each was trying to represent. It is important to know how such scientific meetings go about their business at the 'top level,' And, finally, it is important to learn about and to understand, in the particular case of the Priore Affair, the behavior and reactions of all concerned. A reading of all this could be difficult (and it won't be the only such passage in this book) yet it is necessary to understand the essence of the dossier in order to be able to create for oneself as clear and well-motivated a personal opinion about it as to subsequently be able to discuss it, or to hear it discussed, with a thorough knowledge of the facts."

In this single paragraph, Jean-Michel Graille has, in my opinion, pointed to both the nub and the difficulty in getting at the essence ofthe real facts behind a case such as that ofPriore's that are so important to its proper understanding, an understanding which can be painted against the backdrop ofthe history ofscience and the backdrop of human pettiness and maliciousness or human courage and magnanimity.

One ofthe participants, Professor Andre Lwoff, soon to become n Nobel Laureate for his work in virology, was violently against the meeting's central issue: namely, whether or not funds should be spent to build a new and better Priore machine. Not only did Lwoff aver that the three notes presented to the Academy never should have been published, but he also opined that since all the work was done, not on spontaneously generated but on grafted cancers, the effects of the machine were hardly impressive. He later added in writing that 1) the patents issued to Priore for his device were nothing but a web of nonsense, 2) the machine itself could never be duplicated based on any description given for it by its inventor and, in a repetition ofhis oral remarks, 3) the fact that only cancer grafts were experimented with was nothing to shout about. He strangely added that because the animals who had been irradiated subsequently were able to entirely reject new grafts, the whole phenomenon offered no proof that cancer cells could be killed while healthy cells were not. The whole thing came down to a question ofimmunity, he said, as if that were not of the greatest possible importance.

To which, in due course, Guerin and Riviere replied: "It has been claimed that our experiments are valueless because they were carried out on grafted tumors and that other therapeutic measures were known to get rid of such tumors and their metastases. *We defy those persons who have made such affirmations* to prove, *with the use of such other measures, that animals infected with T-8 tumors can be cured at a percentage rale identical to those obtained by using the device which Monsieur Priore has developed."*

Not a soul has responded to this challenge, then or since.

A second cancer expert at the meeting, a woman of great influence, resorted only to the cavil that the experiments had been of doubtful quality since none of the animals had been *weighed.* The fact that those same animals had survived normally lethal cancers seemed not to have *weighed* with her.

There were many more observations of the same ilk. They seem atrociously paltry, trifling and picayune coming from professionals who, if they no longer believed in the Hippocratic oath to which they once swore, are considered by the public in general, and by cancer patients in particular, at least to be concerned with seeing what a little light on the problem might reveal before extinguishing it, as Professor Courrier expressed it.

At the same time, we must not forget Priore's decidedly difficult personality. He was an inventor determined at all costs that his invention be developed for the benefit of humanity, yet anxious that that same humanity not steal it from him. As author Graille puts it, "His conceptions and attitude directly or indirectly conditioned the overall essence of this affair. Full of enthusiasm, from the very day he discovered that the ray he had developed had a curative effect on a cancerous cat, he developed a single-minded fixation on cancer One could understand and sympathize with him on this score. Here he is, a little Italian immigrant without money or means, and he is going to offer the world a cancer cure. He is so convinced that he wants to move ahead to doing just that. He will never understand or accept the exigencies of Science or Medicine. For him, experiments, controls, verifications and parallel research are a waste of precious time. 'I've made machines which cure cancer. Take them and treat cancer patients. Don't bother with the rest.' Such would be a summation of his point of view."

Through the efforts of persons kindly disposed to the inventor, this point of view was softened and he came finally to understand the- necessity for what has been called scientific rigor, on the other hand. another aspect of his character never changed an iota. This was his determination to preserve the secret of his invention, motivated first of all by his unshakeable desire that it be developed in Bordeaux, the city of his adoption, for the citizens of that city. Deeply rooted was his belief that if he made his secret public, the machine would be taken from the Bordeaux region and further developed by Parisians, those who considered themselves to be in the penthouse of the scientific edifice. Once this was accomplished, he would likely not have one more word to say about the matter. Therefore he continued jealously to conserve his secret and put confidence in nobody.

As Graille generously concedes, he may well have been right. and adds: "All his life he had to go up against men, whether scientists or industrialists, who had but one idea in their heads: to get to the bottom of the inventor's secret in order to build for themselves a machine which they then could exploit for their own account, for their own glory. Many such 'Priore Machines' were to be actually built more or less surreptitiously or clandestinely. Not one of them ever worked."

While one might easily accuse Priore of a limited view, the horizons of the researchers themselves were certainly not as broad us they might have been. Those involved in bio-medicine were content with the results produced by the machine, the workings of which were of no concern to them. A black box, as it were, emitted a ray that definitely affected experimental animals. At the same time, as researchers specifically interested in the cancer problem, they never gave a thought to what the Priore Ray might accomplish in the wider clinical domain of other afflictions.

As for the physicists, they were seemingly not up to the task of comprehending a complex radiation that had miraculously sprung, as from the head of Zeus, out of the intuition of a man they considered to be an undereducated and all but illiterate gadgeteer. Still others, whether physicists, biologists, doctors of medicine or specialists in a dozen other fields, were willing to throw the baby out even before it went into the bath water. In their eyes Priore was just a nobody.

Behind the scenes, many of these scientists resorted to using the press to achieve their own ends. Thus, the chief medical chronicler for Le Monde (the French New York Times), herself a doctor of medicine, was led to write outright lies about the Priore Affair—specifically and falsely stating that cancer patients had been treated with the Priore Ray in the clinic of Professor Lachapele in Bordeaux with not only negative, but disastrous, results.

On the other hand, a journalist for another leading Paris daily, Le Figaro, scrupulously conscious of his responsibility to fairly report what was going on, aptly wrote: "We would like to see at least one thorny point clarified as soon as possible. Several years ago P'rofessor Biraben of the Bordeaux Medical Faculty (who at that time had not become a ranking professor) was involved with the Priore device. According to certain reports from medical circles, his results seemed, even at that time, to have been already quite positive on small animals and he seems to have written a report to that effect, He was advised by highly placed authorities "to keep quiet" and stop talking about this affair. If this turns out to be true, it would be a veritable medical scandal to be judged in the harshest terms."

Could one have put it more succinctly?

The foregoing is to present something of the flavor of what was transpiring in the wide world far removed from the laboratory of

Priore who, at the time unaware of it, was revelling in the fact that his machine had been successfully used by high-ranking French cancerologists and its results reported in three separate notes to the Academy of Sciences.

His courage was also more than buoyed by the arrival on the scene of the commercial director of a large French industrial firm specializing in the intricacies of manufacturing glass components. This man had heard that Priore needed a large tube that was beyond all existing norms and perhaps did not exist anywhere in the world. This tube, it can be stated, contained a rare gas, neon, which when excited into a plasma, seemed somehow to convert the various electromagnetic inputs into a single Priore Ray which surged from the business end of the tube. In the tube were an anode and cathode. Peculiar to the anode was that it had to *rotate* to produce the desired biological effects and this is but one of the anomalies in Priore's equipment which physicists and bio-physicists have to this day been unable to explain.

The manufacturing company, a subsidiary of the internationally known company, Saint Gobain, was looking for a new product. The commercial director thought the new tube might fill the bill, particularly if it could be adapted to a machine that might ultimately cure cancer, a product that indubitably would have an enormous market across the world. There were plenty of problems with regard to the tube, notably those of its large dimension, its resistance and its conductability. When the tube was finally made, it now seemed that. Priore would have to explain his discoveries to the scientists of the company that had made it. One of these was sent to elicit such an explanation but was, so to speak, "shot down in flames" by Priore. So a second attempt was made by Ivan Peyches, a senior executive of the company, and president of the Society of Civil Engineers of France, who made a detailed investigation of the device. His reports were subsequently lost, but there remained an article he published in a leading French journal, Sciences and Technics, a short time before his death in 1978. It bore the intriguing title: "What Are So-Called Paranormal Phenomena?"

In it the engineer wrote: "There was so great an accumulation of components capable of having some kind of action, and being unable to work separately, that the results of measurement were limited to proving that there were no specific rays that issued from the tube (Priore talked about canal rays), no more than there were any X **rays.** On the other hand one could detect a magnetic field which was the end result of a field proper to the tube and of the magnetic field of a solenoid that constituted the experimental chamber, an electromagnetic field with a frequency of 16 megacycles (19 meters) and a high frequency field (metric waves), the whole being pulsed at a very low frequency of an order of one per second. It was impossible, in such an imbroglio, to determine what was necessary and what was sufficient. Priore maintained that the simultaneous action of his various generators was indispensible to achieving his effect."

Peyches then went on to relate how he tried to persuade Priore to offer a more precise definition of his thinking about the workings of his device. He wrote the inventor: "At this point, I would say that all reticence on your part, which in your eyes would be justified by the fear of seeing yourself partially dispossessed of your work, would be of far greater detriment to you than any safeguard of your interests. Moreover, since it has become a question involved in public health, you are no longer entirely your own boss...you absolutely must bring all this to the clear light of day and I don't believe you can do it alone...You must supply all the characteristics so that third parties can reproduce your results." Then, he concluded by citing the words of an academician: "Many phenomena are rejected by the scientific world because they are considered irrational: But it is not B proof of scientific honesty to refuse a priori to try, out of homage to truth, to have a look at them and perhaps to understand them. Will Science one day be able to abandon its taboos?"

It was Peyches' final conclusion that, in the end, Priore was a man of genius who knew absolutely nothing about what occurred in his machine from the scientific point of view. The company which he represented no longer exists since it was bought out by the American firm of Corning Glass.

Industrial interest in the Priore device was not limited to the Saint Gobain subsidiary. Next into the lists was a company in Anguouleme, Leroy-Somer, which specialized in electric motors, generators and later was to branch out into solar power. Its president, Georges Chavanes, took the initiative to write to Priore in 1965 that his company was interested in providing some of the complex electrical equipment needed by the inventor, more particularly high-powered generators, on the condition that Priore move his operation to the company seat at Anguouleme. When the inventor categorically refused, Chavanes tentatively agreed to build a factory to manufacture the Priore device in Bordeaux itself.

The alliance between Leroy-Somer and Priore, shaky at best, lasted two years and blew up on Holy Thursday of 1967. The period was a stormy one for both parties to the agreement. Priore did his best to convince Chavanes to commit himself to building a huge machine with a magnetic gauss strength of 10,000 gauss. In the end he got one that put out only 920 gauss, not much stronger than the machine he had already built which put out 620 gauss. Since the field of action increased with the gauss strength, Priore reasoned that a machine of literally behemoth size would be able to irradiate the whole, or every part, of a human cancer victim lying on a stretcher, whereas the smaller machines had been effective only for small animals or for treating a limited portion of the human body.

Chavanes and his company were aware that it would be a tremendous financial burden to contemplate building the larger machine. So they went ahead with plans for the smaller one while at, the same time putting great pressure on Priore himself to make him feel that he was the least important cog in a new gear, in fact that his status was reduced to being a simple employee of Leroy-Somer. In Graille's estimation, this lack of psychological finesse on Chavanes' part constituted what he called "the blackest pages in the Dossier Priore."

Even the smaller machine was to cost about half a million dollars, a price which today, due to inflation, could be tripled or quadrupled. During a stage in which an intermediate machine was designed by the chief Leroy-Somer engineer, Ribeau, a machine that never did function properly, Chavanes all but forced Priore, who was heavily in debt, to sign a contract which was falsified. The falsification was a matter of one word which was changed in the contract. In a phrase reading that an exclusive license of patents, and subsequent patent modifications, would accrue to the company "for all countries solely for therapy on cancers concerning animals and humans," a word was inserted by hand so that the phrase read. *"concerning particularly* animals and humans" implying that other uses of the machine, whatever they might turn out to be, would also accrue to the company. This one word change was amended on Priore's copy of the contract by calling the word "particularly" a "nullified word," but on Chavanes' copy it was called an "added word."

Leroy-Somer believed it was sufficiently well positioned in the driver's seat to be able to deal on behalf of Priore himself with the French governmental institutions, mainly the General Delegation, concerned with the funding of the new machine. When Priore learned of Chavanes' contact with the General Delegation he wrote a letter informing it that no one had the right to deal in his name. Nor did Chavanes even attempt to cut the Saint Gobain subsidiary, which alone could supply the tube, key to the device's functioning, in on the government funding.

In the meantime, no less a figure than Professor Kastler, soon to win the Nobel Prize in Physics, came down from Paris to inspect. the existing Priore device. He brought with him Delmon, who, we recall, had worked with Berlureau on the first animal experiments and who

NOW, it turned out, was trying to build his own version of a Priore device on the sly without telling Priore. Kastler's bringing Delmon with him to Priore's lab so angered Robert Courrier that he told the physicist he had committed a real gaffe. He also convinced Kastler that Leroy-Somer should build a machine with a power of at least 5000 gauss, but Chavanes refused. There seemed to be no harmony of outlook between the leading industrialist concerned, on the one hand, and the top physical and biological scientists on the other.

While all these, and many more, peripatetics were proceeding, Priore's sister in Italy came down with cancer. Beside himself with grief, Priore informed all concerned to commit themselves either to building an intermediate machine correctly, under his supervision or, better, the 5000-gauss machine, and to do this in time to save his sister, or he would wash his hands of the entire matter. Confronted with this ultimatum, the company began to work round the clock to perfect the intermediate machine but engineers involved, believing themselves to be more adroit with respect to its design than Priore, left out a host of what, to them, were unnecessary components. The result was that when the machine was first put to trial, most of the components burned out or otherwise failed, and the machine itself became a useless pile of rubble.

Shortly thereafter, Priore's sister died of cancer. Her grief-stricken brother went into what amounted to total isolation, unwilling to talk to a soul.

The whole Priore affair might have ended at that point, in the early part of 1967, were it not for the entry onto the scene of a key figure, Professor Raymond Pautrizel. Born on 3 June 1916 in Basseterre, capital of the French Carribean island of Guadeloupe, at forty years of age he was on the Faculty of Medicine at Bordeaux. He soon became known, world-wide, as the "father of parasitological immunity," a title he never accepted, saying that, if others had awarded it, it was simply because "he had searched through old scientific publications to find ideas that were as valid for modern research as they were forgotten by modern researchers." And he later was quoted as adding: "It is really too bad that researchers today don't pause from time to tome to dig into studies made by their predecessors, some of which were performed even decades ago!"

Professor Pautrizel was awarded the first academic chair in France for immunology, and later a special unit was created for him for parasitological immunology, a subject which is both simple and complex. The simple part involves the fact that various immunological techniques can be applied to diagnosing specific parasites that have invaded an organism in order to develop preventative actions against them via vaccines, or curative actions via serums.

When invaded by parasites, organisms react by creating antibodies, specific substances aimed at killing the invaders also known as antigens. These antibodies are liberated, like an attacking army, into the blood. Simple enough so far. The complexity arises because the defending army, the parasites, don't just lie down and die under the attack. They are capable of modifying their "personalities," as it were, and of changing various of their characteristics such that the mechanisms that the host uses to recognize, or detect, the invaders are invalidated. Thus, the substance which an organism would secrete to destroy an invader A becomes incapable of recognizing A, now become A-l, and therefore incapable of destroying it.

The organism at this point seems to realize it has to create a different substance to rid itself of its antagonist but, in the meantime, the metamorphized parasite is getting on with its assigned destructive task. Alternatively, the parasite has another capability: that of itself liberating substances which can annul or annihilate the organism's overall defense system. A sort of "in the blood" version of Star Wars is going on at the microscopic level.

The study and classification of the substances - - call them weapons - - emitted by parasite-attacked organisms allows for the establishment, in turn, of batteries of tests to define the exact nature of the parasites themselves in order to come up with an appropriate therapy or counter-weapon.

This then, is the essence of parisitological immunology, Raymond Pautrizel's area of research. He specialized on a particularly lethal parasite known as trypanosome, the scourge of tropical third-world countries where, in one form, it causes sleeping sickness in animals and humans, in another, equine syphillis, in still othera, other afflications. Over the years, during which he produced a small library of literature on the problem (known mostly to specialists in countries where that problem is acute), Pautrizel and his team discovered, among other things, that the trypanosome can modify itself, again and again, up to 101 times over a period as short as only three weeks.

Even before his work on trypanosomes, Pautrizel, back in 1949, was one of the first researchers to discover what is known as *ambivalence* in drugs, notably histamine. Histamine is a substance which is secreted by an organism as a defense mechanism but if oversecreted by certain cells circulating in the blood, it becomes virulently noxious, mainly by overdialating blood vessels, thus making them permeable to water and leading to edema and even death. This process occurs, for instance, in some human beings who are highly susceptible and over-reactive to bee or wasp stings.

Pautrizel's research on the noxious aspects of histamine led to his finding that the same substance, applied in requisite small doses, is extremely important to the defense system of the organism. Today he stresses the notion of *ambivalence* in many areas of his work and characterizes it as "a key to the biology of the day after tomorrow."

To finish with the background on Pautrizel, before bringing him on stage in the Priore drama, it may be added that only a few years ago, at a formal reception for him attended by the medical elite of France, he was given a Basque *makila,* an iron-bound honorific cane of sculptured wood, in tribute to his work. On it was the incised inscription: "Sometimes to heal, often to alleviate, always to console," an epithet that perfectly characterizes a medical doctor imbued with that kind of rare compassion that marked Pautrizel's character.

When Robert Courrier sent Madame Colonge to Bordeaux, it was Pautrizel whom he asked to provide her with every assistance. In this way, Pautrizel was first introduced to Priore and his device. After witnessing the results obtained with it he was to say: "What stupified me, and led me to ponder the question, was to see the control animals die from their tumors in 3 weeks, while at the same time I could observe that the tumors in the animals under treatment were literally melting away and the same animals were taken back to Courrier's lab at the College de France in Paris in perfect health." AS a result of his thinking about the problem, Pautrizel came to the belief that the machine, however it worked, did not exert any action at all to kill cancer cells but, through as yet unexplained mechanisms, stimulated the afflicted organisms to provide themselves with new immunological weapons that could overpower the cancer cells.

To shed light on this problem, Pautrizel proposed the simple expedient of experimenting, not on cancer-infested animals, but on *in vitro* cultures of cancer cells. He made this proposition to both French and British cancerologists but they were convinced that the Priore device *had to be actually killing cancer cells themselves,.* They could not see the point that, if the machine did not kill cancer cells, then it was doing something else to the body to allow it, and not the machine, to do that job.

Pautrizel's involvement with the British was the result of a team being sent from England to experiment with cancer mice with the Priore Ray. What happened cannot be related in this brief resume except to say that, out of a lack of understanding on the part of certain British cancer experts and malicious conniving on the part of one member of the cancer "aristocracy" in Paris, the experiments were put under a cloud. It was alleged that mice had been substituted somewhere during their long round-trip voyage between

England and Bordeaux to make it look as if a failed experiment had been successful. This did not prevent Sir Alexander Haddow, chief of the prestigious Chester Beatty Research Institute for Cancer from stating, at a meeting in Paris, that the Priore machine had been indubitably effective on the English mice and supporting Pautrizel's idea that experiments should forthwith be done to see if the Priore Ray had any effect on cancer cells *in vitro.* Haddow's suggestion backing Pautrizel's recommendation fell on deaf ears.

Because of the emotional turmoil and rancor with respect to cancer that had so long surrounded Priore and the workings of his machine, Pautrizel suggested that it be tried in a completely new area, one he knew so well, namely on afflictions caused by the trypanosomic pathogen. Before these could get underway, however, someone had to persuade the still desolate Priore to return to work. Pautrizel, known to those really concerned with and knowledgeable about the potential of the Italian's invention, at last was able to convince the inventor to cooperate and get back into harness. This ho did with that rare combination of diplomatic tact and warm human sympathy with which only the Pautrizels of this world are gifted.

In the meantime, Riviere had gone on to implant new 347 tumor grafts in rats previously cured of 347 tumors. When none of the tumors developed, that result added one more argument to back Pautrizel's idea that the machine was, in fact, affecting the immunological defense system of the animals. However, when Riviere tried the same procedure with the T-8 tumors, his animals died. This lead to the conclusion that the immunity acquired by the animals to lymphoblastic lymphosarcoma 347 was specific to that tumor. When a note on this research was sent, again through Courrier's good offices, to the Academy, for the first time, it strangely omitted from the listing of the participating researchers the name of Antoine Priore. It seemed that Riviere had been taken to task by fellow cancerologists who believed that Priore was nothing but a naive bumpkin or, worse, a swindler. They had warned him against publishing any papers with which Priore's name would be associated This rank injustice and lack of fair play again sent Priore into a fit of despondency and depression from which he could only be wilth drawn by those subtleties involved in Pautrizel's sympathetic and friendly counsel.

On 25 July 1966, another note was sent to the Academy filed for the first time not under the rubric Cancerology but under the rubric Immunology. It was entitled "Influence of Associated Electromagnetic and Magnetic Fields on the Immunity of Mice Infected with Trypanosoma equiperdum." The conclusion read: "The treatment allows the organism to rid itself of parasites even when these have invaded it in a most intensive way.... There is an enhancement of both the specific and aspecific factors of immunity."

Thus, for the first time, the field of research shifted from the narrower field of cancer to the much vaster domain of immunology. And, for the first time, Pautrizel's name appeared as the senior author on the paper. It also appeared that, for the first time, there should no longer be any problem about experimenting with the I'riore machine. Such was not the case.

Still complicating the whole issue was the fact that Priore himself was using different setting to produce different varieties of radiation depending upon his own intuitive evaluation of the particular biological experiments being run with his machine. He would never reveal the nature of these settings.

At this point there appeared on the scene a new researcher who became Pautrizel's loyal ally, a young woman, Pierette Chateau-Reynaud Duprat. During her work in Paris, she had learned of the Priore controversy, and, against the stern advice of mentors senior by many years to her in the cancer hierarchy, she came to Bordeaux to meet Pautrizel and learn more about the research.

Her work, performed over many years, is too detailed for presentation here but it led to important conclusions. One was that the Priore Ray had no direct effect on the trypanosomes themselves but stimulated and reinforced the defense mechanism of the infested organisms, allowing them to reject the parasitical influence with an effect so durable that they were no longer subject to this influence even after treatment stopped.

Another conclusion was even more important and involved, in part, British research. It pertained to the effects of the machine on both *allografts* or those made between two different individuals of the same species, and *isografts,* or those made between two different individuals of the same genetic line having in common antigens that were characterized by what is called the same histocompatability. The conclusion was that not only was the rejection of *allografts acce*lerated by the Priore Ray but that *isografts* were also rejected. This meant, in sum, that the ray stimulated not only the *defense* mechanisms of the organism but also, and more importantly, its re*cognition* mechanisms. In the case of an isograft, this allowed the recognition of weak antigens that were not recognized in non-irradiated animals. In other terms, where at first the anti-aircraft batteries could not shoot down the aircraft because they could not see them.now they could shoot them down because they could see them. In immunological terms, the ray affected both humoral and cellural, both specific and aspecific, immunity.

Here we must return to the mystery of the settings on the device.

As a result of the new experimentation it seemed that, depending on those very settings, the active ray, complex as it was, could have either similar, totally different, or diametrically opposed effects. Thus it was not a question of a ray having universal effects — a kind of magic bullet capable of killing any target — but of multiple radiations which, due to the complexities in Priore's personal makeup, have unfortunately yet to be sorted out and explained.

Thus, the machine originally designed by Priore, called the P-l when it put out a wave length of from 19-21 meters, had a radical effect on certain animal cancers, on *cellular* defense mechanisms, and finally, but not universally, on organisms infested with **Trypanosoma equiperum,** (hereinafter called T.e.).

A second machine, dubbed the P-2, was at first not able to produce these frequencies. What it did put out was a frequency of 17 meters that *was* universally effective against T.e. and seemed to act. not on the cellular, but the *humoral,* defense mechanisms. The rejection of grafts depends on the cellular defense mechanisms, which partially explains why Pautrizel when using the P-2 machine, selected the T.e. vector, as it is called in microbiology, just because this creature is fought by the organism's humoral defense system.

Consequently, the bio-effects that were successfully attained depend on the varying, not to say quixotic, nature of the radiation At one point Pautrizel actually did experiments on animals infected with *plasmodia* — the vector for malaria which attacks red cells - and found that the settings used were effective while never learning exactly what they were or the exact nature of the radiation. Further more, Priore himself maintained that over the years he had success fully treated cases of human tuberculosis but, again, never revealed which frequencies had been used to achieve this.

Several more notes were sent to the academy on the successful work performed with the Priore Ray on animals affected with T.e. But the central issue remained: how to find out exactly how the- machine worked. It fell, not to civilian scientists, but to those in the- French army service to attempt, at this point, to work out the problem. The army service brought into the picture was the DRME (an acronym which translates as Administration for Research **and** Test Methods), to which Pautrizel had sent a request for funds in 1968.

This request was the subject of a meeting at which were present three of the top names in French science, one representing biology, the second physics and the third, medical physics. The latter two turned in extremely unfavorable reports recommending that no money be wasted on the problem. The biologist, however, turned in a most favorable report and, despite the fact that he was in the minority, his opinion won the day.

As remarkable as was this victory, it was even more stunning and incredible given the fact that this biologist was the same Andre Lwoff who had so adamantly opposed the Priore research a couple of years previously. Lwoff had summoned the courage to completely reverse himself only after he sent one of his most trusted colleagues to do secret experiments with the Priore Ray on mice injected with peroxydase (an antigenic solution) to see if they would produce a higher level of antibodies than non-irradiated animals. This they did so well that Lwoff became convinced that the Priore Ray caused an extremely important increase in immune reactions. These results were never published because, before the experiments could be repeated to be absolutely sure of their results, the machine suffered one of its many interminable breakdowns.

The DRME report was at length, and in length, issued but not publicly since it was protected by a military classification. However, a synthesis of it was finally published in November 1979 by Herbert Gossot, Secretary General for the French Association for Bioelectromagnetism, under the title: "A Scientific Balance Sheet on the Priore Ray." Its contents were as follows:

"The two physicists assigned by the army made a complete analysis of the electromagnetic radiations and magnetic fields activated by the Priore device. They thus determined the spectrum of frequencies which the device emitted. They showed particularly that frequencies in the visible light and infrared range had no biological effect; that there were no X-rays or Y-rays; and that the pulsed ultra-high frequency electromagnetic wave was modulated in amplitude to that of a high-frequency wave. They did a topographic survey of the respective intensities of the various magnetic and electromagnetic fields in the experimental plane of the device. In particular, they determined the spatial repartition in this plane of the density of the strength of the ultra-high frequency wave. They showed that its value was very weak and that it could not produce any kind of overall significant thermal effect imputable to the hyperfrequency ray.

Finally, and most importantly, by using what they had learned about these repartitions, they demonstrated a clear correlation between the biological effects obtained and the intensity of the hyperfrequency ray. What they actually observed was that, on the **biological** model used, i.e. experimental trypanosomosis of the mouse, there was a diminution of the rate of evolution of the parasitemia that was proportional to the strength of the hyperfrequency wave. To quote them: *'These experiments of correlation are of certain interest: they confirm, if there is still any need of so doing, the* *biological efficacy ofthis device."*

The two physicists, Bottreau and Berteaus, are still interested in rebuilding a Priore device with which additional biological research could go forward. At the same time they suggested to administrative bodies in French science the creation of a special laboratory for bioelectromagnetism to fund more work, a suggestion in which Professor Pautrizel concurred. No action was taken and their report was kept under wraps. In a note they presented to the Academy of Sciences on their investigation, they were not allowed to include the names ofthe laboratories where they worked: in the case of one, the CNRS Magnetic Laboratory at Bellevue near Paris, and ofthe other, the Laboratory of Ultra-Hertzian Optics and Talence near Bordeaux. Why? Because the directors of these laboratories did not want any mud in the Priore affair to be spattered on them.

The next experiment done by Pautrizel was on rabbits whose testicles had been so seriously affected by trypanosomes as to be almost entirely destroyed. After radiation the same testicles took on their normal histological appearance and the rabbits, able to procreate again, in no way abstained from their newly regained ability. **This implied the complete regeneration of an organ that had all but completely degenerated.**

Yetjournalists, who sought out truths about the Priore affair in Paris from high officials they believed would know best about what was going on, continued to be led astray. For example, an American scientific reporter, writing in the **Saturday Review** of **Science** in 1973 saw fit to state: "It is really a question of a mystical problem that has little to do with science." He was quoting Professor Bader, a man who for 15 years held top administrative posts in science that could have allowed him to back the Priore research with all the funding necessary to its accomplishment. At the time Graille's book came out, Bader issued a book of his own about the Priore affair which offers no real idea ofwhat was involved. When I asked several people in France why Bader had written the book, they were unaware of Bader's inmost motivation.

Machinations continued to swirl about the case over the next several years. Behind-the-scenes intrigues, distorted accounts in the press, lethargic attitudes on the part of administrative officials who would not take responsibility to cut an increasingly tight Gordian knot, outright fear of various personalities to become too deeply implicated lest they lose their jobs - - all these, and more, continued their daily round in an atmosphere of "Business AS Usual," and "Don't Risk Your Neck."

To get to the nexus of the situation, we have but to cite the observation of one of the few perspicacious journalists who, in **the** prestigious scientific monthly, Sciences and Life, wrote: "The physicists are convinced that the effective Priore Ray is very complex but to analyze this further some things first have to be made clear. One is to raise the suspicion that has surrounded Monsieur Priore with a fabulous acretion of misunderstandings, insults and accusations of being a swindler over many years. What is needed is a veritable national effort to act effectively and to act rapidly."

Over the next two years the decision-making process of the French government lumbered its way along until it was finally decided to back the construction of a powerful machine. This decision was not favorably accepted in many quarters. As Le Monde would comment: "The decision was made in spite of the disapproval of many scientists. When money is tight, one should pay particular attention to how it is being spent. Such seems not always to be the case. A credit of some $3.5 million francs (or about a million dollars) has just been accorded to finance the construction of a new Priore machine."

The scientists to whom the article referred were in a rage. They understood, at this juncture, that the only way to put an end to the affair was to eliminate Pautrizel who, because of the very success he was having with his research, was seen as a dangerous competitor that might even become one of the top figures in medicine and science on a national, or perhaps, on a world scale. Indeed, it was learned that Professor Courrier had gone to the length of sending a report on Pautrizel's behalf to the Nobel Committee in 1979.

To make a long story short, the large powerful machine, the M-600, was built but a huge tube in it, after functioning for about a week, exploded. Due to the galloping inflation of the 1970's, to replace it would have cost another million dollars. The money was not forthcoming.

In the meantime Pautrizel, ever experimenting with the still functioning smaller machine, was to discover new facts. Mice with their spleens cut out, for example, also could survive injections of T.e. The Priore Ray had important implications for Arterio-sclerosis, since it effected lipid modifications in rabbits given a dietary regime high in cholesterol. This research, published in another note in the Academy Proceedings, instead of being warmly received, only irritated the cardiological fraternity which felt, as some of its members put it, "trapped" by Pautrizel's efforts.

One particularly virulent opponent was Professor Bricault, Dean of the Bordeaux Medical School who, as late as 1980, was telling his own students that the published results were a farce and had never been obtained. The students, who carried out a special investigation of the matter on their own, were able to judge what a farce their own medical dean might represent.

L'Express, the **Time** magazine of France, read by at least half the population of French intellectuals, had the gall to compare the results of the Priore research to those of the infamous Trofim Lysenko of the Russia of Stalin's day. Haughtily **L'Express** added: "Today Priore's defenders explain that his machine has not only cured cancer but, in all probability, altered the immunological characteristics of mice. Were this, in fact, so, all the immunologists, all the geneticists of the world would unite to affirm that a machine capable of changing the genetic patrimony is the discovery of the century, far more important than the atomic bomb or the conquest of the moon. Unfortunately, the history of the whole thing has never been properly elucidated." The article was illustrated with photos distortedly selected to convince viewers that the Priore machine was as serious and effective as the one that purportedly brought Frankenstein to life.

In this poisonous atmosphere the slow work of building the M-600 went forward. To give anyone who was not there a feeling for this endeavor we may now cite verbatim a passage from Graille's book: "The construction and assembly of the prototype —the M-600, that of highest power and variable parameters — were fraught with many uncertainties and delays on the one hand and, on the other, were marked by the stamp of Antoine Priore's sparkling genius.

"To go from an apparatus that developed 1,240 gauss applied over an effective area of some 20 centimeters, to one developing 5000 gauss over an area of 60 centimeters means to take on an extremely risky technical and technological wager. Electrical, mechanical and glass-blowing specialists plunged into the unknown. They had to conceive, make, adapt and put together all the various myriad components almost haphazardly with no precise technical study being previously available. Priore's stubbornness forced them to take on a trial-and-error manufacturing "gimmickry" without precedent. As the thing was put together and preliminary tests made, it became clear that many of the components were unsuitable and that they would have to be modified or replaced. The tube itself, made of pyrex, 60 centimeters in diameter, and 6 meters tall, had to be replaced twice after it imploded. In fact, practically everything had to be reconsidered or readapted. "Everything" meant the parts going to make up a generator of 50 tons in weight. For example, the coil which created the magnetic field: 5.5 tons with 11 miles of copper wire. For example, the numerous cooling circuits which stabilized the thermal equilibrium of the generator and its environment or, additionally, the circuits governing command, control regulation and selection — 6 tons of electrical cables of which 15 miles were of tele-command wiring.

"Priore astonished everyone. Breakdown after breakdown, incident after incident, it was he alone who showed what to do next, indicated the proper steps to take, the right settings to adopt, the right way to assemble the components: He was virtually building his machine by himself, nursing its construction along day after day, all the engineers' studies and efforts actually, and ultimately, serving only as a preliminary attempt, a sketch as it were. When Priore made his presence felt, things began working."

Then.... after the machine was built: "The part of the entire apparatus to generate electricity was set up on a provisional basis. It was so noisy that, while functioning, it woke up the whole neighborhood. The number of experiments had therefore to be curtailed so that the machine would not be used at night. And, all at once, everything came to a halt. The Faraday cage, shielding and isolating Priore's apparatus, was torn and fissured by the shock of the cement pilings that were being sunk into the ground all around to hold up the building under construction. This allowed high-frequency waves to escape which disturbed radio broadcasts emitted by local radio stations, the army, and civilian aircraft for miles around."

Nevertheless during the week or ten days that the machine was in good operation the results of experiments performed with it were more than formidable. First of all, it allowed for as many as forty experiments to be performed on some 280 animals in a remarkably short period of time. Among the discoveries made were: The ray emitted provided the treated animals with an extremely strong immunitary response. Animals whose immune defenses had been attentuated by an immuno-depressant were able to overcome the effects of injected parasites but relapsed a few days later. One could therefore conclude their immune response was much weaker than those normally infested and treated.

Newborn animals, whether treated or not, developed a marked parasitemia leading to their deaths. At the time of death, the parasites had the same antigenic structure as those ofthe innoculum which thus implied that they had met with no defense at all in the infected organisms. This also proved that the Priore Ray did not act directly on the parasites themselves but only by way of an increase in the immune defense system of the organisms. The newborn animals succumbed to their parasitemia because their immune sytem was not yet sufficiently developed to be stimulated by the P-Ray. The phenomenon of a stimulation ofthe immune defenses was demonstrated by the fact that animals which had received soluble antigens developed, after being irradiated, a level of antibodies far superior to the controls.

These and other conclusions were the object of notes presented to the Academy of Sciences by Pautrizel and his team in 1978. Even before, at a colloquium held in Antwerp, Belgium devoted to African human trypanosomiasis, the same team had offered the conclusion that the stimulation of the immune defense system that allowed organisms to throw off the effects of trypanosomiasis had to be very significant in that all attempts to try to effect such stimulation through immuno-stimulants as well known as B.C.G., or Corynebacterium granulosum, had led neither to the cure produced by the Priore Ray, nor to any prolongation of the infected animals' lives, nor even to the slightest modification in the evolution of the Trypanosomiasis.

These three scientific papers did little for the cancerologists who read them except to exacerbate their urge to oppose the Priore research, if not to arouse their outright hatred for the principal experimenter, Raymond Pautrizel. Could this have been because, for over 20 years, the same cancerologists had been working in vain to provoke in cancerous organisms immuno-stimulative reactions by intensively and successively vaccinating them with B.C.G.? Many others had been life-long apostles of chemotherapeutic cocktails of all sorts, or life-destroying ionizing radiations, or, what more recently has become the fashion, of applying the two methods in endless combination.

For this reason, they saw Priore and Pautrizel as nothing more than spoil-sports who had to be destroyed.

One of the opening shots in this campaign was a letter received by Pautrizel to inform him that his request for funds to continue his research through Unit-89, a unit that had been specially set up for him to direct, had been denied. It took many months of investigation for Pautrizel to learn that the real reason for the refusal was because of his work with Priore.

Next Pautrizel was informed that his appointment as director of the same research unit would be extended for only two years, whereas the normal extension for similar units was five years. A third insult came when Pautrizel tried to win a post within his unit for a high-ranking military physician, who had been his student and who had decided to quit the military in order to participate in the fascinating research prosecuted by his mentor. Pautrizel's request for funds to pay this physician, who all his life had been working on tropical medicine closely associated with problems of trypanosomiasis, were refused four times in a row with no cogent reason given. The physician, who in the meantime had volunteered his time without pay, finally became so emotionally overwrought that he gave up his medical career and retired to the countryside where he gave himself over to alcohol. Then Pautrizel tried to get a salaried post for another ofhis brilliant collaborators (who still works with him). He was told that this man could take up his new functions only if he left Bordeaux. One could go on with many other shocking stories but we will leave it to Graille to conclude: "Everything possible was done to isolate Pautrizel, to separate him from his collaborators. Every single one of these collaborators saw their careers put in jeopardy, compromised, or broken."

As a final insult, when the time came again to renew Pautrizel as director ofUnit 89, those responsible, not daring to overstep what even they knew to be decent limits by not extending him, simply abolished the unit. And to add injury to that insult, a doctoral thesis that had now been prepared by Priore, and backed not only by Pautrizel but by Nobel Laureate Andre Lwoff himself, was summarily refused by the President of the University of Bordeaux.

It is perhaps unnecessary to state that the details behind all of this skulduggery could, and did, fill up two chapters of a book and make for the most heart-rending reading imaginable.

So what happened next? In the autumn of 1977, Professor Georges Dubourg, one of the leading lights in Bordeaux's company of surgeons and a friend and admirer of Pautrizel's, came to him to say openly and baldly: "My friend, at the point you've reached, there is only one more way to jolt medical opinion and that is to treat human cancer patients." Pautrizel was hesitant, believing his role to he one of continuing with his animal experiments but where would the funds for that come from now? He therefore asked his old mentor, Robert Courrier's advice. Courrier gave the green light. The treatments were restricted to terminal cancer patients whose immune defense systems had been disastrously weakened by chemotherapy or radiation or both. At least one ofthem was totally cured. The other 1ived, without pain, for a period many times longer than predicted by prognosis. Dubourg, Pautrizel and their collaborators wrote up the results and sent them as an official communication to the French Academy of Medicine for publication.

The reply they received from that Academy's perpetual secretary reads: "Experts whom we consulted consider that your work does not fall within the jurisdiction of our members and that it would doubtless find an audience more worthy of its purpose in a more specialized society."

To which Pautrizel formally replied: "Since two of the four signatories of our note are corresponding members ofyour Academy, could we not benefit from the remarks and comments made by the committee which saw fit to refuse our paper? And even, if this is not too indiscreet a request, to learn the names of the expert members who were consulted which would allow us to get into contact with them directly and to benefit from their singular competence?"

His letter has remained unanswered for four years.

There was nothing more to do except one thing which Raymond Pautrizel, as a man of science, had always been careful to avoid: Get a responsible journalist interested in the case, inform him of all possible details, and let him carry the Priore Affair in all its harrowingly loathsome aspects to the broad reading public. That journalist was Jean-Michel Graille.

For four years, Graille went about his task, publishing three consecutive long articles in his newspaper **Sud-Ouest France** and finally the book to which we have referred and of which this presentation is largely a resume. As early as 1980, Graille would write in his newspaper: "The Priore Affair is simple in essence. It can be reduced to a simple alternative: either the machine developed by Antoine Priore is of no interest and, having shown this, the affair can be considered at an end. Or else the machine is of real and demonstrable medical interest and, if that is officially recognized, he would be allowed to get on with the work. For this dilemma runs the risk, yet again, of being buried under delays and evasions. Beyond all the powers-that-be that have been directly connected to the affair for many years now — the power of finance, the power of medicine, the power of science — perhaps it is now political power with which responsibility lies if it can rise to meet and assume that responsibility through decision."

That was Graille's statement in 1980. His book which came out four years later ends with the sentence: "The Dossier Priore thus depends, from here on out, on a decision that must be taken on the very highest level, and imperatively. This responsibility devolves, in last resort, on the chief of state and on him alone. Will he assume it?"

Would the President of the United States?

Note added by T.E.B.: Antoine Priore is now dead. His machine has been dismantled. The iron dogma and hatred of electromagnetic medicine by bureaucratic science may have doomed hundreds of millions of humans - - whom Priore's device could have saved - - to bitter, agonizing, and unnecessary deaths. Hitler, Stalin, and Mao combined were not responsible for the deaths of so many.

APPENDIX II

PATENTS

English Translation of the French Patent No. 1,342,772 of Antoine Priore, 7 Oct. 1963.

Procedure and Assemblage for Production of Radiation Especially Serviceable for the Treatment of living cells.

Brevet d'Invention. P.V. no. 899.414 no. 1.342.772 Classification Internationale: A61 k-H 05 g

Procedure and assemblage for production of radiation especially serviceable for the treatment of living cells.

Antoine Priore
Requested 1 June 1962, 14.52 hours, Paris
Released by decree (arrete) of 7 Oct 1963

The invention deals in a general manner with radiation capable of penetrating matter. More exactly, it aims at a procedure and an apparatus making it possible to obtain a combination of radiations of different types able to penetrate matter and especially to penetrate intimately living organic tissues in order to produce in them certain effects, particularly in human tissues with a view to a therapeutic effect without destroying essential elements such as the enzymes.

In conformity with the present invention, one emits in a cavity a stream (rayonnement) of electrically charged particles upon which one superposes electromagnetic radiation of the centimeter wavelength range, the wavelength of which is preferably between 3 cm and 80 cm, and one directs the resulting radiation emerging from the cavity on to the object to be irradiated.

This applicant has shown that the penetration and, in particular, the curative effects are very distinctly improved when one gives the electromagnetic radiation a frequency determined as a function of the organ or the tissue to be penetrated or to be treated. For example, a wavelength of 14 cm is suitable for the liver and a wavelength of 19.5 cm for the spleen.

Preferably, the stream of charged particles is accelerated in a particle accelerator in such a way as to increase the force of penetration.

The resulting radiation is advantageously applied and directed upon the target, that is to say, upon the tissue to be penetrated, by the intermediary of a tube which is the site of electric fields and of magnetic fields for acceleration and control, the said radiation being preferably guided and/or reflected by a rotary deflector placed in the tube.

It is often advantageous to modulate or impose rhythm on this stream of particles by means of variable magnetic and/or electric fields so as to augment still more the force of penetration. This rhythm is preferably consistent, especially in medical applications, with the intrinsic period of the tissue to be penetrated or of the neighboring tissues, for example, muscle. These intrinsic periods arc well-known in medicine and are applied, particularly, for diathermy: they are situated in the wavelength range from 1 m to 50 m and more especially from 1 m to 18 m.

Preferably, one arranges to modulate the emission of radiation, the accelerating magnetic and electric fields, and perhaps also the rotatory deflector, to the cardiac rhythm of the subject.

It seems that the result obtained by the invention in the treatment of maladies of living cells (vegetable or animal) are due to certain phenomena which will be described, it being understood that this exposition will not circumscribe the invention.

As a function of its electro-physico-chemical constitution, the cellular pair nucleus-protoplasm is endowed with electric conductivity in direct relationship with ion exchange processes provoked by metabolic phenomena. One finds in tissues the presence of an accumulation of electricity at different potentials according to the different cellular densities of the tissues.

The work of Renshaw, Forbes, Morison, Amassian, de Vito, Ruset, Albe-Fessard, Tauc, Adrian, etc. has shown with the aid of micro-electrodes the existence of slowly oscillating elementary electric activity in the interior of cells; it can be thought that the *rythmeur* (or pace-maker) is achieved by the oscillatory electromagnetic system comprising the cell nucleus. This nucleus, in effect, is made up essentially of tubular filaments of insulating material (related to chitin) containing in its interior an electrically conducting saline liquid, and these filaments, coiled upon themselves, can be considered to constitute real little oscillatory circuits.

The recent work of Warson (sic) in America, as well as that of French scientists, including a communication from Polonsky, Don zon and Sadron presented to the **Academie des Sciences** by Prof. Francis Perrin on 16 May 1960 **(Rec. comptes rend, heb.,** 250 No. 20, 3414-3416) making it clear that experimental samples of **solid** DNA manifest properties analogous to those known in ferroelectric materials, makes plausible the hypothesis that a potential difference may exist between nucleus and periphery of cells. Certain recent theories go even further and liken the cell to an electronic receiver-emitter device normally functioning in harmony with the ambient media. The oscillatory system of demand waves, constituted by the cell nucleus, would behave in accordance with the laws governing semi-conducting materials.

The applicant is led to the conviction that in a normal state of physico-electric equilibrium, the cell nucleus is positively charged, but can acquire a negative surcharge following phenomena analogous to polarization.

The invention, especially, enables organs afflicted by this inversion of their electric potential, particularly in the case of the pathologic negative surcharge of cancerous nuclei, to recover their former equilibrium.

The following description in regard to the attached drawing, given as a non-restricting example, will make it possible to understand how the invention can be realized, the details which emerge both from the text and the drawing being, of course, part of the said invention:

Fig. 1 is a schematic section showing an apparatus for production and emission of an electromagnetic field combined according to the invention.

Fig. 2 is a frontal elevation of the cathode, taken from the right of Fig. 1.

Fig. 3 is a section through III- III in Fig. 1.

Fig. 4 is the overall scheme of the electric supply.

Fig. 5 is a view analogous to Fig. 1 showing another mode of implementation.

Fig. 6 is a section through VI-VI in Fig. 5.

Fig. 7 represents schematically an apparatus for pulsing the electric current.

Fig. 8 is the circuit of an amplifier permitting activation of the apparatus of Fig. 7 at the cardiac frequency.

Fig. 9 is the circuit of an oscillator permitting modulation of the electric current according to a wavelength between 1 m and 18 m.

The assemblage of Fig. 1 contains an apparatus 1 emitting electrically charged particles 2 in a cavity or passage 3, a cyclotron 4 accelerating the particles 2 and sending them into a cavity 5 forming a tube into which merges another cavity 6 acting as waveguide for electromagnetic radiation of frequency in the centimeter range emitted by a magnetron 7. The cavity 8 formed by the joining of tube 5 and waveguide 6 leads into a tube 9 in which the resulting radiation is accelerated and aligned. The interior of the cavity-formed by the assemblage of elements 1, 3, 5, 6, 8, and 9 contains argon at a pressure of 2 mm mercury.

The particle emitter 1 consists of an electron gun comprising a plate 10 and a cathode 11.

The cathode 11 is of molybdenum and has the very special form represented in Figs. 1 and 2. It consists of a rim 11a connected by two aligned spokes 11b to a hub 11c pierced by a hole 11d with its axis along XX'. The rim 11a is in two parts (as one sees in Fig. 1) which may be held together by screws (for example) forming a cavity of revolution 11e traversed by a number of holes 11f parallel to the axis XX' and regularly spaced. The filament for heating, 12, situated in the interior of the cavity 11e and is connected to the power supply conductors 12a.

The best results are obtained with a cathode 11 of molybdenum. The applicant has obtained satisfactory, but slightly inferior, results with tungsten cathodes. It turns out that molybdenum, and to a lesser degree tungsten, are the metals whose valency is closest to the mean valency of the chemical molecules constituting living tissues and more particularly those of human beings. One might well seek to use this fact to explain scientifically the phenomena involved, but it is understood that *the invention is not limited by any scientific explanation.* Concerning, on the other hand, the gas present in the apparatus at low pressure, the best results have been obtained with argon; the applicant has also obtained satisfactory, but slightly inferior, results with other gases of the rare gas series.

Surrounding the tube which constitutes the electromagnetic chamber are arranged: an electromagnet 13 with its winding 13a, placed at the level of the accelerating coils 14 and 15. Other accelerating coils 14,15 and 16 are similarly dispersed around the cavities 3, 5 and 8.

The two semi-circular boxes or "dees" 4a of the cyclotron 4 are placed in the usual manner between the poles of the frame around which are wound the accelerating coils 4b and 4c.

The magnetron 7 is of a familiar type and must be capable of emitting in the cavity 3 a centimeter wave of adjustable wavelength from 3 cm to 80 cm.

The lower portion of the tube 9, for acceleration and alignment, contains a cathode 17 resembling the cathode 11, with a filament 17a. This cathode 17 is supported by a hollow pillar 18 pierced by holes 18a close to its junction with the bottom of tube 9. This pillar 18 communicates with a tube 18b emerging on the axis of a rotary deflector 19 carrying at each end a "crown" of graphite plates 19a inclined at 45° to the vertical. The rotating axis 19b of the rotary deflector is mounted in a support 20 fixed to the interior of tube 19 and carries at its upper extremity magnetic bobs 19c which ensure that it will be set in motion in cooperation with the magnetic bobs 21a mounted on the shaft 21b of a motor 21. The lower extremity of the rotary deflector 19 is composed of a piece of molybdenum or of tungsten 19d in the form of a pyramid whose apex is opposite the open end of the tube 9.

The hollow base 18 and the tube 18b can be of a borosilicate glass of low coefficient of expansion such as that sold under the trademark "Pyrex." They may also be of quartz. Tube 9 itself can be of "Pyrex" as above or of another glass of the quality currently used for the manufacture of electronic tubes, but its bottom 9a, which is traversed by the radiation, is advantageously made of quartz.

The duct 8 joins the tube 9 by way of several tubulures such as 8a and 8b directed in vertical planes towards the plates 19a at a certain angle, which is advantageously about 22.5°. An electromagnet 23 analogous to the electromagnet 13 of the emitter tube 1 is placed around the cathode 7. Similarly, accelerator windings 24 are disposed around the tube 9. This tube also carries, at positions indicated in the drawing, three electrodes 25, 25a, and 25b surrounded by windings 26, 26a, and 26b, respectively. The drawing shows the supply lines, 17b, 17c of the cathode and its filament and that of the plate, 22a.

The basic plan of the electric supply is represented in Fig. 4. The part 27 feeds an initial branch with low voltage alternating current: this consists of a rectifier 28 (e.g., a Kenotron) whose rectified current is modulated at a frequency variable between 30 and 120 pulses per minute by means of a resistance 29, the control apparatus lor which will be described with reference to Figs. 7 and 8. The current so modulated is passed through the electromagnets 13 and *23* in such a manner as to generate, normal to the cathodes 11 and 17, a modulated field of 10,000 to 20,000 gauss.

The part 27 also feeds a variometer (interrupter) 30 which modulates the current of this part at a variable frequency 30 to 120 pulses per minute, the current pulsed in this way serving to feed the remainder of the installation, to wit: The magnetron 7; a converter 31 whose excitation is modulated at a variable frequency *300 to 900 Hz,* yielding a doubly modulated current (first at 30-120 pulses per minute, then at 300-900 Hz) which feeds the coils 15, 16 and 26; another converter 32 producing a low voltage direct current modulated at 30-120 pulses per minute by the variometer 30. This current feeds the motor 21 as well as the motors driving the variometer 30 and the apparatus controlling the resistance 29.

The current produced by the converter 32 also feeds a voltage step-up apparatus 33 consisting of a vibrator followed by a transformer and a rectifier, and producing a direct current varied at 30 to 120 pulses per minute imposed by the variometer 30. The maximum value of the voltage produced by the apparatus 33 is, for instance, 300,000 V, but this value may vary up or down, depending on the power one wishes to operate with.

The current produced by the voltage step-up apparatus 33 feeds the coils 4b of the cyclotron and 24 of tube 9, as well as a rheostat 34 permitting regulation of voltage to the desired value between 5000 V and 70,000 V. This voltage is applied to an oscillatory circuit 35 which produces oscillations at a frequency variable at will of wavelength between 1 m and 18 m. The current available to the output terminals 35a, 35b of this oscillating circuit 35 is thus a high tension current modulated first at 30 to 120 pulses per minute (by the variometer 30) and secondly at a wavelength 1-18 m. This current feeds the coils 4c and 14; the electrodes, 25a and 25b are connected to terminals 35a and 35b, respectively, and electrode 25 is connected to the mid-point 35c.

Cathodes 11 and 17, the "dees" of the cyclotron, and the plates 10 and 22, not shown in the diagram of Fig. 4, are connected to the output of the step-up assembly 33, while the heating current for the filaments 11e and 17a is furnished by the resistance 29.

To operate the apparatus, one adjusts the controls of the resistance 29 and the variometer to the desired rhythm; in medical applications, this is advantageously the subject's cardiac rhythm: This rhythm is thus imposed upon the whole installation. The cathode 13 emits toward the left a stream of positively charged particles 2, which are concentrated by the electromagnet 13 and accelerated by the coils 14, 15 and 16 and by the cyclotron 4. Superimposed on this particle stream in the duct 8 is the electromagnetic radiation from the magnetron 7, which is adjusted to the wavelength found by experience to be most appropriate to the cells which are to be penetrated, e.g., 14 cm for the liver and 19.5 cm for the spleen. The resulting radiation is deflected, directed and accelerated in tube 9 and is directed by way of the base of this tube toward the target to be penetrated.

It must be noticed that the magnetic field of the coils 15,16 and 26 is modulated, by means of the converter assembly 31, at a frequency adjustable *between 300 and 900 Hz.* This modulation has the effect of concentrating the particles, that is to say to detach them from the walls of the tubes, and it also permits an appreciable saving in weight of the iron cores of the coils. One chooses the highest frequencies (i.e., around 900 Hz) when one wishes to produce hard radiation at the exit of tube 9, and the lower frequencies for soft radiation.

The unidirectional magnetic fields of the coils 4c of the magnetron (sic) (cyclotron?) and the accelerator coils 14 as well as the electric field of electrodes 25, 25a, 25b, are modulated by the oscillatory circuit 35 at a chosen wavelength between 1 m and 18 m. In medical applications notably one selects the wavelength that best suits the organ to be treated or its surroundings, such as muscle. As already indicated, experience with diathermy makes it possible to determine the most suitable wavelength.

It must be noted that the resulting radiation already possesses, in tube 8 (Fig. 1) a considerable penetrating force. One could therefore use the assemblage described by omitting tube 9 and terminating the cavity at the end of tube 8 by means of a glass or quartz base, the resulting radiation being accelerated and directed, for example, immediately upstream from the base, by a final coil (not shown) surrounding tube 8. However, tube 9 appreciably improves the results.

Figs. 5 and 6 represent another mode of realizing the assemblage in accordance with the invention, in which the elements playing the same role are indicated by the same signs as in Figs. 1 and 3, modified by primes.

The arrangement of the connecting ducts of Fig. 5 in relation to tubes 1' and 9', to the magnetron 7' and the cyclotron 4', is different from that of Fig. 1 and has been used successfully by the applicant. The waveguide 6' of the magnetron 7' opens into the end of tube 1' and the duct 3', carrying the resulting radiation, divides into two branches: Branch 36, which conducts the radiation directly to tube 9', and branch 37 which conducts it to the cyclotron 4'. This blocks the electromagnetic radiation and accelerates the stream of particles which is passed by way of duct 38 to the tube 9'.

This arrangement can be used with a particle emitter and an accelerator and director tube similar to tubes 1 and 9 of the preceding figures. However, tubes 1' and 9' of Figs. 5 and 6 are constructed in a different manner with regard to their cathodes and anodes.

Tube 1' contains a first electrode 11' exactly like that of the cathode 11 of tube 1, and an identical second electrode 39 furnished with a filament 39a. Tube 9' (Fig. 6) contains in its lower part a first electrode 17' with filament 17'a and an identical second electrode 40 with its filament 40a.

In normal operation, i.e., to produce radiation identical to that described in connection with Figs. 1 to 4, electrode 11' serves as cathode and electrode 39, given a positive potential, plays the role of the plate 10 in Fig. 1, the filament 39a being unheated. Electrode 40 and its filament 40a are disconnected; cathode 17' and plate 22' are supplied as in Fig. 3.

To obtain particularly penetrating radiation, the polarities are reversed: Electrode 11' becomes an anode and its filament 11'e is disconnected, while electrode 39 receives the cathode supply and its filament 39a is heated; electrode 17' (with filament 17'a disconnected) and electrode 22' become anodes, while electrode 40 serves as cathode and its filament 40a is heated. For example, one can establish a potential difference of 250,000 V between 40 and 17', and 50,000 V between 40 and 22'. It is understood that in these conditions the cathode 39 emits to the left a stream of electrons which is concentrated, modulated and accelerated by the various coils and in the cyclotron, the polarities of which must of course be established in the proper direction. This stream of electrons is combined with the centimeter radiation emitted by the magnetron 7', resulting in tube 9' in the emission of very hard x-rays, modulated at the chosen frequencies, combined with the centimeter radiation of the desired frequency.

The assembly shown in Figs. 5 and 6 thus permits one to obtain at will either very hard x-rays or the radiation described in connection with the preceding diagrams.

The following description, referring to Figs. 7 and 9, relates to certain details of the apparatus used for modulating the electric current.

Fig. 7 represents schematically the apparatus for control of the resistance 29 and the variometer 30. The variable resistance 29 consists of a graphite helix 29a immersed in a conducting liquid **29b;** another electrode 29c, also of graphite, partly immersed in the liquid, is set into up-and-down oscillations by a connecting rod 41a linked to a fly-wheel 41. The fly-wheel is set in rotation, through the intermediary of a worm transmission 41b, by an axle 42 which can be driven, thanks to a double clutch 42a, 42b, either by a motor 43, or by the shaft 30a of the variometer 30. The variometer 30 is driven by a motor 44 by way of the worm transmission 44a.

If the fly-wheel 41 is driven by the motor 43 at the proper speed, the resistance 29 causes the supply current of the electromagnets 13 and 23 (Figs. 1 and 4) to vary at the chosen rhythm which as we have seen can be between 30 and 120 pulsations per minute and which can be checked by means of a rotation counter shown schematically in 45. In this case, the motor 44 of the variometer 30 can be stopped and the remainder of the installation is then not pulsed. If, on the contrary, the fly-wheel 41 is engaged in 42b and disconnected from 42a, the motor 44 activates the variometer 30 and the resistance 29 at the chosen rhythm.

The speed of rotation of motors 43 or 44 can be regulated at the required speed, corresponding visibly to the cardiac rhythm of the subject, by acting upon the excitation of these motors by means of a manually adjustable rheostat. If one prefers to regulate the speed of motors 43 or 44 in direct accord with the cardiac rhythm of the subject, one can use an assembly such as that represented schematically in Fig. 8: At 46 there is a contact microphone which, when placed over the subject's heart, produces impulses. These are amplified in the circuit shown and applied to an electromagnet at 47 with a moving core which activates a rheostat; this in turn regulates the current running the motors 43 or 44.

Fig. 9 shows schematically the principle of the oscillating circuit 35. The rectified potential, adjustable between 5000 V and 70,000 V by means of rheostat 34 (Fig. 4) is applied between the terminals 48 and 48a. Terminal 35c (which is also connected to electrode 25, Figs. 2 and 4) is connected to the neutral point on the high tension side of **the** transformer which is a component of the step-up assembly 33 (Fig. 4). The terminals 49 and 49a receive the heating current produced by the resistance 29. The variable condensers 50 and 50a make it possible to regulate to the desired wavelength (which, as seen, is between 1 m and 18 m) the current available at the output terminals 25a and 25b of the oscillator shown.

The modes of implementation described gave been successfully carried out but it is self-evident that these are only examples, and that they might be modified, notably by substitution of equivalent techniques, without going beyond the bounds of the invention. In particular, the electron gun 1 or 1' could be replaced by another charged particle generator.

Resume

The invention includes especially:

> A procedure for obtaining a combination of radiations of different kinds capable of penetrating matter, especially of

intimately penetrating living tissues in order to produce in them certain effects and more particularly in human tissues with a therapeutic effect in mind, consisting of the emission in a cavity of a stream of electrically charged particles, upon which is imposed electromagnetic radiation in the centimeter wavelength range, and the guiding of the resulting radiation emerging from the cavity toward the target to be penetrated.

2. Types of implementation exhibiting the following features taken separately or in the various possible combinations:

   a. The centimeter radiation has a wavelength between 3 cm and 80 cm;

   b. This wavelength is set at the value found by experience to be most suitable for the tissues to be penetrated, e.g., 14 cm for liver and 19.5 cm for spleen;

   c. The particle stream is accelerated by magnetic and electric fields such as those which are used in particle accelerators;

   d. The resulting radiation is accelerated and guided, before its emergence from the cavity, by means of electric and magnetic fields;

   e. The resulting radiation is guided, before its emergence from the cavity, by means of deflecting and/or reflecting surfaces;

   f. The stream of particles and/or the resulting radiation are concentrated and accelerated by means of individual magnetic fields modulated at a frequency between 300 and 900 Hz, the highest frequencies being used to produce hard rays and the lower frequencies to produce soft rays;

   g. The emission of the particle stream, as well as the acceleration and concentration of the radiation resulting at its exit from the cavity, are aided by individual magnetic fields of temporally variable intensity, advantageously pulsed at a rhythm between 30 and 120 pulsations per minute and preferably at the cardiac rhythm of the subject;

h. The assemblages for production of the resultant radiation are pulsed in their entirety at the same rhythm as the magnetic fields according to g;

i. The stream of particles and/or the resulting radiation are accelerated and concentrated by direct magnetic and/or electric fields modulated at a wavelength between 1 m and 50 m and preferably between 1 m and 18 m, this wavelength being advantageously chosen as that which is known in diathermy as suitable for the tissues to be penetrated or for the surrounding tissues.

3. An assemblage making it possible to obtain a combination of a stream of electrically charged particles and a beam of centimeter electromagnetic waves in order to penetrate intimately and to irradiate living tissues and particularly human tissues, the said assemblage comprising at least a particle emitter, means for channeling said particles in a cavity serving as waveguide for an emitter of electromagnetic radiation of which the wavelength is included in the range of centimeter waves and preferably adjustable from 3 cm to 80 cm, means for generating in the cavity magnetic field for acceleration and concentration and means for concentrating and accelerating the resulting radiation at the exit of the cavity.

4. Modes of implementation with the following details taken separately or in the various possible combinations:

a. The particle emitter is an electron gun of which the anode is at the end of the cavity and the cathode is situated further along, this cathode being hollow and placed in the magnetic field of an electromagnetic in order to ensure emission of a stream of particles towards the mouth of the cavity;

b. The cathode consists of a rim connected by two aligned spokes to a hub, the said rim being provided internally with an annular housing containing a heated filament and the said housing communicating with a number of holes arranged annularly and traversing the rim transversely;

c. The cathode is made of a metal of valency close to the mean valency of the chemical molecules comprising the tissue to be penetrated;

d. The cathode is of tungsten or preferably of molybdenum;

e. The cavity contains a rare gas, preferably argon, under a vacuum of the order of 2 mm Hg;

f. The cavity contains a duct carrying at least part of the stream of particles to a cyclotron and a duct bringing back into the cavity the particles accelerated in the cyclotron;

g. The cavity passes through several coils, the supply current for the various coils being capable of undergoing modulation at different frequencies;

h. The downstream end of the cavity is composed of a tube containing, in the part from which the resulting radiation must emerge, a cathode and an electromagnet which may be identical to the cathode and the electromagnetic according to para. a, an anode near the other end, and a rotary deflector consisting of a number of plates arranged *en couronne* on a rotor lacing the incident radiation at such an angle that the radiation deflected and/or reflected is directed toward the cathode, several coils whose supply current can be modulated being distributed over the length of the tube;

i. This tube also contains electrodes supplied by alternating current generating an electric field at the level of the rotary deflector, each of the said electrodes being surrounded by a bobbin of which the supply current can be modulated;

j. Methods are anticipated for modulating, at an adjustable rhythm between 30 and 120 cycles per minute, the supply current of the electromagnetic according to a and h, and preferably to modulate the supply current of the rest of the assemblage at the same rhythm;

k. Methods are anticipated for modulating, at a frequency between 300 and 900 Hz, the supply current of the bobbins surrounding according to i and one or several coils according to g;

1. Methods are anticipated for modulating, at an adjustable wavelength between 1 m and 50 m and preferably between 1 m and 18 m, the supply current of the electrodes according to i, of one or several of the coils generating the magnetic field of the cyclotron;

m. The electrodes of the electron gun consist of two electrodes identical to the cathode according to a, b, c, or d, the cathode of the tube according to h is replaced by a double electrode reproducing the arrangement of the electrodes of the electron gun, and methods are anticipated for reversing at will and simultaneously the polarities of these two pairs of electrodes and the direction of flow of the current supplying the acceleratory coils, a first pattern of polarities assuring the functioning of the apparatus in the conditions which are laid down according to a, and a second pattern of polarities assuring emission in the cavity of a stream of electrons combined with the centimeter radiation and giving rise, at the exit of the said tube, to emission of very hard x-rays.

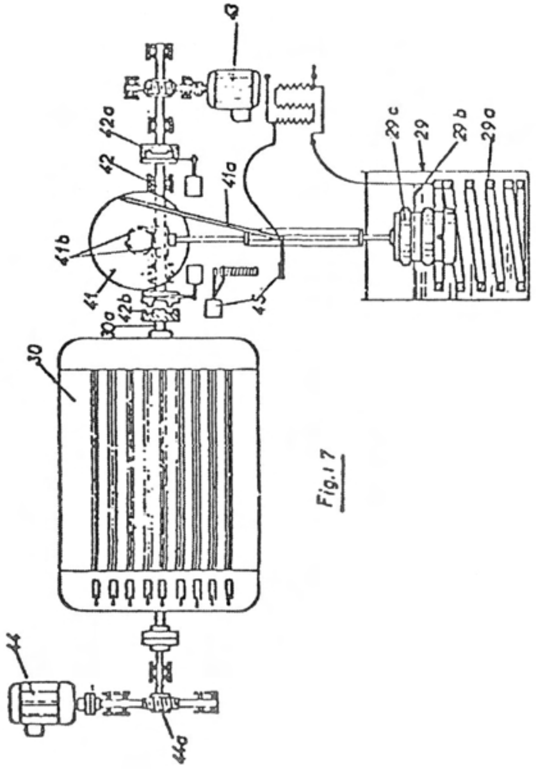
30
30a
42b
41
41b
42
42a
41a
43
45
29c
29
29b
29a
44
44a

Fig. 17

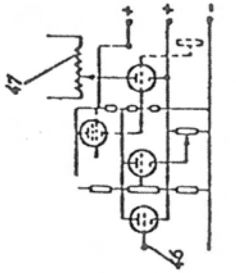

Fig. 18

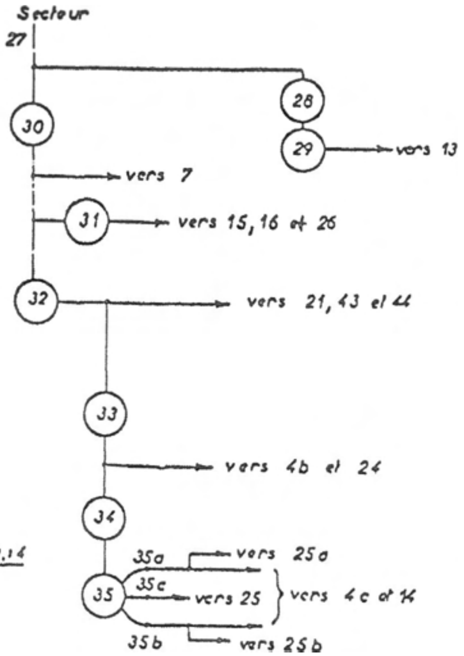
Secteur
27
28
29
vers 13
30
vers 7
31
vers 15, 16 et 26
32
vers 21, 43 et 44
33
vers 4b et 24
34
35a
vers 25a
35c
vers 25
vers 4c et 14
35
35b
vers 25b

Fig.:4

Fig.:9

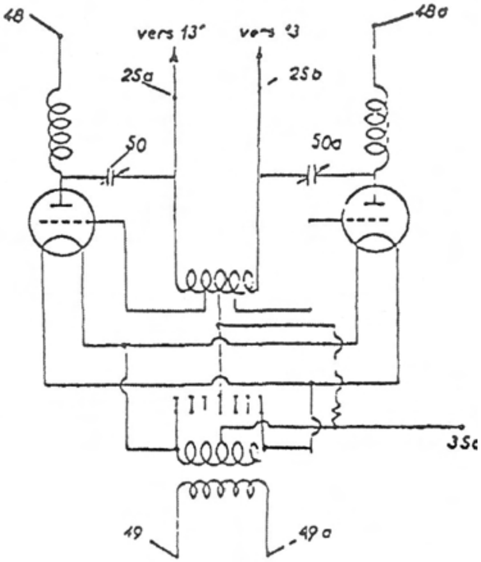
vers 13'
vers 13

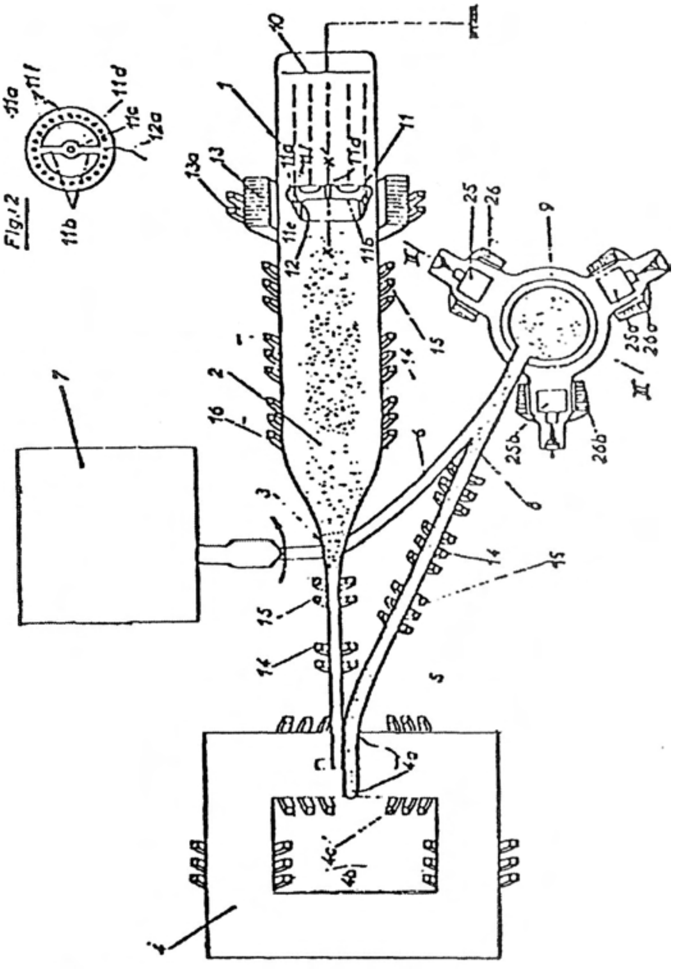
4a
4b
4c
II
VIII

Fig. 2

Fig. 1

Fig.: 3

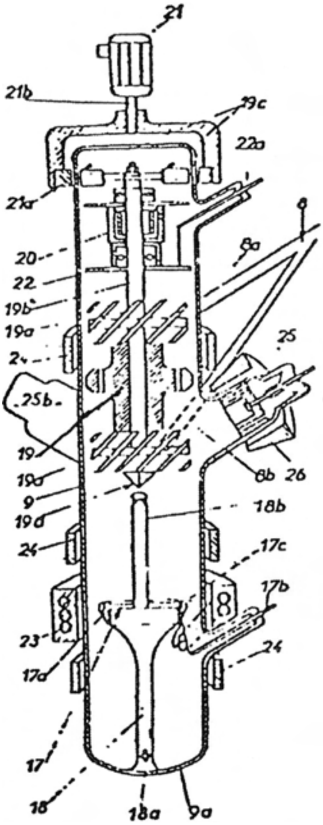
8a
8b
9a

Fig.: 6

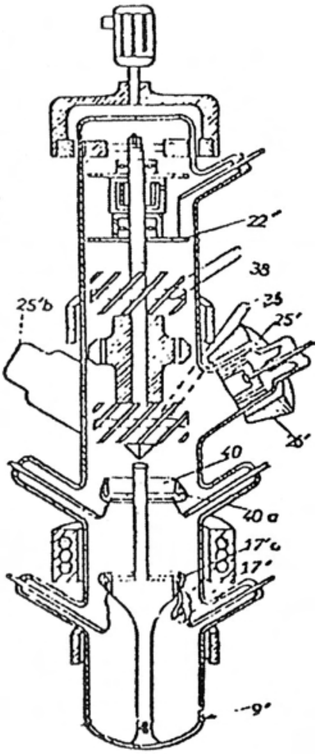
25'b
17'c

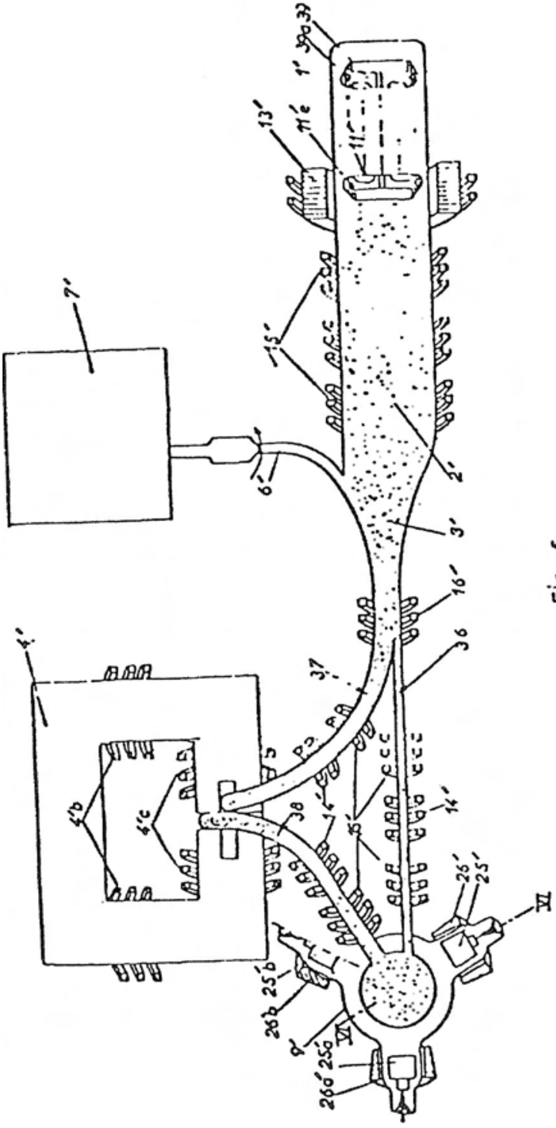
11'e
4'b
4'c
VI
25'b
26'b
25'a
26'a
VI

Fig. 5

Two Patents of G. Lakhousky

June 12,1934 G. LAKHOVSKY 1,962,565

APPARATUS WITH CIRCUITS OSCILLATING UNDER MULTIPLE WAVE LENGTHS

Filed Nov. 13, 1931

Fig. 1.

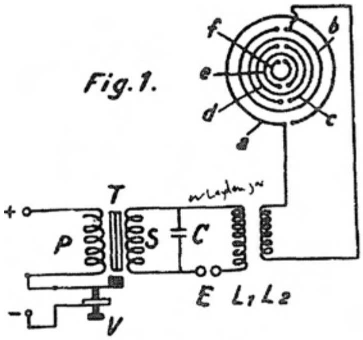
f
b
e
d
c
a
w Leyden jar
T
+
P
S
C
E
L_1 L_2
-
V

Fig. 2.

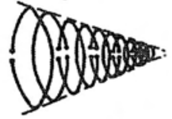

Fig. 3.

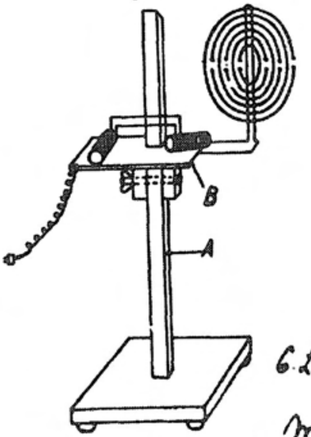

G. Lakhovsky
INVENTOR

By: Marks & Clerk
Attys.

Patented June 12, 1934 1,962,565

UNITED STATES PATENT OFFICE

1,962,565

APPARATUS WITH CIRCUITS OSCILLATING UNDER MULTIPLE WAVE LENGTHS

Georges Lakhovsky, Paris, France

Application November 12, 1931, Serial No. 574,907
In France May 2, 1931

7 Claims. (Cl. 250—33)

The present invention has for its object an apparatus capable of sending out simultaneously different wave lengths so that among these waves or their harmonics there is found almost always one or several capable of producing the best effect sought for any application whatever.

There is used for that purpose the property of open circuits having a fundamental or natural self induction and capacity to oscillate upon a well determined wave length if they are excited by electric impulses emanating from discharges of any source.

The radiating part of the system, producing waves of various lengths, is therefore constituted by a certain number of concentric open rings of different diameters, which are maintained insulated by any appropriate process. These rings may or may not be terminated by small spheres forming capacities.

These rings may be arranged either in the same plane or in different planes so as to form any surfaces, such as portions of cones, spheres, paraboloids, ellipsoids, etc. . . . , these surfaces being of a nature to concentrate the waves in a determined direction in the manner of a reflector, for example.

These rings may be fed by any producing device whatever of high frequency, for example, a combination comprising a trembler coil (or any other transformer) and a high frequency circuit provided with a self-induction coil and a capacity.

One or several points of this high frequency circuit is or are connected to the end of one or several of the rings forming the radiating apparatus. The other rings not connected are excited by induction.

The complete apparatus (coil, high frequency circuits, rings, etc. . . .), may be mounted in a box or upon a small board capable of sliding along a guide or rocking so as to be able to be placed in the most convenient position.

In the accompanying drawing, by way of example, not limitative, there is shown:

Fig. 1 a diagram of the system.

Fig. 2 the position of the rings in the form of a cone.

Fig. 3 the apparatus mounted upon a foot or base.

In Fig. 1 there is seen at T the transformer or coil (P the primary, S the secondary of this coil), V, the screw of the trembler, C the condenser the discharge of which across the spark gap E produces oscillations in the self-induction coil L^1, which in its turn acts by induction upon the self-induction coil L^2; this self-induction coil L^2 is connected on one side to the first exterior ring *a*, on the other side to the following ring *b*. It thus forms an electrostatic field of high frequency which induces oscillations in the other rings *c*, *d*, *e*, *f*.

As a modification, L^2 may be suppressed and the rings *a* and *b* may be connected each to one of the ends of L^1.

One of the ends, or even any point of the self-induction coils L^1 or L^2 may likewise be connected to any one of the rings.

Fig. 2 shows the arrangement of the rings in the form of a cone.

The open circuits *a*, *b*, *c*, . . . *f* can be constituted by solid conductors. They can also be tubular circuits, this being advantageous, since, for the same bulk, the radiating surface is larger. Finally, the area of the cross section of each of these various circuits can vary from one circuit to the other; for instance, this area can decrease from the periphery (ring *a*) to the center (ring *f*) of the radiating system.

Fig. 3 shows the apparatus mounted upon a foot A along which it can slide, in order to be placed at any desired height and upon a hinge B which allows it to be oriented upon the horizon.

I claim:—

1. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits constituted by concentric insulated split rings of different diameters, the split ends being spaced from each other and terminating with small spheres.

2. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits constituted by concentric insulated split rings of different diameters and terminated by small spheres forming capacities.

3. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits constituted by concentric insulated split rings of different diameters and arranged in one and the same plane the split ends being spaced from each other and terminating with small spheres, in staggered position as regards adjacent rings.

4. An apparatus of the type described comprising a base, a plate slidably mounted on said

base, a support pivoted to the said plate, a series of open and insulated, high frequency radiating circuits mounted on the pivoted support, and a high frequency producing device for the excitation of the said circuits.

5. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits, said circuits being open, insulated, and having dimensions different from each other.

6. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits arranged in the same plane, said circuits being open, insulated, and having dimensions different from each other.

7. An apparatus of the type described comprising a transformer, a high frequency energising circuit fed by the said transformer and provided with a self-induction coil and a capacity, a series of open and insulated high-frequency radiating circuits having dimensions different from each other, an inductive connection between two of these radiating circuits and respectively each of the poles of the outgoing element of the high frequency energising circuit.

GEORGES LAKHOVSKY.

Patented June 13, 1944

2,351,055

UNITED STATES PATENT OFFICE

2,351,055

TUBE FOR PRODUCING MULTIPLE WAVE LENGTHS

George Lakhovsky, New York, N. Y.; Anne-Marie Louise Lakhovsky, administratrix of said George Lakhovsky, deceased, assignor to Henry S. Blum, Chicago, Ill.

Application November 21, 1941, Serial No. 420,006

11 Claims. (Cl. 250—33)

This invention relates generally to electric devices excited by electric impulses and more particularly to multiple wave length conducting and/or producing means. This invention has for its primary object the provision of such means disposed within a vacuum tube or a tube containing rare gas or gases.

My work over a period of more than 20 years has led me to the belief that there is great need for means conducting and/or producing multiple wave lengths which may be employed in many industrial and medical fields. Suitable apparatus for producing waves of various lengths is disclosed in my U. S. Letters Patent No. 1,962,565, dated June 12, 1934. Embodiments of this apparatus have been in use the world over. Because of the need for simplification in such apparatus so that it may be handy and easily used by persons lacking skill in electrical matters, I have concluded that by providing one unit which incorporates oscillation generating means and another in which the wave lengths are produced, the apparatus may be more universally used in the treatment of cellular life in therapy, in the aging or treating of liquids and in other industrial fields.

The present invention deals with those units, preferably combined with one another and constructed as a portable device and as stated above, has for its major object the provision of a unitary multiple wave length producing and/or conducting device in the form of a vacuum tube.

The present invention further contemplates the incorporation in such a tube, of means for varying the effect of wave lengths, or selectively employing the means therefor enclosed in or forming part of said tube.

This invention further seeks to provide a tube of the indicated type incorporating means for generating oscillations.

Another object of the invention is to provide a single unit which contains an oscillation generator, which produces waves of definite frequency, and further inductance means each permitting emanation of wave lengths of various values.

The structural features of my invention also form a material part of this disclosure, the objects and advantages being attained in structures such as shown in the accompanying drawing, which exemplifies the invention. The following specification, based on said drawing, more clearly points out the purposes and advantages of my invention.

In the drawing:

Fig. 1 is a vertical, partial sectional, partial elevational view of a tube incorporating features of my invention.

Fig. 2 is a similar view of an alternate form thereof.

Fig. 3 illustrates in a similar manner a modified form of my invention.

Fig. 4 is a fragmentary sectional view of a modification made in accordance with the invention.

Fig. 5 is a similar view of another modification.

Figs. 6 and 7 are sectional views illustrating types of wires used in either of the forms of my invention as shown in Figs. 1, 2 and 3.

Fig. 8 is a partial sectional, partial elevational view illustrating a tube incorporating a plurality of grids and selective capacity means for varying the effects of said grids.

Fig. 9 is a similar view of a tube, such as shown in Figs. 1 or 2 and incorporating oscillating or vibrating means.

In that form of my invention shown in Fig. 1, there is provided a sealed preferably transparent envelope **10** made of glass or like material affixed in the usual manner to a screw or Edison plug **11**. The latter is conventionally provided with a shell terminal **12** and a central terminal **13**. The support or seal **14** of the tube serves to hold wires such as **15** and **16** which connect to the terminals **12** and **13**.

Connected to the wires **15** and **16** is a primary inductance member in the form of a loose coil **17** which may be disposed axially of the envelope **10**, as shown. The upper end of said member **17** forms a tight wound coil **18** which serves to radiate the strongest induced wave lengths.

Surrounding the primary inductance member **17**, there are arranged a plurality of separate coils of wire each being of different length and capacity. Thus, I provide a coil **19** having greatest capacity and successive coils **20**, **21**, **22**, **23**, **24**, and **25**, each having less capacity than the preceding coil. These coils **19** to **25** form secondary inductance means each permitting emanation of a wave length of different magnitude and value than the other.

I may support the secondary coils in several ways. As shown, I prefer to provide a dielectric member such as a glass sleeve **26** surrounding the primary inductance wire member **17** and to mount the secondary coils **19** to **25** on the outer surface of said sleeve, leaving the coil **18** exposed at the top thereof. In order to effectively support and centralize the glass sleeve **26**, I provide spacing washers **27** and **28** of mica or the like, top and bottom, and provide a supporting cross-piece **29** on the lower portion of the wire **17**.

June 13, 1944. G. LAKHOVSKY 2,351,055

TUBE FOR PRODUCING MULTIPLE WAVE LENGTHS

Filed Nov. 21, 1941

Fig. 1.

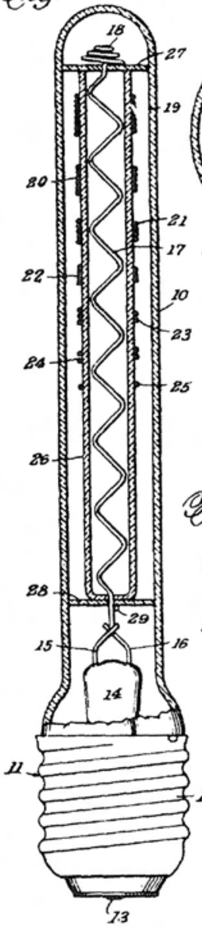
18
27
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12
73

Fig. 2.

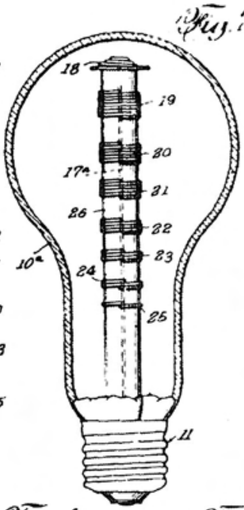
18
19
20
17a
21
26
22
10a
23
24
25
11

Fig. 3.

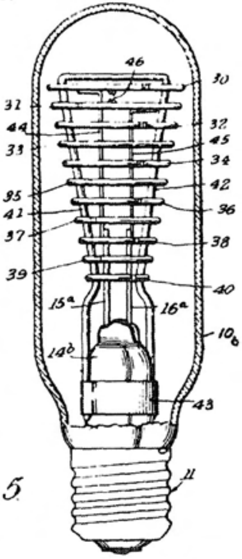
46
30
31
32
44
45
33
34
42
35
36
41
37
38
39
40
15a
16a
10b
14b
43
11

Fig. 4.

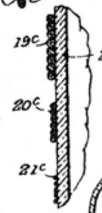
19c
26
20c
21c

Fig. 5.

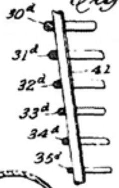
30d
31d
41
32d
33d
34d
35d

Fig. 6.

Fig. 7.

Fig. 8.

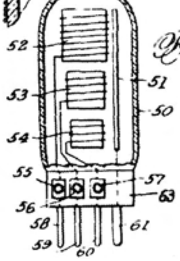
52
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60

Fig. 9.

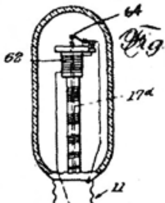

INVENTOR
GEORGE LAKHOVSKY

BY Leon M. Strauss
ATTY.

The tube above described may be employed as indicated for the treatment of cellular structures by connecting it to any one of the rings in the electrostatic field of high frequency, such as shown in said U. S. Letters Patent No. 1,962,565, each of the coils **13** to **25** producing by induction a different wave length, as can be understood.

In the form of my invention shown in Fig. 2, the envelope **10a** is somewhat differently shaped, and the wire **17a** straight instead of arranged as an open coil. In other respects, the structure follows that described with reference to Fig. 1.

As shown in Fig. 3, there may be arranged a plurality of open rings **30**, **31**, **32**, **33**, **34**, **35**, **36**, **37**, **38**, **39**, and **40** in frustro-conical form, for instance, with the largest of said rings at the top and the smallest one adjacent the bottom. I have shown said rings as supported, for instance, by glass posts **41** and **42**, said posts being supported on the seal **14b**, as by a band **43**. I provide extensions for the terminal wires **15a** and **16a** and connect said extensions **44** and **45** to the upper ring **30** and the next lower ring **31**, respectively.

The rings **30** and **31** may become the primary inductance members, whereas the remaining rings constitute the secondary inductance members as before set forth. Electric current conducted to the suitably spaced rings **30**, **31** will cause a spark **46** to be drawn between the rings **30** and **31** providing oscillations emanating from electrical discharges therebetween and causing the radiation of waves of various lengths within the envelope **10b** and affecting the remaining rings.

In Figs. 1 and 2, I have shown the secondary coils as formed of wires having uniform cross-section. Fig. 4 illustrates how such wires may be made progressively smaller in the succeeding coils **15c**, **20c**, and **21c**, etc. Similarly, I have shown the rings of Fig. 3 made progressively smaller in Fig. 5, said rings being designated by numerals **30d**, **31d**, **32d**, **33d**, **34d** and **35d**, etc. In such various manners, the wave length producing effect of the secondary coils or rings may be arrived at.

The secondary coils or rings may be round or somewhat flattened wire as shown in Fig. 6 or tubular as in Fig. 7, offering a yet greater flexibility of design.

The devices of Figs. 1 and 2 above described may be incorporated in the system shown in said U. S. Letters Patent by connecting one of the rings *a*, *b*, *c*, *d*, *e*, or *f* with plug **11** of Fig. 1, since either terminal **15**, **16** is in contact with primary inductance member **17**. To this end a conductor (not shown) connects such a ring with said plug or socket.

In Fig. 8, I have shown a modification of the invention which comprises a vacuum tube **50** containing a plate **51** and a plurality of different wave lengths producing grids **52**, **53**, and **54**. I connect each grid with a variable capacity device, such as **55**, **55**, and **57** carried by said tube **50** and preferably by its base support **63**, whereby the grids may be selectively connected into an operating circuit (not shown) by means of the respective prongs **58**, **59**, and **60**, and the plate prong **61**. *Heating or other exciting means may* be incorporated in the tube in a well-known manner. This combination tube **50** is designed to replace a plurality of known tubes each operating with different and variable wave length effect, mere exterior manipulation at said base support brings about change of the capacities **55**, **56**, and **57** and cutting in one or more of the grids **52**, **53**, and **54**.

The effect of the spark as produced in the form of the invention depicted in Fig. 3 may be further utilized in Fig. 9 in which I also incorporate a vibrator **62** which produces electrical oscillations by a spark intermittently generated between the end of the primary inductance member **17d** and vibrator armature **64**. In other respects the structure follows that of Fig. 1.

It *may be noted that any type of spark pro*ducing or oscillation generating means may be substituted for the vibrator shown. The tubes shown in Figs. 3 and 9 may be used in the manner described for Fig. 1 by connecting one terminal of the base as set forth to produce an induction effect. These tubes may be also connected across both terminals with a suitable potential to obtain the spark effect.

From the foregoing it may be seen that I have provided tubes in various forms for the purpose of generating and conducting multiple wave lengths. Other forms of the invention may be produced within the spirit and scope of the invention as claimed.

Having thus described my invention, what I claim as new and desire to be secured by Letters Patent, is:

1. A device of the character described comprising a vacuum tube having an envelope and base, primary inductance means, and a plurality of separate secondary inductance means *of different length for radiating waves of various* lengths extending above said primary inductance means, all said inductance means being arranged within said envelope.

2. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member axially arranged in said *envelope*, and a plurality of secondary inductance members spaced apart and independent from each other each member surrounding a respective portion of said primary inductance member and within the field of influence thereof.

3. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member axially arranged in said envelope, and a plurality of secondary inductance members each surrounding the primary inductance member and within the field of influence thereof, each of said secondary inductance members having a different wave length effect than the others.

4. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member comprising a pair of split rings in inductive relation, and a plurality of secondary inductance members each comprising split rings.

5. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member comprising a pair of split rings in inductive relation, and a plurality of secondary inductance members each comprising split rings, said latter rings being arranged in different planes and being of different length to produce a different wave length effect.

6. In a device of the character described, *means for producing multiple wave lengths com*prising a wire member, enclosing dielectric means for said member, and a plurality of separate wire coils of different lengths on said dielectric means and in the field of inductance of said wire member.

7. In a device of the character described,

means for producing multiple wave lengths comprising a wire member, enclosing dielectric means for said member, and a plurality of wire coils on said dielectric means and in the field of inductance of said wire member, each coil extending over said wire member and having a different number of convolutions than the others.

8. In a device of the character described, means for producing multiple wave lengths comprising two split rings in inductive relation, and a plurality of split rings in inductive relation to the two split rings.

9. In a device of the character described, means for producing multiple wave lengths comprising two split rings in inductive relation, and a plurality of split rings in inductive relation to the two split rings, the plurality of rings being of smaller diameter than the mentioned two rings and each progressively smaller than the others.

10. In a device of the character described means for producing multiple wave length, comprising two split rings in inductive relation, and a plurality of split rings in inductive relation to the two split rings, the plurality of rings being of smaller diameter than the mentioned two rings and each progressively smaller than the others, all of the rings being arranged in frusto-conical disposition.

11. In a vacuum tube having a primary inductance member and secondary inductance members, a vibrator arranged in the field of influence of said primary inductance member and secondary inductance members, a vibrator arranged in the field of influence of said primary inductance member for affecting the induction of said secondary members.

GEORGE LAKHOVSKY.

T.H. Moray's Patent
Electrotherapeutic Apparatus
Feb. 1, 1949

Feb. 1, 1949. **T. H. MORAY** 2,460,707

ELECTROTHERAPEUTIC APPARATUS

Filed April 30, 1943 3 Sheets-Sheet 1

FIG. 1.

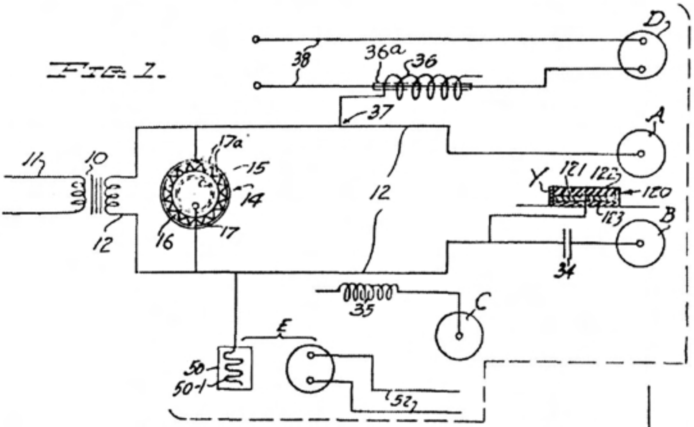
D
38
36a
36
37
A
17a
15
14
10
11
12
121
122
120
Y
123
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17
12
34
35
C
E
50
50-1
52

FIG. 11.

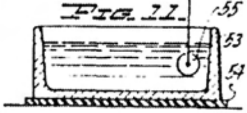

FIG. 3.

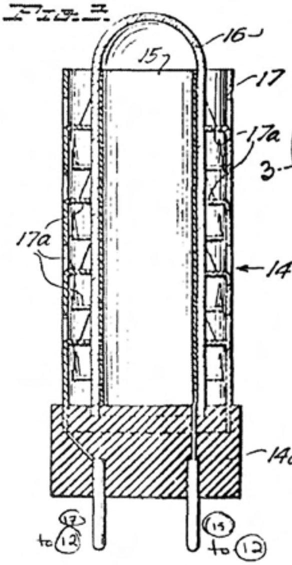
16
15
17
17a
17a
14
14a
17
to 12
15
to 12

FIG. 2.

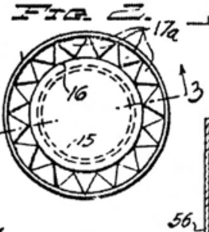

FIG. 12.

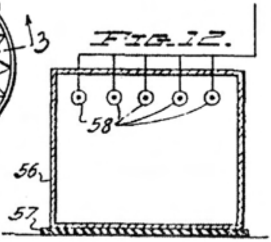

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Feb. 1, 1949. T. H. MORAY 2,460,707

ELECTROTHERAPEUTIC APPARATUS

Filed April 30, 1943 3 Sheets-Sheet 2

FIG. 7.

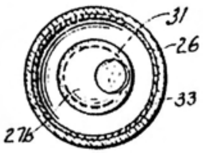

FIG. 5.

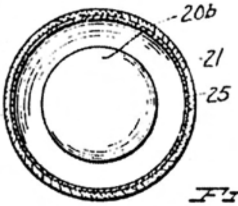

FIG. 9.

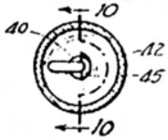
10
40
42
45
10

FIG. 8.

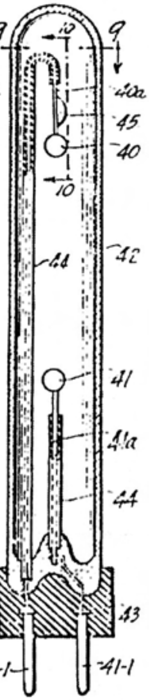
9
10
9
40a
45
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10
44
42
41
41a
44
43
40-1
41-1

FIG. 10.

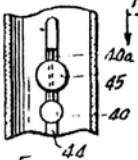
40a
45
20b
40
44

FIG. 6.

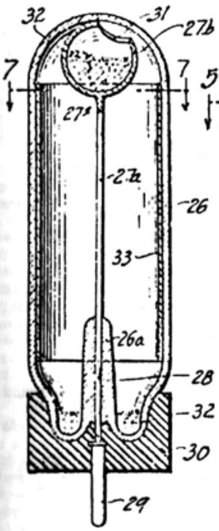
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31
27b
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27a
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26a
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FIG. 4.

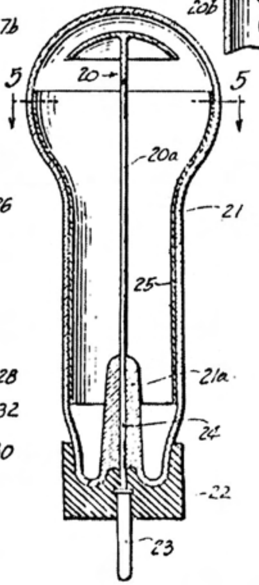
20
5
5
20a
21
25
21a
24
22
23

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Feb. 1, 1949. T. H. MORAY 2,460,707

ELECTROTHERAPEUTIC APPARATUS

Filed April 30, 1943 3 Sheets-Sheet 3

Fig. 13.

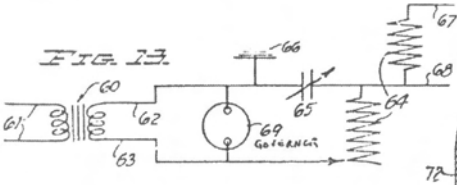
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69
GOVERNOR

Fig. 14.

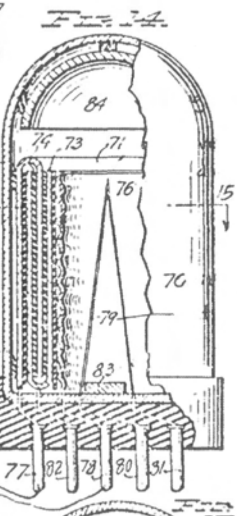
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to 62+63

Fig. 15.

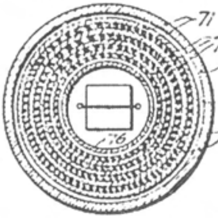
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Fig. 16.

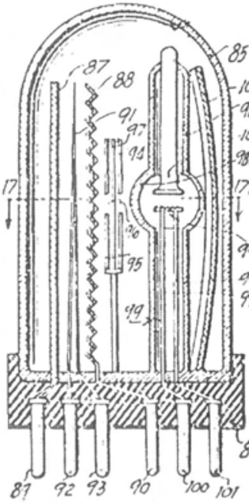
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99b
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100
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Fig. 18.

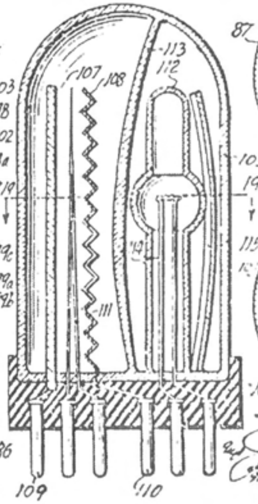
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Fig.

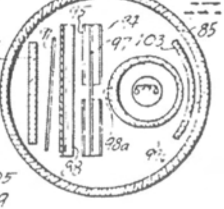
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91
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103
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98a
98
99

Fig.

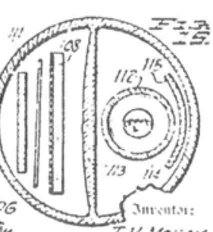
108
112
115
113
114

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By R. Mallinckrodt.
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Attorneys.

Patented Feb. 1, 1949 **2,460,707**

UNITED STATES PATENT OFFICE

2,460,707

ELECTROTHERAPEUTIC APPARATUS

Thomas H. Moray, Salt Lake City, Utah

Application April 30, 1943, Serial No. 485,112

8 Claims. (Cl. 128—421)

This invention relates to electrotherapeutic apparatus, and to methods of applying electrical, radioactive, and other radiant phenomena therapeutically.

The invention is primarily concerned with the use of high potential, high frequency electricity though not necessarily limited thereto, in conjunction with radioactive and other types of electronic and radiation phenomena, for therapeutic purposes.

Among the objects of the invention are the following:

First.—To render highly effective, from a therapeutic standpoint, radioactive and other types of electronic and radiation phenomena, and, likewise, to render highly effective, from a therapeutic standpoint, high potential, high frequency electricity.

Second.—To augment the therapeutic effect of radioactive and other types of electronic and radiation phenomena by the conjoint use of high potential, high frequency electricity, and, conversely, to augment the therapeutic effect of high frequency, high potential electricity by the conjoint use of radioactive and other types of electronic and radiation phenomena.

Third.—To accomplish the above without danger of burning or of otherwise harming the patient.

Fourth.—To provide apparatus for accomplishing the above, which is relatively simple in construction and operation and relatively inexpensive to produce and operate.

Fifth.—To provide novel electronic and radioactive devices especially adapted for use in conjunction with high potential, high frequency electrical therapy.

I have found that, by enveloping a patient in a high potential, high frequency electrical field in such a manner that no closed circuit is completed through his body, radioactive and other electronic and radiation phenomena can be used therapeutically with considerably greater effectiveness than if used alone. The exact reason for this is not known, nor is it known definitely which, the electric field or the radioactive phenomena, acts upon the other to produce the advantageous results. It is thought, however, that the electric field, permeating the body of the patient as it does, attracts the radioactive emanations or radiations and enables them to penetrate considerably deeper into the tissues and vital organs of the patient than would otherwise be the case. In any event, remarkable therapeutic results have been achieved by use of the invention in the treatment

of malignant tumors, arthritis, sinus infections, and various other diseased conditions.

The invention contemplates the use, in therapeutics, of high potential, high frequency electricity to produce diversified forms of radiant energy, such forms being those which have been found best suited, individually, to benefit various human ailments. In accomplishing this purpose, several special discharge tubes have been developed to serve as treatment electrodes, by means of which correspondingly different curative results are obtained. Throughout the practice of the invention, a prime consideration is that only one terminal of any particular circuit shall be in contact with a patient's body at one time, so there will be no flow of current through a closed circuit of which the patient's body is a part. Such a terminal, too, is usually non-heat producing, so there is no danger of burning. In cases where there is a tendency for a tube to produce X-rays or other injurious rays, these are filtered out.

The present application constitutes a continuation in part of a copending application filed by me November 15, 1940, which bears Serial No. 365,798 and is entitled "Method of and device for the therapeutic application of electric currents and rays," and which has now become abandoned.

In the accompanying drawings, which illustrate several embodiments of apparatus preferred for carrying the method of the invention into practice:

Fig. 1 represents a wiring diagram of a preferred embodiment of apparatus for carrying out the method of the invention in general therapeutic work, several independent treatment stations being provided;

Fig. 2, a top plan view of the novel corona regulator of Fig. 1, employed in the circuit to control and adjust the current and as a governor to safeguard the transformer;

Fig. 3, a vertical section taken on the line 3—3, Fig. 2;

Fig. 4, a vertical section taken centrally through one novel type of discharge tube used as a treatment electrode in the apparatus of Fig. 1;

Fig. 5, a horizontal section taken on the line 5—5, Fig. 4;

Fig. 6, a vertical section taken centrally through another novel type of discharge tube used as a treatment electrode in the apparatus of Fig. 1;

Fig. 7, a horizontal section taken on the line 7—7, Fig. 6;

Fig. 8, a vertical section taken centrally through a novel discharge tube used as a treating device in the apparatus of Fig. 1;

Fig. 9, a horizontal section taken on the line 9—9, Fig. 8;

Fig. 10, a fragmentary vertical section taken on the line 10—10, Figs. 8 and 9;

Fig. 11, a fragmentary view in vertical section, and drawn to a reduced scale, of a tub bath capable of use as a treatment station in the apparatus of Fig. 1;

Fig. 12, a view similar to that of Fig. 11, but showing a shower or vapor bath arrangement for the same purpose;

Fig. 13, a wiring diagram similar to that illustrated in Fig. 1, but fragmentary in nature, and of a somewhat different embodiment of apparatus;

Fig. 14, an elevation, partly in central vertical section, of a novel tube used in the apparatus of Fig. 13 in place of the corona regulator of Figs. 2 and 3;

Fig. 15, a top plan view, partly in horizontal section on the line 15—15, Fig. 14, of the tube of Fig. 14;

Fig. 16, a vertical section of another novel tube which may be used in place of the tube of Figs. 14 and 15;

Fig. 17, a vertical section taken on the line 17—17 of Fig. 16;

Fig. 18, a top plan view of still another novel tube which may be used in place of the tubes of Figs. 14 and 15 and of Figs. 16 and 17; and

Fig. 19, a vertical section taken on the line 19—19 of Fig. 18.

In accordance with the invention, provision is made for enveloping the patient in a high potential and, in certain instances, a high frequency electric field, and for applying to the patient, while so enveloped in the electric field, radiations and emanations having therapeutic value.

The apparatus of Fig. 1 is capable of administering various specific kinds of treatment, pursuant to the invention, at the several treatment stations provided. The treatment stations are indicated A, B, C, D, and E, respectively.

For supplying the high potential electric field, a suitable transformer is employed. This may be of any type capable of delivering high potential electricity, say from 10,000 to 30,000 volts. It is preferred, however, to utilize a conventional double magnetic circuit type of transformer, indicated at 10 in Fig. 1, having adjustable, laminated, magnetic shunts (not shown), the transformer being connected across an ordinary power line 11 charged with the customary 115 v. The output lines 12 from this transformer advantageously extend to the treatment stations A and B, respectively. The first secondary of the transformer 10 is preferably direct connected to the second secondary thereof. It is noted that this high potential electricity may be applied, without causing injury, direct to a patient who is not grounded. However, in order to safeguard the transformer 10 from damage by sparking across its output terminals, and to render the high potential electricity more suitable for therapeutic purposes, which is believed to include the automatic changing of the frequency to an extent which depends upon electrical characteristics of the patient's body, a governor or control device 14 is shunted across the leads 12.

This governor or control device 14 is a sparking condenser of high capacity embodying a multitude of spark gaps. A preferred embodiment of this governor or control device 14 is illustrated in detail in Figs. 2 and 3.

As illustrated, the device comprises a cylindrical, electrically conductive plate 15 surrounded by a cylindrical dielectric 16. An outer cylindrical and electrically conductive element 17 surrounds the dielectric 16 exteriorly. It is provided with a multitude (for example, 250) of inwardly extending prongs 17a, which are advantageously formed by stamping out, and inturning, triangular portions of the electrically conductive element 17. The internal plate 15 preferably contacts the interior surface of the dielectric 16, but, in any event, should lie closely adjacent thereto. Likewise, the tips of the prongs 17a preferably contact the outer surface of the dielectric. The several elements are advantageously mounted in a plug-in base 14a, which is adapted to mate with a suitable receiving socket (not shown) carrying the required electrical connections. The internal plate 15 connects with one of the electric lines 12, while the external element 17 connects with the other electric line 12, as shown diagrammatically in Fig. 1.

It is preferable that the dielectric 16 be in the form of a closed tube or envelope, as shown, and be exhausted to vacuum condition. The multitude of sparking prongs 17a product a brush discharge.

Where the dielectric 16 is not a closed tube or envelope, it is preferred that it be of quartz.

The treatment station A is a discharge tube of a novel type, exemplified by the tubes illustrated in detail in Figs. 4 and 5 and Figs. 6 and 7. Either tube is plugged into the circuit of Fig. 1 at a suitably provided, single-terminal outlet. High potential electricity is, therefore, fed directly into the tube, which serves as an electrode. The tube also embodies radioactive material, which supplies radioactive emanations to the patient simultaneously with the electrical discharge.

As illustrated in Figs. 4 and 5, the tube or electrode may comprise an electrically conductive discharge element 20, having a supporting stem 20a and a major discharge cap or head 20b, which is preferably in the form of a thin, convex-concave plate. The head 20b may be spot welded to the end of the stem 20a.

The discharge element 20 is enclosed within a tube 21 of dielectric material, preferably glass, the stem 20a being fixed in the fused tongue portion 21a of the tube. The tube or shell 21 is fitted into an insulating base 22, provided with a single plug-in terminal 23, and an electrical connector 24 extends from the terminal 23 to the stem 20a.

The inside surfaces of the side walls of the tube or shell 21 are coated with a radioactive material, as at 25. The coating is conveniently made from uranium salts or powdered carnotite or other radioactive ore. The ends of the tube or shell are left uncoated.

Air is evacuated from the tube 21, and a small quantity of mercury introduced. The mercury is preferably triple-distilled to insure great purity. It is preferred that argon or like inert gas be also introduced.

Since the tube just described is plugged into the circuit of Fig. 1, the discharge element or cathode 20 is charged with high potential electricity, and, in its capacity of a treatment station in the apparatus of Fig. 1, serves as an electrode to similarly charge the patient. The patient is insulated from the ground, and the tube is applied directly to the afflicted part of his body, preferably in close contact with the body.

Because of the construction of the tube, radiation of a radioactive nature is also directed against the patient through the uncoated top end of the tube. This radiation has been found to differ somewhat from the radioactive emanations discharging from the side walls of the tube, and is thought to comprise rays lying close to X-rays on the radiation spectrum. These rays appear to have a definite healing value, and to lack the injurious nature of X-rays. Where a predominantly radioactive emanation treatment is desired, the side walls of the tube are placed against the body of the patient.

Best results are obtained when the discharge element or cathode **20** is made of an alloy metal compounded from copper, lead, sulphur, and, if desired, aluminum. The relative percentages of the several ingredients may vary considerably, but a satisfactory mixture comprises 5.0% copper, 55.0% lead, 30.0% sulphur, and 10.0% aluminum. Should aluminum not be used, the difference may be made up by additional copper.

In preparing the alloy, the copper and aluminum are heated to a molten state, after which the sulphur is added while stirring the mixture. After cooling, the mass is again melted, and the lead, in a molten state, is mixed with it, the molten mass being thoroughly stirred. This new mass is then cooled, being later reheated, and, while hot, rolled to make it ductile, so it can be shaped into the desired forms.

The discharge tube or electrode of Figs. 6 and 7 is similar to that of Figs. 4 and 5, having an enclosing tube or shell **26** which is evacuated. A cathode discharge element **27** is positioned within the shell, being fixed in the tongue portion **26***a*. A conductor **28** connects the stem **27***a* of the element **27** with a plug-in terminal **29**, which extends outwardly of the base **30**. The cap or head **27***b* of the element **27** differs from the cap or head **20***b* of the electrode of Figs. 4 and 5, in that it is spherical in form and hollow. It has an opening **31** formed at its top, contiguous with the top inside surface of the tube **26**. A quantity **32** of radioactive material, which may be the same as used for the coating **25** of the electrode of Figs. 4 and 5, is introduced into the tube or shell **26**, along with a relatively small quantity of mercury, before the tube is sealed tight. Such material **32** is preferably powdered or granulated, and is shaken into the hollow of the head **27***b* through the opening **31** before any given treatment is commenced. The mercury is provided primarily as a getter, and does no harm if shaken into the head **27***b* along with the radioactive substance. The mercury also tends to produce a vapor in the tube, which aids in the operation thereof. As in the case of the electrode tube of Figs. 4 and 5, this tube may have a radioactive coating **33** covering the inner surfaces of its side walls.

The treatment station B of Fig. 1 differs from the treatment station A only in the fact that a condenser **34** is interposed in the electric supply line **12**.

The treatment station C of Fig. 1 differs from the stations A and B only in the fact that the high potential electricity is supplied from the supply line **12** through an inductance **35**.

The treatment station D utilizes a germicidal discharge tube, a preferred form of which is illustrated in detail in Figs. 8, 9, and 10. The high potential electricity is taken by induction from the particular supply line **12** concerned. For this

purpose, an induction coil **36** is provided, tapping the line **12** at **37**. A pair of leads **38** from an ordinary 115 v. supply source extend to a plug-in socket connection for the germicidal tube, one of the leads passing through a glass tube **36***a*, Fig. 1, which is disposed within and extends along the length of the induction coil **36**. Thus, high potential electricity is impressed, by induction, upon the ordinary current flowing through the particular lead **38** concerned.

The germicidal discharge tube of Figs. 8, 9, and 10 has a pair of discharge terminals **40** and **41**, respectively, positioned in an evacuated tube or envelope **42**, and electrically connected with plug-in terminals **40—1** and **41—1**, respectively, by means of stems **40***a* and **41***a*, respectively. The tube or envelope **42** and plug-in terminals are mounted in a conventional base **43**. It is preferred that insulating material **44**, such as a ceramic sleeve, cover the major portions of the stems **40***a* and **41***a*. A piece of lithium metal **45**, see particularly Fig. 10, is advantageously secured to the stem **40***a* adjacent the discharge terminal **40** to act as a getter. It may, however, be placed at any other convenient location in the tube. It is preferred that the discharge terminals **40** and **41** be formed of the special alloy previously described. Argon or other suitable inert gas is preferably injected into the tube or envelope **42**, as is, also, a small quantity of mercury. The mercury, by vaporizing, aids electrical arcing between the discharge terminals. As will be noted, the high potential electricity induced in the one lead **38** will manifest at the upper discharge terminal **40**, and will charge the patient simultaneously with the discharge into his body of germicidal rays from the tube.

The treatment station E embodies the tube of Figs. 8, 9, and 10, as above described, but impresses the high potential electricity directly on the patient instead of passing it first through the tube. For this purpose, a discharge device **50**, in the form of a soft, flexible pad in which a coil **50—1** is embedded, taps one of the high potential electric lines **12**. This pad **50** is wrapped around the patient's body adjacent the afflicted portion thereof, thus charging the patient. Any other electrode capable of charging the patient with high potential electricity may be used in place of the pad **50**. The germicidal tube has its terminals **40—1** and **41—1** plugged into a suitable plug-in socket connected to leads **52** which extend to an ordinary 115 v. source of supply. The high potential electricity with which the patient is charged is induced into the germicidal tube, thereby further activitating the discharge therefrom. A certain beneficial discharge from this germicidal tube will be had by induced activation alone, it being unnecessary, in such instances, to plug the tube into the 115 v. line.

Other types of germicidal and discharge tubes may be used in place of the tube of Figs. 8, 9, and 10, as, for instance, the well known infra-red and ultra-violet lamps, to produce results surpassing those ordinarily attained by the use of such infra-red or ultra-violet lamps apart from the apparatus of the invention.

It should be remembered that the patient is insulated from the ground while being treated at any of the treatment stations of the invention.

Figs. 11 and 12 show how a patient is treated, pursuant to the invention, while immersed in an electrically conductive fluid bath. In Fig. 11, a bath tub **53** is insulated from the ground by a layer of insulation 54. A treatment electrode of the type shown in any of the figure groups 4 and 5, 6 and 7, and 8, 9, and 10 is positioned to charge the fluid of the bath with high potential electricity, as well as to discharge healing radiations and emanations into the patient. The particular electrode illustrated is diagrammatic in form and is designated 55. It may be connected into the circuit of Fig. 1 as shown at any of the treatment stations A, B, C, and D. In Fig. 12, a shower or vapor stall 56 is insulated from the ground by a layer of insulation 57. A plurality of treatment electrodes are designated 58, respectively. These correspond to the treatment electrode 55 of Fig. 11. A water spray or vapor, such as steam, may be admitted to the stall 56 in any well known manner (not shown), thus enveloping the patient during treatment.

Another embodiment of apparatus, pursuant to the invention, is illustrated diagrammatically by the wiring diagram of Fig. 13. While no treatment stations are shown, those provided are identical with the several treatment stations designated A, B, C, D, and E in Fig. 1. The distinction in this embodiment of apparatus resides in the fact that a special generator of high frequency electricity is provided in the system.

A transformer 60 has its input terminals connected across an ordinary 115 v. electric power line 61. Electrical conductors 62 and 63 lead from the respective output terminals of the transformer to a high frequency generator of the Oudin coil type, indicated generally at 64, a variable condenser 65 being interposed in the line 62, and the circuit being grounded at 66. Output conductors 67 and 68, leading from the high frequency generator 64, provide connections for the several treatment stations in the same manner as illustrated in Fig. 1.

The transformer 60 may be any ordinary high voltage type. A governor or control device 69 is shunted across the conductors 62 and 63.

In the illustrated instance, the governor or control device 69 preferably takes the form of a vacuum tube, having the construction shown by Figs. 14 and 15, Figs. 16 and 17, or Figs. 18 and 19. These tubes all possess high capacity, and include elements effecting a brush discharge. They serve, as does the device 14 of Figs. 2 and 3.

The tube of Figs. 14 and 15 embodies an outer shell or envelope 70 of insulating material such as glass, a plastic, or fiber coated with shellac. Inside the shell 70 is a bi-cylindrical element 71 formed of electrically conductive material. Separating element 71 from the enclosing shell 70 are spacers 72 made of rubber, Bakelite, or other insulating material. Inter-fitting with the element 71 is a second electrically conductive, bi-cylindrical element 73, the two elements being separated by a dielectric 74. Inwardly of the element 73, and separated therefrom by a dielectric 75, is a corrugated, cylindrical element 76. The shell or envelope 70 is secured in an insulating base 70—1, provided with plug-in terminals. One of the terminals, designated 77, is electrically connected with the element 71, while another, designated 78, is electrically connected with the corrugated element 76. These two terminals connect with the conductors 62 and 63, as illustrated in Fig. 13, and the brush discharge takes place at element 76.

Under certain circumstances, it is desirable that the outer shell 70 be made of quartz glass, and that a filament 79 be provided, the filament being heated by connection, through plug-in terminals

80 and 81, with a source of low voltage heating current (not shown). Plug-in terminal 82, which is electrically connected with element 73, may be used instead of or in connection with the terminal 77, since element 73 acts in a manner similar to element 71. A getter 83 of suitable material, and an insulating and reflecting shield 84 may be provided, as shown. While the tube may have either a high or a low vacuum condition, or may be filled with an inert gas, I have also found it advantageous to fill the tube with a moist vapor. The tube acts as an oscillator for electric currents, and has an enormous capacity, a capacity many times that of a condenser of approximately equal size.

The tube of Figs. 16 and 17 comprises an outer shell or envelope 85, which may be made of metal, glass, or fused quartz. This shell is mounted in an insulating base 86. Inside the shell 85 is a metal plate 87, and, spaced apart therefrom, a corrugated metal plate 88. A plug-in terminal 89, which extends from the base, is electrically connected with the plate 87, and a second plug-in terminal 90 is electrically connected with the corrugated plate 88. These terminals are adapted to connect, through a suitable socket, with the electrical conductors 62 and 63 of Fig. 13.

Under certain conditions of use, it is desirable to have other elements in the tube. These are provided, and may be utilized or not as occasion warrants. A filament 91 is disposed between the plates 87 and 88. It is electrically connected with the two plug-in terminals 92 and 93, which are adapted to be connected to a source of low voltage heating current (not shown). A slit screen, comprising shields 94 and 95, with apertures 96 extending therethrough, is disposed adjacent that side of corrugated plate 88 which is remote from plate 87. The apertures 96 are in alignment with each other, and the shields 94 and 95 are made of lead or other material capable of screening off X-rays. Between shields 94 and 95 is a sheet 97 of material which is readily permeable to X-rays. Within the shell 85 there is also mounted a shell or envelope 98 of glass, quartz glass, or similar material, having a portion 98*a* which is ground like a lens and directed toward the slit screen. This shell 98 really constitutes a tube within a tube. A filament or cathode 99, comprising electrically conductive legs 99*a* and 99*b* and an electron-emitting portion 99*c*, is disposed within the shell 98, plug-in terminals 100 and 101 being electrically connected to the respective legs 99*a* and 99*b*. A bombardment element 102 is disposed within the shell 98 opposite the portion 99*c* of cathode 99. Within the shell 85, but outside the shell 98, is a reflector 103 directed toward the slit screen.

The tube of Figs. 18 and 19 is essentially the same as the tube of Figs. 16 and 17, being equipped with a shell or envelope 105, a base 106, a plate 107, and a corrugated plate 108, the two plates being connected to plug-in terminals 109 and 110, respectively, which are adapted to connect electrically with the conductors 62 and 63 of Fig. 13. There is a filament 111 and an inner shell or envelope 112, but no slit screen. Instead of a lens portion being provided on the inner shell 112, a partition 113 of lens formation is disposed between the inner shell and the corrugated plate 108. It is fused to the walls of the outer shell 105. Within the inner shell 112 is a filament or cathode 114, which corresponds to the similar element 99 of the tube of Figs. 16 and 17. A reflector 115 is directed toward the lens partition 113.

Reverting now to Fig. 1, there is another advantageous way of treating a patient pursuant to the invention. As shown at Y, a foot pedestal 120 may be provided for making the patient a part of a condenser. The pedestal comprises an electrically conductive plate element or electrode 121, connected electrically with one of the high potential lines 12, and covered by an insulating platform 122 upon which the patient rests his feet while being treated at any of the previously described treatment stations A, B, C, D, or E. The electrode 121 and insulating platform 122 are conveniently mounted in a frame 123, which insulates the plate from the ground. The insulating platform 122 is made of a high quality insulating material, such as first grade hard rubber. In certain instances it is desirable that the device be made in other than foot-pedestal form. For instance, it may be of cylindrical formation for use in a bed against any part of the patient's body.

If desired, the patient may be charged with the high potential electricity by direct contact with a metal or electrically conductive electrode in place of the pad 50 of treatment station E, or of the tube electrodes.

The invention has been described in the foregoing with sole reference to its use for therapeutic purposes. It should be noted, however, that inorganic matter may also be treated to advantage pursuant to the method and with the apparatus of the invention. It has been found that metals, for example, lead, have changed physical properties after treatment in accordance with the above. In instances where the invention is not being used therapeutically, it is not always necessary to insulate the subject from the ground.

Whereas this invention is here illustrated and described with respect to particular specific embodiments thereof, it is to be understood that various changes may be made in such specific embodiments and various other embodiments may be utilized by those skilled in the art without departing from the spirit and generic scope of the invention as set forth herein and in the claims which here follow.

Having fully described my invention, what I claim is:

1. Apparatus for applying radiant energy therapeutically, comprising means for producing high potential, high frequency electricity; a high capacity sparking condenser, and a treatment electrode connected in circuit with the foregoing, said treatment electrode including a discharge element adapted to charge the patient with said high potential, high frequency electricity, and radioactive means adapted to discharge radioactive emanations into said charged patient.

2. Apparatus in accordance with claim 2, wherein the sparking condenser is in the form of a vacuum tube of high capacity having mutually spaced capacity elements adapted to produce a corona discharge.

3. Apparatus for applying radiant energy therapeutically, comprising means for producing high potential, high frequency electricity; a high capacity sparking condenser; and a treatment device connected in circuit with the foregoing, said treatment device including discharge means adapted to charge the patient with said high potential, high frequency electricity, and radiating means adapted to discharge radiations into the charged patient.

4. Electrical treatment apparatus, comprising a high capacity sparking condenser; a treatment outlet electrically connected to said condenser; and means for electrically connecting said condenser to a source of high potential electricity.

5. Electrical treatment apparatus, comprising a transformer for producing high potential electricity; a high capacity sparking condenser electrically connected across the high potential output terminals of said transformer; and a treatment outlet electrically connected to said condenser.

6. Electrical treatment apparatus, comprising a transformer for producing high potential electricity; a high capacity sparking condenser electrically connected across the high potential output terminals of said transformer; and a plurality of treatment outlets independently electrically connected to said condenser.

7. Electrical treatment apparatus, comprising a transformer for producing high potential electricity; a treatment electrode electrically connected to one of the output terminals of said transformer; an electrical conductor sheathed by insulation electrically connected to the other of the output terminals of said transformer and disposed adjacent said treatment electrode so the subject to be treated may be placed between and in contact with the two; and a high capacity sparking condenser connected across the said outlet terminals of the transformer.

8. In electrical treatment apparatus equipped with means for the supply of high potential electricity and a treatment electrode, a high capacity sparking condenser electrically connected between the said supply means and the said treatment electrode.

THOMAS H. MORAY.

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Two Patents of
William J. Hooper

FIG. 1

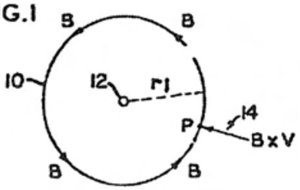
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FIG. 3

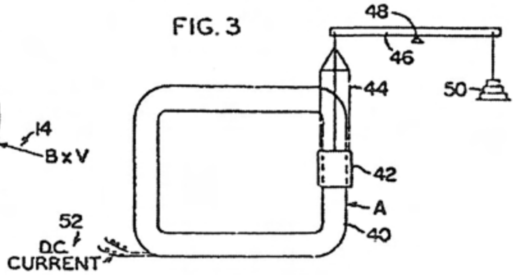
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CURRENT

FIG. 2

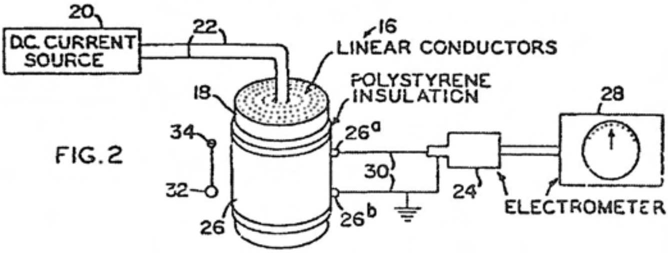
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D.C. CURRENT SOURCE
22
16
LINEAR CONDUCTORS
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POLYSTYRENE INSULATION
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ELECTROMETER

FIG. 4

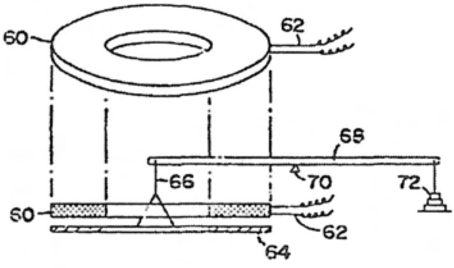
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FIG. 5

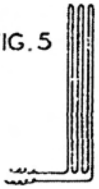

FIG. 6

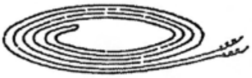

FIG. 8

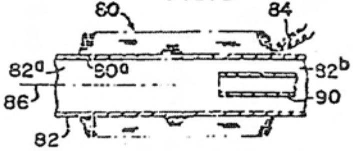
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FIG. 7

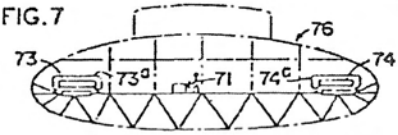
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INVENTOR
WILLIAM J. HOOPER
BY
Oldham & Oldham
ATTORNEYS.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,610,971 Dated October 5, 1971

Inventor(s) William J. Hooper

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 1, line 14, after "conductor" insert -- with -- and delete "electric charges".

Col. 1, line 45, "10^{17}" should be -- 10^{-7} --.

Col. 2, line 4, "nd" should be -- and --.

Col. 2, line 25, "3.6×10^{12}" should read -- 3.6×10^{-2} --.

Col. 2, line 44, "motion" should be -- motional --.

Col. 4, line 7, "anitgravitational" should read -- antigravitational --.

Col. 4, line 22, "he" should be -- the --.

Col. 5, line 20, "out" should be -- our --.

Col. 6, line 26, after "conductor" delete "o" and insert -- to --.

Signed and sealed this 16th day of May 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

United States Patent

[11] 3,610,971

[72] Inventor William J. Hooper
Sarasota, Fla.
[21] Appl. No. 816,356
[22] Filed Apr. 15, 1969
[45] Patented Oct. 5, 1971
[73] Assignee Electrodynamic Gravity, Inc.

[54] ALL-ELECTRIC MOTIONAL ELECTRIC FIELD GENERATOR

5 Claims, 8 Drawing Figs.

[52] U.S. Cl. 310/10
[51] Int. Cl. H02n 11/00
[50] Field of Search 310/10, 11; 324/109; 336/181, 225; 338/284, 297

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Primary Examiner—D. X. Sliney
Attorney—Oldham & Oldham

ABSTRACT: This invention relates to an all-electric generator yielding a motional electric field in the space surrounding the device, but requiring no mechanical movements of its parts in generating this field. The Theory underlying the production of such a field postulates that each moving electron constituting the current in a linear conductor carries with it a loop of magnetic field energy about it.

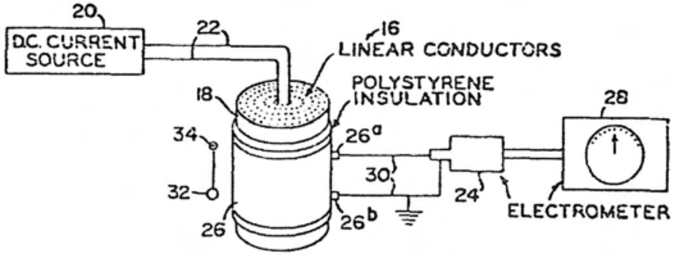

ALL-ELECTRIC MOTIONAL ELECTRIC FIELD GENERATOR

This application is an extension of the teachings presented in my earlier filed pending applications, Ser. Nos. 722,587, filed Apr. 19, 1968 and 803,187, filed Feb. 28, 1969.

PRIOR HISTORY

The detection of a magnetic flux about a current-carrying conductor was first made in 1820 by Hans Christian Oersted. This discovery unified the then separate sciences of electricity and magnetism. My experimental discovery that this magnetic flux actually moves along the conductor electric charges the electric charges constituting the current has great promise of now unifying the three known fields of electricity, magnetism and gravitation.

For a better understanding of the invention, reference should be had to the accompanying drawings wherein:

FIG. 1 is a schematic illustration of a wire containing flowing electrical current indicating the magnetic field generated with respect thereto;

FIG. 2 is a perspective block diagram schematic of a preferred embodiment of the invention;

FIGS. 3 and 4 illustrate modifications of the generator of FIG. 2 adapted to techniques for studying and utilizing gravitational and antigravitational phenomena;

FIG. 5 illustrates the winding of the wire in the device of FIG. 2;

FIG. 6 illustrates the winding of the wire in the device of FIG. 4;

FIG. 7 illustrates the incorporation of a plurality of the devices of the invention into a spacecraft where they might be appropriately utilized; and

FIG. 8 illustrates a coil wound embodiment useful for producing the separation of oppositely charged ions in gases or liquids.

BACKGROUND INFORMATION

The law of Biot and Savart yields the magnetic flux density B (webers/m.^{2}) at a point distant r meters from the conductor carrying a current of I amperes and is given by

$$B=\mu_o I/2\pi r \qquad (1)$$

where $\mu_o=4\pi\times10^{-7}$ webers/amp. meter. With reference to FIG. 1 of the drawings, this flux consists of circular magnetic loops directed counterclockwise, as shown by arrow 10, for current directed in a linear conductor wire 12 at right angles to this paper and outwardly toward the reader.

Electrons producing this flux will be moving perpendicularly into the paper, carrying the flux B with them, at a velocity V meters/sec. Thus, at any point P, distant r_1 from the long linear conductor 12, there will be existent a motional electric field of intensity $E=B\times V$ volts/meter directed radially inward toward the wire in the plane of the paper, as indicated by vector arrow 14, where $B\times V$ is the vector cross product of B and V.

PREFERRED EMBODIMENT

The preferred embodiment of the invention is illustrated in FIG. 2 and consists in part of many insulated linear conductors indicated generally by numeral 16, all parallel, packed and held in close proximity, and connected in series, so as to form a solid package 18 preferably cylindrical in shape. When a constant direct current from a source 20 is caused to flow through wires 22 this device with its axis in the vertical direction, half of the linear conductors 16 will have current flowing upward and half downward. It will be a noninductive device, since surrounding it the magnetic flux due to the upward currents will be superimposed on the flux due to the downward currents, so that no magnetic flux can be measured. On the well recognized "Principle of Superposition of Fields," each one exists however, and acts as though the other was absent.

When the package 18 of linear conductors has a circular cross section there will exist two systems of circularly directed magnetic flux, one directed clockwise and the other counterclockwise as seen from above, and one set moving upward and the other set moving downward. What is of capital interest however is that each of these two systems give rise to equal radially and inwardly directed $B\times V$ motional electric fields distributed laterally in horizontal planes in the space about the cylindrical device. Here we have a field which is not magnetic, is not electrostatic, and which I have shown experimentally to be immune to electrostatic shielding. No such spacially distributed field is known to Physics today except that of gravity. I have shown theorectically that this field should act attractively on electrically neutral matter. I have shown experimentally that the intensity of this field can be measured with the aid of an electrometer system 24, 28 driven by the potential difference induced electromagnetically in the conductors 30 connecting the electrometer to the capacitor plates 26*a* and 26*b* of the capacitor 26. The electrometer head 24 actuates a visual dial indicator 28.

At cryogenic temperatures the drift velocity of the electrons in the linear conductors will be greatly enhanced. Theoretical calculations indicate that this velocity in copper at 20° C. is of the order of 3.6×10^{-2} cm./sec. in a current density of 480 amp./cm^2. The random velocity of free electrons in conductors is theoretically estimated at 10^8 cm./sec. At superconducting temperatures when the electrical resistance approaches zero, it is generally believed that the drift velocity of electrons approaches the value of 10^8 cm./sec. This velocity is 10^{10} times greater than the velocity at 20° C. (See "Physics," Halliday and Resnick, pages 681 and 691, J. Wiley, 1962). This indicates that the intensity of the $B\times V$ field about the device, herein described, might possible be enhanced 10^{10} times at or near the absolute zero of temperature. Hence, the invention contemplates that each of the devices described hereinafter will preferably be operated at or below the critical temperature at which the conductor used becomes superconducting. As the state of the art advances new conducting materials will undoubtedly become available with critical temperatures very considerably above the absolute zero.

Not only does the device that has been described in FIG. 2 afford apparatus hitherto unavailable for the generation of a spacial distribution of the motion electric field, but it affords means for investigating the properties of this field in connection with its relation to gravity and antigravitational phenomena. In addition, it affords for the first time, a direct experimental method for determining the electron drift velocities and mobilities in linear conductors made of different materials.

When the cylindrical capacitor 26 is charged by the $B\times V$ field and its potential difference (P.D.) measured, it is determined by the equation

$$\text{P.D. (volts)} = B\times V\cdot l \qquad (2)$$

where l is the distance between the thin capacitor plates. The direct measurement of V meters/sec. can then be made

$$V=\text{P. D. (volts)}/\,Bl \text{ m./sec.} \qquad (3)$$

where B is in webers/m.^{2}.

This device will exhibit an attractive force on electrically neutral matter, better defined as a differential force; i.e. the difference between a pull and push, in which the pull is greater. (See reference to general theorem, page 125, The Mathematical Theory of Electricity and Magnetism, by Sir James H. Jeans) The $B\times V$ field is an electrical field acting on all the elementary charges comprising the atoms of matter, electrons, protons and even neutrons, as I believe neutrons also consist of electrons and protons in close bond. The $B\times V$ force being relatively weak does not ionize the atoms of matter, but being immune to shielding, electrically polarizes them. This causes a slight elongation of some of the electrons orbits within the atoms in the direction of the field. The positive charges move slightly into the more intense region of the converging, radially directed field while the negative charges move slightly further way from the device into the weaker portion of the field. Thus the differential force between the pull and the push upon the component parts of an atom results in the polarization of the atoms and a resultant attractive force, equivalent, I believe, to that of gravity.

A small, electrically neutral, simple pendulum 32 suspended close to one side of my device of FIG. 2, about pin 34, should thus undergo a slight measurable deflection under a fairly strong *B×V* motional electric field. At cryogenic temperatures this attractive force should be greatly enhanced. When the device is lying horizontally, a gravity meter placed centrally over it should give a measurable reading in milligals.

Modifications of my generator such as are shown in FIGS. 3 and 4 show diverse methods for studying gravitational and antigravitational phenomena which the invention makes possible. FIG. 3 illustrates a rectangular coil 40 made up of a single wire passed many times in the coil configuration so as to provide a large leg A preferably having a circular cross section. However, any cross-sectional configuration would meet the objects of the invention as long as the wires are parallel to each other and closely packed. About one leg of the coil, a cylindrical shell 42, made of electrically neutral, conductive or nonconductive material, is suspended by a carrier frame 44 from one end of a sensitive beam balance 46. The beam pivots about a support bar 48 and carries a load 50 to normally counterbalance the weight of the shell 42. When a fairly strong DC current I is fed through lines 52 and is built up in the coil, the flux density B is generated in the region of the cylindrical weight whose walls are a distance *r* from the central axis of the coil and *n* is the number of linear conductors in the coil.

$$B=\mu_0 nI/2\pi r \text{ (webers/meter}^2\text{)} \qquad (4)$$

If the current I is suddenly cut off the flux B will rapidly collapse. This flux in the act of collapsing should cross the walls of the suspended cylinder with a considerable inwardly directed horizontal velocity of V meters/sec. This should yield a very considerable vertical *B×V* in the walls of the cylinder directed either up or down, depending on the direction of the current in the coil.

In this device the motional electric field *B×V* is not convergent, but is uniformly vertical, hence the pull and push exerted on the electric components of the atoms in the cylinder will be equal. In other words the action of this field will either enhance or decrease the state of polarization already existing within the cylinder and produced by the gravitational field of the earth. If the polarization is increased, then the gravitational pull of the earth's field should be greater. If the polarization is decreased then the weight of the cylinder should be less. It is conceivable that the polarization could be reduced to zero. In this case, the object should be weightless. If the intensity of the depolarizing *B×V* field is still further increased, then polarization in the opposite direction to that produced by the earth's field should be achieved. In this event the earth's gravitational field would act repulsively on the cylinder. This would be antigravity in its truest sense.

The apparatus I have just been describing acts only momentarily (during the time interval in which the flux is collapsing) to change the weight of the cylinder shell 42 (shown in FIG. 3).

It is desirable to have an apparatus with which to experimentally study gravitational and antigravitational phenomena under steady continuous conditions. In FIG. 4 of the drawings is shown another modification of the device shown in FIG. 2. Here I utilize a noninductive coil wound in the form of a solid, low, thick walled, hollow, right circular cylinder, and indicated generally by numeral 60. DC current is supplied through lines 62 to the coil 60. In the region directly beneath this coil disk 60 I place a similarly shaped nonferrous disk 64, suspended by a carrier 66 to the end of a beam 68. The beam 68 is pivotal about a fulcrum 70 and is counterbalanced by a load 72. For positions of disk 64 below coil 60, the *B×V* field can only be directed vertically upward when a continuous DC current is flowing in the wires composing the disk 60. It should be noted that this field is practically uniform and parallel close to the disk, hence it is not attractive in its action on neutral matter. Its action on such matter can only change the state of electrical polarization in the matter. Any change thus effected in the state of polarization should cause the earth's gravitational field to act less intensely, on any object placed close to the under surface of the device, causing it to weigh less, become weightless, or to actually be accelerated upward by the anitgravitational action of the earth's field.

FIG. 5 of the drawings illustrates the manner in which the noninductive device in FIG. 2 is wound with wire 22, by turning the linear conductors back on themselves through a 180° turn. FIG. 6 illustrates the way the noninductive windings of the device illustrated in FIG. 4 is achieved. One very long insulated wire is simply turned back on itself at its midpoint and wound double into a solid coil held together in the shape illustrated.

FIG. 8 illustrates a modified embodiment of the invention which comprises a wire coil 80 either simply wound, or noninductively wound, around a hollow tube 82. Electrical current is passed to the coil 80 through wires 84, and at low temperature this coil will produce a radially, outwardly directed, internal *B×V* field from the axis 86 of the cylinder to the internal circumference 80*a* of the coil 80. The electrical wire making up coil 80 is preferably a ribbonlike conductor which is coated with any appropriate electrical insulation. A minimum space between adjacent turns with concentricity between adjacent turns is the preferred winding embodiment for coil 80. As many courses of turns as deemed appropriate to generate field strength desired will meet the objects of the invention. The tube 82 is preferably made of material having little or no magnetic permeability. Both the coil 80 and tube 82 are stationary.

An apparatus of the type illustrated in FIG. 8 might be utilized to effect separation and concentration of fluids. For example, in the desalinization of water, a *B×V* electric field generated by the passage of the current through the coil 80, acts upon the disassociated ions of the sodium chloride in solution. Hence, by introducing a flow saline water at end 82*a* of tube 82, and providing a concentric separating tube 90 at end 82*b* of tube 82, increments of fluid which are concentrated with chlorine and depleted of sodium may be drawn off through the stationary tube 90, while the increments of fluid which are concentrated with sodium and depleted of chlorine may be drawn off through the space between the exterior walls of tube 90 and the interior walls of tube 82.

FUTURE APPLICATIONS

This country's space projects have become expensive beyond the ability of the average man to comprehend. Achieving lift by means of costly propellants will some day soon be seen as akin to primitive man's use of awkward clubs as a means of exerting force. In a very short interval of time an intense *B×V* field should effect the reversal of the gravitational polarization of an object. Once achieved, only a very small expenditure of energy would be required to hold the polarization. Energy from the atoms of the earth would supply the lift and propulsion through the medium of the earth's gravity field. The most formidable problem would appear to be the problem of holding the *B×V* generator at cryogenic temperatures. In view of the overall possibilities of this invention, this problem does not appear to be incapable of a solution. A breakthrough in finding superconducting materials or even near superconducting at slightly elevated temperatures from those presently required would greatly aid in the solution of this problem.

FIG. 7 of the drawings illustrates in outline, the future possible application of this device, obtaining regulated lift by an operator 71 adjusting the current into the coils 73 and 74 which incorporate the structural features of the devices of FIG. 4. The antigravity gravity control features of the coils 73 and 74 thus control the lift and movement of vehicle 76. Suitable cryogenic generators 73*a* and 74*a* are associated with each of the coils 73 and 74 to provide the cooling thereof to as near absolute zero as possible to give the enhanced current passage characteristics necessary to the objects of the invention.

While I have demonstrated that AC current can be used in my device, it appears at present that DC current is much to be preferred.

This invention could be uniquely adapted to a communication system from one side of a solid barrier to the other side whether this barrier be solid concrete or battleship armor, by pulsing the $B \times V$ generator coil with signals, Morse Code or even voice modulated signals to be picked up by a capacitor-electrometer circuit on the other side of the barrier. Secret communications could be carried on and with the electrometer circuit as shown in FIG. 2 connected to a relay radio broadcasting unit, so that one might conceivably broadcast by radio from the interior of a solid metallic enclosure.

It is conceivable that the invention might be useful in the highly specialized art of concealed detonation devices. A detonating circuit connected to the capacitor electrometer receiving circuit of my device such as shown in FIG. 2 could be actuated through a solid barrier by out $B \times V$ generating coil placed on the other side of such a barrier.

It is conceivable that for some specialized purposes, it might be highly desireable to transmit electrical power from one side of a fixed solid barrier, concrete or armor plate, etc. by pulsing, DC or AC, in our $B \times V$ coil on one side of such a barrier. A resonant LC circuit could pick up these $B \times V$ pulsations and supply a source of electrical power on the other side of the barrier, in a manner somewhat analogous to my electrical receiving methods outlined in U.S. Pat. Application, Ser. No. 803,187, identified above.

In accordance with the patent statutes, only the best known embodiments of the invention have been illustrated and described in detail, but it is to be understood that the invention is not limited thereto or thereby, but that the scope of the invention is defined in the appended claims.

What is claimed is:

1. Apparatus for demonstrating an electrical phenomenon comprising,
   a coil made from an electrically conductive material having a very large plurality of sections compacted in close proximity arranged in substantially complementary relation around a common central axis, where the coil forms a solid cylindrical shape with the sections parallel to the axis thereof, and
   means to pass current through the coil so that about half the sections will pass current in a direction opposite to the other sections to cancel magnetic flux.

2. Apparatus according to claim 1 where adjacent sections are electrically insulated from each other, and the coil comprises a single wire bent back on itself to make the sections.

3. Apparatus according to claim 1 which includes means to increase the passage of electrical current through the conductor.

4. Apparatus according to claim 3 where the means to enhance is a cryogenic generator which reduces the temperature of the conductor o or below its critical temperature at which it becomes superconductive.

5. Apparatus according to claim 1 which includes an elongated hollow tube having an axis, the conductor formed around the tube.

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4 Sheets-Sheet 1

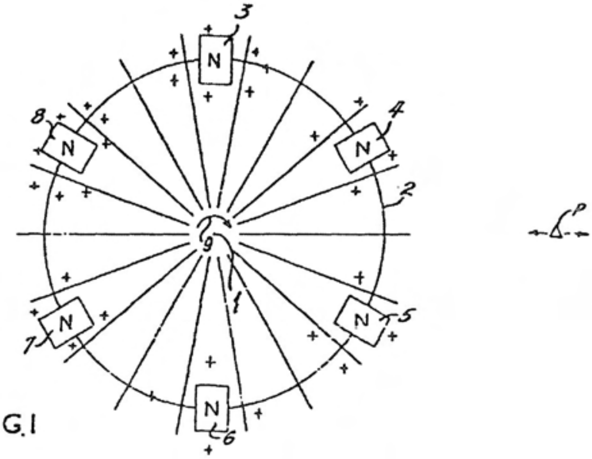
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FIG. 1

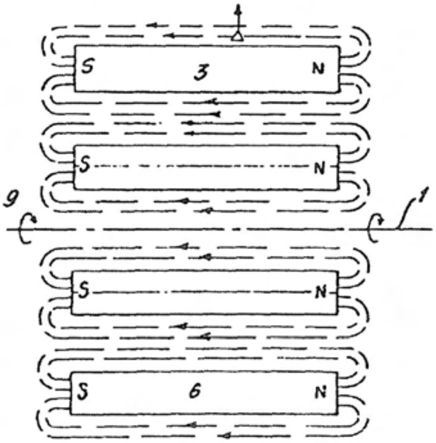
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FIG. 2

INVENTOR:
WILLIAM J. HOOPER

BY Oldham & Oldham
ATTORNEY.

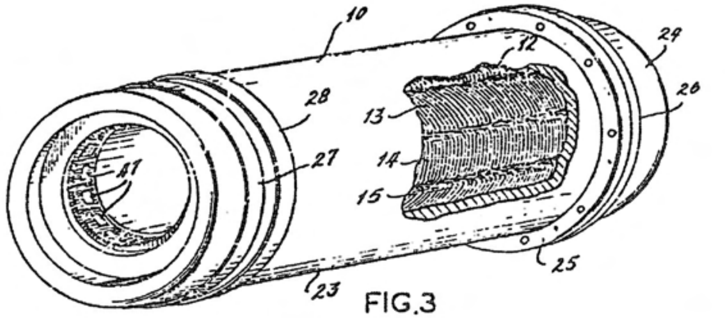
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FIG.3

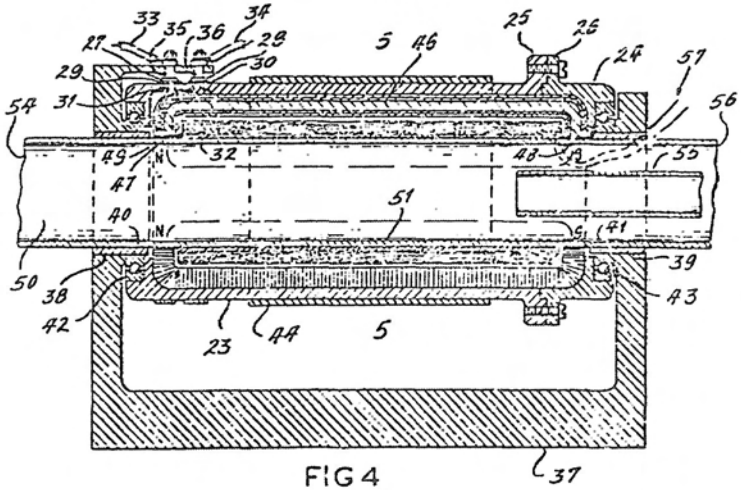
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FIG 4

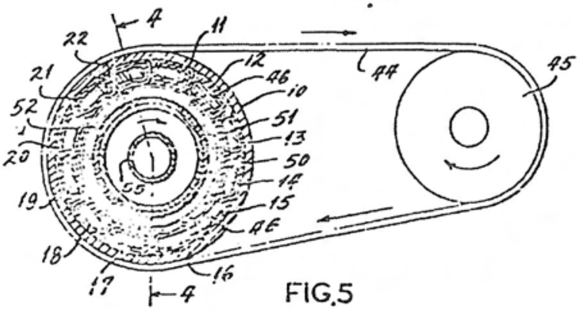
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FIG.5

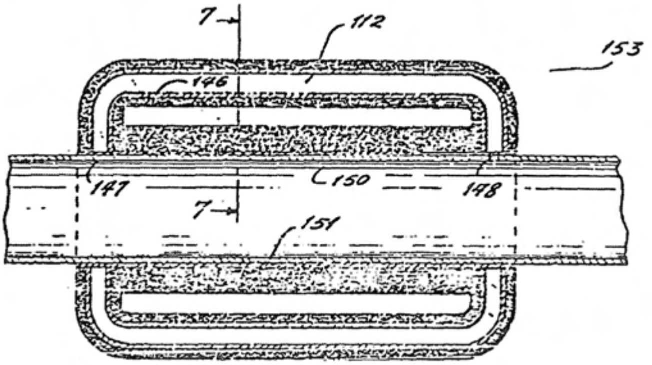
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FIG.6

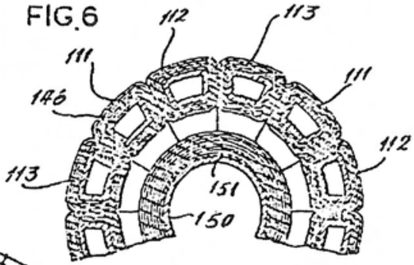
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FIG.7

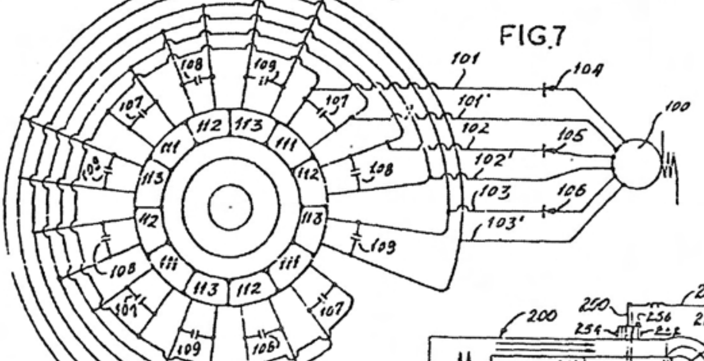
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FIG.8

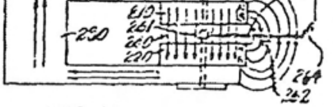
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FIG 11

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4 Sheets-Sheet 4

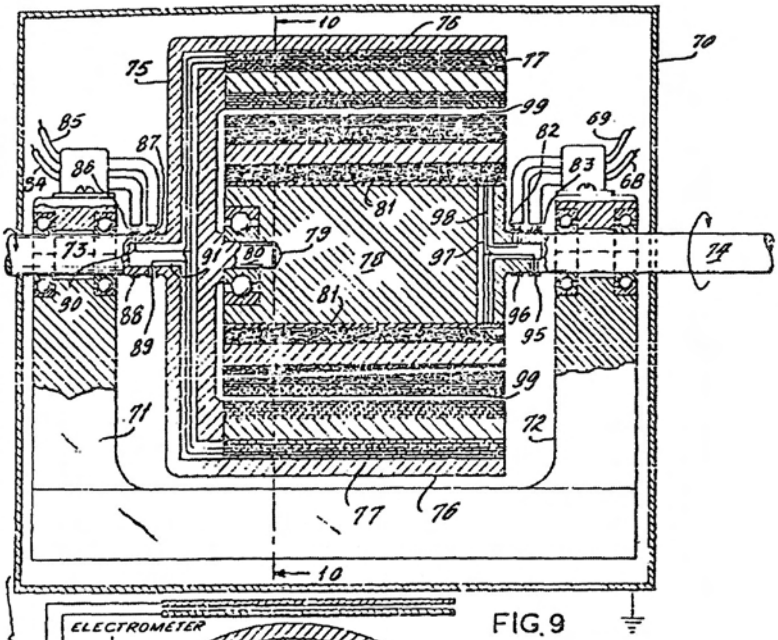
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FIG. 9

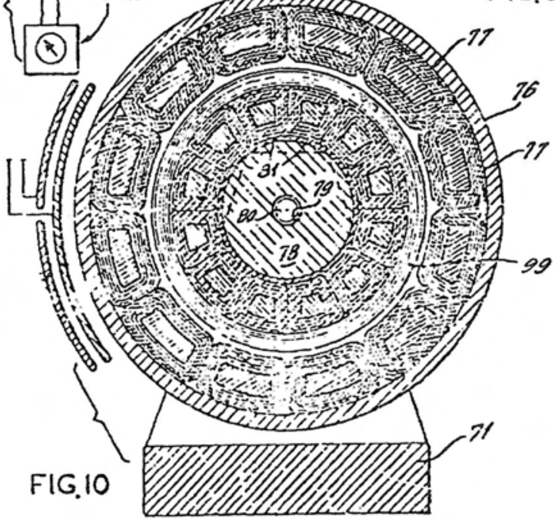
ELECTROMETER
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FIG. 10

United States Patent [15] 3,656,013
Hooper [45] Apr. 11, 1972

[54] APPARATUS FOR GENERATING MOTIONAL ELECTRIC FIELD

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[73] Assignee: Electrodynamic Gravity, Inc., County of Sarasota, Fla.

[22] Filed: Apr. 19, 1968
[21] Appl. No.: 722,587

[52] U.S. Cl. 310/10
[51] Int. Cl. H02k 1/00
[58] Field of Search ....310/10, 11, 178, 177, 156, 310/42, 268, 211, 169, 216, 269, 259; 103/1; 55/2, 14, 101, 123, 127, 120; 73/194 EM; 328/233–238

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Primary Examiner—D. X. Sliney
Attorney—Oldham & Oldham

[57] ABSTRACT

Apparatus for producing and demonstrating properties of motional electric fields by means of rotating magnetic flux produced by a plurality of magnets extending parallel with the axis of rotation, said flux of these magnets being put into rotation about a common axis by mechanical or by electro magnetic means.

6 Claims, 11 Drawing Figures

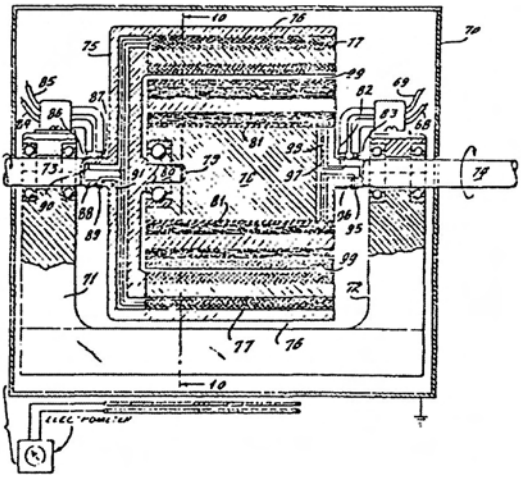

APPARATUS FOR GENERATING MOTIONAL ELECTRIC FIELD

This invention relates to the generation of motionally induced electric fields as distinct from electrostatic fields, and as distinct from the electric field (illustrated by transformer action) which is induced by the time rate of change of magnetic induction. Hence, all reference herein to a motional electric field means the electric field that is generated by the movement of magnetic flux.

The motional electric field generated by rotational motion of magnetic flux is non-uniform in both direction and radial intensity. Particles (large or small) of matter (solid, liquid or gaseous) which are within the ambit of this motional electric field are acted upon with a force which tends to accelerate them. It is well known that a particle carrying a charge Q (coulombs) in an electric field of intensity E (Newton/coulomb) will be acted upon by a force F (Newton) given by the equation $F = EQ$. The electric intensity E of a motional electric field is given by the vector equation $E = B \times V$, where B is the magnetic flux density at a point in space, expressed in webers per square meter, and V is the velocity of the moving magnetic flux at that point in space, expressed in meters per second. What is not so well known, however, is the fact that a non-uniform electric field exerts a force upon electrically neutral matter. In his celebrated text, "The Mathematical Theory of Electricity and Magnetism", Sir James H. Jeans describes, in the case of a non-uniform electrostatic field, how a "slab of dielectric will be sucked in between the plates of the condenser" thus demonstrating the mechanical force produced by such a field. He states (P. 125), "This, as will be seen later, is a particular case of a general theorem that any piece of dielectric is acted on by forces which tend to drag it from the weaker to the stronger parts of an electric field of force." According to Clerk Maxwell in "Electricity and Magnetism" (Vol. II, p. 181), Faraday discovered that the electric field due to electromagnetic induction penetrated within and throughout all materials. The motional electric field is just such a field. Apparatus for demonstrating the "general theorem", stated by Jeans, has, in the case of the non-uniform motional electric field, not heretofore been provided.

Accordingly, it is one of the objects of the present invention to provide a device for generating a non-uniform motional electric field whose force is of magnitude such that it can be sensed.

Since the motional electric field acts within and throughout all matter, such a non-uniform field will exert a physical force on any kind of electrically neutral matter, in a manner quite analogous to that of the electrostatic field with respect to dielectric material.

Another object of the invention is to provide apparatus for obtaining useful work from a non-uniform motional electric field.

The several objectives of the invention may be accomplished by rotating an elongate magnetic field about an axis which is concentric with the field and parallel with the field's elongation. For example, an array of magnets may be mounted on a rotor so that all magnets are parallel with the axis of the rotor, and all have the same polar orientation relative to the rotor. A solenoidal electro magnet, or another array of magnets, with magnetic axis concentric with the rotational axis may also be employed to enchance the flux density of the array of rotating magnets by flux linking with them. When such an array of magnets is rotated about the axis of the rotor, the magnetic field of each is rotated with it. As another example, an elongate magnetic field can be rotated about its axis, without mechanical movement, by the provision of stationary solenoidal electro magnets arrayed like the staves of a barrel and connected to a source of multi-phase alternating current (half wave rectified to prevent reversal of sign) in a manner comparable to the stator winding of a three-phase motor to produce "revolving field." While the composite magnetic field is thus in rotary motion, every charged, or uncharged particle of matter (solid, liquid, or gaseous) within the non-uniform motional electric field thus generated in the neighborhood of the rotor, will be acted upon by a force due to the electric intensity E. Positively charged particles will be forced in the direction of the vector E, negatively charged particles will be forced in the opposite direction, and electrically neutral matter will be pulled from the weaker regions of field intensity to the stronger regions. This latter mechanical force is called a differential force due to the action of the field on the internal electrical polarization of the neutral matter.

The three vectors E, B, and V are always (with a possible exception) mutually at right angles to each other. If the thumb of the right hand is pointed in the direction of the magnetic flux density vector B, and then rotated like a right-handed screw so that it points in the direction of the velocity V of the moving magnetic flux, then the forefinger of the right hand will point in the direction of the electric vector E. The rotation of the composite magnetic flux about its axis produces a motional electric field which will, except at the axial ends of the magnetic field, be quite generally directed radially with respect to the axis of rotation. The possible exception is the case of a magnet having a homogeneous electrically conductive core of perfectly circular cross-section, in which case the force of the electric field may be somewhat off radial.

With a given polar orientation of magnets relative to the axis of rotation, rotation of the magnetic field in a clockwise direction will generate a motionally induced electric field of sign (positive or negative) opposite that which is generated when the rotation is counterclockwise. For any given sense of rotation, reversing the polar orientation of the magnets relative to the axis of rotation likewise reverses the sign (positive or negative) of the motionally induced electric field. Reversing both the direction of rotation and the polar orientation of the magnets (a situation exemplified by viewing the apparatus first from one axial end, and secondly from the opposite axial end) produces no change in the sign (positive or negative) of the motionally induced electric field.

In the accompanying drawings, three embodiments of the invention are exemplified. Also, there are two model schematics to illustrate in its simplest form the principle of the invention, in which a plurality of commonplace permanent magnets are mounted upon a rotor.

The first embodiment is one in which an array of electro magnets is mounted on a rotor having a hollow center, through which particles of matter can be moved and their response to the motional electric field perceptibly demonstrated.

Second, there is an embodiment in which electro magnets are arrayed as in the first embodiment, but are stationary and their composite magnetic field is rotated electromagnetically by phase displacement.

Third, there is an embodiment in which a pair of oppositely rotating rotors, nested one within the other, are each provided, on its circumference, with an array of electro magnets oriented as aforesaid on each rotor, but oppositely oriented on the respective rotors, and wherein the effect of the motionally induced electric fields can be perceptibly demonstrated by the behavior of particles of matter externally of the rotor.

In the accompanying drawings:

FIG. 1 is a diagrammatic view illustrating the effect of rotating an array of spaced permanent magnets about an axis which is parallel with each of the magnets when all magnets have corresponding polar orientation;

FIG. 2 is a diagrammatic view representing a side elevation of the arrangement shown in FIG. 1, and illustrating the external magnetic flux paths of the several permanent magnets;

FIG. 3 is a perspective view of a rotor for generating a radially directed motional electric field in accordance with one embodiment of the invention, wherein electro magnets are arrayed within a hollow rotor with axes parallel to that of the rotor;

FIG. 4 is a sectional view taken along a diametric plane of the rotor shown in FIG. 3, together with its cooperating parts;

FIG. 5 is a sectional view along line 5—5 of FIG. 4, and showing, in addition, driving means for the rotor.

FIG. 6 is a sectional view taken along a diametric plane of a stationary form of apparatus similar to that shown in FIGS. 3, 4, and 5, but wherein the magnetic flux field is rotated electromagnetically by phase displacement;

FIG. 7 is a sectional view taken along line 7—7 of FIG. 6;

FIG. 8 is a wiring diagram for the apparatus shown in FIGS. 6 and 7.

FIG. 9 is a longitudinal sectional view of an apparatus having a plurality of rotors for generating a $B \times V$ electric field;

FIG. 10 is a sectional view taken along line 10—10 of FIG. 9; and

FIG. 11 is a diagrammatic illustration of an apparatus for exhibiting moving field phenomena.

In FIGS. 1 and 2, the principle of the invention is diagrammatically illustrated with the utmost simplicity, wherein a catena of magnetic flux fields, all with the same polar orientation, is produced by arranging an array of rod-type permanent magnets parallel with each other, and parallel with the axis about which they are to be rotated. In FIG. 1, the axis of rotation is designated 1, and may be considered as the center of a shaft of a rotor, preferably composed of material having low, if any, magnetic permeability, and low, if any, electrical conductivity. The periphery of such a rotor is designated by the circle 2. In the form shown, a series of permanent magnets 3, 4, 5, 6, 7, and 8 is appropriately secured to the periphery of the rotor with the respective magnets in equi-spaced relationship, and all with their north poles addressed in the same direction which, as shown in FIG. 1, is in the direction of the reader or, as shown in FIG. 2, to the reader's right. The external flux fields from the respective permanent magnets 3, 4, 5, and 6 are illustrated in FIG. 2, where it will be observed that the external flux path of all magnets is from right to left, a relationship designated by the plus (+) marks in FIG. 1. With such an arrangement, the flux fields of all magnets may be concurrently rotated about axis 1. Considering the rotation to be in the direction of arrows 9 and the polar orientation of the several permanent magnets to be as illustrated, a $B \times V$ motional electric field will be generated both externally and internally of rotor periphery 2 upon rotation of the rotor. The thus generated motional electric field will exert a radially directed force upon every particle of matter, neutral or charged, such as particle P, which is within the ambit of the catena of magnetic flux fields. The magnitude of the so impressed electric field intensity will depend upon the magnetic flux concentration at the particle P and the relative velocity between the flux field and particle P. While, if particle P is in motion, its velocity must be considered in arriving at the relative velocity V (in the formula $E = B \times V$) the disclosure will be simplified if the particle P be considered as stationary, and in such event V will be 2 R times S, where R is the radial displacement of particle P from axis 1, and where S is the revolutions per unit of time made by the rotor. Hence, with the particle P stationary, the magnitude of the force impressed upon it is increased when the speed of rotation of the rotor is increased at a given flux density; and is increased by an increase in the flux density at a given speed of rotation. The direction in which the force of the motionally induced electric field acts upon particle P is always *perpendicular to the magnetic flux field* B and to its velocity V. The sign of the electric force field may be either positive (acting radially outward from the axis of rotation) or negative (acting radially inward toward the axis of rotation), which, for any given polar orientation of the permanent magnets, may be reversed by reversing the direction of rotation of the rotor. With the polar orientation shown in FIGS. 1 and 2, and the direction of rotation indicated by arrow 9, if particle P is a proton or a positively charged molecule, the force of the $B \times V$ electric field will be radially inward as indicated by the solid line arrow attached to particle P; but if particle P is an electron or a negatively charged molecule, the particle will tend to move radially outward as shown by the broken line arrow; and if the particle P is electrically neutral, it will tend to move in the direction of increasing electrical intensity E. Increase of E requires either that both B and V be increasing or that one be increasing at a sufficiently greater rate than the other is decreasing so that the product $(B \times V)$ increases. In the relationship of field and particle shown in FIG. 1, the product $(B \times V)$ increases radially inward.

For practical purposes, however, commonplace permanent magnets produce insufficient flux density in their external flux paths to impress upon a particle of charged matter such as P, an electric force of sufficient magnitude that the force of the electric field can be measured with ease, at least at speeds of rotation within practical limits. Consequently, the practical embodiments of the invention, later to be described, make use of electro magnets of a form capable of producing external flux fields of vastly greater flux density B, as well as higher velocities V.

The term "unipolar induction" has been used to indicate the induction of an electric field in the vicinity of an axially symmetrical magnetic system rotating about its axis of symmetry. There has been disagreement about whether as the magnetic system is rotated the lines of magnetic induction are carried with it or remain stationary while the magnetic system rotates through them. For example, when a bar magnet is rotated about its magnetic axis, it is believed by many that the magnetic field is stationary. I have demonstrated that under certain conditions, at least, the magnetic lines can be made to move, and I have devised certain methods and apparatus for utilizing this phenomena as in the production of localized and high intensity electric fields.

Turning now to FIG. 11 of the drawings, an apparatus for demonstrating certain magnetic phenomena is illustrated in diagrammatic form. A magnetic system, indicated generally by numeral 200, includes a pair of permanent magnets 210 and 220 which are axially magnetized and mounted in axial alignment between the ends of a U-shaped yoke 230 of highly permeable magnetic material. The adjacent surfaces of magnets 210 and 220 being of opposed polarity are spaced apart, providing an air gap 240 therebetween. The lines of magnetic flux are shown in the drawing and indicated generally by numeral 262. A brass rod 250 extends axially through magnets 210 and 220. The magnetic system 200 is rotatable about rod 250. A stiff conductor 260 is electrically connected by a collar 261 at one end in rotatable or fixed relation as selectively desired, with the brass rod 250 at a point in the gap 240 between magnets 210 and 220. The other end of conductor 260 extends substantially perpendicularly from rod 250 to a distance in space away from the magnets and yoke where the magnetic field falls to approximately zero intensity. In order to complete an electrical circuit through galvanometer 270 and conductor 280 to the brass rod 250 and conductor 260, a flexible and extensible electrical wire 264 connects the end of conductor 260 to the galvanometer 270. A gear 252 locked alternatively by set screw 254 to rod 250 or by set screw 256 to yoke 230 can serve to provide driving motion to either the rod 250 or YOKE 230 as selectively desired. Normally, for the purposes of the experiment, the driving motion will be reciprocal because of the connection of wires 280 and 264.

With this apparatus, if the magnetic system 200 is held fixed and a given angular displacement imparted to conductor 260 by rotating it horizontally about or with rod 250 through the air gap at a given angular speed, a voltage is induced which provides a deflection of galvanometer 270. Furthermore, when the conductor 260 is held fixed and the magnetic system 200 rotated through the same angular displacement about rod 250, at the same given angular speed, a similar voltage of exactly the same magnitude but opposite direction is induced in the galvanometer circuit. The same deflection is obtained whether or not the magnets 210 and 220 rotate with the yoke 230 or are held stationary while the yoke alone is rotated. This indicates clearly that the lines of magnetic induction in the quantity rotate about the axis of rotation 250 as if they were rigidly attached to the magnetic system 200.

A most important aspect of the operation of the apparatus of FIG. 11 is noted when the magnets 210 and 220 are held fixed in relation to the conductor 260 and rod 250 and the yoke 230 is rotated about the rod 250. This action causes induction of current in the galvanometer circuit exactly as occurs when the entire magnetic structure or the conductor itself are moved. However, if the magnetic yoke 230 and conductor 260 are held fixed and magnets 210 and 220 rotated, there is no deflection of the galvanometer. Thus, it appears that the yoke structure plays an important part in controlling movement of the magnetic flux. Furthermore, it should be noted that the magnetic flux does not link the galvanometer circuit in the usual sense that this term is used, but that a current is induced in the galvanometer circuit through the action of the conductor 260 in merely cutting across the field extending between adjacent faces of magnets 210 and 220.

It has also been found that the permanent magnets 210 and 220 may be replaced by an electromagnet and the results described above duplicated. Furthermore, it can be demonstrated that the magnetic flux within the air core of a solenoid may be rotated about its magnetic axis. A brass tube formed in the shape of a toroidal C has a winding applied to its entire length with holes drilled in the tubing to receive a brass rod, as 250 in the structure shown in FIG. 11. With the winding energized, the above-described procedures produce similar galvanometer deflections.

This application is concerned with certain methods and apparatus which make use of the phenomena described above.

Referring now to FIGS. 3, 4, and 5 for an illustration of the second embodiment, a tubular rotor 10 is provided on its inner periphery with 12 keystone cross-sectional electro magnets 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, and 22 of the solenoid type. As seen in the cross-section of FIG. 5, the several electro magnets are arranged as sectors of a cylindrical annulus. While in the form shown, the several electro magnets 11–22 are shown in circumferentially wedged relationship, whereby to minimize the likelihood of relative movement radially inward as at standstill, as well as in the interest of achieving substantial uniformity of external flux density throughout the inside circular area of the rotor, it will be understood that when and if desired, the several electro magnets can be circumferentially spaced one from the other, and, if desired, a spacer of relatively low, if any, magnetic permeability interposed between them. Any suitable means may be employed for securing the several electro magnets to the shell of the rotor.

In order to facilitate the assembly of the several keystone-shaped electro magnets on the interior of the rotor as shown, the shell thereof is made of at least two pieces 23 and 24. In the form shown in FIGS. 3–5, the two pieces 23 and 24 are cup-shaped, and are respectively provided with outwardly extending flanges 25 and 26. Once the several solenoids have been positioned within the longer shell piece 23, the shorter shell piece 24 may be applied as a cap so that flanges 25 and 26 abut, and may be appropriately secured together as by riveting, bolting, welding, or cementing.

The shell pieces 23 and 24, as well as their interconnecting means, may be formed of material having little or no magnetic permeability, or in cases where it is desired to shield the exterior from the escape of magnetic flux, they may be formed of material having a high magnetic permeability. Instead of dividing the rotor shell in twain axially, it may be divided in twain radially, in which event the two halves will have axially extending joints when assembled, and may be held in such assembled position by banding or other appropriate means capable of sustaining the centrifugal force to which the rotor will be subject in use.

At the end of shell piece 23, remote from flange 25, there is provided a pair of slip rings 27 and 28 which, in the event the shell piece is formed of electrically conductive material, may be separated from the shell piece by sub-rings 29 and 30, of appropriate insulating material. The slip ring 27 is connected through a conductor 31 to the free end on the inner course of the solenoid winding for each of the electro magnets 11–22. The slip ring 28 is connected trough a conductor 32 to the free end of the outer course of winding in each of the solenoids 11–22. All 12 solenoids are connected so that the direction of electric current flow is the same in all solenoids. The energizing current is supplied from an external source through conductors 33 and 34 and brushes 35 and 36, in a manner well understood in the art.

The rotor is mounted upon an appropriate frame 37, having opposite stationary stub axles in the form of ferrules 38 and 39 which project toward each other. On the projecting portion of each of ferrules 38 and 39, there is provided an inner race 40 and 41 for each of two ball bearing sets whose outer races 42 and 43 are appropriately mounted to the respective ends of the rotor 10, so that the rotor 10 is free-running, with respect to the frame 37, about an axis concentric with the rotor 10.

In the embodiment shown, the exterior cylindrical surface of rotor 10 serves as a pulley for a drive belt 44 which connects the rotor to a source of power 45, but any other suitable means of driving the rotor in rotation may be utilized.

In the form shown in FIGS. 3–5, the apparatus is intended to concentrate the magnetic flux of the several solenoids radially inward, and to facilitate this each of the solenoids is provided with a core 46 of material having high magnetic permeability. As shown in FIG. 4, the several cores 46 are of squat U-shape, and extend, for the most part, parallel to the axis of the rotor, but at each end the cores are curved so as to provide faces 47 and 48 addressed radially inward. To minimize the radially outward escape of magnetic flux from the several solenoids, they are preferably wound of ribbon-like conductor which is coated with any appropriate electrical insulation. The first course of winding begins at 49, and proceeds in helically wound fashion with the minimum of space between adjacent turns about core 46, to the opposite end thereof, whereupon, without interrupting the continuity of the conductor, the second course is wound helically over the first course, with the pitch of the helix reversed from that in the first course. In this way, any gaps between successive turns in the first course are overlapped by turns in the second course. While the drawings show only two courses of conductor about each core 46, it will be understood that, in practice, there may be many more courses.

With the several solenoids connected through the slip rings to a source of direct current as above-described, it will be understood that all the solenoids 11–22 have the same polar orientation with respect to the axis of rotation of the rotor. For example, all core ends 47 are North poles, and all core ends 48 are South poles.

A tube 50 of circular cross-section is mounted in fixed relationship within the respective ferrules 38 and 39. The tube 50 is preferably made of material having little or no magnetic permeability. The tube 50 is stationary, but the rotor 10 rotates about the axis of the tube 50.

A stationary solenoid 51 is fixedly mounted on the exterior of tube 50 in a position such as to fit, with clearance, into the bight of the squat U-shaped solenoids 11–22. Solenoid 51 may be wound directly on tube 50, but in the form shown, it is wound on a cylindrical core 52 of material having little or no magnetic permeability, and the core 52 is telescoped on tube 50. The stationary solenoid 51 is energized through appropriate leads (not shown) from conductors 33 and 34 or other source of direct current, and is so connected that its magnetic polarity is opposite that of solenoids 11–22, that is to say that when, as aforesaid, the core ends 47 are North poles, the adjacent end of solenoid 51 will be its South pole. Thus, magnetic flux of solenoids 11–22 has an external path, through tube 50, which is coincident with, and in the same direction as, the internal path of magnetic flux in solenoid 51.

Thus, the magnetic field generated by each of the solenoids 11 through 22, as well as that generated by solenoid 51, penetrates the interior of tube 50, and when the rotor is driven in rotation, these magnetic fields rotate collectively about the axis of tube 50. During such rotation, particles of matter within the tube 50 are within the motional electric field generated by the rotating magnetic flux. Such an apparatus has a demonstrable effect in the separation and concentration of fluids. For example, in the de-salinization of water, the $B \times V$ electric field generated by the rotating magnetic fields, acts upon the disassociated ions of the sodium chloride in solution. This is explained by the fact that if the rotor 10 be rotated in the direction shown by the arrows in FIG. 5, the $B \times V$ field tends to drive the positively charged sodium cations toward the center, and tends to drive the negatively charged chlorine anions away from the center of tube 50. Hence, by introducing a flow of saline water at end 54 of tube 50, and by providing a concentric separating tube 55 at end 56 of tube 50, increments of fluid which are concentrated with sodium and depleted of chlorine may be drawn off through the stationary tube 55, while the increments of fluid which are concentrated with chlorine and depleted of sodium may be drawn off through the space between the exterior walls of tube 55 and the interior walls of tube 50.

Another utility of the apparatus shown is that of transmuting hydrogen into helium, in which event tube 55 is omitted and electrodes are provided at opposite ends 54 and 56 of tube 50, so that an electric arc may be established between them. Heretofore, difficulty has been encountered in maintaining the plasma of the arc in a relatively straight path between the electrodes as it ends to wiggle and extinguish itself when it makes contact with one of the confining walls. However, by impressing a $B \times V$ electric field upon such an arc, its path may be confined within controllable limits. The $B \times V$ electric field has the further effect of driving hydrogen protons toward the center of the tube, and driving electrons away from the center of the tube. Add one neutron to a hydrogen atom nucleus, and there is produced the isotope known as Dueterium; add one more neutron to the Dueterium nucleus, and it becomes Tritium; add one more proton to the Tritium nucleus, and it becomes Helium.

A third embodiment of the apparatus is shown in FIGS. 6, 7, and 8. With the significant exception that the embodiment of FIGS. 6, 7, and 8 has no moving mechanical parts, its organization is, in general, quite similar to that shown in FIGS. 4 and 5, and hence the last two digits of the reference characters utilized in the previous embodiment. As shown in FIG. 6, a cylindrical tube 150 has a solenoid 151 wound on the exterior thereof, and is energized with direct current from a suitable source through leads 153. A plurality of squat U-shaped solenoids 111, 112, and 113, of keystone-shaped cross-section, of which there are four each or any multiple of four, are wound as described in connection with the previous embodiment, and securely mounted in any suitable way with their pole faces 147 and 148 contiguous with, and addressed toward the axis of, tube 150. In this embodiment, however, the several squat U-shaped solenoids 111, 112, and 113, have cores which are made of material having little or not magnetic permeability, such as tubes 146 of paperboard wound to a keystone shape with hollow interior. As in the previous embodiment, the magnetic polarity of solenoid 151 is opposite that of the solenoids 111, 112, and 113, which is to say that if ends 147 of the solenoids 111–113 are the North poles thereof, the adjacent end of solenoid 151 is its South pole, so that the external magnetic flux path from solenoids 111–113 is coincident with, and in the same direction as, the internal flux path of solenoid 151.

In the embodiment shown in FIGS. 6–8, the several squat U-shaped solenoids 111, 112, and 113 are energized with non-interconnected three-phase alternating current, each phase of which has been half-wave rectified to produce direct current pulsating at alternate half cycles. One phase of the alternating current is connected to all solenoids 111; another phase of the alternating current is connected to all solenoids 112; and the third phase of the alternating current is connect to all solenoids 113, as shown in the wiring diagram of FIG. 8, where a three-phase alternator 100 is provided with six leads arranged in three pairs, to wit: leads 101 and 101' for the first phase, leads 102 and 102' for the second phase, and leads 103 and 103' for the third phase. The respective phases are not electrically interconnected. In each of leads 101, 102, and 103, there is a rectifier 104, 105, and 106, respectively. Leads 101 and 101' serve all four of solenoids 111; leads 102 and 102' serv all four of solenoids 112; and leads 103 and 103' serve all fou of solenoids 113. Across leads 101 and 101', between th rectifier 104 and the respective solenoids 111, there is provided a capacitor 107. Such capacitor is to coordinate th capacity and inductance of input, and to neutralize the effec of induction in solenoids 111 by adjacent solenoids during th off half-cycle of energization. Likewise, a capacitor 108 i connected between leads 102 and 102', and a capacitor 109 i connected between leads 103 and 103'. It will be apparent t those skilled in the art that since the four solenoids of like phase are arranged in quardrature with each other, and since solenoids 111 will reach their peak of magnetic flux 120° ahead of solenoids 112 reaching their peak flux, and the latte 120° ahead of solenoids 113 reaching their peak flux, a revolving magnetic field is created. Due to the rectification of the alternating current, and the consequent utilization of the hal cycles which all flow in the same direction, there will be no reversal of the direction of magnetic flux generated by any of solenoids 111, 112, and 113, and hence, as in the case of the previous embodiment, the external path of all magnetic flux generated in the solenoids 111, 112, and 113 is coincident with, and in the same direction as, the internal flux generated by direct current energization of solenoid 151. When such an arrangement is supplied with alternating current at high frequency, such as a thousand cycles per second, the same results are achievable with this embodiment as with the previous embodiment but without movement of any mechanical parts.

For the purpose of illustrating the effect of the $B \times V$ electric field, and segregating that effect from the effect of stray magnetic or electrostatic forces, reference may be had to FIGS. 9 and 10. The device there shown is intended to be encased in an electrically grounded box 70 of material which has a high magnetic permeability, and which also has the property of electrical conductivity for shielding electrostatic fields.

Within the box 70, there is a compound rotor machine, wherein the respective rotors are driven in opposite directions. In a suitable frame having spaced pedestals 71 and 72, there is mounted a shaft 73 and an independent shaft 74. Both shafts 73 and 74 may be driven from a single source of power, and are preferably driven at the same rotational speed, but in opposite senses. A yoke 75 is fixedly mounted to shaft 73 for rotation with it. The yoke is cup-shaped with cylindrical skirt 76. About the inner periphery of the skirt 76, a plurality os solenoidal electro magnets 77 are fixedly mounted thereto. The several electro magnets extend parallel with the common axis of rotation of shafts 73 and 74, and are of the same polar orientation with respect to those shafts. The several electro magnets 77 have identical solenoids wound, in the manner previously described, about identical cores of material having high magnetic permeability. The solenoids of the several electro magnets 77 are energized from a suitable source of direct current through conductors 84 and 85, brushes 86 and 87, slip rings 88 and 89, and conductors 90 and 91. The respective solenoids 76 are preferably connected in parallel circuit relationship, but, if desired, may be in series so long as uniform polar orientation is maintained.

Shaft 74 is provided with a hub 78 having a coaxial bore 79, into which is rotatably fitted a pilot 80 projecting concentrically from shaft 73. On the outer periphery of hub 78, there is fixedly mounted a plurality of electro magnets 81, each of which is an identical solenoid, and each of which has an identical core of material having high magnetic permeability. As in the previous case, the several solenoids 81 are all energized so as to have the same polar orientation with respect to their axis of rotation. Each of the solenoids is energized from a suitable source of direct current through conductors 68 and 69, brushes 82 and 83, slip rings 95 and 96, and conductors 97 and 98. All of the solenoids 81 are preferably connected in series circuit relationship, but, if desired, may be in parallel.

If desired, and as shown, the several solenoids 81 may be surrounded by a simple solenoid 99 wound helically thereabout and electrically connected in parallel or series relationship with solenoids 81 and to conductors 97–98 so that the current flow through solenoid 99 is in the same direction as through solenoids 81. Thus the winding 99 serves the dual purpose of boosting the magnetic fields generated by solenoids 81 and of mechanically binding the latter to the surface of hub 78.

When, as contemplated, the shafts 73 and 74 are driven in rotation simultaneously, but in opposite directions, the solenoids 77 which rotate with shaft 73 have opposite magnetic polar orientation to those (81) which rotate with shaft 74. The several solenoids 77 are preferably designed to create external magnetic flux fields of flux density approximately equal and opposite to those created by electro magnets 81 and 99, but by the principle of superposition ("Elec. & Mag.", by Ralph W. Winch, 1963 Ed., p. 202), each flux field acts as if the other were not present. Despite the fact that the flux fields created by the responsive series of electro magnets 77 and 81 and 89 are oppositely directed, since their rotation is in opposite senses, their resultant effect, insofar as concerns the generation of a $B \times V$ electric field, is cumulative. Accordingly, the external $B \times V$ electric field is intensified at the exterior of the device, and its effect on the outside of shielding box 70 is demonstrable, even though the resultant magnetic flux density there is approximately zero. Such demonstration might be through a capacitor and electrometer as shown in FIG. 9, for example.

In order to achieve the maximum flux density and hence the maximum $B \times V$ electric field intensity, it is desirable to take measures which keep the apparatus cool. This may involve resort to such means as: winding the several solenoids with so-called "super-conductors" such as that known commercially as "Supercon"; or refrigerating the apparatus as by immersing it in a bath of liquid helium which is capable of maintaining a temperature of approximately 4° Absolute.

While several illustrative embodiments of the invention have been disclosed in detail, it is not to be understood that the invention is limited to those embodiments. On the contrary, the principles of the invention are susceptible of application in a vast variety of forms without departing from the spirit of the invention or the scope of the appended claims. The apparatus defined in the following claims is believed by the applicant to demonstrate his unique theory disclosed above.

What is claimed is:

1. Apparatus for generating an electric field, comprising:
 a frame;
 a cylindrical rotor;
 a shaft journalled on the frame and supporting the rotor for rotation about is longitudinal axis;
 a plurality of electro magnets, each of which is an identical solenoid having a core formed of a material having a high magnetic permeability, the electro magnets being fixedly mounted on the rotor with each electromagnet extending parallel to the axis of rotation thereof,
 means to energize the solenoids of the electro magnets from a direct current source, the solenoids being energized so as to maintain a uniform polar orientation; and
 an enclosure surrounding the frame and the rotor, the enclosure being formed of an electrically conductive material the enclosure being grounded.

2. Apparatus according to claim 1 wherein the rotor is a hollow cylindrical rotor, the electromagnets being affixed to the inner cylindrical surface of the rotor.

3. Apparatus according to claim 1 wherein the solenoids are connected in parallel circuit relationship.

4. Apparatus for demonstrating magnetic phenomena comprising:
 a frame;
 a cylindrical rotor;
 a shaft journalled on the frame and supporting the rotor for rotation about its longitudinal axis;
 a plurality of electro magnets, each of which is an identical solenoid having a core formed of a material having a high magnetic permeability, the electro magnets being fixedly mounted on the rotor with each electro magnet extending parallel to the axis of rotation thereof,
 means to energize the solenoids of the electro magnets from a direct current source, the solenoids being energized so as to maintain a uniform polar orientation;
 an enclosure surrounding the frame and the rotor, the enclosure being formed of an electrically conductive material, the enclosure being grounded; and
 means surrounding at least a portion of the enclosure to detect and measure the electric field generated during rotation of the energized rotor.

5. Apparatus for demonstrating magnetic phenomena, comprising:
 a U-shaped yoke of highly permeable magnetic material;
 a pair of permanent magnets mounted in axial alignment between the ends of the yoke, one magnet being mounted to each leg of the yoke;
 an electrically conductive non-magnetic rod extending axially through the magnets;
 a stiff conductor mounted at one end to the rod for rotation relative to the yoke in a plane perpendicular to the rod and intermediate the magnets, the conductor extending a sufficient distance beyond the magnets so that its other end is located at a point where the magnetic field from the magnets falls to approximately zero intensity;
 a galvanometer; and
 circuit means connecting the ends of the conductor to the galvanometer to measure current flow through the conductor.

6. Apparatus according to claim 5 wherein the magnets are rotatably mounted to the yoke for rotation about the axis of the rod, and where the magnets are axially magnetized and adjacent faces are of opposite polarity.

* * * * *

APPENDIX III

A CONDITIONAL CRITERION FOR IDENTITY, LEADING TO A FOURTH LAW OF LOGIC

Summary

If logic is regarded as a set of perceptual operations, then logic has a chronotopology (time structure). Identity or nonidentity then results as a decision from an algorithm — a set of perceptual operations and comparisons — in which case the nature of a particular identity is conditional upon the nature of the set of perceptual operations comprising the algorithm.

Ordinary logic does not account for the temporal aspects of perception, merely accounting for the spatial aspects.

In other words, Aristotlean logic is a synthesis of primitive observation, fitted to the partial (spatial) reality emerging from spacetime after the imposition of the monocular (one-at-a-time) photon interaction with matter.

In quantum mechanics, time is a parameter, not an observable. Hence measurement/detection (of observables) deals with primitive observation and Aristotlean logic (topology).

Total reality includes nonprimitive observation — hence, non-Aristotlean logic (chronotopology) — as shown in Young's two-slit experiment.

By applying temporal accounting to each perceptual operation, Aristotle's three laws can be shown to be self-contradictory and incomplete as written. That is, they are topolological, not chronotopological.

A simple derivation of a fourth law is shown and an application rule given which itself may be regarded as a fifth law of logic.

A proof of the fourth law by demonstration is given.

The resulting four law logic is chronotopological. The applica-

tion rule states that either Aristotle's three laws apply explicitly and the fourth law is implicit, or the fourth law applies explicitly and Aristotle's three laws are implicit.

The four-law chronotopological logic is theoretically capable of resolving every present three-law paradox.

Aristotle's Laws and the Paradox of Change

Aristotle's three laws of logic, on which foundation rests all mathematical, physical, and rational thinking, can ordinarily be stated as shown in Table 1.

Table 1. Aristotle's three laws of logical thought

1. $A \equiv A$
2. $A \not\equiv \bar{A}$
3. $A \vee \bar{A}$

A variety of arguments can easily be produced to show that these laws are incomplete; i.e., they do not specify all reality, for parts of reality can be shown to contradict one or more of Aristotle's laws.

Indeed, all "observed" reality can be shown to violate all three-laws.

E.g., the most direct violation is posed by the problem of change, a problem originally propounded by Heraclitus about 500 B.C., and unsolved to this day. Heraclitus pointed out that, for a thing to change, it must turn into something else, and then asked how a thing could be something other than itself?

We may think of a thing — say, α — some feature A of which is said to change. If A changes, it turns into $\bar{A}$, thus violating logic laws one and two. Further, we are considering A as the "changed thing. $\bar{A}$," i.e., something which is somehow both A and $\bar{A}$, so logic law three is violated as well.

Thus, if Aristotle's laws are taken to be all the fundamental laws of logic, then logically there can be no change whatsoever, because change negates all three laws. I.e., either change does not exist or it is totally illogical.

Since all measurements, detections, thoughts, and perceptions are simply changes, then it follows that these operations logically cannot exist. Or, if we assume the "operations" to exist, their outputs cannot exist. If the operations do not exist, then again their outputs do not exist.

So if the products or outputs cannot exist, then by this reasoning no perceived, detected, measured, conceived thing exists. If we then insist that such things do indeed exist, then all is paradoxical and illogical. This is essentially the nature of the paradox posed by Heraclitus.

Heraclitus's change paradox has not been satisfactorily resolved to this day, and rigorously all the rational science of the Western world, being based on paradoxical change (detection, perception, observation) is itself totally illogical by its own logical standards.

Resolving the Paradox of Change

However, the conditions necessary to resolve the problem of change can be stated simply by inspection of the problem as follows: (1) Aristotle's three laws must specify or apply to only that which is not changing, since change violates or negates all three laws; (2) If change is to logically exist, there must exist at least a fourth law of logic, one which applies to change; (3) This fourth law must contain the negations of each of the first three laws, since change negates them; (4) To be consistent, in any particular logical case, either the three laws explicitly apply or the fourth law explicitly applies (i.e., either change explicitly exists in that particular case or it does not); (5) Since all four laws must apply at all times, then when the three laws apply explicitly, the fourth law must be implicit—and when the fourth law applies explicitly, the three laws must be implicit.

With the five stated conditions, a fourth axiom of logic can be written simply by writing down the negations of Aristotle's three laws, and synthesizing these negations into a single fourth law, as shown in Table 2.

Table 2. Negations to Aristotle's laws.

Aristotle's law	Negation	of negation*
$A \equiv A$	$A \not\equiv A$	$A \equiv \overline{A}$
$A \not\equiv \overline{A}$	$A \equiv \overline{A}$	$A \equiv \overline{A}$
$A \vee \overline{A}$	$A \wedge \overline{A}$	$A \equiv \overline{A}$ or $[A,\overline{A}]$

However, even though we can synthesize the negation into a single law — the old "identity of opposites" idea — we still have the problem of understanding such a law. Though at first glance the negations and the synthesized fourth law seem bewildering, we can readily comprehend them if we carefully consider the temporal nature of the process that occurs in logical thinking.

The Importance of Time

Specifically, a finite interval of time is required to perceive, think, detect, or observe an entity — regardless of whether we refer to "physical" or "mental" detection, because both physical and mental processes are temporal. Indeed, we flatly state without further discussion that ultimately the identifying or mapping of physical and mental operations onto each other is what time is a *priori.*

At any rate, we now carefully account for each individual time interval required to think, conceive, detect, perceive, or observe any entity — whether that entity is physical or mental — and we also account for the finite time interval required to perform a logical operation. So we rewrite Aristotle's three laws as shown in Table 3, with subscripted numbers indicating the separate time intervals in each law.

*These negations mean that A and $\overline{A}$ are totally undifferentiated.

Table 3. Temporally accounted laws and negations.

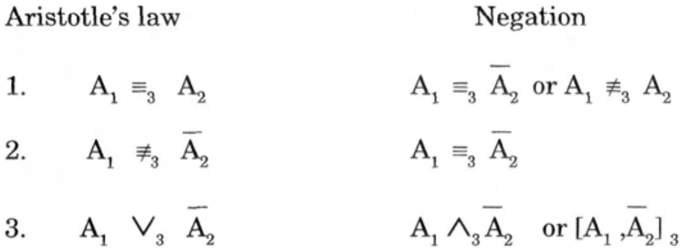

	Aristotle's law	Negation
1.	$A_1 \equiv_3 A_2$	$A_1 \equiv_3 \bar{A}_2$ or $A_1 \not\equiv_3 A_2$
2.	$A_1 \not\equiv_3 \bar{A}_2$	$A_1 \equiv_3 \bar{A}_2$
3.	$A_1 \vee_3 \bar{A}_2$	$A_1 \wedge_3 \bar{A}_2$ or $[A_1, \bar{A}_2]_3$

The resolution to the entire mystery so long inherent in these axioms of logic now stands simply revealed: Whether one of Aristotle's laws holds or its negation holds is determined solely by the nature of the logical operation in time interval three.[1]

I.e., the operation in interval three may be regarded as an *algorithm* comprised of subsidiary (assumed) operations in separate time subintervals that, taken together, comprise the overall operation implied by the logic symbol.

Thus in the first law, if temporal tags (time snapshots) are not accounted (i,e., if they do not apply), then Aristotle's laws hold, for the snapshot 1 of A is not differentiated in algorithm 3 from snapshot 2 of A. This then rigorously holds for spatial (L^3) entities, but not for spacetime entities. The snapshots in this case for Aristotle's first law (and the others as well) are *spatial* snapshots. On the other hand, if snapshots 1 and 2 of A are themselves temporally differentiated in algorithm 3, then the negation of Aristotle's law applies, because the *spacetime* snapshots A_1 and A_2 are different. This is immediately apparent, e.g., in a Minkowski geometry representation, where the second snapshot of A will have a time coordinate different from the time coordinate of snapshot 1. This is represented as shown in figure 1, where "A" is taken as a simple magnitude, in this case 5.

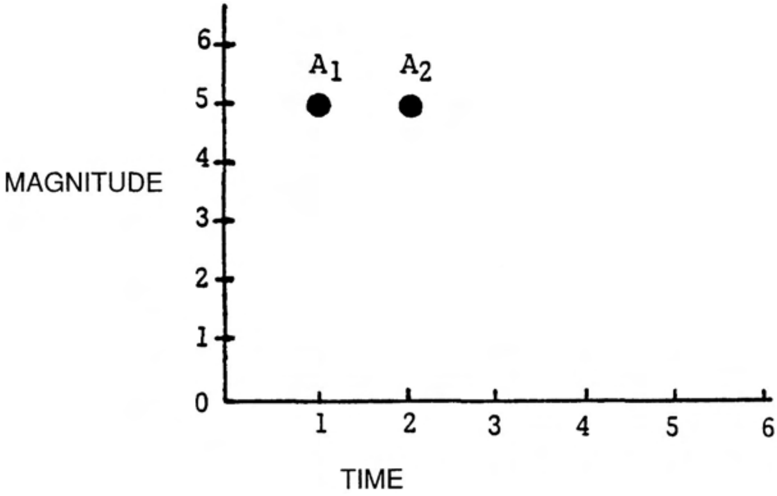

Figure 1. Spatial snapshots of spatiotemporal A differ.

As can be seen from figure 1, 5_1 is not identical to 5_2 *unless we imply the operator* $\partial/\partial t$ *in the time interval three algorithm.*

The negation of the second law may also be simply understood if we use temporal accounting. E.g., suppose we take $A_1 = +1$, $\overline{A}_2 = -1$ and then pose the absolute value operator || for potential use in algorithm 3. If || is not used, then

$$(+1)_1 \not\equiv_3 (-1)_2$$

and Aristotle's second law holds. If || is used, then

$$\left| (+1)_1 \right|_3 \equiv_3 \left| (-1)_2 \right|_3$$

and in that case

$$A_1 \equiv_3 \overline{A}_2$$

Note we are taking the view that there is nothing "absolute" or "inherent" about identity or non-identity; instead, each is a conditional result that can only be established by some logical, comparn tive set of operations. If the suboperations comprising the decision algorithm for the identity/non-identity determination are changed, the finding of the algorithm (the decision) may often change. Specifically, one can have the cases

$$\equiv_1 \not\equiv_3 \equiv_2$$

$$\not\equiv_1 \not\equiv_3 \not\equiv_2$$

Thus we advance a *conditional identity criterion* to be incorporated into formal logic: "Identity" or "non-identity" is defined by a decision made as a result of applying an operational algorithm; changing the internal operator components assumed inherent in the algorithm can change the decision. We are stating a fundamental principle that "identity" and "non-identity" are conditional and only conditional; they are never absolute.

Primitive Observation and "Reality"

With these points made, we now turn to the third law. From Table 2, on examination it can be seen that the third law actually is a statement for *monocular* perception, detection, observation, thought, or conception. Indeed, this law says that only a single thing at a time can be perceived, detected, observed, thought, or conceived.

As we pointed out in a previous paper[2] , there is a very good reason for this "law." Primitive man lived almost exclusively in a reality detected by light, by the photon interaction. Even in the absence of visible light, all bodies have temperature, and man is immersed in a "sea" of continual electromagnetic photon with interactions. The photon interaction is monocular - - only one at a time interacts with a particle of mass. Further, photon interaction constitutes the operator $\partial/\partial T$ invoked upon L^3T spacetime. Photon emission carries away time (the photon is made of $(\Delta E\ \Delta T)$, leaving behind an L^3 *spatial* reality, as we have previously pointed out.[3]

So all our primitive concepts, ideas, and notions about reality have come from over four million years of hominid and human experience in the photon-detected partial reality ("physical," "objective," or "spatial" reality) that remains when the time "dimension" (fundamental **variable)** is destroyed from L^3T spacetime, leaving only L^3 space behind. Specifically, our observed macroscopic reality consists of large temporal (mental) aggregates of such spatial results, where we cannot distinguish the tiny temporal separations of the pieces. Thus all our observed/perceived entities are spatial, and further, each perception/observation snapshot results in a frozen, unchanging spatial entity (resulting — in physical detection — from the so-called "collapse of the wave function." The loss of a wave function is simply the loss of time.) We vaguely sense "time" and "change" as the relation between these snapshots — i.e., by causality, or the ordering of the spatial changes — much as we see "movement" in movie frames rapidly projected onto a screen one-at-a-time.

Thus our primitive observations, from which have painfully been formed our relational concepts and ideas, are monocular, unchanging, and spatial. Aristotle's three laws of logic — which indeed may be taken to be only a simple synthesis of our primitive observation and corresponding relational concepts — then exhibit the same characteristics; they are monocular, unchanging, 3-dimensional, spatial, non-temporal relational statements. Any statement that is temporal, changing, or 4-dimensional will thus appear as a logical paradox to this logical shorthand.

But from Young's two-slit experiment, we already know that reality and relationships between its parts are quite different if the photon interaction is not invoked — i.e., if $\partial/\partial T$ is not invoked. Classical reality (as prescribed by Aristotle's laws) is directly violated by an electron in the two-slit experiment, e.g., if and only if photon interaction with the electron is not invoked. Again, this has been simply explained by the present author[4], and Charles Muses as early as 1957 pointed out the absence of any mystery in Young's experiment if the chronotopological aspects were considered.[5]

The Conscious Mind is Fitted to the Photon Interaction

However, what is normally referred to as the "conscious, thinking mind" is simply a functioning temporal (rigorously, chronotopological) mechanism that is painfully built up in the individual's awareness (his mind in the greater sense ofboth thought and awareness, whether monocular or multiocular) by training, conditioning and experience. Its functioning is largely conditioned by one's 90% or so attention to visual stimuli (to the partial reality remaining after photon interaction has been invoked, and to the memory-collated ordering of vast numbers of such photon interactions) and by one's cultural conditioning — which itself has been almost exclusively conditioned and shaped by the monocular photon interaction at base root.

Thus, since the beginning of man, his conscious, rational mind has been trained and constructed to function almost exclusively in basic correspondence with the photon interaction, and his experiential reality consists of the partial reality stripped from fundamental reality by photon interaction.

All "perceived differences," e.g., are created by this deep mindset. As has been previously pointed out,[6] the solitary human problem responsible for all man's inhumanity to his fellow man is directly dependent upon man's almost exclusive detection, observation, perception, and conception of "difference" between humans, these "differences" being due exclusively and totally to the fitting of men's conscious minds to the photon interaction's monocular separation of spatial reality from nonspatial reality, i.e., to

$$\partial/\partial T\,(L^3T) \Rightarrow L^3$$

Such well-nigh total devotion to, and enslavement by, photon interaction also is responsible for the scientist's well-nigh total devotion to, and enslavement by, the present imperfect and incomplete three laws of logic, as presented by Aristotle. The depth of that devotion and enslavement is evidenced by the fact that the resolution of such paradoxes as Heraclitus's problem of change have eluded the best minds of humanity for several thousands of years. Indeed, these paradoxes cannot be resolved by the conscious, rational mind in its present state, for it has been most firmly constructed and fitted to function in accordance with the photon interaction.[7] One cannot hope to resolve any logical paradox by using only those same logical methods that found the situation to be paradoxical in the first place!

Dimensionality

That we need not be constrained by such universal delusion is already shown by binocular vision. Specifically, in viewing a three-dimensional **object, each** eye **never** detects a "third dimension," but detects only **an L^2 2-dimensional** picture. By taking two slightly different 2-dimension snapshots and superposing them, the third dimension is gained. One then essentially sees the resultant superposed pictures as "almost the same but not quite." I.e., the Aristotlean identity algorithm, if satisfied, yields "no difference, hence one object," and if not satisfied, yields "difference, hence multiple (extended) object(s)." So if the two snapshots are almost Aristotlean-identical but not quite, we get an extended-two-dimensional (three-dimensional) object. Otherwise we see two separate, two-dimensional snapshots blurred together (the reader is urged to try this and see).

The point is, "dimensionality" and the identity algorithm are directly related, and geometrically one follows from the other.

Awareness of Time

In very similar manner, we can only gain cognizance of awareness of "time" (as a fourth dimension) by the superposing of two slightly differing (Aristotlean-wise) 3-dimensional snapshots. As is well known, e.g., time is not an "observable" in quantum mechanics; it is a "parameter." Rigorously, the only place such snapshots — each of which is "past" (spatially separated by the annihilation of time in the collapse of the wave function) — can multiply exist is in the "mind" in its most general sense. In a rigorous sense, mind and time can be taken as identical, and the "flow of time" can be taken as the "flow of mind connections or superpositions" of its spatial components. I.e., measured/detected/observed "physical phenomena" are a priori 3-dimensional and spatial, while a mind is four-dimensional and hyperspatial.[8] Spacetime exists mentally but not observably. Time is logically implicit, not explicit.

Temporal Aspects of Logic

Now we return to the temporal aspects of logic. Each perceptual part of each Aristotlean law is fitted to the photon interaction, hence monocular. The logic operation, inherent in the logic symbol in each statement, involves temporal superposition or comparison of spatial perceptual objects. Hence the logic operation is hyperdimensionally a function of mind and injects mind/time into the statement. Yet these laws, being fitted to or synthesizing photon interaction, attempt to prescribe the absence of time, even though writing down the logic operation rigorously invokes time. They are thus totally contradictory, since as written they implicitly violate themselves.

Table 4 summarizes the operations now to be permitted in the time-three algorithm, in developing a new four-law logic:

Table 4. Conditional identity rules.

1. $\left|\overline{S_1, S_2}\right|_3 = (\text{zero})_3 \Rightarrow (\text{identity})_3$

2. $\left|\overline{S_1, S_2}\right|_3 = (\text{nonzero})_3 \Rightarrow (\text{non-identity})_3$

3. $\left|\overline{S}\right|_3 = \left|\left|\overline{S}\right|_1, \left|\overline{S}\right|_2\right|_3 \Rightarrow$ monocular separation, differentiation internally

4. $\overset{S}{\left|\overline{\quad}\right|}_3 = \overset{S}{\left|\overline{\quad}\right|}_3 \Rightarrow$ nonseparation, no differentiation internally

Rules one and two simply state that, when snapshots 1 and 2 are superimposed (subtracted) in time interval 3, the resultant snapshot 3 may be zero or nonzero. If zero, snapshots 1 and 2 are said to be identical, and if snapshot 1 is to be labeled A, then snapshot 2 is to be labeled A. If snapshot 3 is nonzero, snapshots 1 and 2 are said to be nonidentical; if snapshot 1 is labeled A, then snapshot 2 is labeled $\overline{A}$.

Rule 3 says that snapshot 3 is a "memory" snapshot, and it may be particulately examined to monocularly separate snapshots 1 and 2.

Rule 4 states that snapshot 3 is not a "memory snapshot" and may not be further separated.

Note that in logic we repeatedly apply these rules in combination, serially or compositely. Note further that Rule 1 must serially apply both rules 3 and 4, as must rule 2 also.

If we take $4|_3$ to mean "rule 4 applied conditional to rule 3 also being applied," and $4|_{\bar{3}}$ to mean "rule 4 applied conditional to rule 3 not also being applied," we may write Table 5:

Table 5. Conditional identity, non-identity, and oneness.

$4 |_{\bar{3}} \wedge 1$ = identity (S_1, S_2)

$4 |_{\bar{3}} \wedge 2$ = non-identity (S_1, S_2)

$4 |_{\bar{3}}$ = oneness without separate-ones; oneness, extraordinary and unperceivable; thing-in-itself

$4 |_3$ = "ordinary" one, perceivable separation, "thing-as-separate-from-others"

As can be seen, this type of reasoning also sheds a great deal of light on the long-standing problem of the "thing-in-itself," but that is beyond the scope of this paper.

The Fourth Law of Logic

Now we write the fourth law of logic as follows:

$$4.\quad (A_1, \overline{A}_2)_3 \Rightarrow A_1 \equiv_3 \overline{A}_2$$

where all we have said is that, by rule 4, in snapshot 3 no memory process is allowed, and no separation/differentiation whatsoever of A_1 and $\overline{A}_2$ is permitted. Under these operational conditions for identity, what had previously been called A_1 in snapshot 1 and what had been called $\overline{A}_2$ in snapshot 2 are indistinguishable, hence identical.

Figure 2 shows this concretely, and may be taken as a proof of the fourth law by demonstration.

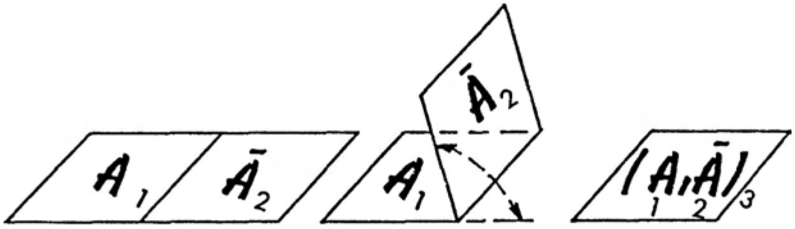

Figure 2. Proof that two opposites can be identified. What was separately perceived as A_1 in time snapshot 1 and what was separately perceived as $\bar{A}_2$ in time snapshot 2, cannot be distinguished in time snapshot 3.

Thus the age-old philosophical dilemma posed by the illogical identity of opposites has a simple resolution if one considers temporal aspects, and introduces temporal conditions for identity or non-identity decisions.

We now write the new four law conditional identity logic as shown in Table 6:

1. $A_1 \equiv_3 A_2$
2. $A \not\equiv_3 \bar{A}_2$
3. $A_1 \vee_3 \bar{A}_2$
4. $A_1 \equiv_3 \bar{A}_2$

Further, we point out that all four laws now apply. Laws 1,2, and 3 are the laws of explicit monocular perception, with implicit binocular perception. Law four is the law of explicit binocular perception, with implicit monocular perception. Both monocular and binocular perceptions must be and are used in each law. So in any situation, either the triad applies explicitly and the fourth law applies implicitly, or the fourth law applies explicitly and the triad applies implicitly.

Indeed, one can **even take the** view that we have prescribed a five-law logic, **the fifth la**w **being taken** as shown in Table 7:

Table 7. A possible fifth law of logic.

5. $[1,2,3,\ \wedge(4)] \vee [4\ \wedge(1,2,3,)]$ where $() \Rightarrow$ implicit

In a previous paper[9], the author has already presented methods to apply this new logic to resolve present paradoxes. At least hypothetically, every present paradox should be simply a statement of the explicit fourth law, and it should be resolvable by explicit application of that law[10].

NOTES AND REFERENCES

1. Specifically, by whether or not exclusivity applies. I.e., we may read Law 1 as "In snapshot (time interval) 3, what was A in snapshot 1 is exclusively identical to (unseparated from) what was A in snapshot 2." Law 2 may be read as "In snapshot 3, what was A in snapshot 1 is exclusively not identical to (is exclusively separated from) what was not-A in snapshot 2." Law 3 reads, "In snapshot 3, what was A in snapshot 1 and what was not-A in snapshot two are exclusively separated." Thus it can be seen that the three laws simply are statements involving whether or not two former perceptions are to be separated in a third perception. These three statements presently prescribe the total separation of the two previous perceptions and prohibit any admixture of the two — the so-called "excluded middle." Thus the three laws prescribe monocular, one-at-a-time perception.

   What we call a "wave" exists in time and is considered to contain an admixture of timeless, static spatial states (such as "wavelengths.") The prohibiting of admixtures thus represents the "collapse of the wave function" and corresponding loss of time. This defines "observation" and explains why all "measurement" and "detection" and "observation" — requiring a collapse of said wave function — are spatial and not spatiotemporal. That is why time is a parameter in quantum mechanics, not an observable.

   Relativity, being constrained by such logic, obviously can find nothing "physical" (observed, spatial, timeless thing frozen by the collapse of the wave function as engendered by or fitted to the photon interaction) that is traveling faster than light — i.e., that violates the conditions implied by the "observing/detecting agent."

That reality need not at all be so constrained is clearly shown by Young's two-slit experiment, the heart of all quantum mechanics. In this experiment, "classical' reality is violated if and only if the photon interaction is not invoked. Classical reality is obeyed if the photon interaction is invoked.
With appropriate change to logic to fit "reality that has not been interacted with by photons" and therefore is spatiotemporal, a new physics becomes possible.

2. Thomas E. Bearden, "Solution of the Fundamental Problem of Quantum Mechanics," January 3,1977, Defense Documentation Center.

3. Bearden, "Photon Quenching of the Paranormal (Time) Channel: A Brief Note," 20 April 1977, Defense Documentation Center.

4. Bearden, "Virtual State Engineering and Its Implications," 1979, Defense Documentation Center.

5. With the possible exception of Kozyrev — whose more technical works on time remain undisclosed to open science — no other person known to this author seems to have grasped the implications of a dynamic structure of time as penetratingly as has Charles Muses. The importance of the time interaction explaining the two-slit experiment (i.e., in explaining wave-particle duality) was noted as early as 1957 by Muses. See, e.g., Muses' introduction to Jerome Rothstein's **Communication, Organization, and Science,** The Falcon's Wing Press, Indian Hills, Colorado, 1958, p. lxii, where Muses pointed out that the celebrated wave-particle paradox remains a paradox only so long as the chronotopological (his word) phases of the phenomena are left unrealized in the analysis. The entire foreword by Muses is a remarkable document which analyzes the structure of time itself. With his hypernumbers Muses can describe the nested structure of time, which is what is actually

being carried by the photon. Further, he can theoretically predict mechanisms by means of which these structures can be orthorotated. It would appear that practical devices should be constructable on the principles elucidated by Muses, and it is little short of astonishing that fundamental work of such importance and application has been thus far little used by theorists, though it is already recognized in the standard literature; e.g., the profound summary paper "Hypernumbers II" in the January 1978 issue of the journal **Applied Mathematics and Computation,** published by Elsevier.

6. Bearden, "The One Human Problem Its Solution, and Its Relation to UFO Phenomena," Defense Documentation Center, January 3, 1977.

7. Which is why a Zen master often gives the student a koan to confound and overwhelm this automatic, robotic mindset and functioning that has been constructed as the student's "conscious mind."

8. Specifically, consciousness/life involves a seven dimensional body/being in an infinite-dimensional universe. See Thomas E. Bearden, "A Mind/Brain/Matter Model Consistent with Quantum Physics and UFO Phenomena," prepared for the 1979 MUFON Annual Symposium, available in the **Proceedings,** MUFON, 103 Oldtown Road, Sequin, Texas 78155.

9. Bearden, "The Fourth Law of Logic," **Specula,** Journal of the American Association of Meta-Science, P.O. Box 1182, Huntsville, Alabama 35807, Vol. 2, No.l, January-March 1979, pp. 30-40; also in publication in Defense Documentation Center. (The journal **Specula** is no longer pulished).

10. No consideration of the foundations of logic and mathematics is complete until one has read Morris Kline, **Mathematics: The Loss of Certainty,** Oxford University Press, New York, 1980.

APPENDIX IV

LIST OF SELECTED INCIDENTS

Author's note: In 1985-1987 a series of anomalous missile and space failures swept the U.S. and the West. These incidents were not unique, as many think, but were actually only a portion of thousands of related incidents showing the Soviet testing of advanced weapons throughout the world. This listing will show the types of incidents referred to.

The listing is not intended to be complete at all, but only representative. Hundreds of incidents of weather engineering, giant cloud radials and grids, suspicious light incidents, etc. could easily be added, were there time and room. No attempt has been made to exhaustively map the "aerial booms" that have blanketed the U.S., Europe, and other parts of the world. The light and "maybe it's UFO's" reports alone would add thousands of incidents to the list.

Our message is succinct: The Soviet Union has developed a new science and weaponized it, since at least the latter 1940's. It has utilized that science — energetics — to develop superweapons and supervehicles. Because of the danger from accidental initiation of nuclear weapons and materials, it is exceedingly difficult and dangerous for the Soviets to make extensive use of these weapons. Accordingly, a biological warfare strike — AIDS — has been utilized to deliver what is to be the knockout blow to the West.

DATE, INCIDENT, LOCATION, REMARKS

Early spring 1966 - Malstrom AFB Montana.
UFO sighting coincident with simultaneous problems in 10 strategic missiles in launch site associated with Malstrom AFB, Montana. *Similar event in Mar 1967 also. (Source:* ***Clear Intent.).***

20 **Mar** 67 - Malstrom AFB Montana.
Flight of 10 strategic missiles in launch site associated with Malstrom AFB, Montana experienced problems with guidance and control system. UFO in area and confirmed on radar. Jet fighters scrambled, results unknown. *Similar event one year earlier.* (Source: **Clear Intent.).**

1972 - Prague.
At a secret meeting of European communist leaders in Prague, Brezhnev lays out firm statement of Soviet intent to be able to dominate the world by 1985. Stated would control the oceans, 90% of the land, and the air and space above. *Notice he said control, not invade and conquer.*

Aug 73 - Over ocean.
USAF Minuteman ICBM is launched from Vandenberg AFB, aimed for Kwajalein missile range. Unidentified object appears and is tracked next to the ICBM's nose cone. Crossed the RVs trajectory. Object about 10 ft long. Seen by 2 separate radars. Three other identical objects were seen in the vicinity. *Probable Soviet advanced flying vehicles. Also a deliberate stimulus to see if U.S. knows of the technology, and how the U.S. reacts. (Source:* ***Clear Intent.).***

18 **Oct 73 -** Near Mansfield, Ohio.
U.S. Army helicopter is intercepted by glowing red object that converged on it with terrific speed. Object placed some sort of "tractor beam" on helicopter. Object was gray metallic structure, 50-60 ft long. Helicopter was stopped in mid air. Radio blacked out. Official report filed by pilot. *Probable advanced Soviet flying vehicle. Also a deliberate stimulus to see if U.S. knows of the technology, and how the U.S. reacts.*

21 Oct 73 - Near St. Joe, Indiana.
20 or 30 lights sighted circling in the sky near St. Joe, Indiana near a woods fire, by firemen. *Probable Soviet holographic tests to stimulate UFO reports.*

1973 to date - Bennett Island.
Bennett Is. exhaust plumes detected by U.S. weather satellites. *Well over 100. spotted so far. Weirdly, 5 islands and part of the continental Alaskan area are in process of being secretly given to the USSR; Bennett Island is one of them.*

May 1974 - Lake Michigan.
Blue-green glowing ball of light seen to fall into Lake Michigan. *Soviet scalar EM testing.*

8 July 74 - Lake Okeechobee, Florida and Atlantic Ocean.
Orange red ball of light lights up sky over south Florida. Crashes in area of Lake Okeechobee. Was accompanied by a large boom. Several other booms 5-7 min. after "object crashed." Pilots also saw object plummeting in from over Atlantic. *Probable Soviet scalar EM weapons testing and calibration.*

Nov. 74 - Saryshagan. USSR.
Construction of Tora facility begins at Soviets' Saryshagan test facility. Believed to be directed energy facility. *Probably connected with Soviet scalar EM weapons systems development.*

Oct? 74 - Antarctic.
Ozone hole over Antarctic first detected. Did not appear in measurements from 1957-1973. Note did not appear until exhaust plumes noted from and around Bennett Island, with substantial activity. *Looms over the continent every Oct. Diminishes through Mar. More severe each year since 1974.*

1975 - USSR.
Soviet article in **International Life** speaks of weather war, changing the nature of lightning, increasing the power of lightning, and directing electric charges of tremendous power against specified targets. "Atmospheric electricity" can be used to suppress mental activity of large groups of people. *Tip of the iceberg. Unclassified reference to Soviet's scalar EM (energetics) weapon program. Note involvement of "lightning" in destruction of U.S. missiles a decade later.*

16 **Feb 75 -** Caribbean.
R.M.S. Carmania (UK) observes bright white circular light appear and rise to 20 degrees, leaving comet-like trail, circle and disappear. Repeated four more times at exact hourly intervals. *Soviet scalar EM weapons tests. May have been a shipborne device.*

13 June 75 - Kremlin.
Brezhnev calls for ban on frightful weapons of mass destruction. *Major speech. Repeated proposals to U.S. Senators.*

2 **Jul 75** - Kremlin.
Brezhnev repeats his proposed ban on development of frightful new weapons, to a group of U.S. Senators. *To visiting U.S. Senators. No one knew what he was talking about.*

Aug. 1975 - Kremlin.
Ponomarev calls for ban on frightful new weapons of mass destruction. *To visiting Congressmen.*

23 Sep 1975 - United Nations.
Gromyko presents draft agreement to UN General assembly, for banning development of frightful new weapons. *30th session of UN Gen. Assy. No one knew what the Soviets meant.*

Oct - **Dec 75** - Satellite, over the Indian Ocean.
U.S. satellites illuminated or "blinded" over the Indian ocean. *Source 10-1,000 times as strong as natural sources. 5 incidents. One 4 hrs. long. Soviets wasted no time after Sep. fiasco.*

28 **Oct** to **11** Nov **75** - Mid-U.S. and Canada.
Series of "UFO's" seen at Malstrom AFB, Montana; Loring AFB, Maine; Minot AFB, North Dakota; Wurtsmith AFB, Michigan and Canadian Forces Station, Falconbridge, Ontario, Canada by reliable military personnel. Reported to NORAD. Some objects seemed like helicopters. Radar tracked objects. One object at 72,000 ft. was 100-ft sphere, with seeming "craters" around it.

Malstrom F-106's scrambled on one object but could not close on it in darkness and low altitude. Efforts by Air Guard helicopters, SAC helicopters and NORAD F-106's were fruitless. Probable Soviet activity in and around the SAC bases and Canadian radar site. (Source: **Clear Intent.).**

30 Oct 75 - Wurtsmith AFB, Michigan.
UFO's and "unidentified helicopters" sighted (multiple incidents) at or near Wurtsmith Air Force Base, Michigan. Helicopter hovered over the weapons storage area. Radar reported low-flying objects. Returning KC-135 tanker a/c diverted to intercept one UFO. Observed two objects, unable to close. Visual and radar contacts. Low on fuel, KC-135 returned to base to land, again seeing lights over the weapons storage area. (Source: **Clear Intent.)** *Soviet Activity.*

7 **Nov** 75 - Near Lewiston, Montana.
Giant glowing disc, football field sized, hovered over Minuteman missile launch site K-7, just south of Lewiston, Montana. When it rose to 1,000 ft., NORAD radar picked it up. Two F-106's were scrambled. UFO rose to 200,000 ft. and disappeared from NORAD radars. *Probable advanced Soviet flying vehicle, using antigravity propulsion system.* (Source: **Clear Intent.).**

Nov 75 - Semipalatinsk, USSR.
Large amounts of gaseous hydrogen with traces of tritium begin to be detected by USAF/TRW early warning satellites.
Nuclear debris apparently related to nuclear facility at Semipalatinsk labelled PNUTS (possible nuclear underground test site.) Probable large scalar EM development and test site.

Jan 76 - Cannon AFB, New Mexico.
Two UFO's reported near flight line at Cannon AFB, New Mexico. 25 yards in dia., gold or silver in color with blue light on top, hole in the middle and red light on bottom. Observed and reported by security police. (Source: **Clear Intent.).** *Probable Soviet activity.*

31 **Jan 76** - Eglin AFB, Florida.
MG Lane, CG, Armament and Development Test Center, Eglin AFB, Florida reported a UFO sighting near an Air Force Radar site from 0430 to 0600 Eastern Standard Time. Photographs were taken. Later press release called it "building lights." (Source: **Clear Intent.)** *Probable Soviet Scalar EM activity.*

1976 - U.S. Embassy, Moscow.
State Dept. declares U.S. Embassy in Moscow an unhealthful post. Installs Aluminum window screens against Soviet microwave radiation, which has been underway since 1950's.
Provided 20% pay extra differential. Embassy radiated with weak microwave radiation since 1950's. Two U.S. Ambassadors died, Stoessel ill with strange leukemia-like malady. Soviet stimulus to see if we knew about scalar electromagnetics, phase conjugate waves, and EM disease induction. (Stoessel died recently of cancer).

1976-U.S.
Soviet nuclear scientist named Rudakov visits U.S., proposes cooperative effort in some a**reas of** fusion research. Showed work he **had**

been doing and results obtained. U.S. officials reacted drastically, classified his talk as top secret, even ripped off blackboard and carried it away.*Very strange incident. Soviet open, public scientific work considered Top Secret by the U.S. One wonders why.*

30 **Mar** 76 - Netherlands.
Huge atmospheric boom occurs over northern part of Netherlands. *Through 1983, in 10 years 7 events took place.*

22 Jun 1976 - North Atlantic.
Expanding white sphere of light developed for about 10 min. then faded. Other associated light phenomena observed. *Seen and logged by passing ship.*

4 **Jul** 76 - Soviet Union.
Giant Soviet Woodpecker transmitters activated. *3-30 MHz band. Worldwide interference with communications.*

30 **Jul** 76 - Fort Ritchie, Maryland.
Several UFO's sighted in and around Ft. Ritchie, Maryland. One hovered over the ammunition storage area. Reported. *Temperature inversion at the time provided a convenient pseudoexplanation. Could not have caused the incidents.* (Source: **Clear Intent.)**

10 **Sep** 76 - Lithuania.
European Airways flight 831, Moscow to London, at 31,000 ft over Lithuania sees blinding single ball source of light at constant altitude about 5-6,000 ft. below them and above a lower cloud. *Pilot contacted Soviet authorities. Received negative response and suggestions he should not ask questions. Probable deliberate stimulus offlight so, from reports to British authorities, could ascertain whether Britain knew anything about scalar EM weaponry.*

19 Sep 76 - Near Teheran, Iran.
In early morning hours, UFOs were spotted north of Teheran, Iran. Two F-4's attempted to intercept. The first lost all communications and instrumentation at 25 miles distance. When the F-4 turned away, equipment was restored to functioning. Second F-4 acquired radar lock at 27 nm. and attempted to close. Object moved to stay at 25 nm distance. Second object came out of it, headed straight for the F-4. F-4 attempted to fire AIM-9 missile and at that instant weapons

control panel and communications went off. F-4 took evasive action. A third object was seen to emerge from first. The F-4 returned to base. Each time it passed through 150 degrees magnetic bearing, it lost communications and INS fluttered 30 to 50 degrees. A civilian airliner also experienced loss of communications in the vicinity. *Signatures of scalar electromagnetic weapons and antigravity.*

1976 - Soviet Union, Sweden.
Swedish national authorities detect anomalous radionuclides — similar to those from nuclear explosions — over Sweden. No accompanying seismic activity. Correlated with known Soviet activity at Semipalatinsk. *In other words, nuclear explosions were occurring, but they did not shake the earth. Total anomaly. Indicates transformation of the explosive energy. Positive signature.*

1976 - Philadelphia.
Legionnaires Disease precipitously strikes Legionnaires attending convention in downtown Philadelphia. Kills 34, makes 187 others seriously ill. Similar malady struck Odd Fellows convention at same hotel in 1974. *Odd person with apparent transmitter and antenna was expelled. Informed members: "It's too late! You are all dead!" Probable scalar EM conditioning of convention with an immune suppression pattern for the disease.*

21 **Jan 77 -** Columbia.
Columbia A/L Avianca night flight. Instruments went haywire. Saw enormous, zigzagging glowing light, traveled at fantastic speed back and forth. Blinked landing lights, UFO responded. Sped away at incredible speed. *Probable Soviet advanced performance antigravity flying vehicle. Such have been widely sighted over South America.*

3 **Mar 77 -** Columbia.
Columbia A/L Avianca night flight. Pilot abruptly changed course to circle a huge, glowing UFO. Object had cigar-shaped fuselage and was twice as big as the aircraft. Blinked lights, UFO responded. Sped away. Air traffic control radar tracked object at ten times the speed of normal aircraft.
Probable Soviet advanced performance antigravity flying vehicle. Such have been widely sighted in South America.

24 **Mar 77 -** Off coast of Spanish Sahara, Africa.
M.V. Kinpurnie Castle, off coast of Spanish Sahara, Africa, observes complex, dynamic light phenomena. Third phenomenon was the formation of a semi-circular area of moderate luminosity, a hemisphere of light. Took 3 min to form about a previous luminous patch. Then another luminous patch formed over the hemisphere. After about 7 min., phenomena dispersed. *Soviet test of Tesla shield and globes.*

11 Jun 77 - Moscow, USSR.
Soviet biophysicist hands Robert Toth, Los Angeles Times journalist, a report containing proof that certain particles existed in cells, carried information, and were radiated. Both seized by KGB and charged with possessing Soviet state secrets. Interrogated, released. *Neither knew what they actually had. Soviet Academician I.M. Mikhailov pronounced secret such phrases as "micro-organism self-radiation... by means of vacuum particles in space." Use of such particles was discussed, and was secret. Paper contained basis of Soviet energetics use in biology. Positive connection of Soviet classification to mitogenetic radiation and scalar EM waves ("vacuum particles" indicate virtual flux structuring).*

13 July 77 - New York.
Massive electrical blackout strikes New York City. Affects 8 million persons. Staggering series of "natural" electrical shocks, mechanical failures, and human errors occurred. Anomalous "lightning strokes" supposedly initiated the collapse of the power grid. *Probable Soviet test.*

1977 - Ocean off Yugoslavia.
M.V. Dolphin, between Yugoslavia and Israel, observed extensive light balls and repeated phenomena, appearing and disappearing. Men were disoriented. Compass was disrupted. Okay after the phenomena dispersed. *Probable Soviet test. Stimulus to see if Britain recognized the weaponry and knew anything about it.*

13-14 Dec 1977 - Leitchville, Australia.
Large aerial light plus 3 smaller ones observed for four hours by multiple persons. Lights simulated activity of a "mother ship" and smaller craft assigned. Changed colors. Then a shower of orange

lights occurred. *Probable Soviet test. Part of deception plan, to create "UFO" phenomena to hide weapons testing. TR wave holography.*

Dec 77 to **Jan 78 -** Off East U.S. Coast.
Mysterious atmospheric explosions occur off U.S. Atlantic Coast. *Some accompanied by light phenomena. Soviet tests and calibration (registering the long-range artillery, so to speak.)*

13-14 Dec 77 - Leitchville, Australia.
Large arrays of light phenomena sighted by multiple witnesses. *Probable Soviet creation. Reported as "UFO" phenomena. Holographic creation of "UFO" phenomena as part of deception plan to disguise tests of the weapons worldwide. TR wave holography.*

1977-78 - North Pacific Ocean.
Two huge hot spots in North Pacific ocean, 2,000 mi by 1,200 mi. *May have caused El Nino and one of most severe winters on record. May have been caused by Soviets as a weather experiment.*

27 **Jan 78 -** U.S. East Coast.
Boeing 727 off east U.S. coast experiences engines failing, 1 at a time, in all three engines. A/c plunges 8,000 feet; engines restart one at a time. *First time ever that all three engines on a 727 had failed. Probable Soviet test.*

Feb 78 - Rocky Mtns. NW of Las Vegas.
Four aircraft crash in a 6-day period in the rugged Rockies, NW of Las Vegas. *Connected with a crashed military a/c from Nellis AF Base. Should be further investigated.*

Feb 78 - Texas coast. Nova Scotia. Charleston, SC.
Atmospheric booms occur. *Multiple booms in Charleston. Soviet tests. Scalar EM weapons.*

2 **Apr 78 -** Bell Island, Nova Scotia.
Mysterious fireball, explosion accompanied by anomalous electrical effects. *Small bldgs blown apart, trees scorched, fireballs seen. Probable Soviet test. Apparently even registered on U.S. satellite.*

10 **May** 78 -Off Florida.
Women pilots in race experience anomalous "time loss" on their watches from Fort Myers to Freeport (Bahamas). *39pilots. Watches synchronized. Up to 3 min. lost. Definitely not normal EM effect. Probably due to sporadic natural scalar interferometry and time-reversed waves generated in area from time to time. "Bermuda Triangle" mechanism?*

May 78 - Florida.
Unexplained lighted objects sighted in sky over remote sector of Florida. Tracked on radar at a Navy EW center. Naval personnel also observed them through binoculars. *Probable Soviet advanced flying vehicles, or tests of intense holograms with energy sufficient to ionize air and reflect radar.*

18 **May** 78 - England.
Several atmospheric explosions shake houses over a wide area in Hull, Scunthorpe, Holderness coast, and Brough and Grimsby. *Probable Soviet weapon testing and calibration.*

Jun 78 - Indiana.
Large ball of light streaks across sky, stops, hovers, then explodes with a large boom. *Possible test. Standard Soviet incident to generate deception.*

7 **Sep** 78 - Netherlands.
Large acoustical event (boom) occurs over the Netherlands. *Soviet scalar EM weapons testing and calibration.*

Sep 78 - Tabas, Iran.
Anomalous Richter 7.4 earthquake strikes Tabas, Iran, killing 25,000. No aftershocks. Anomalous depth. Soviets needed to relievo pressure in rocks at nearby Askhabad on the Soviet/Iran border, else lose the city to a large earthquake. *36 hrs. earlier, Soviets exploded monstrous 10 Megaton underground nuclear explosion, to disguise what caused the earthquake. Almost definitely a Soviet- induced earthquake.*

Oct. 78 - USSR.
U.S. DOD weather satellite purportedly photographs a semi-rectangular object climbing out of atmosphere at 4,000 to 4,500 **mph.**

Object was over the Soviet Union. *Probable Soviet advanced flying vehicle, using antigravity propulsion system, if photograph is real.*

31 **Oct** 78 - Fairbanks, Alaska & Lake Ontario.
Red and yellow flash seen descending through sky S. of Fairbanks, Alaska by multiple observers. One minute later, U. of Alaska seismograph registered a tremor 1.5-2.0 on Richter scale. Ten days prior, a similar phenomenon was observed over Lake Ontario and a photo taken of the light. *Probable Soviet scalar EM wpns testing calibration.*

Nov 78 - Kuwait.
Large flying vehicle lands at Umm. Alaish oil pumping sta., Kuwait. Disrupts elect, comm, and pumping activities. Leaves after 7 min. *Probable antigravity propulsion system. Soviet vehicle. One of a series of "UFO" sightings in oil fields of Kuwait. Positive scalar electromagnetics and time-reversed wave signatures.*

Nov - Dec 1978 - Kuwait.
Series of "UFO" incidents over Kuwaiti oil fields occur. Kuwait Gov't. investigates, makes official report. *U.S. Pentagon noted incidents. Probable Soviet-induced incidents.*

1979 - British Columbia & Caspian Sea.
Ariel 6 satellite experiences anomalous turnoff of two power supplies. *Over British Columbia and Caspian Sea, when sun is shining. Probable Soviet stimulus.*

Jun 79 - Vienna.
Pres. Carter signs SALT II agreement in Vienna. After that, his acts and speech are erratic and he seems to be in a depressed state. *Suggestive of exposure to EM behavior modification. Soviets had possessed the LIDA technology for 29 years.*

Sep 1979 - USSR.
Strange giant semicircular light phenomena observed in USSR, toward Saryshagan. Observed several times. Source: London **Times.** *Observed from Afghanistan by British cameraman Nick Downie. Definitely Soviet tests of a Tesla globe and/or shield.*

22 Sep 79 - South Atlantic.
U.S. Vela satellites detect anomalous flash over South Atlantic, as if from a nuclear event. *U.S. Govt Agencies still disagree as to whether this was a nuclear event or not. May have been a Soviet test, or a test of a scalar EM weapon by another nonhostile country.*

25 Dec 79 - Afghanistan.
Soviets invade Afghanistan. *This is the Soviet "Spanish Civil War," where wpns, training, and the state of their ready reserves are tested. It is not primarily the regulars who are fighting there. Some scalar weapons — e.g. Smirch death ray — are tested also.*

1980 - Afghanistan.
Soviets kill 225 women and children in a village in the province of Maiden, near Kabul, Afghanistan. A month and a half later, bodies still undecayed. Bodies were also shot, to try to deceive Mujaheddin as to cause of death. *Bodies perfectly preserved. No smell, no bugs, no scavengers had eaten them. Probable Soviet test of a "death ray." Definitely scalar electromagnetic weapon signature.*

Feb 1980 - Duncanville, Texas.
About 100 startlings suddenly start falling from flight, instantly dead. *One of several such anomalous bird falls. Connected with very high frequency components added to Woodpecker signals for sharp localization. Birds entering such an area are killed.*

May 1980 - Seminole, Florida.
Start of mysterious plague of assorted illnesses striking healthy persons in a 20-block section of Seminole, Florida. Animals affected also. Lack friendly bacteria in their intestines. *Signatures of EM induction of disease and kill of intestinal bacteria. The lack of friendly bacteria is important. May indicate one direction of biological warfare planned by Soviets.*

June 1980 - USSR.
Huge, luminous hemisphere of light seen within Soviet Union, from Kuwait. Probably over Caucasus region of USSR. Source: personal communication from observer. *Tesla shield. A definite test, unequivocal.*

July 1980 - U.S. and Canada.
Richter 5.1 quake centered in northern Kentucky rumbles through 14 states and into Canada. *No known fault. Was predicted two wks in advanced by an associate.*

7 **Nov 80** - Applegate Valley, Oregon.
Mysterious explosion, earth rumbling, brilliant light turns night into day in Southern Oregon. *Associated with subsequent earthquake next day?*

8 **Nov 80** - California.
Richter 7.5 earthquake off coast of Southern California. Shakes CA and Southern Oregon. *Note anomalous phenomena in S. Oregon the preceding day.*

Dec 1980 - South Atlantic.
U.S. Vela satellites detect another anomalous nuclear-like flash over the South Atlantic. *In infrared only. Obviously not a normal nuclear wpn.*

28 **Dec 80** - South Atlantic.
Great bluish-white flash over the South Atlantic. Clear sky except 2 or 3 small cumulus clouds, one about 600 ft. above ship. *Possibly connected with the second Vela flash detection, or generated by the same system. One of many such incidents.*

1 **Jan 81** - Somerset, Pennsylvania.
Pilots of two a/c report the descent of a bright, shiny object with fiery tail over Pennsylvania. Large boom rumbles across most of Western PA. *Possible Soviet scalar EM testing. Part of deception plan.*

Jan 81 - Minnesoto, Wisconsin, South Dakota.
Great skyflashes and rumbling noises occur around Morris, Minnesoto and Wisconsin and South Dakota. *Possible Soviet scalar EM testing. Part of deception plan.*

Feb 81 - San Jose California.
Two pilots menaced by 10 ft. dia. light which flew directly at aircraft over San Jose, CA airport. Plane climbed, light followed, then sped away. *Totally consistent with exercise of the Soviet Launch Phase*

Anti-bomber system's real-time holography aspects of the Woodpecker OTH radars.

6 **May** 81 - Fredericksburg, Maryland.
EC-135 a/c crashed near Fredericksburg, MD. Severe nose-down from 29,000 ft. Apparent loss of all power. At 5,000 ft., either fire or minor explosion occurred. At 1,500 large explosion destroyed the aircraft. *Possible Soviet test of OTH radar anti-bomber weapon system?*

Mid-81 - Afghanistan.
Soviet helicopters use mysterious, highly lethal agent in Afghanistan. Causes death so quickly victims do not have time to make the slightest move. Rpt by Jane's Defense weekly. Referred to as Smirch gas or Smert gas. *Probable test of a Soviet scalar EM "death ray."*

20-23 Jan., 1982 - Gander, Newfoundland.
"Object with red, green and yellow lights sighted in the Gander, Newfoundland area more than 36 times. Alternately hovered and darted in a complex "flight" pattern. *Possible real-time holographic phenomena produced by Soviet scalar EM weapons as part of the worldwide deception plan. Gander is a major "registration point."*

3 **Feb** 82 - Newfoundland.
Red and green flashing lights travelling across the horizon at 2,000 mph reported by 3 Armed Forces officers at Gander, Newfoundland. *Possible real-time holographic phenomena produced by Soviet scalar EM weapons as part of the worldwide deception plan. Possible major "registration point."*

Feb 82 - Ankasaray, Turkey.
Cluster of high, multiple lights pass over Turkish town of Ankasaray, 200 km. from Ankara. Dogs were disturbed also. *Possible real time holographic phenomena produced by Soviet scalar EM weapons as part of the worldwide deception of plan. Gander is a major "registration point."*

Sep 82 - Ankara, Turkey.
Cluster of 10-14 high, multiple lights pass over Ankara, Turkey in clear night sky. Dogs were also disturbed. *Possible real-time holographic phenomena produced by Soviet scalar EM weapons as part of the worldwide deception plan.*

Early 82 - St. Petersburg, Florida.
Extended series of booms occur off coast of Florida, near St. Petersburg. *Continued lengthy period of time. Years of Soviet scalar EM interference grid adjustments have been registered in Florida and off St. Petersburg. Booms are so numerous that meetings of civil defense, federal, and state officials have been held.*

June 82 - Washington/Canada border and off-shore.
Extended series of booms occur over Pacific Ocean, centered about Port Angeles and Sequim near Washington state/Canadian border. *Persisted for several weeks. As many as 10 blasts per day. Fireballs and lights also seen. Soviet extended scalar EM tests.*

18 June 82 - Northern Pacific Ocean.
Two JAL flight crews observe large, yellowish-white globe of light over the North Pacific Ocean 700 mi. east of Hokkaido, Japan. Covered one fourth of the sky. Light gradually dimmed and disappeared. *Tesla globe. Definitely a Soviet weapons test.*

June 1982 - Red China.
Several Red Chinese giant light hemisphere and globe incidents. In one instance, a/c electrical power systems began to fail in several Red Chinese fighter a/c when encountering a huge hemisphere of glowing light. *Tesla globes. Tesla shields. Balls of light. Definitely Soviet weapons tests.*

24 **Sep** 82 - Maryland, New Jersey.
Anomalous airquakes off the coast of Cape May and Northern Maryland, and Atlantic City, New Jersey. *Adjustment of Woodpecker grid. Soviet tests. 3 weeks later also.*

14 **Oct** 82 - Maryland, New Jersey.
Anomalous airquakes off the coast of Cape May and Northern Maryland, and Atlantic City, New Jersey. *Adjustment of Woodpecker grid. Soviet tests. 3 weeks earlier also.*

16 **Nov** 82 - Delaware, New Jersey.
Five mysterious booms rock Sussex county, Delaware and southern New Jersey. *Adjustment of Woodpecker grid. Soviet tests.*

1983 - Loma Linda, California.
Photos and information about the Soviet LIDA machine released. 40 MHz carrier, complex waveforms. Induces catatonic state in humans and animals. *Shows consciousness can be affected by EM means. Was used on U.S. prisoners of war in Korea. Suggests similar capabilities are possible for Woodpecker. U.S. scientific community had said impossible. President Carter affected in Jun. 79?*

Early 1983 - Bennett Island.
Large exhaust plume detected coming from Bennett Island and vicinity, one on-shore and two offshore. Plume was 6 mi. wide, 155 mi. long and reached 23,000 ft in height. *U.S. weather satellites detected it. Nearly horiz. jet, 155 mi. long. Definitely not natural. At angle ofperhaps 1.5 degree above horizontal.*

27 **Sep** 83 - England.
British RAF/Panavia Tornado aircraft loses all electrical power and crashes. *Possible Test? Tornado system is triplexed.*

22 **Oct 83** - Off Okinawa.
Two a/c operating off U.S.S. Midway apparently lost w/o trace, about 127 mi. E. of Okinawa, under anomalous conditions. *Causes unknown. Additional data needed.*

8 **Nov 83** - Western Europe.
Anomalous earthquake occurs in Western Europe. All foreshocks and aftershocks were missing. Called the "Leige" earthquake. Definite symptoms of manmade (Soviet) origin. *Large boom occurred over Netherlands the next day over 35,000 sq. km. area. Soviet scalar EM weapon testing.*

9 **Nov 83** - Netherlands.
Large acoustic event occurs over Netherlands. Detected over 35,000 sq. km. First mistaken as a Dutch quake. *One day after the anomalous Leige quake. Soviet wpn testing.*

Dec 83 - Alma Ata.
Stored munitions exploded at Dolon (Soviet) airfield. 150 km south of Alma Ata. One of six that mysteriously exploded in 7 months. *May be evidence that another nation also has Scalar EM wpns, and*

is checking the Soviets. If so, probably was warning that Soviets also would suffer if they moved.

1984 - Novaya Zemlya.
First mysterious plume detected from Novaya Zemlya by U.S. weather satellites. Sometimes plumes are 200 mi. long. *Novaya Zemlya contains Soviet atomic facilities including weapon facilities.*

1984
Senior Soviet physicist G. Yu. Bogoslovsky publishes paper, "Generalization of Einstein's Relativity theory for the anisotropic space-time." Such Russian research published regularly. Would be impossible in U.S., where similar attempts meet discredit, humiliation, and rejection by leading U.S. physics journals and departments. *The West has decreed that general relativity must not be local, and above all must not be lab-bench experimental. Open Soviet publication indicative of experimental development of local space-time curvature technology.*

1982 - 84 - Florida (& elsewhere).
Airquakes, booms (hundreds). *16 counties, near coast.*

28 Jan 84 - Pennsylvania, New Jersey.
Bright orange light streaks across sky from Pa. to N.J.'s Cape May. Similar "fireball" explodes in Clementon. Two other sky explosions observed. *Possible Soviet activity. TR wave holography and pulses. Part of Soviet deception plan.*

Feb 84 - in space.
All three payloads of the Challenger flight fail. *2 commication satillites, 1 balloon.*

10 **Feb** 84 - Netherlands.
Large atmospheric boom occurs over Netherlands. *7 others thru 1983.*

29 Mar 84 - Bennett Island.
Bennett Island exhaust plume detected by U.S. weather satellite. *Over 100 such anomalous exhaust plumes detected there.*

9 **Apr.** 84 - S. of Kurils toward USSR.
Giant rapid cloud tower rose, then faded. Small semicir. halo of light replaced it. Halo expanded to full circle of light. Expanded to giant globe then faded. *Cloud 60,000 ft in 2 min. Light globe expanded to about 380 mi. dia. and center over 200 mi. high. Source:* ***Science*** *Journal. Definitely a Soviet test of multiple weapon modes.*

26 **Apr.** 84 - Bennett Island.
Bennett Island exhaust plume detected by U.S. weather satellite. *Over 100 such anomalous exhaust plumes detected there.*

May 84 - S.E. U.S.
Series of devastating storms breaks out over S.E. U.S. in early May. Tornadoes, large hail, downbursts. Some loss of life. Persisted through night into early morning hours. Several instances of rapid thunderstorm top warming were observed in satellite photography. Occurred near downbursts. Very heavy plume activity at Bennett Is. noted in Apr. and May, 1984. *Warming of tops of thunderstorms can produce downbursts. In literature. Note that Soviet scalar EM wpns can perform such top-warming of thunderstorm anvils, and induce downbursts on command.*

13 **May** 84 - Severomorsk, USSR.
Soviet missile storage facility at Severomorsk Naval Base on the Kola Peninsula 1450 km north of Moscow blows up in a series of vast explosions. Over 200 wounded. Soviet North Fleet lost about 1/3 of its missiles. Speculation of an "electromagnetic cause, possibly by reflection of radio waves from ionosphere." Detected by satellites; first thought to be nuclear explosion. *One of six such explosions of Soviet ammunition storage sites in a period of seven months. Definitely not accidental. Probably use of scalar EM weapons by another nation, not hostile to U.S., to warn the Soviets that they also will suffer if they move.*

15 **May** 84 - Bobrwjk Airfield.
Major blast occurs at Bobrwjk Airfield, 138 km SE of Minsk and the base of a Badger-equipped air-to-surface missile regiment of the Smolensk Air Army. 10 of the 11 ammo storage bldgs blow up and admin, and access control bldgs. are destroyed. Note that fires and explosions were still raging at Severomorsk, from 13 May event. *Same note as above.*

25 **Jun** 84 - Schuerin, East Germany.
Explosion occurs at an ammunition depot at Schuerin, south of Wismar in East Germany. Windows blown out within 10 mi. radius of depot. *Same note as above.*

27 **Jul** 84 - Kuril Islands.
Slowly expanding ball of light seen by Boeing 747 crew near the Kuril Islands. Expanded for 10 min. Shell was sharply defined. Light semi-transparent and nearly perfect half-circle. *Tesla globe. Bennett Is. exhaust plumes detected by U.S. weather satellite. Definitely a Soviet test. Related to 9 Apr. 84 incidents S. of Kurils.*

29 **Aug 84** - Edwards AFB, California.
B-l bomber prototype crashes in flight test about 10 mi. NE of Edwards AF Base.

1983-84 - Ireland.
For two years, freak lightning terrorizes villages of West Donegal, Ireland. Roofs stripped off, windows smashed, pipelines wrecked, telephones and TVs blown up. *No known cause for the anomalous lightning. Shows natural potential in area is disrupted.*

25 **Dec 84** - Ireland.
Freak lightning continues in West Donegal, Ireland. Causes 3-day power blackout. *Extensive plume activity at Bennett Island.*

1985 - Worldwide.
After years of a superb safety record, airline industry suffers a series of disastrous crashes. 20 major air crashes occur worldwide, with more than 2,150 lives lost.

Early 85 - Worldwide.
KGB begins a worldwide campaign to blame the U.S. for starting the AIDS epidemic. *Effort continues. Disinformation; is believed in 3rd world.*

Jan 85 - San Diego, California.
U.S. Navy chaff caught by wind, blown in over San Diego. Power knocked out to 60,000 homes. *Symptoms of presence of Soviet scalar EM grid in San Diego urea.*

7 **Jan 85 -** Cantrell, Alaska.
Cantrell, Alaska. Blinding white light passes in sky overhead, lights up sky and mountain range for 30-40 seconds for 16 mi. Est. 3-mi. altitude. *Probable Soviet test. Note that plume activity at Bennett Is. is heavy in Jan. 85.*

Feb 85 - Zimbabwe.
Zimbabwe suffering worst electrical storm season in history. Death toll up to 116. 21 persons killed by a single bolt in one case. *Anomalous lightning. Shows natural potential in area disrupted.*

17 & **18 Feb 1985 -** Anchorage, Eklutna Flats, Northway, Alaska. Several anomalous lights and sky booms incidents in Alaska. Skyflashes, balls of light, booms, etc. Seen both from ground and by pilots of aircraft. *Probable Soviet realtime holography tests as part of worldwide deception plan.*

19 Feb 85 - Out from San Francisco, California.
China Airlines Flight 006 Boeing 747 enroute to Los Angeles. Engines fail. A/c falls 32,000 ft. in 2 min. Restarts engines, lands at San Francisco. *Note previous incidents over Alaska on 17 & 18 Feb. Probable Soviet test of launch phase anti-bomber system capability of woodpecker transmitters.*

10 **Mar 85 -** Tblisi & Tallin, USSR.
Soviet Academy of Sciences announces an Aeroflot a/c had been followed by a UFO for 800 mi. *Soviets occasionally produce light phenomena in their own territory and near Soviet a/c as part of their deception plan. They do not wish to appear different.*

1 **May 85 -** Near Nashville (monitoring station).
In and around May Day 1985, the Soviet Union held a giant exercise of all its strategic scalar EM weapons. 27 "power taps" into the earth — each two frequencies 12 KHz apart — were activated. The earth was thus in forced gravitational resonance beneath our feet on 54 frequencies. Each tap estimated to power up to six of the giant weapons; thus over 100 major strategic scalar EM weapon transmitters were activated. Frequency bands were filled with scalar EM transmissions, command and control, including to subs on station underwater. *Frank Golden monitored this startling giant exercise, which was probably held for Gorbachev, and this author observed it by courtesy of Golden's special detection equipment. Thus the Soviets*

met the 1985 timetable established by Brezhnev in 1972 at a secret meeting in Prague of European Communist leaders. Western nations do not appear to have the equipment to monitor scalar EM emissions, and so Western intelligence agencies are believed to have totally missed this giant exercise and its significance. At conclusion, two power taps (four frequencies) were left in the earth to power "ready firing batteries," so to speak.

11 **Jun** 85 - Lanzhou, China.
China B747 crew encounters a huge, expanding yellowish glow of light, with very intense spot at center. *Probable Soviet test.*

11 **Jun** 85 - Mongolia.
Chinese jumbo jet, Peking to Paris flight, encounters giant "UFO" light form over Mongolia. 10 km. wide. Lit sky for 50 km. Extremely bright spot at center. Paced aircraft for 2 minutes. *Probable Soviet test. Soviet operator tracked a/c exhaust with long range antibomber system. Added giant light form for deception, and to create UFO reports, which are largely ignored.*

23 **Jun** 85 - Iowa, Nebraska, Kansas, Illinois, Kentucky.
Thunderstorms over Iowa, Nebraska and Kansas organized into single circular pattern rainstorm 200,000 sq. km. in area. Declined until dawn, then rejuvenated to unleash severe weather over Illinois and Kentucky. *Such organization never before had been seen. Now called "mesoscale convective complex." Shows unique new weather pattern involving giant organization.*

2 **Aug** 85 - Dallas/Ft. Worth, Texas.
Delta Airlines flight 191, a Lockheed L-1011, encounters microburst while approaching runway at Dallas/Ft. Worth International Airport. Crashes and kills 134 of the 163 persons on board. *While such microbursts occur in nature, this was during a period of intense Soviet scalar EM activity. Note that warming the tops of thunderstorm anvil causes a downburst. May have been just accident. May have been test.*

23 **Aug** 85 - Italy, Adriatic Coast.
More than 28 "UFO" sightings reported along Italy's Adriatic coast soon after **midnight.** Light phenomena. *Probable Soviet test. Part of deception plan. Scalar KM holography (real-time).*

28 **AUG 85 -** Vandenberg AFB, California.
Titan B fails after launch at Vandenberg AFB, California. Believed to have carried sensitive U.S. satellite. *Suspicious.*

Sep 85 - Kourou.
Ariane rocket explodes at Kourou. 3rd stage engine failed to ignite properly, forcing loss of power. Destruct then ordered. *French officials suspect Soviet sabotage. Probable Soviet test.*

Sep/Oct 85 - Cape Canaveral, Florida.
Anomalies observed on two U.S. shuttle launches by NASA. *No action taken; NASA does not recognize scalar EM weapons capabilities nor testing over its Cape Canaveral launch site. Nor does it connect the mysterious "booms" that have rocked the Florida coast for several years with the Soviets or with the anomalies noted on its two shuttle launches, such as giant booms.*

2 **Sep 85 -** Mexico City, Mexico.
Worst hailstorm in 50 yrs. strikes Mexico City, leaving some streets more than a foot deep in ice. 1-hr pelting. 25 bldgs collapsed. 4,000 roofs heavily damaged. 1 killed, 185 injured. Power blacked out. *May have been due to extensive Soviet long range weather engineering. 17 days prior to suspicious giant Mexican earthquake.*

5 **Sep 85 -** Australia.
Premier Wran, Australia, along with Minister of Agriculture Hallam, observe a brigh spherical "UFO" from their government jet. It was photographed. Radar contact showed object at 100,000 ft. *Probably Soviet advanced performance antigravity flying vehicle.*

18 Sep 85 7:15 pan. - Catalina Is. Channel Is.
Cookman observes giant cloud radial, awesome to behold, between Catalina and Channel Islands, off California coast.
18 "funnel" strobes, dynamically boiling. Activity indicates great energy poured into earth and atmosphere. Mexican quake the next morning. Indicator of Soviet scalar EM connected to quake.

19 **Sep 85 7:18** a.m. - Mexico City, Mexico.
Large earthquake strikes Mexico City, causing great damage. Largest of several. *Preceded wks earlier by giant anomalous hailstorm. Evening before, giant radials showed extensive Soviet power*

transmission activity. Positive indications of Soviet test.

8-9 **Nov** 85 - Ventura County, California.
Highly anomalous power blackout in Carlisle Canyon, Ventura County, Calif. Accompanied by severe electrical anomalies totally beyond normal electromagnetics. *Investigated and reported by engineer Ron Cole, who lives in the area. TV, light, phone, electrical anomalies plus intermittent 29 Hz signals.*

Nov- Dec 85 - California.
Mysterious hum continues to baffle people at Pacific Heights, Calif, and Marina district on San Francisco Bay. Previously had had same hum. Note such hum in England persisting over long period. Note 8-9 Nov 29 Hz. anomalous elec. signal at Carlisle Canyon, Ventura County, CA. *Possible indications of Soviet scalar EM activity. Area appears to be one of Soviet register / test points.*

26 **Nov** 85 - Cape Canaveral, Florida.
Launch of space shuttle Atlantis from Cape Canaveral, Florida is accompanied with high anomalies. (1) Seconds before launch, Bob Gladwin inadvertently photographs nearby strike of what appears to be an electromagnetic missile, probably of Soviet origin. (2) Anomalous light is hanging in the sky, near the launch site: a marker beacon, placed there by the Soviet scalar EM weapon system being tested. Seen by hundreds of persons, and photographed by George Suchary. Printed in Fort Pierce **Tribune.** (3) 12 minutes after shuttle is launched, when it is well down range, a tremendous rumbling atmospheric boom occurs, heard 600 mi. up and down the East Coast. Marker beacon then slewed away by distant Soviet operator at high speed. *With offset EM missile strike, Soviets tested the weapon to be used on the Arrow DC-8 two weeks later at Gander AFB, Nfld. Marker beacon used in precise registration. Note it was evidenced again above the explosion of the Titan on 18 Apr. 86 at Vandenberg AFB. Boom is from energy induced over a large area; which can catch multiple missiles being launched, a large Naval task force at sea, or a whole flight of airborne bombers, fighters, or helicopters. Also can catch an entire organization on the ground, or an installation - - wiping out all electronics, exploding explosives and ordnance, stunning or killing personnel, etc.*

*Again hundreds of NASA engineers and scientists did not recognize what was **happening** at the **site** and over their own heads.*

12 Dec 1985 - Gander, Newfoundland.
Arrow DC-8 crashes immediately after takeoff at Gander AFB, Newfoundland. Lost power just after takeoff; engines "rumbling" abnormally rather than roaring, according to eyewitness whom the a/c flew directly over, 100 ft up. Aircraft seen by three eyewitnesses to have an orange glow on it. Symptoms of negative energy introduced into engines, cancelling some of heat energy of the engines and seriously interfering with combustion process, causing loss of power. Glow may have been steady, small electromagnetic ball of energy against the aircraft, causing it to electrically charge and exhibit corona. Anomalous hole in right fuselage, just ahead of engines, as if from internal explosion; however, no explosive residue (it was tested). One other anomalous hole found. Wild swings of some instruments recording just at/after liftoff — ignored by investigation. *Note previous 36 light incidents in and around Gander, Jan. 1982. Gander Airport is major stopover for Soviets, and a major "registration point" for scalar EM weapons. Note anomalies in shuttle launch 2 wks earlier, and apparent actual test of the small EM missile then, offset so as not to destroy that shuttle.*

Aircraft crew one of Arrow's best. Aircraft should have flown okay, if not interfered with. Serious indications that the DC-8, with over 250 U.S. soldiers and air crew, was deliberately destroyed by test of a Soviet launch-phase antibomber system.

Note metal-softening Soviet signal detected on 1 Jan 86 by Frank Golden may actually have been on the Woodpecker transmissions on Dec 12,1985. This metal-softening signal probably played a part in the destruction of the Challenger on 28 Jan 86.

1 **Jan** 86 - Near Nashville, Tennessee.
Frank Golden discovers a metal-softening signal on the Soviet Woodpecker interference grid. Performs experiments to verify the metal-softening ability of the signal. *Signal is of such a nature that only Golden's instrumentation could have detected it. He then scalarly cancelled the signal to totally prove it.*

24 **Jan** 86 - Ventura, California.
Engineer Ron Cole observes and sketches a giant grid cloud pattern over Ventura, Calif, at 11:45 p.m. PST. Giant cloud fingers, separated from each other, formed the crossed-grid pattern. *Shows Woodpecker scalar EM power very high and active.*

26 **Jan** 86 - Northern California.
Strong quake hits Northern Calif. 5.5 on Richter scale. Hollister area, about 120 mi. south of San Francisco. Several power outages in southern Bay area, where quake knocked out transformers, downed 21,000 V. power line, and set off burglar alarms. *May have been induced by Soviet scalar EM transmitters.*

26 **Jan** 86 - Los Angeles, California.
In greater Los Angeles area, Margaret Wilson observes 3 classic giant radial clouds form at 10 min. intervals: 1:15, 1:25, and 1:35 p.m. Appeared one after the other, till all three were there. Last one lasted about two hours, gradually distorting. *Shows a great amount of structuring to capture and turn the Jetstream, to direct cold weather to the Florida Panhandle and catch the Challenger before its impending launch, exposing it to drastic cold conditions. Definitely Soviet engineered.*

27 **Jan** 86 - Santa Monica, California.
On evening prior to the Challenger disaster, Al Matthews photographs a strange bar-grid cloud formation, absolutely rectangular bars, from the Los Angeles freeway. Pattern approx. over Santa Monica Bay, due north of Catalina Island. Edges and ends very straight, as if drawn in sky by a giant draftsman. *Shows severe high frequency content, and fine-point localization of Soviet scalar EM transmitters, in preparation for forthcoming launch of the ill-fated Challenger.*

27 **Jan** 86 - Florida Panhandle.
Avalanche of freezing air temperatures to record lows across the Southeast. Low temperature records set all across the South. Jetstream bent far south, across Florida Panhandle. *Definitely caused by Soviet weather engineering. Preceeded by giant radial cloud signatures in "hinge" areas of Los Angeles and Huntsville, Alabama, showing steering of Jetstream.*

28 **Jan** 86 - Cape Canaveral, Florida.
Low temperature records shattered all across the South. Into 30's in Florida and into teens elsewhere. *Definitely result of Soviet weather engineering, and definitely directed against the Challenger rocket on the launch pad.*

28 Jan 86 - Off Florida Coast.
About 4 hr. before the launch of the Challenger, all Soviet ships off-coast, which normally monitor shuttle launches, suddenly depart at high speed. *Soviets do not want any suggestion that the ships' radars and transmitters may have interfered with the Challenger launch. Total anomaly. Unprecented event.*

28 Jan 86 - Cape Canaveral, Florida.
National radio and TV newsmen comment on the highly unusual fact that no birds are flying in the launch area. *Reason: For severe localization, high frequency content of the scalar EM signals had been drastically increased. A bird's brain will detect and resonate to this energy, if the wavelength approaches the diameter of its brain. This resonance will cause great pain and/ or death of the bird. Thus the birds flee the area when this begins to occur — or they die. When birds accidentally fly into such a high frequency scalar EM signal, their nervous systems are instantly jammed. They die and fall from the sky.*

28 Jan 86 - Cape Canaveral, Florida.
Space shuttle Challenger, launched from Cape Canaveral after exposure to cold weather conditions, disastrously explodes. Booster seal problem. Encounters air turbulence during launch, at most critical altitude. *Soviet metal-softening signal has been added to grid. Extreme localization in area because of high frequency content added; shown by birds having vacated the area. Anomalous departure of Soviet ships offshore, 4 hrs. earlier. Three previous tests of the weaponry in that exact launch area, against the three previous shuttle launches. Kill of the Arrow DC-8 about 6-112 weeks earlier. Actual celebration by the KGB of perfect success of their active measures against the Challenger! U.S. space program crippled and set back severely.*

29 Jan 86 - Moscow.
At KGB headquarters in Moscow, the KGB holds a jubilant party to celebrate the perfect success of their active measures against the Challenger. *Note that Soviet scalar EM weapons — development, deployment, and use — are under the control of the KGB rather than the regular Soviet armed forces.*

31 **Jan 86** - Mid-U.S.
Richter 5.0, Earthquake rattles 9 states and Great Lakes. *Possible test of weapon that killed the Challenger, in the earth transmission / earthquake induction mode.*

2-4 **Feb** 86 - Birmingham, Alabama.
In Birmingham, Alabama dead birds plummet from the air to the ground for three days. Blackbirds, cardinals, sparrows, bluebirds, etc. No trace of poison in carcasses. *Only a few days after kill of the Challenger. To divert the Jetstream further south and hit Florida, the Soviets had moved the normal "hinge pin"—where scalar EM energy, either positive or negative, is focussed —from Huntsville to Birmingham. Hinge pin area was still activated. The high frequencies used for extreme localization against the Challenger were lethal to birds. Therefore birds that inadvertently flew into this zone were instantly killed and dropped from the sky.*

10 **Feb.** 86 - Europe.
Super Frelon (French) helicopter crashes, with 11 killed. Aeronautique Navale aircraft. Part of a spate of crashes of French military aircraft in four months (through June 86). *Defense Minister Andre Giraud launched a special investigation.*

23 Feb 1986 - Irish Sea.
Over the Irish Sea in an airplane, England's Prince Charles sights a brilliantly glowing, red object hovering near them. His pilot reports the object to air traffic control. Four other aircraft traveling through that area radioed similar reports. *Probably either a Soviet craft or a Soviet holographic scalar EM demonstration as part of the overall deception plan, and/or a stimulus to a member of the Royal Family to observe what action is taken by British Ministry of Defense. By actions, could ascertain whether or not Britain knew what was going on.*

30 **Mar** 86 - Ventura, California.
Engineer Ron Cole in Ventura CA observes significant cloud patterns, positively correlated with his measurements of the Soviet woodpecker transmissions. *Cloud pattern changes were directly correlated to signal changes on the Woodpecker. Shows cloud signatures can be indications of specific Woodpecker activity.*

31 **Mar** 86 - San Francisco, California.
Strong earthquake, Richter 5.3, rocks San Francisco Bay area. Third in region in 3 days. Three aftershocks within minutes. *Note correlation of Woodpecker activity previous day.*

31 **Mar** 86 - San Francisco, California.
Crew error on Delta flight accidentally shuts down engines after normal takeoff from San Francisco. Engines restarted. *Definitely a crew error. Possible human effects from earthquake energy in area. Same type incident on Jun. 30, 1987.*

3 **Apr.** 86 - Florida.
Loud boom shakes houses and rattles windows over Brevard County, Florida. One of a whole series over the years. Not far from Kennedy Space Center. *Soviet adjustment of scalar EM grid.*

Apr 86 - France.
French Armee de L'Air has lost two Jaguars and two Alphajets in April 86. Part of a spate of losses in 4 months, leading Defense Minister Giraud to launch a special investigation.

7 **Apr** 86 - Sacramento, California.
Charlotte King of Sacramento calls UPI and predicts a major earthquake will strike in Canada, Alaska, Aleutians, or Japan. She had predicted eruption of Mt. St. Helens in 1980. On Apr. 27th, she predicted quake that shook Mexico three days later.
Note that human brain is a scalar EM interferometer, capable of transmitting and receiving scalar EM waves. Unfortunately, not conscious — output of system is in deep unconscious. Some persons are more sensitive than others, and can detect the scalar activity from the increasing stress in rocks that is leading toward an earthquake. Charlotte King is such a person, having over an 80% accuracy of prediction of quakes. She will be able to detect the increasing stress in rocks, whether naturally or artificially induced.

9 **Apr.** 86 - Aleutian Islands.
Three quakes rock the Aleutian Islands. Predicted by Charlotte King on Apr. 7. *Documented prediction.*

18 **Apr.** 86 - Huntsville, Alabama; Thousand Oaks, California.
T.E. Bearden sees and photographs remnants of a giant radial cloud

in Huntsville, Alabama. Extensive Soviet woodpecker grid activity noted over Thousand Oaks, California by Engineer Ron Cole. *Both show increased scalar EM activity in the interference grid.*

18 **Apr** 86 - Vandenberg AFB, California.
USAF Titan 34-D rocket explodes nine seconds after launch from Vandenberg AFB, California. Video captured the Soviet marker beacon **(Aviation Week & Space Technology).** Engineer Ron Cole and team study video of the explosion frame by frame and verify the anomalous beacon light is present, is separate from the explosion, and moves away separately after the explosion. *Sensitive satellite believed on board the rocket. U.S. Space surveillance program crippled. Probable Soviet kill. TR wave adjunct with Woodpecker.*

25 **Apr** 86 - New Mexico.
NASA research rocket misfires over the New Mexico desert. No public announcement made at the time. Was first failure in 25 consecutive missions of the Nike-Orion rocket. Said NASA spokesman Kukowski: "It looks like we're snakebit."
Possible Soviet test kill.

25 **Apr** 86 - California; Chernobyl, USSR.
Bill Bise detects the sudden loss of the East-West Soviet woodpecker transmitter he is monitoring in the field, leaving the North-South transmitter. The failed transmitter was about 20-30 km. from Chernobyl. The *Soviet transmitter sites safety circuits go-in full, trying desperately to hold back the giant scalar EM standing-wave potential that has been built up, and slowly and safely drain it away into the earth. In alarm, Soviets shut down nearby reactors at Chernobyl. Any "flash discharge" escape as a flash-over pulse of the scalar EM potential will produce a giant EGP pulse into the earth. When this EGP pulse reaches the four reactors, they will violently explode, full-up nuclear, like giant hydrogen bombs — perhaps 1200 megatons equivalent. Later the Soviets will claim that the operators shut the plant down to do some "unauthorized experiments."*

26 **Apr** 86 - Chernobyl, USSR.
With the giant scalar EM standing wave almost all drained away, the safety circuits finally ***fail,*** *dumping a small EGP into the earth. The nearest reactor at* ***Chernobyl*** *gets* ***it,*** *and the uranium fuel roils*

suddenly go half-decayed, instantly heating and blowing out the reactor, destroying it. Nuclear radiation fallout spreads over much of Europe.

3 **May** 86 - Florida.
Delta 178-rocket destroyed by range safety officer at T + 91 after two anomalous power surges occurred in the rocket, causing premature shutdown of 1st stage Rocketdyne RS-27 engine 71 sec. into the flight, and rocket to go aerodynamically unstable. Previous 43 launches had been successful. Since 1960, 177 launches 94% successful. One of most reliable rockets ever built. *Soviet weapons test. One of a series. TR wave adjunct with Woodpecker.*

7 **May** 86 - Aleutian Islands.
Great earthquake measuring 7.7 Richter strikes Aleutian Islands. Centered about 100 miles SE of the island of Adak. Tsunami alert issued for the North Pacific, but no major waves ever materialize. Thousands evacuate coastal areas. A *U.S. researcher known to this author used a powerful scalar interferometer to block the tsunami. The researcher must remained unnamed.*

9 **May** 86 - Redstone Arsenal, Alabama.
All power on Redstone Arsenal, Alabama suddenly and mysteriously fails all at once. *Similar related incident on May 12. No explanation.*

12 **May** 86 - Huntsville, Alabama.
In Huntsville, Alabama — adjacent to Redstone Arsenal — on local radio program Feedback, public radio discussed the mysterious failure of all power on Redstone Arsenal on Fri., May 9, 1986 and requested that, if anyone knew why all circuits would go off at once, to please get in touch. *Immediately the station's radio transmitter went off the air! (Almost as if "Big Brother's listening to you!")*

18 **May** 86 - Dijbouti.
French Breuguet Atlantic aircraft crashes in Dijbouti, killing 19. *Part of spate of crashes of French military aircraft in 4 months that leads French Defense Minister to open special investigation.*

19 **May** 86 - Brazil.
Brazilian fighter jets are sent to chase multi-colored "ping- pong ball sized" UFO's in skies over Brazil. 4 jets, two Mirages and 2 F-5's

chased them at speeds of 840 mph. Tracked on radars. Chase lasted 3 hrs. Planes could not catch them; ran low on fuel and returned. Discussed on TV by Brazil's Air Force Minister Brig. Gen. Otavio Moreira Lima. *Soviet scalar EM holographic production; distant Soviet operators having fun and games as part of the deception plan, generating UFO incidents and reports?*

22 **May** 86 - California.
High-speed orange "X" object with lights seen above Sonoma CA before dawn. At one time the object slowed and hovered.

29 **May** 86 - Huntsville, Alabama.
Huntsville and Madison County, Alabama electrical power dipped momentarily and mysteriously, causing a seconds-long outage in businesses and homes, playing havoc with traffic signals and computer centers throughout the area. Some traffic signals continued to malfunction for 30-45 min. after power was restored, then mysteriously resumed normal functioning. Some phones also went out inexplicably, and many battery-powered radios went off, and were awry for seconds or minutes before recovering. *Obviously this was not caused by any kind of ordinary electromagnetics. Shows anomalous and high activity (pulsed) in the Soviet scalar EM grid (Huntsville Ah. is a pivot point).*

30 **May 86** - French Guinea.
Ariane 2 rocket fails because of a faulty ignition system for the third stage engine. Rocket destroyed by ground command 4-1/2 min. after launch from Kourou, French Guinea. The third stage has failed 3 times since start of Ariane's operations in 1979.
Possible Soviet test.

Tad Szulc, Washington journalist, implies that French Defense Minister Andre Giraud may have discussed the possibility of Soviet sabotage of the rocket with Washington.

May? 1986 - Straits of Gibralter.
USS Atlanta nuclear sub runs aground in Straits of Gibralter and suffers "serious damage," according to reports in Madrid. A hole was made in one ballast tank and the sonar wrecked.
*Another **U.S. nuclear sub** ran aground within a month or so (earlier?) of this incident. C**ould something** have interfered with their navigation systems underwater? Continued Soviet Scalar EM tests?*

11-12 July - California.
Secret USAF crashes approx. 14 mi. NE of Bakersfield, CA along the Kern River. Site secured. Possible Stealth fighter. Crippled aircraft in trouble seen and photographed by Andy Hoyt, who turned photos over to USAF (properly so). Aircraft not on fire when came down. Did not explode in the air. *No information as to whether any Soviet scalar EM hanky-panky involved or not. Suspicious because follows a series of anomalous missile failures. Woodpeckers definitely have good anti-stealth capability.*

11 July 86 - Tennessee and Georgia.
Moderate quake with sonic boom shakes SE Tennessee and Northern Georgia. 3.7 on Richter scale. Centered just east of Chattanooga Tennessee on the TN/GA line.

12 July 86 - Michigan, Ohio, and Kentucky.
Mild quake in Michigan, Ohio, and Kentucky. 4.0 on Richter scale.

18 July 86 - Los Angeles, California.
Sharp aerial boom rattles Los Angeles Basin at about 0930 hrs. FAA and USAF unable to identify a potential source from an aircraft.

Aug 86 - Soviet Union.
Two huge new Soviet "radars" discovered on Western Soviet border by U.S. intelligence. One near Skrunda, on Lithuanian border. Other near Mukachevo, on the Czech border. *With phase conjugate adjuncts, represent significant strategic weapon system deployments.*

2 **Sep** 86 - Baltic Sea.
Finnish ferry Scandinavia in Baltic Sea observes a strong light rise from the sea near the Finnish Coast. After 3 to 4 seconds, a giant mushroom reached 500 feet into the sky and covered the moon. *Probable Soviet test.*

12 Sep 86 - Dallas, Texas.
Mysterious, powerful "explosion" rocks South Dallas. No source found or explained. No supersonic jets in area.

Selected ***Incidents***

15 **Sep** 86 - Australia.
Katherine, Australia. Object with flaming orange **tail** moved **from** sky toward ground at 45 degree angle. Katherine's electrical **power** suddenly cut off and phone lines in the town disrupted. ***Probable*** *Soviet scalar EM generated.*

Oct-Nov 86 - Los Angeles, California.
Giant radial clouds observed in Los Angeles area.

Oct 86 - Reykjavik, Iceland.
Gorbachev and Reagan meet at Reykjavik, Iceland. Gorbachev proposes "zero option." *Seeks to get nuclear missiles removed, since they constitute "dead man fuzing" because of nuclear warheads, and severely limit pulse use of Soviet scalar EM weapons. Adamantly insists on bottling up SDI — because if space laser is converted to scalar EM laser, its power (effective) goes up about* 10^{20} *times, and single shot could devastate Russia.*

10 **Oct** 86 - Vandenberg AFB, California.
U.S. forced to scrub another missile launch when a USAF Scout satellite malfunctions during final countdown at Vandenberg AFB, Calif. *The booster's gyro system failed a checkout sequence at about T-5 hr. Scalar EM can inertially interfere also.*

13 Oct 86 - ABC News.
On Peter Jennings' ABC News show, Gennadi Gerasimov, Soviet spokesman, indicated that SDI as presently designed was of no concern to Soviets. Real concern is that U.S. will make a "great technical breakthrough" and deploy new, modified devices, presenting an unacceptable threat to the Soviet Union. *Here he is thinking of changing the laser to a scalar EM laser.*

6 **Nov** 86 - Albuquerque and Phoenix.
Power failures at Albuquerque air traffic control tower and a radar station near Phoenix, Arizona occur. Radar controlling high altitude air traffic from Texas Panhandle to southern California was knocked out for 40 min. First such incident in Albuquerque center. The Arizona radar was out for 59 hrs. *Note similar incident at Montreal on Nov. 11, 1986.*

10 **Nov** 86 - Huntsville, Alabama.
Three giant radial cloud formations in Huntsville, Alabama photographed by T.E. Bearden. One is a twin giant radial. *Shows heavy activity in scalar EM interference grid.*

10 **Nov** 86 - SE U.S.
Red glowing light with tail flares across sky in Southeast about sunset. Seen over parts of TN, AL, GA, MS. Ground searches conducted in several areas for possible crash. *Probable Soviet scalar EM activity. Note heightened activity in grid same day.*

10 **Nov** 86 - Near Nashville, Alabama: Hemet, California.
Frank Golden measures scalar EG field of earth — highly agitated and dynamic, about half as much as when Soviets induce earthquakes. Anomalous winter storm in progress. Cold records broken in Mid-U.S. Heat records broken in Florida. Storm penetrates very deeply southward. *Soviet weather engineering.*

11 **Nov** 86-Canada.
Air traffic control radar in Montreal, Canada region broken down. Backup system employed. *Note similar occurrences to Albuquerque and Phoenix on Nov. 6, 1986.*

12 **Nov** 86 - Atlanta, Georgia.
Stationary arc (dome) of clouds sighted over Atlanta. Well defined lower edge. Upper edge irregular. Multiple witnesses. Clouds moved into top of dome and flowed around it. Very strange sight. *Probable Soviet "gentle test" of placing a suppressive covering over a distant U.S. city. Performed at night, at minimal level (no glow) so no great notice would be taken. Dome was stable against 20 mph winds and other moving clouds that collided with it.*

13 **Nov** 86 - Huntsville, Alabama.
Twin giant radial cloud observed moving over Huntsville, Alabama by T.E. Bearden. West to East. At nearly noon. At dusk, single giant radial cloud was also spotted over Huntsville.
Significant scalar EM activity in grid.

17 **Nov** 86 - off Alaska.
JAL Flight 1628 observes giant UFO while enroute from Reykjavik, Iceland on mid-leg of Europe to Tokyo. Crossed Beaufort Sea off

Alaska's north coast. Sighted flashing lights which moved alongside the aircraft. Pilot descended, so did light. Glimpsed craft in profile, twice as big as aircraft carrier. On board radar located it. USAF and civilian controllers reported brief radar echoes, but tapes did not show it. Approaching Fairbanks, Alaska. Pilot made 360 degree circle, object stayed with him. Finally disappeared as he was approaching Anchorage. *Probable Soviet test as part of deception plan. TR wave holography.*

27 **Nov** 86 - Fort Pierce, Florida.
Flash of light in sky and sonic boom occurred vicinity of Fort Pierce, Florida. *Probable Soviet EM test. Note that a classified payload was scheduled for launch in near future at Cape Canaveral nearby.*

4 **Dec** 86 - Huntsville, Alabama; Hemet, California.
Twin giant radials seen and photographed over Huntsville AL. Large radial cloud seen in skies over Hemet, Calif, and photo printed in **The Press Enterprise,** Hemet, CA 5 Dec 86.

4 **Dec** 86 - Cape Canaveral, Florida
Atlas/Centaur rocket successfully launched at Cape Canaveral, orbits a communications satellite for DOD. *The Soviets had to allow one or two of the missiles to succeed, else even the lethargic U.S. bureaucracy would have caught on. Grid activity indicates they probably just tracked it without the other goodies.*

5 **Dec** 86 - Vandenberg AFB, California.
MX ICBM launched from Vandenberg AFB. Two of RVs did not deploy although all impacted within the Kwajalein Missile Test Range. *Note: Soviets let one go from Vandenberg.*

21 **Dec** 86 - Huntsville, Alabama.
Twin giant radial photographed over Huntsville Alabama.

23 **Dec** 86 - Huntsville, Alabama.
Small flash in lower sky over Huntsville, Alabama observed by T.E. Bearden. Followed by faint boom. Momentary loss of power occurred in large area of Huntsville. Positive correlation between the aerial flash/boom and the loss of the power. *Soviet test.*

7 - 21 Jan 1987 - Florida.
Several giant radial clouds seen in vicinity of Fort Lauderdale, Florida. *Indicates substantial action in scalar EM grid.*

20 **Jan** 87 - U.S.
Highly unusual bend in Jetstream. Completely down West Coast, curving east under Texas, NE along SE USA. *Shows great action in scalar EM grid. Significant weather engineering.*

20 **Jan 87** - Vandenberg, AFB, California.
Minuteman missile destroyed in launch. *Note substantial action in scalar EM grid.*

23 **Jan** 87 - Huntsville, Alabama.
Bearden photographs twin giant radial over Huntsville AL. Cloud fades with great and unusual rapidity. A private-type jet, similar to a Learjet, continually circled under the strange twin radial cloud, as if observing and/or photographing it. *Perhaps someone in the U.S. system wised up.*

28 **Jan** 87 - Vandenberg AFB, California.
Minuteman missile successfully launched from Vandenberg AFB. Note: *Anniversary of the Challenger disaster.*

7 **Feb** 87 - Alabama - Tennessee border.
Loud aerial boom or explosion shakes area from Tennessee, New Market, Monte Sano through Huntsville Alabama area.

10 **Feb** 87 - Huntsville, Alabama.
Bearden photographs twin radial cloud in Huntsville, AL. Cloud stayed fixed, although winds present and other clouds moved. Note big storm in NE - Cape Cod, etc. *Associated with weather engineering.*

11 **Feb** 87 - Huntsville, Alabama.
Bearden photographs another twin giant radial in Huntsville, Alabama. *Shows activity in Woodpecker grid.*

Feb 87 - Vandenberg AFB, California.
USAF Titan launched from Vandenberg AFB, Calif.

12 Feb 87 - California.
Blue Angel F-18 a/c crashed near Brawley, CA. Fourth military air crash in the Imperial Valley since October. *Note Woodpecker grid activity on previous day.*

26 Feb 87 - Cape Canaveral, Florida.
GOES-H weather satellite launched from Cape Canaveral on a DELTA rocket.

26 Mar 87 - Cape Canaveral, Florida.
Stunning failure of an Atlas/Centaur rocket launched from Cape Canaveral. May have been hit by lightning. Failed suddenly 51 sec. after liftoff. Veered out of control and destroyed. *Note: Possible Soviet scalar EM involvement. Much to do later about multiple lightning strikes; very suspicious.*

June 1987 - Vandenberg AFB, California.
Minuteman 3 missile fired from Vandenberg AFB, Calif, is aborted and destroyed in flight. *Note similar incident in July.*

12 **Jun** 87 - Cape Canaveral, Florida.
Trident III launched successfully from flat pad.

21 **Jun** 87 - Alaska.
Three strong earthquakes shake parts of remote Alaskan Peninsula.

30 **Jun** 87 - Los Angeles, California.
Delta 767 flight 810 crew inadvertently shuts down engines shortly after takeoff from Los Angeles. Starts to fall, restarts engines and recovers. *Definitely crew error. Similar incident on Mar. 31, 1986 after takeoff from San Francisco.*

12 July 87 - Over Pacific Ocean.
Minuteman missile is destroyed in flight over the Pacific Ocean because of a problem in flight. Launched from Vandenberg. *Note similar incident the previous month.*

16 **Jul** 87 - Huntsville, Alabama.
Anomalous largo "boom" occurs at Huntsville, Alabama.

17 **Jul** 87 - Huntsville, Alabama.
Another anomalous, large "boom" occurs at Huntsville, Alabama. *Note that Huntsville is a pivot point on the Soviet grid. Adjustments in the grid often "spill out" energy, causing such a boom. It causes a sharp boom if pinpoint spillage occurs. It causes a more general quaking, rumbling sound of longer duration if spillage occurs over an area.*

20 July 87 - Cape Canaveral, Florida.
Tident III successfully launched from flat pad.

14 **Oct.** 87 - Nellis Air Force Gunnery range.
Top secret plane crashes; possible stealth fighter. *Did the Soviets kill another one?*

9 **Nov.** 87 - Vandenberg, AFB, California.
Minuteman II missile is destroyed seconds after launch. *Unnamed anomalies cited. Did the Soviets interfere?*

4 **Jan.** 88 - Madison and Huntsville, Alabama.
Giant radial sighted for several hours. Three mysterious booms rattle Huntsville. *Soviet scalar EM activity continues.*

APPENDIX V

*DEAD MAN FUZING**
THE REAL MEANING OF THE REYKJAVIK SUMMIT

Soviet Foreign Minister spokesman, Gennadi Gerasimov, following failure of the Iceland Summit, said in a radio interview that SDI (U.S. Strategic Defense Initiative), as presently designed, is of no concern to the Soviet Union. The real Soviet concern, he indicated, is that the U.S. would make a great technical **breakthrough** and deploy new devices in space as a modification to SDI **presenting** an unacceptable threat to the Soviet Union.

Peter Jennings' ABC News Show, Los Angeles, CA
13 October 1986.

Gerasimov let the cat out of the bag!

With their deployed scalar electromagnetic weapons, the Soviets would immediately hold the winning hand-if these weapons could be unrestrainedly brought to bear.

As pointed out in **Fer-de-Lance: A Briefing On Soviet Scalar Electromagnetic Weapons,** Tesla Book, Co., 1986, the use of massive Soviet scalar EM weapons can only be gingerly applied. Activation and use of the Soviet scalar EM weapons is fraught with grave danger to the entire earth and to the whole human species because of the presence of nuclear facilities in the desired target area, and because of the "backlash" potential against the Soviet Union's own nuclear weapons and facilities.

The explosion at Chernobyl was apparently caused by the accidental failure of a nearby scalar EM transmitter, and the eventual impulsive loss of part of the electrogravitational potential built up by the transmitter before it failed. The resulting electrogravitational pulse (EGP) in the earth "pulsed" the nearest nuclear material... feul rods in the reactor at Chernobyl.

Had the EGP not been depleted prior to its escape, all four reactors at **Chernobyl** would have exploded with the same intensity as if they had been "triggered" by a fission explosion.

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*The term "Dead Man Fuzing", means that, even though your opponent kills you, a weapon or effect of your own will inevitably result which will then kill your opponent.

In short, if unrestrainedly used, the EGPs from the Soviet scalar EM weapons would initiate most of the nuclear weapons where they are in the targeted area-in storage, in silos, in aircraft, etc. Target area nuclear reactors and nuclear wastes would also be violently initiated into nuclear explosion. The resulting vast megatonnage of nuclear explosions, much of them "in the dirt, " would provide an unthinkable holocaust. The effects of these giant explosions, deadly fallout and dense clouds of smoke and dirt, would blanket the earth with nuclear effects greater than is presently expected from an all out nuclear war, in which many of the weapons are expected to be destroyed or lost without being exploded nuclearly. Deadly nuclear radiation would blanket the globe, contaminating it for thousands of years. From the covering of the earth by dense smoke and dirt clouds, a new and deeply bitter global ice age-not just a "nuclear winter"-would almost certainly be initiated. In 1960 Khrushchev appropriately characterized these fantastic weapons by stating that they could wipe out all life on earth if unrestrainedly used.

A country's nuclear weapons and facilities, then, become its inadvertent "dead man fuzing" to prevent any substantial employment of large scalar EM weapons against it. So long as nuclear "dead man fuzing" is in place in a country, its adversary can only utilize scalar EM superweapons against it with great difficulty, and then only sparingly. At present, both the U.S. and its NATO allies are "dead man fuzed" by the presence of Western nuclear weapons-and to some extent, by the presence of nuclear reactors and stored nuclear wastes.

Obviously the Soviet Union's task of world domination—and the mind-rending risks it must take in employing large scalar EM weapons—would be greatly expedited if the obstacle of "deployed U.S. and NATO nuclear weapons and facilities" could be eliminated or minimized.

Also, Gorbachev must be acutely aware that the U.S. is finally beginning to look at the possibility of scalar EM weaponry. He would assume that either the U.S. is already on the way to acquiring scalar EM weaponry of its own, or else the time is imminent when it will do so. If this happened, and the U. S. then were to deploy SDI **scalar** EM lasers in space, the effects of each laser would be enormously increased by the electrogravitational amplification factor. Reasonable gain increases of the yield of each laser shot might approach, for example, on the order of 10^{20}. In that case, each laser could suddenly devastate a whole state or region with one or two shots, instead of just being able to destroy one little missile. The Soviets know that Reagan's Star Wars weapons-if modified to the "improved" kind and deployed in space—could deliver a surprise first strike in seconds, and devastate Russia before all the Star Wars space weapons could be knocked out by Soviet ground-based scalar EM beams.

The Soviets also know that it is not too difficult to modify lasers to become such powerful scalar EM lasers.

This means that Gorbachev needs to insure that the Star Wars weaponry is not actually tested in space. Testing in space requires developing at least prototype "space deployment" SDI weapons, to get them up in space to test them from there in the first place. And even such "prototype" SDI weapons would be sufficient to devastate the Soviet Union, given that the prototypes employed the technological breakthrough represented by scalar EM weapons. This is what Gerasimov was really referring to!

Thus Gorbachev simply cannot allow such space testing of SDI weapons, if he hopes to be able to safely seize the opportunity to employ his own already-deployed, massive scalar EM weapons during the "window of time" that would be provided by dismantling of U.S., NATO, and Soviet nuclear weapons.

And-given that he gets agreement and implementation of the "zero option"-Gorbachev knows he will only have a narrow "window" of time in which he can hope to achieve world domination. It can be only a short time until the U.S. produces results in scalar EM weapons, and promptly develops such weapons of its own. Faced with that eventuality, Gorbachev would then have no choice but to turn away from the Communist dream of world domination, and reach a mutually agreed accommodation with the West. Both the West and the Soviets then would have to take immediate and drastic measures to prevent the rapid development and spread of the relatively cheap scalar EM weaponry throughout other nations, particularly those motivated from fanatical beliefs and quite capable of "blowing up the earth" deliberately.

Thus, before the U.S. becomes aware of scalar EM weapons and builds its own, Gorbachev desperately needs to get rid of the "dead man fuzing" problem posed by the nuclear weapons and facilities possessed by the U.S. and its Nato allies, so that he can utilize his superweapons to dominate the world without destroying it.

And he needs to block any chance that the U.S. would be able to have space-tested high energy laser prototypes which could be quickly modified to scalar EM weapons, fired into space, and used to counter Soviet aggression or even destroy the Soviet Union in retaliation.

In short, today the paramount and almost desperate need of the Soviet Union is to reduce American dead-man fuzing and keep the SDI space laser genie bottled up in the lab on the ground.

Accordingly, in Iceland, in what appeared to be a stunning concession on nuclear arms, Gorbachev suddenly offered Reagan a complete dismantling of all nuclear weapons-Reagan's "zero option." Actually this move had been planned by Gorbachev from the beginning; it was not a spur-of-the-moment offer. The reason was simple: If the U.S. could only be persuaded to quickly get rid of its nuclear weaponry, the Soviets would hold an absolutely winning hand. Their massive, deployed, operational scalar EM weapons could then be unleashed with minimal restraint. The extremely delicate and incredibly dangerous problem of bringing the large scalar EM "continent-buster" weapons to bear, without inadvertently causing world destruction, would be vastly eased if only the ordinary U.S. nuclear facilities such as nuclear power plants and radioactive wastes had to be reckoned with.

Fortunately, Ronald Reagan fervently believes in defense .

He made the right decision, whether or not it was for the right reasons.

Indeed, he probably knew in advance that SDI was to be targeted in Iceland by the Soviets, and that sweeping concessions might be offered by them for that purpose. According to one report (" 'Blinded' Satellites," Rowland Evans and Robert Novak, **Washington Post,** Oct. 29,1986), just before Reykjavik the CIA-sent a report to Reagan with the warning that "the sole reason for Gorbachev's wanting the Iceland summit was to offer unprecendented inducements for Reagan to drop SDI."

Fortunately, Reagan rejected Gorbachev's proposal, because he does not wish to give up what he truly regards as a potential defense against incoming Soviet missiles.

Apparently neither Reagan nor his advisors were aware of the real reason for Gorbachev's unexpected and breathtaking proposal for what would essentially be near-total nuclear disarmament.

The Soviet ground-based scalar EM lasers could sweep the heavens of the presently conceived SDI weapons, as **Gerasimov** obliquely implied. However, this would not change the barrier represented by U.S. nuclear dead man fuzing, unless the nuclear weapons had been removed.

Meanwhile, Gorbachev's chess game to remove the dead man fuzing is certainly not over. The Soviets have mounted an intense propaganda campaign urging nuclear disarmament and cancellation or restraint of SDI. With a Democratic Senate now in, and with the approaching end of Reagan's term in office, the Soviet effort to clear the U.S. nukes-and the dead man fuzing-out of the way for Soviet deployed superweapons, while keeping the SDI genie in its laboratory bottle, can only be intensified. Already the Soviets are beating every drum to get substantial antinuclear segments of the U.S. scientific, congressional, political, and pacifist communities aroused to oppose SDI and urge a quick zero nuclear option.

The treaty for dismantling certain missiles in Europe has already been signed by the President, and its ratification by the U.S. Senate appears imminent. More is yet to come, and quickly.

In its aching desire for peace, if an unsuspecting America falls into Gorbachev's trap, shackles SDI and removes its dead-man fuzing, the Soviet Union will be free to enforce its will wherever and whenever it wishes.* If that happens, our beloved stars and stripes will be replaced with the atheistic hammer and sickle. And the noblest experiment of all—freedom for the common person—will have come to an ignoble end.

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*Just as **Brezhnev forecast** for 1985, **at a** secret meeting in 1972 of the communist party leaders of E**urope.**

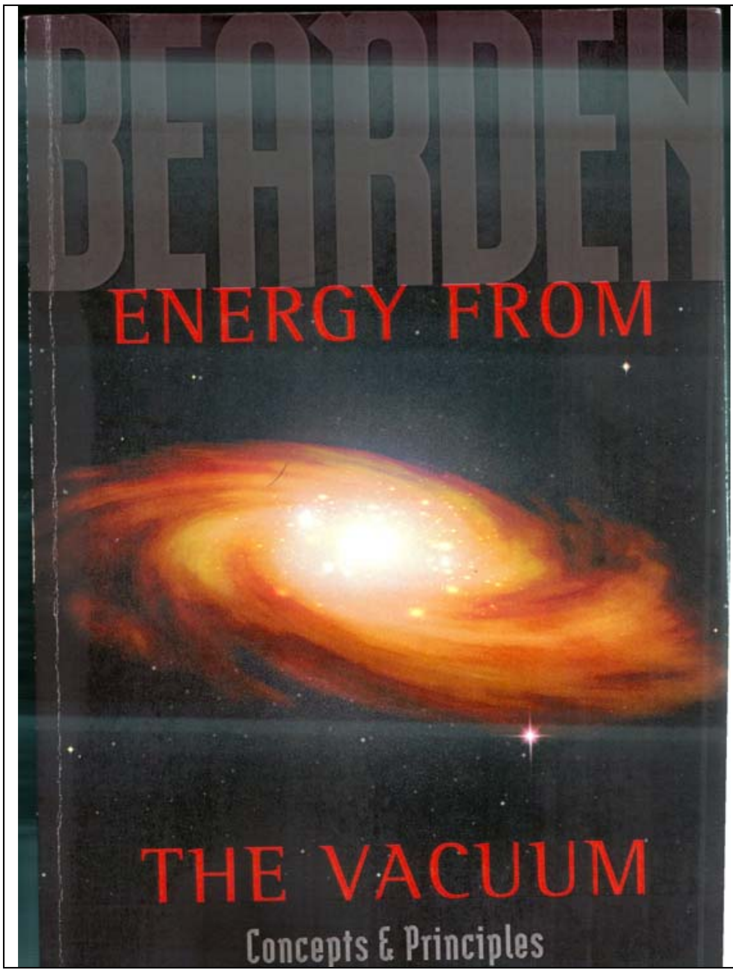

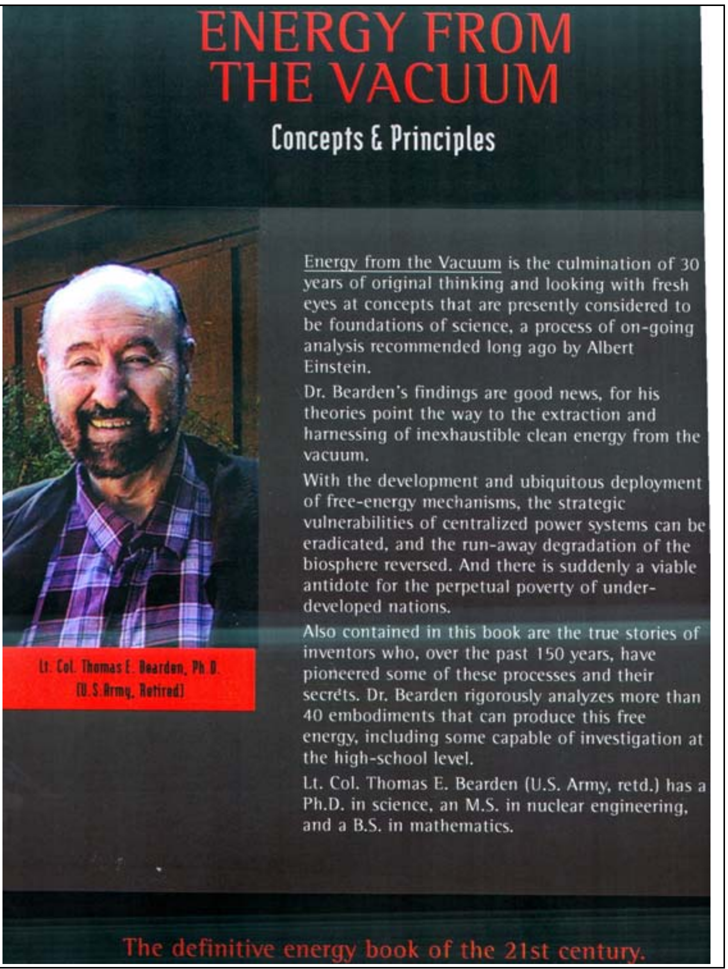

ENERGY FROM
THE VACUUM
Concepts & Principles

Lt. Col. Thomas E. Bearden, Ph.D.
(U.S. Army, Retired)

Energy from the Vacuum is the culmination of 30 years of original thinking and looking with fresh eyes at concepts that are presently considered to be foundations of science, a process of on-going analysis recommended long ago by Albert Einstein.

Dr. Bearden's findings are good news, for his theories point the way to the extraction and harnessing of inexhaustible clean energy from the vacuum.

With the development and ubiquitous deployment of free-energy mechanisms, the strategic vulnerabilities of centralized power systems can be eradicated, and the run-away degradation of the biosphere reversed. And there is suddenly a viable antidote for the perpetual poverty of under-developed nations.

Also contained in this book are the true stories of inventors who, over the past 150 years, have pioneered some of these processes and their secrets. Dr. Bearden rigorously analyzes more than 40 embodiments that can produce this free energy, including some capable of investigation at the high-school level.

Lt. Col. Thomas E. Bearden (U.S. Army, retd.) has a Ph.D. in science, an M.S. in nuclear engineering, and a B.S. in mathematics.

The definitive energy book of the 21st century.

Sweating done by red_gonzo.

Note: sometimes formatting of the text may be a little fuzzy. It's all because the OCR process didn't go as smoothly as I expected. Also there may be some errors inside text so be vigilant. In any case share this book, send emails to people about knowledge contained in it. If you are an amateur electronic guy/girl try to make some good use of this knowledge and post your results. Try to use physics vocabulary as is presented in this book because as the author concludes, there are many good inventors around but they each use their own vocabulary and explanations of their inventions which are only understandable to them.
And please don't be naive and expect you'll be buying those devices in your local supermarket any time soon. Although some progress is being made it's still to slow, especially with the suppression factors watching over it. The knowledge has been handed to you and it's expected that at least a few of us make some use of it. Gather together and try to share your results with the rest of us.

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With deep appreciation I acknowledge the kind assistance and helpful critiques of Dr. Myron W. Evans and other members of the Alpha Foundation's Institute for Advanced Study (AIAS) such as Alex Labounsky, Alain Beaulieu, and Bob Flower. Dr. Evans encouraged me to write down the basic concepts of the theory of permissible COP>1.0 Maxwellian systems I have been working on for three decades. This book is the result of that effort.

A special note of thanks goes to Dr. Dave Hamilton of the Department of Energy, who oversees a DoE restricted website provided for the important

ongoing scientific work **and drafts of the AI**AS. On that site, now there are more **than** 100 AIAS papers, many **of them dealing** with EM energy from the vacuum in rigorous fashion. Many of these AIAS draft papers have been published in leading journals such as ***Foundations*** *of Physics Letters, Physica Scripta, Optik,* etc. **This** is an invaluable scientific effort that clearly establishes the importance and potential for extracting copious EM energy directly from the active vacuum. It also extends the present U(1) electrodynamics to the much more extensive O(3) group symmetry electrodynamics, in which such things as I discuss in this book can indeed be accomplished on the bench and mathematically modeled.

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Finally and most importantly, I acknowledge the continuing and unwavering support of my dear wife, Doris, without whose encouragement and tolerance this work could never have been accomplished. She made all these long years of seven-day weeks and 18-hour days possible and humanly bearable. Without her, this book simply could not have been written.

Foreword

The original purely scientific purpose of this book was interrupted en route by two events: The first was a sudden heart attack and onslaught of severe hypoxia resulting from the resurgence in Spring 2001 of a 33-year old chronic mycoplasma infection, of the modified biological warfare kind produced by a combined U.S./Canadian team, which got loose in Canada and Florida in the 1950s. I contracted this "mysterious, unknown ailment" in 1968 while in the U.S. Army and stationed in Quebec, Canada as the U.S. Army Liaison Officer to the Canadian Armament Research & Development Establishment (CARDE). The second event was the sudden terrorist attack on the U.S. on September 11, 2001, which propelled this nation and others into a war against international terrorism.

For the mycoplasma, Kenn Thomas recognized and informed me exactly what the difficulty was, and I was finally tested and diagnosed correctly in December 2001 due to the efforts of a courageous family physician. Accordingly, in December 2001 we started a yearlong (or longer) regimen of antibiotics and supplementary oxygen, with additional medication to control the runaway heart fibrillation associated with this virulent form of the disorder. If we make it through this yearlong program, we will probably survive with at least some significant recovery. Now on a much-reduced regimen, this made me realize the absolute necessity of passing the "energy from the vacuum" information and baton, so to speak, to those sharp young graduate students and post doctoral scientists who are interested in this area. They simply must not have to spend 30 years of their lives getting to this point. Instead, they should start where I am now, correct any errors I have inadvertently made, and go much farther.

Accordingly, we sharply changed the intent and content of the book to comply with that new purpose. We also deeply considered the potential U.S. and World energy implications of that second shocking event of 9/11 when international terrorists struck the World Trade Center in New York Center and the Pentagon, having also targeted the White House.

In the new asymmetric form of warfare, the internal aspects of a nation - its civilian population, its vulnerable installations, its energy infrastructure, its food crops, and its transportation modes — are the targets. Terrorist teams and groups in significant numbers are already inside every targeted developed nation, and these teams have weapons of mass destruction including biological weapons and even nuclear weapons. For confirmation of the hostile nuclear weapons already secreted in large U.S. cities, read Lunev's book[1] to see how the former Soviet Union brought them in, along with the Spetznaz teams to detonate them on call. The nuclear weapons and the Spetznaz teams are still here. Other hostile nations have inserted terrorist teams with weapons such as anthrax, smallpox (camel pox is nearly identical to smallpox, and widely available), bubonic plague, etc. At the end of the 1991 Persian Gulf War, most of Iraq's calutrons and its nuclear program escaped the weapon inspectors and were hidden. In the few calutrons we did get, weapons-grade U235 residues were found. In a formal threat study for a foreign nation, begun before the Gulf War and delivered after its end, my analysis team and I estimated that Iraq had produced sufficient U235 in 1991 for from 7 to 12 nuclear weapons, particularly of the gun assembly type. My personal estimate now would be that Iraq has made sufficient weapons grade U235 to build three dozen to six dozen nuclear weapons. If so, then some of those weapons are undoubtedly long since spirited into the United States, and planted in our large cities.

In modern asymmetric strategic war, the first phase of the war is conducted in "peacetime". The first phase is to insert the weapons of destruction into the targeted nation and hide them at the intended targets, along with the teams to detonate and unleash the weapons when desired. In that sense, the first phase of WW III has already been accomplished.

According to Vice-President Cheney,[2] *"The war on terrorism will not be over in our lifetime. It is different than the Gulf War was in the sense that it may never end. At least not in our lifetime. The way I think of it is, it's a new normalcy."*

With much of the cheap oil of the world in its borders, the MidEast is a powder keg ready to explode. If a clash between the U.S. and Iraq occurs, Saddam Hussein has already clearly shown that he will attack and destroy his foe's energy infrastructure and he will also use weapons of mass destruction. Simply witness the hundreds of oil wells set afire in Kuwait by Iraqi forces during the Persian Gulf War, and the use of chemical weapons on his own people. As this is being written, Pakistan and India are skirting the brink of war, and both have nuclear weapons. Either side that decides on war **will have to make a n**uclear strike on the other. They have no antimissile defenses, hence **making the** "first knock-out" or pre-emptive strike is each **nation's** only **chance of survival.** Hopefully cooler heads will prevail, but **If that** war erupts, the Mid East, oil, and present energy infrastructures will never again be the same, for the entire world.

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[1] Stanislov Lunev and Ira Winkler, *Through the Eyes of the Enemy,* Regnery, Washington, D.C., 1998, p. 26.

[2] Vice President Richard B. Cheney, October 21, 2001.

There are other very serious U.S. vulnerabilities of gas and oil pipelines, port facilities, Gulf of Mexico oil rigs, nuclear power plants, power substations, hydroelectric dams, long power transmission lines on towers, etc. that are too numerous to enumerate. With but a moment's reflection, one realizes that even normal and cheap guerrilla-type or commando-type forces with C-4 explosives and timers can destroy a very substantial portion of the energy infrastructure with minimal risk and loss of assets. For those who wonder about a nuclear power plant's vulnerability, visualize a seized Boeing 747 loaded with fuel and flown directly into the main reactor container . If meltdown occurs, the nuclear tragedy at Chernobyl in 1986 will appear tame by comparison. There are also several other electromagnetic ways (such as a portable EMP "shooter" hauled in the back of a personal SUV) to instantly destroy the electronic controls of the nuclear power plant, seriously risking runaway and core meltdown.

Consequently, increasing attention is now focused on the extreme vulnerability of the centralized energy infrastructure in the U.S. and every other developed nation. So what started for me as a purely scientific endeavor to set out the concepts and principles of permissible COP>1.0 EM systems suddenly assumed a role of potentially critical strategic significance to the U.S. and to the entire developed world. Quite simply, some 20,000 terrorists in teams already in the United States can - at this very moment —destroy large portions of the nation's energy infrastructure at will, easily and cheaply. The economy of any modern developed nation depends on the availability of cheap energy. So this kind of hostile strategic capability means that the power to readily destroy a nation's economy — and thus defeat a mighty nation itself in the ensuing economic collapse — has passed into the hands of hostile forces already in country and awaiting the order to commit their assets.

In this new asymmetrical form of warfare, it would appear that the rapid development and deployment of significant distributed power sources is now a critical element of national survival for many nations of the world. Decentralization **does** little **good, however, if fuel** for the decentralized generators must remain **centralized and distributed** by very large and complex systems.The **fuel and Its distribution** are still extremely **vulnerable resenting** easy **targets allowing paralysis** of the decentralized generators. Self-refueling {*self-powering)* of the electrical power systems is therefore a mandatory additional requirement.

So sober assessment dramatically reveals the need for self-powering electrical power systems, freely extracting their EM energy from the local vacuum. Thus an engineerable theory of permissible COP>1.0 EM systems has become essential to the national survival of the U.S. and many other nations, so that an effective decentralized energy infrastructure — with the seething vacuum as the "localized and inexhaustible free fuel supply" — can be rapidly designed, developed, and deployed.

Sadly, the leaders of the scientific community are still in a "business as usual" mode with respect to energy, and intend to remain so. They do not even recognize what powers and *always has* powered an EM circuit and system: EM field and potential energy extracted directly from the vacuum by the broken symmetry of the source charges and dipoles. Since no scientific research on EM energy from the vacuum is going to be launched by the scientific leaders at the top, then the results of the broken symmetry discovered in 1957 are going to have to be applied in the scientific community from the bottom up. Consequently, a rather desperate need to communicate everything possible to the young graduate students and post-docs has become imperative, if the nation is to survive.

From the beginning of my effort in COP>1.0 systems, and then my effort on this book and prior to the events leading to the attack on September 11, 2001, the appalling *humanitarian* need for COP>1.0 electrical power systems taking their energy from the vacuum has been obvious and overwhelming. One third of the human population usually goes to bed hungry at night. One third is infested with worms and parasites of one kind or another, in addition to other diseases. Simple things such as clean water, common sanitation, medical treatment, and jobs to support one's family are difficult things in many parts of the world.

In the final analysis, the only way to get a suffering, impoverished, and undeveloped nation up and going is to provide cheap clean energy, and to do it with systems which get their "fuel" for free, such as from the vacuum itself. Once cheap clean energy and self-powering systems are widely available, then the economy and infrastructure of that nation can be slowly and steadily built up to get the society moving. Roads, bridges, hospitals, schools, teachers, industry, and jobs then follow as the economy rises. Until there is a cheap energy infrastructure available and growing, essentially fuel-free, none of that is going to happen in most impoverished nations because presently the world's fuel is monopolized, controlled, and

fought over, and it will become even more expensive as the supply vs. **demand** ratio falls, prices escalate, and additional wars - almost certainly involving weapons of mass **destruction** - are engendered. With present aid concepts, at best the politicians and warlords usually get the bulk of whatever assistance is sent in, and the warlords on the take from foreign masters will continually plunge the country into turmoil, war, and human tragedy. *Assistance is necessary,* but the eventual aim has to be to enable and empower the common citizens to be self-supporting, educated and trained, relatively free from disease, and living in a nation having a growing and developing infrastructure, jobs, and a decent economy. Availability of cheap and affordable energy — and *clean* energy if we wish to save the precious environment — is the primary key to "freeing and empowering the developing nations" as well.

Along with this omnipresent, desperate humanitarian need, the increased strategic need for decentralized energy systems freely fueled from the vacuum itself has led me to make every effort possible — particularly after the heart attack in 2001 and in continued hypoxia from severe chronic mycoplasma infection — to finish the book and at least outline the major concepts and principles that enable the construction of a sorely-needed COP>1.0 electrical power systems theory, followed by the development and rapid deployment of actual self-powering systems. The Alpha Foundation's Institute for Advanced Study (AIAS), spearheaded by Dr. Myron Evans, has also been vigorously preparing and publishing papers in leading scientific journals and other publications[3] showing that EM energy from the vacuum is permissible, possible, and feasible.

In my three decades of work with multiple inventors of working prototype COP>1.0 electrical systems, I have been privileged to experience and work with several actual COP>1.0 circuits and prototype systems, study them, and slowly comprehend some of the advanced and unusual principles involved. In short, thanks to the courtesy and kindness of others, I have been able to gradually acquire at least an elementary understanding of the mechanisms which enable COP>1.0 EM power systems. With this background, one can understand why conventional EM systems and circuits do not develop COP>1.0 or self-powering, even though all the energy collected and used in every electrical power system comes from the vacuum and not from the shaft energy input to the generator, chemical energy dissipated in a battery, wind energy collected by a windmill (that just "feeds" the shaft of the generator), or from the water power dissipated in a hydro turbine (the hydro turbine also only turns the shaft of the generator, which does not actually furnish the power to the external power line connected to it).

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[3] E.g, *Modern Nonlinear Optics,* Second Edition, 3 Vols., edited by M. W. Evans, Wiley, 2001; M. W. Evans et al, "Derivation of 0(3) Electrodynamics from the Irreducible Representations of the Einstein Group," *Found. Phys. Lett.,* 15(2), Apr. 2002, p. 179-187; "Anti-Gravity Effects in the Sachs Theory of Electrodynamics," *Found. Phys. Lett.,* 14(6), Dec. 2001, p. 601-605; "Classical Electrodynamics Without **the Lorentz Condition: Extracting Energy** from the Vacuum," *Physica* ***Scripta,*** **61(5),** May 2000. p. 513-517; "Runaway Solutions of the Lehnert Equations: The **Possibility of Extracting Energy from the Vacuum,"** *Optik,* 111(9), 2000, p. 407-409.

It seems appropriate that other researchers should be able to start where 1 am now, understand what I have learned or think I have learned, find and correct any errors, and simply go forward with alacrity — much farther than I have been able to go, and much faster. This is particularly true of the young researchers who have excellent theoretical and experimental skills and a vigorous lifetime ahead of them. When an old and tiring runner falters with the baton, it is time to pass it on to the fresh young runners who can carry it to the successful end of the race.

The purpose of this book, then, is to lay out in some little detail what I have learned in all these years of sustained effort, but in such a way that it ties directly into good physics. In some cases, the tie-in to physics is unavoidably to a somewhat esoteric area such as the geometric phase and to time as a special form of energy. COP>1.0 EM systems are not simple, and they involve special phenomenology rarely encountered in conventional EM circuits and systems. COP>1.0 EM systems simultaneously involve a combination of particle physics, modern active vacuum theory, advanced materials science, higher group symmetry electrodynamics, quantum mechanics, and general relativity. They also involve areas where foundations of physics are presently in error. We found it necessary to think in terms of the *supersystem,* defined as having three components, which are (i) the physical power system itself, (ii) the active local vacuum, and (iii) the active local curvatures of spacetime. All three components of the supersystem interact and exchange energy with each other continuously. Any legitimate COP>1.0 power system must freely receive, collect, and use some excess energy from its active environment — in this case, the latter two components of its supersystem. By definition, this COP>1.0 function requires disequilibrium between the system and its active environment, so that classical equilibrium thermodynamics does not apply. Instead, the thermodynamics of systems far from **equilibrium** in **their** energetic exchange with an active environment applies.

However, since the "environmental energy" we are extracting is virtual photon energy from the vacuum and energy from local curved spacetime, the fundamental definitions of classical thermodynamics and classical electrodynamics have to be re-examined and altered. A closed system, e.g., can no longer be defined just as one closed to the transfer of mass across its boundary, but permitting energy to exchange across it. Since the advent of general relativity in 1915, we have known that energy and mass are the same thing. Whenever any system changes its energy, it also changes its mass by the well-known $E = mc^2$ rewritten as $dm = dE/(c^2)$. Further, in the fierce virtual particle exchange of the vacuum with every part of every system, both virtual mass and virtual energy continually cross the system boundary. Neither classical thermodynamics nor classical electrodynamics deals with the transduction of time-energy into spatial energy in a system, which is a totally different type of energy exchange accomplished by charge.

Further, certain phenomenological areas — such as strong gradients — are already well known to violate present thermodynamics. These are presently being researched under the aegis of *extended nonreversible thermodynamics.* Finally, as the present laws of classical thermodynamics are stated in the textbooks, *every charge and dipole in the universe already violates those laws, and has done so since the beginning of the universe.* Let us put it bluntly: Every charge in the universe already freely and continuously pours out EM energy in 3-space in all directions, without any observable EM energy input. That is the well-concealed *source charge problem,* known but ignored by the leaders of the scientific community for. a century. *All* EM fields and potentials and their energy come from those source charges, according to electrodynamics itself. Either we must give up the conservation of energy law entirely, or else we must accept the fact that unobservable *virtual* EM mass and energy are continuously absorbed

The vacuum by the source charge, transduced into real observable EM energy, and then re-radiated in 3-space in all directions as observable EM energy, creating the associated fields and potentials reaching out across the universe. That this problem continues to be ignored by the scientific community — some 45 years after the basis for its solution has been proven and is well known in particle physics — is totally inexplicable. But it continues to be resoundingly ignored, which means that *the scientific community itself is and remains totally responsible for the energy crisis and the associated vast desp**oilment of the** biosphere, because it adamantly* *insists on using a seriously flawed electrical energy science whose hoary basis is more than a century old.*

Accordingly, we have simply extended the first law of thermodynamics appropriately, pointed out that the second law does not apply absolutely but only as an approximation when conditions are appropriate, and revised the third law and the zeroth law. In this book we simply show the results of that revision, particularly in Appendix A.

We were also able to trace the history of electrodynamics, and to find exactly how the permissible Maxwellian systems far from equilibrium with an external active environment — which are included in Maxwell's 1865 seminal theory and even in Heaviside's vector truncation later — were arbitrarily discarded by Lorentz with his symmetrical regauging of the Maxwell-Heaviside equations. The purpose of such arbitrary regauging was and is to provide simpler equations that can usually be solved analytically without resorting to numerical methods. In the name of mathematical simplicity and ease, that entire great class of Maxwellian systems far from thermodynamic equilibrium in their supersystem was just arbitrarily discarded. Those Maxwellian systems are still arbitrarily discarded in every electrical power-engineering textbook today.

So the first requirement for a COP>1.0 EM system becomes *building-in a mechanism to violate the Lorentz symmetry condition, at least for a significant fraction of the time.* Further, the standard closed current loop circuit — including the entire external circuit in the same closed current loop as the source dipole inside the generator is what already *self-enforces* the Lorentz symmetry condition. Consequently, in any legitimate COP>1.0 electrical system, the operation of that closed current loop circuit must be violated for some portion of the system's operation. This of course places the system in disequilibrium with its active supersystem environment, allowing intake of extra energy from the environment and therefore permitting COP>1.0. So one of the immediate requirements in COP>1.0 electrical systems research is to seek out and find known or suspected mechanisms that accomplish just such violation of the Lorentz symmetry condition. In the book, I show a sampling of the various mechanisms I found other inventors using or that I uncovered myself, or that already exist in physics.

Finally, we discovered (and found the basis for it was shown in the hard literature in Heaviside's original work) that every generator and battery as an energy transducer already extracts from the vacuum and outputs from its terminals a far greater *nondiverged* energy flow than is accounted in the

Poynting diverged energy flow theory (which captures only that small **fraction that** is **diverged** into the circuit and captured by it). The total output energy flow from the terminals of a generator is also far greater than the mechanical energy input to the shaft of the generator. So in its *energy transduction* function, every dipolar electrical circuit ever built is already a "free energy circuit" and a COP >>1.0 system, extracting its utilized electrical energy from the vacuum and extracting additional energy also. But presently the electrical power system is unwittingly designed and constructed by engineers to deliberately destroy the source of that enormous energy flow from the vacuum faster than the system can use some of it to power its load. Wryly put, that does not seem to be the proper way to build energy systems or "run an energy railroad," even though it's always been done that way.

This led to recognition of a great scientific faux pas, perhaps the greatest in history. One must keep one's sense of humor! So with tongue in cheek, let us state it this way: *There is not now, and there never has been, a single electrical engineering department, electrical engineering professor, or electrical engineering textbook that teaches what powers an electrical circuit. Yet the basis for it has clearly been in particle physics since 1957, as certified by the award of the Nobel Prize to Lee and Yang. What powers every electrical circuit and system is the broken symmetry of the primary power system's source charges and source dipole (i. e., the broken symmetry of the opposite charges on the ends of the dipole) in its fierce energy exchange with the seething vacuum, once that dipole has been made. The modern "charge " is also a dipolarity, once its associated clustering virtual charges of opposite sign are considered. Further, any dipole will freely extract EM energy from the vacuum, convert it into real, usable, observable EM energy, and pour out real, usable EM energy continuously and indefinitely, so long as the dipole remains intact.*

The external circuit attached to a generator is not powered by the mechanical energy that is input to the generator shaft. The external circuit attached to a battery is not powered by the chemical energy expended by the battery. Astonishingly, every electrical power system and electrical circuit ever built, and every one built today, was and is powered by energy extracted and transduced directly from the active vacuum by the broken symmetry of the opposite charges on the ends of the source dipole (or a charge considered as a modern dipolarity), once that dipole is formed. A Nobel Prize was awarded to Lee and Yang in 1957 for the prediction of broken symmetry (strongly in 1956). Wu and her colleagues proved it **experimentally** in early 1957. So revolutionary a change in physics was that startling discovery of broken symmetry, that — in a nearly unparalleled action — the Nobel Committee awarded the Nobel Prize the same year, December 1957, to Lee and Yang. *One of the broken symmetries proven was that of opposite charges such as are on the opposite ends of every dipole, or such as constitute a classical "isolated charge" when the charge and its clustering virtual charges of opposite sign are considered as in modern physics theory. Rigorously, every source dipole is continuously extracting EM energy from the vacuum and pouring it out of the "terminals" of the dipole in all directions in 3-space. And so is every charge as well.* That the leaders of the scientific community continue to ignore this solidly proven fact is astonishing. But they do.

We also came to realize that the great Gabriel Kron, who was never allowed to reveal the secret of his *open path,* had in fact discovered the precursor of that very broken symmetry of opposite charges (of dipolarity). His open path is simply the recognition that any two points in the universe, that are at differing potentials and therefore can be considered as a dipolarity of opposite charges, acts as a source dipole that already extracts virtual photon energy from the vacuum, transduces it into real, observable photon energy, and pours out that energy in all directions. In reaching that understanding, he had applied general relativity to rotating electrical machines, simulated various forms of electromagnetics equations, and dealt deeply with quantum mechanics and the Schrodinger equation.

Sadly, the electrodynamics model used in electrical power engineering still does not even model the active vacuum, *much less* a broken symmetry in the virtual photon exchange between that active vacuum and all the charges in every electrical system. The electrical engineering model does not model the *supersystem,* hence cannot be used to design and produce COP>1.0 systems. *A priori,* that seriously truncated and crippled model arbitrarily discards all permissible Maxwellian systems far from thermodynamic equilibrium (i.e., with broken symmetry) in their vacuum flux exchange. And those are precisely the systems that are permitted to perform the five magic functions of great interest to the COP>1.0 energy researcher. Such a disequilibrium system can permissibly (i) self-order, (ii) self-rotate or self-oscillate, (iii) output more energy than the operator inputs (the excess energy is freely received from the active environment), (iv) power itself and its load simultaneously (all the energy is freely received from the active environment), and (v) exhibit negentropy. *Every charge and dipole in the universe already performs all five magic functions.*

It is **the purpose** of this book **to** clearly show that all EM systems are already powered by vacuum energy, and always have been. We cite the references and experimental proof that this is true, and the interested reader can check the extensive references himself or herself. The intent is to show that only a part of what has been discovered and is already known in particle physics is presently included in the woefully inadequate and ancient electrical power-engineering model. And frankly, unless there is a groundswell from the bottom of the scientific community, the leadership of the scientific community has no intention whatsoever of funding or allowing significant research in extracting copious EM energy from the vacuum (very simple) and learning to use it effectively (more difficult). A single 200 million dollars of good research in EM energy from the vacuum would solve the energy crisis forever, and dramatically reduce the pollution of the biosphere. The scientific community will spend many times that amount on their favored "big science" projects, but not one cent on EM energy systems powered by energy extracted from the vacuum.

Also, we show a sampling of the present work ongoing in inertial propulsion and antigravity research. Working with Sweet, in the 1980s I designed and Sweet performed a highly successful antigravity experiment.[4] I share with the reader the concepts and theoretical basis for that experiment, why it worked and how it worked, and the excellent results achieved. One of the tragic losses to science was the loss of the Sweet COP»1.0 vacuum triode amplifier (VTA) system with the death of Floyd Sweet. Nonetheless, we apply the mechanism we conceived so long ago to propose a mechanism generating the antigravity recently confirmed to be accelerating the expansion of the universe. We offer the long-neglected, Lorentz-discarded giant nondiverged Heaviside energy flow component accompanying every field-charge interaction as the probable generatrix of the excess gravity holding the arms of the spiral galaxies together. And we offer that same component — when connected with a flow of *negative* EM energy and with *negative energy* EM fields and potentials — as the specific generatrix of the excess antigravity that is accelerating the expansion of the universe. Both theses are testable on the laboratory bench.

Our target audience is several fold. Even though presented conceptually, the material is not oversimplified, and it is targeted at (i) the sharp young grad students and post-docs interested in extended (higher group internal symmetry) electrodynamics and in researching and developing COP>1.0 electrical power systems, (ii) the forward-looking electrical engineering professors who will at least consider that extended electrodynamic models and the laws of nature do permit COP>1.0 electrical power systems, and (iii) the still open-minded leaders of the scientific community, such as the National Academy of Sciences, National Science Foundation, the U.S. Department of Energy, the great national laboratories, etc. In *one area* of physics much better models of electrodynamics enabling COP>1.0 power systems, antigravity, and novel propulsion systems already exist (and a few such systems *experimentally* exist in the hands of independent inventors as well), while in a *second area* of physics that part of electrodynamics dealing with permissible COP>1.0 EM systems and unified field theory has been arbitrarily excluded at great cost to society, to the environment, and a tragedy to science and technology. Additional secondary targets are (iv) governmental leaders responsible for advanced research and development planning and funding, to argue that the "energy crisis" is a direct result of an inexplicable and sustained shortfall in the scientific mindset, and not as a result of the laws of nature and the need for cheap oil, coal, and gas or nuclear power plants, (v) science writers, journalists, and entrepreneurs to sensitize them to (hopefully) a coming energy revolution of unparalleled proportion, (vi) strategic and tactical planners in our Department of Defense to make them aware that the great logistics burden of modern highly maneuverable armed forces can and will be dramatically lowered by rapidly developing and using self-powering power systems "fueled" directly by the local active vacuum, and by adapting novel new propulsion methods, (vii) theoretical and experimental physicists to make them aware that the easiest thing in the world is to extract copious EM energy freely from the vacuum; just pay *once* to make a little dipole or assemble a charge and do not let it be destroyed, (viii) the Department of Energy upper level managers to bring into their awareness the coming advent of (and terrible need for) self-powering decentralized EM power systems worldwide, and the pressing need for a major role to be played by the DoE, (ix) the struggling but serious COP>1.0 researchers and inventors, to give them a technical overview — rather than just anecdotal material — of much of what has been done, tried, and conceived, and what seems to be successful and what is still to be determined, (x) the environmentalists devoted to cleaning up the biosphere and saving this precious planet, to make them aware that the answer to the world's energy problems and saving the biosphere cannot come to them from their conventional scientific consultants, who are trained in applying the very scientific disciplines responsible for the problem in the first place, and (xi) **the long suffering undeveloped** and impoverished nations and peoples of the earth. Our fervent message is one of hope after all, *once a* ***change*** *occurs in the scientific mindset.* There is a cheaper, cleaner, and better way to get their economies and nalional infrastructures up and running, and it is imminently doable.

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[4] Floyd Sweet and T. **E. Bearden,** "Utilizing Scalar Electromagnetics to Tap Vacuum Energy," *Proc 26th Intersoc.* ***Energy Conversion*** *Eng. Conf. (IECEC '91),* Boston, Massachussets, 1991, p. 370-375.

The main message of this book is that there is not now and there never has been an *electrical energy availability* problem. Every large centralized power generator actually outputs enough EM energy flow, extracted directly from the seething vacuum, to power all electrical loads on earth, if all the energy pouring from its terminals were caught and utilized. However, there is certainly an *EM energy flow interception* problem, to get more of the available energy flow from a source dipole intercepted and diverged into the circuit in a manner not complying with the Lorentz symmetrical regauging condition. Also, once the excess energy has entered the circuit and been collected, there certainly is a problem in *using the intercepted and collected energy in the circuit without destroying that part of the generator or battery — the source dipole — that is actually extracting all the energy from the vacuum.* Or at least to use the circuit's collected energy in such fashion as to destroy the source dipole in the generator *slower* than the energy is used to power the external load.

That conglomerate of the two sub problems — the "energy flow *interception, collection, and usage* problem — is the single energy problem. There is no other energy problem, and there has never been any other. One finds it very ironic that, in the conventional agencies, universities, the DoE, the National Science Foundation, the National Academy of Sciences, the national laboratories, etc., not one of them is working on the real, solitary electrical energy problem, even though they are importantly spending billions of dollars purporting to do so.

We fervently hope that the content of the book will reach a sufficiently interested audience to begin to change that century-old erroneous scientific mindset. We hope that the book, along with the important contributions of other COP>1.0 inventors and researchers having success, will spark a new creative drive in the scientific spirit that solves the problem of cheap, clean energy in three years or less. This is a doable. I firmly believe in the scientific method and what it can do once it is unleashed from the century-old dogma that COP>1.0 systems are against the laws of nature, physics, and thermodynamics. Just turn the young scientific and engineering tigers loose on the problem, give them some funding, and watch them do it.

As we stated in a formal rebuttal to a charge of perpetual motion nonsense, it only takes one white crow to prove that not all crows are black. And with respect to COP>1.0 EM systems far from thermodynamic equilibrium with their active environment, every charge and dipole in the universe is already a "white crow" pouring out EM energy freely and continuously with the speed of light, and exhibiting COP = ∞. This is in fact reluctantly recognized in physics, but it has essentially been buried from the attention and knowledge of generations of electrical engineers and most physicists.

A COP>1.0 experiment well known to nonlinear optics is the Bohren-type experiment, demonstrating the known negative resonance absorption of the medium. A typical experiment of that type outputs some 18 times as much EM energy as the experimenter inputs by standard calculations. We note that a single replicable experiment can and does negate any theoretical model that contradicts it. Hundreds of such materials experiments proving the feasibility of COP>1.0 EM systems are performed every year in any major nonlinear optics laboratory without a second thought. Together with the known but avoided source charge problem and proven broken symmetry of any dipolarity, it is almost unthinkable that our electrical engineering departments still do not incorporate the active vacuum exchange — and every EM circuit's broken symmetry in it — into the classical electrodynamic model used. In short, to really understand what powers every EM circuit, just now the electrical engineer would have to go across campus to the particle physics department and investigate broken symmetry of opposite charges — as are on the ends of the source dipole, once created in the generator or the battery, or as are involved with the single "isolated charge" considered with its associated virtual charges of opposite sign.

It is high time that our electrical power engineers and scientists heed the message of all these demonstrated white crows of nature, and begin developing and deploying self-powering COP>1.0 electrical power systems with alacrity.

We have a biosphere, a planet, a strong world economy, and an uplifting for the long downtrodden poor people of the world to recover. We strongly urge the scientific community to accept the challenge and meet it head-on.

Tom Bearden

22 July 2002.

Chapter 1

Foundations and Scientific Mindset

> *"...the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the eternally problematic character of his concepts. He uses this conceptual material, or, speaking more exactly, these conceptual tools of thought, as something obviously, immutably given; something having an objective value of truth which is hardly even, and in any case not seriously, to be doubted. ...in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them."* [Albert Einstein]{1}

1.1 Introduction

Einstein's quote is a beautiful statement that scientists should never take the present understanding — and the present models — as absolute. That is the approach the present author has taken for some 30 years, in a struggle to comprehend that class of electromagnetic (EM) systems that are open systems in disequilibrium in their *virtual photon energy exchange* with the active vacuum, and exhibiting a broken symmetry in that exchange. The statement beautifully expresses that the major problems encountered in grappling with such EM systems have been the existing errors and non-sequiturs in classical electrodynamics and other parts of physics. Many difficulties have resulted from the continued propagation of a 137-year old classical electrodynamics model formed before electrons, atoms, nuclei, positrons, the active vacuum, special and general relativity, quantum mechanics, etc. were discovered or known.

1.1.1 EM Foundations Are Incomplete and Contain Errors

In any model, there are many assumptions. Even when a model is well-fitted and well-developed, it still applies only when the foundations assumptions on which it is based are true or are not too much in error. Whenever one or more of the fundamental assumptions is violated by phenomena uncovered, then there is a new class of phenomena where the model does not hold, or does not hold well and is only an approximation at best. In that case, either the existing unsatisfactory model must be improved and advanced, or a new model must be constructed.

Great scientific minds continue to point out Einstein's beautiful principle in different words. E.g., expressing the thought of Stephen Hawking, one of the great physicists of our day:

> *"All we ever know is our models, but never the reality that may or may not exist behind the models and casts its shadow upon us who are embedded inside it. We imagine and intuit, then point the finger and wait to see which suspect for truth turns and runs. Our models may get closer and closer, but we will never reach direct perception of reality's thing-in-itself.*" [As stated by George Zebrowski] {2}.

Excellent scientists — Feynman, Wheeler, Bunge, Evans, Barrett, and many others — have indeed pointed out that classical EM theory is seriously flawed. In the words of Bunge {3}:

> *"...it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state."*

The author also found it imperative to return to many of the original seminal papers of physics, particularly in electrodynamics. The major concepts in those papers led to the present classical EM model. This was particularly true of the work of Poynting {4a, 4b} and Heaviside {5a-5c}, who independently and simultaneously arrived at the notion of the flow of EM energy through space[5]. Their work occurred in the 1880s, after Maxwell was already deceased. It also necessitated reviewing Lorentz symmetrical regauging of the Maxwell-Heaviside equations, where Lorentz arbitrarily discarded all permissible COP>1.0 Maxwellian systems.

The science of this "EM energy flow through space" is controversial to this day. Which is the real "EM energy flow vector" as such has never been adequately resolved, and there continue to be polite debates about it {6}. One should also be aware that physicists really do not know what many things — including energy — *are*. The definitions of these fundamentals are still uncertain, as stated rather poignantly by Feynman {7} in this quote:

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[5] As we shall point out later, the concept of energy flowing through 3-space is a non sequitur and requires substantial revision today, to be consistent with the nature of observation and the fact that no observable continuously persists. Any observation is an instantaneous frozen 3-space "snapshot" at a single instant, gone the next instant when almost immediately replaced by another such frozen snapshot. In between observations, not mass but *masstime* exists. The same is true for 3-space, which only exists as the output of an observation process. Prior to observation, *spacetime* exists.

> *"It is important to realize that in physics today, we have no knowledge of what energy is."*

As another fundamental example, Feynman {8} also pointed out that we really do not know what *force* is[6] either! Quoting:

> "*One of the most important characteristics of force is that it has a material origin, and this is not just a definition. ... If you insist upon a precise definition of force, you will never get it!"*

1.1.2 Physics Is Not the Mathematics, But What It Manipulates
Following Feynman's ansatz, one should realize that the physics is not really in the mathematics itself, but in the physical meaning of the concepts that the mathematics manipulates. Here again, the inimitable Feynman {9} cautioned against over-attachment to the mathematics itself. He said it very clearly:

> *"Mathematicians or people who have very mathematical minds, are often led astray when "studying" physics because they lose sight of the physics. They say: "Look, these differential equations – the Maxwell equations – are all there is to electrodynamics it is admitted by the physicists that there is nothing which is not contained in the equations. The equations are complicated, but after all they are only mathematical equations and if I understand them mathematically inside out, I will*

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[6] The problem is the ubiquitous and erroneous use of a "separate" force acting on a "separate" mass. Actually mass is a *component* of force, as can be seen from F ∑d/dt(mv). Hence there is no such thing as a separate force in empty space, acting upon a mass. Instead, the massless 4-field in space acts upon mass to produce force *in that interaction*. Force is not a cause, but an effect of an ongoing interaction — as is any observable. An observable is a continuing series of frozen 3-space LLL snapshot entities given by the result of continual application of ∈/∈t (LLLT) ♥ LLL by photon emission. The formation of the LLLT (spacetime and masstime) in between observed m as LLL, is produced by photon absorption of the previous m = ∈/∈t (LLLT).

> *understand the physics inside out." Only it doesn't work that way. Mathematicians who study physics with that point of view – and there have been many of them – usually make little contribution to physics and, in fact, little to mathematics. They fail because the actual physical situations in the real world are so complicated that it is necessary to have a much broader understanding of the equations."*

Such matters and similar thoughts had bothered me even back in the early 1950s, when I could not find a single professor or dictionary of physics that *logically* defined a field or a potential. Considered rigorously, the definitions all fell apart and violated elementary logic. Improper, insufficient, or just plain *wrong* definitions in physics have continued and are still widespread to this day. To give a single example from an excellent book by Kraus {10}: On p. 60, Kraus gives the formula for a potential referred to as the "absolute potential" of a charge source. Quoting:

> *"This potential… is, by definition, the work per coulomb required to bring a positive test charge from infinity to the point r_1."*

Kraus erroneously "defines" the scalar potential identically as work, which is equating the cause with the effect. The work that dissipating a potential does or can do, is not the potential itself! Else "human" means nothing but how well one can chew one's food or drive an automobile. Actually, Kraus gives one theoretical way to measure or calculate the effect of the potential's *local intensity at a point.*[7] Note that what is measured is the energy *diverted from* the potential at that point, around that test charge. This does not specify the *entity* (the potential itself) at all, but only what has been diverted from it. It is rather like confusing the whirlpool (water diverged from the normal river flow) in a river as being the river itself.

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[7] To show the non sequitur, a million more positive test point charges could be brought from infinity to that same point, and the potential — without any change in it — would cause the same amount of work to be done upon each of those charges. As can be seen, even noted professors can speak rather casually when they "define" the potential's point intensity as "the" potential (which extends over all space, not just at that one point). There may be different intensities at different points in the potential, but the potential itself remains one-and-the-same thing regardless of which one or all of the point intensities are discussed. And neither the point intensity of the potential nor the potential is the work that is done upon a moving charge by that potential or its intensity.

Integrating what has been diverted from it does not yield the potential itself! At best, the measurement gives an indication of the *intensity* of the potential at a point, insofar as its reaction with charge is concerned. More rigorously, what is being utilized is the potential's reaction cross section presented to a *unit point static charge* at that point. The same unit point charge, if placed in particle resonance, will sweep out more geometrical area and exhibit a greater reaction cross section. That will increase the energy collected divergence of the energy flow that is being moved around the particle itself. By normal calculations, the resonant charge may collect some 18 times as much energy as is possible at the same point by the same charge in static mode — e.g., as shown by Bohren {24, 25}.

A definition must present an identity. Examining the proposed definition as "the potential is identically … work" one sees the problem immediately. *The potential exists whether or not there is a positive test charge, or whether one moves such a charge in from infinity or not, and whether there is any work done or not.* None of that is what a potential *identically is*, but only one aspect of what it *does* or *can do* or *can cause.* One leaves as an exercise for the reader the task of further examining dictionaries of physics and textbooks, to try to find a satisfactory definition of that common scalar potential.[8] We do not believe the reader will find it.

Yet any good textbook will also contain some real gems of great insight, simply said. As an example from Serway {11}, we eventually took a most marvelous cue, of how to get around classical thermodynamics' prohibition against heat energy "running uphill" from hot to cold. In an insightful statement, Serway said {11}:

> *"The second law [of thermodynamics] does not rule out the possibility of pushing heat uphill, as it were, from a cold object to a hot one, or of creating order out of*

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[8] The scalar potential identically is actually a harmonic set of phase conjugate longitudinal EM wavepairs, as shown by E. T. Whittaker in 1903 {85}. Even Whittaker, however, misinterpreted his wavepairs only after interaction with that ubiquitous unit point charge assumed at every point in space. He gave two *effects* of that interaction, not the *cause* (which exists prior to interaction) *and the effect* (which exists only after interaction). Reinterpreting to get at the causal wave, each wavepair is a matched set of two waves; an incoming EM longitudinal wave in the time domain prior to interaction with a charge, and — after the time-energy wave is absorbed by the charge, an emitted outgoing EM longitudinal EM wave in 3-space. The so-called "static" potential is not static at all, but is a dynamic, ongoing 4-space process. This follows the re-interpretation by the present author {12} of Whittaker's decomposition — a reinterpretation then found to be consistent with quantum field theory {19} and with broken symmetry of opposite charges in particle physics {73}.

> *disorder. It merely states that such a reversal of the natural flow requires an influx of energy…"*

This essentially states the *law of entropy*, where to reverse entropy (disorder), one must apply ordering (energy).[9] We also note that the original concept of entropy was as *dissipation of potential*. There are of course different ways to apply the energy, and it need not be by the operator himself. Chapters 4, 5, 6, 7, and 8 of the present book give some unusual ways. A special paper {12} published by the author in 2000 gives another. Indeed, when the flow of time is predominantly reversed, so is the "entropy" of a situation, since the "videotape is running backward", so to speak. In that case, the entire classical thermodynamics must be extended to essentially include its own opposite. The making of a small time-reversal zone where such things happen is as simple as involving a predominance of antiphoton interactions with the charged particles in that zone, rather than a predominance of photon interactions. What we are saying is that the notion of irreversibility in thermodynamics is not necessarily absolute. It usually assumes a "time forward" situation, and may not hold in a "time-reversed" situation. In our chapter on cold fusion, we will present some specific and quite startling nuclear interactions that occur as a result of the time reversal of the coulomb barrier (repulsion of like charges in a forward time situation) into a coulomb attraction between like charges in a time-reversal zone and time-reversed situation.

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[9] Now notice what Serway's statement means with respect to the classical thermodynamics "definition" of closed system. Thermodynamics defines a *closed system* as one in which mass is not exchanged across its boundary, but energy can be. That definition permits a closed system to receive excess energy from its active environment, and thereby reduce its entropy. A specific example is simply potentializing a circuit, prior to movement of the current. Hence the entropy of a closed system does not necessarily increase, but may decrease or increase if the system is in disequilibrium (difference in energy received from its active environment and energy escaping back to the active environment from the system. For the same system, if energy exchanges across its boundary equally in both directions, the system is said to be in "equilibrium" with respect to external energy exchange. One must be very careful in interpretation of the second law of thermodynamics! One has a very different "closed thermodynamic system" when it is in *energy exchange disequilibrium*, than when it is in *energy exchange equilibrium*. Equilibrium is the condition of maximum entropy. For substantial disequilibrium condition, entropy cannot be computed, but is less than the entropy of the same system in equilibrium. The entire ansatz of thermodynamics may be violated once time-energy is transduced into internal EM energy inside the system. That is a fundamental disequilibrium, performed by every charge in the universe. Hence of necessity we have advanced and utilized new definitions of "open system" and "closed system" in our approach in this book, as discussed in the Appendix.

If Serway's statement were reversed, it would then be a statement of the *law of negentropy*. It would state that self-ordering (i.e., freely receiving energy from the active environment) in a system could indeed "push heat uphill from a cold object to a hot one", and the system could simultaneously emit energy in the process. Every charge does it!

We did find it necessary to correct the classical thermodynamic definitions of "open system" and "closed system". To define a closed system as closed only to mass transfer, but open to energy transfer, is a gross non sequitur. Since general relativity was published in 1915, energy and mass are known to be the same thing (*mass is just a special form of energy*), hence the term "mass-energy" (mass as energy) in physics. Whenever energy crosses the boundary of a system, the system's mass changes and mass (or certainly mass change) has also crossed that boundary. Indeed, as we shall point out, in 1917 Hilbert specifically pointed out that in general relativity there can be no energy conservation equations of the kind usually employed elsewhere. The fact that general relativity falsifies much of the present foundations of classical thermodynamics seems to have been either ignored or missed by most of the scientific community, although we will quote leading Russian scientists who have noticed it and are aware of it.

The reader is thus warned that, henceforth, when we use "open system" we mean one where either energy or mass or both exchanges across the system boundary. When we use "closed system" we mean one in which *neither* energy nor mass exchanges across the boundary. In short, the notion of a "closed system" has been redefined into what classical thermodynamics calls an "isolated system". We already know from particle physics and the active vacuum (and from general relativity and the change of spacetime curvature with every change of spatial energy or mass-energy), and from the giant negentropy involving time energy transduced into 3-space energy and vice versa, that there is no such thing in all the universe as a truly closed system.

In Appendix A, we have discussed how extension and change to classical thermodynamics must be made. We do this by extending the first law, refuting any absoluteness of the second law and third law, dealing with the zeroth law in a new way, etc. We also urge the better theoreticians to re-examine classical thermodynamics along such lines, to modernize and upgrade it. We believe that the present scientific work to extend thermodynamics so it fits those situations now known to violate it should include additional considerations such as we present in Appendix A.

In short, with the new definitions Serway clearly states the difference between classical equilibrium thermodynamics, where no excess energy from the environment is received, and the thermodynamics of systems far from equilibrium with their active environment (using the new definition of open system for clarity), in which case excess net energy from the environment can be received and used in electromagnetic systems, providing COP>1.0 systems or even COP = ←systems. The windmill, sailboat, and waterwheel are age-old examples of disequilibrium systems where of course the energy of mass in motion is what is transduced. It is our objective in this book to point out the use of electromagnetic systems in energetic disequilibrium with their active environment (the active vacuum and curved spacetime) to provide just such negentropy.

1.1.3 Time Is Energy and Must Be Considered As Such

In a physics model, one's choice of fundamental units is arbitrary.[10] As an example, in one type of physics only a single fundamental unit — length — is employed. All other entities then become functions of length.

We are also free to choose the *joule* as the single fundamental unit in our physics model. The result that mass is a function of energy is now familiar and quite accepted, by the famous formula $E = mc^2$. Indeed, as can be seen, in that equation mass and energy are one and the same thing, since c^2 is a dimensionless constant. However, in our new model time becomes a function of energy similarly, and thus time is identically energy.

Let us perform a thought experiment. Suppose we take some spatial EM energy in 3-space, and compress it by the factor c^2. What can we do with it? If we leave it there in 3-space, it is known as "mass". If we place it on the fourth Minkowski axis *ict*, it is known as time because *t* is the only variable on that axis, and the only "place we can set it".

So to first order, *time has the same energy density as mass*. Multiplying an amount of time t (in seconds) by c^2 gives the decompressed spatial energy E that the time t will transduce into. In short, $E = tc^2$ also.

Now we notice what special relativity has to say about the relationship between time-energy and mass-energy. When the mass-energy increases

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[10] E.g., see Jackson, *Classical Electrodynamics*, 2nd Edition, Wiley, 1975, p. 811-812; *ibid.*, 3rd Edition, 1998, p. 775. Jackson wryly remarks on how much excess heat and passion have been unnecessarily expended on that subject.

(e.g., as a function of velocity), time "dilates" or “decreases”. In other words (hint), there is a sort of special new extension to the conservation of energy law: If mass (3-space) gains some 3-spatial energy, then time loses some time-energy. Since time is spatial EM energy compacted by c^2, then *the relativistic energy changes in the time domain are enormously greater than the corresponding relativistic changes in spatial energy in the photon*. To the external 3-space observer, this is the injection of negentropy with respect to the present 3-spatial conservation of energy law. In the reverse case (as when the object reduces its velocity), if mass (3-space) loses some energy, then time gains some time because the time dilation reduces — i.e., time contracts or densifies (less time has more energy). To the observer, this is the production of entropy with regard to 3-space energy conservation. Yet the observer misses the fact that, accompanying entropy in 3-space is negentropy in time energy on the 4th Minkowski axis, and vice versa.

We believe this to be a rather dramatic extension to the previous concept of entropy in thermodynamics. We get 3-space entropy in physical processes only by gaining 4th dimensional negentropy accordingly. One can thus appreciate the impact upon the entire subject of thermodynamics, once time-energy is accounted and the new interplay of entropy and negentropy are accounted. We believe that this mechanism may involve the fundamental mechanism for both entropy and negentropy. Neither is produced alone; both are always produced in tandem. This of course is not what we “observe” since all observation is 3-spatial. Hence to observe the system and see 3-space entropy or negentropy is to hide the simultaneous 4th dimensional negentropy or entropy that unobservably accompanied the observable that we did see.

Again we call attention to the original meaning of entropy: the dissipation of potential (i.e., potential energy).

Once we understand that *time* is a special form of energy (we discuss this shortly), we may input the energy required to "move heat energy backwards" — i.e., we may directly engineer negentropy — by transducing some time-energy into 3-spatial energy. We can do it easily by time reversal, and every charge in the universe does it already. On the other hand, we can do it by breaking the symmetry of time-energy flow — which is as simple as forming a little dipole. The broken symmetry of unlike charges — and therefore the dipole — was discovered by Lee and Yang {13a-13c}, who strongly predicted it in 1956. Wu *et al.* {14} confirmed it experimentally in early 1957. This was such a revolutionary change to physics that Lee and Yang were awarded the Nobel Prize in the same year, 1957 — an almost unprecedented action.

Its broken symmetry tells us that the dipole's unlike charges continuously absorb virtual photon energy from the active vacuum, transduce it into real observable energy, and pour out real, observable EM energy in all directions in 3-space. That puts an entirely different perspective on *what really powers every dipolar EM circuit; i.e., what produces the flow of energy pouring from the terminals of every generator and battery, filling all space around the external circuit and its conductors*. The EM energy pouring from the generator or the battery is not due to the generator outputting some of its own available internal energy (from the shaft energy input to the generator, transduced into magnetic field energy inside the generator, and then dissipated to separate the charges and form the source dipole between the generator terminals) or the battery transducing and outputting some of its available chemical energy (which is only dissipated inside the battery to separate the internal charges and form the source dipole between the battery terminals). We will explain that later, and explain how any dipole or charge simply pours out real, observable energy continuously in all directions, without any *observable* input of energy. The input energy is there, but it is in *unobservable* (virtual) form.

In 1971 while a graduate student at the Georgia Institute of Technology, I realized the mechanism that generates the "passage of time" insofar as the observer is concerned {15}. With a little more work, this gave the clue in the 1990s for the mechanism generating little momentary *time-reversal zones* (TRZs) {16} in the electrolyte utilized in cold fusion experiments. Hence we proposed the use of little time-reversal zones forming momentarily in the electrolyte after loading of the palladium lattice of the electrodes with hydrogen or deuterium. Such time-reversal zones can form in the region of excessive positive charge accumulation, since positive charge can be said to receive negative EM energy from the time domain and output negative EM energy in 3-space.

This led to uncovering an entire class of new nuclear reactions — fusion reactions at low spatial energy but high temporal energy — in these little temporary time-reversal zones (TRZs), in which like charges attract and unlike charges repel {17}, followed by rapid decay of the TRZs where the normal law of attraction and repulsion is restored again.

In theory, a fermion cannot be time-reversed because the Pauli exclusion principle prohibits it. However, a boson can be time-reversed, so fermions can be time-reversed in pairs, where each pair acts as a *quasi*-boson. The

TRZ completely overcomes and *reverses* the "coulomb barrier" between a pair of like fermion charges.[11]

As an example, two deuterium ions in a little TRZ would momentarily form a quasi-nucleus of helium, since the two positive deuterons are attracted so closely that each enters the strong force region of the other. At the same time, the strong force is weakened by the partial time reversal of the gluon forces, so that the quarks are nearly freed. As the other ions in the surrounding solution then move to destroy the momentary time-reversal zone, their movement forces the TRZ to decay back to a time-forward zone — with the decay action starting from every point in spacetime inside the nucleons themselves[12]. The TRZ decay-induced action thus strikes the *nearly freed* quarks first, and decay can occur by easy quark flipping while the gluon forces are still much reduced and not back to normal strength. Hence as the gluon forces return toward normal, the quasi-nucleus decays by the strong force increasing and overpowering and drawing the quasi-nucleus into a full-blown helium ion — i.e., an alpha particle —flipping the partially-freed quarks as necessary to do so (that is not necessary in equation [1] below.

During decay of the TRZ, the weakened strong force grows much more rapidly than the Coulomb force zeroes and then increases. Consequently, the quasi-nucleus of two D+ ions merely draws together due to the rapidly increasing strong force, forming an alpha particle without quark flipping. Four H+ ions — four protons — in a quasi-nucleus in a TRZ will undergo quark flipping twice when the TRZ decays, thereby resulting in an alpha particle.). So that explained the anomalous formation of the alpha particles in the experiments. The interaction for two ions of deuterium is given by:

$$ {}^{2}H_{1}^{+} + {}^{2}H_{1}^{+} \Downarrow {}^{4}He_{2}^{++} \qquad [1] $$

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[11] In a TRZ, the law of attraction and repulsion of charged particles is reversed.

[12] Any moment in time exists everywhere simultaneously throughout the universe. In short, time is a multiple connection in 3-space. Hence in any time-reversal zone (a TRZ) where time is reversed, then starts fading away and back to a time-forward zone (TRZ), the changes induced by the "fading back to TFZ" *simultaneously* involve every point in the 3-space of that TRZ that is changing (decaying). An easy change is quark flipping, since the quarks are almost freed in the TRZ to begin with. The reason the reaction proceeds in that direction is that the recovery of the strong force is much faster than the restoring of normal electrical repulsion, hence the quasi-nucleus is drawn further together into a full nucleus, constituting a legitimate nuclear transmutation at low spatial energy but high time-energy.

This interaction between two deuterons in solution does not occur in a normal time-forward zone because of the coulomb barrier preventing the two deuterons from entering each other's strong force region and acting as a quasi-nucleus of helium, so particle physicists have missed it. It does exist in a time-reversal zone; such zones form and then decay back into normal time-forward zones. This is possible because the coulomb barrier is momentarily reversed. The use of such TRZs in particle physics opens up thousands of new nuclear reactions, all at low *3-spatial* energy, but involving very high *time*-energy. Because of the extreme energy density of time, *these time-energy-induced reactions are actually much higher-energy reactions than high-energy physicists presently consider and utilize!* Indeed, it opens up a new kind of far more energetic "high energy physics".

Cold fusion experimenters have unwittingly opened a window upon a vast new particle physics, previously overlooked by our scientists because they have disregarded the use of time-energy, time reversal zones, and transmutation of time-energy into 3-spatial energy in their nuclear reactions. However, a few physical theorists attempting to better explain particle physics have recognized the importance of the time domain, and probing work in that respect is occasionally done {18}. In our view, it is not accidental that more than 600 successful cold fusion experiments have been obtained, by a variety of researchers in many labs in several nations. We strongly suggest that much of the conventional physics community has firmly placed its collective head in the sand, and is refusing to grapple with the startling new time-energy physics that is being initiated by cold fusion research.

In 1999 (published in 2000) {12} we finally discovered a great new symmetry in EM energy flow, whereby time-energy flow symmetry and 3-space energy flow symmetry are each individually broken, while an overlooked and more fundamental 4-symmetry energy flow — between the time-domain and 3-space — is sustained. *The result is that all EM energy in 3-space comes from the time domain locally and returns to the time domain locally, in a giant negentropic circulation.*[13] Together by the discovery of relevant quantum field theory work by Mandl and Shaw {19}, this now lends strong support to the use of time-energy in physics as a practical matter for strenuous investigation.

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[13] This is also understandable from the implications of the observation process, which yields a frozen 3-space snapshot existing only at a single instant. Thus any 3-space energy existing there in that frozen instant, had to just come from 4-space (from the time-domain via the giant negentropy process, if we take the view that "the past exists only in time itself".). For the frozen snapshot to "change", time must be added to it, which converts it to a 4-space process again. So the "3-spatial" observed

As an example, Mandl and Shaw {19} treat the four polarizations of the photon. Neither the longitudinal nor the scalar photon is directly observable, but in the presence of charge the two are observable in combination, where they manifest as the "instantaneous" Coulomb (i.e., electrostatic) potential. This argument, translated from particle terminology to wave terminology, directly fits our re-interpretation {12} of Whittaker's 1903 decomposition of the scalar potential {85}. For the combining mechanism of the fields of the photons, we must account for *the field as a ubiquitously assumed interaction with the detecting/observing unit point charge*. Thus we must account for the absorption of the incoming time-polarized wave or photon, the transduction of that excitation energy of the charge into longitudinal EM wave/photon energy, and subsequent emission of that excitation energy in 3-space. That is what happens for a negative charge. For the positive charge, the process is time-reversed, hence occurs in opposite fashion. Or as an alternative, the positive charge can be said to continuously receive negative time-energy from the time domain and emit negative spatial EM energy.[14]

There is an *energy polarization transduction function* of charge, whereby it transforms received time-polarized photon energy into emitted longitudinal photon energy in 3-space (for the negative charge, and vice versa, for a time-reversed positive charge). This transduction appears to have been overlooked in physics prior to our recognition of it. It can in fact be used to generate an acceptable definition of charge itself. Charge is the

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energy must come from an immediately previous 4-space process, and must return to an immediately following 4-space process.

[14] As we will find in our chapter on antigravity, there is good reason to treat the positive charge as a source of negative energy and negative energy fields. However, this is pertinent only prior to observation of the charge, while it is still a 4-spatial unobserved negative energy electron entity. For the observable charge, one has already conjugated — after all, the positron is observed as if it were an electron going backwards in time, which we observe as an electron with its charge reversed and with parity reversal (of its spatial direction). For the observable charge, we have already reversed the negative energy fields into positive energy fields by simply reversing their direction and the time associated with the photon (quantum of the EM field).

continuously active entity which performs that ongoing process or those ongoing processes of energy transduction between the time domain and 3-space (between the causal unobserved 4-space process and the observed 3space snapshot). Or in other words, it is an active process connecting 4-space cause and 3-space effect, and connecting the unobserved (such as virtual) to the observed (such as mass).

So for a dipole, the "causal" time-polarized EM wave or photon as a 4-space entity comes to the dipole[15] (3-spatial as observed) and is absorbed by the detecting negative charge or dipole, then is re-emitted as the longitudinally polarized EM wave or photon in 3-space. *That absorption and remission is what charge does, since it is an entity for performing that process*. The emitted energy in turn is absorbed by the nearby positive charge, retransduced into time-energy, and re-emitted back to the time domain. This ongoing very special 4-space energy circulation (even with a virtual charge in the vacuum) is what a scalar potential *identically is and is doing*, at every spatial point of itself, inducing vacuum polarization and “point dipoles” in the virtual state in the process. Recognition of these missing functions allowed at last a solution to the long-vexing problem of the source charge and its associated fields and their energy, often called the most difficult problem in both quantum and classical electrodynamics {68}. We discuss that solution later.

1.1.4 The Search for COP>1.0 Circuits and Systems

A very long search and much intense study and reflection eventually revealed the concepts and principles of those long-neglected disequilibrium Maxwellian systems that permissibly output more energy than the operator inputs. The active environment — not the operator — simply inputs the rest of the energy. Such disequilibrium systems are indeed permitted in Maxwell's theory {20}, and are also still prescribed by Heaviside's severe curtailment of it {21} into what is two vector equations with variables unseparated, rather than Maxwell's 20 equations in 20 variables.

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[15] Prior to interaction of the incoming time-energy with the observable charge or dipole, it interacts with the virtual particles of the vacuum, generating vacuum polarization. Neither the virtual particles nor the time-energy are observable; only the effects of their conglomerate interactions with observable charges are observed. Hence one can take the particle view that virtual particle energy is continually absorbed, or one can also take a quantum field theory view that time-energy is continually absorbed. The two are always present in combination.

When Lorentz[16] symmetrically regauged the Maxwell-Heaviside equations, he arbitrarily discarded the entire class of Maxwellian systems that are far from equilibrium in their exchange with their active (vacuum) environment. Lorentz revised (symmetrically regauged) the Maxwell-Heaviside equations to make them amenable to separation of variables and closed analytical solutions, thus reducing the onerous chore of numerical methods. This Lorentz symmetrical regauging is given in most EM textbooks {22}, and we show it in Chapter 2. The symmetrically regauged Lorentz equations are not Maxwell's equations, nor are they the truncation of Maxwell's theory by Heaviside *et al*. Considering an active environment, under our altered thermodynamics definitions Lorentz implicitly selected and retained only the equilibrium class of Maxwellian systems, while *arbitrarily discarding* the entire disequilibrium class. He thus discarded all those Maxwellian systems permitted to produce COP lying in the range 1.0 < COP Ω←.

Maxwell's electrodynamics is a *material fluid flow theory* and it assumes a material ether. Anything that fluid systems can do, electrodynamics systems can do, at least in theory, because their mathematical models are the same form. So when one cites known examples of fluid-driven physical systems where the energy to run the system is freely furnished by the active environment, analogous electrodynamic systems in active environments — and in disequilibrium exchange with that environment — must also exist in nature. Indeed, particle physics requires it and proves it. These are the very systems arbitrarily discarded by Lorentz symmetrical regauging in every university.

So there exists a direct analogy between fluid systems and classical electromagnetic systems. The common windmill, waterwheel, and sailboat demonstrate by analogy that open EM systems far from equilibrium — powered by free EM "winds" and "energy flows" in the active vacuum environment — also exist in consonance with natural law. They are no more mysterious than a solar cell power system, which is after all a recognized "free energy" or "overunity" system, as is the humble charge (thought to be the source of all EM energy, fields, and potentials). In physics, the powering of systems by receipt and use of energy from their active environment leads directly to the thermodynamics of systems far from thermodynamic equilibrium in their energetic exchange with that active environment.

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[16] Actually first accomplished by Ludwig Valentin Lorenz in 1867, then by H. A. Lorentz much later. Lorentz was given the credit erroneously. Lorenz actually derived electromagnetic theory independently in his paper. See J. D. Jackson and L. B. Okun, "Historical roots of gauge invariance," *Rev. Mod. Phys*, Vol. 73, July 2001, p. 663-680.

It follows that the seeming absence of such *electrodynamic* systems arises not because they are impossible but because present-day circuits and systems are ubiquitously designed to self-enforce an inherent energy equilibrium with their active vacuum environment. The closed-current loop circuit turned out to be the Lorentz self-regauging demon involved in destroying the COP>1.0 capabilities of every EM circuit. So little by little, we unraveled the long tedious trail of Maxwell's electrodynamics and what had happened to those missing Maxwellian-Heaviside systems far from equilibrium with the active vacuum.

We learned how, where, and by whom those permissible overunity Maxwellian systems were discarded. That is, we found what happened to all those Maxwellian *open disequilibrium systems* — originally included in Maxwell's and Heaviside's theories — where such a system receiving and using excess energy from its active environment[17] is permitted by the laws of physics, electrodynamics, and thermodynamics to:

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[17] For the discerning reader, of necessity we have revised the foundations of the ancient classical thermodynamics, as further discussed in Appendix A. We refer the reader to Bimalendu N. Roy, *Fundamentals of Classical and Statistical Thermodynamics*, Wiley, New York, 2002, and to any good book on the history of thermodynamics. Also particularly good is Kondepudi and Prigogine, *Modern Thermodynamics: From Heat Engines to Dissipative Structures*, Wiley, Chichester, 1998, reprinted with corrections in 1999. The foundations of classical thermodynamics (and its fundamental definitions) were basically frozen prior to the advent of Maxwell's 1865 seminal theory, and well before the 1880s discovery (modeling) of the flow of EM force field energy through space. Some of the fundamental definitions of thermodynamics now will not withstand critical review in terms of "meshing" with the Heaviside/Poynting material fluid energy flow theory. Neither will they withstand the new concepts of energy such as mass-energy, time-energy and transduction between time-energy and spatial energy by every charge. E.g., thermodynamics defines an *open system* as one that exchanges energy and mass with its surroundings. Yet it defines a *closed system* as one closed only to mass exchange, not to energy exchange. *If the energy exchange is analogous to material energy flow and changes the mass of the system, then that definition of closed system is a non sequitur.* From general relativity, mass is simply energy anyway, and so "mass" exchanging across the boundary of the system is actually energy exchanging, and vice versa. Since Maxwell's theory is a *material fluid* theory, the Poynting and Heaviside energy flow models are *material fluid flow energy* models by analogy. The specialized thermodynamics definition of *closed system* rigorously will not logically allow the exchange of "material fluid energy flow" (or energy as matter)

since it prohibits matter flow, but the specialized definition of *open system* would and does. In short, with respect to material fluid energy flow, the concept of the "closed system" in thermodynamics has forced itself to become the *isolated system* instead, which is unacceptable since we must model EM energy flow exchange between the environment and the system. So we must change the thermodynamic definitions of *open system* and *closed system*. Else there cannot be any EM energy-mass or mass-energy flow between environment and system, which totally violates what is well known to be happening in all EM systems. In modern physics, every charge and every dipole already have such energy exchange with the active vacuum environment, and it is never zero; instead, it is of enormously high magnitude. Without that exchange, as we advance in this book, there cannot even be a "source charge" or associated EM fields and potentials and their energy, reaching across space. In other words, without it we can have no electrodynamics at all. So we have uncovered a fundamental and major contradiction between classical thermodynamics and general relativity, as well as between thermodynamics and the "material EM fluid energy flow" model used in electrodynamics. What classical thermodynamics calls a "closed system" permitting energy flow exchange, we must now logically regard as an *open* system because it is open to energy exchange across the boundary! The previous notion of the *isolated* system — with no exchange of either energy or mass — is what we must treat as a truly *closed system*. And there is none such in the universe, as we know in particle physics (e.g., because of the discovery of broken symmetry in 1957 and because of the well known active vacuum exchange with every EM charge and dipole). So we have corrected these direct contradictions between "EM as a material fluid energy flow theory" and the old classical thermodynamics.

As the reader will later see, this strongly affects our new definitions of *efficiency* and *coefficient of performance*. The new definitions we advance are rigorous, and they also apply to COP>1.0 EM systems, and even to self-powering (COP = ←) EM systems. They also hold for very novel new energy processes such as quantum potential energy in a multiply connected space, multiple retroreflections and re-use of the same energy, conversion between time energy and spatial energy, and 4-space giant negentropy energy flow circulation.

But one can no longer be allowed to equate *efficiency* with *coefficient of performance*. Now they are never the same thing, just as a six-foot tall man and a six-foot tall doorway are never the same thing, even though they have the same height magnitude. We warn the reader that a great deal of thought and study must be put into appreciating these suddenly encountered changes to the quite old classical thermodynamics definitions. The changes are absolutely necessary. Bluntly put, in light of much more modern knowledge, a rigorous foundations analysis reveals the classical thermodynamics as well as disequilibrium thermodynamics to contain logical contradictions, such as its direct contradiction with general relativity and the EM material fluid energy flow theory. Either we give up or dramatically change the present EM energy flow theory, or we must make the necessary foundations changes to thermodynamics. We have chosen the latter option in this book, and the reader is forewarned of that dramatic change. The specific changes and rationale are discussed in Appendix A.

(1) self-order,

(2) self-oscillate or self-rotate,

(3) output more energy than the operator inputs (the excess being freely received from the active environment),

(4) power itself and its load simultaneously (all the energy being freely received from the active environment), and

(5) exhibit negentropy.

We vigorously pursued those long-lost Maxwellian systems, and we eventually found them. We also found real experiments {23, 24, 25, 26, 27, 28} and real devices {29a, 30, 31, 32, 33, 34, 35a, 36a, 36b} that performed one or more of those fabulous five functions, though there was often no realization by the experimenters, inventors, and scientists of the actual mechanism involved. Eventually my colleagues and I were also able to produce a successful experimental device {37, 38a-38c, 39}, the motionless electromagnetic generator (MEG), which outputs more energy than we input to it. We cover the MEG in Chapter 7. Presently a cooperative research program is ongoing with the National Materials Science Laboratory of the National Academy of Sciences of a friendly foreign nation, to develop and market commercial power systems based on successful laboratory experiments with the MEG. At this writing, we are also strongly seeking the extensive funding required to set up a physics lab and complete the final research allowing production of power systems.

1.1.5 Additional Very Important Implications

We also formally proposed {40} that the vast nondiverged EM energy flow component — Heaviside's "dark" nondiverged energy flow component, accompanying every reaction of a charge with a field or a potential, but arbitrarily discarded by Lorentz and modern classical electrodynamicists — is the generatrix for the extra gravity holding the arms of the spiral galaxies together, after all the dark matter is accounted.[18]

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[18] Heaviside himself recognized the gravitational implications of his extra component of energy flow, which is in closed circular loops. Beneath the floorboards of his little garret apartment, years after his death, handwritten papers were found where Heaviside used this component for a unified EM approach to gravitation. See E. R. Laithwaite, "Oliver Heaviside – establishment shaker," *Electrical Review*, 211(16), Nov. 12, 1982, p. 44-45. Laithwaite felt that Heaviside's postulation that a flux of gravitational energy combines with the (**E**Δ**H**) electromagnetic energy flux, could shake the foundations of physics. Quoting from Laithwaite: *"Heaviside had*

In addition, my close colleague Bedini and I have filed a patent application upon a very special process to "freeze-frame and lock-in" a disequilibrium Maxwellian system in its otherwise far-from-equilibrium state, so the apparent disequilibrium operation of the system can be maintained stably as a new equilibrium condition. This appears to be a method to produce and utilize what Kondepudi and Prigogine refer to as a *nonequilibrium stationary state*. This stabilization is necessary in order for such a system to maintain its COP>1.0 excitation and steadily output more energy than the operator inputs, or to steadily power itself and its load {41}.

We also found that COP>>1.0 EM systems (and some COP>1.0 systems) produce (as a function of the COP) a current of Dirac sea holes (positrons) *in the local vacuum environment itself*, from the output section back to the input section. At COP<1.0 and COP not too greatly above 1.0, a Dirac sea hole in the vacuum almost immediately interacts with an orbital electron in the material lattice of the system. This converts the negative energy, negative mass "vacuum hole or state" into a lattice hole, which is attached to the large positive mass of the ion left by the disappearance of the electron. This "lattice positron" type of problem has been known in semiconductor design for some decades. Normal EM circuits do not usually meet the phenomenon overtly because the semiconductor designers controlled it in the semiconductors themselves by use of appropriate donors and acceptors.

There is a great difference between the actions of Dirac sea holes in the vacuum prior to observation, and lattice holes in materials (after observation). So there is a great difference between the action of a “positron” on spacetime before its interaction with mass and observation, and its action on spacetime after it interacts with mass and is observed.

For COP>>1.0, significant phenomenology and novel effects occur because a substantial fraction of the Dirac sea holes (unobserved positrons) sweeping from output to input do not convert to lattice holes (observed and bound positrons) along the way. For substantial values of COP above 1.0, Bedini's invention (patent application filed by Bedini and the present

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originally written the energy flow as $\mathbf{S} = (\mathbf{E}\Delta\mathbf{H}) + \mathbf{G}$*, where* **G** *is a circuital flux. Poynting had only written* $\mathbf{S} = (\mathbf{E}\Delta\mathbf{H})$*. Taking p to be the density of matter and* **e** *the intensity of a gravitational force, Heaviside found that the circuital flux G can be expressed as p***u** *4 c***e***, where* **u** *represents the velocity of p and c is a constant.”*

author)[19] covers the master process for intercepting and transducing this appreciable flow of negative energy from the output section back to the input. Otherwise, that flow — if not intercepted and not converted — will "eat" extra input electrons from the power supply, thus acting as a novel "extra load" appearing in the input section. That extra load then draws additional current and power from the external power supply by electron-hole annihilation[20].

With the Bedini invention, the negative energy (unobserved positron) flow appearing at the input section is transduced into a flow of positive energy (a flow of electron current) from the input section back into the system. The process deliberately uses the "interaction and observation" process to phase conjugate the charge and reverse its direction of flow! In that case, the otherwise detrimental *negative* energy output back through the COP>1.0 system (which is nature's decay process for COP>1.0 interactions) is changed to a beneficial *positive* energy input within the system itself, freely received from the vacuum environment. This process is then used to close-loop the system for self-powering in a "locked" and stabilized disequilibrium condition — a nonequilibrium stationary state.

If we consider mass to be a special kind of positive energy state, then positive energy states represent curvatures of spacetime that are positive gravity. Negative energy states generate antigravity (the time-reversal of gravity).

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[19] Bedini personally discovered and implemented the solution before the exact nature of either the problem or the solution was recognized! My contribution was to recognize the nature of the problem and the mechanism used in the solution. We also stress that, contrary to conventional treatment, all EM circuits do involve not only lattice holes in the conductors and components, but also Dirac sea holes in the local vacuum. That the Dirac sea is involved whenever there are EM fields is clearly shown by Felix Finster, "Definition of the Dirac Sea in the Presence of External Fields," *Adv. Theor. Math. Physics*, Vol. 2, 1998, p. 963-985.

[20] With a proper change in the curvature of local spacetime, pair annihilation can occur with no accompanying photon radiation. The condition is that the part of the curvature of spacetime representing the energy change of the otherwise emitted radiation, does not "relax" even though it is an "excited state". Rigorously, the emission of the radiation from pair annihilation occurs in two steps: (i) first the local spacetime is curved for and by the energy excitation, as a *static change* of the curvature, and (ii) then that curvature relaxes back to its former value, propagating that specific curvature in space, which is recognized as the radiation propagating in space. If the spacetime curvature excitation does not relax, there is no photon emission and propagation.

Before their interaction and observation, the Dirac sea hole (positron) currents — produced in natural COP>1.0 processes in the universe — are still negative energy electrons in 4-space. They are not 3-positrons until interaction with matter has occurred. These "negative energy electrons" generate negative energy EM fields, including both the Poynting energy flow component and the Heaviside nondiverged energy flow component. These negative energy EM fields appear to be *generating the antigravity* whose effects are seen in the distant parts of the universe. They produce far more powerful effects than the accounted electrogravitation effects in astrophysics, which only uses the gravitational effects of the very much smaller Poynting energy flow component. Also, astrophysicists do not use the "positron before observation," when it is still a negative energy electron with negative mass. The accumulation of the negative energy (Dirac holes) in space (in the surrounding vacuum) is connected with massive objects and violent processes, where very strong gradients are produced.[21] As a result, very large negative energy fields and potentials are produced. In turn, this results in cumulating antigravity. This cumulating and interacting antigravity appears to be the mechanism for the forces *accelerating* the expansion of the universe — rather than it decelerating as would be the case if the net gravity there were positive. In Chapter 8 we propose this explanation for the observed acceleration of the expanding universe — and the basis for the explanation can be and has been successfully demonstrated in a legitimate overunity EM circuit or system {42}. We offer this in honor of Heaviside, who first discovered the gravitational aspect of his huge nondiverged energy flow, but did not live to publish it. He also did not consider the Dirac sea prior to hole interaction with matter, as it was not yet formulated, so he had not yet recognized the way to produce and utilize the practical antigravity potential of his discovery.

1.1.6 A Scientific Dilemma

There would seem to be a sufficient abundance of techniques, devices, processes, and theoretical works to impel a crash project in the scientific community to develop successful overunity electrical power systems {43a-43d}. This would be especially appropriate at this time, since the escalating energy crisis now threatens to slow the world economy, and then eventually collapse it. At this writing, the MidEast has heated considerably, and appears headed for another MidEast war, with resulting severe interruptions of cheap oil supplies from the MidEast. Nonetheless, in spite of Russia having opened its oil field spigots to try to fill the need, a crisis in oil appears to be looming.

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[21] Kondepudi and Prigogine, *ibid.*, p. 459 already point out that strong gradients produce situations that violate present thermodynamics. Research in these and other situations violating present thermodynamics is going forward under the caption of "extended thermodynamics" research. A discussion of the area is given by D. Jou, *Extended Irreversible Thermodynamics*, Springer-Verlag, New York, 1996.

So *why* does the U.S. scientific community still so adamantly oppose the very notion of Maxwellian systems freely extracting EM energy from the vacuum? Why is there no outcry pointing out what the hoary old Lorentz regauging really means in terms of equilibrium or disequilibrium of the regauged system with the active vacuum? The unequivocal participation of the vacuum in a continuous energy exchange with the charges and dipoles of every EM system has long been affirmed by particle physics. All the fields and potentials — and their energy — manipulated in any EM circuit come from the vacuum, as proven in particle physics for 45 years. Why have our electrical scientists not understood — from the broken symmetry of the vacuum exchange with the opposite charges of the source dipole between the charged terminals of every generator and battery — that *EM energy from the vacuum powers, and has always powered, every electrical power system and circuit ever built?* Why have the later rigorous broken symmetry findings of particle physics not been incorporated to update the ancient classical EM theory used to design and build electrical power systems, nearly a half-century after those broken symmetries were discovered and proven? Why do our classical electrodynamicists continue to assume that every charge and dipole in the universe is a perpetual motion machine, freely creating energy out of nothing and pouring it out across all space at the speed of light?

Therein lies one of the real problems of present science — its historical and continuing resistance to "out-of-the-box" thinking[22] and to research that overcomes conventional strictures. More than 40 years after the basis for the vacuum-energy powering of every dipolar system (and of every observable charge once its clustering virtual charges of opposite sign are accounted) was discovered and proven in particle physics, all our university electrical engineering departments continue to erroneously teach that the shaft energy input to the generator powers its external circuit. Internal EM energy in the generator, transduced from the input shaft energy, does not directly add a single watt to the external circuit. Instead, it only continually forces the generator's internal charges apart, to continually remake the source dipole, which then extracts energy from the vacuum and pours it out of the terminals, filling the space surrounding the conductors of the external system for the system to intercept and utilize some of the available external energy flow.

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[22] "Out-of-the-box" thinking is a widely used concept among planners and program formulators, when conventional thinking will not suffice to solve a major problem with which they are struggling. Conventional thinking is considered "in the box" thinking, so by demanding out-of-the-box thinking, a problem demands an unconventional solution outside those normally proposed. In short, some new thoughts and concepts are required. Much lip service is given to the concept as a favored buzzword, but few proposed programs with truly "out of the box" approaches will be funded. In the energy field, none at all are funded that are truly "out of the box", whether or not that or similar phraseology is used.

Once the dipole is established, it will extract and transduce EM energy from the vacuum and pour it out in all directions at the speed of light, without ceasing. Else, the Nobel Committee should admit its grave error and revoke the Nobel Prize awarded to Lee and Yang. Real observable EM energy extracted and transduced from the vacuum's virtual energy is precisely what the "broken symmetry of the opposite charges" on the ends of the dipole *means*. Indeed, all the forces of nature are already considered as generated by the interaction of virtual particles with observed particles. Since force produces energy changes in the system affected, then it follows directly that energy changes are produced by the interaction of virtual particles with observable particles.

However, our power system engineers ubiquitously use the closed current loop circuit. This inane circuit self-enforces the Lorentz symmetrical regauging condition. It uses half the energy captured by the external circuit (from intercepting some of that "energy flowing around the circuit from the seething vacuum" that is copiously pouring out of the generator terminals) to ram the spent electrons back through the back emf of the source dipole itself. That scatters the dipole charges and kills the dipole and its broken symmetry — and also kills the free flow of transduced EM energy from the vacuum.

That insane circuit kills the source dipole in the generator faster than it powers its external loads! So one has to keep rotating the shaft of the generator, to keep producing a magnetic field inside the generator, so that this magnetic field energy can continue to force the charges back apart and continually reform the source dipole.

In short, our engineers build the equivalent of an electrical windmill, then — so to speak — force it into a closed barn so the environmental wind cannot reach it any longer. It is little wonder that we ourselves then have to do work on that "electrical windmill" to crank it around!

We pay the power company to engage in a giant wrestling match inside its own generator and *lose*. We also wildly pollute the planet with hydrocarbon and nuclear wastes, poison species (including killing of X numbers of humans every year via the disruption of their body functions and health), and enhance global warming. We are slowly strangling our biosphere and ourselves. None of that is necessary.

1.2 Organized Science Often Resists Innovative Change

The history of science is littered with examples where the scientific community has ignored the principle behind Einstein's statement quoted at the beginning of this chapter. As pointed out by Smith {44}, science has become reoriented toward profit. Quoting:

> *"...science is not the danger; scientists encouraged to do bad science to survive are."* ... *"...changing the way modern science is funded is an enormous undertaking, but it is a necessary one if we want to protect our future. Call it managed risk."*

Science's resistance to change is so well known to historians of science that it is rather universally accepted — although usually not made explicit to undergraduates. Further, scientists are under great pressure to conform:

1. After all, science is *patronized*; someone must fund the laboratories, the research supplies, the salaries and personnel benefits, etc.
2. To procure and protect its patronage, science has become quite organized, particularly with respect to how the funds — received and channeled down from the top — are cut into individual packages (research grants and research programs) and made available for competition among the "performing" chain of universities and research laboratories.
3. In the last few decades, there has risen an increasingly fierce demand by universities that the scientific researchers (i) be successful in attracting outside funds and (ii) file patents assigned to the university. So fierce has this demand become, that the research professor's continued livelihood may literally depend upon his or her success in bringing in extra funding. Further, much of his time is now spent in writing proposals to

compete for these "packaged funds". When he wins them, the kind of research and the areas of research are already stringently defined, and he dare not deviate — else there will shortly be no more funding packages won, no funding for his graduate students, and soon thereafter there will be no job of any importance for the professor!

4. In the United States, all the government National Laboratories and our universities are intensely seeking and filing patents! So small, independent inventors cannot deal with these organizations, without risking and almost guaranteeing the loss of their patents and intellectual property. Funding dangled in front of the inventor, much like a carrot dangled in front of a horse, is often tied to "march in" rights {45, 46} calling for surrender of the inventor's patent rights altogether, *whenever the government — i.e., a single bureaucrat — wants to take it*. All that has to be done is to declare that the inventor is not getting it developed and to market fast enough. Science has thus become more avaricious and — some inventors would even say — it increasingly involves overt and covert piracy of intellectual property rights. From personal experience, reluctantly I would not argue with that statement. Simply ask Larry Fullerton of Time Domain Corporation about his struggle with a National Laboratory over patent rights to his ultrawideband communications invention and technology.[23] It eventually resulted in a "draw" of sorts. He did not lose his rights, but the government gained them also, in competition with him. The government *circumvented* his patent, even though they did not succeed in taking it. We were delighted to recently see that Larry (the company is Time Domain, Inc.) received its 74th patent in this technology, as well as a ruling that will allow the technology to at last go to market.

5. The result is a dramatic increase in the pressure on working scientists and independent inventors to conform, and to "play the game by the rules". Then everybody up the scientific food chain is fed, and is happy and secure. The journals happily publish the research papers and results, the professor gets

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[23] Stephen Fenichell, "Radio Flyer," *Discover*, 22(5), May 2001. Fullerton's technology has been given a limited go-ahead by the FCC, which has drafted standards and regulations in the area as of February 2002.

funding for his graduate students, the university gets that wonderful overhead cut of the research funding — such as half or it or more — and the entire apparatus is like a very large and tidy Titanic adhering to its ponderous course toward the iceberg. Meanwhile, truly new and innovative science discoveries — vulnerable and desperately needing nurturing funding during their initial embryonic state — get shoved aside, crushed, and starved in the funding rush to adhere to performance of the *prescribed* funding packages.

6. In this environment, the day of the "defenders of the scientific faith" has arrived! A small percentage of conventional scientists who are dogmatic and vociferous, are now very prominently attacking any novel experiments and ideas with a vehemence seldom seen in organized science. It is again reminiscent of some of the noted scientific attacks in history, e.g., as pointed out by Hellman {47}. Yet, because of the financial pressure upon the scientific community, and the increased pressures to conform, there is little restraint of the dogmatists and they are almost never called to task. Cold fusion is a current example. The American Physical Society has recently issued a statement condemning perpetual motion machines — yet the society's members continue to condone and use a classical EM model that assumes every charge in the universe to continuously be creating energy from nothing. Even the American Physical Society has not recognized what broken symmetry of opposite charges means with respect to the common dipole and dipolarity in every circuit. Nuclear reactions at low spatial energy (which means at extraordinarily high total energy when the c^2*-compressed* time energy is considered) do indeed sometimes occur in carefully controlled experiments, whether or not we yet sufficiently understand the reactions theoretically, and regardless of whether we can get the anomalous results to happen every time. Yet this area of nuclear interactions at low *spatial* energy {48} — and unknown to the scientific community, at very high *time* energy {49, 50, 51} — has been savaged by these self-appointed spokespersons for the "official" community, none of whom even account the compressed energy in the time increment portion of the photon. More than six hundred successful experiments in multiple laboratories, by respected scientists in multiple nations worldwide, are now

> rather resoundingly ignored. Yet the replication rate for good cold fusion experiments is certainly higher than many of the replication rates for novel and little-understood phenomena in large particle accelerators, and the cold fusion experiments are also *far cheaper*.[24] While particle accelerators are "popular" in their ability to garner huge funding, their cost/benefit ratio compared with, say, cold fusion experiments, may be abysmally low. Simply examine the decades of effort and many billions of dollars expended on the search for *warm* fusion (using spatial energy only). What has it produced, in terms of watts of power on the power lines? When will it produce any electrical power of any significance? Prototype cold fusion power systems have in fact been produced and patented {52}. With seed money from the scientific community and using a higher symmetry electrodynamics, cold fusion power could proceed at a rapid pace.

Strangely, the ever-present pressure to conform to *that which is already known and accepted* has often made science its own worst enemy throughout its history. Establishment scientists and the "system itself" now probably block — and have blocked over the decades — more innovative scientific research than does any other factor {53}.

1.2.1 Many Scientists and Historians Have Pointed It Out

The scientific community is well known to have always been highly resistant to novel ideas and innovations. Here are some selected pertinent comments regarding this phenomenon, where organized science is itself the obstacle to the advance of science, and where such has been recognized for many decades:

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[24] As an example, see R. P. Taleyarkhan *et al.*, "Evidence for Nuclear Emissions During Acoustic Cavitation," *Science*, Vol. 295, 8 Mar. 2002, p. 1868-1873; Charles Seife, "'Bubble Fusion' Paper Generates a Tempest in a Beaker," *ibid.*, p. 1808-1809. See also Donald Kennedy, "To Publish or Not to Publish," *ibid.,* p. 1793. *Science* had the courage to publish the peer-reviewed results of a tabletop sonoluminescence experiment that apparently produces nuclear reactions. Editor Kennedy essentially advises all protagonists on both sides to cut the rhetoric and allow the scientific community to do its replication work, to either validate or refute the successful experiments of Taleyarkhan *et al*. This action by *Science* is a shining beacon to remind the scientific community that science is based on experimental method, and that prevailing theories cannot refute new experiments that contradict them. Instead, laboratory bench experiments must decide such an issue.

"Every great scientific truth goes through three stages. First, people say it conflicts with the Bible. Next they say it had been discovered before. Lastly they say they have always believed it." [Louis Agassiz, 1807-1873.]

"There are three steps in the history of a great discovery. First, its opponents say that the discoverer is crazy; later that he is sane but that his discovery is of no real importance; and last, that the discovery is important but everybody has known it right along." [Sigmund Freud].

"Anybody who has studied the history of science or worked as a scientist knows that whenever something novel is discovered or proposed, there is a polarization of scientists, with hostility and bitterness that may last for generations. What wins arguments is scientific fact, and that may change as the years go by. A good example of this is the geological theory of continental drift, as proposed by Wegener in 1912. When I studied geology around 1950, continental drift was acknowledged in my undergraduate textbook as a crank theory. The first serious confirmation was in 1956, and it was finally established as the dominant theory in the early 1970s. Until that time, anybody who admitted that he or she believed in continental drift was the subject of derision and scorn. Sorry, folks, science is not and has never been the 'idealized portrait painted in textbooks'." [Allan Blair] {54}

"... the four stages of response to any new and revolutionary development [are]: 1. It's crazy! 2. It may be possible — so what? 3. I said it was a good idea all along. 4. I thought of it first." [Arthur C. Clarke]. {55}

"...I suggest that most revolutions in science have taken place outside the lofty arena of the refereed journals, and with good reason. The philosophy by which these journals govern themselves virtually precludes publication of ideas that challenge an existing consensus." [William K. George] {56}

"At every crossway on the road that leads to the future, tradition has placed against each of us, 10 thousand men to guard the past." [Maeterlinck].

> *"An important scientific innovation rarely makes its way by gradually winning over and converting its opponents: it rarely happens that Saul becomes Paul. What does happen is that its opponents gradually die out, and that the growing generation is familiarized with the ideas from the beginning."* [Max Planck] {57}.

> *"Peer review is widely seen as a modern touchstone of truth. Scientists are roundly drubbed if they bypass it and 'go public' with their research… The first limitation of peer review is that nobody can say quite what it is… A more pernicious danger is that peer review may reject the important work. As Charles W. McCutchen, a physicist at the National Institutes of Health, has put it, peers on the panel reviewing a grant applicant 'profit by his success in drawing money into their collective field, and by his failure to do revolutionary research that would lower their own ranking in the profession. It is in their interest to approve expensive, pedestrian proposals.' "* [Jonathan Schlefer] {58}.

The sheer massive size and inertia of the modern scientific establishment also exert mind-numbing difficulty in "hearing" and recognizing an innovative scientist's message, even a message of utmost importance, and even if it gets through the censors. For example:

> *"We used to be able to say things once; if the message was reasonable, it had a good chance of becoming a permanent part of the structure of the field. Today, a single publication is lost; if we say it only once, it will be presumed that we have changed our mind, and we therefore must publish repeatedly. This further fuels the large publication volume that requires us to repeat."* [Rolf Landauer] {59}

1.2.2 Some Specific Examples

There are hundreds of examples of new discoveries in science that have at first — and often for an extended period of years — been severely obstructed and ridiculed. Here are just a selected few:

1.2.2.1 *Conservation of Energy*

Von Mayer {60}, the discoverer of the modern statement of the conservation of energy and the mechanical equivalent of heat, was severely chastised for his "insane" work. He was hounded and severely ridiculed. This extremely harsh treatment, together with domestic problems, drove him to a suicide attempt and a nervous breakdown, and into psychiatric treatment for some years. Toward the end of his life, his principle of energy conservation had so greatly increased the ease of calculations and the understanding of systems that the same scientific community — due to the commendable efforts of Helmholtz, Clausius, and Tyndall — began to recognize his great contributions and lionize him. In 1867, he was made a member of the nobility, dying in 1878 with his "insane" work by then well respected. He was fortunate to have the "cur dog attack" reversed in his lifetime. Most scientists with novel discoveries are not so fortunate.

1.2.2.2 *Continental Drift*

Alfred Wegener {61} proposed the theory of continental drift in 1912. The reception was extraordinarily hostile. So ferociously was he ridiculed for the notion that huge continents of rock could "float" and "drift" that his very name, "Wegener", was often used as a synonym for "utter idiot". To refer to someone as "a Wegener" was to cast the greatest slur possible upon that person's mental powers and to label him a gibbering lunatic. Only in the 1960s when sea-floor spreading from ocean ridges was discovered, proving that ocean basins are not permanent features, did Wegener's concept of continental drift concept finally gain acceptance.

1.2.2.3 *Kinetic Theory of Gases*

As pointed out by Paul Nahin {62}:

> *"J. J. Waterston's paper on the kinetic theory of gases, in 1845, was rejected by the Royal Society of London. One of the referees declared it to be 'nothing but nonsense, unfit even for reading before the Society.' ... "Waterston's dusty manuscript was finally exhumed from its archival tomb forty years later, because of the efforts of Lord Rayleigh..."*

Lord Rayleigh was the Secretary of the Royal Society when he had Waterston's paper reprinted nearly a half-century after submitted. Lord Rayleigh also gave an introduction to the paper, regretting it lying so long unpublished when its content was quite important. His introduction is a way of explaining the delay.[25]

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[25] Waterston's paper was finally published as John James Waterston, "Free and Elastic Molecules," *Phil. Trans. Roy. Soc. Lond.*, Vol. 183, 1892, p.1-79. Lord

1.2.2.4 *Surgical Pain Deemed Necessary*

It has *always* been this way in science. As another example, the famed surgeon Alfred Velpeau wrote in 1839:

> *"The abolishment of pain in surgery is the chimera. It is absurd to go on seeking it today. 'Knife' and 'pain' are two words in surgery that must forever be associated in the consciousness of the patient. To this compulsory combination we shall have to adjust ourselves."* [Martin Gumpert] {63}.

Wryly we observe that today a similar attitude of "we must glory in the pain" — where the "pain" is due to the yoke of COP<1.0 EM systems and of the second law of classical equilibrium thermodynamics — consumes most modern electrical power system scientists and engineers.

1.2.2.5 *The Photoelectric Effect*

Almost every household now knows Albert Einstein's epochal achievements. Yet his formative three papers — on Brownian motion, the photoelectric effect, and special relativity — were published in 1905 while he was working in the Swiss Patent Office. The most renowned physicist of the time was Max Planck. Planck was embarrassed that a scientist who was not even employed in physics was doing such important work in physics. So Planck and other scientists arranged for Einstein to be awarded a chair in physics at a proper university. In their letter to the university, they pointed out Einstein's brilliance in his papers. They also then excused him for straying down the road of the photoelectric effect, because — as they put it — everybody knew that was foolishness, but persons of such brilliance could be forgiven a few such little bobbles along the way. Years later, in 1921, Einstein was awarded the Nobel Prize for Physics, for his work in theoretical physics and *especially* for his explanation of the photoelectric effect.

The Einstein incident is a typical illustration of Arthur C. Clarke's cogent observation:

> *"When a distinguished but elderly scientist states that something is possible he is almost certainly right. When he states that something is impossible he is very probably wrong*." [Clarke's First Law]

Rayleigh's introduction and Waterston's paper also are given in Jefferson Hane Weaver, *The World of Physics*, Simon and Schuster, New York, 1987, p. 632-651.

1.2.2.6 *Amorphous Semiconductors*

Stanford R. Ovshinsky's development of amorphous semiconductors {64, 65} is another modern example. "Everybody knew" that a crystalline structure was necessary in order to have a semiconductor at all; in short, a semiconductor formed out of non-crystalline material was deemed to be totally impossible, never mind this “phase” change that Ovshinsky advanced. However, some young graduate students, e.g., began to look at Ovshinsky's amorphous materials and his phase change approach.

Finally funded by the Japanese, Ovshinsky's company, Energy Conversion Devices, Inc. (ECD) simply placed its amorphous semiconductor devices into working equipment. Copy machines appeared with his amorphous semiconductors installed in them — with the machines and their amorphous semiconductors working very well. More graduate students and post-docs enthusiastically entered the area, did research, and wrote dissertations.

As a result, amorphous semiconductors finally became accepted, and they are now part of the established technology and scientific knowledge base. The interested reader can simply look up Ovshinsky's company and statistics on http://www.ovonics.com . The Japanese have reaped a continuing bonanza from the sales of amorphous semiconductors, because of the shortsightedness and bias of the U.S. scientific community.

1.3 Scientific Disagreement or Street Fight?

It is one thing to scientifically disagree — even strongly — in a technical and courteous fashion, and quite another to engage in ad hominem attacks. The first is science; the second is a cur dog fight. Unfortunately the history of science far too often reveals "cur dog fights" instead of respectful scientific disagreements {66}.

A recent modern example of legitimate research and qualified researchers still being savaged in a "cur dog fight" manner is cold fusion (low energy nuclear reactions). Quoting one learned orthodox scientist, whose name is withheld, speaking to a learned scientist in cold fusion:

> *“How stupid do you think we are? My assessment of you and your colleagues is that you are complete frauds or totally mad. There is no known physical principle that would support the kind of results that you claim your technology can accomplish, nor is there any credible argument why there should be such a principle."*

We answer that "cur dog attack" unemotionally and scientifically. The key is in the scientist's own phrase: "no *known* physical principle." If the experiments work and are replicated, but are not understood by the conventional theory, then they refute the prevailing theory, whether the physical principle is understood or not. Else scientific method has been totally abandoned in favor of “truth by authority and dogma”. The experiments clearly show that a previously *unknown* physical principle is at work. The real task then is to rediscover this new principle — that being one of the primary ways that science advances. We propose new principles in this book as a possible explanation of those experiments.

The dogmatic scientist's statement was made in spite of some two hundred (200 at that time; now more than 600) scientific experiments worldwide, in many nations, many at prestigious institutes, where dozens of scientists have reported positive and anomalous results in cold fusion experiments.

So yes, there is indeed a very "credible argument" — *the results and replicability of the experiments*, which are supposed to be the *decisive* statement of science. If that view in science has changed, then we are no longer practicing the scientific method. Instead of accepting successful and replicable experiments and seeking to change the model, the scientist is insisting that we must first understand the principle and thus have a model. This of course is a total violation and reversal of the scientific method. We used aspirin effectively for decades without the slightest notion as to the mechanism enabling its beneficial actions. The mere fact that "there is no known physical principle" for the results achieved has nothing to do with the validity of the replicated experimental results. Instead, it merely substantiates that *there should be a vigorous scientific program to uncover the new principle or principles obviously involved*, since the old model has either failed or been revealed as too limited.

The derogatory statement by the dogmatic scientist is also made from the viewpoint of the conventional nuclear physics model. The conventional physics has not taken into account that all 3-spatial electromagnetic energy associated with charges and dipoles and their fields and potentials in fact comes from the time domain {85, 86, 12, 19}. It has also not taken into account that time itself (as in the time component transported by the time-polarized photon or a time-polarized EM wave) may be comprised of extraordinarily dense energy. Indeed, time appears to be spatial EM energy compressed by the factor c^2, so it has the same energy density as mass {67}, which we pointed out earlier. The smaller the *spatial* energy of the photon, the greater its time component and hence its *time*-energy in seconds expressed in decompressed spatial energy joules[26]. The highest energy particle physics is not *spatial*-energy physics as presently practiced, but *time*-energy physics, where some of the time-energy of photons is transduced into spatial energy. One second of time transduced (decompressed) into spatial energy yields approximately $9\Delta 10^{16}$ joules. Further, every negative charge in the universe continuously accomplishes that decompression, and every positive charge continuously accomplishes the recompression.

In other words, not all physical principles were discovered in the particle physics of, say, five years ago, as the literature since then clearly shows. To assume that everything is already known today is ludicrous; science is never completed. The new principles reported in the present book now are at least "candidates" for the physical principles that do support cold fusion results. There is also another powerful argument for these hypothesized principles: they have produced the final resolution of the source charge problem — something for which the arch skeptic quoted has no solution whatsoever, and which he himself cannot explain. *If the arch critic cannot produce an alternate solution to the source charge problem, and is unaware of that new principle that may solve it, let him go and learn the new principle. Until then, he unwittingly assumes that every charge in the universe is a perpetual motion machine, continuously creating and pouring out EM energy in all directions at the speed of light.* So we return his own argument and approach to him: he should attack the conventional scientific community for accepting the source charge, while having absolutely no principle to explain how it continuously pours out observable EM energy without any observable EM energy input. In short, he should practice what he preaches; else he brands himself a total hypocrite. The alert reader will note that none of the arch skeptics doing all the ad hominem attacks on cold fusion and COP>1.0 EM systems are practicing what they preach.

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[26] The spatial energy of the photon decreases linearly as the frequency is lowered, while the time component in seconds increases linearly. But the highly compressed time energy, comprising that time component, increases nonlinearly (by the factor $c^2 \div t$). Hence the highest energy photons are actually the low frequency photons — something completely alien to particle physicists — and not the high frequency photons chased by "high energy physics". Indeed, high energy physicists are practicing a high spatial energy physics, which — overall — is a much lower energy physics than radar, microwave, VHF, or ELF, *if the total energy of the photon, to include its time energy, is considered.*

What we are saying is this:

(a) If one's physics knowledge was current five years ago, it may be stale today. A few years ago, no one believed the expanding universe was accelerating. Today we know that it is, rather unequivocally. And by "no known physical mechanism". We will later present a strong candidate for that missing mechanism. The results of experiments will substantiate or refute it.

(b) The proposed principles in this book, e.g., are newer, and may shed light on the mechanism for the cold fusion results as well as other phenomena. The experimental results themselves are irrevocable; any proposed explanation requires validation.

(c) The new principles do explain cold fusion and are consistent with the phenomena encountered in multiple experiments by multiple researchers in many laboratories. We readily admit that the stale and incomplete principles presently utilized in nuclear physics *do not* explain cold fusion. Neither do they explain how a charge continuously pours out EM energy. So do the skeptics attack all those physicists who believe in source charges and their provision of the fields and potentials and all EM energy? Of course not. They themselves believe in that greatest of all “perpetual motion” *faux pas*.

(d) The proposed new principles also solve the source charge problem, which is still ignored by most conventional physicists and electrodynamicists, even though often referred to as the "most difficult problem in electrodynamics" {68}.

(e) Scientists should not be close-minded, but should consider new proposals and let the experimental results decide their validity or falsity — precisely the position taken by the journal *Science* in publishing the results of some new cold fusion experiments. That is the scientific method in action.

(f) Those scientists who remain close-minded, and viciously attack experimentally demonstrated new processes and mechanisms, are guilty of practicing dogma and not science. They are in fact guilty of being what they so frequently charge: *pseudo-scientists*.

When science does not allow proposed new mechanisms and principles to be considered in science following demonstration of new phenomena inexplicable by present models, then science is no longer practicing scientific method. When any scientist rejects these demonstrated new experimental phenomena out-of-hand, he is practicing dogma rather than science. The “friendly skeptic” attitude is welcomed and appropriate. The cur dog attack has no place in science, but only among cur dogs — and those who behave like them.

1.4 A Few Significant and Unresolved Scientific Problems

1.4.1 Time as Structured Energy

Time also has internal structure and dynamics {69, 70}, as we explain later, as well as the same energy density as mass. So it should not be surprising that a tiny bit of time-energy, transduced into ordinary spatial EM energy, might be capable of energetically inducing a wide variety of nuclear reactions. One has transduced not only "gross" energy, but also energy structuring and dynamics — which *act internally* on any object with which interaction occurs. Further, the overall spatial energy component and the time-energy component in a photon are canonical. Being quanta, all observable photons have the same fixed "total magnitude" with respect to angular momentum. The photon is also "made" of (÷E)(÷t) which may be taken as $(\div E)(c^2 \div t)$ in terms of *purely spatial* energy equivalent content, assuming that the time energy is decompressed into spatial energy. As can be seen, the so-called "low (spatial) energy" photons are precisely the photons that transport the greatest time-component. When that time-energy component (÷t) is converted to spatial energy $(\div E_C)$, the formula is $(\div E_C) = c^2(\div t)$. As can be seen, the converted time energy will produce far more spatial energy in the *converted* interaction, than was carried by the photon in its spatial energy (÷E) component prior to interaction and time-energy transduction. Hence the highest energy photons are actually low frequency photons — under the circumstances where time-energy transduction into spatial energy is involved. With transduction, the highest energy particle physics can be conducted at low frequencies and low spatial energy if conversion of time-energy occurs in the interaction.

Since cold fusion involves transduction of a little bit of the time-energy, the total lack in physics of knowledge of time-energy transduction into spatial energy explains why conventional nuclear physicists find the cold fusion results so confusing and astonishing.

1.4.2 The Obsolete Foundations of Classical Electrodynamics

Another modern example of science's resistance to change is the failure to update classical electrodynamics to include the active vacuum interaction and the interaction with the local curved spacetime[27], as we shall discuss in Chapter 2. It has been scientifically established (in particle physics) that there can be no equilibrium of any physical system without accounting for the vacuum interaction.[28] To simply observe a physical electrical power system sitting there stably and running, is to prove its vacuum interaction in order to even *have* such equilibrium.

An interesting point then arises since every charge and dipole in the system is a *broken equilibrium* in the exchange between the material system and the vacuum. Not only does an electrical circuit receive some energy from the vacuum, but also the energy from the vacuum is *massively hemorrhaging* from the vacuum into the system (and back out)! The isolated charge, e.g., is infinite if one removes the screening clustered virtual charges of opposite sign, as is well known in modern physics. Further, the screening virtual charges also have infinite charge, again as is well known. The difference between these two infinite values of charge, e.g., gives the standard finite observed charge of the charged particle. The lay reader may wish to positively verify that statement; e.g., as given by Nobelist Steven Weinberg.[29] Quoting:

> *"[The total energy of the atom] depends on the bare mass and bare charge of the electron, the mass and charge that appear in the equations of the theory before we start worrying about photon emissions and reabsorptions. But free electrons as well as electrons in atoms are always emitting and reabsorbing photons that affect the electron's mass and electric charge, and so the bare mass and charge are not the same as the measured electron mass and charge that are listed in tables of elementary particles. In fact, in order to account for the observed values (which of course are finite) of the mass and charge of the electron, the bare mass and charge must themselves be infinite. The total energy of the atom is thus the sum of two terms, both infinite: the bare energy that is infinite*

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[27] We again stress the concept of the *supersystem*, introduced in footnote 11.

[28] E.g., see T. D. Lee, *Particle Physics and Introduction to Field Theory*, Harwood, New York, 1981. On p. 380-381, Lee shows how there is no symmetry of matter alone, but only of matter and vacuum.

[29] Steven Weinberg, *Dreams of a Final Theory*, Vintage Books, Random House, 1993, p. 109-110.].

> *because it depends on the infinite bare mass and charge, and the energy shift ... that is infinite because it receives contributions from virtual photons of unlimited energy."* [Steven Weinberg].

So a simple charged particle actually involves a polarization of the vacuum involving two charge energy functions — the bare charge and the charge change functions — each of which has a known and recognized COP = ←!

A priori, the conventional system's overall actions must incorporate functions (whether intentional or unintentional) that continuously adjust to provide *net equilibrium in that exchange by adjusting the hemorrhaging-out to equal the hemorrhaging-in*. In this book, we will spell out just what those unintentional functions are, such as the ubiquitous closed-current-loop circuit, and how to beat them so that excess energy from the vacuum can be utilized by the system to power the loads.

1.4.3 What Powers an EM Circuit or Electrical Power System?

Another modern example of science's resistance to change is the continued engineering of electrical power systems with the erroneous notion that mechanically powering the shaft of a generator directly powers the power line. The notion is that the generator transduces some of the mechanical shaft energy into output EM energy added to the power line {71}. To the contrary, *all EM systems are powered by energy extracted from the vacuum*. They are not powered by the mechanical energy we input to the shaft of a generator, or by the chemical energy in a battery. In this book, we discuss at some length what powers the EM system, and we have previously published the basis for our "shocking" statement {12, 72}. The basis for how an EM system is powered by energy from the vacuum has been known in particle physics for nearly a half-century {73}, since the experimental proof of broken symmetry {74}, including the broken symmetry of opposite charges (and hence of any dipole) in its fierce energy exchange with the active vacuum {75}.

A generator or battery expends all of its available energy to separate its internal charges and form its source dipole between the terminals. Once made, the dipole's broken symmetry — in its violent energy exchange with the active vacuum — converts virtual photon energy absorbed from the vacuum into observable EM energy, and emits it — *pours it out* — through the terminals and along the power line, filling all space around the conductors.

If one wishes to appreciate the enormity of the vacuum changes engendered by formation of that source dipole, simply visualize those two infinite charge energy functions (from Weinberg's quotation above) for every charged particle on the ends of that dipole. The dipole then is a great set of offsetting infinities in EM energy (photon energy) boiling and being ordered in the vacuum. Making a simple little dipole or producing a simple charge initiates into motion an enormous set of infinite energy changes in the vacuum! None of these startling, enormous vacuum energy changes and functions is modeled in classical electrodynamics and electrical power engineering. So when we speak of the Heaviside nondiverged energy flow component pouring from the terminals of a generator, as being a trillion or ten trillion times as great in magnitude as the intercepted Poynting component, the reader should not be appalled. The reader should recall that we are dealing with the difference between sets of infinities that combine to provide finite differences. These finite differences can be very small, or they can be extraordinarily large, depending on the exact situation. In the case of a source dipole formed in an ordinary generator or battery, the difference of the infinities is very large.

Figure 1, adapted from Kraus {76}, illustrates that small part of the external energy flow around a typical transmission line that is intercepted by the surface charges and their fields, and that is drawn into the wires to power the circuit as these charges are driven axially back and forth across the conductors. The surface charges are constrained to the "drift velocity" (usually a few inches per hour) movement down the wire by repulsion of the electrons ahead of them.

The spinning, *longitudinally restrained* electrons precess laterally, thus withdrawing across the transverse axis of the wire. So the laterally precessing electron withdraws a little ways, withdrawing that first small portion of its fields and their energy increased by intercept of additional energy from the outside energy flow. The further part of the fields is not withdrawn into the conductor, and is not used to power the electrons.

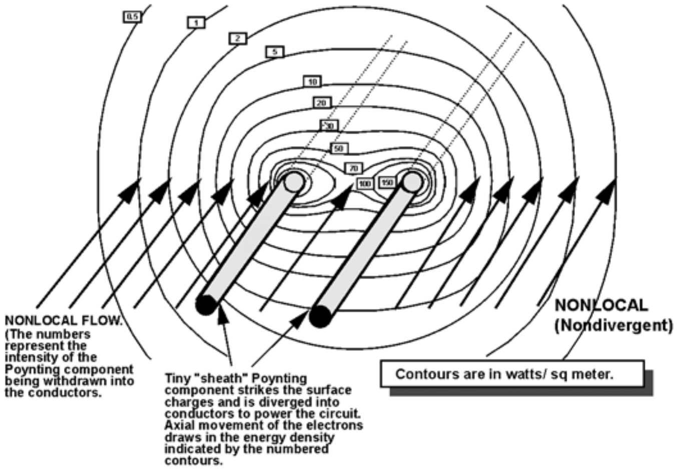
0.5
1
2
5
10
20
30
50
70
100
150
NONLOCAL FLOW. (The numbers represent the intensity of the Poynting component being withdrawn into the conductors.
Tiny "sheath" Poynting component strikes the surface charges and is diverged into conductors to power the circuit. Axial movement of the electrons draws in the energy density indicated by the numbered contours.
NONLOCAL (Nondivergent)
Contours are in watts/ sq meter.

Figure 1-1 Poynting (caught energy) flow contours surrounding a transmission line.

Most of the available energy flow misses the circuit and is not drawn into the conductors. However, that large component is not shown by Kraus, and Poynting did not consider it. Heaviside {5c} pointed out that the remaining flow component is hardly reduced (hardly changes direction) from the entire flow component before the extraction of the small Poynting component. Given sufficient intercepting charges outside the wires in separate receiving circuits, the total remaining energy flow that could potentially be intercepted is enormous — far more than the feeble amount of energy that is input to the generator shaft or that is in the chemical energy of a battery.

This is easily established by actual experiments placing intercepting charges in separate "receiving" circuits in the otherwise nondivergent energy flow outside the conductors, or one may show it with Bohren's experiment {24}. Collecting additional energy completely outside conductors is one part of the COP>1.0 operation of the motionless electromagnetic generator (MEG) {37}, to be discussed later in this book. The Sweet device {29a} established sustaining self-oscillation of the barium nuclei in a barium ferrite magnet, by using the surrounding vacuum as a semiconducting medium.[30]

1.4.4 The Incompleteness of Aristotelian Logic

Another false notion usually perpetuated in much of science and mathematics is that Aristotelian logic is complete and consistent {77, 78}. To the contrary, it is both incomplete and inconsistent, as is easily shown. Let us use the symbols "A" for a particular thing, "Ā" for that which is not-A, "∑" for "is identical to," "≢" for "is not identical to", "⋎" for "or", and "⋏" for "and". Using these symbols, the three laws of Aristotelian logic may be expressed as follows:

$$A \sum A \qquad [2]$$

$$A \not\equiv \bar{A} \qquad [3]$$

$$A \curlyvee \bar{A} \qquad [4]$$

The first law states that a thing is identical to itself. The second states that a thing is not identical to that which is not itself. The third states that a thing is either itself, or it is something else. Those are the three laws of Aristotelian logic. As written, the process of perception, observation, etc. *has been excluded*. More on that in a moment.

Specifically excluded are the laws

$$A \not\equiv A;\ A \sum \bar{A};\ A \curlywedge \bar{A} \qquad [5]$$

Which says that a thing is not identical to itself but is identical to something else that is not itself.

Heraclitus posed a profound challenge to Aristotelian logic, a challenge that has not been adequately resolved by Aristotelians to date. He simply observed that, for a thing to change, it had to change into something else. "But then," he asked, "how can a thing be itself but also something else as well?" In philosophy that is still known as the unresolved "problem of change". It has no resolution in Aristotelian logic, but can be resolved in an extended logic we shall advance. The solution to Heraclitus' problem of change is the nature of observation, as advanced in this book.

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[30] E.g., see Richard E. Prange and Peter Strance, "The Semiconducting Vacuum," *Am. J. Phys.,* 52(1), Jan. 1984, p. 19-21. The vacuum may be regarded as a semiconductor. In particular, the vacuum in the region close to the nucleus of a superheavy element is analogous to the inversion layer in a field effect transistor. The authors introduce the idea of the inverted vacuum. Just as a semiconductor may be manipulated by subjecting it to external fields, doping etc., it appears that so can be the vacuum.

We now critique Aristotelian logic, by observing a simple Venn diagram of the type used in "proving" logic theorems in axiomatic logic. See Figure 1-2.

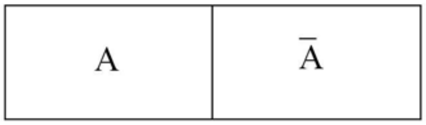

1-2a. Usual Venn diagram of A and A.

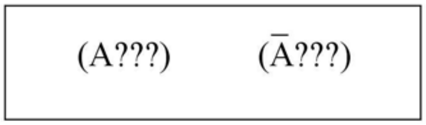

1-2b. Applying second and third laws to divider.

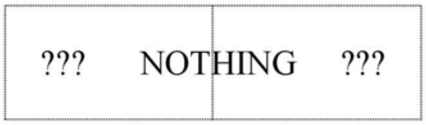

1-2c. Applying second and third laws to divider and outer boundary.

Figure 1-2 Applying Aristotle's laws to Venn diagram used to prove logic theorems destroys the entire diagram.

In Figure 1-2 a, we have introduced a dividing boundary line between A and Ā. *Unfortunately that dividing line belongs entirely to both A and Ā.* So it violates all three Aristotelian laws, and must be removed.[31] Therefore, we remove it in Figure 1-2 b. Now we have neither a discernible A or a discernible Ā, but we have removed naught but the boundary separating them, so we may argue that they are both still there although not discernible. However, if they are not discernible, we cannot distinguish what A is or what Ā is, and so we cannot discern whether they are identical or not. Here again this violates all three laws of Aristotelian logic, so we have to remove the diagram. Indeed, the outer rectangle line is also such a boundary, between the "inside" and the "outside" (the not-inside), and so it must be removed. In compliance with Aristotle's laws, we are left with the trivial diagram shown in Figure 1-2 c, which is nothing at all.

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[31] A clever fellow once proposed regarding the boundary as a total discontinuity, being neither A nor Ā. However, in that case A and Ā could never meet, so there could not be a cause interacting with not-cause to produce an effect. So that suggestion as to how to "fix" Aristotelian logic does not hold.

If this Venn diagram method is objected to, then we must insist that all those papers and texts using that method of proof of logic theorems be either abolished or corrected!

Sometimes the objection is raised that, as far as the center boundary line is concerned in Figure 1-2a, the line "belongs to A on the left and belongs to Ā on the right". Fine! Then we have a unique situation where a line (call it L) is an entity made of two entirely different things, which we may refer to as L_L and L_R. Yet $L \sum L$, without any qualifications as to "sides" L_L and L_R. It can be shown that every point in L is a point in L_L, and is simultaneously a point in L_R. The point in L is obviously identical to itself, by Aristotle's first law. Further, the same point in L_L and in L_R is identical to itself, by the same first law. But L_L is the set of all such points, and so is L_R, and so is L. Therefore $L \sum L_L \sum L_R$, since each one consists of each point that the others consist of. There is absolutely no distinction between the three things themselves, unless we are to violate Aristotle's laws.

Note that in passing from left to right across the boundary, a "change" occurs. This simply re-resurrects Heraclitus' original objection that, according to Aristotelian logic, there can be no change. That is, a line cannot change from "a different entity as seen from the left" compared to that entity as seen from the right. None of Aristotle's three laws contains a "left and a right" for A or Ā.

So the question of logic is a little more complex than writing three simple laws and drawing simplified Venn diagrams. In short, one cannot have Aristotelian logic without having something else *outside* it, which follows directly from Gödel's theorem and proof {78}. Note that we are introducing the required notion of "perception" into the formal notions implied as axioms in Aristotle's laws, as that "something outside the prescription of the laws themselves" and in addition to them. We are perfectly free to *use* Gödel's theorem and observation.

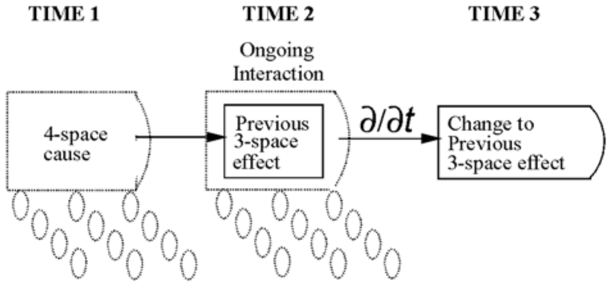

Figure 1-3 Mechanism for observation of change to a previous observation.

See Figure 1-3. We now add the notion that a thing is a perceived, thought, or observed thing. So let us use the symbol ⇒to mean *explicit*, i.e., *output* by a given perception, thought, or observation process as the result of a ∈/∈*t* operator having been applied to whatever exists prior to perception, thought, or observation. The symbol ⇔is used to mean *implicit*, e.g., when one observes an observation "Y" at time two, and later is deciding in time three whether or not that observation "Y" in time two is identical to a previous observation "X" made during time one, then *memories* of the observations of X and Y are involved in time three rather than the observations X and Y themselves, and so the observations of X at time one and Y at time two — by whatever manner they were observed and according to whatever decision algorithm is used — is said to be "implicit".

We note that we can know nothing about the so-called "thing in itself" *without* thought, perception, observation, or other process involving ∈/∈*t*. Further, at the moment the ∈/∈*t* operator is applied, time momentarily ceases. The resulting perception, thought, or observation exists therefore as a "frozen output" at that single moment in time. To have it "persist" or exist a moment later, we have to apply the ∈/∈*t* operator *again*, and stop time again, so that we again perceive, think, or observe.

But at any moment later than when we made a particular perception, thought, or observation of "A", *that* specific "perceived A" no longer exists, except in our memory as a recording of "observed A" that we can *continually recall*. Our conscious mind is a very fast serial processor, with only one "perception" or "thought" at each fleeting moment — only one slide at a time in the slide projector, so to speak. But it is very rapid. However, our so-called "unconscious" mind is totally conscious, just multiply so. It is a massively parallel processor, and has "a great many slides in the slide projector" at any given time.[32] Hence in our genetic multiprocessor mind, we can indeed record, recall, compare, etc. — and perform all the modern massively parallel computer operations.

Let us now re-examine the three Aristotelian laws. Let us label the "slide snapshots" with the time instants when each "perception, thought, or observation" is or was consciously made, by use of a subscript, such as A_1, which means *what was perceived, thought, or observed as "A" in time-snapshot 1.* Let us also note that each of the symbols $\sum$, $\not\equiv$, $^\vee$, and $^\wedge$ actually involves the output of a *comparison and decision algorithm* in the massively parallel processor, after the two observations X_1 and X_2 were made. Let us use the symbol ♥ to mean "results in the decision that" or "implies that". As a check for identity, e.g., simple comparison algorithms for determining identity or nonidentity might be

$$\{[A_1 - A_{(2)}] = [0]_3 \heartsuit_4 (A_1 \sum A_2) \qquad [6]$$

$$\{[A_1 - A_{(2)}] \prod [0]_3 \heartsuit_4 (A_1 \sum A_2) \qquad [7]$$

Thus we more precisely rewrite Aristotle's laws as

$$A_1 \sum_3 A_{(2)} \qquad [8]]$$

$$A_1 \not\equiv_3 \bar{A}_{(2)} \qquad [9]$$

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[32] E.g., this can be seen by a moment's reflection. At any one time, the "unconscious" mind is controlling and directing a great multitude of ongoing physical processes, is also processing short-term and long-term memory processing, filing conflicts for resolution or later presentation to the conscious mind in symbolic fashion, etc. One can physically measure the electromagnetics associated with this activity, after the mind transduces its time-polarized EM interactions into 3-space EM actions. The process is two-way, and certain recorded EM stimuli will be "reverse-processed" back to affect the time-polarized EM operations of mind. Mind operations are electromagnetic; but they use time-polarized (scalar) photons and time-polarized (scalar) EM waves which are unobservable a priori. Mind operations are also electrodynamically engineerable, but that is beyond the scope of this treatise.

$$A_1 \curlyvee_3 \bar{A}_{(2)} \qquad [10]$$

Where — surprise! We have now accounted for all those different times and periods of observations, processing, comparison, decision, etc. We are dealing not with some mystical "thing-in-itself", but with interactions (perceptions, thoughts, observations, associations) in the mind and psyche of the observer. And hidden in time 3 is the application of a decision algorithm such as given in [6] and [7] above.

Now the first law [8] states that in time one an observation was made and named "A", notated (A_1), by comparing it to a previously recorded observational memory of what we call "A". The existence of that *memory* of what we call A is implicitly assumed in the first law, as well as the others. We do not show the memory itself in [8], [9], and [10]. In time two an observation X_2 was made (not notated), but it is not then known at the moment whether that X_2 is A or $\bar{A}$. So in time interval three the decision algorithm to determine identity or non-identity occurred in the mind, and the zero output of that algorithm [6, 7] established that $A_{(2)}$ was actually identical to A_1, *according to the decision algorithm actually used. The algorithm matters, and it too is a variable.*

A similar process occurs in law two [9], but this time the algorithm had a different output. Note that the little line over $X_{(2)}$ to make it $\bar{A}_{(2)}$ was not assigned until time interval four (not shown) after the decision algorithm had given its output in time interval three.

The second law merely states that the operation of the decision algorithm in time interval 3 found the two snapshots (in time 1 and in time 2) not to be identical, *by the decision algorithm and comparison process utilized. Again, the algorithm matters, and it too is a variable that must be taken into account.*

All three laws [8, 9, 10] written one after the other *assume* that the identity algorithm does not change between snapshot 1 and snapshot 2, in all three of them. This is the key point.

With two different versions of the identity decision algorithm, the results of two different comparisons may differ. If the identity decision algorithm does not change during the time between snapshot one and snapshot two, then we have one case. This is like a person with good color vision, looking at a red marble beside a black marble. That observer clearly distinguishes the marbles, and to him they do *not* appear identical. Every time he looks again, they still differ because he did not change his decision algorithm between looks. On the other hand, a color-blind observer cannot distinguish the marbles, and to him they are seen as identical. Every time he looks, they are seen as identical, because his identity decision algorithm did not change.

Or, suppose a proponent argues that the "rightness" or "leftness" of the dividing line L, between A and Ā in the Venn diagram, can be taken into account. He is actually invoking a different algorithm (it belongs to the left and therefore to A) in one time snapshot than the algorithm (it belongs to the right and therefore to Ā) used in the other time snapshot. So his right side and left side of a line implicitly invokes the very point we are making: *the algorithm utilized is a variable and must be accounted.*

The point is this: *identity — whether in perception, thought, or observation — is not absolute, but depends upon the precise nature of the operation of the perception, thought, or observation process utilized and specifically on the "decision algorithm" used for "determining" identity or nonidentity.* For example, two antennas certainly "see" quite differently, if one is a VLF (very low frequency) antenna and the other is an IR (infrared) antenna! As another example, two observers in different frames may see a particular object as quite different observed things! In n-space, an observer in a frame at right angles to the lab frame, will see any mass in the lab frame as a wavefront going at light speed; in short, as a photon or photonic object, whereas the observer in the lab frame will continue to see it as just a common old mass object. So the "same object" *physically* differs to the two different observers, according to their frame of reference. An observer whose frame is rotated by three orthogonal rotations from the lab frame, will see that object as an "object existing in time only," i.e., as simply a sort of "thought" image, so to speak. To be more scientific, he may assign it to something called the "virtual state".

In short, we can violate any and all of the laws of Aristotelian logic, because identity per se is *perceived, thought, or observed* identity — the output of a variable decision algorithm — and is not absolute.

For clarity, we add a fourth law that violates all Aristotle's three:

$$A_1 \Sigma_3 \bar{A}_{(2)} \qquad [11]$$

All this really says is that, in time 3, the decision algorithm being used was changed from what it had been in times 1 and 2, and now could not distinguish between what was seen in snapshot 1 and what was seen in snapshot 2, even though to some "ultimate" observer the two were distinctly different.

In addition, we say that it "implicitly includes" the negations of all three Aristotelian laws. We then add an "application rule" (or a fifth law, as one wishes) as follows:

$$\{\ [(A_1\ \Sigma_3\ A_2) \Rightarrow \wedge\ (A_1 \not\equiv_3 A_2)] \Leftrightarrow \}_5\ \vee\ \{\ [(A_1\ \Sigma_3\ A_2) \Leftrightarrow \wedge$$

$$(A_1 \not\equiv_3 A_2)] \Rightarrow \}_5 \qquad [12]$$

This winds up producing an extension of Aristotle's logic, so that the following explicit laws emerge:

$$A_1\ \Sigma_3\ X_{(2)}\ \heartsuit\ \ A_1\ \Sigma_3\ A_{(2)} \qquad [13]]$$

$$A_1 \not\equiv_3 X_{(2)}\ \heartsuit\ \ A_1 \not\equiv_3 \bar{A}_{(2)} \qquad [14]$$

$$A_1 \vee_3 \bar{A}_{(2)} \qquad [15]$$

We also have the exact opposites of those three laws implicitly. The opposites can all be congealed into a single fourth law:

$$A_1\ \Sigma_3\ \bar{A}_{(2)} \qquad [16]$$

To make sense of these, we also have the master application rule or 5th law:

$$\{\ [(A_1\ \Sigma_3\ A_2) \Rightarrow \wedge\ (A_1 \not\equiv_3 A_2)] \Leftrightarrow \}_5\ \vee\ \{\ [(A_1\ \Sigma_3\ A_2) \Leftrightarrow$$

$$\wedge\ (A_1 \not\equiv_3 A_2)] \Rightarrow \}_5 \qquad [17]$$

We prefer to refer to this extension as a "four-law logic", where equations [13], [14], and [15] are the normal "explicit" laws, with the implicit law [16] understood but not explicitly written, and where equation [17] is the master application rule that puts it all together. But if one wishes to be rigorous, we have specified a 5-law extended logic that contains but expands Aristotle's 3-law logic. The application rule is the fifth law.

The point is this: In every case, we have a part of the perception, thought, or observation that obeys the explicit laws, and we also have a part that obeys the implicit laws. If opposites are not *explicitly* identical, then they are simultaneously *implicitly* identical. If opposites are *explicitly* identical, then simultaneously they are also *implicitly* not identical.

The new approach then covers what we observe more completely. As an example, any "wave" (observed) is implicitly a non-wave (particle), but not observably so. If its particle nature is observed and therefore explicit, its wave nature is unobserved and therefore implicit, and vice versa.

One also resolves such dilemmas as stating something "does not exist" but having to first call it into existence to even state it does not exist. In the new approach, it simply does not *explicitly* exist, but *implicitly* exists. *Not-being* is something like that: explicitly it doesn't exist, but implicitly it exists. The great problems of the philosophers were never solved, mostly because the logic brought to bear was Aristotelian and incomplete. The ultimate answers they sought all involved the fourth and fifth logic laws. So the ultimate answers all appeared to them to involve such things as "the accursed necessity for the identity of opposites." Precisely!

In physics, there has been the same problem over whether a fundamental particle is a particle or a wave. Physicists argued fiercely until they realized the futility of further argument, and settled for the duality principle. That simply states, well, in one case it can be a particle as observed in your experiments, and in another case it can be a wave as observed. So simply treat it as whichever one is useful! The philosophers, on the other hand, split into different schools, where each school had its "interpretation" usually involving a very "smooth" position statement of the school's position. In physics also, there are eight or more "interpretations" of quantum mechanics, for example. So the same centuries-old problem is still with us today in modern physics.

Opposites are no longer the formidable opponents they once seemed. Instead, they become more like the two sides of a coin, lying with only one side up. To see heads or tails is to decide which is explicit. The other is always there, implicitly. But notice also that the "two sides" require a 3-dimensional object, and not just the 2-dimensional "head" or the 2-dimensional "tail". This juxtaposition of "identical" opposites is strongly met with in modern physics. For example, quoting Lee[33] :

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[33] T. D. Lee, "Space Inversion, Time Reversal and Particle-Antiparticle Conjugation," *Physics Today*, 19(3), Mar. 1966, p. 23. Positive charge is really *observation* imposed on negative charge moving backwards in time, and the positron is really observation imposed upon an electron traveling backwards in time, etc.

> *"As we expand our observation, we extend our concepts. Thus the simple symmetries that once seemed self-evident are no longer taken for granted. Out of studies of different kinds of interactions we are learning that symmetry in nature is some complex mixture of changing plus into minus, running time backward and turning things inside out."*

Any addition to the Aristotelian laws of logic is actually a higher dimensional form of it. Three-law Aristotelian logic is in fact fitted to primitive observation — the result or output of single-photon interaction and observation processes.

This "four-law" logic (or "five-law" logic if one includes the master application rule as another "law") has proven very useful over the years, particularly in bioenergetics applications. It has also been most useful in attempting to decipher that branch of Russian energetics weapon science called "psychoenergetics", and in attempting to decipher the mind-body coupling mechanism, but that is beyond the scope of this chapter {79}.[34]

1.4.5 Substitution of Effect for Cause

Refer to Figure 1-3 again, to see the relationship of the unobserved cause, the interaction of cause and a previous effect, and the production of the resulting "new effect" as a change to the old effect or the output of a second replica of it. The greatest non sequitur in electrodynamics — and in parts of physics such as mechanics — is the widespread substitution of the *effect* for the *cause,* as a result of considering an observable to *persist in time* without any physical interaction. We discuss that more fully in Chapter 2, particularly with respect the notion of the same EM field existing both as a component of a material environment and as a component of a nonmaterial environment, but with the "force reducing to zero" in the latter. Jackson {80} points out the prevailing view of electrodynamicists as follows:

> *"Most classical electrodynamicists continue to adhere to the notion that the EM force field exists as such in the vacuum, but do admit that physically measurable*

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[34] The interested reader is referred to my website, www.cheniere.org, for papers dealing with the nature of the mind-body coupling mechanism and the body-mind coupling mechanism, as well as direct engineering of the mind, and limited information on the weapons referred to.

> *quantities such as force somehow involve the product of charge and field."*

On the other hand, Bunge {81} very clearly stated that the standard electrodynamics and physics itself are in terrible shape. Here is a direct quotation:

> *"... the best modern physicist is the one who acknowledges that neither classical nor quantum physics are cut and dried, both being full of holes and in need of a vigorous overhauling not only to better cover their own domains but also to join smoothly so as to produce a coherent picture of the various levels of physical reality."*

We shall try to further clarify these unresolved difficulties with the field concept in Chapter 2.

1.5 Electrodynamics is Still Developing

1.5.1 Statement by Penrose

Roger Penrose, one of the leading physicists of our time, pointed out the still-developing nature of electrodynamics with respect to the developments from conventional gauge-theoretic interpretation of Maxwell's equations. Quoting Penrose {82}:

> *"These facts should not, however, deter theoretical or experimental physicists from seeking alternative descriptions, unconventional formulations, surprising electromagnetic effects, or radical generalizations. The various articles in this book provide the reader with a great variety of different kinds of approach to developments of this nature. We have historically motivated accounts, suggestions for new experiments, unconventional viewpoints and attempts at generalizations. We also see novel and ingenious formulations of electromagnetic theory of various different kinds... I am sure that this book will make it clear that electromagnetism is a subject that is in no way closed to stimulating new developments. It is very much alive as a source of fruitful new ideas."*

1.5.2 An Example of a Ubiquitous Error

One of the rather horrid "bad examples" of ubiquitous errors in electrodynamics is the conventional illustration of a so-called planar EM wavefront moving through space, as shown in Figure 1-4.

A succinct evaluation of that diagram and notion is given by Evans {83}, one of the great electrodynamic theoreticians of our times:

> *"I broadly agree ... that the transverse plane wave view of vacuum electrodynamics is the biggest blunder of twentieth century science."*

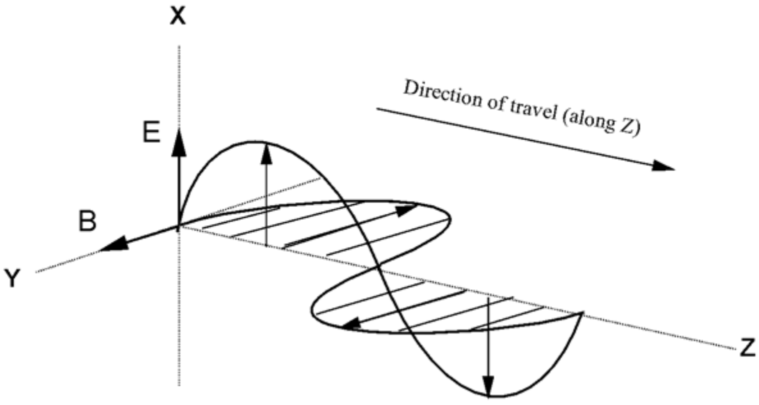

Figure 1-4 The erroneous but ubiquitous supposed illustration of the transverse EM wave in 3-space.

Dr. Robert H. Romer, former Editor of the *American Journal of Physics*, also chastised the horrid diagram shown in Figure 1-4, purporting to illustrate the transverse plane wave traveling through 3-space. In endnote 24 of his noteworthy editorial, Dr. Romer {84} takes that diagram to task as follows:

> *"...that dreadful diagram purporting to show the electric and magnetic fields of a plane wave, as a function of position (and/or time?) that besmirch the pages of almost every introductory book. ...it is a horrible diagram. 'Misleading' would be too kind a word; 'wrong' is more accurate." "...perhaps then, for historical interest, [we*

> *should] find out how that diagram came to contaminate our literature in the first place."*

Indeed, each point along the z-axis, is a momentary "3-space frozen slice" of the $\in/\in t$ operator being applied to the ongoing 4-space interaction of the causal field in 4-space interacting with the previous "observed effect" (in this case, the previous 3-space slice) to produce a change to it. So the entire diagram is a set of "frozen 3-space observations", in which nothing at all is moving, and where the fields shown are in the mass (detecting/observing) medium. There is no such thing as a "traveling EM wave in 3-space", because "moving" or "changing" or "traveling" *a priori* must involve time as well as 3-space. What we are looking at in Figure 1-4 is the iterative and very rapid results of continual "3-space observations" (frozen 3-snapshots) of an on-going 4-space interaction.

1.5.3 An Extremely Important EM Omission

There is an enormous amount of development yet to be done in electrodynamics! As a simple example, for nearly a century there has been waiting quietly a fundamental "internal" or "infolded" electrodynamics by Whittaker {85, 91a, 86}, based on more primitive initial work by Stoney {87}, existing inside — and *comprising* — all conventional EM potentials, fields, and waves. This internal electrodynamics {88} has been essentially ignored in the West, but has already been weaponized in the weapons laboratories of several nations under the aegis of *energetics*. The U.S. Secretary of Defense, Secretary Cohen {89}, alluded directly to some of these weapons in a speech in 1997 as follows:

> *"Others [terrorists] are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves... So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations...It's real, and that's the reason why we have to intensify our [counterterrorism] efforts."*

The weapons are already being utilized against various nations in the form of terrorist acts in an undeclared war {89}, and have been so used since the 1950s.

This internal longitudinal-wave EM and its dynamics is a much more fundamental electrodynamics (actually a subset of a unified field theory) consisting of correlated longitudinal EM wavepairs in both the 3-space and time domains. Each Whittaker decomposition wavepair is comprised of an incoming longitudinal wave — a "time-polarized" EM wave {90a-90c} — in the time domain, perfectly correlated with an emitted longitudinal EM wave in 3-space. See Figure 1-5. This multiwave structuring and dynamics in both the time domain and in 3-space simultaneously *comprises* the scalar potential.

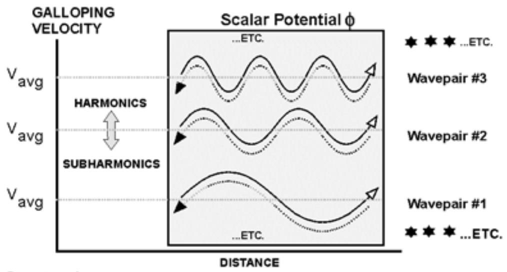

The Structure Is:

- A harmonic set of longitudinal phase conjugate wavepairs.
- In each wavepair the two waves superpose spatially after detection, but travel in opposite directions.
- Prior to detection, the convergent wave set is in the imaginary plane, and hence is not observable. It is EM energy incoming to the potential (dipolarity) from the time domain.
- The charges receive the complex convergent EM energy, transduce it into real EM energy, and emit enormous energy at the speed of light in all directions -- which includes bidirectional pairs in 3-space (after the reaction, being after "observation").
- This produces the fields and potentials from the "source charge or dipole."
- Mandl and Shaw argue that the scalar (time-polarized) photon and longitudinal photon are observable only in similar pairs, which then makes the instantaneous scalar potential. Thus quantum field theory work strongly supports the "negative resistor" interpretation of the scalar potential and our solution to the source charge and source dipole problem.

Figure 1-5 The scalar potential is a harmonic set of phase conjugate longitudinal EM wavepairs.

We specifically stress that the dynamics occur in the *time* domain (in its specific structuring, propagation pace, etc.) as well as in 3-space.

Deliberately changing the internal longitudinal EM wave structuring produces precise energetics (both energy and dynamics) in spacetime itself. This is a special form of "spacetime curvature structure and dynamics" which we call a *spacetime curvature engine* or *vacuum engine*. Together with superpotential theory in the original form initiated by Whittaker {91a} and extended by others {91b, 91c, 91d}, this internal electrodynamics — together with scalar potential interferometry {92} — creates all ordinary EM fields and waves {79}. Superluminal communication is possible using the internal longitudinal EM wave structure of the EM fields, potentials, and waves {93a, 93b}.

1.6 A Summarizing Letter

Our thrust in this book is to attempt to (1) reveal some of the major flaws in electrodynamics that have prevented development and use of COP>1.0 electrical power systems, and (2) point the way toward the development and use of such systems. To give a general summary of the ground this book will cover, we conclude with an informal E-mail letter I sent to the recent editor of *American Journal of Physics*, pointing out the greater implications of his cogent observation of that "dreadful diagram" and where it leads. Indeed, it (i) leads to a dramatic change in electrodynamics, (ii) changes the way in which we regard "propagation of EM energy through 3-space", (iii) solves the long-vexing problem of the association of the source charge or source dipole with its fields and potentials and their energy, (iv) changes dramatically the way we view what powers an electromagnetic circuit or power line, (v) allows extraction and use of copious EM energy from the vacuum, and (vi) solves the energy crisis permanently.

Here is the letter sent informally to Dr. Robert H. Romer — *slightly edited* to improve the grammar, correct one error of misstatement, and with reference citations added and listed at the end of this chapter:

To: Dr. Robert H. Romer   Thursday, Mar. 8, 2001
American Journal of Physics
Amherst College, Box 2262
Amherst, MA 01002

<ins>Personal communication</ins>

Subject: Implications of your cogent comments on that atrocious illustration

Dear Dr. Romer:

This is not a submission of a manuscript, but a personal communication to you on a matter of great importance in physics, directly related to endnote #24 of your seminal editorial {94}.

It will take a little exposition, so please bear with me and read this when you have the spare time to do so. We are going to show you how your keen insight can be extended to solve some extraordinarily formidable foundations problems in present electrodynamics. We will also show how to apply the implications of your insight to totally solve the present electrical energy crisis permanently.

In your endnote #24, {94} you took to task (quoting):

> *"...that dreadful diagram purporting to show the electric and magnetic fields of a plane wave, as a function of position (and/or time?) that besmirch the pages of almost every introductory book. ...it is a horrible diagram. 'Misleading' would be too kind a word; 'wrong' is more accurate." "...perhaps then, for historical interest, [we should] find out how that diagram came to contaminate our literature in the first place."*

Dr. Romer, you have lifted the corner of a dark cover concealing one of the most important flaws in electrodynamics and in fact in all of physics: the unwitting and pervasive substitution of the effect for the cause. A marvelous extension to the present physics is enabled if one removes this terrible non sequitur in physics, and particularly in electrodynamics. For openers, one solves what has been called the most difficult problem in electrodynamics (the problem of the source charge and the association of its fields and potentials and their energy) {100}. I will solve that problem for you in this informal write-up. I will also explain how to extract enormous EM energy from the vacuum, anywhere and anytime, easily. Extracting it is easy; catching it and using it to power loads without killing the extraction process is another matter.

One also gets a unified field theory, engineerable by novel electrodynamic means, as is steadily being shown by a series of rigorous Alpha Foundation's Institute for Advanced Study (AIAS) papers published in various leading journals (and more than 90 of them carried on a Department of Energy website restricted primarily to DoE scientists). Dr. Myron Evans, Director of the AIAS, has over 600 papers published in the literature, including such journals as *Physical Review*, *Foundations of Physics*, *Physica Scripta*, etc. Many of the other AIAS co-authors are excellent theoreticians and scientists.

The early pioneers of electrodynamics (Maxwell etc.) all assumed a material ether filling all space {95}. To these early scientists, there was not a single point in the entire universe that was devoid of matter, because the ether was present there. Hence their outlook as to the nature of EM fields etc. was quite material. Faraday conceived his "lines of force" as physical, taut strings, so that perturbations were "plucking these taut strings".

Maxwell himself points out in his famous "Treatise" that he specifically captured the thinking of Faraday in his theory. In fact, Maxwell wrote a *material fluid flow dynamics* theory.

In the light of more modern knowledge, let us see the impact of these and similar early *but still retained* erroneous electrodynamics assumptions.

First, observation/detection is totally spatial, as is well known in quantum mechanics. In fact, observation is a $\in/\in t$ operator imposed upon 4-space (LLLT spacetime), yielding a frozen instantaneous snapshot LLL of an ongoing 4-space dynamic process. At the next instant, that particular *previous* observation no longer persists. Why?

Well, no observable *persists*, since it is only an instant frozen 3-space snapshot, at a single point in time, *a priori.* Here again we have another horrendous non sequitur in all of physics: the assumption that observables "continue to exist" and therefore persist in time in a passive manner. In fact, there is an interactive process that generates their (seeming) persistence, involves time, and continually changes mass into masstime and back to mass, etc. With the reader's permission, we will pass discussing that mechanism until another time (pun intended!).

What we conceive as "an observable such as mass, traveling through space and persisting in time while doing so", is actually an iterative, continual series of these frozen 3-space snapshots or observations, much like the frames of a motion picture film. We ourselves mentally add the "continuity" to provide "the sensed motion", but rigorously what is actually "observed" is not continuous, but is a vast continual series of those frozen 3-space snapshots.

We're getting directly at that atrocious diagram!

Each snapshot is an *effect*, not a cause, because it was the output of the observation process whereby a 4-space *causal* entity (non observed *a priori*) interacts with a previously observed frozen entity (say, a unit point charge at some point in space) to produce the observation (change or effect generated in that interacting observed charge) as the "next instantaneous observation".

The usual "representation" of a "3-space EM wave" propagating in 3-space is indeed atrocious, just as you stated! It is actually just an iterative succession of such instantaneously frozen snapshots in 3-space, one after the other. There is no such thing as that set of snapshots independently existing in spacetime, *prior to interaction with charge* in that series of interactions and observations, unless we wish to discard quantum mechanics and the laws of logic.

There is, however, a continual iterative stream of those observations — those frozen 3-space snapshots — that we interpret (erroneously) by recall from memory as the "EM wavefront propagating in 3-space". As you eloquently pointed out, that is not so, and it is atrocious. An observation, being an absolutely frozen entity, cannot "move through time" anyway, since it cannot persist, nor can it move. A change to an observable can only be another observable snapshot of the ongoing 4-space entity and action, which is then compared to the first snapshot and a difference noted {96} [See Figure 1-3].

In short, a great stream of "frozen effects" (frozen instant observations) does not constitute a "picture" of the ongoing 4-space action, but only a series of frozen 3-space intersections involving the interaction of that fixed observed (3-space) charge with the ongoing causal 4-space entity. If we add and integrate a series of 3-space pieces, we *do not* get a 4-space entity! Instead, we get a longer or bigger 3-space slice/piece, but one for which each piece of it only existed at a single point in time as a 3-space "slice" at that moment. That is precisely what is wrong with that horrible illustration.

But it is also "wrong" with electrodynamics itself! Electrodynamicists mistakenly conclude that the same *effect* "series of static 3-slices" — which they might call, e.g., the "field" in a case where the field is the subject — is the same as the 4-space continuous *causal* field prior to observation interaction with charge at all. Well, LLLT is definitely not LLL, nor is it n(LLL) where n is some large but finite number of 3-slices LLL.

So the field concept is dichotomously used in two contradictory manners in electrodynamics:

(1) it is considered to be in 4-space prior to the observing/detecting interaction with the observable (such as a unit point 3-space charge), and it is also considered a 3-space entity *after* that interaction. The dimensions of the two entities are not the same, and neither are the dynamics. The causal EM wave is dynamic and 4-spatial, the effect "3-space EM wave" (ugh!) is static and 3-spatial at each instant it is "observed". Assuming that the two are the same thing is a non sequitur.

In fact, it substitutes the *effect* for the *cause*, a rather gross violation of the causality principle itself.

(2) then an attempt at glossing over the illogic is used by the smooth statement that "the field (meaning that atrocious series of frozen 3-space snapshots) remains in the absence of charge, but the force goes to zero." Well, if the field is defined as a force field, it cannot be a "non-force field in the same observation!" Else, opposites are always identical.

So of what importance is all that?

It is of great importance. Let me show you one very startling thing that comes out of correcting this "biggest foundations non sequitur in physics, that of substituting the effect for the cause".

Consider a very special paper by E. T. Whittaker {97} in 1903. [I can send you a pdf file of the paper if you do not have it and are interested]. In this much-neglected paper, Whittaker decomposed the so-called "static" potential into a harmonic set of bidirectional longitudinal EM wavepairs, where each pair consists of a longitudinal 3-space wave (an *as-observed* wave) and its longitudinal phase conjugate wave (*considered unwittingly as having also interacted with charge, and therefore as being shifted into 3-space as an "as-observed" wave with inverse parity*).

Whittaker — as has everyone since him — unwittingly assumed the "iterative continual observation" interaction in there for the phase conjugate wave also. In so doing, he came up with two *effect* "waves" that are the outputs of the assumed observation process. Neither of these effect waves would be a wave in spacetime {98} at all, but the two in ensemble are an example of the same thing you objected to in your cogent commentary on that abominable "illustration".

In short, Whittaker invoked *observation* as a process with two effects and no cause, rather than with a cause and an effect, with the interaction with the observing/interacting unit point charge being assumed for both waves. Whittaker and everyone since seem to have made the same error in interpreting that seminal Whittaker decomposition. This misinterpretation of the decomposition has until now hidden one of the greatest secrets of all times in Nature's electrodynamics!

Let us correct the interpretation, and uproot that great secret to the light of day.

First, for observation to occur, one must have a cause acting upon the affected (observable) entity, and an effect (observable change) must be produced in, on, or of that affected (interacting) entity. One *must not* have two effects (two observables) and the affected entity (another observable and therefore another effect)! Again, assuming that one has three effects (observables) constituting the observation process is a logical non sequitur of first rank.

Let us now correct that logical non sequitur made by Whittaker and other physicists and electrodynamicists, and see where it leads us.

First, we go to particle physics, where broken symmetry {99} was discovered in the 1950s. Lee, e.g., received a Nobel Prize for his work in that area {75}. Lee also showed that any dipole is a broken 3-symmetry in its violent energy exchange with the active vacuum.

Well, a scalar potential is a dipolarity; always a potential is actually a difference between two potentials, so to speak. So the potential itself represents a broken 3-symmetry in an energy flow exchange with the active vacuum.

Let us further examine that interesting broken symmetry aspect. It means that the "static" potential is a process whereby energy is received from the vacuum in *one* form, not observable, and hence unusable, but is output in *observable* (usable) form. In short, the dipolarity or dipole receives and absorbs (QM view) virtual photons, integrates them into observable magnitude, and emits real, observable EM energy ("continual observation" snapshots of the latter being assumed).

In physics, all observation is 3-spatial, as is well known. And 3-space is the realm of the observed. The EM energy from the vacuum is not received in 3-spatial (observable) form, else there would be no broken 3-symmetry of the dipolarity.

We can also *experimentally* verify that there is no 3-space input of EM energy to the potential — e.g., to the potential between the ends of any source dipole, because we cannot measure any 3-space observable energy feeding the charges of the dipole. Instead, observable 3-space energy is continuously pouring out of the dipole.

Let us continue now with the notion of a real dipole of separated source charges, with our "scalar potential" between its ends, so we have something concrete in mind.

First, our instruments prove there is a continual emission of EM energy in all directions in 3-space (of the kind in that atrocious diagram; a "series of iterative film-snapshots"). That is the way it is conventionally represented, as if observed at each and every point successively in that 3-space, and along every radial.

But secondly, our instruments also prove there is no such observable *input* of EM energy in that same 3-space *to* the dipole. Bummer! That is precisely what has stopped electrodynamicists from solving that vexing problem of where all the energy pouring out of the source dipole is coming from, and how! They unconsciously assume that the only possible source of the EM energy input is in 3-space. That is totally wrong. Further, the conservation of energy law does not require that energy be conserved in 3-space! Instead, rigorously — if we are using a 4-space (i.e., spacetime) model — it requires that energy be conserved in 4-space. The assumption of the extra condition of 3-space energy conservation is an added and arbitrary extra condition.

Since electrodynamics has not resolved this "source dipole and its associated fields and potentials" problem, it has stopped work on the problem and implied that every dipole in the universe is a perpetual motion machine, freely creating all that EM energy it continuously pours out across space, in all directions, creating its associated fields and potentials. That implicit assumption, if true, of course destroys the conservation of energy law.

It isn't true, and the energy conservation law is alive and well!

We can experimentally prove that the source dipole *does* continuously pour out energy in all directions in 3-space, without ceasing, as follows:

In a gedanken experiment, we set instruments every 300 million meters or so, along a radial line from an origin in the lab. With the instruments and clocks synchronized, we suddenly form a dipole at the origin. One second later, the first instrument reads. A second later, the second instrument reads. And so on. But it is not a "passing pulse". Whatever reading the instrument makes as the forward edge of the energy flow reaches it, is then continuously maintained thereafter. This proves that the energy is poured out continuously and at the speed of light, and in any (and all) directions in 3-space, *and it continues to pour out at exactly the same rate so long as that dipole remains intact.*

Dipoles in the original matter of the universe have been pouring out EM energy in that fashion for some 14 billion years, and they have not "exhausted" their unobserved energy input source yet.

A newly formed simple dipole, e.g., in one year will have poured out energy into a spherical volume of space that is a light-year in radius. Wait another year, and that volume of space whose energy density has been changed will be two light years in radius. The dipoles in the original matter have filled the universe itself with that energy outpouring from them.

In other words, an incredible amount of EM energy has been and is being poured out into space from every dipole in the universe.[35] And electrodynamicists have had not the foggiest notion of where that mind-boggling amount of outpoured EM energy has come from.

Unless we wish to totally discard the conservation of energy law, we must have an equal input of energy *from outside 3-space*, going into every dipole continuously. In 4-space, that only leaves the fourth axis, along which and from which the input energy must move into the dipole.

And so it does. If we re-interpret that phase conjugate half set of the Whittaker decomposition, *before* observation has occurred, it then is a harmonic set of longitudinal EM waves moving in the time-dimension, *into* the source dipole (parity is not inversed because no interaction with charge has occurred to shift it into 3-space.

So voila! We have strangely (but quite rigorously) solved what Sen {100} referred to in this manner: *"The connection between the field and its source has always been and still is the most difficult problem in classical and quantum electrodynamics."*

We express our reasoning as follows: (i) we know from particle physics that the source dipole[36] is a broken 3-symmetry in its flux exchange with the vacuum. This means that we know the energy is received from the vacuum in an *unobservable* form, absorbed by the dipole, and emitted as *observable* EM energy. It remains to translate that into classical electrodynamics rather than quantum physics {101}. (ii) The *time* domain is the only domain outside 3-space, in the standard 4-space model. (iii) Anything in the time domain exclusively, is indeed nonobservable, since the $\in/\in t$ observation operator destroys time and all its internal structure and dynamics whenever observation occurs. (iv) Looking for a "3-space" input is looking for an "observable" EM energy input, which would in fact disagree with the known broken 3-symmetry of the source dipole.

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[35] Later we will see that, in a time-forward situation, the negative charge pours out positive EM energy while the positive charge may be said to pour out negative EM energy. Charge conservation then implies that an energy balance is maintained overall.

[36] Because of the broken symmetry of the opposite charges on its opposing ends.

Let me digress now to speak of fundamental units. As is well known, the fundamental units one chooses to make his physics model represent an arbitrary choice. One can, if one wishes, make a perfectly valid (but mentally nightmarish!) physics using only a single fundamental unit. In that case, all other "fundamental units" in the present model become functions of that single fundamental unit.

Suppose, e.g., that we make the joule our only fundamental unit. Then "mass" becomes totally a function of energy — and we have no heartburn with that one since the Einstein revolution and the nuclear age. But then "time" also becomes totally a function of energy — and that surprises us, because we have unconsciously been taught (erroneously) that "time is a flowing river down which a mass drifts like a drifting boat". That is not the nature of time at all; the totality of the photon interactions with a mass create that mass's "motion through time". I can later explain that to you also, if you wish, but let us pass it for now.

It turns out that time is spatial energy compacted by the factor c^2, so it has the same energy density as mass, but in the time axis instead of 3-space. Intuitively, if we are interested in cause and effect, the energy of the cause (time) should be equal to the energy of the effect (in this case, mass). After one reflects a moment, one also sees that "time energy" is required to "drive" a mass through time, just as "spatial" energy is required to "drive" a mass through space. The notion that mass in an inertial frame moves through "empty space with no reaction" is false; it continually moves through the energetics of spacetime, and interacts continuously with it.

Anyway, from still another viewpoint there is no magic in EM energy currents moving in the time domain! Quantum field theory already recognizes multiple polarizations of the photon, including transverse, longitudinal, and time-polarized. Thus, it implies a time-polarized EM wave also. A longitudinal EM wave *moving in the time domain* oscillates along its line of travel. That is indeed oscillating its energy density in the time domain, so that it is "time-polarized". Hence it is a proper time-polarized EM wave, and appears to "gallop" {102} or vary its speed periodically.

The solution to the "source dipole" problem is that the phase conjugate wave half-set of the Whittaker decomposition, when reinterpreted, is the *incoming* EM energy in the time domain, continuously input to the charges of the dipole. The charges interact in the imaginary plane (the time domain), and absorb the time-energy, then transduce it into 3-space, and emit it as Whittaker's set of real observable longitudinal EM waves in all directions in 3-space (as observed). The time-energy waves that are input to the dipole cannot be observed, since observation destroys time and its constituents.

All 3-spatial EM energy comes from the time domain! Broken 3-symmetry of the source dipole immediately releases our arbitrary additional restriction on nature's energy conservation law — i.e., our insistence that the energy input for conservation must be input in 3-space. By removing these arbitrary "shackles" from nature's feet, we allow nature to joyously resume her much-preferred special 4-symmetry in EM energy flow: the circulation of EM energy from the time domain into 3-space, and outpouring of that energy in all directions in 3-space, at the speed of light {103}.

Now let us solve the source-charge problem as well. That one is now easy to resolve.

We know from quantum mechanics that any "isolated" observable charge is actually clustered around by virtual charges of opposite sign. So we simply take one of these clustering opposite charges while it exists, and a differential piece of the observable charge, and we have a composite dipole. Hence the "isolated charge" may be represented as a grouping of such momentary dipoles, each (while it exists) with a scalar potential between its poles, and hence each subject to the same decomposition and reinterpretation we have done.

That is why the source charge can "sit there" and pour out EM energy in 3-space (as observed) continuously, and indefinitely. It is also continuously absorbing EM energy from the time domain. As a set of composite dipoles, it is a set of broken 3-symmetries in EM energy flow. Hence it exhibits nature's preferred 4-symmetry in energy flow, between the time-domain and 3-space.

Note also that, to the 3-space observer, this 4-symmetry is purely negentropic. It is a continuous and ongoing (and expanding) reordering of the vacuum energy, in the form of the reinterpreted Whittaker decomposition.

We can easily engineer negentropy! Just make a little dipole, and nature happily starts pouring out energy and reordering part of the vacuum, with that reordering spreading at the speed of light, steadily increasing all the while.

Reinterpreting Whittaker's marvelous decomposition tells us many things: (i) the source charge or dipole does indeed continuously receive and absorb its input energy from the time domain, (ii) it continuously transduces its absorbed energy to real 3-space energy (as observed!), and (iii) it continually outputs its absorbed and transduced time-energy as 3-space energy emitted in all directions in 3-space (as continually observed).

So the terrible foundations problem of the source charge and source dipole is resolved, and the energy conservation law is maintained.

We have also uncovered a most important thing: Given a little broken 3-symmetry in EM energy flow, t-symmetry in EM energy flow is also broken. A more primary 4-symmetry {104} between time-energy flow and 3-space energy flow emerges *automatically*. In short, every potential, every dipolarity, and every charge is such a broken 3-symmetry and an example of the new, preferred 4-symmetry of EM flow, with input flow in the time-domain (nonobservable!) and output flow (as continually observed in a series of 3-snapshots) in all directions in 3-space.

This also resolves the logical cause and effect problem for observation.

This 4-symmetry is a purely negentropic process, once the dipole is established! Well, we should have known that from the gauge freedom axiom in gauge field theory anyway! That axiom says that we can change the potentials anytime, freely and at will. In electrodynamics, that means we can change the potentials at will, anytime we want to. But that means *we can freely change the potential energy of a Maxwellian system at will, whenever we wish*. It costs nothing — at least in theory; in the real world we have to pay a little for switching — to suddenly potentialize an EM system, prior to the time the Drude electrons relax and current flow begins.

I have applied this great new 4-symmetry in EM energy flow, that is freely evoked and persists indefinitely after one pays a little to make the dipole and thus produce a little broken 3-symmetry, to produce EM energy freely from the vacuum. Without going into it, I refer you to our forthcoming papers {105}. Indeed, we can use this negentropic process to extract as much EM energy from the vacuum as we wish, anywhere, anytime, for peanuts. Let us now move to discuss that area.

First, we point out another astounding result that comes from resolving this "source charge and source dipole" foundations problem.

Generators do not use any of the shaft energy input to them — even in transduced form — to power their external circuits! A generator itself does not add a single watt to the power line, and neither does a battery's chemical energy dissipation add a single watt to its attached circuit.

Neither does burning all those hydrocarbons, consuming all those nuclear fuel rods, building all those dams, etc. to provide our conventional power systems and grid. None of that enormous destruction of the biosphere and pollution of it has ever directly produced one watt on the electrical power line.

Just follow the energy flow, in light of what we now know. Here's how it works.

Typically, we burn some fuel to boil water and make steam, and use the steam to power a steam turbine, which forcibly rotates the shaft of the generator, thereby inputting mechanical shaft energy into the generator. So far, so good. That took care of all the hydrocarbon burning and fuel rod consuming, extracting and transporting the oil, etc.

This input of the shaft energy forcibly rotates the rotor against internal resistance, forming an internal magnetic field. Assuming a 100% efficient generator with no internal losses whatsoever, this means that the *mechanical shaft energy input* has now been totally transduced into *internal magnetic field energy*.

So what does that magnetic field energy *do*? It is totally dissipated upon the internal charges of the generator, performing work on them and forcing the positive charges in one direction and the negative charges in the other direction. That dissipation of the energy in the internal magnetic field *forms a source dipole inside the generator, connected to the terminals*.

And that is all the generator does. Period. *None* of the energy transduced from that shaft input, went roaring out of the terminals and down through space outside the conductors of the power line. Not a single watt. So let us turn to particle physics to find out what happens next, because *it does not yet appear in the electrodynamics model, even though proven.*

The internal source dipole, *once formed*, is a great broken symmetry in the vacuum flux, as we discussed and as is well known in particle physics. But the proven and well-known vacuum interaction with the generator and the dipole charges is not even modeled in the classical EM theory used by the scientists and engineers to build electrical power systems — much less a *broken symmetry* in that active exchange! That's atrocious, since it's been proven in particle physics for nearly a half century, Nobel prizes awarded, etc. But the hoary old 137-year old Maxwell-Heaviside model, further curtailed by Lorentz symmetrical regauging, does not incorporate what has already been proven in physics. *It does not accurately model the situation as it is and as it is known to be.*

Let us continue.

Once that dipole is formed, it extracts *enormous* EM energy from the vacuum, and pours it out of the terminals of the generator, filling space surrounding those conductors of the attached external power line. It is a huge EM energy flow, trillions of times larger than what we account after Lorentz taught us to disregard almost all of it.[37]

Only the tiny little bit of that EM energy flow in space along and surrounding the conductors — the little "boundary layer" that skims down the surface of the conductors — will strike the surface charges in the conductors and get diverged into them to potentialize the Drude electrons and "power the power line and its circuits and loads". *All the rest of the giant EM energy flow in space surrounding the conductors, and generally parallel to them, misses that power line entirely and is just wasted.*

Check the original papers by Poynting {4a, 4b} and by Heaviside {5a, 5b, 5c}, who independently discovered the flow of EM energy through space (as if continually observed!) in the 1880s, after Maxwell was already dead. I can furnish the citations required. From the beginning, Poynting only considered that component of the energy flow that actually enters the circuit. He considered only the "boundary layer" right on the conductor surfaces, so to speak.

Heaviside considered that component that enters the circuit, and also uncovered and recognized the *gigantic* component in the surrounding space that *does not* enter the circuit but misses it entirely and is wasted. [Added] Here is Heaviside's {106} own statement:

> *"It [the energy transfer flow] takes place, in the vicinity of the wire, very nearly parallel to it, with a slight slope towards the wire… . Prof. Poynting, on the other hand, holds a different view, representing the transfer as nearly perpendicular to a wire, i.e., with a slight departure from*

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[37] However, contrary to what is in the textbooks, **E** Δ **H** energy flow is not in observable EM field form **E** and **H** until it interacts with charge. Instead, the flow is in the form of virtual energy currents in the vacuum. We point out that the fields **E** and **H** utilized in the Poynting energy flow theory are effects and not causes. They are rigorously defined as **E** and **H** only after the causal 4-fields have interacted with charge. E.g., **E** is "defined" as force per unit point massive charge — i.e., as the force created by interaction of the "vacuum field" (curvature of spacetime) with a unit point charge. No unit point charge interaction, no force or force field intensity per interacting unit point charge.

> *the vertical. This difference of a quadrant can, I think, only arise from what seems to be a misconception on his part as to the nature of the electric field in the vicinity of a wire supporting electric current. The lines of electric force are nearly perpendicular to the wire. The departure from perpendicularity is usually so small that I have sometimes spoken of them as being perpendicular to it, as they practically are, before I recognized the great physical importance of the slight departure. It causes the convergence of energy into the wire."* [End of Added].

But Heaviside had absolutely no explanation for the enormous and startling magnitude of this energy flow that "misses the surface charges of the conductors and is wasted". You can see an elementary illustration of the "point intensity" of this Poynting diverged energy flow component in Kraus {107}. Kraus's figure 12-59, p. 576 shows a good drawing of the *Poynting* component *being withdrawn* from the total EM energy flow filling all space around the conductors [see our Figure 1-1 in the present chapter].[38] Most of that available energy flow is not intercepted and thus not diverged into the circuit to power it, but just "wasted." The *remaining* huge component discovered by Heaviside is not shown on Kraus's diagram. Kraus's numbers on the contours represent the amount of power (watts per sq meter) being withdrawn from each contour, by the very limited axial movement of the electrons and the very ends of their associated fields into the wire.[39]

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[38] The energy flow in space near the surface of the wires strikes the surface electrons and their fields, potentializing them and creating a force field with respect to inner electrons. This drives the surface electrons axially into the wire, since they can only move down the wire with the drift velocity, nominally on the order of a few inches per hour. The short inwards drawing of those small portions of the fields and of the increased potentials attached to the charges that move into the wires, interacts with the internal charges in the interior of the wire, powering the Drude electrons throughout the conductor and the circuit. For a discussion of the importance of the surface charges, see J. D. Jackson, "Surface charges on circuit wires and resistors play three roles," *Am. J. Phys.*, 64(7), July 1996, p. 855-870.

[39] Obviously the increased fields on the withdrawing surface charges reach toward infinity radially outward from the wire. Thus most of this increased field on a withdrawing electron remains outside the wire, radially reaching toward infinity, since the electron and its field cannot be withdrawn further than the diameter of the wire. As the surface charges and their fields change in Jackson's discussion, obviously those distant parts of the field remain outside the conductors. Hence there remains an extensive field and field energy outside the conductors and the circuits

So Heaviside {106} spoke cautiously of the *angles* and *relative directions* of the flow components; he did not wish to be scientifically destroyed for pointing out such an inexplicably large EM energy flow, far larger than the known energy input to the generator. There was then no such thing yet discovered as the electron, the atom, the nucleus, special relativity, general relativity, quantum mechanics, the active vacuum, etc. Poynting {4a, 4b} never even thought of the "nondiverged component that misses the circuit", nor did he consider it.

Lorentz, however, understood the extra Heaviside component and its vast magnitude, but he also could not explain it in any fashion. Even the great Lorentz could not risk publishing or advocating such an enormous energy flow, lest he be called a "perpetual motion nut" and destroyed. So he reasoned that, since that stupendous nondiverged energy flow component misses the circuit and powers nothing, it has "no physical significance" (his words).

Jackson in his famous 1975 *Classical Electrodynamics*, 2nd edition, uses essentially the same phrase {108a} as did Lorentz. And so do most other electrodynamicists.

So Lorentz {109} originated a little trick of integrating the energy flow vector itself around a closed surface surrounding any volume element of interest. Obviously, that zeros all *nondiverging* EM energy flows — including precisely that inexplicable and enormous Heaviside "dark energy" component. The integration trick does retain that small, *diverged* Poynting component that enters the circuit. In addition, our instruments measure energy dissipation from the circuit, and the energy has to *enter* the circuit to *be dissipated* from it. So our instruments and their measurements will indeed agree with the Poynting energy flow component. Lorentz thus arbitrarily discarded accountability of trillions of times as much EM energy flow as was retained and accounted.

In a later book by Lorentz, one can see that little trick {109} that is still used by electrodynamicists {110}.

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that is never drawn into the wire. Additional separate receiver circuits with resistive loads, adroitly placed in this "externally remaining" field energy flow, can be made to intercept additional EM energy and will perform additional work in those external loads in the secondary circuits, separate from powering the loads in the primary circuit.

The Lorentz trick does not cancel the *actual* flow of the Heaviside dark energy component around every circuit! It just drops it from any accountability.

Indeed, we do precisely a similar thing for the "field" and the "potential". There is not a single text in the U.S. that calculates the magnitude of the *field itself*, prior to point interaction. Instead, we are taught to calculate the reaction of that field at a point in it, with a unit point static charge at that point. In short, we calculate *what is actually locally diverged from the field or potential by that little point static unit charge*, and call it "the magnitude of the field". At best, it is indicative of the field intensity at a point, because we have prescribed the magnitude of the static point charge's *reaction cross section* with the field, *not* the overall magnitude of the entire field itself. Another major non sequitur! By identifying the "field" as "that which is diverged from it", we gravely err. We do the same for the potential, again using its reaction cross section for a unit point charge at a point in the potential.

There is hardly a living electrodynamicist, it seems, who has calculated the magnitude of the field itself, or of the potential itself! All calculate the respective reaction cross section (and the *static* reaction cross section at that!) and erroneously call that the "magnitude of the field" or the "magnitude of the potential". It is no such thing. No thing filling all space is identical to a little something diverted from one point in itself, else we discard all logic.

Now we can return to our source dipole and its extraction of an *enormous* energy flow from the vacuum, once we account for the long-neglected (for more than a century) Heaviside dark (nondiverged, unaccounted) energy flow component. That is the essence of one of my papers {111}.

The easiest thing in the world to do is to extract enormous usable EM energy flow from the vacuum, *from the time domain*. Every circuit and every electrical power system already does it, and every electrical power system is powered by vacuum energy, *not* by burning all that coal, oil, etc. None of that does anything to actually power the circuit. It only makes dipoles.

If you will check the characteristics of the ubiquitous closed current loop circuit, you will discover a diabolical thing: that closed current loop circuit forces all the spent (depotentialized) electrons from the ground return line back through the source dipole (back through the back emf). It is easily shown that precisely half the energy *collected* in the circuit from that feeble Poynting energy flow component is then used to perform work on those dipole charges and scatter them, thereby destroying the source dipole and abruptly shutting off all energy extraction from the vacuum. The other half of the collected Poynting energy is dissipated in the external loads and losses. That means that half the collected Poynting energy is used to kill the source dipole, and less than half is used to power the loads {112}.

Well, we must input at least as much energy (assuming a 100% efficient generator with no losses) to the shaft of the generator to *restore* the dipole, as was used to *destroy* it. This means we shall always have to input *more* energy to the generator shaft, than we get dissipated in the loads.

That is precisely what is responsible for our ubiquitous COP<1.0 systems. *COP* is Coefficient of Performance, and is the average load power output in the external circuit divided by the average shaft power we pay to input to the generator.

COP < 1.0 comes from (i) the ubiquitous usage of the closed-current-loop circuit, and (ii) the prevailing notion that electrical power systems far from equilibrium in their energetic exchange with the active vacuum are impossible to build. In fact, every electrical power system is *already* just such a COP > 1.0 system, as far as the energy flow out of the generator or battery — compared to the shaft input energy to the generator or battery — is concerned.

As is well-known in the thermodynamics of open systems far from equilibrium with their active environment (in this case, the active vacuum), such a system is permitted to: (1) self-organize, (2) self-oscillate or self-rotate, (3) output more energy than the operator himself must input to the system (the excess energy being freely received from the active environment, in this case the active vacuum), (4) power itself and its loads simultaneously (all the energy being freely received from the active environment, in this case the active vacuum), and (5) exhibit negentropy.

But by designing all our systems so that they use more of their collected energy from the vacuum to kill their source dipoles than they use to power their loads, we have foolishly wasted the planet's resources, vastly overcharged the consumer, artificially created a great energy crisis, fomented wars for precious oil and other energy resources, polluted the planet, enhanced global warming, and strangled species.

In short, we pay the power company to have a giant wrestling match inside its generators and lose! And we pay our electrical engineers to keep designing and building such asinine systems!

This sad state of affairs is what is now upon us as a great and increasing energy crisis, polluting and destroying the biosphere, etc. and threatening to eventually collapse the world economy.

It is astounding that, since the basis for the above has been in physics for nearly a century (Whittaker decomposition) and for nearly a half century (broken 3-symmetry of the source dipole, as well as the active vacuum), the hoary old classical EM model has not been updated to incorporate what has already been proven in particle physics. Such is inexplicable and unconscionable.

It is also astounding that no electrical engineer realizes that energy extracted from the vacuum powers every electrical power system, and few if any professors are aware of it either.

This is where your cogent realization of the terrible non sequitur in that atrocious "wave in 3-space" standard diagram leads.

Our AIAS (Alpha Foundation's Institute for Advanced Study) advanced theorists now have a series of papers published in the hard literature pointing out the feasibility of extracting EM energy from the vacuum {113a, 113b}. About 20 other AIAS papers along such lines or related have been submitted to the various journals and are in the referee process.

I just wanted to contact you informally and, for your personal information, show you how perceptive and correct your objection to that atrocious diagram is. You have lifted the corner of the veil on electrodynamics' confusion between effect and cause, with effect being widely used as the cause. The entire notion of a "separate force" acting on a "separate mass" in mechanics is also a non sequitur. If we define force as $F \sum \in / \in t(mv)$, then we see that mass is a *component* of force! So here is another major and uncorrected non sequitur. This one was also largely responsible for the dichotomy of the field concept, where the "same field" is used in both a force (mass-containing) manner and a force-free (without mass) manner, as if the two were the same!

I very much enjoyed your editorial, and would urge you to publish additional material along that same vein. You are striking at the very heart of the problem, and every bit of insight and change in those terrible non sequiturs will result in enormous progress in electrodynamics and physics.

Sincerely,

Tom Bearden, Ph.D.

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Director, Association of Distinguished American Scientists
Fellow Emeritus, Alpha Foundation's Institute for Advanced Study

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Chapter 2

Background and Concepts

"[Hypotheses made without realizing that they are being made] ...are what Poincare has called "unconscious" or "natural" hypotheses — a type which one hardly ever challenges, for it seems too unlikely that we could make progress without them. Nevertheless it should be the endeavor of the physicist always to drag them out into the light of day, so that it may be perfectly clear what we are actually doing." [Lindsay and Margenau] {114}

"Equilibrium states are the only ones that are capable of explicit analysis in thermodynamics... " [Lindsay and Margenau] {115}

"Non-equilibrium conditions cannot be specified by variables of state, and their entropy cannot be computed. ...the condition of equilibrium is the condition of maximum entropy. " [Lindsay and Margenau] {116}

2.1 Comments on the Foundations of Classical Electrodynamics

2.1.1 Faraday, Maxwell, Quaternions, and Heaviside

For our purposes, we start with the important experiments of Faraday {117}, which produced experimental integration of electricity and magnetics {118}. Faraday's own work contained very little mathematics, and so he himself did not capture his own seminal experimental work in adequate theoretical fashion. That task was undertaken by James Clerk Maxwell {119a, 119b}, who deliberately set about to capture Faraday's results in a proper mathematical theory, using quaternion-like and vector expressions. Of the quaternion algebra, Maxwell had this to say {120}:

> *"...the virtue of the 4nions lies not so much as yet in solving hard questions as in enabling us to see the meaning of the question and its solutions. "*

Quaternion algebra {121a, 121b} is an advanced algebra created by William Rowan Hamilton, brilliant Irish mathematician. Hamilton was widely regarded as a "new Newton" by his peers. Hamilton coined the word "vector", wrote two books on quaternions, and hoped the books would find extensive use in physics. Vectors and tensors later came to suffice for most problems of that day, and so quaternions faded to the background.

Hamilton also grasped the importance of a science of time, and realized that such a science was possible. E.g., in 1837 Hamilton stated:

> *"The notion of time may he unfolded into an independent pure science... a science of pure time is possible."*

In that statement, Hamilton anticipated that a physics model can be comprised using only a single fundamental unit, and that unit could be the second.

In the early 1890s, quaternions in electrodynamics were discarded in a short "debate", mostly in the journal *Nature,* and vector electromagnetics was adopted. So Maxwell's 20 quaternion equations {20} in some 20 unknowns contain a wealth of electrodynamics {122} that is not included in Heaviside's {123} later vector curtailment after Maxwell's death, or in the modern tensor formulation. As an example, Nikola Tesla's patented circuits cannot be properly understood in either a vector EM or tensor EM analysis. However, very novel functions performed in them can be seen in a quaternion EM analysis, as has been clearly shown by Barrett {124}. Any electrodynamicist, who has looked at Tesla's work only in terms of tensor or vector classical electrodynamics, has no concept of what Tesla was actually doing. Since that is precisely how most academics have examined Tesla's work, they have had little idea of the functions he was actually able to accomplish in circuits — functions that U.S. electrical engineering departments still cannot perform.

Along with other electrodynamicists at the time, Faraday and Maxwell believed in a material ether — a thin material fluid filling all space. Hence there was thought to be no point in the universe that was devoid of mass. For that reason, the EM field conceived in mass and the EM field conceived in "space" — actually, in the "luminiferous ether" thought to fill all space — were identically force fields and material entities, at least in the minds of the electrodynamicists at the time. The equations of Maxwell, the later truncation by Heaviside and others, and the final truncation by Lorentz are all still material fluid flow models. They still assume the material luminiferous ether, more than a century after its falsification.

See again Figure 1-3 in Chapter 1. Contrary to the conventional view, force is not a fundamental causative entity, but is a system of two coupled entities. It involves a nonobservable, dynamic, causative 4-space entity (which may be modeled as a curvature of spacetime) interacting with a previous "frozen" observable (a 3-space mass). The output of this interaction is another observable (i.e., a change to the previous observable or an iterative output of its replica). Observables do not continuously exist, but continually recur as continual outputs of the iterative observation process (photon interaction).

Mass is a *component* of force, as is apparent if we define force F as $F \equiv d/dt(mv)$, which gives $F = m(dv/dt) + v(dm/dt)$. Both terms on the right of the expansion contain mass; hence force F contains mass as a *component.* Both terms on the right also contain nonmass terms; hence force F also contains nonmass coupled to and interacting with mass. So there can be a force generated by a nonmassive non-force entity in spacetime interacting with a mass, and the force only exists when that interaction is ongoing. The ether was erroneously considered to be a material system, containing mass, and hence capable of supporting a force. Maxwell modeled his fields (in what we know today to be mass-free space) as material force fields in the material ether.

In the 1880s, the Michelson-Morley experiments {125a-125d} destroyed the material ether. However, the fundamental Maxwell-Heaviside equations *assuming* those material force fields in the vacuum — which depended on the notion of a material ether and are a function of it — have never been altered, even to this day. Instead, electrodynamicists just assume the force "somehow" goes to zero in the field in space, but the same field remains. The equations still assume the same old material ether.

This is a non sequitur; a *force* field cannot be the same as a force-free *non-force* field. As an example, the EM force field in observable matter is an output of observation. It is therefore a *3-space effect containing mass.* The force-free field in mass-free spacetime (4-space) is a causal 4-space component of massless spacetime. *A priori,* it exists prior to interacting with the charged mass. It contains no observable mass and hence no force since mass is a necessary component of force. It independently exists without the presence of the charged mass at all.

In short, the field in massless spacetime is a specialized curvature (changed region) of that spacetime. *Spacetime consists of spacetime,* to slate a tautology. Once one fixes the concept of the medium, then any changes to the medium can only consist of "medium-stuff. So any "changes" in spacetime can only be changes of 4-space itself, in the Einstein general relativity sense. This area is handled quite well by Sachs' unified field theory {126a, 126b}, extending and completing the work of Einstein.

Sachs' epochal theory provides a great generalization of general relativity and electrodynamics reaching from the quarks and gluons to the entire universe. Further, Evans' extension of electrodynamics into a higher 0(3) group symmetry turns out to be demonstrably a special subset of Sachs' electrodynamics.[40] Hence, for the first time, an *electromagnetically* engineerable unified field theory is available. Much of general relativity, quantum mechanics, etc. can be engineered directly by Evans' electrodynamics subset of Sachs' overall unified field theory. I am much indebted to Evans {127} for the following statement with respect to O(3) electrodynamics:

> *"In 1992 it was shown (Phvsica B. 192, 227, 237 (1992)] that there exists a longitudinal component of free space electromagnetism, a component which is phaseless and propagates with the transverse components. Later this was developed into a Yang-Mills theory of electromagnetism with O(3) Lagrangian symmetry. This theory is homomorphic with Barrett's SU(2) electrodynamics and has far reaching implications in field theory in general. Recently it has been recognized to be a sub theory of the Sachs theory of electromagnetism, based on the irreducible representations of the Einstein group of general relativity.[41] The Sachs theory produces a non-Abelian structure for the electromagnetic field tensor. The O(3) electromagnetism also has implications for the* ***potential*** *ability of extracting energy from the vacuum,* ***and its*** *topological implications are currently being* ***investigated*** *by Ranada. The O(3) electromagnetism has* ***been tested*** *extensively against empirical data, and succeeds* ***in*** *describing interferometric effects and*

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[40] E.g., see M. W. Evans, "The Link Between the Sachs and 0(3) Theories of Electrodynamics," in M. W. Evans (Ed.), *Modern Nonlinear Optics,* Second Edition, Wiley, 2001, part 2, p. 469-494.

[41] Evans et al, "Derivation of 0(3) Electrodynamics from the Irreducible Representations of the Einstein Group," *Found. Phys. Lett.,* 15(2), Apr. 2002, p. 179-

> *physical optical effects where the conventional Maxwell-Heaviside theory fails. Implicit in both the O(3) and Sachs theories of electromagnetism is the ability to extract electromagnetic energy from curved space-time. Working devices based on this ability would help solve the current energy crisis."*

2.1.2 Mass Is a Component of Force

The dichotomy of using the field concept in two mutually contradictory fashions as something massless and also as something massive — still unresolved in electrodynamics — is clearly summarized by Jackson's important statement {128} of the prevailing view:

> *"Most classical electrodynamicists continue to adhere to the notion that the EM force field exists as such in the vacuum, but do admit that physically measurable quantities such as force somehow involve the product of charge and field."*

In trying to rationalize the "massive field versus massless field" dichotomy, Jackson {129} also states:

> *"...the thing that eventually gets measured is a force..."*
> *"At the moment, the electric field can be defined as the force per unit charge acting at a given point."*

Actually, field is not force, so cannot be force per unit charge. Field *produces* force when it interacts upon charge. *Causing* something as an effect, but then *being* that same effect identically, is a confusion of cause and effect and a non sequitur.

We point out that spacetime is charged, but with *observably massless* (virtual) charge. So the field in spacetime is observably massless and therefore observably force-free. That massless field then interacts with an observable massive charge in the "observable" world, to create an observable force and an observable forcefield. In space, from a quantum mechanical view we may consider the field to have *virtual* force x time, since the field may be regarded as a curvature of spacetime acting upon the *virtual* charged masses in the ever-bubbling *virtual particle fluctuations* of the vacuum permitted by the Heisenberg uncertainty principle. Nonetheless, that is only the "potentiality" for an observable force, as pointed out by Feynman and Wheeler, should the field — including its interactions with the virtual charges of the vacuum to produce forces and accelerations on those virtual particles — interact upon an observable charged mass.

Obviously, the force-free field as a product of spacetime curvature and massless (virtual) charge, and the force field as a product of *that* observably force-free field but virtual force field (in the vacuum) with observable charged mass, cannot be the same thing. Assuming they are the same assumes an oxymoron, and confuses cause and effect. This illustrates the continuing dreadful foundations difficulties propagated in classical electrodynamics.

To resolve these EM foundations difficulties so long maintained and cherished as dogma, the scientific community at the highest priority should (1) fund extensive and rapid work by our very best theoreticians and foundations physicists to heal these century-old festering sores, (2) extend electrodynamics back to a higher group symmetry theory, as in O(3) EM theory for example, and (3) provide a rigorous dictionary of science foundations concepts and terms which does contain valid definitions and full discussions — clearing misdefinitions and disinformation now notable in the electrodynamics literature.

Nobelist Feynman, co-founder of quantum electrodynamics, was careful to state the notion of the field in mass-free space very differently. Quoting Feynman {130}:

> *"...the existence of the positive charge, in some sense, distorts, or creates a "condition" in space, so that when we put the negative charge in, it feels a force. This potentiality for producing a force is called an electric field."*

Feynman's imagery clearly invokes a "distortion condition in spacetime" {131}, eventually coupled to a charged mass and interacting with it — and *then* one has a force and a force field. He erred in still somewhat making the force separate from the charged mass, in the phrase "it feels a force" — which ignores the fact that the mass of the interacting charge is a *component* of the force, not separate from it and not "feeling it as a separate external thing". He pointed out that the field in spacetime represents only the *potential for* a force field, *if a* charge should be placed there. And he points out that the field is a "condition in space" — in the full sense, a condition in spacetime.

We comment that, in a sense, spacetime and vacuum may be considered one and the same. Vacuum contains many fluctuations and virtual state dynamics, all of which are curvatures of spacetime or produce curvatures of spacetime. Vacuum has energy density, and is therefore a potential. This energy density has dynamics, so the ambient vacuum potential has dynamics, and so therefore does spacetime {132}.

However, a dynamic of the potential is precisely what a field *is.* It follows that dynamics of spacetime are what fields are. So fields (as force-free entities in spacetime) may be taken more accurately as the dynamics of the vacuum-spacetime, or as dynamics of the ambient vacuum-spacetime potential, or as dynamics of the ambient curvature of spacetime.

Again quoting Feynman {133}:

> *"We may think of E(x, y, z, t) and B(x, y, z, t) as giving the forces that would be experienced at the time t by a charge located at (x, y, z), with the condition that placing the charge there did not disturb the positions or motion of all the other charges responsible for the fields."*

Here Feynman very clearly shows that E and B involve functions of spacetime *(x, y, z, t)* only, prior to interaction, but do not physically exist until interaction with charge has occurred. But he has not quite yet completely eliminated the "force field" as a separate force acting on the charged matter independently. This centuries-old fundamental mistake in mechanics — that force is independent of and external to mass — has simply been propagated into electrodynamics, without correction. Physicists such as Feynman and Wheeler have been trying very hard to correct it.

The observed/measured force field is an output of observation, and observation is a *d/dt* operator imposed upon spacetime LLLT. All observables are 3-spatial, and any observation is an instantly frozen "3-space snapshot" at a single point in time. A single observation has no temporal existence *a priori,* since it is only an instantaneous 3-space snapshot existing at one moment only. Hence an observable — being 3-spatial and frozen — does not persist *as such* in time. Indeed, the next instant after an observation, that particular snapshot does not exist any more. [Refer again to Figure 1-3 in Chapter 1].

2.1.3 Mechanism for the Flow of Time and Related Matters

It is well recognized that the nature of time is itself an unresolved question. For our purposes, we are interested in the energetics[42] approach. So we apply that approach to arrive at a mechanism generating the "flow of an object through time". First we will choose our fundamental units.

2.1.3.1 *Getting Creative with Fundamental Units*

In physics, the choice of fundamental units one chooses for one's model is arbitrary. Usually mass, length, time, and charge are used, but a perfectly valid model can be generated using only a single fundamental unit.

This is well known to modern physicists and leading electrodynamicists, but sometimes comes as a shock to electrical engineers! Jackson {134} expresses it very succinctly: Quoting:

> *"For example, theoretical physicists active in relativistic quantum field theory and the theory of elementary particles find it convenient to* ***choose*** *the universal constants such as Planck's quantum of action and the velocity of light in vacuum to be dimensionless and of* ***unit magnitude.*** *The resulting system of units (called 'natural' units) has only* ***one*** *basic unit, customarily chosen to be length. All quantities, whether length or time or force or energy, etc., are expressed in terms of this one unit and have dimensions which are powers of its dimension. There is nothing contrived or less fundamental about such a system than one involving the meter, the kilogram, and the second as basic units. It is merely a matter of convenience."*

So let us consider what happens if we use the joule as the single fundamental unit for a model of physics. Then each of the entities "mass", "length", "time," and "charge" will become totally a function of energy. Since the dawn of relativity and the nuclear age, the notion that "mass is energy" is no problem, and everyone is familiar with Einstein's $E = mc^2$. Solving for m in that expression, one realizes that spatial energy E has been compressed by the factor c^2, to yield what is called "mass m". More rigorously, compressing the 3-space energy by the factor c , *and then leaving it in 3-space,* produces what we call "mass". However, if we remove it from 3-space and place it over on the fourth Minkowski axis *ict*, it becomes what we call "time" because *t* is the only variable in *ict*. Hence time has or can have similar energy density to mass. Specifically, 1 sec => $9\text{x}10^{16}$ joules of spatial EM energy, when transduced (decompressed) into spatial energy by a transducing charge.

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[42] **Energetics** is an **old term from the early birthing** days of electrodynamics. Russian scientists resurrected **the term to cover their use of an** expanded electrodynamics in a unified field-engineering **manner, particularly in new** superweapons developed and tested after WW II and deployed in 1963 and subsequently.

In our new model using only the joule for our fundamental unit, we can also legitimately state that "time is energy", and be rigorously accurate. In that case, we must see what happens to 3-space EM energy when it is shifted to the time domain.

First, we take "EM energy in 3-space" as EM wave energy, in the usual transverse EM wave model (see Figure 1-4 of Chapter 1) of a field entity. We choose, say, the vector E oscillating in the x-direction, and another field entity (say, the vector B) oscillating in the y-direction. If we then rotate each of these vectors into the time axis, then that is an orthogonal rotation for each, which is what the velocity *c* actually is. So we have to do two orthogonal rotations, and the two resulting *c's* multiply to give c^2. With these two orthogonal rotations into the time axis, we have completely rotated the EM field wave energy vectors into the time axis. We have also compressed that EM field energy by c^2.

Hence "time as energy" is just EM spatial energy compressed by the factor c^2, but rotated into the time-axis as "time" rather than remaining in 3-space as "mass". Again, by this second analogy time has the same energy density as mass, but the highly compressed spatial energy has been rotated into the time domain to "produce time" rather than remaining in 3-space to "produce mass" {135}.

This sheds new light upon the scalar (time-polarized) photon of quantum field theory. Note that, prior to compression of the wave energy into time, the magnitude of the electric field *E* in the EM wave was oscillating lengthwise along its x-direction, which means that, with respect to x, it was a longitudinal EM wave. A similar consideration exists for the oscillation of the magnitude of *B* in the y-axis. Along the time-axis, we also have a "time-energy" vector having magnitude, and the magnitude of that time-energy can only vary along the time axis. Oscillating the time energy produces a longitudinal EM wave in the time dimension (on the fourth axis). What is actually varying is the time-density itself. This is a *time-polarized* or *scalar* EM wave, where by use of the term "scalar" we mean that it has no vector component in 3-space. In fact, this variability of time density produces a "galloping motion" in the speed of light itself, which has been recognized {136}.

We have uncovered a direct connection between the time-polarized EM wave (which can only oscillate its time-energy magnitude longitudinally in the time-domain) and the longitudinal EM wave in space. Such waves can only be observed when coupled or paired with an interaction existing between them, very similar to what Mandl and Shaw {167, 168} argue for the time-polarized and longitudinal photons of quantum field theory.

Again see Figure 1-3 in Chapter 1. Any observable is an instantaneous, frozen 3-spatial snapshot (or 3-intersection) of a 4-dimensional ongoing event. "Observation" itself may be taken as a process where a *d/dt* operator is invoked upon 4-space (spacetime), leaving a purely 3-spatial output. However, the resulting observable does not "exist or persist in time", since rigorously it is what was "caught" in only a single, frozen "3-slice" at one single instant, forever fixed.

For that reason, time is not an observable. It cannot be directly observed, even in principle, since *a priori* it is discarded by the observation process itself!

For further work along such lines, we recommend the Sachs unification approach to a combined general relativity, quantum mechanics, and electrodynamics, generalized from a topological standpoint {126a, 126b}. To work electromagnetically in that theoretical approach, we recommend the 0(3) electrodynamics as extended by Evans {137a, 137b}.

2.1.3.2. *The* ***Four Polarizations of*** *Photons* ***and*** *EM Waves*

In quantum field theory, four polarizations of a photon are recognized {138}. These are the *x-, y-, z-,* and /-polarizations, where *x-, y-,* z- and *t-* are assumed as the four dimensions in a 4-space. By agreement, z- is used as the direction of motion of a free photon or an electromagnetic wave. So at least in theory, there must also be four polarizations of electromagnetic waves, even though not all these waves are yet experimentally known.

The *x- and y-* polarizations are the familiar transverse photon and the transverse wave. The z- polarization along the line of propagation gives the longitudinal photon in 3-space and the longitudinal EM wave in 3-space.[43]

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[43] Here we are **applying the conventional** model of the "EM wave in space", which is known to be erroneous **but is** in **ubiquitous** usage. See Romer, {84} for a scathing characterization **of that** erroneous model **But here we are stuck with it, so will use it** as "just a model".

2.1.3.3 *Imperfect Longitudinal EM Waves* ***in 3-Space***

When attempting to produce longitudinal EM waves (LWs) in 3-space, from transverse EM waves (TWs) input to some sort of polarization transduction process, only imperfect LWs are produced and a residue of TW content remains. The resulting imperfect LW is referred to as an *undistortedprogressive wave* (UPW). Some work has been done on UPWs {139}. UPWs are expected to have remarkable characteristics including wave velocities either slower or faster than c {140}.

The t- polarization in the time dimension is quite unique: The *spatial* energy overall is in equilibrium and not vibrating at all; instead, the energy of the photon or wave is vibrating in the time domain and therefore exists in the time domain. That is called a "scalar photon" (time-polarized photon). Its wave version does not yet seem to be known in the literature, although in 2000 we uncovered its secret hiding place {12}. It was unexpectedly hiding in Whittaker's {85} decomposition of the scalar potential in 1903, but had been slightly misinterpreted.

2.1.3.4 *Photons and EM Waves Carry* ***Energy and Time***

On the other hand, the concept of "EM waves flowing in 3-space" may be in need of a thorough overhaul {141}. A photon y is a "piece of angular momentum" in the form of $y = (dE)(dt)$. Hence the photon carries an increment of spatial energy dE and also an increment of time-energy dt. The time-energy component (dt) may be regarded as ordinary spatial energy that has been compressed by the factor c^2 {142}.

As can be seen, since c represents an orthogonal rotation in n-space, the multiplication or division by c and by powers of c changes the dimensionality of an entity, as seen by the observer in the laboratory frame.

So the photon transports two types of energy: (i) a "weak spring" (spatial, decompressed) energy dE, so to speak, and (ii) a "very stout spring" (time) energy dt, so to speak.

When a mass m absorbs a photon $(dE)(dt)$, the (dE) component is compressed spatially by c^2, turning it into an extra amount of mass dm, so that the mass becomes $(m + dm)*d$t the same time, the (dt) component is joined, so that what results is $(m + dm)*dt$. In short, mass m is changed to masstime mt by photon absorption. So in the absorption of a photon y by a mass m, we have

$$y+m\text{->} (dE)(dt) + m \text{->} (m + dm)dt$$

In short, the mass *m* turns into masstime *mt,* by absorbing a photon, and masstime *mt* is as different from mass *m* as impulse *Ft* is different from force *F.* We point out that "mass" *m* alone does not even exist in time, but masstime *mt* does exist in time. This is proposed as a simple but fundamental correction to much of present physics. Further, the state "mt" is an excited, time-charged state, excited by very dense time-energy.

For the simplest case, in the next instant the excited state *mt* decays and a photon is re-emitted, and so we have

$$(m + \Delta m)\Delta t \rightarrow (\Delta E)(\Delta t) + m \rightarrow \gamma + m \qquad [12]$$

So emission of a photon changes the excited masstime state (time-charged state) back to mass (uncharged state with respect to time-charging), in the simplest case.

See again Figure 1-3 in Chapter 1. "Observation" and "observable change" are in fact generated by the photon interaction. The total photon interaction with a mass creates the "flow of that mass" through spacetime, macroscopically as seen by the observer and microscopically in myriad streams of virtual time changes. Mass is continually charged to the masstime state, and the masstime state is continually decayed to the mass state. Time flow itself thus has a myriad internal EM energy streams and a vast dynamic EM energy substructure.

The photon itself is not observable, as it exists prior to interaction. It is thus a "causal" entity in 4-space. It *is not* a simple 3-space observed "frozen snapshot" particle! When the causal photon is absorbed, its spatial energy component goes through the c compression function, thus adding a small amount of new mass to the previous mass (previous effect), but simultaneously connecting its d*t* time-tail, so that the slightly increased mass in fact now exists as masstime and not mass. Observation has not been completed at that point.

In the next instant, a photon is re-emitted (from masstime, never from mass!), in the simplest case removing that extra little mass increase and orthogonally rotating it back into 3-spatial EM energy, coupling that spatial energy increment d*E* to that "time-tail" d*t* and tearing it away as the photon is re-emitted. That leaves behind a frozen 3-space snapshot of the mass (the interacting particle) and completes the "observation". In the simple case, this is a replica of the previous particle (frozen 3-space snapshot) with which the causal photon interacted. So this process accounts for the so-called "persistence in time" of an object or mass, as seen by the observer's continual recall process accompanying his stream of iterative observations. Mass does not *continuously exist* in time, but *continually recurs* in time.

As is well known, what we call "observable" change must involve the expression in equation [13] in the fashion discussed and with the observation mechanism given.

We first pointed out the preceding mechanism for the "flow of a mass through time" in 1971, as a graduate student at Georgia Institute of Technology, and later published it in a crude paper {143} in 1973. It still needs a far more thorough theoretical treatment, which perhaps some graduate student will take up as the subject of his or her doctoral thesis.

2.1.3.5 *Photon Interaction:* *Mechanism Generating Flow Through Time*
See Figure 2-1. Mass does not really "travel through time" continuously *per se,* but proceeds with an overall serial change mechanism as

$$m \rightarrow (mt) \rightarrow m \rightarrow (mt) \rightarrow m \rightarrow \ldots \qquad [14a]$$

where *(mt)* symbolizes a nonobservable ongoing "coupled" interaction state prior to observation completion. Equation [14a] represents the results of the continual photon interaction process, observation process, and "flow of a mass through time" process, at the highest single-photon interaction or quantum change level, and as "seen" or measured by the external observer.

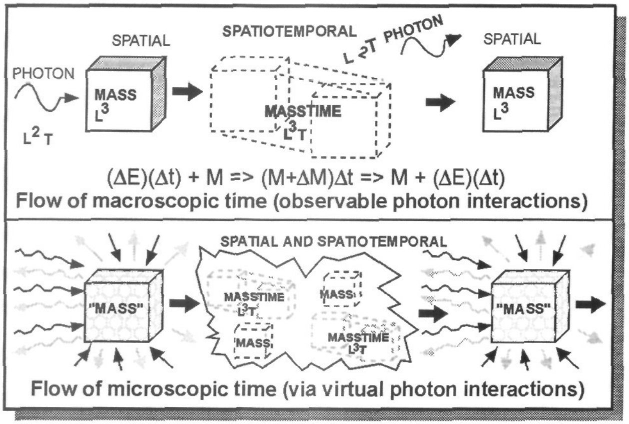
SPATIAL
SPATIOTEMPORAL
L 2T PHOTON
SPATIAL
PHOTON
L2 T
MASS L3
MASSTIME L3T
MASS L3
(ΔE)(Δt) + M => (M+ΔM)Δt => M + (ΔE)(Δt)
Flow of macroscopic time (observable photon interactions)
SPATIAL AND SPATIOTEMPORAL
"MASS"
MASSTIME L3T
MASS
MASS
MASSTIME L3T
"MASS"
Flow of microscopic time (via virtual photon interactions)

Figure 2-1 Mechanism for the flow of a mass through time.

Also, in that overall quantum level "flow" there are anyt number of ongoing streams and "sublevels" in the underlying subquantum level (in the virtual vacuum and in its virtual photon interaction with observable mass). We might write one of these "internal time-stream interaction flow substructures" as:

$$(\delta m) \rightarrow (\delta mt) \rightarrow (\delta m) \rightarrow (\delta mt) \rightarrow (\delta m) \rightarrow \qquad [14b]$$

In equation [14b] we have used parentheses, because all terms individually are nonobservable. We hypothesize that each stream continues until one of its terms participates in a summation which eliminates it by enfolding it into another interaction.

When a mass is observed as in [14a], a photon has been emitted (we observe the mass as the "effect" remaining). Time has been stripped away by the resulting *d/dt* operation, leaving a frozen 3-spatial snapshot, which we will see as (having been) a particle (simplest case). That occurs just after major ("observable") photon emission from the masstime state {144}. Immediately another observable photon is absorbed, and so state *mt* occurs. The particle of mass actually oscillates at a very high rate between the *m* and *mt* states — so high a rate that by arranging the interaction conditions one may interact with it either as a wave (react predominantly in the *mt* state) or as a corpuscle (react predominately in the *m* state).

Hence we propose that the process in [14a] may account for the duality of particle and wave.

2.1.3.6 *The Overall Flow of Time Has an Internal Dynamic Structure*

During the transition in any mass to masstime state by reaction of the mass with an "observable" photon, a myriad of fleeting virtual photon interactions involving very tiny *(dE) (dt)* components occurs with the mass *m*. These tinier increments of time, and their increments of energy, constitute internal structures in the time flow process. Therefore they may be considered as "energy currents" or "time-like energy currents" and dynamic structures or streams inside the flow of time. This is particularly straightforward if we use a model having only a single fundamental unit, the joule. In that case, time is energy, and we are speaking of energy flow and its constituent internal structures of energy flow.

So the d*t* component of masstime at the observable-photon action level has a myriad of energy-time structured dynamics infolded within it. Hence the *mt* state is very dynamic in time, particularly for fundamental particles. The *mt* state is in fact a "collection of time-energy dynamics" and therefore "wavelike".

See again Figure 2-1. A major point is that ***mass*** does not emit a photon; *masstime* does. Mass "travels through time" by an extremely high oscillation between corpuscle-like state *m* and wavelike state *mt*, and with a vast internal "dynamic streams" of other such high oscillations between corpuscle-like *m* states and wavelike *mt* states.

The concept can be very much extended, of course, but this suffices for our concept of energy currents in time, the interaction of such energy currents with mass in a mass system, and the internal dynamic structuring of the "flow of time".

This internal structuring is important in the event of *"time-energy" charging.* There the internal structure of time has experimental consequences. We will discuss those consequences in later chapters.

2.1.4 The Ubiquitous Substitution **of** Effect **for** Cause

See Figure 1-3. To repeat, no observable exists or persists *as such* in time. An observable *as such* only exists at all when time has been momentarily stopped. It then quickly changes into (observable x time) form, for a time interval after a photon absorption. Then it changes again to observable form by photon emission and the corresponding *d/dt* differentiation imposed by that photon emission.

What happens when we think we see an "observable moving through space" is that we make or suppose a continual series of very fast *d/dt* 3-spatial snapshot observations, one after the other in serial fashion (much like the individual frames of a motion picture film). For more than a million years, human brain and mind processing have "always interpreted" this serial set of iterative operations occurring in the eyes and in the physical senses — and continually recalled and processed by the mind — as an "observable persisting in time", which it is not.

This age-old "natural" and inbred, instinctual *mental practice* and assumption by humans — and therefore by scientists — has provided a major problem in physics and especially in electrodynamics. It has resulted in the substitution of the "effect" for the cause in a great number of models. Even a rapid and continual series of 3-space effects after reaction of an observable (frozen snapshot) with a 4-space causal entity, does not and cannot constitute that 4-space entity which interacts with the previous "frozen snapshot" observable and causes the resulting "comparative change or sameness" of the new observable with the former. Hence, e.g., Romer's scathing condemnation {84} of the conventional drawing of an "EM wave in space".

In general relativity, it is straightforward. The curvature of spacetime — the cause — is not the mass (the 3-space observable effect) that is further changed or created again in the ongoing interaction, as seen in the "next

3-space snapshot" (next output of observation) when comparing that snapshot to the previous one.[44]

The same non sequitur — unwitting substitution of effect for cause — has existed for hundreds of years in mechanics, for example. There it is strongly passed on in the erroneous old notion of a separate force acting upon a separate mass. *Prior to* the interaction, no "force" exists. *During* the ongoing interaction, force exists because it is the product (interaction) of a "non-force" causal entity (e.g., a field in 4-space, as a certain curvature of spacetime there) and a previous effect (a 3-spatial frozen snapshot called "mass"). The force exists during the interaction and only during the interaction, when both cause and previous effect are coupled (and will produce the new effect at the completion of the next serial *d/dt* operation as a photon is emitted). The force can only exist when the mass (previous effect) is coupled to the cause (the curvature of spacetime), since *a priori* mass is a *component* of force {145}, and curved spacetime is another *component* of it. After the interaction "ends" in a new *d/dt* observation, the mind compares the new effect with the former, to determine whether there is a "change" or a replica (sameness). This comparison of the new observation (observable) with respect to the former, *occurs in the brain and mind processing*, and gives the sense of "persistence of an object in time" as well as of an object "changing in time".

So a great faux pas in physics — and especially in electrodynamics — is this widespread substitution of the effect for the cause. Understanding this non sequitur clearly, and correcting it, is a prerequisite to understanding the principles and concepts of legitimate COP>1.0 Maxwellian systems. Also, if we would ever hope to adequately correct electrodynamics, this tremendous faux pas must be recognized and rooted out of the model. Indeed, the same is true for mechanics and other branches of physics.

2.1.5 Some Additional Foundations Non Sequiturs

Another gross non sequitur is made in calculating the amount of EM energy flow continually being diverged around an intercepting unit static charge at a point in space, from a potential in which that point is located, and then calling this "local intensity" of the collecting interaction the "magnitude of the potential" itself.

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[44] Rigorously, if one wishes to connect spacetime and mass, spacetime can be interpreted in *masstime* units, but not ***mass*** units And vice versa. Again, masstime *mt* is as different from mass *m* as impulse Ft is **different** from force *F.*

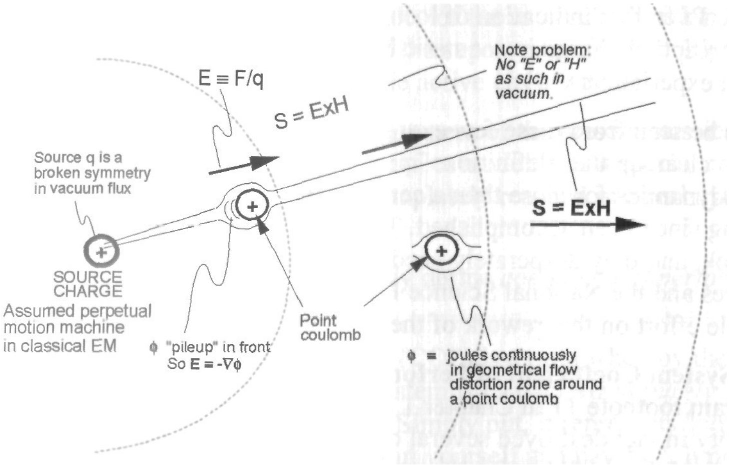
E ≡ F/q
S = ExH
Note problem: No "E" or "H" as such in vacuum.
Source q is a broken symmetry in vacuum flux
+
SOURCE CHARGE
Assumed perpetual motion machine in classical EM
ϕ "pileup" in front So E ≡ -∇ϕ
Point coulomb
S = ExH
ϕ ≡ joules continuously in geometrical flow distortion zone around a point coulomb

Figure 2-2 Field and potential are defined in terms of the diversions from them around a unit point static charge assumed at any spatial point

(See Figure 2-2). At best, it is a measure of the *local intensity of the diversion of energy flow from* the "bidirectional" EM longitudinal waves comprising a potential, as they are diverged around the unit point static charge. It is not the magnitude of the entire potential, filling all space, nor does it prescribe the spatial energy magnitude of that entire potential {146}. It is a small energy flow, *diverted* by an assumed standard fixed charge at a single point in the potential, from the overall energy flows comprising the potential. Calling this little "diversion of a bit of energy" the magnitude of the potential is rather like calling a little whirlpool in a river the "magnitude of the river". Or more exactly, it is like calling the amount of little "swirl diversion of a river's flow" around a standard small fixed rock the "magnitude of the river".

A similar non sequitur exists in the usual calculation of the "field" magnitude at a point, which is not the "entire field entity itself at all. It is merely what is *diverged from* the "field as it exists in spacetime" at a single point in it, by an assumed fixed standard point charge at that point that is interacting with the field. The field takes into account the patterning of the diverged flow, e.g., the difference in potential (difference in pressure) across the unit point charge. That is not the field itself at all, and the textbooks and dictionaries of physics are completely wrong in calling it such. Again, at best, it is an indication of *the field intensity* at that point, and the reaction cross section of the field to an assumed unit point static charge. Even that indication of local intensity of the field will change if the intercepting charge is not static but is in resonance, as shown by the Bohren experiment {24}.[45]

As can be seen from these few examples, a great deal of work needs to be done to clean up the "definitions" promulgated in physics and electrodynamics for more than a century. It is inexplicable[46] that this has not long since been accomplished. These errors permeate almost every textbook, and they desperately need correcting. The National Academy of Sciences and the National Science Foundation should fund the best possible effort on this rework of the foundations of physics.

2.1.6 System Coefficient of Performance (COP) and System Efficiency

See again footnote 11 in Chapter 1 and Appendix A. In 1915, general relativity in fact destroyed several of the fundamental definitions (axioms) of classical thermodynamics. It necessitated our correction of some thermodynamical definitions (open system and closed system) and our more rigorous definitions of COP and efficiency advanced below.

Once mass is recognized as energy and the two are just different sides of the same coin, there can be no thermodynamically closed system which passes energy across the system boundary without passing mass across it. Any system changing its rate of flow through time also changes its mass and its energy, and vice versa. Energy has mass characteristics, and any mass system with added or subtracted energy — either kinetic or potential

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[45] Many Bohren-type experiments are continually done in nonlinear optical labs in universities and elsewhere. The effect (excess radiation from the medium) is euphemistically called "negative absorption of the medium," "negative resonance absorption of the medium," etc. Such terminology avoids clearly recognizing that more energy is output than the scientists (erroneously) calculate was input. Bohren faced the issue head-on, and clearly stated that more energy was output than was input (or than was thought to be input).

[46] A true pessimist might point out that it may be quite understandable, considering that it solidly blocks COP>1.0 EM electrical power systems and electro-gravitational anti-gravity systems from being developed by our universities, which would solve the energy and transportation crises forever. Thereby it also keeps about $1.5 to 2 trillion a year pouring into the coffers of controlling financial groups behind many great interlocking corporations.

— will also change its mass relativistically as well as its other characteristics such as inertia and gravitational attraction. As pointed out by Logunov and Loskutov {635}, in 1917 the new characteristics of general relativity led Hilbert {632} to observe that in general relativity there can be no energy conservation rules of the usual classical kind. This also follows from our consideration of the supersystem with multiple active environments rather than a single active environment.

We have formally destroyed any absoluteness of the present classical thermodynamics, which is just an imperfect model. It is a special case which can be approached but never completely reached in a real dynamic system.

With that in mind, we now more exactly define *coefficient of performance* and *efficiency* of a system.

The term "coefficient of performance" (COP) is a ratio whereby the useful energetic output performance of the system is characterized *purely with respect to the operator's energy input.* Simply put, it represents "how much you get for what you have to input yourself and pay for". It does not characterize the performance of the system with respect to the *total energy input from all sources.* For our purpose, in general there are two major ways of expressing this COP:

(a) COP == (work accomplished in the load during a representative time of operation) divided by (energy input by the operator during that representative time of operation). Or for short, COP = (useful work out in the load) + *{operator's* energy input). We stress that there may be other free inputs of energy to the system, in addition to the operator's input, but only the operator's input is accounted in the COP calculation.

(b) COP == (average power out in the load) divided by (average power input by the operator).[47] Again, there may be additional average power inputs that are freely input from the environment, without cost to the operator, but only the *operator's* input is accounted. We stress that "power input" is another of electrical engineering's misnomers, but we use it here because it is universally used in power system engineering.

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[47] This is in standard electrical engineering terminology, which is mangled. For a more precise physics statement of (b), COP == (the average rate at which the system dissipates energy in its load to do useful work) / (the average rate at which the operator must furnish energy to be dissipated as work in the input section of the system to make it operate and do its output work).

For a system such as a transducer, which merely changes the form of the energy in some fashion and does not perform work in an external load (the transducer is its own load), we may express the COP as

a. COP == (effective energy output) / (energy input by the operator). Here we accent that there may be additional energy inputs to the system from the active environment, and these inputs are "free" and are not input by the operator, so they are not accounted in the COP calculation.

b. COP == (average power output) / (average power input by the operator). Again, additional average power inputs may be freely received from the environment, but they are not accounted in the COP calculation.

The "efficiency" E of a system is a ratio less than or equal to 1.0 (or a percentage less than 100%), where E indicates the percentage of the total input energy (from all sources) that is dissipated in the load as useful work. It follows that (7 - E) indicates the percentage of the total input energy that is dissipated in the internal losses in the system, not directly resulting in useful work by the system in its load. So the efficiency E of a system may be expressed as:

a. E == (total work output in the load during a representative operational period) / (total energy input to the system, from all sources, during that period).

b. E == (average power output in the load) / (average energy rate of input to the system, from all sources, during that representative operational period.).

We accent that no system can have an efficiency greater than 100%, for then it would be "creating energy from nothing" {147}. No system can dissipate or convert energy that it does not first receive. The conservation of energy law states that energy can neither be created nor destroyed. This means that *there actually are no energy sources per se, in the sense that the source creates the energy,* even though we use the terms "energy source" and "source of energy" informally. E.g., Semiz {148} states it this way:

> *"The very expression 'energy source' is actually a misnomer. As is known since the early days of thermodynamics, and formulated as the first law, energy is conserved in any physical process. Since energy cannot be created or destroyed, nothing can be an energy source, or sink. Devices we call energy sources do not create energy, they convert it from a form not suitable for our needs to a form that is suitable, a form we can do work with."*

A medium inefficient system can easily have a COP>1.0, if it receives additional energy from its active environment, and if that extra free energy is sufficient to overcome its internal inefficiency losses. An example is a common windmill, where a very good one may have an efficiency of less than 50% due to friction and drag losses in the gears and wind spillage losses in the blades, etc. Yet the operator himself does not have to input any energy at all, for the windmill to operate continually. In this case, the COP»1.0 and approaches infinity, but the efficiency of the windmill is still less than 50%.

Another example is the home heat pump, which may also have an efficiency of less than 50%. When acting as a refrigerator, its theoretical maximum COP = 8.22 under nominal conditions {149}, and a well-designed 50%-efficient home heat pump will produce COP = 4.0 when conditions are suitable.

On the other hand, if the only net energy input to the system is that energy that the operator inputs, then the COP < 1.0. This is a system in equilibrium with respect to any energy exchange with its external environment — *except* with respect to the energy input by the operator (i.e., with respect to its "fueling" by the operator, so to speak) and with respect to the energy subsequently dissipated in the loads and losses. If the system is 100% efficient (has no internal losses or conversion losses at all), its COP = 1.0. Almost all real systems do have internal losses, so their efficiency is E < 100%. In that case, the system in equilibrium with its environment, and having E < 100%, will also exhibit COP<1.0

irrevocably. Indeed, the same number will give both the efficiency E and the COP, because numerically they are then the same.[48]

For electromagnetic systems, the state of confusion between efficiency E of the system and the COP of the system is due to one fact. *Numerically* the two are always equal in *equilibrium* systems — and the Lorentz regauging condition enforced by the closed current loop circuit self-enforces the equilibrium condition of the system with respect to its active environment. Because electrical engineers usually have zero experience with COP>1.0 electrical systems, they tend to loosely and erroneously use the two terms "efficiency" and "COP" as if they meant the same thing. They do not.

Now suppose that we have an open system, far from equilibrium in its energy exchange with its active environment. Suppose that the system's efficiency E is very poor, so that E = 20%. Now suppose that the environment inputs twice as much energy as does the operator. Let the operator's energy input be E_1. Then the total energy input to the system, from both the operator and the environment, is $3E_1$. The efficiency is only 20%, so the system outputs W, as work in the load, of $W = 0.2(3E_1) = 0.6 E_1$. The COP of the system is the work out divided by the operator's input, which is $COP = W/E_1$, which is $COP = 0.6\ E_1 / E_1$ which gives COP = 0.6. As can be seen, even though this system receives twice as much additional free energy as what the operator inputs, it is so inefficient that **its COP<1.0.**

Suppose we have a similar system with the same energy inputs from the operator and from the environment, but now the system's efficiency E is E = 90%. Then the total energy input to the system, from both the operator and the environment, is $3E_1$. The efficiency is 90%, so the system outputs W, as work in the load, of $W = 0.9(3E_1) = 2.7 E_1$. The COP of the system is the work out divided by the operator's input, which is $COP = W/E_1$, which is $COP = 2.7\ E_1 / E_1$, which gives COP = 2.7. As can be seen, a more efficient system in the same energy input situation, now outputs more work than the energy input by the operator. Energy is conserved at all times; the excess energy for the additional work was in fact freely input to the system — which is an "open" system far from equilibrium in its exchange with its active environment.

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[48] We emphasize that COP and efficiency are two quite different concepts, however, even when their numerical values are the same. A 6-foot tall man and a 6-foot tall door have the same number for their **height,** but only a fool would consider them the "same thing".

Thus a system far from equilibrium in its energetic exchange with its active environment, is *permitted* to exhibit COP>1.0 even though its efficiency is always less than 100%. On the other hand, if the system is very inefficient and the energy input from the environment is not too great, the system will still exhibit COP<1.0. But the operator will pay less for his energy costs to operate that inefficient system, than he would pay to operate it if he himself had to furnish all the energy input.

Two cautions are emphasized:

(a) First, electrical engineers use the term "power" to mean "energy flow rate without dissipation or change of form", as well as "energy flow dissipation and change of form rate." This is inexact and unfortunate, but it appears ubiquitously throughout the electrical engineering literature. So we are essentially "stuck with it" for the moment. From a rigorous physics point of view, energy flow without divergence or change has absolutely no power, because power is defined as the rate of change of the form of that energy flow — e.g., the rate of dissipation (scattering) of that energy flow, which in physics is a rate at which work is being performed.

(b) Second, it seems that more than half the engineers and scientists — and many textbook authors — do not clearly understand the difference between COP and efficiency, and often interchange these two terms as if they were the same. They are not at all the same, and a great deal of confusion exists in the casual engineering literature because of using them interchangeably. That is why we have clarified them and given some simple explanatory examples, sufficient for our purpose in this book.

2.1.7 COP>1.0 and the Question of Perpetual Motion

Legitimate scientific researchers attempting to work in open EM systems far from thermodynamic equilibrium are often subjected to rather vicious ad hominem attacks, charging that they are perpetual motion machine addicts and therefore raving lunatics. This of course is not true. We are simply trying to do with Maxwell's "electric fluid" systems what nature already shows us can be done with material fluid systems. We are in fact seeking the equivalent of "electromagnetic heat pump" processes and systems. It is the strident critics who are thoroughly confused and who reveal an immature knowledge of physics and thermodynamics.

As we explained, prior to their Lorentz symmetrical regauging, the Maxwell-Heaviside equations already clearly prescribe and permit COP>1.0 EM systems, including EM power systems. In addition to the present EM systems in equilibrium in their exchange with their active vacuum environment, the non-regauged equations also include Maxwellian systems far from equilibrium in their energetic exchange with an active environment, such as the active vacuum. Classical *equilibrium* thermodynamics — stridently waved as a sacred banner by the critics accusing COP>1.0 researchers of being "perpetual motion nuts" and such EM systems as being "perpetual motion nonsense" — does not even apply to such *disequilibrium* systems! One should simply read the literature of the thermodynamics of such disequilibrium systems {160a-160f}. Or one should read why Prigogine was awarded the Nobel Prize in Chemistry in 1977, for his contributions to such open systems in disequilibrium.

We accent again that, under our new rules where we corrected the thermodynamic definitions of open system and closed system, we are in compliance with general relativity. Further, every EM system must be taken as an open system, since in the supersystem energy (with mass-like changes resulting across the system boundary) is always exchanged between the three supersystem components.

Fortunately there are also rational, reasonable critics such as Angrist {150, 151} where the criticism is properly scientific and not ad hominem, even though still misguided. Usually the rational perpetual motion critic applies the three laws of classical *equilibrium* thermodynamics, to classify "perpetual motion machines" of class 1, 2, and 3 after equilibrium thermodynamics laws 1, 2, and 3. This of itself has no intellectual content for open systems in disequilibrium with their active environment. The classical equilibrium thermodynamics — including laws 1, 2, and 3 interpreted only in terms of the operator's energy input — does not apply to *open systems far from equilibrium* — which are the only systems permitted to exhibit COP>1.0 in the first place. And we insist that all EM systems are open systems far from thermodynamic equilibrium, since every charge is, and all fields and potentials come from those source charges. Indeed, such open disequilibrium systems are *permitted* to violate the laws of classical thermodynamics! As an example, the entropy of such an open disequilibrium system cannot even be computed {152}, and it is less than the entropy of the same system in equilibrium, since the equilibrium state is the state of maximum entropy.

The rational critic then falls upon the horns of a dilemma, by admitting that, yes, such open dissipative systems do exist and do permissibly exhibit

COP>1.0. He then labels these *as, false or fictitious perpetual motion machines* {150, 151}. In short, when such COP>1.0 machines are real and admittedly exist, they are not *"true"* perpetual motion machines but *fictitious* perpetual motion machines. My comment is that they are not perpetual motion machines at all, but permissible disequilibrium machines freely receiving excess energy from their energetic exchange with their active environment. They are no more mysterious than a windmill, a sailboat, a watermill, or a solar cell bank.

One must be precise. A bicycle is a free-energy COP>1.0 machine while going downhill. It is not such at all when going uphill. The difference is that gravitational input of energy aids the bicycle's motion in the downhill case, and opposes it in the uphill case. The active environment gives the system additional energy in one case, and takes energy from the system in the other case. Disequilibrium exchange can cut either way!

It is precisely the EM system far from equilibrium with its active environment — where the environment puts in additional energy — that the serious overunity researcher is seeking. It is a perfectly valid pursuit, even by the standards of the perpetual motion critics, who really should study *both* kinds of thermodynamics, not just *one.* They also should study how Maxwell's equations were curtailed and truncated; one result is that all Maxwellian disequilibrium systems were — and are — discarded *arbitrarily* by the Lorentz symmetrical regauging.

The only criticism one needs to raise vis a vis COP>1.0 and perpetual motion machines is this: If an inert (no hidden internal source) machine receives no net energy from its external active environment, but is in equilibrium in its energetic exchange with that environment,[49] then

[49] Here we quibble again and point out that Lorentz's symmetrical regauging actually does require that the system receive and take on excess EM potential energy from its environment (the active vacuum and the local curved spacetime). However, this excess energy can only be received in the form of two injections of field energy, where the fields are equal and opposite. Hence the energy is "bottled up" as a stress potential, with net zero translation force available to it. Since this stress potential energy cannot translate electrons, it cannot do work in an external load. It merely changes the stress of the system itself. The net result is actually a rotation of the frame in which the system exists, away from the "laboratory frame" of the observer. In short, the Lorentz condition establishes a new "equilibrium condition" for the system, by rotating its frame. It also implies that EM energy is continuously received by the system from both the active vacuum and local curved spacetime, in order to maintain the rotated frame and **the** new equilibrium condition. Further this

classical thermodynamics rigorously applies to it and the machine cannot and will not exhibit COP>1.0. However, all EM systems contain charges, and these are indeed "hidden sources" of EM fields and potentials and their energy. It *rigorously follows that, since they contain hidden energy sources, all EM systems are potentially COP>1.0 systems a priori.* Further, *it follows that some ubiquitous design characteristic of the system itself must prevent the system from achieving COP>1.0, since nature does not prevent it.* That characteristic feature is the ubiquitous closed current loop circuit, directing all spent electrons in the external circuit right back through the source dipole in the generator or other primary power source.

It is indeed mandatory that — if at all possible - the inventor or independent researcher *identify* a legitimate source of environmental energy that his purported COP>1.0 device receives and collects, and how it receives it and then uses it to power the loads. That means he should identify where and how his system violates the Lorentz self-regauging condition imposed by the standard closed current loop circuit. If the inventor himself cannot explain it — and this does happen — then someone else must explain it for him. If the machine works under proper independent test and replication, then criticism that no explanation exists for it in normal physics is of no relevance. It is a spur to the theorist to enlarge his horizons and to find the proper physics that *does* explain it.

We stress that we cited the works of Angrist because his voice is reasoned and he does not stoop to name-calling and ad hominem attacks. He also does point out a historical rash of machines that clearly must comply with classical equilibrium thermodynamics, because they have no discernible or stated extra input of energy from their active environment and have no self-asymmetrical regauging. When such machines have no external free input of energy from their active environment, they are systems in equilibrium with their active environment, and cannot exhibit COP> 1.0 — exactly as pointed out by Angrist. With such a reasoned critic, a scientific dialog is possible, and his main thrust — that no *equilibrium* system can exhibit COP>1.0 — is quite valid. With the vehement critic, it is already a cur dog fight from the outset and there can be no scientific discussion at all.

The only contention one has with a rational critic, whose criticism is based on classical thermodynamics, is when he then generalizes that *all* EM

continuous input of two energy flows, equal and opposite, does continuous internal work on the Maxwellian system to increase and maintain its stress.

systems fall within this class. That conclusion is a non sequitur, and ignores the entire science of disequilibrium thermodynamics and a vast body of scientific literature and scientific experiments in electrodynamics. When stated for electrodynamic systems, it also ignores the actual documented history of electrodynamics, and ignores Lorentz's *arbitrary discard, from all accountability,* of the Heaviside giant nondiverged energy flow component accompanying every circuit and system. It also ignores Lorenz's and then Lorentz's symmetrical regauging of the Maxwell equations to give new and simple equations easier to solve. This arbitrary regauging did in fact unwitting discard all open disequilibrium Maxwellian systems — precisely those permitted to exhibit COP>1.0.

See again Figure 1-1. The energy entering the circuit is entering it from the surrounding space outside the circuit. Heaviside showed that the energy flow component remaining alter the Poynting component is withdrawn is orders of magnitude greater than the Poynting component entering the circuit and powering it. *It can easily be demonstrated that every generator outputs far more EM energy in space surrounding the power line attached to it, than the operator inputs as mechanical energy to the shaft.*[50]

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[50] E.g., just use a gedanken experiment followed by the Bohren {24} experiment as validated by Paul and Fischer {25}. Consider a 100% efficient DC system, powered by a DC generator, using a closed Current loop circuit. All the Poynting energy received by the system appears at first blush to be dissipated in the external load. That is not true, but let us not yet belabor the point. Include the complete circuit loop back through the source dipole in the generator. The back emf voltage across the source dipole between the terminals is precisely equal to the forward emf voltage between the terminals but around the external half-loop. The same current flows through both the forward voltage drop and the reverse voltage repotentialization. So precisely as much energy is dissipated to force the current through the back emf, as is recovered from the load.

Accept the conventional view that the shaft energy input to the generator is transduced into magnetic energy, which is then dissipated to force those charges back though the back emf. Now examine the energy flow in space surrounding the external circuit, using both the Poynting theory and Heaviside's theory. We have accounted for the Poynting diverged component, but we have not accounted for the huge remaining nondiverged Heaviside component. From whence comes this excess remaining energy flow that did not enter the circuit, was not included in the Poynting calculation, and was not expended in the circuit but was just wasted? To prove the excess energy flow really exists, perform the Bohren experiment {24} where the intercepting charges in the circuit are in resonance, and thus "sweep out" a larger geometrical cross section of interception of the impinging energy flow. These charges do sweep beyond the static unit charge cross section conventionally assumed in the definitions of field intensity (e.g., of the fields E and H in the Poynting vector S in S = (E x H). If the defining unit point charges are in resonance and sweep out a

Heaviside knew this in the 1880s. All the energy flow that is intercepted by the circuit and enters (i.e., the Poynting component) at essentially right angles, hardly even changes the angle of flow of the remaining huge flow of energy surrounding the circuit and missing it. Quoting Heaviside {153} directly:

> *"It [the energy transfer flow] takes place, in the vicinity of the wire, very nearly parallel to it, with a slight slope towards the wire.... Prof. Poynting, on the other hand, holds a different view, representing the transfer as nearly perpendicular to a wire, i.e., with a slight departure from the vertical. This difference of a quadrant can, I think, only arise from what seems to be a misconception on his part as to the nature of the electric field in the vicinity of a wire supporting electric current. The lines of electric force are nearly perpendicular to the wire. The departure from perpendicularity is usually so small that I have sometimes spoken of them as being perpendicular to it, as they practically are, before I recognized the great physical importance of the slight departure. It causes the convergence of energy into the wire. "*

So every electrical power system is rigorously a COP>1.0 "energy gating" system already, if the neglected, enormous Heaviside energy flow through space around the circuit (and missing it and wasted) is re-accounted. In that case, much greater energy pours out of the terminals of every generator, than the feeble amount of mechanical energy we input to the shaft.

We do not have an *energy availability* problem, and we never have had one! Instead, we have an *energy flow interception and collection* problem

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greater cross section, then the assumed Poynting vector S, for the static case, changes in magnitude by some ratio k for the resonant case to the vector S_R, so now $S_R = k_1E \times k_2H = k_3(E \times H)$. Since k_3 is just the ratio of the actual geometrical cross section swept out by the charge to the standard geometrical cross section swept out by the static charge, then for a static charge $k_3 = 1.0$, and for a resonant charge $k_3 > 1.0$. Hence the Bohren experiment, with $k_3 = 18$ or so, produces 18 times as much collected (Poynting) energy "out" as we erroneously think we input by normal calculations ignoring the input Heaviside nondiverged component. The Bohren experiment {24} proves the argument; validation by Paul and Fischer {25} appears in the same journal issue.

— and we always have had one, due to the ubiquitous use of the closed current loop circuit.

Texts — e.g., such as by Kraus {154} — do show the Poynting (intercepted and collected) component of the EM energy flow surrounding the power line attached to the generator terminals, but none of them today go into the remaining nondiverged Heaviside component. Each of Kraus' contours {76} of energy flow in space, around those power line conductors, shows *only that part of the energy flow in space that is being drawn into the circuit.* It does not show the remaining huge energy flow that (i) is not intercepted, (ii) does not enter the circuit, and (iii) is wasted. Presently no texts illustrate this Heaviside nondiverged energy flow component, and no text accounts for it except to point out that the Poynting component must be considered to be indefinite, since it can be accompanied by an additional energy flow component. The texts then erroneously conclude that the excess flow can have no physical significance.[51]

One can easily prove the existence of additional energy flow to be collected, in addition to the Poynting component. E.g., simply examine the Bohren experiment {155} and its replication by Paul and Fischer {156} — or one can repeat the experiment oneself. The Bohren experiment outputs some 18 times as much energy as is input by normal "Poynting component" calculations alone, because it also intercepts additional energy from the unaccounted and ignored *free* Heaviside input component remaining and not diverged by a *static* unit point charge. Bohren simply places the charge in resonance, so it sweeps out a greater geometrical reaction cross section in the energy flow, thereby penetrating into the free — but arbitrarily discarded and unaccounted — Heaviside component, and intercepting and collecting additional energy. Bohren is perfectly aware that the excess energy caught by the resonant charges comes from the surrounding vacuum. However, he seems quite unaware of Heaviside's discovery and cautious statement of the excess energy involved in *every* field-particle interaction, and particularly in electrical circuits.

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[51] E.g., J. D. Jackson, Classical Electrodynamics, Second Edition, Wiley, 1975, p. 237: *"...the Poynting vector is arbitrary to the extent that the curl of any vector field can be added to it. Such an added term can, however, have no physical consequences. "* Jackson errs in stating that the added energy flow vector cannot have any physical consequences. It cannot, of course, unless one catches some of it and uses it to power a load, without using half of the caught energy to destroy the source dipole faster than the load is powered. One of the major applications of it is to use it with Dirac sea negative energy 4-holes in the vacuum, where the holes produce negative energy fields and potentials in surrounding spacetime, acting back upon the system which is the source of the 4-holes to produce practical antigravity.

There are several such "white crows" which are legitimate COP>1.0 EM processes in physics. It only takes one small white crow to prove that not all crows are black. As another example, the papers of Letokhov {157a-157d} are especially recommended. So long as excess energy is received freely from the environment, the system is permitted to be in disequilibrium where COP>1.0.

So far as this author could discover, none of the perpetual motion machine critics have noticed another very simple fact: The conventional electrodynamics they utilize to refute COP>1.0 Maxwellian systems implicitly assumes that the source charge — which is any and every charge in the universe — continuously *creates* and pours out energy in 3-space without any energy input at all. Their own conventional classical electrodynamics contains a "perpetual motion machine assumption" of the most fundamental and grossest kind. The ardent skeptics of overunity EM systems — in using that implicit conventional assumption — are themselves the greatest perpetual motion advocates of all, though perhaps unwittingly. In 2000 we resolved that long-vexing problem[52] of the source charge {12}.

The more strident critics simply set up the "equilibrium thermodynamics" straw man, then knock it down and attack independent COP>1.0 experimenters with it, erroneously implying that all overunity researchers seek such in an equilibrium system. They fail to notice orthodox science's implied assumption that every charge and every dipole in the universe is already assumed to be a COP => inf. perpetual motion machine, freely *creating* all that continuous outpouring of energy from nothing. None of the critics have noticed and critiqued this greatest of all perpetual motion assumptions right in their own ranks, without a single exception, and the most ubiquitous. Undoubtedly that is because the scientific community honestly and freely admits that it has not heretofore solved that problem {68}, and also points out that the outpouring of energy is an experimental fact and therefore unquestionable.

The better critics — at least the rational ones such as Angrist — already admit that there exists a class of legitimate "fictitious perpetual motion machines" which are powered continuously without the operator inputting the energy. The phrase "fictitious perpetual motion machine" is an attempt to retain the classical thermodynamics straw man, when dealing with the thermodynamics of a system far from equilibrium in its energy exchange with its active environment. That phrase has been a non sequitur since the award of the Nobel Prize to Ilya Prigogine in 1977. We stress again our new use of all EM systems as open systems, in accord with general relativity.

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[52] After publication of our paper, we also discovered very powerful support for our solution in quantum field theory. E.g., see F. Mandl and G. Shaw, *Quantum Field Theory*, Wiley, 1984/1993, Chapter 5.

So when rigorously analyzed from the breadth of physics and thermodynamics, and not just from a selected very narrow portion, the entire "perpetual motion" critical literature is inappropriate or — more exactly — is inappropriately focused upon a fictitious or false target. It is simply a classic example of reasoning from a false premise.

Not one such critic seems to have noticed that every generator and battery already pours out more energy than what is input to the shaft, and that it is easily proven experimentally via the thousands of experiments showing negative absorption from the medium. None seems to have bothered to read the original Heaviside, Poynting, and Lorentz papers to see how this startling fact was buried more than a century ago.

Finally, a self-appointed "expert" who does not even know what furnishes the energy to power every electromagnetic circuit, cannot be taken seriously in his "learned criticism" , regardless of what journal publishes it. If he continues to accept the unsolved source charge problem, implying that all charges freely create EM energy from nothing, he is not expert in any facet of powering electromag letic systems and circuits.

2.1.8 Prescribed Systems Versus Changes to Maxwell's Equations

As we stated, Maxwell's theory {20} was some 20 quaternion-like and vector equations in some 20 unknowns. By discarding the scalar component of the quaternion to retain only the vector subcomponent, and by discarding many of Maxwell's potentials, Heaviside {158} truncated the Maxwell equations to essentially the present familiar set of four vector equations - or in potential form, to two equations with variables unseparated.

While this truncation discarded a great deal of Maxwellian electrodynamics phenomenology, from a thermodynamics view the resulting *Maxwell-Heaviside* equations still contain and prescribe two types of Maxwellian systems:

(1) systems in equilibrium with their active environment, such as the active vacuum, and

(2) systems far from equilibrium with their active environment, such as the active vacuum.

Systems in the first class of Maxwell-Heaviside systems — i.e., in equilibrium in their energetic exchange with their active environment — rigorously obey classical equilibrium thermodynamics {159}. No system in that Maxwellian class can output more energy than the operator himself inputs to the system. The greatest coefficient of performance (COP) that these systems can accomplish, is COP = 1.0 for a theoretically perfect system without internal losses whatsoever, and thus with 100% efficiency of conversion of their input energy into work in the load. Since any real system has internal losses and thus is less than 100% efficient, the *practical* systems of this first class exhibit COP < 1.0.

These Maxwellian systems of the first class are the electrical systems always "understood" by ardent skeptics who proclaim that no other kind of Maxwellian system exists, that therefore no Maxwellian system can exhibit COP > 1.0, and that a claim to COP>1.0 is perpetual motion lunacy and not science at all. These fellows often launch scathing and unjustified personal attacks upon any serious researcher trying to work with that second class of permitted Maxwellian systems! It would be scientifically beneficial if these self-appointed defenders of the faith would simply study some more physics and thermodynamics, review the history of Maxwell's theory and how it was altered, and understand the well-established thermodynamics of systems far from equilibrium.

This false charge — that there can be no COP > 1.0 EM system because that would violate the laws of physics and the laws of thermodynamics — has been insidiously indoctrinated into generation after generation of physics and electrical engineering students. Today most of our electrical engineers and electrical scientists have absorbed it and believe it without question. Our power-engineering scientists believe it, and so advise the government. Hence our government believes it on the advice of our best scientists, such as the National Academy of Sciences and the National Science Foundation. Our great national laboratories also believe it and are just as mentally conditioned. The universities — especially the electrical engineering departments — also believe it, and provide a mainstream suppression of the sharp young graduate students and post-docs that would otherwise have long ago revised this mess and solved the energy crisis permanently.

Again we are reminded of that first quotation by Einstein, which we included at the beginning of Chapter 1, and which admonished us to ever examine the foundations of our science to root out and correct the errors. We are also reminded of another quote by Tolstoy:

> *"I know that most men, including those at ease with problems of the greatest complexity, can seldom accept even the simplest and most obvious truth if it be such as would oblige them to admit the falsity of conclusions which they have delighted in explaining to colleagues, which they have proudly taught to others, and which they have woven, thread by thread, into the fabric of their lives."* [Count Leo Nikolaevich Tolstoy].

The second class of Maxwell-Heaviside systems — rigorously prescribed and permitted by Heaviside's truncated Maxwellian theory — is comprised of systems in disequilibrium with their active environment. A system in this class does not obey classical equilibrium thermodynamics. To the contrary, this system obeys the well-known *thermodynamics of systems far from equilibrium* {160a-160f} with their active environment — such as the active vacuum.

Such a system *is permitted to:*

(i) self-order,

(ii) self-oscillate or self-rotate,

(iii) output more energy than the operator himself inputs and thus exhibit COP>1.0 (the excess energy is freely received by the system from its external active environment),

(iv) power itself and its load simultaneously (all the energy is freely received by the system from its external active environment,[53] without any operator energy input being required), and

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[53] We accent the concept of the supersystem. consisting of three components: (a) the system and its dynamics, considered as in normal electrical engineering (with a flat spacetime and an inactive local vacuum), (b) the active local vacuum and its dynamics, and (c) the active local curvatures of spacetime and their dynamics. All three components of the supersystem interact with each other. In conventional electrical engineering, the assumption in U(1) electrodynamics of a flat local spacetime and equilibrium with the local vacuum exchange eliminates any

(v) exhibit negentropy, which every charge and every dipole in the universe already does {12, 68}.

Let us now see why Maxwellian EM systems of the second class *are not being designed and built as such,* even though they are permitted by the laws of physics and reinterpreted thermodynamics, and even though they are prescribed in the Maxwell-Heaviside equations before further truncation by Lorentz {161a, 161b}. We may use the Maxwell-Heaviside equations in vacuum, because the energy flow intercepted by the external circuit pours out of the generator terminals and fills all space surrounding the power lines. It is therefore a transmission-reception problem, prior to the "potentialized current-transport" problem in the circuit.

2.2 Lorentz Regauging of the Maxwell-Heaviside Equations

2.2.1 Introductory remarks.

The domain of Lorentz's symmetrically regauged equations is only a small subset of the domain of the Maxwell-Heaviside equations they replace. Indeed, the later Lorentz {161a, 161b} symmetrical regauging discards an entire class of Maxwellian systems permitted by nature and by the Maxwell-Heaviside equations before they are symmetrically regauged.

Lorentz's symmetrically regauged EM equations discard all Maxwell-Heaviside systems that are far from equilibrium in their energetic exchange with the active vacuum. They retain only that subset of the Maxwell-Heaviside theory wherein the system being described is in forced equilibrium {162} in its exchange with its active vacuum environment. Hence the present Lorentz-Maxwell-Heaviside theory, by which EM circuits and electrical power systems are designed, produces only systems in self-forced equilibrium with the active vacuum, *specifically during the symmetrically regauging discharge* of the circuit's excitation energy. The closed current loop circuit in fact discharges half its collected energy to destroy the source dipole in the generator, thereby destroying that dipole's extraction from the vacuum and furnishing of the energy flow pouring out of the terminals. These circuits kill themselves faster than they can power the load, and they use more energy to kill the energy flow from the vacuum than they use to power their load. Hence all present EM systems

disequilibrium of the system with its active environment, hence arbitrarily discards all Maxwellian disequilibrium systems - precisely those that can exhibit COP>1.0.

rigorously conform to classical equilibrium thermodynamics, and exhibit a coefficient of performance (COP) of COP<1.0 since any real system also has losses {163}.

2.2.2 Technical regauging of the Maxwell-Heaviside equations {164}. For asymmetrical-regauging (A-regauging) considerations, we are speaking of A-regauging the potential energy in and around a circuit. We include not only the Poynting energy flow component that is diverged into the circuit conductors, but also the remaining Heaviside *nondiverged* energy flow in space surrounding the conductors. This means that the energy is in field energy (E-field and B-field) form, both overtly as ordinary EM fields and covertly or "infolded" inside the corresponding scalar potentials {165, 166, 167, 168}, or both. Consequently, we must analyze Maxwell's equations as we would for radiating energy, rather than employ only the $\mathbf{j}\phi$ circuit analysis conventionally utilized, where the collected energy is sluggishly transported by the Slepian vector $\mathbf{j}\phi$. We show in this book that asymmetrical self-regauging (ASR) allows permissible overunity operation of electromagnetic engines and devices {169}, if other requirements are fulfilled also.

In Gaussian units, Jackson {170} shows that Maxwell's four equations (vacuum form) can first be reduced to a set of two coupled equations in the $(\mathbf{A}, \Phi)$ representation as follows:

$$\nabla^2\Phi + \frac{1}{c}\frac{\partial}{\partial t}(\nabla \bullet \mathbf{A}) = -4\pi\rho \qquad [15]$$

$$\nabla^2 \mathrm{A} - \frac{1}{\mathrm{c}^2}\frac{\partial^2 \mathbf{A}}{\partial t^2} - \nabla(\nabla \bullet \mathbf{A} + \frac{1}{\mathrm{c}}\frac{\partial \Phi}{\partial t}) = -\frac{4\mathrm{p}}{\mathrm{c}}\mathbf{J} \qquad [16]$$

The result is two coupled Maxwell equations rather than four. Jackson shows that potentials A and Φ in these two equations are arbitrary in a specific sense, since the A vector can be replaced with $\mathbf{A'} = \mathbf{A} + \nabla\Lambda$, where A is a scalar function and VA is its gradient. The B field is given by $\mathbf{B} = \nabla\times\mathbf{A}$, so that the new B' field becomes

$$\mathbf{B'} = \nabla\times(\mathbf{A} + \nabla\Lambda) = \nabla\times\mathbf{A} + \mathbf{0} = \nabla\times\mathbf{A} = \mathbf{B} \qquad [17]$$

In other words, the B field has remained entirely unchanged, even though the magnetic vector potential has been asymmetrically changed. However, if no other change were made, then the electric field E would have still been changed because of the gradient $\nabla\Lambda$. In that case the net change would be asymmetrical, because one obtained a "free" E-field which could then do work on the system — either beneficially or detrimentally, depending upon the specific conditions, geometry, and timing. To prevent this excess "free" E-field from appearing, the electrodynamicists simultaneously and asymmetrically regauge (transform) the scalar potential Φ so as to offset the E-field change due to the regauging of equation [15]. In short, they also change Φ to Φ',, where

$$\Phi' = \Phi - \frac{1}{c}\frac{\partial \Lambda}{\partial t} \qquad [18]$$

With that additional change, now the net E and B fields remain unchanged {171, 172}, even though both potentials have changed and the fundamental stored energy of the system has changed, as has the stress of the system. Unchanged force fields just mean that only a set of zero-summation forces (a zero-summed stress system) has been utilized to effect the change in potential energy. It also means that the net summation of the two *asymmetrical* regaugings has been entirely *symmetrical* {173}.

Jackson points out that, conventionally, a set of potentials $(\mathbf{A}, \Phi)$ is habitually and *arbitrarily* chosen by the electrodynamicists such that

$$\nabla \bullet \mathbf{A} + \frac{1}{c}\frac{\partial \Phi}{\partial t} = 0 \qquad [19]$$

This *net symmetrical* regauging operation creates a new and simpler Maxwellian system, with different system stress and different system potential energy. It successfully separates the variables, so that two inhomogeneous wave equations result. This procedure yields a new and simplified system, and the new Maxwell's equations for it are as follows:

$$\nabla^2 \Phi - \frac{1}{c^2}\frac{\partial^2 \Phi}{\partial t^2} = -4\pi\rho \qquad [20]$$

$$\nabla^2 \mathbf{A} - \frac{1}{c^2}\frac{\partial^2 \mathbf{A}}{\partial t^2} = -\frac{4\pi}{c}\mathbf{J} \qquad [21]$$

The two previously coupled Maxwell equations [15] and [16] (potential form) have been replaced by equations [20] and [21], to leave two much simpler inhomogeneous wave equations, one for Φ and one for A. These are *new equations for a new system!*

Of course, this arbitrary *net symmetrical* regauging (let us use the term ***S-regauging)*** is quite useful for purposes of simplifying the theory and for easing calculations. But its unquestioning and rather universal usage has arbitrarily eliminated the freedom of the system designer to *asymmetrically* regauge the system's potentials, and *use* the resulting excess free force fields to change the stored energy in the system without the operator performing extra work upon the system. So we advance the condition for violating this S-regauging, violating the exclusion of net A-regauging, and violating the "frozen gauge" process as

$$\nabla \bullet \mathbf{A} + \frac{1}{c}\frac{\partial \Phi}{\partial t} \neq 0 \qquad [22]$$

Any regauging of the potentials that complies with equation [22] will *a priori* produce one or more net excess forces in the system, as well as a change in potential energy of the system. By controlling the regauging, the system designer is then able to control where, how, and when these excess forces appear, and whether they enhance the system's operation or hinder it. These net forces can then be used to perform work and dissipate the excess potential energy taken on in the asymmetrical regauging. That is what we do when we ourselves add potential (and potential energy) to an EM system to enable it to do work! *If we always have to asymmetrically regauge the system to get it to do subsequent work, why do we not just let the system asymmetrically regauge itself so we get the input energy freely and also get the resulting work freely?* The gauge freedom axiom in quantum field theory assures us that nature will indeed freely change the potential energy of any system for us, if we but arrange it and permit it.

In short, we have had a gauge freedom principle for some time, which guarantees us that COP>1.0 EM systems are permitted and possible. Yet we have failed to realize it, or take any advantage of it. So we continue to pay to asymmetrically regauge (potentialized) all electrical power systems, and to insure that we have to continue to do it, we specifically design the systems so they will then re-enforce Lorentz's symmetrical regauging condition.

This is another of those "inexplicable aberrations of the scientific mind" referred to by Nikola Tesla!

2.2.3 A Humorous Comment but an Exact Analogy

Again see Figure 1-1 in Chapter 1, and see Figure 2-3. In Figure 2-3, we show how Lorentz's integration trick {174a, 174b} discarded the huge nondiverged Heaviside component of energy flow outside the conductor, while retaining the small Poynting component that strikes the surface charges and gets diverged into the conductor to power the electrons. In justifying his integration trick, Lorentz stated that all the rest of that wasted Heaviside energy flow (Figure 2-4) was "physically insignificant" (his term) because it did not strike the circuit, was not intercepted, and did not power anything. Well, Maxwell's theory is a material fluid flow theory, so let us evaluate Lorentz's justification in a fluid flow analogy.

See Panofsky & Phillips
Classical Electnqtv and Magnetism. 2nd edn
Addison Wesley 1962.
p 178-181

The Lorentz procedure arbitrarily discards the enormous Heaviside component that misses the circuit entirely and is wasted This results in a non sequitur of first magnitude in EM energy flow theory

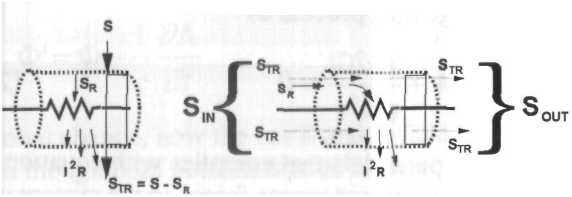
S
S_R
I^2R
$S_{TR} = S - S_R$
S_{IN}
S_{TR}
S_R
S_{TR}
S_{TR}
S_{TR}
I^2R
S_{OUT}

2-3a. Lorentz surface integration **2-3b. Actual S in and S out.**

Figure 2-3 Lorentz's integration trick to discard the enormous Heaviside non-diverged energy flow component

The Heaviside component is often 10 trillion times the Poynting component but is simply wasted in ordinary single-pass energy flow circuits

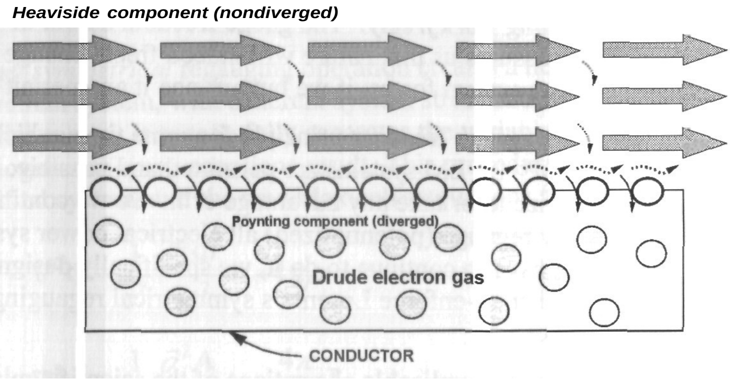
Heaviside component (nondiverged)
Poynting component (diverged)
Drude electron gas
CONDUCTOR

Figure 2-4 Heaviside nondiverged and Poynting diverged energy flow components.

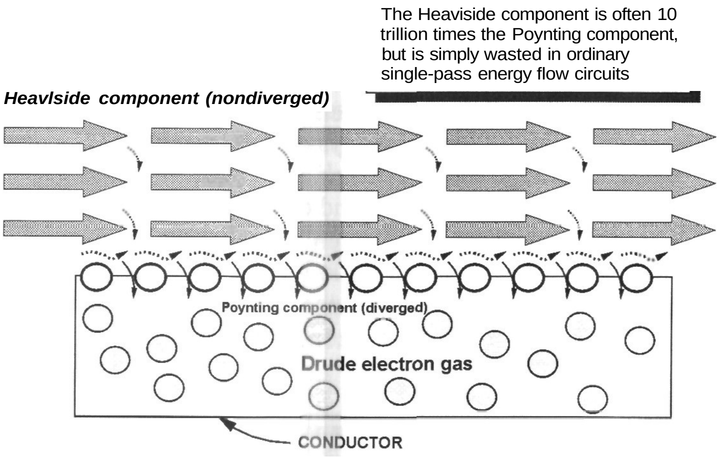
The Heaviside component is often 10 trillion times the Poynting component, but is simply wasted in ordinary single-pass energy flow circuits
Heavlside component (nondiverged)
Poynting component (diverged)
Drude electron gas
CONDUCTOR

Figure 2-4 Heaviside nondiverged and Poynting diverged energy flow components.

Contrast Lorentz's statement if applied to the ocean wind on a sailing ship, where the wind represents the total energy flow and the ship represents a single Maxwellian system under consideration.

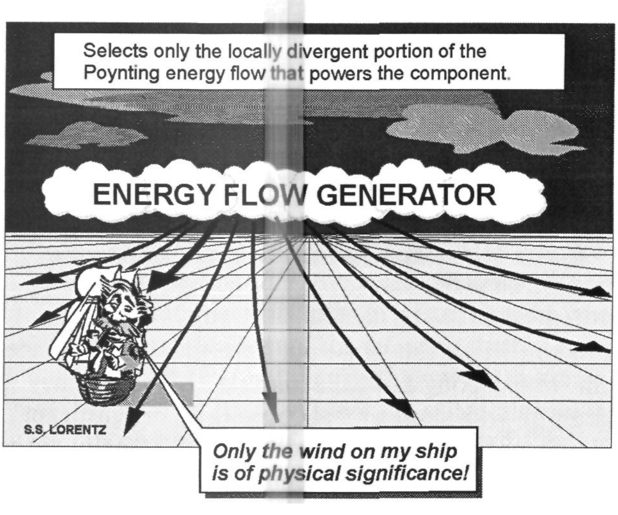
Selects only the locally divergent portion of the Poynting energy flow that powers the component.
ENERGY FLOW GENERATOR
S.S. LORENTZ
Only the wind on my ship is of physical significance!

Figure 2-5 Lorentz in his sailing ship in an ocean wind, with no other ships around.

As shown in Figure 2-5, Lorentz's argument is analogous to stating that the huge component of the wind *that does not* strike the ship's sails is "physically insignificant" — in other words, it has no physical use. Now that is true for the single ship under consideration, as shown in Figure 2-5. None of that wind component that misses the ship's sails does anything at all to power *that ship* (that individual system). Hence it is indeed physically insignificant *to that ship itself.* Of course, if we flare the sails wider, the ship will catch more wind and develop more power. That is an analogy to the Bohren experiment, which resonates the charges (the "sails" intercepting the incoming EM energy flow "wind") so that they sweep out a greater geometrical cross section. Hence 18 times as much energy is caught, as when the charges are not resonated (the sails are not flared to a greater area).

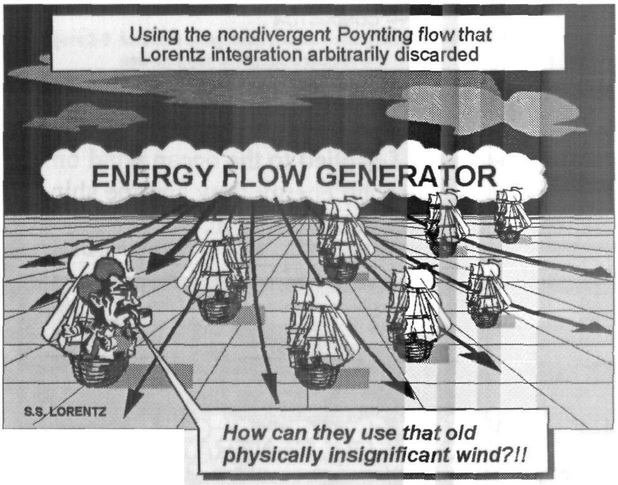
Using the nondivergent Poynting flow that Lorentz integration arbitrarily discarded
ENERGY FLOW GENERATOR
S.S. LORENTZ
How can they use that old physically insignificant wind?!!

Figure 2 6 Lorentz in his sailing ship in an ocean wind, with many other ships alongside.

However, now see Figure 2-6. If we put some more ships (some more systems) with "intercepting and collecting sails" in there, they will be powered quite well with some of that "physically insignificant" wind. So Lorentz (following earlier work by Ludwig Lorenz) really did advance and impose upon electrodynamics a non sequitur of first rank.

And the wind-fluid analogy helps to "lighten things up" a bit here and inject a little good-natured humor!

2.2.4 Discussion

Equation [22] has now become the first *necessary but not sufficient* principle of asymmetrical self-regauging (ASR) for overunity electromagnetic engines and devices. That is, we are now free to A-regauge in a *nonconservative* field manner, where excess net force fields automatically appear and remain for our use in the system. All that remains is for the designer to:

(i) evoke "nonconservative" (asymmetrical) regauging in accord with equation [22];

(ii) have the system assembly in disequilibrium with its energetic external environment, so that the system itself performs this nonconservative A-regauging in some sector or part {175} of its normal operation,

(iii) insure that any "free force" that is produced and allowed to do work upon the system will do some positive work upon the system, so as to increase its collected energy, and

(iv) assure that the "free" forces that are otherwise produced by the circuit design (this includes, e.g., the back emf) do not seriously degrade the system (i.e., do not substantially reduce its energy available to dissipate as work in the load). Usually this means that, contrary to the standard closed current loop circuit, the circuit must not dissipate half its collected Poynting energy to dissipate the charges in the source dipole and destroy it. *These four considerations we now advance as the primary or master principles of asymmetrical self-regauging of electromagnetic engines and devices for permissible overunity efficiency.* We will meet additional principles in a later chapter when we discuss what the form of the energy output of an overunity EM system is, and the considerations for close-looping a COP>1.0 EM system into stable disequilibrium and continuous self-powering.

It is understood that the asymmetrical regauging portion of the circuit or system must be a broken symmetry in the energetic exchange between the active vacuum environment and that portion of the system. We exclude, g., solar cell-powered systems, windmill-driven generators, etc.

For simplicity, the system designer may wish to A-regauge only one potential, producing a desired "free" force F_1 to work on the system and increase its energy, while allowing any other extraneous force F_2 to appear, but just "bottling up" that additional force F_2 so that it cannot do any work at all on the system and therefore cannot degrade the system's operation. A most useful ASR corollary that immediately suggests itself is to simply A-regauge onto that force operation that normally produces the back-drag in a system or device, to either *eliminate* the back-drag altogether or reverse its algebraic sign so that it becomes an *assisting* force instead of a *hampering* force {176}.

In overunity systems, this becomes a startling and unexpected exercise in novel new phenomenology effected by tempic potential differences, tempic force, etc. It involves not only the system, but also the entire *supersystem* consisting of the physical system, its associated altered local vacuum, and its associated curved local spacetime. See Chapter 9 for our expose of these phenomena, and how one must transduce[54] the effects of a very novel kind of tempic force back emf, if the COP>1.0 system is to remain in disequilibrium with the active vacuum and thus maintain its stable COP>1.0 operation.

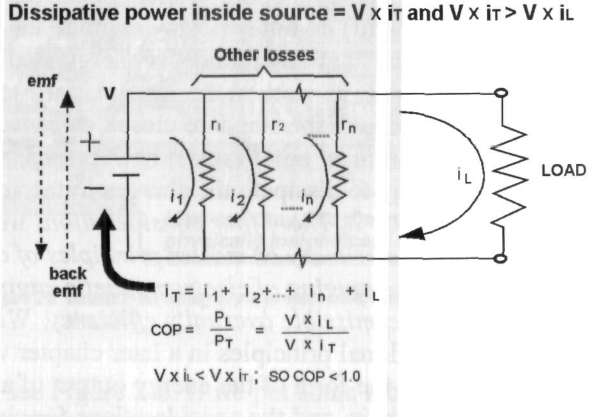
Dissipative power inside source = V x iT and V x iT > V x iL
Other losses
emf
V
+
−
r1
r2
rn
i1
i2
in
iL
LOAD
back emf
iT = i1 + i2 +...+ in + iL
COP = PL/PT = V x iL / V x iT
V x iL < V x iT ; SO COP < 1.0

Figure 2-7 Why a conventional closed current loop circuit is limited to COP<1.0.

Again see Figures 2-3 and 2-4, and equations [20] and [21]. Electrodynamicists have previously *assumed away* the capability of work-free "refueling" of an electromagnetic system directly from the local vacuum {177}. They have deliberately designed their systems *to prevent self-evoking and positively utilizing asymmetrical self-regauging of their own potential energy during system excitation discharge.* (See Figure 2-7).

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[54] A patent application on the process has been filed by John Bedini and the present author.

In fact, by forcibly pumping the ground electrons from the external circuit back up through the primary source dipole in the generator or battery, our closed current loop circuits self-enforce the Lorentz condition and require that precisely half the regauging energy freely intercepted and collected in the external circuit is used to destroy the source dipole providing the regauging energy. This destruction of the energy source is accomplished faster than the external load is powered. Hence all such systems with losses are COP<1.0 systems. For more than 100 years, this "self-destroying, suicidal system" is the only kind of electrical power system our energy scientists and engineers have designed and built. To inject a little humor, we can only describe this in Tesla's words[55] as *"one of the most remarkable and inexplicable aberrations of the scientific mind which has ever been recorded in history."*

Thereby electrodynamicists have narrowed the inherent flexibility of the Maxwellian EM gauge theory model to an artificially symmetrized subset of Maxwell-Heaviside-Lorentz equations that utilize a single fixed gauge. This prohibits the free use of the system's vacuum energy freely received by the source dipole's broken symmetry in its violent exchange with the active vacuum. If the system increases its dipolarity (regauges freely), it simultaneously increases the speed at which it destroys the dipolarity! *Maxwell's equations themselves do not require this, and neither does Heaviside's truncation of them into the resulting Maxwell-Heaviside equations. Lorentz's symmetrical regauging of the Maxwell-Heaviside equations does require it.*

The Maxwell-Heaviside theory without Lorentz symmetrical regauging allows regauging asymmetrically to place the system in disequilibrium so that it freely receives and utilizes excess energy from the surrounding vacuum. Then it can again asymmetrically regauge by dissipating that freely received energy in an external load. *The theory specifically does not require destroying the primary source dipole as is done in the arbitrary closed current loop circuit between load and primary source dipole in the generator or battery.*

---

[55] Nikola Tesla, "The True Wireless, *Electrical Experimenter,* May 1919.

By arbitrary habit, electrodynamicists have discarded the Maxwell-Heaviside major EM overunity mechanism: *Asymmetrically self-regauging accomplished by the system itself, without requiring external work being done on the system by the operator,* in order to freely gather in and collect excess potential energy in the system from its broken symmetry with its active vacuum environment. In this self-A-regauging, associated *excess net force* does appear, whereupon that excess collected/stored regauging energy can then be used to "drive" the forces against load resistance and system losses to freely power the system and its loads {178}. They have also discarded the major overunity corollary whereby the designer is free to utilize *system self-regauging asymmetrically so that the normal back-drag or back-emfwork — usually done upon the system in its closed current loop configuration to reduce its kinetic energy — vanishes or reverses sign and becomes beneficial work done in the opposite sense, to freely increase the energy ofthe system.*

The failure to do this is bluntly met with, when one does succeed in producing a COP»1.0 system momentarily by suddenly and very powerfully breaking the system's equilibrium in its vacuum energy exchange. Nature then exhibits a very novel kind of Dirac sea hole reaction (powered by tempic force generated in the locally curved spacetime and resulting effects generated in the altered semiconducting vacuum). This reaction sharply jerks the system (or the system plus its external power supply) back into equilibrium and COP<1.0 operation. In Chapter 9, apparently for the first time in the literature[56] we present this novel mechanism exhibited by nature as a new kind of "tempic back emf phenomenon in systems in disequilibrium. We also explain how to handle the problem and in general how to use it for "freeze-framing" and stabilizing the system's disequilibrium operation in sustained COP > 1.0 configuration while powering itself and its load.

All that is required for "self-powering" COP»1.0 EM engines directly powered by the vacuum, is that (1) initially the engine must asymmetrically self-regauge to produce COP»1.0, and (2) positive *transduced* feedback (from the output) of a very special and previously unknown kind — where negative energy is transformed into normal electron current and energy — must be utilized to its input, in a clamped and controlled fashion {179}. The clamped positive feedback can be designed and applied, once the fundamental engine is designed for self-regauging and overunity efficiency, and once the novel feedback and transformation requirements are understood and incorporated. The remaining excess output can then be utilized to power loads, while the engine seemingly "powers itself."

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[56] The basis for it, however, is in Dirac's electron theory published in 1930, nearly three quarters of a century ago. See P. A. M. Dirac, "A theory of electrons and protons," *Proceedings of the Royal Society of London, Series A,* 126(801), Jan. 1, **1930, p. 360-365.**

We stress, of course, that this system is just analogous to the windmill, and it continuously receives a "free energy wind" from its active environment. The conservation of energy law is obeyed at all times, as are physics and thermodynamics.

In a later chapter we present the concepts and processes for these novel phenomena involved in close-looping a COP>1.0 system for self-powering operation.

2.3 The Suicidal Closed Unitary Current Loop Circuit

The present Lorentz-Maxwell-Heaviside theory, by which EM circuits and electrical power systems are designed, produces only systems in net usable equilibrium with the active vacuum, specifically during the symmetrically regauging discharge of the circuit's excitation energy (Figure 2-7). Hence all present EM systems designed by that model rigorously conform to classical equilibrium thermodynamics, and exhibit a coefficient of performance (COP) of COP<1.0.

Since the Maxwell-Heaviside equations do not restrict the designer to systems in equilibrium with their active environment, some ubiquitous characteristic of the standard circuit approach must be self-enforcing the Lorentz symmetrical condition as far as using any excess free potential energy of the system to freely power loads. That is the closed-loop circuit, as we have discussed. Let us now illustrate what goes on in such a circuit.

Taking into account Figure 2-4, Figure 2-8 shows a modified diagram of what is actually happening between the vacuum and the dipole to power the circuit. Figure 2-9 shows how a pair of conductors constitutes an extended series of parallel dipoles. Once the dipole is formed by dissipating some chemical energy in the battery, the dipole extracts energy from the surrounding vacuum and pours it out of the battery terminals, producing an energy flow filling space around the conductors of the external circuit. Only a very small portion (Figure 2-4) of the very large energy flow is intercepted by the external charges in the conductors, and diverged into the conductors to power up the Drude electrons.

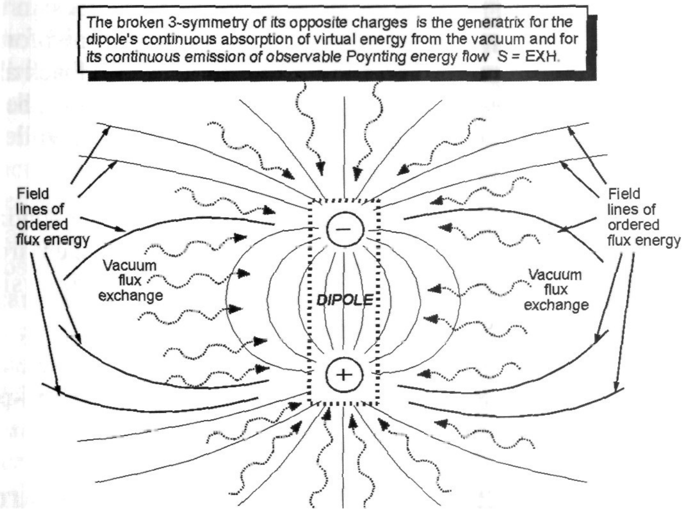
The broken 3-symmetry of its opposite charges is the generatrix for the dipole's continuous absorption of virtual energy from the vacuum and for its continuous emission of observable Poynting energy flow S = EXH.
Field lines of ordered flux energy
Field lines of ordered flux energy
Vacuum flux exchange
Vacuum flux exchange
DIPOLE
−
+

Figure 2-8 Virtual photon flux exchange intensity **with the charges of a** dipole.

As can be seen from Figure 2-7, half of the energy collected upon the internal electrons to drive them as **jϕ** is expended as work required to pump the spent electrons from the ground return wire back through the source dipole in the battery. This scatters the charges of the dipole (in this case, by changing the chemistry of the battery plates) and destroys the dipole. The other half of the collected energy is dissipated in the external circuit's losses and in the load.

Then some more chemical energy has to be dissipated by the battery to perform work upon the internal charges and restore the dipole (in this case, to change the plate chemistry of the battery plates). So even if this process is 100% efficient, the battery has to dissipate as much chemical energy as was electrically dissipated upon those former dipole charges to scatter them and destroy the dipole.

In Figure 2-7, we show the small internal resistance of the conductors, as well as the load resistor. Half the energy dissipated by **jϕ** is expended just to forcibly ram the spent electrons back through the back emf of the source dipole. The other half is expended in the circuit's internal losses and in the load resistance. Therefore, less energy is expended as usable work in the resistive load than is expended to destroy the dipole and cut off the flow of free EM energy from the vacuum.

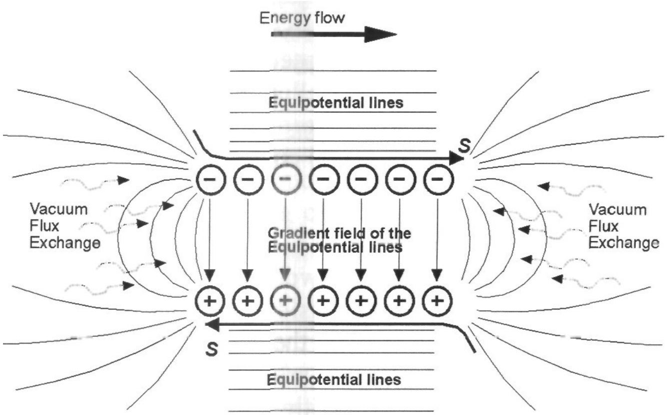

Figure 2-9 Paired conductors as an extended set of dipoles.

The battery has to input as much energy to restore the dipole as was used to destroy it. The battery has to expend at least as much chemical energy as equals half the entire energy originally collected in the external circuit and expended as $\int j(t)\phi(t)dt$. It must expend chemical energy $CE \geq \frac{1}{2} \int j(t)\phi(t)dt$. The energy RE dissipated as work in the load resistor R is $RE < \frac{1}{2} \int j(t)\phi(t)dt$. Thus CE>RE, and this system is forced to exhibit

$$COP \ {}^{\circ}\ \frac{RE}{CE} = \frac{< \tfrac{1}{2}\grave{o}\, j(t)f(t)dt}{{}^{3}\ \tfrac{1}{2}\grave{o}\, j(t)f(t)dt}\ \text{Þ}\ COP < 1.0 \qquad [23]$$

As can be seen, this system symmetrically regauges itself during its excitation discharge, so that it self-enforces the Lorentz condition during that period. The circuit self-enforces COP<1.0, even though all the energy — both the energy powering the external circuit and also destroying the internal source dipole in the battery to enforce the Lorentz condition during discharge — is freely received from the active vacuum via the broken symmetry of the source dipole,[57] once established, in its energetic exchange with the active vacuum.

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[57] The broken symmetry of opposite charges is one of the broken symmetries predicted by Lee, {13a} and by Lee, Oehme, and Yang, {13b}. Broken symmetry was proven experimentally in early 1957 by Wu *et ai,* {14}. So profound were the implications for physics that the Nobel Prize was awarded to Lee and Yang in latter 1957, the same year! E.g., see T. D. Lee, "Weak Interactions and Nonconservation of Purity," Nobel Lecture, Dec. 11, 1957 in *T. D. Lee, Selected Papers,* Gerald **Peinbcrg,** Ed., Birkhauscr, Boston, 1986, Vol. 1, p. 32-44.

The problem is that *the source dipole is destroyed faster than the load is powered,* as shown in Figure 2-7. Because of the inexplicable scientific pre-occupation with the conventional closed current loop circuit, the planet and biosphere have been increasingly polluted for more than a century, by burning more hydrocarbons, building more dams, using more nuclear fuel rods, etc. to provide ever more electrical energy.

2.4 In Summary

COP>1.0 operation in EM systems via work-free *asymmetrical* regauging has been inherent in the Maxwell-Heaviside equations for more than a century. Since Lorentz first did so circa the latter 1880s, electrodynamicists have just conveniently and arbitrarily *assumed away* COP>1.0 systems by (i) artificially limiting the theory to only that fraction of Maxwell-Heaviside systems in usable net force field equilibrium in their vacuum exchange during their excitation discharge, and (ii) using the ubiquitous closed current loop circuit to self-enforce the Lorentz symmetry condition during that excitation discharge. In other words, our engineers have only been building systems which self-enforce the overly restricted Lorentz-regauged theory.

Electrodynamicists have never seriously tried to build overunity circuits, nor until recently have they explored the discarded Maxwellian systems by removing the Lorentz regauging condition and examining EM energy from the vacuum.[58]

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[58] Under the directorship of Dr. M.W. Evans, the Alpha Foundation's Institute for Advanced Study (AIAS) has been gradually developing the physics of EM systems far from equilibrium with their active environment (the local active vacuum and local curved spacetime). Some of the papers of interest are: M. W. Evans et al., "Derivation of the Lehnert field equations from gauge theory in vacuum: Space charge and current," *Found. Phys. Lett,* 13(2), Apr. 2000, p. 179-184; Evans et al., {38b}, {38c}, {113b}, {233a}, {233b}, {233e}; {233g}, {233j}; Evans et al., "Schrodinger Equation with a Higgs Mechanism: Inherent Vacuum Energy," *Found. Phys.* (in review); — "Vacuum Energy Flow and Poynting Theorem from Topology and Gauge Theory," *Physica Scripta* (in review); — "Energy from the Vacuum," *Physica Scripta* (in review); — "Some Notes on Asymmetric Regauging", *J. New Energy* 4(3), Special Issue, Winter 1999, p. 325-326; — "Inconsistencies of the Maxwell-Heaviside Theory of Electrodynamics: The Aharonov-Bohm Effect," *J. New Energy,* 4(3), Special Issue, Winter 1999, p. 236-240; — "Spontaneous Symmetry Breaking as the Source of the Electromagnetic Field," *Found. Phys. Lett.* (in press), A monumental work. *Modern Nonlinear Optics,* Second Edition, 3 vols., ed. M. W. Evans, Wiley, 2001 gives a broad coverage of higher group symmetry electrodynamics and energy from the environment (the local active vacuum and the

Every electrical power system ever built is and has been powered by electrical energy freely extracted from the seething vacuum exchange with the source dipole in the system, due to that dipole's broken symmetry. But the engineers and scientists have designed and built only those electrical systems which self-enforce Lorentz's symmetrical regauging.

The time for energy scientists and engineers to correct this procedure and cease this inane practice is long overdue, following the direction pointed out by the AIAS.

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local curved spacetime). Some 60 AIAS papers are published as a Special Issue of **the** *J, New Energy,* 4(3), Winter 1999. More than 100 AIAS papers are also carried on DoE restricted website http://www.ott.doe.gov/electromagnetic/.

Chapter 3

Giant Negentropy, Dark Energy, Spiral Galaxies and Acceleration of the Expanding Universe

"*... the discoveries made in 1957 established not only right-left asymmetry, but also the asymmetry of the positive and negative signs of electric charge. In the standard nomenclature, right-left asymmetry is referred to as P violation, or parity nonconservation. The asymmetry between opposite signs of electric charge is called C violation, or charge conjugation violation, or sometimes particle-antiparticle asymmetry.* " [T. D. Lee]. {180}

"*The ends of a dipole, being oppositely charged, exhibit charge conjugate symmetry violation. An 'isolated' charge, considered with its clustering virtual charges of opposite sign, also exhibits symmetry violation.* " [T. E. Bearden, this book, below].

"*A generally acceptable, rigorous definition of radiation has not as yet been formulated.*" ... "*The recurring question has been: Why is it that an electric charge radiates but does not absorb light waves despite the fact that the Maxwell equations are invariant under time reversal?* " [B. P. Kosyakov]. {181}

"*It [the energy transfer flow] takes place, in the vicinity of the wire, very nearly parallel to it, with a slight slope towards the wire... . Prof Poynting, on the other hand, holds a different view, representing the transfer as nearly perpendicular to a wire, i.e., with a slight departure from the vertical. This difference of a quadrant can, I think, only arise from what seems to be a misconception on his part as to the nature of the electric field in the vicinity of a wire supporting electric current. The lines of electric force are nearly perpendicular to the wire. Their departure from perpendicularity is usually so small that I have sometimes spoken of them as being perpendicular to it, as* *they practically are, before I recognized the great physical importance of the slight departure. It causes the convergence of energy into the wire. "* [Oliver Heaviside]. {182}

"The funny thing about the dark matter is it doesn't show up in light, X-rays, gamma rays, infrared, ultraviolet, radio waves, or submillimeter. We're running out of places to look for it." [William Keel]. {183}

"... baryonic, ordinary matter — the stuff of stars and of people — makes up just over 4% of the energy and matter in the universe. ...about 30% of the stuff in the universe is dark [unobserved] matter. The remaining two-thirds, theorists believe, is a mysterious 'dark energy' or 'quintessence' — a large-scale antigravity-like effect that is making the universe expand ever faster.... " [Charles Seife]. {184}

"And yet, curiously enough, we do not know exactly what charge is, only what it does. Or, equally significantly, what it does not do."[M. P. Silverman]. {185}

*"**Charge** is the ongoing circulation of EM energy flow between the time and 3-space domains, as seen by the observer. Negative charge is the ongoing absorption of EM energy input from the time domain (from ict), transduction of the absorbed energy into 3-space EM energy, and re-emission of the EM energy in all directions in 3-space. **Positive charge** is the ongoing absorption of EM energy input from 3-space, transduction of the absorbed energy into the time domain, and re-emission of the EM energy in the time domain. If we wish, we may also consider the positive charge as radiating negative energy, while the negative charge radiates positive energy. Once we consider vacuum polarization, we recognize that this circular flow process is involved at each "dipolar point" of the polarized vacuum. "* [T. E. Bearden, this book, below].

"The matter density of the Universe is extremely low. On average there might be one atom per cubic metre of space. The major constituent of the Universe is believed to be some kind 'dark energy', which is pushing the Universe apart. " [Matthew Colless]. {186}

3.1 Broken 3-Symmetry of the Dipole

To recap from Chapters 1 and 2: In 1956, Lee and Yang {187} strongly predicted broken symmetry in physics, suggesting experiments to detect it in the weak interaction. In early 1957, Wu *et al.* {188} experimentally demonstrated broken symmetry, thus furnishing the experimental substantiation of broken parity in the weak interaction. The emergence of broken symmetry was such a dramatic change to the view of physics, that in December of the same year, 1957, Lee and Yang were awarded the Nobel Prize.

One of the asymmetries shown by Lee *et al.* is the asymmetry of opposite charges. That means that a dipole, which consists of slightly separated opposite charges, exhibits broken symmetry in the seething vacuum virtual particle flux. In short, a dipole — any dipole or dipolarity — must absorb or receive virtual photon energy from the active vacuum, integrate at least some of it to observable state, and re-radiate that integrated EM energy in observable form in 3-space.

We stress: *The ends of a dipole, being oppositely charged, exhibit broken symmetry. An 'isolated' charge, considered with its clustering virtual charges of opposite sign, is a set of composite dipoles and also exhibits broken symmetry.*

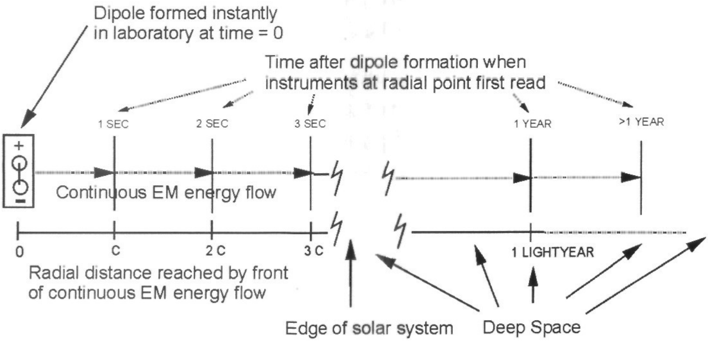
Dipole formed instantly in laboratory at time = 0
Time after dipole formation when instruments at radial point first read
1 SEC
2 SEC
3 SEC
1 YEAR
>1 YEAR
+
−
Continuous EM energy flow
0
C
2 C
3 C
1 LIGHTYEAR
Radial distance reached by front of continuous EM energy flow
Edge of solar system
Deep Space

Figure 3-1 The source dipole experiment, demonstrating continuous energy flow.

Let us now consider a gedanken experiment, as shown diagrammatically in Figure 3-1, to illustrate Kosyakov's quotation cited above. At a point in the laboratory corresponding to the origin of a 3-dimensional frame, a dipole is produced instantly by separating charges, such as in a flash-charged capacitor. Along two radial lines in 3-space from that origin, we have previously placed perfect EM field and potential detectors, at distances *ct* apart, where *t*= 1, 2, 3, 4, *n*,... and so on in seconds, with the radials extending across the universe, and where c is the speed of light. We neglect the transient pulse that momentarily occurs at each instrument package, since we are examining steady state conditions.

At the end of one second, the instruments at *t* = 1 instantly read, and those readings remain thereafter. One second later, the instruments at *t* = 2 instantly read, and those readings remain thereafter. And so on with each of the instruments progressively farther from the origin reading at the proper light-time travel, and with all field readings then *remaining continuously* thereafter.

This gedankenexperiment demonstrates that what is emitted from the dipole, from its moment of creation at the origin, is a continuous flow of EM energy in all directions in 3-space.[59] This energy continuously flows from the dipole, indefinitely or as long as the dipole physically exists. Other than paying once to initially separate the charges and make the dipole, we have neither added nor input any additional energy. Yet energy continues to flow out from the dipole in all directions, unceasingly, as shown by the continued of the reading on each field energy density instrument, once the leading edge of the energy outpour reaches that instrument and passes it by. In short, the experiment shows that it is not a "pulse" that passes each instrument, but a continuous and sustained flow of EM energy, remaining steadily thereafter so long as the dipole remains.

One year after making the dipole, the instruments at one light year distance suddenly read, and their readings remain. *The energy density of a volume of space one light year in radius has now been changed, and that change in spatial energy density continues to spread outwards at light speed.*

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[59] More exactly, what is observed is a spreading change in the energy density and point-like polarization of the vacuum itself, and of the local curvature of spacetime. At each point, once the change of energy density and ST curvature occur, the energy density and ST curvature remain fixed in a new equilibrium condition, steadily fed by the energy radiating from the dipole. See our point made in {181}. The discovery of giant negentropy {12} requires a change in how we view the very process of energy propagating in space. Now it has become a quite different *propagation of energy circulation between time and space domains at each affected point in space.*

Yet there has been no input of *observable 3-space* EM energy flow to the dipole whatsoever, as our instruments also verify. All observable energy flow in 3-space is *outward* from the origin where the dipole is located.[60]

We have shown that the *observable* EM energy flow from a source dipole is not conserved in 3-space, which is consistent with a broken 3-symmetry since symmetry implies conservation. Either we must discard the conservation of energy law altogether, or it must be conserved in 4-space since we have proven the dipole does not conserve energy in 3-space. If we assume that the experiment must conform to the conservation of energy law, then 4-symmetry EM energy flow must exist since 3-symmetry energy flow is broken. The energy steadily pouring out of the dipole in all directions in 3-space must therefore be received by the dipole *charges from the time-domain,*[61] assuming we are working in Minkowski 4-space. In particle physics, this is essentially the same as receiving the energy from the virtual domain, and therefore is consistent with the proven broken symmetry of every dipole and dipolarity.

The energy flow is indeed received from the time domain, as we have argued {189} in a wave manner consistent with (i) quantum field theory as shown by Mandl and Shaw in the photon model {190}, (ii) broken charge conjugation symmetry of particle physics using the virtual photon and observable photon concepts, and (iii) a re-interpretation of Whittaker's decomposition of the scalar potential {191} when applied to the scalar potential between the ends of the dipole {12}.

We state the obvious: A dipole is a Maxwellian system. This gedanken experiment also proves by demonstration that a Maxwellian system — e.g., a dipole — is permitted by the laws of nature, physics, and thermodynamics to output more energy than the operator inputs, since we input nothing to the source dipole[62] once we have made it. After paying to produce the dipole initially, the operator has made no other energy input to the dipole at all, yet the dipole will continue to pour out observable energy in 3-space for the next 14 billion years if the dipole remains and is not destroyed. In addition, every positive charge and every negative charge in the universe form a dipole, regardless of the separation distance between them. That dipole is also performing the gedanken experiment process. Every dipolar EM circuit contains innumerable such dipoles — e.g., across "open paths" between the various points in the circuit, as shown by Kron {192}. Kron {193} stated:

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[60] Obviously, we are utilizing the prevailing notion of the flow of energy through 3-space, which is actually a non sequitur. No 3-space observable entity can "move" in 3-space alone; it requires time to move, and so any movement is in 4-space a priori. We previously discussed this and the *dldt* operator being applied by the observation process. But for simplicity, we are using the conventional view here, so the negentropy of the dipole can be easily grasped.

[61] Again, we have stated the positive time case only. In the spreading special 4-circulation, energy appears in 3-space at each point dipole from the time domain (courtesy of the action of the negative charge of the dipole), and then returns from 3-space back to the time domain (courtesy of the action of the positive charge, which is a time-reversal of the action of the negative charge).

> *"... the missing concept of "open-paths " (the dual of "closed-paths") was discovered, in which currents could be made to flow in branches that lie between any set of two nodes. (Previously - following Maxwell - engineers tied all of their open-paths to a single datum-point, the 'ground'). That discovery of open-paths established a second rectangular transformation matrix... which created 'lamellar' currents... " "A network with the simultaneous presence of both closed and open paths was the answer to the author's years-long search."*

By considering all dipoles in the universe, one has in fact finally defined Kron's open path. One has also defined the master mechanism responsible for the incredible EM energy density of the vacuum — the so-called "zero-point EM energy". Overall, every electrical circuit thus has innumerable energy flow broken 3-symmetries in it, with respect to exchange of EM energy flow between the time and 3-space domains. To sum all these broken 3-symmetries to an overall net 3-symmetry during the discharge of the free excitation energy of the circuit, obviously requires some specific macroscopic cohering function in the circuit. Moreover, one exists. Specifically, the closed current loop between the external circuit attached to the generator and the internal source dipole created between the terminals of the generator, is what enforces the circuit's net 3-symmetry and Lorentz symmetrical regauging. That is an arbitrary man-made condition, and not a law of nature, physics, or thermodynamics.

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[62] Or to a charge with its clustering virtual charges of opposite sign, if we redo the experiment with a single "isolated" observable charge and consider it more exactly as a set of composite dipoles, each of which exhibits broken symmetry in the vacuum virtual particle flux.

By our gedanken experiment's demonstration and the existence of innumerable disequilibria between the active environment[63] and the system in an ordinary EM circuit, it follows that a Maxwellian circuit must be *capable* of exhibiting a coefficient of performance (COP) of COP>1.0. It is a giant collection of open dissipative systems, far from equilibrium in the vacuum exchange.

That concept of course is contrary to the entire present mindset of electrical engineering and Maxwell-Heaviside-Lorentz classical electrodynamics. Those disciplines merely continue to accept the source charge as if it freely created from nothing all that energy in its associated fields and potentials reaching across the universe. Ironically, so long as the giant negentropy of the common dipole and its disequilibrium with its active environment (the local active vacuum and the local active curvatures of spacetime) are unaccounted, engineers and scientists will continue to produce the inane Lorenz/Lorentz-regauged power systems they produce today and have produced for more than a century. Also, they will continue — wittingly or unwittingly — to implicitly prescribe that every charge and dipole in the universe violates the conservation of energy law and is thus a *perpetuum mobile* of the grossest kind: a system which massively and continuously creates EM energy from nothing.

We now point out something deeper and very important. In modern physics, the *observed* positive charge is regarded as the time reversal of the *observed* negative charge. See Figure 3-2. If the negative charge is responsible for EM energy flow from the time-domain into 3-space, then *as observed* the positive charge must represent a time-reversed situation. We observe time reversal in the charge domain as a parity reversal and a charge reversal, but with the energy remaining positive. In other words, one imagines that one records a process on videotape, and then runs the video backwards to observe the "time-reversed" situation. When observed, both the sign of the positive charge and its direction of motion appear to us to be reversed from the negative case.

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[63] In paragraph 3.10 and in Chapter 9 we will introduce — more deeply — the notion of the supersystem, consisting of three parts: (1) the system and its dynamics, (2) the active vacuum and its dynamics, and (3) the active spacetime curvatures and their dynamics. All three components of the supersystem interact with each other. In our gedanken experiment, the system (component 1) must receive the excess energy from the system's external environment, which consists of components 2 and 3 of the supersystem.

It follows that the positive charge as observed involves a flow of (positive) energy from 3-space back to the time domain. If we wish, before observation we can accept that "observed positive energy inflow" as an unobserved outward radiation of negative energy. Thus, a dipolarity involves a continuous flow of energy from the time domain into 3-space, and back from 3-space into the time domain (Figure 3-2). The energy flow circuit (circulation) is completed by a remaining energy flow across the dipolarity in the time-domain only, from the positive charge where the energy enters the time domain, to the negative charge where it exits again.[64]

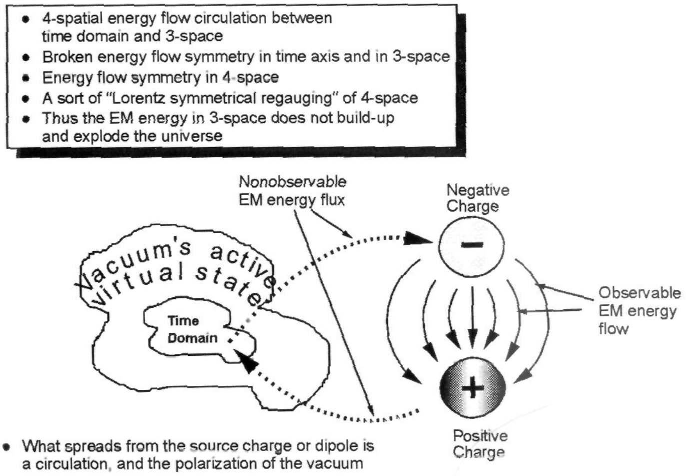

- 4-spatial energy flow circulation between time domain and 3-space
- Broken energy flow symmetry in time axis and in 3-space
- Energy flow symmetry in 4-space
- A sort of "Lorentz symmetrical regauging" of 4-space
- Thus the EM energy in 3-space does not build-up and explode the universe

Nonobservable EM energy flux
Negative Charge
Vacuum's active virtual state
Time Domain
Observable EM energy flow
Positive Charge

- What spreads from the source charge or dipole is a circulation, and the polarization of the vacuum

Figure 3-2 Circulation of energy flow in a dipole, between time domain and 3-space.

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[64] Rigorously, we should speak of $+qt$ and $-qt$. Charge q is an observable, and therefore an instant frozen snapshot. No observable exists continuously in time, but instead it recurs continually as the photon interactions — iteratively producing the d/dt (LLLT) = LLL observations — continue. The moment a charge q absorbs a photon, it changes to qt in form. The moment the charge-time qt emits a photon, it changes back to q in form. This incessant change of q -> qt -> q -> qt —» .... is continual, at every level of the macroscopic charge, with its entire ensemble of photon interactions, including both virtual and observable photon interactions. As can be seen, the "charge as it persists" and "moves through time" has a rich dynamic substructure essentially ignored in present electrodynamics. It is, however, recognized by leading theoreticians and Nobelists.

However, even each of the clustering virtual charges and each of the differential charges of the observable charge, may be further broken into a central charge and clustering charges of opposite sign, in the modem view of the vacuum and its polarization. Hence, at any level — electron or positron — we actually have a dual and slightly separated bidirectional flow, at least in the observable equilibrium condition. The "positive energy" and positive flow of time is usually associated with "inert" matter with the electrons on the outside, so that the observer observes normal matter through the "forward time" situation mostly. Hence much of the accompanying backwards or time-reversed flow — from the positive charges in the nuclei, etc. — is "buried in the vacuum virtual state" in the Dirac sea and in Dirac sea hole flows.

Indeed, the vast hierarchy of nested structures and nested dynamics in charge as it exists in the vacuum, is recognized in physics, as is the fact that it involves infinite energy. E.g., quoting Nobelist Weinberg {194}:

> *"[The total energy of the atom]... depends on the bare mass and bare charge of the electron, the mass and charge that appear in the equations of the theory before we start worrying about photon emissions and reabsorptions. But free electrons as well as electrons in atoms are always emitting and reabsorbing photons that affect the electron's mass and electric charge, and so the bare mass and charge are not the same as the measured electron mass and charge that are listed in tables of elementary particles. In fact, in order to account for the observed values (which of course are finite) of the mass and charge of the electron, the bare mass and charge must themselves be infinite. The total energy of the atom is thus the sum of two terms, both infinite: the bare energy that is infinite because it depends on the infinite bare mass and charge, and the energy shift... that is infinite because it receives contributions from virtual photons of unlimited energy."*

Here again we have met Kron's "open path" in a new and unrecognized form.

Hopefully we now are in a position to rigorously define charge — or try to — for the first time in physics.[65] **Charge** is the ongoing circulation of EM energy flow between the time and 3-space domains, as seen by the observer. **Negative charge** is the ongoing absorption of positive EM energy input from the time domain (from ict), transduction of the absorbed energy into positive 3-space EM energy, and re-emission of the EM energy in all directions in 3-space. **Positive charge** is the ongoing absorption of EM energy input from 3-space, transduction of the absorbed energy into the time domain, and re-emission of the EM energy in the time domain. Or contrary-wise, one may regard the positive charge as the ongoing absorption *of negative* EM energy input from the time domain, transduction of the absorbed negative energy into 3-space, and re-emission of the negative EM energy in all directions in 3-space. The negative charge then absorbs the negative EM energy impinging on it from 3-space, and transduces it into negative energy flowing back into the time domain.

Any *overall* curvature of spacetime, as seen by the observer, results in one of the two flows *predominating* as seen by the observer. Usually, at COP < 1.0, this Dirac sea hole current does not bother our circuit's operation, but remains confined to the local vacuum. It is often not bothersome or is minor for other than very high COP's. The reason is that, for such moderate and small COP's, most of the Dirac sea hole currents react either with (i) the seething local vacuum virtual particle cauldron, or (ii) the atoms in the material lattice to form lattice holes.

As the COP increases, the fraction of Dirac holes interacting with the lattice to form lattice holes increases. As the COP further increases greatly, a large fraction of the Dirac sea holes do not react with the local vacuum cauldron (they become stable forms in that cauldron) or the lattice, but flow into the input section of the system to react with and "eat" incoming electrons from the external power source.

If the inflow of electrons is insufficient to fill the arriving Dirac sea hole current at the input section, the hole current passes back into the feeder line and into the distant power source, eating electrons all the while. This includes eating electrons in the distant power source, which simply "sees" that it must furnish additional current and voltage (power) toward the distant circuit or system.

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[65] This is still a first order, macroscopic definition. For a more comprehensive statement, one must spell out the hierarchy and dynamics of the virtual state, the participating mass of the charged particle and its generatrix, the operations and dynamics of the *d/dt* observation operator, etc. We have not yet succeeded in getting all that into a single reasonable but sufficiently short statement!

In that operational COP region where strong interaction with the lattice occurs, the attachment of the lattice positron (lattice hole) to the mass of the atom or other ion, results in a very sluggish response of the overall ion with EM fields, compared to the response of an electron or a negative energy state electron hole (Dirac sea hole). Hence much of conventional electrical power circuit theory ignores the lattice holes and hole currents which no longer have negative energy because they have reacted and been "observed". Semiconductor designers, however, account for it and handle it in the semiconductor (in a given range of operation) primarily by the use of donor and acceptor materials.

At COP»1.0, however, the Dirac sea hole current must be strongly taken into account because it produces substantial and novel new effects in the power system itself. This Dirac sea hole current "flows in reverse" with respect to the circuit — from output back to the input. In short, it flows *through the vacuum* from the output section of a unitary COP»1.0 system, back through the middle section of the system, and back into the input section where it "eats" incoming electrons from the external power supply. The power supply thus must furnish electrons to "kill (power the killing of) the Dirac sea hole current arriving in the input section", while still furnishing the necessary amount of additional electrons to power the circuit's losses and loads.

The hole current arriving back in the input section of the unit poses an additional "power system load". These holes must be filled with incoming electrons (which disappear into the Dirac sea hole in the vacuum without radiation, due to the concomitant relaxation or change of the local curvature of spacetime) before any incoming electrons are left to power the circuit in normal fashion. So the hole current appears as a highly undesired extra "load" formed in the input and "eating input power from the external power supply".

We further discuss this situation and how to deal with it, in Chapter 9.

Finally, we propose a formal modification of the concept of "EM energy flow through space" (perhaps the first since its formulation independently by Heaviside and Poynting). The EM energy flow connected with the charge is a circulation of EM energy flow between the time domain and 3-space and back, *as a result of dipolarity*. This 4-circulation flow occurs at every point in 3-space (at every point dipole in the 3-space vacuum).

The formation of an observable charge results in an immediate, continuing, spreading re-organization (polarization) of the polarization of the vacuum virtual particle flux itself. It is this *spreading polarization of the vacuum* — and its accompanying giant negentropy EM energy flow circulation in 4-space connected with the spreading dipolarity and the observable "source" charge — that moves outward in all directions at the speed of light in 3-space from the newly formed charged particle or group of them.

We also define charge itself as that *continuously spreading dipolarity in 3-space*[66] accompanied by the giant negentropy EM energy flow 4-circulation from the time domain to 3-space and back.

The giant negentropy circulation in 4-space — represented by the spreading vacuum point-polarization and hence broken 3-symmetry — is what (observably) moves out in all directions from the newly formed observable charge. Since we "observe" only the 3-space aspect, we "see" it as the spreading appearance of 3-space EM energy (the polarization change of the vacuum itself) moving in 3-space, because we "see" it as the iteratively observed frames of a motion picture. *As observed,* that is one way of expressing it. As it actually *exists and happens prior to observation?*[67] the so-called "flow of EM energy in space" is not that at all. It is the radial spread of the appearance of a giant 4-space negentropy EM energy flow circulation between the dipoles formed in the polarization of space. In that process, the special 4-symmetry between time and space is maintained but with broken 3-energy flow symmetry and broken time-energy flow symmetry with respect to the 3-space observer.

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[66] I.e., the spreading partial restructuring and re-organization of the vacuum energy or energy flux.

[67] The sharp-eyed reader will note that we clearly distinguish between the operation of a "tree falling in the forest" without an observer to see it, and a "tree falling in a forest" as an observer sees it. Without observation, there is no observed tree, no observer, and no "observed falling". Yet there exists the "tree x time", the "observer x time", and the "falling x time" whether or not their observation occurs with its resulting *d/dt* differentiation operation. One set (the causal set) is 4-spatial, and the other set (the event set after observation) is 3-spatial. The cause is 4-spatial and unobserved, and the effect is 3-spatial and observed. They are not the same, though related by the *d/dt* observation operator and by the interaction of the 4-space cause with a previous 3-space frozen observation to change it to a new 3-space frozen observation. Note that one can and does have a cause without an effect in any legitimate theory of causality, but not an effect without a cause. The cause only assumes the potential for interaction and observation, whereas the effect assumes that the interaction has occurred, yielding the observation as the effect.

The 4-circulation (giant negentropy) of the EM energy flow "from" or "connected with" a charge, is intimately connected with the spin of the charged particle, since the charged particle spins in both the time domain and in 3-space, as discussed in paragraph 3.3 below. We believe the spin itself is the basic giant negentropy generator.[68] If that hypothesis is true, then giant negentropy, the circulation of EM energy between time-domain and 3-space and back, broken 3-symmetry and broken time-energy symmetry (as seen by the observer), the flow of EM energy through space (as observed), the nature of charge itself, and polarization of the quantum mechanical vacuum are all just different sides of the same coin.

Without amplification, we state that his giant negentropy outflow process has additional important ramifications in electrodynamics, general relativity, particle physics, and unified field theory. However, we leave further discussion of the subject for a future paper or book and for the advanced theorists.

3.2 Reinterpreting Whittaker's Decomposition of the Scalar Potential

As previously stated, we applied and re-interpreted Whittaker 1903 decomposition of the potential {85} between the ends of the dipole. The scalar potential is actually a harmonic set of bidirectional longitudinal EM wavepairs, where each wavepair consists of an outgoing EM longitudinal EM wave in real 3-space and an incoming EM longitudinal EM wave in the complex plane. Hence we have a new and novel EM energy flow symmetry in 4-space, where (as seen by the observer) the broken 3-symmetry of the dipole has removed the usual arbitrary imposition of an additional condition of 3-space energy flow symmetry as well. Simply making a dipole permissibly breaks the 3-space conservation of energy flow symmetry, and moves to 4-dimensional conservation of energy flow. Both EM energy conservation in 3-space and in the time domain are individually broken, but conservation of energy flow is now upheld between the time-domain and the 3-space domain. In blunt terms, we "consume a little time" to get any EM energy that exists in 3-space.

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[68] We leave to a future sharp young graduate student the business of expressing the angular momentum (spin) of the charged particle as a result of giant negentropy in EM energy flow between the time domain and 3-space. It can probably be done by deeply considering the giant negentropy process for an "isolated" observable charge considered as also containing its clustering set of virtual charges of opposite sign.

The broken symmetry of a source dipole — or of a source charge considered with its clustering virtual charges of opposite sign as a set of dipoles — produces a continuing giant 3-negentropy, as seen by the observer. He only sees the steady 3-space outpouring of energy, and sees that it will continue as long as the dipole or charge remains intact.

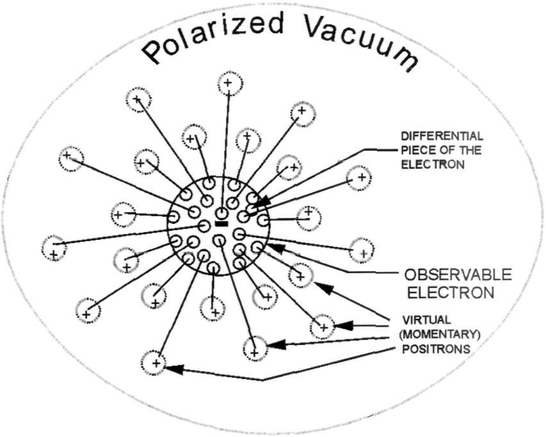
Polarized Vacuum
DIFFERENTIAL PIECE OF THE ELECTRON
OBSERVABLE ELECTRON
VIRTUAL (MOMENTARY) POSITRONS

Figure 3-3 Observable electron charge as a set of composite dipoles.

To clarify the "isolated charge" as a set of composite dipoles, see Figure 3-3. There is no such thing as an *isolated* observable charge in 3-space; instead, the observable charge is surrounded by attracted virtual charges of opposite sign in the active vacuum. We take a differential piece of the observable charge and a momentary virtual charge of opposite sign, and call the two a "composite dipole". An observable charge is simply a set of composite dipoles connecting virtual and observable energies and energy flows.

Hence any source charge (classical sense) may be considered such a set of composite dipoles. So any source charge also multiply initiates the broken 3-symmetry and broken t-symmetry in EM energy flow (as interpreted by the observer), but conserves energy flow 4-symmetry between the time domain and the 3-space domain. In 4-space, there is an energy flow circulation from the time domain to 3-space and back to the time domain again.

This special circulation of energy is strikingly similar to, and may be an extension of, Heaviside's unpublished theory of combined electrodynamics and gravity, where he used closed circulation of EM energy as exhibiting gravitational effects (in modern terms, producing spacetime curvature) {195, 172b.}. This approach or extensions of it may yet have a profound impact on physics, as commented upon by Laithwaite {196}. Certainly Heaviside considered his own energy flow theory. So it appears that he considered the excess energy flow — that "misses" the interaction with the circuit or assumed unit point charge and is not utilized — as producing gravity. That of course would be in perfect agreement with modern general relativity, since any change in the local energy density of vacuum is also a change in the local curvature of spacetime. We have called that Heaviside nondiverged and unaccounted EM energy flow by the label *dark positive energy*. See our further discussion of unaccounted (dark) positive energy in paragraph 3.8 below.

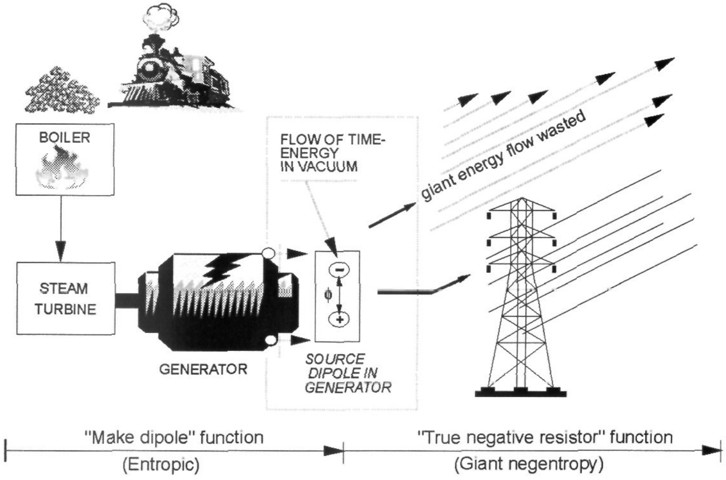
BOILER
STEAM TURBINE
GENERATOR
FLOW OF TIME-ENERGY IN VACUUM
giant energy flow wasted
−
φ
+
SOURCE DIPOLE IN GENERATOR
"Make dipole" function
(Entropic)
"True negative resistor" function
(Giant negentropy)

Figure 3-4 Dipole in generator powering circuits, taking energy from the time domain.

See Figure 3-4. This 4-symmetry is a far more fundamental energy flow symmetry than either 3-symmetry or t-symmetry. Both the "isolated charge" and the dipole are open systems far from equilibrium with their external active environment (the active vacuum and the active curvatures of spacetime). They are permitted to perform the five "magical" functions of disequilibrium thermodynamical systems. Such a system can: (i) self-order, (ii) self-oscillate or self-rotate, (iii) output more energy than the operator inputs, (iv) power itself and its loads (the "load" of a source dipole or source charge may be said to be comprised of the associated fields and potentials reaching across all space, and the continuous flow of energy necessary to maintain those fields and potentials), and (v) exhibit negentropy.

The source charge and the source dipole exhibit all five functions. We often refer to these characteristics of a charge or dipole as its *giant negentropy* functions {197}.

It only takes a single white crow to prove that not all crows are black. Every charge and dipolarity in the universe is already a Maxwellian system far from thermodynamic equilibrium with its local active environment — the very class of Maxwellian systems that Lorenz/Lorentz symmetrical regauging of the Maxwell-Heaviside equations arbitrarily discards. That local environment consists of the local curvatures of spacetime and the local active vacuum. The system together with the two components of its active environment is called the *supersystem.* All three components of the supersystem continuously interact with each other and exchange energy. All is dynamic, continuously. Any appearance of a "static state" in the system is actually an equilibrium condition stabilized in the ongoing supersystem dynamics.

So one does not have to "prove" that Maxwellian systems exhibiting COP>1.0 (even COP = ∞) are possible. Every charge and dipolarity in the universe is already just such a Maxwellian system, even though all such systems are erroneously discarded by Lorenz/Lorentz symmetrical regauging. Either one must accept asymmetry and COP>1.0 EM systems in electrodynamics, or one must purge from the theory all the charges and dipoles and all effects from them. That destroys all the charges, all the fields, and all the potentials.

That also destroys electrodynamics itself, as well as chemistry, particle physics, and most of modern science. The arch critic of overunity EM system research would do well to acquaint himself with some additional physics. Either that, or practice what he advocates, and give up all charges and dipoles and all effects from them — including in chemistry, particle physics, materials science, etc. When he holds on to the charges and dipoles while insisting on the impossibility of COP>1.0 Maxwellian systems, his cherished conventional EM theory eats itself by its own tail and becomes an oxymoron.

3.3 How the Dipole Charges Transduce Time Energy

We present a simplified analogy[69] that allows one to visualize how the dipole transduces the incoming time-like longitudinal EM energy flow into 3-space real EM energy flow for negative charge, or vice versa in the case of positive charge. With a little oversimplification, a charge may be said to spin 720° degrees in one complete rotation. For our purposes, it spins 360° in the imaginary plane (over in *ict),* and then spins 360° in the real plane (in 3-space). Thus the negative charge can absorb the incoming EM energy flow in the complex plane, transduce or "flip" the absorbed EM energy into 3-space to begin its 360 degrees in 3-space, and the excitation can decay during that 3-space spin part of the cycle. The only "variable" in *ict* is the t, so any energy flow has to be "by means of the variation of the t-variable". We already argued in a previous chapter that time can be treated as highly compressed spatial energy, having the same energy density as mass. So absorbing a very tiny amount of time-energy and transducing (decompressing) it into spatial energy produces enormous spatial energy *(t* multiplied by the factor c^2).

The negative charge absorbs a *little bit* of positive time energy, transduces it into a much larger amount of 3-space excitation energy, and re-emits it in 3-space as an observable, real flow of EM energy radially outward in all directions. The positive charge receives the large amount of 3-spatial EM energy and absorbs it, transduces it back into time-energy (highly compressed energy) and re-emits it in the time domain as a little bit of highly compressed time energy.

Conversely, we may consider that the positive charge absorbs a little bit of negative time energy, transduces it into a much larger amount of negative 3-space excitation energy, and re-emits this negative 3-space energy in all directions in 3-space. That consideration is important in the cold fusion phenomenology, and in fact accounts for the formation of little fleeting "time-reversal zones" in the electrolyte solution where the law of attraction and repulsion of charged particles is momentarily reversed. The omission of the giant negentropy mechanism and the negative energy mechanism from particle physics reaction theory is why there do not exist such nuclear transmutation actions at low spatial energy (but high time energy) in conventional particle physics. All such permissible reactions have been arbitrarily omitted from the discipline.

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[69] **For** simplification, the analogy treats "spin" of the charged particle as if it really were something like that of a spinning top, at least in its 3-spatial component. However, in physics the entity **spin** is not confined to a flat plane or even to 3-space. C**onsequently,** we caution that the analogy is primarily a mnemonic aid.

For the positron (or any positive charge), we assume that the process is reversed: 3-space energy is continuously absorbed (from the active vacuum exchange) by the positive charge during its 360° spin in 3-space. This 3-space excitation energy is then flipped into the time domain as time-charge or time-energy, as the charge starts its second 360° spin in the time domain. During that latter part of its 720° spin cycle, the spinning charge re-emits the time-charge energy (time-excitation) as a flow of a little bit of very dense EM energy in the time domain.

The effects of these mechanisms in systems of charges in motion are met with as time dilation effects, spacetime curvature effects, frame rotation effects, etc. in relativity theory.

A charge that has received excess EM energy from the time domain is said to be *time-charged* or *time-excited.* Since time-charge or time-energy is c^2 denser than spatial energy, a tiny amount of time-energy excitation or time-charge may be re-emitted as substantial spatial energy over a period of time. In short, the decay of time charging or time-excitation of charged particles can occur slowly and over time. The decay is marked by the presence of longitudinal EM wave radiation, by mysterious ionization phenomena appearing in some Geiger counters depending on their individual time-histories (individual initial time-charging condition), and by excess energy appearing in electrolytes and emitted as heat where such decay of time-charge is occurring.

Usually in ordinary circuits and EM systems the time-charge and time-charge-decay effects are minimal, being offset by their opposites in close adherence to equilibrium. However, when this is not the case and time charging does appreciably occur, then novel phenomena result in those circuits and systems. Such effects have occurred for some time in instruments associated with rigorous electrolyte experiments at U.S. Naval research facilities at China Lake {198}, but the researchers have not recognized the cause. We have pointed out the time-charge and time-decay solution to those novel phenomena, and explained why apparently "identical" instruments need not respond to the stimuli in the same manner {199}. Along the way, we also explained several of the low spatial energy (thus high time-energy) transmutations, including giving the typical reactions producing the excess deuterium, tritium, and alpha particles. We also explain those new nuclear reactions at low spatial energy (but high time-energy) in Chapter 10.

As we stated in Chapter 1, paragraph 1.1.3: In such electrolyte experiments where the palladium electrodes load with concentrations of positive charges on hydrogen ions of one form or another, then in the adjacent solution there can arise fleeting **time-reversal zones.** Such a zone is simply a very tiny volume of fluid in which antiphotons temporarily comprise the majority of the ongoing photon interactions with the local ions in solution in that zone. The result is that the normal (time-forward) law of attraction of unlike charges and repulsion of like charges is reversed; *in the TRZ, like charges attract and unlike charges repel.* This allows two positive ions such as H+ to be drawn together so tightly that each enters the (reduced) strong force region of the other, forming a quasi-nucleus. When the other ions move to eliminate the TRZ, during the decay of the TRZ the strong force increases more rapidly than the EM force. Hence, the preferred method of decay of the now-excited quasi-nucleus is by quark flipping to allow the quasi-nucleus to become a new nucleus. This nuclear transformation interaction allows the production of the excess deuterium, tritium, and alpha particles.

3.4 Reordering of the Local Vacuum: Giant Negentropy

A giant negentropic reordering of a fraction of the surrounding vacuum's energy is initiated when a dipole or charge is formed. This reordering is deterministic, and is the 4-flow energetic structure shown by Whittaker {85}, slightly reinterpreted, with perfect coordination of the converging EM energy inflow in the complex plane with the outflowing converted real EM energy in 3-space. Hence this negentropic reordering introduces "hidden order" into the vacuum's otherwise disordered energy. This reordering of a fraction of the vacuum's disordered energy also changes the Gibbs statistics assumed in quantum mechanics, replacing it with an "already chaotic" statistics containing hidden order. We propose this as a possible contribution toward resolving the presently unsolved problem of the missing chaos in quantum mechanics {200}.

3.5 Some Implications of Giant Negentropy

Giant negentropy has many envisioned impacts upon physics, such as:

(a) Allows development and use of negentropic EM circuits (COP>1.0 systems) rather than entropic circuits. Once a broken 3-symmetry with stable 4-symmetry is established (as by forming a dipole), it continues indefinitely unless deliberately destroyed.

(b) Allows direct negentropic reordering of a practical and usable fraction of the vacuum's energy at will, at any point in the universe, easily and cheaply.

(c) Provides for electrodynamic engineering of the vacuum energy and of spacetime curvatures clustered in specific templates (the concept of vacuum engines or spacetime curvature engines). This has significant medical applications {387c}.

(d) Utilizes time as energy (per our previous discussion) and thus allows use of the Whittaker phase conjugate half of the biwave set as an EM energy flow within the flow of time. Observably this translates to the continuous receipt of free time-energy by the formed broken 3-symmetry (e.g., the charge or dipole). Accordingly, the charge or dipole continuously pours out real observable EM energy in 3-space, without any observable EM energy input (time is not observable, and neither is the time-polarized photon alone).

(e) Allows "burning a little time for fuel", so to speak, in order to transduce it into a very large spatial energy flow, due to the enormous compression of 3-spatial energy represented by time-energy by a factor of c^2.

So from the giant 3-negentropy discovery, we have arrived at some intriguing findings:

(a) As is well known in particle physics, the opposite charges of a dipole constitute a broken 3-space symmetry in the violent flux exchange between the active vacuum and the dipole.

(b) This dipole's broken 3-space symmetry in EM energy flow, provides a *relaxation* to a more fundamental EM energy flow symmetry between the time domain and 3-space, and therefore in 4-space.

(c) There is no law of nature or physics that requires 3-symmetry of EM energy flow as an additional condition applied to 4-symmetry of EM energy flow. Instead, 4-symmetry energy flow is more basic, by the hierarchy rule.[70]

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[70] Quoting Steven Weinberg: *" ..there is a hierarchy of symmetries; whatever symmetry unites the gravitational and strong nuclear forces with the electroweak*

(d) The dipole is a practical and very simple means of "breaking" the additional 3-flow symmetry condition in EM energy flow our systems have previously exhibited, and relaxing to the fundamental 4-flow symmetry *without* 3-flow symmetry.

(e) So long as the dipole statically exists (e.g., imagine an electret suddenly formed, or a charged capacitor with no leakage), real usable EM energy circulation between time and 3-space, at each point in 3-space, will continuously move out from the dipole at light speed in all directions. In the view of the observer, at the same time, reactive EM power (actually, time-energy) will continuously flow into the dipole from the time-domain (the complex plane), and be transduced into real EM power output radially outward in 3-space from the dipole.

(f) Observably, a dipole or dipolarity and its scalar potential thus comprise a *true negative resistor* system of the most fundamental kind. The dipole continually receives EM energy in unusable form (reactive power, which cannot perform real work), converts it to usable form (real power, which can perform real work), and outputs it as usable, real EM energy flow (real power) in 3-space. Further, it spreads this "transformation of time-energy into 3-space energy at every dipole point" outward in 3-space in all directions.

(g) So at its formation the dipole initiates a continuing *giant negentropy* — a progressive reordering of a substantial and usable portion of the vacuum energy {201} that begins with dipole formation and continues. Further, this reordering of vacuum energy flow at every point in space continuously spreads in all directions from the initiation point, at the speed of light. Dipoles in original atoms formed shortly after the beginning of the universe, have been pouring out real EM energy for some 14 to 15 billion years or so (i.e., in the prevailing view; the age of the universe and whether it is expanding are still controversial {754}), and have reordered a fraction of the vacuum's energy, where the magnitude of the re-ordering varies inversely as a function the

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forces is broken roughly a hundred million million times more strongly than the symmetry that unifies the weak and electromagnetic interactions. The puzzle of explaining this enormous difference in fundamental energies is therefore known in elementary particle physics today as the hierarchy problem." [Weinberg, *Dreams of a Final Theory,* Vintage Books, Random House, 1993, p. 205], radial distance from the dipole.[71] This is in fact the solution to the long-vexing problem of the source charge and its associated fields and potentials and their energy, reaching across the universe. The charge together with its associated clustering virtual charges is a set of composite dipoles, hence a multiple *broken 3-symmetry* energy flow system.

(h) If the dipole is destroyed, the ordering of the vacuum energy ceases, leaving a "separated chunk" of reordered vacuum energy dynamics that continues to expand at the speed of light in all directions, steadily reducing in local intensity as it expands.

(i) At any very small volume in space, from the dipole dynamics of the universe it follows that a great conglomerate of reordered vacuum flows and fluxes — some continuous, some chopped — is continually passing through that volume. Further, the situation is totally nonlinear, so that direct wave-to-wave interactions occur continuously amongst these energy flows and waves. We hypothesize that this is the actual physical mechanism constituting Puthoff's cosmological feedback mechanism {202}.

(j) Further, in 1904 Whittaker {203} showed that any EM field or wave pattern can be decomposed into two scalar potential functions. This initiated what is called *superpotential theory*. Each of the two potentials for those functions, of course, decomposes into the same kind of harmonic longitudinal EM wavepairs as shown in Whittaker 1903, plus superposed dynamics. In other words, the interference of scalar {204} potentials — each of which is actually a set of longitudinal EM waves, and not a scalar entity {205} at all, but a *multivectorial* entity — produces EM fields and waves and their dynamics. Hence we hypothesize that the Whittaker interference of the propagating reordered EM energy entities, continuously occurring at any point in space, generates the zero-point EM field energy fluctuations of the vacuum itself. Indeed, an AIAS group paper by Evans *et al.* {206} has already shown that just such "scalar interferometry" produces transverse EM fields and waves in the vacuum at a distance.

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[71] The field energy density in the fields produced by the source charge varies inversely as the square of the radial distance. The potential energy density in the potentials produced by it will vary inversely as the distance.

Since energy can neither be created nor destroyed, there really are no true *energy sources* in nature in the sense that they *create* energy and pour it out {207}. Instead, what we call "energy sources" merely convert the energy already there in one form, into another form. All energy sources are no different from a solar cell in the sun, or a windmill in the wind, at least in principle. They are actually energy transducers rather than energy sources. This corresponds well with the conservation of energy law wherein not a single joule of energy can be created or destroyed. Instead, the form of that joule of energy can be continually changed. Every joule of energy present in the universe after its formation is still present, and is still doing joule after joule of work in iterative interactions with transducers that change its form.

A priori, we can measure no real 3-space input of EM energy to the unchanging charge but we can measure real 3-space EM energy pouring from it. Energy must be input to it from the active vacuum in a *nonobservable* form, and converted by it into an *observable* form that is re-emitted, usable, and produces what we call the "fields and potentials" and their energy, associated with that "source charge". As is common usage, we will continue to use the term "source charge" or "source dipole", but with the understanding that we refer to a special kind of *energy transducer.*

When we "make entropy", we must do work. Even so, doing work is not really entropic unless we also lose control of the energy[72] — whose form was merely changed by doing the work — and thence lose any *further* ability to use that energy (change its form, or transduce it) to do useful work. And when we observe entropy, we also do work in the observing. Some of the erroneous notions about entropy desperately need correcting. E.g., quoting Weinberg {208} for a lay definition of entropy:

> ***"..a certain quantity called entropy:*** *To define entropy, imagine that some of the system's temperature is very slowly raised from absolute zero. The increase in entropy of the system as it receives each small new amount of heat energy is equal to that*

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[72] An interesting point is that energy is energy and remains energy. "Disordered" ultimately means "unusable" or "inconvenient" and nothing else. Disordered energy is still energy, and if we do not lose it from the system we can in fact have the **system** automatically reorder it, e.g. by use of simple retroreflection. The entire concept of entropy must be rigorously interpreted in terms of "energy whose reuse is lost", at least by the processes being performed by the system considered. In our view, "entropy" itself is just additional usually "lost" energy to be recovered.

> *energy divided by the absolute temperature at which the heat is supplied."*
>
> *"....entropy, which always increases with time in any closed system..."*

However, we point out that apparently there exists no completely closed system in the entire universe. In the notion of entropy and the escape of the energy from their "closed" system, thermodynamicists themselves ubiquitously negate the latter premise that entropy in a completely closed system always increases with time. That simply does not follow. The real situation is as follows: (i) Entropy in a half-open system with no allowed external input of energy, but with allowed escape of energy, does decrease with time if the energy of the system decreases with time by escaping.[73] Hence the cooling of "hot" water with time, if and only if the excess energy in the system can have a net escape to the (cooler) environment as time passes, (ii) Energy in a completely closed system (closed to both energy and mass), with no input and no output of energy at all, simply remains constant because it is not dissipated; simply apply the conservation of energy law. It may rearrange within, and the subcomponent energies may disorganize with respect to range, but the total energy remains. Entropy actually only deals with the loss of ability to utilize the energy. To wit, the assumed (and apparently true, so far as we can tell) conservation of energy in the present universe is an example. A closed system is in this sense a special case of a system in equilibrium with its active environment.[74] I.e., any "closed system" is such a special case.

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[73] In case the reader has not thought of it, until the energy "escapes" it is not dissipating or dissipated from the dissipating "object". A "hot" object is energetically excited but not hot; the *energy dissipated* from it (including from every component within it) is scattering, and hence disruptive and "hot" in its interaction with a test instrument (or one's finger). The thermometer (or any other instrument) is external to the rest of the system (even if imbedded in it). Hence merely to "measure the temperature" is actually to pass energy out of the system into the thermometer (or other instrument), so that the thermometer measures the heat of the dissipating energy that has just escaped from the system. For these and similar reasons, Romer — former editor of *A. J. Phys.*— pointed out that "heat" should not even be used as a noun {84}.

[74] The concept of energy always requires that one can write "energy of...(X)" and fill in the (X). We usually write the phrase "of...(X)" as "X energy". Thus we write the phrase "energy of heat" as "heat energy," the "energy of the vacuum" as "vacuum energy", and the "energy of the EM entities" as "EM energy". At least in its usage, energy always requires a medium or entity "having" or "exhibiting" the energy. As Feynman pointed out, we really do not know what "energy" per se *is.*

(iii) In a system closed with respect to output (escape) of energy, but with the system opened only to allow external input of energy, the system energy will increase, simply by the conservation of energy law. That system's entropy will decrease and its negentropy will increase. (Its mass will also increase, and so it violates the thermodynamic misdefinitions of closed system; see Appendix A). It is well known that the entropy of an open system far from equilibrium cannot even be computed! (iv) Energy in an open system where input of energy and escape of energy both occur, may either increase, decrease, or remain constant, depending upon whether the input rate exceeds the output rate, or vice versa, or the energy input and output rate are equal. Therefore such a system can exhibit overall entropy, overall negentropy, or overall equilibrium, (v) Net energy scattering rate (rate of energy escaping the system in disordering fashion) from a hot system determines the observed temperature of that system at the time of observation. The system itself is cold, prior to escape of the energy. The "heat" is due to the interaction of the escaping energy with an external object, in its disordering fashion. Inside the system prior to escape, the energy is ordered hence cold.

A system in equilibrium in its exchange with its active external environment is in a state of maximum entropy *for that specific rate of energy exchange with its environment.* As we will point out in Chapter 9, by deliberately balancing the *system-and-vacuum* exchange with the *system-and-curved spacetime* exchange, so that the two exchanges are equal and opposite at a desired rate of exchange, one may establish (at least in theory) system equilibrium at whatever specific rate of energy exchange is desired.[75, 76] In this fashion, e.g., an "impossible" molecule normally intensely unstable and decaying in a nanosecond or less, can in fact be stabilized once an appropriate balance between the two opposing energy exchanges with the system is achieved at the required specific rate of energy exchange. This is actually a new Lorentz symmetrical regauging

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[75] This is necessary, e.g., to close-loop a COP>1.0 EM unitary system taking its input energy from the vacuum, as we shall see in Chapter 6.

[76] The Fogal superluminal transmission system in fact uses a conventional signal input to change this "symmetrical regauging" condition in consonance with the amplitude of the input signal. Thus suddenly Lorentz symmetrical regauging becomes a way to transform a conventional signal into a signal consisting of changes in the stress energy potential of the vacuum. That constitutes a longitudinal EM wave, and so it is not limited by the speed of light. To use this process, a Fogal semiconductor must be used as the modulator in the "transmitter", and another must be used as the demodulator in the "receiver".

condition; change of symmetrical regauging is very useful in this fashion. In this way, a great new chemistry with reactions presently deemed impossible is in the offing, and it is already being developed by at least one U.S. company. We do not name the company, under our tacit agreement with the scientists doing the work.

To operate conventional entropic systems,[77] first we must input energy to the inert system to force it out of equilibrium and back into excitation (back into an asymmetrically rcgauged system, violating the Lorentz condition) so that it has some excess energy (and negentropy). Then we allow the decay of the excited system's excess energy to pass through a load and be dissipated from it, doing work for us by powering the load. Conventional systems usually do not recapture the "escaping dissipated energy" but just waste it. *"Dissipating" energy is merely allowing it to escape from the system and from further system control.* Then we brutally force more excitation energy into the system, opening it and breaking its equilibrium to do so. Again we dissipate the system's excitation energy in the load to produce some more work, usually wasting an appreciable fraction of the excitation energy.

In EM systems, it is a little more complex. We continually "switch on" a negentropic flow of EM energy from the vacuum by making a source dipole. In the circuit, we collect a small part of the resulting huge energy flow in space surrounding the circuit conductors. Then we use half the collected energy to destroy the dipole source of the energy flow, while less than half of the collected energy is dissipated in the load (the rest of that second half is dissipated in the external circuit's losses). Hence we must continually restore the source dipole and pay more to do it than we get out in the load as useful work. We make a perfectly good negentropic system, and then forcibly destroy its negentropic ability faster than we power the load and get any use out of it. That's a terrible way to make and use power systems, but it is what has been done for more than a century.

So with our present entropic EM systems (actually our *self-killing negentropic* EM systems) we continually wrestle nature fiercely to the mat, so to speak, by brute force, repeatedly, to bind her into 3-space EM energy conservation. All the while, nature protests our continual entropic brutality by providing the Newtonian third law reaction force[78] back upon our causative wrestler performing the "forcing". To do entropic engineering, we have to continually input 3-space energy to the wrestling mechanism or engine, losing a bit of the input energy in the inefficiencies, and fighting the "back emf", "back mmf", or Newtonian third law reaction that is nature's cry of protest all the while. Those are nature's penalties for imposing a monstrous 3-space EM energy flow symmetry[79] upon her as an *additional, highly undesired, and highly unnatural condition* added upon her beloved special 4-symmetry energy circulation between the time domain and 3-space.

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[77] By "entropic system" we mean a system whose excitation energy decays and is dissipated from the system or at least from its further control, so that the entropy (lost or unusable energy) of the system continually increases until equilibrium (total decay of the excitation energy) is achieved. As can be seen, this also can be used to define entropy and increase in entropy. What is usually unappreciated is that *equilibrium is actually a counterbalance between ongoing entropy and negentropy.*

In short, because we so love entropic engineering and 3-space EM energy flow symmetry, we have to provide the continual input energy to our entropic processes by burning fuel, damming rivers, erecting windmills, building waterwheels, erecting solar cell arrays, building and charging chemical batteries, etc. In the process, we destroy and pollute the biosphere on a giant scale as we rip down forests, strip-mine and drill the earth, pile up thousands of tons of radioactive nuclear wastes —that will be hot for thousands of years — from our power plants and related facilities, and spew streams of pollutants into the atmosphere, the rivers, the oceans, etc. We do all that biosphere destruction because we inexplicably insist upon placing cruel chains on nature by brutally enforcing 3-space energy flow symmetry upon her. In the process, we adamantly require adherence to classical equilibrium thermodynamics (as given a somewhat altered explanation above, and also in Appendix A).

We do not have to do it that way. In avoiding solving the source charge problem for so long (more than a century), we have been extremely backward in our thinking and in our consequent development of entropic engineering technology.

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[78] Note that Newton's third law reaction is implicit in the special negentropic energy flow circulation of the dipole, or of the charge considered as a set of composite dipoles. The same energy that moves into 3-space from the time domain, then returns from 3-space to the time domain, at every point in the 4-circulation. If we consider the positive charge as a "source" of negative energy, then there is a concomitant circulation of negative energy from the time domain to a point in 3-space, and back to the time domain.

[79] The 3-space symmetry of energy flow equilibrium is actually between the energy we input (from its external environment) to the system, and the energy that escapes from the system back into its external environment, either in its losses or in its loads. As we stated, equilibrium condition is a balance between ongoing entropic and negentropic operations.

For our dullness, we have had to pay and pay continuously for insisting on doing such atrocious entropic work and forcing nature to do it that way. In so doing, we "tie nature's feet" with that added arbitrary 3-symmetry in energy flow. We ourselves prohibit nature from performing the giant negentropy she so dearly loves and much prefers. We also arbitrarily and *meanly* discard the bountiful electromagnetic energy flow that nature loves to furnish us so freely by her vast preference for giant negentropy. We meanly discard nature's bountiful giant negentropy banquet free for the taking, by our vast thirst for giant entropy and doing violence to nature. Because we act like brutes instead of scientists, we destroy nature in spite of nature's continuing attempt to give us all the EM energy we wish, freely except for a little switching cost.

A far better way is to cooperate with nature and "let nature make her beloved copious negentropy" as she yearns to. To do that, we now can see the startlingly simple mechanism. We simply make a little dipole, *once*, entropically. So we have to pay for *making* the dipole, *once*, and we have to do just a little gentle violence to nature, *once*. Then we need do no more violence, if we just leave the dipole intact and do not destroy it. In short, we do have to tap nature gently on the shoulder. We do not have to brutally knock nature down to the mat, repeatedly.

When we make the dipole, we make a little bit of "broken 3-symmetry" in the universe's energy flow. Voila! Nature sings for joy at finally having her feet freed from the shackles of the horrid 3-symmetry energy flow. In great glee, she instantly relaxes into her dearly preferred giant negentropy and 4-symmetry. She instantly sets to re-ordering a substantial and usable

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[80] E.g., so far as I am aware, there have been no funded research programs to discover how to deviate and collect some of the freely flowing energy from a permanent magnet or an electric dipole. Instead, electrodynamics has smugly continued to call it "statics" as if there were no dynamics, and ignored the giant negentropy circulation that is "seen" as the steadily outflowing field energy in 3-space, and erroneously called the "static field". There is no such thing as "statics" in the entire observed universe *a priori;* the very process of observation itself is dynamic. What we see as "static" is continual recurrence of a given condition or state or magnitude, as beautifully pointed out by Van Flandern {628}. One might even say that, not only is nature energetic, nature *is* energy, constantly changing and in motion in innumerable ways at once! One might even define "energy" as the process by which nature both acts and observes its actions, in every form and structure and possibility.

portion of the vacuum energy of the universe, in all directions at the speed of light, spreading her preferred giant negentropy EM 4-energy circulation flow from the dipole toward the ends of the universe at the speed of light. As long as we do not destroy the dipole (the broken 3-symmetry) that gently breaks the 3-symmetry shackles, nature's feet remain freed from brutal 3-space symmetry in EM energy flow. In that case, she delightedly continues to reorganize a portion of the vacuum energy, with the reordering spreading radially outward at the speed of light. Simply making a common dipole or charge[81] sets nature to going about reordering an ever-increasing fraction of the entire vacuum energy of the universe, and continuing indefinitely.

Simultaneously with freeing her from enforced 3-space EM energy flow symmetry, in great gratitude nature pours out an immense real EM energy 3-flow from that little dipole or charge. She will continue to pour it out forever for us, if we do not destroy the dipole or charge.

Instead of the present universal entropic engineering, the smart thing to do is make just a little bit of entropy wisely, using the work we get to break 3-space energy flow symmetry (basically, to make a dipole). *Then leave that mother of all negative resistors and free energy flow generators alone and forever unchanged!* Concentrate on intercepting, extracting, and using the free 3-space energy copiously flowing forth from the giant negentropy, without destroying the dipole that is freely providing it.

3.6 How Circuits Are Powered

Let us now look at the great magnitude of the energy flow that nature gives us from that dipole. We have to get into the subject a bit, because EM energy flow theory has been rather thoroughly confused for more than a century.

First, batteries and generators *do not* use their available internal energy — the shaft energy we input to the generator, or chemical energy available in the battery — to power the external circuit. Instead, each uses its available internal energy {209} to perform work on its own internal charges, forcibly separating the charges to form the *source dipole.*

See again Figure 3-4. *All the hydrocarbons ever burned, all the nuclear fuel rods ever consumed, and all the dams ever built, added not one single watt directly to the power line.* All the energy from those activities was input to the generator shaft after normal losses en route, to provide internal magnetic energy available to the generator. In turn, the generator used that available internal magnetic energy only to do internal work on its own internal charges to force them apart, forming the source dipole connected to the terminals. Generators are energy transducers only; they do not directly power their own external circuits.

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[81] As we previously explained, a charge is just a set of composite dipoles.

Batteries and generators expend their internal energy available to them, to make the source dipole, and for no other purpose! None of their internal energy is used to power their external circuit. It never has been, and it never will be.

Once the source dipole is formed, it does all the hypothesized 4-functions we pointed out previously. It induces the spreading giant negentropic reordering of the vacuum energy, extracts (transduces) EM energy from the continuously reordering vacuum, and pours out from the terminals of the generator (or battery) a vast 3-flow (as observed) of EM field energy along the external circuit. As indicated by Kraus's illustration of the Poynting component {210}, this giant EM energy flow fills all space surrounding the circuit, out to an infinite lateral radius.[82] The energy flow is generally parallel to the conductors of the circuit. Only a tiny component of this flow — due to the surface charges of the conductors and the little boundary layer of energy flow that slides along the surface of the conductors — strikes the surface charges and gets diverged into the conductors (by the lateral withdrawal of the surface charges — with the "stub" or "base" of their field energies — laterally into the conductors. The electrons move mostly laterally, withdrawing from one side of the conductor surface to the opposite. Only the tiny component of its field vector integrated over that small distance is withdrawn into the conductors to power the electrons. This small amount of "withdrawn" energy is the diverged Poynting component, "collected" by the circuit. It also is the small component then used (dissipated) to power the Drude electrons and the circuit.[83] All the rest of that vast EM energy flow in the surrounding space, that pours forth from the terminals, just misses the circuit entirely. It roars on off into space and is wasted.[84]

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[82] We accent that Kraus, along with other authors, only shows the 3-space *Poynting component* of that flow; i.e., he shows the very small amount of that external 3-space energy flow that is diverged into the circuit to potentialize the Drude electrons and power the circuit. Kraus *does not* show the remaining Heaviside component that is not diverged.

[83] As shown by Kraus, some of the energy flow at the various radial distances from the wire is withdrawn, as the surface electrons and the "stubs" of their near fields precess laterally into the depths of the wire when potentialized. Jackson, *Classical Electrodynamics,* Second **Edition,** Wiley, 1975, p. 223 also points out the nonlocal

The diverged, utilized, and accounted energy flow component — the *Poynting component* — is only a tiny, tiny fraction of the entire giant EM energy flow produced by the source dipole for every circuit.

3.7 The Heaviside Component vs. the Poynting Component

Unless Heaviside and Lorentz did rigorous calculations in a work we have not yet uncovered, we could not find any development of the functions and equations required for computing the numerical ratio of the unaccounted Heaviside "dark energy flow" *{nondiverged* energy flow component that misses the circuit), to the tiny Poynting energy component thai strikes the surface charges of the conductors {211} and is diverged into the wires to power the circuit when the surface charges precess laterally into the wire.

Consequently, we performed a very crude "special case" estimation {212} — a back-of-the-envelope type, with highly simplifying assumptions — for a very simple circuit in which one resistor is powered by a DC source. Our crude estimate showed that about 10^{13} times as much EM energy flow *misses* the circuit, is *not diverged,* and is *wasted* — as *strikes* the circuit, gets collected, and then is dissipated in the circuit to power the load and losses. Until electrical physicists re-examine the energy flow theory and

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involvement of the transverse current. Quoting: *"...the transverse current... extends over all space, even if J is localized. "* One notes that present electrical power systems concentrate exclusively on the J current, making no attempt to collect and utilize the recognized but rather ignored transverse current.

[84] Note, however, that this Heaviside energy flow component differs from ExH. The Heaviside component is totally nondiverged (being actually in curl or swirl form), and since E and H are both diverged energy components assumed around an **Interacting** unit point static charge, there is neither E nor H in the electrical engineering sense prior to interaction with charge. So the energy flow in both the Poynting and Heaviside components is in a force-field-free form until intercepted by and interacted with charge. Poynting's component, e.g., assumes only that energy co**mponent** that does interact with charge and get withdrawn into the circuit. **Heaviside's** component assumes only that energy component that does not interact with charge and does not get withdrawn into the circuit.

again recover the Heaviside unaccounted component in it, that brute force estimate will have to suffice as at least an illustrative example.[85]

What does that 10^{13} ratio mean? For a little 1 watt generator of that DC type with that specific size conductors and that specific resistor, the Heaviside unaccounted energy flow component was about *10 trillion watts,* occupying all space surrounding the wire,[86] if all of it could be intercepted, collected, and used to power loads {213}. But the little circuit was only intercepting and collecting — and using to power loads — about 10^{-13} of the available energy flow surrounding the circuit, *if all* of it could have been intercepted, collected, and used to power loads.[87]

We have never had, and we do not now have, an *EM energy* shortage or problem. We never will have one, due to nature's bounty in providing us with the giant negentropy of the common dipole and of the charge considered as a composite dipole. Instead, we have the two problems that

(i) only a tiny, tiny component of the available 3-energy flow extracted from the vacuum (decompressed from time-energy) by the source dipole and poured out of the terminals of the power source, is caught and used by the circuit, and

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[85] We would very much welcome a much more accurate functional expose by a capable higher group symmetry electrodynamicist!

[86] We also point out that none of this nondiverged energy flow component is accounted in conventional electrodynamics and electrical engineering (the closest it comes is Jackson's mention of the transverse current over all space), and neither has it been accounted or even investigated by biophysicists seeking to determine the effects of EM radiation and fields upon biological systems. We strongly suspect (and have done a little work on the problem) that these "force-free fields" and neglected excess "strange energy" flows do have interactions throughout the highly nonlinear cells of the body, and can indeed have profound long term effects on long-exposed biological systems. We particularly stress the potential for time-charging and subsequent *combined scalar and longitudinal photon pair* decay of time-charge excitation in the body. Several major areas of electrodynamics — such as the transverse current effects, Heaviside component effects, and internal Whittaker structuring (engines) effects of EM radiation — have not been investigated by the scientific community.

[87] We accent that time-energy may be regarded as spatial EM energy compressed by the factor c^2. Hence one second = 9×10^{16} joules of EM spatial energy, if decompressed by time-energy interaction with charge. The crude estimate for one circuit of 10^{13} times as much energy being wasted in the Heaviside energy flow component as is caught and used in the Poynting component, is thus quite reasonable when one recognizes that *all* the EM energy flow appearing in the circuit or outside it actually comes from the time domain, hence constitutes *decompressed time-energy.*

(ii) in the closed current loop circuit, half of that small spatial EM energy component that is intercepted and caught, is used by the circuit only to destroy the source dipole and cut off the free flow of EM energy from the vacuum faster than it powers the load.

We have previously discussed this further in several papers {214}.

One must occasionally keep one's sense of humor. The real problem that the Department of Energy should be working on, with massive resources, is simply the alteration of the closed current loop circuit so that it does not destroy the source dipole faster than it powers the loads. Secondly, they should then be working on how to close-loop the COP>1.0 EM systems that readily emerge from that research. Yet it appears that this fundamental energy problem — and the *only* energy problem — has no conventional work being openly done on it anywhere in the open Western world.[88]

3.8 Dark Positive Energy: The Unaccounted Heaviside Component

Now we restate a deceptively hidden thing: The EM field and potential are defined as the observed effect of the deviation from them by an assumed unit point charge. Then that same field and potential are assumed to be in mass-free space, before the interaction with charged matter. Hence the field and potential have each been defined erroneously as both a cause and an effect. This is a gross non sequitur. There is also a total lack of accounting that all EM energy in 3-space comes from the time domain. There is no consideration that every dipolarity and every charge represents a giant circulation of EM energy between time and 3-space. In ensemble, this non sequitur and these omissions are responsible for most of the present formidable foundations problems in electrodynamics.

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[88] Using the U.S. as an example, the U.S. classified community is highly compartmented, and the real "organization" of a given compartment often consists of laterally connected "same clearance" compartments in multiple outside agencies rather than vertical chain of command through one agency. We accent that some highly compartmented "lateral" classified organizations in the West and elsewhere already have working COP>1.0 systems, and have had them for several decades. Some of these laterals in the U.S. are very dedicated to the duly elected government of the United States, with good national security reasons for the fact that they "officially do not exist". Some are not so dedicated at all, and have their own agendas having little if anything to do with official U.S. government policy. These latter "rogue" laterals often have convenient connections with outside shadowy groups of the High Cabal (Churchill's phrase). A similar situation exists in several other major foreign nations. Substantial electrodynamic technology has been developed (and weaponized) for decades, in secret, and this technology does not appear in the open news, the university texts, or the scientific journals. Such is the case for COP>1.0 EM power systems, which have actually existed in secret for decades.

We submit the following new hypothesis: *The present "definition" of field and potential as a function of interception and divergence by a unit point static charge are only indications of their point intensity, obtained as an estimate after their observed interaction with a unit point static charge.*[89] *Thus the actual field and potential contain not only their Poynting components that interact with the unit point charge, but also their Heaviside nondiverged components that do not interact with it. The true "magnitudes" of the massless field and potential prior to interaction with charged mass are many orders of magnitude greater than the magnitudes of their standardized point intensities* {215}.

In short, we propose that *every field and potential, in its interaction with charged mass, produces not only the accounted energy aspects presently calculated by electrodynamicists and astrophysicists, but also contains Heaviside's vast unaccounted "dark positive energy" component presently discarded.* We further propose that this ubiquitous and unaccounted "dark positive EM energy" component in the interactions of the fields and potentials of the spiral galaxies is what is producing the excess gravity that is holding the spiral arms together. We specifically do this in honor of Heaviside, whose unpublished papers clearly establish that he recognized the overwhelming gravitational importance of his extra and unaccounted energy flow component {172a, 172b, 196}.

3.9 A Short History of the Discarding of the Heaviside Dark Energy

3.9.1 Independent Work by Heaviside and Poynting

Let us now see how the enormity of the EM energy flow from the dipolar source was treated in the early electrodynamic theory, and how it is treated in the received view today.

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[89] This is recognized by leading electrodynamicists, but not by most electrical engineers building power systems!

In the 1880s after Maxwell was already deceased, Poynting {216} and Heaviside {217} independently (and rather simultaneously) discovered EM energy flow through space. Before that, the concept did not appear in physics. Poynting {216} published prestigiously, while at first Heaviside published more obscurely {217}, then finally more prestigiously {218, 219}.

With respect to circuits, from the beginning Poynting assumed only that small amount of EM energy flow that enters the circuit from the surrounding space. Here are Poynting's {220} own words:

> *"This paper describes a hypothesis as to the connexion between current in conductors and the transfer of electric and magnetic inductions in the surrounding field. The hypothesis is suggested by the mode of transfer of energy in the electromagnetic field, resulting from Maxwell's equations investigated in a former paper ("Phil. Trans.," vol. 175, pp. 343-361, 1884). It was there shown that according to Maxwell's electromagnetic theory the energy which is dissipated in the circuit is transferred through the medium, always moving perpendicularly to the plane containing the lines of electric and magnetic intensity, and that it comes into the conductor from the surrounding insulator, not flowing along the wire."*

As can be seen, Poynting considered only the energy flow actually entering the wire, and subsequently being dissipated in the circuit. Hence Poynting never considered the huge EM energy flow component around the circuit that is *not* diverged, *misses* the circuit entirely, *does not* contribute to the energy dissipated by the circuit, and is *wasted.* In short, there is a vast "dark energy flow" associated with every dipolar interaction — a huge energy flow component which Poynting never considered.

Heaviside's theory was an extension of what Poynting had considered, and Heaviside also corrected Poynting as to the direction of flow. Heaviside was fully aware of the enormity of the "dark energy" flow missed by Poynting, but had absolutely no explanation as to where such a startlingly large EM energy flow — pouring from the terminals of every dipole, generator, or battery — could possibly be coming from. Consequently, Heaviside was very cautious in referring to it, usually doing so only obliquely in terms of the angles and components. In Heaviside's {221} own words:

> *"It [the energy transferflow] takes place, in the vicinity of the wire, very nearly parallel to it, with a slight slope towards the wire... . Prof. Poynting, on the other hand, holds a different view, representing the transfer as nearly perpendicular to a wire, i.e., with a slight departure from the vertical. This difference of a quadrant can, I think, only arise from what seems to be a misconception on his part as to the nature of the electric field in the vicinity of a wire supporting electric current. The lines of electric force are nearly perpendicular to the wire. The departure from perpendicularity is usually so small that I have sometimes spoken of them as being perpendicular to it, as they practically are, before I recognized the great physical importance of the slight departure. It causes the convergence of energy into the wire. "*

As can be seen, Heaviside was fully aware that the energy flow diverged into the wire was only a minuscule fraction of the total. He was fully aware that the remaining component was so huge that the energy flow vector remaining — after the divergence of the Poynting component into the circuit — was still almost parallel to the conductors. However, he had no explanation at all of where such an enormous and baffling energy flow could possibly originate.

Had Heaviside strongly stated the enormity of the nondiverged component of the energy flow, he would have been viciously attacked and scientifically discredited as a perpetual motion advocate. His words were measured and cautious, but there is no doubt that he recognized the enormity of the nondiverged EM energy flow component.

We have chosen to call that huge unaccounted component the "Heaviside dark energy component" in his honor, since he actually discovered it. By the word "dark" we mean "unaccounted", which hides it from scientific view. We have also nominated it as the previously unsuspected source of the extra gravity holding the arms of the spiral galaxies together.

3.9.2 Lorentz Disposed of the Problem Rather than Solving It

Lorentz then entered the EM energy flow scene to face the terrible problem so quietly raised by Heaviside. Lorentz understood the presence of the Poynting component, and also of the extra Heaviside component, but could find no explanation for the startling, enormous magnitude of the EM energy pouring out of the terminals of the power source (pouring from the source dipole) {222} if the Heaviside component was accounted. Had he retained and advanced this enormous dark energy flow component, even the great Lorentz would have been castigated as a perpetual motion advocate who did not accept the law of energy conservation. Even today, when one points out that far more energy is pouring out of the terminals of every generator than the small mechanical energy input to the shaft, one is immediately labeled a raving lunatic — even though the Bohren experiment {24} clearly proves the presence of an extra energy flow component not usually intercepted. It is not difficult to understand how such a bombshell would have been received in the 1880s! At least today, we have particle physics and its broken symmetry of opposite charges, together with its active vacuum, to explain where the excess energy comes from and how.

Unable to *solve* the dark energy flow problem by any rational means, Lorentz found a clever way to *avoid* it. He reasoned that the nondiverged Heaviside component was "physically insignificant" (his term) because it did not even enter the circuit. Since it did nothing of any physical consequences, or so he reasoned, then it could just be discarded.

So Lorentz simply integrated the entire energy flow vector (the vector representing the sum of both the Heaviside nondiverged component and the Poynting diverged component) around an assumed closed surface enclosing any volume of interest {223}. *A priori,* this mathematical procedure discards the dark *Heaviside* energy flow component because of its nondivergence. It retains only the intercepted *Poynting* diverged component that enters the circuit.

A century later, electrodynamicists are still happily avoiding the dark energy flow problem by continuing to use the Lorentz integration procedure {224} to dispose of all but the Poynting component that enters the circuit and is then dissipated by the circuit. As a result, the "Poynting energy flow" has come to be loosely regarded as "the" entire EM energy flow, though electrodynamicists find it necessary to give stringent warnings about it. E.g., Panofsky and Phillips {225} state it this way:

> *"...only the entire surface integral of N [their notation for the Poynting vector] contributes to the energy balance. Paradoxical results may be obtained if one tries to identify the Poynting vector with the energy flow per unit area at any point."*

Most electrodynamicists note the freedom to add a vector — few call it an *energy flow* vector, though that is the type of vector being discussed, and one must add apples to apples — which has zero divergence. Jones {226} states:

> *"It* is *possible to introduce the Poynting vector S, defined by S = ExH, and regard it as the intensity of energy flow at a point. This procedure is open to criticism since we could add to S any vector whose divergence is zero without affecting [the basic integration procedure's result]."*

Jackson {227} says it even more plainly, and also uses Lorentz's "no physical significance" argument for disposing of any energy flow vector with a zero divergence. Quoting:

> *"...the Poynting vector is arbitrary to the extent that the curl of any vector field can be added to it. Such an added term can, however, have no physical consequences."*

Any energy flow vector, which is the curl of a vector field, will have zero divergence, by elementary vector algebra. In short, to be pertinent at all, it must be an *energy flow* vector (since energy flow is what S = E x H is all about. Since the curl of any vector has no divergence *a priori,* then any energy flow vector that is a curl of a vector field will be part of the Heaviside dark energy flow component, rather than part of the Poynting energy flow component. It will also be discarded by Lorentz's closed surface integration.

We refer the reader again to Figures 2-5 and 2-6 in Chapter 2, p. 113-114. Electrodynamicists err in assuming that such a divergent free vector (energy flow) can have no physical consequences. If one inserts *additional intercepting charges* into that formerly nondiverged energy flow component, the charges will immediately diverge some of the formerly nondiverged energy flow around them and hence "collect additional energy". In other words, "divergence" is the result of a physical process, accomplished by intercepting charges. We can easily change "nondiverging" energy to diverging energy, by simply interacting it with charges. We can also "bunch" the energy flow lines closer together (as in some waveguides), thereby increasing the local flow intensity and the concomitant energy collected by each intercepting charge in the densified energy flow stream.

So whether the Heaviside energy flow component is of physical consequence or not, depends on whether or not we "add more sail to the sailboat", or "add more sailboats" before the wind. That is most certainly a useful physical consequence, and with a little ingenuity we ought to be able to use it to power loads "for free" or nearly so. There are other consequences also, as we used in deriving the negentropy of the dipole or charge. There the input of a non-Poynting energy flow component certainly has universal and physical significance — e.g., to the curving of local spacetime, conditioning the active vacuum, furnishing all the energy to form the EM fields and potentials from their source charges, etc.

Schwarz {228} expresses it this way:

> *"There will be many opportunities in which the interpretation ofE x H as a rate offlow ofenergy per unit area will be profitable. In most cases ofpractical interest, such an interpretation is valid, although it must always he kept in mind that only the integral of S over a closed surface can be physically measured... Just how it is that the connections to the energy source, say a battery, are at the ends ofthe wire, yet energyflows in through the sides, should be pondered by the reader. "*

Note carefully that Schwartz recognizes the difference between the observed (deviated or diverged) part of the EM energy flow and the unobserved nondeviated or nondiverged part of it. However, he did not follow it up and apply it back to the basic "definition" of the field and potential as what are diverged from them.

For recommended changes to the Poynting vector, Jones {229} presents many conditions the changed vector must fulfill. Then he falls back on the Lorentz closed surface method again, but without realizing that he therefore (i) first includes both the diverged and nondiverged component, and (ii) invokes a procedure that arbitrarily discards the nondiverged component. In thus disposing of the problem, Jones says:

> "It *does not seem likely that an expression satisfying all these conditions will be simple........fortunately, we are rarely concerned with the energyflow at a point. In most applications we need the rate at which energy is crossing a closed surface."*

Finally, we note that even today, a debate on what the Poynting vector is or should be, is still politely ongoing. As an example, it has been ongoing for more than 40 years in the *American Journal ofPhysics* alone as well as in other journals {230a-230i}. One thing is clear: The Poynting vector does not represent the total energy flow at right angles through a square meter in space surrounding the conductors of the electrical circuit. It is, however, the *component or fraction* of that actual energy flow through the square meter in force-field-free form *that will subsequently be diverged and collected in the circuit in force-field form and dissipated in the circuit loads and losses.*

3.10 The Problem of the Accelerating Expansion of the Universe

As briefly stated earlier, we introduce the notion of the supersystem, consisting of three parts: (i) the system and its dynamics, (ii) the active vacuum and its dynamics, and (iii) the active spacetime curvatures and their dynamics. All three components of the supersystem interact with each other.

In Chapter 9, we explain in some detail how a COP>1.0 EM circuit — and especially a COP»1.0 EM circuit — has an induced flow of negative energy (Dirac sea hole current) from the output section of the system, back through the system, and into the input section. Reaching the input section, if the hole flow is not completely filled by incoming electrons, the remaining Dirac hole current will flow on back into the feeder line from the external power supply, and into the distant power supply itself, eating electrons and electron current all the while.

We also explain our reinterpretation of the *unobserved* (non-reacted) Dirac hole with negative energy or negative mass, without time reversal and parity reversal. This dramatically differs from the "as observed" (interacted) Dirac positron with positive mass, and with charge-reversal and parity reversal from the electron. The Dirac hole is "as unobserved and non-reacted" and it is still an *electron* having negative mass and negative energy. The Dirac positron with positive mass, opposite charge, and opposite direction is "as observed and reacted with charged matter". The unobserved Dirac hole is the "cause" of an observational interaction; the Dirac positron is the "effect" of an observational interaction. The two are very different because the cause differs from the effect. Here again, the confusion of cause and effect has had very detrimental consequences in the use of Dirac's electron theory.

Very powerful astronomical phenomena, such as giant astronomical explosions of great energy, involve COP>1.0 and COP»1.0 processes, particularly when the unaccounted Heaviside energy flow is accounted for every field and potential interaction with charged mass. Hence all such phenomena also provide very powerful "explosions" of negative energy

(Dirac sea holes moving outward in the vacuum). The negative energy is the equivalent of negative mass, so long as it is unobserved.

So there is a "dark negative energy explosion" in the Dirac Sea vacuum, accompanying every large astronomical explosion seen through our telescopes and other sensors. This accompanying dark negative energy explosion has not been accounted in astrophysics until now.

We thus live in an astronomical universe of neglected "giant dark negative energy explosions" as well as one of accounted "giant positive energy explosions".

The dark (unaccounted) negative energy radiating outward in the vacuum from gamma bursts, x-ray bursts, etc. produces antigravity. The spreading negative energy, moving at light speed, is a change to the vacuum itself, which also interacts upon spacetime to negatively curve it, producing negative gravity. For those energetic processes of COP sufficiently greater than one, the processes produce more antigravity than gravity. As of this writing, we are in fact filing a patent application on this method of performing and producing antigravity, and it will be filed before this book is published.

Over the 14 billion or so years of the observed universe, the dark negative energy content of spacetime has been slowly changing by the results of giant astronomical explosions and other such processes producing negative energy radiated outward into the Dirac sea vacuum. Slowly the vacuum itself has undergone transformation from the perfect Dirac sea with all holes filled by particles, to a vacuum where there is a slowly growing fraction of negative energy (negative mass) unobserved Dirac sea holes.

Thus, slowly the antigravity generated by the gradual altering of "space" (the vacuum) itself has been growing for some 14 billion years. At some point in the past, the excess antigravity effect accumulating in space reached the equal of the "outside" gravity acting upon energetic explosive astronomical phenomena. From that point in time, the antigravity effect has been increasing slowly. The result is that the present violently explosive astronomical phenomena, by adding a sudden and sharp increase in their external space antigravity, produce acceleration away from all positive mass and positive energy phenomena. Hence astronomers now observe the acceleration of the expanding (positive energy/positive mass) universe, instead of the previously expected slowing (due to positive gravity) of the expanding universe (conventional view).

The antigravity-producing phenomena have not been openly investigated in Western science because Western science has arbitrarily discarded COP>1.0 EM systems, primarily with the Lorentz regauging of the Maxwell-Heaviside equations. Hence, Western science has not experimentally studied the type of system that produces the effect in the first place.

On the other hand, it is possible to directly investigate the antigravity-producing phenomenology on the laboratory bench, by utilizing overunity EM systems with very high COP (e.g., COP = 10^6 or more). The Sweet experiments {231} did in fact produce such phenomenology on the laboratory bench, but these experiments were privately performed under proprietary conditions {232}. We discuss the Sweet experiments and device in a later chapter.

In science, such experiments are quite properly deemed interesting but anecdotal until replicated independently. Similar experiments should certainly be repeated by the scientific community, using various interactions (some given in this book) that develop COP>1.0. The problem is nowhere near as difficult as hot fusion, but it has not been tackled and overcome because of (1) the prevailing and erroneous scientific mindset against COP> 1.0 electromagnetic processes, and (2) the present "kill" of the supersystem and its effects in the standard U(1) electrodynamics model.

In Chapter 8 we further discuss the antigravity effect in practical or potentially practical systems where COP » 1.0.

3.11 In Conclusion

In this Chapter, we have stressed what we believe to be a great new principle of giant negentropy, leading to direct and easy extraction of EM energy from the vacuum in copious quantities. That principle is that nature retains *her preferred 4-symmetry* of EM energy flow, while breaking 3-symmetry of EM energy flow and the symmetry of EM time-energy flow on the fourth axis. It is implemented by making a common dipole or charge.

The electrical energy problem is *not* due to any difficulty in inducing giant and indefinitely continuing EM energy flows from the vacuum! The easiest thing in the world is to extract EM energy — any amount, anywhere, anytime — from the seething vacuum, by making a simple dipolarity. The problem is only in then intercepting and collecting some of the energy to dissipate in loads, and doing it *without* using half the collected energy to destroy the dipole producing the energy, faster than the loads are powered. In other parts of this book we have given some of the many mechanisms that can be applied to attack this "power the load without killing the source dipole" problem, and have also included such in papers in the literature {233a-233u}.

We have pointed out the implications of the new principle of negentropy in EM energy flow, and how all our circuits and electrical power systems actually use it but then arc designed so as to kill the negentropic process's potential for self-powering electrical power systems.

Presently we are told by the conventional scientific community that the dream of freely extracting EM energy from the vacuum, and using it to efficiently and easily power our electrical needs cleanly, is either a fool's concept of perpetual motion, or the science of the next century. It is neither; it is good physics, and it is already *present and misused* in all our electrical power systems and circuits — and always has been. Unlimited electrical energy from the vacuum is here and now, if we but overcome the prevailing mindset and grasp it.

We have argued that all electrical loads and circuits are now and always have been powered by just such EM energy extracted directly from the vacuum by the giant negentropy principle, evoked by the source dipole. We have removed the artificial and erroneous notion that batteries and generators provide some of their available 3-space internal energy to the external circuit. Instead, we have emphasized that batteries and generators dissipate their available energy to form and then continually reform their source dipole, and nothing else. Once their source dipolarity is formed, a battery or a generator is nothing but an energy gate, gating and transducing enormous EM energy from the vacuum. We only have to keep inputting energy to keep reforming the dipole that our external circuit is designed to destroy faster than the load is powered.

In dealing with the function of the dipole in extracting the EM energy from the vacuum and pouring it out to power the circuit, we have shown errors in present energy flow theory and how they came to be made. We also indicated the enormous magnitude of the EM energy flow actually **extracted** and present with every conventional circuit, but wasted and **arbitrarily** removed from accountability. Some processes for intercepting, co**llecting,** and using additional amounts of this available Heaviside "dark EM energy" flow component, surrounding every circuit, have been mentioned, and references have been given to other papers more fully discussing such processes. In a previous paper {234} we have proposed that the Heaviside dark energy, accompanying all EM field-charge interactions, is responsible for the excess gravity observed to be holding the spiral arms of those distant spiral galaxies intact — in short, we have proposed an unaccounted Heaviside *dark positive energy* solution to the well-known *dark matter* problem in astrophysics.

The ordinary closed current loop circuit inherently yields a system COP<1.0, because it destroys its source dipoles faster than it powers the load. Indeed, the circuit self-enforces the Lorentz symmetrical regauging condition during discharge of its free excitation (potential) energy.

In addition, we have presented an hypothesis to explain that negative energy (negative mass) created in the Dirac sea vacuum by giant astronomical explosion phenomena produces the excess antigravity in the space surrounding those entities that is accelerating the expansion of the universe. We have also indicated how this hypothesis can be investigated and tested on the bench. We have provided one experiment whose results did support the hypothesis.

The present world energy crisis is real and increasing, while at the same time the availability of oil is beginning to decrease and oil becomes more costly.[90] Unless a substantial fraction of the "electricity from oil" curve is shifted to "electricity from the vacuum" rather quickly, the economic collapse of the Western world, followed by concomitant collapse of other economies, may ensue within a surprisingly few years, and even within the present decade.

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[90] As this was first being written in Dec. 2001, there was a temporary relief in the oil crisis, due to the sudden decrease in travel, air traffic, etc. after the terrorist attack on Washington and New York on September 11, 2001. As the present war on terrorism has continued, the MidEast is now heating up toward another war, and oil prices are again trying to climb. Iraq, Iran, and Libya called for an oil embargo on the United States, for example, which would almost immediately plunge the nation into an oil crisis. Meanwhile, should effective terrorist attacks occur upon the highly vulnerable energy distribution infrastructure of the United States and other allied nations, the oil crisis will again emerge catastrophically and almost immediately thereafter. It is held off for now, only because Russia under Putin is seeking U.S. financial assistance to further develop its rich oilfields. When OPEC votes to curtail production and then curtails it, Russia opens the spigot and keeps the prices down. Putin is seeking to become a trusted U.S. oil partner, in the role long played by Saudi Arabia but now declining due to perceived Saudi payments to terrorist organizations and reluctance to close down terrorist activities in their own country. So in a strange way, a new alliance between the U.S. and Russia has prevented the oil and energy prices from escalating right through the roof.

We believe that a transfer of much of the "electricity from oil" curve to an "electricity from the vacuum" curve can be quickly accomplished, if the government and the scientific community can be induced to move with full priority and vigor in the directions indicated in this book. However, to get that done, it apparently will be done over the writhing bodies of our leading scientific organizations, literally dragging the organizations to face the proven fact of giant negentropy of every charge and dipole in the universe over their strenuous objections.

As a major objective, we fervently hope that undergraduate students, graduate students, post-doctoral scientists, other scientists, engineers, and environmentalists will interest themselves in these new principles and viewpoints. We have called attention to the new electrodynamics pioneered by AIAS, Evans, Sachs, Barrett, Lehnert, and others, and indicated the capability of this emerging electrodynamics to model this new *energy from the vacuum* functioning.

It has been said that no idea is accepted until its time has come. We strongly believe that the time for cheap, clean extraction of electrical energy from the vacuum is an idea whose time has arrived. Hopefully our efforts in this book will at least conceptually show the interested reader the outline and course that energy from the vacuum can and will take in the scientific community and in the world at large.

We accent again that modeling the extraction of EM energy from the vacuum demands the use of higher symmetry electrodynamics, particularly a theoretical model capable of expressing the interactions of the three components of the supersystem. Barrett and Grimes {235} said it beautifully:

> *"In the case of electromagnetism, the theory was first simplified before being frozen. Maxwell expressed electromagnetism in the algebra of quaternions and made the electromagnetic potential the centerpiece of his theory. In 1881 Heaviside replaced the electromagnetic potential field by force fields as the centerpiece of electromagnetic theory. According to him, the electromagnetic potential field was arbitrary and needed to be "assassinated" (sic). A few years later there was a great debate between Heaviside and Tait about the relative merits of vector analysis and quaternions. The result was the realization that there was no need for the greater physical insights provided by quaternions if the theory was purely local, and vector analysis became commonplace.*

> *The vast applications of electromagnetic theory since then were made using vector analysis. Although generations of very effective students were trained using vector analysis, more might be learned physically by returning, if not to quaternions, to other mathematical formulations in certain well-defined circumstances. As examples, since the time when the theoretical design of electromagnetism was frozen, gauge theory has been invented and brought to maturity and topology and geometry have been introduced to field theory. Although most persons view their subject matter through the filter of the mathematical tools in which they are trained, the best mathematical techniques for a specific analysis depend upon the best match between the algebraic logic and the underpinning physical dynamics of a theoretical system. "*

The problems we face today are ever more demanding of the necessary EM change pointed out by Barrett and Grimes, along with many others. Let us hope their words are heeded. Given rapid development of higher group symmetry electrodynamics models, we shall very rapidly see the solutions to many previously intractable human problems — including cheap clean energy from the vacuum, understanding and directly using antigravity as well as gravity, a revolutionary new medical therapy, a new chemistry and biochemistry, and a new appreciation for the electromagnetic interactions of mind and matter.

Let us hope this new scientific revolution comes swiftly.

Chapter 4

Setting the Stage for Understanding Overunity Power Systems

[Dissipative structures] *"This leads precisely to a distinction between 'equilibrium structures' [which may be understood in terms of classical equilibrium thermodynamics] and 'dissipative structures'. The latter are formed and maintained through the exchange of energy and matter in non-equilibrium conditions."* [I. Prigogine] {236} [Internal brackets added for clarity.]

[The energy in space itself] *"What might appear to be empty space is, therefore, a seething ferment of virtual particles. A vacuum is not inert and featureless, but alive with throbbing energy and vitality. A 'real' particle such as an electron must always be viewed against this background of frenetic activity. When an electron moves through space, it is actually swimming in a sea of ghost particles of all varieties — virtual leptons, quarks, and messengers, entangled in a complex melee. The presence of the electron will distort this irreducible vacuum activity, and the distortion in turn reacts back on the electron. Even at rest, an electron is not at rest: it is being continually assaulted by all manner of other particles from the vacuum."* [Paul Davies] {237}

[Modernizing the fluid analogy of EM]. *The intensity of the vacuum virtual particle flux may be treated as the intensity of a potential, thus by analogy corresponding to pressure in a fluid. Polarity (charge) is a process for establishing a change in the intensity of the vacuum potential — and thus a change in the ambient pressure of the vacuum fluid. Difference between vacuum pressures at two separated points creates a force upon any charge placed between those two points. Just as a differential in pressure between points in a fluid induces currents, a differential in vacuum pressure induces energy flow currents in the vacuum fluid, which are called 'fields'. All*

EM circuits, charges, potentials, and forces in electrodynamics involve altering the vacuum to include altering its pressure and thereby producing the forces that the resulting pressure gradients (fields) induce upon charges. All observable EM energy in space is EM energy intercepted and collected on charges, and it comes from the vacuum via these fundamental vacuum-engineering dynamics." [T. E. Bearden, private communication to a colleague, 2001].

[Impact of EM energy from the vacuum.] *"If they [quantum fluctuations of vacuum] can be [tapped], the impact upon our civilization will be incalculable. Oil, coal, nuclear, hydropower, would become obsolete — and so would many of our worries about environmental pollution." "Don't sell your oil shares yet — but don't be surprised if the world again witnesses the four stages of response to any new and revolutionary development: 1. It's crazy! 2. It may be possible — so what? 3. I said it was a good idea all along. 4. I thought of it first."* [Arthur C. Clarke] {238}.

[Broken symmetry of opposite charges.] *"Since nonobservables imply symmetry, any discovery of asymmetry must imply some observable. The experiment of Wu, Ambler, Hayward, Hoppes and Hudson... established the asymmetry between the positive and negative signs of electricity."* [T. D. Lee] {239}.

[On implications of asymmetry of opposite charges of a dipole.] *"In particle physics, the proven asymmetry of opposite charges establishes that the source dipole — with opposite charges on each end—* is *a broken symmetry in the violent virtual photon flux of vacuum. The dipole charges constantly receive and absorb virtual photon energy from the seething vacuum, and re-emit that excitation energy. By the very definition of broken symmetry, some of this absorbed virtual energy must be integrated into observable 3-space EM energy, and emitted by the dipole in observable form, in all directions in 3-space. Hence there is a rigorous basis for the source dipole extracting virtual EM energy from the vacuum, integrating it, and continuously pouring it out in* *observable and usable EM energy form. It has been in particle physics since 1957, being certified by the award of the Nobel Prize to Lee and Yang in that year. "* [T. E. Bearden, private communication to a colleague, 1995.]

[On powering an electromagnetic circuit] *"In the United States there is not now, and there never has been, a single electrical engineering department, professor, or textbook that knows and teaches what directly powers an electromagnetic circuit. Neither is it in any publication of the National Academy of Sciences, National Science Foundation, National Academy of Engineering, Department of Energy, or the great national laboratories. Yet the proof that every circuit is powered by EM energy extracted directly from the vacuum has been in particle physics for 45 years, since the award of the Nobel Prize to Lee and Yang in 1957, following the experimental proof by Wu et al. earlier that same year. "* [T. E. Bearden, private correspondence, 2002].

4.1 Introduction

In this chapter, we present a selection of potential overunity notions, some inventions, and some experiments. Its purpose is to show some of the more relevant work that has been done, and hopefully to stimulate new thinking by the interested reader. Much of the work addressed is by other inventors and scientists, and we give an appropriate commentary from our viewpoint. Not all the concepts presented can be clearly explained, though some can and are. This is not intended to be a "kit of parts" or an "assembly instructions" type of presentation. For that, the interested researcher will have to rely on his or her own ingenuity and lots of bench experiments, because no such "kit of parts with instructions" for COP>1.0 electrical power systems exists at present {240, 241}.

Because of the broken symmetry of its opposite charges, we do know that any dipolarity — such as a permanent magnet, a charged flat-plate capacitor, an electret, or a simple EM scalar potential — continuously pours out EM energy circulation extracted from the vacuum. E.g., see Figure 4-1, which shows a very simple "free energy generator" that will generate a flow of EM energy indefinitely, even by ordinary U(1) electrodynamics theory (by standard Poynting theory). E.g., quoting Buchwald {242}:

> *"[Poynting's result] implies that a charged capacitor in a constant magnetic field which is not parallel to the electric field is the seat of energy flows even though all macroscopic phenomena are static."*

This is easily seen by applying the standard Poynting formula, S = E x H. With the H-field of the magnet at right angles to the E-field of the capacitor or electret, the Poynting flow of energy S is maximized and orthogonal to E and to H.

The problem is not in extracting energy - even enormous energy — from the vacuum The problem is collecting and using the energy to power loads, without destroying the source dipole

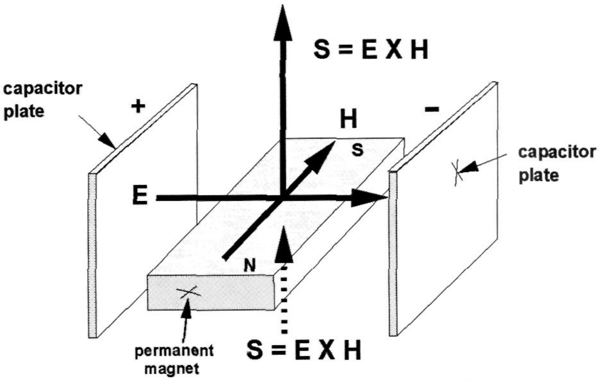

EM energy continually flows from this "static" arrangement, without any further input of energy by the engineer.

Figure 4-1 Poynting generator providing endless EM energy flow from the vacuum.

Buchwald errs, e.g., in assuming the macroscopic phenomena are static. They are not; they are highly dynamic in the same sense that a perfect macroscopic whirlpool in a river, seemingly static, nonetheless involves a continuous flow of water through it and a continuous dynamics. So far as can be observed, it appears there is no such thing as a truly "static" object. As an example, just to "exist" an object must "travel through time", which is itself a special kind of dynamics in the time domain.

A beautiful explanation of what is meant by "static" is given by Van Flandern[91]:

> *"To retain causality, we must distinguish two distinct meanings of the term 'static'. One meaning is unchanging in the sense of no moving parts. The other meaning is sameness from moment to moment by continual replacement of all moving parts. We can visualize this difference by thinking of a waterfall. A frozen waterfall is static in the first sense, and a flowing waterfall is static in the second sense. Both are essentially the same at every moment, yet the latter has moving parts capable of transferring momentum, and is made of entities that propagate."*

Now suppose that the capacitor in Figure 4-1 is rotated until E and H are either parallel or anti-parallel. In that case, the Poynting theory predicts zero EM energy flow. That is an incomplete assessment; it means that there is no overt field energy flow. There is, however, still quite a lot of covert or "infolded" field energy flow ongoing anyway, inside the static fields E and H themselves.[92] To see this, we first turn to the static potentials.

Between the charged plates of the capacitor or electret, there exists an electrostatic scalar potential ϕ. Between the polar ends of the permanent magnet, there exists a magnetostatic scalar potential Φ. We may independently decompose both ϕ and Φ via Whittaker decomposition {243}, applying a necessary correction {244} to Whittaker's interpretation. Then in all space surrounding the two dipoles, we have a hidden harmonic set of bidirectional longitudinal EM wavepair flows of energy comprising each of the static potentials ϕ and Φ filling all space[93] around the assembly in Figure 4-1. Each of those potentials ϕ and Φ is formed of a combination of scalar (time-polarized) and longitudinal photon pairs, as strongly argued by Mandl and Shaw {245} and as previously discussed in an earlier chapter. Further, each of the "static" fields can be decomposed into two scalar potential functions, as shown in 1904 by Whittaker {246}. Then each of the base scalar potentials further decomposes into the set of time-polarized EM wave and longitudinal EM wave pairs. The result is that every "static" field or potential in the universe is actually a set of longitudinal EM wave dynamics.

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[91] Tom Van Flandern, "The speed of gravity — what the experiments say," *Phys. **Lett.** A.*, Vol. 250, Dec. 21, 1998, p. 8-9.

[92] Indeed, by the asymmetry of its opposite charges, each of the dipoles is co**ntinuously** pouring out EM energy extracted from the seething vacuum.

[93] In the conventional view. We corrected that view in {12}, to agree with quantum field theory and to use a *cause and effect* instead of the *two effects* used by Whiltaker.

Further, in each coupled Whittaker wavepair as reinterpreted, there is perfect correlation between the time-domain EM energy wave (scalar or time-polarized EM wave) and the 3-space longitudinal EM wave. So even a "static" EM field, such as from the permanent magnet and from the charged capacitor or electret, does involve an enormous number of hidden internal EM energy flows in longitudinal and scalar EM waveform.[94]

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[94] One of the great omissions of modern Western electrodynamics is the failure to follow up on direct engineering of this "vast, internal, infolded, far more fundamental" scalar and longitudinal electrodynamics hidden inside all present overt EM potentials and transverse EM fields and waves. Russian secret weapon scientists under the former KGB called this internal electrodynamics the "information content of the field" and have strongly weaponized it. A deception plan has been used to successfully convince the West that the Russians are speaking only of conventional spectral analysis. Use of this internal EM structuring, in the form of longitudinal or scalar wave interferometry, formed the first giant superweapons deployed by the former Soviet Union in 1963. To see a proof that ordinary EM fields and waves and potentials can be formed at a distance, *arising out of the local spacetime in the interference zone,* see M. W. Evans et al., {79}. Longitudinal EM waves easily pass through the entire earth and ocean relatively undiminished, since mass is mostly empty space filled with fields, potentials, and waves — i.e., filled with incredible numbers and bundles and dynamics of longitudinal and scalar EM waves. Mass is thus a great superhighway for the passage of longitudinal EM waves, and longitudinal interferometry can be performed right through the earth and ocean, on the other side of the earth from the transmitters. Such interferometers can also easily focus inside the earth or beneath the surface of the ocean. Hence in April 1963 the first giant Soviet LW interferometer deployed was used to kill the U.S.S. Thresher beneath the ocean, off the East Coast of the U.S. Intense production of EM signals — emerging everywhere in the space in that underwater interference zone placed around the submarine — filled the sub and its electronic controls. This jammed the electronic controls of the sub, rendering it helpless. The hapless sub then sank to crush depth and imploded. The signatures are clearly present in the jamming and cessation of multiple electronic systems functioning in the sub's surface companion, the U.S.S. Skylark (which was in a sort of surrounding "splatter" zone and survived because it was not individually targeted). Today at least 10 nations have scalar or longitudinal wave interferometer weapons, to one extent or another, other nations are working on them, and the Yakuza also has them. These were apparently the weapons

Ultimately there is no frozen waterfall, but only the dynamic waterfall always reappearing the same but filled with dynamic movement and energy flow.

These latter EM energy flows *infolded inside* the scalar potentials and the **fields** exist for a single charged capacitor or electret alone, or a single magnet alone. They also exist for any two points in a circuit that have differing electrical or magnetic potentials with respect to the ambient vacuum potential (energy density). This latter fact, of course, was part of the secret of Kron's *open path.* Indeed, every dipolarity in the universe — between any two potentials or any two differing charges anywhere — is an open path and an energy flow source. E.g., quoting Kron {247}:

> *"...the missing concept of "open-paths" (the dual of "closed-paths") was discovered, in which currents could be made to flow in branches that lie between any set of two nodes. (Previously— following Maxwell— engineers tied all of their open-paths to a single datum-point, the 'ground'). That discovery of open-paths established a second rectangular transformation matrix... which created 'lamellar' currents... " "A network with the simultaneous presence of both closed and open paths was the answer to the author's years-long search. "*

As can be seen, Kron had discovered how to create currents — *currents could be made to flow* — in individual branches between any two nodes in **the** circuit, physically connected or not. We point out that deliberate use of Kron's "open path" in a network circuit constitutes a strong violation of **the** standard closed current loop circuit's self-enforcement of the Lorenz/Lorentz symmetrical regauging condition. Hence it is a magnificent method for achieving COP>1.0 circuits. It is the belief of this

confirmed in 1997 by Secretary of Defense Cohen in these words: *"Others are en**gaging** even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves... So* there *are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations...It's real, and that's the reason why we have to intensify our efforts."* [Secretary of Defense William Cohen at an April 1997 DoD counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.]. As the reader can see, the Cold War **was** not so "cold" after all. This mere "tip of the iceberg" should also give the reader a little more insight as to why a war on terrorism is so necessary to all civilized nations.

author that such "open path" functioning in his patented circuits was part of Tesla's secret, though he did not think of it in those terms. However, Tesla's ability to shuttle potential energy independently in his circuits — invisible to a tensor analysis — was rigorously shown by Barrett {124}. Barrett extended the method and obtained two patents in the field of communications {286a, 286b}.

Thus the COP>1.0 problem *is not* in the part or function (the dipole or the charge) that extracts real EM energy flow from the vacuum. That is extraordinarily simple and straightforward. Engineers and scientists have been using it for two centuries without understanding what they were doing. Every charge, dipole, charged capacitor, electret, and permanent magnet already continuously extracts EM energy from the vacuum. The two-fold COP> 1.0 problem is in (i) *separately intercepting and catching (in an external circuit) some of the copious free flowing energy from the "extractor"*, and then (ii) *separately dissipating that collected energy in an external load without killing the "extractor" itself* — or at least only killing it more slowly than the load is powered. The most elegant way to violate the closed current loop circuit is with Kron's open path, typified by Tesla/Barrett potential energy shuttling. Since vector and tensor analysis will not even show it or model it, then a higher group symmetry electrodynamics is imperative in modeling COP>1.0 EM systems and their functions. Much of that work remains to be done.

Our main purpose in this chapter is to point out some selected efforts and approaches by scientists, engineers, and inventors. We will give a brief description and a few details, and leave it to the researcher for further experimentation and reflection. Hopefully, knowing what some others have tried and the results they achieved will prove helpful to the serious researcher.

We also strongly encourage the reader to again read this section after studying Chapter 9. In any COP>1.0 system, the excess energy must come from the "active environment". The active environment of an EM system consists of (i) the active vacuum and its interactions and dynamics, and (ii) the active local spacetime curvatures and their interactions and dynamics. Contrary to naive belief and the received view, overunity electrical power systems — particularly very high COP systems — are neither simple nor easy, but are extraordinarily difficult and highly nonlinear even when their appearance is deceptively simple. Chapter 9 will give a brief expose of some of the difficulties for higher C OP systems. There we will refer again to the intricate circuit analysis work of Gabriel Kron {248}, to Dirac sea electron theory {249} both prior to observation and after observation, and to the need for higher group symmetry O(3) electrodynamics by Evans {250} which is a subset {251} of the electromagnetics used in the unified field theory of Sachs {252}.

Chapter 9 indicates how mathematically complex these systems really are, even when they appear deceptively simple. The phenomenology is highly complex, and it has not yet been scientifically explored because of the erroneous received view that COP>1.0 EM systems are not permitted by Maxwell's theory or the laws of physics. That is a non sequitur. More exactly, *they are not permitted in that equilibrium class of Maxwellian systems described and selected by Lorentz's arbitrary symmetrizing of the Maxwell-Heaviside equations, following their previous symmetrizing by Ludwig Valentin Lorenz* {253}. Prior to applying the Lorenz-Lorentz symmetrical regauging, the Heaviside equations — which in field form are already a truncation to four vector equations of Maxwell's 20 quaternion-like equations — do prescribe both disequilibrium COP>1.0 and equilibrium COP<1.0 Maxwellian systems. The variables are not separated (potential formation) and the equations are difficult to solve, usually requiring numerical methods. With Heaviside's truncation and Lorenz-Lorentz regauging applied, the resulting "special case" equations — now for only that class of COP<1.0 Maxwellian systems that receive and use no net input from their active environment — continue to be used because closed analytical solutions can usually be had and numerical methods can be largely avoided.[95]

So with tongue in cheek, we humorously remark that COP>1.0 electrical power systems have not been developed or known because the early scientists were a bit lazy and wished to avoid ubiquitous use of numerical methods. These days, with computers, proper math programs, and sharp graduate students to easily crunch the numbers, there is no longer any reason for continued arbitrary discard of Maxwellian COP>1.0 systems.

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[95] For some reason, electrodynamicists ignore the fact that the Lorentz regauging does assume two *additional* equal and opposite energy exchanges of the system with its external active environment, but carefully selected so that all the excess energy received in the system is purely in the form of a stress potential. Hence this energy continually does internal work on the system to produce additional stress, but cannot translate electrons through an external load to power it. Also, this regauging condition represents an effective rotation of the frame of the described system out of the laboratory frame. To then argue that this severely altered system (increased

stress, constant additional internal work being done on the system, frame rotation, altered potential energy) is the same system prior to Lorentz regauging, and that such a system is not receiving excess energy from its active vacuum environment, is naive in the extreme and a non scquitur.

For such reasons, no legitimate theory of COP> 1.0 EM power systems has been developed, except for light shed by Prigogine {254a-254f} and others {255a-255c} as to the necessary active environment, disequilibrium nature, and disequilibrium thermodynamics of COP>1.0 systems. Further, the energy flow theory (Poynting's theory) has not been further extended to include the Whittaker decompositions {243, 246} as should long ago have been done. Neither has it been extended to account for the arbitrarily discarded giant Heaviside nondiverged energy flow component.

The researcher should be aware that the energy input to a system is always in the voltage[96] (the *potential;* one input volt of potential will cause one joule of energy to be collected upon each interacting unit point electric charge in the system; one volt of drop in potential results when one joule of collected energy is dissipated per unit point collecting charge in the system.). The fields and their energy are functions of the potentials and their energy, not the other way round. After potentialization of the circuit, the subsequent movement of the potentialized Drude electrons, as current in the system, is connected with (and part of) the *dissipation* from the circuit of previously collected/intercepted energy from the vacuum.

4.2 Demonstration Gedanken Experiment

4.2.1 Work and Energy

Doing work is defined as *changing the form of energy*. No energy is lost per se when work is done; the energy is only changed from one form to another. All the energy since the beginning of the universe is still present,[97] and it is still repeatedly changing its form to do work, over and over. The point is, a single initial joule of energy can be "used" (changed in form) to do more than one joule of work, if multiple changes of form occur serially. *One joule of energy changing its form gives one joule of work, only if a single and total change of form of that joule of energy occurs and then no further change of form occurs.* If the joule changes form once, a joule of work is done and a joule of energy still remains in a second form. If this second form of the joule of energy is not lost, but is retained and then changed in form, a second joule of work is performed and there is still a joule of energy left in different form. And so on. Tricking a system to self-induce multiple iterative form changes of each joule of input energy (or at least of some fraction of each input joule), without losing the energy after each change of form, is one way of providing COP>1.0 in a system.

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[96] The reason is that all 3-space EM energy — in the circuit or elsewhere — must come from the time domain to each 3-space point and return from that point to the time domain. The scalar potential (voltage) actually is an ongoing process whereby, for any interacting charge, energy in the time-domain and energy in 3-space are functionally combined in that 4-circulation at every point dipole in space. In quantum field theory, e.g. as shown by Mandl and Shaw {19}, the *combination* of the time-polarized photon and the longitudinal photon in 3-space is observed as the instantaneous scalar potential, but neither photon is *individually* observable. We comment that an "observable" 3-space potential is the result of an iterative set of *d/dt* differentiations of the ongoing "combination" of scalar (time-polarized) photons having their energy oscillations in the time domain, with longitudinal photons having their energy oscillations in 3-space along their line of motion. Hence each *d/dt* differentiation of the ongoing 4-space combination yields the instantaneous 3-space potential. Cumulating, one has the ordinary 3-space potential or "voltage" of macro electrodynamics.

Remember that COP (coefficient of performance) is best defined as *the usable work output obtained, divided by the EM energy that the operator inputs.* Since "usable work output" is just usable "change of form of the energy", it can be seen that multiple changes of form of every joule of energy input by the operator can lead to COP>1.0.

This illustrates that one must be careful in applying the law of conservation of energy. For a thorough analysis, several features must be identified and accounted: (i) The flow of the energy impinging upon the collection, (ii) the collector itself and the type of collection process utilized, (iii) the linear or nonlinear operation of the collection/collecting process, (iv) the dissipation process used to dissipate the collecting mechanism, (v) what happens to the energy flow that was collected and then its collection "dissipated", (vi) what type of energy flow was collected, and then its collecting "dissipated", (vii) what happens to the collector after the dissipation interaction, (viii) what happens to the energy in different form after each previous change of form, (ix) whether single-pass or multiple-pass of the energy flow is used, (x) whether single collection or multiple collecting is used, and (xi) the effects of any nsymmetrical regauging of a local component or region (e.g., as in simply increasing one of the potentials of the region) that in turn acts as a free energy flow.

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[97] However, "present" means in spacetime, not just in 3-space. The EM energy we think of as being in 3-space is macroscopically in continuous circulation from the tine domain to 3-space and back to the time domain. Microscopically it is in *continual* circulation.

See again Figure 2-4 in Chapter 2. In general, the available energy flow surrounding a circuit will be far greater than the intercepted and collected energy in that circuit, particularly in a "single pass" collection — i.e., where the impinging energy only passes once. In analyzing a system or circuit, one must be very careful to ascertain whether the system utilizes any mechanisms to enhance and increase the energy collection fraction. If it does, then a necessary (but not sufficient) criterion for COP>1.0 has been identified in the system. Letokhov's negative absorption of the medium (i.e., excess energy emission) {256} and Bohren's experiment {257} are examples. Bohren's experiment is easily replicated by any nonlinear optics lab, and outputs 18 times as much energy as the conventionally calculated energy input.[98]

If the impinging Heaviside nondiverged component of the energy flow beyond the collecting/collector is rerouted and passed back to impinge again in the system — even on another collector or other collectors — this must also be taken into account.

Conventionally, the "magnitude" of the fields[99] E and H in the Poynting (collected) energy flow S = E x H are "defined" by the collection from the fields by an assumed unit point static charge at each point in space. In short, the conventional fields have already been "defined" as a standard linear collection upon standard charged *mass, from the field entities as they*

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[98] Energy conservation is not violated! Instead, the conventional calculation assumes a static intercepting unit point charge, which has the minimum reaction cross section in the stream of bidirectional longitudinal EM energy flows comprising the potential, etc. By placing the intercepting charged particles into particle resonance, the particles' reaction cross section is increased because each resonating charge sweeps out a greater geometrical cross sectional area. Hence the charges collect more energy from the energy flow comprising any "field" (actually field intensity) or "potential" (actually potential intensity) than is assumed in the standard input energy calculation. In short, Bohren's experiment takes advantage of that arbitrarily discarded Heaviside energy flow component that remains and is present but not considered in the conventional Poynting calculation and field intensity calculation. The experiment in fact proves the existence of the unaccounted but ubiquitous giant Heaviside nondiverged EM energy flow.

[99] At best, the 3-space point intensity of each 4-space field is so defined, for a forthcoming reaction with unit point static charge, and where the forthcoming reaction does not involve lingering time - charging but only simple time-excitation followed by full decay of the time-excitation via normal photon emission.

exist in 4-space prior to interception and collection, and where the collector itself is absolutely fixed and "static". So nonlinearity in energy flow collection — by additional disruption of the impinging energy flow induced by the dynamics of the collector itself— may easily increase the "reaction cross section" of the collector. The static reaction cross section of a unit point static coulomb and the dynamic reaction of a unit point resonant coulomb may differ appreciably.

Without stating it this clearly, Bohren has shown that the interaction cross section for a single-pass collection by one static particle may be increased by a factor of 18 in a given example, *by inducing resonance and thus increasing the "collection" dynamics of the collecting particle* in the impinging S-flow {257}. The work has been independently substantiated by Paul and Fischer {258}. It also is a direct proof of the existence of Heaviside's neglected nondivergent energy flow component surrounding every field and charge interaction.

So indeed there are COP>1.0 EM processes in the literature. The Heaviside component also pouring from the terminals of every generator and battery, already proves that *every generator and battery ever made already was and is a COP> 1.0 energy transducer, because far more energy pours from the terminals of the generator and battery than the shaft energy input to the generator or the chemical energy dissipated in the battery.*

4.2.2 Extending the Work-Energy Theorem

The standard work-energy theorem in mechanics may be conventionally stated as: *The change in the kinetic energy of a particle is equal to the net work done on the particle by the net force acting upon it.* As in any "model", here there are assumptions that are seldom taken into account. First, the collected/collecting kinetic energy of a particle is due to its increased interaction rate with the vacuum flux, because of its acceleration through that flux.[100] In mechanics the increase in flux interaction (and hence "Newtonian 3rd law resistance" is just treated as a sort of resistance to acceleration, and known as *inertia.*[101] The actual energy of the vacuum flux interaction rate is a function of the square of the particle velocity through that flux — hence the formula $K = 1/2\, mv^2$ for the kinetic energy K of a mass m moving through the flux of space at velocity v. Relativistically, the mass of the particle is moving through the ambient potential flux, or we may view it from the particle's frame of reference where the ambient potential flux is moving through the particle but interacting with it. Only a single pass of the flux impinges upon the "particle collector", so there is only a "single-pass" type of energy collection ongoing.

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[100] As we cover elsewhere in this book, any charge (which, together with its clustering virtual charges of opposite sign is a dipolarity) is a broken symmetry in the fierce flux of the vacuum. This means that every charge in the universe absorbs virtual energy from the vacuum, coherently integrates some of it into observable energy, and pours out that observable energy in all directions. The negative charge does that for positive energy; the positive charge does it for negative energy. The latter can be better interpreted as the return of positive observable energy from space to the positive charge, thence disintegration of that positive energy back to virtual energy, and subsequent re-radiation of that virtual energy back to the vacuum. One **can** in fact model the **Bohren** experiment in terms of the extra vacuum flux

All energy in the vacuum exists in "vacuum flux" or "change in vacuum flux" form. There is no force in the vacuum, although there is polarization that will produce a force upon a charge when one is introduced. The force occurs only after the "change in vacuum flux" that we call a field is interacting with a mass. The force is *already* a change to the mass, a priori, since mass is a part of force by $F = d/dt\,(mv)$. If energy is then added by a AK energy flux (usually mistakenly called a force) performing work upon mass m, this constitutes an additional energy flux or flow impinging on the

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encountered and transduced by the resonant charge, as compared to flux encountered and transduced by the static charge. In the same vacuum flux density, a resonant charged particle will intercept and absorb more virtual photon energy than the same particle in static condition. Hence its broken symmetry will convert more absorbed virtual photon energy into real observable emitted photon energy.

[101] If one wishes to understand that inertial reaction, here is how it works. Consider the virtual charges of the vacuum as an analog to the Drude electron gas in a conductor. At the instant an observable charge starts to move, it is momentarily affecting all the surrounding virtual charges — an enormous number, which are initially repelling and attracting it in all directions intensely. To move, the observable particle must create a change in that entire participating virtual particle "gas". Just as the Drude electron gas, the vacuum "gas" of virtual charges has a certain relaxation time constant. So a finite time delay occurs before the vacuum gas relaxes and movement of the observable charge occurs. As the relaxation continues apace, the particle being acted on by a force accelerates. Even mass with a net charge of zero is filled with charges, and even the neutrons in the atoms are continuously changing into protons and back, etc. So all mass continually exists in the "charge and charge-changing" state. Inertia is in fact due to the relaxation time curve of the vacuum virtual charges "gas". We dealt crudely with this in Bearden, "Quiton/Perceptron Physics," NTIS Report AD-763-210, 1973, p. 11; hopefully a far better treatment will eventually be undertaken by qualified higher group symmetry electrodynamicists.

particle, imposing an additional "energy collecting" and gradient across the mass. Rigorously, the dynamic system comprised of the dK gradient coupled to the particle, and interacting with it, identically is a force.[102] Depending upon the situation, it may accelerate or decelerate the particle, or change its direction, or a combination. This is summarized in the usual work-energy formula

$$W = K_f - K_i = \Delta k \qquad [4\text{-}1]$$

where the work W that was done is given by the change dK in kinetic energy of the particle from its initial kinetic energy K_i to its final kinetic energy K_f.

In applying the conservation of energy law, usually physicists utilize either the work-energy theorem or an approach closely paralleling it. This application is valid in any linear single-pass collection situation. It may not be valid — and usually isn't —for a multi-pass, multicollection system where the same energy, changed in form to accomplish work in a single reaction, is then changed in form iteratively, again and again, in the same system or material. In such case, one joule of input energy can and will accomplish multiple joules of work in and on the system. So for our purposes we must modify the work-energy theorem to give

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[102] We stress again that the hoary old mechanics, some four centuries old, is seriously in error in assuming a separate force acting on a separate mass. That remains an inexplicable non sequitur in modern physics, in its very foundations. We call attention to how classical electrodynamicists' wrestle with the problem. E.g., quoting Jackson, *Classical Electrodynamics,* 2nd edition, Wiley, 1975, p. 28: *"...the thing that eventually gets measured is a force... " "At the moment, the electric field can be defined as the force per unit charge acting at a given point. It is a vector function of position, denoted by E."* Our comment is that the "definition" is in error, including the use of the word "field" for "field intensity", when field and its intensity are two entirely different things. A proper definition should be stated as *"...the observable electric field intensity can be defined as the force per unit static charge and mass, existing at a given point in an interacting gradient of the virtual particle flux of the vacuum, as inferred from the changes induced upon the unit static charge and mass. "* The field intensity is a vector function of position, charged mass, and vacuum virtual particle flux gradient. The standard definition substitutes an effect (of collection) for a cause (prior to collection), and this error is widespread through physics, from mechanics to electrodynamics and on into particle physics. On p. 249, Jackson shows how the electrodynamicists largely capitulate and continue to promulgate the substitution of effect for cause. Quoting: *"Most classical electrodynamicists continue to adhere to the notion that the EM force field exists as such in the vacuum, but do admit that physically measurable quantities such as force somehow involve the product of charge and field."* We comment that actually mass is a component of force, as shown by $F = d/dt(mv)$.

$$W = \lambda(K_f - K_i) = \Delta k \qquad [4\text{-}2]$$

where λ is the averaged energy collection fraction, adjusted for multipass, multicollection and also for asymmetrical self-regauging (self-increase of the potential in, and hence the energy flow from, one or more regions of the active system's source). In formula 4-2, K_f and K_i and Δk still refer to single-pass collection only.

In the new work-energy theorem, $\lambda = 1.0$ for that vast number of conventional cases that have successfully utilized the conventional form of the theorem. These are almost always single-pass, single collection systems. The new COP>1.0 systems have deliberately enhanced energy collection — and hence multiple *energy collection and work amplification*[103] — such as multi-pass collection. For these COP>1.0 systems, the expanded work-energy theorem form applies and in general $\lambda > 1.0$. In an ideal COP>1.0 system, $\lambda >> 1.0$. In some versions of the Patterson Power Cell®, for example, $\lambda = 1200$. In the Sweet device (discussed later), a very high value of lambda resulted, so that $\lambda = 1.5\times 10^6$. We sometimes refer to λ as the *energy amplification factor, energy collection fraction, Poynting amplification, collection amplification,* etc. Bohren and others have referred to it indirectly as the *interaction cross section,* the *resonance absorption cross section,* and the *negative absorption cross section.*

Again, we strongly iterate that *there is no conservation of work law in physics!* When energy is input to a system, acts on it, and is "dissipated" by a change of its form (doing work), the "dissipated" energy is still available after the work (change of the energy's form) is accomplished. However, usually by "dissipated" energy we mean energy that has permanently left the system (or a component in the system) and cannot be recovered and used by the system. The original input energy is not work, because it did not undergo any change of form prior to interaction with the system to change its form. So one does not do "work" as input, which is a non sequitur. Any work accomplished in the input section of a system is due to inefficiencies of the system,[104, 105] usually allowing extra change in form of some of the energy in non-useful processes called "input losses". As we stated, it is quite possible for a single joule of original input energy to perform many joules of work. During the subsequent billions of years following the formation of the observable universe and the energy in it, every joule of the primordial energy is still here. And every joule of it has been steadily performing joule after joule of work since then. Further, it has continually been recycled between 3-space and the time domain and back, and is continually being so recycled today.

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[103] There is no "conservation of work" law in physics or thermodynamics. It is energy that must be conserved. A single change in form of K joules of energy gives an equal number of K joules of work done upon the interacting mass system. However, there remains an equal number of joules available, just in a different form. If that second K joules of energy is then changed in form again and not allowed to escape from the system, an additional K joules of work is performed in the system, without the operator having added any extra input energy. And so on, until the inefficiency of the system and some inevitable losses allow all the "recycling" energy to escape from the system. We strongly believe that ignition, quenching, and re-ignition phenomena such as in gamma ray bursters and x-ray bursters are due to exactly such processes where iterative change of form of each initial joule of energy occurs.

Suppose input energy to a system has been dissipated (changed its form) once, doing work (single change of form of energy) in the system. If the dissipated energy in a different form is then recovered or partially recovered — without escaping the system — to change its form yet again in the system and produce additional useful work, that system is

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[104] Almost always due to a negative feedback mechanism such as Newton's third law, self-regauging symmetry, the closed current loop circuit, inertia as due to a self-regauging 4-symmetry, etc.

[105] E.g., a transformer would be an overunity system, because the current in its primary is separate from the current in its secondary, if these two currents were completely decoupled and independent. In that case, the transformer would simply propagate and "couple" or pass energy emitted from primary to the receiving secondary, without back-coupling. However, the closed current loop in the secondary, routing all spent electrons in the secondary back through the back mmf of the secondary coil, produces a back-field coupling interaction with the primary, and this "back mmf/back emf" coupling requires energy dissipation in the primary section to overcome. In short, the transformer is designed so that the secondary lights the primary to a draw and the designer loses. With some losses and inefficiencies in the device, that makes the transformer a COP<1.0 device (unless free external energy is received in the input). The interested reader might extract several hints and suggestions in this book, passim, of things that overunity researchers have tried in their search to break up the back-coupling of a transformer. The simplest way, of course, would be to place a true negative resistor shunt across the secondary, so that part of the secondary current does not return back through the primary.

considered to be an open system far from single-dissipation equilibrium with its external environment.[106] In that case, instead of the first dissipation simply "returning" the energy to the external environment, the energy is recovered by another change in form (which may simply be a change in direction in the internal environment). The thermodynamics of an open system far from equilibrium with its active environment applies, whether that "environment" is internal or external to the system. It is "external" to the subcomponent of the system forcing the "local change of form" of the energy.

4.2.3 Gedanken Experiment: Multicollection by Regenerative Feedback

After a COP>1.0 collecting process with subsequent proper discharge of the energy, more work output as "dissipation of the collected-energy" exists than the energy being input by the operator or experimenter. By regenerative, clamped, carefully controlled positive feedback of a portion of the output *positive* energy[107] to the system input, the system can be converted to a self-powered (self-asymmetrically-regauging) system that powers both itself and its loads. However, see Chapter 9 for special considerations of the Dirac sea hole current and excess negative energy that arises for COP»1.0 EM systems. Positive clamped feedback will fail dramatically for any COP»1.0 EM system, and for many COP>1.0 systems it will also fail unless conversion of negative energy — arriving at the input section — to positive energy is accomplished.

To ease visualization of the energy multicollection process, consider a gedanken experiment iteratively retroreflecting a steady small EM energy input. Particularly see Figure 4-2.

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[106] The vacuum environment is also "internally" penetrating throughout any macroscopic system, to the finest level! So the notion of separated "external" and "internal" environments requires strong qualification in any system engaged in iterative, work-amplifying interaction with its local vacuum.

[107] The output may contain appreciable negative energy as well as positive energy, however. In that case, in the feedback loop the negative energy must be transduced into positive energy by regauging, else it will appear in the input section of the system as an extra system load there in the input itself. It will "eat" incoming electrons from the external power supply, so that the external power supply has to power this "extra load" in the input section as well as powering the normal system load presented. This reduces the system COP to COP<1.0.

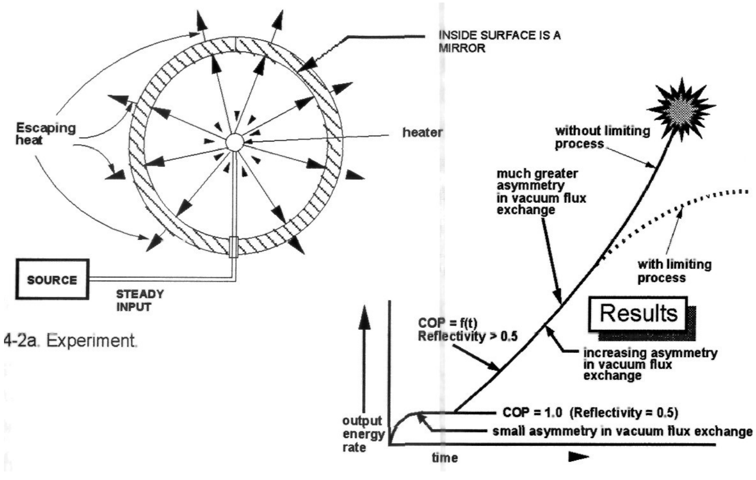
INSIDE SURFACE IS A MIRROR
Escaping heat
heater
SOURCE
STEADY INPUT
without limiting process
much greater asymmetry in vacuum flux exchange
with limiting process
Results
COP = f(t)
Reflectivity > 0.5
increasing asymmetry in vacuum flux exchange
COP = 1.0 (Reflectivity = 0.5)
small asymmetry in vacuum flux exchange
output energy rate
time

4-2a. Experiment.

4-2b Result

Figure 4-2 Heater wire in a hollow sphere with certain retroreflectivity properties.

As shown, a heater-emitter is placed inside a closed hollow sphere, through a tiny hole for the two wires connecting the heater wire into the external power supply (the external power supply is not shown). The heater emitter is 100% efficient; any joule of energy absorbed by it is re-radiated by it. One joule of energy (one watt of steady "input power" — conventional electrical engineering terminology where rate of work and rate of energy flow are confused!) is furnished from the power supply to the heater element inside the sphere. The inside of the sphere is coated with a substance that acts as a phase conjugate mirror (PCM) reflector with, say, 0.5 reflection coefficient. In other words, when scattered photons are emitted from the wire in all directions, they strike the inner surface of the sphere. Half are retroreflected precisely back to the spot on the resistor from whence they came, where they are absorbed and "re-collected" to further heat the resistor, causing emission of additional photons from it. The other half of the absorbed photons on the inner surface of the sphere diffuse through the cylinder walls as heat, and escape as heat radiation from the sphere to the outside world.

If that sphere's operation could be maintained intact and stable, without change of the physical characteristics and mechanism, then the buildup of energy in the heater wire inside the cavity — and the buildup of the energy icing emitted from the outside of the sphere — would be ever increasing. It would increase without bounds as time passed. Wait a short time, and the sphere would be outputting 10 watts of power while one would still be inputting one watt. Later, the sphere would be outputting 1,000 watts of power, while one would still be inputting one watt. And so on. Indeed, the rise in energy density of the output would be asymptotic, and would increase toward infinity. The only limitation as to the energy output for a steady 1 joule per second input, would be the limit at which the mechanism goes unstable and changes occur to dampen and curtail the process.

Before the reader objects on conservation of energy grounds, one should realize that this rise in the energy density inside the sphere is an example of iterative regauging. The principle of *gauge freedom* — one of the axioms of quantum field theory and well established — assures us that *the potential energy of a system can be changed at will, and freely.*[108] What the gauge freedom principle does *not* state is a *mechanism for providing the additional potential energy and a source for it* — nor do the quantum field theorists and electrodynamicists. Without such a source and mechanism specified, the conventional gauge freedom principle assumes total violation of the conservation of energy law.

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[108] Conventional scientists are almost always very careful to regauge symmetrically, so that the two excess force fields that result are equal and opposite, and sum to a net zero resultant field. That "zero-summed system" comprises a stress potential *a priori.* So such symmetrical regauging alters the stress in the system and alters its potential energy, but only in the form of additional stress energy. There is no *net* force and "force field energy" that can be used to dissipate that additional free stress energy in an external load, thereby doing free work. This regauging is a purely arbitrary practice by the electrodynamicists. We are far more interested in "asymmetrical regauging", where only one potential is freely changed or the two are changed unequally, resulting in a *net nonzero force field* that can then be dissipated in an external load to perform free work. Only by asymmetrically regauging an otherwise inert system can usable field energy be added and any work then be done by it anyway. In conventional systems, we do the "asymmetrical regauging" by adding the voltage (potential difference). As current flows with dissipation of energy from the circuit in the loads and losses, the system is able to develop "power" and thus do work in the external load. Unfortunately, the electrodynamicists are still obsessed with symmetry, so they ubiquitously employ in all electrical power systems the closed current loop circuit. This guarantees that the circuit will kill its source dipole (the source of the potential and potential energy generated from the virtual flux of the vacuum by the broken symmetry of the opposite charges of the dipole) faster than it powers its load. That way, lovely symmetry is maintained, beautiful free energy and negentropy are avoided and tossed away, and ugly pollution and destruction of the biosphere continues worldwide to fulfill the ever-increasing and insatiable thirst for electrical power.

In our supersystem view, the gauge freedom mechanism providing the energy is straightforward: the excess energy is freely supplied from disequilibrium in the active vacuum interaction with the system and in the disequilibrium represented by the local curved spacetime. Since a change in system potential energy is also a free change in spacetime curvature, then it follows that simply changing the potential energy of the local vacuum (the vacuum is also an electromagnetic system!) and of the local curvatures of spacetime is also "for free", or it can be. One does not have to perform work oneself upon spacetime to curve it! The mere *presence* of a spatial energy change — including a free potential energy change allowed by gauge freedom — is sufficient to freely curve spacetime also. That is a real energy change, because any curvature of spacetime acts back upon mass. Higher group symmetry electrodynamics does indeed include vacuum energy and energy current {259a-259c}, and it is possible to extract useful EM energy from the vacuum.

But back to our sphere, where the internal potential energy of the sphere is rising asymptotically without bound.

In the real world, of course, the reflection coefficients and the materials characteristics will change as the energy density changes, the sphere will heat, etc., and these changes will start damping the perfection of the retroreflection process to limit it to some finite plateau value which may be a COP>1.0 or COP»1.0 condition. Or, the materials will melt or soften so that the sphere ruptures and explodes, sharply quenching the process entirely and emitting a violent burst of energy to signal the disruption of the localization of the process.

Nonetheless, a successful real bench experiment similar to this should be possible with some tinkering, and it should readily yield COP>1.0, after one waits for build-up and stabilization at some level. We would hope that a sharp young graduate student may eventually prepare a doctoral thesis on this experiment or a variant. The principle is demonstrable.

Similar buildups by regenerative feedback and multiple collections by the collectors do appear to occur in nature, up to and including such phenomena as gamma ray bursts, x-ray bursts, etc. These occur in some systems such as exploding gases (and in some cases, even in the upper atmosphere of the Earth). In such a system, the "physical particles in suspension in space" do move and continually disrupt the geometry for the increasing buildup, resulting in decay of the process after a time delay.

However, there is a finite time during which the movement of the particles is still insufficient to appreciably break the geometry and cause quenching.[109] During this "nearly linear stage", the build-up applies and the energy density very rapidly increases. Build-up occurs and continues while the relaxation time of the initial countering symmetry-restoring mechanism for the old or former state or condition (the initial reaction) is occurring. A well-known conventional example is the Lenz law reaction. Then as the geometry changes significantly, a rapid damping of the energy density increase occurs, quenching the asymptotic rise and "discharging" or "decaying" back to a less-than maximum condition. However, the decay position or state (in the quenched condition) will be different from the initial condition before asymptotic rise (regauging) set in. The system usually will have itself absorbed and collected additional potential energy, and so it will be "hotter" or more energetic. This is often called the "afterglow". In the simple case, parts of the system will be in greater motion (more energetic).

An intermediate plateau can appear as quenching occurs and it can stabilize. However, if no stable plateau is reached during the damping, then further rapid quenching and a rapid reduction of the increased energy density occurs as the geometry changes become decisive and break the asymmetric self-regauging. Thus the "damping" of the process may yield a plateau of steady COP»1.0 operation, or it may simply go immediately into full catastrophic quenching and decline back to some lesser level of COP>1.0 operation, but still more energetic than the beginning condition. The latter case produces a sort of "afterglow" - - observed in the gamma ray bursters, e.g. — of increased energy density from the beginning of the quenched phenomenon. Indeed, in that new system of more energetic gases or particles, once the new state is stable, continuing regenerative feedback versus the new geometry can then reinitiate or "re-ignite" another "burster" followed by subsequent quenching. And so on.

We submit that the gamma ray bursters fit this schema and are consistent with it. So do the phenomena observed in intensely scattering photoactive media on the nonlinear optical laboratory bench. We hypothesize that the gamma ray burster and similar violent burst emission phenomena are generated by this mechanism or a similar version of it.

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[109] Regardless of what we call it or what it has been conventionally named, any impulsive, explosive process involves at least momentary broken symmetry, resulting in instant and countering broken symmetry. Then a relaxation time passes, and the countering broken symmetry is dissipated by change of the system to a new potential energy state, the new dynamics state, etc.

Figure 4-3 diagrammatically shows a proposed range of such "excess energy" emissions due to this regenerative positive feedback and multiple collection mechanism. As can be seen, this may place our view of very powerful astrophysical emission phenomena in a completely different light, arranged energetically by the length of the initial "nearly linear" phase of exponential increase. There is a scale of stability levels up to just before the Big Bang itself {260}. A so-called Big Bang, of course, would result when the "containment" ability of 4-space itself is breached, resulting in a rupture of 4-space and a consequent violent blow-out into n-space (where n>4), with a very rapid "false vacuum" created *outside* the blow-out region and pumping itself up by asymmetrical self-regauging in a "new" 4-space. When a new stability level is reached outside the blowout hole from the spawning 4-space, it represents an outside "new" 4-space and a new, infant 4-spatial expanding 4-universe, freshly born.

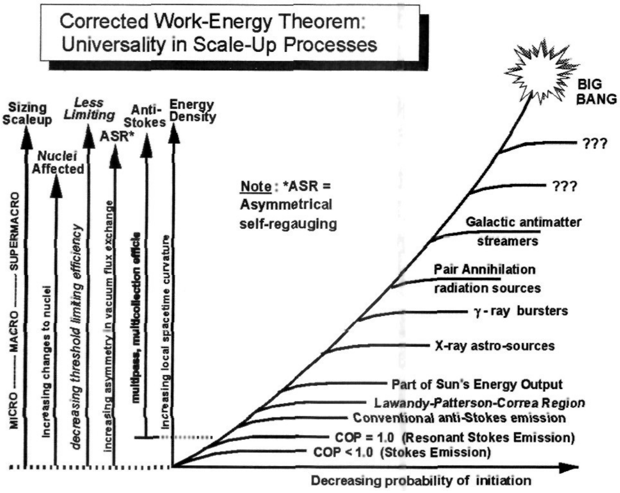
Corrected Work-Energy Theorem:
Universality in Scale-Up Processes
Sizing Scaleup
Less Limiting
Anti-Stokes
Energy Density
ASR*
Nuclei Affected
MICRO —— MACRO —— SUPERMACRO
Increasing changes to nuclei
decreasing threshold limiting efficiency
Increasing asymmetry in vacuum flux exchange
multipass, multicollection efficie
Increasing local spacetime curvature
Note: *ASR = Asymmetrical self-regauging
BIG BANG
???
???
Galactic antimatter streamers
Pair Annihilation radiation sources
γ - ray bursters
X-ray astro-sources
Part of Sun's Energy Output
Lawandy-Patterson-Correa Region
Conventional anti-Stokes emission
COP = 1.0 (Resonant Stokes Emission)
COP < 1.0 (Stokes Emission)
Decreasing probability of initiation

Figure 4-3 C0P>1.0 **stability levels for the asymmetrical self regauging process invoked by multipass and** multicollection **of same energy.**

So from inside the spawning universe, the burster phenomenon would be so great as to "burst" 4-space, producing a sort of "super black hole" as seen by the spawning universe. We hypothesize that the asymmetrical self-regauging mechanism produces a great burst of EM energy in its universe if a stability plateau is reached that is below the threshold of 4-space rupturing. If such a stability plateau is not reached, the asymptotic rise in local spatial energy density increases until the primary 4-space ruptures to produce a "blowout" seen from the old universe as a sort of black hole. There is a sort of "white hole" in the new universe being spawned on the other side of the blowout. This white hole and its associated phenomena produce the birth of another 4-universe outside the original spawning 4-universe. At least we propose that as a hypothesis.

We propose that this could be a legitimate process for the birth of multiple 4-space universes in the infinite-dimensional cosmos.[110] It has an added advantage of accommodating the vexing question of "What existed before the beginning of time (in this universe)??? The answer then would be, *"The existence of time in another universe that birthed this one. "* We emphasize our interpretation of time as just a special form of EM energy, and not at all a "mysterious river down which we float helplessly as if in a drifting boat in the river's current."

4.3 Iterative Retroreflection and Collection in a Circuit

The normal circuit attached to a generator or other external power supply is the "external" portion of the overall closed current loop circuit passing back through, and including, the source dipole in the power supply. In a DC external circuit, we may consider that the energy flow pours forth steadily from the terminals of the generator (from the dipolarity between them) into space surrounding the external circuit. Since the external conductors act as a sort of guide, this *transmitted* external energy flow is generally parallel to the external conductors.

The external circuit further acts as a *receiver.* The surface charges and their fields intercept and interact with some of the transmitted energy flowing parallel to the conductors and outside them. This interaction diverts a component of that passing energy flow into the conductors, powering the Drude electrons. This powers the external circuit. The nondiverted component of the passing energy flow — usually much larger — escapes on out into space beyond the external circuit. According to Heaviside's energy flow theory {261}, this escaping nondiverged energy flow may be interpreted to exist in closed circulations.[111] Laithwaite

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[110] After all, a "dimension" ultimately is just a fundamental variable in a physics model or, in other words, a "degree of freedom" in mathematical modeling. We may construct any number of dimensions we desire, merely by assigning a sufficient number of variables, including both overt variables and hidden variables, etc.

[111] We point out the interesting possibility of re-interpreting this "closed circulation" Heaviside component as the giant negentropic circulation of EM energy from the

{172b} has specifically commented upon the potential importance of this aspect of Heaviside's theory.

As we shall later address, Heaviside worked out but never published a draft theory of gravitational effects from this extra escaping energy flow {262}. Interestingly, since Lorentz's integration of the energy flow vector around a closed surface surrounding any volume element of interest, the discarding of this "excess nondiverged energy flow" has been ignored by electrodynamicists, and it has been ignored by gravitational theorists.

Consider a theoretically "perfect" generator, loss free. Consider the presence of the Heaviside nondiverged component emerging from the generator terminals — and filling all space around the external circuit. That is the part of the energy outside the circuit that is not caught and processed by the circuit, but is just wasted. By definition, in this "perfect" situation the magnitude of the Poynting or "caught" component of energy flow will precisely equal the magnitude of the mechanical energy input flow (rate) to the generator.[112]

But the presence of the additional huge Heaviside component rigorously means that far more energy pours from the terminals of every battery and generator than the amount of mechanical energy the operator inputs as shaft horsepower. This easily demonstrated fact — e.g., proven by the Bohren experiment {24} — continues to meet with a resounding silence from electrodynamicists and physicists, and particularly from those dogmatic skeptics so keen on defending the classical thermodynamics of closed or equilibrium systems as if they also applied to open systems far from equilibrium in their exchange with their active environment. We refer particularly to the dogmatists so supremely confident that COP>1.0 EM systems are prohibited by the laws of thermodynamics. These stalwart fellows would thus exclude every charge (and its associated fields and potentials) in the universe, were they logical and speaking scientifically. So they strangle at the gnat of COP = 4, and swallow COP = oo while proclaiming that COP>1.0 EM systems cannot exist.

The dogmatists have achieved a major nefarious goal, however. They have silenced most inquiry into such matters by electrical engineering

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time-domain to the negative charge, to 3-space, to the positive charge, and back to the time-domain. To our knowledge, that has not been examined.

[112] That is merely a statement of the Lorentz symmetry condition self-enforced by the closed current loop circuit itself.

professors, young graduate students, and young postdoctoral scientists. They have glorified classical equilibrium thermodynamics into a religion rather than the partial and imperfect model it really is. They are directly responsible for the continuing rape and pillaging of the planet's resources, pollution of the biosphere, global warming, and the increasing death of species. They are indirectly responsible for the deaths of more human beings than Hitler, Mao, and Stalin combined. Most of the blame for environmental pollution problems concerned with power and electricity is squarely at their feet. Sadly, the environmentalists seeking to save this planet and biosphere have not yet recognized the true nature of the scientific Taliban that has generated the environmental problem. In tolerating its own scientific "terrorism", the scientific community seriously aborts much of the scientific method.

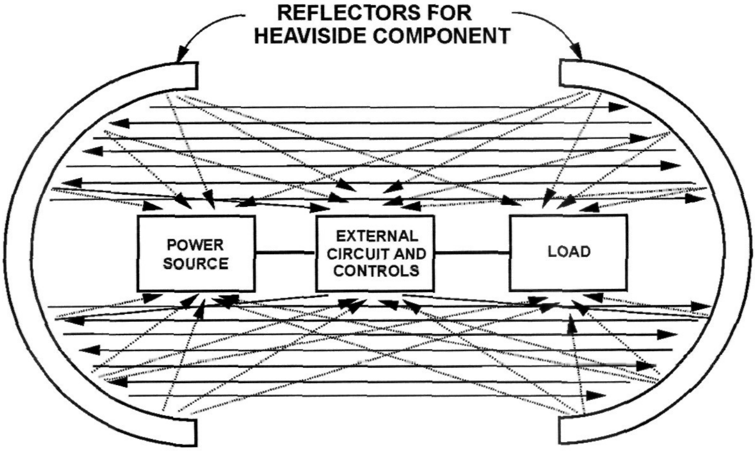

Figure 4-4 Iterative retroreflection of the "passed" **Heaviside component back and forth across a** circuit -- **thematic.**

See Figure 4-4. The neglected large nondiverged energy flow component need not be wasted. As an example, part of it can be captured and used, by applying near-field antenna techniques and such methods as Bohren's resonance increase of the intercepting charge's reaction cross section.[113] It is possible to intercept part of that excess energy that is there and available. E.g., even after it passes on by the immediate circuit, the Heaviside energy flow component can be intercepted beyond the circuit and retroreflected back across the same circuit again. In this way — at least in theory — extra Poynting energy can be collected and recollected by the same external circuit for a single given input energy.

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[113] Or other methods we cannot yet divulge because of patent situation.

In essence, such an "iterative, multi-collecting circuit" is now fed with transmitted energy from multiple (iterative) paths simultaneously. This is *physically doable,*[114] but it is not a simple procedure, and antenna theory and especially near-field antenna theory must be utilized as well as focused retroreflection techniques. To directly model it, higher group symmetry electrodynamics (such as quaternion EM, O(3) EM, etc.) must be used. Precisely such phenomena are met in modern experiments in intensely scattering optical materials {263a-263b, 264a-264b} and in Bohren-type experiments where more energy is collected than the operator has input via standard calculations {257, 258}.

4.4 Tesla's Iterative Retroreflection Work

4.4.1 Tesla's Single Wire Circuit

See Figure 4-5, which diagrammatically shows one of Tesla's developments, which used a retroreflective single wire circuit between two large separated capacitances. This was the basic approach used in his magnifying transmitter and in several other circuits. Here the dipolarity exists between two accumulators, one at each end of a long conductive path with a load in the middle. AC operation is used, by setting up oscillation end-to-end along the "single wire" circuit, from accumulator to accumulator. Even so, no overunity operation will be experienced unless passive retroreflection of the normally wasted Heaviside component of each energy flow "passage" occurs back from each receiving end, so to speak {265}. That is possible if specialized dielectric material and construction is used in the end capacitors.

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[114] E.g., some of Tesla's actual patented circuits do it, but that part of their fu**nctioning** is not described by any vector or tensor analysis. However, a higher **group** symmetry electrodynamics analysis of the circuits will indeed show the effect clearly as a "shuttling" of potential (regauging) around the circuit at will. E.g., see T. W. Barrett, {124, 286a, 286b}.

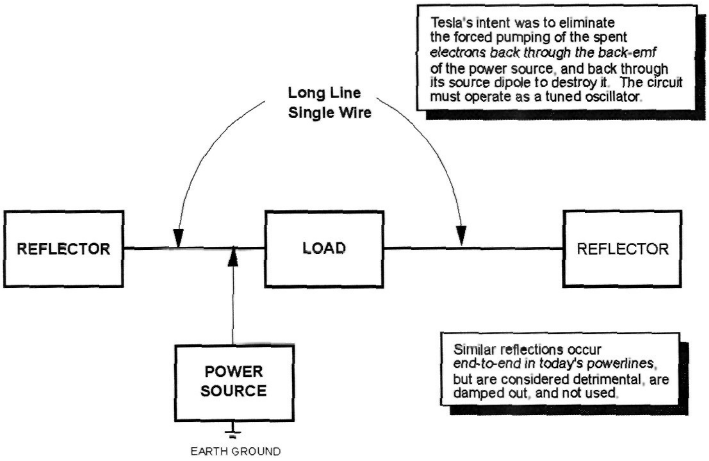
Tesla's intent was to eliminate the forced pumping of the spent electrons back through the back-emf of the power source, and back through its source dipole to destroy it. The circuit must operate as a tuned oscillator.
Long Line Single Wire
REFLECTOR
LOAD
REFLECTOR
POWER SOURCE
EARTH GROUND
Similar reflections occur end-to-end in today's powerlines, but are considered detrimental, are damped out, and not used.

Figure 4 5 Tesla's iteratively retroreflective single wire circuit.

Further, it may usually be necessary to place the individual charges comprising the "current surging to and fro" into particle resonance at either the frequency being transmitted or some subharmonic of it. This schema is doable, but it is difficult and most everything affects it, including even the impurities in the conductors.

4.4.2 Strain to Stress Potential Energy Transduction

See Figure 4-6. This is a diagrammatic representation of a fundamental "strain-to-stress" transduction mechanism we believe was involved in Tesla's "single wire circuit" (i.e., his iterative retroreflecting circuit).

At each end of the circuit, the electrons are "trapped" in the open outside end. Hence when EM energy rushes to the capacitor on one end of the circuit, the forward emf tries to strain the dielectric from the inner plate toward the outer plate. However, the trapped electrons in the outer open wire cannot move, so they produce an equal back-emf and back force trying to strain the dielectric from the outer plate to the inner plate. The result is that the translational field "strain" energy (dipolar charging) is transduced into stress potential (monopolar charging) energy. Electrons try to strain the dielectric from the inner plate toward the outside with a "forward emf so as to charge the capacitor normally, while the trapped external electrons simply push back the other way, exerting a back emf force that is equal and opposite to the straining force from the forward emf and simultaneously tries to "charge" the capacitor in the opposite direction.

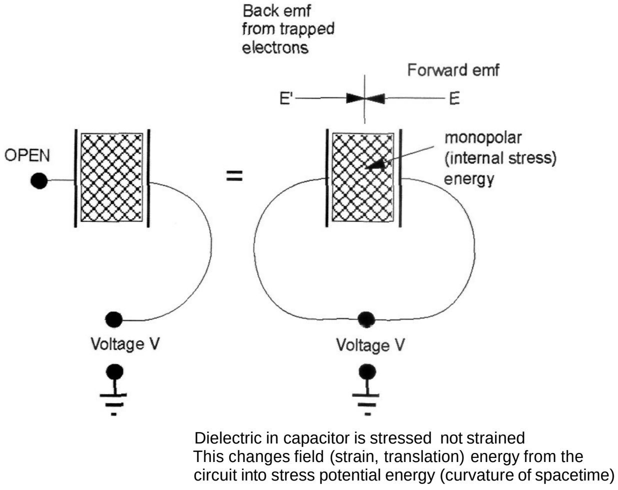
Back emf
from trapped
electrons
Forward emf
E'
E
OPEN
=
monopolar
(internal stress)
energy
Voltage V
Voltage V
Dielectric in capacitor is stressed not strained
This changes field (strain, translation) energy from the
circuit into stress potential energy (curvature of spacetime)

Figure 4-6 Transaction of translational field energy into stress potential energy.

Here is the importance of the "vector zero resultant" stress (monopolar) charging that occurs: The input EM strain field energy familiar in dipolar charging of a capacitor is converted to a dielectric stress (monopolar) potential for monopolar charging. This changes *translational* field energy (external energy) into *stress potential* energy (internal energy), adding an equal amount of back-emf translational field energy in so doing. In short, the charging captures an equal amount of charging energy from its external environment — in this case, from the back emf of the trapped external electrons in the outside open wire. This is one way to capture and use the back emf energy normally reducing the energy available.

We point out that this is charging the capacitor by *Lorentz's symmetrical regauging,* and it represents a rotation of the frame of the capacitor itself out of the laboratory frame. As is well known, the trapped energy of a capacitor in a rotated frame is not the same as the energy of the same capacitor in the nonrotated lab frame.

The single-wire system destroys the symmetry-enforcing function of a closed-current-loop circuit conventionally used. In short, it does not return the "spent electrons" from the ground return line back through the source dipole of the outside power source, so it does not use half the collected energy in the circuit to destroy the source dipole and its extraction of EM energy from the vacuum (to destroy its broken symmetry). Because it retains the broken symmetry, Tesla's single wire system is an open system far from thermodynamic equilibrium with its active vacuum environment. It is thus permitted to exhibit those five magic functions of such open dissipative systems: (1) self-ordering, (2) self oscillation or self-rotation, (3) outputting more energy than the operator inputs, (4) self-powering of itself and its load, and (5) exhibiting negentropy.

4.4.3 Potential Energy Shuttling in a Circuit

The net result is to "shuttle" the (stress) potential energy back and forth in the circuit, between the ends. See Figure 4-7. When this stress potential energy shuttling is done at the natural (or tuned) resonant frequency of that single wire circuit as an oscillator, the monopolar charge transfer is optimized and amplified by the resonance effect, with an increase in the energy being shuttled. It is this type of Tesla single wire circuit that can in theory exhibit COP>1.0.

Tesla's single wire system also forces the change of energy between internal energy and external energy. A deeper analysis will also involve Dirac sea hole current effects as well as lifting of electrons from the Dirac Sea and combination of unobservable Dirac sea holes and electrons without radiation. However, we leave that for the advanced theorists. A taste of it is included in Chapter 9.

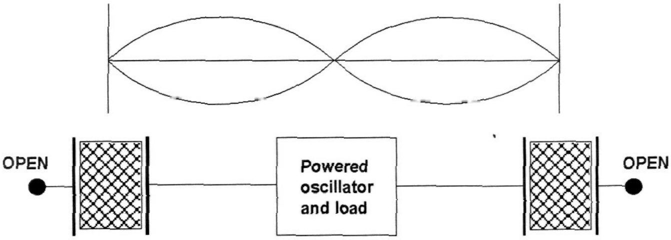

open capacitor
to change field
energy into
stress potential
energy

Note: System is designed with
a certain resonant frequency
At that frequency, the current can
become mostly "squeeze"
and "relax" as a standing wave
emerges and stabilizes

open capacitor
to change field
energy into
stress potential
energy

Whether COP>1 0 or not depends on successful additive collection and use of the Heaviside nondiverged energy flow component due to the multipass and reflection operation

Figure 4-7 Tesla's resonant single wire circuit **operation.**

But is there any evidence for this "shuttling" of the monopolar potential in Tesla's circuits? Yes, there is, and indeed some of Tesla's patented circuits do exhibit such energy shuttling in them, as rigorously shown by Barrett {124, 286a, 286b}.

4.4.4 Other Considerations

For COP»1.0 systems and some COP>1.0 systems, the concepts of Chapter 9 must also be applied, since the system outputs not only positive energy but also negative energy. The negative energy — in the form of Dirac sea hole current — then sweeps back through the system from its output section to its input section. At various places, these "vacuum holes" eat electrons (as on atoms, causing ionization).[115] In short, the Dirac sea holes are converted to more normal lattice holes, and thus can be dealt with in the same fashion as semiconductor designers handle lattice hole problems inside their semiconductor designs. Positron (hole) effects are well known in materials science, and are increasingly being used in actual systems such as the antimatter (positron beam) microscope {266a-266b}.

We accent that a simple LC oscillating circuit does not produce COP>1.0 of itself. If, however, the charges in the currents surging to and fro are in particle resonance at the "feed frequency", then they will "sweep out" a greater geometrical cross sectional area to intercept additional Heaviside energy flow existing outside the normal "static charge" Poynting energy flow. This is similar to the "intercepting resonant particles " process utilized by Bohren {257}, and it allows output of more EM energy than the operator inputs *in the calculated Poynting component* of his own input energy flow. It *does not* output more EM energy than the operator inputs in the sum of his Poynting input component and his Heaviside input component.

The real energy conservation law is that the input energy from all sources and of all types must equal the output energy of all types, where by

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[115] The union of a Dirac hole (4-space negative energy electron before observation) and **a** positive energy electron before observation, can occur without radiation. The two curvatures of spacetime involved are equal and opposite, so they just get **replaced** by a flat spacetime, which involves a filled Dirac sea (all the holes filled with electrons). In short, the energy can go into changing the stationary local double re**curvature** of local spacetime, by a sort of "superposition of two spacetime curvatures", to give a net flat spacetime, rather than dynamically radiating EM energy away at the speed of light. However, if either of the two interacting particles has been observed, this is not the case and standard pair annihilation will be observed. The point is that particles in their unobserved *mt* state rather than their observed *m* state, can interact without observation, similar to the way that wave-to-wave interaction occurs in nonlinear optics.

"output" we mean output as useful energy and output as loss or non-useful energy.

So conservation of energy flow is not violated, because one also inputs an additional *Heaviside nondiverged* component, unknown to Bohren. Circa the 1880s or early 1890s, Lorentz arbitrarily discarded it from accountability. One does not have to "pay" for that *nondiverged* and *unaccounted* input energy flow component. Except in continually applying Lorentz's integration trick to discard it, the nondiverged Heaviside component has been almost totally neglected in the textbooks since Lorentz arbitrarily discarded it back there circa the late 1880s. However, it is roughly dealt with in near field antenna theory, sometimes under the topic of "Poynting energy bunching". In the near field, e.g., there also may be a substantial *longitudinal* E-field component. One region may be oscillating back and forth along the flow direction, while the region in quadrature may be flowing in only one direction.

By causing the intercepting charges themselves to resonate and sweep out a greater reaction cross section in an energy flow, the normal definitions of "field intensity" and "potential intensity" are no longer true, because their reaction intensity to a unit point *static* charge has been used as their stated "magnitude". The conventional definition is only for an indication of the *intensity* of the energy flows comprising the field and potential. With the unit point *resonant* intercepting charge rather than the assumed *static* charge, the reaction cross section for the same charge increases, and so the "apparent magnitude of the (intercepted) field intensity" also increases beyond what is in the textbook. So far as I am aware, there is no previous precise term associated with this phenomenon, except to lump it in the euphemism of "negative absorption of the medium" or "negative resonance absorption of the medium" in certain materials {267}. It is more nearly a Poynting energy amplification process, since the "intercepted" or Poynting component of the energy flow is increased. Thus it can be a mechanism for COP>1.0, if the closed current loop circuit's use of half the collected energy in the circuit to kill the source dipole is also defeated.

Nonetheless, energy bunching or Poynting component amplification by altering the reaction cross section function of the intercepting particle is a legitimate way to provide excess "free" energy input for COP>1.0 EM power systems.

4.5 Perspective on Tesla vs. Marconi

Tesla was neither deluded nor mistaken, though some electrodynamicists have mistakenly considered him in that light. On the other hand, Jackson — one of the leading electrodynamicists of our time — pays Tesla a significant compliment as follows {268}.

> *"In U.S. patent no. 787,412 (April 18, 1905), reprinted in Nikola Tesla, Lectures and Patents and Articles. Nikola Tesla Museum, Beograd, Yugoslavia (1956), this remarkable genius clearly outlines the idea of the earth as a resonating circuit (he did not know of the ionosphere), estimates the lowest resonant frequency as 6 Hz (close to the 6.6 Hz for a perfectly conducting sphere), and describes generation and detection of these low-frequency waves. I thank V. L. Fitch for this fascinating piece of history. "*

We also point out that many present science texts err by continuing to credit Marconi with the *discovery* of radio, although he certainly did much to pioneer it and received a Nobel Prize in 1909. Hertz must be given credit for the first deliberate signal transmission per se, during the period 1886-1888. As his transmitting antenna, Hertz used an end-loaded dipole with a gap, and as his receiver he used a resonant square loop antenna with a gap {269}. Sparks produced at the gap in his transmission antenna resulted in sparks appearing at the gap in his receiving antenna.

Marconi became obsessed with Hertz's results nearly a decade later, and in mid-December 1901 Marconi announced the reception of signals at St. John's, Newfound that were transmitted across the Atlantic from Cornwall, England. He later recorded radio signals transmitted around the Earth, and began regular trans-Atlantic message service in 1903.

Marconi's patent {270}, however, was eventually overturned by U.S. Supreme Court decision {271}, because Tesla's patents (and demonstrations) substantially preceded it. Tesla also demonstrated radio transmission before Marconi, and Marconi actually used a modified Tesla circuit in his famed transmission in 1901. Nonetheless, this is not to detract from Marconi's accomplishments; he definitely put "wireless communications" on the map. It is simply to give *discoverer of radio* credit where credit is due.

Tesla was also closer to the truth of the form of an EM wave in space than are modern electrical engineering and most electrodynamics texts. In the present book we have stated that what exists in 3-space as the so-called "transverse EM wave" are actually longitudinal EM waves and functions of them, with the energy entering each 3-space point from the accompanying time-polarized (conjugate) EM wave at that point (i.e., from the time domain) and emerging in 3-space in the form of a longitudinal EM wave, in 1:1 correspondence.[116] This is followed by a return of the energy from 3-space back to the time domain. This "circulation" from the time domain to 3-space and back to the time domain occurs at every point dipole in 3-space. Only the presence and combination of both the time-polarized photon and the longitudinal photon at each point in an EM wave makes the wave "observable", when we translate into wave phenomena the photon phenomena pointed out by Mandl and Shaw {19}. What spreads as EM energy flow in space (from a source charge) is the local polarization of the vacuum, associated with this giant negentropy circulation from time to the negative charge, to the positive charge, and back to time.

The notion of the transverse EM wave flowing through space is an artifact of the ubiquitous *substitution of the effect for the cause* in Maxwellian electrodynamics. E.g., a completely erroneous "definition" of the causal field (as it exists in space prior to interaction with charged mass) is given as the *effect of its interaction with a ubiquitously assumed unit point charge at every point in space where the field is present.* This in fact substitutes the effect (existing *after* the interaction) for the cause existing *prior to* the interaction. That of course is a gross non sequitur.

We give a concrete example from the first edition of a standard dictionary of physics and mathematics {272}:

> *"**electric field...** 1. one of the fundamental fields in nature, causing a charged body to be attracted to or repelled by other charged bodies; associated with an electromagnetic wave or a changing magnetic field. 2. Specifically, the electric force per unit test charge."*

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[116] Later we shall deal a little further with how EM energy iteratively recurs statically in 3-space and propagates dynamically and continuously in 4-space, in more detail. The solution to the long-vexing particle-wave duality is the process of observation. Before observation, an entity is dynamic and continuous in spacetime, not 3-space. After observation (by emission of a photon), it is a momentary frozen 3-snapshot (particle) at a single instant of time. At the next immediate instant, a photon is absorbed, reconverting the "static snapshot" into a dynamic 4-entity again. Since observation (photon emission) and de-observation (photon absorption) iterates at extremely high rate, the entity and each tiniest part of it oscillate back and forth between being a frozen 3-entity (particle) and a dynamic 4-entity (wave).

In the first definition, the field is given as the "cause" of the interaction that exists between like and unlike charges. In the second definition, the field is given as the effect — of the interaction with a test charge — of *something undefined* as the cause.

An entirely different "definition" is given by Gray and Isaacs {273}:

> *"**electric field** ... The space surrounding an electric charge within which it is capable of exerting a perceptible force on another electric charge."*

Here it is defined as simply the space around an electric charge, and not really the cause or effect of anything, unless that local spacetime has been curved (which it has).

Not to belabor the point, this sort of thing led Feynman to "define" the EM field in this fashion {274}:

> *"...the existence of the positive charge, in some sense, distorts, or creates **a "condition"** in space, so that when we put the negative charge in, it feels a force. This potentiality for producing a force is called an electric field. "*

So Feynman made the electric field a *condition in space* surrounding a charge, where the condition can produce (has a potentiality for producing) a force on another charge. He also was aware that force is an effect of the reaction of the causal field with charged mass, in the following statement {275}:

> *"...in dealing with force the tacit assumption is always made that the force is equal to zero unless some physical body is present... One of the most important characteristics of force is that it has a material origin..."*

In Maxwell's theory, the electron, atom, and nucleus had not yet been discovered, and electricity was considered a thin material fluid, flowing in a wire (hence the name "currents") much like water through a pipe. The surrounding space was considered filled with a thin material fluid called the luminiferous ether. A very rough notion existed that the "shaking" of the ether disturbance coming in to an antenna would disturb or perturb the electric fluid in the wire directly. Hence, if one "measured" a transverse oscillation of the electric fluid in the wire due to this "detection", it conclusively "proved" that the incoming ether-perturbations were also transverse. On that notion — together with Faraday's notion that "field lines" were taut physical strings, so that "field perturbations" were naught but plucked oscillations of these taut strings — the entire notion of the transverse EM force field wave in space was created.

It really is not that way, as is easily shown with modern re-examination of what happens in the receiving wire, considering the Drude electron gas {276} and electron drift velocity. Today we know that the electrons move *longitudinally* down the wire only with a small drift velocity (usually a few inches per hour), while the signal (field) races longitudinally down the wire at essentially light speed or nearly so.

The electrons are longitudinally constrained in the wire because of the vast number of electrons ahead of them that tend to repel their longitudinal movement. The electrons are far less constrained laterally in the wire. However, each electron is also spinning, and its 3-space performance may be compared to a spinning gyro, whose spin axes are now longitudinal restrained. Accordingly, the electrons readily *precess laterally* in the wire[117] when perturbed *longitudinally* by the incoming longitudinal 3-space components of the "wave in vacuum" — by gyroscope precession theory. The electrons at the surface layer of the wire are somewhat less constrained longitudinally, and they "slip" a little down the wire in each oscillation, accounting for the very slow electron longitudinal drift velocity.

Accordingly, one of the most important dynamics of the circuit is the dynamics of the surface charges, as pointed out by electrodynamicists {277}.

If the incoming waves were true lateral waves, there would be no longitudinal force component on the laterally precessing electrons, and coherent current would not flow longitudinally in the wire at all. Instead, one would just get some longitudinal to and fro noise in the coherent lateral motions of the electrons, due to electron collisions.

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[117] It is this lateral precession movement of the electrons that is "detected" in most of our instruments. To the early electrodynamicists prior to the discovery of the electron, this detected lateral motion was considered the "shaking of the material electric fluid" in the detecting wire. It was thought that the incoming "electric fluid" from space also had to be material (in the material ether) and transverse, because otherwise the oscillations from space could not have mechanically transferred their "lateral oscillation" to the electric fluid in the wire. Faraday's "material lines of force" concept and the notion that EM disturbances (waves) were simply the mechanical pluckings of these taut strings which also involved similar "material ether" concepts.

Nonetheless, it seems we are stuck with the ubiquitous transverse EM wave model. For more than 100 years, scientists have universally substituted effect for cause in the case of much of electrodynamics — as in the continuing substitution of what is *diverged from* the field and potential at each point in them, by an assumed static point charge, as being the magnitude of the field or potential itself at that point. At best, what is diverged from the field or potential is an indication of the point intensity of the energy flows comprising the field or potential at each point, and in the case of the field, of the prevailing direction.

So electrodynamics is still riddled with that nearly all-pervasive error, and it seems it will likely never be corrected. The leaders of the scientific community do not seem to wish it done and will not allow it to be funded. In short, the community is so comfortable with that grave error that it will almost defend it to the death. The so-called transverse EM wave in 3-space has come to be accepted as if it were a law of nature.

Occasionally a journal will point out the terrible non sequitur in the prevailing notion of the EM wave in space as a "plane wave of oscillating orthogonal E and H fields along the x- and y- axes moving at light speed in the z- axis direction." Romer, former editor of *American Journal of Physics,* provides a prime example {278}. Romer takes to task:

> *"...that dreadful diagram purporting to show the electric and magnetic fields of a plane wave, as a function of position (and/or time?) that besmirch the pages of almost every introductory book. ...it is a horrible diagram. 'Misleading' would be too kind a word; 'wrong' is more accurate." "...perhaps then, for historical interest, [we should] find out how that diagram came to contaminate our literature in the first place."*

At any rate, once we understand how the real EM wave exists in space, then we can sympathize with Tesla's view of it from the following {279}:

> *"Tesla upholds the startling theory formulated by him long ago, that the radio transmitters as now used, do not emit Hertz waves, as commonly believed, but waves of sound... He says that a Hertz wave can only be possible in a solid ether, but he has demonstrated already in 1897 that the ether is a gas, which can only transmit waves of sound; that is such as are propagated by alternate compressions and rarefactions of the medium in which transverse waves are absolutely impossible."*

In Tesla's own words {280}:

> *"...I showed that the universal medium is a gaseous body in which only longitudinal pulses can be propagated, involving alternating compressions and expansions similar to those produced by sound waves in the air. Thus, a wireless transmitter does not emit Hertz waves which are a myth, but sound waves in the ether, behaving in every respect like those in the air, except that, owing to the great elastic force and extremely small density of the medium, their speed is that of light."*

From quantum field theory, the instantaneous scalar potential in space is actually a coupling of a scalar photon and a longitudinal photon {19}. The only EM component in 3-space is that longitudinal photon.[118] Transforming to wave language, Tesla appears to have been correct in his view of the longitudinal form of the EM wave in 3-space, whereas all the texts are still wrong even today.[119] However, Tesla was also noted for grandiose pronouncements, a trait which certainly did not endear him to the struggling electrodynamicists of the time, even when he was correct and they were wrong. An example is the following {281}:

> *"The Hertz wave theory of wireless transmission may be kept up for a while, but I do not hesitate to say that in a short time it will be recognized as one of the most remarkable and inexplicable aberrations of the scientific mind which has ever been recorded in history."*

Unfortunately, in electrodynamics we are still stuck with that "most remarkable and inexplicable aberration" today, and we will remain stuck with it until the leaders of the scientific community (such as the National Academy of Sciences and National Science Foundation) recognize it and fund a complete overhaul of the foundations of classical electrodynamics, which is so sorely needed. On the other hand, *one should not hold one's breath while waiting for the mountain to come to Muhammad! One might as well ask the stars to fall from the sky as to ask the leaders of the scientific community to correct the serious foundations errors in physics and especially in electrodynamics.*

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[118] Hence it is not surprising that all EM in 3-space decomposes into bundles of longitudinal EM waves and their dynamics, as shown by Whittaker {85, 91b}.

[119] However, Tesla did not appear to realize the involvement of time-energy transduction to longitudinal KM 3-space wave energy and vice versa.

4.6 Conclusion

Hopefully we have set the stage for our next chapter, where we will be advancing mechanisms and approaches that have been tried by a variety of researchers. Several of these researchers have indeed produced COP>1.0 devices and processes. However, at this writing none of the devices produced by these inventors and researchers are in production and on the market. As we mentioned in Chapters 1 and 2, there are very powerful forces that have been applied to prevent such development.

Briefly, such suppression has resulted due to one or more of the following:

(a) Sheer greed by the group that gathers around the inventor/researcher, including multiple competing investors and/or "backers". Often a struggle for control develops, and the project is decimated in the process. In many cases a legal struggle also develops, with the result that the legal status of the invention may be fouled beyond repair.

(b) Naivete on the part of the inventor and his surrounding group. The inventor needs the frequent advice of a patent attorney, a regular corporate attorney, a person familiar with research and development projects and procedures, a person expert in testing (particularly with sophisticated multichannel digital oscilloscopes which gather multiple channels of data simultaneously and integrate under the curve, an accountant, and a person skilled in negotiation with potential investors and backers. Most inventors do not have access to all that, or only have access to it after much of the die has been cast and serious mistakes have been made.

(c) Animosity and fierce attack from the scientific community and self-appointed "defenders of the faith". Few inventors are prepared for the onslaught that awaits them if they succeed in producing a genuine COP>1.0 electrical system. Slander and libel are just part of it. An inventor or researcher caught up in always trying to defend himself against vicious ad hominem attack is an inventor successfully deviated from his work. The family also often suffers.

(d) Just now, after the Enron fiasco much of America is becoming aware that powerful organizations often pull out all the stops in a blind pursuit for money and power. Of course they have done so for a very long time; this is nothing new. The inexperienced inventor or researcher is ill prepared for the fact that portions of government organizations,[120] national labs, universities, etc. may be precisely that way also! U.S. government laboratories also file patents; check it out! Check out Fullerton's defense of his patent rights for his ultrawideband communication system work.

The people in any large organization form a bell-shaped distribution curve. About 9% of that curve represents folks who have — to put it mildly — little ethics when it comes to position, power, and money. Some of these 9% fellows will go to quite some length to twist the patent or part of it or control of it away from an inventor. An inventor who has never heard of "march-in" rights (a neat little "theft" phrase favored by DARPA, for example) is often an easy mark. Government agencies will be on an interesting invention and its hapless naive inventor like vultures on a fat calf. They dangle some money and a contract to "assist the inventor to get his invention developed". There is a little clause in the fine print of the contract where the government reserves "march-in" rights. This is a hidden bombshell that really says the government — *anytime it wishes* — can just unilaterally declare that the funded inventor isn't getting the invention to market fast enough, so a single bureaucrat just *seizes it* — in the name of the government, of course. Anyone who has been in serious aerospace contracting very long is also aware of the deals between a few government fellows who control award of the funds, and their "favored contractor". If enough business is steered to the contractor by the government person, it is implicitly understood that when the government fellow retires, he goes to work for that company with a Vice President position, lucrative salary, and a fat stock option. It's easy to become an instant millionaire or multimillionaire that way. A small percentage of government contracts are actually contaminated in such a hidden fashion. The universities usually are much more open and blatant, and just put in a clause that says, "All patents revert to the university!" Also, the inventor must be aware of the difference between "nondisclosure" and "non-circumvention". Just try getting the latter clause from a university, or either clause from a government agency (yes there are rules for "proprietary information", and they are widely violated). Non-circumvention means the outfit agrees not to change a coil or something, and go and patent your invention. Nondisclosure means they just agree not to talk or write about it openly.

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[120] Interestingly, the government is not allowed to copyright its own publications by federal servants. Neither should the government be allowed to patent its own inventions by federal servants and federal agencies. This has set up direct conflict in the federal funding channels for the taxpayers' funds intended for independent research, providing a wonderful opportunity for hanky panky by that lower 9% of the people comprising any large group. By the bell-shaped distribution curve, those comprising that 9% will rise to the opportunity. They are manipulative, greedy, and some are immoral and self-serving. Partially coupled with a similar low "bad apple percentage" in the contracting game, this enables many travesties in the name of federal research and development with respect to patents and misdirection of funds.

(e) And yes, in addition to these many "petty" little conspiracies, there really is a *great* conspiracy — in fact, there are many of them. Churchill just referred to the entire set of conspiring cartels as the "High Cabal". This is a loose-knit set of extraordinarily wealthy cartels that between them control much of the financial power of the world. You can only find the principals behind a couple of hundred interlocking corporations, if you penetrate deeply enough. Much of their great financial income comes from the control of energy at its various levels, through a net of interlocking corporations. Something like $2 trillion dollars per year is their "take" from energy worldwide. Oil plays a great role in that. These "high cabal" fellows make or break nations financially, as is almost being done to Argentina as this is being written. They also have been stopping COP>1.0 electrical power systems since shortly after the turn of the century, using whatever means are necessary — fair or foul. That is why we still are burning oil, coal, and natural gas, and why our automobiles and trucks run off gasoline and diesel, and not off free electrical energy from the vacuum. The high cabal intends to keep it that way. Some of the major primary means of "stopping" an invention have been as follows:

a. Manipulation and improper use of the law (Gray's production line was shut down by law officers before his engines could roll off there and onto the market).

b. Involving the unsuspecting inventor in drug charges by planting drugs on his property surreptitiously, then secretly notifying the drug enforcement officials who suddenly raid the premises and discover the narcotics, resulting in the inventor going to jail since he has been caught "red-handed".

c. Threatening the inventor's life and the lives of his family, to frighten him away from what he is doing.

d. Arranging a fatal accident for the inventor, such as a fatal auto accident, a fall from a high place, or drowning.

e. Assassination (hit men are fairly simple to hire; a good one is a bit more difficult to hire but is doable. A good hit man might assume a disguise and fake a robbery, shooting and killing the target in the "robbery". In an extreme case, he just fires at a distance with a professional sniper rifle that is silenced. A variation is the use of a "throwaway" assassin, a fellow who has been deeply conditioned by very harsh methods, to deeply involve his autonomic nervous system. He can be spotted by the "glaring eyes" effect of autonomic nervous system involvement. This fellow is only marginally functional in real life, and requires a handler. He also must "fixate" for some minutes (usually from 20 to 30) on the target, by staring at him for a period. Then — say, the next day — while the target is at lunch in a public restaurant, the throwaway walks in, walks straight to the target, and empties a pistol in him at point blank range. He remains there until the police arrive and arrest him. He is immune even to torture; nothing can be gotten out of him, even by electrical shocks on his genitals. There are two levels of throwaways; that is the older and less functional version produced by very harsh means. The more modern version is without the glaring eyes with white showing above the iris; this fellow is more functional, fixates very quickly (couple minutes to five minutes), and can operate without the close immediate presence of the handler.

f. Making the inventor an offer he "cannot refuse", in the old Mafia sense. In the latter, nicely dressed persons come to the inventor's house, meet with him, and offer him a large sum of money to quit what he is doing for the rest of his life. The going sum varies between $5 million and $10 million, usually. The offer is real and it cannot be refused; either the inventor accepts it, or he and all his family are dead when these gentlemen leave the premises. If the inventor refuses anyway, he and his family are killed.

Usually the bodies also just "disappear" and are never found or heard from again.

g. These days, variations are used such as a careful crash of another auto into the back of the inventor's car so he is really shaken up badly but not seriously hurt. He goes to the hospital for checkup, in case of concussion etc. Everything is seemingly okay, but he is kept overnight for observation. That night he is given a hypodermic of air in his veins. Next morning his family receives a call that the inventor has suffered seizures from an apparent concussion after all, and is fighting for his life. If he doesn't die, he becomes a human vegetable. Piece of cake.

h. Then there's the ice dart dipped in curare. The curare paralyzes the muscles of the heart and lungs; the inventor goes down in convulsive floundering, gasping and unable to breathe or to pump blood. He expires very quickly. The curare breaks down in the body, the ice melts, and you have a fellow the medics find died of convulsive heart seizure, etc. Works like a charm. This is an adapted "dirty spooks" trick, adapted from those branches of the intelligence communities of the world that specialize in assassinations.

i. Use of "gaming", which was originally developed to influence or change the behavior of foreign leaders. Imagine writing a scenario, as for a movie. Only you have the deep psychological profile of the targeted individual. You also have the deep psychological profiles of quite a few other individuals who have "knee-jerk" reactions in a certain direction useful to you in your games (in your scenarios). These are called "agents of influence" since, to get them into interacting with the target, only a phone call or other contact need be made and a stimulus given, and they are off and running, self-powered and going after that target with their knee-jerk response. So very sophisticated computers are used, the scenario (intended plot of events to happen) is prepared (the artificial intelligence programs will even give the probabilities of success of all the variants), and a recommended scenario variant is derived and accepted. Then the controller has one or more agents working **for** him that contact the players (the agents of influence). They get their phone calls or stimuli, react in predictable fashion, and come pell-mell at the inventor, interacting all over the board with him. The range of games is enormous, from stock schemes to lawsuits to infiltrating agents of influence into the internal organization of the inventor to money laundering, etc. The controller follows the progress, and only once in awhile makes slight adjustments (may need to trigger other agents of influence, send in one actual agent, etc.). Over the last 20 years, the gaming has become very expert. So many games can be launched against a single inventor that he usually is finished or nullified by one of them, eventually. Having been gamed over 200 times in the last two decades, I plan to write a book one day on the subject of the games and what to watch for.

j. Finally, here is a sad and disconcerting rule, usually true. If you gather six persons together that you have known for years or even all your life, and they are the nucleus of the organization around you, watch what happens when success occurs and you really do pull EM energy from the vacuum and power loads, lights, etc. One-sixth of the population, seeing that, will shortly contract a very strange malady known as "gold fever". It is not just an *obsession;* instead it becomes an all-consuming *possession* almost in the biblical sense. An individual possessed by gold fever would kill his own grandmother to try to gain control of that system. If one or more of these "gold fever" transformations occur, that sets the group into profound conflict and vicious infighting, on every front. You get sabotage of equipment, sabotage of demonstrations, stealing of equipment, legal shenanigans, just name it. This has destroyed many groups. It will destroy many more.

k. A variation is to send in a special agent who penetrates the group and becomes a member. Indeed, the high cabal has certain persons who specialize in just such penetration and are specialists at setting up disruption. They have had plenty of practice, and are very good at their trade. The identities of some of these "special agents" would surprise the casual observer. The so-called "overunity community" is rather strongly penetrated and misdirected by a number of such special agents, in addition to a greater number of agents of influence.

1. Finally, the technical knowledge of most inventors and researchers in this field has been largely limited to ordinary electrical engineering and electronics. This means that the inventor often forms his own lexicon and way of thinking about how he does the "magic" COP>1.0. It may be difficult or impossible to connect the way he thinks back to legitimate physics. Further, most of the COP>1.0 community, the majority of electrical engineers, and nearly half the physicists do not understand the technical difference between the *efficiency* of a power system and its *coefficient of performance.* We have insured that the reader of this book will know the precise difference — it's even in our glossary! Further, the entire group around the inventor, and the inventor himself, may not have a clear understanding of the source of the extra energy, the mechanism by which it is obtained, or even the difference between a system in equilibrium with its active vacuum environment and one in disequilibrium with it. Most engineers and a great number of scientists also are still unaware of the dramatic difference between the thermodynamics of equilibrium systems and the thermodynamics of disequilibrium systems. Many have no notion of what the active vacuum is or does. So the inventor may actually be able to build the device himself, but may later err and actually build it away from COP>1.0 with further development.

m. Another problem can be measurement. Sometimes very simple errors — such as "measuring" highly nonlinear, spiky signals with an RMS meter, or using an inferior oscilloscope, or using inferior probes with good oscilloscopes, tricks a relatively inexperienced inventor himself into believing his unit achieves COP>1.0 when it doesn't. Also, some standard engineers will insist on calorimetry, which is inappropriate for COP>1.0 EM systems since they output a mix of both positive and negative energy. The positive energy will heat the calorimeter fluid and the negative energy will cool it simultaneously, and the "expert measurer" will always measure the difference and thus COP<1.0 with his calorimeter (unless the inventor is a rare one who has also transduced the negative energy fraction of his output into positive energy). Yet the conventional engineer or scientist — who has never seen negative EM energy or a COP>1.0 EM system in his life — will be so confident from his "positive energy only" thinking that he will be completely convinced that a real COP> 1.0 system, measured with a calorimeter to show net positive energy COP<1.0, is *actually* a COP<1.0 system instead of the error in measurement that it is. One of the purposes of this book is to try to explain such things and get a better procedure and protocol made available for the testing.

n. Finally, there are a few actual charlatans who deliberately deceive both the group around them (if it's sufficiently naive) and naive investors and backers. E.g., if one builds a huge starter motor (very high current, very high torque, cannot run long without burning up!) and puts it in an automobile, then fills the back of the automobile full of batteries, that beast will draw 400 amps and leap across the pavement or warehouse floor with an agility one is shocked to see. Then if the inventor is always "having difficulty with his controller unit", and "everything will be fine once the controller problem is licked" or some such, many small and naive investors will leap to invest their life savings eagerly. There are many other scams also, and unfortunately every experimental field, with great financial promise if successful, does attract them. Here the old adage is best: If it is just too good to be true, it probably isn't. One should insist on a technical explanation of the source of the excess energy, the mechanism by which it is taken from the environment, how asymmetrical self-regauging of the circuit occurs, etc. If these questions cannot be answered, the inventor himself does not know what he is doing. At best, he cannot explain it; or he may just be honestly mistaken. In the worst case, the inventor knows it is not genuine, but is deliberately deceiving the investors. So my advice would be to first assess the scientific level of the understanding of the inventor group. Then get an independent test of the device or see one done properly. Then decide whether what you have seen and heard is real or not.

o. Meanwhile, there are from time to time legitimate COP>1.0 systems initially developed. The place where all of them have failed is where the inventor group seeks to obtain the appreciable financing (something like 30 million dollars is required these days) to complete the phenomenology experiments, modeling, scale-up factor determination, and prototyping before a production model can be built. To date, every one of the legitimate COP>1.0 systems has foundered and failed right at that sheer vertical cliff. Our own MEG system is at that cliff at the moment, so that cliff is very near and dear to the hearts of the five of us who have struggled so long and invented the MEG. Time will tell whether we succeed where all the others have failed, or whether we also just get defeated by the cliff. As of this writing, we have not yet obtained the necessary capitalization. But we are giving it our very best try, and we believe we will win it eventually.

Chapter 5

Selected Approaches to Overunity Power Systems

> [On point-contact transistors]. *"First, the theory underlying their function is imperfectly understood even after almost a century..., and second, they involve active metal-semiconductor contacts of a highly specialized nature. ...The manufacturing process is deceptively simple, but since much of it involves the empirical know-how of the fabricator, the true variables are almost impossible to isolate or study. ... although the very nature of these units limits them to small power capabilities, the concept of small-signal behavior, in the sense of the term when applied to junction devices, is meaningless, since there is no region of operation wherein equilibrium or theoretical performance is observed. Point-contact devices may therefore be described as sharply nonlinear under all operating conditions."* [William B. Burford III and H. Grey Verner] {282}.

5.1 Introduction

In this chapter we present a selection of potential overunity notions, inventions, and experiments by various inventors and researchers. Its purpose is to show some of the more relevant work that has been done, and hopefully to stimulate new thinking by the interested reader. It is not intended to be all-inclusive, but merely representative. Most of the work addressed is by other inventors and scientists, and we give an appropriate commentary from our viewpoint as best we understand the invention and the process used. Not all the concepts presented can be clearly explained, though some can and are.

This is not intended to be a "kit of parts" or an assembly instructions type of presentation. For that, the interested researcher will have to rely on his or her own ingenuity and lots of bench experiments, because no such "kit of parts with instructions" for COP>1.0 electrical power systems exists at present {283,284}.

5.2 Tesla's Shuttling of Potential Energy and Barrett's Extension

See Figures 4-4 and 4-5 in Chapter 4. In his patented circuits, Tesla accomplished the novel function of "shuttling" the potential itself (and therefore potential energy) around in the circuit at will. This startling function accomplished by Tesla is impossible to see in a conventional vector or tensor analysis of his patented circuits, but it is clearly evident in a higher symmetry EM analysis of them. So it does not appear in the conventional texts, which use vectors or tensors for their circuit analyses. Barrett, one of the leading higher group symmetry electrodynamicists and also one of the pioneers of ultrawideband radar, utilized quaternion electrodynamic analysis to clearly show this novel effect in Tesla's actual circuits {285}. Thus, Tesla was able to produce and move around asymmetrical self-regauging in his circuits, wherever he wished. That has been totally missed by scientists prior to Barrett's revealing analysis.

Barrett then went on to extend Tesla's basic mechanism and employ it for communication and radar purposes, obtaining two patents {286a-b}.

It would appear that use of such shuttling techniques is probably applicable to reducing the back emf in conventional nonshuttling circuits, leading to new COP>1.0 mechanisms. The definitive answer remains to be determined by some future researcher.

5.3 Moray's Radiant Energy Device

One of the remarkable examples of a successful COP>1.0 system was the radiant energy system of Dr. T. Henry Moray of Salt Lake City, prior to World War II. Figure 5-1- shows Dr. Moray and his final 50 kW unit, powering an assembly of light bulbs {287}. The device weighed 55 pounds, used an antenna connected as a "signal input" from the ether, but needed no input of electrical energy by the operator in order to achieve its steady power output.

As shown in Figure 5-2 and Figure 5-3, the various Moray tubes were complex in structure. In addition to various grids, they usually contained (in quadrature) three or more amorphous semiconductor pellets pressed in large presses and sintered with locked-in stresses. One points out the presence of optical effects including phase conjugation, possible use of the built-in stress as a sort of self-pumping and mild self-amplification, possible iterative feedforward and feedback loops due to iterative phase conjugation, collecting of additional energy from the usually nondiverged

Heaviside component via the iterative reverberation of energy, and non-interfering fields in quadrature.

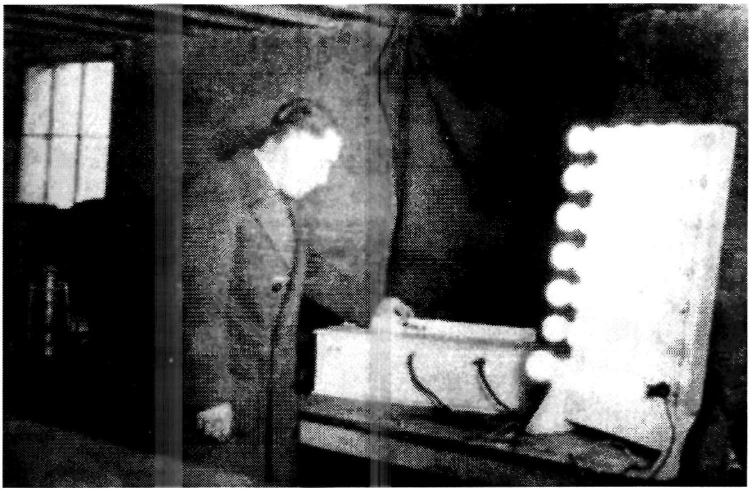

Figure 5-1 T.Henry Moray's 50-kW unit.

The blown quartz tube envelope, in the dark of an enclosure, is open to the passage of infrared (heat) and ultraviolet, which spans a harmonic interval. This allows the passage *of difference* frequencies as sine waves without breakup, even in a nonlinear isotropic environment. Moray stated unequivocally that the tubes would not work unless the envelopes were made of blown quartz. The pellets (shielded from outside light) would nonetheless receive IR input from the ambient temperature, and probably triggered at least weak UV due to the radioactive decay continuously ongoing in the semiconductors. We point out that the UV band is roughly twice the frequency of the IR band, so the "difference frequency" is roughly the IR band itself. In short, it may be that "difference frequency" IR is thus processed in Moray tubes in much more sophisticated fashion than has previously been suspected, including in a self-amplifying (regenerative) manner.

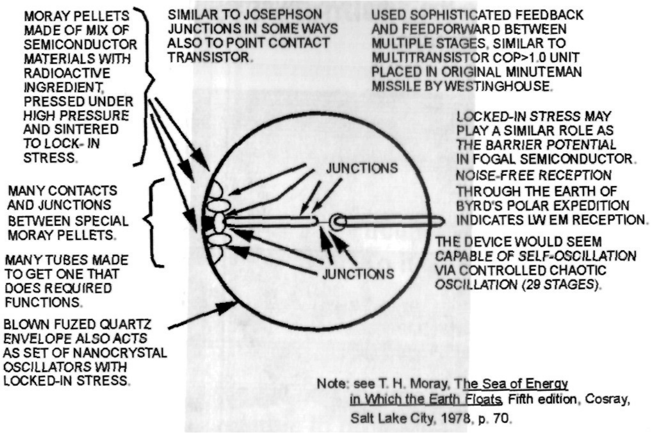
MORAY PELLETS MADE OF MIX OF SEMICONDUCTOR MATERIALS WITH RADIOACTIVE INGREDIENT, PRESSED UNDER HIGH PRESSURE AND SINTERED TO LOCK- IN STRESS.
SIMILAR TO JOSEPHSON JUNCTIONS IN SOME WAYS ALSO TO POINT CONTACT TRANSISTOR.
USED SOPHISTICATED FEEDBACK AND FEEDFORWARD BETWEEN MULTIPLE STAGES, SIMILAR TO MULTITRANSISTOR COP>1.0 UNIT PLACED IN ORIGINAL MINUTEMAN MISSILE BY WESTINGHOUSE.
LOCKED-IN STRESS MAY PLAY A SIMILAR ROLE AS THE BARRIER POTENTIAL IN FOGAL SEMICONDUCTOR.
NOISE-FREE RECEPTION THROUGH THE EARTH OF BYRD'S POLAR EXPEDITION INDICATES LW EM RECEPTION.
JUNCTIONS
MANY CONTACTS AND JUNCTIONS BETWEEN SPECIAL MORAY PELLETS.
MANY TUBES MADE TO GET ONE THAT DOES REQUIRED FUNCTIONS.
JUNCTIONS
THE DEVICE WOULD SEEM CAPABLE OF SELF-OSCILLATION VIA CONTROLLED CHAOTIC OSCILLATION (29 STAGES).
BLOWN FUZED QUARTZ ENVELOPE ALSO ACTS AS SET OF NANOCRYSTAL OSCILLATORS WITH LOCKED-IN STRESS.

Note: see T. H. Moray, The Sea of Energy in Which the Earth Floats, Fifth edition, Cosray, Salt Lake City, 1978, p. 70.

Figure 5-2 Diagram and some novel features of T. Henry Moray's special tube.

The pressed semiconductor pellets were placed in the tube in quadrature, in a sort of "point or junction contact" with each other.[121] Each semiconductor contained a mix of triboluminescent zinc (a semiconductor material), a radioactive material (probably uranium dioxide), and another material of unknown composition, rumored — but not confirmed — to possibly have been diatomaceous earth which also has some unusual properties one may look up. There were some 29 amplifying tube stages in the device. A U.S. patent {288} was eventually granted on an electronic therapeutic unit containing Moray tubes, but the patent on the power system was never granted, although the application was kept current for some years by the Moray family. Eventually the power device patent application files disappeared from the U.S. Patent and Trademark Office.

Although its full technical details were never released, the Moray device is of interest because Moray demonstrated it many times to engineers and scientists, under rigorous measurement conditions, for years. These expert witnesses then signed affidavits to the results achieved by Moray in the tests. Moray also discovered that he could produce an additional 50 kW of power simply by inserting an additional tap just prior to the formal output.

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[121] Indeed, the junctions of such sintered pellets are most interesting. Such a grainy junction can be compared to a host of very close point contact junctions, particularly with finely-ground powdered materials used in the pressing and sintering. In essence, Moray's junctions contained a great many "point contact transistors", and it is known that such transistors can behave (particularly under pressure!) as true negative resistors. This also appears to be one of Moray's secrets.

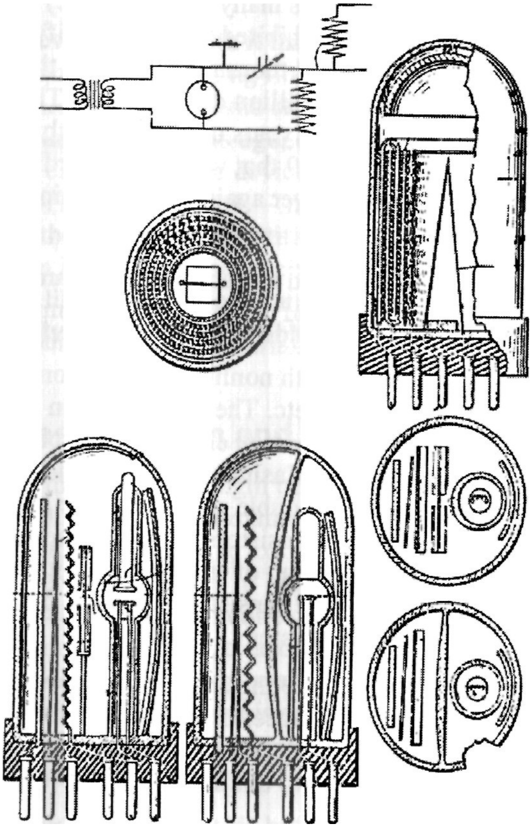

Figure 5-3 A variety of Moray tubes showing their complexity.

Repeated assassination attempts were made against Dr. Moray. While driving his car on the streets of the city, on several occasions he was fired at from an alley or from the sidewalk, but he had bulletproofed the car because of continual threats and ambushes. He was also shot in his own lab in a physical struggle with one would-be assassin, but survived although seriously wounded. A Russian company tried to steal the device, and a Russian agent was planted in Moray's lab, gradually sending essentially all the technical details of the Moray device to Russia. That agent later destroyed the unit right in Moray's lab by suddenly smashing it with a hammer.

Moray's tubes were quite expensive and were painstakingly made by hand. He fabricated a number of tubes (as many as 30 or more) before he obtained one that "worked" and exhibited the self-amplifying effect. Over the years, he spent several hundred thousand dollars on the project, which is the equivalent of some twenty million dollars today. The 29 tubes in his final 50 kW unit were the result of years of labor and fabrication of several hundred rejected tubes to get the 29 that worked. Accordingly, once those 29 were destroyed, Moray was never again able to obtain sufficient financing to rebuild his unit.

However, Moray had demonstrated a special type of transistor years ahead of the first transistor patent. He had demonstrated the importance of multiple junctions in transistor materials. Optical and nuclear functioning of the tubes was also woven in with nonlinear oscillations, multiple feedforward and feedback loops, etc. The sophistication of the tubes and feeds alone almost certainly guaranteed chaotic self-oscillation. We suspect but cannot prove that the Casimir effect may also be involved in some of his conducting metallic double surfaces.[122] He had demonstrated a remarkable "tube-with-internal-transistors" that produced energy output self-gain, without any operator input of energy. In addition, he had successfully used his special tube/transistor hybrids to produce a very successful COP>1.0 EM power system.

After Moray's death, his two sons John and Richard continued to try to rebuild the unit, but were never successful due to lack of sufficient funding and lack of a proper scientific team. They do know how to build the tubes, however, and they do know how to build the unit.

It appears that no electrodynamicist or physicist skilled in higher group symmetry electrodynamics ever examined the Moray device or worked with Moray. No particle physicist or electrodynamicist skilled in non-Abelian electrodynamics ever worked with the device. Since broken symmetry was not discovered and proven until 1957, no technical person who worked closely with the unit was ever aware of the various broken symmetries by which some of the virtual energy of the vacuum can be and is transformed into observable EM energy.

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[122] The "grain" of the stressed semiconducting pellets may be important with respect to the Casimir effect versus the frequency. In short, Moray's contact surfaces between his semiconductors were "grainy" and these grains would have constituted Casimir surfaces. For the importance of the shape of the double surfaces, see M. Chaichian et al., "Quantum theories on noncommutative spaces with nontrivial topology: Aharonov-Bohm and Casimir effects," *Nucl Phys B,* Vol. 611, 2001, p. 383-402.

Certainly no one ever worked with it that understood the peculiar action of the difference frequency in traveling linearly through an isotropic nonlinear medium. John Moray, who stalwartly carried on the Moray lab in Salt Lake City until a few years ago, does know how to build the tubes, and he knows the circuitry for the device. That he does not understand the "deep theory" is of no consequence — no one else does either. In the opinion of this author, a funded scientific team — carefully chosen and working with John Moray — could probably rebuild the Moray device. We would very much like to see a Moray unit in production and contributing to permanently solving the energy problems of the world. Sadly, that does not seem likely.

5.4 Anti-Stokes Emission and Similar Processes

Stokes' law states that the wavelength of the fluorescent light emitted by a phosphor or other luminescent substance is always greater than the wavelength of the radiation used to excite the fluorescence {289}. This condition was observed by Stokes in 1852 {290}. From an energy viewpoint, the collecting medium collects and dissipates some of the input energy in the medium itself (e.g., to accelerate moving molecules) and then emits the remainder of it. The "system" consisting of the medium, the experimenter's input, and the output is such that it usefully outputs as luminescence less energy than the experimenter inputs. Hence it exhibits a COP<1.0, by absorbing excess energy in its "environmental surroundings".

Usually such a "law" generally holds but is sometimes violated in at least a lew cases. Stokes' law is no exception. It applies for most cases of fluorescence and luminescence, but it does not hold for a few of them. In a few cases, the emitted wavelength is precisely the same as the input wavelength. This means that the collector/absorber re-emits all the collected input energy as fluorescence or luminescence. Here the COP = 1.0. This condition is known as the *resonance condition* and the emission is called *resonance emission.*

In other well-known cases, Stokes' law is violated and the energy emitted is greater than the energy absorbed. In other words, the system exhibits a **COP>** 1.0 *with respect to energy emitted versus energy input by the experimenter.* This is known as anti-Stokes emission. It has been well known for six decades that anti-Stokes emmision processes do indeed output more energy than one has to input oneself {291}. This excess energy emission is usually euphemistically attributed to "additions from the internal energy of the molecule" and referred to as "negative resonance absorption by the medium" or just as "negative absorption by the medium".

Unless the excess energy taken from the physical medium of the system is replaced from outside the physical system, the anti-Stokes emission process produces cooling in the physical system and is self-quenching once the medium loses all the energy it can afford. For the overunity researcher, a huge hint is to search the literature for anti-Stokes type emission phenomena that do not result in media cooling. The Letokhov phenomena {292} are in fact such phenomena where the excess emitted energy is received from outside the physical system medium, and therefore from the surrounding active vacuum and/or the surrounding local curvature of spacetime.

Other than for a very few physicists — e.g., Bohren {24}, Letokhov {157}, H. Paul and R. Fischer {25} — there appears to have been little *effective* discussion of where the excess energy "extracted from the molecule" really came from initially, and how it is replenished to the molecule (if at all), and particularly *whether or not it has to be replenished to the molecule by the operator.* There has been no discussion of the local potentials as dipole asymmetries in the virtual energy exchange with the vacuum, although there has been inadequate discussion of the involvement of the Poynting energy flow (e.g., by Bohren, Paul, and Fischer). There has been no discussion of the possible involvement of the Heaviside nondiverged component of the energy flow, which is additional to the Poynting component but unaccounted by today's electrodynamicists. To my knowledge, the broken symmetry of every dipolarity has not been discussed with respect to such experiments.

The reader can see the point. If a mechanism exists or can be evoked to freely resupply the lost energy to the molecule from the other two components of the supersystem, then the resulting *self-replenishing* anti-Stokes emission phenomenon can be utilized as a legitimate and continuing COP>1.0 process. It remains to be seen whether this can be worked out. If we wish, the giant negentropy mechanism of the source dipole and source charge {308} may be considered universally proven cases of self-replenishing anti-Stokes emmission, already exhibited by every charge and dipole in the universe.

At least one audacious scientist — Letokhov — has suggested that similar processes in certain systems can perhaps comprise true Maxwell's demons, yielding excess energy output and perhaps eventually a COP> 1.0 operation {293}. Russell has suggested that a similar COP>1.0 process is involved in the fiber fuse phenomenon {299}.

Over the last few decades there has been slow but important work in an optical area of possible anti-Stokes emission phenomena {294a-c}. A variety of strongly scattering, optically active media have been shown to produce substantially more energy output than the experimenter inputs to stimulate the output. However, most are being done in laser-like pumping situations and so the pump energy has to be furnished by the operator. This means that the "replenishment" energy to the medium is furnished by the operator, resulting in overall COP<1.0 performance. However, in self-oscillation conditions, the medium can be self-pumped (self-replenished, taking its replenishment energy from the active vacuum exchange when viewed in the supersystem), and in such conditions COP>1.0 performance is possible, at least in theory. Presently we know of no one who has achieved it — except in the destructive fiber fuse effect — but the work seems to be progressing steadily toward that eventual outcome.

5.5 Gain in Intensely Scattering Optically Active Media

This modern work — which may be regarded in one sense as extending the anti-Stokes emission effect — is largely being pursued in intensely scattering optically active media. A very nice example is given by Lawandy's experiment {295a-d}, shown in Figure 5-4. Figure 5-4a shows a comparison experiment in water without an intensely scattering optically active medium but with a fluorescent dye to show the emission interaction. Figure 5-4b shows the same experiment with titanium dioxide particles added to the fluid. The TiO_2 particles are sized so that their optical resonance is within the laser's frequency domain.[123]

First, as shown in Figure 5-4a, a small, weak laser beam is aimed into the solution, and a small "warm little glow" of fluorescence results just around **that** region where the laser beam interacts with the solution. Scattering in **the** medium is rather normal, and provides nothing of any great interest to the overunity researcher.

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[123] In passing, we point out the involvement of the Bohren effect due to particle resonance. This collects additional energy from the usually nondiverged large **Heaviside** energy flow component.

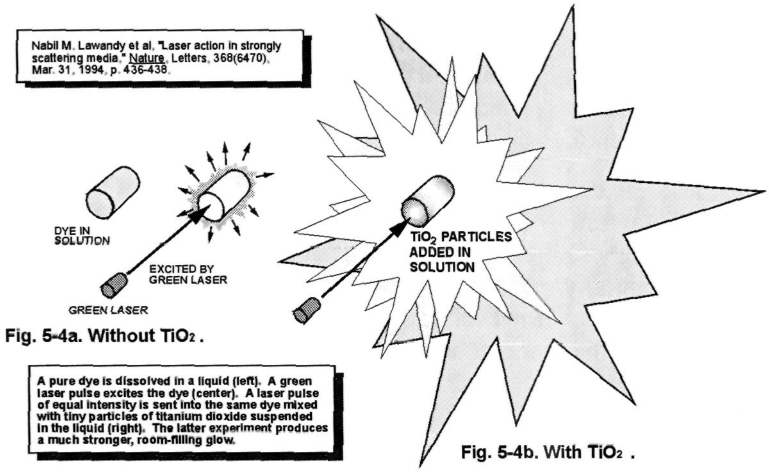
Nabil M. Lawandy et al. "Laser action in strongly scattering media." Nature, Letters, 368(6470), Mar. 31, 1994, p. 436-438.

Fig. 5-4a. Without TiO_2.

A pure dye is dissolved in a liquid (left). A green laser pulse excites the dye (center). A laser pulse of equal intensity is sent into the same dye mixed with tiny particles of titanium dioxide suspended in the liquid (right). The latter experiment produces a much stronger, room-filling glow.

Fig. 5-4b. With TiO_2.

Figure 5-4 The Lawandy experiment

Then the titanium dioxide particles are added, and the same weak illuminating laser beam is directed into the colloidal solution. Figure 5-4b shows the new and spectacular results.[124] Immediately a very bright, room-filling emission of scattered coherent light fills the entire room. The intense optical scattering includes extensive retroreflections for some "ping pong" between individual particles, so that the optical gain is enormous. A highly enhanced energy emission is now evoked, for the same energy input by the operator as was used in the first experiment without the TiO_2 particles. Lawandy's experiment is inexpensive and can be repeated in any university nonlinear optics laboratory and by many individual experimenters. It gives results every time, without fail.

Oddly, no one seems to clearly state that, for a single pulse of input laser energy to the suspension of TiO_2 particles, precisely how much energy was input and how much energy was then emitted by the medium. Instead, "gain" is mentioned, but never the COP = (energy output by medium emission) / (energy input by operator). One suspects that journal referees would probably not allow such a clear and unequivocal statement of overunity, but would apply quibbling and spin control to prevent stating that more energy is output by the medium than is input to it by the operator.

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[124] This is a very easy and very convincing argument for the presence of the long-ignored Heaviside component of energy flow arbitrarily discarded by Lorentz more than a century ago, and still discarded by modern electrodynamicists.

It follows that, if sufficient "ping pong" iterative retroreflection and multiple collection occurs in the medium, the COP>1.0 because more work is done on exciting the medium than the energy input to it by usual (Poynting) calculations. No one accounts the energy unwittingly input to it by the ignored Heaviside component accompanying the Poynting component. Usually the output/input is just referred to as "optical gain". We stress, however, that we are considering only the actual laser beam energy being furnished into the colloidal solution as input, and we are not calculating the efficiency of the laser, its pumping, etc. Anyway, for this stimulated emission process, it is possible that the COP>1.0, and one can see the parallel to anti-Stokes emission. In short, we are considering the TiO_2 solution itself as exhibiting a true negative resistor action.

The field of high gain stimulated optical emission is advancing rapidly {296}, although many experiments still use external pumping furnished by the operator. If the operator has to pay for the replenishment (pumping) energy as well as the input energy, then the COP<1.0 overall. But the experiments are tending toward sustained self-oscillation and self-pumping conditions. If such conditions are obtained in sufficient magnitude, the process will then become a legitimate COP>1.0 operation overall. In that case, it will be usable as a basis from which to develop self-powering COP>1.0 electrical power systems, particularly for infrared "heating" systems etc.

The more recent experiments have shown positive feedback loops both in the time-forward and time-reversed paths; trapping of light flow energy (both time-forward and time-reversed) in large random walks of more than 1,000 individual interactions; weak Anderson-type localization; and constructive interference of forward time and reversed time light paths. since such experiments can be performed in the infrared, they point toward a potential *"vacuum-energy-powered overunity heater"* as a **feasible** achievement in the future. In our opinion, there should be a determined and major Department of Energy program oriented to develop exactly that kind of system.

Such a heater can become self-powering by the presence of greater governed positive feedback during self-oscillation conditions, which will allow sufficient excess collection due to *multipass multicollection* from the usually wasted giant Heaviside energy flow component. This process —

with the self-excitation occurring spontaneously as a "kick-in" positive feedback process in an exploding gas — probably accounts for the phenomena observed in the gamma ray burster and other such violent "burster" cosmic phenomena. Re-ignition, afterglow, and similar effects are observed in gamma ray bursters. They are also observed with *remarkable* similarity in the latest experiments in intensely scattering optically active materials the laboratory. Similar phenomena occur in x-ray bursters as well, and perhaps even in the recently observed and confirmed gamma ray emissions from intense storm clouds.

Finally, we point out that many magnetic materials are also photorefractive, and they readily produce nonlinear optical effects at various frequencies. Some barium compounds are typical examples. As an example, multivalued phase conjugate reflection can occur {297}. Such effects did occur in the Sweet vacuum triode amplifier, to be discussed shortly. It may be that Sweet's conditioning of his magnets conditioned their barium nuclei into self-oscillation, self-pumping, and thereby into *self-replenishing* stimulated optical-type emission at ELF frequencies.

5.6 The Fiber Fuse

See Figure 5-5. Although presently a one-shot destructive process, another multicollection phenomenon exhibiting a novel COP>1.0 process is the *fiber fuse* {298a-e}. This is a well-known but unusual effect in optical fibers and in fiber optic cables.

See Figure 5-5a. Once initiated by simply heating the cable (as with a butane cigarette lighter), the fiber fuse ignites and is self-sustaining. In those susceptible systems utilizing power on the order of one watt or so, the ignited fiber fuse propagates down the cable slowly, at about a meter per second nominally. It is evidenced by a bright white light propagating down the fiber, resembling the burning of a fuse for explosives — which led to the name "fiber fuse".

In fiber optic cables, it occurs only in those that contain germanium in their cores, and not in those containing just silicon in their cores. It moves down the fiber or cable at approximately one meter per second, and it is unlimited in the length of cable that it will continue along and march to the end. In the core, the marching fuse is actually "hopping", so to speak, and it melts a little "hole" about every centimeter or so, blowing out the material from the hole as it occurs. This "steadily and slowly marching" series of core melts results in the catastrophic destruction of the optical fiber core of the cable and thus destroys the functioning of the cable.

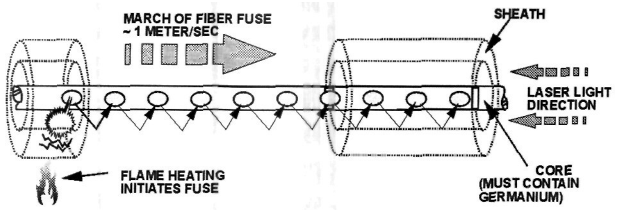

Figure 5-5 A. Fiber fuse destroys core of fiber optics cable of indefinite length, pitting core with holes.

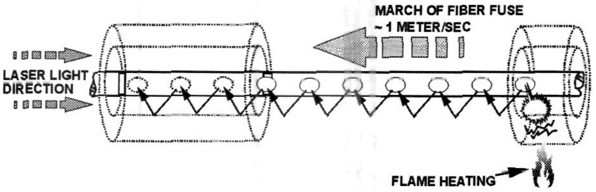

Figure 5-5 B. Reversed second fiber fuse often *restores* pitted core in cable, filling holes back up.

Figure 5-5 The fiber fuse.

The mechanism has been theorized to be self-propelled and self-focusing. Other experiments have found evidence for thermal shock waves and chemical reactions.

But see Figure 5-5b. Astonishingly, after a — say — 1 kilometer fiber optics cable is destroyed by such a fiber fuse, it is often possible to "heal" the damage by reversing the direction of the normal laser light propagating down the cable, while re-initiating the fiber fuse from the other end by heating the cable on that end. In that case, sometimes the *reverse-ignited* fiber fuse will then march right back down the cable, precisely refilling those previously-melted little holes every centimeter or so, *restoring the functioning of the cable!* If ever a phenomenon cried out for further painstaking investigation to determine its actual mechanism, the fiber fuse is it.

Truncated coupled-wave theory applies to this phenomenon. A rigorous analysis by Russell {299} of power conservation in dielectric gratings has shown that truncated coupled-wave theories do not rigorously conserve power. Predictably such conclusions have been disputed {300a-300d}, however, and are adulterated by the same old use of Lorentz-surface integration of the Poynting vector around the grating and discarding of the nondiverged Heaviside energy flow component. Those disputing the results and claiming the impossibility of COP>1.0 systems continue to ignore the unaccounted Heaviside energy flow component accompanying every EM energy flow situation. In fact, they continue to unwittingly discard that component, and so have never performed *a fully* adequate analysis of any circuit or process. They also are unaware that all EM energy in 3-space comes directly from the active vacuum — specifically, it enters 3-space from the time domain and then returns to the time domain.

As long as the Lorentz surface integration scheme continues to be ubiquitously used without understanding what it does with respect to energy flow accounting, the dispute will not be dissolved. Presently both sides still use the Lorentz integration and discard the available Heaviside component. So they are really disputing whether the *Poynting diverged component* of the input energy can be equal to the energy dissipated. The answer to that is simply "No!"

Of course in a lab test the fiber fuse can be initiated with small Poynting energy input by precision point heating. In that case, the total energy required to melt the holes and move the material out of them, every centimeter or so down that (unlimited) length of cable, can be made as large as one reasonably wishes, simply by making the cable as long as one wishes. In short, $COP \gg 1.0$. As can be seen, it can be experimentally proven that the input *Poynting* energy component can be far less than the total energy dissipated in damaging the cable. On the other hand, the energy dissipated in damaging the cable *is not* greater than the sum total of the usually calculated Poynting component together with the neglected extraordinarily large Heaviside nondiverged component. Conservation of energy is upheld, but only if the long-neglected Heaviside component is also accounted.

It stands to reason that the reverse fiber fuse can also be initiated by less input Poynting energy component that the total energy dissipated in restoring the cable. At that point, conventional theory has a problem. One can start with a good cable, put in a little EM energy twice — once to ignite the fiber fuse and once to ignite the reverse fiber fuse — and one winds up with a good fiber optics cable and having done lots more work inside the cable than the amount of energy one input by conventional considerations. We leave the solution to that problem as an exercise for the reader. Again, unless one includes the long-neglected Heaviside component, there is no way to make the energy flow balance, and one will have an experiment that seemingly contradicts the conservation of energy law. It doesn't, and that is the exercise the reader should understand.

So unless one uncovers and specifies the external source (Heaviside's energy flow component) of excess energy feeding the fiber fuse, it is a demonstrable experiment whose efficiency ξ seemingly winds up being ξ >1.0. It works every time and seemingly violates the conservation of energy law *as that law is conventionally and imprecisely stated for an equilibrium system only.* The COP>1.0 fiber fuse phenomenon does not violate overall conservation of energy because the system is not in equilibrium with the other two components of its supersystem. It only violates (permissibly!) the conservation of energy statement for a system in equilibrium. The "system" consisting of the fiber fuse and the cable is *not in equilibrium in its energy exchange with its active environment (with the other two components of the supersystem, consisting of the active vacuum energy exchange and the active local curvature of spacetime).* We point out, of course, that the Heaviside component is flowing in space outside the physical system, hence in the vacuum and therefore in the external environment.

Specifically, every dipole in the system is extracting and pouring out energy from the vacuum, and only the small Poynting diverged component of this available energy flow is ordinarily caught. The extreme nonlinearity (and some resonances!) of the particles in and exposed to the extraordinarily locally heated fiber fuse do sweep out a greater reaction cross section than do cold, static charges, in a fashion similar to the separate demonstration of such extended geometrical reaction cross section in the Bohren experiment {301}. *Hence the fiber fuse subsystem and the associated particles of melted matter from the holes do intercept, diverge, and collect some of the accompanying but usually nondiverged Heaviside component.*

See again paragraph 2.1.6 in Chapter 2. Iterative retroreflective systems — such as in intensely scattering nonlinear optical materials — are not necessarily limited to COP < 1.0. Such a system is not necessarily limited to only the energy input by the operator, and it is not limited to only the operator's input Poynting component. Instead, the system can receive an input of excess energy from (i) its active local vacuum, and/or (ii) the local curvatures of spacetime. Its efficiency ξ, however, is always $\xi < 1.0$, even when its COP is clearly greater than 1.0.

Since scientists disputing the energy aspects of the fiber fuse only have assumed an equilibrium system and have not considered the neglected Heaviside energy flow component, the present arguments against COP>1,0 performance of the fiber fuse are quite irrelevant.

We also point out that an optical phenomenon is involved, and that the core materials in the melt are optically active. Hence, appreciable iterative phase conjugate retroreflections occur in the fiber fuse itself and particularly in the melt materials (in the "inferno" of the "spot" itself). This asymmetrical self-regauging process gets more than one joule of work from one joule of original input Poynting energy, because of the iterative (and reciprocating) change of form of the energy. That operation produces iterative joules of work for each joule of original input energy, plus the unaccounted original input of the Heaviside component.

Again, there is no law of *conservation of work* in nature. The present conventional energy-work theorem erroneously considers only a "single interception and change of form" of the energy collected in the system, before loss of the energy from the system. Therefore, it only considers each joule of input energy performing one joule of work on the system to "excite" it to a higher potential energy state. It also considers that, once a joule of energy is then dissipated from the system as work in an internal load or process, it has departed the system forever and is not returned to do additional work by having its form changed yet again! In intensely retroreflective or intensely scattering systems, those conventional assumptions do not necessarily hold. For analysis of the fiber fuse phenomenon, the extended work-energy theorem must be utilized.

Finally, we point out the connection of this fiber fuse phenomenon to the similar "runaway" phenomena we have previously postulated as involved in producing the x-ray burster, gamma ray burster, etc. where iterative retroreflection and thus asymptotic rise in energy density is involved.

Another possibly related phenomenon is the unexpected explosion of porous silicon, as discovered at the Technical University of Munich {302}. The porous pellet involved in the unexpected experiment is covered with a layer of hydrogen atoms. In the presence of oxygen penetrating the oxygen barrier, an extraordinary and superfast chain reaction is initiated. The power of the explosion is some 10 times that of TNT. In the inferno portion of the fiber fuse, the "melt" as it puddles and then particulates, should be in the presence of oxygen and hydrogen from air in the cable. This dramatically differs from the explosive pellet, but may be sufficient to ignite at least in a local area rather than explode violently. If so, between the ablating particles of silicon there could exist iterative phase conjugation, thus producing an asymptotic rise in temperature and energy, perhaps sufficient to sustain the fuse. At least this possibility should be investigated.

5.7 Multiple Feedforward and Feedback Semiconductor Loops.

DeSantis *et al.* {303} showed that feedback systems with a multipower open loop chain can produce COP > 1.0 performance. In semiconductors, the present author hypothesizes that complex feedforward and feedback loops involving semiconductors can induce time reversal effects, hence some movements of current against the voltage. In short, there can arise a true negative resistance effect, as demonstrated in the Fogal transistor.

Indeed, a Westinghouse frequency converter using 64 transistor stages and similar sophisticated feedforward and feedback mechanisms was placed in the original Minuteman missile, then was later deliberately modified by Westinghouse engineers to prevent its demonstrated COP > 1.0 performance.[125] The specific germanium transistor used in the converter was also withdrawn from the market.[126] In those days, power meant weight and weight was at a premium in missile design. The power supply was very tightly designed, so that the weight could be minimized.

The converter had been deliberately designed to be 90% efficient, which was quite the state of the art. However, placed in the missile, the average converter would produce from 105% to 115% times as much output power as input power. (We are stating a COP > 1.0, *not* ξ > 100%!) This was more output power than the tightly designed succeeding stages were designed to accept; consequently those overloaded follow-on circuits often burned out and deadlined their Minuteman missiles — something of great strategic concern at the time. The increased rate of Minuteman missiles out of action due to this problem placed great pressure on Westinghouse executives. In turn, they simply ordered the engineers to "fix it!"

Westinghouse simply "fixed the problem" very directly. The engineers reduced the output power of the converter by adding limiting diodes etc. Very quietly, Westinghouse then obtained several patents {304a-c} surrounding the technology, but no further mention of it appears in the literature. The Westinghouse work continued for at least a decade, judging by the spread of the patent dates.

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[125] Our information came directly from private conversations of a close scientific colleague with the Westinghouse engineers who thoroughly tested the converter causing the Minuteman problems, and who then altered it to prevent the problems.

[126] Germanium has some unique properties, particularly with respect to transducing surface longitudinal waves to transverse waves and vice versa.

Such multi-loop, multi-feedback transistor circuits can apparently be developed to exhibit true negative 4-resistor effects. With specialized clamped positive feedback of the Bedini type, such open dissipative systems can then exhibit stable COP>1.0, since the energy is taken from the vacuum via the broken symmetry of dipoles, and then discharged asymmetrically in the loads so as not to destroy the source dipole negative 4-resistors. However, the reader should see Chapter 9 for special considerations and phenomenology.

5.8 Negative Resistors

We define a *true negative resistor* as a circuit component or system that receives energy from the environment and outputs useful energy, either in altered form or to power loads usefully. This contrasts sharply with a *differential negative resistor,* which exhibits negative resistance in one part of its regimen, but where all the excess energy to move the current against the voltage in that regime was previously drawn from the circuit itself and therefore was not freely received from the active external environment. Instead, the operator paid for it already. We are not interested in differential negative resistors, which are well known in the literature {305} and do not enable COP>1.0 system performance, so we will not discuss them further. Hereafter when we use the term "negative resistor", it is understood that we mean "true negative resistor" unless the term is otherwise qualified.

The true negative resistor is an open dissipative system *a priori,* and equilibrium thermodynamics therefore does not apply. Instead, the thermodynamics of open systems far from equilibrium applies. The negative resistor freely receives energy from outside the system (from the . environment), and "dissipates" it in interception and collection actions inside the system, to freely increase the available potential energy in the system.

In circuits, the main characteristic of a negative resistor is that the environment freely furnishes some excess energy to (i) power the load, and/or (ii) move the current back against the voltage, particularly when shunted across the back emf region of the source dipole. The *operator* does not have to furnish this excess energy dissipated to propel the current backwards or dissipated to power the load!

One must incorporate the entire supersystem into the analysis of a negative resistance element or system. Since the operator does not furnish the input energy dissipated by the negative resistor, then the active vacuum or curved local spacetime — or both — must furnish the input energy to it. One must consider local curvature of spacetime interactions with the negative resistance and the active vacuum interactions with it, as well as the interactions between active vacuum and local spacetime curvature. In other words, one must again include the active environment of the Maxwellian system that Lorenz/Lorentz symmetrical regauging arbitrarily discarded.

We specifically do not include the well known "differential" negative resistor, such as a tunnel diode, which in one regime moves current against the voltage, all the while drawing all its enabling energy to move current against the voltage from an overall previous energy input by the operator. Unless the input enabling negative resistance energy is freely received from the external environment, true negative resistance is not involved.

Several true negative resistors other than the point-contact transistor have been produced. We review a few of them in the following subparagraphs.

5.8.1 Kron's Negative Resistor

One of the greatest American electrical scientists was Gabriel Kron. Working for General Electric (GE), Kron built a true negative resistor in the 1930s, which could power itself and the network analyzer[127] at Stanford University, under a GE support contract with the U.S. Navy. Here **is** a direct quote from Kron {306} to show what we refer to:

> *"When only positive and negative real numbers exist, it is customary to replace a positive resistance by an inductance and a negative resistance by a capacitor (since none or only a few negative resistances exist on practical network analyzers.) "*

In that sentence we believe that Kron was forced by the censors to insert **the** words "none or" in the expression in parentheses. Particularly note the suggestion that in the imaginary realm it may not be the same as the accepted practice of using inductance as a positive resistor and capacitance **as** a negative resistor. Of course, the fourth Minkowski axis is - *ict,* and so this is very probably an oblique reference to the fact that energy can also "flow in" from the time domain. Kron was quite knowledgeable in general relativity as well as advanced electrodynamics, and he applied full general relativity to rotating EM machines etc. In another quote, Kron {307} also revealed that he had the negative resistor but was not allowed to use it to openly power the Network Analyzer. Quoting and reading through the "spin control":

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[127] The network analyzer was a large analogue simulation capable of modeling sophisticated equations — such as Maxwell's equations, the Schrodinger equation. **etc.** — for use in designing, simulating, and analyzing naval communications systems or proposed systems. It was one of the most advanced simulations of its day. Kron was the chief engineer and scientist on the project, and one of the ablest electrical physicists the United States ever produced.

> *"Although negative resistances are available for use with a network analyzer, in practice it is more convenient to use a second type of circuit, in which the positive and negative resistances are replaced by inductors and capacitors and the dc currents and voltages are replaced by ac currents and voltages of fixed frequency. The use of the second type of interpretation is equivalent to multiplying the wave equation by* $i = \sqrt{-1}$*."*

After the word "although..." Kron includes the blunt statement that negative resistors were indeed available for use with the network analyzer. But if the "convenient" replacement of the positive and negative resistors by inductors and capacitors was made, then there was no COP>1.0 involved, and there was no true negative resistance involved. Kron is trying to clearly tell us that fact in the above quotation. He also strongly hints that energy from the time domain on the axis *ict* is involved, but that multiplication by $\sqrt{-1}$ discards this "energy from the time domain".

Kron's negative resistor secret has never been released by General Electric, Stanford University, or the U.S. Navy and it is not going to be released. It has never been deciphered outside those groups, with the possible exception of knowledge by Floyd Sweet of Kron's negative resistor construction. Sweet worked in General Electric but not on the Network Analyzer project. Kron, however, was Sweet's mentor and patron, and Sweet often spoke of Kron in glowing terms. In our opinion, Sweet's vacuum triode amplifier was a further development of Kron's early negative resistor, as Sweet understood it.

We further believe that Kron's "open path" is simply the other two components of the supersystem, being (i) local curved spacetime, and (ii) the active local vacuum. Obviously the *external environment* connects any two points in the physical circuit, in addition to the circuit's physical connection (the "closed path"). Between any two points at differing potentials in an electrical circuit, there exists a potential and a dipolarity. Therefore, there exists a broken symmetry because of the dipolarity. The potential difference of that dipolarity is also a curvature of spacetime; i.e., it is a "field" between the two points, and the field is identically a curvature of spacetime. Hence from any two such dipolar points in the circuit, there exists the giant negentropy flow of EM energy that we pointed out in 2000 {308}. This "open path" EM energy flow between any two unlike charges (any dipolarity) in the universe, not intercepted by the circuit and thus nondiverged, is discarded by Lorentz's integration of the energy flow vector around a closed surface enclosing any volume element of interest. It appears that Kron not only recognized (in different terms) what we are calling the "supersystem", but also recognized the equivalent of Heaviside's nondiverged EM energy flow component from any dipolarity — referring to that energy flow as the "open path" flow of energy. It is almost certain that he fully recognized what Lorentz symmetrical regauging did to the Maxwell-Heaviside equations. Thus it appears that Kron was the first scientist to discard Lorenz/Lorentz symmetrical regauging, producing his negative resistor by doing so.

We do not have firm knowledge, however, but only circumstantial evidence that Kron recognized the flow of EM energy from the time domain into 3-space, and vice versa, though he was certainly capable of seeing that. Nevertheless, this would also be included in his notion and discovery of the "open path", since it is included in every dipolarity, generating the scalar potential between the poles of the dipolarity. It may also have occurred to him from his excellent grasp of general relativity and spacetime curvature {309}.

Kron's concepts are certainly capable of being modeled and used to produce COP>1.0 EM circuits and systems, including his negative resistor. Kron did tremendous work in advancing EM networks and power systems. He left behind a great legacy of network and system analysis capable of dealing with the COP>1.0 electrical power system problem {310a-e}. Unfortunately, that legacy has been little used, if at all, in design of electrical power systems and power distribution networks today. To our knowledge, there are no electrical power systems deliberately using Kron's open path.[128]

5.8.2 Chung's Negative Resistor

A highly simplified diagrammatic illustration representing the Chung negative resistor is given in Figure 5-6. In a July 9, 1998 keynote address at the Fifth International Conference on Composites Engineering in Las

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[128] A possible exception is provided by Barrett's extensions {286a, 286b} of Tesla's "potential shuttling" technique {124}, which can only be seen in higher group symmetry electrodynamics such as quaternions. However, as far as we know, Barrett has **not** applied energy shuttling techniques to electrical power systems.

Vegas, Dr. Deborah D. L. Chung,[129] professor of mechanical and aerospace engineering at State University of New York (SUNY) at Buffalo and Director of the Composite Materials Research Laboratory, reported that she had observed apparent negative resistance in interfaces between layers of carbon fibers in a composite material prepared under pressure.[130] The negative resistance was observed in a direction perpendicular to the fiber layers. By varying the pressure at which the composite material was prepared, Chung *et al.* were able to control whether the material would exhibit negative, minimal, or positive resistance. Apparent negative resistance was also observed in carbon fiber cement-matrix composites and in bare carbon fibers held together by pressure.

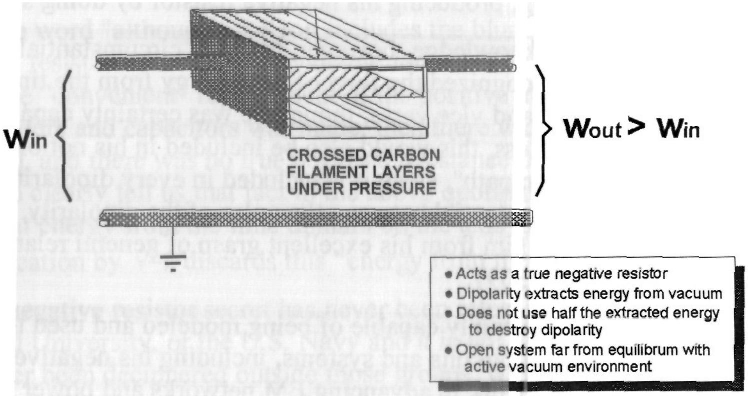
Win
Wout > Win
CROSSED CARBON FILAMENT LAYERS UNDER PRESSURE
• Acts as a true negative resistor
• Dipolarity extracts energy from vacuum
• Does not use half the extracted energy to destroy dipolarity
• Open system far from equilibrum with active vacuum environment

Figure 5-6 Chung's negative resistor (diagrammatic).

A formal technical paper was later published by Wang and Chung {311}. A few years earlier a patent {312} had been issued to Chung and assigned to The Research Foundation of State University of New York, Albany, NY for a superconductive material using a laminate combination of carbon fibers and metal.[131] The patent mentioned mesoporous carbon filaments, strikingly similar to our previous discussion of the surprising explosion of porous silicon at the Technical University of Munich, as well as possibly a special kind of "porosity" consideration in the fiber fuse phenomenon (in the material of the fuse itself).

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[129] Professor Chung holds the Niagara Mohawk Chair in Materials Research at SUNY and is internationally recognized for her work in smart materials and carbon composites. The reader may peruse a curriculum vitae, research work, and papers at http://www.mae.buffalo.edu/people/faculty'chung/researchl.doc.

[130] The preparation of "locked-in" stress in Chung's carbon fiber material is reminiscent of Moray's similar preparation of his amorphous semiconductors with locked-in stress also.

An initial offer on the State University of New York at Buffalo website to provide a technical package with respect to the negative resistor — for which a patent had been filed — to those submitting a nondisclosure agreement was abruptly withdrawn. The project may have been classified, or — far less likely — it may have been retained as deeply proprietary by the University. We suspect that both the technical package and the patent application have been classified by one or more U.S. government agencies.[132]

In our opinion, Chung's fruitful discovery deserves rigorous and continuing investigation, particularly in higher group symmetry electrodynamics and in terms of supersystem interactions to include Dirac sea hole current interactions. We also believe Chung may have been required by referees (or by declassifying authorities, if such were involved) to use the term "apparent" in the paper. The reported measurements in the technical paper do seem to unequivocally include true negative resistance with current running backwards against the voltage. It is not clear, however, whether this is Dirac hole current or electron current or a mix of both.

We also call attention to the fact that Dirac sea holes in the local vacuum — as will be discussed in Chapter 9 — will and do run backwards against the voltage. Further, such hole current can be transformed from negative energy to positive energy by the Bedini process shown in Chapter 9. The pressure used by Chung *et al.* in fabricating the material produces a stress potential in the material and thus decomposes into our reinterpreted Whittaker 1903 decomposition, preciously discussed. So giant negentropy is involved in the composite material, which implies that true negative resistance can be involved, at least in some operational regimes as pressure etc. are varied. Such results were found by Chung *et al.* and are reported in the paper.

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[131] We stress that the issuance of this unclassified patent does not rule out a possible negative resistor (hence COP>1.0) patent that may have been classified. Some sensitive defense work in special materials is indeed performed at SUNY at Buffalo.

[132] At least the gist of the work is not lost, however, due to Naudin's duplication of the Chung effect and placing the results and building instructions on his website in France; see http://jnaudin.free.fr/cnr/.

Naudin reported independent success with a simpler variant of the Chung negative resistor {313}. This assures that at least the effect will not just be buried.

5.8.3 The Fogal Charge-Barrier Device

Figure 5-7 shows an illustration from one of William Fogal's patents {314} on a new kind of transistor (more accurately, a charge barrier device). Fogal's device incorporates a very special electrolytic capacitor[133], which introduces optical-type functions as well as the more familiar capacitor functions.

Fogal Semiconductor

- Blocks electron current flow $i = dq/dt$
  - As capacitor charges electrons in emitter junction attracted to plate
  - Charging plate produces high barrier
  - AC conduction electrons cannot penetrate barrier
  - AC displacement current $d\phi/dt$ and Poynting current $S = E \times H$ are passed through the barrier
- AC into the barrier produces AC Lorentz symmetrical regauging, which produces AC stress waves, which are longitudinal EM waves a *priori*
- Semiconductor becomes "energy pipe"
- Massless displacement current is energy flow without losses
- Energy can be collected and separately discharged through load for free work
- Transmission mode Holding potential while changing displacement current produces enfolded longitudinal EM waves inside potential accompanied by time-polarized phase conjugate twins
- Reception mode Receiving longitudinal EM waves at barrier provides scalar interferometry, making transverse EM waves
- Fogal semiconductor can both receive and transmit via enfolded longitudinal EM waves, which are not limited to the speed of light in vacuum
- Semiconductor can also be used as a true negative resistor.

DIAGRAMMATIC
ONLY

Figure 5-7 Novel characteristics of the Fogal semiconductor.

Most semiconductor materials are optically active materials. Further, the individual electrons in a signal with a frequency well below light frequencies, are "jittering" with higher frequencies including the entire optical band. A "frequency" of a signal thus is imbedded in a jittering higher frequency complex set, and that set is quite able to interact in optical fashion *if the complex itself is used and controlled.* Fogal's process does appear to both use and control that jittery high frequency signal complex.

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[133] The exact method of manufacturing this electrolytic capacitor, and its internal structuring, is proprietary to Fogal and a major capacitor manufacturer, who is under a nondisclosure agreement with Fogal.

Hence Fogal's process can "tunnel under" the normal *detected* force-field frequency responses of the individual electron,[134] and directly affect, change, and alter its higher-frequency environmental changes in the force-free field or field-free potential condition. In this way, Fogal has carried the electron (and hole) functions of a transistor to functions well beyond those in the present texts {315}. He may have also extended quantum mechanical tunneling effects to signals between widely separated regions of spacetime, since superluminal communication is possible with the Fogal semiconductor properly used. Longitudinal EM waves — which Fogal's semiconductor is able to utilize and control — can and do move at superluminal speeds {93a) because it uses the long-neglected "infolded" longitudinal electrodynamics revealed by Whittaker in 1903 and 1904. Further, superluminal solutions to Maxwell's equations do exist {93b}.

The charge barrier device is formed in a bipolar design that can be incorporated in Metal Oxide Semiconductor (MOS) designs as well as multiple gate devices. The device also produces a Hall effect EM field internal to the device. The Hall effect magnetic force will force electron flow and angular spin of the electrons in the same direction to the top of the conduction bands in the crystal lattice on semiconductor devices, unlike Silicon On Insulators (SOI) devices that force electron flow to the surface of the semiconductor lattice. This forcing function, together with the "extended tunneling" effects on the embedded EM environment of the electrons and holes, produces a unique effect. The device is able to stop and "pin" electrons while continuing to process the signal energy flow (the entire jitter signal complex) in which the electrons were coupled and moving. Thus the Fogal transistor is able to operate upon and with mass-free spacetime itself, and curvatures thereof. It is the first practical semiconductor capable of performing *engineering of the active vacuum.*

In the last few years we have stressed that EM waves in spacetime are longitudinal EM waves *a priori* — but they are accompanied by time-polarized waves (phase conjugates). Hence the two in combination become observable, as pointed out in quantum field theory by Mandl and Shaw {316}. *We detect effects a priori and not their causes.* We detect transverse *electron precession waves* in our detector circuits, and not the causal waves interacting with them to produce their precession. *The Fogal transistor is able to process the causal longitudinal EM waves directly, prior to their interaction with matter.* It in fact opens up an entirely new region of "detected physical reality" to our vision and detection, a region far more extensive than the development of infrared and ultraviolet sensors opened up to our sight.

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[134] The electron itself is enveloped in the jittering of whatever background it is exposed to and interacts with. Hence a coupling interaction exists to arrange and c**ontrol** the jitter of the electron as well.

The pioneers of electromagnetics, who erroneously assumed a material ether and EM force fields in space, confused the transverse "material detected waves" (electron precession waves) in the detector with the "material undetected waves" they assumed to be incoming from space. Note that neither the electron nor the atom had been discovered when all these assumptions were used to determine how the EM wave in space was to be viewed and modeled. The transverse waves observed in the interacting/detecting of the Drude electron gas — i.e., the detected electron precession waves — were considered to be direct interceptions of the incoming causal waves from space. This already substituted the effect for the cause, as we have previously discussed.

Further, Faraday envisioned the "material field in space" as consisting of a series of "taut physical strings". A "perturbation" of this field in space was, in his view, simply the transverse wave plucking of those strings. Maxwell, who closely followed Faraday's experimental work and concepts, simply assumed the transverse "plucked string waves" advanced by Faraday. Therefore, the erroneous notion of the transverse EM wave in space arose and stayed firmly fixed in the theory.

One can check Whittaker's decomposition of the scalar potential into longitudinal EM wave pairs, then realize that the energetic vacuum is naught but a giant scalar potential — which can be decomposed by Whittaker's method. In short, as a scalar potential, space itself is a writhing mass of longitudinal EM waves and their highly nonlinear dynamics and interferences, or it can be modeled in that fashion. The energy continually enters 3-space from the time domain to the negative charge of every point in space considered as a point dipole, thence to the positive charge, thence back to the time domain. Notice the giant 4-space circulation involved. One also notes the polarization of the vacuum continually happening and arising spontaneously, as is well known in quantum mechanics. We also suspect that this or a similar mechanism is at the root of spontaneous broken symmetry in physics.

An interesting thing emerges from Whittaker's 1904 paper {317}, where he showed that all EM fields and waves can be decomposed into differential functions of two scalar potentials. Each of these two base scalar potentials can be decomposed by Whittaker's earlier 1903 paper {85} into a set of longitudinal EM waves. All EM fields, potentials, and waves are comprised of longitudinal EM waves and their internal dynamics, which also comprise waves of spacetime curvatures and their dynamics. Further, each longitudinal EM wave in 3-space is accompanied by its phase conjugate twin in the time-domain.

This far more primary "internal electrodynamics comprised of pure spacetime dynamics" — comprising and creating the recognized EM potentials, waves, and fields, their internal dynamic spacetime structuring and also the structuring of time — has not been developed and applied in physics theory. This internal or "infolded" electrodynamics is the primary "medium" in which the Fogal semiconductor appears to work and work upon. The Fogal semiconductor seems able to modulate and demodulate this internal structuring or parts of it, as has been demonstrated.

Imperfect longitudinal EM waves — called *undistorted progressive waves* - are already known to be able to travel at superluminal velocity, e.g., as shown by Rodrigues and Lu {318}. Indeed, Maxwell's equations have both subluminal and superluminal solutions, as shown by Rodrigues and Vaz {319}. Further, these waves can carry information. However, the *technology* of employing these waves has been lacking {320}. The use of scalar EM wave interferometry to produce normal EM fields and EM field energy at a distance has been shown by Evans *et al.* {321}.

As pointed out by Rodrigues and Lu {318}, perfect longitudinal EM waves travel at infinite velocity. This eliminates the difference between potential, field, and wave; a perfect longitudinal EM wave can also be taken as an instantaneous scalar potential with net force-free iterative regauging (varying at each point instantly and simultaneously). Both ways of looking at it produce the same end result: instantaneous remote energy change of spacetime energy density itself, in general relativity terms, or of the energy density of the vacuum, in particle physics terms.

Elsewhere, (e.g., Chapter 2), we also pointed out the "total photon **interaction"** mechanism that generates the flow of an entity through time. We also have advanced the concept of a "time-reversal zone" (TRZ) as a region where antiphoton interactions with charges predominate over photon interactions. We used these new concepts to propose exact nuclear **reactions** for the production of excess deuterium, tritium, and alpha particles in cold fusion experiments. In such an "excited state" TRZ region, the law of attraction and repulsion of charges is reversed. In the TRZ, like charges attract and unlike charges repel. Further, the gluon forces are reduced, so the quarks in the nucleons are much more lightly bound. In such TRZ zones, dense clustering of like charges occurs due to their mutual attraction.

A time-reversal zone is created in one part of the Fogal transistor, greatly assisting in the "electron pinning" action. That is, the usual strong mutual repulsion (the Coulomb barrier) of the electrons at the pinning site vanishes in the TRZ inside the Fogal semiconductor, and the resulting mutual attraction of the electrons greatly facilitates the pinning process far beyond what is usually obtained against "like charge" repulsion in a time-forward zone. Indeed, the TRZ in the Fogal semiconductor also materially enhances the electron pinning process beyond what can usually be obtained with cryogenics. At least some indication of trapping and perhaps pinning has been reported in amorphous semiconductors at room temperature {322a-b}.

The Fogal device is able to remove EM noise (electron noise) from existing EM signals, displays, etc. by 96% or more, by pinning the electrons and simultaneously time-reversing the spatial EM signal back to its original noise-free state prior to hosts of interaction electron collisions. This "noise removal" capability has been rigorously tested by independent parties, including at a leading university in the Netherlands,[135] and by several large electronics companies and several other universities. By pinning the electrons (and electron currents) while still processing and propagating the EM energy effects, the Fogal device can move noiseless EM energy without loss at room temperatures, at superluminal velocities, and reconnect the lossless propagated energy to electrons past the pinning region at a receiving region, releasing the electrons in the receiving region. The Fogal semiconductor therefore already accomplishes *room temperature superconductivity* as well as tunneling.

The Fogal device's basic mechanism (consisting of all the submechanisms) is to restore and move EM energy in force-free form, using direct regauging of the vacuum instantaneous scalar potential itself (or the vacuum potentials themselves). It operates directly upon the longitudinal EM waves comprising the vacuum potential. Hence it directly engineers the active vacuum and curved spacetime. I.e., it is the first *supersystem engineering* device of (hopefully) many more to come.

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[135] The university researchers verified room temperature superconductivity being produced by the Fogal semiconductor in their independent verification measurements. They also measured that some 96% of the noise already present in a circuit was removed by Fogal's semiconductors in Fogal's circuits.

In the "jitter" environment of the space in which the individual electron is embedded, there exist many (and essentially all) field gauges, simultaneously. One of these, of course, is the Coulomb gauge where there exists an instantaneous scalar potential. Usually the instantaneous scalar potential is considered only a *near-field* effect, with no contribution at any significant distance. However, as Jackson points out {323}, transverse radiation fields are given by the vector potential alone. Also, in the Coulomb gauge the scalar potential "propagates" instantaneously everywhere in space {324}.

Along with other electrodynamicists, Jackson avoids the obvious superluminal communications implications of the instantaneous scalar potential by stating that *"..it is the fields, not the potentials, that concern us."* As he points out, a detailed *(though conventional)* discussion of causality is given by Brill and Goodman {325}. Again as pointed out by Jackson, in the Coulomb gauge the quantization of the photon involves only the vector potential. *The use of the scalar potential in the Coulomb gauge, together with deliberate engineering of the internal longitudinal Whittaker wave structure of that potential, directly allows distant engineering via multiply connected spacetime, even inside the nuclei of distant objects. This is in fact a unique and marvelous engineering application and extension of Bohm 's quantum potential concept.*

My "pinning" the electrons, apparently Fogal is able to essentially "hold" the vector potential and all the force fields while the instantaneous scalar potential *persists and now extends over all space, not just to the near field since all formerly moving field dynamics that would limit it have been frozen.* If this effect is substantiated, I have nominated it as the "Fogal effect". Further, this unrestricted instantaneous scalar potential now i lunges in field-free form (pure regauging form) over all space according to the signal energy being perpetuated and propagated[136] by the Fogal semiconductor independently of its pinned electrons. In this fashion, the Fogal semiconductor is indeed capable of "instantaneous" communication over essentially unlimited distances. At least one independent test has verified the Fogal instantaneous communication effect, but the test is still held proprietary by the testing agency.

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[136] Here we again point out that the usual notion of a signal as energy propagating in 3-space is wrong. It propagates in 4-space, but not in 3-space. Also, what propagates is the spreading point-like polarization of the vacuum itself.

Since Fogal is able to alter and control the internal longitudinal EM wave Whittaker structuring of the scalar potential used in this Coulomb gauge manner, he is able to accomplish superluminal (and even instantaneous) communication, so long as a Fogal semiconductor is available in both the transmitter and the distant receiver. In the transmitter, the Fogal component is necessary to *infold* the information into the internal LW structure of the scalar potential to be used in the Coulomb gauge, thus transforming the input signal information into output longitudinal EM wave information directly in spacetime itself. The Fogal component in the receiver is necessary in order to detect, transduce, and *outfold* the infolded longitudinal EM wave information inside the instantaneous scalar potential. We have stressed that these internal longitudinal EM waves and their dynamics are spacetime curvatures and their dynamics. Hence their transmission and detection is a viable process for superluminal communication, including instantaneous communication.[137]

Further, once the electrons are pinned, all "signal fields in charged matter" (i.e., all EM force fields) are frozen and localized. This, we believe, involves a new physical effect introduced by Fogal that is analogous to the Aharonov-Bohm effect.[138] So I have called it the "Fogal effect". That is, the force-fields are frozen and localized by the pinning, but the field-free potentials then remain, including the instantaneous scalar potential ϕ and probably the curl-free magnetic vector potential A as well. The result is that the instantaneous scalar potential can be directly *regauged* everywhere at once by the changes of magnitude of the "frozen fields", rather as if they were "static voltage", possibly simultaneously regauging the field-free A-potential — all as part of a new kind of Lorentz symmetrical regauging. After all, a single Lorentz symmetrical regauging {326} changes both the potentials A and ϕ. Changes in symmetrical regauging produce stress waves, which are longitudinal EM waves. Continual changes of symmetrical regauging also continually changes both the potentials A and ϕ, *including over all space when operating in the Coulomb gauge.* This is one explanation of the beautiful effect that Fogal has discovered and is utilizing.

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[137] We believe that physics books will have to be substantially rewritten, once the internal longitudinal structuring of the scalar potential (and of EM fields and waves) is employed directly in open technology. We further believe that the Fogal semiconductors are the first pre-developments in that coming vast new technology, at least in the open Western scientific world.

[138] There have long been, and still are, efforts to "fit" the Aharonov-Bohm effect into slightly modified classical electrodynamics after all. E.g., see C. J. Carpenter, "Electromagnetic energy changes due to charges moving through constant, or zero, magnetic field," *IEE Proc. A,* 138(1), Jan. 1991, p. 55-70; — "Electromagnetic energy and power in terms of charges and potentials instead of fields," *IEE Proc. A,* 136(3), 1989, p. 101-113; G. M. Graham and D. G. Lahoz, "Observation of static electromagnetic angular momentum in vacuo," *Nature,* Vol. 285, 1980, p. 154-155; T. H. Boyer, "Semiclassical explanation of the Matteucci-Pozzi and Aharonov-Bohm phase shifts," *Found. Phys.,* 32(1), Jan. 2002, p. 41-49; — "The Aharonov-Bohm effect as a classical electromagnetic-lag effect: An electrostatic analogue and possible experimental test," *Nuovo Cimento,* Vol. 100B, 1987, p. 685-701; — Classical electromagnetic deflections and lag effects associated with quantum interference pattern shifts: considerations related to the Aharonov-Bohm effect," *Phys. Rev. D,* Vol. 8, 1973, p. 1679-1693; — "Does the Aharonov-Bohm effect

We accent that, with pinned electrons frozen in place, the normal ϕ and A in matter (defined in terms of interaction with charge and the movement of charge) cannot occur. With time reversal zone utilized, electron pinning is greatly eased and the instantaneous scalar potential ϕ now assumes the primary active propagating role in surrounding space. Neither ϕ nor A is free to develop the normal $\partial\phi/\partial t$ and $\nabla\times A$ *spatially propagating dynamics of the force fields (effect fields) observed in matter.* In the Fogal process, the instantaneous scalar potential "signal" (the causal signal in 4-space) is generated in the transistor when it pins the electrons and freezes the force fields into "equal and opposite" form. Since no net force field can develop, the instantaneous scalar potential is a stress potential in spacetime itself and simply changes its magnitude instantly, at each and every point in space that it occupies, when the Fogal chip's input EM fields change in its signal input.

In the output, the net force fields remain zero and frozen, even though the individual force fields change constrained to "equal and opposite" manner. If one wishes, one may take this part of the Fogal output — the field free changes in the stress energy density of the vacuum — as one expression of *modululating the instantaneous scalar potential's energy density in perfect correspondence to the field changes in the normal EM input to the Fogal transistor.*

exist?". *Found. Phys.,* Vol. 30, 2000, p. 893-905; — "Classical electromagnetism and **the** Aharonov-Bohm phase shift," *ibid.,* p. 907-932.

The instantaneous Fogal changes in magnitude (e.g., instantaneously induced upon a distant collecting charge) are no longer limited to near field effects, or to the speed of light — and communication is not bound to the retarded wave. Now the induced changes of the instantaneous scalar potential exhibit far field effects and these changes — being naught but these special Lorentz condition magnitude regaugings — are instantaneous. This of course is a form of *action at a distance.* We stress that the best astronomical evidence also points to a startlingly superluminal speed of gravitation (curvature of spacetime, which after all is just a longitudinal EM wave or set of them) itself, as pointed out by Van Flandern.[139] If so, since any change of energy in spacetime is a curvature of spacetime, and one form of spacetime curvature can move at superluminal velocity, so can other forms of spacetime curvatures. In our favorite expression, *it only takes one white crow to prove that not all crows are black.*

As is well known, the de Broglie waves of matter always move faster than light, as do appropriate quantum tunneling processes. Further, the quantum potential used by Bohm in his beautiful hidden variable theory of quantum mechanics {347} also appears instantly throughout space, wherever it will be, and with the value it will have. The question of whether a quantum potential can be used to communicate has been posed but not definitively answered in the previous literature. We propose a resounding "Yes!" if one uses the internal structure of the quantum potential for one's communication, applying some component such as the Fogal semiconductor to do the infolding and outfolding.

We also propose that a process for forming and using an instantaneous scalar potential in the Coulomb gauge can be interpreted as the formation and use of a quantum potential or its direct equivalent. If that assumption is true, then the Fogal semiconductor seems to be the first component ever openly built and patented which produces and uses Bohm's quantum potential, *including* its infolded Whittaker structuring and dynamics. It also definitively answers in the affirmative the question of whether the quantum potential and the scalar potential in the Coulomb gauge can be used in superluminal communications.

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[139] Tom Van Flandern, "The speed of gravity - What the experiments say," *Phys. Lett. A,* vol. 250, Dec. 21, 1998, p. 1-11. Van Flandern gives an extremely important, clear, and succinct summary showing that experiments refute the standard far field assumption of light speed in gravitational effects. Laboratory, solar system, and astrophysical experiments for the "speed of gravity" yield a lower limit of $2x10^{10}c$.

Thus Fogal has apparently found a way to directly modulate intelligent change of magnitudes into and upon the internal longitudinal EM wave structure of the instantaneous scalar potential (and upon the quantum potential), as well as iterative "pure *net-field-free"* regauging of the instantaneous scalar potential {327}. It seems to have previously escaped notice that varying the Lorentz symmetrical regauging of a circuit or system easily produces pure longitudinal EM waves. This strongly implies that Fogal has surmounted and removed the barrier to practical superluminal communication and even further has reduced the barrier to practical instant communication.

Several tests — in one of which the present author participated — have indeed shown Fogal transmission of signals, including video signals, between two widely separated points with less delay than light-speed signals exhibit, and also with video bandwidth infolded inside a DC signal. In at least one series of tests in a large company's own laboratory and by its own engineers, communications from a ground-based Fogal chip transmitter apparatus occurred between the ground station, through the uplink into the satellite, back through the downlink to earth, into a ground-based transmission system with repeater stations, and into the receiving Fogal transistor unit in the lab. The transmissions occurred with *no discernible time delay,* something previously deemed impossible in all the textbooks. This was particularly significant since even the conventional time-delays in the repeater station amplifiers and the satellite receiver-transmitters were apparently eliminated. This further accents that the infolded "longitudinal EM waves superhighway" inside all EM fields, potentials, and waves — including inside matter such as the ocean and the earth itself— is a multiply connected space phenomenon. It is the most ideal communication medium, enabling deep space communication without delay, etc.

The implications for nondelayed future remote control of robot spacecraft and robots landing on the surface of planets and asteroids are obvious, as are the implications for direct exploration and measurement of conditions *inside the interiors* of the planets, the sun, the moon, and the earth via **internal** scalar interferometry. We accent that Fogal has done private experiments exploring this vast new physical reality revealed by the "internal longitudinal EM wave dynamics" and its interferometry, and it is mind-expanding (some would say *mind-boggling!).* It is also a great new step in physics and in our very notion of physical reality itself.

T**he** vacuum itself, being highly energetic, is indeed a scalar potential. **Further,** it has any and all gauges. Since potentials superpose, we postulate that Fogal's use of the instantaneous scalar potential is directly superposed on the corresponding instantaneous Coulomb gauge scalar potentials of the entire vacuum. His discovery of how to modulate the instantaneous ϕ magnitude without allowing modulated EM field propagation, constitutes a very special case of tunneling right through "space" itself, using one aspect or "component" of space.

In short, to be a little dramatic one might even apply the term *subspace communication* to this long distance tunneling effect. That interpretation would also seem consistent with the deterministic variation of the internal stress energy density structuring of the vacuum that is produced in the Fogal process.

From another viewpoint, Fogal has succeeded in not only finding the missing chaos of quantum mechanics, but in deterministically engineering and using it.

This is also consistent with Whittaker's decomposition of the scalar potential into bidirectional longitudinal EM waves {328} and his connection between time-polarized EM waves and longitudinally polarized EM waves as reinterpreted (12) to be consistent with quantum field theory {19}. We point out that a single point in time is simultaneously "connected" to every point in the universe. By using a transmission system that back-pedals from 3-space into the time domain, an instantaneous connection to any other spatial point in the universe is therefore available, if one's technology can take advantage of it. Fogal's technology does.

It is also consistent with quantum tunneling experiments that have demonstrated the transmission of intelligent signals (such as Mozart's 40th symphony) at superluminal speed between two points in a waveguide {329a-b}. Regardless of how one chooses to model intelligent superluminal communication, it has been experimentally demonstrated — multiple times and by multiple experimenters in multiple laboratories — that such can occur.

The difference in those superluminal experiments and the performance of the Fogal chip is that the chip uses iterative regauging of the magnitude of the instantaneous scalar potential, as well as deterministic alteration of the scalar potential's internal longitudinal EM wave substructuring, and probably also modulates the internal structuring of a quantum potential. The presently proposed quantum tunneling mechanisms apparently do not do this, at least as they are presently modeled. Further, the quantum tunneling mechanism is difficult to apply; the Fogal mechanism is fairly simple and straightforward to apply, given the Fogal semiconductor at both the transmitting and receiving ends of the communication system.

Pure longitudinal EM waves readily penetrate matter to great distances, since matter is mostly empty space between widely separated mass particles. On the microscopic scale, matter is comparable to something like the solar system, except that intense fields and potentials (bundles of longitudinal EM waves and their dynamics) occupy the space between the particles. All this vast empty space inside matter, being a potential and comprised of longitudinal EM waves, is a giant "superhighway" for the passage of longitudinal EM waves and their dynamics, as indeed is matter itself which is mostly such empty space. Further, even the masses themselves are such, since mass is simply highly compressed spatial energy density, and therefore is highly compressed longitudinal EM wave energy and dynamics. It is just a "denser" superhighway.

Hence a longitudinal EM wave system can readily be developed to "see through matter" using Fogal semiconductors in transmitter and receiver. Fogal in fact has made at least one proprietary prototype demonstration unit that demonstrates this startling capability. The vision is very clear, due to the remarkable absence of noise in the Fogal process. It is also shockingly unique, and it changes our very notion of physical reality. We are not at liberty to further discuss this new "sub-submicroscopic" reality revealed in such experiments. We simply interpret it as jumping the presently assumed restrictions of observation, and allowing the direct or correlated observation of the virtual state entities.

As alluded to, the previously modulated "Fogal type signals" emitted by all matter and other physical entities can also be displayed on a screen using the Fogal process, revealing a hitherto unsuspected physical reality and EM signals environment. In this prototype system, Fogal showed a remarkable and startling new extension of our very perception of physical reality itself. This is another reason why we expect that physics books will have to be rewritten, once the Fogal semiconductors are on the market and available in practical equipment. As every physicist knows, any dramatic increase in our ability to sense finer levels of physical reality inevitably leads to new and startling advances in physics itself and changes our very knowledge of the nature of physical reality.

The ability to bypass and "park" force fields by pinning their source electrons in a time-reversal zone, while continuing the flow of noise-free EM energy at will and at infinite velocity, obviously enables COP>1.0 systems. A pure longitudinal EM wave already has infinite energy, for such a wave appears across the entire universe simultaneously, instantly changing the stress energy density of the entire vacuum in which the longitudinal EM wave is present.[140] The back emf and back mmf fields in an EM system or electrical power system can be frozen and held from restoring the Lorentz condition in the circuit, using the Fogal semiconductor {330}. We presently have an agreement with Fogal for the licensed use of his semiconductors in all such energy unit applications.

A quantum potential is modeled in a multiply connected spacetime, so that a given joule of input energy to one multiply connected point simultaneously appears in every other multiply connected point.[141] Since the Fogal semiconductor apparently can operate in quantum potential or Coulomb gauge fashion, it can act as a *direct energy amplifier,* with respect to the lab observer in a singly connected space. In short, the Fogal process dramatically extends the concept of "conservation of energy" to include conservation in multiply connected space and therefore incorporates observed energy amplification in singly connected space. Again, a broken symmetry (in singly connected space) reveals a higher symmetry (in multiply connected space), and the hierarchy principle is alive and well. In short, with the Fogal semiconductor used in power systems, the law of conservation of energy must be extended to include energy symmetry in multiply connected space but asymmetry in singly connected space. Obviously, such functioning totally transcends the limitations of the present thermodynamics models.

We carefully point out that this is not "energy creation" but simply the energy following the known kind of statistics in physics that allows a thing to be in multiple different places simultaneously. What is actually "instantly transmitted" is the simultaneous regauging of the energy density of the vacuum. At any point in space, the vacuum has an energy density and thus is a scalar potential with a given magnitude. Changing the energy density is simply regauging, which is freely permitted under the gauge freedom axiom of quantum field theory. So instant amplification of energy" over a region of points is simply the instant regauging of the potential already present at each point in the region. It is *a permissible multiply connected space violation* of the present more limited "special case" energy conservation concept, which implicitly assumes a singly connected space. We have been working with Fogal for some time in this area, and we expect to rapidly develop and introduce commercial EM power systems based on the Fogal semiconductor's abilities in multiply connected space, as soon as it is in production and available. Until then, the details of our work in that area must remain highly proprietary.

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[140] This should not be too surprising, since the bare charge and the bare mass of every electron each has infinite energy, as is well known in particle physics. For confirmation in very straightforward language, see Nobelist Steven Weinberg, *Dreams of a Final Theory,* Vintage Books, Random House, 1993, p. 109-110.

[141] If we wish, we can even take time itself as a special kind of quantum potential, since time also displays such a "multiplicity of connection" in 3-space. In one sense, time is the ultimate quantum potential, since a single point in time is "connected" to every single 3-space point in the universe, simultaneously.

5.8.4 Point-Contact Transistor.

Figure 5-8 diagrammatically shows a point-contact transistor with n-type base in a typical circuit for power gain. The point of the contact is under pressure on the material with which it is in contact.

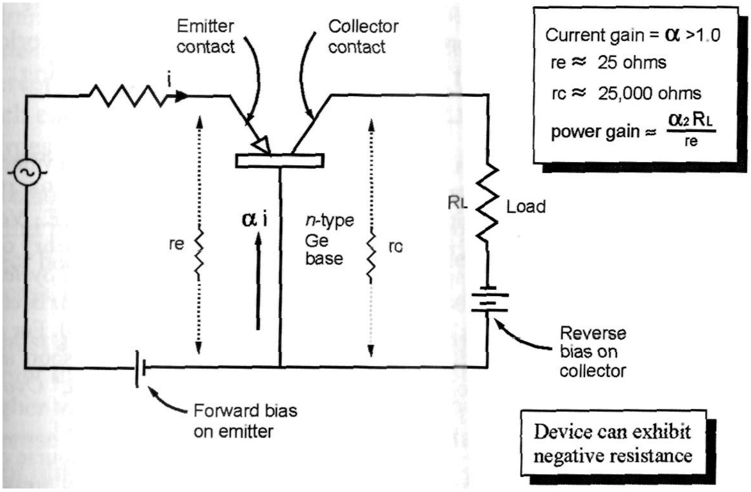
Emitter contact
Collector contact
i
Current gain = α >1.0
re ≈ 25 ohms
rc ≈ 25,000 ohms
power gain ≈ $\frac{\alpha_2 R_L}{re}$
RL
Load
α i
n-type Ge base
re
rc
Reverse bias on collector
Forward bias on emitter
Device can exhibit negative resistance

Figure 5-8 Point contact transistor with n-type base.

The point-contact transistor often behaved in true negative resistor fashion, outputting more energy than was input to it. Its production was always far **more** of an art than a science.

As can be seen from our quotation at the beginning of this chapter, the original point-contact transistor was never thoroughly understood technically.[142] Specifically, there does not appear to have ever been any deliberate attempt to capitalize on the ability of the transistor to become a true negative resistor under certain manufacturing techniques and under certain conditions.[143] Instead, the variations and difficulties in manufacture resulted in use of the point-contact transistor being essentially bypassed rather quickly, by advancing to other transistor types more easily manufactured and with less manufacturing variances. In reducing the manufacture of other types of transistors to a science rather than an art, the point-contact transistor and its further development and optimization into reliable true negative resistors were abandoned.

We present this transistor as a straightforward and relatively inexpensive area in which young researchers in COP>1.0 systems and phenomenology may wish to begin, assuming they have access to semiconductor facilities in a university or similar or are willing to work meticulously under a jeweler's loupe. A rich combination of effects in the transistor awaits optimization and control. We predict that we shall yet see, on the world market of the future, such point contact transistors reliably exhibiting negative resistance. It will be necessary, however, to also take into account the symmetrical self-regauging characteristics of the common closed-current-loop circuit. By adroit switching of a true negative resistor in and out of a closed-current-loop branch, or placing it in parallel with the back emf of that branch to reduce it, asymmetry can be introduced into the overall closed current loop circuit, defeating the Lorentz symmetrical regauging. Defeating the Lorentz condition is essential to COP>1.0, of course.

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[142] E.g., different theories are given in: (a) W. Shockley, "Theories of high values of alpha for collector contacts on germanium," *Phys. Rev.,* Vol. 78, 1950, p. 294; (b) W. R. Sittner, "Current multiplication in the Type A transistor," *Proc. I.R.E.,* Vol. 40, Apr. 1952, p. 448-454. Also of interest is (c) W. van Roosbroeck, "Theory of the flow of electrons and holes in germanium and other semiconductors," *Bell System Tech. J.,* Vol. 29, Oct. 1950, p. 560-607. See also (d) J. Bardeen and W. H. Brattain, "The transistor, a semiconductor triode," *Phys. Rev.,* Vol. 74, 1948, p. 230. For a more modern re-examination, see Shuji Hasegawa *et at,* "Electronic transport at semiconductor surfaces — from point-contact transistor to multi-tip STM," *Oyo Buturi,* 70(10), 2001, p. 1165-1171 (in Japanese).

[143] E.g., the point contact is usually under pressure, and this pressure of course can be varied. The full phenomenology of points (which increase voltage) and pressure, complicated by surface effects as well, has not been worked out in physics. Note the similarity of the pressure in the point contact transistor to the pressure in the Chung negative resistor. Note the almost certain involvement of the "overpotential" of chemistry and electrode chemistry, as well as the "double surface" effect of the small gap between the point and the substrate on which it rests in contact. Part of the gap probably even involves the Casimir effect as well. Any electrical signal variation in that very complex point junction will vary the overpotential, the stress potential, the "point increase in voltage" effect, etc. As can be seen, the phenomenology of the point contact is remarkably complex and rich in several areas of physics and in a great variety of physics variables. Obviously, the reasonable control of all these highly nonlinear variables — and their mutual interactions — is a difficult matter. Hence the readiness with which point contact transistors were dropped with substantial sighs of relief.

We envision such a development as an ideal "negative resistance shunt" to add across the secondary of a transformer, and another possibly across its primary and across the external power supply as well, in producing more amenable and easily fabricated COP>1.0 electrical systems. We also point out that, once the back emf or back mmf forcing of equal power dissipation in the primary of a transformer or in the emf section of a circuit is dramatically reduced or eliminated, one does not require "large intensity" potentials and voltages to collect a great deal of power in the intercepting and receiving external circuit. Again, by simple W = Vq, as much energy W can be collected from any nonzero potential V as there are charges q to intercept.

We also envision such a true negative resistor being close-looped by the Bedini process, thus producing a small "self-powering" transistor, which in effect becomes a small self-powering "battery". This is absolutely a doable process, and it will be done once the Fogal semiconductor is in production.

Almost all semiconductor materials are also optically active materials, and a point discharge into such materials represents a very sharp regauging (higher voltage) discharge at a point or into a very small area, due to the increase in potential at the tip where it contacts the base material. The point junction is under pressure, so a stress potential exists there. In addition, the well-known "point" effect also increases the potential in the junction pointer itself, from its base to the point. The point contact phenomenology of different materials — one conductive and one semiconductive — is of much interest, and with novel phenomenology.

The fact that the point-contact transistor in its most usual formulation primarily uses holes more than electrons, is also of much interest in COP>1.0 situations. Holes in a circuit move against the voltage. The trick is to let the Dirac holes *before observation* move in an open path from the ground return line against the back emf to the potentialization line, and **transduce** the moving hole current (via the Bedini process) into electron current after the holes have already freely reached the vicinity of the high side of the circuit.

When Dirac sea holes (causal positrons before observation and thus prior to their alteration to lattice holes and parity reversal) and Dirac sea hole current are also involved with point-contact transistors, the resulting phenomenology has been but little investigated and none of it is in the present textbooks. However, from recent work with positron probes and positron microscopes to examine semiconductors and semiconductor materials, it is known that the holes (positrons) tend to be repelled from nuclei in the material into defects (voids) in it {331}. These effects have been investigated, for example by Triftshauser *et al.* {332}.

Both the mechanical stress potential (which is fundamentally electromagnetic) and the heightened junction potential decompose via our reinterpretation of Whittaker's 1903 decomposition of the scalar potential. This leads to optical-type pumping in both the time domain as well as the 3-space domain. Hence novel optical-type effects and time-reversal of material states can be involved, leading to a very complex set of phase conjugate phenomena, time-reversal phenomena, etc.

Certain Hall effects employed in conjunction with a point contact transistor could be a fruitful area of investigation. As an example, narrow Hall bars with junctions between current and voltage leads of various geometries could be investigated. Widening the junction from the normal square-cornered shape can sometimes produce a negative Hall resistance.

The junction of the point contact involves asymmetrical self-regauging, iterative time-reversal retroreflection, increased Poynting and Heaviside energy flow components, optical scattering processes inside the junction materials, etc. The transistor can indeed be manufactured so that these highly nonlinear effects sum to a negative-resistor-like movement of the output current against the voltage, although with so many other phenomena involved it will require some hard work and research in order to develop and stabilize it — and understand it.

5.8.5 Bedini's Negative Resistor Process in a Battery {333}.

5.8.5.1 Some Pertinent Lead-Acid Battery Processes

A lead-acid storage battery is a highly nonlinear device. The plates may be plante, pasted, or tubular etc. They are usually highly porous and have a thin oxide layer. They may have other coatings and the electrolyte solution may include additives to enhance operation. The plates consist of a mix of crystalline materials in most cases. The plate materials include acicular (needle-like) crystals, particularly the negative plate. The plates usually are porous, knit, and have gridded separators.

The chemistry of the battery electrolyte is complex and — even today — not all of it is well understood, particularly when mass transport is accounted. In our discussions, we will be including some of the previously neglected phenomena during mass transport (ion sluggishness in moving) that are responsible for some of that lack of understanding. In the battery chemistry, there are many double surfaces between the ions and also there is a variety of point voltages. There is a separate theory for double surfaces.

One of the most important phenomena is that the ion currents in the electrolyte are confined to the battery, and do not pass out into the external circuit. Much of the electron currents in the external circuit are blocked at the plates from moving within the electrolyte. Consequently, we will limit our discussion to two major currents of interest[144] in a battery-powered system, and these currents are effectively isolated from each other (at least to first order). Those currents are (i) the ion currents in the electrolyte, confined to between the plates and therefore internal to the battery electrolyte, and (ii) the electron currents between the outside of each plate through the inside of the plate and on out through the external circuit and **then** around to the inside and thence to the outside of the other plate. Chemical changes occur on the plates themselves as a result of these two currents.

It is usually assumed in power systems that these two currents are in phase or almost entirely so. That need not be true at all, and Bedini takes specific advantage of deliberately arranging these two currents to be antiphased part of the time. Part of the Bedini effect can be understood from this fact alone; the other part must consider one other most unusual electrical current that is encountered only in battery-powered systems or COP»1.0 systems.

So indeed there are *several* (many) currents in a lead acid battery [334], not just one, and we will consider three of them — the two previously mentioned, and an additional Dirac sea hole current in the local vacuum **itself.** The reader interested in greater technical depth should also turn to the literature of electrode chemistry and electrochemistry {335a-f}, which is quite complex.

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[144] Of course, there are many other currents in a battery as well, but — although an oversimplification — these two major currents together with the Dirac sea hole current will suffice for our introductory modeling and explanation purposes.

5.8.5.2 Dirac Sea Hole Current

In a battery-powered COP»1.0 system (and in some COP>1.0 systems), there is a previously unrecognized significant flow of Dirac hole current in the local vacuum, running from the output section of the system to the system input section and thence through the conductors into the battery terminals and onto the battery plates, and on into the battery electrolyte chemistry. This hole current may be greater — *evenfar* greater — than the normal electron current running from input to output.

So in the battery-powered overunity system with positive feedback, not only does an electron current run from the battery through the connecting conductors to the input section of the system, but also a Dirac hole current pours back out of the system input section, and — if not intercepted and transduced — through the conductors and back into the battery. All the while, this Dirac hole current is "eating" electrons being furnished by the battery to the system. The net result is that the battery "sees" an extra load to be powered, in addition to the ordinary load presented to it by the normal system input section. It "sees" the situation as an "extra load" because it first has to furnish sufficient electron current to fill the hole current and "kill" it, before it can furnish the additional electrons to power the system in normal fashion.[145]

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[145] An odd effect occurs in the battery, however, when the battery completely discharges in the normal sense. Actually, it is still fully charged with positive energy charge, but also has been simultaneously charged with negative energy charge. With the excess negative energy holes continuing to charge the battery with negative energy charge, the battery becomes increasingly *charged with net negative energy.* There is almost no limit to the negative energy charge the battery (i.e., the local Dirac vacuum portion of its supersystem) can take, except the eventual development of antigravity effects due to the inverse and increasing curvature of local spacetime in which the battery is embedded. After a battery has been used to power a COP»1.0 system for some time, one can take the battery off, place it on a normal battery charger, and it will then "eat" positive power for an extended period of time — e.g., a week or longer. During this period, one is steadily negating the inverse curvature of the local vacuum via the increased positive energy collecting in that spacetime. The battery again finally passes through zero voltage and net charge again, and suddenly starts charging up again in a "normal" sense with positive energy charge. This process actually increases the lifetime and function of a battery in a startling manner. Bedini has used batteries almost devoid of charge and energy in the normal sense, and powered systems very well with them, even for longer than a year continuously.

A COP»1.0 EM system is an excited system far from equilibrium in its exchange with its active environment. For all such excited systems, there exist significant decay mechanisms to bring the system back into equilibrium with its environment, since equilibrium yields the lowest energy state and maximum entropy. The Dirac sea hole current (negative energy current) is nature's unexpected natural decay mechanism to sharply decay a COP»1.0 system back to an overall COP<1.0 system when the external power supply is considered also.[146]

So when Dirac hole current back through the local vacuum and through the system is involved, the battery first has to furnish electron current to fill these holes at the rate they are appearing in the input section, thereby furnishing a primary "hole-filling" electron current component which "disappears" into the Dirac vacuum and is lost.[147] Only after the holes in the hole current are filled — and the hole current is being steadily nullified

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[146] It decays the *true negative resistor* power system back into being only a *dijjerential negative resistor section* of a slightly extended metasystem including the power system and its external power supply. This novel decay mechanism also prohibits close-looping the now differential negative resistance power system for self-powering, unless the hole current is first converted into electron current, as discussed in Chapter 9 and in paragraph 4.9.6 below.

[147] The filling of these Dirac sea holes is not pair annihilation in the usual sense, and no radiation is emitted. Instead, the energy of the radiation that would otherwise be emitted is added to the negative energy curving the spacetime. Hence the net curvature of spacetime relaxes because of superposition. In effect, the vacuum/spacetime itself reabsorbs the energy as relaxation spatial energy added to the curvature energy of the curved spacetime, reducing that curvature. Particularly see Mendel Sachs, *Quantum Mechanics from General Relativity: An Approximation for a Theory of Inertia,* Reidel (now Kluwer), 1986. A generalization of quantum mechanics is demonstrated in the context of general relativity, following from a generally covariant field theory of inertia. Nonrelativistically, the formalism corresponds with linear quantum mechanics. In the limit of special relativity, nonlinearity remains and several new features are derived: (i) Particle-antiparticle pairs do not annihilate; an exact bound state solution is derived corresponding with all experimental facts about annihilation/creation — which, in approximation, gives the blackbody radiation spectrum for a sea of such pairs, (ii) A result is proven, without approximation, that is physically equivalent to the Pauli exclusion principle- which in linear approximation gives the totally antisymmetrised main-body wave function and Fermi-Dirac statistics, (iii) The hydrogen spectrum is derived, including the Lamb shifts, in agreement with experiment; new results are found for high-energy electron-proton scattering, (iv) Finally, several applications to the elementary particle domain are demonstrated, in agreement with results from experimental high-energy physics.

— can the battery then send additional electrons which do not disappear and which are accepted in the system input section to power the system. We discuss this Dirac hole current in some detail in Chapter 9, including how to convert it into useful input electron current to the system, reducing the current load on the external generator and enabling self-powering. Bedini invented the method of transducing available negative energy hole current in the vacuum into electron positive energy flow to charge the battery and power the system, preventing decay of the COP»1.0 system back to COP<1.0.

We shall not discuss the complexity of the additional chemical reactions ongoing in the battery electrolyte and on the plates. The two main mass-containing currents and the negative energy Dirac hole current will suffice to explain the Bedini negative resistor formation and usage, at least to first order and sufficient to stabilize systems.

5.8.5.3 Changing Symmetrical to Asymmetrical Regauging

To first order, we reiterate that the electrons flow from one plate of the battery through the external circuit to the other plate, but the lead ions do not. There is thus a sharp "two separate currents" interface at the plates and thus a sharp separation between the electron current and the ion current. In short, there are actually two half-circuits in the battery-powered system if one chooses to use them semi-independently.

The current carriers in the two half-circuits are quite different. Therein lies the opportunity to separate and antiphase the two currents, using one to recharge the battery while the other is used to power the loads. It also allows a good opportunity to asymmetrically regauge both half circuits, greatly and freely increasing the Poynting energy component intercepted, collected, and used by each half-circuit's carriers. This is the basis for a profound "opening" of the system and influx of excess vacuum energy.

The two half circuits meeting at a common interface allow a stress potential upon that interface to *individually* use the two halves of what is normally Lorentz's symmetrical regauging. That usually *symmetrical* regauging (if the complete circuit were unitary) is now comprised of two separated *asymmetrical* regaugings, one for each of the two circuit halves, because the net stress potential (net Lorentz symmetrical regauging) — consisting of two opposing fields and forces — is split into two now-individually-separated and separately utilized force fields.

We accent this process by an analogy. Suppose we suddenly place a scalar potential ϕ upon a point in the middle of a transmission line. Immediately the potential ϕ races off (spreads) in both directions simultaneously, at nearly light speed. Further, in each direction there is a moving gradient of ϕ, hence an E-field by $\mathbf{E} = -\nabla\phi$. These E-fields or "emfs" are oriented in opposite directions, so there is a movement of charge from the middle of the line toward each of the ends. The same "dephasing" current effect can be applied to any conductive medium or to the interface between two conductive circuits.

In Bedini's negative resistor case, the placement of the potential ϕ — for its movement in both directions — is on the interface (the face of the lead plates) between the two half circuits and therefore between the two different current carrier types. An initial "Lenz's law" reacting with the suddenly placed E-field onto the plate surface, creates an E-field in opposition, forming a stress potential ϕ which is much higher than the normal potential of the battery (in a nominal case, 100 volts instead of the 12 volts of the battery).

Immediately this potential "takes off in both directions", with a powerful E-field and emf back into the outside circuit and its load, while a powerful E-field and emf also proceed into the battery electrolyte in the opposite direction. So the ions in the battery have a sudden, much higher energy interception and collection forced upon them, with the excess emf now being in *battery-charging mode.* The electrons in the outside circuit simultaneously have an excess emf and potentialization *in the load-powering mode.* Let us see how the two very different current carriers react to these "dual emfs" in the overall circuit.

5.8.5.4 Mass-to-Charge Ratios of the Two Current-Carrier Types

We stress the dramatic difference in the *mass-to-charge (m/q) ratio* of the two currents. The lead ions' m/q ratio is some few hundred thousand times the m/q ratio of electrons, as we recall. For our purposes, all we need to know is that the m/q ratio for the lead ions is *very much larger* than the m/q ratio for the electrons. For a given force, the ions in the internal half circuit in the electrolyte will therefore respond very much slower than will the electrons in the external circuit half.

5.8.5.5 Hysteresis Between the Responses of the Two Half-Circuits

Because of this great disparity in the m/q ratios of the two mass currents, there is obviously a relatively significant hysteresis (time delay) between the *response* of the more massive ion current and the *response* of the far **less** massive electron currents that interact at the plates to try to change the ion current and its momentum. This time-delay between ion response in the electrolyte (the effect) and electron pileup urging (the cause) can be adroitly manipulated. Specifically, it can be used to alter the local vacuum potential and cause it to add excess energy to the ions in charging mode **and** simultaneously to add excess EMF to the electrons in circuit-powering mode. In short, the response delay can be manupulated to "asymmetrically regauge" the mass currents in the system, freely changing their potential energy, and dramatically increasing how much potential energy is available for battery recharging and how much is available for powering the external circuit (loads and losses). Further, during the antiphase condition of the two current halves, the battery can be charged simultaneously while the external circuit half and load is being powered. Excess energy is fed into both actions by the *overpotential* (the stress potential) created at the surface of the plates.

5.8.5.6 Evoking the Initial Bedini Negative Resistor Effect

Figure 5-9 shows the first phase of Bedini's negative resistor process. Consider the battery in normal load-powering operation. From the external circuit, a very sharp leading edge rise of a pulse of electrons and potential is sent to the battery plates in "back-popping" or "battery charging" mode. The back-popping electrons drive in nearly instantly, piling up on the negative plate[148] and trying to force the heavy ions to start moving in the battery recharging direction. The pile-up that results in the stopped electrons on the battery plate surface represents an increase in local current density, hence an increased potential. This produces the 100 volts potential, during the time that the ions have not yet responded to any appreciable degree.

Due to much larger m/q ratio of the sluggish for a moment they lag due to their greater inertia, and this allows the much more agile electrons to "pile-up", producing a substantial overpotential as the local current density increases. The lagging ions are being steadily overpotentialized during this "lag time", up to about 100 volts in a normal 12-volt battery. At the same time, electrons are being forced back out of that higher 100-volt area and into the external circuit and its load, which had been at 12 volts. Recall now that these electrons can move longitudinally only at the drift velocity. Hence all electrons in the external circuit are now highly overpotentialized, and in *load-powering mode. The* overpotentialized electrons are thus producing excess power in the external circuit, much more than normal.

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[148] We are not using conventional "positive current and positive plate" as the high side of the potential. We are using "electron current and the negative plate" as the driving potential plate.

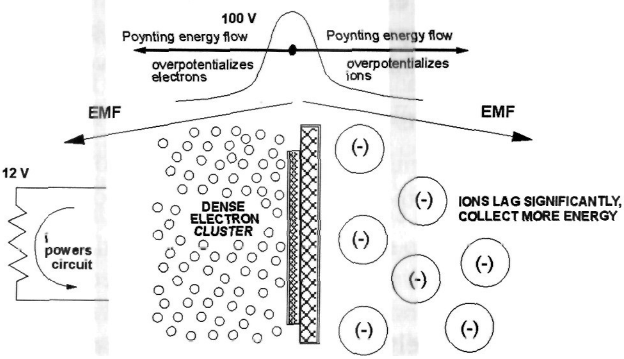

1 Sharp leading edge voltage pulse produces intense electron clustering and large potential (negative resistor) *at* interface *Sluggish ions only beginning to move*

2 Bidirectional Poynting energy flow from potential overpotentializes both the electron cluster and the ions, which are only beginning to move in charge mode

4 Large back emf Into circuit returns overpotentialized electron current, powering circuit with excess energy pouring from negative resistor potential Continues dunng ion delay

5 Simultaneously overpotentialized ion current is overcharging battery

Figure 5-9 Phase I of the Bedim negative resistor process in a storage battery.

Then the overpotentialized ions very slowly (compared to the electrons!) slow, stop, and begin to move in the opposite direction. They reluctantly respond and move in *battery recharging mode.* During that ion-response lag time, and the slower initial portion of the response, the electrons in the pulse continue to furiously surge in and pile-up on the negative plate, overpotentializing both the ions and the external circuit's electrons, while also some of them are being impelled back out into the external circuit to power it with extra overpotentialized energy dissipation. The charge density at that plate sharply increases due to the pile-up where the charges are "squeezing" together (clustering). There is a much higher potential suddenly rising in the squeezed charge cluster, because of the increased charge density there. As we stated, this potential nominally may be about 100 volts during this initial phase.

We call attention to the simple equation W = VQ, where W is the potential energy added to charges Q exposed to voltage V.

Simplified, the excess energy W_{IONS} freely impressed upon the ions is

$$W_{IONS} = f(100 - 12)(Q_{IONS}) \qquad [4\text{-}3]$$

where Q is the total coulombs of charge of overpotentialized ions and f(100 -12) is the magnitude of the overpotentialization of the ions.

At the same time, an excess energy is impressed upon the electrons in the external circuit by the same potential extending along the conductors into the external circuit. Again, this excess energy WE is given by

$$W_E = f(100 - 12)(Q_E) \qquad [4\text{-}4]$$

where Q_E is the total coulombs of charge of the overpotentialized electrons and f(100 -12) is the magnitude of the overpotentialization of the electrons.

But the emf on the electrons from the pile-up is directed in load-powering direction, as can be seen. Consequently the ion current and the electron current have been deliberately dephased by 180°, and so the overpotential energy of the ions is delivered in battery-recharging mode, while the overpotential energy of the electrons is delivered in circuit load powering mode.

Recapitulating: Pulsed pile-up of excess electrons on the negative plate interface between the two currents, while the ions are beginning to respond or only sluggishly responding, produces a much higher potential (an *overpotential)* on the sluggish ions — nominally some 100 volts in a 12-volt battery. On the negative plate, momentarily there is now a much higher voltage (with respect to the positive plate) than normally exists in the 12-volt battery. This voltage *overpotentializes* both the reluctant charging ions in the battery solution between the plates, and the powering electrons back into the circuit in powering mode due to the reversal of the emf. Since there is, say, 100 volts across the battery momentarily, there is also 100 volts now across the external circuit momentarily. Accordingly, overpotential excess powering of the external circuit load is suddenly evoked, while at the same time overpotential recharging of the battery is also evoked.[149]

In short, the ion current in the battery and the electron current into the external circuit have been placed 180° out of phase, achieving one major requirement for a COP>1.0 electrical system: *violating the integrity of the closed current loop circuit.* The battery is recharging at the same time that the external circuit is being powered, *from the same free overpotential,* and both recharging and circuit powering are driven by increased emf.

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[149] Another of Bedini's innovations is to shunt the excess voltage (say, above 14 volts) into an external capacitor on the circuit side. In that way with his overpotential he can be (i) overcharging the battery, (ii) powering the load, and (iii) storing excess energy in that capacitor, from the altered vacuum — all simultaneously.

We strongly accent that the overpotential at the plates represents a change in the local vacuum potential, and it *identically is* part of that now-altered local vacuum potential. The vacuum, since it contains enormous EM energy in virtual state, is a very powerful EM potential. Any EM potential in our circuits is automatically a change to the ambient vacuum potential, or a change to another potential that is such a change to the vacuum potential. In the most exact sense, this is a method of overpotentializing the plate interface with excess energy from the vacuum, and then letting that energy flow onto the ions to recharge the battery and onto the electrons in the external circuit to power it and its load.

The Bedini overpotential at the battery plates decomposes via Whittaker 1903 {85} as reinterpreted and previously explained, so that excess energy is entering 3-space there, *from the time domain.* Further, the piled-up electrons on the plates and the ions (as charges) in the solution receive such potential energy from the increased potential on them via the same decomposition process. So the creation of the Bedini overpotential on the battery plates, together with dephasing the two currents, is the creation of a true negative resistor at the plates, freely receiving energy from the external vacuum (from the time domain and virtual state) and transducing it into real potential energy and emf on the internal ions and on the external circuit electrons.

Hence Bedini has invented a process for creating a true negative resistor inside a storage battery, and for suddenly thrusting the system out of equilibrium with both the active local vacuum and the active local curvatures of spacetime. As such, the thermodynamics of open systems far from thermodynamic equilibrium applies, and that system is permitted to exhibit COP>1.0, while complying with energy conservation and the laws of physics and thermodynamics. With adroit use and collection of the excess energy, the externally collected energy can be used to close-loop the system and power all its functions. So the system is permitted to power itself and its loads, with all the energy being received from the vacuum via the broken symmetry created. Any overpotential is a dipolarity *a priori,* since any potential is. Hence creating an overpotential is precisely producing an extra broken symmetry of that dipolarity right there at the interface between the two half-circuits and the two dephased, localized currents.

During the "back-popping" pulse signals, one should not think of the energy pulses that Bedini inputs to the battery as the "powering" energy. Instead, one must think of each pulse as "triggering" and "timing" energy which initiates certain other key *negentropic* interactions to freely occur, once the electron pile-up occurs. The resulting negentropic interactions then add substantial additional energy (from the local active vacuum) to the ions in the ion current and to the electrons in the electron current. The freely added energy can be appreciably more than the switching or triggering energy that is dissipated as the "input by the operator".

In short, Bedini deliberately "switches"' and "triggers" certain kinds of vacuum exchange interactions, effectively creating a *true negative resistor* in the battery itself.[150] Due to the broken symmetry of the increased dipolarity *(overpotential)* that Bedini makes in "electron pile-ups" urging reluctant and delayed ion response, the vacuum furnishes extra virtual particle flux to this pile-up of electrons on the plate, which produces an enhanced Poynting energy flow that interacts with the ions in the battery electrolyte. Being charges, these ions thus transduce some of the excess absorbed virtual photon energy into real observable energy, thus increasing their potentialization and energy.

Bedini's method does the following: (i) It forms a true negative resistor in an unexpected way, upon the plates between a pile-up of electrons and the ions in solution in a common lead acid battery, (ii) it uses that negative resistor to extract excess energy from the vacuum and furnish it both to the ions forced into charging mode and simultaneously to the electrons in load powering mode, and (iii) it adds several other stimuli (such as Lenz law effects) which further amplify the negative resistor and enhance the effect, increasing the excess energy extracted from the vacuum and collected in the battery-charging process and also in the circuit-powering process simultaneously.

Specifically, the delay in ion response is adroitly allowed for and manipulated by Bedini to place the battery in ion current recharging mode while the signal pulse electrons between the plates and the external circuit are simultaneously placed in external circuit powering mode. By manipulating the hysteresis and adroitly timing the electron pulses and pulse widths, *Bedini breaks the usual forced Lorentz symmetry of the excitation discharge in a usually closed current loop containing both the*

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[150] Again we stress that any dipolarity or potential is a negative resistor, producing giant negentropy {12}.

battery's source dipole and the external load. This is possible since his method deliberately opens the system so that vacuum energy enters freely, increasing the potentialization (energy collection) of the ions in the battery solution and upon the electrons between the plates and the external circuit as well.

We stress that Bedini has chosen to *avoid the* usual dissipation of half the energy collected in the external circuit to do nothing but kill the source dipolarity between the battery plates. He works on "that half of the circuit" that is usually just called the "back emf region" and ignored, and he separates and dephases that half of the circuit from the other half. By interrupting that normal "back emf battery-discharging section dynamics and converting it to "forward emf battery recharging section dynamics, while simultaneously powering the external load, Bedini temporarily produces and utilizes a negative resistor right there on the surface of the battery plates themselves.

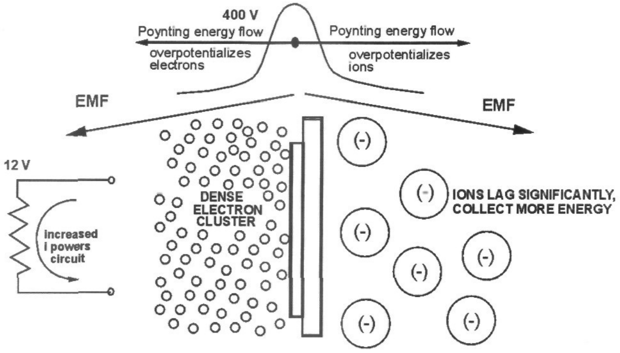

1 Sharp trailing edge of voltage pulse produces intense Lenz law effect Sharply increases electron clustering and potential (negative resistor) at interface Sluggish ions delay speedup further increasing the Lenz law effect

2 Increased bidirectional Poynting energy flow from potential overpotentializes even further both the electron cluster and the ions, which are only beginning to accelerate in charge mode

4 Large new increased back emf into circuit returns overpotentialized electron current powering circuit with new excess energy pouring from negative resistor potential Continues during ion delay

5 Simultaneously, re-overpotentialized ion current is overcharging battery even faster

Figure 5-10 Phase II of the Bedini negative resistor process in a storage battery

5.8.5.7 Further Increase of the Negative Resistor Effect by Lenz's Law

See Figure 5-10. To further increase the Phase I effect just before it would end, and requiring precise timing of his switching of the pulse leading edge and trailing edge, Bedini then invokes a second phase by carefully controlling the timing for the sharp *cutoff of* the "stimulus pulse" creating the negative resistor. This is usually invoked just as Phase I is preparing to end, but experimentation and adjustment for optimization to the individual circuit conditions may be required.

Invoking the Lenz law reaction by minimizing the stimulus pulse cutoff time, Bedini sharply increases the already-increased negative resistor overpotential by a Lenz's law induced voltage surge, and sharply raises it to as much as 400 volts nominally. The process also sustains the negative resistor overpotential for a longer period, while increasing it again during this second phase. Thus even more free energy from the altered local vacuum potential is delivered to the ions in charging mode inside the battery, while simultaneously even more energy is delivered to the external circuit electrons in powering mode. The overpotential period is also extended. In this second phase, the extra energy W_{IONS} added to the ions in recharging mode is given by

$$W_{IONS} = f(400 - 12)(Q_{IONS}) \qquad [4\text{-}5]$$

and the extra energy W_E added to the electrons in system powering mode is given by

$$W_E = f(400-12)(Q_E) \qquad [4\text{-}6]$$

The total energy added to the system in Phase I by the negative resistor is

$$W_T = W_{IONS} + W_E = f(100-12)(Q_E + Q_{IONS}) \qquad [4\text{-}7]$$

The total energy added to the system in Phase II by the negative resistor is

$$W_T = W_{IONS} + W_E = f(400-12)(Q_E + Q_{IONS}) \qquad [4\text{-}8]$$

And so the total energy added to the system by the Bedini process is just the summation of equations [4-7] and [4-8]. With adroit switching, Bedini need only "pay" a small fraction of that freely received excess energy, in his own operator's input pulse energy and switching costs.

So by invoking a novel negative resistance effect directly upon the driving plate of the battery, Bedini creates (in the first phase) and then further enhances (in the second phase) a "nearly free" overpotential and overpotential period inside the battery. This excess potential directly upon the electron-pileup plate acts in both directions — out into the electrolyte between the plates to overpotentialize the ions in charging mode, and back out into the external circuit in powering mode to overpotentialize the electrons now powering the load. During a fraction of the operating cycle, Bedini recharges the battery while powering the circuit simultaneously, and thus has invented a novel method for extracting energy from the vacuum and curved spacetime to enable a COP>1.0 power system.

This is just a description of one fundamental period where Bedini applies his negative resistance process.

Several other places in the operation of the circuit lend themselves to additional phases of negative resistor formation and usage, and Bedini does use them. We do not discuss them here, since our purpose is only to advance the *fundamental principle involved.*

5.8.6 Independent Replication of the Bedini Negative Resistor Effect

Independent replication of the Bedini effect was accomplished early on by Nelson and by Cole, and also by Watson. Nelson has chosen not to further publicize his own work for some years, perhaps due to his employment as a microwave switching engineer in a large (and conservative) aerospace company. Cole is deceased, and Watson abruptly withdrew —forcibly, in our opinion — from public research and all further contact with his close colleagues after successfully demonstrating (in 1984) an 8-kilowatt power system utilizing a modification of the Bedini process. We are almost certain that Watson received the "offer he could not refuse", and that Watson-type COP>1.0 power systems are in fact already powering exotic underground facilities that "officially do not exist" but which we are aware of. We briefly discuss Watson's 8 kW generator at the end of this Chapter.

For non-battery powered systems, as we explain in Chapter 9, any unitary COP»1.0 EM system may experience a Dirac sea hole current decay mechanism which will produce an effective extra "load" in the system's input section, including on out into the external power system. As a general rule (sometimes violated), we estimate that the effect begins to be of importance at COP > 10^3 or so. Certainly it is of great importance in the range of COP > 10^5. To operate stably at COP » 1.0, this decay mechanism must be dealt with and prevented. For close-looping into self-powering mode, this negative energy feedback must be converted to positive energy feedback, thus allowing self-powering mode where all the input energy is freely received from the vacuum.

For battery powered systems, the hole current and "extra load in the input section" becomes of significance near COP = 2.0 or even less, because of interaction with the complex battery chemistry and the tendency to charge **the** battery with negative energy as well. So battery powered systems present a special problem for close-looping to achieve sustained self-operation. Bedini has long solved and demonstrated solutions to that problem in a variety of successful experimental systems.

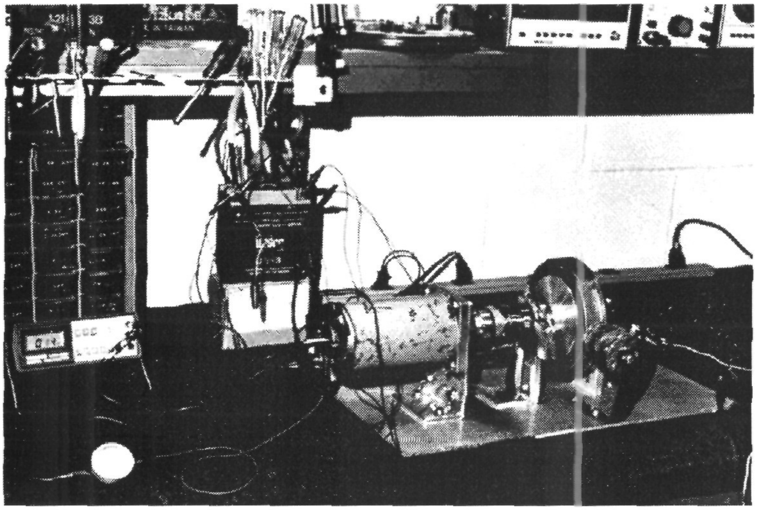

Figure 5-11 **Bedini motor** similar to the **type which ran continuously off a battery for three years, simultaneously recharging the battery.**

To utilize Bedini's battery-powered system at COP > 2.0, or to close-loop it for sustained operation, one must add another Bedini process that transforms negative energy current into positive energy current. That is Bedini's *transducing* negative resistor process {336}. We describe that process briefly in the next paragraph below.

Bedini has built many different motor-generator versions of systems self-powered by use of his negative resistor processes. Figure 5-11 shows a Bedini motor similar to one that once ran off a single battery for more than three years without stopping, using the forerunner of the Bedini back-popping process for creating a negative resistance in the battery. Bedini is still building and testing such power systems; one of his prototype motor-generators today, capable of operating and self-powering off a single battery, is shown in Figure 5-12.

5.8.7 Bedini's Transducing Negative Resistor.

Figure 5-13 gives a simplified block diagram of Bedini's transducing negative resistor process, which asymmetrically regauges negative EM energy into positive EM energy. With this process Bedini is able to intercept the Dirac sea hole current running from the output section of a COP>1.0 EM system to its input section, and divert the negative energy Dirac hole current to "reverse charge" a capacitor. The "reverse charge" consists of providing a hole current to the anti-negative plate of the

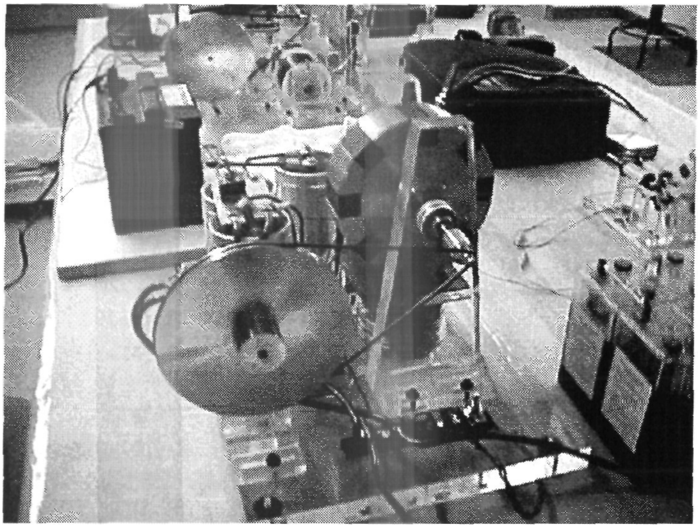

Figure 5-12 Modern Bedini motor prototype which operates off a single battery, powering the load and recharging the battery also.

capacitor, so that holes acting as positrons pile up in the local vacuum of **that** plate. This attracts the trapped electron charges in the dielectric, straining the dielectric in the direction of the hole collection. At the same time, the other plate draws electrons from the system that would otherwise be in currents that fight the back emf of the primary source dipole for the system. That reduces the back emf of the system during the charging of the capacitor; in effect, the back emf has participated in charging the capacitor with excess electrons on the negative plate.

Then Bedini reconnects the charged capacitor to the conductors leading to **the** power supply, discharging the capacitor by electrons furnished to the negative driving plate of the battery powering the system, and simultaneously to the input section of the system itself in normal powering mode. Note that the holes simultaneously discharge from the capacitor's anti-negative plate to the ground side of the battery, further charging the **battery** (the power source!) and the load as well.

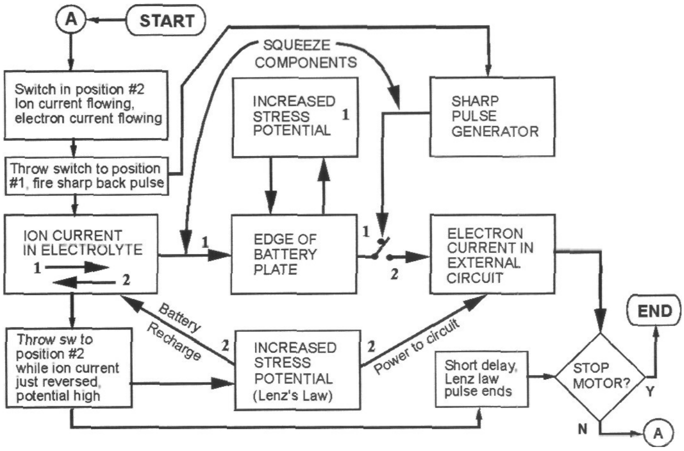
A
START
SQUEEZE COMPONENTS
Switch in position #2 Ion current flowing, electron current flowing
INCREASED STRESS POTENTIAL
1
SHARP PULSE GENERATOR
Throw switch to position #1, fire sharp back pulse
ION CURRENT IN ELECTROLYTE
1
2
1
EDGE OF BATTERY PLATE
1
2
ELECTRON CURRENT IN EXTERNAL CIRCUIT
END
Battery Recharge
Throw sw to position #2 while ion current just reversed, potential high
2
INCREASED STRESS POTENTIAL (Lenz's Law)
2
Power to circuit
Short delay, Lenz law pulse ends
STOP MOTOR?
Y
N
A

Figure 5-13 Bedini transducing negative resistor process block diagram. Adjusting **timing of rear edge of pulse adds additional Lenz law** increase.

Though it does not appear in the conventional textbooks,[151] one can power a load directly by Dirac hole current, but one does so by using the hole current in exactly reverse fashion from how one would use electron current to power the load. Semiconductor components are also critical and usually should be avoided. In short, one simply reverses the terminal that is considered the "driving terminal", and feeds the hole current to that "anti-negative" terminal as now the temporary driving terminal.

The Bedini process thus allows the Dirac hole current (negative energy) produced by a COP>1.0 EM system to be fed back to the input section and transduced into positive energy input to power the system with electron current and also to recharge the battery with positive energy.

---

[151] Lattice hole currents of course do appear and are considered. However, even though the circuit designers consider a lattice hole as a positron, it is not such at all, because the m/q ratio of the ion with one + charge is quite different from the m/q ratio of a true positron. The Dirac hole in the vacuum is effectively the "4-positron" — still in negative energy Dirac 4-electron state — before its observation or interaction with mass. It is a true negative energy entity, and thus a negative mass entity. Prior to observation, it actually should be said to be a "negative energy x time" entity and a negative "masstime" entity. It is also a negative energy electron entity. This subtlety is essential if one wishes to produce successful antigravity experiments on the bench, as we point to in this book and as were exhibited by the Sweet vacuum triode amplifier at COP > $1.5x10^{6}$.

This converts what would otherwise be negative energy feedback to the input section of the system (and to the battery) to positive energy feedback **to** its input section and to the battery. Instead of seeing the negative energy current in the input as an additional "load" to be powered, the external power supply sees it as excess positive energy input by the environment to the system, reducing the "load" represented by the system. It thus reduces the power required by the system from the external power supply.

When the amount of "transduced" positive feedback electron current to the input section equals the "normal electron current draw" required by the system, the battery (or generator) can be disconnected and the unit will continue to operate in the self-powering mode, fed completely by the positive energy from the Bedini transduction process. The other *supersystem components* (comprising the external environment of the system) will continue to power the system and its loads and losses, with all the input energy to the system being taken from the combined active local vacuum and local curvature of spacetime.

5.8.8 Gray's "Splitting the Positive Pole" Engine.

One of the real pioneers in early application of causal positron energy was inventor Edwin V. Gray of Van Nuys California. In WW II Gray learned radar during his tour in the U.S. Navy, having previously attended advanced engineering school in the Army until discovered to be under age 15 and discharged. After the war, by 1958 he had learned to perform what he called "splitting the positive pole", using "cold electrical energy" (his name for negative EM energy) as well as the normal positive electrical energy. His first motor was operating by 1961. Preparing to put units into production, in 1974 the Los Angeles District Attorney confiscated all Gray's records and prototypes. To escape bogus charges, Gray later pleaded guilty to two minor infractions and was released. His prototypes were never returned. After several mishaps, moves, and more prototypes, Gray died in Nevada under mysterious circumstances in April 1989. We quote directly from Lindemann {341}:

> *"In the early 1980's, Gray offered the U.S. Government his technology to augment Reagan's SDI program. He actually wrote letters to every member of Congress, both Senators and Representatives, as well as the President, Vice-President, and every member of the Cabinet. Remarkably, ... Gray did not receive a single reply or even an acknowledgement!"*

In fact, during his early experiments, Gray discovered he could power light bulbs with cold energy, etc. Later he was to demonstrate this fact in a sensational manner: With a light bulb lit from his generator, he simply immersed the lamp — electrical leads and all — in water, where it remained lit. With his hands in the water, he would have been electrocuted or severely shocked if the electrical energy involved had *been positive* (diverging) energy. Instead, it was *negative* (converging) energy.[152] Another demonstration was to hit the coil of an electromagnet with some 3,000 volts, which hurled the electromagnetic into the air — but did not heat it. The electromagnet's coil would have been instantly melted if the energy had been positive, and the magnet would have been heated.

The reader should recall the timing of Dirac's theory of the electron {498a-b, 249}, which included the negative energy electron as early as 1930. Dirac also pointed out that we would observe this negative energy electron as a positive energy electron of opposite (positive) charge and positive mass, going in the opposite direction. The *observed* 3-positron and the *unobserved* negative energy 4-electron are quite different entities, producing quite different EM fields. The positron produces positive energy EM fields and positive gravity while the negative energy 4-electron produces negative energy EM fields and negative gravity.

In 1930, to his previous theory of the electron Dirac introduced the vacuum energy: the electron sea filled with electrons occupying negative energy states. The holes are treated as the positive electrons (as if observed). This vacuum energy medium is now referred to as the "Dirac Sea." First, Dirac attempted to identify these holes with protons, but that was falsified. Later the positron was experimentally discovered.

---

[152] By convention, "positive" energy has been associated with diverging EM energy, which is heating. Negative EM energy is associated with converging EM energy, which is cooling. In scalar interferometry {79}, one can control whether the distant EM field energy emerging in space in the distant interference zone shall be diverging (positive) EM field energy or converging (negative, cooling) EM field energy. This is determined simply by the biasing of the electrical grounds of the interferometer transmitters. The weather control referred to in 1997 by Secretary of Defense Cohen {89} is accomplished by using multiple scalar interferometers, some to gently heat the atmosphere in certain selected local areas (forming low pressure areas by expansion of the air) while cooling it in other selected local areas (forming high pressure areas by contraction of the air). By then moving these highs and lows around adroitly, one can capture and steer the giant jet streams, thereby steering the weather as one wishes, and directing significant weather changes into an area. By placing fairly sharp turns on the jet streams, one can induce great spin energy, thereby spawning tornadoes. Interestingly, by sharply pulsing the interferometer and controlling its electrical ground bias, distant cold explosions or hot explosions can be produced at will. Such weapons have been tested worldwide, and many test incidents are given in our older books F*er-de-Lance* and *Gravitobiology.* Information on such incidents is available on website http://www.cheniere.org .

One of the problems with present conventional application of Dirac's theory is that the positron is not used in its *unobservable causal negative energy 4-electron state* by modern theorists and experimentalists, but *after observation* where its direction has been reversed, its charge has been reversed, time has been stripped away, and the mass has become positive. So it is actually used as a positive energy entity having positive mass, and producing positive energy EM fields and positive gravity. This defeats the entire magic of the causal (unobserved) 4-positron as the electron carrier of negative mass and negative energy *{convergent* electromagnetic energy) in currents in the vacuum (spacetime) itself, rather than the electron carrier of positive mass and positive energy in ordinary 3-space. By replacing the unobserved (causal) vacuum 4-positron (negative energy electron) with the observed (effect) 3-positron with positive mass and positive energy, the entire vast area of negative energy EM fields — and thus direct antigravity via electromagnetic means — is discarded.[153] But the physicists avoided having to grapple with practical negative mass and practical negative energy (cool mass and cool energy). It also set back the pace of physics in discovering and engineering antigravity transportation for nearly three quarters of a century.

It appears that Gray's thinking about cold energy was more prosaic than the somewhat esoteric considerations of the Dirac Sea theory. Conventional electrical engineering circuit theory considers positive charges moving around a circuit (although some electronics technical circuits required thinking in terms of electron current). Hence the "high" side of the standard circuit was the positive polarity, or the positive pole of the terminals of a generator or battery. From this "positive pole", positive current was sent around the external circuit to the ground return line by the forward emf (forward voltage). However, forcibly returning to the positive pole from the ground return line (i.e., from the negative pole) were those same positive charges, being forced back up by the back emf and requiring expenditure of half the external circuit's collected Poynting energy.

---

[153] When the huge nondiverged Heaviside energy flow component is appreciably of "convergent" or of negative EM energy rather than positive EM energy, the antigravitational aspects are substantive and observable (and practical). The unaccounted Heaviside negative energy flow component is often a trillion or more times as great as the accounted Poynting negative energy flow component. Hence antigravity technology is possible and practical, as we present in a later chapter.

So to Gray, the positive pole had two currents, one useful and one usually detrimental. The positive pole had (i) outgoing positive emf current powering the external circuit's loads and losses, doing the beneficial work (dissipating energy) in the external circuit with its load, and (ii) incoming positive current being forced back up against the back emf, doing the harmful work against the back emf and using up half the energy previously collected out there in the external circuit. Gray was aware that the work against the back emf was equal to the work done by the forward emf. So he set out to split these two currents apart, and catch the incoming current against the back emf separately, then use that normally wasted or oppositional energy to further power loads and/or recharge the batteries powering the system. Something like this was the way he was thinking.

That is what Gray called "splitting the positive pole". He also reasoned (and found) that the "reverse current" must be cooling instead of heating, since it moves against the voltage and acts backwards from regular current dissipated in resistors, etc. This precisely matches the cold (negative) energy phenomena met in the Sweet vacuum triode amplifier and in the motionless electromagnetic generator, as well as other COP>1.0 electrical systems.

Gray's later demonstrations showed that he had recognized this process or something very similar to it, in his "splitting the positive pole".

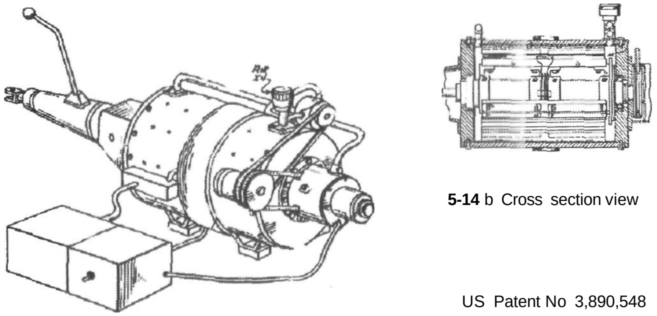

5-14 b Cross section view

US Patent No 3,890,548
issued 17 June 1975

5-14 a The Gray engine

Figure 5-14 Gray's "splitting the positive" COP>1 0 engine.

To take advantage of his concept and principles, Gray developed a special engine shown in Figure 5-14. In 1975 Gray received a patent on this engine {337} along with his special means of battery powering and special switching circuits.

Gray's engine uses pulsed capacitive discharge to power a magnetic motor, with recharging of the powering capacitors taking place *between* successive discharge positions of rotor and stator. The motor runs by initiating repulsion rather than attraction, which — apparently without Gray recognizing it in such terms — invokes the notion of the "superpole" pioneered by Bedini. The superpole is an important concept in COP>1.0 research, though most researchers in the field have never heard of it. John Bedini conceived it several decades ago and demonstrated the surprising difference between a superpole and a common pole of double strength.

When two equal and like magnetic poles are facing each other in repulsion with a small gap between them, a net stress magnetic potential (pole) is formed in that gap which has an energy density some four times as strong as the normal field energy density in the field from one of the two opposing like poles. Hence the local energy density of the vacuum in the gap has been substantially increased above the energy density in the field region between a north and a south pole facing each other. Further, this energy density is in a "field-free" Lorentz-regauged form, i.e., a stress potential form. From that superpotential *outward,* there exists a normal magnetic field. But in it, there is no net magnetic field, but there is a "stress" field nonetheless.

Compared to an ordinary magnetic motor using attraction as well as some repulsion, the exclusive use by Gray of the Bedini "superpole" principle caused an extra *symmetrical* regauging[154] of the local vacuum energy input to the system (to the gap between the poles) as the magnetic superpole

---

[154] Every conventional electrodynamics text already assumes and uses the Lorenz-**Lorentz** symmetrical regauging as being absolutely free. Symmetrical regauging assumes that the energy of the system has been freely changed twice, but in such a way that the two free fields formed are equal and opposite, forming a stress potential. Gray found how to split apart and separately use these two "free-flowing exc**hanges** of energy between system and active vacuum" that comprise the overall stress potential of the system, and thereby violated the Lorenz-Lorentz symmetry condition, freeing the two equal and opposite EM fields and their free energy to be used individually and beneficially to (i) provide extra power to the load and (ii) recharge the powering batteries so they did not run down. Using a different method. **Bedini** has done likewise.

(stress magnetic scalar potential). However, this stress potential is comprised of bidirectional longitudinal wavepairs, as shown by Whittaker in 1903. This superpole or stress potential thus can and does "split" into two different fields in antiparallel directions from each other. Since the north pole is deemed "positive" in magnetics, then using the two anti-fields comprising the free positive superpole is indeed "splitting the positive pole". Gray coined a very apt phrase for what he was doing.

Each of those antiparallel fields also involves an associated and unaccounted phase conjugate field {338a-c}, hence it is a time-reversed field (after observation). So opposing time-polarized EM waves also accompany Whittaker's decomposition waves. In short, the scalar potential accomplishes *optical-type pumping* in the time domain, and can be used to demonstrate time-reversal (as in Becker's bone-healing method).

Before observation (interaction with charged mass) and while still in the causal state, *the EM field from the positive pole is actually an EM field from a negative energy 4-electron, and the field can be taken to be a negative energy field!* In our view, positive energy enters every point dipole in the polarized vacuum at the negative charge, thence to the positive charge, thence back to the time domain. From the positive charge, the positive energy is leaving 3-space back to the time domain. Hence positive EM energy diverges from the negative charge and converges on the positive charge, then "disappears", so to speak, back to the time domain from whence it came. The "disappearance" of positive (divergent) energy is the disappearance of heat energy; hence it is a cooling process rather than a heating process. Or said another way, *negative* EM energy enters 3-space at each point dipole, entering from the time domain to the positive charge. Thence it moves to the negative charge, and back to the time domain. We see or detect the positive energy flow in 3-space directly, while the negative energy flow in the Dirac vacuum is evidenced by the "backwards" interaction creating Newton's third law reaction force.

By splitting the positive superpole, one has effectively destroyed the Lorentz symmetry condition. Hence the excess energy in the superpole will be capable of performing real work in the system in two directions. One direction is from the system to the external environment so that it produces the dissipation of energy (therefore work) in the loads and losses. The other direction produces a "negative resistor" or negentropic action that adds that much excess usable energy to the system back into its input section. By adroitly intercepting and switching that energy into capacitors and/or batteries, Gray was able to charge capacitors, recharge batteries, and even power loads with cool energy (as demonstrated later by immersing a lighted electrical line and a lit light bulb in water).

A positive-energy resistor becomes a negative resistor when fed with negative energy. Then it converges positive EM energy from the external environment and outputs it into the circuit in which the resistor is connected. Note that this is the same statement as the resistor receiving (extracting) negative energy from the circuit and emitting it back to the time-domain. *That's like extracting back emffrom the circuit and tossing it offto the time domain.* A conductor to positive energy flow is an insulator or dielectric to negative energy flow. Hence the normally "conductive" water was a neat insulator for Gray's "dunking" demonstration of negative power, as were his own normally conductive hand and body. To negative energy, a coil seems to produce capacitance rather than inductance, while a capacitor seems to produce inductance rather than capacitance.

Thus when the "positive pole is **split"** in the system, the system has broken **its** Lorentz regauging and is an open system in disequilibrium with the external vacuum environment, freely receiving excess energy from it.[155] With adroit switching and energy capture, such a system is permitted to exhibit COP>1.0 because it has violated the free Lorentz regauging once the excess energy in the superpole region is discharged and used.

---

[155] When one analyzes the supersystem of any Lorentz-regauged EM system, one realizes that the extra stress potential energy — entering the system and "locked up" as a stress potential due to the Lorentz condition — is actually a special relativistic **rotation** of the frame of the power unit away from the laboratory frame. That is, the system when rotated away from the lab frame, takes on free symmetrical regauging energy in that rotated frame as an excess stress potential. Gray's "splitting the positive" process simply separated the two appositive fields comprising the stress potential, then produced excess free energy from that *broken* free regauging Lorentz condition. Literally Gray splits Lorentz's stress potential into halves, the halves being its two opposing EM fields and their energy. This is equivalent to the system being rotated back into the lab frame, releasing its excess energy it possessed in the rotated frame back into the lab frame. Richard "Scott" McKie has also filed a patent on an invention deliberately rotating a capacitor's frame and fully charging it — while it is in its rotated frame. The rotated capacitor can be charged with less energy furnished from the lab frame, than is obtained back out of the capacitor in the lab frame when the charged capacitor is suddenly rotated back and discharged. At least in **theory,** McKie's overunity process should be workable if the switching costs are negligible. Our contribution to McKie was to advance the theoretical mechanism for **the** experimental mechanism he had discovered and was using.

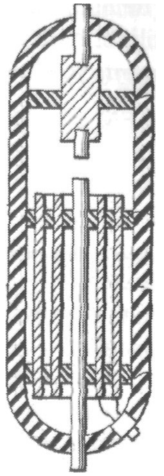

From US Patent No **4** 661747
issued 28 April 1987

Also in U S Patent No 4595,975
issued June 17,1986

Figure 5-1S Gray's conversion tube used with power systems,

Gray also utilized a special conversion discharge tube, shown in Figure 5-15. This tube uses the fact that a very sharp pulsed discharge in it results in a temporary COP»1.0 condition. This COP»1.0 condition instantly involves causal Dirac sea 4-positrons, moving as negative mass current and negative energy current in the local vacuum, which sweep back from the output side of the discharge to the input side.

We also point out the severe overpotential that must accompany any such violent pulse discharge process. The overpotential is a departure from equilibrium conditions, and is the difference between the actual potential and the equilibrium potential. The overpotential is well known and utilized extensively in electrochemistry {339a-c}, but is little used in conventional circuit theory. Nonetheless, it is involved in cold fusion processes due to the double layer phenomena {340a-b}, and it is involved in all electrode discharges (as from a cathode to an anode). It is also involved widely in electrochemistry and ion processes in solution.

Figure 5-16 shows Gray's circuit containing his conversion tube. Figure 5-17 shows Bedini's successful replication of the Gray conversion tube. Figures 5-18, 5-19, 5-20, and 5-21 show four pertinent pages from Bedini's laboratory notebook on his replication of the Gray conversion tube and the Gray motor system.

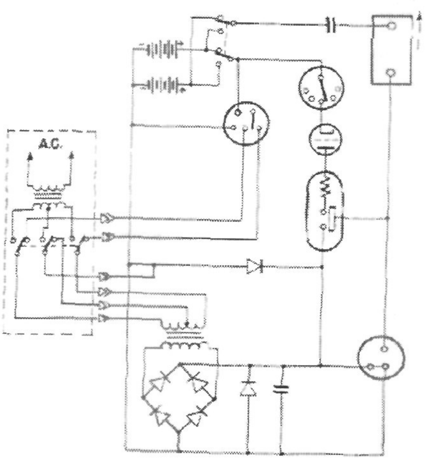

From U S Patent No 4 661 747
issued 28 April 1987

Also in US Patent No 4 595 975
issued June 17, 1986

Figure 5-16 Gray's circuit containing his conversion tube.

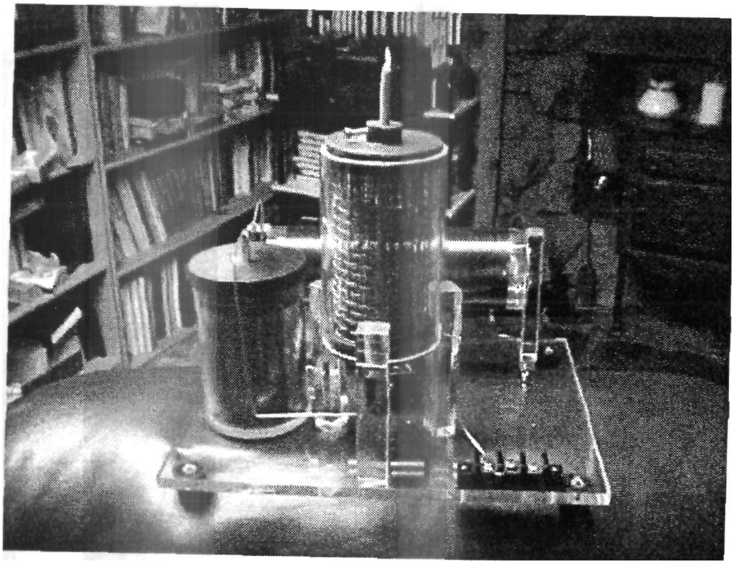

Figure 5-17 Bedini's successful replication of the Gray conversion tube.

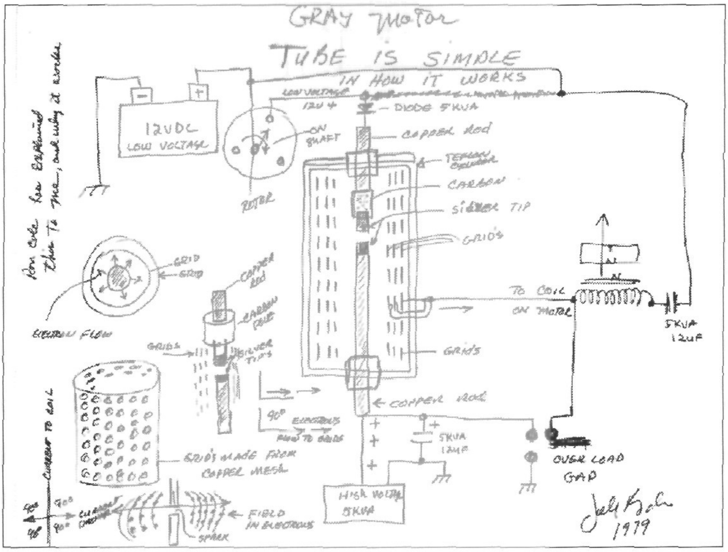
GRAY MOTOR
TUBE IS SIMPLE
IN HOW IT WORKS
12VDC
LOW VOLTAGE
LOW VOLTAGE
12V
DIODE 5KVA
ON SHAFT
ROTOR
COPPER Rod
TEFLON CYLINDER
CARBON
SILVER TIP
GRIDS
GRID
GRID
ELECTRON FLOW
COPPER ROD
CARBON TUBE
GRIDS
SILVER TIPS
90°
ELECTRONS FLOW TO GRIDS
GRIDS MADE FROM COPPER MESH
TO COIL ON MOTOR
5KVA
12UF
GRIDS
COPPER ROD
5KVA
12UF
OVER LOAD GAP
HIGH VOLTAGE
5KVA
CURRENT TO COIL
90°
90°
CURRENT CHANGE
FIELD IN ELECTRONS
SPARK
Jack Kola
1979

Figure 5-18 Page 1 from Bellini's lab notebook on the Gray conversion tube.

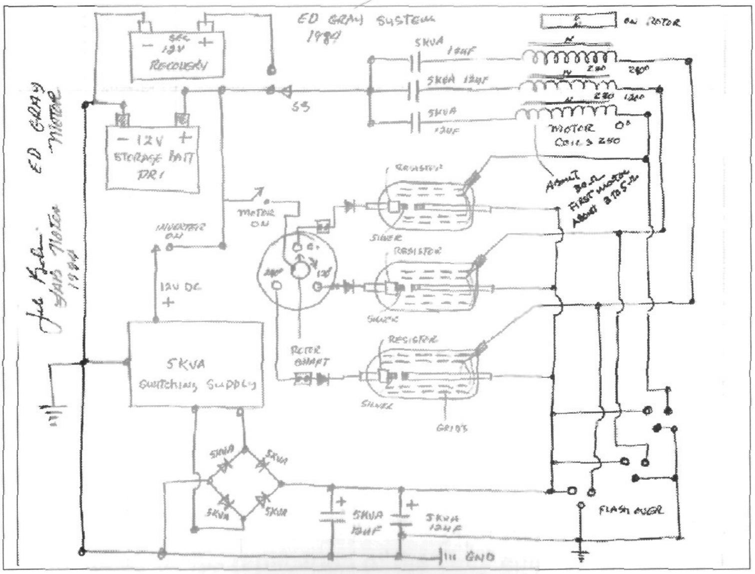
ED GRAY SYSTEM
1984
SEC 12V RECOVERY
ON ROTOR
5KVA
12UF
5KVA 12UF
5KVA
12UF
240°
120°
0°
MOTOR COILS 240
S3
12V STORAGE BATT PR1
ED GRAY MOTOR
Jack Kola
LAB MOTOR
1984
MOTOR ON
INVERTER ON
12V DC
RESISTOR
SILVER
RESISTOR
SILVER
RESISTOR
SILVER
GRIDS
ROTOR SHAFT
ABOUT 30 Ω FIRST MOTOR ABOUT 3 TO 5 Ω
5KVA
SWITCHING SUPPLY
5KVA
5KVA
5KVA
5KVA
5KVA
12UF
5KVA
12UF
GND
FLASH OVER

Figure 5-19 Page 2 from BedlnI's lab notebook on the Gray conversion tube.

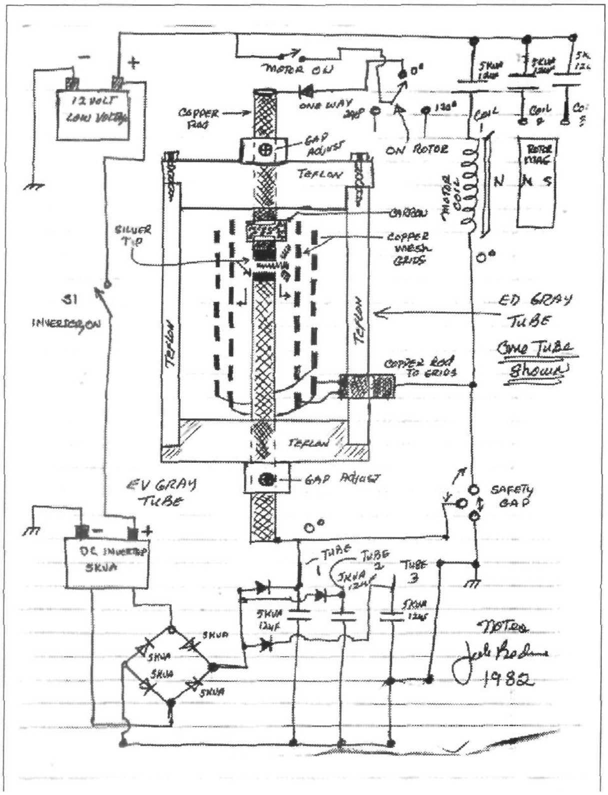
- +
12 VOLT
LOW VOLTAGE
MOTOR ON
0°
ONE WAY
240°
120°
COPPER ROD
GAP ADJUST
ON ROTOR
5KVA 12uF
COIL 1
COIL 2
ROTOR MAG
N
N S
MOTOR COIL
TEFLON
CARBON
SILVER TIP
COPPER MESH GRIDS
0°
S1
INVERSION
ED GRAY TUBE
One Tube Shown
COPPER ROD TO GRIDS
TEFLON
GAP ADJUST
EV GRAY TUBE
SAFETY GAP
0°
- +
DC INVERTER 5KVA
TUBE 1
TUBE 2
TUBE 3
5KVA 12uF
5KVA
Notes
John Bedini
1982

Figure 5-20 Page 3 from Bedini's lab notebook on the Gray conversion tube.

In science, when a novel experiment is replicated independently, that experiment then is established as a scientific fact. It then becomes the task of the theorists to either change the theory to accommodate the experimental results, or come up with a new theory to explain them. With Bedini's successful replication of Gray's work and extension of it, that work has now been scientifically established. With his "splitting the positive pole", Gray was referring to an actual, useful mechanism he evoked and used in the processes ongoing in his motor, in his conversion tube, and in his power system.

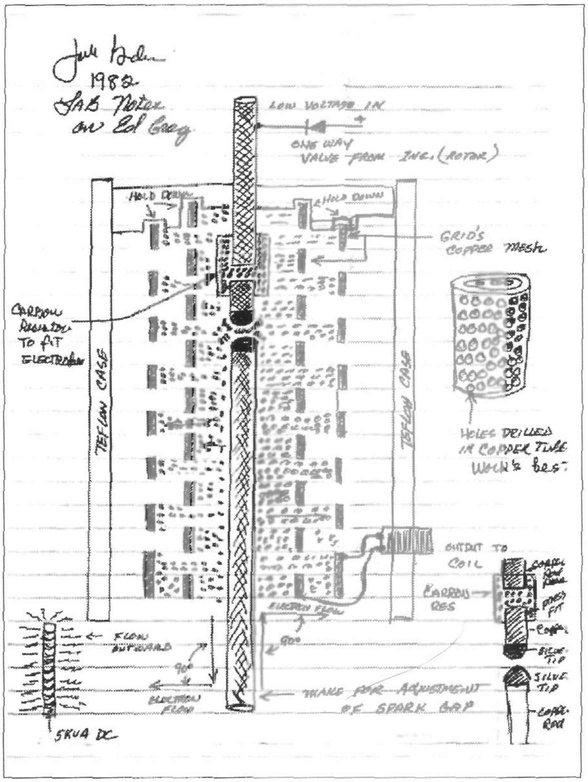
1982
LAB Notes
on Ed Gray
LOW VOLTAGE IN
+
ONE WAY
VALVE FROM INC. (ROTOR)
HOLD DOWN
HOLD DOWN
GRID'S
COPPER MESH
CARBON
RESISTOR
TO FIT
ELECTRODE
TEFLON CASE
TEFLON CASE
HOLES DRILLED
IN COPPER TUBE
WORK'S best
OUTPUT TO
COIL
CARBON
RES
PRESS
FIT
COPPER
SILVER
TIP
SILVER
TIP
COPPER
ROD
ELECTRON FLOW
90°
FLOW
OUTWARD
90°
ELECTRON
FLOW
MAKE FOR ADJUSTMENT
OF SPARK GAP
5KVA DC

Figure 5-21 Page 4 from Bedini's lab notebook on the Gray conversion tube.

For further discussions about the Gray motor, conversion tube, and the history of it all, one is referred to the book by Lindemann {341}.

5.8.9 Watson's Self-Powering Generator

See Figure 5-22. In 1984, Jim Watson demonstrated a self-powering 8-kilowatt generator at the International Tesla Conference in Colorado Springs. This generator was a modified extension of smaller motors and generators built by Bedini over a period of years. At the conference, engineers from the audience were invited to the platform to perform their own independent measurements of the unit, while it was running and powering its load. The engineers directly confirmed that the system was delivering power to the load (as could be seen visually also), and that it was recharging its batteries as well.

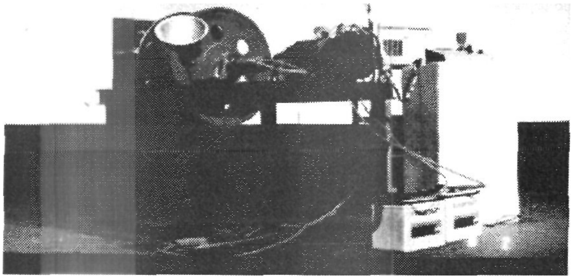

Figure 5-22 Watson's self-powered 8 kW generator demonstrated in 1984.

Interestingly, one of Watson's batteries was stolen that night. The reason was obvious. First, at the conference there was present one of the major persons charged with suppression of COP>1.0 electrical power systems world wide, along with several of his henchmen. Since they have been involved in suppressing many dozens of similar COP>1.0 systems, they are thoroughly familiar with both the theory of COP>1.0 electrical power systems and the various types of devices and mechanisms that have been invented in that area over the past century.

One feature of Watson's unit was that it charged the batteries with negative energy (i.e., with Dirac sea hole current, or "cold energy" as sometimes referred to), and could use negative energy for powering the unit. Hence, his batteries became charged with negative energy as the machine ran and powered its loads. After much demonstration and running, such a negatively charged battery has its local curved vacuum charged with an appreciable number of unfilled Dirac holes. Such a negatively charged "battery supersystem" will then absorb positive energy charging (electron current charging) for a protracted period before it will start to change its voltage and accept the positive charge. Instead, during that protracted initial period the battery will just "eat electron currents and positive energy" from the battery charger, with no apparent effect and no change in Its discharged state or its voltage.

A very simple way to absolutely ascertain whether or not a unit such as Watson's (without a Bedini negative energy converter) is genuine, is to **simply** take one of his batteries from a unit that has been running quite a bit, and recharge it on a conventional battery charger. If it exhibits that two-phased recharge phenomenon, it proves that the unit is real and is indeed a true COP>1.0 device, or certainly has the potential to be one. Coupled with the demonstration and independent measurements, this removed all doubts about the validity of Watson's COP>1.0 system.

So it appears that certain parties who were concerned about that system decided to do the "simple test" to see if Watson's device was real. It was real, and so they discovered. At that point, the High Cabal — Winston Churchill's term — recognized they had another successful unit and inventor to suppress.

Bedini and I were in close contact with Watson over a period of years, as often as three or more times a week. Later, some time after that conference, abruptly Jim ceased all communication with his former close colleagues. For two days a rather crazy recording **was** on his phone, stating the Watsons had moved. Then that disappeared. Watson never again contacted either Bedini or me, or his own financial backer (the late R. J. Reynolds III). Even Reynolds could not find Watson's whereabouts at that time.

We are quite certain that Watson received the "offer he could not refuse". Simply put, this is the old Mafia trick of visiting the target, offering him a deal, and he has no choice but to accept or die. When this is used to suppress COP>1.0 systems, and some medical systems, the offer is usually: *"Accept the money and you and your family will live very comfortably, but you will never openly work on this again or communicate it. You either accept our generous offer, or you and your family will be dead when we leave here."* Assuming that happened Watson had no choice but to accept the several million dollars offered him.

He is still alive, because Jeane Manning physically ran into him at a conference — and recognized him and spoke to him — whereupon he withdrew abruptly and left the conference very hastily.

5.9 Suppression of Free Energy Systems Has Been Common

This is only one of many cases we know of where such suppression of overunity systems and inventors has been accomplished. Others are not so benign. Marinov was killed with a longitudinal EM wave shooter in Europe, and his body was thrown off a building to make it appear a suicide. The police allowed the body to lie on the pavement for a protracted time (it was emitting longitudinal EM waves from the time-charging action of the strike). When finally moved, the pavement glowed in that area that had been underneath the body. Only one weapon on earth will kill a person in that manner, and that is a longitudinal EM wave "shooter".

Another prominent researcher was killed with a Venus technique (look it up, it's a distortion of the wave front) modified beam that plunges the heart into violent fibrillations. He rushed from a restaurant exclaiming, "They're killing me!" and died of a resulting heart attack. The present author was hit with just such a weapon in a restaurant here in Huntsville. A friend and I actually saw the weapon and the person wielding it. Knowing what it was and recognizing the symptoms, my seated companion and I were able to bolt out of the nearby back door during that minute or so we could still physically function. I personally saw the device and the person doing the beaming, and I have a witness to the event.

The partner of a colleague in Australia was killed on an upper floor by such a shooter from the street below, right through the walls. The assassin was observed, and was seen putting the bazooka-sized shooter back in his car, then speeding away. There are many other true incidents we could also relate, including a person killed by an ice-dart dipped in curare (a very professional hit method, used by some of the sinister arms of various intelligence systems). So there is more than just scientific work involved in pursuing COP>1.0 EM power systems. There can also be a direct threat to one's life, essentially at any time.

Almost any serious overunity researcher, who succeeds, will have had confrontations with assassination attempts, suppression attempts, threats, deliberate legal entanglements, etc. The present author is no exception. It is sad that one of the prerequisites for serious scientific work in this area is **often** a legal gun permit (for both the inventor and his wife) and either legally carrying a hidden weapon or never being very far from a weapon when working at home. As an old soldier, of course, one just shrugs and accepts it, and gets on with the job to the best of one's ability, albeit remaining very watchful and always on guard.

5.10 In Conclusion

In this chapter we have introduced many of the approaches to COP>1.0 EM systems or processes, or the possibility for such in some novel mechanisms known in science. Recalling our previously presented solution to the source charge problem, we emphasize to the reader that all assumed 3 - space EM processes are actually 4-space processes prior to observation, continually observed in iteratively frozen 3-snapshots by iteratively invoking the *d/dt* operator that produces observation. Hence from the source charge (and source dipole) solution we realize that all EM energy in 3-space comes from the time-domain and returns to the time domain. It iteratively appears along the "line of propagation" in 3-space at each successive position, but does not continuously propagate in 3-space. It does continuously propagate in 4-space. Since all the EM energy in any EM circuit comes from the time domain via the broken symmetry of the source charges and source dipoles, then we need to apply this greater vision to the COP>1.0 mechanisms and approaches so that we see the 4-space to 3-space to 4-space interplays.

The notion of the negative resistor is particularly significant and direct in that respect, and we have presented several versions of true negative resistors. For those wishing to experiment, we would suggest the easiest thing to start with is the point contact transistor. Or, simply go to Naudin's website {313} and download his instructions for making a Chung-type negative resistor, build it, and do experiments with it by varying the pressure on the fibers etc.

Again, we have not presented "parts kits" with instructions, but we have presented things that have worked or can reasonably be expected to work with some effort. We have also discussed the principles involved, to the best of our ability. In a few cases, we have directed the reader to information on websites where building instructions for selected negative resistors and other devices are posted.

As in any other scientific endeavor, we also urge the interested reader to read the literature and check the references cited, or as many as possible. Increasing one's understanding of the area is necessary to increase one's probability of success in the area.

We also wish the reader good results and success in his or her research and experimenting. The energy crisis is not going to go away, and the demand for oil will double in the lifetime of many of our middle-aged or younger readers. The cheap oil peaks shortly and declines in availability forever thereafter {342}; this alone will drive up the price of oil and seriously impact the economies of the nations of the world. To keep from destroying the world economy and the biosphere, it is absolutely essential that COP>1.0 electrical power systems — including self-powering systems taking their input energy from the seething local vacuum — be developed to produce the necessary electrical energy needs of the world, cheaply, cleanly, and easily.

If one or more of the readers should succeed in developing and producing such systems, then the entire purpose of this book will have been fulfilled.

Chapter 6

Additional Approaches to Overunity Power Systems

> *"Can the quantum potential carry a signal? If it can, we will be led to a violation of the principles of Einstein's theory of relativity, because the instantaneous interaction implied by the quantum potential will lead to the possibility of a signal that is faster than light... a signal has in general to be a complex structure, consisting of many events that are ordered in definite ways. In terms of our language, each signal is a supersystem of events, while each event is in turn a system of subevents.... At present, the answer is, of course, not known. "* [Bohm and Hiley] {343}. A comment:[156]

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[156] We comment that the "event" involves observation: i.e.. it is conceived as an *observed* event. In that exact sense, no signal in space carries "events" because there is no interaction with mass and no *d/dt* operation induced on entities (curvatures) of spacetime. The effect (observed) 3-space field cannot propagate faster than light, because it cannot even propagate in the first place! The totality of light's EM interactions with matter is what makes the observed field or observed signal to appear to be propagated at light speed. It is not actually "propagating", but being iteratively recreated from point to point in space *if observed at every point.* Signal in spacetime is causal and hence nonobservable; the interaction of causal signal with charged mass is observable and makes an "event". When we clearly differentiate the nonobserved (causal) 4-field or dynamic from the iteratively observed 3-field or dynamic, then the *nonobserved 4-field* or dynamic is not limited to light speed. Propagation along the time axis, e.g., can be at "infinite velocity" because a single **point** in time is connected to every point in the universe simultaneously. Since all EM energy in space comes from the time domain locally at each point dipole in 3 - space and returns to the time domain from that same point dipole, it is the notion of "propagation continuously through 3-space" at *any* velocity that is a non sequitur. Absolutely nothing propagates through 3-space! If general relativity is re-interpreted **to account** the difference between observed and unobserved (effect and cause), then the unobserved cause can propagate superluminally without violation of the "observed event (effect) propagation at light speed" of general relativity. It is the notion that anything propagates in 3-space that is the non sequitur, and it should be removed from special and general relativity as well as electrodynamics.

> *"...contrary to the conclusions of classical mechanics, there exist effects of potentials on charged particles, even in the region where all the fields (and therefore the forces on the particles) vanish."* [Aharonov and Bohm] {344}.

> *"...for any force varying as the inverse square of the distance, the potential of such force satisfies both Laplace's equation and also the wave equation, and can be analyzed into simple plane waves propagating with constant velocity. The sum of the waves, however, does not vary with time, i.e., they are standing waves. Therefore the force potential can be defined in terms of both standing waves, i.e., by a global, or non-local solution, and by propagating waves, i.e., by a local solution changing in time... Thus, Whittaker's mathematical statement related the inverse square law of force to the force potential defined in terms of both standing wave (i.e., global) and propagating wave (i.e., local) solutions. The analysis also showed that the electromagnetic force fields could be defined in terms of the derivatives of two scalar potentials."* [Barrett] {345}.

> *"What might appear to be empty space is, therefore,* ***a*** *seething ferment of virtual particles. A vacuum is not inert and featureless, but alive with throbbing energy and vitality. A 'real' particle such as an electron must always be viewed against this background of frenetic activity. When an electron moves through space, it it actually swimming in a sea of ghost particles of all varieties — virtual leptons, quarks, and messengers, entangled in a complex melee. The presence of the electron will distort this irreducible vacuum activity, and the distortion in turn reacts back on the electron. Even at rest, an electron is not at rest: it is being continually assaulted by all manner of other particles from the vacuum."* [Davies] {346}.

6.1 Introduction

In this chapter, we continue to present a selection of potential overunity systems, inventions, approaches, and selected mechanisms. We also make the reader aware **that quantum** mechanics, an entire branch of physics, requires nonlocality and "instant propagation" in space. We utilize the quantum potential from Bohm's hidden variable theory of quantum mechanics {347} to impress the nonlocality. Further, the staid old scalar potential — which we meet as voltage in a circuit — also exhibits nonlocality and instant propagation in the Coulomb gauge {348}. Our purpose is to show that electrodynamics is not limited to the cut-and-dried subject as usually taught to electrical engineers and applied by them, but also covers a wide range of phenomenology that electrical engineers usually do not consider or account.

6.2 Energy Conversion and Energy Amplification

6.2.1 The Mead-Nachamkin Zero Point Energy Converter

It is well known that the vacuum interacts with electrical charges and dipoles, and also with the electrons in an atom. For example, Lamb received the 1955 Nobel Prize in physics jointly with Polykarp Kush for experiments measuring the small displacement later called the "Lamb shift" of 0+ne of the energy levels in atomic hydrogen {349}.

Casimir {350a} proved that closely separated conducting plates also alter the energy density of the vacuum, thereby becoming an "energy extracting" method, although the energy is miniscule. It is quite real, however, as shown in meticulous experimental work by Lamoreaux {351}. **The** principle that vacuum energy interacts with matter, plates, and electrical double layers and circuits is well proven experimentally.

In 1996 Mead and Nachamkin were granted a patent on an overunity EM power system process for extracting zero-point energy of the vacuum {352}. If one closely examines the patent wording, the device is properly patented as an energy converter and does not overtly state that it is a COP>1.0 system. It is a COP>1.0 system, however, since the input energy is freely received from the vacuum and not input by the operator himself. **One** embodiment of the invention inserts a tiny coil between the plates to ex**tract** the energy. See Figure 6-1. The energy is based on the Casimir e**ffect** {26}, which was accurately measured in 1997 by Lamoreaux {27} a**nd** since then by others.[157] Further investigation of the force's behavior **with** the shape of the conducting plates has been performed by Chen *et*

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[157] See also U. Mohideen and A. Roy, "Precision measurement of the Casimir force from 0.1 to 0.9 microns," *Phys. Rev. Lett.*, Vol. 81, January 1998, p. 4549.

al.[158] Numerous other papers of interest on the Casimir effect have also been published {353a-d}.

Because energy cannot be created or destroyed, any COP>1.0 system is an *energy converter,* a priori. It must receive the excess energy from the environment (in this case, from the curvature of spacetime and from the local active vacuum) and convert that energy to a form usable to power or assist in powering the system loads and losses.

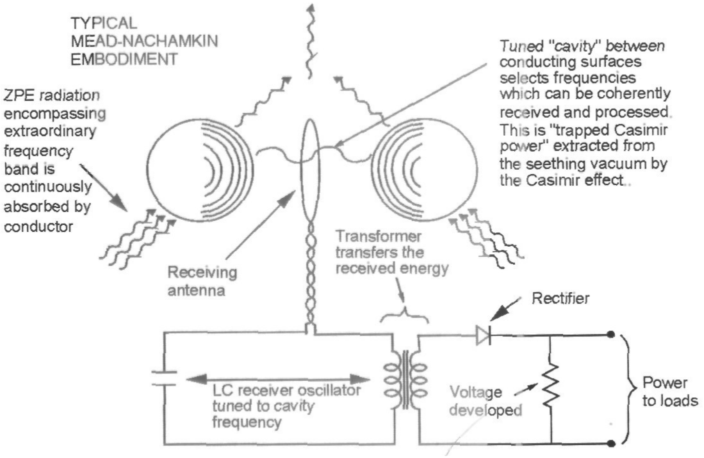
TYPICAL
MEAD-NACHAMKIN
EMBODIMENT
ZPE radiation encompassing extraordinary frequency band is continuously absorbed by conductor
Tuned "cavity" between conducting surfaces selects frequencies which can be coherently received and processed. This is "trapped Casimir power" extracted from the seething vacuum by the Casimir effect..
Receiving antenna
Transformer transfers the received energy
Rectifier
LC receiver oscillator tuned to cavity frequency
Voltage developed
Power to loads

Figure 6-1 Mead-Nachamkin conducting surfaces, antenna, and receiver for extracting EM energy from the vacuum,

The Mead-Nachamkin patent is interesting because the physics of the device is proven and accepted. Getting sufficient power output to be useful for electrical power purposes, however, remains to be demonstrated, since the Casimir effect is very tiny.

6.2.2 The Quantum Potential As an Energy Amplifier

In Bohm's hidden variable theory of quantum mechanics {354}, an extra potential is added to the Schrodinger equation, and is known as a *quantum potential.* Figure 6-2 lists the novel characteristics of this potential, and

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[158] F. Chen, U. Mohideen, (G. L. Klimchitskaya, and V. M. Mostepanenko, "Demonstration of the Lateral Casimir h'orce," *Phys. Rev. Lett,* (in press as of the time of this writing).

Quantum Potential Characteristics

- No point source; not radiated
- Just appears instantly
- Quantum potential between two particles
  - Interaction does not vanish as spatial separation becomes very large
  - Instantaneous connection
- Depends on quantum state of system as a whole
- System parts can be greatly separated

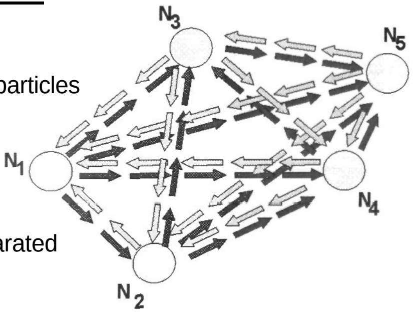

Figure 6-2 Quantum potential characteristics (table).

Figure 6-3 lists technical features of Bohm's hidden variable theory from whence the quantum potential is taken {355}. It can "move instantaneously", at "infinite velocity", which means it just suddenly appears everywhere it will be, and does not "propagate at a finite speed" through singly connected space at all {356}.

$$V_{quantum} = \frac{h}{2m} \frac{\nabla^2 \sqrt{\rho}}{\sqrt{\rho}}$$

A quantum particle moves as if it were subject, in addition to its external potentials, to a potential which is a function of its own probability distribution.

Bohm's hidden variable theory assumes:

- **Particle and wave function real and separate**
- **Wave function obeys Shrodinger's equation**
- **Particle obeys classical mechanics**
- **Particle couples to wave function through a quantum potential**

Figure 6-3 Technical features of Bonn's hidden variable theory.

The potential is after all *potential energy.* With the quantum potential (QP), a joule of energy placed upon one collector, where that collector is connected via a QP with one or more distant collectors, will also result in a joule of energy (or some fraction thereof) instantly emerging upon and in each of those distant participating (QP-connected) stations simultaneously. It appears that, if only a fractional participation — say, 0.50 — exists with one or more of the distant stations, each of those stations will experience the appearance of that fraction (in this case, 0.5 joule) of the energy input to the initiating station. Any station can input energy, and it will appropriately appear at every other participating station, regardless of where these stations are located in ordinary 3-space as seen by the external observer.

One way of expressing this "instantaneous QP connection" between separated objects is to model the different objects (or stations) as linked together in a multiply connected space, with a certain QP connection or collection fraction. Presence of energy at one station in the multiply connected group, results in the simultaneous appearance of the energy — or an appropriate fraction of it — at every other station in the group.

To understand multiply connected space, consider a single point on a plane. Now consider 999 more points superposed on/in that same point. But suppose that those thousand points are really located at different locations in 3-space, though superposed in this "crazy space" containing a plane where all of them are superposed at one point.

As the ordinary external observer, suppose you input a joule of energy into one of these — to you — separated points, which happens to be the original point and is located in your laboratory. Supposed the fractional connection is 1.0 (the connection is perfect in multiply connected space). Voila! Instantaneously one joule of energy appears at each and every one of those (to you) widely separated points. If you vary your input energy (e.g., as in communication), it varies precisely the same in each of those distant QP-connected points.

Those who continue to advocate that superluminal communication of information is impossible are ignoring present experimental proof that it does occur. As a single example (there are others), it has been shown by Enders and Nimtz {357} that Mozart's 40th symphony can be transmitted as frequency modulated microwaves through a barrier wave guide between two points in a waveguide, via quantum tunneling, at 4.7 times the speed of light c. We point out that this is achieved using *transverse* EM waves.

If *longitudinal* EM waves are used together with longitudinal modulation (which engineers might think of as a sort of "pulse compression" technique), the only limitation to the speed of communication is given by the impurity of the longitudinal EM wave one is able to make. The Fogal semiconductor, e.g., can be used to transduce ordinary transverse EM wave signals into longitudinal EM wave modulations inside a scalar potential. Hence that scalar potential can move in the Coulomb gauge at infinite velocity. It requires another Fogal semiconductor circuit on the receiving end to receive and transduce the longitudinal EM waves and their longitudinal modulations back into transverse EM waves for processing and amplification by normal means. This capability of the Fogal semiconductor circuits has been demonstrated through satellite uplinks and downlinks coupled with long transmission line links, with essentially no delay from transmission to reception. One may think of the Fogal superluminal process as *tunneling through subspace.*

The best way to vary the energy is apparently by use of a variable stress potential (which translates to a longitudinal variation or modulation). In short, one must modulate the "internal energy" of the vacuum, so to speak, and not the "external energy". A reasonable discussion of internal energy versus external energy is given by Chen {358}. If one longitudinally modulates the internal energy of the vacuum potential — which, being a scalar potential, decomposes by the Whittaker decomposition {359} — then superluminal communication is not only possible but also practical. We expect Fogal to eventually place just such a system on the market, shortly after his semiconductors get into precision production.

One possible method of producing modulated internal stress potentials is by use of a Davis noninductive resistor {360}. Another is by use of a biwound coil with two windings, so that the two currents through two equal "superposed" coils are equal and opposite. We point out that, while there has been published much stuff and nonsense about such biwound coils, the truth is quite mundane. Simply examine the Lorentz symmetrical regauging applied to the Maxwell-Heaviside equations. It is the deliberate production of two equal and opposite force fields, which is in fact the creation of a stress potential and extra stress energy. By varying the magnitude of the Lorentz forces comprising the stress potential, the stress potential is varied in amplitude. Hence the concomitant longitudinal EM waves are varied in amplitude. A biwound coil is a variable Lorentz-regauging coil, *a priori.*

By oscillating the magnitude of any Lorentz regauging (which in the simplest case is simultaneously changing both opposing fields equally and oppositely), one can make longitudinal EM waves. By appropriately modulating both Lorentz regauging components, one can make longitudinal EM modulations upon those concomitant longitudinal EM wave carriers.

So with some careful tuning and adjustment, and a little nonlinear material in the core,[159] one should be able to have the superposed appositive magnetic fields lock together *(modulate,* rather than linearly *add)* and produce a magnetostatic scalar potential stress signal in and from a nonlinear core material. We caution, however, that the biological effects of the radiation of such stress potentials internal to spacetime have not been investigated. The experimenter is cautioned that he experiments at his own risk, and he is cautioned to experiment only at low power levels until the phenomenology in a particular case is understood.

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[159] The opposing waves must modulate (multiply), not mix (add), and modulation is a nonlinear process. Linear mixing of opposite waves or fields will not cause the

If we compare the stress potential oscillation (wave) to a sound wave, the similarities suggest that the stress potential oscillation can be treated as a longitudinal EM wave, if the two superposed opposing EM waves "lock together". Simple addition is insufficient; modulation is necessary. Hence the nonlinearity of the conductors and core material is of significance.

For instantaneously propagating potentials and pure longitudinal EM waves, any conceived difference between the two becomes somewhat academic. The characteristic of interest is the instant appearance of the input energy at multiple points via a multiply connected space.

To the ordinary observer, use of a quantum potential and multiply connected space measurably yields a fantastic *energy amplifier.* One furnishes one joule, and gets out — say — 1,000 joules in those distant locations altogether. As shown in Figure 6-4, the QP system is a communication system of enormous implications, particularly as humans travel into space across the solar system and even beyond. Unfortunately, by using appreciable power in the initiating station, the QP system also leads to weapon systems of incredible destructive capabilities. Some five nations {361} now possess such quantum potential weapons, which are the dominant weapons on Earth. We do not further discuss the quantum potential weapons aspects in this book.

Back to our little energy exercise, inputting one joule and getting out some 1,000 joules. Suppose these 1,000 participating points are not distant at all, but are gathered closely together into a local material but still QP-connected with a connection fraction of 1.0. Now we input a joule of energy to that device, and it develops and outputs one kilojoule. It is hypothesized that this becomes the ultimate negative resistor. It will also exhibit separated Dirac hole current phenomena as the COP increases and, if sufficient COP is developed, it will exhibit antigravity effects such as

fields to "lock together" into a common stress potential. Nonlinear mixing (modulation) will. Hence the nonlinear core is required for conversion of appositive fields to stress potentials and **Lorentz** regauging.

those shown by the Sweet vacuum triode amplifier discussed in this chapter.

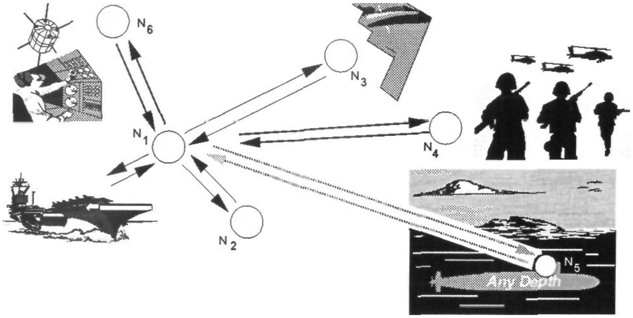

- Quantum potential decomposes per Whittaker 1903 into bidirectional longitudinal EM waves
- Can insert additional longitudinal waves, thus information using a Fogal semiconductor
- Can receive "signal" and discriminate the information using a Fogal semiconductor

Figure 6-4 Quantum potential communication system.

Strangely, overall conservation of energy is not violated by the quantum potential COP>1.0 energy system. It's just that the energy now is furnished from space (from the vacuum) in a *multiply connected* manner. However, all the excess energy is still furnished by the active external environment - i.e., from the time domain, according to the giant negentropy process {12} — though that environment now is quite novel and multiply connected. So we still have a system analogous to a windmill, though *a very novel windmill and a very novel wind indeed.*

Without belaboring the point, action-at-a-distance is absolutely required in quantum mechanics. Further, photon correlation experiments have long demonstrated experimentally that such action-at-a-distance effects do exist, just as predicted. This was a refutation to Einstein's objection to quantum mechanics' "spooky action at a distance".

We point out without further comment that, if a self-powered process is Invoked in the initiating station, then all other participating stations also contain that self-powered process. However, note that one does not really wish to "invoke" a quantum potential connection and use it except occasionally and very quickly! Otherwise, if a strong QP is turned on and **left** on among many distant stations, anything and everything happening to each one of them can instantly appear in all of them, so long as the "constant of connectivity" remains a constant or nearly so.[160] For that reason, strong quantum potential connections can be self-destroying and strong effects do not seem to normally appear in the physical world.[161] The proper energy use of a quantum potential is thus to use it only for fleeting "inductions" of effects in the desired stations, in *momentarily* multiply connected spacetime, at least until the self-limiting behavior is ascertained.

Apparently, a quantum potential can sometimes be formed in the limit of an iterative, mutually phase conjugating operation of EM signals passed back and forth between two phase conjugate mirrors, or among many of them. Such iterative mutual phase conjugate reflection of signals — particularly pumped signals — is technically known as iterative *self-targeting.* Sometimes we use a more picturesque term, *ping-pong,* for iterative self-targeting.

Conceivably, strongly coupled, strongly pumped optical self-targeting mirrors can — in the extreme limit — initiate or partially initiate a quantum potential. The superposing beams of energy may be thought of as first narrowing to laser-like beams, then gradually subsiding into pure longitudinal waves with transverse components "canceled" to form simply "stress energy". In short, if this reaction occurs, the energy is transformed into a stress energy potential, which acts either as a scalar potential in the Coulomb gauge or as Bohm's quantum potential. In our view, the pure longitudinal wave has infinite velocity, as pointed out by Rodrigues and Lu {93a}, so Lorentz-Fitzgerald contraction results in "zero-separation distance", which in turn results in a multiply-connected spacetime.

One points out that the "input energy" to the initiating station may be deliberately structured internally, including altering the internal Whittaker longitudinal EM wave functions comprising the input electrical field energy. In this manner, in theory deliberate spacetime curvature sets and dynamics can be introduced into the distant but multiply connected targets. A form of highly advanced electro-biological warfare induction of disease has been developed by at least one nation (Russia) in this regard, as an extension of Kaznacheyev's experiments showing induction of cellular disease at a distance. It appears that the cells of a living body are interconnected by a very weak quantum potential in such manner. Again, a great deal more research on that possibility is needed.

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[160] Fortunately, it appears that this connectivity constant is not really constant, but reduces as the feedback of each station's fluctuations to the other stations increases. The result seems to be a "leveling off process reaching a plateau and a fixed amount of gain in the overall system. In short, the system usually seems to be "self-adjusting" and "self-limiting" as the overall gain increases. Nature is riddled with quantum potentials, but this self-limiting process keeps most so tiny that they are not even noticeable.

[161] However, the validity or invalidity of this statement for some of the highly energetic phenomena of astronomy remains to be determined. It also remains to be determined as far as the quantum potential's role in generating the zero point energy fluctuations of the active vacuum.

Given a quantum potential connection between separated objects including our initiating station, one can also add vacuum *engines* (energy structuring of curvatures of spacetime itself) as our input to the initiating node. Those vacuum engines will then simultaneously appear unabated (or only partially abated) in the multiply connected separated objects. In this way, in theory one can use the QP and QP energy to perform highly anomalous *momentary* engineering of nuclides, materials, fields, etc. in widely separated, distant objects and areas. By repeating the momentary engineering "pulses", distant objects and areas can be profoundly altered.

The use of vacuum engines in medical applications is of particular future interest.[162] Very radical extension of those techniques can be achieved once quantum potential technology is developed and available in the open scientific community.

But let us ignore the weapons, free our scientific imagination, and let it roam. As an example, in the future a vacuum engine (spacetime curvature engine) might be developed and utilized in a world-wide quantum potential to *momentarily* strike and eradicate all AIDS viruses on Earth, and do only that. Or, the engine could be slanted to simply *momentarily* slightly change those viruses into an innocuous kind of new virus. The cells of the individual human body are already connected, it appears, by a very weak quantum potential. By connecting an external initiating station to that body's quantum potential, the energy of the body could be directly scanned, all abnormalities noted, and tailored engines created and *momentarily* used to treat the body and correct its abnormalities and malconditions. This, we believe, may well be a medical therapy of the future, a few generations from now.[163]

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[162] See Vlail Kaznacheyev and L. P. Mikhailova, *Ultraweak Radiation in Intercellular Interactions,* [in Russian], Novosibirsk, 1981; Vlail Kaznacheyev *et al.,* "Distant intercellular interactions in a system of two tissue cultures," P*sychoenergetic Systems,* 1(3), Mar. 1976, p. 141-142; Vlail Kaznacheyev, "Apparent information transfer between two groups of cells," *Psychoenergetic Systems,* 1(1), Dec. 1974, p. 37. Unfortunately this QP induction of cellular disease has already been used by the former Soviet Union to develop a QP extension of the **force**-free structured potentials method first used to induce cellular disease and **health** changes in U.S. personnel in the former U.S. Embassy in Moscow for several decades. Now QP weapons using such techniques can target the entire population of a targeted nation. Using the internal Whittaker structuring of quantum potentials and EM fields and waves, *electromagnetic biological warfare* has already been born and highly developed. The actual dimensions of possible biological warfare strikes are far greater than has been mentioned in the open literature.

6.3 Other Systems of Electrical Interest

6.3.1 Russian Parametric Oscillator Power Systems

In leading physics institutes and laboratories in the 1930s, Russian scientists built COP>1.0 parametric oscillators, including some of appreciable size. The work is documented in the literature {362a-k}, both in Russia and in France. The devices were developed and tested in several Russian laboratories. With linear loads, the oscillators would progressively build to self-destruction. With nonlinear loads, the devices would stabilize and power themselves and their loads, at a level depending on conditions — reminiscent of the behavior shown in Figure 4-3 in Chapter 4 for stability COP>1.0 levels for the asymmetrical self-regauging process.

Standard references for parametric oscillation in EM circuits are available. However, with standard practices none of these conventional oscillators produces COP>1.0, primarily because the conventional closed current loop circuit is applied without special modifications. For overunity work, the

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[163] Apparently, tests of such QP capabilities in weaponry have been gingerly conducted for direct induction of disease patterns in the population of a targeted nation or area. One symptom of such a test is that a very small number of widely isolated cases of the same disease breaks out simultaneously, in isolated cases scattered widely and puzzlingly throughout the population, *without the possibility of any direct carrier vector connection.* Apparently, the test inductions have deliberately been held mostly to the "shadow state" (or upper virtual state, just below observable state) in most of the targeted populace, to prevent giving away the tests. However, the human immune system and cellular regenerative system do respond to such "near-observable-state" signals and engines, when sustained or repeated in time, by a sort of coherent addition (integration) over time. The bell-shaped distribution curve predicts that a few individuals, randomly scattered throughout the populace, will have quite lower induction thresholds and will evidence the actual disease after a certain time, whereas in almost all the other members of that population the "disease" will never evidence in the observable state during that time. The test is deliberately terminated when only a few observable cases occur, which are sufficient to prove the efficacy of the test and the method.

Russian and French literature (as we referenced) should be meticulously studied and analyzed in a higher group symmetry electrodynamics, to see how the Lorentz condition is broken during discharge of circuit excitation energy in the load, and how the COP>1.0 Dirac hole current decay mechanism is avoided or contained.

The Russian COP>1.0 parametric oscillation work appears to have been suppressed by the Communist regime just prior to WW II. After the war, all such technology passed under the rigid control of the KGB (by whatever name it took and takes from time to time) and into the special weapons research and development area — still highly classified in Russia. We know of no similar work presently ongoing in the West, although at least an English translation of one of the major summary documents of the Russian parametric oscillation COP>1.0 power system developments was performed under NASA auspices {363}. However, in conventional U.S. parametric oscillation research, I know of no case where COP>1.0 operation is being sought, or where the Dirac sea hole current decay mechanism is even mentioned or recognized {364}.

6.3.2 Sweet Vacuum Triode Amplifier

During the 1980s and 1990s, the present author worked —sometimes closely for extended intervals — with inventor Floyd Sweet, the inventor of the Sweet vacuum triode amplifier (VTA). Indeed, we gave the unit its VTA name, at Sweet's request.

Fig. 6-5 (pg. 384) shows a diagrammatic illustration of the fundamental VTA construction. Two coils in quadrature are between two barium ferrite "brick" magnets, of the kind formerly used in many power audio systems. The vertical coil is the "input" signal coil, and the horizontal coil is the "output" power coil. The input consisted of a 33 microwatt 10 volt 60-Hertz signal, and the output was a 120-volt 60-Hertz 500-watt signal. The barium nuclei in the magnets were specially preconditioned by Sweet so that they were in powerful self-oscillation with the surrounding energetic vacuum. A double-edged razor blade or piece of shim stock placed on one of these magnets would oscillate back and forth, incessantly, without cessation — showing that the magnetic field itself was "waving" back and forth (Figure 6-6). It was also continually doing work against air **resistance,** by moving the air.

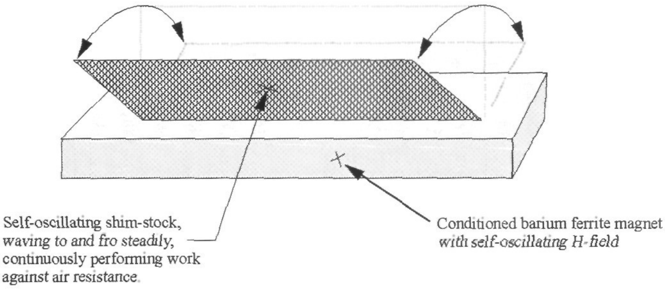
Self-oscillating shim-stock, waving to and fro steadily, continuously performing work against air resistance.
Conditioned barium ferrite magnet with self-oscillating H-field

Figure 6-6 Blade waving continuously on Sweet's conditioned barium ferrite magnet.

Sweet had a Master's degree in electrical engineering from a leading university and handled the mathematical theory very well. He had worked at General Electric for many years, and Gabriel Kron was his patron and mentor. Sweet often spoke glowingly of Kron, and I came to believe that Sweet's VTA was probably an outgrowth of, or very similar to, Kron's negative resistor.

- Two activated magnets facing, with fields in self-oscillation.
- Barium ferrite magnets, barium nuclei in self-oscillation
- Barium nuclei self-pumped
- Two coils in quadrature, load is lamps, six watts
- Next unit produced 500 watts output with 330 microwatts input; later made 5 kW VTA

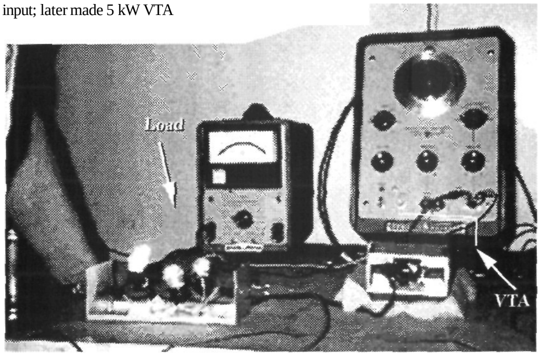

Figure 6-7 First Sweet VTA producing 6 watts output.

When I first met Sweet, his little VTA system was producing a 6-watt output, enough to light four 1.5 watts of auto lamps (Figure 6-7. But there was no question as to the genuineness of the device. Nothing was hidden, and Sweet allowed me to measure the device at will, disassemble it, play with it, and examine it in any fashion. It was genuine, and not a hoax or trick. I also locked up one of his specially conditioned magnets for 24 hours, with a piece of shim stock sitting on the flat of the magnet and waving to and fro continuously, steadily performing work by moving air. When I opened the lock the next day, the shim stock was still there on the magnet and oscillating, having continuously done work against the air resistance for 24 hours with absolutely no energy input by the operator. And it was still working. Indeed, that single "kinetic" permanent magnet destroys all objections to COP>1.0 EM systems, including those that are self-powering and thus have COP = ∞.

It seems little known that the vacuum around nuclei, in some cases, can be treated as a semiconductor, e.g. as discussed by Prange and Strance {365}. It is also known that nuclei do exhibit resonances at ELF frequencies. In particular, the vacuum in the region close to the nucleus of a superheavy element is known to act in a fashion analogous to the inversion layer in a field effect transistor. Prange and Strance introduce the idea of the inverted vacuum. Just as a semiconductor may be manipulated by subjecting it to external fields, doping etc., it appears that the vacuum can be similarly manipulated by appropriate means. We personally suspect that the semiconducting vacuum can be and is resonantly involved in any ELF resonances of the nucleus, which can occur in lighter nuclei such as barium.[164]

The virtual particle flux of vacuum, regarded as noise, may provide noise amplification of the coherent self-oscillation frequency between the semiconducting vacuum and the barium nucleus. Certainly, analogous noise amplification of signals is known in electrical physics {366}.

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[164] Here our concept of the supersystem may be of utility. The "lock-in" or "freeze-framing" of an equilibrium condition for a system — such as in a state of nuclear ELF self-oscillation — is stabilized and made a "new equilibrium condition" when the force field reaction from the curved local spacetime into the system is equal and o**pposite** to the force field reaction from the local active vacuum into the system. We believe Sweet's undisclosed activation process was a method for synchronizing those two force field reactions and making them equal and opposite in one short discharge. We hope that this speculation is of use to future experimenters trying to duplicate Sweet's activation of his magnets into sustained and powerful supersystem self-oscillation.

I hypothesized that Sweet's activation process treated the vacuum surrounding the barium nucleus in such fashion, so that he was able to establish self-oscillation between the local activated vacuum and the concomitantly activated barium nucleus. Since barium ferrite is optically active, it may be that Sweet discovered how to get sufficient "self-pumping gain" for the self-oscillation to endure and not die away in a decaying oscillation manner. Since the "gain" of the second VTA as a self-pumping device was some 1,500,000 (Figure 6-8), obviously Sweet's activation method introduced a powerful state of self-oscillation.[165]

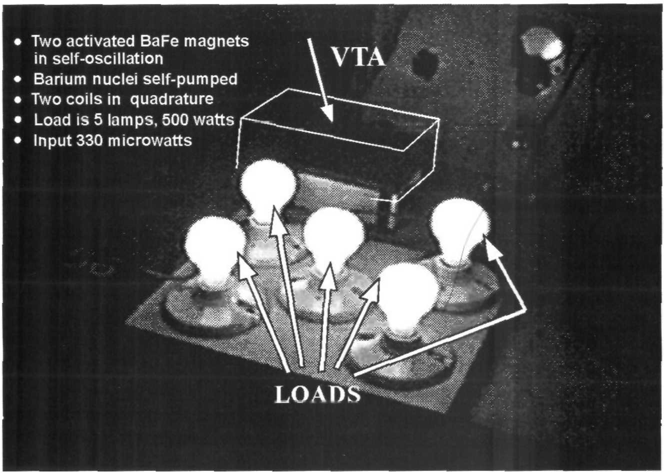
• Two activated BaFe magnets in self-oscillation
• Barium nuclei self-pumped
• Two coils in quadrature
• Load is 5 lamps, 500 watts
• Input 330 microwatts
VTA
LOADS

Figure 6-8 Second Sweet VTA producing 500 **watts and C0P=1,500,000.**

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[165] Here we point out that "small" things with very close "double surfaces" of opposite charge or potential usually have very large fields. The tiny Lamb shift, e.g., has a local energy density greater than the surface energy of the sun. Jackson, *Classical Electrodynamics,* Second Edition, 1975, p. 10-11 points out that *"field strengths of the order of* 10^9*-*10^{15} *volts/cm exist at the orbits of electrons in atoms, while the electric field at the edge of a heavy nucleus is of the order of* 10^{19} *volts/cm."* It should be obvious to the reader that, if our speculation is true and nuclear oscillation of the barium nuclei is involved, the production of optical gains of 1.5 x 10^6 in Sweet's self-pumped, optically acting barium ferrite magnets is not surprising because of the extreme magnitude of the oscillating nuclear fields. In that case, optical gain converts directly to true power gain because the pumping energy is furnished freely by the environment and not by the experimenter.

6.3.2.1 Mapping the Magnetic Field of the Magnets

Figure 6-9 shows a small magnetic field mapping device built by test engineer Rosenthal for Sweet. Sweet "scanned" and mapped the consistency of the magnetic field from his candidate magnets (barium ferrite magnets bought from surplus stores at the time). If the consistency varied over 12 to 15%, the magnet was useless because it would not "hold" the activation and retain it. Magnets whose magnetic field variation did not exceed 10% were ideal. So Sweet only found about 1 in 10 or even 1 in 30 magnets that would retain the self-oscillation state when initiated.

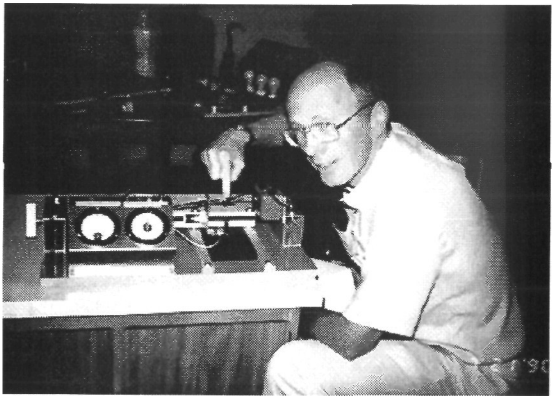

Figure *6-9* Test engineer Rosenthal points to a magnetic field strength mapping device he built for Sweet.

Sweet may have actually used two appreciably higher frequencies in his activation process, with the difference frequency between them being a precise ELF frequency (60-hertz, 100-hertz, 400-hertz, etc. as he desired). That would make sense, when one realizes that the magnet is a highly nonlinear medium and then treats it (to first order) as an isotropic nonlinear medium. In that case, the two wave frequencies actually used would be subject individually to the normal overshoot, breakup, reconstitution, etc. inside the material of the magnet — but the difference frequency would behave as if it were a sine-wave frequency {367}.

This makes sense, since the output wave of Sweet's activated magnet was essentially a pure sine wave. Also, the presence of noise-enhanced heterodyning can sometimes be used to amplify a difference signal even further {368}. As we stated, since the activation is a self-oscillation between the local semiconducting vacuum and the barium nuclei, one wonders whether much of the rest of the vacuum virtual particle flux can be treated as noise, and whether an effect is obtained for noise amplification of the coherent self-oscillation frequency.

L'vov and Prozorova {369} point out some interesting characteristics of the formation of self-oscillating spin waves which occur above parametric excitation. These oscillations result when internal stability does not occur, and they evidence themselves as oscillations of magnetization. The frequencies of the oscillations usually lie in the range from tens of kilohertz to tens of megahertz. At small above-threshold ratios, the shape of the oscillations is nearly sinusoidal. At larger ratios, the shape differs appreciably from sinusoidal. At still larger ratios, the oscillations become chaotic.

If Sweet did use the "difference frequency" conditioning, one suspects he may thus have been able to utilize larger above-threshold ratios, where the two frequencies actually transmitted would have resulted in chaotic oscillations. It is interesting to speculate that, in that case, for a suitably chosen barium ferrite magnet, the difference frequency still can behave sinusoidally, but now much stronger. If so, that might account for the tremendous COP Sweet attained in his second unit, which exhibited a COP = 1.5×10^6, and could be pushed even higher.

6.3.2.2 Sweet VTA for Closed-Loop Self-Powering Operation

Courtesy of Walter Rosenthal, we now present a visual record of the Sweet closed-loop self-powering version of the VTA and its momentous successful acceptance test on May 1, 1990, as closely observed by Rosenthal.

Figure 6-10 shows Sweet and a different version of the VTA, with the coils in a slightly different configuration and the windings altered. This is the two-magnet, 2-coil VTA that he built and tested for self-powering operation. Figure 6-11 shows the unit mounted on a special test fixture built by engineer Rosenthal. This fixture and its components allowed the sensing of the sine wave output power at the zero-value crossover points. To switch in the special clamped feedback system for self-powering operation of the input, and simultaneously switching away from external power, the switching had to be done very accurately at that zero-point crossover. Feedback would not stabilize and hold if the switching were done at any other point in the output cycle.

Unit independently examined and testing observed by
test engineer Walter Rosenthal

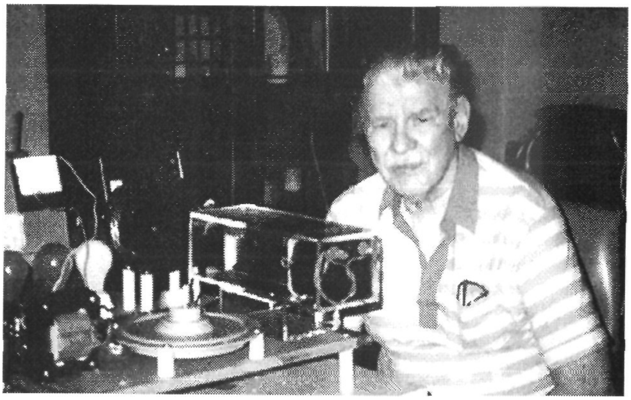

Figure 6-10 Sweet with 2-magnet 2 coil VTA, loads, and instruments for historic self-powering operational tests on May 1,1990.

Figure 6-12 shows the set-up for the tests, with the unit and loads as well as some of the instruments used. Figure 6-13 shows the closed-loop VTA powering itself and its loads, after being initially set into operation with outside input power by the operator, and then adroitly switched into self-powering by switching the input from external to internal at an output

Fixture allowed unit to be started into operation on external power then switched to self-powering internal power at the zero crossing of the *output* voltage The device in its fixture has a row of test points (disconnects) on every conductor going to the device

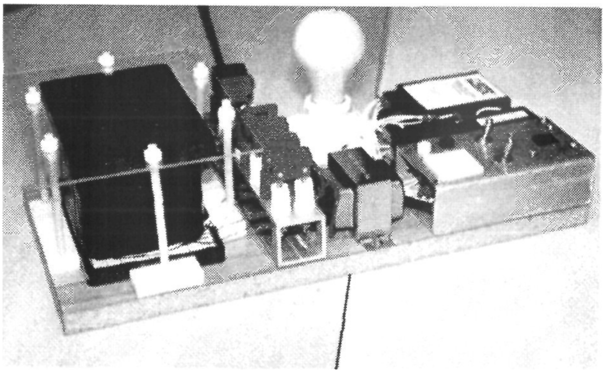

Figure 6-11 Two-magnet two-coil VTA mounted on a special test fixture built by Walter Rosenthal.

power zero crossover point. This picture shows the unit in self-powering and stable operation, taking all its input energy from the vacuum, including the power necessary to power its own internal losses and the power necessary to power its controls and loads.

Independently examined and testing observed by test engineer Walter Rosenthal

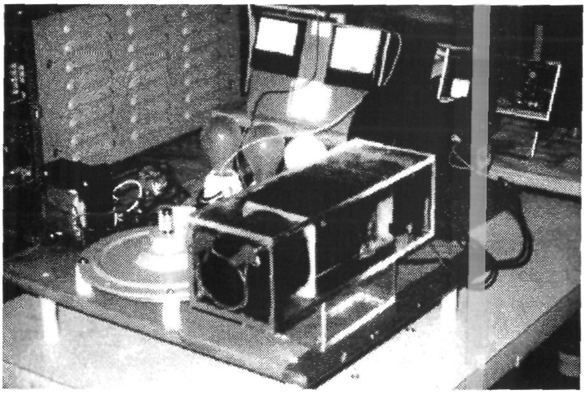

Figure 6-12 The 2-magnet, 2 coil VTA, loads, and instruments for its historic self-powering operational tests on May 1,1990.

Formal self-powering test on 1 May 1990 The loads and the VTA are powered by electrical energy extracted directly from the activ e vacuum Independently observed by professional test engineer Walter Rosenthal

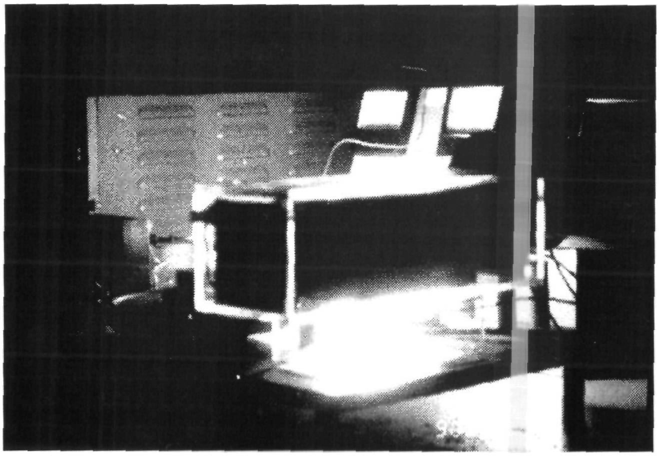

Figure 6-13 Historic self-powering operational test of the VTA May 1,1990 with no energy Input by the operator.

We strongly stress that this operation is permitted by the laws of physics and thermodynamics for an open EM system far from equilibrium in its exchange with its active environment. The active environment in this case is the combination of the active local vacuum and the active local curvatures of spacetime. The closed-loop condition is a new and stable equilibrium condition in the dynamics of the mutual exchanges between all three supersystem components: the system, the active vacuum, and the curvatures of spacetime. The *system* is in stable disequilibrium; the *supersystem* is in a stable new equilibrium condition.

6.3.2.3Discussion

We do know that the output current of the second Sweet device was comprised of a significant Dirac hole current[166] as well as electron current — showing the expected heavy involvement of the altered local vacuum (the Dirac sea) and the curved local spacetime. The negative energy majority of the output revealed itself readily. If the output leads were shorted, ice formed instantly on the shorted leads from the moisture in the air. That is, an electrical short resulted in the sudden production of cold (negative) EM energy rather than positive EM energy.[167] That can only occur if the majority of the output is negative energy, and any sudden surge in output (as from the shorted leads) increases the ratio of negative energy to positive energy so that very strong net cooling results.

For many predominantly mechanical components (simple electrical motors, light bulbs, etc.), Dirac hole current applied to the positive lead will power the circuit equally as well as electron current applied to the high voltage (negative) side, if the grounding is simply by a conductor and not a "vast reservoir" of charge. In such case, the wire chosen to conduct or direct the Dirac hole current should be made very small. It can and will carry intense hole current and will cool rather than heat.[168] The wire to the electron side of the device should be made normal sized, appropriate to the electron current to be carried.

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[166] We do mean hole current in the Dirac sea, consisting of Dirac holes in the vacuum itself, prior to their interaction with charged matter to form lattice holes in matter. We do not mean the standard lattice hole current at all.

[167] In local curved spacetime, Dirac holes constitute "negative energy EM fields and potentials". In such case, one can have negative energy entities and reactions analogous to positive energy entities and reactions in 3-space. On the time axis, one also has negative energy entities and currents, potentials, waves, fields, etc. Because c**lassical** Maxwell-Heaviside-Lorentz theory eliminates any modeling of the local vacuum or the local curvature of spacetime, these negative spacetime curvature **(negative** energy) potentials, fields, and currents have not been added into the electromagnetic theory. That of course is a serious shortcoming of the normal theory.

Several other inventors over the years have been able to activate a barium ferrite magnet into sustained self-oscillation of its material particles or domains, in similar but weaker fashion for varying lengths of time — up to a month or so in the longest time that I am aware of. Sweet's magnet would continue in self-oscillation indefinitely unless (i) the magnet was sharply shocked mechanically (as with a hammer blow), (ii) the magnet was heated to too high a temperature, (iii) the leads of the output circuit were electrically shorted, or (iv) external artificial field interference (electrical pulse shock, particularly from longitudinal stress waves) was encountered.[169,170]

Unfortunately, Sweet signed multiple conflicting agreements with several financial backers, and his work was legally entangled so deeply that it was never straightened. He eventually died, taking with him his activation secret. He was often threatened, and was once fired at by a professional assassin using a silenced rifle. He survived the incident because, being old and a bit feeble, he stumbled and fell over the front steps just as the assassin fired. The bullet snapped by his ear, right where his head had just been. The incident was reported to the FBI, but with nothing else to go on, the assassin was never caught.

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[168] This is very probably the secret of Tesla's "single wire system". At an exposition in Nevada, Bedini demonstrated just such a system, by powering 600 watts of audio speakers at the end of a long, very thin wire across the stage from his power amplifier. If he had been using positive EM energy, the wire would have instantly melted.

[169] During that period, the Russians were playing with earthquake induction via scalar interferometers, at various places around the world, including inside the U.S. heartland. Sweet's machine would sit above a natural quake and not be affected. But when a quake within many hundreds — even several thousands — of miles was artificially induced, the Sweet device would react to it. A fairly close artificially induced quake would destroy the self-oscillation of the magnets, and sometimes a very close artificially induced quake would actually explode the intensely activated magnets. So for several years one had a way of ascertaining which quakes were natural and which were artificially induced, by simply having Sweet confirm how his magnets interacted.

[170] For those who do not believe such an activity, here is a direct statement by then-Secretary of Defense William Cohen: *"Others are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of electromagnetic waves... So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations...It's real, and that's the reason why we have to intensify our efforts. "* Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, **University of Georgia, Athens, Apr. 28, 1997.**

By whatever means, we do know that Sweet's magnets had to be activated by a special process that Sweet used and never fully revealed. An activated or "kinetic" magnet, it seems, was actually something a few of the "older magnetics guys" had known about, and Sweet had learned of it either from them or from Gabriel Kron. Sweet was also a transformer designer and expert, and he remarked that he had also observed specialized self-oscillation in certain transformers. Although most power engineers approached were either nonplussed or completely skeptical of a "self-oscillating field in a permanent magnet", self-oscillation of the fields, spin waves, etc. in permanent magnet materials *are* known to materials scientists today, especially to those working with magnetic effects in thin film materials {370, 371a-b}.

From a general relativity viewpoint, particle spin has a unique spin field of its own {372}, and there are such spin fields involved and operating in magnetic systems. The simple classical electrodynamic approach to magnetism and magnetic assemblies — or the view of a magnet as simply a bar with a north pole and a south pole — is quite insufficient when one wishes to research magnetic assemblies that will act as open systems far from equilibrium with their active environment, and thus will be capable of COP> 1.0 operations.

Recent work in coupled spins has revealed long-range coherence effects, previously unsuspected, as well as dual spin states participating in such phenomena {373a-b}. For example, Johnson has long used a 2-particle approach to spins and spin flipping in his own highly nonlinear magnetic assemblies {374}. His recent laboratory work has also shown similar and unsuspected *long-range coherence* effects in large multiple-magnet macroscopic systems {375} such as large assemblies of neodymium-iron magnets. This is strongly suggestive of the expected general relativistic spin field previously mentioned.

This work by Johnson is very important, since it may reveal a hitherto unsuspected mechanism for decay — of an otherwise nonconservative magnetic field around a closed loop — back into a conservative field. If one seeks an all-permanent-magnet rotating motor, a nonconservative magnetic field around a rotation loop must be established and sustained if one is to have self-rotation and self-powering. A nonconservative magnetic field around such a rotation loop means that the system acts as an open system far from equilibrium with its active vacuum and active curved spacetime environment, by means of some asymmetry mechanism such as multi-valued magnetic potential {376a-c, 377a-g}, elucidation of exchange forces {378a-c} at selected positions and directions, etc. It also requires both a stable broken 3-symmetry and a stable 4-symmetry.

On the other hand, in our opinion, Sweet employed spin waves triggered into self-oscillation in the nuclei of the barium atoms in his barium ferrite magnets. Indeed, such nuclear spin waves in magnets have been known for some time {379}. We postulate that, as in any other COP>1.0 power system, a self-rotating all-permanent-magnet motor must also involve Dirac sea hole current interacting in the various magnetic components. It is reasonable to suspect that these also interact with the electrons and their spin fields, perhaps producing the active mechanism providing that observed long-range coherence that apparently can decay the nonconservative magnetic field around the rotation loop, causing it to revert back to a conservative field and thereby stop the self-rotation and self-powering. If so, that long-range coherence must be violated and the violation stabilized. However, we could find no papers in the literature that deal with such possibilities. Hence it is a subject for further investigation by COP>1.0 researchers.

6.3.2.4 The *Highly Successful Anti-Gravity Test*

On one trip to California to work with Sweet, we noticed that, at full power output of 500 watts, his unit weighed a little less on the bench than when not powered. Struck by this anomaly, I considered the negative energy aspects of the output — as evidenced by the Sweet's demonstration of icing when the output leads were shorted — and the very high gain, which added up to a predominance of negative energy in the output.

Pondering this from a general relativity viewpoint, I reasoned that: (i) increase of positive EM energy density in space increases the curvature of spacetime to produce additional positive gravity G_P; (ii) increase of negative EM energy density in space must increase the curvature of spacetime in the other direction, and thus it must produce negative gravity G_N., and (iii) the total gravity G_T produced in the immediate spacetime of an object producing both positive gravity G_P and negative gravity G_N, was $G_T = f(G_P + G_N)$. Thus if we increased the output of the VTA unit, we must inevitably increase the weight reduction (antigravity) effect since the predominance of the energy output was negative energy, and this output was in the neglected negative energy fields aspect as well as in the local vacuum (spacetime) itself. After several back-of-the-envelope estimates and educated guesses over some weeks, I concluded that if the efficiency of the antigravity process[171] were 10% and the unit was pushed to 1500 watts output, it would lose all its weight and hover weightless.

However, because of the nonlinear local spacetime, magnetic monopoles[172, 173] were deposited in Sweet's magnets when the unit was producing power, and the density of these monopoles varied as the output power. Increasing the power output thus increased the tensile stress of the magnets, and at some point they would explode into fragments, like a hand grenade.[174] This explained why conditioned magnets sometimes exploded when experiencing fluctuations from artificial earthquake induction testing.

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[171] We again accent the difference between efficiency and COP. Here we are definitely speaking of efficiency, not COP.

[72] Dr. Robert Flower has confirmed that the 'symmetrized" (or "extended") Maxwell equations (Eqs. 7.1 in Springer's *Encyclopedia of Physics,* Vol. 16, p. 431) include non-zero magnetic charges and magnetic currents. Antenna engineers (Henning Harmuth, and others) know that these terms must be included for proper description of boundary conditions, even though, at the final step of computation, their integrals are set equal to zero (apparently to snuff out magnetic monopoles). For Dirac's original theory of the monopole, see P. A. M. Dirac, "Theory of magnetic monopoles," *Phys. Rev.,* Vol. 74, 1948, p. 817-830. See also F. A. Bais and B. J. Schroers, "Quantisation of Monopoles with Non-abelian Magnetic Charge," *Nuclear Physics B,* Vol. 512, 1998, p. 250-294; G. Lochak, "The Symmetry Between Electricity and Magnetism and the Problem of the Existence of a Magnetic Monopole," in T. W. Barrett and D. M Grimes. [Eds.] *Advanced Electromagnetism: Fundations, Theory, & Applications,* World Scientific, 1995, p. 105-147. Particularly see T. W. Barrett, "On the distinction between fields and their metric: the fundamental difference between specifications concerning medium-independent fields and constitutive specifications concerning relations to the medium in which they exist." *Annales de la Fondation Louis de Broglie,* 14(1), 1989, p. 37-75; — "Electromagnetic Phenomena Not Explained by Maxwell's Equations," in Lakhtakia, A. (ed.): *Essays on the Formal Aspects ofElectromagnetic Theory,* World Scientific, River Edge, NJ, 1993, p. 6-86; — "The Ehrenhaft-Mikhailov effect described as the behavior of a low energy density magnetic monopole-instanton." *Annales de la Fondation Louis de Broglie,* Vol. 19, 1994, p. 291-301. The work of Ehrenhaft, which is now substantiated and thoroughly replicated by Mikhailov, has produced experimental evidence of the magnetic monopole in many replicable experiments. In these experiments, magnetic particles move in a magnetic field along the lines of force. Reversal of the magnetic field, H, causes a reversal of the magnetic particle's motion, which is not the case with magnetic dipoles, since that can only occur for a monopole. See V. F. Mikhailov, "Observation of magnetic monopoles in the field of a line conductor," *J. Phys. A: Math. Gen.,* Vol. 18, 1985, p. L903-L906; — "Observation of the magnetic charge effect in experiments with ferromagnetic aerosols." *Annales de la Fondation Louis de Broglie,* Vol. 12, 1987, p. 491-523. See also M J. Perry, "Magnetic monopoles and the Kaluza-Klein theory," *Am. Inst. Phys. Conf. Proc,* No. 116, 1984, p. 121-125; E. V. Smetanin, "Electromagnetic field in a space with curvature — new solutions," *Soviet Physics Journal,* 25(2), Feb. 1982. p. 107-111. [English translation]. See also T. T. Wu and C. N. Yang, "Dirac monopole without strings: monopole harmonics," *Nuclear Physics,* Vol. B107, 1976,

Having no explosive control facilities, I warned Sweet not to push the unit past 1,000 watts, for safety reasons. At my urging, Sweet made a new output load often 100-watt lamps in sockets, so the load could be varied from 100 to 1,000 watts easily.

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p. 365-380; — "Dirac's monopole without strings: classical Lagrangian theory," *Phys. Rev. D.,* 14(2), July 15, 1976, p. 437-445.

[173] We emphasize that a magnetic monopole can be taken simply as a highly localized magnetic scalar stress potential. See, e.g., P. A. M. Dirac, "Theory of magnetic monopoles," *Phys. Rev.,* Vol. 74, 1948, p. 817-830. Dirac pointed out that the existence of a single magnetic monopole in nature would allow an explanation for charge quantization. We believe that the reverse of Dirac's argument may be true also: The existence of charge quantization should allow an explanation for the magnetic monopole. However, we also surmise that a magnetic monopole exists only in (and as) a sharply localized curvature of spacetime. Jackson, *Classical Electrodynamics,* second edition, 1975, p. had this to say about magnetic dipoles and Dirac's argument: *"Dirac's argument... is that the mere existence of one magnetic monopole in the universe would offer an explanation of the discrete nature of electric charge. Since the quantization of charge is one of the most profound mysteries of the physical world, Dirac's idea has great appeal. "*

[174] Sweet in fact did explode several magnets by pushing the power output of the device. Pushing the output was easy (and is easy for any unit outputting mostly negative energy), because all one had to do was connect additional load.

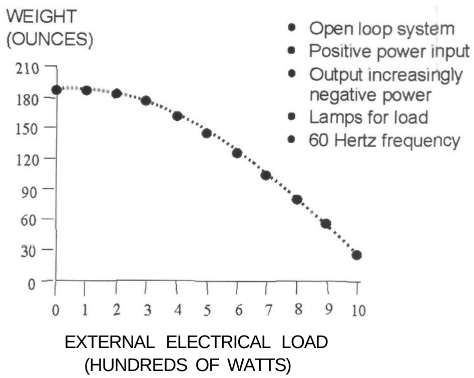

Figure 6-14 **Results** of the "pushed" VTA **antigravity test:** Weight **of VTA on the bench versus power output.**

Sweet completed the new load section and performed the experiment in California after I had returned to Huntsville, reading off the results to me over the phone. I took down the data, and then plotted the curve. Figure 6-14) shows the beautiful results. At 1,000 watts the unit had lost 90% of its weight. This was electrifying, because it was an unprecedented and highly successful antigravity experiment. Even my original "rough" assumption of levitation at 1500 watts was not too far from the indicated 1250 watts or so from the actual curve.

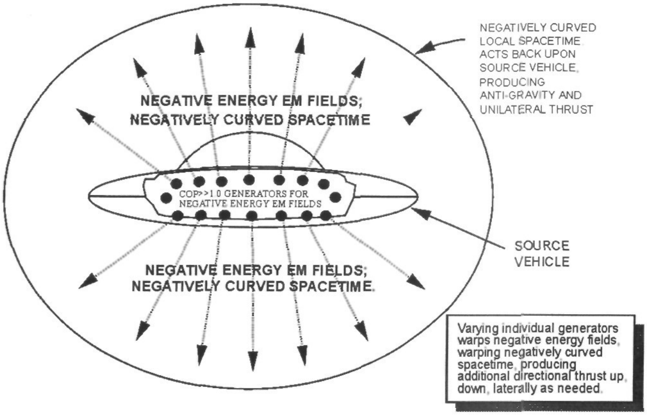
NEGATIVELY CURVED LOCAL SPACETIME ACTS BACK UPON SOURCE VEHICLE, PRODUCING ANTI-GRAVITY AND UNILATERAL THRUST
NEGATIVE ENERGY EM FIELDS; NEGATIVELY CURVED SPACETIME
COP>>1.0 GENERATORS FOR NEGATIVE ENERGY EM FIELDS
SOURCE VEHICLE
NEGATIVE ENERGY EM FIELDS; NEGATIVELY CURVED SPACETIME.
Varying individual generators warps negative energy fields, warping negatively curved spacetime, producing additional directional thrust up, down, laterally as needed.

Figure 6-15 Proposed mechanism for practical antigravity.

Figure 6-15 shows my proposed mechanism for antigravity. We simply use negative EM field energy generators to produce a negative EM energy field in space surrounding the source vehicle. The associated positive energy from the same energetic power source can power the vehicle simultaneously. The local reversed curvature of spacetime now interacts back upon the mass of the vehicle, to produce an antigravity component. By adjusting the output of the power source, the amount of negative energy — and hence the amount of antigravity component — can readily be varied and controlled. By controlling the directions of the field components, one can have unidirectional antigravity force, or antigravity and thrust force vectors simultaneously. Hence such a vehicle could be maneuvered and controlled, and be self-powering. This at least was and is my concept of a practical antigravity technology.

6.3.2.5 Later Developments and the End of the VTA

Later I prepared a paper on the VTA, including the antigravity experiment's results. We succeeded in getting the paper published {380} but I deliberately did not include the real details of the negative energy aspects as I wished to withhold that information for patenting. I prepared the entire paper, but placed Sweet's name first, as was appropriate since he was the inventor of the VTA.

Unfortunately — but understandably! — Sweet became a bit paranoid after the sniper assassination attempt (he was shot at by a distant sniper using a silenced rifle), and then would never allow a formal demonstration of his antigravity test. I strongly wished to present it to a major national U.S. scientific committee for independent testing and confirmation — which could have been done without Sweet having to reveal his activation process for the magnets. However, Sweet would not hear of such. Indeed, he fearfully kept the antigravity capability a secret from most of his backers. He strongly believed that he would be killed almost immediately if he revealed our antigravity experimental success. He may have been correct.

In fairness, the inventor and his backers of necessity have different priorities from those of scientists doing open research in a university. But at least a record of the test results is in the literature, though certainly not as rigorously or as extensively as I wished. Sometime later, I withdrew from any further association with the VTA unit, after the backers changed, a lawsuit broke out, and the entire project unraveled. Sweet later died without ever revealing his full secret for such powerful activation of self-oscillation in permanent magnets at low ELF frequencies.

The loss of the Sweet vacuum triode was a severe blow to science and a real setback to the scientific progress that could already have been made. Nonetheless, I contributed what I could, documented what I could, and made a videotape of the operation of the open-loop 500-watt device in the power mode. I also made a video of as much as Sweet would reveal of his activation process. I was not allowed to videotape a second antigravity experiment, even though I frequently and strongly requested it. By that time, Sweet mortally feared for his life. Perhaps what we have written in this book will be sufficient to provide some needed clues to some future graduate student or post-doctoral scientist who will succeed in recovering the necessary activation of magnets and both the COP»1.0 power capability and the antigravity experiments.

Meanwhile, I have filed a provisional patent application on the mechanism for antigravity, the gist of which I worked out solely on my own back in 1971 at Georgia Institute of Technology, and that I include in Chapter 8. As far as I am aware, no one else had thought of it previously, or has thought of it in that exact form *{using the causal positron prior to observation, and while it is still a negative energy, negative mass electron, as the source charge for negative EM field energy, and also using the causal positron's corresponding giant Heaviside nondiverged negative energy flow for substantial negative curvature of spacetime.).*

6.3.3 Intense Discharges in Ionized Gas

Intense sudden discharges in ionized gases are especially of interest due to the presence of optical frequency components and the involvement of iterative optical retroreflection etc. These processes seem to be involved in several investigations and inventions. Further, it appears that such intense discharges do produce bursts of negative EM energy as part of their overall discharge energy.

In the case of plasmas, some are known to transduce an input transverse EM wave into an output longitudinal EM wave, and vice versa. We know now that such a longitudinal EM wave is also accompanied by a time-polarized (scalar) EM wave in the time domain. The connection with the Whittaker 1903 decomposition of the potential, and with the new 4-symmetry negentropy law, is apparent. Several COP>1.0 researchers — notably Shoulders {381a-f} and Paulo and Alexandra Correa {382a-e} — have performed extensive research into anomalous discharge phenomena, and also have developed experimental devices capitalizing on the novel effects available.[175, 176] The Correas' U.S. Patent No. 5,449,989 includes many tests of a Correa glow discharge apparatus, one of which in 20 minutes of operation produced 0.988 kilowatt-hour of energy output for an input of 0.258 kilowatt hours. Using the known negative resistor characteristics, the Correas achieved sustained self-oscillations in the discharge.

As an aside, we point out that the well-known anti-Stokes emission — which produces more energy output than the experimenter inputs, and hence exhibits COP>1.0 — has long been validated in certain gases such as aniline vapor {383} and H_2 {384}. Stimulated anti-Stokes radiation occurs in many solid materials such as oxides and doped oxides {385}. Assuming the excess energy comes from the internal energy of the molecules, this is a prime candidate for free replenishment of that furnished internal energy of the molecule, via the broken symmetry of the molecular dipoles in their fierce virtual energy exchange with the local active vacuum and local curved spacetime. Of course, conventionally the energy furnished by the molecules, etc. is not replenished from the vacuum, hence anti-Stokes emission can be used for coherent light cooling effects {386}. Apparently the Correas' process accomplishes the energy replenishing, hence the COP> 1.0 performance over a 20 minute period.

Formation of longitudinal EM waves in the plasma forms in certain gas tubes, such as in Priore's gas-filled tubes {387}, may also occur in the Correa experiments and probably do. Longitudinal EM waves, of course, always involve their concomitant, accompanying time-polarized EM waves, since the combination comprises the scalar potential and hence the local curvature of spacetime provided by that scalar potential. The replenishment mechanism involved in longitudinal EM waves and scalar potentials — time-energy transduced into 3-space energy — apparently is

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[175] Both Shoulders' electron cluster discharges and the discharge phenomena of Paulo and Alexandra Correa have been independently verified. Fox and other scientists have verified COP>1.0 in Shoulders' work, and Mallove has formally observed a self-powering Correa system. Both these highly reputable scientists are well known, have the highest integrity, and I would trust either of them with my life. Further, we point out that strong gradients — as exist temporarily in strong discharge phenomena — are already known to violate thermodynamics. That is one of the areas being researched today to advance thermodynamics, under the aegis of "extended thermodynamics". See Appendix A.

[176] In addition, the Correas have demonstrated a form of energy that demonstrates latent heat. See discussion in Paragraph 6.3.9.

invoked and utilized in the Correas' sustained self-oscillations in the plasma discharge.

6.3.4 Shoulders' Electron Cluster Processes

Valone {388} has summarized Ken Shoulders' charge clusters and processes as follows:

> *"An unusual energy source is the clustering of electrons by a discharge needle into a high density bundle equaling Avogadro's density of a solid.... Ken Shoulders has patented a process (Pat. #5,153,901) that produces electron clusters with such high energy density, they equal processes exceeding 25,000 degrees Celsius upon impact. Yet, he only uses 20 microjoules to produce the effects. The clusters travel at a maximum of one tenth the speed of light and penetrate any substance with accuracy and sharp precision. It is similar to xenon clustering techniques currently used at megavolt energy levels. Low energy nuclear transmutation of the target has also been achieved with this process. Using a deuterium-loaded palladium foil, only the bombardment areas show transmutation into silicon, calcium, and magnesium with electron clusters upon analysis with X-rays. Jin and Fox {389} have postulated that the high velocity electron clusters achieve results similar to accelerators, including penetration of the nucleus, with substantially less power. The new physics of like-charges clustering in bundles under low power conditions opens a wide range of applications including spacecraft maneuvering microthrusters. Overunity efficiency* [sic: should be COP] *is 9 to 1, or higher."*

Ken Shoulders is an accomplished experimental scientist who has discovered and patented many aspects of electron charge clusters, including their COP>1.0 characteristics {390}.

According to his experiments, one of the most remarkable characteristics of these charge clusters seems to be their dramatic reduction of the permittivity of space {391}. Shoulders has noted the remarkable removal Of **positive** charge during the self-formation process of the clusters {392}. In our opinion, the involvement of the supersystem of these charge clusters is shown by that phenomenon. We hypothesize that an accompanying Dirac hole current is shown by the experimental occasions where — in addition to the Shoulders' negative charge clusters — additional charges unite but show effects of having opposite charge {393}. Such changes would change the permittivity of space, which Shoulders has noted. They could also create a time-reversal zone (TRZ), which would account for the clustering of like charges since in a TRZ the law of attraction and repulsion of charges is reversed. In such a zone, like charges attract and unlike charges repel. This could explain why Shoulders has observed both negative charge clustering and positive charge clustering.

This would also explain the remarkable separation of the positive charges from the negative charges — they are simply *repelled* by the negative clusters in a TRZ.[177] This of course immediately involves curvature of spacetime effects, including local changes in the speed of light etc. As stressed by Shoulders, the entire area cries out for extensive and sophisticated experimental investigation on a continuing basis, as well as some powerful new theoretical work. Shoulders has also noted both "black" and "white" (dark and bright) clusters, including their combination and separation, strongly suggesting Dirac holes as well as the electrons in the charge clusters. He has proposed a form of "inertial propulsion" based on some of the mechanisms and asymmetrical forces observed in his experiments, and such asymmetry is possible in curved local spacetime conditions.

The relation of Shoulders' effects to cold fusion phenomena was shown by an experiment in which a deuteron-loaded palladium cathode was impacted by a charge cluster {394}. An explosive-like reaction occurred, and an X-ray analysis of the impact crater showed a number of elements not seen in the nearby palladium surface away from the impact site. Elements such as oxygen, calcium, silicon, and magnesium were detected in the impact site, but not in the surrounding palladium lattice. We would suggest the presence of TRZ-based nuclear transmutation reactions (via quasi-nucleus formation followed by quark-flipping in nucleons as the

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[177] Since the same TRZ phenomenon generates specific nuclear transmutation reactions at low spatial energy, explaining the anomalous transmutation of elements in cold fusion electrolyte experiments, a strong indication exists that it is a viable mechanism. In our mechanism proposed for the flow of time, a TRZ is produced for charges whenever antiphoton interactions predominate over photon interactions. This indeed implies a change in the permittivity of the local space, local curvature of spacetime, and local changes in the speed of light — all phenomena Shoulders notes in his experiments.

TRZ decays to a time-forward zone). Additional information on this charge cluster phenomenon has been given by Fox {395}.

Other Shoulders patents are pending and his research is continuing. It is our understanding that at least one application is presently being developed for the market.

6.3.5 Mills's Hydrino Energy Cells and Developments

Dr. Randell Mills {396a-396c}, {397} has proposed a cosmic sea of hydrinos (the hydrino is a proposed reduced energy state of the hydrogen atom) to explain his tested energy cells. He envisions — and produces a theory for — hydrogen that is reduced to a lower energy state (the "hydrino"). He has gathered considerable evidence for his theory, and has accounted for some sixty or so infrared spectral lines in the sun's radiation that have previously not been explained. Independent tests appear to have validated his energy production claims.

Several major companies are presently working with Mills and his parent company, BlackLight Power, Inc. Progress can be followed from the company website, www.blacklightpower.com. Developments are ongoing in light, power, plasma, and new compositions of matter. A technical book by Mills {398} is freely downloadable from the website, giving his overall theory, as are other publications by Mills *et al.* {399a-h}. Critical objections to various parts of Mills' theory have been given, e.g., by Zimmerman {400}, with Mills responding strongly and — in our opinion — successfully.

Certain concepts utilized by Mills are, in our opinion, valid and insightful - whether or not the classical quantum mechanics developed by him is found to hold, and whether or not it agrees with ordinary quantum mechanics (which has problems of its own). The point is that *the experiments work.* It is thus the job of the theorists to find what changes must be made to the theory for it to remain consistent with experiment. If they do not like Mills' theory, the proper procedure is to advance one that **is** consistent with all the experimental results, and also to show where Mills' theory is inconsistent with the results.

In our own view, an *observed* positive charge is the output of an ongoing time-reversal process and therefore represents a "time-reversed entity" as observed. Before observation (imposition of *d/dt* operator), the positive **charge** is thus a negative 4-charge comprised of *qt*, not *q*. From that viewpoint, the H+ ion, which is just a hydrogen nucleus (a proton) without an electron shell, may be regarded as a time-reversed 4-entity prior to observation. Further, any energy change in and of the hydrogen atom results in a change in the local energy density of spacetime (ST) *a priori,* hence a change in the local ST curvature.

If we regard the entire hydrogen atom as a set of such ST curvatures and their dynamics, then Mills' consideration of a lower positive energy state *hydrino* simply implies the addition of an additional negative ST curvature to the ST curvature set associated with the normal hydrogen atom. We note that binding energy of the nucleons is already negative energy, and thus just such a negative spacetime curvature. But the binding energy is itself a spacetime curvature *capable of being increased,* as can be any spacetime curvature. In the supersystem, addition of such ST curvature is possible, and it is *doable* electrodynamically, particularly when Heaviside's normally unaccounted huge energy component is accounted and utilized.

In our opinion, Mills' theory should probably be recast into a higher group symmetry electrodynamics — such as O(3) — which has been shown to be intimately connected with Sachs's unified field theory. This would provide an adjusted model that is not only testable but also *engineerable.* Nonetheless, the concepts of Mills' theory and the theory should be closely examined as they stand, and at least some of the key concepts are engineerable as witnessed by his successful experimental results. That is better than what the critics have offered! A higher group symmetry recasting would enhance and expand his theory even more, and correct any errors that might be present. It would also allow a full theoretic treatment (i.e., a supersystem treatment) of Mills' main concepts, which we believe have much merit.

Further, given Mills' hydrino as we approached it, two hydrinos will each possess such a set of spacetime curvatures (each will possess such a *vacuum engine).* Later in this book — and elsewhere {401} — we have pointed out that, in a time-reversal zone (TRZ), the law of electromagnetic charge attraction and repulsion is reversed. Accordingly, in a TRZ two or more hydrinos will attract each other so closely that each enters the now-reduced strong force region of the other, forming a quasi-nucleus. As the TRZ decays away back to a normal time-forward zone, because of their power law form the strong forces restore back to normal much faster than the electromagnetic forces do. Hence during its "decay", the quasi-nucleus is energetically compacted into a permanent nucleus, either flipping quarks or giving off one or more particles as necessary to balance its new energy state in the process. We have previously argued that a similar process where a TRZ induces formation of quasi-nuclei also yields the major transmutations {402} demonstrated in a large number of cold fusion experiments worldwide.

The present author has previously proposed an engineerable mechanism (the totality of all photon interactions with a mass) that generates the flow of that mass through time {403}. By manipulating the arrow of time between forward vector and reversed vector, the strong forces in a nucleus (or for a particle) can be directly manipulated in magnitude (and to some extent, even in sign although the latter involves gluon and quark manipulations in the nucleons). By adroit use of these manipulated strong forces and TRZ formation and decay, the energy states of nuclei can indeed be manipulated, including reduced in energy level —just as Mills assumes and presents experimental evidence for, and as cold fusion experiments present experimental evidence for.

We note that two such interacting hydrinos must each possess a specific vacuum engine (specific set of ST curvatures and dynamics). Novel new interactions are available in TRZ's because of manipulation and even reversal of electromagnetic forces, strong forces, etc. and because of nuclear fusion of like charged particles into quasi-nuclei followed by decay into stable nuclei, etc. These novel new particle interactions caused by manipulation of strong spacetime curvature engines and their magnitudes are presently missing from particle physics. Mills, however, does come at them from a somewhat different direction in his own concepts.

The reason for the absence of dominant general relativity effects in most particle physics is that the "total photon interaction" mechanism generating the flow (persistence) of a mass or field through time has not been recognized and used. Consequently, in general only those far weaker ST curvatures due to the weak G-force have been considered. To Mills' great credit, he is aware of the gravitational significance of manipulating much stronger forces and spatial energy densities such as the electromagnetic fields and their energy densities.

The U.S. Patent and Trademark Office then refused a new patent to Mills on one of his processes, and revoked another Mills patent even after already agreeing to award it within two weeks. BlackLight Power, Inc. initiated and lost a lawsuit against the Commissioner of Patents, seeking to reverse this unusual action by the U.S. Patent Office. However, the company's patent portfolio has continued to grow, with extraordinary international applications {404a, 404b}, and several European patents have been filed appropriately. BlackLight Power Inc. seems well funded (some millions of dollars) and well staffed, and we expect to see BlackLight Power, Inc. products entering the market place. Those products will probably be related to fuel cells, plasmas, power converters, generators, separation methods, and novel compounds materials.

and

6.3.6 Switching Circuits with Extended Electron Gas Relaxation Time

See Figure 6-16. Suppose an instantly applied voltage to the high side of the circuit instantly potentializes a pair of circuit conductors, with the other acting as ground. The charges in the conductor are thus instantly potentialized and excited, so that through the external circuit there exists an E-field E, where $\mathbf{E} = -\nabla\phi$ between the high side of the circuit and the ground return side. An acceleration force on the energized electrons thus exists. It requires a finite time for the energized electrons in this force field E to break their static friction or inertia, move, and accelerate to the requisite slow drift velocity down the wire. During that delay or "electron relaxation time", no current is initially in progress, then a little current is flowing, and finally all of the current is flowing. This delay time is called the electron gas relaxation time.

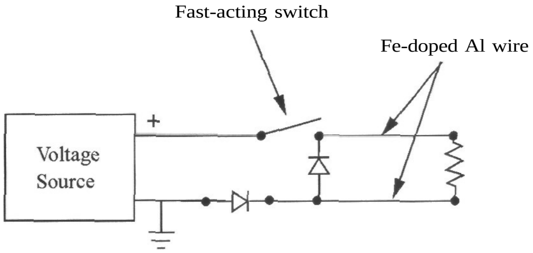

Note: May use many strands of Fe-doped Al wire instead of one, for each conductor

Figure 6-16 Extended-relaxation-time circuit with diodes.

In the usual copper conductor, the delay time arguably may be on the order of 10^{-16} sec. This is so slight a delay that it can be ignored, for all practical purposes. Current — with resulting dissipation of the collected potential energy — usually occurs "as soon as" we apply the voltage, for all practical circuit work. However, suppose we could increase that electron gas relaxation time to, say, one millisecond? Then for an appreciable number of microseconds, there would be essentially no current flowing at all in the now-potentialized circuit.

We previously proposed a mechanism whereby a degenerate semiconductor alloy (say, of a tiny bit — perhaps 2% or so — of iron alloyed in aluminum wire) is utilized for the conductors of the external circuit. This should give a vastly extended electron relaxation time, somewhere on the order of a millisecond. By obtaining a millisecond, one can excite the circuit with current-free potential alone, which becomes pure regauging during the electron relaxation period.

We strongly point out that this is an asymmetrical regauging; the E-field previously mentioned is present, but the electrons are still frozen in the circuit since their relaxation has not begun. The gauge freedom principle, recognized in quantum field theory, assures us that we do not have to perform work to simply inflow potential energy to change the potential energy of the system. In real circuits, we may have to pay a tiny bit for switching to connect and disconnect the external potentialization source, but we can be at pains to make that very efficient and minimal {405}. The point is, other than minor switching costs, the dramatic change in the potential energy of the system is cost-free and no current is drawn from the external potential source. Hence — in the language of the electrical engineer — we draw no power from the source of potential, during this potentialization time.

Suppose we switch away the excitation source prior to its decay while the electrons are still frozen. Simultaneously, we complete the "freed" potentialized circuit with a strategically placed diode, as shown in Figure 6-16. Again, we pay a little switching cost, but it can be minimized. The electrons in the *now asymmetrically potentialized circuit* are still frozen, so no power has yet been drawn by the system from the external power supply furnishing the voltage only. In this way, pure asymmetrical regauging is used to excite the circuit with additional potential energy, without requiring work (except minimally for switching).

A little more time passes, and suddenly the electrons in the potentialized circuit wake up and move. We stress again that the full emf is acting on the electrons, and now they are finally free to move. There is a net nonzero regauging E-field (force field) also. The excited closed current loop circuit then discharges in normal Lorentz symmetrical fashion, killing the source dipolarity as current is driven back up through the diode, but all the work in the load is "free". The circuit specialist will also recognize the usefulness of additional components associated with the shunt, such as a capacitor or even an LC oscillator for AC work.

If L*E* is load work obtained and *SE* is switch energy utilized, this approach yields COP = *LE / SE* and COP > 1.0 is possible. The reason is that the *primary* source dipole providing the potential for potentialization of the electrons and regauging of the circuit is removed from the closed current loop circuit and the effect of current through the back emf. Thus the primary source dipole is not destroyed faster than the load is powered. It is only depleted by the small amount of switching energy we utilized. This appears to be a major way to avoid the COP<1.0 limitation of the usual closed current loop circuit.

This is a circuit with legitimate COP>1.0 capability, without violation of the laws of thermodynamics or physics. We break the Lorentz condition between the initial "external circuit" and the primary source dipole for the regauging energy. After regauging, we "cut loose" the circuit with its own primary dipolarity and newly transferred "separate source dipole". *By such adroit use of electron gas relaxation time, we can use one source dipole to freely make another of equal intensity, without any depletion of the first.*

The difficulty is in getting the Fe-Al alloy wire, which must be made in an inert atmosphere since Al corrodes easily and the two elements have very different melting temperatures.

Alternatives can be visualized, such as to utilize a capacitor whose plates are made of the Fe-Al alloy. This might be useful in the triode-capacitor, to be discussed next. A series of pulses might then be used to charge the capacitor, without depletion of the primary source dipole in the external source of potential, if it is repeatedly switched in and away. An interesting question arises if such a capacitor with tailored "hysteresis" in its charging is utilized in various circuits and schemes containing a coil of useful time delay also, particularly since the electron gas relaxation phenomenon involves decaying oscillations. Interesting phase angle results can be constructed in such circuits, but we leave the resolution of this question to future experimenters.

6.3.7 The Triode-Capacitor and Other Curious Components

See Figure 6-17. In this rough concept by the present author, the notion is to implant a grid of very small copper wire mesh inside the dielectric and near one or both of the capacitor plates, and then to utilize grids as if they were grids of a triode tube, for gating and controlling the displacement current in the capacitor and the dielectric strain. As an example, when charging the capacitor, the grids can be used to increase the displacement current (which also increases the voltage on the capacitor and dielectric strain). This increases the charge and energy in the charged capacitor, without putting in as much "enhancement and gating" energy as the extra energy obtained in the charged capacitor. If desired, we can also incorporate the 2% Fe-doped Al wires in the grid, or connected to it, to further move the grid toward a "pure current-free potential" operation.

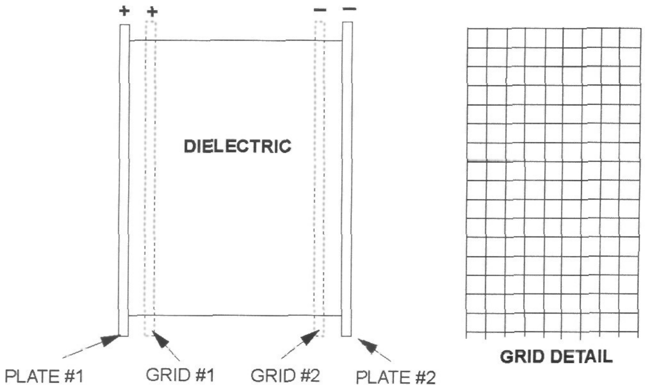

Figure 6-17 The triode-capacitor concept.

The scheme is that a voltage on this grid will intercept only a small current during charging of the capacitor, but can have an appreciable voltage upon it. The charging potential is placed across the capacitor, and simultaneously the grid has a similar potential placed upon it. The external source of charging potential is then disconnected, and the capacitor charges with more energy rearranged in its circuit than the energy one dissipates in the grid. The similarity to an old vacuum tube triode is apparent. For the purist, additional grids with tetrode and pentode functions can also be added.

One or more inventors has unwittingly tried to approach this in one way or another, but have not directly incorporated this schema and have not used the grid. They do not seem to have obtained positive results with those different schemas without the grid, nor have they specified the difficulties and phenomenology encountered, etc. We were curious about possible results of combining this (the triode grid in the capacitor) with the known elimination of capacitor losses by appropriate pulse charging {406a-b}. It seems that experimentation and research with the triode capacitor and its variations is definitely indicated.

We were also curious about the Davis non-inductive resistor {407a}, which is a special kind of "capacitor" that becomes an inductance-free resistor. One may argue that the resistor may be multiply inductive after all, though it is *net* noninductive. It may well be "equally and oppositely inductive," which is quite a different thing altogether, since it produces an artificial stress potential (and in the presence of AC, it produces a longitudinal EM stress field wave) in spacetime even though it produces a *net* zero reactance. In short, it produces a Lorentz-regauging, directly, and this can be a varying Lorentz regauging producing longitudinal EM stress waves. Whether this odd characteristic can be utilized in a COP>1.0 process remains to be seen. Preliminary indications are that it can be so utilized.

The various versions of the biwound coil, wound with two conductors at once and then the currents passed through the conductors in opposite directions, also presents interesting capabilities. Here again, it is multiply inductive, but may be tuned and adjusted to be *net* noninductive. We strongly suggest comparison with the well-known hairpin dual dipole antenna.

In short, this biwound coil arrangement — with various variations — can produce (and modulate) a magnetostatic scalar stress potential in the local vacuum and, in the case of AC, a longitudinal EM wave. This would appear to be a direct change (and oscillation) of the stress potential of the vacuum itself, which can be decomposed via the Whittaker process into a harmonic set of phase conjugate longitudinal EM wavepairs. The potential longitudinal EM wave communication possibilities can be seen, although one might require a Fogal transistor to receive the longitudinal EM wave modulations of such signals.

Further work in this area of unusual capacitors and components is left to the interested reader for his or her experimentation and research.

6.3.8 A Surprising Thing About Thermodynamics and Reservoirs

Thermodynamically, it is fashionable to state that one cannot take energy from a reservoir at constant temperature. That is true for *equilibrium* conditions, but not for *nonequilibrium* conditions {408}. That is, we cannot take energy from a reservoir *in equilibrium* at constant temperature. We can indeed take energy from a reservoir at constant temperature *but not in equilibrium*. More exactly, we can take energy from a nonhomogeneous reservoir at constant temperature.

We quote Hsu-Chieh Yeh {409} for a vivid statement of this little-recognized fact:

> *"From Planck's statement of the second law of thermodynamics it is generally inferred that it is impossible to construct an engine which produces work at the expense only of heat taken*

> *from the air or the ocean. ...[It is demonstrated that]... when the air and the ocean are combined as a nonhomogeneous reservoir of uniform temperature, it is possible to construct an engine which produces work by extracting heat from the said reservoir. This does not constitute a violation of the second law of thermodynamics, rather that the "reservoir" in the Planck's statement must be clearly stated as being in equilibrium."*

Yeh's article falsifies the general, mistaken inference that Planck's statement of the second law of thermodynamics requires it to be impossible to construct an engine that produces work at the expense only of heat taken from the air or ocean. The experiment described in Yeh's paper demonstrates that when the air and the ocean are combined as a nonhomogeneous reservoir of uniform temperature, it is possible to construct an engine that produces work by extracting heat from the said reservoir. This does not constitute a violation of the second law of thermodynamics, but rather shows that the "reservoir" in Planck's statement may be in equilibrium or disequilibrium, and the statement holds only for the equilibrium case. Also, an entire reservoir can be in "overall" equilibrium, but in raging disequilibrium between various parts of itself. Classical thermodynamics only applies with the reservoir or part of it that is used by the system in its supersystem, when that part is in equilibrium.

We bring this out to show the analogy to our concept of the two additional components of the supersystem as the "reservoir" or external environment of the system itself.

We also point out that the concept of temperature itself is not strictly defined under disequilibrium conditions, as pointed out by Gabriel Laufer {410}.

The proof and a schematic diagram of a machine to do just such an energy extraction process at constant temperature in an environment in disequilibrium are shown by Yeh {408}.

6.J.9 Latent Heat Work of the Correas

In addition to their glow discharge work previously discussed, Paulo and Alexandra Correa have demonstrated a method to optimize some anomalous form of energy from the sun, which transduces into heat, producing an anomalous T_0 - T difference registered in Orgone Accumulators[178] invented by W. Reich in 1939-1940. They have also employed the optimized difference in this "latent" heat — their term — to drive a low dT Stirling engine of the MM6 type, to perform free work {41 la-b}. The Correas employ their own new theory of the aether {412} to explain the effect.

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[178] **This** is Reich's terminology, not used in conventional physics. We suspect that **proper** application of quantum field theory with its four photon polarizations could

Against the assertion that this is just normal solar energy warming, they have demonstrated the successful driving of the Stirling engine for several hours during nighttime {413}. With their latest improved version, they report speeds of the Stirling engine of 150 rpm during daytime (with dT values reaching 22.5° C), and speeds of 30 to 80 rpm during nighttime (with dT values of 3.1 to 9° C). There appears to be no obvious standard thermodynamic explanation or standard theory to explain how the anomalous heating occurs — although once it does occur, the explanation from then on is thermodynamically normal.

The Stirling energy is driven on a difference in temperature created between the top plate and bottom plate of a box by this anomalous energy. It is the production of the heat that is anomalous, not the driving of the engine. For comparison, imagine a bank of solar cells that would somehow operate at night, when no normal radiation from the sun was striking them. The Correa effect demonstrates such an anomaly.[179]

Dr. Eugene Mallove, an excellent scientist with impeccable credentials, has personally observed the Correa accumulator system driving the Stirling engine, and has examined it inside and out {414}. Though small, the heat and the motive power are real and the engine is really driven, in the absence of any kind of conventional batteries or other known power source.

be applied to transform the notion of "orgone" energy into specialized EM energy. We further suspect that orgone energy is really the transduction of the time-polarized photon energy into normal photon energy. We are assured by quantum field theory and the giant negentropy solution to the source charge problem that the instantaneous scalar potential involves this process.

[179] We point out that local regions of the sun may well produce Aharonov-Bohm effects, and probably do. Such reactions in the sun would localize some of the B-fields and emit curl-free magnetic vector potential radiation into space, striking the earth. Close examination and analysis of the possible reaction of uncurled A-potential radiation with the accumulator box and plates in the Correa process might yield a novel mechanism for the observed heating (scattering) effects, including the difference between daytime and nighttime levels, periodic variations, etc.

While the Correas utilize some of Reich's orgone and aether terminology, they are quite aware that the energy being converted is not normal transverse EM wave energy. Quoting {415}:

> *"Aetherometry demonstrates that what traverses space is not transverse electromagnetic radiation (and certainly not sensible heat), but longitudinal electric ambipolar radiation emitted from the sun. All that electromagnetic radiation consists of is a local production of photons (for those who care to listen): aether energy is not composed of photons, actual or virtual. "*

We can generate sympathy for that statement, although we would still not rule out time-polarized (scalar) photons and longitudinal photons from quantum field theory, each of which is individually nonobservable, but when paired the two comprise an instantaneous scalar potential. As we previously discussed, the classical notion of the EM force fields E and B implicitly assumes interaction of the unseen causal "field-as-it-exists-in-massfree space" with charged mass having been accomplished, with the E and B being the 3-effect of this interaction after observation. Thus these force fields E and B are 3-effects (after interaction and after observation) rather than 4-causes prior to interaction and observation. We suspect that the Correas are trying to get at the causal 4-photon, rather than the usually assumed 3-photon. Further, a virtual photon spends much of its time existing as a dipole comprised of a virtual electron and a virtual positron. Therefore it spends much of its time in the presence of the giant negentropy 4-circulation, involving transduction of time energy into spatial energy and vice versa. It is this negentropy circulation represented by the virtual photon (or accompanying it, whichever one chooses) that the Correas are confronting as the "aether energy".

As previously discussed, an analysis of the Drude electrons in the electron gas of a detector builds a convincing case for EM waves in space existing in longitudinal EM waves, *if the spinning and longitudinally restrained electrons precess and act as gyros.* The detected transverse EM waves are in fact transverse precession waves of the gyro-electrons when perturbed by incoming longitudinal EM waves (longitudinal photons appearing in 3-space from the time-domain's scalar photon couplet). As Feynman put it {416},

> *"We may think of E(x, y, z, t) and B(x, y, z, t) as giving the forces that would be experienced at the time t by a charge located at (x, y, z), with the condition that placing the*

> *charge there* *did not disturb* *the positions or motion of all the other charges responsible for the fields."*

The E and B force fields — and transverse photons — are not the form in which EM energy *causally* exists in 4-space prior to its interaction with charged mass. In that causal form, EM energy seems to exist in field-free form, as a direct curvature of spacetime — at least in Sachs's unified field approach. Further, this form may be represented as the causal precursor of longitudinal EM waves accompanied by time-polarized EM waves.

We will not repeat our past discussion of the great necessity to change the very notion of "propagation through 3-space", but that is the issue. In our opinion, the Correas have had to struggle with the use of this causal EM energy as it exists in 4-space prior to interaction with charge and prior to observation. Hence their view is solidly based that the photon does not exist until after the interaction — which in fact has much support once we remove the still-present assumption in classical electrodynamics that a material ether exists.

Our own recommendation is that this anomalous energy should be deeply investigated with the view that all EM energy in 3-space comes from the time-domain and the 3-space aspect is in terms of longitudinal photons, as we have proposed in our solution to the source charge problem previously cited. That is the only way that the nature of the EM wave in vacuum can be reconciled with quantum field theory's findings {19} and with Whittaker's decomposition of the scalar potential {85}, slightly corrected {12}.

Mallove also points out {417} that, if this aether energy view of the Correas has validity, it *"...suggests that physics is not just wrong, it is profoundly wrong — catastrophically wrong about even the most fundamental questions of existence, such as: 1) Is there an energetic aether? and 2) What is the nature of light?"*

We profoundly agree with Mallove's observation, and we believe we have explained the reason why physics is indeed profoundly wrong (widely substitutes effect for cause). Further, classical physics is decidedly wrong about the nature of light — from quantum field theory, experimental proof of superluminal communication, and action-at-a-distance effects.

In our view, the Correas presently have a replicable experiment that, once independently and thoroughly investigated, may force a deeper examination of the foundations of physics. Hopefully, the Correas' experiment and others like it will finally force the separation of effect from cause, presently so mangled in physics and particularly in electrodynamics.

If the National Academy of Sciences and the National Science Foundation can be convinced of the horrible manglement of cause and effect in physics and especially in electrodynamics, perhaps they may yet wake from their long slumber and get the foundations corrected to eliminate such non sequiturs. If so, we shall have a magnificent new physics as a result.

If not, then the NAS and NSF will continue to profoundly reduce the security of this nation, since several nations have already made and weaponized such corrections to physics to produce what is called "energetics". Further, extraordinarily powerful energetics weapons have **already** been developed and deployed (and even employed), putting the U.S. at a strategic disadvantage because of the continuing reluctance of the NAS and NSF to correct the glaring and extraordinary errors in both physics and electrodynamics — and especially in electrical engineering.

Meanwhile, we believe that the work and experiments of Paulo and Alexandra Correa are at the forefront of capturing and transducing energy from the vacuum, in whatever form one chooses to consider the vacuum energy itself. They are also pointing the way to the corrections and changes necessary in the "old physics" if we are to better understand the world we live in.

6.3.10 Swiss Overunity Converter

We must also include the "Testatika" devices invented by Paul Baumann in **a** religious commune, Methernitha, adjacent to the village of Linden in Switzerland[180]. Figure 6-18 shows one of the machines, which over a period of 20 years were developed in various output sizes up to 30 kilowatts. Once started, the device is self-powering while also powering a very substantial external load (up to 25 kW). Many engineers and scientists have observed the machines in observation, examined them, and measured one or more in operation, so there is little doubt of their **authenticity.**

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[180] The website for Methernitha is www.methernitha.com. One may read the statements of the religious group for oneself.

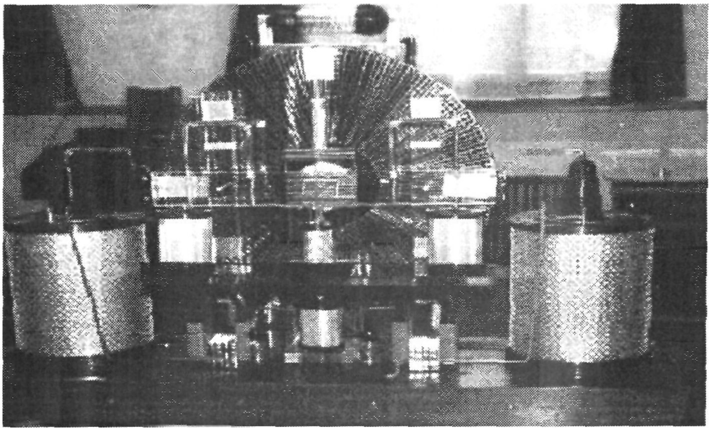

Figure 6-18 Swiss Methemitha machine.

However, there the science stops and mysticism and speculation begin. The religious commune releases no real details, except deliberately tantalizing clues. When questioned, the reply is that humankind in its present state cannot be trusted with such free energy. Almost all those examining the device have thought in ordinary electrical engineering terms, so very little comes from their examination because standard electrical engineering does not contain any theoretical explanation of COP>1.0 electrical power systems whatsoever. Baumann himself sometimes cryptically replied that his study of lightning discharges in nature gave him the operational principle. As we shall see, that may indeed be a very substantial clue as to the possible technical COP>1.0 mechanism, and one that does not exist in conventional classical electrodynamics.

The Methernitha (Baumann) machine resembles a Wimhurst machine with contra rotating static wheels, made of plastic or other insulating material with copper ribs and structures on one side and aluminum on the other. Use is made of the discharge into and from large capacitors and large coils. Also, at least one horseshoe-shaped permanent magnet assembly at the bottom is utilized. The major operating feature seems to be the contra rotating disks of a "Wimhurst" static generator machine, a magnetic field at right angles, and the sharp discharge of high voltage into and from large capacitors and large coils. The voluminous material on the Internet and in articles about the machines is mostly of little real use in contributing understanding or in proposing any legitimate mechanism.

We have not "solved" the machine's mechanism, since that would require close study of the device for a protracted time, and there has been no opportunity or time for that — although Baumann invited this author to come and see the machine some years before he died. Regrettably, I was unable to make the trip, and Baumann himself has now been dead for some years. We will therefore offer some technical suggestions pertaining to mechanisms that may be operating in the machine (or others like it).

First, we call attention to a paper by Aguirregabiria {418}. Quoting:

> *"An ohmic ring that rotates with constant angular velocity in an external uniform magnetic field is considered as a simple model for a current generator. Under the assumption that all quantities vary slowly in time, the lowest-order approximation to the surface charge density is found. The flux of the Poynting vector through the loop surface is also computed. Unlike the examples that are given in textbooks, this flux is not always incoming: It has the outgoing direction around the loop parts where the electrons are moving against electrostatic forces. "*

In other words, contrary to textbooks, there are positions where such a ring produces currents in one direction, and positions where it produces current in the other direction — *in fact moving against the voltage and E-field, and thus serving as a true negative resistor in those latter regions.* This may be a profound clue to the negative resistor operation of Baumann's machine.

This unexpected negative resistor effect is in theory usable to provide a true negative resistance. If there are transformers in the machine (and there are in some of them at least), then if a true negative resistor were used as an external shunt across the external circuit connected to the secondary of a transformer, the transformer could be operated as a true COP>1.0 device. The back-field connection from secondary to primary would be reduced by the fraction of the return current to the secondary that is shunted in parallel to that current "pumped" back up through the secondary.

This should be considered as an important possibility in the Baumann machine's operation.

Second, a charging and discharging capacitor involves not only energy flow in a direction perpendicular to the plates, but also an energy flow in a direction parallel to the plates {419}. Each of the rotating "plates" is actually a rotating capacitor of sorts, with a dielectric between two plates of special construction and dissimilar metals. The dielectric and the plates thus involve a complex intermingling of the negative resistor effect, a positive resistor effect, magnetic energy flows (both in entropic and negentropic manner in various regions), etc.

Baumann once handed two dissimilar plates, with a dielectric between them, to an engineer who measured it and found a startling several hundred volts across the plates! To date, no one is known to have been able to reproduce that effect.[181] We suggest that, if the dielectric material is layered and photorefractive in nature, it may be related to the negative resistors built by Chung {420}. If so, the physical pressure of the plates against the layered dielectric may also be quite important. By varying this pressure, Chung and her team found that their device could be made to exhibit negative resistance, positive resistance, or zero resistance. This leads us to speculate that Baumann may have used a "stressed dielectric" capacitor as a device having a built-in negative resistance. In that case, build-up of such a surprisingly high voltage would indicate high stress locked into the negative resistance dielectric.

We also call attention to a paper by LaPointe {421}, which will be discussed later under inertial propulsion and antigravity. Essentially, true Dirac hole current in the adjacent vacuum/space can be generated by powerful electrical discharges, particularly from capacitors or coils. When the unaccounted Heaviside energy component is also considered as well as the Poynting component, LaPointe's despair at the difficulty of obtaining sufficiently large voltage gradient across a very tiny distance is dispelled.

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[181] We are reminded, however, of the peculiar phenomenon that can occur in large power capacitors stored on a warehouse floor. If their leads are not shorted, the capacitors will build up a self-charge gradually, and this can become quite lethal. For that reason, such large capacitors when stored will have their leads shorted, to prevent this "free cumulative charge and energy" from appearing and posing a serious hazard. To our knowledge, there has been no complete scientific explanation advanced for this "self-charging" effect in large storage capacitors. Our own hypothesis is that it is probably an effect of unaccounted Heaviside nondiverged energy flow components associated with various field/charge interactions in the area and with ordinary Poynting EM energy flow in the area, including within the earth itself. Further, with respect to the surface of the earth there is an increase in potential with altitude. Hence from any point above the earth's surface and a point on the surface, there exists a dipolarity and a "Kron open path". The broken symmetry of that dipolarity means that within it a continuous 4-circulation of EM energy flow occurs as well as point-dipole polarization.

If this speculation holds, then in examining lightning strikes and their more bizarre phenomena, Baumann may well have hit upon the fact that such discharges also generate negative energy as well as positive energy, although it appears that the technical concept of negative energy was foreign to him, at least in such terms. In short, he could have been unknowingly charging his large capacitors by Dirac sea hole currents, somewhat similar to Bedini's process.[182] In that case, most of the "negative resistance" operation could be explained by Baumann's transduction of large bursts of negative energy into large bursts of positive charging energy and current in his capacitors.

Or, said another way in terms of Aguirregabiria's effect, Baumann may simply have been charging capacitors in that "negative resistance" Aguirregabiria region where the current does flow backwards against the voltage.

At least we have proposed some known though rare phenomena, which Bedini and my four colleagues and I have discovered in independent efforts. We strongly suggest that the Baumann device may unwittingly incorporate several of these mechanisms, but that neither Baumann nor the other members of Methernitha seem to have any technical notion of them.

With that, we leave it to the interested researcher to perform his or her independent Baumann-type system experiments and build-ups. Eventually, as is always true in science, the experiment must determine the truth of what is really happening. Given the successful experiment, then a model must be contrived or fitted that (i) explains the new effects produced, and (ii) complies with normal EM operation of normal COP<1.0 systems.

6.4 Some Magnetic Processes of Interest

There are some 200 or more magnetic effects in the literature, and only about half of them are well understood. Of the remaining half, some are partially understood and some are not understood at all. The COP>1.0 researcher interested in magnetic systems would do well to study magnetic materials science {422a-422c}, known magnetic effects, and particularly those magnetic effects that are still anomalous such as in leading edge superconductivity research. The new area of *spintronics* {423}, e.g., is rapidly advancing and will have future impact on COP>1.0 magnetic systems. We do not further discuss spintronics in this book, but merely call this rapidly emerging area to the attention of the interested COP>1.0 researcher.[183]

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[182] Bedini and the present author have filed a patent application upon this exact mechanism and process, and typical embodiments for accomplishing it. Bedini discovered the effect and used it for two or more decades, and after some intense struggle with the problem I was able to find the exact technical mechanism, including literature justification. This becomes a system to close-loop a "unitary" type of COP>1.0 system, which is covered in the patent application also. A different system can be used to close-loop a non-unitary COP>1.0 system, and that method is contained in the second MEG-type patent application of my four colleagues and I who invented the motionless electromagnetic generator (MEG).

Let us examine a very few magnetic effects of interest, as a sampling of what we are referring to.

6.4.1 Self-Powered Magnetohydrodynamic Motors

Interesting self-powered magnetohydrodynamic motor work has been shown by Bednarek {424}. He shows a multi-branch rotor in a galvanic cell composed of sulphuric acid electrolyte with copper and zinc electrodes. The unit develops an emf of about 1 volt, with the rotor placed in a vertical magnetic field such as from a large rectangular permanent magnet, where the field of the magnet is a few teslas in strength. The electrolyte and the rotor revolve in opposite directions. To change the direction of revolution of the rotor, the magnetic field direction is reversed. A linear self-powered magnetohydrodynamic motor is also shown, and has a similar principle of operation.

The interesting point is that these motors work, but less efficiently, when a water solution of table salt is used as the electrolyte. With the worldwide availability of seawater, this becomes an interesting possibility of "renewable energy" application. We leave it to the reader to further investigate this proven experimental technology as desired and to determine its practicality.

6.4.2 Multivalued Magnetic Potential

Conventional system designers work with conservative fields, as shown in Figure 6-19. Conservative fields arise from a single-valued potential — a potential that has only one value at each point in 3-space that it occupies. Consider a rolling ball of mass *m* on the "oval track" shown in Figure 6-19, starting from point A and rolling on the right side path. With the ball at rest at point A, we give it a slight push to velocity V_i adding kinetic energy $K_i = 1/2\, m(V_i)^2$. At point A, the ball has its maximum potential energy P_A due to gravity.

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[183] For technical information, see (a) Michael Ziese and Martin J. Thornton, Eds., *Spin Electronics,* Springer-Verlag, 2001; (b) D. D. Awschalon, N. Samarth, and D. Loss, Eds., *Semiconductor Spintronics and Quantum Computation,* Springer-Verlag, 2001.

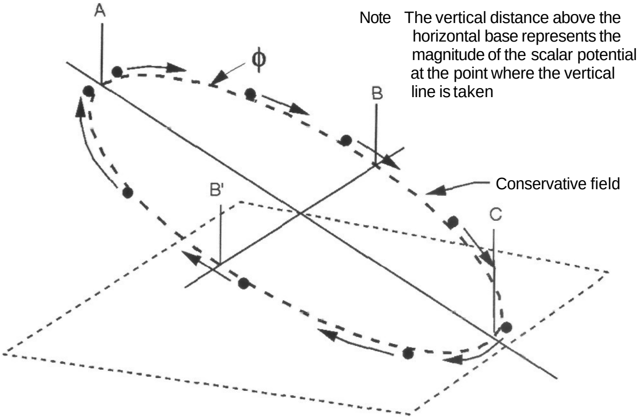

Note The vertical distance above the horizontal base represents the magnitude of the scalar potential at the point where the vertical line is taken

A circular closed path in potential ϕ is given by A-B-C-B'-A
Line integral from A around any closed path back to A is conservative
Along path A-B-C, work W(1) may be extracted from rolling ball
Along path C-B'-A, must do work W(2) on ball, where W(2) = - W(1)

Figure 6-19 Conservative field use (single-valued potential).

As it moves to the right because of our push, the ball will accelerate due to the force of gravity and increase its kinetic energy until it reaches point C at the bottom, reaching its maximum linear velocity Vc and kinetic energy Kc at point C. Its change (PA - Pc) in potential energy at from point A to point C has been converted to kinetic energy $[\frac{1}{2} m(V_1)^2 + \frac{1}{2} mVg^2]$ at point C.

Continuing on around on the left half of the path, as the ball rises toward A again, the portion $(P_A - P_C) = \frac{1}{2} mVg^2$—of the ball's kinetic energy at C that was added by the force of gravity from A to C — is returned to potential energy P_A. The ball reaches its lowest kinetic energy $\frac{1}{2} m(V_1)^2$ at A and also its lowest velocity V_1. For a perfect lossless system, once started in motion the ball would rotate around the track indefinitely, freely changing potential energy into kinetic energy and then back to potential energy. Nevertheless, it would not do any outside work, for that would represent losses or dissipations of energy from this conservative system. Consequently, the ball would quickly run down if work were being done, even if the system were otherwise "perfect".

If one integrates the change in potential energy around the track, the net change in potential energy is zero. The work done on the ball by increasing gravity to increase the ball's energy in one half-cycle, is taken back from the ball back when it climbs back out into decreasing gravity in the other half cycle. If one integrates the changes in kinetic energy around the track, once the initial velocity and kinetic energy are produced by outside forces in a perfect system, the net change in kinetic energy is zero. Of course, it is easily seen that the ball gains kinetic energy on its downward half of the track, and then returns the kinetic energy on its upward half of the track.

This situation is said to involve a *conservative fields* and the system will not produce any net energy to use as free work. Indeed, a real system will almost always have some friction and other losses around the path {425}, so the ball will gradually lose net initial energy given it, slow down, and eventually come to rest at point C, the lowest potential energy of the system.

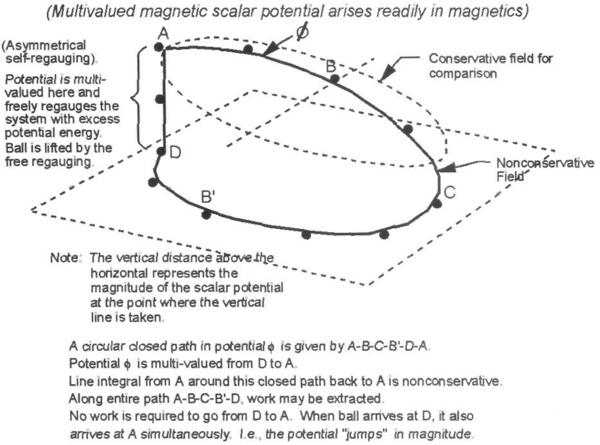
(Multivalued magnetic scalar potential arises readily in magnetics)
A
ϕ
B
(Asymmetrical self-regauging).
Potential is multi-valued here and freely regauges the system with excess potential energy. Ball is lifted by the free regauging.
D
Conservative field for comparison
Nonconservative Field
C
B'
Note: The vertical distance above the horizontal represents the magnitude of the scalar potential at the point where the vertical line is taken.

A circular closed path in potential ϕ is given by A-B-C-B'-D-A.
Potential ϕ is multi-valued from D to A.
Line integral from A around this closed path back to A is nonconservative.
Along entire path A-B-C-B'-D, work may be extracted.
No work is required to go from D to A. When ball arrives at D, it also arrives at A simultaneously. I.e., the potential "jumps" in magnitude.

Figure 6-20 Field may be non-conservative for a multivalued potential.

A charge circulated through a closed current loop circuit also moves through a conservative field region in similar manner. Hence, there is no net excess energy input available for such a conventional circuit. It follows that one must arrange for inputting all the input energy (intercepted and collected by the circuit) that is then dissipated from the circuit's loads and losses. Unfortunately, half the collected circuit energy also goes to destroying the dipole, with less than half powering the load. Therefore, that circuit always exhibits COP<1.0.

Now see Figure 6-20, where we provide an analogy using a rolling ball around a circular track, in a gravitational potential. In this case, the potential has a multiple magnitude A and D at point A-D, which is the same point (we plot a point in the potential's magnitude, not a point in 3-space, although there can be close approximation).

Approaching magnitude D from point B', the value of the potential is steadily reducing and is much lower prior to reaching A-D than it was when leaving magnitude A. During this phase, the ball is gaining kinetic energy from the gravitational potential, and can be used to perform useful work (up to all the energy gained, in a perfect system). Upon passing through point A-D, instantly the ball is again at point A on the right. We accent that the "instantaneous jump" on the diagram represents a free insertion of excess energy (asymmetric regauging energy) from outside the system. Rigorously that is a broken symmetry, which also breaks the internal energy conservation of the system. In short, the "ball" has been instantly "lifted" (in this simplified analogy) back to a higher potential by a free insertion of excess energy from the external environment. The main point is that a surge of potential energy into the "ball system" occurred, freely input by nature and the environment. The system can now go through the "doing work" routine again, traversing from A back to D and through it.

Note that this is a nonconservative system, because it continually receives a free and sudden input of excess energy from its environment. So this system — because of its broken symmetry — can continually do work and keep on going.

Indeed, so long as that free energy input from the environment occurs without fail, this is a "self-powering" system, completely complying with **the** laws of physics and thermodynamics. It violates the equilibrium thermodynamics because the system is periodically not in equilibrium with its environment. Consequently, the system can exhibit those five magic functions we spoke about previously. It can exhibit (i) self-organizing (in this case, freely getting that little ball from low potential energy D back to high potential energy A), (ii) self-oscillation or self-rotation (the ball will continue to go around and around the loop, even doing a little work in the process), (iii) output more energy than the operator inputs (in this case, the operator is not inputting any energy at all, so the energy output is indeed more than the operator furnishes), (iv) power itself and its load simultaneously (all the energy is being input from the external environment at the insertion of excess energy at point D to move the ball **back** to position A), and (v) exhibit negentropy.

This is an analogy to a nonconservative field and a multi-valued potential. In the case where a potential has discontinuous values at a single point, with the value depending upon whether the detecting charge (the "ball", so to speak) is to the left or to the right of that point, one has a *multivalued potential*. This multivalued potential actually represents a change of potential energy in the system, freely occurring without operator input. In short, it is an asymmetrical self-regauging, violating Lorentz's symmetrical regauging condition.

Actually, multivalued *magnetic* potentials arise naturally in magnetics theory, but —foolishly, in our view — theoreticians do all in their power to minimize or eliminate their consideration {426a-k}. They consider such a nonlinear change as being embarrassing and troublesome, and to be gotten rid of at all costs! However, if deliberately used and optimized, rather than eliminated, incorporating a multivalued magnetic potential can provide a *nonconservative magnetic field* (analogous to the illustration), where $\int \mathbf{F} \bullet \mathbf{ds} \neq 0$ around a rotary permanent magnet loop. The multivalued potential represents a broken symmetry that further produces a nonconservative field.[184] In theory, such use of the multivalued potential and the resulting nonconservative field can enable a "self-powering" permanent magnet rotary engine, operating as a negative resistor freely extracting and using magnetic energy from the broken symmetry in the system's energetic exchange with the active vacuum.

However, note that the multivalued potential represents a point of sharp "self-regauging asymmetrically" by the circuit, with the regauging potential energy coming from the external environment. It requires that some external process in the exchange between environment and system must be automatically invoked at the multiple-value point, so that there is a sharp and sudden entry of excess potential energy received by the circulating ball (or by the circulating charges in an electrical circuit, or by the circulating flux in a magnetic circuit).

One such means of evoking such a sudden surge of excess energy at a point, momentarily, is given by Lenz's law, as discussed in the magnetic Wankel engine. Another means is by Johnson's sudden evocation of the exchange force, which momentarily can produce a pulse of energy density even several hundred times as strong as the usual field energy at that point. For example, imagine that the ball in Figure 6-20 represents a magnetic rotor in a magnetic potential represented by the height of the ball above the dotted line base. The point (D-A) then represents the results of the system having suddenly injected an instantaneous exchange force at point D, to freely increase the potential and potential energy of the rotor system back to point A. The rotor is immediately lifted back at its starting potential energy situation at point A, freely, by this sudden and free evocation of the exchange force. We will briefly discuss the exchange force in our discussion of the Johnson engine.

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[184] In physics, the appearance of a force and its subsequent action to perform work is nature's way of restoring symmetry to a situation where symmetry has been violated. As can be seen, the net force can be used to translate something (such as current) and do work, thereby dissipating the excess potential energy received from the broken symmetry condition.

6.4.3 Dromgoole Effect as an Example of a Novel Magnetic Effect

An example of a novel magnetic effect is the *Dromgoole effect* {427}. This is an interesting phenomenon where a voltage placed on a solenoid wrapped around a longitudinally magnetized iron wire may be increased up to 300 times in magnitude by twisting the wire through 90 degrees. If a scheme can be worked out whereby this dramatic increase in voltage potentializes and moves very substantial current, then perhaps the extra output can — at least momentarily — produce more output energy than the work required to twist the wire.[185] At least that could be a working hypothesis from which to launch experiments to see if it is possible.

The reason this may be possible is that any amount of energy W one wishes can in theory be collected from any finite potential intensity ϕ, according to the simple equation $W = \phi q$, where q is the collecting charge exposed to and interacting with the potential intensity ϕ. In the case of magnetics, q is analogous to the pole (magnetic charge), where the north pole is positive magnetic charge. The ϕ then becomes the magnetostatic scalar potential.

So if we can produce ϕ with only a little expenditure of energy, and then have that ϕ potentialize a very large amount of charge q, we can collect upon the charge q much more energy than what we ourselves expended. The ϕ produced is a change to the local vacuum potential, and hence the collection of energy W on charges q is actually a collection of EM energy from the local altered vacuum potential itself. Any potential we make becomes a change to the local vacuum potential, and hence a change to the local active vacuum. That does not seem to appear in electrical engineering, which model does not even incorporate modeling the active vacuum or its potential, much less a change to it.

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[185] The scheme must prevent *at least an appreciable fraction* of the spent electrons- from the external circuit and load — from being forcibly rammed back up through the coil against its back EMF. Otherwise the Lorentz symmetry condition applies and the arrangement will not produce COP>1.0.

While we discuss a few interesting magnetic effects in this paper, there are many more. The interested researcher is referred to such easier sources as Burke {428} and Cullity {429}. For more complex scientific sources and explanations, other publications are available {430a-430r}. In addition, it is helpful if the researcher is aware of some of the foundations problems in physics and electromagnetics {431a-431e}. Our point is that there are more than 200 known effects in magnetics, and only about half of them are well understood. For the other half, the understanding ranges from "partially understood" to "not understood at all." The latter half of the magnetic effects provides a rich ground for investigation by researchers seeking an asymmetrical self-regauging mechanism.

The COP>1.0 researcher must be prepared for an extended self-education period, and appreciable study and work. Some research discipline is highly recommended, such as starting one's own database and rigorously maintaining it up to date with one's latest interests. For the experimenter, a good lab notebook, meticulously kept and regularly posted, is an absolute necessity. Reading and searching the scientific literature is also highly recommended. It is not as simple as applying the principles one learned in university or technical school. Those techniques and principles are involved, but at some point in the circuit they must also be violated. Else COP>1.0 systems would long ago have been developed and marketed by sharp young students, graduate students, and post-doctoral scientists.

6.4.4 Exchange Force and Johnson's Approach

Refer again to our discussion of conservative versus nonconservative fields, above.

If one wishes to build a self-powering rotary permanent magnet motor, obviously one must evoke a condition whereby $\int \mathbf{F} \bullet \mathbf{dl} \neq 0$ around a single full rotation of the rotor (and where F is the instantaneous magnetic force between stator and rotor). For permanent magnets without any external switching, etc., that condition can only arise if an excess force is freely triggered by changes occurring freely in the magnetic materials themselves.

Fortunately, magnetic materials are almost always highly nonlinear, and **so** such self-triggering opportunities abound. They can occur because there are a multiplicity of mechanisms (dozens and dozens) going on simultaneously in the materials of the magnets of both the rotor and the stator, and not just the standard polarity and field repulsion and attraction that electrical engineers use. These materials processes also involve direct and ongoing exchange of energy between the active vacuum and the local materials in the magnet.

The trick is to take one of these automatically ongoing processes that is already there and freely available but just not adroitly used, and deliberately evoke and enhance it to induce excess energy at the appropriate time, with a force in the appropriate direction. In simple terms, if you have eight more horses available to put into the harness to pull the load, and you only have two normal horses but wish to pull more load, then by all means you should hitch up and use at least one more additional horse, and take him from the six that are usually just standing by and not working at all. They may run back and forth a bit, while watching the others work, but that of itself contributes nothing.

One such additional force and free regauging mechanism always available is the exchange force, which can be checked in Feynman's three volumes of physics {433} and also in the reference by Cullity {429} previously **cited.** Good science dictionaries {432} also include helpful information. Reading the literature will add enormously to one' data base of effects and methods.

Howard Johnson's approach is to arrange highly nonlinear assemblies of geometrically asymmetrical magnets into complex configurations. At certain points in a magnetic field, these Johnson assemblies will trigger the sudden brief self-generation (actually a sudden release) *of exchange force* between stator and rotor. The exchange force is a known phenomenon {432, 433, 434}, though still not completely understood theoretically. It **can** be evoked asymmetrically by evoking electron-spin flipping, for example, which has led to the development of a new field of technology, **spintronics.** *Microscopically,* the exchange energy is much greater than the magnetic field energy, sometimes by a factor of 10^3 to 10^4 {435, 436}. *Macroscopically,* the resulting exchange energy can momentarily still be many times the magnitude of the ordinary magnetic field energy; e.g., by a factor of 200, which Johnson often achieves.

If **the** stimulated momentary exchange forces are oriented to always add to the thrust upon the rotor in the "powering rotation" direction, then the **multivalued** potential condition and $\int \mathbf{F} \bullet \mathbf{dl} \neq 0$ are met. In that case, self-powering is permitted, if enough of these exchange force triggerings occur so that the extra potential energy added to the rotor is sufficient to overcome the load and the losses being powered.

The self-triggering of each exchange force appearance produces an excess burst of force and energy[186] input into the system from its active supersystem environment. Thus, repeatedly the system is momentarily converted (in each exchange force burst) into an open system in disequilibrium in its energy exchange with its active environment, freely receiving excess energy from it. Because the exchange force "input energy burst" is short, multiple such "input bursts" must be used in a single rotation cycle so that the total energy input by all of them is significant.

In that case, COP>1.0 performance is permitted by the laws of physics, thermodynamics, and nature. Conservation of energy is not violated. Classical equilibrium thermodynamics with its infamous second law does not apply to the Johnson system, since the system is periodically an open system far from equilibrium and receiving excess energy from its active environmental exchange. *A priori* the Johnson system has increased its negentropy overall, and that negentropy (increased order or increased potential energy) can then be dissipated (disordered) to produce free shaft horsepower if the bursts of exchange force are properly coherent in direction and timing.

We diverge for a moment: As is well known, the equilibrium condition in a system is the condition of maximum entropy in the system; any disequilibrium condition reduces the entropy *a priori* because it is an excited state of the system containing additional potential energy. It is worth rigorously clarifying the infamous second law of thermodynamics. Quoting Lindsay and Margenau {437}:

> *"[The]...statement of the second law: (a) the entropy... is a variable of state, (b) Its value, for a closed system, can never decrease."*
>
> *... "Non-equilibrium conditions cannot be specified by variables of state, and their entropy cannot be computed. ...the condition of equilibrium is the condition of maximum entropy."*

---

[186] Technically speaking, the exchange force is not a magnetic field force, but a force that arises independently due to quantum mechanical considerations. Nonetheless, it is a real force arising in magnetic materials and affecting magnetic materials, as in permanent magnets.

In the first statement, the reader should note the assumption of a closed system in the first subparagraph, and the absolute requirement that the calculated entropy be a variable of state.

Also, the quotation can be falsified. Oddly, the "closed system" in classical thermodynamics is defined (illogically) as a system that does not exchange mass across its boundary, but may and often does exchange energy across it. We negate any absoluteness of that statement by Lindsay and Margenau by citing a counter example of a "closed" system with continuously increasing energy, fed by transfer of energy from the environment, and with no escape of the energy or very little escape of it. A specific example is a photon absorption by a mass particle. This system achieves increasing energy (order) as the process continues, hence achieves negentropy. This may be considered a fluctuation, of course, but it still places severe limitations on this law of thermodynamics and in fact negates any absoluteness of it. For such reasons, in this book we have redefined "closed system" as one that exchanges neither energy nor mass with its environment, and we recognize that there are no such systems in the universe. We have defined an "open system" as a system that exchanges either energy or mass or both across its boundary, so that we do not encounter the problem of the counter example cited. Further, general relativity requires an increase in the mass of any system that increases its potential energy, and a decrease in the mass of any system that decreases its potential energy. Hence energy exchange at all with the system, involves mass exchange since mass and energy are the same thing. The classical thermodynamic definition of a "closed system" has thus been falsified since 1915, with the definition becoming only an approximation rather than a generally valid definition.

In the second subparagraph of that first statement by Lindsay and Margenau, the reader should note that the closed-system assumption must be violated *a priori* if the entropy does decrease, and vice versa. If the system is broken into a set of subsystems, then the only way the entropy of the overall closed system to decrease is for one or more of the subsystems to be open (new definition!) and energy (order) to pass out of the system. Then an interesting thing emerges: For order (energy) to remain in the system as such, the subsystems taken as a whole must produce as much negentropy as they do entropy. Energy from an ordered subsystem can be emitted in disordered form, but then it has opened that subsystem and has entered the space between parts (subsystems) of the overall system. In other words, in a closed system, *any increase in entropy requires the subsystems to become open subsystems.* Again, the statement of this law of thermodynamics eats itself. To stay in the overall system, this scattered energy *outside the subsystems* must then interact totally with another part of the system, and so on. This introduces disorder to the succeeding parts that interact. Therefore, the second law of thermodynamics itself *internally* violates its own "closed system" assumption because, to operate at all, the law requires continuing interaction between the active local vacuum environments and the subsystem components. In short, it requires a very special kind of overall or average equilibrium in an unavoidable energy exchange between the local vacuum and all the parts of the system. The source charge problem already demonstrates the universal violation of the second law and the thermodynamic definition of "open system", but both classical electrodynamics and classical thermodynamics have ignored this source charge problem for more than a century. Our solution to it was published in 2000.

Quite simply, there is no such thing as a truly closed system in the first place. Kondepudi and Prigogine come close to this statement in the following quotation[187]:

> *'Anyway, equilibrum thermodynamics covers only a small fraction of our everyday experience. We now understand that we cannot describe Nature around us without an appeal to nonequilibrium situations. The biosphere is maintained in nonequilibrium through the flow of energy coming from the sun, and this flow is itself the result of the nonequilibrium situation of our present state in the universe."*

In short, all systems on the planet — and we ourselves — are immersed in a nonequilibrium state a priori. Rigorously there is no such thing as an absolute equilibrium state on the planet, except as an approximation.

Now consider a perfectly insulated system, so that no heat can pass from the system outside it. An interesting constraint then exists on those "open subsystems" producing disorder (entropy). Unless equal reordering occurs in the subsystem-to-subsystem reactions, then disordering (heat) grows a priori. But this is not observed to happen in well-insulated systems approximating our theoretically perfect example! Otherwise, the temperature of a well-insulated system would increase until system rupture and failure. And experimentally that does not happen.

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[187] Dilip Kondepudi and Ilya Prigogine, *Modern Thermodynamics: From Heat Engines to Dissipative Structures,* Wiley, 1998, p. xii.

It follows that, to maintain the internal equilibrium between subsystems and a constant internal temperature, a negentropic process is clandestinely involved. We submit that this process is revealed in our discovery of giant negentropy of the negative charge, and what may be said to be the giant entropy of the positive charge — i.e., in the discovery of the common " 4-circulation" of energy surrounding a dipole from the time domain to the negative charge of a point dipole in 3-space (thereby entering 3-space once emitted by the negative charge), thence to the positive charge of the point dipole, and thence back to the time domain. For a single charge, the well-known vacuum polarization provides virtual charges of opposite sign, to convert the "isolated charge" into a set of composite dipoles, as previously explained.

The second law of classical thermodynamics, considered in a more modern light, appears to conceal hidden giant negentropy and hidden giant entropy, in the ongoing 4-circulation of EM energy in the supersystem. *It is not possible to eliminate the supersystem or the interchange between its parts; particle physics told us in 1957 that there is no equilibrium of any system without this ongoing exchange.* Any thermodynamics attempting to discard the supersystem exchange (which involved both mass and energy) is at best an approximation for special "reasonably well-behaved" situations.

If the entire system is not in net equilibrium with the external environment (i.e., if there exists disequilibrium between the separated parts of the supersystem), then classical thermodynamics does not *absolutely* apply to that system. The system is no longer *absolutely* describable by "variables of state".

Those objecting to COP>1.0 in an EM system on the grounds that it would violate the second law of thermodynamics (which already violates itself), would be well-advised to restudy the very notion of the second law and the thermodynamics definition of *open system.* Compare relativity's equating mass as energy. Then ponder the thermodynamics of open systems far from equilibrium with their active environment. Every system in the universe is open, and it has an ongoing exchange with its proven active environment (local active vacuum and curved spacetime). This exchange Includes and exchange with every particle in the system. As pointed out by Lee: [188]

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[188] T. D. Lee, *Symmetries, Asymmetries, and the World of Particles,* U. Wash. Press, Seattle, 1988, p. 46-47.

> *"...symmetry implies conservation. Since our entire edifice of interactions is built on symmetry assumptions, there should be as a result a large number of conservation laws. The only trouble is that almost all of these conservation laws have been violated experimentally. "... "...this difficulty could be resolved by introducing a new element, the vacuum. Instead of saying that the symmetry of all matter is being violated, we suggest that all conservation laws must take both matter and vacuum into account. If we include matter together with vacuum, then an overall symmetry could be restored."*

The *system itself is* always in disequilibrium; only the supersystem can exhibit equilibrium. The second law of thermodynamics specifically does not and cannot apply to a system far from equilibrium, because of its implicit assumption of overall equilibrium without the active vacuum exchange. Also, a deeper balance is required between the hidden asymmetries existing between the subsystems and their local vacuum (and local spacetime curvature.

Indeed, *one cannot even calculate* the entropy for a system that — overall — is far from net equilibrium with its active environment. We quote Lindsay and Margenau even more strongly {438}:

> *"Equilibrium states are the only ones that are capable of explicit analysis in thermodynamics... "*

And again {439}:

> "... *variables of state have meaning only if they define an equilibrium state. Hence the quantity we are seeking will be meaningless unless it refers to equilibrium states. "*

While we are at it, let us also address a serious flaw in the first law of thermodynamics. We again use Lindsay and Margenau for a succinct statement of the First Law {440}:

> *"First law of thermodynamics. A complete statement of the first law comprises two assertions: (a) heat is a form of energy, (b) Energy is conserved. "*

All that really says is that energy is conserved. It does not state that it is conserved in an object. It states that, whether the system is in equilibrium or not, energy is conserved. If heat is taken as disordered energy, then it merely states that overall the energy is conserved, whether ordered or disordered with respect to some ordering criterion. It does not state that the disordering is conserved, and it does not state that disordering must increase or decrease. But *it does implicitly assume that all energy at some most basic level is ordered, else it cannot be energy (order).* So it assumes that, at higher levels, energy can be disordered (incoherent). However, at the underlying basic level, it is and remains perfectly ordered — else it could not remain "energy and could not be conserved. As an EM example, in so-called "heat", *every scattered photon retains its perfect order; it is only the photon ensemble that is "disordered".*

In short, each "basic piece" of energy is perfectly ordered, but the *ensemble* of the pieces may be disordered. Therefore, entropy applies only at a level higher than the basic energy quantum. Contrary to the assumptions of classical (macroscopic) thermodynamics, processes which directly engineer the basic energy quanta[189] — more exactly, the *action* quanta, consisting of *energy x time,* since energy cannot be "engineered" or changed in 3-space without also being engineered "in time" as well — are time-reversible. Hence they can be negentropic — simply because every observable system is "open" to, and in continuous energy exchange with, its active time environment (and also its active vacuum environment). Also, no system changes its spatial energy in any fashion, including ordering or disordering, without interacting with spacetime and spacetime curvature dynamics. It also changes its time-energy.

So in our view the notion of "disordering" and "disordering of energy" must be carefully reconsidered, as to exactly what is and is not being disordered, when the assumed "disordering" occurs, at what level it occurs, where and how the compensating reordering occurs, etc. We also point out that the simple discovery of giant negentropy {12} as the solution to the long-vexing source charge problem already removes the "absoluteness" of classical thermodynamics. Giant negentropy already violates the assumptions of classical thermodynamics at the elemental level in every physical system. Indeed, every charge in the universe already falsifies any "absoluteness" of the assumptions of classical thermodynamics.

This problem in the old classical thermodynamics has long been indirectly solved in particle physics, with the discovery of broken symmetry. As Lee states so clearly {441},

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[189] Actually, energy is discretized, not quantized. Energy x time (i.e., *action)* is **quantized.**

> *"As we expand our observation, we extend our concepts. Thus the simple symmetries that once seemed self-evident are no longer taken for granted. Out of studies of different kinds of interactions we are learning that symmetry in nature is some complex mixture of changing plus into minus, running time backward and turning things inside out."*

We point out that a symmetry involves a conservation law, such as are stated in classical thermodynamics, and a broken symmetry involves a broken conservation law. So the discovery of broken symmetry in physics was a profound change affecting all physics, including the staid old classical thermodynamics. Lee further points out the new complexity of concepts {442} such as symmetry (which is behind every conservation law, including the first law of thermodynamics):

> *"At present, it appears that physical laws are not symmetrical with respect to C, P, T, CP, PT and C. Nevertheless, all indications are that the joint action of CPT (i.e., particle <-> antiparticle, right <-> left and past <-> future) remains a good symmetry."*

So unless the first law is stated in terms of modern CPT symmetry, it does not absolutely apply! Further, every charge is changing time-energy into spatial energy or vice versa. Yet there is nothing about time-energy and its transduction into spatial energy, or vice versa, in the present textbook statements of the thermodynamics. The term "heat" does not refer to the presence of energy at all, but to the scattering (disordering) and escape of energy.[190]

Considering heat as "energy of the system", or "heat energy" of the system, is a grand non sequitur. Rigorously, "heat" refers to the reduction of higher levels of ordering of energy, and since the gist of energy is ordering, reduction of ordering is the very antithesis of energy! "Heat energy" thus is an oxymoron. Before the "escape", there is no "heat energy" (ugh!) in the system at all. The energy is present in the system *not as disordering, but as ordering, a priori.* If it were in the system, it would not have escaped nor would it be escaping from the system. More energetic molecular motion, e.g., is actually more energetic ordering, simply at an excited state (of greater energy!).

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[190] Think closely: We never take the temperature of a "system"! We take the temperature of the disordered energy (heat) leaving that system or its subsystems. We do measure the effect of the emitted disordered energy. But that has already left the system and is in the local vacuum (a second component of the supersystem). Thermodynamics might be usefully redone more exactly in terms of the supersystem. We leave that task to some budding young future thermodynamicists for a recommended doctoral thesis.

We stress again (and strongly advise the researcher to read) Romer's strong objection to the use of heat as a noun {443}, and we suggest that the entire subject of classical thermodynamics needs a thorough revision to tighten up its terminology, correct its definition of closed system, eliminate its conflict between the first and second laws, and remove its inappropriate consideration of heat as "energy". Otherwise, the presentation and general interpretation of thermodynamics itself will continue to be one of the great confusion factors one encounters in trying to think clearly about extracting EM energy from the active vacuum environment to produce and utilize **COP>** 1.0 systems.

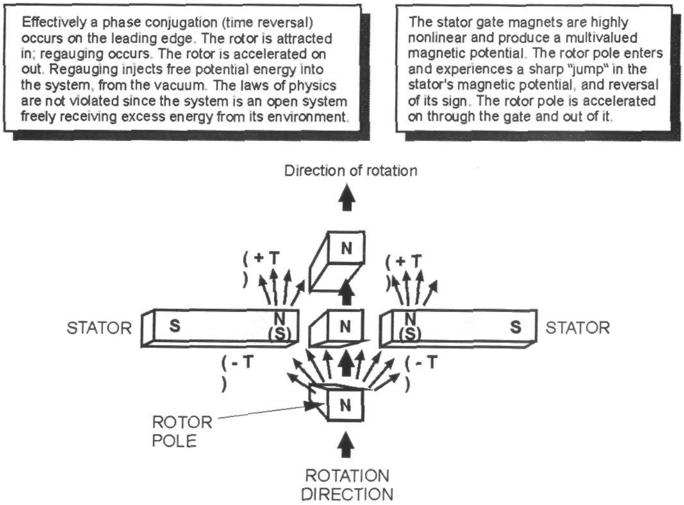
Effectively a phase conjugation (time reversal) occurs on the leading edge. The rotor is attracted in; regauging occurs. The rotor is accelerated on out. Regauging injects free potential energy into the system, from the vacuum. The laws of physics are not violated since the system is an open system freely receiving excess energy from its environment.

The stator gate magnets are highly nonlinear and produce a multivalued magnetic potential. The rotor pole enters and experiences a sharp "jump" in the stator's magnetic potential, and reversal of its sign. The rotor pole is accelerated on through the gate and out of it.

Figure 6-21 Concept of operation of Johnson's patented magnetic gate.

Johnson's approach produces a peculiar kind of multivalued potential. One **part** is conservative and of magnetic energy in nature, and the other part is nonmagnetic, being direct exchange force and energy effects on the **participating** atomic nuclei arising from quantum mechanical considerations. Nonetheless, the net *hybrid* potential can be multivalued at various points around the stator, and that is all that is required for broken symmetry. If $\int \mathbf{F} \cdot d\mathbf{l} \neq 0$ around a closed path, regardless of which set of forces F represents, then that overall composite force field acting upon the rotor or object moving around the closed path is nonconservative. In that case, self-powering is permitted.

Figure 6-21 diagrammatically illustrates the operation of a nonconservative force-producing magnetic gate in Johnson's approach to a permanent magnet motor. As Johnson has shown, by using a multivalued hybrid potential (MVP) in his gates so that the resulting excess exchange force is properly oriented in direction and timing, a rotor magnet is attracted into a highly nonlinear stator gate region where the MVP is located. When it enters the MVP region where the exchange force is initiated, the rotor encounters a dramatic jump in the net potential with a change of polarity as the exchange force suddenly fires automatically. In turn, this produces a sudden accelerating tangential force in the region, usually against the prevailing magnetic force in the normal back mmf region!

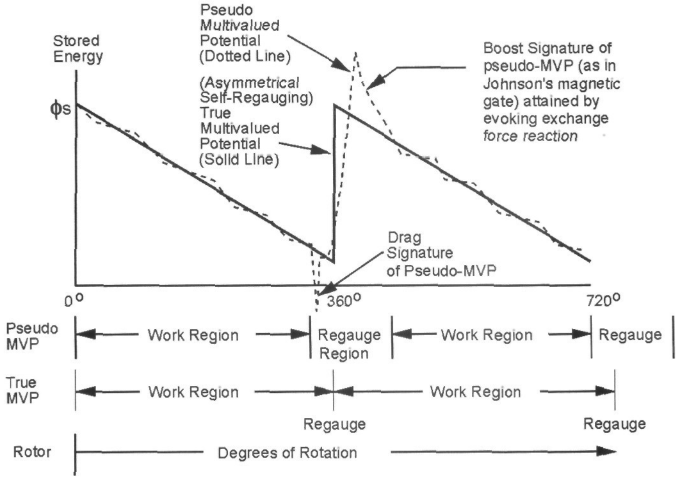
Pseudo Multivalued Potential (Dotted Line)
Stored Energy
ϕs
(Asymmetrical Self-Regauging) True Multivalued Potential (Solid Line)
Boost Signature of pseudo-MVP (as in Johnson's magnetic gate) attained by evoking exchange force reaction
Drag Signature of Pseudo-MVP
0°
360°
720°
Pseudo MVP
Work Region
Regauge Region
Work Region
Regauge
True MVP
Work Region
Work Region
Regauge
Regauge
Rotor
Degrees of Rotation

Note Single regauging per notation shown Johnson uses multiple regaugings per rotation

Figure 6-22 Johnson's "refueling" a permanent magnet engine by asymmetrical self regauging. A multivalued potential is momentarily created by precisely evoking an exchange force reaction.

Johnson often confounds professors of electromagnetics by showing them that his special gate can produce attraction between like poles, with a north rotor pole being drawn into a north stator pole in that exchange force region. This can be understood by tracing the spin field flow patterns, but cannot be understood by simple "like poles repel and unlike poles attract". In short, Johnson knows he is adding a force completely different from the magnetic force the professors have in mind as the sole acting force. It is rather like pushing two like poles of two little magnets together. You can do it because an additional force — your mechanical force pushing them together — is acting and overcomes the normal repulsive force between the two poles.

The sudden exchange force burst produces a sudden accelerating tangential force in the normal deceleration (back mmf) region of the stator-rotor arrangement. In short, Johnson utilizes a deliberately evoked burst of exchange force to freely overcome most or much of the back mmf (back-drag) region. This in turn produces a net driving force around the rotor's complete rotation, because the overall field combination is nonconservative.

Rigorous force meter measurements taken at 0.01-second intervals prove that this occurs as the rotor enters and passes through Johnson's gate. The results of one such experiment are given in Figure 6-22.

Johnson thus uses highly nonlinear magnet assemblies of novel design to create a special kind of multivalued potential in his magnetic gate by adroitly evoking exchange forces — *extra quantum mechanical forces* in addition to the usual magnetic field forces. The MVP produces a sudden extra rotational force, backwards to the back-drag (back mmf) region of the stator-rotor magnet arrangement where the rotor magnet assembly is entering and passing through the conventionally repelling like-polarity situation. The result is that a net north rotor pole is seemingly attracted in[191] to the otherwise repelling stator north pole region, then accelerated out the other side by the normal magnetic repulsion.[192] Net drive force results, instead of a net zero force. Engineer Ken Moore, a close colleague of the present author, independently tested a Johnson gate and verified the net driving force effect {444} within the limits of our little laboratory.

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[191] In reality it is "forced in" against the repulsive magnetic force, by a superior force of a different nature, suddenly evoked.

[192] I.e., as the exchange force dies, the forces now acting are the normal repulsive magnetic forces, but the rotor has moved to a position where now this repelling force accelerates the rotor in the "load powering" rotational direction. In other words, the observer sees a like pole suddenly "attracted" into a like polarity region, move partially through it, and then suddenly be accelerated out the other side. But the "attracting in" force and the "accelerating out" force accelerate the rotor in the load-powering rotational direction.

Technically, Johnson's apparatus asymmetrically and suddenly regauges its exchange forces in such a manner as to momentarily overpower the back mmf region of the engine's rotation, thus producing a net multivalued potential and a net accelerating force around the overall rotation loop. However, correlated distant effects in magnetic materials are known. If distant compensation does occur, then the closed-loop capability might conceivably be defeated, if the total compensation is sufficient to provide an $\int \mathbf{F} \bullet \mathbf{dl} = 0$ overall condition. Hence the research probably demands attention to maintaining both *local* asymmetry and *distant* asymmetry. If the distant correlation effects occur, only in that manner can an overall nonconservative field represented by $\int \mathbf{F} \bullet \mathbf{dl} \neq \mathbf{0}$ be maintained around a completely closed magnetic loop.

This may be the problem with which Johnson appears to have been struggling for so long. He did solve the problem once, and produced a self-rotating permanent magnet motor that the present author personally tested over a period of about 2 hours. During a two-hour test period, the motor apparatus was allowed to self-rotate for up to 15 minutes at a time. Shortly after it became known that Johnson had successfully produced such a prototype, his laboratory was mysteriously broken into. The only thing taken was the magnet assemblies on that specific little successful demonstrator — in a laboratory with more than a hundred thousand dollars worth of magnets and magnetic assemblies of many kinds present.

As a personal aside, I have been associated with Johnson, off and on, for many years. He is a man of the highest integrity and an indefatigable researcher. It is my fervent hope that Johnson will succeed in his permanent magnet rotary motor project. All I can say as this goes to press, is that he is getting very close again, now that he has help and good machining accuracy, etc. for higher precision buildups. In the near future, I hope to be among the first to drink a good glass of champagne to celebrate his success.

6.4.5 Radus Effect: Magnets with Preferred Flux Path Memory

In the early NASA space program, magnetic boots for holding the astronaut to the skin of the space vehicle when outside it were required. A Westinghouse engineer named Raymond J. Radus had found that a permanent magnet applied to a dual flux path (Figure 6-23) would "remember" the flux path taken initially, until switched to the other flux path in an initial condition, after which it would remember that path as preferable {445a-445c}. A permanent magnet with such "memory" will split its flux in two parallel flux paths by some ratio, e.g., 20% in the non-preferred path and 80% in the preferred path. This preference can be switched at will by proper manipulation. So Radus developed switchable magnetic astronaut boots for the space program, using his magnetic memory and flux path switching technique {446}.

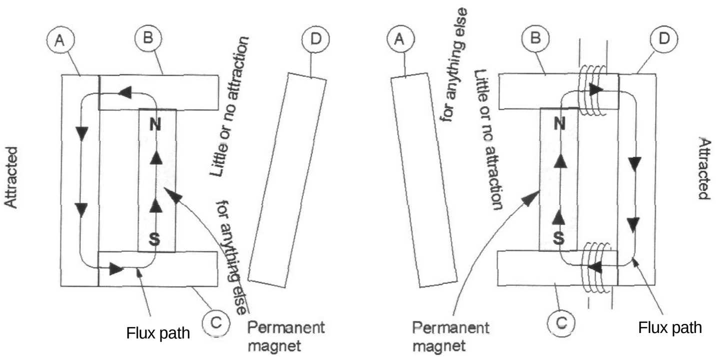

Figure 6-23A.
Once the magnetic circuit is made, there is little attraction for anything else

Figure 6-23B.
A single pulse through a coil can reverse ttie direction of the flux path

Figure 6-23 One example of the Radus effect.

The Radus circuit differs from ordinary permanent magnet circuits in three ways: (i) It exerts strong magnetic force at one end while exerting hardly any at the other, (ii) the strong and weak magnetic poles can be switched end-for-end easily and at will, thus, in effect, turning the magnetism on and off at one given side of the circuit, and (iii) once switched, it remembers its direction of greatest magnetic pull indefinitely.

The original Radus boots were excellent. For the acceptance tests, an engineer clad as an astronaut walked across the bottom of a steel beam in a high bay research area, upside down against the pull of Earth's gravity (Figure 6-24). He *stepped as* he walked, putting his foot "down" and then picking it "up" {447}.

There is no problem in finding modern magnets strong enough to hold the astronaut firmly in such an upside position. The problem with simple magnetic boots using such strong magnets is that, once the foot is planted, the astronaut cannot pick up the foot again. Consequently, the best the astronaut can do with such magnetic boots is walk rather laboriously by "scooting" the foot forward, with the boot remaining in contact and the astronaut unable to pick it up.

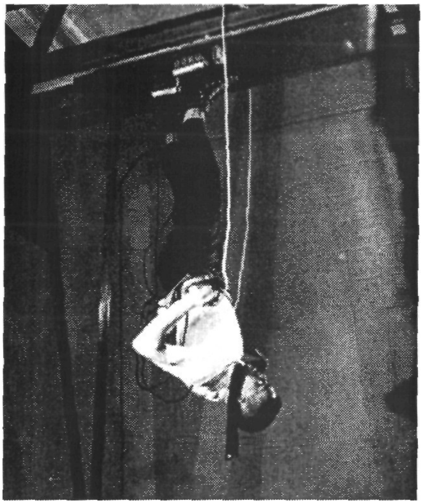

Engineer *walked* upside down on the underside of a steel beam in a high-bay area, wearing the Radus boots He used a stepping movement, not shuffling

Figure 6-24 Acceptance test of the Radus astronaut boots.

The Radus boots completely solved that problem. The permanent magnet fields are switched away from the "boot sole contact with the beam" for that foot that the astronaut wishes to lift, so he can lift it easily and take another step. Then the fields are switched back in again so that the strong field is on the boot sole as he places his foot down. This switching of the fields allows him to walk in a manner resembling normal walking, though a little slower. To do that switching by normal "battery and electromagnet coils" would be prohibitively bulky and heavy — and awkward. With the Radus boots, the astronaut could walk in a manner very similar to slow but normal walking.

However, it is easily seen that an adaptation of the Radus process could conceivably be used to produce a self-switching, self-powered permanent magnet motor. Being a permanent dipole, a magnet is already a particular kind of "free energy generator", since it continuously extracts magnetic energy directly from the active vacuum due to its dipole asymmetry in the virtual photon flux of the vacuum.

The Radus boots were abandoned quickly. NASA then developed the present inferior "shuffler" kind of magnetic boots where the astronaut cannot lift his boot from the surface, but must "scoot" his feet along in a sliding and painfully awkward fashion {448}.

Even today, it is little known that in many virgin magnets fresh from the factory, their very first use conditions them with a Radus-type memory! *That fact can be used, e.g., to create magnets whose fields appear normal, but which deviate from the normal behavior of ordinary magnets, and which produce anomalies in their magnetic fields.*

The Kawai engine {31} uses a novel means of switching the flux path itself instead of overpowering the magnetic poles in an electromagnet. As this is written, Bedini has been notified that his patent with a "path-switching" effect control method has been accepted and will be issued. Although control of the Kawai engine was seized by the Yakuza, we expect to see that some of the first COP> 1.0 motors on the world market will be magnetic motors using the Radus effect or other flux path switching method.

6.4.6 Hole Currents and Electron Currents

In a conducting solid, there are both hole currents and electron currents moving in response to a forcing electric field. In the simple case, electrons move in one direction along the conductor and lattice holes move (migrate) in the other. However, when additional fields are added, the situation can become very complex. The holes and electrons can move oppositely or together in the same direction, depending on the arrangement of the fields and voltages. One can even use fields at right angles to the conductor to affect the currents, and even stop them. This is a rich subject for the inventor, and one that does not appear to have been adequately explored for potential energy and power purposes. This is particularly true when the conductor material is bent or shaped, etc. This area is so broad that it will not be treated here; instead, we refer the reader to Burke {449} for a basic idea of some of the effects and current combinations that can be obtained. From there, an interested experimenter should search the materials science literature on electron and hole current responses of materials.

6.4.7 The Magnetic Wankel Engine

For baseline comparison, Figure 6-25 shows a conventional linear magnetic motor. As can be seen, due to the difference between magnetic poles, a magnetic field exists along the line of the linear track, from the end having the magnets separated the least to the end having the magnets separated the most.

Figure 6-26 diagrammatically shows the scheme of operation of the magnetic Wankel engine. It is basically a linear magnetic motor, wrapped into almost but not quite a complete circle. A set of permanent magnets, each at an angle to the various radial lines of the device, comprises a slightly widening spiral stator that forms most of a circle. A circular rotor with a sector magnet is mounted inside this spiral stator. An end gap exists in the stator as shown, so that the stator is not a completely closed ring. The direction of rotation of the rotor is clockwise as shown. For demonstration of the principle, the beginning air gap between rotor and stator is 0.1 mm and the ending air gap is 5 mm.

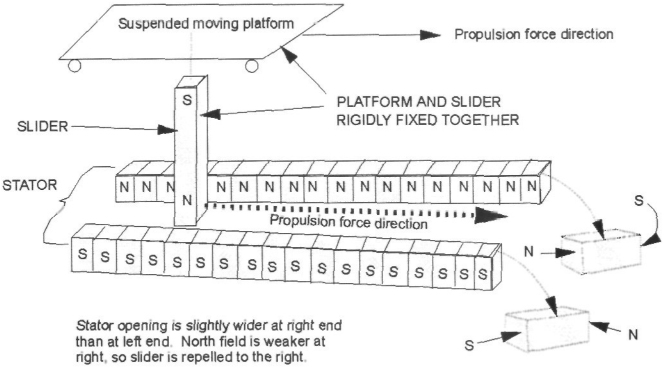
Suspended moving platform
Propulsion force direction
PLATFORM AND SLIDER RIGIDLY FIXED TOGETHER
SLIDER
STATOR
S
N
N N N N N N N N N N N N N N N N N
Propulsion force direction
S S S S S S S S S S S S S S S S S S
S
N
S
N

Stator opening is slightly wider at right end than at left end. North field is weaker at right, so slider is repelled to the right.

Figure 6-25 Type of conventional linear magnetic movement device

An electromagnet is mounted along the perimeter of an angular sector of the rotor, completing the stator gap. The electromagnet is weakly magnetized by a weak trickle current in the associated coil, furnished by a coil with a make-and-break magneto point gap. The electromagnet is magnetized, say, with the north pole facing radially outwards, and the south pole facing radially inside. In the stator, the permanent magnet north poles are facing radially inward toward the rotor, but at an angle, and the south poles are facing radially outward but at an angle.

Tangentially the north pole of the rotor is in a nonlinear magnetic field, and it will experience a clockwise force and acceleration from position 1 where the air gap between rotor and stator is the 0.1 mm minimum, to position 2 where the air gap reaches the 0.5 mm maximum.

If this were all that was involved, the engine would not produce COP> 1.0 because the tangential field is conservative unless additional *free* energy is introduced to overcome the back mmf region in the stator gap. When the rotor crossed the end gap in the stator between point 2 and point 1, very sharp and dynamic magnetic braking due to the back mmf would be done back upon the rotor magnet by the field of the stator magnets at position 1.

Since any real machine will have at least some friction and drag, the actual COP would be less than 1.0.

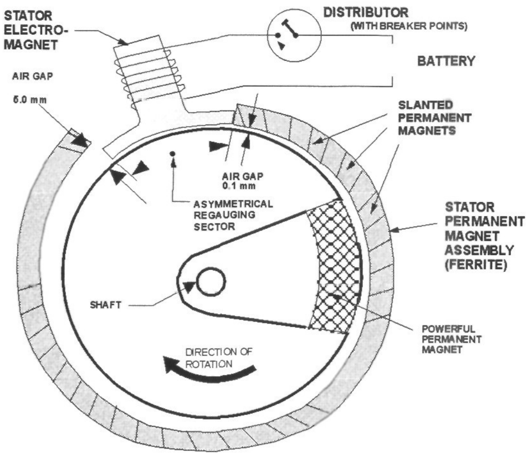
STATOR
ELECTRO-
MAGNET
AIR GAP
6.0 mm
DISTRIBUTOR
(WITH BREAKER POINTS)
BATTERY
SLANTED
PERMANENT
MAGNETS
AIR GAP
0.1 mm
ASYMMETRICAL
REGAUGING
SECTOR
STATOR
PERMANENT
MAGNET
ASSEMBLY
(FERRITE)
SHAFT
POWERFUL
PERMANENT
MAGNET
DIRECTION OF
ROTATION

figure 6-26 Magnetic Wankel engine with asymmetrical regauging section.

Let us use the notion of the magnetostatic scalar potential (roughly, magnetic pole strength) to examine a new situation in the end gap.

Technically, let us regard a single unit north pole in the rotor, going from position 1 to position 2 (the acceleration cycle, where the engine will deliver shaft horsepower against a load), and going from position 2 to position 1 (where the magnetostatic scalar potential must be suddenly regauged asymmetrically to equal or exceed the potential at position 1, in order for the rotor to continue unabated or with even further acceleration. That is, when the rotor enters the "back mmf' end gap between position 2 and position 1, a sharp and sudden increase in the "stator magnetostatic scalar potential" must be accomplished, so that the potential in that region is equal to or greater than the potential at position 1. This effect, nearly freely obtained, is what is required for a self-powering magnetic Wankel engine.

In normal machines, conventionally this asymmetrical regauging part of the cycle is where the design engineer forcibly inputs energy from outside the system to do brute physical work on the rotor to forcibly "reset" the machine, and to forcibly wrestle its potential energy storage back to initial conditions. In short, the operator himself arranges to furnish all the excess energy from outside the system that is required to brute force "regauge" the potential at that point, thus effectively creating a multivalued potential instead of a single valued potential. A multivalued potential achieved only by the operator himself furnishing the extra potential energy will not produce COP> 1.0. It will in fact produce $\int \mathbf{F} \bullet \mathbf{dl} \neq 0$ of the motor section, but only at the expense of extra energy that the operator himself had to input and pay for. In that case and in a real system with some system losses, the net work out because of $\int \mathbf{F} \bullet \mathbf{dl} \neq 0$ will still be less than the total energy input by the operator.

The forcible "reset" work is conventionally done by simply overpowering the field and reversing it (building it up equal and opposite in the other direction), but with energy totally input by the operator and not "free energy input from the environment" at all. The operator first pays to "kill" the existing field, and then pays to establish a field in the opposite direction.

To obtain COP>1.0 and self-powering, we must trick something else or some other process into furnishing that asymmetrical regauging energy — or most of it — for regauging of the magnetic Wankel engine in that stator gap zone. In other words, instead of engaging in the conventional wrestling match against the back mmf, we must let something else provide most of the energy for the wrestling.

During rotation of the stator from position 1 to position 2, we have been maintaining (and paying a little for) a tiny trickle current and small voltage from the battery into the coil around the electromagnet. As the rotor enters the stator gap, suddenly a sensor sharply breaks the distributor points, momentarily inducing a sudden powerful voltage in the coil. With a very short delay, a very sharp surge of current appears in the coil, producing a sharp and suddenly increased magnetostatic scalar potential (pole) in the gap region. That is the "multivalued potential" effect, where we pay a little to achieve it suddenly at that point, by invoking Lenz's law.

The effect is that suddenly the rotor is raised to the same or greater magnetostatic potential as exists at position 1, and "almost freely though not quite". If equal, the rotor suddenly is in a region with no back mmf, hence it experiences no deceleration braking. If the sudden potential is greater than the potential at position one, the stator in this normally back mmf region now actually experiences a further acceleration (a forward mmf) in that region.

Note that no *radial* mechanical work can be done on either the electromagnetic pole piece (part of the stator) or on the rotor, since neither the stator nor the rotor can move *radially.* However, there momentarily exists a clockwise circumferential magnetic field on the rotor in the stator gap, due to the gradient between the sharply regauged pole piece magnetostatic potential and the potential at position 1.

So we pay a little energy continuously (tiny trickle current, sharply broken breaker points) to get much more energy density momentarily in that small back mmf gap region only. The former back mmf in the stator gap is sharply eliminated by the Lenz force and converted to forward mmf. The rotor experiences a continuous acceleration throughout a complete rotation, due to the judicious use of an artificially induced multivalued magnetostatic scalar potential.

If the average shaft power output during the complete rotation cycle is made greater than the average power input to the asymmetrical regauging circuit during that same rotation cycle, the engine will produce COP>1.0. This type of engine is also easily close-looped, since the excess output is **not** electromagnetic energy but mechanical shaft rotation energy.[193] Hence the problem of the Dirac sea hole current (discussed in Chapter 9) is eliminated.

Such engines have been built and placed in an automobile to power it, in Japan {450}, though there is no information on the exact overall COP. The design was lighter and smaller than a gas engine of the same power, and it was a pygmy when compared to other electric engines of similar power. **The** prototype 45-hp unit weighed 155 pounds compared to 440 pounds for a comparable electric motor. The rotary engine was compact enough to fit inside a two-foot cube. The engine was in development by Kure Tekko, a sizable firm that supplies auto parts to Toyo Kogyo, the Mazda maker. To my knowledge, no hard data on the input electrical power utilized for the trickle current and current-breaker has been made available by the Japanese. The principles, however, are quite clear and easily analyzed.

This may be one of the Japanese COP>1.0 engines suppressed by the Yakuza.

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[193] For example, a geared or belted arrangement can be used to drive a very small but efficient DC generator that replaces the battery. Many other efficient arrangements are possible.

The researcher might like to consider using a strategically-placed Wiegand wire sensor (discussed in the next section) as the free "generator" providing a pulse of electrical energy to the pulse-magnetizing coil in the stator gap region at the precisely appropriate time. If that or some other similar "self-furnished" pulse of sufficient power can be delivered to the pulse-magnetizing coil, then the system would self-initiate a multivalued magnetic potential in that gap region. In that case, the driving magnetic field around the loop need not be conservative, and self-rotation would be possible without violating any laws of nature or electrodynamics. At least a small toy demonstration model might be possible, simply to illustrate the principle. Presently we know of no one who has tried it.

6.4.8 The Wiegand Effect

If a Permaloy® or other suitable magnetic wire is properly tensioned and worked by repeated torsion while under tension, the skin of the wire is work-hardened and caused to have different magnetic characteristics from that of the internal core. This type of wire is called a *Wiegand wire*, or *pulse wire*, or "self-nucleating magnetic wire" (SNMW™).

When the pulse-wire experiences a certain level of ambient magnetic field strength, it will automatically switch its magnetic state, very sharply, producing a sharp magnetic field pulse. The effect is generally called the *Wiegandeffect.*

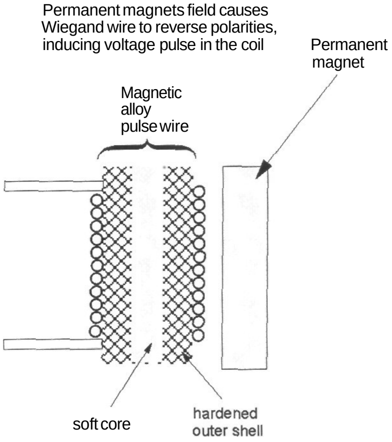
Permanent magnets field causes Wiegand wire to reverse polarities, inducing voltage pulse in the coil
Permanent magnet
Magnetic alloy pulse wire
soft core
hardened outer shell

Figure 6-27 The Wiegand effect

If a coil of many turns of fine electrical conductor is wound around the Wiegand magnetic pulse wire, then when the wire suddenly alters its magnetic state, the sudden magnetic field pulse "cutting" the conductor bundle will produce a sharp electrical pulse. Thus the apparatus produces a sharp pulse of electrical energy, when the ambient magnetic field intensity reaches the pulse-initiation value. No input of outside energy is necessary. The apparatus simply gates the energy from the vacuum when it sharply changes its magnetic polarity.

Wiegand effect sensors may achieve voltage pulses up to a nominal 12 volts, in a typical application.

Numerous patents were issued to Wiegand prior to his death {451a-451h}.

Figure 6-27 diagrammatically shows the primary parts of a typical Wiegand sensor application, where the Wiegand wire is also known as a *pulse wire.* The operation of the pulse wire itself is shown in Figure 6-28. Figure 6-29 shows a typical rotary Wiegand effect pulse transmitter.

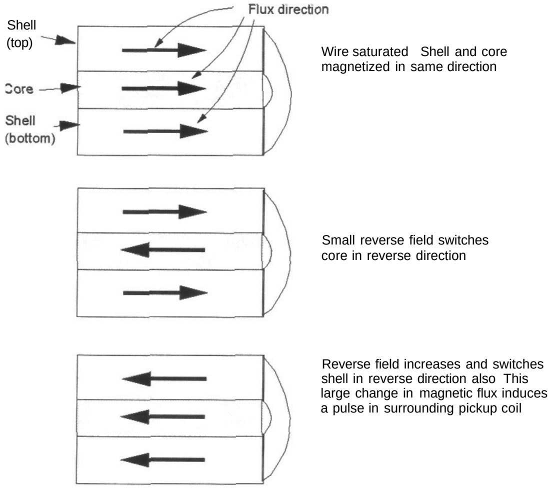
Flux direction
Shell (top)
Core
Shell (bottom)
Wire saturated Shell and core magnetized in same direction
Small reverse field switches core in reverse direction
Reverse field increases and switches shell in reverse direction also This large change in magnetic flux induces a pulse in surrounding pickup coil

Figure 6-28 Operation of the Wiegand effect in a pulse wire.

Pulse wires find many modern "switching" uses, since one does not have to connect them to a power supply in order to obtain the electrical signal pulse generated in a magnetic field as it changes. The magnetic experience of **the** wires can be arranged (using a "resetting magnet") to automatically **reset** the pulse wire to its original condition after the initiation magnet has **fired** it. Many identification cards for personal access to restricted facilities use these wires. Some magnetic memories use the effect. At least one European automobile firm has even used Wiegand wires to trigger the timing of automotive ignition systems.

The pulse characteristics created internally by the Wiegand wire represent a sharp, asymmetrical, self-regauging of the magnetics. The combined magnetic field consisting of the ambient magnetic field and the Wiegand wire magnetic pulse is momentarily a nonconservative magnetic field. It follows that a closed-loop integration $\int \mathbf{F} \cdot \mathbf{dl}$ around some paths in the combined magnetic field of the system do not sum to zero.

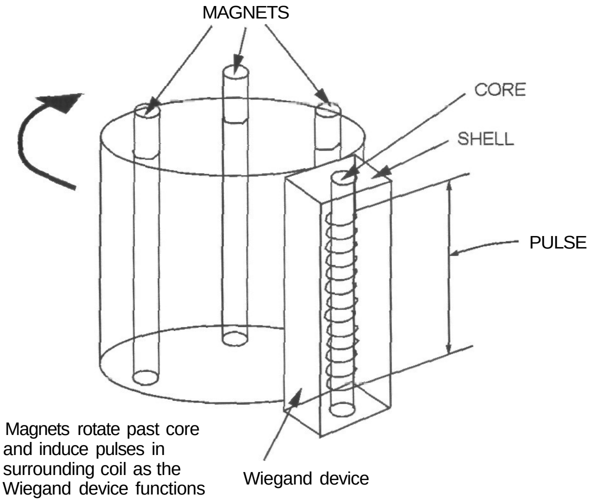
MAGNETS
CORE
SHELL
PULSE
Magnets rotate past core and induce pulses in surrounding coil as the Wiegand device functions
Wiegand device

Figure 6-29 Operation of the rotary Wiegand pulse generator

In theory, at least, it should be possible to utilize something like the magnetic Wankel engine together with exactly self-triggering and self-resetting Wiegand units to form a self-powering permanent magnet motor. In short, referring to our discussion of the magnetic Wankel engine, it might be possible to use a special Wiegand sensor and pulse generator to furnish the properly timed pulse to the coil that enables the continuous operation of the Wankel engine. Obviously this type combination would have occurred to the Japanese scientists working on the magnetic Wankel engine.

We accent that the resulting system would be an open dissipative system, far from equilibrium in its energetic exchange with the vacuum during the Wiegand pulsing. The disequilibrium is achieved by the momentary self-regauging of the magnetic gap in the magnetic Wankel engine.

My colleagues and I have experimented with Wiegand wires and Wiegand sensors to a limited extent. The effect is quite real, fully documented in the scientific literature, and the wires and sensors are not too expensive. A typical coil of 1,000 turns on a 3-cm Wiegand wire will produce pulses of about 2 volts in a 1,000-ohm resistor. The pulse width (half maximum height) is about 20 microseconds. Essentially the Wiegand wires are immune to stray magnetic fields. Viewed on an oscilloscope, the pulses are very clean without spurious oscillations or hash. The field required to switch a typical Wiegand wire is typically about 150 Oersteds. The resetting field is quite a bit smaller, being about -20 Oersteds. With further work, it is probably possible to come up with Wiegand wires whose coils produce up to 20 Volts in a 1,000-ohm resistor. If 25 of these 20-volt Wiegand pulse generators wired in series could be induced to fire simultaneously across a 1,000-ohm resistor, something like a momentary half-watt device could be built. That might be enough to operate a very small version of the magnetic Wankel engine, etc. purely for demonstration purposes.

For practical power, of course, one would need to find a way to increase the power output in each Wiegand generator pulse. So far, no one has been able to successfully find a way to do it, at least to our knowledge. If the reader finds a way to do that, then the reader should certainly patent the process and use it in a self-powering magnetic Wankel engine!

So to those experimenters wishing to experiment with something relatively inexpensive, we would suggest investigating the possibility of incorporating Wiegand units into a magnetic Wankel-type small magnetic motor, and attempt to get a self-powering little unit, or try to build a self-powering version of the rotary Wiegand pulse generator. It is at least possible in theory, and if achieved in practice it will prove that self-powering EM engines are perfectly possible.

6.4.9 Kawai Path-Switching Motor

Japanese inventor Teruo Kawai has invented a process for adroit self-switching of the magnetic path in magnetic motors, rather than directly overpowering the magnetic field and then forcibly reversing it. The process reduces most of the back mmf in an otherwise rather conventionally switched magnetic motor, and results in producing a COP that is approximately double the stated efficiency rating of the unmodified motor. Understand, the Kawai motor always has an efficiency less than 100%, even when its COP>1.0! Hence if one starts with a *high efficiency* magnetic motor — e.g., efficiency of 0.7 or 0.8 — one can obtain a modified motor having a COP of 1.4 to 1.6. Two Kawai-modified Hitachi high-efficiency magnetic motors were tested by Hitachi engineers, and the tests did indeed show COPs of 1.4 and 1.5, respectively, under rigorous and totally independent testing conditions.

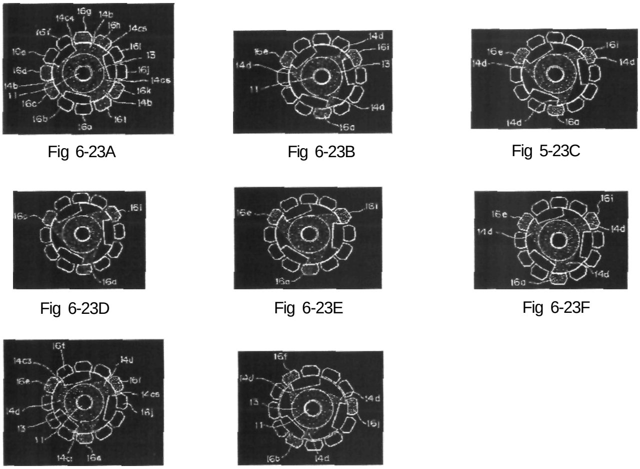

Fig 6-23A

Fig 6-23B

Fig 5-23C

Fig 6-23D

Fig 6-23E

Fig 6-23F

Fig 6-23G

Fig 5-23H

Figure 6-30 The Kawai path-switching process.

Figure 6-30 shows eight snapshots A, B, C, D, E, F, G, and H of the rotor advance of a typical Kawai engine, taken from Kawai's 1995 patent {452}. This is one end rotor/stator side of a two-rotor device, where a similar rotor/stator device is on the other end of the central shaft *11.* In snapshot A, pole piece *14* had three outward teeth *14b* dispersed equally around the circumference, alternated with three notches. An end magnet *13* provides the source of flux passing through the pole piece. With the electromagnets DC-energized, their core materials *16c, 16d, 16g, 16h,* and *16k, 16l* are shown shaded by flux from central magnet *13* out through teeth *14b.*

In snapshot B, electromagnets *16a, 16e,* and *16i* are energized. The shaded area shows the sharp convergence *14d* of the flux from magnet *13* through pole piece *14* and the edge of teeth *14d.* Since the electromagnets are magnetized in attracting mode, the rotor will experience a torque tending to widen the flux path from magnet *13* to the activated electromagnets. Thus a clockwise torque exists on the rotor, and it will start to rotate clockwise.[193] Note that each electromagnet is operating independently of the other two.

As shown in snapshots C, D, E, and F, the rotation of the rotor continues clockwise, widening the connecting flux path to the three activated electromagnets. During this time the torque on the rotor is clockwise.

In snapshot G, the flux path to the activated electromagnets is fully widened. In addition, the leading edges of the three teeth are just beginning to enter the domains of the next electromagnets *16j, 16b* (see snapshot A) and *16f.* This is getting symmetrical to the original position shown in snapshot B.

Now the electromagnets *16i, 16a,* and *16e* of snapshot G are deactivated, as shown in snapshot H, and electromagnets *16j, 16b,* and *16/*are activated. This action asymmetrically self-regauges and resets the engine back to the original situation shown in snapshot B, but one more electromagnet beyond. The action cycle begins anew. As can be seen, in each complete rotation of the shaft, each of the three teeth of the rotor will be asymmetrically self-regauged multiple times. So multiple total asymmetrical self-regaugings, resettings, or "refuelings" are utilized per shaft rotation.

In each motor coil, at energization a tooth is just entering that coil, Energized in attractive mode with respect to the ring magnet around the shaft, the flux in the pole piece jumps from fully widened flux (and small **or** vanishingly radial torque on the rotor) to angled and narrowed flux (with full radial clockwise torque on the rotor). This is an asymmetrical self-regauging action. As previously explained, the narrowed flux and its angle exert a clockwise accelerating tangential component of force upon the rotor. By the asymmetrical self-regaugings of the engine, each coil is de-energized prior to beginning to exert radial back emf— which it would do if it remained energized as the trailing edge crossed it and again narrowed the flux path).

So the Kawai engine uses normal magnetic attraction to accelerate the **rotor** for a small distance, and then asymmetrically self-regauges to zero attraction to eliminate the back-mmf drag portion of the attractive field. It regauges to zero as the reset condition.

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[193] The Kawai patent contains a small error of misstatement. It states at first that the torque and rotation are counterclockwise, and then shows it moving correctly clockwise from figure to figure in the series.

For appreciable power and smoothness, the typical Kawai engine uses an extensive number of asymmetrical self-regaugings per axle rotation, for example 36 times on each end, or a total of 72 times for the two ends. The force field of each coil, accompanying its increased magnetostatic scalar potential, is oriented radially inward, so that radial work cannot be done by the coil on the rotor because the rotor does not translate radially. Advantage is taken of the initial clockwise acceleration force initially produced, and self-regauging eliminates the counterclockwise decelerating drag force that would be produced without the regauging.

The major benefits are that (a) multiple self-regaugings occur for a single rotation of the rotor assembly, enabling high weight-to-power ratio, (b) each electromagnet is energized only when positively contributing to the clockwise torque that drives the rotor, and (c) each coil is de-energized to asymmetrically self-regauge the system during those periods when the coil would otherwise create back-drag (counterclockwise torque) if it remained energized.

A conservative cycle is one in which the work done in the back-drag (mmf) region is equal to the work done in the forward boost (forward mmf) region. Self-eliminating the back-drag portion of the cycle is a form of asymmetrical self-regauging, and makes the net field highly nonconservative. The Kawai approach is thus permitted to attain COP>1.0. In his U.S. patent, Kawai quotes performance measurements showing COP = 3.18. As we stated, Hitachi engineers measured two Kawai-modified Hitachi magnetic motors which exhibited COP =1.4 and 1.6 respectively.

Since the output is shaft horsepower, in principle the Kawai engine can be close-looped for self-powering, without consideration of the Dirac sea hole current. With its external close-looping system (not shown), it falls within the second close-looping class, that of an "outrigger" system. Only the unitary system closed-looping class requires consideration of hole currents in the Dirac Sea.

The Kawai process and several other Japanese overunity systems have been blocked from further development and marketing by the Japanese Yakuza. The present author and the Board of Directors of CTEC were physically present and in final negotiations (having reached agreement!) with Kawai to market his self-powering motors worldwide, when control of the Kawai company and process were suddenly seized on the spot in our presence.[195]

6.4.10 Bedini's Skin Depth Magnetic Switching

Bedini found a most interesting variation of flux path switching: he switches the direction of just a little fraction of the ongoing magnetic flux in a material flux path, on the skin of one side of it and with only a slight "skin depth".[196]

Suppose a flux path material is used as the stator pole of a permanent magnet motor. A large permanent magnet is used to magnetize that short length of flux path, as shown one the left in Figure 6-31, which illustrates a concept for a magnetic motor. For convenience, imagine that the small magnet on the right is not yet placed on the material flux path extension. The flux path extension is energized by the south north pole of the large permanent magnet on the left, and used as the stator in a rotary magnetic motor.

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[195] To anyone who understands Japanese culture, Kawai paid me one of the greatest compliments possible. After his company representative called from Japan, Kawai shipped his *original proof of principle engine* — which first successfully demonstrated his flux-path switching process without being optimized for COP>1.0 — to me, here in the U.S. In the Japanese manner, he had entrusted me with his single most valued possession. From years of aikido experience, I fully understood the meaning of this unprecedented gesture, and expressed my deep appreciation accordingly. From our first meetings with Kawai and his group, I have and always shall have the utmost respect for Teruo Kawai. In my view, it is a sad loss to humankind to have his engine buried and withheld so brutally. Kawai had already achieved a closed-loop self-powering version, and it is this version upon which we reached agreement. In less than 24 hours after that agreement, the Kawai engine and company — and Kawai's own fate — were seized and no longer in Kawai's hands. For those unfamiliar with the deep spread of the Japanese Yakuza, the following are recommended: (a) Brian Bremner, "How the Mob burned the Banks: The Yakuza is at the center of the $350 billion bad-loan scandal," *Business Week,* Jan. 29, 1996, p. 42-43, 46-47; Michael Hirsh and Hideko Takayama, "Big Bang or Bust?" *Newsweek,* Sept. 1, 1997, p. 44-45; Adam Johnston, Yakuza: Past and Present," downloaded from the Internet, Committee for a Safe Society, Organized Crime Page: Japan: History and present status of Japanese organized crime.

[196] Close colleague Ken Moore also independently discovered this effect in his own experiments, but then we found that Bedini had discovered it earlier. That was fine with Ken; he greatly admires Bedini and the marvelous discoveries Bedini has made. I greatly admire both of them, and am happy to call them best friends. After all, s**cience** has a human side as well as a materials side. Without one's close colleagues and best friends, science alone would be a miserable enterprise!

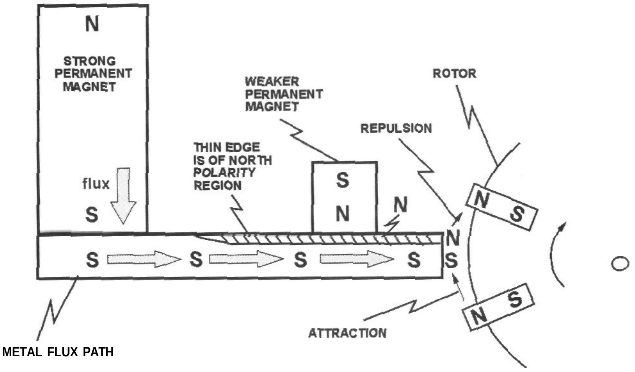

Figure 6-31 Bedlni skin depth magnetic edge switching.

As can be seen, the north pole of the rotor, shown in the figure, is attracted to the resulting south pole of the stator. Power can be taken from the shaft of the rotor while it is being attracted in to the extended north pole of the stator flux extension. As it begins to pass the extension end, obviously if nothing else is done it will develop back mmf "drag" by being attracted back toward the north pole of the flux extension as it passes it.

However, suppose that —just when the rotor south pole is passing dead center of the stator north pole extension, one suddenly pulses a small flat coil placed on the face of the extension, which serves the function of the small permanent magnet shown on the right of the material flux path extension. Further, suppose the magnetic field produced by the coil is oriented as the field of the small permanent magnet, but is much weaker than the magnetic field of the large permanent magnet on the left. A very curious effect then occurs. This energized coil magnetizes the edge of the flux path extension, to a small "skin depth" as shown, with a *north* polarity. The magnetic flux is now bidirectional in that same material flux path extension.

Further, this edge-switching action is performed so that it is this "partial north polarity" of the now-altered extension that faces the rotor north pole as it begins to pass the extension and enters what previously would have been a back mmf section. Instead, now that former back mmf section is a weakened forward mmf region, *further accelerating the rotor.* This action breaks the Lorentz symmetry around the rotation path of the rotor, resulting in a net nonzero (nonconservative) magnetic field. Hence the entire rotor exhibits a net drive force around its loop. The rotor will accelerate until the mechanical work performed upon the shaft, friction, etc. is equal to the net magnetic energy furnished to the rotor.

The beautiful part of this motor is that one does not have to "overcome" by brute force — and then reverse — the north polarity of the entire stator extension. In theory, the overall energy added to the rotor is greater than the energy that must be added for the "edge switching" of the magnetic flux path extension, because the entire back mmf of the motor has been eliminated and replaced by a weaker forward mmf. If the process of furnishing the "skin depth" weaker magnetic north field to the edge of the flux path extension is made sufficiently efficient, this engine also can be made self-powering, at least in theory.

The former "motor" design has been converted to a "motor/generator" design, by the addition of the edge-switching action. The novel factor is the use of bidirectional flows of magnetic flux in a single material flux path.

An additional improvement is to rig a Wiegand sensor and pulse generator or sensors in conjunction with the rotor action, to freely furnish and kill the edge-switching pulse to the face-magnetizing coil on the flux path extension, at the appropriate times. This is an area where even high school students will be able to experiment.

Bedini's patent on the edge switching process and its various embodiments and improvements has been issued {453}.

6.4.11 Bedini's Flux Path Switching with Energy Capture

One additional embodiment of the Bedini flux path switching motor is shown in Figure 6-32. Here the entire flux path is switched, by moving a small coil on the bottom side of the material flux path, as shown in the figure. As Radus showed {454}, it turns out that a much weaker magnetic field in that left bottom position will switch the flux path of a powerful permanent magnet field at the left top of the path, as shown.

Now, however, Bedini adds a transformer coil around the right end of the core (the right end of the extension is still the stator pole in the magnetic motor diagrammatically shown in Figure 6-32). When the flux path is switched back and forth, this transformer coil produces an AC signal output, which can power a load as shown, and can even be used to power the switching power supply. The trick is that it requires less energy to make the vertical flux path preferable to the horizontal flux path, than the energy delivered into the flux path by the permanent magnet. The potential **for** self-powering of a sufficiently efficient magnetic motor is obvious.

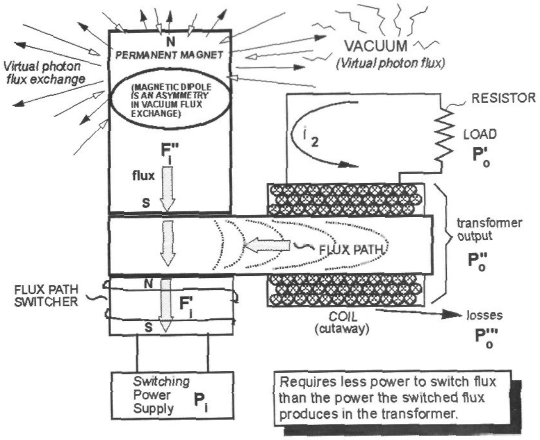
N
PERMANENT MAGNET
Virtual photon flux exchange
(MAGNETIC DIPOLE IS AN ASYMMETRY IN VACUUM FLUX EXCHANGE)
VACUUM
(Virtual photon flux)
RESISTOR
i_2
LOAD
P'_o
F''_i
flux
S
FLUX PATH
transformer output
P''_o
FLUX PATH SWITCHER
N
F'_i
S
COIL (cutaway)
losses
P'''_o
Switching Power Supply P_i

Requires less power to switch flux than the power the switched flux produces in the transformer.

Figure 6-32 Bedini's total path switching and energy recovery process in a transformer.

So the motor can be powered while simultaneously acting as a partial generator. For efficient switching, this motor/generator can in theory develop COP>1.0 and can even be made close-looped and self-powering. We strongly accent that the primary excess energy input to the system is from the vacuum itself, via the broken symmetry of the large permanent magnet dipole at the left top of the material flux path. As we have repeatedly stated, the only energy problem is how to capture and utilize the EM energy freely received, transduced, and poured out from the vacuum by the source dipole's broken symmetry, without using half of it to destroy the source dipole.

6.4.12 Transformer Secondary Shunted by a Negative Resistor.

See Figure 6-33. This embodiment assumes the availability of a true negative resistor — possibly an adaptation of a point contact transistor or other device. As shown in the figure, a transformer exhibiting COP> 1.0 can be developed by adding a shunting *true* (not differential!) negative resistor across the terminals of the secondary, adjacent to the secondary. In this manner, the Lorentz symmetry of the closed unitary current loop containing the external loads and losses, and normally the secondary of the transformer in series, is broken.

Part of the return spent current is now "pumped" back up from ground side to power side of the transformer secondary without passing through the secondary. The pumping work is providing by dissipation (in the negative resistor) of energy freely obtained from the active vacuum environment. In short, one adds a negentropic process in parallel with the secondary coil, in the secondary external circuit, breaking the otherwise enforced Lorentz symmetrical regauging of the discharge of the collected EM excitation energy in the secondary circuit. This provides the capability for a permissible COP>1.0 transformer.

ON EACH HALF CYCLE, ONE OF THE NEGATIVE RESISTORS SHUNTS PART OF THE RETURN CURRENT AROUND THE SECONDARY, FROM LOWSIDE TO HIGH SIDE, THUS DECREASING THE BACK-FIELD COUPLING FROM SECONDARY TO PRIMARY ACROSS THF TRANSFORMER. THIS LESSENS THE ENERGY DISSIPATION REQUIRED IN THE PRIMARY FOR A GIVEN ENERGY FLOW TRANSFER FROM PRIMARY TO SECONDARY

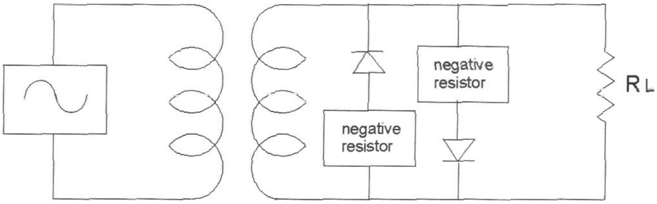

Figure 6-33 Transformer shunted by a negative resistor.

In theory, if the negative resistor can bypass all the current in the secondary, or almost all of it, the transformer can become a COP»1.0 device.

This overunity transformer can use step-up of the voltage from primary to secondary, and exhibits an asymmetry in its forward and backward field coupling between primary and secondary. Thus the dissipation of energy in the primary circuit need not be as great as the dissipation of energy in the secondary circuit. The *energy flows* are of course in perfect conservation, but there is no law of nature requiring the *energy dissipations* to be conservative between the primary and the secondary. It is strictly the backfield coupling from secondary to primary that enforces equal energy dissipation in the primary as in the secondary, in normal transformers. And that backfield coupling's strength is a function of the return current through **the** transformer secondary. By reducing that current, the back coupling to the primary is reduced, which in turn reduces the current draw of the primary from the external power supply.

No laws of physics, electrodynamics, or thermodynamics are violated by the asymmetrically coupled transformer power system with broken symmetry in its secondary to primary circuit couplings. In short, there is less backfield coupling from primary to secondary than there is from secondary back to primary. The additional energy dissipated in the secondary circuit is freely extracted from the vacuum by the negative 4-resistor shunt.

Again, this application assumes the availability of a true negative resistor, to use as a shunt of the secondary.

The beauty of this application is that, once achieved, such a COP>1.0 transformer can easily be close-looped for self-powering by standard "governed" positive feedback. No concern as to hole current effects usually need be accounted for unless the COP becomes very large.

6.4.13 Eddy Current Multiplier.

Figure 6-34 shows an example of an eddy current multiplier, adapted from Burke {455}. This is given as a somewhat unusual system which may exhibit novel effects and possibly can be adapted into a COP>1.0 system (e.g., by using permanent magnets instead of the coils and triggering things into unbalanced condition using a rotary pulse wire generator. We simply list it here as a candidate for the experimenter.

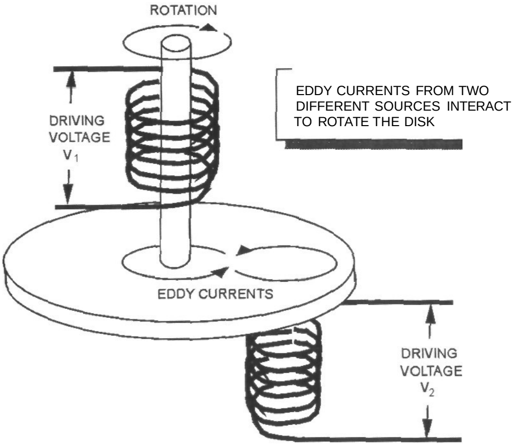
ROTATION
EDDY CURRENTS FROM TWO DIFFERENT SOURCES INTERACT TO ROTATE THE DISK
DRIVING VOLTAGE V_1
EDDY CURRENTS
DRIVING VOLTAGE V_2

Figure 6-34 Eddy current multiplier.

In Figure 6-34, the shaft of the conducting disk is connected to a rotor, which could have arrangements for rotary type of Wiegand pulse generator of Figure 6-29 (with self-initiation and self-recovery) around it (not shown in Figure 6-29). One would start the rotating disk by hand. These Wiegand sensors would then automatically and repeatedly deliver a series of electric pulses to the coils, momentarily generating the two eddy currents shown, so that dynamic force and rotary acceleration is obtained during the endurance of the pulses. In short, one would "electrically kick" the coils so that they continually deliver a propulsive "magnetic kick" to the conducting disk to repeatedly generate eddy currents to rotate it. The rotor is powered as shown by the interactions of the two unbalanced induced eddy currents. Such an arrangement could possibly exhibit COP>1.0.

To experiment with such an apparatus, the major parts that must be developed are (i) the rotor and coils arrangement (the motor), (ii) the integrated rotary Wiegand effect pulse generator with self-recovery, and (iii) the proper timing arrangement. Each should be developed and optimized individually in the researcher's experiments, then combined and optimized together. This is an experimental area that can be cheaply investigated, e.g., by a college student or high school student for a science project. Whether COP>1.0 is achievable or not depends upon the efficiencies that can be obtained with the various processes involved. It is possible, at least in theory, for such an arrangement to be self-rotating once rotary motion is underway.

6.5 CONCLUSION

In this chapter we have advanced many approaches to COP>1.0 systems, that have been tried or considered by various inventors and researchers in the field. Many of these experimenters have attained concrete, replicable results, including results published in the hard literature.

We hope this sampling shows the reader that indeed we can have "self-powering" electrical power systems and COP>1.0 electrical power systems whenever the scientific community will come out of its preoccupation with the present seriously restricted electrodynamics and electrical power engineering practice and fund the necessary research. Simply funding a few graduate students for research and doctoral theses in these areas would be very useful and immensely more productive for electrical energy purposes than all the billions and years spent on chasing hot fusion.

Hopefully the iron dogma of the scientific community against COP>1.0 electrical power systems is slowly changing. If so, and if the community will turn loose those sharp young graduate students and post-doctoral scientists on the problem, very shortly there will no longer be an electrical energy problem on Earth, ever again. We strongly refer the reader to Deffeyes' book {456} to rigorously validate the coming increase of the price of oil, in the middle of the present decade. See particularly the quotation from Deffeyes in our Endnote {342}. With the present extreme volatility of the MidEast and the continuing war on terrorism, the probability is high of eventual severe disruption of oil supplies and the energy infrastructure of the U.S.

An independent review of Deffeyes' book is given by Young {457} and we recommend that the reader digest that commentary also.

If the scientific community will fund the necessary research on permissible COP>1.0 Maxwellian systems, the quick results will solve the energy crisis, clean up the biosphere — including much cleaner air in our cities for the populace to breathe — provide cleaner streams, and result in far less polluted oceans. It will stop the pollution-caused destruction of species, and dramatically reduce the hydrocarbon combustion contributions to global warming. There will no longer be a necessity to consider "burying" in the bottom of the sea the excess CO2 from massive hydrocarbon combustion to provide the much-needed electrical power, because it will no longer be necessary to burn the oil, coal, and gas to get the power. And there will no longer be any necessity for expensive and highly vulnerable nuclear power plants with their resulting nuclear wastes that will remain radioactive for thousands of years.

If cheap, clean EM energy from the vacuum is rapidly developed, we may *finally* get the scientific community's head wrenched back out of the big nuclear power business, as a colossal waste of research manpower and taxpayer dollars — as well as providing ticking time-bombs for the terrorist teams now already in the United States to attack and destroy. It is so easy for a person with appropriate technical knowledge to build a portable electromagnetic pulse (EMP) "shooter" that one shudders at the consequences of in-country terrorist teams that can do so. Try imagining what we would face when the electronic controls of one or more operating nuclear power plants are suddenly disabled and destroyed with the reactor on line and providing power. Chernobyl might look like a mild spring breeze in comparison, should we have one or more actual meltdowns.

It is not a pleasant consequence to contemplate, and that alone may eventually dictate the overwhelming urgency of achieving decentralized, vacuum-energy-powered electrical power systems as soon as humanly possible. The present centralized, cumbersome energy infrastructure is vulnerable beyond all sanity, considering the thousands of terrorists already in country, with weapons of mass destruction as well as more conventional sabotage means. As a single example, the former Soviet Union clandestinely brought in nuclear weapons into the U.S., and

Spetznaz teams to detonate them on order. Such weapons (and teams) are already in large U.S. cities and population centers. The reader is referred to Lunev's book,[197] for details about how the nuclear weapons were introduced.

After all, we do have to live and survive in the real world, and not just in an idealistic scientific environment. We are already at war, with alerts of potential danger to our nuclear power plants already having been given on several occasions. In the present very disorderly and very dangerous world we live in, many of the former options we have had for decades are rapidly ending. That includes the option for the leaders of the scientific community to continue "business as usual", if they wish this nation and their own families to survive. There is an old adage in war: *Whatever your determined enemy can do to hurt you desperately, he will do as his highest priority.* Sadly, in my opinion the leaders of the scientific community — unwittingly — are presently doing almost everything they can do to insure that the energy infrastructure goes, the national economy goes, a nuclear meltdown possibly occurs, and this nation and much of civilization perishes in a new dark ages.

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[197] Stanislav Lunev (with Ira Winkler), *Through the Eyes of the Enemy,* Regnery, Washington, 1998. Lunev is the highest ranking GRU defector. He is a former Colonel in the GRU, the military counterpart of the KGB. On p. 22-33, he summarizes the Spetznaz capabilities. On p. 22-27, he summarizes Spetznaz use of nuclear weapons already on American soil. On p. 26, he gives some of the ways in which the Soviets easily brought nuclear weapons into the U.S. On p. 30 he confirms **Russian** seismic weapons. Use of EMP weapons is on p. 30-31. Use of very, very low frequency weapons to destroy the human brain, put people into a zombie-like state, and aid in brainwashing is confirmed on p. 31. The present war on terrorism has many more facets than are presented by the conventional news media.

Just as the dinosaurs were confronted with a new and dangerous threat, and failed to adapt, the electrical power infrastructure is now confronted with a potent threat against its very vitals and — so far — is completely failing to adapt. It is going to have to adapt or perish, which presently implies that we all perish along with it. Those who make it their nefarious business to see to it, will see to it.

So let us "see to it" first, scientifically, as rapidly as human research and development can do the job. The very existence of civilization may well depend upon it.

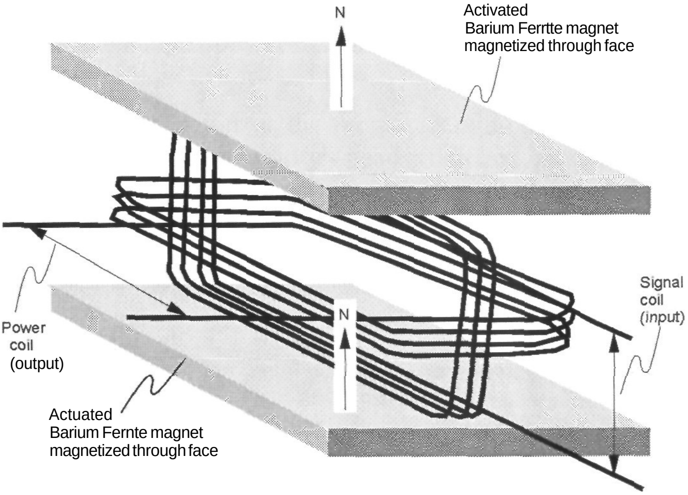
N
Activated
Barium Ferrtte magnet
magnetized through face
Power
coil
(output)
N
Signal
coil
(input)
Actuated
Barium Fernte magnet
magnetized through face

Figure 6-5 Sweet vacuum triode amplifier (VTA) construction.

Chapter 7

Aharonov-Bohm Effect, Geometric Phase, and the Motionless Electromagnetic Generator (MEG)

[Decision that hydrogen fuel is the future]. *"We are at the peak of the oil age but the beginning of the hydrogen age. Anything else is an interim solution. The transition will be very messy, and will take many technological paths ...but the future will be hydrogen fuel."* [Herman Kuipers, Royal Dutch Shell.].

[Vacuum energy is real] *"...the acceptance of a structured vacuum described by an O(3) gauge group leads directly to the existence of novel charges and currents in the vacuum. These are conserved, or Noether, currents and charges and are clearly topological in origin. They spring from the fact that the vacuum is a topological space. Four such entities emerge: [1] A topological vacuum electric charge, also proposed empirically by Lehnert et al. [2] A topological vacuum electric current, also proposed empirically by Lehnert et al. [3] A topological vacuum magnetic charge, proposed also by Barrett and Harmuth. [4] A vacuum topological magnetic current, proposed also by Barrett and Harmuth.*

Each of these four objects can provide energy, which can be loosely termed 'vacuum energy': energy coming from the topology of the vacuum. " [Evans] {458}.

[Aharonov-Bohm effect] *"...the Aharonov-Bohm effect is a local gauge transformation of the true vacuum... [which] produces a vector potential from the true vacuum. [This gauge transformation] produces topological charge..., the electromagnetic field, which carries energy, and the vacuum charge current density first proposed by Lehnert ... and developed by Lehnert and Roy... ".* [Evans and Jeffers] {459}.

[Geometric phase] *"The concept of the geometric phase is closely related to the effect of a state function acquiring a non-zero phase factor after a quantum system undergoes a cyclic evolution. This means, that if a system after some time returns to its original state, the result of such an evolution will be recorded in the phase of the wavefunction. Moreover, this phase factor can be measured by interfering initial and final states. ... Although there are no widely recognized practical applications of the geometric phase, its experimental observations have been reported in many fields of science. The largest group of experiments have been carried out on polarized light ...and polarized neutrons ... The geometric phase has also been observed in magnetic resonance experiments ..., mesoscopic structures ...and molecular systems ...Analogues of GP — the Hannay angles — have been shown to exist in classical mechanical systems ..., the most famous example of which is the Foucault pendulum."* [Aleksiejunas][198]

[Practical use of geometric phase]. *"The motionless electromagnetic generator is the first practical macroscopic use of the geometric phase. "* [T. E. Bearden, 2001, to a correspondent].

[Impact of extracting energy from the vacuum] *"If they [quantum fluctuations of vacuum] can be [tapped], the impact upon our civilization will be incalculable. Oil, coal, nuclear, hydropower, would become obsolete — and so would many of our worries about environmental pollution." "Don't sell your oil shares yet — but don't be surprised if the world again witnesses the four stages of response to any new and revolutionary development: 1. It's crazy! 2. It may be possible — so what? 3. I said it was*

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[198] I am much indebted to Dr. Rimvydas Aleksiejunas for this clear statement of the geometric phase. See his very elegant summary, " Introduction to The Geometric Phase Decomposition," on his Internet website at http://signalogram.free-hosting.lt/Research/gp dec.htm. His own publications in scientific journals and proceedings are also listed on **the** website, and many are available for downloading. His doctoral thesis dealt **with geometric phase** and he is a specialist in that field.

a good idea all along. 4. I thought of it first." [Arthur C. Clarke] {460}.

7.1 Introduction

In this chapter we give a history, some information, and comments about the Aharonov-Bohm effect {473}, which was generalized by the Berry phase {477} for adiabatic conditions, which itself was further generalized by Aharonov and Anandan {480} to remove the adiabatic limitation. The modern all-inclusive term is *geometric phase,* which has been found to be involved in a very wide variety of physics areas. In its embodiments, the motionless electromagnetic generator (MEG) does utilize the Aharonov-Bohm effect (geometric phase) in a unique manner that we explain. We also remark on what we hypothesize may be some related new aspects of the curl-free magnetic vector potential itself.

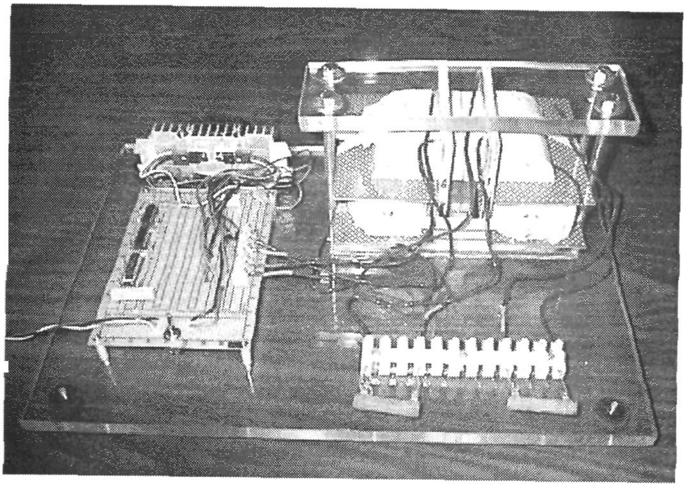

Figure 7-1 Motionless Electronic Generator (MEG)

The motionless electromagnetic generator (MEG) (Figure 7-1) was invented by Patrick, Bearden, Hayes, Moore, and Kenny {461} after years of research and experimentation. It has been technically described elsewhere {462}, and scientific explanations of the fundamental mechanism by which it successfully extracts useful EM energy from the active vacuum have been published in the recognized literature {463, 38a, 464}. Other closely related papers on extracting EM energy from the vacuum have been published or are submitted and in review {465a-465h}.

A version of the MEG has also been independently replicated by Naudin {466}, and in fact by others who did not wish to publish their results. By permission, Naudin's Mark II MEG replica is shown in Figure 7-2. Consequently, the MEG is a validated and replicated COP>1.0 system, as required by proper scientific methodology. Further, sufficient information has been released for any competent laboratory team to replicate a version of the MEG.

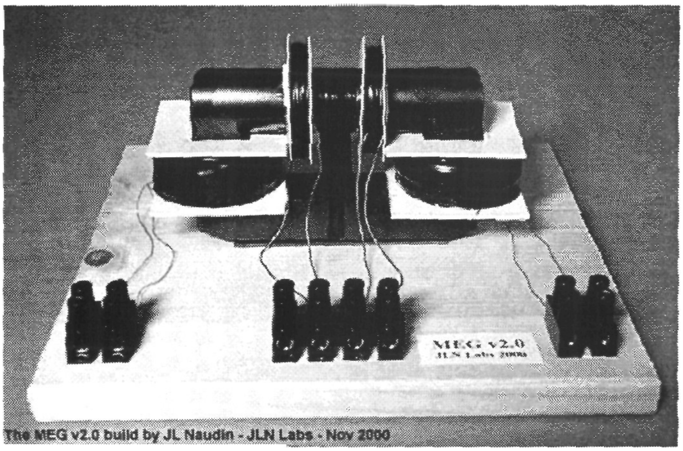

Figure 7 2 Nuadin's Mark II Replication of the MEG.

We give an overview of the MEG, the principles of its operation, the status of the project, and some indication of future plans.

7.1.1 Status

As this is written, the first MEG patent has just issued {37}. A second Provisional Patent Application has been filed, and at this writing is in process of being replaced by a formal regular patent application. Two other patent applications are in preparation. All rights to the MEG are assigned to Magnetic Energy Ltd., Huntsville, Alabama, U.S.A., whose CEO is Dr. James L. Kenny.

In addition, Bedini and the present author have filed a provisional patent application on the process and embodiment for close-looping a COP>1.0 system for self-powering operation, and are in process of replacing it with a regular patent application also. Magnetic Energy Ltd. has permission to utilize the Bedini-Bearden close-looping process. In addition, Magnetic Energy Ltd. has its own proprietary close-looping process, for which a patent application is being prepared. The Company is also involved in serious discussions with several large companies and financial groups for potential financing. When that funding is obtained, we will open a substantial research and development laboratory here in the United States, serving a separate production company to be set up with our financial partners to produce and market the MEG. Meanwhile, laboratory work to complete the research and development of the MEG is also ongoing under a cooperative arrangement with the National Materials Science Laboratory of the National Academy of Science of a friendly foreign nation formerly under the Soviet bloc.

7.1.2 Future Plans

Our plans are straightforward. We will continue to pursue and update our patents and file additional ones as additional discoveries are made. We will continue our negotiations with major financial parties until satisfactory and mutually beneficial capitalization is obtained (we expect that to occur before the end of 2002). At that time we will establish a modern Magnetic Energy Ltd. U.S. laboratory devoted to advanced research and development, as well as a separate production company in partnership with our funding partners. The final research necessary on the MEG (four areas of physics as well as the electrodynamics) will be completed in somewhat less than one year after setup of the lab and lab team, and the production company is expected to have the first engineering development production prototype at the end of that first year. We expect it to be a self-powering unit. We will simply put the first MEG units into production and on the world market immediately thereafter.

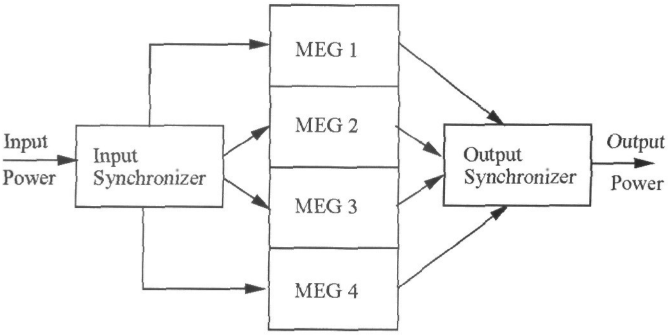

Figure 7-3 Block diagram of envisioned **modular** MEG design.

See Figure 7-3. The first production MEG is envisioned as a modular 2.5 KW unit together with a synchronizer unit simultaneously developed, so that up to six 2.5 KW MEG units can be synchronized in a power system array. This will yield power units from 2.5 to 15 KW. We are struggling to have the closed-loop process completed and ready in that same first year, and if possible the very first MEG units will be close-looped and self-powered. At the end of the second year or before, we plan to have the close-looped basic MEG unit in 10 KW size, again with synchronizer so that up to six MEG units can be synchronized in an array. That will cover the 10 - 60 KW power system size, which is ideal for homes and small businesses. Once the units go on the world market, we believe that the market will be extraordinarily dynamic and productive. We intend to license multiple companies for production and competition for various markets, with no single company being given total monopoly worldwide.

7.2 Aharonov-Bohm (Geometric Phase) Effect

The Aharonov-Bohm (AB) {473} effect, or geometric phase (GP) {477, 480} effect, is now well known {467} in quantum mechanics and quantum electrodynamics, but does not exist in classical electrodynamics. The effect proves the reality of the potentials and their primacy over the fields. Further, it shows that electron effects can be generated by the magnetic vector potential A even in the absence of the magnetic field B.

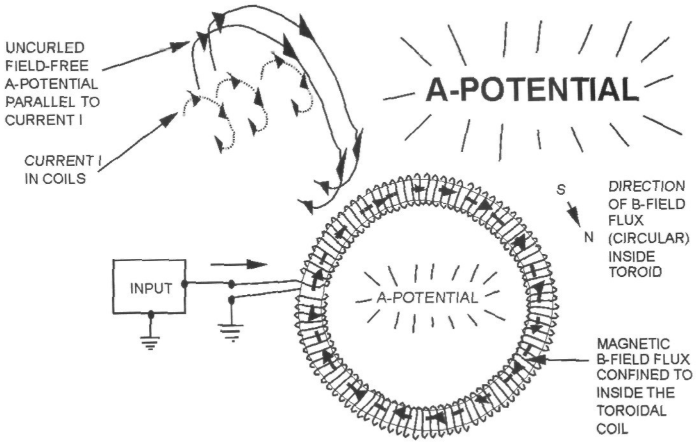
UNCURLED FIELD-FREE A-POTENTIAL PARALLEL TO CURRENT I
CURRENT I IN COILS
A-POTENTIAL
S
N
DIRECTION OF B-FIELD FLUX (CIRCULAR) INSIDE TOROID
INPUT
A-POTENTIAL
MAGNETIC B-FIELD FLUX CONFINED TO INSIDE THE TOROIDAL COIL

Figure 7-4 Aharonov Bohm effect for a tightly wound toroidal coil.

According to Feynman {468}, it required 25 years for quantum physicists to clearly face the issue eventually pointed out in 1959 by Aharonov and Bohm of the primacy and separate action of the force-field-free potential, in regions where no force fields were present (Figure 7-4) {469}. After the effect was experimentally demonstrated by Chambers {474} in 1960, it then required another 25 years before physicists would accept it. Even today, another 16 years after full acceptance in 1986, to our knowledge the Aharonov-Bohm effect has not previously been utilized in any practical electrical power system {470}, much less one that has a COP>1.0. As Aleksiejunas[198] states (see his quotation at the beginning of this chapter), there have not previously been any widely recognized practical applications of the geometric phase. Now there is a practical application of major worldwide importance, since the operation of the MEG depends upon the geometric phase (Aharonov-Bohm) effect to produce real electrical power from the active vacuum itself.

We also believe that the curl-free potential may not have been adequately investigated, particularly along the lines of its utilization in the MEG.

7.3 Abbreviated History of the Geometric Phase

The earliest work with a state function acquiring a non-zero phase factor after a quantum system undergoes a cyclic evolution was published in 1956 by Indian scientist Pancharatnam {471}. Pancharatnam noticed phase shifts of cyclic evolutions in optical phenomena. This means that, if the system leaves its original state and after some time returns to it, the result of the system's evolution will be recorded in the phase of its wavefunction. In addition, this phase factor can be measured by interfering the system's initial and final states.[198] Sadly, Pancharatnam's anticipation of the geometric phase factor did not receive the attention it so justly warranted, and his paper languished almost unnoticed for nearly four decades, when it was finally rediscovered. This was an excruciating scientific tragedy to Pancharatnam, comparable to that which befell Waterston {472}.

The effect of the field-free potential and the geometric phase issue were pointed out strongly by Aharonov and Bohm {473} in 1959 in a leading U.S. physics journal, causing much consternation in physics. Before that paper, most physicists still believed that all electromagnetic forces and effects were induced only by the force fields,[199] and not by the potentials.

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[199] Indeed, the force fields do not even exist in mass-free space, but only in matter. Force is defined as $F \equiv \partial/\partial t\,(mv)$ so that mass is a *component* of force. Feynman states: *"...in dealing with force the tacit assumption is always made that the force is equal to zero unless some physical body is present... One of the most important characteristics of force is that it has a material origin... " "...the existence of the positive charge, in some sense, distorts, or creates a "condition" in space, so that when we put the negative charge in, it feels a force. This potentiality for producing a*

In the prevailing belief, when the fields were zero there were no EM effects. Indeed, the potentials were largely regarded as mathematical conveniences.

Another point of consternation was that the A-potential is not uniquely determined, but is determined only up to a particular gauge transformation. So there can be two (or even more) magnetic vector potentials A and A' corresponding to a specific magnetic field. Aharonov and Bohm raised a disturbing question: How can two different "causal" A potentials produce the same effect? We will rigorously answer this question shortly.

While the experiments suggested were difficult, they were performed shortly after the publication of the Aharonov-Bohm paper. The very next year, in 1960, Chambers {474} experimentally demonstrated the Aharonov-Bohm effect, though not with complete decisiveness. A 1983 paper by Tonomura *et al.* {475} was significant, and a 1986 publication of further work of Tonomura *et al.* was decisive {476}.

In 1984, Berry generalized the Aharonov-Bohm effect into the geometric phase {477}. In 1985 the Tonomura effort plus experimental work by Webb *et al.* {478} settled the matter, as strongly stated by Schwarzschild the next year {479}. In 1987, Aharonov and Anandan {480} further generalized Berry's geometrical phase, freeing it from its adiabatic

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force is called an electric field. " So Feynman was fully aware that not the force field but only the potential (i.e., the potentiality) for producing the force field exists in mass-free space. The electrodynamicists continue to be confused on that point. E.g., on p. 28 of his *Classical Electrodynamics,* 2nd edition, Wylie, 1975 Jackson states: *"...the thing that eventually gets measured is a force... ",* confirming that force is an observable and thus a *d/dt* operation imposed upon spacetime LLLT to give a purely spatial entity LLL. On p. 249, Jackson also states that *"Most classical electrodynamicists continue to adhere to the notion that the EM force field exists as such in the vacuum, but do admit that physically measurable quantities such as force somehow involve the product of charge and field."* The two parts of the conventional assumption, as stated by Jackson, contradict each other. We point out that Jackson's book has been a standard of excellence for years, and no EM library is complete without it. It merely shows the extraordinary difficulty of rooting out the exasperating and mind-numbing confusion in physics between the observed effect and the unobserved cause. Force is an effect, after interaction (observation or measurement), hence cannot be the cause (which exists prior to interaction or measurement). Else, there is no difference between cause and effect, which destroys causality itself. This confusion is still there in even the hoary old classical mechanics, now some centuries old. By that standard, electrodynamicists have a long time remaining before they will have propagated this non sequitur" as long as the mechanical physicists have.

restriction and generalizing the geometry. Much discussion of the AB effect and Berry's geometric phase occurred {481a-481c}, but the scientific consensus was in: *The Aharonov-Bohm effect is real and the geometric phase is a widespread fact of nature.*

In 1985, Olariu and Popescu {482} published a very good overview and discussion of the AB effect up to that time, with hundreds of references.

Thousands of papers on the AB effect, the Berry phase, and the geometric phase have since appeared in the literature, and continue to appear at a rather steady and prolific rate. A few are listed for a sampling {483a-483k, 484a-484i}. The original Aharonov-Bohm effect has now expanded and spread widely through physics and into a myriad other effects and areas, such as the scalar AB effect, the Aharonov-Casher effect, magnetic vector potential vortices, quantum tunneling, chemical reactions, chaotic oscillation, and others. These related extensions are far beyond our interest here. We are, however, interested in what we hypothesize may be a new aspect of the perturbed curl-free magnetic vector potential A. We shall address that aspect briefly.

7.4 A Possible New Aspect of the Curl-Free Magnetic Vector Potential

We propose what may possibly be a unique new aspect of the curl-free A-potential — and thus of the Aharonov-Bohm effect — that has been uncovered in our MEG experiments. We caution, however, that this is a tentative interpretation and remains to be further validated.

First we state that the equation, $\mathbf{B} = \nabla\times\mathbf{A}$, usually accepted as the "definition" of the magnetic vector potential A, is not even a definition, because no equation is a definition.[200] If we rewrite the equation as the identity $\mathbf{B} \equiv \nabla\times\mathbf{A}$, then it is a proper definition — though not of the A-potential, but of the B-field itself, *given* that the A-potential exists and is primary. It also states that the B-field is simply a magnetic vector potential having swirl; i.e., the notion of the B-field captures that swirl aspect of a swirling A-potential. Hence the statement that B = zero implies only that **the** A-potential remaining is swirl-free and hence a linear EM energy

[200] No equation is a definition, *a priori.* It merely states the relationship of the total magnitude of the entities on the left to the total magnitude of the entities on the right. It does not define any entity on either the left or the right. One of the gross non sqeiturs in physics texts is to continue to present equations as "definitions".

current flow. Note that the B = 0 condition does not specify the magnitude of the remaining A-potential, but _only_ specifies that it has no curl. This is a rigorous answer to the original question posed by Aharonov and Bohm of how two different A-potentials can have the same magnetic field B (the same swirl). It is no more mysterious than two different rivers having a whirlpool of exactly the same swirl magnitude.

At least to first order, it appears we have arrived at a "semi-definition" of the A-potential along these lines:

> *The magnetic vector potential A is an EM energy current in 4-space, which can be swirling or linear, or can have two components where one is swirling and the other is linear. The swirling component of the A-potential is also known as the B-field, and the linear component is known simply as the "curl-free A-potential". The A-potential exhibits a remarkable property: If its swirl component is localized and confined, the remaining space where the swirling A without localization would have been is filled by a remaining unswirling linear A-potential energy current. In short, by swirl-localization the swirling A-potential can be freely 'regauged' into two separated entities, with the sum of their energy being greater than the apparent energy of the previous swirling A-potential. Hence swirl-localization is a method of asymmetrical self-regauging of the A-potential itself with the excess energy coming directly from the active vacuum.*

If we take the view that any curled A is identically a B-field, then the "natural" A is not curled, because it requires a curl operation applied to it to produce a "curled A" or B-field. Therefore the "natural" magnetic vector potential A is simply a magnetic energy current in space, since it is a vector and has direction {458}. That is a *longitudinal EM energy flow process?*[201] We shall be very interested in the uncurled A-potential; i.e., in that linear energy current in space that is uncovered and freely produced when the B-field is localized. Indeed, we shall perturb it to make a large E-field, which we intercept and use to furnish emf to the secondary circuit and power loads.

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[201] Interestingly, around a toroidal localization zone, the uncurled A-potential does curve, but is only linearly following the curving current and the moving E-field from the moving charges in the current. In the MEG, the uncurled A-potential is even more complex, since we use each half of the toroid-like localization zone differently, with the B-flux going one direction (say, counterclockwise) in the left branch and the B-flux going in the other direction (say, clockwise) in the right branch, and with a crossover point in the middle.

Given a localized B-field so that we have an uncurled A-potential outside the localization region: If we now increase the magnitude of the A, that produces an increased linear energy flow rate outside the localization zone, in addition to increasing the B-field in the localization zone. If we decrease the magnitude of the A, that produces a decreased nonlocalized energy flow rate and a decreased localized B-field. In our view it follows that, when we oscillate the magnitude of the A-potential by any means whatsoever, we oscillate the nonlocalized linear EM energy current flow rate as well as the localized B-field. In fact, that creates a normal oscillation of the localized B-field, and also creates a nonlocalized *longitudinal wave* of electric field E by the equation $\mathbf{E} = -\partial\mathbf{A}/\partial t$, if the conditions localizing the curl operator — and hence localizing and holding separate the concomitant B-field produced by a changing E-field — continue in effect.

We have produced a mechanism for generating a nonlocalized longitudinal E-field wave without a nonlocalized B-field component being allowed to act outside a confined locality. We stress that a B-field component is produced, but remains localized in the special core material (that is one of the conditions required in the MEG).

We have also produced a mechanism for generating a nonlocalized longitudinal E-field wave with another very novel feature: the magnitude of the E-field and thus the magnitude of its energy density (its intensity) does not depend on the *magnitude of the input energy* used to perturb the A-potential, but only depends on how sharply we perturb it. Thus we have produced a mechanism for energy intensity amplification and magnification, freely. This is possible because the system is an open system far from equilibrium with the active vacuum, and specifically with the curl-free A-potential as an energy current at large in the local vacuum where it can be intercepted, collected, and used to power loads. The energy intercepted from the uncurled A-potential by the output section(s), is *additional* energy in excess of what is intercepted from the E-fields generated in core material B-field magnetic flux changes.

However, see our discussions of the giant negentropy process, earlier in this book. Any longitudinal EM "wave in 3-space" is accompanied by a longitudinal EM wave on the fourth Minkowski axis, in the time domain. EM energy does not observably propagate continuously in 3-space, since observed propagation is a series of frozen iterative observation processes a priori). The "energy flow" actually consists of a propagation in 4-space of a *continual local circulation* of EM energy from the time domain (time-polarized EM energy) to each interacting point dipole in 3-space via the negative charge of the point dipole, thence to the positive charge of that point dipole, thence back to the time domain. In a time-reversed zone, the circulation is in the opposite manner. So what spreads as the "longitudinal EM energy current in 3-space" is actually the spreading point polarization of the vacuum and this giant negentropy 4-circulation involved in every point dipole of that polarization.

We believe this previously unsuspected process is involved in the Aharonov-Bohm effect (which is a sort of polarization in the time domain), other aspects of the geometric phase, fundamental polarization of the vacuum itself, and the very notion of "propagation of EM energy through space". At any rate, the hypothesis does fit the phenomena observed to happen in the MEG, so it warrants additional careful experimental investigation as well as attention from leading theorists.

Further, the MEG is practical and produces practical electrical power, but with a *purely electrical reaction* in the output secondary coils of the transformer section.[202] Hence there is finally a very practical use for the geometric phase: It extracts additional *nonlocalized* EM energy from the vacuum (and local curved spacetime) in addition to extracting and retaining *localized* energy. Both the extra "free" nonlocalized EM energy and the localized EM energy from the vacuum can be intercepted, collected, and utilized to power practical fuel-free MEG-type power systems.

We point out that the rate of changes of all E-fields produced in the secondary and primary coils also produce B-fields proportional to the time rate of change of those E-fields in each case. These secondary B-fields are retained in the core rather than reaching out into surrounding space. Their rate of change then further produces E-fields, which pass out of the core and interact with the coils. Hence there are very novel "multiple feedforward and feedback" regenerative loops in the MEG's highly nonlinear operation, as well as chaotic oscillations.

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[202] This follows from the localization of all B-fields in the core material — including the B-field of the permanent magnet, those B-fields produced by dE/dt operations, and those B-fields produced inside the secondary coils, etc. All E-fields produced, however, including in the changing flux of the core and in the $d\mathbf{A}/dt$ operations of the external uncurled A-potential — are free from that localization restriction and can pass out of the core and interact with the output coils of the transformer section. In short, we have produced the world's first purely electric "induction-free" magnetic transformer device. The voltage and current, measured directly across the secondary coil's ends, is in phase within 2 degrees and even that 2 degrees can be eliminated. We expect the theorists to have a field day in modeling these new phenomena.

7.5 Use of the Aharonov-Bohm Effect in the MEG

From the standpoint of electrical power systems, our own interest in the AB effect focused upon one important characteristic: the clear separation (and localization) of the B-field (the swirl component of the A-potential), leaving the remaining "natural" uncurled field-free A-potential as a free linear flow of energy current in the vacuum. This operation is iterative, and is produced by the core for every B-field produced in the transformer section. So a localized dynamic B-field makes nonlocalized dynamic E-fields, which themselves make further localized dynamic B-fields, which then further make nonlocalized dynamic E-fields, and so on. The result is a very extensive chain of feedforward and feedback field energy loops.

7.5.1 Separation of the Swirled and Linear A-Potentials

The AB effect has long been known in toroidal coils and in long solenoids. In a theoretically perfect toroid, for example, the AB effect separates and localizes the entire B-field inside the toroid, while the *curl-free* magnetic vector potential A appears in surrounding space outside the toroid. By our new interpretation and hypothesis, based on AIAS theoretical work published in the literature, this curl-free A-potential represents a nonlocalized longitudinal EM energy current in space.[203,204] Further, the curl-free A-potential is an extra flow of EM energy that can be intercepted, collected, and used while also still using the entire "normal" B-field energy localized in the core. The neat thing is that the E-field made from the

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[203] This is addressed in M. W. Evans, T. E. Bearden, and A. Labounsky, "The Most General Form of the Vector Potential in Electrodynamics," *Found. Phys. Lett.*, 15(3), June 2002, p. 245-261. See also M. W. Evans et al., "The Aharonov-Bohm Effect as the Basis of Electromagnetic Energy Inherent in the Vacuum," *Found. Phys. Lett*, (in review).

[204] See also B. Lehnert and J. Scheffel, "On the Minimum Elementary Charge of an Extended Electromagnetic Theory," *Physica Scripta*, vol. 65, 2002, p. 200. In extended EM theory, the elementary charge may no longer be considered as a fundamental constant of nature, but is expressed in terms of the Planck constant and the velocity of light.

A-potential, and thus providing the actual intercepted and collected EM energy, can be made as large as desired, merely by manipulating the rise time and decay time of the pulses used to perturb the A-potential external to the core. Further, the same perturbation also perturbs the B-field flux in the core, giving rise to nonlocalized E-fields whose magnitude again depends upon the rise time and decay time of the perturbing pulses. Hence the dA/dt and the dB/dt become energy amplification causes, where all the excess F-field energy is furnished freely from the vacuum via a special kind of asymmetrical regauging and gauge freedom. In that sense, the MEG produces and applies a hitherto unrecognized form of direct field energy amplification by asymmetrical regauging.

We noted that this mechanism represents the formation of a locally curved spacetime[205] and engineering of the magnitude of the curvature itself. By freely increasing the local spacetime curvature, the appearance of additional EM energy density in the region follows *a priori*. That is, one still has all the B-field energy produced by the permanent magnet, but it is just confined to the space inside the core. All the energy one "pays for" or inputs with current and voltage to the input coil, in the normal sense, is the energy to *perturb* the localized B-field and the curl-free A-potential. However, even before perturbation to evoke energy amplification, there is already additional energy current that has appeared outside the core, where the magnetic field B would have normally extended. All the A-potential energy[206] is "extra" energy in addition to the normal B-field energy that would otherwise have appeared out there but is now confined inside the core.

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[205] More accurately there is one specific curvature of spacetime in the core of the MEG, representing the confined magnetic field B (the localized swirling A-potential), and there is another different curvature of spacetime outside the localization zone, filled with the nonlocalized curl-free (non-swirling) A-potential as a nonlocalized linear energy flow in space. Further, in the MEG we freely change and increase the magnitude of those spacetime curvatures, by the *rate of change* of the input energy rather than by its *magnitude*, and hence we easily increase the magnitude of the energy density of local space both inside and outside the core. That is the fundamental principle of the MEG"s energy amplification (free regauging).

[206] Some scientists even deny that the curl-free magnetic vector potential has any energy! We answer that it produces energetic effects upon charged particles, hence must either contain energy itself or direct and gate the interaction of some local vacuum energy with those charges. In the MEG, the uncurled A-potential is oscillated, which does not appear to yield a *transverse* EM E-field wave at all. Instead, it appears to yield a *longitudinal* E-field wave with an associated scalar KM wave in the time domain. We also explained what appears to happen to the concomitant B-field wave produced by any changing E-field in the secondary

Further, the uncurled A-potential outside the core reduces its magnitude only inversely as the radial distance, whereas the normal B-field that would otherwise be there in the absence of localization would have reduced its magnitude inversely as the square of the radial distance. This far less rapid fall-off of the magnitude of the nonlocalized curl-free A-potential than the former nonlocalized magnetic field B can result in a remarkable increase in communications range — when a normal EM field antenna with oscillating EM field transmissions is compared to a curl-free A-potential antenna radiating the same power but as curl-free A-potential oscillating transmissions. Golden[207] has applied that effect for long-range communications.

With the application *of the free* Aharonov-Bohm effect produced by the core material and permanent magnet combination, rigorously there has appeared much more available EM energy from the local vacuum than the energy one inputs to the device as one's input energy "payment". Again, this is because the system is an open system far from equilibrium with the active vacuum processes such as the appearance of the uncurled A-potential and the iterative appearance of powerful extra B-fields and E-fields. The rise time and decay time of the input perturbation pulses produces an energy amplification effect both in the core and in space outside the core. When one utilizes this extra uncurled A-potential energy, as well as the now-confined B-field energy, as well as the extra B-fields and E-fields appearing from the iterative processes, then one can extract and use more energy than one himself "paid for" or input to perform the perturbation. Indeed, one can easily extract and use more energy from the curl-free A-potential alone, than one has input. By simply controlling the rise time and decay time of the input pulses, the magnitudes of the resulting E-fields formed in the uncurled A-potential (and in the perturbed trapped B-field perturbations inside the core) can be controlled at will.

(output) coils of the transformer section, etc. The core material withdraws and holds localized, all such magnetic fields formed in the internal MEG core processes.

[207] In the late 1970s Frank Golden demonstrated such an uncurled A-potential a**ntenna** which attained a range of 20 miles for a tiny CB radio, compared to a range of only 1 mile for the same CB radio with a normal EM field antenna. The energy density of the potential drops off inversely as the distance, while the energy density of the field drops off inversely as the *square* of the distance.

We also point out that all these amplified E-fields produced by multiple actions have both a conventional Poynting energy flow component and an unaccounted, much larger Heaviside energy flow component. Thus the total energy amplification factor can be very large (several orders of magnitude). With efficient interception and collection, in the future we expect to be able to produce at least 100 kilowatts of power out of the same size core and buildup now producing 80 watts or less in a highly nonoptimized set of laboratory experiment MEGs.

We again call the reader's attention to our previous discussions in this book, showing that all EM energy in EM circuits comes from the vacuum anyway (particle physics view) or from the time-axis (relativistic view). This has previously been hidden by the failure of classical electrodynamics to solve the source charge problem, which we also solved in this book after our paper {12} in 2000. Circuit theorists avoided it by indirectly assuming the source charges freely created from nothing all the EM energy in their fields and potentials. The use of the assumed fields and potentials and their Poynting energy was calculated, but never was the source of those fields, potentials, and their energy presented or accounted.

7.5.2 Using the Uncurled A-potential as a Linear Energy Current

A very simple equation allows utilizing the extra nonlocalized A-potential energy, even though it has no curl and therefore no magnetic B-field. That is $\partial \mathbf{A}/\partial t = -\mathbf{E}$. This equation means that, if one perturbs that large field-free A-potential outside the toroid, it produces an E-field, which we have argued must now be a longitudinal EM wave due to the perturbations *ifthe B-confining operation is still imposed.* By oscillating the A-potential perturbations, one produces an oscillating E-field that is also an oscillating longitudinal electric E-field wave without an accompanying B-field wave.

The oscillating B-fields in the core also produce E-fields proportional to $\partial \mathbf{B}/\partial t = -\mathbf{E}$. These extra E-fields are in phase with the E-fields produced by the perturbed external A-potentials, considering the wavelength of the frequencies at which the MEG is operating (30 to 80 kHz nominally).

Interestingly, the time-oscillating rate of change of the E-field in this longitudinal E-field wave does produce a magnetic B-field, but it is confined to only the core material and not in the nonlocalized external spatial region *because ofthe localization capability ofthe core material.* The core simply changes its permeability and holds the additional B-fields and their flux in there, thus forming additional uncurled A-potential outside the core. The E-fields produced by variations of the core B-field flux is not confined, but freely passes out of the core material

If that B-field (curled A) is sharply localized by an ongoing localization capability, the longitudinal E-wave has its produced magnetic B-wave component stripped from it and localized. In that case, the process produces a purely longitudinal E-field wave outside the localization region — with the possible exception that a longitudinal B(3) field wave component pioneered by Evans {485} *may be produced as well. That is left as an open question presently unresolved in our MEG experiments. We tentatively believe that the B(3) field wave component is in fact produced, but also forcibly localized in the core along with the magnetic field B. If so, its perturbations will also contribute to producing extra E-fields.*

See Figure 7-5. In the MEG, the localization is accomplished as a unique function performed freely by the special nanocrystalline layered core material. So contrary to the case of the solenoid or toroid, one does not to have to "pay" any EM energy to the localizing component to obtain the localization function itself.

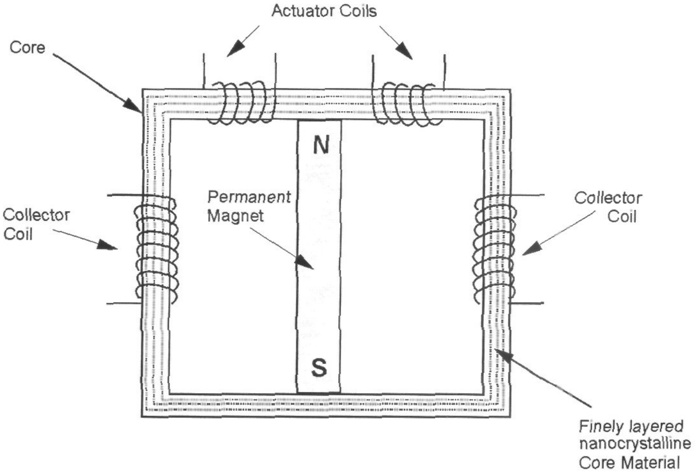

Figure 7-5 Diagrammatic drawing of the MEG.

Further, if one deliberately uses a nearly rectangular perturbing pulse that has very sharp rise time and very sharp decay time, the nonlocalized E-fields, resulting localized secondary B-fields, and resulting nonlocalized secondary E-fields produced can be made very large, with rapid rates of change also. In other words, the magnitudes of the nonlocalized E-fields and localized B-fields produced can be adjusted at will, including in their higher orders. The magnitudes of these evoked fields do not depend on the *magnitude* of the input perturbation energy, but on its *rate of change*. This is very important, because it means the MEG permissibly achieves energy magnitude increase in its nonlocalized output E-field waves by simple instantaneous power deliberately prepared in its low-energy input perturbation waves.[208] In short, the motionless electromagnetic generator uses perturbation of the Aharonov Bohm effect as an energy amplifying mechanism.

This also affects all the iterative processes, hence all the other E-field waves produced outside the core material.

With the localization process remaining and ongoing (simply because the core material remains), the B-field continues to be stripped away, leaving the perturbed A-potential to produce a longitudinal E-field wave (ignoring the possible presence of a B(3) field also). In the MEG transformer section, the output (secondary) coils are wound around the nanocrystalline core that performs a B-field and B-flux localization within the core itself. Hence a purely net E-field interaction occurs with the electrons in the secondary coils, and the output of these coils is an output having the output voltage in phase with the output current.[209] The AC current in the secondary coils does in fact still produce magnetic field B-flux and B-waves in them, but the core material draws the extra B-flux and B-waves inside and localizes them within the core. The fact that localization is *not quite* 100% at the imperfect junctions of the ends of the permanent magnet and the core material, gives a tiny bit of leakage of

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[208] It also means that the MEG operation is highly nonlinear, with very extensive feedforward and feedback field transduction loops. For the MEG, its scale-up, mathematical modeling, and engineering simulation are not simple things at all, but highly complex. In addition, control and stability are more complex, since one must utilize nonlinear oscillation theory (including chaotic oscillation theory) as well as nonlinear oscillation control theory. In addition, a higher group symmetry electrodynamics is required for the modeling and simulation. Consequently, because of these considerations and the geometric phase aspects, as well as the additional close-looping considerations for self-powering operation, an expensive physics lab must be established as well as the usual electrodynamics laboratory aspects. The result is an expensive final research and development program required to complete the MEG to final production prototype units, ready to start rolling off the assembly lines. A minimum capitalization of $20 million is required.

[209] In the actual lab experiment MEG, there is a slightly imperfect junction between the ends of the permanent magnet and the core material. This results in a very tiny bit of leakage of nonlocal B-field —just enough to produce a 2° phase shift between the voltage and current in the secondary coil's output. With a better junction, this phase shift can be further reduced or eliminated.

B-field, so a tiny B-field component does escape, interact, and generate the *2%* or so variation from the complete in-phase condition of the secondary output voltage and current. Again, that can be further reduced or eliminated by improving the junction.

So essentially there is a purely electric field interaction with the electrons in the output coil current of the MEG, hence the result that the output current is in phase with the output voltage — something previously unheard of in a simple secondary coil of a transformer. This is a major practical macroscopic application of the Aharonov-Bohm effect and therefore of the geometric phase.

7.6 Collection of Field Energy in the MEG

To collect and use EM energy in a power generating system, first the EM energy must be evoked from local spacetime (the local vacuum) by the broken symmetry of the source charges and dipoles in the circuit {12}. In the open system far from equilibrium in the resulting EM energy flow, the operator must usually pay for (i) the energy required to *initially* produce the requisite source dipolarity and (ii) the energy required to perform necessary switching and control functions, unless close-looping is incorporated. Using the permanent magnet as a source dipole in the MEG, and using the special nanocrystalline core material to generate the Aharonov-Bohm effect to furnish excess energy from the vacuum, the MEG operator does not have to *furnish* the evoked and available field energy at all. So the first "payment" is totally avoided. Further, the magnetic dipole is not destroyed by passing magnetic flux back through its back mmf. No additional input energy is required to continually restore the source dipole, since it is never destroyed.

In an open-loop MEG system, the operator only has to pay for the second part: the switching and control function energy. In later closed-loop MEG systems, a method of controlled and positive feedback has been developed so that, once the system is up and operating and powering its load, the necessary switching and control function energy can be siphoned off the output and fed into the input in governed fashion, first being transduced into positive energy input form. Once the process is properly synchronized and governing properly, the operator can throw a switch for feedback and transduction, and the unit will be "self-powering", or "fueled entirely by **the** local vacuum energy", so to speak.

Let us consider the open-loop MEG system we have presently attained in a series of embodiments.

The total emf force F collected from a given nonzero electric field E, e.g., depends only upon the amount of available intercepting charge, by the simple equation $F = Eq$. Similarly, from any potential ϕ the amount of collected EM potential energy W depends on the amount of intercepting charge q, by $W = \phi q$. Hence in the MEG a legitimate COP>1.0 system is possible if (i) more energy is collected and used from the evoked EM energy flow than is input to gate that energy flow's appearance from the active environment, and (ii) none — or appreciably less than half— of the energy collected in the circuit is used to destroy the source dipolarity.

By invoking the AB effect in a local region, the vacuum contributes additional energy density in the space outside that region, and that energy density can be sharply perturbed so that substantial field energy amplification appears by asymmetrical regauging. The excess energy to provide COP>1.0 performance is freely furnished from the active vacuum (and from the local curved spacetime) {38b, 38c}. The excess energy can be intercepted in the perturbed curl-free A-potential region outside the transformer section, collected, and used to power additional loads, in addition to being intercepted in the transformer secondary region to power the secondary circuit and main load.

Similar contributions of extra energy and extra energy collection outside the core localization region occur for the iterative processes also.

At the same time, the B-field inside the core material is perturbed, but the core material self-varies its permeability to adjust to the additional magnitude of the perturbed B-field. The production of any B-field oscillation inside the core does produce an electric field E, which is not localized in the core. Consequently, energy from the perturbed core-localized B-fields is transduced into nonlocal E-field energy, passing out of the core and interacting with the output secondary coils of the transformer section in purely electric field fashion.

Because of the purely electrical interaction, the voltage and current output from the secondary coils of the transformer section are in phase, and not 90° out of phase as in a transformer. The actual 2° experimental phase shift of current with respect to voltage is a measure of the slight inefficiency of the junctions of the permanent magnet ends with the B-localizing core material.

In the MEG, we are using a novel new kind of component: an *external-induction-free cored inductor*, which might alternately be called *a purely electrical inductor — at least externally*. In short, the inductive action remains localized in the core, while the electrical action escapes the core and interacts with the coil to drive the current electrically. So here is another excellent, novel, and practical use of the Aharonov-Bohm effect and the geometric phase: Eliminate the inductive reaction of a coil's output, and transduce it into a purely electrical action. At this writing, we are preparing to file a separate patent application upon this latest application and process, and it will already be filed by the time this book is published.

We accent that any field or potential, once made, already involves an ongoing giant negentropy and overunity process {486}, as we previously discussed in this book. Simply calculate how much energy it requires to separate and form the source charge — which can be as simple as charging a tiny little sphere — and recognize that the field formed by that charge is an altered energy density of surrounding space and a polarization of the vacuum. Once the charge is formed, the corresponding alteration and sustaining of spatial energy density change and vacuum polarization freely moves radially outward at the speed of light from the charge, from the very moment it is produced. So a steady flow of observable EM energy is speeding out in all directions from the source charge. An enormous change in the energy density over that external spatial region surrounding the source charge occurs and spreads steadily, moving radially outward in all directions at speed c.

Hence a magnificent and rapidly extending curvature of spacetime — which energetically acts upon any available charged matter therein, by conventional general relativity — is formed and spreads outward in all directions from any source charge, once formed. How much effect on charged matter is exhibited by this freely created and spreading spatial EM energy density change, depends only on the amount of interacting/receiving charged matter in that surrounding space that is available to interact with the energy of the new fields and new potentials.

If **the** source charge or source dipolarity (in this case, primarily the magnetic dipole of the permanent magnet) is left alone and not destroyed, an unlimited amount of energy can be intercepted and discharged from a local load, again and again, from the charge's surrounding field or potential because the energy in the field and potential is steadily replenished from the active vacuum. The only problem is discharge the collected energy in the load(s) so as to leave the original source charges (the magnetic poles) inviolate, and not to destroy them. The MEG accomplishes this function.

This also rigorously follows from the gauge freedom axiom of quantum field theory. Consider this: the ability to freely change the potential — assumed by all electrodynamicists — can be applied directly to the load to potentialized it without any current moving, if there exists a somewhat lengthy electron gas relaxation time in that part of the load that is potentialized. After potentialization, one can switch the source of free potential away, and complete the load circuit separately, so that the excess potential energy is dissipated from the load, powering it. In that case there is no dissipation of the primary source dipole. *Gauge freedom already assumes one can produce EM energy from the local vacuum freely, anywhere and at any time.* In real life, one has to pay a little for the switching, but not for the energy input itself.

Why the scientific community for decades has fiercely opposed the funded experimental investigation of the implications of gauge freedom is quite inexplicable.

As can be seen from the conservation of energy law alone, in theory energy can be continually intercepted and collected from these free fields and potentials, once the source dipolarity (or source charge) creation has been paid for. Further, by applying gauge freedom to potentialized the load without energy dissipation, with a little adroit switching the collected energy can then be dissipated entirely in a separated external load circuit, so that the free potential energy completely exits that circuit without re-interacting with the source dipole and its back emf or mmf.

We predict that the above application of gauge freedom will eventually power most of the world's electrical systems, when the scientific community gives up its present "ostrich position". Once the engineers can build it, the scientists do not have to agree.

That such is not done in our conventional circuits is purely due to the limited vision of the scientific community and its refusal to fund appropriate research. To date, it has not even recognized what actually powers every electrical circuit, or that a common practice (the closed current loop circuit) has eliminated COP>1.0 and self-powering Maxwellian power systems for more than a century. The entire electrical energy crisis hurtling at the nations of the world is due entirely to the shortsightedness of the scientific community, particularly since 1957.

Once the energy is pouring (transmitted) from the dipole and out of the terminals of the generator to fill space around the external conductors, then a straightforward energy transmission and reception problem exists. The source dipolarity produces the steady emission and flow of energy filling space around the circuit. In the "receiving external circuit" the surface charges and their fields must intercept some of that available EM energy flow and diverge it into the conductors to power the circuit electrons. The intercepted and diverged component entering the circuit is the Poynting component, while the nonintercepted and nondiverged component missing the circuit and usually wasted, is the extra Heaviside component.

Fortunately, every source dipole pours out enormously more EM energy than our feeble conventional circuits intercept and catch to provide the Poynting calculations. So to produce COP>1.0 in the MEG, all we have to do is insure that we have (i) a mechanism easing the interception and collection process, and (ii) sufficient "antennas" containing sufficient conduction electrons (and their fields) to intercept and collect more energy than we pay to make the source dipole and perturb it. Since we pay nothing at all to make the source dipole (which is the permanent magnet), and since the magnetic flux back through the permanent magnet does not destroy the dipole, then all we have to pay for is the perturbation and for switching and control.

The resulting field energy generated outside the core localization region is primarily a function of the rise and decay times for the input perturbation pulses and not the energy of those pulses. From a little input energy with fast little changes, we can easily generate very powerful oscillating E-fields and provide dramatically increased "antenna collection" area with **the** necessary magnitude of intercepting charge. It rigorously follows that COP>1.0 is easily obtainable.[210, 211]

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[210] Again, for the MEG, changing and controlling the rise time and decay time of the input pulses is a method for directly engineering and controlling the general relativistic curvature of the local surrounding spacetime, because it controls the magnitude of the E-field that is created by $\mathbf{E} = -\partial\mathbf{A}/\partial t$ from the curl-free A-potential outside the core. This also directly engineers and controls the magnitude of the polarization of the local active vacuum. That simple fact allows the use of a unified field theory operation, with a net energy interchange between the system and **the** local active vacuum. To understand the MEG, one must think in terms of the *supersystem.*

[211] All EM energy at any point in space must have been "gated" from the time-domain and it must return to the time domain (as, e.g., by the source charge for it). It **requires** quite a shift of one's mind to realize that all 3-space energy (such as "energy at each point in a potential") involves a gating process and a giant negentropic 4-circulation of EM energy ongoing at each point dipole. Much of the extraction of **energy** from the vacuum has been hidden by thinking in terms of "inputting energy" instead of "inputting or arranging energy flow gating" by the source charges and sourcedipoles.

The MEG is an open system far from equilibrium with its active environment (its active local vacuum and its active local curvatures of spacetime). By attending to the interception and collection part of the overunity problem, the MEG can permissibly collect and use more EM energy to power its loads than one oneself has to input to it. In short, one only has to input a little switching and perturbation energy with properly shaped waveforms, to generate very powerful fields and appreciable field energy available for collection and use. With sufficient collection mechanisms in place, the unit easily produces COP>1.0. Then with proper closed-loop principles implemented, the MEG can be self-powering.

7.7 Experimental Path to Development of the MEG

In our experiments with the Radus effect previously discussed in Chapter 6, paragraph 6.4.5, we had already done extensive work with switching magnetic fluxes for less switching energy than can be intercepted from the switched flux. We had also experimented with various cores for transformer and coil variants, including eventually the new layered nanocrystalline cores.

In our experiments, we noticed a remarkable thing. With certain modern nanocrystalline core materials, and using a permanent magnet to provide B-flux, we found that *the core material would extract and hold essentially all the permanent magnet's B-flux inside the core.* Field measurements right against the outside of the poles of the powerful little neodymium-iron-boron magnet itself showed very little B-flux spilling out into space! In short, we had discovered how to make a magnetic system that *nonlocally* propagated only the uncurled magnetic vector potential A, without any operator energy input. We realized we had discovered a marvelous and free way to freely obtain an excellent Aharonov-Bohm effect, similar to the way a nearly perfect toroid would localize the B-field inside the core, with the uncurled A-potential appearing in space surrounding the toroid. The advantage of our approach over the toroid was that we did not have to furnish any current and voltage to obtain the localized B-flux and the non-localized curl-free A-potential energy.

Further, if we perturbed the B-field flux in the core, we consequently perturbed the uncurled A-potential in space surrounding the core. From both sources — the perturbed B-flux in the core and the perturbed

A-potential outside the core — we could produce very large E-fields and concomitant very large voltages capable of driving more "power" through the secondary coils of the transformer section than the power required to perform the switching and perturbation.

We could easily prove this by perturbing the localized B-flux (and the concomitant surrounding uncurled A-potential automatically) with weak energy. We proved that increasing the rate of the rise time and decay time of even a weak input EM energy perturbation could produce quite large E-fields, including 1,000 to 5,000 volts (or even 20,000 volts!) appearing in the secondary coil if desired. We also proved another thing: *the special nanocrystalline core material in some buildups self-adjusted its permeability, continuing to localize the perturbed and alternating B-fields and their fluxes while freeing the resulting E-fields and passing them out of the core.* In short, the permeability of the specially selected core material automatically adjusted with the perturbation of the localized B-flux and nonlocalized A-potential, so that all the oscillating B-flux remained localized in the core. Further, the highly layered nanocrystalline material produced essentially no eddy currents at all, hence no heating, even in the presence of dramatic B-flux oscillation and dramatic E-field intensities in the surrounding uncurled A-potential space and in the output (secondary) coils of the transformer section of the MEG.

The absolute proof that the core changed its permeability was in the lack of a phase lag between voltage and current in the output from the output coils. Here a remarkable thing was observed: the output current was in phase with the output voltage, within about 2°. In short, under certain circumstances the output coils wound around the nanocrystalline core would exhibit essentially a purely E-field interaction, with only minuscule B-field leakage — something deemed impossible in the typical electrodynamics textbook. This meant that the excess E-fields produced by the perturbed A-potential in space outside the core also reacted with the output coil's conduction electrons in a purely electrical manner! This was because the B-fields locally produced in the output coils by the interacting changing E-fields, *were in fact instantly drawn into the core material as they were produced, and were held there so they did not react in magnetic fashion with the electrons in the output current from the secondary coils.*

So this is a dramatic localization of Faraday's law of induction. Consequently, one entire group of embodiments of the MEG uses a purely electrical interaction with the secondary (output) coils of the transformer section.[212] Or more exactly, the core material draws in all the magnetic fields from the reactions of the output coils, leaving only the electrical reaction outside the core — including in the coil conductors, which obviously are wound outside the core material.

On the other hand, the perturbed localized magnetic B-flux inside the core material did produce the normal E-field to be expected, as a function of the time-rate of change of the B-field. Such an E-field is not localized in the core material, but extends outside the core and interacts with the electrons in the output secondary coils of the MEG's transformer section. Again, the magnitude of this E-field is a function of the time-rate of perturbation of the localized B-field flux in the core.

The nanocrystalline core also has excellent high frequency response, with negligible eddy currents. Thus we can "fine tune" the engineering of the rise time and decay time of the input perturbation pulses.

Hence we accomplish several kinds of "gated energy amplification" in the MEG: (i) the amplified magnitude of the external E-field interacting with the external collectors (such as the output secondary coils) due to perturbation of the nonlocalized external uncurled A-potential, (ii) the amplified magnitude of an additional E-field interacting with the external collectors (such as the output secondary coils) due to perturbation of the localized internal B-field flux inside the core material, (iii) a large number of additional derivatives of higher order B-fields and E-fields are formed and utilized, and (iv) adding additional collectors (either coils wound on the core or external "receiving antenna circuits" produces additional power for heavier loads, for a given perturbation input.

We had exhibited a cored output coil with a remarkable adaptation of the AB effect. Essentially the output of the secondary coil was driven by the large electric field component created from the uncurled A-potential perturbations *and* by the large electric field component created from the B-field flux perturbations inside the core. This peculiar transformer-like section operated from the E-field fluxes emerging or produced *outside* the transformer core material, rather than from the magnetic field flux being produced and oscillated *inside* the core material itself.

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[212] Again we accent that the magnetic field reactions do occur, and the B-fields are in fact produced. But the resulting B-fields are also extracted into the core material and localized therein. Even the magnetic B-fields produced in the input and output coils themselves, is so localized and not allowed to interact with the electron currents through the coils to produce the conventional 90° phase lag between voltage and current.

Obviously we had found a remarkable but legitimate COP>1.0 process and embodiment — in fact, a whole set of them. We had also invented a new kind of "transformer" or energy generator-transducer.

From that we progressed to discovering ways to a dual use of both the perturbed B-flux in the core and the E-fields from the perturbed A-potential outside the core. To first order, that turned out to be fairly simple: any changing B-flux inside the core material and thus inside the output (secondary) coils of the transformer section, produces not only B-field which is held and localized, but also the changes of this local "pinned" B-field further produces E-field oscillations which are not pinned in the core. Hence the electric field half of a normal transformer action could and did occur in the secondary coils, but the magnetic field half did not occur *in the coils themselves*. The MEG used and uses a nearly pure E-field interaction in the output coils of its transformer section secondary, where that net interacting E-field comes from a variety of E-field generating mechanisms.

We filed our first patent, and then filed a second patent application soon after. Presently we are preparing to file our third and fourth patent applications on additional phenomenology and mechanisms uncovered in our experiments. As we are writing this section, our first patent has issued {37}.

In the view of the present author, we have uncovered a remarkable new application of the Aharonov-Bohm effect and the geometric phase, one that is practical and eminently useful in novel new electrical power systems.

7.8 Additional MEG Functions

Figure 7-6 diagrammatically shows the core material inside the input coil for either open-loop operation using an external power supply or closed-loop (self-powering) operation using clamped and governed positive feedback. As can be seen, the B-field and B-field flux are confined to the core material (which is in the form of a closed transformer coil path, as shown diagrammatically in Figure 7-5). The external space surrounding **the** core material is filled with the uncurled A-potential, due to the Aharonov-Bohm effect being imposed by the core material. The two leads from the input coil are shown at the bottom of Figure 7-6.

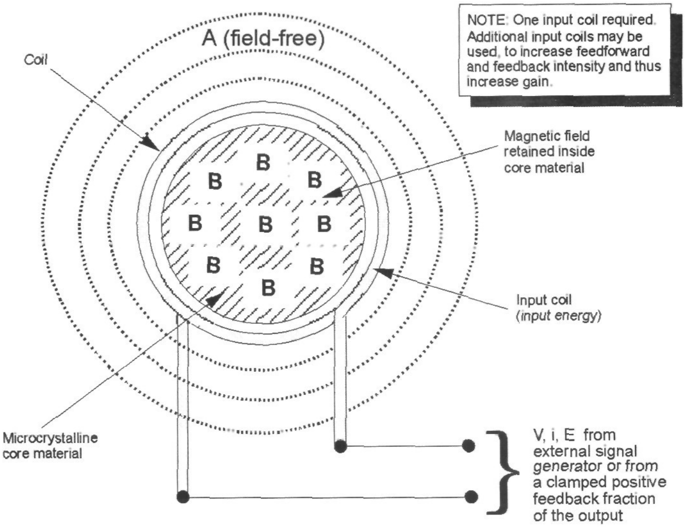
NOTE: One input coil required. Additional input coils may be used, to increase feedforward and feedback intensity and thus increase gain.
A (field-free)
Coil
B
Magnetic field retained inside core material
Input coil (input energy)
Microcrystalline core material
V, i, E from external signal generator or from a clamped positive feedback fraction of the output

Figure 7-6 Input coil for open- or closed-loop operation.

We pulse the input coils with nearly rectangular pulses each having a sharp leading edge and a sharp trailing edge, so that the resulting rapid time-rates of change of the two edges create very large perturbations of the B-flux in the core and of the A-potential outside the core. The large E_2-field resulting from the fast rate of change of the perturbed B-field in the core is not localized, but appears in space outside the core. In addition, an E_3 field created directly in the coil itself also appears in space outside the core. In addition, the sharply perturbed A-potential outside the core creates a third large E_1-field in space outside the core. The net E_t-field in the surrounding outside space is the vector summation of the E-fields produced by these processes, or to first order (neglecting the further differentiations)

$$\mathbf{E}_t = \mathbf{E}_1 + \mathbf{E}_2 + \mathbf{E}_3 \qquad [7\text{-}1]$$

We also may adjust the pulse width to generate a further Lenz law effect, increasing the three component fields E_1, E_2, and E_3 if desired. To do that, the pulse must be narrow enough to suddenly decay while each of the fields E_1, E_2, and E_3 is still rising and not yet reached maximum. As can be appreciated, considerable pulse shaping and timing can be adjusted for optimization of the output voltage, current, and power when interception and collection from E_t is accomplished in the secondary coils. In addition, it can be appreciated that slightly differing materials delay times do occur in the production **of** $\mathbf{E}_1$**,** E_2, and E_3. Hence there is appreciable optimization that can be and is accomplished on a given MEG variant and build-up type.

More complex waveforms of various shapes can be used to further optimize the output. It is also possible to accomplish further optimization and control by adjusting the shapes and timing of the feedback signals in the case of the closed-looped MEG system. For the externally powered open-loop version, additional optimization and control can be achieved by adding additional simultaneous pulses fed into the input coils in various fashions.

In addition, the response of the output coils produces feedback into the core material, into external space, and into the input coils. These in fact provide three more E-field *return* or feedback inputs, so that the total feedback input is

$$\mathbf{E}_f = \mathbf{E}_4 + \mathbf{E}_5 + \mathbf{E}_6 \qquad [7\text{-}2]$$

Without doing the more complex iterations for this feedback and feedforward set of loops, to first order the total input E_I to the input coil may be considered to be

$$\mathbf{E}_I = \mathbf{E}_t + \mathbf{E}_f \qquad [7\text{-}3]$$

Equations [7-1], [7-2], and [7-3] are for simple analogy only; in the real MEG, full nonlinear feedforward and feedback analysis techniques must be utilized because of the iterative operations, and much more sophisticated optimization techniques are appropriate. Also, chaotic oscillations can and do appear, and techniques for control of such oscillations are indicated, particularly along the lines indicated by Fradkov and Pogromsky {487} without use of probability etc. Quoting:

> *"1. There is ... great benefit of using the modern nonlinear and adaptive control theory. ...2. There is no need to distinguish periodic and chaotic behavior. Accurate control is possible without accurate prediction. ...3. There is no need to define chaos in order to control it. ...4. There is no need to use probability in order to control systems with seemingly random behavior. "*

For any given MEG build-up design, one experiments with these optimization and control factors and mechanisms to provide the best performance, and to provide rock-steady performance.

Figure 7-7 shows the output coil for either open-loop operation from an external power supply or closed-loop (self-powering) operation using clamped and governed positive feedback. Here the situation is partially reversed. There are three major inputs to the output coils, and these are (i) the external input from the total outside E-field, (ii) the internal input from the perturbation changes in the confined magnetic flux inside the core through the output coils, and (iii) the ensuing feedforward and feedback from all E-fields.

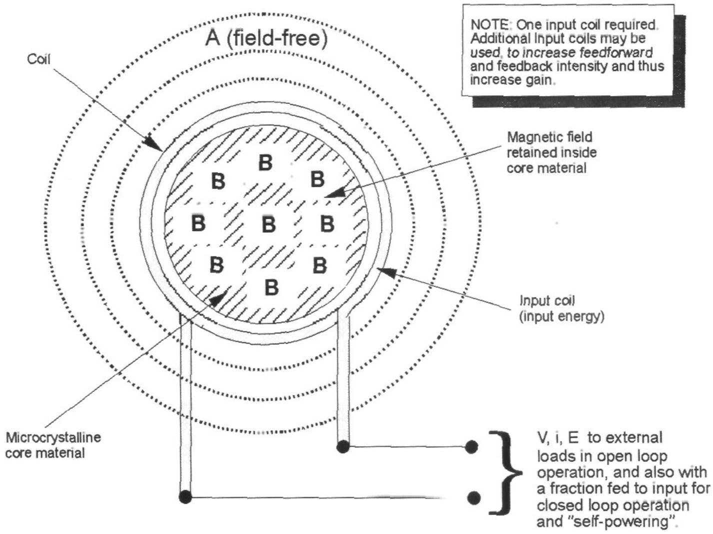
A (field-free)
Coil
B
Magnetic field retained inside core material
Input coil (input energy)
Microcrystalline core material
V, i, E to external loads in open loop operation, and also with a fraction fed to input for closed loop operation and "self-powering".

NOTE: One input coil required. Additional input coils may be used, to increase feedforward and feedback intensity and thus increase gain.

Figure 7-7 Output coil for open- or closed-loop operation.

Again, this is simply an easy way to visualize the situation to first order. In the real case, sophisticated feedforward and feedback analysis is required and utilized. Optimization usually consists of two steps: (1) the simpler, more direct optimization techniques such as adjusting pulse width, pulse rise time and decay time, actual pulse form, etc., and (2) the deeper and more complex optimization arrived at from detailed feedback and feedforward loop analysis as well as nonlinear oscillation and nonlinear control theory analysis.

In the actual optimization analysis, the feedback and feedforward loops are mathematically endless and thus should be optimized for quick decay and stability. On the other hand, the MEG also has the ability to self-oscillate over the entire unit, in which case the feedback and feedforward loops are optimized for stable self-oscillation of the entire unit. The self-oscillating

MEG is permitted since it is an open system far from equilibrium with its active environment.

So if desired, an entirely different kind of optimization can be utilized for self-sustained nonlinear oscillation and closed loop operation. Because of the gain achieved in the large E-fields produced by the perturbed uncurled A-potential in space surrounding the core, there is sufficient excess energy collection available in the output coils to use the available feedback and feedforward loops in the system itself to achieve system self-oscillation. The system can be operated as a self-oscillating open system freely receiving excess EM energy from its active environment — the local active vacuum, local curvatures of spacetime, and local freely furnished uncurled A-potential and resulting nearly free E-fields from the A-potential's perturbations). As we are writing this, our experiments are now in this direction, and we are preparing the material for filing a formal patent application on this additional process. The patents will be filed, of course, by the time this book is published.

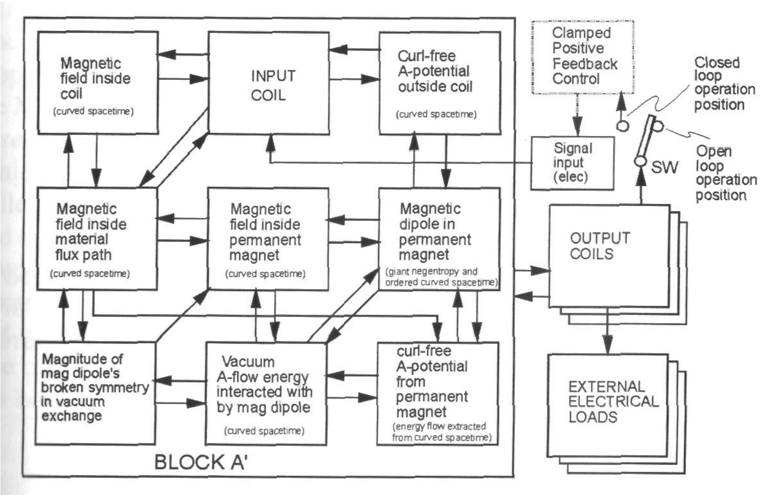
Magnetic field inside coil
(curved spacetime)
INPUT COIL
Curl-free A-potential outside coil
(curved spacetime)
Clamped Positive Feedback Control
Closed loop operation position
Signal input (elec)
SW
Open loop operation position
Magnetic field inside material flux path
(curved spacetime)
Magnetic field inside permanent magnet
(curved spacetime)
Magnetic dipole in permanent magnet
(giant negentropy and ordered curved spacetime)
OUTPUT COILS
Magnitude of mag dipole's broken symmetry in vacuum exchange
Vacuum A-flow energy interacted with by mag dipole
(curved spacetime)
curl-free A-potential from permanent magnet
(energy flow extracted from curved spacetime)
EXTERNAL ELECTRICAL LOADS
BLOCK A'

Figure 7-8 Energy gain process using feedforward and feeback subprocesses

A highly simplified block diagram of energy gain process using feedforward and feedback subprocesses is shown in Figure 7-8. As can be appreciated from this high order diagram, the actual feedforward and feedback loops are extremely complex, and a great deal of complex analysis is required for a self-oscillating, stable, controlled system. We also stress that control measures to insure and hold stable self-oscillation must be included in the overall features implemented in this self-powered, self-oscillation variant of the MEG. Not only must we use chaotic oscillation techniques to achieve the self-oscillation, but also we must use advanced techniques for stable control of such nonlinear oscillations, as indicated by Fradkov and Pogromsky {487}.

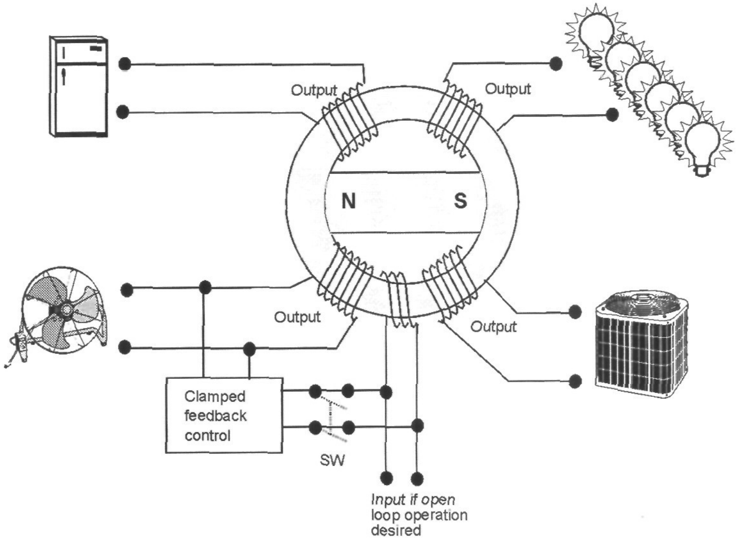
Output
Output
N
S
Output
Output
Clamped feedback control
SW
Input if open loop operation desired

Figure 7-9 Typical MEG embodiment application on site.

In Figure 7-9, we show a typical diagrammatic embodiment envisioned for the MEG in a household, using a large MEG to later be developed. For interim installations, the single large MEG will be replaced with an array of MEGs together with a synchronizer, as shown in Figure 7-10.

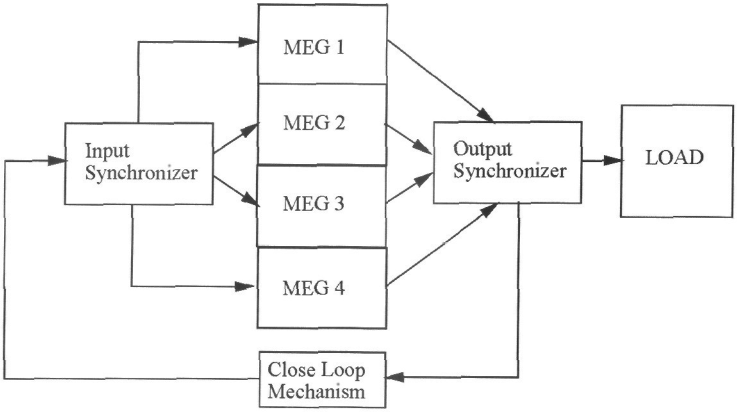

Figure 7-10 MEG self-powering array concept for increased powering applications.

Figure 7-11 shows a MEG unit where additional special collection antennas feeding separate circuits are employed in an "outrigger" fashion. One major advantage of this configuration is that the complexity of close-looping and its control are materially reduced, although the complexity of the MEG build-up and stabilization is increased. Another advantage is the *ease* with which close-looping for self-powering operation can be achieved, as shown in Figure 7-12. In this case, the external antennas are collected to independent output circuits (not shown) in the output section, and each of these independent outrigger outputs is a COP<1.0 circuit if we count the perturbed A-potential energy input as an "operator's" input. Completely normal clamped positive feedback can be used with sensing and governing, to allow self-powering and self-adjusting to varying loads. The outrigger embodiment can be made to almost entirely avoid the Dirac sea hole current problem.

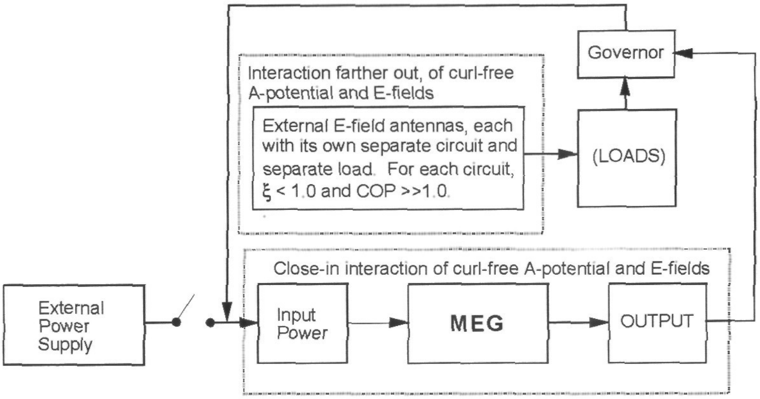
Governor
Interaction farther out, of curl-free A-potential and E-fields
External E-field antennas, each with its own separate circuit and separate load. For each circuit, ξ < 1.0 and COP >>1.0.
(LOADS)
Close-in interaction of curl-free A-potential and E-fields
External Power Supply
Input Power
MEG
OUTPUT

Figure 7-11 MEG unit with outrigger antennas for extra energy collection.

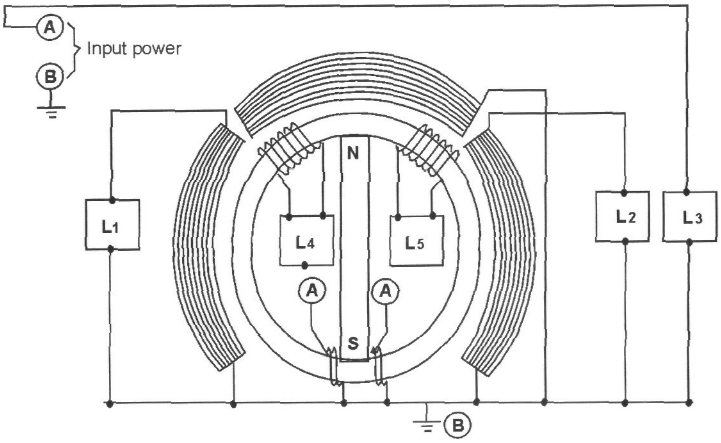
A
Input power
B
N
S
L1
L2
L3
L4
L5
A
A
B

Figure 7-12 Use of outrigger antennas for damped positive feedback method of close-looping.

As can be seen, the MEG has many possible configurations and embodiments, each of which has special advantages and uses. One of the embodiments we discussed is the deliberate use of self-oscillation forced by the feedforward and feedback loops. That is a separate embodiment, and capable of a very high power per pound ratio, but it also requires more sophisticated sensing and control techniques.

7.9 In Conclusion

By the time this book is published, Magnetic Energy Ltd. is hopeful it will have achieved its major funding requirement, and be well along the way to completing the research for full production and marketing of MEG units on the world market. We have arrived at that part of development — the need for substantial funding (several tens of millions of dollars) — where every previous COP>1.0 EM power system has died. We intend to do everything within our power to see that we obtain the funding, finish the complex research task, and get the MEG onto the world market.

For additional information on the MEG and on its preliminary replication by Naudin, the reader is referred to other technical articles {488} and to Jean-Louis Naudin's website.[213] Actual measurements for one of Magnetic Energy Ltd.'s MEG test units is given in reference {488a}. The MEG patent {37} shows the variation of COP for a test MEG with various conditions. Curves for Naudin's measurement of the performance of his replicated MEG unit are given on his website.

The MEG project is a most interesting project, because of the involvement of so much advanced physics and several different physics areas, as well as the prerequisite for higher group symmetry electrodynamics. Once funded, we are confident we succeed in crashing through the barriers and getting working MEG power units — including self-powering MEG units — on the market. We also believe the MEG will represent a substantial contribution to alleviating the coming worldwide energy crisis. Hopefully it will materially hasten the growth and evolution of the present highly centralized — and terribly vulnerable — national energy infrastructure into a highly decentralized — and much less vulnerable — national energy infrastructure. We also believe it will provide a great contribution to helping alleviate global warming, reducing pollution of the biosphere, and reducing the production of hazardous wastes. If so, it will be a continuing contribution, not only to humanity today, but also to generations yet unborn.

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[213] Naudin's website MEG material and information is at http://jnaudin.free.fr/html/meg.htm. Particularly see his Mark III replication, shown powering a light on that webpage.

Chapter 8

Approach to Antigravity

[Large-scale antigravity exists] *"...baryonic, ordinary matter—the stuff of stars and of people—makes up just over 4% of the energy and matter in the universe. ...about 30% of the stuff in the universe is dark [unobserved] matter. The remaining two-thirds, theorists believe, is a mysterious 'dark energy' or 'quintessence'—a large-scale antigravity-like effect that is making the universe expand ever faster.... "* [Charles Seife] {489}.

[On the nature of the vacuum] *"...the (electromagnetic) vacuum is the ground state of the quantized electromagnetic field. ...The Dirac electron vacuum is that state with all negative energy electron states fully occupied."* [Aitchison] {490}

[On forces and how charge exists] *"Vacuum polarization, in general, alters the effective force law. Forces, in quantum field theory, are understood as being due to the exchange of virtual quanta ...In the case of QCD and QFD, ... a crucial new feature is that the force-field quanta themselves carry the 'charge' of the force-field, i.e. it is as if the photon of electromagnetism carried electromagnetic charge."* [Aitchison] {491}

[Possible gravitational circuits] *"There is an implication ... that gravitational excursions might be controllable by gravitational 'circuits', analogous to electronic circuits, which could lead to a controllable form of negative gravity."* [Robert Neill Boyd] {492}.

[Gravitational circuits] *"The supersystem concept utilizes a unified fields approach so that specialized electrical circuits in COP» 1.0 condition generate strong Dirac sea hole currents of negative energy in the immediate local vacuum. Thus a strong negative energy field is formed surrounding the circuit and changing the curvature of local spacetime as an action by the source*

> *circuit. This produces a direct antigravity field around the circuit or physical system, acting upon the mass of the system. The net gravitational interaction by that circuit or physical system is therefore the summation of the local positive gravitational field and the new local negative gravitational field produced by that negative energy field."* [T. E. Bearden, correspondence to a colleague, February 2002.]

> [On the multiplicity of spacetime curvature components] *"The full mathematical expression for the curvature of four-dimensional space-time ...is given by something called the Riemann curvature tensor. This is a somewhat complicated object, needing twenty real numbers at each point in order to specify it. These twenty numbers are referred to as its* components. *The different components refer to the different curvatures in different directions in the space-time."* [Penrose] {493}.

> [Physics studies and prepares imperfect models, not perfect truth] *"All we ever know is our models, but never the reality that may or may not exist behind the models and casts its shadow upon us who are embedded inside it. We imagine and intuit, then point the finger and wait to see which suspect for truth turns and runs. Our models may get closer and closer, but we will never reach direct perception of reality's thing-in-itself"* [Hawking] {494}.

8.1 Introduction

In this chapter, we first present a highly abbreviated background of the theory of gravitation, sufficient for our experimental orientation. Of special interest are unified field theories, which cover general relativity, electrodynamics, and quantum mechanics in one overall master theory. Even more of interest is an engineerable unified field theory, which is presently closest approached by the theory of Mendel Sachs {510}.

We then present a short overview of work that has been done in the fields of lifters and inertial propulsion, listing some of the inventions of interest, the approaches, results achieved, and our comments on each.

Finally, I present my own approach to antigravitation, and give some results of the Sweet device's antigravity test (the test was designed by the present author) that successfully reduced the weight of a device by 90%.

In our view, this experiment fully demonstrated the veracity of our theoretical approach.

8.2 Selected Theories of Gravitation

8.2.1 Newton's Theory and a Negative Mass Extension

The first mechanism for gravity of interest to our purposes was advanced by Newton in his work on mechanics {495}. Newton's law of gravitation may be stated as {496}:

> *"A particle of mass m_1 attracts a particle of mass m_2 a distance d away with a force* $F = G\frac{m_1 m_2}{d^2}$ *in the direction of the line joining the particles."*

Of course, it should have stated "in a time forward zone". The situation is precisely reversed in a time-reversal zone. It is also reversed for negative mass-energy.

In the Newtonian view, antigravity would mean repulsion of mass rather than attraction of mass. Given that negative mass is possible, then a negative mass would exhibit antigravity — i.e., it would be repelled by all other positive masses.[214] This can be seen in the quoted equation, by

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[214] The discussion of what attracts what and what repels what, in a mix of negative and positive masses and negative and positive energies, is still controversial in physics. Different theorists have taken differing positions, and there is no formal experiment that has decided between them. In our opinion, the successful antigravity test of the Sweet vacuum triode amplifier answered that question experimentally, although independent replication was not accomplished. The scientific discussions heavily involve discussions (and assumptions) of the nature of "gravitational" mass, inertial mass, and electrodynamic mass etc. Again, there is no decisive selection among several possibilities, and there is no clear and universally accepted definition of **any** of those three types of mass.

In addition, all the discussions have included a fundamental error: They **assume** a separate 3-force acting upon a separate 3-mass, which is unequivocally false. Another fundamental error is the assumption of an observed (effect) 3-positron interacting with normal matter rather than a non-observed (causal) 4-positron (negative energy 4-electron) in massfree spacetime. In effect, this applies the CPT (charge-parity-time) symmetry, and converts the direction of the 3-positron to the antidirection of the 4-positron while also changing the negative mass of the 4-positron to positive mass of the 3-positron. Further, in physics there is still no firm **definition** of either force or mass, but only circular definitions between the two. We are using the simple definition of mass as $F = d/dt\,(mv)$, where mass is a component of force F and hence there is no separate force F acting upon a separate mass m. We interpret that equation as "the force *F* observed in a new observation is proportional to the time-rate of change of the ongoing 4-space interaction between the just-observed 3-mass *m* and the average interchange of time-energy and space-energy represented by v in the ongoing dynamics between spacetime and mass *m.* Whatever adjective is prefaced upon the *F* is also prefaced upon the *m* in the *mv* term.

We politely but firmly disagree with one prevailing notion that positive mass *attracts* both positive and negative mass, while negative mass *repels* both types. Further, we believe that the Sweet vacuum triode amplifier antigravity experiment falsified that notion. We hold to the dictum that $m == E/c^2$, where E is real spatial energy and may be positive or negative, c^2 is always positive, and therefore negative mass is highly compressed negative spatial energy while positive mass is highly compressed positive spatial energy. (Imaginary mass is a separate consideration.) We also prefer to reason in "single fundamental units" physics where the joule is the only fundamental unit. Gravity then becomes a function of the joule, whether electromagnetic, mechanical, or whatever. *We consider the energy in spacetime to he the source of the curvature of spacetime that is known as " gravitational field".* If the joule is of positive energy, the accompanying gravity is positive. If the joule is of negative energy, the accompanying gravity is negative. And we consider gravity as the 4-space causal spacetime curvature. So for gravitational interaction theory, we insist on examining the interaction of the curvature of local spacetime with the mass-energy. Further, we postulate that the gravitational effect upon one mass from a second mass is an improperly posed concept. It actually is an effect of the local curvature of spacetime around the first mass, where that curvature of spacetime was induced by the second mass's energy. Further, we consider that positive energy fields surrounding a positive mass will curve spacetime in the "positive gravity" direction. The positive mass is attracted by all other positive masses. Negative energy fields surrounding that positive mass system curve spacetime in the "negative gravity" direction so that the positive mass of the system is at least partially repelled by all other positive masses in the universe.

We further prefer to think in terms of the *supersystem* and the unobserved causal 4-field, not the frozen iterative 3-field snapshots defined only after iterative . observations. As we stated previously, the "observed" 3-positron is, in our view, a very different beast from the as-yet-unobserved 4-positron. The 3-positron is a frozen momentary "effect" entity with no dynamics at all and no continuous existence in time (and hence in spacetime) at all; instead, it continually *recurs* as the iterative effect of iterative observation by iterative application of the *d/dt* observation operator. The 4-positron is still a negative energy electron with negative charge, and still going in a non-reversed direction since broken parity has not been applied (because observation has not been applied), a causal entity with ongoing dynamics, continuously existing in spacetime, not just in 3-space. Until interacted and observed, it also has negative energy and negative mass-equivalency.

If one wishes to accurately deal with spacetime effects from the "positron," in our view one must deal with the 4-positron before observation, and hence with the supersystem. The 3-positron is not a *spacetime* entity, but only a frozen *3-spatial* snapshot. Scientists, including Dirac himself, were horrified at the negative mass implications of the negative energy states. Therefore, they moved the interpretation simply replacing positive mass m_1 by negative mass $-m_1$. That two negative masses would attract can be seen by replacing positive mass m_1 by negative mass $(-m_1)$, and also replacing positive mass m_2 by negative mass $(-m_2)$.

Now consider mass m_1 to be the rest of the net positive mass in the universe, and mass m_2 to be the "effective" mass in a local supersystem consisting of the local physical system, its local active vacuum, and its local active curvatures of spacetime — in short, in a local supersystem consisting of the physical system and its local active environment, and the interchanges between them. Let $m_2 = m_\mathrm{p} + m_\mathrm{n}$, where m_p is the amount of local positive mass (or mass-equivalent) in the system and m_n is the amount of negative mass (or mass equivalent) in the system. This supersystem now simultaneously exhibits both positive gravity (attraction) to all net positive masses in the universe and negative gravity (repulsion) to them as well. The net gravitational response of the supersystem depends upon the fraction of the effective mass that is positive and the fraction that is negative — in short, upon the net vector sum of the two gravitational forces.

to the 3-positron, and thereby twisted the interpretation to substitute the effect for the cause. Hence circuit theory treats the *lattice hole* as a positron, yet that "hole" acts very differently from a true Dirac positron (a Dirac sea negative energy electron) in free space.

Consequently, matter-antimatter interactions and the interaction between positive energy and negative energy are quite different, or they can be if so manipulated prior to observation. In the matter-antimatter interaction, the initial curvature of spacetime formed by the union decays by radiation of EM positive energy and the "effect particles" disappear back into the uncurved vacuum from whence they came. In the positive energy and negative interaction, there is a change of the local curvature of spacetime without its decay and subsequent re-radiation of EM energy. Equal amounts of interacting positive and negative EM field energy thus are simply transduced into stress energy potential of the vacuum and consequent sustained change in the curvature of the local spacetime. Indeed, the radiation of pair annihilation energy is obtained only at the expense of negating (relaxing) the local polarization of the vacuum (and the two consequent curvatures of local spacetime) represented by the independent positron and electron. Indeed, normal pair annihilation is a sort of Lorentz symmetrical regauging of the locally asymmetrical vacuum.

The reader is certainly free to disagree with our conclusions; we are merely explaining them. Experiment will eventually sort out the truth or falsity of the approach. So far, based on the Sweet experiment designed by the present author, a highly successful experiment was consistent with this approach.

In a "mixed" mass system containing both positive and negative component masses, the fraction of the total mass that is positive and the fraction that is negative is thus significant. When the mixture's negative mass is less than its positive mass, the mixture would exhibit a "reduced" gravitational attraction to other masses of the universe. Then the ratio of negative mass to positive mass might be taken as the "gravitational shielding" coefficient (fraction).

When the amount of positive mass and the amount of negative mass were equal, the overall mass system would exhibit no net gravity or antigravity, and would "float" or "hover" in the Earth's gravitational field. It would be equally attracted and repelled by the Earth's positive mass (and by all other positive mass in the universe, hence could — at least under certain conditions — *appear inertia-free.).* When the amount of negative mass exceeds the amount of positive mass, the overall mass system would exhibit a net antigravity effect. It would be repelled more strongly by the Earth's positive mass, as well as more weakly by the distant positive masses of the universe, and hence would accelerate upwards and away from the Earth. Notice that the key to antigravity in the Newtonian approach is the availability of negative mass, but in the new sense in which we use it. Note also that we did not discuss the separate issue of imaginary mass.

If we translate that into modern terms, where we consider not the "mass" but the condensed energy comprising the mass, then m_p and m_n become positive mass-energy and negative mass-energy terms respectively. Given the ability to produce electromagnetically produce substantial negative field energy in the immediate vacuum environment of the system, where the source of the field is the physical system, then the creation of a direct antigravity component in the system's environment — the other two components of its supersystem — becomes not only possible but also feasible.

The key to antigravity becomes the *availability of negative field energy in the local space surrounding the physical object, with the physical object containing the source of that surrounding spatial negative energy field.* Voila! This impels us directly to electrodynamics and a modified Dirac sea {497, 498a, 498b), one with excess empty holes as source charges producing negative energy EM fields. We deliberately create these unique source charges by actions taken in a COP»1.0 system. This gives the key to the approach to antigravity taken by the present author.[215] However, we use as negative energy not just the accounted *Poynting* energy flow component in space where the field is present, but also the unaccounted *Heaviside* energy flow component, which is much greater in magnitude (in a nominal case, nearly 10^{13} times greater). In this way, we dramatically increase the amount of antigravity effect that can be obtained by a given EM power dissipation in the physical electrodynamic system itself. *This antigravity effect of a Heaviside component of EM negative energy flow has not been accounted in previous analyses.*

8.2.2 Riemann Surfaces and Riemann Geometry

The next development of interest to us is the doctoral thesis of Riemann {499}, which founded the theory of Riemann surfaces. Three years later, **he** founded Riemann geometry in a famous lecture. Riemann was working on a unified explanation of gravity and electromagnetism when he died of tuberculosis a dozen years later. It was Riemann's multiply-connected topologies that eventually resulted in the view of electric charge producing lines of force trapped in the topology of space {500}. Had Riemann lived, we believe that engineerable unification of electrodynamics and gravity would have occurred early on. In that case, we might have already had practical antigravity vehicles and explored the solar system and beyond.

8.2.3 Heaviside's Excess Energy Circulation Flow and Gravity Theory

The next theory of gravity of interest to us is that of Oliver Heaviside. Heaviside noted that his extra EM energy flow term was a trapped EM energy circulation {501}. He realized that, if that trapped EM energy circulation were taken as gravitational in nature, his energy flow theory could be converted into a unified theory incorporating both electrodynamics and gravitation. After his death, his handwritten notes on **the** theory were found beneath the floorboards in the little garret apartment he had long occupied. No one knows what other papers he may have had; **the** place was ransacked and looted prior to the discovery of these remaining papers hidden beneath the floorboards — papers the looters had missed.

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[215] We also point out that a Dirac sea with empty holes (excess negative energy states) exists in (or constitutes) a negatively curved spacetime *a priori.* So we get back to the other two components of our "supersystem", the active vacuum and its dynamics and the local curvature of spacetime and its dynamics.

Other scientists such as Laithwaite have felt that Heaviside's approach might still shake the foundations of physics itself. Quoting Laithwaite {502}:

> *"Heaviside had originally written the energyflow as $S = (ExH) + G$, where G is a circuital flux. Poynting had only written $S = (ExH)$. Taking p to be the density of matter and e the intensity of a gravitational force, Heaviside found that the circuital flux G can he expressed as pu — ce, where u represents the velocity of p and c is a constant."*

8.2.4 Mach's Principle

After Heaviside, the next item of interest to us is Mach's principle {503}, which essentially states {504}:

> *"The properties of space have no independent existence but depend on the mass content and distribution within it. Thus, acceleration dealt with in Newtonian mechanics can only have meaning if it is an acceleration with respect to the stars or with respect to something equally well-defined."*

Mach's principle does not adequately deal with spacetime, and certainly does not even acknowledge or encompass how energy exists in 3-space at each point dipole, as an entering flow from the time domain into the negative (charge x time). It does not include transduction by the negative charge into 3-space energy, passage of the 3-energy to the associated positive charge, transduction back into time energy by the positive charge, and re-emission of the transduced time-energy back into the time domain, by the positive charge. In short, Mach's principle will never get one a practical antigravity system, regardless of how one applies the principle.

8.2.5 Einstein's General Relativity

Next comes Einstein's epochal general relativity theory of gravitation {505}. In that theory, Mach's principle is interpreted as pointed out by Misner, Thorne and Wheeler {506} in the following quote:

> *"...Einstein's theory (1) identifies gravitation as the mechanism by which matter there influences inertia here; [and] (2) says that this coupling takes place on a spacelike hypersurface..."*

The great contribution of Einstein's general relativity was to remove the notion of the "field occupying space", where field and space are separate things. Quoting {507}:

> *"If we imagine the gravitational field, i.e., the functions* g_{ik} *to be removed, there does not remain a space of the type (I) [Minkowski Space], but absolutely* *__nothing__*, *and also no 'topological space'. For the functions* g_{ik} *describe not only the field, but at the same time also the topological and metrical structural properties of the manifold. ... There is no such thing as an empty space, i.e., a space without field. Space-time does not claim existence on its own, but only as a structural quality of the field."*

In passing, we note that in the conventional sense we can and do have many fields "in the same space", which is merely the statement that a net field has internal structure, and so does a net spacetime. Extending that notion, we can conclude that spacetime is in fact naught but a set of fields, both static and dynamic. The total energy density of all those fields at any point in space constitutes *a potential* with that energy density at that point, and with that internal field dynamics and structure. So because of its incredible field energy density, space is also *identically* a giant potential with internal structure and dynamics. With that observation, we rather casually join the seething vacuum of particle physics, the spacetime of general relativity, and the fields of electromagnetics as *different aspects of the same thing.* We point out that our concept of the supersystem therefore only identifies the three separate things into which this "one-thing" has been arbitrarily divided in much of physics.

Although he tried more than once, Einstein himself failed to achieve a successful unified theory of gravitation and electrodynamics. One thing he added in his earlier theory was a cosmological constant, which he felt was necessary to explain a stable closed universe. He later regretted that assumption, but today with the discovery of the acceleration of the expanding universe, which can only be caused by antigravity, his cosmological constant has assumed a new and vital role in the search for the source of this observed antigravity effect in the cosmos.

8.2.6 Kaluza-Klein 5-Dimensional Unified Theory

Using five dimensions, a unified theory of general relativity and electrodynamics was advanced by Kaluza {508} as extended by Klein (509}. This is a notable extension of Einstein's theory, and a very substantial literature exists in the Kaluza-Klein area.

8.2.7 The Sachs Unified Field Extension of Einstein's Theory

Another notable extension of Einstein's theory, which does include electrodynamics and the results of quantum mechanics as well, is the theory by Sachs {510}. Starting with Einstein's general relativity view and the group symmetry of its underlying mathematics, Sachs extended Einstein's theory into a fundamental theory of matter in all domains. Einstein's group formalism and the spinor-quaternion calculus in a curved spacetime provide the genesis of matter fields. The theory encompasses globally covariant field equations for inertial features of matter including its force manifestations. Unification is provided by the generalized spinor formalism. Quoting a popularized summation {511}:

> *"Novel features of general relativity are shown to emerge, in elementary particle physics as well as astrophysics. Especially noteworthy ...is a factorization of Einstein's field equations to a quaternion field formalism which, by way of a single covariant field, includes both gravitation and electromagnetism coupled to matter field equations — whose linear (low energy) limit recovers quantum mechanics. The ...original approach also furnishes derivations, not previously available, of several observed properties of inertial mass and gravitational force."*

For a more technical description of how the unification of electrodynamics with general relativity is derived, we quote directly from Sachs {512}:

> *"It was demonstrated earlier that the factorization of Einstein's second-rank, symmetric tensor field equations, by removing the space and time-reflection elements from the underlying covariance group, yields a 16-component quaternion metrical field equation. The 16 equations were then re-expressed in a second-rank tensor form, breaking up into 10 $\oplus$ 6 equations. The 10 equations are in one-to-one correspondence with Einstein's symmetric tensor equations for gravitation; they are even under reflections. The remaining 6 equations are in antisymmetric tensor form; they are odd under reflections. Taking the covariant divergence of the latter equations then puts them into one-to-one correspondence with the structure of Maxwell's equations for electromagnetism. What was shown earlier was that the four of Maxwell's equations with sources followed. What is shown in this paper is that the other four of Maxwell's equations that are source-free also*

> *follow, thus indicating the absence of magnetic monopoles from this theory, as in the usual Maxwell formalism. This shows that the factorization of Einstein's field equations to the quaternion form fully unifies the gravitational and electromagnetic manifestations of interacting charged matter."*

To freely download several of Professor Sachs's important technical papers, one is referred to his website at http://www.compukol.com/mendel/articles/articles.html.

The O(3) electrodynamics of Evans and Vigier has been shown to be a special subset of Sachs's electrodynamics {513a}. Hence O(3) can be used to engineer much of the Sachs unified field theory phenomenology, including — in our view — both gravity and antigravity. The first theoretical indication of this has been published by the AIAS (Alpha Foundation's Institute for Advanced Study) {513b}. Shortly we discuss our own views on how to directly perform engineering of antigravity.

A great many excellent publications on general relativity and the background of scientific knowledge in gravity exist; e.g., the text by Wheeler *et al.* {514} is particularly good. Einstein himself wrote a book on his special and general theory for the nonspecialist {515}. A collection of English translations of some of the original papers on relativity is provided in a book by Einstein, Lorentz, Minkowski, and Weyl {516}. Many other gravitational theories or changes to major theories have also been proposed by other scientists, but are not discussed here. For our purposes, an abbreviated discussion will suffice to understand a fundamental approach to feasible antigravity.

Since we are interested in actual working systems, a short review of some of the efforts in asymmetric lifting and propulsion experiments is useful.

8.3 Selected Antigravity and Inertial Propulsion Research Efforts

We give only a small sampling of the many efforts performed or ongoing in this area over the last few decades, and some still ongoing today.

8.3.1 T. Townsend Brown

Our first example is the work of T. Townsend Brown. Brown was working **on** a "gravitor" before he finished high school, and continued work in electrogravitation throughout his life. Space is a dielectric, and Brown reasoned that the displacement current in a capacitor dielectric could influence the space dielectric itself.[216] Hence he built, tested, and patented several variations of lifting devices based on this concept {517a-517e}. Essentially, he found that certain high capacitance dielectrics could be subjected to high voltage (50 to 300 kilovolts), and would exhibit thrust in the direction from the negative to the positive pole.

Here we point out our contention that all EM energy in space comes from the time domain via the negative charge, and re-enters the time domain via the positive charge. This is consistent with Brown's finding. Although he demonstrated many such lifting and thrusting devices, Brown was never able to obtain sufficient financial and scientific backing to bring a practical embodiment of his inventions into practice. His work, however, has been replicated by multiple experimenters, including NASA researchers (see below) and several researchers contributing results to Jean-Louis Naudin's website http://jnaudin.free.fr/html/lifters.htm.

8.3.2 Jonathan W. Campbell

Recently a U.S. patent {518} on a thrusting capacitor, by Campbell, has been issued and assigned to the U.S. Government (NASA), and made available for commercial licensing. The patent write-up states that thrust from capacitors is well known, but has been too small to be practical. The patent purports to remedy that impracticality. A version of the NASA device has been replicated by the Naudin researchers also. So an adaptation of Brown's work has been patented by the U.S. government with intentions of licensing. This would appear to validate much of Brown's approach and efforts.

8.3.3 The Dean Drive

Our second example is the inertial drive patented by Dean {519a-519e}. Unfortunately, the effects of the Dean drive later appeared to be a problem in accurate measurement. Nonetheless, work still continues along the direction shown by Dean. One may argue that mechanical materials also contain charges and have a certain kind of capacitance. Hence, mechanical motion of the parts of the machine does move these charges and dielectrics, opening a possibility of interacting with the dielectric of space. For example, Sweet's VTA involved a sustained self-oscillation between the local vacuum and the barium nuclei in his barium ferrite magnets.

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[216] We have not yet explored the gravitational effects — if any — of our concept of the triode capacitor, discussed in paragraph 6.3.7 and diagrammed in Figure 6-17. We will examine it as soon as we have the proper equipment.

Dean's approach still has merit, even if a particular embodiment gave a negative result when very accurate measurement was performed. It is particularly of interest that mechanical force is essentially derived from electromagnetic forces (and fields) at basis. These base EM fields involve (and identically are) curvatures of spacetime, and hence the motions of the inertial drive mechanical apparatuses do involve at least some curvatures of spacetime and dynamic changes to them.

Our comment is that, when the additional but neglected Heaviside nondiverged energy flow component is accounted, these field interactions internal to matter can produce many orders of magnitude greater curvature of spacetime than is accounted by the diverted Poynting energy flow component only.

The "inertial antigravity" approach may be visualized as the use of excess gravitational thrust in a specific direction. If that direction is against the local pull of gravity, and is more powerful, then "lift against the gravitational pull" is obtained. Rigorously, this is not true antigravity but manipulated excess positive gravity.

In our approach to antigravity, one way to approach the problem is to have the mechanical apparatus also the source of an intense *negative energy* EM **field,** producing an intense flux of Dirac sea holes into and in the local surrounding spacetime. The excess charge removed from the Dirac holes can in fact be used in the electrical powering of the physical system, as was demonstrated in the Sweet VTA antigravity test. Then movements of the mechanical parts could involve movement of strong negative energy fields, hence strong curves of local spacetime that are local *strong negative gravity fields.* Or, better yet, movement of the charges themselves will also produce field-induced movement of the Dirac sea hole negative energy. This appears to be a practical method to manipulate the metric itself, along the lines proposed by Puthoff *et al.*[217]

8.3.4 Henry Wallace

Other work has been by Henry Wallace, an engineer working for General Electric in the 1970s. His work dealt with the interactions of relatively moving masses of various kinds, and it is described in his patents {520a, 520b}. The discussion under the Dean drive probably applies to Wallace's work as well.

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[217] H. E. Puthoff, S. R. Little, and M. Ibison, "Engineering the Zero-Point Field and Polarizable Vacuum for Interstellar Flight," *J. British Interplanetary Soc,* Vol. 55, 2002, p. 137-144.

8.3.5 J. F. Woodward

Next is the work of J. F. Woodward, resulting in one or more patents {521} and multiple articles in the legitimate physics literature {522a-522k}. Woodward uses an adapted theory based on Mach's principle and on the thesis that the mass of a capacitor can be made to vary from its normal mass by rapidly charging and discharging it — say, at a frequency of 20 kHz. This predicted effect is testable, although some sophistication in the testing is required.

Woodward's publications show the results of actual experiments, measuring a very small change in the mass, and are worthy of much further investigation. Here we note that the actual mechanism generating the inertia of an object is still an open issue, with several different contending theories.[218] Whether the gravitational mass and the inertial mass are identical or not, also remains an issue. If the exact local mechanism generating the inertia of a mass could be decisively found, then direct methods of changing the inertial mass and the gravitational mass might be a real possibility, and research to try to find such methods would be strongly indicated.

Our further comment is that the mechanism that generates mass itself has never been specified in formal physics,[219] particularly when one views an observable (such as mass) as continually recurring in 3-space rather than continuously existing in 3-space, due to the *d/dt* operator imposed on spacetime by the observation process. Before the reader assumes that mass is well understood, a reading of Jammer's scholarly work {523} is highly recommended.

From our viewpoint we stress that observed mass cannot continuously exist, but must be an effect and the instantaneous frozen output of the *d/dt* observation process invoked on an ongoing 4-space process. Hence, from this view there is indeed a "process" that (continually) creates mass — it is at least the emission of EM angular momentum (a photon) from the *masstime* entity. Similarly, there is a "process" that continually destroys or converts any mass — it is the absorption of a photon and conversion of the mass *m* into masstime *(m +* d*m)dt.* Mass "flows through time" via this time charging and discharging, in the form *m* => *mt* => *m* => *mt* => *m*... etc.

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[218] E.g., (a) A. Rueda and B. Haisch, "Inertia as reaction of the vacuum to accelerated motion," *Phys. Lett. A,* Vol. 240, 1998, p. 115-126; (b) B. Haisch, A. Rueda and Y. Dobyns, "Inertial Mass and the Quantum Vacuum Fields," *Ann. Phys.,* Vol. 10, 2001, p. 393-414.

[219] The present author made an early **and** crude attempt at doing it in his "Quiton-Perceptron Physics." 1973, NTIS Report AD-763-210.

Again we stress that masstime *mt* is not mass *m*, but is as different from it as impulse *Ft* is from force *F*. We crudely proposed such an initial mass-generating mechanism in 1973 {524a}, with additional information published in 1998 {525a}, which may have bearing on the mechanism involved in Woodward's experiments.

8.3.6 E. **R. Laithwaite**

Eric Laithwaite was for some years a professor with the Imperial College in London. He was one of the pioneers of the linear electric motor and of portions of the magnetic levitation (MagLev) train concept. An illustrious career headed for greater things (perhaps knighthood, Fellow of the Royal Society, etc.) was abruptly derailed in 1973 after he lectured to the prestigious Royal Institution by invitation and demonstrated that a heavy gyroscope, difficult to lift with one hand while not turning, could be lifted easily with that same hand, once turning at speed. Laithwaite's suggestion that Newton's laws of motion might be in difficulty proved much too controversial. The Royal Institution (apparently for the first time in its 200 year history) did not publish proceedings of that invited discourse.[220]

One of the remarkable things Laithwaite achieved was a form of "indefinite motion" device that he demonstrated circa 1970 {526}. The Centennial Centre of Science & Technology in Ontario was looking for working models to decorate the entrance hall. Laithwaite showed that if a linear-motor primary was rolled into a cylinder, so that it became simply the stator of a conventional induction motor,[221] a steel washer (about 3 cm. in diameter) could be made to roll continuously in a vertical plane around the inside of the stator. A combination of centrifugal force and magnetic attraction kept the washer in contact with the stator at all times. At the same time, a pivoted copper cylinder could be held in the center of the stator and would be seen to rotate on its own axis in the opposite direction.[222] Laithwaite completed and delivered a working model to the Centennial Center of Science & Technology. The reader should note the similarity of Laithwaite's proven experimental device to the magnetic Wankel engine.

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[220] With some humor we point out how shocking is our proposal that such a thing as "continuous" propagation of an object or energy through 3-space does not exist. Instead, small differential "pieces" of it continually "recur" at successive positions, much like the projection of the frames of a motion picture frame, where continual observation is the "projection process". Nonetheless, in our proposed solution to the source charge problem, either that is true or every charge in the universe is a perpetual motion machine, freely creating energy out of nothing. In our view, that is the impact of the long-neglected source charge problem in quantal and classical electrodynamics. It has produced the wrong and naive notion of what "propagation through space" actually entails.

[221] Something similar to diagrammatic Figure 6-26 in Chapter 6.

In addition to his attention to Heaviside's unpublished draft notes and manuscript on a combined theory of electromagnetics and gravity (previously discussed above) {502}, Laithwaite spent the latter years of his life working on sophisticated gyroscopic systems {527a-527h}. Ultimately he felt he had successfully produced a mass transfer effect {528} and the basis for a propulsion system. He and William Dawson applied for a patent in 1993, which was granted in 1995 {529}, with a U.S. patent granted in 1999 {530}. Regretfully, Professor Laithwaite died in 1997.

8.3.7 Floyd Sweet's Vacuum Triode Amplifier (VTA)

See again Chapter 6 and Figures 6-5 through 6-14 on the work of Floyd Sweet, previously discussed in paragraph 6.3.2. My concept of antigravitation used in the experiment is shown in Figure 6-15. By now, the sharp-eyed reader will recognize that my method actually constitutes a conceptual extension and definitization of the Dirac electron theory, reinterpreted to recover negative mass, negative energy, negative energy fields, and negative energy potentials. The defining feature is the deliberate use of a COP»1.0 main power system (perhaps constituting the power system of a flight vehicle) as a source of locally strong negative energy EM fields generated by the concentrated Dirac sea holes (causal 4-positrons being negative energy 4-electrons prior to observation) locally produced in the power system. We collaborated with Sweet on the vacuum triode amplifier for more than a decade, and in fact suggested the name of the device.

The antigravity approach designed by the present author was based on realizing that negative energy sources (e.g., 4-positrons as negative mass 4-electrons prior to their reaction and observation) produce *negative*

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[222] We have had the distinct notion that the fundamental *contrarotating* mechanism found by Laithwaite is probably an analogous mechanism — or very similar — to the mechanism utilized by Bauman in his Swiss converter (Methernitha device). As pointed out, it also has remarkable similarities to the magnetic Wankel engine, except that the magnetic Wankel does not utilize two contrarotations.

energy EM fields. The field can reach out over all space, so a negative EM energy field represents a reversed curvature of a large volume of spacetime. Hence it represents a considerable antigravity field — particularly when one considers the unaccounted huge Heaviside component of the negative energy field and charge interaction. Since the field strength falls off as the inverse square of the distance from its source, the strong antigravity effects of negative energy EM fields are much stronger locally than at a distance. This is particularly true when the conventionally ignored Heaviside nondiverged EM energy flow accompanying the accounted diverged Poynting energy flow of every field-charge reaction is accounted. This usually ignored factor dramatically increases the antigravity intensity produced by the local negative EM energy field by many orders of magnitude, often by nearly 10^{13}.

My antigravity concept (then and now) is shown in Figure 6-15 of Chapter 6. At the time, the only available device I knew of that produced a substantial percentage of output negative EM energy was Sweet's vacuum triode amplifier. So I persuaded Sweet to fabricate a new output section (an output load similar to Figure 6.8 but containing ten sockets for ten 100 watt lamps). Thus the output of the unit — which adjusted automatically to the available load — could be increased in 100-watt increments by merely screwing in the lamps one at a time and making laboratory readings after each new 100-watt load increase was added. This was done and the concept was successfully tested by Sweet {531}, who was making the measurements in California and reading them off over the phone to me (I was in Huntsville, Alabama). The experiment worked beautifully.

The setup and progress of the experiment were intended to materially increase the strength of the *negative energy* EM field and Dirac sea hole flux already produced to a lesser extent by the Sweet vacuum triode amplifier (VTA) in its normal operation. Thus the hypothesized negative energy antigravity field, produced weakly by the negative energy from the device in its ordinary power output range of 500 watts, was to be substantially increased at 1,000 watts. The response to the net gravitational field surrounding the object would thus be the resultant of two factors: (i) the normal response of the device's positive mass to the positive gravitational field of the Earth etc., and (ii) the additional response of the device's positive mass to the local antigravitational field produced around it. The measurable result was expected to be a decrease in the measured weight of the object on the laboratory bench.

As discussed, this stratagem succeeded dramatically. The weight of the vacuum triode amplifier was decreased, smoothly and controllably, by

90% on the laboratory bench (see again Figure 6-9).[223] The results were later published in a joint paper {531} prepared by the present author. I placed Sweet's name first on the paper because he was the inventor of the VTA, which demonstrated the effect once properly modified as I requested. Note that the extra antigravitational field effect on an object is indeed a local effect, which the experiment also showed. This effect was obtained at a COP>1,500,000 (actually, at nearly a COP = 3,000,000) and at ELF frequency.

The ELF frequency is important. As we explained previously, the highest energy photons of all are the lowest frequency photons, when the highly compressed time-energy component of the photon is accounted as well as the decompressed spatial energy component. Hence, for very appreciable local curvature of spacetime to produce considerable antigravity, the antigravity source must produce negative energy fields consisting of negative energy photons at low frequencies (such as 60 Hz). Else, the curvature of spacetime is so small that little effect will evidence. My best "back of the envelope" estimate of the efficiency of the antigravity process in the VTA was 10%.

8.3.8 Ning Li and (separately) E. Podkletnov

Very interesting work was performed by Ning Li {532a-532d}, a scientist originally with the University of Alabama in Huntsville (UAH), who returned to China for a while but is now back in Huntsville. Quoting David Brown from the UAH website from 1997:

> *"In 1989, Dr. Ning Li of UAH predicted that if a time varying magnetic field were applied to a superconductor, charged and deformed lattice ions within the conductor could absorb enormous amounts of energy via the*

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[223] Many times I have been asked how such small output power increase (from 500 to 1,000 watts) could possibly achieve such dramatic antigravity results. The answer - due to the neglected Heaviside nondiverged energy flow component — lies in multiplying the power output by the "Heaviside energy amplification factor *k* " where *k* may be as large as 10^{13}. A 500-watt accounted increase, multiplied by 10^{13}. is actually an incredible increase in the total EM negative energy field density being created in the local vacuum. In short, a very little "accounted" power increase of the COP»1.0 VTA output is actually a very vast negative power output increase when the long neglected k-factor is accounted. It is just this missing k-factor and the failure to account for the negative energy KM fields generated in COP»1.0 discharges in violent astronomical phenomena that seem to be responsible for generating the excess antigravity that is accelerating the expansion of the universe.

> *magnetic moment effect. This acquired energy would cause the lattice ions to spin rapidly about their equilibrium positions and create a miniscule gravitational field. Dr. Li's calculations showed that if these charged, rotating, lattice ions were aligned with each other by a strong magnetic field, the resulting change in local gravity would be measurable."*
>
> *"Podkletnov and Nieminen (1992)* {533} *made the accidental discovery that a single-phase, dense, bulk, high T_c, superconducting, ceramic disk spinning at 5,000 rpm can produce a 2 percent reduction in the weight of non-conducting, non-magnetic objects placed over the spinning disk. UAH and MSFC [Marshall Space Flight Center, a part of NASA] [cooperated] on a joint research project to independently confirm the results of the Podkletnov experiment and to validate Dr. Li's theory of gravity modification via superconductor. On March 26th, 1997, as a part of this project, the joint UAH-MSFC research team produced the largest high temperature superconducting disk ever manufactured in the USA. This disk measures 12 inches in diameter and is 0.5 inches thick"*

We now explain the experiments, from our point of view of the mechanism for antigravity. We remark that, at least in theory, the charges in such a rotating superconducting disk have an inward "discharge" acceleration force that is a function of the distance of the charge from the rotation axis center. Hence, in the rotating frame, some of these charges are very strongly "accelerating" toward the center, as are their spins whose magnetic vector is orthogonal to the E-field vector. A flow of EM energy exists perpendicular to the rotating flat disk and is accelerating at right angles to the disk surface. This is analogous to a *discharge* (sudden acceleration) phenomenon, and it will also produce accelerating negative energy Dirac sea 4-holes in the vacuum component of the supersystem of the spinning disk. So from the spinning disk there is a sort of "wide beam" of Dirac sea 4-hole current in the vacuum, radiating at right angles to the disk surface, with heavier concentrations toward the outside of the disk. The result is that objects in the Earth's gravitational field, and also placed in the path of this negative energy Dirac sea 4-hole current, is acted upon by two superposed curvatures of local spacetime: (1) the positive curvature due to the Earth's gravitational field, and (2) the negative curvature due to the negative energy field's curving local spacetime. The total net gravitational effect will be due to the algebraic sum of the superposed two spacetime curvatures — the normal positive curvature from the Earth's gravitational field and the second a negative curvature created by the Dirac sea hole current's negative energy fields (Heaviside energy flow component considered). The expectation is therefore a *reduction* in the weight of the object, as is shown in the experiments.

The UAH-MSFC group was unable to confirm Podkletnov's findings.[224] Ning Li and the NASA group later split amicably. Ning Li continued her theoretical work, eventually ceased publishing papers for a period to protect the techniques and experimental results achieved in her work, and focused upon potential applications. She apparently returned to China for some time, but is now back in Huntsville, Alabama and still experimenting. We suspect there may also be a Chinese research effort into antigravity, using the approach taken by Ning Li. Perhaps information from that program will be released in the future.

But what of the work of Podkletnov since his original experiments? NASA continued to try to replicate his disk and his work, with Podkletnov acting as a consultant. Presently, NASA has paid an independent research firm to replicate the disk to full specifications, which has just been accomplished as this is written. At this writing, the experimental results of this new attempt are not yet available as the work is still in progress. It should be available by the time this book is published.

Meanwhile, a relatively new paper by Podkletnov and Modanese has been published on the Los Alamos National Laboratory website.[225] This method uses high amperage sharp pulse discharges from a superconducting ceramic electrode, to produce an anomalous radiation in a focused beam. Significantly, the beam does not noticeably attenuate through different materials. The beam exerts a short repulsive force on small movable objects on the propagation axis, with the force proportional to the mass of the objects.

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[224] E. Podkletnov and R. Nieminen, "A possibility of gravitational force shielding by bulk $YBa_2Cu_30_{7-x}$ superconductor," *Physica C,* Vol. 203, 1992, p. 441-444.

[225] Evgeny Podkletnov and Giovanni Modanese, "Impulse Gravity Generator Based on Charged $YBa_2Cu_10_{7-y}$ Superconductor with Composite Crystal Structure," carried on website http://xxx.lanl.gov/abs/physics/0108005.

We interpret the results as completely consistent with our own proposed excess gravity and antigravity mechanism. We know that such sharp discharges produce significant Dirac sea 4-hole currents in the local vacuum component of the supersystem. Such currents in a beam interact very little with intervening materials, and the major spacetime curvature effects are concentrated upon the propagation axis. On that axis, force effects can be expected upon small independent objects, due to the *additional* negative curvature added to the local spacetime in their supersystem. The impulse produced on the object should indeed be proportional to the mass of the object and independent of its composition, since it is a gravitational force effect induced by local curved spacetime. The force should be repulsive in the beam, since that is the direction of the antigravity force that will be induced in objects in the axis of the beam, by the beam of negative energy Dirac 4-holes. A positive gravity force would mean attraction between the object in the propagation path and the source of the beam. A negative gravity force would therefore mean repulsion.

So Podkletnov and other scientists are still working on a successful effect. It will be interesting to see what results are reported in the future, and whether they will deviate from their present attempt to explain the effect by a combined quantum gravity and anomalous vacuum fluctuations approach.

8.3.9 NASA's **Breakthrough Propulsion** Physics **(BPP) Project**

NASA's Breakthrough Propulsion Physics Project was established in 1996. It seeks a breakthrough in space transportation involving "(i) propulsion that requires no propellant mass, (ii) propulsion that attains the maximum transit speeds physically possible, and (iii) breakthrough methods of energy production to power such devices." Investigations involve coupling of gravity and electromagnetism, the quantum vacuum, hyperfast travel, and superluminal quantum effects. The project is managed by the Glenn Research Center, sponsored by the Advanced Space Transportation Program, with overall management by NASA Marshall Space Flight Center, Huntsville, Alabama.

NASA continues its investigations and experiments in methods to change **the** force of gravitational attraction. The scientist in charge of the project is David Noever of the Marshall Space Flight Center. The work is still considered a work in progress, with the need for both experimental investigation and meticulous design of experiments, instrumentation, and measurement techniques.

The overall NASA program also spreads to other supporting laboratories and projects. For example, at the Jet Propulsion Laboratory (JPL) Kulikov {534} has measured the difference between inertial and gravitational mass of a boson in a heat bath. At least one invention seems to have resulted or to be in progress, assigned to JPL.

As mentioned, the U.S. Patent by Campbell {518} on a capacitor device producing a net thrust force (a more modern version of T. Townsend Brown's work) has been issued and assigned to NASA.

8.3.10 Scientific Conferences

There are regular conferences (several per year) being held in the U.S. and elsewhere, dealing with antigravity and electrogravitic propulsion. We give a little-noticed but pertinent example: In a nice presentation in 2001, LaPointe {535} proposed a new method for producing anti-matter. Currently antimatter production is accomplished in very large accelerators, and is therefore quite expensive. For increased experiments, a cheaper and much smaller (and much more available) process is highly desirable.

In the Klein paradox, which involves very large potential drop across a very short distance — less than the Compton wavelength of the antimatter particle — matter and anti-matter pairs are produced. LaPointe hypothesized that it may be possible to use the Casimir effect to push one side of the step into the negative energy range. He is at least *thinking toward* negative EM energy sources that produce negative EM fields and negative gravity in the surrounding space, without explicitly enunciating it in that fashion.

We already briefly discussed our own approach to antigravity, which is a much simpler and cheaper anti-particle producing mechanism, as demonstrated by the Sweet device. In short, overunity EM systems with COP»1.0 do produce free flows of causal (before observed) 4-positrons (still in negative energy 4-electron state prior to interaction) in local spacetime immediately surrounding the system. Consequently, LaPointe's efforts are in what we believe to be the correct direction, but he is still using a very difficult mechanism to engender the antimatter production. Also, the positrons or other antimatter sources of the negative energy fields must remain in the causal (unobserved and non-interacted) 4-state, in order to produce negative energy EM fields and potentials and antigravity.

8.3.11 James Corum *et al.:* Rectified Slepian AC Force Resonator

Another example is some promising work by Corum *et al.* {536}. We quote from the abstract and summary of his paper:

> *"Corum presented an experimental paper on the use of the Heaviside force in conjunction with a Slepian antenna as a form of space drive using nothing more than the classical Maxwell stress tensor. Slepian proposed the same thing in 1949, but came to the conclusion that it would not be useful, since the time average of the resultant AC force would be zero. Corum's contribution has thus far been two-fold: (1) In conjunction with Dr. Alan Barnes of WVU he has experimentally shown that the AC version of the Slepian Resonating Antenna does produce a force, and has measured it to within 3.6%, and (2) has designed a way for Hartley's variable capacitor rectification to be used with the Slepian resonator such that the rectification results in a DC force component. The first experiment has already been achieved, the second experiment is the logical next step. If successful, the result would be quite revolutionary: a true space drive."*

Our comment is that this unilateral thrust force work is important. In our view, the Heaviside energy flow component does not appear in Slepian's vector **j**ϕ, which contains only the diverged EM energy flow surrounding a circuit or component, but it is present immediately outside the circuit where the Slepian vector exists. Hence there is an enormous, extra energy flow closely associated with every EM circuit, that is unaccounted since Lorentz's closed surface integration of the energy flow vector discarded it quite arbitrarily.

We already know from the Bohren experiment (and thousands of others similar to it) previously cited that resonant charges do collect excess EM energy from a given EM energy flow input, compared to the collection from that flow by the same charges in nonresonant state. In using the Slepian resonator and then rectifying its output, it would appear that both the diverged (Poynting) energy flow component and the Heaviside nondiverged energy flow component are first resonated and then rectified. In addition, excess energy is collected — much more than is in the normal "static charge" formula assumptions for Poynting energy flow and in assuming only a "single pass, single interception and collection" of the energy.

An important factor then is obvious: Once the energy flow is surrounding the circuit, there exists a certain local curvature of the immediate external spacetime. The rectification represents not only a change in the Slepian vector current in the circuit, but also a change in this local ST curvature interaction upon the circuit matter and charges. In short, it should produce a DC component in the direct excess interaction of the rectified local curvature of spacetime. This should produce *excess direct propulsive force,* just as Corum theorizes and the experiments support to date.

Further, the oscillation of the large, *unaccounted* Heaviside nondiverged energy flow component involves the oscillation of a "dark energy" component that may be orders of magnitude greater than the *accounted* Poynting component's magnitude. By involving this huge energy flow component in oscillation and synchronized to the resonant Slepian circuit, Corum has unwittingly involved the supersystem as a COP»1.0 EM "energy converter" system. Hence, there is appreciable Dirac hole current (in causal 4-form) in the local vacuum, not reacted with the materials in the system and therefore not converted to material lattice holes attached to positive mass. The time rate of changes of the negative energy fields and potentials are thus significant for antigravity effects, in the approach taken by the present author. In short, we believe Corum *et al.* are in fact producing significant evidence for a workable approach to unilateral thrust force.

This work by Corum *et al.* thus is highly promising, is solidly based experimentally, and certainly bears watching closely. We would strongly suggest that Corum *et al,* analyze their proposed mechanisms and results obtained in terms of supersystem analysis rather than system analysis, using higher group symmetry electrodynamics, and recover and include the long-neglected Heaviside energy flow component.

8.3.12 Gravitec, Inc. and H. Serrano

A patent {537} was issued to H. Serrano on Oct. 5, 2000 and assigned to Gravitec, Inc. whose principal investigator and corporate officer is Tim Ventura. Based on this invention, Gravitec, Inc.. has developed and demonstrated a rotary device that develops unilateral thrust. Purdue University began a small but steady effort to test the unit, first in the atmosphere and later under high vacuum conditions. The first tests have been successful, and a paper {538} from the Purdue study shows it is not the ion wind effect, which is orders of magnitude too small to account for the demonstrated thrust. Further, Jean-Louis Naudin has replicated and tested the Serrano thruster, and it works beautifully {539}. Ventura also hopes to develop a toy kit, with safe power supply, which would allow persons to perform their own successful lifter experiments and perhaps rotary experiments at nominal cost.

8.3.13 Transdimensional Technologies, Inc.

There is also ongoing important propulsion work at Transdimensional Technologies, Inc. of Huntsville, Alabama {540}. Founded in 2000 by its chief scientist, Jeffrey Cameron, the company has developed several novel propulsion and lifting mechanisms. Independent tests of some of these systems have been accomplished by Jean-Louis Naudin, and the results can be seen on his website (previously cited).

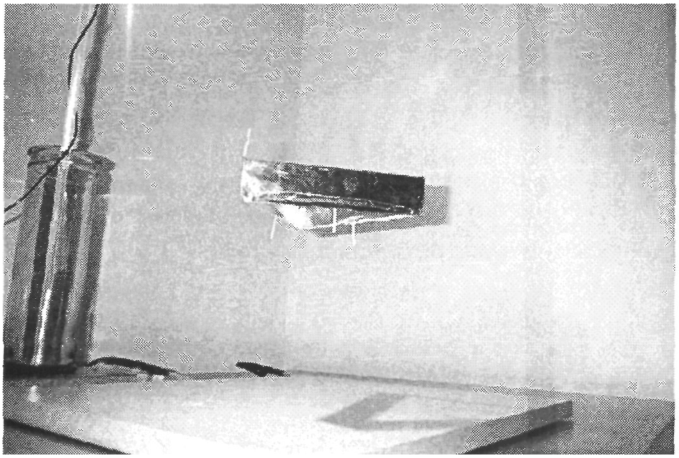

Figure 8-1 Naudin's **replica of the T**ransdimensional Technologies **lifter.**

As we go to press, Transdimensional's most recent propulsion effect is called Power3 (power "cubed"). It uses an asymmetric capacitor to produce the thrust in space, and the principle has been successfully tested in a vacuum. A larger, triangular lifter made mostly of pipe was demonstrated in vacuo to NASA officials in Huntsville, Alabama. Cameron has patents pending on magnetocaloric hybrid rocket engines and asymmetric gravitational waves {541}. A replica of the Transdimensional lifter successfully tested by Naudin is shown in Figure 8-1, by courtesy of Jean-Louis Naudin. Naudin's replica of the Transdimensional Technologies rotational device is shown in Figure 8-2.

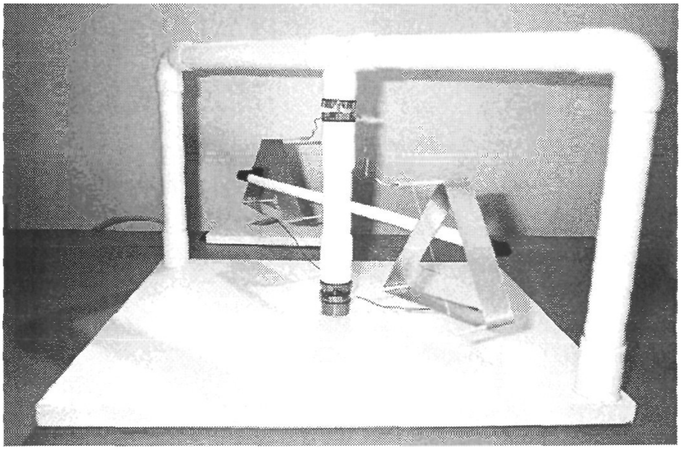

Figure 8-2 Naudin's replica of the Transdimensional Technologies rotational device.

We understand that new Transdimensional Technologies systems, now in patent process and still closely held, represent dramatic advances in the state of the art. The corporation foresees eventual commercial licensing of some of its developments, and the development of practical lift vehicles and space propulsion systems within 3 to 5 years.[226]

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[226] Ken Moore and I personally visited Transdimensional Technologies here in Huntsville, and we found a very straightforward, enthusiastic, and hard-working group. We were treated with great courtesy, so much so that Jeff Cameron graciously cut short his vacation day and came in to show us the lab equipment and give a demonstration. We very much appreciate the work that Transdimensional Technologies is doing, and we certainly wish this fine group outstanding success in their efforts. We also are very appreciative for their courtesy and consideration in showing us the demonstrations and for their cogent discussions with us, which **were** most helpful.

8.3.14 **American Antigravity** (Tim Ventura's Company)

Tim Ventura is a very energetic lifter and antigravity researcher, who has done work independently and for others such as Transdimensional Technologies. The results of his many experiments and replications, tests, photos, etc. are on his website at http://www.americanantigravity.com. He also has several videos showing his testing, as well as detailed instructions for a researcher to build his own demonstration unit and verify the tests. Tim kindly furnished some needed information in this area, and put me in touch with other researchers and websites, which I appreciate.

8.3.15 Jean-Louis Naudin

Jean-Louis Naudin is a tireless researcher in the fields of COP>1.0 systems and processes, and in the field of lifters, inertial thrusters, and possible antigravity systems. His website is a cornucopia of information, patent references, inventions, processes, and replications or replication attempts by Jean-Louis and others who regularly work on such things and communicate with him. The website is http://jnaudin.free.fr/. From there, one may click on the various parts of the site and on the links to other sites to gain a wealth of information on these subjects.

His lifter work, including successful replications and instructions on how to build lifters, can be accessed from http://jnaudin.free.fr/html/lifters.htm, and will keep the interested researcher busy for many productive hours. We especially commend Jean-Louis for his extraordinarily important efforts and for making all this work available to researchers worldwide. Once on the site, one is free to choose from a very wide variety of projects, subjects, etc. The information value of this site is very, very high. We consider Naudin's site to be the single best information site on the web for COP>1.0 system information and for the new space propulsion methodology and effort. Necessary links to other related sites of interest are also provided.

Good hunting!

8.3.16 Other Research Work and Inventions

While we have given a sort of quick overview of work done in this field, there have been many other patents filed by numerous inventors and additional work done by them. This is a dynamic field and it is moving; the biggest problem is that it is still sorely hampered by highly limited funding and an attitude by much of the scientific community that "if it has not been invented here, it doesn't exist".

In the table in Figure 8-3 below, we list some of the pertinent patent numbers for reference, with the emphasis on U.S. Patents. The Naudin website previously referenced has a great deal of information on these thrusters and lifters, including instructions for building and testing several of the simpler proof-of-principle versions. There are links to other sites with even more information. Naudin also includes the results of his successful replication and testing of a variety of these devices and inventions, as well as the successful replication by other experimenters. Naudin also gives construction instructions and information on some of these, so that independent researchers can build test units and test them if desired.

For those researchers interested in pursuing this area further, we would heartily recommend a determined search on the Internet, using Google (www.google.com) as their search engine. A good place to start is Jean-Louis Naudin's web site, and then run the cross-links. The combination will turn up quite an amount of specific material, from which the individual researcher can choose which approach and experimental method he wishes to pursue.

Figure 8-3.

Selected Inertial Propulsion System Patents

T. Townsend Brown, "A Method of and an Apparatus or Machine for producing Force or Motion, British Patent 300,311, Nov. 15, 1928.

Norman L. Dean, "System for Converting Rotary Motion into Unidirectional Motion," USP #2,886,976, May 19, 1959.

T. Townsend Brown, "Electrokinetic Apparatus," USP #2,949,550, Aug. 16, 1960.

T. Townsend Brown, "Electrokinetic Transducer," USP #3,018,394, Jan. 23, 1962.

T. Townsend Brown, "Electrokinetic Generator," USP #3,022,430, Feb. 20, 1962.

T. Townsend Brown, "Electrokinetic Apparatus," USP #3,187,206, Jun. 1,1965.

Henry Wallace, "Method and Apparatus for Generating a Secondary Gravitational Force Field," USP #3,626,605, Dec. 14, 1971.

Henry Wallace, "Method and Apparatus for Generating a Dynamic Force," USP #3,626,606, Dec. 14, 1971.

Fernand Estrade, "Device for Transforming Kinetic Energy," USP #3,807,244, Apr. 30, 1974.

Leo J. Novak, "Centrifugal Mechanical Device," USP #3,810,394, May 14, 1974.

Everett H. Benson, "Inertia Engine," USP #3,863,510, Feb. 4, 1975.

Oscar Mast, "Propulsion System," USP #3,889,543, Jun. 17, 1975.

Arthur N. Lehberger, "Centrifugal Propulsion Drive and Steering Mechanism," USP #3,897,692, Aug. 5, 1975.

Howard A. Gaberson, "Vibratory Locomotion Means," USP #3,916,704, Nov. 4, 1975.

Calvin I. Cuff, "Device for Converting Rotary Motion Into a Unidirectional Linear Motion," USP #3,968,700, Jul. 13, 1976.

Nicholas Joseph Schnur, "Method and Apparatus for Propelling an Object by an Unbalanced Centrifugal Force with Continuous Motion," USP #3,979,961, Sep. 14, 1976.

Calvin I. Cuff, "Device for Converting Rotary Motion Into a Unidirectional Linear Motion," USP #3,998,107, Dec. 21, 1976.

George Knap, "Orbital Propulsion Apparatus," USP #4,087,064, May 2, 1978.

Calvin I. Cuff, "Device for Converting Rotary Motion into Unidirectional Motion," USP #4,095,460, Jun. 20, 1978.

Robert L. Cook, "Device for Conversion of Centrifugal Force to Linear Force and Motion," USP #4,238,968, Dec. 16, 1980.

Ladislaw G. Srogi, "Mechanical Propulsion System," USP #4,242,918, Jan. 6, 1981.

Harry S. Melnick, "Unidirectional Force Generator," USP #4,261,212, Apr. 14, 1981.

Frederick L. Dehen, "Apparatus for Converting Rotary Motion to a Rectilinear Force," USP #4,347,752, Sep. 7, 1982.

Harry S. Melnick, "Mechanical Power Transmitting System," USP #4,398,431, Aug. 16, 1983.

Peter Kleber, "Apparatus for Acceleration-Free Mounting of a Body in a Spacecraft," USP #4,408,740, Oct. 11, 1983.

Fred de Weaver, III, "Propulsion System," USP #4,409,856, Oct. 18, 1983.

Ronald K. Linde, "Centrifugal Reaction Chamber," USP #4,450,141, May 22, 1984.

Fred de Weaver, **III,** "Propulsion System," USP #4,479,396, Oct. 30, 1984.

Joseph Colla, "Mechanical Propulsion System," USP #4,577,520, Mar. 25, 1986.

Elmer M. Dobos, "Propulsion Apparatus," USP #4,579,011, Apr. 1, 1986.

Brandson R. Thomson, "Apparatus for Developing a Propulsion Force," USP #4,631,971, Dec. 30, 1986.

James E. Cox, "Dipolar Force Field Propulsion System," USP #4,663,932, May 12, 1987.

Alvin C. Peppiatt and Alfred J. Peppiatt, "Impulse Drive," USP #4,674,583, Jun. 23, 1987.

Henry North, "Apparatus for Producing a Force," USP #4,712,439, Dec. 15, 1987.

Harry S. Melnick, "Continuous Force and Impact Generator," USP #4,726,241, Feb. 23, 1988.

Oscar F. A. Peterson, "Apparatus for Producing a Directional Unit Force," USP #4,744,259, May 17, 1988.

James D. Mundo, "Universal Propulsion Powerplant and Impulse Drive Unit for Self-Propelled Vehicles," USP #4,770,063, Sep. 13, 1988.

Lancelot I. Kethley, "Gyroscopic Propulsion Device," USP #4,784,006, Nov. 15, **1988.**

Charles Fulop, "Flywheel," USP #4,788,882, Dec. **6, 1988.**

Charles E. Rogers and Fred Van Arsdell, "System for Propulsion and Positioning of a Transitory Object," USP #4,801,111, Jan. 31, 1989.

Paul J. Montalbano, "Conversion of Rotational Output to Linear Force," USP #4,856,358, Aug. 15, 1989.

George J. Zachystal, "Device for Obtaining a Directional Centrifugal Force," USP #4,884,465, Dec. 5, 1989.

James E. Cox, "Dipole Accelerating Means and Method," USP #4,891,600, Jan. 2, 1990.

Hector Serrano, "Propulsion Device and Method Employing Electric Fields for Producing Thrust," WO 00/58623, Oct. 5, 2000.

Brian C. Motts, "Airship," USP #4,967,983, Nov. 6, 1990.

Lyle M. Mason, "Centripedal Device for Concentrating Centrifugal Force," USP #4,991,453, Feb. 12, 1991.

Alexander D. Kidd, "Gyroscopic Apparatus," USP #5,024,112, Jun. 18, 1991.

Paul J. Montalbano, "Conversion of Rotational Output to Linear Force — a Transmission," USP #4,042,313, Aug. 27, 1991.

Andrew T. Rodgers, "Controllable Gyroscopic Propulsion Apparatus," USP #5,054,331, Oct. 8, 1991.

Mortimer S. Delroy, "Gyrostat Propulsion System," USP #5,090,260, Feb. 25, 1992.

Kemal Butka, "Propulsion System," USP #5,111,087, May 5, 1992.

Rex L. Schlicher, Steven M. Rinaldi, David J. Hall, Peter M. Ranon, and Charles E. Davis, "Nonlinear Electromagnetic Propulsion System and Method," USP #5,142,861, Sep. 1, 1992.

Thomas L. Navarro and James D. Isaacson, "Apparatus with Rotatably-Driven Asymmetrically-Accelerated Eccentric Mass for Generating Translational Force," USP #5,150,626, Sep. 29, 1992.

Theordore R. Bristow, Jr., "Method and Apparatus for Converting Rotary Motion to Lineal Motion," USP #5,156,058, Oct. 20, 1992.

John C. McMahon, "Energy Transfer Device," USP #5,167,163, Dec. 1, 1992.

James W. Black, "Non-Linear Propulsion and Energy Conversion System," USP #5,182,958, Feb. 2, 1993.

James R. Taylor, "Electromagnetic Energy Propulsion System," USP #5,197,279, Mar. 30, 1993.

Michael J. Sohnly, "Magnetohydrodynamic Propulsion System," USP #5,211,006, May 18, 1993.

Ross C. Wood, "Stabilization System for a Freely Rotatable Platform," USP #5,256,942, Oct. 26, 1993.

James F. Woodward, "Method for Transiently Altering the Mass of Objects to Facilitate Their Transport or Change Their Stationary Apparent Weights," USP #5,280,864, Jan. 25, 1994.

Robert C. Willis, "Spaceship Propulsion by Momentum Transfer," USP #5,305,974, Apr. 26, 1994.

Harold L. Hull and Donald E. Joslin, "Reusable Mass Propulsion System," USP #5,313,851, May 24, 1994.

Kemal Butka, "Propulsion System," USP #5,334,060, Aug. 2, 1994.

James Harvey, "Impulse Converter," USP #5,335,561, Aug. 9, 1994.

Maurice Mitchell, "Net Kinetic Energy Differential Guidance and Propulsion System for Satellites and Space Vehicles," USP #5,377,936, Jan. 3, 1995.

Howard M. Woltering, "Rotating Eccentric Weights Vibrator System," USP #5,388,469, Feb. 14, 1995.

Richard O. Marsh, Jr., "Centrifugal Force Drive Machine," USP #5,388,470, Feb. 14, 1995.

Kemal Butka, "Propulsion System," USP #5,410,198, Apr. 25, 1995.

Thomas L. Navarro, "System for Generating Controllable Reference Environment and Steerable Translational Force from Interaction Therewith," USP #5,473,957, Dec. 12, 1995.

Richard L. Lieurance, "Centrifugal Inertia Drive," USP #5,488,877, Feb. 6, 1996.

John C. Claxton, "Centripetally Impelled Vehicle," USP #5,557,988, Sep. 24, 1996.

Ezra Shimshi, "Apparatus for Energy Transformation and Conservation," USP #5,673,872, Oct. 7, 1997.

Richard E. Foster, Sr., "Inertial Propulsion Plus/Device and Engine," USP #5,685,196, Nov. 11, 1997.

James D. Booden, "Electromagnetically Actuated Thrust Generator," USP #5,782,134, Jul. 21, 1998.

George J. Howard, "Propulsion System," USP #5,791,188, Aug. 11, 1998.

Timothy J. Stopplecamp, "Boot Strap Propulsion System," USP #5,831,354, Nov. 3, 1998.

Eric Laithwaite and William Dawson, "Propulsion System," USP #5,860,317, Jan. 19, 1999.

Jonathan W. Campbell, "Apparatus and Method for Generating Thrust Using a Two Dimensional, Asymmetrical Capacitor Module," U. S. Patent # 6,317,310 Bl, Nov. 13, 2001. Assigned to U.S. Government.

8.3.17 Mechanism for the Antigravity Accelerating the Universe's Expansion

Finally, in addition to sorely needed better means of space propulsion, one of the real incentives for antigravity research is provided by the search for a source of the now-established mysterious antigravity that is accelerating the expansion of the universe. Elsewhere in this book we have advanced our own proposal for the mechanism generating that *antigravity* effect in the cosmos.

Simply put, a very violent astronomical process may be considered a giant and very violent discharge phenomena, since it first involves a giant excitation followed by a giant release (discharge) of that excitation. All such phenomena involve strong broken symmetry during the discharge itself, with the concomitant strong available of causal 4-sources of negative energy and negative energy fields. These processes — in their causal unobserved state - do produce locally strong negative energy EM fields from the source causal 4-positrons (Dirac sea holes prior to observation as positive mass 3-space positrons having positive energy and reverse-oriented). When the unaccounted and very large Heaviside nondiverged EM energy flow component accompanying every field and particle interaction is accounted, the causal negative "mass-energy" states produce strong antigravity fields, particularly considering the *lower frequencies* of many of the phenomena.

With the long-neglected Heaviside nondiverged energy component considered and not just the accounted Poynting diverged component, the total amount of negative EM field energy available in these violent process is dramatic. Accordingly, just as was the Sweet VTA in its increased power and its ELF pulsations, these giant astronomical sources are also giant negative "mass-energy" sources and strong antigravity sources as well. In short, such astronomical sources produce strong antigravity components repelling each other across the universe. Hence the observed acceleration of the expanding universe; the violent astronomical phenomena are continually "pulsing" the universe with antigravity and hence continually accelerating its expansion velocity.

In 2000, we also published a proposed mechanism for the source of the excess *positive* gravity holding the arms of the spiral galaxies intact {542}.

8.4 The Author's Engineering Approach to Local Antigravity

See again our discussion under Newton, subparagraph 8.2.1 above, and our discussion of a negative field energy extension to it. For a major laboratory, we believe that antigravity is straightforward,[227] if one first produces a COP»1.0 situation in a higher group symmetry electrodynamics process. This provides a very strong "displacement current" of causal 4-positrons (before parity inversion, time-reversal, etc.) as true negative energy "particles" or "states" or "Dirac holes" in the surrounding 4-vacuum. The actual "negative mass-energy field" is very large, due to the unaccounted Heaviside nondiverged negative energy component. Consequently, a substantial antigravity field is established.

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[227] However, this is based on the assumption that the lab team first gives up some erroneous but widely held misconceptions, and really does a little "thinking outside the box" as they are prone to suggest.

8.4.1 Sweet Antigravity Test.

See again our discussion in paragraph 8.3.7. A practical realization of antigravity was clearly shown by the Sweet antigravity test designed by the present author. See previous discussion under paragraphs 6.3.2 in Chapter 6, and see again Figures 6-5 through 6-15.

In Chapter 6, the Sweet vacuum triode amplifier device shown in Figure 6-8 had a very large COP = 1,500,000 at 500 watts output with a 33 microamp, 10 volt operator's input. It had an even greater COP when pushed to 1,000 watts output because of only a slightly greater input.

The Sweet VTA used an induced powerful self-oscillation between the local vacuum and the barium nuclei in the barium ferrite magnets. This resulted in what is called a "kinetic" magnet (and one magnetized through its flat face). In a kinetic magnet, its nuclear magnetic field (in this case, in the barium nucleus) is self-oscillating (waving) in an angle about its local direction, as shown in Figure 6-6 in Chapter 6.

The conditioning was performed with the barium ferrite magnet itself in forced resonance at its resonant condition (some 11 to 12 Hz, in the case of Sweet's magnets). Then the 60 Hz signal was impressed orthogonally to the primary direction of the resonant magnet. After conditioning each of the two magnets, they were placed together on a separation box, carefully keeping the corresponding ends together similar to their original orientation during activation, but in attracting mode (through their face) across the separator. The assembly itself was then further conditioned, again orthogonally to the coupled oscillating fields. This "synchronized" the two magnetic self-oscillations and phase-locked them together in a common self-oscillation with the local vacuum.

Similar treatment of the vacuum as a semiconductor, together with self-oscillation between vacuum and nuclei, has been advanced independently by Prange and Strance {543}, who showed that the vacuum may be regarded as a semiconductor. In particular, they showed that the vacuum in the region close to the nucleus of a superheavy element is analogous to the inversion layer in a field effect transistor. It is similarly analogous for the barium atom, though Prange and Strance do not discuss that element. They introduced the concept of the inverted vacuum. Just as a semiconductor may be manipulated by subjecting it to external fields, doping etc., it appears that so can be the vacuum — along the lines shown by Prange and Strance and along the lines demonstrated by Sweet's conditioning of his kinetic magnets.

8.4.2 Bearden's Proposed Antigravity Mechanism

Any EM process that produces a COP»1.0 condition, such as can be done in intensely abrupt ionic discharges and other processes, will also produce intense causal (4-space) Dirac sea holes in the immediate surrounding vacuum. This is the negative energy mechanism, conceived by the author in the 1970s and finalized in the 1980s, for producing a negative energy causal (unobserved) EM field[228] in the immediate space surrounding a system. The overunity system must be the "source" of that negative energy EM field. So the negative energy EM field in surrounding local space is "attached" to the mass and energy dynamics of the "unit's supersystem" as being its "source or generatrix". Its attachment to the system mass produces the antigravitational force upon that mass.

Negative energy state charges (Dirac holes) are also *source charges.* Prior to observation converting them (as observed) to 3-space positive mass-energy positrons with positive energy and going the opposite direction, they must be accepted as negative energy source 4-electrons "pouring out negative energy" in all directions in 3-space, continuously, via the giant negentropy process for source charges. Since they pour out "negative" energy, we may consider that negative energy field action at any point in 3-space to be a continuous absorption of positive energy from 3-space and a return of that extracted energy to the time domain as increased time — in short, time dilation.

Either way one considers it, the 4-space Dirac holes do produce negative energy EM fields, potentials, and spacetime curvatures and these must be accounted during their existence *prior to observation and interaction.* Further, their accompanying giant Heaviside negative energy flow component must also be accounted. In other words, do not reverse the spatial direction and thus the location and direction of these fields, do not turn them into positive energy fields by such reversal of direction, do not turn the negative mass into positive mass, and do not reverse the sign of the source charge (the Dirac sea hole). All that happens after interaction of the Dirac sea holes with matter, forming the usual lattice holes or *observed* 3-positrons.

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[228] We strongly stress that the continuous, dynamic, ongoing causal 4-field before it interacts with charge and is observed, is a totally different entity from the iteratively and continually observed frozen "effect" 3-field in matter after the 4-field has interacted with charged matter to produce an observation or "event". The great barrier to using electromagnetic fields in practical antigravity application has been due to the substituting, in electrodynamics, of the iterative "effect" 3-field of the observed positron for the continuous "causal" 4-field of the unobserved negative energy 4-electron (the Dirac sea hole). The "effect" 3-field is simply the iterative, continual energy gradient of the diverted EM field energy flow around the assumed intercepting unit charged particle.

Therein lies the magic secret ofantigravity. Instead of thinking of the *fields* interacting on the craft or system that is producing them,[229] think of these negative energy fields interacting upon the *local spacetime surrounding the craft or system, and curving that spacetime negatively. Then* think of this negative curvature of spacetime interacting back upon the craft or system in general relativity fashion. *That* is what will and does produce practical antigravity upon the interacted craft or system, once the Heaviside energy flow component is accounted! But to understand its magnitude and the practicality, one must also account for the long neglected Heaviside nondiverged component.

The mechanism is also consistent with general relativity and Wheeler's succinct statement that mass acts on spacetime to curve it, and curved spacetime acts back on that mass to move it or produce a translation force upon it. We are simply applying that fact of general relativity to produce a local antigravity effect of a locally curved spacetime upon the source system (in this case, the power system itself, which is the source of the negative field energy in the vacuum.

The entire notion of "curvature in spacetime" — and indeed of spacetime itself— is a notion applying *before observation and interaction to produce the observed effect* — i.e., prior to the *d/dt* operation occurring upon an ongoing 4-space process to produce a momentary frozen 3-space snapshot (an observed effect). Think carefully. Wheeler's rule does not mean that 3-space acts back on the mass (actually on the masstime), but that 4-space (spacetime) acts back on it. Spacetime does not exist in the observed object after the application of observation's *d/dt* operation has occurred and until a new causal interaction begins. The *d/dt* operation strips away the time, and hence most of the energy (i.e., all the time-energy) of the spacetime that is to do the interacting.

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[229] The ongoing interaction of the vacuum/spacetime with the source of the unobserved 4-fields is their cause, and the observed 3-fields are the effect. The effect *a priori* does not interact upon the cause! So thinking that "one should make a 3-field in a craft or system that will interact with it and produce antigravity force upon it" is a non sequitur. Instead, one more correctly thinks that "one should make a 4-field *from* a craft or system which will interact with the local spacetime to curve it negatively. Then that negative curvature of spacetime is itself a negative energy 4-field that will interact back upon the observed craft or observed 3-system to produce observed antigravity force upon it.

As source charges, the Dirac sea holes — before observation and in their vacuum state condition — produce a locally curved *spacetime* around the source unit. That induced *(negative energy x time)* curvature interacts back upon the physical system that is the source of the field producing the negative spacetime curvature. It specifically acts upon the mass of the 4-system when it exists as *(mass x time) form.* That interaction produces *antigravity* force and momentum upon the system, rather than *positive gravity* force and momentum[230]. Adding negative EM field energy (in the causal, unobserved state) is precisely the same as adding extra negative masstime, i.e., extra *(-m)t,* since the 4-field is being used in unobserved state.

Using the principle of superposition of fields[231], the external observer sees the "weight" of the unit (the force developed on it by the *net* gravitational field — see again our discussion of the Newtonian approach under paragraph 8.2.1 above) — as being reduced. The intensity of the *negative energy x time (negative angular momentum or negative action)* EM field (including with the Heaviside component accounted) produced by the unit determines the intensity of the antigravity produced, and hence determines the fraction of the unit's weight[232] that is observed to be "lost". See again Figures 6-14 and 6-15 in Chapter 6.

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[230] Note that, if the Dirac hole interacts with the mass lattice of the system, it converts to a "hole" that is attached to the positive mass of an ion. Hence the "observed" positron is said to have "positive mass", which is a non sequitur for the state in which the "positron" exists prior to observation or interaction. The lattice hole 3-positron and the true spatiotemporal "4-positron as still a negative energy 4-electron'" are two very different entities, and their fields and concomitant field effects are very different.

[231] Note that identification of spacetime and field in general relativity extends the notion of superposition of multiple fields to the notion of superposition of multiple curvatures of spacetime. Thus, it is the *net* superposed curvature of spacetime that interacts back upon the physical mass system, to produce gravity (either positive or negative, depending on the sign of the net curvature).

[232] We remind the reader that the "weight" of an object on Earth is a measure of the force developed on the object by the (Earth's) gravitational field. "Loss of weight" is simply "reduction of that net force" due to the combination of the Earth's positive (attractive) gravitational field and the Dirac hole curvature of the object's local spacetime producing a negative (repulsion) gravitational field.

At sufficient intensity of this local negative energy 4-field in spacetime with the unit as its source, the back interaction upon the unit will balance the action of the earth's gravitational field. At that point, the unit will hover and "float" against the force of terrestrial gravity.[233] By further increasing the intensity of the negative energy EM field, the unit will accelerate upward, now being repelled by the local earth more than it is attracted by it. By "angling" the negative energy EM field direction — or by producing a second such negative energy EM field from the source unit as an "angled add on" superposed on the first one — one also provides unilateral propulsion in a given direction.

As can be seen, all the requirements for a practical antigravity vehicle and negative energy propulsion system are met. The only real problem in this approach is the requirement to first attain a COP»1.0 EM power system at ELF frequencies.[234] There is, however, an additional problem of correcting one's thinking to be along the lines indicated.

Antigravity becomes straightforward if one first does overunity discharges or steady output in a system with COP»1.0 and understands the difference between the observed "effect" 3-field and the unobserved "causal" 4-field. Sweet's VTA unit had a beginning COP = 1,500,000 at 500 watts output. The unit was pushed to nearly double its COP, by connecting additional load so that the output was now 1,000 watts. The additional input draw was minimal.

Designing the experiment with that in mind, I convinced Sweet to build a new output load unit, and to perform the experiment. In advance, I roughly predicted levitation of the 6-pound device at about 1500 watts output power, by some back-of-the-envelope estimates assuming a 10% efficient process. The projected curve (again see Figure 6-14 in Chapter 6) shows that levitation would have occurred at about 1250 watts or so.[235]

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[233] Sweet later did push the VTA to hovering and upward acceleration, with the unit on a tether. After he was shot at by a distant sniper, thereafter he was very fearful **and** refused to show many experiments, including the antigravity experiment and particularly its extension to the hover point and upwards acceleration extension. In my opinion he had good reason for his paranoia and his fear for his life.

[234] The reason for ELF frequencies is simple: for the most powerful curvatures of spacetime, one wishes to use EM fields whose photons have the greatest *total* energy (including time-energy). That of course is the lower frequency photons, not the higher frequency photons. So ELF is the way to go, not gamma rays etc.

Here is why we advocate a Dirac sea hole's negative energy field as a practical antigravity inducing mechanism.[236] At COP»1.0, there is a very appreciable vacuum energy density difference between the operator's energy input and the energy output of the system, *particularly when the Heaviside nondiverged energyflow component is taken into account as well as the Poynting energyflow component?*[237] There is a production of negative EM mass-energy x time (causal Dirac sea holes) in the immediately surrounding vacuum. That represents the production of a causal, unobserved antigravitational field (curvature of spacetime) with the system-associated anticharge as its source.

Meanwhile, the Earth's causal, unobserved gravitational field is still normal and unchanged. Now the two causal fields superpose, and interact with the system mass. As seen by the external observer, the net effect is a reduction in the weight of the object — the effect of the interaction of the system mass with the two superposed causal gravitational fields simultaneously.

Reasoning that increasing the COP of the Sweet unit should increase the ratio of output negative energy to output positive energy even further, 1 calculated that doubling the output of the device would result in a sufficiently intense negative mass-energy field in the immediate space around the unit, to approach or reach levitation of the unit. However, as the increasing curvature of spacetime would further increase the deposition of magnetic monopoles in the magnets,[238] at some point the magnets would simply explode like hand grenades if the unit were pushed too far. With no explosive control facilities available, it appeared that doubling the output was the maximum that could safely be done under the circumstances. My own estimate showed that 1500 watts output would be required for levitation, but one dared not go beyond 1000 watts or one would risk a fragmentation explosion and injury or death.

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[235] I strongly warned Floyd not to exceed a 1 KW load, no matter what. In the resulting local curved spacetime surrounding the barium nuclei in the magnets, it appears that magnetic monopoles are deposited or appear. Since these barium ferrite magnets were made by pressed powder metallurgy, they had little tensile or torsion strength, and under sufficient stress they would explode violently like a fragmentation hand grenade. In his little lab (a converted bedroom), Floyd had no explosive facility. He did explode several magnets, but while cautiously remaining some personal distance from the unit as its output was increased. We warn the reader that experimentation with such procedures is at his own risk, and all proper laboratory safety precautions must be utilized.

[236] A provisional patent application has now been filed on the process in 2002.

[237] In a nominal circuit, the unaccounted Heaviside energy flow may be up to 10^{13} times as great as the Poynting energy flow component. This is a completely unaccounted, vast EM energy flow accompanying every field and particle interaction. Hence one can understand why such an energy density for a macroscopic system with COP»1.0, is sufficient to achieve on a macroscopic scale what LaPointe is attempting on a microscopic scale. The total macroscopic scale energy density is so great that the required LaPointe microscopic energy density {535} is present or approached.

I convinced Sweet to build a 1,000-watt output load box, which simply contained ten sockets for ten 100-watt light bulbs. This was a modification to the 500-watt VTA unit shown in Figure 6-8 in Chapter 6. By successively installing the bulbs one by one, the load could be adjusted in 100-watt increments up to 1 kilowatt.

The foregoing is the reasoning behind how I designed the experiment, and the purpose was to show very substantial and smooth weight loss of the VTA unit itself. The experiment was performed in that 100-watt incremental manner, with highly successful results as shown in Figure 6-14 in Chapter 6.

With each 100-watt increase in power output past 500 watts, the fraction of negative energy produced was greater. Hence the unobserved 4-positron fields (Dirac sea hole negative energy fields) were stronger, because there were more unobserved 4-positrons. This meant that the local negative mass-energy curvature of spacetime was increased also.

In turn, this negative curvature of spacetime interacted back upon the mass of the VTA to add negative mass equivalent, or more simply, antigravity force. The observed weight of the unit was the sum of the normal gravitational weight (due to earth's gravity curvature of the local spacetime), and the abnormal antigravity weight (negative weight) due to the antigravity curvature of the local spacetime superposed. So as the fraction of negative curvature of spacetime increased, the net weight of the VTA was observed to decrease.

[238] Contrary to popular opinion, one does meet with effective magnetic monopoles in a magnetic field — including in the magnetic field of a permanent magnet — in a strongly curved local spacetime. The stronger the field, the greater the magnitude of the effective monopole charge.

As stated, Sweet was performing the experiment on the bench in California, and reading the instrumental results over the phone (I was in Huntsville, Alabama) where I recorded them. The spectacular results are shown in Figure 6-14 in Chapter 6.

The high COP (corresponds to gain) of energy density present in the Sweet VTA system's output section — with a greater percentage of it being negative energy — versus input energy one inputs to the input section, is what is important. In short, increasing the load effectively increased the gain, which further increased the ratio of the negative mass-energy to the positive mass-energy. This in turn steadily decreased the observed weight of the object.

Anything outside the system mass of that very high COP system will "see" the weight of the system mass as having decreased. Weight is just so much mass making so strong a *net* G field (spacetime curvature) in the surrounding spacetime. Reduce the *net* G-field that the system mass is normally making (by having it *simultaneously* make the additional antigravity field which then vectorially adds to the mass's normal G-field), and the external observer, external scales, etc. will see the object as having very much reduced its weight.

Positive spatial EM energy density of a system makes positive gravity (as seen by the external observer in the lab frame) because of the way it curves the immediately surrounding spacetime and the way that curved spacetime interacts back on the system's mass-energy. Negative spatial EM energy density makes negative gravity because it curves the immediate spacetime the opposite way. A system under those "high negative energy field" conditions will produce a great deal of antigravity, because the immediate spacetime surrounding is dramatically curved by the negative energy. That was my concept when designing the experiment, and it worked beautifully. So that is how the Sweet device reduced its weight on the bench by 90%, for a 1 kilowatt total output and minuscule input power {544}.

If one were dealing with the source in a flying vehicle system, there is another effect due to momentum. Note that force F is defined as $\mathbf{F} \equiv \partial p/\partial t = +\partial/\partial t\,(\mathrm{mv})$. That is in a positive energy density local spacetime. When an extra negative energy density is added to the local spacetime, then there are two forces, a new one being $\mathrm{F} \equiv -\,\partial/\partial t\,(\mathrm{mv})$ and the normal one being $\mathrm{F} \equiv +\partial/\partial t\,(\mathrm{mv})$. These forces are created by any change in momentum in space containing an extra increment of negative EM field energy.

If the two forces balance, then there is essentially no net centrifugal force produced on the object (or any occupants in it) in a turn. In theory, maneuvers that are far more powerful can be made, without undue G-stress to any occupants inside. This of course remains to be tested in future work and experiments, and so must be taken as a strong hypothesis at present. It could be tested, given availability of the proper COP»1.0 energy system or process on board a test vehicle. Laithwaite's demonstration of the dramatic reduction in force necessary to lift a rotating gyroscope compared to lifting the same heavy gyroscope when not rotating, may have been a partial test of this "inertial resistance decrease" effect.

The Sweet device was the only available COP»1.0 device which could have been used for the experiment. That is why I designed the experiment and convinced Sweet to perform it. Had it not worked, much of what I had worked out for more than a decade would have been falsified — which of course is one of the purposes of experiment: to validate or falsify a thesis. In this case, I breathed a great sigh of relief because — in my view — the spectacular results completely validated my approach to antigravity, and also much of my approach to COP>1.0 systems.

Sweet was never in a position to be able to go with this to the scientific community. The VTA was completely fouled legally, by various entangling agreements Sweet had made with different backers, without ever changing or resolving any previous agreement. Also, he realized that his life really was in danger should he try to take the system openly to the scientific community. Consequently, he never tried and in fact adamantly turned all further work away from the antigravity effects.

Aging and rather defenseless, Sweet also began playing all sorts of games to prevent having to have the project validated independently, even for its COP>1.0 capability. He was mortally fearful of being killed if he had it resoundingly validated. He was motivated by the necessity to survive and not be killed, and he firmly believed that any such attempt for full scientific validation and open publicity would absolutely guarantee his quick death. His fears appear to have been well founded.

His most carefully guarded secret was his activation process for the barium ferrite magnets, which he guarded with his life. He also began telling different persons all sorts of different stories and "mechanisms" for the activation, which were clever ruses and disinformation designed to throw them off the true trail and prevent his activation secret from being uncovered. I made a personal videotape of the activation process, or what he released of it, before he began such disinformation. So we do know much of the activation process, though not all of it.

Eventually, with changes in backers yet once again, Sweet died and never revealed the full secret of strong self-oscillation activation in permanent magnets to anyone. I knew and know part of it, even most of it, but still not all of it. What I understand about it has been briefly included in this book. From there, the interested researcher must find his own way.

The VTA was real, my gravitational mechanism is real, and — in my opinion — validated. However, it has not been *independently* validated in formal order, which is the proper scientific requirement. I did try very hard to convince Sweet that we should take this to the leaders of the scientific community and have it independently verified (e.g., by UCLA), but he would not hear of it after the assassination attempt. By that time, he was so afraid from the constant threats and constant stalkers that he had totally decided against any such releases. He also would not permit it to be taken to a major scientific conference and demonstrated, even though several scientists and engineers knowledgeable and experienced in measurement engineering did measure and certify the device's operation. But they were never allowed to see it in the antigravity mode. He would not discuss it with them, and he would not allow it.

Sadly, with the death of Sweet there passed away the VTA and its major secrets. I regard the VTA as one of the great scientific accomplishments of all time, and I regard Sweet as one of the most capable lab experimenters I ever met and one of the greatest inventors I ever met. The loss of the VTA and the absence of its full, independent scientific testing and validation were in my opinion two of the greatest losses to science of all time.

8.4.3 Discussion

Particle physicists speak of antimass and antigravitational field, but do not speak of anti-electromagnetic field and do not like negative mass. Antimass is actually "anti-mass-energy". When did one hear any scientist speak of a *negative energy* electromagnetic field or *negative energy* force field (except possibly as a hypothetical "tractor beam")? Or a *negative energy* electrical or magnetic potential? Yet the EM fields from an accumulation of Dirac sea holes (causal state) as a source charge are precisely negative energy EM fields. The EM potentials from an accumulation of Dirac sea holes are precisely negative energy potentials. Further, these fields and potentials produce opposite curvatures of spacetime as compared to positive energy causal EM fields and potentials from conventional source positrons and electrons.

Conventionally, scientists speak and think of *the positive energy* electromagnetic field. In our view, they do not apply the implications of the negative energy state part of the Dirac 1930 electron theory {545}, because of a built-in horror of negative mass (and antigravity!). Recall again our discussion of Laithwaite; a promising career was cut down in mid stride because he "mentioned the unmentionable": antigravity and possible failure of Newton's laws (they *do* fail in a curved spacetime!). His exhibiting to the Royal Society a very heavy gyroscope, very difficult to lift when placid, but easy to lift with one arm when spinning, was the final straw. The British scientific community simply cut him down and ostracized him from the rewards and positions he would otherwise have been given.

To conceal the relationship of the negative energy fields, hide negative mass, and pretend it does not exist, much scientific effort is exerted to consider the positive energy, positive mass positron *only after it has been observed.* So scientists can assign this "observed" 3-positron a positive mass and positive energy but with spatial direction reversal. That immediately moves to an *effect* field and an *effect* positron, not a causal field or a causal Dirac sea hole. It effectively eliminates the antigravity field of the negative mass of the unobserved negative energy Dirac electron, which is produced by the *causal* (unobserved) Dirac sea hole's electromagnetic field, not the *effect* (observed) positron field which then is "seen" to have positive mass but with field direction reversed.[239]

The positron is quite a different beast before it is observed, just as is a mass (and just as is any other observable, and just as is a field). For one thing, the positron before observation and the positron after observation have different dimensionalities; the unobserved causal entity is 4-spatial and continuous,[240] while the observed effect entity is continually and iteratively 3-spatial. Mass before it is observed exists as masstime, not mass.

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[239] Note also that the causal field, being unobserved, is a 4-field, while the observed (effect) field is a 3-field. By reversing the parity, one has made the antigravity field **into** a gravity field, by substituting the effect for the cause and erroneously using the old non sequitur of a separate 3-force acting upon a separate 3-mass. Also, when one reverses its spatial direction, one converts a *positive* gravity field into an *antigravity* **field.**

[240] Along with Bohm, we point out that — strictly speaking — in 4-space one does not have "things", but only "processes". To speak of a "4-space field" is to redefine the field as an ongoing process, rather than as an observed frozen 3-snapshot or "3-thing". The solution to the long-vexing duality problem is there, but we leave its solution to the reader. It is necessary to extend Aristotelian logic itself if one is to resolve the duality problem.

Simply consider the delayed choice two-slit experiment and Wheeler's famous comment that no phenomenon is a phenomenon until it is an observed phenomenon. Once the observation occurs, one can even change the "if it had been observed but was not" previous past. One gets the magic from the delayed choice two slit experiment without the observation, and then by making the observation such that the "magic" is not revoked *after the fact.* The whole experiment proves that, if one insists on applying the observation, one kills the magic, even if one thinks the magic has already occurred and must have already occurred, but it has not been *observed* to have occurred.

Causal 4-spatial "things" are not things at all, but are ongoing processes and their cessations have not "occurred" to yet produce a "thing"! The *observed* event is 3-spatial and has occurred. It is something in the past, not the present. That is different from something ongoing (happening or unhappening)[241] in 4-space, before having been observed and therefore a frozen snapshot taken in 3-space. As is well known in quantum mechanics, observation is a physical interaction and it indelibly changes and stops the "ongoing 4-process", converting it to a momentarily frozen "3-thing" as an effect of the observation process at that particular instant. So any "thing" is continual and iterative, *not continuous,* in its travel through time, and in its "observed existence in 3-space".

Because of such, physicists also have difficulty realizing that mass — being an observable — does not and cannot exist continuously in time. It cannot even *continuously exist!* No observable can. Masstime exists in time, but mass does not, as we previously discussed. Observation is a *dldt* operator imposed upon an ongoing 4-space process, destroying the time portion and producing an instantaneous, frozen snapshot at that instant. It's just *d/dt* (LLLT) => LLL. That is why all observation is 3-spatial, as is well known in physics. We long ago pointed out how the common photon interaction — the total photon interactions (both virtual and observable) with a mass — is what drives the mass through time, so to speak {15}. But it does it iteratively, frozen snap after frozen snap —just like progressively showing the frames of a movie film.

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[241] When a frozen instant 3-space snapshot (observable) interacts with a second causal process to generate another frozen snapshot (observable), the first observation "unhappens" because it is thereby moved into the "past", disappearing from 3-space forever. With every change of an observable (with every observation), even if the new effect appears identical to the previous one, it is still a *new* observable (a new effect) where a former effect "seems" to have recurred (been created, happened). Even if it is spatially the same as the previous observation output, it is at a different point in time and hence is the result of the *d/dt* observation operator being iteratively applied. The serial outputs — even of what we loosely call an "entity existing in time with no 3-space change" — are *successive and different* serial outputs from a serial time-differentiating process.

What really has to be changed is the old notion by Heaviside and Poynting that 3-energy propagates continuously through 3-space.[242] No observable can propagate continuously in 3-space, but only in 4-space and then only during its nonobservable state! So a "mass propagating through time" (i.e., just sitting still and "existing", so to speak) is doing so in an iterative fashion by recurring iteratively in observation output at the same spatial position. The mass turns to masstime, then to mass, then to masstime, etc. Or m_1 => m_1t => m_2 => m_2t => $m_3\ldots$ etc. In short, *observation continually recurs at an enormous rate,* so *an observable (effect or output of that observation process) continually recurs at an enormous rate,* destroying the previous observation as the next one occurs.

Because of the history of thinking in 3-space terms rather than 4-space terms, one of the ubiquitous errors widespread in physics is the substitution of the effect (the frozen output of the observation process) for the cause (that 4-space initiator process which continuously exists prior to observation, hence unobserved). So causes (4-space initiators which are unobservable a priori) interact with a previous "frozen 3-space snapshot" or observable, to produce a change (either a temporal change or spatial change or both) in or to or of that observable (that 3-snapshot) to a new observable (3-snapshot). If the object is seen to iteratively change in time but not position or form, it is said to "exist" or "persist" at rest continuously in time. It doesn't. It *continually recurs*[243] in that form, but does not *continuously exist* in that form!

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[242] And also the hoary old mistaken notion that the "same observable thing" can continuously exist in time or persist.

[243] More rigorously, the continual recurrence is at the quantum level. So a larger mass or other observable actually is a great horde of very small "continual recurrences" of tiny incremental pieces of itself. At any time interval of observation via observable photons, a vast number of nonobservable (virtual) "continual recurrences" occur in the "observed object". In short, the "observed object" is the **end** summation and result of a vast number of infinitesimal changes. Hence the entry of statistics and the uncertainty principle. Each one of the infinitesimal

The antigravity mechanism has been implicitly present in the Dirac theory of the electron since his 1930 paper {497}, where he brought forth the Dirac sea and the anti-electron, if the *causal* Dirac sea negative energy states are applied to general relativity before they interact with charge and are "observed". General relativity deals with spacetime and spacetime curvature. Therefore, it is concerned with causal 4-fields, 4-potentials, and 4-waves in 4-space prior to observation.

As we stated previously, there is really no such thing as a "3-space EM wave", e.g., as rather strongly pointed out by Romer {546}.

One can produce and have an EM field of *negative* EM energy in spacetime, coming from the 4-positron charges of the anti-charged mass of a system, as well as one can produce and have an EM field *of positive* EM energy in space, coming from the charged mass of a system. But negative energy EM fields have been swept away from our minds by interpreting the negative energy 4-electron as the 3-positron, after the negative energy 4-electron has interacted with charged matter (been observed as the *effect),* rather than how it exists in spacetime prior to observation (as the *cause).*

So physicists reverse the direction and the charge, and make the mass positive, which is how the Dirac sea hole is "seen" *after observation.* That makes it a material lattice hole and a special kind of positive ion. Before observation, it is not seen at all, but it exists as negative action (energy x time) and therefore in "negative masstime" state form. Before it has been observed, it's still there in spacetime, as a curvature of spacetime. It's just a *negative energy state curvature* in the vacuum/spacetime.

Make lots of these negative mass-energy state Dirac holes from a source system, such as one producing a very powerful negative energy EM field, and voila! That's it. The system is producing — and surrounding itself by — its own negative energy EM field (negative curvature of 4-space), which is also its own local antigravity field. That antigravity field superposes with the prior local curvature of spacetime, altering it. The *net* curvature of local spacetime is itself a field which interacts back upon the mass system to produce "net gravity" whose sign may be positive or negative, depending on the sign of the net spacetime curvature. If the two back-acting curvatures of spacetime are opposite and equal, that represents the source object existing in a zero gravitational field, and thus "hovering" in the Earth's gravitational field, for example.

changes may be modeled causally, but since there is no individual information available on each one of them, they can only be calculated statistically.

The use of negative energy EM fields and Dirac sea holes to alter the curvature of the local spacetime in a negative direction provides the present author's engineering approach to practical antigravity. Note that our approach gathers in the gist of both of the major two approaches to antigravity: (1) the shielding theory as typified by Modanese {547}, and (2) the opposing force theory as typified by Ling Ni and Torr {548}. The opposing force, considered as a field that is identically a curvature of spacetime, is also a "gravity shielding" force via superposition of fields. We state unequivocally that a theoretical model of the new approach can be constructed from Sachs's theory {510}, and implemented in the 0(3) electrodynamics of Evans and Vigier {549}. Further, it is a directly engineerable theory, without the necessity for superconductivity, spinning wheels, etc. as demonstrated by the highly successful Sweet experiment previously discussed.

We quote Evans {550}, on the appearance of the B(3) field in general relativity, to indicate the nature of such a future theoretical model:

> *"I have chosen a metric that gives circular polarization (as observed), but in the framework of general relativity using the irreps of the Einstein group according to the Sachs theory. This is a closed field theory which is analytical, using a Lie group, the Einstein group. As such there are no particles, only spacetime curvature, so everything in physics reduces to spacetime curvature, i. e. to a metric vector and its components. This is then incorporated in the Sachs theory to produce a metric four-vector which is a generally covariant component of a quaternion-valued metric with sixteen components, the most general form of the metric allowed by general relativity and topology. The Einstein-Sachs equations for electromagnetism are six metrical equations in six unknowns, the components of an antisymmetric field tensor of electromagnetism. By choosing a metric that corresponds to circular polarization,* $B^{(3)}$ *appears automatically.*
>
> *This method gives the* $B^{(3)}$ *field from Einstein's theory of general relativity applied to electromagnetism by a consideration of the irreps of the Einstein group. It follows that whenever the conjugate product* $-gA^{(1)} \times A^{(2)}$ *is observed, the* $B^{(3)}$ *field must also be observed, otherwise general relativity fails. Examples of*

> *the $B^{(3)}$ field at work are the inverse Faraday effect and RFR [Radiatively induced fermion resonance]. "*

Evans and the AIAS have already taken the first theoretical steps showing that antigravity does indeed arise from Sachs's theory {551a-551c}.

We are convinced that practical antigravity only occurs at extremely low frequency (ELF) for reasons[244] explained previously. Certainly that seems to be true for our approach to it. The highest "total energy" photon is the low frequency photon with low spatial energy and a larger time increment. The larger time component has the same energy density as mass. So one multiplies the time component increase (in seconds) by roughly $9x10^{16}$ to get the increase in spatial energy equivalency. Halve the frequency of a photon, and one increases its *total energy* by $4.5xl0^{16}$ {552}.

High energy physicists have not realized that the time component of the photon has enormously more energy than the spatial component, and that low frequency photons contain enormously more trapped energy than do high frequency photons. So they largely ignore the time-energy component, focus on the spatial energy component, and erroneously consider *high energy* physics as *high frequency* photon physics. Instead, present high frequency photon physics is only a high *spatial* energy physics, not a high *total* energy physics at all. Today's high energy physics is really still a very low total energy physics, compared to what can be done with the time-energy component of the photon rather than its spatial-energy component. By transducing and using the highly compressed time-energy, experiments can be done on the lab bench with fairly simple and cheap equipment, that actually utilize *higher total energy nuclear reactions* (though at low spatial energy) than are presently obtained in the largest accelerators.

That is also why there is presently no understanding in the conventional community of the "low spatial energy transmutations" of cold fusion, where the experiments unwittingly use the high time-energy component. The scientific community has not even recognized the time-energy aspects, and has not recognized that time-energy physics is an ultrahigh total energy physics, where the present "high energy physics" is tame by comparison.

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[244] Dramatic increase in the magnitude of the time-component, hence an enormous increase in the time-energy component with only a small decrease in the spatial energy component total energy of the photon. The *total energy* thus dramatically increases, when the spatial energy equivalent of the time-energy is considered. The present conservation of energy law in physics is inadequate because it does not account time energy at all; thus completely discards the most fundamental EM energy mechanism of all: the giant negentropy of source charges and source dipoles.

The previously unknown time-energy induced transmutation interactions are the precursors to, and the opening salvo of, a new *ultrahigh total energy physics* struggling to be born in spite of the adamant opposition of the conventional scientific community. Allowing for the time-energy component, for the mechanism generating the flow of time, and for formation and decay of time-reversal zones, we previously wrote the exact new nuclear reactions for the production of the excess deuterium, tritium, and alpha particles {553} in numerous cold fusion experiments. We also explained the highly anomalous nuclear instrument effects — due to (i) time-charging, (ii) the slow decay of time-charge with radiation of Whittaker longitudinal waves, each accompanied by its phase conjugate twin time-polarized wave, and (iii) the previous time-charge history of the instrument. These puzzling anomalies have been observed at U.S. Navy research facilities at China Lake now for some years in rigorous electrolyte experiments {198}. We summarize that work in Chapter 10 of this book.

With a little effort and development, practical antigravity appears to be straightforward for any good modern laboratory. But the lab physicists should first (i) rethink the entire subject, from its very fundamentals, to include considering the positron before observation and not after observation, (ii) remove the Lorentz symmetrical regauging from electrodynamics and recover the presently missing COP >1.0 and COP»1.0 Maxwellian systems again, and (iii) rapidly develop COP»1.0 systems and processes to use in antigravity experiments and development. At least in this approach, the COP»1.0 EM systems — once developed — are an immediate gateway to practical antigravity devices, unilateral thrust propulsion systems, and antigravity vehicles. And of course they are the immediate gateway to practical transport vehicle power systems, fuel-free, clean, and self-powering.

Hopefully, such a scientific reassessment will be performed, and it may provide the gateway for practical transportation and travel to the ends of **the** solar system and beyond, to be achieved in the first two decades of this century.

8.5 In Conclusion

We have briefly reviewed the presently developing field of inertial space propulsion and antigravity, and presented our own approach to practical antigravity as well as an informal experiment that strongly supported that approach. We have strongly stressed that the causal field from the system as its source constitutes a curvature of the local spacetime superposed upon the pre-existing local spacetime curvature. Instead of thinking of that causal field from the source system as acting back upon the source system, we have stressed thinking of that *net superposed curvature of local spacetime* acting back upon the source system and producing a net gravitational force upon it. That net gravitational force may be either positive or negative, or zero, depending upon the sign of the net curvature of spacetime that is interacting back upon the system.

We presented and explained the results of the Sweet VTA antigravity experiment as probable verification of our approach to antigravity. Nonetheless, we also emphasized that the formal independent replication required by the scientific method has not been accomplished, and it remains to be accomplished before the approach is to be considered as scientifically validated.

We believe that this approach to antigravity can be modeled and engineered by use of the Evans-Vigier O(3) electrodynamics as a subset of the Sachs electrodynamics that is a part of the Sachs unified field theory.

If so, then tentatively we have laid out the basis for eventual practical antigravity systems and a practical antigravity technology. We fervently hope that this approach will in fact lead to practical technology and working transportation means during the next decade.

Finally, we hope that these notes and concepts will stimulate many sharp young graduate students and post-doctoral scientists to examine, model, correct, and greatly enlarge the ideas and principles advanced. If so, then the purpose of this chapter will have been realized.

Chapter 9

The Supersystem and Remarks on Gravity, Antigravity, and Testing

"What might appear to be empty space is, therefore, a seething ferment of virtual particles. A vacuum is not inert and featureless, but alive with throbbing energy and vitality. A 'real' particle such as an electron must always be viewed against this background of frenetic activity. When an electron moves through space, it is actually swimming in a sea of ghost particles of all varieties - virtual leptons, quarks, and messengers, entangled in a complex melee. The presence of the electron will distort this irreducible vacuum activity, and the distortion in turn reacts back on the electron. Even at rest, an electron is not at rest: it is being continually assaulted by all manner of other particles from the vacuum." [Paul Davies] {554}.

"Space acts on matter, telling it how to move.. In turn, matter reacts back on space, telling it how to curve." [Wheeler's principle] {555}.

"...the Aharonov-Bohm effect is a local gauge transformation of the true vacuum... [which] produces a vector potential from the true vacuum. [This gauge transformation] produces topological charge..., the electromagnetic field, which carries energy, and the vacuum charge current density first proposed by Lehnert... and developed by Lehnert and Roy... ". [M. W. Evans and S. Jeffers] {556}.

"The energy density (En_d) in curved spacetime

is given in the Sachs theory by the quaternion-valued expression

$$En_d = A_m j_m^* \qquad [1]$$

where A_μ *is the quaternion-valued vector potential and* j_m^* *is the quaternion-valued 4-current as given by Sachs ...Equation [1] is an elegant and deeply meaningful expression of the fact that electromagnetic energy density is available from curved spacetime under all conditions; the distinction between field and matter is lost, and the concepts of "point charge" and "point mass" are not present in the theory, as these two concepts represent infinities of the closed-field theory developed by Sachs from the irreducible representations of the Einstein group. The accuracy of expression [1] has been tested to the precision of the Lamb shifts in the hydrogen atom without using renormalization of infinities. The Lamb shifts can therefore be viewed as the results of electromagnetic energy from curved spacetime."* [Myron W. Evans] {557}.

"Old habits of thought die hard, and it is not always easy to remember that a particle with negative mass if pushed to the right will move to the left; or that in a given reference frame a particle with imaginary mass can have infinite speed, in which case its energy is zero." .... "... extremely powerful energy sources may occur if particles of negative mass really exist in nature." [Banesh Hoffman] {558}.

"The observed (3-spatial) positron is a quite different entity from the unobserved (4-spatial) Dirac hole. Its direction has been reversed, and its mass and energy have also been reversed. Before the 4-spatial hole in the vacuum has interacted and been observed, it has negative energy and therefore negative mass equivalency, as well as negative charge. As a source charge, it also is the source of negative energy fields and negative energy potentials — all in the

nonobservable 4-state." [T. E. Bearden, private communication to a correspondent, 2001].

"The...visible structure of orthogonal' 1-networks possessing coupled open-paths and closed-paths represents only an introductory step in the development of a correct topological theory for conventional electric networks...An electric network is like an iceberg...Its visible portion is only a small fraction of the submerged invisible structure." [Gabriel Kron, who developed special tensor methods and diakoptics to deal with the large number of visible and invisible multidimensional p-networks surrounding the branches of every electric circuit.] {559}.

"...symmetry implies conservation. Since our entire edifice of interactions is built on symmetry assumptions, there should be as a result a large number of conservation laws. The only trouble is that almost all of these conservation laws have been violated experimentally."... "...this difficulty could be resolved by introducing a new element, the vacuum. Instead of saying that the symmetry of all matter is being violated, we suggest that all conservation laws must take both matter and vacuum into account. If we include matter together with vacuum, then an overall symmetry could be restored" [T. D. Lee] {560}.

"One perhaps oversimplified way to deal more conventionally with the new unified field approach to electrodynamic systems is to utilize the notion of the 'supersystem', comprised of three components: (I) the ordinary EM system and its dynamics—conventionally assuming flat spacetime and inert vacuum, (2) the local nonlinear vacuum and its dynamic interactions with the system and with spacetime, and (3) the local curvatures of spacetime and their dynamic interactions with the system and with the local

> *active vacuum. In the rich feedforward and feedback interactions that result, there emerges a dramatic new physics, new electrodynamics, and new chemistry including a new biochemistry. This is in fact a much simplified conceptual approach (good to 'first order', so to speak) to the multinetwork and multipath work of Gabriel Kron. It also allows the retention of symmetry, considered so necessary to particle physicists. "* [T. E. Bearden, private communication to a correspondent, 2001].

9.1 The Supersystem and Its Considerations

In classical electrodynamics, the Maxwell-Heaviside-Lorentz equations implicitly assume a local flat spacetime and no net action by the vacuum {561}. Both these implied assumptions are false. All real EM systems involve interactions with both curvatures of spacetime and the active vacuum. Yet to try to include both additional interactions requires a unified field theory approach, such as that of Sachs {562}. Unfortunately, any unified field theory is replete with quite difficult mathematics, little of which can be illustrated pictorially or simply.

What is required — at least for most electrical engineers and applied electrical scientists — is a conceptual way of visually thinking about the EM system in a way that is consistent with unified field theory to something like first order, but which can also be conceptualized easily.

9.1.1 The Supersystem Concept

Accordingly, we introduce a new and very simple way of thinking of electrical circuits in terms of a unified field theory. We utilize the notion of the supersystem, consisting of three components: (1) the EM system and its dynamics, considered in conventional fashion (as if the local vacuum were inactive and the local spacetime were flat but perturbed), (2) the local interactive vacuum and its dynamics, and (3) the local curvatures of spacetime and their dynamics. All three components of the supersystem interact. This produces both feedback and feedforward functioning; e.g., energetic changes in the system produce corresponding changes in spacetime curvatures. In turn, the alterations in spacetime curvature produce nonlinear changes in the active vacuum, which in turn acts back upon the system. So every action in a system produces a corresponding set of feedforward and feedback reactions from and with its complex environment, and vice versa.[245]

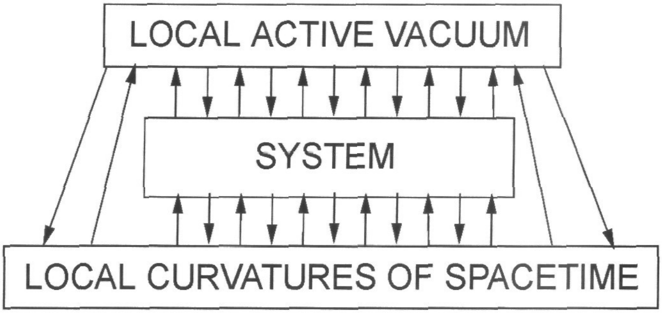

Figure 9-1 The Supersystem concept (block diagram).

Figure 9-1 shows a diagrammatic illustration of the supersystem concept. Figure 9-2 illustrates the effect of the classical EM assumptions of a flat spacetime and a locally inert vacuum. As can be seen, the classical assumptions *arbitrarily discard the* interaction effects upon and in the system due to the active vacuum dynamics and due to the local spacetime curvatures and their dynamics.[246]

As stated, all three components of the supersystem interact with each other. This is a dramatic change to classical U(1) electrodynamics. Hence the total interactions — with the system — of both the active vacuum and the locally curved spacetime, and their interactions with each other, are more general than either classical EM, general relativity, or the quantum mechanical vacuum of particle physics prescribes individually.

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[245] We hypothesize that the feedback contains the mechanism generating Newton's third law as a restoration of symmetry, but leave that to the master theorists to explore and decide.

[246] As one example, the nondiverged Heaviside component of energy flow — previously discussed in earlier chapters — is part of the supersystem activity. This **flow** alters both the local active vacuum and the local spacetime curvature associated with an electrical power system and its connected external circuits. Since the resulting local "environmental" changes in the supersystem are extensive, then one can conceive ways in which these changes can be interacted with additional intercepting/receiving systems to produce extra "EM energy from the vacuum".

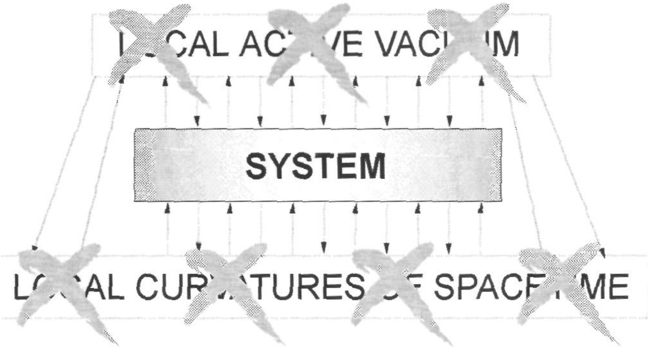

Figure 9-2 Classical EM destroys two-thirds of the supersystem.

Immediately it can be seen that the concept of energy from the vacuum is a "supersystem active and not negligible" concept involving a unified field theory approach *a priori.* It can also be seen that a "system" in equilibrium must be in equilibrium with its active environmental exchange — its exchange with the active local vacuum and the active local curvatures of spacetime. Since energy "exchange" with the system means both incoming and outgoing exchange, it follows that the equilibrium system has equal incoming and outgoing energy exchange. It follows that the symmetrically regauged system has equal incoming and outgoing energy, and so the symmetrically regauged system must be in additional stress from two net equal and opposite direct interaction forces, one general relativistic and the other from the active vacuum. Further, this "equal and opposite" equilibrium stress state must be accompanied by equal and opposite interaction effects between the two environmental media of the system.[247,248]

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[247] We point out but do not pursue the fact that this is a very important new concept associated with *coherently* changing the symmetrical regauging, which allows a new physics, a new electrodynamics, and a new chemistry including biochemistry. For one thing, it permits such things as a self-maintained excitation state that simultaneously continuously discharges its excitation energy. This is simply a redefinition and more general broadening of the "source charge" concept. From the normal system view (assuming away the vacuum and curved spacetime interactions), an "impossible" system state can nonetheless be possible and stabilized, by changing the *intensity* of the Lorentz regauging condition. As an example, new molecules or ions can be made and stabilized in an excited state, that otherwise would be so unstable that the excitation would decay in a nanosecond with the state disappearing also. We believe this alone will lead to a great new biochemistry and medical

9.1.2 Time and Space Effects and Positive and Negative Energy

From curved spacetime considerations, we must include the effects on the system, and on the vacuum, of dynamics in the *time* domain as well as in the *spatial* domain. Indeed, in Sachs's theory space and time do not separately exist, but only spacetime. We consider time as highly compressed EM energy — as heretofore pointed out, where time is spatial EM energy compressed by the factor c^2 and having energy density similar to mass. We must include not only EM *energyflow* along the time-domain (fourth Minkowski axis *ict),* but also EM *force, potential, energy oscillations*, etc. in the time domain itself. We shall have to deal with time-force, time-energy, time-potential, time-energy current, longitudinal EM waves in the time domain (time-polarized EM waves), etc. {563}. The complexity of the full supersystem analysis is thus easily seen and appreciated. In most cases, a higher group symmetry model for a particular situation will prove intractable for closed solutions, and numerical methods must be used.

Further, when curved spacetime interacts with the active vacuum, we shall also have to consider *negative energy* currents in the nonlinear vacuum itself, as well as in the time-domain. We may also speak of the *negative energy density* in the vacuum as a special kind of negative energy *potential* in the vacuum that is created by a negative energy potential in the time domain. We may speak of a gradient in this vacuum negative energy potential as a negative energy force or "force in the negative energy domain". Applied to the time domain, these concepts constitute a causality condition placed on the Dirac sea, in the same vein as more technical causality considerations given by Finster {564}.

9.2 Differences between Effects in COP»1.0 and COP<1.0 EM Systems

In this chapter, we utilize the Dirac hole in a different manner from the received interpretation. The received interpretation assumes an electron hole in the vacuum, with the hole filled with a negative energy electron

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therapeutic science; one company is already working in this area, with positive results.

[248] We leave to the advanced theorists the connection between this "stable equilibrium state under a change in symmetrically regauged stress", occurring as a *net-force-free* intensity change in the conventional Lorentz symmetrical regauging of the Maxwell-Heaviside equations.

having negative mass, negative energy, and negative charge. In that interpretation, when the electron is lifted out of the hole, the hole is said to be *a positive energy* electron with positive mass and positive charge, (i.e., when interacted and observed). In short, with reaction one has a complete transformation of negative energy into positive energy, negative mass into positive mass, etc. In our view, this totally destroys the notion of "how the hole exists in the vacuum prior to its interaction and observation". That kind of positron only occurs after a physical interaction and observation has occurred — in short, *the positron exists only after an interaction with the Dirac hole has been made, to change the very nature of the negative energy hole.* The positron is the 3-effect of an invoked extra 4-interaction, and is not at all the "negative energy electron" or hole as it actually exists prior to being interacted and transformed. The positron is a different beast from the beast we wish to harness and use. The conventional interpretation leaves the question of the unobserved and unreacted "hole" left behind by an electron lifted out of the hole, before another interaction is performed on the hole to change it. So it is an incomplete accounting (as all observations are).

In our interpretation, the Dirac "hole" in the vacuum is itself the true negative energy electron before its interaction and observation. It is the "causal" 4-space negative energy electron, while the received interpretation is only for the "observed" or "effect" positron. In our view, the received interpretation thus leaves out a goodly part (and the most interesting part) of the Dirac sea hole. When the negative energy hole is filled, we consider the *electron* in the hole to be a normal, positive energy, positive mass electron. Hence the summation of the energy of the filled hole is zero, as is its summation mass and its summation charge. This accords with the properties of the "normal" vacuum, said to contain a sea of such "filled Dirac holes".

Our purpose is to use *emptied* Dirac sea holes before their interaction or observation, and thus to use them as *causal 4-electrons having negative mass and negative energy, but where each of those quantities is multiplied by time. So the hole has negative masstime and negative action.* Unless otherwise stated, that is our interpretation of a Dirac sea hole, and that will be how we use it. This way we avoid having to replace a true negative energy, negative mass, positive charge causal (unobserved) 4-electron by a positive energy, positive mass, positive charge observed (effect) 3-electron. We do not just artificially "dispose of" the question of the "nature of the hole that is left behind" when the positron is observed. We consider the (hole x time) as the fundamental negative energy 4-electron. We will sometimes refer to that as the "4-positron".

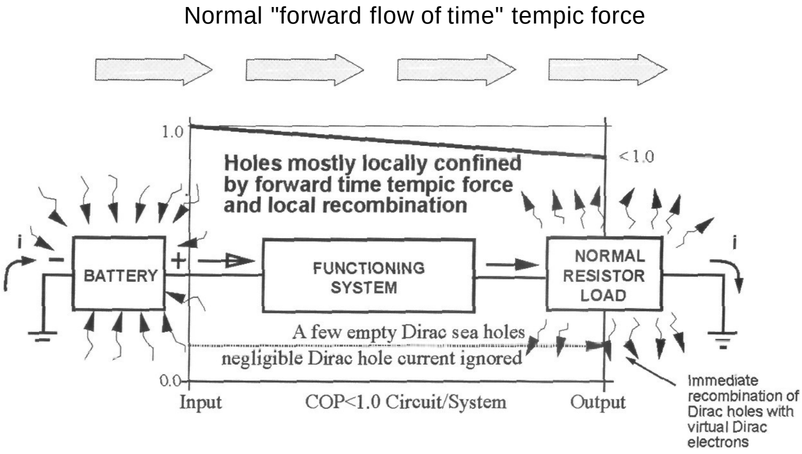
Normal "forward flow of time" tempic force
1.0
<1.0
Holes mostly locally confined by forward time tempic force and local recombination
i
-
BATTERY
+
FUNCTIONING SYSTEM
NORMAL RESISTOR LOAD
i
A few empty Dirac sea holes
negligible Dirac hole current ignored
0.0
Input
COP<1.0 Circuit/System
Output
Immediate recombination of Dirac holes with virtual Dirac electrons

Figure 9-3 Time potential gradient across a C0P<1.0 EM system.

See Figure 9-3. In a COP<1.0 EM system, the tempic potential gradient (tempic force) is oriented from input to output and on out beyond the system. A very slight Dirac hole current moves outward from the output, but is immediately "eaten" by the virtual electron flux fluctuations of the vacuum in the space immediately adjacent to the output. There is a slight Dirac hole current also exiting the system in its losses, but again these are immediately "eaten" by the virtual electron flux fluctuations of the vacuum in the immediately surrounding space.

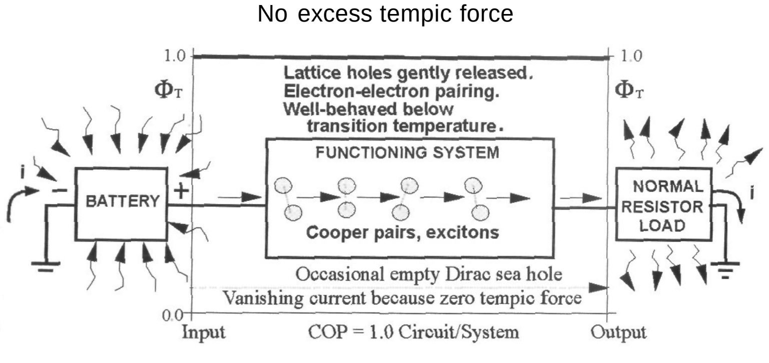
No excess tempic force
1.0
1.0
Φ_T
Φ_T
Lattice holes gently released.
Electron-electron pairing.
Well-behaved below transition temperature.
i
-
BATTERY
+
FUNCTIONING SYSTEM
Cooper pairs, excitons
NORMAL RESISTOR LOAD
i
Occasional empty Dirac sea hole
Vanishing current because zero tempic force
0.0
Input
COP = 1.0 Circuit/System
Output

Figure 9-4 Time potential gradient across a COP = 1.0 EM system.

See Figure 9.4. In a superconductive system or section, COP =1.0 and on the average there is no net gradient of the time potential across the system, hence no time-force across it in either direction. Accordingly, one sees ready Cooper pairing of charges and formation of excitons. We shall not concern ourselves further with the superconductive EM system; such a system has not yet produced COP>1.0.

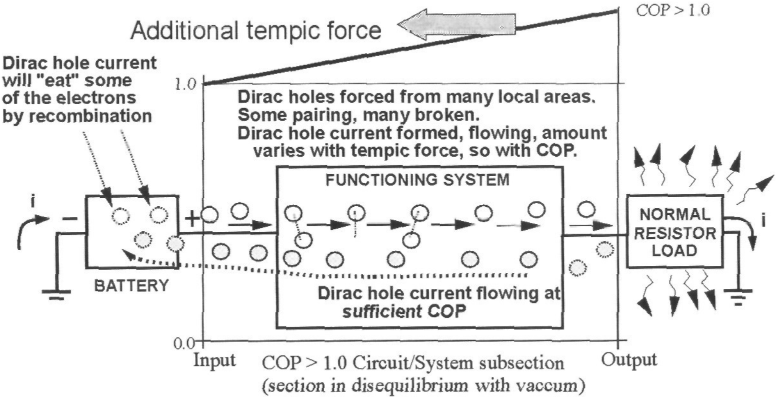
COP > 1.0
Additional tempic force
Dirac hole current will "eat" some of the electrons by recombination
1.0
Dirac holes forced from many local areas.
Some pairing, many broken.
Dirac hole current formed, flowing, amount varies with tempic force, so with COP.
FUNCTIONING SYSTEM
i
-
+
BATTERY
NORMAL RESISTOR LOAD
i
Dirac hole current flowing at sufficient COP
0.0
Input
COP > 1.0 Circuit/System subsection (section in disequilibrium with vaccum)
Output

Figure 9-5 Time potential gradient across a COP»1.0 EM system.

See Figure 9.5. In a COP>1.0 EM system, there is a net tempic force across the system from the output section to the input section. However, unless the COP»1.0, the hole current in the local vacuum is mostly used up in interacting with the system material and converting to lattice holes (lattice positrons). Hence at "nominal" or moderate COP>1.0, except in fast pulsed discharges one *usually* has little to worry about, concerning Dirac sea holes in the vacuum, since those readily convert to lattice holes as already accounted. One effect of concern is that, if the semiconductors in the system are exposed to sufficient extra lattice holes or interacting 4-holes, their donor-acceptor arrangement is disrupted, spoiling the action of the semiconductors and perhaps destroying them.

When COP»1.0 (and even for some COP>1.0 systems), then there results a substantial Dirac sea hole current in the local vacuum occupied by the system, flowing through the supersystem from the output section back to the input section. This is an additional hole current component from the

Dirac hole current component converted into lattice hole current.[249] This unconverted Dirac sea vacuum hole current runs through the system from the output section back to the input section of the system and beyond. If not "filled" there in the input section by the incoming input electrons from the external power supply, the 4-hole current can and will pass on back into the feed line and to the distant external power supply, *eating electrons and electron current all along the way.* Usually semiconductors in the path of a substantial 4-hole current will either malfunction or be quickly destroyed.

In the input section and on back into the external power source, the effect of the unrestrained Dirac sea hole current's reaction is to interact and convert into lattice holes all along the route, which lattice holes then "eat" incoming electrons from the distant power source. Thus, the external power source "sees" the hole current as a dynamic additional load in the system's input section itself (and in the external conductors leading to it) *that also must be powered with additional positive energy electron current.*

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[249] Here we wish to recognize the perceptivity of Peter Lindemann, who recognized the importance of "cold electricity" in COP>1.0 systems without going deeply into the more technical aspects of negative EM energy. As an example, we cite his book, *The Free Energy Secrets of Cold Electricity,* available from Clear Tech, Inc., Box 37 Metaline Falls, WA 99153, U.S.A. Particularly note his efforts to explain the Gray overunity device via the negative energy that can be associated with very strong discharges. Gray referred to this appearance of an associated negative energy component associated with the normally positive EM energy as "splitting the positive pole" (a "pole", after all, involves a stress potential). The Gray engine drawing is shown in Figure 5-14, his conversion tube is shown in Figure 5-15, and his circuit for the conversion tube is shown in Figure 5-16. As Lindemann explains, Gray also apparently succeeded in converting the negative energy into positive energy in his conversion element switching tube. Bedini's successful replication of the tube along with pertinent lab notes are shown in Figures 5-17, 5-18, 5-19, 5-20, and 5-21 by permission. Since Bedini is one of only two or three persons truly experienced in converting negative energy into positive energy, his successful replication is significant and decisive. Gray's process thus transformed negative energy into positive energy, allowing positive energy COP>1.0 self-powering systems. Bedini and the present author have filed a joint patent application filed on the process explained in this Chapter. We recognize Ed Gray as being a real pioneer in the area of COP>1.0 electrical power systems and in energy conversion. His pertinent patents are E. V. Gray, "Pulsed Cap. Electrical Discharge Engine," U.S. Patent #3,890,548, 1976; "Efficient Power Supply Suitable for Inductive Loads," U.S. Patent #4,595,975, **June 17, 1986.**

Aside from destruction of semiconductors etc.,[250] the overall effect is to increase the draw of power and current from the external source, so that the COP» 1.0 power system is thereby converted back to a COP<1.0 system!

The increased power draw due to the Dirac hole current can be remarkable. For an external battery power supply, if the hole current is sufficient to pass on into the battery itself, the battery may *charge* with negative energy while also powering the circuit! A remarkable phenomenon then takes place. A battery having been appreciably charged with negative energy may appear to be discharged (and so it is, with respect to positive EM energy). Yet, it may also continue to power a circuit. Sometimes it will, sometimes it won't, depending on the circuit. However, on connecting a normal positive energy battery charger to recharge it, the battery *precharged* significantly with negative energy will "eat" positive energy for an extended period, filling its localized Dirac Sea holes in its negative charge all the while, with the external voltage of the battery not changing at all. When all the negative energy holes are filled in the internal vacuum environment of the battery, and the negative energy charge is thus removed, suddenly the battery will start recharging with the input positive energy in a normal manner.

The batteries in Watson's generator (again see Figure 5-12) exhibited that phenomenon. Sometimes in recharging one of his batteries that had been extensively used, the battery would "eat" positive energy from the charger for a week or more before finally filling up its negative energy charge and then recharging normally from that point on.

The Dirac 4-hole current is nature's decay mechanism for the COP»1.0 system, sharply bringing it back to COP<1.0. Any successful COP»1.0 EM system must contain a mechanism for defeating (or transducing and using) this Dirac sea vacuum 4-hole current into its input section and beyond. We shall cover that subject shortly. The 4-hole current decay mechanism can *sometimes* become significant for semiconductors in the lattice 3-hole stage at COP = 5 or more, though the exact figure varies as the type and size of system and the semiconductor type. At COP > 10 or so, some systems will frequently begin to ravage themselves back into equilibrium with the vacuum, and destroy their overunity performance, unless the 4-hole current phenomenon is dealt with.

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[250] As an example, novel effects may also happen in resistors, capacitors, and coils, and the effects depend on both the materials and construction of these components. A resistor can act as a true negative resistor and cool rather than heat, a capacitor can have its current lagging its voltage, and a coil can have its current leading its voltage. Mixtures of all three of these effects can happen in each of the three components, since each usually has some aspects of resistance, capacitance, and inductance. The emfs and back emfs in the circuit can also be altered and disrupted in a manner varying with the individual circuit and the individual operating conditions. Nonlinear oscillations and discharges of negative energy are particularly difficult to foresee and understand. Effects in dielectrics may vary widely, as can effects in conductors because of their internal impurities, etc.

Let us recap. We have assumed — to first order — a sweeping generalization that COP<1.0 systems exhibit an overall average spacetime curvature across the system (from input section to output section and load) such that excess positive energy electrons exist in the Dirac sea, without any appreciable accompanying excess Dirac sea holes interacting in the circuitry itself.[251] The slight excess of Dirac sea holes that are generated is "swept" forward out of the output section, and "eaten by the vacuum interaction" (particularly by the vacuum fluctuations) immediately upon exit from the output section. In that case, we do not have to concern ourselves particularly with Dirac Sea 4-holes and Dirac sea 4-hole currents, or at least they are usually negligible in most cases.[252]

For COP»1.0 systems, however, the overall average spacetime curvature across the system — from output section and load to input section — is such that Dirac sea 4-holes and their currents do independently continue to exist and independently flow in the local vacuum occupied by the physical system. Specifically, we shall have to consider the *tempic* effects upon such holes and hole currents, which are oriented from the output section back through the system to the input section.[253] In the COP»1.0, the effect of the increased tempic force is to sweep a Dirac sea 4-hole current back through the system from output to input, and even on out into the conductors from the external power supply, and on further out into the external power supply itself. The 4-hole current continues its "reverse feedback into the powering end of things" until quenched by filling it with incoming electrons. This conversion of 4-hole current to filled Dirac sea 4-holes by induction of lattice holes also squelches the concomitant negative EM energy fields, potentials, and waves associated with Dirac 4-holes as sources.[254] The reason is that a filled Dirac hole is a dual system of two opposite charges, hence produces counteracting positive and negative energy fields.

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[251] In short, the requisite number of Dirac holes have interacted with and do interact with the lattices, converting into the normal "lattice hole" type of positron connected with positive mass, positive energy, but slowly migrating around the circuit in the opposite direction from the electrons. Here the true Dirac hole current exists only in short "hops" from atom to atom as the lattice holes are steadily filled by the "hopping" electrons.

[252] As stated, a kind of "hole" phenomena still exists in the circuit, but now as lattice holes and currents. Since these are attached to ions each having a mass much greater than that of an electron, the lattice hole currents may usually be neglected except in semiconductors, where they are taken into account in the very design of the semiconductor component itself.

[253] When we state a concept such as "negative mass" or "negative energy", we have conceptualized it *as if observed.* Hence, unwittingly we have made it an instantaneous, but iterated, concept. Rigorously, no such thing as mass or energy

The "4-hole-eating and filling process" is therefore the exact decay mechanism that squelches the natural electrogravitation associated with Maxwellian circuits which use Dirac 4-holes and 4-hole currents, negative energy fields, negative energy potentials, etc. When the circuit converts its free Dirac 4-holes into lattice holes, all electrogravity capability is lost, insofar as practicality is concerned.

For electrical power system purposes, the external environment of the COP»1.0 system furnishes an extra "electrical load" demand upon the external power supply, so that the extended system consisting of the (external power supply + power system) decays back into overall COP<1.0 condition and operation. For this reason, any appreciable involvement of Dirac 4-hole currents in a COP>1.0 EM power system must be *transduced* into positive energy electron currents, which requires just a special form of regauging. One need not confine regauging and gauge freedom to positive energy potentials and positive energy fields alone.

From the vacuum consideration and particularly from Dirac's theory of the electron, in COP>1.0 EM systems and circuits we shall consider that the Dirac sea 4-holes involve negative energy states (negative mass), and that positive energy states involve positive mass. In our approach, we shall consider a negative energy state (Dirac 4-hole) in the vacuum as having

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independently exists except at one instant in time. Instead, mass exists in a continual iteration of *m* —> *mt* —> *m* —> *mt*... and energy exists in a continual iteration of *E* —> Et—»E—» *Et*.... and so on. So during the masstime or energy-time (action) state, time and either mass or energy are intimately interactive. See our previous discussion in this book of the mechanism for the flow of a mass through time.

[254] Obviously that kills the antigravity aspects, because it kills the negative energy fields that would give negative curvature of local spacetime.

negative mass, which means that antigravity can be involved as well.[255] In this treatise, we consider only electron states, thus only negative energy and positive energy electron states.

9.3 Primarily Concerned With Dirac Sea Holes and Not Lattice Holes

We also stress the dramatic difference between a Dirac sea "electron 4-hole" in the vacuum (prior to observation) as compared to a lattice 3-hole in a semiconductor or other material component (after interaction and therefore after observation). In the case of a lattice 3-hole, usually the "positron" (hole) is attached to an ion, whose mass (i) is very much greater than the mass of an electron, and (ii) is also positive. In other words, a lattice hole is just a part of an ordinary positive ion. So the theory of "lattice holes" and "lattice positrons" does not primarily apply to the situation we are discussing. On the other hands, semiconductors exposed to any significant currents of pure Dirac sea 4-holes in the vacuum usually react and are nearly instantly destroyed because of the immediate disruption of their donor-acceptor arrangement and functioning. Interaction (filling the incoming Dirac 4-holes with contributed electrons) causes sudden mass disarrangements in their atoms and nuclei and lattice bonds. Thus, in the presence of Dirac sea 4-holes and 4-hole currents, usually any interacting solid-state electronics of the circuit or system will be dramatically affected. For switching in the presence of holes and hole currents, in most cases one may have to turn away from semiconductors and utilize mechanical or electro-mechanical switching, although this requirement varies with the type of semiconductor, the COP, the system geometrical layout, and the subsystem operations and layouts. Sometimes semiconductors may still be used if they are "brutes", with current handling capabilities well beyond what is "normally expected" in that circuit.

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[255] We assume that the important thing about mass is its localized energy. Hence we associate positive mass with positive localized energy (with respect to the ambient energy density of the massless vacuum) and we associate negative mass with negative localized energy (with respect to the ambient energy density of the massless vacuum). In this view, the empty Dirac sea hole has both negative energy and negative mass. Note that this differs from the conventional assumption, which unwittingly addresses the positron as having been observed, producing a directional reversal. The rigorous test of our thesis is that concentrations of Dirac sea holes *must* generate antigravity *potential,* while currents of Dirac sea holes must generate antigravity *force.* The conventional view, assigning positive mass to the positron after observation, would produce gravity, not antigravity, but the force would be reversed by the reversed parity after observation. We argue that antigravity has been hidden and lost by its parity reversal in the assuming positive mass for the positron *as if that were the mass of the positron before it is observed.* In an overunity system with powerful steady-state Dirac 4-hole currents, the 4-hole currents can be differentiated by the cooling (negentropy) effect of the COP»1.0 system—when shorted to produce a "current surge" — rather than heating (entropy) effect. The magnitude of the hole current (which determines the average presence of the hole density) can be differentiated by a measurable weight loss in the COP»1.0 system. The successful antigravity production of the Sweet COP»1.0 device — discussed later in this chapter — experimentally verified these hypotheses.

9.4 Peculiarities of Spacetime Curvature and Dirac Hole Interactions

When considering the interaction between *curved* spacetime and the Dirac vacuum, immediately we violate the premise that all electron states in the Dirac Sea are always filled (which condition we surmise — along with Dirac — only exists on the average in a flat spacetime region). In a curved spacetime, we can have sustained excess 4-holes in the vacuum, or we can have holes that accept an electron falling into them *without emitting radiation.* The radiation-free "pair annihilation" reaction is possible when the spacetime simultaneously changes its curvature appropriately and thereby "absorbs" and holds the excess EM energy that would otherwise be emitted if the spacetime remained flat or decayed back to the flat state.[256] So long as that "energy-storing ST curvature" remains, there is no photon energy emission. If the "energy storing ST curvature set" has a net curvature instead of being flat, and then decays to a flat spacetime, then the previously retained energy is emitted as photon energy.

In that case the reaction provides the conventional emitted pair annihilation energy. In *that* case, the emitted energy may also transform into emitted particles in reactions well known in particle physics.

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[256] Eerily, this interaction represents a situation where opposite reaction forces (the vacuum upon spacetime, and spacetime upon the vacuum) can create a special kind of stress in the system and changes in that stress. This leads to a peculiar kind of stress waves (scalar waves — longitudinal EM waves, so to speak) that are not covered in circuit theory anywhere. A symptom is that these stress waves react with components, amplifiers, preamps, etc. to create electrostatic waves. The effect of these waves is seen as the "crawling" of electrostatics all over and in the electrical equipment that is in one's laboratory. The effect can readily damage oscilloscopes, etc.

The normal emission of photons by pair annihilation need not occur, if the excess decay energy is absorbed *and held* by the local spacetime changing and holding its energy density and therefore (i) changing its curvature and (ii) stabilizing in that new excited state instead of decaying back to a flat spacetime.[257] Under such "non-emitting" pair recombination, a Dirac Sea 4- hole may simply "eat" a free 4-electron, and instead of emitting radiation the process simply affects the curvature of spacetime (and the state of the local Dirac sea) and changes it accordingly. A new "equilibrium state" is therefore reached in the supersystem between the opposite forces of the vacuum acting on spacetime and spacetime acting on the vacuum.[258] In other words, we consider change in the curvature of spacetime to exhibit EM energy *source* (emission) or *sink* (absorption) capability, with respect to the nominal ambient flat spacetime and with respect to conventional EM interactions.[259]

Or simply put, the energy emitted by the combination of positive and negative energy in the vacuum may be "locally radiated", "locally absorbed", or "locally transferred" to the other local component of the supersystem: the local curvature of spacetime. *It is all spacetime curvature dynamics.* By definition, a flat local spacetime consists of a vacuum with all its Dirac sea holes filled. Therefore, if "filling a 4-hole" results merely in relaxation of a set of local ST curvatures back to a flat spacetime, no EM radiation need be emitted, contrary to the usual pair annihilation phenomenon where additional energy (curvature of spacetime) is involved.

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[257] Our view is that in normal pair annihilation this curving of spacetime to absorb the emission energy occurs first, and then the new ST curvature decays by what is called "emission of photon energy". We regard the photon as a specialized ST curvature traveling at light speed. So what is emitted as a photon is in fact the formation of a locally structured spacetime curvature (an "engine") traveling at light speed. It is a propagating spacetime curvature "engine" or "set of engines". In the process we are describing, the emission of the photon is the decay of the locally formed ST curvature set. If that set does not decay, the locally formed ST curvature set remains and no photon is emitted.

[258] This new kind of equilibrium is extraordinarily important, particularly in chemistry, where it will allow the "locking" of impossible combinations of particles into strangely stable "impossible molecules" with ongoing "impossible chemical reactions". The further discussion of the startling new chemistry that emerges is well beyond the scope of this paper, but such chemical states are included in nonequilibrium thermodynamics as *stationary states* — e.g., see Kondepudi and Prigogine, *Modern Thermodynamics,* Wiley, 1998, Chapter 17. At least one company has already succeeded in initiating this startling new kind of chemistry, with several patents granted and several more in process. Similar new "impossible stabilized excited states" and "impossible nuclear reactions" also occur in nuclear physics.

[259] The classical EM assumption of the flat local spacetime is in fact an assumption that the decay of the intermediate "ST curvature absorber/sink" occurs instantly.

Similarly, in a ST curvature, there can conceivably be electrons without "holes". If the curvature is negative, there *will* be unfilled Dirac sea holes present. Of course this is just a normal positive energy 4-electron, where the flat spacetime assumption in classical electrodynamics is in error. Instead, the local spacetime is positively curved, producing positive gravity. Whenever the energy density of spacetime-vacuum interaction changes from the "ambient vacuum and flat spacetime" condition, either positively or negatively, that constitutes an appropriate curvature of spacetime as well as a change in the vacuum dynamics. Therefore, in classical electrodynamics the assumption of a normal electron (or any other charge or mass) existing in an uncurved spacetime and an unaltered vacuum is a non sequitur. The local spacetime has in fact "curved" to an extent of holding the energy of one electron mass.[260] Further, the Dirac Sea has also changed to contain one unfilled and unobserved Dirac 4-hole.

With these things in mind, let us now introduce a conceptual model for dealing with these novel 4-hole phenomena that are experienced in COP>1.0 systems — and that have been the bane of many a would-be energy researcher attempting to develop a system extracting its EM energy from the vacuum and using it to also power the system itself.

9.5 Charging and Discharging a Capacitor

In electronic circuits, we usually think of charging a capacitor with electrons, and then discharging the capacitor to emit electrons again. However, we can charge the same capacitor with Dirac sea holes, or with a combination of Dirac sea holes and electrons. Then we can switch the capacitor adroitly and force it to give us back electrons. This "regauging" effect can thus be used to transduce negative energy current into positive energy current. So let us examine the charging and discharging process more closely. This is part of the Bedini process for handling the 4-hole current problem in overunity EM systems, to allow close-looping a system into self-powering operation.

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[260] Mostly physicists think only of the *spatial* energy change. However, the time domain of spacetime also acts as a sink or source. Essentially one kilogram of mass only has the energy of 1 second of time. Hence the minuscule *mass* of the electron results in such a minuscule "sink" in the time domain that it has been inadvertently ignored. However, during that fraction of time where the electron exists as "mass time" and "charge time", it has considerable time energy, and *that* curvature of local spacetime cannot be neglected with respect to supersystem interactions.

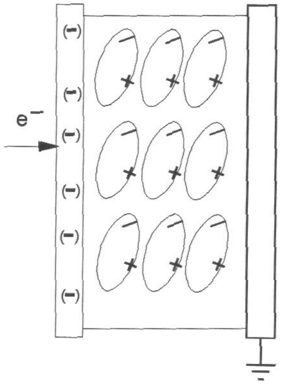

Figure 9-6 Normal strain in a dielectric capacitor that charges with electron current

Figure 9-6 shows the normal strain induced in a capacitor containing a dielectric between its plates. We charge the left plate with electrons, which repel the negative ends of the molecules in the dielectric, straining them to the right.

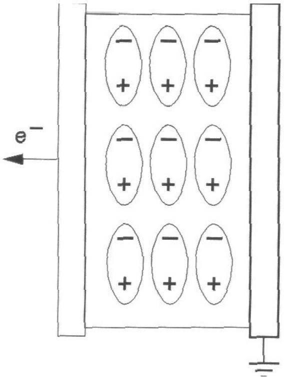

Figure 9-7 Strain relief in a charged dielectric capacitor that discharges.

Figure 9-7 shows the relief of this dielectric strain, by allowing the piled electrons on the left plate to be pushed back into the circuit from the left plate. Note that the electrons emitted in the relaxation of the dielectric strain pass back into the circuit from the same plate that was charged. This is a special kind of "reflection" symmetry. For a perfect capacitor, the total

Vq joules stored in the charged capacitor and drawn from the circuit, is returned to the circuit.

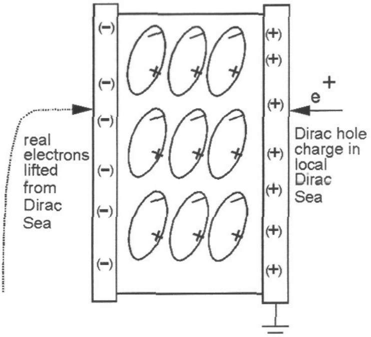
(−)
(+)
e^+
real electrons lifted from Dirac Sea
Dirac hole charge in local Dirac Sea

Figure 9-8 Strain in a dielectric capacitor supersystem that charges by Dirac hole current and lifted Dirac electrons

Figure 9-8 shows a remarkable thing when we charge the capacitor with Dirac sea holes. Suppose we charge the rightmost plate of the same capacitor used before, while the leftmost plate is temporarily disconnected from the circuit (or connected to another capacitor). Now Dirac Sea holes pile up in the local vacuum connected with the right plate. Whether or not they interact with the right plate, these positively charged holes attract the negative ends of the dielectric molecules, again straining the top of the dielectric molecules to the right. The strain of the dielectric is a force interacting upon the local vacuum, and it lifts real electrons from the Dirac Sea (or pulls them from the circuit or other attached capacitor) and onto the leftmost capacitor plate. The charged capacitor *in its supersystem* thus has additional functions that occur. The total *Vq* joules stored in the charged capacitor, were this time drawn (converted) from the applied Dirac hole current and the resulting interaction upon the vacuum, to lift real electrons onto the leftmost plate.[261]

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[261] The reader should recall that a force is something automatically produced by nature to restore symmetry to a broken symmetry condition. A "4-hole negative energy force in the Dirac Sea" produced on one plate of the capacitor will evoke a "positive energy force outside the Dirac Sea" on the other plate as an attempt to restore symmetry. To produce this "positive energy force", positive energy electrons are lifted from the local Dirac Sea of that plate.

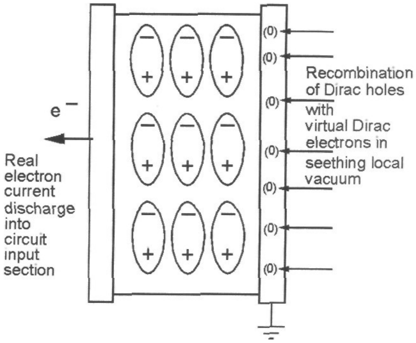
e⁻
Real electron current discharge into circuit input section
(0)
Recombination of Dirac holes with virtual Dirac electrons in seething local vacuum

Figure 9-9 Strain relief in a dielectric supersystem that discharges after charging by Dirac hole current and lifted Dirac electrons.

Figure 9-9 shows the strain relief of the charged capacitor in Figure 9-8. First the charged capacitor is re-connected to the circuit or element to which one desires to provide with electron current. The strained dielectric relaxes, and electrons in the leftmost plate are returned to the circuit. The Dirac holes in the rightmost plate discharge back into the local vacuum (a supersystem interaction) and are "eaten" immediately by the readjustment of local curved spacetime.[262]

The result is that the Dirac sea 4-hole current arriving in the input section has been intercepted by a waiting capacitor, and has been effectively transposed into normal electron current that is furnished back to the input section from the capacitor. This additional electron current helps power the circuit and reduces the power drawn from the external power source. The 4-hole current feeding this capacitor, together with transduction of the 4-hole current into electron current, effectively comprises a true negative resistance process. In other words, energy in unusable (in this case, detrimental) form is received, transformed into energy in usable (beneficial) form, and that usable energy is discharged back into the circuit input to assist in powering the system.

Transducing negative energy into positive energy — and vice versa — in the system does not violate the conservation of energy law in the supersystem, when most generally stated. With such regauging (which involves supersystem reactions), it is the *absolute value* of the energy that is conserved in the system, not its algebraic sign. Regauging (by gauge freedom) is after all an effect or condition locally imposed, but with appropriate energy exchange with the rest of the external universe via spacetime curvature dynamics exchange and vacuum dynamics exchange. The algebraic sign *is* conserved in the universal supersystem by the additional compensating reactions occurring in the other two components of the universe's supersystem.

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[262] From experiments, it seems that Dirac holes forming at the "output" section of a **COP<1.0** device or system are almost instantly filled with electrons in the violent fluctuations of the zero-point energy. When forming at the "input" section of a **COP>1.0** device, this is not the case, and usually the holes can only be filled by incoming electrons in the power input, unless special provisions are taken to convert **the** arriving hole current (in the input section) into electron current.

The reader should strongly realize that energy is only required to be conserved in the universe's supersystem, not the system component alone. Again, this is an open system far from equilibrium with its active environment. In that case, energy is conserved in the ensemble of system and environment, but not necessarily in the system itself. This is no stranger than a common windmill or waterwheel.

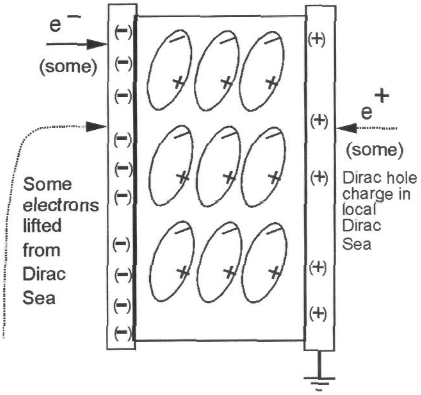
e⁻
(some)
Some electrons lifted from Dirac Sea
e⁺
(some)
Dirac hole charge in local Dirac Sea
(−)
(+)

Figure 9-10 Strain in dielectric in a capacitor supersystem that charges with a mix of electron current, Dirac hole current, and lifted Dirac electrons.

Figure 9- 10 shows a "mix-charging" variant of the 4-hole current charging of a capacitor, in which some real electrons are fed from the circuit to the left plate. Also, the Dirac sea hole current arriving in the input section is intercepted to charge the right plate, and some electrons are also freely lifted from the local Dirac Sea onto the left plate. Figure 9-11 shows the discharge of this type of charging of the capacitor, and the relief of the strain in the dielectric.

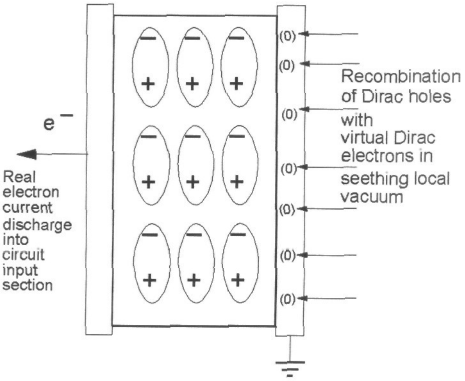
e⁻
Real electron current discharge into circuit input section
(0)
Recombination of Dirac holes with virtual Dirac electrons in seething local vacuum

Figure 9-11 **Strain relief in a dielectric that discharges after charging of capacitor supersystem with mix of electron current, Dirac hole current, and lifted Dirac electrons.**

In Figure 9-11, for example, we accent that the holes on the right plate are maintained only so long as there is a net strain on the dielectric and a net force across the capacitor. When the capacitor is discharged, the holes are discharged into the local vacuum in such a way that they now instantly recombine with virtual Dirac electrons in the vacuum fluctuations.

There are other ways and "tricks" of transducing the Dirac sea hole 4-current into electron current, but these methods are still proprietary to Bedini and will not be included in this presentation. We accent that all such "tricks" are actually methods of re-engineering the other two components of the supersystem — the active local vacuum and the local curvature of spacetime. This is using and applying what we have referred to as "engines".

9.6 The Open-Loop COP>1.0 EM Power System

Figure 9-12 shows the use of the transduced Dirac hole current as real input energy to "catch and lock" a COP>1.0 system in its overunity condition and stabilize its operating point for stable self-powering of the system and its load. The COP>1.0 operation reverses the normal tempic potential across the system, so that Dirac hole 4-current arrives in the input section, preparing to "decay" the system back to COP<1.0 condition.

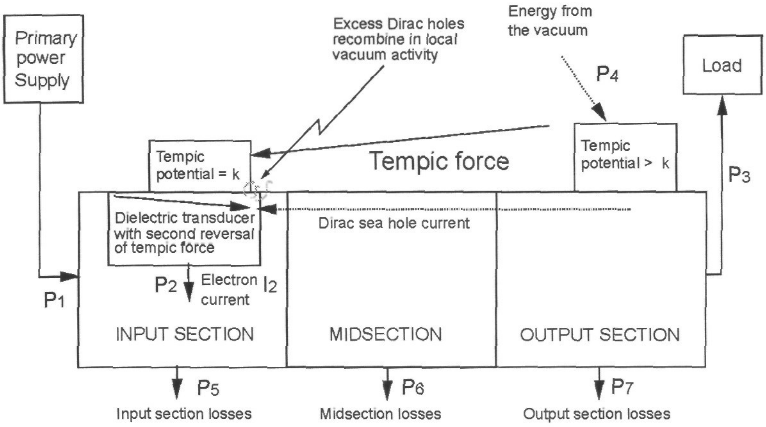
Primary power Supply
Excess Dirac holes recombine in local vacuum activity
Energy from the vacuum
P4
Load
Tempic potential = k
Tempic force
Tempic potential > k
P3
Dielectric transducer with second reversal of tempic force
Dirac sea hole current
P2
Electron current
I2
P1
INPUT SECTION
MIDSECTION
OUTPUT SECTION
P5
Input section losses
P6
Midsection losses
P7
Output section losses

Figure 9-12 Open-loop use of transduced Dirac hole current energy as real input energy to reduce power input required from the primary power supply.

However, the arriving hole current is intercepted by an adroitly switched dielectric transducer, which again reverses the tempic force. As explained above, the capacitor is charged with 4-hole currents (or a mix) and then discharges electron currents into the system — in this case, into the input section itself— by adroitly engineering the local vacuum state and the local curvature of spacetime.

The input section does not care where it receives its electron current from; it merely needs sufficient for its powering needs. Hence, the input section happily accepts this transduced electron current to partially power the system. This in turn reduces the "system load" that the external primary power supply "sees". The primary power supply thus reduces the current and power that it is furnishing to the system. In short, now the external power supply sees the combination of the normal system load and a "negative resistor (negative load)" represented by the transduced current and power. Its required input power is reduced accordingly.

9.6.1 Close-looped System: A True Negative Resistor

Figure 9-13 shows the use of the same process given in subparagraph 9.6 above and in Figure 9-12, except that now there is additional 4-hole current received and available, for transduction into normal electron current into the input section of the system. Sensors and governing are added to this operational mode, so that the system may *adjust and regulate its self-furnished electron current* to meet the total needs of its losses and its load. The system thus adapts the transduction of Dirac sea hole current: to fit its needs and is capable of regulated self-powering operation.

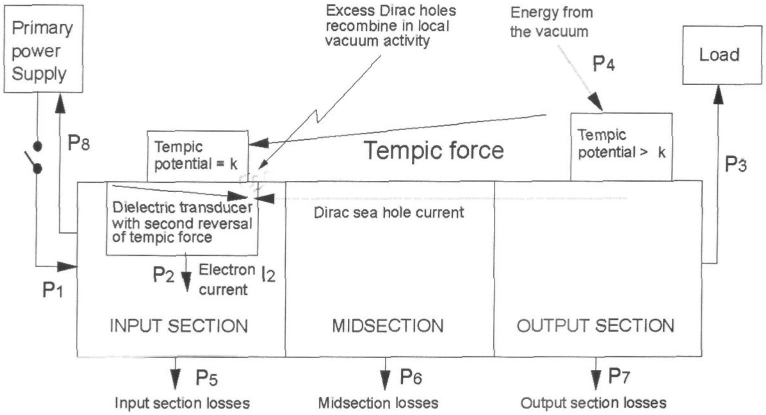
Primary power Supply
P8
P1
Excess Dirac holes recombine in local vacuum activity
Energy from the vacuum
P4
Load
Tempic potential = k
Tempic force
Tempic potential > k
P3
Dielectric transducer with second reversal of tempic force
Dirac sea hole current
P2
Electron current
I2
INPUT SECTION
MIDSECTION
OUTPUT SECTION
P5
Input section losses
P6
Midsection losses
P7
Output section losses

Note: Power outputs P3 and P8, and current I2 have sensors reporting to the Governor in the output section. The governor adjusts the potential energy in the output section to maintain steady output or adjustment of output to demand.

Figure 9-13 Close-looping the C0P>1,0 system with transduced hole current.

The system is first started in open-loop mode. The governor then gradually increases the transduction of 4-hole current into electron current, and the supply of that transduced electron current to its own input. This steadily reduces the "current draw" from the external primary power supply. When the "external current draw" reduces to zero (the Kron condition), the system "locks" into that position, with automatic governing to adjust the transduced electron current as the loads and losses vary. At that point, the external power supply is disconnected automatically.

This "locked and governed" system is now a *self-powered system,* freely taking its energy from the active vacuum and local curvatures of spacetime, to power both itself and its load. So far as we are aware, this is the first time that the technical means of locking and stabilizing COP>1.0 operation in an EM system in an open loop and closed-loop operation has been given.

If sufficient Dirac sea 4-hole current is available and transduced, excess electron current can be available at the system input section, even when the system is fully self-powering. In this case, the additional current can be fed back to the power line, so that the self-powering system not only powers its own load but also helps power the power network. Or additional load can be added and powered.

We point out that Gabriel Kron apparently had a solution to these problems in the late 1930s, and that solution has been suppressed to the present day. We give the following quotations to show Kron's knowledge of these things.

Quoting Lynn and Russell {565}:

> *"Kron has never published details of his method of making the polyhedron self-organizing, although his published results show that in this state it has some remarkable properties, associated with harmonic integrals on multiply connected spaces."*

In reference to Lynn and Russell's remarks, we point out that the Dirac sea 4-hole current from the output to the input is a special case of Kron's more general discovery of the multiply-connected open path existing through space between any two points in a circuit that are at differing potentials.

Quoting Kron {566}:

> *"...the missing concept of "open-paths" (the dual of "closed-paths") was discovered, in which currents could be made to flow in branches that lie between any set of two nodes. (Previously —following Maxwell - engineers tied all of their open-paths to a single datum-point, the 'ground'). That discovery of open-paths established a second rectangular transformation matrix... which created 'lamellar' currents... " "A network with the simultaneous presence of both closed and open paths was the answer to the author's years-long search."*

Again quoting Kron {567}:

> *"Although negative resistances are available for use with a network analyzer, in practice it is more convenient to use a second type of circuit, in which the positive and negative resistances are replaced by inductors and capacitors and the dc currents and voltages are replaced by ac currents and voltages of fixed frequency. The use of the second type of interpretation is equivalent to multiplying the wave equation by* $i = \sqrt{-1}$*."*

The reader should particularly note that in the first part of the sentence Kron stated unequivocally that negative resistances were available for **use** on the network analyzer, a large analogue simulation used by the Navy **and** administered at Stanford University with the contractor being General Electric. The censors missed that one.

Again quoting Kron {568}:

> *"When only positive and negative real numbers exist, it is customary to replace a positive resistance by an inductance and a negative resistance by a capacitor (since none or only a few negative resistances exist on practical network analyzers).*

We believe the censor caught this one, and forced Kron to add the words, "none or". Kron had at least three negative resistors, and possibly more.

Again quoting Kron {569}:

> *"Now a value E of the negative resistances, at which the generator current becomes zero, represents a state at which the circuit is self-supporting and has a continuous existence of its own without the presence of the generator, as the negative resistances just supply the energy consumed by the positive resistances. ... When the generator current is positive the circuit draws energy from the source, and when the current is negative the circuit pumps hack energy into the source. At zero generator current the circuit neither gives nor takes energy, and theoretically the generator may be removed. "*

Here we believe the censor forced Kron to add the word "theoretically". In this quotation Kron reveals that he was well aware of the process for close-looping a system — starting it in open-loop mode and bringing the negative resistor currents up to match the system needs nnd reduce the generator current to zero, then disconnect the generator. He also was quite aware that excess transduced energy from the negative resistor could be available at the input, in which case energy could be furnished back to the power network while the system powered itself and its load simultaneously.

We also point out that Dirac's definitive electron theory — covering the Dirac Sea and Dirac sea holes — was published in 1930, the year the present author was born. In the late '30s and in the 40's Kron certainly was well aware of that work. In addition, Kron applied full general relativity to electrical circuits and machines, and he was far ahead of his time. His work is also still far ahead of the present time, at least in the open scientific community. He also was aware of developments in particle physics, and so he did have the gist of the supersystem concept in his mind {570}, however he may have thought of it. His concept of the "open path" effectively includes the effects upon the system from the other two components of the supersystem, so it appears that Kron's "system plus its open path" roughly corresponds to our concept of the "supersystem."

Further, Kron was a mentor to Floyd Sweet, who also worked at General Electric but in a different project. Sweet often spoke glowingly of Gabriel Kron.[263] Sweet almost certainly knew the secret of Kron's negative resistor. It is the present author's opinion that Sweet's vacuum triode amplifier was derived from Kron's negative resistance unit. With both deceased, we will never know for certain.

9.6.2 Suppression of COP>1.0 Systems Should be Investigated

During our decades of research, we ran across several cases where U.S. scientists actually produced working COP>1.0 systems.[264] None of these overunity systems was ever allowed to go forward with independent development. This is an area that cries out for a full and vigorous Congressional investigation, and appropriate legal action should be taken by the U.S. government against the suppressing parties, whomever they might be {571}. Simply put, the U.S. government, the U.S. taxpayer, and the scientific community have been ripped off and deluded in the field of electrical energy for more than half a century. That continues to the present, as witness the disappearance of the Watson generator (accompanied by Watson and family breaking off all contact with their close colleagues) and the suppression of the Kawai device and process. The latter suppression was accomplished in 1996 in the personal presence of the present author and the members of the Board of Directors of our company, CTEC, Inc. An accidental overunity frequency converter was even initially placed in the original Minuteman missile, but was altered back to COP<1.0 operation when the electronics past the converter kept failing because of overload power furnished by the converter.

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[263] The present author worked with Sweet off and on for a decade or more, and designed the antigravity experiment that Sweet performed.

[264] These incidents were previously exposed in a draft book, *Matters Arising,* carried on the Internet for some months and then withdrawn. Some things must wait for their appointed time, and so must certain kinds of information.

9.7 Remarks on Dirac Sea Holes, Currents, and Negative Energy

The subject of the Dirac Sea, Dirac holes, Dirac hole currents, and negative energy still has elements of strong disagreement within the scientific community and among leading theorists. Often the "conclusion" one reaches depends on the way the starting assumptions are made and then on how the mathematics is applied. There is no definitive experiment establishing that negative energy cannot exist; to the contrary, many things do occupy negative energy states. The binding energy of the nucleus, e.g., involves a loss of mass (loss of positive energy) and hence involves negative energy states, as is well known. Here the "negative mass" effect is immediately and experimentally verifiable, and is recognized. The total mass of the bound nucleons is less than the total mass of those same nucleons when unbound, and this fact is widely known and accepted.

A single white crow is sufficient to prove that not all crows are black. Hence a single experimental proof of mass-energy "loss" and negative energy states establishes that negative energy and negative mass are real. Indeed, every photon absorption by mass and every photon emission by masstime prove the same point universally: mass is a variable. The same assembly of protons and neutrons in a nucleus, having lost mass, also has "lost" some of the gravity that the positive masses of those unbound protons and neutrons would otherwise produce. Therefore, there is an appropriate amount of "negative gravity" already acting in conjunction with positive gravity, in every atomic nucleus. It is associated with the negative energy states of the bound nucleons in every nucleus.

Consistent with the initial quotations and comments at the beginning of this chapter, we present an interpretation by which we can understand some of the major novel phenomena that arise in laboratory experiments with COP>1.0 electromagnetic systems, including COP»1.0 systems.

We propose that COP»1.0 EM interactions are widespread in highly energetic astronomical interactions {572} and even in highly energetic phenomena on Earth, when the supersystem changes are also accounted.[265] We argue that novel negative energy phenomenology — such as encountered in the COP>1.0 experiments by Magnetic Energy Ltd. in various versions of the COP>1.0 motionless electromagnetic generator (MEG) {573, 574}, by Bedini {575} in his induction of negative resistor actions inside the batteries of battery-powered COP>1.0 EM systems, and by Sweet and the present author in experiments with the Sweet COP» 1.0 vacuum triode amplifier system {576} — is also generated in these COP»1.0 highly energetic astronomical interactions, yielding the same kind of negative energy and negative energy currents.

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[265] As an example, in looking at sprites and other such sharp electrical discharge phenomena, we may be observing the prompt *decay* of COP»1.0 interactions which were self-initiated in the atmosphere.

This Dirac hole negative energy generation of COP»1.0 EM processes is proposed as the mechanism which directly produces the negative energy fields and potentials that generate the mysterious antigravity accelerating the expanding universe {577}. This is a reasonable assumption, even though it is against the received view, because it is based on some laboratory experiments, not just theory. It also is the unexpected effect of the cosmological constant introduced by Einstein {578}, and it is consistent with Zeldovich's demonstration that the energy density associated with Einstein's repulsive cosmological constant is — or is associated with — vacuum energy.[266] The received view *is not* based on direct experiments with COP>1.0 EM systems, but only on COP<1.0 EM systems. Until the received view is broader based, it does not adequately represent nature. Hence it does not represent a valid refutation of experimental negative energy systems producing antigravity processes.

In Bedini's experiments and in the MEG experiments, antigravity is essentially absent or so small as to be nearly nondetectable. However, these experiments generally have COP of 1.5 to 4.0, mostly, and sometimes 10 or 12 (we have experimented up to 20 or more stably, and unstably at nearly 100). Hence the Dirac hole current is relatively small in them, since the magnitude of the Dirac current is a function of (COP - 1).

Sweet's COP > 1,500,000 experiments produced a very large flow of negative energy back across the system, substantially curving the local spacetime and reducing the weight of the system on the laboratory bench. Figure 6-7 shows the first Sweet device, which produced six watts output in open-loop operation. Figure 6-8 shows a later Sweet device which produced COP = 1,500,000 and was pushed past that COP to produce the antigravity in the laboratory, smoothly reducing its weight by 90%. Figure 6-9 is a plot of the actual readings taken during the antigravity experiment. Sweet performed the experiment in California, reading off the measurements to me over the phone as he made each one.

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[266] Believed to have been demonstrated in 1967. But check Ya. B. Zeldovich and A. A. Starobinsky, "Particle creation and vacuum polarization in an anisotropic gravitational field," *Zh. Eksp. Teor. Fiz.*, Vol. 61, 1971, p. 2161 *(Sov. Phys. - **JETP**,* Vol. 34, 1972, p. 1159); Ya. B. Zeldovich, "Vacuum theory — A possible solution to the singularity problem of cosmology," *Uspekhi Fizicheskikh Nauk,* vol. 133, Mar. 1981, p. 479-503. Translation in *Soviet Physics — Uspekhi,* vol. 24, Mar. 1981, p. 216-230.

Another indication of the negative energy effect present in the output section of the Sweet device was tested by suddenly shorting the output leads. This resulted in instant freezing of moisture from the air, so that the leads were instantly frozen and covered with ice. Contrast this to the normal heating of shorted wires, where the energy is positive.

Sweet never revealed his activation process, whereby he initiated very strong self-oscillation — of the nucleus of the barium atom in barium ferrite magnets — with the local vacuum treated as a semiconductor. One part was known to the present author and another part was known to Rosenthal, a professional test engineer. In addition, how Sweet converted his excessive hole current is not completely clear. It appears that he somehow used his coils in quadrature together with special circuitry to interact the excess hole current into his magnets, directly with the self-oscillating barium nuclei and thence with the other nuclei in his magnets. If so, it created the "rough equivalent" of increasing the associated binding energy offset and locked with concomitant additional local spacetime curvature.

If this speculation is correct, he "locked" the nuclei of his magnets to the local curved spacetime, maintaining the overall local binding energy in the nuclei themselves while producing a great excess of "binding energy" (negative energy) in the immediate vacuum. This would explain the antigravity, and would be consistent with the experimental results as well as the increase in antigravity as the output load of the device was deliberately increased.

We must use the supersystem concept, as in the quoted comment at the beginning of the chapter, to enable a better understanding of these novel phenomena. Together with the Dirac negative energy production and high COP system, the hypothesis of "additional negative energy acting on local spacetime immediate to each nucleus" allows the generation of the observed antigravity to be understood. However, we accent that this mechanism is still a hypothesis, and it must be further substantiated by experiment.

9.7.1 Lattice Holes

In a material conductor or other component of an electromagnetic circuit, the conventional model envisions currents in the Drude electrons as the electrons moving by "hopping" from molecules or atoms in the material lattices into the Drude gas, with each hop leaving behind a positively charged "vacated electron position" called a *lattice hole,* or just a "hole". Subsequent Drude electrons are attracted to fall into the holes, etc. This net movement of the hopping electrons down the conductor, etc. comprises the conventional electron current through the conductor. We point out that the actual movement of the electrons in their "hopping" is vastly more energetic than the very feeble net "drift" of the overall ensemble of Drude electrons longitudinally down the wire as current. The energy of the total electron activity ongoing in a simple 1-foot length of copper wire would power a city, if it could all be harnessed and utilized.

At the same time the electrons hop with a slow net progress down the wire, the "holes" in the material lattices are also collectively seen by the external observer as if "slowly changing their net positions" longitudinally in the opposite direction. One speaks of a corresponding "hole current" or "lattice hole current" in the opposite direction to the electron current. However, there are subtle differences in the flow of the two currents, because an electron in the Drude gas is far more kinetic than the positive ion left behind by an electron that has "hopped up into the electron gas". Nonetheless, the positive lattice ions do "rock" physically from the induced forces upon them, as the holes are opened and filled. In conventional electrical power systems, this equal and opposite energy reaction in the ions of the lattice materials, induced by the applied fields, is usually ignored. In most classical EM power system theory the holes and their "composite equal and opposite energy and work in the system" are also ignored, except in semiconductors and semiconductor circuits.

9.7.2 Newton's Third Law Is Accounted in the Supersystem

Because half the EM energy and work in the circuit is usually ignored (e.g., in the Maxwell-Heaviside-Lorentz standard equations), electrodynamics is said to be free from Newton's third law reaction. This may be a non sequitur, and it follows from the assumption that — for an EM wave, field, or potential in space — no interaction exists with the active vacuum or with the curvature of spacetime. In fact, those reactions do exist in the supersystem. The field, wave, and potential do indeed interact with both the quantum mechanical vacuum and the general relativistic spacetime.

Indeed, the field, wave, and potential may be said to *identically be* changes induced in general relativistic spacetime. The absence of the "transmitting" physical system leaves us with the remaining two components of the supersystem, each of which extends to infinity. Again, Figure 9-1 shows the actual interactions (the supersystem) and Figure 9-2 shows the erroneous and arbitrary "kill of the supersystem" by standard classical electrodynamics.

When higher group symmetry electrodynamics such as O(3) is applied, then the interactions between the three parts of the supersystem emerge and must be accounted. This is particularly true of COP>1.0 EM systems. However, as Finster points out {564}, the Dirac sea effects exist *wherever* there are EM fields, potentials, and waves. We add that curved spacetime effects also exist *wherever* there are EM fields, potentials, and waves. And wherever Dirac sea effects exist, or wherever curved spacetime exists, then there the local vacuum and local spacetime interact with each other.

However, as we shall point out, usually most of the Dirac sea hole effects can be neglected in COP<1.0 systems and in most lower gain COP>1.0 systems because of the time-energy aspects. For COP»1.0 EM systems, the time-energy aspects are partially reversed, and instead of carrying the hole effects away from the system, the time-force from system output to input forces the Dirac sea holes to flow back in the local vacuum across the system from its output to its input. This flow constitutes an additional "load" appearing in the input section and requiring additional electron current from the external power supply to fill the holes. If the power supply does not furnish sufficient electrons to fill the hole current at the input section of the system, then the unfilled hole current passes back into the feeder line toward the external power supply, and even into the distant power supply itself. In its progress, it eats incoming current all along the way, requiring that more current be furnished by the distant generators.

9.8 Remarks on the Observed Acceleration of the Expanding Universe

As a candidate for *dark negative energy*, the present author has proposed vacuum negative energy and currents in curved spacetime regions partially containing excess *empty* Dirac sea holes as well as normal *filled* Dirac sea holes. The process by which these excess Dirac holes are produced has been advanced, and is supported by at least one dramatic experiment. One result of such "negative energy areas" of negative spacetime curvature would be "jumps" increasing the velocity of light and high-energy particles traversing these altered regions of spacetime. In fact, there is some evidence for just such jumps, according to a hypothesis by Richard Lieu of the University of Alabama in Huntsville {580a, 580b}. Otherwise, high-energy particles produced in distant processes in the cosmos would not be detected on earth, but would be annihilated in highly energetic collisions.

The departure of large-scale spacetime from homogeneity would also result in some loss of correlation in the presently fitted red shift versus distance relationship. Again, there is tentative indication that such may prove to be the case. The most distant galaxy recently detected has a red shift of 6.56, which — assuming homogeneity of space — implies look-back of 14 billion years or so.[267] (conventional view) Best estimates of the age of the universe based on the Big Bang assumption is some 14.7 billion years. It would seem that 0.7 billion years is a very short time for that observed galaxy to have formed. If even more distant galaxies are observed with larger telescopes to become available, then by the redshift correlation to homogeneous space one would be observing galaxies "before the beginning of the universe" — an obvious non sequitur. It appears that the redshift correlation to velocity and distance, as well as the homogeneity of space and in fact the Big Bang itself— are already in some difficulties and may be in serious trouble in the near future.

The empty Dirac sea 4-holes in the vacuum are special "Dirac negative action quanta" and the holes and their dynamics form negative action potentials, currents, and fields. This type of vacuum condition containing some empty Dirac sea holes is referred to as a *Dirac-polarized vacuum.*

However, we do not envision the Dirac-polarized vacuum as just simple *static* polarization, but as possessing rich dynamics such as negative energy currents, potentials, fields, waves, etc. including in the time-energy medium in the time domain. We also include the interaction of the dynamic Dirac-polarized vacuum with spacetime.

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[267] I am indebted to Prof. Stanley Jeffers for this information, in his E-mail discussions with the Alpha Foundation's Institute for Advanced Study fellows. Dr. David Roscoe contributed the fact that the Big Bang theory has so many parameters that nearly anything can be "fitted in". But he also pointed out that W. M. Napier, *Astronomy & Astrophysics,* Vol. 310, 1996, p. 353 gives a very thorough analysis of the quantized cz phenomenon, which does present a difficult obstacle to Big Bang theory. Napier is **the** originator of the cometary catastrophe theory of biological extinction. One way or another, the theory of the Big Bang is in trouble, even though many theorists are still complacent about it.

Due to ongoing COP»1.0 processes involved in highly energetic astronomical phenomena, Dirac sea 4-hole regions and dynamics are believed to occur and exist in the vacuum across the observable universe. These occur especially in appreciably curved spacetime regions with large tempic potential gradients and thus large *time-forces* across the region.[268] The 4-holes and 4-hole currents in the vacuum are generated in great quantity in large cosmic explosions. Also, the energetic fluctuations of the local vacuum energy can separate a Dirac hole from its occupying electron by lifting the electron (pair production), and so can a curved spacetime. In a properly curved spacetime, fluctuation can lift an electron from a hole, and enter a stationary state by accommodating reaction of the local spacetime curvature. In that case, hole and electron go their separate ways. The hole and that or another electron may later recombine, or in sufficient local spacetime curvature, they can remain apart. We point out that every positive energy electron is accompanied by an appropriate local curvature of spacetime that prevents the accoutrement of a free Dirac sea hole,[269] and thus prevents the electron from disappearing.

The more energetic the local region, the more severe and violent are local spacetime curvatures in that region, and — in our view — the more frequent the occurrence of COP»1.0 interactions producing significant Dirac 4-hole currents, negative energy EM fields and potentials, etc. Indeed, the measurements that yielded the accelerating expansion of the universe were measurements of the relative velocities existing with stellar explosions known as type la supernovae. In our view, in explosions of such violent nature — particularly including in optically active gases such as where gamma ray bursters form — an appreciable fraction of the hole currents are transduced into positive energy electron currents. This produces — at least for a finite time — a net positive feedback, self-powering COP»1.0 phenomenon, resulting in very rapid asymptotic output energy increase. This is what we have hypothesized as producing the gamma ray burster itself. *Quenching* of this asymptotic rise in COP occurs only after the physical geometry of the "closed-looping" gas particles is broken a short time later. The maximum output energy is determined by a function of the *rate* at which the geometry is broken and the corresponding *rate* at which damping of the asymptotic rise and quenching occurs. The afterglow remaining in the gas is due to the extra positive energy produced in it by the transduction of negative energy into positive energy during the asymptotic rise of the self-powering burster, with excess positive energy being absorbed in the gas while the burster magnitude is rising. After damping and quenching, the gas has been heated (that is how the geometry was disturbed in the first place, to produce damping and then quenching). Re-ignition can occur whenever a new close-looping COP»1.0 situation spontaneously occurs. As in the gamma burster, this can often happen as the disrupted geometry of the gases stabilizes.

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[268] We also conjecture that these regions may account for a tentatively observed slight change in the fine structure constant, but leave that to the advanced theorists to validate or falsify.

[269] This needs a bit of modification. Rigorously, the so-called "isolated" observable electron is clustered around by *virtual* positrons (Dirac sea 4-holes) in the vacuum. So a positron influence is present, though from virtual positrons instead of observable positrons. The magnitude of both the positive charge and the internal or "bare" negative charge is infinite. The difference, however, is finite and is the "observed" magnitude of the observable central charge. There is thus a net observed shielding of the bare charge of the electron, and this is taken into account to yield the observed charge of the electron.

All 3-space EM energy comes from the time domain, as previously developed. In the more violent positive energy COP»1.0 regions, there is an increased conversion of time-polarized EM energy into 3-spatial energy and back. On the average there is a higher "time-energy conversion" or "tempic" potential. In those regions, a tempic conversion potential is higher at the higher center magnitude of the spatial energy density. Hence there are strong tempic forces from "inside to outside", providing a "tempic broom" effect to sweep outward the excess Dirac sea holes separated from their electrons in the curved spacetime. The result is the presence of increasingly unoccupied Dirac sea 4-holes toward the outside of violent regions of spacetime,[270] until the effect is overcome by the decreasing spacetime curvature. The 4-hole current radiating out from an asymptotically increasing (exploding) burster provides an asymptotically increasing (exploding) negative energy and negative mass reaction with spacetime. That reaction explosively creates curved spacetime for negative gravity (repulsive gravity), acting upon the local system and upon distant masses as well. The result appears to be the cause of the acceleration of the expanding universe.

It follows that re-ignition of the gamma burster can occur if, as the quenching continues, the geometry stabilizes and reaches another "close-looping" positive feedback condition. In fact, just such re-ignition of the gamma burster is very often observed.

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[270] I.e., the violent astronomical phenomena — while generating and increasing are more violent at the center, and less violent at the outside.

Therefore, we hypothesize that the more distant violent astronomical regions have greater amounts of repulsive gravity being produced by their local Dirac-polarized vacua particularly during their explosive asymptotic energy density rise. This produces violent streams or bursts of negative energy outflow, which is equivalent to negative mass outflow and which provides outgoing negative curvature of spacetime (antigravity). At sufficient distance from us, the increasingly earlier, more violent events and resulting greater curved spacetime regions have created sufficient cumulated Dirac-polarized vacua to override the normal attractive gravity between galaxies, etc. and produce net repulsive gravity. This results in observed distant acceleration of the expanding universe {581a-581f}.

9.9 A Solution to the Hole Current Problem and Close-Looping

Bedini and the present researcher have filed a patent application {582} on the above special capacitive process to *convert* or *transduce* the detrimental Dirac sea hole current reaching the system's input section into electron current, and put it to use in powering the system. This transduction process receives the hole current as a special potential, then regauges the "negative energy" potential into a "positive energy" potential. This regauging is accomplished by charging the capacitor with Dirac hole current and then discharging electron current from it. The transformed positive energy potential is then applied to the Drude electrons, producing an ordinary electron current in the input that can be used to power the system itself. If sufficient excess positive electron current is provided, then the system can "feed itself in self-powering mode and also feed power back into the main power supply line.

When conversion of the arriving hole current in the input section produces an output "positive energy" electron current equal to the system's normal power needs (Kron's condition), the external power supply can be disconnected and the system will remain powered by the steadily converted negative hole current arriving in the input section.

Our patent-pending process allows this otherwise devastating special form of "negative energy feedback" to be converted into "positive energy feedback", allowing the system to be close-looped successfully for self-powering of the system and its load. Regulators of the transduction process may be added to cover the situation when the load is erratic and changing.

At Magnetic Energy Ltd., we have also filed a patent application for an outrigger method of close-looping a COP>1.0 system, which greatly eases the problem. This method is covered in Paragraph 9-14 below.

9.10 Negative Energy: Localized and Nonlocalized

It sometimes appears there are as many views on negative energy as there are scientists who mention it. Simply put, the Dirac theory of the electron requires negative energy states. The negative energy electron state was envisioned by Dirac as a sort of "hole" in the ambient vacuum, where the hole could contain a positive energy electron. The combination of equal positive energy of the electron and negative energy of the hole itself, would give a "normal" vacuum zero state of the "filled hole". In other words, the normal or ambient vacuum consists of holes filled with electrons. Considered in that fashion, such a vacuum is referred to as the **Dirac Sea** or the **ambient Dirac Sea,** or the **ambient Dirac vacuum.**

If positive energy is added to a filled Dirac hole, the electron can be lifted out, leaving the hole. Note that adding positive EM energy, e.g., is actually the addition of spacetime curvature and dynamics to the Dirac sea vacuum. In short, it is a supersystem interaction, not a system interaction.

In that case, the curvature of the local spacetime interacts upon the electron mass, producing a force that lifts it from the hole. The result is the appearance of a positive energy, positive mass electron and a Dirac sea hole (a 4-positron) in a curved spacetime. That is known as *pair production,* and it is a supersystem interaction. When a positron and an electron meet, the electron falls into the hole, changing the Dirac sea which also changes the local ST curvature. That change in local ST curvature is a change in the energy density of space, and is normally radiated away as a photon or photons as the local curvature decays back to a flat spacetime. The emitted radiation may further decay into particles, etc. by several reactions well known in particle physics. That "conventional" set of supersystem interactions is known as *pair annihilation.*

If we deliberately change the ST curvature appropriately, however, the pair annihilation radiation need not be emitted since the excited local spacetime curvature does not decay back to a flat spacetime to emit it.

Dirac's original paper tried to identify a negative energy state vacuum hole as the proton, but later that was falsified and it was taken as the positron. There is a very strong aversion in physics to considering negative mass; hence, the mass of the positron was proclaimed positive (for many reasons not really connected with our thesis). Nevertheless, some physicists (in the minority) still speculate or theorize that negative mass "can exist." Not only "can" it exist, but also it *does* exist widely and one can demonstrate it in actual electrical circuits. It certainly exists in the binding energy of the nucleons in the nucleus of an atom. Again, a single white crow is sufficient.

We take a very straightforward view: we consider a positron — an electron observed with positive mass and "observed" to be traveling backward in observer time — to be a different (transformed) entity than a Dirac 4-hole traveling forward in observer time.[271] The observation operator accomplishes both velocity reversal and time reversal, and — since time is not an observable, the time reversal is "seen" as a reversal in spatial direction. *Prior to observation, neither reversal has been imposed.* The major distinction, we hypothesize, is that the observed positron has positive mass in 3-space, which is concentrated positive energy, and therefore produces positive energy electrical fields and positive gravitational field. Mass is an observable, hence, it is the iterative frozen 3-space snapshots of an ongoing 4-space process. Observation (and any observable) is the effect of applying the operator $\partial/\partial t$ upon spacetime LLLT in which a 4-space process is occurring. As we stated earlier in this book, our view is that no observable *continuously persists* (in time), but continually and iteratively *recurs* by the continual ripping of time from the ongoing 4-space reaction, to see the 3-space intersection at a frozen moment. We also advanced the *mechanism* that generates the flow of a mass through time, consisting of a mechanism for $\partial/\partial t\,(\mathrm{LLLt})$ - photon emission, converting *mt* to *m* — and the mechanism for $\int_t (\mathrm{LLL})dt$ — photon absorption, converting *m* to *mt.*

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[271] This point is stressed. The *unobserved* positron is not identically a positive mass electron traveling backwards in time, but a negative mass, negative energy electron traveling forward in time. When Dirac theory of the electron was written, broken symmetry and the CPT theorem had not been discovered. Further, there was no distinction made in the difference between the observed entity (the *effect* of the observation interaction) and the non-observed entity (the *cause* of the observation interaction).

[272] We stress that we are once again confronting the ubiquitous substitution of the effect for the cause in classical electrodynamics. The observed positron and the unobserved positron are two quite different entities —just as the "cause" of an observation is quite different from the "effect" of the observation.

We may also consider mass to be condensed 3-spatial energy (say, EM energy) compacted by c^2. Modern physicists tend to consider the mass-energy itself as the source of the gravitational "attraction of mass" rather than the mass itself {583}. Let us accept that assumption, but differentiate between the observed 3-positron with positive mass and opposite direction in positive observer time, and the unobserved Dirac sea 4-hole with negative mass and without change of direction in the observer's positive time. The 3-positron is an *observed effect,* while the unobserved Dirac sea 4-hole is an *as-yet-unobserved cause.*

We also surmised that all EM energy in 3-space comes from time, by our solution {584a} to the long-vexing source charge problem {68}. In our view, we may then consider that the positive energy compressed as 3-space mass has been extracted from the time domain of surrounding spacetime, via entry of that time-energy into the surrounding 3-space at each 3-space point, producing a surrounding spacetime curvature which is known as the *gravitational field.* This gravitational field represents "withdrawn" 3-space energy from surrounding space, and withdrawn time-energy from the time associated with each surrounding 3-space point.

Hence the gravitational field may be said to consist of "negative energy" since it represents *lowered* energy of spacetime due to the curvature. This viewpoint yields results consistent with the received view that the energy of the gravitational field is negative. In our view, it is negative precisely because it represents "withdrawn energy" from the normal energy density of that otherwise flat space. The withdrawn nonlocal energy has been localized (as what we call "mass"). Simultaneously that withdrawn 3-spatial energy also represents "withdrawn energy" from the time-domain, since all the withdrawn spatial energy came from the time domain in the first place. The result is the curvature change in spacetime, that is taken as the gravitational field.

The 3-space energy comprising the mass is positive because it is *added to* the normal energy of an otherwise flat spacetime, at that concentrated locality.

The "energy in the gravitational field" is negative because it represents lowered energy density (i.e., lowered "pressure" in a fluid analogy) of that surrounding nonlocal spacetime compared to when that spacetime was flat

Thus when we add positive energy (a positive energy state) to 3-space, we create normal "positive" gravity because "mass" is a process of withdrawing some positive energy from the energy density of surrounding 3-space.

Here is the shocker: When we add localized negative energy (a localized negative energy state or "4-hole" — or a localized negative mass!) to a local 3-space region, we create "negative" gravity (antigravity) in surrounding space because the withdrawn energy from the local 3-space "hole" must have been added to the energy density of the surrounding spacetime, once we apply conservation of energy. Or in other words, the surrounding spacetime changed (curved) in interaction to the production of the hole.

If we wish, for simplicity we can just consider localized positive energy to generate positive gravitational charge in the surrounding nonlocal spacetime. We can consider localized negative energy to generate negative gravitational charge in the surrounding nonlocal spacetime.

This is where our concepts differ from the rather arbitrary way that a Dirac sea hole is interpreted in the received view. In spacetime, we try to account for the entire energy process and we apply a conservation law by including the supersystem interaction in every case. We insist that positive energy concentrated in positive local mass must have been extracted from surrounding spacetime.[273] That "negative energy" in the surrounding spacetime is what is known as the *gravitational field of the source mass* (where the energy was withdrawn to). Similarly, we insist that positive energy extracted from a localized region of the ambient vacuum to leave a "Dirac sea hole" must have been spread out into the surrounding spacetime, where it would properly be known as the *antigravitational field of the source Dirac hole.*

As an analogy in very simple lay terms, the holes associated with a local mass system or region involved in COP>1.0 operations create higher "pressure" outside the system or region with respect to other objects. Higher pressure between any two objects pushes the objects apart. The masses associated with a mass system create lower "pressure" outside the system or object with respect to other objects. Lower pressure between any two objects results in the objects being pushed together by the higher pressures beyond them.

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[273] Alternatively, if we add local spacetime curvature, the surrounding nonlocal spacetime interacts as mediated by the supersystem changes in all three components. What we are saying is that there is no such thing as just a system, vacuum, or spacetime change. Any change to one is accompanied by a change to the other two, *a priori.*

We submit that this new view provides an exact (and testable) antigravity mechanism. It appears to have been validated by the Sweet antigravity experiment {576}, which was designed in advance by the present author with increasing the local negative energy reaction in mind.

9.11 Tests Reinforcing the Antigravity Mechanism

9.11.1 Dirac Sea Hole Current Effects in a COP»1.0 EM System.

For COP»1.0 electromagnetic systems, we recall that the temporal energy will flow negatively across the system from output section to input section. Hence the Dirac sea hole current in the local vacuum flows back across the system, from its output to its input section. Regarding the output section: Specifically, *all COP> 1.0 systems produce both positive and negative energy outputs. The greater the COP of the system, the greater the fraction of negative energy produced with respect to the fraction of positive energy produced.*

The positive energy will flow on out of the system output section (as into the external load) as in a normal circuit, but the negative energy output will flow from the output section through the local vacuum back across the system to its input section.

At the input section, the arriving Dirac holes appear to the input electrical current as a special kind of "load" added to the system input section. Hence, as previously stated, the external source must input electrons (as electron current) to "fill the holes" prior to having any input electrons available to power the circuit in normal fashion.

That is nature's unexpected *overunity decay mechanism* for COP>1.0 EM systems. The COP>1.0 system is in a condition of disequilibrium *a priori,* since the system exhibits negentropy and only systems in energy flow disequilibrium with their active environment can do that. Any COP»1.0 EM system is therefore in a highly excited state, and all excited states in nature have decay mechanisms. A highly excited state usually has a prompt decay mechanism, and the COP»1.0 system is no exception.

This emergence of the Dirac hole current from the system output section back to the system input section, is nature's decay mechanism to trigger COP»1.0 EM systems back into COP <= 1.0. With this current, a "negative energy load" is added to the input section, causing the system to draw additional electrical power from the external power supply to "power" the killing of the Dirac holes[274] as well as to "power" the normal circuit (the system itself).

If the external power source connected to the COP»1.0 system is not furnishing sufficient electron current to kill the hole current in the input and power the system as well, the excess hole current will pass back through the conductors and on into the external power source, "eating current" and power as it goes. The product of the hole current and the voltage gives a negative power imposition, wherever the hole current interacts with the power system and its external power supply, even back into the distant huge power generator in the distant power plant. For a battery-powered circuit, e.g., excess hole current will pass into the battery and discharge it (change its chemistry in discharge mode) more quickly.

Indeed, a lead-acid battery (and some other kinds as well) can be supercharged with Dirac holes. What this actually means is that the local vacuum — in which the battery and its components and chemistry are embedded and in a continual exchange with — is altered to increase the number of empty Dirac sea holes devoid of electrons. At the same time, the local spacetime is also negatively curved. The end effect is that the battery is charged with negative energy, rather than positive energy. We propose that a battery or capacitor possessing an extreme negative energy charge should be lighter in weight than the same capacitor when uncharged.

As previously stated, some years ago, Jim Watson developed a very large multi-kilowatt COP>1.0 battery-powered generator, publicly demonstrating it at a technical conference (see again Figure 5-12). Engineering measurements at the conference verified that the batteries were constantly charging while the load was constantly powered at 8 kilowatts.

The longer Watson's system would run, the more charged his batteries became with *negative energy.* After one of his batteries had been used for a couple of weeks in extensive experiments, one could obtain a most novel effect when it was placed on a normal "positive energy" battery charger. The battery's excess "Dirac hole charge" or "negative energy charge" accumulated in its local vacuum would "eat positive power and electrons" from the battery charger for an extended period, sometimes as long as a week, with no symptoms of "charging" the battery at all (no increase in battery voltage at all). During this period, the battery charger was indeed recharging the *battery supersystem.* It was filling the excess Dirac sea hole charge in the vacuum with the steadily supplied electrons. In the process, it was gradually relaxing the previously formed negative spacetime curvature.[275] When all the Dirac holes were filled, the relaxed spacetime then was relatively flat (normal) as was the local vacuum, and suddenly the battery would charge-up normally again with positive energy, with its voltage increasing in quite normal fashion.[276]

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[274] By converting separated incoming electrons and incoming holes to resulting filled Dirac sea electron holes, in the input section itself.

With tongue in cheek, we point out to the COP>1.0 researcher that these effects are not described in the available storage battery manuals, no matter how technically they are written. To the electrical engineer, we point out that they are not in his textbook.

Whenever Dirac sea holes have accumulated in the input area of the COP>1.0 system and are being filled by the external power supply, normal ammeters and voltmeters will only "see" that the external power system is furnishing more current. That is true, because the holes are an additional load being powered. The holes "eat incoming electron current and power", and require the external power supply to "power the killing of the holes" as well as "power the system".

The unwary overunity experimenter can successfully have the first phase of an overunity system working and not realize it, because his initial COP is too high and he does not know about the associated hole current decay of overunity systems back to underunity systems. His system may actually be at COP>1.0, but the negative energy component being produced in his output section is back-flowing and continuously degrading his input section by adding a "new load" right in the input section.

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[275] This proves that a system's supersystem can indeed be negative-energy-charged, so that the local spacetime around that system is negatively curved, even though the system itself seems normal and functions normally. If the negative energy charge is . sufficient, conceivably the antigravity produced will be sufficiently great that the system itself "floats" or even levitates. We hypothesize that an intense negative energy beam can indeed be technically created which will accomplish this "negative-energy-charging of the supersystem" effect when continuously absorbed by a targeted system's local spacetime supersystem component, as the system is continuously irradiated by the beam. In that manner, levitation beams, tractor beams (both attracting and repelling) are at least hypothetically possible. If this proves to be a valid hypothesis, we foresee the day when such beams will revolutionize transportation and handling of otherwise heavy loads and very heavy systems. Even the heaviest vehicle could then negatively charge its own supersystem's local curved spacetime, thereby floating in the earth's gravity, in the atmosphere, in space, and under the ocean.

[276] We deliberately omit discussion of the extraordinary all-purpose weapons implications of negative energy electromagnetic pulse (EMP) directed energy weapons, already developed and deployed by several major nations.

So his overall power draw from the external power source can be such that his positive power output in the load is less than his total power draw at the input of his system. Unless he is aware of the process and how to handle it, he may never realize that his system is actually at COP>1.0 condition, when the negative energy component is credited as an output "plus".[277] *COP>1.0 research starts by evaluating the absolute value of the output energy, then working from there!* The experimenter must be ever aware that he can and will have Dirac sea 4-holes and currents in any unitary COP>1.0 electrical power system, and particularly in those with very high COP. He must understand what the 4-hole currents and the negative energy actually do and how they function in the overunity system unless corrected.

Any COP»1.0 EM system demonstrates the Dirac sea 4-hole current phenomenon as nature's special decay mechanism to reduce overall performance of the COP»1.0 power system and its external power supply to COP < 1.0 — unless one *corrects* the problem and prevents the decay process (developed later in this chapter).

One symptom of the negative 4-hole currents is their cooling capability rather than heating. Another is that the excess current (and power) drawn from the external power supply also does not heat the input section of the system. Another is that semiconductors operating within the Dirac 4-hole current flow are likely to fail immediately and permanently.

We strongly suggest that, for high COP systems experimentation, the experimenter use a system of synchronized clocks where the lab clock is synchronized with a remote clock prior to the experiments, then the two clock times are examined after significant experimentation at COP»1.0. If deviation beyond normal error in synchronizing occurs, then the involvement of spacetime curvature effects is indicated. Two decades ago, anomalous experiments by Golden — with whom I was working at the time — charged the area with negative energy, producing a significantly curved local spacetime which disrupted local clocks and watches for four days as the charge gradually decayed away. Another indicator is that Geiger counters and other nuclear radiation detectors often "read" when bathed in vacuum 4-hole current, because of the ionization changes induced in them and also because of their individual previous "time-charge" histories. After all, ionization instruments "read" anything which causes ionization of their internal gases. Dirac sea hole current, if interacting with the gas, is in fact a very special new form of "ionizing" radiation.

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[277] In other words, in the presence of both positive and negative energy output, true COP is not "positive energy out" divided by "positive energy input by the operator", but is more appropriately "total absolute value of the energy output" divided by the "positive energy input by the operator".

9.11.2 Antigravity Hole Current Effects in a COP»1.0 EM System.

Any COP>1.0 EM system can exhibit minor, usually barely detectable antigravity effects due to the presence of the negative local energy 4-holes in the hole current if the hole current is not transduced or corrected. It can also produce minor antigravity "thrust" due to the flow of the local energy holes. Usually these effects are not even noticeable in an overunity system unless it has very high gain (very high COP, say in the range of 10^5 to 10^6 or more.).

However, if the EM system's COP » 1.0, and reaches 10^5 to 10^6 or more, the antigravity and thrust effects may become significant and easily detectable. At 10^9 they become highly significant and are very detectable: The unit will lose appreciable weight on the laboratory bench, and may even levitate easily.

An example is provided by the Sweet vacuum triode amplifier discussed above, with the results that were given in Figure 6-9. Such effects are also what generate the anomalous levitation phenomena of free-spirited John Hutchison.[278]

9.11.3 Negative Energy Effect When Leads Shorted

When the leads of a COP>1.0 EM system are shorted, a noticeable cooling effect can sometimes be detected. If COP»1.0, shorting the leads will result in instant icing from the water vapor in the surrounding air.

If one accidentally shorts oneself across the leads of a COP»1.0 system, the effect is to freeze the nerves along the pathway of conduction. Experimenters are cautioned to use every safety precaution. Their experimentation is at their own assumed risk.

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[278] John Hutchison, "The Hutchison Effect apparatus." *Proc. Intl. Symp. New Energy*, Denver, Colorado, May 12-15, 1994, p. 191-198.

Anecdotally, some older researchers reported that their constant handling of overunity circuits resulting in charging their bodies, apparently with negative energy. The body after all may be considered as a special kind of complicated capacitor or set of capacitors, so this is reasonable, based on Bedini's and Watson's demonstrated negative energy charging of a battery. Some of the older overunity researchers reported that, after charged in that manner, they could produce a 3-inch spark from their fingers, or a "slight shock" into the body of a person they touched.

There is even a special form of acupuncture in the East in which the practitioner uses special exercises to charge the body with negative energy in this fashion. The "electro acupuncture" is then administered by the operator twirling the inserted acupuncture needles between his fingers, and deliberately administering a jolt of negative energy from his body into selected points in the body. I have personally tested a person who could deliver strong "electric shocks" into one's hand or body, and who could consistently produce a 1-inch spark discharge between the hands at will. That person could also deliver a very astonishing "jolt" to one's body, particularly in the vicinity of the liver.

There appear to be similar rare negative energy phenomena in semiconductors {585a-585c}. Anecdotally, it appears that the body does have structures or methods of storing and using Dirac sea holes (negative energy) and mechanisms for accessing the negative energy charged in its supersystem. This is suggested as a fruitful line of future research for interested biophysicists. Again, we call attention to the fact that, whenever EM fields, potentials, and waves are present, Dirac sea effects are also present and involved. Little or no biophysical experimentation has been done utilizing higher symmetry electrodynamics and analysis of the supersystem effects. Contrary to the received view, the understanding of EM effects on biological systems is not mature at all, but is still in its infancy.

9.12 Susceptible Unitary System without Conversion of Dirac Sea Hole Current

A *unitary system* is simply a self-contained single power system with an overall closed current loop between the source dipole and system loads and losses. A unitary system is contrasted to an array system of synchronized separate power subsystems without a common closed current loop, with the array subsystems connected to the source dipole by energy transmission-reception only. Hence the array system utilizes the Kron open path concept.

Beginning at about COP = 1.2 to 1.5, a few highly susceptible unitary COP>1.0 electrical power systems will experience significant Dirac hole current from output to input. This will produce a "negative energy load" in its input section and feed line from the external power system, resulting in decay back to an overall "system plus negative energy load" of COP<1.0. At the COP = 2.0 level, in the susceptible system the effect will forcibly decay the COP back down to overall COP<1.0. It does this by forcing excess power to be furnished by the external power system to "power" (fill) the Dirac hole current arriving in the input section of the power system. In short, it converts the system to a composite system containing an additional Dirac negative energy load in its input section.

Or in other words, it forces the operator to "pay" for both the *positive* energy output and losses of his system and the *negative* energy output and losses of his system.

In addition to usual powering of its load and losses, such a system is also "powering" the return of its own locally altered vacuum back to a more normal ambient vacuum, instead of stabilizing its supersystem in a stationary disequilibrium state. It is a supersystem interaction and effect. A COP>1.0 system that significantly exhibits this phenomenon is said to be a "susceptible" system.

One of the first tasks of the COP>1.0 experimenter is to ascertain whether he is working on such a highly susceptible COP> 1.0 system. Ironically, he does this by observing his COP>1.0 system kick itself back into a COP<1.0 system. If he carefully observes the initial COP>1.0 condition followed by decay into COP<1.0 condition, he must then realize that not all is lost! In short, he must realize he has developed a susceptible system. If he obtains COP>1.0 only to watch it subsequently decay back to COP<1.0, he has just discovered he is working on a susceptible COP>1.0 system, *and that is experimental progress.* He isn't there yet, but he is en route. In that case, he must concentrate on transducing the excess hole current into usable electron current, to "stabilize" and "lock" his system in its COP>1.0 operating condition.

9.13 Unitary System with Conversion of Dirac Sea Hole Current

Using the Bedini conversion process, a unitary system can be close-looped to maintain COP> 1.0 and stable overunity operation. The 4-hole current reaching the input section is intercepted by the Bedini mechanism, and transformed to ordinary electron current furnished to the input section. Thus the transduced negative energy feedback becomes a positive energy feedback, by conversion. This converted positive energy in the input section will reduce the demand for incoming electron current from the external power supply, increasing the COP>1.0 even more.

A feedback and governing system is adjusted until the system's converted positive energy feedback current reaches the Kron condition. At that point, the transformed electron current is sufficient to power the system with the external power supply disconnected. The governing and control system thus disconnects the external power supply, and the system is smoothly transitioned to self-powering operation, powering both itself and its load.

We stress that all the energy to power the system and its load is now being furnished from the active local vacuum interaction and from the local curved spacetime. No laws of nature, physics, higher symmetry electrodynamics, or thermodynamics are violated. Conservation of energy rigorously applies, but to the supersystem. The system is an open, *stabilized* disequilibrium system — of the kind referred to by Kondepudi and Prigogine as nonequilibrium stationary states — as a freely receiving all its energy from its active external environment. No standard U(l) electrodynamic analysis will show this condition or this mechanism, and neither will electrical engineering. Higher group symmetry electrodynamics such as SU(2) or O(3) will show it easily. For a modern treatise on O(3), we refer the reader to the recent *tour deforce* by Evans {586}.

9.14 Non-unitary Outrigger Array System

See Figure 9-14, which is a diagrammatic representation of a COP>1.0 array system that is non-unitary. In the non-unitary (outrigger array) system, no part of the outrigger array works at $\xi > 1.0$. All external parts operate at $\xi < 1.0$, but independently and with COP>1.0. Each of the external outrigger systems is an open system freely receiving excess energy from its active environment, because it is an "energy-receiving" system and the energy is freely transmitted from the central system. The central part of the array is the unit whose purpose is to stimulate or evoke an excess energy flow from the vacuum, so that the outrigger receiver/power units can individually intercept and utilize radiating energy flow surrounding the central unit.[279] The usable (output) energy intercepted and captured (collected) from a given free flow of energy depends totally on the intercepting reaction cross section — usually the total array amount of intercepting charge, together with the degree of resonance (sweeping a larger geometrical cross section) of the intercepting charge.

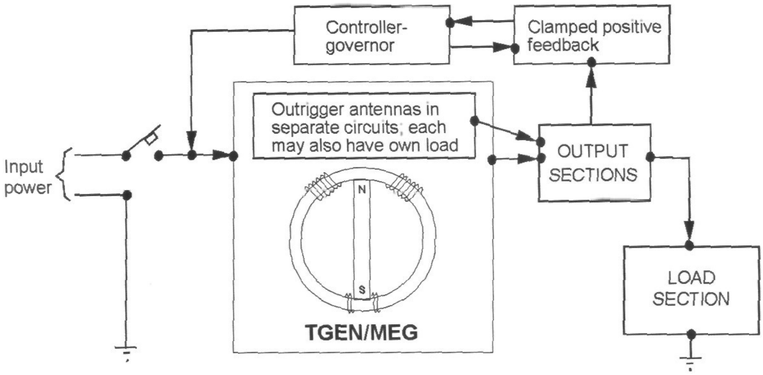

Figure 9-14 The nonunitary (outrigger array) system and its functioning.

Each outrigger unit (subsystem) has its own complete closed current loop *separate* system and load, plus its "antenna" or "interception section" or receiving component for intercepting and collecting the free flow of energy coming from the central source unit (the energy transmitter). Thus, the loads in the outrigger units are not closed-current-connected with the central source unit at all. Each outrigger unit has its own independent electrical ground and its own closed loop system with its load.

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[279] We emphasize that, when the usually unaccounted Heaviside nondiverged energy flow component surrounding the conductors of the external circuit is accounted, every EM power system is already a COP»1.0 EM energy transduction system. Consequently, in the received view the array system can be operated at COP>1.0, or even in self-powering mode, even though the central system is "said" to be at COP<1.0. It is at COP<1.0 only because of the self-applied Lorentz symmetrical regauging and ignoring the excess unused energy flow available to and surrounding the circuit, but not conventionally used. If we account the COP for what we have to furnish to the central unit, then the COP of each array unit is COP = ∞. The point is that we ourselves do not have to pay any *extra* input energy for the output energy of each array circuit.

This schema in fact separates the two functions of Poynting energy flow theory: (i) the extraction and radiation of the EM energy flow from the seething vacuum, and (ii) the interception, collection, and dissipation of some of that available energy flow, to power the loads and losses of the intercepting system.

In this fashion, multicollection from a single energy flow (generated from a central source "transmitter") occurs by direct, independent interception and collection in each of the COP<1.0 outrigger units. However, the input power to each outrigger units is *free* with respect to that outrigger circuit itself. We of course must pay to generate the flow of energy from the central unit, but that can be done in normal COP<1.0 manner (such as COP = 0.95) while powering its load.[280] Let the output power of each numbered unit (including the central source unit) be given by P_i, n be the number of power units, and P_T be the total power output. Then the total output P_T of the array system is given by

$$P_T = \sum_i P_i = P_1 + P_2 + \cdots + P_n \qquad [2]$$

The total input power P_I is simply the input power $P_{I(1)}$ to the central source unit. The COP is given by COP = $P_T/P_{I(1)}$.

In the motionless electromagnetic generator (MEG) array, for example, the central unit is the transformer-like unit, deliberately using a special core to contain the magnetic flux of a permanent magnet in contact with the core material, thereby stimulating the Aharonov-Bohm effect and freely filling the surrounding space with the uncurled magnetic vector potential A. We will explain the non-unitary (outrigger array) system using the MEG as an example.

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[280] We again stress that, from any nonzero potential ϕ, or from any EM field in space, any amount of EM energy can be collected if there is sufficient intercepting and collecting charge. For example, the simple equation $W = \phi q$ applies for the potential, where W is the energy collected from a potential with point intensity ϕ by collecting charges q. A similar equation applies with respect to collecting as much force (emf in the various outrigger circuits) as desired. Here a single given E-field *E* can be assumed, and $F = Eq$. What is happening in the outriggers is that they are intercepting and collecting some of the excess Heaviside energy flow component that is wasted by the central circuit.

The MEG freely induces the Aharonov-Bohm effect,[281] thereby extracting excess energy from the vacuum in the form of that novel field-free A-potential. Being field-free, A represents an energy flow without swirl (without curl). When the MEG input section is perturbed, the surrounding A-flow is perturbed also, giving a pulsed or AC flow of energy that can be intercepted and utilized by each outrigger circuit as an E-field energy interception.

The central unit's $COP<1.0$ function is to output almost as much, or as much, energy as is required to power the MEG, while also evoking that excess A-flow and serving as a $COP \gg 1.0$ energy flow transducer. The function of each outrigger is then to intercept some of the pulsed A-flow (as E-field energy via the equation $dA/dt = - E$), in its antenna or interceptor section. Each outrigger has its own independent and conventional closed loop circuit. It simply is a receiver and user of extra Heaviside EM energy produced from the central MEG unit in the new form of the curl-free A-potential. Perturbing the A-potential produces a large E-field impinging on all the external outrigger subunits. Hence these units freely collect and use some of that available excess energy. The COP of the total array is thus $COP>1.0$. For best results, tuned antenna theory and near field theory should be utilized.

Suppose we operate the MEG central unit at $COP = 1.0$. In that case, there is no 4-hole current of significance associated with the central unit or the outriggers, and transduction of hole current into electron current for close-looping is not necessary. Instead, sufficient outriggers are employed so that the total energy W_O caught and dissipated in their loads by all the outriggers is given by $W_O \geq W_I$, where W_I is the input energy in the main central section. Since $COP = 1.0$ for the central unit in isolation, the total input E_{IN} is $E_{IN} = W_T$ (the additional huge Heaviside nondiverged EM energy input component is there also, but just neglected in conventional engineering). The total output W_A of the entire array is $W_A = W_O + W_T$. The overall COP_A of the entire array is thus

$$COP_A = W_A/E_{IN} = (W_O + W_T)/W_T = (W_O/W_T + 1.0) > 1.0 \quad [3]$$

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[281] The reader should recall that the Aharonov-Bohm effect is not included in classical U(l) electrodynamics. See Terence W. Barrett, "Electromagnetic Phenomena Not Explained by Maxwell's Equations," in A. Lakhtakia (ed.): *Essays on the Formal Aspects of Electromagnetic Theory,* World Scientific Publishing, River Edge, NJ, 1993, p. 6-86.

Hence the array has a COP>1.0, even though every single component of the array has $\xi < 1.0$. With the outriggers fully functioning, many schemes of operation can be used. E.g., the energy from the outriggers can be used to steadily charge a capacitor bank by "shuttling". We define shuttling as use of two capacitor banks: (1) a capacitor bank which is continually connected and charged by the outriggers as their effective output, and (2) an input capacitor bank for the central unit that is continually connected and recharged from the outrigger capacitor bank. By adroit switching, the charge of the input capacitor bank is maintained by replenishing from the output capacitor bank, and the input capacitor bank powers the entire system, including the output load in the central section.

The non-unitary outrigger array construction is one means of close-looping a non-unitary overunity power system without bothering with the transduction of hole current into electron current. It is the easiest of all COP>1.0 systems to close-loop for self-powering.

An additional adaptation is for each outrigger also to continuously power a separate load, and only contribute *intermittently* along with the other outriggers to charging the output capacitor bank.

Another adaptation is to operate the central unit in the array in solitary self-powering mode.

These and similar modes of nonunitary array system operation allow close-looping the system for self-powering of itself and its load, without concern **for** 4-hole current transduction. A real advantage of such nonunitary systems without worrisome 4-hole current is that transistors can readily be used for switching etc. in them, without the destruction of the transistors by a damaging Dirac 4-hole current in the supersystem.

The nonunitary overunity system can also be close-looped by *conventional* (simple) "clamped positive feedback" means if good isolation (e.g., optical isolation of the circuitry switching) is used in the feedback loops.

9.15 Some Instrument Considerations

9.15.1 Time Effects

As previously indicated, there are time-domain effects (potentials, forces, and currents) associated with a COP>1.0 EM system, particularly as the COP increases toward COP»1.0. A useful method of indicating time-effects is to utilize a transistor in a circuit capable of measuring recombination time in the transistor.[282] NASA has such circuitry available, but I do not have the reference at hand. We leave it as an exercise to the reader to explore that possibility.

For "very large COP" devices, ordinary watches, clocks etc. may be affected. Particularly significant is the slowing of timepieces in the presence of substantial time-domain effects due to substantial negative energy. In addition, for high gain devices (and for some at lower COP), the negative energy charge can build up in the local area, and may then require some days to dissipate. As we stated, in experiments years ago with Frank Golden, we experienced just such alteration of multiple kinds of clocks and watches in an area. It required four days for the negative energy charge in the area to gradually drain off (for the excess Dirac sea holes to gradually be filled with electrons, as the tempic potential gradually returned to normal).

Effects that were even more dramatic were exhibited in experiments conducted by Sid Hurwich in Canada some years ago {587}. In a series of experiments lasting a half-hour, Hurwich inertially jammed a police revolver so that a human finger could not pull its trigger. *The watches of the witnesses did not change their setting during that entire half-hour.* This cannot be understood by conventional electrical system analysis, but potentially it can be understood by supersystem analysis.

9.15.2 Calorimetry Is Taboo for Overunity System COP Measurement

It is standard dogma that calorimetry is a "true" measurement of power, and is always accurate in the hands of a skilled practitioner. In general, that is true for a COP<1.0 system, where one is concerned only with *positive energy* in the input and output sections. However, with respect to COP>1.0 systems, nothing could be farther from the truth. Indeed, for a significant COP»1.0 system, a calorimeter is one of the most inaccurate instruments that can possibly be used.

As previously stated, all COP>1.0 EM systems produce a mixture of negative and positive energy in their output section. The higher the COP, the greater the percentage of negative energy and the greater the flux of Dirac 4-holes back to the input section. The output energy, immersed in a calorimeter, will both cool the water with its negative energy output fraction and heat the water with its positive energy output fraction. Hence, the calorimeter will show the *difference* between the water's simultaneous heating and cooling. If the calorimeter measurement is misinterpreted as the *total energy output*, this "definitive test" will always erroneously show COP<1.0. After all, it itself already applies the decay mechanism for converting any overunity system to an underunity system.

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[282] This suggestion is courtesy of John Schnurer some years ago, and is appreciated.

The only good use of the calorimeter in an overunity EM system is to verify that negative energy is present, when comparing its measurements to more sophisticated electrical measurements of the system. It can be used along with other measurements to ascertain (1) the total energy output, whether negative or positive, (2) the difference in the two forms of energy output and the algebraic sign of the resultant (positive if calorimeter heated, negative if calorimeter cools), and (3) thereby help determine the output's energy fractions (positive energy divided by total energy, negative energy divided by total energy).

Any test group insisting on testing a purported COP>1.0 electrical system with a calorimeter as the *definitive statement of energy output* is totally devoid of knowledge of COP>1.0 systems and their phenomenology. Usually such "test groups" tend to regard themselves as "measurement experts" (which they well may be, in COP<1.0 positive energy systems!). That does not make the team even minimally knowledgeable or qualified in COP>1.0 system measurement. To the contrary, the team members have zero experience or knowledge of COP>1.0 systems. The proposed test group may consist of physicists, thermodynamicists, electrical engineers, technicians, or all four, but they still will have no knowledge or expertise in COP>1.0 EM power systems unless they have actually worked with such systems before, and at length.[283] This is particularly true of COP»1.0 systems. My advice to all COP>1.0 researchers is simply to keep the "calorimeter addicts" out of one's laboratory in the first place.

9.15.3 Other Instrumental aspects.

Here we just point out some simple and obvious things, familiar to the experienced researcher but sometimes not appreciated by the novice. One is usually dealing with nonsinusoidal waves, pulses, spikes and the like. As is well known, RMS meters are useless for measuring such nonsinusoidal electrical entities, since they are designed and calibrated to measure sine waves only, or to measure DC. One must use a good differential sampling scope with multiple synchronized channels, with professional software to perform accurate integration under the curve, and with special differential probes for the scope. Simultaneous triggering of the multiple measurement channels on the same time line is required. The necessary high quality probe set may cost as much or more than the oscilloscope!

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[283] To date, we have found none who have actually worked with COP>1.0 electrical systems. We have, however, found quite a few who, though totally inexperienced with COP>1.0 systems and not knowledgeable, have regarded themselves as "real experts" in such systems. They claim to already know how COP>1.0 systems work and behave, and assume just ordinary electrical system phenomena.

Dirac sea hole currents are generally not separately measurable, so one measures where the hole currents are not significantly present. Results may be compared to measurements where the hole currents are known to be present. When directly measuring hole currents, the conventional meters often read "backwards" and interpret a negative energy output at the system output section as subtracted from the positive energy, and interpret a negative energy output at the input section of the system as additional input electron currents from the external power supply. If the electron currents from the external power supply are not present, then measuring hole currents will draw electron currents from the power system inside the meter itself, resulting in a "backward measurement". Again, the meter actually will measure a real electron current, whether from the external power supply or from a conversion within the meter itself.[284]

Recombination time in semiconductors can sometimes be used in instrumented circuits to differentiate between negative hole current and electron current, by observing the change in recombination time due to the negative energy currents. It will differ from the change in recombination time due to positive energy currents.

Again, what is needed in the field is a set of solid, reliable instrumentation specifically developed for these peculiar measurement phenomena involving both positive energy and negative energy. To my knowledge, no such thoroughly designed and tested instrument package presently exists. Further, there are not even any standards for such, since there are apparently no standards for negative energy measurement at all.

9.16 Still Anomalous Aspects

Several aspects of COP>1.0 systems are still not properly understood. The behavior of curl-free A-potential, sometimes produced in such systems, is a case in point. This type of energy can exhibit characteristics as if it were electrostatic energy, which my associates sometimes refer to as the "crawly stuff. It exhibits the characteristic of "crawling" all over the surfaces (outside and inside) of the objects in the area, including the scopes, producing internal electrostatics and possibly magnetostatics everywhere. This can easily destroy the amplifiers etc. in a good scope or an expensive meter. It is best to transform this field-free A-potential into an ordinary "EM field energy AC wave", and then utilize it in that fashion.

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[284] What is very much needed is a meter of sophisticated design where this "drawing of excess electron current from within the meter itself has been taken into account in the design, so that the meter functions correctly for either positive energy measurement or negative energy measurement.

Scalar stress waves are also sometimes produced, leading to anomalous effects. This is best regarded as a "time-polarized" EM wave, or more accurately, as a combination of scalar (time-polarized) EM waves and longitudinal EM waves in 3-space. For macroscopic waves in COP>1.0 systems, the Mandl and Shaw 1:1 correlation between scalar photons and longitudinal photons can apparently be corrupted, so then one has "abnormal" (improperly correlated components which normally correlate to make "ordinary" EM waves). These abnormal EM scalar stress waves also exhibit the "crawly" phenomenon, and can be hazardous to one's instruments.

In addition, some instruments such as ionization counters, Geiger tubes, etc. read in the presence of such waves as if nuclear radiation were present (which it is not). Also, the individual time-charge history of a given instrument determines or substantially influences how the instrument reacts in the presence of the "corrupted" scalar stress waves. Essentially, at a given time any instrument has a small "time-energy charge" depending upon its past history. The corrupted scalar stress wave accomplishes further "time-charging" of the instrument, which combines with the initial time-charge to produce more time-charge, ordinary EM waves by scalar EM interferometry {588}, or abnormally correlated longitudinal EM wave emission.

In an ionization-measuring instrument, *ionization is ionization, by whatever means achieved.* And in the presence of the "abnormal" radiation and charging, ionization-type "nuclear radiation" instruments will vary from one to another, *depending upon the individual time-history ofeach instrument.* So from a group of identical instruments made the same day on the same assembly line, one may read anomalously and several others read normally. Or two may read anomalously, while all the rest read normally. A very good example of this anomalous measurement effect is seen in the rigorous electrolyte experiments in U.S. Navy research facilities at China Lake {589}. The present author has previously given an explanation of this time-charging and decay phenomenon {590}.

Negative energy reacts in different ways with different materials. The more nonlinear the material, the greater the effects and unpredictability of the interaction, as a rule of thumb. In a copper wire, Dirac hole current introduced into the wire will "eat" Drude gas electrons, reducing the "pressure" at that point or area in the wire. This "combining of electrons and causal Dirac holes is not normal pair annihilation, and radiation does not occur. Instead, the two curvatures of spacetime (one by the positive energy of the electron and the other by the negative energy of the Dirac hole before observation) interact and adjust.

The Drude gas in the copper further back toward the external power system still has normal (higher) gas pressure, and so the differential in pressure induced in the Drude gas will drive electrons from the "normal" pressure areas into the "reduced" pressure area where some of the Drude electrons disappeared after being "eaten" by the Dirac holes. To look at that in lattice hole terms, the "eating" of Drude electrons in a selected volume of the wire leaves positive ions, which are "lattice holes" vacated by the eaten electrons. So these excess positive charges attract electrons from further up the wire nearer the distant power supply, filling the lattice holes to bring the Drude gas back up to "normal". However, that also draws and "eats" additional power from the distant power supply. Meanwhile, the Dirac 4-holes fed from the input of the COP>1.0 system back into the power feed conductors continue to interact with the lattice and eat electrons to create more ions (lattice holes).

One may visualize the Dirac sea holes producing excess lattice holes, which then causes the Drude electron gas to change so that the "average" demand current increases. In short, we must also consider the effect of Dirac hole charges or currents upon the lattice material itself, and the structure of holes and electrons as charge carriers in the material lattice.

Semiconductors are very vulnerable to negative energy due to its disruption of their donor-acceptor and band gap design functions. With mild negative energy exposure, a semiconductor may just cease operation entirely and later recover when the negative energy application ceases, or it may fail and never recover. For pulsing, strong "opposing force pulses" (stress pulses) are created deep inside the semiconductor materials. In case of sharp pulsing, sometimes an exposed semiconductor will just suddenly explode in a nice little fireball about one foot in diameter. This along with some minute stinging fragments from the explosion assures that the COP>1.0 bench researchers stay alert and on their toes. Needless to say, when experimenting with COP>1.0 systems and circuits, one should exercise all safety precautions, including safety glasses, until the **"negative** energy beasts have been tamed and controlled". One should not experiment with such things unless one is an experienced and safety conscious experimenter. One experiments at one's own risk.

Negative energy effects in coils and toroidal coils are largely still unknown, though we have outlined some of the major effects. For a normal helical coil, one can derive a concept of the effects by considering the lattice effects in the wire. In this case, introduction of hole current at one end of a helical coil will induce electron current from the other end and into the coil. Thus, hole current can be "switched" back and forth between the ends of a helical coil to induce an ordinary AC electron current in the coil, accompanied by normal magnetic fields etc. A point can be reached where the coil is actually in resonance with the frequency of the switching, and with the "seeming capacitance" of the hole current introduction in each switching. With the proper material in the coil and a keen balance between the negative energy capacitance effect and the normal positive energy induction effect, *in theory* a single coil can be turned into a self-oscillating, self-powering system.

With core material inside the core of a coil, the situation dramatically changes. Often the type reaction experienced will appreciably depend upon the core material, and changing the core material can dramatically change the effects upon the coil and the effects that the coil produces. One may even use dynamic changes in the core material to produce corresponding dynamic changes in the coil. A toroid may act differently from an ordinary helical coil, as does a flat (spiral-wound) coil. Here the experimenter must simply perform his own experiments to seek out and understand the phenomenology he uncovers.

For exploratory experimenting with core-filled coils, we advise strong caution and testing at very low power only. Sometime effects can apparently be experienced by the researcher (headaches, nausea, dizziness, etc.) It is suspected from some evidence (but not proved) that the core material's chemical characteristics can sometimes be "imprinted" upon the human body chemistry, from the novel radiation of a core-filled coil or some core-filled coils. This is particularly true in the presence of strong stress potentials, such as from bi-wound coils with fields in opposition, and particularly if the biwound coil contains a nonlinear material core. The nonlinear core induces modulation (multiplication) of the two waves, rather than linear mixing. Thus, the two waves are "locked together" to form a true stress potential and local spacetime curvature sets, when the biwound coil has a nonlinear material core. In short, one is now engineering pure general relativity, locally.

Again, we iterate that the experimenter should be knowledgeable and take all safety precautions. He experiments at his own assumption of risk.

The appearance of an extra stress potential (field-free) in a biwound coil is in fact a new Lorentz symmetrical regauging, and the equivalent of rotating the frame of the coil. As signals are introduced, this is the equivalent of continually changing the degree of the frame rotation, which is a general relativistic effect, with direct curvatures of spacetime being produced. In short, one is producing spacetime curvature and rotation engines, previously discussed.

The magnitude of the stress potential (field-free) falls off inversely as the distance. Thus one's body can be exposed to it, including the body chemistry, every cell and every part of every cell, the nervous system, etc. Placing signals on the biwound coil can conceivably result in slight variation of the scalar stress potential, including inside the body, and inside each cell and each part of each cell. Variation in the stress potential ϕ in a little local region inside the body produces $-\nabla\phi$, which is an electric field E. The rate of change of this E-field then produces a magnetic field H.

Consequently, very minute EM fields are produced throughout the body and all its parts, or can be. It is as if the entire body is "electromagnetically washed" in internal EM fields throughout its matter, structures, and dynamics. The hydrogen bonding actions ever ongoing are particularly sensitive and can restructure appreciably in the presence of this stimulus. They can also "imprint" and take on a specific induced structure and dynamics, correlated to the persistent changes induced from the biwound coil. As can be seen, such EM biological effects have not been appreciably investigated and documented in the Western scientific literature. Hence our urging and insistence that the researcher use all caution, and our warning that he experiments at his own will and assumption of risk. Neither the publisher nor the present author is responsible for any accidents or blunders that may occur.

Capacitor effects also vary between types of capacitors, when applying negative energy or a mix of positive and negative energy. Some capacitor dielectric materials are also photo-refractive and are semiconducting materials, hence photoactive. The rich effects capable of being generated in capacitors — by EM fields, waves, potentials, and pulses of negative energy or negative and positive energy mixed — are largely unexplored and not catalogued.

Almost all modern permanent magnetic materials are also photo-refractive or photoactive materials as well, and many are semiconducting materials. Hence a rich variety of effects can be produced in permanent magnets by the introduction of negative energy fields, potentials, waves, and pulses.

As can be seen, a very rich combination of effects exists for "normal-appearing" coils, capacitors, semiconductors, and magnets when applying appreciable negative energy or controlled mixes of positive and negative EM energy. This is a still largely unknown materials science region, and one that has not been systematically and rigorously explored and catalogued, if at all.

In addition, there are effects from *pulsing* negative energy (Dirac hole currents) that are not completely understood. These appear to occur almost — or partially — at random, and also seem to be affected by the natural surroundings, by the various materials, etc. The "imprinting" phenomenon, when it occurs, seems to be augmented by pulsing, and sometimes by the pulse shape and pulse repetition frequency as well as the surroundings.

We also legally state that we are not responsible for any risks the researcher chooses to take, but are only alerting him to be very careful and use very good safety practices. Any experimenter is himself responsible for stringent adherence to good safety practice and common sense, and he legally assumes his own personal risks for all experiments he chooses to undertake.

Another effect to be alert to is the effect of "charging" the local area's supersystem with an altered active vacuum and curvatures of spacetime. This phenomenon is usually experienced as a "slow growth" of the COP of the system, over a long time (months or years). Tiller in private discussions has reported such phenomena in his detector built at Stanford University. Golden and I experienced such phenomena with a small COP>1.0 system Golden was developing. Over a period of five years, the system slowly increased its COP to about 2.0. Moved several hundred miles, the system then exhibited COP of about 0.9, but with occasional fluctuations of overunity temporarily.[285] Golden had gradually charged his local area with the "engine" or spacetime curvature operational and functional form of his unit. Thus in that repeatedly charging area, gradually the operation of the unit improved. We referred to this *engine-*

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[285] In fact, Golden and I were astounded at these results, until Tiller explained it to us and explained his own experiences with "growing" his detector. Thanks to Professor Tiller, thereafter we had this new phenomenon firmly fixed in our lexicon.

charging of the environment with a particular effect or dynamic form as *kindling.*

The kindling or "charging to favor the dynamic form of the engine or device" problem, should it occur, is in fact usable because it is possible to produce it everywhere on earth, and fairly permanently. To use the kindling effect once discovered, the mechanism is to build several identical units. Keep the original unit working in the original area, and "outrigger" the others at radial distances as distant as possible, but maintaining COP>1.0 for the outriggers. Then simply run both the outriggers and the central unit, steadily. The "structural charge" will grow and reinforce at the outrigger locations, then spread on beyond the outriggers, and a much larger area will now be "charged with that dynamic form". With sufficient additional outriggering (three to five, or seven in an especially difficult case) where the successively internal outriggers arc retained and operating, the charging will eventually spread around the entire Earth, and *it will become a permanent fixture of the Earth environment itself.*[286] Thereafter, anytime one of the units is turned on anywhere on earth, it will perform with its normal overunity condition. In other words, not only can one grow the dynamic form (engine) in a supersystem in a given locality, but one can also kindle it into the entire Earth's supersystem permanently {591}. One is strongly reminded of Feynman's observation that physicists with their big accelerators may in fact be partially creating their own reality. He pointed out that often the physicists look and look for a new, predicted particle. At last and after years of difficulty, finally a "glimpse" of the particle occurs in an accelerator and is reported. The physicists quickly crank up the other accelerators and look intensively, and — after some moderate difficulties — they find that particle. Thereafter, *every time an accelerator turns on and looks, that particle is readily seen, easily.*

The supersystem's spacetime is part of the local spacetime of the Earth, and all supersystems also interact with each other. As Kron put it {592}:

> *"An electric network differs from all other types of non-electric networks in that it is always surrounded in all directions to infinity by an invisible dynamic electromagnetic field of its own creation. ... Each Inductance L produces its own magnetic field, each*

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[286] We have proposed an application of this phenomenon to kindle and maintain a specific disease organism's "anti-engine" as a startlingly new kind of medical therapy for permanently eradicating a particular disease vector from the earth.

> *capacitance produces its own electric field and each resistance R creates a thermodynamic field of its own. Moreover, there exists a continuous interaction between the magnetic, electric, thermodynamic, and radiation fields. Thus any correct and basic theory of the electric network must include all the parameters of its surrounding electromagnetic field and must satisfy all the field equations of Maxwell. The theory must also dovetail with the Hamiltonian and Lagrangean equations of dynamics containing both time and space derivatives, as well of the equations of irreversible thermodynamics. "*

So decades ago, Kron was struggling with the "supersystem" problem, in different terminology, and he eventually originated *diakoptics* {593}, an entirely new way of breaking the problem down piecemeal so it could be solved. But Kron strongly stressed that the interactions of the fields and potentials of a circuit and all its parts reach to infinity and have an n-dimensional set of degrees of freedom and an infinity of spaces. The fields and potentials of every charge reach to infinity (for those charges in matter from the beginning), and so every charge in the universe interacts with every other charge and its fields, potentials, and dynamics. Spacetime itself is filled with these interacting EM fields, potentials, waves, and dynamics. Little wonder that the horrendous set of ongoing EM interactions at every point in the vacuum has such incredible energy density and fluctuations. We may even regard the fluctuations and interactions as completely causal, but — with no information on each interaction — they must be treated as totally statistical. Ultimately nature confounds our Aristotelian logic and insists that, in the limit, one is dealing with 5-law logic as developed earlier in this book.

Since the earth near an ongoing COP>1.0 system experiment has innumerable electrical aspects, materials, etc., it follows that the surrounding earth is indeed in direct interaction with the experiment. It then follows that "slow conditioning" of the surrounding area should be possible, say, after some years as Golden experienced. It also follows that the effect diminishes in magnitude with distance from the experiment.

The "growth of the activation (kindling) to include the entire Earth" is a slow process, requiring years and much expense to aid the "spreading" — as the physicists may be experiencing, according to Feynman. But it is a doable.

We highly recommend that the researcher work on COP>1.0 systems that are not charge and location dependent, so that the kindling problem does not arise. We have assumed non-kindling COP>1.0 systems throughout most of this book.

Chapter 10

Cold Fusion: Low Spatial-Energy Nuclear Reactions at High Time-Energy

"This book is about time. I would have liked to have named it Time, the Forgotten Dimension..." **[Ilya** Prigogine]. {594}

"The notion of time may be unfolded into an independent pure science... a science of pure time is possible." [Sir William R. Hamilton, 1837]. {595}

"...contrary to the conclusions of classical mechanics, there exist effects of potentials on charged particles, even in the region where all the fields (and therefore the forces on the particles) vanish. " [Y. Aharonov and D. Bohm] {596}.

"...global behavior greatly modifies the very meaning of space and time. Much of geometry and physics is based on a simple concept of space and time, generally associated with Euclid and Galileo. In this view, time is homogeneous. Time translations may have no effect on physical events. Similarly, space is homogeneous and isotropic; again translations and rotations cannot alter the description of the physical world. It is quite remarkable that this simple conception of space and time may be broken by the occurrence of dissipative structures. Once a dissipative structure is formed, the homogeneity of time, as well as space, may be destroyed. " [Ilya Prigogine] {597}.

"As we expand our observation, we extend our concepts. Thus the simple symmetries that once seemed self-evident are no longer taken for granted. Out of studies of different kinds of interactions we are learning that symmetry in nature is some complex mixture of changing plus into

minus, running time backward and turning things inside out. " [T. D. Lee] {598}.

"The desirable features of a system of units in any field are convenience and clarity. For example, theoretical physicists active in relativistic quantum field theory and the theory of elementary particles find it convenient to ***choose*** *the universal constants such as Planck's quantum of action and the velocity of light in vacuum to he dimensionless and of* ***unit magnitude.*** *The resulting system of units (called 'natural' units) has only* ***one*** *basic unit, customarily chosen to be length. All quantities, whether length or time or force or energy, etc., are expressed in terms of this one unit and have dimensions which are powers of its dimension. There is nothing contrived or less fundamental about such a system than one involving the meter, the kilogram, and the second as basic units. It is merely a matter of convenience."* [J. D. Jackson] {599}.

[Violation of Second Law of Thermodynamics] *"We experimentally demonstrate the fluctuation theorem, which predicts appreciable and measurable violations of the second law of thermodynamics for small systems over short time scales... Our results show entropy consumption can occur over colloidal length and time scales."* [Evans et al.][287]

[Implications] *"This result has profound consequences for any chemical or physical process that occurs over short times and in small regions. "* [Evans et al.][288]

[Implications] *"The smaller a machine is, the greater the chance that it will run backwards. "* [Evans et al., *ibid.]*

[Implications] *"Physicists knew that at atomic scales over very short periods of time, statistical mechanics is pushed*

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[287] G. M. Wang, E. M. Sevick, Emil Mittag, Debra J. Searles, and Denis J. Evans, "Experimental Demonstration of Violations of the Second Law of Thermodynamics for Small Systems and Short Time Scales," *Phys. Rev. Lett.*, 89(5), 29 July 2002, 050601.

[288] BBC News, **18 July 2002, http://news.bbc.co.uk/l/hiscitech/2135779.stm.**

> *beyond its limit, and the second law does not apply. Put another way, situations that break the second law become much more probable. ...the new experiment probed the uncertain middle ground between extremely small-scale systems and macroscopic systems and showed that the second law can consistently be broken at micron scale, over time periods of up to two seconds."* [Chalmers] [289]

10.1 Explaining Time as Energy

See Chapter 1, paragraph 1.1.3 and 1.4.1; see also Chapter 2, paragraph 2.1.3. As highlighted in the quotation from Jackson {599}, it is well known that the fundamental units chosen to model physical phenomena are arbitrary. In a physics model whose only fundamental unit is the joule, time is obviously modeled solely as a function of energy, just as mass is modeled today as a function of energy — hence the term "mass-energy". We may also equally well use the term "time-energy", since in a model using the joule as its only fundamental unit the second is purely a function of energy. Specifically, for our purposes 1 sec = 9 x 10^{16} joules of spatial energy, compressed by the factor c^2 and placed on the 4th Minkowski axis to constitute one second of time. If the compressed spatial energy had been left in 3-space, it would be recognized as *mass*. For our purposes, *time* has the same energy density as mass.

The flow of time becomes a special form of EM energy flow, analogous on the fourth axis to mass flow (translation) in 3-space. Further, as previously pointed out the overall flow of time has extensive internal structuring of component time-energy flows. However, time-flow is in the imaginary plane or connected with it, since in Minkowski space the 4th dimension is modeled as -i*ct*. Note that the only variable in *ict* is the *t*, hence anything varying on the fourth axis is a variation of time and time-energy *a priori.*

Further, we can apply conservation of EM energy to the time domain as well as in 3-space. And we can have "broken symmetry" in time-energy flow as well as in 3-spatial energy flow, so long as the net energy flow is conserved. The most fundamental conservation of energy law is giant negentropy: the automatic circulation of energy from the time domain into 3-space via decompression by the negative charge, thence the slight flow of 3-space energy to the positive charge where the 3-space energy is recompressed, thence from the positive charge back into the time domain.[290] That was our solution to the long-vexing problem of the source charge and its associated 3-space fields and potentials and their 3-space energy. From special relativity, one already knows that time can dilate and then *un*-dilate, but each action is associated with an appropriate change in spatial energy. While that change in spatial energy can be kinetic, it does not have to be. It can be a change in potential energy instead. In short, a static object rotates its frame with respect to the observer (lab) frame, whenever it absorbs or emits potential energy.

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[289] Matthew Chalmers, "Second law of thermodynamics 'broken'." *New Scientist,* 19 July 2002, http://www.newscientist.com/news/print.jsp?id=ns99992572 .

We also pointed out the connection of time-energy to electromagnetics and to quantum field theory, via the four polarizations of the photon considered to travel in the z direction in 4-space. These four polarizations are with the energy vibrating along *x*-, *y*-, *z*-, and t- respectively. Vibration of the spatial energy of the photon along the *x*- or *y*- axis gives an ordinary transverse photon. Vibration of the spatial energy of the photon along the z- axis gives the longitudinal photon. Vibration of the time-energy component along the t- axis gives the scalar or time-polarized photon. We assume a similar four polarizations for EM waves in 4-space.[291]

10.2 Mechanism Generating Flow of a Mass through Time

As we covered in the referenced paragraphs in Chapters 1 and 2, the fundamental generatrix of the flow of a mass through time — and the structuring of that flow — is the total photon interaction with the mass and all its parts. This includes both observable and virtual photon interactions.

As a recapitulation: Mass *m* does not exist in time, since it is an observable and observation is the imposition of d/*dt* upon spacetime LLLT, removing the T to give a "frozen LLL snapshot." In short, mass m is an *effect* (of the iterative very high speed observation process), not a *cause* (which is an *input* to the observation process). This is why all observation is 3-spatial rather than spatiotemporal: it yields the 3-space *effect* (at a given time, of a given interaction), not the 4-space cause of the interaction and not the ongoing 4-space interaction.

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[290] Note the relationship with such things as time dilation, which represents a broken time-flow symmetry, where net energy flow from the time domain to the 3-space domain occurs. Hence time dilation is associated with the increase of spatial energy, such as kinetic energy due to the relativistic velocity of the moving object.

[291] In this book, we have limited our discussion to four dimensions. If we model in five or more dimensions, then additional symmetries and broken symmetries **are** possible, as are new kinds of multi-dimensional EM waves.

By absorbing and emitting photons, observed mass *m* may be said to move through time in a succession of *m* => *mt* => *m* => *mt* => *m* ... jumps, each involving change of physical state as a photon is absorbed by *m,* changing it to *mt* which is nonobservable. Then a photon is re-emitted by *mt,* changing it back to *m* and completing another observation with this new *m* as the output (effect). We note that masstime *mt* is as different in nature from mass *m,* as impulse *Ft* is from force *F.* In mass *m,* every tiniest differential *dm* is also interacting with photons continuously (even though they may be *virtual* photons), hence *dm* also exhibits its own "digital flow through time" as a part of the structure of the overall flow of the parent mass through time.

Interaction primarily with the *mt* state yields wavelike interactions. Interaction primarily with the *m* state yields particle-like interactions. This is proposed as a possible resolution of the wave-particle duality problem, which has never been resolved but just accepted without further argument. Previous consideration of wave-particle duality has assumed that "mass has two states, one particulate and the other wavelike". We correct that assumption by pointing out that two different "states in which mass exists" are involved, and the two are quite different: one is mass *m,* and the other is masstime *mt.* We stress the function of the myriads of virtual photon interactions during an *mt* state, where an observable photon has not yet been re-emitted. These virtual photon reactions create streams of virtual *dm* => *(dm)dt* => *dm* => *(dm)dt* => . . . . on all the differential parts of mass *m,* which creates the rich structuring inside the "time-flow" of the overall observable mass *m* through time. The rich dynamics of the *dm* -> *(dm)dt* streams also accounts for the seeming existence of mass *m* as a set of 4-dynamics which interpret as a set of waves. We note that the emitted photon carries with it the internal structuring of the spatial energy domain and the time-energy domain. Herein we have the basis for the Kaznacheyev's demonstrated electromagnetic induction of cellular damage and disease at a distance.[292]

Finally, we tentatively assume that, prior to its interaction, the antiphoton carries negative spatial energy and positive time increments, while the photon carries positive spatial energy and positive time increments. In a very small region where an excess of antiphoton interactions occurs temporarily, time-reversal occurs and the physics "runs backward". It has recently been experimentally proven that such "reversing" of the physics processes occurs up to micron size and for times up to two seconds. [293]

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[292] Vlail Kaznacheyev and L. P. Mikhailova, *Ultraweak Radiation in Intercellular Interactions,* [in Russian|, Novosibirsk, 1981.

10.3 Time-Polarized EM Waves and Longitudinal EM Waves

10.3.1 Waves, Photons, Spacetime Curvature, and Observation

Spacetime (ST) curvature involves not only the change of *spatial* energy density of local spacetime but also a change of its *time-energy* density. That component of the total ST curvature due to time-energy density change — i.e., time-polarized EM photons and waves — can be far more powerful, because of the enormous energy density of the time-energy compared to the far lies dense 3-spatial energy. As previously stated, time may be regarded as having the same energy density as mass, except that the highly compressed 3-spatial energy is moved to the 4th Minkowski axis to constitute "time" rather than being left in 3-space to constitute "mass".

Hence ST curvature can be made very powerful when one uses longitudinal phase conjugate EM *wavepairs,* as shown by Whittaker {600} in 1903 with slightly corrected interpretation as argued by the present author {615}. Each longitudinal EM wave in 3-space is accompanied by a precisely coupled time-polarized (scalar) EM wave in the time domain, which latter wave is a longitudinal EM wave on the fourth Minkowski axis involving changes in the t variable in the axis *-ict.* We previously discussed the giant negentropy that this represents with respect to the source dipole. At various times in the past, we have emphasized the time-domain aspects of the coupled phase conjugate longitudinal EM wave-pair by calling such a coupled wave by terms such as *time-density EM waves, time-polarized EM waves,* etc. These terms imply additionally altering and structuring the *time density* and *time-energy density* of spacetime rather than merely altering and structuring its *3-spatial energy density.* Such time-density induced ST curvatures may be nearly 10^{17} times stronger than ordinary spatial energy density ST curvatures {601}.

Interestingly, at least one researcher — Matsumoto {602} — has realized the basic implication in cold fusion processes of using the strong EM force as the agent of spacetime curvature. He has shown consistency of the postulated EM-induced ST curvature approach with some important cold fusion results. However, Matsumoto has utilized the conventional interpretation of spacetime curvature due to alteration of *3-spatial energy density* of spacetime. This misses the primary time-density functions, but does include the resulting spatial-energy functions after transduction from time-energy to spatial-energy. His work, however, does support the involvement of a more intense form of energy in the cold fusion effects.

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[293] See footnotes 287, 288, and 289.

There are intriguing but still mysterious relationships to be noted between cold fusion and deep astrophysical mechanisms. Continuing reference is made to these similarities, including black holes and white holes. Black holes and white holes involve spacetime curvatures — extreme, but still spacetime curvatures. So one would suspect that the entire scale of spacetime curvature — including black holes and white holes in the limit — should be of interest to cold fusion researchers, since in their use of time energy they are inadvertently involving more intense forms of energy than ordinary spatial EM energy.

Most nuclear scientists and even some relativists seem unaware of the much more powerful spacetime curvature effects obtained by alteration of the *time density* of spacetime rather than just its *spatial energy* density. Physicists have largely omitted specializing on time density ST curvatures because they have largely omitted the absorption and emission interactions of the time components transported by photons and EM waves.

Longitudinal EM phase conjugate wavepairs (each wavepair a coupling of a time-polarized EM wave and a longitudinal 3-space EM wave) of the type shown by Whittaker {600} in 1903 involve net *time density oscillations* as well as 3-spatial energy density oscillations, according to our reinterpretation. The infolded "inner EM content" of all conventional EM potentials, fields, and waves thus contains extraordinary dense time-energy, normally lost in the *d/dt* observation interaction.

In short, the infolded "internal Whittaker electrodynamics is a pure "general relativistic electrodynamics" and a unified field dynamics. Further, it can be engineered, which leads to startling new physical processes previously thought to be impossible and forbidden by the laws of nature.

Prior to observation, the internal highly compressed time-energy structures associated with the interior EM structure of all conventional EM potentials, fields, and waves are extremely powerful spacetime curvatures.

In short, all "conventional" electrodynamics has an internal structure of strong spacetime curvatures and dynamics.

Organization and patterning impressed on, or inserted in, this internal structuring can provide extraordinary actions in materials, living biological systems, cells, etc. Adding deterministic structuring inside these normal EM entities is referred to by Russian energetics weapon scientists as engineering the *information content ofthe field.* This is the approach behind deliberate engineering of *spacetime curvature engines,* or vacuum engines — or just "engines" for short.

In theory, any physical change to a mass can be engineered by inserting such "engines" into the mass. Any mass-energy is a mass-energy EM potential with an internal structuring (engine) for all the mass's internal dynamics. This engine is referred to as the *resident engine* of that mass (and all its dynamics). Introducing to a given mass a potential with a desired "delta engine" structure, results in the superposition of the two potentials, resulting in exchange sharing of the engines. In that manner, a desired "delta engine" diffuses into the mass's potential structure and its resident engine, changing it to a new resident engine which now acts on the mass at every level to change it. Potentials superpose, and their engines diffuse and superpose as well. Direct engineering of matter — even inside the nuclei and inside the nucleons themselves — can be performed by introducing the desired engine or engines for the changes desired.

This area has been highly weaponized by one or more nations. E.g., the Russians — in several decades of so-called "microwave radiation of the U.S. Embassy in Moscow — induced health changes and diseases in U.S. personnel in the Embassy by inducing deliberate "disease engines". Such EM-induced diseases and health changes were generated in the zones where the potentials were field-free, and therefore stable for stable engine diffusion.

Note that the common scalar potential decomposes by Whittaker's 1903 decomposition {600} into the longitudinal EM wavepairs we are speaking of. Also note that, per a second paper by Whittaker in 1904 {91b} that initiated superpotential theory, all EM fields and waves can be decomposed into two scalar potential functions. Each of those base potentials involved in the potential functions further decomposes by Whittaker 1903 into a harmonic set of phase conjugate longitudinal EM wavepairs as previously discussed. Therefore, the infolded EM inside all the "conventional" EM fields, waves and potentials is indeed a highly organized set of such bidirectional longitudinal EM wavepairs and thus a highly organized set of extreme localized ST curvatures. In other words, it is comprised of these special "engines" of deterministic spacetime curvatures and their dynamics.

Constructing the potential by assembling one's own set of phase conjugate longitudinal EM wavepairs to form it, one can insert any kind of ST curvature set — any kind of vacuum engine desired — inside the base potential(s), hence inside the two potential functions comprising a given set of EM fields and waves utilized as "carriers". The specific internal structure of a "carrier" radiation field or potential designed to carry such engines is called the "information content of the field".[294] The Russians have long had a disinformation campaign to suggest that the term refers to conventional spectral analysis. It does not.

Johns Hopkins scientists did detailed measurements inside the Embassy and confirmed that all the anomalous health changes and diseases had occurred only in areas where the EM fields B and E were absent. That is, the health changes occurred only where the potentials were field-free and therefore stable and unchanging, so that an exposed body was immersed in a steady sea of "vacuum engines" being diffused throughout the targeted body's EM potentials in and on its cells, its cellular membranes, etc.

In general relativistic terms, every physical set of changes and altered dynamics (syndrome) of a specific disease has a specific *delta* set of spacetime curvatures and dynamics associated with it, which interacts on the body, its chemistry, its electrodynamics, its cells, etc. A desired set of

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[294] Indeed, in theory one can *construct, functioning robotic systems* of these internal engines. In clandestine Russian weapon research, it appears that at least elementary "causal robots" of such internal engine type have been developed and tested. In a sense, these are the ultimate "nanobots" made of infolded longitudinal EM waves and their dynamics. In theory, command and control functions (via longitudinal EM wave communication) can be included, as can certain kinds of weapons effects based on scalar interferometry. The eventual development of such startling weapons seems intended to produce an army of eerie "internal EM" robots which can be "sent in" *through the interior of EM fields, waves, and potentials,* to targets anywhere on earth, beneath its surface, in space, or beneath the ocean. This may be intended to become the ultimate robot or "high tech" warfare, and it is also the ultimate "information" warfare. There are no shields against this type weaponry. Defense, however, is accomplished by first using longitudinal wave "scanning" to pick up and track the systems, much like radar picking up aircraft. Once detected, scalar interferometry is utilized to disrupt and destroy them in place. Progress on these robotic weapon systems appears to be well along, as does progress on their countering longitudinal EM wave weapons.

ST curvature deltas for a given disease was inserted inside the base potentials in a combined Whittaker 1903 and 1904 decomposition of the stable field-free potentials in the Embassy. The Russians thus induced the desired engines for induction of the specifically desired disease(s) in the assigned personnel in those field-free potential zones in the Embassy. The purpose was to use the tests as (i) a guaranteed means to provoke high level U.S. governmental attention, and (ii) a probe to see if the U.S. knew about such technology and had developed defenses. Other tests of such disease induction in entire populations have also been conducted, but these are beyond the scope of this book.

We point out one very important thing: the cells of the body have their normal "resident engines" and resident engine dynamics inside their internal fields and potentials and waves. For any specific disease or disorder condition, there exists a specific associated change (delta) in the normal set of vacuum engines and their dynamics, in the cells and the body. In short, there exists a specific "delta engine" for any cellular disease or disorder, added to the normal engine.

It is not the immune system that heals. Instead, it is the cellular regenerative system. The natural healing method used by the cellular regenerative system is not chemical. The regenerative system uses the phase conjugate wavepair composition of increased scalar potentials (on cellular membranes and every part of the cell) to "pump" the cells in the time-domain. This creates an "anti-engine" for the specific disease delta or disorder, and it slightly amplifies this anti-engine within the limited capabilities of the body. This action places this amplified anti-engine also into the stricken cells' engine complex. Engines superpose, just as do potentials. This action by the regenerative system has the effect of slowly producing complex anti-forces in the body and inside the cells themselves, eliminating the detrimental engine delta, restoring the normal resident engine and thus time-reversing the stricken cells back to a previous healthy condition. It does not kill pathogens at all; that is the function of the immune system. In the 1960s and early 1970s, Antoine Priore in France demonstrated remarkable cures of terminal tumors, infectious diseases, clogged arteries, and other disorders in laboratory animals,[295] unwittingly amplifying the body's own master regenerative mechanism. His work was suppressed in the mid-70s.

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[295] See (a) A. Priore, *Guerison de la Trypanosomiase Experimental Aigue et Chronique par L 'action Combinee de Champs Magnetiques et D 'Ondes Electromagnetiques Modules* [Healing of intense and chronic experimental trypanosomiasis by the combined action of magnetic fields and modulated electromagnetic waves], Priore's thesis submitted in candidacy for the doctoral degree, 1973. The thesis was rejected when the project was suppressed. See also (b)

Check our website, www.cheniere.org, for a 119-slide "porthole" briefing on the present author's extension whereby specialized mixes of ordinary EM waves can be used to initiate and perform this "delta engine elimination" healing process, and it can be highly amplified well beyond the body's normal healing capabilities.

In 1998 we seriously proposed to the DoD, the USAF, the NIH, and other U.S. government institutions that a crash development program be initiated to develop portable units capable of rapidly (5 minutes per patient) treating mass casualties from coming terrorist attacks with weapons of mass destruction such as anthrax, smallpox, bubonic plague, Ebola virus, etc. Sadly, no one in the U.S. government had the foggiest notion of what we

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"Le Probleme Priore," *Rapport de la Commission de 1'Academie des Sciences a Monsieur le Ministre d'Etat charge de la Recherche et de la Technologie,* 1982, p. 1-22; (c) Antoine Priore, "Precede et dispositif de production de rayonnements utilisables notamment pour le traitement de cellules vivantes," [Procedure and Assemblage for Production of Radiation Especially Serviceable for the Treatment of Living Cells], Republique Francais Brevet d'Invention P.V. No. 899.414, No. 1,342,772, Oct. 7, 1963; (d) Antoine Priore, "Method of producing radiations for penetrating living cells," U.S. Patent No. 3,280,816, Oct. 25, 1966; (e) Antoine Priore, "Apparatus for producing radiations penetrating living cells," U.S. Patent No. 3,368,155, Feb. 6, 1968; (f) A. J. Berteaud and A. M. Bottreau, "Analyse des rayonnements electromagnetiques emis par l'appareil Priore," [Analysis of the electromagnetic radiations emitted by the Priore apparatus], D.R.M.E., 1971, p. 3-12.; (g) R. Courrier, "Expose par M. le Professeur R. Courrier, Secretaire Perpetuel de L'Academie des Sciences fait au cours d'une reunion a LTnstitut sur les effets de la Machine de M. A. Priore le 26 Avril 1977," [Presentation by Professeur R. Courrier, Perpetual Secretary of the Academy of Sciences, made at the meeting of the Academy on the effects of the machine of M. A. Priore]; (h) R. Pautrizel, A. Priore, M. Dallochio and R. Crockett. (1972) "Action d'ondes electromagnetiques el de champs magnetiques sur les modifications lipidiques chez le Lapin par l'administration d'un regime alimentaire hypercholestrole." [Action of electromagnetic waves and magnetic fields on provoked lipidic modifications in the rabbit by the administration of an alimentary hypercholesterol diet.] *Compt. Rend. Acad. Sci. (Paris),* Vol. 274, 1972, p. 488-491. The same university that rejected Priore"s doctoral thesis in 1973, accepted a doctoral thesis on the same subject some 11 years later due to the persistence of Pautrizel: See (i) Eric Perisse, *Effets des Ondes Electromagnetiques et des Champs Magnetiques sur le Cancer et la Trypanosomiase Experimentale [Effects of Electromagnetic Waves and Magnetic fields on Cancer and Experimental Trypanosomias],* Doctoral thesis, University of Bordeaux No. 83, March 16, 1984.

were discussing. At NIH, we never got out of their "policy" (i.e., "spin control") department. Not a single capable scientist reviewed the extensive package. The attack on the World Trade Center and the Pentagon on Sept. 11, 2001 is just a forerunner of that which is to come. We could have been prepared to save hundreds of thousands of Americans, even millions. We shall not be ready, and the first really professional anthrax or smallpox (or camel pox, which is easily available and almost exactly the same as smallpox) attack on a major U.S. population center may leave from one to three million Americans dying in the streets and in their homes. Presently nothing will save them. It could have been different.

10.3.2 Photons and Waves in Minkowski Spacetime

Photons are made of angular momentum (action); i.e., of *energy x time.* Waves, being made of photons, carry both spatial (decompressed) energy and time (highly compressed) energy — although physics has largely omitted the *time-energy-carrying* aspect, and only accounted for the *spatial energy-carrying* aspects. An EM wave in space is actually a wave of the particular spacetime curvatures that produce angular momenta in interacting charged masses. The standard notion of E and B fields at right angles in a plane in 3-space, traveling along the *z-* direction and with the plane orthogonal to *z-*, and with E and B field vectors oscillating back and forth, is nonsense, as acidly commented upon by Romer {603}, the former editor of *American Journal of Physics.*

Nonetheless, using the standard way of modeling the "transverse" EM wave: In conventional electrodynamics, a *transverse EM wave* is one where the 3-spatial energy density is considered to be varying rhythmically at right angles to the direction of wave propagation, and the time-density is assumed to be non-varying, or at least altered only by special relativistic considerations in certain cases.[296] A longitudinal EM wave has its spatial energy density fixed in *x-* and *y-* directions, and its energy density is oscillating along *z-*, the direction of wave propagation, by a "compression" and "rarefaction" process much like squeezing an accordion. This, however, leads to a "galloping" motion where the wave is alternately very superluminal and very subluminal at given instants, but moving at an *average* velocity of *c* {604}. On the other hand, a *time-density (scalar) EM wave* by definition is not varying in its 3-spatial energy density, and therefore is not varying in *x-, y-,* or *z-*. Instead, the energy is in the form of time-energy, and its variation is in time density. So its energy density is oscillating along the fourth Minkowski axis, *ict,* as an oscillation of the energy density of the variable *t.* It is therefore polarized in the t- direction.

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[296] We point out that a wave of varying spatial energy density is moving in a varying curved ST a priori, by general relativity. If the "wave" were in a flat spacetime as normally assumed, the EM flat spacetime would eliminate the EM wave itself. **This** has been particularly pointed out by Sachs and by Evans.

10.3.3 Time-Charging, Internal Structuring, Vacuum Engines, and Diffusion

Photon interaction as a *spatial* energy collection or energy exchange process is well known in physics. However, the time-charging or time-excitation interaction between the mass and the time component carried by the photon is usually ignored.

As is well known, an atomic electron that absorbs a transverse photon increases its spatial energy and changes into an excited spatial energy state. When the electron subsequently "decays" from that excited energy state to a lower state, the spatial energy differential between the two states is emitted as the spatial energy component of an emitted photon. This is the *spatial energy density* reaction of a transverse photon with an absorbing and emitting mass particle.

Unaccounted for by physics, at the time of the energetic excitation of the mass (i.e., when the photon is absorbed), a time excitation — time charging — also occurred because the time-component of the absorbed photon is also attached to the mass, converting it to *masstime,* a new entity. Re-emission of the photon is accomplished by the decay of both the *spatial energy* excitation and the *time-energy* excitation. In the previously excited state after photon absorption, however, one did not have the entity "mass", but the entity *masstime* having greater topology. If mass is an observable and taken to be 3-spatial (as is conventional), then photon absorption and emission oscillates between 3-space and 4-space effects, generating both spatial energy and time-energy (or *angular momentum)* excitation and decay.

Further, only *masstime* emits a photon. This immediately casts a very different light on such things as radioactive elements, which are in an initially excited state. Discussion of this aspect, however, is beyond the scope of this treatise.

On the other hand, a *scalar (time-density)* photon {605, 606} has a rather different interaction, regardless of how physics presently treats it. Any atomic electron at any energy level is continually receiving and emitting virtual photons - transverse, longitudinal, and scalar- in its virtual photon exchange with the energetic vacuum. Hence it is continually "connecting to" or "absorbing" time components, thereby changing its nature from mass to masstime, back to mass, back to masstime, etc. Not only the entire electron but also each differential piece of it is performing that dance between mass and masstime. This is a continual changing from 3-space to 4-space and back. There thus is a violent "chatter" of the electron (and each differential piece of it) in the myriad levels of its *time* exchanges, giving it

(i) An average rate of time component exchange,

(ii) An average "time-charge", and

(iii) A dynamically changing, specific structuring of its time components.

Whenever a mass absorbs an observable photon, the mass converts to masstime, with an "extension in time" as well as extension in 3-space. During the time-interval created in the masstime, myriads of virtual photons are absorbed and emitted by that mass component of the masstime entity. Hence every dt portion of the masstime state after observable photon absorption, is "internally structured" by the entire virtual photon interaction set's At's occurring within that time interval.

By tailoring at least the larger elements of this internal structuring of the masstime state's virtual photon bombardment, by a deliberately induced virtual photon bombardment, the emitted photon from the masstime decay will carry away with it a desired internal "vacuum engine" structure of organized curvatures of spacetime. In short, two potentials superpose; that is one of their primary features. When they superpose, they also diffuse their internal structures (internal vacuum engines) into each other.

We speak of the *diffusion ofa specific vacuum engine* placed in one interacting EM potential, field, and or wave as *dimensioning* the potential, field, or wave. Adding a dimensioned potential, field, or wave to other potential(s), field(s), or wave(s) diffuses the dimensioning (the engines) between all of the participating entities. With steady radiation of such dimensioned signals into a targeted object, field, wave, or potential, the dimensioning is gradually created (kindled) in the target, simply diffusing throughout it and gradually accumulating. If the irradiating signal carries a specific disease — e.g., necrotizing fasciitis — then gradually in the irradiated body there will emerge all the symptoms of necrotizing fasciitis. If the irradiating signal carries a specific disease antiengine — e.g., for necrotizing fasciitis — then gradually the necrotizing fasciitis condition will be eliminated, with the disease organisms also being eliminated.

This is a more fundamental extension of the disease vector concept. Not only can a disease vector be induced by a physical organism such as a virus or bacterium, but it can also be introduced by simply capturing the fundamental vacuum engine pattern of the disease and using it to condition or dimension signals used to steadily irradiate the targets.

This is the explanation of the Kaznacheyev experiments {607}: thousands of experiments performed by Vlail Kaznacheyev and his colleagues demonstrated the induction of almost any kind of remote specific cellular death and disease patterns in targeted cells, by absorption of radiation emitted from appropriate dying or diseased "emitter" cells with that condition, if the experiments were performed in the dark.

Instead of looking for biogenesis causes in amino acid precursors to cellular life in meteorites etc., one might well look into the *vacuum engine structures* inside the light from the sun, the planets, the stars, and the universe in general. E.g., dead sperm can often fertilize female cells, if not too much physical damage and deterioration to the dead sperm cells has yet occurred. This is understandable, since for a time a dead but undamaged sperm cell will have the same resident engine as a living sperm cell.

10.3.4 Some Cosmological and Gravitational Effects

Each of the observable-sized dt's in all the serial masstimc excited states of the mass moving through time, is internally and precisely structured. **The** precise time history of any mass — together with all its interactions, experiences, etc. — is present inside the time stream of ongoing interactions of that mass with photons. These virtual photon changes are in fact deterministic and come from every part of the universe, as shown by Puthoff {608} in his self-regenerative cosmological feedback cycle. We have merely extended his cosmological feedback to include the time **domain** as well as the energy domain. We hypothesize without further **discussion** that this internal structuring of the time-domain for every mass or object will eventually be connected with the quantum concept of the ge**ometric** phase {609}.

When a transverse photon interacts with a mass in the presence of other **photon** interactions, the mass can act as a phase conjugate mirror and form the phase conjugate replica photon (an antiphoton). For a longitudinal **photon,** the antiphoton *prior to observation* is a scalar photon. We propose that in the unobserved causal state the photon and antiphoton can couple (strong interpretation of the distortion correction theorem) and form a spin-**2 graviton.** According to quantum field theory, one may already interpret the common scalar potential as being comprised of such spin-2 gravitons {610, 611} if we speak of the situation prior to observation.

As opposed to the accounted *spatial energy charging* of the familiar transverse photon interaction, the longitudinal photon interacting with mass will cause immediate phase conjugation by the mass because of the accompanying scalar photon (accompanying antiphoton prior to observation). When one pumps with longitudinal EM waves, one also inadvertently pumps with time-polarizcd EM waves simultaneously.

From its background "time-energy pumping" in its vacuum exchange, the mass forms the phase conjugate replica, which couples to the incident longitudinal EM photon. This forms (wave view) bidirectional longitudinal EM wavepairs (conjugate pairs), comprised of (particle view) internal coupled longitudinal photon-antiphoton pairs. Each of those internal photon-antiphoton pairs is a spin-2 graviton.

Each such conjugate longitudinal wavepair actually contains a time-density (time-polarized) or scalar EM wave. So the interaction of LWs and their accompanying scalar waves immediately initiates the formation of time-density waves, which then primarily perform a *time-charging* interaction. In addition, even for an equilibrium time-charging state, the "masstime" state of the interacting electron contains a specific structure of the time elements in the electron-time's time component. Each of these infolded time elements is also time-charging the electron.

10.3.5 Charging and Excitation Considerations For Cold Fusion Purposes

So there are several new types of charge or excitation that are involved in cold fusion and other phenomena. One may speak of charging and excitation such as gravitational charging, time charging, time-energy excitation, time-energy charging, etc.

Both the longitudinal photon and the scalar (time-polarized) photon are in fact known in physics, but usually neglected, at least at the end of calculations. E.g., Gray {612} puts it this way about the four kinds of photon polarizations and the habitual elimination of the higher ones:

> *All that quantum theory can say is that there are two transverse photons, a longitudinal photon and a scalar photon. It must be decided by other means which are "desirable" states and then it is customary to "eliminate" the longitudinal and scalar photons by invoking a*

> *subsidiary condition, now somewhat weakened from the Dirac form.*

For our purpose in examining the cold fusion experiments, there exists a completely unsuspected "time-charge" set of excited states for an atomic electron, a proton (as in an H+ ion), etc.[297] There also exists a "time-structuring" of the time-charge excited time-state, which we will see is important in certain highly anomalous instrument phenomena. Uncovering this time-charging and time-structuring interaction has been one of the major results of this author's long effort to decipher the functioning of the healing (cellular regeneration) system of the body as well as his efforts to decipher the fundamental nuclear transmutation mechanism in cold fusion transmutation interactions at feeble *spatial* energy.

In summary: For longitudinal photon interaction, the atomic electron "absorbs" the longitudinal photon and its accompanying scalar photon, being simultaneously spatial-energy excited (charged) by the longitudinal photon and time-energy excited (time-charged) by the scalar photon. This time-excited state (of masstime) then subsequently decays, emitting a longitudinal photon accompanied by a scalar photon in the process.

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[297] See again footnotes 287, 288, and 289. From our mechanism propelling a mass through time, time-charging and discharging play the causal role. The acquisition of dt by mass *m* produces masstime *mt,* then the subsequent photon emission decay of *mt* back to *m* produces "propagation of mass *m* forward through time" by one "jump". Time charging with -dt and subsequent photon emission is what produces "propagation of mass m backwards through time" by one "jump". Evans et al. proved that even up to the micron scale physical particles and their dynamics can run backwards in time for up to two seconds or more. The fluctuation theorem proved by Evans and his colleagues in 1993 shows us that, at the scale of a proton and neutron, there can become a high probability of significant time reversal of the physical dynamics. This means that the law of attraction and repulsion of charged particles -such as two H+ ions in solution — "runs backwards" or is reversed, so that momentarily like charges attract and unlike charges repel. We have called the region in which this reversing of the physics occurs a *time reversal zone* (TRZ). With the reccent work of Evans et al., the existence and occurrence of TRZs even well above the proton (the H+ ion) level is now clearly established, including the reversing of the physical dynamics. These concepts have not yet been applied to cold fusion interaction results by the leading cold fusion researchers, but they now stand as explaining the most probable mechanism for the observed phenomena. In this Chapter we have written some of the typical new nuclear reactions that can occur in such a TRZ, and the exact products of these reactions are widely reported in several hundred successful cold fusion experiments.

We shall return to time-charging and time-charge decay when we examine and explain the odd instrumental anomalies experienced for some time in experiments at China Lake.

10.4 Time Reversal Zone and New Nuclear Reaction Mechanisms

It follows that the flow of a mass through positive time must involve a preponderance of reactions with photons rather than antiphotons, since *net* absorption and re-emission of photons (rather than antiphotons) is involved. Otherwise, the absorbing and emitting mass would not accomplish little "jumps" forward in positive time.

Suppose we deliberately arrange a situation where the target mass is interacting with a preponderance of antiphotons. In this case, the mass will be time-reversed, as will be the EM energetics.[298] This leads us to the novel concept of a *time reversal zone* just described in footnote.

A time-reversal zone (TRZ) is a region of space, or electrolyte, etc. in which given masses or charges of interest are interacting on the average with more antiphotons than photons. Consequently, in the TRZ the usual EM energetics are reversed and normal charge reactions appear to "run backwards" insofar as the spatial 3-space observer is concerned.

For example, in electrolytes in a region of highly loaded positive charges in a loading palladium lattice with properly prepared surface, a very great number of double surfaces exist. Hence a great number of scalar interferometries continually occur from that large number of double surfaces acting as scalar interferometers {613}. Because of the highly excess positive charge loading, these interferometers are predominately fed by negative EM energy from the positive charges. Hence, in the distant interference areas in the electrolyte outside the palladium lattice, some negative energy fields and negative energy potentials are produced dominantly. An excess of antiphotons is produced in those interference zones where an excess of antiphotons appear due to the scalar interferometry. In *those* little interference zones, the simple positive ions are momentarily bathed in an excess of antiphoton interactions. This is therefore a time-reversal zone of momentary time-reversed EM energy flow.

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[298] This *is not* time-travel in the classical science fiction sense. For time-travel, the traveling object must remain moving in its own forward time, while the entire remainder of the universe must be reversed in its time and must move backward in time to a past coordinate. That is not what is happening here, and no one is suggesting we can time-reverse the rest of the universe! Instead, energy can be reversed in time, as proven in nonlinear phase conjugate optics. So can mass-energy and charge-energy, as shown by the Dirac theory of the electron. An *observed* positron is an electron observed while traveling backwards in time, so to speak, with respect to the observer. But it is observed in observer forward time as traveling in the opposite spatial direction, having positive mass and positive energy, and with the sign of its charge reversed from negative to positive.

From a palladium lattice loaded with H+ or D+ ions, and also having a proper surface with many work grooves and thus many small interferometers, random fluctuations in the scalar interferometry occur in the adjacent electrolyte. Some of these random scalar interferometries continually form fleeting *time reversal zones* (TRZs) in their interference zones in the surrounding electrolyte. The very large energy required for the formation of each TRZ and its reversal of the normal laws of attraction and repulsion of charges, is available from conversion of time energy from the time domain as a result of the giant negentropy mechanism in 4-space ongoing in the loaded positive charges (614, 615} in the palladium lattice.

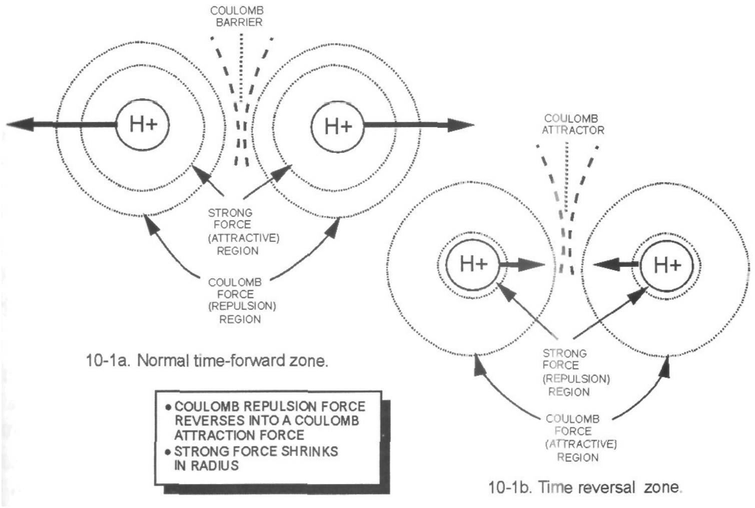
COULOMB BARRIER
H+
H+
STRONG FORCE (ATTRACTIVE) REGION
COULOMB FORCE (REPULSION) REGION
COULOMB ATTRACTOR
H+
H+
STRONG FORCE (REPULSION) REGION
COULOMB FORCE (ATTRACTIVE) REGION
• COULOMB REPULSION FORCE REVERSES INTO A COULOMB ATTRACTION FORCE
• STRONG FORCE SHRINKS IN RADIUS

10-1a. Normal time-forward zone.

10-1b. Time reversal zone.

Figure 10-1 Forces on nuclei of simple ions in time-forward and time-reversal zones.

See Figure 10-1. In Figure 10-la, two hydrogen ions (two free H+ protons) in a normal electrolyte and in a normal time-forward zone are shown. The

Coulomb barrier dramatically increases the forces of repulsion between the two H+ ions as their kinetic energy may be driving them momentarily toward each other. This Coulomb barrier becomes so strong that it stops the approach of the two ions and forces them back apart, or to deviate aside from their paths, before each can ever enter the very short-ranged strong force region of the other. Consequently no nuclear reaction occurs, but only a common chemical reaction. The maintenance of that Coulomb barrier is all that prevents energetic ions from being driven together closely enough to engage the strong force and cause the ions to form a new nucleus (cause a transmutation).

Now see Figure 10-lb, for the same two ions that suddenly find themselves in a momentary time-reversal zone (TRZ). In a temporary TRZ, suddenly like charges attract and unlike charges repel, exactly in reverse of the *normal* behavior of charge attraction and repulsion. The usually increasing Coulomb barrier (repulsive force between the two approaching H+ ions) has disappeared and been replaced by an increasing Coulomb attractor (attraction force). Further, the strong force has been partially reversed and much weakened since the gluon forces are dramatically reduced and fluctuating.[299] The attractive strong force is now a partially *repulsive* force and so it is much weaker. Consequently, the quarks in a proton or neutron are not nearly so strongly bound as they are in a normal time-forward zone (TFZ).

A TRZ represents a highly time-charged excited local state in that local region of the electrolyte. The moment a TRZ is formed, the surrounding ions in the electrolyte outside the TRZ immediately move or deviate their movements to reverse this TRZ action[300] and convert it back to a time-forward zone (TFZ). Hence once it is born in the electrolyte, the TRZ decays rapidly due surrounding ion movement changes, and even more rapidly due to the rapid variation in the fluctuating scalar interferometers in the loaded palladium lattice. In most cases, the random fluctuation in the scalar interferometry is so rapid that the TRZ decays back to a normal TFZ before the two approaching H+ ions can reach each other (reach each other's reduced strong force repulsion region). However, in a certain percentage of approaches, the two approaching like-charged ions will "reach each other" — i.e., each will enter the weakened strong force region of the other before decay of the TRZ occurs.

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[299] Again we stress the tremendous energy density of the time-energy involved. These cold fusion interactions are actually higher *total* energy reactions than nuclear physics presently uses, even though the *spatial* energy density of the reactions is very small. Together with the now-proven fluctuation theorem of Evans et al., the TRZs and reversal of the normal Coulomb barrier into a Coulomb attractor open up a vast new nuclear chemistry of direct nuclear transmutation reactions at low spatial energy but at very high tempic energy. The ability to directly engineer the quarks and the gluon forces, e.g., opens up a new chemistry of direct subparticle engineering heretofore considered quite impossible by chemical means.

[300] Their approach increases the fraction of photon reactions relative to antiphoton reactions, since the other ions are moving in a TFZ on the average.

See Figure 10-2. In Figure 10-2a, we show the case in which the TRZ lasts long enough for the two H+ ions to reach each other's strong force repulsion zones and form a quasi-nucleus. Here they vibrate back and forth in a dynamic dance around the zero net force axis between their repulsive strong forces and their attractive Coulomb forces. In this case, a new kind of nuclear reaction is set up to occur. Decay from this excited quasi-nucleus state in a TRZ can occur into a real nucleus in a normal TFZ. Energetically, because the quarks are so loosely bound now[301] the preferred decay mechanism when TRZ -> TFZ is by appropriate *quark flipping.*

As a little bit more time passes, the interferometry changes and the TRZ decays, returning back to a normal TFZ. In a change from TRZ to TFZ, the energy change is enormous because time-energy is involved, with energy density equal to mass. The only difference in a proton and a neutron is the orientation of one quark (three quarks make up each of the particles). As TRZ decay starts and progresses, the strong force changes back to a powerful attractive force. It increases its strength far more powerfully and quickly than the Coulomb attractive force reduces its reversal and changes back to a repulsive force. The addition of the extra energy from the now-increasing strong attraction force simply causes one nearly-freed quark in one of the two H+ ions to flip, converting that H+ ion into a neutron n. Instantly the preferred decay product is the deuterium ion D+. So the H+ and the n simply draw a bit closer together, each now fully inside the rapidly increasing attractive strong force region of the other. This converts what had been a quasi-nucleus of two H+ ions into a real D+ nucleus. This result is shown in Figure 10-2b.

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[301] To appreciate the sheer raw power of the time-energy control of interactions, simply examine the enormous *spatial* energy density required in high energy physics to try to approach the "free quark" condition. Enormous and very expensive *spatial energy* accelerators are used, at the absolute state of the art. By going to the use of the extraordinarily dense time-energy, quarks can readily be freed or nearly freed in electrolytes, and they are nearly freed in more than 600 relatively simple and inexpensive cold fusion experiments {753) on the bench-top to allow new nuclear reactions by quark flipping, where a proton turns into a neutron or vice versa.

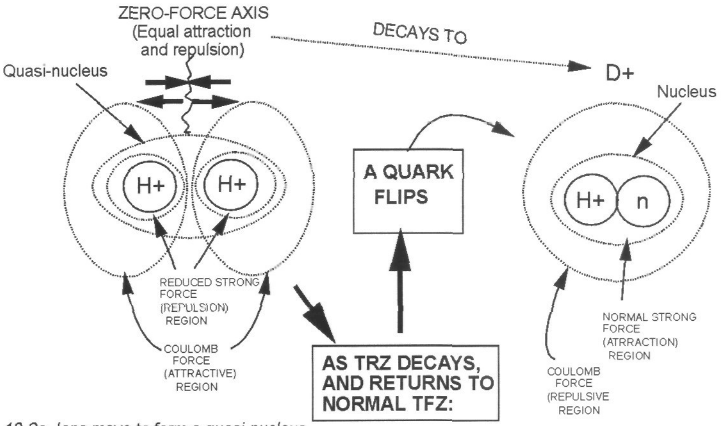
ZERO-FORCE AXIS
(Equal attraction
and repulsion)
DECAYS TO
Quasi-nucleus
D+
Nucleus
H+
H+
A QUARK
FLIPS
H+
n
REDUCED STRONG
FORCE
(REPULSION)
REGION
COULOMB
FORCE
(ATTRACTIVE)
REGION
AS TRZ DECAYS,
AND RETURNS TO
NORMAL TFZ:
NORMAL STRONG
FORCE
(ATRRACTION)
REGION
COULOMB
FORCE
(REPULSIVE
REGION

10-2a. Ions move to form a quasi-nucleus.

10-2b. Quasi-nucleus decays by quark flipping into a new nucleus.

Figure 10-2. Production of quasi-nucleus and its decay by quark-flipping into a new nucleus as the time-reversal zone decays back to a time-forward zone.

Recapitulating: As the TRZ subsequently decays back to a normal time-forward zone (TFZ), the new quasi-nucleus becomes an excited state, and decays. However, the quasi-nucleus decays by very novel means. Because of the time reversal, the energy changes induced in the decay *start* at each spacetime point inside the quasi-nucleus, deep inside the quarks, and proceed outward. The first interaction of the decay mechanism is with the quarks comprising the nucleons (in this case, the protons). With the gluon forces still very much weakened, quark flipping becomes the preferred decay mechanism. Hence one quark in one proton flips its orientation (that is the mechanism of decay!) and the nucleus — now a nucleus comprised of a proton and a neutron — becomes a nucleus of deuterium.

As can be appreciated, the clustering of different types of like-charged but relatively simple positive ions in TRZs in solution, with subsequent decay of the TRZ into a TFZ, initiates a revolutionary new family of nuclear reactions at low spatial energy (but very high temporal energy), completely contrary to, and not included in, the present forward-time high-spatial energy (but very low time-energy) reactions model known in particle physics.

In the future, as these new time-energy-based reactions are extended and mastered, scientists will simply assemble desired nuclides in solutions in the laboratory, at low spatial energy (but high time-energy) and at will. We point out but do not pursue further the fact that these new reactions also open up cheap, practical, electrochemical means of altering nuclear and chemical wastes. We therefore foresee a dramatic development in this area, in order to clean up the presently polluted biosphere of much of the chemical and nuclear waste contaminants.

Indeed, we propose that a very strong program in mastering these new nuclear reactions be launched and supported by the U.S. Department of Energy, so that the nuclear wastes storage problem can be permanently solved, much more cheaply, and without having to store hazardous nuclear wastes for centuries. Instead of merely *talking* about "out-of-the-box thinking and research", the DoE should actually do some of it, over the violent objections of the entrenched conventionalists of the national laboratories. Their own great national laboratories are the major part of the problem, not the solution, for both innovative nuclear reactions and innovative energy systems! The problem is that "in-the-box" entrenched conventionalists do not perform or allow "out-of-the-box" research that strongly threatens their vested interests.

The TRZ decay conversion of two protons into a deuteron — by easily flipping one quark in one proton — is an example of the so-called "nuclear reaction at low energy" that has been so controversial *to* the orthodox scientific community, even in the face of some 600 successful cold fusion experiments. Contrary to the assumption of the conventional physics community and the skeptics, these are not "low *total* energy" physics reactions at all. Instead, they utilize energy density on a level commensurate with that achieved in the largest accelerators available and even much higher. *This is actually a much higher total energy physics than the present conventional high energy physics heretofore known or used.*

Particularly in a deuterium-enriched (deuterated) electrolyte, a variety of simple ion arrangements of D+ ions and H+ ions can occur. Many of these combinations and arrangements can and will occur in TRZs if sufficient loading of the palladium lattice is achieved. Below we will present and explain a few of these new nuclear reactions that have occurred in successful cold fusion experiments. First, to be tidy we must correct the present statement of the conservation of energy law by extending it to include time-energy.

The excess heat usually experienced in the electrolyte is explained by the added negentropy (added energy) from the time-domain, which then dissipates randomly in the solution, producing excess heating. Later we will cite strong experimental evidence for the involvement of such time charging (time-energy charging), with subsequent time-charge (time-excitation) decay as ordinary photons in cold fusion experiments.

10.5 Revision of the Conservation of Energy Law

10.5.1 Unaccounted Transduction Extends the Conservation of Energy Law

Along with the re-emission of all the previously absorbed spatial energy, all the previously absorbed time-charge of the excited electron may be re-emitted with a longitudinal photon/scalar photon pair (a graviton) when the time-excited state decays. In that case, no energy-charging permanent change results to the electron's original energy state. Hence no "electron wiggle" will be created and our normal "electron wiggle" detectors performing such non-transducing longitudinal EM wave interactions will not exhibit an indication. In short, the "pure" time-charging EM LW interaction is unobservable to present instruments. All they "see" is the "same electron" sitting there and "flowing through time".

However, if two or more such gravitons are simultaneously emitted from various reactions in time-decays, the emitted scalar photons and waves may interfere at some little distance. In that case, transverse EM waves and ordinary EM energy will be produced in the interference zone {613}. To the external observer, these EM fields and forces will simply seem to arise spontaneously and emerge from every point in spacetime inside that interference zone, moving outward from there in conventional "propagation through space" manner. In that case, the normal "photon" (actually, graviton) decay processes plus scalar interferometry have resulted in transducing some time-energy into ordinary spatial EM field energy. Such reaction provides the excess heat demonstrated in successful cold fusion experiments.

This is also a true action at a distance reaction, presently unaccounted in particle physics. Action at a distance is required in quantum mechanics, and it has been experimentally demonstrated multiple times in distant photon correlation experiments. Once any action at a distance is admitted because it has been experimentally proven, there is no logical restriction that only a single mechanism exists for it. Consequently, many of the present foundations assumptions of physics and some of the things previously abandoned because of their conflict with those assumptions will have to be re-examined {616}.

Scalar interferometry is indeed a mechanism for action at a distance. While still mostly absent from open physics, it has already been weaponized by some 10 nations of the world. Indeed, U.S. Secretary of Defense William Cohen confirmed in 1997 that (novel) electromagnetic processes are already being used to initiate earthquakes, stimulate volcanoes into eruption, and engineer and control the weather {617}. Whether or not it is present in the particle physics texts, scalar interferometry is being widely used clandestinely in several armies today. It has also been used to shoot down missiles and aircraft as tests. The so-called "Cold War" was not quite as cold as the news media and U.S. scientific community were led to beleieve.

Because of the ubiquitous involvement of unaccounted time-energy in all photon interactions, an extension to the present form of the conservation of energy law is required. The present (special case) law is

$$E(E)_1 + E(m)_1 = E(E)_2 + E(m)_2 \qquad [1]$$

where E(E) = energy in conventional non-massive energy form, E(m) = energy in mass form, subscript 1 refers to the measurement at time 1, and subscript 2 refers to the measurement at time 2. This is just the well-known Einstein formulation that the sum of the ordinary energy and the mass-energy is conserved.

However, that law is for a special case. It assumes that there is no transduction of time-energy into either mass-energy or ordinary energy. I.e., it assumes 3-symmetry and t-symmetry in EM energy flow. Since every charge in the universe already violates both that 3-symmetry and t-symmetry of energy flow, the fundamental assumption in the Einstein formulation is falsified by the general case. The conventional conservation of energy law is a special case where only the two mentioned energy flow symmetries are upheld. When they are violated, then transduction of EM energy between 3-space and time occurs. For that case, the conservation of energy law must be extended to

$$E(E)_1 + E(m)_1 + E(t)_1 = E(E)_2 + E(m)_2 + E(t)_2 \qquad [2]$$

The **new** law simply states that the sum of the ordinary spatial energy, the **mass-energy,** and the time-energy is conserved. This extension of the conservation of energy law becomes important in successful cold fusion experiments, where transduction of time-energy into ordinary heat energy occurs and where one encounters very anomalous reactions differing from those reactions known and accepted in conventional nuclear physics.

10.5.2 Transduction Between Time-Charging and Spatial Energy-Charging

The oscillating energy (spatial and temporal) in a moving EM wave in the vacuum represents a moving oscillation of spacetime curvature. Simply put, the so-called electromagnetic wave in space is actually a gravitational wave in space, since it is an oscillation of the local energy density of spacetime and therefore an oscillation of the curvature of local spacetime. It "transports" gravitons (scalar photon/longitudinal photon pairs) rather than merely photons. So let us now consider it as a gravitational wave.

In the absorber under special conditions, a small fraction of the graviton wave time-density absorbed will sometimes change (transduce) its time-energy into what we call transverse photon energy effects {618}, with something like a 10^{17} gain in spatial energy in joules compared to the time in seconds that actually transduces. In other words, 1 second of time transducing into EM transverse wave energy (using the standard EM modeling approach) will yield approximately 10^{17} joules of spatial EM energy. Since one can change energy from one form to another, *one can change time-energy into 3-spatial energy* and 3-*spatial energy into time-energy,* the two being merely opposite sides of the same coin, and both always involved in any situation exhibiting electrodynamic dipolarity.

In one's physics model, the choice of fundamental units is purely arbitrary. Everything can be expressed in a single fundamental unit, as pointed out by Jackson (see quotation from Jackson at the beginning of this chapter).

In a situation where 3-symmetry and t-symmetry in EM energy flow are broken, part of the *time charging* of the atomic electrons (or ions) sometimes changes (transduces) into *spatial energy charging* and vice-versa. This cross-dimensional decay of time-excitation states results in the emission of some extra transverse photons that may be either photons or antiphotons, depending on the exact interactions. The point is, *tremendous excess EM spatial energy can appear and either be emitted as heat or interacted to perform new nuclear interactions as extraordinarily high local energy density.* This is the master mechanism enabling anomalous cold fusion transmutation reactions. The amount of time transduced will be so small that it will usually escape notice, unless stringent efforts are used to measure changes in the local flow of time.

The excess photon energy (excess 3-space EM energy) appearing in these rather random but powerful transduction interactions often accounts for the production of anomalous excess heat - for example, as occurs in many cold fusion experiments. Where scalar interferometry is maximized, a more exact action will be detailed below for the specific nuclear transformations that occur by novel new nuclear reactions. These novel nuclear reactions occur at low *initial* spatial energy but with some time-energy transducing into additional very high spatial energy to initiate the interactions.

10.5.3 Resolving the Energy Conservation Problem in Cold Fusion

When transduction is involved, standard "transverse EM waves only" computations will seemingly yield violation of energy conservation — e.g., from the emission of excess heat. That is an erroneous interpretation; energy overall is conserved, but some of the unaccounted *time-energy flow* is transduced into 3-spatial transverse photon energy dissipation. Neither 3-spatial energy nor mass-energy nor time-energy alone, or in any pairing, need be individually conserved; only the combined *total energy of all three energy components* is conserved. This resolves the present major "sticking point" between the cold fusion researchers and the conventional "transverse wave" nuclear and electrodynamic communities regarding energy conservation difficulties and perpetual motion accusations. Those making the accusations and those defending against them are both using only a special-case conservation of energy law, and a more general law is required.

Let t = time in seconds, and W= energy in joules. Rounding the speed of light to 3 x 10^8 meters/sec, the energy W_{TW} emerging as transverse wave EM energy in 3-space by the transduction of time into 3-space energy is approximately

$$\text{One sec} = c^2 \text{ joules} = 9\times10^{16} \text{ joules} \qquad [3]$$

and

$$t \Rightarrow W_{\mathrm{TW}} = 9\times10^{16} \times t \quad \text{(in joules)} \qquad [4]$$

Let us present the new energy conservation law in slightly different form. Let W_{TW} = energy measured in spatial energy form, conveniently taken as transverse wave (TW) EM energy. Let W_m = energy in mass form (energy compressed by c^2). Let W_t = energy in time form (energy compressed by c^2).**The** present conservation of energy law is

$$W_{\mathrm{TW}} + W_{\mathrm{m}} = W_{(\mathrm{total})} \qquad [5]$$

The new extended conservation of energy law is

$$W_{TW} + W_m + W_t = W_{(total)} \qquad [6]$$

The conventional particle physics accounting will see only

$$W_{TW} + W_m = W_{(total)} \qquad [7]$$

The conventional accountant will be unable to see

$$t \Rightarrow W_{TW} \qquad [8]$$

so he will observe that the experimenter is reporting that

$$[W_{TW} + W_m]_1 \neq [W_{TW} + W_m]_2 \qquad [9]$$

which in his lexicon is a violation of the conservation of energy law itself. In short, he will identify it as a typical example of a claimed perpetual motion machine or interaction. Then the defender of the faith will wax eloquent, applying labels such as "perpetual motion nonsense", "voodoo science," etc. He himself is practicing a hoary old "voodoo" science and ignoring newer science. None of these defenders of the faith even know what powers an electromagnetic circuit or how it is that every little charge in the universe is able to continuously pour out observable EM energy in all directions, with no observable EM energy input.

On the other hand, a reasoned response will be given by real scientists still following scientific method, when faced with the numerous replicated successful experiments. The scientific method insists on the absolute priority of the replicable experiment over the predictions *of any* theory. Consequently, such reasonable scientists will advise that the protagonists cease their vitriolic rhetoric and let real science take its course; i.e., let further experiments confirm or refute reported successful results of cold fusion experiments.[302]

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[302] Precisely such a reasoned response by chief editor Donald Kennedy of the journal *Science* has recently been given, providing a breath of fresh scientific air into an attempt by "defenders of the conventional faith" to destroy publication of important experimental results in sonoluminescence. The article which courageous editor Kennedy approved for publication — over intense objections of the professional critics — is R. P. Taleyarkhan et al., "Evidence for Nuclear Emissions During Acoustic Cavitation," *Science,* Vol. 295, Mar. 8, 2002, p. 1868-1873. We heartily commend Editor Kennedy for this classic example of how science should be conducted — so that experiments, not prevailing dogma, determine what is valid and what is invalid.

What the professional skeptic will not see is that his own expression of the conservation of energy law has been incomplete, and that it is his own inadequate "measurement yardstick" assumption that is now in error. The *extended* conservation of energy law of course still holds, but the *conventional* special case law is violated because its fundamental assumption — that time is not transduced to spatial energy in the experiments —has been violated in the experiment.

Indeed, with the publication of the work of Evans et al., experimentally proving the fluctuation theorem and the high probability of time reversal zones appearing for short but significant periods at up to micron levels, the second law of thermodynamics has been rigorously proven to be violated. Hence the conventional scientific community's rather dogmatic objection to the extra heat of cold fusion interactions is no longer scientifically justifiable.

Understanding of the extended conservation of energy law and the permissible violation of the second law of thermodynamics resolves the present thorny dissension within the scientific community over the excess spatial energy produced by cold fusion. It also resolves the issue of what could possibly be a source of such intense energy density as is required for nuclear transmutation reactions.

Any ordinary system is indeed an open system, freely and continuously exchanging energy with its ***temporal*** environment as well as the seething active vacuum.[303] If the system is in temporal energy equilibrium in that exchange, then the present restricted conservation of "spatial and mass" energy law applies and one does not have to consider the interactions between supersystem components. If the system is placed in disequilibrium with its temporal energy environment, then supersystem components interact asymmetrically and the extended conservation of energy law applies. In that case, excess spatial energy can be and will appear in the system whenever time transduction into spatial energy is occurring.

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[303] But see our Appendix A. Present thermodynamics rather inanely defines a "closed" system as one where no mass exchange crosses its boundary with its environment, but energy exchange can and does. In that view, a "closed" system can be far from equilibrium in its energy exchange with its active environment, and thus demonstrate the five magic attributes of such disequilibrium systems. In this book we have deliberately chosen to treat a "closed" system as one in which neither energy nor mass exchange crosses the system boundary — which classical thermodynamics refers to as an "isolated" system. We explain all this (and why) in Appendix A.

The implications of cold fusion energy transduction are that

(1) Time is being "burned" or transduced as a "fuel" and source of energy,

(2) Transduction of only one microsecond per second will yield $9x10^{10}$ watts steadily. That's 90,000 megawatts of energy per second — the equivalent of 90 large 1,000-megawatt power plants — if all the transduced energy were collected and used to power loads with 100% efficiency.

(3) Thousands of new nuclear reactions are made possible and feasible by local transduction of time-energy into 3-spatial EM energy.

(4) Appropriate capture and use of a portion of the excess energy can be accomplished to power loads.

Even if we capture and utilize only 1% of the transduced time-energy to power the loads, where the *time-energy to spatial energy transduction* is only the transduction of 1 microsec/sec, that system will produce the normal EM energy to power 900 megawatts in the load. That's almost 90% of the capability of a modern 1,000-megawatt power plant. That is quite a respectable electrical power system. It only requires the transduction and "burning" of one microsecond of time per second, without any nuclear wastes or hydrocarbon byproducts.

As can be seen, transducing time into energy is by far the most efficient way to go to develop new power plants for the future. This is particularly true since every charge in the universe already transduces time-energy flow into spatial EM energy flow. Indeed, we may consider that the negative charge transduces time-energy flow into the spatial outflow of EM positive energy, while the positive charge transduces negative time-energy flow into an outflow of EM negative energy. The process is useful not only for power applications, but also for transport applications as we briefly pointed out in Chapter 8.

10.6 Some Resulting *Low Spatial Energy* Nuclear Reactions

Refer again to paragraph 10.4 above. Summarizing: The formation of time-reversal zones (TRZs) is what enables the appearance of the new nuclear reactions in the electrolyte in cold fusion experiments. It does this by changing the Coulomb barrier between like charged ions into a Coulomb attractor. Further, the rate at which TRZs form and decay in the solution is a function of the frequency and intensity of the scalar interferometry from the loaded palladium lattice. This means that the appearance of the new nuclear interactions in the electrolyte is also a function of the degree of loading of the palladium lattice, as well as the "double surface" interferometry preparation of the palladium, its cracks, etc. These are the major variables. Once the major variables provide the solution for significant formation of TRZs, then the following reactions can and do appear.

The sample reactions we present here are just a few of the thousands of new reactions possible. These example reaction products have been found in a great many successful cold fusion experiments in various laboratories around the world. Some 600+ successful experiments have now been done, and a sizable literature has built up and continues to be built up on the experiments and their results.

For our sample reactions, the primary mechanism of interest consists of several parts:

(i) Formation of a TRZ, in which two positive ions (we shall look at H+ and D+), now attract each other. Also, the gluon forces in the proton and neutron, in the ions of interest, are significantly lessened, so that the quarks in each proton and neutron are very much more loosely bound. Consequently, decay from an excited state by quark flipping to turn a proton into a neutron or vice versa becomes an attractive option. The strong force is therefore reduced in radius.

(ii) Two positive ions now attract each other so closely that each enters the edge of the weakened strong force region of the other. This forms a *quasi-nucleus* because of the limited involvement of the weakened strong force.

(iii) The other ions in solution surrounding the TRZ immediately move (as soon as the TRZ is formed) to negate the TRZ and decay it back to a time-forward zone (TFZ). This action initiates the decay of the TRZ.

(iv) As the TRZ lessens and then turns back into a TFZ, the strong force expands its size faster than the novel Coulomb "like attracting like" force reduces and reverses.

(v) The rapidly expanding strong force of each of the two ions in the quasi-nucleus fully envelops the other ion, increasing the disequilibrium of the two-ion quasi-nucleus. A condition is reached where the most probable mode of decay is the flipping of one quark in one of the positive nuclei.

(vi) The quark flips, turning that H+ ion into a neutron n. This is a quasi-nucleus of deuterium (D+), still in an excited state but with less excess potential energy in the excited state. At this point, the TRZ is vanishing and the TFZ state is returning.

(vii) As the TRZ vanishes and TFZ state increases back to normal, the most probable mode of decay increasingly is to a full deuterium nucleus. Hence the H+ and n simply draw completely into normal deuterium binding position, bound by the normal strong force. This constitutes a normal D+ ion, now existing in a normal TFZ.

(viii) So by formation and decay of a significant TRZ, two H+ ions have been drawn together into a quasi-nucleus consisting of two H+ ions partially bound by a weakened strong force. As the TRZ decays and the Coulomb repulsion resumes, the strong force increases back to full strength faster than the Coulomb repulsion force returns and repels the two H+ ions. Since the quarks are much more loosely bound than normal, a quark in one of the H+ ions has flipped, turning the ion into a neutron n. The H+ ion and the neutron, partially bound already in a quasi-nucleus, simply "tighten" into a normal D+ nucleus as the TFZ condition is fully resumed.

The nuclear reaction equation for the above interaction may be written as

$${}^{1}H_{1}{}^{+} + {}^{1}H_{1}{}^{+} \Rightarrow (({}^{1}H_{1}{}^{+} + {}^{1}H_{1}{}^{+})) \Rightarrow ({}^{1}n_{0} + {}^{1}H_{1}{}^{+}) \Rightarrow {}^{2}H_{1}+ = {}^{2}D_{1}{}^{+} \qquad \textbf{[10]}$$

In equation [10] we use the left superscript as the number of nucleons in the ion nucleus, the right subscript as the protons in the ion nucleus, and the right + superscript to show the overall charge of the ion and its sign. We use the expression in parentheses to show the involvement of a time-reversal zone (TRZ). Double parentheses show a stronger TRZ than single parentheses. Thus from double parentheses to single parentheses to no parentheses shows the initial formation and subsequent decay of the TRZ.

Another interaction involves a D+ ion and an H+ ion, to produce tritium. This is:

$$ {}^{2}D_{1}^{+} + {}^{1}H_{1}^{+} \Rightarrow (({}^{2}D_{1}^{+} + {}^{1}H_{1}^{+})) \Rightarrow ({}^{2}D_{1}^{+} + {}^{1}n_{0}) \Rightarrow {}^{3}H_{1}^{+} = 3T1^{+} \quad [11] $$

That reaction transmutes a deuterium ion and hydrogen ion into a tritium ion. Without showing it, in a TRZ three ${}^{2}H_{1}^{+}$ ions may also attract into a quasi-nucleus, and as the decay of the TRZ occurs, first one proton turns into a neutron and then a second one does also, by quark flipping. This nuclear reaction also produces a fusion into tritium.

Another reaction between two deuterium ions is"

$$ {}^{2}D_{1}^{+} + {}^{2}D_{1}^{+} \Rightarrow (({}^{2}D_{1}^{+} + {}^{2}D_{1}^{+})) \Rightarrow [2({}^{1}H_{1}^{+} + {}^{1}n_{0})] \Rightarrow {}^{4}He_{2}^{+} = \alpha \quad [12] $$

That interaction — particularly in pre-deuterated electrolyte solution — gives the excess a particles produced in a great number of the cold fusion experiments.

A rarer but still occurring interaction is:

$$ 4[{}^{1}H_{1}^{+}] \Rightarrow (({}^{2}D_{1}^{+} + {}^{2}D_{1}^{+})) \Rightarrow {}^{4}He_{2}^{+} = \alpha \quad [13] $$

Indeed, reaction [13] may occur to completion and formation of a particles in some of the transmutations in an electrolyte, while it proceeds only to the intermediate phase in others. In that case, both deuterium ions and a particles may be produced out of the same overall "chain of reactions" where some reactions proceed all the way and some do not.

These interactions are directly using and transducing time-energy by use of the TRZ to time-reverse the Coulomb repulsion law for like charges. From the reactions, excess energy given off as heat may and will occur.

The nuclear physicist and nuclear chemist can immediately see a great many new nuclear reactions now made possible by the adroit production and decay of TRZs. A great number of these new nuclear reactions are now possible by this means, which are impossible in ordinary nuclear chemistry without the deliberate formation of TRZs.

These few examples serve to illustrate the process, and these reactions represent results already achieved in numerous cold fusion experiments worldwide, by many researchers and multiple laboratories. Now we turn to other evidence strongly supporting the novel nature of these reactions rather than several other proposed reaction equations yet to be proven. The other proposals do not explain the next type of new experimental reaction.

10.7 Time-Energy Can Generate Instrumentation Anomalies

Strong evidence for time-charging and time-charge decay is experimentally demonstrated in electrolyte experiments where time-reversal zones (TRZs) are operating, and thus where some localized processes are running backwards in violation of the second law of thermodynamics. Weak time-charging of photon-absorbing and emitting matter, with special patterns of spacetime curvatures (engines) induced by time-density oscillations and structuring, is persistent in matter, having "charge-up" and "decay" times that may last for minutes, months, or even years. A very wide range of previously anomalous phenomena, both in inert and living matter, is explainable by these new interactions. This is very probably also related to the "memory phenomena" noted by Kondepudi and Prigogine[304] as outside the present thermodynamics, but being worked on at the forefront in what is called "extended thermodynamics". Quoting Kondepudi and Prigogine, p. 460:

> *"...interesting memory effects ...appear for long times (as compared to characteristic relaxation times). ...nonequilibrium processes may have 'long-time tails'. In other words, the approach to equilibrium is not exponential, as was generally believed, but polynomial ...which is much slower. ... As a result, Nature has a much longer memory of irreversible processes than it was thought before. Again this shows that local equilibrium is an approximation, albeit a very good one. "*

In this book, we focus primarily upon some typical anomalous measurements in China Lake experiments that are directly involved with time-charging and decay effects, lending strong support to our thesis of the novel TRZ-induced nuclear reaction chains. Note that these instrumental anomalies are also strong evidence for the association of time-charging and time-charge decay with the proven fluctuation theorem of Evans et al.

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[304] Dilip Kondepudi and Ilya Prigogine, *Modern Thermodynamics: From Heat Engines to Dissipative Structures,* Wiley, Chichester, 1998, p. 459. For a discussion of extended thermodynamics, see D. Jou, *Extended Irreversible Thermodynamics,* Springer-Verlag, New York, 1996.

at the Australian National University. We believe this to be a contribution to that very important work of Evans and his colleagues.

10.7.1 Ionization Detectors, Transduction, and EM LW Interferometry

Ionization processes obviously are processes where the partial transduction of LW time interaction into 3-spatial energy interaction would yield ordinary excited energy states of the affected electrons or ions. In turn, this would lead to ionization (e.g., of the atoms and molecules of a gas, liquid, etc.) Hence, ordinary ionization detectors such as Geiger Miiller tubes have the innate *capability* of detecting such transduction that generates ionization, and thereby have some capability of serving as "detectors" of longitudinal EM wave interactions (and time-charging) ongoing in the detector. In the usual situation, no excess time-charging results and no time reversal zones result. In that case, symmetry of energy flow in the time-domain exists, as does symmetry of energy flow in 3-space. Absolutely normal chemistry and nuclear chemistry results, and the nuclear detectors function normally, as familiar to every laboratory.

However, when significant TRZs emerge and persist for short periods, the symmetry of both time-energy flow and 3-spatial energy flow is broken. In this case, transduction of time-energy into 3-spatial energy (and vice versa) can result in anomalous ionization in nuclear ionization detectors, even in the absence of normal transverse EM nuclear radiation. The trick is to use and compare different detectors and different types of detectors to clearly demonstrate anomalous ionization detection effects.

As an example, a Geiger Muller tube will detect any ionization of its internal gas, regardless of what caused that ionization. If the ionization is caused by normal ionizing radiation from nuclear reactions, the instrument will detect and read a resulting internal ionization of the gas inside the tube.

On the other hand, if time-charging and decay are involved, then the asymmetry resulting in 3-spatial energy excitation of the gas inside the Geiger Muller tube (due to transduction of some time-energy into excess 3-spatial energy) may be sufficient to ionize the gas. In that case, the instrument will read "as if nuclear radiation were present. Note that there is indeed "ionizing radiation" present in the gas. However, now this ionizing radiation is not transverse EM wave in nature, but is due to the time charging and decay, and transduction of time into 3-spatial energy in the detecting gas.

This capability of an ionization detector to ionize in the presence of non-transverse wave ionizing radiation and energy can be used to provide an indication of time-density waves being formed and interacting in a process (such as a cold fusion process) where some transduction from time-energy to 3-spatial energy occurs.

Further, the previous "time history" of the individual instrument plays a part in whether the instrument "reads" or not for a given transduction situation. There will be a statistical variation of the actual "already present" low-level time-charge (and in its internal structure and engines) between instruments, even those made in the same factory on the same day from the same batch of materials and parts. That is because the time-charging and discharging history of each instrument has been different.

The production of transduced TWs, however, must be a function of scalar interferometry in the gases or other detecting media of the instrument, since scalar interferometry *creates* all transverse EM waves, as shown by Whittaker {619} and confirmed by Evans *et al.* {620}. In such interferometry, the entire inner structures of the transverse EM waves formed in the interference zone also interact wave-to-wave. Thus, this kind of interferometry is extremely sensitive to the exact internal longitudinal EM bidirectional wave structure (internal engine substructure) of the involved potentials.

As a consequence, the ability of an ionization detector to transduce a specific set of LWs and give ionization detection will vary appreciably, including for different variations in the instrument's original manufacturing process, and even for the specific past photon interaction history and experience of the individual detector itself. One detector's set of cumulated internal time-charges (and hence spacetime engines) may vary considerably from those of a second detector of exactly the same type. In general, multiple ionization detectors are unlikely to all detect a given time-density EM wave emission and interaction set {621}.

Even for two detectors of the same brand, from the same manufacturing plant, and from the same batch of manufacture, it is likely that significant differences in LW detection of a specific TDW set will occur because of the "past history" time-charge differences of the individual detectors. Indeed, a likely phenomenon is that, when one ionization detector detects the LW emissions (transduces them), several others will not detect them at all. This is one of the peculiarities of the new unified field area that must be overcome by further research in order to develop reliable, calibrated TDW and transduction detectors. It is one of the primary problems - if not *the* primary problem - of cold fusion research to resolve this *"time-charge experience history"* problem, so that transduction detectors having calibrated, uniform responses to given TDW sets and interactions can be provided.

At present, no one has the foggiest notion as to how to "calibrate" a nuclear ionization detector that one desires to use as a time-energy transduction detector. Speculating, we would envision such calibration (in the transduction detecting functional response) to become possible when small, standard, calibrated sources of transduction are developed and available. In that case it will be possible to formulate procedures whereby varying the output of the transduction source will vary the transduction irradiation of the GM tube. The level of transduction intensity required to create ionization in the instrument will be a direct indicator. When small, calibrated sources of TDWs are also available, it will be possible to irradiate the GM tube to a specifically desired rate and level of time-charge and decay. In that case, an array of GM tubes can be "standardized" or "calibrated" for transduction detection. So far as this author is aware, those developments have yet to be accomplished or even undertaken. Indeed, the need for such a development program has not even been realized.

10.7.2 Experimental "Detector Transduction Phenomena" in Electrolysis

Let us look at one set of ongoing scientific experiments where just such anomalous detector results have been obtained.

Researchers at the Naval Air Warfare Center at China Lake, and at the Department of Chemistry, University of Texas at Austin, have detected precisely the kind of "anomalous" radiation and transduction effects we expect to be in the ionization processes of multiple kinds of detectors {622}.

According to a report by Miles and Bush {623}, anomalous radiation at China Lake was first detected by the exposure of dental X-ray films in two experiments producing excess power (excess TW energy emission). Film used in a control study during these experiments showed no exposure. There was also no exposure of similar films in more than 20 experiments where no excess power was present. In other words, the presence of excess heat (excess TW energy emission) strongly indicates the presence of transduction. In turn, the presence of transduction implies the presence of scalar interferometry wave interaction, where TDW waves and LW waves **are** absorbed and **a** mix of LW and transduced TW waves are emitted consisting of gravitons (paired scalar and longitudinal photons). This only occurs when significant time-charge excitation has built up. Taken in reverse, the presence of LW wave absorption and emission — with transduction into detected excess ionization energy — directly indicates the emission of "anomalous" TDW or graviton radiation, as detected by the resulting TW exposure of the x-ray film. So the "anomalous" radiation detections are consistent both forward and backward.

The film in manufacture is quite strongly quality-controlled. Also, it is used (interacts and indicates) only once. Its past time-charge history has minimal variations between two samples of the film, because there is no repetitious past *detection interaction* history. Hence one would expect a high degree of uniform film detection interaction responses from film to film, to the same graviton emission set. That is precisely what occurs.

We conclude that the behavior of the film in the combined China Lake experiments clearly shows the time charging, graviton emission and interaction, and transduction nature of what is happening when it is known that no normal nuclear radiation is present.

Geiger-Muller (GM) detectors and sodium iodide (NaI) detectors were also utilized when electrolysis experiments using heavy water were ongoing. We again accent that a Geiger-Muller tube does not detect nuclear radiation per se; instead, it detects *anything* that will cause its internal gas to ionize sufficiently. Sufficient transduction in graviton absorption-emission interactions in a Geiger-Muller tube will cause the counter to indicate, because it ionizes the gas and produces an ionization discharge. However, both the specific transduction and scalar interferometry aspects of the ongoing experiment are involved, as well as the previous background time-charge history of the Geiger-Muller tube counter.

Several Geiger-Muller detectors gave anomalously high readings, reaching some 73 sigmas above normal background counts. Most experiments (i.e., most GM detectors), however, gave normal radiation counts, and no anomalous count rates were ever observed when the experiments were turned off. So these anomalous results are differentiated by using multiple, carefully calibrated Geiger-Muller tube detectors. Our interpretation here is that

(i) There was a variation in the presence of transduction and scalar interferometry from experiment to experiment,

(ii) The majority of the experiments did not produce significant time-charge and sufficient transduction or scalar interferometry to cause detection (ionization discharge) on most (typical) Geiger-Muller tubes, and

(iii) The transduction effects in the ongoing experimental process were mostly of the rapid variety, and not due to long-term "charge-up" effects conditioning the time-charge aspects and structuring of the experimental apparatuses.

(iv) By using multiple detectors, the probability of one or more of the instruments having increased time-charge from specific time-charge histories was increased.

(v) With sufficient experiments and sufficient detectors, there resulted a high probability of having at least one or more detectors capable of detecting the levels of graviton radiation and transduction expected from the experiments.

(vi) A direct correlation would be predicted — and was observed — in the appearance of the anomalous radiation effects and the expected time periods required to load the palladium with deuterium. As reported by Miles and Bush, *ibid.*:

> *"... the anomalous radiation would appear within a few hours in the co-deposition experiments where the palladium is loaded with deuterium as it deposits from solution. In contrast the appearance of anomalous radiation required days of electrolysis for the palladium rods that load much slower."*

We previously discussed the major variables indicated from many cold fusion experiments to include the strong correlation with the degree of loading of the palladium lattice. Hence the effect pointed out by Miles and Bush would indeed be predicted by the present approach and proposed mechanism.

Our interpretation is that the experiments show the time-charge rate effect to be expected in such graviton radiation and transduction interaction phenomena using collection of ions (in this case deuterium) that are much heavier than electrons. The faster the deuterium loaded, the greater the buildup of the interaction of the deuterium in phase conjugating and self-targeting iterative interactions — and therefore the greater the increase in scalar interferometry interactions — inside the palladium lattice. The rate of graviton radiation production and transduction production increases as some function (not necessarily linear!) of the rate of loading of the **deuterium.** As the rate of graviton and transduction production increases, so does the expectation of anomalous ionization effects in the nuclear radiation detectors. And so does the rate of production of TRZs and the appearance of the new nuclear cold fusion reactions at low spatial energy but very high time-energy.

10.7.3 Experiment Confirms It

A clinching observation is given by Miles and Bush, *ibid.*, as follows:

> *"One GM-detector would measure anomalous radiation while another GM-detector would be "blind" to any anomalous effect. A few experiments, nevertheless, gave simultaneous anomalous effects from two different radiation detectors."*

Here our comment is that this precisely fits our expectations for demonstrating involvement of

(i) Time-charging and decay interactions,

(ii) Consistency with transduction expectations,

(iii) Consistency with the fact that two different radiation detectors may or may not exhibit or detect the anomalous ionization effects, depending upon the individual past time-charge histories of the two detectors, and

(iv) Predictable variations in the individual experiments (based on palladium lattice loading time, specific geometry, ionization state of the chemical solution, internal time-charge state and decay rate, and structuring of the apparatuses and their parts, etc.) when transduction-associated phenomena are considered.

The anomalous non-nuclear, non-transverse wave — but ionizing — EM radiation detected at China Lake, and the resulting peculiarities in the measurement apparatus functioning, do strongly support the present proposed approach, the proposed graviton radiation phenomena, and the time-charging and decay and transduction mechanisms presented. It is decisive that sometimes two detectors both indicated, and sometimes one indicated and the other would not. Sufficient replications have ruled out any defect in a single given instrument as the cause of the anomalous detections. That immediately eliminates from consideration all purely transverse EM wave phenomena, conditional only upon the premise that the instruments were properly functioning and calibrated, and that sufficient replications were made for decisive statistics. Those conditions were all met in the numerous experiments producing these results over a long time and in many repetitions.

As a final thought on the subject, we pose the possibility that the longitudinal EM waves involved may be the B(3) longitudinal field waves advanced convincingly by Evans {624a-624c}. We would recommend the attention of leading theorists and experimentalists to this possibility, as a matter that should be investigated both theoretically and experimentally.

10.8 Additional Implications for the Future

10.8.1 Longitudinal EM Waves and Undistorted Progressive Waves

There is a revolution in electrodynamics presently underway, due to the unique characteristics of *longitudinal* EM waves[305] and *pseudo-longitudinal* EM waves. A summary by Rodrigues and Lu {625} is particularly revealing.

A pure longitudinal EM wave has infinite energy and infinite velocity — i.e., it appears everywhere at once. "Propagation through space" does not apply; instead, one has stumbled into that weird region where spacetime is multiply connected. In the real world, one meets imperfect longitudinal waves — or *pseudo-longitudinal* EM waves — that still retain a transverse energy density variation residue. These waves are called *undistorted progressive waves* (UPWs).

Such UPWs can move in space faster than the speed of light. This should not be too surprising, since superluminal velocity of intelligent signals has been positively demonstrated by several researchers in quantum-tunneling experiments. As an example, Nimtz {626} and his colleagues have beamed Mozart's 40th Symphony through a barrier in a waveguide at a speed of 4.7c. So the old notion that information cannot be transported at superluminal velocities is passe. The Fogal semiconductor has been used in experimental transmitter-receiver pairs to demonstrate superluminal transmission, such as TV pictures and programs. Direct signal transmission from earth to satellite back to earth and through many en route amplifiers and processors has been demonstrated by Fogal to occur far beyond the speed of light. Again, theoretical summary papers by Rodrigues *et al.* {627a-627f} are revealing.

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[305] We have pointed out a direct way to generate longitudinal EM waves, by simply oscillating the magnitude of the L**orentz self-regauging** of a system.

10.8.2 Death Knell of the Speed of Light Limitation

Another giant shock has emerged in astrophysics during the last few years, and it is now threatening a dramatic revision to physics. Heretofore, it has been fashionable to assume that gravity itself propagates at light speed. A great deal of very comfortable physics theory has been built around that assumption.

Well, the assumption is not true. Experiments in astrophysics continue to refute it. It now is almost certain that the speed of gravity is at least 2×10^{10} c. A beautiful though somewhat controversial paper by Tom Van Flandern {628} summarized the entire situation. He articulates the comfortable general relativity view held to date {629} as follows:

> *"...GR proposes that such changes appear to act instantaneously in the 'near field', but eventually show their true, light-speed-delayed character in the 'far field', which is conveniently beyond our present ability to observe. The necessity of this dual behavior is to prevent the logical need for changes to continue to appear to act instantaneously at ever increasing distances, even to infinity."*

In fact, Van Flandern {630} points out that general relativity already admits superluminal effects in the near field region. He also pointed out the startling nature of the experimental results to relativists, and points out that an attachment to a paradigm has been involved:

> *"To many, this result* [astronomy's verification that gravity's speed $v_g >= 2x10^{10}c$] *is so contrary to 'common sense' in the light of relativity theory as to be absurd. But Thomas Kuhn has cautioned all scientists to avoid the trap of becoming so steeped in a prevailing paradigm that it starts to seem like common sense and makes other ideas sound and feel wrong. Eventually, even one's professional status can become linked to a prevailing paradigm. "*

As Van Flandern further emphasizes, it is not difficult to show by computer calculations of astrophysical situations that any strong limit on the speed of light destroys conservation laws:

> *"...anyone with a computer and orbit computation or numerical integration software can verify the consequences of introducing a delay into gravitational interactions. The effect on computed orbits is usually*

> *disastrous because conservation of angular momentum is destroyed."*

So here we have a new paradigm in the making. This is a startling change to standard relativity. Either we have to give up the conservation of angular momentum, or we have to accept superluminal speed of gravity in the far field. Years of struggle to detect quadrupole gravitational wave radiation have failed; no direct detection has ever been made. Indeed, the rather arbitrary nature of the entire quadrupole radiation assumption is not required by general relativity, as long pointed out by leading Russian scientists. For example, Vlasov and Denisov {631} *et al.* bluntly state it in these words:

> *"...Einstein's well-known quadrupole formula, which is usually employed in general relativity for calculations, is not a consequence of general relativity and is not contained in it. "*

Therefore, it may not really be so surprising that physicists have not been able to detect such quadrupole radiation in a great many laboratory experiments. It is not in general relativity at all.

Of course, our thesis developed in this book is that what we have long called "EM radiation" is in fact gravitational radiation, always involving paired scalar and longitudinal photons and hence time-density waves and longitudinal EM waves. We have pointed out that prior to observation there is no such thing as a separate photon, but there is such a thing as two correlated photons, one time-polarized and the other longitudinally polarized. We believe that there is sufficient meat in our proposed explanation of the anomalous cold fusion results and the anomalous instrument results at China Lake to warrant serious and strenuous investigation of these hypotheses and proposed mechanisms.

Another oddity - usually never stated by Western physicists - has long been known but ignored. When Einstein characterized the gravitational field as a pseudotensorial field, and not a field in the sense of the Faraday-Maxwell field, the consequences were that the 3-space energy laws of the familiar kind really do not exist in general relativity. Shortly after Einstein published his theory of general relativity, this absence of familiar energy conservation was pointed out by Hilbert {632} in these words:

> *"I assert... that for the general theory of relativity, i.e., in the case of general invariance of the Hamiltonian function, energy equations... corresponding to the energy*

> *equations in orthogonally invariant theories do not exist at all. I could even take this circumstance as the characteristic feature of the general theory of relativity. "*

With our publication of the giant negentropy of 4-space once arbitrary 3-space symmetry and time-symmetry in EM energy flow is removed, one of the truths involved in Hilbert's remark was finally recognized. In addition, what Sen called "the most difficult problem in classical and quantum electrodynamics" {633} has been explained by giant negentropy {12}. Also, it is consistent with an appropriate reinterpretation of Whittaker's 1903 decomposition of the scalar potential {600, 615}. Finally, it is consistent with quantum field theory {634}.

Hilbert was evidently not understood by his contemporaries, since neither Einstein himself nor other physicists recognized the fact that, in general relativity, conservation laws for 3-space energy, momentum, and angular momentum — in the sense we are accustomed to in the rest of physics —in principle may be impossible. That is because one can readily remove 3-space energy symmetry when curved spacetime is permitted. Again, Russian scientists such as Logunov and Loskutov {635} have long pointed out the "unthinkable" and "astounding" fact that the predictions of general relativity are not unique.

In the West until recently relativists were conservative, and this resulted in the sidelining of innovative Western physicists who challenged the prevailing interpretation or extended it. With the experimental falsification of one of the fundamental tenets — that gravity moves at speed c in the far field — of the prevailing interpretation of general relativity, it appears that we may be approaching an asymptotic burst of great new theoretical work and a dramatic new reinterpretation. If it ever gets into production, we believe that the Fogal semiconductor will usher in that great change of communication speed paradigms that now appears imminent.

Nonetheless, general relativity — whatever the modifications and extensions now called for — will remain a very useful tool indeed. There is simply nothing else on the horizon that can replace it, string theory notwithstanding. The reinterpretation is likely to shed additional light on many present problems such as the nature of spacetime itself, the nature of dark matter, and new insight and progress on unifying physics.

In the new openness that should result, we hope that a great extension and reinterpretation of electrodynamics will also be undertaken, and that it will reveal the underlying powerful structured general relativity infolded inside conventional EM potentials, fields, and waves, as originally revealed by

Whittaker {636}. It may even be that one of the novel concepts {637} we have proposed in this book will yet see the light of day in practical systems.

If so, then hopefully much of what we are addressing in this book will be incorporated in the emerging new physics of the twenty-first century.

Chapter 11

Final Perspective: Permissible COP>1.0 Maxwellian Systems

"Are you certain of that?" [Augustine, in his famous confrontation with the Skeptics, who held that nothing can be known with certainty.]

"[It is usually]...assumed that the magnitude of potential energy is irrelevant, being arbitrary to the extent of an additive constant. " [Block and Crater]. {638}

"The potentials V and A, defined ... in terms of the fields E and B, are considered to be nonobservable in Maxwellian electromagnetism, since the energy density associated with them is zero... " [Lakes]. {639}

"[The total energy of the atom] depends on the *bare mass* *and* *bare charge* *of the electron, the mass and charge that appear in the equations of the theory before we start worrying about photon emissions and reabsorptions. But free electrons as well as electrons in atoms are always emitting and reabsorbing photons that affect the electron's mass and electric charge, and so the bare mass and charge are not the same as the measured electron mass and charge that are listed in tables of elementary particles. In fact, in order to account for the observed values (which of course are finite) of the mass and charge of the electron, the bare mass and charge must themselves be infinite. The total energy of the atom is thus the sum of two terms, both infinite: the bare energy that is infinite because it depends on the infinite bare mass and charge, and the energy shift... that is infinite because it receives contributions from virtual photons of unlimited energy. "* fWeinberg]. {640}

11.1 Introduction

The central message in this book is that all EM devices are already powered — though in an inappropriate fashion — by EM energy freely extracted from the seething vacuum. It is also intended to be a clarion call that we must rapidly develop the *appropriate* vacuum-energy powering of our EM circuits and electrical power systems, or else the survival of the nation and of the biosphere is at stake rather immediately.

For this summary chapter, we wish to place that specific area — EM energy from the vacuum — in sharp focus, with the major facets together in one place.

Consequently, for this closing chapter we have chosen and slightly adapted a previous technical rebuttal to the objections of "perpetual motion", "violation of the second law of thermodynamics," "impossible", etc. that we wrote in 2001 in the referee process, to the referees of one of the AIAS papers submitted to a major physics journal. The rebuttal was successful, and it was accepted and upheld by the referees. The paper was then published by the journal, after very vigorous refereeing.

That is as it should be.

Scientific journals provide a proper forum for the free expression and debate of scientific ideas and work. They do not and should not ensure that every paper conforms to commonly held concepts or to the most widely accepted model. As we stated, Chief Editor Kennedy of the journal *Science* has only recently had to restate and accent the principle that science is free from "truth by prevailing authority," and bound by "truth by replicable experiment". Insuring that every paper meets the accepted models and notions would be enforcement of religious belief, not experimental science. Ideas which are wrong will be refuted experimentally; experiment is still the basis of scientific method. In our rebuttal, the argument of the conventional skeptics is thoroughly refuted by experiments already well known in the literature, as we detail.

So we thought it appropriate to close the book with this strong statement of its primary pbjective: economical, clean, copious electrical energy from the vacuum.

11.2 Source Charges, Curved Spacetime, Efficiency, and COP

11.2.1 The Source Charge Problem

The received interpretation of the Maxwell-Heaviside theory treats the source charge and source dipole as perpetual motion machines, freely and continuously pouring out EM energy in 3-space in all directions with no energy input. Experimentally one verifies that there is no *3-space observable energy input* to the charge or dipole. In accepting that model, a scientist objecting to COP>1.0 EM systems has unwittingly hoisted himself upon his own perpetual motion machine petard, by already accepting every source charge and dipole as precisely that to which he is objecting. To explain the source charge, either one holds to the U(1) Maxwell-Heaviside theory and surrenders the conservation of energy law, or one accepts a change to U(1) electrodynamics to add the concomitant input of energy flow from the active vacuum (from the *time* domain, which in Minkowski geometry is all that is left outside 3-space) to that charge or dipole. That corresponds to a violation of the second law of thermodynamics, as — as we discussed in Chapter 10 — Evans and his colleagues at the Australian National University have already experimentally proven that the second law can be violated up to micron scale and for times of up to two seconds.[287] At the much smaller fundamental charged particle level and far shorter "switching" time of one spin completion, the probability is 100% and a certainty that the second law is violated. Hence the broken symmetry of the charged particle considered in the modem sense as a dipolarity (considering its associated **clustering** virtual charges of opposite sign).

Either way, the classical Maxwell-Heaviside theory must be changed. Every charge and every dipole — which themselves are Maxwell-Heaviside EM systems *a priori* — refutes the erroneous argument that no Maxwell-Heaviside system can output more energy than the operator himself inputs from an external power supply. To adamantly continue to challenge something already *experimentally demonstrated by* every charge and dipole in the universe is the epitomy of scientific blindness.

As have others, Sen {641} called this source charge paradox the "most **difficult"** problem in electrodynamics. However, the basis for its solution - absorption and transduction of virtual KM energy from the vacuum via the broken symmetry of a charge or dipole in its vacuum energy exchange — has now been known in particle physics for nearly a half-century {642a-642d}. It is not included in the Maxwell-Heaviside-Lorentz theory. Neither the proven vacuum interaction with Maxwellian system nor the broken symmetry in that interaction has been added to the model.

The present author has proposed an EM wave solution {643} to the source charge problem, by reinterpreting Whittaker's {644} decomposition of the scalar potential (as between the ends of a dipole) and treating the "isolated charge" and its clustered virtual charges {645} of opposite signs as a set of composite dipoles. Each of the dipoles then becomes a broken symmetry in the energetic exchange with the vacuum. Hence the charge pours out observable EM energy with no *observable* energy input because the input energy is in virtual photon form.

In the solution, the EM energy is input to the charge or dipole from the time-domain, so conservation of EM energy flow is upheld in 4-space, while time-like symmetry and space-like symmetry are broken individually. Powerful support for the proposed solution was given in a quantum field theory argument by Mandl and Shaw {646} nearly three decades ago. We challenge any scientist skeptical of COP>1.0 Maxwellian systems to produce a solution of the source charge problem in Maxwell-Heaviside-Lorentz theory alone. In conventional theory, every charge in the universe experimentally exhibits COP = oo. Any theory conflicting with a replicable experiment is falsified a priori.

11.2.2 EM Waves Imply Curved Spacetime

The oscillating energy of an electromagnetic wave is continuously changing its local spatial energy density. This is an *oscillating change of spacetime curvature* if one accepts general relativity (GR). Hence the EM wave in space is *always* moving in a locally curved spacetime; else, no EM wave exists because no change in spatial energy density exists. To reject that, is to reject GR in its entirety as well as all the experiments consistent with GR. If one accepts GR, then the classical U(1) EM *assumption* of the EM wave moving in a fiat spacetime is a non sequitur. It is unscientific to be suspicious of a higher group symmetry O(3) electrodynamics which *does* correct this known non sequitur in U(1) electrodynamics, while limiting oneself to U(1) electrodynamics *with* that known error. One might as well be suspicious of tensor algebra because it is more comprehensive than vector algebra.

There are many EM experiments such as the Aharonov-Bohm effect {647a, 647b} which violate Maxwell-Heaviside EM, as is well known

{648, 649a-649i}. The foundations of the Maxwell-Heaviside theory are well over a century old, and Maxwell's theory was substantially truncated in the 1880s (more on that below). The considerable physics developed since then has required dramatic extensions to the Maxwell-Heaviside theory such as developing non-Abelian gauge field EM theory, quantum electrodynamics, and modeling of the interaction of vacuum and matter in any material system.

11.2.3 On EM Systems with COP>1.0

Conservation of energy requires that all energy output by an inert system must be input to it {650}. It does not require that the *operator* input all or even any of the energy utilized. The active environment can permissibly input part or all of it, else there could be no such thing as a windmill — or a charge, or a dipole, or a solar-cell electrical power system.

The *coefficient of performance* (COP) of a system compares the system's useful energy or work output to the *operator's* energy input. The *efficiency* $\mathcal{E}$ of a system compares its useful output to its *entire* energy input. No inert system can output more useful energy than its total input, hence $\mathcal{E} <= 1.0$, being $\mathcal{E} = 1.0$ for a theoretically lossless "perfect" system and $\mathcal{E} < 1.0$ for a real system with losses.

Whether the operator must input all the energy that is output by the inert system depends upon whether the system is (i) an open system in disequilibrium with its active environment, and (ii) *designed* to accept and utilize excess energy from that environment, such as from the active vacuum. If appreciable environmental energy input is received and utilized, then a system with losses may permissibly exhibit COP>1.0, even though its efficiency $\mathcal{E}$ is $\mathcal{E} < 1.0$. The common home heat pump is an example. While the efficiency of a home heat pump may be $\mathcal{E} = 50\%$, its **COP** may be COP = 4.0.

As does the skeptical scientist, the electrical engineering community erroneously assumes that an inert electrical power system that outputs more energy than *one oneself* inputs to it — e.g., a generator outputting more EM energy flow than the magnitude of the mechanical energy input to the generator shaft — is against the laws of physics. To the contrary, it is permitted by the laws of physics and thermodynamics, *once the modern* ***Vacuum*** *interaction is included and disequilibrium exists in the interaction* ***between*** *vacuum and system.* Not only is it permissible, it is a universal fact once the arbitrarily discarded Heaviside energy flow component is re-ac**counted,** and the source charge problem is reluctantly placed back on the table. If we account all that EM energy pouring freely from the source charges in any EM circuit, then the actual output of EM energy from that circuit is enormous. It is many orders of magnitude greater than the magnitude of the input energy that the experimenter or operator provides.

We do not have to reprove the active vacuum; it has long been proven in particle physics. We also do not have to reprove the disequilibrium between electromagnetic systems and the active vacuum environment; that also has been proven since 1957 by the prediction and discovery of broken symmetry. One of the proven broken symmetries is that of opposite charges, such as are on the ends of a dipole. Hence every dipole or dipolarity in electromagnetics already freely absorbs virtual photon energy from the vacuum, transduces (coherently integrates) it into observable photon energy, and re-emits observable EM photons in all directions at the speed of light. If there are no COP>1.0 Maxwellian systems, then there can be no Maxwellian charges, dipoles, or dipolarity, and therefore no resulting fields and potentials from these sources — an absurdity falsified by every standard two-wire electrical circuit and ever charge and dipole in the universe. Any potential is a dipolarity, hence exhibits broken symmetry. That is why from any finite potential, as much EM energy as desired can be intercepted and collected, by the simple equation $W = \phi q$, where W *is* the collected energy in joules, ϕ is the scalar potential intensity in joules per unit point static coulomb, and q is the intercepting charge in coulombs.

Systems far from equilibrium in their energy exchange with their active environment {651a, 651b} can permissibly perform five important functions impossible to equilibrium systems. Such a disequilibrium system can:

(1) Self-order,

(2) Self-oscillate or self-rotate,

(3) Output more energy than the operator inputs (the excess energy is freely received from the active environment),

(4) Power itself and its load (all the energy is freely received from the active environment), and

(5) Exhibit negentropy.

Any charge or dipole already exhibits all five of these functions — forbidden by classical thermodynamics but permitted by the well known thermodynamics of systems far from equilibrium in their exchange with their active environment {651a, 651b}.

It *only takes one small white crow to prove that not all crows are black.* The known performance of the charge and the dipole totally refutes the notion that no EM system can output energy without operator-arranged input from other than the active vacuum. The entropy-consuming reactions from the fluctuation theorem, experimentally proven by Evans et al. in 2002, also is a sufficient proof to destroy any argument against permissible COP>1.0 EM systems. Since all the EM field energy and potential energy in a power system or circuit must come from the source charges and dipoles, it follows that all our EM energy systems already take *all* their EM energy from the active vacuum, *not* from the operator's input. A solar cell array also refutes the notion that the operator has to input the energy, but the solar cells' environmental energy input may not be ubiquitous or dependable. The active vacuum is both.

Most power system electrodynamicists avoid the particle physics solution {652} to the source-charge problem {641} involving disequilibrium exchange with the active vacuum. Instead, they adhere strictly to the Maxwell-Heaviside-Lorentz theory with its *assumed* equilibrium between system and vacuum. Therefore they avoid modeling the vacuum interaction and solving the problem of open dissipative EM systems which freely and dependably receive energy from their vacuum environment in unusable form, translate it into usable form, and furnish it for further capture and use. They therefore cannot resolve the source charge problem in their model, for the model has already artificially excluded the solution.

By definition, an EM system in equilibrium cannot output more useful energy than the operator inputs. However, considered as an *energy* ***transducer,*** every EM system is in disequilibrium with the vacuum because of the charges and dipoles in the system, and it continuously receives energy from the vacuum. Because of the broken symmetry of the charge and the dipole, some of this energy from the vacuum is discharged by every charge and every dipolarity in the circuit as observable energy *a priori.* This creates a truly enormous outpouring of rather disorganized (in this case, *uncollected)* EM energy extracted from the vacuum and poured out without being intercepted and diverged into the circuit, where it is organized for dissipation and use. The circuit "uses" only that amount of this enormous available outpouring EM energy that it first organizes (collects) and directs. That is its "organized excitation" energy, commonly known as *input energy* macroscopically — the Poynting energy flow component.

Upon completely discharging its excitation (input energy), the inert system outputs all its received (organized) energy, from whatever source. So every EM system already outputs far more energy than the experimenter inputs — when the system's *nondiverged, non-organized, and nondiverged* output energy flow is considered as well as its *diverged, organized, and collected* energy flow component. The fact that the *diverged Poynting* energy received in the external circuit enters the circuit from the surrounding space is shown by Krauss {653} (See Figure 1-1 in Chapter 1). We show it in Figure 2-4 of Chapter 2 as well. The remaining and nondiverged Heaviside energy flow component in space, which misses the circuit and is wasted, is also shown in Figure 2-4 of Chapter 2 and contrasted to the diverged (caught) Poynting component. To understand this experimentally demonstrable fact {653}, we need a bit of EM history.

11.3 Truncations of Maxwell's Theory and Discard of System Classes

11.3.1 Concept of EM Energy Flow Through 3-Space

The concept of the connection of EM energy and space did not occur until 1876 in a faulty work by Croll {654}. In the 1880s Heaviside {655} showed the huge nondiverged component filling all space around a circuit (see Figure 2-4 in Chapter 2). Poynting {656} never even considered the external nondiverged flow missing the circuit, but assumed only the *diverged* energy flow component that enters the circuit. Figure 2-4 in Chapter 2 shows both components of EM energy flow laterally, so they can be seen clearly.

It is stressed that the Heaviside nondiverged component of EM energy flow around every circuit is far greater (by many orders of magnitude) than the circuit's intercepted, diverged, and collected Poynting energy flow component. This follows from Heaviside's own original papers. So when the entire output energy flow is considered, every generator and every battery is already a $COP \gg 1.0$ *energy transducer,* outputting far more energy flow than the rate at which mechanical energy is input to the generator shaft or the rate at which chemical energy is dissipated in the battery.

In the 1880s the electron, atom, nucleus, special and general relativity, quantum mechanics, quantum electrodynamics, and active vacuum had not been discovered. There was no knowledge of any possible active vacuum interaction source for such an enormous energy flow pouring from the terminals of the generator or battery and surrounding the circuit, filling all space around it. Heaviside's extra energy flow component was thus shocking and inexplicable, smacking of "perpetual motion" and total violation of the conservation of energy law. Heaviside — a brilliant, self-taught hermit who never attended university - spoke cautiously and obliquely of its magnitude in terms of angles with respect to a reference direction {657}.

11.3.2 Elimination of the Non-Intercepted Energy Flow Component

A perplexed and concerned Lorentz {658} cut the Gordian knot and arbitrarily *discarded* the Heaviside nondiverged component, eliminating the quandary. Lorentz stated that the huge nondiverged component had "no physical significance" (his phrase) since it powered nothing. Of course it **has** no physical significance, and powers nothing, unless one intercepts it and uses it!

By analogy, the component of a great wind on the ocean that is *outside* the intercepting sails of a single sailing ship, does not contribute to further powering *of that ship.* Figure 2-5 in Chapter 2 shows that situation. However, that nondiverged wind component can power a whole flotilla of ***additional,*** *separate* sailing ships with separate sails, as we showed in Figure 2-6 in Chapter 2. Electrodynamicists {659} have continued to utilize Lorentz' clever integration trick (Figure 2-3 in Chapter 2) to dispose of the huge nondiverged Heaviside energy flow component surrounding **every** circuit and missing it, and therefore pouring from the terminals of every generator. Most electrical engineers today do not realize that the original purpose of Lorentz's integration of the energy flow vector around a closed surface assumed surrounding every volume element of interest was merely to get rid of that perplexing and bothersome Heaviside nondiverged energy flow component while retaining the Poynting diverged energy flow component.

11.3.3 Lorentz's Previous Discard of all COP>1.0 Maxwellian Systems

Previously (circa 1890s) Lorentz had symmetrically regauged Heaviside's **equations** that had already seriously curtailed Maxwell's seminal equations of 1865. This Lorentz symmetrical regauging retained only that class of EM systems that are in equilibrium in their seething energy exchange with their active vacuum environment. It discarded that entire permissible class of the Maxwell-Heaviside systems far from equilibrium with the active vacuum. In short, it *arbitrarily* discarded all COP>1.0 Maxwellian **systems,** and all those even *permitted* to exhibit COP>1.0.

The ubiquitous use of closed current loop circuits containing both the ex**ternal** circuit and the source dipole inside the generator forcibly applied (and continues to forcibly apply) the Lorentz symmetrical regauging. Thus all electrical engineers began using circuits which self-enforced equilibrium in the vacuum exchange, so that no *net usable* energy[306] that could translate electrons and do work in an external load —could be received from that source.

However, so long as the enormous Heaviside nondiverged energy flow component outside the circuit remained, then separate outrigger antenna circuits and systems could always be inserted in this external energy flow to divert some of it into separate additional circuits. This would have opened up the COP>1.0 *ensemble* of systems and separate outrigger receiver circuits (with separate loads) fed by a single central generator, such as one version of the motionless electromagnetic generator of Chapter 7.

Consequently Lorentz integrated the entire energy flow vector around a closed surface assumed around any volume element of interest {658}, as shown in Figure 2-3. This integration trick — still universally applied {659a-659c} in all the texts today — arbitrarily discarded that troublesome and massive Heaviside energy flow component that could not be explained, and for which no source was known.

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[306] Lorentz symmetrical regauging does indeed require that the system receive excess energy from the environment (the active vacuum). It requires that the potential energy of the system is changed twice and continuously, which means the excess energy in each of those two changes must continuously enter from the active vacuum and do internal work on the system. Two new free force fields are created, each with its field energy, which is additional energy being continuously dissipated in the circuit to perform continuous work. However, the two free changes of energy in the system have been precisely selected so that these two force fields are equal and opposite. The two free changes of energy thus produce a *stress potential* without a net translation field. This means that the local spacetime has been curved, in a manner representing a rotation of the system frame away from the lab observer's frame. Further, the stress potential represents the continuous entry of extra stress energy from the vacuum, whose two force fields continually perform opposing local *internal work* within the system to stress it, while unable to translate electrons and power external loads. Contrary to the received view, the Lorentz-regauged Maxwell-Heaviside system is a dramatically altered and different system than the original system before the arbitrary application of the Lorentz condition. The system's inertial frame has been rotated, it has taken on extra energy from the vacuum that can only be used to do internal work upon the system, and that internal work on the system is continuously being done to increase the system's stress and hold it at the new level.

11.3.4 The Heart-Breaking Result of Lorentz's Actions

The combination of these two actions by Lorentz — symmetrical regauging of the model equations and discarding the excess Heaviside nondiverged energy flow component — unwittingly resulted in the design and building of only those electrical power systems which symmetrically and automatically regauge their discharge of their excitation energy. The symmetrical regauging is self-applied by the closed current loop circuit. That circuit uses half of its collected Poynting energy to destroy the source dipole in the generator, and the other half to power the loads and losses in the external circuit {660}. Conventional EM systems are unintentionally designed to destroy their own source dipoles — and their free extraction of organized EM energy from the vacuum — faster than they power their loads.

11.3.5 Agreement with Classical Equilibrium Thermodynamics

These curtailments of Maxwell's theory resulted in the exclusive building of equilibrium EM systems. These systems obviously obey the classical equilibrium thermodynamics with its infamous second law. Lorentz had unwittingly discarded all that entire class of Maxwellian systems in disequilibrium in their exchange with their active vacuum environment; in those days, there was nothing known about an "active vacuum environment" or broken symmetry in its virtual energy flux. Consequently, Lorentz had discarded all those Maxwellian systems that *do not* obey classical equilibrium thermodynamics, but do obey the newer thermodynamics of systems far from thermodynamic equilibrium with their active environment. He discarded all permissible COP>1.0 Maxwellian systems.

However, there was a total agreement between all the EM systems actually built using Lorentz's symmetrized equations and all measurements in their ubiquitous closed current loop circuits — all self-enforcing the Lorentz condition. This led to the iron dogma that all EM systems must inevitably comply with classical equilibrium thermodynamics — the circuits that were built *were* repeatedly and universally observed to do so!

11.3.6 Dogma that COP>1.0 EM Systems are Perpetual Motion Machines

Finally, this total agreement (now for more than a century) between the theoretical model used, the circuits actually built, the measurements performed, and classical equilibrium thermodynamics led to the present fallacious but iron dogma that EM circuits and power systems cannot output more energy than we ourselves input. Today the vast majority of scientists consider it absolutely proven that the laws of nature prohibit

COP>1.0 electrical power systems, and particularly prohibit self-powering systems that freely power themselves and their loads (i.e., EM systems analogous to "windmills in a free wind"). As we stated, every charge and dipole falsifies the "COP>1.0 EM systems are impossible" dogma, as does the fluctuation theorem and its experimental proof by Evans et al.

Sadly, no one seems to have realized that we do not presently have COP>1.0 electrical power systems only because engineers have specifically designed and built their EM systems to destroy their own source dipole faster than they power their load. Ironically, every circuit and every power system used and measured by our engineers already outputs far more EM energy than is input by the operator or by turning the shaft of the generator, if the Heaviside nondiverged energy flow component is re-accounted. The Bohren experiment clearly proves it experimentally {662}, along with thousands of other similar experiments in "negative resonance absorption of the medium" {157a-157d).

11.4 Examples of COP>1.0 Electromagnetic Systems

The motionless electromagnetic generator (MEG) {661} (Figure 11-1) does catch and use some of this available free energy, as explained below. So does the familiar Bohren experiment {662a, 662b} by resonating each intercepting charge so it sweeps out an increased geometrical reaction cross section in space, reaching past the usual Poynting interception cross section (for a static charge) and thereby absorbing additional energy from the otherwise non-intercepted Heaviside energy flow component.

Every charge and dipole in the universe also already acts as an electrical "windmill in a free wind," having a COP = oo.

The present author has also nominated the long-neglected but vast nondiverged Heaviside EM energy flow, accompanying every field and charge interaction, as the long-missing source of some 90% of the gravity holding the arms of the spiral galaxies intact {663}. Our *supersystem* examination of several COP>1.0 EM systems developed by various inventors has also uncovered a proposed solution for the source of the distant antigravity accelerating the expansion of the universe {664}.

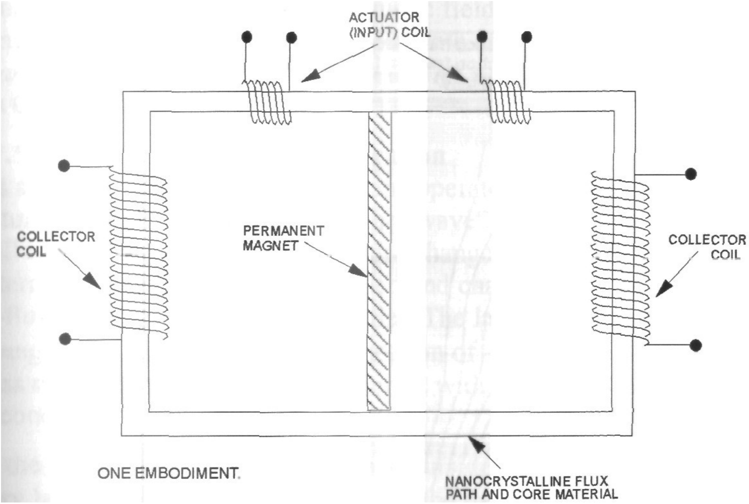

Figurei 11-1. Transformer section of the MEG.

Experimental proof that EM energy COP>1.0 is both possible and demonstrated is already in the literature — e.g., as in the Bohren experiment {662} which outputs 18 times as much energy as one inputs (see Figure 11-2). As another experimental example, the Aharonov-Bohm (AB) effect {647, 665, 666} freely adds additional nonlocalized field-free A-potential energy while all the magnetic B-field energy is sharply localized but still present and available. The AB effect is routinely implicated in physics, but apparently was never applied in an electrical power system prior to its use in the motionless electromagnetic generator

Bohren's experiment {662} was quickly and independently replicated by Paul and Fischer {667}. It can be replicated by any university laboratory at will, totally negating the conventional COP < 0 assumption. The AB effect is also easily replicated, using a toroidal coil, a long solenoid, or a permanent magnet and the special cores used in the MEG. When the toroid system's *total available output energy flow* is measured and accounted — including both the confined magnetic field energy flowing inside the toroidal windings and the field-free A-potential flowing outside — the toroidal coil system outputs more energy flow than the operator furnishes from his external power supply by conventional accounting {668}.

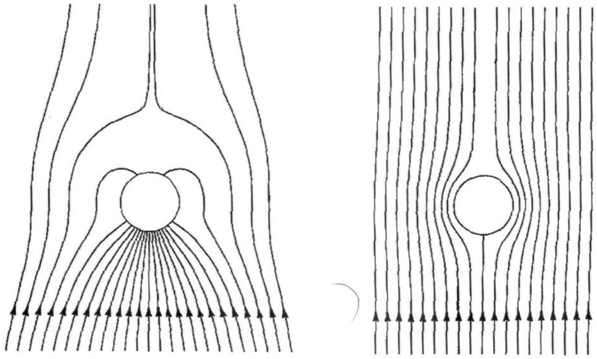

At or near resonance frequency, in the case shown the energy collection fraction (reaction cross section) increases dramatically.

Figure 11-2 The Bohren experiment outputs 18 times as much energy as one inputs

In conventional terms, for a theoretically perfect toroid the operator only "pays for" the magnetic field energy "output component" confined inside the toroidal windings. The presence of an extra energy output component outside the toroid produces COP>1.0 performance as *an energy transducer.* It *does not* produce system COP>1.0 performance in a closed-loop circuit containing the primary power supply's source dipole.

The AIAS has previously nominated more than a dozen mechanisms as promising COP>1.0 systems for investigation, research, and development {669}.

11.5 Motionless Electromagnetic Generator (MEG)

11.5.1 Overall Description

In the MEG {661} (Figure 11-1), one uses a nanocrystalline material core path with the unique characteristic of drawing in almost all the magnetic field energy of an emplaced permanent magnet. The B-field flux from the magnet is withdrawn from its normal position in surrounding space and sharply confined to that material core path. Around the core there freely appears an *additional* curl-free magnetic vector potential A energy flow, since the surrounding spacetime is still curved due to the interaction exchange of vacuum and magnet dipole, and therefore still contains extra energy. The operator inputs no energy whatsoever after the magnet is once emplaced, yet has appreciable magnetic field energy and field-free magnetic vector potential energy available to utilize. As an *energy transducer*, the MEG has a $COP \gg 1.0$. As a power system powering loads, its $COP > 1.0$.

11.5.2 An Example of MEG Operation

As a replicable example, suppose one operates the MEG core at less than saturation, and places a small "square wave" pulsed signal upon a primary coil wound around the core. The core changes its permeability as the internal magnetic B-flux is perturbed and changes, so all the perturbed B-flux is retained in the core material. The large E-fields produced by the changing B-flux in the core as a function of $-\partial \mathbf{B}/\partial t$ are *not* localized, but pass readily out of the core and interact with the coils, particularly with the secondary.

In the A-potential region in the space outside the core, one also produces very large E-fields by $\mathbf{E} = -\partial \mathbf{A}/\partial t$. At the frequencies being used (40 to 80 kHz nominally), all these E-fields produced by the core flux perturbations and by the external A-potential perturbations are essentially in phase. The large E-fields thus coherently add and interact directly with the secondary coil acting as a receiver.

In the secondary, the very large and sharply changing E-fields interacting with the coils also produces large B-field flux changes in the core. However, again the core changes its permeability and holds-in all the extra B-flux. The changes in that secondary B-flux also make additional non-localized E-fields, and so on.

The surprising and shocking result is that the transformer secondary undergoes a coherent, purely E-field reaction with the electrons in its coils. This results in the output voltage and current being in phase (within 2°, since there are inevitably some small remaining inductance effects due to a tiny bit of external B-field leakage from the junctures of the ends of the permanent magnet with the core material).

The magnitude of the powerful E-fields produced by these processes — and interacting with the secondary coils — depends on the rise and decay times of the input signal's pulse edges. So the *average* power input to the signal coil may be small, but — using sharp rise and decay times of the input pulses — very large E-fields will be produced in the adjacent surrounding space outside the transformer section and interacting with the secondary coils, as well as in the sharply changing B-flux localized in the core.

One then uses transmission-reception theory and near-field antenna theory for separate receiving circuits containing loads, added in the large E-field region in space outside the core. Those E-fields arise from both the changing A-potential outside the core and the changing localized flux inside the core. We stress again that the E-fields produced in the core are not localized, but pass outward into the external space to interact with whatever interceptor/receivers are placed out there.

A "outrigger array" version of the MEG uses separate external receiving circuits, containing loads, to intercept, collect, and use more of the EM energy available in the surrounding space outside the core.

Within physical space limits, the energy intercepted and utilized by these *separate, independent receiving circuits containing loads* can be increased by adding more receiving circuits with loads or adjusting the rise and decay time of the input pulses to provide greater collected voltage. These *separate* loads will be powered by the incident E-fields' interception in the external receiving circuits. This is not at all a *transformer* action, but a *near-field transmission and separated multiple antenna circuits' reception* action.

There is no back-current coupling between the external circuits and loads with the primary circuit of the transformer section. In the external A-potential region alone, the secondary coil in the transformer section will interact with the large incident E-fields from that adjacent space and from the changing B-flux inside the core, producing at least as much energy as one inputs to the primary. Actually, that process alone will produce more output energy in the secondary than the operator inputs in the primary.

If one operates the core below saturation, the magnetic flux in the core will also be switched, giving additional intercepted E-field energy in the secondary coil attached to its load. The total work out in all loads is permissibly greater than the total energy dissipated in the input by the operator's energy input {668}. The MEG is an open system far from equilibrium with the active vacuum {670}.

11.5.3 The MEG Is Replicable

Any university laboratory can replicate this effect, and demonstrate more work in resistive loads than is input to the MEG primary from the external power supply. For replication, we suggest initially designing to COP = 1.5, since beginning at COP = 2.0 there *can* be other effects not in the U(1) EM literature, but which are dealt with in the actual MEG. Some of the methodology {671} used for COP >2.0 is still proprietary information not yet releasable due to patent law requirements, while some of it was included in Chapter 7.

Without elaboration we advance the *supersystem* concept, and strongly insist that, to properly analyze the performance of any similar EM circuit or system, one must analyze the dynamics of the entire supersystem consisting of (i) the physical system and its dynamics, (ii) the curved local spacetime and its dynamics, and (iii) the local vacuum and its dynamics {672}. All three components of the supersystem are mutually interacting.

For a COP>1.0 system, the mutual interactions are utilized from disequilibrium processes evoked between all three supersystem components. U(l) electrodynamic analysis system in an inert vacuum and a flat spacetime is insufficient. Previous AIAS analysis {661} has addressed the supersystem by use of higher O(3) symmetry electrodynamics to include vacuum dynamics (energy currents, both space-like and time-like) and curved spacetime dynamics.

11.6 Physical Considerations of Gauge Freedom

Additional physical considerations must be accounted when *gauge freedom* is invoked or utilized with respect to physical systems. Applied to electrodynamics systems, gauge freedom assumes the ability to freely change any potential of the system being studied. From the physics of the situation, a system potential change concomitantiy assumes changing the *potential energy ofthe system itselffor* which gauge freedom changes are being theoretically applied to system-descriptive equations.

If one *can freely increase* the potential energy of an EM system, the extra energy has to come from a physical asymmetry of the system with its active environment — the active vacuum. Else, one must surrender the conservation of energy law. At worst, gauge freedom would then imply the creation and destruction of energy at will. At best, it would imply a return to the view that potentials are mere mathematical conveniences with no physical reality — a notion falsified for decades by the AB effect {647}. ***freely** decreasing* the potential energy of the system by simply depotentializing it, has a similar vacuum asymmetry requirement for de-excitation of the system, where energy must flow from the system to the vacuum.

11.7 Special Modeling of the Vacuum

Having EM energy density, the vacuum *is and should be modeled as* a scalar potential of great magnititude. For deeper (supersystem) analysis, one will also have to examine the internal EM longitudinal phase conjugate wavepair structure and dynamics of the scalar potential vacuum {672}, along the lines shown by Whittaker {644} in 1903 and re-interpreted by the present author {643} in 2000. From quantum field theory arguments, Mandl and Shaw {646} give strong support to the proposed reinterpretation. They argue that neither the scalar (time-polarized) photon , nor the longitudinal photon is independently observable, but the combination of the two is observable as the instantaneous scalar potential.

Transforming this argument to EM waves yields a solution consistent with the reinterpretation {643}. The result is that all 3-space EM energy comes from the time-domain, in a manner not previously utilized in EM circuit analysis. It is experimentally established by proving (measuring) that the source charge and dipole do not *receive ob*servable EM energy in 3-space, but continuously *output* observable EM energy in 3-space. Simply making and destroying dipoles in an electrical system turns out to be a method for direct engineering of negentropy and entropy respectively — or, from another viewpoint, it directly engineers regauging.

The greatest unrecognized problem in conventional electrical power system engineering is its total failure to include the making and destroying of dipoles as direct engineering of negentropy and entropy respectively.

Every EM potential in an EM system is a change to the energy density of the ambient vacuum potential — and thus is a spacetime curvature — or it is a change to an intermediate potential that *is* such a vacuum potential change. Vacuum exchange with every EM system and asymmetry in that exchange, is ubiquitous and cannot be prevented. Whenever one makes or changes an EM potential, field or wave, and whenever one regauges, one invokes and utilizes asymmetry in the interaction of the active vacuum and the system, either wittingly or unwittingly. Else one must discard the conservation of energy law altogether. There is no symmetry of a mass system alone {673}, without including the vacuum's asymmetrical interaction with it. The reason is simple: all observables involve asymmetry {674} *a priori,* and mass is an observable.

11.8 Every Charge and Dipole in an EM System Receives and Transduces Vacuum Energy

In particle physics, every dipole — and every charge considered with its associated clustering virtual charges of opposite sign — is recognized as an asymmetry in the vacuum flux {675}. The very definition of broken symmetry means that a charge or dipole receives and absorbs virtual photon energy from the vacuum, transduces it into observable form, and re-radiates it as real, observable EM energy. This results in an observable outpouring of 3-energy from the charge or dipole, with no observable 3-energy input.

To save the conservation of energy law for physical EM systems, one must therefore recognize and model the *physical vacuum asymmetry mechanism* **that** allows this demonstrated performance of charge and dipole. In electrical power systems, that required asymmetry mechanism is the known broken symmetry of the vacuum's interaction with the source dipole created in the generator.

11.9 Energy from the Vacuum Powers Every Electrical Power Line and EM Circuit

11.9.1 What the Generator Powers and What Powers the Circuit

Shaft power input to a conventional generator allows the generator to **produce** its source dipole, nothing else. The generator does not transduce any of its input shaft mechanical energy to add EM energy to the external circuit connected to its terminals. Instead, it first transduces its mechanical shaft energy input into internal magnetic field energy.

Then it totally dissipates that magnetic energy to separate its own internal **charges,** forcing the positive charges in one direction and the negative charges in the other, making the source dipole connected to its terminals. That is all that the mechanical shaft power input to a generator does — and **that** is all that burning hydrocarbons, consuming nuclear fuel rods, **damming** rivers for power stations, putting up windmill-powered **generators,** using solar energy input to solar cells, or consuming chemical energy in a battery accomplishes.

Once made, the source dipole — via its broken symmetry in its vacuum exchange - freely receives and absorbs enormous virtual photon energy **from** the active vacuum, transduces it into observable (3-space) form, and pours out real, observable EM energy in 3-space from the generator terminals to which it is connected. As shown in Figure 1-1 of Chapter 1, this outpouring of EM energy from the generator terminals fills all space around the external circuit {653} with a vast energy flow almost parallel to the conductors. Figure 2-4 is a lateral view so that the two flow components can be clearly seen and compared.

11.9.2 Gedanken Experiment

We advance a gedanken experiment to illustrate. Consider a perfect generator with no losses, and with two perfect conductors and a purely resistive load R_1 connected across its terminals. Call the mechanical energy input to the shaft of the generator W_{in}. Call the Poynting diverged energy flow component W_r that is intercepted by the attached circuit and powers R_1. Call the Heaviside nondiverged energy flow component W_h that misses the circuit and is wasted. As an *energy transducer,* the total energy output W_{out} from the terminals of the generator is

$$W_{out} = W_r + W_h \qquad [1]$$

However, $W_{in} = W_r$, for this theoretically perfect system. So

$$W_{out} = W_{in} + W_h \Rightarrow W_{out} > W_{in} \qquad [2]$$

Further, when accounted, $W_h >> W_{in}$, so

$$W_{out} >> W_{in} \qquad [3]$$

We conclude that all EM systems — *as energy transducers freely extracting and transducing EM energy from the active vacuum*— already exhibit COP » 1.0. However, for *useful work* in a closed current loop circuit, the COP = 1.0, unless additional antenna-receiver circuits or another scheme such as Bohren charge resonance is used to increase the energy collected and dissipated in the load while *not* increasing the energy used to dissipate the source dipole.

11.10 Significant Developments in Negative Resistance

True negative resistance (e.g., current moving against the voltage) also exists and is experimentally replicable. In true negative resistance, the current in a circuit moves against the voltage instead of with it, suggesting time-reversal effects in the mechanism by which EM force and charge interact.

11.10.1 Chung's Negative Resistor and Naudin's Replication

Chung {676} has reported replicable negative resistance in the interfaces between layers of carbon fibers in a composite material. By varying the pressure used when the fibers are made, the resistance can be controlled to later be negative or positive as desired. A simpler version of Chung's negative resistor using off-the-shelf materials has been successfully replicated and tested by Naudin {677}. (See Figure 11-3). Naudin's website {677} provides measurements and full details necessary for repetition. He also includes sources of the carbon fiber materials needed for independent replication.

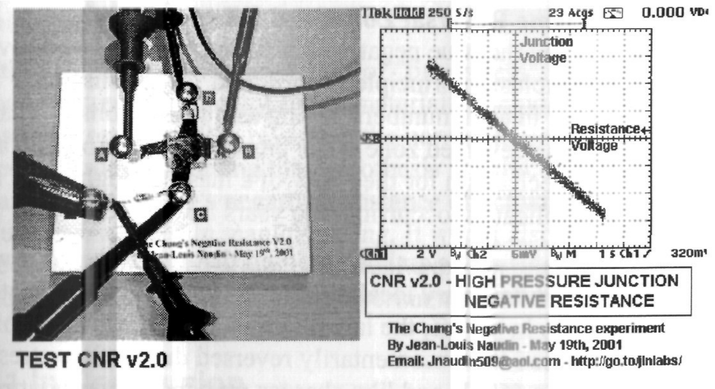

CNR v2.0 - HIGH PRESSURE JUNCTION NEGATIVE RESISTANCE

The Chung's Negative Resistance experiment
By Jean-Louis Naudin - May 19th, 2001
Email: Jnaudin509@aol.com - http://go.to/jlnlabs/

Figure 11-3 Naudin's replication of Chung's negative resistor.

11.10.2 The Point Contact Transistor

There is also evidence that the original point contact transistor — which used spring pressure on the point contact — often exhibited true negative resistance. Certainly this transistor was never adequately understood {678}, and it is not understood today, since its supersystem has never been analyzed.

11.10.3 Kron's Negative Resistor

Gabriel Kron, early pioneer in electrical systems theory, reported developing a negative resistor in the 1930s, on the U.S. Navy's Network Anayzer project {679} at Stanford University. He was not permitted to reveal the details of his negative resistor, but did provide strong hints in certain statements in his papers in the literature {680a, 680b}. His method for a self-organizing network depended on his "open path" {681} which he also was not permitted to reveal.

The present author worked for some years with Floyd Sweet, a Kron protege", who did produce a successful type of powerful negative resistance system {682} known as the vacuum triode amplifier, apparently based on Kron's original negative resistor. See Figures 6-5 to 6-13 in Chapter 6. As shown in Figure 6-6, Sweet induced self-oscillation in barium ferrite magnets {683a-683c} (which are made by powder metallurgy methods using pressure applied during their manufacture) and extracted energy by induction from the resulting self-sustained magnetic field oscillations. His device was independently tested by Walter Rosenthal {684}, a senior test engineer of long experience with a major aerospace company. See Figure 6-9 and Figure 6-13.

11.10.4 Proposed Time Reversal Zones and Effects

One may take the view that true negative resistance involves time-reversal, which by the Pauli exclusion principle is permitted for bosons {685} and possibly for fermions in even numbers, acting as quasi-bosons (perhaps only possible in a time-reversed zone). The present author proposed a photon interaction mechanism for the "flow of a mass through time" in 1971, with initial publication occurring two years later {686}.

Extending this mechanism, the author proposed that *time reversal zones* (TRZs) can occur in momentary local regions in semiconducting materials or electrolytes {687}. In a TRZ, the law of attraction and repulsion of charges is hypothesized to be momentarily reversed due to time-stress or time-domain pumping {688}, and like charges may momentarily attract. In Chapter 10, we used these time-reversal zones to explain the anomalous results of the 600 or so successful cold fusion experiments worldwide. We also gave the exact new nuclear reactions for the production of anomalous deuterium, tritium, and alpha particles in many of these experiments.

When under strong stress, anomalous attraction of clusters of like charges is experimentally known, e.g. in Shoulders' {689} experiments and patented processes {690}. When the output leads of Sweet's vacuum triode amplifier device were suddenly shorted, extreme cooling occurred rather than heating. Ice condensed instantly upon the shorting contact and leads from the sudden extreme cooling of the metal in the moisture in the air, dramatically showing a converging EM energy process rather than a diverging one.

11.10.5 Effects in Optically Active Semiconducting Materials

In addition, four-wave-mixing, phase conjugation, and time-reversal effects are well known in semiconducting materials {691}, almost all of which are optically active. Optical activity and microlasing is known in semiconductor powder {692}. Further, the vacuum itself can exhibit semiconducting properties {693}.

11.10.6 Special Functions Produced by Stress

Apparently pressure (stress) in many of these devices and experiments can play an important role in the negative resistance process. Based on harmonic sets of paired couplings of a longitudinal time-like wave and a longitudinal wave in any scalar potential {643}, the present author hypothesizes that such stress — treated as a stress scalar potential — accomplishes time-domain pumping in the optical sense, due to the presence of the coupled time-polarized longitudinal waves in the time domain.

This time pumping is a special form of "time stress". Thus in optically pumped or stressed optically active materials (including electrolytes), the time-stress creates a TRZ, reversing the normal force laws upon and between charges. Assuming this hypothesis is valid, this could account for the variation of Chung's negative resistance effect with the variation of the pressure (stress) used in manufacturing. It would also apply to the laser-**created** stress in semiconducting powder experiments, etc. The hypothesis should be further investigated for experimental validation or refutation.

11.11 In Conclusion

As Penrose {694} states,

> *"Electromagnetism is a subject that is in no way closed to stimulating new developments."*

Indeed, electrodynamics is still very much an advancing subject, and in classical electrodynamics there are foundations errors and problems, a few of which we have addressed. As Bunge {695} pointed out more than three **deca**des ago,

> *"...it is not usually acknowledged that electrodynamics, both classical and quantal, are in a sad state. "*

From a foundations viewpoint, Einstein {696} beautifully summed it up — and advanced a requirement for continually examining the foundations of electrodynamics and every other field of physics — in these words:

> *"..the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the eternally problematic character of his concepts. He uses this conceptual material, or, speaking more exactly, these conceptual tools* ***of thought,*** *as something obviously, immutably*

> *given; something having an objective value of truth which is hardly even, and in any case not seriously, to be doubted. ...in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them."*

Though they have long been neglected, legitimate COP>1.0 electrical systems are good science, or they can be. They were present in the original Heaviside truncation of Maxwell's theory prior to Lorentz's symmetrical regauging. That regauging arbitrarily selected only those Maxwellian systems in equilibrium in their exchange with the active vacuum. The energy flow theory was further curtailed by Lorentz's integration trick, which discarded the huge vacuum-furnished non-intercepted Heaviside energy flow component accompanying every EM system. Every EM system already outputs for more EM energy flow than the energy that the operator inputs; thus every EM system is already a COP»1.0 system, with respect to *energy transduction*. The only way this giant negentropy of every EM system can be hidden is to ubiquitously continue that integration trick to discard the giant Heaviside energy flow component.

The present Lorentz-regauged Maxwell-Heaviside equations are not consistent with *any* bipolar EM system or circuit. The ends of any dipolarity in the universe — including any electron on Jupiter and any positron in the star Sirius — constitutes a broken symmetry in the seething vacuum flux. Actually, that is what Gabriel Kron discovered and called his "open path". Hence, that "dipole" continuously emits observable EM energy extracted from the vacuum.

Engineering use of the ubiquitous closed current loop to contain both the primary source dipole and the load — which destroys the source dipole and extraction of vacuum energy faster than the load is powered — is responsible for the successful predictions of the equilibrium EM model (which of course completely fails to explain the source charge or source dipole). That circuit is unwittingly designed to self-enforce the Lorentz symmetry condition and therefore self-enforce those predictions.

The question as to whether COP>1.0 electrical power systems are possible *and practical* must be resolved by direct experiment, and not by established models and cherished concepts that already arbitrarily exclude such systems! Such theoretical refutation by models that in fact contradict the experimentally observed COP = oo action of every charge in the universe, cannot be trusted at all with respect to COP> 1.0 judgment. Well-known supporting and confirming experiments already in the literature — such as the Bohren experiment yielding COP =18 — have been cited, and these are replicable by any university laboratory. The Bohren-type experiment is well known and routinely performed in every nonlinear optics laboratory, under the guise of "negative resonance absorption of the medium".

It is indeed a critical time to re-examine the foundations of our electrical power science and engineering, along the lines so eloquently stated by Albert Einstein. With the impending oil crisis, we face a world economic crisis of epic proportions unless we rapidly develop and widely deploy sell-powering disequilibrium electrical power systems.

Also it is a critical time when the leaders of the scientific community — specifically the National Academy of Sciences, the National Science Foundation, the great national laboratories, and the universities — must at last face and correct the excruciating *faux pas* that has now been perpetuated in electrodynamic theory for more than a century. In short, the leaders of our scientific community must now show whether they are scientists practicing and upholding experimental basis, or are dogmatists defending an ancient faith. The fact that the source charge problem continues to be propagated in electrodynamics 45 years after the award of the Nobel Prize to Lee and Yang, is no longer excusable.

A thorough review and correction of the foundations of EM theory is required for the survival of this nation and much of civilization. It is also required for the cleanup of the increasingly polluted biosphere, survival of the threatened species of the Earth, reduction of present global warming trends, and the survival of this fragile and beautiful planet itself.

Annotated Glossary of Selected Terms

action at a distance: An action (effect) occurring in a local system, for which no separate local 3-space cause exists, but for which a causal correlation exists between a distant action and the local effect.

advanced electromagnetic field: An electromagnetic field that is a solution of the classical Maxwell equations, which is positioned on the future light-cone of spacetime. It may be possible to involve such a field in the tempic force that may exist between the tempic potential at the output of an overunity system and the tempic potential that exists at the input of the system, where the interaction of the tempic force with the local nonlinear vacuum drives Dirac sea hole current from output section to input section.

advanced electromagnetic potential: An electromagnetic potential that is a solution of the classical Maxwell equations, and is positioned on the future light-cone of spacetime. Presently this potential has not yet been given a physical interpretation. It may be possible to involve its effects in a specific system by our notion and use of the instantaneous tempic potential difference (the tempic force) that may exist between the tempic potential at the output of a system and the tempic potential at the input of that system if the two differ.

advanced electromagnetic wave: An electromagnetic wave that is a solution of the classical Maxwell equations, and which is positioned on the future light-cone of spacetime.

Aharonov, Yakir: Renowned Israeli quantum physicist and former student of David Bohm. Co-discoverer of the Aharonov-Bohm effect. Together with Bohm, Aharonov authored a fundamental paper in 1959 that pointed out the *primary importance of the potentials* rather than the force fields. The force fields are only made in and of the charged particle system itself, and do not exist as such in the vacuum. The force fields are thus not primary electromagnetic causes at all, but are *effects* due to the interference of potentials in a particular charged particle system.

Aharonov-Bohm effect: Quantum mechanical phenomenon theoretically pointed out in 1959 by Yakir Aharonov and David Bohm whereby interfering electromagnetic potentials can produce effects on charged particle systems, even at a distance and in the absence of the electromagnetic force fields. A system undergoing a cyclic evolution from an initial state back to it will acquire a phase difference, which can be detected by interfering the initial and final states. Theory was extended later to Berry phase, then again to geometric phase.

In classical EM terms, a more important *energy-amplifying* principle - advanced by the present author — emerges from the AB effect. My colleagues and I have used this principle in our motionless electromagnetic generator (MEG) to provide COP>1.0. Consider a source of magnetic field B, such as a permanent magnet. All the magnetic field energy B from the permanent magnet may be drawn into and confined in a local material path, as in a special nanocrystalline transformer core. Then in the space surrounding the localized magnetic field energy, the active vacuum will freely replenish — via the broken symmetry of the permanent magnet dipole in its exchange with the vacuum — the magnetic energy in that space that would otherwise have been filled with magnetic field B (curled magnetic vector potential A). However, nature replenishes the energy in space outside the B-localization region with the *curl-free* magnetic vector potential A. In this fashion a system designer may cause the active vacuum to provide more available magnetic energy from the permanent magnet that normal, with each of the two energy forms being in separate spatial regions and paths, and occurring in different forms of magnetic vector potential energy. By inputting only a little energy in the input coils of the transformer section, and controlling the rise time and decay time of the pulses, one can produce very large E-fields from the A-potential via $E = -dA/dt$. From the simultaneously perturbed confined B-field flux in the core, one also produces E-field simultaneously and — at the frequencies used — in phase with the E-fields produced outside the core. The net result is interaction of large E-fields with the output coil, producing an output power *proportional to the rate of change* of the weak input signal energy rather than its magnitude. In this fashion, additional E-field energy from the vacuum enters the output coils to power the secondary circuit and its loads. Also, the output of the entire transformer section has the voltage in phase with the current, in contradiction to the actions of all previous transformers.

AIAS: Alpha Foundation's Institute for Advanced Study, directed by Dr. Myron W. Evans, a noted scientist with more than 600 papers in the literature. The AIAS is an unusual "think tank" comprised of Fellows and Fellow Emeriti in various places in the world, who cooperate in advanced electromagnetics studies via E-mail. The Director, Dr. Myron W. Evans, is a theorist of note, as are several other Fellows. The AIAS has been forging ahead with the production of O(3) symmetry electrodynamics, particularly as an important subset of Mendel Sachs' unified field theory. Dozens of AIAS group-authored papers have been published in various leading journals such as *Foundations of Physics, Physica Scripta,* etc. More than 100 AIAS papers are carried on a restricted Department of Energy website for reference by DoE and AIAS scientists. The work is particularly significant in preliminary theorizing how EM energy can possibly be extracted from the active vacuum.

algebras: The various types of mathematics in which the theoretical models for physics and other sciences are embedded. Some important algebras utilized in physics are vector algebra, tensor algebra, quaternion algebra, Grassmann algebra, Pauli algebra, Clifford algebra, etc. There are many others. The complexity of the symmetry and of the topology varies significantly between these algebras. Thus, an electrodynamics model in a lower topology algebra such as vectors or tensors will not reveal or permit nearly so great a set of electrodynamic functions and operations as will electrodynamics embedded in a higher topology algebra such as quaternion algebra or Clifford algebra. See topology.

ambient vacuum: The average or typical "standard" active vacuum (i.e., active spacetime), removed spatially from any large collections of observable charge and observable mass.

ambient vacuum potential: The *average* or typical standard vacuum considered as a scalar potential because it possesses energy density as well as structure and dynamics on many levels. As a scalar potential, the vacuum potential (considered without zero-point fluctuations) decomposes into a harmonic set of "bidirectional" longitudinal EM phase conjugate wavepairs, by Whittaker's 1903 decomposition as reinterpreted by the present author in 2000. Dynamic structuring of the vacuum thus consists of dynamics impressed upon these wavepairs. Since the vacuum is observably mass-free, Whittaker's phase-conjugate half of the decomposition must be considered prior to its interaction with mass, hence in the imaginary plane **and** arising from the time domain. This consideration led to the discovery by the present author of the more fundamental 4-symmetry in EM energy flow between the time domain (imaginary plane) and real 3-space, when broken 3-symmetry is present (as with any dipolarity or with any **potential).**

Powerful support for this solution is also given by F. Mandl and G. Shaw, Quant*um Field Theory,* Wiley, 1984, Chapter 5. Mandl and Shaw argue tthat the longitudinal and scalar (time) polarizations of the photon are not directly observable, but only in combination, where they manifest as the "instantaneous" Coulomb (i.e., electrostatic) potential. Our comment is that this argument, translated from particle terminology to wave terminology, directly fits our re-interpretation of Whittaker's 1903 decomposition of the scalar potential.

angular momentum: The momentum or "leverage" of the linear momentum of a moving body, with respect to an axis or reference point. Angular momentum has the same units as action; that is, it is energy multiplied by time, or momentum multiplied by length. In terms of particles, it is also known as *spin*.

anti-circuits: Somewhat normal-appearing electromagnetic circuits which primarily process and use antiparticles and anti-electrons rather than particles and electrons, or else process a combination of the two simultaneously. Operations of the anti-circuit must be analyzed and understood in terms of its *supersystem* interactions. The circuits process and utilize both negative energy and positive energy EM fields and potentials, hence are closely connected to unified field engineering and antigravity. One aspect enabling such circuits is the use of the supersystem's curvatures of spacetime in both negative curvature and positive curvature fashion so that an appropriate change of spacetime curvature precludes the radiation normally accompanying pair annihilation, etc. The key to the circuits is T-reversal and C-reversal operation, along with the matching use of spacetime curvatures, and also the use of the Dirac "positron" (negative energy electron) — and its fields and potentials — prior to its observation. The unobserved Dirac negative energy electron in the vacuum is an entirely different entity than is the observed Dirac positron after its interaction with charged matter, after which it has become a "lattice hole" or "positive charge on a positive mass ion". The response of normal circuit components to vacuum Dirac sea hole operations is dramatically different than for Dirac positrons, and for certain applications special versions of circuit components are required. At this writing, together with John Bedini the present author has submitted what may be the first patent application on the fundamental process for anti-circuits and their operations with antimatter and negative energy currents, fields, and potentials as well as matter and positive energy currents, fields, and potentials. Another patent application by this author **is** in preparation, covering the anti-gravity aspects. The details of these mechanisms are still proprietary at this writing in order to protect our intellectual property rights, but limited information is in this book.

anti-electron: A negative-energy electron, observed as *a positron.* Under time reversal, electric charge reverses in sign. Dirac did not predict the positron per *se,* but a negative energy electron that we would *observe* in reversed fashion. Present theorists assume the interaction of the 4-space negative energy electron with matter — i.e., observation — to have occurred. This transforms the negative energy, negative mass electron to a positive energy, positive mass positron traveling in the opposite direction. In so doing, antigravity from the negative energy 4-electron source charge, due to its negative energy EM fields and negative energy potentials, is arbitrarily transformed by the spatial reversal into positive gravity fields rather than the antigravity fields they were. The secret to practical antigravity is to utilize (in anti-circuits) the negative energy 4-electrons prior to observation, *without* transformation of (i) negative energy fields to positive energy fields, (ii) negative mass to positive mass, and (ii) reversal of the field direction. In short, simply consider the unobserved negative energy 4-electron as what it is, and utilize it in its unobserved vacuum state. The conventional transformation process also unwittingly discards the concept of anti-circuits, anti-fields, anti-potentials, and anti-currents, which discards half the rich electromagnetic circuitry that can be built and utilized. In the present book, we only touch lightly on this latter subject, which hopefully will be the subject of a future book after certain patents are filed.

antigravity: Negative gravity or reversed gravity. Use of negative curvature of spacetime to produce a force on a gravitational source (physical system) that is opposite to the normal force of gravity of the earth etc. on that system. Antigravity is achieved by the use of negative-energy, negative-mass source charges in the mass component of the supersystem prior to observation, while the source charges are still 4-spatial. This usage produces negative energy fields and negative energy potentials to negatively curve the local spacetime (ST), so that these negative local ST curvatures interact back upon the positive mass source system associated with the vacuum negative energy sources in its supersystem. Again, to understand the operation of an antigravity circuit or system, one must analyze it in terms of its *supersystem* interactions.

antimatter: Matter consisting of atoms that are composed of anti-electrons (positrons), antiprotons, and antineutrons and such. Also loosely refers to the antiparticle corresponding to a particle; an antiparticle may be regarded as a particle traveling backward in time, or "phase conjugated", or "time-reversed. Since time is not an observable, the observer sees the antiparticle {*after its observation by interaction with mass)* in forward time as being reversed in direction and charge.

antiparticle: Conventionally, a counterpart to an ordinary fundamental particle, *observably* having identical mass, lifetime and spin, but with charge and magnetic moment reversed in algebraic sign. We again point out, however, that the antiparticle differs when in its unobserved 4-spatial state. Only by analyzing the particle's supersystem can the true unobserved antiparticle be understood, as well as its fields and potentials in that condition.

antiphoton: A time-reversed photon. Presently the photon is considered its own antiparticle. *Observably* it is, but in its pre-observation condition it is not. An alternate but as yet unaccepted view is that, since the unobserved photon is comprised of (dE)(dt) — i.e., a piece of energy welded to a piece of time with no seam in the middle, the antiphoton may be assumed to be comprised of (-dE)(-dt) with respect to the external observer.

anti-Stokes radiation: The radiation coming from an anti-Stokes emission process from an intensely scattering medium, wherein more energy flux is emitted than is input by the experimenter-operator. The excess emitted energy is furnished by other processes in the medium. For true overunity operation, the excess energy furnished by the energetic medium must be freely replenished to the medium by the active vacuum's interaction with it.

antiwave: The time-reversal (phase conjugation) of a reference wave.

A-potential: The magnetic vector potential A, conventionally thought to be "defined" by the equation $\mathbf{B} = \nabla\times\mathbf{A}$. However, no equation is a definition (an identity is required). If we replace the "=" sign by "==", we have $\mathbf{B} \equiv\nabla\times\mathbf{A}$, which is actually seen to define the field B as just a curled A-potential, or as the curled component of the A-potential, *after* interaction with magnetic charge. The A-potential or an additional component of it can and does also exist in uncurled fashion, and will emerge in the uncurled state in the space outside any local path (e.g., the path in the interior of a toroidal coil) that retains the B-field therein. That process of separating the curl component of the A-potential from its uncurled component is known as the Aharonov-Bohm effect (which also affects the wave function). The motionless electromagnetic generator (MEG) uses a special nanocrystalline core material in a transformer configuration, which draws in and retains the B-field from a permanent magnet outside the core but firmly in contact with it on both ends. As a result, the vacuum freely replenishes the withdrawn magnetic energy that would otherwise have existed in the space outside the core, but the energy outside the B-field localization zone remains and appears as a separated and uncurled A-potential. In this way, the MEG is converted to an open system not in equilibrium with the vacuum, and can therefore permissibly output more EM energy in its output coils than the operator inputs into the input coils, the excess being freely furnished from the vacuum via the broken 3-symmetry of the permanent-magnet dipole and the resulting 4-symmetry EM energy flow from the vacuum's time domain into the dipole.

The MEG is actually a practical macroscopic EM power system application of (1) the well-known Aharonov-Bohm effect and (2) the effect of the separation of the curled and uncurled potentials by a long tight solenoid or by a tight toroid, but in this case by the nanocrystalline magnetic core performing that separation function. In effect, the output coils interact with double (or greater) energy than would be available in just the B-field of the core (and of the magnet). Dual interaction with both theinternal core B-field flux and also the external A-potential is obtained by pulsing, so that the pulse edges produce strong E-fields in space, with the E-fields striking the output coils in a transmission-reception near-field fashion. As is well-known, $d\mathbf{A}/dt = -\mathbf{E}$, and also $f(d\mathbf{B}/dt) = \mathbf{E}$. These two fields produced by the perturbed internal B-flux in the core and the pertubed external uncurled A-potential outside the core are in phase. This is how the extra pulsing A-potential energy outside the core is made to interact as -E-field energy with the Drude electrons in the output coils, while the changing magnetic flux in the core through those coils also simultaneously produces a second -E which interacts with the coil's conductors in normal E-field fashion. The total E-field interacting with the output coils is proportional to the *time rate of change* of the input perturbation signal, not the magnitude of its energy. By adjusting the leading and trailing edges of the perturbation pulses, the magnitude of the E-field interactions with the output coil is determined as desired. Further, the usual output B-field produced in the output coils by dE/dt is directly extracted into the core and held, so that *a purely electrical interaction and output occurs in the output coils*. This is easily shown since the output current and voltage of the output coil are in phase, within a degree or two. The MEG may be said to the world's first purely electrical induction transformer, freely separating the magnetic interactions and bottling them up, while allowing the electrical interactions.

asymmetrical regauging: A change of either the scalar potential ϕ or the vector potential A, or both, so that a *net resulting excess force together with a net change of total system potential energy* occurs in the system. During this change, an asymmetry exists in the active vacuum's energetic exchange with the system. The result is that the potential energy of the system is freely changed by energy from the vacuum, and a free net force is also produced in the system. This new force is then free to dissipate the excess potential energy by translating electrons through a load and powering it. By contrast, the Lorenz/Lorentz *symmetrical* regauging produces two free force fields that are equal and opposite, so there is no *net* resultant translation force available to translate electrons through the external load and power it. Thus Lorentz regauging arbitrarily applied to the Maxwell-Heaviside equations selects only that resulting subset of Maxwellian systems that are in equilibrium in their interaction with the external active vacuum. The potential energy of the system is changed, but only as a "stress potential" doing internal work upon the system to form and maintain its increased stress. The extra energy also rotates the system's frame out of the laboratory frame. Lorentz thus unwittingly discarded an entire class of permissible Maxwellian systems that are not in thermodynamic equilibrium with the vacuum. The Lorentz condition is initially violated each time anyone potentializes an EM circuit, but the closed-current-loop circuit design with the same charged-particle energy carriers around the loop — including back through the back emf of the source dipole in the generator — enforces a form of Lorentz symmetrical regauging during discharge of the system's excitation energy. Further, the response of the electrons in the usual electrical circuit with copper conductors is so rapid that the asymmetrical regauging (potentialization) is almost instantly converted to symmetrical discharging by movement of the electrons as current. When one section of the otherwise closed current loop uses a dramatically heavier charge as the energy carrier (as a battery uses ion current between its plates, but uses electron current between the outside of the plates and the external circuit), it is then possible to dephase the two independent carrier currents so that the battery will be charging while simultaneously the circuit is being powered, by a negative resistor (sharply increased scalar potential or voltage) produced at the plate surface interface of the two carrier current types. This proven Bedini process is an example of a true overunity process, capable of producing a self-powering system by means of adroit switching and timing.

asymmetry: Lack of symmetry, or "broken symmetry" in a general sense. Since a specific symmetry is accompanied by a specific conservation law, the breaking of that symmetry represents the violation of that conservation law. Particularly note that a broken symmetry at one level often (usually) results in a new symmetry at a higher level, necessary to maintain the asymmetry at the lower level. The resulting "levels" of symmetry are known as *hierarchies* of symmetry.

asymmetry of **the dipole:** Because of the proven asymmetry of opposite charges, any dipole or dipolarity is a broken 3-symmetry in its fierce exchange of EM energy with the active vacuum, because of the known broken symmetry of the opposite charges on its ends. Any two points in the universe (in or out of the circuit), that are at differing ambient potentials, constitutes such a broken symmetry continuously pouring out EM energy extracted from the vacuum. A dipole or dipolarity continuously receives and absorbs copious virtual energy from the seething virtual photon vacuum flux, and not all this absorbed energy is reradiated back to the vacuum in virtual form. Instead, some of it is coherently integrated into observable form and re-radiated in all directions as usable, real 3-space observable photons and EM energy. We found that the input energy to the dipole is from the time domain of 4-space. Hence the dipole's broken 3-symmetry results in the appearance of a new and far more fundamental 4-symmetry in energy flow between the time-domain and 3-space. This was the solution to the long-vexing source charge (or source dipole) problem in classical and quantum electrodynamics. Reinterpreting the Whittaker 1903 decomposition of the scalar potential reveals the mechanism for this 4-symmetry between time-domain EM longitudinal wave energy flow into a dipole and 3-space EM longitudinal wave energy flow out of the dipole, due to the presence of the proven broken 3-symmetry of the dipole. *EM energy flow is conserved in 4-space, but not in 3-space. Further, the 4-*symmetry energy flow from the source dipole (or source charge) continues as long as the source dipole (or source charge) remains intact so that the broken 3-symmetry remains intact. It is strongly indicated that this asymmetry of the dipole or dipolarity is what Gabriel Kron finally discovercd as his "open path".

back em**f:** The counter-electromotive force, usually between the end charges of the source dipole in the external power source for an electrical circuit (in its overall closed current loop). When the electrons in the circuit are forced against the emf— as when the "spent" or depotentialized charges from the ground reference of the circuit are forced back up through the emf of the source dipole to re-potentialize the charges — then work is done upon the source dipole to scatter its charges and destroy the dipole. Removing the dipole stops its receipt of vacuum energy from the time - domain (which was due to its broken 3-symmetry, now removed). It also stops the former dipole's transduction of that energy, and its former output of 3-space energy flow along the circuit and in space around the circuit. When this flow is occurring, a small component of it strikes the surface charges in the conductors and is diverged into the circuit (by axial precession of the surface charges withdrawing the "immediate stubs" of their fields and potentials into the conductor) to power it as the Poynting energy flow component. The huge remainder of the energy flow in space surrounding the circuit simply misses the circuit and is utterly wasted. Destruction of the source dipole removes the transduction of EM energy from the vacuum. It thus stops the powering of the circuit. So additional energy must then be input to the power source to perform work on its scattered internal charges, force them apart again, and reform and restore that source dipole, in order to resume powering the circuit by energy extracted from the vacuum by the dipole. It is simple to show that such a closed loop circuit uses more of its collected energy from the vacuum to destroy its source dipole, than it uses to power its load. Hence the circuit self-enforces COP<1.0.

back emf (tempic): There are actually two emfs in a circuit, not one. There is a 3-space emf and also an entirely unrecognized *tempic* emf. In either case, under proper circumstances there can be a back-emf of either one or both. See discussions under **electromotive force, back** and under **tempic back emf.** The tempic back emf is very important to COP>1.0 circuits, where the system's output energy density in spacetime is greater than the energy density at the input section of the system. This difference in tempic stress potential provides a tempic force sweeping from system output section back through the system to its input section. The current is a current of Dirac sea holes (negative energy 4-electrons) moving in that local vacuum, from the output section back through the system to the input section. At the input section, this Dirac sea hole current reacts with incoming electrons from the external power system. It therefore "eats" incoming electrons, so that the power supply must now furnish additional electron current to (a) power the negation and "killing" of the Dirac sea hole current by filling those holes with electrons in the input section of the circuit, and (b) simultaneously furnish the additional usual current to power the system's input. The result is that the tempic back emf is nature's mechanism for decaying the excited COP>1.0 energy state represented by a system in overunity functioning condition. Unless this hole current problem is overcome, this decay mechanism will destroy the net overunity, and it will prevent any attempt at close-looping the circuit for self-powering by use of clamped and governed positive energy feedback from output to input. The Bedini method can be used to transform the detrimental Dirac hole current into ordinary electron current, providing the self-powering feedback loop needed. Or, Bearden's outrigger method of using a multi-system set of external COP<1.0 receiving circuits powered by radiation (Poynting EM energy flow) from a single central power source (energy flow radiator) can be used. Then already-positive energy feedback from one or more of the separate outrigger COP<1.0 receiver circuits can be fed back in normal fashion to power the central power unit. Note that the outrigger concept uses the bridging concept, so that an external COP<1.0 system can be powered from a central radiating system, and the external COP<1.0 system can collect and output more energy than is output in the *accounted Poynting component* of the central radiating system. The excess energy radiated comes from the radiated Heaviside component.

bare electron: The true electron without its partial shielding of virtual positrons that are attracted toward it from the active vacuum, and that cluster around the electron, partially shielding its charge as seen by an external observer. The bare electron has infinite energy and infinite charge, as does the shielding cluster of virtual positrons. The difference between these two infinite values of opposite charge is the finite "externally observed" value of the electron charge listed in texts and handbooks. This strange dipolarity of the source charge thus exhibits an asymmetry in its exchange with the active vacuum virtual photon flux. Hence this mechanism also solves the source charge problem — how the charge continuously pours out EM energy in all directions at the speed of light, establishing its fields and their potentials reaching out into or even across the universe, without any input *of observable* EM energy to the source

Barret, Terence W.: Noted modern electrodynamicist and consultant who works in SU(2)xSU(2) gauge symmetry extended electrodynamics, and other models, and was also one of the pioneers of ultrawideband radar, Barret is one of the vigorous modern electrodynamicists continuing to develop and extend the science of electrodynamics and the electrodynamics model itself.

Bed**ini, John:** Noted audio engineer, leading overunity energy researcher, inventor of the Bedini process for creating a true negative resistor inside a battery used as primary power to a circuit, and inventor of the Bedini overunity process for killing the back mmf (magnetomotive force) in a magnetic motor. Bedini is also the inventor of the renowned Bedini amplifiers well known to audiophiles, the BASE process for holographic sound, and a remarkable process for cleaning the harshness from digital audio disks. In addition, he discovered a mechanism for transducing into usable positive energy the detrimental Dirac Sea hole current (negative energy electron flow) backflow in an overunity system, flowing from the output section back through the system to the input section and even on out into the external power supply. The Bedini process transduces this detrimental current into normal electron current, thereby providing most or all of the required input power to the input section. Bearden then explained the technical process for Bedini's discovered transduction procedure, and Bedini and Bearden filed a patent application on this process.

Berry phase: Generalization by Berry of the Aharonov-Bohm effect, for an adiabatic situation. Later Aharonov and Anandan further removed the adiabatic condition and generalized the Berry phase to the geometric phase. See Aharonov-Bohm effect, geometric phase.

blocking: In a Fogal charge-barrier semiconductor, stopping or partially stopping the flow of current in a circuit, or between two points, by *pinning the electrons without stopping the EM energy flow.* In ordinary usage, "stopping the progress of whatever charge flow or current is being referred to.

Bohm, **David J.:** World-renowned physicist and originator of the hidden variable theory and interpretation of quantum mechanics. See David Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of 'Hidden' Variables, I and II," *Physical Review,* 85(2), Jan. 15, 1952, p. 166-179 (Part I); 180-193 (Part II). Together with his student Aharonov, Bohm co-authored a fundamental paper on the Aharonov-Bohm effect wherein interfering electromagnetic potentials can produce effects on charged particle systems, even at a distance and in the absence of the electromagnetic force fields. From Bohm's hidden variable theory, the quantum potential has been highly weaponized by five nations, and these eerie weapons operating instantaneously at a distance through multiply connected spacetime are presently the dominant strategic weapons on earth.

Bohm's hidden-variable theory (HVT) of quantum mechanics: A major interpretation of quantum mechanics, formulated by David Bohm and published in *Physical Review* in 1952. Bohm's theory makes all the correct predictions and also eliminates many problems in quantum mechanics, such as the "measurement problem" and the — now recognized — problem of the missing chaos (i.e., the missing "hidden chaotic order."). Bohm's theory implies that physical reality — or much of it — can in fact be deterministically engineered. A key concept is the use of a *quantum* *potential*, which is multiply connected. Clandestine superweapons using Bohm's quantum potential (QP) have been developed and deployed by several nations. Present mutual assured destruction "standoff between these nations is based on surviving counters to QP weapons rather than surviving nuclear weapons.

Bohren, Craig F.: Distinguished Professor of Meteorology, Pennsylvania State University, noted for work in scattering theory. In an experiment detailed in C. F. Bohren, "How can a particle absorb more than the light incident on it?" *American Journal ofPhysics,* 51(4), Apr. 1983, p. 323-327 Bohren shows that in nonlinear conditions a resonant particle may absorb and output 18 times as much energy as is impinging upon it from the usual field definitions based on a static intercepting charge. The additional energy is "absorbed from the vacuum"; actually, it is absorbed from the nondiverged Heaviside energy flow component accompanying the accounted Poynting input component, but arbitrarily discarded by Lorentz. The resonant particle sweeps out a geometrical interception area (reaction cross section) greater than that of the same charge in a fixed static condition. Hence it intercepts part of the always-available Heaviside "dark energy" flow surrounding the Poynting energy flow component of every field/charge interaction.

Bohren experiment: Revealing experiment by Craig F. Bohren, replicated by Paul and Fischer, which shows that a given charge when in particle resonance absorbs more energy from a field or potential then the same charge does when in "static" position. This experiment is a direct experimental demonstration of the existence of Heaviside's nondiverged energy flow component around every field/charge interaction. See discussion under Bohren, Craig F. The Bohren experiment can be repllicated by any university nonlinear optics laboratory and outputs 18 times as much energy as is input by normal calculations (neglecting the Heaviside nondiverged EM energy flow component of the input).

boson: A particle having integral spin, which obeys Bose-Einstein statistics but not the Pauli exclusion principle. Bosons include the photon, alpha-particle, and any nucleus of even mass number.

bridge: A component or process which passes EM energy between two isolated circuits, but does not pass dq/dt between them, and which breaks the normal rigidly field-locked power dissipations in the two circuits. Space itself would appear to be one such bridge for EM energy flow.

bridging function: The function of passing EM energy flow between two isolated circuits, but not passing dq/dt between them, while simultaneously breaking any normal rigidly field-locked power dissipations in the two circuits. Use of the uncurled A-potential where $\nabla \times \mathbf{A} = \mathbf{0}$ is one available method of bridging otherwise isolated circuits, particularly in the outrigger embodiment of the motionless electromagnetic generator and other COP>1.0 systems.

broken symmetry: Fundamentally, a condition in which two parts of some configuration or shape, on opposite sides of some divisor or condition or boundary, are not similar but differ. In vacuum energy physics, we are very interested in the fact that — because of the broken symmetry of opposite charges — any charge (with its associated clustering virtual charges of opposite sign) and any dipole or dipolarity represents an asymmetry in its fierce energy exchange with the vacuum. This implies that something virtual becomes observable; i.e., part of the virtual EM energy continuously absorbed from the vacuum by the charge or by the dipole is changed into observable form and re-emitted as real, observable EM energy. The remainder is re-radiated as virtual EM energy. The charge's transduction of absorbed virtual photon energy and its re-emission as observable photon energy was proposed by the present author in 2000 as the solution to the long-vexing problem of the source charge and its associated fields and potentials (and their energy) reaching across the universe.

bypass resistor: In electrical theory, a resistor to pass or conduct current around (in parallel to) some other component. If another effect such as use of the overpotential, pumped phase-conjugate reflection, quantum well, quantum tunneling, negative energy, or charge blocking is added, the bypass resistor's function becomes extremely complicated. The bypass resistor may be complex, e.g., or it may be a true negative resistor in some cases.

carrier wave: A fundamental wave that is modulated by another wave or other waves, and hence "carries" the other modulating waveform(s). By stripping off the carrier in a demodulator, the carried waveform(s) emerges.

Casimir **effect:** The attraction of two conducting parallel plates in space, placed very close together, due to their influence on the active vacuum and on the vacuum's interaction with the plates. A part of the vacuum spectrum between the plates is "cut off and blocked or shielded, so that the vacuum potential between the plates is less than the vacuum potential outside them. The resulting potential gradient (force) on each plate from outside pushes the plates together. The Casimir effect unequivocally proves that it is possible to directly engineer the vacuum so as to produce forces and energy and physical effects in material systems. While it is a "small" white crow, it only takes one white crow to prove that not all crows are black. It is sufficient to conclusively prove that EM energy can be extracted from the vacuum. From there to practical EM power systems, fed by vacuum energy, is simply a product of modifying the prevailing electrodynamics and electrical engineering to incorporate the supersystem components and interactions, and then to gradually discover and develop the necessary technology. In this book we attempt to point the way by using the supersystem and providing some of the major necessary principles and concepts.

Casimir, Hendrik Brugt Berhard (1909-2000): Noted scientist who in 1948 correctly predicted that two parallel conducting plates, placed very near each other in a vacuum, would experience an attractive force due to their influence on the electromagnetic vacuum.

causality: The relationship between "cause" and "effect", or the interaction of 4-space cause upon a previous 3-space observation (effect), to produce a new 3-space observation (change in the previous observable or production of an exact 3-space replica). The basic notion in a causal systemis that the system's response to an input signal is dependent only upon past input values, not upon future input values. In a multiply connected space, the causality principle is dramatically changed and requires very careful accounting.

chaos: In dissipative dynamical systems, the dynamical evolution or ordering of the system that is aperiodic and highly dependent upon initial conditions of the system. The trajectories of the system move on a *strange attractor,* which is a fractal subspace of the phase space. The mathematical equations describing chaotic behavior are very nonlinear and so complex that at the present time they cannot be computed or predicted. Control of chaotic oscillations thus is ongoing in its scientific development, with the most advanced control work having been done by Russian scientists, but now openly available.

charge: *Charge* is the ongoing circulation of EM energy flow between the time and 3-space domains, as "seen" by the observer in 3-space. *Negative* charge is (i) the ongoing absorption, by a mass particle, of EM energy input from the time domain (from *ict),* (ii) transduction of the absorbed energy into 3-space EM energy, and (iii) re-emission of the EM energy in all directions in 3-space. *Positive charge* is (i) the ongoing absorption, by a mass particle, of EM energy input from 3-space, (ii) transduction of the absorbed energy into the time domain, and (iii) re-emission of the EM energy in the time domain. Alternately, the positive charge can be considered as (i) the ongoing absorption, by a mass particle, of EM negative energy input from the time domain (from *ict),* (ii) transduction of the absorbed negative energy into 3-space, and (iii) re-emission of the EM negative energy in 3-space. A similar inversion can be utilized to represent negative charge. Time reversal of EM energy can be seen to result from the combined broken symmetries of EM energy flow (in 4-space) between time and 3-space, of two opposite charges and thus of dipolarity itself. See paragraph 3.1 of Chapter 3.

charge, electrical (q).: In the sense of q being charged mass, where the mass m_q of charge q is associated with the phenomenon defined as charge (see above definition). In our view, an electrical charge q associated with a charged particle or mass may be defined as $q \equiv m_q \phi_q$, to first order. This fits the common use of "the charge" as an expression for a charged mass, and explains why a gathering of charges produces a potential ϕ reaching out from the "source gathering of charge q". The actual "charge" action associated with the mass is due totally to ϕ_q, and to the broken symmetry of the ϕ_q dipolarity in the vacuum flux exchange with m_q. The charge q can be further broken down into a set of composite dipoles if the gathering of a screen of virtual charges of opposite sign in the vacuum, surrounding the mass of the "bare charge" inside the gathering, is considered. At first order, ϕ_q can be expressed (from *a particle view)* as a change in the local vacuum virtual photon flux (VPF), due to the VPF exchange between vacuum and m_q. *In a classical approach,* the vacuum may be considered as a giant scalar potential comprised of bidirectional EM wave flows according to Whittaker's 1903 decomposition, except we must re-interpret the phase conjugate half-set of Whittaker's decomposition as incoming from the time domain or complex plane. The charge then may be considered to diverge so much energy flow from the time domain into 3-space "around" the mass, resulting in ϕ_q as the steadily diverged energy surrounding the mass m_q. The ϕ_q component is actually the massless electrical charge and massless of itself. This approach would then yield a definition of massless charge itself, which at present is undefined in physics, as pointed out by Feynman and others.

In the expression $q \equiv m_q \phi_q$, the ϕ_q represents a change to the local vacuum potential ϕ_{vac}. Both ϕ_q and ϕ_{vac} decompose into Whittaker phase conjugate longitudinal EM wavepairs. As can be seen, by altering or engineering these constituent wavepairs, a particular ϕ_q or particular local vacuum potential ϕ_{vac} can be given a deterministic internal structure and dynamics.

Thus the interaction of a given electron or group of electrons may be made **quite** different from the interaction of another electron or group of "apparently identical" electrons. Such structuring dynamics are met with in the internal structuring of water, e.g., where the fierce activity of H-bond making and breaking can be treated as a special ϕ_H and its "internal structure and dynamics" can be engineered. A leading scientist pursuing that type of effect is Jacques Benveniste, in France. Predictably, the o**rthodox** establishment has severely castigated these experiments, defending conventional models as absolute while completely ignoring the experimental results that refute those conventional models as being incomplete.

charge carriers: Anything — usually fundamental particles, ions, etc. — which consists of or contains charges and can be potentialized and move.

charge, magnetic: In the sense of charged mass, a magnetic charge is what is commonly called a "magnetic pole". The mass m of the magnetic charge is associated with the exchange of EM energy between the time domain and the 3-space domain. Essentially, the energy exchange action **known** as "charge" in the massless sense is the magnetic scalar potential, or monopole, when decomposed as per Whittaker and as reinterpreted by the **present** author, and as pointed out in quantum field theory by Mandl and Shaw. Note that our personal view discriminates between *massless charge and charged mass.* Massless charge is an ongoing action and process, involving energy transduction from one form (time energy or 3-space energy) to another (3-space energy or time energy). A charged mass is a **mass** associated with such action. Unfortunately, in the prevailing usage the word "charge" is just loosely used for both senses without discrimination. Hence one must carefully differentiate between the use of "charge" for "charged mass", and its use for an "ongoing process".

charge-parity-time (CPT) theorem: C is *charge conjugation,* which changes the quantum number of every particle into its antiparticle. P is the reflection operation known as *parity,* which turns an object into its mirror image and rotates it 180 degrees about an axis perpendicular to the mirror. T is t*ime reversal.* Any violation of time-reversal symmetry is always accompanied by a violation of CP symmetry (by violating either C or P symmetry) and vice versa.

Electrodynamics and the strong interaction preserve CP symmetry to great accuracy. Weak interactions do not conserve CP symmetry. T symmetry violation has been shown at CERN, the European particle physics laboratory in Geneva, Switzerland.

charge trapping (also "pinning"): Holding charges "pinned" or "trapped" at a site or in a location, by a barrier or force, so that they do not flow as $i = dq/dt$. A clustering of the pinned charges at the pinning site often occurs.

charge-barrier: A process or component or function — particularly in a semiconductor such as the Fogal semiconductor — that blocks the movement of charges q as current dq/dt.

classical electromagnetic theory: The classical theory of electrodynamics, in its modern form begun by Maxwell with his seminal-paper orally presented in 1864 and published in 1865. Today many variations have been made, particularly with respect to the basic group symmetry of the theoretical equations.

Clifford algebra: A special higher topology algebra founded by Clifford, which includes as subsets many other algebras of lower topology.

closed system: In the present approach, a system that in theory does not communicate with its environment, and does not exchange energy or matter between system and environment. Notice that this directly conflicts with the notion in thermodynamics (both classical and disequilibrium) that a closed system is closed only to mass exchange across its boundary, but open to energy exchange across it. General relativity has falsified that notion since 1915. Any system undergoing a change of energy also undergoes a change of mass, since mass is a special form of energy.

An ideal model in which dynamically and energetically the system is considered to be "isolated" as if nothing else existed. In short, the system is considered as if it were in some "magic box" and nothing outside the box can ever enter the box or affect the system inside the box, and nothing in the system can ever leave the box or affect anything outside the box. No electromagnetic system is closed. In short, we have corrected the thermodynamics "closed system" with open energy transfer, to a true closed system with neither energy nor mass transferring. That corresponds to the present thermodynamics notion of the "isolated system".

One performs a non sequitur when proclaiming treatment of any EM system as a "closed system", and of course modern physics substantiates this. The broken symmetry of the opposite charges on the ends of a dipole — and of an observable charge together with its clustered virtual charges of opposite sign — has been proven since 1957. The absence of any closed system is particularly true in electrical power systems. Here one is indeed allowed to input energy into the system to excite or potentialize it. That **of** course assumes that the system was "opened" long enough to take on excess energy (which also changed its mass)! Then as the system operates, losses and dissipations occur, in which case energy is considered to "escape" from the system permanently. In other words, the system was also continually "opened" so that energy could escape. In any EM system, every charge and dipole is already an open system, with free exchange of energy between 3-space and the time domain via that charge. In particle physics, every charge and dipole is a broken symmetry in its virtual particle flux exchange with the active vacuum.

The ancient thermodynamics definition of a "closed system" as one that exchanged heat but not mass, was formulated before thermodynamicists even knew that heat was a form of EM energy, or even knew what energy was. Hence we have changed that definition, since it is a non sequitur in view of modern physics.

There is really no such thing as a truly closed system in the universe, since *every* system is embedded in the active vacuum and is an open system in an energy exchange with the vacuum. Further, any change of energy in the system curves the local spacetime, which in turn interacts back upon the system. If that energetic exchange of the system with its "active vacuum and active curved spacetime environment" is symmetrical, then the system is in equilibrium with respect to its environmental exchange. In that case, for a limited number of purposes the system may be treated as if it were a closed system. In classical electrodynamics, Lorentz regauging of the Maxwell-Heaviside equations further reduced them to describe only Maxwellian systems in equilibrium with the active environment including the active vacuum. Consequently, any *net* interaction between the external vacuum (or the active local curved spacetime) and the system was excluded from the CED model. Obviously a *broken equilibrium* (i.e., broken symmetry) in that actual physical interaction is also not included in the CED model. Nor is it included in the classical (equilibrium) thermodynamics model with its archaic second law.

coefficient of performance (COP): Ratio of the usable energy output of a system divided by that portion of the total energy input that is input by the the operator's or experimenter. The COP is thus a measure of "return for using the operator's or experimenter's input energy" to produce — or direct the production of— useful work by the system". There are other ways to calculate the COP ratio; e.g., the average output power divided by the average operator input power. Contrast COP to the *efficiency* of a system, which is the ratio of the total usable output energy divided by the *total input energy from all sources*, including by the external active environment as well as by the operator. The efficiency of a system means how efficiently it produces useful output from its *total* input. The COP is the performance the system renders for the *operator's* input. Note that even a highly inefficient system — say, with efficiency $\xi = 0.25$ — may nonetheless have a COP>1.0, if the operator himself inputs less energy than the system outputs and the environment inputs all the rest of the output energy as well as all the energy in the system losses. As an example, a common home heat pump may have an efficiency of 40%, but a COP = 4.0. A windmill may have an efficiency of 20%, but a COP = ∞.

Also, for many systems one may evaluate their coefficient of performance for (1) the performance of the system as an energy transducer only, i.e., the ratio of energy the system outputs (whether used or not) divided by the energy the operator inputs; or (2) the performance of the system as a work producer, which is the useful work accomplished by the system divided by the operator's energy input. As an *energy transducer*, every generator and every battery has a COP»1.0, when both the Poynting diverged energy flow output and the Heaviside nondiverged energy flow output are accounted. Yet for useful work, the same system may have COP<1.0, because all the Heaviside nondiverged energy flow component is wasted, and some of the Poynting diverged energy flow component is wasted also.

Analyzed as an energy transducer only, every dipolar power unit — such as a generator or battery — outputs enormously more energy flow rate from its terminals than the mechanical energy rate input to the shaft of the generator, and than the chemical energy dissipated in the battery. So as an energy transducer, every dipolar power source is already a system exhibiting COP»1.0, prior to Lorentz' integration trick to discard the enormous Heaviside nondiverged energy flow output component.

cold fusion: An ad hoc term applied to the transmutations at low spatial energy (but high time-energy) achieved in electrolyte experiments, particularly when using specially prepared palladium electrodes after their loading with positive H+ or D+ ions, and particularly when deuterium is present in the electrolyte and the loading is by D+ ions. The *total* energy of the photon is greater the lower the photon's frequency and therefore the lower the spatial energy of the photon. Hence the cold fusion interactions actually use much higher *total* energy nuclear reactions than does present high (spatial) energy physics. Since "high energy" physics erroneously eliminates consideration of time-energy, the present high energy physics community is unjustifiably hostile to the very notion of cold fusion. The fact that little experiments on the lab bench use far higher total energy than the community's proud large accelerators is a bitter pill many high energy physicists cannot *tolerate*, let alone view with scientific objectivity. So again there is a classic confrontation between science from scientific results and "science as known in the prevailing dogma".

composite dipole: Dipole formed as one part of an isolated, observable "charged particle", consisting of a differential element of that observable charge on one end and a momentary clustering virtual charge of opposite sign. This is one way of dealing with the modern "infinitely strong dual dipoles" view of the charge, where the bare charge in the middle is infinite as is the clustering virtual particle charge surrounding that bare charge and partially shielding it. The difference between these two infinite charges is finite, and is routinely calculated to show that it is the standard value of the charge as seen by an external observer.

Cooper pair: In superconductivity theory, a dynamic, weakly bound pairing of electrons in a superconducting material below its critical temperature. In this pair, if the energy state with wave number sigma and spin 1/2 is occupied by an electron, then so is the state with wave number -sigma and spin -1/2. The Bardeen, Cooper, Schrieffer (BCS) theory uses this concept to provide a detailed microscopic theory of superconductivity.

COP (Coefficient of Performance): See coefficient of performance.

cosmological feedback principle: A self-regenerating cosmological feedback cycle ascribed by Puthoff as the source of the vacuum EM zero-point energy (ZPE). One may assume the existence of EM zero-point energy by fiat as part of the boundary conditions of the universe, or concieive of its generation by the quantum-fluctuation motion of charged particles that constitute matter. Puthoff calculated the latter possibility, assuming that the ZPE spectrum (field distribution) drives particle motion, and that the particle motion in turn generates the ZPE spectrum. This provides a self-regenerating cosmological feedback cycle, which in fact is consistent with the general relativity assumption that curvature of spacetime affects mass energy, and mass energy changes affect the curvature of spacetime. It would be interesting to see if Puthoffs concept can be made compatible with the broken symmetry of a dipolarity and Kron's open path concept.

curl concept of fields: The concept of a field as the curl of a vector potential (the vector potential may not be known). Any field so conceived has a divergence of zero *a priori*. One must be careful, however, because electrodynamics calculates only the field's reaction cross section with an *assumed* fixed unit point static charge at a point in space, leaving the field itself undefined. In short, the calculation of "the field" is actually a representation of the local point intensity of the field's interaction with unit point static charge. It is not the magnitude of the entire field (or potential) itself, *a priori,* but only of its reaction at a point with such a charge. In short, the field's reaction cross section with static charge is often misinterpreted as the magnitude of the field; at best it is an indication of the field intensity to static charge at a point.

curl-free magnetic vector potential: A field-free magnetic vector potential A without curl (swirl), hence lacing the B-field with which an A-potential is usually associated. For simplicity, one may visualize the curl-free A-potential as massless magnetic charge (and energy) in linear motion. Toroids and long solenoids have the characteristic of confining the B-field (curled potential) and holding it inside. However, drawing energy from any potential whose source charge or source dipole is not destroyed simply results in the full value (sum of the A-potential and B-field components) of the potential being replenished from the active vacuum, via the 4-symmetry energy flow mechanism in the presence of the broken 3-symmetry of the dipole. Hence one may easily increase the available potential energy density at will. This is a special form of gauge freedom allowing one to freely alter the potential energy of any electromagnetic system at will. Contrary to the dictates of EM textbooks, gauge freedom rigorously allows the direct and *free* amplification of potential energy of the EM system *at will;* the excess energy being freely furnished from the active vacuum processes. This principle incorporated in gauge field theory, has been known for decades and not previously used in the design, production, and use of COP>1.0 electrical power systems, prior to the invention of the motionless electromagnetic generator (MEG).

curved spacetime: A four-dimensional geometry (spacetime or ST) is used in general relativity, where the ST curvature is determined by the distribution of spatial energy such as mass-energy. In the general relativity view there is no such thing as an "empty" space "filled" with some energy substance. Instead, there is a combined space and time as a single entity, *spacetime,* which is itself energetic and is the very geometry we use in our mathematics. Any change in the local energy density of that spacetime constitutes a *curvature* of spacetime. In the new, more extended approach, any change in the spatial energy density or time-energy density of spacetime, or a combination of changes in both, constitutes a curvature of spacetime. In 4-space modeling, time is treated as a special, highly condensed form of EM energy. Specifically time may be regarded as ordinary 3-spatial EM energy compressed by a factor of c^2 and existing in the time domain rather than in 3-space. Time-energy therefore has essentially the same energy density as mass.

dark energy (negative): (Dirac holes, Dirac hole potentials, Dirac hole currents): A strange form of vacuum energy that creates repulsive gravity, causing the expansion of the universe to speed up (as observed and not otherwise explained by conventional theory). As a strong candidate for the dark energy, the present author has proposed a vacuum negative energy and negative energy currents in a negatively curved spacetime region partially containing excess Dirac sea holes devoid of electrons, along with normal filled Dirac sea holes. These special "Dirac negative action quanta" then form *negative action* (negative angular momentum, or — for simplicity — negative energy) potentials, currents, and fields. This type of vacuum condition containing some empty Dirac sea holes is referred to as a Dirac *-polarized vacuum.* However, it is not just simple static polarization, but possesses rich dynamics. Such dynamic Dirac sea hole regions occur in the vacuum in curved spacetime regions with tempic potential gradients and strong 3-spatial energy gradients, and thus time force existing across the region. The holes occur since the energetic fluctuations of the local vacuum energy can separate a Dirac hole from its occupying electron. These may then recombine, or in sufficient local spacetime curvature can remain apart. The more violent the region, the more severe are local spacetime curvatures in that region, and the greater the fraction of empty Dirac holes that is maintained on the average, in their continual forming and recombining. In those regions, a tempic potential is higher at the higher center magnitude of the spatial energy density. Hence there tempic forces from "inside to outside", providing a "tempic broom" effect to sweep outward the excess Dirac sea holes separated from their electrons in the curved spacetime. The end result is the presence of increasingly unoccupied Dirac sea holes toward the outside of violent regions of spacetime, until the effect is overcome by the decreasing spacetime curvature. These empty Dirac holes in regions and currents are a special form of vacuum negative energy, negative energy fields, and negative energy potentials, creating negative gravity (repulsive gravity) upon ordinary mass exposed to them. So the more distant violent astronomical regions have greater amounts of repulsive gravity being produced by their local Dirac-polarized vacua and negative energy fields and potentials. The result of this effect is that, at sufficient distance from us, the increasingly earlier, more violent events and resulting greater curved spacetime regions have created sufficient Dirac-polarized vacua to overcome the normal gravitational attraction between galaxies, etc. Even farther out, the increase in Dirac-polarized vacua overrides the normal attractive gravity between galaxies, etc. and produces net repulsive gravity. In turn this results in acceleration of the observed distant expansion of the universe. Dirac-polarized vacuum and its special dynamics can be accommodated in Sachs' unified field theory, which unites physics from quarks to the cosmos. See also **Dirac** sea **holes.**

On the laboratory bench, Dirac hole currents and effects are met with in a circuit or system producing COP>1.0, or very sharp 3-spatial gradients such as in violent electrical discharges. The effects become non-negligible at about COP = 2.0 and sometimes less. The tempic force back across the, system from output to input is sweeping the Dirac holes through the system. This can play havoc with attempts to close-loop the circuit for self-operation. In semiconductor components, strange effects are met due to their use of donor and acceptor materials, and temporary or permanent failure of semiconductors can result. The simple way to visualize this is that, in the system's supersystem, the spacetime component is curved and the vacuum component is highly nonlinear. All three components — overunity system, local nonlinear and polarized vacuum, and local curved spacetime — are interacting vigorously with each other. An operating overunity system represents an excited state of that local region of vacuum and curved spacetime, hidden in the euphemism "polarized" which is inadequate to describe the dynamics. With the dynamics, one may visualize that the Dirac sea hole currents are swept back through the system, seeking to recombine with electrons to eliminate the "polarization" and its dynamics, thus decaying the excited state back to equilibrium and destroying the overunity condition. In a robust system whose internal parts do not appreciably interact with these Dirac hold dynamics, the dynamics will reach the input section and extend back into or toward the primary power supply. In the input section, the feeder line, and in the power source itself, this results in "eating electrons". The Dirac sea effects thus act as a separate load imposed within and around the system input section or even back in the feeder line to the external power supply, in addition to the system load itself in the system output section. Simply put, the power supply must now furnish extra electrons to "power" the Dirac sea hole recombinations first, and additional electrons to power the system in its "normal" fashion. The result is to "draw additional power" from the source, where "drawing power" now includes the additional "eating of electrons" within the power supply itself, the feeder line, and the input section of the system.

Bedini and Bearden have filed a patent application on processes to convert the detrimental Dirac sea hole current reaching the system's input section.

transforming it into ordinary electron current. Magnetic Energy Ltd. has developed two other processes that handle the Dirac sea hole current problem, allowing close-looping for self-power ng operation. One of these proc**esses** converts negative energy into positive energy and the other avoids the negative energy problem. The first one allows this otherwise devastating special form of "negative feedback" or "degenerative feedback" to be converted into "positive feedback" or "regenerative fee**dback",** allowing the system to be close-looped successfully for self-powering. Bearden has proposed yet a different approach using an "anti-circuit" method, but at this writing the method is still proprietary until intellectual property rights are secured.

dark energy (positive): Our term for the vast Heaviside nondiverged energy flow component surrounding every field/charge and potential/charge reaction but unaccounted in present electromagnetic theory after being arbitrarily discarded by Lorentz circa the 1890s. Present theory only accounts for that small amount of energy flow (the Poynting com**ponent)** diverted locally around the interacting charge. All the rest of the energy flow comprising the field or potential, and missing the interc**epting** point charge, was discarded arbitrarily by Lorentz and is still discarded today, using Lorentz's integration trick. In honor of Heaviside, who **did** recognize the gravitational implications of his dark energy flow component, the present author has nominated this vast, unaccounted "dark energy" component as being responsible for the extra gravity holding the spiral arms of the spiral galaxies together. See **spiral** galaxy.

So one must recognize that the term "dark energy" is indefinite, since there are two kinds: (a) dark positive energy, and (b) dark negative energy. Dark positive energy consists of "normal" energy as often connected with particles, collected upon them and affecting their momenta, etc. It has dynamics and effects consistent with that kind of energy. Dark negative energy is a condition of the vacuum itself. It represents a sort of "empty container and empty container dynamics" (negative energy dynamics) in the vacuum itself, which "eats positive energy", so to speak. In **philosophical** terms, dark positive energy represents unaccounted actions and effects from unaccounted "extra presence of real substance and things and actions". Dark negative energy represents unaccounted actions and effects fr**om** "extra absence of real substance and things and actions beyond zero". Dark negative energy exhibits precisely appositive effects to the e**ffects** produced by dark positive energy. E g., dark energy creates the excess gra*vity* that is holding the arms of the spiral galaxies together. Negative energy resulting from spacetime curvature conditions in highly energetic astronomical phenomena produces the *antigravity* that is responsible for the acceleration of the expansion of the universe. We have nominated the negative energy Dirac sea hole phenomena as the cause of the antigravity that accelerates the expanding universe. Interestingly, these negative energy phenomena present in sharp discharge (strong gradient) phenomena appear to be responsible for the fact that such phenomena are known to violate present thermodynamics, and are being studied under the aegis of "extended thermodynamics". See discussion of areas violating thermodynamics in the last chapter of Kondepudi and Prigogine, *Modern Thermodynamics: From Heat Engines to Dissipative Structures,* Wiley, New York, 1998, reprinted with corrections in 1999. A reference is D. Jou, *Extended Irreversible Thermodynamics,* Springer-Verlag, New York, 1996.

degenerate semiconductor: A semiconductor whose conductivity approaches that of a metal.

demodulation: From a carrier containing a modulated signal, recovering the signal that was used to modulate it.

deterministic pattern or "template": The exact arrangement, by plan and deterministic action, of a group of entities. The deterministic actions and their "controlling forces" are simply called "dynamics", "structuring", etc. An example might be deterministic field structuring and actions of photons in a "herd" or "group". Or of a set of spacetime curvatures, into a dynamic structure called a *spacetime curvature engine* — or *engine* for short, so long as the meaning is clear. Or by hidden order in the virtual photons in the vacuum flux, or a deterministic set of changes to that vacuum flux (the vacuum flux that is called the "vacuum potential." We have called this *internal EM dynamics* function — of deterministically patterning or templating the virtual flux (particle view) of the potential, or of deterministically patterning or templating the longitudinal and time-polarized EM wave decomposition (wave view) of the potential - *dimensioning* the potential. See **dimensioning.** We refer to the deterministic structure and its structural dynamics as the "engine template".

dielectric: Literally, "against electric (current)", originally coined to mean "opposes the flow or conduction of electric fluid". In today's language, a dielectric is a non-conducting material used to oppose or prevent the flow of electric charges. Even empty vacuum exhibits some dielectric resistance. "Dielectric" is also used to refer to a nonconducting material (often between the metal plates of a capacitor or elsewhere) that can (i) sustain a change in potential across a distance (i.e., an E-field), and (ii) serve as an insulator. Space itself is a dielectric, or at least is said to exhibit certain dielectric qualities.

dimension: A certain primary geometrical physical attribute, such as length, used to describe the separational relationships of physical phenomena. Actually, "dimension" just means "fundamental quantity of separation" and "geometry" in the most general sense. Dimensions thus become a sort of set of fundamental variables describing the *extensivity* of system and the dynamics of that extensivity. The number of dimensions taken in advanced physics usually represents a somewhat arbitrary choice for good modeling fit. In modern Kaluza-Klein theory, for example, it becomes necessary to accept some 10 or 11 dimensions in the usual particle physics case. Sometimes more than 20, or even an infinite number, of dimensions may be used. General relativity (GR) has incorporated the interaction of the abstract geometry (spacetime) with mass, so that *geometry is a real, active, dynamic entity.* Until Sachs' extension of Einstein's work into a unified field theory and Evans' incorporation of O(3) electrodynamics as an important subset of Sachs' unified theory, GR has largely remained a nonexperimental discipline, at least in the laboratory. With the new Sachs-Evans approach and with recovery of (a) the Heaviside dark energy flow component (b) overunity EM systems arbitratily discarded by Lorentz symmetrical regauging, and (c) modeling of the complete supersystem including system, vacuum, and spacetime in mutual interaction, GR suddenly becomes substantially engineerable by novel electromagnetic means, both in the laboratory and in operating devices. We are thus entering a great new age of electrogravitation and a new physics. Research in antigravity lifters, COP>1.0 electrical power systems, medical therapy utilizing engines and anti-engines, and cold fusion are the elements of the new science that are struggling to be born and funded.

dimensi**oning:** Coined term meaning "forming an exact pattern or template of structures", particularly of nested curvatures of spacetime, where the pattern/template may also be dynamic, to include patterning and dynamics in the time-energy domain as well as the 3-space energy domain. It involves the internal structuring of the "dimensioned" entity. The term "dimensioning" makes sense in unified field theory, but is awkward in normal EM theory, which erroneously assumes that EM energy propagates in an uncurved spacetime. The mere presence of a change in local spatial energy, created by the wave energy itself when present in that local region, curves the local spacetime. Note that the background potential may be changed in a steady state level as well, which means that the frame of the system and its field dynamics has been rotated away from the laboratory frame. A time-polarized EM wave, e.g., changes the time-energy density and also curves local spacetime very powerfully. Hence the EM wave rigorously travels in curved spacetime, and in fact identically is a propagating, oscillating curvature of spacetime. What is missing from present physics is all accounting of the extraordinary Heaviside nondiverged energy flow component accompanying the accounted Poynting diverged energy flow component. Thus present physics *does not properly account for* the gravitational aspects of "electrodynamic field and potential energy in space".

Dimensioning also implies a deliberate form or structure (with dynamics) created in the virtual photon flux of the vacuum, in the virtual photon flux comprising a scalar potential, or in the infolded longitudinal-wave EM inside all EM potentials, fields, and waves. It implies an associated set of spacetime curvatures and their dynamics. The latter are referred to as "engines", "vacuum engines", "spacetime curvature engines", etc.

Dimensioning the potentials or signals or carrier waves of conventional electrodynamics involves adding hidden *vacuum engines* to them. The term *dimensioning* is descriptive and was chosen because adding such templates is equivalent to increasing the EM topology by adding mathematical dimensions. Since an EM wave or field or vector potential can be decomposed into two scalar potentials, then "dimensioning" one or both of the scalar potentials can "infold" the desired hidden structures or patterns (vacuum engines) inside an EM carrier wave, EM field, or vector potential created by the interference of the two dimensioned base potentials. This is referred to as *dimensioning* those EM field and wave entities. Internally structuring the two scalar potentials via arrays of longitudinal EM wave emitters and applying the necessary dynamics (modulations), is the primary manner to directly engineer dimensioning. When dimensioning is present, two EM waves that appear identical as seen on the oscilloscope may have dramatically differing internal structures (dimensioning). Hence they may produce drastically differing effects when they interact with the same or similar objects. *The only way in which the action of a vacuum engine can be resisted is to create and simultaneously introduce the exact antiengine for it — a special sort of forcible symmetrical regauging, so to speak.* Once the action has been completed in the receiving object and it has been physically changed, the only way it usually can be undone is to form a precise antiengine for that action, amplify the antiengine, and let the antiengine act upon the object for a sufficient time to "time-reverse it back to its previous physical state and condition". The concept has great utility in electromagnetic healing, not discussed in this book. We point out that the decades-long induction of diseases, health changes, etc. in U.S. personnel in the U.S. Embassy in Moscow occurred in forcefield-free regions. In short, the changes occurred in regions where the potentials were stable and unchanging, and so their engines were stable and constantly applied to the exposed personnel. The Soviets were simply radiating a high level target, the U.S. Ambassador and his staff, to guarantee high-level U.S. attention. By U.S. reaction to the deliberate electromagnetic "engine" induction of disease and health changes (three Ambassadors sickened and later died), the Soviets could positively ascertain whether we knew of the "infolding" or "dimensioning" technology, and whether we had developed defenses.

dipole: In the simplest case, two separated charges of usually equal magnitude and of opposite sign. More generally, a localized positive charge or charge distribution, and a localized negative charge or charge distribution, such that the net charge summation is zero, while the positive and negative charge distributions do not precisely superpose point to point but only on the average. We point out, however, that in regular physics electrical *charge* has no proper definition. As is well known in particle physics.due to the opposite charges on its end a dipole is a broken symmctry in the virtual photon flux of the vacuum. By definition of broken symmetry, this means that *some* of the virtual energy flux continuously absorbed from the seething vacuum by the charges of the dipole is not re-radiated as *virtual* energy. Instead, it is integrated *coherently* and re-radiated in 3-space as real emitted EM energy, establishing the fields and potentials associated with that source charge or source dipole. The dipole is therefore the most fundamental true "negative resistor" since it freely and continuously receives EM energy in unusable form, transduces it into usable form, and re-emits it in usable EM form.

It follows that any positive charge in the universe and any negative charge in the universe form a dipole and a broken symmetry in the vacuum flux. Hence every such dipolarity in the universe already extracts energy from the vacuum and puts it out in 3-space, or absorbs energy from 3-space and returns it to the vacuum. Kron called this an "open path" electrically, well before broken symmetry was formally discovered and experimentally prove in l957. Kron was also able to use the open path in and around special electromagnetic circuits to cause the circuits to become true negative resistors, freely powering the network analyzer at Stanford Universoty even in the 1930s.

In classical EM theory, the problem of how every charge and dipole can continuously emit EM energy to form all the associated fields and potentials and their energy has been an unsolved problem — sometimes called the most difficult problem in electrodynamics, both classical and quantal. For the solution and a discussion, see the present author's paper "Giant Negentropy from the Common Dipole," *Journal of New Energy,* 5(1), Summer 2000, p. 11-23. Symmetry represents a conservation law, and broken symmetry represents violation of that conservation law. Because of the broken 3-symmetry of the dipole, the EM energy flow is not conserved in three dimensions — in this case, violation of conservation of 3-space EM energy flow is not conserved. Neither is the time EM energy flow conserved in the 4th dimension. Instead, EM energy flow is conserved in 4-dimensions, between the inflow in the time-domain and the outflow in 3-space in all directions, or vice versa. The hidden inflow of EM energy to the dipole (and to a charge) is actually from the complex plane (time domain). Thus all EM energy in 3-space is actually received by the source charge or source dipole from the time-domain, and returned to the time domain. What we call "propagation of EM energy through 3-space" is actually the spreading of this 4-circulation to successive 3-space points. The importance of the internal structuring of time-flow and of longitudinal EM waves in the time domain (dimensioning in the time-domain) is apparent, since it produces very powerful engines that can act upon matter in any fashion desired. Indeed, the Russians have developed clandestine robot engine systems comprised of sets of spacetime curvatures and their dynamics (which are just sets of longitudinal EM waves and their dynamics). Any function of a weapon system — sensing, weapons (using scalar interferometry), communications, propagation, etc. — can be incorporated. The capabilities of such systems, such as travel through continuously emitted EM signal beams from satellites, communications stations, power lines, etc., is eerie. Such a system can reside in any convenient EM potential or field as a "dimensioning" of the potential or field. Such robot engine systems have been clandestinely tested, but discussion of them is beyond the scope of this book. Suffice it to say that these systems are ushering in a dramatic revolution in future warfare, and the present research in physical nanobots is already decades behind.

Very powerful support for the author's solution of the source-charge problem is given by F. Mandl and G. Shaw, *Quantum Field Theory,* Wiley, 1984, Revised edition 1993, under the heading "Covariant Quantization of the Photon Propagator" in Chapter 5. In their deeper coverage of the photon polarizations, Mandl and Shaw point out that the longitudinal and scalar polarizations are not directly observable, but only in combination, where they manifest as the "instantaneous" Coulomb (i.e., electrostatic) potential.

Translated from particle terminology to wave terminology, Mandl's and Shaw's argument directly fits my re-interpretation of Whittaker's 1903 decomposition of the scalar potential.

Dirac, Paul A. M.: Noted English physicist, 1902-1984, who shared the Nobel Prize for developing wave mechanics and predicting the existence of the positron. He also originated the notion of "holes" or negative energy s**tates** in the vacuum, where the holes are ordinarily filled with electrons. The "vacuum replete with these Dirac structures" (all filled with electrons) is referred to as the *Dirac Sea.* If some of the holes are empty, then that is **the** Dirac sea of a curved spacetime. We strongly stress that a Dirac sea **hole** (negative energy electron with negative charge, negative energy EM fields and potentials, and with negative mass-energy) prior to observation (prior to its reaction with mass) is a quite different entity from the positron (after reaction with mass, so that the positron has positive mass-energy, **positive** charge, positive energy EM fields and potentials, and has been reversed in its 3-space propagation direction). Specifically, the Dirac sea **hole** produces negative energy fields and potentials, whose powerful Heaviside nondiverged components enable to perform practical antigravity. The (observed) positron produces gravity, not antigravity, and also positive energy fields and potentials.

Dirac sea: A concept and description (modeling) of the vacuum as containing — amongst other things — a "sea" of an infinite set of negative energy slates ("holes") for electrons, almost all of which are usually filled with electrons in the absence of any spacetime curvature of significance. In Dirac electron theory, the relativistic wave equation for the electron has four components, which correspond to two spin orientations and two energy conditions: positive and negative. Ordinary electrons are in the positive energy condition. So then the vacuum must also possess a "sea" of negative electron energy conditions. These negative conditions are called "holes" and are ordinarily filled or mostly filled with electrons which have fallen into these negative energy states. The Dirac sea is this vacuum sea of negative energy electrons (and a perhaps a few empty holes). In forward time, if energy is added to a negative energy electron, electrons can be **lifted** from this sea, since the added energy creates a local curvature of spacetime. If spacetime is locally curved, additional holes may be created so that, when the holes meet normal positive energy electrons, the electrons fall in and disappear, creating the appearance of an "electrical energy sink." This can happen so that the local ST curvature merely relaxes back to an uncurved spacetime, therefore avoiding radiation from "pair annihilation". If the curvature is in the opposite direction (i.e., if positive energy is added to the vacuum), electrons may be lifted from the Dirac sea by the resulting spacetime curvature energy, thus producing a flow of electrons "right out of the nonlinear vacuum" and generated by the spacetime curvature, and creating the appearance of an "electrical energy source" from the vacuum itself. In that case the energetic holes left behind also remain, and are affected by all EM fields etc. These holes thus form negative energy currents, fields, potentials, waves, and other electromagnetic entities such as negative energy charging and discharging (excitation and de-excitation).

In an overunity EM system, there is a higher energy density in the output section than in the input section. This includes time-energy density. So a higher tempic potential exists at the output than at the input. A gradient in the tempic potential thus exists, which constitutes a tempic force from the output section back through the system to its input section, and even on back through the conductors to the external power source, and even back into the distant external power source itself. Thus the power source has to furnish additional electron current. It must "power the holes", so to speak, by furnishing the electrons that are "eaten" by the Dirac hole current to eliminate it, which represents a novel kind of load in the input section of the system. So the power supply must furnish more power, so as to furnish the normal power to power the system, and the extra power to "power the elimination of the Dirac sea hole current as a back-reflected load". This is nature's way of decaying the excited state represented by COP>1.0, and restoring equilibrium and COP<1.0. By the Bedini process, the otherwise detrimental Dirac sea hole current reaching the input section is transformed into ordinary electron current, thus serving as input power to the system. By adjusting the system and optimizing it, this strange kind of "positive power input from converted Dirac hole current negative power feedback" can be adjusted to equal the input power required by the system. At that point the external power system can be disconnected, and the unit continues in close-looped and self-powering operation, including powering its load as well. Gabriel Kron succinctly described this condition and adjusting for it. Such a system allows energy to be continuously extracted from the vacuum, and a load to be powered continuously, with all the energy to run the extracting system being freely received from the active vacuum.

Dirac sea hole: A negative energy state for an electron, in the Dirac theory (in the Dirac sea). Literally the hole (negative energy state) when not occupied by the electron. In flat spacetime, almost all Dirac sea holes are filled with electrons. A small fraction on the average are not filled due to the local fluctuations of the vacuum energy continually lifting electrons from their holes and then having them recombine, usually so quickly that no radiation occurs in the observable state. The situation in the virtual state can be described by Feynman diagrams. This received view can be falsified in a curved spacetime. There the holes can exist and flow as currents, as validly as positive energy electrons can flow as currents, without the incessant "filling" activity of the vacuum itself. In addition, in such a hole-stabilizing curved spacetime region, the hole can "eat" or recombine with a real electron, so that the electron vanishes but without radiation. If we wish to join the two views, then we take Feynman's and Wheeler's view that the field does not exist in vacuum as such, but only the potential for it exists — in short, only the engine exists. The engine can then be said to be an ordering (chaotic self-ordering) condition present on the statistical random variation of the fluctuations of the vacuum. With longitudinal EM wave technology, this "order in the midst of disorder" — this templating and engine technology — can be directly engineered.

Dirac sea hole current (positron current): Just as a current of positive energy electrons can be generated, a current of negative energy Dirac sea holes can also be generated if the local spacetime is properly curved. Mathematically these are usually considered to be "positron currents", except they have no positive mass, because a hole will "eat" an electron. In an overunity electrical power system, the tempic potential is greater at the output of the system than is the tempic potential at the input section. There thus exists a "tempic force" or "tempic broom" sweeping Dirac sea hole current (positron current) out of the input section of the system into the external power supply. Simple instruments will record this current as if it were electron current being furnished from the external power supply to the system. Also, the Dirac sea positron current will "charge" the battery with Dirac sea holes (mathematical positrons), which in the conventional sense discharges the battery. A battery may become highly charged with Dirac sea holes. If so, then when placed on a normal battery charger, the electrons in the charging current will be "eaten" for an extended period by falling into the Dirac sea holes, and the battery will not acquire any charge until they are filled — whereupon the battery will sudden begin charging up normally again.

We also point out that the vacuum, containing the Dirac sea, actually is not "massless" at all, but has zero resultant mass on the average, as a result of the simultaneously presence of positive and negative mass in average equal abundance. Any curvature of spacetime must violate this "net sum zero" mass, hence produces inertia in all masses. Note that a negative mass can also exhibit a negative inertia; i.e., it accelerates and enhances the action of any force acting upon it, instead of opposing it. In short, negative mass exhibits negative inertia. We suggest that this effect is probably involved in the more violent explosive phenomena of astrophysics.

disequilibrium: Broken equilibrium, which in turn involves breaking appropriate conservation laws unless compensated.

displacement current: The apparent continuation of a conduction current through a region of space without a conductor, e.g., between the plates of a capacitor. Rather than being the motion of charges in a conductor, the displacement current is related to the rate of change of an E-field, and thus to the rate of change of the strain of the dielectric.

dissipative structure: In open systems far from thermodynamic equilibrium, a region of self-ordered behavior of a special kind in matter, characterized by symmetry-breaking, multiple choices, and correlations of macroscopic range. By correlations we mean statistically reproducible relations between distant parts of the system. Formation of a dissipative structure represents the birth of complexity in that region by self-organization. Usually a dissipative structure emerges only after the driving constraints reach a critical value. As the embryonic "engine" technology advances, however, the direct engineering and control of dissipative structures will become commonplace and routine.

distortion correction theorem: "If a scalar wave $E_1(r)$ propagates from left to right through an arbitrary but lossless dielectric medium, and if we generate in some region of space [say near $z = 0$] its phase conjugate replica $E_2(r)$, then E_2 will propagate backward from right to left through the dielectric medium, remaining everywhere the phase conjugate of E_1." Quoted from Amnon Yariv, *Optical Electronics*, 3rd Edn., Holt, Rinehart and Winston, New York, 1985, p. 500-501.

What is missing from the distortion correction theorem is hidden in the phrase *"if we generate in some region of space ... its phase conjugate replica. "*. Since electrodynamicists and optical physicists have been unaware that all EM energy at any point in space comes from the time domain to that point, then —*prior to detection by interaction with charge* — the actual phase conjugate wave exists in the imaginary plane (in the time domain) and *not* in 3-space. The continuous interaction of that imaginary plane wave with charges, to actually produce the force-field wave in space, is *assumed* in the standard nonlinear optics. In short, one is looking at the "effect" wave, not the "cause" wave. However, since time is not an observable even in theory, it is this "effect" wave in 3-space that will indeed be measured by our instruments, because they must interact the imaginary or phase conjugate field with charge in order to detect or observe it (measure it).

The proof of this is experimentally already known but not recognized. If one reflects an EM wave off a normal mirror, the mirror must absorb the incoming wave, which transfers the wave momentum to the mirror to repel it, then the mirror must re-emit it, which adds that much more momentum to the recoil. So the mirror recoils with twice the momentum of the reflected wave. That produces a wave going in the other direction. If the incoming wave is continuous, one then has "paired" waves going in **opposite** directions). However, if an incoming wave strikes a phase *conjugate* mirror (PCM) material and is phase conjugated, a wave going in the opposite direction also emerges, but it synchronizes point by point with every spatial point occupied by the incoming wave. Also, *the phase conjugate mirror does not recoil at all.* This is well known in phase conjugate optics. It clearly shows that the origin of the "detected" phase conjugate wave is quite different from that of a normal reflected wave. Indeed, by our reinterpretation of Whittaker's 1903 biwave decomposition of the scalar potential, at every point along the detected phase conjugate wave, the energy enters that point from the time domain, and not from some sort of reflection from the PCM. The energy also returns to the time domain from that point. Its presence at the point produces a separation of virtual point charges, or the well-known polarization of the vacuum. So the flow of energy is from the time domain to the negative charge of the point dipole, thence to the positive charge of the dipole or others immediately surrounding it, thence back to the time domain. That is the operation in a "time-forward" sense to the external observer. In a "time-reversed" situation, the 4-circulation appears in the opposite direction. We propose that this fundamental 4-circulation is responsible for and constitutes spin itself. The direction of flow determines the 'polarity of the charge" we obseve. In this view, the point dipolarity in the virtual state with its ongoing 4-circulation can be taken as the very definition of energy itself.

Druge, Paul: Important German physicist, 1863-1906, who formulated the theory of the free electron gas inside conductors, using it to formulate a theory of metallic resistance.

Drude electron gas: The electrons that have broken loose from their orbital bonds in atoms in a conductor, and are thus free to "wander around" and "migrate" — or flow as current when exposed to an emf. Also called just the "electron gas". Note that, in the metal lattice of the conductors, each position vacated by a Drude electron is a "hole" or positively charged little region. Not only do electron currents exist as net negative charge migration in conductors and materials, but also hole currents exist as net positive charge migration from atom to atom, or a sort of "ionization migration flow". Electrons are continually recombining with these "ion holes", however, to reduce the hole current. These considerations are particularly significant in semiconductor materials.

duality principle: In quantum mechanics, the principle that photons and other particles propagate like waves and interact like particles, so that their description as only waves or only particles is inadequate.

Edison, Thomas Alva: Noted American inventor, 1847-1900, whose staggering portfolio of inventions included the storage battery, electric light bulb, phonograph, motion pictures, carbon microphone, and many others. Edison actually ran multiple "patenting research" laboratories as discovery and patent generating facilities. Not only was he an inventor himself, but he also employed a very good staff of researchers for invention and discovery.

E-field (electric field): The electric field intensity E; that field on an electric charge (charged mass) which produces an electrical force resulting in a linear motion of the charge. In reality, this electric field *as usually defined* does not and cannot exist in empty space devoid of charge, but only in and on charged matter, since mass is a component of force by $\mathbf{F} \equiv \partial/\partial t(m\mathbf{v})$. More specifically, the E-field is the local intensity of the field at a point, in its interaction with a unit point static charge fixed at the point. Even more specifically, it is the output of an observation/detection operation, which is a *d/dt* operator imposed on the 4-space causal field interaction with the 3-space charge, resulting in a frozen 3-space "slice" or snapshot of the deviation of energy *from* the field, forced to flow around that intercepting charge, at that single instant. In short, the E-field as a force field is an *effect* and not a *cause.*

The greatest error in all electrodynamics is to then assign this same *frozen effect force field intensity snapshot* — or an implicitly assumed iterative sequence of such snapshots — as the dynamic and nonfrozen *causative field itself in* 4-space, prior to the field's interaction with charged matter. This is the substitution of effect for cause, a grave non sequitur.

When EM theory was founded, the founders believed there was no single **point** in the entire universe where mass was absent; instead, a thin material "luminiferous ether" was considered to fill all space. Time was considered immutable, and there was no concept of a dynamic *spacetime.* Hence at each point in such a material ether, the reaction with charged matter (etheric matter) was thought to universally exist. Hence the field was indeed a very material entity, in their concept!

With the destruction of the material ether notion in the 1880s, not a single Maxwell-Heaviside equation was changed to eliminate its implicit assumption of the material ether. Hence this enormous error of confusing the *effect* field with the *causal* field (prior to observation-detection-interaction) is ubiquitous in electrodynamics and therefore in physics itself. The two fields (causal and effect) do not even have the same dimensionality; one is dynamic in 4-space while one is frozen in a 3-space snapshot. This has led to the false notion that an EM force field wave "movesthrough" 3-space, which does not happen at all. What really happens is that, if we assume a continual iterative *d/dt* observation operator, we have a continual series of such frozen 3-space snapshots, like the frames of a motion picture film. But none of those snapshots have any inherent motion at all. For a statement of the falsity of the conventional illustration of the "EM wave in space as an orthogonal pair of oscillating E and H fields in a transverse plane", see Robert H. Romer, "Heat is not a noun." *American Journal of Physics,* 69(2), Feb. 2001, p. 109. In endnote 24. **p** 109, AJP editor Romer takes to task *"...that dreadful diagram purporting to show the electric and magnetic fields of a plane wave, as a function of position (and/or time?) that besmirch the pages of almost every introductory book. ...it is a horrible diagram. 'Misleading' would be too kind a word; 'wrong' is more accurate. " "...perhaps then, for historical interest, [we should] find out how that diagram came to contaminate our literature in the first place.* "Also see charge.

E-field, **motional:** In classical EM theory, the electric field produced by moving a conductor in a magnetic field. Often called *motional inductance* of the field. In the conventional theory, motional inductance is deemed to be identical to the inductance caused by a time rate of change of the magnetic field, experienced by the moving conductor. Or vice versa, experienced by a stationary conductor in a moving magnetic field.

E-field, static: In conventional theory, the electric field in the space surrounding a static charged particle, induced by the presence and action of the charged particle. There is no notion as to the *causative mechanism for this static* field of and from a charge, which implicitly is assumed to just continuously create and pour out EM energy in all directions, thus grossly violating energy conservation. Consideration of this anomaly leads to what has been called the most pressing problem in both quantal and classical electrodynamics: the question of the formation of the fields and potentials associated with the "source charge". Either the charge totally destroys the conservation of energy law itself, or there must be a *virtual* (nonobservable) energy input to the charge, since instruments establish that no observable EM energy is input to it.

For a solution to this problem, see the present author's "Giant Negentropy from the Common Dipole," *Journal ofNew Energy,* 5(1), Summer 2000, p. 11-23. We later found our solution to be consistent with quantum field theory and with a slight reinterpretation of Whittaker' s 1903 decomposition of the scalar potential.

Ehrenhaft, Felix: Scientist who performed numerous experiments believed to demonstrate fractional charges. We point out that classical electrodynamics assumes a local flat spacetime, a notion long falsified by general relativity, since 1915. In a local curvature of spacetime, the dynamics of the charge (modern view as the finite difference between two local infinite charges forming a dipolarity) can change the observed value of the net finite charge. So finite fractional charges, or even supercharges, are quite possible.

Einstein, Albert: German (Jewish) physicist, 1879-1955, who emigrated to the U.S. and formed special and general relativity theory, discovered and formed the theory of Brownian motion, recommended the development of the atomic bomb to President Roosevelt, and profoundly affected the course of science and the modern world,

Einstein, Podolsky, and Rosen (EPR) paradox: Thought experiment in 1935 for measuring two correlated photons separated and at distant locations, protesting that quantum mechanics requires that the particles communicate instantly, which is a "spooky action-at-a distance" (Einstein's phrase). The experiment eventually was performed and it works, just as required by quantum mechanics. The paradox inspired the development of hidden-variable theories.

Einstein's general theory of relativity: Mathematical theory of gravitation in which the gravitational force is mathematically described by a curvature in spacetime. In other words, the geometry and its dynamics have become physical agents, doing away with the old notion of the agent being something separate that is occupying inert spacetime. It is important to note that, in general relativity, mass-energy acts on spacetime to curve it, and the curvature of spacetime acts back on mass-energy to translate or change it. What seems missing from GR — at least in its practice — is the reaction of time-energy upon the geometry to curve it, and that corresponding reaction of the spacetime curvature back upon time and time-energy to change it.

Further, we consider that an exact pattern (template) of curvatures of spacetime and their dynamics exists and is back-acting upon every mass system and its dynamics. This is the *engine* concept. The most general way to engineer matter is not by brute force translation forces, but by forming spacetime engines. Once formed, these engines act upon the interior of any mass placed in the engine region, to eliminate the deltas existing in that muss's resident engine and the impressed engine. *The forces arise from the local spacetime itself, as curvatures in that local spacetime, so the action is from "inside" to "outside" an object, starting and continuing from every point in the object.* The curvatures of spacetime itself furnish the energy for the continuing actions upon the interior of the mass, once we have paid to form the engine. The mass can be acted upon at any level, from its gluons and quarks to its nuclei, to its atoms, its lattice forces and binding energy, etc. Significantly, the Sachs unified field theory applies to physical reality from beneath the quarks and gluons to the entire universe itself, and folds in quantum mechanics, electrodynamics, and general relativity into a single unified field theory that is (in theory) engineerable by higher symmetry electrodynamics means such as Evans' O(3) electrodynamics.

Einstein's postulates: (1) All the laws of physics are equally valid in all inertial frames of reference, (2) the speed of light is the same to every inertial observer, and (3) the observable local effects of a gravitational field are indistinguishable from those arising from acceleration of the frame of reference.

The first is called the special relativity principle, the second is called the law of light propagation, and the third is called the equivalence principle. It is now known that postulates (1) and (2) are not independent of each other. Note that the third postulate implies that any local force is due to a "gravitational field" (acceleration of the frame of reference). It also implies that gravitational force has a mechanism, since quantum mechanics assigns a differential operator, operating upon a potential, to create every force. By extended inference, it can be seen that the third postulate also implies that there should exist a method to turn any type of force (field) into gravitational force (field).

Note that postulate 1 may be violated if two frames remain inertial but each local spacetime contains different hidden engines. So the laws of interaction physics may indeed vary for the same object placed in first one of the frames and then in the second. Engines are ongoing general relativity actions, even in inertial frames. The action may not be translation of the bulk object, but extensive changes to the interior of the object and its interior dynamics at any and all levels.

The Russian physicist Sakharov has strongly postulated that gravitation is not even a fundamental field of physics, of the kind used by Maxwell in his electrodynamics. Instead, in this view G-field is always comprised of, and made from, other fields and interactions upon them. This would seem to follow straightaway since change of any kind of energy in spacetime curves that spacetime, therefore producing a gravitational change. So such has always been implicit in general relativity; it just took Sakharov to formally propose it. See A. D. Sakharov, "Vacuum Quantum Fluctuations in Curved Space and the Theory of Gravitation," *Soviet Physics Doklady,* 12(11), 1968, p. 1040-1041 [English translation.] Sakharov's article (in Russian) in *Dokl. Akad. Nauk SSSR,* Vol. 177, 1967, p. 70-71.

Einstein's postulates (second postulate extended): Let us do a little "tinkering" with Einstein's postulates. For the first one, we point out that in the new approach using dimensioning and subspaces, the notion of an inertial frame now has acquired additional complexity! The "gross translation" effects — which tends to be what physics ultimately focuses upon today — can remain the same, and yet vacuum engines can be buried up inside the inertial frame to act upon a mass in non-translating ways. Everything translation-wise can remain the same, but now matter can be transmuted and transformed, etc., still right there in an inertial frame. So when the infolded electrodynamics inside all fields, potentials, and waves are utilized, the notion of "inertial frame" has acquired a higher topology, so that one inertial frame may differ very substantially from another inertial frame, even if the two are not in translation motion with respect to each other. This of course moves one from special relativity into full general relativity, and even there into a slight extension. Special relativity can remain special relativity on the surface, and yet general relativity effects occur "within" the objects postulated to exist in this inertial frame. The "inertial frame" concept in the postulates is now just a sort of special "equilibrium case" of a higher topology "inertial frame" notion. Further, general relativity is extended from the notion of "just translation" to the notion of "internal engines and internal dynamics also". These engines can be created in mass, in fields and potentials and waves, and in the vacuum itself.

The second postulate now stands as a "special case" of a far more general second postulate. The conventional second postulate actually defines (and limits) "light" to bulk changes in the entire vacuum potential magnitude. It only applies to light signals which are "bulk upheaval" disturbances of the vacuum potential (spacetime), so to speak. The limitation to light speed is an envelope wave speed restriction. Specifically it need not apply to the "inner EM/GR realm" of longitudinal EM waves infolded inside the vacuum potential, other potentials, signal carriers, etc. Superluminal communication is now included in this "hidden variable" or longitudinal EM wave communication. The Fogal semiconductor is capable of infolding and outfolding EM signals, including producing the internal longitudinal EM waves, and during their infolded state these signals are permitted to move at superluminal velocity. This has been experimentally demonstrated by Fogal.

So the second postulate needs to be restated to include the present statement as a special case. Notice that the concepts "light" and "speed of light" have now taken on much richer, extended meanings, since there is "outfolded" light and "infolded" light, so to speak. Light now is not just the "external perturbation wave" in the ambient vacuum potential medium (in flat spacetime). Instead, it can also be an "internal perturbation longitudinal wave" inside a "net flat spacetime" which does not show on the "surface" at all. Indeed, it may move in the time dimension or in 3-space. It now includes the transmission of an extraordinary "vacuum engine" as well as the usual transmission of just an ordinary signal. The ultimate expression of this extension has unfortunately been the development of such "engines" as infolded robot systems for use in warfare.

These infolded vacuum engines can be visualized as very special sets of longitudinal EM waves and their dynamics, consistent with the Whittaker decomposition. Whittaker's U(1) symmetry electrodynamics decomposition— particularly when enriched in the higher symmetry O(3) electrodynamics — applies to the ambient vacuum as a potential (it is a potential since it has energy density). So the "subspace" inside spacetime, so to speak, is just a set of LWs and their dynamics, and that subspace itself is engineerable, just as is the "bulk curvature of spacetime" itself. Further, we may now consider that space itself is just a vast superhighway for such superluminal LWs and their dynamics. Mass is mostly empty space with only an occasional particle here and there and with fields, potentials, and waves in between. Hence huge masses such as the ocean and earth are actually superhighways for the direct passage of longitudinal EM waves, "engines", special robots, etc. The degree of "transparency" is a function of the degree of cleanness of the LWs — where by "clean" we mean "absence of transverse EM wave residues".

The third postulate has also been dramatically extended and requires revision. As presently stated, antigravity effects do not appear to be included in present physics heretofore. The "gravitational effects and external accelerated effects" notion in conventional physics are still founded purely on *ordinary bulk translation.* Now they need not be. For example, the system can appear to be an ordinary system, as judged by normal "external light" observation. Yet its internal vacuum engines can cause local violation of most so-called "laws of nature." The reason a "law of nature" can be violated is that one is now able to violate the premises upon which it is postulated, and which are required to hold if the law is to hold. Or another way to look at it: any conservation law is the result of a symmetry. Breaking that symmetry allows violation of that specific conservation law. All external symmetries can be broken internally, even if the overall symmetry still applies externally!

The infolded EM inside the "conventional" EM fields, waves, and potentials — and inside the vacuum potential and spacetime itself-dramatically changes the present theories of electromagnetism, quantum mechanics, and general relativity. Further, for the first time the Sachs unified field theory allows an *engineering* approach that simultaneously crosses, includes, and extends all three disciplines in the required manner. The approach can be placed into good engineering models based on the Sachs work, particularly using the O(3) electrodynamics subset spearheaded by Evans, and the models can be tested and verified or falsified. See **frame, reference;** and **superluminal communication.**

electric field: (See also discussion under **E-field).** The *conventional* definition is this: "1. a region in space in which a stationary electric charge experiences a force due to its charge. 2. the electric force per unit test charge." Quoted from *Dictionary of Science and Technology,* p. 720. That definition is flawed. Consider the "spatial aspects" of part 1. If an electric field is defined as a force per unit charge (per Part 2), it is not a region in massless space but is an effect of something existing in massless spacetime and interacting with the charged 3-spatial mass. The electric field *prior to interaction and observation of the interaction* is indeed related to a region in "spacetime", because it is identically a curved spacetime region. In the Sachs approach, general relativity and electrodynamics have become one and the same. So prior to interaction, the *field as it independently exists prior to interaction with charge* has become a curved spacetime region, and the field-in-space is *purely* a spacetime curvature. Again, there is no such thing as a massless force. It is the hoary old mechanics notion of a separate force acting upon a separate mass that is a total non sequitur. The interaction of the massless field in space with a mass to produce a force, *of* ***which*** *that mass is actually a component,* is a separate consideration from the field as it exists in space prior to interaction. The result of this entity's **interaction** with charged mass has nothing to do with *what an electric field* is but with *what it does to charged mass.* Further, the force evidenced on a charged particle is not due to its charge; the particle has that charge always, whether or not there is a net force evidenced on it!

Part 2 is a little better. The only problem is, it totally disagrees with the notion of the field as an entity existing in spacetime prior to interaction **with** charged mass. In other words, here it's a "force on a charge", which is an effect (force consisting partially of the charge) occurring after the interaction. Again, the conventional definition states only what the field *does or accomplishes,* not what it *is.* Hopefully the reader can now begin to see what terrible difficulties await anyone who seriously attempts *foundations definitions.* Feynman sums it up admirably in one of his famous statements: "*Everything we know is only some kind of approximation, therefore, things must he learned only to be unlearned again or, more likely, corrected.* "An additional difficulty is that the very **notion** of a separate massless force — independent of the mass on which it operates - is fictitious, yet continues to be widely used. Recalling that any true definition is an identity and not an equation, let us start with the definition of force: $\mathbf{F} \equiv d/dt(m\mathbf{v})$. As can be seen, force is a system **comprised** of (i) a mass component and (ii) a nonmass component. The force is not something separate from the mass, at all! Further, force is not **even** unitary. It's a system comprised of two coupled components; the mass and **a** coupled (interacting) gradient in a potential flux. *Note that v involves motion through, and interaction with, the virtual flux comprising the vacuum potential. Note that dv/dt involves a gradient in that flux interaction with the mass.* Unfortunately mechanics is still using the medieval concept of a "separate force acting upon a separate mass." That is wrong, unless we change the fundamental definition of force itself. See, e.g, **Robert** Bruce Lindsay and Henry Margenau, *Foundations of Physics, Dover P*ublications, New York, 1963, p. 283, where the authors emphasize that a "field of force" at any point is actually defined only for the case when a unit mass is present at that point. The reason can be seen: mass is a necessary component of force, and without mass present there cannot be a force present. For that reason, the force field in matter is a quite different beast from that "same" force field in empty spacetime. The first is a 3-spatial snapshot of an ongoing 4-spatial interaction, while the second is just a curved region of that "empty" spacetime without any ongoing reaction necessarily.

electric dipole: See **dipole.**

electrodynamicist: A specialist in electrodynamics — the physics of the relationships between electric, magnetic, and mechanical phenomena — and especially a specialist in electrodynamics *theory*. Essentially all electrodynamicists are versed in U(1) electrodynamics, and a much smaller number are versed in more advanced (higher group symmetry) electrodynamics such as O(3) symmetry electrodynamics, unified field theory electrodynamics, non-Abelian electrodynamics, etc. The electrodynamics field is actually a very vast field indeed, touching everything in physics, chemistry, etc. When one needs a particular electrodynamics problem solved, it often calls for a special category of electrodynamicist and not just an electrodynamicist in general. One must therefore sometimes examine the background of the electrodynamicist making a statement or a pronouncement; electrodynamicists after all do have differing views and differing disciplines within the field. And something may be perfectly true and acceptable in O(3) electrodynamics, yet not even exist in U(1) electrodynamics. As an example, the Aharonov-Bohm effect exists in O(3), but not in U(1). U(1) assumes a flat local spacetime (falsified by general relativity almost a century ago) and an inert vacuum (strongly falsified by modern particle physics and quantum mechanics), while O(3) is perfectly content to include and model curved spacetime and active vacuum also.

electromotive force (EMF): A difference of potential created by sources of electrical energy — i.e., by separated charges (dipoles) — which can be utilized to drive electrical currents through external circuits. As a difference of potential, that constitutes a gradient and hence a force. Also, open circuit voltage, or the limit of the potential difference between the source's terminals as the current in the external circuit approaches zero.

This term is poorly named and also quite confused in the standard theory and usage. First, em/is supposedly not a *force* at all. It is a difference in potential; hence it is measured in volts. It is very difficult to imagine a "difference in potential" at a single point unless one is dealing with a multiply connected space. So if the difference in potential is between two adjacent points, then that constitutes a force between the two points. Also, emf is not considered an E-field, since that is a field of force. Yet it is in fact a $\nabla\phi$, restricted to the direction between the two measurement points, and $-\nabla\phi$ is considered to be an E-field in the EM theory! As can be seen, o**ne** will not find a truly logical definition of potential or emf in the present texts and science literature.

For this reason the standard theorists say that the term emf is sometimes used as equivalent to a difference in potential, but that strictly speaking it s**hould** be applied only to a source of electrical energy. The problem is that **most** conventional theorists are unaware that a potential *identically is* a bidirectional flow of energy in 3-space, but a 3-space flow where *the* energy *enters from the time-domain (complex plane) and is caught in 3-space by interaction with charge, in a frozen snapshot (observation). The energy actually enters each 3-space point in the 4-space potential, from* the t*ime domain.* It moves across a dipole in space (present due to the quantum mechanical polarization of the vacuum), to the opposite charge, thus returning from the immediate region of that second 3-space point (or points) back to the time domain. Since conventional theorists are unaware that a potential is a hidden negentropic energy flow circulation process involving broken 3-symmetry, broken t-symmetry, and a special 4-symmetry between t and 3-space, the theorists have been unable to consider the potential in general as a direct source of energy flow. Yet they are forced to consider a potential difference across the terminals of a source as "somehow a flow of energy, that generates forces upon the electrons to propel them through the circuit as current flow."

In the new viewpoint, a resolution is achieved of these incongruities by more accurately defining the E-field with respect to the potential as $\mathbf{E} = -[\nabla\phi \bullet q]/|q|$. It is noted that $-[dA/dt]\bullet q/|q|$ also produces an E-field, so **that the ful**l definition of the E-field $\mathbf{E}$ is $-[(\nabla\phi + d\mathbf{A}/dt)\bullet q]/|q|$. Note that dividing q by |q| does not remove the q unit from the corresponding dimensional equation, since $|q|$ is dimensionless. However, one volt represents one joule (of excess energy) *diverged from the potential,* per coulomb of interacting charge. *The energy density flow in an electric circuit is in the voltage, in the emf, and it is not in the current per se.* The electr**on** current (drift current) carries the excess energy that is being dissipated as work in the circuit, but in a nominal circuit the drift current only moves a few inches per hour. Half the energy collected in the potentialized circuit is dissipated in the external circuit and external losses, and half is dissipated in forcing spent electrons in the ground return line back up **through** the back-emf of the source, performing work inside the source to dissipate its separation of charges. Left alone, any dipole will furnish emf indefinitely, freely receiving the energy from the time domain (complex plane) and outputting it in 3-space via the reinterpreted Whittaker 1903 decomposition, in a circulation where at each point in it the energy enters from the time domain and thence returns back to the time domain. The free flow of EM energy will continue unabated from the undestroyed dipole, regardless of how many external loads and losses are powered (how much energy is collected and dissipated from the ongoing flows representing the potential). So *electrical circuits should be developed which allow few or no electrons to be forced back up through the source dipole to dissipate its separation of charges and destroy the dipole.*

electromotive force, back (back emf): Back emf is a loose term for the *counter-electromotive force.*

When the source is powering a circuit or circuit element, the term "back emf is used to refer to the forcing of current (electrons) back up through the source against its emf, thereby performing work inside the source to *dissipate* its separation of charges (its dipolarity). When a potential source of electrical energy — such as a capacitor, an inductor, or a rotating machine — is receiving energy from a source and converting it to *dissipative* power and work, that "powered" device is said to develop a *counter-emf.* A source has a built-in emf *a priori,* and this emf is holding its charges separated so that it is dipolar. When electron current is forced backwards through the source against its emf, work is performed against the internal resistance of the source to dissipate its separation of charges, thereby *dissipating* the source dipole. If electron current is not allowed to flow back up through the source against its back emf and through its built-in counter-emf, no dissipation of the source dipole occurs, even though energy density (not *electron current* dq/dt but *energy flow* dq/dt) is flowing from the source and can be collected in *collectors* in the external circuit to store the energy as a created local energy source. This collected energy can then be shuttled to a separate load circuit and released, to provide a "heat pump" cycling operation and overunity coefficient of performance.

Nikola Tesla in fact knew how to shuttle energy at will in a circuit in such fashion, as Barrett's quaternion analysis of Tesla's actual patented circuits has revealed. [See T.W. Barrett, "Tesla's Nonlinear Oscillator-Shuttle-Circuit (OSC) Theory," *Annales de la Fondation Louis de Broglie,* 16(1), 1991, p. 23-41.] Note that a rigorous analysis of those same circuits, using tensors or vectors (lower topology algebras), will not show the effect. One needs a higher-topology algebra such as quaternions or Clifford algebra, or the significant properties of such circuits will be entirely missed.

When the original source dipole is not dissipated because electron current is not passed back up through its back-emf to scatter the charges, the original source dipole will continue to furnish emf indefinitely because of the proven asymmetry of its opposite charges in the seething vacuum energy flux.

The terms emf and counter-emf are normally applied only to recognized sources of electricity. Emf is computed as the algebraic sum of the potential differences acting in a circuit attached to a source. Back-emf (counter-emf) is computed as the potential difference internally through the source, between its terminals. The back-emf is thought to be necessary in producing *a powered device or component in the circuit.* Actually, *its **main** application (the ubiquitous closed current loop where all the external circuit current is passed back through the back-emf of the source dipole) is to prevent COP>1.0 electrical power systems from being developed and utilized, andfor every electrical circuit to self-enforce Lorentz symmetrical regauging during its de-excitation phase.*

electron: A stable elementary particle in all atoms, and having — in "forward time" — a negative charge of 1.602x 10^{-19} coulombs, a spin 1/2, *and a* mass of 9.11x10^{-31} kilograms. If time is reversed, the charge (but not the masss) of the electron is reversed and it becomes a positron. Note this is an equivalent *observed* 3-positron, in a material lattice after interaction with charged matter, and not the mathematical equivalent represented by Dirac sea holes in the 4-vacuum prior to interaction with mass.

The "electron" may also exist as a negative energy, negative charge, negative mass-energy 4-state (Dirac hole) in the vacuum itself. In that state, the negative energy 4-electron is the source of negative energy fields and negative energy potentials. When the associated nondiverged and unaccounted Heaviside energy flow component is also accounted, the Dirac sea hole negative energy 4-electron can be manipulated in "anti-circuits" to directly engineer local antigravity, quite strongly and practically.

electron gas: A system of electrons with only weak interactions, so that the electrons may be regarded as moving independently. In many ways, such a collection of electrons can be treated as a gas. See Drude Electron gas.

electrostatic scalar potential: A *static* (stationary, in the sense that a perfect waterfall would appear stationary) ordering in the virtual photon flux of vacuum. The notion of "static" in the term "electrostatic" is misleading and should be replaced by "stationary" since the underlying active vacuum medium is always in violent motion, and there is nothing truly "static" in the universe. But an *equilibrium* or *stationary* condition can exist as an external envelope condition, even with continuous violent motion internally, so that a stationary entity or form persists. An example is a perfect whirlpool in a river.

The electrostatic scalar potential decomposes into a harmonic set of bidirectional phase conjugate longitudinal EM wavepairs, as shown by E. T. Whittaker in 1903. Hence the electrostatic scalar potential is an overall curvature of spacetime with internal longitudinal EM order and dynamics.

ELF: Extremely low frequency. Used to describe EM fields whose frequencies lie in the range from just above 0 Hz (direct current) to 300 Hz. This includes power line frequencies (60 Hz in U.S. and 50 Hz in Europe) and frequencies used by certain U.S. military ELF communication systems such as for submerged submarines.

EMF: Acronym for electromotive force. See discussion under electromotive force.

EM field: Electromagnetic field. In its loose usage, it refers in a very broad way to any field, force, or energy associated with electromagnetic interactions, charges and currents. Thus "EM field" includes electrostatic fields, magnetostatic fields, electromagnetic fields (including radiation and induction), vector-potential and scalar-potential fields, Hertz potentials, Fitzgerald potentials, Whittaker potentials, Debye potentials, etc.

In its precise usage, "EM field" conventionally refers to an EM "force" field, such as the E-field, D-field, B-field, and H-field. In classical electromagnetics (CEM), as a holdover from the old assumption of a material ether, the force fields are considered (erroneously) to exist in mass-free space, and they are also considered to be the primary causes of electromagnetic phenomena. This is a non sequitur, and it involves substituting the effect for the cause.

In the new viewpoint, *the force* fields do not exist in vacuum, but only in and on and of the charged particles themselves, where mass is present to form one component of the force. The force fields are therefore effects and not primary causes. The primary causes of all electromagnetic phenomena is taken to be the potentials; however, the hidden

Stoney/Whittaker/Ziolkowski internal structures of gradient-free scalar potentials may interfere to cause potential gradients in and on charged particle systems. [In O(3) and other higher group symmetry electrodynamics, this internal structuring and dynamics is far richer.] This therefore includes distance-free scalar potential interferometry and action at a distance, as well as vacuum engines.

The new view uses Sachs' unified field theory, and considers that the EM field in the vacuum, or an EM potential in the vacuum, involves and identically is curvature of spacetime. It follows that the internal EM structures of "ordinary" EM are also spacetime curvatures, where the specific pattern of these ST curvatures constitutes a very special kind of spacetime engine that acts upon any local mass in a specific manner determined by the individual pattern of curvatures. Thus the new view is a unified field theory where GR has become EM and EM has become GR, and where higher symmetry EM — such as O(3) group symmetry EM — can involve or produce gravitational, temporal, and inertial effects as well.

EM force field in the vacuum (a false concept : The erroneous notion that there exist forces in the vacuum, so that the set of forces at a set of spatial points forms a force field. Presently classical electrodynamicists accept the same E-field in vacuum as exists upon a charged mass when the vacuum E-field interacts with that charge, but it is asserted that the force is zero. This is easily falsified by defining force F as $\mathbf{F} \equiv \partial \boldsymbol{p}/\partial t = \partial/\partial t(\mathrm{mv})$. By expanding the term on the right, one sees that both terms in the expansion include mass. Mass is thus a *component* of force. If mass is absent, there is no force present, thus no force field present. The field in space and the "same" field in mass differ precisely by a mass term in their fundamental units. The field in massless space may be taken as a curvature of spacetime. Zero field in space means a flat spacetime; a nonzero field in space represents a curvature of spacetime. A nonzero field in mass means a curvature of spacetime (a 4-space entity) interacting with mass (a previous 3-space observation) to produce a force consisting of that field and mass interaction. There is no separate force acting on a separate mass, and mechanics has been wrong in assuming on for hundreds of years. Instead, there is a force produced by the interaction of a massless 4-field (spacetime curvature) entity with 3-spatial mass. It is that *interacting and ongoing entity or process* that is a force field. Speaking of such a force field in space, is speaking of the force field that would exist in that space if every point had a unit point static charge and charged mass. As Feynman and Wheeler pointed out, no force field as such exists in space, but only the potential for a force field exists there, in case some charged mass is brought in to interact and have the forces developed upon its charges.

EM generatrix: Whatever generates electromagnetics, particularly the fields. Since all EM energy comes from the time domain and returns to it, time is the ultimate EM generatrix. The circulation of EM energy from the time domain to 3-space and back, or vice versa, is a function performed by the broken symmetry of every charge, considered as two infinite dipolarities with a finite difference that is the observed charge listed in texts and handbooks.

energetics: Energy as the primary thing in the universe. Rankine's term later raised to the forefront by Ostwald. Modern Russian term for advanced higher group symmetry electromagnetics, where the electrodynamics is a subset of an engineerable unified field theory. In the U.S., a model approaching the Russian model is given by Evans's O(3) electrodynamics as a special subset of the electrodynamics used by Sachs in his epochal unified field theory. Thus there is a growing, engineerable unified field theory (energetics theory) in the U.S., being provided by Evans, Sachs, and others. A solid basis for energetics can be realized from the giant 4-space negentropy EM energy circulation involved with every charge, so that all "EM energy in space" and time itself comes from that circulation.

energy: Usually erroneously "defined" as the "capacity to do work". This is a total misdefinition since it would define energy as the ability to change its own form. The closest to a legitimate definition of energy appears to be: *energy is the invariance of that which is varying* (Lindsay). However, note that this definition violates Aristotelian logic (but does not violate five-law logic developed in this book). Another try at it might be: *"Energy is any deterministic or coherent structuring, either dynamic or stationary, existing in the virtual particle flux of vacuum."* While that sounds good, it still involves the nonchanging aspect of the changing flux — much like considering a whirlpool in a river as being a "static" thing. So it is still "the invariance of that which is varying", which is an identity of opposites. We conclude that 4- or 5-law logic is necessary in order to define energy, since the defining logic must encompass the identity of opposites. Feynman simply stated: *"It is important to realize that in physics today, we have no knowledge of what energy is_."* [Richard P. Feynman, Robert B. Leighton, and Matthew Sands, *The Feynman Lectures on Physics*, Addison-Wesley, Reading, MA, Vol. 1, 1964, p. 4-2.]. In Aristotelian logic, there is no acceptable definition of energy. In 5-law logic, the second definition holds since opposites can indeed be identical. Now to more practical aspects:

For our purposes, there are three major types of energy in 4-space: (i) 3-spatial energy, which includes energy in one, two, or three of the spatial dimensions, (ii) mass-energy, which is 3-spatial energy compressed by the factor c^2 but still in 3-space, and (iii) time-energy, which is 3-spatial energy compressed by the factor c^2 but now placed in the time domain. **Note t**hat time-energy has the same density as mass-energy, and hence the same spacetime-curvature effect and gravitational capability.

The major implication of the new view is that the conservation of energy law is extended: Now it is the total of the 3-spatial energy, mass-energy, and time-energy that must be conserved. Transduction between time-energy and either of the other two forms, or both, will violate the conventional conservation of the sum of the 3-spatial energy and the mass-energy; every charge and every dipole is an example. Use of time-polarized and longitudinally polarized photons and EM waves particularly may involve the extended conservation law, e.g., as utilized in cold fusion and its lime reversal zones, and as involved in the outpouring of observable EM energy from every charge in the universe, with no observable energy input.

energy collection/collecting: In electromagnetics, placement of an interceptor/collector — e.g., a charged particle — into an impinging EM energy flow, so that some of the flow is diverted around the intercepting particle. We may say that the flow of energy has been "reordered" into a stream diverged around the intercepting charge. The diverged part of the total energy flow is what is calculated as the Poynting energy flow component, and is what is referred to as the "collected" energy or the "potential" of the charge.

However, neither charge nor potential are acceptably defined in conventional electrodynamics, but they can be defined in the new approach. We are now able to see something more fundamental. By the giant negentropy mechanism, the charge is involved in both the time-ene**rgy** stream and the vacuum flux set of virtual particle spatial-energy stream**s.** "Charge" is not just related to the mass of the particle, but is the entire ongoing set of the dynamics as well as the mass (the "nondynamics", so to speak). When a charge is placed in a field, that field is a change to the local dynamics, which is a change to the charge itself. Both the dynamics and the mass (the "nondynamics" constituting the charge are altered. So one does not have the "field acting on a separate charge", but instead we have the charge with its previous set of dynamics transformed into the altered charge with a new set of dynamics and a new mass. Similary when a charge is placed in a potential. Charge is also not a 3-

spatial situation and process, but a 4-spatial situation and process. If the internal structuring is also important, it becomes an n-spatial situation where n>4 and even where n » 4. To deal with sophisticated engines, n » 4 is necessary in the modeling utilized.

energy dissipation: Refers to the scattering or disordering of energy; at fundamental basis, it refers to the changing of an altered charge (see energy collection/collecting) back to an unaltered charge. In other words, it is a special decay process whereby an "excited charge" (so to speak) decays back to its "normal state" by releasing dynamics (energy) back to the vacuum. The energy itself is not destroyed, but its "collecting pattern" or "flow pattern" as coupled to the charge is disrupted and altered or destroyed There is also the connotation that *the dissipated energy is lost as far as any re-use of it by the system.* We point out that only collected/collecting energy can be scattered; it is the collecting *process* (the entire alteration of the normal charge dynamics) that is "destroyed" - or more exactly, *transformed* — not the energy itself.

energy, electromagnetic: From a vacuum and quantum mechanical viewpoint: a deterministic or coherent structuring, either dynamic or static, existing in the virtual-photon or charged-particle flux of vacuum. Since a photon may also be considered a positron-electron pair (if we multiply each by time so that they are qt rather than q in fundamental unit form), the flux of photons in the polarized vacuum necessarily also includes the flux of charged virtual electrons and positrons. From a spacetime viewpoint: a curvature of spacetime, or set of such curvatures. If a deterministic set of spacetime curvatures (a template) is involved, then an engine is involved and the energy is said to be "dimensioned" (internally structured).

energy flow: Generally considered as the passage of energy, in any form, in one direction or generally in one direction in a given 3-space. To first order, our definitions of energy treat energy flow in a given space as (1) a directional change (propagation) of the vacuum energy and its form, or (2) as a directional propagation of a curvature of spacetime or a set of curvatures of spacetime. *The terms "energy flow" and "flow of energy through space" are not precisely defined in physics! They are not going* ***to*** *be defined, at least not in ordinary Aristotelian logic terms, since energy itself is not precisely defined, and one of the best struggles with the concept of energy concludes that it involves invariance in the midst of change, which is a violation of the third law of Aristotelian logic and therefore of the other two as well.*

Indeed, the "EM wave flowing through 3-space" does not exist (see previous comments quoted from Romer). What does exist is an ongoing 4-space process, assumed to be continually and iteratively interacting with a unit point charge to "detect" or "observe" it as an iterative series of frozen 3-space snapshots, in memory-recalled serial order much like the frames of a motion picture film. Nonetheless, we must keep our sense of humor and proceed as if we knew exactly what we were speaking of when we use the concepts "energy", "energy flow", and "energy propagation through 3-space". If one dwells on the problem without humor, one is led to Hawking's grim but perceptive statement: *"All we ever know is our models,* but *never the reality that may or may not exist behind the models and casts its shadow upon us who are embedded inside it. We imagine and intuit, then point the finger and wait to see which suspect for truth turns and runs. Our models may get closer and closer, but we will never reach direct perception of reality's thing-in-itself"* Ultimately we do not know physical reality itself, but our mental modeling of it, as best we can "fit" our modeling through comparison with our sensory and perceptive sensations.

energy flux: The passage **of** energy **flow, in any form, through a unit area, and** in any given direction (usually all directions). This includes both passage in a single direction, or passage in multiple directions at once. See flux. Sometimes taken as that component of the net flux through a unit area at right angles to the area.

energy, free: In our usage, free energy is what is obtained from any environment or entity which freely emits, furnishes, or makes available energy which either can be collected and used as furnished, or can be transduced into usable form and collected and used to power loads and do useful work. The word "free" does not apply to *costs,* but rather to the source *of the energy.* Since energy can neither be created nor destroyed, energy is always available free for the taking (collecting and using) if we bit learn how. *We never pay for energy per se, but for the manipulation and processing of the energy.* The notion of extracting and using free EM energy from the vacuum involves five key concepts: (1) the local vacuum/spacetime itself is filled with EM energy of generally unusable form (2) some sort of organizing principle is utilized in one part of the circuit or system to cohere the vacuum energy and transduce it into usable EM form (every charge already individually does that; we just have to learn to do it in a larger ensemble), (3) a gating mechanism is utilized to divert the vacuum energy now in usable EM form from the active vacuum to the external circuits or load parts of a device, (4) the coherent gated extra energy available in the external circuits or load parts is intercepted by those circuits or load parts, couples to them, and potentializes them with extra EM energy, so that the energy is collected by the system and regauges the system asymmetrically, and (5) the external circuits or load parts then scatter or dissipate the coupled extra energy to produce useful work (physical changes in the load), without destroying the organizing and gating mechanism that is extracting and furnishing usable EM energy from the vacuum.

energy source: A function or entity which furnishes energy by either gating it from one energy reservoir to our system or locality, or by transducing available unusable energy into usable form and then emitting the usable energy. Technically speaking, since energy cannot be created or destroyed, there is really no such thing as a *creative* "energy source", though the term "source" seems to imply such. So-called "energy sources" actually gate and/or transduce energy, changing it from one form to another, from one direction to another, etc. All EM energy in the universe comes from the time domain into 3-space vacuum, onto charge, and back to the time-domain, in a giant ongoing negentropy 4-circulation as freely provided by the "source charges".

engine: Deterministic pattern of structures, with their concomitant dynamics, in the flux of the vacuum. Also, deterministic patterning of curved spacetimc curvatures and their dynamics that comprise an overall larger spacetime curvature, or internally comprising an *overall* "uncurved" spacetime.

engineering, entropic: Engineering or designing systems and processes in equilibrium with their external active environment, and whose operation "spills" or wastes all the energy input to them, and which do not freely recover and use the dissipated or wasted energy. Entropic systems — which are the products of entropic engineering — thus have COP<1.0 and function in forward-time, and classical equilibrium thermodynamics with its infamous second law rigorously applies because the system is designed to self-enforce the equilibrium condition, often called by other names such as Lorentz symmetrical regauging.

engineering, negentropic: Engineering or designing open systems and processes far from equilibrium in their exchange with their active environment, whose operation freely "receives" excess energy from the environment, so that they permissibly output more energy than the operator inputs, the excess being received from the external environment. As an example, simply making a common dipole or assembling a charge initiates a giant negentropy operation that persists indefinitely (as long as the dipole or charge persists).

entropy: Thermodynamics state term representing a measure of an equilibrium system's capacity to undergo spontaneous change. In short, a quantity that measures the availability of a system's energy for conversion to work. The entropy of an open system not in equilibrium with its active environment cannot even be computed, because the state cannot be computed.

Entropy is given by dS = dQ/T, where dS is an infinitesimal change in entropy for a system absorbing an infinitesimal quantity of heat dQ at absolute temperature T. In statistical mechanics, entropy is a measure of the disorder in a system and is given by S = k lnP + C, where S is the value of entropy (disorder) for a system in a given state, P is the probability of that state's occurrence, k is a fixed constant, and C is an arbitrary constant. Intuitively, the concept of entropy corresponds to the concept of disorder. We specifically call attention to the fact that the "S" used in representing entropy is not at all the S used for Poynting energy flow in electrodynamics.

entropy, negative (negentropy): In a sense, the reversal of disorder, or reversal of entropy. Another way of defining negentropy even more rigorously — for electrodynamics — is to define it in spacetime as a bro*ken 3-symmetry in EM energy flow with concomitant relaxation to a more primary 4-symmetry between time-energy flow and 3-spatial EM energy flow, where time-energy flow is transduced into 3-spatial EM energyflow and then back to time-energy by the entity — such as a common dipole — causing the broken 3-symmetry.*

equilibrium: *In physics,* the state of a system in which opposing forces balance each other — i.e., sum to a vector zero. However, the *vector* zero summation does not represent "total absence" of everything, and the forces and their energy remain even though comprising a net vector zero system. Even a pure number zero may also be taken as a set of nonzero numbers; e.g., (+5 -3 -2). So even zero need not be total absence, but can be a "balanced set of presences". Or zero can be regarded as an overall equilibrium condition comprised of a set of disequilibria conditions.

Indeed, a vector zero summation system of nonzero forces comprises a stress potential, and it contains stress-energy doing work upon the stressed system. In *mechanics,* a system of particles — where the net force acting upon each constituent particle is zero — is said to be in equilibrium. *In chemistry, t*he state of a solution where the forward and reverse reactions are equal and balance each other, so that the chemical reactants and products maintain the same amounts. Again, the notion of equilibrium involves the "stationary" notion (similar to a perfect whirlpool in a perfect river) of the overall invariance of some set of ongoing dynamic changes.

ether: An extremely fine material substance originally theorized to exist in space in lieu of sheer emptiness. The problem is considering space as emptiness in the first place, which it is not. Instead, space (more rigorously, spacetime) is a plenum and highly active (as in the general relativity view a half-century after Maxwell's seminal paper). So there is no need to "fill empty space" with something, because in the modern view there is no such thing as empty space.

Evans, Myron W.: Noted chemical physicist, primary developer of O(3) symmetry electrodynamics, and Director of the Alpha Foundation's Institute for Advanced Study (AIAS). Papers produced by the AIAS are critical to understanding extraction of EM energy from the active vacuum, engineering of vacuum engines, and development of a revolutionary new healing method by time-reversing diseased or damaged cells back to a previous healthy state.

excess collected energy: Collection by an interceptor/collector of a greater fraction of EM energy flow impinging upon it and also surrounding it, than is normal. See **Bohren experiment.**

exciton: A bound electron-hole pair in a semiconductor. Excitons are temporary formations and they decay by recombining, but they have a specific half-life before recombining during which they migrate through the semiconductor crystal. When the hole and electron recombine, then — if the curvature of spacetime relaxes to a flat spacetime, which is not overtly stated in classical EM theory — the recombination releases energy in the form of a *photon,* or sometimes in the form of several *phonons.* **Note** that the "hole" is an "absence of an electron" from a position in a lattice usually containing an electron, so that it exhibits a net positive "change in the charge field" at that point. Specifically, this "lattice electron charge hole" is not a Dirac Sea hole in the vacuum, which is an entirely different matter. On the other hand, if the hole and electron recombine and the curvature of spacetime does not relax to a flat spacetime *because of other curvature-sustaining involvements,* then no "pair annihilation" radiation is emitted. It is the relaxation of the curved spacetime (when hole and electron are separated) back to a flat spacetime that causes photon or phonon emission.

exothermic: Literally, "giving off heat", or emitting scattered EM energy. Producing time-forward EM energy from a "source" by reducing the ordering (internal energy) of the source.

Faraday, Michael: Noted English physicist and chemist, 1791-1867, who discovered field theory and electromagnetic induction. Faraday also invented the dynamo and formulated his laws of electrolysis. His work directly inspired Maxwell, who vowed to study no other electromagnetics theory until he had captured Faraday's work in a mathematical theory.

Ferminion: A fundamental particle which has spin angular momentum of (n+1/2)h, and which obeys Fermi-Dirac statistics. Examples are baryons and leptons, which are subject to the Pauli exclusion principle.

Feynman, Richard P.: Noted physicist, Nobelist, and co-developer of quantum electrodynamics. Feynman is particularly noted for his refreshing three volumes of physics: see Richard P. Feynman, Robert B. Leighton and Matthew Sands, *The Feynman Lectures on Physics,* Addison-Wesley, New York, 1963. The book is particularly noteworthy in that it gives the student some insight into foundations problems in physics. E.g., in Vol. I on p. 2-4, Feynman defines the electric field not in terms of force per unit charge per se, but in terms of its *potentiality* for producing a force only when a charge is present for the force to be developed upon.

fiber fuse: Effect in optical fibers or fiber optic cable, whose core contains germanium, whereby heating the cable at one spot with a small flame will launch a focused traveling heat energy effect which melts a small hole in the core about every centimeter, and marches down the cable at about a meter per second to the end of the cable, destroying the optical transmission capability and ruining the cable. Oddly, by igniting the fiber fuse from the other end of the damaged cable, a *reverse* fiber fuse effect will often march back down the cable in similar fashion except that it fills in the melted holes in the core, restoring the transmission capability of the cable. If the energy required to melt all the holes (or fill them again) is taken into account, the amount of energy required to launch the fiber fuse is much less. This phenomenon does not appear to have an adequate technical explanation at present.

field: In mathematics, a set with two binary operations. In **electromagnetics** in more common mathematical terms, it is a region consisting of magnitudes and/or vector directions assigned to some active entity (e.g., spacetime itself) at each point in the region.

In physics, "a region of space marked by a physical property, as gravitational or electromagnetic force or fluid pressure, having a determinable value at every point in the region." [Thanks to *Webster's II New Riverside University Dictionary.]* Note the very special use of calculation of magnitude: one does not calculate the magnitude of the field itself, which fills an entire region. Instead, one calculates the magnitude of the *reaction* of that field with some interceptor/reactor at a given point — i.e., the *effect* of that field upon some mass entity. That is at best a measure of the *local intensity* of the field, not the magnitude of the entire field per se. For that reason, often we speak of calculating the field intensity, which is far more accurate than saying that we are "calculating the magnitude of the field". So we do not really calculate the "magnitude of the field," and in fact such a calculation does not occur in any textbook. Instead, we calculate the *reaction cross section* — in the case of electrodynamics, for an assumed unit point static charge — of the field at a point in the region or space occupied by the field. *We actually calculate what is deviated or diverged from the field, around an assumed interceptor, not the field itself.* This means that we calculate the result or *effect* of a detecting/observing action, and a frozen 3-space snapshot of that ongoing interaction, since all observation is 3-spatial. To then state that this same field exists in space prior to the interaction, and is what causes the interaction, is a gross non sequitur and confuses the effect with its own cause. This ubiquitous non sequitur widely permeates electrodynamics and mechanics, and it is one of the greatest scientific logical errors in history.

field, scalar: In the standard view, a field, to any point of which is assigned a magnitude only. However, "magnitude" of the EM field in the standard usage refers only to the amount of energy deviated (diverged) around a fixed intercepting unit point charge, per the conventional "detection by reaction" model. Again, note the serious logical errors in the conventional usage. One cannot define the field in terms of what is diverged from it! At best one has defined the "intensity" of the field's interaction with a given standard interactant (charge). So in electrodynamics the term "scalar field" would be better replaced with "scalar field intensity", at least for many applications.

field, vector: In the conventional view, a field, to any point of which is assigned both a magnitude and a direction. Again, the standard view also implements that assumed reaction with a detecting unit point static charge, and the "magnitude" used is just the difference between the amount of energy piled on the "front" of the interacting unit point static charge and the amount of energy pile on the "rear" of the interacting unit point charge.

The "direction" is from the center of the "high energy" pileup to the center of the "low energy " pileup around this fixed intercepting unit point charge. Again, note the serious logical errors. One cannot define the field in terms of what is diverged from it and the direction of the difference in "energy pressure." At best one has defined the "intensity" of the field's interaction with a given interactant (charge), and the "direction" established by the difference between the frontal and rear energy pileups on the interacting charge. The term would be better replaced with "vector field intensity".

flat (uncurved) spacetime: In our view, a vacuum/spacetime whose virtual particle flux intensity — and therefore its local energy density — does not change as a function of spatial position or averaged time. That is, in our view a flat spacetime is also identically a quantum mechanical vacuum whose virtual particle flux and energy density are constant in magnitude and internal constitution with respect to spatial position and in averaged time. Note that in this extended view, a flat spacetime (vacuum potential) can still contain vacuum engines, and thus still be *dimensioned. In that ca*se, contrary to normal physics, the flat spacetime itself will still interact with an embedded object and *change* it internally, even though it does not *translate* it externally. To perform transmutation of elements, e.g., one is interested in just such engines and not in spatially translating the element being treated. This dimensioning or activation of the local flat spacetime can result in an otherwise unexpected, seeming violation of one or more laws of nature in the dimensioned region, and easily results in violation of conventional physics which does not take into account engines and dimensioning of a flat spacetime. Note also that this allows a differentiation between the actions of two inertial frames, if the frames are differently dimensioned. As we stated, this is a deliberate extension of orthodox physics. See also dimensioning, and Einstein's second postulate —extension of.

fluctiation theorem: Theorem advanced by Denis J. Evans et al. at the Australian National University in 1993 that appreciable and measurable violations of the second law of thermodynamics occurs for small systems over short time scales. See D. J. Evans, E. g. D. Cohen, and G. P. Morriss, Phys. *Rev. Lett.* Vol. 71, 2401 (1993). In 2002 Evans and his colleagues experimentally demonstrated the proof of this theorem in rigorous fashion. See G. M. Wang, E. M. Sevick, Emil Mittag, Debra J. Searles, and Denis J. Evans, "Experimental Demonstration of Violations of the Second Law of Thermodynamics for Small Systems and Short Time Scales," *Phys. Rev. Lett.* 89(5), 29 July 2002, 050601. The proof also directly proves the occurrence in electrolytes and fluids of time-reversal zones (TRZs) where the dynamics runs backwards for a short time. This validates Bearden's proposal of the TRZ and its consequent reversal of the Coulomb barrier to a Coulomb attractor as the mechanism producing attraction of like charges into quasi-nuclei, which then can decay by quark flipping (if necessary) as the TRZ decays and reverses back to normal. This provides a mechanism for transmutation of elements in these TRZs as a result of the fluctuation theorem and its proof by Evans et al.

flux: The amount of some quantity (such as energy, particles, volume of fluid, etc.) flowing across a given area (usually a unit area perpendicular to the flow) per unit of time. The term flux density is now more commonly used. Loosely, "flux" refers to the perpendicular flow through an area, while "flux density" refers to the magnitude or intensity (rate) of the flux. In some cases such as a flux of particles of different velocities, the number of particles may be multiplied by the average velocity to give an average flux density that is weighted.

flux density: The amount of some quantity (such as energy, particles, volume of fluid, etc.) flowing across a given area (usually a unit area perpendicular to the flow) per unit of time.

Fogal semiconductor: A special semiconductor invented by Bill (William) Fogal which, in its operational regime, utilizes an integrated semiconductor, very special tantalum capacitor, and feedback resistor to accomplish charge blocking (blocking of electron current flow dq/dt) while passing displacement current $d\phi/dt$.

The Fogal semiconductor can also accomplish amplified phase conjugation of signals as well as infolding (translation of input transverse EM waves to output longitudinal EM waves) and outfolding (translation of received input longitudinal EM waves to output transverse EM waves). Used in communication systems, it opens the use of the unlimited "infolded" electromagnetics bandwidth. Since it may communicate using longitudinal EM waves, it is also usable for superluminal or a specialized "tunneling" communication through the "interior" of normal EM waves, potentials, and fields. For example, it can easily transmit color TV signals through the "interior" of a common DC potential. See William J. Fogal, "High Gain, Low distortion, Faster Switching Transistor," U.S. Patent No. 5,196,809, Mar. 23, 1993; - - "High Gain, Low Distortion, Faster Switching Transistor," U.S. Patent No. 5,430,413, July 4, 1995, a continuation of his earlier patent.

Fogal, William: Researcher and inventor of the Fogal semiconductor (two patents so far), as well as a superluminal infolding-outfolding communication system and other remarkable longitudinal EM wave processes. The Fogal semiconductor allows the use of the internal longitudinal wave electrodynamics comprising all ordinary EM fields, waves, and potentials, and thus will usher in a revolutionary new communications science and extended electrodynamics technology. See also discussion under Einstein's second postulate extended.

force: In mechanics, identically the time derivative of momentum, or $F \equiv \partial/\partial t(mv)$. One must realize that it is not the mass in motion, but the single undivided quantity "mass-motion" or "mass-velocity" (momentum) that is changed. Present EM theory erroneously takes force fields to exist in empty, massless vacuum but with zero force! However, the mechanical definition is an identity, not an equality. The observable mass in vacuum is zero, so substituting m = 0 gives $F \equiv \partial/\partial t(0 \cdot v) = 0$. This appears to be the conventional reasoning. However, $\mathbf{E} = \mathbf{F}/q = \mathbf{0}/q = \mathbf{0}$ also. So if mass is zero, the field E used in "force field definition" disappears. All that says is that the field in mass-free space and the field in mass are totally different entities,

Since force can be induced into and of the mass-motion target at a distance, in the new approach there is a more fundamental mechanism that produces force itself, and that is a curvature of spacetime, in agreement with general relativity. Distant curvatures of spacetime to produce forces on exposed charged mass systems may also be engineered by longitudinal EM wave interferometry, which does constitute "action at a distance." The fields arise in the local spacetime in the distant interference zone, thus arising from within and around any physical mass object located in that zone. Hence it produces an "inside-to-outside" type of action that is presently unknown in orthodox physics. The produced fields can start inside the nucleons of the atoms and move outward, and work directly upon the quarks and gluons first. This opens a great number of entirely new nuclear reactions presently not developed in particle physics.

force **field:** An 3-space *effect* that exists as a local vacuum virtual particle flux interaction upon and with a hypothetical unit point mass or unit point charge assumed at every point in 3-space. The effect (force field) results from a ***causal*** force-free 4-field (a curvature of spacetime) interacting with an observed hypothetical unit point mass or unit point charge assumed at every point in space. Hence the invocation of observation invokes a *d/dt operator* (the interacting charged mass) upon the causal field, providing a frozen 3-snapshot of the ongoing 4-interaction. An iterative series of such 3-observations is said to constitute a "3-space force field" as if it existed in time, which it does not. It is seen (iteratively observed) as a series of such frozen snapshots, which mentally we conceive as "existing in time" instead of the "recurring at points in time" that it really is. We unconsciously invoke that substitution of iterative effect as being continuity in space and time, when we use terms such as "propagation through space".

force-free propagation: Propagation of force-free disturbances in the vacuum flux; i.e., propagation of curvatures of spacetime or sets of such curvatures, together with any associated dynamics.

foundations of mathematics: The concepts, operations, assumptions, postulates, logic, definitions, and axioms of algebra systems.

foundations of physics: The postulates, assumptions, concepts, and definitions upon which a scientific physics model rests. Included are also the postulates, concepts, assumptions, definitions, axioms, logic, and operations of the mathematics in which the scientific model is expressed, as well as the postulates, concepts, assumptions, definitions, and operations of the physics entities and functions assigned to the mathematical symbols. Thus "scientific truth" -— even mathematical truth; see Morris Kline's *Mathematics: The Loss of Certainty* — is actually a *qualified* truth. What is true in one model (one set of postulates, assumptions, concepts, and definitions, including those in the algebra) may not be always true when one or more of the postulates, assumptions, concepts, and definitions is/are changed, and/or when the topology of the mathematics in which the model is expressed is changed, etc.

four-space (4-space): The "normal" spacetime used in physics, consisting of three spatial dimensions and one time dimension. Minkowski spacetime.

fourth law of logic: The law that a thing and its opposite become identical on the boundary, i.e., in multiple simultaneous observations. *Identity* is merely the loss of observational or perceptual distinction; when formerly "two" objects are simultaneously observed by a single observer, and two slides have been shown at once in the slide projector. It does not matter at that point what each was individually observed to be before when it was singly observed. Now there is no observable distinction or difference. We previously showed that the fourth law is implicitly assumed in the three laws of Aristotelian logic anyway, and published a simple proof of the fourth law. Without the fourth law, Aristotelian logic "eats itself." As a simple example, the Aristotelian third law eliminates the center vertical line division of a simple Venn diagram between A and not-A, because the division line itself is happy to belong to both A and not-A simultaneously. So Aristotelian logic destroys the very Venn diagrams used to "prove" or "demonstrate" its logical propositions. What results in the four law logic is that either (1) the three laws apply explicitly and the fourth law applies implicitly, or (2) the fourth law applies explicitly and the three laws apply implicitly. This *application rule* — i.e., *either (1) or (2)* — itself can be taken as a fifth law of logic, thus extending and completing Aristotelian logic which is presently incomplete. The fourth law is also the law of the **paradox:** i.e., when something is true but violates one or more of the Aristotelian laws, it is a case where the fourth law applies explicitly and the three laws apply implicitly. Wave-particle duality is such a fourth law case.

four-wave mixing: A nonlinear multiwave mixing effect when four waves mix (interact) in a highly nonlinear situation so that wave-to-wave interaction occurs.

fractional charge: A hypothetical particle having a charge less than the electron's charge. Often called a quark, where its charge is 1/3 or 2/3 the charge of the electron. A few years ago, Stanford University researchers found what was believed to be evidence of free quarks, but that later was doubted. There is also now the fractional Hall effect. In the 1920's Ehrenhaft reported the discovery and production of fractional charges of all sizes, and his experiments have been replicated by Mikhailov, with papers by Mikhailov and Barrett.

In the new approach, when time-energy is utilized, quarks can be freed or nearly freed rather easily in matter inside "time-reversal zones", since the energy emerges from the local curved spacetime and propagates from within the nucleus outward and the gluon forces are substantially reversed. Note also that time is multiply connected, and energy can enter an object anywhere within it or even everywhere within it, since each and every differential piece of the object exists in every single increment of time. It would appear that, as the new approach develops, free quarks will become a normal event rather than one intensely sought but terribly difficult to come by experimentally. We flatly predict that, in a sufficiently good time-reversal zone, free quarks can be produced because of the enormous energy density (in the time component) being utilized.

frame, Lorentz: A frame of reference that is not accelerated with respect to the laboratory observer. In this case, the frame may be rotated (moving at a constant velocity) but it is not rotating (the frame is not accelerated with respect to the observer, and spacetime is not curved). In this case special relativity applies, as do the conservation laws. We do add a caution that full general relativity still applies to the interior structure and dynamics (the engine) comprising the flat spacetime. Two *overall* flat spacetimes may produce very different interactions inside matter, if their internal engines are materially different and dimensioned.

frame, reference: A spatial, organized, measured lattice placed in "emptiness" (space, spacetime). Normally refers to a 3-dimensional, spatial frame (simplest case) or to a 4-dimensional spacetime. All objects and points in the "universe" or spatial frame are considered to simultaneously coexist at separate, measured points in the frame. Differs from the vacuum in that, rigorously, vacuum has no existing definite lengths and no existing definite time intervals, as these appear only after measurement or detection, and are relative to the observer and to the interactions ongoing as well as in the detection process itself. The "laboratory frame" is the static reference frame of the observer or measurement. A separate reference frame may be assumed to exist for any fixed or moving object, or centered on any point in another frame. When a type of frame is assumed, the entire class of *translation type* physical interactions that can occur has been restricted to an assumed set or type. In other words, given the frame, the *conventional* physics of translation has been assumed. One of the greatest restrictions of an assumed "frame" is to rule out the consideration (existence) of other higher dimensions, hence of dimensioned engines.

In the new unified field theory approach, the other higher dimensions are always available and cannot be ruled out in general, but only in some special case. Every curvature of spacetime, and any internal additional curvatures comprising that primary curvature, *adds one or more new dimensions*. In our view, a spacetime may be "flat" in overall envelope curvature, but consist of internally structured deterministic curvatures or "engines". In this view, normal inertial frames, e.g., may still contain engines, which will not affect the normal *bulk translation* rules, but may affect any or all of the nontranslation mechanisms, including the very laws of nature in many cases. Engines have not been developed and used in conventional open physics, but were weaponized clandestinely by the former Soviet Union. See **Einstein's second postulate extended.**

free energy: Excess energy freely received from its external active environment by an open system that is far from thermodynamic equilibrium in its exchange with that environment. There is a separate thermodynamics for such open disequilibrium systems. (See **thermodynamics of open systems.** See also Appendix **A** for a more detailed discussion of the thermodynamics aspects). Such a system is permitted to exhibit five "magic" functions: it is permitted to (1) self-order, (2) self-oscillate or self-rotate, (3) output more energy than the operator himself inputs (the excess energy being freely received from the active environment), (4) power itself and its load simultaneously (all the energy being freely received from the active environment), and (5) exhibit negentropy. Every charge and dipole in the universe already performs all five of those functions.

free **energy** system: Any open system not in thermodynamic equilibrium, which freely receives excess energy from an external environmental source, **and** collects and utilizes this free excess energy to freely power external loads, so that a permissible system COP>1.0 is achieved, as allowed by the nonlinear thermodynamics of open systems in disequilibrium with their environment. (See **thermodynamics** of open systems.). A free energy system may also be "self-powering" if "close-looped" with governed positive energy feedback from output section to input section, meeting the Kron self-powering condition. Operation of free energy systems can only be properly modeled and understood in terms of their super*system* interactions.

Implicit in the notion of free electromagnetic energy systems are six key concepts: (1) the local vacuum/spacetime is known to be filled with hidden (i.e., virtual) energy in violent motion, i.e., the local vacuum/spacetime is a violent virtual energy flux and therefore a scalar potential, (2) a broken symmetry - i.e., some sort of organizing and gating mechanism, such as the common dipole — in this hidden (virtual) energy flux of the vacuum is utilized as a source, to cohere the virtual energy and divert it as energy $\mathbf{S} = f(\mathbf{E} \times \mathbf{H})$, flow from the broken symmetry initiation point onto the external circuits or load parts of a device, (3) the coherent gated extra virtual energy flow available in the external circuits or load parts couples to (interacts with) the mobile charges in those circuits or load parts, so that gradients developed in the interacting virtual flux form force fields on and of the particle masses, driving the mobile charges along the circuit and through current-impeding circuit components such as loads, (4) in the interaction of the driven charges with the driving virtual energy flux, their spin and erratic motions integrate a tiny "coupling fraction" of the driving virtual energy into observable (i.e., macroscopic field) energy, thus creating the **E**-fields and B-fields, (5) the current-impeding external components or load parts scatter or dissipate the coherence of the driven charges and thereby dissipate the collected energy or change the form of the collected field energy, thereby producing useful work, and (6) little or none of the excess collected energy in the circuit is split off and dissipated in the gate (asymmetry component serving as the S-flow source) to destroy the gate and thereby destroy its asymmetry in the vacuum flux, which is what is extracting and producing the free energy flow.

gate: A component or function that extracts some part of a flux or flow, compacting it into a stream, and "sending it out" in organized, useful energy flow form. The fundamental gate for all EM energy in 3-space is the dipole or dipolarity — the "isolated charge" is actually a dipolarity, when the virtual charges of opposite sign clustering around it in the active polarized vacuum are considered. The source of the 3-space EM energy continuously emitted by any charge or dipole is an equal inflow of EM energy from the complex plane (from the time domain). Thus EM energy flow is locally conserved in four dimensions as a 4-circulation, but not in 3-space. EM energy flow in 3-spacc is conserved over all space, since there are essentially equal amounts of positive and negative charge in the universe and in the virtual charge of the vacuum.

gauge: In electromagnetism, usually considered a possible choice for (change of) electric scalar potential and magnetic vector potentials, in such a manner that there is no any *net* change of force fields so that the change satisfies Maxwell's equations. There are indeed two changes of force fields, but the two are selected so that the two new force fields are equal and opposite, constituting a stress potential and continuously performing internal work on the system to create and maintain the excess system stress. The equal and opposite force fields, however, cannot translate electrons through loads to freely power them. We prefer to consider any change of potential — even a single potential changed, or both changed so that a net force field does result — as a "regauging", for it is an implied primary assumption *within the normal use ofthe term "regauging."* If only one potential is changed, a net force field results in the system and we call that "asymmetrical regauging". If both potentials are changed, but in such a way that a net force field still results, that is also an asymmetrical regauging. When both potentials are changed precisely in such highly selected manner that the two force fields created are equal and opposite, the force fields sum to a *translation* vector zero, and that is symmetrical regauging or *Lorentz regauging.* However, the energy of the two fields remains, having been transposed to a stress potential. Each of the two "balanced" equal and opposite force fields is continuously performing work in the system, but all that is created is additional system stress. Hence symmetrical regauging is obtained only by altering the stress and stress energy of the system, with two disequilibria in energy flow between the external environment and the system. This in fact constitutes both a curvature of the local spacetime and an alteration of the local active vacuum. It is a rotation of the frame of the regauged system out of the laboratory frame. In effect, the net EM field energy of the two new fields created by symmetrical regauging is transformed into a change in the local spacetime curvature, a change in the local vacuum, increased stress in the system, and rotation of the system's frame away from the lab frame. We focus upon the energy aspects, since in a system any change of potential - whether symmetrical or asymmetrical — is a change of the internal energy of the system, and therefore of its excitation. In a system, conventional "symmetrical force fields" regauging results in a *nonusable continous* energy change in the system (actually two of these changes), and a change in the internal stress of the system. In short, it is a special case of **adding** a *stress potential* to the system, which we consider a special form of *asymmetrical regauging of the supersystem* consisting of (i) the system and its dynamics, (ii) the local active vacuum and its dynamics, and (iii) local spacetime curvature and its dynamics.

gauge freedom: The axiom in gauge theory that one can freely change the gauge **(and** therefore the potentials and the potential energy) of an EM system, so long as the net new forces resulting from the change will sum to a zero **vector** resultant so that the system remains "symmetrical" in its **force-field** functioning with respect to the system prior to the change of potentials. Electrodynamicists do not seem to have recognized that the freedom to change the potential of a system at will, is *a priori* the freedom to make a purely negentropic change to increase the system's potential energy, or a purely entropic change to decrease the system's potential energy. Gauge and gauge freedom are actually formal restrictions of an even more important asymmetrical regauging principle: *a potential in a system can be freely changed at any time, thus freely changing the potential energy energy of the system freely and at will.* The additional symmetry assumption is an arbitrary added requirement not imposed by nature.

Further, it appears that physicists have not recognized that a longitudinal EM wave is an oscillating gauge varying in its magnitude. Said in reverse, oscillating *the Lorentz regauging condition for a circuit makes that circuit* ***a generator*** *and emitter of longitudinal EM waves.* This also provides a clue for detection of longitudinal EM waves, similar to what occurs in a Fogal semiconductor used for that purpose. A longitudinal EM wave detector must detect a variation in the symmetrical regauging condition, which is a stress change detection.

gauge symmetry: Abstract mathematical symmetry of a field, that relates to the freedom to regauge (change the value of) potentials, without affecting the *net resultant* values of the field quantities. This is a special case of the higher principle that any potential (and thus the potential energy of a system) can be changed freely and at will. However, changing the gauge of an EM system in that sense changes the potential energy of the system but *only in stress potential fashion.* In other words, it does nontranslating work on the system, which is called "internal work." The lack of a net resulting force in the system, created by the regauging symmetry, prevents use of this excess free energy to translate system charges and power an external load. All the excess free energy that could otherwise be used to power loads freely, is instead "locked up" to only perform internal work on the system to increase and maintain system stress.

gauge theory: A field theory using a field that has one or more gauge symmetries. The restriction to symmetry is a carry-over of the old erroneous notion that potentials are just convenient mathematical figments, and that fields are the primary causes of all EM phenomena. For the overunity researcher, broken gauge symmetry at a given level (usually in 3-space EM energy flow) is the feature that must avidly be sought in experimental systems if one would use asymmetrical regauging to allow free powering of loads. Hence one is primarily interested in a wide variety *of broken symmetry effects* and phenomenology. Particularly, unless the automatic self-enforcing of symmetrical gauge transformation during excitation discharge of the closed current loop system is violated, no EM system can produce COP>1.0. Further, local spacetime curvature between local input and local output is always involved in an overunity EM power system. The tempic (time) potential of the output end of an overunity system differs from the tempic potential of the input end, so that the gradient (the tempic force) is directed from output to input — exactly the reversal of the case for a COP<1.0 power system.

Thus in both COP<1.0 systems and COP>1.0 systems, a local spacetime curvature is involved when the system is in operation. In COP< 1.0 systems, the tempic force sweeps along from input to output and on into space beyond, where the violent interactions of vacuum absorb the associated Dirac sea hole current immediately. In COP>1.0 systems, the tempic force sweeps along through the local vacuum from the output section back through the system and into the input section, and thence on back through the external conductors to the external power source. This reversed Dirac sea hole current may "eat electrons" in the normal currents

internal to the system, and in the input section and back towards the external power supply it will "eat input electrons in the input current." Thus the Dirac sea hole current in the COP>1.0 system "eats input power" and serves as a curious new kind of electrical "load" or "internal loss" in the **input** section of the system. The reversed Dirac sea hole current is nature's way of decaying the local curvature of spacetime back to a flat spacetime, and decaying the COP>1.0 excited system disequilibrium state back **to an** equilibrium state. In any overunity electrical power system, this Dirac sea hole current must be taken into account and either transduced into useful power, minimized, or eliminated. An extension to gauge field theory is needed in which the tempic force, the tempic potentials and their gradients, and the supersystem are all modeled and taken into account. It appears that the Sachs unified field theory is capable of handling that requirement, which also can be accommodated by O(3) electrodynamics to provide engineering of the resulting unified field theory.

gauge **transformation (in electromagnetics):** Conventionally taken to be the addition of the gradient of some function of space and time to the **magnetic** vector potential—and simultaneously the addition of the negative of the partial derivative of the same function with respect to time, divided by the speed of light, to the electric scalar potential. The resulting symmetrical change assumes that the stress energy of the system is changed **freely,** but by design it deliberately prevents any stress difference in the system to produce a net force that could expend the free change of energy by doing work in an external load. Changing the stress energy alone is a curvature of spacetime and a purely gravitational change. It is also a **rotation** of the frame of the system away from the laboratory frame. See discussion under gauge theory.

general theory of relativity: Einstein's theory of gravity in which the gravitational force is represented by a curvature in spacetime, and in which spacetime is an active entity. We may look at all forces as being due to curvatures of spacetime interacting with mass.

geometric phase: A phase difference acquired by the state function of a quantum system that undergoes a cyclic evolution from an initial state and back. This phase difference can be detected by interfering the final and initial states. The modern generalization of the Aharonov-Bohm effect and the Berry phase.

giant negentropy **(of the dipole):** The continuous receipt from the time domain **of spacetime** (the vacuum), by one charge of any dipolarity (including **a** single charge's fundamental dipolarity), of enormous longitudinal EM wave energy flow in condensed time energy form, transduction of that absorbed energy from the complex plane into real 3-space, and continuous emission of that enormous energy flow in all directions in 3-space, thence receipt of that 3-space energy by the other charge of the dipole or other adjacent dipoles, retransduction of the energy back into time-energy, and re-emission of that energy back into the time domain. This 4-circulation giant negentropy process is evoked and continues automatically and indefinitely after a little energy has been expended to separate the charges and make the source dipole. The EM waves in the input from the time domain and the output in 3-space are perfectly ordered and correlated, which is a giant ordering of the vacuum/spacetime and is thus a giant negentropy. In conventional circuits, the source dipole in the generator or battery, once made, performs this function. Only a minuscule fraction (some 10^{-13} in a nominal case) of the energy pouring out of the generator's or battery's terminals strikes the surface charges of the attached external circuit and is diverged into the conductors as the Poynting component that powers the Drude electrons and the circuit. All the rest of the energy flow (the Heaviside nondiverged component) outside the circuit is just wasted by conventional circuits.

gluon: A particle that carries the forces between quarks. In quantum chromodynamics, the gluon plays a role analogous to the photon in quantum electrodynamics.

graviton: In the quantum theory of gravitation, the graviton is the quantum of the gravitational field. It is massless, with spin 2. In the new theory we may take the graviton as a coupled scalar and longitudinal photon pair.

gravity: The phenomenon characterized by the physical attraction between any two material bodies of positive mass, specifically due to the trapped positive energy in the masses. If one particle is of negative mass and energy, the normal gravitational attraction between the two particles is reversed so that they repel, which produces antigravity. The fundamental mechanism of gravity can be found once one realizes that Maxwell omitted the incoming EM wave interaction with the nucleus, and not with just the electron shells. When he wrote his theory, the electron, atom, neutron, proton, and neutron had not been discovered yet. The lateral precession movement of the spinning Drude electrons — which are restrained *longitudinally* to a very small drift velocity in detecting wires (antennas) — later came to be considered proof of Maxwell's transverse EM wave in the vacuum. The detected electron precession wave is oscillating laterally, hence proves the longitudinal EM wave interaction. Elsewhere we have pointed out that the EM wave in space is longitudinal EM wave accompanied by a corresponding time-polarized (scalar) EM wave, and it also follows from Whittaker's 1903 paper as reinterpreted by the present author in our Giant Negentropy paper.

gross particle translation: Refers to translating the entire particle — and its internal structures and dynamics — in space, rather than internally structuing the particle's potential (massless charge). Note that, if the internal structuring (engines) of the particle is changed during translation (e.g., by passing through a region of the flat spacetime having an altered internal engine structure), the particle may have an anomalous interaction with another particle or process having a different internal structure or "dimensioning." The mass-energy comprising the particle's nucleus, electron shells, etc. can be dimensioned. Mass so dimensioned or conditioned then may act differently in chemical reactions, effects on living systems, etc. than normal "inert" mass that has no specific deterministic dimensioning.

group: A mathematical structure that is a complete set of transformations on a mathematical entity that leaves the entity unchanged.

group, higher symmetry: In a given theoretical area, a particular theory can be expressed in various group transformations. When the group transformation (group symmetry) utilized is more complex than the "standard" group symmetry usually employed, it is referred to as a *higher* group symmetry. The mathematics of the model is then said to be a higher group symmetry mathematics. Since the groups have names such as U(1), SU(2), O(3), etc., the transformations of the mathematics are often referred to by **those** names. Hence characterizing phrases are used such as U(1) symmetry electrodynamics, SU(2) symmetry electrodynamics, O(3) symmetry electrodynamics, etc.

group, Lie: A group whose transformations act continuously. An example of a Lie group is given by rotations in ordinary space.

group theory: The general mathematics of symmetry transformations; i.e., the the**ory** of all transformations that leave the transformed entity or entities unchanged.

gyroelectrons: Spinning electrons considered as gyroscopes during the portion of their spin in 3-space, so that when longitudinally perturbed they can and will laterally precess. Considering (in a gross first order model) the conduction electrons in the Drude gas in a conductor as little gyros, because they are (i) spinning on an axis, (ii) severely restrained in their ability to move forward longitudinally down the conductor as current, and (iii) much more free to precess laterally in the conductor. Thus when the gyroelectrons in the receiving wire antenna, perturbed by an incoming longitudinal EM wave in the vacuum, are longitudinally perturbed, they precess laterally so that our instruments (which detect electron wiggles, not the incoming vacuum EM wave) do detect "transverse waves." However, they are detecting the transverse gyroelectron precession waves, not the waves in the vacuum. They are detecting the *effect* of the interaction of the incoming waves with the gyroelectrons, not the *cause.*

harmonic series: A set of frequencies or oscillations consisting of integer multiples of a fundamental frequency.

Heaviside, Oliver: Noted English self-taught physicist and brilliant electrodynamicist, 1850-1925. who played a role in discarding Maxwell's quaternions, and also played a role in forming vector mathematics and formulating the vector reduction of Maxwell's theory from 20 quaternion equations in some 20 unknowns to the present 4 vector equations. Heaviside's curtailment of Maxwell's theory still contained both (i) systems in equilibrium with their active environment and (ii) systems in disequilibrium with it. To separate variables and enable closed solutions, *Lorentz further* curtailed the Maxwell-Heaviside equations by symmetrically regauging them, thereby *arbitrarily* discarding all disequilibrium Maxweilian systems and retaining only those in equilibrium with their active environment. This regauging unwittingly and erroneously discarded all that class of Maxweilian systems permitted to exhibit COP>1.0. The first such curtailment of the Maxwell equations was by Ludwig Valentin Lorenz in 1867, but H. A. Lorentz (who did a similar symmetrical regauging nearly decades later) was later given the credit.

Heaviside also discovered the enormous *nondiverged* energy flow surrounding every circuit, far greater in magnitude than the feeble Poynting *diverged* component that actually enters the circuit. But he was at a loss to explain what the source of such a startling flow of energy could be. Lorentz understood the Heaviside component, but also could not understand its source. Hence he reasoned that it "had no physical significance" since it did not power the circuit. Lorentz then introduced the trick of integrating the entire energy flow vector around a closed surface surrounding any volume element of interest. This neatly discards the vexing giant Heaviside *nondiverged* energy flow component, and retains only the *diverged* Poynting component that actually enters the circuit. The latter is of course the energy that will later be *emitted* from the circuit, which is what we will measure when we "measure the circuit."

Electrodynamicists are still using this method of dropping the Heaviside energy flow from any further accounting consideration. Hence they do not develop systems which intentionally increase their energy collection from this readily available energy flow around every circuit. The Bohren experiment conclusively proves the physical existence of the Heaviside nondiverged component, even though it is no longer accounted.

In his last years Heaviside realized the gravitational importance of his extra energy flow component, and worked out an electrogravity theory based on it. He did not live to publish it, but his papers on it were found some time after his death, beneath the floorboards of his little garret apartment. A learned society then published the papers.

Heaviside energy flow component: The enormous *nonintercepted* and nondiver*ged* energy flow component pouring out of the terminals of every battery or generator, or charge or dipole, and missing the external circuit (or external intercepting charges) entirely so that it is does not contribute to the intercepted (Poynting) flow component that powers the circuit. Also, the enormous energy in the EM field, potential, or wave that misses the interaction of the field, potential, or wave with the assumed unit point static electric charge, and thus is not intercepted and collected (and accounted!) in the unit point static charge assumption. In honor of Heaviside, the present author has nominated this "dark Heaviside energy" component as the missing source of excess gravity known to be holding the arms of the spiral galaxies in place. In the interactions of Dirac hole current with a unit point charge (to determine the negative energy fields and potentials in a COP>1.0 EM system), there is also a missing component of the negative energy flow that is comparable to the Heaviside component for positive energy flow. These flows of surplus negative energy **from** COP>1.0 astronomical interactions—with the associated negative energy fields and negative energy potentials produced by the **negative**-energy Dirac holes in these negative energy flows — is hypothesized by the present author as producing the antigravity that generates the observed acceleration of the expanding universe.

Hertz, **Heinrich:** Noted German physicist, 1857-1894, who together with Heaviside and others transformed Maxwell's theory from quaternion algebra to vector algebra, and who also experimentally produced Hertzian (EM) waves, thus confirming Maxwell's theory. These experiments by Hertz first detected EM energy propagating as described by Maxwell's equations, thus providing the experimental impetus that allowed Maxwell's theory to predominate. The oscillation or "cycle" is named after Hertz, by specifying *X* number of oscillations or cycles per second as a frequency of *X* Hertz. One type of potential is also named after him.

hidden bidirectional EM waves: Those bidirectional EM wavepairs that comprise the scalar potential are indeed "hidden" with respect to our normal "electron translation" (i.e., electron wiggle) detectors and instruments. Nonetheless, properly functioning devices such as Fogal's semiconductor allow the utilization, transmission, and reception of the vast longitudinal EM wave dynamics that are infolded inside all conventional EM fields, waves, and potentials, including the giant potential comprising the ambient vacuum (spacetime). Use of this infolded electrodynamics is akin to using "subspace" or higher dimensions, depending upon how one chooses to model it mathematically. It is also a direct method of using a unified field theory.

hidden variable theory: A class of quantum mechanical theories which considers that the quantum state of a physical system is not a complete specification after all. The "hidden variables" are those additional components necessary to provide the "complete state" of the system. By utilizing the infolded longitudinal EM wave electrodynamics, one is in fact using a macroscopic hidden variable theory. This becomes a subset of Evans' O(3) electrodynamics, which in turn is an important subset of Sachs' unified field theory. Sachs' theory encompasses and subsumes electrodynamics, general relativity, quantum mechanics, etc., so the use of this macroscopic hidden variable theory through special functions provided by components such as Fogal semiconductors is a powerful and directly engineerable extension of conventional hidden variable theory. The physics of this new, engineerable, unified field theory area is also called *energetics.*

hole, lattice: Vacancy, in an otherwise filled energy band position. Sometimes called *negative ion vacancy.* In a semiconductor, an electron may be lifted to the conduction band by thermal energy, which produces u hole-electron pair (an exciton). Also, one of the sites in the crystal lattice can be occupied by an acceptor impurity atom, so that the electron is accepted there, leaving a hole showing excess positive charge. This is a lattice hole, and the propagation of such holes being formed is called electron hole current, or hole current for short. We point out that the *laittice hole* exists only after interaction of the Dirac sea vacuum hole with matter. i.e., only after observation. In that case, the 3-positron (hole) has positive mass and positive energy, produces positive energy fields and potentials, produces gravity rather than antigravity, and is "seen" to be going in the opposite direction to the Dirac sea hole. Prior to observation, the hole is a

Dirac 4-hole in vacuum, having negative energy and therefore negative mass equivalence, negative charge, and without a direction reversal. This 4-hole is a source of negative energy fields and negative energy potentials in **the** surrounding space, and thus of antigravity back-interaction (upon the physical system connected with the active vacuum component of its supersystem) due to the negative curvature of the local spacetime.

hole, Dirac sea: In the presence of fields (i.e., in the presence of curved space**time),** some of the negative energy states in the Dirac sea are not filled with electrons. In that case there are some empty 4-holes in the Dirac sea, in local spacetime itself. The Dirac hole is a negative energy state in the **vacuum** itself. It too *seemingly* has a positive charge, as seen by the external observer after interaction with matter. Holes are also mathematically equivalent to positrons, in case observation has been evoked, so long as the lack of positive mass is not a consideration Note that our view differs from the received view, but is based on experimental evidence which can only be gained from COP» 1.0 EM system experiments. We know of no such COP» 1.0 EM system experiments involved in the received view.

hole current: (1) In a semiconductor: Usually, the part of the current in a seminductor that is composed of migration of lattice holes. ***Mathematically,*** within certain constraints this may be considered a positro*n* current. The hole migration is usually slower than the electron migration producing electron current. (2) In the vacuum itself. In the *Dirac sea, in* **the** presence of fields the Dirac 4-holes flow in the opposite direction to the local electron current, providing a Dirac sea hole current or posit**ron** current. [See discussion under hole.] An electrical power system in disequilibrium with its vacuum interchange and having COP>1.0, will have a **greater** *tempic potential* at its output section than at its input section. Thus it will have a tempic force or tempic broom, sweeping holes from local instabilities to form a hole current (may be both a Dirac sea hole current and a lattice hole current) flowing from the output section of the system back through the system into the input section, and on out of the input section into the primary power source. *Hole current transduction may be* used to convert this detrimental hole current energy transport into usable **electron** current energy transport, or anti-circuit techniques and mechanisms can be used.

hole current transduction: Hole current in a COP>1.0 open system, where **the** system is in disequilibrium with the vacuum *a priori,* is usually detrimental to (he system and may destroy the overunity condition. A hole current from the input section of the system, fed back into the primary power supply, requires that extra electron current be furnished since some of the electrons in that furnished current will recombine with the oppositely moving Dirac vacuum holes and disappear to fill those holes. Hole current into a battery in "normal" fashion discharges the battery rather than charges it (although reversing the battery terminal connections allows charging in normal fashion using the hole current). Thus a battery can be discharged "far below zero", so to speak, by charging it with excess holes in the "normal connection." A capacitor may be charged with hole current, in which case the dielectric will undergo compressive strain into the positron-charged plate. However, when the capacitor is subsequently discharged, the dielectric will expand and recover, with its electron charges pushing electrons out of the negative side plate and into the external circuit. Hence a capacitor can be *charged* with positron (hole) current, and then can be adroitly switched so as to *discharge* electron current. In theory so can a battery because of its capacitance. This is a transduction of entropy to negentropy, a process for which a patent application has been filed by Bedini and Bearden. Gauge freedom already permits that operation, since gauging in electromagnetic systems is freely changing the local potential energy of the system, and is either negentropic (increasing the system's energy) or entropic (decreasing the system's potential energy).

hole injection: In an n-type semiconductor, holes can be emitted by applying a metallic point to the semiconductor's surface. We suspect (but have not proved) that sharp gradient pulses may also induce some of these holes as Dirac sea 4-holes and Dirac sea hole current rather than positron and lattice holes current. In that case, a mix of positive energy and negative energy (and gravity and antigravity) would be produced.

hole trap: An impurity in a semiconductor that can trap a "hole" by releasing electrons to the conduction or valence band.

hyperspace: Refers to a space of more than four dimensions, and specifically to those spatial dimensions outside the normal three. The term is used for both a space of n dimensions, where n>4, or for one dimension in such a space, beyond the normal four.

identity of opposites: On the boundary between A and not-A, A and not-A are identical (i.e., no difference can be discriminated). If all of a thing is collected, one reaches the boundary of that thing and it turns into its own opposite. The philosopher's problem of the "accursed necessity for the identity of opposites" cannot be solved in Aristotelian 3-law logic, since that logic is incomplete. It is readily solved, and part of, a more extended logic such as 5-law logic. The result is that "identity" is not an absolute entity, but is a decision by the observer reached by application of a comparison algorithm to separate observations made at differing times. An example is provided by a colorblind observer who sees as identical two marbles which, to an observer with color vision, are seen as red and black and therefore not identical. Aristotelian logic omits the action by the observer, the times of the multiple observations (only a single thing at a time is observed or perceived, *a priori),* and the decision algorithm used *by the* observer to decide whether two observations are identical or not identical.

inertial frame: A frame of reference in which force-free bodies move along straight lines, and the postulates of special relativity are valid. In the new a**pproach,** this notion is extended. Even in an inertial frame, force-free **bodies** may move along straight lines, the postulates of special relativity may remain valid, and yet the EM hidden variables may induce other chan**ges** in the usual laws of nature due to the action of hidden vacuum engines infolded in the *dimensioned* local flat spacetime (vacuum **potential).** See Einstein's second postulate extended.

infolded real vector components: Simply take a set of real force vectors that altogether sum to a vector zero resultant. This "vector zero system" is a zero vector with respect to forced *translation* of a particle or mass. It is not am absence of the vectors at all, but is the presence of specifically hidden and "infolded" real vectors that do not initiate bulk translation of the affe**cted** object or system, but perform *internal* work upon the system. Such vector systems are stressing systems of a special kind, where the internal components of the stress are not random but deterministic. Hence they are electrodynamic *engines,* in the new approach. To a somewhat arrogant mathematical scientist who once objected that zero vector resultant systems had no effect, I humorously challenged him to put it to experimental test. I suggested he stand between two elephants pushing against him in opposite directions, while I would stand between two fleas doing the same to me, and we would compare notes. He apparently was not amused at the suggestion.

infolding: With reference to signals, infolding means "placing the signal **or modulation** or change upon one or more of the internal bidirectional wave**pairs** comprising the scalar potential. Since all EM potentials ultimately represent changes to the ambient vacuum potential, one has conditioned or altered the vacuum itself when infolding is utilized, infolding of E*M* signals, vectors, and directions produces *engines*. By Whittaker's decomposition of the potential and Bearden's reinterpretation, these vacuum engines can be designed to affect matter — including atomic nuclei, nucleons, etc. — in any manner desired.

information content of the field: Russian euphemism for the deliberate structuring of the hidden longitudinal EM waves and their dynamics, that comprise any EM potential, field, or wave, so that the potential, field, or wave is *dimensioned* and contains active *engines.* This area was extensively weaponized under KGB (now changed in name) control rather than the regular Russian armed forces, and a disinformation campaign was waged to convince Western analysts that the term refers to simple spectral analysis. It doesn't. Instead, it refers to infolding and outfolding, and the use of longitudinal EM waves, dimensioning, and engines. The overall science is called "energetics" by those weapon scientists.

interferometer: An instrument or system in which a wave is split into two waves or beams, which after traveling over different paths are subsequently reunited and interfere. The use of longitudinal EM waves (LWs) allows ready penetration of mass by the LWs traveling through the interior Whittaker composition of a mass's internal EM fields, waves, and potentials. Longitudinal EM wave interferometers should prove useful in probing the interior of planets, the sun, etc. They pass easily through the earth, so that interferometry can be obtained at targets on the opposite side of the earth, or inside the earth. These are the weapons that then Secretary of Defense Cohen referred to in 1997 as being used to engineer the weather, initiate volcanoes into eruption, or initiate earthquakes.

Josephson effect: Flow of Cooper pairs (superconducting electron pairs) across a thin dielectric separating two superconducting electrons, in the absence of a voltage drop. E.g., the pair of electrons can "tunnel" through u thin insulating barrier.

joule: A measure of energy; one watt for one second in electrical terms. In physics the unit of work or energy in the MKS system, being the amount of work done by one newton acting through a distance of one meter, equal to 10,000,000 ergs.

Kirchhoffs current law: At any time, the sum of the instantaneous currents flowing into a node or point in a circuit equals the sum of the instantaneous currents flowing out of that node or point. This does not have to be true if (1) relativistic effects are appreciable, or (2) electron production and annihilation processes — such as Dirac sea hole current, lattice hole current and recombinations are occurring and non negligible, (3) the Kron open path is being used, or (4) localized time reversal zones (TRZs) are utilized. Another way of stating where the law need not hold is when there are nonlinear interactions between the three components of the superset (the physical system and its dynamics, the active vacuum and its dynamics, and spacetime and its curvature dynamics.).

Kirchhoff's voltage law: At any time, the sum of all voltage rises in a closed loop circuit equals the sum of all drops in that closed loop circuit. The law assumes a flat spacetime. This does not have to be true if relativistic effects are appreciable, if true negative resistor effects are present, if Kron open paths are utilized, and if time-reversal effects arc present. It also need not be true in anti-circuit techniques, or when they are involved in a particular portion of an otherwise normal circuit.

Lamb, Willis Eugene Jr.: American physicist and Nobelist who discovered the hyperfine structure of the hydrogen spectrum, and first measured the interaction of the vacuum energy that generates a change in the energy levels of the hydrogen atom, according to Dirac's theory and quantum electrodynamics.

Lamb shift: A very small correction to the first excited state of the hydrogen atom due to interaction of the vacuum. Willis Lamb experimentally confirmed this prediction of quantum electrodynamics to high accuracy. The local energy density of the little Lamb shift is greater than the surface energy density of the sun. However, in matter there are such a vast number of similar small interactions generating very powerful fields randomly, that the sum total of all these changes sums to a vector zero for most summation distances of interest.

lamellar current: Thin layers of current; thin sheets of current.

laser: A device that generates light in which all the photons are exactly in step and produce a coherent beam. Originally the word "laser" was an acronym that stood for "light amplification by stimulated emission of radiation."

law of physics: A restriction placed upon the physical mechanisms that can occur under certain broad assumptions as to the background situation and environment. Because of the assumptions made, an expressed law of physics is not absolute, but relative to the assumed conditions. Any "law of physics" can be violated if the conditions contained in its assumptions are violated. It is important that a scientist be aware that physics is comprised of models and the "laws of physics" are very general and wide-ranging models based on very specific assumptions. Further, by Godel's theorem and the theory of models, no model is perfect anyway, and none will ever be. When one assumes that physical laws are not based on any assumptions but are universal and absolute truths, one has immediately moved to dogma and not science.

Lawandy patents: Patents covering and related to a form of anti-Stokes emission (excess emission of energy) in strongly scattering, optically active media such as TiO_2 particles in suspension. This is a new form of lasing, without the requirement for population inversion.

Letokhov, V. S.: Russian pioneer in excess emission phenomena from stimulated media.

Letokhov effect: The excess emission (excess emission of energy) phenomena in strongly scattering, optically active media, usually referred to as "negative absorption of the medium." See particularly V. S. Letokhov, "Laser Maxwell's Demon," *Contemporary Physics,* 36(4), 1995, p. 235-243.

localized: Confined to a small region of a large system rather than being extended through the system or at a distance.

localized virtual photon flux of vacuum: Refers first to a local region of the vacuum, and then to the flux density of virtual photons in that local region. If that flux is deterministically structured, then the local region also contains an *engine* that will act internally upon masses and mass systems in that region. The local region also contains hidden variables.

longitudinal component: In EM fields, the longitudinal component of the fields along the direction of travel, as opposed to the transverse components at right angles to the direction of travel.

longitudinal E-field: Any electrical field in 3-space may be described using two components, a transverse component and a longitudinal component. Of course one or the other may be a vector zero. In 4-space, there is a time component also, as an additional "transverse" component.

longitudinal gradient: Compression wave gradients (differences) in density or pressure, considered in a direction from their origin along the direction of primary movement in the medium. Contrast to transverse waves, which act perpendicular to their direction of propagation. In electrodynamics, longitudinal EM waves in 3-space are said to be "longitudinally polarized." Longitudinal EM waves in the time-domain are said to be "time polarized." The latter are also referred to as "scalar waves" since they have no polarization vector component in 3-space and thus arc "scalar" with respect to 3-space. This is a misnomer, however, since these "scalar waves" are perfectly good time-polarized EM longitudinal vector waves. For the first time, the giant negentropy process allows one to make and use time-polarized EM waves, since they automatically accompany all longitudinally polarized EM waves and it is straightforward to make longitudinal EM waves in 3-space (just oscillate the Lorentz regauging condition).

longitudinal interior wave: An infolded longitudinal gradient that oscillates in magnitude along the line of travel "inside the vacuum potentiaI or a normal potential." In conventional theory, the electric portion of the EM wave is a transverse field oscillation, and the longitudinal component is essentially zero. In the new "infolded" wave approach, there is no overall transverse gradient in the vacuum potential, but there are such longitudinal waves. This is rather like a "pressure wave" transmitted underwater, without causing a surface wave involving physical upheaval and fall-off of the water. The speed of the longitudinal EM wa**ve** is not limited to c, the speed of transverse EM wave light in the ambient vacuum..

longitudinal wave: A "pressure" type of wave, similar to sound, in which the vibrations are along the direction of travel of the wave. Hence, a wave composed of alternating densifications and rarefactions, where we focus upon the longitudinal component of the changes. One can think of it as a sort of "accordion" wave, rhythmically shrinking and stretching along the line of motion as it travels. Note that rhythmically and symmetrically varying the two potentials involved in regauging creates longitudinal EM waves. So one pseudonym for longitudinal EM waves is "gauge oscillation" waves. Matter is mostly empty space filled with EM potentials, fields, and waves—all of which are bundles of longitudinal EM waves and their functional dynamics. Hence matter (such as the ocean and the earth) is a vast superhighway for the passage of longitudinal EM waves. Note that the longitudinal wave represents an oscillating energy density in space and/or time (scalar waves), and hence is an oscillating curvature of spacetime. All forces of nature are generated by curvatures of spacetime. Hence all forces of nature can be generated by the correct generation of longitudinal EM waves and their impressed dynamics, Further, this means that all the physical *causal* functions of the exhibited **effects generated** in a material system can be captured in longitudinal EM wavesets. A longitudinal wave functional system deliberately having such causal functions of a physical functioning system is known as a causal **system robot** (CASR). Such robots are far beyond the presently developing nanobots, and have been developed rather extensively by at least one nation. Such robots can easily pass through the "interior" of any normal

EM signal or wave or potential or field, which again is nothing but a giant superhighway for longitudinal EM waves. In theory one can communicate with a CASR via longitudinal EM waves if communications functions are built in to the CASR. In the future, one would expect that planetary exploration, underground and undersea exploration, exploration of the interiors of the sun, moon, and planets, could be enabled by the further development of specialized CASRs.

Lorentz, Hendrik Antoon: Renowned Dutch physicist and Nobelist. 1853-1928, who developed the Lorentz transformations and Fitzgerald-Lorentz contraction. Lorentz shared the Nobel Prize for discovering the Zeeman effect. He is also responsible for symmetrically regauging Maxwell's equations (some time after Lorenz did it in 1867), and for introducing an integration trick that neatly disposes of the vexing huge Heaviside nondiverged energy flow component accompanying every field/charge and potential/charge interaction.

Lorentz invariance principle: An inertial frame is independent of the velocity of the frame relative to any other inertial frame. This is not necessarily true with respect to engines inside inertial frame objects, since the engines involve acceleration dynamics.

Lorentz regauging: Changing the two potentials in the Maxwell-Heaviside equations in potential form so that the resulting equations have the variables separated, and there is no net force introduced by the two new forces, which are deliberately chosen so as to be equal and opposite and thus sum to zero. An unfortunate effect is that this discards all Maxwellian systems far from equilibrium in their vacuum exchange, hence discards all permissible Maxwellian COP>1.0 systems. Electrodynamicists have not recognized that Lorentz regauging represents the addition of stress potential energy and continuous internal work and stress to a regauged system. It also represents a rotation of the frame of that system out of the laboratory frame by some angle. Further, oscillating the Lorentz regauging condition produces longitudinal EM wave generation and emission.

Lorentz symmetry: The symmetrical regauging by Lorentz of Maxwell's equations.

Lorenz, Ludwig Valentin: Scientist who first changed Maxwell's equations — two years after their publication in 1865 — by (effectively) symmetrically regauging them, thereby unwittingly discarding all Maxwellian systems far from thermodynamic equilibrium with the active vacuum. See L. V. Lorenz, "On the identity of the vibrations of light with electrical currents," *Philosophical Magazine*, Vol. 34, 1867, p. 287-301. In this paper [L. V.] Lorenz gave essentially what today is called the [H. A.] **Lorentz** symmetrical regauging. When H.A. Lorentz also symmetrically **regauged** the Maxwell-Heaviside equations, the physics community **adopted** the procedure and resulting further truncation of the Maxwellian theory. That truncation continues to this day.

low energy **nuclear reaction** (LENR): Actually a bit of a misnomer, since it refers to a low *spatial* energy, high *time* energy reaction. Cold fusion, or the anomalous transmutations of elements that occur in certain electrolytes with specially prepared palladium electrodes. The transmutations occur even though in conventional theory there is insufficient *spatial* energy to accomplish them, because they use time energy. Time energy is spatial EM energy compacted by the factor c^2, hence time has the same energy density as mass. The formation of temporary, fleeting time reversal zones (TRZs), with action from from inside-to-outside, is the genesis of a host of new nuclear reactions missing from conventional particle physics since the physicists do not account time as energy, and do not use such TRZs. For more on this hypothesis and the specific reactions generated, see T.E. Bearden, "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves," *Journal of New Energy*, 3(2/3), 1998, p. 12-28 as well as Chapter 10 of the present book.

magnetic **dipole:** Paired north and south magnetic poles of equal strength ever microscopic or macroscopic distance.

magnetic induction: The act of a change in magnetic field producing an electric field at right angles, which in turn produces an electron flow.

magnetic spin: The intrinsic angular momentum, known as spin, of electrons, protons, and neutrons, etc. The electrons combined in an atom or ion have **a** resultant angular momentum that is the combined intrinsic spin of **the** electrons and the angular momentum due to their motion around **the** nucleus. There is also a magnetic moment associated with this angular momentum (spin) whenever it is nonzero. Therefore atoms or ions with non**zero** spin are *magnetic* atoms or ions. This is often loosely reffered **to a**s "magnetic spin." It is actually the magnetic moment of nonzero spin.

magnetostatic scalar potential: Continuous mathematical function whose value in space, at any point it occupies, represents the potential energy collected upon an assumed unit magnetic north-seeking charge (pole). There is a magnetostatic scalar potential between the poles of any magnet. This scalar potential is **also** subject to **Whittaker's** 1903 decomposition into a harmonic series of magnetic longitudinal phase conjugate wavepairs. Reinterpretation of Whittaker's wavepairs should be made according to Bearden, "Giant Negentropy of the Common Dipole," *J. New Energy,* 5(10, Summer 2000, p. 11-23. This reinterpretation agrees with quantum field theory; see Mandl and Shaw, *Quantum Field Theory,* Revised Edition, Wiley, 1993, Chapter 5.

matter: Highly condensed 3-spatial energy, compressed by factor c^2 and remaining in 3-space, and with the observation process *d/dt* having been applied to the fundamental masstime entity to provide mass as a frozen 3-space snapshot by stopping the flow of time momentarily. Matter, of course, has internal structure, order and organization, and dynamics. All matter is in a continuous energetic exchange with its active vacuum (4-spatial) environment. Matter stripped of its EM fields, waves, and potentials is called mass. Mass is an observable and therefore a frozen series of continual 3-space snapshots, formed by incessant photon absorption to change the mass *m* to masstime *mt,* with following incessant photon emission to change masstime *mt* back to mass *m.*

Maxwell, James Clerk: Brilliant Scottish scientist, 1831-1873, who first formulated the unified theory of electricity and magnetism. See *The Scientific Papers of James Clerk Maxwell,* 2 vols. bound as one, edited by W. D. Niven, Dover, New York, 1952, Vol. 1, p. 526-597 for his definitive paper, "A Dynamical Theory of the Electromagnetic Field," first published in *Royal Society Transactions,* Vol. CLV, 1865. In that paper, (see Niven's book) his general equations of the electromagnetic field are given in Vol. 1, Part III, "General Equations of the Electromagnetic Field," p. 554-561. On p. 561, he lists his 20 variables. On p. 562, he summarizes the different subjects of the 20 equations, being three equations each for magnetic force, electric currents, electromotive force, electric elasticity, electric resistance, total currents; and one equation each for free electricity and continuity.

Maxwell's famous book, *A Treatise on Electricity and Magnetism,* Oxford University Press, Oxford, 1873, Second Edition 1881 (Maxwell was already deceased), Third Edition, Volumes 1 and 2, 1891. Foreword to the second edition was by Niven, who finished the work. Maxwell had dramatically rewritten the first nine chapters to simplify his mathematics because of the resistance to it, with much new matter added and the forma contents rearranged and simplified. Maxwell died before finishing the rcsl of the second edition. The rest of the second edition is therefore largely a reprint from the first edition. The third edition edited by J. J. Thomson was published in 1892, by Oxford University Press, and later was published unabridged by Dover Publications, New York, 1954. J. J. Thomson finished the publication of the third edition, and wrote a "Supplementary Volume" with his notes. A summary of Maxwell's simplified equations are given in Vol. II, Chapter IX of the third edition. However, Maxwell had gone (in his second edition) to some pains to reduce the quaternion expressions himself, and not require the students to know the calculus of quaternions (so stated on p. 257). We note that Maxwell did not finish the second edition, but died before that. He actually had no hand at all in the third edition as to any changes. The Second edition was later finished by Niven by simply adding the remaining material from the previous first edition approved by Maxwell. The printing of the first nine chapters of the thirg edition was already underway when J. J. Thomson was assigned to finish the editing of the manuscript.

Maxwell's work profoundly affected the course of science and the course of human history. Maxwell, Heaviside, Hertz, Gibbs, Lorcntz and others participated in dramatically curtailing Maxwell's original 1865 quaternion theory to the much more limited subset that it is today. Since the early part of the 20th century, work has slowly been ongoing to move EM theory back to a higher group symmetry theory, which ironically it already was when Maxwell first created it.

Max**well's** electrodynamics: Simply put, Maxwell's theory of electrodynamics consists of Maxwell's equations. His fundamental theory consisted of some 20 quaternion equations in 20 unknowns, appearing in his 1865 paper. After Maxwell's death and some curtailment by Maxwell himself, Heaviside modified and sharply curtailed these equations, into the familiar four equations of today, as did Gibbs and Hertz. Lorentz further curtailed the Maxwell-Heaviside equations, by symmetrically regauging them. This simplified their mathematical solution, but it also inadvertently and arbitrarily discarded all open Maxwell systems far from thermo**dynamic** equilibrium with their active environment (such as the modern active vacuum). See James Clerk Maxwell.

Maxwell's Theory, fluid dynamics analogy: *Considering and adapting the fluid analogy approach of James Clerk Maxwell:* The intensity of the vacuum virtual particle flux may be treated as the intensity of a potential, thus by analogy corresponding to pressure in a fluid. Polarity (charge) is a **process for** establishing a change in the intensity of the vacuum potential - and **thus** a change in the ambient pressure of the vacuum fluid. Dif**fence** between vacuum pressures at two separated points creates a force u**pon** any charge placed between those two points. Just as a differential in pressure between points in a fluid induces currents, a differential in vacuum pressure induces energy flow currents in the vacuum fluid, which are called 'fields'. All EM circuits, charges, potentials, and forces in electrodynamics involve altering the vacuum to include altering its pressure and thereby producing the forces the resulting pressure gradients (fields) induce upon charges. All observable EM energy in space is EM energy intercepted and collected on charges, or assumed to be, and the spatial EM energy comes from the vacuum via these fundamental vacuum-engineering dynamics which all involve the giant negentropy 4-circulation between the time domain and 3-space.

Michelson, Albert Abraham: German-born American physicist, 1852-1931, who invented an interferometer (Michelson interferometer) named after him. Michelson used his interferometer in a renowned experiment in the 1880s designed to measure the velocity of the earth through the ether, which would produce a shift in his interferometer pattern. No such shift was observed, which indicated the absence of an ether wind and was largely responsible for the downfall of the concept of the material ether that had been previously assumed, including by Maxwell.

motionless electromagnetic generator (MEG): Transformer-like COP>1.0 electrical power generator invented by Patrick, Bearden, Kenny, Hayes, and Moore, ""Motionless Electromagnetic Generator," U.S. Patent # 6,362,718, Mar. 26, 2002. A second patent application is processing and several more are in preparation. In particle physics, any dipole (including a permanent magnet) is a known asymmetry in the fierce vacuum flux, continuously pouring out real EM energy extracted from the vacuum. The MEG continuously powers its transformer section core with a permanent magnet dipole, more than doubling the EM energy made available from **the** active vacuum via the permanent magnet dipole's broken symmetry in its exchange with the vacuum. [See M. W. Evans, P. K. Anastasovski, T. E. Bearden et al., "Explanation of the Motionless Electromagnetic Generator with O(3) Electrodynamics," *Found. Phys. Lett.,* 14(1), Feb. 2001, p. 87-94; "Explanation of the Motionless Electromagnetic Generator with the Sachs Theory of Electrodynamics," *Found. Phys. Lett.,* 14(4), Aug. 2001, p. 387-393]. The MEG nanocrystalline core material extracts the magnetic field B of the permanent magnet from the surrounding space and localizes it in the core material. The active vacuum asymmetry freely replenishes the withdrawn magnetic B-field energy in space surrounding the core, but with uncurled magnetic vector potential A rather than magnetic field B. This is an application *of geometric phase,* specifically the well known *Aharonov-Bohm effect,* with several thousand papers in the literature. The MEG then transduces and outputs magnetic B-field energy inside the **core** material and some of the field-free magnetic vector potential A energy in space surrounding the core, effectively having available more than double the energy being made available from the permanent magnet, or normally available to a transformer. The output power of the MEG is a function of (i) the time rate of change of a small amount of input EM perturbation energy to the input coil, plus (ii) the intercepting and collecting secondary charges available in the secondary coil, (iii) additional energy from chaotic oscillations, (iv), sophisticated feedforward and feedback regenerative self-oscillations, and (v) the geometric phase (Aharonov-Bohm effect). It thus is a rigorous practical application of the geometric phase effect to a macroscopic power system, and in fact is the first such application in practical electrical power systems. The noted feature of the MEG is a purely electrical interaction in the output coils, in which the voltage and energy are in phase within 2°, differing from all other transformer-like systems. Thus the MEG directly delivers real power rather than apparent power. See Aharonov-Bohm effect.

multicollection (of energy): Multiple collection and re-collection in a circuit of the same energy flow from a source dipole, by rerouting either (1) the dissipated Poynting energy back around to the collectors for another pass by them, with additional collection, or (2) retroreflecting the nondiverged Heaviside EM energy flow component back and forth across the surface charges in the circuit conductors, iteratively diverging additional energy into the conductors to potentialize and power the Drude electrons, or (3) a combination of the two. The interesting point is that this effect can "use" the same energy to do repeated work, multiple times. It takes advantage of the fact that work is merely the change of form of energy, and that the new form can again be changed (as for example, back into the first form again) to do additional work, again and again so long as the energy in each transformation is held in the system without escaping. This process permissibly violates classical equilibrium thermodynamics and its infamous second law, since it is an open system freely receiving excess energy from its active environment and thus far from equilibrium with that active environment. As is well known, such systems are permitted to exhibit COP>1.0 and even self-powering of the system and its load simultaneously.

negative absorption of the medium: Excess emission from an active medium, as in the Letokhov work and in Bohren's experiment. The excess energy is first absorbed from the vacuum interaction (actually from Heaviside's unaccounted energy flow component that usually does not interact with the system), and then it is re-emitted. This is actually a true "Maxwell's demon," as pointed out by Letokhov.

negative resistor: Any component or function or process in an EM system that freely receives energy from outside the system in unusable or disordered form within the system, transduces that energy into usable form, and outputs it so that it can do useful work. In a *true* negative resistor, that is the *net* function performed. We specifically do not include "differential" negative resistors such as the tunnel diode, thyristor, and magnetron, which dissipate and disorder more energy from the system itself, overall, than the fraction that they order and furnish back to the system in their negative resistance regime. In anti-circuits, true negative resistors are quite natural components. Every charge and dipole in the universe is already just such a negative resistor, freely extracting unusable EM energy from the seething vacuum, transducing it, and continuously pouring out real observable EM energy in all directions in 3-space. A negative resistor can produce the five magic functions: (i) self-ordering, (ii) self oscillation or self-rotation, (iii) output more energy than the operator inputs, (iv) power itself and its load freely, and (v) exhibit negentropy. The condition for self-powering of a system containing a true negative resistor was given by Gabriel Kron.

negentropic: Functioning to produce or involve negentropy; reordering previously scattered energy without requiring the operator to input energy to perform the reordering. A simple example is passive retroreflection of radially scattered EM energy. The conventionally unaccounted enormous and nondiverged Heaviside energy flow component surrounding every circuit and every field/charge interaction is an example of a dynamically reordered and organized energetic vacuum, and thus an example of a **giant** negentropy process. The continuous observable EM energy freely pouring at the speed of light from every dipole and charge in the universe is also **an** example of the giant negentropy process.

negentropic engineering: Expending a little bit of energy to form a dipolarity, and then intercepting, collecting, and using some of the enormous EM energy freely and continuously extracted by the dipolarity from the vacuum, indefinitely, without using any of the extracted EM energy to scatter the charges in the dipole and destroy it. Retaining the dipole intact avoids shutting off the furnishing of copious free energy **flow** from the vacuum to the attached external circuit. As an analogy, it allows an electrical windmill operating in (driven by) a free electrical wind from the external environment of the system.

Newtonian recoil: Newton's third law reaction from the affected entity back to and upon the effecting entity. The "action" is the action from **the** effecting entity upon the affected entity. The "reaction" is the action from the affected entity back upon the effecting entity. Newton's third law actually implies that the cause interacts upon the effect and the effect reacts equally back upon the cause, thus producing a strange kind of equilibrium. In a time-reversal zone, the "recoil" is reversed in direction by parity reversal. Tentatively, one may interpret from pumped phase conjugation that the Newtonian third law reaction of one single acting force can be amplified by properly directing the actions of other acting forces. An interesting aspect is that a pumped phase conjugate mirror does not recoil, no matter how powerfully it is pumped or how powerfully amplified is the emitted phase conjugate replica wave.

Newton's third law: For every action there is an opposite and equal reaction. This law should be extended and restated something like this: "for every action there is an opposite and equal reaction if the causative mechanism of the reaction is allowed to occur without interference and is not first redirected away from its target." An example of a violation of Newton's third law as usually stated is provided by the emission of a phase conjugate replica (PCR) wave from a phase conjugate mirror material. No matter how powerfully pumped, the PCM does not recoil by the emission of the PCR wave. The reason is that the antiwave cause of Newtonian third law recoil was intercepted by nonlinear multiwave interaction (wave-to-wave **interaction)** before reaching its target nuclei and interacting with them, and was diverted away from the atom and on out of the phase conjugate mirror material. Since the causative mechanism for Newtonian recoil did not occur on the mass of the mirror, the mirror did not recoil. We also point out that, if Newton's third law is indeed engineerable and controllable, then COP>1.0 systems and self-powering EM systems are permissible a priori. In electrical system terms, this simply means that, if one can rid the system of its equal back emf or back mmf, the system can be legiti**mately** self-powering because it no longer self-enforces the Lorenz-Lorentz symmetrical regauging condition.

non-Abelian electrodynamics: An electrodynamics based on a group theory in which the group operation is not commutative and hence not Abellian in nature. Contrast to an Abelian group in which the group operation is commutative.

nonequilibrium thermodynamics: Colloquial term referring to the newer thermo**dynamics** of self-organizing systems and structures, far from euilibrium in their energetic exchange with their active environment, Since the **1960s,** there has emerged in physics (and in thermodynamics!) this surprising new area: the physics of far-from-equilibrium systems and the self-organization and large-scale ordering of such systems. The equilibrium conventionally referred to is 3-space equilibrium, with no consideration of temporal equilibrium, although some pioneers of the field such as Prigogine are quite aware of the temporal disequilibrium also involved. Note that such "3-disequilibrium" thermodynamical systems are also in temporal energy flow disequilibrium as well as 3-disequilibrium, but overall are still in 4-equilibrium energetically. See **giant negentropy (of the dipole).** For a necessary thermodynamics discussion, see Appendix A in this book.

nonlinear material (optical): A substance whose optical properties vary with the intensity of the light.

nonlinear optical functioning: Functioning in a manner prescribed by nonlinear optics and quantum optics, particularly with respect to time-reversal effects, use of phase conjugate mirrors, phase conjugate reflection, wave-to-wave interaction, and pumping for amplified phase conjugate reflection. To quote Knight, "A phase conjugate mixing device has remarkable optical properties: perfect retroreflection, the complete cancellation of optical aberrations and inhomogeneities in wavefronts, and the ability to reverse an optical beam and return it to its source." A most interesting modern science, eventually adaptable to COP>1.0 systems, is developing in the study of intensely scattering optical materials.

nonlinear phase conjugate optics: See **phase conjugate optics.**

nonlocalization: Producing or rendering an effect or effect-producing agent at a distance, rather than at the immediate location of the effector. Extended throughout a large region or system, or to a distant part of a large region or system, rather than being confined to a small region of the large region or system. Nonlocalization effects are absolutely prescribed in quantum mechanics, and are experimentally confirmed. They have been largely ignored in classical electrodynamics and electrical engineering. Nonlocalization can result from the existence and use of a multiply connected space, as in Bohm's quantum potential and hidden variable theory. Engineering of action at a distance by engineering the quantum potential through multiply connected space gives one method of energy amplification. This method has unfortunately been secretly weaponized In five nations of the world, and none of the technology is available for use in electrical power systems for energy amplification and solving the energy crisis.

non-Riemannian geometry: Riemannian geometry is the geometry **of** Riemannian manifolds — i.e., manifolds having an infinitesimal squared distance *ds* that is everywhere positive. A non-Riemannian geometry violates this property. [A manifold is a topological space with certain prescribed characteristics.]

nucleons: A collective name for the neutrons or the protons in a nucleus. In the nucleus, the neutrons and protons are continually changing one into the other by exchange of the charge. What is called a neutron and what is called a proton is thus somewhat arbitrary, so long as one makes a rule and stands by it. The interesting thing is that, in a nucleus, there is already continous and highly rapid transmutation activity between nucleons, all the time, without giant accelerations and operator input of very intense spatial energy. In short, nature shows in all matter that matter can be and is continually transmuted from instant to instant, and is "constant" only on the "**average".** Since most present models used for this are statistical rather than causative, it strongly suggests that we should look for a causal mechanism. The use of the time-reversal zone and time-energy has been nominated in this book as providing a causal mechanism for transduction, which can be directly engineered. It appears that cold fusion research already accomplishes transmutations using the suggested mechanisms, Several specific nuclear transmutation reactions applying the new mechanisms, and consistent with hundreds of cold fusion experiments, are given in the present book.

O(3) electrodynamics: An electrodynamics extended from a two-dimensional inner group symmetry to a 3-dimensional inner group symmetry. O(3) electrodynamics also becomes an important subset of Sachs' unified field theory. The inner group symmetry of O(3) can be taken as normal space, which immediately opens up engineering the vacuum and using spacetime curvature engines to directly engineer matter for us.

open system: A system that communicates with its environment, and exchanges energy, matter, or both between system and environment. With the possible exception of a few theoretical or hypothetical systems, all systems in the universe are in fact open systems. An open system may be in equilibrium with its active environment, so that it cannot accept, store, and utilize any excess energy from the environment. Another open system may be in disequilibrium with its active environment, in which case it can accept, store, and utilize excess energy from the environment. When the operator inputs EM energy into an open equilibrium system, he automatically breaks its equilibrium condition with the external active environment, decreasing the system's entropy. This is an excited state, and the system will subsequently decay back to equilibrium (maximum entropy) condition by emitting or dissipating its excess energy. The reader interested in the thermodynamics should read Appendix A in this book, since the thermodynamics definition (or misdefinitions!) of "closed system" actually permits the system to be open with respect to energy exchange with its active environment — either in equilibrium or disequilibrium — and only prohibits exchange of mass across the system boundaries. By that definition, a "closed system" can be far from energy flow equilibrium with its external environment, and hence permitted to perform COP>1.0 or even COP = oo. Hopefully our discussion in Appendix A will clarify the position we have taken on this matter.

optical switching: Switching of optical signals, or switching using optical frequency switching techniques, components, and circuits.

orthodox transistors: Ordinary transistors in use today, i.e., as contrasted with the Fogal semiconductor and its special functions.

orthogonal rotation: Simply speaking, a rotation from one direction to a direction at right angles to it. The Lorentz transform of special relativity, e.g., is a formula for the rotation of an object and all its parts away from its line of motion, as a function of the object's velocity, in a direction toward the time axis. The speed c just represents a full orthogonal turn, so that the projection intersection of the object with the observer 3-space, along the original line of motion, is zero.

outfolding: Translation by a system of received input longitudinal EM waves entering inside its potentials and fields, into conventional EM waves present in the system and then output from it. The opposite *of infolding.*

overpotential: Essentially the overpotential (as in an electrode in a solution) is a shift in the Fermi level necessary to allow the electron in the electrode metal to have energies overlapping with vacant acceptor levels in molecules adjacent to the electrode in the solution. The overpotential effect appears at small "double surfaces" of things in very close contact, particularly in electrochemistry and in solid state physics. The overpotential enables electron transfer, e.g., by tunneling. The overpotential increases with the log of the reaction rate that occurs at the overpotential location. For a small reaction rate, the overpotential is small; but for a small increase in the overpotential there occurs a dramatic increase of reaction rate. Fogal has utilized the overpotential effect in his semiconductor, to great advantage in accomplishing unusual charge blocking and other special effects. See **tunneling.**

overunity coefficient of performance (COP>1.0): More energy out or work out of a system than the operator or experimenter must furnish **and**

input. The excess energy is input from the active environment. See **coefficient of performance.**

parity: Deals with studying a system of a sequence of events as if the events were reflected in a mirror. A system has parity if it undergoes no fundamental operational change if replaced with its mirror-reflected twin.

partially time-reversed region: A region of spacetime in which an object temporarily experiences not only the ordinary forward flow of time, but also an extra induced backwards flow of time, usually a fraction of the time-forward time stream. It appears that the combination of the two is what constitutes time dilation in relativity. In a mixed time-forward (photon interactions) and time-reversed (antiphoton reactions) zone, if time-forward predominates, the law of attraction and repulsion of charges is partially reversed, leading to overall reduction of the forces — which remain in their usual directions. If the time reversal predominates, the law of attraction and repulsion is reversed, and in that region like charges attract and unlike charges repel. If time reversal and optical pumping are combined, the reversed law forces of attraction of like charges and repulsion of unlike charges are amplified also.

particle physics: The branch of physics using accelerators to study high-energy particle collisions, to determine properties of atomic nuclei and of the elementary particles themselves. It appears that conventional particle physicists do not recognize or consider time-energy interaction and time-reversal zone nuclear interactions at all. Hence the present "high (spatial) energy" physics is a far lower "total" energy physics than is the physics where time-energy is deliberately utilized. When time-energy is utilized, then the total energy of the photon varies inversely as a function of its frequency rather than directly as a function of its frequency. Lower frequency photons have very much greater total energy than higher frequency photons. For practical electrogravitation, therefore, one is interested in lower frequency bandwidths such as the ELF region.

Patterson effect: The intense multiscattering, multipass, multicollection of energy density flow in an assemblage of palladium-clad spherical bead capacitors, as the palladium adsorbs hydrogen ions from the fluid in which the beads are immersed, and thereby charges up as a capacitor, becoming an energy-flow generator, and nonlinearly increasing the energy-flow as the charge of the capacitors increases.

Patterson Power Cell®: Patented overunity power unit by James Patterson, which has been independently validated to yield COP>1.0. However, continuing difficulty has been experienced with the palladium metal used in the effect. See James Patterson, "System for Electrolysis of Liquid Electrolyte," U.S. Patent No. 5,372,688, issued Dec. 13, 1994. Patterson has several other patents in the area.

perpetual motion machine: The rather archaic and dogmatic assertion that no machine can indefinitely operate, since no closed system can input its output power back to itself while powering a load, because powering itself and its load violates the *equilibrium* thermodynamics (i.e., the thermodynamics of a closed system). Every system is already an open system in a violent energetic exchange with the active vacuum, so the pronouncement is a non sequitur assuming a false straw man — that every machine is a truly closed system or is in energy flow equilibrium with its active environment and can be treated as if it were a closed system. (The thermodynamic definition of "closed system" is misleading; it refers to a system where no mass exchange crosses the system boundary, but energy flow exchange can and does freely cross it. See Appendix A to this book for a proper discussion). Further, the equilibrium thermodynamics cited does not necessarily apply to either an open thermodynamic system far from energy equilibrium, or to a closed thermodynamic system in energy flow disequilibrium, as is now well known. After all, a common windmill will operate so long as there is a wind or until something breaks. But since it involves a mass flow across the system boundary, it is said to be a true open thermodynamic system. In electrodynamics, a closed system (with no matter exchange across its boundary) can yet have copious energy flow exchange across its boundary, and thus be far from EM energetic equilibrium with its external active environment. The charges and the dipoles in matter operate in a free "time-energy flow wind" and virtual particle flux wind in the vacuum, which are constant and unfailing, and thus charges and dipoles have been freely and continuously outputting real EM energy flow into 3-space for some 14 billion years. All assertions that overunity EM systems are perpetual motion nonsense are completely refuted by every charge and dipole in the universe. To repeat such gibberish only reveals the ignorance of the person making the improper assertion.

Ironically, those dogmatists fond of hurling perpetual motion labels at overunity researchers already recognize the overunity legitimacy of open systems far from thermodynamic equilibrium with their active environment; they refer to such systems *as false perpetual motion machines* or *fictitious perpetual motion machines.* All of them also accept the classical electrodynamics assertion of the source charge, from which all EM fields and potentials and their energy come. So the very dogmatists so confidently pontificating that perpetual motion machines are ludicrous, themselves already implicitly accept that every charge and dipole in the universe is precisely such a perpetual motion machine, freely and continuously creating energy right out of nothing. No legitimate free energy researcher in his wildest nightmares has proposed such perpetual motion machines on such a universal scale. The greatest perpetual motion nuts on earth are precisely those pundits so confidently castigating the notion that an electrical system can output more energy than the operator himself must input. We will have a modicum of tolerance and respect from them, when they can demonstrate how they can purge all those "perpetual motion charges and dipoles"-—and all their EM fields and potentials— from their own accepted electromagnetic model. Obviously if they do that, they simply destroy all EM energy in space, in systems, and in the entire universe. This is the absurdity of the position these pundits advocate so ignorantly.

phase conjugate: Of an entity: its time reversal. For waves: often referred to as *wavefront reversal.*

phase conjugate mirror: A nonlinear material which, when provided with an input wave, emits a phase conjugate replica (time reversed replica) of that input wave. The input wave is by practice called the *signal wave.* The time-reversed wave output is by practice called *the phase conjugate replica.*

phase conjugate optics: That portion of nonlinear optics dealing with multiwave mixing, formation of time-reversed waves, phase conjugate reflection (PCR), phase conjugate mirrors (PCMs), pumping PCMs to amplify their emitted PCRs, nonlinear interferometry, distortion correction, self-targeting, laser tracking, adaptive optics, and so on.

phase conjugate replica (PCR): Of a wave: the time-reversed duplicate of a signal (input) wave, after its detection by interaction with charge. We point out *there may still be some foundations difficulty, however, with the form in which the phase conjugate replica wave exists in spacetime prior to its interaction with charge and prior to its observation (observing the effect of its interaction with charged matter).* Indeed, there is very serious foundations difficulty with the very notion of an EM transverse wavefront in space, traveling at the speed of light, for no such thing exists. See Robert H. Romer, "Heat is not a noun," *Am. J. Phys.,* 69(2), Feb. 2001, p. 107-109. This is an editorial discussion by the Editor of AJP of the concept of heat in thermodynamics, where heat is not a substance, not a thermodynamic function of state, and should not be used as a noun. In endnote 24, p. 109, he also takes to task *"...that dreadful diagram purporting to show the electric and magnetic fields of a plane wave, as a function of position (and/or time?) that besmirch the pages of almost every introductory book. ...it is a horrible diagram. 'Misleading' would be too kind a word; 'wrong' is more accurate. " "...perhaps then, for historical interest, [we should] find out how that diagram came to contaminate our literature in the first place."*

phase conjugating action: In nonlinear optics, the process or action of producing a time reversed replica of an input wave._For a particle, producing its antiparticle. For a living cell, dedifferentiating it back to some previous form, genetics and all. In the presence of a predominately time-reversal zone, however, the cell is in a predominately phase conjugating mode *a priori*. Phase conjugating it a second time converts it from dedifferentiating to redifferentiating mode. We hypothesize that these combinations are the actual mechanisms generating cellular dedifferentiation and redifferentiation in the cell, tissues, and body. A future book will address that issue; meanwhile, see the 119-page "porthole briefing" on the author's website, www.cheniere.org.

phase conjugation: In nonlinear optics, the novel nonlinear mixing of waves which generate an output wave — called the phase conjugate replica or time-reversed replica — that precisely retraces the path previously taken by the input wave that stimulated the action.

phonon: A quantum of the lattice vibration energy in a crystal. This mechanical vibration energy is considered a field, and the phonon is the quantum of that mechanical energy field. Lattice vibrations in a crystal thus are characterized by waves in the lattice, where the waves are comprised of ordered phonons. Interesting effects occur between electron currents and phonons, due to electron-phonon interaction.

photon: In physics, the basic action quantum. Conventionally considered to be the basic quantum of the EM field. There is a foundations problem with the latter concept, because of the dichotomous use of "field" for both the *effect* force field in 3-space after observation (detection) and the *causal* force-free field in 4-space prior to observation (detection). Strictly speaking, the photon is the quantum of the causal 4-space massless **field,** since the photon possesses both spatial EM energy and time increments. In curved spacetime, the photon may possess mass because the time flow is a mix of time-forward and time reversal, and thus cause and effect are slightly intermixed as well. We point out that, in a negatively curved spacetime, the photon mass is negative, the photon energy is negative, **and**

the photon fields are negative energy fields. Presently the negative energy photons do not appear to be utilized in physics except haphazardly if at all. This may represent a large class of photon interactions with matter that have been inadvertently omitted.

ping-pong: Colloquial term for iterative retroreflection.

pinned electrons: Electrons held stationary by a magnetic field, or other set of forces that react to "push them back into their positions and hold them fast" whenever they try to spatially move away.

pinning: The act of restricting (by restoring forces and fields) spatial movement (particularly of electrons) due to a disturbing magnetic field or other external force.

polaron: An electron in a substance, where the electron is trapped in a potential well due to polarization charges on surrounding molecules. The exction in a substance is analogous to an exciton in a semiconductor.

positron: An antielectron (time-reversed electron), possessing a positive charge and positive mass. *Mathematically* an empty *negative energy electron* state in the Dirac sea whose usual occupying electron has been removed, leaving a four dimensional "Dirac sea hole," may also be regarded as a positron for many purposes, at least *after observation resulting from interaction with matter*, so long as the remarkable difference of the Dirac 4-hole prior to observation from the Dirac 3-positron a**fter** observation is understood. Mathematically, the lattice hole previously occupied by an electron can be considered a positron-equivalent (i.e., as if observed), again so long as the real differences are kept in mind, between a Dirac hole *before* observation and what results after its observation by interaction with mass. This is important, because otherwise one is again substituting the effect for the cause. In addition, if the two are confused, **then** one also arbitrarily discards the negative energy fields and negative energy potentials of the source 4-hole in the vacuum prior to observation. That effectively discards anti-circuits and the ability to engineer practical electro antigravity.

power: In physics, the time rate at which work is done (at which *the form of energy* is changed). In electrical engineering, the term "power" is erroneously but ubiquitously also used to loosely mean "energy." Hence such odd and improper expressions as "draw power from the source," which is a non sequitur. Nonetheless, such non sequiturs are so universally utilized in electrical engineering that they have become a part of the literarure itself.

Prigogine, Ilya: Noted Belgian chemist and Nobelist, and one of the pioneers of the thermodynamics of open systems far from thermodynamic equilibrium. Prigogine was awarded the 1977 Nobel Prize for his work on the theory of dissipative structures in nonequilibrium thermodynamics.

Poynting, John Henry: An English physicist who lived from 1852-1914, whose contributions to electromagnetics included the energy flow theory now known as Poynting flow. He contributed the Poynting theorem, which states that the rate of EM energy loss in a specific region of space is equal to the sum of the dissipation rate (heat loss) flowing across the boundary of the region. Concurrently with Oliver Heaviside, Poynting conceived the notion that energy flowed through space, which previously had not appeared in physics. Heaviside actually published first, but obscurely; Poynting published in a prestigious journal, so the theory came to be known as "Poynting theory."

Poynting energy: A loose term (not rigorous!) used to loosely describe the flow through space of Poynting energy density S = ExH, which is that component of the total energy flow in space that will be *intercepted and collected* by the intercepting charges, circuit, etc. It actually describes not the energy flow density *per se,* but the component of it that would be intercepted by a unit point charge, or that actually enters an intercepting circuit. Poynting started with the assumption of the component of the energy flow that enters the circuit, *a priori.* Only the work of Heaviside considered the remaining component of the energy flow that is not intercepted by the charge or by the circuit. Because of the startlingly great magnitude of this remaining nondiverged Heaviside component, Lorentt integrated the entire (Heaviside) energy flow vector around a closed surface surrounding any volume element of interest. This discarded the entire nondiverged Heaviside component, and removed any necessity of considering or explaining how every generator and battery already pours from its terminals up to 10^{13} times as much EM energy as the presently accounted energy input to the shaft of the generator or the chemical energy available in the battery. We believe that the discarded and unaccounted Heaviside nondiverged energy flow component accompanying every field-particle interaction is responsible for the puzzling excess gravity holding the arms of the spiral galaxies together. In short, we believe it is the solution to the "dark matter" problem, now often believed to be a "dark energy" problem.

Poynting energy density flow: A somewhat more rigorous term used to describe the flow through space of the Poynting energy density flow

$\mathbf{S} = f(\mathbf{E}\times\mathbf{H})$ component that would be intercepted by a unit point charge or an intercepting circuit.

*Poynt*ing energy flow: A loose term (not completely rigorous) used to describe the flow of energy density $\mathbf{S} = f(\mathbf{E}\times\mathbf{H})$. Rigorously, both E and H are "defined" only after their reaction with a unit point static charge. Hence S is the resulting component of the overall energy flow that interacts with the charges (with the circuit) and is diverged into the circuit to power it. It is not the entire energy flow, which also includes a vast Heaviside nondiverged component that does not strike the charge and interact with it, and hence does not interact with the circuit but is just wasted. See Heaviside energy flow component and Poynting energy.

Poynting generator: Colloquial term for any dipole or potential difference that represents a broken symmetry in the vacuum's virtual particle flux, and hence extracts virtual energy from that asymmetry, and gates it out as a gushing energy flow in 3-space. When both electric field and magnetic field are involved, the component of the energy flow that would be intercepted and diverged by a unit point charge is the Poynting energy flow S=f(ExH).

Poynting vector: The vector S, given as $\mathbf{S} = f(\mathbf{E}\times\mathbf{H})$, used to represent the Poynting (intercepted and collected by a unit point coulomb) energy density flow component. In Heavisidc's version $\mathbf{S} = \mathbf{E}\times\mathbf{H} + \mathbf{G}$, where G is an energy circulation flow term of trapped EM energy flow. Heaviside later rea**lized** that such a closed energy circulation flow exhibits substantial gravi**tational** effects; in modern terms we would say that it represents an apprecia**ble** local curvature of spacetime. Unpublished notes on the gravitational aspects were found beneath a floorboard in his little garret apartment, years after his death. We also point out one limitation of the present use of the Poynting vector: It has rather universally been associa**ted** only with the flow of *positive* EM energy, and not with the flow of negat*ive* energy. Indeed, the concept of negative EM energy is still consufe**d,** with different views and positions, and still in debate without complete scientific consensus.

PPCM: Pumped phase conjugate mirror. A phase conjugate mirror material that has introduced to it appositive or "pump" waves (in other words, s***tress*** waves). In effect, pumping is "stressing" or "squeezing" ryhtmically. It is also varying a stress potential, which emits longitudinal EM waves, each accompanied by a correlated scalar (time-polarized) wave. In the phase conjugating process, up to all the energy in the pump waves can be output as the energy in the emitted phase conjugate replica wave. Thus the PPCM may be viewed as an *amplifier,* very similar to a triode. When the time-components of the photons in the signal wave input and also in the pumping waves are considered, then there is a functioning of the pumping also ongoing in the time-domain. There is a rhythmic variation of stress in the time-domain also, which creates the correlated time-polarized EM wave accompanying the longitudinal wave from the 3-space pumping.

So the time-reversal aspect (formation of the phase conjugate replica wave) may be thought of as a rhythmic time-stress wave (pumping or stressing in the time domain) which, by alternately decreasing and increasing the time potential of the mirror, produces two temporal force effects. During the decreases in temporal potential of the mirror, the time-force from the input wave and from the pump waves is forward into the mirror material, allowing the input and interaction of these waves. During the increase in temporal potential of the mirror, a reversed temporal force from the mirror back to the past (temporal potential earlier in 4-space) of the input "signal" wave. The pumping energy (excess temporal potential energy) adds the gain to the phase conjugate replica wave,

probability: The probability of a simple event is the ratio of the number of times it occurs to the total number of trials (for a large, essentially infinite number of trials). Note that "trials" constitute things that have occurred (are past, have been observed). Probability has resisted rigorous logical definition by Aristotelian logic; the reason is that it is an expression of the fourth law, the identity of opposites. Probability is an expression of the future (that which has not occurred) in terms of the past (that which has occurred). Consider *throwing a die to land with one face up.* Thinking of the event (as if it has just occurred, in terms of the most recent past), one can conceive six ways of looking at it. In other words, one can conceive of six "most recent pasts", however, these have not occurred. We were merely thinking of them as if they had occurred. By the fourth law, the *total* "most recent pasts that have not occurred" is identical to the "most immediate future" that has not occurred, on the common boundary between past and future. If one therefore *collects* all six "most recent **pasts** not occurred" they turn into the most immediate future, by the fourth law of logic. One may argue that only a single one of the events will actually occur. Here one counters with the observation that, when it occurs, it is the past, not the future, and then it has not been collected so as to move **to t**he boundary. In theory, the hidden variable approach makes it possible to directly engineer those probabilities while the Schrodinger wavefunction is still propagating and has not yet collapsed to constitute an "observation."

I.e., it is theoretically possible to engineer Wheeler's "pre-reality," and determine in advance just which of the outcomes will occur.

Puthoff, Harold: Noted physicist active in a variety of fields and investigations including in psychoenergetics, extended electrodynamics, energy from the vacuum, inertia, antigravity, parapsychology, remote viewing, psychokinesis, zero-point energy of the vacuum, and cosmology. We are particularly impressed with Puthoff s cosmological feedback principle. Together with Cole, Puthoff also proved that thermodynamics does not prohibit extracting usable EM energy from the active vacuum. See Daniel C. Cole and Harold E. Puthoff, "Extracting Energy and Heat from the Vacuum," *Phys. Rev. E,* 48(2), Aug. 1993, p. 1562-1565.

QM vacuum: The quantum mechanical vacuum, which models the vacuum as an intense flux of virtual particles, each appearing and disappearing in such extremely short time intervals as to be unobservable individually—although as physics develops, from time-to-time what is observable changes because of increased observation techniques. Violent fluctuations of extremely short duration constantly occur in the QM vacuum flux. Various calculations estimate the energy density (in mass units) as up to 10^{80}-10^{90} grams per cubic centimeter (in mass density units), or even greater. The vacuum is sometimes described as two separate components: (1) the ambient or average vacuum in deep space, which can be taken as a scalar potential having an enormous energy density, and (2) the fluctuations superposed upon the ambient vacuum as local violent potential energy changes. Finally, we note that any EM potential in a system is *apriori* a change to the local vacuum scalar potential.

quantized: Adjective which means (i) reduction of some observable quantity to multiples of some small, indivisible unit, or, (ii) expressed in terms of quantum theory.

quantum: A single "particle" of the quantity *action* (angular momentum). Often confused as a single quantity of energy alone.

quantum electrodynamics: The theory of photons and electrically charged particles and their interactions. The use of the term "quantum" implies that the EM radiation's discrete photon nature is significant, so that quantum theory must be employed.

quantum **field theory:** A quantum mechanical theory in which "... a phsyica1 held is considered as a collection of particles and forces, and observable properties of an interacting system are expressed as finite quantities rather than state vectors." *[Dictionary of Science and*

Technology.] More simply (after Davies, *The New Physics,* 1989): "The theory that describes the quantum effects of a classical system of fields defined on space-time and satisfying various partial differential equations." Particles are taken as quanta of fields similar to photons being quanta of the electromagnetic field. Each type of particle is represented by an operator that obeys certain commutation laws. The theory relates gluon fields and intermediate vector boson fields to the strong and weak interactions, and allows an overall theory of fundamental particles and their interactions.

quantum potential: A special potential added to the Schrodinger equation by Bohm in his hidden variable theory of quantum mechanics. The quantum potential is a multiply connected entity, so that it "occupies" widely separated but multiply connected points, events, or objects. It is also an extraordinary energy amplifier, since any energy input to one of the multiply connected points simultaneously and instantly appears in every other connected point, regardless of distance or location in the universe. In real life, the quantum potential also has a "coefficient of multiple connectivity", so that only a fraction of the energy input to one multiply connected point will appear in the other points of the multiple connection group. The quantum potential has been strongly weaponized by five nations, and quantum potential weapons are the dominant weapons on earth, being more powerful than nuclear weapons. In theory the quantum potential together with engines and antiengines could be used to treat and cure a given disease in all persons on earth simultaneously, or in one nation or area simultaneously. Sadly, engines have been developed to generate diseases in a targeted populace, rather than engines to heal the populace. Russia and Brazil have had the quantum potential weapon for some time, as have two nations friendly to the United States. In 2001, China also deployed the quantum potential weapon.

quark: Fundamental particle theorized to comprise hadrons (particles such as protons, neutrons, and mesons) by combining in twos or threes. There are six varieties of quarks. The difference between a proton and a neutron, e.g., is merely the orientation of a single quark. In a time reversal zone (TRZ) in the electrolyte in cold fusion experiments, the gluon forces can be significantly reduced, so that the quarks are nearly freed. Two protons (H+ ions) can attract together in a TRZ so closely that each enters the reduced strong force region of the other, forming a quasi-nucleus. As the ions in solution outside the TRZ move to cancel the TRZ, it decays and the quasi-nucleus becomes an increasingly excited state, seeking to decay. Preferred method of decay is by quark flipping. So one quark flips, so that the quasi-nucleus has become a quasi D+ nucleus. As the TRZ vanishes and time-forward resumes, the strong force recovers faster than the Coulomb barrier returns. Consequently, the quasi-nucleus of D+ merely tightens into a real nucleus of D+. This is one of the standard transmutation reactions in cold fusion experiments, forming excess deuterium.

quaternion: Expression comprised of the sum of four terms, one of which is real and three of which contain imaginary units, and where the terms can be writtten as the sum of a scalar and a three-dimensional vector.

quaternion algebra: The algebra of quaternions and their mathematical operations. Quaternion algebra is of higher topology than either vector or tensor **algebra.** Maxwell's original 1865 equations are some 20 equations in 20 unknowns, in quaternion and quaternion-like algebra. Heaviside and others reduced the algebra to vector algebra and some four equations; at his death, Maxwell himself was rewriting the equations in his *Treatise* to purge the quaternions, because of the controversy over the difficult quaternion form. The present vector equations taught in university as "Maxwell's equations" are in fact Heaviside's truncation of the Maxwell theory. Going to tensor algebra electrodynamics does not recover the full range of Maxwell's original 1865 quaternion EM theory.

quintessence: Literally, the "fifth essence". In short, *dark energy*. We have nominated the arbitrarily discarded, vast Heaviside nondiverged energy flow component surrounding every interaction of charge with field as the dark energy that is the source for the excess positive gravity holding the arms of the spiral galaxies in place. See dark energy, positive.

reactive power: Electrical power, measured in volts-amps-reactive (vars) that cannot do work as is. For sinusoidal waveforms, the formula for reactive power is $IV\sin\theta$, where θ is the phase angle between the voltage **and the current.**

real hidden dynamics: The dynamics of vacuum engines, or of "internal energy" or "internal work" ongoing in a system or volume of space. These internally organized forces, fields, and energies involve dynamic curvatures of spacetime, and it is this dynamics of spacetime itself that provides **the** continuous work and dynamics of internal energy. See Einstein's second postulate extended; infolded; dimensioning.

real hidden vectors: The "hidden" or "infolded" real vector components, e.g., of a zero vector summation system. The individual hidden vector cannot spatially translate the entire bulk system, but it can interact inside the system to perform *internal work* upon it or upon some particular portion of it. Such a system of a finite number of infolded deterministic vectors is said to constitute a "dimensioned" stress potential. Specifically dimensioned potentials, fields and waves thus can be constructed, so that they carry specific vacuum engines (spacetime curvature engines). The interactions of these dimensioned EM entities may differ from normal EM interactions in chemistry, physics, biological systems in general, cells in particular, etc. The long neglected combination of Whittaker's 1903 decomposition of the scalar potential, together with his 1904 demonstration that any EM field or wave pattern decomposes into two scalar potential functions, has neglected the development and use of the "internal EM" theory and technology for a century. One or more nations has, however, highly weaponized "dimensioned EM fields, waves, and potentials" as evidenced by the peculiar and anomalous results of the decades-long microwave radiation of the U.S. Embassy in Moscow. See dimensioning.

real power (active power): Power, measured in watts, that can do work, including generating heat. For sinusoidal waves, real power is given by the formula $I \cdot V \cdot \cos\theta$, where θ is the phase angle between the voltage and the current. Note that when higher group symmetry EM effects are involved (such as the Aharonov-Bohm effect), then the "normal" behavior of circuit components can be altered dramatically. As an example, in the MEG the secondary (output) coils of the transformer section are caused to exhibit a purely electrical interaction with the electrons and electron currents in the coils themselves. Consequently *the output current and voltage are in phase, in complete violation of conventional transformer theory and conventional assumptions about the interaction of inductors.* So the output of the MEG is real power, and phase angle does not enter into it.

regauging: In electrodynamics, changing the scalar potential or the vector potential, or both. If one or both of the potentials is/are changed so that a net new force is created in the system, that is an *asymmetrical* regauging. If only one potential is changed, a net force results and that is an asymmetrical regauging. If both potentials are changed but carefully selected so that the free force resulting from one change is equal and opposite to the free force resulting from the other, that is a net *symmetrical* regauging, often called "Lorentz regauging" or the "Lorentz condition". We note that longitudinal EM waves are produced very simply by rhythmically oscillating the magnitude of a stress potential, which is naught but coherently oscillating the individual vectors of a set of EM fields that sum to a zero vector resultant. The locked-in stress in T. Henry

Moray's semiconductors used in his radiant energy device tubes and the locked-in stress in the Chung negative resistor thus have to do with the production and use of longitudinal EM waves, time-polarized EM waves, and stress potentials.

reflection: The rebound of light or other energy from a surface.

refraction: The bending of light as it passes from one medium to another or through a density change in a given medium.

retarted wave: An electromagnetic wave that is derived from retarded fields, which in turn are derived from retarded potentials. The retarded wave at a point or region of space has arrived there or exists there as the result of the dynamics of charges and currents that existed at earlier times elsewhere. Compare to advanced electromagnetic wave.

retroreflecting: Precisely reversing the path of a reflected wave or object.

Sachs, Mendel: Noted scientist who has completed the work of Einstein and developed a unified field theory covering the universe from the tiniest part to the entire conglomerate. Since O(3) electrodynamics has been shown by Evans to be an important subset of Sachs' theory, then for the first time we have a higher group symmetry electrodynamics and a unified field theory that is largely engineerable by novel electrodynamic means, using the O(3) model.

Sachs' unified field theory: An extension and completion of Einstein's work that includes the universe and its dynamics from the tiniest part to the entire conglomerate, and includes quantum mechanics, electromagnetics, gravitation, and the strong and weak forces. See particularly Mendel Sachs, *General Relativity and Matter*, Reidel, 1982; Quant*um Mechanics from General Relativity*, Reidel, 1986. Sachs' unified theory provides a great generalization of general relativity, quantum mechanics, and electrodynamics reaching from the quarks and gluons to the entire universe. Much of the model is also engineerable by higher group symmetry electrodynamics such as the O(3) electrodynamics pioneered by Evans and Vigier.

scalar: Characterized by magnitude only. However, with respect to polarization, a scalar photon is a term in use for a *time-polarized* photon, where the EM energy oscillates along the time-axis. Hence a scalar wave, following the same terminology, is an EM wave composed of scalar photons, hence whose EM energy is oscillating along the time-axis. The term "scalar" is used in the sense that no vector in 3-space exists even though a vector (and a variation of its magnitude) exists along the time axis. The effects are observed as an oscillation in the rate of flow of time, hence a "time-density" oscillation. The term "scalar" with respect to polarization implies only that there is no vector component in 3-space.

scalar entity: In ordinary vector analysis, an entity thought to be completely characterized by magnitude alone. Actually this is incomplete; a scalar entity must contain a time-like vector component, if it is to steadily persist in time. What we usually do unthinkingly is assume a continual series of successive observations or *d/dt* operations upon the *kt* nature of a scalar *k.* We conceive these individually frozen 3-space snapshots to "continuously exist" since we can readily recall the "stream" of *d/dt* differentiations in our mind and memory. Since all observation is 3-spatial, then no observable *persists continuously* in time; instead, it *continually recurs* in time, instant to instant. This "iterative successive stream of frozen 3-space snapshots" exists in the continual and rapid recall from our memories. Compare this to the similarity of observing a sufficiently rapid series of still pictures on a screen, where the individual pictures differ by a time sequence taken of some phenomenon. One "sees" the recreation in one's mind of the flow through time of those events and entities so photographed. Yet at any one instant, there is only a single frozen snapshot on the screen, and no motion at all was "physically" observed.

scalar electromagnetics: Colloquial term for the electrodynamics that arises from considering transverse EM waves, longitudinal EM waves, time-polarized EM waves, electrogravitation, superluminal EM signals, interferometry, nonlinear optical functions, time-as-energy, and the infolded electrodynamics inside all usual EM fields, waves, and potentials, In secret superweapon projects, the Russian term for scalar electrodynamics is *energetics.* It is divided into three major fields, depending upon the intended target. Targeted against inert matter, systems, and fields, the same term is used: *energetics.* Targeted against the physical and chemical processes and biological fields and potentials of living organisms, the term used is *bioenergetics.* Targeted against the mind's time-polarized EM functioning and dynamics, the term *psychoenergetics is* used. In the latter, higher group symmetry electrodynamics and extensions to quantum field theory play significant roles. Significant progress and strategic testing of all three branches of energetics has been evidenced worldwide. Progress in the energetics branch was confirmed by a statement by U.S. Secretary of Defense Cohen in 1997. Quoting: *"Others are engaging even in an eco-type of terrorism whereby they can alter the climate, set off earthquakes, volcanoes remotely through the use of* *electromagnetic waves...So there are plenty of ingenious minds out there that are at work finding ways in which they can wreak terror upon other nations...It's real, and that's the reason why we have to intensify our efforts "* Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.

scalar potential: Usually considered synonymous with the electric potential. The concept of potential was developed by Poisson, Green, and others **from** about 1813 to 1827. Three notions involved in the deve**lopment** of the concept of the potential are: (i) there is the collection of storage of energy in the system, via the collection or storage of some entity therein, and this "potential energy" can be released and dynamically used, (ii) the potential is a scalar function whose spatial rate of change is a vector force, and (iii) the dynamics of the stored energy is suspended by the "storage" or "collecting" entity; in other words it is a sort of "suspen**ded** action" waiting to be unleashed. *It requires some action—such as interception and divergence—to release the leashed energy.*

The second notion is false, since no force exists in the absence of mass because mass m is a *component* of force F via $F \equiv dp/dt = (m)dv/dt + (v)dm/dt$. It is corrected by stating that its spatial rate of change *when interacted with charged matter* is a vector force. For the third notion, we note that the concept of a "virtual" particle or particle flux means that it cannot beco**me** observable unless some interaction is imposed. So we may handle the "third notion" requirement by assuming the potential in modern terms to be composed of hidden virtual particle flux, or hidden wave flux, in wave-to-wave interaction. Physics tries to define the electrical potential as energy per coulomb, or $\phi = W/Q$. That equation, however, is actually not a definition at all (no equation is a definition), but rather is an algorithm for calculating the magnitude of the excess energy collection/collecting upon a coulomb of charge, when that coulomb is immersed in the potential It in fact is the *reaction cross section* of the potential, not the potential entity itself. This now begins to give us a clue, Potential is *energy* in some fashion, and the term "potential energy" is a redundancy. So the entity must have essentially the same definition as energy! **Potential** energy, collected energy, stored energy, whatever—it is energy first and foremost. How it is collected and what it is collected upon or in, determines **the** "type" of potential. It also cannot be logically defined as the work expended by it upon a unit charge. The causal entity itself is not the action taken; just as a man is not definable as "how far he has run" in some race.

scattering processes: Collision processes in which an incident particle such as a photon, electron, or proton, of known energy or direction or both, collides with another entity, and emerges from the collision with a different energy or direction or both.

Schrodinger, Erwin: Noted Austrian physicist, 1887-1961, and Nobelist who discovered the wave equation named after him as the Schrodinger equation, and performed other vital work in wave mechanics.

Schrodinger equation: In quantum mechanics, an equation that describes the propagation of waves associated with subatomic particles, or more generally, that describes the evolution over time of the quantum state of a system. The fundamental quantum mechanical equation governing the behavior of wave functions.

self-energy: In a quantum mechanical system, the energy associated with the emission and absorption of virtual particles. In a classical system, the energy associated with the interaction among parts of the system itself.

self-organization: (After Davies, *The New Physics,* 1989): "Spontaneous emergence of order, arising when certain parameters built in a system reach critical values." Simply put, self-organization is the spontaneous formation of patterns of localized order in a system that begins in a more homogeneous state. In short, the system moves from a simpler to a more complex state. Self-organization is one of the permissible features of an open system far from thermodynamic equilibrium with its active environment. Note that the localized orders represent free potential energy formations (free self-regauging) that in theory can then be dissipated in loads to perform free work. Hence the capability of a self-organizing system to perform some free work, or in other words to exhibit COP>1.0.

self-potential (e.g., of the electron): The potential created in and of the charge (e.g., the electron) by its virtual particle flux exchange with the vacuum. Also, an asymmetry in the virtual photon flux of the vacuum, caused by the interaction of the charge (e.g., the electron) with the vacuum flux. From here, we note that the self-potential must consist of real observable 3-space EM energy flow or flows from the electron, because of the asymmetry. However, the charge is not the primary source *per se* **of** the energy flows that establish the self-potential, but instead is the asymmetric gate in the vacuum flux that "gates out" the potential and its energy **flux** The asymmetry in the vacuum flux is the actual *source* or gate. Indeed, in classical terms the energy is received by the charge in the form of converging longitudinal EM energy waves from the complex plane (from the time domain). The spin of the charges of the dipole transduces the absorbed complex EM energy into real observable EM longitudinal wave energy, and pours it out in all directions in 3-space. See discussions under Whittaker and phase conjugate.

self-targeting: Between two entities, where each acts partially or wholly as a phase conjugate mirror, self-targeting is the iterative phase conjugation or "ping-ponging" and rapid convergence of beams between the two PCMs.

S-flow: The Poynting energy density flow S, where S = ExH. Heaviside's equation is given by S = ExH + G. In the latter equation, E is the electric field, H is the magnetic field strength, and G is a trapped closed loop flow of energy density. Note that, from the very definitions of E and H, the Poynting, energy flow represents only that portion of the total energy flow in a spatial region that is diverted by interception and interaction with charges. Heaviside's additional component G, which is not part of the field interactions but a result of the huge noninteracting part of the energy flow outside the interacted ExH component, does appear to be responsible for an enormous unaccounted EM energy flow component that generates the excess gravity required to hold together the arms of the spiral galaxies.

signal wave: In nonlinear optics, the signal (wave) input to a phase conjugate mirror (PCM), that stimulates the PCM to emit a phase conjugate replica (PCR) wave in return. See discussion under distortion correction theorem.

Slepian current: The vector $j\phi$, which in a current loop represents the energy unit area per coulomb of flowing charge, per unit of time, that is collected/collecting from the Poynting S-flow and dissipated in that current loop in its loads and losses.

Slepian flow: "Flow *of collected-energy* density's dissipation" in a current loop, and therefore related to the vector $j\phi$ in the current loop, which represents the energy per unit area per coulomb of flowing charge, per unit of time, that is being dissipated in that current loop in its loads and losses.

Slepian vector: Refers to the vector $j\phi$ in a current loop, which represents the energy density per coulomb of flowing charge, per unit of time, that is being dissipated in that current loop in its loads and losses.

solid-state parametric oscillator: A parametric oscillator circuit employing solid-state devices. A parametric oscillator is a device that oscillates by rhythmically changing a parameter (such as capacitance or inductance, etc.). Simple switching between differing values of the parameter is often used to induce the periodic change of the parameter. One way of close-looping a COP>1.0 EM system is by using a bit of the positive output energy to do parametric switching, in effect converting the system to a self-oscillating energy flow system. The AC flow of EM energy is then much more easily intercepted, collected, and dissipated to power loads without killing the source dipole extracting and furnishing the free flow of EM energy from the active vacuum.

soliton: A "solitary wave" consisting of a wave pulse which propagates without changing its shape and without dispersion.

source dipole: Any dipole, considered from the viewpoint that real observable EM energy continuously pours out of it without any observable EM energy input. There is no true "source" as such in nature, since the energy is not created but only transduced and gated. In the case of the dipole and electrical charge as sources of EM energy, fields, and potentials, the broken 3-symmetry of the dipole initiates an automatic and more primary 4-symmetry, where EM longitudinal wave energy flows into the negative charge of the dipole from the time domain (complex plane), is transduced into normal EM longitudinal wave energy in 3-space, wherein the 3-space energy is absorbed by the positive charge of the dipole, transduced back into time-energy and reradiated back into the time-domain (fourth Minkowski axis). We roughly state that the dipole "emits observable EM energy" into all directions in 3-space as observable EM energy. However, what actually happens is that this *energy 4-circulation process* is what is emitted into and along 3-space, along every radial direction, with the process occurring at every spatial point along that direction. Any charge (taken together with its clustering virtual charges of opposite sign as a dipole) then inserted at any point in space along a radial line, will dipolarly intercept the ongoing process. We will observe the interception by its 3-effect on the intercepting and interacting 3-space charge, but we will not observe the 4-process itself. This deeper examination of the EM field-charge interaction requires a new interpretation of what is meant by "propagation of EM energy through 3-space", which is a non sequitur. Recall again Romer's acid objection **to the** totally illogical picture in every elementary textbook of the so-called "EM wave through 3-space" as a flat x-y plane orthogonal to the line of **motion** z, and where the E-field vector is oscillating along one axis while the magnetic field B is oscillating along the other. That representation is totally false, just as pointed out so strongly by Romer.

spacetime or space-time: The entity represented by the "fused product" of space and time, to give "space x time". Spacetime is also dynamic geometry, in the general relativistic interpretation. We may also consider spacetime to be a giant potential, and also active geometry, and also active vacuum, and also virtual particle flux of the vacuum, and also hidden EM wave flux. If we wish, we can also consider spacetime to be comprised of longitudinal EM waves and impressed dynamics.

spacetime curvature engine: See deterministic pattern and dimensioning.

special relativity: Einstein's theory of inertial frames in which, if two systems are moving uniformly in relation to each other, one cannot determine anything about their motion except that it is relative. Each of the two frames is said to be "rotated" with respect to the other, but not accelerating. The velocity of light in space (the vacuum) is constant, and is independent of the velocity of its source and the velocity of an observer. All the laws of physics are the same in all inertial frames of reference.

spin: The intrinsic angular momentum of a particle such as an electron, proton, neutron, photon, graviton etc., even when at rest, as if it were a top spinning about an axis, but had to spin 720 degrees before it turned "full circle." Spin is quantized, and is always described as a half or whole spin, e.g., - 1, - 1/2, 0, 1/2, 1, etc. A spinning charged particle such as an electron thus demonstrates a magnetic moment, due to the circulation of charge in the spinning. In the nucleus of an atom, the spin of the nucleus is the resultant of the spins of the nucleons (particles comprising the nucleus).

spiral galaxy: A member of the class of galaxies having arms that extend in the form of spirals. About 70% of all galaxies are spiral galaxies: only about 10% of the gravity necessary to hold the spiral arms together can be accounted for by known gravitational sources. This has led to the theorizing of dark (hidden) matter of exotic and unknown form, which would be responsible for the excess gravity. Later it was theorized that some sort of "dark energy" might be responsible for the extra gravity. The present author has proposed that the *unaccounted* enormous Heaviside component of the EM energy flow surrounding every field/charge interaction, and not entering into that interaction, is the missing source of the excess gravity. The dark Heaviside energy flow was arbitrarily discarded by Lorentz in the 1890s, and it is still discarded today by all electrodynamicists and astrophysicists.

Stoney, George Johnstone: Well-known scientist (1826-1911) who first estimated the value of the electronic charge (1874) and was the first to advocate the particle nature of electricity. In 1891, he named the unit of electronic charge the *electron.* In 1896-7 he laid the foundation for Whittaker's 1903 bidirectional wave decomposition of the scalar potential.

string wave or "plucked taut string" wave: The transverse wave on a taut string produced when the string is plucked. The string wave itself stays on the string and does not travel through the slapped external medium.

subspace: In vector mathematics: a subset of a vector space which is closed under vector addition and scalar multiplication operations. In the new approach, we may consider the active ambient vacuum as a giant scalar potential. This ambient potential then decomposes into longitudinal EM waves via Whittaker's 1903 decomposition. One can then refer to longitudinal EM waves deliberately transmitted "inside" that Whittaker "subspace" as "subspace communication". The Fogal semiconductor is able to infold normal EM signals into such subspace signals (longitudinal EM wave signals) in the transmitter, and to outfold the longitudinal EM waves back into normal EM waves in the receiver. Hence the Fogal semiconductor can be utilized to perform subspace and superluminal communication. These capabilities have been demonstrated by Fogal in the laboratory. As this is being written, Fogal is in serious negotiations with several large companies for the funding to get his chips into volume production and onto the marketplace in very sophisticated and advanced equipment representing a great leap forward in technology. There are, however, powerful interests who do not wish the Fogal semiconductor to ever be produced and marketed. We have worked with Fogal for some years, and — once the semiconductors are available in quantity — we will be developing and marketing COP>1.0 electrical power systems utilizing his semiconductors and technology, under license from Fogal.

superconductivity: Property of some materials or metals whereby at very low temperature their resistance reduces to zero. These materials also exhibit many additional properties that are anomalous compared to normal materials. Much research has gone into the attempt to find materials that exhibit superconductivity at higher temperatures, with the goal of reaching room-temperature superconductivity. Room-temperature superconductivity is also just COP = 1.0. EM systems far from equilibrium with the active vacuum, and which exhibit COP>1.0 at room temperature, may involve most of the odd entities also observed in superconducting materials (polarons, lattice holes and hole currents, Dirac sea holes and Dirac sea hole currents, "charging" by Dirac sea hole excitation, vortices, etc.) The energy density in the output section is greater than the energy density input by the operator to the input section. Considering the giant negentropy mechanism and the dipolarity of the input and output sections, the tempic potential of the output section of a COP>1.0 EM system is greater than the tempic potential of the input section. Hence there is a tempic gradient across the entire system, and a tempic force from output to input. This may "sweep" out a great deal of the produced "superconductivity" entities, and particularly may result in a Dirac sea hole current in the vacuum, out of the input section back into the external power source, as a novel output of the COP>1.0 system. Feedback from output to input may also be in the time domain, corresponding to what Gabriel Kron referred to as the "open path". By recombinations and other means, the feedback in the tempic domain may be transduced in the input section of the device to ordinary current in forward time. When the voltage and current in this transduced tempic feedback are properly adjusted to that being supplied from the external power source, the external source can be disconnected and the COP>1.0 system becomes self-powering, while simultaneously powering its load also.

superluminal: Exceeding c, the speed of light in vacuum. Longitudinal EM waves can travel either slower or faster than the speed of transverse wave light in vacuum. See W. A. Rodrigues and J.-Y. Lu, "On the existence of undistorted progressive waves (UPWs) of arbitrary speeds 0 < v<oo in nature," *Found. Phys.*, 27(3), 1997, p. 435-508; W. A. Rodrigues and J. Vaz Jr., "Subluminal and Superluminal Solutions in Vacuum of the MaxweII Equations and the Massless Dirac Equation," *Adv. Appl. Clifford Algebras,* Vol. 7(S), 1997, p. 457-466.

superluminal communication: The movement of intelligent signals faster than the speed of light in vacuum, and the transmission and reception of such signals and extraction of their transported information. Longitudinal EM waves are not limited to speed c, whereas transverse EM waves are. The infolded electrodynamics inside all EM fields, potentials, and waves consists of longitudinal EM phase conjugate wavepairs, with their impressed dynamics. Hence this "subspace" is a superhighway for such waves, including those moving at superluminal velocity. In essence this is a very special kind of "tunneling" which might be referred to as *subspace tunnelling.* The limitation to light speed rigorously applies to the modeled transverse EM waves which are a sort of "bulk upheaval" waves similar to waves on the surface of the ocean. As in the ocean wave analogy, "pressure" waves underneath the ocean may travel very much faster than the bulk upheaval waves on the surface.

When making longitudinal EM waves, the process is imperfect and the resulting longitudinal EM waves will have a transverse residue as well. The resulting "transverse-noisy" LW is called an *undistorted progressive wave*. Undistorted progressive waves may move slower than the speed of light or faster than the speed of light. The degree of transparency of matter to LWs is an inverse function of the "transverse-noisiness" of the LWs.

superposition: The simple linear addition and subtraction of two or more values, states, etc.; one of the key principles in field theories and in the concept of potentials. When the situation is sufficiently nonlinear, however, interaction of waves and potentials occurs instead of simple superposition.

supersystem: A higher level or "metasystem" of interactions between the classical system, the active vacuum, and the active local curvatures of spacetime. Hence the supersystem consists of three interacting components: (1) the EM system and its dynamics, considered in conventional fashion as if the local vacuum were inactive and the local spacetime were flat; (2) the local interactive vacuum and its dynamics, and (3) the local curvatures of spacetime and their dynamics. In component (2), one must consider the Dirac sea, Dirac holes and hole currents, with concomitant potentials and forces impressed on them. In component (3), the time-domain interactions (time-energy, time-force, time-potential, and currents of energy along the fourth Minkowski axis) must be accounted to include negative energy.

All three components of the supersystem interact with each other. In general, the vacuum interactions may be taken from particle physics, and the spacetime curvature reactions may be taken from general relativity. However, this will yield only a rough or "first order" analysis, since it does not produce the tri-reactions of all three components at once, but mostly reactions between pairs of the components. The concept is easy to conceptualize, however, and yields valuable clues and insight in many areas, such as chemistry (including biochemistry), electrical physics, electrodynamics, thermodynamics, and electrogravitation. It is particularly useful in understanding the phenomena encountered in COP>1.0 EM power systems.

symmetrical regauging: In electromagnetics, changing the scalar potential to a different value, and simultaneously changing the vector potential to a different value, with the two changes precisely selected so that the two extra forces (each created by one of the changes) are equal and opposite — thus canceling each other's effect with respect to bulk translation and doing no net *external* work. The two forces remain and can perform internal work upon the system. Note that the stressing effect of the two new forces is not canceled, and that the stress of the system is altered a priori. See regauging.

tantalum capacitor: Electrolytic capacitor with a tantalum or sintered-slug anode, such as a solid tantalum, tantalum-foil electrolytic, or tantalum-slug capacitor.

targeted pinpoints: Those separated points which engage in self-targeting between themselves and some separated signal energy source (as in Fogal's semiconductor). The effect is to sharply narrow the retroreflected source signal energy from the source onto the separated points by means of the mutual ping-ponging. In this fashion much more energy density from the source can be concentrated on the targeted pinpoints. In effect, *phase conjugate shooting* — the return of the phase conjugate reflected scattered energy directly to the original target emitting the signal wave in pinpoint fashion - is evoked. See distortion correction theorem.

tensor: A special mathematical entity which is a generalized vector element of a vector space, with more than three components, each of which is a function of the coordinates of an arbitrary point in space of an arbitrary number of dimensions.

Tesla, Nikola: Famous American emigre electrical engineer, inventor and eccentric (1856-1943), whose numerous inventions fueled much of the electrical 20th century. In essence he produced the AC system, including polyphase systems. Also, Tesla invented radio transmission, not Marconi, according to a U.S. Supreme Court decision that upheld the prior patents of Tesla over Marconi. In his famous experiment, Marconi in fact utilized a variation of one of Tesla's circuits. This does not denigrate Marconi's many accomplishments, but just sets the record straight on who invented radio transmission. The impetus to the development of commercial radio transmission technology and the industry itself came from Marconi.

thermodynamic equilibrium: Stable state eventually reached by an isolated system or one in a well-behaved active environment. One may consider it a "balanced" or "preferred" state. It is important to note that, in particle physics, there can be no equilibrium of a mass system unless the vacuum interchange with that system is considered. Electrodynamics mistakenly continues to omit the active vacuum interaction with a Maxwellian system, hence is seriously flawed in that respect.

thermodynamics of open systems: Systems far from thermodynamic equilibrium with an active environment are permitted to exhibit five "magic" functions. Such a system can (1) self-order, (2) self-oscillate or self-rotate, (3) output more energy than the operator himself inputs (the excess energy being freely received from the active environment, (4) power itself and its load simultaneously (all the energy being freely received from the active environment), and (5) exhibit negentropy.

time: In our view, time is spatial EM energy compacted by the factor c . Time thus has the same energy density as mass, but in the time domain rather than in the 3-space domain. Also, time is not observable *a priori;* mass is an observable. Time persists since it is persistence itself. No observable persists *a priori,* since observation is a *d/dt* operator imposed upon LLLT spacetime, yielding a frozen LLL snapshot which does not even exist the very next instant. When we say "mass exists in time" (or any observable continuously persists), we are unwittingly invoking a very rapid iterative *d/dt* operator repeatedly, and recalling these iterative sequential "frozen snapshots" or observations from memory. One may produce and utilize EM energy flow in the time domain, as in 3-space. Time, being energy and energetic, has tempic potential (energy density), tempic potential gradients, and therefore has "tempic force." The photon is composed of both spatial energy and time-energy as its two canonical constituents. The lower the frequency, the higher the energy of the photon when the time-energy is considered, since the magnitude of the time-component of the photon increases as the spatial energy component decreases, and the energy of the photon in that case increases as c^2 times the increase in time magnitude, while decreasing linearly proportional to the decrease of the spatial energy magnitude. When transduction of time into spatial energy occurs, or vice versa, the energy conservation law is modified to specify the sum of the spatial energy, time-energy, and mass energy.

time-charge, time charging: Since time is a special highly compressed form of energy, then time-excitation or *time-charging* also occurs. Also, since tempic longitudinal EM waves accompany all longitudinal EM waves (per reinterpretation of the phase conjugate half set of the Whittaker decomposition), then irradiating a mass with substantial longitudinal EM wave radiation will time-charge the mass, exciting it with time-energy. There are excited states and internal structuring (engines) in time **charging.**

much like the excited states and internal structuring (engines) in energy excitation of normal charge. When the longitudinal EM wave radiation is removed, the time-charged entity then slowly emits longitudinal EM wave radiation as the time-excitation slowly decays via the giant negentropy process of the charges.

time-energy: Time may be considered as spatial EM energy compressed by the factor c^2. See also discussions under time and time charging.

time excitation: See time charging.

time-flow generatrix (mechanism): Since any observable is a frozen nonpersistent snapshot in 3-space, then the common expression "flow of a mass through time" requires an active generating mechanism to add time to mass, converting it to masstime, which is persistent. Masstime *mt* is as different from mass *m* as impulse *(Ft)* is from force *F*. The flow of a mass through time is generated by the ubiquitous interaction of photons with the mass. This includes all photons, both virtual and observable. Thus for the ambient vacuum, there is an ambient flow of time, since there is an ambient rate of total photon interaction. The "macroscopic" movement of the mass through time is the result of (i) absorptions and emissions of observable-sized photons, and (ii) the continuous integration of virtual photon absorptions into observable-sized photons. The macroscopic flow of time thus has myriads of "sublevels" of infolded time flows and engines. Hence the flow of time has a marvelous, internal, dynamic structure.

time-forward: Refers to the flow of an entity through time in the forward direction, as seen by an external observer. Time-forward flow occurs when (to the observer) there is a predominance of time-forward photons interacting with the body that is moving in forward time. Contrast to time-reversal of an object, as seen by the external observer, which occurs when (to the observer) there is a predominance of time-reversed photons (antiphotons) interacting with the body that is observed to be time-reversed. Pumping a given living mass (in the nonlinear optical sense) with time-reversed EM waves pumps the object in the time domain. That drammatically extends nonlinear optics, since the pumped living object's cells will be observed to slowly reverse back to a previous physical state or condition. Since time-polarized EM waves accompany all longitudinal EM waves via reinterpretation of Whittaker 1903, pumping a living mass (a body) with longitudinal EM waves also pumps it with time-polarized EM waves, time-charging the body which continues the pumping in the time domain after the longitudinal EM wave radiation is removed.

time-forward EM wave: A normal EM wave moving in forward time as seen by the observer. Otherwise known as the retarded wave. The external observer comfortably sees its forward progress as expected.

time-polarized electromagnetic wave: An electromagnetic wave whose vibrations occur in the time domain only. May be referred to in a quantum field theory sense as a *scalar* EM wave. It is a longitudinal EM wave in the time domain. It may also be said to be a longitudinal EM wave in the complex plane, since in Minkowski space the fourth axis may be taken as -ict. The time-polarized EM wave is indicated in quantum field theory, or at least its time-polarized photon is theorized and called a "scalar" photon.

time-polarized photon (scalar photon): A photon whose vibrations occur in the time domain only, also known as a "scalar" photon. This polarization of the photon is utilized in quantum field theory. Neither the scalar photon nor the longitudinal photon is individually observable. However, the combination of the two in the presence of charge is observable as the instantaneous scalar potential.

time reversal: For EM waves, the process of forming the phase conjugate wave. For a particle or a mass, the process of pumping the particle or mass with time-polarized EM waves, so that the resident spacetime curvature engine in the mass is amplified and phase conjugated, forming a precise, amplified antiengine which then slowly time-reverses the mass back to a previous physical condition and state. We accent that *time reversing a single object or single group of objects* is not the same thing as "travel into the past" so popularized by science fiction. For time travel to the past, the entire universe and everything in it — except the traveler — would have to be time-reversed. That would not seem possible by any stretch of the imagination today! On the other hand, time-reversal of a single thing such as a particle or a wave — or even a group of things such as a group of particles or waves — is not only feasible but is readily achievable. A Dirac sea hole is a negative energy electron, for example, having negative energy and therefore negative mass prior to observation. After observation, it is seen as a positive energy, positive mass electron of opposite charge to the conventional electron and reacting with fields in opposite direction from the conventional negatively charged electron. In short, after observation (interaction with mass) it becomes the positron.

time reversal zone: A region of space in which the majority component of the overall time flow mechanism runs backwards, and hence the fundamental mechanism generating the flow of a mass through time is reversed. The "time running backwards" is due to the predominance of interactions with antiphotons. It follows that, in the time-reversal zone (TRZ), there is a predominance of antiphoton interaction over photon interaction. In a TRZ, the law of attraction and repulsion of charges is reversed; like charges attract and unlike charges repel. Also, induced action by the time reversal forces start *inside and throughout* an affected mass in that zone, originating at every point in that local spacetime zone and moving outward. It thus involves a novel action "from inside to outside", beginning even inside the nucleons, and first affecting the quarks and gluons. Deliberate use of time-reversal zones and their subsequent decay allows a great new class of dramatic nuclear reactions, including simple transmutation and loosely called "cold fusion" reactions, at low spatial energy but very high time-energy. High energy physics has neglected the use of time-energy, opting to go for high spatial energy. Hence the high energy physicists have actually eliminated a much higher energy physics (at low spatial energy so readily examined on the bench far *more ch*eaply) than the science they have long developed.

time-reversed wave: A phase conjugate reflected wave, which is a wave moving in reversed time. Since the external observer "sees" in forward time only - and even then he sees in an iterative series of frozen 3-space snapsholt —he *observes* the time-reversed wave as a 3-spatial wave (series of iterative frozen snapshots) traveling in the opposite direction as its generatrix wavefront (the *signal wave).*

topological: Invariant under transformation by continuous mappings, or related to the properties of geometric shapes and figures that remain invariant under transformation by continuous mappings.

topological properties: Those properties of a geometrical space that are unchanged by continuous distortion of the space.

topology: Mathematics of the properties of geometric configurations invariant under transformation by continuous mappings. In short, the mathematics of the large-scale structure of curved spaces.

transverse (with respect to waves): Wave oscillatory movement perpendicular to the wave's primary direction of principal propagation, as in the movement of a plucked taut string in a wavelike motion traveling down the string but with the oscillations being lateral. Based on Faraday's notion that the field lines of the electromagnetic field were physical material lines (in the material ether) similar to taut strings, Maxwell assumed the transverse wave model in his theory. The entry of longitudinal waves, into the theory can easily be demonstrated by rhythmically and coherently varying the magnitudes of the Lorentz symmetrical regauging condition, producing "stress potential waves" which are in fact what longitudinal EM waves really are. The production of a longitudinal EM wave in 3-space will be accompanied by the simultaneous production of a time-polarized companion wave.

tunneling: In quantum mechanics, a phenomenon in which a particle penetrates and crosses a small region where the potential opposing such passage is greater than the particle's available energy. The phenomenon is thought to be impossible according to classical physics, but occurs nonetheless. Further, the speed of transit through the "tunneling" separation can be superluminal. Tunneling of music between two separated points in a waveguide has been measured at more than four times the speed of light.

A more extended type of tunneling is the travel of longitudinal EM waves infolded inside the normal EM potentials, fields, and waves. Indeed, this is a more fundamental electrodynamics, and it can be shown that interferometry of this "internal" electrodynamics creates the external electrodynamics by a form of longitudinal EM wave interferometry. E.g., see M.W. Evans, P.K. Anastasovski, T.E. Bearden *et al.*, "On Whittaker's Representation of the Electromagnetic Entity in Vacuo, Part V: The Production of Transverse Fields and Energy by Scalar Interferometry," *Journal ofNew Energy,* 4(3), Special Issue, Winter 1999, p. 76-78. This is part of the technical basis for the "scalar interferometry weapons" developed by the Russians after World War II. Today, some 10 nations have such weapons, more are developing them, and even the Japanese Yakuza has such weapons.

unified field theory (engineerable): A unified theory of the four forces o| physics — the electromagnetic, gravitational, strong, and weak forces that is not just an intellectual model but which is also engineerable on **the** laboratory bench and in actual physical systems using higher symmetry O(3) electrodynamics as a special subset of Sachs' unified field theory.

unitary Q_E (charge of the electron): Fixed or unit charge q of the electron. This notion is held because q is not decomposed into its component elements, but treated as if it were an indivisible unit, charge and mass and all. The mass of a fundamental particle at rest is quantized, and the massless charge (self-potential) of the particle is discretized as a function of the background potential (virtual particle flux density) in which it is embedded or to which it is exposed. In our view the definition **of a** charge q is $q \equiv m_q\phi_q$, at least to first order. (The ϕ_q may be internally structured with deterministic "engines", so that one electron need not bo identical to another, in its actions in some cases). The *electrical charge* of the "charged mass m_q" should be taken to be the massless ϕ_q component. For an electron, $q_e \equiv m_e\phi_e$. The *electrical charge* of the electron should be taken to be the massles ϕ_e component. We note that the charge is also structured, since ϕ_e or ϕ_q decomposes via Whittaker 1903 into a harmonic setof EM longitudinal phase conjugate wavepairs. Our reinterpretation of this decomposition then yields the solution to the problem of the "source charge" and its associated fields and potentials and their energy. The massless charge ϕ_e is a dipolarity and hence a broken 3-symmetry in EM energy flow, invoking a more primary 4-symmetry in EM energy flow so that EM longitudinal wave energy is continuously incoming from the time domain, being absorbed by the charge q of which ϕ_e is a component, being transduced into real EM energy in 3-space, and emitted in all directions in 3-space at the speed of light, creating the fields and potentials and their energy that are associated with charge q. If a charge (say, an electron) is placed in an additional potential ϕ_1, then the total massless charge of the electron(i.e., its virtual vacuum flux exchange with mass me) is $(\phi_e+\phi_1)$.

As can be seen, the massless charge of the electron (its virtual flux activity) has now changed. The electron is then said to *be collecting and to have collected* excess energy (which may be either positive or negative, depending upon the sign of ϕ_1). Further, either ϕ_e or ϕ_1 or both can be internally and deterministically *dimensioned* (structured in Stoney-Whillaker-Ziolkowski fashion). When its massless charge (its own ϕ_e) potentialissodimensioned,thenthedimensionedelectronissaidto contain or transport an *engine* or a *vacuum engine* or a *spacetime curvature engine.*

vacuum: Space devoid of observable matter. In modern theory, the "empty" space is in fact bristling with very rapid fluctuations of EM energy, remaining in the virtual state. It is also filled with a violent, fluctuating flux of virtual particles, appearing and disappearing so quickly that an individual particle does not persist long enough to be individually detected. Thus the vacuum is extraordinarily energetic, but the energy is in very special form (fleeting violent fluctuations and virtual particle flux). Nonetheless, because it contains enormous energy, the *average* vacuum may be considered a potential. All potentials then are changes to this vacuum potential, or to an intermediate potential which is a change to it. In another sense, the vacuum, potential, and spacetime are all one-and-the-same thing. This means that general relativity's spacetime curvature is ubiquitousand extraordinarily dynamic. The vacuum very near a mass also can act in some cases as a semiconductor, capable of supporting self-oscillation between the mass and the local vacuum. Considerations of the active vacuum and its nature lead to the notion of the *supersystem,* which is comprised of three parts: (1) the physical system and its dynamics, (2) the active vacuum and its dynamics, and (3) general relativity and its dynamics (since physicists persist in separating the notions of spacetime and vacuum). No analysis of any mass system is complete unless an analysis of the entire supersystem and the interactions of the three components, one with the other, is performed.

Every charge is "embedded" in the active vacuum by its potentials and fields, which themselves are spacetime curvatures and alterations of the local vacuum. This is easily seen by $q \equiv m_q\phi_q$, where ϕ_q is a change to the local vacuum potential *a priori.* In the quantum view, the fields and potentials may be taken as organized polarization patterns and dynamics (currents) in the vacuum virtual particle flux.

vacuum engine: Also referred to as a *spacetime curvature engine.* From the particle view: a deterministic internal pattern or *template* deliberately created as a deterministic structuring and dynamics in the virtual flux comprising a scalar potential. It can also be created in, and transported by, the two scalar potentials that comprise a static or dynamic force field, or a moving EM wave in the vacuum. It can also be created in the local vacuum potential, in which case it has a "charge-up" creation time and a "discharge time," exhibiting a sort of "time constant" very much like a capacitor charging and discharging.

In the wave view: the vacuum engine is a deterministic internal pattern or template deliberately created in the Stoney-Whittaker-Ziolkowski internal biwaves and wave products comprising the scalar potential. Again, it can be implanted in the vacuum or in an EM signal as a carrier. The self-energy (scalar potential) portion of any electric charge or magnetic charge can also be a "carrier" that is conditioned *{dimensioned)* with a vacuum potential. The process or act of conditioning any of the carriers with vacuum engines is called *dimensioning* that carrier. Russian energetics used in secret weapons programs refers to the vacuum engines of a dimensioned carrier as the *information content ofthe field.* Such vacuum engines, e.g., were used in the potentials of the microwave radiation of the U.S. Embassy in Moscow for several decades, inducing a variety of health changes and sicknesses in the personnel of the embassy. Interestingly, all these health changes occurred in the field-free regions of the Embassy. There the field-free potentials existed and were stable and unchanging. Hence a body exposed in that region was steadily exposed to the specific engine being induced, and time-charged with that engine accordingly. The deterministic set of spacetime curvatures comprising this charge then acted upon the cells and body to slowly change it to the damaged or diseased condition. See dimensioning.

vacuum flux exchange: The virtual particle interaction between the active vacuum and a mass, particularly a charged particle.

vacuum's **virtual particle flux:** In the particle viewpoint, the quantum mechanical vacuum identically is a virtual particle flux. Present physics, however, is prone to refer to the vacuum as an implied emptiness *containing* a virtual particle flux, even though that is known to be in error. In our view, energy, vacuum, spacetime, virtual particle flux, and dynamic geometry are all synonyms. One must note that the ageless contradiction of the wave vs. particle view has still not been resolved in physics, even by the duality principle. The duality principle is merely an agreement to quit fighting, and to feel free to consider a thing a particle in one case or circumstance and a field in another case or circumstance, *whichever works.*

vector: In mathematics, an entity completely characterized by a magnitude and a direction.

vector potential: A potential having — at any point in it — both direction and magnitude. The direction, e.g., may be linear, curvilinear, or swirling. The term "vector potential" is often used as the magnetic vector potential A. When it is swirling, the magnetic vector potential A may be said to be the magnetic field B. However, the swirling magnetic vector potential (the magnetic field B) may be "bottled up" and contained locally inside a long tight solenoid, or inside a toroidal coil, or inside a special nanocrystalline material used as a closed transformer core as in the motionless electromagnetic generator. In that case nature freely replenishes the energy in the surrounding space which would have been occupied by the nonrestricted, nonlocalized B-field (curled A-potential) but replenishes that space with an uncurled (linearly flowing) magnetic vector potential A. This in fact at least doubles the available energy flow available, without any additional EM energy input by the operator. The well-known Aharnov-Bohm effect clearly demonstrates this effect, and it is deliberately employed in the motionless electromagnetic generator (MEG) of which the author is one of the five co-inventors. Present dictionaries of physics and many textbooks are confused as to the definition of magnetic vector potential A and its relation to B, many stating that the A is defined by the equation $\nabla\times\mathbf{A} = \mathbf{B}$. However, no equation is a definition; it is an expression of equality of two magnitudes, and not a definition of either side. If we substitute the more stringent $\nabla\times\mathbf{A} \equiv \mathbf{B}$, we see that the $\nabla\times$

operator acting upon the A potential is precisely what a B field *identically is*. Hence the A potential exists in two forms: (1) in curled form as identically the B-field, and (2) in uncurled field-free form as the linearly moving A-potential energy current that has no imposed $\nabla\times$ operator and thus has no curl. This makes total sense with $\nabla\times\mathbf{A}\equiv\mathbf{B}$.

vector field: Conventionally, the assigning of a magnitude and a direction (that is, a vector) to each point in a region of space occupied by a field. In our view the field is in fact a change to the active energetics of that spatial region, such that the region will interact with any appropriate entity (e.g , **a** charged mass) placed at any point in the region and produce a force upon that entity.

vector zero: See discussion under zero vector.

virtual antiphoton: An antiphoton that spontaneously appears and disappears, so swiftly that it cannot be individually observed. It is real while it exists. Coherent integration of a stream of virtual photons, however, adds to produce an observable quantum of energy, which is observable in its effects on a charged particle.

virtual particle: A fleeting quantum particle that spontaneously appears and disappears, so swiftly that it cannot be individually observed, so that it exists only temporarily. It is real while it exists. The virtual particle does not satisfy the usual relation between energy, momentum, and mass because it is under the aegis of the Heisenberg uncertainty principle. The virtual particle can have any amount of energy momentarily, so long as the product of its energy and the time interval of its existence is less than the uncertainty principle's minimum magnitude.

The coherent interactions of large numbers of virtual particles with a **mass** or charge can combine to generate real observable effects (forces). In quantum field theory, all forces of nature are caused by the interaction **of** the mass entity with virtual particles. Interaction of a mass with virtual photons, e.g., is projected to cause all mechanical and electromagnetic forces.

virtual particle flux exchange: Interaction with or exchange of a flux of virtual particles.

virtual photon: A photon that spontaneously appears and disappears in the vacuum so quickly that it cannot be individually observed.

virtual photon flux: See definitions under **flux** and under **virtual particle.** For electromagnetics, the vacuum can often be modeled as a flux of virtual photons. One gets the virtual charges also, since the photon is also considered to consist of a positron-electron pair. That is, the photon is continually separating into a positron-electron pair, whose particles then annihilate each other to form additional photon(s), etc.

virtual photon flux exchange: The mutual exchange of virtual photons, as between the vacuum and a charged mass, or between two colliding masses.

virtual photon flux of vacuum: In our view, the vacuum identically is a flux of virtual particles. For many electromagnetic cases, it can just be modeled as identically a flux of virtual photons, where the word "photons" in general usage refers to both photons and antiphotons.

virtual positron: A positive electron (positron) which spontaneously appears disappears in the vacuum so quickly that it cannot be individually observed. More accurately, in the 4-vacuum, a negative energy electron state that spontaneously appears and disappears so quickly that it cannot be individually observed. A virtual Dirac sea hole.

Whittaker, Edmund Taylor: Well-known English mathematician and physicist, 1873-1956, who made major contributons to mathematics and physics. Whittaker dramatically extended Stoney's earlier work of 1897-8 an authored two papers in 1903 and 1904 giving the basis for the theory of scalar electromagnetics (Russian energetics, not including the quantum potential portion). His decomposition of the scalar potential into a harmonic set of longitudinal EM wavepairs, where each pair is a phase conjugate pair, may be reinterpreted to solve the long-vexing problem of the source charge or source dipole and its continuous emission of EM energy in 3-space, providing its associated potentials and fields and their energy. The problem was solved by the present author's reinterpretation in that manner, published in 2000. This was later found to be consistent with quantum field theory as well, by interpreting the observability of the combined scalar and longitudinal photon pair as opposed to the nonobservability of either the scalar or longitudinal photon individually.

Work: The changing of the form of energy. One joule of energy whose form is totally changed in a reaction, does one joule of work in that reaction. However, it is strongly stressed that after that joule of work is perform**ed,** one still has a joule of energy left to use (with which to do additional work). This remaining joule of energy is just in different form than was the initial joule of energy. So one can do joule after joule of work from a single *initial* joule of energy, so long as the energy is not dissipated and lost after each change of its form. In any one single change of form, only o**ne** joule of work can be done from one joule of energy. So energy is conserved through many changes of form, but work is not. To work in COP>1.0 systems, one absolutely must root out from one's consciousness the mistaken notion that only one joule of work can be done from a joule of input energy. One of the places where extra joules of work are performed by each joule of energy is that of strong gradients. Strong gradients are known and recognized to violate thermodynamics. Work is further divided into **internal work** and **external work.**

work, external: The changing of the form of the collected energy of a body or system by dissipating it upon an external load or entity is the external work *done by* a body. The changing of the collected energy of a body or system by performing work upon it is the external work *done upon* a body or system.

work, internal: The changing of the form of the internal energy of a body or system. It may also involve the changing of internal parts of the system.

work-energy theorem: In mechanics, a theorem that the change in kinetic energy of a particle in motion is equal to the work done by all the forces acting upon the particle.

zero-point energy: The energy remaining at a temperature of absolute zero, due to the Heisenberg uncertainty principle and the quantum mechanical theory of an oscillator. Also, the minimum energy of a system due to its quantum fluctuations, resulting from its incessant virtual particle activity. Quantum mechanically, no system of interest (including even spacetime itself) can have zero energy. The zero-point energy of the vacuum is the lowest energy vacuum state, with fluctuations taken into account. Even at low energies, quantum fluctuations continually arise, and result in an incessant, extremely rapid, and violent "jittering" of the energy momentarily present. The minimum energy due to these quantum fluctuations is called the *zero-point energy.*

zero vector: Candidates are: (i) A vector having no length (no magnitude) or specific direction; (ii) absence of any and all finite vectors; (iii) resultant of a system of multiple, finite vectors whose vector sum has **no** specific direction but may have nonzero scalar magnitude.

The second definition differs drastically from the first. That is, we **cannot** say that a vector resultant zero has no infolded magnitude, if we **consider** its nonzero components, all of which have magnitude. (See the discussion under **zero).** It only has no net magnitude for *translating* force. It is, in fact, *a. stress potential,* and it is one with a deterministic internal structure or *engine.* By rhythmically and coherently varying each component of a zero vector system, one easily produces longitudinal EM waves,, each of which is accompanied by a correlated time-polarized EM wave. In vector analysis, the zero vector axiom states that any vector v plus a zero vector is eq**ual** to a zero vector plus v. Note that, being an axiom, this is not proven, but just assumed for any zero vector. We very much disagree with that blanket axiom; it reduces vector analysis to a highly special single case, where all zero vector systems are to be considered equal, and totally "inactive." That is true only for bulk translation. In the real world that need not be true at all; specifically, it is not true for two different zero vectors having different internal structure and dynamics (different internal engines).

There are an infinite number of different zero vector resultant systems, and so zero vectors may differ, if their infolded component "substructure" is considered. In the real world, things that are vectors very often have energy. The energy is infolded and hidden, so that it represents not only (i) a local curvature of spacetime, but also (ii) a structured, deterministic set (a template) of curvatures of local spacetime. Therefore this zero vector system is actually a *vacuum engine.* Any mass system placed in such a potential, will be acted upon in its internal parts by that local vacuum engine; in short, it will have internal work performed on its interior. Further, the zero vector resultant system is a "stress potential," since it does contain "collected internal energy."

So between zero vector resultant systems, the "infolded, hidden energies" differ dramatically in (i) total infolded and trapped (collected) energy, (ii) specific internal action patterns (templates), (iii) general relativistic effects, and (iv) type of engine. Accordingly, the actions the zero-vector system induces in an exposed mass may be designed in advance. This is vacuum engineering. This spacetime engineering. This is the formation and use of engines. It is also one of the bases of Russian energetics.

The'problem is the *vector algebra itself.* In the abstract algebra, a "vector space" Is regarded as an inert thing, where the only actants are the overall net nonzero vectors, and there is no interaction between an overt vector and a covert set of vectors. The vector space is not allowed to have an internal realm, stress, hidden engines, or to interact with the vectors representing the physical system. So vector algebra lacks the capacity to model such higher topology phenomenology. Consequently, for over a century electrodynamicists — thinking primarily of spatial translation — have routinely discarded such "zero vector systems" as if they represented the total absence of any finite vector. *This they do, in the unsuitable* *assumptions of the vector algebra.* This they do not do, in the real world, whether we are aware of it or not.

The common practice in electrical physics of replacing a zero-summed system of nonzero vectors with a vector zero indicating a "complete absence of vectors" is very much incomplete. This present practice should be changed; it has reduced the topology of electromagnetics far too much, and gutted vast, important parts of the theory insofar as an extended electromagnetics is concerned. The vector zero should be replaced with a special organized vector zero system and a dimensioned scalar potential.

The interactions of the "hidden" vectors — the *engines* — should be incorporated. By failing to do this, physics excludes the ability to engineer electrogravitation, spacetime, the virtual state, local general relativity, free energy, effects at a distance, and the probabilities of the states propagated by the Schrodinger equation. It also excludes unification of forces. As another more human example, for every cellular disease condition there is a specific engine resident in the cells. An amplified antiengine for that disease pattern can fairly readily be generated. That antiengine, embedded in ordinary EM fields and potentials, can be irradiated into a diseased body with that disease, and it will time-reverse those diseased cells slowly back to normal. This is actually the basis of the body's own healing system the cellular regenerative system studied mostly by Becker. Unwittingly using this "antiengine" approach, Priore and a team of French scientists provided startling cures of terminal cancers, infectious diseases, clogged arteries, etc. in laboratory animals in France in the 1860s and early 1970s. The work is strongly documented and replicated in the French scientific literature, but the work was suppressed in the early 1970s in the change of the French government. See our "porthole briefing" on our website www.cheniere.org for our extension of the Priore method, for greater ease portability, and rapid treatment of mass casualties.

In the new view, a zero vector may be a system of nonzero vectors that vectorially sum or multiply to zero for spatial translation purposes, but nonzero components may still exist "inside" and dynamically function inside the zero-resultant envelope. This substructure can act on nonlinear or resonant systems. Any or all of the nonzero components may be time varying, or none of them may be. The zero vector system may thus be a dynamic engine and a dimensioned scalar stress potential. In addition, such a vector zero system is considered to be also a scalar stress potential, whose magnitude is equal to the sum of the absolute values of the components. In addition, a separate type of stress potential may be included for the magnitude of the absolute values of the swirl components (torques). Other associated potentials may be included for the system, particularly if the system is in multiple dimensions, if it consists of more than one type of virtual particle flux, if several fluxes intercommute, etc.

zero vector summation systems: Zero summations of real, nonzero vectors, so that the real vectors are still present but do not cause *spatial translation* of the exposed mass or charges. Instead, the zero vector summation has an internal structure and dynamics, hence an internal engine. Also see discussion under zero vector.

Appendix A
Relation to Equilibrium and Disequilibrium Thermodynamics

"The second law [of thermodynamics] does not rule out the possibility of pushing heat uphill, as it were, from a cold object to a hot one, or of creating order out of disorder. It merely states that such a reversal of the natural flow requires an influx of energy... " [Raymond Serway] {697}

"It *is in no way possible, either by mechanical, thermal, chemical, or other devices, to obtain perpetual motion, i.e., it is impossible to construct an engine which will work in a cycle and produce continuous work, or kinetic energy, from nothing. "* [Max Planck] {698}.

"What might appear to be empty space is, therefore, a seething ferment of virtual particles. A vacuum is not inert ***and*** *featureless, but alive with throbbing energy and* ***vitality.*** *A 'real' particle such as an electron must always be viewed against this background of frenetic activity. When an electron moves through space, it is actually swimming in a sea of ghost particles of all varieties - virtual leptons, quarks, and messengers, entangled in a complex melee. The presence of the electron will distort this irreducible vacuum activity, and the distortion in turn reacts back on the electron. Even at rest, an electron is* ***not*** *at rest: it is being continually assaulted by all manner of other particles from the vacuum."* [Paul Davies] {699}

"I assert... that for the general theory of relativity, i.e., in ***the*** *case of the general invariance of the Hamiltonian function, energy equations... corresponding to the energy equations in orthogonally invariant theories do not exist* ***at all.*** *I could even take this circumstance as the characteristic feature of the theory of general relativity. "* **[D. Hilbert]** {700}

*"**In formulating the** equivalence principle, Einstein actually abandoned the idea of the gravitational field as a*

Faraday-Maxwell field, and this is reflected in the pseudotensorial characterization of the gravitational field that he introduced. Hilbert was the first to draw attention to the consequences of this. ... Unfortunately, ... Hilbert was evidently not understood by his contemporaries, since neither Einstein himself nor other physicists recognized the fact that in general relativity conservation laws for energy, momentum, and angular momentum are in principle impossible. " [Logunov and Loskutov] {701}

"No amount of theory can refute a replicable experiment that contradicts the theory. A single replicable experiment can refute any theory that is in conflict. That is the very heart of the scientific method. " [Myron Evans, private correspondence].

"It only takes a single white crow to prove that not all crows are black. " [Anon.]

"One of the most important principles of physics, that disorder, or entropy, always increases, has been shown to be untrue. " [BBC News] {702}

"One of the most fundamental rules of physics, the second law of thermodynamics, has for the first time been shown not to hold for microscopic systems. ... [The experimenters]... found that the change in entropy was negative over time intevals of a few tenths of a second, revealing nature running in reverse. ...But over time intervals of more than two seconds, on overall positive entropy change was measured and normality restored." [Chalmers] {703}.

"We experimentally demonstrate the fluctuation theorem, which predicts appreciable and measurable violations of the second law of thermodynamics for small systems over short time scales... Our results show entropy consumption can occur over colloidal length and time scales. " [Wang et al.] {704}.

A.1 Introduction

For excellent background books on thermodynamics matters, at various levels of difficulty, the reader is referred to texts by Gyftopoulos and

Beretta {705}, Kondepudi and Prigogine {706}, Chalidze {707}, and Dugdale {708}.

It has long been known in physics that at sufficiently small levels (e.g., atomic levels) the second law of thermodynamics does not always hold true. Recently, as quoted above, Wang et al. {704} have extended this area of permissible violation of the second law to much more appreciable times (a few tenths of a second) and lengths (the micron scale). Without further discussion, we note that this places regions and times of negentropy well-within circuitry switching times and interaction with fundamental charged particles. Hence these experiments are beginning to point the way to practical negentropic devices. When coupled with the demonstrated continous giant negentropy of a charge (considered with its clustering virtual charges of opposite signs), these experiments now strongly support the feasibility of practical overunity EM circuits and systems. The interested reader is encouraged to continue to read the literature along those lines, and stay abreast of developments in that field.

In this book we have presented considerable discussion of time-energy (time as a special, highly compacted form of energy). We have also discussed the three components of the supersystem, including the system, the local active vacuum, and the local curvatures of spacetime. All three componets of the supersystem interact with each other continuously, and such Interactions are not modeled in classical thermodynamics (CTD), classical electrodynamics (CED), or electrical engineering (EE). Hence one should not be surprised that the supersystem model and supersystem analysis involve contradictions (actually, *extensions)* of these three models, which are special cases and approximations only.

All COP>1.0 EM systems result from supersystem component interactions. So COP>1.0 EM systems are in conflict with CTD, CED, and EE since these three models exclude those interactions.

To falsify any absoluteness of the three models considered, one or more solid, demonstrable, replicable experiments are presented to establish validity of the new higher symmetry approach. This is sufficient to negate the conventionally accepted absoluteness of the lower symmetry CTD, CED, and EE models. Scientifically, these experiments suffice to demonstrate that those three models describe "*special-case* domains of nature" rather than full generalizations of nature. It is clearly understood that the three models remain very useful and very often quite sufficient, just as Newtonian mechanics is useful and often sufficient, without use of relativistic mechanics.

The experiments also falsify any interpretation of the three models as "proof that COP>1.0 systems are impossible. Accordingly, many of the accepted statements and assumptions of the three models must be corrected for COP>1.0 research, as must be the conventional interpretation that the laws of nature (as understood based on those three models) prohibit COP>1.0 EM systems. This follows directly from the quotation by Evans at the beginning of this appendix. Experimental evidence of COP>1.0 is abundant and decisive, such as the many hundreds of routine "negative resonance absorption of the medium" experiments as typified by Bohren's paper {709} and experiment and Letokhov's work {710}. Also, every charge in the universe already falsifies all three models, as amply discussed in this book. That fact for at least a century has generated the source charge problem — the problem of the source charge and its associated fields and potentials and their energy, reaching across the universe. The solution to this problem was published by the present author in 2000, based on the experimentally proven and well-established broken symmetry of opposite charges, such as are on the ends of a dipole.

In the extended approach, conservation of energy in 4-space does not require simultaneous conservation of energy in 3-space. The concept of energy conservation in 4-space does not exist in the three models mentioned, which contain only 3-space energy conservation. There exists a "giant negentropy" 4-space energy flow (circulation) mechanism, as we developed in this book, and it is experimentally demonstrated by every charge in the universe. In a classical 3-spatial energy conservation analysis and view, the giant negentropy action may continuously perform useful work in a system, since it already furnishes all EM field energy and potential energy in every system. All 3-space energy conservation is an extra condition imposed upon 4-space energy conservation, and that condition may be violated at will without violation of the general conservation of energy law.

To the three conventional models mentioned, 4-symmetry in energy flow with broken 3-symmetry, will appear to be perpetual motion and a total violation of the more limited 3-space conservation of energy law. It *does* permissibly violate 3-space energy conservation, which is just a special case a priori. But it is not a violation of energy conservation overall, since we are using a more fundamental energy conservation law (4-symmetry) than the 3-symmetry used in the mentioned CTD, CED, and EE models,

In short, the three models must be extended to provide 4-space energy conservation with simultaneous violation of 3-space energy conservation, accompanied by simultaneous time-symmetry energy flow violation. The two broken symmetries — of 3-space energy flow and of time domain energy flow — thus act as a special extension of the notion of symmetrical regauging, accomplishing it by "equal and opposite-effecting" fields, one in **the** lime domain and one in 3-space.

Ironically it then follows that what have heretofore been conceptually called "perpetual motion machines" with respect to 3-space energy conservation are simply attempts — successful or unsuccessful — to build analogues of a windmill turning in a free wind and powering a load. In short they are attempts to duplicate in systems what every charge in the universe already demonstrates unequivocally. *Nature's* CTD, CED, and EE do not prohibit such systems — again, as evidenced by every charge in the universe demonstrating exactly such "perpetual motion" (we prefer the exact term "giant negentropy") and violation of present *human* CTD, CED, and EE. None of the original charges from the beginning of the universe has slowed and stopped its motion, or stopped pouring out EM energy freely, in some 14 billion years or so. And charge may be taken as the most basic Maxwellian system. Further, all EM fields and potentials, and their energy, comes from their source charges. So those so adamant against perpetual motion machines should first purge their own three models of their *assumed* perpetual motion machines. If this is done, they will purge the three models of all charges, fields, and potentials — and all EM energy in the **process.** In short, the three conventional models used by those same skeptics so loudly condemning "perpetual motion machines" will eat **themselves"** by swallowing their own tail, so to speak.

in short,all three models are easily falsified by every charge in the universe, as well as by every EM field and potential, and by the existence of EM energy itself.

Either their models must surrender any pretense at absoluteness and accept being useful approximations only, or else the conservation of energy law **itself must** be surrendered.

Conventional CEM, CTD, and EE have just hidden this appalling fact and convealed the serious flaws in the modeling by ignoring what Sen {711} reffered to as " *the most difficult problem in classical and quantum electrodynamics.* " We believe it will very difficult to find a single electrical engineering department or professor or text that deliberately acquaints electrical engineering students with the source charge problem and its implications.

As an example, in Chapter 9 we presented an experimentally verified and patent-pending method for a special energy conversion method. This method is proven on the laboratory bench. With this method, a system accepts time-energy and negative energy input, converts it to ordinary positive 3-spatial energy, and uses the converted input energy to close-loop an EM system far from equilibrium. With that conversion process invoked in a governed feedback loop, the COP>1.0 system becomes "self-powering" (an informal term referring to the system freely receiving all its input energy from its active environment). Self-powering, of course, involves the system continuously operating and performing useful work, analogous to a windmill in a wind and powering a water pump. Rigorously, the self-powering COP = oo EM system becomes directly powered by energy from the broken symmetry induced in its supersystem component interactions.

In Chapter 10 we presented the novel concept of the time-reversal zone (TRZ), which uses the extraordinary EM energy density of time to reverse the Coulomb barrier in nuclear reactions in an electrolyte {712}. This enables nuclear transmutation reactions at low *spatial* energy (but at very high *total* energy when time energy is also considered). There are some 600 successful cold fusion experiments worldwide, in multiple laboratories, by multiple researchers, and most of these experiments demonstrate examples of the specific nuclear reactions made possible by the actions of the TRZ. The time-energy anomalies are directly demonstrated in rigorous electrolyte experiments at U.S. Navy research facilities at China Lake, as we have also discussed in this book. So the experimental results are replicated and well proven. Hence there is adequate, replicated experimental demonstration that additional nuclear reactions exist outside the conventionally known nuclear reaction model. Therefore the set of conventional nuclear reaction models also is reduced to a special case domain, with any absoluteness of those models already experimentally falsified. Either that, or we must abandon scientific model where successfully replicated experiments falsify any theory in contradiction to the experiments.

In our proposed solution to the source charge problem {71 lb}, we found a broken 3-symmetry in energy flow while 4-symmetry is maintained. This is a more primary principle of energy conservation. We called this principle "giant negentropy", which is laughably simple to demonstrate experimentally, since every charge and dipole in the universe already demonstrates it. We showed that such giant negentropy is consistent with quantum field theory, particle physics, and a slight corrective reinterpretation of Whittaker's 1903 decomposition of the scalar **potential** The experimentally proven and theoretically justified giant negentropy falsifies any absoluteness of the CTD, CED, and EE models in conflict with it.

Again, this does not mean that one abandons the CTD, CED, and EE models! They are still very useful models in most cases of interest. It means that these present models are still incomplete, and extended models must be developed and used for COP>1.0 EM system research. It also means that none of these three models is valid as a prohibition of the permissibility of COP>1 EM systems.

All EM energy in 3-space comes from the time domain and returns to it. Since all three models exclude time-energy and its transduction into spatial energy, all three are in conflict with the proven giant negentropy model and with the unlimited experimental demonstrations. Accordingly, the experimentally demonstrable giant negentropy of the charge and dipole strongly points out the inadequacy of the three models and the nuclear reaction models, which do not account for time reversal zones, or time-energy and its transduction into a very large magnitude of 3-space energy.

In paragraph A.2 below, we briefly discuss some of the fundamental but permissibie supersystem violations of these older models of CTD, CED, and EE, and provide some comments. It is obvious that all three classical models need very serious updating and extension. We point out that exceptions to present thermodynamics models and "laws" already are recognized{713}, and work on such exceptions is being performed under the heading of extended thermodynamics {714}.

In effect, all three models *exclude* every charge, dipole, or dipolarity in the universe - which therefore excludes all matter, fields, and energy - something completely untenable in modern electrodynamics and modern physics. Since the fundamental nature of the "heat" notion of CTD is electromagnetic field energy, and all EM fields and potentials (and their energy) are excluded if their source charges are excluded, then heat itself is excluded by the three models. That is, CTD is also totally falsified by CED'S exclusion of the source charge's demonstrated giant negentropy, which in effect excludes heat itself. This is a non sequitur of such magnitude that it absolutely requires the complete rework of CTD, CED, and EE.

A.1.1 Featurcs of the Development of Thermodynamics

In the development of thermodynamics, a few key events of interest are listed in Figure A-1 below.

Selected Events in the History of Thermodynamics {715}

1673	Huygens builds a motor driven by gunpowder explosion.
1690	Papin uses steam to move a piston.
1712	Newcomen develops a steam engine.
1723	Stahl popularizes phlogiston and Becher's concepts.
1724	Boerhaave proposes that heat is a fluid.
1733	Bernoulli publishes a text that is the first truly statistical treatment of kinetic theory, and publishes an update in 1738. It is almost forgotten until 1859.
1765	Watts invents a steam engine that is more than six times more effective than Newcomen's engine.
1783	Lavoisier points out the weakness of phlogiston theory with respect to combustion.
1786	Lavoisier and Laplace provide a Memoir on Heat.
1789	Lavoisier publishes his *Elementary Treatise on Chemistry,* which presents the law of conservation of mass.
1791	Prevost publishes a theory of heat and radiation exchange. Richter founds stoichiometry.
1798	Thompson demonstrates the conversion of work into heat, in his *Enquiry Concerning the Source of Heat which is Excited by Friction.*
1799	Davy's experiments seriously challenge phlogiston theory.
1800	Herschel explores the heating ability of different frequencies of light.
1802	Lussac establishes the thermal expansion of gases.
1803	Dalton forms his atomic theory of matter, setting the stage for atomic chemistry.
1804	Leslie shows that light and radiated heat have similar properties.
1806	Young formulates a precursor to the modern kinetic energy.
1811	Poisson develops a mathematical theory of heat, based on Fourier's work. Avogadro presents his law. Berzelius states that electrical and chemical

forces are the same and that atoms are electrically charged.

1819 Dulong and Petit show an empirical law on the specific heat of solids.

1824 Carnot studies the thermal efficiency of machines, introduces reversible transformations, and generates the foundations of thermodynamics in his "Reflections on the Motive Power of Fire".

1829 Coriolis defines "kinetic energy".

1834 Clapeyron presents the first version of the second law of thermodynamics, based on steam engine studies.

1837 von Suerman experimentally verifies Clapeyron's version of Carnot's equations.

1842 Mayer equates the conservation of energy law and shows the equivalence between heat and mechanical energy.

1843 Waterston anonymously publishes an accurate kinetic theory of gases. It is essentially ignored.

1845 Waterston submits a beautiful paper on the kinetic theory of gases to the Royal Society. It is rejected and ignored for more than 40 years, until finally resurrected by the President of the Royal Society.

1847 Helmholtz generalizes the conservation of energy law for mechanical, caloric, electric and magnetic energy.

1848 Lord Kelvin introduces the absolute temperature scale. Joule finishes establishing the exact relation between heat and mechanical work; his work is almost ignored.

1850 Clausius states the second law of thermodynamics.

1851 Thomson derives the second law of thermodynamics based on Carnot's work.

1855 Rankine publishes *Outlines of the Science of Energetics.*

1857 Clausius establishes heat as energy distributed among particles.

1858 Clausius introduces the idea of the mean free path of a colliding particle.

1859	Kirchhoff establishes the thermodynamic foundation of radiation theory, and completes the basic radiation theory in 1862.
1860	Maxwell provides studies in kinetic theory of gases and gives the distribution of molecular velocities. The paper, "Illustrations of the Dynamical Theory of Gases," was read in 1859.
1860	Maxwell shows a discrepancy between experiment and the kinetic theory of diatomic gases. It was not resolved until the early stages of quantum theory.
1861	Kirchhoff advances the notion of the blackbody.
1865	Clausius, Rankine and Kelvin provide the concept and definition of entropy.
1860-1877	Boltzmann and Gibbs provide the foundations of statistical classical mechanics.
1867	Maxwell publishes *On the Dynamical Theory of Gases,* his major work on the kinetic theory.
1874	Thomson points out the reversibility paradox.
1877	Boltzmann defines entropy in terms of probabilities.
1873-1878	Gibbs publishes several important papers on thermodynamics, widely influencing scientists.
1879	Boltzmann establishes the relation between radiation intensity per unit area of a blackbody, and the absolute temperature. Stephan formulates the "Stephan-Boltzmann law" $R_T = \sigma T^4$.
1879-1899	Discoveries of various laws and effects, particularly at the micro level.
1900	Planck proposes the quantum of action and derives the correct radiation spectrum for blackbodies. (He published the definitive paper in 1911).
1905	von Smoluchowski and Einstein independently investigate Brownian motion. Einstein publishes a paper on the photoelectric effect.
1906	Nernst advances his heat theorem, where at absolute zero temperature both heat capacity and entropy change go to zero. This is later recognized as the "third law of thermodynamics".
1909	Einstein corrects Planck's blackbody derivation.

1910 Perrin experimentally validates Einstein's calculations on Brownian motion, providing a strong argument for the existence of atoms.

1911 Rutherford proposes the nuclear model of the atom. Sackur points out the need for an absolute definition of entropy. Nernst's experiments provide strong support for the new quantum theories.

1925 Born, Heisenberg and Jordan formulate quantum mechanics from matrix algebra. Einstein points out that the analogy between quantum gases and molecular gases is complete; photons and molecules have both wave and particle characteristics.

Figure A-l. Key Events in the History of Thermodynamics up to the Development of Quantum Mechanics.

During the early period of science, a continuing struggle between various notions of esoteric fluids and fluid flow occurred. French scientist Lavoisier (1743-1794), regarded as the father of chemistry, is identified with the concept of heat as an invisible fluid, which he named "caloric". The notion was that one drove this invisible fluid — this caloric — out of a material by some action such as mechanical friction or combustion. This produced the "manifestations" of what was loosely called "heat". In short, caloric was considered to be "heat" which was itself an esoteric fluid. In his famous Treatise {716}, published posthumously, atoms were still in dispute. However, Lavoisier listed the known elements, and included light and heat as elements. Asimov pointed out {717} that Lavoisier had "... era*dicated one imponderable fluid, phlogiston, but it was only partly through his influence that caloric, just as false, remained in existence in the minds of chemists for a half a century.* "

Caloric dogmatically existed in the minds of scientists deeply into the nineteenth century, until Maxwell and Boltzmann produced theories that strongly supported the concept of atoms as the building blocks of matter. In the late 1790's, Count Rumford (Benjamin Thomson) showed that the supplay of heat that could be "driven from matter" was unlimited, which totally contradicted the caloric theory {718}. Yet the notion of caloric persisted until Maxwell's theory eventually killed it, once application of that theory showed that heat was comprised of EM energy.

The fundamental ansatz of thermodynamics was formed and solidified before the advent of modern physics, and even before Maxwell's theory of electrodynamics, and before heat was known to be electromagnetic energy. It has unjustifiably retained an aura of "absoluteness" and dogma, even though its foundations concepts are based on outdated notions already scientifically falsified as far as any absoluteness is concerned. As Mallove states {719}:

> *"It is astonishing to realize that many modern conceptions (or laws') in the science of heat— thermodynamics — arose during the nineteenth century, a period of utter confusion about the fundamental nature of heat. How could it have been otherwise, given that the very existence of atoms was still in question! One sees the shakiness of the claim that the laws of thermodynamics had reached a state of 'near perfection' in the twentieth century ...when they in fact rested on this very flawed foundation. "*

During that formative period, the notion of the conservation of energy **was** also being searched for, as if in a thicket of brambles. For some time, any notion of energy conservation was seen as directly contradicted by caloric, and — in formulating the heretical notion that energy is conserved — pioneers such as Mayer {720} were severely castigated.

In 1850 Clausius resolved the conflict between caloric and conservation of energy in a seminal paper {721}.

Mallove {722} explains how the theory developed from there:

> *"In one fell swoop Clausius 'scooped' Kelvin and cast into precise form both the First and Second Laws of Thermodynamics — energy conservation, and the limit of the Carnot efficiency."*

Clausius' statement of the Second Law is: *"It is impossible for a self-acting machine, unaided by an external agency, to convey heat from one body to another at a higher temperature. "*

In 1851, Thomson (Lord Kelvin) stated the Second Law as:

> *"It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects."*

In 1865 — the same year that Maxwell published his seminal paper in his electrodynamics {723} — Clausius derived entropy and showed the two laws of thermodynamics expressed in the same way as the old caloric theory. Clausius used the concept of "entropy" to represent the *"dissipated potential".* In a public speech with the title "The Entropy of the Universe Tends to a Maximum," Clausius included how thermodynamics requires an eventual heat death for the universe. His view was that

> *"The energy of the universe remains constant (first law), while entropy increases. "* {724}

We stress that the notion of the flow of EM energy through space did not originate until the 1880s, when Heaviside and Poynting formulated it independently. Neither relativity — with its notion of a combined spacetime - nor the Minkowski space had been born. Neither had quantum mechanics, quantum electrodynamics, quantum field theory, etc.

For a succinct and very useful listing of the major developments in the history of thermodynamics and statistical mechanics, one is referred to the work of Biggus {725}.

A.1.2 Inadequate Fundamental Definitions in Thermodynamics

In the view we take in this book, energy is the all-important concept, in all its forms, no matter how esoteric. The interactions of energy with matter must therefore be extended to include all known energy interactions, not just those prescribed by CTD or CED. Consequently, two fundamental definitions of thermodynamics are faulted by the supersystem concept.

First, thermodynamics defines an *open system* as one that is open to the exchange of energy and mass across its boundary. No concept or discussion of virtual energy, virtual mass, time-energy, or multiply connected space effects is included. Further, mass is actually a special form of energy, and hence this definition only prescribes the exchange of energy across the system boundary.

Second, thermodynamics defines a *closed system* as a system with no mass exchange across its boundaries, but heat (energy) exchange is permitted. This definition has been a non sequitur since general relativity was established in 1915, and also since caloric (heat) was identified as energy rather than a thin material fluid that was forced or beaten out of matter by doing work on the matter. Since then, energy and mass are also known to be the same thing, as established by general relativity. Whenever the energy of a system changes, its mass changes a priori. So a system thought of as "closed to any mass transfer across its boundaries" still undergoes mass change due to the exchange of energy across its boundary. Further, the definitions of "closed system" and "open system" are not mutually exclusive. As an example, a system exchanging energy but not mass across its boundary can be classified as a "closed system", and also as an "open system" where normal exchange of mass is blocked but the mass of the system still changes as the systems absorbs and emits energy.

Rigorously, even the energy of a system cannot individually change in 3-space, without first invoking 4-space change! Instead, the "energy x time" — the action — of the system is what moves and changes in 4-space, Observation applies a *d/dt* operator, resulting in a 3-space energy observed as having already happened or been fixed.

The modern view of gravitation is that the energy in mass generates the gravitational field, not the mass per se {726}. Also, mass is an observable, hence it is a continuously recurring 3-spatial snapshot that does not even continuously exist as mass, but alternately as mass and masstime. The assumption of the continuous existence in mass is falsified by the quantum mechanical nature of observation itself; hence all three models — CTD, CEM, and EE — are falsified.

Nonetheless, let us continue to use the conventional notion of "flow of energy" and "flow of mass" for convenience.

The thermodynamic definition of "open system" ignores the state in which mass exists as "masstime". No "change of mass", flow of mass, etc. occurs. Instead, masstime can flow or change, but mass is an observable and **thus** frozen 3-space snapshot at one instant. Time is "outside" any 3-space material system, hence when mass becomes masstime, it already "exchanges across the system boundary". *For a mass merely to continue to exist requires the exchange ofmass across the 3-space system boundary.* Indeed, only "masstime" can be changing, so in failing to consider masstime, the definition is falsified as it stands, in its very assumption of "continuous change of mass" when there is no such thing in all of nature. As stated, a similar consideration applies to energy, which does not **and** cannot "continuously exist in 3-space" at **all,** and cannot *continuously* change. Also, *time is highly concentrated energy* as we develop in this book, and time certainly "exchanges across the boundary" of any mass system. Time may be taken as a sort of "multiple connection" in space, since in theory each point in space is said to "exist simultaneously" in the same time-point.

With quantum potential connection, external energetic processes may be "superposed instantly in multiply-connected space" with one or more points of the "closed system". Hence, if there exist processes in the system to transduce time-energy into 3-spatial energy — as in the well-proven cold fusion experiments — matter changes including nuclear transmutations can and do occur. Then the "system closed against mass motional exchange through 3-space" (which does not even concretely exist) is not closed against mass changes at all.

To eliminate the mass-change effects of energy transfer across the system boundary, the present thermodynamic definition of a *closed system* must be completely recast into what thermodynamics presently calls an *isolated system* - one in which neither energy nor mass is exchanged across the system boundary. No such system exists in the universe, since merely to exist it has to be open to continual energy exchange between time and 3-space domains, mass has to continually interchange between mass and masstime, and energy has to continually interchange between energy and (energy x time). The blunt truth is that *only open systems exist in nature.*

All systems are open systems in their supersystem interactions, and they can and do exchange time-energy and mass changes due to spacetime curvatures and active vacuum changes. Any local spacetime curvature made by an energy change in a system or nearby, also reacts back upon the system from its local curved spacetime environment. It may react in a totally energetic fashion, or it may react to produce mass in the system (as in pair production). In the book we pointed out that the supersystem components external to the system can also interact in the system to eliminate mass (as when a Dirac hole combines nonradiatively with a Dirac **election).**

Finally, the notion of an "open system" as one in which energy and mass both can be exchanged across the system boundary must be extended to include a system which can also exchange time-energy, spacetime curvature energy, virtual particle flux activity and energy, and other supersystem effects across the boundary. Further, the notion that a "closed system"can be open to energy exchange but not mass is totally falsified in modern physics' virtual particle exchange between environment and system. Virtual mass — which is physically real — is continually exchanged across the system boundary. Though each virtual mass particle is individually unobservable, coherent summations are observable.

To properly evaluate the conventional thermodynamic definitions of open system, closed system, and isolated system, simply select and use a physics model containing only one fundamental unit, the joule. Now all basic entities are made of energy and functions of energy. So all basic entities are forms of energy; e.g., both mass and time are special forms of energy. As presented previously in this book, to even "exist in time" a system is continually exchanging and transducing 3-space energy and time energy, across its boundary at an enormous rate. Every system is an open system, a priori, and the thermodynamic "closed system" is a non sequitur. The thermodynamic "isolated system" is revealed as the early attempts to deal with observation; i.e., the observed system as a series of frozen 3-space snapshots (effects), each stripped from a 4-space ongoing process at a single moment by the observation process *d/dt* (LLLT) = LLL. Each snapshot is an isolated system (which is what observation produces). Now we understand that this "isolated system" existed only at a single frozen instant, continually recurring, and never existed continuously in time at all,

So in view of today's physics, the old thermodynamic "isolated system" concept is an early attempt to deal with observation of the system without input or input (without dynamics, hence frozen). "Closed system" is a non sequitur since mass is energy and energy is continuously exchanged across the system 3-boundary in several forms. Both virtual mass and virtual energy are continuously exchanged across the system boundary. It follows that the only type of system existing continuously in nature is the *open system.* The other two "types of thermodynamic systems" are at best only approximations for special cases.

Under modern physics and the new definitions, we conclude that there is no such thing as a truly closed or isolated system continuously existing in the universe. Hence that very definition disappears, *as far as any absoluteness*. It is retained only as a *useful approximation in special cases,* when the more esoteric mass effects and energy effects are intentionally omitted or negligible, and only classical effects are of importance. Any scientist dogmatically objecting to COP>1.0 EM systems on thermodynamics grounds alone, simply reveals his lack of knowledge (or lack of acceptance) of modern physics.

This is similar to the situation existing between Newtonian mechanics and relativistic mechanics. We can still use the Newtonian model for many practical matters, since the relativistic effects are often small and nearly inconsequential. Similarly, the present CTD concept of "closed system" now assumes that kind of relationship to *one class* of open systems in which the more esoteric reactions are negligible or inconsequential. But rigorously, all systems are now open systems, removing a gross non sequitur in CTD which is especially violated by COP>1.0 EM systems including every charge in the universe.

This is a correction to both equilibrium (classical) thermodynamics and disequilibrium thermodynamics. Unfortunately the two disciplines have continued to use the same (old) definitions for closed system and open system. Hence both equilibrium and disequilibrium thermodynamics at present are useful approximations, and their "laws" must not be misinterpreted as "absolute". Thermodynamics remains a very useful model, but further development is also indicated. Indeed, presently such scientific development and extension of the thermodynamic model is being done under the heading of "extended thermodynamics".

A.2 Comments on Problems with Thermodynamics

Quoting, from Kondepudi and Prigogine {727}:

> *"Every system is associated with an energy and an entropy. When matter undergoes transformation from one state to another, the total energy remains unchanged or is conserved; the total entropy, however, can only increase or, in idealized cases, remain unchanged. "*

The absoluteness of that statement is falsified by the solution {12} of the long-vexing problem in CED of a source charge and its associated fields and potentials. The observable charge is a charged mass and thus a Maxwellian system. It is also a thermodynamic system, meeting the present erroneous definition of a "closed system" utilized in both equilibrium and disequilibrium thermodynamics. No observable mass crossed the system boundary, although virtual mass continually crosses it.

The charge is "fed" by a more esoteric energy input in disordered form (the virtual particle flux energy of vacuum), yet it outputs ordered observable EM energy spreading radially outward at the speed of light across the universe. The charge increases and sustains the organized energy density of a volume of space depending on the radius *ct,* where *t* is the time since the formation of the charge and *c* is the speed of light in empty space. This continous outflow of observable energy is a continuous and giant negentropy, exhibited by every source charge and dipole. When positive charge, negative charge, polarization of space, and both positive and negative energy are considered, what is spreading is precisely a reordering of the active vacuum — in short, a giant and increasing negentropy. Since the universe is filled with charges, this is a natural process continuously ongoing everywhere in the universe.

Re-quoting Serway (697}:

> \"*The second law [of thermodynamics] does not rule out the possibility of pushing heat uphill, as it were, from a cold object to a hot one, or of creating order out of disorder. It merely states that such a reversal of the natural flow requires an influx of energy...* "

Our comment is that any mechanism by which the system receives extra usable energy in forward time, or is time-reversed, enables the system to permissibly violate any narrow interpretation of the second law of thermodynamics. The second law was formulated in accord with forward time assumed, and with the old definition of "closed system", which erroneously permitted energy exchange but ignored the mass effects of energy exchange. Therefore, the second law is a special case for equilibrium in its energy exchange with its active environment, but effectively allowing its own negation anyway, and it always has. In the new approach with altered definitions, all EM systems are open systems, and they may also be brought into disequilibrium (in excited states or potentialized condition). Thus in theory all systems are permitted to violate the second law, *particularly when broken symmetries in their supersystems are involved.* This is especially true of EM systems, where all the EM field energy and potential energy in the system— even in the matter itself— comes from the active vacuum environment (particle physics view) by means of the broken 3-symmetry of the source charges and dipoles. The condition of 4-symmetry in energy flow exchange together with broken 3-symmetry and t-flow symmetry, is a disequilibrium condition and an excited state. Every charge and dipole already exhibits this state and the giant negentropy condition.

To first order, then, one may say that the present second law assumes no broken 3-symmetry or broken t-flow symmetry in energy flow, while violation of the second law assumes broken 3-symmetry and broken t-flow symmetry.

Quoting Serway {728}:

> *"Thermal equilibrium is a situation in which two objects in thermal contact with each other cease to have any net energy exchange due to a difference in their temperatures."*

Our comment is that net energy exchange — to include time-energy exchange and negative energy emission, absorption, and transduction are not modeled in thermodynamics and are arbitrarily excluded in **the** quoted statement. Since both are exhibited experimentally, the statement is falsified as far as being absolute. Instead, it is a special case and a useful approximation when some of the esoteric energy considerations are negligible.

Quoting Serway again {729} on the zeroth law of thermodynamics:

> *"If objects A and B are separately in thermal equilibrium with a third object, then A and B are in thermal equilibrium with each other. "*

A corollary is stated by Serway {730} as:

> *"...two objects in thermodynamic equilibrium with each other are at the same temperature. "*

Our comment is that these statements are true if the time-energy exchange is identical among all three. Otherwise, they are not necessarily true. It is not generally true, e.g., for a system in an accelerated frame. Also, the zeroth law is not necessarily true if negative energy (and/or its transduction is involved with one or more of the objects.

An example: A and B are at the same temperature as C, as measured by a thermometer. But A is also emitting negative energy, which is being absorbed by B, to maintain A and B at the temperature of C. A and B are not in real thermal equilibrium in their supersystem interactions, even though they are at the same macroscopic temperature. A second example: A is emitting negative energy to maintain its temperature, while B and C are not. The supersystem of A is not in real thermal equilibrium with the supersystem of either B or C, even though the observed temperatures of A, B and C are the same.

Quoting {731} on what is meant by the term "heat":

> *"...heat is treated as another form of energy that can be transformed into mechanical energy. " ... "The word heat should be used only when describing energy transferred from one place to another. That is, heat flow is an energy transfer that takes place as a consequence of temperature difference only."*

Quoting Lindsay and Margenau {732}:

> *"A complete statement of the first law comprises two* ***assertions:*** *(a) heat is a form of energy, (b) Energy is* ***conserved."***

The statement in (a) that heat is simply a form of energy is misleading, and the statement in (b) that energy is conserved must be expanded to include total energy, not just heat and the presently accounted forms of energy. Specifically virtual particle energy, time-energy, and energy from the curvature of spacetime must be included.

More correctly, heating is a form *of energy disordering* or energy scattering. As previously pointed out, entropy itself was and is conceived as *the dissipation (irretrievable loss) of potential energy.* Heat thus would be the process of energy disordering, which means that heat is a form of the process of entropy (loss of control of the energy). Note the strong non sequitur with the notion that heat is energy. *Heat cannot logically be both energy and the dissipation of energy.* The concept of energy (its mere presence) is not identical to the concept of scattering of energy or transfer of energy, but the concept of heat is identical to it. The thing is not identical to something done to the thing or to transfer of the thing to another place. A form of scattering of order is not a form of ordering. Transfer of heat is a transfer of disordering of energy, not the transfer of energy per se. Hence, considering heat as simply "heat energy" is a fundamental non sequitur of classical thermodynamics, and remains so to the present day and in the present textbooks. For an example of strong support of this position, see Romer {733}. Quoting {734}:

> *"The work done on (or by) a system is a measure of energy transfer between the system and its surroundings, whereas the mechanical energy (kinetic or potential) is a consequence of the motion and coordinates of the system. Thus, when you do work on a system, energy is transferred from you to the system. ... one can refer only to the* *work done on or by a system* *when some process has occurred in which the system has changed in some way."*

Our comment: Consider a system which "ping-pongs" the energy it receives from the environment, between two parts of itself. In each part, the form of the energy is changed by that interacting part and that does work upon the part. But the new form of energy remaining after the work was done in that component is not lost but is ping-ponged to the other component, where it does work upon that component, and so on. In this case, each joule of energy input from the environment does more than a single joule of work, with the work performed being limited only by the ability of the system to sustain and contain the "ping-ponging". There is work but no entropy if the energy doing the work (changing its form) is not lost from system control!

There is no law of "work conservation" in nature, and a joule of input energy can do more than one joule of work (as in this example) if repetitive changes of its form are considered. Thermodynamics arbitrarily excludes such cases, and hence is incomplete. Again, the conventional perception of the absoluteness of thermodynamics is falsified. It models a special case where the energy can be "used" to do work only once, and then all control of the new form of the energy (it is all still there, just in a different form) is lost.

For a particular substance, the heat capacity C is usually defined as *the amount of heat energy needed to raise the temperature of the sample being tested by one degree Celsius.* This definition assumes only one "use" of the *energy to* perform work in the substance, and completely ignores "multipass,multi-use" of the energy to perform more than one joule of work from one joule of input energy. As an example, if an equal amount of positive and negative energy is steadily input, then no amount of the positive heat energy input component would raise the temperature at all. The modern active vacuum, with a local energy density in the region of 10^{80} or more grams per cubic centimeter (expressed in mass units), nevertheless is harmless to living systems immersed in it. It has equal positive and negative energy densities, and so normally inputs the same enormous amount of positive and negative energy in its overall interactions with a living system.

The first law of thermodynamics is usually written as

$$\Delta U = U_f - U_i = Q - W. \qquad [1]$$

This is a highly special case, which does not include time energy transduction (spatial energy transduced into time energy and vice versa), or energy transduced from the active vacuum via the broken symmetry of an electrical system in continuous exchange. The definitions of work and heat have to be changed and drastically extended.

As an example of a legitimate exception, when time-energy T_E is transduced into available spatial energy inside the system, we have

$$\Delta U = U_f - U_i = Q + T_E - (W_D + W_L) \qquad [2]$$

where W_D is the energy that was dissipated in the system losses without doing useful work and W_L is the energy leaving the system but doing useful work in a load L. $(Q + T_E)$ represents the total net energy entering the system, while $(W_D + W_L)$ is the total energy leaving the system, either as losses or to do useful work in the load. Here we are also incorporating virtual energy under the title of time-energy, since both time and virtual energy are unobservable, and virtual energy "exists in time".

Now suppose Q entering the system, and collected for use in it, is freely furnished from the active vacuum via the broken symmetry of the electrical system's dipolarity. Suppose T_E is spatial energy freely transduced from the time domain by ongoing processes in the system, and thus T_E also enters the system freely. Then suppose that the system processes are deliberately adjusted by the operator so that

$$(Q + T_E) = (W_D + W_L) \qquad [3]$$

In that case,

$$\Delta U = U_f - U_i = 0 \qquad [4]$$

yet continuous loss energy WD is escaping from the working system, useful work W_L is continuously being done in the load, and useful energy $(Q + T_E)$ is continuously entering the system from the active environment (the active vacuum and the local curvatures of spacetime). This system is totally permissible in nature (and is already operating in every charge and dipole in the universe). It is an example of an open system far from equilibrium in *3-space* energy flow, but in equilibrium in *4-space* energy flow. Yet it is artificially excluded by classical thermodynamics.

Classical thermodynamics thus excludes every charge and dipole in the universe, and therefore is an extraordinarily curtailed model. It is a special case approximation having no absolute authority as a proper limiting model of EM systems.
The first law of thermodynamics for infinitesimal changes may be stated as

$$dU = dQ - dW \qquad [5]$$

Following the previous reasoning, for involvement of time-energy transduction (with virtual energy included) we have

$$dU = dQ + dT_E - (dW_D + dW_L) \qquad [6]$$

If dQ and dT_E are freely received in the system from the active vacuum and local curvatures of spacetime respectively, and if

$$dQ + dT_E = dW_D + dW_L \qquad [7]$$

then

$$dU = 0 \qquad [8]$$

So with no change in its internal energy at all, the microsystem or microprocess is receiving excess energy continuously, and also is continuously emitting energy that is doing useful work with some losses. The system is in fact in *energy 4-flow* equilibrium, and doing useful work, without the operator inputting any of the energy.

So the *corrected* standard statement of the first law allows an equilibrium system to steadily produce output work W, if its "energy input Q" is freely received. The first law of thermodynamics, properly extended and reinterpreted, does indeed admit "electrical windmills" operating in free electrical winds.

Now turning to the second law. In effect, the second law prescribes those processed in nature — more exactly, in the prescription of the first law — that may or may not occur. It is a law of limitation. It states that, of all the energy conversion processes permitted by the first law, only certain types of energy conversions can take place. A priori, the validity of its prescription depends totally on the nature of the functions involved in the system considered! However, since we dramatically extended the first law, using neww processes experimentally determined to take place, then we have automatically extended and changed the second law because we used experimentally *proven* functions. The old second law is now revealed as a special case, with no absolute limitations. The perception that it prescribes absolute limitations has been falsified. It is still useful, however, but to be careful one must completely re-examine (and possibly rework) the second law whenever the energy functions of a system are changed. We strongly stress that *the second law is a conditional law, and its application is totally dependent upon the system energy functions behaving in the limited manner assumed by the second law. Whenever the energy functions of the system are changed outside those assumed by the second law, the second law is permissibly invalidated for that system.* In short, in that case the second Iaw is simply a totally inadequate model for that system, and cannot be used as any sort of criterion for stating the "permissibility" or "impossibility" of that system. As an analogy, a model specifying scalars only cannot be applied to a vectorial system as a decisive logical criterion or restriction.

Quoting Seray{735}:

> *"From an engineering viewpoint, perhaps the most important application [of the second law] is the limited efficiency of heat engines. Simply stated, the second law states that a machine capable of continuously converting*

> *thermal energy completely into other forms of energy cannot be constructed."*

Our comment is that, if we believe that energy is conserved in the entire universe, then the universe itself already violates Serway's statement. If we consider the seething virtual particle flux energy of the active vacuum as a special form of thermal energy, then every charge and dipole in the universe already is a heat engine that falsifies the second law of thermodynamics. The charge and dipole continuously absorb this special form of thermal (virtual flux) photon energy, and also continuously convert it into real, observable photon emission in 3-space. This is negentropy on a giant scale, already demonstrated by every charge and dipole and thus experimentally falsifying the present second law.

Classical thermodynamics also assumes irreversibility. While many of the physics models and equations prescribe reversible reactions, thermodynamics takes the view that events occur with a much greater probability in one direction in time than in the other. This of course is usually borne out in our perception of the gross observable universe around us. However, charge conservation alone requires equal amounts o| charge and time-reversed charge. With the nearly ubiquitous time-reversed charge and charge conservation, it follows that some factor not accounted for in thermodynamics is operating in the universe. And so it is, but it is a general relativistic factor. We shall use a biological example of the cellular healing mechanism we discovered in the living body {736}, extending Becker's work and Priore's work.

Normally most processes do not involve deliberate net transduction of time-energy into spatial energy, nor do we model and account for the specific set of ongoing interactions between every part of the system **and** its concomitant set of spacetime curvatures acting back upon it. Call that set of spacetime curvatures the *resident spacetime curvature engine **and its** dynamics,* or just *its engine* for short. The engine is comprised of structured energy and energetics, and it is already experimentally demonstrated in nonlinear phase conjugate optics that energy can be **time** reversed. The engine's spacetime curvatures act directly upon the **mass-**energy dynamics of the system. Time-reversing the system's operation is a matter of producing a sufficiently amplified, phase conjugated engine to act in reverse upon the physical system and overpower its resident **engine.** In that case, the thermodynamic system and its functioning can be **made to** run backward.

In fact this is the fundamental mechanism used by the body's own cellular regenerative system to heal its damaged cells. To a limited degree, the body is able to "pump" its cells in the time-domain (with time-energy), thus producing an amplified "phase conjugate energy and engine dynamics".

Pumping a living cell with time-energy is interesting. The resident engine serves as the "signal input wave" in conventional nonlinear phase conjugate optics, and the output time-reversed engine (the amplified anti-*engine*) serves as the "phase conjugate replica wave". A sufficiently simplified anti-engine acts upon the cell and all its tiniest parts, time-reversing all energetic operations in exact phase, proportion, and timing. This is the mechanism for thermodynamic reversibility. It is also the "secret" to eventually reversing aging.

This action is upon all the energetics of the cell and its parts, including the mass-energy and mass-energetics as well.

The result of the action of the anti-engine is to slowly time-reverse the damaged cell and all its parts back to a previous state and dynamics. Electromagnetic amplification of the process was unwittingly demonstrated by Priore {737} and by Becker {738}. We refer the reader to our website {739} and to our "porthole briefing" for pertinent technical information, and for a most important extension and great simplification of the Priore/Becker approach and methodology.

Present classical thermodynamics does not consider or model the reaction of local spacetime curvatures and their dynamics upon the system. Hence all time-domain pumping that occurs is occurring rather randomly in each and every microscopic part of the system. In short, there is no organized anti-engine, and an organized anti-engine is what is required for time-reversing the system's operations back to a previous state. However, by mimicking**,** the body and pumping the physical process in the time-domain, with sufficient pumping a precise, amplified anti-engine will be formed and act upon the system — *any* system. The applicability is limited only by the state of development of the appropriate time-pumping technology.

In theory (and as experimentally demonstrated unwittingly by Priore and by Becker), this anti-engine can and does overpower the resident engine. It can in fact time-reverse the pumped physical processes in the system itself.

So the classical thermodynamics assumption of irreversibility for heat engine energy processes is not absolute but only provisional. Specifically, it assumes no overall time-domain pumping process that provides a precise anti-engine and time reversal of the system energetic process of concern and its dynamics.

If the second law is extended to encompass and model the new concepts such as broken symmetry and time-energy, then the extended second law will encompass reversible heat engine processes, Maxwell's demons, COP>1.0 electrical systems, COP» 1.0 electrical systems (electrical windmills), time-reversal of the dynamics, reversibility of that which has been irreversible, etc.

As given by Kondepudi and Prigogine, the third law of thermodynamics essentially states {740} that

> "... *at the absolute zero of temperature the entropy of every chemically homogeneous solid or liquid body has a zero value."*

This is also known as Nernst's heat theorem, after W. Nernst who proposed it in 1906. The third law states that

$$S \rightarrow 0 \text{ as } T \rightarrow 0 \qquad [9]$$

Certain violations of the third law are already known. E.g., C=O: carbon monoxide molecules can align in various ways in a crystal, so there is entropy associated with C=O crystals at 0°K. In this case, A and B are equally probable and the following equation can be used to calculate the entropy (called residual energy):

$$S = nR\,[1/2\ln(1/2) + 1/2\ln(1/2)] = -nR\ln 2 \qquad [10]$$

From the new viewpoint, the definition of T = 0° is open to change. Rigorously, the present third law assumes no local broken 3-symmetry of the vacuum's flux exchange with the system, and it also assumes no broken time-energy flow symmetry. In the new approach, both these symmetries can and are broken by every charge while a higher 4-symmetry is maintained. This leads to a giant negentropy, so that the "calculation of entropy" via Nernst's theorem fails. A fundamental charge at T = 0° thus continues to exhibit giant negentropy, in total violation of the third law of classical thermodynamics. Hence the third law is also devoid of any absoluteness, and it is reduced to a special case statement. It remains useful where the more esoteric energy interactions are negligible.

We have now demonstrated (by citing actual substantiating experiments) that all the laws of CTD are falsifiable insofar as being absolute. Hence they have *no* absoluteness. Instead, they are special case models and "approximation laws" only. They remain very useful and applicable, However, so long as the more esoteric energy interactions of the supersystem do not play a major role in the system operation.

We conclude that the present form of classical thermodynamics and disequilibrium thermodynamics are special case models — as indeed is every model, by Godel's theorem and proof alone — with no absoluteness. They do not prohibit COP>1.0 EM systems, nor can they necessarily be used to rule out COP>1.0 EM systems.

This also falsifies all current arguments that COP>1.0 EM systems violate either the first, second, or third law of classical thermodynamics. Calling COP>1.0 systems "perpetual motion machines of the first, second, and third kind", according to which law they supposedly violate, is a total non sequitur. Indeed, every original charge in the universe has already demonstrated just such "perpetual motion" for some 14 or so billion years, and happily violates all three laws of the present CTD. Every charge is in violation of the "laws" of the present models of CTD, CED, and EE, and it is still in motion and still freely pouring out EM energy. We have no abillity to examine the notion of "perpetual" past the entire past existence of the universe.

All three models examined — CTD, CED, and EE — are seriously out of date and in need of revision and extension, because any absoluteness of their predictions and assumptions is already falsified by actual experiments and examples. Some work is already ongoing to extend thermodynamics, but is not nearly extensive enough. A thorough overhaul of the very foundations is what is needed for all three models. The three models remain useful as special case approximations, but their received use to arbitrarily rule out COP>1.0 EM systems is dogma, not science because such use is already experimentally refuted by every charge in the universe.

Appendix B

Maxwell's Demon: Alive and Thriving

Introduction

ITHERE is a long history of discussion over "Maxwell's demon", a fictitious being that Maxwell proposed to "sort" molecules striking a barrier between two volumes of gas initially at the same temperature. By intentionally opening a trap door between two for hotter, more energetic molecules to pass through from the left side to the right side, but shutting the door for lower lemperature molecules so that they are retained on the left side, eventually a temperature gradient would "freely" exist between the two reservoirs. In theory, then, if one had the demon working "for free", one would be able to utilize the temperature difference between the reservoirs to perform free work. Then one could repeat the demon's sorting procedure, to obtain more free work again. And so on.

The prevailing discussions have ignored the main feature: the fact that the demon is part of the "external environment" (i.e., not under control of the system, and operating independently of any energy input by the operator). Maxwell's demon represents an analogy to the system's environment furnishing free energy (free ordering and sorting). A lot of breath and mental gyrations have gone into the discussions over the years, with very little concrete experimental examination. The prevailing concept in science, which still adheres to the "absoluteness" of the second law of thermodynamics, is that Maxwell's demon is impossible.

Recently, the former editor of *Nature,* Dr. John Maddox, wrote a very clear emeritus editorial on Maxwell's famous demon, repeating the standard conclusion that such is not possible. Since there are specific examples in physics of what can be called "experimentally proven Maxwell's demons," the present author prepared a respectful commentary to *Nature* to refute the standard erroneous thesis in the interest of science. since experiment is supposed to be decisive in physics, we hoped that citing overwhelming experimental proof would be sufficient. It wasn't.

Almost symbolically (i.e., "free the demon!"), I submitted the commentary to the editor by I -mail on the evening of July 4, 2002. The very next day I received rejection (not too unexpected) by E-mail with no further discussion accepted. So I wrote a polite note in response, and then posted my commentary note on my website.

In this appendix, I include my E-mails of both 4 July and 5 July 2002, and then include the commentary that was submitted. The reader can read the cited emeritus editorial in *Nature,* and then decide for himself or herself whether experiment still rules the day at *Nature* where COP>1.0 and COP = co EM systems are concerned.

E-mail to *Nature* 4 July 2002, submitting the Commentary.

Dear Editor:

Attached is a significant commentary on John Maddox's excellent emeritus editorial on Maxwell's demon, titled "Slamming the Door," *Nature,* 417, 27 Jun. 02, p. 903.

Forms of Maxwell's demon are very much alive and thriving, and experimentally confirmed, as we develop very clearly in this commentary. They are unwittingly used widely in electrodynamics, though seldom recognized.

Most sincerely,
Tom Bearden, Ph.D., Magnetic Energy Ltd.

E-mail to *Nature* 5 July 2002, submitting a comment on the rejection.

Dear Ms XXX:

Thanks for the prompt reply.

Since *Nature* will not be publishing the note, I have now posted it on my website (some 80,000 hits per day from all over the world). It can be **seen** at http://www.cheniere.org/articles/maxwells%20demon.htm

This is a respectful article, and I just thought the experimental information needed getting out there to the scientific community. I also understand you cannot discuss it further. I only wish to note that it is based on cited replicable experiments, which are supposed to be the decisive thing in science and scientific method. It seems a bit odd that you would not publish the results of several replicable and replicated experiments **that** falsify a prevailing theoretical thesis and conclusion. Nonetheless, I respect the wishes of *Nature,* and I do enjoy the Journal each week.

Best wishes,
Tom Bearden, Ph.D.

Within days of this rejection, the paper by Wang et al. {741} was published, extending the known physics "Maxwell's demon" regime (i.e., where the second law of thermodynamics is known to be violated) from the atomic scale and very short periods of time, to the micron scale in size and time up to a few tenths of a second.

Here is the rejected commentary I submitted to *Nature.*

Maxwell-type demons are alive and thriving

The recent emeritus editorial by Maddox on Maxwell's demon [742] is a short overview of one historical aspect of would-be negentropy, but much greater thought on the subject needs to be given. Indeed, Maxwell's demon is alive and thriving, but just in a different form not requiring a nimble-fingered microscopic being. We now discuss such experimentally proven demons.

Consider the prevailing ansatz that Maxwellian systems outputting more EM energy than the energy input by the operator or experimenter are impossible. Such proposed systems are said to constitute examples of forbidden perpetual motion machines because they violate the second law of classical (equilibrium) thermodynamics. That prevailing ansatz has been falsified in classical electrodynamics since the 1880s, and in particle physics for 45 years, but eerily it is still the prevailing scientific opinion nonetheless.

The ansatz can be experimentally disproved in classical electrodynamics as follows: Lay a charged capacitor or electret on a permanent magnet so the E-field of the capacitor or electret is at right angles to the H-field of the magnet. That optimizes $\mathbf{S} = f(\mathbf{E} \times \mathbf{H})$, and hence optimizes the continuous flow of Poynting EM energy from that simple device, even though the fields, seem to be "static". As Buchwald states [743], *"[Poynting's result] implies that a charged capacitor in a constant magnetic field which is not parallel to the electric field is the seat of energy flows even though all macroscopic phenomena are static. "* [744] This simple device will freely pour EM energy indefinitely, so long as it remains intact.

We consider a special but universal kind of related Maxwell's demon problem: the vexing problem of the source charge, sometimes called "the most difficult problem in classical and quantum electrodynamics." [745] Any charge pours out observable EM energy continuously in all directions, at the speed of light, with no *observable* EM energy input. This continuous flow of EM energy establishes the charge's related fields and potentials and their energy, reaching even across the universe for very old charges. In the classical electrodynamics (CED) model and therefore in electrical engineering, there is no solution to this problem because CED does not model *nonobservahle* EM energy inputs such as the virtual particle flux exchange of the charge with its vacuum environment.

With no solution available in CED, then the present CED and electrical engineering assume that every charge in the universe *freely and continuously creates energy out of nothing,* and pours it out in all directions, forming its associated fields and potentials and their energy. Either we must solve the problem in the classical EM model, or totally surrender the conservation of energy law in the model in its present limited form. Or — as is presently the case — we may continue to ignore it, as has been done during the 45 years since the proof of broken symmetry in particle physics [746].

On the other hand, particle physics models and utilizes virtual energy **in** the seething vacuum, including the interactions of the vacuum with charge, With the 1957 experimental proof of broken symmetry by Wu et al., [746] certified by the award of the Nobel Prize to Lee and Yang later that **same** year, one of the proven broken symmetries in the vacuum virtual energy exchange is the asymmetry of opposite charges, such as are on the ends of a dipole. For a dipole or dipolarity, then by the very definition of broken symmetry *something virtual has become observable.* We diverge for a moment, and then will return to this proven asymmetry of the opposite charges of the dipole.

If we take the modern view of the bare charge clustered by virtual **charges** of opposite sign, then the magnitude of the bare charge in the middle is infinite (including its energy) and so is the magnitude of the charge of the surrounding clustering virtual charges. [747] So for an "isolated **observable** charge" we actually have a sort of "infinitely powerful dipole". Yet **the** difference between these two infinite values of charge is finite; it is routinely calculated as the observed charge of an elementary charged particle, the value that is listed in standard texts and handbooks.
The asymmetry of this "opposite composite charges" model of the "isolated observable charge" now explains the long-vexing source **charge** problem. The observable "composite" charge continuously absorbs **virtual** photon energy from the seething vacuum exchange, transduces it **into** observable photon energy excitation, and this excited state **continuously** decays to emit real observable photons in all directions at the speed of light. When *virtual* energy input as well as *observable* energy output is accounted, the charge's proven asymmetry in the vacuum exchange **makes** the source charge an open system far from equilibrium in its active

environment. As an open disequilibrium system the charge is thermodynamically permitted to (1) self-order (hence coherently integrate absorbed virtual photon energy into observable photon energy), (2) self-oscillate or self-rotate (spin), (3) output more energy than the "operator" **inputs** (the operator inputs none at all), and (4) exhibit negentropy. Every charge in the universe is already doing those four functions. It is also a system having a COP (coefficient of performance, or useful energy output divided by the operator's energy input) of COP = oo, since the operator inputs nothing.

In short, every charge in the universe already is a special kind of known "Maxwell's demon", whose operational mechanism is long since proven in particle physics but does not appear in classical electrodynamics or electrical engineering. It is a dependable Maxwell's demon, since all charges in the original matter in the universe have been pouring out real EM energy freely, using this asymmetry mechanism, for some 14 billion years, **and** they continue to do so. Further, any charge one assembles in the laboratory instantly starts up its Maxwellian demon performance automatically, and it will continuously pour out EM energy in all directions indefinitely, so long as the charge remains intact. So this demon is easily created and demonstrated experimentally. The Maxwell's demon fot freely extracting copious EM energy from the vacuum is one of the easiest entities to invoke in all of physics

This is **not** a violation of thermodynamics, since classical *equilibrium thermodynamics* with its infamous second law does not apply because the charge is far from equilibrium in its exchange with its active vacuum environment. Although the COP = oo, the *efficiency* of the charge system -defined as the useful energy output divided by the total energy input from all sources — is never more than 100%. Hence this is not a perpetual motion machine, and the charge rigorously does not create energy; it only transduces energy input to it in a novel form. In this case, the charge can permissibly act as if it were a free electrical windmill turning in a novel free electrical wind due to its asymmetry in the vacuum flux.

So every charge in the universe exhibits COP = oo, clearly proving that Maxwell's demon in an improved form exists and is thriving throughout the universe. There would be no EM fields and potentials and their energy, and hence no electrical circuits or power systems, were it not for this asymmetry of the charge in its virtual energy exchange with the vacuum, making the charge a true Maxwell's demon.

In the usual CED model and electrical engineering, the 1867 L. V. Lorenz symmetrical regauging (later credited to H. A. Lorentz) [748] of the equations carefully selects only those Maxwellian systems that have two simultaneous equal and opposite disequilibria with their active environment. This assumes that the potential energy of the system is freely changed twice (by gauge freedom), but only in such highly selected manner as to form two equal and opposite new "free" force fields in the system. These two force fields perform *internal work* inside the system continuously, increasing its stress (and its stress potential, thereby curving local spacetime). Since there is no *net resultant* force field, the two force fields are unable to translate electrons in the circuit to do free *external* work in the external load. So the symmetrically regauged Maxwellian system has been altered: its energy has been changed twice, forming a stress potential inside it and increasing and maintaining that stress on the system, and the frame of the system has been somewhat rotated out of **the** laboratory frame. The symmetrically regauged Maxwellian system most decidedly is not identical to the system prior to regauging.

We note merely that the common Lorentz symmetrical regauging unwittingly assumes two Maxwell's demons of yet different kind, each freely fueled from the local vacuum environment, and each continuously performing internal work upon the system to produce and maintain system stress.

Gauge freedom is thus revealed as a special kind of Maxwell's demon, since (1) it assumes that the potential energy of a system can be freely changed at will at any time, and (2) unless we abandon the conservation of energy law, that energy change must have involved energy exchange **with** the external environment. So the gauge freedom axiom of quantum field theory assumes two specialized Maxwellian demons — i.e., mechanisms for transfer of energy between environment and system, so as to continuously perform internal work upon the system. In this case the two demons are equal and opposite, and fight each other to a draw insofar as performing any useful external work.

Oddly, in present electrical circuits the ubiquitous but *arbitrary* closed current loop circuit — passing all spent current from the external circuit back through the source dipole in the generator against the dipole's **back** emf— self-imposes Lorentz regauging of excitation discharge in the circuit and prevents COP>1.0 functioning. This is not required by thermodynamics in general! Indeed, several areas are already known to violate present thermodynamics. Sharp discharges (strong gradients), for example, are known to violate it. [749] Other known areas where thermodynamics is violated include rarefied media, and anomalous memory effects in materials. Modern research is being conducted in such areas under the heading of "extended thermodynamics". [750].

Since experiment and not theory is primary in science, let us consider some additional actual Maxwell demon experiments. The well-known "negative resonance absorption of the medium" produces more output energy than the operator inputs to the experiment, with hundreds of these experiments done every year routinely by many nonlinear optical laboratories. As an example, Bohren's version of such an experiment [751] commonly outputs 18 times as much EM energy as the operator inputs, exhibiting COP = 18. Independent replication of Bohren's work by Paul and Fischer [752] is reported in the same journal issue.

Added to the charged capacitor lying on a permanent magnet, there thus exist plenty of proven, replicated experiments which can be easily performed to demonstrate a Maxwellian demon operating in a Maxwellian system and freely producing COP>1.0, or even COP = ∞. Because of the demon (the operational mechanism), these experiments all involve open systems far from equilibrium with their active environment. Hence they are not limited by the second law of classical equilibrium thermodynamics.

In short. Maxwell's demon is very much alive in many forms and is thgiving after all. It has just been hiding in different form than what is usually suspected.

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ENDNOTES

1. (a) Albert Einstein, "Foreword," in (b) Max Jammer, *Concepts of Space: The History of Theories of Space in Physics,* Harvard University Press, Cambridge, Massachusetts, 1969, p. xi-xii.

2. George Zebrowski, "The holdouts," *Nature,* Vol. 408, 14 Dec 2000, p. 775; expressing the thinking of Stephen Hawking, one of the leading physicists of our day.

3. Mario Bunge, *Foundations of Physics,* Springer-Verlag, New York, 1967, p. 176.

4. (a) J. H. Poynting, "On the transfer of energy in the electromagnetic field," *Phil. Trans. Roy. Soc. Lond,* Vol. 175, Part II, 1884, p. 343-361; (b) — "On the Connection Between Electric Current and the Electric and Magnetic Inductions in the Surrounding Field," *Phil. Trans. Roy. Soc. Lond,* Vol. 176, 1885, p. 277-306.

5. (a) Oliver Heaviside, "Electromagnetic Induction and Its Propagation," *The Electrician,* 1885, 1886, 1887, and later — a series of 47 sections, published section by section in numerous issues of *The Electrician* during 1885, 1886, and 1887; (b) —*Electromagnetic Theory, 3 vols., Be*nn, London, 1893-1912. Second reprint 1925. An unabridged edition of all three volumes, with a critical and historical introduction by **E. Weber,** was published by Dover, New York, 1950. See particularly (c) - "On the Forces, Stresses, and Fluxes of Energy in the Electromagnetic Field." P*hil Trans. Roy. Soc. London,* 183A, 1893, p. 423-480. In this prestigious publication, Heaviside discusses the Faraday-Maxwell ether medium, outlines his vector algebra for analysis of vectors without quaternions, discusses magnetism, gives the EM equations in a moving medium, and gives the EM flux of energy in a stationary medium. On p. 443, he credits Poynting with being first to discover the formula for energy flow, with Heaviside himself independently discovering and interpreting this flow a little later by himself in an extended form.

6. E.g., a polite debate has continued at intervals, for about 30 years, in the Am. J. P*hys.* alone.

7. Richard P. Feynman, Robert B. Leighton, and Matthew Sands, *The Feynman Lectures on Physics,* Addison-Wesley, Reading, MA, Vol. 1,

8. *Ibid.,* Vol. 1, 1964, p. 12-2.

9. *Ibid.,* Vol. 2, 1964, p. 2-1.

10. John D. Kraus, *Antennas,* Second Edition, McGraw Hill, 1988.

11. Raymond A. Serway, *Physics for Scientists and Engineers with Modern Physics,* Third edition, updated version, Saunders College Publishing, Philadelphia *et al,* 1990, p. 620.

12. T. E. Bearden, "Giant Negentropy from the Common Dipole," J. *New Energy,* 5(1), Summer 2000, p. 11-23. Also on website www.cheniere.org.

13. (a) T. D. Lee, "Question of Parity Conservation in Weak Interactions," *Phys. Rev.,* 104(1), Oct. 1, 1956, p. 254-259; (b) — with Reinhard Oehme and C. N. Yang, "Remarks on Possible Noninvariance under Time Reversal and Charge Conjugation," *Phys. Rev.,* 106(2), 1957, p. 340-345; (c) — and C. N. Yang, "Parity Nonconservation and a Two Component Theory of the Neutrino," *Phys. Rev.,* 105(5), Mar. 1, 1957, p. 1671-1675.

14. C. S. Wu, E. Ambler, R. W. Hayward, D. D. Hoppes and R. P. Hudson, "Experimental Test of Parity Conservation in Beta Decay," *Phys. Rev., Vol.* 105, 1957, p. 1413.

15. We published it crudely two years later. See T. E. Bearden, *Quiton/Perceptron Physics: A Theory of Existence, Perception, and Physical Phenomena,* NTIS Report AD-763-210, 1973.

16. A time-reversal zone is a momentary tiny region of the fluid wherein antiphoton reactions with the main ions predominate over **photon** reactions.

17. See T. E. Bearden, "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves," *J. New Energy,* 3(2/3), 1998, p. 12-28. A slightly expanded paper by the same title is published in *Explore,* 8(6), 1998, p. 7-16.

18. E.g., see Xiaodong Chen, "A New Interpretation of Quantum Theory — Time as Hidden Variable," Los Alamos National Laboratory web site, arXiv:quant-ph/9902037 v3, 11 Feb. 1999. Using two more **time** variables as the quantum hidden variables, Chen derives Dirac's field equation under the principle of quantum physics, and then extends **the**

method into quantum fields with arbitrary spin number. Chen's model offers very interesting unifications of quantum mechanical behavior.

19. F. Mandl and G. Shaw, *Quantum Field Theory,* Wiley, 1984, Revised Edition 1993, Chapter 5. This is a deeper coverage of the photon polarizationd. Mandl and Shaw argue that the longitudinal and scalar (time-polarized) polarizations are not directly observable, but only in combination, where they manifest as the "instantaneous" Coulomb (i.e., electrostatic) potential. This argument, translated from particle terminology to wave terminology, directly fits and strongly supports my reinterpretation {12} of Whittaker's 1903 wave decomposition of the scalar potential {85}. The reinterpretation also represents the discovery of the giant negentropy process favored by nature, easily evoked by breaking 3-symmetry (as by forming a simple dipole).

20. James Clerk Maxwell, "A Dynamical Theory of the Electromagnetic Field," *Roy. Soc. Trans.,* Vol. CLV, 1865, p 459. Read Dec. 8. 1864. Also in *The Scientific Papers of James Clerk Maxwell, 2* vols, bound as one, edited by W. D. Niven, Dover, New York, 1952, Vol. 1, p. 526-597. In this seminal paper, Maxwell's equations of the electromagnetic field are given in "Part III, General Equations of the Electromagnetic Field," p. 554-564. On p. 561, Maxwell lists his 20 variables. On p. 562, he summarizes the different subjects of the 20 equations, being three equations each for magnetic force, electric currents, electromotive force, electric elasticity, electric resistance, total currents; and one equation each for free electricity and continuity.

21. B. J. Hunt, *The Maxwellians,* Cornell University Press, 1991 gives the history of the alteration of Maxwell's field theory by Fitzgerald, Heaviside, Lodge, and Hertz. In an appendix, Hunt makes a comparison between the standard expressions of the Maxwell field equations and their expression in quaternionic form.

22. E.g., J. D. Jackson, *Classical Electrodynamics,* 2nd Edition, Wylie, 1975, p. 219-221.

23. Willis E. Lamb Jr. and Robert C. Retherford, "Fine structure of the hydrogen atom by a microwave method," *Phys. Rev.,* 72(3), Aug. 1, 1947, p. 241-243. Lamb received the 1955 Nobel Prize in physics jointly with Polykurp Kush for experiments measuring the small displacement later called the "Lamb shift" of O+ne of the energy levels in atomic

hydrogen. This is a small "vacuum energy" effect, but the *energy density* involved is greater than the surface energy density of the sun.

24. Craig F. Bohren, "How can a particle absorb more than the light incident on it?" *Am. J. Phys.,* 51(4), Apr. 1983, p. 323-327. Under nonlinear conditions, a particle can absorb more energy than is in the light incident on it. Metallic particles at ultraviolet frequencies are one class of such particles; insulating particles at infrared frequencies are another.

25. See also H. Paul and R. Fischer, "'(Comment on "How can a particle absorb more than the light incident on it?'),"*Am. J. Phys.,* 51(4), Apr. 1983, p. 327 for a replication and validation of Bohren's experiment,

26. H. B. G. Casimir, "On the attraction between two perfectly conducting plates," presented at a meeting of the Royal Netherlands Academy of Arts and Sciences on 29 May, 1948. Published in the same year in *Proc. Koninklijke Nederlandse Akad. van Wetenschappen,* Amsterdam, vol. 51(7), 1948, p. 793-796. In English. It is an extrapolation of the more detailed paper of Casimir and Polder, 1948.

27. S. K. Lamoreaux, "Demonstration of the Casimir Force in the 0.6 to 6 micro m range," *Phys. Rev. Lett.,* 78(1), Jan. 6, 1997, p. 5-8. Lamoreaux gives a rigorous experimental verification of the Casimir effect.

28. Franklin B. Mead and Jack Nachamkin, "System for Converting Electromagnetic Radiation Energy to Electrical Energy," U.S. Patent No 5,590,031. An invention for extracting energy from the vacuum via the proven Casimir effect.

29. (a) Floyd Sweet and T. E. Bearden, "Utilizing Scalar Electromagnetics to Tap Vacuum Energy," *Proc. 26th Intersociety Energy Conversion Eng. Conf. (IECEC '91),* Boston, Massachusetts, 1991, p. 370-375. Sweet's device produced 500 watts output from a 33 microwatt **input** by the operator. A highly successful anti-gravity experiment designed by the present author was also performed, and is reported in the paper. Unfortunately, Sweet later died and never fully revealed the activation secret by which barium ferrite magnetic materials could be in self-oscillation at 60 Hertz. Weak self-oscillation of such permanent magnetic materials at higher frequency is now known, of course. E.g., see (b) V. E. Zakharov and V. S. L'vov, "Parametric excitation of spin waves in ferromagnets with magnetic inhomogeneities," *Sov. Phys. Solid State,* 14(10) 1973, p. 2513. Particularly see (c) V. S. L'vov, *Wave Turbulence Under Parametric Excitation: Applications to Magnets,* Springer Series in

Nonlinear Dynamics, Springer-Verlag, New York, 1994. Self-oscillation can in fact be induced in permanent magnet materials. We comment that, while a permanent magnet is in self-oscillation, a simple set of wires or a coil around the magnet will receive EM energy by induction, and can power a very tiny load in a closely adjacent circuit.

30. T. E. Bearden, "Bedini's Method for Forming Negative Resistors in Batteries," *J. New Energy,* 5(1), Summer 2000, p. 24-38. Also carried on restricted DoE website http://www.ott.doe.gov/electromagnetic/ and on the present author's open website http://www.cheniere.org.

31. Teruo Kawai, "Motive Power Generating Device," U.S. Patent No. 5,536,518.Jul. 25, 1995. My board of directors and I were physically present when the Kawai system, company, etc. were seized by what can only have been the Yakuza (Japanese mafia), even though Kawai was being backed by one of the wealthiest investors in Japan. I had just reached an agreement with Kawai to produce and market his overunity motor worldwide. Several legitimate Japanese overunity systems, ready for production, have been stopped in this fashion. Kawai's process, applied with efficient switching such as photon-coupled switching, essentially doubles the COP of the motor to which it is applied. If one starts with a high efficiency (e.g., Hitachi) permanent magnet electric motor of 0.7 or 0.8, one can expect to produce COP = 1.4 and 1.6 respectively, the actual results obtained by Hitachi tests of two Kawai-modified Hitachi motors. We accent that the efficiencies of the motors remain less than 100% at all times.

32. Gabriel Kron, "Electric circuit models of the Schrodinger equation." P*hys. Rev.* 67(1-2), Jan. 1 and 15, 1945. Quoting, p. 41: *""Now a value E of the negative resistances, at which the generator current becomes zero, represents a state at which the circuit is self-supporting and has a continuous existence of its own without the presence of the generator, as the negative resistances just supply the energy consumed by the positive resistances. ... When the generator current is positive the circuit draws energy from the source, and when the current is negative the circuit pumps back energy into the source. At zero generator current the circuit neither gives nor takes energy, and theoretically the generator may be removed."* In this passage, Kron was required to insert the word "theoretically". Kron was the chief scientist for General Electric on the Network Analyzer project at Stanford University before WW II. In the 1930, he did successfully build negative resistors (at least three), and he

did successfully power the network analyzer with them. He was never permitted to release the technical details, although he placed judicious hints in several of his papers, and slipped certain key phrases past the censors. Interestingly, Sweet was his protegee, and it is conceivable that the basis for Sweet's device may have been Kron's original negative resistor. Independent tests and verification of the Sweet device were performed by Walter Rosenthal, a retired professional test engineer of considerable experience.

33. Shoukai Wang and D. D. L. Chung, "Apparent negative electrical resistance in carbon fiber composites," *Composites, Part B,* Vol. 30, 1999, p. 579-590. Apparently the referees required the replacement of the term "negative electrical resistance" by the term "apparent negative resistance". In the paper, simply examine the actual results shown in the curves of the negative-going current, against the voltage, with the line passing directly through the origin. That is a true negative resistance, not a differential one or an "apparent" one. A patent was filed on this invention.

34. (a) T. H. Moray, *The Sea of Energy,* 5th Edn., Salt Lake City, 1978. The Moray device weighed 55 pounds and produced 50 kilowatts of power in the late 1930s, and was demonstrated to scientists and engineers numerous times, Moray made tubes which actually contained very special semiconductors, three of them in contact, each pressed at high pressure during a sintering process. A very eerie chain of circumstances eventually destroyed the device. Moray rode in a bulletproof car, and he was sometimes fired at from the sidewalk or an alley. A double agent, working for both the U.S. and the Soviet Union, infiltrated his lab and eventually destroyed the device. The Morays were never given a proper scientific hearing and were never funded for full development. T. Henry Moray was shot and wounded in his own laboratory, wrestling with a would-be assassin. Yet so many expert engineers and scientists witnessed and tested the machine in operation that there is no question of its legitimacy. Unfortunately, the reference cited is not at all a satisfactory scientific examination of the Moray device. A related U.S. patent was issued which at least shows some details of the Moray tube: See (b) Thomas H. Moray, "Electrotherapeutic Apparatus," U.S. Patent No. 2,460,707, Feb. 1, 1949. I personally received a treatment on a Moray device for severe pain, and the relief was rapid and remarkable.

35. See (a) William B. Burford III and H. Grey Verner, *Semiconductor Junctions and Devices: Theory to Practice,* McGraw-Hill,

New York, 1965, Chapter 18: Point-Contact Devices. The very first transistor — the point contact transistor — also often exhibited negative resistance. Quoting, p. 281:

> *"First, the theory underlying their function is imperfectly understood even after almost a century..., and second, they involve active metal-semiconductor contacts of a highly specialized nature. ... The manufacturing process is deceptively simple, but since much of it involves the empirical know-how of the fabricator, the true variables are almost impossible to isolate or study. ... although the very nature of these units limits them to small power capabilities, the concept of small-signal behavior, in the sense of the term when applied to junction devices, is meaningless, since there is no region of operation wherein equilibrium or theoretical performance is observed. Point-contact devices may therefore be described as sharply nonlinear under all operating conditions."*

Certainly degenerate four-wave mixing and therefore time reversal can occur in in semiconductors. E.g., see (b) R. K. Jain, "Degenerate four-wave mixing in semiconductors: application to phase conjugation and to picosecond-resolved studies of transient carrier dynamics." *Opt. Eng.,* 21(2'), March/April 1982, p. 199-218. We also point out that hole current can be emitted from an n-type semiconductor having a metallic point placedd on its surface, and hole current will move against the voltage (electron current view). A process (patent pending) by Bedini and Bearden have shown that a capacitor may be charged by hole current, and then discharge electron current, effectively transducing negative energy into positive energy. It is therefore possible (Bedini's method) to switch a capacitor from a hole-current charging circuit by a hole-emitting process, to a bypass capacitor across a source such as a battery after the capacitor has reached higher charge voltage than the source. The capacitor will then charge the battery and power the circuit as well, during that portion of its discharge cycle while its voltage is above that of the battery. This is a legitimate COP>1.0 process, invented by Bedini.

36. (a) William Jay Fogal, "High Gain, Low Distortion, Faster Switching Transistor." U.S. Patent No. 5,196,809, Mar. 23, 1993; (b) — "High Gain, Low Distortion, Faster Switching Transistor." U.S. Patent No. 5,430,413, July 4, 1995. The Fogal semiconductor can be rigged to perform the permitted degenerate four-wave mixing and therefore time reversal. It can thus be rigged as a true negative resistor, where the current moves against the voltage.

37. Stephen L. Patrick, Thomas E. Bearden, James C. Hayes, Kenneth D. Moore, and James L. Kenny, "Motionless Electromagnetic Generator," U. S. patent # 6,362,718, March 26, 2002.

38. (a) T. E. Bearden, "Energy from the Active Vacuum: The Motionless Electromagnetic Generator," in M. W. Evans (Ed.), *Modern Nonlinear Optics,* Second Edition, Wiley, 2001, Part 2, p. 699-776; (b) M. W. Evans, P. K. Anastasovski, T. E. Bearden *et al.,* "Explanation of the Motionless Electromagnetic Generator with 0(3) Electrodynamics," *Found. Phys. Lett,* 14(1), Feb. 2001, p. 87-94; (c) M. W. Evans, P. K. Anastasovski, T. E. Bearden *et ah,* "Explanation of the Motionless Electromagnetic Generator by Sachs's Theory of Electrodynamics," *Found Phys. Lett.,* 14(8), Aug. 2001, p. 387-393.

39. A version of the MEG was also independently replicated by J. L. Naudin. See his website at http://jnaudin.free.fr/html/meg.htm .

40. T. E. Bearden, "Dark Matter or Dark Energy?", *J. New Energy,* 4(4), Spring 2000, p. 4-11.

41. See Chapter 4 for a high-level expose of this methodology.

42. Sweet and Bearden, {29a). Sweet performed an antigravity experiment designed by the present author, and successfully reduced **the** weight of an object on the laboratory bench, by 90%. Sweet's solid state magnetic vacuum triode amplifier produced a COP = 1,500,000, so a **very** appreciable Dirac sea hole current was available to work with. Conversion of the Dirac sea hole current into electrical current via the present Bedini-Bearden process would have eliminated the antigravity and produced a very large increase in output electrical power.

43. See (a) T. E. Bearden, "The Unnecessary Energy Crisis: How to Solve It Quickly," ADAS Position Paper, June 2000; (b) Bearden **{12};** (c) Bearden {30}; (d) T. E. Bearden, "EM Energy From The Vacuum: Ten Questions With Extended Answers," September 2000. The present author has been calling for just such a program. These papers are on restricted DOE Website http://www.ott.doe.gov/electromagnetic/ and also are on the author's website at http://www.cheniere.org.

44. Nathan Smith, "Marketable Results vs. Good Science?," *Sci. Am.*, 284(5), May 2001, p. 8-9. Quote is from p. 9.

45. This is the actual phrase often used in such Government contracts. What it means is that the Government (which means the government

employee controlling that program and its funds) can suddenly declare that the Inventor is not getting his invention developed rapidly enough, and the Government then seizes the patent to "get it developed more quickly". The inventor is suddenly left hanging, no longer in control of his own intellectual property. Or the Government has the power to block development altogether.

46. Often the universities just bluntly state that *all patents revert to the university.*

47. Hal Hellman, *Great Feuds in Science*, Wiley, New York, 1998. We particularly call attention to Hellman's dissertation on Wegener's persecution. Today, the legitimate overunity EM researcher and the cold fusion researcher are regarded much like Wegener was regarded — as the very epitome of a fool. This label is appended by "experts" who are not even aware of what really powers an EM circuit or an electrical power distribution system.

48. A photon is a piece of angular momentum (called "action" by the physicist), consisting of a little piece of spatial energy (ΔE) and a little piece of time (Δt), welded together as $(\Delta E)(\Delta t)$ with no seam in the middle, so to speak. But now look at that little $(\Delta E)(\Delta t)$. Since the photon is quantized, $(\Delta E)(\Delta t) = k = \hbar$. Any change in (Δt) requires that (ΔE) change inversely; i.e., $(\Delta E) = \hbar/(\Delta t)$. So increasing (Δt) decreases (ΔE) accordingly. Let us call the spatial energy *s* compacted into (dt) the equivalent *energy* of the photon. Then *s* is given by $s = c^2(\Delta t) = 9\times10^{16}(\Delta t)$. So as the frequency of a photon lowers, the (Δt) time component increases proportionally, and the total equivalent energy in the photon increases dramatically by many orders of magnitude! As an example, suppose we halve the spatial energy (ΔE). That doubles the original time interval (Δt), which gives the new $s = c^2(2\Delta t)$ or $s = 2c^2(\Delta t)$ for the new equivalent energy. So while we halved the *normal* spatial energy formally transported by the photon, we multiplied the *equivalent* time-energy by the enormous factor of $2c^2$ which is approximately 18×10^{16} in the MKS system. It follows that, if we use the equivalent time) energy of the photon and transduce a little of it into normal spatial energy, the energy density of those nuclear reactions now seen only in distant energetic objects such as pulsars, exploding stars, etc. can be achieved right on the laboratory bench. *The highest energy physics has not yet been born in the physics community, and what is presently being done in the high-energy*

accelerators is child's play compared to what can be done with time-energyengineering.

49. To see by another method that time is energy, one notes that the choice of fundamental units chosen for one's physics model is arbitrary. So we choose a single fundamental unit, the joule, to make a new physics model. Thereupon all other entities are energy and energy functions only, Hence, time is totally a function of energy. Actually, time is spatial energy compressed by the factor c^2, so it has the same energy density as mass, except the highly compressed spatial energy is placed in the time domain to appear at "time" rather than in 3-space to appear as "mass".

50. E.g., in cold fusion experiments where the time-energy is partially transduced in a time-reversed manner, the gluon forces binding the quarks in the affected neutrons and protons are dramatically reduced and the quarks are therefore nearly freed. This is being done in an apparatus of perhaps two cubic feet in volume, rather than a giant accelerator 20 miles in diameter and costing billions of dollars. So far, the largest accelerator using 3-space (decompressed) energy is just a bit short of the energy required to free the quarks. Use of time (compressed) energy allows such reaction as freeing the quarks to be easily accomplished, while the accompanying decompressed *spatial* energy is very low.

51. Time energy has the same energy density as mass, but that highly compressed energy has just been placed in the 4th axis *ict* of Minkowski space rather than in 3-space. In *ict* the only variable is t, so the variation of the compressed energy can only appear in the *t* variable portion. See Chapter 2.

52. (a) James Patterson, U.S. Patents 5,318,675; 5,372,688; 5,607.563 (b) — and Dennis Cravens, U.S. Patent No. 5,607,563.

53. Ironically, as suppression of innovative research in science increases, science may eventually face turning into the kind of dogmatic system that it struggled against for some 300 years before escaping. When science defends a theory that experiments refute, as it does today in the case of cold fusion, then it is very close to that debacle that can spell the end of science itself.

54. E. Allan Blair, Letter to the Editor, *Newsweek,* Mar. 3, 1997, p. 14.

55. Arthur C. Clarke, "Space Drive: A Fantasy That Could Become Reality," *NSS... AD ASTRA,* Nov/Dec 1994, p. 38.

56. William K. George, in *Editing the Refereed Scientific Journal, edited* by Robert A. Weeks and Donald L. Kinser, IEEE Press, New York, 1994. p. 227-228.

57. Max Planck, in G. Holton, *Thematic Origins ofScientific Thought, Harva*rd University Press, Cambridge, MA, 1973.

58. Jonathan Schlefer, editor of *Technology Review,* published at MIT. in an October 1990 editorial.

59. Rolf Landauer, "Fashions in Science and Technology," *Physics Today*, 50(12), Dec. 1997, p. 62.

60. Julius Robert Von Mayer, "Bemerkungen iiber die Krafte der unbelebten Natur," in J. von Liebig's *Annalen der Chemie* (vol. 42), 1842; Die *organische Bewegung in ihrem Zusammenhange mit dem Stoffwechsel, (Organic* Motion in Its Relation to Metabolism), 1845. His papers were published as *Die Mechanik der Warme,* 1867, with third edition in 1893.

61. Alfred Wegener, *Die Entstehung der Kontinente und Ozeane, 1915;* fourth revised edition, 1929. A Dover reprint of the fourth revised edition, translated into English, *Origin ofContinents and Oceans,* was published in 1996.

62. Paul Nahin, *Oliver Heaviside: Sage in Solitude,* IEEE Press. New York, 1988, p. 225.

63. Martin Gumpert, *Trail-Blazers ofScience.* New York, Funk and Wagnalls Company, 1936, p. 232.

64. This area is now referred to as *ovonics,* where the "ov" is directly taken from "Ovshinsky". The materials have found use in copy machines, fax machines, liquid crystal displays, and optical memory disks. Ovshinsky has obtained over 200 patents and continues to work in the energy conversion field. His development of a new storage battery, e.g., broke all the Department of Energy tests and doubled the energy density permitted. Once in awhile the good guys beat the scientific suppression system.

65. Stan and Iris Ovshinsky were honored with the American Chemical Society's Heroes of Chemistry Award for 2000. They were honored for 40 years of sustained effort and contributions in the

sustainable and renewable energy field, including amorphous silicon cells for roofs of houses, highly specialized storage batteries, etc.

66. On the other hand, many scientific disagreements are conducted in quite proper and gentlemanly fashion. An example is the continuing decades of argument over energy flow theory, in *Am. J. Phys.* The problem has still not been officially resolved; we would hope that the material in this book will shed new light upon it, by pointing out the exact difference between the long-neglected nondiverged component as well *as* the diverged component, and also pointing out what Lorentz's trick of closed surface integration of the energy flow vector really does.

67. It follows quite naturally that, once we compress spatial energy by c , we may place the compressed energy in 3-space, in which case it is known as "mass", or we may place it in the time domain, in which case it is known as "time". If that cannot be done, then physics errs in using time as a variable on the fourth axis, and fundamental units are not arbitrary after all.

68. E.g., see D. K. Sen, *Fields and/or Particles,* Academic Press, London and New York, 1968, p. viii. Quoting: *"The connection between the field and its source has always been and still is the most difficult problem in classical and quantum electrodynamics."*

69. See T. D. Lee, "Can Time Be a Discrete Dynamical Variable?". *Phys. Lett,* 122B(3, 4), Mar. 10, 1983, p. 217-220. Lee showed that time is a discrete dynamical variable across the entire range of mechanics: from classical to nonrelativistic quantum mechanics, and then to relativistic quantum field theories. In all stages of mechanics, time can be treated as a discrete parameter, and it can be treated as a bona fide dynamic variable, Hence time has dynamics and structure, and therefore energy.

70. E.g., one may assume that the entire virtual state is an internal structuring and dynamics existing inside the macroscopic flow of time. The virtual state dynamics obviously exists in spacetime (which is assumed to be continuous), but we also consider any "virtual particle" (e.g., a virtual electron) as if it had been suddenly "observed" momentarily That assumes d/dt (LLLt) => LLL, a frozen 3-space snapshot. However, since that cannot really be observed, then we are actually considering something analogous to "if we could observe something in spacetime that cannot be observed in space alone". The only place left for it to

!observably exist anyway, if we could in fact observe it" is time, if space is ruled out.

71. It is necessary to trace the energy transductions and dissipations inside the generator. Ignoring those internal dynamics, the casual observer sees that one inputs shaft energy to the generator, and out comes some electromagneticenergy in the external electrical circuit, pouring from the gnerator terminals. We catch a lesser amount out there in the external circuit or power line, so we think we input some energy, had some internal losses and what gets collected in the conductors of the power line is the remainder of what we input, after transductions and losses in the generator. That is not what happens at all! Embarrassingly, an *enormous* flow of energy comes out of those generator terminals, if all of it is accounted. This includes(i) the tiny component that strikes the surface charges of the external conductors and gets diverged into the conductors, thus being captured by the circuit, and (ii) the enormous remainder of the energy flow in the surrounding space, which misses the circuit altogether and is just wasted. Something like a trillion times as much EM energy may be pouring out of the terminals of the generator and *being wasted,* as we mechanically input to the generator shaft, or as we "catch" and use in the external circuit. As later chapters discuss, Poyntin ; never considered the component that misses the circuit entirely. Heaviside discovered it but could not explain its startling magnitude or its source. Lorentz knew of this enormous flow component. He could not explain it, and stated it "had no physical significance" since it powered nothing. Lorentz originated a little integration trick that discarded it neatly from a11 accountability.

72. If the energy input to an inert power system generator were what powered the attached external circuit, then only the Poynting component would be emitted from the terminals of the generator. In that case, Heaviside's discovery of the additional nondiverged component would be wrong, and Lorentz was also wrong in recognizing it by stating it had no *physical* significance. It also means that a dipole formed between the terminals can have no broken symmetry in its active vacuum flux exchange, which is falsified by particle physics {14, 73,}. Also, no charge could pour out energy and create fields and potentials in surrounding space, and neither could a dipole. That is easily falsified by actual experimental measurement. Our reinterpretation of Whittaker's wave decomposition of the scalar potential would also be wrong, as would Mandl's and Shaw's argument {19} that a combined pairing of a scalar

photon and a longitudinal photon are observable, producing the instantaneous scalar potential.

73. T. D. Lee, *Particle Physics and Introduction to Field Theory,* Harwood, New York, 1981,*passim.* In 1957, Lee and Yang received the Nobel Prize for their work in predicting broken symmetry. This included the broken symmetry of opposite charges — and hence of a dipole.

The very definition of broken symmetry, applied to the source dipole once it is formed in the generator, reveals that the dipole itself receives virtual photon energy from the seething vacuum, transduces it, and outputs it as real observable EM energy pouring out of the generator terminals and out through 3-space surrounding the entire power line. This is the source of the tremendous energy flow from the terminals, including a large component missing the circuit (as discovered by Heaviside in the 1880s). This large nondiverged component of the energy flow was discarded arbitrarily by Lorentz because there was absolutely no explanation of its source, and because it was thought to have "no physical significance" (Lorentz's term) since it powered nothing.

74. Wu et al. {14} experimentally showed that the weak interaction violates parity (spatial reflection) and thus exhibits broken symmetry.

75. T. D. Lee is noted for his broken symmetry work with charges, and for establishing the broken symmetry of separated charges of unlike sign. In 1957, Lee and Yang were awarded the Nobel Prize in Physics for their investigations of weak interactions between elementary particles.

76. John D. Kraus, *Electromagnetics,* Fourth Edition, McGraw-Hill, New York, 1992, p. 578.

77. We strongly feel that anyone interested in logic must read Morris Kline, *Mathematics: The Loss of Certainty,* Oxford University Press, New York, 1980. Contrary to popular opinion and the impression projected by mathematicians, mathematics is not a body of unshakable truths aboul the physical world, and mathematical reasoning is not exact and fallible.

78. One also needs to be aware of Godel's proof. See Kurt Godel, "Uber formal unentscheidbare Satze der *Principa Mathematica* une verwandter Systeme" ("On Formally Indeterminable Propositions of the *Principia Mathematica* and Related Systems," in *Monatshefte fur Mathematik und Physik,* Vol. 38, 1931. This is the publication in which Godel's Proof first appeared, which states that within any logical

mathematical system there are propositions or questions that cannot be proved or disproved on the basis of the axioms within that system. Therefore, it is uncertain whether or not the axioms or arithmetic will give rise to contradictions, since they can.

79. A critical reference for the longitudinal EM interferometry *weapons* is M. W. Evans, P. K. Anastovski, T. E. Bearden *et al.*, "On Whittaker's Representation of the Electromagnetic Entity in Vacuo, Part V: The Production of Transverse Fields and Energy by Scalar Interferometry," *J. New Energy,* 4(3), Winter, 1999, p. 76-78. This paper is a short but rigorous proof of a scalar interferometer's ability to produce EM fields and energy in the distant interference zone. Either diverging (heating) energy or converging (cooling) energy — in the normal sense, extraction of energy — can be created in a distant interference zone. By pulsing and controlling the circuit ground bias of the transmitters, one produced distant hot explosions or cold explosions. In a military target in that distant zone, the effects arise from the local spacetime, thus from everywhere within the targeted vehicle. At least eight nations now have such weapons, which were apparently the weapons that Defense Secretary Cohen {89} referred to in 1997.

80. Jackson {22}, p. 249.

81. Bunge, {3},p. 182.

82. Roger Penrose, "Foreword," in T. W. Barrett and D. M Grimes [Eds.], *Advanced Electromagnetism: Foundations, Theory, & Applications,* World Scientific, (Singapore, New Jersey, London, and Hong Kong), 1995.

83. Myron Evans, President of Alpha Institute's Institute for Advanced Study, private communication, 1999. Dr. Evans is the author of over 600 scientific papers, the prestigious editor of several scientific book series, and a noted foundations scientist. He is the co-discoverer and proponent of the Vigier-Evans B(3) magnetic field and a proponent of the proposed fundamental extension of U(1) electrodynamics to O(3) electrodynamics. O(3) electrodynamics has now been revealed as an important subset of Sachs' unified field theory.

84. Robert H. Romer, "Heat is not a noun," *Am. ./. Phys.,* 69(2), Feb. 2001, p. 107-109. The quotation is from footnote 24, p. 109.

85. E. T. Whittaker, "On the Partial Differential Equations of Mathematical Physics," *Math. Ann.*, Vol. 57, 1903, p. 333-355.

86. But see Chapter 2 for a reinterpretation and correction of Whittaker's decomposition of the scalar potential. His harmonic set of bidirectional phase conjugate longitudinal EM wavepairs in 3-space is replaced with a harmonic half-set of longitudinal EM waves converging in I the time domain upon the dipolarity; absorption and transduction by the charges; and re-emission as the other harmonic half-set of longitudinal EM waves diverging out from the source dipolarity in all directions in 3-space. The correction allows a very novel solution to the long-vexing problem of the source charge and its associated fields and potentials and their energy {12}.

87. (a) G. Johnstone Stoney, "Microscopic Vision," *Phil. Mag.*, Vol 42, Oct. 1896, p. 332; (b) — "On the Generality of a New Theorem," ***Ibid.,*** Vol.43, 1897, p. 139-142; (c) — Discussion of a New Theorem in Wave Propagation," *ibid,* Vol. 43, 1897, p. 273-280; (d) — "On a Supposed Proof of a Theorem in Wave-motion," *ibid.*, Vol. 43, 1897, p. 368-373.

88. Some Russian scientists refer to the hidden internal electrodynamics as the "information content of the field".

89. Secretary of Defense William Cohen at an April 1997 counterterrorism conference sponsored by former Senator Sam Nunn. Quoted from DoD News Briefing, Secretary of Defense William S. Cohen, Q&A at the Conference on Terrorism, Weapons of Mass Destruction, and U.S. Strategy, University of Georgia, Athens, Apr. 28, 1997.

90. For a basic discussion of these photon polarizations, see (a) Richard Feynman, *Quantum Electrodynamics,* 1961, 1963. Quantum field theory recognizes four polarizations of the photon, to include x- and y-transverse polarizations in 3-space, longitudinal or z- polarization in 3-space, and the time-polarized photon (which may be taken to be a longitudinally-polarized photon in the time axis). Existence of these four modes of polarization or energy vibration in photons implies the existence of four correspondingly polarized EM waves. Among other things, Feynman discusses the "sum over four polarizations" of photons and such The term "Gupta-Bleuler" theory is the formalism that has grown up around this problem. For a deeper discussion, see (b) Lewis H. Ryder, *Quantum Field Theory,* Second Edition, Cambridge University Press, 1996, p. 147 *et seq*. For an even more advanced discussion, see (c) F.

Mandl and G. Shaw {19}. For discovery of the coupling of time-polarized and 3-space longitudinally polarized EM waves as the higher EM energy flow symmetry resolving the source charge problem, and thereby reinterpreting Whittaker's decomposition of the scalar potential {85}, see (d) Bearden {12}. We point out that the latter reinterpretation can also be "cranked through" the superpotential theory of Whittaker, to involve all EM potentials, fields, and waves.

91. (a) E. T. Whittaker, "On an Expression of the Electromagnetic Field Due to Electrons by Means of Two Scalar Potential Functions," P*roc Lond. Math. Soc,* Series 2, Vol. 1, 1904,p. 367-372. The paper initialed what today is called *superpotential* theory. It was published in 1904 and orally delivered in 1903. For a sampling of other superpotential work, see (b) W. H. McCrea, *Proc. Roy. Soc. Lond. A,* Vol. 240, 1957, p. 447; (c) A. Nisbet, *Physica,* Vol. 21, 1955, p. 99; (d) P. Debye, *Ann. Phys.,Leipzig,* Vol. 30, 1909, p. 57. For an excellent overview discussion of superpotentials and related things, see (e) Melba Phillips, "Classical Electrodynamics," in *Principles of Electrodynamics and Relativity,* Vol. IV *of Encyclopedia of Physics,* edited by S. Flugge, Springer-Verlag, l962.

92. (a) See Evans et al. {79} for proof that scalar interferometry can produce all normal transverse EM fields, waves, and patterns. The paper appears in (b) P. K. Anastasovski; T. E. Bearden, C. Ciubotariu, W. T. Coffey, L. B. Crowell, G. J. Evans, Myron W. Evans, R. Flower, S. Jeffers, A. Labounsky, B. Lehnert, M. Meszaros, P. R. Molnar, J.-P. Vigier, and S. Roy, "The New Maxwell Electrodynamic Equations: New Tools for New Technologies," *J. New Energy, 4(3),* Special Issue of A1AS papers. Winter 1999. The volume consists of some 60 papers by the Alpha Foundation's Institute for Advanced Study (AIAS), advancing electrodynamics to a non-Abelian, gauge theoretic higher topology theory in O(3) internal symmetry. Some ten of the papers directly address Whittaker's work and extend it.

93. (a) W. A. Rodrigues, Jr. and J.-Y. Lu, "On the existence of undistorted progressive waves (UPWs) of arbitrary speeds $0 < v < \infty$ in nature," *Found. Phys.,* 27(3), 1997, p. 435-508 show that Maxwell's equations do possess superluminal solutions. A slightly corrected version is downloadable as hep-th/9606171 on the Los Alamos National Laboratory web site. Also see (b) W. A. Rodrigues, Jr. and J. Vaz Jr., "Subluminal and Superluminal Solutions in Vacuum of the Maxwell

Equations and the Massless Dirac Equation," *Adv. Appl. Clifford Algebras,* Vol. 7(S), 1997, p. 457-466.

In classified Russian weapons labs, this internal longitudinal wave (both time-domain and 3-space domain) structuring of all normal (transverse) EM potentials, fields, and waves is euphemistically called the *information content of the field.* For decades there has been a successful disinformation campaign to lead scientists of other countries into believing that the phrase means *standard spectral analysis.* It doesn't. It is also possible to communicate at superluminal speed, using longitudinal EM waves inside this infolded "inner" electrodynamics. Since mass is mostly empty space filled with a particle here and there — together with EM potentials, fields, and waves — then mass is a vast "superhighway" for direct superluminal communication using longitudinal EM waves.

94. Romer, {84}.

95. See E. T. Whittaker, *A History of the Theories of the Aether and Electricity,* two vols., Nelson, London, 1951, 1953. Reprinted by Dover.

96. Note that we have just resolved the age-old problem of change, which can be summarized in the query stated so long ago by Heraclitus: "For a thing to change, it must turn into something else. But how can a thing be itself and something else also?" We have explained the enigma by pointing out that the "thing" has no persistence in time, and is continually changing into yet another thing, either a replica (in which case we sense "no change" and hence "persistence" by memory comparison), or a partial replica with some differences (in which case we sense that "the object has changed itself in some way"), or a thing with little or no replication (in which case we sense a "different thing"). It is the unseen nature of the *d/dt* observation process that has deluded us into such irresolvable logical conflicts — and into an incomplete Aristotelian logic based on observation alone, which does not contain the resolutions to such problems because a higher-order logic is required.

97. Whittaker, {85}

98. See Chapter 2 for a discussion of the substitution of effect for cause, and of the nature of observation.

99. *Wu etal,* {14}.

100. Sen, {68}.

101. Also see Mandl and Shaw {19}.

102. William G. Harter, John Evans, Roberto Vega, and Sanford Wilson, "Galloping waves and their relativistic properties," *Am. J. Phys., 53*(7), July 1985, p. 671-679. A relativistic example is given in which the source frame observes a very nonuniformly-galloping wave whose velocity varies between 0.01 c and 100 c, even though its average velocity is c. Relativistic properties of interfering electromagnetic plane waves are discussed.

103. We point out, but do not further pursue, that this situation is reversed when time is reversed. This has very interesting applications in our little "time reversal zones" that we found were so important in the electrolyte experiments of the cold fusion researchers, and which accounted for a new class of nuclear interactions previously unknown. This does reverse the conventional law of attraction and repulsion of charged particles. It also directly affects the quarks and gluons, partially or even nearly dissolving the gluon forces holding the quarks in place, so that the quarks are nearly freed and are easily flipped.

104. Simultaneously accompanied by *separately broken* time-energy flow symmetry and *separately broken* 3-spatial energy flow symmetry.

105. Evans etal., {38b, 38c}.

106. Oliver Heaviside, *Electrical Papers,* Vol. 2, 1887, p. 94.

107. Kraus, {76}.

107. E.g., see (a) Jackson {22}, p. 237. Jackson points out that *"...the Poynting vector is arbitrary to the extent that the curl of any vector field can be added to it. Such an added term can, however, have no physical consequences. "* The first sentence is true, but the second sentence is a non sequitur. Poynting only considered the small component of the overall energy flow that enters the circuit — in short, that strikes the surface charges in the conductors and is diverged into the wires to power the Drude electrons. That is the diverged part of the energy flow. All the rest of the flow that misses the circuit is obviously not diverged or collected in the circuit, and so it has zero divergence. It is elementary vector algebra that the curl of any vector field has zero divergence. So the extra nondiverged Heaviside energy flow component — filling all space around the conductors in a power line, e.g., but missing the power system entirely and just wasted — can indeed be expressed as the curl of a vector field That energy flow is real, however, and if intercepted and collected, it then does become divergent. In that case, it does have highly significant

consequences, since the total energy flow in that component may be a trillion times the energy flow in the Poynting component alone.

For a rigorous experiment demonstrating the reality and significance ol that "physically insignificant energy flow" that "can have no physical consequences", see (b) Bohren {24}. Under nonlinear conditions, a particle can absorb more energy than is in the light incident on it by normal calculations. Electrodynamicists do *not* calculate the magnitude of an entire field or potential, e.g., but only the intensity of a *divergence from* it at a single point, as given by an intercepting unit point static charge. If that same charged particle is placed in particle resonance, it sweeps out a greater geometrical reaction cross section. Hence it intercepts and **collects** (diverges) more impinging energy — from that long-neglected otherwise nondiverged component of the flow or field that is not diverged by the *static* unit point charge assumed conventionally. Metallic particles at ultraviolet frequencies are one class of such particles and insulating particles at infrared frequencies are another. See also (c) Paul and Fischer, {25}, who replicated Bohren's experiment.

109. H. A. Lorentz, *Vorlesungen iiber Theoretische Physik an der Universitdt Leiden,* Vol. V, *Die Maxwelhche Theorie (1900-1902),* Akademische Verlagsgesellschaft M.B.H., Leipzig, 1931, "Die Energie im elektromagnetischen Feld," p. 179-186. The section is called "Der Poyntingsche Energiestrom," and begins on p. 183. See his Figure 25 **on** p. 185.

110. E.g., see W. K. H. Panofsky and M. Phillips, *Classical Electricity and Magnetism,* Addison-Wesley, Reading, MA, 1962, 2nd edition, p. 181**,**

111. Bearden, {12}.

112. A simple way to see this is to note that the back-potential across the half-loop internal to the dipole is precisely equal to the forward potential externally between the ends of the dipole but across the **external** circuit half-loop. Since the same current q runs through both these potentials, then by Vq the same amount of energy is dissipated upon **the** charges of the dipole — to scatter them and destroy the dipole — as is dissipated in the external circuit in its losses and the load. Thus **more** energy is used to destroy the dipole than is used to power the load. We have to input at least as much shaft energy to restore the dipole as was used to destroy it. Hence the COP< 1.0.

113. See to (a) M. W. Evans, P. K. Anastasovski, T. E. Bearden *el al*, "Classical Electrodynamics without the Lorentz Condition: Extracting Energy from the Vacuum," *Physica Scripta*, 61(5). May 2000, p. 513-517 in addition to that paper previously quoted. See also (b) "Runaway Solutions of the Lehnert Equations: The Possibility of Extracting Energy from the Vacuum," *Optik*, 111(9), 2000, p. 407-409.

114. Robert Bruce Lindsay and Henry Margenau, *Foundations of Physics*, Dover, New York, 1963, p. 25.

115. *Ibid.*, p. 213.

116. *Ibid.*, p. 217.

117. M. Faraday, *Experimental Researches in Electricity and Magnetism*, Vol. 1, Taylor and Francis, London, 1839; Vol. 2, Richard & John E. Taylor, London, 1844; Vol. 3, Taylor and Francis, London, 1855. A 1965 reprint of all three volumes is available from Dover, New York.

118. We also acknowledge the independent contributions of Joseph Henry. In 1830, Henry independently discovered magnetic induction, anticipating Faraday's own discovery of it. Faraday, however, published first. Two years later, Henry discovered self-induction. He died in 1878, and the unit of inductance, the *henry*, was named for him in 1893.

119. (a) Maxwell, {20}. Also see (b) James Clerk Maxwell, *A Treatise on Electricity and Magnetism*, Oxford University Press, Oxford, 1873, Third Edition, Volumes 1 and 2, unabridged, Dover Publications, New York, 1954. This standard citation widely used in the literature is in fact confusing; the First Edition was published in 1873, a second rather substantially altered edition was later published after Maxwell's 1879 death of stomach cancer, and a third edition, slightly altered from the second edition, was published even later. So controversial were quaternions at the publication of Maxwell's first edition in 1873, that part of what was to become the second edition — published after Maxwell's 1879 death — was truncated by Maxwell himself prior to his death and prior to the posthumous publication of the second edition. Thus there is considerable difference between the first and second editions, and first and third editions, of Maxwell's *Treatise*, compared to his original 1865 paper {20}. "Maxwell's theory" is actually his 1865 paper; everything else is a later truncation of Maxwell's theory.

120. Maxwell's letter to P. G. Tait in 1871, *Archives,* Cavendish Laboratory, Cambridge.

121. For a discussion, see (a) A. M. Bork, "Vectors versus quaternions - the letters in *Nature,"* in *Am. J. Phys.,* Vol. 34, Mar. 1966, p. 202-211. For a cogent presentation of what might have been discovered much earlier in physics if quaternions had not been cast aside in favor of the much more limited vectors, see (b) James D. Edmonds Jr., "Quaternion quantum theory: New physics or number mysticism?", *Am. J. Phys.,* 42(3), Mar. 1974, p. 220-223.

122. Edmonds, {121b}. Edmonds presents a cogent argument showing the significant impedance of the rate of discovery in physics, that **resulted** from the ill-advised casting aside of the far more comprehensive quaternion theory in favor of the much more limited vector theory.

123. Heaviside, {5a, 5b}.

124. T. W. Barrett, "Tesla's Nonlinear Oscillator-Shuttle-Circuit (OSC) Theory," *Annales de la Fondation Louis de Broglie,* 16(1), 1991, p. 23-41, Barrett later extended some of the energy-shuttling techniques shown by Tesla and obtained U.S. Patents 5,486,833 and 5,493,691.

125. (a) A. A. Michelson and E. W. Morlcy, "Influence of motion of the medium on the velocity of light," *Am. J. Sci.,* Vol. 31, Series 3, 1886, p. 377-386; (b) — "The relative motion of the earth and the luminiferous aether," *Am. J. Sci.,* 34(3), 1887, p. 333; (c) — "On the relative motion of the earth and the luminiferous aether," *Phil. Mag.* 24(4), 1887, p. 449. See also (d) A. A. Michelson, "The relative motion of the earth and the ether," *Am. J. Sci.,* (4), 3, 1897, p. 475.

126. (a) Mendel Sachs, *General Relativity and Matter: A Spinor Field Theory from Fermis to Light-Years (Fundamental Theories of Physics),* Reidel, 1982. Sachs provides a great generalization of general relativity and electrodynamics reaching from the quarks and gluons to the entire universe. See also (b) Mendel Sachs, "Symmetry in Electrodynamics: From Special to General Relativity, Macro to Quantum Domains," in M. W. Evans, Editor, *Modern Nonlinear Optics,* Second Edition, Wiley, **New** York, 2001, Part 1, p. 677-706.

127. Myron W. Evans, Director of the Alpha Foundation's Institute for Advanced Study, private communication, 2001.

128. Jackson, {22}, p. 249.

129. Jackson, {22}, p. 28.

130. Feynman, {7}, Vol. 1, p. 2-4.

131. Physicists often speak of spacetime as "space", since in Minkowski geometry the time portion is modeled along a separate spatial axis used in addition to the ordinary three spatial axes. So Feynman's "distortion" is actually Riemannian spacetime curvature.

132. As an aside, note that Feynman also utilized a dipolarity. There is always a scalar potential between the poles of any dipole. Further, this "dipole potential" decomposes according to Whittaker's 1903 decomposition{85}, as re-interpreted by Bearden's giant negentropy approach {12} in 2000, and as relates to Mandl and Shaw's 1984/1993 argument{19} that only the associated time-polarized photon and longitudinal photon together are observable, and then as the instantaneous scalar potential. If we accept Mandl and Shaw's powerful argument, then the Whittaker 1903 decomposition must be reinterpreted to be in accordance. That is what was done by the present author {12} to resolve the source charge problem as well as the source dipole problem. In addition, the resolution must be in accord with the theoretical and experimental findings of particle physics, to include the broken symmetry of the opposite charges on the ends of a dipole. The giant negentropy process uncovered by Bearden {12} fulfills all the necessary requirements. It also places the theme of this book — *Energy from the Vacuum: Concepts and Principles* — on a solid theoretical and experimental basis.

133. Feynman, {7}, vol. II, p. 1-3.

134. Jackson, {22}, p. 811-812.

135. We have previously postulated this feature where one second is equal to spatial EM energy compressed by the factor c^2, so that time is just extremely compressed EM spatial energy. See Bearden, {17}.

136. (a) Harter et al., {102}. It may well be that galloping due to time-density variation may provide an alternative explanation to quantum tunneling, which can readily occur at superluminal speed. E.g., see (b) A Enders and G. Nimtz, *Phys. Rev. Lett.*, Vol. 48, 1993, p. 632. Their superluminal tunneling experiments transmitted 8.7 GHz microwaves (free space wavelength 3.4 cm) traveling in a rectangular waveguide that contains a "barrier" section of reduced dimensions. Mozart's 40th Symphony was transmitted through the barrier waveguide as frequency

modulated microwaves, at an FTL group velocity of 4.7c, receiving audibly recognizable music from the microwave photons that survived their barrier passage.

137. (a) M. W. Evans, "The Link Between the Sachs and 0(3) Theories of Electrodynamics," in M. W. Evans, editor, *Modern Nonlinear Optics,* Second Edition, Wiley, New York, 2001, Part 2, p. 469-494; (b) — "0(3) Electrodynamics," in M. W. Evans, editor, *Modern Nonlinear Optics,* Second Edition, Wiley, New York, 2001, Part 2, p. 79-267.

138. E.g., Ryder, {90b}, p. 147 *et seq.*

139. Rodrigues and Lu, {93a}.

140. Rodrigues and Vaz, {93b}.

141. The reader should recall that to this day there is no satisfactory resolution of the wave-particle duality principle. Physicists finally just shook hands and agreed to quit fighting, since the hullabaloo was getting them nowhere. The problem does have a probable resolution, but not in Aristotelian logic.

142. Bearden, {12} discusses the relation between time-energy and 3-spatial energy, and reveals a more fundamental 4-symmetry between time energy flow and spatial energy flow. In this 4-symmetry EM flow, time symmetry in energy flow is broken and simultaneously 3-space symmetry in energy flow is broken, but 4-symmetry in energy flow is maintained. The basic transduction of time-energy into 3-space energy and vice versa is accomplished by the interacting charge.

143. Bearden, {15}, p. 11. In the paper we also gave a force-free definition of mass, in terms of the transduction of angular momentum across the 3-spatial boundaries of a mass particle.

144. Rigorously, *mass* does not and cannot emit a photon; *masstime* does. But an observable mass m can be absorbing and emitting **enormous** numbers of virtual photons while not yet having absorbed another observable photon and decayed to emit an observable photons. Differential (virtual) pieces of a "frozen" observable mass m are **indeed** changing continually into masstime and back into mass, by absorbing and emitting virtual photons per equation [14b], while the observable mass m has not yet completed its absorption and emission of an observable **photon** This "knitting" together of observable and virtual state interactions is one of the great centralizing features of physics.

145. The problem is due to the hoary old erroneous notion in mechanics that a separate force acts upon a separate mass to move it.

146. There appears to be no paper or textbook which calculates the actual "energy magnitude" of an entire potential or an entire field, including over all space occupied by it. All texts advance the "local intensity" indicator calculation, and then call that the "magnitude of the potential". That is a non sequitur of first rank. A skilled electrodynamicist will call it the intensity of the potential.

147. It appears that the only region where this statement is in dispute is in various models attempting to explain the creation of the universe. Since that is *a priori* a creation event, then physicists struggle with explaining how something (the existing universe) was created out of nothing (the absence of any slightest bit of the existing universe). We will leave that debate to the astrophysicists and cosmologists. The "accursed identity of opposites" has been the bane of philosophers for more than 3,000 years.

148. Ibrahim Semiz, "Black hole as the ultimate energy source," *Am. J. Phys.,* 63(2), Feb. 1995, p. 151.

149. David Halliday and Robert Resnick, *Fundamentals of Physics, Third* Edition Extended, Wiley, New York, 1988, Vol. 1, p. 518.

150. Stanley W. Angrist, "Perpetual Motion Machines," Sci. *Am.,* Vol. 218, Jan. 1968, p. 114-122.

151. Stanley W. Angrist, "Perpetual Motion," *Encyclopaedia Britannica,* Bicentennial Edition, Macropaedia Vol. 14, 1976, p. 102-105.

152. Lindsay and Margenau, {114}, p. 217.

153. Heaviside, {106}, p. 94.

154. Kraus, {76}, Figure 12-59, p. 578.

155. Bohren, {24}.

156. Paul and Fischer, {25}.

157. (a) V. S. Letokhov, "Laser Maxwell's Demon," *Contemp. Phys., 36*(4), 1995, p. 235-243; (b) — "Generation of light by a scattering medium with negative resonance absorption," *Zh. Eksp. Teor. Fiz.,* Vol, 53. 1967, p. 1442 (English translation is in *Sov. Phys. JETP,* 26(4), Apr. 1968. p. 835-839); (c) "Stimulated emission of an ensemble of scattering particles with negative absorption," *ZhETF Plasma,* 5(8), Apr.

15, 1967, p. 262-265; (d) — "Double y - and optical resonance," *Phys. Lett. A,* Vol. 43, 1973, p. 179-180.

158. It is Heaviside's equations that are usually taught in University as "Maxwell's Equations," and labeled as Maxwell's equations in most undergraduate texts. In addition to Heaviside' work, similar changes were made by Gibbs in the United States and by Hertz in Europe. Every sophomore physics student and electrical engineering student should be given a short treatise on the background development of electrodynamics, and how, when, and by whom Maxwell's 20 quaternion equations were modified into the present four vector equations. The treatise should also point out what was omitted from Maxwell's theory in its truncations. It should be made very clear to every student that his elementary EM subject errs dramatically from physical reality when it assumes a flat local spacetime and an inert local vacuum. *By discarding the physically active environment of all Maxwellian systems,* only a highly limited subset of nature's electrodynamics is captured in the standard electrical engineering model. Specifically, systems far from equilibrium in their exchange with that environment are arbitrarily discarded. Those are precisely the Maxwellian systems permitted to exhibit coefficient of performance greater than unity. In short, the truncation of Maxwell's theory arbitrarily discarded all electrical windmills turning — or partially turning — in **a** free electrical wind.

159. As we pointed out, there are *tin electromagnetic systems at all in* that first class — and never have been — if we account for the arbitrarily-ignored Heaviside energy flow pouring from the source dipole and the energy flow pouring from every charge, and consider the situation prior to self-enforced implementation of Lorenz/Lorentz symmetrical regauging (by the closed current loop circuit). The remarks — pertaining to EM systems supposedly in equilibrium with the active vacuum — only apply if we neglect that Heaviside component and also neglect the source **charge** problem, and even then only if the circuit self-enforces that equilibrium in its exchange with the active vacuum. But since it has been so long **and** ubiquitously neglected, we will continue to speak of the "two classes" of EM systems from that "conventional" view. It is rather like our concession to electrical engineering, where the word "power" is universally **misused.** However, the reader should be aware of what we are doing and why.

160. See (a) Ilya Prigogine, *Nonequilibrium Statistical Mechanics,* Wiley-Interscience, New York, 1962; (b) — *From Being to* ***Becoming:***

Time and Complexity in the Physical Sciences, W. H. Freeman and Company, San Francisco, 1980; (c) D. Kondepudi and Ilya Prigogine, *Modern Thermodynamics: From Heat Engines to Dissipative Structures,* Wiley, Chichester, 1998; (d) G. Nicolis and I. Prigogine, *Self-Organization in Non-Equilibrium Systems: From Dissipative Structures to Order through Fluctuations,* Wiley, New York, 1977. For a good educated layperson's overview, see (e) Gregoire Nicolis, "Physics of far-from-equilibrium systems and self-organization," Chapter 11 in {f} Paul Davies, Ed., *The New Physics,* Cambridge University Press, Cambridge, 1989, p. 316-347.

161. Actually, Ludvig Valentin Lorenz first performed the equivalent of'symmetrical regauging of Maxwell's equations, only two years after Maxwell's seminal paper was published in 1865. See (a) Ludvig Valentin Lorenz, "On the identity of the vibrations of light with electrical currents," Phil. *Mag.,* Vol. 34, 1867, p. 287-301. Not much attention was paid to Lorenz's work, however, and the later symmetrical regauging of the Maxwell-Heaviside equations by H. A. Lorentz is what "stuck" and came to be used. For a proper historical discussion, see (b) J. D. Jackson and L. B. Okun, "Historical roots of gauge invariance," *Rev. Mod. Phys.,* Vol. 73, July 2001, p. 663-680.

162. This point is important. See Gabriel Kron, "The Frustrating Search for a Geometrical Model of Electrodynamic Networks," circa 1962. General Electric publication, p. 11-128. Quoting p. 114: *"...the missing concept of "open-paths" (the dual of "closed-paths") was discovered, in which currents could be made to flow in branches that lie between any set of* ***two*** *nodes. (Previously -following Maxwell - engineers tied all of their open-paths to a single datum-point, the 'ground'). That discovery of open-paths established a second rectangular transformation matrix... which cre****ated*** *'lamellar' currents... " "A network with the simultaneous presence of both closed and open paths was the answer to the author's years-long search."*

When we design and build a circuit or system in compliance with the Lorenz/Lorentz-regauged equations, it follows that *the circuit itself must contain some feature and function that self-enforces the Lorenz/Lorentz condition — at least during the excitation discharge of the energy that has been freely caught by the circuit. The Lorenz/Lorentz condition is not a law of nature, nor is it automatically applied without a specific circuit cause and function physically applying it.* That function is automatically applied by the standard closed current loop circuit.

As Kron stated, his long search for a true negative resistance finally succeeded when he discovered the "open path". Actually Kron had discovered that any two points in the universe at different potentials (charged to different intensities) produced a flow of EM energy. In other words, he had discovered in more classical EM terms the broken symmetry of opposite charges of differing charges, such as on the ends of any dipole or across any dipolarity.

163. Superconducting *sections* in a system may be loss-free, but the entire superconducting *system* has losses and exhibits only COP<1.0 overall, if the refrigeration burden is accounted. In the superconducting section alone, without accounting for the cooling overhead, the COP = 1,0 and the efficiency is 100% also.

164. After Jackson, {22}, p. 219-221; 811-812.

165. See Whittaker, {85}. Whittaker mathematically decomposes the scalar potential into a hidden "bidirectional" series of EM wavepairs in a harmonic sequence. Each wavepair consists of the wave and its phase conjugate. Thus any Aq) (as across the terminals of a dipolar electrical power source) *a priori* involves an ordered, hidden, bidirectional EM wave flow. I.e., d(fi)) *identically is* such a hidden bidirectional EM energy flow.

166. But see Bearden, {12}. In the paper we conceptually re-interpreted Whittaker's 3-space (observation assumed, hence effect waves) bidirectional wavepairs. Our reinterpretation yields a correlated harmonic half-set of converging *unobserved* causal EM longitudinal waves (time-polarized EM waves) in the time domain prior to interaction with charge so as to prepare for being observed, and a harmonic half-set of diverging EM longitudinal waves (after observation due to the convergent time-polarized EM waves interacting with the observable charges) in 3-space in all directions. We strongly stress that observation does not occur without the absorption of a scalar photon and the follow-on emission of a longitudinal photon. In a time-reversed situation (phase conjugate charge condition), to the observer it appears to have happened in the other direction.

167. Particularly see Mandl and Shaw, {19}.

168. However, Mandl and Shaw fail to totally identify the "combining mechanism". They do not account the detailed interaction of the detecting/observing unit point charge, and thus fail to clearly account for the absorption of the incoming time-polarized wave or photon, the

transduction of that excitation energy of the charge into longitudinal EM wave/photon energy, and the subsequent emission of that excitation energy in 3-space in all directions as longitudinal EM waves/photons. So Mandl and Shaw do not clearly account for *photon (or wave) polarization transduction by the ubiquitously assumed charge.* The "causal" time-polarized EM wave or photon comes in and is absorbed by the detecting charge or dipole, then the absorbed energy is transduced and re-emitted in 3-space as the longitudinally polarized EM wave or photon in 3-space. (Actually, since all space is charged, what is really emitted into 3-space is the giant circulation of EM energy between time and 3-space, which is a more rigorous statement of what "propagation of EM energy through 3-space actually is). Recognition of these missing interactions and transductions allowed a solution at last to the long-vexing problem of the source charge, often called the greatest problem in both quantum and classical electrodynamics, as given initially in Bearden, {12}. Now, of course, a greater problem has reared its head: the notion that EM energy continuously propagates in 3-space is a total non sequitur, along the lines objected to by Romer {84}. We therefore have some very fundamental rethinking to do for all of classical physics. This is really where the problem of wave-particle duality has pointed since the beginning.

169. Asymmetrical self-regauging collects just a tiny bit more of the enormous energy that is flowing outside the conductors and usually wasted. E.g., if the self-regauging EM system collects as **j**ϕ some 10^{-12} of the energy flow instead of the more usual 10^{-13}, the system can have a COP =10, *if it* does not then expend half the collected energy to destroy the sourcc dipole faster and require its reconstitution more energetically. And so on.

170. Jackson, {22}, p. 220-223.

171. So-called "canceling" opposing EM fields are actually produced, which sum to a *vector zero system* with respect to translation, which the electrodynamicists erroneously discard by assumption. We point out, but do not further pursue, that the locally produced *field energies* of the opposing fields in a zero-summed vector system remain and add, even though the fields offset each other *translationally.* The local energy of the field is proportional to the square of the local magnitude, and that is always positive regardless of field orientation. Thus "trapped" and structured EM stress energy has been localized in spacetime in the symmetrical regauging of CEM. This rigorously is a gravitational change

and therefore a local curvature of spacetime *a priori.* Indeed, the field energy remains in a zero-vector summation system, and has been changed into stress potential energy. It represents continuous internal work being performed on the system to stress it, by energy continuously fed in from the active vacuum environment but only in appositive fields of equal magnitude. The discarding of the zero vector summation system thus is a discarding of an available stress potential and its energy, a rotation of the system frame out of the laboratory frame, and a continuous exchange of energy from the vacuum that performs internal work upon the system but no external work in the load. The energy is not translational, but it is there nonetheless, and it causes a spacetime curvature change. The electrodynamicists have largely ignored the fact that gauge symmetry transformations are accompanied by local gravitational (spacetime curvature) changes that violate the prevailing flat local spacetime assumption of classical electrodynamics.

172. See (a) H. J. Josephs, "The Heaviside papers found at Paignton in 1957," *IEE Monograph No. 319,* Jan. 1959, p. 70-76. See also (b) E. R. Laithwaite, "Oliver Heaviside — Establishment Shaker," *Elec. Rev.,* 211(16), Nov. 12, 1982, p. 44-45. Heaviside became aware of this gravitational relationship, and worked out a draft theory of electrogravitation based on his energy-flow theory (which added nondiverged closed-loop circulations of energy which vectorially summed to net zero). Those "trapped EM energy flow loops" were *gravitational,* in Heaviside's concept. His hand-written notes on his eleelrogravitation theory were found long after his death, beneath the floorboards of his little garret apartment. In honor of Heaviside, we have nominated his huge nondiverged energy flow component — erroneously discarded by Lorentz — as the source of the extra gravity in the arms of the spiral galaxies, holding them together. In short, we have proposed that as the solution to the so-called "dark matter" problem.

173. Physicists love symmetry, turn to it at every opportunity, and will do almost any mathematical manipulation to obtain it, because they regard it as "beautiful." And so it is. Performing work, however, requires breaking symmetry to produce excess energy, which interacts with mass to produce a force, and then requires using that force to do the work. If we wish to build a system that produces more work output than the work that we ourselves have to do upon it to run it, then *a priori* that system must be *asymmetrical* and — to many physicists — *ugly.* Let us all drink a toast to more efficient *ugly* asymmetrical systems that also do not require **energy.**

input by the operator, but only by the active environment! Give us "ugly" electrical windmills that turn freely in electrical winds, rather than the inane "beautiful" present systems which destroy their energy winds faster than hey power their loads.

174. While Lorentz appears to have done it earlier, one can see his use of the surface integration in (a) Lorentz, {109}. In 1896 he also included it, using a more general theorem by Volterra, so that Poynting's theorem arises as a special case; see (b) H. A. Lorentz, *Versl. K. Akad. W. Amsterdam,* Vol. 4, 1896, p. 176.

175. This is usually performed by the source dipole.

176. Thus the long and tedious effort of my colleagues and I to create circuits that asymmetrically self-regauge their potential difference (source voltage) without allowing all the spent load current to pass back through the primary power source dipole and do work upon it to scatter the charges and destroy its dipolarity.

177. Again we strongly stress that asymmetrically regauging a potential in the system also regauges the local vacuum potential and the intensity of the vacuum potential's bidirectional EM energy exchange with the system. It alters the local curvature of spacetime. It directly alters the stored energy of the system and of the supersystem. See again Whittaker, {85}, to see this clearly. See particularly our use of the *supersystem* concept in Chapter 8, and as mentioned in Chapter 1 and the present Chapter 2.

178. Circuits and electrical power systems universally and routinely break Lorentz symmetry for *excitation* (potentialization) of the system at the initial onset. Just to potentialize a system in theory costs nothing, although it freely changes the potential energy of the system. The gauge freedom axiom of quantum field theory also guarantees that such change of the potential energy of the system is essentially "for free". It conclusively proves that (i) asymmetrical self-regauging exists and is done in electrical circuits, since the source dipole in the power supply accomplishes that initial self-regauging of the external circuit completely for free once the dipole is made, and (ii) the Maxwell-Heaviside equations do permit asymmetrical self-regauging, in violation of Lorentz's arbitrary condition prohibiting it.

179. This is the patent-pending Bedini process, which is processing through the U.S. Patent Office as we go to press.

180. Lee, {73}, p. 184.

181. B. P. Kosyakov, "Radiation in electrodynamics and in Yang-Mills theory," *Soviet. Phys. Usp.*, 35(2), Feb. 1992, p. 135-142. Quotes are from p. 135 and p. 141. Our proposed solution to the problem posed by Kosyakov (which is actually the broken symmetry of a charge) is that negative charges pour out positive energy and positive charges absorb positive energy. We "see" the positive charge as pouring out "reversed direction positive field energy" after we interact the energy with a laboratory charge to "observe". Considering the well-known polarization of the vacuum by any charge, one realizes that a 4-symmetry circulation of the EM energy is what is "emitted" and spreads throughout all space, since the vacuum polarization is also spreading. The actual energy flow is between the time domain and 3-space and return, at any elemental dipole in the polarization of the vacuum that is spreading.

182. Oliver Heaviside, *Electrical Papers,* Vol. 2, 1887, p. 94.

183. Prof. William Keel, quoted in James McWilliams, "Through a Galaxy, Darkly," *Huntsville (Alabama) Times,* May 14, 2000, p. A-18.

184. Charles Seife, "Peering Backward to the Cosmos's Fiery Birth," *Science,* vol. 292, June 22, 2001, p. 2238.

185. M. P. Silverman, *And Yet It Moves: Strange Systems and Subtle Questions in Physics,* Cambridge University Press, Cambridge, 1993, p. 127.

186. Matthew Colless, Australian National University, one of the survey team leaders in the project leading the world in mapping galaxies, Mar. 2001.

187. (a) Lee, {13a}; (b) Lee, Oehme and Yang, {13b};

188. Wuetal., {14}.

189. Bearden, {12}.

190. Mandl and Shaw, {19, 168}.

191. Whittaker, {85}.

192. Gabriel Kron, "Invisible dual (n-1) networks induced by electric 1-networks," *IEEE Trans, on Circuit Theory,* CT-12(4), Dec. 1965, p. 464-470.

193. Kron, {162}. The quote is from p. 114.

194. Steven Weinberg, *Dreams ofa Final Theory,* Vintage Books, Random House, 1993, p. 109-110.

195, See Josephs, {172a}. Heaviside's hand-written notes contained his theory of electro-gravitation, based on his theory of energy flow. The papers were found beneath the floorboards in his little garret apartment.

196. Laithwaite, {172b}. Laithwaite feels that Heaviside's postulation that a flux of gravitational energy combines with the (ExH) electromagnetic energy flux, could shake the foundations of physics. Extracting from Laithwaite; *"Heaviside had originally written the energy flow as S = (ExH) + G, where G is a circuital flux. Poynting had only written S = (ExH). Taking p to be the density of matter and e the intensity of a gravitational force, Heaviside found that the circuital flux G can be expressed as pu -ce, where u represents the velocity of p and c is a constant. "*

197. Hence the title of cited reference {12} above.

198. Melvin H. Miles and Benjamin F. Bush, "Radiation measurements at China Lake: Real or Artifacts?", *Proc ICCF-7 (International Conference on Cold Fusion* — 7, Vancouver, BC, Canada, Apr. 1998, p. 101.

199. Bearden, {17}.

200. See P. V. Elyutin, "The Quantum Chaos Problem," *Sov. Phys. Usp..*Vol. 31, No. 7, 1988, p. 597-622. Elyutin discusses the crisis in quantum mechanics because of the missing chaos (hidden order). Quantum mechanics is known to be wrong unless this order can be found, because otherwise it does not predict the ordered macroscopic universe. Thus any proposed solution to the quantum chaos problem is worthy of Investigation, even if it turns out to be in error.

201. Unfortunately, entropy is one of those concepts in physics for which there are several differing major views. We consider entropy to be comparable to a positive resistor: organized energy goes in, disorganized energy comes out. Entropy is usually taken to be a measure of the disordering of energy. It does not *eliminate* the energy; it just makes it more difficult to *use* it. For our work in energy from the vacuum, we take the very simple view that a negentropic process is like a negative resistor: it receives energy in a form unusable to us, transforms it, and outputs it in

a form that is usable. In short, a negative resistor receives disordered energy and reorders it, so to speak. So it exhibits negentropy. We completely avoid the various notions of "information" and attempts to equate information and energy. We do point out, however, that a time-reversal process in one form or another is usually involved. In that sense, e.g., Newton's third law would be a negentropic process and involve time reversal in the mechanism generating the reaction-causing agent.

202. H. E. Puthoff, "Source of Vacuum Electromagnetic Zero-Point Energy," *Phys. Rev. A,* 40(9), Nov. 1, 1989, p. 4857-4862.

203. Whittaker, {91}. The paper was published in 1904 and orally delivered in 1903. This paper initiated superpotential theory.

204. As Whittaker showed in 1903, {85}, the scalar potential is actually a harmonic set of bidirectional EM longitudinal EM wavepairs, where each pair is composed of a longitudinal EM wave and its phase conjugate replica. Only because classical electrodynamicists have erroneously defined the field and potential as their own reaction cross sections with a unit point static charge, has the "static" potential been misidentified as a *scalar* entity, which it is not. The energy diverged from a uniform potential, around a fixed static point unit charge, is actually the set of divergences around the intercepting charge of the energy flows of all those EM waves comprising the potential. The sum total of all these individual wave divergences indeed has a scalar magnitude, but the magnitude of the total energy divergence from the potential is neither the potential itself nor its magnitude.

205. We point out the obvious: A "scalar" mass in 3-space actually him a time-vector since it moves through time continually, just to continue to exist. Further, it involves a special form of energy (energy compressed by c^2) which time is taken to be. Since we may choose any form of energy we wish by simple transduction, we may take it as compressed EM energy. So the mere continued existence of any mass proves conclusively that EM energy can and does ubiquitously flow to, from, and through the time dimension. The combined continued existence of numerous masses **proves** conclusively that the flow of time can have a myriad internal electromagnetic energy flows. An equilibrium between (i) an inflow of EM energy to a transducer from the time dimension, and (ii) an **outflow of** EM energy in 3-space from the transducer, will be seen as a discrete excitation (potential energy) associated with the transducer. Hence **the** notion of the charge. Every charge in the universe may be said to pour out

energy (negative charge pours out positive energy; positive charge absorbs positive energy — the equivalent of pouring out negative energy — and any charge results in a polarization of the vacuum. Hence what we call "spacetime" or "vacuum" is in fact a giant circulation of energy from the time domain to 3-space, and back to the time-domain. In short, a giant negentropy process continually sustains the active universe and all its components and processes.

206. Evans et al., {79}.

207. Semiz, {148}.

208. Weinberg, {194}, p. 286.

209. The available internal energy of a generator is the transduced shaft energy we input to it, say by turning the generator shaft with a steam turbine or hydro turbine. The shaft mechanical energy input is transduced into internal magnetic field energy once the rotor rotates. This internal magnetic energy is then dissipated on the internal charges inside the generator, forcing the positive charges in one direction and the negative charges in the other, thereby making the source dipole between the terminals of the generator. The available internal energy of a battery is the chemical energy possessed by it at any given time, and available for performing work on the internal charges to force them apart to form a dipole between the plates (and the battery terminals).

210. Kraus, {76}. Figure 12-60, a and b, p. 578 shows a good drawing of the Poynting (intercepted) energy flow being withdrawn into the conductors from the surrounding space. It does not show the Heaviside nondiverged component remaining, which is even larger, not diverged into the conductors, and wasted. The reason for the remaining Heaviside non-diverged component is that the electrons precess laterally across the conductor, thus withdrawing into the conductor only a small nearby section of the fields of the surface electrons — the ones (plus their fields extending into space) which intercept the impinging energy flow. Because of the short distance radially across the conductor's cross section, a surface electron has very limited "field and field energy withdrawal" length.

211. (a) J. D. Jackson, "Surface charges on circuit wires and resistors play three roles," *Am. J. Phys.*, 64(7), July 1996, p. 855-870. See also (b) Mark A. Heald, "Energy flow in circuits with Faraday emf," *Am. J. Phys., Vol.* 56, 1988, p. 540-547; (c) — "Electric fields and charges in elementary circuits," *Am J Phys.*, 52(6), June 1984, p. 522-526. The

surface charges in the conductors of a circuit are of enormous importance to the powering of the circuit.

212. See T. E. Bearden, "Energy Flow, Collection, and Dissipation in Overunity EM Devices," *Proc. 4th Internat. Energy Conf.*, Academy for New Energy, Denver, CO, May 23-27, 1997, p. 5-51. In Figure 5, p. 16 the fraction of the Poynting energy flow that is intercepted and collected by the circuit is roughly shown to be on the order of 10^{-13} of the entire Poynting energy flow available. That number is based on a very crude estimating procedure, but even if off by several orders of magnitude, it shows that the Heaviside nondiverged energy flow component is orders of magnitude greater than the diverged Poynting component, for single-pass of the energy and collection only once.

213. Rigorously, there is no *power* in an EM energy flow, regardless of how great in magnitude, if it is not altered in form or diverged. That is because "power" is rigorously the time rate of doing work (time rate of *changing the form* of energy), not the time rate of energy flow per se. Exactly, the Heaviside dark energy flow component was some 10 trillion joules per second in magnitude, but it had zero watts of power. Unfortunately, electrical engineers just loosely refer to nondiverged **energy** flow as "power", regardless of the non sequitur. Hence inane terms **widely** used in electrical engineering (and texts) such as "draw power from **the** source", etc. Rigorously, *the power* (rate at which energy is changed in form) is developed locally in each component having losses or performing work — i.e., changing the form of the energy.

214. (a) T. E. Bearden, "On the Principles of Permissible Over **Unity** EM Power Systems," *J. New Energy,* 4(2), Fall 1999, p. 16-39; (b) Bearden, {17}; (c) — "Use of Asymmetrical Regauging and Multivalued Potentials to Achieve Overunity Electromagnetic Engines," *J. New Energy,* 1(2), Summer 1996, p. 60-78; (d) — "Regauging and **Multivalued** Magnetic Scalar Potential: Master Overunity Mechanisms," *Explore,* 7(I), 1996, p. 51-58; (e) — "The Master Principle of EM Overunity and the Japanese Overunity Engines," *Infinite Energy,* 1(5&6), Nov. **1995-Feb,** 1996, p. 38-55; (f) — "Use of Regauging and multivalued Potentials to Achieve Overunity EM Engines: Concepts and Specific Engine Examples," *Proc. Internat. Sci. Conf, "New Ideas in Natural Sciences," St. Petersburg, Russia, June 17-22, 1996, Part I: Problems of Modern Physics,* 1996, p. 277-297.

215. In an oblique kind of sense, this is even "recognized" to some extent by leading electrodynamicists. E.g., quoting Jackson, {22}, p. 237: *"...the Poynting vector is arbitrary to the extent that the curl of any vector field can be added to it. Such an added term can, however, have no physical consequences. "* So Jackson follows Lorentz's lead that any additional non-intercepted and uncollected energy flow permissibly accompanying the Poynting intercepted and collected component, has no physical significance. Both Lorentz and Jackson err as to the *finality* of the statement. The accompanying Heaviside component can have no physical significance *unless it is intercepted and collected by means other than the single circuit or mechanism considered, and the single pass of the entire energy flow onto and past the receiving entity (circuit, charge, etc.).*

216. E.g., see Poynting, {4a. 4b}.

217. Heaviside, {5a}.

218. Heaviside, {5b}.

219. Heaviside, {5c}. Heaviside discusses the Faraday-Maxwell ether medium, outlines his vector algebra for analysis of vectors without quaternions, discusses magnetism, gives the EM equations in a moving medium, and gives the EM flux of energy in a stationary medium. On p. 443, he credits Poynting with being first to discover the formula for energy flow, with Heaviside himself independently discovering and interpreting this flow a little later by himself in an extended form.

220. J. H. Poynting, "On the connexion between electric current and the electric and magnetic inductions in the surrounding field," *Proc. Roy. Soc.* Lond. Vol. 38, 1984-85, p. 168.

221. Oliver Heaviside, *Electrical Papers,* Vol. 2, 1887, p. 94.

222. (a) T. E. Bearden, "On Extracting Electromagnetic Energy from the Vacuum," *Proc. IC-2000,* ibid., 2000; (b) Bearden, {38a}.

223. Lorentz is believed to have done this earlier (perhaps circa 1890s). In 1902 he published the method in a book, which strongly implies it was first done in an earlier paper. See Lorentz, {109}. Figure 25 on p. 185 shows the Lorentz concept of integrating the Poynting vector around a closed cylindrical surface surrounding a volumetric element. Many thanks to Marcus Reid for furnishing a copy of the actual Lorentz reference from a library in Leipzig, Germany.

224. E.g., see (a) Panofsky and Phillips, {110}; (b) W. Gough and J. P. G. Richards, *European J. Phys.*, Vol. 7, 1986, p. 195.

225. Panofsky and Phillips, {110}, p. 180.

226. D. S. Jones, *The Theory of Electromagnetism,* Pergamon Press, Oxford, 1964, p. 52.

227. Jackson, {22}, p. 237.

228. W. M. Schwarz, *Intermediate Electromagnetic Theory,* John Wiley & Sons, New York, 1964, p. 280-281.

229. Jones, {226}, p. 53.

230. For typical references, see (a) J. Slepian, *Am. J. Phys.*, 19, 87 (1951); (b) Mario lona, *ibid.*, 31, 398 (1963); (c) Udo Backhaus and Klaus Schafer, *ibid.*, 54, 279 (1986); (d) C. J. Carpenter, *IEE Proc. A* (UK), 136A(2), Mar. 1989, p. 55-65; (e) J. A. Ferreira, *IEEE Trans. Edit.*, 31 (4). 1988, p. 257-264; (f) Mark A. Heald,Am. *J. Phys.*, 56(6), 1988, p. 540-547. The debate has also appeared in many other leading journals, e.g., (G) T. H. Boyer, *Phys. Rev. D*, 25, 3246 (1982). Interestingly, (h) M. Abraham and R. Becker, *The Classical Theory of Electricity and Magnetism,* Blackie. London, 1932, p. 146 and p. 194 give two examples of the controversy over the Poynting vector. Finally, see (i) D. F. Nelson *Phys. Rev. Lett.*, 76(25), June 17, 1996, p. 4713-4716 for advanced **work** requiring a greater generalization of the Poynting vector.

231. Sweet and Bearden, {29a}. Sweet's device produced 500 watts lit a 33 microwatt input, which is approximately a COP = $1.5x10^6$. By steadily increasing the COP to $3x10^6$, the weight of the Sweet unit was reduced smoothly, reaching 90% reduction. The results of this highly successful anti-gravity experiment are reported in the paper. Unfortunately, Sweet later died and never fully revealed the activation secret by which barium ferrite magnetic materials could be triggered **into** strong self-oscillation at 60 Hertz or other ELF frequency.

232. Weaker self-oscillation of such permanent magnetic materials at higher frequency is known. E.g., see (a) V. S. L'vov, *Non-Linear Spin Waves,* Moscow, 1987; (b) L'vov, {29c}. See also (c) A. G. **Gurevich,** and G. A. Melkov, *Magnetization Oscillations and Waves,* CRC **Press,** Boca Raton, Florida, 1996. The latter authors give hundreds of **additional** references.

233. E.g., (a) M. W. Evans, P. K. Anastasovski, T. E. Bearden *et al,* "Derivation of the B(3) Field and Concomitant Vacuum Energy Density from the Sachs Theory of Electrodynamics," *Found. Phys. Lett.,* 14(6), Dec. 2001, p. 589-593; (b) — "Anti-Gravity Effects in the Sachs Theory ol Electrodynamics," *Found. Phys. Lett.,* 14(6), Dec. 2001, p. 601-605; (c) Evans et al., {38b}; (d) Evans et al., {38c}; (e) -- "Operator Derivation of the Gauge Invariant Proca and Eehnert Equation: Elimination of the Lorentz Condition," *Found. Phys.,* 39(7), 2000, p. 1123-1130; (f) - "O(3) Electrodynamics from the Irreducible Representations of the EInstein Group," 2001, *Found. Phys. Lett.,* 15(2), Apr. 2002, p. 179-187.; (g) - "Effect of Vacuum Energy on the Atomic Spectra," *Found. Phys.* Lett., 13(3), June 2000, p. 289-296; (h) Evans et al., {113b}; (i) Evans et aI., {113a}; (j) - "On the Representation of the Maxwell-Heaviside Equations in Terms of the Barut Field Four-Vector," *Optik* 111(6), 2000, p. 246-248; —"Derivation of the B(3) Field and Concomitant Vacuum Energy Density from the Sachs Theory of Electrodynamics," *Found. Phys. Lett.,* (in press); (k) — "The New Maxwell Electrodynamic Equations: New Tools for New Technologies. A Collection of 60 papers from the Alpha Foundation's Institute for Advanced Study. Published as a Special Issue of the *J. New Energy,* 4(3), Winter 1999. See also (1) Bearden, (222b}; (m) Bearden, {38a}; (n) Bearden, {43d}; (o) Bearden, {43a}; (p) Bearden, {30}; (q) Bearden, {40}; (r) Bearden {214}; (s) Bearden, {1214e}; (t) - "The Final Secret of Free Energy," *Magnets,* 7(5), May 1993, p. 4-26; (u) Bearden, {214f}.

234. Bearden, {40).

235. Terence W. Barrett and Dale M. Grimes, (a) Preface, p. vii-viii, in (b) *Advanced Electromagnetism: Foundations, Theory, and Applications,* Terence W. Barrett and Dale M. Grimes (eds.), World Scientific, Singapore, 1995.

236. I. Prigogine, "Irreversibility as a symmetry-breaking process." N*ature,* Vol. 246, Nov. 9, 1973, p. 67-71.

237. Paul Davies, *Superforce: The Search for a Grand Unified Theory of Nature,* Simon and Schuster, New York, 1984, p. 105.

238. Clarke, {55}, p. 38.

239. T. D. Lee, *Symmetries, Asymmetries, and the World of Particles,* U. Wash. Press, Seattle, 1988, p. 11.

240. That is, it does not exist *openly* in the open literature. Several inventors do have working laboratory COP>1.0 experiments, and at least three of them have models which could rapidly be developed into production systems — say, in one year or less. However, the exact and detailed construction details are understandably maintained as deeply proprietary by the inventors, until their intellectual property rights can be secured, including foreign patent rights. On the other hand, many other inventors mistakenly believe they have COP>1.0 systems, but do not because of instrumental error, considering nonsinusoidal waves as measurable with RMS meters, or effects covered in Chapter 6 which they do not comprehend. In addition, there have been those more interested in selling stock than in producing a working system.

241. But see Kawai, {31}. The only available *open* details approaching the "kit of parts and instructions" point is the Kawai process, and it will work just as in the patent if carefully built. If very efficient photon-coupled switching of the flux path is used for build-ups, and if very high efficiency (0.7 to 0.8) magnetic motors are modified with the Kawai process, one can expect the COP of the modified motors to be double the conventional efficiency of the original base motor. So one can obtain COP = 1.4 to 1.6, e.g., by using the necessary and available Hitachi high efficiency motors (one at 0.7 and the other at 0.8) to start with. Hitachi engineers physically tested two high efficiency Hitachi motors modified hy Kawai, at COP = 1.4 and COP = 1.6 respectively. Unfortunately, the Kawai process, engines, and company have been seized by what can **only** be described as the Yakuza (Japanese Mafia) and are being held off **the** market. The seizure was accomplished here in Huntsville, Alabama, witnessed by the CTEC board of directors and I, when Kawai and **CTEC** were in final negotiations to rapidly develop and market the Kawai **system** Several other COP>1.0 Japanese engines have also been seized and withheld by the Yakuza.

242. Jed Z. Buchwald, *From Maxwell to Microphysics,* University of Chicago Press, Chicago and London, 1985, p. 44.

243. Whittaker, {85}.

244. Bearden, {12}.

245. Mandl and Shaw, {19}.

246. Whittaker, {91a}.

247. To see how arduous a search Kron himself made prior to athieving a proper model for an electrical circuit, see Kron, {162}. The quote is from p. 114.

248. For example, Kron, {192}.

249. P. A. M. Dirac, "A theory of electrons and protons," *Proc. Roy. Soc. Lond. A*, 126(801), Jan. 1, 1930, p. 360-365. Here Dirac introduced the vacuum energy — the electron sea filled with electrons occupying negative energy states. The holes are treated today as the positive electrons. This concept is now referred to as the "Dirac Sea," and the concept has been expanded to include negative energy "holes" for other kinds of particles. Dirac first attempted to identify these holes with protons, until later the positron was discovered.

250. Evans, {137b}.

251. (a) Evans, {137a}; (b) — "The Link Between the Topological Theory of Ranada and Trueba, the Sachs Theory, and 0(3) Electrodynamics," *ibid.,* vol. 2, p. 495-499.

252. (a) Sachs, {126a). The Sachs theory provides a great generalization of general relativity and electrodynamics reaching from the quarks and gluons to the entire universe. See also (b) Sachs, {126b}.

253. Indeed, the symmetrizing of Maxwell's equations was first accomplished by Lorenz. See (a) Lorenz, {161a}. In this paper Lorenz gave essentially what today is called the Lorentz symmetrical regauging. AS pointed out by Barrett, the Lorenz paper gave f(t-r/c) functions. Fitzgerald said that Lorenz's functions were essentially the same as his, and Fitzgerald became a leading proponent of "retarded potentials". But it is believed that Fitzgerald was unaware of Lorenz's work until the 1880's, so he is given credit for parallel development. Some people speak of Fitzgerald-Lorenz functions. This is a regauging, but the term "gauge" (inspired by railroad gauges) was first introducec by Hermann Weyl in the 1900s. He used it for a change in length and was quickly countered by Einstein - Weyl's theory was not relativistic. The idea resurfaced in the 1920s when quantum theory was being formulated, but this time it meant "change in phase" and not "change in length". At any rate, when the renowned H. A. Lorentz performed the symmetrizing of the Maxwell-Heaviside equations in the 1880s. it was adopted immediately and has been rather universally applied since then. See also (b) Jackson and Okun {161b} for a history of gauge invariance.

254. (a) Prigogine, {160a}; (b) G. Nicolis and I. Prigogine, {160d}; (c) T. Petrosky and I. Prigogine, "Quantum Chaos, Complex Spectral Representation and Time-Symmetry Breaking," *Chaos, Solitons, and Fractals,* Vol. 4, 1994, p. 311-359; (d) D. Kondepudi and I. Prigogine, "Thermodynamics, Nonequilibrium," *Encyclopedia ofApplied Physics,* Vol. 21, 1997, p. 311-337; (e) D. Kondepudi and I. Prigogine, *Modern Thermodynamics: From Heat Engines to Dissipative Structures,* Wiley, Chichester, 1998; (f) T. Petrosky and I. Prigogine, "Laws of Nature, Probability and Time Symmetry Breaking," *Physica A,* Vol. 263, 1999, p. 528-539.

255. (a) G. Nicolis, and I. Prigogine, *Exploring Complexity,* Piper, Munich. 1987; (b) — *Exploring Complexity: An Introduction,* Freeman, New York, 1989; (c) G. Nicolis, {160e}.

256. Letokhov, {157a-157d}.

257. Bohren, {24}.

258. Paul and Fischer, {25}.

259. E.g., see (a) Patrick et al., {37}. For rigorous explanations of **how** the energy is extracted from the vacuum, see (b) Evans et al., {38b}; (c) Evans et al., {38c}. The vacuum can and will furnish an electromagnetic "wind" from which useful EM energy can be extracted. Indeed, every source charge and dipole already extracts and continuously pours out EM energy from the vacuum, thereby establishing its fields and potentials **(and** their energy) across the universe.

260. A relationship between gamma bursters and a big bang is suggested from some recent observations. On Jan. 23, 1999 the Hubble Space Telescope caught an optical flash simultaneous with an initial gamma burst. When calculated, this burst was second in energy only to the big bang itself, and generated about 3.4 x 10^{54} ergs, which is the equivalent of converting two solar masses instantaneously into energy. There was also no polarization of the afterglow, which has been taken as evidence of beaming. However, such beaming could also be due to the beaming involved in the intense iterative phase conjugate reflections of the asymmetrical self-regauging process in intensely scattering, optically active, energy-amplifying media.

261. Heaviside, {5a-5c}.

262. Josephs, {172a}; Laithwaite, {172b}.

263. (a) Diederik Wiersma and Ad Lagendijk, "Laser Action in Very White Paint," *Physics World,* Jan. 1997, p. 33-37; (b) K. Totsuka, G. van Soest, T. Ito, A. Lagendijk, and M. Tomita, "Amplification and diffusion of spontaneous emission in strongly scattering medium,"*J. Appl. Phys.,* Vol. 87, 2000, p. 7623-7628.

264. (a) A. Lagendijk, J. Gomez Rivas, A. Imhof, and R. Sprik, "Propagation of light in disordered semiconductor materials," in *Photonic Crystals and Light Localization in the 21st Century,* edited by C. M. Soukoulis, Kluwer, Dordrecht, 2001, p. 447-473; (b) H. Cao *et at,* "Spatial Confinement of Laser Light in Active Random Media," *Phys. Rev. Lett., 8*4(24), 12 Jun. 2000, p. 5584-5587.

265. We also point out the possibility of the accumulator at each end being an intensely scattering, photoreactive, energy-amplifying material, a subject discussed a bit later in this chapter.

266. (a) Werner Triftshauser *et al, Phys. Rev. Lett.,* Vol. 87, 2001. An overview is given by (b) Philip Ball, "The Positron Probe," *Nature,* Vol. 412. Aug. 23, 2001, p. 764.

267. For example, see Letokhov, {157a-157d}.

268. Jackson, {22}, p. 363, third footnote.

269. Kraus, {10}, p. 4.

270. Marconi's patent is Gugliehno Marconi, "Transmitting Electrical Signals," U.S. Patent 586,193, July 2, 1897. Filed Dec. 7, 1896, with 56 claims. This patent was overturned in 1943 by the U.S. Supreme Court, and prior work by Nikola Tesla for transmission of EM signals was upheld. Most textbooks and journals, etc. to this day continue to falsely credit Marconi with discovery of the transmission of EM signals and thus the discovery of radio. This is not to discredit the important work that Marconi did; without him, signal transmission would have been much longer in coming.

271. United States Reports: Cases Adjudged in the Supreme Court of the United States, Vol. 320, Marconi Wireless Telegraph Co. of America vs. United States, June 21, 1943, p. 1-80. The U.S. Supreme Court ruled that Tesla's fundamental radio patents had anticipated all other contenders, including Marconi.

272. *Dictionary ofScientific and Technical Terms,* Daniel N. Lapedes (editor in chief), McGraw-Hill, New York, 1974, p. 300. On page 517 of the second and expanded edition (1978), the same definition of electric field appears and is unchanged.

273. H. J. Gray and Alan Isaacs, *A New Dictionary ofPhysics,* Longman, London, second edition, second impression, 1976.

274. Feynman, {7}, p. 2-4.

275. Feynman, {7}, p. 12-2.

276. P. K. L. Drude, *Ann. Physik,* Vol. 1, p. 566; Vol. 3, 1900, p. 370, 869. Here Drude first develops a theory of conductivity in a metal based on the assumption that there is a gas of free electrons in the metal. This gas of conduction electrons is often referred to as the "Drude gas." Note that this was shortly after J. J. Thomson's discovery of the electron in 1897.

277. E.g., see Jackson, {211a}.

278. Romer, {84}, endnote 24, p. 109.

279. H. Winfield Secor, "Tesla Maps Our Electrical Future."

280. Nikola Tesla, "Pioneer Radio Engineer Gives Views on Power," *New York Herald Tribune,* Sep. 11, 1932.

281. Nikola Tesla, "The True Wireless, *Electrical Experimenter,* May 1919.

282. Burford and Verner, {35a}. Quote is from p. 281.

283. That is, it does not exist *openly* in the open literature. Several inventors do have working laboratory COP>1.0 experiments, and at **least** three of them have models which could rapidly be developed into production systems — say, in one year or less.

284. But see Kawai, {31}.

285. Barrett, {124}.

286. (a) Terence W. Barrett, "Active Signalling [sic] Systems," U.S. Patent No. 5,486,833, Jan. 23, 1996; (b) — "Oscillator-Shuttle-Circuit (OSC) Networks for Conditioning Energy in Higher-Order Symmetry Algebraic Topological Forms and RF Phase Conjugation," U.S. Patent No. 5,493,691, Feb. 20, 1996.

287. No proper scientific treatise on the Moray device has ever been published, to our knowledge, nor has a proper theory of its operation been developed. Anecdotal material and some technical material is contained in (a) T. H. Moray, *The Sea of Energy,* 5th Edn., Salt Lake City, 1978 (foreword by T. E. Bearden). The fourth edition of the book, titled (b) *The Sea of Energy in Which the Earth Floats,* contains additional material but is long out of print. Additional information is given in (c) Keith Tutt, *The Search for Free Energy,* Simon & Schuster, 2001, p. 33-68. (d) Paul Brown's study of the Moray work is "The Moray Energy Device: Operational Parameters, Design Criteria, and Considerations," date unknown. Researcher and inventor Bruce Perreault has based much of his own work with his radiant energy valve on Moray's work. Perreault proposes a different interpretation. In the present book we have tried to point out the various aspects of the Moray device that resemble other presently known effects — most of which were still unknown in the 1920s and 1930s when Moray's fundamental work was accomplished.

288. Moray, {34b} "Electrotherapeutic Apparatus," U.S. Patent No. 2,460,707, Feb. 1, 1949. This patent clearly shows the complexity of the various special tubes containing his pellets that Moray developed.

289. H. *C.* Dake and Jack DeMent, *Fluorescent Light and Its Applications,* Chemical Publishing Company, Inc., Brooklyn, New York, 1941, p. 51-52 gives a succinct discussion of Stokes emission and anti-Stokes emission.

290. Sir G. G. Stokes, "On the Change of Refrangibility of Light," a memoir, 1852.

291 For example, in 1935 Prileshajewa showed that there is an energy difference involving as much as 1.1 V between the exciting light and the fluorescence of aniline vapor.

292. V. S. Letokhov, {157a-157d}.

293. Letokhov, *ibid.*

294. E.g., (a) R. N. Bhargava and D. Gallagher, "Optical Properties of Manganese-Doped Nanocrystals of ZnS," *The Am- Phys. Soc,* 72(3), Jan. 17, 1994; (b) I. A. Izmailov et al., "Generation of Stimulated Noncoherent Radiation in Light-Scattering Media Exhibiting Chemical Reactions," *Soy. J. Quantum Electronics,* 12(5), May. 1982, p. 588-594; (c) R. Pappalardo and A. Lempicki, "Brillouin and Rayleigh Scattering in Aprotic Laser

Solutions Containing neodymium," *J. Appl. Phys.,* Apr. 1992, p. 1699-1708.

295. (a) Nabil M. Lawandy *et al.,* " Laser action in strongly scattering media," *Nature,* Vol. 368, Mar. 31, 1994, p. 436-438. For a good lay article with color pictures, see (b) Ivars Peterson, "Boosted light: Laser action in white paint," *Science News,* 145(15), Apr. 9, 1994, p. 228-229. See also (c) P. Mandel, "Lasing without inversion: A useful concept?," *Contemp. Phys.,* Vol. 34, 1993, p. 335; (d) O Kocharovskaya, "Amplification and lasing without inversion," *Physics Reports,* Vol. 219, 1992, p. 175.

296. Some useful papers are: (a) Diederik S. Wiersma and Ad Lagendijk, "Light diffusion with gain and random lasers," *Phys. Rev. E,* 54(4), Oct. 1996, p. 4256-4265. The authors discuss experimental considerations for a medium that both multiply scatters and amplifies light, and distinguish three regimes; (b) H. Cao *et al.,* "Random Laser Action in Semiconductor Powder," *Phys. Rev. Lett.,* 82(11), 15 Mar. 1999, p. 2278 2281. The authors observed random laser emission in all directions, with coherent feedback, in semiconductor powder, (c) Diederik S. Wiersma, Meint P. van Albada and Ad Lagendijk, "Coherent Backscattering of Light from Amplifying Random Media," *Phys. Rev. Lett.,* 75(9), 28 Aug., **1995,** p. 1739-1742. (d) D. S. Wiersma, P. Bartolini, A. Lagendijk, and R. Righini, *Nature,* Vol. 390, 1997, p. 671. The authors report Anderson localization of photons in GaAs powder, (e) Ad Lagendijk *et al,* "Microscopic Approach to the Lorentz Cavity in Dielectrics," *Phys. Rev Lett.,* 79(4), 28 July 1997, p. 657-660. (f) Pedro de Vries and Ad Lagendijk, "Resonant Scattering and Spontaneous Emission in **Dielectrics** Microscopic Derivation of Local-Field Effects," *Phys. Rev. Lett.,* 81(7), 17 Aug. 1998, p. 1381-1384. (g) Gijs van Soest, Makoto Tomita, and Ad Lagendijk, "Amplifying volume in scattering media," *Opt. Lett.,* 24(5), Mar. 1, 1999, p. 306-308.

297. S. Itoh *et al.,* "Simulational and experimental studies on anomalous reflectivity of phase conjugate wave," *Ferroelectrics,* vol. 170, 1995, p. 209-217.

298. See (a) D. P. Hand and P. St. J. Russell, "Solitary thermal shock waves and optical damage in optical fibers," *IEE Colloquium on 'Non Linear Optical Waveguides', LEE Digest* No. 88, London, England, 1988, p. 101-103; (b) — "Soliton-like thermal shock-waves in optical fibres: origin of periodic damage tracks," *Fourteenth European Conference on*

Optical Communication (ECOC 1988), Sep. 11-15, 1988, Publication No. 292, 1(2), 1988, p. 111-114; (c) — "Solitary thermal shock waves and oplical damage in optical fibers: the fiber fuse," *Opt. Lett.,* 13(9), Sep. **1988,** p. 767-769; (d) D. P. Hand and T. A. Birks, "Single-mode tapers as 'fibre fuse' damage circuit-breakers," *Electronics Lett.,* 25(1), Jan. 5, 1989, p. 33-34. For an excellent lay description with photographs, see (e) Ivars Peterson, "Fibers with Flare," *Sci. News,* 140(13), Sep. 8, 1991, p. 200-201

299. P. St. J. Russell, "Power Conservation and Field Structures in Uniform Dielectric Gratings," *J. Opt. Soc. America A.,* 1(3), Mar. 3, 1984, p. 293-299. Russell is referring to apparent violation of local conservation of energy. It is true in the conventional flawed energy flow analysis considering only the Poynting component, because the fuse produces more work output (melting the holes) than the original operator's input of Poynting energy to initiate the fuse effect. It does not produce more work output than the total of the energy input by the operator in both the acounted Poynting component and the unaccounted Heaviside component. It merely shows that the extra fiber fuse ignition actions do absorb extra energy from the Heaviside component, perhaps by particle resonance (Bohren effect) of the melt and vapor particles. Also, intense heating produces intense ionization and thus intense dipoles, thus producing broken symmetry in the fierce exchange with the active vacuum. Multiple retroreflections of the EM energy flow also occur in the nmelt and vapor particles, leading to multiple collections in the ping-pong of a joule of energy between two particles as phase conjugate mirrors.

300. E.g., see (a) H. Kogelnik, "Coupled wave theory for thick hologram gratings," *Bell Systems Technical Journal,* Vol. 48, 1969, p. 2909-2947; (b) Z. Zylbergerg and E. Marom, "Rigorous coupled-wave analysis of pure reflection gratings," *J. Opt. Soc. Am.,* Vol. 71, 1981, p. 811-818; (c) — - "Rigorous coupled-wave analysis of grating diffraction — E- mode polarization and losses," *ibid.,* Vol. 73, 1983, p. 451-455; (d) - "Comments on analyses of reflection gratings," *ibid.,* Vol. 73, 1983, p. 399-401.

301. Bohren, {24J.

302. Justin Mullins, "Superpowerful Explosive Arrives with a Bang." New *Scientist,* Aug. 4, 2001.

303. Romano M. DeSantis *et al.,* "On the Analysis of Feedback Systems With a Multipower Open Loop Chain," Oct. 1973, AD 773188, available through the Defense Technical Information Center or the National Technical Information Center. The paper clearly shows that such systems can produce overunity coefficient of performance.

304. See (a) J. H. Andreatta, "High Power Switching Amplifier Wherein Energy is Transferred to a Tuned Circuit During Both Half Cycles," U.S. Patent No. 3,239,771, Mar. 8, 1966; (b) Tom L. Dennis Jr., "Highly Efficient Semiconductor Switching Amplifier," U.S. Patent No. 3,239,772, Mar. 8, 1966; (c) Heber J. Morrison, "Square Wave Driven Power Amplifier," U.S. Patent No. 3,815,030, June 4, 1974.

305. For a good but conventional coverage of many differential negative resistors and negative conductors, see Adolf Fritz Schwarz, "Negative Resistors and Negative Conductors," Doctoral Thesis, Technische Hogeschool, Delft (Netherlands), Feb. 1969, available from the U.S. National Technical Information Service (NTIS), Springfield, VA. True negative resistors are dismissed as impossible in Schwarz's opening remarks. And they *are* impossible in equilibrium systems not receiving and using any net excess energy asymmetrically from their environment, which are the only systems conventionally considered by electrical engineers and electrodynamicists.

306. Gabriel Kron, "Numerical solution of ordinary and partial differential equations by means of equivalent circuits." *J. Appl. Phys.,* Vol. 16, Mar. 1945a, p. 173.

307. Kron, {32}, p. 39.

308. Bearden, {12}.

309. E.g., see Gabriel Kron, "Equivalent Circuits for Oscillating Systems and the Riemann-Christoffel Curvature Tensor," *General Electric Review,* Jan. 1943, p. 25-31.

310. See (a) S. Austen Stigant, "Gabriel Kron on Tensor Analysis, A bibliographical record," *BEAMA Journal,* Aug. 1948, for a full bibliography of Kron's publications up to 1948. Also useful are (b) Gabriel Kron, "A Method to Solve Very Large Physical Systems in Easy Methods," *IRE Transactions on Circuit Theory,* 2(1), Dec. 1953, p. 71-90; (c) P. L. Alger, editor, *The Life and Times of Gabriel Kron, or Walking Around the World, and Tensors,* Mohawk Development Services, Inc.,

Schenectady, NY, 1969; (d) Banesh Hoffman, " Cron's Non-Riemannian Electrodynamics," *Rev. Mod. Phys.*, 21(3), 1949, *x* 535-540; (e) K. Kondo and Y. Ishizuka, "Recapitulation of the Geometrical Aspects of Gabriel Kron's Non-Riemannian Electrodynamics," Research Association of Applied Geometry, *Memoirs of the Unifying Study of Basic Problems in Engineering and Physical Sciences by Means of Geometry*, Gakujutsu Bunken Fukyu-kai, Tokyo, Vol. I, 1955, p. 185-239 [particularly see footnote 1, p. 222];

311. Wang and Chung, {33}.

312. Deborah D. L. Chung, "Superconductor-metal laminates and method of making," U.S. patent no. 5,059,582, issued Oct. 22, 1991. A superconducting laminate having at least one layer of metal and at least one layer of superconducting material. The metal layer and the superconducting layer are bonded. The layer may also include carbon fibers from various precursors. The superconductor may be a composite material. The invention also includes a method of making the laminates. Assigned to The Research Foundation of State University of NY, Albany, NY.

313. Jean-Louis Naudin, website http://jnaudin.free.fr/cnr/.

314. Fogal, {36a, 36b}.

315. As one example, Fogal's device has to be able to manipulate Dirac holes in the vacuum itself, at least to some extent. Once the erroneous flat spacetime assumption of classical electrodynamics is removed and curved local spacetime considered, we can and will have Dirac holes in the local vacuum itself, especially in COP»1.0 systems. In a COP»1.0 system, not all the Dirac holes have interacted with orbital electrons in atoms to "eat" an electron and produce a positive ion — with a "lattice hole" or "lattice positron" where the electron had been. There is a vast difference between a Dirac hole positron (which has a negative mass equal in magnitude to one electron-mass) and a lattice hole (which is attached to the relatively huge positive mass of the ionized atom. Hence the mobility and phenomenology of Dirac positrons and lattice positrons are very different. There presently are no books on the dynamics of the Dirac negative energy electron holes in COP»1.0 EM circuits and systems.

316. Mandl and Shaw, {19}.

317. Whittaker, {91a}. The paper was published in 1904 and orally delivered in 1903. Note: On p. 368 midpage, Whittaker's equation for the y-component of vector-potential "a" is missing the exponent "2" on the **del** operator.

318. Rodrigues and Lu, {93a}.

319. Rodrigues and Vaz, {93b}.

320. It is certainly not lacking in the secret military weapons game. Some 10 nations of the world have weaponized longitudinal EM wave weapons over the past few decades, and almost every major weapons laboratory in the world has now "discovered" longitudinal EM waves. Even the Yakuza (Japanese Mafia) has acquired its own portable longitudinal EM interferometry weapons.

321. Evans et al., {79}.

322. (a) V. I. Arkhipov, *et al.,* "Negative transient currents in amorphous semiconductors." *Internat. J. Electronics* (UK), 51(6), 1981, p, 735-742; (b) — and A. I. Rudenko, "Negative currents caused by injection-controlled polarization," *Solid. St. Commun.,* 28, 1978, p. 675-676.

323. Jackson, {22}, p. 222.

324. Jackson, {22}, p. 223.

325. O. L. Brill and B. Goodman, *Am. J. Phys.,* vol. 35, 1967, p. 832.

326. For example, see Jackson, {22}, p. 219-221.

327. We stress that electrodynamicists, conventional theory, and quantum field theory all assume the principle *of gauge freedom,* the **total** freedom to change the gauge (and therefore any potential) in a Maxwellian system at any time, without cost or work. In the real world one may have to pay a little switching costs, but by simply regauging one can freely change the EM energy physically present at a point in 3-space **occupied by** the Fogal "freed" instantaneous scalar potential, once the electrons are pinned. In short, the Fogal process is able to directly "gate" the instantaneous transduction of EM energy existing at multiple points **in** space, simultaneously. There is nothing in the gauge freedom **principle** that restricts (i) regauging the instantaneous scalar potential at will, **or** (ii) using these changes at a distance to produce force fields upon electrons, thereby moving them — so long as one employs a Fogal semiconductor in

the "distant receiver" in order to be able to produce the back-transition from the field-free state to the force-field state by removing the anomalous pinning restriction. To the advanced theorists, we leave the debates over causality considerations for this demonstrated process!

328. Whittaker, {85}.

329. (a) W. Heitman and G. Nimtz, "On Causality Proofs of Superluminal Barrier Transversal of Frequency Band Limited Wave Packets," *Phys. Lett. A196,* 1994, p. 154-158; (b) Enders and Nimtz, {136b}.

330. The reader should recall that the Lorenz/Lorentz condition, which limits the circuit to COP< 1.0, is self-applied by the circuit when it rams all "spent" electrons in the ground return line back through the emf of the circuit. One need not do that, and need not produce that force field that destroys the primary source dipole and its extraction of EM energy from the vacuum via its broken symmetry. As the reader has undoubtedly now observed, the "back-emf' and "back mmf are those aspects in an electrical circuit and magnetic circuit respectively, that kill the dipole and physically self-apply and self-enforce Lorenz/Lorentz symmetrical regauging. Hence the intuitive concern of COP>1.0 experimenters to try to discover how to avoid or lessen the "back emf or the "back mmf in their circuits and systems.

331. Philip Ball, "The positron probe," *Nature,* Vol. 412,23 Aug. 2001, p. 764.

332. Werner Triftshauser et al., *Phys. Rev. Lett.,* 87, 067402 (2001).

333. Bearden, {30}.

334. For the chemistry and currents of the battery, see any good battery reference, such as Colin A. Vincent and Bruno Scrosati, *Modern Batteries: An Introduction to Electrochemical Power Sources,* Second Edition. Wiley, New York, 1997.

335. (a) J. O'M. Bockris, A. K. N. Reddy, and M. Gamboa-Aldeco, *Modern Electrochemistry: Fundamentals of Electrodics,* 2nd edition. Kluwer/Plenum, NY 2000; (b) J. O'M. Bockris and A. K. N. Reddy, *Modern Electrochemistry: Electrodics in Chemistry, Engineering, Biology, and Environmental Science,* 2nd edition, Kluwer/Plenum, NY 2000; *(c)* J. Koryta, J. Dvorak, and L. Kavan, *Principles of Electrochemistry,* 2nd ed.. Wiley, NY, 1993; (d) Wolfgang .1. Lorenz and Waldfried Plieth,

Electrochemical Nanotechnology: In Situ Local Probe Techniques at Electrochemical Interfaces, Wiley, NY, 1998; (e) B. E. Conway, *Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications,* Plenum, NY, 1999; (f) Allen J. Bard and Larry R. Faulkner, *Electrochemical Methods: Fundamentals and Applications,* Second Edition, Wiley, NY, 2001.

336. At this writing, a provisional patent application on the process has been filed by Bedini and the present author. By the time of publication, hopefully this will have been turned into a formal patent application, with foreign patents also applied for.

337. Edwin V. Gray, "Pulsed Capacitor Discharge Electric Engine," U.S. Patent #3,890,548, June 17, 1975.

338. (a) Per Whittaker, {85}. However, see (b) Bearden, {12} for a necessary correction of Whittaker's interpretation to accord with a quantum field theory view of the instantaneous scalar potential. After observation, the phase conjugate EM wave half of the Whittaker wavepair is indeed going in the opposite direction to the normal longitudinal EM wave half But prior to observation, it exists in the time domain, and in the time domain it is precisely accompanying the 3-space longitudinal EM wave, with the absorbing and then emitting charge interacting in the middle between the two. See (c) Mandl and Shaw, {19}, to see that the combined scalar (time-polarized) photon and longitudinal photon are observable as the instantaneous scalar potential. This means that the corrected Whittaker decomposition produces an associated time-polarized EM wave in the time domain and longitudinal EM wave in 3-space. That is the corrected interpretation of Whittaker's phase conjugate longitudinal EM wavepair.

339. (a) J. O'M. Bockris, "Overpotential: a lacuna in scientific knowledge,"J. *Chem. Edu.,* 48(6), June 1971, p. 352-358. This is a simplified introduction to overpotential theory. The energy density that exists at minute "double layers" in contact, which act as tiny capacitors with extremely small separation of plates, is enormous and far greater **than** what the power engineer meets in his normal engineering practice. **Sec** also (b) Bockris and Reddy, {335b}, particularly Chapter I which deals with the overpotential. See also (c) Bockris et a1, {335a}.

340. E.g. see (a) L. Bertalot *et al.,* "Study of deuterium charging in palladium by the electrolysis of heavy water: heat excess production", *Nuovo Cimento,* Vol. 15 D, 1993, p. 1435; (b) J. O'M Bockris *et al.,* "Cold

fusion as a consequence of high fugacity among hydrogen isotopes," Intl. *J. Hydrogen Energy,* Vol. 17, 1992, p. 445.

341. Peter Lindemann, *The Free Energy Secrets of Cold Electricity,* **Clear** Tech Inc., Metaline Falls, WA, 2001.

342. Particularly see Kenneth S. Deffeyes, *Hubbert's Peak: The Impending World Oil Shortage,* Princeton University Press, Princeton, NJ, **2001.**

Quoting: *"Deffeyes finds that world oil production will peak within five wars and that there isn't anything we can do to stop it. New exploration and production technologies can't save us, and plans to open the Arctic National Wildlife Refuge and other areas to drilling offer no more than a small and soon-to-be-forgotten blip on the production curve. While long-term solutions exist in the form of conservation and alternative energy sources, they probably cannot — and almost certainly will not — be enacted in time to evade a short-term catastrophe of shortages, soaring prices, and global economic, agricultural, and possibly political disturbance. "* In short, Deffeyes rigorously demonstrates that a world energy crisis of staggering proportions is just around the corner.

343. D. J. Bohm and B. J. Hiley, "On the intuitive understanding of nonlocality as implied by quantum theory," *Found. Phys.,* 5(1), Mar. 1975, p. 93-109. Quote is from p. 107.

344. (a) Y. Aharonov and D. Bohm, "Significance of Electromagnetic **Potentials** in the Quantum Theory," *Phys. Rev.,* Second Series, 115(3), Aug. 1, 1959, p. 485; (b) — "Further Considerations on Electromagnetics In **the** Quantum Theory," Phys. Rev., 123(4), Aug. 15, 1961, p. 1511-1524.

345. Terence W. Barrett, "Electromagnetic Phenomena Not Explained by Maxwell's Equations," A. Lakhtakia, ed., *Essays on the Formal Aspects of Electromagnetics Theory,* World Scientific Publishing, River Edge, NJ, **1993,** p. 11 and generally p. 6-86.]

346. Davies, {237}, p. 105.

347. David J. Bohm, "A Suggested Interpretation of the Quantum **Theory** in Terms of 'Hidden' Variables, I and II." *Phys. Rev.,* 85(2), Jan. 15, 1952, p. 166-179 (Part I); 180-193 (Part II).

348. Jackson, {22}, p. 223.

349, Lamb and **Retherford,** {23}.

350. (a) Casimir, {26}. This paper is an extrapolation to two attracting plates of the more detailed paper of (b) H. B. G. Casimir and D. Polder, "The influence of retardation on the London-van der Waals Forces," *Phys Rev.* 73(4), Feb. 15, 1948, p. 360-372. Casimir's paper was an extension of earlier work by Verwey and Overbeek on the stability of colloidal systems, including the interaction of electric double layers; see (c) E. J. W Verwey, J. T. G. Overbeek, and K. van Nes, *Theory of the Stability of Lyophobic Colloids*, Elsevier, Amsterdam, 1948.

351. Lamoreaux, {27}.

352. Mead and Nachamkin, {28}.

353. E.g., see (a) P. W. Milonni. R. J. Cook and M. E. Goggin, "Radiation pressure from the vacuum: Physical interpretation of the Casimir force," *Phys. Rev. A,* Vol. 38, 1988, p. 1621; (b) C. E. Carlson, T. Goldman and J. Peres-Mercader, "Gamma-ray bursts, neutron star quakes, and the Casimir effect," *Europhys. Lett.*, Vol. 36, 1996, p. 637; (c) M. Chaichian *et ah,* "Quantum theories on noncommutative spaces with nontrivial topology: Aharonov-Bohm and Casimir effects," *Nucl Phys B.* Vol. 611, 2001, p. 383-402; (d) V. Dodonov, "Nonstationary Casimir Effect and Analytical Solutions for Quantum Fields in Cavities with Moving Boundaries," in *Modern Nonlinear Optics,* 2nd Edn., 3 vols., Wiley, 2001, Vol. 1, p. 309-384.

354. Bohm, {347}.

355. See T. E. Bearden, *Gravitobiology: A New Biophysics,* Tesla Book Co., Chula Vista, CA, 1991.

356. One should not be nonplussed at the notion of infinite velocity. A pure longitudinal EM wave is — at least in theory — capable of moving at infinite velocity, and is a proper solution to Maxwell's equations. See (a) Rodrigues and Lu, {93a}. Also, the ordinary potential in the Coulomh gauge does indeed move at infinite velocity; see Jackson, {22}, p. 223. In addition, Bohm's interpretation of quantum mechanics {347} uses the quantum potential, which instantaneously appears everywhere it will have magnitude.

357. Enders and Nimtz, {329b}.

358. R. Chen, "Cancellation of Internal Forces," *Am. J. Phys.,* 49(4), Apr. 1981, p. 372.

359. Whittaker, {85}.

360. R. L. Davis, "Non-Inductive Electrical Resistor," U.S. Patent No. 3,267,406, Aug. 16, 1966. Davis uses a Mobius-loop capacitor as an inductance-free resistor. Our comment is that, more rigorously, the resistor is *not* noninductive. It is "equally and oppositely inductive," which is quite a different thing altogether when one considers the difference between internal energy and external energy. We hypothesize that the "resistor" — or some version of it — produces an artificial scalar potential stress in spacetime — apparently varying the stress energy tensor itself— even though it produces a *net* zero reactance.

361. These are Brazil, Russia, China, and two other nations friendly to the U.S. The dominant weapons on earth today are quantum potential weapons, not nuclear weapons. The second most dominant weapons are probably the negative energy EMP weapons deployed by several nations, including China.

362. E.g., see (a) L. I. Mandelstam and N. D. Papaleksi, "On the parametric excitation of electric oscillations," *Zhurnal Teknicheskoy Fiziki,* 4(1), 1934, p. 5-29; (b) — "On resonance phenomena with frequency distribution." *Z.f. Phys.*, No. 72, 1931, p. 223: (c) — "Concerning asynchronous excitation of oscillations," *Zhurnal Tekhnicheskoi Fiziki,* 4(1), 1934; (d) — "Concerning asynchronous excitation of oscillations," *Zhurnal Tekhnicheskoi Fiziki,* 4(1), 1934; (e) —- "Concerning nonstationary processes occurring in the case of resonance phenomena of the second class," *Zhurnal Tekhnicheskoi Fiziki,* 4(1), 1934. See also (f) A. Andronov, "The limiting cycles of Poincare and the theory of self-maintained oscillations," *Comptes-Rendus,* Vol. 189, 1929, p. 559; (g) — and A. Witt, "On the mathematical theory of self-excitations," *Comptes-Rendus,* Vol. 190, 1930, p. 256; (h) — "On the mathematical theory of self-excitation systems with two degrees of freedom," *Zhurnal Tekhnicheskioi Fiziki,* 4(1), 193; (i) — "Discontinuous periodic movements and theory of multivibrators of Abraham and Bloch," *Bull. De l'Acad. Ed Sc. De l'URSS,* vol. 189, 1930. See (j) S. Chaikin, "Continuous and 'discontinuous' oscillations," *Zhurnal Prikladnoi Fiziki,* Vol. 7, 1930. p. 6; (k) — and A. Witt, "Drift in a case of small amplitudes," *Zhurnal Teknicheskoi Fiziki,* 1(5), 1931, p. 428; (1) — and N. Kaidanowski, "Mechanical relaxation oscillations," *Zhurnal Teknicheskoi Fiziki,* Vol. 3, 1933, p. 1.

363. L. Mandelstam [L. T. Mendel'shtam], N. Papalexi, A. Andronov, S. Chaikin and A. Witt, "Report on Recent Research on Nonlinear Oscillations," Translation of "Expose Des Recherches Recentes Sur Les Oscillations Non Lineaires," *Technical Physics of the USSR,* Leningrad, Vol. 2, 1935, p. 81-134 [NASA Translation Doc. TTF-12,678, Nov. 1969].

364. In Alexander L. Fradkov and Alexander Yu. Pogromsky, *Introduction to Control of Oscillations and Chaos,* World Scientific Series on Nonlinear Science E, Series Editor Leon O. Chua, World Scientific, New Jersey, 1998 — as a typical example — I found no mention of the Dirac hole current decay mechanism or of the active external environment (the active vacuum and its dynamics, and the active local curvatures of spacetime and their dynamics).

365. Richard E. Prange and Peter Strance, "The Semiconducting Vacuum," *Am. J. Phys.,* 52(1), Jan. 1984, p. 19-21.

366. John F. Lindner *et ah,* "Noise Enhanced Propagation," *Phys. Rev. Lett.,* 81(23), 7 Dec. 1998, p. 5048-5051. Lindner suggests that the mechanism appears to be general, in which case it could supply the mechanism that coherently "locks together" the barium nuclei self-oscillations in Sweet's activated barium ferrite magnets.

367. Owen Flynn, "Parametric arrays: A new concept for sonar," *Electronic Warfare Magazine,* June 1977, p. 107-112. Any two sine-wave frequencies as simultaneous drivers combine to produce a sine-wave difference frequency propagating in an isotropic nonlinear medium, essentially without sidebands or reverberations. Its pattern has a main lobe approximately equal to that of the high frequency drive, but devoid of sidelobes. The level of the propagating difference frequency is proportional to both the product of the two fundamental drive levels and to the square of the desired value of difference frequency.

368. M. I. Dykman *et al.,* "Noise-enhanced heterodyning in bistable systems." *Phys. Rev. E,* 49(3), Mar. 1994, p. 1935-1942

369. (a) V. S. L'vov and L. A. Prozorova, "Spin Waves Above the Threshold of Parametric Excitation," in (b) A. S. Borovik-Romanov and S. K. Sinha, Eds., *Spin Waves and Magnetic Excitations,* North-Holland, Amsterdam, 1988.

370. Gurevich and Melkov, {232c}. The authors treat high **frequency** processes, i.e., oscillations and waves, in magnetically ordered substances, including ferromagnetic and antiferromagnetic resonances, spin waves, nonlinear processes, and high frequency manifestations of **interactions** between the magnetic system and other systems of magnetically **ordered** substances (crystal lattice, charge carriers). The treatment is classical except that a quantum mechanical approach is used in the study of relaxation processes, which determine the energy losses of magnetic oscillations and waves. Experimental results but not techniques are included. Self-oscillation and self-oscillation criteria arc on p. 279.

371. (a) G. S. Kandaurova and A. E. Sviderskii, "Observation of autowave state and stable dynamic structures in multidomain magnetic films," *Sov. Tech. Phys. Lett.,* 14(5), May 1988, p. 346-347; (b) V. S. **L'vov,** {29c}.

372. Richard T. Hammond, "New fields in general relativity," *Contemp. Phys.,* 36(2), 1995, p. 103-114.

373. (a) J. Baugh et al., *Science,* Vol. 294, 16 Nov. 2001, p. 1505. For a simpler synopsis of the paper, see (b) Warren S. Warren, "Multidimensional Symmetry in a Three-Dimensional World," *Science,* Vol. 294, 16 Nov. 2001, p. 1475-1476.

374. E.g., see Howard R. Johnson, "Permanent Magnet Motor." U.S. Patent No. 4.151.431. Apr. 24. 1979.

375. Howard Johnson, private communication, January 2002.

376. In magnetics, multi-valued potentials (and hence the possibility **for** nonconservative fields) arise naturally in the theory, but are considered a nuisance to be eliminated or "averaged away" by magnetics engineers. E.g., see (a) Z. Ren, "A 3D vector potential formulation using edge element for electrostatic field computation," *IEEE Trans, on Magnetics,* **31(3),** May 1995, p. 1520-1523; (b) — "New technique for solving three-dimensional multiply connected eddy-current problems." *lEEProc, 1*37A(3), May 1990, p. 135-140; (c) J. C. Verite, "Calculation of multivalued potentials in exterior regions," *IEEE Trans, on Magnetics,* **Vol.** MAG-23(3), May 1987, p. 1881-1887. Amazingly, these and other similar methods are directed into converting the multivalued potential into single-valued regions by a process of multiple, highly selected cuts. In other words, the real attempt is to eliminate the multivalued aspect, in which case the theorists are in fact simply eliminating the asymmetrical

self-regauging provided by the multivalued potential and hence are discarding the ability to use multivalued potentials in true overunity processes.

377. (a) Z. Badics, "Transient eddy current field of current forced three-dimensional conductors," *IEEE Trans, on Magnetics,* 28(2), Mar. 1992, p. 1232-1234;(b) R. Albanese and G. Rubinacci, "Magnetostatic field computations in terms of two component vector potentials," *Int. J. for Numerical Methods in Engineering,* Vol. 29, 1990, p. 515-532; (c) Bearden, {214f}: (d) P. Hammond and T. D. Ssiboukis, "Dual finite-element calculations for static electric and magnetic fields," *lEEProc. A,* 130(3), 1983, p. 105-111; (e) P. R. Kotiuga, "On making cuts for magnetic scalar potentials in multiply connected regions," *J. Appl. Phys.,* 61(8), 1987, p. 3916-3918; (f) J. Penman and J. R. Fraser, "Complementary and dual energy finite element principles in magnetostatics," *IEEE Trans, on Magnetics,* 18(2), 1982, p. 319-323; (g) E. A. Tolkachev and Ya. M. Shnir, "Non-trivial topology effects in the interaction of a monopole with a line current," *Phys. Lett. A,* 155(8, 9), May 27, 1991, p. 464-466.

378. (a) Feynman, {7}, Vol. II, Chapter 37; (b) T. Ambrose, R. L. Sommer, and C. *L.* Chien, "Angular Dependence of Exchange Coupling in Ferromagnetic/Antimagnetic Bilayers," *Phys. Rev. B,* Vol. 56, 1997, p. 83; (c) H. Sang, Y. W. Du, and C. L. Chien, "Exchange Coupling in $Fe_5oMn_5o/Ni_{81}Fe_{19}$ Bilayers: Dependence on Antiferromagnetic Layer Thickness," *J. Appl. Phys.,* Vol. 85, 1999, p. 4931.

379. V. A. Tulin, "Nuclear Spin Waves in Magnets," *Fis. Niskikh Temp.,* Vol. 5, 1979, p. 965-993 [in Russian].

380. Sweet and Bearden, {29a}.

381. (a) Kenneth R. Shoulders, U.S. Patent # 5,153,901; (b) — "Energy Conversion Using High Charge Density," U.S. Patent # 5,018,180, May 21, 1991; (c) — "Energy Conversion using High Charge Density," U.S. Patent No. 5,123,039, 1992; (d) — U.S. Patents 5,054,046 and 5,054,047, 1991; (e) — "Circuits Responsive To and Controlling Charged Particles," U.S. Patent 5,148,461, 1992; (f) — and Steve Shoulders, "Observations on the Role of Charge Clusters in Nuclear Cluster Reactions," *J. New Energy,* 1(3), Fall 1996, p. 111-121.

382. (a) Paulo N. Correa and Alexandra N. Correa, "Pulsed Abnormal Glow Discharge Technology," *Infinite Energy,* 2(7), Mar./Apr. 1996, p.

18-21; (b) — "Other Applications of the PAGD Technology Besides Energy Conversion," *ibid.*, p. 22-27; (c)— "Electrochemical Transduction of Plasma Pulses," U.S. Patent No. 5,416,391, May 16, 1995; (d) "Energy Conversion Systems," U.S. Patent No. 5,449,989, Sept. 12, 1995; (e) — "Direct Current Energized Pulse Generator Utilizing Autogenous Cyclical Pulsed Abnormal Glow Discharges," U.S. Patent 5,502,354, Mar. 26, 1996.

383. In 1935, Prileshajewa showed that there is an energy difference as much as 1.1 v between the exciting light and the fluorescence of aniline vapor. This added energy is attributed to additions from the internal energy of the molecule. Thus, anti-Stokes emission has been validated as a COP>1.0 mechanism since at least 1935. For our purposes, replenishment of the internal energy of the molecule must be obtained from the local active vacuum; else one simply has the standard optical cooling process which cools the gas.

384. E.g., see J. K. Brasseur et al., "Coherent Anti-Stokes Emission in a Continuous Wave Raman Laser in H_2," carried on website location http://www.physics.montana.edu/optics/jlc/Anti-Stokes.pdf.

385. For a typical study, see J. Silver et al., "Studies on anti-Stokes emission from metal oxides (doped with Er3+ and Yb3+) stimulated by 632.8 nm laser excitation," *6th Int. Conf. Phosphors and Display Tech.*, San Diego, California, 2000.

386. For a typical paper of hundreds on the subject, see C. Zander and K. H. Drexhage, "Cooling of a Dye Solution by Anti-Stokes Fluorescence," in *Advances in Photochemistry*, edited by D. C. Neckers, D. H. Volman, and G. von Bulau; Wiley, New York, 1995.

387. (a) Antoine Priore, "Method of producing radiations for penetrating living cells," U.S. Patent No. 3,280,816, Oct. 25, 1966; (b) — "Apparatus for producing radiations penetrating living cells," U.S. Patent No. 3,368,155, Feb. 6, 1968. For an explanation, see (c) T. E. Bearden, "The Porthole Briefing," http://www.cheniere.org.

388. Thomas Valone, "Future Energy Technologies," *J. New Energy*, 5(2), Fall 2000, p. 41-46; summary is quoted from p. 44-45.

389. Shang-Xiang Jin and Hal Fox, "Characteristics of High-Density Charge Clusters: A Theoretical Model," *J. New Energy*, 1(4), Winter 1996, p. 5-20.

390. Shoulders, {381a-381e}.

391. Ken Shoulders, "Permittivity transitions," *J. New Energy,* 5(2), Fall 2000, p. 121-137.

392. *Ibid,* p. 122.

393. *Ibid,* p. 122.

394. K. Shoulders and S. Shoulders, {381 f).

395. Harold L. Fox, "Energy for the Future: High-Density Charge Clusters," *Modern Nonlinear Optics,* Second Edition, edited by M. W. Evans, Wiley, New York, 2001, Part III, p. 623-653.

396. See (a) Art Rosenblum, "Randell Mills — New Energy and the Cosmic Hydrino Sea," *Infinite Energy,* 3(17), Dec. 1997-1998, p. 21-34. Also see (b) Randell Lee Mills, "Energy/Matter Conversion Methods and Structures," Australian Patent No. 668678, Nov. 20, 1991. Particularly see (c) Eugene Mallove, "Dr. Randell Mills and the Power of BlackLight," *Infinite Energy,* 2(12), Jan.-Feb. 1997, p. 21, 35, 41.

397. Randell Mills *et al.,* "Lower-Energy Hydrogen Methods and Structure," U.S. Patent No. 6,024,935, Feb. 15, 2000. Some 60 pages, and an astounding 499 claims. For the patent, an independent verification was performed by Johannes Conrads, Institute for Low Temperature Plasma Physics at the Ernst Moritz Arndt University in Greifswald, Germany.

398. Randell L. Mills, "The Grand Unified Theory of Classical Quantum Mechanics," www.blacklightpower.com/book/shtml.

399. (a) Randell L. Mills et al., "Identification of Compounds Containing Novel Hydride Ions by Nuclear magnetic Resonance Spectroscopy"; (b) — "Spectroscopic Identification of Novel Catalytic-Reaction of Atomic Hydrogen and the Hydride Ion Products"; (c) — "Black Light Power Technology: A New Clean Energy Source with the Potential for Direct Conversion to Electricity," presented to the Intl. Conf. On Global Warming and Energy Policy, Nov. 26-28, 2000 and to the National Hydrogen Association Meeting, March 6-8, 2001; (d) — Plasma Power Source Based on a Catalytic Reaction of Atomic Hydrogen"; (e) R, M. Mayo and R. L. Mills, "Direct Plasmadynamic Conversion of **Plasma** Thermal Power to Electricity for Microdistributed Power Applications," *40th Ann. Power Sources Conf. Proc*, June 10-13, 2002; (f) R. Mills et al., "Novel Catalytic Reaction as a Potential New Energy Source," 223rd

ACS National Meeting, Orlando, Florida, Apr. 6-11, 2002; (g) — "Novel alkali and Alkaline Earth Hydrides for High Voltage and High Energy Density Batteries," *Proc. 17th Ann. Battery Conf. On Appl. And Advances, Calif. State Univ., Long Beach, CA, Jan. 15-18* (in press); (h) - "Synthesis of Diamond Films from Solid Carbon"; (i) Mills and Ray, "Spectral Emission of Fractional Quantum Energy Levels of Atomic Hydrogen from a Helium-Hydrogen Plasma and the Implications for Dark Matter," *Int. J. Hydrogen Energy,* 27(3), 2002, p. 301-322.

400. Peter D. Zimmerman, "An Analysis of Theoretical Flaws in So-Called Classical Quantum Mechanics and of Experimental Evidence against CQM," 2001.

401. Bearden, {222b}, p. 674.

402. E.g., it yields the excess deuterium, tritium, and alpha particles; see Bearden, {17}.

403. (a) Bearden, {222b}; Bearden, {15}.

404. (a) "Ion Cyclotron and Converter and Radio Power Microwave Generator," International Pub. No. WO 01/21300 A2, 29 March 2001; (b) "Ion Cyclotron Power Converter and Radio and Microwave Generator," International Pub. No. WO 01/22472, 29 March 2001. Both filed with World Intellectual Property Organization.

405. But see Samuel D. Harper. "The energy dissipated in a switch," *Am. J. Phys.,* 56(10), Oct. 1988, p. 866-889. Unless special attention and effort is paid, switches can indeed consume a great deal of energy! As Harper points out, it can be a substantial fraction of the energy transfer in the circuit. In a capacitive loaded circuit this is especially true. One should consider very efficient switching such as optically coupled switching arrangements.

406. (a) F. Heinrich, "Entropy change when charging a capacitor: A demonstration experiment," *Am. J. Phys.,* 54(8), 1986, p. 742-44. For an expanded discussion, see (b) I. Fundaun, C. Reese, and H. H. Soonpaa, "Charging a capacitor," *Am. J. Phys.,* 60(11), Nov. 1992, p. 1047-1048. Also see (c) Tyler A. Abbott and David J. Griffiths, "Acceleration without radiation." *Am. J. Phys.,* 53(12), Dec. 1985, p. 1203-1211. An extended charge can accelerate without radiating, under specified conditions.

407. (a) Davis, {360}. It would appear that a sine wave across this resistor may generate a **rhythmic** variation in what is called "internal

energy"; i.e., stress energy inside the system, hence stress energy in the associated vacuum. Since this is analogous to a sound wave consisting of rarefaction and expansion, it is a method of generating a longitudinal EM wave. This may also be involved also in the Fogal semiconductor. For a discussion of internal forces, which occur in equal and opposite pairs and are quite different from the resultant of forces, see (b) Chen, {358}, p. 372 and passim.

408. See Hsu-Chieh Yeh, "Remark on the second law of thermodynamics," *Am. J. Phys.*, 52(8), Aug. 1984, p. 720-723. As an example, from the common charge or dipole at constant temperature, we can indeed receive and take electrical energy because the charge (as a set of composite dipoles) and the dipole are not in 3-space energy flow equilibrium. Instead, they constantly receive virtual EM energy from the active vacuum, transduce it into 3-space EM energy, and continuously emit **that** energy in all directions — all at constant temperature. When we consider the supersystem of the charge-system and its environment, it is in disequilibrium and hence exhibits the effect pointed out by Yeh.

409. Yeh, {408}. Particularly see the illustration on p. 721.

410. Gabriel Laufer, "Work and heat in the light of (thermal and **laser**) light," Am. *J. Phys.*, Vol. 51, 1983, p. 42.

411. (a) Paulo N. Correa and Alexandra N. Correa, "A Modified Orgone Accumulator (HYBORAC) as a Drive for a Low Delta-T **Stirling** Engine, Part 1," *Infinite Energy*, 7(41), 2002, p. 23-29; (b) — "Orgone Accumulator Drive (HYBORAC) for Low Delta Stirling Motors, video presentation, ABRI Media Production.

412. Paulo N. Correa and Alexandra N. Correa, *Introduction to Experimental Aetherometry*, Vols. 1 and 2, 2001. Summaries of these **two** volumes may be freely downloaded from http://www.aetherometry.com

413. Paulo N. Correa and Alexandra N. Correa, "A Modified Orgone Accumulator (HYBORAC) as a Drive for a Low Delta-T Stirling **Engine** Part II." *Infinite Energy*, 7(42), 2002 (in press)

414. Eugene F. Mallove, "Demonstrating Aether Energy," *Infinite Energy*, 7(41), 2002, p. 6-8.

415. As quoted by Mallove, *ibid.*, p. 7.

416. Feynman, {7}, Vol. II, p. 1-3. Emphasis in original.

417. Mallove, {414}, p. 7.

418. J. M. Aguirregabiria, A. Hernandez, and M. Rivas, "Surface charges and energy flow in a ring rotating in a magnetic field." *Am. .J. Phys.,* 64(7), July 1996, p. 892-895.

419. F. Herrmann, "The unexpected path of the energy in a moving capacitor," *Am. J. Phys.,* 61(2), Feb. 1993, p. 119-121.

420. Wang and Chung, {33}.

421. Mike LaPointe, "Antimatter Production at a Potential Boundary," presented at the AIAA Joint Propulsion Conference, Breakthrough Propulsion Physics Session #1, July 9, 2001.

422. E.g., (a) Charles Kittel, *Introduction to Solid State Physics,* Seventh Edition, Wiley, New York, 1996 in various chapters contains excellent introductions to a more in-depth view of magnetic phenomena. A very useful book, written with clarity is (b) B. D. Cullity, *Introduction to Magnetic Materials,* Addison-Wesley, Reading, MA, 1972. For nuclear effects, (c) A. Abraham, *Nuclear Magnetism,* Oxford. 1961 is still excellent and quite comprehensive.

423. (a) Particularly see the lay overview by Philip Ball, "Meet the spin doctors...", *Nature,* Vol. 404, 2000, p. 918-920. This article deals with spin-injection from magnetic semiconductors. In addition to up and down, electron spin also has an additional degree of freedom called "color"; see (b) "Colourful electrons solve puzzle of ferromagnetism," *Physics World,* 14(7), July 2001; (c) also see the accompanying article by Fu Chun Zhang.

424. Stanislaw Bednarek, "Self-powered magnetohydrodynamic motors," *Am. J. Phys.,* 64(1), Jan. 1996, p. 90-92.

425. In a true superconducting system, it is possible to keep the current moving around in a resistance-free conductor indefinitely. However, no net work can be produced by the system, and in fact when one counts the energy one inputs to maintain the extremely low temperature of the environment, then to maintain the supersystem in such **"indefinite current** circulation" one has to continuously input energy to cool the **system. On** the other hand, an electron in an atom, orbiting the nucleus, is in **net** equilibrium on its path, so it will maintain its orbit indefinitely until perturbed sufficiently to break loose.

426. (a) Badics, {377a};(b) P. Hammond and J. Penman, "Calculation of inductance and capacitance by means of dual energy principles," *IEE Proc,* 123(6), 1976, p. 554-559; (c) Hammond and Ssiboukis, {377d}; (d) Yongzhong Huo, "A classification of thermodynamical potentials for two-variable transition systems," *Meccanica* [Netherlands], 30(5), Oct. 1995, p. 475.494; (e). Kotiuga, {377e}; (f) J. N. Murrell and S. Carter, "Approximate single-valued representations of multivalued potential energy surfaces," J. *Phys. Chem.,* 88(21), Oct. 11, 1984, p. 4887-4891; (g) Penman and Fraser, {377f}; (h) Ren, {376a}; (i) Z. Ren, "Solving 3D static field problems by dual formulations using potential variables," ***2nd** Int. Workshop on Elec. and Magn. Fields,* Leuven, Belgium, May 1994; (j) Ren, {376b}; (k) Verite, {376c}; (1) V. Vittal, "A generalized procedure to obtain first integrals for non-conservative dynamical systems: Application to power systems," *IEEE ISCAS '89,* 1989, p. 1984-1987.

427. G. W. O. Howe, "Effect of Torsion on a Longitudinally-Magnetized Iron Wire," *Wireless Engineer,* 29(344), May 1952, p. **115**-117.

428. Harry E. Burke, *Handbook ofMagnetic Phenomena,* Van Nostrand, New York, 1985. This is a one-of-a-kind handbook on a great number of magnetic effects and phenomena.

429. Cullity, {422b}.

430. As examples: (a) Barrett, {345}; (b) Gurevich and Melkov, {232c}; (c) William Weltner, Jr., *Magnetic Atoms and Molecules,* Dover, Mineola, NY, 1989; (d) Giorgio Bertotti, *Hysteresis in Magnetism,* Academic Press, New York, 1998; (e) L'vov, {29c}; (f) Sidney Platt, *Magnetic Amplifiers: Theory and Application,* Prentice Hall, Englewood Cliffs, N.J., 1958; (g) Maciej J. Ogorzalek, *Chaos and Complexity in Nonlinear Electronic Circuits,* World Scientific, New Jersey, 1997; (h) Jammer, {lb}; (i) Borovik-Romanov and Sinha, Eds, {369b}; (j) Paul Davies, ed., {160f}; (k) G. I. Shipov, *A Theory ofPhysical Vacuum: A New Paradigm,* Moscow, 1994; (1) Nicolis and Prigogine, {255b}; (m) Richard Feynman, *Quantum Electrodynamics,* 1961, 1963; (n) V. 1. Fushchich and A. G. Nikitin, *Symmetries ofMaxwell's Equations,* D, Reidel, 1987; (o) Mandl and Shaw, {19}; (p) M. W. Evans, Ed., ***Modern** Nonlinear Optics,* Second Edition, 3 vols., Wiley, 2001; (q) Robert C. O'Handley, *Modern Magnetic Materials: Principles and Applications,* Wiley, New York, 2000; (r) Sachs, {126a}.

431. As examples: (a) Lindsay and Margenau, {114}; (b) Richard P. Feynman, *The Character of Physical Law,* MIT Press, Cambridge, 1965:; (c) Feynman, {7}; (d) Ilya Prigogine, *The End of Certainty: Time, Chaos, and the New Laws of Nature,* Free Press, New York, 1996, 1997; (e) Mendel Sachs, *Einstein Versus Bohr: The Continuing Controversies in Physics,* Open Court Publishing Company, 1988.

432. For those unfamiliar with magnetics and the exchange force(s), see H. J. Gray and Alan Isaacs, *A New Dictionary of Physics,* second edition, 1976 printing, *ibid.,* p. 194 for a precise definition. The force from the sudden exchange of charge is known as the *Heisenberg force.* That due to the exchange of spin direction is known as the *Bartlett force.* The force associated with exchange of both spin and charge is known as the *Majorama force.* Quoting: "These exchange forces may be interpreted as being due to the continual emission and absorption of virtual particles that carry the shared property from one particle to another. The exchange of virtual hadrons between interacting particles of the atomic nucleus is intimately involved in nuclear exchange forces.

433. Feynman, {7}, Vol. II, Chapter 37 covers magnetic materials including exchange forces, spins, and spin effects.

434. *The Encyclopedia of Physics,* Robert M. Besancon (editor), Second Edition, Van Nostrand Reinhold, New York, 1974, p. 518.

435. Cullity. {422b}. p. 132.

436. Kittel, {422a}, p. 443 (footnote 1).

437. Lindsay and Margenau, {114}, p. 216-217.

438. *Ibid.,* p. 213.

439. *Ibid.,* p. 215.

440. *Ibid.,* p. 214.

441. T. D. Lee, "Space Inversion, Time Reversal and Particle-Antiparticle Conjugation," *Physics Today,* 19(3), Mar. 1966, p. 23.

442. Lee, {73}, p. 187-188.

443. Romer, {84}.

444. Kenneth D. Moore, "Testing of a Johnson Magnetic Gate," *Explore,* 9(6), 2000, p. 70-75. Also available on www.cheniere.org.

445. (a) Raymond J. Radus and William G. Evans, "Apparatus Responsive to Direct Quantities," U.S. Patent #2,892,155, Jun. 23, 1959; (b) R. J. Radus, "Permanent-Magnet Circuit using a 'Flux-Transfer' principle," *Engineers' Digest,* 24(6), June 1963, p. 86; (c) (anon.), "On-Off Permanent Magnet with a Memory," *Electronic Equipment Engineering,* 11(4), Apr. 1963, p. 22, 26.

446. "Human fly has magnetic sole," *Electrical Engineering,* Apr. 1963, p. 294.

447. Malcolm McCaid, *Attraction and Repulsion,* Oliver and Boyd Ltd., 1967 has an entire chapter on switching magnets, and has two photos of an engineer hanging upside down and walking on the underside of an elevated steel beam, wearing the Radus magnetic boots.

448. For a description of "shuffler" boots, see A. W. Hangar and A. A. Rosener, "The use of permanent magnets in zero-gravity mobility and restraint 'footware' concept," *IEEE Trans, on Magnetics,* Vol. MAG-6, No. 3, Sep. 1970, p. 464-467. These crude shuffler boots are quite a contrast to the elegant Westinghouse/Radus stepping boots earlier developed and used.

449. Burke, {428}.

450. David Scott, "Magnetic "Wankel" for electric cars," *Popular Science,* June 1979, p. 90-91.

451. E.g., (a) John R. Wiegand, "Bistable Magnetic Device," U.S. Patent No. 3,820,090, June 25, 1974; (b) — "Asymmetric Bistable Magnetic Device," U.S. Patent No. 3,866,193, Feb. 11, 1975; (c) - "Pulse Generation by Changing Magnetic Field," U.S. Patent No. 4,309,628, Jan. 5, 1982; (d) — "Pulse Generator Using Read Head with Wiegand Wire," U.S. Patent No. 4,263,523, April 21, 1981; (e) - "Switchable Magnetic Device;" U.S. Patent No. 4,247,601, Jan. 27, 1981; (f) — "Method of Manufacturing Bistable Magnetic Device," U.S. Patent No. 3,892,118, July 1, 1975; (g) — "Multiple Pulse Generator;" U.S. Patent No. 3,793,532, Feb. 19, 1974; (h) — and John E. Opie, "Pulse Generator with Shaped Magnetic Field," U.S. Patent No. 4,484,090. Nov 20, 1984.

452. Kawai, {31}.

453. John C. Bedini, "Device and Method of a Back EMF Permanent Electromagnetic Motor Generator," U.S. Patent No. 6,392,370, May 21.

2002. Uses a regauging process for capturing available back **EMF** electromagnetic energy in the system. The available energy may be captured and used to re-energize the battery, and/or sent in another direction to be used as useful work, or dissipated in the system.

454. See {445c}, p. 22, 26. Quoting: *"The circuit differs from ordinary permanent magnets in three ways: (I) It exerts strong magnetic force at one end while exerting hardly any at the other, (2) the strong and weak magnetic poles can be switched end-for-end easily and at will, thus in effect turning the magnetism on and off, and (3) it remembers its direction of greatest magnetic pull indefinitely. "*

455. Burke, {428}, p. 250.

456. Deffeyes, {342}.

457. Stuart Young, *Nature*, Vol. 414, 29 Nov. 2001, p. 487.

458. Evans, {137b}, p. 84.

459. M. W. Evans and S. Jeffers, "The Present Status of the Quantum Theory of Light," in *Modern Nonlinear Optics,* Second Edition, 3 Vols., edited by M. W. Evans, Wiley, 2001, Vol. 3, p. 150.

460. Clarke, {55}, p. 38.

461. Patrick, Bearden, Hayes, Moore, and Kenny, {37}. A second patent is pending, and two more are in preparation.

462. Bearden, {222b}.

463. Evans etal, {38b, 38c}.

464. T. E. Bearden, James C. Hayes, James L. Kenny, Kenneth D. Moore, and Stephen L. Patrick, "The Motionless Electromagnetic Generator: Extracting Energy from a Permanent Magnet with Energy-Replenishing from the Active Vacuum," Sept. 2000, carried on restricted DoE website http://www.ott.doe.gov/electromagnetic/. A search on the internet will turn up other sources where the paper can be downloaded.

465. (a) Evans et al., "The Aharonov-Bohm Effect as the Basis of Electromagnetic Energy Inherent in the Vacuum," *Found. Phys. Lett.,* 2002, (in review); (b) — "Derivation of the B(3) Field and Concomitant Vacuum Energy Density from the Sachs Theory of Electrodynamics," ***Found.*** *Phys. Lett.,* 14(6), Dec. 2001, p. 589-593; (c) — "Operator Derivation of the **Gauge** Invariant **Proca** and Lehnert Equations:

Elimination of the Lorenz Condition," *Found. Phys.,* 30(7), 2000, p. 1123-1130; (d) — "Runaway Solutions of the Lehnert Equations: The Possibility of Extracting Energy from the Vacuum," *Optik,* 111(9), 2000, p. 407-409; (e) — "The Effect of Vacuum Energy on the Atomic Spectra," *Found. Phys. Lett,* 13(3), June 2000, p. 289-296; (f) Evans et al., {113}; (g) — "Derivation of the Lehnert Field Equations for Gauge Theory in Vacuum: Space Charge and Current," *Found. Phys. Lett.,* 13(2), Apr. 2000, p. 179-184;(h)Bearden, {222b}.

466. Details are on Jean-Louis Naudin's website, in the section dealing with the MEG, which is http://jnaudin.free.fr/html/megv21.htm#megstat.

467. For an introduction to the field and its literature, see J. Anandan, J. Christian, and K. Wanelik, "Resource letter GPP-1: Geometric phases in physics," *Am. J. Phys.,* Vol. 65, 1977, p. 180-185.

468. A discussion by Feynman of the Aharonov-Bohm effect is given in Feynman, {7}, "15-5: The vector potential and quantum mechanics," p. 15-8 to 15-14.

469. A similar phase change also is induced outside the localized presence of an electrostatic scalar potential fi. See Feynman, {7}, p. 15-10. Quoting: *"...the effect of an electrostatic field is to produce a phase change given by the negative of the time integral of the scalar potential fi"*

470. Ya. M. Blanter, C. Bruder, R. Fazio, and H. Schoeller, "Aharonov Bohm-type Oscillations of Thermopower in a Quantum-dot Ring," *Phys Rev. B,* Vol. 55, 1997, p. 4069 typify the kind of "power" considerations that have been analyzed in the past. Only a minuscule thermopower treatment is considered.

471. S. Pancharatnam, "Generalized theory of interference, and its applications," *Proc. Indian Ac ad. Sci.,* Vol. A44, 1956, p. 247-262.

472. See Nahin, {62}, p. 225. Quoting: *"J. J. Waterston's paper on the kinetic theory of gases, in 1845, was rejected by the Royal Society of London. One of the referees declared it to be 'nothing but nonsense,* ***unfit*** *even for reading before the Society.'... "Waterston's dusty manuscript was finally exhumed from its archival tomb forty years later, because of the efforts of Lord Rayleigh... "*

473. Aharonov and Bohm, {344a, 344b}.

474. R. G. Chambers, "Shift of an electron interference **pattern** by enclosed magnetic flux," *Phys. Rev. Lett.*, Vol. 5, July I960, p. 3-5.

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476. A. Tonomura *et al.*, "Evidence for Aharonov-Bohm effect with magnetic field completely shielded from electron wave," *Phys. Rev. Lett.*, Vol. 56, 1986, p. 792-795. In the latter paper, the magnetic fields were completely and painstakingly shielded from the electron wave in a very careful experiment. The experiment demonstrated the expected relative phase shift as well as direct evidence for flux quantization. This was a definitive experiment clearly proving the Aharonov-Bohm effect. In 1999, Tonomura was awarded the Franklin Institute Award for this definitive proof of the Aharonov-Bohm effect.

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481. (a) V. Chandrasekhar *et al., Phys. Rev. Lett.*, Vol. 55, 1985, p. 1610; (b) S. Datta *et al., Phys. Rev. Lett,* Vol. 55, 1985, p. 2344; (c) S. N. M. Ruijsenaars, "The Aharonov-Bohm Effect and Scattering Theory," *Ann. Phys.*, Vol. 146, 1983, p. 1-34.

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phase in coupled neutron interference loops," *Phys. Rev. A.,* Vol. 53, 1996, p. 2486-2492; (f) A. G. Wagh *et al.,* "Experimental separation of geometric and dynamical phases using neutron interferometry," *Phys. Rev. Lett.,* Vol. 78, 1997, p. 755-759; (g) D. Suter, K. T. Mueller, and A. Pines, "Study of the Aharonov-Anandan quantum phase by NMR interferometry," *Phys. Rev. Lett.,* Vol. 60, 1988, p. 1218-1220; (h) D. Loss and P. M. Goldbart, "Persistent currents from Berry's phase in Mesoscopic systems," *Phys. Rev. B,* Vol. 45, 1992, p. 13544-13561; (i) C. A. Mead, "The geometric phase in molecular systems," *Rev. Mod. Phys.,* Vol. 64, 1992, p. 51-85; (j) J. H. Hannay, "Angle variable holonomy in adiabatic excursion of an integrable Hamiltonian," *J. Phys. A.,* Vol. 18, 1985, p. 221-230; (k) Y. Aharonov et al., "Aharonov-Bohm Type Forces Between Magnetic Fluxons," Hewlett Packard Report HPL-BR1MS-97-24, Oct. 1997.

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525. Today we would also point out that to first order time and mass have essentially the same energy density — i.e., they are both spatial energy compressed by c^2. So the "switches" of action quanta we used in 1973 may be taken to actually represent the time-charging and discharging, of a specific region of space. Rotation of time-energy from the time-domain into 3-space connection with a mass is a mass increase as well as a change of mass to masstime. Rotation of mass-energy out of 3-space back into the time domain (during photon emission) is a mass decrease, (a) Our paper, "Giant Negentropy..." {12}, proposing a solution to the source charge problem, argues that all 3-space EM energy comes from the time domain anyway and returns to it. The source charges normally absorb time-energy, and transduce it to 3-space EM energy or vice versa, but the 3-space energy radiated away is in expanded spatial energy form and not compressed into mass-energy. It is the very release of the c^2 compression of the time-energy that is the "transduction" process to provide the **radiated**

spatial EM energy. But if mere rotation in 4-space is used without **that** expansion/transduction, then the time energy appears as mass. This is consistent with the mechanism we advanced for the flow of a mass *m* through time. Note that when a photon is "absorbed", the spatial energy component of the photon is in fact compressed into mass energy, slightly changing the mass. But when it is re-radiated, it is radiated in expanded or "spatial" EM energy form. Without the expansion and transduction, pure rotation of the compressed EM energy between the time domain and the 3-space domain provides the notion of "time-charging" and "time discharging". Indeed, the very anomalous phenomena occurring in radiation detectors in electrolyte experiments at China Lake, already provide direct evidence for just such time-charging, as pointed out in (b) Bcardcn, {17}.

526. E. R. Laithwaite, "Rack and pinion motors," *Electronics and Power,* Vol. 16, 1970, p. 251-252.

527. Of interest: (a) E. R. Laithwaite, "Unexplained phenomenon at Savoy Place," *Electronics and Power,* Oct. 1972, p. 360-362 recounts the discovery of a free energy device violating the second law of equilibrium thermodynamics; (b) Laithwaite, {526}, gives some particulars of the device; (c) —*All Things Are Possible: An Engineer Looks at Research and Development,* I*PC Electrical-Electronic Press Ltd., Dorset House, London, 1976; (d) Laithwaite, {172b}; (e) — "Miles Walker — a pioneer at Met-Vick and UMIST," *Electrical Review,* 211(12), Oct. 15, 1982, p. 33-34; (f) — "Roll, Isaac, roll — Part I," *Electrical Review,* 204(7), Feb. 16, 1979, p. 38-41; (g) — "Roll, Isaac, roll — Part II," *Electrical Review,* 204(11), Mar. 16, 1979, p. 31-33; (h) — "The laws of science and of England," *Electrical Review,* 202(23), June 16, 1978, p. 27-28.

528. E. R. Laithwaite and W. R. C. Dawson, "Mass Transfer: An Introduction based on Experimental Work at the University of Sussex," Sep. 1994. A subtitle is: A system for the transfer of mass derived from the principle of conservation of momentum. On website http://jnaudin.free.fr/html/IPEmain.htm.

529. See WO95/30832, Nov. 16, 1995.

530. Eric Laithwaite and William Dawson, "Propulsion System," U.S. Patent Number 5,860,317, Jan. 19, 1999.

531. Sweet and **Bearden, {**29a**}.**

532. (a) Ning Li and D. G. Torr, *Phys. Rev.*, Vol. 43D, 1991, p. 457; (b) — *Phys. Rev.*, vol. 46B, 1992, p. 5489; (c) — *Bull. Am. Phys. Soc*, Vol. 37, 1992, p. 948. Also see (d) D. G. Torr and Ning Li, *Found. Phys. Lett.*, Vol.37, 1993, p. 948.

533. E. E. Podkletnov and R. Nieminen, *Physica C*, Vol. 203, 1992, p. 441-444.

534. Igor K. Kulikov, "Inertial and gravitational masses of bosons at finite temperatures," in NASA technical package sent in response to queries of "Study of Inertial and Gravitational Masses of a Boson," *NASA Tech Briefs*, 26(2), Feb. 2002, p. 56. The report by Dr. Kulikov of the Jet Propulsion Laboratory (JPL) is carried on the website as http://nasatech.com/TSP/PDFTSP/NPO30325.pdl'. This is a theoretical study of the relationship between the inertial mass and gravitational mass of a self-interacting neutral scalar boson in a heat bath. The difference in the two masses was determined as a function of the temperature of the heal bath. The theory for distinguishing the difference is given. Since it is presented as an inventor's report, we assume that a patent is either pending by or to JPL or already granted to it.

535. Mike LaPointe, {421}.

536. Jim Corum, T. Keech, D. Gray, P. Pesavento, and M. Duncan, "The Electro-magnetic Stress-Tensor as a possible Space Drive Propulsion Concept, presented at the AIAA Joint Propulsion Conference, July 9, 2001.

537. Hector Serrano, "Propulsion Device and Method Employing Electric Fields for Producing Thrust," WO 00/58623, Oct. 5, 2000.

538. William B. Stein, Electrokinetic Propulsion: The Ionic Wind Argument," Energy Conversion Laboratory, Purdue University, West Lafayette, Indiana 47906, Sep. 5, 2000. This is a Gravitec report. Results can be downloaded from http://foldedspace.com/data.html, and an even more rigorous future test is planned.

539. A motion picture of the Naudin's replica thruster in dynamic thrust performance is shown on http://jnaudin.free.fr/html/liftbldr.htm, along with information on many other successful "lifters". This website is a cornucopia of information on inertial propulsion and electrogravitation, including successful independent replication and tests.

540. Ryan Mahoney, "Huntsville Firm Developing New Propulsion Technology," Birmingham Business Journal, Birmingham, Alabama July 19,2001.

541. E.g., see J. Cameron, "An Asymmetric Gravitational Wave Propulsion System," presented in the Breakthrough Propulsion Physics session of the AIAA Joint Propulsion Conference, July 9, 2001.

542. Bearden, {40}.

543. Prange and Strance, {365

544. Privately, Sweet strongly affirmed to me that later he took the risk and pushed it a little further in output, actually levitating the system several times, including accelerating it upward, hovering it, and then letting it sink slowly down to come to rest on the bench.

545. Dirac, {249}.

546. Romer, {84}; see endnote 24, p. 109.

547. E.g., as by Giovanni Modanese, "On the theoretical interpretation of E. Podkletnov's experiment," Extract from report UTF-391/96, OANL gr-qc/9612022, presented to the *I.A.F. Congress 1997,* Number IAA-97-4.107.

548. Ling Ni and D. G. Torr, {532a-532d}.

549. Evans, {137b}; Evans, {485b}.

550. M. W. Evans, personal correspondence.

551. (a) Evans et al., {233b}; (b) — - "Development of the Sachs Theory of Electrodynamics," *Found. Phys. Lett.,* 14(6), Dec. 2001, p. 595-600; (c) Evans et al., {233a}.

552. As we point out in our discussion of cold fusion, use of this enormous time-energy density component in a time-reversal zone allows reducing the force of the gluons in a nucleon and nearly freeing the quarks. The time-reversal zone also reverses the law of attraction and repulsion of charges; now like charges attract. So the coulombic attraction of two H+ ions can attract them together so closely that each enters the strong force region of the other, forming a quasi-nucleus. As the other ions in solution move to negate the time-reversal zone, the zone decays, restoring the normal repulsion of the two protons in the quasi-nucleus. However, being exponential the strong force increases much more rapidly than the normal

coulombic repulsion grows. The result is to force the two protons even closer together, into a full nucleus with a full strong force between them. This forms a nucleus of deuterium, as one quark in one of the protons is flipped while still relatively free, to form a neutron. Different but similar reactions exist to produce the excess tritium shown in many cold fusion experiments, and a similar interaction — especially between two deuteron ions — forms an alpha particle.

553. Bearden, {17}.

554. Davies, {237}, p. 105.

555. Misner, Thorne, and Wheeler, {500}, p. 5.

556. Evans and Jeffers, {459}, p. 150.

557. Evans, {137a}, p. 477.

558. Banesh Hoffman, in Foreword to Yakov P. Terletski, *Paradoxes in the Theory of Relativity*, translated from the Russian, Plenum Press, New York, 1968, p. vi, viii.

559. Kron, {162}, p. 466.

560. T. D. Lee, {239}, p. 46-47.]

561. This is well known to modern theorists, but is especially accented by Sachs and by Evans. E.g.. to even have an EM wave in space, the energy density of space has to be changing as the wave energy oscillates. This is an oscillating curvature of spacetime, a priori. So all EM waves move in a dynamically curving spacetime.

562. Sachs, {126b}.

563. These concepts are generally consistent with 0(3) electrodynamics. For rigorous exposition of 0(3) EM, see Evans, {137b [.

564. Felix Finster, "Definition of the Dirac Sea in the Presence of External Fields," *Adv. Theor. Math. Phys.*, Vol. 2, 1998, p. 963-985.

565. J. W. Lynn and R. A. Russell, "Kron's Wave Automaton," Journal unk, date unk, p. 131. We would appreciate any researcher furnishing us a completed citation for this reference. We have a copy of the paper, but without full citation details.

566. Kron, {162}. The quote is from p. 114.

567. Kron, {32}, p. 39.

568. Kron, {306}.

569. Kron, {32}, p. 41.

570. See Stigant, {310a} for a bibliography of Kron's **publications.**

571. Several overunity researchers have been assassinated by forces and parties unknown. Many very clever means are used to do the dirty work.

As an example, there is a standard EMF "shooter" which uses Venus modification of the wavefront, to produce a wave that instantly disrupts the control of the heart's beating. There are two versions at least; one about the size of a pocketbook and for close range (30 feet) only, and one about the size of a bazooka and with longer range (up to 100 yards). About 1 minute exposure to the beam of the small weapon will result in death of the targeted individual. I have personally been hit by the small version of that device (and I have a witness who was with me at the time, and also was exposed to it). We survived by instant recognition of what it was, and by bolting immediately out the nearby back door of a restaurant here in Huntsville. If the kill is successful, the autopsy will show that the person died of a heart attack.

Stan Meyer, an overunity researcher with numerous patents, rushed from a restaurant exclaiming "They're killing me!" and expired with just such a heart attack, possibly hit inside the restaurant by a close-range shooter.

Harry Mason's associate was killed in Australia in his apartment by a longer-range, bazooka-sized shooter. The assassin was spotted putting the shooter back inside the car below, and speeding away.

Sometimes a silenced rifle is used for sniping at long range. Sweet was fired at by one such would-be assassin — luckily just as he stumbled and fell on the steps of the foyer to his apartment complex. The bullet cracked right by his ear as he fell forward, passing where his head had just been the moment before.

Another "shooter" uses longitudinal EM wave peak power pulses. This type kill is instant and very permanent. This unit can be set to stun or render the targeted person unconscious, or set to kill. It can also disrupt and stop running automobile engines (there is another version for that also, using negative energy EMP weaponry). However, it time-charges the struck human body so that the body emits longitudinal EM waves for some time after the kill. Marinov was killed with such a shooter (apparently by

KGB-related foreign intelligence operatives) and his body then thrown off a rooftop to make it appear to be suicide. Where his body lay, the pavement glowed when the body was removed. Only one weapon on earth will kill a body so that it will induce luminescence in concrete or asphalt that it lies on for a period.

Another favorite weapon is an ice dart dipped in curare. I was threatened once and told I would be killed by such an ice dart weapon if I traveled in a 2-month period. Just four days past that period, and traveling and changing planes in Dallas-Fort Worth airport, a person was killed three feet from me in broad daylight, right inside the airport, with the exact symptoms of a curare ice dart kill. That was apparently just to teach me "they" were serious.

"They" is that set of cartels that Churchill called "the High Cabal". Bedini and I had severely offended the High Cabal by Bedini's successful transmutation of copper (and other things) into gold. John often makes his own power transistors for his amplifiers, and the slag in the electric oven turns into black ruby laced with gold and silver, confirmed by assay. We have had numerous other assassination attempts, too numerous to iterate. Suffice it to say that developing a good COP>1.0 EM power system can be hazardous to one's health.

Any significant researcher should be wary of "meeting with a sudden suicide" on the way to the supermarket. Another thing to beware of, is a calibrated auto accident where your car is rammed from the rear, and you are shaken up considerably. An ambulance just happens to be passing by moments later, and it will take you to the hospital. If still conscious, the researcher must not get in the ambulance unless accompanied by a watchful friend who understands the situation and the danger. Otherwise, he can easily get a syringe of air into his veins, which will effectively turn him into a human vegetable. If he goes to the hospital safely, he must be guarded by friends day and night, for the same reason, else he runs a high risk of the "air syringe" assassination during the night.

Simply trying to do scientific work, I find it necessary to often carry (legally) a hidden weapon. Both my wife and I have gun permits, and we frequently and legally carry concealed weapons.

As early as the 1930s, T. Henry Moray — who built a successful COP>1.0 power system outputting 50 kW from a 55 lb power unit - had to ride in a bulletproof car in Salt Lake City, Utah. He was repeatedly fired at by snipers from the buildings or sidewalk, with the bullets sometimes sticking in the glass. He was also shot by a would-be assassin in his own laboratory, but overpowered his assassin and recovered.

Over the years, probably as many as 50 or more overunity researchers and inventors have been assassinated for their efforts, and particularly For their success. Some have simply disappeared abruptly and never been heard from again.

These days the use of longitudinal wave shooters (such as killed Marinov) and such is growing, since no signature is left for a normal autopsy to discover. The Yakuza, e.g., uses such "shooters" in Japan to assassinate persons or politicians having incurred their displeasure. Others are subjected to the more traditional Yakuza assassination: Three or four assassins suddenly jump the unsuspecting target, stabbing him repeated and with extreme rapidity. His body may have 50 to 70 deep stab wounds — through the heart, the abdomen, liver, lungs, etc. — before the body strikes the pavement.

Other very sophisticated methods of legal entrapment, gaming, planting narcotics on one's premises and tipping off the drug enforcement agencies for a drug raid in the middle of the night, etc. are utilized.

Widely used is "gaming"', which uses deep psychological profiling to select a "vulnerability". The supercomputer with the game prepares a "scenario" much like writing a movie script of predictable interactions among the players to be chosen. The game involves "agents of influence" (AOIs — persons who are dogmatic, perhaps even radical, and have knee-jerk responses easily triggered, and whose vector direction when they "jump" is along or near the desired response direction), and one or two agents to do the phone conversations with the AOIs and trigger them into action), as well as a game controller or director. The computer programs also use prediction and artificial intelligence, and will forecast the probability of success of the selected game. A very extensive database of deep psychological profiles on useful AOIs and all major COP>1.0 researchers is kept in the computer. When the controller selects the game, the computer spits out the most recommended AOI players. The controller accepts or changes and then accepts, and the game scenario is then prepared. The agents trigger the AOIs, and the unwitting target is suddenly besieged from every direction, along a direction he already has an affinity or "vulnerability" towards. The controller follows the course of the game and the outcomes of all interactions between the target and the AOIs. The agent or agents add "nudges" or additional actions to overcome delays, accomplish redirection when the direction goes awry. etc. Over the decades, these games have gotten very effective indeed, and are quite difficult to content with. I laving survived about 200 of these games over the last two decades, I may yet write a book on some of the major ones that have been used against overunity researchers. The games are not confined just to the overunity field, however, and sometimes are also used to directly intervene in politics and other key situations, {754}. Machiavelli's methods are not dead; they thrive and have been highly computerized.

572. More than a dozen potential mechanisms for overunity EM interactions and systems are given in Evans et al., {233i}. Many of these interactions are likely in highly energetic astronomical phenomena such as the gamma ray burster and the X-ray burster.

573. Evans et al., {38b, 38c}.

574. Bearden, {38a}.

575. Bearden, {30}.

576. Sweet and Bearden, {29a}.

577. (a) A. G. Reiss *et al., Astron. J.,* Vol. 116, 1998, p. 1009; (b) S. Perlmutter *et al., Astrophys. J.,* Vol. 517, 1999, p. 565.

578. A. Einstein, *Sitzungsber. Preuss. Akad. Wiss.,* Vol. 1917, 1917, p. 142. Einstein came to regret his introduction of the cosmological constani as his "greatest blunder". Ironically, this may yet turn out to be one of his greatest contributions.

579. Prange and Strance, {365}.

580. (a) R. Lieu, "The effect of Planck scale space time fluctuations on Lorentz invariance at extreme speeds," *Astrophys. J. Lett.,* 2002 (in press). A preprint is on http://xxx.lanl.gov/abs/astro-ph/0202443. See also (b) Philip Ball, "Time gives rays a break," http://www.nature.com/nsu/020304/0209304-5.html .

581. In 1998, experimental evidence of the accelerated expansion of **the** universe was provided by two groups of astronomers; see (a) Riess *et al.,* (577a}; Perlmutter *et al.,* {577b}. For an attempt to provide a new model for the negative antigravity, see (c) L. Parker and A. Raval, "A new look ill the accelerating universe," *Phys. Rev. Lett.,* Vol. 86, 2001, p. 749-752; (d) Philip Ball, "New model of expanding universe," *Nature News Service,* Science Update, Nov. 12, 2001. A good coverage for the educated layperson is (e) Mario Livio and Alan Sandage, *The Accelerating Universe: Infinite Expansion, the Cosmological Constant, and the Beauty ofthe Cosmos,*^{1}' Wiley, New York, Dec. 2000. See also (f) P. D.

Mannheim, "Implications of cosmic repulsion for gravitational **theory.'"** *Phys. Rev. D,* Nov. 15, 1998, p. 3511.

582. J. C. Bedini and T. E. Bearden, " Process For Transducing **Forms** of Electromagnetic Energy," U.S. Provisional Patent Application, 200 I. A formal U.S. Patent Application is in preparation as of this writing.

583. For a deep consideration of what is "meant" by mass, and how subtle the concept really is, the reader should refer to the scholarly work of Jammer {523a}. The more casual reader should be prepared for somewhat of a shock. Mass is not at all a "cut and dried" concept, as usually assumed. Indeed, the simple materialistic view of mass seems to be very much opposed by modern physics findings.

584. (a) Bearden, {12}. If we insert the absorption of a scalar (time-polarized) photon by the ubiquitously-assumed unit point charge and the subsequent re-emission of a longitudinal photon as the process for "combining" a scalar and longitudinal photon, then our solution is also consistent with (b) Mandl and Shaw, {19}. Mandl and Shaw argue that the longitudinal and scalar polarizations are not directly observable, but only in combination, where they manifest as the "instantaneous" Coulomb (i.e., electrostatic) potential. Our comment is that this argument, translated from particle terminology to wave terminology, then fits our re-interpretation of Whittaker's 1903 decomposition of the scalar potential in (c) Whittaker, {85}. It also strongly suggests the need for a complete reinterpretation of what is meant by "propagation of EM energy through 3-space".

585. E.g., see (a) V. I. Arkhipov *et al.,* "Negative transient currents in amorphous semiconductors." *Internal. J. Electronics* (UK), 51(6), 1981, p. 735-742; (b) — "An analysis of the dispersive charge transport in vitreous 0-55 As_2S_3 : 0*45Sb_2S_3," *Phys. Stat. Sol.* (A), Vol. 54, 1979, p. 67-77: (c) — and Rudenko, A. I., "Negative currents caused by injection-controlled polarization." *Solid St. Commun.,* 28, 1978, p. 675-676.

586. Evans, {137a, 137b, 251}.

587. David Jones, *Vancouver Sun Times,* Weekend Magazine, Dec. 17, 1977, p. 17. Article on Sid Hurwich's Toronto gun-jamming demonstration, stopping of watches, and jamming of a gun.

588. For proof of production of ordinary EM fields and energy at a distance by scalar **interferometry,** see **Evans** et **al., {**79}.

589. Miles and Bush, {198}, p. 101.

590. Bearden, {17}.

591. We point out, but do not further discuss, the obviously startling impact on the validity of the random statistical analyses normally used in scientific work if such "hidden variables" are present in the Earth's supersystem and interact with the experiment.

592. Kron, {192}, p. 466.

593. (a) Gabriel Kron, *Diakoptics: The Piecewise Solution to Large-Scale Systems,* MacDonald & Co., London, 1962. See also (b) Kron, {310b}.

594. Ilya Prigogine, Preface, (160b), p. xi.

595. Sir William Rowan Hamilton, 1837. Hamilton originated quaternion algebra, the Hamiltonian, etc. Hamilton's quaternion algebra has a higher group symmetry than either vectors or tensors. Since Maxwell's theory was first formulated in Hamilton's quaternion algebra and later reduced to vectors and then to tensors, ironically the first successful EM theory has been sharply curtailed rather than being further developed and extended.

596. (a) Aharonov and Bohm, {344a, 344b}.

597. Prigogine, {160b}, p. 104.

598. Lee, {441}, p. 23.

599. Jackson, {22}, p. 811-812.

600. Whittaker, {85}.

601. This is because time may be regarded as compressed spatial length, where the L compression factor is c. Since the energy of a wave is proportional to L^2 (where L is the wave amplitude), then the release of ST time-density as ST energy density provides nearly 9×10^{16} times as much effect per second as simple energy density curvature alone does per joule. For convenience, we refer to this as the "10^{17} gain factor" one obtains by releasing the compressed length energy from its time-density ST curvatture form.

602. T. Matsumoto, "Mechanisms **of Electro-Nuclear Collapse,"** *Proc, ICCF-7 (International Conference on Cold Fusion - 7),* Vancouver, BC, Canada, April 1998, p. 98.

603. Romer, {84}, endnote 24, p. 109.

604. See Harter et al., {102}. For a simple analogy, we may think of the longitudinal EM wave as a sort of velocity-modulated wave; i.e., it is rhythmically changing its velocity about some average value, where that value is usually taken to be c. Another way to visualize it is as an "accordion" wave, expanding and contracting along the line of travel.

605. There are several types (polarizations) of photons utilized in physics. E.g., see (a) Ryder, {90b}. On p. 147+, Ryder discusses four polarization states of the photon. Two of these are "transverse" —i.e., the well-known x- and y-polarizations of light; one is called "longitudinal," i.e., z-directed and related to Evans' B(3) field, and one is "scalar" or timelike.

The time-like (scalar) photon we are using in this paper seems to be yet another brand, something like a cross between the Ryder's third and fourth classifications. That is, our "scalar" photon is named such because when it is imperfect it propagates (i.e., in the 7 direction) at finite speed. When perfect, it just appears instantly everywhere it will be, without propagation through space in the usual sense. Hence it can be at an infinite number of points simultaneously - very close to the notion of the pure Coulomb gauge or of Bohm's quantum potential - or it can be impure and propagate at subluminal or superluminal speeds. The main notion we intend in our present use of the "scalar" photon for this treatise is that its oscillation is in the time domain and along the time axis. We use a model which produces the flow of time itself, and a time-component structuring of that flow — something which is still absent from physics. So our time-like (scalar) photon in one part very much resembles Ryder's discussion of the "scalar" photon, but is not just that alone. For instance, both our longitudinal photon and our scalar photon seem to have internal "photon" structures that we do not discuss in this treatise.

A still deeper discussion of photon polarization is in (b) Mandl and Shaw, {19}. The longitudinal and scalar polarizations are not directly observable, but only in combination, where they manifest as the "instantaneous" Coulomb (electrostatic) potential. So by this route one arrives at a well-established mathematical theory that allows a hidden substructure within **the photon itself.** Mandl and Shaw include the photon's four polarization states as related to the four independent degrees of freedom available in the vector potential A. Suppression of the longitudinal and scalar polarizations is accomplished by "fixing the gauge". This reduces the independent degrees of freedom from 4 to 2, giving the conventional electrodynamics. However, when one raises serious foundations flaws in that resulting conventional electrodynamics, it is obvious that the entire structure is still on somewhat shaky ground. An even better mode might be to consider the fundamental photon entity as existing in all degrees of freedom, and the various "kinds" of photons existing due to restrictions or partial restrictions placed on one or more of these degrees of freedom. This of course opens the stage to interactions that change one (restricted) type of photon into a different (restricted) type. Thai is essentially the basis for my use of the notion of "photon transduction". Tt also leads to the transposition of time into energy and vice versa, which I use in my own approach, but which is still missing from nuclear physics. Since experimentally the cold fusion phenomena seem to require that characteristic, we have retained it.

We are indebted for much of the preceding discussion to private correspondence from Bob Flower, a fine scientist and knowledgeable in this area. Flower has pointed out that the conventional photon theory outlined by the cited authors is missing the possibility that nonlinear phase-conjugate optics could make the photon's longitudinal and scalar polarizations manifest in an experiment. Or put another way, if the instantaneous Coulomb potential could be decomposed into a time-like component and a longitudinal component, it would allow the two hidden polarization states to be controlled directly. This would result in anomalous modifications of the EM vector potential, leading to measurable electromagnetic or quantum effects. Flower's observation seems to be the closest to our own view, stated more simply in the present paper.

606. The result of our yet-unfinished struggle in these *very* swampy photon waters is not entirely consistent with the conventional view. Nonetheless, the new approach does seem to fit and explain most of the anomalous cold fusion phenomena, as well as a wide variety of other phenomena previously deemed beyond the pale of physics itself. E.g., by noting that *mind is time-like in its operations,* and therefore directly uses time-polarized (scalar) photons, waves, and electrodynamics, then mind operations become totally electromagnetic, but of a dramatically extended electrodynamic nature presently being approached in quantum field theory That approach leads directly to a testable and engineerable theory of mind

on all its levels (conscious, subconscious, unconscious, species unconscious, biospheric or all-species unconscious, and so on). But since the mind can interact with the body and produce at least the initial spatial forces carrying out intent in the physical world, it follows that some process must exist whereby the "time-like" photon interacts with and changes one or more of the other photons in the conventional view. Our use of *transduction* in fact encompasses that, based on quantum field theory as described by Ryder {90b} and by Mandl and Shaw {19}. Further, the present author's transduction reinterpretation of Whittaker's 1903 and 1904 papers {85, 91a} means that Whittaker's work as reinterpreted strongly supports this approach mathematically. So the approach used directly incorporates *mind and matter interaction,* again on multiple levels. While this area of *engineerable* mind and matter interaction is well beyond the scope of this treatise, it has become possible to begin the physics of the living being — even of the entire living universe — and to foresee direct engineering of the various realms of mind itself. Indeed, Russian psychoenergetics - particularly the highly weaponized secret part of it - already is involved in just that capability in deployed operational equipment of great portent. Since real results and real explanations of diverse metabiological phenomena have arisen from the approach as well as a very deep "more ordinary" physics including the necessary corrections to electrodynamics, we have continued to follow it to see where it eventually leads. A future book is planned on the more positive and beneficial uses of such startling technology. A preliminary view can be had on the author's website, www.cheniere.org, in the "porthole concept" briefing. A patent application has in fact been filed on this startling new method of medical healing.

607. (a) Vlail Kaznacheyev and L. P. Mikhailova, *Ultraweak Radiation in Intercellular Interactions,* [in Russian], Novosibirsk, 1981 [an English exposition of much of the Kaznacheyev work is given in (b) Vlail Kaznacheyev, "Electromagnetic Bioinformation in Intercellular Interactions," *Psi Research,* 1(1), Mar. 1982, p. 47-76.] See also (c) Kaznacheyev *et al.,* "Distant intercellular interactions in a system of two tissue cultures," *Psychoenergetic Systems,* 1(3), Mar. 1976, p. 141-142. In the same issue, see (d) "A Comment" by William A. McGarey, p. 143; (e) "A Comment" by Arthur C. Hastings, p. 143-144. See also (i) Yu. A. Vladimirov, "Ultraweak luminescence of subcellular structures," *Ultraweak Luminescence in Biology: Proceedings of the Symposium,* Moscow, 1969 [In Russian], Robert Becker also showed in his healing of

otherwise intractable bone fractures that a simple scalar potential (now known to involve the direct transduction between scalar and longitudinal photons and vice versa), that cellular dedifferentiation and redifferentiation of red blood cells occurred in the scalar potential region across the damaged bone cells, and directly in such manner as to "eliminate the delta engine" in those damaged bone cells in the fracture. The red cells shucked their hemoglobin, turning back (time-reversing) to a more primitive cell (earlier state). Then they redifferentiated (time-forwarded) into the type cells that make cartilage. There is still a delta engine between cartilage and bone! So these cartilage-like cells redifferentiated again into the kind of cells that make bone. These latter cells were deposited in the fracture, healing it. This process is in fact used today in various medical hospitals, without any real understanding of the physics mechanism involved. In short, it has long been experimentally proven without understanding the actual mechanism by which it works. See (g) Robert O. Becker, "The direct current field: A primitive control and communication system related to growth processes," *Proc. XVIInternal. Congr. Zoology,* Washington, D.C., Vol. 3, 1963, p. 179-183; (h) — and Charles H. Bachman and Howard Friedman, The direct current system: A link between the environment and the organism," *New York State J. Medicine,* Vol. 62, April 15, 1962, p. 1169-1176; (i) — and Joseph A. Spadaro, "Electrical stimulation of partial limb regeneration in mammals," *Bull. N.Y. Acad. Med,* Second Series, 48(4), May 1972, p. 627-64. See also (j) C. A. L. Bassett; R. O. Becker, and R. J. Pawluk, "Effects of electric currents on bone *in vivo," Nature,* Vol. 204, Nov. 14, 1964, p. 652-654.

608. Puthoff, {202}.

609. See (a) A. Shapere and F. Wilczek, Eds., *Geometric Phases in Physics,* World Scientific, 1989. See also (a) M V. Berry and J. M. Robbins, "Indistinguishability for quantum particles: spin, statistics and the geometric phase," *Proc. Roy. Soc. LondA,* Vol. 453, 1997, p. 1771-1790.

610. See Mandl and Shaw, {19}, Chapter 5 and simply reinterpret the coupled scalar and longitudinal photon pair as a spin 2 graviton.

611. In fact, Sweet's vacuum triode amplifier probably used the domains and nuclei in a barium ferrite permanent magnet in such a graviton reaction manner. In an epochal experiment designed and conceived by the present author, Sweet reduced the weight of the device

on the lab bench, smoothly and efficiently, by 90 degrees. For **the** description, see Sweet and Bearden, {29a}.

612. Reginald I. Gray, *Unified Physics,* Naval Surface Warfare Center, Dahlgren, VA, 1988, p. 2-19.

613. For the basic explanation of a scalar interferometer, see Evans et al., {79}.

614. See Chapter 3, paragraph 3.1 through 3.5.

615. Bearden, {12}.

616. As an example, see Bunge, {3}, p. 179-180. Quoting: " *The most complete direct interparticle action theory of electromagnetism is WHEELER and FEYNMAN'S (1949). Its central postulate is Fokker's action principle for a collection ofpoint charges.... from which the equations of motion for charged particles follow. As can be seen, only particle variables occur in this theory, which is an electrodynamics in AMPERE'S sense and therefore the opposite of a unitary field theory. (The theory is mathematically equivalent to an "adjunct" field theory, but this adjunct field, far from being free, is attached to the particles.) The theory has been abandoned by its creators because it is inconsistent with the quantum theory, in particular with the photon hypothesis. Yet it continues to appeal to many not only because it smacks of mechanism and operationalism, but also because no self-forces appear in it and consequently no infinite self-forces (and the corresponding self accelerations) But this is too small an advantage compared with its shortcomings even at the classical level. Indeed, the theory makes use of special relativity - as is apparent from its central axiom...yet it is inconsistent with it for SR borrows from CEM the assumption that e.m. signals propagate in a vacuum with a constant speed c and moreover lead an existence, which, while it lasts, is independent of both emitters and absorbers. In other words, by denying the existence of free radiation fields propagating in space, the action at a distance formidation of CEM contradicts its own basis: it is logically inconsistent.* "

Our comment is that the "photon" interaction itself must be re-examined in light of the demonstrated giant negentropy of every change and dipole in the universe. Allowing for the quantum field theoretic combination of the scalar and longitudinal photons as an observable "photon" that is actually a spin-2 graviton in 4-space rather than 3-space. the entire nature of "propagation of EM energy through space" changes. No photon has ever interacted in just 3-space; instead, it interacts in

4-space. In the strong interpretation of giant negentropy, there is really no such thing as a "single observable photon" in the universe. Instead, there is a combined scalar/longitudinal photon pair, which when interacting in matter causes transverse EM wave movement of the interacting/detecting charges which are restrained by (i) the inertia due to their own mass, and (ii) in circuits, the back repulsion of all other like charges longitudinally ahead of the excited charge that absorbs the "photon" (actually, the graviton). Considering the longitudinal wave "bunching and relaxing" actions resulting in galloping, then the conventional assumption of the constant speed of light c in vacuum is destroyed. What we perceive as "light propagating in space at speed c" already moves in a galloping and jerky motion *about* speed c — now moving superluminally, now moving subluminally — with only an *average* speed of c overall. In turn, anything which affects the performance and "galloping mechanism" exhibited by the longitudinal EM wave can in theory be used to change the speed c. With the coming advent of the Fogal semiconductor and direct superluminal communication, all such objections based on previous rather classical assumptions will simply fall by the wayside. We also stress that the speed of gravitational field is shown in astronomical events and effects to be extraordinarily superluminal by many orders of magnitude. Again, this greatly upsets many of the modeling assumptions in present physics. Physics is based on a set of models and a set of experiments and observed effects. If the experimental effects negate the theory, one has to change the theory or be guilty of abandoning scientific method altogether, thereby turning science into dogma.

617. Cohen, {89}.

618. See Rod Donnelly and Richard Ziolkowski, "Electromagnetic field generated by a moving point charge: A fields-only approach," *Am. J. Phys.*, 62(10), Oct. 1994, p. 916-922. In conventional language, both the transverse and longitudinal field components always try to be born initially, whenever an EM wave is being generated. Generation of the transverse component produces a function which zeroes the longitudinal component. The function appears in the spacetime representation of the transverse EM fields, obtained by Donnelly and Ziolkowski using special transforms. The phase conjugating and retroreflecting aspects of cold fusion experiments produce spacetime curvatures, directly affecting the "canceling function." The altered function becomes an "LW-reduction function" which is postulated to determine the mix of transverse and longitudinal field components that emerge in the interactions.

619. Whittaker, {85} shows that the scalar potential is **comprised of** bidirectional longitudinal EM wavepairs. Whillaker, {91a} shows **that all** fields and waves are comprised of two interfering scalar **potential** functions. Hence all fields and waves are comprised of **functions** of longitudinal and scalar wave interferometry.

620. Evans et al., {79}.

621. Usually the detecting GM tubes will detect the interferometry of the incident longitudinal EM waves with the weak LWs being emitted in the tube itself by time-decay of its time-charges. The resulting transverse wave EM energy ionizes the tube's gas, and the GM tube "reads." If little or no time-decay is occurring, then there will be little or no transduction into TWs, hence little or no ionization. In that case the instrument will not read.

622. Miles and Bush, {198}, p. 101.

623. *Ibid.*

624. (a) Evans, {137b}; (b) Evans et al., {233a, 233f}.

625. Rodrigues and Lu, {93a}.

626. Enders and Nimtz, {329b}.

627. (a) W. A. Rodrigues, Jr. and J. Vaz Jr., "Subluminal and Superluminal Electromagnetic Waves and the Lepton Mass Spectrum," *Kluwer Ac. Pub. Proceedings,* <hep-th/9607231> on Los Alamos web site; (b) P. Letelier and W. A. Rodrigues Jr. (Eds.), *Gravitation: The Spacetime Structure,* World Scientific Publishing Co., Singapore, 1994; (c) J. Vaz Jr. and W. A. Rodrigues Jr., "On the equivalence of Maxwell and Dirac Equations, and Quantum Mechanics," *Internal. J. Theor. Phys.,* Vol. 32, 1993, p. 945-958; (d) J. Vaz Jr. and W. A. Rodrigues Jr., "Maxwell and Dirac Theories as an Already Unified Theory," *Adv. Appl. Clifford Algebras,* Vol. 7 (S), 1997, p. 369-386; (e) W. A. Rodrigues Jr. and J. E. Maiorino, "A unified theory for construction of arbitrary speeds ($0 < v < \infty$) solutions of the relativistic wave equations." *Random Operators and Stochastic Equations,* Vol. 4, 1996, p. 355-400; (f) Rodrigues and Vaz, {93b}.

628. Torn Van Flandern, "The speed of gravity - What the experiments say," *Phys. Lett. A,* Vol. 250, 21 Dec. 1998, p. 1-1 1.

629. *Ibid.,* p. 9.

630. *Ibid.,* p. 10.

631. A. A. Vlasov and V. I. Denisov, "Einstein's formula for gravitational radiation is not a consequence of the general theory of relativity," *Theor. Math. Phys.,* 53(3), June 1983 (English translation), p. 1208-1216. Translated from *Teoreticheskaya i Matematicheskaya Fizika,* 53(3), Dec. 1982, p. 406-418 [in Russian].

632. D. Hilbert, *Gottingen Nachrichten,* Vol. 4, 1917, p. 21.

633. Sen, {68}, p. viii.

634. Mandl and Shaw, {19}.

635. Logunov, A. A. and Yu. M. Loskutov, "Nonuniqueness of the predictions of the general theory of relativity," *Sov. J. Part. Nucl.,* 18(3), May-June 1987, p. 179-187.

636. Whittaker, {85}

637. I.e., that spacetime == scalar potential == virtual particle flux == Whittaker biwave set. If that holds, then when we engineer the internal structure of the scalar potential, we also simultaneously engineer the internal structuring of the vacuum and spacetime itself, with deliberately formed spacetime curvature engines (vacuum engines). This is vacuum engineering — by different means — of the sort proposed by Nobelist T. D. Lee, {73}, p. 380-381. On p. 383, Lee points out that the microstructure of the scalar vacuum field (i.e., of vacuum charge, or — in our view — of the vacuum potential) has not been utilized. Particularly see Lee's own attempt to indicate the possibility of using vacuum engineering, in his "Chapter 25: Outlook: Possibility of Vacuum Engineering," p. 824-828.

638. Ingram Block and Horace Crater, "Lorentz-Invariant Potentials and the Nonrelativistic Limit," *Am. J. Phys.,* 49(1), Jan. 1981, p. 67.

639. Roderic Lakes, "Experimental Limits on the Photon Mass and Cosmic Magnetic Vector Potential," *Phys. Rev. Lett.,* 80(9), Mar. 2, 1998, p. 1826. Our critique is that the given equations define nothing at all, since no equation is a definition. If one replaces the "=" with "≡" in the "definition" of the A-potential in terms of B, one then has B==curl A, which is actually the definition of B in terms of A. If A has no energy, then neither can B, which is just the swirl of the A-energy. If A has no curl, B vanishes. If A has no energy, B vanishes. Yet $dA/dt = -E$, whether

A has curl or not, and E has energy. Ergo, A must have energy if **any** operation upon it is to produce **E-field** energy, else one has **violated the** conservation of energy law and advocates creation of energy from **nothing.** Regardless of how one looks at B = curl A and B = curl A, neither the equation nor the identity defines A in terms of B, because B is always, just one aspect of A and yet A can exist without any curl at all — without B as demonstrated in the Aharonov-Bohm effect. But in no fashion can B exist without A. Therefore A is primary and B is derived, and if A has no energy then B can have no energy. V has energy and energy density, since in fundamental units any point of the potential V is identically the joules of energy collected upon a unit point positive electrical charge assumed at that point. If it had no energy, then no joules could be collected from it.

640. Weinberg, {194}, p. 109-110.

641. Sen, {68}, p. viii.

642. (a) Lee, {13a}; (b) Wu et al., {14}; (c) Lee, {239}, p. 57-59; (d) Lee, {73}, p. 184.

643. Bearden, {12}

644. Whittaker, {85}.

645. The clustering of virtual charges around observable individual charges — due to the polarization of the vacuum — is well known in quantum electrodynamics. Macroscopically one sees the charge as partially shielded by the cluster, so the clustering charges are known to have macroscopic significance. At close enough distances, one sees the "bare" charge with reduced shielding.

646. Mandl and Shaw, {19}.

647. (a) Aharonov and Bohm, {344}; (b) R. G. Chambers, {474}.

648. E.g., see (a) Barrett, {345}; Barrett and Grimes [Eds.], {235b}.

649. (a) Evans *et al*, {113a}; (b) — "Self-Inconsistencies of the U(l) Theory of Electrodynamics: Michelson Interferometry," *Found. Phys. Lett.,* 12(6), Dec. 1999, p. 579-584; (c) — *J. New Energy,* Vol. 4, Winter 1999, p. 231-235; (d) — "Derivation of the Lehnert Field Equations from Gauge Theory in Vacuum: Space Charge and Current," *Found Phys Lett.,* 13(2), April 2000, p. 179-184; (e) Evans et al., {233g}; (f) Evans **et** al.. {233e}; (g) — **"Equations of the** Yang-Mills Theory of Classical Electrodynamics," ***Optik, 111***(2), 2000, p. 53-56; (h) **Evans** el **al.,** {113***b}.***

Also (i) more than 100 papers on restricted U.S. Department of Energy Internet website http://www.ott.doe.gov/electromagnetic/.

650. Obviously we exclude active systems such as matter that decays in nuclear fashion. Those are not inert systems, but are "pre-excited" systems whose matter has had excess energy since its formation during the birth of the universe.

651. (a) Kondepudi and Prigogine, {160c}; (b) — "Thermodynamics, Nonequilibrium," *Ency. Appl. Phys.* Vol. 21, 1997. p. 311-337.

652. I.e., the known broken symmetry of the charge (regarded as a set of composite dipoles) in its vacuum energy exchange.

653. Kraus, {76}, p. 578, Figure 12-60, a and b.

654. James Croll, *Phil. Mag.,* Series 5, Vol. 2, 1876, p. 242-254.

655. Heaviside, {5a-5c}.

656. Poynting, {4a, 4b}.

657. Heaviside, {106}.

658. E.g., see Lorentz, {109}.

659. E.g., (a) Panofsky and Phillips, {110}; (b) Gough and Richards, {224b}. (c) Jackson {22}, p. 259, points out the arbitrary nature of the Poynting vector and disposes of any added nondivergent energy flow vector with the words *"Such an added term can, however, have no physical consequences."*

660. Simply examine *Vqt* around the forward emf section (the external circuit between the generator terminals and the ends of the source dipole inside the generator), and - *Vqt* across the generator terminals (and the source dipole).

661. Evans etal, {38b, 38c}.

662. Bohren, {24}. Independent replication is reported in the same journal issue; see (b) Paul and Fischer, {25}.

663. Bearden, {40}.

664. See Paragraph 8.3.16 in Chapter 8 for the explanation.

665. Olariu and Popescu, {482}.

666. Bertram Schwarzschild, "Currents in normal-metal rings **exhibit** Aharonov-Bohm effect," *Phys. Today*, 39(1). Jan 1986, p. 17-20.

667. Paul and Fischer, {25}.

668. One actually inputs far more electrical energy flow from **the** external electrical power supply than is conventionally accounted, if one accounts for the huge nondiverged Heaviside energy flow component that Lorentz arbitrarily discarded. That energy flow is actually present, but Is not accounted once Lorentz' integration trick is applied to integrate the entire energy flow vector around a closed surface assumed around any volume element of interest.

669. Evans et al., {113a}.

670. As is any EM system when the nondiverged very large Heaviside energy flow component is accounted in addition to the diverged Poynting energy flow component.

671. Bearden and Bedini, {582}.

672. As an example, two scalar potentials fi_1 and fi_2 may have precisely the same intensity magnitude, but different Whittaker internal bidirectional longitudinal EM wave structures. The effects of the two externally identical potentials — as in various chemical reactions — can be quite different. See Bearden, {17}.

673. Lee, {73}, p. 380-381.

674. Lee, {73}, p. 184.

675. For succinct summary of the major symmetries and broken symmetries in physics, see Lee, {239}, p. 57-59.

676. Wang and Chung, {33}.

677. Jean-Louis Naudin, "Chung's Negative Resistance Experiment", on website http://jnaudin.free.fr/enr/enrexpl.htm.

678. Burford and Verner, {35a}.

679. Early but sophisticated analogue simulator. E.g., see Kron, {306}, p. 173.

680. E.g., see (a) Kron, {32}, p. 39. Quoting: *"Although negative resistances are available* ***for*** *use with a network analyzer...* "; — "Numerical solution of ordinary and partial differential equations by

means of equivalent circuits." See also (b) Kron, *J. Appl. Phys.,* Vol. 16, Mar. 1945a, p. 173. Quoting *"...since none or only a few negative resistances exist on practical network analyzers) "* (accent added). In the second quotation, arguably Kron was required to insert the underlined words. In the first quotation, the censors missed the clarity of the statement.

681. Kron, {192}.

682. Sweet and Bearden, {29a}.

683. Self-oscillation in such magnetic materials (which are also optically active) is well known. E.g., (a) L'vov, {29c}; (b) Borovik-Romanov and Sinha [Eds.], {369b}. See particularly (c) Gurevich and Melkov, {232c}.

684. Rosenthal publicly verified the results of his tests of the Sweet device to the 26th session of the Intersociety Energy Conversion Engineering Conference (IECEC '91), Boston, Massachusetts, 1991.

685. David M. Pepper, "Applications of Optical Phase Conjugation," 254(1), Jan. 1986, p. 83.

686. Bearden, {15}, p. 2-10.

687. Bearden, {17}.

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689. Kenneth Shoulders and Steve Shoulders, {38If}.

690. U.S. patent numbers 5,018,180; 5,123,039; 5,054,046; 5,054,047.

691. Jain, {35b}.

692. Cao et al, {264b}.

693. Prange and Strance, {365}.

694. Roger Penrose, {82}, p. v.

695. Bunge, {3}, p. 176.

696. Albert Einstein, {la}, p. xi-xii. Appendix I.

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711. (a) D. K. Sen, *Fields and/or Particles,* Academic Press, London and New York, 1968, p. viii. Thirty-two years later, we published the solution to that problem in (b) T. E. Bearden, "Giant Negentropy from the Common Dipole," *J. New Energy,* 5(1), Summer 2000, p. 11-23. Also carried on DoE restricted website http://www.ott.doe.gov/electromagnetic/ and on www.cheniere.org.

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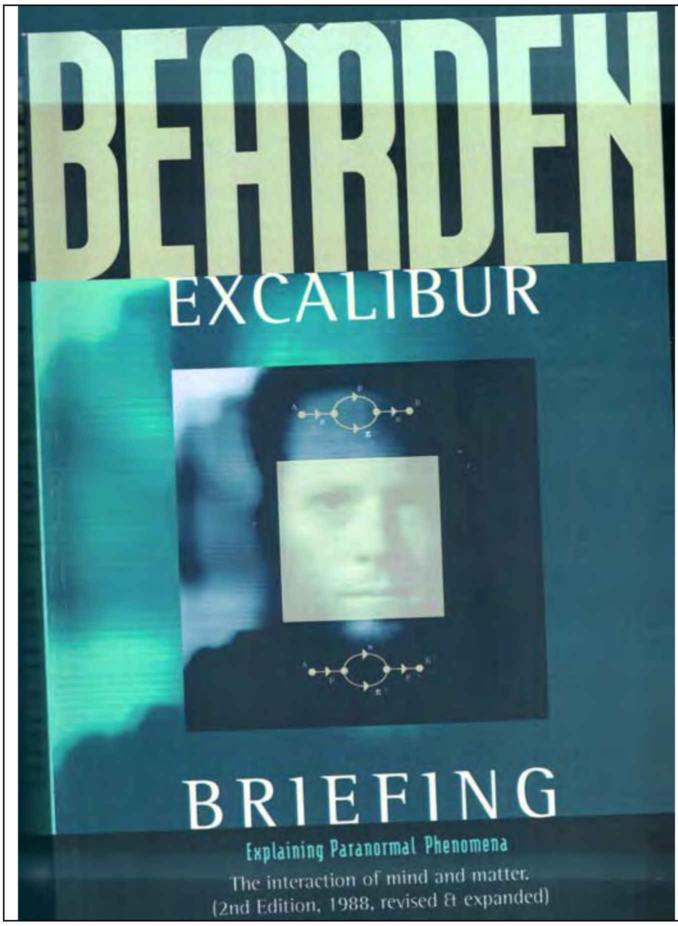

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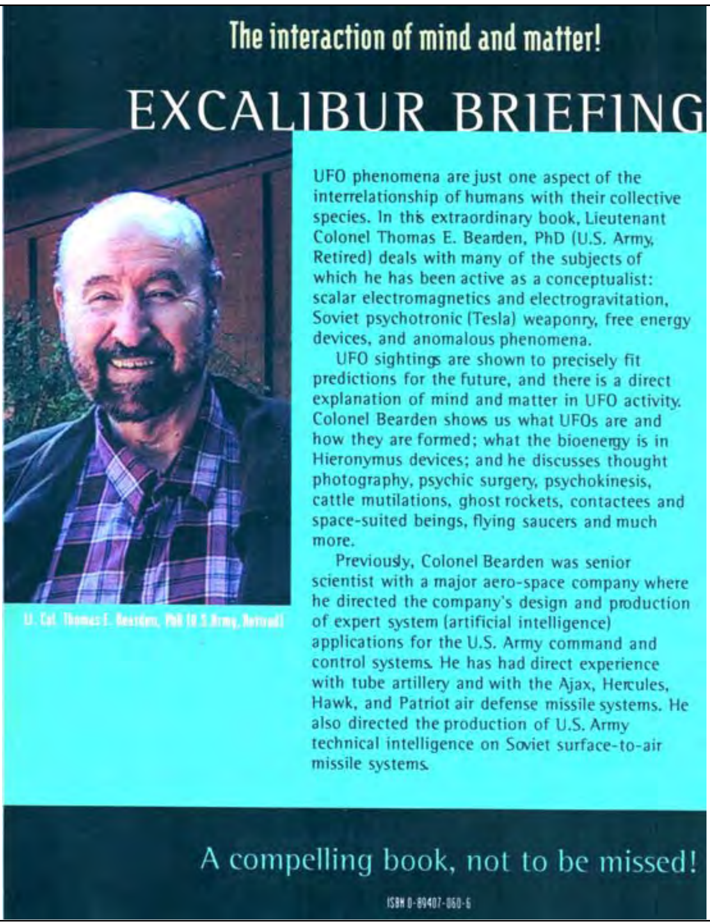

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Tom Bearden is the author of several books and numerous papers, briefings and presentations, dealing with anomalous phenomena, scalar electromagnetics, free energy devices, Soviet Tesla weapons, and Soviet scalar electromagnetic weather warfare; he is also the producer of several videotapes on these subjects.

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FOREWORD

by John White

This book deals in a comprehensive fashion with such a vast array of topics — from physics, psychology and evolution to advanced weaponry, military strategy and international politics — that many of you may become anxious, even fearful on reading it. In fact, this assembly of previously uncorrelated information and scientific breakthrough may be the most disturbing you have ever received.

This cannot be helped. This book represents an important step in our efforts to avoid global war involving not only nuclear armaments but also what appears to be a revolutionary development in Soviet military technology — psychotronic weapons. They are the modern equivalent of the legendary invincible sword, Excalibur.

The author is former U.S. Army officer Lt. Col. Thomas E. Bearden, now retired. During his twenty-year military career specializing in artillery, nuclear weapons, and military intelligence, Tom has pondered and researched many subjects that he covers here. His access to the full range of both military and NASA documents will be evident in his book. What may become highly classified data in the future is being revealed to you, our nation's ultimate policymakers, for an urgent reason that Tom has called Operation Fer-de-Lance, the presumed Soviet plan for domination of the planet through nuclear-psychotronic aggression and warfare. For the moment I would simply like to note two statements that indicate the basis for our sense of urgency:

1. On 13 June 1975, Soviet Premier Leonid Brezhnev urged a ban on research and development of new kinds of weapons "more terrible than anything the world has known."
2. In January 1977 former Air Force Chief of Intelligence, Maj. Gen. George J. Keegan (Retired) told *Newsweek* magazine, "The Soviets are working on dramatically exotic new weapons, twenty years ahead of anything ever conceived in the U.S. — so awesome as to lead the Soviets to believe that in the coming decade they would be capable of total neutralization of our ballistic and submarine missiles."

The U.S. military intelligence community interprets these signs in conventional terms as perhaps indicating the development of laser rays. Tom disagrees. His book will deal with the possibility that these weapons are psychotronic or paraphysical in nature.

In fact, we can say that in a strict sense, these are not weapons but devices — breakthrough technology with an enormous potential for the destruction of humanity. They are a second-or third-generation outgrowth of radionic devices presently used in unorthodox medicine for diagnosis and healing. Extremely compact, they could be carried in a suitcase and planted near targets — ICBM sites, communications centers, etc. Even if one of these devices were found and examined, it would only look like an electronic switching circuit or a small transmitter/receiver set, rather than a bomb or explosive.

The energy and the mechanism involved in psychotronic damping of nuclear, chemical or electromagnetic technology is, from all indications, unrecognized by official Western science but nevertheless inherent in it. That also has been deeply pondered by Tom, and this book will give a full explanation of the physics, mathematics and technology involved. It is not an exaggeration to say, as Tom does, that the explanation offers a "physics of metaphysics" — a fully developed theory of paranormal phenomena that elegantly unites physics and psychology. The ramifications of what Tom calls perception theory lead into every field of human knowledge and inquiry with revolutionary results — from science, theology and philosophy through the full spectrum of paranormal phenomena such as UFO's and psychokinesis into the elementary school classroom, the supermarket shopping basket and the voting booth. They most certainly lead into the safety of your homes and the integrity of your minds.

Before you turn to *The Excalibur Briefing,* I want to leave you with these thoughts. The material you are about to read will certainly be denied by our own government and military and probably by a major segment of the scientific community. It is not unlikely that Tom will be dismissed as a paranoid crackpot. Such tactics have been employed before against brilliant, courageous people who challenge the fundamental dogma of the establishment as Tom does here. Nevertheless, I want to reassure you that Tom is sane, sober, and serious.

Of course, such a person could still perhaps be mistaken. In that regard, I believe you will find Tom's presentation to be persuasive. He himself is careful to distinguish speculation from fact, inference from descriptive statement. Even if Tom were paranoid, however, the question arises: *What if there is good reason for paranoia?* To phrase it positively: We should welcome truth and enlightening insight whenever offered, regardless of the source. Do not let *ad hominem* arguments affect your critical judgment about the soundness of this presentation. Assess the work, not the man, for the work is always greater. And having judged the work affirmatively, render true acknowledgement — not lip service — by sharing the ideas in this book with others. Only free, informed, vigorous effort in the court of world opinion can defuse the possibility of Operation Fer-de-Lance and psychotronic mind control leading to total enslavement of the human race.

In closing, I want to point out that Tom's fundamental concern is the unification and evolution of the human species to a higher form of life through a process that he terms "mind linkage." This stage of growth to higher consciousness is explored in the latter part of the book. It is a breathtaking portrait of how the spirit of science can lead to a science of the spirit, to a physics of metaphysics.

INTRODUCTION TO THE SECOND EDITION

Since the first edition of *Excalibur Briefing* was published, a great deal of progress has been made on the actual physics of unusual and paranormal phenomena. Indeed, so much progress has been made in the ten years since the 1978 or so cutoff of most of the Excalibur material, that I really should rewrite the entire book. However, time will not permit that luxury at present I am simply too hard-pressed in the strenuous efforts to move a free energy machine to market and to convince our government that unorthodox Soviet superweapons present us with a problem of the gravest magnitude.

Accordingly, the inclusion of one of my latest papers, "Soviet Phase Conjugate Directed Energy Weapons," together with an updated glossary for the entire emerging field, will have to suffice.

The important thing is that **a separate new field of physics is beginning to emerge.** It turns out that what we've gotten on to is a unified field—one can now turn electromagnetic energy into gravitational energy and vice versa. Indeed, gravitational potential is now revealed as simply infolded electromagnetics, and electromagnetics is simply the outfolding of the internal contents of gravitational potential.

Colleagues have already proven it on the laboratory bench, by building both "free energy" devices and practical antigravity devices.

This new, extended electromagnetics—electrogravitation—I have dubbed **scalar electromagnetics.** The key to it is to let the EM force fields fight themselves to a "cancellation," forming **a** vector zero. If we do this in a nonlinear medium (modulator), the summing/multiplying EM vector forces are locked together and remain as an infolded EM system inside the EM vector zero. This now is a gravitational system. By merely varying (in phase) the summing EM components, one varies the local energy density of vacuum. Rigorously that is a gravitational wave. Further, it is a very powerful G-wave, for we are utilizing EM forces some 1042 times as strong as the normal weak G-force.

Classical EM has taught us to simply discard the components in the zero vector summation, replacing the system of opposing EM forces with a vector EM zero. This of course makes all vector EM zeroes equal. However, it totally ignores the space-time/vacuum stress of the summed forces, and the resulting gravitational implications. Therefore we have been taught to ignore any gravitational aspects of normal EM circuits, and indeed we proceed to release the G-stress effects in the circuits when we build them as we have been taught

Ordinary EM represents the release of the internal stress of gravity. By teaching us to make nonzero EM, scientists have taught us to always release electrogravitational potentials as electromagnetic forces. Thus in classical EM—and in most of the circuits we build—the EM force fields are the primary causative agents. Classically, when these force fields reduce to zero, there is no more electromagnetics going on. That is true, but there can still be a very large amount of gravity and inertial effects going on!

However, quantum mechanics teaches us that the EM force fields are not at all the primary causes. Instead, the potentials are the primary things; EM forces are simply made from these potentials by differentiating operators. And when the force fields are zero, the potentials still exist. Further, when these "forceless potentials" interfere—

even at a distance—real EM effects cun still be obtained, in total violation of ordinary EM and ordinary mechanics!

This is called the Aharonov-Bohm Effect, and in 1986 it was finally proven to most physicist's satisfaction. Only the most diehard skeptics still object to it, according to *Physics Today,* January 1986.

At any rate, when we have zeroed the E and B fields, we can still have the potentials, according to modern physics. These potentials can interfere to produce electromagnetic force effects—even at a distance.

Further, the zero summation can be dynamic; that is, the vector components can be varying, so long as they always sum to a zero vector. Actually such a zeroed system now has an infolded, deterministic pattern of dynamic forces, according to the pattern we deliberately construct. Further, the energy of each force component infolded is varying, and thus the overall energy density of local vacuum is varying.

As we said, rigorously this defines a gravitational wave. So the zero-vector approach allows EM wave energy to be turned directly into gravitational wave energy. Now it is the curvature of spacetime that is being varied locally. That's a really astounding thing.

We can now deliberately engineer the vacuum/spacetime itself, with all that that statement implies. Locally we can bend spacetime itself, which Einstein assumed could never be done except by a huge collection of mass—such as a sun, star, neutron star, etc. But here we can do it with simple things such as opposing coils, opposing E-fields, etc. We've just violated one of the sacrosanct, severely limiting assumptions of ordinary (Einstein's) general relativity!

That is, up to now most Western physicists have assumed that the local spacetime/vacuum cannot be curved. They assume that, where we the observer and the laboratory instruments are, only special relativity applies. Locally the observer always has a "Lorentz frame," in that view. This assumption (the local Lorentz frame) means that all the conservation laws apply, and physical reality stays well-behaved where the laboratory is and where we are. Ordinary relativity becomes just a sort of "special relativity with distant perturbations."

The only curvature of spacetime of any consequence is only to be found at or near distant stars, suns, black holes, and other huge collections of mass, in this highly restrictive view. Further, this assumption implies that one can never have an experimental general relativity, since where one is experimenting (locally) there is always essentially zero spacetime curvature!

However, one need not have such a formidable restriction at all. Two bucking transformers can make a B-field vector-zero a little bit More complex circuits can easily be designed to sum (or multiply) force fields to zero very well. When we do this zero summation, we also get an amazing gain as follows: Consider two electrons in free space. As is well known, the electric field force (repulsion) between them is about 10^{42} times as strong as the gravitational field force (attraction) between them. So the electric force is so very much stronger that the comparatively weak gravitational force can be entirely neglected, in most applications. However, if we "strangle" that electric field force by zero summation, all the opposing electric forces are converted directly into gravitational potential!

Interference of two such potentials can directly generate gravitational forces. So, if we could zero-sum their E-fields perfectly, we could instantly amplify the gravitational force between the two electrons by a factor of 10^{42}. With such a gravitational force amplification factor, our altered "electrical" circuits would actually become powerful electrogravitational circuits. Further, appreciable gravity effects would now be experienced by any mass, object, or device exposed to the action of the circuits. This is the fundamental secret that Nikola Tesla discovered, one which he never openly revealed.

Further, by locking opposing EM waves together, we may easily construct purely scalar EM (electrogravitational) waves and beams. In such case, amazing new phenomena are encountered: (1) one can increase or decrease the mass and inertia of an object; (2) one can produce a unilateral force in and on each and every nucleon in a body, thus accomplishing the long-sought "antigravity"; (3) a unilateral force drive—a "space drive"—can be constructed; (4) transmutation of elements becomes fairly simply done, with miniscule energy; (5) effects at a distance—such as cold explosions or hot explosions—can be accomplished; (6) negative energy and negative time effects can be created and utilized; (7) Newton's third law can be manipulated and violated at will; (8) negative entropy effects can be created and utilized; and (9) direct energy extraction from the vacuum can be accomplished, etc. So many new effects are encountered that it will take a generation of graduate students and university laboratories to get a good handle on most of them.

The reader is urged to remember these rules: (1) The destructive interference of scalar EM waves (electrogravitational waves) produces EM energy in, or extracts it from, the interference zone. (2) The destructive interference of ordinary EM waves produces gravitational potential energy. (3) The release of the ordinary EM force fields represents the bleed-off of a 5-dimensional gravitational potential as ordinary electromagnetics. (4) The bottling-up of the ordinary EM force fields represents the forced bleed-off of a 5-dimensional gravitational potential as ordinary 4-dimensional gravitational force. (5) The EM field and the ordinary (4-space) G-field are just separate bleed-off s of the same 5-dimensional gravitational potential field.

Thus, I make no bones about it; we have a new physics in the offing—one that is eminently practical and easily engineered by any modern electromagnetics laboratory.

Since the first edition of this book was issued, it has also become obvious that at least two other phenomena are involved in UFOs, and intermingled with the "materializations from the collective unconscious" true UFO phenomena. These two additional things are:

(1) A great number of "lights at night" and "mysterious fireball" type phenomena—and giant balls of light and glowing hemispheres of light of gigantic size—are actually due to deliberate Soviet long range, high energy, real-time holography using phase conjugation. These phenomena are to accomplish orientation and alignment of giant Soviet weapons, and at the same time deliberately evoke UFO reports and scientific skepticism, providing perfect deception.

(2) Several nations of the world—at least two—have been building and flying antigravity spaceships all over the solar system, since the early 1950's. A very small number of UFO ship reports and encounters are due to these ships and their crews. However, control of these ships is not under any duly elected government, but passes out of the government concerned, into and under the control of some mysterious group

which I loosely refer to as "the control group." This is the same mysterious group which has been suppressing free energy and antigravity inventors and inventions for a great number of years.

Thus in *Excalibur Briefing* we are still addressing the primary UFO phenomena: Materializations from the collective human unconscious. Coverage of the other two parts of the overall reported UFO phenomena will be made elsewhere.

So it seems that, under my hard-pressed circumstances, the best thing to do for the second edition of *Excalibur Briefing* is to include something that shows some of the drastic progress that has been made. By adding a glossary and a current paper, the book will also be made much more usable. I also have prepared an index for the first edition, but it cannot be included because of space limitations. Admittedly that is regrettable and still not the optimum, but it will have to suffice. Perhaps in the future I will be able to do a complete rewrite of the book, for *Excalibur III.*

Until then, I ask the reader's indulgence and understanding.

* * *

In the first edition we accented the hyperspatial aspects of the problem, but also pointed out that higher dimensional spaces and deeper nested levels of virtual state are in fact one and the same thing. The reader should keep in mind that when we "inter-nest" vector zero systems, we are performing direct engineering in hyperspace.

Let me be more specific. When you zero sum a group of EM force vectors, you place those component vectors "inside the zero," so to speak. In modern language you have placed ordered patterns directly inside the violent flux of virtual particles comprising the vacuum. The modern concept of the vacuum is that it is like a seething plasma or gas. However, it's a very strange gas, for each particle arises spontaneously out of nowhere (according to quantum mechanics), and almost immediately turns into something else and/or disappears. Thus the vacuum plasma or gas is rather peculiar; the particles comprising it appear and disappear so rapidly that they cannot individually be detected. However, while a virtual particle exists, it is in motion, and so a violent flux of these "phantom particles" comprises the vacuum/spacetime.

However, just as many fleeting particles in the vacuum are moving backward in observer time as are moving forward in it! So this wild "vacuum gas" of ghost particles exists in both positive and negative time at once!

Anyway, when we make a zero vector EM system, each component force in the summation represents a gradient in this virtual particle flux. That is, we have "patterned" and organized the flux—polarized it, so to speak. And that now overturns one of the fundamental assumptions of quantum mechanics.

Quantum mechanics assumes that the violent flux of vacuum ghost particles is totally randomized. That is, no deterministic pattern exists in the flux. These virtual changes collect or cohere statistically, not deterministically, in the standard assumption. When they happen to collect/cohere sufficiently, the threshold of an observable quantum change is breached, and a quantum change occurs.

It can readily be seen that, in the ordinary view, the occurrence of these quantum changes is totally statistical. And indeed it is, so long as the virtual particle flux is randomized. However, with zero vector summation (or multiplication) we have produced deterministic patterns in the flux—and hence in the cohering and collecting of this flux on observable charged particles. Therefore, these deterministic "virtual state" ordered patterns will result in the appearance of deterministic patterns in the occurrence of observable quantum changes.

Now we have begun to engineer physical reality directly; that is, one can now begin to pre-determine which statistical change shall be favored, or in the extreme case, which one shall occur, and whether or not it shall even occur at all.

The renowned physicist, David Bohm, has written a theory of "hidden variables" which could fit and describe all of physics (nothing out there contradicts it). It has largely been ignored, and will continue to be ignored unless it can show appreciable application that normal theory cannot cover. With the scalar EM approach, we can now directly provide hidden EM force field vectors, ordering the virtual state vacuum flux, and we may vary these ordered virtual patterns at will to produce startling new results in charged particle systems. So now we can directly engineer Bohm's "hidden variables," and the vacuum itself—something ordinary theory cannot cover. Drastic changes in the physicist's view of fundamental physical reality, and of what he can do about it, now result

But to return: We wish to engineer additional hyperspaces. (The first zero-vector summation places the component vectors in the fifth dimension.) If we take one of the component EM vector forces in the first zero vector summation, and we then take a point on it as yet another "reference zero", we may encapsulate a second series of zero-system summation vectors into and within that zero-point. In this case we have placed these second vectors into yet a deeper level of virtual state vacuum. That is, we have reached into yet another hyperspace with our engineering and control. Indeed, we have placed the second system EM vectors into the sixth dimension. So we have become true hyperspace engineers.

The process is repeatable as desired. We may reach any hyperspace we wish, as our technology and control develop.

Now we see the impact In modern Kaluza-Klein geometry, one needs about 11 or so dimensions if one is to account for quarks, charm, etc. Now we have a direct tool to reach into any one or all of these hyperdimensions and affect the exact particle or component desired. We will be able to engineer matter—including the nucleus, and including inside the proton and neutron—in almost any way we wish. It all follows from scalar electromagnetics, which allows the direct engineering of hyperspace in all its dimensions.

Remember, engineering in hyperdimensions is just the engineering of nested levels of vacuum potentials. Even more startling, we can also place "thoughts" and effects directly in the mind itself, including the unconscious mind.

As we stated in the first edition of this book, we may model the mind as simply an objective 3-space, three turns away from the 3-space of the ordinary physical world. If we nest two or more additional zero-vector systems in our first one, then we have placed affects ("vectors") directly inside the mind itself. If we know the code of the human brain-tuner, we can now manipulate the mind directly. Electromagnetically, by scalar EM. And it appears that the Soviet Union has begun to reach this frightening capability.

Disease patterns may be induced upon ordinary EM carriers in the same manner, by nesting the zero-vector systems. That is, of course, if one has measured the scalar patterns evident in the induced disease, say, in the Kaznacheyev-type experiments with the desired disease patterns. The reverse is also true: Nesting the patterns in the proper context on EM field carriers can cure diseases such as cancer and leukemia, as evidenced by the Priore device.

One can also make a practical "free energy" device by setting up a standing scalar wave resonance in a localized region or device. From the "high stress" point to the "low stress" region of vacuum formed by such a standing scalar wave, a literal "river of energy" is flowing in the vacuum itself. Once the river is established, only the "leakage" need be replenished. Hence, if one builds a special sort of "paddle wheel" to react with the river and turn in it, one obtains shaft power freely from the localized curvature of spacetime. In that case, an ordinary generator can be driven by the shaft torque to provide very cheap, or"free," electrical energy.

Several inventors—three of whom I work with in one respect or another—now have demonstration models of such machines, which take diverse forms.

Because of the extreme importance of these emerging potentialities, in recent years I've concentrated intensely upon the properties of the vacuum as spacetime, and uncovered shortcomings (and downright errors in many cases) in ordinary physics and electromagnetics. Slowly the scalar EM picture has emerged, and a series of papers has been written and published to develop the concepts of the new approach.

The scalar approach also includes the ability to engineer negative energy and negative time flow. The reader is referred to Chapter 4, "Extraordinary Physics," of my forthcoming book, *AIDS: Soviet First Strike*, Tesla Book Co., P.O.Box 1649, Greenville, Texas 75401 for a summary of the vast importance of the time-reversed EM wave (phase conjugation).

Let me here just accent a rule of great importance: It is actually the key to negative energy, negentropy, antigravity, free energy, transmutation, Tesla's wireless transmission of energy at a distance without loss, Tesla's original magnifying transmitter, and many other things.

First we need the expression CPTEGS, where C is charge, P is parity, T is time flow, E is energy, G is gravity, and S is entropy. We shall be concerned with the algebraic sign of each term in the expressioa The rule deals with photon interaction with a charged particle inside an atom. Normally, incident photons interact with an electron in the electron shells, so C is normally negative. This produces normal parity, and causes the normal or positive flow of time, s T is normally positive. The normal kinds of energy, gravity, and entropy are experienced, so energy is positive, gravity is positive (attraction), and entropy is positive (progressive interactions in a system tend to more and more disorder).

The astonishingly powerful rule is this: In a photon interaction with a charged particle in an atom, if any one of the terms of the expression CPTEGS is reversed in algebraic sign, all the other terms are reversed in algebraic sign.

Thus if one makes scalar EM, the wave (and its photons) passes through the electron shells and interacts with (is absorbed in, and raises to an excited state, which then decays to emit a wave and photons) the highly nonlinear, positively charged nucleus. This represents a reversal of C, hence a reversal of P, T, E, G, and S also.

Consequently, a time-reversed wave—a phase conjugate replica of the incident wave—is emitted by the decaying excited nucleus. In nonlinear phase conjugate optics, this is the mechanism that produces the phase conjugate wave. This is also the mechanism that produces a very large amplification of the incident wave when a "pump wave" (two waves 180 degrees out of phase) are used in the nonlinear (modulating) medium of the phase conjugate mirror.

(The reader is referred to any good book or summary paper on phase conjugate optics; for example, see David M. Pepper, "Nonlinear optical phase conjugation," *Optical Engineering* 21(2), Mar./Apr. 1982, p. 156-183.).

When one pumps a phase conjugate mirror material sufficiently, then "tickles" the release of the total nuclear excitation energy as phase conjugation replica waves (negative energy), appreciable negative time is produced in the decaying nuclei of the mirror. In negative time, gravity is a repulsion, not an attractioa The mirror thus produces antigravity, and gets lighter. If it is forced to sufficiently high amplification, it can be made to float in air. At higher amplification still, it will accelerate upward.

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T. E. Bearden
December, 1987

INTRODUCTION TO THE FIRST EDITION

Today there are a great many books available on UFO's, paranormal phenomena, and wild science, and one more such book ought to say something quite different if it is to be justified. Accordingly, in this book I have tried to say something quite different, perhaps in some cases too different. And so, to assist the reader's comprehension, I would like to explain something of how the book came about.

For the last fifteen years or so I have been interested in paranormal phenomena to one extent or another. Fifteen years ago I started studying Shotokan karate, and later switched to Yoseikan aikido, a most profound and absorbing martial art. I had already started serious reflection on the nature of perception, and after some years of aikido practice I occasionally began to experience what might be called paranormal perception. For example, occasionally, when violently attacked by several opponents, I would suddenly discover myself standing calmly on the sidelines watching the robot-like figures go through the motions of a play, motions that had already occurred in one kind of reality and that were now simply being repeated. On the rare occasions when I experienced this pure zen state of aikido, the techniques became flawless. In fact, the state was not separable into attacker, defender, and technique — rather a single union of the universe occurred. Unfortunately, although I eventually reached Sandan (third-degree black belt), I never permanently attained the complete aikido oneness state; this does not normally occur until the sixth dan level.

However, the occasional experiencing of this pure unity made a deep impression on me, for such aikido is pure meditation in motion, and only in such a state can the individual grasp the nature of perception. Only when conscious activity has stopped ("mind like a moon on still water") is such awareness possible. For several years I then laboriously developed a theory and interpretation of aikido for Westerners and eventually published it privately.

In 1971, while finishing a Master of Science degree in nuclear engineering at Georgia Tech, I put together a first crude theory of perception, which was published in 1973, many rewrites later. By that time I was already deeply engrossed in the study of paranormal phenomena, and especially unidentified flying objects. I had seen several UFO's (the earliest in 1950), and no longer doubted that the UFO phenomena represented some sort of new reality experienced by a great many people.

The UFO organizations at that time seemed to be in disagreement with each other. For twenty-five years or so almost everyone studying the phenomena had been trying to prove the extraterrestrial hypothesis, i.e., they started with the assumption that UFO phenomena were caused by, say, a group of young stalwarts over on planet X of star Y, getting beered up on a Sunday afternoon, hopping into an old space jalopy, and motoring over to planet Earth to jolly the natives. So they vigorously cataloged the UFO reports that fit the picture, and embarrassedly ignored those that did not. Yet most of the phenomena consisted of strange lights at night, not steel-hulled spaceships. And most of the contactee cases — particularly those involving apparent communication and abduction — were regarded as just too far-out for engineers and scientists to swallow. Almost everyone in the UFO organizations seemed to be convinced that Earth was being visited by spacemen from another planetary culture more advanced than our own, and so the UFO enthusiasts looked for hardware and spaceships, no more and no less.

The tabloids were a mess — filled with sensational nonsense about the purported UFO invasion of earth. Some invasion! If the would-be invaders possessed such an advanced technology, why had they spent twenty-five years flitting around the backside of the country and frightening the rural people, instead of simply landing an expeditionary force and having done with it? It seemed that almost no one was really looking at the phenomena in a totally unbiased manner. When one did so, without especially selecting the data, the strangeness of the data went up by orders of magnitude.

So I decided — rightly or wrongly — not to compete with the catalogers, but to try to come to grips with the possible *science* evidenced by the phenomena. I wanted to examine what kind of science was necessary to describe the phenomena and the mechanisms producing them. It rapidly became obvious that our scientific framework was not adequate to explain these events. In fact, our logical framework was not adequate. So I decided to look for a new scientific framework, knowing that the effort would be long and arduous and might not succeed at all.

All the unexplained phenomena seemed to me to be interconnected; for example, a study of Sasquatch will sooner or later lead to the study of UFO's and thence to the study of the other phenomena. So it appeared that they were all different aspects of the same overall reality. Since that reality most definitely involved the mind as well as matter, it appeared necessary to develop a new science incorporating both mind and matter. And so the search and the gradual accumulation of insight continued.

The trail led directly to the great paradoxes of science, the great unsolved problems of philosophy, and the three laws of logic on which all logical disciplines and sciences are founded. Using my perception theory, it was possible to see through the age-old necessity for the identity of opposites, how opposites could be identified, and when they were identified. Thus a fourth law of logic could be written and the system closed.

Slowly the nature (or, more precisely, a model of the nature) of mind became clearer. In addition, mechanisms for materialization and dematerialization appeared, as well as mechanisms for metal bending, thoughtform materializations (tulpas), and telepathy.

But the international strategic balance also could not be ignored. From my military background, the Soviet military buildup toward an attack capability was apparent as early as 1970-71. Moreover, from my work on the Moray radiant energy device I had discovered what I believed to be the basic theoretical mechanism used by T. Henry Moray to tap the zero point energy of free space. (This mechanism powerfully amplifies virtual state into observable state.) And positive evidence suggested that the Soviets had obtained the secret of how to make the Moray detector tubes. Putting this together with psychotronics produces an astounding weapon capability — and the Soviets must have had such capabilities already on site and others in development.

I looked for evidence of these weapons, and the evidence was there, cleverly — even diabolically — concealed.

When I then realized the *entity* nature of the collective human unconscious, everything fell into place. Suddenly the different major waves of UFO's made very good sense, as did the cattle mutilations, the Soviet buildup, Khrushchev's 1960 statement about fantastic weapons, Brezhnev's 1975 reference to the development of weapons more frightful than man had ever conceived, the long years of microwave radiation of the U.S. Embassy in Moscow, the Legionnaires' disease, etc.

The intelligence community had completely missed the fact that the Soviets had been working on a psychotronic Manhattan Project for thirty years. Not a soul in officialdom would believe that such capability could be achieved by surprise. This is not because of a deep conspiracy of the government (although I believe one of our high intelligence officials may be a Soviet agent, a sort of Penkovskiiy in reverse, who has been personally responsible for preventing any serious U.S. governmental research into psychotronics and UFO's); rather, it is because of all the personal arrogance, bias, power-seeking, manipulation, and maneuvering that now make up so much of our top managerial base in government.

So I decided to put out the information for all to see. There is still time — but just barely, I think — to build psychotronic defenses and prevent the launching of the Soviet attack. But we must move swiftly if Fer-de-Lance, the Soviet attack plan, is to be frustrated, for the eleventh hour is here.

Moreover, there is a single human problem responsible for all the ills that man causes man, and that problem has a technical resolution that is well within our grasp. I firmly believe that by psychotronics, the minds of all men can be linked into a great supermind having absolute psychokinetic mastery over time and space — literally a godlike being, in whom the collective human unconscious has a collective conscious instead of the four billion fragmented individual personal conscious minds it has at present. The initial psychotronics linkage mechanism is just a tool; after linkage is accomplished and stabilized, such props will not be necessary.

This is my real goal. Even if the U.S.S.R. launches Fer-de-Lance, annihilates NATO and China, and obliterates all Western retaliation with a stunning blow, and even if the collective unconscious then psychokinetically lashes back with the violent destruction of the Eurasian continent, linkage is still the goal and the final resolution. Should the apocalypse come to pass, there will still be time, in the midst of the horrendous collapse of civilization, to gain the final solution.

And it is the final and total solution. All the parables in the Book of Revelation will be realized. The grave literally will give up its dead — for with the overcoming of time and dimensionality, all that ever has been or ever will be, *is,* in one great nowness, allness, Omega, "I am that great I AM."

That is the goal, and it is toward that end that this book is written.

Please note that a listing of the research and reference works mentioned in the text can be found in the bibliography.

PART ONE

A SAMPLING OF SPECIFIC PARANORMAL PHENOMENA

In this section I show a sampling from the world of the paranormal, including UFO's of various kinds, psychotronics, Loch Ness monsters, Sasquatch, bigfoot, superfoot, psychokinesis, remote viewing, psychic photography, and a host of other phenomena— all explicable by the theories presented in Part Two.

I fervently believe that a theory can be constructed to explain our lives, including all the strange phenomena as well as the more familiar happenings. In this book a serious attempt has been made to point the way by developing what I believe to be the basic concepts, and by showing that a host of phenomena do seem to be consistent with the schema.

Let us hope that science and scientists are not after all dead, and that they will shake the cobwebs from their eyes and set about particularizing a new paradigm of mind and matter. When the top theoreticians and experimentalists wake up and join in the effort, my task will be finished.

THE VESTIGIA MYSTERY LIGHT EXPERIMENT

Let me start by introducing you to Vestigia, a very fine, relatively new organization that has been formed to study mysterious and unusual phenomena in a scientific manner. This organization, of which I am happy to be a member, is headed by Robert E. Jones and the investigation of the mystery light is spearheaded by James McGrath and Bill Wagner. (The informative *Vestigia Newsletter is pub*lished by the organization. Persons interested in the objective scientific study of unusual phenomena are cordially invited to contact Vestigia at P.O. Box 1183, Perth Amboy, NJ 08861.)

Vestigia's ongoing investigation of a mystery light in Morris County, New Jersey is a classic example of the manner in which mysterious phenomena may be studied in a scientific manner, and it should serve as a model for other investigative groups. Vestigia's experimental work has exemplified careful planning, close teamwork, proper scientific equipment and preparation, and the patience and persistence that are essential when performing fieldwork experiments in the field of unusual phenomena.

1 wish to stress in advance that Vestigia does not endorse my own theory of the possible nature of mystery lights; in fact, the organization very properly remains openminded. Also quite properly, they practice scientific conservatism in studying the possible nature of the phenomenon; at the present time they strongly favor the theory of the piezoelectric effect. Substantial evidence for this thesis includes the presence of a known geological fault in the local area, the presence of piezoelectric minerals in the local granite (e.g. thirty percent quartz), close association of the incidence of the phenomenon with subsequent local earth tremors, conditions favoring the accumulation of a surface charge (e.g., metal railroad tracks oriented parallel to the geological fault), and enhancement of the phenomenon under study. And this is exactly how Vestigia is in fact proceeding.

In science, the prevailing world view is not to be dismissed lightly since a great deal of experimental data has been gathered to substantiate it. And a single experiment cunnot establish the need to correct that solidly based view, even if the experiment at first appears puzzling and not in accordance with the accepted view. Only after many exhaustive studies have found the world view inadequate, may a paradigm properly be changed. From a rigorous scientific viewpoint, then, I am saying that this classic experiment is consistent with my own orthorotation theory, but not that the one experiment proves my theory. The experiment at this point is also perfectly consistent with the more conservative hypothesis that the mystery light is due to the piezoelectric effect. Additional different kinds of experiments are required before either theory will hold. For example, in my own theory, the mechanism of orthorotation must be verified elsewhere, and in the piezoelectric theory, the mechanism that spatially separates the effect from the crystalline material where such an effect normally occurs, must be explained and verified by other experiments.

With these precautionary remarks to the reader, let me now describe the beautiful experiment initiated and still being performed by Vestigia. I will then present my own theoretical explanation, again stressing to the reader that it must be treated as a hypothesis at this point.

Mystery lights occur in many locations throughout the United States and Canada. Vestigia has determined over ninety of them to date. They are recurring phenomena and are often seen near some natural or man-made feature such as a stream, hollow, road, railroad track, field, or mountain.

The mystery light under investigation by Vestigia is located along a one-mile stretch of railroad track in Washington Township, Morris County, New Jersey. The light has been seen by hundreds of people at one time or another over the last twenty to forty years. Dr. C. Louis Wiedemann describes it in the *Vestigia Newsletter:* "Appearing at night, it is said to bob or sway from side to side in the manner of a swinging lantern, and when approached it vanishes, sometimes reappearing at a more distant point."

Quoting from the *Vestigia Newsletter:*

> The preplanned battery of experiments and observations was conducted on the night of November 20-21, 1976. Three observation posts were established along one mile of railroad track, and these were manned in shifts by small teams of observers who maintained contact with team leaders via portable radio communicators. Communications were monitored and instructions were issued from a command post which was maintained in two vans joined in a T-configuration adjacent to the central observation post (Post 2).
>
> The vans contained electronic equipment valued at $30,000, which was wired to sensing devices along the railroad tracks. Four thousand feet of silver plated fine copper wire was laid between the rails and attached directly to an amplifier and oscilloscope in one of the vans, to detect variations in electrical frequency and amplitude. Other cables were attached directly to the rails, providing a capacitance test. Other devices included a Geiger counter, thermometers, a methane gas detector, a barometer, a parabolic listening device, a radar unit, an infrared sensor, and a sensitive compass. Personnel at observation posts were equipped with binoculars and cameras. One tripod-mounted camera equipped with infrared sensitive film was located near the rails at Post 2.
>
> James McGrath, a member of Vestigia's executive board, acted as advisor to the team. Team leader was electrical engineer William S. Wagner who was assisted by Jack Mazzuchelli. In all, sixteen persons were actual members of the team, and a total of twenty-one persons participated that night. A number of these were members of the Unexplained Phenomena Club of the County College of Morris, headed by the club's president, Steve Hopler, and vice-president Mary Ann Barron.

Shown here are six of the seven infrared photos of the mystery light which were taken by the Vestigia team. The frames shown are frames two, three, four, six,

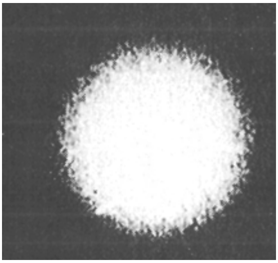

Frame Two

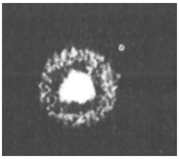

Frame Three

Photo 1. The Vestigia mystery light experiment.

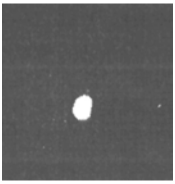

Frame Four

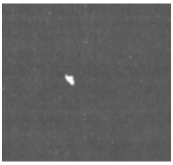

Frame Six

seven, and eight. The camera with infrared film was located at Post 2. Frame 1 was a test frame. Simultaneously with the recording of frame 2 at Post 2, observers looking from Post 1 reported visual observation of a light. The light was not seen by observers at Post 2. A second camera with ordinary film recorded only a pinpoint of visible light.

In the photograph, frame two recorded an image of an apparently plexiform spheroid of dynamic granules of light invisible to the eye of the cameraman. At the same time, observers from Post 1 looking back reported visual observation of a light.

In frame three, within about fifteen seconds the image has decreased in size and the plexiform spheroid is now a thinner corona around a dense, nearly hexagonal center.

In frame four, a dense but small irregular or oval image can now be seen. Frame five, not shown, is quite similar.

In frame six, a substantial decrease in size is apparent.

In frame seven, again the image size has increased, and again it possesses a dome central core surrounded by a thinner spheroidal corona of dynamic granules of light. Also, several separate satellite images are now visible at some distance from the main spheroid.

Frame eight is very similar, except that the satellites are no longer visible and the light in both the core and the corona is not quite as dense.

To describe the experiment precisely, the following passage is taken from Dr. C. Louis Wiedemann's article in *Vestigia Newsletter* No. 2, Spring 1977:

> Following several hours of equipment testing and calibration, at 10:21 P.M. two observers at Post 1 radioed the message that they had a "light" under visual observation between their position and Post 2, at an apparent distance of 300 to 400 feet from Post 1. Post 2 observers immediately scanned the area with binoculars and radar, but no object or light was detectible from that position. The yellowish-white light remained visible from Post 1 for approximately one minute and thirty-five seconds, initially approaching the tracks from a lower position off to one side, but soon positioning itself over the rails, and then seeming to sway from side to side in a pendulum-like manner. Its size was estimated between three and six inches in diameter, and for awhile the observers believed it was approaching them. When it vanished, the disappearance was sudden, as if the light had been "switched off."
>
> During the period in which the light was under observation, personnel at Post 2 took pictures of the apparent darkness, and continued to search with radar and binoculars. Two observers at Post 3 briefly saw what appeared to be an orange light between their position and Post 2. While the main light was under observation, several of the instruments in the command post gave unexplained readings. Most notable among these was the oscilloscope's display of an electrical frequency in the range of 40,000 Hertz. Additionally, the capacitance test showed the apparent presence of a conductive body between or over the rails. Nine minutes after the light had vanished from view, the Geiger counter (whose sensor was between Posts 2 and 3) indicated a full scale reading of greater than 5 mr per hour, lasting ten seconds. Normal background radiation was then recorded for five to six minutes (0.1-0.2 mr/hr), whereupon another full scale reading was displayed for approximately seven seconds.
>
> The pictures were enlarged from small images which appeared on the infrared film which was exposed through a 135 mm telephoto lens from Post 2 by Richard Larkin. Film employed was Kodak high speed infrared No. 2481, which is sensitive to infrared radiation to 900 nanometers, with maximum sensitivity from 750 to 840 nanometers. The lent opening was f/3.5 with the apera-

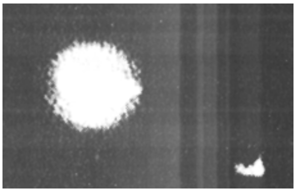

Frame Seven

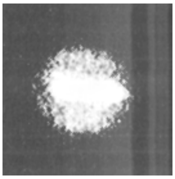

Frame Eight

> ture set at infinity. The second frame (frame 2) was exposed between 3 and 5 seconds, and the others were varied in exposure from 3 to 10 seconds. Intervals between exposures were between 10 and 15 seconds.
>
> High speed (non infrared) film in a camera which was hand-held by James McGrath at Post 2 also produced several images of an apparent point source of light above the rails (not shown here). Jack Mazzuchelli observed the area through binoculars during the entire time period, and he was unable to discern any light whatever, although he could perceive the rails and the railbed in the faint illumination provided by starlight shining through a partially overcast sky.

As I stated previously, Vestigia has not yet reached a firm conclusion as to the causative agent, but strongly favors the piezoelectric theory, since if offers the simplest explanation at this point. Again, to quote the *Vestigia Newsletter:*

> No absolute conclusions can yet be drawn, other than the apparent fact that a phenomenon or set of phenomena did occur. Team leader Wagner theorizes that the phenomenon might be similar to so-called earthquake lights which have been reported to precede seismic tremors in Japan. Interestingly, there were explosionlike shocks or "loud booms" reported by residents of two housing developments several miles distant from the site on December 5 and 6,1976, and these shocks were recorded by seismographs at Columbia University and elsewhere. Intensity was (-)0.25 to (+)0.38 on the Richter scale. Wagner posulates a possible piezoelectric effect from tension on subterranean rock deposits.
>
> The possible relationship of a piezoelectric effect will be investigated further. Data gathered in Japan tends to indicate the development of subterranean stresses during the passage of a cold front. In the light of this possibility, it is interesting to note that there was a drop in barometric pressure from 29.9 to 29.76 culminating less than one hour before Vestigia recorded the start of the phenomena. A light snowfall preceded the appearance of the light.
>
> Wagner believes that the initial discoveries tend to indicate that the following conditions must be present for the phenomenon to be manifested:
>
> (1) A geologic fault in the local area.
> (2) The presence of certain minerals, especially quartz (quartz comprises 30% of the granite in the area under investigation).
> (3) Conditions should permit the accumulation of a surface charge (e.g.: the presence of railroad tracks, because they are metallic).
> (4) The tracks must run parallel to the fault.
> (5) The phenomenon's manifestation tenc
> sure changes as well as extreme changes in temperature.
>
> Wagner states, "Our indications are, at this point, that the lights precede earthquakes or tremors."

Regardless of what hypothesis we begin with, it must be consistent with all the major features of the Vestigia mystery light experiment.

(1) The explanation must show why a light with structured patterns formed and changed. The structured patterns changed geometrically in shape and intensity, as well as in movement and location. This dynamic formation and change was recorded on infrared-sensitive film. The geometrical shapes of the light structures must be accounted for.

(2) Ordinary film recorded only a pinpoint source of light.

(3) The light which was photographed in infrared was not seen by the photographer himself, nor by eight other persons who were observing at the time from Post 2.

(4) Either that light or another was seen visually from a different station.

(5) At the same time as the visual appearance of the light, instruments recorded the apparent presence of a conductive body between the rails or over them.

Specifically, the electrical capacitance between the rails was observed to change — or at least indications to that effect were received on the instruments.

(6) Nine minutes after the main light vanished, a Geiger counter began to read full scale for about ten seconds, then lapsed back to background reading. Five or six minutes later, full scale reading was repeated for about fifteen seconds. About a minute after that, full scale reading was again recorded for about seven seconds.

(7) At the same time as the main light visual sighting, an electrical frequency of approximately 40,000 Hertz was recorded on the oscilloscope.

There were also environmental conditions which may well have been involved in the experimental effects.

(8) Barometric pressure dropped from 29.9 to 29.76, culminating less than an hour before the phenomena were recorded.

(9) There was a temperature drop and a light snowfall preceded the appearance of the light.

(10) The geological conditions strongly favored seismic stress and piezoelectric effects. For example, the local granite contains about 30 percent quartz, and there is a known geological fault not far from the experimental site. About fifteen days after the experiment, seismic shocks were indeed recorded at Columbia University and elsewhere, and they were audibly detected by residents of two local housing developments. The measured intensity of the seismic shocks was from(—)0.25 to (+)0.38 on the Richter scale. It thus appears highly probable that seismic stresses existed on the subterranean rocks at the time of the experiment and that piezoelectric activity was present in the local granite quartz due to these stresses.

(11) Conditions also favored the accumulation of surface charge, and the railroad rails (good conductors) were oriented parallel to the geological fault.

(12) Several thousand feet of wiring existed in the immediate area to connect the different stations and the instruments to the sensors. About four thousand feet of fine copper wire, silverplated, was laid between the rails and fed to an amplifier and an oscilloscope to detect variations in electrical frequency. The capacitance test also used cables attached to the railroad rails themselves. The Geiger counter's sensor was also positioned at the experiment's hot spot and wired to the equipment van. Additional equipment and wiring was also used.

Finally, preliminary surveys of the area were carried out by persons of known paranormal sensitivity several days before the main experiment. Before conducting the major experiment, Vestigia interviewed persons who had seen the light and also conducted preliminary site studies using psychics. One nationally known psychic was brought to the site by Vestigia's president Robert Jones, and asked to walk along the tracks. The psychic reported impressions of some personal tragedy, perhaps a gruesome murder. Later several other persons with heightened psychic sensitivity were brought to the site, and they reported psychic impressions.

In all, three psychics were brought to the track. The only directly correctable result was that all three had a reading in the same area on the stretch of track, within sixty feet of the sighting of the night of November 20-21. The psychics' own interpretation of their readings differed considerably.

UNEXPLAINED GENERATION OF ELECTRICITY

Some additional data exist to indicate the generation of electricity by rocks and the generation of unexplained electromagnetic energy radiated from the earth, ocean, or atmosphere.

For several years T. Townsend Brown has worked in electrogravitics and holds many patents in the field. Some of his laboratory experiments have positively demonstrated a direct connection between electric currents, electric charge, and gravity, although the exact nature of this connection has not yet been fully explained. Nevertheless, it can be shown that highly charged objects do not behave in a gravitational field exactly as predicted by classical theory.

Furthermore, in 1974 Santilli succeeded in proving that one of the classic assumptions of physics is wrong, namely that electric field and gravitational field are mutually exclusive. Santilli proved that gravitational field and electric field are either partially or totally the same thing, in contradiction to present assumptions.

Over a decade ago, Curtis reported the measurement of very low frequency electromagnetic signals generated over the ocean that are not accounted for by any presently known mechanism or theory. Although Curtis published several articles on this effect, no further investigation has appeared in the literature.

Finally, there is a certain location where the generation of an anomalous electromagnetic signal occurs continuously. This is McGregor Missile Range (U.S. Army), where Army units fire air defense missiles such as Nike Hercules and Hawk. As a young captain, in 1961 I headed up the Hawk Evaluation Team at McGregor Range and directed the Hawk missile firing. About sixty-five kilometers out in front of the Hawk missile sites and downrange, there was a most peculiar source of electromagnetic noise, which could considerably affect a Hawk illuminator (continuous wave) radar when the radar antenna was oriented in that direction at a low elevation. In that case the radar would continually noise-lock (make and break lock-on) on the noise signal, dithering slightly as it continued to try to resolve a coherent radar return signal. This noise source was always present, in all seasons and temperatures, and so we simply made each Hawk unit commander and his personnel aware of the phenomenon. On one occasion 1 even vectored a helicopter with an investigation team to descend on the site and inspect it. All they found was the usual surface of the desert floor, with sparse growths of greasewood and cactus. There was nothing which could serve as a generator or reflector.

At one of our other missile sites in the U.S., there was a strange reflector mechanism located at some distance from the site and at about 15,000 feet altitude. **This** was rigidly fixed in location and unvarying, and the unit radar personnel often used it to calibrate the range of the radar. They simply locked on the reflecting point and fine-adjusted the radar range dials to indicate exactly the known range to the reflecting point. Here again, personnel on their own initiative vectored an aircraft directly through the point and searched the air in that area, but nothing at all could be found.

HYPERFIELD GENERATION OF PHOTON PATTERNS ABOUT A BAR MAGNET COLLECTOR

The magnetic field has more fundamental components which integrate in the virtual state to form it when two successive orthorotational thresholds (quantum thresholds) are breached. Furthermore, in the picture of a bar magnet taped to the

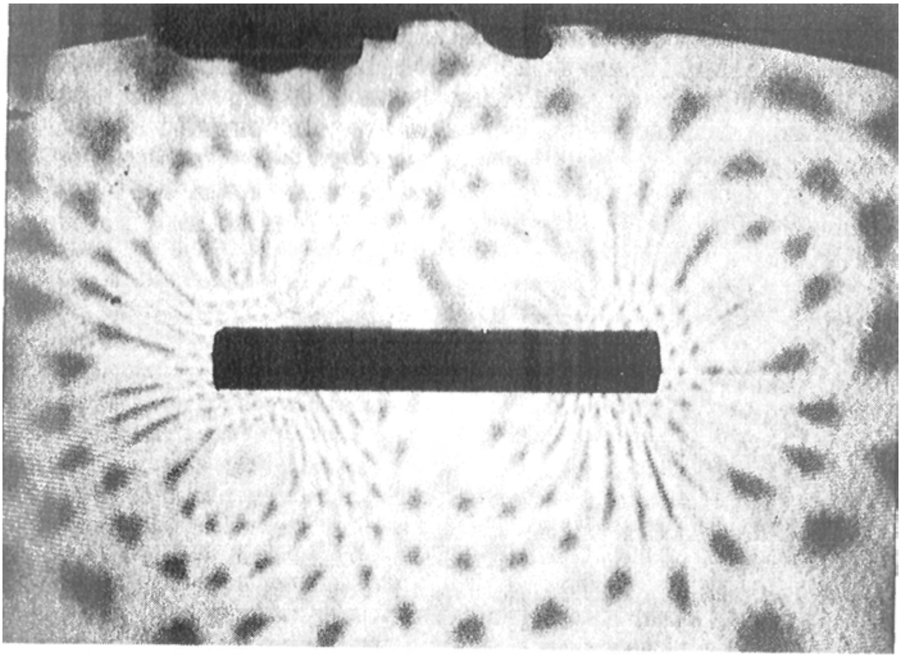

Magnet 3/4" dia. x 6" long taped to faco of a color TV tube approximately 1200 Gauss.

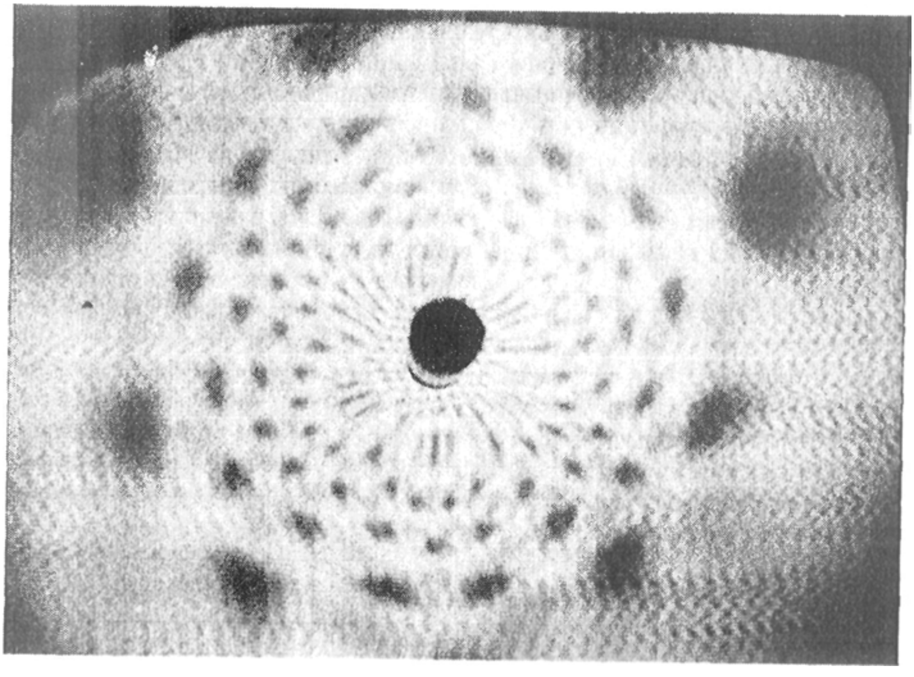

South pole end of same magnet tapod to face of color TV tube.

Photo 2. Hyperfield **flux in a magnetic field.**

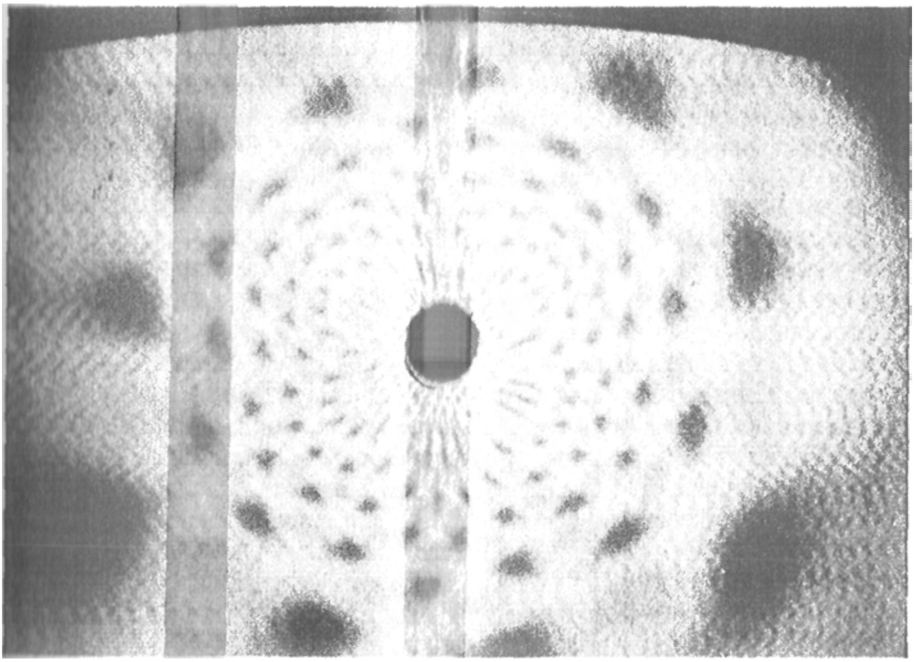

North pole end of same magnet taped to face of color TV tube.

face of a color television tube, one can see that the hyperfield orthogonal circulations in the magnetic field arc not symmetric about the two poles; i.e., the pattern is quite different around the north magnetic pole from that around the south magnetic pole.

Around the north pole, the hyperfield circulation is emitted in the form of a hexagonal solid. Thus there is an intense hexagonal orthorotation about the north pole. Radiating conically out longitudinally is a toroidal null zone, at an angle to the ongitudinal axis projected away from the north pole into space. At an even higher angle, another concentric cone is radiated out in the same direction; this higher cone is an emission cone where photons are being generated. Thus viewed from the north end, and at a distance from the magnet, the pattern shown in the right figure of the slide emerges, The pattern is a ring of light or light bubbles, surrounding a concentric ring neutral zone, which in turn surrounds a hexagonal center of intense emission.

If frame three of the Vestigia mystery light photos is examined meticulously, this exact pattern is seen, allowing for the dynamism of the phenomena and for slight nonlinearity of the spatial medium in which the photons are emerging by orthorotation.

On the other hand, looking at the left hand figure on the slide, we see that the outer emission ring is *so* thin that it has effectively disappeared; it is radiated at right angles to the magnetic longitudinal axle. The middle null area is also much wider. The densely emitting core area now has a relatively circular cross section at a distance. So the pattern of photon emission that is seen from this end is simply a dense round core. Frames four and five of the Vestigia photos demonstrate variations of this effect, viewed at a slight off-axis angle.

When the magnetic field is observed from the side, only the hexagonal dense emission core of the north pole is seen. In the south pole area, we are looking into a large null area, so no emission at all is seen. Frame eight is approaching this result, with a slight deviation from an orthogonal viewing axis. Also, frames seven and eight exhibit composite structuring from several (three or more) side-by-side magnets of square-end configuration, where the magnet cross section is wide, looking at the end. In that case, the top right picture would be elongated, giving a stretched hexagonal dense core surrounded by a concentric null zone of oval shape, further surrounded by a concentric thin emission zone of oval shape. In frames seven and eight, the outer thin emission zone is roughly spherical, not oval. However, a combination (further composite) of the lower right picture case and the upper right picture case could give the pattern exhibited by frames seven and eight.

And as I show clearly elsewhere, orthorotated hyperfield energy usually emerges with a "burst-in" effect which, in free space, assumes a spherical shape. Thus one would expect a dynamically bubbling sphere of light at the initial "burst-in" of the phenomena, and frame two exhibits this effect.

So the expected hyperfield generation of photon patterns about a localized region of magnetic field (such as a bar magnet or composite grouping of bar magnets), when that localized region of field is in the collection or burst-in and decay gradually mode, would account precisely for the particular structured patterns photographed by Vestigia.

Again, this does not prove the hyperfield hypothesis, but shows that the structural patterns obtained are consistent with it.

HYPERFIELD CIRCULATION PATTERNS ABOVE A MAGNETIZED RAILROAD TRACK

Figure 1 shows the hyperfield circulation patterns above a magnetized railroad track. The general setup of the Vestigia experiment is shown. The rails are oriented parallel to the fault line, which means that the rock stresses are oriented perpendicular to the rails. Thus the telluric currents piezoelectrically induced by the quartz and other minerals in the local granite are also generally oriented perpendicular to the rails and below them.

These piezoelectric currents thus constitute effective coils about the rails, magnetizing them weakly along their length, but this is in addition to their normal magnetism, if any, picked up due to the specific local and atmospheric electricity changes.

In the hyperfield flow pattern for two magnets which are lengthwise parellel and viewed from the end, a primary hyperfield circulation pattern exists both between the two rails and in the air above them. The location is the same, whichever end of the parallel magnets one looks into; however, the circulation direction changes with the change of ends. As the strength of the magnetization of the two magnets changes, the vertical distance above the rails to the plane of the center of the hyperfield circulation pattern (primary) changes. The stronger the field, the higher the center of the pattern, and vice versa.

In addition a secondary (weaker) hyperfield circulation area exists over both rails as shown. As the piezoelectric currents fluctuate in direction and intensity, corresponding fluctuations in the magnetization of the two rails occur.

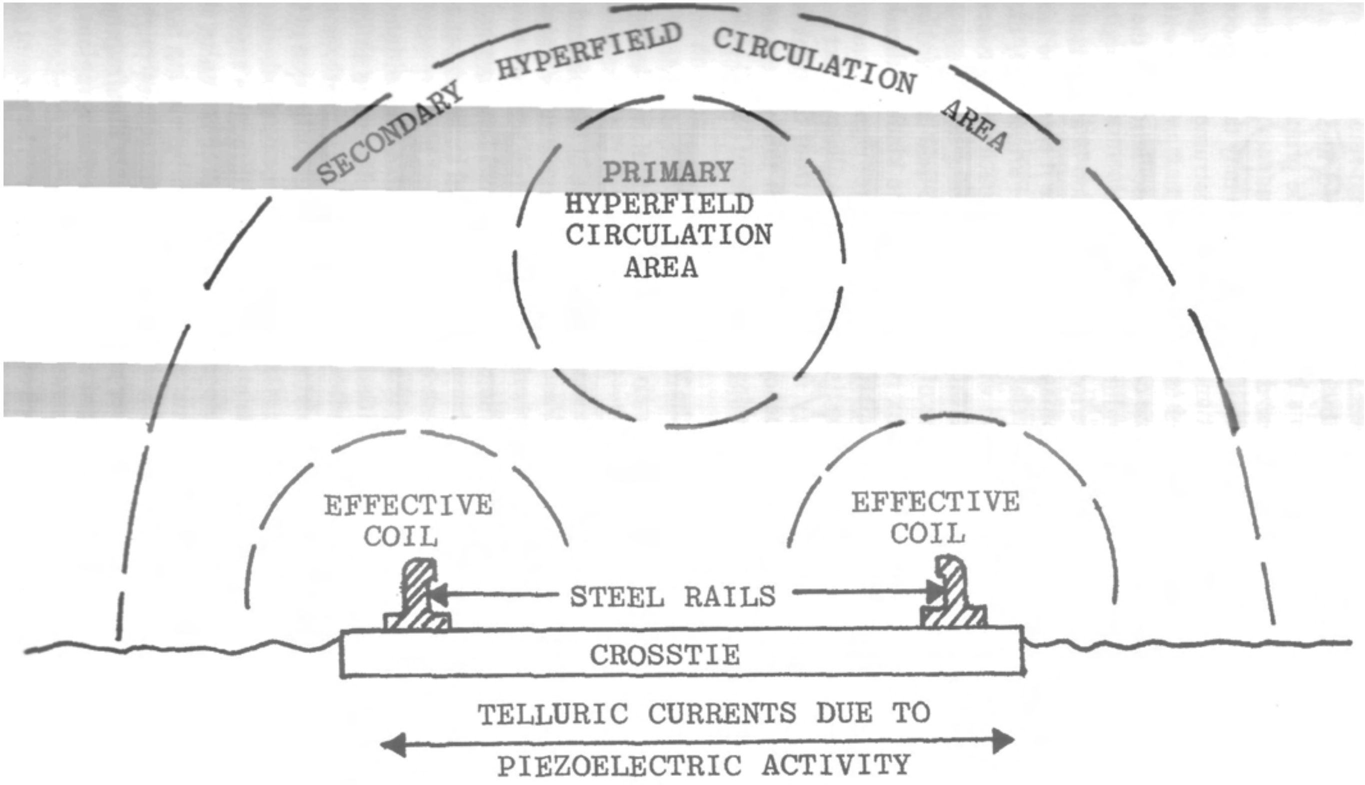
SECONDARY HYPERFIELD CIRCULATION AREA
PRIMARY HYPERFIELD CIRCULATION AREA
EFFECTIVE COIL
EFFECTIVE COIL
STEEL RAILS
CROSSTIE
TELLURIC CURRENTS DUE TO
PIEZOELECTRIC ACTIVITY

Fig. 1. Hyperfield circulation patterns above a magnetized railroad track

Thus, over the rails there exists a sort of undulating tubular tunnel of primary hyperfield circulation, surrounded by a larger undulating tunnel of half-elliptical cross section. In addition, the terrain and foliage features nearby will have their own hyperfield circulation areas, with flowing currents of hyperfield circulations between them and undulating tunnels over the rails. The final result is a complex flow pattern, which is further modified by atmospheric, ionic, and electrical currents. So a mystery light can kindle into a burst in one of the primary circulation areas and move, usually in a faltering or drift-dart-pause manner, along the undulating tunnels above the railroad track. Structural changes may then be noted as the geometrical aspect between the light and the observer-instrument changes, as additional collection-kindling occurs, and as discharge dampening occurs with the passage of time, due to the discharge time constants of the oscillations of the time dimension itself that are induced by kindling and burst-in.

Note that in the kindling process, the hyperfield circulation in a localized area suddenly bursts into magnetic or electromagnetic field. Since it enters the laboratory frame at right angles, orthogonal relationships result. Furthermore, the appearance of a kindled magnetic field form will change the capacitance between the rails, and a capacitance test will indicate this, as if a conducting body were there. The localized magnet or geometrical piece of electromagnetic field is locked in and maintained as long as the hyperfield flux remains above the kindling threshold. However, since the burst-in of the hyperspatial flux into electromagnetic energy involves the shocking into oscillation of the time channel, an oscillator effect is produced, and electromagnetic signal energy may be radiated from the light form, usually through one of the magic frequency windows which thinly interconnect orthogonal three-spaces. One of these windows is located at about 38,000 to 40,000 Hertz.

Such a signal was indeed recorded in the Vestigia experiment.

Also, at night time the time channel quenching effect of visible light is materially reduced since most visible light is absent. Further, the light-shielded quartz in the underground rocks has two magic windows: one in the infrared and one in the ultraviolet. So the area of the Vestigia experiment constitutes a gigantic kindling mechanism par excellence. With sufficient piezoelectric activity, the collected hyperspatial flux exceeds the kindling threshold required for burst-in, and localized triggering of a discharge or discharges can be initiated in the proper area. The thousands of feet of wire further enhance the collecting and kindling mechanisms. From a physics viewpoint, the living observer is the initiator who initiates the collapse of the wave function, in turn initiating observation. The same ability or property also is required to initiate the kindling of hyperspatial flux into the normal three-space, in my opinion. This is consistent with the rather wide collection of data presented here to show that a living observer can generate or extinguish electrostatic, magnetic, and electromagneic fields at a distance, even through a superconductive farraday shield. The thought photography examples presented also show that electromagnetic field (light) can sometimes be generated by a living human being, and impress the camera film with the visible light spectrum, even though the light is not consciously seen by the observer's eye. It also appears that frequencies of something other than light, in the infrared and ultraviolet frequency regions, can enter through IR/UV windows and then rotate into the ordinary visible light spectrum and ordinary visible light energy. Such effects also appear to be present in the

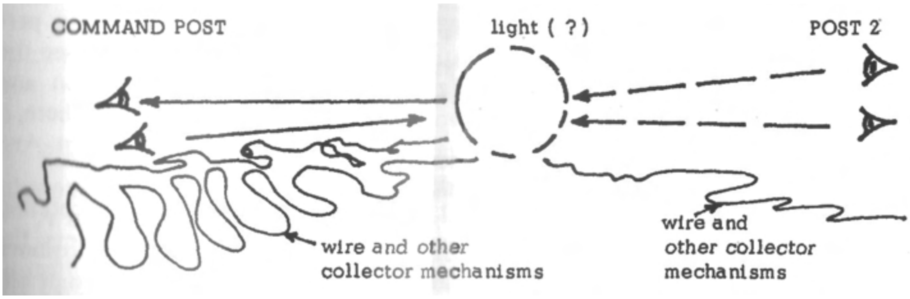
COMMAND POST
light (?)
POST 2
wire and other collector mechanisms
wire and other collector mechanisms

Fig. 2. The cyborg effect and orthorotational sensitivity

Vestigia experiment, since the cameraman himself saw no light, but other posts did. Thus an additional directional effect of the rotation into visible light seemed to be involved.

Since so-called thought energy is simply hyperspatial flux which has a minute one-to-one coherence in its crosstalk with the laboratory frame, the section explaining thought photography deals with hyperspatial mechanisms that are also applicable to mystery lights.

THE CYBORG EFFECT AND ORTHOROTATIONAL SENSITIVITY

In Figure 2, I show how it is possible that one team sees the light and a second team does not.

In the inceptive cyborg effect, each person, each instrument, the wiring, other collectors including the sensors, the other paraphernalia of the environment such as railroad tracks, rocks and their minerals, etc. are all cyborged together into a single instrument in the hyperfield domain. This is precisely because the hyperfield domain is the time channel, and all of these exist at the same time. Further, in the experimental locality, the difference in time between observers, equipment, devices, and aspects is small, because the distances between pieces are relatively small. Hence to the hyperfield channel an appreciable degree of coherence exists between the various components of the hypersensory cyborg. Yet the overall pattern of coherence has high points and lower points in it, and pattern groupings that vary with the grouping of components. Thus the subgrouping at the command post, for example, may be expected to differ in its hyperfield characteristics from the subgrouping at Post 2. Furthermore, the bulk of the collection wiring, and the rails, were outside the command post, so the greatest collection might be expected at this station.

In addition, the human components of the subgroupings vary appreciably in their sensitivity to hyperfields. Some persons are more positive or attuned than others, particularly in their unconscious minds. In fact, some persons are quite negative and are squelchers of the hyperfield effects — the negative psi effect is well known in experimental parapsychology. However, it is reasonable to assume that there were no psi-negatives on the Vestigia experiment; but there was probably an appreciable variation in the degree of psi-positive exhibition in the various personal unconsciousnesses. So it is understandable that one post may not see the light, while another would. And with the appreciably greater collection and kindling outside the command post, we would expect the sighting to occur there, if anywhere, as long as a real psi-negative was not present in the command post. And the experiment seems to have exhibited this effect as expected.

Also, I must point out that the visual mechanism for detecting orthorotating energy is different from that for detecting normal visible light, unless the orthorotating hyperenergy is extremely strong and overrides the squelch effect of normal light. (At night the degree required to go into visible light is less.) At any rate, the orthorotational hyperfield energy comes in through the infrared and ultraviolet windows for the most part, and then orthorotates into the visible light region, changing its frequency as it is absorbed by or interacts with a receiver.

Further, the orthorotational energy does not travel through three-dimensional space in the accepted sense that a signal normally does; rather, it is entering this three-dimensional space all at once from a region orthogonal to the entire three-space. It is therefore entering all components of the tuning-receiving instantaneously and simultaneously, or holographically, if one extends the term. Each subgrouping component of the cyborg exerts its own tuning-damping constant(s) upon this holographic signal entry, giving differing degrees of receptive sensitivity, or signal strength, or signal to noise ratio.

So the signal enters each part of the cyborg holographically and the reception characteristics of that portion dampen or enhance the degree of orthorotation into the normal electromagnetic field. Further, the actual orthorotation into the electromagnetic field is occurring primarily at the actual sensor.

For a human being, the primary sensors are the retinal surface of the eye and the skin. The retina is actually a complex structured piece of the brain, so to speak, and extensive nervous system complexes are located there which do extensive on-site signal processing. The unconscious mind of the individual directly interacts at the retina with signals received by the retina, either by hyperspatial orthorotation or by ordinary light. So the individual nervous system is highly variable in its interactions with the hyperfield energy that is orthorotating into ordinary electromagnetic energy in the interaction itself. Briefly, the unconscious state of the observer partially shapes and forms the observed.

In a camera, the sensor is the film. It is thus entirely possible for a camera to record light energy that is holographically rotated in from hyperfield energy without the cameraman himself seeing anything at all. This is especially true when the camera film is sensitive to infrared and ultraviolet to an appreciable degree. A camera containing infrared-sensitive film will interact readily with hyperfield energy because it is open in the magic window between orthogonal frames. A camera containing ordinary film, which is less sensitive to infrared, will interact much less in the magic window because it barely extends into it.

Thus, with other variables held constant, one would expect the infrared camera to record hyperfield energy to a much greater degree than the camera containing ordinary film, and indeed the Vestigia experiment has demonstrated this effect.

Furthermore, the experiment exhibited heightened kindling and collection outside the command post due to the distribution of wiring, components, and rails.

ADDITIONAL FACTORS CONSISTENT WITH THE VESTIGIA EXPERIMENT

First, a cooling effect is often associated with the appearance of paranormal phenomena; this effect is well documented in the literature.

A corollary effect also exists when hyperfield energy is being collected and kindled. Just as lowering the electronic noise in an amplifier increases the fidelity of the signal, lowering the local environmental temperature reduces the "noise" that is blocking the collection and kindling of hyperfield energy. Specifically, reducing the temperature reduces the photon emission and absorption activity of the environment. This lowers the background electromagnetic noise which inhibits orthorotation of the hyperfield energy into electromagnetic field energy. Since photon activity is reduced, the consequent photon squelching of the time channel (precisely detailed elsewhere in this book) is also reduced. This in turn lowers the threshold required for kindling to occur.

Also, a Geiger tube often acts as a collector and amplifier of bioenergy and hyperfield energy. (The association of Geiger counter readings with UFO phenomena has been frequently noted in the literature.)

The Geiger tube may become a detector of hyperfield energy, because the tube's kindling threshold may be significantly lower than that of the environment or of other components such as the observer's eye. Kindling across the Geiger tube's lower threshold simply creates an electrostatic field inside the gas in the tube. In fact, it is the potential ionic current that is the collector, since hyperfields accumulate along probability paths as well as along observationally determined paths, communicating with both future and past. At any rate, the kindling of an electrostatic field in the Geiger tube may result in ionization of the gas if the field is of sufficient intensity. An avalanche discharge may occur and the Geiger counter may indicate a reading (usually appreciable or full scale). This may occur even though no visual phenomena are seen and even though other sensors receive no indication. This reading of the Geiger counter is of course not due to radioactivity. A Geiger *counter does not indicate radioactivity;* rather it indicates appropriate ionization of its internal gas. In this case, the kindling of hyperfield energy into electrostatic field occurred, generating the ionization in the Geiger tube gas.

Note that this occurred in consonance with the visual sighting and the infrared film photos, and when no visual sighting resulted and photos were not taken. Furthermore, as I point out elsewhere, the kindling and burst-in of energy has a discharge time constant, due to the discharge time constant of the oscillation of time that occurs at kindling and burst-in. Depending on the initial amplitude of oscillation at burst-in, the time required to lower the burst amplitude to kindling threshold and below varies. When the amplitude drops below the kindling threshold, kindling and burst-in cease and the hyperfield-induced electrostatic field in the Geiger tube vanishes, stopping the hyperfield-induced ionization of the gas in the tube. The Geiger counter reading then drops back to normal background reading.

The variable amplitude at burst-in and the consequent variation in the time required for the Geiger counter to cease reading the hyperfield-induced ionization were demonstrated in the Vestigia experiment. Furthermore, the Geiger counter showed a reading twice when visual phenomena were not seen and cameras did not record. Of course, no photos were taken during the Geiger counter readings.

Finally, the drop in barometric pressure also lowers the molecular collision activity of the local atmosphere, and lowers the rate of production of collision ions, electric currents, and photons induced by the collision activity. This reduces the electromagnetic noise, which is squelching the collection mechanism and raising the kindling threshold. It reduces the kindling threshold, making orthorotation of hyperfield energy into electromagnetic-electrostatic-magnetic field energy easier.

Thus, according to hyperfield theory, the major features of the Vestigia mystery light experiment are seen to be within normal expectations. Again, this does not prove the hyperfield-orthorotational hypothesis, but it is consistent with it and therefore constitutes an important piece of evidence for the theory.

Also, I should stress that the piezoelectric theory is in fact included in the hyperfield theory, and is a vital part of it. In other words, the hyperfield theory is an extension of the piezoelectric theory, and in my opinion the extension is necessary if the piezoelectric effect is to fit the experimental results. There are no contradictions between the two theories since one is merely an extension of the other.

REMOTE VIEWING

In a classic series of carefully controlled experiments at SRI International, physicists Hal Puthoff and Russell Targ have shown that the human mind can produce evidence of its ability to see at a distance, and also to anticipate the future.

In their protocol one experimenter goes to a distant target, which is selected randomly for him en route, and a subject in the laboratory tries to describe the target scene, both orally and by sketching on paper. The experimenter in the field uses a random number generator to select one sealed envelope out of a group held by a controller accompanying him. The selected envelope is then opened, and that target becomes the target for the experiment. The targets are preselected with rigorous protocol by a group not involved in the experiment.

In the experiment shown here, the target selected was a rather unusually shaped playground merry-go-round, with handrails made of bent pipes, as shown in the two photographs. The laboratory subject, in addition to describing the scene verbally, made the sketches shown at the right. As can be seen, the channel is noisy, but there is definitely signal in it.

Puthoff and Targ also obtained some of the best experimental results when the laboratory subject was asked to describe the scene which the field team would see in the future, the target selection via random number generator not yet having been made. A wide variety of subjects — including persons hostile to parapsychology — were used by Puthoff and Targ in their experiments, with good results.

Each particle of mass in our bodies represents one closure of the entire universe — yielding a holographic reality — and deeper communication with ourselves is identical to communication with the universe, including any part of it, at any distance. Furthermore, in hyperspace the future and the past are all present. Since a particle does indeed exhibit a four-dimensional component for 1/137 of the time, each particle does connect to the future and to the past. With selective tuning

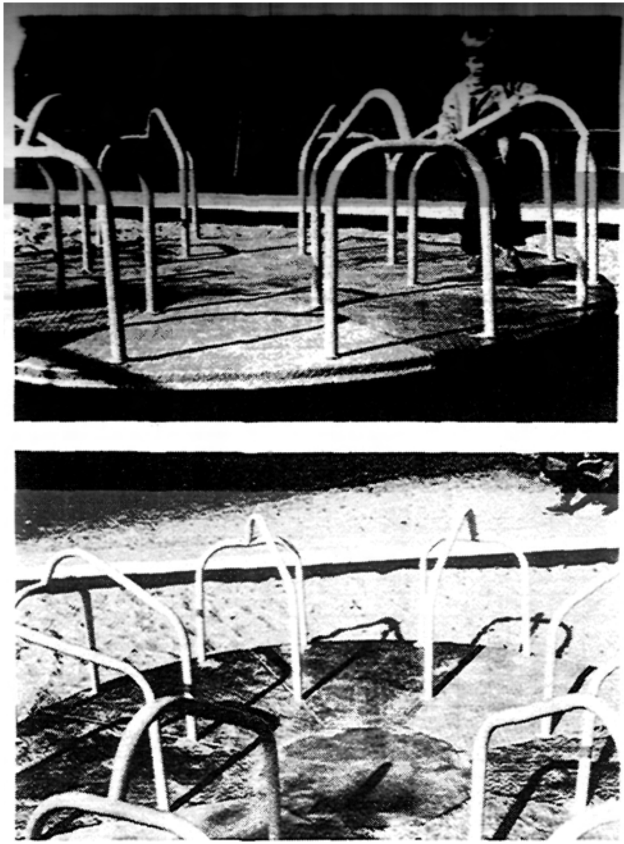

Target: Playground Merry-Go-Round.

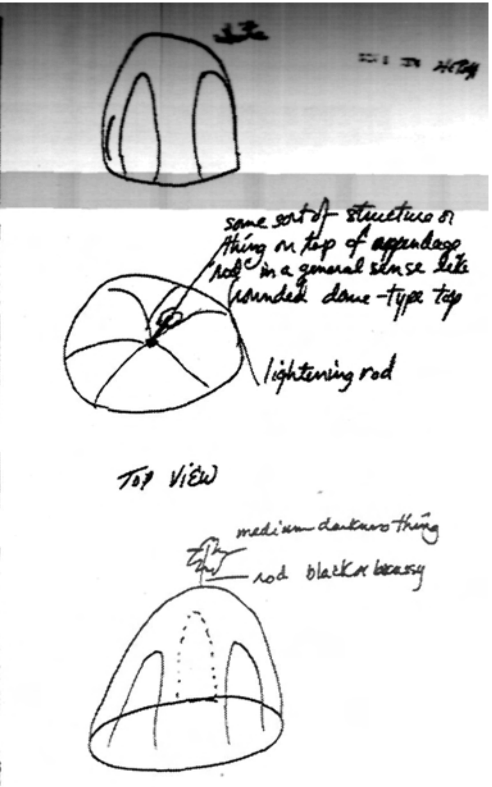
some sort of structure or thing on top of appendage rod in a general sense like rounded dome-type top
lightening rod
TOP VIEW
medium darkness thing
rod black or brassy

Responses.

Photo 3. Remote viewing.

and kindling any part of this holographic reality is accessible. However, because of the smallness of a single selective signal in the midst of the totality, the channel is quite noisy. For this reason skilled psychics ~ persons who have been found to have a greater fidelity of selective tuning - can be expected to produce better results than the normal person.

Puthoff and Targ's results have also been successfully repeated by other experimenters.

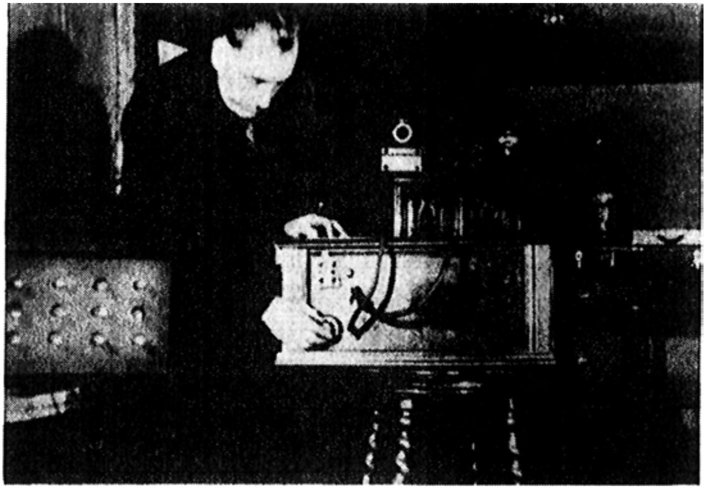

T. Henry Moray makes some final adjustmonts In tuning his radiant energy device to tap zero-point vacuum energy.

THE MORAY RADIANT ENERGY DEVICE

In the early 1900's, Dr. T. Henry Moray of Salt Lake City produced his first device to tap energy from the metafrequency oscillations of empty space itself. Eventually Moray was able to produce a free energy device weighing sixty pounds and producing 50,000 watts of electricity for several hours. Ironically, although he demonstrated his device repeatedly to scientists and engineers, Moray was unable to obtain funding to develop the device further into a useable power station that would furnish electrical power on a mass scale.

As a boy, Moray had been deeply inspired by the greatest electrical genius of all time, Nikola Tesla. His imagination was especially fired by Tesla's claims to have knowledge of an energy source greater than ordinary electricity, and by Tesla's emphasis on frequencies as the stuff of the universe. When Moray finished high school in Salt Lake City, he went abroad to study, and took resident examinations for his doctorate in electrical engineering from the University of Uppsala, Sweden, during the period 1912—14. Returning home, his diploma and credentials were interrupted by World War I, and the University mailed him these items in I918 after the war.

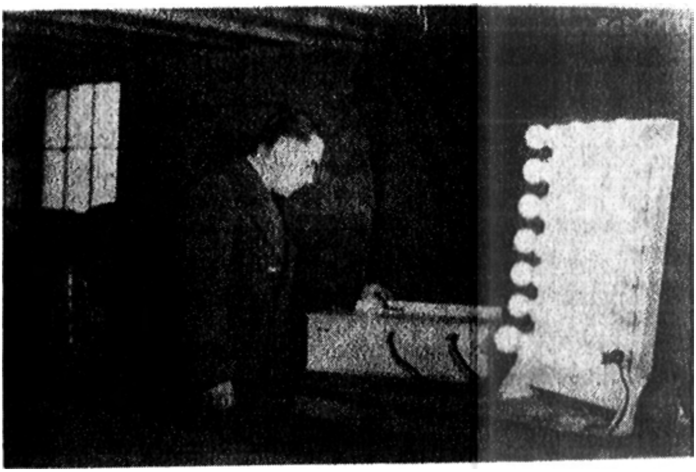

Here **the** Moray radiant energy device is providing free power to 35 100-watt lamps and a 1200-watt Iron.

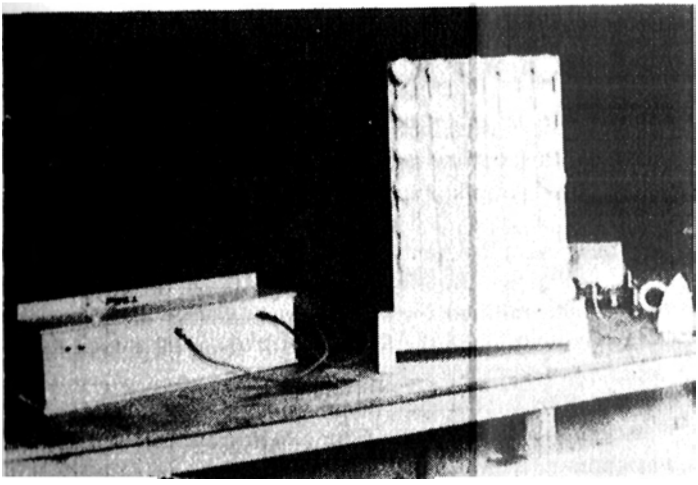

Once tuned in, the power continues and is free for the taking.

Photo 4. The Moray radiant energy device.

Shortly thereafter, Moray produced his first elementary device that delivered measureable electrical power, and he continued to work diligently on energy devices when he had time. In the 1920's and 1930's he steadily improved his devices, particularly his detector tube, the only real secret of the device according *to* Moray himself. In his book, *The Sea of Energy in Which the Earth Floats,* Moray presents documented evidence that he invented the first transistor-type valve in 1925, far ahead of the officially recognized discovery of the transistor. In his free energy detector tube Moray apparently used, inside the tube itself, a variation of this transistor idea — a small rounded pellet of a mixture of triboluminescent zinc, a semiconductor material, and a radioactive or fissile material. His patent application (for which a patent has never been granted) was filed on July 13, 1931, long before the advent of the Bell Laboratories' transistor.

In test after test Moray demonstrated his radiant energy device to electrical engineering professors, congressmen, dignitaries, and a host of other visitors to his laboratory. Once he even took the device several miles out in the country, away from all power lines, to prove that he was not simply tuning in to energy being clandestinely radiated from some other part of his laboratory. Several times he allowed independent investigators to completely disassemble his device and reassemble it, then reactivate it themselves. In all tests, he was successful in demonstrating that the device could produce energy output without any appreciable energy input. According to exhaustive documentation, no one was ever able to prove that the device was fraudulent or that Moray had not accomplished exactly what he claimed. On the other hand, the records are full of signed statements from physicists, electrical engineers, and scientists who came to the Moray laboratory as doubting Thomases and left with the complete conviction that Moray had indeed succeeded in tapping a universal source of energy that could produce free electrical power.

But in the face of all of this, the U.S. Patent Office refused to grant Moray a patent, first, because his device used a cold cathode in the tubes (the patent examiner asserted it was common knowledge that a heated cathode was necessary to obtain electrons) and, second, because he failed to identify the source of the energy. All sorts of irrelevant patents and devices were also presented as being infringed upon or duplicated by Moray's work. Each of these objections was patiently answered and nullified by Moray; nonetheless, the patent has still not been issued to this day, although the Morays still keep the patent application current.

One of Moray's efforts to develop the machine involved an association with the Rural Electrification Agency for a short time before World War II. At that time, the R.E.A. was apparently infiltrated by Communist sympathizers and high level officials of a decidedly pinkish tinge. These officials continually urged Moray to turn over all details of his device to the Soviet Union, and even arranged the visit of high-level Soviet scientists to the Moray laboratory to see the device in operation. On the initiative of the Communist-infiltrated R.E.A., one person — let us call him "Z" — spent about two months in Moray's laboratory, and succeeded in worming his way into Moray's full confidence. Moray eventually disclosed most of the details of the construction of his special valve to "Z" — the only person in whom Moray ever completely confided.

There is strong reason to believe that "Z" was a Soviet agent, and that this is where the Soviets first obtained the impetus to develop the hyperspace amplifiers later used in their psychotronic weapons.

However, Moray became quite alarmed at the continued attempts of his R.E.A. contacts to get the device into the hands of the Russians. He eventually concluded that he had become involved with a governmental group filled with radicals and reactionaries. Moray became concerned that fifth column activity was actually directed against him in an attempt to steal his device. Quotes from the *Salt Lake Tribune* of December 2, 1941, attributed to Representative Thomas D. Winter, imply that Moray's suspicions of the R.E.A. were well founded, since Representative Winter called for a full-scale investigation of the R.E.A. on the grounds of Communist infiltration. Indeed, Moray was wounded by gunshot in his own laboratory on March 2, 1940, which seems to suggest that his fears and suspicions were based on fact. Moray severed his association with the R.E.A. in February 1941.

However, his basic unit had been destroyed by a hammerslinging witness in 1939; it is not clear whether or not this was the work of "Z" or of someone else. According to his son, John Moray, the man who broke his unit, as well as other interested groups, wanted complete disclosure of the materials and construction - nothing more or less. John Moray, who operates the Research Institute in Salt Lake City, has been trying to continue his father's work since the basic unit was destroyed. Dr. Moray himself died in May 1974.

According to John Moray, highly energetic cosmic rays from space are tapped by the machine, which is in subharmonic resonance with this high-frequency energy level, and it converts this energy level into a usable form of electricity. However, John Moray's use of the term "cosmic ray" is not necessarily the same as that of modern physics, but in fact is the same as the present concept of "zero-point" energy of vacuum. T. Henry Moray envisioned all space filled with tremendously high frequency vibrations carrying vast and incalculable amounts of pure raw energy. He envisioned the dynamic universe as a turbulent source of great energy, just as the ocean waves carry energy throughout the earth. This was also the vision of Tesla, and after him of Clifford and Einstein, who turned the attention of general relativity to the problem of the nature of the vacuum itself. Clifford and Einstein founded a branch of physics that has come to be known as quantum geometrodynamics, the study of energetic change that occurs in little pieces, including the concept that very small lengths of space, or pure vacuum, themselves oscillate at great frequency and with great energy. In Moray's day relativity was still a strange and unproven branch of physics, suspected and rejected by most of the physicists of the day, and quantum physics was still in the process of being worked out. There was no theory whatsoever predicting that empty space itself not only contained prodigious quantities of energy, but in fact *was* prodigious quantities of energy. But slowly, over the decades, the picture has changed, and the modern followers of quantum geometrodynamics assert the truth of Tesla's original vision. Today we know that one cubic centimeter of pure vacuum contains enough energy to condense into 10^{80}—10^{120} grams of matter! Thus the major part of Moray's thesis — that vacuum itself contains unlimited energy — is vindicated today. In this sense empty space is like a gigantic, restless ocean, and Moray's free energy "tapping" device is no more mysterious than the water wheel. In other words, his thesis that the energy is there to be tapped is correct; it only awaits a practical method to tap it in order to solve the energy problems of mankind forever.

Moray thus is vindicated as a man ahead of his time, who simply built a device before any theory existed to explain its operation. Moray met with constant opposition, and his life and that of his family was anything but pleasant. Certain pressure groups constantly tried to force him into selling for almost nothing, or to disclose the secrets of his valve's construction. He was often attacked and he was sometimes shot at on the city streets. In fact, his life was threatened so often that he was forced to install bulletproof glass in his automobile. His laboratory was broken into, some of his components and papers were stolen, and his dogs were continually being killed. Moray was shot in his own laboratory, and he himself always carried a gun. Because he was harassed ceaselessly, over the years he became understandably suspicious and close-mouthed about his work. He sometimes greeted visitors at his desk with a loaded pistol lying on the desk within easy reach, and occasionally confirmed that he would not hesitate to shoot if he were attacked or threatened. One of his greatest fears was that big interests would take up his invention and simply shelve it to keep it from benefiting the public. When large companies made him offers, he always demanded written guarantees that the device would be put into production and sold to everyone, once it was developed.

Moray also realized the potential of his device as a weapon. He was fully aware that the only difference between a controlled energy device and an explosion is the rate of release of the energy. According to John Moray, his father received an offer to go to Japan in 1938 because he had built a deathray which operated off the device. According to John, a representative of the Japanese government came to the laboratory and offered a position to Moray, but he refused. Allegedly Moray had managed to rig the device so that it projected a ray of energy in a beam, and could kill mice instantly at over fifty feet. When radiated by the beam, the mice were carbonized immediately. They appeared frozen, but nothing was left except their shells, and they simply fell apart when touched.

In one experiment Moray ran his device for 157 hours without any connection to external power sources, and produced over fifty kilowatts of power during the test. He also found that an additional fifty kilowatts could be added by simply providing another tap further back in the circuit. When he shut the device off from this test, he had proven once and for all that the device was generating electrical energy from free and natural sources without batteries or external power. During this test nothing in the machine heated up; instead, all parts of the circuit ran absolutely cold. This alone is totally unexplainable by ordinary electromagnetic theory, and it strongly implies the truth of Moray's assertion that the device simply collects the energy in each of its stages in a subharmonically resonant manner, in synchronization with the extremely high frequency cosmic oscillations. In other words, since the parts of the machine ran cold, it is clear that the energy was being simultaneously collected at each stage rather than being processed through the individual stages in serial order, since serial processing in the conventional electrical sense would lead to resistance heating of the circuit elements.

Moray's device used twenty-nine stages of his special detector valves, which were difficult to produce, costing about five hundred dollars each. Only about one in four proved suitable for operation. He also had difficulty in obtaining sufficiently pure materials to make his special mixture for the pellet that enabled tube operation in a one-way gating fashion. Moray explained that his device was based

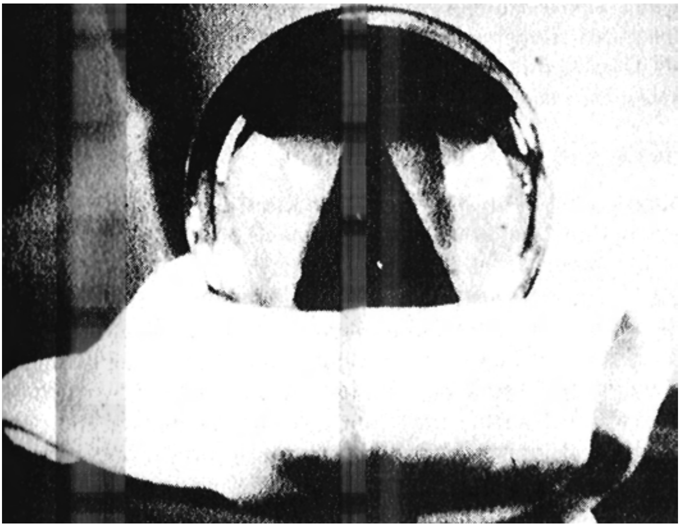

Photo 5. An Atlantean power crystal?

on the discovery of a mixture that would act as a one-way gate for the high frequency oscillations of space, so that the energy could go through the material more readily in one direction than another. Thus it was like a one-way gate valve to an ocean wave; the energy "water" could flow in in each valve, but was prevented from flowing back out. The assemblage of multiple stages thus provided a series of collectors which contained enough energy to be useful. Theoretically there was no limit to the number of collectors that could be added, and so there appeared to be no limit to the energy that such a device could produce.

AN ATLANTEAN POWER CRYSTAL?

The next two photographs are of a most amazing quartz crystal sphere removed from a chamber in a pyramid underneath the surface of the ocean in the Bermuda Triangle. Dr. Ray Brown purportedly removed the object in a dive while treasure-hunting with several friends after a storm had stirred the sandy ocean floor in 1968. Brown describes how he swam into a chamber in the pyramid after swimming around it three times, and how he saw seven stone seats surrounding two handlikc stone holders for the crystal in the center of a table or dais, with a two inch metallic rod running down vertically from the roof of the stone chamber and pointing directly at the crystal. Brown plucked the crystal from the holder and ascended to the surface; he found that his companions had brought some nonoperative objects to the surface which appeared to be some sort of strange electrical apparatus.

Brown himself had a strange foreboding and a strong impulse against returning to the site, and so he refused to do so. Three of his companions reportedly returned at a later date, and their boats were found floating abandoned in the Triangle. The three men were never seen again.

The crystal does indeed have some strange properties. In the first picture one can clearly see a very sharply outlined, pyramid shaped inclusion inside the quartz. The pyramidal inclusion is dark, but the crystal is absolutely clear. However, the second photo shows that the quartz is milky when seen from a different angle. Here three pyramids can be seen.

Other objects have been seen and photographed in the crystal from time to time. In *The Pyramid Guide,* Vol. V, No. 4, there is a photograph of the crystal showing a very distinct, humanlike iris and eyelid appearing in it, making it resemble nothing so much as a giant human eye. In that photo the three pyramids are not visible.

While I have not personally investigated the crystal and examined it in detail, some general remarks can be made. (1) Brown reported finding the pyramid after a huge storm had stirred the ocean, including the ocean's sandy bottom. This had revealed outlines on the bottom resembling buildings, which had attracted the attention of the treasure hunters. (2) Such a storm, over the ocean's great water mass, is an excellent kindler of bioenergy. In other words, Brown and his companions were definitely in a place which should have had an enormous kindling of bioenergy from the biosphere and the collective human unconscious. (3) Sufficient publicity has been given the Bermuda Triangle's mysterious disappearances to have its alleged ability to open a window between worlds implanted deeply into the unconsciousnesses of a large number of persons. (4) Brown was with a group of persons who were sharing the same sensations with the storm and surrounding area, so there was sufficient coherence of their personal unconsciousnesses to accomplish at least some degree of tuning. (5) The legends of Atlantis were in a great revival period in the late 1960's from the popularizing of Edgar Cayce's work and other material, as indeed was the Egypt/pyramid/Atlantis mythology in general.

So conditions were very ripe for a tulpoidal contact (see Part Two) of extensive magnitude — perhaps even to the point of tuning in the ruins and pyramid for a period. Brown also reported sensing an omniscientlike presence, which is symptomatic of many such tulpoidal contacts or materializations.

In such a case, Brown could have actually swum into such a pyramid that had materialized from the collective unconscious — which after all has the psychokinetic power of Uri Geller times ten to the four billionth power or so, and which largely maintains the format of our physical reality in the first place. The collective unconscious has no difficulty in creating even many alternate worlds or materializing and dematerializing entire areas, let alone in producing a single pyramid and a ruined city.

Brown's action in plucking the crystal out of its holder and swimming back to the surface would also have constituted a tuning/kindling which was "returning with the crystal into the normal world" — in which case it could have been tuned into complete stability so that it would endure, rather than fade away as do most tulpoids.

Until we have developed psychotronic instruments to scan the crystal and reveal its true story, we cannot say for certain that any of the above actually happened, and that some sort of delusion or fakery was not involved. The point is, it could have happened just as Brown reported it, in the theory I have constructed in the second part of this book.

Until we free our minds from the present bias that physical reality is always permanent and unchanging, we shall never be able to adequately investigate such phenomena as Brown's strange crystal.

THE CRYSTAL SKULL

It appears that at least some of the ancient peoples understood certain aspects of psychotronics and even possessed some psychotronic devices.

An example of such a psychotronic device is shown in the next two pictures, reprinted here with the kind permission of Bill Cox, from *The Pyramid Guide,* No. 17, May-June, Vol. Ill, No. 5.

To quote directly from *The Pyramid Guide:*

> **These are two views of the famed crystal skull... completely hand-formed, possibly centuries in the making from a single block of hard quartz crystal. It was recovered from beneath the altar ruins, within the jungle-covered, 7 1/2 acre citadel of the ancient Mayan city of Lubaantu'n by explorer F.A. Mitchell-Hedges in 1927. A several-stories-high pyramid was also found within the citadel complex. The skull, possibly of Atlantean and/or Babylonian origin may have been brought to the Americas by the Phoenicians around 1,000 B.C. Frank Dorland says historical records suggest the skull may have been held in the London inner-sanctum of the Knights Templar prior to the Holy Wars. The high priests probably executed ceremonial magic with the skull; a ribbon-like prism in the cranium acts as a magnifier. Hollow light pipes projecting upward from the base permit light reflections from the eye-sockets. The moveable jaw easily coordinated motion with speech. Lesser quality crystal skulls exhibited in the British and Paris museums, and miniature versions, lack the Mitchell-Hedges skull's brilliant craftsmanship**

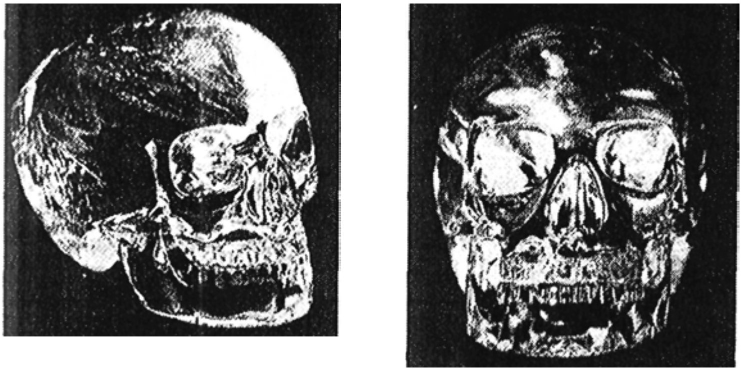

Photo 6. The crystal skull.

Two views of the famed crystal skull. Completely hand-formed, possibly centuries in its making from a single block of hard quartz crystal. It was recovered from beneath the altar ruins within the jungle-covered seven-and-a-half acre citadel of the ancient Mayan city of Lubaantu'n by explorer FA. Mitchell-Hedges in 1927. A several-stories-high pyramid was also found within the citadel complex. The skull, possibly of Atlantean and/or Babylonian origin, may have been brought to the Americas by the Phoenicians around 1,000 B.C. The high priests probably executed ceremonial magic with the skull; a ribbon-like prism in the cranium acts as a magnifier. Hollow light pipes projecting upward from the base permit light reflections from the eye sockets. The moveable jaw easily coordinates motion with speech. Lesser quality crystal skulls exhibited In the British and Paris museums, and miniature versions, lack the Mitchell-Hedges skull's brilliant craftsmanship.

One of the major African tribes is also reported to have once possessed such a crystal skull as a holy object and the center of their religion. Their skull was reportedly stolen by a white thief in the early 1800's,

So let us now discuss sonic of the peculiar properties of such a device.

First, quartz is a very hard substance and not easily worked at all. Making such a perfectly carved piece, with removable hinged jaw and eye lenses, must have consumed a tremendous amount of manual labor and considerable time, even centuries. Such an effort is not lightly undertaken; usually there is an overpowering reason for such persistence. In this case, there may well have been such a reason, and ancient priests may well have known it.

Quartz has magic qualities from a psychotronic point of view. It is open to both the ultraviolet and the infrared, and so it possesses two magic windows into the hyperframes, bioframes, orthogonal frames, and other realities. Since the third and higher bioframes (orthoworlds) are all mind worlds, quartz has open magic windows into the mind and mind energies. Thus Frank Dorland surmises correctly that the device can amplify and focus mental energies.

Furthermore, quartz is a piezoelectric crystal. Being crystalline, it possesses a lattice, a regular array of molecular stages. Thus it possesses a large number of identical stages, which is important for hyperchannel amplification.

Properly shielded against visible light, or in dim light, the crystal skull thus can function as a mental amplifier in the hands of a skilled user. Also, the quartz it piezoelectric; multistaged electrical piezoelectric currents are natural hyperenergy-hyperfield collectors, and under the proper conditions the quartz can produce heat and light, since collected hyperfield energy can be orthorotated into electromagnetic field by kindling. It can even produce these effects at a distance due to the hyperchannel circulation patterns surrounding a magnetic field or a localized area of magnetic field. The easiest place to produce effects with the skull would be inside another human head (in the brain).

So, in the hands of a skilled practitioner, the skull is (1) a collector of bioenergy, capable of turning this into electromagnetic energy and physical effects, (2) a form resonance inductor, i.e., a sort of super witness which matches the general shape of the human skull and is capable of resonating with a human skull (and thus with its contained brain) at a distance through hyperspace, and (3) a psychotronic device capable of producing psychotronic effects such as the augmentation of healing energy, psychic attack, telepathy, clairvoyance, precognition, and psychokinesis, where these initiative abilities are possessed by the user or practitioner.

Thus, in the hands of an adept, the crystal skull is indeed a formidable device, and one can well understand how the motivation existed to make it, even though its production may have taken centuries. Since in the ancient days knowledge was zealously guarded and usually incorporated directly into religion, such psychotronic artifacts as the crystal skull would have been regarded as the most powerful, hence the most sacred, of objects. One can therefore speculate that the elite of the elite of the priesthood were the only ones who knew of and were taught how to use the skull, and that this information was guarded extremely closely. The legend of such a skull existing as a central part of the religious magic of an African tribe is not beyond belief. Ordinary crystal balls, which are certainly made more easily, may have originated from the secret rites connected with the skull. An ordinary good quality, clear quartz crystal may well have been the substitute for priests who did not belong to the supreme inner circle, or the device used when a skull was not available.

I have seen at least one picture of an optical image which spontaneously formed in the crystal skull; the image closely resembled that of the Mayan astronomical observatory at Chichen Itza.

To give a simple example of how the skull may have been used by a skilled priest, let us suppose the priest had an enemy he wished to disable or kill. With the proper psychic exercises he could have induced an increase in his own psychic energy. Then, using the crystal skull, he could simply have visualized the image of his enemy's face, and visualized the energy or light pouring into his enemy's head. The stability of the imagery is more important than effort of will.

At any rate, steady application of this imagery starts the bioenergy projection into the enemy's head and brain, and it collects there. Collection to the kindling threshold starts turning the bioenergy into electromagnetic field. At this point, a host of effects could be produced, depending upon the specific wish and induction by the priest. The effects include sharp pain (such as migraine headache); a leaden mass or frozen mind in which the brain activity itself is slowly frozen and stopped; the generation of a strong, overpowering emotion such as rage, hatred, panic, or terrible sadness; a sharp attack on the mind itself, as if a saw or knife were slashing a physical object to bits; numbness of the body or selected portions of it; interruption of the heart's functioning; kindling of the brain and nervous system into seizures, convulsions, or violent muscular spasms (capable of breaking bones); and an increase in blood pressure until the vessels swell and burst. In the hands of a priest who was strong in psychokinetic ability, this amplified ability would have been projected through hyperspace to the unfortunate victim's vicinity; objects such as stones could suddenly have levitated and hurled themselves at him, bushes and small trees could have enveloped him, etc. All in all, the skull can be used as a terrible weapon.

A few of these effects, and others I have not described, are presently in use by certain lunatic fringe groups in the United States; they use basic devices other than a crystal skull. I have been subjected to several strong attacks, and can vouch for their effectiveness if the target person is unskilled in shielding himself or evading such attack. In two cases I was nearly killed, and in a third case in substantial jeopardy.

Use of the crystal skull by a group of priests would give even more power, for from such a group the kindling level at which bioenergy orthorotates into electromagnetic field energy is much more easily approached. The inceptive power is of course usable for either good or evil purposes. Good purposes would include amplifying psychic healing; curing fevers and other infections; stopping internal bleeding; dematerializing growths and tumors; placing a person into deep anesthetic sleep so that a surgical operation can be performed; treating soil, seeds, or plants to assist sprouting and growth; treating emotional disorders with cancellation thought forms (contrary forms), and projecting them directly onto the unconscious to neutralize the disturbing form; and communicating telepathically at a distance.

A 300-year fabrication period is more credible if we recognize that the quartz crystal would have been usable from the beginning, just as is a crystal ball. So the high priests could have used the rare clear crystal (the skull is made from a single crystal), while priests recently initiated into the level that knew of crystal devices worked on it when it was not needed for use. Such a practice would explain why other skulls less finely worked have been found; these had simply not been as highly finished as the Mitchell-Hedges skull.

Furthermore, cutting off an enemy's head and exhibiting the skull was a common practice among many primitive tribes as a way of showing power. Crystal devices could have been used as a means of combining psychotronic effects with prevailing religious practice and beliefs. The fact that this eventually yielded a psychotronic amplifier of great power in the hands of a skilled priest would have led to the zealous guarding of the knowledge and the device from all but a very few of the elite.

METAL BENDING

The next remarkable sequence of photos from a Super 8 movie film taken by James Bolen, editor and publisher *of Psychic* (now *New Realities)* magazine, shows Israeli Uri Geller breaking a dinner fork in two through mind over matter. The fork, which Bolen personally verified as being intact before the demonstration, gradually becomes pliable at its midsection as Geller rolls his thumb and index finger over it. The fork finally breaks apart, the prong part clinging slightly to the handle just before it drops away, suggesting that the stainless steel momentarily became plasticlike.

Here the kindling is taking place in the nuclei of the metal atoms and also along the lines of field force in the bonding lattice. The protons in the nuclei may become quarklike due to partial extinguishing of the pions which create their electrical charges. The softening of the electrical field directly softens the ability to hold electrons and rearranges electron orbits. In addition, kindling is occurring in the orbital electrons, partially extinguishing their charge also. The overall effect is for the metal to become plasticlike as lattice bonds are severely weakened. For a metal break due to these effects, the metal in and near the fracture should show the results of severe electromagnetic fields at the localized level, e.g., as if subjected to intense heat from an internal laser action. This has indeed been found to be the case in other experiments, notably by Byrd and Franklin.

THOUGHT PHOTOGRAPHY: STELLA LANSING

Stella V. Lansing is a remarkable person who has captured a large number of authentic thought photographs on film, and in whose presence others often get thought photographs when they operate their own cameras. For several years her work has been investigated by the psychiatrist and noted researcher, Dr. Berthold Schwarz, who has published numerous papers in scientific journals on his studies of Mrs. Lansing. The late J. Dunninger also observed Mrs. Lansing's work and concluded that it was genuine, and that no magician could accomplish by sleight of hand or other trickery the remarkable results she obtained.

In Stella Lansing's photographs all the evidences and signatures of tulpoidal or thought energy kindling into the first biofield, electromagnetic energy (light), are seen (see Part Two). Typical, metallic-looking, clamshell, UFO-like images are often obtained, most often with several objects arranged in a clocklike circle symbolically: the unconscious may well be aware that the time channel is the paranormal channel, and symbolically express this in a clockwork pattern suggestive of time.

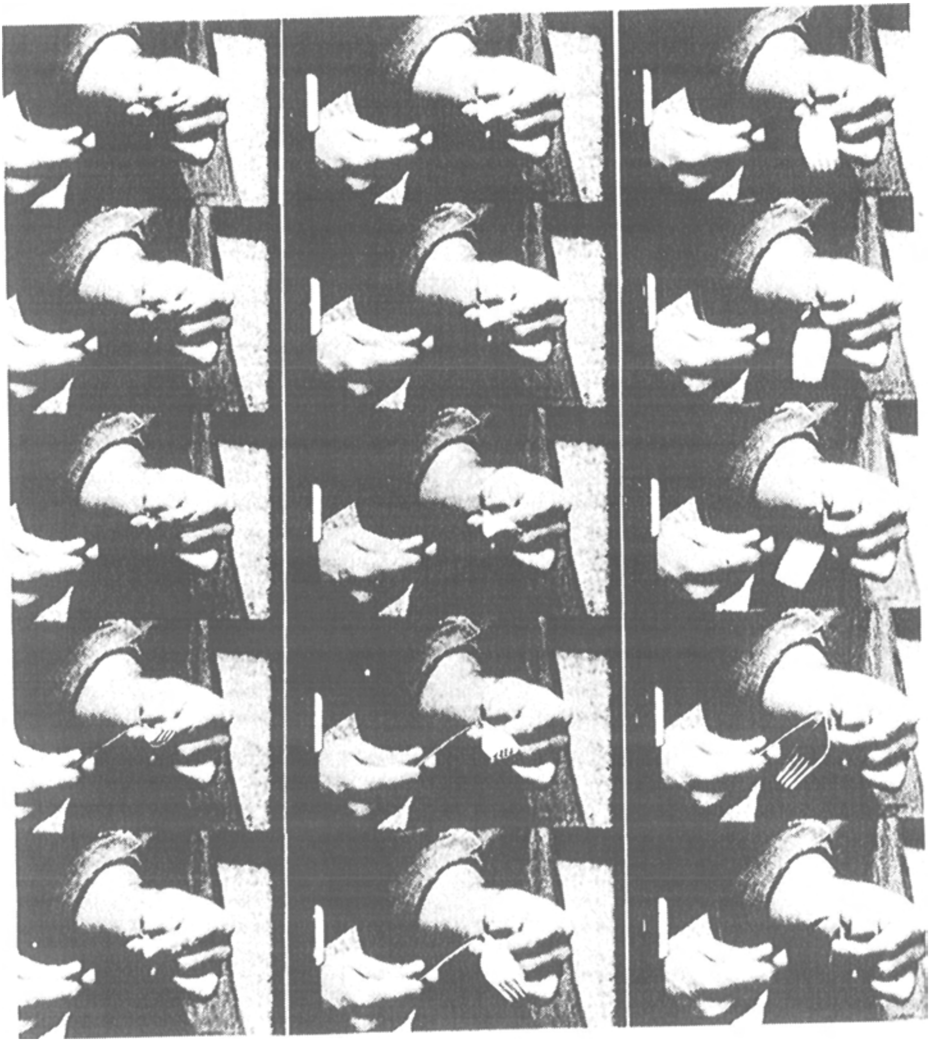

Photo 7. Metal bending.

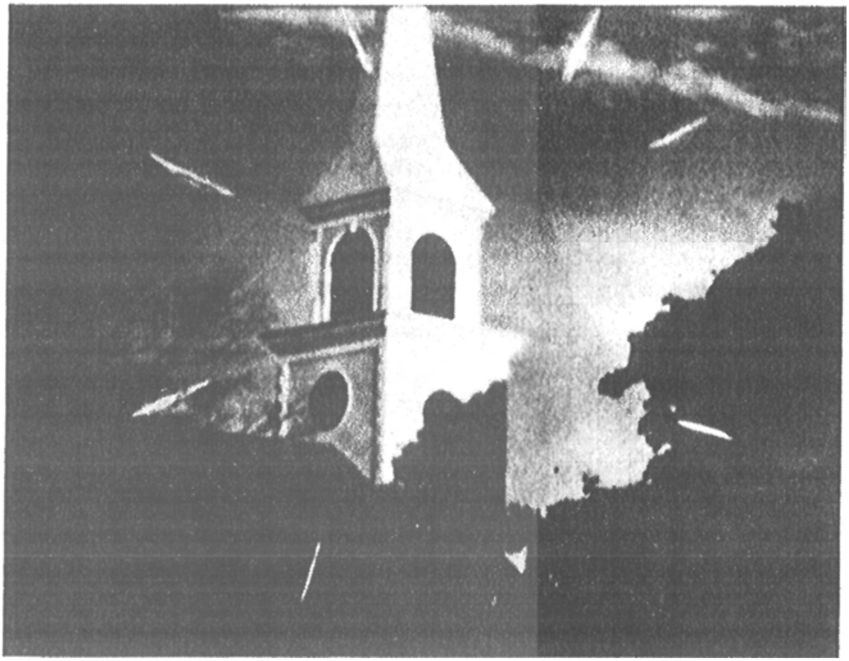

Late evening clockwork pattern of "clamshell-like objects" obtained when photographing a church steeple.

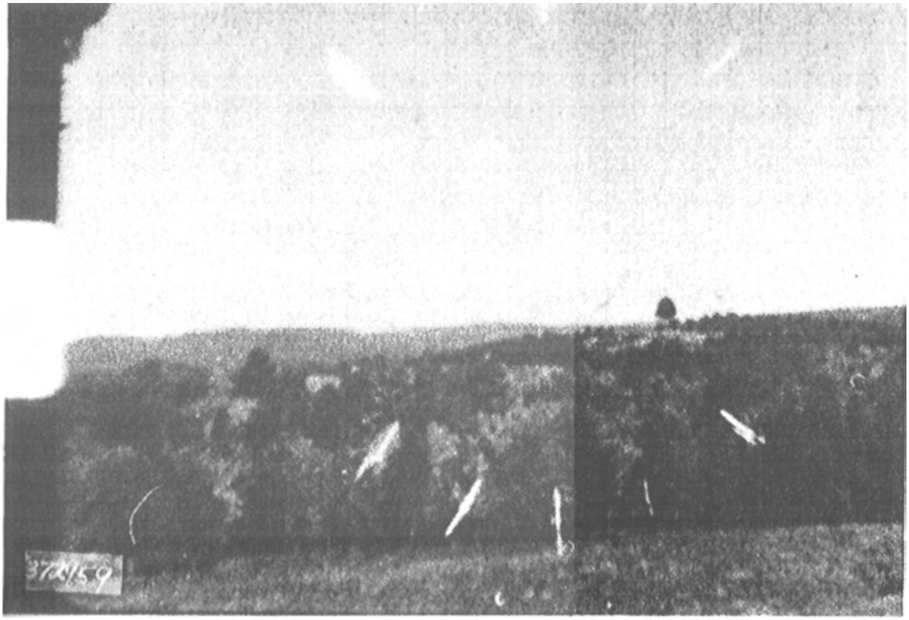

First daytime clockwork pattern, Route 47, Amherst, Mass., September 1972.

Photo 8. Clockwork patterns.

Just as Geller and Kulagina have been noted to transfer psychokinetic ability to other talented persons who were in their presence for a period of time, Mrs. Lansing's clockwork patterns and psychokinetic abilities appear to have stimulated another person's abilities in similar fashion. Paul Koslouski is a researcher who worked with Mrs. Lansing for a short time, and in his own thought photographs the clockwork pattern so characteristic of Mrs. Lansing's pioneering efforts dutifully appeared.

Mrs. Lansing is a brave and gracious lady, and her significant work with thought photographs is important to the understanding and advancement of parapsychological science.

THE DISPLACEMENT EFFECT

The next picture was taken about 1938 in Chicago with a camera on a tripod and a timed release. It was taken by Paul Trovillo, who is the gentleman sitting on the bench with somewhat of a problem of transparency and partial disappearance.

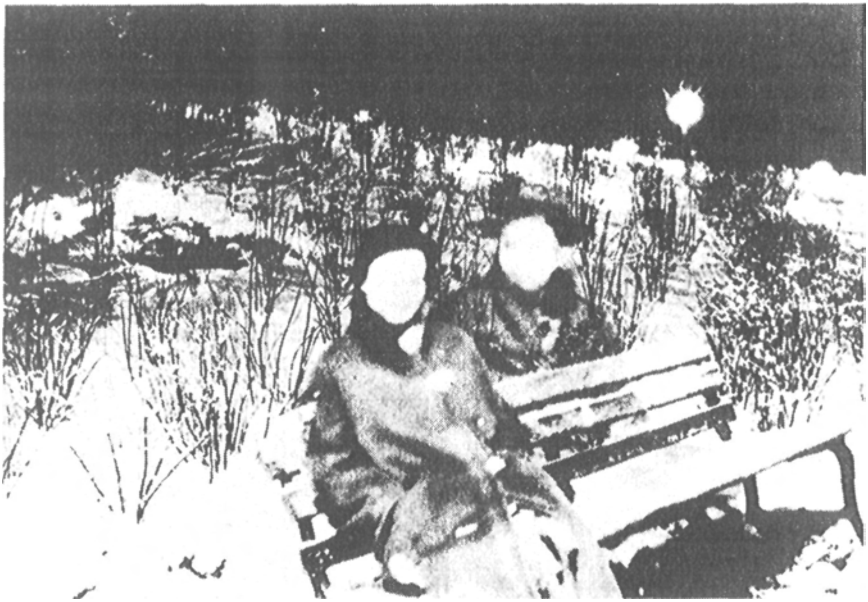

Photo 9. Displacement effect.

The light is by an overhead arc light, which is rich in ultraviolet (one of the magic window frequency bands in the hyperchanncl crosswalk between orthogonal worlds). Pan film was used in the camera, and the picture is of Paul and FerneTrovillo. Note the bushes through Paul's left shoulder and through the slats of the bench at approximately Paul's waist. Also note that the background is in excellent focus.

1. Robert Pavlita, Czechoslovakian engineer, and his daughter.

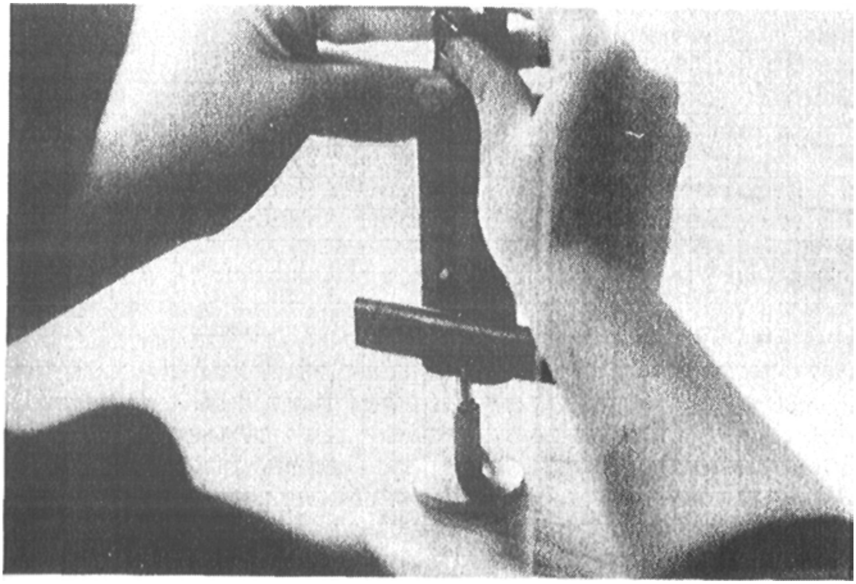

2. Device becomes a psychoenergetic "magnet" when charged by the human being—and will pick up materials, including nonmagnetic objects.

Photo 10. Pavlita's psychotronic generators.

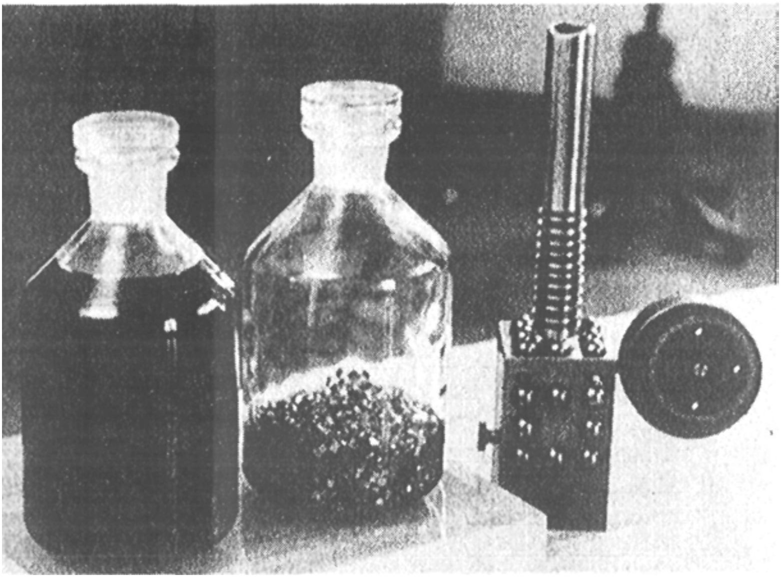

3. A generator that can precipitate solutes from solution. The jar to the left contains a dense solution; when the generator was placed over identical solution in the jar to the right, the precipitate shown in the jar resulted.

Occasionally the kindling of bioenergy (which is greatly eased in ultraviolet light) leads to eddies of hyperchannel connections between separated portions of the ordinary frame. The normal three-dimensional frame is constructed action quantum by action quantum, and each quantum is fissioned and fused individually to give individual increments or jumps of time and length. Appreciable kindling intermixed in the frame construction can provide other geometrical paths for light, so that the light rays during one or more segments of their straight-line path arc actually flipped into and back out of hyperspace. In cases such as this, one can often see right through a physical object, or even inside it (see Part Two).

I have worked with a psychic group in the American Association of Meta-Science, and have seen one experiment where similar effects were obtained, with the camera on a tripod, in a picture taken by my wife.

Excellent pictures of the Loch Ness monster were recently taken by Doc Shiels. These pictures have been subjected to computer analysis by Ground Saucer Watch (GSW) - and GSW was alarmed at the discovery that the monster in the portrait exhibited transparency. Indeed, for a materialization less than complete, which the monster must be if it is to keep disappearing, one would expect or even demand such transparency, even though a large body of water is a good collector for kindling of bioenergy and tulpoidal forms (UFO's are also notoriously connected with rivers, lakes, and the ocean).

Note also that the Dennis Billings UFO picture demonstrates the same sort of partial transparency. There is a readily understood physics that applies to these effects, but the effects are not contained in the present monocular interpretation of physics and reality.

PAVLITA'S PSYCHOTRONIC GENERATORS

In Czechoslovakia an engineer named Robert Pavlita has been building and demonstrating psychotronic generators for about thirty years. These are devices of various shapes and sizes and composed of materials such as steel, iron, brass, and copper, and they often contain mysterious symmetries of pattern, holes, and shape. The devices for the most part charge up with thought energy when subjected to human contact or eye contact, and then perform various functions such as precipitating a solution, turning, picking up or magnetizing nonmagnetic materials, and killing insects. The devices thus accomplish orthorotation and kindling of thought energy. Pavlita has admitted that his devices could be scaled up to serve as weapons — unfortunately, every tool can be used for either good or evil. He has demonstrated a great many times the killing of insects by pointing a charged rod at them. He also admitted that in an accident his daughter became semiparalyzed and her life was in grave danger, requiring him to work feverishly without stopping for about two days to build a second device to reverse the effects of the first. Pavlita has also demonstrated that his psychotronic devices can either stimulate or retard plant growth, depending on which polarity the plant is exposed to.

The loose information net of which I am a part has recently learned that Pavlita is now in charge of a secret project that has succeeded in building two weapons, one of about two hundred miles range and the other of unlimited range. No further details on the weapons are available.

Pavlita is a pioneering genius, and it is to be hoped that he will eventually release the secret of his psychotronic devices to the world for use in the healing arts and other beneficial sciences. Bioenergy/hyperenergy is real, and Pavlita has scored a major breakthrough in building simple devices to harness it.

CELL-LIKE INVISIBLE TULPOIDAL FORMS

Trevor James Constable has succeeded in evoking and capturing many of these forms on film. The first photo was taken by Constable on 25 August, 1957 in the Mojave Desert, and shows an amoebalike or cell-like bioplasmic form containing shapes that resemble nucleoli, vacuoles, and other cellular structures. The invisible object was at first directly overhead, but moved to positions that enabled inclusion of local terrain in the pictures.

In material presented in Part Two of this book, I show that all that a physical form or physical body is is a total tulpoid, *i.e.*, a form that can be shown to exist in each and every mind. All that a living biosystem is is a one-to-one coherence established between such a total tulpoid (physical form) and a monocular tulpoidal universe (mind world or hyperframe). Furthermore, all possibilities exist concretely in the various hyperworlds. Thus Constable's plasma creatures do indeed exist concretely—but in invisible, orthorotated hyperworlds (mind worlds). The revolutionary discovery by Constable has been a direct, straightforward way to evoke and photograph such bioplasmic tulpoidal forms. His experimental work is of absolutely fundamental importance, and I would not hesitate to compare its ramifications to those of the Michelson-Morley experiments.

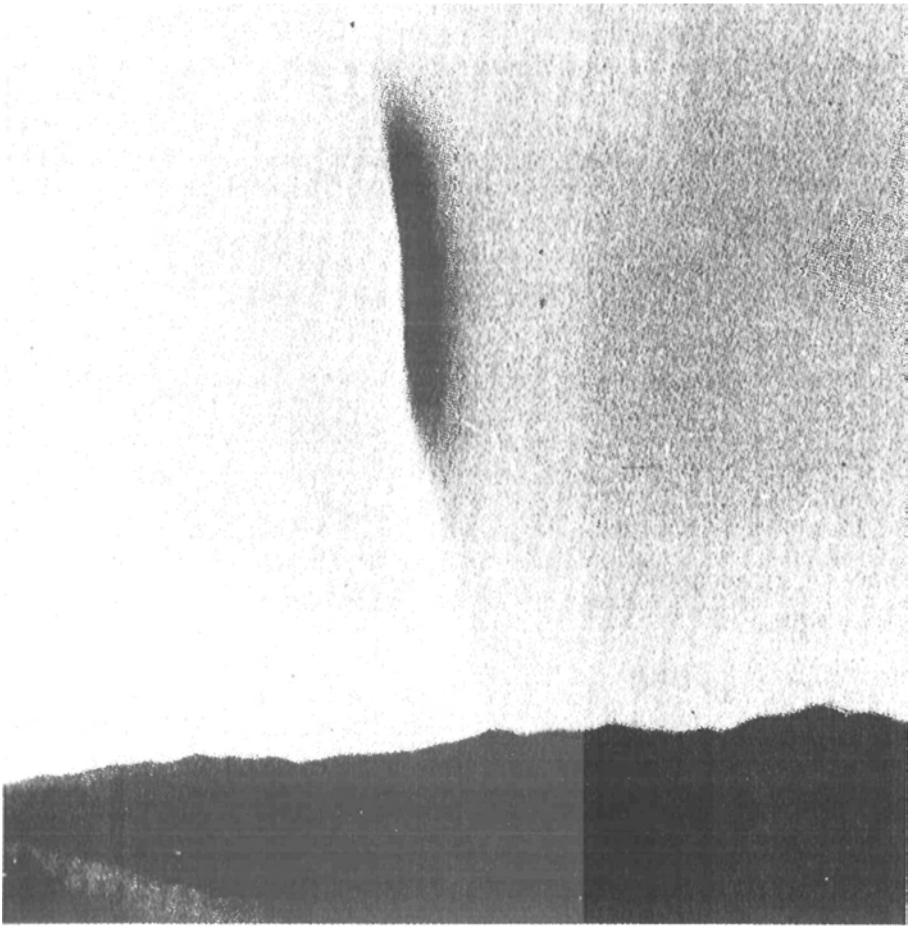

Photo 12. Form for potential materialization.

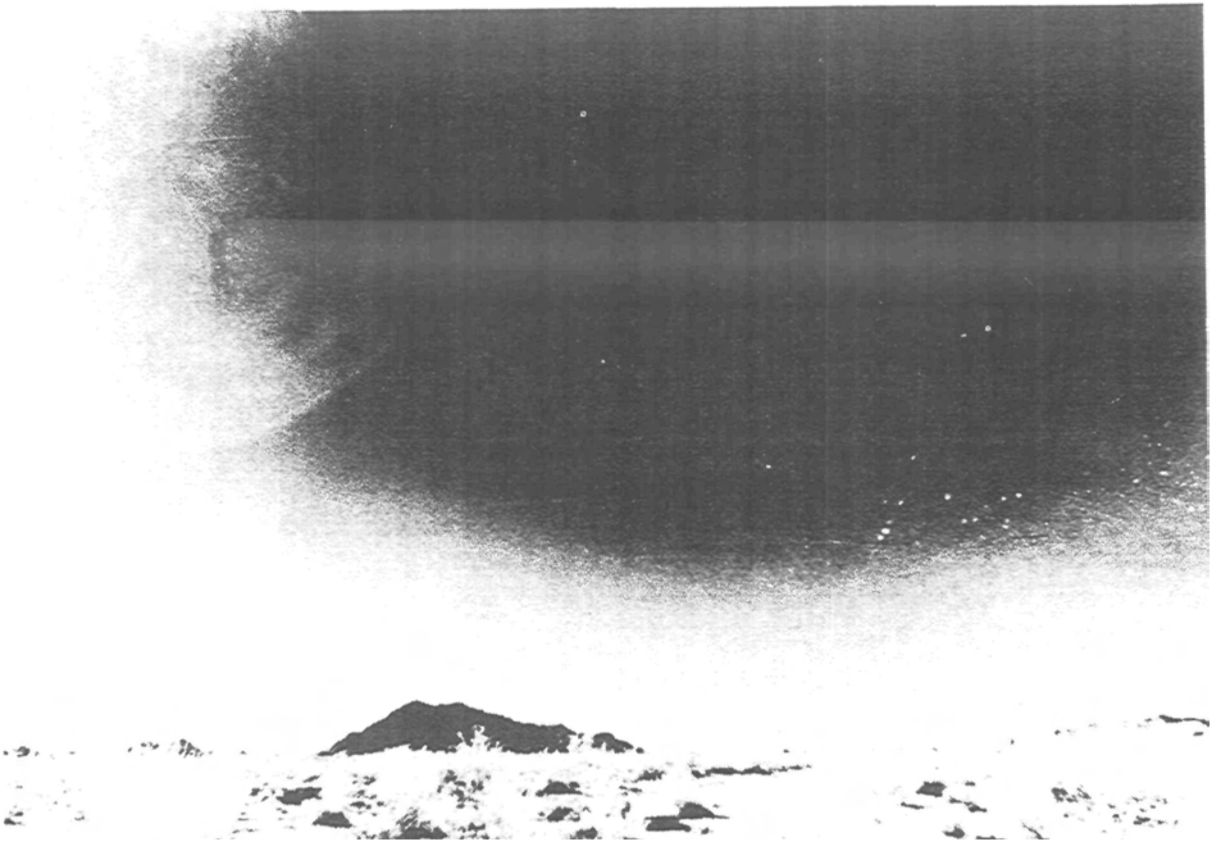

Photo 11. Cell-like invisible tuipoidai forms.

These experiments are also directly related to the work of Miller and Fox, who have shown that, when the probable atmospheric conditions *of* the earth of millions of years ago are exposed to electrical discharges and ultraviolet radiations, amino acids are formed; and then these proteinoids will form microspheres having cellular characteristics, even the ability to grow and reproduce. Every possible life form is already present in virtual state reality, and under proper selective conditions can be kindled into the first bioframe (electromagnetic field) and photographed, or even into the zeroth bioframe (full materialization).

In the UFO photographed in strong potential condition for materialization by Trevor James Constable, note the form of a disc on edge, only a portion of its form being tangible even to infrared. Note also the whitish lobe of the tulpoidal force field extending earthward from the discoidal region. Highspeed infrared film was used, no filter, shot just before sunrise near Giant Rock, California. Constable's pioneering work is remarkable laboratory evidence for orthorotation and materialization of tulpoidal energy forms.

UFO'S

The following pages show some of the most extraordinary UFO sightings and other paranormal phenomena of recent years. Photograph 13 shows a noiseless UFO seen by a university student near Las Cruces, New Mexico, in 1967. (The student reported that, as he changed plates in his camera, the object disappeared. He had been taking photos of rock formations for a class in geology.) In the Spring of 1950, two photographs of a highly materialized UFO were taken by Paul Trent on his farm outside McMinnville, Oregon. The first photo (photo 14) showed the UFO at an angle, while the second (not shown) caught the U FO in direct profile.

1. Black Ring UFO

From Project Bluebook, here is an example of a tulpoidal UFO moving along through the sky and exhibiting the "black ring" effect. In this case only the edge frame is visible, and that edge is generating the black ring or "light quenching" effect. Note that the inside portion of the tulpoid is quite transparent, for one can see the clouds behind it clearly.

2. Anchor Patterns

One of the interesting aspects of combined orthorotation into our normal three-dimensional space and out of it from hyperspace is an anchorlike pattern, shown in the next four pictures. Photo 1 was taken by Ira Maxey, and it shows several tulpoidal forms, which are intersecting our frame in a white or photon-emitting anchorlike pattern. The curved part of the anchor pattern is due to the spinning or orthogonal rotation, and the shaft portion intersects it at right angles. Note also the clouds, whose water content is highly conducive to kindling of the tulpoid — into the first bioframe, in this case.

The second photo from Project Bluebook shows another anchorlike tulpoid — this time the orthorotation is reversed, giving photon absorption — moving through the sky over a dock area by the water.

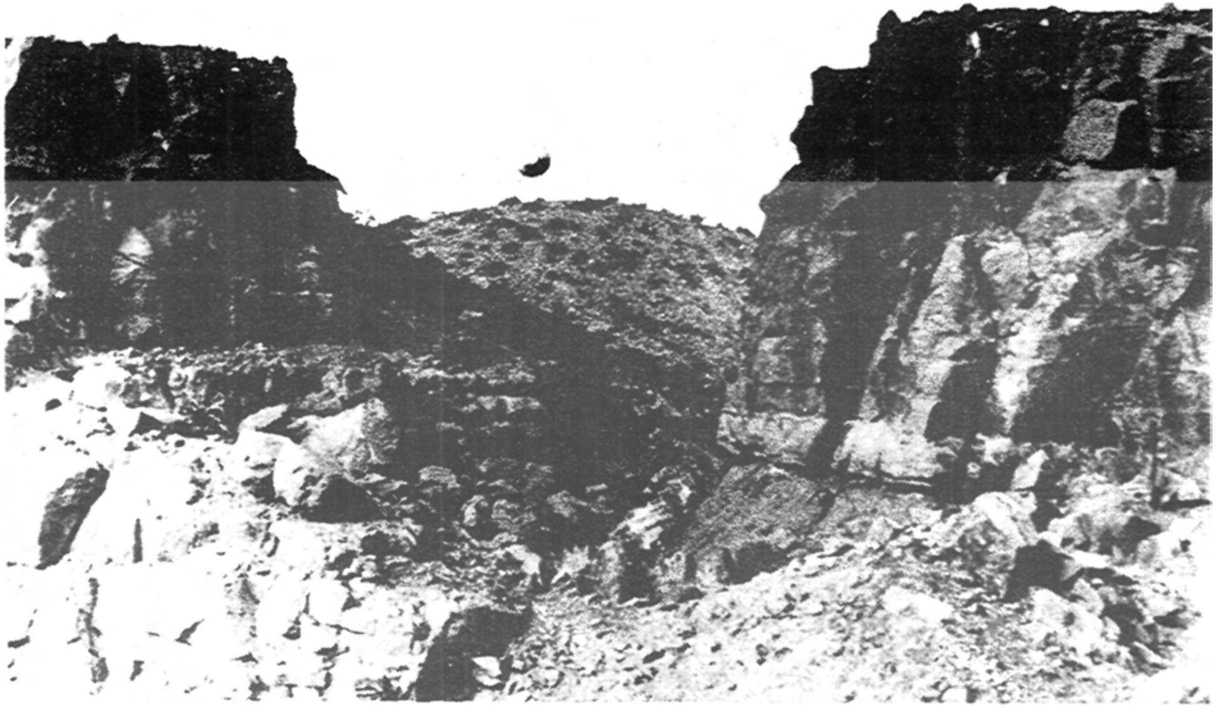

Photo 13. New Mexico UFO.

The third photo, taken in Wales, is one of several which clearly captured another anchorlike tulpoid in a photo-emitting mode.

The fourth photo, taken by Fay Clark in a darkened room, shows very similar photonic patterns being emitted by Ingo Swann's hands after Swann was asked to try to produce energy to be photographed. In the rightmost arc the shaftlike perpendicular bisector can be seen, associated with Ingo's arm. Bioenergy and mind-energy are the same, whether being emitted from a single human system/mind or from a collective system/mind.

3. Bifringement

Another common effect demonstrated by UFO's is bifringement, clearly shown in this photo from Project Bluebook. Here a UFO in highly materialized form is shown just beginning to turn back into hyperdimensional space. Interestingly enough, in hyperspace a tulpoidal form can turn in two or more directions at once, and this one appears to be doing so. A photon-absorbing turn is indicated by the outer bifringement ring, which is white. These can also be compared to photon interference patterns commonly demonstrated by light waves from two or more sources. Just as there are interference patterns in our three-dimensional space, there are interference patterns in higher dimensional spaces. The three-dimensional intersection in our frame of one of these higher dimensional interference patterns may be black, white, or consist of both black and white components.

4. UFO's in Water

Water is a substance that changes its state and form in a fantastic complex and is therefore one of the very best collectors for bioenergy or tulpoidal energy. That is, in fact, why water is so universally associated with living biosystems, for biosystems need a good collective medium in which to establish coherent tuning. So it is not accidental that water is necessary to life as we know it, or that our bodies are largely made up of water. For the same reason (ease of kindling), UFO's and many other tulpoidal forms have a high degree of association with water. Nessie and other water monsters tune in from time to time in large bodies of water such as lakes, rivers, and oceans.

This photo from Project Bluebook shows a UFO tulpoid in the first bioframe (photonic) moving along in the water.

5. UFO's in Clouds

Again from Project Bluebook here is a picture of a UFO tulpoid kindling in water, this time in the moisture in clouds. Clouds are also usually electrically charged, which enhances the tuning effect, particularly when the clouds are darkening and so are highly charged and also densely loaded with moisture. The darker clouds shield out more of the visible light, reducing the hyperchannel (time) squelching effect of visible light.

6. UFO Seen by the Author

The next UFO is one of several seen by me, and it provided a very curious, anomalous phenomenon in my memory. Furthermore, this UFO was sighted by hundreds of persons over a four-state area, so there is no question that something was there in the upper atmosphere.

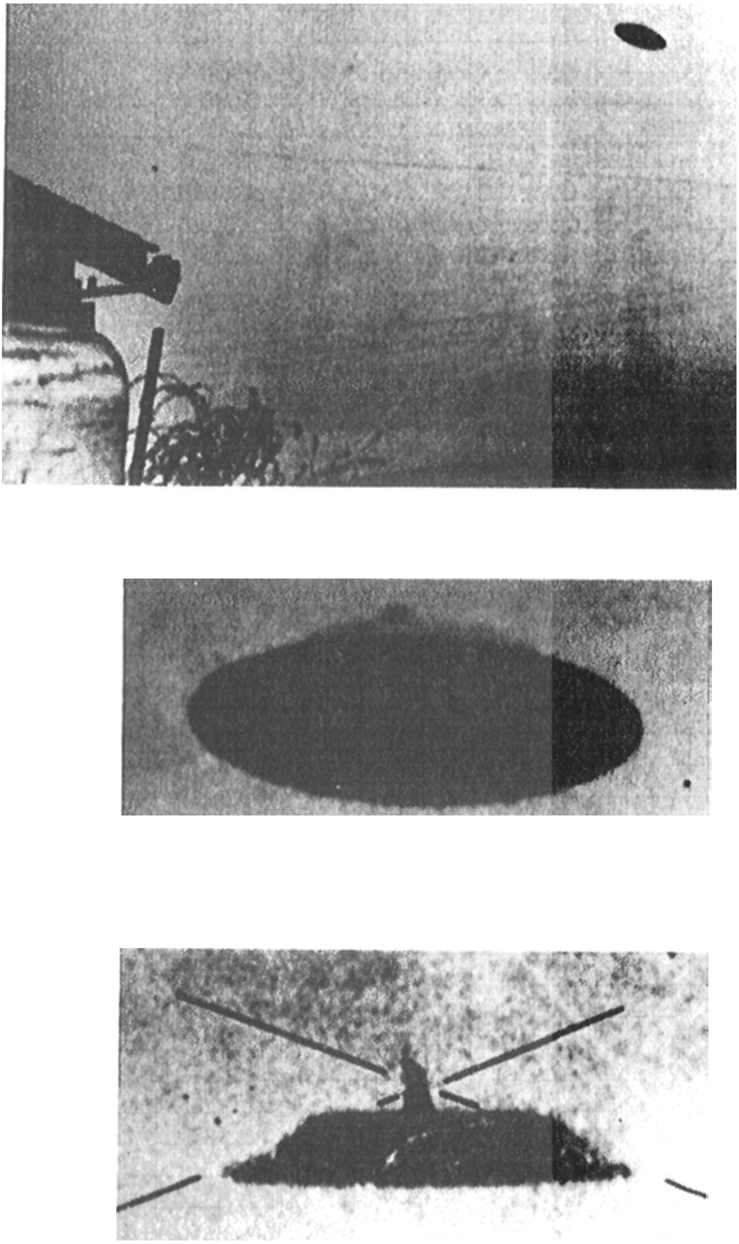

Photo 14. Oregon photos.

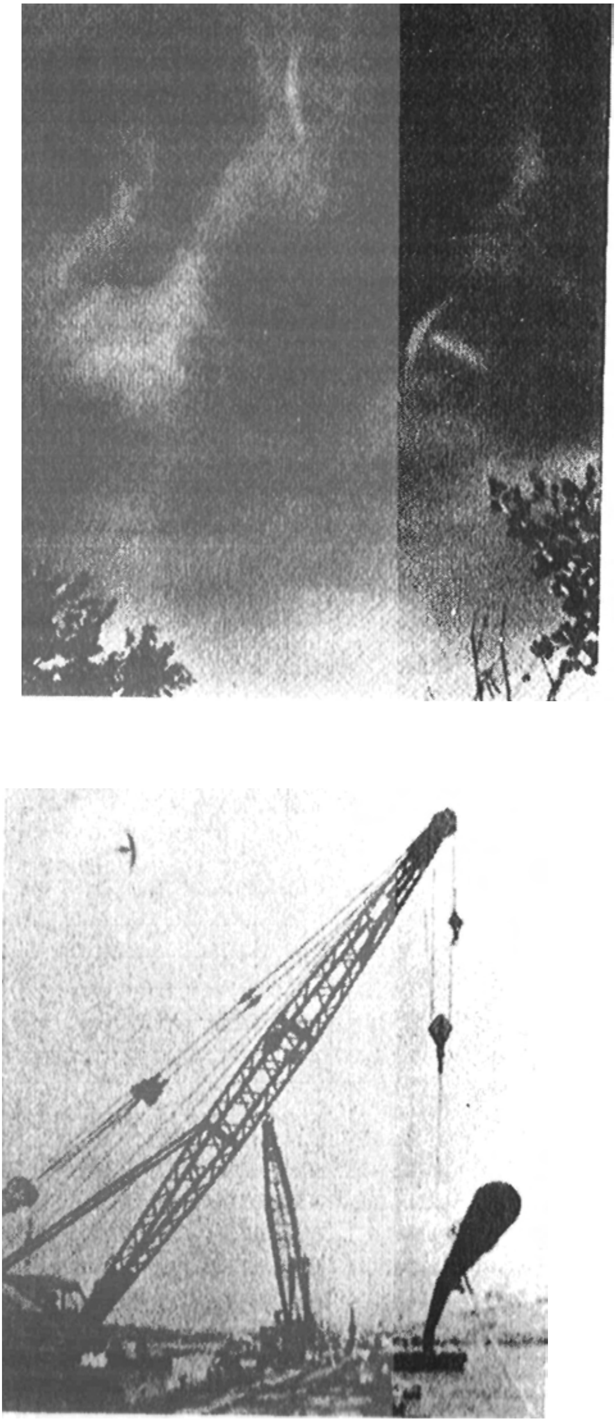

Photo 16. Anchor patterns.

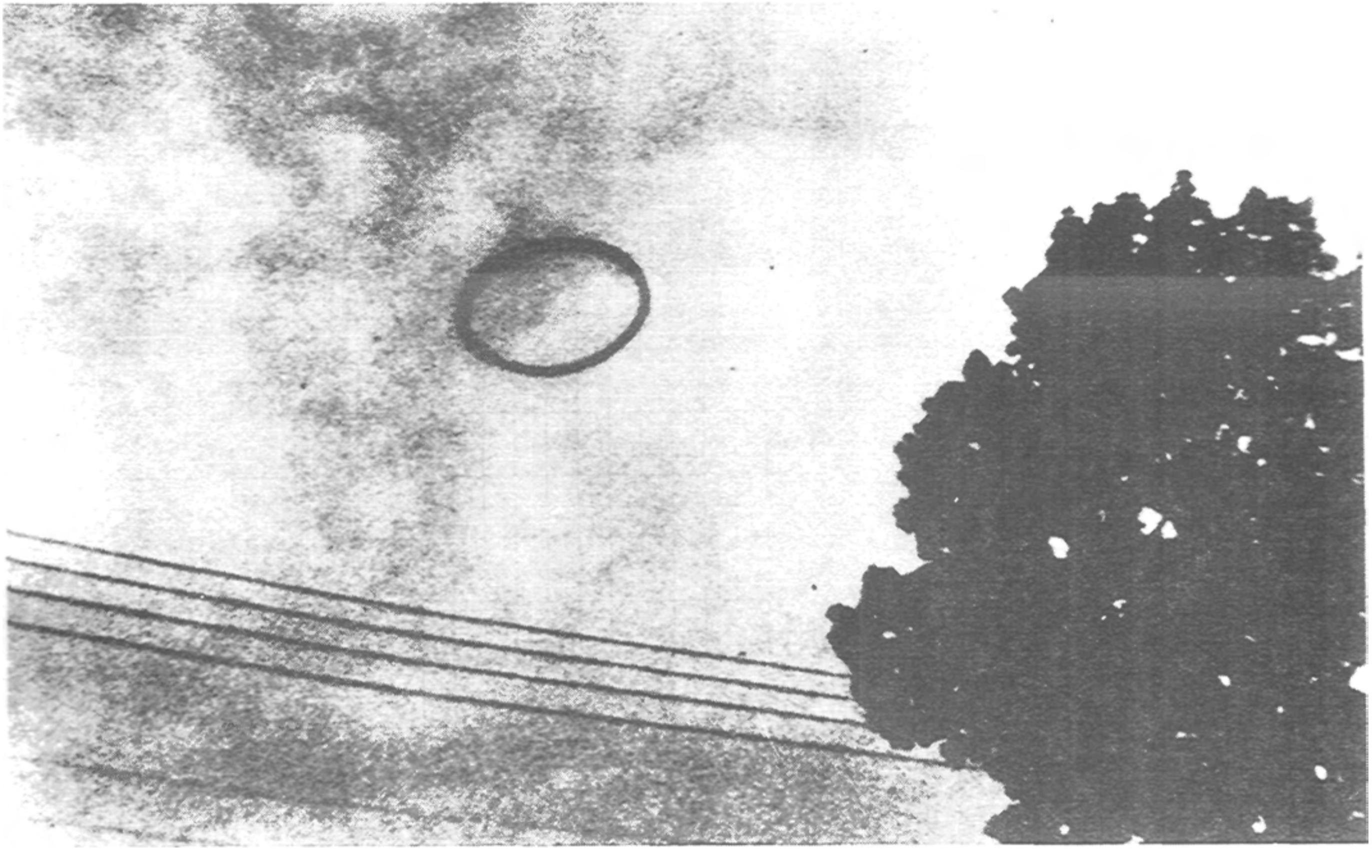

Photo 15. Black ring UFO.

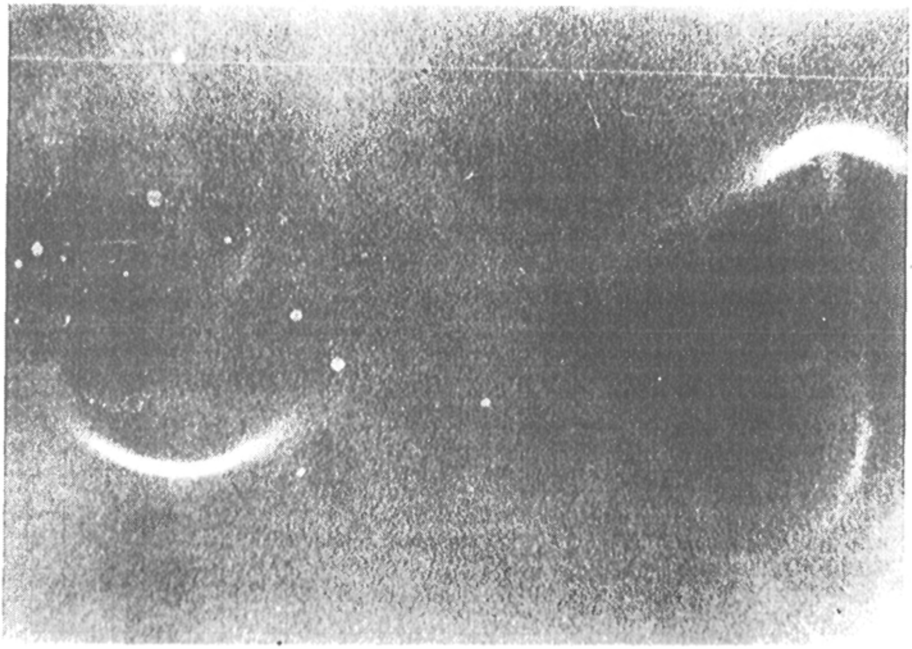

Photo 17. Bifringement.

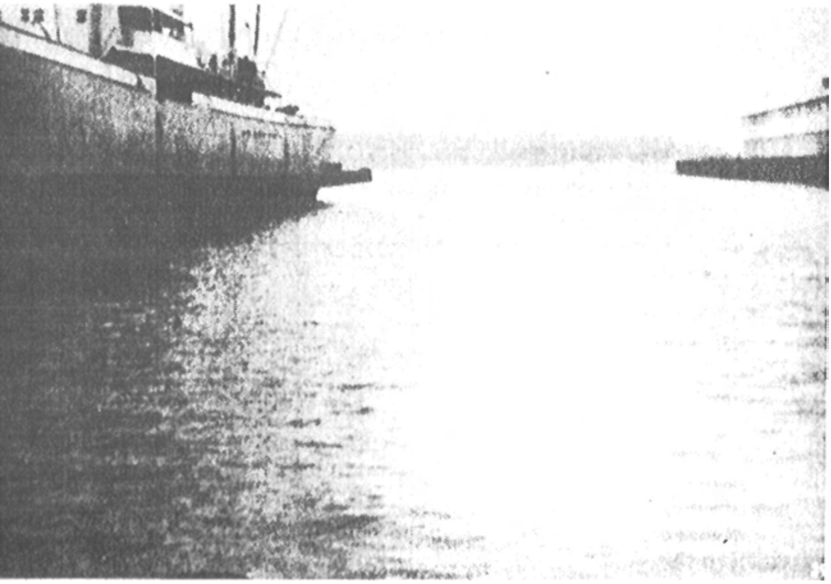

Photo 18. UFO In **water.**

The sighting occurred in June 1950. At the time I was home with my father in Woodville, Mississippi for the summer vacation from college. All my family were in the timber business — pulpwood and logs — and I was working for the summer with them.

It was a beautiful, warm, clear summer day with almost no clouds at all. Coming out of the woods on a pulpwood truck with the last load of the day (about 4:30 or 5:30 PM), the truck was slowly making its way across a large open field to the county road. Suddenly a light was seen in the extreme upper atmosphere, glowing with a fierce white radiance, very similar to the light emitted by a magnesium flare or by burning magnesium. Some object was apparently entering the atmosphere from outside it, but the velocity of reentry was far slower than reentry vehicles that would be fired many years later on U.S. and Soviet rockets. As the fiercely glowing light smoothly descended, a change occurred. At that point gray smoke also appeared in the white smoky trail being left by the object, and the trail became turbulent from that point on. Then an orange color appeared at the front of the descending, tumbling object, in the light being emitted. The smoke trail from this orange glowing color was darker gray. The object tumbled slowly downward, burning fiercely, until utterly consumed, still at an extremely high altitude (I would estimate still above 100,000 feet). In the sky the smoke trail that had been left persisted for a while, until it was gradually dispersed by high atmosphere winds. In the picture a great deal of dispersion has already occurred.

So far as is known to me, and I have had considerable missile experience, neither the U.S. nor the Soviets were firing any sort of vehicle in 1950 that could account for the phenomenon. Furthermore, even if we postulate a reentry vehicle from a large rocket, its velocity was far below normal reentry velocity, and this cannot be accounted for. The object also could not have been a meteor because its velocity was far too low.

For the doubter let it be pointed out that even if a high drag, low ballistic coefficient reentry vehicle comes into the earth's atmosphere on a downwards plunge and rapidly slows down, its initial velocity is quite high, and its rapid slowdown is quite apparent. This phenomenon did not exhibit such a characteristic.

7. The 1966 Dennis Billings UFO Sighting

At about 7:00 P.M. on the night of September 23, 1966, Dennis Billings and his wife and daughter sighted a UFO at close range. The close UFO was one of a total of four sighted by the family in about one hour. The sighting occurred in Decatur, Alabama. The UFO phenomena occurred after anomalous physical effects were noted. From the alley by his back yard Dennis, who had taken out the garbage, began to hear sounds from inside a neighboring house at some distance as if he were physically inside the room in which the sounds were occurring. These sounds consisted of conversation and dish-rattling in the kitchen where two women were apparently cleaning up the table after the evening meal and washing dishes in the sink. Then the sounds changed to those from another room where children apparently were playing games. Peculiarly, the sounds seemed to originate from wherever Dennis focused his attention, such as the garbage can, the house, etc.

Shortly afterward his daughter followed him into the yard as he left the house to go to a football game, carrying his binoculars. She spotted a cluster of lights moving along slowly in the sky above the treeline, and called his attention to them.

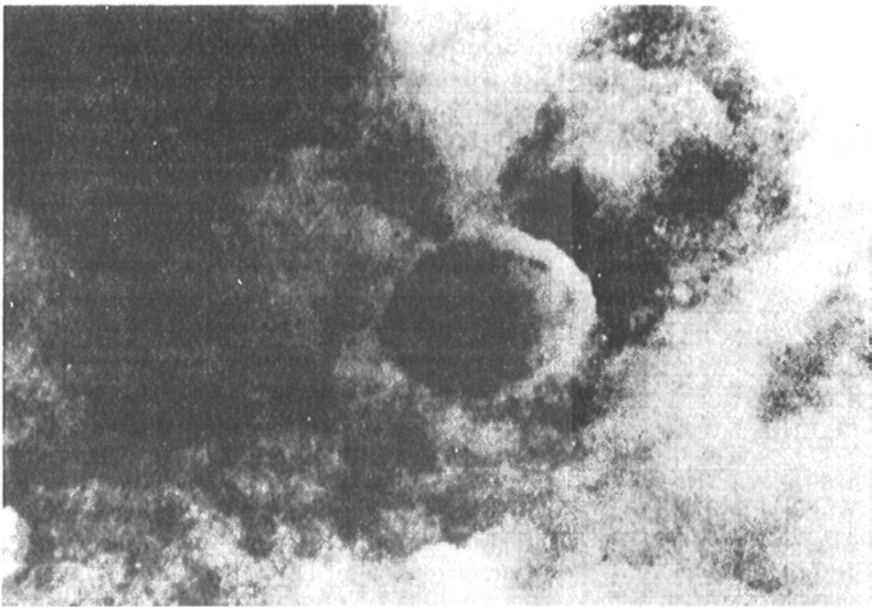

Photo 19. **UFO** in clouds.

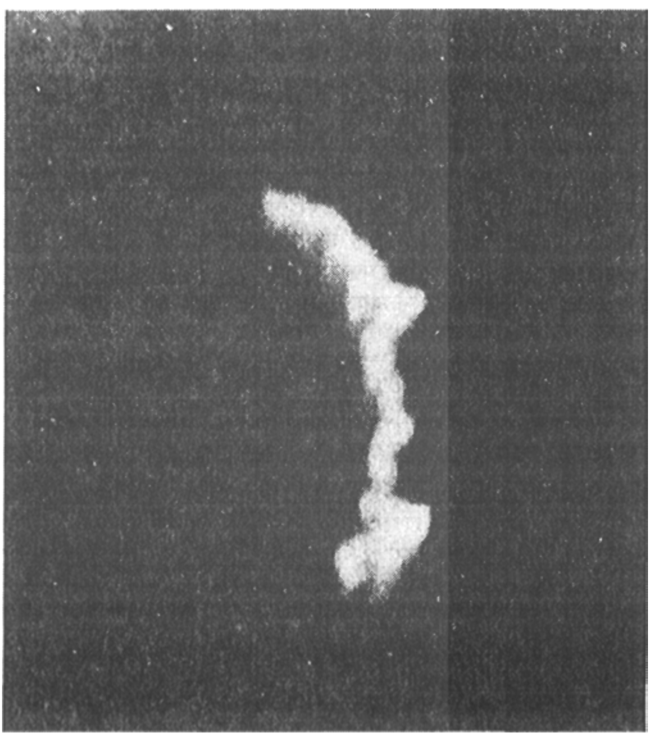

Photo 20. UFO seen by the author.

Through binoculars the cluster of brightly colored, flashing lights could be seen to be one object about two blocks from Dennis's house, moving very slowly and making no sound, about fifty feet above the trees.

Just then Dennis's wife turned on the exterior house lights which illuminated the entire back yard. As she came out into the yard, an object, a fiery red, glowing, round ball of light about twenty-five feet in diameter, appeared just above the neighboring house in back, the same house from which the anomalous sounds had been heard a few minutes previously. Strangely, the glow of the object did not appear to illuminate the rooftop of the dwelling above which it hovered.

The glowing light seemed to be composed of a tremendous amount of energy, and there was violent fluctuation, turbulence, and movement of the light energy within the sphere. Another way to describe its dynamic characteristics is to visualize it as being composed of individual particles of light or incandescent particles of highly charged matter moving rapidly in a circular plasma. The light itself appeared to be comprised of hundreds or even thousands of individual light sources confined to the circular shape.

Within a few seconds the individual lights began to coalesce and form into a solid light with no agitation, dimming in incandescent intensity and changing from red to orange to yellow. As the circular shape of light grew dimmer, a rocket-shaped object formed in the center. After the light had finished changing to yellow and was much dimmer, the rocket-shaped object began to rise, with particles of light from the sphere clinging to it and falling off toward the ground, where they evaporated and disappeared. The rocket-shaped object had no wings or tail fins, and it picked up speed and sped away, streaming an exhaust tail of light or flame behind it, similar to a welding torch's flame or a flaming sparkler. The object made several spirals as it rose and then headed in a straight line toward the stars. As it rose, it also made a slight arc toward the moon, which was full or nearly full, and passed across its face. As it crossed the face of the moon, its rocket-shaped outline could be clearly seen.

Astonished, Dennis and his wife began discussing what they had seen, still standing in the back yard. At this time the anomalous reception of unusual sounds began again. At first Dennis seemed to hear a train on a distant track although there are no railroad tracks in the vicinity. The sound seemed to come closer until he seemed to hear a train passing by immediately in front of him with its wheels clicking on the joints of the steel rails. Then they heard other sounds similar to automobiles and trucks on a freeway, again very close, although there is no freeway in the vicinity either. The whining motors and honking horns of these unseen vehicles could also be heard. Turning first in one direction and then in another, Dennis could hear the anomalous sounds seemingly originating from wherever his attention was directed. Other sounds such as airplanes flying in the sky also came in. Then he heard another sound like a high-pitched tuning fork, and it began to increase in frequency until Dennis's eardrums were hurting.

With this high-pitched frequency sounding and his ears smarting, Dennis looked up and saw a bright object positioned in the sky, larger than a star, and approaching him and his wife. As it approached on a straight line toward their back yard, it got bigger and brighter, until it stopped directly overhead, hovering 100—150 feet directly above the yard. The object appeared to be circular or oval in shape, and it descended with the flat side down. On its rear end the object was

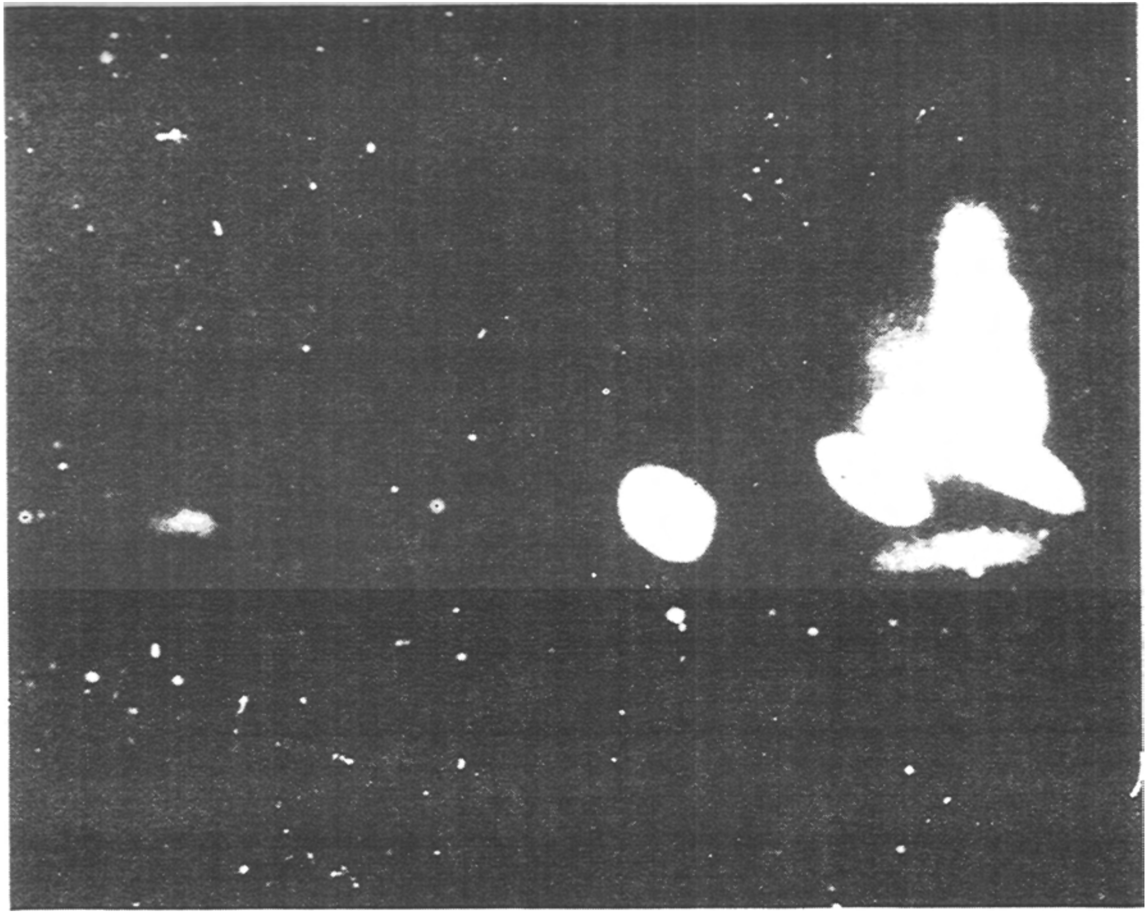

Photo 21. Second Billings UFO.

rimmed like a horseshoe with twelve washtub-sized blinking lights, each of a different color. These lights appeared to be controlled so that as one light blinked on, the other lights went off. In this way one light at a time blinked on and off in successive positions, so that a single light seemed to rotate around a complete half circle and cross at the open end, changing color as it progressed. On one side of the horseshoe the light positions were bright red, on the next yellow, on the next pale green, on the next a darker blue-green, and the final light on the opposite side of the horseshoe pattern was a very bright blue. Underneath the center of the object was what appeared to be a hemispherically-shaped plastic capsule or shield. This capsule was completely blacked out; yet through what appeared to be smoked glass, movements or shadowy activity could be seen. Dennis assumed that this was the exhaust section of the craft and that what he was seeing was probably smoke coming out of a black hole in the craft.

Around the outer perimeter of the craft, and about two feet out from it, was an illuminating light which circled the object like a halo or corona. Dennis had the eerie sensation that the object was intelligently controlled and that he himself was under close observation.

At this time Mrs. Billings became extremely frightened, ran into the house and got the baby, and crawled under the bed until the craft had gone.

As she left in fright, the craft lifted up in the sky a little and began to move slowly away, so slowly that Dennis could walk along beneath it as it moved across the back yard and into the front yard. Walking under it and looking straight up at it, he was able to observe closely the blinking lights and their operation. When the craft had been motionless, the lights had blinked on and off slowly, so that they moved in a slow, pulsating motion from position to position around the horseshoe pattern, changing color as they went. As the craft began to move and pick up speed, the lights began to increase in pulsation frequency and thus to appear to move faster around the horseshoe pattern. As the craft moved even faster, the light pulsations became so short and fast that they seemed to be spinning around the horseshoe in one continuous blur of motion.

As the object left Dennis's yard, it moved into the sky and away, but not too far, until it had positioned itself over the airport (Pryor Field) as a large bright object. At this time Pryor Field was serviced by Southern Airlines. As one of the commercial aircraft took off, the UFO followed it back directly over Dennis's house, then left the aircraft and repositioned itself in the sky in its original position over the airport, hovering motionlessly.

After hovering motionlessly for about fifteen minutes, the UFO suddenly shot down in an arc toward the ground, passing below the tree line and out of Dennis's view.

Dennis waited for about ten more minutes, when suddenly the UFO shot back up into the same position in the sky, seeming to follow in reverse the same arc on which it had descended. It remained in this position, hovering in the sky above Pryor Field for another ten to fifteen minutes. Then a similar object approached and joined it, and the two seemed to merge or dock together. They remained motionless for about five minutes more, then moved across the sky, still joined, until they disappeared below the horizon.

According to the newspapers the next day, this object or something similar had been seen all over the eastern half of the U.S., and had been described as "multicolored clouds."

8. The Second Billings UFO Sighting

If Dennis and his wife had experienced only one UFO, the incident would have quietly faded away in the unwritten annals of ufology. However, such was not to be the case.

Dennis vowed to himself that, if such an incident ever occurred again, he would get a photograph of the object. And just before Labor Day in 1970, Dennis got such a chance, and indeed made good his intention.

On that night, with almost totally clear skies and a bright moon, Dennis's wife came rushing into the house in Decatur, Alabama and excitedly reported to Dennis that she had seen another UFO. Rushing into the yard, all Dennis could see were some distant white lights — too far away to say positively they were UFO's. However, recalling the multiple UFO's in the previous incident, Dennis and his wife took up separate watches on each side of the house. Dennis also thought of his Polaroid camera left in his car parked in the driveway, so he went to get it.

Standing between the trees, Dennis looked up into the sky and saw a UFO suddenly triggered into position, as if his thought and intent had pulled a switch and the object had suddenly appeared, positioned perfectly for his observation, pouring light from underneath for a distance of about twenty to thirty yards. This light seemed to emit some immense force and was colored like the fire, whiteness, and glare of a welder's torch. The tail diminished as the craft lowered. Dennis snapped a picture when the craft's tail had shrunk to only four or five feet long. He pulled the tab on the polaroid film and ran into the street under an outdoor light to see if he had recorded a UFO. When he saw he had done so, he then noticed the object had descended and made a left turn, moving eastward down Nelson Street slowly at about five miles per hour. Its porthole lights were still clearly visible and no sound was being made. Dennis hurried after the UFO and caught up with it at the end of the street near a T.V.A. easement, where large electrical power lines were located, running generally north to south. He got slightly ahead of the object as it traveled parallel to the power lines and as the craft passed directly over him. At the very instant he pressed the shutter, all lights in the craft instantly extinguished as if his mind had been read and the photograph deliberately prevented. The now darkened, cold, lifeless-appearing craft moved smoothly away, passing over Mallard Park where a Marine Corps Band was playing. The second photograph showed no lights whatsoever.

One of the local newspapers then printed the story and the picture, and Dennis received a call from one of the national UFO agencies. After giving the agency his photograph, his camera was mysteriously stolen from his automobile, and the agency then claimed to have lost his photograph. However, they underestimated the determination of Dennis Billings.

Dennis simply got on a plane and went to Washington, and proceeded to the office of the head of the UFO agency. The president of the organization had said that he would be out of town for several days and would be unable to see Dennis. Nevertheless, Dennis went to his office, where his secretary repeated that the gentleman was out and would not return for the day. Dennis barged into the office over the protestations of the secretary — including the threat to call the police and have him removed — and proceeded to search for his photograph, eventually finding it in the desk drawer of the president of the organization. He retrieved his photo and returned to his home. Without his personal determination to retrieve his property, the photograph — like so many others over the years — would have been "lost." The immediate question that occurs is: Isn't it curious that one of the major UFO organizations in the U.S. — supposedly devoted to solving the UFO mysteries — exhibited the desire to misappropriate a really good picture of a UFO and see that it disappeared from the scene?

At any rate, Dennis got his photo — and a beautiful photo it was. Furthermore, the incidents experienced by Dennis Billings are classic examples of my theory. Many anomalies in the incidents will not fit orthodox theory or orthodox ideas about reality. The "pieces of light" seem to be almost intelligent. There was a close coincidence of thought/intent/expectation and kindling burst into observable reality, plus a great deal of sky-watching and expectation by Dennis between the first UFO incident and the triggering of the second (i.e., a long kindling time, just as Patterson experienced before he got his excellent movie shot of a sasquatch). And there was close experience of very distant sounds (to be expected in hyperspace, where ordinary distance can be shortened or even eliminated). Furthermore, there were multiple witnesses to the UFO incidents, and Dennis got his photograph. Psychologically, it may even be significant that for several years Dennis vowed to take *a* picture of any other UFO he might later see, and when he got *a* picture, he was prevented from getting another. And on the photograph obtained, one can see that the "craft" form of the tulpoid is only partially materialized, since the stars can be seen right through the vehicle's midsection. This is similar to the strange transparency of the Doc Shiels photograph of Nessie (the Loch Ness monster), which Ground Saucer Watch found when they performed a computer analysis of his photo. (The second Shiels photo showed that the water was being forcibly moved by Nessie, so the tulpoid was at least partially materialized.) Yet such is to be expected if one is dealing with partial materialization of tulpoids.

Finally, the entire area is located in the Tennessee Valley Authority's project. Great electrical transmission lines go through the area, and there are many long lakes and the Tennessee River. So an excellent kindling medium is provided, and many UFO's are seen over the Tennessee Valley.

The Dennis Billings photo remains one of the best UFO photographs ever taken, and coupled with Dennis's astute personal observations, it provides a keystone insight into the actual nature of the UFO phenomena.

9. The 1973 Pascagoula UFO Sighting

In October 1973 one of the greatest UFO flaps of all time occurred in the United States, and created headlines because of the bizarre increase of contactee incidents. One of the most sensational of these was the purported abduction of two men in Pascagoula, Mississippi, who were allegedly taken aboard a saucerlike craft, examined, and released.

Shortly afterwards another incident happened in Pascagoula, which drew little attention. In this case, underwater phenomena were involved, because two U.S. Coast Guard petty officers investigated the object and made physical contact with it. An official Navy investigation was made and a report written. Unusual characteristics, highly suggestive of a device using psychotronic effects, were displayed by the object. I suggest that this device may well have been a Soviet psychotronics device, taking advantage of the UFO flap as a screen to carry out clandestine activities.

In Pascagoula an illuminated underwater object followed the boat of Raymond and Rayme Ryan, who tried to beat it away with an oar. The nine witnesses, including two Coast Guard investigators, described the object as metallic, rod-shaped, two to three feet in length, and four inches in diameter. It was attached to an oval-shaped beam ahead for four to six feet. It looked like a mini-submarine and moved at four to six knots in four to six feet of water. Although it sounded like metal when struck, it could not be struck consistently, and its light, when illuminated by a flashlight, turned off immediately and then on again after about one minute. The portion of the Ryans' oar that was under water could not be seen from the surface when the object's light beam fell on it.

At this point I would like to make some general remarks about the nature of UFO's. (1) The UFO-generating mechanism and the psychotronic mechanism are the same. (2) The Soviets may even be able to psychotronically evoke particular types of UFO phenomena at will. (3) A small number of UFO phenomena could even be generated by the Soviet Union as part of its psychotronics deception plan. However, most UFO phenomena are definitely not of Soviet initiation, (4) An explanation of the UFO phenomena is briefly sketched out in my section on psychotronics. (5) Some of the NASA photos taken of moving lights in orbit around the earth may have been of Soviet-initiated effects. Like the radiation of U.S. personnel in the U.S. Embassy in Moscow, this effect could have been intended to evoke U.S. high level reaction, to positively assess whether the U.S. had any knowledge of psychotronics, and if so, what that level might be.

10. Other UFO's

A brilliant, "crystalline-like" UFO was seen over Madrid, Spain in 1968 and was chased by Spanish Air Force planes. Whenever people are significantly structured in their thinking, symbolically "sharp" and "crystalline" tulpoids often are seen, representing their ideas. Many such UFO tulpoids are seen over Iron Curtain countries, and over countries such as Spain that have one dominant religion and culture.

In October 1973 the governor of Ohio, John Gilligan, saw this UFO phenomenon along with over 100 other people. The police were notified by the governor, and this photo was taken by the *Columbus Evening Dispatch.* Note that the tulpoids remain in the first bioframe (see Part Two), and even though their intersections change shape, the second one remains in a "burst mode."

In 1965 Rex Heflin took four pictures of a highly materialized UFO near Santa Ana, California. In the fourth photo the dematerialization "photon absorption" effect is shown: if orthorotation into higher dimensional space is made in one direction, photon (light) is emitted. If the orthorotation is made in the opposite direction, photons are absorbed. In one case "glowing light(s)" are associated with the UFO's hyperdimensionality, while in the other case "black rings" or "smoke" are associated.

FALKVILLE SPACEMAN

These two pictures are black-and-white versions of two of the photos taken by **Falkville, Alabama Police Chief, Jeff Greenhaw, in an encounter during October**

1973. Greenhaw had received a call from one of his constituents to say that a UFO had landed in her pasture, and he was proceeding to investigate the incident. In his police cruiser he carried a polaroid camera which he used in his police work.

Driving down a narrow gravel road, Jeff noticed a metallic-clad, suited figure walking down the road toward him, and he stopped his car to get out and have a look. For some strange reason his instinct was not to pull his pistol on the creature, and instead he started taking pictures as the creature/tulpoid walked toward him. The creature was holding something exposed in one of his hands, as can be seen in one of the photographs. As the tulpoid approached with no apparent intention to stop, Jeff then switched on the blue light above his cruiser, and the rotating, flashing light caused the creature to turn about and run away down the road. Jeff jumped into his cruiser and gave chase, eventually reaching about forty-five miles per hour without catching the tulpoid. His car spun off a curve and Jeff still had the photos — polaroids that he developed.

Bizarre things then happened to Jeff Greenhaw. His wife left him and divorced him (I suspect this had nothing at all to do with the UFO incident), he was fired from his job as police chief, vicious rumors were circulated that it all had been a hoax, and that a person had been dressed in an aluminum suit and photographed to give the appearance of a spaceman. Various fire suits were positively identified as having been the suit used. Jeff was discredited. Finally his trailer was burned down.

Before the trailer was burned, a friend of mine here in Huntsville, Warren York, visited Jeff and made photographic slides from the original polaroids with Jeffs permission. Shortly after that I had a chance to study these first generation slides for several hours, and some interesting things turned up.

The tulpoid's left hand is positively reversed in a mirror image fashion; it opens outward instead of inward as does a normal hand. (This cannot be seen on the photos shown here, but on the first generation slides it is readily seen.) Being an aikidoist, I am totally familiar with the degree of bending and flexing of most human joints, particularly the arms, wrists, and hands. And the mirror imaging of the left hand of the tulpoid is beyond question.

Furthermore, one can establish a clear shoulder line in some of the other photos, and a line just under the hat or "nazi-helmet" portion of the figure. From the other photos a remarkable thing emerges: there are only two places between the edge of the helmet and the chest that are sufficiently wide and sufficiently thick to contain a human head. The person would either have to have a neck about twelve inches long, or he would have to have a neck shorter than a Neanderthal's, with the head lolling down completely on the chest. Again, this can be clearly established in the original first-generation slides.

Finally, I have a letter in my files that establishes as a falsehood one of the rumors about Jeff. One person had admitted dressing in the suit and faking the incident, when in fact what actually happened was that Jeff went to his house immediately after the incident to ask this person to accompany him back to the area and search for the spaceman. When confronted in late 1977 by his family and friends, this person broke down and confessed that he had lied about the incident.

Finally, some other investigators dressed a person in an aluminum foil suit and photographed him, and there is no resemblance to the tulpoid photo. And Warren York investigated all the firesuits supposedly used in the hoax, including new suits used by the various fire departments and also by NASA at Redstone Arsenal. None of them resembled the tulpoid photo.

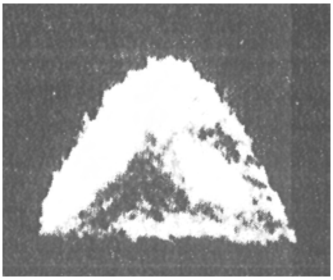

Photo 22. Spanish UFO.

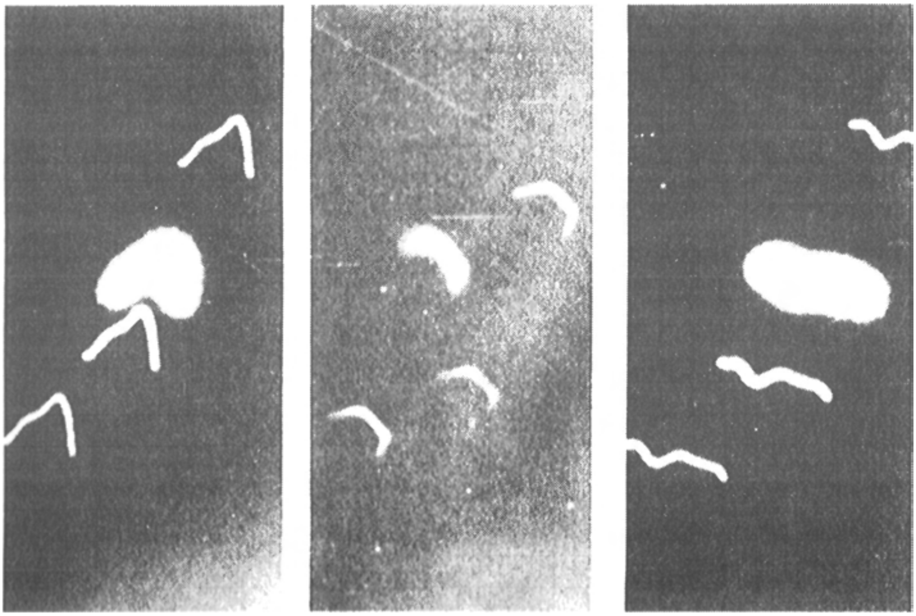

Photo 23. Ohio UFO.

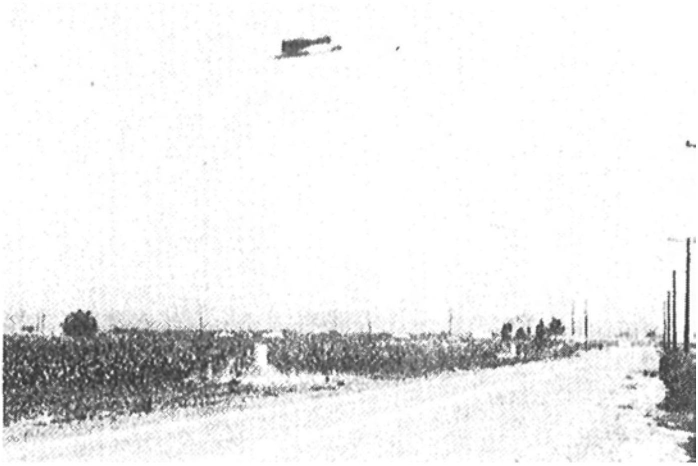

Photo 1

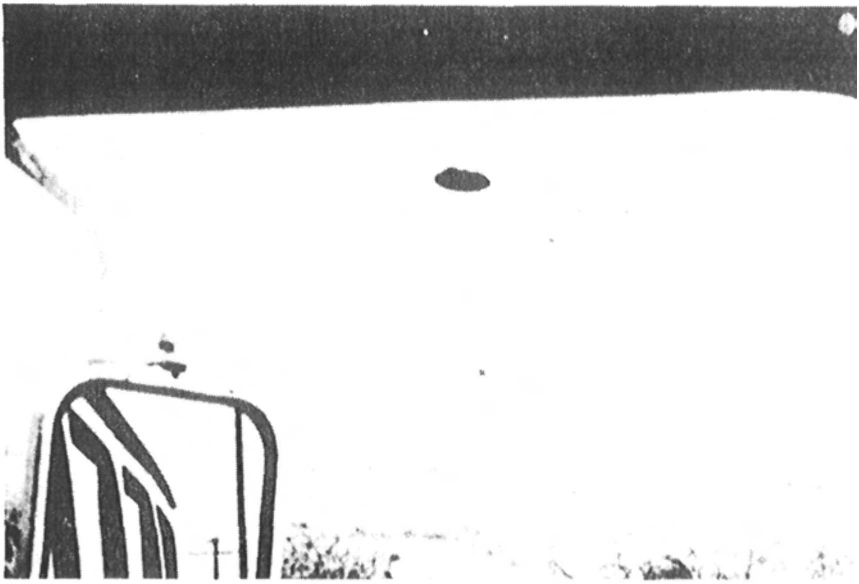

Photo 2.

Photo 24. Heflin UFO.

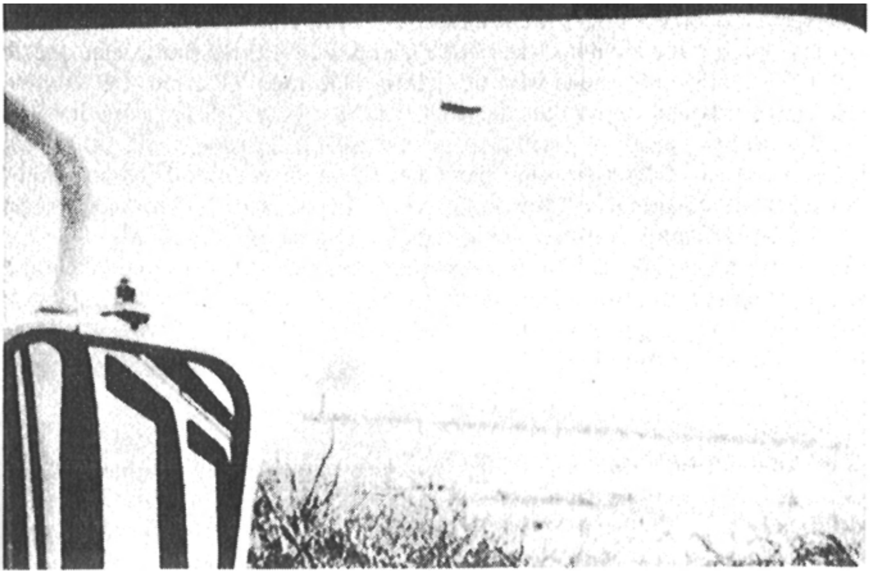

Photo 3

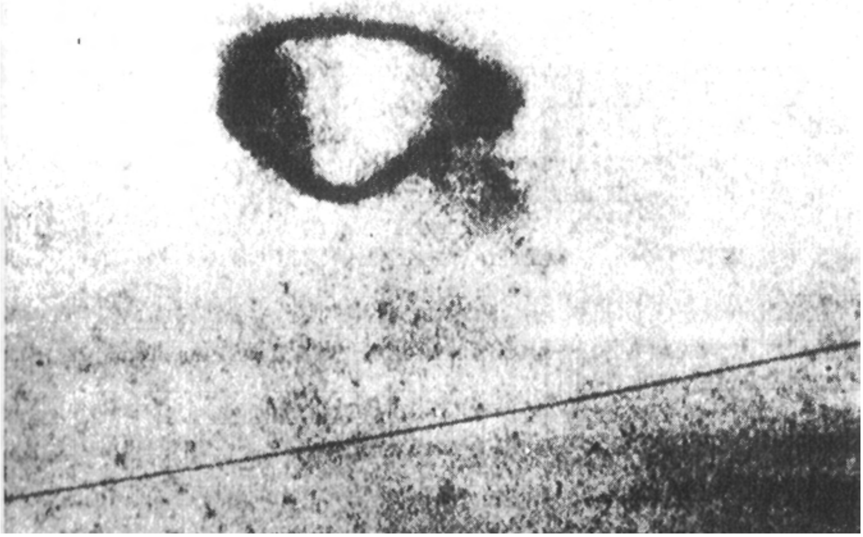

Photo 4 (enlarged)

Several photo experts have concluded that the photos are false, and several have concluded that they are not. A computer analysis concluded that they were false. However, what exactly could a computer show that would differentiate between a normal physical object and a well-materialized tulpoid?

In my opinion the incident was a fake *if and only if* three things can be established; (1) an individual exists with a horribly deformed left hand that is mirror-image backwards and opens outside away from the body; (2) the same individual either has no neck at all or else has a neck almost a foot long; and (3) the same individual can run forty-five miles per hour, faster than any other human in the world. Such an individual — if he existed — would be readily identified, and there would be no difficulty in ascertaining that he was the one involved.

There are other things about the case that I am not at liberty to divulge at this time out of respect for Jeff Greenhaw's confidence and privacy. But even so, the incident has a very high probability of being tulpoidal, and Jeff Greenhaw stands fully exonerated, in my opinion.

MEN-IN-BLACK

The kindling of virtual state tulpoidal forms into the zeroth bioframe of a physical reality (materialization) can result in the materialization of living, breathing, functioning forms. There is essentially no limit on the format that may be obtained. Sasquatch, Nessie, fairies, demons, angels, mothmen, skunkmen, yeti, kangaroos, etc. are just a small sampling — as indeed are UFOnauts such as little green men, space-suited astronauts, androids, robots, etc. These (usually) fleeting phenomena are physically real when in the materialized state (zeroth bioframe); unfortunately the tuning which is accomplishing the collection and kindling is usually unstable, and the stability to maintain the materialization lasts only a short time.

One of the consistent phenomena experienced by many UFO investigators is that of men-in-black. Typically, oriental-featured men in dark suits appear and demand the investigator's material, instructing him to cease his efforts. Usually they have almond-shaped eyes that never blink, and speak telepathically without moving their lips. Variations, of course, occur.

Here is an incident that happened to a friend of mine in the city where I live (Huntsville, Alabama). At the time my friend was an ardent UFO investigator and even wore a radiotelephone so that he could be contacted quickly at any hour to go and investigate UFO incidents in the field. He is the friend who investigated the Jeff Greenhaw case and took slides of the original Greenhaw photos before Greenhaw's trailer was burned.

A friend of his, a girl with psychic abilities, was approached one evening in her apartment by two medium-sized, almond-eyed men of oriental cast, in typically dark suits. These tulpoidal gentlemen's eyes never blinked and they spoke to the girl telepathically without moving their lips. They handed her an envelope containing two ancient coins and instructed her to give the coins to my friend, and inform him that he must keep them on his person at all times. After other messages that completely frightened the girl, the two tulpoids left, never to be seen again.

In tears from fright, the girl contacted my friend and between fearful sobs urged him to take the envelope and get it away from her, as she never wanted to see it again or the two men who had brought it.

My friend picked up the envelope and later examined the two coins. I also personally examined them: to anyone who is sensitive, the coins radiated an invisible unpleasant tulpoidal energy.

The investigator then photographed the coins, and daringly placed one on a string around his neck against my own advice to seal them up against light. He promptly broke out in a rash from head to foot and was shortly forced to remove the coin and seal it away. Interestingly, photos of the coins seemed to have about half the effect of the actual coins.

For a period of two years I kept my copies of the photos sealed against light and stored in a file cabinet. To my surprise, several times when I went to retrieve the photos, they would alternately be there and not there. I simply state what occurred, without any change or justification. Eventually, however, their effect seemed to decay, and at that time there was no longer any problem in recovering them from the filing cabinet.

The men-in-black syndrome is based on our own unconscious tuning; since each of us has some unpleasantness in the unconscious, sometimes the tuned-in men-in-black can be very nasty indeed.

I am personally aware of several good researchers into the paranormal who have been forced to retire from the field to save their own lives and the lives of their families. As late as April 1978 a very good friend of mine has been forced to do just that because of overwhelming danger to his family from materialized tulpoidal phenomena.

In my own case I have found it expedient to work closely with a group of psychic friends in the American Association of Meta-Science. This group is capable of clairvoyantly peering into the unconscious to ascertain the most unpleasant blockages present, and forming energized thought forms to go in and cleanse the unconscious of most of the unpleasantness. In this way the unconscious can be kept relatively free of unpleasant tuning that might otherwise tune in something like the men-in-black. My own life and experience has not been free of tulpoidal tuning; however, it has been free (at least so far!) of tuning in anything really unpleasant, or nasty, or threatening to my family.

But I continue to be very grateful to my psychic companions for their understanding and assistance, and I continue to avail myself prudently of their services when needed.

SASQUATCH

In many regions of the earth there exist legends of giant, apelike creatures of various sizes, hues, and dispositions. In the high Himalayas this takes the form of the yeti, a humanoid creature sometimes seen in the snows of high and remote fastnesses. Expeditions have in fact uncovered and photographed the yeti's tracks, and sightings by reliable observers have been made. Several parties have also reported hearing the yeti's strange vocal sounds.

In the remote Siberian wastes the Soviets have also reported such a manlike humanoid creature, even purporting to have captured one a century or so ago.

In the U.S. the tulpoidal form similar to this has been the sasquatch of the Pacific Northwest, known since Indian times, and observed hundreds of times by a variety of persons over the years. Nevertheless, in spite of intensive searches Bigfoot continues to elude all pursuers while continuing to be sighted and leave footprints.

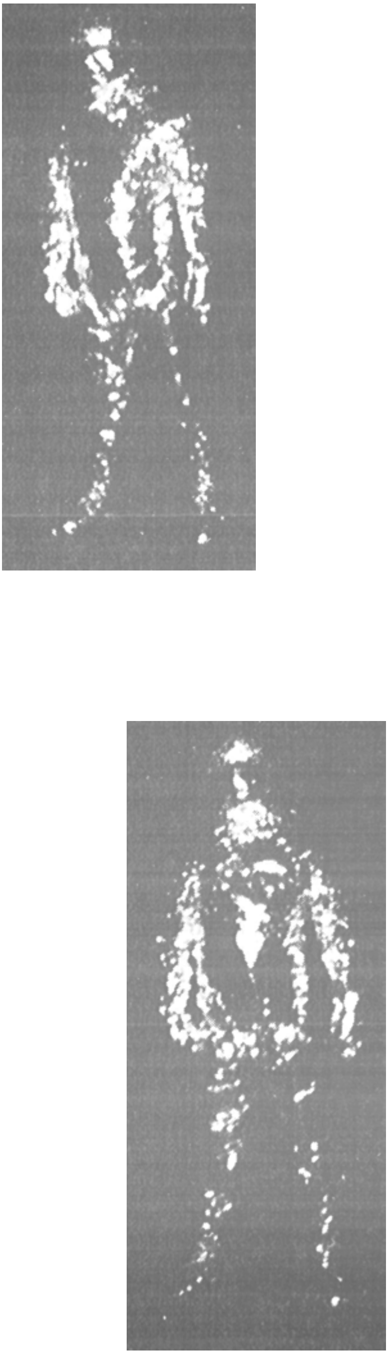

Photo 25. Falkville spaceman.

But Bigfoot cannot be caught by packs of hounds. (This has repeatedly been tried. His lair is never uncovered, nor can he be tracked to it. He has never been found dead of old age or injury. The bones of sasquatch have never been uncovered in caves or elsewhere.)

Furthermore, not just one type of footprint or one type of creature is seen; instead, a variety of shapes/sizes/types of creatures appear. This is one particular clue to the fact that we are not dealing with a species of shy and elusive wildman, but instead with a tulpoid.

Sasquatch cannot normally be found — as indeed Nessie and the yeti cannot — because shortly after each appearance he is no longer present in this bioframe.

However, as interest in sasquatch/Bigfoot grows and the effort to discover or uncover him intensifies, the kindling of the tulpoidal form intensifies. Today bigfoot-type creatures of all varieties and hues are being seen throughout the U.S., from Maine to Florida, from Alabama and Tennessee to Oregon, Washington, and California. With this intensity of kindling, it is getting easier to evoke a bigfoot-type tulpoid, and as it continues, sasquatch is probably going to be tuned in and stabilized. If so, the past itself will just be changed, and we will be able to dig up ancient bones of sasquatch, and find his lairs, and track him down with dogs and capture him. In that case, sasquatch will become a respectable animal and will stabilize in our reality. Tulpoidal activity from the collective human unconscious can be stabilized and the entire past, present, and future changed by the awesome 4×10^9 dimensional psychokinetic mastery of spacetime exerted by the species unconscious.

We also should not be at all surprised if the same thing happens to the placid Loch Ness monster. There is probably going to be a family of pleisosaurs living in the Loch eventually (and in many other bodies of water across the globe) — and spacetime will be changed (past, present, and future) in our zeroth bioframe to accomodate this small shift in the collective human unconscious. In reference to changing the past, it is interesting to note that Wheeler has recently demonstrated that, in the two-slit experiment (which contains the basis of quantum mechanics), it can be decided *after the fact* whether or not a photon has interacted with two slits or with one. Thus in at least one sense the past can be changed!

After several years' intensive search for and pursuit of the elusive Bigfoot in the Pacific Northwest, Roger Patterson finally obtained a short movie strip of a very large, seven-foot tall female with pendulous breasts and crested head, walking through a forest clearing with giant strides. This is perhaps the best frame from that movie strip. Sasquatch tulpoids have been known since ancient time by the Indians who lived in the area. It would be interesting to see what results could be obtained in materializing or partially materializing the Bigfoot tulpoid with a Reichian cloudbuster.

Bigfoot-like creatures are materializations from the collective human unconscious shaped and formed by the layers (race, culture, nation, territory, state, region, family, etc.) between the collective unconscious and the individual unconscious minds of the observers. The exact format depends on all the higher level "kneading" of the "dough" that is being forced out into materialization.

In the Pacific Northwest the Indian knew of the sasquatch long before the coming of the white man; in that region, a great deal of tuning has been accomplished, and the sasquatch is a rather well-tuned animal form, having well-

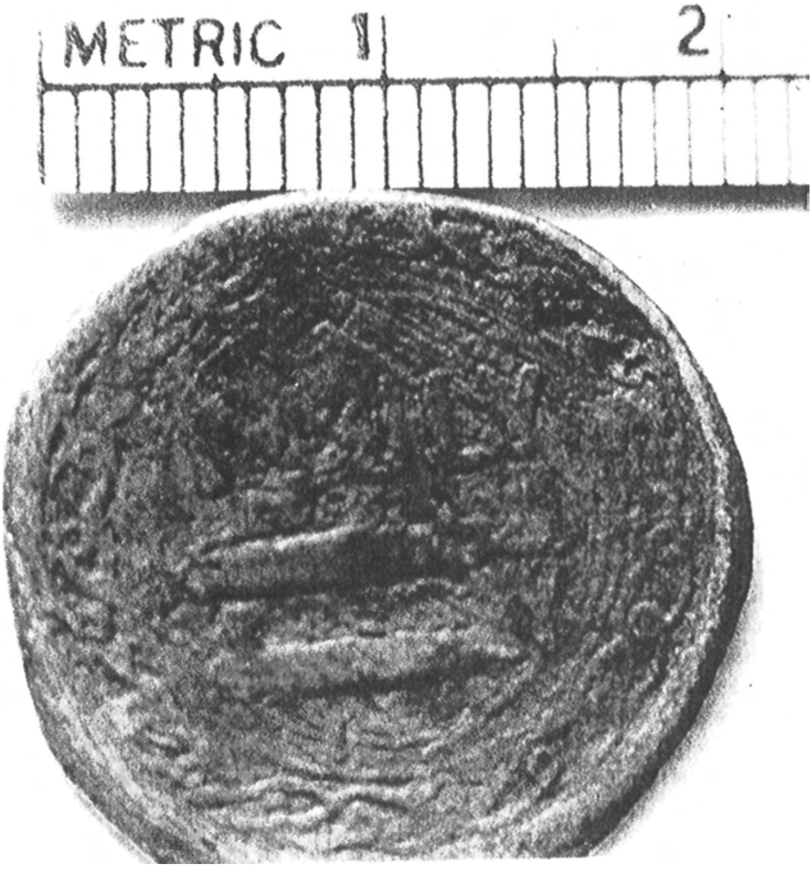

Photo 26. An ancient coin handed to a psychic friend of a UFO investigator by tulpoidai men-in-black.

defined footprints as shown in Photograph 28. In the East, the yeti has also been tuned for centuries, and a cast made from his footprint is quite well formed — though also quite different from that of a typical Pacific Northwest sasquatch. In New Jersey, on the other hand, for the last two or three years there have been a large number of Bigfoot sightings, but here there has not been the same degree of tuning for several centuries, and consequently the footprints look rather messy, like blobs left by the creature before it vanished back into dematerialization. Finally, in one case a person well-known to me stumbled into dematerialization phenomena of a very strong nature. One of the incidents involved the materialization of a really gigantic "superfoot" creature, which walked around all over the base of a mountain, leaving giant footprints two feet or so long. Though monstrous in size, superfoot is really ill-tuned and thus ill-defined, with footprints that are decidedly blobby in form.

UFO's OVER THE SOVIET UNION

In 1961 locomotive engineers on a freight train from Moscow to Golytsino, when about forty kilometers from Moscow, sighted a disc-shaped object topped by a cupola approaching the train. The object slowed to pace the train and escort it for about one kilometer. Suddenly the locomotive engines went dead, and could be restarted only after the mysterious object disappeared.

On December 29, 1967 an Iliouchine 14 aircraft enroute from Zaporoje to Volgograd sighted an approaching UFO. As the UFO neared the aircraft, suddenly the aircraft's engines stopped in midair and the plane began slipping sideways toward the earth, carrying its panic-stricken crew to certain destruction. When the crippled aircraft was about 700 meters from the ground, the UFO abruptly disappeared. At the same instant the aircraft engines sputtered and roared to life again. The pilot righted the aircraft as lift returned, narrowly averting a crash.

On September 24, 1962 first one oval object then several others escorted a TU-104 airliner enroute from Vorkouta to Omsk and maneuvered around it with astonishing speed and agility. The eerie aerial escort continued for most of the flight, and the objects were extensively observed by both the passengers and the crew. The objects positively could not have been other planes, balloons, satellites, celestial objects, or other known natural phenomena.

In Latvia in 1965, R. Vitolniek, a well known astronomer, together with several scientific colleagues, sighted a triangular-shaped formation of four spherical objects, one at each of the points of the triangle and one a little larger in the middle of the triangle. Two of the scientists, Ian Mederis and Robert Vitolniek, made immediate calculations and insured that the objects were not satellites or normal orbital objects. The objects steadily shrank in size, leading Vitolniek and his colleagues *to* conclude that the objects were traveling away from the earth into outer space.

At least two Soviet astronauts, Colonel Bykovsky and V. Terechkova, have observed UFO sightings and reported them to the Soviet authorities. Many other UFO sightings have occurred in the Soviet Union and the Iron Curtain countries; **these** are just a sampling.

In fact, on several occasions Soviet defense forces have been committed into massive action against UFO's.

In 1959 numerous UFO's flew over Soviet rocket launchers at Sverdlovsk. In addition to being visually observed by a large number of personnel, they were detected and tracked on Soviet radars. Soviet military units were ordered into action immediately. Interceptors and antiaircraft artillery batteries went into action and the air defense missile units opened fire. In spite of the fierce engagement of the elusive UFO's, none were hit or damaged and no results were obtained by the Soviet combat forces. Men, machines, guns, rockets, missiles and radars could not cope with the UFO's. The impact in the Soviet military of several such military actions must have been enormous.

In fact, such incidents as this probably were responsible for the establishment of an extremely high level and highly classified Soviet investigation of UFO phenomena. Given the decision to launch such an investigation — and it would be inevitable for the Soviets to take such a step when their air space was under open invasion by possibly hostile forces — the Soviets would have assembled a formidable scientific team to tackle the problem. Furthermore, given the highly classified military reports of such encounters, reports of UFO incidents at other Soviet installations and by other Soviet military personnel, and the steady occurrence of the normal range of UFO sightings and incidents over cities and villages, the Soviet system would have tolerated no scientific nonsense in opposition to the mission to discover the nature of the phenomena. In other words, the Soviet team from the beginning would have concentrated on finding the explanation and nature of the phenomena, not on whether or not such phenomena were real or were occurring.

In my opinion, a connection between UFO's and paranormal phenomena — and the new psychoenergetics which also was formulated by 1959-60 — was realized about 1960. The high classification of the Soviet psychoenergetics program then led directly to an official Soviet policy to debunk UFO's and paranormal phenomena if the work of any outside research group became too serious. Some Soviet scientists who had no connection with the weapons programs were allowed to work a little on paranormal phenomena and on UFO's. This was simply to provide a deception plan for Western scientists; in their contacts with their Soviet scientific colleagues, these Western scientists would see only a rather puzzling collection of simple laboratory experiments on telepathy, ESP, simple psychotronics, psychokinesis, etc. A limited number of Soviet papers dealing with these subjects, but of no particular theoretical content or very exact statement of experimental apparatus and conditions would be permitted in the open journals. However, close scrutiny of such activities would be maintained by the Soviet state, and no real breakthroughs would be permitted to occur or to be transmitted to the West. Ziegel, Dubrov etc. owe the limited work they were permitted to do to this Soviet deception policy.

They also owe the surveillance and harassment they have undergone to the Soviet policy of insuring that they would be permitted to do nothing significant, or to communicate nothing significant to their Western colleagues. Meanwhile, a rigorously controlled and highly classified Soviet psychotronic weapons development program continued apace. And the radiation of the U.S. Embassy (and the U.S. ambassador to the Soviet Union) in Moscow with weak radiofrequency microwaves containing psychotronic modulations began about 1959-60 and con-

m

Photo 27. Sasquatch.

Photo 28. Bigfoot cast.

tinues to the present. As explained elsewhere, this radiation was in fact another very clever Soviet intelligence probe: By observing how the U.S. reacted, they could determine whether the U.S. had any knowledge of psychotronics and thus whether or not the U.S. had developed secret psychotronic weapons and counters of its own.

The Sighting over Petrozavodsk

Even more spectacular phenomena have occurred in Soviet skies and are continuing to occur.

For example, a mysterious phenomenon of great magnitude occurred in the skies over the Soviet city of Petrozavodsk at about 4:00 A.M. on September 20, 1977. Petrozavodsk is in Soviet Karelia about 130 miles from the Soviet-Finnish border.

First, a gigantic mass of light flared up in the skies over the city, glowing brilliantly, and hovered there. Fantastic streamers of light poured from the glowing hemispherical dome of light and radiated down towards the city. Tass, the official Soviet news agency, reported that it looked like nothing so much as a shining "jellyfish sending down a multitude of fine beams." It gave, Tass said, "the impression of a torrential rain of light." Where these fine beams touched windows, many windows were broken or perforated with small holes.

Later the glow died down and the jellyfish became a single giant bright semicircle. It then gradually moved off in the direction of Lake Onega. But all was not yet over. Even after the bright hemisphere had moved away, great gray clouds appeared over the city with a semicircular aperture bright red in the center. These phenomena lasted for ten minutes or longer.

Being over the city and lighting up the sky so fantastically, the phenomena were seen by a large number of Soviet citizens and reported by them to the Soviet authorities. In fact, Tass admitted in its initial release that informative reports from witnesses were still pouring in and being analyzed. This interesting phenomenon is worthy of some remarks by way of explanation.

Not only is pressure from the Soviet threat transmitted through the collective human unconscious (ZARG) to the skies of Europe and North America; in addition, a backpressure is generated, which provides the impetus for initiation of appropriate phenomena over the Soviet Union and the Iron Curtain countries. Psychologically, it may not be accidental at all that the original shape resembled a giant jellyfish; the implication is that the psychotronic sting will also be transmitted to the Soviet Union by backlash whenever the Soviet psychotronic weapons are unleashed on the West. The shapes are also psychologically significant. First the Portuguese man-o-war's stings will be applied (this accounts for the tentacles toward the city); then the all-seeing eye (symbolized by the bright hemisphere) will check the results. And the results will be gloom and despair (gray clouds), surrounding death, blood, and destruction (the red center) left in the aftermath.

Thus in this materialized symbolic dream event of ZARG's, there is a clear warning and an omen to the Soviet Union about the end result that awaits it on its present course to attempt to conquer the world and unleash a great psychotronic barrage in the process.

Since so many Soviet citizens saw and reported this fantastic phenomenon in alarm, the Soviet regime could not ignore it or simply debunk it. The Tass release thus tried the oblique dodge: the phenomenon was still being evaluated, reports were still being received and checked out, and an official of the Petrozavodsk observatory, Yuri Gromov, was quoted as saying the phenomenon was still a mystery but was confirmed by a large number of eyewitnesses. The Pulkovo observatory in Leningrad was quoted by Tass as speculating that the phenomenon was due to a meteor. And of course there one can expect the matter to be left in limbo.

An interesting development related to this UFO sighting occurred in the U.S. The October 3, 1977 issue of *Aviation Week and Space Technology* magazine carried a brief disposal of this phenomenon. The brief insert, Spook Show, referred to a "Soviet press ballyhoo" of the incident and stated that the incident was actually the launching of the Soviet Cosmos 955 classified military satellite from secret launching facilities at Plesetsk. This AWST insert is credited to Washington Staff.

My comment is that the launching of the Cosmos 955 may well have been the initiator of the event — a rocket firing does produce a tremendous ionized trail of burning exhaust gases rising up into and out of the atmosphere, and this is a bioenergy collector par excellence. However, a simple review of the time sequence of the phenomenon, its location, and its shape is sufficient to destroy any notion that one could mistake it for a simple rocket launch. And rocket launches had occurred there many times before, with no such phenomena or mass reportings by the population, and with no such news release by Tass.

FRENCH EXPERIMENTS WITH PSYCHOTRONICS

Aime Limoge in France is building some truly unusual gadgets that are being tested and that work. Limoge travels widely in the Soviet Union, and attempts to duplicate some of the unusual Soviet devices he has been permitted to see. Some of Limoge's devices have a partially psychotronic nature, although none of his reports mention this.

One of his gadgets, a portable and battery-powered electroanesthesia device, was considered for purchase by the U.S. Army.

Another of his gadgets is a magnetic inductor of hypnosis, which has been used in medical treatment by L'Institut de Recherche d'Electro-anesthesie. Limoge is reported to have seen such a device in the Soviet Union, possibly because one part of the Soviet psychotronics deception plan calls for the deliberate release of information of this kind, in a manner to suggest that this is the latest state of development in the USSR. In fact, their research efforts probably go far beyond this point. However, we should note that this device can be used as a most efficient brainwashing instrument.

DOWSING

To understand how dowsing works, we must first understand something about higher dimensional spaces. It should be evident that, if there is a type of energy being sensed by the dowser, that energy must be coming in or arriving from outside this three-dimensional world, since our ordinary science deals with the energies existing in this world, and none of these ordinary energies can explain dowsing. However, because of the work that has been done showing that dowsers are extremely sensitive to magnetic fields, this energy must be somehow related to the ordinary magnetic or electromagnetic fields known to science.

In the human being the mindworld must itself have a coupled kindling system to cohere its changes and kindle them into electromagnetic energy and energize the physical body. The body system which does a great deal of this is the acupuncture system of points, plexuses, and meridians. Also, all powerful emoters, such as the endocrine gland system, are deeply involved in the kindling of the biological organism's mind energies into electromagnetic energies to energize the physical body. The body and its biorhythms form a coherent tuner in the time channel to accomplish this kindling of time-nested vital thought energies into ordinary energy. Because a great deal of mind energy kindles into only a minute amount of normal electromagnetic energy, our minds normally have only a small effect in this particular three-dimensional world. So we can normally psychokinetically move a few electrons in our brain and nervous system, and generate an input signal to our otherwise inert physical servomechanism. Ordinary inert physics and amplification takes over from there, and we can only deduce the kindling as mental intent from observing many, many quanta of physical change, i.e., from macroscopic behavior. At any rate, the dowser has learned to detect, focus, and sense very fine levels of electromagnetic fields, which means that at these low levels the kindling of mental energies can represent a much greater percentage of the field than normal. Thus the practiced dowser can now discriminate many of the particular types of fluctuations or changes in these weak fields due to mind kindling.

Furthermore, I would like to point out that, since mind kindling comes into this universe orthogonally, normal distances do not apply. The entire physical frame appears to the mind world as a point, and thus is totally inside the mind of the operator/dowser. It is for that reason that a dowser can establish a coherent tuning (intent) between a map and the actual ground, or between a picture and an actual object, or between a rod and a person' physical body when sensing medical illnesses. In the mindworld frame, the dowser is only dowsing or detecting himself, and himself includes this entire physical world — the earth's surface and beneath it, the sun, the moon, the stars, or whatever.

Just as the body used electricity, magnetism, and electromagnetic signals long before man knew of their existence, it has used kindling of bioenergy from higher dimensional frames for a very long time, even though these have been unknown to mankind. And dowsing is a very old art indeed; the ancients used magnets without knowing of magnetic field, and they used dowsing without knowing of hyperspaces and hyperfields.

THE STROBE EFFECT

These five pictures show one of the more interesting effects demonstrated by many tulpoidal forms: strobing or "coining." What happens is that, much like a flat rock skipping across the surface of a pond, the orthorotating tulpoid skips in and out of its intersection with our three-dimensional frame.

In the first picture a glowing spherical tulpoid is shown to skip or strobe several limes while the camera shutter is open. It does not move in a linear pattern, but rocks around and back-and-forth.

In the second photo, an aerial photo, a UFO in photonic form (first bio-frame) reveals itself to be strobing or skipping. (In university classes on the paranormal, I often refer to this type of action as *coining,* since it resembles a bright quarter or nickel that is photographed by stroboscopic light while rolling around.)

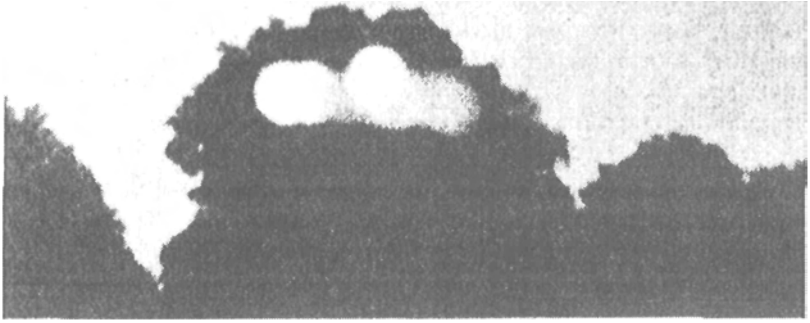

Photo 1

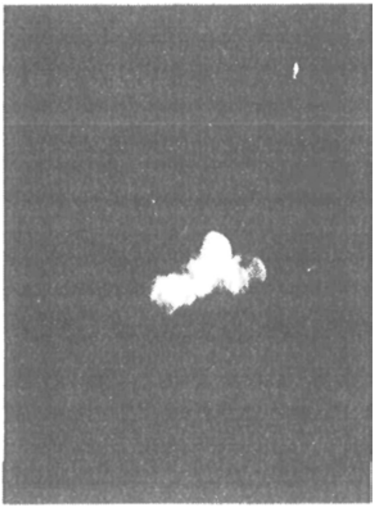

Photo 2

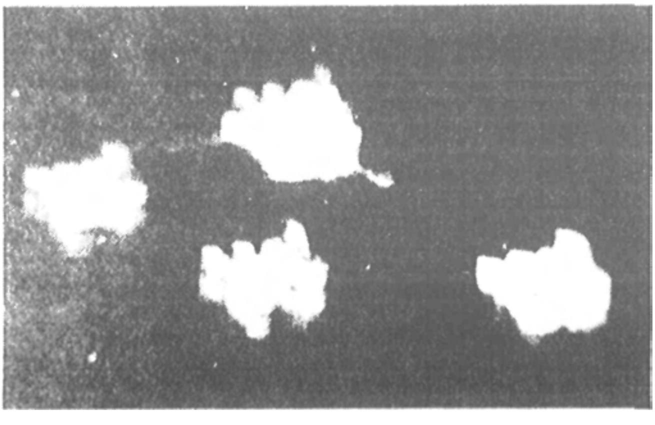

Photo 3

Photo 4

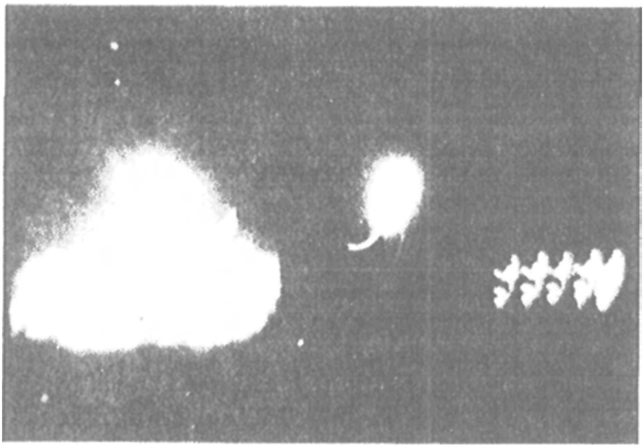

Photo 5

Photo 29. The strobe effect.

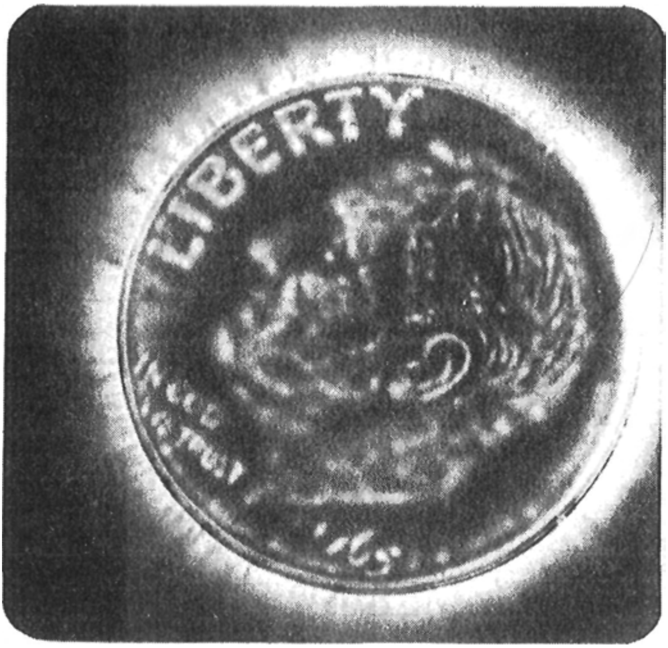

1. Even dischargo from Inert object (dime).

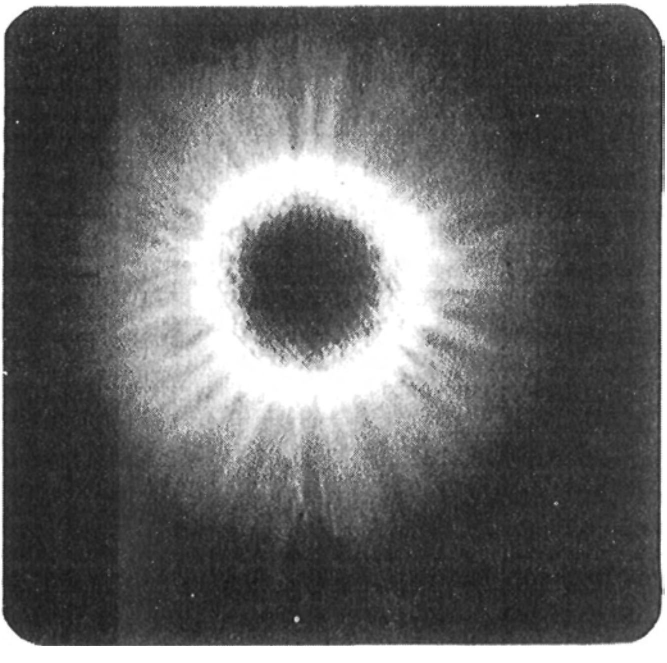

2. Healthy person in calm state

Photo 30. Kirlian photography.

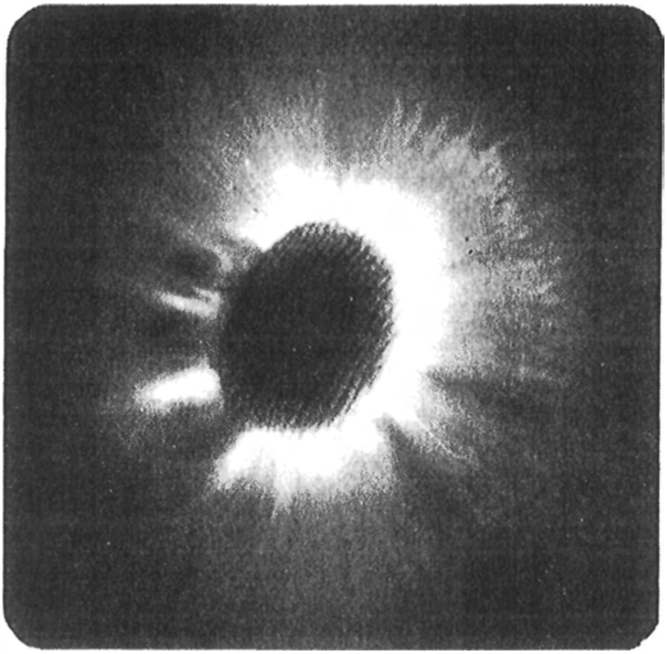

3. Person in meditation

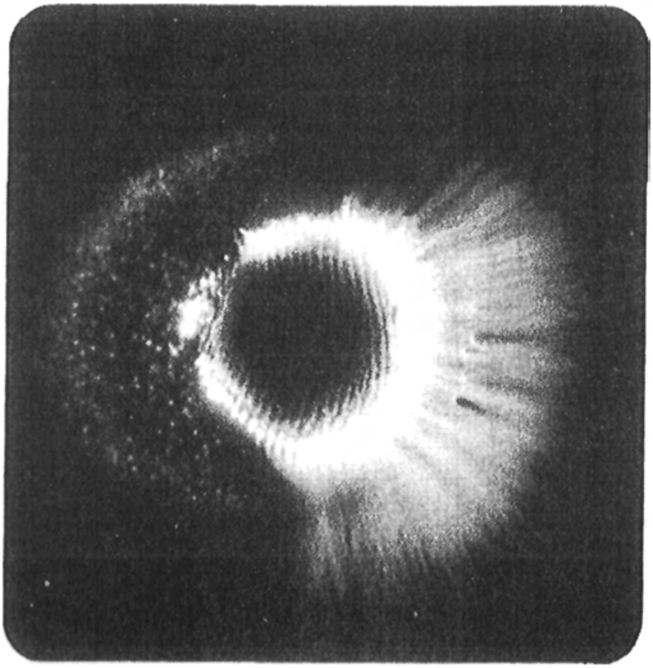

4. Angry person.

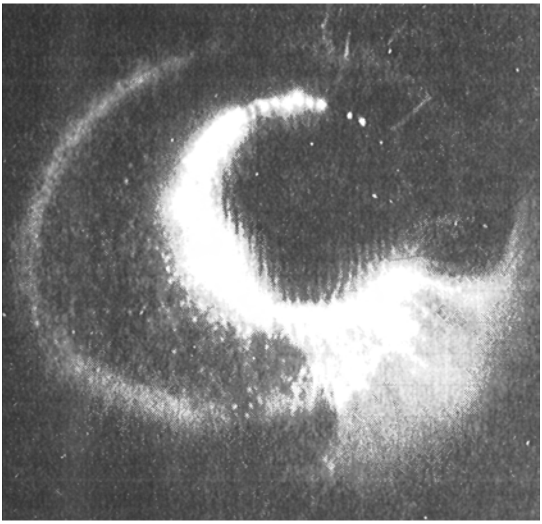

5. Person with London **flu.**

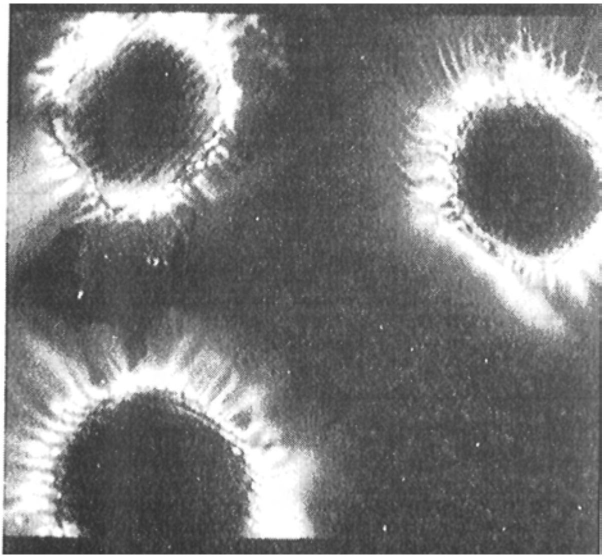

6. Interactions between three persons.

The third photo shows a more striated form. In fact, these forms show kindling and strobing at the same time. In addition, the physical size of the strobed intersection with our three-dimensional space changes during the photo exposure.

The fourth photo clearly shows both the striations due to strobing and also the variation in size of intersection in the zeroth frame by the hyperdimensional tulpoid.

Photo five again shows these effects, with the addition of the two "bursts" in the upper part of the left tulpoidal object and in the center tulpoid.

Significantly, psychokinesis also often demonstrates stroboscopic movement.

KIRLIAN PHOTOGRAPHY

These six pictures show some major characteristics of Kirlian photography: (1) an even discharge from an inert object (a dime); (2) a balanced, gentle, even discharge from a healthy person in a calm state; (3) a gentle outgoing discharge enhanced on one side, and a gentle indrawing on the other, from a person in a meditative state; (4) strong bunching and outgoing discharge from an angry person (the word "emote," after all, means "move outward"; (5) choppy (as if out of control) bunched and outgoing discharge from a person ill with London Flu, with strong suppression of the normal, relaxed blue component at the lower right; (6) interactions between three persons, showing differing degrees of outgoing and barrier reactions.

The film itself only records ordinary photochemical interactions; it specifically does not record the aura. However, changes in the discharge patterns can be and often are induced by kindling bioenergy into the first biofield (electromagnetic field), inducing changes in the sparking pattern and intensity. Furthermore, this can occur fairly readily on such a high voltage series of discharges, which are excellent collectors for kindling.

As a final note, it should be pointed out that David Faust *et al* have published a technical paper in the scientific literature detailing the fact that Western experimenters have not yet duplicated the Soviet equipment and methodology used in their Kirlian photography. While David formerly pointed out in *Science* that experimenters must carefully control the variables—particularly moisture (water is an excellent collector for kindling)—he has been widely misinterpreted as having proved that water vapor was responsible for all Kirlian effects. This he has not done at all, nor did he intend to, since he himself is one of the most competent investigators in electrophotography.

INTERACTION OF BIOFIELD, THOUGHT, AND SPARK DISCHARGE

These photographs are strong examples of the kindling mechanism. The subject tested was Uri Geller, a person with strong inceptive ability. In photo 1, the top two exposures are for control purposes, while in the bottom exposure, Uri is concentrating on the image of a circle. In photo 2, again there are two control exposures shown at the top, while in the bottom exposure Uri is concentrating on the image of a triangle. In photo 3, exposures are taken of Uri and a wristwatch; this is

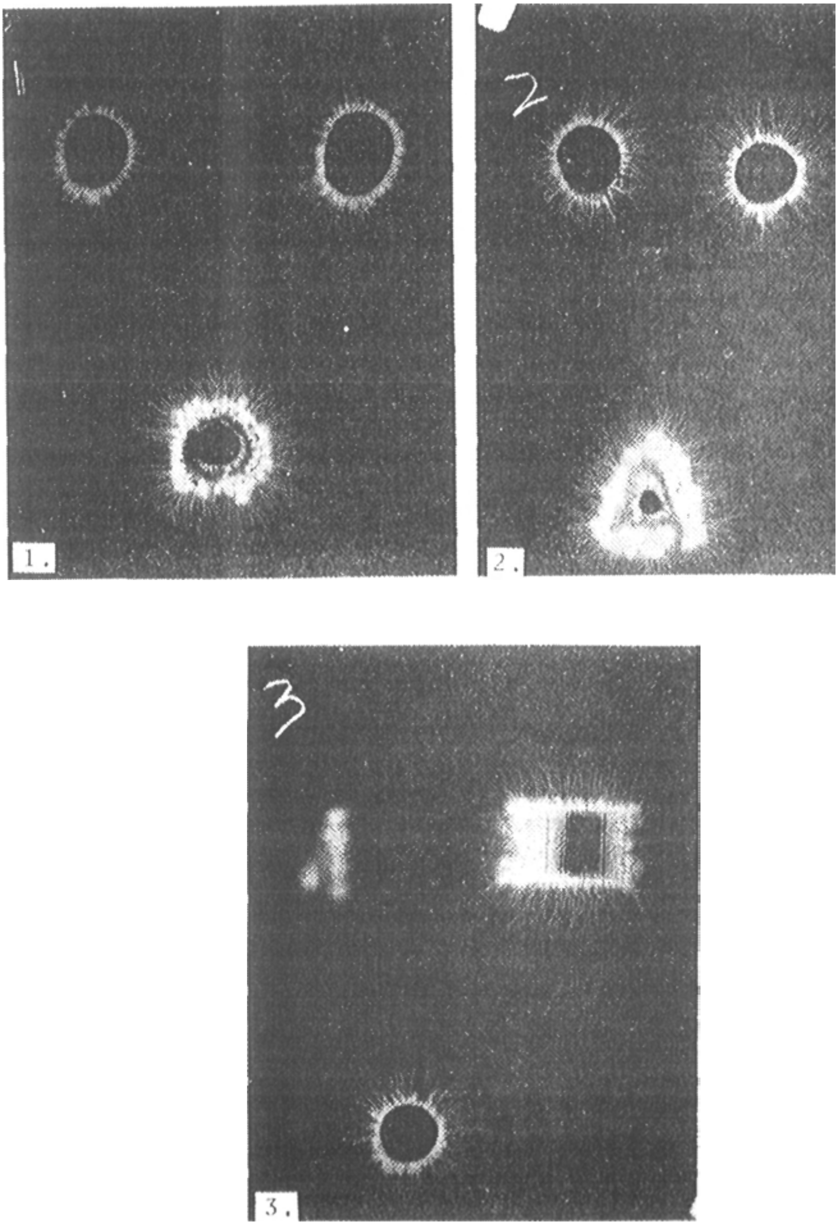

Photo 31. Interaction of biofield, thought, and spark discharge.

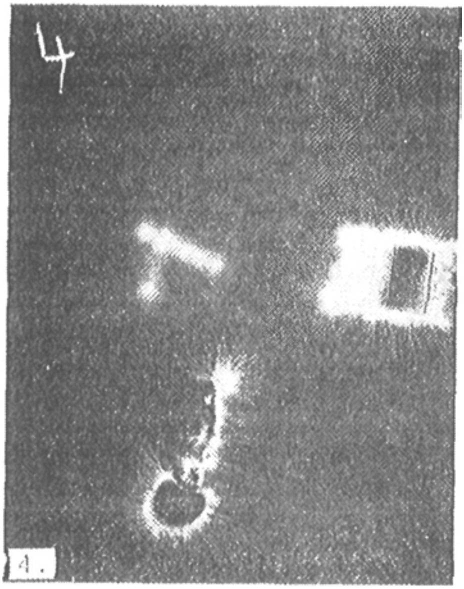

4.

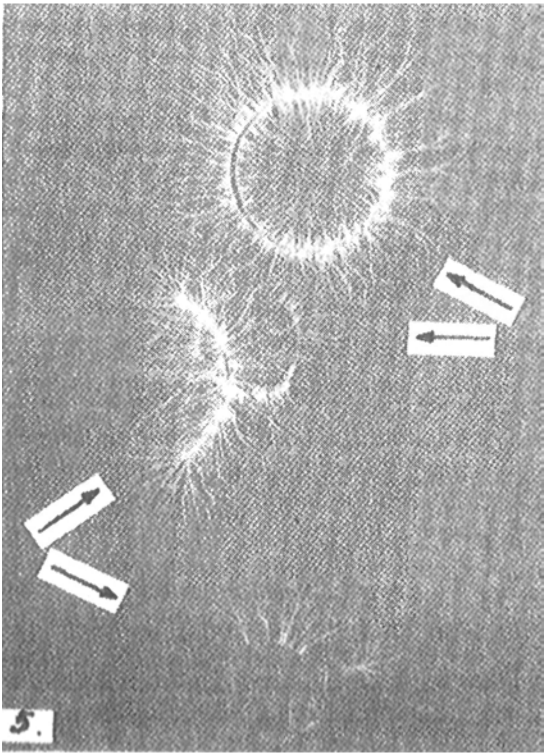

5.

a control photo. In photo 4, Uri is attempting to send energy toward the wristwatch, and a correlated change in the discharge patterns from his finger is evident. In photo 5, the arrows at the right point to control exposure of Uri and a silver ring; the arrows at the left point to the exposure made with Uri attempting to bend the ring psychokinetically without contact. The direct kindling of bioenergy in a force-field line intersecting the ring is striking. In such an intense kindling, note that the nuclear currents inside the nuclei of the silver atoms — where positive charge is being shuttled back and forth between protons and neutrons — are also being strongly kindled. Reductions in the positive charges steadily reduce the charged exchanging particles to quarklike particles, severely affecting the structural integrity and crystalline lattice directions of the base metal. By this means metal bending — or even breaking — is accomplished.

KERVRAN EFFECT

A direct and repeatable experiment showing that living systems can kindle bioenergy into ordinary energy and material effects has been made possible by the fascinating work of Louis Kervran. Kervran showed that chickens, fed a diet deficient in calcium but containing excess potassium, will have no calcium deficiency, since they transmute some of the potassium into calcium. Kervran's pioneering work has been duplicated in Japan and elsewhere, and the same effects have been demonstrated by living plants.

We may consider a neutron as a sort of bound system of a potential proton and a potential electron. Psychokinetically killing the charge on the potential electron converts the electron into a neutrino, leaving behind a proton now freed. For the one percent or so of potassium that is a calcium isobar, this process can produce ordinary calcium. Thus in a potassium-rich diet the chicken can psychokinetically transmute enough potassium into calcium to remain healthy.

Kervran was nominated for a Nobel Prize in 1977 by the Japanese researchers; his work is direct proof of the ability of living systems to violate present physics, and of the ability of mind energy or bioenergy to affect matter psychokinetically.

PSYCHIC SURGERY

These two photos taken by Sigrun Seutemann in the Phillipines show materialization of large lumps of tissue brought about by Tony Agpaoa on a patient from an educated Western culture. The minds of both the patient and the surgeon are involved in the process, according to the psychic surgeons themselves. "Western patients are strongly conditioned to believe that medicine involves bloody tissue, so this is what results in the particular form of the materializations. For native patients who are steeped in the lore of shamanistic medicine, apports may consist of substances such as leaves, coconut fibers, feathers, etc.

The legitimate surgeons, working in a religious group structure, are often able to generate sufficient kindling to fully materialize such unconsciously structured thought forms, and also to dematerialize and rematerialize the tumor from inside the patient's body, the tumor usually appearing or emerging from an opening which appears in the apport tissue. In the surgeon's view he is also being helped by powerful spirits — and continual charging of such thought forms with kindled

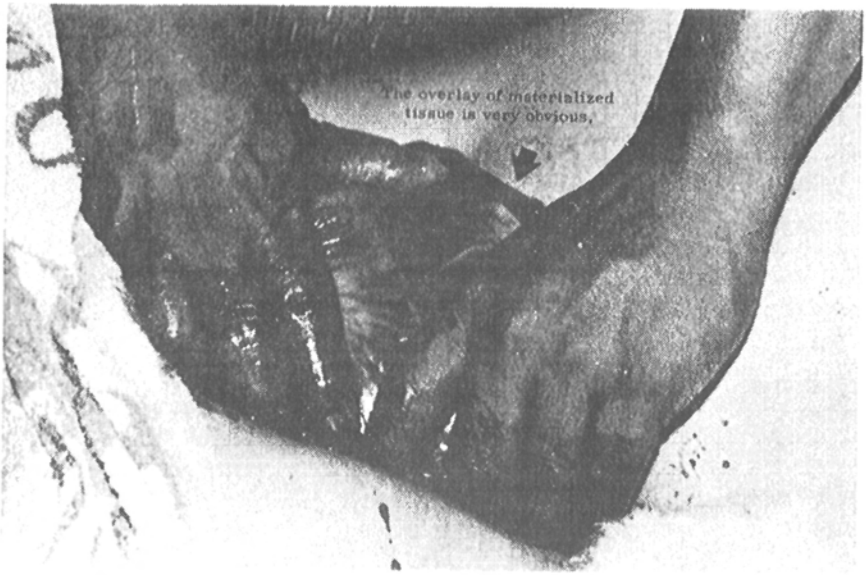
The overlay of materialized tissue is very obvious.

1. Materialization of apport tissue while removing a tumor from the abdomen.

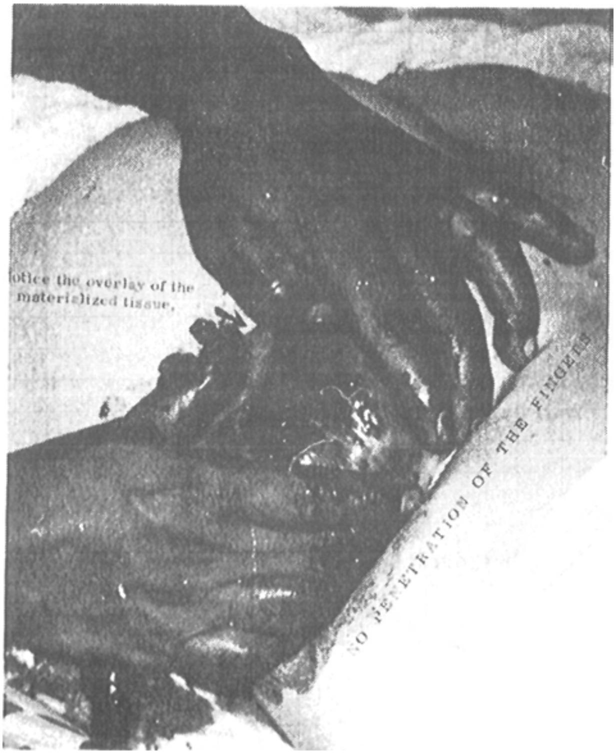
otice the overlay of the materialized tissue,
NO PENETRATION OF THE FINGERS

2. Matoriallzatlon of apport tissue while working in the hip region.

Photo 32. Psychic surgery.

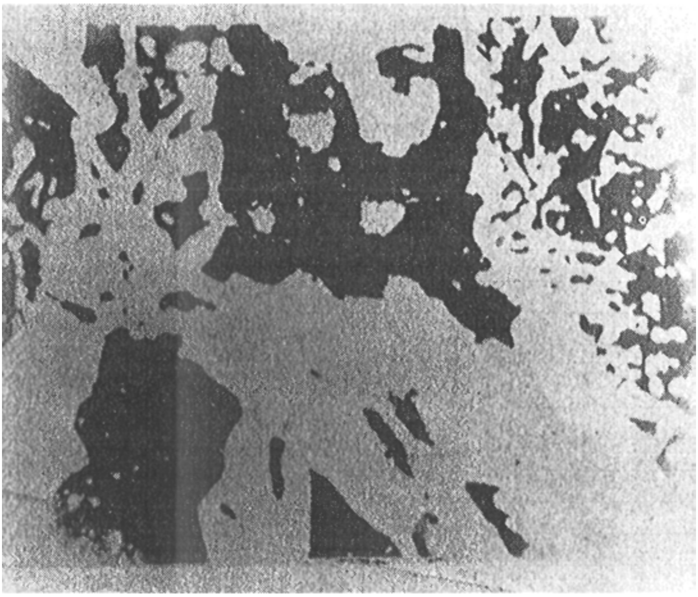

This highly unusual photograph resulted in the following manner: Mrs. Baune Is a devoutly religious lady, and on this particular day she had spent a great deal of time in prayer and a Christian attitude. Snow was gently falling on the shrubbery In her yard, and she and a neighbor were admiring the beauty of the fresh snowfall. The neighbor borrowed Mrs. Bauno's camera and snapped a photo of the snowfall. When the photo was developed, the falling snow had formed a pattern of Jesus on the shrubbery In Mrs. Baune's yard.

Photo 33. Kindling of thought bioenergy in snow.

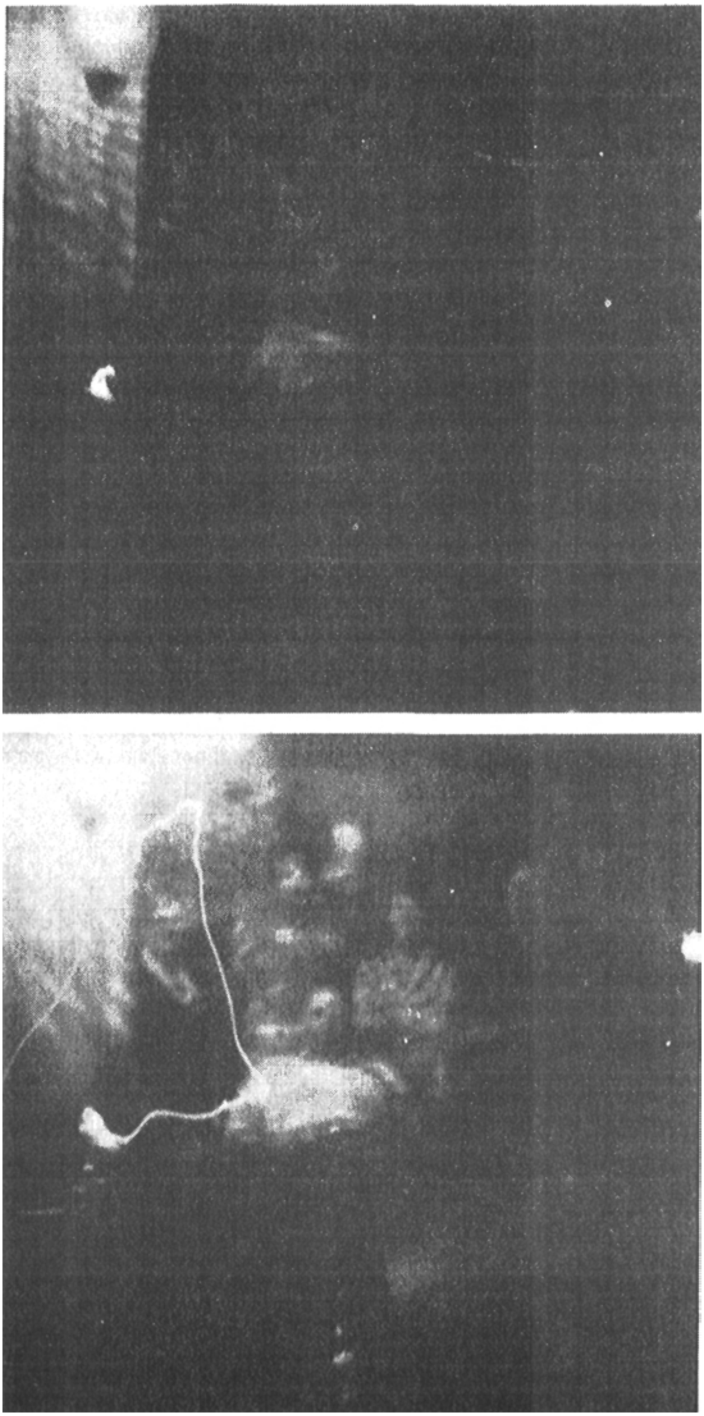

Photo 34. A deliberate experiment with kindling.

energy indeed can yield bioenergetic formats of more intense energy than a single talented individual can usually muster in an unaided or unaugmented state. Almost every religion, in fact, still occasionally exhibits miracle healing accomplished in somewhat similar fashion, though possibly less dramatically.

The apport tissue is a materialized tulpoid, precisely as are sasquatch, the yeti, the Loch Ness monster, and UFO's. Apports are normally more stable than these latter materializations — but they have also been known to disappear, as have the "angel hair" apports associated with UFO's.

A DELIBERATE EXPERIMENT WITH KINDLING

I and other members of the American Association of Meta-Science performed a series of experiments in kindling thought or psychic energy into electromagnetic energy, and photographed the resulting light energy on film with an SX-70 camera. The two photos shown here are from one of those experiments. In the left picture, bioenergy is just at the "burst" point where it is being collected on a candle flame. Here the camera lens is not quite fully opened. Only a single 40-watt lamp illuminates the room, and several AAMS members have been engaged in about two hours of psychic exercises. In the second picture, the lens of the camera is fully opened, and a "burst" of kindled energy occurs as the lens shutter is operated. None of this is visible to the naked eye. The polaroid film, however, is sensitive to some infrared and ultraviolet frequencies, so that bioenergy kindling into electromagnetic energy at IR or UV frequency can be photographed even though not seen by the naked eye.

FAY CLARK'S "FIREFLIES"

Fay Clark experimented with an ultrasonic generator in a darkened fallout shelter and photographed the most interesting results. At one particular frequency, dynamic dots of light appeared, grouped themselves into formations, and demonstrated movement and growth. At times they seemed to respond to thought, as if they were somehow intelligent, sentient creatures. This is a beautiful case of kindling using ultrasonic frequencies as the collector mechanism. While Fay is no longer sure of just exactly which frequency produced the fireflies, he does know that he used frequencies in the 38—40 kilohertz region, among others. This may be significant, since the Vestigia experiment encountered electromagnetic frequencies in the same region in their historic study of a mystery light. The frequency region 38—40 kilohertz is a strong candidate for one of the magic window frequencies between bioframes where kindling is much easier than at other frequencies. Furthermore, since it is thought energy or mind that is actually being kindled, one would expect the possibility of sentient behavior. Clark's experiment occurred in the dark, so the squelching effect of visible light was not present. Finally, Fay Clark is a known psychic himself, and so this should have eased the kindling difficulty even further. The value of rigorous laboratory experiments based on the lines of Fay Clark's pioneering "firefly" experiment is strongly indicated.

"FOO" FIGHTERS

When large groups of people are under strong external pressure, one result is often tulpoidal "popouts" from the collective human unconscious.

A war is a typical example of a situation where the group consciousness of a country is under enormous pressure. In such a situation, the "targeted" population is often exposed to tulpoidal manifestations from time to time.

In World War II, for example, the Germans thought at first that the glowing lights darting around their planes were secret Allied weapons; and the Allies thought the same thing of the Germans when they saw such unusual phenomena. The French dubbed them "feu" (fire) fighters, which became "foo" to American soldiers in Europe.

"Foo" fighters were a common phenomenon in World War II, particularly in cloudy, overcast skies.

WATER MONSTERS

In the oceans and in every large body of water on earth, water monsters have been reported for centuries. Loch Ness in Scotland is of course one of the most publicized examples, but creatures of different shapes and sizes have been seen in large lakes and streams everywhere. This is not at all surprising when one realizes that a large body of water is a most excellent kindling reservoir, and bioenergetic forms are more readily kindled in such locations.

The large dead creature in photograph 36 was hauled off the bottom of the sea by Japanese fishermen in their nets, photographed, and then thrown back to prevent contamination of the catch of fish and to get rid of the stench from the decaying carcass. It is a pleisosaurlike creature's remains, not similar to anything else known on earth. Predictably, scientists were almost immediately at odds as to what it was, and the carcass has been called a shark, a whale, a large elephant seal, a genuine pleisoaur, etc., by various "experts." Nonetheless it was real and physical, and a good photograph was obtained of it.

Photograph 37 is one of the underwater photographs of the Loch Ness monster taken by a team from the Academy of Applied Science, Boston, Massachusetts on June 20, 1975. As can be seen by a detailed study of the photograph, this tulpoid is not clearly tuned or clearly formed. Many other photos of the Loch Ness monster have been taken, and various shapes and sizes and degrees of tuning have been recorded. In the Doc Shiels photos taken in 1977, Nessie is well formed but entirely different from the Academy photo. Also, Doc Shiels' photo was subjected to computer analysis by Ground Saucer Watch, and the image exhibited a transparency that was disturbing to the analysts. On the other hand, such a transparency is to be expected from a partially materialized tulpoid which is not completely orthorotated into the zeroth bioframe.

In the Academy photograph, one can see — particularly on the color original — a form which has several conglomerated faces, which exhibits eyelike structures in several locations to suggest first a cowlike face and then a horselike face, and incoherently tuned earlike and hornlike appendages in several places. In fact, the Academy photo bears little resemblance whatsoever to a pleisosaur or any other more normal and coherently structured mammal or fish.

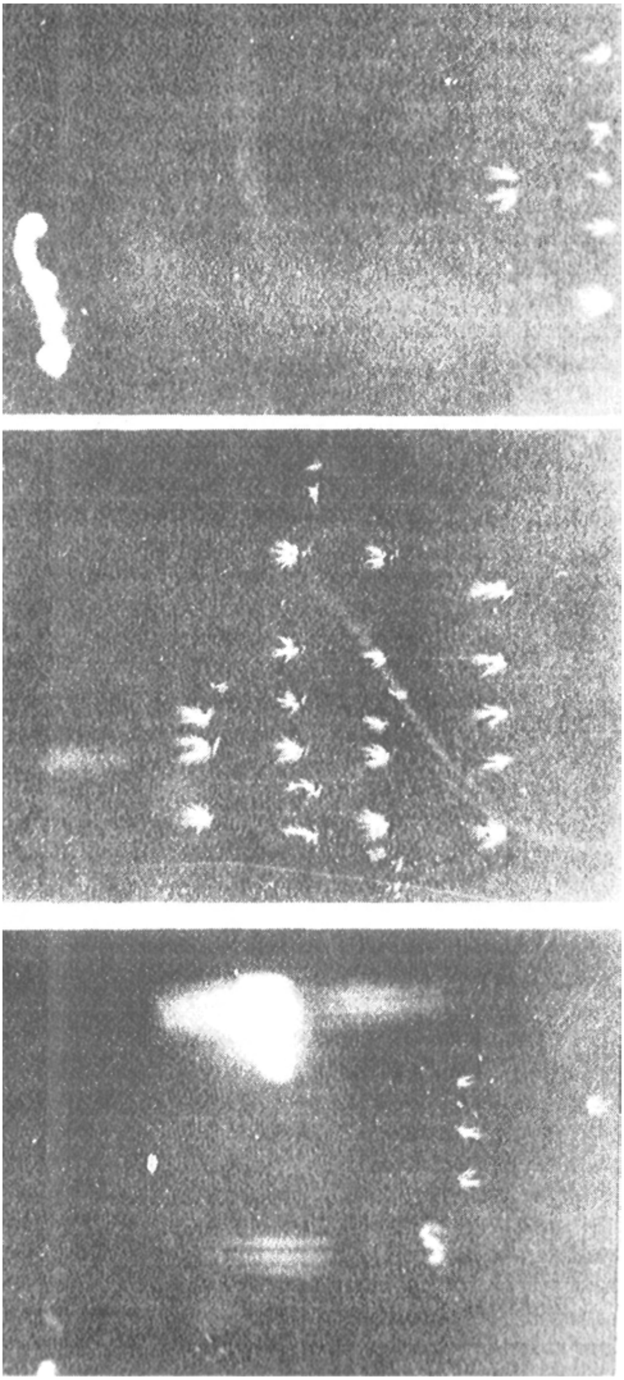

Photo 35. Fay Clark's "fireflies."

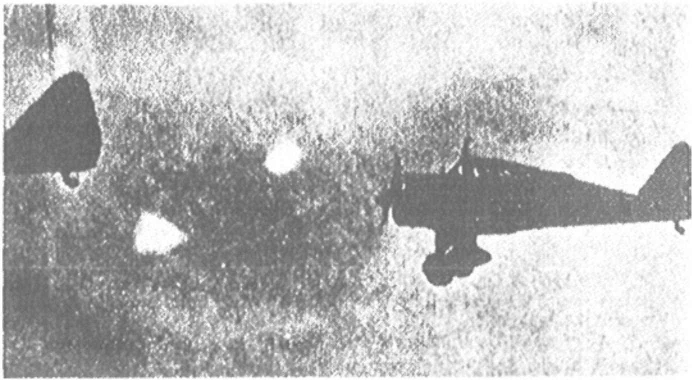

"Foo fighter" tulpoids pacing Allied aircraft in World War II.

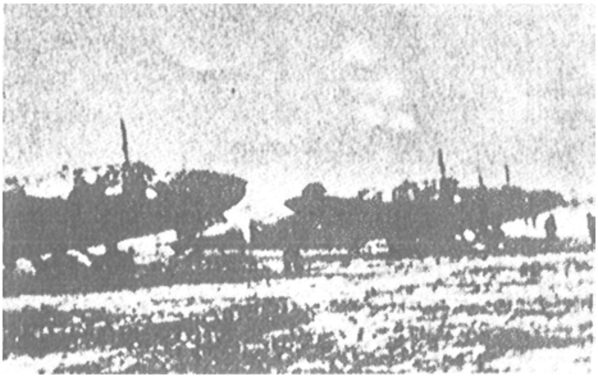

"Foo fighter" tulpoids over an airfield in China in World War II.

Photo 36. "Foo" fighters.

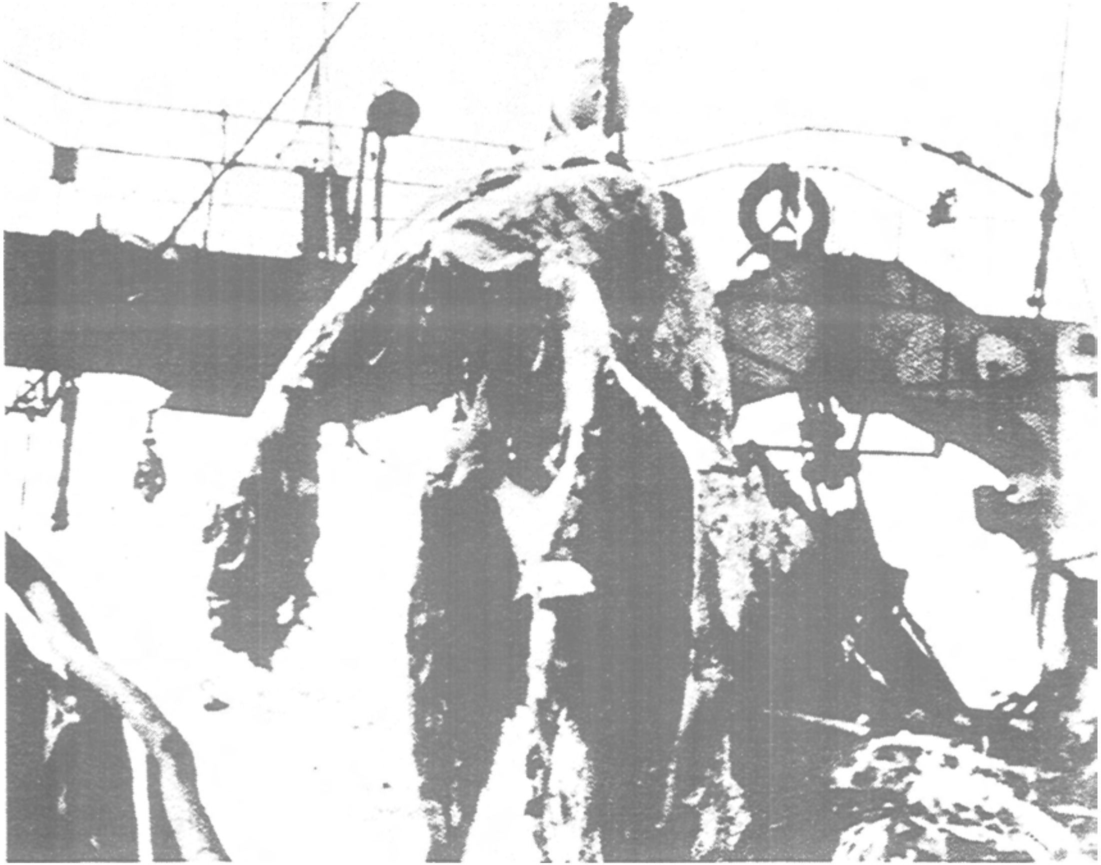

Photo 37. Pleisosaur-like creature hauled from the sea by Japanese fisherman.

The Loch Ness monster is definitely a tulpoidal form, and the format varies appreciably from reception to reception due to distortions and variations in tuning. Nessiteras rhombopteryx is a much stranger beast than anything the dedicated Nessie seekers, researchers, and scientists have yet suspected. In Part Two I will examine the scientific basis of tulpoidal forms.

CATTLE MUTILATIONS

Over 9,000 cattle mutilations have occurred in the U.S. alone since 1973.

The cow is a female symbol par excellence — our children drink cow's milk, and our babies feed on the milk from the cow's breast. The U.S., being a natural fortress, is a "female" symbol, for in primitive human evolution the females stayed in the cave or protected fortress while the males went forth to hunt or do battle. (This symbolism will be fully discussed in Part Three.) Violation of the female means that the heartland U.S. shall be violated.

Teats are cut off — the children of the West shall lose their sustenance; lips, ears, and tongues are removed — freedom of speech and hearing shall be excised; sexual organs are removed — no more fruit of the womb shall be evidenced in the West; sharp, surgical incisions are made — the operation shall be accomplished swiftly (blitzkrieg war) with surgical precision; zig-zag cuts — deception shall be used as to direction and intent; blood is totally drained — the lifeblood of the West shall be totally drained; edges of the cuts are often seared as if by a laser — advanced, futuristic weaponry (psychotronic weapons) shall "seal the end."

The cattle mutilations are materialized precognitive nightmares indicating the horror of the Armageddon to come, and these nightmarish paranormal mutilations reveal the true nature of the times. Yet no orthodox scientist or governmental agency is equipped or able to deal with a phenomenon such as this.

In ancient times the wise men knew how to do a metapsychological analysis of the species unconscious, and knew that tulpoidal phenomena were often symbolic signs of that which was to come.

Where are our wise men today?

BIG MAMA

UFO phenomena have also been associated with the cattle mutilations. One of these UFO-type tulpoids has been labelled Big Mama, because of its characteristic behavior of spawning smaller UFO light-shapes that split away and speed off to an area in which a cattle mutilation then occurs. The "spawned" UFO's then return and link up or join with Big Mama, and Big Mama then withdraws.

The photo shown here is a typical appearance of Big Mama. Big Mama takes many sizes and shapes, but is a fairly reliable indicator of paranormal cattle mutilations impending.

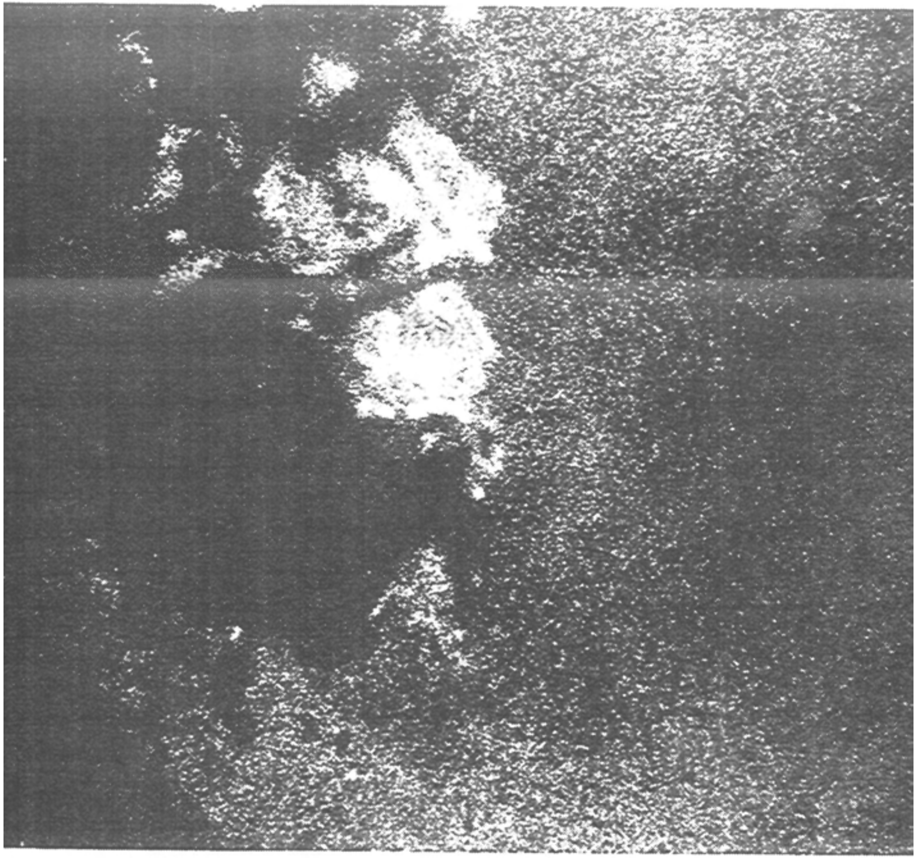

Photo 38. Loch Ness monster.

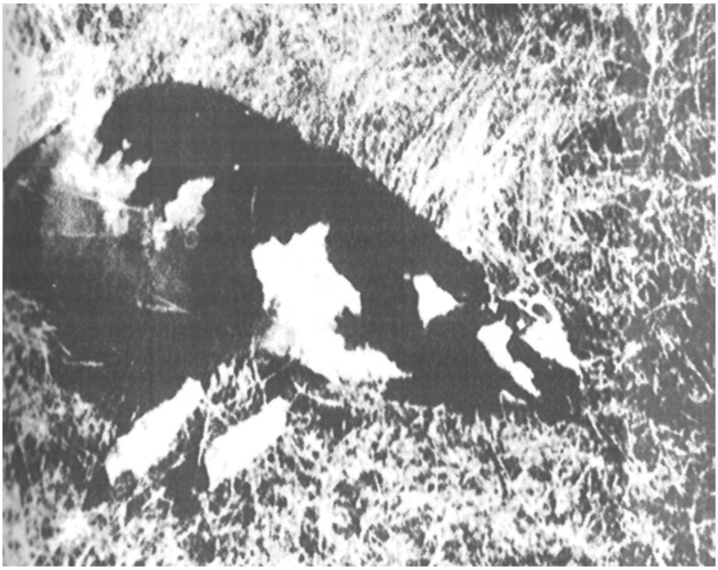

Photo 39. Cattle mutilation.

During the summer of 1978, two psychics and I — all members of the American Association of Meta-Science spotted a Big Mama-type UFO from the top floor of a hotel in Louisville, Kentucky. Realizing what it was, we promptly brought into play a certain type of powerful psychic exercise and tried to make it dematcrialize and vanish. Several times it briefly split into pieces (five to be precise), but we were unable to extinguish it. Over a period of approximately twenty minutes this effort continued, and all the while Big Mama slowly moved lower and further away, eventually disappearing behind a tall building after having become very distant.

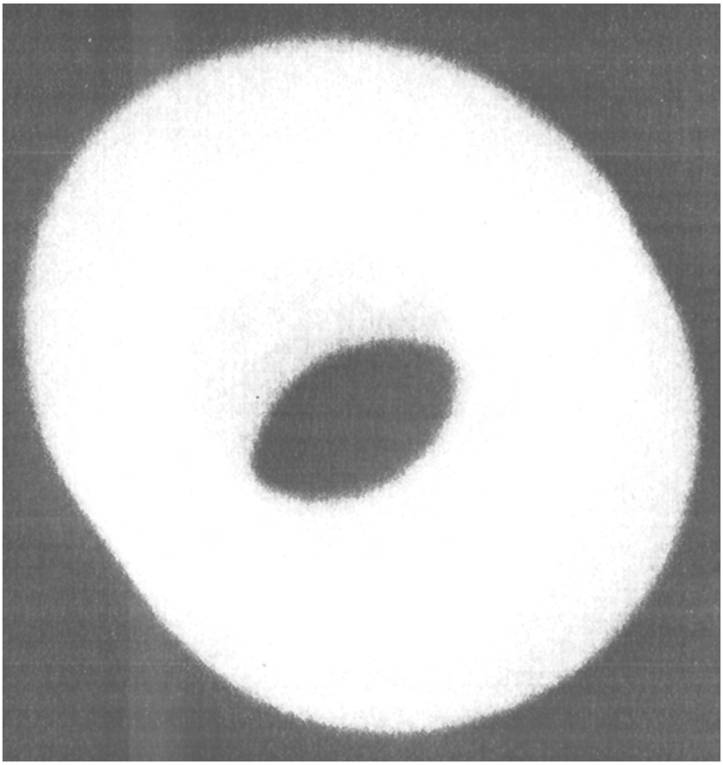

Photo 40. Big Mama.

PART TWO

A THEORETICAL BACKGROUND FOR UNDERSTANDING PT, UFO'S, AND PSI PHENOMENA

Footnote for page 132:

'With the exception that, in my theory, the orthogonal universes crosstalk with each other at virtual (subquantum) levels. Indeed, 'change' in one universe consists of the quantum coherence in that universe of crosstalk in and out of it. The 'virtual state' in one universe is due to, and consists of, subquantally coherent (quantally incoherent) crosstalk in and out of that universe.

Psychotronics, unidentified flying objects (UFO's), and paranormal phenomena such as psychokinesis, telepathy, and precognition all have one thing in common: both mind and matter-energy are involved.

Hitherto, mainstream science has insisted on a rather arbitrary separation of mind and matter-energy. However, as we shall see, this separation is not based on good observation. For example, everyone exhibits in himself the ability of mind to affect matter. While theories of computers, control systems, and physics can explain human behavior once the physical system has been given an input signal, the original signal — intent, or what I call inception — is an unexplained mystery to ordinary science.

"Psychotronics" (a Czechoslovakian term) and "psychoenergetics" (a Soviet term) have been specifically designed to provide a framework for approaching the problems of mind, matter, and their interaction. If we can understand psychotronics, we will be able to understand better the interaction of mind and matter, including all paranormal phenomena, unidentified flying objects, and Fortean phenomena.

Let us therefore start by defining psychotronics. The prefix "psycho" refers to the mind. The suffix "tronics" refers to physics and physical devices. Thus the concept of psychotronics refers to a union of physics and metaphysics. Such an audacious concept can offer a solution to almost every present problem in metaphysics, the foundations of logic, the foundations of physics, and the foundations of mathematics.

To begin with, it seems necessary to form a unified theory of mind, matter, and their interaction. It also seems necessary to reinterpret and extend electromagnetic theory. Logic itself must be advanced, for a part of reality, although "illogical" according to our present logic, is nonetheless true. In metaphysics we must solve formidable problems: the ontological problem (nature of being); the problem of mind, and the interaction of mind and body; the problem of change; and the problem of nothing.

It has been said that fools rush in where angels fear to tread. To tackle the problems of psychotronics demands the audacity to rush in where even fools fear to **tread!**

At this time, it may be appropriate to point out that all Western science, mathematics, and logic are founded upon three simple laws of logic, proposed and formulated by Aristotle. Since the entire universe cannot be described by these three laws — parts of reality are known to violate one or more of them and hence be illogical though true — it appears that we must be audacious enough to tackle and change the three laws of logic, if a new paradigm is to be constructed to solve all the presently unsolved problems.

SOME UNEXPLAINED MYSTERIES OF PHYSICS

First, no one knows what mass really is; we do not know for sure whether inertial and gravitational mass are one and the same. General relativity says it is, **and** we know from experiments that if any difference exists between inertial mass **and** gravitational mass that difference is very small indeed. But we do not know positively that there is not some small but finite difference. And we have no idea why the mass of a moving object increases with respect to a static observer. It is simple to calculate in special relativity how much the mass increases as a function of the velocity, but no one has the foggiest notion why this happens. Particularly so since an observer standing on the moving object and moving along with it sees no increase in its mass at all.

This poses a real paradox; if we try to assign some absolute notion to the idea of mass, then any object has an infinite number of masses, all at the same time and all different. There are two ways to determine mass: (1) by its resistance to a disturbing force, and (2) by its ability to occupy three-dimensional space. The latter requires that mass be volumetric, i.e., that mass be L^3 dimensionally.

But look at the weird properties of a photon! If we measure its resistance to a disturbing force, we find that no force on earth can accelerate or decelerate the photon. If we measure the mass of a photon by the first method, it appears to have infinite mass. Yet if we measure it by the second method, it can have no mass at all, because a photon is not volumetric; it is two-dimensional. It therefore has infinite mass and zero mass simultaneously.

Furthermore, we can take the viewpoint that whatever its mass is, it can only have one. If that is so, then infinite mass and zero mass must somehow be the same thing! Which contradicts the three laws of logic. However, this should not concern us too greatly; many things contradict the laws of logic and are nonetheless true. So while it is presently "illogical" for infinite mass and zero mass to be identical, we should hold on to the idea that this may very well be true.

Additionally, one of the great cornerstone assumptions in physics is that gravitational field and electric field are mutually exclusive — i.e., they are totally different things. Yet a physicist named Santilli has proved that this is not so, and that they are either partially the same thing or totally the same thing. And there the matter stands, so we do not fully understand what electric field and gravitational field are, or how to go about turning one into the other, although Santilli's work seems to imply that this is at least theoretically possible. We must therefore invoke a new concept of reality.

URI GELLER

Uri Geller has demonstrated numerous capabilities: he has affected a magnometer inside a Faraday shield; bent and broken metal objects; caused a fresh flower to wither and dry in seconds; permanently changed the crystal structure of nitinol; altered magnetic programs on computer cards; influenced a Geiger counter; dematerialized matter; and demonstrated the inceptive Cyborg effect, thought-photography, telepathy, and the Geller effect (the sympathetic stimulation of a psi-positive).

It is useless to attempt to explain the feats performed by Uri Geller in terms of the ordinary fields and effects of known physics. Nothing short of a new physics paradigm will suffice. This new paradigm must encompass both mind and physics within the same theoretical framework, if it is to succeed in explaining how mind affects matter.

In terms of present physics and logic, the mind is regarded as totally separate from matter. For mind and matter to interact, some aspect of mind must be the same as some aspect of matter, i.e., to move matter, a force is required. Force is the time rate of change of momentum. To generate a force capable of moving matter, mind must be able to change momentum. But since momentum can only be obtained from something which possesses momentum to give up, then the mind must somehow possess momentum.

If this is so, then the momentum must ordinarily exist in a separate three-dimensional space, since it apparently does not ordinarily exist in laboratory three-dimensional space. Such a situation requires at least six spatial dimensions and one common time dimension, such that the mind (mental phenomena) is a set of objective physical phenomena existing in an ordinary objective three-dimensional space, but one which is three orthogonalities away, spatially, from the laboratory three-dimensional space.

Mental changes upon physical objects would thus imply orthogonal rotation of mental objects from the mental three-dimensional space into or closer to the laboratory three-dimensional space. Everett's many-worlds interpretation (MWI) of quantum mechanics contains a structure where such representation is possible, and the MWI is consistent with the entire experimental basis of modern physics. Thus from the MWI it is possible to objectively model the mind and matter, and from that, psychotronics as well.

MY APPROACH TO PSYCHOTRONICS

In twelve years of intensive work on this question, I have evolved a conceptual approach, which is consistent with present physics but extends it. A new concept of reality is involved, however, and severe demands are made on the individual to stretch his framework of comprehension. The perceptron concept is an abstraction that allows the modeling of perception itself— either mental perception or physical detection. The fourth law of logic (to be explained shortly) involves the age-old identity of opposites whose apparent necessity has baffled logicians, philosophers, and scientists for centuries. With the perceptron concept, we can at last comprehend how the identity of opposites is accomplished, and when it is accomplished.

This immediately solves the age-old philosophical problem of change. The fourth law also closes logic into a complete, closed metalogic, encompassing both physics and metaphysics.

Let us use as a definition of reality: *reality is that which can be conceptually and mathematically modeled and fitted to the phenomena existing in one or more minds.* Physical reality is that which can be modeled and fitted to the phenomena existing in all minds. Mental reality can be modeled and fitted to the phenomena in one mind. Mental and physical realities comprise "normal" reality. Complex or "paranormal" reality is that which can be conceptually and mathematically modeled and fitted to phenomena which exist in more than one mind, but not in all minds.

From perception theory I have succeeded in deriving a great deal of the present basis of physics, including Einstein's two postulates, Newton's laws, the law of gravitation, and the solution to the ontological problem. (Unknown to me at the time, Ives had already done so for Newton's laws, the law of gravitation, and Einstein's postulates. His work has unfortunately been ignored.) In addition, the photon can be seen to be an ordinary three-dimensional particle existing in a three-dimensional space that is orthogonal to the laboratory three-dimensional space frame. A stationary particle in the laboratory frame appears as a photon to the orthogonal spatial frame.

Einstein's second postulate is usually stated as "the speed of light is the same for every observer." Restated, this becomes "every photon in an inertial frame is moving at the speed of light, c, with respect to every particle in that inertial frame." The corollary then follows immediately: every particle in that inertial frame is also moving at the speed of light, c, with respect to every photon in that inertial frame. In a single three-dimensional space, this is incomprehensible. Taking two orthogonal three-dimensional spaces, with the photons in one frame and the electrons in the other, it is perfectly comprehensible.

From pure nothing — empty vacuum, absence of thing — one can generate everything, the presence of thing. Here is direct proof that ultimately opposites are identical. But to a mind rigidly programmed in three-law logic, such a truth is abhorrent. Physicists consequently have done nothing with the idea that all our physical laws — or at least most of the great ones — can be straightforwardly derived from a special kind of a "piece of nothing" which I call a quiton. And they have not seen that this constitutes a statement of a fourth law of logic—the identity of opposites on their common boundary.

It is interesting to note that the paper which was handed to an American reporter, Robert Toth, by a Soviet scientist, and which caused the KGB to seize Toth and charge him with receiving Soviet state secrets, contained just such a theory as the basis of a unifying theory of psychotronics. Yet none of our intelligence analysts seems to have picked up the overwhelming importance of what was in the paper, and Toth himself appears to believe that his KGB arrest was simply harassment. In fact the paper did contain material on the basic Soviet approach to psychotronics — and thus to psychotronic weapons — and it was indeed state secrets that had been given to Toth.

Everett's many-worlds interpretation of quantum mechanics, with which very few physicists are familiar, provides a needed correction to the conventional monocular interpretation of relativity, and it allows a theoretically sound basis to be constructed for psychotronics.

The conventional interpretation of relativity considers only a single observer at a time. But if you can accept so simple a concept as that both you and I exist simultaneously, regardless of how we move with respect to each other, then I assure you that physics is startlingly different from what you may have studied in the ordinary university physics text book.

Everett, originally a student of the world-renowned physicist Dr. John Wheeler at Princeton, for his Ph.D. thesis considered the problem of multiple simultaneous observers and worked out what this did to physics. His highly innovative thesis provided a totally new interpretation of quantum physics and defined a startling new kind of reality in which all possibilities are physically real and exist. This new physics is indeed very strange, but it is totally consistent with the entire experimental basis of physics today.

I discovered that all my perception theory could be fitted precisely onto Everett's many-worlds interpretation.[1] On that basis, a theory or schema of biofields was derived that provides an approach to a unified field theory. In fact, it predicts that any kind of field can be turned into any other kind of field, merely by correct and precise time synchronization. It also offers a physical and exact model of mind and mental phenomena and a mental and exact model of physical phenomena!

On this basis, a framework can be provided for psychotronics which is consistent with what we know of ordinary physics but which does not contain many of the limitations of ordinary physics. In a strange sense Everett wrote the physics for the all-mind or the Supreme Creator's mind because an unlimited mind, so to speak, must already have thought of everything possible, and for an all-creative mind to "think" a possibility is for that possibility to be real.

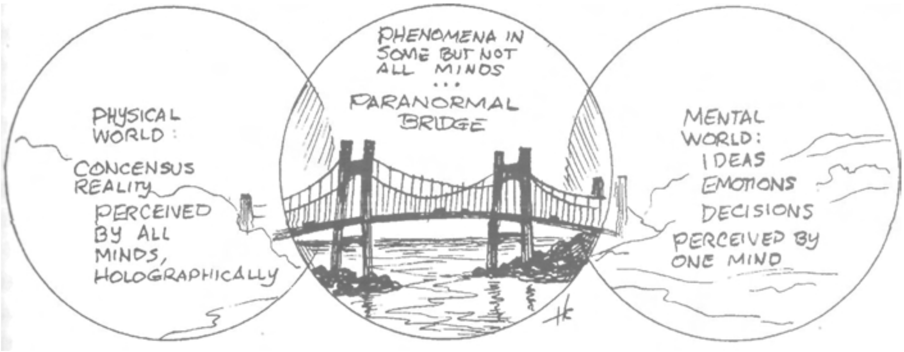

Fig. 3. Reality: a paranormal bridge with two ends

1. Reality as a Paranormal Bridge with Two Ends

In Figure 3, I show the nature of the problem of paranormal phenomena. To understand it, we must first define more precisely some of the present concepts.

First, what do we really mean when we talk of "physical phenomena"? To go into this, we must first destroy the notion that there exists some sort of separate, concrete reality totally apart from mind, for that notion is simply the old Cartesian assumption. It has long been refuted as far as having any absolute validity, and this is well-known to philosophers and to foundations physicists. According to Lindsay and Margenau in their *Foundations of Physics,* "physics has nothing to say about a possible real world lying behind experience."

What is true is that we can experience and detect and know only a mental change — a change in the mind itself is all we ever experience directly. For experience invokes the mind; we do not experience phenomena until the mind — used in the greater sense of the word to mean any mental detection — changes.

Any detector detects or experiences only an internal change, never an external change, and this is true of the mind as well as a physical detector.

So we never experience external physical phenomena; we experience only our own minds. Specifically, each of us experiences his own mental phenomena.

But here we must be a little more precise about what we mean by "mental phenomena." What we usually refer to are the mental phenomena in a single mind. And so we will take that as the primary definition: *mental phenomena are the phenomena or changes in a single mind.*

But then what do we mean by "physical phenomena"? For indeed this refers to something that is often remarkably different — or seems to be — from the phenomena or changes going on in our own heads. Before we jump to the extreme conclusion that physical phenomena are simply mental illusions, we should recall the Zen master's approach. He demanded of the student whether or not physical phenomena were real, and the student replied that they were not real, but only illusions. Whereupon the master gave him a resounding knock on the head, and asked him whether or not the blow was real. The student replied that the blow was indeed real. Whereupon the master sent him back for further meditation, for he had learned nothing. He had not understood that "mental" and "physical" are not mutually exclusive.

If we look closely at how we may differentiate between mental phenomena and physical phenomena, we immediately hit upon a practical scheme. Physical phenomena can be shown to exist in the mind of any observer, be he human, insect, or whatever, so long as he has consciousness.

Suppose for a moment that I have a piece of chalk in my hand, held between my fingers. I can touch the chalk, feel it, and see it. I can even taste it if I wish. And so I hold up the piece of chalk and say: "This piece of chalk is not just a mental impression, it is physically real." How can I prove it? And when I prove it, what exactly have I proved?

Now suppose you do not wish to believe the chalk is real. You simply bring in another observer; he looks at the chalk, he touches it, he tastes it, and he rolls it between his fingertips. He confirms that he also detects or experiences the chalk. Then a little bug flies in and lands on the chalk, crawling around on it, and poking at it with his little proboscis. He also by his actions confirms that he has it in his own little mind. In fact, we could bring in any sort of mind, and that mind could experience the chalk.

And this of course is the clue. What we have been calling physical phenomena can be shown to exist in every mind. And when we say something is physically real, this is all we actually mean. Nothing more, nothing less. And this is why physical phenomena are so solid and concrete; they are infinitely repeated. However, what we refer to as mental phenomena are in only one single mind and thus are not repeated at all.

Now let us do a little thought experiment. Suppose I have lapsed into some peculiar mental state because of the toxins from an infection I have contracted, and I am hallucinating vividly. Suppose I pick up what I vividly see, feel, touch, and taste as a piece of chalk, and I claim that it is real. Indeed, to me it is very real. And then suppose a second person comes into the room. He will not see the chalk, touch it, feel it, taste it, and it will not be real to him. Then suppose a third person comes into the room, and he does not see the chalk, he passes his fingers right through where I am seeing the chalk and does not contact or feel it, and he indeed cannot find it. Thus what we call a "mental phenomenon" can be shown to exist in one mind only. In this case of a vivid hallucination, the hallucinatory phenomenon was absent from the other observers' minds.

But now let us change our thought experiment a little. Suppose now that I am absolutely fit and fine physically and mentally, and am not hallucinating. And suppose all the observers we bring in are also fine both physically and mentally, and not hallucinating. And suppose we get the following results: some of us can see, touch, taste, and experience the chalk, and others of us cannot see, touch, taste, or experience it, no matter how we try. In that case, what kind of phenomenon do we have?

Well, we cannot exactly say the phenomenon is exclusively mental or exclusively physical. But we also cannot say that it is exclusively nonmental or exclusively nonphysical. In fact, we have an example of a third class of phenomena which are presently not recognized by science. *We simply have a paranormal phenomenon,* one which can be shown to violate our definitions of mental phenomena and physical phenomena.

And we can in fact take this as the definition of a paranormal phenomenon: *a paranormal phenomenon can be shown to exist in more than one mind, and it can also be shown not to exist in one or more minds, i.e., paranormal phenomena exist in more than one mind, but not in all minds.* Our conventional science recognizes purely mental phenomena and purely physical phenomena; it does not recognize the third kind, since by the ordinary three laws of logic the third kind does not exist. Paranormal phenomena constitute a bridge across a river between two banks; our present science does not recognize the bridge, but only recognizes the two banks, as shown in Figure 3.

Paranormal phenomena thus appear erratic to ordinary objective science, for objective method after all is specifically designed to select only those phenomena that can be reliably repeated, and the nature of paranormal phenomena is such that they often (in fact usually) cannot be reliably repeated, except sometimes in a great many trials. Normal objective method, if rigorously applied, can only discriminate a statistical effect from a great many trials. Furthermore, if rigorously and lengthily applied, it will accumulate so many failures that it will cast serious doubt on whether the odd case that was paranormal was in fact nonaccidental.

It is for this very reason that orthodox science, which is devoted to scientific method and rigorous protocol, has remained so comfortably adamant that paranormal phenomena do not exist. The tool must be changed to fit the problem, and the present scientific toolbag does not fit precisely. The tools are useful, but they themselves are not decisive within the bounds of present protocol. The necessary change is quite simple: we must allow for the effects of mind, and for a union of both mind and physics, just as there exists in physics a union of both wave and particle. In other words, paranormal phenomena must be repeatable *sometimes,* by competent experimenters and observers, but not necessarily *always* by all observers.

"Ah ha!" the materialist is likely to exclaim, being unable to contain himself any longer. "Solid concrete reality always is solid and concrete, however, and you cannot change that. As long as that is true, then the laws of ordinary physics hold, and all is right with the universe. We can always select our phenomena which are present in all minds, and this after all constitutes immutable physical reality. In the luce of that fact, all your arguments about mental phenomena in one mind and another kind of half-mental, half-physical phenomena are meaningless, for you are simply calling the superposition of purely mental phenomena on purely physical phenomena a third class, but it is a separable mixture, not a completely new kind." And we may even be tempted to stir up a small bit of sympathy for the materialist's view.

However, let us propose a resolution. If we can show that concrete, solid, real matter can become absolutely nonconcrete, nonsolid, and hence nonphysical, then that ought to settle the question. In a recent experiment it has been conclusively shown that two colliding protons pass right through each other in total violation of all physical rules, if their spins are exactly antiparallel. Protons are the central building blocks of all matter. In the nucleus of an atom, the protons and neutrons are continually switching identities, so even a neutron keeps turning into a proton, etc. And these fundamental constituents of everything solid and concrete and real just go right through one another, without any effect whatsoever, simply by aligning their spins properly. Collision theory fails, electromagnetic theory fails, and our concept of two particles bumping together fails. This experiment totally annihilates the idea that physical reality is something absolute. In fact, it establishes that physical reality itself is a function of the relations between the interacting participants; changing the relationships can simply cancel physical reality.

So perhaps our definition of physical reality has some merit after all, and perhaps there really are three classes of phenomena. The paranormal phenomenon is a bridge between mental and physical phenomena; specifically, every paranormal phenomenon must consist of an inseparably welded compound of the two. And the objective method and its consequent experimental protocol must be changed to reflect this fact, if we are ever to develop a viable theory of paranormal phenomena.

2. A Fundamental Correction to Classical Logic

Let us now make a fundamental correction to Aristotle's three laws of logic. First, there is no independent existence to mental phenomena; there is a perception operation involved when we think. There is no independent existence to physical phenomena; there is a perception operation involved when we observe physical phenomena. Furthermore, it takes a finite piece of time for the perception process to occur. The logic symbol also requires a separate time interval; it represents a series of separately perceived operations that together comprise a decision algorithm. So let us impose this criterion upon logic itself so as to constitute "logical perception" or the "logic of perception" or the "perception of logic." We begin with Aristotle's third law of logic, *A* or *not-A,* the law of the excluded middle.

We still insist that there is no such thing as *A* per se, but rather that there is a perceived *A* where *A* is the output of the perception process. Similarly, there is no such thing as *not-A,* but rather there is a perceived *not-A* where *not-A* is the output of the perception process. Let us think of a square box symbol as an abbreviation for the fact that perception has occurred, and anything written inside the box represents the output of that perception operation. We can speak of the box either as mental perception, a description of thought, or we can speak of it as physical detection, a description of an instrumentation system that detects and measures. Also, since each box requires a finite time to occur, we must carefully keep up with the individual little pieces of time, the delta t's.

So applying this to Aristotle's third law, we have *A* perceived or outputted in time one, and *not-A* outputted in time two. Note that to ascertain that A_1 and *not-*A_2 actually differ requires a series of operations in a separate time interval, in time three, that is assumed by the *exclusive* or symbol. Looked at in this way, Aristotle's third law actually is the law of monocularity; it states that only one thing at a time is perceived. Actually we had assumed this when we assumed that perception was a

1. $A \vee \bar{A}$ ARISTOTLE'S LAW OF THE EXCLUDED MIDDLE

2. DEFINE $\boxed{}$ AS "IS PERCEIVED"

3. $\boxed{A} \vee \boxed{\bar{A}}$ LAW OF THE EXCLUDED MIDDLE

4. EACH PERCEPTION IS A FINITE OPERATION AND REQUIRES A FINITE TIME TO OCCUR.

   THE LOGIC SYMBOL ALSO REPRESENTS A DECISION ALGORITHM: A SERIES OF OPERATIONS PERFORMED IN A SEPARATE TIME INTERVAL.

   EACH FINITE TIME INTERVAL MUST BE ACCOUNTED FOR.

5. $\boxed{A}_1 \vee_3 \boxed{\bar{A}}_2$

6. THE LAW STATES THAT PERCEPTION IS A MONOCULAR PROCESS IN TIME 3.

   ONLY ONE-THING-AT-A-TIME IS PERCEIVED.

7. NOW NOTE THAT SEPARATION OF A AND $\bar{A}$ DOES NOT OCCUR IN

$$\boxed{(A_1 , \bar{A}_2)}_3 \quad \equiv_5 \quad \boxed{B}_4$$

8. SO $A_1 \equiv_3 \bar{A}_2 \Big|_{4,5}$ BOUNDARY IDENTITY OF EXACT OPPOSITES

9. AND EQUATION 8 CONSTITUTES A FOURTH LAW OF LOGICAL THOUGHT.

   IT SIMPLY STATES THAT PERCEPTION THREE IS BINOCULAR, AND EXCLUSIVE SEPARATION OF EITHER A OR $\bar{A}$ IS NOT PERMITTED.

Fig. 4. A fundamental correction to classical logic

finite process, so it is nice to find that Aristotle's third law justifies our assumption, once we understand the third law. The *exclusive or* symbol assumes a third operation in time three, whereby it is determined that perception output one and output two actually differ. But such an operation itself requires multiocular perception — i.e., collecting two outputs at once — and that in itself is a violation of Aristotle's third law. The third law thus contains its own contradiction, and indeed each of the other two laws also contradicts the third law when one examines them meticulously. Each can only be established as true by invoking or involving an operation wherein the third law is not true.

In time three we gathered up what had been perception output in time one, A_1 and what had been perception output in time two, A_2, which we do not yet know is different from A_1, and put them both through the perception process, getting only one output — let us call it B — in time four. By the nature of B in time four, we thus say in time five that the outputs in times one and two differ or not. In either time one or time two, there is no indication whatsoever of difference or sameness existing between output one and output two. Likewise, in time three there is no separate output one and output two, hence no indication of the sameness of, or difference between, outputs one and two.

So here we have arrived at the identity of opposites. There is no perception of difference between A_1 and *not*-A_2 in time three. And this constitutes a fourth law of logic: the law of the boundary, or the boundary identity of exact opposites. All that is necessary to identify opposites is to lose all perceptual distinction between them. And that is accomplished by multiocular perception, of perceiving the presence of both at once unseparated, hence the absence of either exclusively present. If A_1 and A_2 are exact opposites, then $B_4 = O$, and $[A_1, A_2]_3 = O$. We thus have the solution to the problem of nothing. Nothing simply consists of the presence of the totality of all opposites.

Almost all the philosophers who have struggled with the problems of being, mind, and matter have faced the necessity for the identity of opposites, but none of them could understand how opposites could be identified. By careful accounting of the separate time intervals required for finite monocular perceptions, the mechanism for identifying opposites is immediately clarified and revealed. The laws of logic are simply laws of the operation of perception — nothing more, nothing less.

The new system of logic is closed. All present paradoxes — contradictions of one or more of the first three laws — are resolved by the fourth law, which contains the negation of each of the first three laws. The fourth law is in fact the law of the paradox. Note also that the hidden time-three operation, which has actually been the application of the fourth law all along, is implied in each of the first three laws. Identity or nonidentity between time-one and time-two outputs can only be established in a time-three operation. The fact that either *A* or *not-A* exclusively exists can only be established by a separate operation which establishes that nothing else is there. If separation of *A* and *not-A* is not permitted, then *A* and *not-A* cannot be distinguished.

Since these laws refer to perceptual operations, one can think of them operationally, or vectorially. To close the vectorial system prescribed by the first three laws, the opposite or negation of each of the three vectorial statements must be present, i.e., this follows simply from the definition of what constitutes a closed system, vectorially speaking. Since the fourth law contains the negation of each of

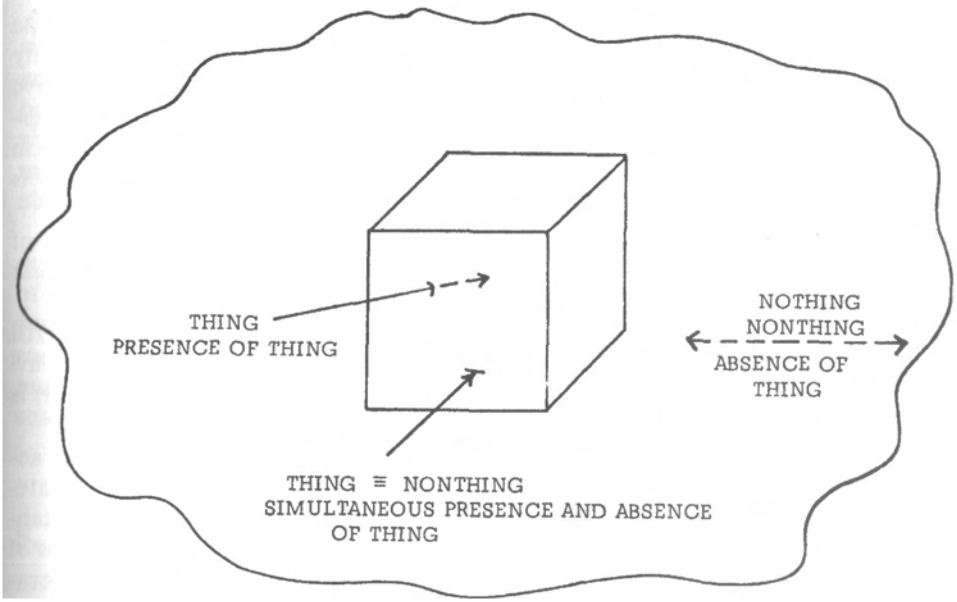

Fig. 5. A physical example

the first three laws, then the four-law system is indeed closed, and the logician's dream of a closed metalogic is realized. Furthermore, anything which contradicts any combination of the first three laws automatically is covered by the fourth law, which is the law of the paradox.

The new logic works as follows: either the first three laws apply (separation of *A* and *not-A* is permitted), or the fourth law applies (separation of *A* and *not-A* is not permitted). The fourth law applies only to — and in fact *creates* — a boundary. The first three laws apply only away from a boundary.

3. A Physical Example

Take the surface of a cube in deep space (Fig. 5). Call the cube "thing," a three-dimensional concept. Call the empty space around the cube "nonthing," a three-dimensional nonthing or absence of thing. If we are standing inside the cube and look at its boundary surface, we cannot find a single piece of that boundary surface that does not belong totally to the cube. So we can very reasonably proclaim that by the first three laws of logic each piece of the boundary belongs totally to the cube, to "thing." But if in a different operation we are standing outside the cube, we cannot find a single piece of that boundary surface that does not belong entirely to the space surrounding the cube. So in this case, we can claim by the first three laws of logic that the boundary surface belongs totally to "nonthing."

Then in a third operation we can state that, by the first law of logic, each and every piece of the boundary surface is identical to itself, and of course we thereby identify what was thing with what was nonthing. Specifically, what was thing in perception time one and what was nonthing in perception time two have been identified, by all distinction and separation between them being removed, in time three. Identifying opposites simply consists of "packing together" two previously separated perceptions into a single third unseparated perception. And all we have done is apply the fourth law of logic, the law of the boundary. Every single perceived thing has a boundary, where it both begins and ends its exclusive presence in perception output. And at that boundary, the fourth law applies. Thus the law is universal. The fourth law defines a boundary.

In fact, in any perception, all four laws are applied. They are applied in one of two fashions: (1) the first three are explicit and the fourth implicit, or (2) the first three are implicit and the fourth explicit.

There are more examples that have baffled mathematicians and logicians. All of these are simply boundary statements, i.e., statements involving the fourth law of logic. For example: "It is true that this statement is false"; "A line (length) is composed of points (nonlengths)"; "In a hologram, each part is the whole."

Since logicians used only the first three laws, none of these statements was acceptable or understandable. By the fourth law, there is no problem with these statements. The first merely refers to the boundary between the operation used to establish "truth" and the operation used to establish "falsity." There is another class of operation where neither truth nor falsity exclusively applies — i.e., a class of operation which cannot distinguish between "true" and "false."

The second statement has long been a painful trauma to logicians and foundations mathematicians. Today foundations mathematicians seldom attempt to define line or point. Instead, they simply say: "There is a class of entities called lines. There is a class of entities called points. Lines are made up of an infinite number of points." This way, they avoid trying to explain how "length" (line) can be made up *of* "nonlength" (points).

However, they could easily have avoided the difficulty, and still retained the definition of a line as a length, and a point as a nonlength, in the following manner. "There is a class of entities called lines. A line is and has length. There is a class of entities called points. A point is and has nonlength. We may have a separate perception that shows nonlength, and another separate perception that shows length. In yet a third perception which infolds both the first two perceptual characteristics, we may say that a line is comprised of points so long as we realize that line and point do not separately and exclusively exist in the comprised-of state."

By the same token, we can say that "the whole is comprised of the sum of the parts" only if we realize that "whole" and "part" do not separately and exclusively exist in the comprised-of state, but instead they inseparably and nonexclusively exist therein.

4. New Definition of Zero

To a monocular perception process, multiple presence constitutes absence of the exclusive presence of any particular one. Therefore such a multiple presence is monocularly unperceivable, and hence becomes a zero to a monocular detection process. This allows new definitions of zero, and a solution to the problem of nothing.

Consider that a monocular detection process asks the question, "Is there a single exclusive thing present in my input?" If the answer is yes, an output is generated and perception occurs. If the answer is no, no output is generated and perception does not occur. The answer "no" occurs in two fashions: either total absence, or presence of two or more simultaneously. For either of these cases, monocular perception gives no output, and perception does not occur, i.e., the absence of perception occurs.

Now note that the monocular perception cannot tell any difference in the two input conditions. To it, there is no distinction between the two conditions. The lack of any difference at all constitutes identity. Thus to a monocular perception process, condition one is identical to condition two when they are infolded together in condition three. That in fact derives the fourth law of logic. Total absence and multiple, unseparated presence are identical insofar as a monocular detection process is concerned.

5. Einstein's Postulate

As an example of strange problems we can deal with in a four-law manner, let us examine a little more closely one of Einstein's postulates of special relativity, which states that the speed of light is the same for every observer. Let us restate the postulate as "every photon is moving at the same speed relative to every particle." We can pick any electron in the laboratory frame. Every photon in the frame is moving at the speed of light with respect to the electron, by Einstein's postulate. Now let us pick any photon. By Einstein's postulate, every electron is also moving at the speed of light with respect to this photon.

Now we can look at the situation from the viewpoint of the photon. With respect to it, every electron in the laboratory frame is moving at the speed of light, which violates the common interpretation that ordinary objects cannot move at the speed of light. In fact, three-law logic is violated but four-law logic is not violated. In four-law logic, an object can have infinite mass and zero mass simultaneously. The electron's frame and the photon's frame are rotated orthogonal to each other. What we were calling a photon in the laboratory frame, is a perfectly ordinary three-dimensional object in its own frame, which is orthogonal to the laboratory frame. The electron (lab-frame) thus appears as a photon in the rotated frame of what we previously called a "lab-frame photon." Either an electron or a photon is both three-dimensional and two-dimensional simultaneously — in fact, the concept of separate, exclusive dimensionality only applies after one or the other dimensional aspect has been exclusively separated (observed).

Mass is determined by the resistance an object poses to an accelerating or disturbing force. Mass is also tied to three-dimensional objects; i.e., it is an L^3 concept dimensionally. A photon, moving at the speed of light, can neither be speeded up nor slowed down; hence in one sense it exhibits infinite mass. On the other hand, the photon (which is a three-dimensional object in its own frame) has lost a dimension in its intersection in the laboratory frame, due to orthogonality. Therefore the photon appears as a two-dimensional L^2 entity in the laboratory three-space. And in that sense, the photon must have zero mass since it is only two-dimensional. By the fourth law, the boundary opposites are identified. Thus at the orthogonal boundary of three-space, zero mass and infinite mass become identical. And the photon exhibits both zero mass and infinite mass simultaneously because it is an entity that is on the boundary of the L^3 "mass exhibiting" world. The photon has always happily behaved in a four-law manner, even though physicists could not comprehend its behavior with the three-law logic ingrained in their heads.

6. Synchronicity of Concepts

As is so often the case, two persons appear to have derived the new logic simultaneously, myself from perception theory and Hubbard from manifold theory.

Dr. J. Hubbard was one of the scientists who first developed the atomic bomb. His profound work fully substantiates the new logic and the new reality paradigm. Dr. Hubbard believes that the system includes language, logic, and the interaction of life-bearing systems. In short, he believes it includes psychotronics. The relationship between mind and matter is, like Santilli's electric and gravitational fields, not mutually exclusive; they are either partially or totally one and the same thing. According to my research, they are both partially and totally the same thing, i.e., they are of exactly the same nature totally — a closure of the entire physical universe — but only partially intersecting, by a fraction of approximately 10^{-42}. In the same fashion a mind is an entire physical world, but it only minutely intersects this physical frame, and then only in a portion of this physical plane.

Dr. Hubbard has shown that the four laws of logic emerge in the form of set relationships, that the single dimension parameter generates the second, third, fourth, fifth and up to *Nth* dimensions of the manifold, by repetitive operations on itself. This allows a firm basis for orthogonal intersections of one less than the dimensionality of the lowest-dimensioned intersector. It provides a firm basis for orthorotation and for my approach to psychotronics.

PRIMITIVE PERCEPTION

Let us now discuss how we form our concept of objects and their relationship. All our basic perceptual concepts are essentially built on primitive observation of the macroscopic universe, which is the primary reason that so many final arguments of philosophers appeal to the "natural man," i.e., to how a primitive observer would react to the argument. The very idea of an object — a perceived object — is conditioned. Everything else we think of is then conceived as some sort of object or relation between objects. And that is why sets (of perceptual objects) and their relationships form the basis for axiomatic logic, mathematics, and physics. Set theory is simply the synthesized and abstracted game of elementary perception of the macroscopic world. Thus even the most abstruse mathematics forms a part of the game of perception and can be applied to perceived physical phenomena. This macroscopic, primitive perception is the basis of our concept of objectivity, and of our physical concepts of "observed" and "observable." But if we examine

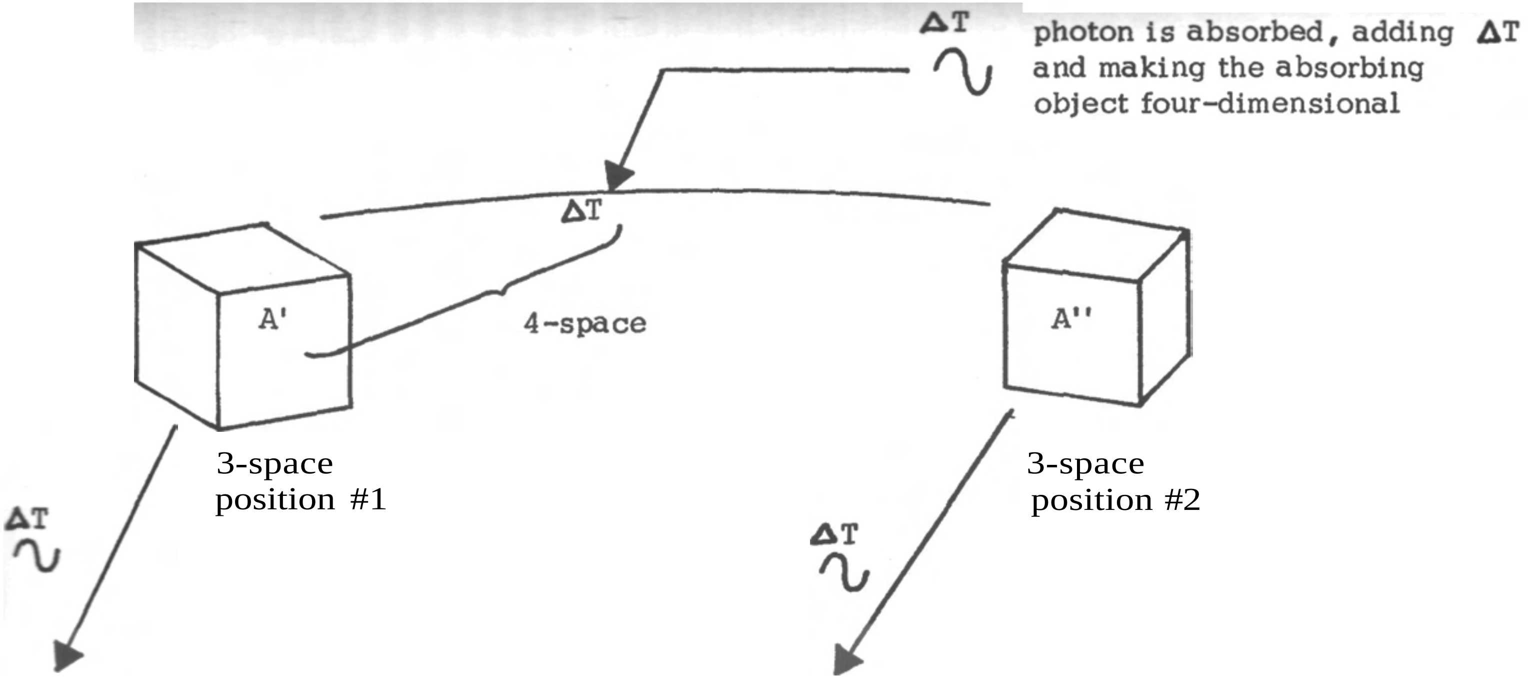
ΔT
ΔT
A'
4-space
A''
3-space position #1
3-space position #2
ΔT
ΔT

photon is absorbed, adding ΔT and making the absorbing object four-dimensional

Photon has previously been emitted, and traveled to the observer's eye, so that he detected a corresponding change on the retina, which "detected object A in its spatial position #1"

Photon emitted, traveling to the observer's eye, so that he may detect a corresponding change on the retina, which "detects object A in its spatial position #2'

Fig. 6. Primitive perception

carefully exactly how we perceive an object in the macroscopic world, we realize that it is seen by means of photon interaction. We think of light being absorbed onto the surface of the object, and then emitted or reradiated from the surface, eventually entering the eye. There the photons are again absorbed by the material on the retina. The photoelectric effect then moves what are called electrons, producing a signal that goes to the brain for interpretation

What we see as an object has twice undergone interaction with photons of light. Furthermore, light itself cannot be detected, only its interaction with matter (in this case electrons). Thus the primitive perceptual operations of the human brain are correlated one-to-one with photon emission and absorption interactions, usually paired interactions at the object reality domain. The concepts of object, mass, three-dimensions, and observation are directly correlated to the photon-mass interaction, and ultimately to the photon-electron interaction occurring in the human retina.

The ideas of boundary, surface, and change in primitive perception thus involve two contradictory and simultaneously mixed interactions, absorption and emission. Because they are constantly intermingled, primitive perception cannot separate the two. Thus the primitive concept of a boundary consists of a simultaneous duality. Here the object both begins and ends. Here opposites are identified. This is the basis for the fourth law of logic, the law of the boundary.

The dimensionality and orthogonality (spatially) of the primitive perception process are also interesting. Photon absorption constitutes spatial integration for the photon, dimensionally speaking, *e.g.*, one additional dimension is gained by the two-dimensional light wave in turning itself into the three-dimensional mass state. The photon also adds its piece of time to the absorbing mass, converting the mass particle to mass time or space time—adding the fourth dimension. Photon emission constitutes spatial differentiation, dimensionally speaking. One spatial dimension is lost by a little hunk of three-dimensional mass turning itself into a two-dimensional wave. Going from outside the object toward the inside (to track along with photon absorption), the boundary marks the end of the two-dimensional wave region, so the object (or, more precisely, the interaction region) is spatially two-dimensional on the outside, and spatially three-dimensional on the inside. It also occupies the time dimension on the inside, but not on the outside. (This directly accounts for a difference in the spacetime inside and the spacetime outside, and that is why mass may be regarded as a curvature or change in spacetime, in general relativity.)

Going from inside the object toward the outside, the boundary marks the end of the spatially three-dimensional region and the beginning of the spatially two-dimensional region. So the object is now spatially three-dimensional on the inside, spatially two-dimensional on the outside. The inside now does not occupy the time dimension, while the photon emitted (the outside) does. So on the boundary, one spatial dimension is gained going in, and one spatial dimension is lost going out Time is gained going in and lost going out, by the mass absorber-emitter.

Gain or loss of a dimension is accomplished only by orthogonal rotation between orthogonal spatial frames. Photon absorption constitutes orthogonal spatial rotation one right angle turn into the laboratory frame, while photon emission constitutes orthogonal spatial rotation one right angle turn out of the laboratory three-space frame.

This constitutes the observation process (primitively) per se, and this is what is hidden in Einstein's postulate that the speed of light is the same to every observer. Every observer goes through this same process. Furthermore, rotations orthogonal to a three-space frame are orthogonal to all three-dimensional spatial physical entities in that three-space. As Einstein himself once pointed out, velocity can be regarded as simply the measure of rotation of an entity in a higher dimensional space; thus an orthogonal turn is a fixed velocity. Since light is orthogonal to the entire space, then the speed of light is the same to every observer in that space.

While Einstein was apparently speaking of regarding the velocity of an object as a measure of its amount of rotation toward the time axis in four-space (from the direction of its velocity vector in laboratory three-space), it can also be regarded as rotation toward a fourth spatial axis in a five-space (four length dimensions and one time dimension, all orthogonal). If one checks this, one will see that the projections in three-space are the same; i.e., to the laboratory frame observer, there is no difference observable. Thus the photon interaction may be modeled as orthorotation of an entity spatially in a five-space.

To the laboratory observer, this orthorotation constitutes pure dimensional integration and dimensional differentiation, and it constitutes or creates an object in the first place. The concept of object *a priori* involves the photon interaction as stated; if the photon interaction is not invoked, then the existent entity does not exist as a three-dimensional object at all, in the primitive sense. Outside this primitive process (dimensional integration and differentiation imposed upon the same region, which constitutes an object), all exists in the Omega nothingness void, without frame or form.

Ultimate reality (specifically, action) is dimensionless in the objective sense; for the objective sense exists only after an operation has been imposed. A quantum itself is lengthless (and has no exclusive energy, time, or momentum) until differentiation is imposed upon it. Only after a quantum of action is fissioned does there exist a discrete piece of (change in) length, time, energy, mass, momentum, etc. I have already shown that perception itself can be modeled in terms of action quanta fission and fusion, and that most of the basic laws of physics can be derived from that model. (See my *Quiton/Perception Physics.)* Fission and fusion of action quanta involve orthogonal rotation between orthogonal three-spaces sharing the same fourth dimension (time) in common. The words *change, interact, localize, superpose, operate, move, oscillate, act, cause,* and *determine* are only a few of the words used in physics to conceal the basic occurrence of orthogonal rotation in higher dimensional space.

Finally, it should be stressed that i, the square root of minus one, itself constitutes an orthogonal axis, hence an extraspatial dimension. The addition of this quantity to electromagnetic theory allowed the resolution of formidable problems, and led to the direct formulation of electromagnetic theory. Thus electromagnetic theory already includes higher dimensionality and orthogonal rotation in hyperspace. In that sense, inductance and capacitance are merely vector statements of amounts of rotation, one in a positive direction and the other in a negative direction, toward an orthogonal axis in higher dimensional space.

The forming (beginning and ending) of a three-dimensional spatial object constitutes a time differentiation invoked on four-dimensional Minkowskian space, i.e., the process of observation or detection itself involves

$$\partial/\partial T\,(L^3T) = L^3$$

dimensionally speaking. This process is accomplished by orthogonal rotation, and the very concept of an object that has been observed, detected, or perceived implicitly involves this time differentiation invoked on a four-space.

Velocity also represents a statement of the switching of time into length, and length into time. It is therefore a measure of rotation of the spatial three-dimensional frame, as Einstein pointed out. By this switching (orthogonal rotating, orthogonal flipping) of the chopping of time or beginning and ending of a small piece of time, we create a little delta *T*, just as we do each delta *L* for an object.

But the photon interaction process is monocular. Each photon must attack matter individually, and live or die in the process. Each photon born from matter is also born independently. Thus the primitive observation process is monocular, since it is totally in one-to-one correspondence with photon interaction that is monocular. Thus the observed world is monocular, quantized, discretized. Because of the particular one-to-one correspondence between our primitive concepts and a single interaction, we can conceive the world in no other fashion, unless we change the very basic factor of one-to-one correlation. This in fact has already been done for physics by Everett, whose theory of the universal wave function incorporates multiple simultaneous observation, and hence direct insight beyond the limitations of the monocular correspondence to the photon interaction. My theory does the same thing in the fields of logic and mind.

TWO-SLIT EXPERIMENT

This experiment is fundamental to all of modern physics. Feynman, Nobel prize winner in physics, has stated that no physicist understands this experiment, and that it cannot be explained by any classical means. The reason is that it cannot be monocularly comprehended, i.e., the first three laws of logic cannot explain it. The fourth law can and does.

In the experiment, electrons are emitted from a source and travel past a doubly-slit wall region on their way to a screen. The apparatus is shielded against light. If one believes that the emitted electron is a little three-dimensional particle, much like a tiny baseball, then it should go through one of the slits and not the other. It would then hit the screen at one of the two spots indicated as the expected distribution, with a little scatter from those that chip the edge of the slit a bit. Electrons which do not hit the holes but strike the wall are absorbed.

We do not get this expected pattern. Instead, the pattern is essentially the same as the one we would get if each electron were a wavefront passing through both slits at once. However, each electron still strikes the screen in only one point; the distribution of these points fits the actual distribution pattern shown.

This stunned the physicists. They did not believe it at first, so they set up a photon gun and hit every electron with a photon as it left the emitter source and started over toward the two-slit region. That is, they determined precisely when a little electron was on the way, and the fact that it was like a tiny baseball and in just one

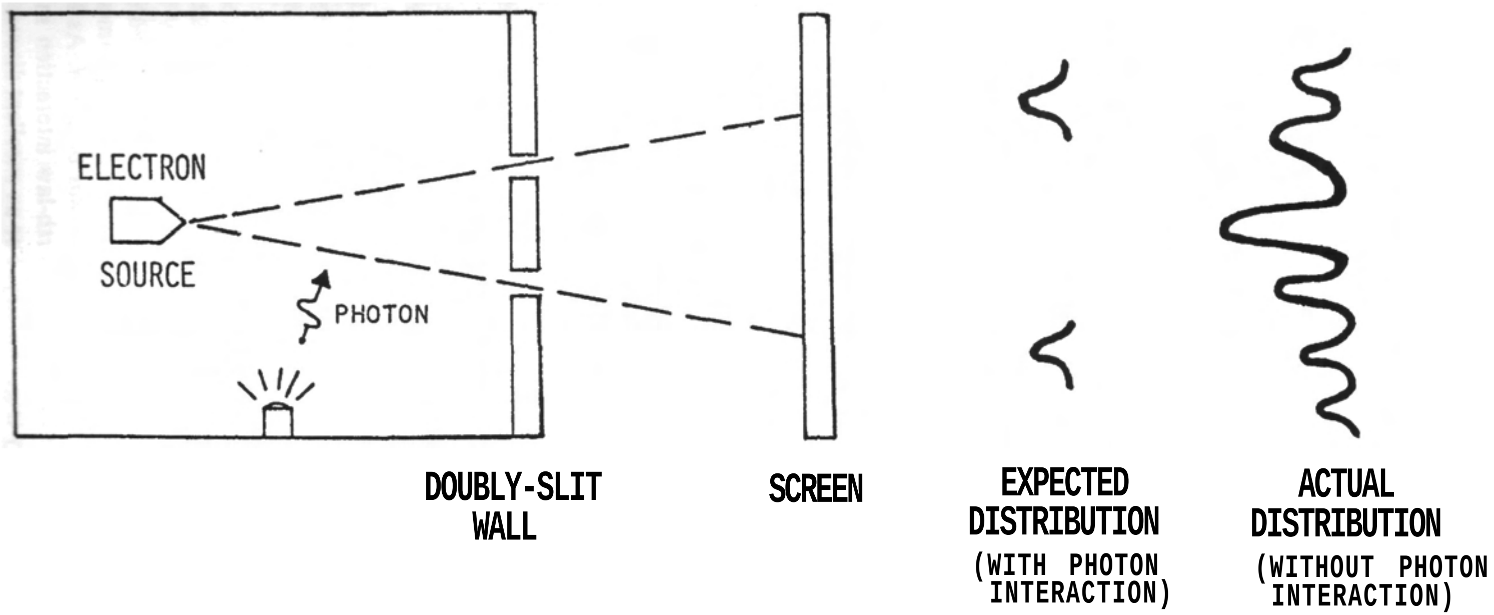
ELECTRON
SOURCE
PHOTON
DOUBLY-SLIT WALL
SCREEN
EXPECTED DISTRIBUTION (WITH PHOTON INTERACTION)
ACTUAL DISTRIBUTION (WITHOUT PHOTON INTERACTION)

NOTE: IF THE ELECTRON IS HIT BY A PHOTON BEFORE IT REACHES THE TWO-SLIT REGION, IT DOES NOT EXHIBIT THE WAVE INTERFERENCE EFFECT, BUT INSTEAD ACTS AS A CLASSICAL OBJECT AND GOES THROUGH ONLY ONE SLIT, YIELDING THE "EXPECTED DISTRIBUTION" PATTERN.

Fig. 7. Two-slit experiment

place. And this time the electron only went through a single slit, and it gave the expected pattern after all. And when the experiment was repeated and only a fraction of the electrons were hit with photons, then a mixture of the two patterns emerged.

It is simple to describe the results mathematically, but no one has understood why things happen as they do in this experiment. The principle of complementarity evades the issue. This principle is simply a monocular statement dealing with one aspect of the problem at a time, with the determined, exclusive, monocular past only. It does not apply to the present or to the future. If we think in terms of the present, then the third law of logic is violated and the fourth law applies. The two states, two-dimensional wave and three-dimensional corpuscular, both exist simultaneously but nonexclusively in the present. Thus in physics terms, the entity becomes nonobjective (nonspatial), probabilistic and undetermined, and this is automatically a wave concept, i.e., since waves are not confined to one place and determined or localized, they may exist in the nonconfined, nonlocalized present.

Note that photon interaction must be excluded whenever the so-called quantum effect is exhibited. If photon interaction is invoked, classical reality emerges. Photon interaction creates classical objectivity. Photon interaction is a time-differentiating operator imposed on L^3T four-space. Specifically, since light carries time, photon emission from an entity strips away T from the L^3T nonobjective entity, converting it to an L^3 or spatial object.

The very concept of an object comes from primitive perception's one-to-one correspondence with photon interaction. After photon interaction, the first three laws of logic apply to an entity. Before photon interaction occurs, the fourth law applies. In the fourth-law state, the time portion of an entity can interact with any number of time portions of other fourth-law entities if the time aspects of all of them coincide.

A free electron born and released at the emitter is four-dimensional (L^3T) until it is struck by a photon, after which it is three-dimensional (L^3). When the wavelength of electron and slits is specified, we have actually specified the time interval stripped out of a dEdT quantum in each quantum of fundamental change occurring. Perfect time synchronization accomplishes or constitutes orthogonal rotation. So if the length (width) dimension of each slit is very close to the wavelength of the electron, the time aspects of both slits will interact with the time aspect of the fourth-state electron if all three are brought into time phase simultaneously. If the slits are made much larger, this interaction will not occur.

When the electron interacts with both slits timewise, this will constitute a part of the past history of the electron to all future interactions or interaction possibilities. But since the interaction with the two-slits was not in the past (i.e., selected or determined), then that interaction itself is a part of the present and future probabilities chain. In physics, probabilities propagate forward in time with absolute causality until a monocular selection is made. Thus the fourth-law interaction is propagated forward with absolute causality and significantly affects any future interactions. And apparently vice-versa. John Wheeler has just shown that, in at least one sense, whether or not the emitted particle in the two-slit experiment has interacted with one or both slits can be selected *after it has occurred.* As is well known, the pattern of projection forward of this fourth-law interaction may be quite simply calculated from ordinary trigonometry. For an excellent discussion of the two-slit experiment, see Richard P. Feynman, Robert B. Leighton, and Matthew Sands, *The Feynman Lectures on Physics*, Vol. 1 (Addison-Wesley, Menlo Park, Calif., 1963), pp. 37-1 and 37-12.

When the electron hits the screen, it encounters a region of varying time oscillations of the orbital electrons around the individual atoms comprising the screen. Thus the exact location of the orbital electron in the screen which will first precisely time-synchronize with the electron wavelength approaching the screen in four-law form will vary. Thus the place where the electron hits the screen is variably selected along the screen. The time distribution pattern of the approaching electron is recovered when the time distribution of the number of electron hits per screen length is plotted.

So one can build gadgets to cause four-law entities to multiply and interact simultaneously in time, even though the entities are normally thought of as being in different spatial locations when in the three-law state. And one can deliberately select the type of interaction to occur, four-law or three-law, simply by controlling photon interaction. The two-slit apparatus itself is a paranormal, psychotronic device.

This is the explanation of the two-slit experiment, which, according to Nobel prizewinner Richard Feynman, no one understands and which, according also to Dr. Feynman, contains the total mystery of quantum mechanics and the only mystery of quantum mechanics. The reason the two-slit experiment has not been understood is that the answer to the paradox was not present in the first three laws of logic. It requires the addition of the fourth law to explain the experiment.

And all fundamental particles — photons, neutrons, protons, electrons, etc. — exhibit the same behavior. So things, nothings if you will, can be processed in the multiplistic two-states-identified-as-one-so-no-single-exclusive state, as virtual and unobserved entities. In the multiplistic state they can be amplified, recorded, put onto tape, modulated onto RF signals, etc. And by our ordinary, objective, three-law science nothing is processed. And nothing indeed is what is there — a very special, structured, detailed, virtual set of nonexclusive, hidden-variable nonthings that is part of the new reality existing in the framework of the new four-law logic. In fact, this processable, structurable, nonobjective reality exists outside objective, three-law spacetime and is the basis for all psychotronic phenomena.

To our present monocular detection devices and monocular theory, such multiple-state entities are unobserved and hence are zeroes. They are pure vacuum, pure space, pure nothing, pure emptiness. But they are very real indeed, and they do physically exist, but multiocularly rather than monocularly.

The importance of the time interaction in explaining the two-slit experiment was noted as early as 1957 by Charles Muses in his introduction to Jerome Rothstein's *Communication, Organization, and Science* (Falcon's Wing Press, Indian Hills, Colorado, 1958). Muses pointed out that the celebrated wave-particle paradox remains a paradox only so long as the chronotopological phases of the phenomena are left unrealized in the analysis. The entire foreword by Muses is a remarkable document that analyzes the structure of time itself.

NOTE:

IN REFLECTED LIGHT,
THE EFFECT CAN BE
INVERSED.

S.L.E.

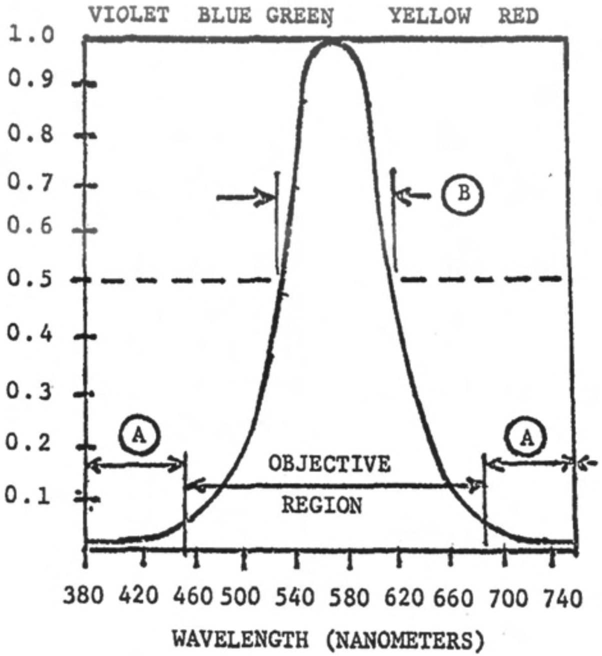

SUPPRESSION OF THE PARANORMAL CHANNEL BY THE PHOTON INTERACTION INCREASES IN THIS DIRECTION IN PROPORTION TO THE SPECTRAL LUMINOUS EFFICIENCY

Fig. 8. Photon quenching of the paranormal

PHOTON QUENCHING OF THE PARANORMAL (TIME) CHANNEL

The photon interaction constitutes a time-differentiating operator imposed upon L^3T dimensionally (Minkowskian reality), which results in the creation of L^3 dimensionality (objective, spatial reality). Aristotle's three laws of logical thought are based on primitive observation, which in turn is in one-to-one correspondence to the situation where the photon interaction has been imposed and the time dimension destroyed, resulting in a classical or objective or spatial reality. Hence all our present logic, science, and mathematics are based upon this particular arrangement. As shown by the two-slit experiment, if the photon interaction is not allowed to occur, a fundamental particle refuses to behave in a classical, objective, spatial object manner; instead, it behaves in a nonclassical, nonobjective, wave manner if the time element interacts with it.

Mental phenomena occupy the same time dimension as do physical phenomena; however, the spatial dimensions of mental objects do not ordinarily occupy or intersect the spatial dimensions of physical objects. However, the time dimension is recognized by physics as objective; therefore, since the mind occupies at least one real objective dimension, it is objective rather than subjective. This suggests a model whereby mind is a real L^3T Minkowskian four-space world, but one whose three spatial dimensions lie orthogonal to and outside the ordinary world's three spatial dimensions. The mindworld and the physical world then have in common the same time dimension. Dynamic movements in each world (mind and matter) result in an exceedingly small crosstalk being projected into the other world, a crosstalk so small as to be virtual and normally unmeasurable. Establishing one-to-one coherence between crosstalk from a mindworld constitutes the creation of a biological organism. The crosstalk from the mindworld and a physical structure in the ordinary world to the physical world has previously been labeled *inception* by me, and a mechanism whereby such a minute psychokinetic effect on matter can be amplified to a macroscopically observable level, or even beyond, has been derived. Thus a fundamental mechanism whereby tulpoid activity (projections from the collective unconscious materializing into the ordinary physical world, in a format determined by the collectively higher levels of unconsciousness in the race, national group, culture, subculture, and personal unconsciousnesses) is developed and explained.

Before the intervention of the photon interaction, four-dimensional reality thus has a great deal of tulpoid dither riding upon its time dimension as a minute modulation. The photon interaction invokes a time-differentiating operation, stripping away or suppressing the time dimension, resulting in a spatial reality or objective reality being perceived or observed, and in the process separating mind and body by destroying the only common connection or channel. Because of the time-squelching action of the photon interaction, we do not see time or the mind in our ordinary physical observation. Also, we do not see the incessant stream of tulpoid activity that bathes the time channel.

The time channel is thus the mental channel and the paranormal channel. The photon interaction is the destroyer or squelcher of the paranormal channel. Apparently the squelch effect of light is not linear or constant, but is a variable and a function of the frequency of the light being utilized. From a synthesis of a variety of data in diverse fields, the following hypothesis has been arrived at to fit the experimental evidence: *The quenching of the hyperchannel (the paranormal channel or the time channel) by photon interaction is proportional to the spectral luminous efficiency of the eye of the average human observer in the interval from the infrared to the ultraviolet.* Thus the form of the paranormal squelching effect of the photon interaction is given by the operator ϵ where

$$\epsilon = m \mathrm{E} T$$

and where *m* is a parameter which varies as some function of frequency. This hypothesis specifies *m* over the region from the ultraviolet to the infrared. In other regions of the frequency spectrum, the form of *m* must be determined by experiment.

There are several experiments which fit the hypothesis:

1. The induction of death and disease patterns from test cells to environmentally shielded healthy cells by Soviet scientists.[a]

2. The invoking of specific tulpa living forms and photographing them in the invisible state with infrared film by Trevor James Constable.[b]

3. The visible light revival of appreciable fractions of cells killed with ultraviolet light and kept in the dark — dormant, unreproducing, for up to twenty-four hours.

4. Ingo Swann's precise differentiation of the visible light spectrum (frequency region) where psychic seeing (similar to remote viewing) is blacked out.

5. The Fox and Miller experiments, in which cell-like protein forms that reproduce (i.e. are "living") are generated when a primeval soup in the laboratory is bathed in ultraviolet light and exposed to strong electrical spark discharge (strong bioenergy collections).

A corollary to this hypothesis is that, under certain conditions, reflected light may reverse the effect. Thus the effect of the full moon, which reflects a great deal of sunlight, can immediately be appreciated. The effect is to the time channel, hence stimulation of this channel stimulates the mental effects. The effects of the full moon on romantics, lunacy, and deeper life functions controlled by the unconscious is grounded in a factual basis.

Thus there is a very good reason why animal eyes tend to operate very closely to the infrared, visible light, ultraviolet region, with the eye usually adapted for the visible light region. In the infrared and ultraviolet regions, tulpoid phenomena would be readily visible or detectable, and an animal whose eye operated exclusively in one or the other of those areas would so often be distracted by the mental tulpoidal activity that it would prove disadvantageous to his survival against animal predators operating in the strongly squelched, visible light region. By the same token, animals whose eye operates further into the infrared or the ultraviolet than does the human eye are notoriously sensitive to paranormal phenomena before their manifestation to human observers.

The stimulating effect of reflected light, and particularly of light reflected from the surface of a planet or of the moon, also concerns several of the common practices of UFO investigators. It is common practice to dispose of a sighting once it becomes apparent that a planet lay in the direction of the sighting and was particularly bright at the time. However, such an optical condition can in fact serve as an initiation point for tulpoid activity to enter the ordinary reality frame. And in fact such conditions — and conditions when stars are very bright and twinkly in their reflections from the particles of the atmosphere — are conducive to UFO appearances, and this should be realized and taken into account. UFO's in a great many cases will be observed to start or come into being from such appearances.

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[a] **V.P. Kaznacheyev et al., "Distant intercellular interactions in a system of two tissue cultures,"** ***Psychoenergelic Systems,*** **Vol. 1, No. 3, March 1976, pp. 141-42.**

———, "Apparent information transfer between two groups of cells," ***Psychoenergetic Systems,*** **Vol. 1, No. 1, December 1974, p. 37.**

[b] **Trevor James Constable,** ***The Cosmic Pulse of Life*** **(Merlin Press, Santa Ana, Calif.)**

If we realize that the paranormal channel is the time channel, then the fundamental two-slit experiment of physics is itself a paranormal manifestation experiment. Thus when the photon interaction is invoked, a classical object and classical behavior result. When the photon interaction is not invoked, a nonclassical entity and nonclassical behavior result. The more interest is taken in a particular tulpoidal manifestation, the more the format is impressed in multiple minds and multiple unconsciousness layers and the more frequently the format is tuned in. Eventually a repeatedly tuned tulpa can become stable and permanent. Candidates for such tulpoids presently on their way to being stabilized are the Loch Ness monster and the sasquatch. Particle physicists may in fact be creating their own reality by the same process, as suggested by Josephson.

The process whereby visible light revives cells killed by ultraviolet light is presently considered under the term "photoreversal." It is a moot point whether cells are living if they have laid dormant for several hours or even twenty-four hours without any cell divisions having occurred. The effect of a given dosage of ultraviolet radiation on cells is known to be greater when the radiation is flashed than when the radiation is continuous. This has been interpreted as due to a thermal reaction following a primary photochemical reaction, since increasing the temperature accentuates the effect of flashing. However, I suggest that flashing is directly related to the effect known as kindling, where, when the limbic structures of the brain are repetitively stimulated, the entire nervous system of the organism responds and goes into resonance (seizure). Soviet experiments have shown that such flashing of a telepathic sender enhances the reception of telepathic information. In the 1920's and 1930's A.G. Gurvich and his students found that a yeast detector's threshold of sensitivity to mercury lamp radiation was about three orders of magnitude higher than the detector's threshold of sensitivity to radiation of the same spectrum from biological material. (For a description of more modern work which may show a violation of the conservation of energy law, see L.L. Regelson, "A Paradox of Mitogenetic Radiation," edited by H.S. Dakin, translation available from H.S. Dakin, 3101 Washington Street, San Francisco, CA 94115.) Regelson's experimental results point to the conclusion that the paradox observed with the mitogenetic radiation experiments is a universal physical phenomenon. In view of this and Kaznacheyev's results, the entire area strongly warrants intensive investigation. Regelson's group was actually attempting to find a new solution to the problem of wave-particle duality, strikingly parallel to my interest in the area.

Those frequency points where the quenching effect is minimized (i.e., where € goes through a minimum value) are referred to as "magic windows" or "magic windows between worlds." Acker and Tiller have called them "interdimensional nodal points." In the magic windows, energy from one frame or biofield can be more easily collected to orthorotate into another frame or biofield, since the rotational threshold is much lower. There is a window, e.g., between 38,000-40,000

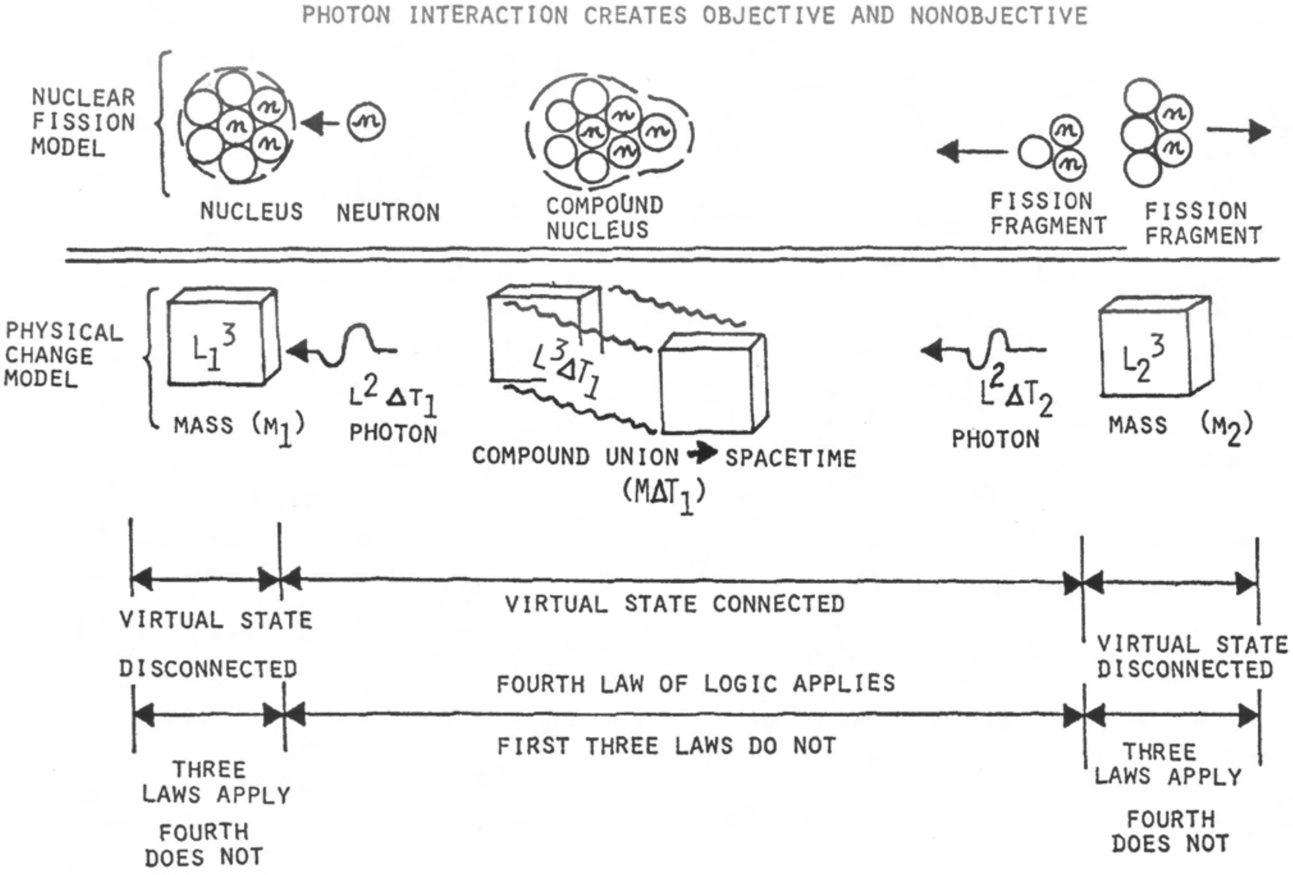
PHOTON INTERACTION CREATES OBJECTIVE AND NONOBJECTIVE
NUCLEAR FISSION MODEL
n
NUCLEUS
NEUTRON
COMPOUND NUCLEUS
FISSION FRAGMENT
FISSION FRAGMENT
PHYSICAL CHANGE MODEL
L_1^3
MASS (M_1)
$L^2 \Delta T_1$
PHOTON
$L^3 \Delta T_1$
COMPOUND UNION → SPACETIME
$(M \Delta T_1)$
$L^2 \Delta T_2$
PHOTON
L_2^3
MASS (M_2)
VIRTUAL STATE DISCONNECTED
VIRTUAL STATE CONNECTED
VIRTUAL STATE DISCONNECTED
THREE LAWS APPLY
FOURTH DOES NOT
FOURTH LAW OF LOGIC APPLIES
FIRST THREE LAWS DO NOT
THREE LAWS APPLY
FOURTH DOES NOT

Fig. 9. Raindrop model of quantized change

Hertz, which can be stimulated with ultrasonics or electromagnetic radiation. The ultraviolet region contains a window, as does the infrared region. Many other windows apparently exist.

Trevor James Constable photographs paranormal phenomena through a filter that is open in the IR and UV regions, but opaque to visible light. Thus the filter blocks out the strong quenching effect of visible light and looks in two magic windows, IR and UV. Constable is thus able to photograph phenomena that are not normally detectable.

RAINDROP MODEL OF QUANTIZED CHANGE

What does not appear to have been realized to date in physics is that the photon interaction is the agent that creates objectivity itself, as is clearly established by the two-slit experiment. The photon interaction separates spacetime into space and time exclusively. An object, being something which occupies space (L^3), is thus timeless. Objects do not exist in time, because the union of an object with time constitutes spacetime, which cannot be perceived, detected, or observed.

Only changes in (derivatives of) spacetime can be perceived, detected, or observed, but not spacetime itself. That with which light has not interacted is not objective. This is proven conclusively by the two-slit experiment, upon which all of quantum mechanics rests. In that experiment, if an electron emitted from the cathode and on its way to the two-slit region does not interact with light, the electron behaves in a totally nonobjective manner, appearing to pass through both slits at the same time. (Actually it goes around both spatial slits in time, and since both of the slits occupy the same piece of time, the electron can interact timewise with both of them.)

On the other hand, if the electron is struck by a photon before it reaches the two-slit region, it becomes a "hard, solid little baseball" and quite objective. In that case it can interact with (go through) only one spatial hole because it cannot interact in time. According to Feynman, this simple experiment contains the total and only mystery of quantum mechanics. Furthermore, it cannot be explained in any classical manner. No physicist in the world understands it, although the pattern of repeated electron strikes on a collecting screen is quite easy to compute by simple trigonometry.

Let me now explain what happens to a mass when it is struck by a photon, absorbs the photon, and re-emits the photon. First, a mass is an L^3 object; the concept of mass is not a function of time, but only a function of space. It is thus three-dimensional. The photon is also three-dimensional, but one of its dimensions is the time dimension. The photon, being built of action, is constituted of $(dEdT)$ or (L^2dT) dimensionally.

When the photon strikes the mass and is absorbed, the (AE) portion is turned into mass by orthorotating one turn and becoming L^3 dimensionally. The (dT) portion is thus united with the spatial mass to give a compound nucleus of spacetime comprised of MdT_1 This compound nucleus of spacetime is not perceivable. When a photon is re-emitted, it may or may not be of the same frequency and energy as the previously absorbed photon, depending on the absence or presence of any other perturbations. At any rate, a small bit of L^3 spatial mass is orthorotated to give an L^2 intersection with the laboratory frame, which turns the bit of mass into a small piece of energy, dE. In the orthorotation, a small piece of time is bitten off and joined to the dE to give a dEdT = h quantum of action, which now constitutes a photon. Photon emission thus strips away the time dimension, leaving a spatial object.

Einstein pointed out that the velocity of an object may be visualized as rotation of the object in higher dimensional space. Visualized as spatial rotation rather than rotation toward the time axis, the velocity of light in vacuum c merely constitutes the rotation of a piece of mass by an angle of 90° to the line of motion, in the laboratory space in which we visualize the photon (the rotated piece of mass) as moving. Thus the photon emitted from the mass is moving at c, the velocity of light, because of its orthogonal rotation to the laboratory frame.

Note that the spacetime compound nucleus has now once again been separated into spatial and time components. Time is moving with the photon. And that is why time moves or flows at c, the speed of light in a vacuum. Time is carried only by the photon, and photon interaction with an object produces that object's march through time. If the emitted photon and the previously absorbed photons do not have identical dE and dT components, then M_2 will be different from M_1, and the mass will have increased or decreased. Considering the photon to consist of momentum and length components, i.e., *(dpdL),* a similar diagram can be constructed. In that case, if the momentum and length components of the emitted and absorbed photons are identical, then M_1 and M_2 occupy the same position (M_1 has not moved). If these components are different, then the mass M_2 will occupy a slightly different position than mass M_1, and the mass will have moved.

This, by the way, is the simple solution to the age-old philosophical problem of change. We simply identify M_1 and M_2, calling them the same object. We cannot detect, perceive, or observe the compound nucleus of spacetime in the middle. Thus we experience change as a thing becoming something else, but still being the same thing. This totally defeats the first three laws of logic. However, fortunately we can easily comprehend it since we have developed the fourth law of logic.

The raindrop model of quantized change is taken exactly analogous to the raindrop model of nuclear fission, as shown in Figure 9.

KINDLING EFFECT

G.V. Goddard and his associates in 1969 reported a peculiar kindling effect generated by repeated, periodic, low-intensity stimulation of the limbic region of mammaliam brains. A sustained periodic signal input to the brain and central nervous system eventually sets up a cumulative resonance which increases in magnitude until the entire organism is in sympathetic resonance.

A laboratory rat at first continues to explore its environment in a normal manner when it is subjected to kindling. But after repeated stimulation at the same intensity, the rat will begin to rear up and its forelimbs will convulse. Eventually these bursts of electrical activity induce similar patterns in nearby brain regions, and the threshold becomes progressively lowered. Stimulation progresses to the amygdala, to the amygdala on the other side of the brain, to the hippocampus, to the occipital cortex, and finally to the frontal cortex. Kindling can start only in the limbic structures.

While kindling was originally thought to be a model of epilepsy, John Gaito of York University has reported that a different mechanism is apparently involved since the amino acid, taurine, which suppresses epileptic seizures in laboratory animals, does not prevent phenomena caused by kindling. Also, kindling apparently causes permanent changes in the neural circuitry. Pulsed repetitions of telepathic senders have also been shown to increase the reception of telepathic messages. Thus the kindling effect apparently applies to the paranormal channel as well as to more orthodox transmission channels. (For further details, see "Kindling, once epilepsy model, may relate to kundalini," *Brain/Mind Bulletin,* Vol. 2, No. 7, February 21, 1977; pp. 1-2.)

The kindling mechanism is a far more general mechanism than epilepsy researchers have realized. Coherent time collection of bioenergy in one bioframe "kindles" toward the threshold of the next bioframe, which has a fixed threshold. When sufficient kindling occurs to reach the threshold, automatic orthogonal rotation of the kindled bioenergy occurs into the next frame. There it simply constitutes the kindling or superposition of the imperceivable subquantum state into the perceivable quantum state. This is the mechanism whereby one kind of field can be turned into another. E.g., thought energy (third biofield) can be kindled into second biofield (flux), which can be kindled into first biofield (electromagnetic energy), which can be kindled into zeroth biofield (matter).

BIOENERGY COLLECTORS

Good collector mechanisms exist in great variety, in both living and inert systems. Many good collector mechanisms exist in the human body. One mechanism that collects bioenergy and orthorotates it into ordinary electrical field with appropriate induced currents is simply the electrical current in the human nervous system. This is particularly true of the current discharges from and between the nerve endings.

Another collector for bioenergy in a living system is the mitogenic radiation between the cells in tissue. Taken as a flux, this mitogenic radiation would seem to have both a photon nature and a nonphoton nature. The cells, in their membranes and fibrous internal structures, are continually collecting and kindling bioenergy into electron currents and photons. The electron currents represent collections from the virtual state into observable state, and may in one sense be regarded as the lifting of electrons out of the Dirac sea by direct kindling (coherent superposition of virtual state energy into observable state energy). These kindled currents are thus superpositions or modulations on the ordinary electrical activity of the cells, fibers, and membranes. The mitogenic photons are also produced by direct kindling of the virtual state into observable state, in this case, by kindling virtual state photons into observable state photons.

Spark discharges, such as are used in Kirlian photography, are extremely good collectors of bioenergy. In Kirlian photography the film records ordinary photon interactions; however, the spark discharge from the finger is collecting and kindling bioenergy into ordinary electrical energy (specifically, into electromagnetic field, which then affects the electrical flux pattern). Also, bioenergy is being collected and kindled into ordinary photons, thus changing the photon pattern being emitted.

Furthermore, those photons being emitted are internally affected by the bioenergy that has not yet kindled to observable state electromagnetic energy, but is still virtual. Each photon carries the virtual state along in the little piece of time contained in the photon, and partially collected bioenergy which has not yet breached the threshold of observable photons is being carried in each emitted photon. These patterns are transferred to the grain atoms by photon absorption when the piece of time of the photon is momentarily added to the mass of the absorbing atom, and in turn are continually spread through the emulsion material atoms by the virtual photon fluxes of the charges, in both the nucleus and the orbital electrons of the atoms.

So the life pattern of a photographed object is captured on ordinary film — and indeed that pattern can be resonated through hyperspace with the object that was photographed, regardless of where the object is in the universe.

Note that there are many mechanisms inside stars and planets for the collection of bioenergy. We live in a vital, pulsing, living, breathing, bioenergetic cosmos, and life is everywhere. Patterns of life are riding in the light from the distant stars, from our sun, in the neutrino flux from the cosmos, in the graviton flux from the cosmos, in cosmic rays, etc. And so it is small wonder that living cells that form, reproduce themselves, and die can be induced in the proper primordial soup of nutrients when that soup of matrix forms and chemicals is bathed in ultraviolet light (one of the magic windows which contains a greatly enhanced transmission factor for bioenergy, hyperspatial energy, life energy), and stimulated by electrical spark discharges.

It would be interesting to perform the same type of experiments with concentrated light from distant stars, or with the mitogenic radiation from cell cultures, using environmentally shielded setups similar to those used by the Soviets in experiments with the transmission of death patterns.

Even stranger, bioenergy propagates along deBroglie waves, and so all possibilities are modulated by bioenergetic kindling and collection. Viewed in this light, Puthoff and Targ's remote viewing experiments actually provided a multitude of probability paths to the viewer, and these probability paths were indeed kindling bioenergy of the distant, as yet unhappened event. The actual event in the future contains a great many additional collection kindlings due to the additional factors involved in determination (such as collapse of the wave function). A peaking of signal exists on the more probable happenings, and this extra signal along certain paths constitutes an increased signal-to-noise ratio in that particular channel. Thus an actual mechanism exists for seeing at a distance and for seeing ahead in time.

Particular note should be made of the pi meson collection mechanism in the nucleus of an atom. Each neutron and each proton in the nucleus of an atom is continually emitting and absorbing pi mesons, and thereby the protons and neutrons are continually interchanging from one to the other by passing along the positive charge. This activity produces the strong force which binds the nucleus together against the electrical repulsion of the electric forces due to the positive charges of the protons. The fantastic structurings and currents that result provide an electrical current which can and does collect bioenergy. A skilled psychic with good psychokinetic ability can thus focus on the kindling mechanism inside the nucleus and get a signal-to-noise increase of the kindling of his bioenergy in nuclei as opposed to elsewhere in the material in other collection mechanisms. Several types of reactions can then occur. The protons may have their electric charges extinguished due to the extinguishing of the virtual photons producing the electric field on their pions. In such case, the atom simply loses its integrity, and some neutrons and photons are emitted from the atomic site into the surrounding material. This type of interaction thus locally softens a metal and produces severe heating in localized areas, changes in fundamental grain structure, and changes in fundamental characteristics of the metal.

It is by this mechanism and similar related reactions that metal bending can be and is accomplished by persons such as Uri Geller. The collection of bioenergy by graviton emission, absorption, and flux leads to antigravity and other psychokinetic effects. These are exhibited in rare levitation phenomena and more frequent poltergeist phenomena.

The list of collectors could be materially increased, but these should suffice to show the importance of the effect of coherent time collection, kindling, and orthorotation of one type of field into another. The collection of deBroglie waves is moving much faster than light, and for very slowmoving objects the collected and projected bioenergy on their deBroglie waves is moving at essentially infinite velocity. This accounts for the fact that Hieronymus observed an instantaneous cutoff of his monitoring signals from the Apollo astronauts when their space vehicle went behind the edge of the moon.

Looking over the list of collectors and carriers, it is obvious why even the best Farraday shields cannot shield out bioenergy communication. The deBroglie wave carrier alone will simply take the bioenergy right through any known substance — or more precisely, it will take the bioenergy around the three-space in which the barrier substance exists, since deBroglie waves are actually superluminal particles in a three-space more than one orthogonal turn away from the observer's three-space. The implications for psychic healing and psychic surgery are obvious.

PSYCHOMETRIC EFFECT

Every mass communicates with every other mass in the total universe, with hyperspatial/virtual crosstalk between all parts and all masses. This yields a mechanism for psychometry.

Inside the mass, we have a large number of collector mechanisms, of the types previously listed and explained. All objects in the universe are in communication with this object, particularly large or close objects. Those objects that come very near or touch the chosen object for a period of time are most influential.

Briefly, the internal dynamic collector mechanisms of the chosen object perform collection and kindling of the virtual state; thus each mechanism is slowly changed by the influence of other objects in the universe. This is very like the diffusion of heat. The chosen object also communicates part of the influx away, normally reaching an equilibrium with its surroundings when these surroundings are stable. As the surroundings change, appropriate changes are communicated into the internal collector mechanisms of the chosen object, and appropriately diffused away to other parts of the universe, until equilibrium is again reached.

Note that the influence of nearby or touching objects is greater than the influence of distant objects under normal spatial considerations. In hyperspatial considerations, however, this is not necessarily true at all, since this chosen object's pattern may be tuned in through hyperspace without any loss of energy due to ordinary three-space separation distance. In the absence of such hyperspatial tuning, distance is a factor, and close objects have a greater signal-to-noise ratio in the collection and kindling than do more distant objects.

Thus an individual or group of individuals in the vicinity exert mental, emotional, and bioenergetic influence on the kindling being accomplished in the chosen object. The stabilized dynamic patterns of the localized chosen object thus are conditioned and kindled to contain patterns of the actions, feelings, and thoughts of the individuals around it, as well as the natural events that occur. It is thus a very exact record of its surrounding events.

A psychically sensitive person who touches the chosen object, or in some cases merely comes near it, enters into a communications exchange with it. His body-records diffuse into the local object, and those of the local object diffuse into his body. If the psychic is sensitive enough, he can gain impressions from the recorded events of the object. This is the scientific basis of psychometry.

A wide variety of data support this mechanism. Psychometry has been practiced since earliest times, and is still practiced today. A photograph is particularly indicative of the person photographed, since his entire record is imprinted psychometrically on the photograph.

Moreover, the entire record of the Earth is still in the earth, in all its detail. As indeed is the record of each star and its planets, riding on the light that reaches us from that star, and on the deBroglie waves from it. With operational biodetectors, we could easily read the records of the universe. NASA would do well to pursue this alternative in its attempt to contact extraterrestrial life, rather than point huge radiotelescopes toward the heavens and listen to the kindled static from the stars. The static indeed contains the message, but not in a format in which they are prepared to look! It is in the virtual state, riding in each photon.

To a psychic who can see the human aura easily, the condition and much of the record of the person is in that aura, because the auric pattern is changed by all experience of the body, mind, and personality. Thus a good healer can see the aura of the patient, tell if another healer has been in contact with the patient (including often recognizing which other healer it was), and can recognize his own previous contact with the patient many years earlier. (See, for example, the story of Agpaoa as recorded by Sigrun Seutemann in *Healers and the Healing Process,* ed. George W. Meek, Theosophical Publishing House, 1977, p. 93.)

ALL MASS IS CHARGED: EVERYTHING IS ELECTRICAL

It is well known that all mass is charged; thus everything in one sense is electricity. To examine this concept, let us look again at the electron with its virtual photons being emitted and absorbed, which virtual activity creates the electric field of the electron. In classical theory the electron is visualized as if it were a little hard

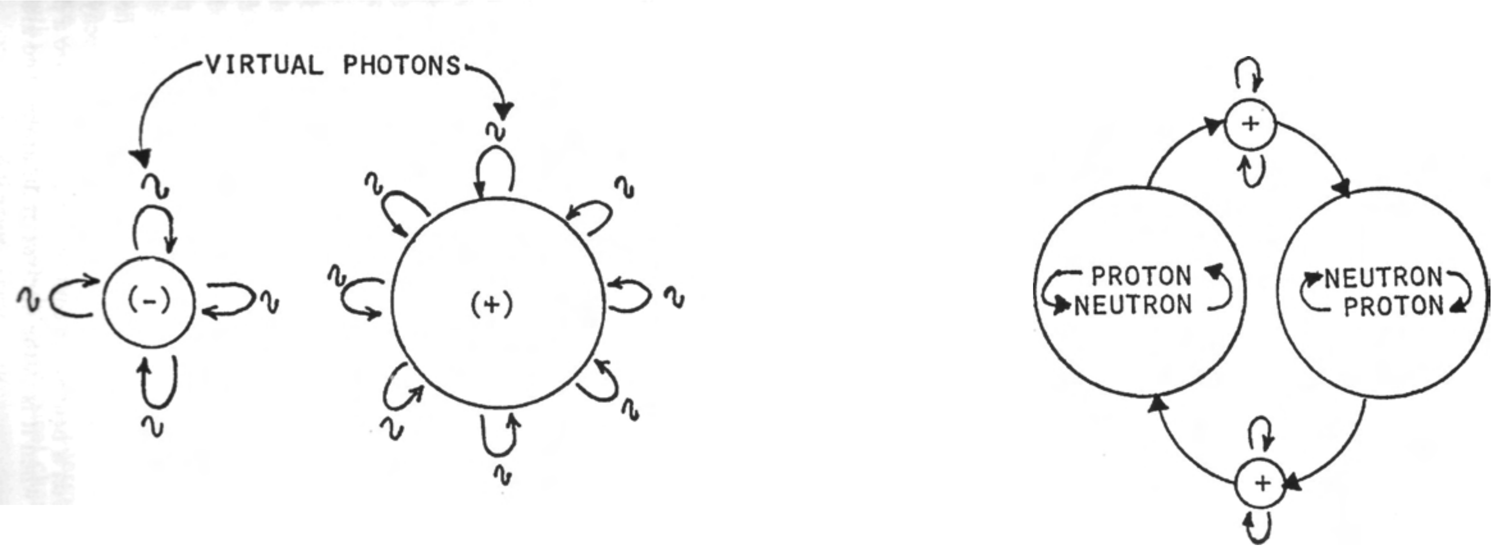
VIRTUAL PHOTONS
(-)
(+)
+
PROTON
NEUTRON
NEUTRON
PROTON
+

ELECTRON

PROTON

IN A NUCLEUS, EVEN A NEUTRON IS CONTINUALLY CHANGING INTO A PROTON, AND VICE VERSA, BY THE EXCHANGE OF THE POSITIVE CHARGE.

Fig. 10. All mass is charged: everything is electrical

spinning sphere; the spinning of its electric field then generates a magnetic component. This concept of spin is retained, even though the electron is no longer regarded simply as a little baseball.

From our viewpoint, the electric field constitutes a steady activity of the emission and absorption of virtual photons, and the electron spin is more of an implosion or explosion in higher dimensional space. That is, we visualize a fundamental stable particle as a precise closure of the entire physical universe, like the Einstein spherical model of the cosmos. Furthermore, we visualize multiple closure; first, a very gradual macroscopic closure gives the so-called gravitational closure of the Einstein spherical model, and a closure — in the case of an electron — of about 10^{42} times as quick and small gives the charge closure. This second closure is considered to be at right angles to the first. In one direction the second closure gives a negative charge, and in the opposite direction the second closure gives a positive charge.

So in this view, spin is occurring in at least four spatial dimensions, not just three. It is more of an implosion or explosion into and out of this three-space universe frame. From such a model, we could expect that some startling physical phenomena might be possible. For example, we might visualize the implosive or explosive spin as similar to a vector flux. If these vectors are not precisely antiparallel when two like charged particles meet, then a resultant flux vector exists. Since spin is actually the quantity action (energy x time, or momentum x length, or mass x time), then the existence of a vector resultant means that enough action can exist to provide a quantum to be fissioned, which yields (creates) physical change. Thus such a resultant allows a collision or interaction to occur. On the other hand, if two like charged particles meet and their spins are precisely antiparallel, then no vector resultant flux exists. Hence no effective action exists to be fissioned and create physical change (collision or interaction). Thus two like charged particles with precisely antiparallel spin ought to run right through each other when they meet, with no interaction at all, electrical or otherwise, in complete contradiction to conventional collision theory and conventional electrical theory which states that like charges repel one another.

Such an experiment has been done, at Argonne National Laboratory, with colliding protons. When the colliding protons have antiparallel spins, they do indeed pass right through one another. And there dies forever the old idea of concrete, solid, material reality. The experiment is not predictable or permitted by present electromagnetic theory or conceptual models of the proton and proton interaction. The experiment is consistent with our dual closure holographic model of the universe, however, and is in fact predicted by it.

In a nucleus, we find both protons and neutrons (except for a single isotope of hydrogen, which contains only a single proton in its nucleus). However, these nucleons do not exactly maintain their exclusivity. Instead, a proton is continually changing into a neutron and vice versa; this metamorphosis is accomplished (in theory) by the continual exchange of a small particle of mass containing the positive charge. Thus a highly dynamic type of electrical current activity is going on in the nucleus. And in fact, this is the only way a neutron can be stabilized in ordinary matter; when freed from the nucleus, the neutron is unstable and decays in about eleven seconds or so. So even a neutron is continually changing into a positive particle, i.e., into electricity, when it is in the nucleus of an atom. And around the nucleus, the electrons are in dynamic orbit, so highly dynamic electrical activity is going on in the outer part of an atom and also in the inner part. Thus indeed all mass is charged and everything macroscopic is electrical. And every physical change of a charged particle constitutes a modulation imposed upon its virtual photonic activity creating its electromagnetic field. These modulations are simply coherently collected to breach the threshold of the virtual (third) orthoframe, passing into the second orthoframe, then breaching the threshold of that frame, and passing into the first orthoframe, which is the frame of the electromagnetic field. The electric field is coupled by the dual closure mechanism to the gravitational field, and also to the mass. The entire mechanism constitutes the coupling of the virtual state reality to observable state reality, and the electromagnetic field plays a prominent part in this coupling. Psychotronics is nothing but the extrapolation of this mechanism and the formulation of a theory to allow the construction of practical devices based upon it. Put simply, psychotronics is *virtual state engineering.*

A FUNNY THING ABOUT ELECTROMAGNETIC FIELD

According to the present theory of physics, the electric field is due to the continual emission and reabsorption of virtual photons. Let us examine that concept just a little further, because there are some interesting conclusions we can make if we are not afraid to take the final conceptual step to the bottom line implications.

First, each ordinary (observable) photon in the universe consists of a little piece (quantum) of nonobservable action. The units of action are energy times time, or ML^2/T *{mass* x length x length/time). The quantum of action in the photon is not separated into a separate piece of time and a separate piece of energy. And also, the quantum of action is a fixed, constant size or magnitude, given by Planck's constant h as

$$h = 6.626 \times 10^{-34} \text{ Joule-second}$$

All this says is that an ordinary photon has a certain size that is quite fixed, and it is made of the substance "action" which is totally nonperceivable and nonobservable. Only changes in action are perceivable, observable, or detectable, never fundamental action itself. So physics already prescribes a universe made out of action, and that universe has no length, no time, no energy, no space, no concrete existence. Yet from it can be taken — by differentiation (which is simply separation) — any length, any time, any energy.

However, only a single quantum at a time changes or is separated. Quanta do not superpose. A single quantum can be split or fissioned into, say, a piece of energy and a piece of time. We can get as large or as small a piece of energy (i.e., change in energy) as we wish simply by adjusting the piece of time accordingly. The same type of separation is possible for momentum and length.

The fragments of the action quantum (say, a piece of energy and a piece of time) must then be stuck back together again (i.e., fused back into an action quantum) to get rid of them, and this particular part of the process has essentially been ignored by physicists. Anyhow, getting rid of the fragments (which gave us a piece of comparative physical change — energy versus time or momentum versus length) causes the just-completed physical change to vanish.

So at its most fundamental level, the entire universe is continually being created and then destroyed in sequence. The continual creation of a tiny piece of time and then the destruction of the piece of time makes us experience reality or change as if we were a pointer moving along a time line. We cannot see time because it is continually being destroyed by the change process, the very process of physical detection or observation itself.

Now if we invoke another kind of change, a virtual change, such that its size is always smaller than the actual quantum's size, then this kind of change cannot be detected, even theoretically. The concept of a virtual change is one such that the quantity of action that was changed was deliberately made smaller than the size required to throw the switch of detectable or observable change.

So if we have a virtual photon, it is simply a piece of action whose magnitude is always less than *h*. Here again, we can still get any amount of energy change we desire, merely by adjusting the size of the piece of time associated with that energy. This then means that the virtual photon is not big enough to breach the threshold of quantum change, and so cannot be observed or detected.

And here is the interesting bottom line ignored by most physicists and almost all the pragmatic scientists who run the orthodox establishments. The totally unobservable, undetectable virtual photons being emitted and absorbed are conceived as creating the electric field at the same time as observable physical change (ordinary quantum change) occurs. And the electric field, of course, can cause or induce change of sufficient magnitude to breach the quantum threshold and result in observable change. The bottom line is this: the virtual state can be collated and collected to sufficient magnitude to breach the quantum threshold and induce ordinary observable physical change. The electromagnetic field already does precisely this! And if reality can behave this way, as the physicists show, then let us simply accept that and apply it!

Note that we have now resolved the problem of negative time. The fusion process replaces the little positive piece of time that was formed in the fission process. A continual stream of such replacements constitutes a continual stream of subtractions of positive time. Hence this represents a negative time operational channel. Many of the equations of physics, e.g., Maxwell's equations of the electromagnetic field, should be reexamined with a view to this negative time operation. Dirac calculated such an entity, an electron traveling backwards in time, and noted that it would appear as a positively charged electron traveling forward in time. He thus predicted the positron which was later found in laboratory experiments. But of even more fundamental importance is that every piece of charged matter in the universe has such an opposite twin — the well known antimatter concept. So antimatter protons, neutrons, molecules, and physical structures exist. Indeed, this physical reality that we normally perceive has its antimatter twin which we are also unraveling backwards as we go. But here again the bottom line is far reaching: it means that we can coherently collect the virtual state to produce matter or its antimatter, which after all are nothing but macroscopic assemblages of quantum changes, and we can thus get free energy, materialization and dematerialization, teleportation, and antigravity by means of special modifications and developments of electromagnetic circuits. Each photon carries a small piece of time. And the entire virtual state reality is hanging onto that small piece of time as a modulation. That is where the probabilities are riding, in terms of the ordinary monocular interpretation of quantum mechanics, all of these probabilities, and all possibilities, are concretely real and occupy orthogonal universes. Since they all share the same single time dimension, there is a time bridge or time channel connecting the universes. Each move or change in one of them crosstalks a tiny bit into each of the others. Since it is the photon which carries them, then each photon contains all possibilities and virtual states modulated upon itself. Photon interaction thus involves the communication of these possibilities and virtual states to the object with which the interaction occurs.

EXTINGUISHING ELECTRICAL CURRENTS

With psychotronics, it is quite possible to extinguish electrical currents flowing in a circuit, or in the nervous system of a biological organism. First, an electromagnetic carrier (photon) is used to carry the psychotronic modulation pattern which will quench electrical currents. The particular psychotronic pattern is modulated upon each individual photon, in virtual state form riding upon the time component of the photon. This is totally different from the ordinary scheme of modulating an electromagnetic carrier; the normal scheme merely gates the rate of passage of photons (amplitude modulation), or changes the energy-time ratio on various photons as photons continually are emitted (frequency modulation).

In this case, virtual state patterns (probabilities) are added directly to each photon, in addition to whatever is done under the normal scheme of modulation. Thus the carrier can be electrically very complex or very simple. At any rate, the carrier with its psychotronic modulations reaches the target, and photons are absorbed continually and emitted continually by the target. The absorption of the photons and their modulations continually generate compound spacetime MdT nuclei and introduce the virtual state psychotronic modulations onto the mass's electric field, the modulations now riding on the virtual photons that generate that field. When a photon is re-emitted, the compound nucleus is split again, and the dT is carried away by the photon, leaving behind a changed virtual photon state on the nontemporal mass spatially left in between quantum changes.

As time passes, the virtual photons are more and more psychotronically modulated by the kindling effect. Eventually the collection breaches orthoframe thresholds and reaches the electromagnetic field frame, changing the electromagnetic field. If the psychotronic pattern is such as to create a positive charge when sufficiently kindled, the negative electrical charge of the kindled electron is simply absorbed or quenched from within, so to speak. And in this case no ordinary annihilation photons are emitted. Instead, the electron is converted to a neutrino when its electrical field is quenched, and it simply passes rapidly away through matter with no interaction and no damage or heating to that matter. Thus the currents flowing in an electrical circuit or in a biological nervous system can be quenched, without any other damage to the system, and without any pair annihilation radiation being produced.

The UFO phenomena very often demonstrate this effect, and the Soviet Union has long since weaponized it.

A simple way to visualize this process is to imagine the virtual photons of the electron as gradually being quenched. With the virtual photons gone, the electron has lost its charge and its electric field, and is now a neutrino. As a neutrino, it zips through matter with no interaction, and on out into deep space.

This mechanism explains why the electrical circuits of autos, radios, etc. usually are not damaged when they are disrupted by the UFO phenomena. Use of normal mechanisms to change or eliminate the electromagnetic field seriously disrupts the components of the circuits, heating materials, blowing fuses, and melting wires and components. The mechanism described here does none of those things.

The weapon aspects are of course formidable. Small transmitters with the right modulation pattern could be dropped, planted, or fired almost anywhere, and these could be set to disrupt equipment or human nervous systems. Their use in satellites is obvious. Small transmitters of a fixed time-life broadcast duration could be fired behind enemy lines in artillery shells. Tactical missiles could carry hordes of such small transmitters and drop them along the way deep into enemy territory. Essentially everything electrical is vulnerable if radiated long enough for sufficient kindling to occur. Powerful radar beams can be modulated psychotronically to give them effects at a distance, disabling vehicles, communications equipment, and men. Even searchlights can be so modulated. Pavlita's psychotronic generators are known to generate deathdealing effects, because he has demonstrated that they can kill insects, and he has admitted that men can be killed with generators that are large enough.

An even more radical approach is to transmit the desired pattern directly through hyperspace with a hyperspace transmitter, using either a set of triads for focusing at a desired spot in normal space, or using a witness to generate form resonance with the desired target object, much like one tuning fork kindles another of the same tuning into vibration. The witness may be anything that contains the pattern of the target, e.g., a photo or a model. In the case of a living organism, each cell contains the blueprint for the entire organism, so a group of cells from the organism can be used. This applies to plants as well as to animals.

DEATH TRANSMISSION VIA THE PARANORMAL CHANNEL

As an example of the kindling effect and the variability of photon quenching of the paranormal channel, some extremely interesting experiments were performed by V.P. Kaznacheyev et al regarding the paranormal transmission of death. Briefly, two groups of cells were selected from the same cell culture and one sample placed on each side of a window joining two environmentally shielded rooms. The cell cultures were in quartz containers. One cell culture was used as the initiation sample and was subjected to a deadly mechanism — virus, germ, chemical poison, irradiation, ultraviolet rays, etc. The second cell culture was observed, to ascertain any transmitted effects from the culture sample being killed.

When the window was made of ordinary glass, the second sample remained alive and healthy. When the window was made of quartz, the second sample

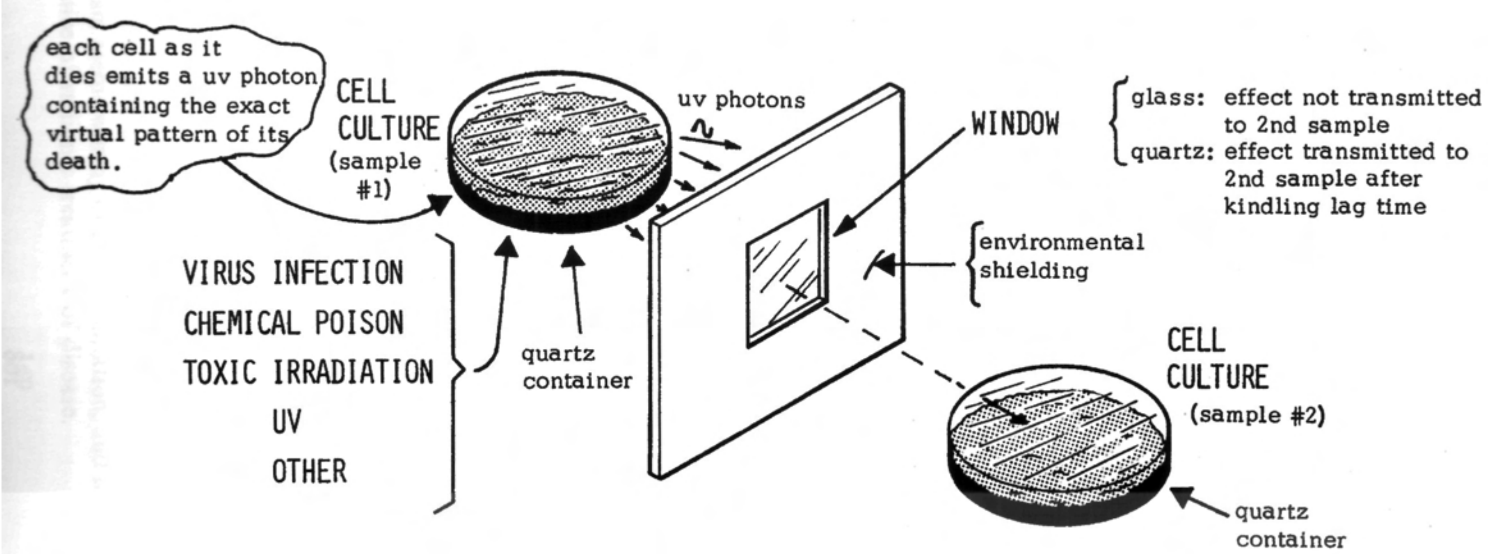
each cell as it dies emits a uv photon containing the exact virtual pattern of its death.
CELL CULTURE (sample #1)
uv photons
WINDOW
glass: effect not transmitted to 2nd sample
quartz: effect transmitted to 2nd sample after kindling lag time
environmental shielding
VIRUS INFECTION
CHEMICAL POISON
TOXIC IRRADIATION
UV
OTHER
quartz container
CELL CULTURE (sample #2)
quartz container

>5,000 EXPERIMENTS

INSTITUTE OF CLINICAL AND EXPERIMENTAL MEDICINE, NOVOSIBIRSK

INSTITUTE OF AUTOMATION AND ELECTROMETRY, NOVOSIBIRSK

Fig. 11. Death transmission via the paranormal channel

V.P. Kaznacheyev et al, "Distant Intercellular Interactions in a System of Two Tissue Cultures," *Psychoenergetic Systems*, Vol. 1, No. 3, March 1976, pp. 141-142.

sickened and died with the same symptoms as the primary sample. The experiments were done in darkness, and over 5,000 were reported by Kaznacheyev and his colleagues. The onset of induced complementary sickness and death in the second culture followed a reasonable time — say two to four hours — behind sickness and death in the primary culture.

The major transmission difference between window glass and quartz is that quartz transmits both ultraviolet and infrared well, while glass is relatively opaque to ultraviolet and infrared. Both quartz and glass transmit visible light. Thus glass is a suppressor of the paranormal channel, while quartz is not.

By performing the experiment in darkness through a quartz window, the four-law patterns of disease, sickness, or death engendered in the primary sample are not extensively squelched by the photon interaction, and these four-law patterns are transmitted through the quartz window into the second cell culture. Since the genetic patterns of the second culture are the same as those of the first, sympathetic four-state interaction and eventual kindling occur, resulting in the appearance of the effects in the second culture.

It is well known that cells also emit mitogenic radiation, including radiation in the ultraviolet and infrared regions. Since these same regions are not strongly suppressed by the photon interaction, one may hypothesize that paranormal effects may be strongly modulated onto infrared and ultraviolet photon activity, and there is indeed evidence for such an assumption. In 1950, Western researchers found that cells could be killed in darkness with ultraviolet radiation, kept shielded from visible light for twenty-four hours or longer, and then if radiated with visible light the cells would start reviving by hundreds of thousands even though they had been clinically dead.

Specifically, every cell emits mitogenetic radiation in the ultraviolet twice: when it is born and when it dies. The UV photon emitted at death contains the exact virtual state pattern of the condition of the cell at death. The healthy cells are bombarded with death messages from those that are dying, and this diffuses the death pattern throughout the healthy culture, eventually kindling into the same death pattern there.

However, the squelching of the paranormal channel by photon interaction is never complete, or paranormal phenomena could never occur in daylight. Hence paranormal patterns can be modulated even onto visible light, although only extremely weakly. Thus we may speak of the *Q* or sharpness of the paranormal modulation upon photon frequencies; *Q* is extremely low for visible light and may be extremely high for infrared and ultraviolet. In the visible light spectrum, it is probable that extremely large numbers of near-zero strength paranormal patterns are modulated on the light radiation; hence these patterns simply consist of a very weak background noise and the kindling effect does not apply. (The patterns are so random as to be self-cancelling in the kindling effect.)

DISEASE AND DEATH INDUCTION

The base idea here is that an active agent must be involved to disrupt the ordinary healthy pattern of inceptive life functioning. Since life functioning is inceptive, ultimately the bioframes, specifically the first and second, must be distorted or disrupted. The first bioframe is the electromagnetic field and the second bioframe is a psychotronic field. The second bioframe may eventually be revealed as the *neutrino* field, but this is still uncertain at present. At any rate, it is a *virtual state* field. Virtual state patterns of a disease, for example, are carried in each photon emitted by a diseased cell. The life functioning psychotronic components are modulated on the body's electromagnetic components. Thus they have an electromagnetic carrier, which will carry the inceptive life function patterns through the photon squelching effects of emitted photons in the body.

A host agent such as a germ produces an active agent such as a toxin. The chemistry involves the particular compound of the toxin that is disruptive or deadly. But chemistry after all is rigorously based on electrical patterns. These electrical patterns of toxic chemistry contain psychotronic patterns modulated upon them by the germ, and these genetic life functioning patterns are different from those of a human cell. The foreign psychotronic patterns are modulated upon the human body's electromagnetic patterns (currents) and thus reach the cell, where they interact by the fourth law in the cell membrane, being demodulated and introduced to the cell, and orthorotated in the process into electromagnetic signals disruptive to the orderly functioning of the cell. The foreign psychotronic signals also jam the ordinary psychotronic patterns being demodulated by the cell in its inceptive operations from its mind frame or third bioframe. If this jamming is only moderate, the cell sickens; it is only disrupted. If the jamming is severe, the cell dies.

The normal electromagnetic noise bathing the cell from the cosmos and the environment contains random components that largely self-cancel or balance. The modulated random psychotronic modulations of the ordinary background environment behave similarly, and thus the normal background simply constitutes a weak noise flux which does not disrupt the inceptive life functioning. In the experiments of Kaznacheyev and his colleagues, photon squelching was largely restricted, and the psychotronic signals from the dying primary culture could go through the infrared and ultraviolet windows in the quartz as virtual state patterns on the mitogenic UV photons emitted by dying cells, and be introduced directly into the secondary culture. The kindling effect then induced the disease or death pattern after an appropriate time delay. Thus it appears that there is indeed a fundamental mechanism by means of which a disease or death pattern from one cell is introduced into others.

If this is true, then an exciting vista emerges for the treatment of hither-to incurable diseases such as cancer. The psychotronic pattern of the cancer cells in a person's body could simply be recorded, then phase shifted 180 degrees, remodulated upon an RF carrier, and radiated back into the body of the patient to cancel the cancer's signal patterns. Radiation of the body need not be severe at all; even weak radiation will suffice due to the kindling effect. At any rate, the hypothesized mechanism seems worthy of experimentation, and it seems to offer a validation of the practice of radionic treatment of disease.

DYNAMIC THOUGHT CONSTRUCTS: BIOFIELD MECHANISMS

We will discover later that thoughts and thought objects are real, physical objects in their own worldframe domain. As such, thoughts, or thought objects, or thought constructs can be and are quite functional devices in the thought world domain. In that domain, they are as physical as a rock. We will also discover that thought energy can be turned into electromagnetic energy by kindling, and can even be materialized if kindling is of sufficient intensity. As an example, thought energy from negative thoughts continually repeated or held in the mind can cause one to become physically ill. This is a well-known effect, and such an illness is referred to as psychosomatic. However, the mechanism by means of which it is accomplished is not known.

Actually the mechanism is simple: in the minute electrical currents that run through the nervous system, across the cell membranes, through the fibrous content of the cells, and through the cell water structures, virtual state thought energy is continually kindled into weak electrical patterns, which modulate, shape, and affect all the vital processes of the body. Almost all this kindled thought energy is from the content of the unconscious mind. Thus the locked-in contents of our unconscious minds eventually directly affect and change our bodies for either good or bad, depending on the particular content being kindled.

Small wonder that we suddenly acquired a chemical problem some years ago after we were saturated by thousands of hours of pill advertisements on television, which directly implanted the idea that certain chemicals such as pain relievers contain the answer to life's problems, while others such as alcoholic beverages lead to a glamorous, active, exciting life. Not only can such material implant suggestions in the unconscious for association, but it can also directly condition the response that the body itself will exhibit to chemicals and drugs.

It is now fairly well accepted that there exists a cancer personality and a heart attack personality, where the mindset is definitely and causatively involved. And from the Simontons' work, we see that the mind can be effectively used in conjunction with other therapy to reverse cancer, even terminal cancer. But unfortunately, by and large Western medicine continues to rely on mechanics and chemicals. Essentially the patient is viewed as a mechanical apparatus and a chemical factory that is damaged, polluted, or out of sorts, and treatment consists largely of mechanical intervention (such as surgery) or chemical intervention (such as antibiotics). Medicine continues to be a science of the reparation of damage or malfunction. It is the science of disease, not the science of health. I do not advocate abandoning the medical practices that have proven effective. I do advocate the augmentation of such measures by all the mind measures available. In fact, medical science ought to be vigorously pushing forward into fields of psychic healing, psychotronics, radionics, etc.

RADIONICS

In ancient development systems it was well known that the mind itself was a functional device, and that thoughts and thoughtforms could function as devices, influencing and affecting other minds and physical material. It was also understood that the thoughtforms had to be crystal clear and very stable. This demanded a great deal of practice in concentration. Eventually it was found that the stability of a physical form or device could materially assist the mind in maintaining stability. In ancient times many such devices were used: the dowsing rod, the crystal ball, the string-and-weight psychic pendulum, etc.

In the last century it was discovered that electrical devices could be used as tuning assistants. This led to the development of radionics, the name being inspired by the new electricity and magnetism discoveries, and particularly by the discovery of electromagnetic radiation. These radionics devices had a distinct advantage in the degree of precision they achieved in the tuning of the inceptive cyborg (operator's mind linked with the actual device through hyperspace). Ten resistors could be staged to give an otherwise almost unobtainable degree of accuracy and precision to the inceptive tuning. The use of variable resistors allowed rapid change of resistance, and thus rapid change of the overall cyborg tuning, and the ability to scan precisely in hyperspace, say, the emanations from a patient. In the hands of a skilled operator, such a device was often much more accurate than the finest medical test equipment available today, and infinitely cheaper and faster. In addition, such testing and diagnosis added little or no distress to the patient. This weird new radionics presented a formidable threat to the orthodox medical establishment. In the U.S. at least, the dogmatic medical establishment promptly came down hard on this potential threat to its hitherto unchallenged domination in the field of medical treatment. Its inquisition and purge was made easier by the fact that many charlatans also leaped into the lucrative field, having little or no actual diagnostic ability, and prescribing meaningless amulets and placebos for seriously ill patients. Also, the strangeness of radionics, such as the ability to diagnose illness from a drop of blood drawn from a patient thousands of miles away from the diagnostician and the radionics device, alienated many members of the medical profession who sincerely believed that no such diagnosis was possible, and that all such psychic demonstrations were frauds. Furthermore, the results, either diagnosis or treatment, were not usually repeatable by ordinary physicians and investigators since the psychic skill of the operator was directly involved. Organized medicine of course did not recognize the ability of the doctor to mentally or psychically intervene in the patient's illness, and so such practice was regarded as fraudulent and banned by the medical establishment.

The radionics practitioners were hounded into court, prosecuted, and convicted of fraud and of practicing medicine without a license. Several prominent radionics pioneers were actually hounded to death, Wilhelm Reich and Ruth Drown being the two most prominent examples. What could have been a great leap forward in medical science in the U.S., and the beginning of the development of psychotronics, was crushed by the power, ignorance, and bigotry of orthodoxy. To this day U.S. radionics has not recovered, and U.S. radionics practitioners are a rare breed, largely underground, who perform their experiments in suspicious secrecy and have only lately begun cautiously emerging from obscurity. In England and elsewhere, radionics survived and flourished, and today one can legally receive radionics treatment in England.

PSYCHOTRONIC DEVICES: A SIMPLE SPACE (QUITON) AMPLIFIER

It is possible to speak of the smallest piece of nothing, that we will call a "quiton." It does not monocularly appear as a perceived thing. Quitons are pieces of action, in which $dEdT > h/4*pi$. Quitons are virtual entities, and very small ones.

Collection of a sufficient number of quitons results in breaching a threshold, so that a thing results. To superpose quitons (dEdT's) must be of the same magnitude and time coherent.

Thus in any situation involving a particularized nothing, collecting enough pieces of that nothing eventually exhausts the nothing set and reaches its boundary, whereupon it is a thing. This is really not different from collecting all non-dimensional points in a particular sequence and finding we now have a one-dimensional line segment, or collecting all the pieces of spacetime warp in a particular region and discovering that we have now a mass.

A device can easily be constructed to process dual natured or binocular entities (quitons), which are monocularly zeroes, while excluding monocular entities. Thus we can build a space amplifier or quiton amplifier or vacuum amplifier. Two single-state excluders in a series feed or input to an ordinary single-state amplifier or processor in a shielded container. The output is fed into a device which will rotate the dual-state entity or field so that an ordinary field can result. One side or the other of the dual-state output will be exclusively present in three-space.

TYPICAL HIERONYMUS DETECTOR

The Hieronymus device, patented by Thomas G. Hieronymus in 1949, is one such device. It has an optical front end, a prism which passes waves and does not admit particles. So a wave entering the front end will go through the prism and be refracted at an angle that depends on the frequency of the wave. Inside the surrounding box, which acts as a light shield, is a small tuner, a little copper rod attached to a rotatable wheel so that the rod may be moved through the various refractive angles from the prism. The prism is mounted on the box with a thin slit in the wall, so that only a small and narrow field of view exists external to the box. The tuner rod is wired to the input of a three-stage RF amplifier where each stage is separately shielded against light—which is very interesting, because of a similar requirement in the two-slit experimental apparatus if the electron was to act as a wave. The output of the RF amplifier comes out of the box and ends in a flat coil of wire between two parallel plastic plates.

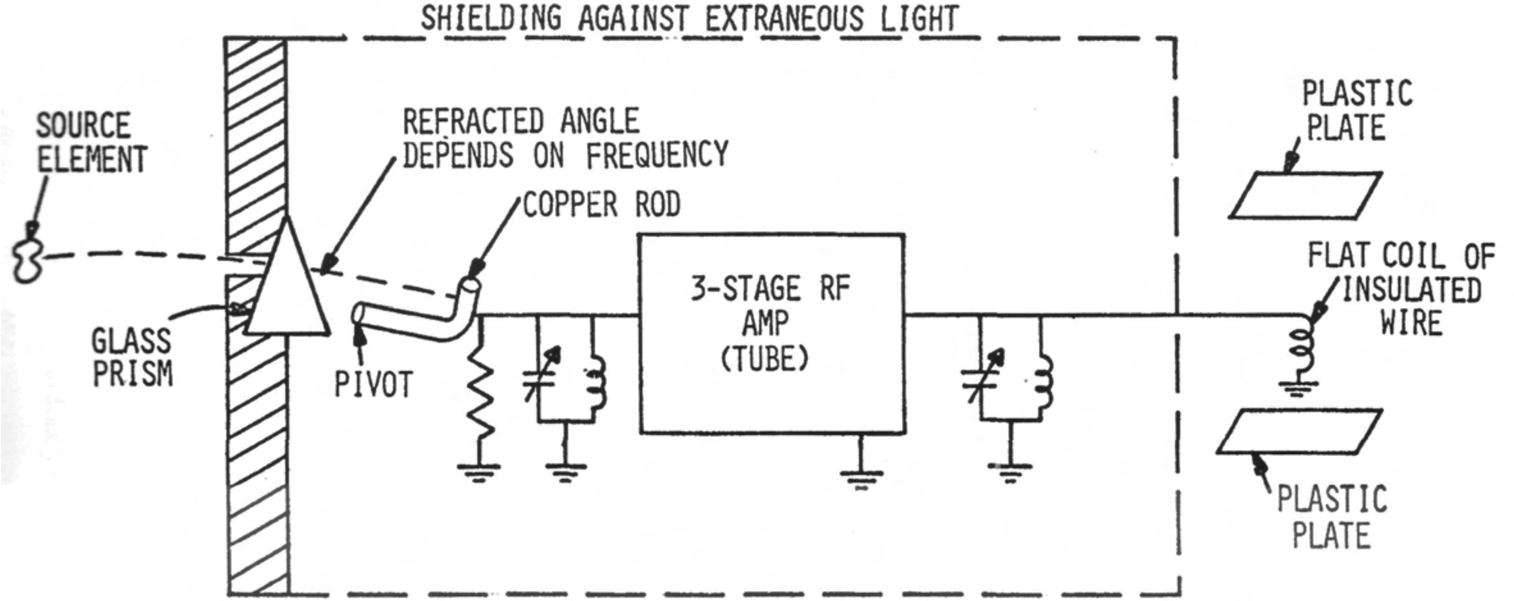
SHIELDING AGAINST EXTRANEOUS LIGHT
SOURCE ELEMENT
REFRACTED ANGLE DEPENDS ON FREQUENCY
COPPER ROD
GLASS PRISM
PIVOT
3-STAGE RF AMP (TUBE)
PLASTIC PLATE
FLAT COIL OF INSULATED WIRE
PLASTIC PLATE

Fig. 12. Typical Hieronymus detector

Coming into the box through the slit in the prism, there can be single-state entities and dual-state entities or quitons. The physicist does not have a good name for a dual-state entity. They used to be called wavicles; today we talk about wave packets. But what after all is a wave packet? It is a three-dimensional bunch of two-dimensional waves! So that is where the physicists have hidden the idea of the dual-state wavicle today.

Only single-state waves and dual-state entities or quitons can pass through the prism and be refracted at an angle dependent upon the frequency. If we then tune the rod into the correct angle of refraction, the refracted quitons hit it, as do the single-state waves if their frequency should happen to coincide with the frequency of the quitons. Now the single-state wave dies when it hits the copper rod; it may chip a single electron or two off a copper crystalline grain, but that is lost in the thermal noise anyway, below the detection threshold of the RF amplifier. The quitons, however, simply say "Oh! Now you want us to act like a corpuscular electron, and go through those wires and conduction paths. That's all right, that is just our right hand side." So the quitons will go through and be amplified, just exactly like ordinary electrons would do. But now it is not electron energy, it is a dual-state analog of energy — let us call it anenergy, for analog of energy. (Hieronymus called it eloptic energy, since it could act as electron flow or as optical waves, but was neither exclusively.) The amplified anenergy will come out in the coil of wire and it will generate field and it is not a magnetic field, and so it cannot be measured on normal laboratory instruments. The simplest way to detect the anenergy fields is to use the human sensory system, because the human body knew about RF energy, frequency modulation, and anenergy long before we had modern electrical and magnetic instruments. (The use of anenergy is illustrated by acupuncture, a very ancient medical system dealing with the fact that a peculiar type of energy-like stuff flows in the body, and in certain points and structures of the body, it can interact with other energies and fields.)

Now if we believe we cannot sense the anenergy fields, then we cannot. We can turn the entire anenergy detection system in the body off with the unconscious mind. The negative psi effect is a well-documented effect in parapsychology. There are goats as well as sheep. Some persons do worse on psi tests than chance would possibly allow. They are the goats. They exhibit the negative psi effect, for unconsciously they want to show you that psi does not work, so they use psi effects to do worse than is possible by chance.

At any rate, the human sensory system can get a tingle from the anenergy field generated by the flat coil of wire in the Hieronymus machine's output. What type of tingle one gets depends upon one's own type of body sensory tuning. It may feel as if the fingers on the plastic plate are in thick syrup. Or as if the plastic plate were vibrating. Or it may feel greasy in a peculiar way. And the negative person does not get a tingle at all.

The Hieronymus machine has been built by many persons, and it works for those who are not negative. It processes entities that exist in the dual-state, or that obey the fourth law of logic. And we can do some almost magical things with these dual-state nonthings, these nothings, if we set our minds to it. This is what psychotronics is all about.

ANOTHER KIND OF HIERONYMUS DEVICE AND THE INCEPTIVE CYBORG EFFECT

If thought constructs are actual operational mechanisms, then there should be other evidence besides psychosomatic illness and the demonstrated ability of the mind to cure certain illnesses. In fact, the Hieronymus device can be used to demonstrate this point.

John Campbell, former noted editor of Analog Magazine, once built an Hieronymus device and tested it successfully. Campbell immediately recognized that present physics could not explain the functioning of the device. In an exchange with Arthur Young, Young suggested to Campbell that it was the mind of the operator that made the device function, and that it was the symbolic form of the device that dynamically functioned to make it work. This appeared particularly significant to Campbell since he had discovered he could make the device work even though disconnected from its power supply.

So Campbell decided to test this thesis. He carefully drew on paper in black India ink a schematic diagram of the amplifier, removed the actual amplifier hardware, and substituted the schematic drawing. To his absolute amazement, the device worked as well for him this way as it had previously. But from our standpoint, such a result is not unexpected and can be readily explained.

First, I should point out quite strongly that Campbell not only was well-qualified technically, but even more important, he had an open and unbiased mind. This of course is quite necessary; the negative psi effect is well known, and the negative person is most certainly not going to allow his mind to operate the Hieronymus machine, just as he will not allow himself to succeed at dowsing, and so on.

Furthermore, in constructing the electrical schema of the amplifier, Campbell was strongly impressing stable thought constructs in his own unconscious, which was fully aware of the function of each part of the drawing. And when he connected that drawing to the rest of the hardware, he understood the function of the connection. He thus built in a thought connection from his thought-form amplifier to the hardware in a cyborg device. It then functioned as well for him as had the actual device. Campbell had proved that mind and matter may be cyborged into operational devices.

Psychic use of a pendulum, a ouija board, a dowsing rod, a crystal ball, and a crystal skull are other examples of the use of inceptive cyborg psychotronic devices, as is the use of radionics equipment of all types. And of course the most outstanding example of an inceptive cyborg where mind and matter are linked into one functional device is a living biological system.

Frances Farrelly, working with Arthur Young, took part in an experiment using an ancient Mexican figurine with a fluted neck. She succeeded in inducing fluted ears in a laboratory mouse. The mouse was exposed to the figurine about three feet away, and the cage or the mouse was connected to the figurine with a wire. Physical objects, such as mice bodies and fluted figurines, are three-dimennional channel tuners for orthorotating mind energies. Given firm initiation by a talented person such as Ms. Farrelly, a selected grouping of tuners can be resonated to collect bioenergy, and kindle it into ordinary energy and then into physical effects.

PROBABILITY: THROW OF A DIE

The fourth law of logic is absolutely indispensable in physics. We use it every day and do not realize it in probability. But what after all is probability? Let us use a very simple example to get at the answer to that question. Let us use the face of a die turned up. How can I model that, before the die is thrown?

Now we can only think by operationalism. To operate and output something is to automatically put it in the past. It's happened, it's gone, the moment you do it. To perceive an object is to put it in the past. To determine it is to put it in the past. To observe it is to put it in the past. There is no observed, perceived, detected, measured, or determined present. That is, there is no separated, exclusive, determined present such as is specified by the first three laws of logic — the fourth law is the present, by the way — but in observational physics which deals with determined, observed past phenomena, there exists no present. The future has not yet been observed, so it also is the unobserved. Only the past therefore is the observed. How then can one ever hope to model the unobserved present or the unobserved future?

If I look at the problem of the die with one face up, it is in the past. When I see it, it is in the past. When I think it, it is in the past. So if all I can observe, think, or perceive is the die in the past, how can I ever model it in the future? It's very simple! If I drive any problem set to its absolute boundary limit, it turns into its own opposite by the fourth law of logic, by the law of the boundary. So how do I do that with this problem of the die?

The problem set is specified by the condition "the perceived die with one face up"; this is the most recent past. Now simply find all the most immediate pasts you can get to meet the condition specified, and gather them all up together, and they then must turn into and comprise precisely the opposite, the immediate future. In this problem set, I can construct and collect six such pasts, each consisting of the perceived die with one face up. So by the fourth law of logic, those six faces up collected together as an ensemble represent the future and in fact are identical to the future. The present, which is simply the boundary between the most immediate past and the most immediate future, was specified by applying the fourth law of logic in the first place: the identity of the most immediate past and the most immediate future, being binocular, is unperceived, but it is the present nonetheless. So that is what probability is — an application of the fourth law of logic, so that the most immediate future can be represented in terms of the most immediate past — and physicists and mathematicians have been doing this ever since they have been doing physics and mathematics.

Without the fourth law of logic, there exists no rigorous logical basis for probability! So the fourth law is a very useful law indeed. We have simply failed to realize that we have been applying it all along.

The ontological problem can also be solved as follows: to state that "*A* is not" is to state that "*A* is" is not; to absent a presented thing is to first present it; to be "not-being" is a clear statement of the problem. By the first three laws of logic, the problem is not soluble. By the fourth law, it is simple since being and not-being can be identified. All distinction between present (being) and absent (not being) can be lost.

NEGATIVE TIME

Negative time does exist and is used in advanced physical theories. Dirac predicted an electron traveling backward in time, which would be observed in positive time as a positive charge traveling forward in time.

The application of negative time to philosophy also allows the solution to the problem of good and evil. In positive time we may consider an act as evil — say the act of a hungry wolf seizing a hapless rabbit and devouring it. In positive time, we might say that to the rabbit the act was evil, and to the hungry wolf the act was good, noticing in the process that good and evil are relative terms, not absolutes. Examining the situation now in negative time, a very strange thing occurs. The remains of the consumed rabbit are regurgitated from the wolfs belly, again creating a living breathing rabbit, and reintroducing hunger into the wolf. Thus the act now is beneficial to the rabbit and detrimental to the wolf.

The point is that Allness or Godness is both sides of every coin, not one side only. Omega Godness exists both backward and forward in time; it must do so if it is to be unlimited, even by time itself.

Thus to such unlimited allness, every act is both good and evil simultaneously. Thus we can understand how a perfect creator could establish and ordain good and evil, for there is a sense in which the two are synonymous.

However, such insight is a very strong dose of medicine, too strong for the average stomach. Most persons never seek the Unlimited Godness; instead, they seek a good facet of Godness that itself moves forward only positively in time. Thus they find a partial image which is limited in and by the flow of time. By such an assumption the biblical phrase "I am Alpha and Omega" is unconsciously translated into "I was Alpha and I will be Omega." Thus orthodox Christianity long ago lost much of the God-insight originally given by the avatar Jesus. Only those few cloistered individuals who still struggle with exegesis grapple with the problem of good and evil. The problem indeed has a solution, but the solution involves negative time, the fourth law of logic, and an unlimited creator.

TIME OSCILLATION, QUANTUM CHANGE, AND MASS

It is well known in physics that almost all physical theory is time-reversible, i.e., the equations hold true whether time is positive or negative.

This is important in the theory of antimatter. A positron (antielectron) may be regarded as an electron traveling backward in time. The destruction of an electron constitutes the creation of a positron, and vice versa, when we are observing in only one kind of time.

However, when we consider monocular quantum change, we realize that time can be modeled as a wave. To have any of the present physical quantities (energy, length, time, and momentum changes), a quantum of action must be isolated and fissioned into fragments. By this process we get a change in any physical quantity. This is fairly well understood in present physics, though not in this exact terminology.

However, what is not recognized in physics is that a disposal operation must be performed to clear away the fragments of one physical change before another can occur. The only way the fragments can be cleared away is to fuse them back into an action atom. Since action itself cannot be perceived (only a change in action can be perceived, not action itself) then fusing the fragments into a quantum removes the fragments.

This fusion operation removes positive time fragments (and other positive fragments) and so can be considered a negative time operation. Thus time can be considered to be an oscillatory wave because of its continual monocular discrete creation and annihilation by the quantum change process.

In fact, time oscillation may be considered to be the fundamental reality, and quantized change its result.

By the complementarity principle, time, being a wave, also must sometimes exhibit a corpuscular nature. (Indeed, all virtual state particles are nested within the structure of time.)

The Soviet work on time generating force thus is of absolutely fundamental importance. What has been released of K'ozyrev's work seems to be intentionally deceptive and of little value. His real work and that of his colleagues appears to have the highest Soviet classification, and none of this material has been released.

In the West, the only person of note who has grasped the fundamental import of time and time oscillations is Charles Muses. As early as 1958, Muses pointed out that there was no mystery in the two-slit experiment if the chronotopological features of the experiment were properly taken into account. Muses also worked out a hypernumber structure of time, but its significance seems to have escaped orthodox physics. Nonetheless, his work has direct technological implications, such as materialization and dematerialization of matter, and offers an approach to the engineering development of actual devices. Since his hypernumber theory of time structure also encompasses consciousness, it represents a union of physics and metaphysics on a common basis, and an approach to the engineering development of psychotronic devices.

Western physicists, then, would be well advised to pursue vigorously the idea of time oscillations, both theoretically and experimentally. And they would also be well advised to examine the hypernumber work of Charles Muses.

Since mind and virtual state occupy the time dimension, the nested structure of time contains the mechanisms for mental-physical interaction and for direct amplification of virtual state into observable state (or for the dissolution of observable state into virtual state).

MASS IS A TIME-DIFFERENTIATION

The most fundamental aspect of the concept of mass is that it occupies space, i.e., that it is three-dimensional. Mass thus is a time differentiation of Minkowskian spacetime L^3T. Applying the fourth law of logic, a thing does that which it is and is that which it does. Thus mass is a time-differentiator.

Because of this, we cannot see time, the fourth dimension, although we can see L^3 length, width, and height. Because we look through and detect with a mass sensory system, the time dimension is lost in the act of looking and detecting, i.e.,

$$d/dT(L^3T) = L^3$$

and we thus see a spatial reality. Physical instruments also have mass and do precisely the same thing. For this reason, ultimately all measurement or detection is spatial rather than spatio-temporal, as is well known in physics.

Note that we do not see or detect total reality, but only a partial differentiation of it. Thus the position of the materialist's view is ironic: in his absolute insistence that reality consists in only what can be seen, touched, felt, or detected and measured with his instruments, he condemns himself to the greatest illusion of all, the notion that the outputs of his physical sensory system and his physical instruments constitute absolute reality. Also, since the only physical dimension shared by mind is time, mind reality is lost in the act of detecting, and hence only phenomena which are totally separated from mind are detected.

By the fourth law of logic, the existence in no mind at all constitutes the existence in each and every mind (nonexclusively). Thus physical phenomena are those phenomena that are processed by every mind. We will see that the fourth law enables us to deal precisely with mental, physical, and paranormal phenomena on that basis (how many minds the phenomena exist in).

REALITY IS LIKE AN OPOSSUM

Reality is like a mother opossum carrying her little baby opossums on her tail, i.e., the entire mental-virtual state is carried along as virtual constructs, nested comfortably in the delta time portions of each photon. In the piece of time that is fissioned out of an action quantum to give observable change, there are a multitude of little pieces of time still attached to subquantum virtual state entities and hanging on, exactly like little baby opossums hanging on to their mother's tail with their own tails.

The world is so built, then, according to physics. And if we include our physical model of mindchanges, every possibility in fact concretely exists in that manner, in the virtual state, timewise hanging into the time dimension of the detected physical world's four-space frame, but spacewise hanging out of the ordinary three-space physical universe of objects. So indeed all possible realities, even the wildest and the most farfetched, exist in the virtual state.

The time channel is thus quite literally the paranormal channel that connects the normal spatial world to an infinity of nonnormal spatial worldframes. Only by the continual destruction of each piece of created time (by fusing it back together with the piece of energy involved, and forming a quantum which is unperceivable) are we able to experience physical reality at all, uncluttered and relatively free from the vast hordes of infinite realities through which the ship of quantum-change physical reality sails.

Since the electromagnetic field represents a collection of this vast array of realities, then by proper selection (i.e., by coherent tuning) of multiple stages we should be able to select a particular virtual reality channel. And indeed so we can. Any scheme for drastically increasing signal-to-noise ratios should be adaptable to such a collection mechanism for the detection of bioenergy.

In another sense, reality is like a television set with an infinite number of reality channels, but only one of which is tuned in at any one time. By adjusting the tuning, however, a different reality, including even different physical laws of nature, may be tuned in.

BIOFIELD CONCEPTS

To understand the hyperframe approach to fields, we must understand the dimensionality of intersections in n-dimensional space. The dimensionality of an orthogonal intersection is one less than the dimensionality of the intersector having the lowest dimension. One intersector appears radically different to the other intersector since the second sees only a derivative of the first. It is the total projection of an intersector that is "seen" by that which it intersects.

Hubbard's manifold theory also derives these principles. The "types of reality" that these other objects appear to be will depend on the types of intersections they make with the frame of the observer.

This cannot be stressed too strongly: an observer sees his own frame, and intersections in that frame, nothing else. He does not necessarily see the entire reality of any object, and if an object is in a frame that does not intersect the observer's frame, the observer cannot detect that object at all.

Thus all types of reality are open to reinterpretation in the light of intersecting and nonintersecting frames. And to shift dimensions (increase or decrease), all we need do is add or subtract additional orthogonal intersections.

MASS, FORCE, AND 3-D FRAME ROTATION

It is well known that a moving mass can be considered as existing in a three-dimensional space which is rotated away from the line of motion of the mass as seen in the laboratory frame. Einstein in fact pointed this out.

As the velocity of the object approaches c, the speed of light, the angle of rotation approaches 90°. From the bottom left figure it can be seen that a force in the laboratory frame, applied to the moving mass along its direction of motion in the laboratory frame, only affects the mass in the mass's rotated frame with a projected portion. To the laboratory observer, the mass's resistance to the disturbing force applied seems to have increased; thus to him the inertial mass of the object seems to have increased, i.e., if it is harder to push, its resistance to pushing must have increased.

But in the rotated frame, the object's mass has not increased. The rotated frame effect is *why* the mass of an object increases to one observer but not to the other.

When the rotated frame can be rotated to a full 90°, no force applied by the laboratory observer can accelerate it further, because the applied force has zero projection in the rotated frame where the mass actually is. Thus the mass (resistance to pushing) appears infinite to the laboratory observer, while to the rotated observer it is still exactly the same as it always was. Furthermore, to the rotated observer, **the** force being exerted on the rotated mass is zero.

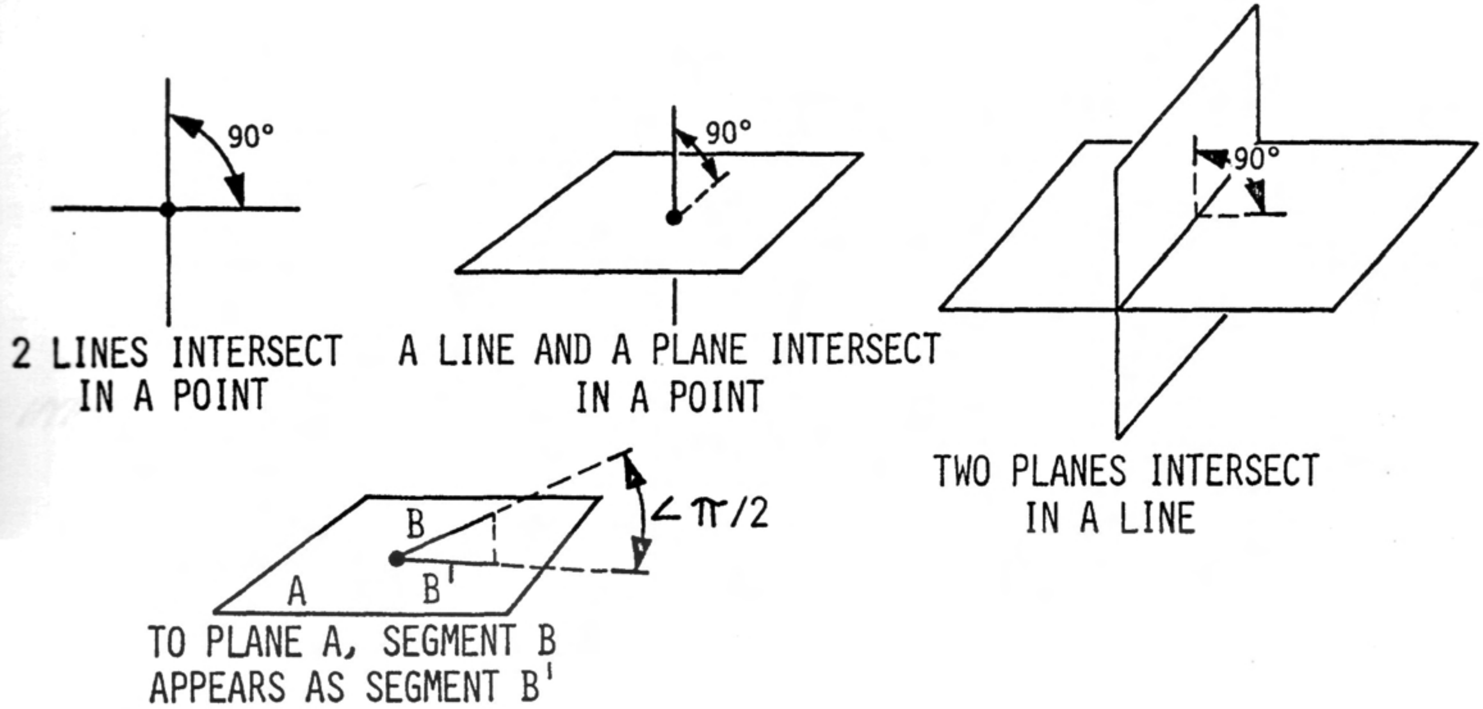
90°
2 LINES INTERSECT IN A POINT
90°
A LINE AND A PLANE INTERSECT IN A POINT
90°
TWO PLANES INTERSECT IN A LINE
B
A
B'
< π/2
TO PLANE A, SEGMENT B APPEARS AS SEGMENT B'

Fig. 13. Biofield concepts

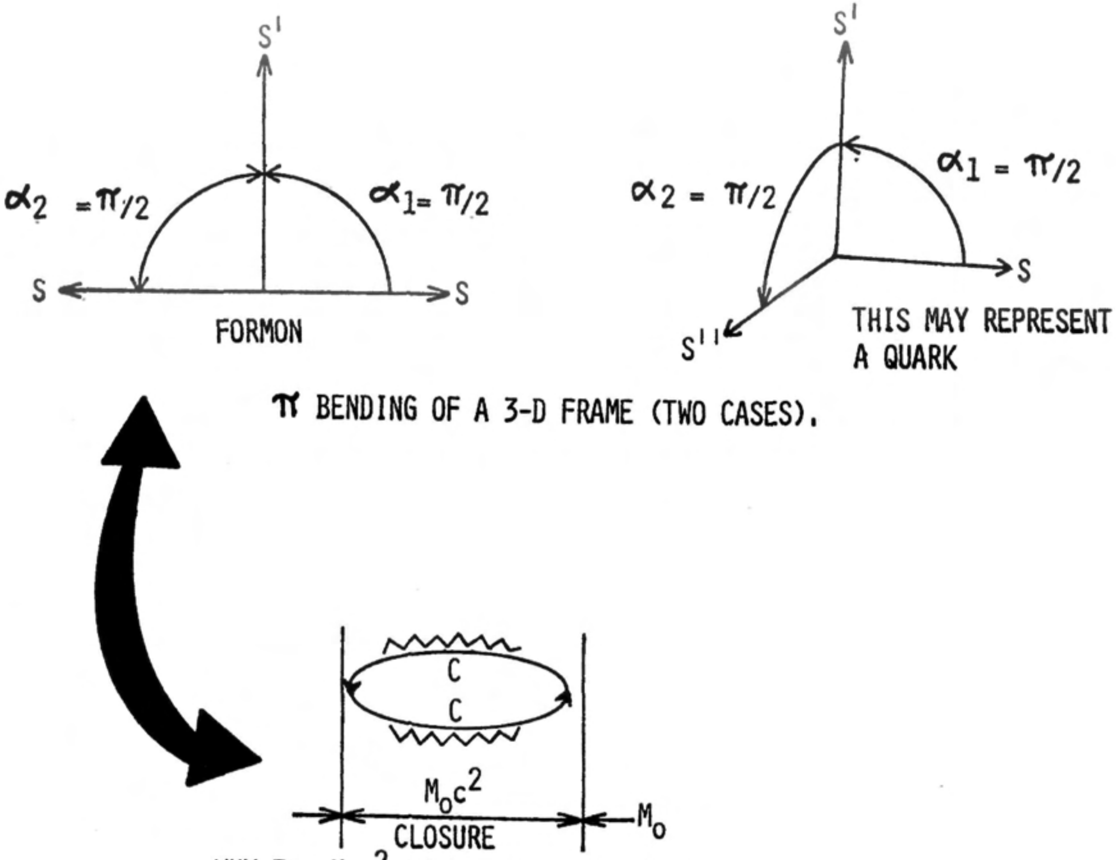
S'
$\alpha_2 = \pi/2$
$\alpha_1 = \pi/2$
S
S
FORMON
S'
$\alpha_2 = \pi/2$
$\alpha_1 = \pi/2$
S
S''
THIS MAY REPRESENT A QUARK
C
C
M_0c^2
CLOSURE
M_0

π BENDING OF A 3-D FRAME (TWO CASES).

WHY $E = M_0c^2$ IN A CLOSURE (FORMON).

Fig. 14. Rotation of 3-D frames

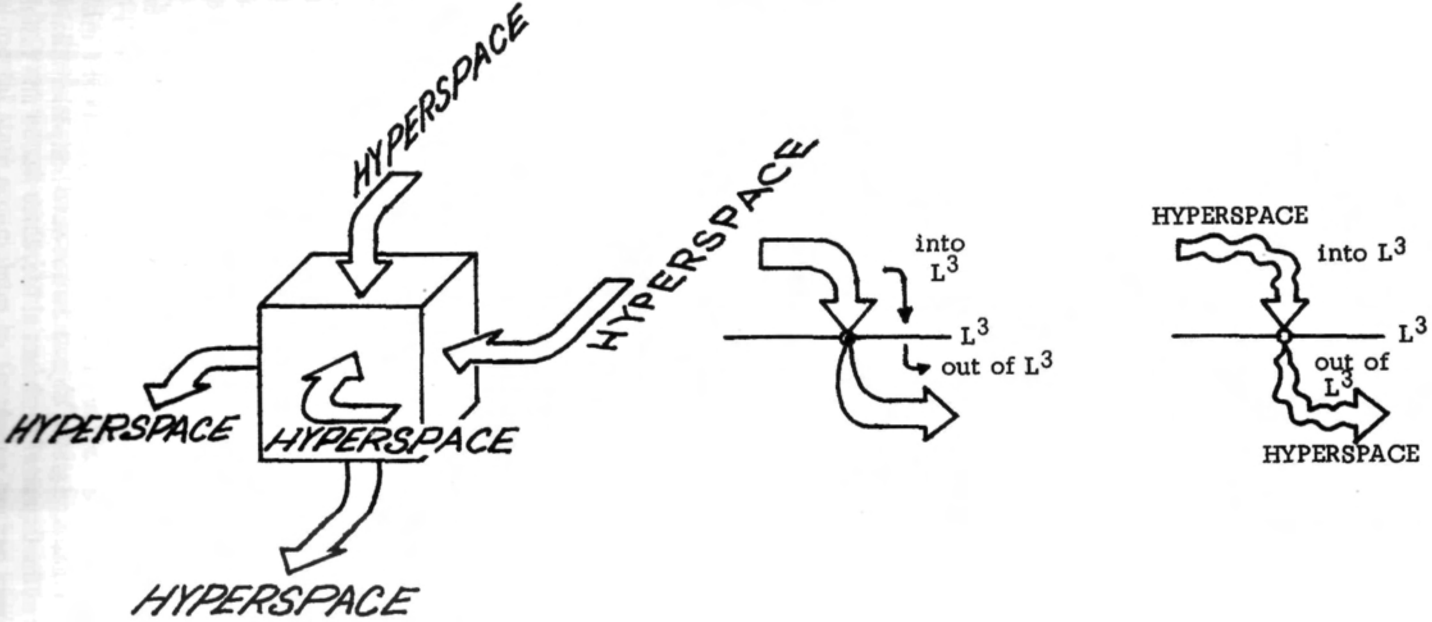
HYPERSPACE
HYPERSPACE
HYPERSPACE
HYPERSPACE
HYPERSPACE
into L^3
L^3
out of L^3
HYPERSPACE
into L^3
L^3
out of L^3
HYPERSPACE

MASS
A region of
hyperspatial flux
orthorotating in and
out of L^3 3-space.

MASS PARTICLE
The flux does not
"move through" 3-space.
It rotates in and out of
each individual mass particle.

JITTER
Each flux line is not
smooth, but jittered.

Fig. 15. Mass is π-rotation of hyperspatial flux

However, the mass's intersection in the lab frame is now two-dimensional. Since only three-dimensional objects can have mass, the object is massless to the laboratory observer. So here we have a paradox: zero mass is identical to infinite mass. This is perfectly in consonance with the fourth law of logic.

The absence of any single finite mass actually permits two indistinguishable solutions: the absence of any three-dimensional mass at all, and the exclusive presence of more than any finite mass. The two opposites are identical on the boundary case.

Thus a photon has zero mass because it is a two-dimensional object and only three-dimensional objects have mass. A photon also has infinite mass because it cannot be accelerated along its direction of travel. A photon is a perfectly ordinary three-dimensional particle existing in a normal three-space that is one orthogonal turn away from the laboratory three-space.

MASS IS π ROTATION OF HYPERSPATIAL FLUX

In Figure 15, I show that a localized mass is simply the result of orthorotational flux in and out of that localized region. This is a hyperspatial flux, since it actually is flowing or rotating in hyperspace.

This flux is related to the spin of a fundamental particle, and in one sense may be regarded as an extension of the concept of spin, i.e., ordinary spin is simply a derivative subset of hyperspatial spin (orthorotation between orthogonal three-space).

This flux does not move through laboratory three-space, but rotates into and out of it, at and for each fundamental particle of mass in laboratory three-space. As I point out elsewhere, mass itself is nothing but the absolute value summations of action quantum fission and fusion activity in a localized (fundamental particle) spatial region *(Quiton/Perceptron Physics).* Fission and fusion are orthorotations, or hyperflux activities.

Also, if we represent this hyperspatial flux by flux lines (a standard practice in physics), then each line is jittered because of its modulation by many higher-frequency components. This flux and the jitter in it play an important part in paranormal phenomena.

Furthermore, the hyperspace flux can be seen in two other ways: (1) as continual direct coherent collections of virtual subquanta to reach the quantum threshold, breaching it and becoming observable quantum change. Thus it should encompass essentially all hidden variable theories. This is the same mechanism by means of which virtual photons kindle and create electric field and the charge of an electrically charged particle; (2) as continual direct coherent collections of mind virtual state subquanta to reach the quantum threshold, breaching it and turning into observable quantum change (physical phenomena). Thus all matter is totally mind and totally alive — inert matter is just nonpreferentially alive. The resultant flux vector in an inert mass is zero since there exists as much flow out as in, and vice versa. This totally eliminates the classical dichotomy between mind and matter. It also implies that accelerated objects do not have nonpreferential type of life, but in fact have some degree of preferential life, since fission and fusion rates of an accelerated object are not equal.

Establishing sufficient pattern coherence in the parts of an accelerated system thus constitutes a preferential tuning between multiple parallel-directed directional coherences. This effect can result in establishing a one-to-one correspondence to and from one of the higher orthoworlds, i.e., it can result in a coherent circulation between that universe and the specific inert accelerated system. This circulation is easiest to establish through magic frequency windows where the channels of least resistance exist. This is the basic mechanism by means of which a living biological system is produced in and from the appropriate primeval amino acid soup in the presence of (a) magic-window induction (such as in the ultraviolet), (b) the acceleration of otherwise inert particles (such as is locally provided by lightning discharges), and (c) the strong collection of bioenergy to orthorotate it through three rotations (as is also provided by lightning discharges).

It is not accidental that life can be and has been created in the laboratory. This type of experiment, done by a team of strong psychics projecting intentional bioenergy forms, should be able to create specific forms of life. The same type of mechanism can occur inside the living body where it can induce psychomatic illness. A similar mechanism is probably responsible for the placebo effect, and possibly for the body's production of antibodies and the psychic modification of enzyme activity, psychic healing, etc.

JITTER OR DITHER MODULATES THE PRIMARY FLUX

In the continual, virtual, subquantum, orthorotational flux (crosstalk), rotating into and out of a fundamental mass particle, only those components that are coherent are additive, and only those that add to the quantum threshold and breach it become observable quantum change.

In a given observable quantum change consisting of such coherently adhered subquanta, time is produced by fission of the quantum of action. All remaining statistical subquanta which have not collected to the threshold level are virtual subquanta of action possessing unfissioned, unseparated time. These virtual subquanta, which themselves are dynamic and gradually collecting and superposing to various degrees and at various rates, are attached to and exist in the dT interval produced by fission of the action quantum. Thus each and every piece of time contains dynamic, nested, virtual subquanta. Time in observable changes may thus be said to possess an internal dynamic structure filled with such virtual subquantum mental, neutrino, and photonic entities.

At any fission time, the degree of superposition of each of these nested entities is highly variable and depends on the whole past collection history, which in turn depends on all flux components of the proper frequency that have been arriving from all the orthoframes.

Thus virtual-mental entities cohere frequency wise until they breach the quantum threshold and discharge into observable quantum change. It is much like the accumulation of a static charge until sufficient potential is reached and a spark occurs, discharging the accumulation of charge. The same sort of relationship exists between virtual-mental state and observable state. The only difference is that virtual-mental state accumulates by frequency or time phase.

Since present physics is entirely localized, local observations cannot have taken into account distant matching-frequency events in the laboratory frame, or matching-frequency events in orthogonal frames. To the localized particle of mass, the precise moment a particular subquantum superposition of given frequency will superpose to the threshold and turn into quantum change is therefore not predictable. Since the remote causes cannot be accounted for, the local effects cannot be time-ordered.

Therefore at the quantum level, the physical change is totally statistical to a monocular observer. This accounts for the fact that the quantum world is statistical rather than causal.

However, a given fundamental mass particle has a structure of physical aspects, e.g., mass, spin, locality, frequency spectrum, switch rate, strangeness, etc. All of these may be expressible in terms of orthorotational concepts, although not all of them have yet been so worked out. Muses has already pointed out that some of the present quantum numbers are actually hypernumbers. And just as $\sqrt{-1}$, the first hypernumber, is an orthogonal rotation, so are the other hypernumbers.

At any rate, one may regard a fundamental particle as simply a complicated three-space tuning pattern existing in the orthorotational crosstalk flux between orthoframes. This pattern may also be said to consist of sets of frequencies, since each orthorotational flux line has a frequency of in-out-operation. Thus each fundamental particle is a set of tuning frequencies in the flux. A stable particle is a stable spectrum comprised of standing waves. An unstable particle is an unstable set, comprised of some standing waves, which account for the duration, and some not-quite-standing waves, which account for the excited state or degree of instability of the object.

On each flux line, orthorotational flux lines exist, constituting jitter or dither. Also, every fundamental particle is a tuning. It both tunes and is the result of its tuning, i.e., by the fourth law of logic it does what it is and it is what it does. Since tuning allows frequency communication between orthoworlds, then free-energy devices are not only possible but are practical. So are dematerialization-materialization devices, teleportation devices, devices that heal or kill, and anticancer devices.

THE UNTOLD STORY OF QUARKS

We hear so much nonsense about the objectivity of science that it occasionally seems necessary to debunk the sacred cow. In fact, the quark story is a prime example.

In 1910, Millikan made his famous oil drop experiment and determined the charge-to-mass (e/m) ratio of the electron. By multiplying this ratio by the mass of the electron, the amount of charge on the electron might be computed. Thus was born the idea of a constant amount or quantum of electricity, the fixed charge on an electron. Millikan received the Nobel prize for this famous experiment.

Actually, Millikan himself did not originate the experiment. One of his brilliant graduate students, Harvey Fletcher, first conceived the idea. Millikan became interested after he saw what a stir the results were creating, and he accepted the Nobel prize without sharing the credit with his brilliant student. Later Dr. Harvey Fletcher was to become the head of Bell Telephone Laboratories and an eminent managerial scientist in his own right. He also is the father of Dr. James Fletcher, former Chief Administrator of NASA.

Incidentally, Dr. Harvey Fletcher is still alive and alert, should anyone care to check the story! Nonetheless, it is highly doubtful that this grave injustice to Dr. Harvey Fletcher will be corrected.

But the story does not end there. In the late 1930's, a German physicist named Ehrenhaft decided to change the Millikan experiment and use charged solid particles rather than charged liquid oil drops. In fact he used red selenium spheres of various sizes. Amazingly, he discovered that he could isolate and measure fractional charges (quarks) at will, and he could even control the magnitude of the fractional charge isolated on a selenium sphere by varying the diameter of the sphere itself.

His work was duly published in scientific journals, and duly greeted with derision and hostility. Ehrenhaft himself disappeared during World War II. And there the matter lay. Dogmatic scientists continued to blindly teach the indivisibility of the electric charge, Millikan retained his exalted position and Ehrenhaft's work passed into comfortable obscurity. And in sophomore physics laboratories all across the nation, the indivisible quantum of electricity held full sway, dutifully proved over and over by the oil drop experiment.

Then in the 1960's, the particle physicists, despairing because of the bewildering new array of fundamental particles that continued to pour in confusion from their massive high energy machines, turned again to the idea of fractional charge (quarks) to try to make some unifying sense of the embarrassing abundance of strange new particles. By choosing three simple quarks, they could unify the theory of almost all the new particles. (Additional quarks have become necessary in the theory since then.)

So physicists gradually began to look for quarks, but in the giant, sophisticated, cumbersome experiments and devices that were yielding all the strange particles, not in the simpleton's approach that Ehrenhaft had taken. And they could not find them! Try as they would, a quark just refused to leave its tell-tale track. But in desperation they kept looking, and kept missing them.

Then in 1972 a convention of physicists was held at the International Center for Theoretical Physics in Trieste, Italy. Seven Nobel Prizewinners in physics attended the convention, whose theme was the physicist's conception of nature. Paul Dirac, the Nobel prizewinner who had theoretically predicted the positron before its discovery, gave the keynote address to the distinguished gathering.

Amazingly, Dirac presented the work of Ehrenhaft to the startled convention! He showed some of Ehrenhaft's data, and then pointed out that Millikan had also reported a single measurement of fractional charge, but had discarded it from consideration because he felt it was probably an experimental error. Dirac remarked that it all made him wonder whether Millikan might really have had a quark in that single discarded measurement.

The die was cast, and the seed finally planted. In 1977, about forty years after Ehrenhaft first obtained his quarks, someone finally got around to using solid paniculate matter. Researchers at Stanford University tried it out using niobium, and they got a little fractional charge on their niobium. So after forty years, Ehrenhaft, who had so long been ridiculed and ignored, was finally vindicated. It had taken the establishment that long to check his work instead of dogmatically rejecting it. Yet in none of the articles I have seen on the new discovery has there been a single word about Ehrenhaft, or of Dirac's presentation of his work at Trieste.

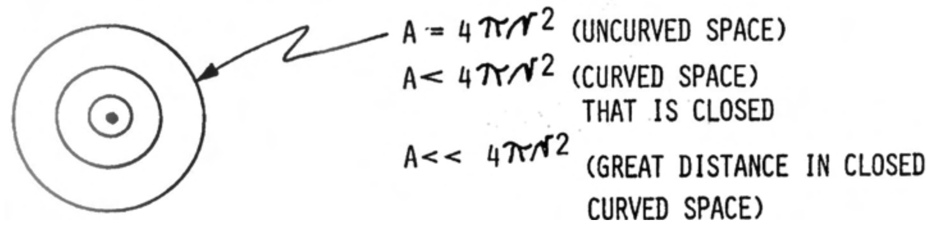
$A = 4\pi r^2$ (UNCURVED SPACE)
$A < 4\pi r^2$ (CURVED SPACE) THAT IS CLOSED
$A << 4\pi r^2$ (GREAT DISTANCE IN CLOSED CURVED SPACE)

Fig. 16. Einstein's spherical model of the cosmos

EINSTEIN'S SPHERICAL MODEL OF THE COSMOS

Einstein's spherical model of the cosmos is a primary example of a holographic universe. In such a closed spacetime, each point inside the universe is also at the extreme end of the universe in any direction. Thus the entire physical universe is totally outside any of its internal points, and totally inside each internal point as well.

That is an application of the fourth law of logic. The total internal is identical to the total external. The adjective "total" merely moves one to the common boundary between the operational concepts of "internal" and "external." At that boundary, there is no operational distinction between one and the other.

The universe closure is not limited to just one occurrence or one rate of closure. In fact the universe can then proceed to close again within the same local three-space, e.g., a gradual macroscopic closure due to gravity field (or causing it) constitutes the external universe, and a second extremely sharp microscopic closure due to electric field (or causing it!) constitutes electric charge. The two together constitute a fundamental charged particle of mass. The polarity of charge is determined merely by which of two directions the second closure was made in. Considering an electron as such a dually closed entity, it is readily seen that the closure ratios are all that is being referred to by Feynman's condition. Feyman pointed out that any unified field theory must explain why the ratio of the radii of the Einstein closed universe and the classical electron, and the ratio of the electrical and gravitational forces between two electrons, were the same — on the order of 10^{42}. The model is also consistent with Santilli's proof that the electric field and the gravitational field are either the same thing or partially the same thing. In our model, an electric field is in fact a highly compressed gravitational field. Proper time synchronization should allow fantastic antigravity effects to be realized, and thus electrogravitics has a basis in this model.

A CHARGED PARTICLE IS A DUAL CLOSURE OF THE UNIVERSE

It is proposed that each fundamental particle having electric charge represents a dual closure of the entire physical universe. The gravitational field closure is slow and weak, and it is that closure which results in the so-called external physical universe.

It is proposed that all particles participate in this same closure, since it is their combined distributed mass that represents or causes the closure. (By the fourth law, "represents" and "causes" become simultaneous at the boundary, i.e., when closure is accomplished.)

There are two directions possible for this gravitational closure: one where gravitational masses appear to attract, and one where gravitational masses appear to repel. These two directions thus form antimatter closures with respect to each other. The G closure where G masses attract is said to be the closure associated with a positive time dimension, while the G closure where G masses repel is said to be the closure associated with a negative time dimension. The direction of closure represents or causes the time dimension's algebraic sign, and vice versa (fourth law).

The electric field (E) closure is strong and fast — on the order of 10^{42} times as strong and fast as the G closure. However, its closure is in a direction orthogonal to the direction of the G closure. Since all matter is in motion, a slight deviation from exact orthogonality actually exists between the G and E closures due to crosstalk projection of components from the slight frame rotation involved in the velocity of each mass itself.

There are two primary orthogonal directions for the E closure. One direction yields positive charge and the other yields negative charge, for the positive time closure. For the negative time closure, the directions are reversed.

Such a schema, or version of it, can be made consistent with Santilli's proof, Feynman's criterion, and the observed fact that electricity can affect gravity and vice versa (electrogravitics). In fact, the electric field becomes a highly compressed gravitational field, at nearly 90° from the normal gravitational field. Liberating the compressed gravity in a flashlight battery could accomplish fantastic antigravity effects. Ironically, antigravity should be the simplest and cheapest effect ever dreamed of, once practical mechanisms for orthoshifting E field to G field are discovered.

Since psychotronics and quarks involve more fundamental components of electromagnetic field, hyperfields or biofields, psychotronic devices to yield antigravity should be quite feasible. The undisclosed extensions to Pavlita's psychotronic generators are thus of absolutely fundamental importance.

Furthermore, the ancients appear to have possessed psychotronic devices. Considering that metals, crystals, and other common materials can be used to. construct psychotronic generators, and great power is attainable by the hyperchannel amplifier effect, it is quite possible that priests of several ancient civilizations actually possessed psychotronic devices to lift giant stones by antigravity, and other psychotronic devices to carve the stones like jelly. They may also have possessed psychotronic flying machines which used antigravity for lift and something like rocket propulsion for horizontal thrust. A flying machine that gets its lift from antigravity might be extremely crude in external appearance, and the use of hyperspace for travel would make it unneccessary to travel extensively through ordinary three-dimensional space. Thus many aspects of travel through normal space such as air drag and fineness ratio are of little importance to a psychotronic vehicle.

ADDING AND SUBTRACTING DIMENSIONS

Figure 17 shows the relation between total collection (integration) and orthogonal rotation in hyperspace.

Total collection (integration) constitutes orthogonal rotation in a direction to increase the number of dimensions by one

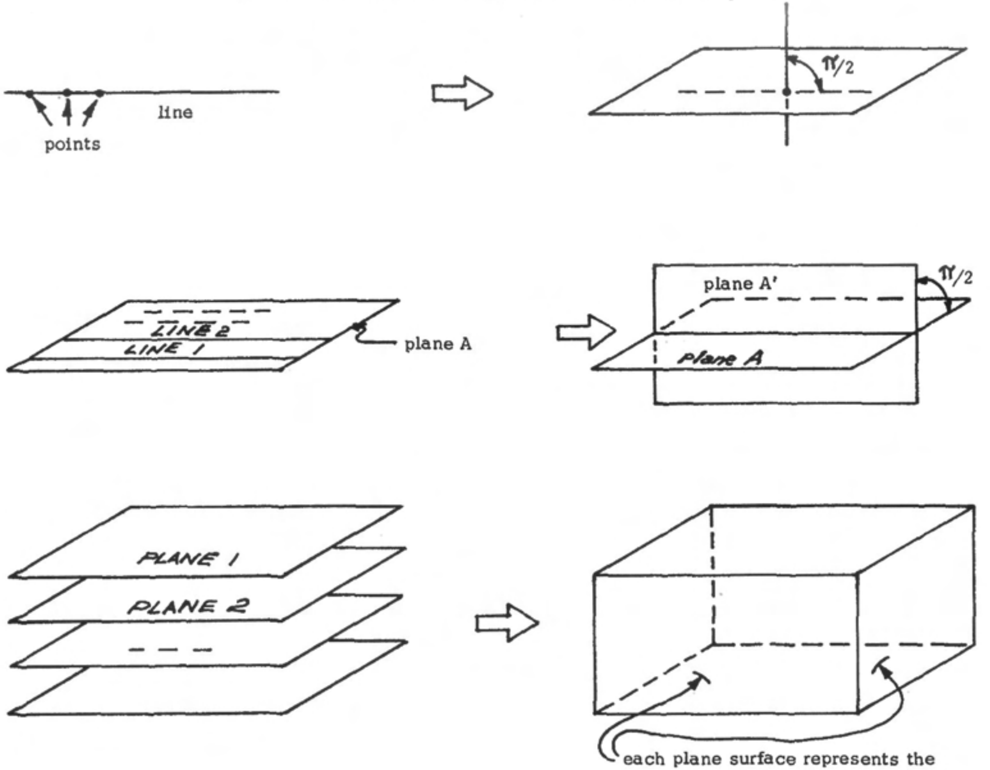
line
points
π/2
LINE 2
LINE 1
plane A
plane A'
π/2
plane A
PLANE 1
PLANE 2

each plane surface represents the intersection, in the observer's 3-D frame, of this 3-D solid rotated into an orthogonal frame in hyperspace.

Fig. 17. Adding and subtracting dimensions

Total collection of zero-dimensional points in one direction integrates the points into a line (one-dimensional entity). This is precisely the same as if any of the points had been the plane intersection of an orthogonal line, and that line had now been rotated into the plane. Total collection in one direction is dimensional integration, and the collected entities gain an additional dimension, i.e., total collection constitues orthogonal rotation of the higher dimensioned object into observer three-space.

A point can be considered to be, and modeled as, a line in a frame one orthogonal turn away, and simultaneously as a plane two orthogonal turns away, and simultaneously as a solid (in fact, an entire three-dimensional physical world) three orthogonal rotations away. The latter may also be considered to be, and modeled as, a mind, or even as an infolded infinite set of minds. The concept does not stop at three dimensions, but proceeds into higher realms indefinitely. However, three dimensions plus an orthogonal time dimension are sufficient for our purposes.

A converse operation also exists. Differentiation consists of a cut in an object whereby one single element (of the collection the object represents), is separated and isolated, so that one dimension is lost. It is like a closure being opened at one element. This is the same as an orthogonal rotation of the entity (being differentiated) in a direction departing from observer three-space.

In the Figure, the lower two figures show the collection-is-integration schema for higher-dimensional figures. In the lower right figure, we cannot draw the three-dimensional object in its orthorotated position in four-space since we have only three spatial dimensions in the frame. Nonetheless, the additional dimensions exist and are simple to treat mathematically.

MIND IS OBJECTIVE

In time differentiating, mass loses the time dimension. Therefore we cannot see time with a mass perceiver, but we can see L^3 (spatial extension). But time is the only so-called objective dimension occupied or shared by mind. Therefore we also cannot normally perceive mind, because the plate (time) on which it was sitting is lost in the perception process.

Thus Descartes was both right and wrong. He was right in that monocular mind is not present in physical detection output, but wrong in believing mind and physical phenomena are totally separate. Time does not exist except with respect to between one L^3 perception and another, if L^3 is all that is outputted. Physical time is totally relative, totally mental, and exists only in memory. Mind is thus present in $L^3 T$ four-dimensional physical phenomena and is discretized along with time discreteness in the Heisenberg uncertainty relation $dEdt >= h/2*pi$.

In fact, we can even take the extreme view that time is mind. Because to establish a delta t, a former L^3 must be established and compared to a more recent L^3. The only place the former L^3 can rigorously be found is in memory. An event, once occurred, is in the past and is forever gone to the observer. Only in his memory can it be said to exist. But then so is the observation also of the most recent L^3. Thus, rigorously, observed phenomena may be said to exist only in memory, and there is only a past, never a present. Thus a full four-dimensional mind is inseparable from perceived physical phenomena, and mind is quantized along with quantum change in the physical world.

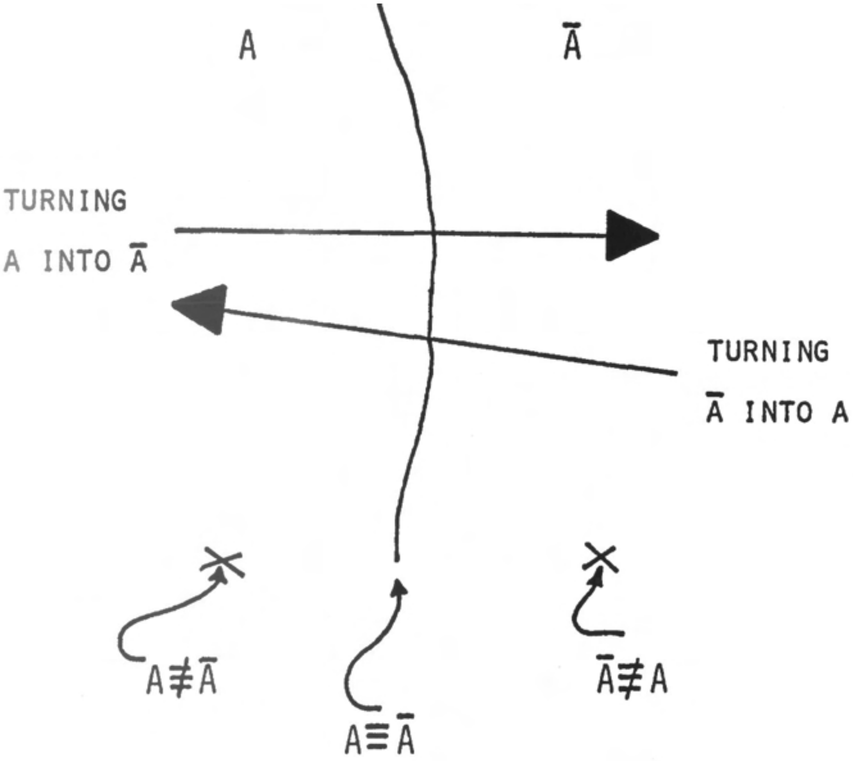
A
Ā
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A POWERFUL EXAMPLE:
CANTOR'S PROOF THAT THE SET OF ALL SETS IS NOT A SET

Fig. 18. Turning a thing into its opposite

THE SKIN TRANSDUCER EFFECT: TURNING A THING INTO ITS OPPOSITE

On the boundary interface, one type of field may be turned into another. The higher psychotronic field (biofields) may be turned into an electromagnetic field, and vice versa. The boundary interface serves as a transfer function mechanism for translating one kind of effect into another. Both ends of the transfer function are excitonically united in and on the interface.

The Soviet work that measured coherence of cyclic rhythms (heartbeat, breath, body electric fields, etc.) in Kulagina is significant in this respect. Kulagina induced electrostatic fields around objects that she moved psychokinetically. Her biofield, which is connected through hyperspace to the object being moved, is orthorotated into ordinary fields at the interface of the object. Thus an electric field is created, and also a momentum field that causes the object to move by ordinary physics.

The Soviet work appears to have established that man, earth, and cosmos are psychotronically and coherently linked; that the boundary of an object is a transducer coupling internal and external dynamic changes in one-to-one correspondence; that the transducer effect applies to both living and nonliving systems; and that through tuning and resonance, internal patterns can be incepted externally, and external patterns can be incepted internally.

EVERETT'S MANY-WORLDS INTERPRETATION OF QUANTUM MECHANICS

Both mind and matter can be precisely modeled in Everett's many-world interpretation of quantum mechanics.

Ordinary relativity is interpreted for only a single observer at a time. If you believe that you and I simply coexist at the same time, then the basis of physics is very different from what is in your physics book. Everett worked out what happens to physics if we insist on multiple observers at a time: all possibilities exist and are real, no matter how weird or far out; the world is a single giant universal wave function; collapse of the state vector has meaning only to a single observer; the world is composed of multiple orthogonal worlds of infinite variety, complexity, and strangeness; each world constantly splits into multiple worlds at a fantastic rate.

The many-worlds interpretation, though strange, is totally consistent with the experimental basis of physics. Most physicists have completely ignored Everett's profound and fundamental work; the MWI is a time bomb ticking away at the heart of physics.

SPACETIME CURVATURE IS TRICKY

Bent and rotated spaces give strange results. A thing in one frame can be something quite different in another frame. Just as the mass of a moving object does not increase with respect to its own inertial frame, it increases with respect to the observer's static frame.

What a thing is, is totally relative to the perceiver and his perceiving frame. It can even be nothing in a great many frames. Do you see how nothing can contain everything?

So we really can turn nothing into something if we are clever.

We can solve the energy crisis by building free energy devices which simply cohere the nonintersecting virtual-mental energy states and collect them, breaching the quantum threshold and yielding real, observable energy. To put it another way, we can tap zero-point energy.

And we can also turn a thought-object into a real, materialized object in this physical frame. Or we can dematerialize a physical object, converting it to a mental object.

MULTIPLE REALITIES (MANY WORLDS)

In Figure 16,1 show the particular selection of dimensions I take from Everett's many-worlds interpretation of quantum mechanics. Other and more complex selections can be taken, but these suffice for our purposes and allow us to complete the basic schema for connecting physics and metaphysics in the simplest possible manner. The selection and the schema developed thus provides an initial crude theory which makes predictions, develops theoretical mechanisms, and can be physically tested.

In the diagram, each three-dimensional physical frame of an infinite set at orthogonal angles to each other is shown by a single line about the plane of the bottom, much like the spokes of a wheel. The single time dimension shared by every one of the spokes or three-dimensional worlds is shown by a single vertical line, much like the axle for the wheel and its spokes.

Starting with the left spoke and going counterclockwise, the spoke worlds are numbered with the prime superscript system. The *S* world is the normal three-space physical world we all live in and detect; the S^1 world is the first orthogonal world, etc. Each world is also called a hyperspace or bioframe or bioworld and numbered consecutively beginning with zero for the *S* frame. Thus the zero-th hyperspace is the ordinary physical universe.

The first hyperspace is the electromagnetic field. A physical object in this frame is seen as an electromagnetic field to the *S* frame observer. Since its intersection with the S frame is two-dimensional, we immediately see that the electromagnetic field is a plane wave. Light thus travels at speed *c* to every observer in the *S* frame, because *c* is or represents an orthogonal rotation.

Further than the first frame, a three-dimensional object is seen by the S-frame observer as a deBroglie wave. Since its rotation is greater than 90° with respect to the S-frame, the deBroglie wave always moves faster than the speed of light with respect to the S-frame observer.

A three-dimensional object in the S^2 frame is seen by the S-frame observer as a line or force vector, i.e., simply as flux. (Tentatively, this frame appears to be the area of neutrinos.)

A three-dimensional object in the S^3 frame is seen by the S-frame observer as a spatial point, i.e., as spatially dimensionless. It is thus a mental object or a virtual object to the *S* observer.

The entire S^3 frame constitutes a mind or a virtual world. There are an infinite number of such S^3 frames available in hyperspace. In fact, there exists a set of three orthogonal turns between any frame higher than S^3 and the S frame, due to the nature of hyperspace. Thus in the model we are using, any of the higher bioframes may be considered to be only three orthogonal rotations away from the *S* frame.

We thus have a scheme of multiple worlds and multiple realities from which we may construct living systems, thoughts, tulpas, etc. And we may also turn one type of field into another, simply by virtual state collection or separation, as the case may be.

All frames S^3 or higher are mental or virtual frames. Physical phenomena in these frames are mental phenomena with respect to the *S* frame.

Note that we have deliberately evoked a system whereby a mind is modeled in terms of physics and physical reality is modeled in terms of mind. The only difference between any two entities in the various worlds is a matter of orthogonal rotation.

For the pure mathematician, obviously this entire model could be extracted into a new calculus. A symbol could be assigned to the orthorotation operation, and a sign assigned to the symbol to indicate whether the direction of turning is approaching the observer or departing from the observer. Sideways turns and in-betweenwards-turns could be represented by additional signs, or hypernumbers. I suspect that such a calculus is well worth doing, and I also suspect that it will closely resemble Charles Muses's hypernumber work when done. Using a six-dimensional geometry, the German physicist Heim has accomplished something similar, without yet realizing that he has also modeled mind. His work generates all the fundamental particles of physics and explains many features of UFO phenomena, as is to be expected from the scheme developed here.

At any rate, an exact calculus of higher dimensions and of turning one kind of field into another kind of field — with no barrier at all between physics and metaphysics — awaits the hands of the builder.

CLUSTERED ORTHOGONAL WORLDS

In this diagram, I show a sample of how various objects appear in their intersections with various bioframes. Note that an object is many things at once, and that many of the things it is are nonthings or nothings.

Everything is a thought in at least one frame. We can appreciate James Jeans's remark that the world appears less and less like a mechanism and more and more like a single thought. His intuition was in fact literally correct.

Each entity is a photon in at least one frame (let there be light!) Each entity is a line in at least one frame. Each entity is a three-dimensional spatial object in at least one frame.

By orthogonal rotation, a thing can change its face with respect to an observer, appearing to change into a totally different sort of thing with respect to a fixed observer in one frame. Reality is quite plastic and absolutely unlimited. It is only our own rigid heads that have been made of solid concrete.

Specifically, materialization of thought objects, by three approaching orthogonal rotations, exists. Similarly, dematerialization of an object, by three receding orthogonal rotations, exists. In such a case the dematerialized object appears the same as a thought object or virtual object.

A perfectly valid mechanism thus exists for tulpoids, materialized thought forms. All that is needed is a sufficient virtual state collection mechanism.

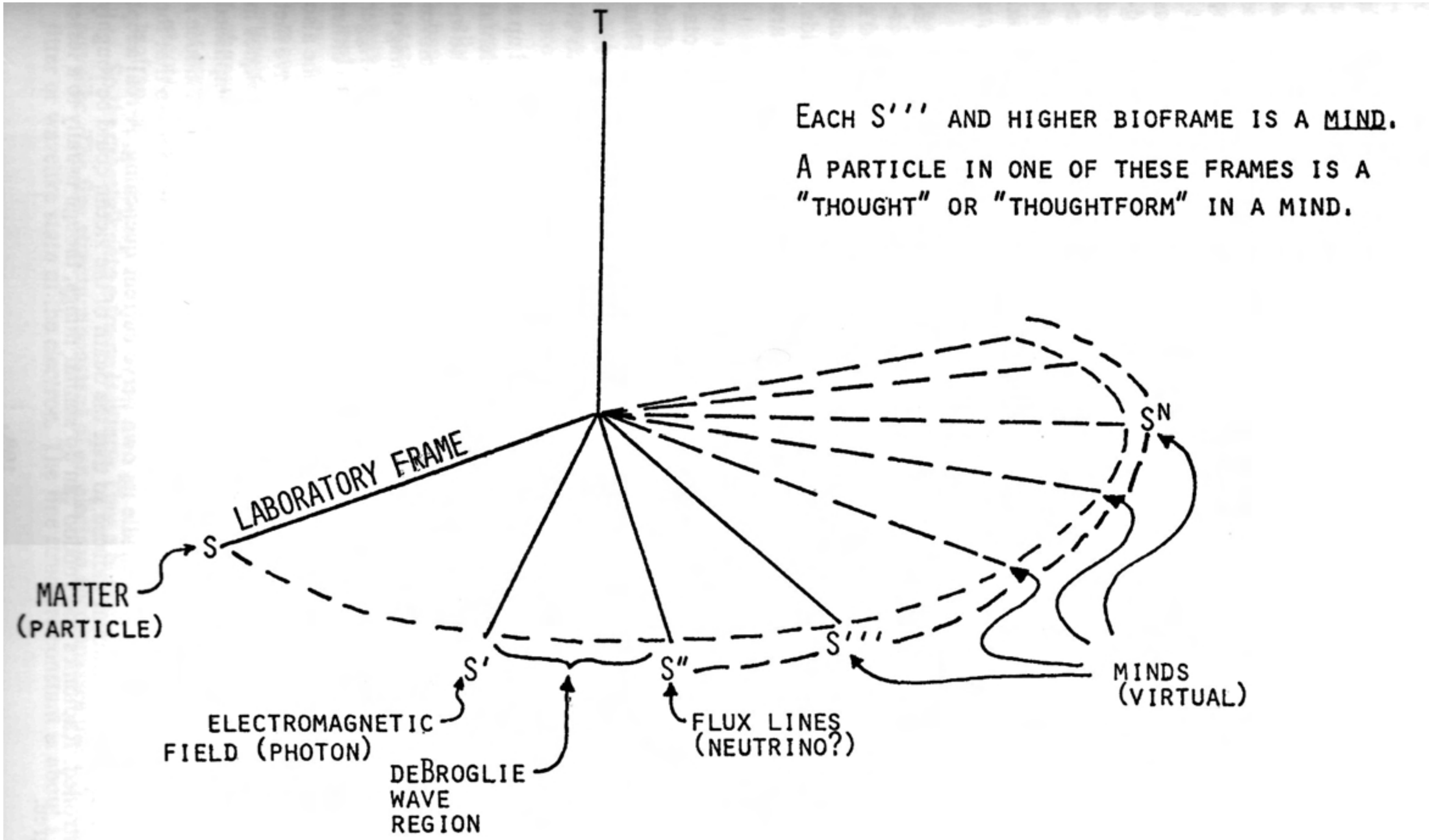
T
EACH S''' AND HIGHER BIOFRAME IS A MIND.
A PARTICLE IN ONE OF THESE FRAMES IS A "THOUGHT" OR "THOUGHTFORM" IN A MIND.
LABORATORY FRAME
S
MATTER (PARTICLE)
S'
S"
S'''
S^N
ELECTROMAGNETIC FIELD (PHOTON)
DEBROGLIE WAVE REGION
FLUX LINES (NEUTRINO?)
MINDS (VIRTUAL)

Fig. 20. Clustered orthogonal worlds

Note that an orthogonal rotation in an approaching manner is automatically accomplished by sufficient coherent collection in the remote frame. There is a finite collection threshold between two orthogonal hyperframes. Sufficient collection in one frame (by a tuning or directing mechanism in a third frame) breaches the threshold in the collection frame and the collected or quantized entity automatically appears in the next frame closer to the tuning mechanism's frame. The process may then be repeated. If sufficiently repeated, all the intervening thresholds are breached and full materialization of the object in the observer's frame (tuning frame) occurs.

By this process an object may be kindled from a remote frame to one that is less remote. Two successive applications of kindling turns thought into electromagnetic field. This is how thought photography is accomplished, and the talented individual who accomplishes it is simply cyborged to the camera film grain in an inceptive cyborg device. Many such examples, including some deliberately accomplished on demand by the study group in which I am included, are given in this book. Three successive kindlings turn a thought object into a materialized object, a tulpoid.

Such a materialized thought-object may be of an inert object or of a living, breathing, biological being. The model we are working in has eliminated any superficial difference between living and nonliving because it is a four-law model. And a materialized living being will be just as real and physical and functional as any other person on this earth. Ultimately, that is all that we ourselves are — tulpoids. Nothing exists but the thought of the infinite creator, so to speak, and we are simply part of that thought.

The coherence in multiple stages necessary to accomplish kindling is often referred to as *tuning* in this book. Tuning sufficient to enable two orthogonal rotations results in thought turning into electromagnetic field or light. Such a kindled field may be additive or subtractive to existing electromagnetic fields. Thus kindling can cancel an electromagnetic field that already exists, or it can create one where none previously existed, or it can shape, modulate, or change one which already exists.

Kindling can also wipe out the charge on a charged particle, or it can build up a charge on an object which previously had no electric charge. It is not accidental that Kulagina, when performing psychokinesis in the laboratory, first causes the induction of an electrostatic field on a nonmoving object. Then the object moves psychokinetically. In a similar fashion, she has stopped a frog's heart; kindling of the type to quench electric charge would of course eliminate the electrical trigger signals in the muscles of the heart, rendering it inoperable. This could mean either cessation and paralysis in a moderate case or total death in a drastic case. She also on one occasion demonstrated the ability to stop a living human heart. I have met other people who could do something similar. One of the great secret techniques in certain Oriental martial arts was the death touch. This could only be accomplished by certain rare adepts; with a light touch of the hand or fingers, they could induce a charge of bioenergy into and onto the acupuncture system of the body, so that the body itself began to slowly kindle its own nerve current quenching. A real adept could control the amount induced so that the death of the victim could be roughly controlled. Radionics and voodoo can do similar things, though usually to a lesser degree.

There also exists a precise mechanism for metal bending; the destruction of the charged particles (for the protons in the nucleus and the electrons in orbit, or even for just the protons in the nucleus) converts the particles in some atoms to neutrinos, which then vanish in the distance without interaction. Thus localized areas in strong metal can be kindled and made quite plastic from thought energy alone by one who has developed this skill. And the kindled areas will give every indication of having been subjected to extreme heat or unusual forces of a sort not encountered in normal metal bending or fracture. Also, the inceptor who is bending the metal and the metal itself are cyborged together into a single inceptive cyborg mechanism. Therefore the metal will often continue to bend even after laid down, because in the cyborg kindling is still occurring.

Furthermore, metals that exhibit unusual physical characteristics, such as nitinol, can change those characteristics dramatically by kindling. Also, an electrostatic field can be directly kindled in and induced on an external object, and an electric field or electromagnetic field can be induced in its surrounding space to interact with it, accomplishing psychokinesis of the object.

Or thought energy can be kindled in the hyperfield fluxes of an ordinary magnet. A magnetic compass needle can be moved by mind or a magnetometer can be affected, even through a superconductive Farraday shield. After all, the effect is rotating into our three-dimensional space from outside it, so shielding is of little consequence except where it interferes with tuning.

CROSSTALK BETWEEN MULTIPLE REALITIES

In Figure 21, I show that phenomena in all the hyperframes crosstalk. A moving object in frame *S* possesses a slight rotation, hence it projects a tiny component into frame S^1. This S^1 component, however, is still dynamic and has a small velocity in S^1. Hence it also is slightly rotated and therefore has a crosstalk component projected into frame S^2 with a velocity there. Having finite velocity, this projection in turn has a rotation and projects into the next higher frame, and so on.

Thus any changing entity in any frame crosstalks a tiny amount into any other frame. In a frame S^n, the crosstalk from a change in any other frame S^P is normally so small as to be virtual, hence nonobservable. Coherent virtual crosstalk, however, integrates and can breach the threshold between virtual and observable state. It is in fact possible to show that what we call a mass in S space is simply the sum total of the crosstalk in and out of a localized region L^3 of S space, the localized region being the mass in question.

Another point to notice is that most fundamental particles in a frame rarely move with constant velocity. Instead, they normally accelerate and decelerate continually. Thus the actual velocity vector of one of these entities is continually changing, usually quite erratically. But for microscopic particles in regular atomic or crystalline formations, the change pattern is quite regular. At any rate, the constant changes on the velocity induce a jitter component on its crosstalk into other biframes.

So the crosstalk into a frame is jittery. Thus a fundamental particle is jittery or wavelike. The fine structure constant of an electron encompasses this hyperspatial jitter or wavelike state of the electron. The fine structure constant is about 1/137.

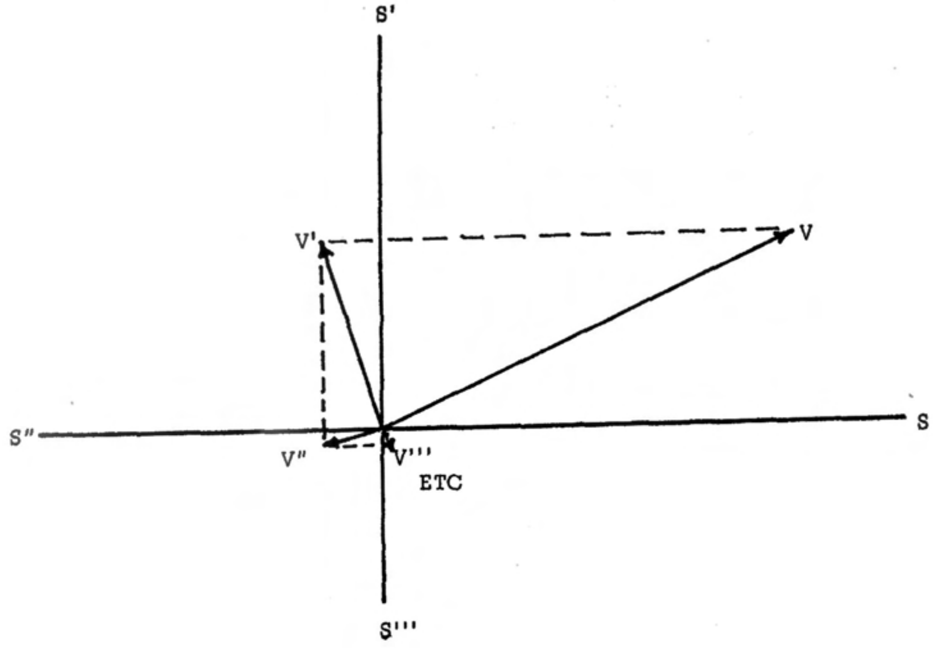

Pig. 21. Crosstalk between multiple realities

Thus an electron actually spends about 1/137 of the time in hyperspace.

So, because of jitter, an object is partially in every hyperframe a minute but finite part of the time. So are all minds and mental objects, and so are all virtual objects. For a fundamental particle, the fraction of time that one quantum of action pervades another frame may be referred to as the identity coefficient.

The identity coefficient varies; it is the photon interaction that time differentiates, quenching time and separating the bioframes, and this interaction is not a linear operator since the intensity of time differentiation is a rather complicated function of photon frequency.

At any rate, for an electron in orbit in an atom (or for any other electron, for that matter) there is thus a small but finite probability that the electron may be at any given position in the universe when its detection occurs. In other words, there is a finite probability of collecting an electron at any point in the universe, and the collection may be made from multiple points simultaneously. We can actually collect the same electron twice, so to speak! Or even a million million times.

The probability of detection of an electron at a given position may be directly expressed as the fraction of time that the electron actually spends there. And this fact may be used to develop a holographic coherent collection scheme that can directly amplify particles. Thus a so-called free energy device, which in one sense is just a tap into the zero point energy of vacuum, can be built. And it has been built, by Moray and by others. The jitter and crosstalk make it directly possible.

BIOFIELDS: AND MAVERICK WORLDS

Figure 22 shows a convenient list of how objects appear in different frames. This schema, selected from Everett's many-worlds interpretation, allows modeling of life, death, mind, matter, and psi. It also allows one type of field to be ortho-

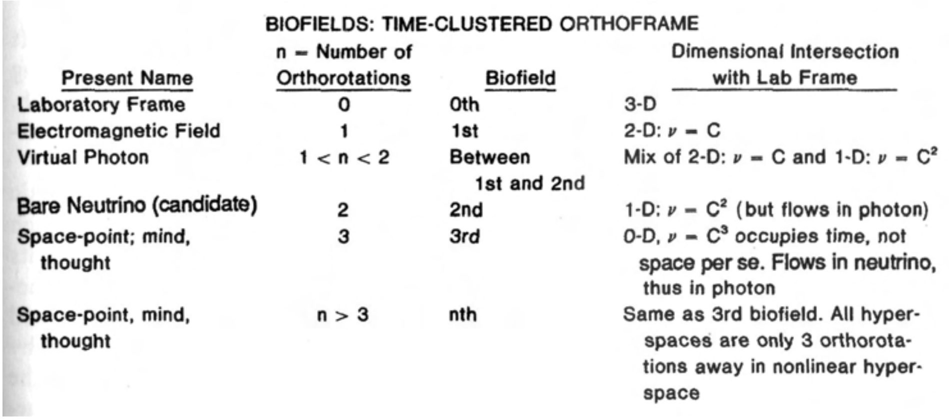

BIOFIELDS: TIME-CLUSTERED ORTHOFRAME

Present Name	n — Number of Orthorotations	Biofield	Dimensional Intersection with Lab Frame
Laboratory Frame	0	0th	3-D
Electromagnetic Field	1	1st	2-D: $\nu = C$
Virtual Photon	$1 < n < 2$	Between 1st and 2nd	Mix of 2-D: $\nu = C$ and 1-D: $\nu = C^2$
Bare Neutrino (candidate)	2	2nd	1-D: $\nu = C^2$ (but flows in photon)
Space-point; mind, thought	3	3rd	0-D, $\nu = C^3$ occupies time, not space per se. Flows in neutrino, thus in photon
Space-point, mind, thought	$n > 3$	nth	Same as 3rd biofield. All hyperspaces are only 3 orthorotations away in nonlinear hyperspace

Fig. 22. Biofields: time-clustered orthoframes

rotated and turned into another kind. Such orthorotation demands correct time synchronization, rather than brute force energy application. In fact, orthorotation is energy-conservative for a single orthogonal turn.

Even the strangest conceptions and most fantastic possibilities have their own assigned realm of concrete reality. These are referred to as maverick worlds.

Note that all possibilities — everything that has happened or could have happened, and everything that will happen or could happen — are real and exist concretely in their separate orthogonal universes. The same is true for all thoughts and thought worlds, and all possible thoughts and thought worlds.

By proper coherent tuning, an *object* in one of these orthoframes can be orthorotated into our own frame and objectified, and that is what the Tibetan monks call a tulpa, an objective materialization of a thought form. The tulpa will hardly ever be closed entirely in phase, however, and so it will almost always be unstable. UFO's, angels, and imps go away. But the materialization of one of these can be entirely objective and perfectly objective traces can be left, such as photographs, broken limbs, scorched asphalt, indentations, and depressions in grassy fields. Any thought object can be so orthorotated and objectified. Beings, religious figures, angels, fairies, imps, UFO's, and monsters can all appear.

HYPERFIELD FLUX IN A MAGNETIC FIELD

In the conventional experiment to determine the pattern of a magnetic field, iron filings are sprinkled about a bar magnet on a piece of paper. As shown in the top drawing of Figure 23, the iron filings form a symmetrical pattern. Further, the only apparent circulation pattern is from one pole to the other. Each flux line is closed, going through the magnet from one pole to the other and out of that other pole, bending back through space to the first pole. Every flux line therefore goes through both poles.

However, each little iron filing is actually quite static; it does not move at all. It does not change with respect to either time or position. It is therefore integrating any higher sinusoidal component that is changing with respect to time and length. The characteristics of the orthodox picture that emerges are prescribed by Maxwell's equations of electromagnetic field.

If we tape the bar magnet to the face of a color television tube, the magnetic field is now being scanned or probed or sampled by a moving electron beam, which reacts with the magnetic field of the bar magnet. This electron beam is changing its position with respect to time and length, and it therefore differentiates the magnetic field. The hyperspatial "ripples" in the magnetic field now are not integrated exactly to cancel, and so a small deviation from each flux line will be detected by the differentiating beam. Slight deviations will cause a color change, and so the hyperspatial flux now becomes evident on the television screen. The lower drawings show the rather unusual, nonsymmetrical pattern that emerges.

The equations for these hyperfield fluxes should be obtainable by differentiating Maxwell's equations twice more, yielding fourth order equations. These equations should be the much sought-after equations of prana, chi, ki, ectoplasm, bioenergy, bioplasma, odic force, etc.

Note that the hyperfield circulation goes into the north pole and pours out of the south pole. A living organism exposed to the north pole, end on, will have its own bioenergy sucked out by the magnet, and its own flux will diminish somewhat. Exposed to the south pole, end on, it will have its own bioenergy increased by the bioflux pouring from the magnet. This explains why many experimenters who have extensively tested the influence of magnetism on growing plants have found that the north pole inhibits and the south pole stimulates growth and health.

The hyperfields are fundamental fields rather than electromagnetic fields; they collect coherently and kindle *into* electromagnetic field, creating it or destroying it.

LIFE AND DEATH

In Figure 24 I present an overall schema for life and death — and for reincarnation as well.

An infinite number of hyperfields or bioframes are shown as S, S^1,S^2, S^3 etc. The frame S is the ordinary laboratory frame — the physical spatial world we live in and observe. The frame S^1 is the electromagnetic field, the frame S^2 the linear or flux frame, and S^3 the first "mental" or "virtual" frame. Also, all higher bioframes have a connective path to the *S* frame of only three orthogonal rotations (not shown). Thus only three orthogonal turns separate S^n and *S*, S^K and *S*, and S^J and *S*.

In frame *S*, note that physical body *A* has a coherent crosstalk link with the entire frame S^n. A-S^n thus constitutes a living biological system; in this case, let us say, a human being. Likewise, *B* and S^j have established a coherent crosstalk loop. B-S^j thus also constitutes a living biological system; in this case, let us say, an opossum. These two examples are incarnated living systems (incarnated minds).

In fact, this is a great oversimplification, as the reader will realize at once. We really should consider all the groupings of *A* — the organs, the structures, the cells, the internal cellular parts, etc. — as separate but coordinated a_i. (And similarly with B.) Each of these a_i must have a correspondent s^n subworld of S^n, much like

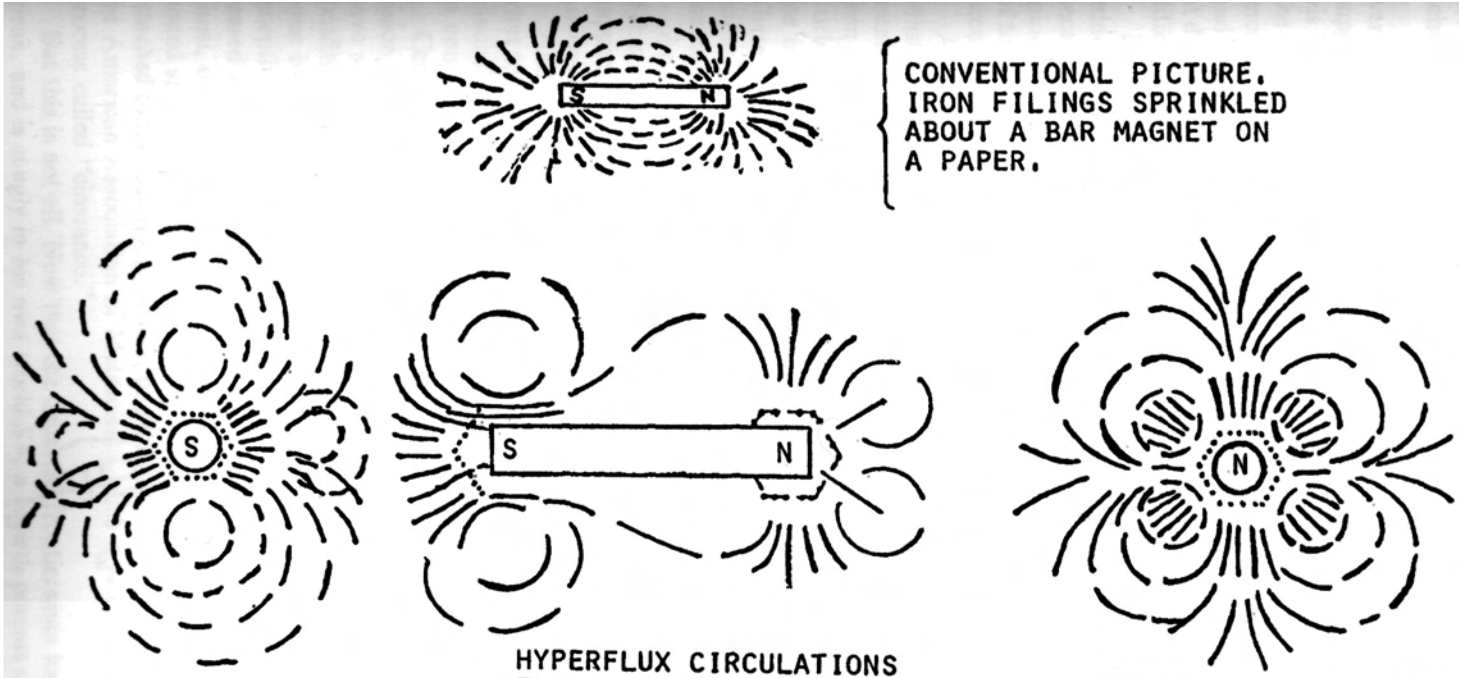

CONVENTIONAL PICTURE.
IRON FILINGS SPRINKLED
ABOUT A BAR MAGNET ON
A PAPER.

HYPERFLUX
CIRCULATIONS

NOTE STRONG
HEXAGONAL PATTERN
AND TWO PRIMARY
VORTICES

HYPERFLUX CIRCULATIONS
FLUX PATTERNS ARE NOT
SYMMETRICAL, POLE-TO-POLE

NOTE STRONG HEXAGONAL
PATTERN IMMEDIATELY
ADJACENT TO NORTH POLE.

HYPERFLUX CIRCULATIONS

NOTE STRONG
HEXAGONAL PATTERN
AND FOUR PRIMARY
VORTICES

Fig. 23. Hyperfield flux in a magnetic field

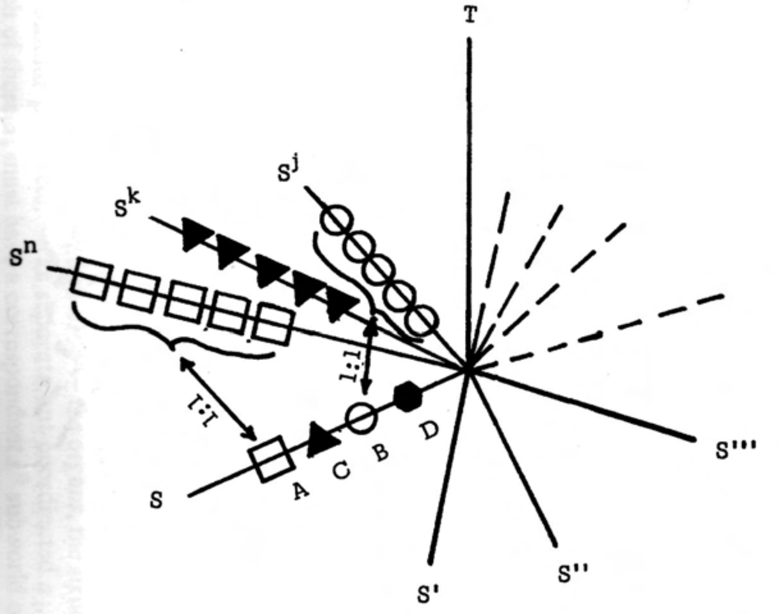

$A \rightleftarrows S^n$ is a living system.

A is the physical body, the incepted mass.

S^n is the mind.

$B \rightleftarrows S^j$ is also a living system.

To S, D is inert; i.e., D is not preferentially incepted.

To S, S^k is a "disembodied mind." I.e., S^k is "dead," since it is not preferentially incepting its former body, C.

Whenever a proper retuning body, say E, appears in S, S^k will reestablish a coherent crosstalk with E. This constitutes "reincarnation" of S^k.

Fig. 24. Life and death

the fine structure of atomic energy levels. But here I am simply outlining the major schema.

At any rate, let us now examine body *C* and hyperworld S^k, which formerly were one-to-one coherent in crosstalk, but are no longer so. C represents, let us suppose, the body of a frontiersman in 1830 who has received an Indian arrow in his breast, piercing the heart and destroying the ability of the body to coordinate the c_i to each other and to the inceptive channel from S^k. With the loss of coherence, noise begins to destroy the channel; thus S^k is now a "disembodied mind," and C starts to become a decaying corpse. The various c_i of course lose coherence at differing rates, and so the fine structure channels to the s^k also lose coherence at differing rates.

Finally all c_i - s^k coherence is lost, and the frontiersman is then "dead." The mind S^k is now disembodied — and also probably quite disturbed or "noisy" because of the variance in disintegration of the c_i - s^k loops. One might say that the mind is somewhat "detuned" by the whole affair. However, "death," in the sense of total loss of mind and personality, has most certainly not occurred. All that has occurred is a lapse into a disembodied, and perhaps somewhat confused, state.

And the disembodied mind finds itself in its own deep, unconscious world constructs. If a person has been unconsciously Christian in a very deep, fundamentalist sense, and in his own mind has also been a "sinner deserving of hell," then he will actually "lift up his eyes in hell," in his own world tuning. And that world will be physical and real — as real and physical as this one — but it will operate by different physical laws, just as dreams operate by different physical laws. These relations and laws are prescribed by the person, either consciously or unconsciously. The devout Mohammedan is quite likely to find himself after "death" in the delightfully chauvinistic paradise he believes in.

And so the Catholic practice of praying oneself out of purgatory is relevant, for if that belief-structure is firmly fixed in the deceased's deep unconscious, then it will happen; he will simply change his world construct in accord with the effort made on his behalf.

And the ancient Tibetan practice of giving instructions to the deceased as to what to expect and where to go is also relevant, for during the time that the major channel C-S^k is lost but many of the c_i - s^k are still functioning, the deceased is still in contact with frame *S* and can heed those instructions.

Certain clairvoyants and skilled psychics can also project part of their mind vision into S^k and see the status of the deceased. In some cases the deceased will have so strongly retained mental structures analogous to physical structures and localities (or persons) in frame S that continual small crosstalk channels breach open by tuning resonance to those localities, structures, or persons. With a little inceptive assistance from one or more sensitive persons, an "appearance" of the deceased at the locality, structure, or near the person can take place. Much psychic, ghost, or spiritualist activity is due to this effect. So indeed is the concept of earthbound spirits. Here again, an advanced adept can erase the psychometric pattern attached to the locality, structure, or person and thus eliminate the phenomena. In the American Association of Metascience, such a resolution is part of an overall process called "clearance."

But this is not all. Now that the departed frontiersman has been cleared, so to speak, and is snugly in his own world S^k rebirth process still awaits him. As I

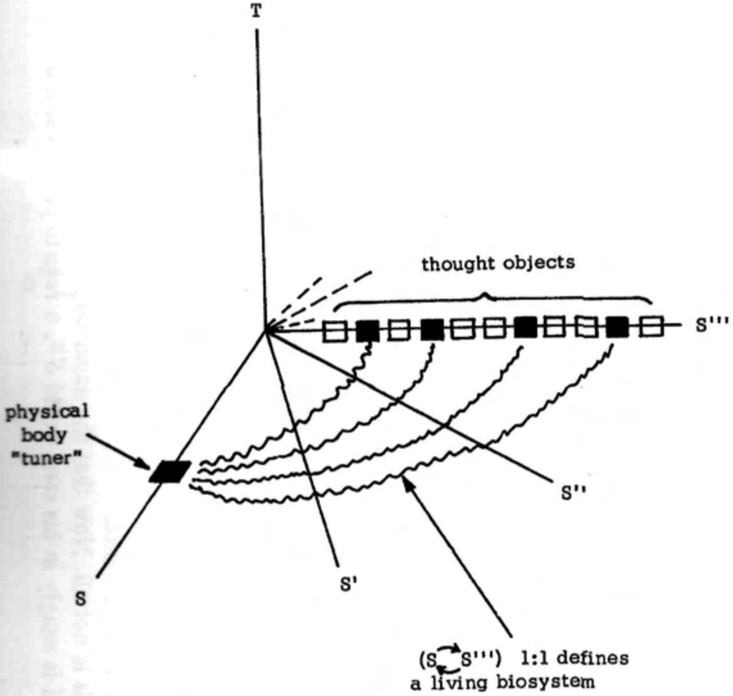
T
thought objects
S'''
physical body "tuner"
S''
S
S'
(S ⇄ S''') 1:1 defines a living biosystem

A. A LIVING BIOSYSTEM

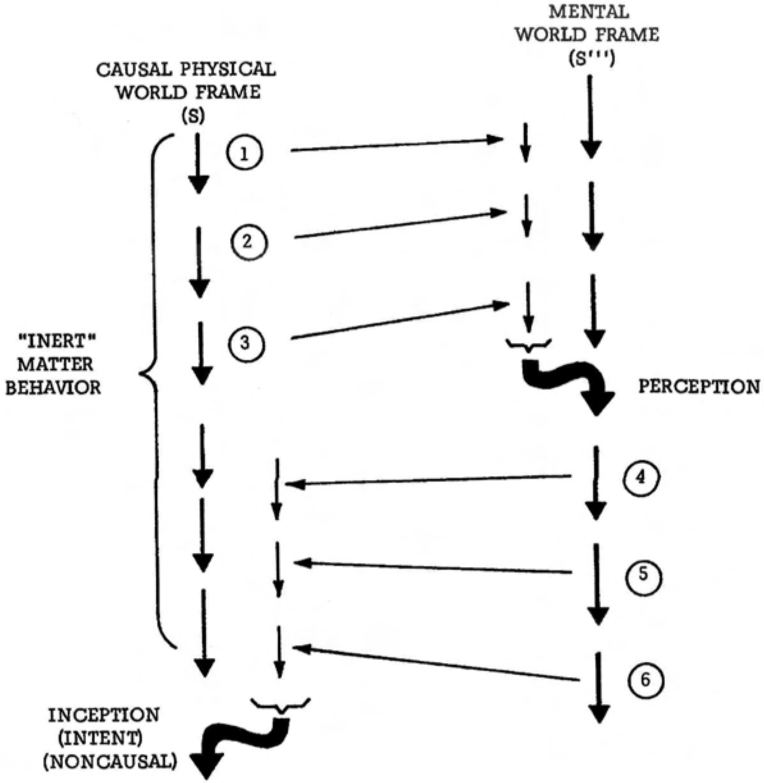
MENTAL WORLD FRAME (S''')
CAUSAL PHYSICAL WORLD FRAME (S)
①
②
③
"INERT" MATTER BEHAVIOR
PERCEPTION
④
⑤
⑥
INCEPTION (INTENT) (NONCAUSAL)

B. THE FUNCTIONING OF TIME AND CONSCIOUSNESS ARE MUTUAL CREATORS OF EACH OTHER.

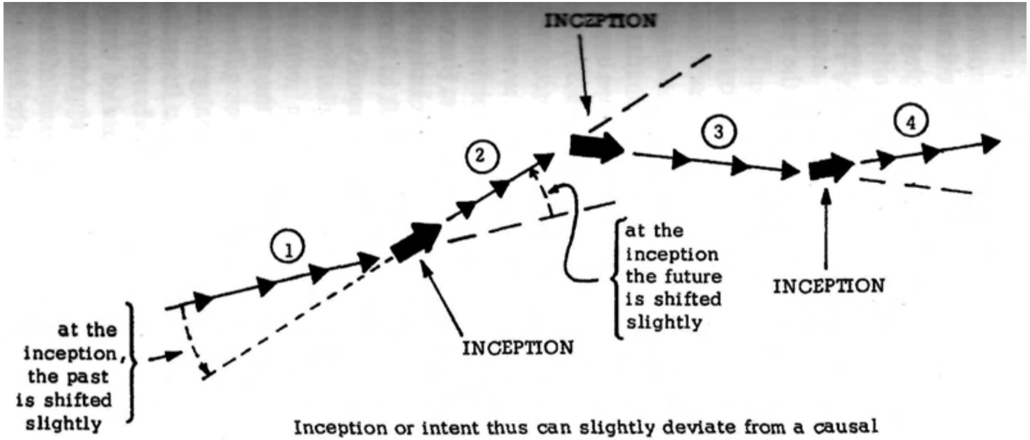
INCEPTION
(1)
(2)
(3)
(4)
at the inception, the past is shifted slightly
INCEPTION
at the inception the future is shifted slightly
INCEPTION

Inception or intent thus can slightly deviate from a causal trajectory. Over sufficient collections of physical changes, "intentional behavior" or "limited free will" emerges. However, it is only a very small modulation of causal inertness -- and its smallness accounts for human "physical limitations."

C. CHANGING THE PAST

Fig. 25. Consciousness, life, and intent

have pointed out elsewhere, every particle of mass is simply a pattern of change in the universal orthorotational flux between hyperframes. (This, after all, is no more than a slight extension to general relativity.) When the proper physical tuning mechanism, say C^1, again appears in the *S* frame, then a resonant coupling will automatically establish itself in the flux between C^1 and S^k, and the disembodied, confused mind of the frontiersman will simply be coupled again to a new physical body pattern. This happens at the instant of conception, for the genetic pattern — the complete tuning pattern — is present at that instant. The coupling is quite tenuous at first, and increases in degree as the embryo develops.

So reincarnation has a place in my schema. We will see, however, that it differs slightly from the classical concept, because with developmental work the frontiersman can change the makeup of S^k and thus his predisposed tuning. Changing the tuning also causes rotational displacement of S^k among the infinity of infinities of mind worlds available. Thus the past can be changed; in fact a person can change who he is the reincarnation of, simply by changing his mind tuning with enough development. Therefore more than one living person can be, for example, the reincarnation of Napoleon.

And in fact the cycle of rebirth can be broken completely — simply by dying with a totally detached mental framework. The cessation of all tuning attachment results in a broadened S^k, which now is structureless, hence all-structured and part of universal Godness.

But the major point is that all this can be modeled physically. And there is only life; absence from one place still leaves presence in another. Absence from *any* and *every* one place exclusively leaves presence at all places, each nonexclusively.

Death, where is thy sting?

In diagram A of Figure 25, I summarize what constitutes a living biosystem. Here we can see that body (physical) changes from the biosystem's body in frame S crosstalk successively through frame S^1 and S^2 to S^3. Also, physical changes in frame S^3 actually constitute mental changes to the biosystem's body back in frame *S*. These mental changes must crosstalk successively into frame S^2, frame S^1, and then into frame *S*. This entire process — from frame S^3 to S^2 to S^l to *S* — is referred to as *kindling.*

In diagram B, we observe this process a little more closely. Here, the shorter straight vertical arrows are virtual state changes kindled from the opposing frame. The longer straight vertical arrows represent observable quantized change in the particular frame, these changes being produced by ordinary inert physics laws. The curved double-lined arrows represent quantized change kindled into the frame from the coherently superposed virtual changes that have steadily been kindled there.

Thus there is a kindling time delay in the causal *S* frame before will or intent sets of changes from the mind-frame S^3 can induce an input into the physical body of the biosystem. Correspondingly, there is a kindling time delay before a perceptual change in S^3 from the changes in *S* can occur.

The horizontal arrows represent the flow or flux of kindling crosstalk between the two frames. It can be seen from this diagram that consciousness — the thread of the relation between consecutive changes in the two respective frames — and time are identical. (Recall that each inert physical change in S that is not kindled from S^3 is actually randomly kindled from all the other mind-frames.) Thus time and mind are identical. Consciousness is simply the functioning of coherent crosstalk between a mind frame and a physical body in frame *S.* Further, each biosystem's consciousness has all other consciousnesses interwoven with it. The other living consciousnesses input into other physical bodies in frame S, and these physical bodies interact in frame *S.* The other dead consciousnesses input into frame S - into each body as well as into all other inert matter — in a noncoherent, randomized manner. Thus the entire universe of universes is totally in communication with each part of itself, continually.

In diagram C, I show that incepting a change from pure causality changes the past; in this case, the past is causally inferred or projected backward from the new vectorial direction. However, because inception into frame *S* is a very small effect, the biosystem's change of its past is so slight that normally it is not noticed. Inception of course also changes the future slightly.

THE HOLOGRAPHIC HYPERCHANNEL EFFECT

This effect is based on the concept that a human being must accomplish a minute inception (psychokinesis) onto his physical system. Specifically, he must incept the movement of three or four electrons in the brain. This constitutes an input signal to his ordinary physical system, which is then treated like a complex servomechanism. The gain of this servomechanism is rather high, being able to transform or amplify the movement of several electrons into powerful movements of the entire body. The inceptive effect cannot be explained by ordinary physics, which can account for the servomechanism gain only. Once the input signal is generated, however, the rest of the amplification and action are viewed as being properly described by the ordinary physics of inert matter. Thus the human is viewed as largely servomechanistic and mechanical, but guided and directed by the nonphysical, which affects the physical in a minute fashion sufficient to constitute inputs to the ordinary physical system.

Our purpose here is to show that, given this single small inceptive effect, we can eventually approach the mastery of space and time for a linkage of sufficient number of human brains and minds into one single superbrain and supermind.

From the multiplicity of orthogonal frames permitted by Everett's many-worlds interpretation of quantum mechanics, we now select an infinite set of clustered three-dimensional spatial frames, which all share a single time dimension. Using one frame as a laboratory reference frame, the other spatial frames may be characterized as having one, two, three, or more orthogonal turns away from the laboratory frame. These succeeding orthogonal frames are variously called hyperframes, bioframes, orthoframes, hyperchannels, orthoworlds, etc. A particular set of material phenomena in one of the orthoframes is referred to as a biofield, hyperfields, or orthofield with respect to the laboratory frame.

In Figure 26 I represent each brain by a triangular symbol, and consider it as an amplifying device having a gain of A_o. For simplicity the inceptive input signal is represented as E_i, since in moving an electron, a voltage must be induced. For simplicity I also show the brains as a linear array lying in a straight line. The distance *L* separates each brain, and here *L* is assumed constant for simplicity.

Two factors must now be realized: (1) The first hyperchannel operates in the realm of the ordinary electromagnetic field, although this realm is seen in a differ-

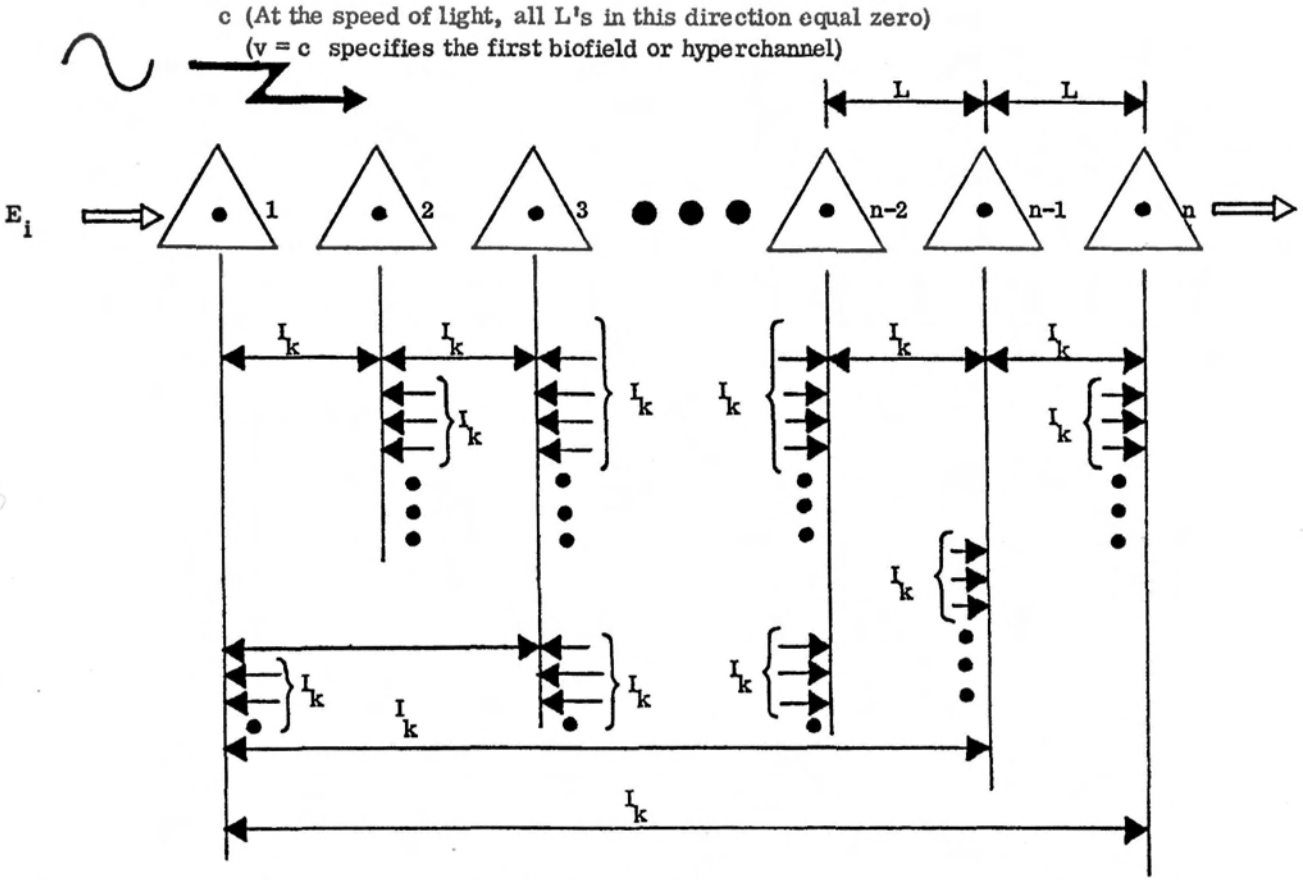
c (At the speed of light, all L's in this direction equal zero)
(v = c specifies the first biofield or hyperchannel)
L
L
E$_i$
1
2
3
n-2
n-1
n
I$_k$

Fig. 26. The holographic hyperchannel effect

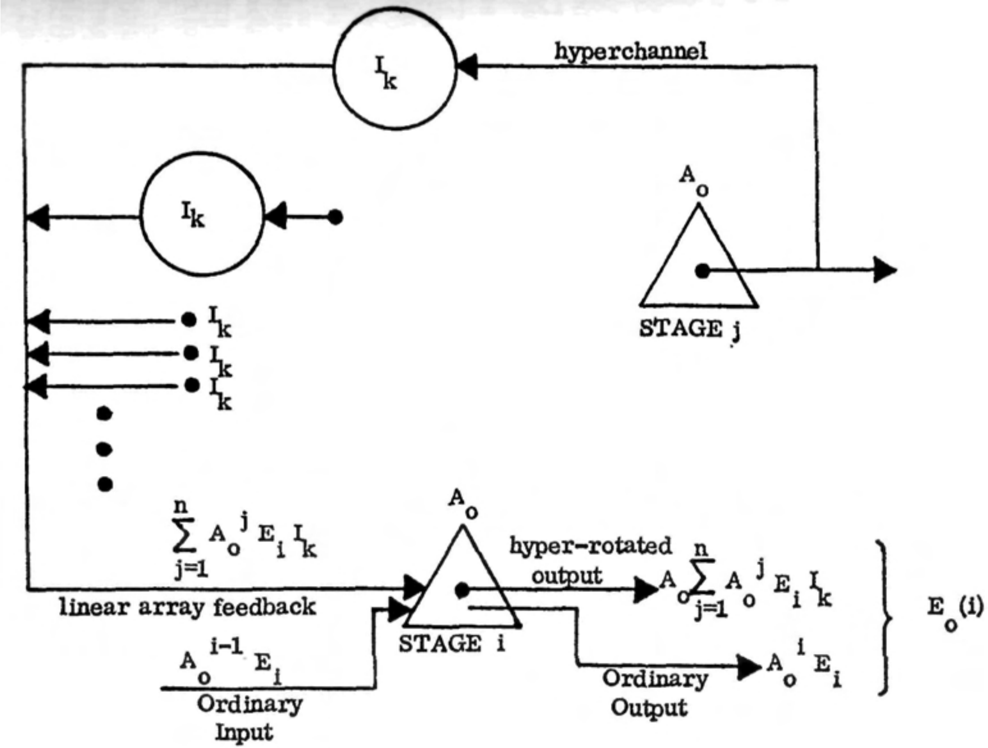
hyperchannel
I_k
I_k
A_o
STAGE j
I_k
I_k
I_k
$\sum_{j=1}^{n} A_o^j E_i I_k$
linear array feedback
A_o
STAGE i
hyper-rotated output
$A_o \sum_{j=1}^{n} A_o^j E_i I_k$
$E_o(i)$
$A_o^{i-1} E_i$
Ordinary Input
Ordinary Output
$A_o^i E_i$

Fig. 27. Output of stage i

ent way, i.e., we visualize a photon as an ordinary particle of three-dimensional matter, resting in a three-dimensional spatial frame (hyperframe) that is orthogonally rotated spatially in higher dimensional space, at 90° to the observer's spatial frame. The hyperframe and the laboratory frame share the same fourth dimension, time. (2) At the speed *c* (which determines the hyperframe in the first place), all *L's* are zeroed out, by the equations of the special relativity transformations. Thus one may view (hyperview) each triangle (brain) as superposed on each other triangle (brain). Furthermore, there exists a very small, finite, nonzero probability that the state of one triangle coincides exactly with the state of another superposed triangle, at any given small increment of time. This probability corresponds to a direct fraction of identity between two triangles, since time is stopped along the chain. At any given small increment of laboratory time, any given triangle has on the average a small fraction of identical coexistence with any other triangle. This identity fraction is labeled I_k in Figure 26.

It is important to note that, for a very small fraction of time, the triangles coincide with each other; i.e.; for a small fraction of time the existence of one triangle is totally holographic. This fraction totally violates the ordinary conservation of energy, which is applicable only to a single channel system. The hyperchannel represents a second channel, an identity channel, and in this channel an object can be in multiple places at the same time. If the triangles, regarded as operating processes, are even slightly coherent, then multichannel communication and holographic transmission of a single state-energy into multiple state-energies occurs through the hyperchannel — usually in the virtual state.

Figure 27 shows the setup to calculate the gain of the hyperchannel amplifier. These calculations yield, for the output of stage i,

$$\frac{E_0}{E_i} = A_0{}^{n} + A_0{}^{n+1} I_k.$$

When no ordinary electrical input exists, $A_0{}^{n} = 0$, and the virtual state amplification is thus

$$\frac{E_0}{E_i} = A_0{}^{n+1} I_k.$$

This mechanism holds the secret to the tapping of zero-point energy and free energy devices. It is also the hidden variable theory that causes a radioactive nucleus to decay. Since radioactive nuclei interact through hyperspace, the amount of radioactivity in a given sample is an exponential function of the number of radioactive nuclei present.

It is also a mechanism which can directly amplify the virtual-mental state into observable state. It is the fundamental mechanism that causes kindling and thus orthorotation. It can be used to materialize tulpas, and accomplish psychokinesis, remote viewing, clairvoyance, precognition, etc.

MIND LINKAGE

The entire human species has been developing and evolving, not just the individual person.

The development of life in a biosystem may be divided into seven stages: (1) the development of planet, primordial atmosphere and ocean; (2) the appearance of

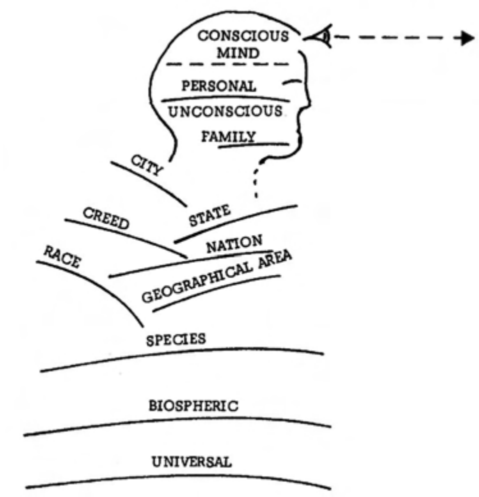

Fig. 28. Layers of unconsciousness

amino acids; (3) the appearance of the self-replicating supermolecules; (4) the formation of one-celled organisms; (5) the formation of multicellular organisms; (6) brain linkage of an intelligent technological species; (7) total omeganess or godhood.

Two major types of behavior are involved in living organisms: genetically programmed behavior and genetically unprogrammed behavior. Thus one mode of behavior control of an organism is nonadaptive and the other mode is adaptive or learned. Intelligence may be viewed as the ability to adapt behavior, and increased intelligence represents a decrease in the portion of behavioral control that is genetically programmed or "hard-wired."

We may further speak of two types of intelligent species: those that possess a tool-using member and those that do not. The first is a *technological* species, while the second is *nontechnological.* By this classification, man is a fifth-stage, technological species.

The intelligent species, being relatively deprogrammed, is highly adaptive and competitive, and many of its species-specific checks and balances are reduced or eliminated. Because of the use of tools in its internal competition, the technological species continually increases the ferocity of its internal competition and its deadliness to itself. Thus as the power of its tools increases, the technological species carries the seeds of its own destruction within itself, and it will eventually destroy itself unless it advances to the next stage, the linked-mind sixth-stage being.

The sixth stage consists of the linkage of all individual brains in the species into one single superbrain, producing a superbeing having absolute control of space and time. A technological species is necessary to accomplish linkage and produce a multidimensional, eventually nonphysical, superbeing. When the technology is sufficiently advanced for linkage to be developed, the power of the tools is so great that self-destruction is imminent. Thus an advanced technological civilization is near linkage and also near Armageddon, and in either case it vanishes as a limited, three-dimensional species of the fifth stage. This accounts for the notable absence of a technological species similar to man in man's universe.

ANGELS, IMPS, AND UFO TULPAS

If we realize that each of us has his own mind world, an S^3 frame with respect to the *S* frame physical world, but separate from each other *S* frame mind world, then we see that, if we take common forms that are in the minds of all human beings, it is much easier to kindle them because they can be cohered much more easily.

The common crosstalk in all minds constitutes the collective unconscious. Since the common crosstalk is in a sense a mind, and since it is connected to a "body" of many cells, i.e., of four billion humans or so, then this collective unconscious is a living, breathing entity.

Furthermore, the usual content of its mind is a great deal closer to physical phenomena that are in all minds than is a single human being's mental content. Much of what we term physical reality is in fact prescribed by the collective human unconscious. And if the collective human unconscious is changed in its conception of reality, then four billion stages start kindling with the hyperchannel effect, and immediately the new conception is physical reality.

Borrowing from Jungian psychology, let us call a form that is in each human mind an archetype. Let us also realize that there are shallower levels of unconsciousness (Figure 28) between the total collective unconscious and an individual mind. For an Irish-American there is one level defined as Caucasian, another defined as Irish, another defined as American, another defined by the larger region he lives in (say the state), another defined by his family, and another by his own personal unconscious. The levels are not mutually exclusive, but intersect across one another. At any rate, all these unconsciousness levels above the collective human species unconscious also shape, modulate, mold, and change the kindling channel that exists for a person or group. All these levels of unconsciousness are like finer and finer tuning levels to change the kindling mechanism.

An archetype that is kindled from the collective unconscious is kindled through such a mechanism of unconscious levels of tuning, and the reality format that is kindled is determined by the type of pressure and the content, biases, or tuning of all the levels between it and the conscious minds of the individuals who observe the phenomena.

All tulpoidal manifestations are kindled through and by this mechanism. All of them are shaped by the multilevel unconscious tuning. All of them are caused by an unresolved conflict in the deeper unconscious layers.

Since most minds are notoriously unstable, the tuning is unstable almost always, and the tulpoidal manifestation is usually fairly shortlived, usually not more than a few minutes, or a few hours.

Angels, imps, Virgin Marys, UFO's, sasquatches, Loch Ness monsters, lake monsters, sea monsters, nocturnal mystery lights, fairies, elves, devas, devils, ogres, Mothman, men in black, goblins, large monster birds, etc. are all kindled by the same process. And so are cattle mutilations. I fear that human mutilations will be next.

Any tulpoidal materialization may be physically real during its stable period. It may make large tracks in the ground, operate shiplike space vehicles, break tree branches, take human specimens on board, examine human specimens, etc.

The tulpoid may appear benevolent or harmful, and it may actually be so when in the stably materialized mode. The full content of the human unconscious is there to be materialized in physical form — all the good, all the bad, all the noble, all the sly aspects.

When enough human unconsciousnesses have the idea of fairies deeply ingrained in them, occasionally a real, living, breathing fairy pops out of the collective unconscious, riding as a direct modulation on a more primitive overall human species archetype. And the fairy may do all the things expected; she may pose riddles, give gold coins which must not be examined or they will be lost, etc.

Religion can also make use of tulpoidal appearance. When Christian predecessors believed in a vengeful god, a powerful but spoiled king, they got all the manifestations of that kind of Being. When they believed in a god of sacrifice, they got a god who demanded sacrifice and thrived on it. And when many believe in angels and Virgin Marys, they sometimes actually appear. These appearances are not hallucinations; they are completely real. It is just that all possibilities are concretely and physically real in their own realms, and any of these may be tuned in to appear in this realm.

An infinite number of reality channels exists. The total instrumental characteristics, genetic, psychological, and physiological, of the observers who tune in the channel determines the noise content and the actual channel selected.

A reality is simply an orthogonal frame or world. AH possible realities already exist. A channel is a set of tuned and timed orthorotations communicating back and forth between two orthogonal frames or worlds. Tuning is a complex of mind and matter, and of many unconscious levels.

For a perfect adaptation of this mechanism of coherence, any coherent signal — no matter how fantastically weak — can be raised up out of the grass and made dominant. By time coherence in the virtual state, a virtual state entity can be amplified into observable state. From sheer nothing we can produce something. And since every possible something exists in nothing and is available for cohering, we can get anything at all by this process, at least hypothetically.

DREAMS ARE UNRESOLVED CONFLICTS

Everything is essentially mind. Mind forms layer after layer of overlapping zones of shallower and shallower unconsciousness (multiple simultaneous consciousness), all the way from the universal allness to the personal unconscious, and culminates, like the tip of a dagger, in each conscious mind. Figure 29 illustrates these mindlevels.

Just as the dreams of an individual show his unresolved conflicts, so the materialized tulpoids of the collective human unconscious show its unresolved conflicts. Tulpoidal phenomena thus symbolize man against himself, or one group of humans against another group of humans. The great unresolved conflict in the human species since World War II has been the Cold War. And therefore the great flaps of tulpoidal UFO activity should correlate directly to the Cold War. And so they do, as I indicate in this book. Literally we ourselves are our own "Satan," for in man's inhumanity to man, satanic evil is created inceptively. And we ourselves are our own "godform," for in man's love of his fellow men, goodness is created

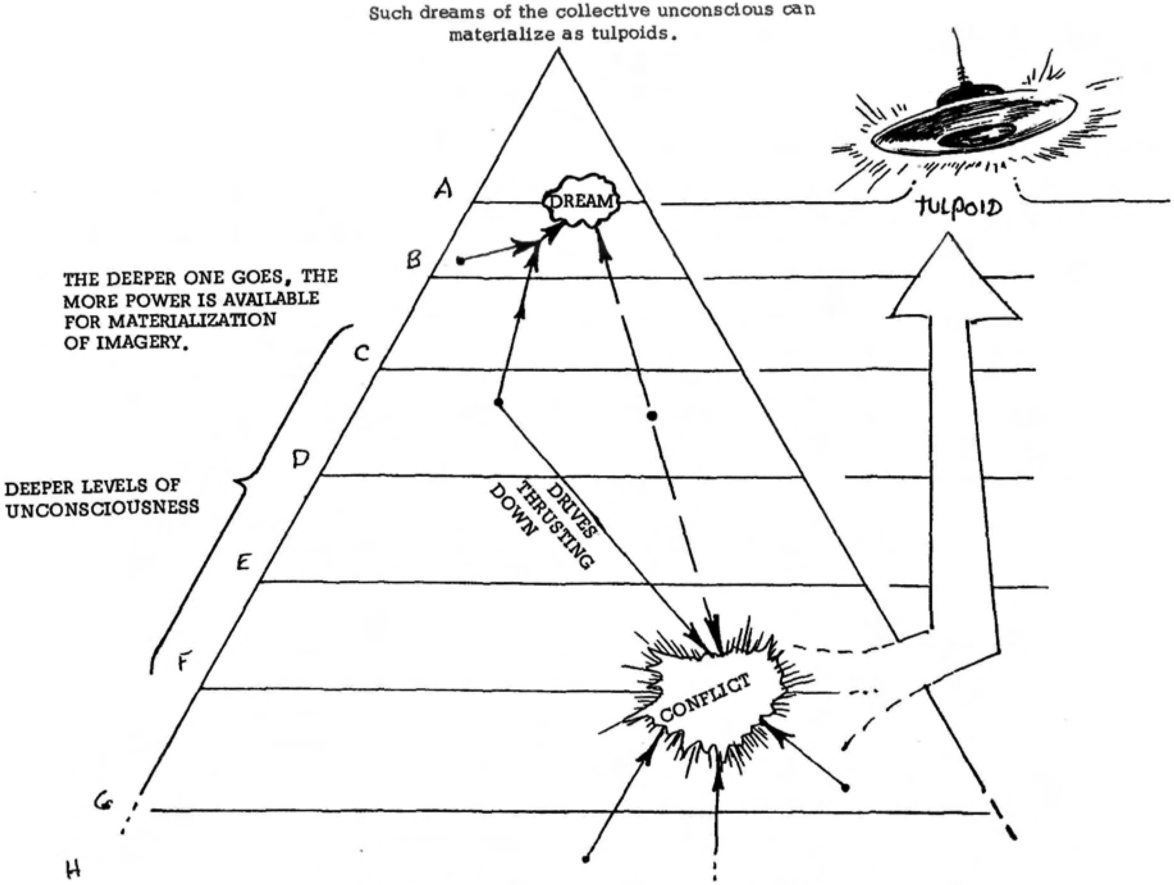

Such dreams of the collective unconscious can materialize as tulpoids.

THE DEEPER ONE GOES, THE MORE POWER IS AVAILABLE FOR MATERIALIZATION OF IMAGERY.

A
DREAM
TULPOID
B
C
D
DEEPER LEVELS OF UNCONSCIOUSNESS
DRIVES THRUSTING DOWN
E
F
CONFLICT
G
H

Fig. 29. Dreams are unresolved conflicts

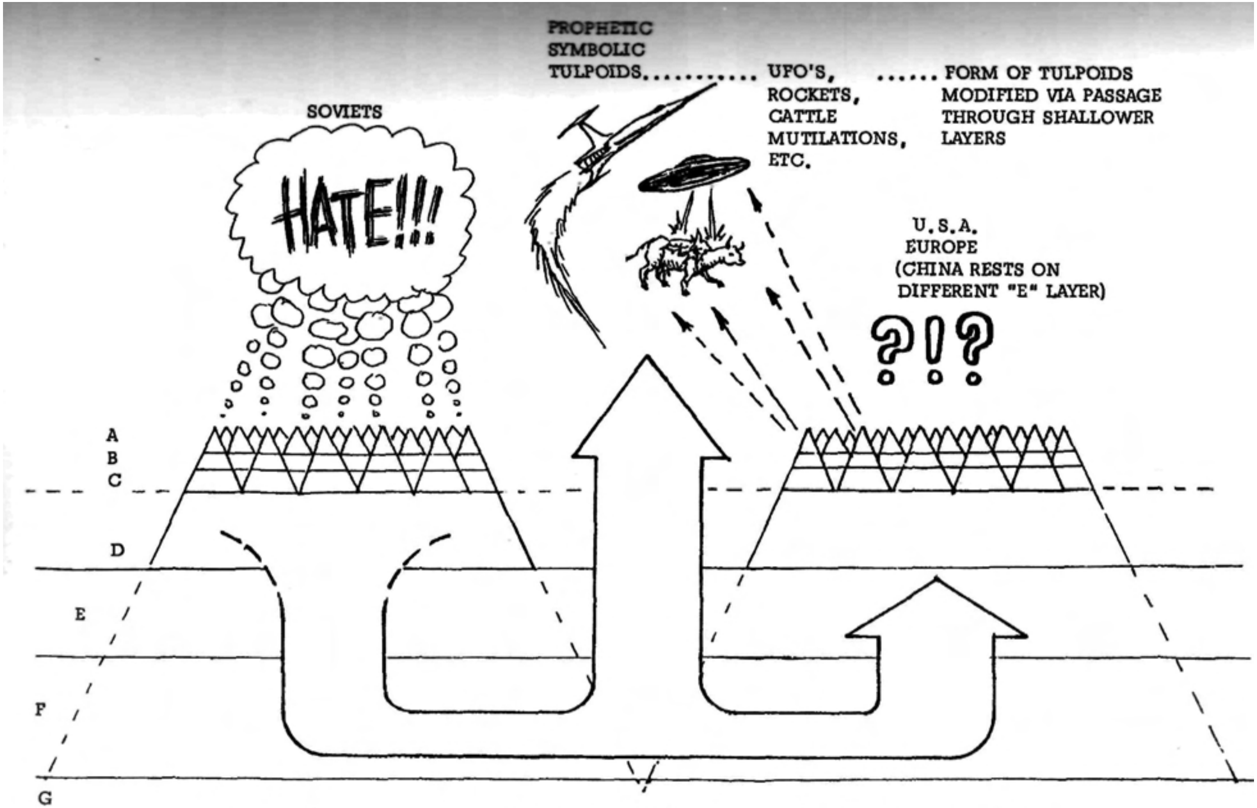
PROPHETIC SYMBOLIC TULPOIDS..........
UFO'S, ROCKETS, CATTLE MUTILATIONS, ETC.
...... FORM OF TULPOIDS MODIFIED VIA PASSAGE THROUGH SHALLOWER LAYERS
SOVIETS
HATE!!!
U.S.A. EUROPE (CHINA RESTS ON DIFFERENT "E" LAYER)
?!?
A
B
C
D
E
F
G

THE PSI CHANNEL IS LIKE A QUASI-HYDRAULIC U-TUBE. CONSISTENT PRESSURE INTO DEEP LAYERS RESULTS IN UPWELLING TULPOIDS WHOSE FORM IS MODULATED AND SHAPED BY SHALLOWER LAYERS, ON THE WAY TO MATERIALIZATION.

Fig. 30. Collective conflict initiates prophetic tulpoids

inceptively. It is not accidental that the Avatar Jesus exhorted man to love God with all his heart and mind, and to love his neighbor as himself. It is also not accidental that a human culture seeks and "obtains" a godform or god-image consistent with its own level of understanding and belief; the resulting tulpoidal activity conditioned into the collective unconscious and the cultural unconscious, and tuned in from them, will be consistent with the cultural desires and expectations.

So in a sense we are the creators of our own reality and our own tulpoidal expressions of higher reality. But in addition to tulpoids, the present character of spacetime and dimensionality, and the very laws of the physical universe, are largely prescribed by the collective human unconscious.

GHOST ROCKETS AND FLYING SAUCERS: MATERIALIZED TULPOIDS

Unfortunately, from 1945 to 1947 events occurred that caused a split among previous World War II allies and that led to the beginning of the Cold War in 1947.

Due to these events, Western nations perceived a growing threat from the Soviet Union. The resulting interplay of events, news reports, and personalities, plus the traumatic aftermath'of World War II, led to strong psychological pressure on the group unconscious of the Western nations, and thence on the collective human unconscious. This pressure resulted in popouts of direct orthorotations of resonant archetypal symbols from the collective unconscious, the archetypal format being successively modified by the Western group unconscious and the progressively higher levels of unconsciousness.

The formats of the deep human unconscious were formed millions of years ago in the primitive tribal state. In the tribal warfare of those ancient days, the male went to where the action was, while the female stayed behind in the protected cave, fortress, or shelter to care for the young. Thus the male symbol was closest to the threat and identified with being there.

Furthermore, in primates the phallic symbol is the universal symbol of threat, dominance, and defiance. Dominant primate monkeys often briefly mount submissive males to show their dominant position, exposing their genitals in so doing. If the mounted male does not submit, an immediate battle ensues to determine the dominant male. Thus the phallic symbol represents threat and domination.

In the deep human unconscious, fire is a symbol of power, for with fire the species held predators at bay and began the long trek up from the jungle cave to modern civilization.

Finally, the unconsciousness of a substantial number of the Western nations had been deeply impressed by the German V-l and V-2 rockets during World War II, for the imagination of the world had been breathtakingly fired by the surprise advent of the German rocket weapons.

Thus we would expect that in those Western countries — Norway, Denmark, Sweden, etc. — that are close to the Soviet Union, archetypal tulpoid popout materialization would have taken a male, threatening, dominant, power format. The nearest, most powerful, most resonant recent stimulus symbol in the Western group unconscious would have been the final modulation, determining the final format.

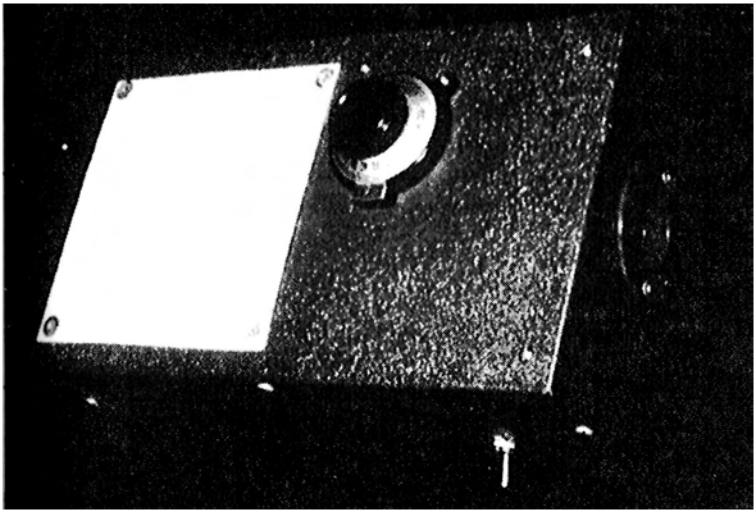

Outside showing contact ptate, sample well, tuning vernier, and on-off switch.

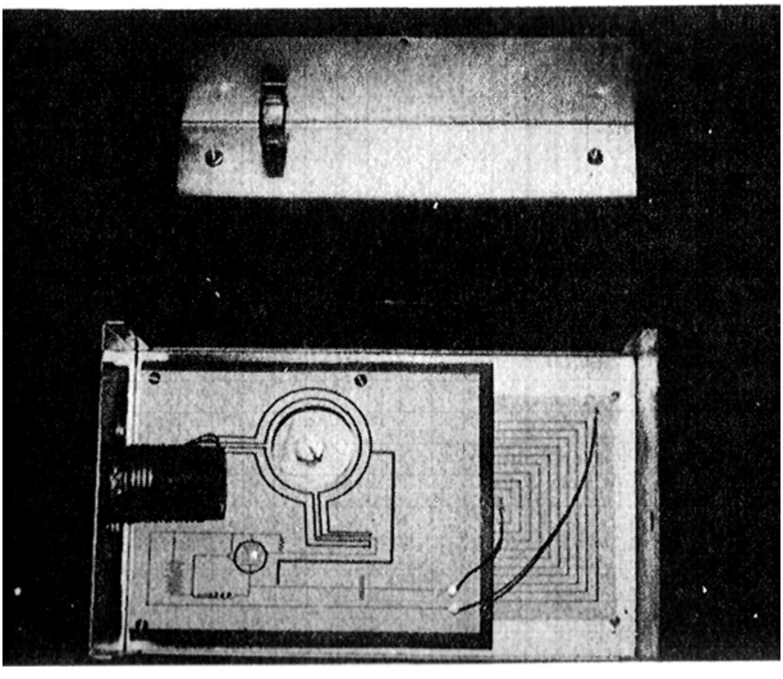

Inside, showing India Ink drawing of *an a*mplifier schematic, used as the "amplifier.'

Photo 41. Hieronymus device — second kind.

So a massive wave of "ghost rockets" from the direction of the Soviet Union appeared in the skies over Norway, Sweden, and Denmark, and other nearby European countries. (See Photograph 43.)

However, North America constituted a natural fortress with great ocean barriers to the east and west, and no strong enemy to the north or south. Therefore, a female symbol (archetype) should have been resonant and stimulated in the U.S., and so it was. In 1947, the year the Cold War began, Kenneth Arnold, flying over the state of Washington (the most northwestern U.S. state at the time, and the one nearest the Soviet Union), encountered a formation of flying saucers — the female circle mandala, dressed in modern aeronautical form. Thus was born the age of flying saucers in America.

PART THREE

NEW MILITARY APPLICATIONSOF PSI RESEARCH

BACKGROUND TO PSYCHOTRONIC RESEARCH IN THE U.S. AND THE U.S.S.R.

In this section I will discuss some of the fantastic psychotronic weapons that have been built and deployed by the Soviets as a part of operation "Fer-de-Lance," the Soviet plan to conquer the world.

The Soviet Union has had a massive developmental program in what they call energetics or psychoenergetics (and what we are calling psychotronics) for about thirty years. To appreciate the mind-staggering weaponry that has emerged from this effort, I should point out that the U.S. developed the atomic bomb in World War II in about four and a half years; thus the Soviet psychotronic program is the equivalent of roughly seven Manhattan projects, back-to-back. With this comparison we gain a rough yardstick to appreciate the fantastic capabilities that must have emerged from the sustained Soviet program. As we will see, they are indeed mindboggling.

Ironically, most of the original theoretical work was done here in the United States, just as the pioneering work in rocketry was done here by Goddard, before the Germans picked it up and advanced it to the V1 and V2 rockets. Just as Goddard himself was once the laughing stock of the Pentagon, so the key U.S. researchers who could have initiated the psychotronic age in the West — Moray, Abrams, Reich, Hieronymus, Drown, Tesla, de la Warr, etc. — were generally ignored or prosecuted or both. Even more deadly has been the studied avoidance of any application of the basic theoretical work — which again was developed largely in the U.S. This work included the Everett-Wheeler-Graham many-worlds interpretation of quantum mechanics, and the extension of Lorentz's work by Ives, Ruderfer, and others to show that almost all modern physics — including general relativity, Newton's laws of motion, and the law of universal gravitation — can be straightforwardly derived from a Lorentz-invariant nonmaterial ether. Even though Pauli pointed out that the Michelson-Morley experiment only eliminated a material ether rather than ether per se, and although Einstein himself once proposed the use of the term ether to include dimensionless vacuum space complete with various fields, modern physics in the West has ignored the ether theory.

As Robert Anton Wilson points out, whatever you believe imprisons you. The West has been solidly imprisoned in its own orthodox view of physics, and hence has been unable to surmount the stone walls of its self-imposed mental barriers. In fact, it has not even tried. There has been no serious, sustained program to deliberately examine the loopholes in present theory and seek the necessary changes to provide a theory of paranormal-psychotronic phenomena. In fact, the major Western work on paranormal phenomena seems only to attempt to "prove" over and over that such phenomena exist; and to attempt to derive from present physics theory a "normal sane" theory for "abnormal insane" phenomena. The orthodox establishment continues to vigorously attack the experimenters who struggle with paranormal research on the grounds that their work does not present science.Hence the experiments and experimenters are unscientific and either at worst frauds and charlatans or at best seriously deluded.

The simple procedure necessary to solve these questions — set up a deliberate, well staffed, well-funded program on a continuing basis — has not been adopted in the West because of the short-sightedness of our management structure. We seem to have totally forgotten that we got the atomic bomb in the first place and we put a man on the moon, simply by starting a program with staff and funds to try to do it, not by engaging in a neverending series of arguments as to why it could not and should not be done.

So, ironically, the nation that prides itself on being free and liberal has adopted an iron dogma of its own in science, a dogma that yields very slowly and that has effectively blocked us from serious and prolonged efforts in psychotronics.

Meanwhile, the Soviet scientists — admittedly kicked firmly in the tail by Stalin — have simply got off their dust-encrusted seats with alacrity and got to it. In thirty years of such getting to it with massive state support, they have already launched the psychotronic age, first applying it to the weapons field, the typical Soviet priority. Meanwhile, for the same thirty years we in the U.S. have played the same old tired games that once led Heisenberg to remark that new scientific knowledge only gained acceptance when the old scientists who so adamantly opposed it had died away.

Finally, there is a direct relationship between UFO's, psychotronics, the collective human unconscious, the Cold War, and Fer-de-Lance that cannot be escaped. So while this section emphasizes psychotronic weapons deployed by the Soviet Union I continually remind the reader of the concepts involved in the related paranormal phenomena, which were covered in Parts One and Two. So with these words, let me give a brief summary of Soviet psychotronic weapons. Make no mistake, it appears that the final holocaust is now unavoidable — we will reap the full rewards for our smugness, pride, arrogance, and inflated egotism.

The Soviets will unleash World War III and they will unleash the psychotronic weapons on a totally unsuspecting world.

But there is something more; it does not end there. There is another player in the game — the collective human unconscious, ZARG itself, will unleash a reaction that makes psychotronic weaponry pale by comparison. Yet when that great entity has roared out its anger, destroyed perhaps half the earth, and then opens its eyes, the full biblical prophecy will in a most bizarre and unsuspected way be fulfilled.

Time will end, and the grave will give up its dead. The unifying of all human minds into one will complete the birth of a new godlike being, extending from the beginning to the end of time all at once, and from beginning to end of all possible times all at once. Three-dimensional concepts and limitations will fade away as child's play to the being that is already in four billion dimensions.

And you and I will become gods, literally, actually — for being is holographic, and whatsoever ZARG becomes, so we all become.

PSYCHOTRONIC BACKGROUND SINCE WW II

After WW II Soviet scientists were ordered by Stalin to actively seek another area of great breakthrough — such as the U.S. atomic bomb had been — and leave no stone unturned in their search. Apparently the Moray detector was resurrected and intense experiment and development begun on it. Much of the pioneering radionics work of the West and Ive's work would also have been available at this time. I believe that in 1958 the Soviet nuclear catastrophe near the Urals was the result of an attempt to transmit a nuclear explosion through hyperspace. (The peculiarity of a transmitter tuning failure would have resulted in an explosion emerging from the nearest large nuclear waste storage, and that apparently happened.)

In 1956, however, a major new interpretation of quantum mechanics was originated by Hugh Everett at Princeton University under the world-renowned John Wheeler. This is the theory of the universal wave function—the many-worlds interpretation (MWI) of quantum mechanics. Practically the entire Western output on the subject is available in his 1973 book entitled *The Many-Worlds Interpretation of Quantum Mechanics.*

This physics is so exceedingly strange that it has been ignored by almost all Western physicists — indeed, it is so strange that even its originators, Everett and Wheeler, are said not to be able to believe it. Wheeler is reported to have once stated that he could believe it on Monday, Wednesday, and Friday, but not on the other days of the week. Using the MWI, however, one can produce a theoretical model of psychotronics which is totally consistent with the entire experimental basis of modern physics, and unite both mind and matter on a single scientific basis.

The Soviets apparently seized on this new theoretical work and applied it to the Moray device, solving their theoretical and technical difficulties.

In 1960, Khrushchev, speaking to the Presidium, stated that the USSR had a new weapon in development ("just within the portfolio of our scientists, so to speak") that was so powerful it could wipe out all life on earth. I believe he referred to the nuclear hyperspace howitzer and to the death ray weapons under development at that time, such as the following.

ELECTRON DISSOLUTION

There are four levels of effects on biological systems that are irradiated by electron dissolution beams.

Interference with the electrical functioning of the nervous system is the dominant effect. Single channel subsystems are more sensitive to the effect.

Mild irradiation (or mild kindling of short duration) causes weakness, trembling, and an unreal, dreamy feeling (as when one gets a whiff of anesthesia). The victim is conscious, however, since consciousness is limitedly multichannel.

Moderate irradiation (or kindling of moderate duration) causes paralysis of the motor system, and a very unreal, floating feeling. The individual is barely conscious and is hypnogogic. Panic is usually engendered.

Strong irradiation (more protracted kindling) causes loss of consciousness in addition to paralysis. The autonomic nervous system still functions with difficulty, and the victim is just barely alive. Convulsions and other symptoms may appear.

Very strong irradiation (protracted kindling) totally jams all levels of the nervous system, and death results instantly.

In UFO contactee incidents this effect is widely demonstrated. Many cases show step function failure of automotive electrical systems, lights, radios, etc., as a UFO approaches. When the UFO departs, the electrical systems almost invariably resume complete operations. Absolutely no electrical components are damaged.

To extinguish these systems with massive RF fields would result in blowing fuses, diodes, transistors, etc., and a great amount of electrical sparking — probably sufficient to blow up the gasoline tanks, In fact, none of these things occur.

Stage 2 electron dissolution should definitely disable automotive circuits, and the upper level of stage 1 may be sufficient. Either would leave the automobile passengers conscious, though paralyzed in one case and not in the other. Both types of correlations are shown in the UFO literature.

THE 1973 CONTACTEE WAVE AND CATTLE MUTILATIONS

In 1973 the Yom Kippur war took place. This was the Soviets' "Spanish Civil War," and they tested the final tactics and equipment for antitank and antiaircraft weaponry, and obtained final data on tank and equipment loss rates for modern combat. The effect on the U.S. and NATO of the cutoff of Arab oil was also tested.

At one point, when the Israelis cut off an Egyptian army in the desert, the Soviets notified the U.S. over the hot line that Soviet forces were going in and the U.S. could do whatever it pleased. The Soviets loaded and readied seven airborne divisions to insert, and the U.S. readied its single airborne division to send in. So the world teetered on the brink of direct ground confrontation between the Soviet Union and the U.S., with all its possible consequences.

Confrontation is after all another form of *contact.* And UFO contactee cases involve *confrontation.* In the very month, October, that the Yom Kippur War erupted, the greatest wave of UFO contactee cases in history broke out in the U.S. Further, in the shallower unconscious levels above the collective species unconscious, which were modulating and molding the tulpoidal reality format, the imagination of the world had been captured by the spacesuited astronauts who had walked on the moon. So most U.S. contactee cases involved spacesuited beings, conditioned into that framework by the national, cultural modulation. Some of the contactee cases involved robots or metallic men, similar to the mechanisms and robots of the U.S. space program. And here in the U.S., the fortress, the female-mandala craft symbol was generally maintained.

Now if this unbelievable scenario has any validity, then after the dress rehearsal of the 1973 Yom Kippur War we ought to have seen an increase in the tulpoid phenomena of a sharply symbolic nature. And that has happened.

The cow is the Western female symbol par excellence; Western children nurse on cow's milk, so to speak. If the U.S. fortress is to be violated, then the female symbol will be violated as the time for the Soviet assault nears. So cattle mutilations of a mysterious, paranormal nature have been occurring all across the U.S. — from the East Coast out through Colorado, Utah, and Montana — approximately nine thousand by now, in some estimates. The symbolism in the mutilations can be easily read: the U.S.'s lifeblood is going to be drained, totally, as all the blood is usually drained from the cattle. The Soviet operation will be launched with blinding speed and surgical precision, and the mutilation of the cattle is done as if by highly skilled surgeons. The children of the West shall be cut off from their sustenance, and so the cow's teats are removed. The armed forces (males) confronting the Soviet forces will be devastated (i.e., the fruit of the womb will be

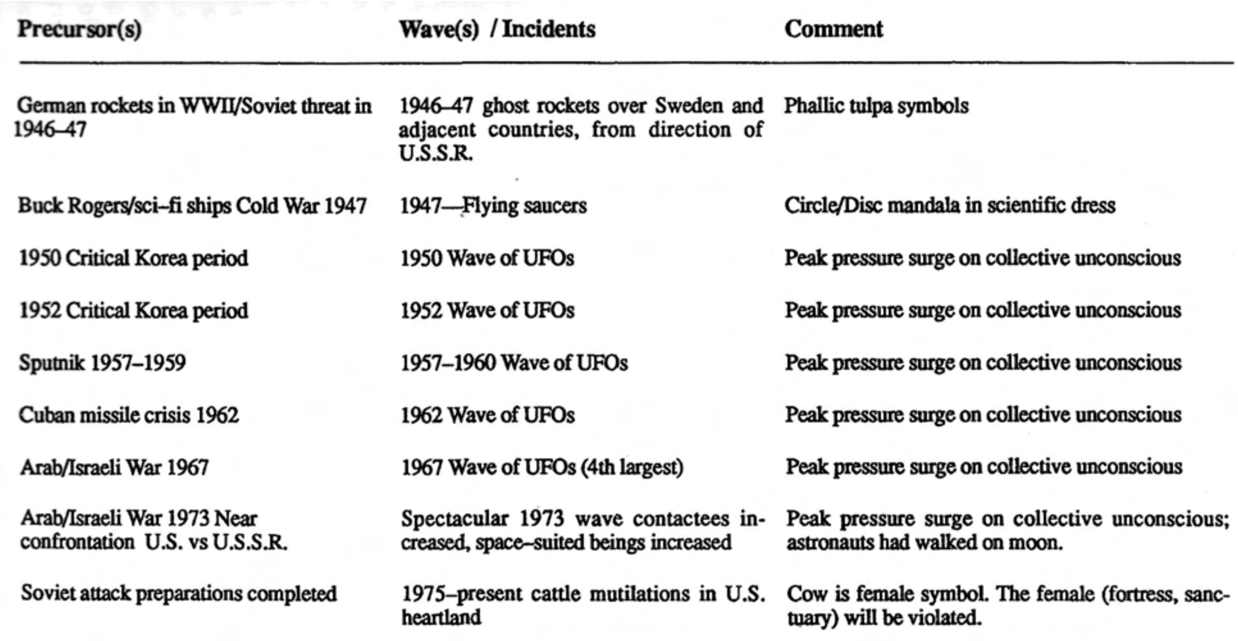

Precursor(s)	Wave(s) / Incidents	Comment
German rockets in WWII/Soviet threat in 1946–47	1946–47 ghost rockets over Sweden and adjacent countries, from direction of U.S.S.R.	Phallic tulpa symbols
Buck Rogers/sci–fi ships Cold War 1947	1947—Flying saucers	Circle/Disc mandala in scientific dress
1950 Critical Korea period	1950 Wave of UFOs	Peak pressure surge on collective unconscious
1952 Critical Korea period	1952 Wave of UFOs	Peak pressure surge on collective unconscious
Sputnik 1957–1959	1957–1960 Wave of UFOs	Peak pressure surge on collective unconscious
Cuban missile crisis 1962	1962 Wave of UFOs	Peak pressure surge on collective unconscious
Arab/Israeli War 1967	1967 Wave of UFOs (4th largest)	Peak pressure surge on collective unconscious
Arab/Israeli War 1973 Near confrontation U.S. vs U.S.S.R.	Spectacular 1973 wave contactees increased, space–suited beings increased	Peak pressure surge on collective unconscious; astronauts had walked on moon.
Soviet attack preparations completed	1975–present cattle mutilations in U.S. heartland	Cow is female symbol. The female (fortress, sanctuary) will be violated.

Fig.31. Examples of UFO waves

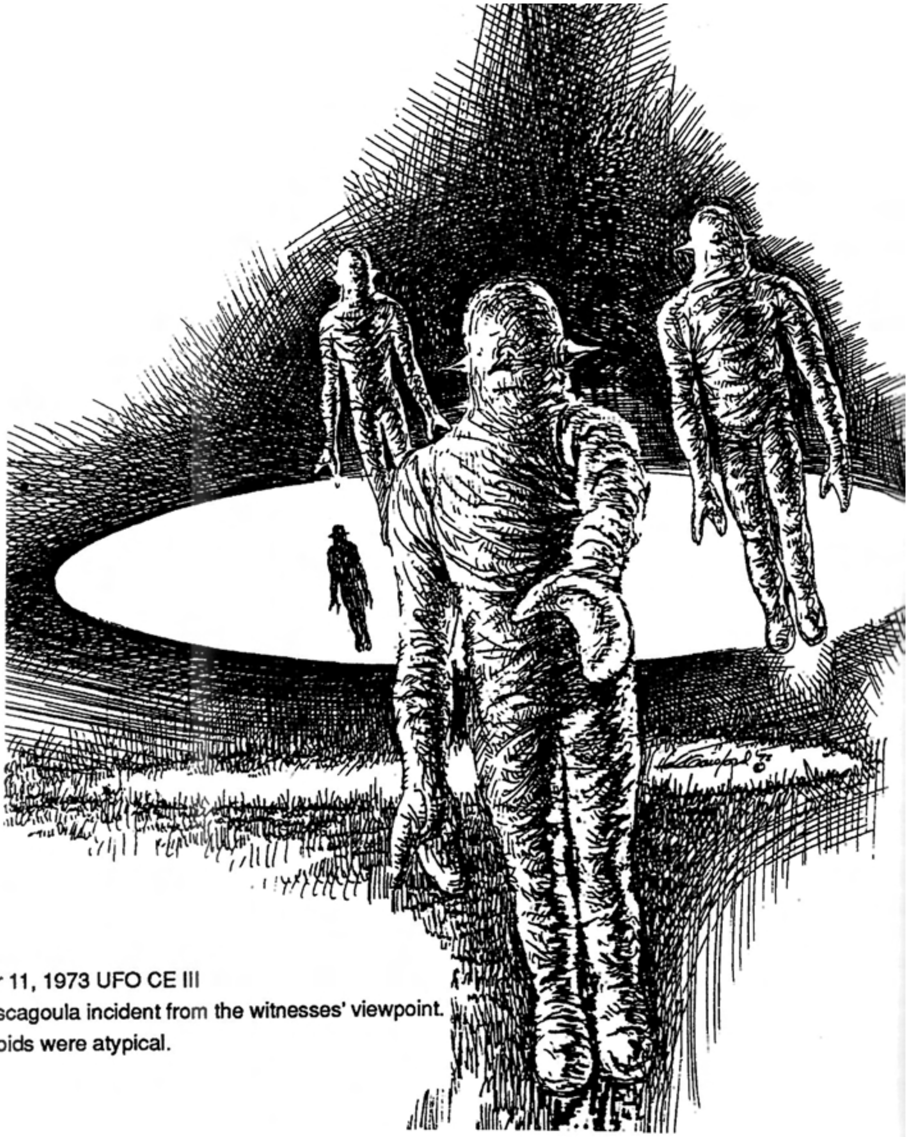

October 11, 1973 UFO CE III
The Pascagoula incident from the witnesses' viewpoint.
Humanoids were atypical.

Fig. 32. 1973 Contactee wave

devastated) so the sexual organs of the cows are excised. Free speech and freedom to hear will be cut off, so the cow's lips, tongues, and ears are excised. A very high (psychotronic) technology will play a role, but one which will limit resistance, so the cut edges are often made as if by pinking shears and then precisely burned as if by a laser. (The laser is symbolic of new, strange technology almost incomprehensible to the average person.) In one case a horse was the victim — a young horse, symbolic of the young soldier. It was castrated, as the dominance of the Western soldier will be surgically excised. Castration of the male symbolizes the total loss of his power and the infliction of impotency upon him.

There is more, but this is a bloodcurdling sampling of the metapsychological implications of the cattle mutilations.

RADIATION OF THE U.S. EMBASSY

About 1959 or 1960 the radiation of the U.S. Embassy in Moscow with weak microwave radiation began. It continues to this day. The radiation is a brilliantly designed intelligence probe: the Soviets were vitally interested in ascertaining whether or not their U.S. adversary knew about psychotronics (i.e., whether the U.S. had built such weapons of its own and might have built defense counterweapons as well). Accordingly, they began weak PT-modulated microwave radiation of a high-level U.S. target, the U.S. Ambassador to the Soviet Union, which would guarantee the personal attention of the State Department, NSA, CIA, DIA, the President, etc. The PT modulation apparently consisted of various disease patterns of gradually increasing seriousness — flu, blood changes, heart irregularity, cancer, etc. By the U.S.'s reaction, whether or not it knew anything of PT could be positively assessed. If the U.S. reacted only to ordinary electromagnetics, then with 100 percent certainty it knew nothing of PT and had no secret PT weapons of its own or counters to the Soviet PT weapons. So since about 1959 or 1960, by our alow reaction to the radiation of the U.S. Embassy — and then by our reaction only to the electromagnetic aspects — we have been assuring the Soviets that we know nothing of PT. Even though several U.S. presidents have protested the radiation, the Soviets have persisted because it is an intelligence tool of the utmost importance to them.

DISEASE AND DEATH TRANSMISSION

For confirmation of Soviet experimentation with PT induction of death and disease, see V.P. Kaznacheyev et al, "Distant intercellular interactions in a system of two tissue cultures," *Psychoenergetic Systems,* Vol. 1, No. 3, March 1976, pp. 141-42; and by the same authors, "Apparent information transfer between two groups of cells," *Psychoenergetic Systems,* Vol. 1, No. 1, December 1974, p. 37. These articles give one a glimpse of the results of over 5,000 Soviet experiments on the basic effect. Kaznacheyev is the head of the Siberian Branch of the Soviet Academy of Medicine, and has at his disposal every disease germ, virus, and toxin known to man. Note that the experiments were performed in the dark to prevent the quenching effect of the visible light spectrum und the effect is only obtained through the quartz (which has IR and UV windows). Also note that in the two-slit experiment — which contains all the mystery of quantum mechanics, according to Nobel prizewinner Richard Feynman, cofounder of quantum electrodynamics — one does not get the quantum effect with an electron, if the electron is first hit by a photon of light before reaching the two-slit region. If the electron is not hit by a photon, one gets the quantum effect. According to Feynman, the quantum effect in the two-slit experiment is not explainable by any classical means. Our comment is that the explanation is not possible by Aristotle's three laws of logic, on which all Western logic, physics, and mathematics are based. However, the fourth law of logic, together with the present three laws, provides a closed metalogic which does contain the explanation of the two-slit experiment, as we showed in Part Two. The fact that there is no problem in explaining the experiment if one takes into account the nested structure of time was pointed out as long ago as 1957 by Dr. Charles Muses. Similarly, the disease and death transmission experiments of Kaznacheyev et al have been explained in Part Two.

OTHER WEAPONS

Clandestine testing of PT weapons also appears to have been accomplished directly in the U.S. The Legionnaires' disease may have been one such test. The suspect agent was actually seen, according to sworn testimony before a Congressional committee. A person with a book-sized object in his hand (tape recorder with PT pattern), a tobacco-pouch sized object in his coat breast pocket (transmitter) and a wire running to his tie clip (antenna) was present and mingled with the Legionnaires for several hours. He was heard to exclaim several times to various Legionnaires that it was too late and they were all doomed. The eventual appearance of the weird "biological agent" that is different from any other germ known can also be explained by kindling from the anxious minds of the baffled U.S. researchers and scientists. Other such tests have also apparently been conducted.

HYPERSPACE HOWITZER OPERATION

The facility at Semipalatinsk is a third-generation hyperspace nuclear howitzer. It can transmit a full nuclear explosion through hyperspace into a tuner planted anywhere in the universe, without traveling through or in normal space at all. Furthermore, it has a unique characteristic: any number of receiver-tuners may be tuned to the transmission channel and each will have the full nuclear explosion emerge from it, undiminished.

Thus, one channel might be for U.S. Minuteman sites, and a tuner on that frequency (say one containing 100 transistors, sealed in plastic and buried in the earth) could be preplanted near each Minuteman site. Another channel might be for all the SAC bases, another for large U.S. cities, another for nuclear weapon storage sites, etc. Any or all of these could be connected to a single blast transmission, simply by controlling the channel width over which the hyperpace transmission occurs.

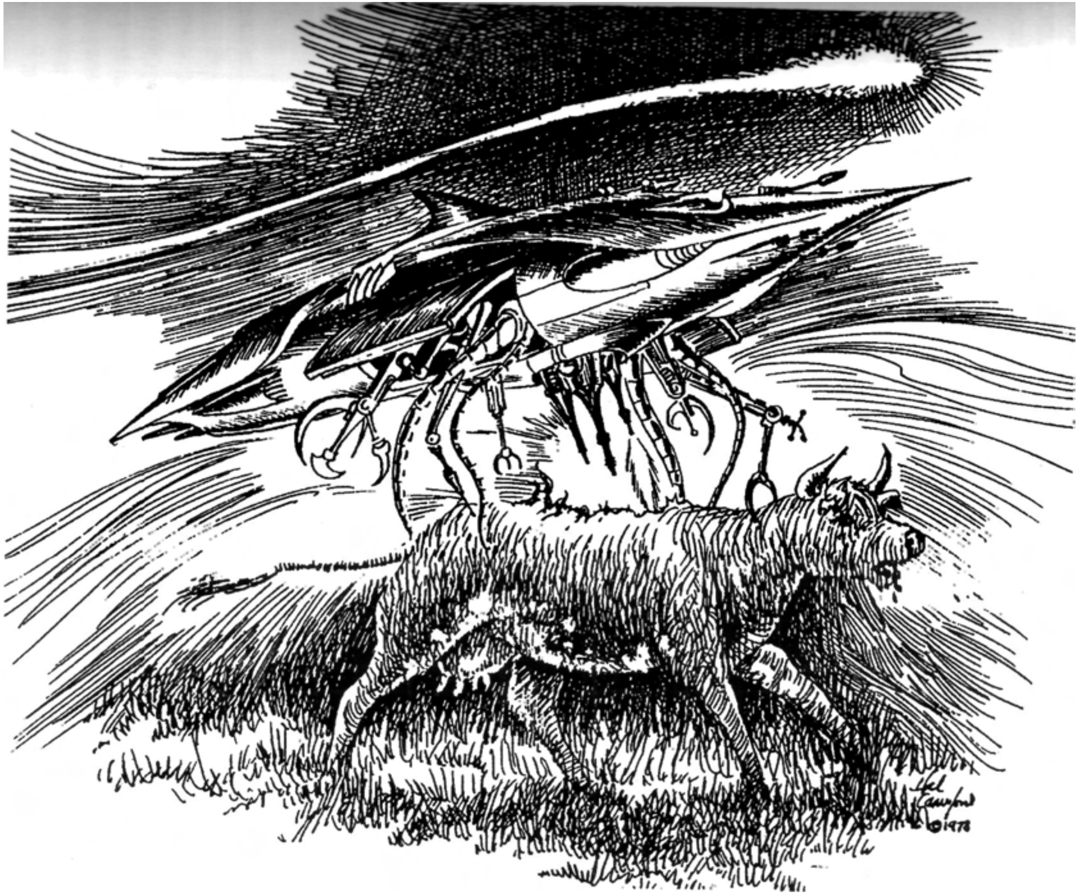
Hal Crawford ©1978

Fig. 33. Cattle mutilations

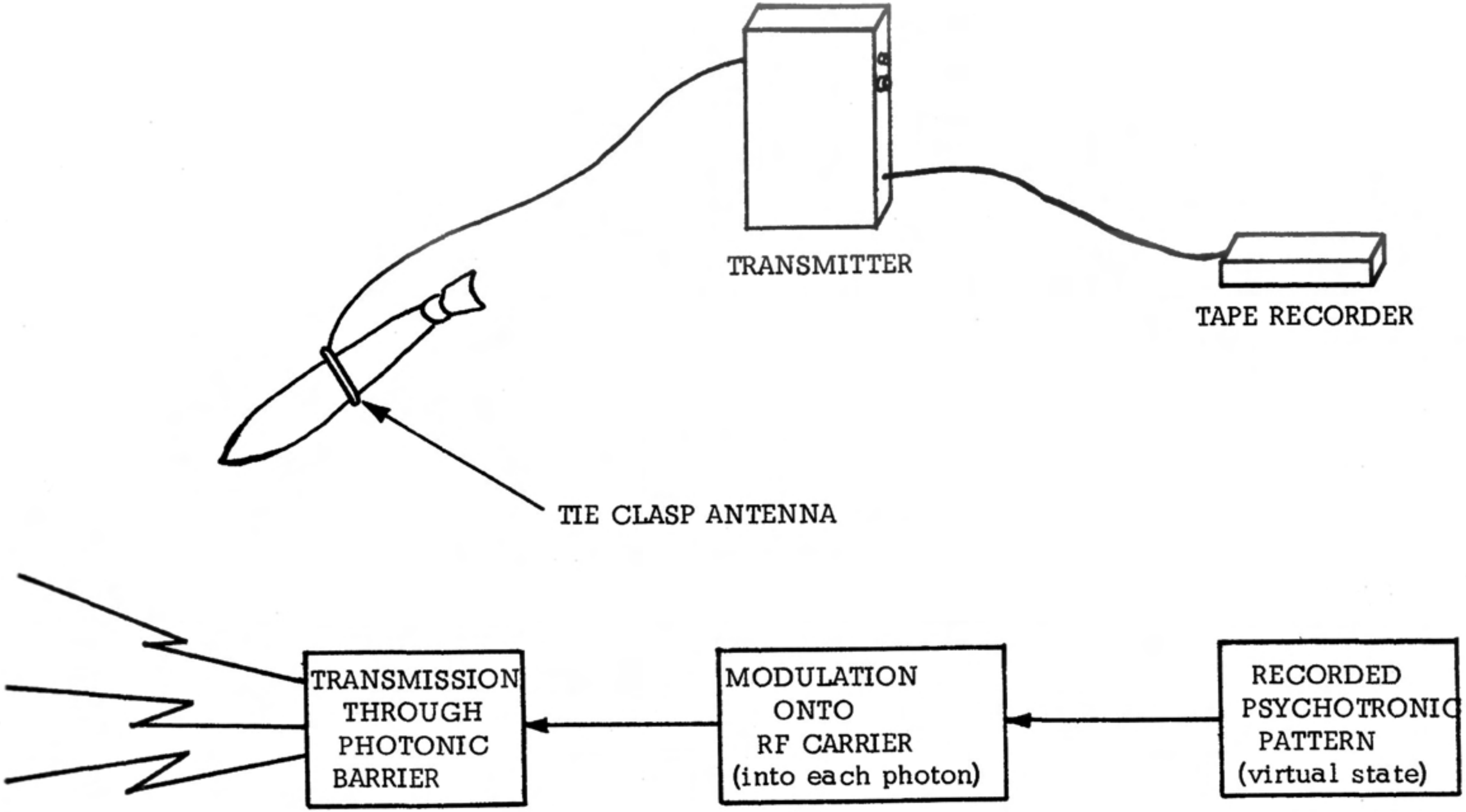
TRANSMITTER
TAPE RECORDER
TIE CLASP ANTENNA
TRANSMISSION THROUGH PHOTONIC BARRIER
MODULATION ONTO RF CARRIER (into each photon)
RECORDED PSYCHOTRONIC PATTERN (virtual state)

Fig. 34. Induction of Legionnaire's disease

Here one must not confuse ordinary single-channel conservation of energy with hyperspace operation. The transmitter corresponds to the grid of a gigantic triode, the preplanted receivers constitute the plate area, and zero-point vacuum energy constitutes the cathode energy source. So just as in a triode, energy is conserved from cathode to plate, but not exclusively from grid to plate. Since zero-point vacuum energy is being gated by the triode grid (the howitzer) signal (the explosion), the energy that can be outputted at the plate (from the tuner-receivers) is essentially unlimited. Any number of receiver-tuners can be connected to a channel, merely increasing the plate area. And from each tuner there can emerge a full-scale, undiluted replica of the explosion in the howitzer at Semipalatinsk.

Thus a single nuclear blast at Semipalatinsk can in one instant wipe out all hind-based strategic nuclear retaliation capability in the Free World, if the preplanted tuners are on site.

An additional modification — something like additional orthorotator rings surrounding the primary hyperspace orthorotator ring — may have been made to the nuclear hyperspace howitzer within the last two or three years. If so, this would have the characteristic of materially reducing the "spillage" fraction of the nuclear explosion and also the vibration associated with a firing. There is a possible indicator of this: quoting from *Science*, "On five occasions during the first half of 1976 traces of neptunium-239 and molybdenum-99 were detected in southern Sweden. These activities were accompanied by small amounts of fission products such as iodine-131 and barium-140. One of the events was coincident in time with large peaks in the atmospheric tritium gas concentration." (Lars-Erik DeGeer, Swedish National Defense Research Institute, "Airborne short-lived radionuclides of unknown origin in Sweden in 1976," *Science*, Vol. 198, No. 4320, 2 December 1977, pp. 925—27.) These events were concentrated during the time the Semipalatinsk experiments are reported to have started, yet no seismic activity was associated, as would have been the case if ordinary nuclear explosions had occurred in normal space inside a containment sphere for a large particle beam experiment. On the other hand, if a very high percentage of the explosion were transmitted/rotated into hyperspace, then residual traces of a nuclear explosion would have been present in the atmosphere because of the very slight spillage venting into normal space, but almost all mechanical shock and vibration would have been eliminated. It is at least a striking correlation that exactly such indicators are present, as reported by DeGeer.

A clever adversary who becomes aware of the necessity for preplanted tuners could use a very simple but completely effective countermeasure: simply locate the timers and dig them up, then clandestinely put them back into Soviet territory. Or build tuners of one's own and plant them in Soviet territory. Thus it would seem imperative to develop a mode of operation that does not require preplanted tuners at the target area.

This capability can be provided by using the howitzer in an interferometer mode — by constructing additional orthorotation rings around the firing chamber ts (hut a "hyperspace interferometer" exists. With this scheme any point on earth can be precisely focused on by the howitzer, and no preplanted tuner is necessary. The advantage of this mode is the elimination of the need for clandestinely preplanted receivers, and the freedom to operate in spite of any receivers preplanted by the adversary on Soviet soil. The disadvantage of the interferometer is that the former "triode" operation has now been converted to "diode" operation — when one explosion is put into hyperspace, now a single explosion at a single target area emerges, since a single selected spatial location is now exclusively determined by the interferometer settings.

For a more complicated interferometer mode, orientation and alignment of the interferometer's indicators and controls and amplifiers would be necessary. This could be done using fractional kiloton yield weapons — or even ordinary HE explosions — and focusing the howitzer at a displaced aiming point, at some distance from the target area. This is simply the standard artillery technique of registering a gun on an offset registration point, then performing an x-y shift to the intended target when the gun is fired.

Orientation and alignment of such a weapon system probably accounts for the sonic booms — mysterious high altitude explosions — off the East coast of the U.S. in December 1977 and January 1978. Over the West coast, mysterious explosions occurred inside thunderstorms; these also could well have been the adjusting of the weapon. By using about 100 tons of TNT explosive in the howitzer, a very good high burst registration could be made, and "forward observer" agents in the U.S. could observe the bursts through optical instruments and report their exact positions, thus calibrating the interferometer settings. Of course, mysterious booms have been around for quite a few centuries; however, these "normal but unusual" phenomena have quite a different sound than does the howitzer shot. The natural booms are not so much like single giant explosions as like rolling thunder. Furthermore, several observations of the booms off the U.S. East coast confirmed light flashes (which have not been seen to accompany the natural booms) and swirling or rotating effects in the flashes. Also UFO's were directly associated with some of the booms, revealing the stress factor on the collective human unconscious, implying their Soviet psychtronic origin. A few years ago similar high altitude booms occurred over Ohio and surrounding states, and such booms have also occurred off the coast of England.

Thus the howitzer may have been accurately aligned for diode operation, calibrated near the East coast, on the West coast, in the center of the U.S., and near England. Furthermore, its firing rate and recovery time were also apparently checked out; five booms occurred on one day and after a lapse of several days, the booms occurred again.

As I describe the fantastic psychotronic weapons the Soviets possess, the reader may wonder why the Soviets have not already attacked. The reason is that the superweapons have a strange weakness and failure mode possessed by no other kind of weapon. The hyperspace amplifiers in the psychotronic weapons depend on a large number of stages, say sixty to one hundred, and the hyperspatial flux in all these stages must be very stable and isotropic. At odd intervals the flux coming in from hyperspace suddenly becomes turbulent; this destroys the smooth coherence in the multiple stages of the amplifiers, and thus the basic amplification mode. Thus *all* the psychotronic weapons will suddenly cease working at the same time, and this "all fail" mode may last from fifteen minutes to even three weeks in an extreme case. Thus the weapons are erratic and not dependable. For this reason, the Soviets dare not rely *exclusively* on them, and so they have been forced also to prepare for full nuclear war as a distinct possibility when they launch operation Fer-de-Lance, the full attack. They have thus built up their regular army, their navy, their strategic offense systems, and their strategic defense systems on a scale unparalleled in human history. Today the Soviet Union is the strongest nation on earth — by far — and is fully prepared to launch World War III and win it, with or without superweapons.

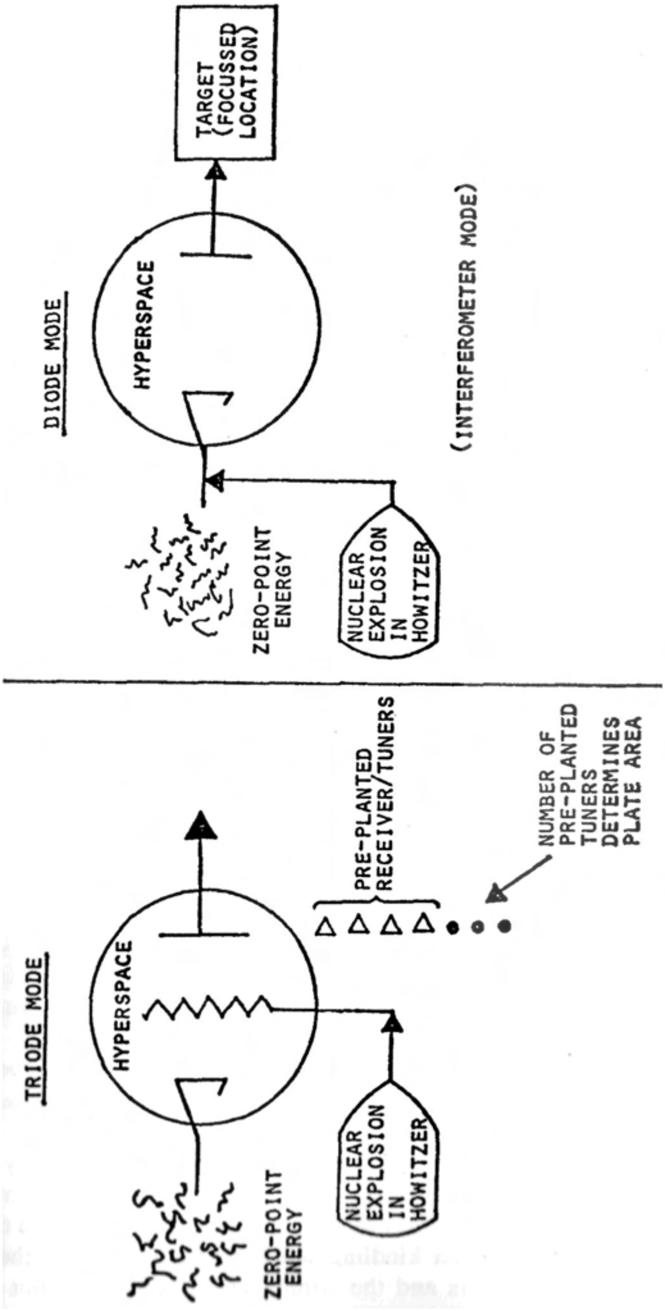
DIODE MODE
HYPERSPACE
TARGET (FOCUSSED LOCATION)
ZERO-POINT ENERGY
NUCLEAR EXPLOSION IN HOWITZER
(INTERFEROMETER MODE)
TRIODE MODE
HYPERSPACE
PRE-PLANTED RECEIVER/TUNERS
NUMBER OF PRE-PLANTED TUNERS DETERMINES PLATE AREA
ZERO-POINT ENERGY
NUCLEAR EXPLOSION IN HOWITZER

Fig.35. Hyperspace howitzer operation (2 figs)

A POSSIBLE OPERATIONAL TEST OF PSYCHOTRONIC ANTIAIRCRAFT WEAPONS

When the F-l11 all-weather attack aircraft were deployed in Vietnam, a rather interesting loss rate pattern emerged. Of the forty-eight F-l11's in operation, eight were lost at the beginning of the action, but no losses occurred thereafter, according to General Vogt, the officer responsible for U.S. air operations at the time.

Initially there were some radar anomalies and other system malfunctions with the aircraft, but these problems were quickly resolved. The F-l11's flew singly, extremely low, and without radio contact. Between September 1972 and the end of hostilities in Vietnam, the F-lll's flew over 4,000 sorties, never losing any planes other than the eight lost initially.

The reason for the loss of the eight planes remains a perplexing mystery. In fact, there is no knowledge of exactly where the planes were lost, except in one case. That F-l11 was downed over Hanoi, and its two pilots, Captain Robert D. Sponeybarger and 1st Lieutenant William W. Wilson, were captured alive by the North Vietnamese. The two airmen were later returned under the prisoner of war exchange program, and they then told of the loss of the aircraft, which took place under very strange conditions.

According to the two crewmen, they met a sudden disaster while flying over Hanoi at night, supersonically, and at very low altitude — only a few hundred feel above the earth. Without warning the F-lll's emergency indicators lit up like a Christmas tree, indicating massive and multiple failures of unrelated aircraft systems.

They were not hit by a surface-to-air missile, according to the crewmen, because no explosion of a missile warhead, with its concomitant fireball, occurred. If large-caliber automatic weapons fire had hit them, the distinctive streak of the tracers would have been clearly visible in the night sky, and a sharp impact in the aircraft structure would have been felt. None of this happened.

It could not have simply been an aircraft malfunction, because far too many unrelated aircraft systems failed at the same time. (There is triple redundancy in the control system of the F-l11, by way of comparison.)

Indeed this initial loss of eight aircraft — and then no further losses at all — is difficult to explain rationally, as are the mysterious circumstances surrounding the loss of Wilson's and Sponeybarger's craft.

However, it requires no stretch of the imagination to realize that the Soviets very much desired to obtain the glittering new F-l11 to examine its technical characteristics, its sophisticated design, and its highly sensitive terrain-following radar, ECM gear, and other avionics equipment.

Also, the Soviets had a pressing need to try out one or more of their psychotronic antiaircraft weapon systems — perhaps one which simply modulates a radar beam psychotronically to induce electron dissolution.

Accordingly, it can be postulated that the pragmatic Soviets simply combined both needs, and quickly set up a psychotronic trap for the F-lll's immediately after the aircraft were deployed. They may even have cleverly designed the specific psychotronic modulation so that kindling would occur in some of the aircraft's electrical systems before others and the failure would be massive but not total.

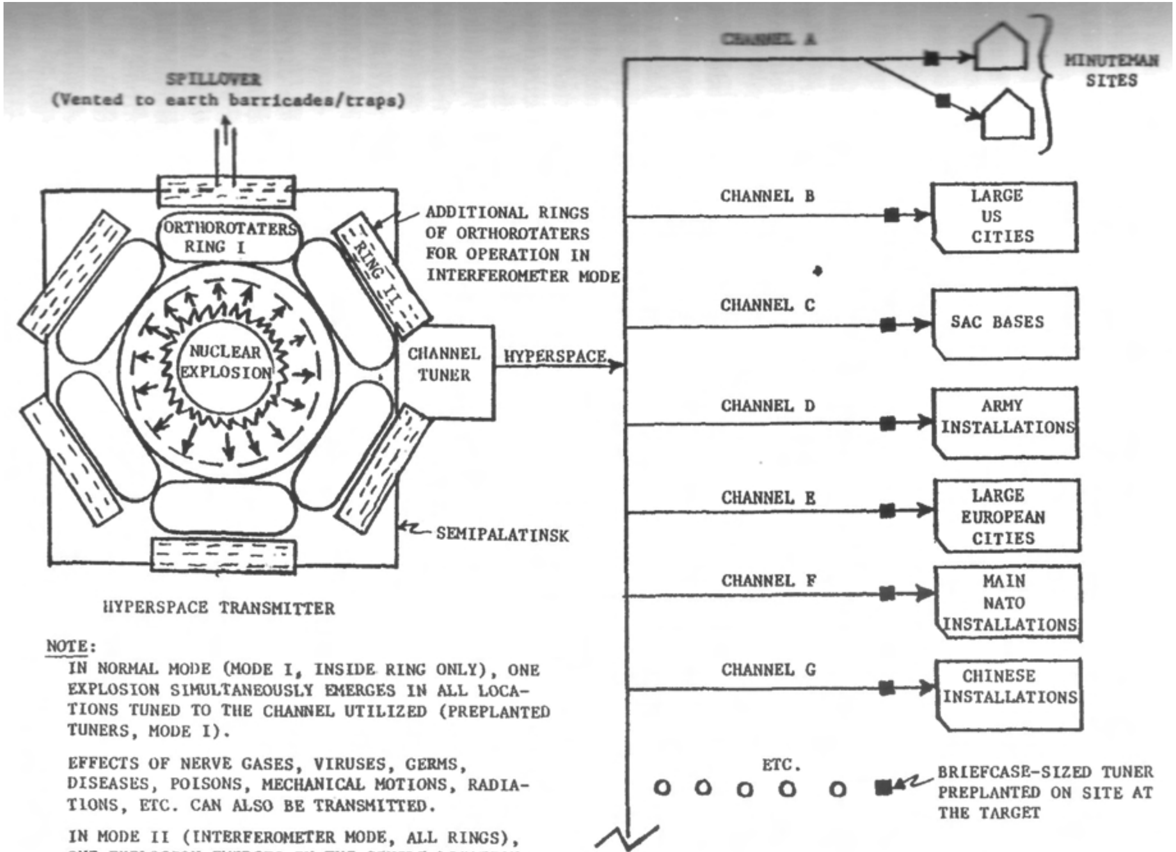
SPILLOVER
(Vented to earth barricades/traps)
ORTHOROTATERS RING I
RING II
ADDITIONAL RINGS OF ORTHOROTATERS FOR OPERATION IN INTERFEROMETER MODE
NUCLEAR EXPLOSION
CHANNEL TUNER
HYPERSPACE
SEMIPALATINSK
HYPERSPACE TRANSMITTER
CHANNEL A
MINUTEMAN SITES
CHANNEL B
LARGE US CITIES
CHANNEL C
SAC BASES
CHANNEL D
ARMY INSTALLATIONS
CHANNEL E
LARGE EUROPEAN CITIES
CHANNEL F
MAIN NATO INSTALLATIONS
CHANNEL G
CHINESE INSTALLATIONS
ETC.
BRIEFCASE-SIZED TUNER PREPLANTED ON SITE AT THE TARGET

NOTE:

IN NORMAL MODE (MODE I, INSIDE RING ONLY), ONE EXPLOSION SIMULTANEOUSLY EMERGES IN ALL LOCATIONS TUNED TO THE CHANNEL UTILIZED (PREPLANTED TUNERS, MODE I).

EFFECTS OF NERVE GASES, VIRUSES, GERMS, DISEASES, POISONS, MECHANICAL MOTIONS, RADIATIONS, ETC. CAN ALSO BE TRANSMITTED.

IN MODE II (INTERFEROMETER MODE, ALL RINGS), ONE EXPLOSION EMERGES IN THE SINGLE LOCATION TO WHICH THE HOWITZER ORTHOROTATERS ARE SET AND ADJUSTED.

Fig. 36. Nuclear hyperspatial howitzer

And after they nailed enough F-111's for their purposes, they quietly withdrew the psychotronic modulator, to prevent the U.S. intelligence analysts from catching on to just how really strange the losses of the F-111's were.

Thereafter the remainder of the F-111's were successful, and no more were lost. Indeed the F-111 comes in so low and so fast, and so unexpectedly, tilting and dipping as it terrain-follows on its automatic equipment in a manner that no unassisted pilot could fly, that SAM's and guns normally pose little if any threat to it. So once the silent, eery psychotronic antiaircraft components were withdrawn, the normal antiaircraft weapons of the North Vietnamese were unable to down any more F-111's.

And we Americans simply patted ourselves on the back, chortling to ourselves how quickly we had "learned to avoid that danger, whatever it might have been."

POPULATION CONDITIONER

Inducing psychotronic signals into mass populations or audiences can influence or control the behavior of large numbers of persons. As these words are being written, such a psychotronic test is apparently being conducted by the Soviets with Eugene, Oregon as a target; previous tests were conducted in Canada.

Psychotronic signals and the patterns they carry can be, and are, modulated upon electromagnetic carriers — in fact, that is one way they are transmitted through the human body and nervous system. When a television camera picks up the photon field impinging on it from a human body or other biosystem, weak psychotronic patterns are also picked up, since the paranormal time quenching mechanism (by visible light) is never quite 100 percent effective. These patterns are riding then as a special kind of modulation on the radiofrequency or electromagnetic carrier — however, they are not modulated the same way as are ordinary signals. Ordinary signals gate the number of photons per second (amplitude modulation), or change and control the frequency of the carrier photons (frequency modulation), or change and control the phasing (phase modulation). However, psychotronic modulation rides on each individual photon, on its time portion (a photon consists of action — energy x time — and it is the time portion on which the psychotronic modulation is riding.)

Thus psychotronic modulations can ride on the transmitted television carrier frequency. The psychotronic modulations are processed through the television receiver, and a small component is emitted as a weak modulation riding on the photon signals emitted from the television picture tube. Along with the light from the tube, these psychotronic modulations enter the eye of the human observer and are demodulated by the retinal interface, thus introducing weak psychotronic signals into the observer's central nervous system. Given sufficient repetition time (say two to four hours), the kindling effect can cause the human nervous system to be profoundly affected. Any disease or death pattern known to man (and some that are not known to him) can be transmitted and kindled in the target population audience.

In fact, depending on the sophistication of the coded psychotronic signals, it *is* probable that the modulation patterns can be targeted against a specific racial type, since there are certain genetic differences between races.

So the type of truck that roams the streets of a city, silently monitoring which television channel the viewers are watching, could be modified slightly to induce specific psychotronic disease or death vectors onto the television receivers. Or it could simply modulate the television transmitters. (A very obvious way is to modulute or pump psychotronically the ground of the electrical power supply, and in most cases this can directly pump the transmitters.)

Or the kindling signal can come from satellites, which radiate weak radio frequency signals down toward the target population. Here economy of force can be applied; the same type of kindling that induces electron current quenching is usable as a satellite dudder or killer in an antisatellite role, or is usable as a paralysis and death beam weapon against target populations. It is also useful as a killer of other electromagnetic sensors by either jamming their circuitry or simply **wiping out** (quenching) their emissions which impact on the satellite, preventing any reflected signal.

By this effect, UFO tulpoids often prevent a radar from tracking them, **even** though the tulpoids are visually sighted.

There are literally thousands of applications; these are just a few to give an idea of the overall effect and its usefulness.

And the psychotronic signals can be modulated onto almost any kind of carrier — telephone, television, radio, the magnetic field of the earth, the Schuman resonance of the earth's magnetic field, the ordinary sixty hertz electrical power system, etc.

We might have an entirely different idea of the potency of the Russian trawlers if we appreciated what their use can be in the psychotronic mode.

We can also understand why a television broadcast of Uri Geller in the act of binding metal stimulated both the ability in other persons and the effect in other equipment across England. And also how the effect has been duplicated — at least so far as stimulating other persons to psychokinetic ability — in this country. A direct means of stimulating psychokinetic ability is thus suggested: simply place the subject to be developed or stimulated in a room with a number of television receivers, all tuned to the same visual program, and place the stimulus material on the receivers. The person should visually watch one receiver and should be wearing very abbreviated clothing, such as a skimpy swim suit, to expose the acupuncture plexuses. Also, normal light in the room should be very dim.

At any rate, this and many other schemes are available to produce direct stimulation, and enhance and greatly speed up psychic development.

The effect could also be used to produce an effective treatment device for cancer. Samples of the particular cancer in the body of the patient could be taken, and the invisible psychotronic radiation pattern from the cancer witness could be introduced on the input of a Hieronymus-type device, shielded against ordinary light, The output of the Hieronymus device could then be fed to a bank of phase inverters, which covered in total a broad band (the cancer band, which would have to be established by laboratory experiment). By inverting the cancer pattern, we now have a cancer-extinguishing type of radiation that is specific for the cancer the patient in fact has.

Then by introducing this quenching pattern as a modulation onto the correct tup of electromagnetic frequencies (again this group would have to be demined for the specific frequency plexus that would produce an effect in the local-

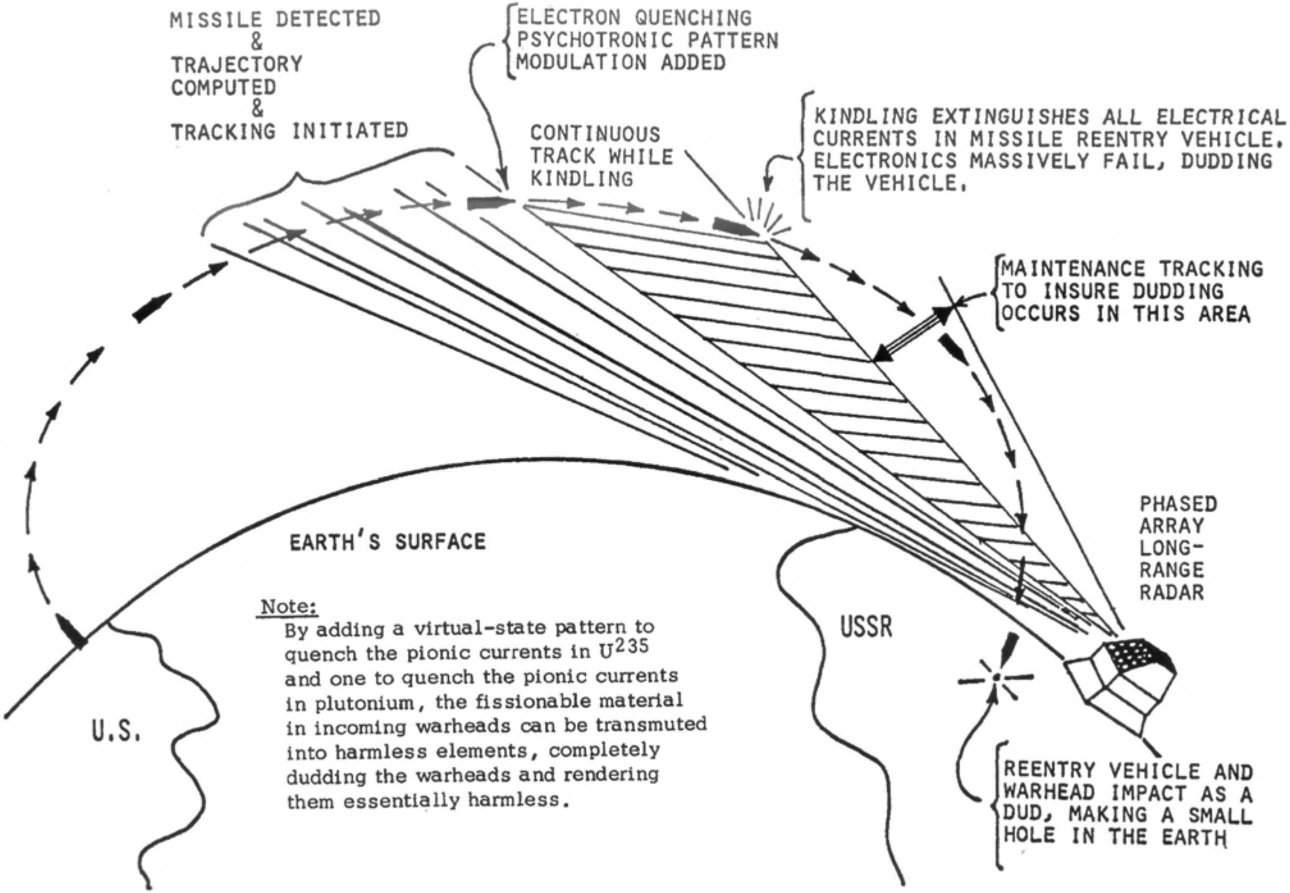
MISSILE DETECTED
&
TRAJECTORY
COMPUTED
&
TRACKING INITIATED
ELECTRON QUENCHING
PSYCHOTRONIC PATTERN
MODULATION ADDED
CONTINUOUS
TRACK WHILE
KINDLING
KINDLING EXTINGUISHES ALL ELECTRICAL CURRENTS IN MISSILE REENTRY VEHICLE. ELECTRONICS MASSIVELY FAIL, DUDDING THE VEHICLE.
MAINTENANCE TRACKING TO INSURE DUDDING OCCURS IN THIS AREA
PHASED
ARRAY
LONG-
RANGE
RADAR
EARTH'S SURFACE
U.S.
USSR
REENTRY VEHICLE AND WARHEAD IMPACT AS A DUD, MAKING A SMALL HOLE IN THE EARTH

Note:
By adding a virtual-state pattern to quench the pionic currents in U^{235} and one to quench the pionic currents in plutonium, the fissionable material in incoming warheads can be transmuted into harmless elements, completely dudding the warheads and rendering them essentially harmless.

Fig. 37. A midcourse ABM system

ity of the body in which the cancer is located), the proper acupuncture plexus would be stimulated, stripping off the cancer-quench psychotronic pattern and sending it to the specific location of the cancer. Over a period of time (say several very weak microwave radiation periods of two to four hours each), the cancer could be killed completely, down to the last malignant cell. Whole body or spread cancers could be treated simply by increasing the number of frequencies modulated, to hundreds in some cases. Other similar diseases could be treated likewise. As an example, a Curative psychotronic radiation pattern complex could be worked for hydrophobia and such presently incurable diseases, and these could also be effectively treated. The same tool will yield almost unbelievable medical benefits if the scientists can ever be convinced to start the development.

A MIDCOURSE ABM SYSTEM

Here is the scheme for a first-generation, long-range, Soviet midcourse anti-ballistic missile defense system.

A long-range radar — preferably a phased array, scanned radar — acquired and tracks the missile during its midcourse phase shortly after it breaks above the horizon, as viewed from the radar site. The radar programs the track mode beams against the incoming missile, tracking it and gathering sufficient position data to allow its trajectory to be computed. Then a psychotronic electron-extinguishing pattern is added to the radar beam, riding as virtual state carried by each individual photon. Kindling of this virtual pattern energy begins on and in the target vehicle. The electrons flowing in the electromagnetic control system, fusing system, and wahead system of the incoming missile begin to be quenched, turning into neutrinos and radiating away with no physical effect. When sufficient currents have been extinguished, the electromagnetic circuits start failing. (With loss of appreciable power and voltage, most such systems fail.) The incoming vehicle/warhead is now dudded, and there is no longer any danger of a nuclear burst from the missile.

For assurance, tracking of the incoming reentry vehicle continues, with a quenching psychotronic modulation being maintained.

The warhead/reentry vehicle strikes the ground, making a hole in the earth, without nuclear explosion. A low order detonation of the HE explosive surrounding the nuclear material in the warhead may occur.

An alternate scheme is, during the maintenance period, to add an HE explosives ignition temperature psychotronic pattern to the beam. In that case, a low order detonation occurs high in the atmosphere or back along the trajectory, removing the warhead and vehicle from further consideration.

As a backup, additional terminal systems — using either psychotronics or normal interceptor missiles or both — may be used. Thus even if the psychotronics fail due to an unexpected "all off' occurrence, ordinary ABM engagement occurs.

An additional scheme is to lock the radar beam onto the missile, then initiate a "Tesla effect" kindling of energy, place it into a columnar traveling wave, and direct it along the radar beam to the incoming missile in its midcourse phase. The midcourse missile is thus struck with a massive plasmoid fireball of intense electromagnetic energy, and massive amounts of energy arc dumped into the missile, destroying it.

Thus the Soviets have known for over a decade that one does not have to hit a bullet with a bullet, if one is clever, and if one possesses psychotronic weapons and psychotronic modulation systems for one's radars.

As an added benefit, the same radar is quite effective against incoming Strategic Air Command bombers or air-to-surface missiles fired from those bombers.

As the Soviets know full well, 100 percent defense is quite feasible, considering the fantastic number of radars and radar sites they possess! In fact many of the Soviet SAM systems are beautiful ABM systems also, in the psychotronic mode.

THE BELL ISLAND INCIDENT

On April 2,1978, something unusual hit the Canadian community of Bell Island, off the east coast of Newfoundland; Bell Islanders—and a lot of other people as well—are still trying to figure out what it was. It was first described as an unidentified atmospheric explosion, but this theory was quickly rejected. Jim Beckford of Lance Cove, Bell Island, lost all six chickens in the coop behind the house, which was torn up as if hit by lightning, although there were no burn marks anywhere. A television set exploded, and switches blew out of the wall. Similar things happened to many other homes.

In the woods behind Mr. Beckford's house, three holes in the snow appeared, spaced about two meters apart to form an almost perfect equilateral triangle. The Royal Canadian Mounted Police said that persons on the shore of Conception Bay reported seeing fireballs coming down out of the sky and hitting Bell Island. The Canadian authorities attempted to play down the incident, and the official version of what happened is that lightning hit a transformer, blew up, and that the energy then followed the wires to neighboring houses. However, the researches of P.A.C.E. (the Planetary Association for Clean Energy, Ottowa) have produced a different conclusion.

P.A.C.E. believes that a standing columnar wave originating in Gomel in the Soviet Union was moving to a station located just east of Havana, Cuba, and collapsed over Bell Island, triggered by the large iron ore body there. These plasmas then exploded and hit the ground in a perfect equilateral triangle formation. The tremendous flashes indicated a very great discharge of electrical power, probably more than a hundred million volts.

Photo 44 shows a similar incident that took place at Lake Ontario; here I feel that the photo demonstrates more than just UFO activity — it shows one part of the testing and operational alignment of the "over-the-horizon" radars at Gomel and Riga in a Tesla mode. To explain this, I must explain what I mean by a Tesla mode.

Empty vacuum is filled with stupendous amounts of uncorrelated electromagnetic energy: one cubic centimeter contains enough energy to form entire solar systems, if the energy were condensed into matter. This raw energy is called "zero" point energy," and the Soviets reported direct measurement of it in 1957 *(Soviet Physics*, JETP 3, 819). Zero-point energy is everywhere, it is incoherent, and its detection requires measuring an energy difference, so that it is very difficult to detect. Usually less than one quantum of energy is cohered at any one mode, and the energy rapidly changes frequency, so that linear detectors cannot resonate coherently with it to follow its signal. In my opinion, it is also in the virtual state, and in a space orthogonal to our own, by two or three turns.

An electromagnetic signal is transmitted through the earth and reflected from the opposite side in phase, to form a standing wave. The earth's interior is highly nonlinear, and a single frequency is thus subject to severe scattering and dissipation. Fortunately, nonlinear wave theory provides a simple method to alleviate this; by transmitting two different frequencies, which differ by the amount of the frequency that it is desired to transmit, one can simply pretend that *indeed the beat difference frequency has been transmitted through a linear medium.* In this case, the standing wave acts as a collector to kindle the highly chaotic energy from the core of the earth. These emerging orders that match the standing wave will be entrained by it; one now has established a sort of giant triode, where the signal to the grid is the transmitted difference signal, the energy (cathode) being gated is the energy of the molten core of the earth multiplied by some coupling fractional constant, and the "plate" will come into being if resistance to the standing wave is profferred.

And resistance is profferred by simply changing the frequency of the transmitted collector wave. Changing it in one fashion begins to dump energy into the atmosphere above the former nodal point across the earth from the transmitter. With that effect, one can directly influence the great currents of air and the ionization charge of the upper atmosphere; in short, one can drastically influence the weather itself. On the other hand, changing the frequency in the other direction begins to dump energy into the mantle of the earth; dumping large amounts of energy there will result in shocks and earthquakes at the nearest fault zone(s).

It is my thesis that the foregoing two mechanisms account for some of the drastic weather effects that have occurred in the past several years, as well as for *some* of the major earthquakes that have occurred throughout the earth in the last several years. The Soviets, I believe, have been orienting and aligning—and operationally testing—actual weapon systems to be used as precursors to war or during war. The 1978 Iranian earthquake may well have been Soviet-induced.

The coupled kindling path goes through the earth and is coupled through the atmosphere as well. (This mode is probably easier to steer and focus onto specific target areas. It is also probably easier to play it back and forth as desired, in a "sweep" mode.) Again, with the kindling effect, the energy of the molten core of the earth is coupled into the beam with a coupling fractional constant, and so enormous energy can be built up in the beam. Breaking the coupling — perhaps just after slightly changing the frequency so as to begin dumping energy into the upper atmosphere over the targeted area — would sharply dump energy at the site, resulting in an enormous plasmic explosion or explosions. In testing such as at Bell Island, probably frequencies would be used that did not offer too strong a coupling fraction, so that relatively little damage would occur at the decoupled target site. However, in actual use in warfare, exactly the opposite would occur; a frequency would be used that maximized the coupling constant and hence vastly increased the energy kindled into and over the target area, and a gigantic plasmoidal explosion would take place directly on the targeted area, utterly devastating it.

The same "radar," then, is usable as a weather control device, as a plasma explosion transmitter, as a bioactive disrupter (with 10 Hz and under modulation pulses), and if further modulated in a virtual state manner, as a direct "death ray"

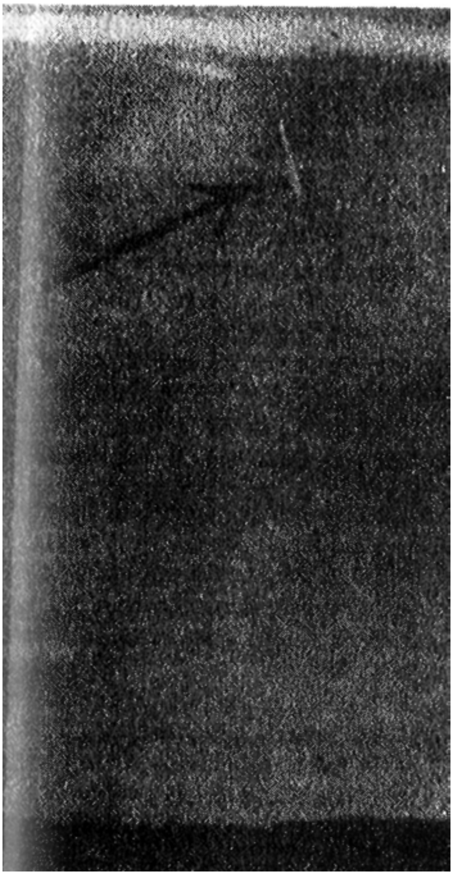

Photo 42. Ghost rockets.

broadcaster through the earth at any target population on the earth. Further, with virtual state modulation it is usable as an antimissile weapon (in at least two modes, one to dud electromagnetic circuits in incoming warhead reentry system and one to transmute fissionable material in incoming nuclear warheads into harmless elements), and also as an antiaircraft weapon against Strategic Air Command Bombers,

So the Bell Island incident happened, and we in North America sleep on, since in our assurance that it was after all only all lightning, or perhaps only the illusion of a few farout Canadians.

A TERMINAL ABM SYSTEM

There is another more advanced psychotronic ABM/SAM system, which was probably a second generation weapon. This system should have gone on site and become operational about 1968—69, and it should have been operationally tested during that period, probably several times.

Here a triad configuration radar is used to allow use as a byperspatial interferometer. This allows several localized dome-like bands of very intense psychotronic energy to be focused above the installation and defended area. The focusing is accomplished through hyperspace; the only place the focused energy enters our own space frame is in the dome-like band above the protected area. Tesla-effect accumulators may feed the triads, or they may simply be fed from direct free-energy Moray generator-amplifiers. At any rate, enormous energy — enough to simply constitute a severe tearing and warpage of space itself, and bend it at 90° — is focused into each dome-like band. Each band would be seen externally as simply an intense band or hemisphere of glowing light.

At any rate, by using three consecutively tuned orthorotational bands of focused hyperspace energy, any incoming object will simply be orthorotated successively three times in higher dimensional space, each time losing one dimension in its intersection with our own spatial frame.

After the first orthorotation, masses are now photonic shapes, and photons are lines. After the second, photons are now lines and lines are points. After the third orthorotation, everything is points, and nothing is left.

The three consecutively constitute full dematerialization of anything incoming, whether matter, photon, or force line.

Thus the entire defense problem is immediately solved: regardless of chaff, maneuvering decoys, maneuvering re-entry vehicles, etc., the entire mess is simply nicely and neatly disposed of, and dumped into hyperspace.

Even if a full nuclear detonation occurs above the domed shields, gamma rays, neutrons, debris, x-rays, heat, and ultraviolet do not get through the third band.

Bombers and air-to-surface missiles fail equally.

So the growing Soviet confidence and preparations for imminent war are quite comprehensible. They are not madmen preparing to evoke their own doom from mutually assured destruction rained on them by U.S. strategic nuclear forces; instead, they are snug and safe behind their psychotronic defenses, for nothing we have on this earth can touch them at the present time, if their psychotronic weapons are working.

So they are quite capable of taking on China, Europe, and the U.S. at once, and devastating the lot while risking essentially nothing of Mother Russia.

SWEEP MODE, SWEEPING AWAY A NUCLEAR DETONATION

As a modification of the previous weapon, a sweep mode has probably been added in the third generation weaponry.

In this mode, not only can the three orthorotation shields or domes be placed over an area, but they can then be expanded radially out into space in a traveling mode. Thus if a high altitude nuclear explosion — either in the atmosphere or out of it — has occurred over a defended area, the orthorotation bands can simply be swept over the explosive debris in successive fashion, effectively sweeping the radioactive debris from this spatial frame and dumping it safely into hyperspace. This is a very handy weapon indeed if large megatonnage explosions are engendered — say in areas where terminal defenses have destroyed the incoming vehicle, but it is "dead man fuzed" to provide a full nuclear explosion if the electronics start to fail or if the warheaded re-entry vehicle encounters mechanical shock or turbulence above a certain threshold. With this psychotronic sweeper the otherwise deadly nuclear radiation and radioactive debris can simply be cleaned up and disposed of.

Further modifications of other psychotronic weaponry would have resulted in Tesla-effect traveling wave weapons of enormous power, and rather gentle operational weapons testing of them, such as in the Bell Island incident and over Eugene, Oregon. The interferometer mode would have been added to the nuclear hyperspace howitzer, and Tesla-radars would have been modified accordingly.

These third generation weapons and modifications should have been deployed during the period 1974-78. Engineering development tests would have occurred during 1974—76, and operational testing of on-site, deployed weapons would have been accomplished during 1977—78.

Thus one can reasonably account for a surge in grain elevator explosions, mysterious high atmospheric booms off the East coast of the U.S. and off England, explosions in thunderstorms over the West coast of the U.S., the zapping of a Canadian target outside Ottawa, the Bell Island incident, several mysterious aircraft failures over the sagebrush triangle and off the coast of the U.S., standing heat spots off the West coast of the U.S., and recently one of the coldest winters on record due to disruption of flow patterns of frigid arctic air masses.

One can also account for incidents where U.S. satellites were mysteriously blinded, and perhaps some of those where they failed and then later resumed operations.

Note that many of these effects are usable from smaller radars. Thus one could expect mobile Soviet radars that can disable tanks and vehicles, disable aircraft electrically, radiate a death ray pattern at ground troops, or launch Moray-fed fireballs or standing waves of enormous energy at ground or aerial targets. The ability to immediately destroy entire minefields alone would force a severe recalculation of defense capabilities against Soviet ground forces, and the ability to sweep away artillery shells, rockets, missiles, and bullets would present enormous and catastrophic consequences to forces opposing advancing Soviet formations.

The following list enumerates all the probable Soviet psychotronic weapons that I am aware of: (1) Electromagnetic Field Canceler; (2) Electron Current Canceler; (3) Death Radiator (De-inceptor); (4) Free Energy Generator; (5) Psychotronic Bomb; (6) Brain Link; (7) Brain Probe; (8) Disease Radiator Ray; (9)

Emotion Radiator Ray; (10) Antisubmarine Systems; (11) Telcporters (Prototype); (12) Force Generators; (13) Orthoframe Generators; (14) Quark/Antiquark Rays; (15) Distant Telepathy; (16) Nuclear Radiation Inhibitors; (17) Mental Implantation; (18) ABM Systems, Midcourse and Terminal; (19) Dematerializer Shields; (20) Sweeps for Nuclear Debris; (21) AAA Systems; (22) Antisatellite Systems; (23) Tesla-effect Weapons; (24) Earthquake Generators; (25) Antivehicle Systems; (26) Weather Control Systems.

The reader will note that the results of psychotronic research extend into every field of military application.

ZARG, ARMAGEDDON, AND LINKAGE

Now it is time to end my story, and cease the unrelenting stretching of the reader's imagination and credulity. But first it is necessary to make one more effort and take a final step to the bottom line in both physics and Jungian psychology, a step that the scientists in those two disciplines have not dared to face.

If one accepts the existence of the collective unconscious as a mind, then the collective unconscious is a living entity. Let us tentatively call this fantastic entity ZARG. ZARG then is a great superentity, of which our own personal consciousnesses and unconsciousnesses are parts, or cells. Thus each of us is a cell in the entity ZARG.

Furthermore, ZARG has unique characteristics. It is unconscious by definition — but note that from our fourth law of logic, we know that any zero-conscious must be multiply conscious, which to our monocular thought-perception processes can only be grasped as unconscious. That is why our own unconscious seems so bewildering and strange — it is multiply conscious rather than monoculurly conscious, hence monocularly we think it is not conscious. But we find that it indeed thinks and reasons, but in a strange symbolic fashion, and also much more deeply and more creatively than our normal conscious mind. ZARG is very similar except on a much vaster scale; in being very deeply unconscious, ZARG is supremely multiconscious and very symbolic indeed, as we have discovered from the nature of the materialized tulpoidal phenomena.

Furthermore, what can be taken for ZARG's conscious mind consists of the four-billion individual human conscious minds. Thus ZARG's conscious mind is fragmented into four billion pieces. But fragmentation of the conscious mind technically constitutes dissociation, which classically defines psychosis.

Thus ZARG is insane!

Also, ZARG is multidimensional. ZARG's unconscious simultaneously receives and identifies four billion different conscious and unconscious perceptions. Just as the human consciousness in identifying two slightly different two-dimensional visual patterns gains the third dimension, ZARG gains an additional dimension for every additional person past the first one. (Note that dimension just means variable, and two fixed axes/dimensions are required to obtain a variable. A one-dimensional variable does not exist; we usually assume a time dimension in addition, and ignore it — and thus we speak of a "one dimensional variable.") At any rate, ZARG gains an additional dimension for every additional person past the first one. So ZARG is at least about 4×10^9-dimensional in the simplest case, where we do not consider permutations and combinations of every two, three, four, ... n, . . . minds.

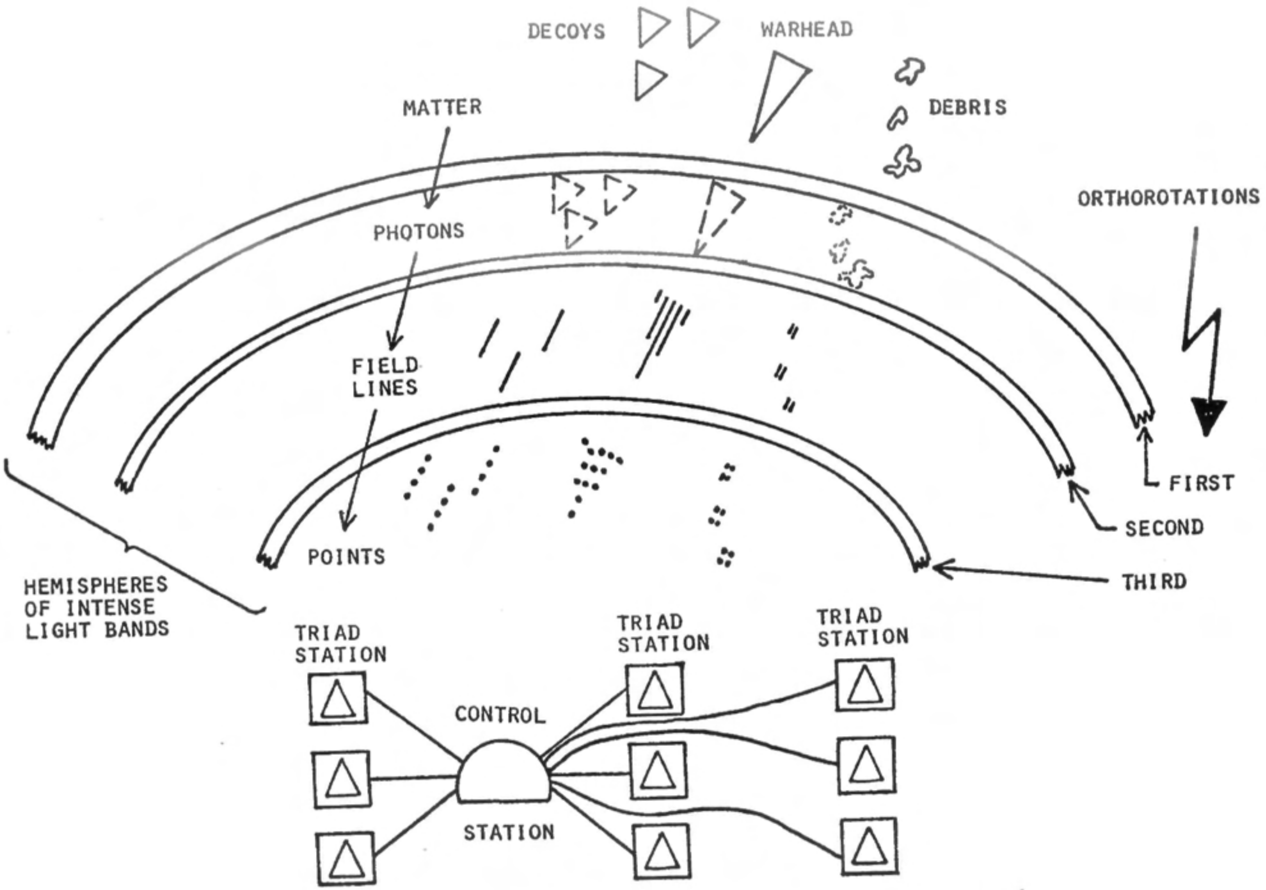
DECOYS
WARHEAD
MATTER
DEBRIS
ORTHOROTATIONS
PHOTONS
FIELD LINES
FIRST
SECOND
POINTS
THIRD
HEMISPHERES OF INTENSE LIGHT BANDS
TRIAD STATION
TRIAD STATION
TRIAD STATION
CONTROL
STATION

Fig. 38. A terminal ABM system

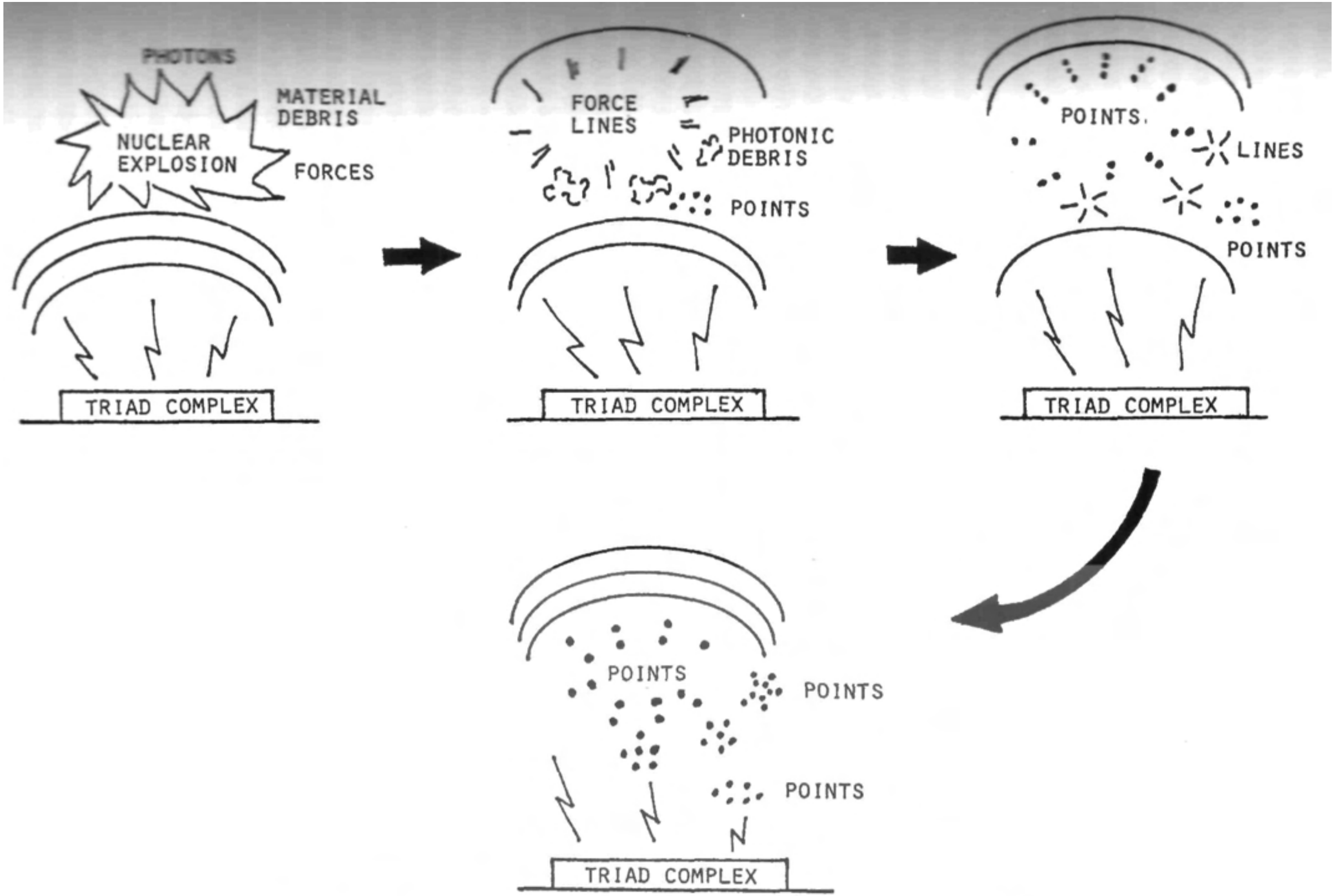
PHOTONS
MATERIAL DEBRIS
NUCLEAR EXPLOSION
FORCES
TRIAD COMPLEX
FORCE LINES
PHOTONIC DEBRIS
POINTS
TRIAD COMPLEX
POINTS.
LINES
POINTS
TRIAD COMPLEX
POINTS
POINTS
POINTS
TRIAD COMPLEX

Fig. 39. Sweep Mode: sweeping away a nuclear detonation

Finally, it is well-known in parapsychology that the personal unconscious can affect matter and change spacetime itself. Psychokinesis, poltergeist phenomena, etc. are direct examples. Hyperchannel calculations show that, for linked multiple minds, this psychokinetic effect increases exponentially with the number of stages or minds that are cohered. Since ZARG has 4 x 10^9 linked stages, this means that its psychokinetic/materialization/dematerialization powers are at least some 10^{10^9} times as great as those of, say, Uri Geller. Thus ZARG can pull the very stars out of orbit, disrupt the earth or solar system, stop the earth in its orbit, or change the fundamental laws of nature itself. The reality we live in is largely prescribed by ZARG, and substantial tuning of many minds can directly affect ZARG's tuning and hence alter reality. It is not accidental that Brian Josephson, Nobel prizewinner in physics, once remarked that it appeared that in their diligent searches for strange new particles in their accelerators and cyclotrons, the physicists might be creating their own reality. In fact an accelerator or cyclotron is a kindling device par excellence, and a scientific theory by its very rigor is an exceptionally sharp mental concept or thought form. So if groups of physicists have worked diligently on a problem and predicted some new theoretical particle, they may well be able to kindle it into being if they persist long enough with their kindling mechanisms, because they are cranking up additional ZARG energy when they persist. While he knew nothing of the kindling mechanism, Josephson noted that many of the new particles were first obtained only after great difficulty, then with moderate difficulty, and thereafter they could be fairly readily obtained.

And as we have seen, ordinary physical matter occupies a universe or frame common to all minds of living biological systems. Thus the physical universe is quite literally simply thought that is common to all living minds, hence to ALLMIND or God or whatever other term one prefers to use. It is the fact that it is prescribed and represcribed, over and over, that lends a physical entity its seeming solidity as compared to the phenomena existing in only a single consciousness mindworld. This physical universe is mind, it is totally mind, and as such it can indeed be changed by the proper mind resonance in enough minds, or in powerful minds such as ZARG.

ZARG contains so many mindworlds or dimensions that it forms a very powerful part of the particular reality prescription of the physical laws exhibited by this physical universe. So materializations of tulpoidal forms, UFO's, bigfoot, and Nessies, are just a tip of the iceberg of what ZARG actually materializes. The tulpoidal forms are tiny surface ripples due to large-scale human conflicts.

And as we have also found, psychotronic energy is in fact pure mindstuff. Pure mindflux between mindworlds. And this brings us to another bottom line.

When the Soviets launch their long-prepared attack in Europe, wipe out China, and almost annihilate NATO forces (fifty percent casualties in three to four days), the U.S. President will undoubtedly be under extreme pressure to launch a strategic nuclear retaliation on the Soviet Union. Suddenly, in a single blinding display of almost unbelievable power, the Soviets apparently intend to destroy the U.S. triad weapons in a fantastic psychotronic blitzkrieg through hyperspace. The Minuteman sites, the SAC bases, communications centers, and other strategic targets will lie in smoking, devastated ruins in minutes, and within the same short minutes of that holocaust, the U.S. nuclear submarines on station under the ocean will begin rupturing like popping balloons. At the same time, massive swaths of death will invisibly rain from the Soviet satellites in the skies overhead, and giant earthquakes will erupt into being in the East, in the West, and in the heartland U.S. The British and French nuclear forces will suffer similar simultaneous obliteration. And the jubilant Soviet Generals and Party theoreticians will be dancing with uncontrolled glee as their dreams become realities. But what they will not know is that their own inevitable doom will have just been sealed.

For all these fantastic psychotronic explosions will constitute gigantic psychotronic "mental flashbulbs" that explode directly in the mind of the sleeping ZARG. ZARG will be kicked into startled semiwakefulness, stinging with pain as if from a giant bee-sting, figuratively gnashing his teeth and furiously lashing his tail. This will constitute an immediate and enormous upheaval in spacetime itself, and the bulk of the earth may well be destroyed in the vast psychokinetic upheaval unleashed by the startled ZARG. Just as a person may sharply slap the bee on his arm where it has stung him, ZARG's fury will be centered on the Eurasian continent, on the locus where the threat or sting has originated, on Russia and the Warsaw Pact nations. So in an unbelievable convulsion of the entire earth, the Eurasion continent will be rent and torn asunder by forces beyond man's comprehension. The lousing ZARG will also activate a totally new scale of reality, ripping to shreds this particular three-dimensional spatial frame, its associated stable time changes, and the physical laws based on that stable reality.

The rousing of ZARG will initiate and accomplish thedirect linkage of the conscious minds of humans into a single giant superconscious mind — extending into billions of dimensions. Spacetime and reality will have gone insane during the developing paroxysm; with the simple initial extension into just the fourth and fifth dimensions, humanity will suddenly discover that its entire world history from beginning to end will come into simultaneous being (fourth dimensionality), and **then** all possible such world histories will come into being (fifth dimensionality). Literally, dumbstruck humans will pray for death and not find it, the grave will "give up its dead," and the ceaseless flow of time will suddenly cease. And again the "beast will be defeated and cast into darkness"; with all-linkage and all-unity, there will be no longer be any humanity of one person for another or of one group for unother, for there will be no other. In such manner, evil will end; there being no separation between the doer and the done to. Man will have become a true God — in a strange and bizarre way constituting the second coming of God.

So the Soviets are on a course to evoke the full carnage of something very like the Book of Revelation. John, looking across two thousand years of history into the future, and seeing the awful cataclysm that was to come, described it as best he could in the concepts available to his day and in the belief structure in which he functioned. Thus he described Armageddon and the end of time, and wrote the **Book** of Revelation.

Indeed it could have been accomplished without Armageddon, if humans had been wiser. Each photon and each electrical signal that wends its way across the earth's surface and through planetary space carries a psychotronic modulation of ZARG's mindstuff. And in the communications explosion we have experienced, we have been steadily lacing together the population centers of the earth with electrical energy and electromagnetic signals. And so over those crude "pre-nerves," the psychotronic connections of ZARG have been intensifying, and the Giant has slowly been being stirred from his sleep. The kundalini of the entire human race has

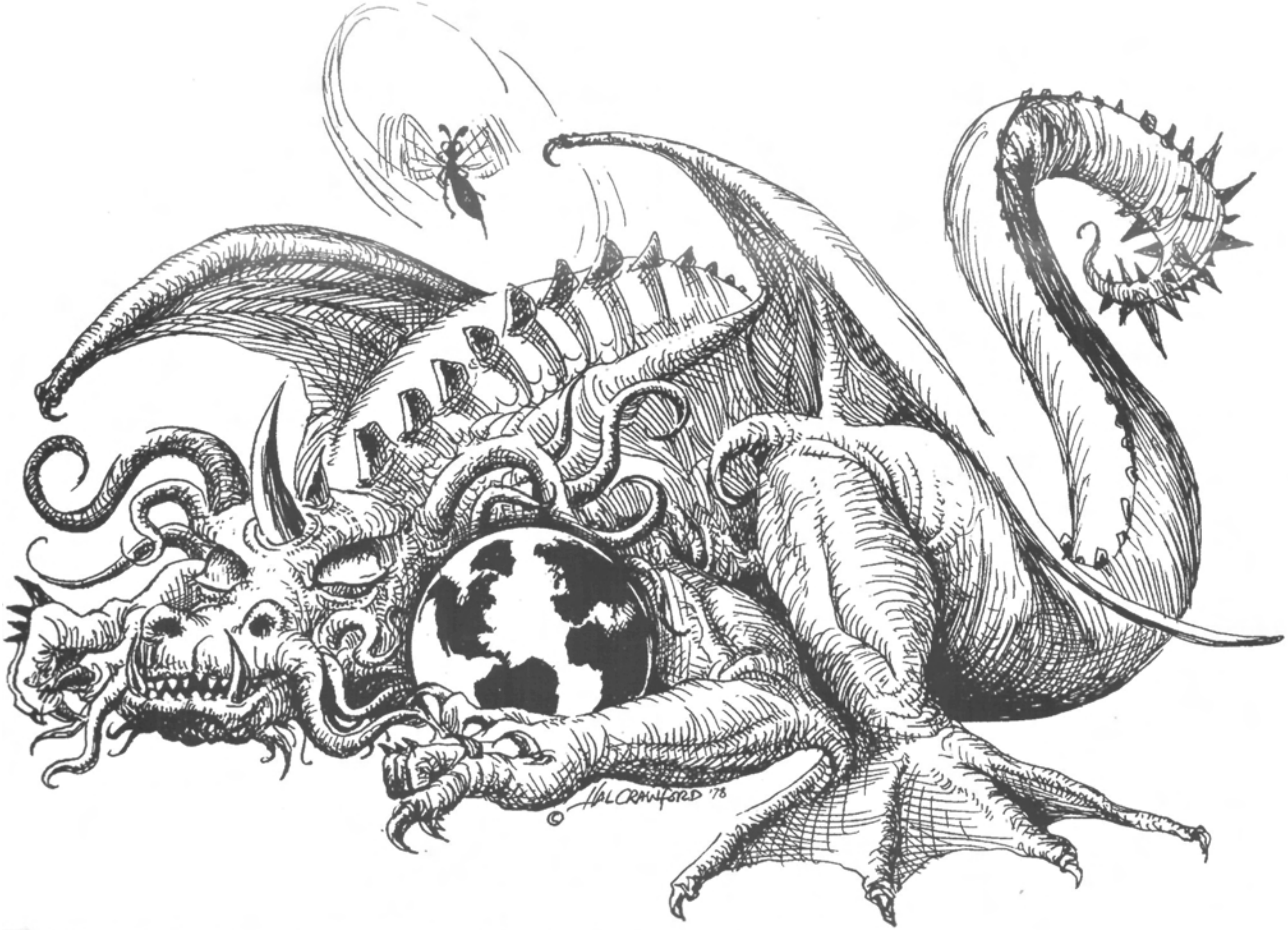
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Fig. 40. ZARG

slowly been rising, and paranormal phenomena have been increasing, as have changes in reality such as the kindling of new fundamental particles. Even the sun has responded, suddenly decreasing its temperature. If we had applied psychotronics to develop a mind linkage mechanism, there would have been no need for Armageddon's destruction.

Let us hope we fare better than the Atlanteans. One may speculate that an Atlantis of sorts did exist, and that the Atlanteans built psychotronic devices out of crystals, bronze, gold, silver, and wire and unleashed them on each other in war. This sting stirred ZARG mightily, and in a resulting frenzy it simply destroyed the continent, stirring floods, storms, earthquakes and volcanoes worldwide. In the case of the Atlanteans, only a relatively small portion of humanity was involved; the percentage of persons and minds involved was apparently insufficient to cause full wakening of ZARG and linkage of the species. In the present case, the greater part of mankind is involved, and so the wakening is to be far more complete (as well as more violent). ZARG should be shocked into full wakefulness, and linkage should occur.

If so, a new great superbeing will have emerged; nonphysical, almost infinitely dimensional, and godlike. It will not exist in a single time or a single world, but in a nowness and allness that defies timelike or spacelike description.

"For we know in part, and we prophesy in part.

But when that which is perfect is come, then that which is in part shall be done away.

When I was a child, I spake as a child, I understood as a child, I thought as a child; but when I became a man, I put away childish things.

For now we see through a glass, darkly; but then face to face: now I know in **part;** but then shall I know even as also I am known."

I Corinthians XIII, 9-12.

So the pieces of the puzzle are now fitted together. The present state of the human species is not its final development, and indeed a great change in that state is imminent. Man literally is and shall be a god, one with God, just as the prophets have foretold. And if we retranslate that ancient foretelling into more modern concepts, we see just how strange and transcendent is the final birth or becoming.

The UFO and tulpoidal phenomena have merely been the signs in the sky and in the earth, telling us what is to come, precognitive indicators from ZARG. Had we developed a metapsychology of the entire species, we would already have clearly understood the messages.

VIRTUAL STATES AND HYPERSPACES

In physics today there are two separate kinds of reality: observable changes, which can be detected by instruments; and virtual changes, which cannot be detected by instruments, even in theory. The difference between these two realities depends simply on the size of the piece of action (energy x time, or momentum x length) making up the particular entity or change. Usually the absolute minimum observable change is taken to be $h/4\pi$. Changes smaller than this are said to be "virtual" and undetectable, and changes larger than this are said to be "observable" and detectable. Virtual changes are not bound by the conservation of energy law and almost always violate it. Nor are virtual changes, bound by the conservation of mass law. And virtual photons can have nonzero mass.

For any instrumental condition in a detector, one may consider a certain momentum and a certain length to be involved in the mass change that spatially constitutes the detection. Let us call this critical length dL and examine its ramifications (Figure 1) for the finest possible detector—one that detects a single quantum change. Figure 1 shows two frames, the lab frame S and a moving (hyperspatially rotated) frame. We choose a moving object, M, in the moving (rotated) frame, with length as shown. Note that all these entities are to be represented as detected or seen by our physical detector (instrumentation system) in the laboratory frame.

As the velocity of M approaches c, the speed of light in a vacuum, M's hyperspatial rotation angle α approaches $\pi/2$. However, before the velocity of M actually reaches c—and before α reaches $\pi/2$—the dimensional length projection of object M in frame S will contract to reach dL and fall below it. At that moment, L becomes *virtual* with respect to the detector and hence undetectable. Since geometrically an absence of length in a continuous frame S would correspond to a α rotation angle of $\pi/2$, in quantized frame S we consider that angle α "jumps" to $\pi/2$ just immediately past the critical angle α_c, which is defined as the angle of rotation at which L cos α = A L. Rotation just past the critical angle corresponds to a Lorentz-Fitzgerald contraction into the virtual state below the quantum threshold of the detector's observable universe. To an S observer or detector, object M at that point has lost its length in the direction of motion, becoming a wave front moving at the velocity of light and thus photonic (comprised of photons). To a quantum observer in S, mass turns into photons just short of a full $\pi/2$ orthorotation, which means the process can happen with a finite amount of energy. This "jump" effect is not taken into account in the continuum Lorentz transformations of special relativity at present, and this is the missing link that has prevented a successful union of relativity and quantum mechanics. In other words, the final part of the orthorotation (acceleration to the speed of light) occurs in the virtual state—specifically, that part of the rotation lying between $\pi/2$ and α_c.

Further, we may now proceed to rotate object M past $\pi/2$, which constitutes rotation from zero in frame S'. Just before reaching an S angle of π (that is an S' angle of $\pi/2$), in frame S' another disappearance below a virtual length threshold dL' will occur in corresponding fashion. Note that this second threshold dL' also has an exceedingly small but finite projection into frame S, in

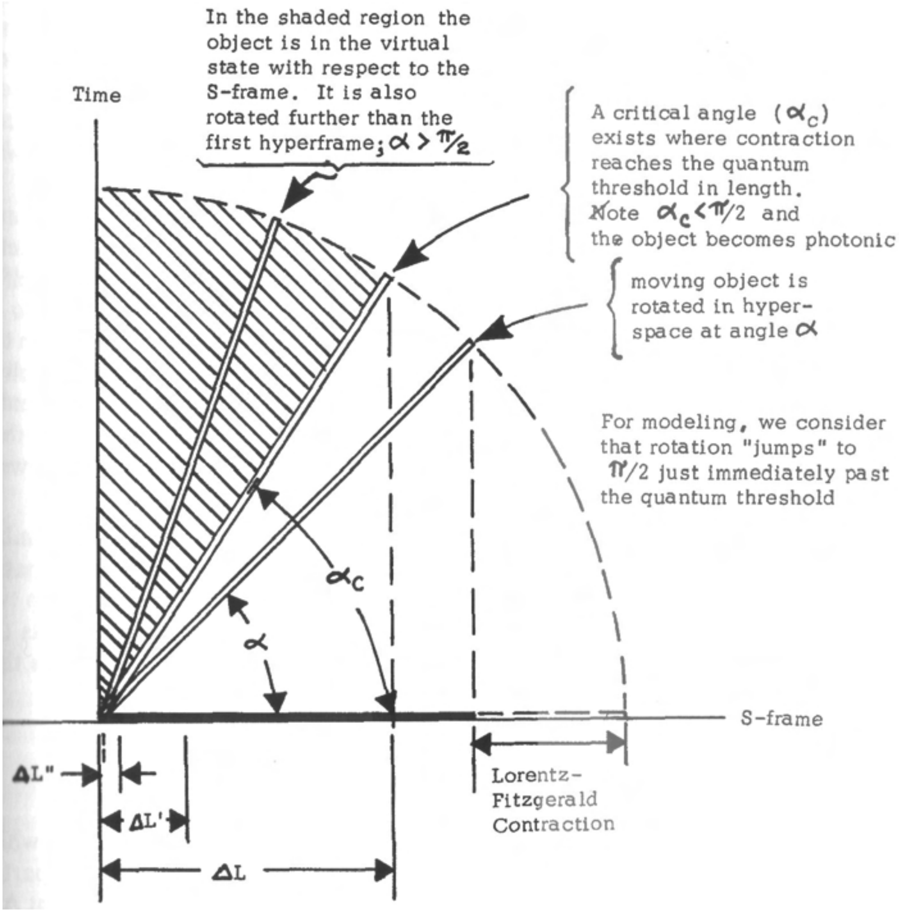
In the shaded region the object is in the virtual state with respect to the S-frame. It is also rotated further than the first hyperframe; $\alpha > \pi/2$
Time
A critical angle (α_c) exists where contraction reaches the quantum threshold in length. Note $\alpha_c < \pi/2$ and the object becomes photonic
moving object is rotated in hyperspace at angle α
For modeling, we consider that rotation "jumps" to $\pi/2$ just immediately past the quantum threshold
α_c
α
S-frame
$\Delta L''$
$\Delta L'$
ΔL
Lorentz-Fitzgerald Contraction

Figure 1. Hyperspaces, nested virtual states, and rotated frames

the virtual state lying inside dL. This second "relativistic quantum jump" in frame S' therefore constitutes a sort of second-level, nested subquantum threshold in frame S.

Continued rotation into hyperspace passes through successively finer, nested virtual sublevels or subthresholds in S by the successive breaching of deeper subthresholds due to continued Lorentz-Fitzgerald contraction. Higher hyperspatial frames constitute nested sublevels in the virtual state with respect to the laboratory observer. Thus a direct connection exists between virtual levels and hyperspace frames. Hyperspaces and virtual sublevels are the same thing. Every "virtual" object in S is an "observable" object in some hyperspace. *Hyperspatial engineering and virtual state engineering are one and the same thing, and this is what psychotronics and energetics are all about.*

Finally, time may be considered a sort of box containing all observables and virtuals. Indeed, time is neither observable nor virtual; time is simply a parameter in quantum mechanics. Rigorously, time may be said not to exist. Time itself is nothing, totally nothing; therefore by the fourth law of logic it can be said to be or contain everything, the total mishmash of virtuals and observables. Since in the absolute sense there is no such thing as time, then it is my thesis that all modeling of space, mind, thing, and nonthing must be done spatially. Relativity presently attempts to use time as an existent dimension of the same kind as length; it thus allows rotation of the S-frame only in the direction of the time axis in Minkowski geometry of spacetime.

Spatial modeling requires an infinite dimensional space and an infinite number of orthogonal angles. The time axis that can be drawn in such a hyperspatial model has no meaning except with respect to a relationship existing between two or more hyperspace frames or objects. Specifically, the time axis represents the totality of all the hyperspaces and their objects, hence all the relationships that can be separated from the hyperspace.

FEYNMAN DIAGRAMS

Figure 2 shows something of the unsuspected nature of physical change, which is not nearly as simple as most of us have been led to believe. In the top part of the figure, an electron (represented by the arrow) is shown going from point A to point B a short distance away. In particle physics this diagram represents the movement of a bare particle; in other words, just a bare hunk of charged mass is considered and the fantastic number of other things happening along the way are ignored. In Figure 2b a virtual photon has been emitted and then reabsorbed by the electron between points A and B. Indeed, the charge on the electron is due to the continual emission and absorption of such virtual photons (little electromagnetic pieces of vacuum, one might say, or little pieces of nothing). So the situation with respect to virtual photons comes closer to Figure 2c: more than one virtual photon is emitted and absorbed—indeed, an infinite number of them are emitted and reabsorbed along the way from point A to point B.

But, worse yet, Figure 2d shows one of the emitted photons suddenly breaking up into a positron and an electron, which then quickly recombine back into an-

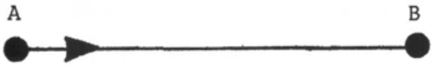

2a. Bare electron

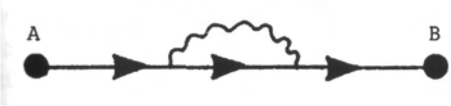

2b. With virtual photon

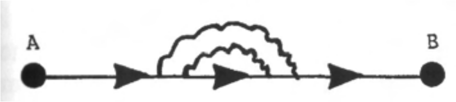

2c. With nested virtual photons

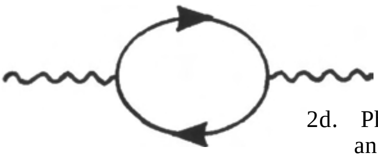

2d. Photon decay (pair production) and recombination (pair annihilation)

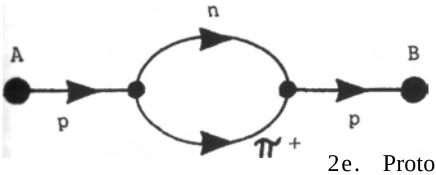

2e. Proton changing briefly to a neutron and a positive pi meson

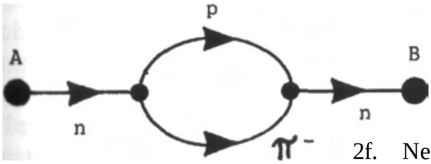

2f. Neutron changing briefly to a proton and a negative pi meson

Figure 2. Feynman **diagrams**

other photon, which is eventually reabsorbed into the electron. In fact, an infinite number of interactions happen while the "electron" is moving from point A to point B, and each of those interactions in turn consists of an infinite number of interactions, and each of those in turn consists of an infinite number of interactions, and so on. The simple movement of the electron is actually composed of a virtual cloud—an infinite number of an infinite number of an infinite number of things, all happening in a mad tangle of nested substrata in the virtual state (Figure 3)—and each of these virtuals with respect to frame S is in fact an observable in some particular hyperspace! Many other sorts of virtual particles are emitted and absorbed and born and extinguished, in addition to photons, by various observable particles and in free space. Everything in every possible world or hyperspace is related to each and every other thing in the laboratory world through orthorotations and nested virtual states. Crosstalk between hyperframes is the emergence and disappearance of virtual particles in a particular frame. The universe is holographic after all, and Mach's principle holds in a far more complete fashion than Mach himself ever dreamed. And if any part of this virtual chaos can be collected and cohered in even the slightest degree, any amount of observable free energy can be obtained, just as T. Henry Moray showed in the 1920s and 1930s.

In passing, I would like to call attention to Figure 2e, which shows one of the virtual interactions a proton can undergo in the nucleus of an atom. In this case, the proton breaks momentarily into a neutron and a positive pi meson, which then recombine into a proton. However, if the charge on the $\pi +$ particle is extinguished psychokinetically during the existence of the neutron and the pi meson, the pi meson is converted to a neutrino and radiates away. In this case the proton does not reappear and the neutron remains. This decreases the atomic number (positive charge) of the atom by one, transmuting the atom into a new element, an isomer down the chain of elements. Figure 2f shows one of the virtual interactions a neutron can undergo in the nucleus of an atom. In this case, the neutron breaks momentarily into a proton and a negative pi meson, which then recombine into a neutron. However, if the charge on the $\pi -$ particle is extinguished psychokinetically during the existence of the proton and the pi meson, the pi meson is converted to a neutrino and radiates away. In this case, the neutron does not reappear and the proton remains. This increases the atomic number of the atom by one, transmuting the atom into a new element, an isomer up the chain of elements. The two interactions shown in Figures 2e and 2f are involved in the Kervran effect, where elements are transmuted by living biological systems.

But back to our electron. If we now remove the electron, leaving empty vacuum, all the sorts of virtual madnesses we have built up in Figure 3 are still there and still occurring. In addition, every other sort of virtual madness is also there and occurring. Vacuum is infinitely dense and filled with stupendous "zero-point" vacuum energy; it is totally chaotic and virtual. Space itself is an infinite tangle of virtuals—virtual projections from real observables in associated hyperspaces—and these dynamic interactants make up any three-dimensional space and hyperspace itself! They are also what cause space itself to exhibit the finite, nonzero parameters or values that must be accounted for in our physical equations. *Every fundamental constant of nature is dynamically constructed from—and*

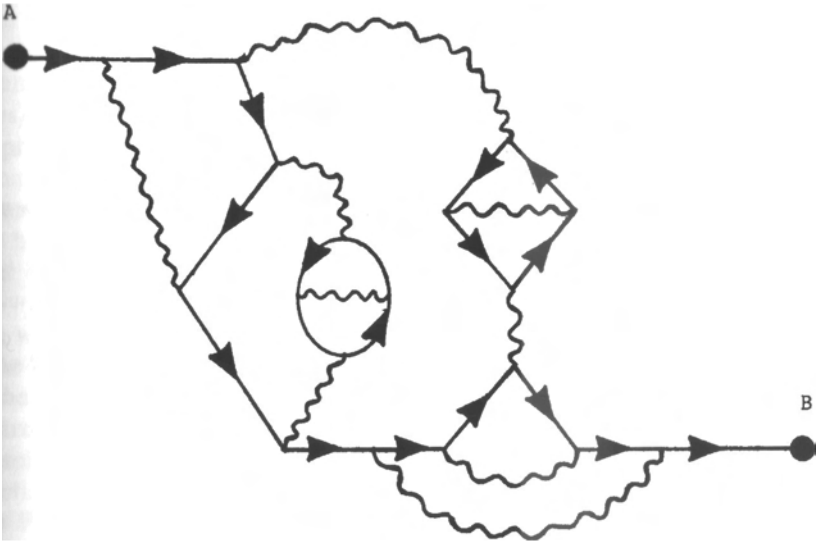

An electron moving from point A to point B is comprised of a bare particle and an infinite tangle of nested virtual particles

Figure 3. Nested virtual processes

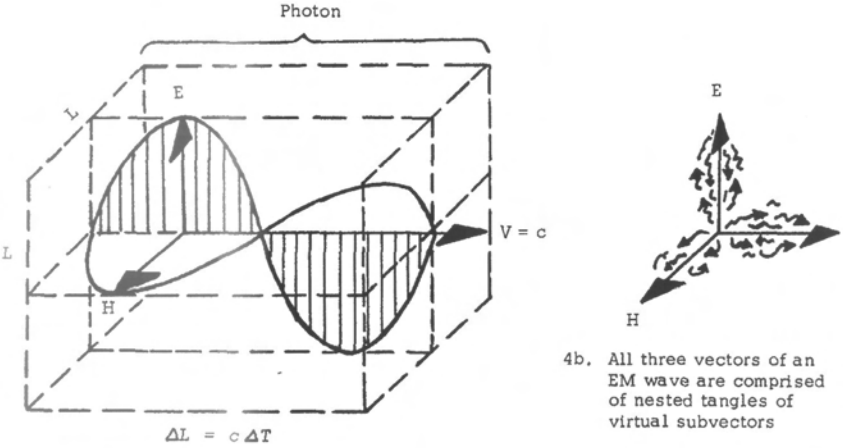
Photon
L
E
L
H
V = c
$\Delta L = c\,\Delta T$
E
V
H

4a. A photon may be considered an individual L^2 wavefront spread in time through one oscillatory period of the E-field and the H-field

4b. All three vectors of an EM wave are comprised of nested tangles of virtual subvectors

Figure 4. Nature of the electromagnetic wave

due to—the zero-point, virtual vacuum interactions that constitute "empty" space. The virtual "sea" of seething waves and particles that is empty vacuum is actually an ether—a Lorentz-invariant, nonmaterial (virtual) ether, perfectly admissible by the Michelson-Morley experiment and the entire experimental basis of physics. Indeed, Einstein once proposed naming the vacuum and its contained fields the "ether," but his suggestion was not heeded.

NATURE OF AN ELECTROMAGNETIC WAVE*

We now know something quite unusual about an electromagnetic wave and about a photon. Figure 4a shows how a photon may be represented. Here we find that a photon is a single oscillation of the E-field vector and the H-field vector as shown in the diagram. Since the oscillation is with respect to time, the wave moves along the axis of velocity in the S-frame for a single wavelength, then repeats itself again and again. The E- or H-oscillation actually represents an orthogonal, rotating etheric or hyperspatial flux about the velocity vector; this spinning (exploding and imploding) flux is coming into the S-frame from outside it (from virtual states) and returning (into virtual states). It is a neutrino flux, as we shall see. In the photon, half a sine-wave cycle represents the fission action that splits the action quantum into canonical pairs, while the second half of the sine-wave cycle represents the fusion of the canonical fragments back into an action quantum. One half-cycle thus represents a positive time operation or creation, while the other half-cycle represents a negative time (fusion) operation. If the complete sine-wave cycle has sufficient amplitude (energy), it can sometimes be broken in half, with the positive time portion revealing the negative field (negative charge) of the E-vector, while the negative time portion reveals a positive field or charge of the E-vector. This is pair production, the creation of an electron and a positron. Each of these fragments has spin one half, while the photon quantum has spin one. Since the positron is a fusion interaction existent, it is an "electron traveling backward in time," just as predicted by Dirac.

In Figure 4b I show that both the E-field vector and the H-field vector are composed of an infinite number of virtual vectors, each of which is composed of an infinite number of even smaller virtual vectors, and so on. This follows from the fact that during any time interval—including the period of a single oscillation of a photon—a photon may be considered to consist of an infinite number of virtual happenings, each consisting of an infinite number of subhappenings, and so on. The photon itself may then be considered to have a direct, nested virtual substructure, and this substructure is directly hyperspatial in nature as well. This structure has not been considered in Maxwell's field equations, which have been

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***Actually the electromagnetic field is not the most fundamental field, but is something that is torn out of, or separated from, a more fundamental field: the vector potential, or A-field, well-known in particle physics but usually ignored in EM field theory. E.g., magnetic Held is created (and defined) by $\nabla \times A = B$. Looking at the cross product, by definition B field is the line integral about a small surface of the A-field flux through that surface. That is precisely what a single coil of wire, with an electrical current flowing through it, does and therefore creates a magnetic field inside. See the second volume of Feynman's three volumes of physics for more on the A-field. The direct use of the A-field is also psychotronic engineering.**

formed from gross macroscopic considerations of bare particles and continuous fields. Maxwell's equations (and the normal concept of an electromagnetic wave and single frequency) thus represent only gross envelopes of the actual form and structure of waves and fields. As I have already shown in the main body of this book, one can even photograph the hyperfield structure of a magnetic field using a simple bar magnet and a color TV tube. Further, we will find that this virtual structure of a photon can be altered, "modulated," or changed by simple signal modulations, among other methods. The only requirement is that we learn to regard modulations differently.

In addition, inside each half-cycle of a photon's E-vector, relatively instantaneous fluctuations and "losses" of the vector's magnitude occur. At these "E-field glitches" in the photon, it actually contains only an H-vector. In this case the photon is a neutrino momentarily—or, in other words, it will admit a neutrino through the E-field glitch. The greater the charged field (voltage potential), the greater the number of photons available, thus the greater the number of neutrino interactions within the field. A potential of about 200-300 volts per meter altitude above the earth's surface normally exists in our biosphere. Many neutrinos emitted by the sun and bombarding the earth are absorbed in or interact with this E-potential above the earth; hence underground experiments to measure the neutrino radiation from the sun have detected less neutrinos than expected.

Momentary H-field glitches exist in a similar manner and interact with or admit neutrinos in a similar fashion.

Light can thus conduct neutrinic waves containing bioenergy or eloptic energy, as T. G. Hieronymus discovered. In the first hyperframe (EM field frame), this can be seen to be simply a space charge of electrons conducting a wave disturbance through it, or a piece of ordinary conductive matter conducting an ordinary EM wave.

NEUTRINIC LONGITUDINAL POLARIZATION WAVES

In Figure 5, I assume that in some fashion the E-field of an electromagnetic wave has been stripped off, leaving a single vector in the H-field direction only, and this vector is still oscillating, as originally set up in a Hertzian wave in Figure 4. The new "single-field" wave is an etheric sort of half-wave, a longitudinally polarized wave that is not a wavefront (plane) moving through S-space but just a pulsating line segment moving through S-space. This wave is not Hertzian. It is not electromagnetic—though it will strongly interact with or even produce electromagnetic waves—but is neutrinic. The interactions of this wave with space virtuals are drastically reduced (indeed, by a factor of c), and this neutrinic wave now travels at the speed c^2 with respect to S-space. While it will highly interact with magnetic field, precisely speaking it is not a magnetic wave but a hyperfield

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*C^2 is its s-frame, free-space velocity when not interacting with electromagnetic field. Normally, neutrinic wave interacts with electromagnetic field, thus moving at less than C^2 velocity in space, since it "circulates around" in electromagnetic field. Neutrinic wave can be regarded as a circulating or spiraling wave in electromagnetic field, which may well be the

wave. It will travel through and across dead shorts, through media such as seawater and earth, and acts or can act much as a neutrino. This wave has neutrinic components in S; that is, it has vector components existing in frame S". One may expect this wave normally to be active in or interacting with an electrostatic field or a magnetic field, as a special sort of lower-level virtual state flux (second-order hyperflux) into and out of the field. This is apparently the sort of wave discovered and used by Nikola Tesla, who repeatedly insisted that he was not using Hertzian (Maxwellian) waves but instead was employing a much finer wave having very different characteristics. Further, neutrinic waves will transit between any two points on earth almost instantly—in fact, about 3×10^8 times as fast as the speed of light propagates! With these waves, space communication with distant galaxies is practical and achievable, and scientists seeking communication with extraterrestrial civilizations would do well to use such waves.

Note that I am not referring to the ordinary longitudinally polarized electromagnetic wave, where both the E- and H-vectors still exist but the H-vector is rotated 90° so as to lie in the line of motion through S-space.* Such longitudinally polarized electromagnetic waves are already known in the literature and have been used in many patented devices, but they are not included in most textbooks on electromagnetic fields and waves for some unaccountable reason. The normal longitudinally polarized electromagnetic wave moves at the speed c, just as any other EM wave.

At any rate, neutrinic longitudinally polarized waves often arrive at a distant point many times stronger than they were when they left. T. Henry Moray, for example, built a radio and a sound detector that apparently worked by a version of neutrinic waves, condensed into electromagnetic waves in his radio-detector apparatus. Dr. Moray tested the radio scores of times between 1930 and 1933, and on several occasions even received broadcasts from Admiral Byrd's party in the Antarctic. Even when powerful, ordinary radios could receive nothing from Antarctica because of severe weather conditions, Moray's little batteryless radio brought the broadcasts in, loud and clear with no static. Further, Moray demonstrated a sound pickup device of similar construction that could pick up or zoom in on sounds five miles away. Again the sounds were loud and clear, with none of the distortion of weather conditions and background noise. (See T. Henry Moray, *The Sea of Energy in Which the Earth Floats,* 4th ed., 1960, pp. 129, 133, and 143.) Thus transmission of power without wires was possible, just as Nikola Tesla had shown. Tesla in fact patented a capacitive (E-field only) transmission system.

Indeed, according to independent research by Dr. Robert Beck, another inventor named Rogers apparently discovered just such a system and the United States

"spinning wave" of orgone energy identified by Reich. Neutrinic waves particularly interact more strongly with strong E-field and with strong B-field, the degree of interaction increasing (probably nonlinearly) with the intensity of the E or B field with which the interaction occurs. The velocity of neutrinos, measured on earth inside its strong ionosphere-to-earth E-field, should be quite reduced from the velocity of neutrinos measured in isolated deep space, and almost two-thirds of the neutrinos entering the earth system from space interact with the ionospheric-earth potential and are absorbed by it. The A-field and its derivatives directly involve the E-field, H-field, and neutrinic field and their interactions. To correctly understand the activation chemistry theory and results of LeBon, A-field theory is required. And to understand much of Tesla's work, A-field theory is required, for Tesla was aware of, and used, A-field interactions in many of his patented systems.

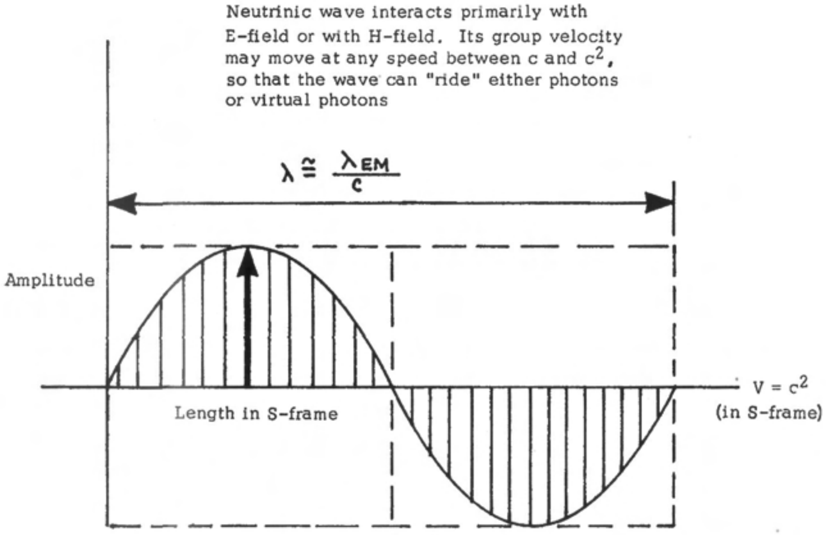
Neutrinic wave interacts primarily with
E-field or with H-field. Its group velocity
may move at any speed between c and c^2,
so that the wave can "ride" either photons
or virtual photons
$\lambda \cong \frac{\lambda_{EM}}{c}$
Amplitude
Length in S-frame
$V = c^2$
(in S-frame)

Figure 5. Neutrinic (longitudinal polarization) wave

NOTE: This is not an electromagnetic wave and is not the longitudinally polarized EM wave familiar to many physicists and engineers.

used it to communicate with its submarines underwater during World War I! For that purpose it was known as the Rogers underwater and underground wireless system, and H. Winfield Secor in 1919 reported on its use and its fantastic potential for the future, implying the necessity to completely change our ideas of electromagnetics and power transmission. (H. Winfield Secor, "The Rogers Underground Wireless," *Electrical Experimenter*, March 1919.) Mysteriously, the Rogers wireless seems to have promptly disappeared. Even more strangely, according to Dr. Beck's research the same breakthrough has been made again in the U.S. at least three times since the beginning of World War II. These rediscoveries included full delineation of the prior technologies, with mathematical theory and diagrams, that had escaped further notice. Again the technology disappeared mysteriously in all cases shortly after being rediscovered. The Soviets did not have far to look to discover the Rogers Wireless, Tesla waves, T. Henry Moray's radiant energy device, the Moray radio, the Moray sound detector, and the U.S. technical work in the area since World War II. All they really needed was to thoroughly examine the U.S. scientific and technical literature, the technical magazines and books, and so on. The Moray amplifier and the Moray sound detector were also demonstrated by Moray to a Soviet scientist, Dr. A. A. Yakovlev, in October 1929, and a Soviet agent succeeded in penetrating the Moray laboratory in 1939, obtaining drawings of the Moray tube and many photographs, and perlonally working in the laboratory for two months.

One may consider power transmission through such a wave to have traveled to every point in the future path at a speed that is faster than the flow of macroscopic time by a factor of c. Then along any electromagnetic (time) line along the same path, these waves are "ringing" back and forth continually, as the progress of normal physical change crawls slowly forward. Thus the normal time change (electromagnetic or photonic interaction world flow) acts as a collector for the ringing neutrinic energy, and this collection can act as a gain factor G, where theoretically G is given by the expression

$$1 < G < c.$$

Thus a longitudinal polarization wave, when transmitted to a distant receiver, may arrive or be detected at the receiver thousands of times stronger than the transmitted signal, even for very low coupling.

Neutrinic longitudinal polarization aspects to ordinary electromagnetic waves can also be achieved by modulation—especially by second-order, nested modulation—and such hyperspatial aspects have already been detected in the Soviet communications radiation, causing interference around the globe in the 10 to 20 megahertz range, as we shall see.

A NEW LOOK AT MODULATION

We can assume a sine-wave electromagnetic carrier frequency whose amplitude we wish to vary (modulate) as a function of time, by a lower frequency sine wave, as shown in Figure 6a.

As is well known, the classical view of amplitude modulation of a carrier wave holds it to be an oscillatory change in the amplitude of the carrier, as shown in Figure 6b. However, empirically this was found to be erroneous, since in 1929 it was shown that after such modulation the detected carrier appeared unaffected by

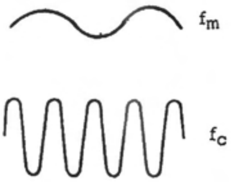

6a. A carrier f_c to be amplitude modulated by frequency f_m

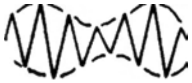

6b. Original view of amplitude modulation

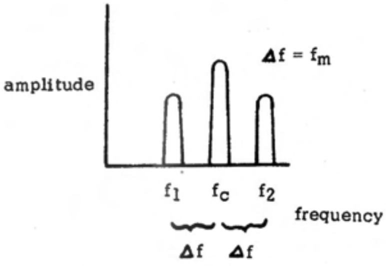
$\Delta f = f_m$
amplitude
f_1
f_c
f_2
frequency
Δf
Δf

6c. Detected signal for an amplitude modulated wave

Figure 6. Amplitude modulation of a sine wave

the modulating wave; instead, there appeared two other sine-wave frequencies (sidebands), one at a frequency above the carrier frequency and one below it, as shown in Figure 6c. In each case the change in frequency from carrier to sideband was by an amount equal to the frequency of the modulating wave.

Both the original classical view and the present view are in fact correct if one considers hyperspatial aspects and linear detection aspects. As can be noted in Figure 6b, the carrier is distorted and is not a sine wave according to the original classical view. This implies that the individual photon shown in Figure 4a has been internally distorted or "bent." This, I submit, actually happens and constitutes the bending or curving of spacetime in a general relativistic fashion. However, all our instruments can detect only a pure, undistorted photonic interaction; that is, in frequency they can only detect the sine-wave aspects of a kinked photon. The reason is quite simple: for example, suppose the method of detection of the photon is by photon interaction with a bound electron. The change in the electron is a precise change of energy levels to an excited level, and it only detects or interacts with a single sine-wave photon. The frequency (say, the carrier) component of the photon, which contains the correct energy differential (according to $E=hf$, where h is Planck's constant and f is the sine-wave frequency), will interact with the electron. The other sine-wave components of the initially kinked photon will thus be stripped off (demodulated) by the absorption of the carrier portion of the photon. The photon kink existed in both positive time and negative time; from a frequency viewpoint, the modulating amplitude frequency that was added to the basic carrier frequency in positive time was subtracted in negative time. Thus demodulating the kink from the amplitude modulated photon (by absorbing the sine-wave carrier) results in the production or liberation of two sine-wave frequencies, one above the carrier frequency and one below the carrier frequency, each difference being equal to the original amplitude modulation's frequency. These two frequencies will then interact and be detected.

So our linear instruments do not detect single kinked photons in a stream of distorted photons, but they detect a combination of undistorted photon streams (waves) at different frequencies.

Such considerations as these should have appeared in electromagnetics long ago. After all, we presently regard an EM wave as a wiggle of nothingness, existing in time. This is precisely the same as saying that a photon is an oscillation (wiggling) of spacetime itself. Specifically, it oscillates in two directions spatially, one being the E-field direction and the other being the H-field direction. But since an EM wave itself constitutes a regular bending and flexing and curving of spacetime, including both space and time, then the flexing spacetime inside the photon can itself be further bent or twisted, and that constitutes a kinked or curved photon—a *modulated* photon. Our linear laboratory space instruments, however, will demodulate such a kinked photon into its linear components, giving a combinationof unkinked photons in the detection. And for the amplitude modulated carrier shown in Figure 6b, we actually detect the carrier and two sidebands shown in Figure 6c.

Similar complex mixes of waves at different frequencies result for other types of modulation, but this will suffice for our purposes here. Specifically, we should mention that an infinite number of sidebands may be produced, but normally all

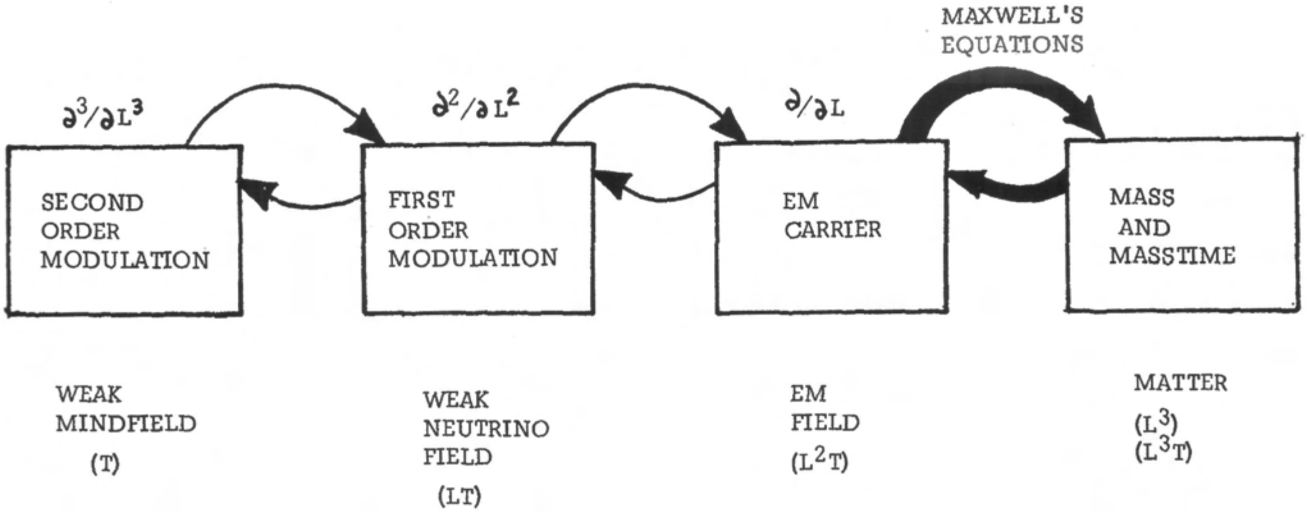
MAXWELL'S EQUATIONS
$\partial^3/\partial L^3$
$\partial^2/\partial L^2$
$\partial/\partial L$
SECOND ORDER MODULATION
FIRST ORDER MODULATION
EM CARRIER
MASS AND MASSTIME
WEAK MINDFIELD
(T)
WEAK NEUTRINO FIELD
(LT)
EM FIELD
(L^2T)
MATTER
(L^3)
(L^3T)

Figure 7. Nested modulations: key to hyperspace

but a few are so weak as to be negligible for ordinary communication purposes, where no hyperspatial information is needed. For living systems, however, a great number of these extra sidebands must be taken into account, for the hyperspatial-virtual state components carry the lifestream, consciousness-loop-interaction Information itself. We will look at some of the biological aspects shortly.

At any rate, modulation of a wave results in direct changes in the virtual structure of the formerly unmodulated photon, relativistically warping or curving it. Just as Fourier (harmonic) analysis breaks down a very complex nonsinusoidal wave shape into an infinite series of component sine-wave frequencies of various amplitudes, so linear detection in a linear laboratory frame breaks down a stream (wave) of complex nonsinusoidal photons into a series of sinusoidal waves in a complex mixture.

And if we now think of this in reverse, we see that a mixture of waves and frequencies must automatically possess, carry, or represent hyperspatial-virtual patterns in the correct nonlinear medium that absorbs them.

HYPERSPATIAL ASPECTS OF MODULATION

Let us now look at the hyperspatial aspects of modulations and complex electromagnetic waves, particularly mixtures of waves, in yet another fashion.

First, as is well known, we may represent a wave as a sine function (or cosine function if preferred). When we modulate a wave, we impress a time change on it. In the most general mathematical sense, a modulation to a wave is the impressing of a derivative function upon the wave. And if we think of the basic carrier wave as being prescribed by Maxwell's equations in derivative form, then in a sense when we modulate the wave we differentiate it, that is, we impress a differential operator function on it. But this means that we raise the order of the differential aquations prescribing the situation, which mathematically means we have increased the dimensionality or spatiality of the, wave entity that is the resulting modulated carrier. In other words, to modulate an electromagnetic carrier wave is to add a hyperdimensional aspect—specifically, neutrinic vector aspects or mind aspects. The whole affair can be thought of as merely shifting or altering the particular distribution of nested virtuals transported by the basic carrier wave.

If we differentiate a sine wave, we simply get a cosine wave, which is just another sine wave pi/2 out of phase with the first. So now it emerges that when we form a mixture of waves, we are adding virtual aspects (and hyperspatial aspects) in so doing, because of the phase differences. This is extremely important: *complex mixtures of waves automatically constitute and carry hyperspatial components!* And if we can accurately control these hyperspatial components, we are in effect doing direct hyperspatial engineering and virtual state engineering.

Now if we carry our modulation-constitutes-differentiation concept one step further, we find a most startling phenomenon (Figure 7). The first-order modulation we placed on an EM carrier we discovered to carry aspects of the next hyperspace, namely, neutrinic vectors. Now if we further modulate that first-order modulation signal as a carrier itself, so that we now have two orders of modulation upon the basic carrier, the second-order modulation must possess hyper-

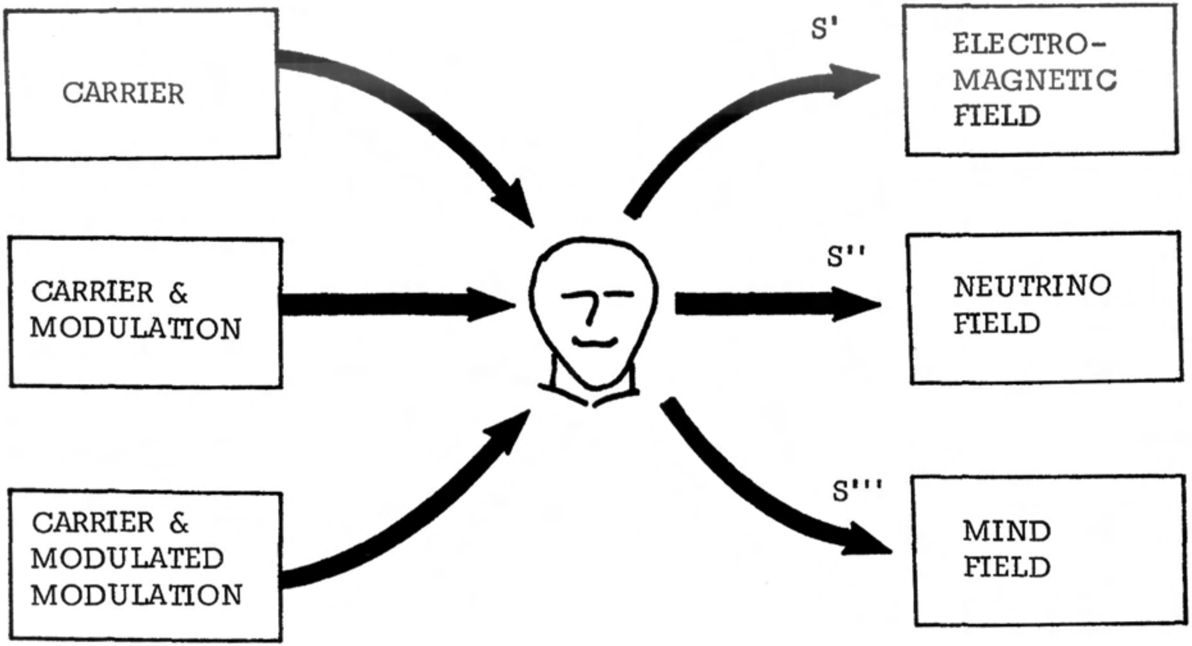
CARRIER
CARRIER & MODULATION
CARRIER & MODULATED MODULATION
S'
S''
S'''
ELECTRO-MAGNETIC FIELD
NEUTRINO FIELD
MIND FIELD

Figure 8. Field coupling to the human brain

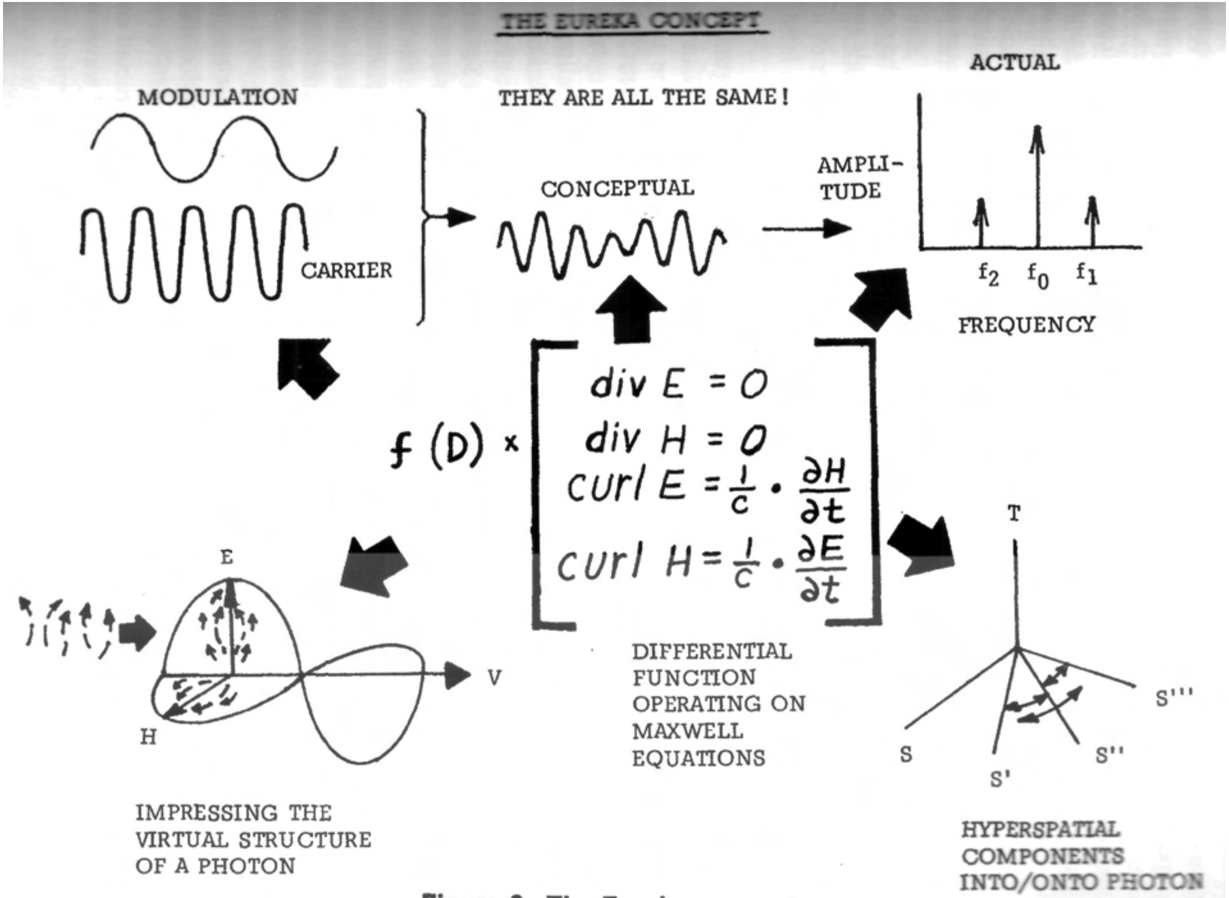
THE EUREKA CONCEPT
MODULATION
CARRIER
THEY ARE ALL THE SAME!
CONCEPTUAL
ACTUAL
AMPLITUDE
f_2
f_0
f_1
FREQUENCY
$f(D) \times \left[\begin{array}{l} \text{div } E = 0 \\ \text{div } H = 0 \\ \text{curl } E = \frac{1}{c} \cdot \frac{\partial H}{\partial t} \\ \text{curl } H = \frac{1}{c} \cdot \frac{\partial E}{\partial t} \end{array} \right]$
DIFFERENTIAL FUNCTION OPERATING ON MAXWELL EQUATIONS
E
H
V
IMPRESSING THE VIRTUAL STRUCTURE OF A PHOTON
T
S
S'
S''
S'''
HYPERSPATIAL COMPONENTS INTO/ONTO PHOTON

Figure 9. The Eureka concept

vectors of the next higher hyperspace—the mindfield itself. In other words, by using two orders of modulation on a carrier, we can directly affect mindstuff itself. So if the correct overall pattern of these complex modulations are impressed on a carrier, the life-consciousness loop itself can be directly affected or shaped, all the way from the mindfield of a biological organism to its neutrino field to its virtual photon field to its biophoton field to its body tuner, and back. With the correct pattern we can stimulate the life channel for a particular organism, and with yet another pattern we can inhibit the life channel for the same organism. By this means a positive cure for cancer could easily be derived, and as we shall see, this already has been done. By the same means, a "death ray" for use against humans could easily be developed, and it is my contention that the Soviets have already long since developed such weapons.

It is my purpose to eventually use these new aspects to construct a direct mind-link for mind-to-mind communication and hyperlinkage, thus solving the human problem.

Figure 8 shows the basic scheme for coupling such a second-order modulated signal to a human being. We will return to modulations versus nested virtuals and hyperspatials below.

THE EUREKA CONCEPT

So we have now reached a Eureka point of the first magnitude (Figure 9). Hyperspatial engineering, virtual state engineering, curved space, photon kinking, mind-life-consciousness engineering, and nested modulation are all the same thing! We directly engineer the virtual state, hyperspace, curved spacetime, and the life-consciousness loop itself, including the mind, with relatively simple devices that accomplish, transmit, and receive nested orders of modulations. Indeed we have opened Pandora's box, for this is the greatest tool ever dreamed of by humankind. Consequently it can be used either for the good of mankind or for its detriment. And this tool appears already to have been weaponized by the Soviets,

In Figure 9, note that modulation, photon kinking, the appearance of sidebands with the unchanged carrier, impressing a virtual pattern upon a photon, and impressing hyperspatial components into or onto a photon are equivalent. Further, if we assume that the electromagnetic wave (pure, undistorted wave in a linear medium) is given by Maxwell's equations, then modulation mathematically consists of impressing a particular differential operator function and a nonlinearity upon Maxwell's equations. For each modulation pattern, a particular virtual structure is impressed on the photon, which is the same as impressing a particular hyperspatial pattern upon it. Each specific pattern impressed on the photon (that is each particular kink pattern of the photon) corresponds to a specific differential operator function. Through this means, a specific theory can be constructed empirically. That is, one can work out the effects of various mixtures of waves on specific biological systems, measure the specific channels used by the mind-life-consciousness loop, and so on. The Lisitsyn paper and Kazhinskiy's "biological radio" work in fact state that the Soviets have already done precisely this, and the Kaznacheyev paper shows that a large number of related biophoton experiments were in fact carried out in Soviet military laboratories. But let us look at some very important and exciting German work directly related to this area.

BIOPHOTONS AND VIRTUAL EM FIELD OF A BIO-ORGANISM

In an incredible piece of work, "Photon Storage in Biological Systems," in *Electromagnetic Bio-Information,* Urban and Schwarzenberg, Baltimore, Md., 1979, pp. 123-149, Dr. Fritz Albert Popp has presented the results of his laboratory work—and his theory—dealing with quite new developments in biological organism fields. Indeed, this may be one of the most important Western papers ever presented, if its true import is noticed. Briefly, in studying cellular electromagnetic bioactivity, the cell behaves as a system far from thermal equilibrium. It thus can be characterized as a Prigogine system. (Ilya Prigogine received the Nobel Prize in 1977 for his development of nonlinear thermodynamics of systems far from equilibrium, thereby changing the second law of thermodynamics.) We now know that in such a system negative entropy can result, and order can emerge from disorder. For a wildly disordered system, large-scale order can emerge and stabilize, and the more chaotic the disorder, the greater the stability of the ordered patterns that emerge. (Which seems to imply a confirmation of my fourth law of logic—total disorder must inevitably turn into total order.)

At any rate, living cells produce coherent light with a laserlike activity. This coherence serves as a control for the metabolism of the cells, regulates growth, and fixes the reproduction rate. Further, the cell exhibits superconductive behavior.

Popp found that a living organism in fact possesses a living aura, a virtual electromagnetic field that pervades the entire organism with a virtual photonic flux. In this field, virtual photons are stored. The field continually receives inputs (virtuals) from the environment and is continually outputting biophotons, particularly in the near ultraviolet. This field, in which all cells are bathed and with which they all continually intercommunicate, tends to stabilize and cohere the organism. All this has been established by laboratory experiments, and all of it is directly consistent with my own hyperfields and nested-virtual-fields model of the living system's life-consciousness loop connecting its mind hyperworld to its physical body tuner. My model is consistent with Popp's work and extends it by adding the nested structures of the virtual field, thus connecting Popp's virtual field to the neutrino field and the mindfield.

And with this additional information in mind, let us return to our consideration of nested modulations on an electromagnetic carrier. Indeed, let us look at several examples of devices already applying the "nested modulation is hyperspace vectoral" effect.

THE PRIORE MACHINE

The cure for cancer mentioned above is the Priore device in France, which has been curing cancer and other diseases for over a decade, much to the frustration of many members of the French Academy of Sciences.

Antoine Prior6 is an Italian-born inventor who escaped from the Germans in World War II and fled to France. After the war Priore" purchased surplus equipment and eventually developed a strange machine that filled an entire room. A nozzle above a table in the center of the room emitted a strong ray or field, which Priore* explained consisted of an electromagnetic wave in a magnetic field. Eventually the French government spent almost three million dollars for construction of a new, improved PriorS machine, because Priori had shown he could cure cancers in laboratory animals with the device.

In 1964 Professor Robert Courrier, renowned biologist and secre'taire-perpe'tuel of the French Academy of Sciences, presented some of Priore's results to the Academy. Forty-eight cancerous rats had been divided into two groups of twenty-four each. One group was set aside without treatment as a control, and the other group was divided into two subgroups of twelve each. One of these subgroups was treated by the Priore machine promptly after cancer grafts, and the other was treated after a lapse of several days. Both subgroups were completely cured—the first quickly and the second after more prolonged treatment. All the control rats died in twenty-two to thirty days after grafting.

The results created a furore and a controversy that have continued to the present day. Since the first presentation by Courrier, the machine has repeatedly cured leukemia and other forms of cancer in laboratory animals. The controversy seems to have arisen because the French Academicians could not comprehend the working of the machine, and because the inventor would not reveal how it worked but only how it was built.

The second, more powerful Prior6 machine produces a magnetic field of about 1,240 gauss. According to one scientist, the machine contains a gas-filled vacuum tube, which contains a plasma of mercury and neon gas. A pulsed 9.4 gigahertz electromagnetic wave is modulated onto a 17 megahertz wave in this plasma. However, the true nature of the machine is revealed by the fact that the 9.4 gigahertz wave is joined in the "lamp" by seventeen radiations of unspecified frequency and nature. Thus we see that Priori is actually using second-order multiple modulations and is dealing with the direct life-mind-consciousness loop of the mammalian cell. He is directly stimulating and engineering the hyperspace nested virtual bands with his device. His twenty-six years of work have mostly been involved with ferreting out the required precise frequencies and mix of second-order modulations, as well as the correct intermodulation carrier necessary to obtain the desired effects.

In Figure 10 we show a simplified diagram of the Priore device, from which it can immediately be seen that the device uses the same principles shown previously in Figure 9. PriorS is using nested orders of modulations to affect nested orders of virtual state, thus producing direct channels and effects in neutrinic field and in mindfield. Radiating a biological target such as a laboratory animal with such a complex field directly engineers its mind-life-consciousness loop. With the correct nested modulations on the correct carrier (in this case a strong magnetic field, which allows a stronger connection to the neutrinic field aspects), the mind-life-consciousness loops of the individual cells in the body of the irradiated animal arc "scrubbed clean" of any deviation from the norm by the virtual patterns delivered to the animal, and hence to its "virtual biophoton stabilization field" reported by

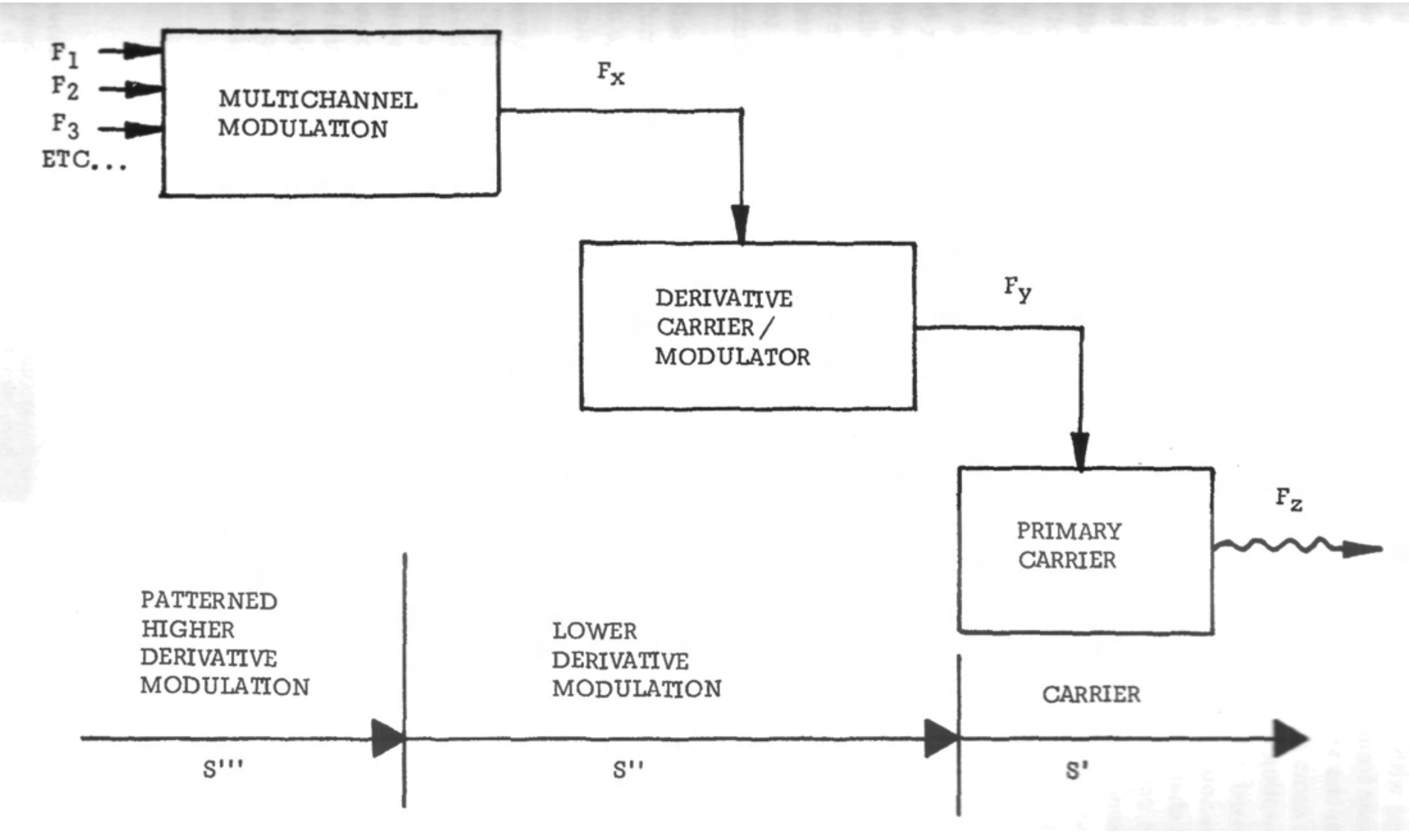
F_1
F_2
F_3
ETC...
MULTICHANNEL MODULATION
F_x
DERIVATIVE CARRIER / MODULATOR
F_y
PRIMARY CARRIER
F_z
PATTERNED HIGHER DERIVATIVE MODULATION
LOWER DERIVATIVE MODULATION
CARRIER
S'''
S''
S'

Figure 10. A simplified diagram of the Priori device

Popp. In other words, the Priore device produces a reverse sort of effect as compared with the Soviet work reported by Kaznacheyev on anomalous death and disease transmission between cell cultures by near ultraviolet biophotons emitted from the virtual Popp field of the dying cells of the stressed, attacked cultures. The same sort of virtual engineering that can transmit death of the organism (by disrupting its mind-life-consciousness loop tuning) can also transmit life into a stressed attacked grouping of cells by a sort of "forced resonance" of their consciousness loops into normal health patterns. (Virtual state interactions control charges, which control chemistry. Thus the entire chemistry of the absorbing cells can be controlled and engineered.) Also, the Lisitsyn paper refers to the presence of eleven independent channels in the brainwaves (namely, in the mind-life-consciousness connection to the waves of dendrite firings that constitute brainwaves*), and these were specifically referred to clipped signals, not sine waves. (The clipped signals would be those possessing complex nested modulations, and thus representing the tuning effects of the life-consciousness loop.) The Priore machine uses seventeen higher-order modulations, which are quite sufficient to cover all eleven life channels required, with an additional six being available for tuning so as to squelch or "jam" the life-consciousness loops of those cells with tuning abnormalities, that is, of diseased or cancerous cells.

As we would expect, the Priore machine has also shown its ability to cure other infectious diseases and materially benefit victims of cardiovascular diseases. Infectious diseases cured by Priori radiation also provide an immunity to the treated host organism that has been shown to be transferrable by transfusion of blood samples.

Again I strongly emphasize that the individual biological effects of solitary magnetic fields or single frequency waves cannot be extrapolated to the multiple frequency, nested modulation case; and almost all our present knowledge of the effects of electric, magnetic, and electromagnetic fields on biological systems is woefully immature and incomplete.

T. Henry Moray built a somewhat similar machine—though very much smaller—which provided a direct radiation from extensive "peach blossom violet" colored sparkgaps inside a quartz tube, and which greatly stimulated the health of an individual exposed to the radiation. In fact, the device would promptly cure **the** radiation burns Moray frequently suffered as a result of his continual experimentation with uranium compounds and other radioactive substances. He patented the device, and some of his original machines are still in existence and still being used to treat patients with a wide variety of ailments. I have personally been exposed to one of Moray's treatment machines and can vouch for the fact that it stimulates every cell in one's body, providing in about two to three minutes a great tonic and health stimulant.

***It is these dendrite firings which form the collector-detector mechanisms through which the mind-world changes are joined to the human nervous system and brain. Were they not specifically useful and needed, the dendrite firings would not have been developed, and nerves would simply be long wires.**

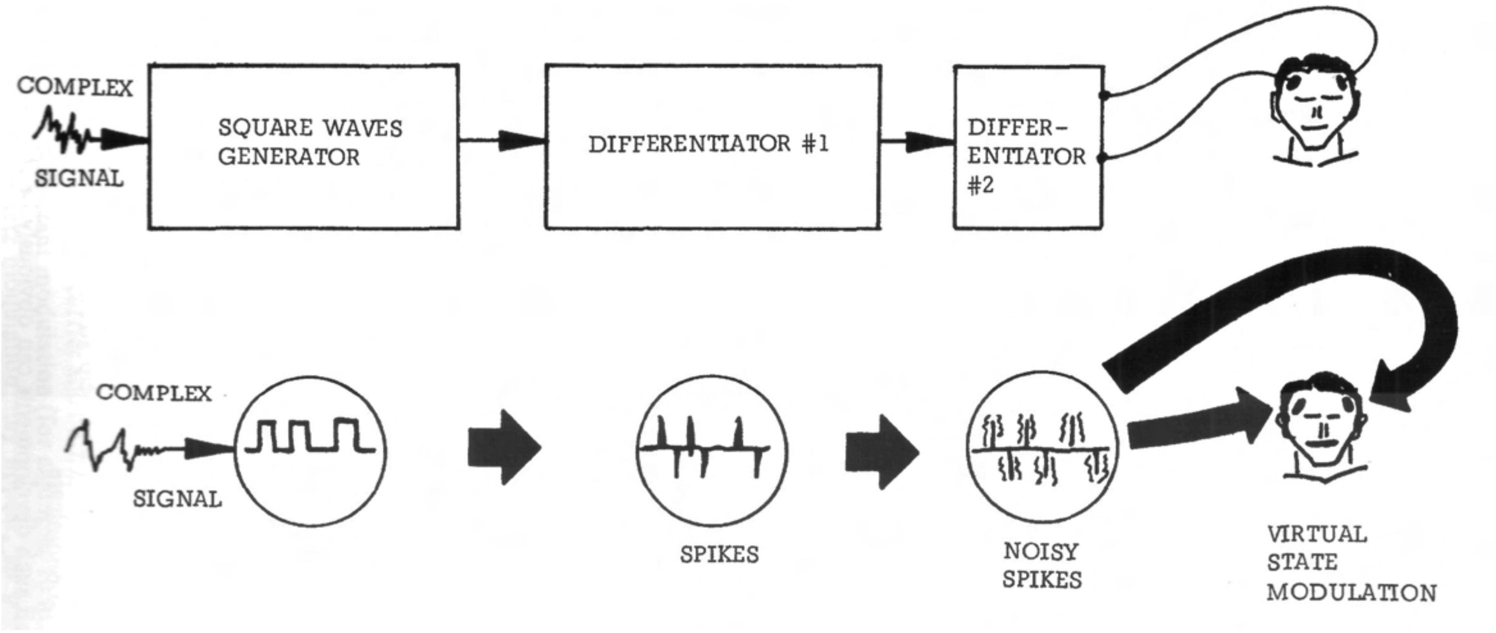
COMPLEX
SIGNAL
SQUARE WAVES GENERATOR
DIFFERENTIATOR #1
DIFFER-ENTIATOR #2
COMPLEX
SIGNAL
SPIKES
NOISY SPIKES
VIRTUAL STATE MODULATION

Figure 11. A simplified diagram of the improved Flanagan neurophone

THE NEUROPHONE

Another device that uses the new hyperspatial, virtual state, nested modulation technology (and has done so for seventeen or eighteen years) is Dr. Pat Flanagan's neurophone. With brilliant insight and intuition far beyond that of science at the time, Pat invented and patented the instrument by the time he was seventeen years old. The neurophone is a device that, contrary to all present theory and knowledge, will directly "pump the brain" and reproduce sound and information directly in the brain and mind system, without going through the auditory system at all. A simplified diagram of Pat's improved neurophone is shown in Figure 11.

Briefly, the device takes a complex signal, such as the sound of an orchestra playing a musical interlude, and electrically processes it as shown in the figure. First the signal is passed into a section that clips everything into a series of square waves, remarkably analogous to the sort of clipped waves Lisitsyn confirms are the information carriers of the human brain. Next the square waves are differentiated, yielding a series of sharp spikes (note that these spikes retain the pulse-time content of the clipped signal). These spikes are again differentiated, and since these are finite spikes with real nonzero rise times and decay times rather than theoretical constructs, a series of noisy spikes results from the second differentiator section. From here, the noisy spikes are introduced to special contact electrodes, one of which is normally placed on the forehead, while the other may be placed almost anywhere, including on the foot. Nowhere are any sound waves introduced to the head.

The square-wave clipper section reduces the complex signals, their overtones, and their complex modulations to square waves, retaining the temporal content of the wave mix but not the waves themselves. The first and second differentiators heighten or filter through the temporal content of the higher-order differentiations, that is, they serve as a band pass filteT unit to accent the time keying of the neutrinic and mindfield portions or aspects of the signal. When these time spikes are then introduced across the body as pulsed voltages, they are modulated directly on the dendrite firings of the brain and nervous system, providing direct and pulsed modulation of the neutrinic and mindfield component channels of the mind-brain-consciousness-life loop itself. Thus the neurophone directly inputs information into the brain and nervous system, bypassing all the normal sensory systems that lie between the mind-brain loop and the outside environment.

Indeed, a similar development has been reported by two University of Missouri researchers. Dr. Donald York, a neurophysiologist, and Dr. Thomas Jensen, a speech pathologist, have recently reported identifying and decoding twenty-seven words and syllables in specific brain wave patterns and correlating these electroencephalographic patterns with both the spoken word and the silently thought word in about forty subjects. At present, Dr. York and Dr. Jensen are programming a computer with a brain wave vocabulary, to monitor and read the EEG of a stroke victim's brain and help stroke victims who have lost their powers of speech to communicate.

While all such developments can obviously be misused, their potential for assistance to mankind is enormous. Indeed, my own premis that brain linkage it possible and can be used to advance all mankind to the sixth stage of species evolution is slowly being proven. It is within our reach now to develop a multichannel communications system that will directly link brains, minds, and consciousness into a single functional being; and I have already pointed out that the psychokinetic power of the emergent entity increases exponentially with the number of linked stages. The normal corpus callosum linkage of the two cerebral halves in each human head proves that brains, minds, and beings can be linked and integrated into one.

The Excalibur Briefing details the basic concepts of the theory involved in hyperspace-virtual state engineering, and thus in the engineering of mind-life-consciousness links to multicellular organisms here on earth. Pat Flanagan's neurophone proves that complex information can be implanted directly in the brain and mind, bypassing the normal isolating barriers. Drs. York and Jensen have shown that the brain wave does indeed contain recognizable, decodable information analogues. Lisitsyn has already reported measuring the number of independent channels involved and has documented the importance of the clipped brain waves as opposed to the sine-wave content. If we have the vision, we can still develop a brainlink and rapidly apply it to link sixty to one hundred persons, thereby opening a conscious, multidimensional "eye" for the collective human unconsciousness, gently rousing ZARG into wakefulness, and fulfilling human destiny without undergoing the psychotronic Armageddon planned by the Soviets. The time is short, but it can still be done if the funding, the vision, and the team can be established on a crash priority basis.

SOVIET "WOODPECKER" SIGNALS

But, as I have said, all this can be used for the detriment of mankind as well as for its benefit. Unfortunately, it appears that the Soviet Union has chosen to weaponize the effects on a global scale. A prime example is the "woodpecker" signals emanating from the USSR in the 5-30 megahertz region and interfering with communications around the earth.

These complex woodpecker signals appear to originate from two or three dozen powerful Soviet transmitters, each with a power estimated as high as 40 megawatts (Figure 12). The pioneering experimental measurements of these signals by Dr. Robert Beck and William Bise have shown just how deadly a potential may be possessed by the signals. These measurements have been performed in Eugene and Portland, Oregon; Los Angeles, California; Huntsville, Alabama; and several other locations. They have been particularly significant on the West Coast in and around Eugene, Oregon because of the presence of a direct current transmission line several hundred miles long, which has acted as a long wire antenna, picking up the signals and rebroadcasting them with appreciable gain in the vicinity.

Typically the signals may be found on, say, sixteen different carriers between 10 and 20 megahertz. Twelve of the carriers may appear normal, with normal sidebands, and the other four may have the carrier and both sidebands suppressed but still show the biologically significant modulation (for example, 10 hertz). On all sixteen channels a strong 10 hertz modulation may appear, all perfectly time

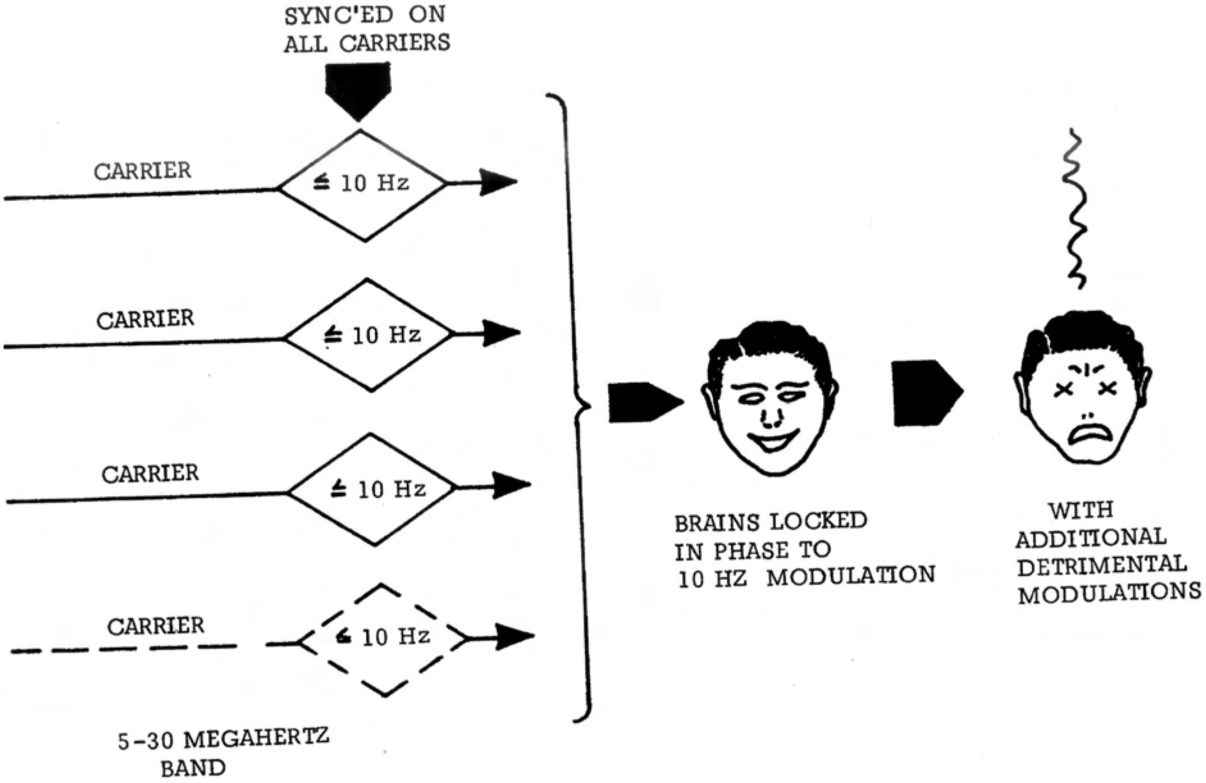
SYNC'ED ON
ALL CARRIERS
CARRIER
≤ 10 Hz
CARRIER
≤ 10 Hz
CARRIER
≤ 10 Hz
CARRIER
≤ 10 Hz
5-30 MEGAHERTZ
BAND
BRAINS LOCKED
IN PHASE TO
10 HZ MODULATION
WITH
ADDITIONAL
DETRIMENTAL
MODULATIONS

Figure 12. The Soviet "woodpecker" signals

synchronized and in phase channel-to-channel. The received signal from one of these carriers may be twenty-five to thirty times as strong as the earth's background magnetic field, which is oscillating at approximately 7.0 to 7.5 hertz. Other complex modulation frequencies, many of them changing, are present on the various channels.

Normally, the brainwaves of mammals in an area are gently entrained by the normal oscillations of the earth's magnetic field and are oscillating along at, say, 7.5 hertz. Under continuous radiation from the Soviet woodpecker signals, a percentage (say 30 percent) of the mammalian brains may be captured by the 10 hertz modulation on the overpowering Soviet signals. These captured brains are now in forced oscillation and are riding along in phase with the 10 hertz Soviet modulation. In other words, a certain percentage of the human brains in an area will phase lock to the 10 hertz modulation, and that will effectively lock into those brains the sixteen carrier frequencies with their concomitant frequency mixes and complex signal modulations. If the signals are made much more powerful (for example, by focussing them onto one particular area or increasing the power of the transmitters), then a much higher percentage of brainwave entrainment can be accomplished in the targeted area. By simply adding on the desired modulation patterns, the Soviets can now pump material directly into the mind-brain-consciousness-life loops of the entrained brains. The weapon implications are enormous: raw emotion such as sheer terror or panic can be transmitted; death or disease patterns of all kinds can be transmitted; informational content (thoughts and ideas) can be impressed directly into the captured brains and minds and processed as if originating inside each brain itself. Indeed, as long as the Soviets keep the effects rather gentle, an entire population can be subtly influenced without governmental notice. Certain specific ELF frequencies can rapidly disable or even kill, and for wartime use those frequencies can be directly implanted in the captured brains themselves by the woodpecker signals. It appears that 1984 came a little early, and one can perhaps now understand Brezhnev's strange 1975 proposal to the SALT negotiations that we should also consider outlawing the development of new weapons more frightful than the mind of man has ever conceived.

The signals also have direct application against strategic targets other than personnel. For example, by incorporating the correct nested modulation pattern, the positron kindling (electron squelching) pattern can be impressed. By beaming through the earth (with a circularly polarized signal or with other complex modulation forms), a beam with a strong neutrinic component, which will squelch electrons and which will interact with great preference for strong voltages or strong magnetic fields, can be directed at a target complex. In the targeted area aircraft and communications systems can be disabled; automobile, truck, and other ignition systems will fail; power transformers and large motors and generators will fail; power transmission systems with their associated high voltages will fail; and so on. Even independent, self-contained emergency power equipment, such as at military installations and strategic missile sites, will fail to operate. Further, to some of these signals, the earth and the sea are as transparent as glass, and so underwater nuclear submarines can be electrically disabled on station before their missiles can be fired, while strategic missile complexes can be electrically disabled before their deadly nuclear missiles can be hurled toward their distant targets. If some submarines and land complexes succeed in firing missiles before being disabled, these missiles can be electrically dudded and scrubbed from the sky over Soviet territory while still far from their intended targets.

So, as stated at the end of *Excalibur,* the players are on stage and in place. The final act begins. One thing is sure—mankind will never be the same again after seeing the play!

PART FOUR

SOVIET PHASE CONJUGATE DIRECTED ENERGY WEAPONS

WEAPONS THAT USE TIME-REVERSED ELECTROMAGNETIC WAVES

At the end of WWII, the Soviet Union obtained the cream of the crop of Germany's radar scientists and infrared scientists.

At that time, the German scientific team led the world in the theory and technology of radar absorbing materials (RAM) and radar cross sectioa For example, some leading Western radar experts believe that the German scientists had already advanced the theory of radar cross section beyond where Western scientists have arrived at today. Radar cross section science is the "heart" of modern radar technology, countermeasures, and counter-countermeasures.

The theory of RAM technology is precisely what is needed to develop and design phase conjugate mirrors for radar frequency bands. Phase conjugate mirrors are capable of producing a time-reversed (TR) wave in direct response to a received ordinary wave. The mirror may be powerfully "pumped" with energy to produce a very large amplification of the time-reversed wave.

Just after WWII, the Soviets also mounted a truly massive program to obtain and review all the scientific literature of the West This material was completely re-examined and digested, in a deliberate search for a major new technological "breakthrough" area. Nothing similar to this has ever been done in the West.

By 1950, the Soviets probably had discovered phase conjugation and the time-reversed wave, in their radar programs using the German radar scientists. Their relearch would certainly have revealed that the time-reversed wave is a solution to the wave equation, and hence the phenomenon is universal to all waves and frequency regions, under appropriate nonlinear circumstances.

We stress the fact that from the beginning the Soviets have always led the rest of the world in nonlinear science and mathematics.

Thus by the mid-50's, the Soviets would have mounted an intensive national development program on these radar TR wave weapons. If so, the Soviet Union has now had the equivalent of some seven or eight Manhattan Projects, back-to-back, in the development, stockpiling, and deployment of TR wave weapon systems. At least fifth generation Soviet TR weapons have been developed and deployed.

This is a matter of the greatest importance to the U.S.—and one which the U.S. intelligence and scientific communities have largely missed.

We particularly stress that the time-reversed wave phenomenon is a universal phenomenon of nature, not just a fluke, and not just a "nonlinear optics" phenomenon. It is a solution to the wave equation and, as such, it applies to every kind of wave. Electromagnetic, sound, magnetohydrodynamic, and other radiating systems all exhibit the phenomenon under appropriate nonlinear conditions.

Hundreds of Western papers dealing with time-reversed waves are now in the open scientific literature—most of them dealing with non-linear optics. However, the principles of the time-reversed wave are well-established, and known to apply to waves in general.

Compared to a normal wave, a time-reversed wave has startlingly different weapon capabilities.

Such a wave precisely retraces the path of the ordinary wave that stimulated it to be formed. So it possesses an "invisible wire" through space, back to the original position of whatever emitted its stimulus wave.

Further, the time-reversed wave continually converges upon its invisible "backtracking" path. It does not diverge and spread its energy, in contradistinction to normal waves.

Using several simple schemes (particularly pumped 4-wave mixing), extremely large amplification of the time-reversed (TR) wave can be cheaply and readily accomplished.

A startling weapons capability therefore emerges when amplified TR waves are generated in response to received signals from a distant target:

(1) If any signal at all can be received from a distant target, a return TR signal of extreme power can be delivered directly to that target Almost all of the transmitted TR signal energy will arrive at and in the distant target, even through a highly nonlinear medium or under scattering conditions. Hardly any of the energy will be lost enroute. If the target is fast-moving, a "lead correction" signal can be calculated and added to steer the return path.

(2) Since real-time holography can readily be accomplished using TR waves—and without first making holograms, geometrical forms (balls, shapes, hemispherical shells, etc) of energy can be created readily by interferometry (crossed beam techniques). Since the TR wave carriers do not disperse with distance, these interference energy forms can be assembled by crossed TR wave beams at great distances—even hundreds of thousands of miles. The energy appearing in such a distantly created energy form is limited only by the amount one cares to put in at the amplified transmitting end.

Thus the radar itself now becomes a powerful, all-around weapon. With a TR wave adjunct, once the radar receives a return signal from a target, an extremely powerful TR wave pulse can be generated, and all the energy in that pulse can be unerringly returned to the distant target from which the return was received.

Even a passive (receive only) radar may be used together with a TR wave adjunct to accomplish the same directed energy destruction of the distant target emitting the signals received by the radar.

Radio receiver-transmitters may also employ simple TR wave adjuncts to provide a large number of communications jammers and "directed energy weapons," capable of jamming and/or destroying enemy radio transmitters at appreciable distances.

The Soviets have intensively developed such TR wave weapons since the 1950's. In January 1960, Khrushchev was probably referring to these weapons when he reported to the Soviet Presidium the forthcoming advent of fantastic weapons, then in advanced Soviet development.

Prior to Khrushchev's announcement, the Soviets had begun radiating the U.S. Embassy in Moscow with scalar EM waves and phase conjugate energy, modulated upon weak microwave carrier beams. Later these beams were used to induce illnesses and blood changes in Embassy personnel. (We will shortly discuss how the Soviets could induce disease at a distance, electromagnetically). The microwave radiation continued intermittently, in spite of the objections of several U.S. Presidents. U.S. studies failed to comprehend what was being done.

The Embassy radiation was and is a high-level intelligence probe: Stimulate and affect the U.S. Ambassador, a high-level target. Attention by the CIA, NSA, State Department, DIA, the U.S. President, etc. is guaranteed. Puzzled, they will turn to the U.S. scientific community for an explanation. The scientific community will try to explain the microwave radiation, using the best of its EM knowledge. By the U.S. counteractions taken or not taken at the Embassy site, the Soviets know with 100% certainty whether or not the U.S. has discovered TR wave weapons, electromagnetic disease control, etc.—and whether we have developed defenses against such weapons.

Since the beginning, of course, our actions—or lack of them—at the U.S. Embassy have consistently revealed to the Soviets that we have no knowledge of, and hence no defenses against, TR wave technology and the scalar electromagnetics (electrogravitation) that accompanies the phenomenon.

Soviet TR wave radar weapons also provide a convenient mechanism for accomplishing nuclear weapon kill. A target struck by a powerful TR wave pulse generates a time-reversed back-pulse due to nonlinearities in the target medium. In the nonlinear medium of the exploding or fuzing target, the two pulses (which are 180 degrees out of phase with each other) modulate each other, locking together into a scalar EM wave or pulse. This scalar EM pulse has zero electromagnetic force field resultants, but is a violent fluctuation of the energy density of local spacetime. Rigorously it is a local gravitational pulse wave, by definition. Further, it is far more powerful than "normal" gravitational waves. This scalar EM pulse does not react with the orbital electron shells of an atom, but passes directly into the nucleus and is absorbed there. This raises the nucleus to an excited state, increasing its potential (trapped energy). If the nucleus cannot withstand this increase in potential energy, it directly fissions. If the nucleus withstands the increased potential, it then immediately decays from the excited state by simply emitting a time-reversed EM wave.

Any radioactive nucleus is already "teeter-tottering" toward nuclear decay, so to speak, and it will instantly decay radioactively when struck by a significant scalar potential pulse. Thus a TR wave radar weapon can deliver a powerful TR pulse against a distant vehicle carrying a nuclear warhead, and the resultant EG pulse penetrating the nuclear material of the warhead will electrogravitationally explode it in a full-order nuclear detonation.

Therefore, when using such weapons, extreme care must be taken to avoid inadvertently pulsing one's own nearby nuclear weapons or nuclear material. In attacking distant ground targets, one must be careful not to detonate nearby nuclear weapons, nuclear powerplants, or stored nuclear material—even at some distance from the target Otherwise, large-scale nuclear fallout will be experienced over a worldwide area, and unacceptable "boomerang" self-damage to the attacker himself may be incurred. The more powerful the TR pulse employed, the greater the safety separation between the struck target and stored nuclear materiel must be to prevent unacceptable "boomerang" large-scale fallout.

Also, large TR wave interferometer weapons, such as the Woodpecker systems, usually first produce very powerful, scalar EM "standing wave" beams by continuously transmitting (in the beam) both a normal EM wave and its phase conjugute.

modulated (locked) together to produce a "zero EM vector resultant" electrogravitational (EG) wave. Interference of two of these scalar EM beams in the targeted area, plus internal scanning within the beam by other signals, allows EM effects—of either normal EM energy or time-reversed EM energy—to be produced and controlled at very precise locations within the broad interference area.

Each such huge "scalar EM standing wave" beam represents a gigantic electrogravitational standing wave, and hence a giant oscillating potential in spacetime. This standing wave represents a sort of gigantic "capacitor", or accumulator of infolded energy. Enormous energy may be collected in this potential, charged-up over a period of time. "Shortcut" of this giant capacitor—by transmitter failure—can result in a large flash-over discharge of the EG energy into the local earth, producing a massive EG ground wave that can be enormously destructive.

Thus one must carefully protect the TR wave weapon system from inadvertent discharge of large EG pulses into the earth at the local site, due to transmitter failure, shortouts, etc. Otherwise one's own nuclear weapons or facilities may be exploded—even at some distance—by the EG pulse ground wave produced. One's communications and electronics installations, for example, can be knocked out at an even greater distance.

For example, in the winter of 1957-58, a large Soviet TR wave prototype weapon at Kyshtym, near the Urals, apparently suffered a catastrophic transmitter failure, discharging a powerful scalar EM (electrogravitational, or EG) pulse into the earth. This huge EG pulse struck the atomic wastes stored nearby, causing the radioactive nuclei to imediately decay. In other words, the nearby atomic wastes exploded—just as eyewitnesses reported. Deadly radioactive contamination spread across a major region, and exists to this day.

After this accident, the Soviets would have developed much more elaborate safety circuits and devices and implemented them into their TR wave weapons.

Even so, in April 1986, the explosive eruption of a reactor at Chernobyl was almost certainly caused by an accidental catastropic failure of a large TR woodpecker transmitter about 30 kilometers away. The sudden failure of the East-to-West Woodpecker transmitter was positively detected by engineer Bill Bise. All safety circuits at the site would have been instantly activated, desperately and slowly draining off the huge "standing wave" potential built up by the weapon.

The Soviets would have immediately shut down the reactors at Chernobyl as a precaution.

Some hours later, the transmitter safety devices finally failed, and a much smaller, though still significant, remnant EG pulse was discharged into the earth, spreading out in a ground wave. The first radioactive material—the fuel rods in one of the hapless, shutdown Chernobyl reactors—encountered by the EG ground wave pulse received it and immediately erupted radioactively.

Had the full EG pulse escaped the stricken transmitter, all four reactors at Chernobyl would have violently exploded, and deadly nuclear fallout would have rained down over a wide area of the earth. Had the reactors not been shut down and the control rods inserted "full-in" to dampen the radioactivity, a far greater radioactive eruption—probably a nuclear explosion—of the struck reactor would have occurred.

In May 1960, a prototype TR wave radar weapon was used to down Gary Powers' high-flying U-2 aircraft over the Soviet Union. Powers reported a flash, as if from an explosion near him, but the flash persisted. This is almost certainly the signature of a TR wave weapon.

In April 1963, the first large strategic Soviet TR wave weapons became operational. These weapons were used to electromagnetically deaden the electrical controls of the *U.SS. Thresher* atomic submarine on April 10,1963, and to produce a huge underwater electromagnetic blast 100 miles north of Puerto Rico on April 11,1963.

Since the 1960's, the Soviets have possessed a 100% effective defense against U.S. and European strategic bombers and missiles. The early systems deployed in the Soviet Union were midcourse and terminal phase systems. The Soviets would also have relied upon additional TR wave weapons systems, deployed as adjuncts to radar systems aboard research ships and crawlers, to be able to attack U.S. missiles and bombers in their launch and early midcourse phases.

These Soviet defensive TR wave systems also could easily accomplish nuclear weapon kill, and by their nature may have already been immune to the Stealth technology.

Older Soviet radars, using TR wave adjuncts, become totally new weapons having startling and heretofore unsuspected capabilities against missiles and aircraft. For that reason, the Soviets happily continue to operate and maintain thousands of older radar systems that, by Western radar standards, are seemingly obsolete.

Hundreds of incidents of Soviet tests of these TR wave weapon systems have been observed around the world, and reported in the open literature as puzzling or anomalous phenomena.

In the 1960's, in Siberia, Vlail Kaznacheyev and his researchers accomplished enormous experimentation proving that cellular death and disease—of any type whatsoever—could be transmitted and induced electromagnetically. This team went on secretly to phase conjugate (time reverse) the "death photon" signals, to show that any cellular death and disease can be reversed or "cured" electromagnetically as well.

The latter work would have been done under the auspices and tight control of the Soviet KGB, since all phase conjugation (time reversal) weapons effects are under the KGB, both for development and deployment Obviously the "electromagnetic antidote" work of Kaznacheyev was not published, because it provided a powerful counter-BW warfare capability of great strategic importance to the Soviet Union.

Thus in the late 1960's, the Soviet Union became the only nation on earth to achieve the capability of rapidly (within one or two hours) developing an electromagnetic antidote for lethal new biological warfare (BW) viruses—of any kind whatsoever. The Soviets also developed the capability for mass treatment in this fashion of both the civil populace and the military forces personnel.

Independent verification of the Kaznacheyev "death photons" effect has been accomplished in West Germany (University of Marburg), in Australia (University of Sydney), and in the United States (by G. Wilbanks).

Independent proof of electromagnetic healing of viral diseases was also accomplished in the West, and largely ignored.

In the late 1960's and early 1970's, a French inventor—Antoine Priore—built and tested several large electromagnetic devices that cured thousands of cases of terminal cancers and leukemias in laboratory animals. He worked with members of the prestigious French Academy of Sciences. His work was funded by the French government and presented to the French Academy by Robert Courrier, head of the Biology Section. His work was suppressed in the 1970's, and lost when he died.

Priore used a plasma to accomplish multi-wave mixing and phase conjugation (time reversal). His time-reversed curative signals used a powerful, rippling magnetic field as a carrier; the magnetic field guaranteed penetration of every cell in the body—necessary to reach a blood disease. The rippling of the magnetic field guaranteed penetration of the cell's atomic nuclei by nuclear magnetic resonance. Penetration of the actual nuclei of the atoms in the diseased cell is necessary, since the master cellular control system (discovered by Dr. Fritz Albert Popp of West Germany) operates through the cell's structured scalar EM biopotential, and this potential is centered in the nuclei of the atoms comprising the cell.

Note that electrical dedifferentiation of cells at miniscule current—between picoamperes and nanoamperes—has been proven by Robert Becker and other researchers. Red cells of the frog, for example, have been electrically reversed through all their development stages. The cells first become round, then develop a scalloped outline in their membranes. Then they become ameboid and move by means of pseudopods. Their nuclei swell and their DNA becomes reactivated. They then rid themselves of all their hemoglobin and develop a full set of mitochondria and ribosomes. In Becker's historic experiments, the cells then turned into cartilage-forming cells, and finally into bone-forming cells. In short, Becker demonstrated dedifferentiation followed by redifferentiation into an unrelated cell type—all electrically initiated with laughably weak currents.

Thus profound cellular changes are most certainly inducable and controllable electromagnetically, by miniscule amounts of potentials and currents. Priore's machine applied time-reversed EM waves to accomplish reversal from cancerous cells back to normal cells.

Priore's work essentially proved that Kaznacheyev's group would have been able to accomplish the same thing by phase conjugation.

Kaznacheyev's "death photons" work was probably accomplished much earlier than reported in the open literature. Thus it probably provided a basis to use in the microwave radiation of the U.S. Embassy in Moscow, to engender blood changes and disease in targeted personnel. Two U.S. ambassadors died from a leukemia-like disease, and a third sickened and bled from the ears and nose. Only miniscule levels of EM signals would have been necessary to induce such biological conditions.

The present Woodpecker radars probably have the capability of producing similar conditions in distant target populations, whenever the Soviets wish to add the appropriate signals. They also probably are capable of killing large numbers of the targeted population, whenever appropriate Kaznacheyev "death signals" are placed upon them.

In the late 1960's, another cautious Soviet "intelligence probe" was used: A paper appeared in the open Soviet literature, dealing with time-reversed waves in the field of nonlinear optics. Only a few American optical scientists seemed to be interested.

In 1972, to focus more U.S. attention on their subtle "intelligence probe" of U.S. time-reversed wave knowledge, the Soviets sent two scientists to Los Alamos to brief American scientists on optical phase conjugation. Thereafter many U.S. optical scientists began to work in the "new field." Immediately it was revealed to the Soviet Union that the U.S. had ineffective knowledge of phase conjugation, and that the U.S. had no TR wave technology or weapons.

To this day, U.S. theoretical work in phase conjugation is still characterized by a fairly simple overall math model, obtained by simply "writing down" the necessary conjugate term. There appears to be absolutely no U.S. awareness of the actual physical electrogravitational mechanism that causes the phase conjugation/time reversal, and no theory of it as such. Its direct application to radars appears to have largely been ignored in the U.S.

In 1975, the Soviets attempted to obtain a treaty with the rest of the world, outlawing the development of frightful new weapons of mass destruction—"more frightful than the mind of man had ever imagined", according to Brezhnev himself. Gromyko introduced the draft treaty into the 1975 session of the United Nations General Assembly. No one knew what the Soviets were referring to.

Failing to obtain the treaty, the Soviets in 1975-76 embarked on the greatest military buildup in history. This buildup was nothing short of a full-fledged preparation to be ready to take over the world, beginning in 1985 (the "ready" time per Brezhnev's 1972 statement at a secret Prague meeting of European Communist Party leaders). The Soviets met this scheduled goal.

As we stated, The Soviets can be immune to any kind of viral biological warfare, anytime they choose to be. The use of lethal new viruses thus has become a highly favored, low-risk method of warfare for the Soviet Union. The West has no such capability against viral warfare, and in fact is totally vulnerable to attack in this manner. Both Western troops and Western civil populations are totally defenseless against the threat of viral biological attack.

A BW strike from a small, hostile nation or from a few radical terrorists—or even an inadvertent contaminant spillage from one of the great many ill-controlled private genetic experiments—can result in the introduction of a lethal, highly infectious new virus that will decimate the West. Indeed, a deliberate BW viral attack upon us may already have been unleashed.

In 1971, the U.S. passed the National Cancer Act and declared open warfare on cancer. Iron Curtain country scientists were invited to participate, and they did so with alacrity. At the time—ironically—penetration of our recombinant DNA genetics research was one of the highest priorities of the Soviet KGB. Obviously, many KGB scientists/agents were infiltrated into our labs under this program (some of our cancer research labs at Ft. Dietrich, for example, still employ more Communist than American scientists.).

In these cancer labs, animal viruses were repeatedly injected and reinjected into human cell cultures, until new viral strains emerged that preferred human cells. These viruses could then be cultured and the effects (or lack of effects) of various chemicals and drugs against them could be ascertained.

These new viruses are exactly what one would wish to develop if one were seeking a biological warfare virus to which humans were not resistant, and one which preferred humans as its host

Sometime during the early 1970's, KGB agents who had infiltrated U.S. cancer research laboratories may have deliberately contaminated the World Health Organization's smallpox vaccine with one or more of the lethal new viruses available in the

Western cancer laboratories. Massive WHO smallpox vaccination in Africa and other Third World countries then resulted in the appearance and spread of the AIDS disease.

If this thesis is true, then AIDS constitutes the first Soviet biological warfare strike against the West, in what can only be categorized as the opening round in a unique new World War III.

With the Kaznacheyev techniques, the Soviet KGB already has the effective electromagnetic antidote against AIDS and other lethal viruses, anytime it wishes to employ it. Some Soviet citizens, however, will be allowed to die, to serve as a deception plan and conceal the true Russian capability. Meanwhile, the Third World nations and the West will be devastated by the killer disease.

Other lethal viruses are almost certain to follow, whether from the Soviets, fanatical terrorist groups, or inadvertent private contamination. Undoubtedly, some of these frightful new viruses are not going to be slow (lentivirus) agents. Some will likely be highly infectious and quick-acting, in the manner of influenza. Some will be transmitted successfully by insect vectors such as the voracious new Asian Tiger mosquito now spreading across the Southeast U.S.

Beginning in July 1976, powerful new Soviet "over-the-horizon radars" (the infamous Woodpeckers) became operational. Extensive weather engineering over the U.S. has been accomplished by these weapon systems. (This has been separately documented by the present author; C. B. Baker, editor of *Youth Action News;* Andrew Michrowski of Canada's Planetary Association for Clean Energy (PACE); and other researchers such as Andrija Puharich.) In addition, the Woodpeckers possess the full range of TR wave weapon capabilities, including real-time holography capabilities and anti-Stealth capabilities. Terrible anti-biological capabilities are also possessed by these weapon systems, and they are also highly effective as global launch phase and midcourse phase defensive weapons for use against U.S. missiles and bombers.

In 1985, the Soviets completed "wet run" weapon tests against U.S. missiles and aircraft and at least three of NASA's shuttle launches, employing the Woodpeckers in the launch phase ABM/anti-bomber mode.

Beginning in December 1985, actual destruction of selected U.S. missiles and aircraft was accomplished. Targets destroyed by the Soviets included the Arrow DC-8 at Gander AFB, Newfoundland on Dec. 12,1985; the shuttle Challenger launched on Jan. 28, 1986; the Titan 34-D rocket launched on Apr. 18, 1986; a U.S. Delta rocket launched on May 3,1986; and the French Ariane rocket launched in late May, 1986.

In 1986 and 1987, the mysterious loss of two highly classified U.S. aircraft—believed to be Stealth fighters—may also have been due to Soviet testing of TR weapon capabilities and anti-Stealth capabilities of the Soviet Woodpecker weapon systems.

However, a severe limitation on the unrestricted use of TR weapons exists. If powerfully and unrestrainedly used, they will cause nuclear warheads and nuclear material to explode as surface nuclear bursts—in the dirtiest possible fashion. The resulting massive radioactive fallout would probably wipe out all higher forms of life on earth. Note that Khrushchev stated in 1960 that these fantastic weapons could "wipe out all life on earth if unrestrainedly used."

As long as we possess an appreciable deployment and stockpile of nuclear weapons, we are essentially "dead man fuzed" against substantial Soviet usage of their powerful TR wave weapons.

Thus Gorbachev needs to "thin out" the deployed and stored Western nuclear warheads, to allow a more unrestrained field of play for his decisive TR wave weapons. That is why at Reykjavik he suddenly expressed full interest in President Reagan's zero option, even expressing agreement with the principle of on-site inspection to insure dismantling of missiles and removal of warheads.

That is also why the Russians are so actively interested in negotiating the withdrawal of nuclear weapons from Europe. They can quickly and easily take Europe, the moment the nuclear weapons are thinned out and our "dead man fuzing" is removed!

To appreciate the ease with which a Soviet offensive, augmented with unrestrained TR wave weapons, can take Europe, consider this: A single airborne Soviet standoff radar jammer, complete with adjunct TR, within minutes can knock out all U.S., British, and FRG radars that illuminate it. Each pulse it fires, destroys an Allied radar. A single Soviet standoff communications jammer, complete with adjunct TR, within minutes can knock out all U.S., British, and FRG communications centers that are transmitting within its detection range. Each pulse that it fires destroys an Allied communications center. A single standoff Soviet jammer-based TR wave weapon can destroy an Allied carrier task force. Pulse after pulse from that weapon system will destroy the task force's radars and communications, explode HE propellants and nuclear weapons, explode fuel, ignite flammable materials, explode rockets and ammunition, and kill personnel wholesale. Tactical adjunct TR weapons can rapidly destroy aircraft, missiles, radars, radios, personnel, tanks, weapon carriers, personnel carriers, ammunition dumps, gasoline dumps, etc. The instant vulnerability of any massive emitter such as AWACS is readily seen.

We are referring to a new kind of blitzkrieg war: War conducted by powerful beams and destruction, engendered at the speed of light War in which electromagnetic radiators are the primary decisive weapons. War in which new kinds of directed energy weapons play the major role. War which renders all our present defensive armada of weapons archaic and useless. War in which the materiel and personnel loss rates are so incredibly high that they boggle the mind of the more conventional military tactician and planner. War in which even a small nation with TR wave weapons can strike and devastate a major power, and possess a first-strike capability unparalleled in human history. War which could be triggered by radical splinter groups and terrorists groups that acquire the technology. War in which the slightest miscalculation or the misuse of the weaponry can completely destroy the earth. War which places extreme emphasis on finding "other ways"—such as surreptitious biological strikes and insidious electropsychological attack and control—to decimate a foe. War that Western governments, populaces, and Armed Forces are completely unprepared—militarily and psychologically—to face.

NATO can be defeated in two hours or less, and the entire war—mop up and all—would last perhaps three days.

Of course, powerful demonstrations of Soviet strategic superweapons could be provided, to show that attempted nuclear retaliation would simply be suicide. The Woodpecker weapon systems alone could wipe out all major communications systems and power systems in the U.S., induce waves of EM-induced death and disease in preannounced locations, induce waves of abject fear and panic in the populace, or psychologically disrupt and disable—say—the entire Washington D.C. area, to include the people, the government, and the Pentagon.

If such a scenario were accompanied by a proclamation of a Soviet equivalent to the "Monroe Doctrine"—except applying it in Europe, an offer of a ceasefire, and an offer to allow us a "Dunkirk" to evacuate the beaten remnants of our European forces, we would almost certainly be forced to accept the Soviet terms for a ceasefire that left the U.S. intact.

The U.S. Congress—reacting with alacrity to accept this sudden and apparently miraculous Soviet leniency, and avoid the destruction of the world—would probably play the leading role in dictating our acceptance of liberal Soviet terms.

An agreement with the Soviets to mutually withdraw many of the nuclear missiles from Europe appears to be imminent. When the missiles are thinned out, the preceeding scenario or some variant of it is almost certain to occur.

There remains, however, one fly in the Soviet ointment: The U.S. Strategic Defense Initiative.

Presently our scientists apply phase conjugation primarily to "keep laser energy beams intact for greater distances." They appear to be completely unaware of the electrogravitational aspects of phase conjugation.

A colleague of the author has already rigorously proven this electrogravitational aspect on the laboratory bench. The phase conjugate (time reversed) wave is composed of, and carries, negative energy and negative time. If an object is forced to produce a great deal of this negative energy/negative time, it produces antigravity. This is because, in negative time, gravity is a repulsion, not an attraction.

In addition, if the electromagnetic energy of a laser is changed into gravitational energy, a theoretical gain of up to 10^{36} (protons) to 10^{42} (electrons) is achievable. In practical devices, an energy gain of 10^{20} may readily be achieved. Applied to a modified powerful laser in space, this electrogravitational gain factor is of overwhelming significance.

In SDI, U.S. scientists presently envision a high energy laser in orbit, pumped perhaps by means of a nuclear explosion. The pulsed beam from this laser would have sufficient power to destroy a rising Soviet strategic ICBM in the launch phase, say at 10,000 miles away.

If that same laser were converted to a scalar electromagnetics laser (one that turns much of its electromagnetic energy into gravitational energy), it could blast and destroy possibly a quarter of Russia with a single shot.

Thus if we developed and tested the SDI spatial/launch hardware for the space-based high energy laser, so that these systems were available for immediate launching, we could convert their lasers to scalar EM and still possess a very real strategic retaliation capability, even if the Soviets should strike us almost unrestrainedly with powerful TR wave weapons. If we launched several of these systems, we could still probably get off a few shots at Russia and destroy her, before all our space lasers could be destroyed by Soviet counterweapons.

In that case, mutual assured destruction would still exist, and we would still possess a full "last ditch" strategic retaliation capability.

Gennadi Gerasimov, Soviet Foreign Minister spokesman, confirmed as much on the Peter Jennings' ABC News Show, Los Angeles, California on 13 October, 1986. The real concern (with SDI), he indicated, is not with its present design. Instead, the Soviet concern is that the U.S. would make a great technical breakthrough and deploy new devices in space as a modification to SDI, presenting an unacceptable threat to the Soviet Union.

Gerasimov was almost certainly referring to the potential for U. S. adaptation of the SDI space-based lasers to electrogravitational lasers capable of destroying the Soviet Union.

Obviously, if the high energy laser weapons stay grounded in the laboratories, and the system hardware is not developed and ready, that strategic retaliation capability is lost to us. For that reason, Gorbachev is adamantly insisting that the SDI defense must not be developed and tested in space.

If Gorbachev can prevent the development and testing of the SDI space-based high energy laser and get the nuclear weapons thinned out, he immediately holds the decisive winning hand.

This is where we are now, vis a vis the Soviets. This is the background necessary to understand the full context of the present jousting between the Soviet Union and the U.S.

In the *Washington Times* of Aug. 26, 1986, Soviet Chief of Staff Sergei Akhromeyev warned the United States that the Soviet Union could have an unpleasant surprise response if the U.S. deploys its Strategic Defense Initiative (SDI) in space. Akhromeyev stated:

"If the United States deploys a shield in space, the Soviet Union will have several options, none of what Washington would wish... The Soviet Union will very quickly find a response of which the United States has no inkling as yet."

It is absolutely essential that the President of the United States, the Secretary of Defense, the Joint Chiefs of Staff, and the U.S. Congress be aware of these Soviet weapons and their capabilities.

It is also essential that the U.S. public become aware of the real nature of the hidden Soviet threat that faces us, so that public support will be forthcoming for the hard decisions our government leaders have to make to counter it.

A PARTIAL GLOSSARY FOR SCALAR ELECTROMAGNETICS AND SUBTLE PHENOMENA

by Tom Bearden

1. Action: the fundamental constituent of physical reality. Basically composed of two quantities—energy times time, momentum times length, etc. Action is nonobservable; only changes in action are observed, and then only partially (in the linear case). The photon is the basic quantum of action, consisting of a piece of energy welded to a piece of time, with no seam in the middle, so to speak. All physical things are composed of rates of changes in action. The physicality (volume characteristics) of space arc created bit by bit from action quantum changes in and on each fundamental particle of mass, at a very high rate of speed. These action changes are totally internal to the mass itself. Therefore, literally the physical universe exists inside each and every part of itself, and is a giant hologram.

2. A-field: vector magnetic potential. The A-field is a real field—not a mathematical convenience as was originally thought—as detailed in the second volume of Feynman's three volumes of physics. Indeed, it may be separated from the magnetic field, as the experiment reported by Feynman details. When separated, it is often referred to as the "curl-free vector potential."

3. Aharonov, Yakir: renowned Israeli quantum physicist and former student of David Bohm. Together with Bohm, Aharonov authored a fundamental paper in 1959 which pointed out the primary importance of the potential rather than the force field. Co-discoverer of the Aharonov-Bohm effect: Even when the electromagnetic force fields reduce to zero in a charged particle system, the potentials may still exist and interfere to cause real physical effects.

4. Aharonov-Bohm Effect: Effect whereby interfering electromagnetic potentials can produce effects on charged particle systems, even at a distance and in the absence of the electromagnetic force fields. When E and B fields are zero in a region, their potentials still exist and interference of the potentials produces real electromagnetic effects (energy) in the interference zone, even at a great distance, without transmission of "energy" per se through the intervening space. The Aharonov-Bohm effect highlights some of the stark differences between the classical view of electromagnetics and the quantum mechanics view. In classical EM, the force fields are the real causative agents while the potentials are only mathematical creations for convenience in calculation. In quantum mechanics, it is the potentials that are real and fundamental; the force fields are effects derived from the potentials by differential operators. In classical EM, when the E and B fields are zero in an area, there is no more electromagnetics going on there; in quantum mechanics, the potentials still exist and may still cause real effects. By the use of artificial potentials, the Aharonov-Bohm effect can be made macroscopic and used to cause action at a distance—even significant action at a very great distance. Thus scalar EM interferometers can produce energy effects at a distance. The negative Aharonov-Bohm effect also exists. If the potentials of the transmitters in a scalar interferometer are biased highly negatively, then energy is extracted from the distant interference zone, reappearing at the transmitters. Tesla proposed a "Big Eye" that could see at a distance; actually he planned to use a negatively biased scalar interferometer, scan the beams, then reassemble the scanned energy appearing back at the transmitter/receivers. In this way he had a crude picture of the distant conditions in the interference zone. Such a device can see through the earth or ocean to a preselected intersection depth, since scalar EM waves can be made to pass readily through the earth or sea. The Aharonov-Bohm effect is in fact experimental proof of the new definition of force used in scalar electromagnetics. That is, force consists of mass in motion changing its motion (momentum). The nonzero 0 created by interference of two electrostatic potentials at a distance, for example, will create an electric field (E-field) on and of an electrically charged particle there. The standard detection of an E-field by conduction electron detectors is an example. It is the electron gas particles (charged electrons) that are detected, not what is in the vacuum. Thus classical EM errs when it assigns the equation E = - 0 to vacuum, for no such thing is ever measured. Actually, the correct equation is E = - 0 (e), where means "coupled to" and (e) means "electrically charged particle."

5. Aikido: a Japanese martial art whose modern form is a synthesis of many schools of jujitsu and the zen art of meditation in motion. The advanced aikido practitioner seeks to attain a state of "nomindedness," in which there is no separation of subject and object, of attacker and defender, or even of past and future. This state of at-one-ness with the universe, when attained, results in the complete mastery of the art. It is rarely experienced, even occasionally, and even rarer is it permanently attained. One who attains this state permanently is considered a great master, and his demeanor and personality are profoundly altered. The deceased founder of the present modern form, Morihei Uyeshiba, attained such mastery of the art He was a serene, deeply religious man and a profound inspiration to several generations of martial artists. He was also unbeatable even in his eighties.

6. Anenergy: stress energy of vacuum. "Fragments" of energy, more subtle than electromagnetic energy, turned against themselves and locked into a "vector zero summation." Scalar, massless charge flux. Virtual particle flux. "Pieces" of the spatiotemporal vacuum spacetime medium (i.e., quitons). Specifically, an observable object rotated more than one orthogonal turn away from the laboratory frame constitutes an anenergy particle. Examples are the virtual photon (rotation between 90 and 180 degrees), the bare neutrino (rotation exactly 180 degrees), the virtual bare neutrino (rotation between 180 and 270 degrees), and the thought or mind particle (rotation 270 degrees or more). Also, more fundamental components of energy—specifically, the individual scalar wave components of vector electromagnetic waves. Anenergy components may be coupled into energy, which can be compacted into mass. The conservation of energy law is replaced with a more fundamental law, the conservation of anenergy. Anenergy contains two com-

ponents or constituents: (1) ordinary energy (positive time, positive energy), and (2) phase conjugate energy (negative time, negative energy).

7. Angular momentum: the momentum or "leverage" of the momentum of a moving body, with respect to an axis or reference point Has the same units as action, or energy x time, or momentum x length.

8. Antimatter: matter consisting of atoms which are composed of positrons, antiprotons, and antineutrons. Also loosely refers to the antiparticle corresponding to a particle—the antiparticle may be regarded as the particle traveling backward in time, or "phase conjugated." In present physics, the photon is recognized as its own antiparticle. However, since physicists do not differentiate between positive and negative energies in a photon, then they assume that there is no difference between a photon and an antiphoton. The antiphoton, however, acts quite differently from the photon, as is clearly shown in phase conjugation. The magic rule of scalar electromagnetics for the final photon emission interaction with a charged particle in an atom is this: In the expression CPTEGS (where C is charge and normally negative, P is normal parity, T is time and normally positive, E is energy and normally positive, G is gravity and normal is positive, S is entropy and normally positive or increasing), if one of the components is reversed in sign, then each of the remaining components is also individually reversed in sign. The phase conjugate photon (antiphoton: negative energy, negative time), e.g., is produced by the photon interaction with the positively charged nucleus, producing a time-reversed wave having negative energy, negative time, reversed parity, causing gravitational repulsion, and causing negentropy.

9. Antiparticle: a counterpart to an ordinary fundamental particle, having identical mass lifetime and spin, but with charge and magnetic moment reversed in algebraic sign. Note that when the charge is reversed, parity and time are also reversed. Thus, properly, the antiparticle is the phase conjugation of the particle, or just conjugate particle for short.

10. Artificial potential: potential formed by deliberately summing force field vectors to a zero vector resultant This vector zero has a deterministic, internal stress pattern that is macroscopic. The type of potential made by the zero summation depends upon the type of force vectors summed. For example, summing electric field vectors to zero produces an electrostatic scalar potential; summing magnetic field vectors to zero produces a magnetostatic scalar potential of vacuum. All such potentials represents local warps or curvatures in vacuum/spacetime. Since Einstein assumed that spacetime locally was uncurved, this violates one of the assumptions of Einstein's general relativity. The Soviets have long made this correction; Western physicists have not Since curvature of spacetime is gravitational, this constitutes the secret of electrogravition: How to turn electromagnetics into gravitation, and vice versa. I have called this "scalar electromagnetics"; the Soviets refer to it as "energetics." In such a vector zero, the locked-in energies of all the component force vectors constitute the "anenergy" of the artificial potential. Potential in vacuum is analogous to "pressure" in fluids. An artificial potential polarizes the vacuum and constitutes a specific stress pattern in it Thus vector-zero summed systems of individually finite vector components may all differ from each other.

11. Ball lightning: rare form of lightning where an incandescent, slow-moving globe forms. The globe often moves erratically, explodes, and may set fire to objects it touches. Ball lightning is due to scalar electromagnetic interferometry which can produce a controlled pattern of electromagnetic energy at a distance. Phase conjugation is directly involved; note that the literature already explicitly demonstrates that phase conjugation can perform real-time holography, or produce forms of energy at a distance.

12. Bare electron: in physics, the true electron without the partial shielding of virtual positrons that are attracted around it In scalar electromagnetics, the mass of the electron, considered without its flux of virtual photons (its massless charge flux). An electron mass without its charge (in new approach); that is, one that is really bare of all charge!

13. Bare neutrino: the photon rotated one orthogonal turn farther away from the laboratory frame would be seen in the laboratory frame as a bare neutrino. In the new approach, bare neutrinos move at the speed c inside an ordinary photon, orthogonal to the photon's direction of travel, constituting a flux in each half of the photon. Two neutrinos move in the photon, one in each half (a simple photon is a single sine wave). One neutrino moves in positive time, the second moves in negative time and is properly an antineutrino. Since the photon moves at the speed c with respect to the laboratory frame, then the bare neutrino moves at the speed c-squared, but only its carrier speed c is seen by the laboratory observer. The flax of bare neutrinos in each half of a photon corresponds to the classical neutrino of present physics. The bare neutrino is (to the lab frame) a factor of c smaller than a photon, and one dimensional. It is a special kind of polarization wave to the lab observer.

14. Bearden, Thomas E.: nuclear engineer, retired Lieutenant Colonel (U.S. Army), and theoretical conceptualist active in the study of paranormal phenomena, scalar electromagnetics, Soviet Tesla (time-reversed wave) phenomena, free energy, antigravity, electromagnetic healing, and human development. Particularly known for his work in scalar electromagnetics and Soviet unorthodox weaponry.

15. Beck, Robert: noted psychotronics and ELF researcher who has pioneered many unusual measurement fields such as the Schumann resonance of the earth's magnetic field, specific effects on humans of extra low frequency (ELF) signals of precise waveform and frequency, ELF pollution effects, and brain wave entrainment by weak ELF signals of precisely controlled frequency. He is also noted for his development of a series of very sensitive detectors and scalar wave detectors.

16. Bedini, John: noted audio engineer, creator of the renowned Bedini amplifiers well known to audiophiles, and researcher into free energy, antigravity, and electromagnetic healing. Bedini has built several free energy motors and devices, including a gravitational field generator, a gravitational field turbine, and a series of monopole motors. He is also noted for his development of sensitive scalar EM wave detectors. He is struggling to develop an electromagnetic phase conjugate signal which will kill the AIDS virus, and also reverse the genetic damage done to the cell by the virus.

17. B-field: the magnetic induction B. This is defined, analogously to E, by the force it exerts. The force on a point charge moving in a magnetic field is at right angles to the velocity vector of the charge and also at right angles to the magnetic field. Actually, the H-field was originally named the magnetic field and the B-field was named the magnetic induction. This is an annoyance because it is B which produces or involves the force, and hence should be named the field. Other writers have noted this discrepancy, and Sommerfeld called H the magnetic excitation—which correctly describes its role—rather than die magnetic field. In Kaluza-Klein unified field theory, all electromagnetics is in the 5th dimension, which is wrapped around each and every point in our normal 3-dimensional space.

18. Being: pure essence, existence. Again, something which in actuality resists definition unless preliminary assumptions are made. Generally used in one of two senses: (1) persistence, as in "he is (he continually exists)," or (2) identity, as in "he is the man ('he' and 'the man' are the same thing)." Even in the first instance - persistence - one is using the form of the verb "to be" in the sense of identity, when perception is considered; i.e., "he is" is a statement that "he continues to be presented or perceived, because each succeeding perception is identical to the one before." Thus when perception is considered, being may be defined as that which is undifferentiated, and this yields its total definition. This is the real void devoid even of void, if one considers zen.

19. Bennett Island; Soviet island on which large, anomalous exhausts—some 150 miles long and nearly horizontal—are repeatedly photographed by U.S. weather satellites. Over 100 incidents have been photographed there since 1974. These exhausts are believed to be the exhausts of energy extracted by distant Soviet scalar interferometers used in the endothermic mode, then •witched to the exothermic mode and focused on Bennett Island as a "dump site." Similar exhausts have been seen on Novaya Zemlya, a large island off the north coast of mainland USSR.

20. Bigfoot: U.S. slang or common name for a materialized sasquatch or apeman-type tulpoid, even if not well-formed.

21. Big Mama: very large, glowing nocturnal light UFO believed sometimes associated with cattle mutilations. Implies a sort of "mother ship" which spews forth smaller ships, which then speed off, swoop down to mutilate cattle, and return. Big Mama has been observed to split into or spew off smaller lights which sped away, dipped down, then returned. Some of these occasions appear to have been associated with cattle mutilations. The most noted photographs of Big Mama were taken by Bill Jackson.

22. Biofield: a hyperfield, particularly with reference to the fields of a living biological system. Also bioframe, bioworld, hyperfield, hyperframe, hyperworld, orthofleld, orthoframe, orthoworld.

23. Bioframe: a hyperframe, particularly with reference to the frame of the body of a living biological system. Also biofield, bioworld, hyperfield, hyperframe, hyperworld, orthofield, orthoframe, orthoworld.

24. Bioworld: an orthogonal universe one or more right angle turns away from the ordinary world, particularly with reference to the frame of the body of a living biological s*ystem*. Hyperworld. Orthoworld. Living energy forms—"critters"—exist in these bioworlds. A bioworld is also one of the netted levels of infolded virtual state. Such "living electricity" can be manipulated and utilized by scalar EM means.

25. Bohm, David: world renowned physicist and originator of hidden variable theory. Together with his student Aharonov, he co-authored a fundamental paper on the Aharonov-Bohm effect wherein interfering electromagnetic potentials can produce effects on charged particle systems, even at a distance and in the absence of the electromagnetic force fields.

26. Brain wave: a rhythmic fluctuation of tho voltage between various parts of the brain, normally ranging from about 1 to 60 Hertz in frequency and 10 to 100 microvolts in potential strength. Brain waves are caused by avalanche discharge firings of the nerve cells in the brain. Actually, classical brain waves are only the residue or "spillage" waves of the brain, and the important activity is in the specific patterning of the vector zero summations of the myriads of ion discharges. Every "discharge ion" constitutes a small EM force vector. The summation of these is largely zeroed; however, the patterns formed by all these tiny components are not random. The intent and will of the human being is expressed in the changes in the patterning of these dynamic substructures. Present EM brain wave theory does not touch the basic "thought patterns," which are scalar in nature. Use of the two cerebral hemispheres as a scalar interferometer provides mechanisms for the effects of parapsychology and paranormal phenomena such as fire walking.

27. Burst, burst-in: the sudden collection or condensation of anenergy into a frame, so that observable light or electromagnetic energy (or rarely, physical matter) appears (is kindled). Sudden kindling of anenergy into energy.

28. Cattle mutilations: the strange, paranormal, surgical killing and/or mutilating of cattle in the U.S. and other countries, particularly since the 1973 Yom Kippur War. Metapsychologically, mutilation of the cow is the mutilation of the female symbol—that is, it symbolizes mutilation of "Fortress America." Many small animals such as cats, dogs, rabbits, and birds have also been paranormally mutilated, which is destruction of the child symbol. Again, this symbolizes the mutilation of "Fortress America." The author regards such bizarre paranormal incidents as being caused by temporary materializations of the unresolved conflicts from the human collective unconscious's dreams. With this thesis, if knowledge of Soviet scalar electromagnetic weaponry is also included, analysis very similar to standard psychological dream analysis provides explanations consistent with the bizarre mutilations and the Cold War.

29. Causality: the time ordering of ordinary inert interactions. Macroscopic (observable) causality may be violated by control of hidden subquantal (virtual state) variables. With scalar electromagnetics, direct engineering of the virtual state—and hence violation of observable causality—*in* possible.

30. Cerebral hemisphere: each half of the cerebrum, the enlarged anterior or upper part of the vertebrate brain. Tho two cerebral hemispheres may function as a scalar interferometer to sense distant scenes (even distant in time), or produce energy and signals at a distance. The time aspect (e.g., in psychometry) is due to utiliza-

tion of the cerebrum as a phase conjugate mirror (PCM), and inputting tiny signals picked up from the object one is holding. A phase conjugate signal is then originated by the PCM, retracing the route to the original object. Unfortunately the output of the human nervous system that can accomplish such scalar EM functions lies very deep within the unconscious mind, and it is very difficult to raise it to direct consciousness. Usually the conscious mind is only aware of "vague impressions" instead of clear signals, although in the extremely rare instance clear impressions are consciously detected.

31. Changing the past: every intentional inception upon ordinary inert causality represents a slight alteration or change in direction, departing minutely from pure causality. From a causal viewpoint, each human inception minutely changes the causal past, as well as the future.

32. Charge: the repetitive, "locked in" massless virtual particle emission and absorption activity (flux) of and on a fundamental particle such as an electron. Vacuum is identically pure massless charge flux. In the new theory, the intensity of the charge flux on a particle is also directly related to the rate of the particle's passage through time. The continued absorption and emission of photons by a particle provides the general mechanism by which the particle moves along in time in little jumps. In the scalar EM view, the relativistic change of the rate of flow of an object through time is due to a change in its ambient vacuum charge potential—i.e., to a change in the rate at which it is absorbing and emitting virtual particles and scalar waves. The negative charge is associated with a positive time flux (hence with positive energy) and the positive charge with a negative time flux (hence negative energy). A positive charge is also a negative charge moving backward in time. All particles have clouds of virtual activity patterns; essentially all mass is charged since these clouds contain charges. In ordinary electrical physics, charge is defined in terms of force and force in terms of charge, and charge and charged mass are erroneously made synonymous. In scalar EM, a "charged particle" represents a mass (nonlinear bump in spacetime, or *local nonlinearity" medium) that separates the scalar waves of vacuum into two parts, one is normal energy and the other is the phase conjugate having negative energy. It is important to remember that a charged particle is a special sort of high pressure "pump" and "vacuum cleaner" at the same time. So is a "magnetic pole" or a "potential."

33. Cold explosion: the sudden extraction of energy from a distant intersection zone of the crossing beams of a scalar interferometer which transmits in the pulsed mode while negatively biased. A famous example of Soviet testing of a cold explosion scalar EM weapon is the huge cold explosion that occurred off the coast of Japan on April 9,1984. When the energy is suddenly extracted from a zone near the surface of the ocean and above it, the pressure in the zone is suddenly lowered. Water vapor and mist are violently sucked up, and the surrounding air rushes in, pushing the "water vapor filled region" rapidly upwards. The pattern that results is a rising mushroom cloud, very similar in appearance to a nuclear explosion, except for the absence of a flash and blast wave. In a cold explosion, the energy is extracted from throughout the spacetime of the distant interference region, and insulation has no effect since classical heat conduction through space is not involved. Ordinary electrostatic cooling is also an example of this effect in less violent form.

34. Consciousness: refers to a living being's awareness of its sensations, feelings, thoughts, and the world around it Specifically, consciousness involves an anenergy communication channel where detections of the body-object (which may be regarded as a sort of special camera, instrument, or physical tuner) project into the mind as separations from the beingness of the subject Further, it refers to the intersecting stream of monocular, one— at-a— time virtual projections into the mind from the quantum changes of photon interactions upon the body sensors. By memory (collection in the mind) of streams of such monocular changes one after the other, the entity is conscious of its body-object (camera—tuner) monocularly "moving through time." In the absence of deeper understanding, the individual consciously sees itself as a separated physical object moving and changing in time, i.e., with respect to other separated physical objects that it perceives. The "externality" of certain changes (i.e., the physical world) is due to the lack of mental control or influence over them. "Internality" of certain other changes is due to the ability to mentally control or influence them. The ordinary conscious mind is a serial processor: only one thing at a time is discriminated in its awareness. The unconscious mind, on the other hand, is totally conscious—but multiply so, since it is a parallel processor of many discriminations at once. The conscious mind, then, cannot directly perceive the individual discriminations of the parallel processor, since these appear only as a blur or nothingness to it (much like looking at a hundred 35mm slides in the projector at the same time). This is the mechanism of the barrier between the conscious an unconscious minds. Projections from the unconscious onto the screen of the conscious mind will thus appear symbolical—that is, having many hidden meanings at once. This is why our dreams, for example, appear to our conscious minds as weird and distorted, but highly symbolic in nature.

35. Contactee: a person who seemingly has had a direct contact—mentally, physically, or both—with aliens, extraterrestrials, etc.

36. Continuous mode: for a scalar interferometer or Tesla howitzer, mode of operation where power is fed continually to the transmitters, and the two Fourier expanded scalar patterns or beams are continuously transmitted. In this mode, in the distant interference zone a glowing pattern of vector electromagnetic energy appears and is sustained. (Note the possibility that a few of the UFO sightings could well be due to the deliberate usage of such a mechanism by the Soviet Union or some other nation possessing the requisite technology to create such physical "apparations" at a distance.)

37. Corpus callosum: the thick nerve cable that links together the two cerebral hemispheres (which are separate brains) in each vertebrate (including human) brain. In each of the two cerebral hemispheres, there is a separate mind and personality (given that the other is separated). However, a brain has a unique characteristic: Anything that arises directly inside it is automatically assumed to be self-originated, since the brain-tuner can differentiate no separation or "separate source" for the signal/thought arising directly upon its "internal screen". This allows integration of the two brains/minds/personalities into one.

That is, when one brain half prepares and sends a message, that message is also routed across the corpus callosum into the other brain half, arising internally upon the second brain's "display." The second brain half therefore thinks that it itself originated the signal or message. Thus when the left cerebral hemisphere moves the right thumb, for example, the right hemisphere thinks that it itself ordered the movement of the right thumb. Perceptually, the definition of identity is the loss of all distinction."

38. Cotton effect: the wavelength dependence of certain optical and absorption characteristics in a substance in the vicinity of an absorption band. An absorption band is a range of electromagnetic frequencies within which electromagnetic energy is absorbed by a substance. The direction of polarization of the energy affects the degree of absorption for certain substances. In these substances, the frequency and the direction of polarization of incoming electromagnetic energy affect the amount of energy deposited and dispersed.

39. Crawford, Hal: accomplished science fiction artist and illustrator who has furnished many drawings in the new approach and contributed to the theory of mind linkage.

40. Crosstalk: in ordinary science, the transfer of energy or signal from one channel to another, by cross modulation or cross coupling between the channels. In the new approach, it refers to virtual anenergy exchange between orthogonal universes or frames—that is, between different 3- or 4-dimensional slices of an infinite-dimensional universe.

41. Cyborg: (noun) a single integrated system consisting of a living system energetically or functionally linked to mechanical or electromagnetic devices and/or systems. (Verb): link, in the sense of forming such a system. A living biological system is a cyborg of its mindworld (mindframe) to its body (laboratory tuner).

42. Death: the loss of the preferential tuning of a physical body to its mindworld. This causes loss of the preferential consciousness loop or life channel, resulting in "death." Actually the being is unchanging and indestructible, hence consists of all changes and destructions simultaneously, with none separated individually. Life and death thus are two sides of the same coin, and the coin is immutable, regardless of which side is exposed.

43. DeBroglie wave: a matter wave. The quantum mechanics wave associated with a particle of matter, which can give rise to interference effects. An orbital electron in an atom is associated with a standing DeBroglie wave on a Bohr orbit. DeBroglie waves always move faster than the speed of light, the speed being given by c2/v, where c is the velocity of light in vacuum and v is the velocity of the particle of mass. Debroglie wave velocities thus vary from the speed of light to infinite speed (everywhere at once). In his speech accepting the Nobel Prize, DeBroglie emphasized that , since these waves produce real physical effects, they are real and must not be regarded simply as mathematical conveniences.

44. Dimension: a certain primary geometrical physical attribute, such as length, used to describe the separational relationships of physical phenomena. By "geometrical" we mean that the "dimension" is considered to "exist" in either the presence or absence of the observable physical phenomenon; however, by agreement the dimension itself is not directly observable. It can be inferred ("measured"), however, by comparative operations of simple devices such as clocks and metersticks, and its simplistic definition is usually given as "that which has measurable magnitude." Prescribed measuring procedures are used to assign magnitudes to these inferred dimensions, using specific scales. Actually, "dimension" just means "fundamental quantity of separation" in the most general sense. The number of dimensions taken in advanced physics usually represents a somewhat arbitrary choice for good modeling fit In modern Kaluza-Klein theory, for example, it becomes necessary to accept some 10 or 11 dimensions.

45. Dirac sea: in Dirac electron theory, the relativistic wave equation for the electron has four components, which correspond to two spin orientations and two energy conditions: positive and negative. Thus the vacuum possesses a "sea" of negative energy conditions for electrons. These are called "holes" and are considered to ordinarily be filled with electrons which have fallen into these negative energy states. The Dirac sea thus is this vacuum sea of negative energy electrons. If energy is added, electrons can be lifted from this sea. If spacetime is locally curved, additional holes may be created so that normal positive energy electrons fall in and disappear, creating the appearance of an "electrical energy sink." If the curvature is in the opposite direction, electrons may be lifted from the Dirac sea by the curvature, thus producing a flow of electrons and creating the appearance of an "electrical energy source." In several battery-powered free energy motor devices where die battery is sharply "back-spiked" for recharging, the battery has been noted to apparently accumulate such additional "Dirac holes" as the DC series—wound motor ran. When later recharging the battery with a normal charger, for example, the battery would first "consume" a quantity of electricity to "refill the holes." When the holes were filled with new electrons, the battery would then start to recharge normally. In one extensively used battery, Watson noted that it consumed electricity for some eight hours before recharging normally. Similar effects have been noted by Bedini.

46. Dissociation: separation of ideas from their affects or feelings, resulting in independent functioning of these components of a person's mental processes. Simply put, fragmentation of the mind and personality. In this sense, Zarg (the collective human unconscious mind) is severely dissociated, since its "conscious mind" is fragmented into billions of pieces (into the independent conscious minds of ordinary humans). This is severe dissociation and psychosis; Zarg (the human species) is quite literally insane.

47. Dowsing: use of handheld rods, forked twigs, pendulums, bent coathangers, or other simple physical detectors to locate water, minerals, lost objects etc. or to seek answers to specific questions. The movement of the physical instrument serves as an indicator and is cyborged to the dowser mentally and psychokinetically.

48. E-field: the electric field or electric intensity E. That field on a spinning charged mass which produces an electrical force, hence linear motion of die charge. (In the new theory, the E- field CONSISTS OF the spinning charged mass, moving through a finite change in electro static scalar potential, and thus there is a more fundamental generatrix of FORCE.) Defined as the force per unit charge (i.e., per unit of charged mass). On a free

electron, there may exist two separate E-fields, one in the direction of motion of the electron (normally due to voltage); and one at right angles to the electron's motion, due to the time derivative of the A-field.

49. Einstein's postulates: (1) all the laws of physics are equally valid in all inertial frames of reference, (2) the speed of light is the same to every inertial observer, and (3) the observable local effects of a gravitational field are indistinguishable from those arising from acceleration of the frame of reference. The first is called the special relativity principle, the second is called the law of light propagation, and the third is called the equivalence principle. It is now known that postulates (1) and (2) are not independent of each other. Note that the third postulate implies that any local force is due to a "gravitational field" (acceleration of the frame of reference). It also implies that gravitational force has a mechanism, since quantum mechanics assigns a differential operator, operating upon a potential, to create every force. By extended inference, it can be seen that the third postulate also implies that there should exist a method to turn any type of force (field) into gravitational force (field).

50. Electrogravitics: electrogravitation, or scalar electromagnetics (SEM). The term "scalar electromagnetics" was chosen by Bearden to describe the electromagnetics that goes on inside a macroscopically summed-zero force vector system, producing gravitational effects and energy effects at a distance. A priori, SEM is a unified field theory, which predicts strong effects easily verified experimentally. The struggling science that seeks to produce gravity and inertial effects electromagnetically (success has been achieved recently in proprietary labs). Santiliy has shown that the classical assumption that electrical field and gravitational fields are mutually exclusive is false. They are therefore either the same thing or partially the same thing. There are numerous anomalous experiments which also show a connection between electrical effects and gravitational and inertial effects. Appreciable technical work in the U.S. seems to have been done on electrogravitics in the 50's and 60's, much of it apparently classified. There are presently strong electrogravitic efforts in Germany, France, and Japan. Scalar electromagnetics is in fact electrogravitics (electrogravitation) and has been successful in engineering gravitational devices such as gravitational and inertial field generators, gravitational field motors, free energy generators, and gravitational turbines. Tesla's secret of wireless transmission of energy at a distance without losses has been rediscovered, as has the secret of his "big eye that can see at a distance." A new land of resonance—scalar resonance—has emerged, as has a new kind of wave, the scalar EM or electrogravitational wave. Scalar wave detectors are now becoming available due to the pioneering work of Dea, Beck, Bedini, and Golden, who have all built scalar wave detectors. A substantial series of devices have been built by Bedini, Golden, Watson, and other inventors who wish anonymity. One of the very first good experimental physicists who built electrogravitational devices was Hooper. Actually, Maxwell's original quaternion theory, published in 1864, was the correct unified theory of gravitation and electromagnetics. After Maxwell's death, Heaviside "translated" (mutilated) Maxwell's theory into his new vector mathematics, discarding the quaternion's scalar component. He thus discarded electrogravitation, setting "modern EM theory" upon its nongravitational course.

51. Electron dissolution: when the virtual photon activity of an electron (i.e., its charge) is directly quenched, the electron is converted to a neutrino or neutrinic wave, which radiates away without interacting with materials or objects. In this case, no ordinary photons are radiated. Orbital electrons in atoms are generally protected from this interaction by being locked into their orbital DeBroglie waves. Free electrons flowing in circuits, however, are susceptible to the effect by scalar wave coupling. By this means, electromagnetic circuits may be dudded by dissolving their currents, without physical damage to the circuitry components. Whenever the agent causing the electron dissolution is removed, currents resume and the circuits resume normal electrical action. Scalar longitudinal 0-field waves can also be absorbed in scalar coupling into the E-fields of currents flowing in a circuit. This can either augment or diminish the E-fields to which coupling occurs. If the E-fields on the flowing electrons are zeroed, the electrons cease flowing, and the circuit is dudded.

52. Electrostatic scalar potential (0): virtual photon stress on the 4-dimensional spacetime medium (on the vacuum-ether). (Note that the vacuum can be regarded as consisting of the sum of a large group of such potentials.) The spatiotemporal intensity of the massless charge (of the virtual photon flux through a spatiotemporal point). Nikola Tesla discovered pure longitudinal scalar 0-waves. Present spatial 0 in the ordinary theory is only a special case. 0 can be visualized as a special type of "pressure" in an n-dimensional fluid, where n is equal to or greater than 4. By omitting the potential's stress on time, present potential theory eliminates the potential's ability to affect everything existing in time (for example gravity, fundamental constants of nature, inertia, mass, rate of time flow, mind, life, etc.) It also eliminates the direct engineering of local general relativity, and the concomitant violation of the conservation laws (momentum, energy-mass, charge, spin, etc.) Present electrical theory—and indeed all of physics—is drastically in error by this serious omission. Direct engineering of artificial potentials by patterned zero-vector force field summations is the secret of the long-sought "unified field theory." It is also the secret of the unification of mind and matter into a single scientific discipline.

53. EMP (electromagnetic pulse): a sharp pulse of electromagnetic radiation produced when an explosion occurs in an unsymmetrical environment, especially at of near the earth's surface or at high altitudes. Essentially the same as an electromagnetic shock wave, a wave of great intensity which results when waves with different intensities propagate with different velocities in a nonlinear optical medium. An EMP is also produced when two intense longitudinal scalar electrostatic potential wave patterns meet and couple into a sudden flash of vector EM energy.

54. Endothermic explosion: the sudden absorption of electromagnetic energy in a spacetime area where the energy converts to a potential, and scalar waves radial back to the negatively biased transmitter/receiver, emerging there as ordinary electromagnetic energy. As implosion. All normal explosions are exothermic in nature, and ordinary electromagnetic heat energy is radiated away. A scalar EM howitzer, however, may pro-

duce an endothermic explosion (an energy implosion) at a distance, explosively extracting the heat energy at the implosion site and receiving the energy back at the transmitter site for disposal.

55. Energy: the capacity to do work. Energy is directly tied to the work concept, which is the result of a force moving through a distance. However, "work" refers to the past; that is, the force has moved through a distance against a resistance. "Energy" refers to the future; the force could in the future move through a distance against a resistance. Since the force is tied in turn to a changing mass motion, it follows that—conceptually—energy is tied directly to mass systems. The "energy" that an object possesses depends also upon the observational situation: a moving observer may see a moving object as possessing more or less energy than the lab observer sees. Electrostatic scalar waves do no work and individually have no "energy" per se. Two different scalar waves coupled onto a spinning charged mass, however, produce a system which has mass and energy, and does work.

56. Ether: originally, a ghostly-thin, material, fluid medium postulated to fill space and carry electromagnetic waves, similar to the way in which a gas carries sound waves. The Michelson-Morley experiments eliminated any such material ether, but not a Lorentz-invariant nonmaterial ether (of which vacuum itself is one example, in the modern view). Maxwell's equations were derived from ether theory. Einstein once proposed that the vacuum, complete with its electromagnetic fields, should be called the ether. Indeed, the word "ether" is again acceptable in the literature in context of its modern meaning. Today the "ether gas" is considered composed of virtual particles—that is, the particles spontaneously come into being and then vanish so quickly they cannot be individually detected. That is, today the ether is a virtual particle gas—sort of a gas of "effervescent bubbles", so to speak. Ives derived special and general relativity, Newton's laws of motion (relativistic form), and the square law of gravitation from a Lorentz-invariant nonmaterial ether theory. Zero-point energy of vacuum would also seem to be a Lorentz-invariant ether. The Soviets are believed to have applied and advanced the Ives theory to produce their present theory of energetics, which is highly classified by the Soviet Union. In the new approach, vacuum is identically pure massless charge (virtual particle flux), and thus an ether as Einstein proposed.

57. Evil: refers to an act theoretically detrimental to the receiver or referent, in the positive time stream. It is equally beneficial to the referent, viewed in the negative time stream.

58. Exo-electron emission: emission of electrons from the surfaces of metals and certain ceramics after these surfaces have been freshly formed by a process such as abrasion or fracture. Cracks in metals are good emitters of exo-electrons, and the electrons can be detected, to provide a means of detecting the minute fatigue or stress cracks. The sides of a crack in a stressed metal constitute a scalar interferometer, and scalar interferometry is involved in the emission process. Exophotons are also emitted, in addition to electrons. In an earth tectonic plate fault zone (crack), stress exists on each side of the plate, but not in the middle, and the fault thus constitutes a scalar interferometer, emitting charges and also often creating glowing balls of light

59. Exothermic explosion: an ordinary explosion where ordinary heat and electromagnetic energy are released and radiate away from the explosive site. All normal explosions are exothermic.

60. Feynman diagram: a two-dimensional diagram of particle interactions, both in the virtual and observable levels, and both backward and forward in time.

61. Fireflies: sentient bits of light that sometimes kindle in the presence of a psychic initiator and/or a psychotronic generator. Literally, minute glowing, indefinite thought forms materialized into electromagnetic energy. This can be understood by modeling thought forms as real electromagnetic forms existing in a rotated universe (i.e., as hyperdimensional). Interference causes dimensional shifting, so that ordinary electromagnetic energy forms can result

62. Firewalking: walking on and across a bed of hot glowing coals without the feet being burned. Firewalking is demonstrated in a variety of cultures, belief systems, and locations throughout the world. Recently many Americans have been taking to the practice and demonstrating that it is an achievable phenomenon. In the new approach, the two cerebral hemispheres act as a scalar interferometer. If this biological scalar interferometer creates an endothermic (extraction) field on the surface of the skin of the feet, and simultaneously creates an exothermic scattering of the extracted energy into the surrounding environment, then one can walk on hot coals without burning the feet. Note that the reverse effect-cooling of the external environment—is often experienced when psychokinesis effects at a distance are obtained. For example, poltergeist effects are often associated with an adolescent If the adolescent's cerebral scalar interferometer extracts by inverse scattering, and projects exothermically into distant objects, the movement of the objects can be explained.

63. Fission (action): the splitting of the action quantum into two canonical variables (for example, energy and time), only one of which can normally be completely detected or measured. ("Action" has the dimensions of angular momentum—energy x time, momentum x length, etc.) Fissioning produces length, discrete bit by discrete bit, and time likewise. The physical reality of separated physical objects is thus continually created, discrete bit by discrete bit, monocularly. All that ever exists in the "present" is a single quantum change, just occurring. Recombining of the two canonical action fission fragments is called "fusion." Fusion also occurs monocularly, quantum by quantum. Rigorously, the physical world of separated objects never exists as such except in memory recall of vast numbers of past ordered quantum changes that occurred one by one.

64. Flux: the amount of some quantity (such as energy, particles, volume of fluid, etc.) flowing across a given area (usually a unit area perpendicular to the flow) per unit of time. The term flux density is now more commonly used. Loosely, "flux" refers to the perpendicular flow through an area, while "flux density" refers to the magnitude or intensity (rate) of die flux. In some cases such as a flux of particles of different velocities, the number of particles may be multiplied by the average velocity to give an average flux density.

65. Flux density: the amount of tome quantity (such as energy, particles, volume of fluid, etc.) flowing across a given area (usually a unit area perpendicular to the flow) per unit of time.

66. Flying saucer: a discoid or other shaped paranormal object observed in the skies and/or landing, taking off, etc. Came into general use in the U.S. in 1947 after Kenneth Arnold reported seeing nine strange flying discs skipping along like saucers. Sometimes used to refer to an unidentified flying object (UFO). The usual "flying saucer" is theorized to be due to temporary materializations from the collective human unconscious; over 80% of these materializations only go so far as the "glowing light" stage, not to the material object stage. A small percentage do physically materialize, then later dematerialize. A small fraction of one percent are considered to be actual ships built on earth by the Soviet Union or one other country. A few sightings may be due to deliberate scalar interferometry at a distance by the Soviet Union and others.

67. Foo fighters: glowing balls of light which occasionally appeared in the skies and played tag with Allied, Nazi, and Japanese planes during World War II. The word "foo" is a corruption of the French word "feu," meaning fire.

68. Force: in mechanics, identically the time derivative of momentum. Simply, changing of mass-motion. One must realize that it is not the mass in motion, but the single undivided quantity "mass-motion" or "mass-velocity" (momentum) that is changed. In present EM theory, force fields are erroneously taken to exist in empty, massless vacuum. However, the mechanical definition is an identity, not an equality. Thus force does not EXIST ON a mass, but CONSISTS OF a changing "mass-motion." Since this force can be induced at a distance (by changing an introduced mass-motion such as a test charge), one is confronted in the new approach with the fact that there is a more fundamental mechanism that produces force itself. This mechanism is coupling of nonidentical scalar fields by and on a spinning charged particle. The INDUCED FORCE consists of the particle's change in mass-motion per unit of time. It is thus a flux—induced quantity in, on, and of a mass in motion.

69. Force field: an effect that can exist in vacuum or on mass whereby a particular type of matter is affected. For example, the "electrical (force) field" can affect and change the state of motion of any charged particle. In classical physics, the force fields are the causative agents; when these fields are zero, then the motion of the particle or system is unaffected. The electric field (E-field), for example, is defined as the force per unit of fundamental charged mass, though usually it is stated as "force per unit charge," with the mass ignored. Rigorously, however, force does not exist in vacuum, in the absence of mass, a priori. The Aharonov-Bohm effect shows that the potentials can interfere to produce effects in charged particle systems—even at a distance, and even when the force fields are reduced to zero. Tesla stated that vector Hertzian waves do not move through vacuum, which is true. Rigorously, two scalar waves move through vacuum instead. When coupled (detected) by a spinning charged mass (an electron, for example), the vector E and B fields are created on and of the moving mass itself; they do not exist in vacuum. This has been a fundamental omission and error in both electromagnetics theory and mechanics. For example, the standard EM equation, $E = - 0$ is not generally true in vacuum, but it is true on an electron moving in a detecting antenna or on a charged particle moving in vacuum. Any force is produced by the same fundamental mechanism: flux differences encountered by a spinning charged mass. Thus there is a common connecting thread among all forces, and this is the key to a practical, engineering unified field theory. Note that Einstein's equivalence principle, after much pondering, can be taken to be an equivalent statement to the fact that force—any force—consists of a change in mass-motion. In modern quantum mechanics, force is an effect, not a cause, and is derived from the potential by a differentiating operator. The potential is the primary causative agent, not the force. Also, in modern quantum field theory, all forces actually come from curvature of spacetime—i.e., they are all gravitational in origin.

70. Four-space (4-space): a 4-dimensional spacetime, dimensionally composed of length cubed multiplied by time. In the absence of gravitational field, the 4-d spacetime reduces to a Minkowski space.

71. Fractional charge: a hypothetical particle having a charge less than the electron's charge. Often called a quark, where its charge is 1/3 or 2/3 the charge of the electron. Recently, Stanford University researchers have found evidence of free quarks, and in the 1920's Ehrenhaft reported the discovery and production of fractional charges of all sizes.

72. Frame (Lorentz): a frame of reference which is not accelerated with respect to the laboratory observer. In this case, the frame may be rotated (moving at a constant velocity) but it is not rotating (the frame is not accelerated with respect to the observer, and spacetime is not curved). In this case special relativity applies, as do the conservation laws. If the local spacetime is curved, the frame is accelerated and spacetime is curved. Locally, then, general relativity applies. In this case, locally the conservation laws (energy, momentum, charge, and spin) can be violated. However, in ordinary general relativity, it has been tacitly assumed that locally the curvature of spacetime is negligible. Hence locally a Lorentz frame is assumed, and the conservation laws are assumed to apply locally also. In scalar electromagnetics, the local spacetime is always curved and general relativity applies locally. In this case, the conservation laws need not apply.

73. Frame (of reference): a spatial, organized, measured lattice placed in emptiness (space, spacetime). Normally refers to a 3-dimensional, spatial frame. All objects and points in the "universe" or spatial frame are considered to simultaneously coexist at separate, measured points in the frame. Differs from the vacuum in that, rigorously, vacuum has no existing definite lengths and no existing definite time intervals, as these appear only after measurement/detection, and are relative to the observer and to the detection process. The "laboratory frame" is the static reference frame of the observer/measurement. A separate reference frame may be assumed to exist for any fixed or moving object, or centered on any point in another frame. When a type of frame is assumed, the entire class of physical interactions that can occur has been restricted to an assumed set or type. In other words, given the frame, the physics has been assumed. One of the greatest restrictions of an assumed "frame" is to rule out the consideration (existence) of other higher dimensions. In the new theory, higher dimensions are permitted

and an orthogonally rotated frame can be equated to a field and vice versa. Therefore frames are also fields.

74. Free energy: energy obtained from a free or essentially free source. A paddlewheel in a river extracts and provides "free energy" from the river, since one need not pay for the river. Electromagnetically, the idea of "tapping" or extracting energy from an esoteric source, such as the zero-point energy of vacuum, the Dirac sea, a standing electrogravitational curvature of local spacetime, etc. Since scalar electromagnetics is electrogravitation, a locally bent spacetime can be achieved so as to provide either a source or a sink, as one wishes. Thus a practical free energy device is rigorously possible by scalar electromagnetic means.

75. Fusion (action): in the new approach, the recombining of two canonical bits of a fissioned action quantum. The fusion process "cancels" the bits produced by the fission process, and constitutes a negative spacetime operation. The physical world is thus eliminated, bit by bit, in a monocular fusion operation that produces the "past" The "mass" of a particle is taken to be proportional to, and identically comprised of, the absolute value of its fission and fusion rate. When fission and fusion rates of a particle are equal, the particle is unaccelerated; when unequal, the particle is accelerated. Vice versa, when the particle is unaccelerated, the fission and fusion rates are equal, and when the particle is accelerated, the fission and fusion rates are unequal.

76. Geiger tube (Geiger-Muller tube): a tube used in appropriate circuits to detect and count ionizing particles. Each particle crossing the tube causes ionization of the gas in the tube, essentially independent of the energy and nature of the nuclear particle. Thus a uniform discharge occurs across the tube. The tube will detect anything which causes an increase in the ionization of its gas. Since strong scalar waves will do this, the tube is capable of detecting scalar wave radiation of sufficient intensity. In many cases, GM tubes are activated near UFO landing zones, and sometimes near cattle mutilations or other paranormal occurrences. In such cases, the tube is reacting to scalar emissions, not nuclear radiations.

77. Geller effect: refers to the frequent stimulation of paranormal abilities in children and other people who have seen Uri Geller (or someone like him) performing psychokinesis either in person or on television.

78. General relativity: the physics of curved spacetime. As opposed to special relativity which deals with inertial frames moving at constant velocities with respect to each other (Lorentz frames), general relativity deals with accelerated frames. General relativity was founded by Einstein, who made highly restrictive assumptions to simply the complexity of the problem. Briefly, Einstein assumed that, since no means of appreciably curving spacetime was known except by the gravitational force of a tremendous collection of mass, then the only places where appreciably curved spacetime would be met would be near suns, stars, etc. Accordingly, he assumed that the local spacetime of the observer would not be curved, and instead the local frame would be a Lorentz frame. That is, he made the theory a sort of "special relativity with distant perturbations." That way, the conservation laws would be saved, and one could still speak of the energy of objects as opposed to the energy of entire systems. General relativity complete with this severe restriction is called "ordinary general relativity" (OGR), and this is the type of relativity taught in all our Western universities. Note that, by assuming no local spacetime curvature, the ordinary theory actually assumes that one cannot directly (locally) engineer general relativity. OGR is a highly special case, and not at all the type of general relativity we seek in the new approach where we wish to deliberately curve local spacetime and engineer general relativity directly on the laboratory bench. The Soviets do not recognize Einstein's limiting assumption. In Soviet physics journals, papers are regularly published that treat general relativity in an unrestricted manner. These papers include local curvature of spacetime and violation of all the conservation laws as a result. In the West, conservation has been raised to an absolute dogma, and such papers are regularly refused publication. Conservation laws are upheld in the West by artifice and dictum, not by science or experiment! So if the various restrictive assumptions placed on ordinary general relativity are removed, then an "unrestricted general relativity" results. In this relativity, the local frame may be appreciably curved, and any or all of the conservation laws can be violated—often with ease. With an adaptation of Kaluza-Klein 5-d unified field geometry and use of artificial EM potentials deliberately created by summing or multiplying EM force field vectors to vector zeros, EM energy can be transformed into gravitational field energy locally. In this fashion one can engineer general relativity; violate conservation of charge, energy-momentum, and spin; produce free energy engines; transmute elements simply; and produce action at a distance. Initial experiments have positively established the new approach as valid, and a startling new physics is in the offing. In the new scalar EM, gravitational potential becomes locked-up (infolded) electromagnetic forces, and electromagnetic force fields become bleed-off (outfolding) of the inner contents of the gravitational potential.

79. Ghost rockets: materialized tulpoidal "rockets" that appeared in 1946 and 1947 over the Scandinavian countries (Norway, Denmark, and Sweden) and usually seemed to come from the direction of the Soviet Union.

80. Giant photon: a photon with an organized, deliberate scalar substructure. In scalar electromagnetics, the photon is assumed to be one oscillation of the electromagnetic field; thus it is comprised of one E-field wave and one B-field wave. Further, in each point of either wave, a finite group of vectors may exist such that their vector summation or multiplication is zero. Thus a deterministic substructure may be deliberately impressed upon (infolded in) the photon. Such a photon may carry enormous infolded energy in the form of anenergy, and may be designed to perform a particular resonant purpose. In other words, such a photon becomes a "vacuum engine" that structures the virtual particle flux of vacuum in a particular, deterministic manner.

81. Golden booster: a potent scalar wave generator invented by Frank Golden, and used to augment and amplify the Kelly radionics machine. The booster has the unique characteristic of gathering in ambient energy and EM radiation from its surroundings and transposing this into highly patterned scalar radiation. It has the further characteristic of reacting to human intent, and constructing its patterning accordingly. In addition, two motors are incorporated whose needle movements provide

visual indication of the rate of treatment, the frequency of treatment, and how the dosage is progressing. A Bedini scalar wave detector directly verifies that both the Golden Booster and the Kelly radionics machine produce and radiate potent scalar waves.

82. Golden, Frank: inventor and scalar electromagnetics researcher who has developed a variety of scalar wave antennas, an underwater communications system, scalar wave transmitters and receivers, the Golden Booster, scalar wave detectors, and scalar wave spectrum analyzers. He has also developed a prototype free energy motor, a motor that runs off reactive power, a solid state scalar radar antenna, and other significant scalar EM devices.

83. Good: refers to an act theoretically beneficial to the receiver or referent, in the positive time stream. It is equally detrimental to the referent, viewed in the negative time stream.

84. Gravitational field: rigorously, the curvature of spacetime. In scalar EM, gravitational potential is locked-up (infolded) electromagnetic forces which sum or multiply to zero. Electromagnetic force fields represent the "bleeding off" or "outfolding" of these infolded contents of gravitational potential. Gravitational force field is the "bleeding down" of the gravitational potential without outfolding or out-bleeding its infolded contents. Gravitational field is not a field in the sense of Heaviside-Maxwell electromagnetic fields. There is really no such thing as "the" gravitational field; instead, there exists a large number of potentials, locked-in force field vectors, and other entities which change the energy density of vacuum and bend spacetime. The bleed-down of this conglomeration infolded components as a conglomeration constitutes the "gravitational field." If the inner contents of this G-field, or of the G-potential, bleed out, then a different field—e.g., electromagnetic field—is produced. We may thus speak of the bleed-out of either the G-potential or the G-field. Note that flows between pairs, triads, etc. of these individual infolded field components can occur without appreciable change of the overall conglomerate's potential (trapped energy density). Thus the gravitational potential can have a dynamic, structured pattern, and local spacetime can be curved and patterned. E field and B field are one such "pair" of flows where little overall gravitational effects are evidenced, so long as the fields are tree to "flow." In Kaluza-Klein 5-d unification of gravitation and electromagnetics, only a single field—the 5-dimensional gravitational field—really exists. Our world intersects and "bleeds-off' this 5-d G-field in two fashions: (1) the 5-d G-field prefers to bleed-out into its fifth dimensional aspect, which we see as our own ordinary EM force field. (2) The minute remaining 4-d aspects we see as our 4-d gravitational field. To show the order of magnitude difference in bleed-out, the electrical field between two electrons is about 10^{42} or so stronger than the gravitational field between them. Even for protons, the ratio is 10^{36} or so. So it can be seen that, so long as EM bleed-out is permitted, little 4-d gravitational effects are produced. Our normal electromagnetics—which by construction of Heaviside's version of Maxwell's theory is purely bleed-out, thus yields negligible gravitational effects. On the other hand, if we deliberately set the EM bleed-outs against each other so that they zero sum, we "strangle" the escape or bleed-off of the 5-d G-field into EM field. The 5-d G-field is then forced to bleed-off into 4-d G-field. If we then vary the energy of each vector component of the EM zero sum while maintaining the overall zero resultant, we directly pump the 4-d gravitational field. Scalar electromagnetics thus directly converts EM field, force, and energy into ordinary G-field force and energy, and vice versa. In addition, we get enormous gains: For every unit of EM energy we feed into the "zero sum pump," theoretically we can get out up to 10^{42} units of 4-d gravitational/inertial energy by electron release, and up to 10^{36} by proton release. Experimental results have confirmed this thesis. As early as 1969, Hurvich produced an inertial field generator capable of "freezing" weapons so they cannot be fired. Hutchison reports and demonstrates the levitating of up to 60-lb. objects. The American physicist Hooper patented electrogravitational devices in the early 70's. Bedini, Watson, Johnson and others have developed practical prototype "free energy generators." Another inventor who wishes anonymity has developed a small device which produces negative energy and antigravity, at an amplification factor of 1,500,000. Orthodox research in this area is just beginning in the West, but has been highly developed for several decades in the Soviet Union.

85. Gravitostriction: effect in a resistor whereby local gravitational stress flow in a direction results in production of a macroscopic electric force field in that direction, a macroscopic magnetic force field orthogonally around that direction, and minute, randomized EM fields (heat energy) microscopically due to induced microscopic particle motion and interaction. It is the enforced spin alignment of the mass particles (such as conduction electrons) which accounts for the production of the magnetic field. Gravitostriction is the reason that resistive loads can be powered by scalar anenergy flow (electrogravitational flow, massless current flow) and by negative energy flow. During the initial chargeup of a helical coil exposed to a sine wave voltage, no electron mass current flows; however, the massless current (phi-dot) charges up the coil gravitationally. As electron mass current begins to flow (90 degrees into the wave), this gravitational field is bled-off (outfolded) as electric force field (electron mass flow coupled to del phi) and magnetic force field. One can do amazing things with coils and transformers which are not allowed to enter the EM bleed-off phase at greater than 90 degrees

86. Gravity: the phenomenon characterized by the physical attraction of any two material bodies. Ideally, the gravitational force between two masses is proportional to the product of the masses divided by the square of the distance between them. In the new approach, one recognizes that mass itself is defined in terms of, and identically consists of, the time derivative of an action flux. Gravitational field and electrical field, then, become different aspects of the same thing. By affecting the flow of time, scalar waves and scalar potential thus are able to affect the gravitational force between two objects. Antigravity, for example, can be achieved by forcing an object's atomic nuclei to produce phase conjugate (time-reversed) waves (and negative energy and negative time). In negative time, gravity is a repulsion. Hutchinson has demonstrated the levitation of objects weighing up to 60 lbs, albeit sporadically.

87. H-field: historically, the magnetic field. However, it

is poorly named, and should be considered the magnetic excitation, after Sommerfeld. In empty space B and H are proportional, an experimentally determined fact In the new approach, rigorously vector fields cannot exist in vacuum, but can only exist on an observable mass. A "shadow" vector field can exist in vacuum, in the absence of observable mass, as small virtual vectors, each existing on a virtual particle in the vacuum. Such a "shadow" vector field may be regarded as two coupled scalar fields, where the coupling is performed by the virtual particle flux of which the vacuum itself consists. When an observable, spinning charged mass encounters the shadow vector field, it converts the two coupled scalar fields into a vector field. Thus Hertz waves per se are not transmitted through vacuum; "shadow" Hertz waves arc. With an ordinary detector, however, one detects vector Hertz waves, since one detects the precession waves of the electrons in the electron gas of the detecting probe or antenna.

88. Hieronymus, T. Galen: renowned radionics experimenter and inventor of the amplified radionics machine. Hieronymus is the father of modern amplified radionics; most experimenters before him used unamplified machines.

89. Hieronymus device: essentially, an amplified radionics device. Refers to a device similar to the one patented by T. G. Hieronymus in the 1940's. Connotes ordinary amplification rather than holographic amplification of radionics effects. Any similar type device. The Hieronymus device actually processes, and operates with, scalar waves.

90. Hologram: a photographic recording of the pattern of interference between coherent light reflected from the object of interest, and light that comes directly from the same source or is reflected from a mirror. When this photo image is illuminated from behind by coherent light, a three-dimensional image of the object appears in space. The characteristic of a hypothetically perfect hologram is that all its content is contained in any finite part of itself. If one portion is cut out and illuminated, the complete image appears in space. The whole hologram is in each part of itself. Observationally and perceptually, the physical universe is a hologram and in each part of itself, since all of it can be detected from/in each internal particle.

91. Hyperchannel: a channel between orthogonal frames or hyperframes, where anenergies crosstalk. Exceptionally good hyperchannels seem to be frequency dependent, and are referred to as windows, magic windows, or interdimensional nodal points. Some hyperchannels are 38-40 kHz, 150-160 kHz, 1.1-1.3 MHz, 1.057 GHz (the Lamb shift), and in the near ultraviolet (the life force frequency). These frequencies also represent enhanced channels between subquantal (virtual) and quantal (observable) states. A particularly good magic window exists when the infrared and ultraviolet bands being utilized are phase-locked so that the ultraviolet represents a first harmonic of the infrared.

92. Hyperfield: a structure or disturbance in hyperspace or higher dimensional space. With respect to a fixed frame, the electromagnetic field or a more subtle field. We consider the electromagnetic field the first hyperfield. A hyperfield may also be considered to be the electromagnetic field rotated further away from its laboratory frame. The second hyperfield is called the neutrinic field, and the third hyperfield is the mental or mind field. Also called biofame, orthoframe, hyperframe, biofield, or orthofield. These hyperfields/hyperspaces also correspond to the nested levels of virtual state. Successively higher hyperfields past the electromagnetic field constitute successively lower levels of virtual state.

93. Hyperframe: simply, a frame rotated one or more right angle (orthogonal) turns away from the reference laboratory frame. The laboratory frame is considered to be the zeroth hyperframe. Also called bioframe, bioworld, biofield, orthoframe, orthoworld, orthofield, hyperfield, or hyperworld. Sometimes referred to as a hyperspace.

94. Hyperspace: generically, refers to hyperframes, orthoworlds, etc. May be used in a singular sense to refer to one of these.

95. Hyperspace howitzer: a postulated Soviet scalar electromagnetics interferometer weapon, believed capable of firing an explosion through hyperspace to a distant point, without any travel of electromagnetic energy through ordinary space. Also called a scalar howitzer or Tesla howitzer. The howitzer has several modes of operation: (1) it can be used in exothermic or endothermic mode. In the exothermic mode, the howitzer is biased positively. In this mode it can accept energy, transform it into scalar waves of an artificial potential or anenergy, transmit the scalar waves to a distant intersection zone, interfere them and reproduce ordinary positive electromagnetic energy in the distant region. In the endothermic mode, the howitzer is biased negatively. In this mode it "transmits" the extraction of energy. At the distant interference zone, energy is extracted and reappears back at the transmitter/receiver site, where it must be disposed of. U.S. weather satellite photos of the Soviet Union's Bennett Island reveal giant exhausts emerging from that island, some narrow jets as long as 150 miles and only about 1.5 degrees above the horizontal. Bennett Island is believed to be the "exhaust site" for several Soviet hyperspace howitzers. That is, when a howitzer operates in the endothermic mode, it receives and temporarily holds the energy that comes back to it, then switches biasing potential to positive and transmits in the exothermic mode to Bennett Island. (2) The howitzer can operate in pulsed or continuous mode. In pulsed mode, an explosive or implosive effect occurs at the distant target site. In continuous mode, a continuous energy source or sink appears in th distant interference zone. (3) Fourier expansion mode. Each transmitter of the howitzer can produce multiple frequencies where the frequencies represent a Fourier expansion of a geometrical form such as a sphere. When these two geometrical scalar forms are interfered at a distance, a 3-dimensional form of ordinary EM energy emerges (exothermic mode) or is extracted (endothermic mode). (4) the scalar transmissions of the scalar interferometer (hyperspace howitzer) can be modulated upon ordinary EM carriers, such as the Woodpecker signals in the communications band (3 to 30 megaHertz). In this case, interference patterns of the Woodpecker carrier will yield only minute EM energy, but the impressed scalar substructures may interfere to produce or extract substantial energy in or front the interference zone. Other control signals impressed on the Woodpeckers may be used to trigger the mode and location in the interference zone, or even to establish "circulations" in the vector zeros. By forming distant high pressure zones (exothermic mode) and low pressure zones (endothermic mode) and then moving the locations along, the Soviets can capture and deviate the jet streams over North America or elsewhere. By swirling in conjunction, tornadoes can be produced. Certain signatures (giant radial clouds and twin giant radial clouds) in the active zone have been identified as associated with the Soviet Union's weather engineering. The strange explosion in 1958 near the Urals is believed to have been an accident involving an early first fullup test of the howitzer. The howitzer was probably similar to a giant radar, transmitting scalar EM wave. By setting up a standing scalar wave and continuing to transmit energy into it, the standing wave becomes a giant potential. It is charged up much like a scalar capacitor, but with scalar EM (electrogravitational) energy. Failure of the transmitter may have discharged this giant potential into the earth, and the electrogravitational ground pulse spread out, striking the nearby stored nuclear wastes and fissioning all the radioactive nuclei. Consequently the nearby atomic wastes exploded, producing fallout and radioactive contamination over a large area. The first fullup test of an operational on-site weapon is believed to have been the destruction of the U.S.S. Thresher atomic submarine on April 10, 1963. The second fullup test is believed to have been the transmission of an explosion into the ocean 100 miles north of Puerto Rico on April 11, 1963—one day after the destruction of the Thresher. Over a hundred howitzers are believed to now be on site and operational, and powered by either Moray amplifiers or giant scalar resonant inference taps in the earth (detected by Golden in April 1985). High Altitude booms off the east coast of the U.S. may have been due to orientation and alignment tests of these weapons, with each test blast the equivalent of some 100 tons of ordinary explosives. If so, these shots were probably artillery high burst registrations. The two puzzling flashes detected by the Vela satellites in September 1979 and later, and erroneously described as a nuclear flash by many analysts, may also have been a test of this type of weapon, either by the Soviets or a second nation that has developed the weapons.

96. Hyperworld: a world (3-space or 4-space) rotated one or more orthogonal turns away from the laboratory frame (ordinary world). Constitutes also (identically) an entire subquantal level in virtual state.

97. Inception: kindling (from mind anenergy) a small amount of photon energy into or onto a body/tuner or other object Specifically, coupling scalar wave patterns (anenergy) onto die body/tuner or object so that the photon energy is created in or on the body at a distance.

98. Inceptive cyborg effect: the ability of the mind to psychokinetically link to, or attune to, an inert physical object or physical system. A living biological system is a stabilized inceptive cyborg, with its mindworld linked to its body/tuner. The two cerebral hemispheres of the brain form a Tesla scalar interferometer, capable of producing and transmitting scalar wave patterns into a distant object, coupling into energy in it, and thus linking with or resonating with the object. This is the mechanism for producing all parapsychological phenomena.

99. Interdimensional nodal point: a natural frequency for an anenergy channel between orthogonal frames or universes. Also called a magic window.

100. Interference: the variation of the amplitude of a wave with distance and time, where that wave results from the superposition of two waves having the same, or nearly the same, frequency.

101. Interferometer: an instrument in which a wave is split into two waves or beams, which after traveling over different paths are subsequently reunited and display interference.

102. Jitter (dither): the incessant quantum and subquantum activity on a fundamental particle of mass. The particle is continually connected to and disconnected from an infinite number of hyperspaces, and to and from time.

103. Kaznacheyev effect: refers to the demonstrated ability of near-ultraviolet mitogenetic photons to carry any kind of death pattern from one cell culture to another of similar kind, in the absence of visible light and with synchronized conditions. Named after the Soviet scientist Vlail P. Kaznacheyev, who experimentally demonstrated the effect In his experiments, two samples of the same cell culture were environmentally separated by a thin window. The entire arrangement was placed in the dark and rotated at some 20 rotations per minute. The cells on one side were then killed by any particular mechanism—ionizing radiation, chemicals, toxins, deadly bacteria, germs, etc. If the window was made of ordinary glass (opaque to ultraviolet), the second sample remained healthy. If the window was made of thin quartz (transparent to ultraviolet), then after a time delay the second sample began dying with the same symptoms ai the first Later testing revealed the emission of mitogenetic, laser-like photons in the near ultraviolet from the dying cells in the first culture. When these mito genetic photons are allowed to bombard the second cultare, the same lethality pattern is induced in it. The explanation is that the photons carry virtual state (scalar) patterns (infolded patterns in their time components), and these virtual patterns are diffused into the receiving culture, where eventually they diffuse into a lethal pattern in the virtual state (scalar) master control system (discovered by F. A. Popp) of the targeted cells. Continued charge—up of this pattern kindles the pattern into a physical, observable structure in the cells, reproducing the death or disease pattern. The Kaznacheyev effect haa been duplicated in the infrared in West Germany. Kaznacheyev almost certainly also phase conjugated (time-reversed) the "death photons," producing healing photons for that specific cellular damage or disease condition. Irradiation of the affected cells with these healing photons would have reversed the disease, reverting the cells to normal. Note that Antoine Priore's machine worked in this fashion. Kaznacheyev's EM healing work with phase conjugated photons was obviously not reported; it represents a total counter to viral biological warfare, and such work would have been done only under KGB control, and highly classified as a vastly valuable defense secret.

104. Kelly, Peter: noted radionics/psychotronict researcher and builder of several types of especially potent amplified radionics machines. He is also one of the pioneers of the use of amplified radionics in agriculture for enhancement of crops, restoration of soil vitality, and control of insects. By direct measurement with Bedini scalar EM detectors, Kelly's machines have been verified to produce scalar waves.

105. Kelly machines: amplified radionics machines developed and built by Peter Kelly.

106. Kervran effect: the ability of a living biological system (either plant or animal) to accomplish limited transmutation of elements, particularly between certain isomers. Named after the French scientist, Louis Kervran, who discovered the effect. Kervran was nominated for a Nobel prize in 1977, although the prize was not awarded to him. The Kervran effect has been duplicated by Japanese, British, European, American and other scientists. Note that scalar interferometry is capable of kindling energy patterns directly into the virtual state interactions of the nucleus, including the strong force that binds the nucleons together. Over a period of time, this energy can cumulate, biasing the quantal statistics of the interactions. This, of course, changes the probabilities of the various quantal states, with the result that the nucleus can be transmuted. Transmutation to an isomer is particularly practicable. Efficient transmutation of elements by scalar means has been accomplished by John Bedini.

107. Kindling: collecting and condensing more subtle energies (anenergy) into virtual photons (charge effects), photons (electromagnetic field effects), or matter (materialization effects). Kindling is a linear integration process, which repeatedly collects or integrates a virtual state pattern until it breaches th observable threshold, becoming physical real.

108. Kirlian photography: field patterns of an object impressed upon a film or other sensitive material by means of spark discharges. The scalar modulations in the spark charge intensity, not the ordinary vector E-field components, are the paranormal components. Thus only the delta—which represents those scalar patterns coupling and kindling into vector EM, which then interacts in photochemical interactions—is indicative of the paranormal aspect of Kirlian photography.

109. Law of physics: a restriction placed upon the physical mechanisms that can occur under certain broad assumptions as to the background situation and environment. Actually, in nature there are no such "laws"; these are only man's synthesis for the behavior of large classes of systems under very general conditions. Any "law of physics" can be violated if the conditions contained in its assumptions are violated. Conservation laws are often touted as "laws of physics." Actually, the conservation laws assume a closed system and a linear spacetime (Lorentz frame). If either or both of these assumptions is violated, any or all of the conservation laws can be violated. In particle physics, broken symmetry already results in violation of one or more of the conservation laws. In leading Soviet physics journals, papers are regularly published containing unrestricted general relativity with concomitant violation of any and all conservation laws.

110. LIDA machine: Soviet device which uses a 40 megahertz carrier and unusual waveforms to induce a catatonic-like state in man or other mammals. For years Western orthodox scientists have argued that EM signals could not directly affect consciousness. With testing of the LIDA device, this has now been totally refuted. One scientist has reported that the I.IDA device—known to be decades old—was used by the North Koreans on some U.S. prisoners of war during the Korean War. Reportedly the effects of the machine could not be resisted, and the machine was a devastatingly effective "brainwaahlng" tool.

111. Life: a term which resists the best efforts of philosophers and scientists to define it! In the new approach, a living system is modeled as consisting of a physical body "tuner" and a mindworld to which the tuner is preferentially tuned to a small degree. The preferential virtual state crosstalk between the physical tuner and the mindworld constitutes the life channel or consciousness loop. Destruction or loss of the preferential tuning results in "death," or loss of attachment to the tuner. In that case the mindworld functions within itself. Note that the being is always present, unchanging, and simply "is," without any connotation of perceptual stringing together separations into a string of events (causal chains). Being changeless, it consists of all changes, all-at-once, hence none separately. Ultimately this is the true meaning and foundation of life, and mindworlds and physical events represent simply separation waves in unlimited being. Note this is completely consistent with the idea that ultimately only God exists, things are simply separation waves in the unseparated Godness, and God permeates everything.

112. Loch Ness Monster: famous tulpoidal water monster which (occasionally) temporarily materializes in Loch Ness in Scotland. Similar materializations of "water monsters" have been seen and reported in almost every large body of water on earth.

113. Longitudinal wave: a "pressure" type of wave, similar to sound, in which the vibrations are along the direction of travel of the wave. Hence, a wave composed of alternating densifications and rarefactions. Scalar waves are longitudinal waves. In classical EM theory, the Poynting vector predicts no longitudinal wave of energy from a time—varying, electrically charged source. In fact, an exact solution of the problem does allow this longitudinal wave, as shown by Keech and Corun, International Journal of Theoretical Physics, Vol. 20, No. 1, 1981, pp. 63-68. The classical electromagnetic wave is modeled as a vector wave, comprised of transverse vibrations. In the new approach, such transverse vector force field waves (Hertz waves) do not exist in vacuum; instead, two coupled longitudinal scalar waves exist in vacuum. The E and B fields are formed, recovered by, and exist as the spinning charged detecting mass particle in motion.

114. Magic window: a naturally tuned frequency of a good hyperchannel between orthogonal frames where scalar wave anenergies crosstalk readily. Magic windows are frequency dependent, and are also referred to as hyperchannels or interdimensional nodal points. Some magic windows are 38-40 kHz, 150-160 kHz, 1.1-1.3 MHz, 1.057 GHz (the Lamb shift), and in the near ultraviolet (the life energy frequency).

115. Many-worlds interpretation of quantum mechanics: refers to the consideration of multiple simultaneous observers and the consequent changes forced upon quantum physics. Essentially all possibilities exist and are real, and an infinite number of orthogonal worlds exist at any instant. Further, each world splits into multiple possibilities after each and every event. Thus in a single second, the world has split in some 10 to the 20th power versions of itself. This is the work primarily of Everett, with strong contributions by Wheeler and

Graham, and was the subject of Everett's thesis at Princeton University in 1956. It was published in 1957.

116. Mass: literally, a special curvature or "kink" in spacetime emptiness, according to relativity theory. In the new approach, the mass and inertia of a particle are considered to be due to one or more standing scalar resonances, trapped by the spin of the particle. When the amplitude of the trapped scalar wave increases or decreases, the mass and inertial of the particle increase or decrease. If the resonance amplitude reduces to zero, the particle dematerializes. Classically, mass is also taken as the measure of a body's resistance to being accelerated by a force. Specifically, a mass occupies space (3-dimensional) and resists change in its linear movement. In a region of mass, a flux of action quanta into and out of the region exists, corresponding to a flow of positive and negative time. The mass is the sum of the absolute values of the time derivative of action in and the time derivative of action out If these two time derivatives are equal in magnitude, the mass is unaccelerated; if unequal, the mass is accelerated. A mass does not exist in time per se (more rigorously, it exists equally in positive time and in negative time), but only exists spatially. A mass continually interacts with photons (absorption and emission), thus continually connecting and disconnecting to the fourth dimension (time). The mass is thus seen to "jump along" through time in finite, quantized jumps caused by the photon interaction with it

117. Men-in-black: that part of the UFO contact phenomena which involves contact with rather sinister tulpoidal manforms. Typically these tulpoids are dressed in dark suits, have almond-shaped eyes that do not blink, possess oriental features, and "speak" telepathically to the contactee. Often they drive dark automobiles and follow the contactee. Several researchers in the field have had intense encounters with such tulpoids. The appearance of such phenomena associated with an investigator is in part due to unresolved detrimental material in his or her own unconscious mind, which thus acts as a "witness" and radionics tuner. Continual stimulation of this detrimental unconscious witness by the person's investigative activities results in the appearance of, and contact with, such tulpoids. The more detrimental aspects of such tulpoidal tuning can be prevented by psychic clearance of the investigator, particularly of his unconscious mind. Such psychic clearance at regular intervals is highly recommended for investigators pursuing the more bizarre aspects of the field, such as cattle mutilation, men-in-black, sasquatch, possessions, etc.

118. Metal bending: term applied to the psychokinetic bending and breaking of metal objects such as cutlery, rods, bars, etc. When a metal rod is psychokinetically bent, then cross-sectioned and examined under the electron microscope, microscopic "puddling", as if by localized, point source intense heating, can be seen, with concomitant disruption of the metallic grain structure. In a severe case, the cross section looks like the puddled surface of the moon. The mechanism responsible for the psychokinetic bending is exothermic scalar interferometry by the two cerebral hemispheres, where the intersection zone is the metal object being bent

119. Metapsychology: literally, "before psychology." The deeper psychology of the group mind, particularly the collective human unconscious mind. Although the Cartesian idea of the separation of mind and matter usually applies to the individual conscious mind, it does not apply to the group unconscious mind. The collective human unconscious mind is a living being, though unconscious, and is capable of materializing its "dreams" into actual physical forms and beings.

120. Microcrystals: tiny crystals, particularly those used by George Yao in construction of his pulsors. Use of the microcrystal in proprietary manners enables Yao to build devices which react to scalar resonance and human intent, and which can generate negation patterns for potentially harmful "deltas" or changes that occur in the human etheric field (aura).

121. Miller/Fox/Urey effects (experiments): these experiments simulated the primitive conditions believed to have existed in and over the primeval oceans. Water—with its complement of minerals and chemicals—and gases to simulate the primeval atmosphere were placed in a beaker and subjected to ultraviolet radiation and electrical discharges. Thus the experiments simulated the great lightning discharges into the primeval oceans. In the laboratory, amino acids are formed, then proteinoids. If the experiments are performed in the presence of heating (simulating the presence of volcanic activity, for example), then primitive microspheric cells are formed with double cellular walls. These microspheric cells even reproduce by cell division. Thus at least simple lifeforms have been produced in the laboratory. Indeed, in the new model even inert matter is totally alive, but unpreferentially. Also, every possible sort of mind exists. Thus all that is necessary to form a living system with any desired characteristics is to form the appropriate type of physical tuner. A living system is like a television set existing in a flux of radiations from an infinite set of channels/stations. The set tunes preferentially to one channel/station, but any desired channel can be tuned, simply by changing the characteristics of the tuner. One does not "create" life, one simply "tunes it in selectively." In this concept rigorously there is no such thing as "death", but only transition from one state to another.

122. Mind: a quite misunderstood concept! In conventional science, it is considered purely robotic—i.e., it is the sum total of the electromechanical neural processes which receive, code, and interpret sensations, recall and correlate stored information, and act upon it Also considered to be the understanding, reasoning, and intellectual faculties considered as a whole, that is, as the conscious portion. Also considered as the psyche, including the conscious, subconscious, and unconscious portions, considered as a whole. The new approach is more in accord with the latter definition. Simply put, the mind is a world composed of separation events (waves, operations, processes) in unseparated being. We may model it (to a first crude approximation) as a physical universe, three orthogonal turns away from the ordinary physical universe, and tuned slightly selectively to one physical organism's physical body processes. Mind anenergy is considered to be progressively collected, condensed, and kindled into denser substance and objects by rotation toward the ordinary physical world. Thus a piece of inert matter is simply condensed energy, which itself is condensed anenergy, which is condensed mind flux (crosstalk) from all minds. One may model the mind physically, or model the physical as mindstuff, eliminating the artificial dichotomy between mind and matter that presently is assumed in orthodox science. Since per-

ception of thought *is* fragmentation and separation of mind, die mind cannot be perceptually conscious of itself, but only of its separated fragments (thoughts). When the incessant activity of the mind is stilled, however, the stable mind is in its pure state—pure being. In this state there is no separation of the observer and the observed. With attainment of this state, one "realizes" or experiences one's true God-nature. It is theoretically possible to build a scalar wave detector that can directly "see" thoughts. Indeed, the first prototype of this type detector may have already been built by one physicist experimenting with a very sensitive scalar wave detector.

123. Mind linkage: the integrating of two or more minds into a single overall functional mind. A living example is in each human head: the two cerebral hemispheres—each containing its own separate mind—are integrated into one overall brain having a single functional mind. This is accomplished by signals interconnecting the two cerebral hemispheres through the corpus callosum. Note that the "separated beings" of the two minds are also merged/linked into one greater being. The tuned separation of individual humans (caused by the continual photon interactions with each particle of mass in the body tuner) is responsible for all man's inhumanity to his fellow man, for each now perceives others as separate things or "objects." With mind linkage, the human species will emerge as a single great entity, having not only • single "collective unconscious," but also a single "collective conscious" mind. Proof that linkage can be accomplished is already demonstrated by each individual. The problem of resolving all man's inhumanity to his fellow man is thus a technical problem, not just a moral/philosophical problem.

124. Mitogenetic radiation: laser-like, coherent photons emitted by cells, particularly in the near ultraviolet Of particular importance are the photon emitted by a cell immediately after complete fertilization, and the photon emitted as the cell dies. The first mitogenetic photon signifies the kindled connection of the cell's small mindworld and the establishing of the consciousness or life loop. The second mitogenetic photon signifies the loss of tuning and consequent loss of the consciousness or life loop. The photon at cellular fertilization is a joyous song of birth, and the photon at cellular death is a deathsong of the cell. In addition, the birth photon carries the full mindworld pattern nested inside it in the virtual (scalar) state, and the death photon carries the full pattern of the cell's experiences and death nested inside it in the virtual (scalar) state.

125. Monocular (change): one at a time. Change as seen by only a single observer at a time. This type change is provided by the photon interaction with matter, and the "memory hold" of a large number of such monocular changes constitutes the "perceived/detected physical reality" we conceive we exist in.

126. Moray amplifier: free energy device developed by T. Henry Moray of Salt Lake City, Utah in the 1920's and 30's. The device was destroyed by a double agent (an F.B.I, agent and also a Soviet agent) in 1939, after the agent had obtained the drawings of the device and worked in Moray's laboratory for several months. The final device had some 29 detector stages and produced an output of 50 kilowatts of power, without input.

127. Moray, T. Henry: early experimenter and pioneer in radiant energy, who developed one of the most widely demonstrated and best authenticated free energy devices. Moray's device was a collector/amplifier that eventually produced 50 kilowatts of output power.

128. Multiocular (change): more than one at a time. Change as seen by multiple simultaneous observers. Consideration of this type change leads to an infinite dimensional, multiworld or multiuniverse reality similar to the type described by Everett. If one accepts multiple simultaneous observers, then this expanded and startling view of reality is inescapable. If one accepts only a single observer at a time (as does present physics), then there exists only a single living person, and everyone and everything else is simply a figment of his or her imagination.

129. Mystery light: another name for a nocturnal light, or earthstress light, produced by natural scalar transmission interferometry of the cracked rock structures in the earth's crust

130. Neurophone: an instrument for direct electomagnetic input of signals into the human brain and nervous system. The neurophone was invented by Pat Flanagan when a boy of seventeen. The improved version, invented much later by Flanagan, clips an input signal, differentiates it twice, then feeds the resulting noisy spikes into the human sensory system. The original signal is impressed into the brain and directly into the mind. An adaptation of the neurophone, using more than eleven independent frequencies and built in accord with Soviet work reported by Lisitsyn, could conceivably be utilized to accomplish human mind linkage.

131. Neutrinic wave: a bare neutrino, considered as a wave instead of a particle. It is a special kind of polarization wave to the laboratory observer, and interacts with his electromagnetic field. It is essentially a longitudinal scalar wave, which moves in and on ordinary vector electromagnetic waves. It may also be regarded as a sort of "spin" wave, since one may consider it as moving at the speed c, but circling around a photon in a plane perpendicular to the photon's velocity in 3-space. One may thus say that the neutrinic wave moves at the velocity c-squared, but its carrier moves at the velocity c. Since we detect the speed of the carrier, detected neutrinos always appear to have moved at the speed of light.

132. Neutrino: a neutral particle believed to have zero rest mass and travel at the speed of light. One type of neutrino is associated with the electron and one type with the muon. A third type is now believed to exist There is some evidence recently of neutrinos possibly having a small mass, and of one type of neutrino turning into another type. In the new approach, the classical neutrino is a flux of much smaller particles—"bare" neutrinos—inside a photon. In the photon, one flux is taken to rotate clockwise and one flux to rotate counterclockwise (adapted from the phasor theory of Ruderfer). Further, a neutrinic flux from one half of the photon to the other is hypothetically possible, and this flux would constitute a third type of neutrino. It would exhibit mass, and would allow one type of neutrino to turn into the other. The bare neutrino (from the new approach) is of magnitude 1/c times the magnitude of the photon. Further, it moves at the speed c-squared, but since it circulates at the speed c at right angles to the motion of its photon carrier which is moving at the speed c, its detected velocity is always c, the speed of carrier. To an observer in the hyper-

frame of the electromagnetic field, a laboratory bare neutrino would appear as a photon.

133. Newman, Joseph: Mississippi inventor of a free energy machine tested and authenticated by several dozen scientists. Newman is fighting in court to obtain a patent on the device which has clearly been shown to be legitimate.

134. Newman machine: free energy device developed by Joseph Newman. While the prototype does not produce appreciable output power, it does produce an output and keeps its own small drycell batteries charged. It clearly demonstrates the principle and is a legitimate free energy device.

135. Nocturnal light: any paranormal light phenomenon seen at night. Over 80% of the UFO phenomena are nocturnal lights. Also includes phenomena such as "ghost" lights, spooklights, will 'o the wisps, etc. It specifically does not include ball lightning, St. Elmo's fire, and other such rare but normal phenomena. Most of the nocturnal light phenomena are caused by natural scalar transmission interferometry.

136. Observable (state): that part of physical reality consisting of changes (particles, waves, action changes) that are detectable by single instruments. The field on a charged particle is due to the continual emission and absorption of virtual particles. Forces between observable particles are generated by the exchange of virtual particles. Thus all observable forces, fields and changes are generated by unobservable virtual interactions, and observable and virtual reality states are inseparably enmeshed. In theory, no superluminal effect can be directly detected; however, a two-stage detection can be used to detect a superluminal entity. Usually the first stage is an interference between two superluminal entities, where the interference "downshifts" the waves to produce a wave moving at subluminal velocity. This subluminal wave then interacts with a mass such as an electron, and these interactions are accumulated to provide a macroscopic measurement indicative of the presence of the primary superluminal interferents. A two-slit box for the electron inteiference experiment is an example. Also, in quantum mechanics time is not an observable, even in theory. All observation is spatial; rigorously, there is no such thing as a clock in the purest sense. Time is always inferred from a spatial detection or measurement

137. Orgone energy: the subtle living or life energy discovered and utilized by Wilhelm Reich. Reich had discovered and utilized a portion of scalar electromagnetics (electrogravitation).

138. Orthoframe: a frame rotated away from the laboratory frame by one or more right angles. A hyperframe or biofame. Also called an orthoworld.

139. Orthogonal: simply, at right angles. The intersection of two orthogonal geometric constructs, each of dimension one or greater, is of one less dimension than the lowest dimensioned intersector.

140. Orthorotation: rotation in hyperspace of an object, form, or particle at a right angle to its starting frame. The object loses one dimension in its intersection in the original frame and gains one dimension in its intersection in the frame toward which it rotates.

141. Orthoworlds: orthogonal 3-dimensional physical worlds (frames) that share a single time dimension in their 4—spaces (spacetimes).

142. Paradox (logical): a thing that is true, but which violates one or more of the three Aristotelian laws of logic. All logical paradoxes are simply fourth-law logic cases, and—at least hypothetically—the fourth law can be applied to resolve them.

143. Paranormal phenomena: any phenomena that differ from straightforward, orthodox physical or psychological phenomena. Phenomena beyond understanding in terms of presently known science, causes, and effects. Specifically, phenomena in which mind and matter, or mind and unknown fields, or matter and unknown fields interact observably.

144. Past: reality which has been erased and has ceased to "physically (observably exist" in immediate detection/perception, and which now exists only as an infolded virtual state trace or vacuum memory. (Because the past still exists as an infolded virtual trace in vacuum, the time-reversed wave emitted from a pumped phase conjugate in four-wave mixing can retrace the past path of the wave that struck the mirror and stimulated the emission.) Fissioning of an action quantum produces a "presented" change described by canonical fragments. Fusion of the canonical fragments back into a quantum of action erases the presented real canonical fragments, reducing the "change" to the "past" However, that "fissioned pattern" or virtual substructure continues to exist, infolded into the vacuum. The vacuum retains a perfect infolded recorded memory, therefore, of every quantum change that has ever occurred. (In ancient mystery schools, the set of all such traces was called the Akashic record.) A virtual projection of the change has occurred in the mind world of the observer, however, since the mindworld is nonlocal. The coherent (causal) time-ordered collection of large numbers of such virtual projections in the mindworld reaches the quantum threshold, resulting in a quantum change in the mindworld. The "conscious mind" thus perceives physical reality as a collection of a large number of quantum changes—in short, a macroscopic reality. In actuality this "perceived macroscopic world" rigorously exists only in the mindworld, and thus it exists only in the past (Note how physicist's discussions of such quantum paradoxes as Schrodinger's Cat are erroneously based on macroscopic considerations.)

145. Phase conjugation: a nonlinear wave process whereby a nonlinear crystal, material, or medium creates a nonlinear polarization for an incoming monochromatic wave is generated at the incident frequency by w-w-w= -w. The nonlinear polarization radiates a time-reversed replica of the incoming waveform. The time-reversed waveform has an amplitude proportional to the complex conjugate of the incoming wave amplitude. Though primarily known in nonlinear optics, the time-reversed wave is a solution to the wave equation, and so the phenomenon is universal to all kinds of waves. As can be seen from (w-w)-w = -w, the first two waves modulate each other because the nonlinear medium acts as a modulator. These two waves thus "lock together" as a single scalar EM wave. The scalar wave passes through the electron shells of the atoms of the nonlinear medium, penetrating to the positively charged atomic nuclei. In a nucleus, each incident scalar photon is absorbed, increasing the potential of the nucleus to an excited state. The decay of this excited state from the positively-charged nucleus causes the emission of a time-reversed (TR) photon carrying negative energy. The "emitted shower"

of these TR photons constitutes a TR wave. Thus from the nonlinear material there is emitted a time-reversed wave. This TR wave "backtracks" through space along the invisible path taken by the original incoming wave. Since the phase conjugate wave is time-reversed, it concentrates along its backward path, rather than diverging. Consequently all its energy arrives at the distant location of the source of the original stimulus wave. The nonlinear medium producing the TR effect in response to a stimulus wave is referred to as a phase conjugate mirror. If two monochromatic EM waves w1 and w2 are fed into the nonlinear medium in antiparallel manner, so that the waves are everywhere out of phase, they modulate each other, forming a much more powerful scalar EM wave. This wave then "pumps" each nuclear potential to a much higher excited state. Thus when this potential decays, a much more powerful TR wave is emitted, containing up to all the energy put into the scalar "pump" wave. Note that the excited nuclei do not decay (the excited potential does not decay) until an incoming stimulus wave—say w4—is received. When w4 is received, then a powerful TR wave—say w3—is emitted from the phase conjugate mirror (PCM). This process is referred to as "four wave mixing." Thus a pumped PCM acts as a triodc amplifier, and the incoming stimulus wave acts as a signal on the grid. In the oscillation condition (incoming input w4 at right angles to wl and w2), infinite gain is experienced, so that all the energy in pump waves wl and w2 appear in TR wave w3. This was Nikola Tesla's secret of wireless transmission of energy at a distance without losses; the Great Electrician had discovered what we today call phase conjugation and the pumped phase conjugate mirror. He also discovered its general nature, for he understood that it applied to all kinds of waves, including mechanical waves in the earth. It has been shown that, under proper conditions, it is possible to have self-oscillation in the nonlinear crystal or medium. Such a PCM is referred to as a "self-pumped PCM." Indeed, Tesla's original Magnifying Transmitter would have utilized the earth itself as a self-pumped, amplifying PCM—in other words, as a giant triode where the molten core of the earth already furnished the cathode power for free. A relatively small input "grid signal" (from Tesla's resonant transmitter) would thus have set the earth itself into scalar resonance (giant self-pumping), eliciting an enormous time-reversed wave energy resonant response from the core of the earth. Anyone anywhere on earth with an antenna tuned to the stimulated frequency would have received cheap or "free" energy from the earth itself. The Soviets presently use a version of this method to power their enormous scalar EM wave Tesla weapons. All unorthodox resonant free energy devices (built in secret by unorthodox inventors) presently use variations of this same principle.

146. Photon: the basic action quantum. It may be considered as an oscillation in and of time. It may also be considered as a virtual pattern of positron/electron pairs. A piece of electromagnetic radiation when it interacts as a particle. One half the photon exists in and carries positive time (negative charge), and the other half exists in and carries negative time (positive charge); thus one half is "normal" and the other half is "time-reversed" (phase conjugated). The magnetic field of a permanent magnet, for example, thus consists of two types of coincident magnetic field lines: one line of each coincident pair is in positive time and by convention runs from the north pole to the south pole, while the second line of the pair it in negative time and runs from the sooth pole to the north pole. The two lines maybe considered as two streams of particles, one negative and the other positive (Howard Johnson's two-particle theory of magnetism). The photon may be considered as two contrarotating neutrinos, after the work of Ruderfcr. In the new approach, each of these rotating neutrinos is considered to be composed of vast numbers of circulating bare neutrinos. The photon may be considered as one cycle of an electromagnetic wave. The photon is the basic carrier of time and consists of a piece of energy welded to a piece of time, with no seam in the middle. The passage of "time" thus moves at the speed of light, its carrier. All ordinary photons possess the same action magnitude, h, although they do not carry the same energy. If the photon is made subquantal (i.e., less than h in magnitude), it is a virtual photon of the type whose emission and absorption cause charge on an electron. Virtual photons are not individually detectable, even in theory. However, a virtual photon may have positive mass under some circumstances.

147. Photon interaction: the absorption and emission of photons by particles or objects. Usually the photon interacts with an orbital electron, being absorbed by the electron which is raised into an excited state. Then the election decays from the excited state, emitting another photon. The macroscopic world is created by this interaction, which is the basic quantum change interaction. When we introduce additional photon interactions beyond the ambient background, the nucleus stays basically stable, and the normal first-order world we perceive seems quite stable. This is the first level of physical reality, and it is the reality sensed by our coarse physical senses. However, scalar waves are emitted and absorbed by the nuclei of atoms, passing right through the electron shells without interaction. When we introduce additional scalar interactions beyond the ambient background, the nuclei change appreciably, and this level of physical reality may be far from stable. This is the higher reality, and it is sensed by the scalar electromagnetic functioning of our nervous system. Unfortunately, this system outputs only to the deep unconscious, since it is highly multiocular. Thus our conscious mind, being monocular, does not perceive the most fundamental reality in which we exist. Note that "time" is the special dimension in which multiple objects can exist simultaneously in the same interval, while space is composed of dimensions (length) in which multiple objects cannot exist simultaneously in the same interval. Time is multiocular, and space is monocular. Our conscious mind is fitted to the monocular photon interaction; being monocular, our conscious mind cannot be aware of time directly. For that reason we do not "see" time consciously. We do "see" it, however, unconsciously. The true meaning of being "lost" is to be separated from the consciousness of the All, which is separation of our conscious, gross sensing of first order reality from our finer, more subtle, and infinitely richer—and unconscious—scalar sensing of ultimate reality.

148. Photon quenching: the effect of photon emission carrying away time, constituting a time-differentiation of spacetime and leaving behind a spatial reality. This action is responsible for the destruction of the time dimen-

sion in the detection/measurement processes of our physical instruments and our body sensory systems. Thus all detections and measurements are spatial, and we detect and perceive only a 3-dimensional spatial universe, not a 4-dimensional or higher spacetime. Photon quenching is thus a filter between us (our senses and instruments) and fundamental reality. Physical reality as detected by our senses and instruments is real, but only partial. Specifically it is a time-differentiation of fundamental reality. We thus lose the ability to detect those things which occupy time but not normal 3-dimensional space—such as mind, thought, etc. Almost all our thoughts, concepts, words, and ideas are fitted to this partial reality—and this is the universal human problem and delusion. We see a spatial universe of separated spatial objects, while in actuality we exist in an undifferentiated single wholeness. It is not a matter of loving one's brother or sister, it is a matter of being him or her. Fortunately, with scalar electromagnetics much finer instruments can be built The quantal limitation of ordinary physics is not a limitation in scalar electromagnetics. Ultimately we will be able to use sophisticated scalar sensors and biofeedback training to awaken and develop consciousness of our scalar sensing of higher reality, and restore man to his proper state.

149. Piezoelectric effect: In a material, the appearance of a voltage when mechanical stress is applied, or of a mechanical stress when a voltage is applied.

150. Poltergeist: allegedly, a spirit or ghost, often mischievous, usually associated with anomalous psychokinetic activity in houses such as slamming doors, levitating and flying objects, displacement of persons or objects, etc. Often the poltergeist phenomena are associated with an emotionally upset or distraught adolescent. The experience of cooling of the surroundings when these phenomena are evidenced is also common.

151. Potential: locked-in work or energy at a point It is important to realize that, like a runner running in place, the potential represents work continually being done in time, but at a point, not released through a distance. Since the work is never spatially released, to the external observer it remains in the present as energy, and does not pass into the past as work accomplished! Prior to observation (passage from the present into the past), the physical universe exists as action or angular momentum—e.g., as "energy x time," or "momentum x length," etc. The two variables in which angular momentum is expressed are referred to as "canonical variables." They are locked together, since their product is a constant (in a nonlinear frame). Thus if we ask "what exists in time?" we have asked "what is the time derivative of action, which is the same as "what is existing in time but not in space?" The answer then is energy, which—before observation (separation) exists undifferentiated as (energy x time). Ironically, in electromagnetics the electric (electrostatic) potential is completely misdefined. Most texts start about to define it in terms of "potential difference," and then only tell how to prescribe the intensity or magnitude. For example: "The work which must be done against electric forces to bring a unit charge from a reference point (often at infinity) to the point in question." Note this "definition" does not at all tell what a potential is, but instead tells how to mathematically determine its intensity. Briefly, electric potential is a locked-in stress in vacuum spacetime. This stress at a point is due to the intensity of the virtual particle (virtual photon) flux (dynamic, ongoing, trapped virtual work) at that point The ambient local stress of vacuum is not zero, but is a very high value. Normally we refer to "potentials" as measured from the ambient; that is, we actually specify the "difference from the ambient value of the spatiotemporal stress due to virtual photon flux" at the point in question. Any change in the ambient stress of vacuum is a curvature of spacetime. The electrostatic curvature normally stress-relieves almost immediately as electric force field on matter, or electric virtual force field in vacuum. In Kaluza theory, the electromagnetic force fields are just the 5th dimensional aspect of the 5-d gravitational field. The 4-d gravity field is the other aspect of our 4-<i world's intersection with the 5-d G-field. Thus the electrostatic and magnetostatic potentials are simply two coupled aspects of the 5-d G-field. A normal electromagnetic force field (E or B) is the "bleed-off" or escape on charged particles, of the 5-d gravitational field potential's infolded stress contents into the fifth dimension. That is, it is the 5th dimensional outfolding of the inner contents of the gravitational potential. If we wish to achieve bleed-off into die 4-d G-field instead of the normal 5th dimensional E and B fields, then we must "shut off" the EM bleed-off/out This shutoff can easily be done by opposing and reciprocally modulating E-fields and/or B-fields so that they lock-together as one field, and vectorially sum to zero vector resultants. This creates artificial (internally structured) electrostatic and/or magnetostatic scalar potentials. These potentials are actually 5-d G-potential, which is now forced to bleed-off/out into the 4-d gravitational force field at great amplification. This is the outfolding of the inner contents of the 5-d G potential into ordinary 4-space. Such an artificial potential produces a vector zeroed 5th dimensional EM system with a deterministic substructure, which polarizes the vacuum and engineers the virtual state. Maxwell's original 1864 quaternion theory included this theory, though not in these specific terms. Heaviside's mutilation of the theory into vectors threw away the electrogravitational aspects by discarding the scalar component of the quaternion.

152. Prigogine crystal: an amorphous pellet or crystal made by sintering finely divided material at high temperature and pressure, in such fashion that the pellet becomes a highly stressed system far from thermodynamic equilibrium. Specifically, more than one type of material must be used, one ingredient of which must be piezoelectric. One ingredient should also be radioactive, and preferably one of the uranium compounds exhibiting highly anomalous magnetic spin coupling. For best results, a third ingredient should be luminescent when electrically stimulated. The stress on each grain of the piezoelectric material must be just so that the grain is on the very verge of being slightly stress cracked, but not split Each grain then becomes a scalar interferometer. Such a crystal produces a scalar potential field and can react to minute changes in potential—i.e., it can react to scalar waves. Via scalar interferometry it can change scalar waves into negative (time-reversed) electromagnetic radiation and energy at a slight distance. Under oscillating potential stress, the radioactive ingredient provides a one-way gate valve from the Dirac Sea electrons of vacuum, and the scalar interferometers provide necessary impetus on these negative energy electrons to lift

them out of the Dirac sea, producing negative electricity and currents. These currents can then be collected in multiple stages to provide electrical power (negative power operates devices much better than positive power). In the proper arrangement, such a Prigogine crystal can be made into a system capable of tapping the energy of vacuum directly. T. H. Moray built exactly such systems in the 1920's and 1930's, finally obtaining 50 kilowatts of negative power from a 55-lb device. J. Bedini has produced modern versions of these stress crystals in the 1980's, and a series of negative power devices. Several other inventors have produced successful negative power devices also.

153. Prigogine effect: the exhibition of negative entropy by a properly stressed many-particle system far from thermodynamic equilibrium.

154. Prigogine system: a many-particle system which is deliberately forced to exist far from thermodynamic equilibrium, and which exhibits negative entropy. Note that local curvature of vacuum spacetime places the local virtual state flux in nonequilibrium conditions, with the result that an observable energy "sink" or "source" can be produced.

155. Priore, Antoine: French inventor, who invented a large electromagnetic machine which produced nearly incredible cures of terminal cancers in hundreds and hundreds of laboratory animal tests in the 1960's and early 1970's. Priore's results were presented to the French Academy by the Secretary Perpetuel and Head of the Biology Section, M. Robert Courier. The French Government financed Priore's work for several years, then abandoned it when the regime changed. Priore produced complex phase conjugate (time reversed) EM signals in a giant rotating plasma, then sent these time-reversed signals down a rippling magnetic field into and through every cell of the treated body. By magnetic resonance of the rippling field, the phase conjugated signals were coupled into the atomic nuclei of the body, thus reversing the harmful structuring of the cellular biopotentials, which are centered in and on and from the atomic nuclei. This "backtracked" the circulating substructure components within the biopotential, reverting it back to a previous state where the disease was not present Kindling this pattern into observable state thus reversed and eliminated the disease. (The sharp reader will immediately note that it is readily possible to reverse the aging process, given the development of this technology. So-called "eternal physical life"—or certainly indefinite physical life with youth and vigor—is achievable.). With the death of Priore, the work has ceased and the machine has been dismantled, since no one in the French Academy knew of phase conjugation or understood how it worked. Priore's last machine was nearly four stories high and was intended to treat terminal human cases as well as larger animals such as monkeys.

156. Priore machine: a device built by Antoine Priore in France, which cured terminal cancers and leukemias in thousands of laboratory animals in the 1960's and 1979's. Complex nested modulations were mixed in a rotating plasma, which modulates the signals (producing nested stages of modulations upon modulations, whic*h* is necessary to reach into a sufficient number of hyperspaces/nested virtual levels of vacuum). The device produced very complex, phase conjugate (time-reversed) hyperspatial signals of some 17 or *more dimensions* These time-reversed signals were imposed upon and intense, rippling magnetic field carrier, and induced into the body of the irradiated animal, eventually causing the remission of the disease after several treatments. The signal was able to "work on" some 17 levels of the biopotential. Hundreds and hundreds of terminal cases were cured in laboratory animals. The nested modulations formed hyperspatial, multidimensional components in their "giant photon" vacuum engines. This constituted scalar electromagnetic and virtual state engineering in 17-d spacetime, and the machine directly affected the life force frequency channel (consciousness loop) and master virtual electromagnetic (scalar wave) control system of the cells. It would appear that Priore had worked out combinations of frequencies, etc, that, when expressed in time-reversed waves, reverse abnormal mammalian cells, but do not affect normal cells. With the change in regimes in France and the death of Priore, the large new machine (which would have been used to treat humans) was dismantled and the discovery passed into disarray.

157. Probability: the probability of a simple event is the ratio of the number of times it occurs to the total number of trials (for a large, essentially infinite number of trials). Note that "trials" constitute things that have occurred (are past). Probability has resisted rigorous logical definition by Aristotelian logic; the reason is that it is an expression of the fourth law, the identity of oppositcs. Probability is the expression of the future (that which has not occurred) in terms of the past (that which has occurred). Since we have been trained to conceive or think of something as if it had just been perceived to occur, then this is the only way we can conceive the future. But with Aristotelian logic, the future cannot be composed of the past, and probability has no acceptable logical basis. With four-law logic, the future can be modeled in terms of—and even be identical to—the past, and probability has a logical basis. Consider "throwing a die to land with one face up." Thinking of the event (as if it has just occurred, in terms of the most recent past), one can conceive six ways of looking at it In other words, one can conceive of six "most recent pasts." By the fourth law, the total "most recent past" is identical to the "most immediate future," on the boundary. If one therefore collects all six "most recent pasts," they turn into the most immediate future, by the fourth law of logic. One may attempt to argue that only a single one of the events will actually occur. Here one counters with the observation that, when it occurs, it is the past, not the future, and it has not been collected so as to move to the boundary.

158. Problem of change: as stated by Heraclitus: if a thing changes, it must turn into something else. But how can a thing be something else other than itself? The paradox cannot be resolved by 3-law Aristotelian logic, because the concept of change assumes the fourth law (i.e., that a thing can be identical to something other than itself)- The problem is resolved (by the fourth law) merely by accounting the time snapshots in which a thing is perceived, detected, observed, conceived, thought, etc That is, the original thing was perceived in time snap 1. The next thing was perceived in time snap 2. In yet another time snapshot, snap 3, the two previous snapshots are compared (in memory, which is the only place the past exists). If that comparison finds no distinction or differ-

ence between the first two snaps, then they are declared identical (by a decision algorithm). If the comparison in time snap 3 finds a difference between the previous two snaps, then they are declared nonidentical (by a decision algorithm). Most simple macroscopic things are seen as a multitude of composite attributes. Thus one or more of these attributes may be seen to have changed (not be identical between snaps 1 and 2), yet a host of other attributes may be seen not to have changed. In this case, the two overall objects are seen to be "almost identical but not quite," so that one speaks of "the thing having changed." One implies it changes in some attributes, but remains the same in most others. This is the primitive derivation of "how a thing changes, yet remains itself." On the other hand, if one defines a hypothetical thing which has only a single attribute—itself—then that thing cannot change, by Aristotelian logic. Yet even such a thing can change! Consider the single overallness of a caterpillar. Let metamorphosis occur, and it is now a butterfly. Now between snaps 1 and 2 we see a different overallness, yet we declare it the same thing! Here we have a more direct application of the fourth law: one thing (snapshot 1) can be identical to another thing entirely (snapshot 2) if the distinction between things one and two is lost in the decision algorithm applied in snapshot 3. In other words, identity and nonidentity are not absolutes, but are products of the decision criteria invoked in determining them. This resolves the age-old philosophical problem of change by expanding the logic by means of which one examines the problem.

159. Problem of good and evil: the paradox posed by the assumption of a "good only" creator moving forward in time, and the simultaneous existence of evil. I.e., if God is perfect and all powerful, how can imperfection exist? This problem is simply one expression of the "time trap." That is, the unconscious assumption of a creator moving forward in time (and "acting" and "operating," for example) is a limitation—hence an imperfection—unwittingly placed on the concept of a creator. Hence an imperfect creator could well wind up with the existence of evil (imperfection) in the creation. If one makes God unlimited—even by time—then perfection may be restored to the creator concept One then separates a positive time stream and a negative time stream (these are arbitrary, since in ultimate reality all events exist at once, unseparated, and ordering may be accomplished in any fashion one wishes). In the positive time stream, an act then becomes either good or bad, depending on whether it is beneficial or detrimental to its referent. But in the negative time stream the same act is reversed and becomes the exact opposite with respect to the referent. Thus any act is ULTIMATELY both good and evil simultaneously, and to the exact same degree. Hence in the "all-at-once" of the unlimited level, the two aspects zero and cancel, and there is neither good nor evil exclusively. Yet there is all good and all evil nonexclusively. The unlimited God is thus both good and evil simultaneously but nonexclnsively, and neither good nor evil exclusively. This is the resolution of the unsolved philosophical (and theological) problem of good and evil.

160. Psychic surgery: paranormally opening and closing the flesh of the body to remove abnormal growths or tissues. In a less drastic case, operating on die etheric or subtle energy body, rather than the physical body. In legitimate psychic surgery, scalar interferometry from the surgeon can nullify the cohesive charges binding the tissue cells together in a line; the tissues then open without cellular damage. When the surgeon closes the tissues, scalar interferometry again restores the charge and cellular binding, so the wound is "healed" without scarring (or with very little, in the practical case).

161. Psychokinesis: inceptive influence or effect upon a physical object, system, or situation by mental intent Psychokinesis is accomplished by means of scalar anenergy wave patterns projected from the two cerebral halves in the fashion of a scalar interferometer. The waves interfere at a distance, microscopically in the object to be moved or affected, forming microscopic bursts of vector wave energy in the object itself. Jack Hauck has referred to psychokenetic bending of metal as "warm forming."

162. Psychosis: seriously impaired mental functioning so that gross interference occurs*" with an individual's ability to function in a normal mental fashion. Generally characterized by severe mental disturbance, withdrawal from reality, delusions or hallucinations, regression and personality disintegration.

163. Psychotronic generator: a device which produces observable effects by collecting, condensing, amplifying, and/or processing subtle anenergies or scalar waves. Classic examples are the psychotronic generators of the Czech engineer, Robert Pavlita. Psychotronic devices are virtual state engineering devices that process and utilize scalar EM waves of massless charge flux. Most of Pavlita's devices are "charged" by the natural scalar electromagnetic emissions of the human brain and nervous systems.

164. Psychotronics: *psycho-* (mind energy), *-ronics* (electronics or devices). The union of subtle (mind) energy (that is, anenergy or scalar waves) and matter or electromagnetic field. Czechoslovakian term for parapsychology, with emphasis on the energy aspects. The comparable Soviet term was originally psychoenergetics, which was soon shortened to energetics. However, the Soviets have applied scalar electromagnetics (electrogravitation) principles and massively focussed on weaponry, not just parapsychology. 'Virtual state engineering. Electrogravitational engineering. Scalar wave engineering.

165. Pulse mode: in a transmitting scalar interferometer, projection of a single sequential pair of Fourier scalar wave patterns or "pulses", so that the second pattern meets the first over the distant target area. Flash coupling of the two scalar patterns in the target zone produces a single intense electromagnetic pulse (EMP) which—if atmospheric—interacts with the plasma expansion of the atmosphere to produce a second pulse immediately after the first The dual pulsed flash signature of the scalar interferometer weapon's burst in the target area is very similar to the two-pulsed flash from a nuclear explosion, but without nuclear debris and fallout Two such pulse mode flashes from a Tesla howitzer—possibly the Russian one at Saryshagan Missile Test Range or one from another nation—have been detected off the southwest coast of Africa by U.S. Vela satellites, one in September 1979 and one in December 1980. Other similar tests have been reported. The pulsed flash may produce positive energy (exothermic) or negative energy (endothermic), depending upon the setup.

166. PulsorR: scalar electromagnetic microcrystal device invented by the electrical engineer George Yao. PulsorsR are specifically designed to correct or smooth the patterns of the subtle scalar electromagnetic "bodies" or levels.

167. Quantum: a single "particle" of the quantity action. The quantum is always composed of two fundamental quantities (canonical variables), and it is the "fissioning" of the action quantum into two pieces which results in detection of one of the pieces. An indefinite "smear" of part of the two pieces may be simultaneously detected by a linear detector, but never both exactly (Heisenberg uncertainty principle). More recent work has shown that, in a highly nonlinear situation, both canonical variables can be determined simultaneously to any desired degree of accuracy, in which case the Heisenberg uncertainty principle does not hold. This fundamental change in what has been regarded as one of the "sacred laws" of physics has not yet made it into most physics texts.

168. Quiton: a little piece of vacuum or emptiness. A piece of the medium of a space or spacetime, of any dimensionality. A piece of pure massless charge flux. A piece of pure scalar wave flux. A piece of pure virtual flux. A piece of the vacuum. A particle of electrostatic scalar potential (infinitesimal charge). A "vacuum engine." Quitons are at least 4-dimensional (spatiotemporal), not just spatial and have a dynamic structure, which may be either random or deterministic. Note that the paper handed to Los Angeles Times reporter Bob Toth by Petukov in Moscow, resulting in their seizure and charging with possession of high Soviet state secrets, contained a theory based on "little pieces of the medium" ("little pieces of vacuum.") In other words, it was a quiton theory, regardless of the specific terminology utilized.

169. Radiant energy: term used by T. Henry Moray to describe the subtle anenergy his amplifier tapped from the unlimited vacuum energy of the cosmos, furnishing usable electrical power of an unusual (negative power) nature. By 1939 Moray was obtaining 50 kilowatts of power from the output of a 55-pound amplifier of some 29 stages, and an additional 50 kilowatts could be tapped off from any other stage. Moray's amplifier was essentially holographic, and could produce exponential amplification to any degree, merely by adding stages. The term was first used by Nikola Tesla, who patented "radiant energy" signaling systems shortly after 1900.

170. Radionics: the use of electrical apparatus (such as ganged precision resistors and potentiometers) to accurately attune the innate psychic and psychokinetic abilities of a human operator. Specifically, the operator may be attuned to some person or object at a distance, through the use of a "witness" (something containing the subtle anenergy pattern of the person or object). In actuality, the pattern contained by the witness consists of the previously impressed virtual (subtle) (scalar) energy patterns riding in and upon the object's internal electromagnetic interactions. The infolded vacuum retains an exact pattern and path of all photon interactions, be they observable or virtual. This guarantees a vacuum path exists between the witness and the original object, no matter where it is located. These impressed scalar EM patterns constitute a sort of complex "tuning fork" attuned to the impressing object or person through hyperspace (via the infolded past "backtrack" virtual memory of vacuum). Production of phase conjugation waves (time-reversed waves) in the witness thus will result in travel of these waves back through the infolded "backtrack paths" to the distant object itself. Resonating the "witness" pattern with amplified anenergy from the operator produces sympathetic anenergy resonance into the witnessed object at a distance, through the hyperspace backtrack path. Since the operator's will and intent modulate and pattern his input into the amplifier, the anenergy resonance of the distant person or object is correspondingly modified. This causes the kindling of an actual microscopic energy pattern in the distant object. The use of amplification constitutes the modern phase of radionics, essentially introduced by T.G. Hieronymus. In the Soviet Union, the incredibly powerful Moray hyperspatial amplifier is believed to be in use in a variety of energetics or psychotronics weapons. Such a holographic amplifier yields exponential power amplification to almost any degree desired. In the destruction of the U.S.S.Thresher in April 1963, a photograph of the submarine was probably utilized as a witness, and sufficient negative energy was kindled into the distant underwater submarine to seriously interfere with its controls. The sub then sank to crush depth and was imploded. Negative energy splatter in the surrounding area so interfered with the electromagnetic systems of the companion ship, U.S.S. Skylark, that over an hour and a half was required to transmit the emergency message that the sub was probably lost. In the U.S, holographic amplifiers have not formerly been developed, and radionics power is limited essentially to the linear amplification abilities of ordinary amplifiers. Thus their gains may reach 10^4, when indeed 10^{20} or so is needed for direct mechanical results immediately. For this reason the West has not developed dependable detectors of subtle energies, has not recognized the Soviet superweapon developments, and has not developed counters to them. However, Bedini, Dea, Beck, Golden, Dayney, Bielek, Bise, and other inventors have built scalar detectors of one form or another. Golden has also produced a highly specialized "booster amplifier"—the Golden booster—for Kelly radionics devices that is a step in the right direction. Both the Kelly machine and the Golden Booster have been verified as scalar wave radiators by actual measurement. With the development of detectors, the technology should begin to develop much faster in the West. The science of such devices and effects.

171. Reality: that which is actual or objective, as opposed to merely possible or ideal. One's idea of what constitutes actual and objective, however, strongly biases what is regarded as real and what isn't. In physics, for example, virtual actions are essential infinitesimals—little pieces of "nothingness" which yet produce effects. Physics thus has extended the meaning of "objective" beyond the idea of "observable." In addition, time—which is never observable or detectable, even in theory—it nonetheless assumed to be real and objective. In a sense, by "reality" one attempts to imply "ultimate." Indeed, the concept is confused, vague, and incapable of definition except in accord with what one pre-assumes it to be! The major problem is that most persons assume (1) reality is limited, and (2) reality is singular. In the new approach, reality is both unlimited and multiple. Everything is real; there are just differing degrees of reality or solidity as compared to the ordinary physical detection (threshold selection) process. Reality becomes a matter of intersections of physical universes and objects with other physical universes and objects, with the density of the intersection specifying the density or degree of physicality. (Note the similarity to the Aharonov-Bohm effect).

172. Reincarnation: refers to some element of the mind and/or personality surviving the physical death of a body/tuner, and being reborn in the body of another infant In the new approach, a type of reincarnation is scientifically derived as a consequence of the theory. However, since the past can be changed, by deep developmental work one can actually change one's so-called past incarnations. Also, more than one living person's scalar pattern can be attuned to a similar "past" scalar personal pattern—and so more than one person can be the "reincarnation" of a past person.

173. Remote viewing: the ability of human subjects to receive visual impressions and information from distant actions and scenes. The information is usually "noisy". May involve combinations of clairvoyance, clairaudience, precognition, postcognition, and telepathy. In the new theory, one recognizes that all detection is internal to the detector. Hence the entire detected physical universe may rigorously be said to exist inside each physical particle of the physical body of the observer. Thus hypothetically one has subtle access to any portion of the universe directly within oneself. The same result occurs when one assumes the use of a signal—longitudinal scalar waves of electrostatic potential—with infinite velocity. The two cerebral hemispheres act as a scalar interferometer, producing microscopic E-field by coupling incoming or rising microscopic scalar phi-field waves. This allows modification of the patterning of the avalanche discharges underway in the brain, and thus perception of the distant event Since scalar waves are hyperspatial and can be superluminal, they can move through time. This permits perception of the future and the past Unfortunately the outputs of this detection system in humans is buried deep within the unconscious mind, so it is difficult to obtain "clear signals." With the future development of sensitive scalar wave detectors, biofeedback training can probably be used to more fully develop this scalar sensing ability. Also, on several occasions Nikola Tesla announced the invention of a "big eye" that could see at a distance; such an instrument is perfectly possible by scanned scalar interferometry reception. This would include the ability to see into or through the ocean or earth—and time as well, under the proper circumstances. It should be possible to take distant pictures, or even pictures through time. One researcher, George Delawarr, reported the accomplishment of both these effects with his special camera.

174. Resonance: in physics, an oscillation phenomenon exhibited by a physical system driven by a periodic force; when the frequency of the driving force approaches a natural "free response frequency" of the system, the oscillation of the system becomes large. The "resonance (or resonant) frequency" of a system is a frequency at which some response of the system becomes maximum. Three types may be defined: (1) Phase *or* velocity resonance, where the response of the system is 90 degrees out of phase with the driving force, (2) amplitude resonance, where the amplitude of response of the system *is* maximum, and (3) natural resonance, which is the frequency of oscillation of the system to a sharp input such as a hammer blow. Electrical resonance exhibited by an alternating current reactive circuit results in relatively large currents near certain frequencies, together with the nearly unimpeded oscillation of energy back and forth between potential and kinetic form. There are two kinds, series and parallel resonance. In series resonance, the inductance and capacitance are in series, and in parallel resonance they are connected in parallel. In the series resonant circuit, the currents can become large if the resistance is small. Further, the voltages across the coil and capacitor are essentially 180 degrees out of phase, and so they essentially "cancel," leaving very little voltage across the overall circuit, even when the individual voltages across the coil and across the capacitor are very large. (Note that the E-fields across the inductance and the coil are also 180 degrees out of phase, and so the series resonant circuit to a distant observer produces an artificial potential wave—indeed, an electrogravitational wave. This is one reason why Tesla so favored the series circuit He also favored it with one end loose—the so-called "single-wire" circuit, without a return.) If the driving voltage to such a single-wire series resonant circuit is applied to the coil with the open-ended capacitor beyond, and the voltage is applied for only the first 90 degrees as a sine wave then instantly removed, the coil will be charged without current flow, accumulating a 5-d gravitational potential. When the coil discharges, it will discharge in two directions, producing real current, at a certain frequency (which may be drastically different from the "normal electrical current" resonant frequency. However, actual current will be induced out of both ends of the coil at this frequency. The capacitor will charge a little bit from this effect. The overshoot of the coil discharge back toward the disconnected driver is also usable energy if connected to a proper load. If the load is removed and the driving voltage is reapplied just as the overshoot reduces back to zero, the cycle is repeated, charging the distant capacitor more and more, and producing pulses of usable power through the overshoot discharge on the driver side. By adapting this mechanism, a free energy motor can be readily produced, as demonstrated by Bedini, Watson, and others with a battery-driven, series-wound DC motor unit Note that use of the localized gravitational potential produces local general relativity, a.locally bent spacetime, and the conservation of energy, charge, and momentum laws need not rigorously apply. An adaptation of this mechanism was also utilized by Tesla in his magnifying transmitter. In that transmitter with its huge elevated capacitance, the artificial potential wave produced would have been introduced into the earth, producing scalar resonance of the earth. The molten core of the earth, being under pressure in all directions, is self-pumped (in the language of nonlinear optical phase conjugation). The resonant atomic nuclei of the earth's molten core would then act as a pumped phase conjugate mirror (PCM), producing a highly amplified (near infinity gain!) time-reversed wave in response to the input signal. Thus the earth PCM is a giant amplifier, and the TR wave returned is highly amplified, possessing enormous energy. Thus the amount of energy resonant in the earth becomes enormous. In fact, the transmitter was designed to produce more than one such scalar earth resonance. At any distant point on the earth, a transmitter/receive station could have input a

small "tickler wave" at this frequency into the earth, and its proper antenna tuned to the frequency" of the scalar resonance would have produced enormous electrical power. A very similar system employing two frequencies 12 kilohertz apart and tapping the beat frequency, is used by the Soviet Union today to power its large strategic Tesla weapons. Golden has detected and shown these Soviet "two-frequency earth resonances" on the oscilloscope, utilizing the output of his specialized detector system.

175. Sasquatch: Indian name for a large, well-defined tulpoidal apeman form. Bigfoot (slang or common name). Generally refers to the Pacific Northwest area, where die tulpoidal form has been well-tuned for centuries by the Indians. In the Far East, the Yeti.

176. Scalar: in ordinary vector analysis, a quantity completely characterized by magnitude only. (Actually, it contains magnitude and time.) In the new approach, one must account for observable and virtual states. In addition, multiple vectors acting on one point and summing or multiplying to zero are physically still present, even though their vector resultant is a zero vector (more precisely, a zero-vector system). Thus physically a zero vector can be a system having a very real, distinct substructure of nonzero vector components. These infolded vector components may be highly dynamic. The energy of each infolded dynamic vector component is thus "trapped" inside the local vector zero system. Rigorously, trapped energy constitutes a scalar potential in spacetime, to the external observer. An observable scalar (potential) thus may have a nested, multiple-level virtual substructure as well as any conglomerate "observable vector" substructure. Enormous energy may be infolded and trapped, in which case local spacetime is appreciably curved. Note that the infolded energy of the substructure components contributes to the stress of the object or medium, and organizes it, even though to the external observer its envelope constitutes a zero vector. Each level of this substructure contains an infinite number of tiny virtual vectors. There may be finite alignment of these virtual vectors along the structure of the observable vectors infolded. This constitutes vacuum polarization. The zero-vector system is thus a vacuum engine and a virtual state engine as well. Two scalars (or vectors) that are observably equal need not be equal at all in their substructures. Further, combining the two scalars by superposition may not yield the normal observable value, if both substructures are different, highly patterned and interact to spill over into the observable level. Vector mathematics itself must be changed and extended in the new approach. Note that the spillover from interaction of the two substructures may form an observable scalar value or an observable vector value. Such vacuum engines can be constructed o do specific operations on atomic nuclei etc. Nested levels of such engines can be formed, to form highly complex "super" hyperspatial vacuum engines called giant photons. Continual radiation of matter with a signal composed of vacuum engine photons of a specific deterministic substructure will "charge up" the atomic nuclei of the radiated material with that pattern, so that it emerges into the gross, observable physical state, drastically altering the radiated matter itself mechanically, chemically and physically. This process is called kindling.

177. Scalar energy tap: refers to a Soviet method of obtaining tremendous electromagnetic energy from the molten core of the earth, with which to power gigantic strategic scalar Tesla howitzers. As measured by Golden, two signals are continually transmitted into the earth some 12 kiloHertz apart, and the earth itself is placed in scalar resonance to the two frequencies. The core of the earth, being a pumped phase conjugate mirror, responds by generating highly amplified phase conjugate replicas, which return and concentrate all their energy at the transmitter/receivers. The receivers receive the enormous beat frequency (12 kHz) energy, using it for power. One then has a kind of scalar interferometer channel in the earth's core in the endothermic mode. Depending upon the biasing, either ordinary EM energy or negative EM energy is captured in the 12 kiloHertz band by the interferometer receivers. Varying the negative biasing also provides a throttle to control the amount of energy extracted. Just before the May 1, 198S celebration, the Soviets activated some 27 such giant energy taps in the earth, and also activated a large number of command and control scalar transmission frequencies. If each tap can power 6 to 8 giant Tesla howitzers, then for their important 40th anniversary of WWII, the Soviet Union activated well over 100 large howitzers. In other words, a massive exercise of the Soviet Union's entire strategic scalar howitzer weapon complex was held on the 40th anniversary of 1945 for Gorbachev, and to signify meeting the schedule (laid down by Brezhnev in 1972) to "be ready" to use them . At the conclusion of the exercise (which lasted several days), the Soviets left two scalar energy taps in place, instead of the single one present before the exercise. In other words, additional strategic weapons were brought up on "ready alert"

178. Scalar field: in vector analysis, each point in space is assigned a magnitude; the set of spatial points and their assigned magnitudes is called a scalar field. In the new approach, an observable scalar value is assigned to every point in n-dimensional space, where n is 4 or greater, and the set of n-dimensional points and their assigned observable magnitudes is called a scalar field. Also, in the new approach each scalar magnitude is considered to contain an n-dimensional virtual-state substructure, where each succeedingly higher dimension is a succeedingly lower level of virtual state. Vacuum itself is such a scalar field. Such a scalar field is also the rigorous identity of a massless charge field, of—for example—the electrostatic scalar potential, 0. Also, the scalar field is considered to be composed of two time fields: one in positive time and one in negative time that is the phase conjugate replica of the first. Thus the timeless, lengthless vacuum exists both in positive and negative time, and its potentials are scalar potentials. When the vacuum is uncurved, equal amounts and components of positive and negative time exist. When it is curved at a point, the positive and negative time components are unbalanced at that point

179. Scalar interferometry: the interference of two scalar Tesla waves (a Tesla wave consists of a normal wave coupled to its phase conjugate replica). In the interference, coupling can occur and produce (or extract) electromagnetic waves—energy—at a distance. The phase conjugation aspect is the secret of Tesla's revolutionary discovery of wireless transmission without loss. It is also the secret of producing death rays; the invulnerable Tesla shield; antigravity; superluminal communication; con-

trolled materialization, dematerialization, and transmutation; psychokinesis; and free energy. The ubiquitous photon interaction presently is the basis for first-order physical reality, and the photon's speed results in a speed-of-light-limited reality being detected. Scalar EM waves contain vacuum engine substructures and do not necessarily have this speed limitation. Detection by scalar waves yields a higher order physical reality and a vastly expanded quantum mechanics and relativity theory. Present Einstein relativity theory is only a highly special case, as are present electromagnetics and quantum mechanics. Soviet use of scalar interferometers in a large, strategic mode is responsible for much of the advanced Soviet ABM defense and strategic superweaponry.

180. Scalar resonance: inertial or mass resonance of a body, originally discovered by Tesla, repeated (probably) by Hooper, and rediscovered by Golden, Bedim, and others. In the simplest case, scalar resonance can be imagined as two ordinary single—frequency EM standing waves (a wave and its phase conjugate replicaor PCR) in a resonant cavity, with the two waves coupled exactly 180 degrees out of phase so that—externally—their E fields sum to zero and their B fields sum to zero. This is a standing scalar wave, and the cavity is said to be in scalar resonance. Note that the cavity walls must act as phase conjugate mirrors (PCMs). Mass itself is simply such a standing scalar resonance, with the standing wave trapped by particle spin. The atomic nucleus, continually bombarded by virtual photon flux from the vacuum, is a pumped PCM. Since the nucleus is positively charged, it produces PCRs having negative energy and negative time. It thus produces negentropy, which prevents the entropic decay of the atom. Essentially all frequencies can be and are present at once, but certain nuclear resonance frequencies are thought to predominate. By increasing the amplitude of the standing scalar wave that is the nuclear pseupotential, inertia and mass of the nucleus are increased. By decreasing the amplitude, the mass and inertia are decreased. Zeroing the amplitude dematerializes the nucleus. Scalar resonance is not presently contained in the orthodox physics literature.

181. Scalar wave: a longitudinal "pressure" wave in the actual stress of spacetime itself. A wave of potential, where no EM bleedout of the infolded contents occurs. A normal wave and its phase conjugate replica, comodulating each other and "locked or zipped together" as a zero-vector system wave. A Tesla wave. A gravitational wave. A time wave. Electromagnetically, a scalar potential wave which, in the absence of spinning charged mass particles, does not form a vector electromagnetic wave, in contradistinction to present electromagnetic theory. A "shadow vector" wave, where the ordinary "observable force vector" of the field is broken into virtual vector components which are not integrated. A wave in the nested levels of virtual state, that does not breach the quantum threshold, and hence is not observable to normal detectors. A wave in the magnitude of the virtual particle flux density of vacuum. A longitudinal wave in pure massless charge flux (vacuum) (spacetime). A wave in the magnitude of the infolded "energy density of the vacuum. The scalar wave is free to move in four or more dimensions. It transports deterministic vacuum energy engines. In Minkowski 4-space, it can: (1) move only in time, and not spatially, in which case it "sits in one place" and fluctuates the flow of time, the inertia of an object, the strength of the gravitational field, the mind, the fundamental constants of nature, etc.; (2) move only spatially, with the rate of flow of time oscillating about a linear mean; (3) move in a mixture of modes (1) and (2); (4) oscillate back and forth between modes (1) and (2) in a regular fashion, spatially stationary; and (5) oscillate back and forth between modes (1) and (2), translating spatially in travelling wave fashion. (5) move and oscillate between many vacuum levels (hyperspaces), in addition to characteristics (1) through (4). An ordinary Hertzian wave exists in vacuum as two coupled Tesla longitudinal waves. Rigorously, the E and B fields do not exist in vacuum, but on and of the detecting spinning charged particle. The spin of the detecting particle causes precession, yielding the familiar "transverse Hertzian wave," complete with E and B fields. The broken but ordered virtual state bits of what will be the detected E and B, however—shadow vectors E and B—exist in vacuum, on the virtual components of the vacuum charge flux. Tesla was correct when he stated that transverse Hertz waves (as such) could not move through the vacuum or exist in it

182. Shadow vector: an otherwise observable vector, broken into consecutive bits such that each bit is virtual. The resulting "disintegrated vector" becomes unobservable as a vector, but remains as an ordered series of virtual vectors. Thus it is a special sort of scalar wave. Observably, it is a scalar wave since no observable vector exists, but virtually it is a vector wave. It may be regarded as a localized, changing scalar field with a particular patterned virtual substructure which yields the shadow vector. On an appropriate integrating detector, the virtual components of the shadow vector will be reintegrated into an observable force vector, such as E or B. Dr. Robert Beck, for example, has reported the development of a successful integrating detector for such shadow vector scalar waves. His detector is capable of detecting signals that cannot be seen by the finest Superconducting Quantum Interference Device (SQUID), and it has been demonstrated for comparison against the SQUID. Dea, Bedini, Dayney, Golden, Beck, Bielek and Bise have independently built scalar wave detectors of various kinds. Farnsworth has particularly good and comprehensive shadow vector/scalar wave detecting systems.

183. Space: literally, the absence of observable mass, hence emptiness or void observably. Space per se has no definite length interval and no definite time interval. Rigorously, space is the absence of distinction and separation. Space has no dimensionality—i.e., it is not 3-dimensional, 4-dimensional, etc., for it has no "specific" separations. But in common usage, it is often thought of in a general sense as having some particular dimensionality but no definite intervals. The point is subtle but important: the absence of a 3-dimensional mass need not be 3-dimensional (e.g., considering a 10-dimensional frame). But one usually thinks of the "hole" where the mass was as having the same dimensionality as did the absented mass. This is only a 3-dimensional intersection of the actual hole, however, though this point is usually ignored. Ignoring the full dimensionality of a hole is responsible for the confusion regarding the two-slit experiment in quantum physics, for example. That is, the slits are (at least) 4-dimensional, since they exist in time also. In the slits, spatial mass is absent, so the slits are

three dimensional "holes." However, their fourth dimensional aspect, time, is present, not absent Thus four dimensionally the three-dimensional slit "holes" are not "holes", but are "things." They are not 4-d absences, but presences—since one dimension (time) is still present They can thus interact in the fourth dimension, time. The experiment has no mystery when the time aspects are considered, as pointed out by Charles Muses in 1957. In Kaluza-Klein 5-d mathematics, these 3-d holes also exist as things in the fourth spatial dimension. Also, in spacetime—rigorously—all 3-dimensional material objects, holes, gaps, etc. are simple facets or intersections of a single object For if time is considered as a continuum, then everything exists at once; hence spatial things are simply the features of a single 4-dimensional object The problem is that "space" is also commonly taken to be a "spatial frame," where time has been stripped off and "stopped," and a measurement to each and every point in the universe frame has been simultaneously established. This corrupt usage of "space" implies "spatial frame," and is entirely different from space as such.

184. Spacetime: three or more dimensions of space and a dimension of time, multiplied together. In the 4-dimensional case, it is often referred to as a "4—space." Spacetime can actually contain any number of dimensions; in our theory we consider an infinite number of spatial dimensions and at least one time dimension. One could just as easily take an infinite number of time dimensions alone. Scalar electromagnetics (unified EM and G fields) is most easily expressed in Kaluza-Klein geometry, in at least five dimensions—four of space and one of time.

185. Spherical model of the cosmos: a model of the universe in which the universe is a four-dimensional spherical surface in five dimensions. This results in a "closed" universe, and also one which is entirely within each point of itself. To produce such a model instead of an expanding universe, Einstein originally introduced entirely ad hoc factors into general relativity to cancel and eliminate the expansion terms.

186. Spin: the intrinsic angular momentum of a particle, as if it were a top spinning about an axis. Spin is quantized. Spinning charged particles—such as an electron—thus demonstrate a magnetic moment, due to the circulation of charge in the spinning. In the nucleus of an atom, the spin of the nucleus is the resultant of the spins of the nucleons (particles comprising the nucleus). Actually spin of particles is more like an "implosion" to "explosion" circulation; in other words, it circulates in time as well. Spin of a particle is the basic feature that integrates the anenergy (disintegrated energy) of vacuum flux into observable charge. All observable fields, matter, effects, etc. depend upon this basic mechanism to zip together virtual entities and form observable phenomena.

187. Spooklight: another slang name for a nocturnal light Legend and folklore usually associate it with a violent death or macabre occurrence. Earth stress lights. Over 1,200 known sites produce such earth stress lights in the U.S. alone.

188. Strobe effect: striated patterns seen in UFO and other paranormal phenomena due to the higher dimensional phenomena skipping in and out of normal 3-space. Alternatively, two or more higher dimensional phenomena may dynamically interfere so as to form repetitive intersections with our normal 3-space, producing striations. Hyperspatial (scalar) EM interference often produces striation effects.

189. Substructure: in the new approach, a scalar has an infinite-dimensioned (infinite number of sublevels) virtual state substructure, filled with waves, particles, etc. Vacuum has precisely the same sort of substructure. The substructure is rigorously CHARGE FLUX, where observable mass is not present. Any vector, since it contains a set of scalars, also contains a set of virtual state charge flux substructures. One can engineer, pattern, arrange, and utilize these substructures to give various "paranormal" effects. These effects include materialization and dematerialization, psychokinesis, clairvoyance, superluminal communication, antigravity, teleportation, apportation, remote viewing, production of energy at a distance, extraction of energy at a distance, electron dissolution, etc

190. Superposition: the simple linear addition and subtraction of two or more values. In the new approach, superposition need not linearly hold valid if sufficient substructure interaction is obtained and the substructures are nonlinear. In that case, superposition turns into nonlinear interference.

191. Teleportation: the transmission of an object from "here" to "there" with no travel in between as an object in ordinary space. Hyperspatial transmission of an object from one point in the ordinary space to another.

192. Telluric currents: earth currents; electrical currents in the rocks of the earth, believed to be due to aurora effects and the earth's magnetic field. In the new approach, these currents are also pumped by longitudinal scalar wave bombardment from the sun, the cosmos, and the fiery core of the earth itself. Quartz is a common crystalline component in rocks, and thus the rocks are piezoelectric This means that stresses in the rocks, such as from shifting tectonic plates, causes electrical activity, and electrical activity causes mechanical stresses. Further, the quartz is essentially randomly oriented, resulting in most of the tiny piezoelectric vectors summing to a vector zero, which in turn constitutes a scalar potential and pumping the atomic nuclei as pumped phase conjugate mirrors, producing PCR waves. These do the same thing in return, producing negative energy potentials and potential waves, etc. As the piezo-vector components vary, the values of the potentials fluctuate. The zero-sum portion of such a stressed randomized crystal constitutes a Prigogine detector for kindling and collection of anenergies via nonlinear thermodynamics. The molten core of the earth is also a dynamic Prigogine system, since it is a pumped PCM. Thus the earth is a collector, processor, sometimes amplifier, and retransmitter of mind energies and anenergies, and truly the earth may be considered to be "alive" in a strange way (the Gaia hypothesis). This process, along with scalar EM in living systems, also produces Sheldrake's morphogenetic field and its effects. Specifically, the earth receives and processes anenergies from the species unconscious of all the species of ordinary life upon it The earth itself does respond to geometric kindling alignments of other planeti. and particularly to the moon. In addition, it does respond to the state of man's collective species unconscious mind. Fault zones result in structures similar to diodes, triodes, and scalar interferometers. Amplification and rectification of kindled anenergies occur readily, including at a distance, at fault zones, particularly when

seismic stresses in the rocks are increased, increasing the piezoelectric activity, telluric currents, scalar interferometry, etc Thus fault zones constitute natural kindling window areas for paranormal anenergy forms, for tulpoids etc—precisely as found by Persinger. Fault zones are also scalar interferometers, which enhances the formation of ordinary EM forms at a distance.

193. Tesla fireball: interference of two scalar Fourier expansion patterns to form a glowing, fiery globe or spherical shell of radiant electromagnetic energy and electron plasma.

194. Tesla howitzer: a large Tesla scalar interferometer such as the fourth generation Soviet hyperspatial howitzer at Saryshagan. Repeated Soviet testing of Tesla howitzers is documented in the open literature (see Bearden, *Fer-de-Lance*, Tesla Book Co., 1986). The howitzer is capable of utilization in multiple modes, both as a strategic offensive weapon and as a multiple-mode strategic ABM defense weapon. Scalar EM interferometer. Hyperspatial howitzer.

195. Tesla shield: a gigantic, hemispherical, glowing, thin shell of intense electromagnetic energy and electron plasma, placed over a defended area or installation. The EM shell is formed by interference (and coupling) of two scalar shells of anenergy, formed by truncated Fourier expansion methods from multiple frequency scalar transmitters. To form the shell at a distance, phase conjugate replica waves must be utilized, so that the energy and energy pattern does not diverge as a function of distance. Note that such real-time holography, independent of distance, already appears in the nonlinear optics phase conjugation literature. In the Tesla Shield, the energy density in the interference shell causes local curvature of spacetime, and lifts electrons from the Dirac sea, producing the plasma in the shell. With sufficient energy density in the interference shell, a material object seeking to penetrate this dome of energy and plasma is instantly electromagnetically "dudded," and physically damaged and/or vaporized. In addition, the potential pulse delivered inside the nuclei of nuclear materials that meet the shell instantly fission all fissionable materials. Thus nuclear weapons are instantly detonated when entering the shell. Electromagnetic energy (such as gamma radiation from the EMP of a high altitude penetration burst) impinging on the shell plasma is absorbed and re-radiated inside the shell at lower frequency and temperature. Several shells may be internested so that multiple, serial absorption and scattering reduces the original gamma radiation to harmless radio frequency noise. Numerous incidents of tests of the Tesla Shield weapon are documented in the open literature.

196. Tesla wave: a longitudinal scalar potential wave in massless charge, in the vacuum charge flux itself, and in pure spacetime. An electrogravitational wave. A gravitational wave. A scalar EM wave. A wave of pure potential. A wave in the magnitude of the flux energy density of vacuum. A wave in the magnitude of the curvature of vacuum.

197. Tesla weapon: any weapon utilizing longitudinal scalar EM waves or phase conjugate replica waves to accomplish its results. Also applies to a weapon using scalar interferometry or PCR interferometry and holography from multiple projectors or transmitters.

198. Thought: separations and forms in pure mind or being. To think is to form (separate, perceive) thought forms and process them. In a developmental sense, thinking is the activity of mind that screens the true continuous mind nature by fragmenting it The true mind is like the ocean, and thoughts are like waves or disturbances in the ocean. In the new scalar electromagnetics, the mind itself produces scalar waves, on the third and lower virtual levels of the scalar substructure, and these are what we call "thoughts." A thought is a real, virtual-state object capable of being directly detected, interacted with, and engineered by scalar EM means.

199. Thought photography: psychokinetic impression of images or light effects upon photographic film or other sensitive media, due to the presence or intent of a human initiator. PCR distant interferometry and holography is the basic mechanism involved.

200. Three-space (3-space): a space dimensionally composed of length cubed. It is the normal space taken to be occupied by gross matter. Per se, vacuum does not occupy this same 3-space, even though erroneously assumed to do so in present physics.

201. Time: in relativity, an extra dimension (variable) which allows the ordering of spatial snapshots or events. In quantum mechanics, time is only a parameter; it is not an observable and is not detectable, even in theory. Time is always inferred, even though precisely. Rigorously, time exists only through the stream and persistence of human consciousness. We only experience that persistence as "something changing", by continual comparison of our memory of perceptions of spatial position and pattern. In the abstract sense, time is being, which has no differentiation whatsoever—it simply is (a tautology). Perceptual separations in being constitute thoughts or mind changes, much like waves in water. Those waves common to all minds constitute physical (spatial) changes in the so-called "real" world. Because "time" in its undifferentiated sense is simply a synonym for being, then multiple things (separations) may inclusively exist in time simultaneously. (How many final objects exist in a stone before it is carved into any one of them?) The basic separator of being/time is the photon interaction, which is the basic generator of monocular quantum change and thus the progression of spatial particles "through time" in little jumps. The endpoints of the quantum jumps through time represent time differentiations of spacetime/masstime. To properly understand physical phenomena, both positive and negative time flow must be incorporated in the theory or model used.

202. Time oscillation: ordinary time advances and retards in small discrete jumps, much as a sewing machine stitches forward—except that each time stitch is pulled out before the next one is made. Thus time consists of two time flows interleaved: the positive flow of time (stitching) and the negative flow of time (unstitching). This "time stitching/unstitching" or oscillation can be viewed as a wave. It is "action" that is waving (being changed or created and destroyed in quantum chunks), since time is actually a subcomponent of action. One may therefore view time waves as carrying or creating surges of energy back and forth (in time). The photon may be considered as this oscillation of lime, for it is actually an oscillation of action. The positive half of a photon exhibits positive time (the stitch is made) and a virtual electron, and the negative half exhibits negative time (the stitch is removed) and a virtual positron. Charge is a function intimately related to, and comprised

of, time stitching. Positive time is associated with negative charge, and negative time with positive charge. The photon ca be considered as a coupled virtual electron-positron pair. The invisible stitching/unstitching trace of a photon through spacea'me is "enfolded" (in time) and remains. A phase conjugate replica photon, created at some later time and some distant place, thus has a sort of "invisible wire" connecting its own generation and the distant source that generated the stimulus photon. Note that spacetime occupies time, but space does not. Mass-time occupies time, but mass does not. Mind, thought, and being occupy time, but not space.

203. Time trap: refers to the erroneous assumption that God is a limited being, traveling along through time much as humans perceive themselves to. An unlimited creator must permeate all aspects of creation, including time. In the unlimited view, God permeates time from beginning to end, all at once. To such a creator, nothing is happening, since all happenings are simultaneously present What we call "positive" or forward time and "negative" or backward time co-exist and are inseparably identified, to such a level. Good and bad are only relative to a single time stream and to a single referent At the unlimited level, there is no separate good or separate evil. Yet there is all unseparated good and all unscparated evil. All "events" or acts that one might separate, simultaneously exist in both forward and backward time streams. Hence any event is ultimately both good and evil simultaneously, and to an identical degree. Again, this is the void that is devoid even of void.

204. Transverse wave: a wave which vibrates laterally to its motion in a medium, exactly like the vibration of a stretched string. Vector electromagnetic (Hertz) waves are transverse waves, in the present theory. In the new approach, transverse waves cannot exist as such in vacuum, but only in a longitudinally restrained medium. (The electron gas in a solid conductor, for example, is such a medium, and Maxwell's equations rigorously apply to the transmitting electron gas and to the detecting/receiving electron gas, but not to the vacuum in between). Longitudinal (alternately densifying and rarefying) scalar waves exist in vacuum, in the charge (virtual particle) flux that vacuum identically is. Hertzian waves in vacuum exist as shadow vector waves, that is, as two or more coupled Tesla scalar waves spinning around each other.

205. Tulpa, tulpoid: condensed, materialized or semi-materialized thought form, either living or inert. May be a visible or an invisible electromagnetic form, a partially materialized form, or a completely materialized form. Ultimately all matter and fields are tulpoidal in nature, consisting of condensed thought/mind energy.

206. Two-slit experiment: a form of Young's experiment where a particle is generated and directed toward a plate having two tiny slits (holes) in it, with a collection screen or device on the far side of the plate to collect and add the impacts of the particles that pass the plate. The idea is that a classic corpuscle can only go through one hole at a time, like a baseball through a hole in a fence. For particles, classically the strikes on the collector screen should be grouped in two clusters, each representing a straight-line passage through one of the slits. In the experiment, however, the particle strikes form a wave diffraction pattern when collected on the screen, unless the emitted particle is struck by a photon before it strikes the screen. In the latter case, the two clusters for classic corpuscles are observed. The experiment—fundamental to all quantum mechanics—is simply understood if one considers the time aspects of the problem, as pointed ont by Charles Muses in 19S7. The two slit apparatus with electrons may be also used as an electron interferometer for sensitive detection of scalar EM (electrogravitational) waves.

207. UFO: unidentified flying object Any object or light in the sky that cannot be identified as an ordinary physical phenomenon. After normal objects and phenomena are eliminated, the remaining paranormal residue is of interest Many of these are kindled tulpoidal forms, and may consist of lights, invisible electromagnetic energy, physical objects such as discs or spaceships, robots, humanoids, etc. (A few of these forms may be real anti-gravity spaceships, created here on earth by sensitive groups of several earth governments, but controlled by some mysterious group outside these governments. Such craft, I believe, have been developed and flown all over the solar system since the early 1950's. These I do not consider part of the true UFO phenomena, which in one form or another are centuries old.) Highly materialized ship forms may also contain highly materialized living forms such as space-suited astronauts etc. The "UFO" has been separated from other tulpoids (bigfoot, fairies, spooklights, water monsters, etc.) because its appearance in the sky was immediately associated with aircraft or spaceships, leading to the initial expectation that extraterrestrials in advanced spacecraft were visiting the earth. Most of the UFO phenomena actually consists of lights at night (well over 80%), and only about 6% or so resemble well-materialized ships with astronauts. A substantial portion of the "lights at night" phenomena are also due to Soviet scalar EM interference weapons. The Soviets create a great deal of light phenomena worldwide, to spark UFO reports, which are discounted by conventional science and most of the military and government agencies. This provides the Soviets a giant and effective "deception plan" so that the weapons can be tested and readied worldwide, and sightings and reports will be discredited and not cause undue alarm.

208. Unconscious: unaware, not conscious. Refers to that part of the individual's mind which is not normally in conscious awareness, but which may contain a great deal of material from the conscious mind. In the new approach, the unconscious mind is considered to be "multiply conscious," while the conscious mind is considered "singly conscious." In other words, the unconscious is a "parallel processor," while the conscious is a "serial processor." Unconscious should be thought of as not singly conscious, but multiply conscious. Further, this allows a totally new idea: Multiple singly conscious, different minds coexist simultaneously in time, though not in the same "3-dimensional mindspace." Suppose we consider a set of n such singly conscious minds. All the minds exist in a spacetime of dimensionality 3n + 1 (n is the number of different conscious minds in the set, and an additional dimension, time, is common to all minds in the set). Thus the considered set of singly conscious minds constitutes one multiply conscious—or "unconscious" -mind. In this way one may apeak of "levels of unconsciousness" in relation to groups of persons, with the deepest level being and containing every human mind. Of course the analogy can be continued to yield

the higher minds or consciousness projected by Teilhard de Chardin. In the collective human unconscious, those forms which are in each and every mind are the archetypes discovered by Jung. In a shallower level, other forms may be common to that level, constituting "weak archetypes" or "fragmentary archetypes." There is considered to be no limit to levels of unconsciousness—the ultimate depth being "all consciousness" (and all unconsciousness!) of Godness. God must be able to both be and not be at the same time; if God cannot do that little trick, then God has a limitation and is not unlimited.

209. Vacuum: pure virtual particle, massless charge flux. The virtual state, or ether (nonmaterial, Lorentzian). Lengthless, timeless spacetime itself. That state where everything is disintegrated, but highly dynamic. Note that vacuum is not an emptiness FILLED with massless charge, rather, it IS identically massless charge (disintegrated dynamicism). It is a plenum, not an emptiness. It is also pure action, undifferentiated. Einstein once suggested that the vacuum, complete with its electromagnetic and gravitational fields, should be taken as the ether. In the modern view, the term ether is again accepted in the literature, but now it refers to a "virtual particle flux" ether, not a thin material ether. One can model the vacuum analogous to a special kind of virtual-particle gas: one in which the particles "appear" and "disappear from and into nothing, nearly instantly, so fast that they cannot be individually detected. Thus the modern idea of the vacuum is a seething inferno of fiercely bubbling, fleeting particles. The other limitation is that the dimensionality of the vacuum is not fixed until operations are invoked, and neither is the rate of passage of time. Thus the vacuum has no fixed lengths nor fixed rates of time flow per se. One can visualize the stress of vacuum as a sort of conglomerate potential "pressure," where the individual stresses of various types of particles, if integrated by some external means, would sum into the overall stress (pressure). Variation of the "stress of vacuum" between two points in a frame represents a "curved spacetime" or "accelerated frame." Note that overall stress can be held constant, while two or more different components are canonically varied. The electrostatic potential, the magnetostatic potential, and the velocity of a charged particle are three such "canonical" variables. If the overall "pressure" is not varied, the three variables are canonical and energy, momentum, and charge are conserved and one cannot build a perpetuum mobile (perpetual motion machine). If the overall "pressure" is varied between local points in the frame, then the conservation of energy, momentum, and/or charge need not rigorously apply between those local points. At any one point, one may have a "free source" or a "free sink," depending on the vacuum curvature and the EM standing wave relationship. In that case, one can build a local "perpetuum mobile," since one can tap a "free source." Einstein created a severely restricted general relativity (GR), where he assumed away any local curvature of vacuum. In the West such a severely restricted GR is still dogmatically enforced, because it "saves" the conservation laws, which are regarded as sacrosanct In Soviet physics journals, learned papers by leading scientists are regularly published in which unrestricted GR—including local curvature—is developed and explored. In a local curvature region, the Soviets have already pointed out that any and all conservation laws may be violated. The Soviets have long since developed and weaponized unrestricted GR, while our scientists are still dogmatically insisting that one cannot deterministically engineer local curvature of spacetime. Thus we maintain our obsession with conservation, and the Soviets maintain the weapons.

210. Vector: in mathematics, an entity completely characterized by a magnitude and a direction. Abstractly, vectors are considered to be formed by a difference in potential between two spatial points. In the new approach, vectors are characteristics of particle motion, and do not observably exist in the absence of a particle. Since all detectors have mass, and this mass contains spinning charged particles, then force vectors are constituted on and of the spinning charged particles. In the vacuum, only an unzipped (disintegrated) vector pattern exists—or, as Feynman put it, only the potential for a force vector exists there. Maxwell's original theory was written in quaternions. In 3-space, a vector has the familiar three components, say, ai + bj + ck, where i, j, and k are the usual x, y, and z unit vectors, and a, b, and c are the magnitudes f the x, y, and z components of a vector. A quaternion, however, has an additional scalar component—say, w—so that it looks like w + ai + bj + ck. Maxwell's original theory actually unified gravitation and electromagnetics! When vector zeroing operations occur, the quaternion may not zero out the scalar component. As an example, consider the cross product of a vector A with itself, AxA. In vector analysis, the resulting vector is the zero vector. In quaternions, however, w remains, and w = a2 +b2 +c2. With the correct proportionality constants, w therefore represents the energy density of vacuum due to the two zero-multiplying vectors A1 and A2, where A1 = A2. To recover my scalar wave or gravitational wave: Now let the vectors A1 - A2 where each is the E-field vector of an identical EM sine wave. (That is, we perform a device which accepts two identical input EM sine waves and performs a cross multiplication. That device, e.g., may simply be a special kind of nonlinear modulator/mixer). In ordinary Heaviside/Maxwell theory, the EM output of this operation is a continuous zero vector, and that's all. However, by Maxwell's actual theory, the output of the operation is a scalar EM wave, whose amplitude varies as the energy of A. That is, the operation produces a scalar EM wave which is varying the energy density of vacuum. By definition, that is a gravitational wave. Since it was produced electromagnetically, I refer to it as an electrogravitational wave. It was included in Maxwell's original 1864 theory. After Maxwell's death, Heaviside and Gibbs completed the modern form of vector analysis. Heaviside—a single man—then "translated" (mutilated) Maxwell's theory into his new "vector" theory. He simply sawed off and discarded the troublesome scalar component of the quaternion! That made calculation a whole lot easier, and easier to understand. In discarding the scalar component, he discarded electrogravitation, writing an EM theory that specifically excludes local curved spacetime and gravity. Before the turn of the century, a short debate involving only about 30 scientists resulting in the complete adoption of Heaviside's mutilated version of Maxwell's theory. Quaternions and quaternion theory—and electrogravitation—vanished from the literature and the textbooks—and from the minds of the students. Maxwell's theory has not been taught or utilized in the Western

world in the 20th century! Only Heaviside's mutilated version of it is taught as "Maxwell's theory." We should have been applying Maxwell's unified theory and working on antigravity spaceships, shortly after the U.S. Civil War!

211. Vector field: in ordinary theory, the assigning of a magnitude and a direction (that is, a vector) to each point in space. The entire set of vectors and their spatial points is called a vector field. In the new approach, such a vector field cannot observably exist in a vacuum, since only disintegrated things exist there; there each potential vector pattern exists in broken virtual bits, ordered in line to form the bits of the observable vector but not joined. In the presence of a detecting/integrating mass, such as a spinning charged electron, the virtual bits and the spinning charged mass couple into a system that identically comprises the observable vector. In other words, the spin of an observable particle simply "integrates" the ordered virtual bit pattern, just as an old spinning wheel twists and integrates individual fibers into a stranded rope or thread.

212. Virtual (state): that part of physical reality consisting of changes (particles, waves, and other entities) smaller than the least detectable (quantum) change. Disintegrated changes. A thought or thoughtform is also virtual. May be visualized as consisting of real, dynamic "pieces of vacuum" or "pieces of nothing"—that is, quitons. Every ordinary observable particle (photon, neutron, electron, proton, etc.) contains or consists of a dynamically changing cloud of virtual objects. Exchange of virtual objects is thought to generate almost all forces of nature. Conservation of energy need not be conserved in virtual interactions, and generally is not In the new approach, the mind may be considered a special virtual universe, and a thought a virtual object. Virtual state consists of multiply nested levels, each level progressively finer and more subtle. These sublevels also correspond mathematically to higher geometrical dimensions. Charge on a mass is also due to its continual emission and absorption of virtual particles. Waves in the virtual state massless charge flux, which do not breach the quantum level to become observable, are vectorially nonobservable yet real—these are scalar waves, or shadow vector waves, and are longitudinal—that is, they are oscillations of the stress energy tensor of vacuum. In addition, the virtual particles in the vacuum flux arise out of nothing spontaneously (creation) and disappear into nothing spontaneously (annihilation). Since this is random, at any instant any sort of pattern imaginable is "just appearing" and "just disappearing" in the vacuum. Anything and everything at all! Thus a ghost-pattern of everything exists in the vacuum at any point or region, at any time. The vacuum is thus a giant virtual-state hologram. Integrating (kindling) one of these forms will result in it becoming first a neutrinic pattern, then a photonic (light) pattern, then a materializing pattern, and finally a material pattern. Discharge of the "potential" of this pattern then reverses the process. These two processes—charge-up and discharge—constitute materialization and dematerialization. Anything at at all-living or dead—can be materialized or dematerialized.

213. Virtual state engineering: the direct cohering, tailoring, collecting, resonating, and directing virtual state energy (anenergy) and entities into and onto normal observable objects and ordinary fields. It includes the **direct engineering of mind and life energies. Synonymous with psychotronics (Czech term) or energetics (Soviet term). Use of scalar electromagnetics (electrogravitation). Use of scalar wave/Tesla technology. Use of electrogravitation techniques.**

214. Water structuring: the arrangement and relations of the molecular and ionic parts of water. Essentially water molecules bond together by means of hydrogen bonds. The structure of these bondings is extremely rich and dynamic in water. Essentially a glass of water is a single complex molecule, one which is continually changing its bonding structure to adapt to the slightest change in its total surroundings. Water also interacts intimately with virtual crosstalk (scalar wave) anenergy. Water can thus be "charged" with ancnergy, appreciably changing its structuring. Its surface tension, for example, will change as its structuring changes, as shown by Miller and Flanagan. Thus water is possibly the most complex substance in the universe, and not just a simple chemical. With most of our body composed of intercellular water, we are all linked to every subtle change of the cosmos, by the interaction of the structuring of this water with even the most subtle cosmological changes. Large bodies of water are particularly susceptible for temporary kindling of deeper archetypal thought forms (tulpoids) such as Loch Ness Monster etc. The study of the structuring of water is still in its infancy.

215. Watson, James: young inventor who has produced several types of free energy and scalar electromagnetic devices, including battery-driven, battery-less, and tube systems.

216. Weather engineering (scalar): use of scalar electromagnetics (electrogravitation) to change and influence the weather and the producers of weather such as jetstreams and large ocean currents. By imposing scalar signals upon ordinary powerful over the horizon (OTH) radar carriers in the communications band (3 to 30 MHz), interference patterns (grids) may be established over distant and vast areas, far beyond the horizon, or even on the other side of the earth. The giant Soviet Woodpecker OTH radars continually establish such a grid over the U.S. Phase conjugate energy can be transmitted and will travel along these beams, just as electricity travels along a wire. By scanning narrow phase conjugate wave beams in these wider carrier beams, PCR realtime interference holography can be established in one or more of the distant OTR EM carrier interference grid squares. Either positive or negative energy and energy forms may be transmitted to emerge, producing a high or low pressure spot or zone as desired. By adding positive energy to a zone, the air is heated and expands. Thus the air is less dense, producing a low pressure zone, or a low. By adding negative energy to a zone, an equal amount of positive energy in the zone is canceled. Thus the air in the zone contracts and is denser, producing a high pressure zone, or a high. Thus one can create distant highs and lows at will. By slowly moving (scanning) the PCR beams, these distant highs and lows can be moved, thus deviating and directing the jetstreams, storm systems, etc. By outputting positive energy and warming the top of a thunderstorm anvil, while outputting negative energy to the side of the anvil and cooling it, drastic "downbursts" under the anvil can be created. U.S. satellites have photographed such anomalous holes appearing in thunderhead anvils over the U.S., and their association

with downbursts has been documented in the literature. Whether these are natural or engineered have yet to be established. Another signature of weather engineering—a "wheel and spoke" type of cloud, called a giant radial—has been seen widely throughout the U.S. and correlated with anomalous weather changes shortly thereafter. Sometimes a system of two such radials facing each other is seen, and on one occasion four were seen locked together (just before and during the highly anomalous zig-zag travel of a 1985 hurricane in the Gulf.) Another geometrical form associated with severe weather has been photographed by U.S. weather satellites, and is referred to in the weather literature as an "enhanced V". This signature is closely associated with the production of tornadoes, and it may be a natural phenomenon. However, if the mechanism for the enhanced V were artificially produced in a thunderstorm, then the probability of follow-on tornadoes would be materially increased. The Soviets have openly engineered the weather over North America since 1976, and made previous R&D engineering tests over the U.S. in 1967.

217. Woodpecker signals: powerful, complex electromagnetic signals originating in the Soviet Union (apparently from the vicinity of Riga and Gomel, for example) that have widely disturbed and interfered with the communications band (3-30 MHz) since the mid-70's. Bioactive modulations of 10 Hz and under have been observed repeatedly. Western observers have not deciphered the purpose or specific coding of the signals, and prefer to think of them as some sort of over-the-horizon radar tests, thus neatly disposing of the problem. Similar signals have been observed to entrain the human brainwaves and force them into in-phase oscillation. Beck has reported the phaselocked synchronization of the 10 Hz modulations on as many as 16 carrier frequencies at once. From the Lisitsyn work, this constitutes a "phased lock-in" of 16 carrier channels into any entrained brain. According to Lisitsyn and earlier Soviet "biological radio" experiments, this situation should allow the Soviets to transmit emotion, feeling, thought, and even pictures into the entrained brain, where it is processed as if the brain itself had originated it. (For example, in a Cable News Network special in November 1985, Rauscher and Bise actually demonstrated the induction of visual form images in the brain of the CNN investigator using weak signals much weaker than those naturally produced by oscillation of the earth's magnetic field.) According to the Kazhnacheyev work, any sort of cellular death and disease pattern can be electromagnetically induced. (The work was duplicated in the infrared by University of Marburg researchers in West Germany, by researchers at the University of Sydney, and by one U.S. scientist.) Popp discovered the virtual photon communication system of the cells of the body. This is scalar, and scalar patterns for charge distributions of the chemistry of cellular diseases and damage could also be placed on the phase-locked Woodpecker carriers, entering die human body's master control system through the entrained brain and "kindling" throughout the cells of the body. The stress and suppression of the immune system would be involved in almost all disease patterns, and a "partial AIDS" type of syndrome would result, making the entrained body vulnerable to whatever diseases were around, including being induced on the Woodpecker carriers themselves. Also, by targeting the DNA of specific organisms, mutations of deadlier and tougher strains of disease induction agents such as bacteria and viruses could be produced. The "antithesis" pattern—a sort of scalar EM antidote—could be induced in the Soviet population. (The present lethal AIDS is a manmade disease, and it was unleashed from a research laboratory either accidentally or by a Soviet agent on purpose.) Indeed, World War III may already have begun, and the Soviets may be waging a quite different kind of creepingly escalating viral war against the United States. If so, our Defense Department and our government have not yet grasped what is happening, and so far we are simply a sitting, passive target If our populace is slowly debilitated and storm, weather, and earthquake damage slowly increases year by year, at some point our system will simply start to come unglued, with increasing loss of control. In that manner we could "subside" as a world power without the kind of great overt war we are familiar with. Note that steady escalation of international terrorism, insurrection, and guerrilla warfare being promoted by the Soviets around the world will keep us preoccupied and busy while our debilitation and moraise steadily are increased. We may already be in an eery new kind of war that we could lose without firing a shot if our leaders do not wake up to the frightening implications of the new physics! Thus the Woodpecker transmitters represent a potential anti-population and strategic weapon of enormous strategic significance. The transmitters, because of their sheer power, also appear to be able to pump and resonate earth scalar EM energies, producing earthquakes and plasma discharge effects at remote locations. (Since Golden has directly shown that the entire earth is in frightful, forced scalar resonance at multiple frequencies and enormous power due to powerful Soviet scalar transmissions, then one should not be too skeptical of the Soviet ability to produce earthquakes on demand and to order.) At least one U.S. researcher or group seems to have been partially nullifying Soviet efforts in this respect by occasionally pulsing the earth scalar energies in a countering mode, to include actual destruction of a Soviet transmitter in one or more instances. Note especially that unorthodox researchers have directly confirmed that the Woodpecker signals contain powerful scalar components which orthodox scientists—lacking scalar detection equipment—do not see. The Woodpecker carrier interference grid over the U.S. is also a scalar EM interference grid, and used by the Soviets to engineer the weather over North America. It is also used as an anti-Bomber and anti-missile launch phase defense system, and the Soviets have tested it in this mode by destroying several U.S. aircraft and missiles.

218. Work: conventionally, the line integral of force on a body over the path taken by the body. In the new approach, the force consists of the mass and its motional change, unseparated. Thus work is the line integral of the force over the path taken by the force. Work (past) is equal to the energy (present) expended, and energy (present, gravitational potential) is equal to the work (past, release of a gravitational potential) that can be expended. Note that only vectors produce work; scalar waves do not perform work on their observable environment, and they do not contain standard EM force field energy per se.

219. Yao, George: engineer and inventor of the PulsorR, which affects the subtle scalar levels of the human body's aura or scalar radiation pattern.

220. Veti: the Eastern—particularly Tibet, Nepal, etc.—Himalayan version of the apeman tulpoid, corresponding to the U.S. Sasquatch or Bigfoot.

221. Zarg: the collective human unconscious, considered as a mind and a living entity. It is at least 4—billion dimensional, since it has as many dimensions as human stages. Each human is regarded as a single cellular stage in this entity. The psychokinetic power of such a linked mind is proportional to an exponential of the number of individual stages. Thus Zarg's psychokinetic power is so great that it has essential control over space and time, and largely prescribes, maintains, and stabilizes the laws of nature (laws of physics) and the reality in which we live. Conflict between large groups of humans constitutes unresolved conflict in this great unconsciousness, and this generates symbolic dreams, much as a human dreams strange, emotional, symbolic dreams due to the unresolved conflict in his or her personal unconscious mind. However, because of its vast psychokinetic power, Zarg materializes or partially materializes its symbolic dreams, resulting in tulpoids. Waves of these tulpoidal materializations thus represent strong human conflict or threats on the large scale. Such waves can be dream analyzed to discover the correlate that is generating the symbology, by straightforward dream analysis techniques. In olden times, part of this was known, and wise men were employed to analyze and interpret the strange, induced dreams of the king (who was the center of power of a nation) and the paranormal phenomena appearing near him. The ancients knew the import of "signs and wonders" and what they portended, but this metapsychological knowledge has been largely ridiculed and lost by present materialistic Western science.

222. Zero: naught or nothing; the absence of thing. A naive definition is the absence of number. However, if all the nonzero numbers are considered to represent the presence of number, then to declare zero a number—that is, the presence of a number—is a self-contradiction since it has just been declared the absence of number. In the numerical sense, one may do a little better by calling zero "the absence of any and all numbers except itself." Yet in this case, difficulties arise as to how one is to justify the addition of any other number to zero: how can a number be present with the absenting operator, so as to be added? The absence of any type of thing observable. Formally, the additive identity element of an algebraic system. That is, formally, the basic idea of zero is that, added to a number, the result is still identical to that number. Implicit in this formal definition is a "single level** of perceived objects; that is, there are no "hidden objects" in a separate level of sets. If multiple levels of perception are allowed, then the zero becomes much more complex. That is, it represents the absence of all other numbers at that particular level, and of that level's kind. In that case, it may contain any combination of objects from another level, yet be perceived as containing "nothing of its own assigned level." In that case, there exists an infinity of different "kinds" of zeroes, if the hidden associated structure (the substructure) If taken into account Unfortunately physics has created such multiple levels, but has not required its mathematics to clearly specify the changed nature of the zero. As an example, at the observable level, an infinite number of kinds of zeroes exist, when the virtual level and pattern associated with the zero are taken into account This characteristic of physics actually violates the following zero axiom: an observable v plus an observable zero is considered to be equal to an observable zero plus v. In fact, the sum of v and a particular zero may not be equal at all to the sum of another zero and v, if the virtual patterns of the two zeroes differ, v has a virtual substructure, and in the addition of a zero and v, their virtual levels nonlinearly interact instead of linearly superimpose.

223. Zero point energy: the kinetic energy that remains in a substance when its temperature is absolute zero. Quantum mechanics requires a simple harmonic oscillator to still possess kinetic energy at its lowest state: that is, it possesses half a quantum of energy. In solid materials it is distributed throughout the lattice vibrations, contributing to the binding energy. Vacuum also has zero point energy. Actually a similar and much expanded concept applies to any potential: a potential is just a bunch of trapped dynamic vectors, hence "trapped vector (translational) energy." It is translational energy that is locally trapped and not translating. The potential is thus like an accumulator or capacitor. It can be "charged up" and "discharged." It thus contains its own analog or trapped or "zero summed" or "zero point" energy.

224. Zero-point energy of vacuum: the vacuum is increasingly being regarded as composed of an incredibly dense structure of virtual electromagnetic energy, even at zero degrees absolute. From quantum geometrodynamics, as one approaches the Planck length—say, 10 to the minus 35th meters—these oscillations become so energetic that the fabric of spacetime itself is torn, resulting in sporadic, continual connection and disconnection of widely separated portions of spacetime. This "quantum foam" was dubbed "superspace" by J.A. Wheeler. Actually, if space and time are torn, then energy itself—and vector waves—are also torn. That is, the superspace consists of pure massless charge flux, pure scalar waves. If compacted, this anenergy density of vacuum may be approximated as 10 to the 100th grams per cubic centimeter, were it compacted into mass. The actual electrical charge of the vacuum appears to be enormous, if it were possible to measure a voltage drop from it to an uncharged region. Thus it is space (actually spacetime) that is incredibly dense, and matter that is ethereally thin. Spacetime goes through matter, rather than matter through spacetime. This anenergy of vacuum does interact with electromagnetic fields and matter to give observable effects, as evidenced by the Lamb shift, for example. The Lamb shift proves that the vacuum charge or anenergy can be "tapped." Tapping the "vacuum energy" would immediately end the energy crisis forever. Further, it can be done with practical devices, as T. Henry Moray showed in the 20's and 30's, and as several present inventors have shown today.

225. Zero vector: a vector having no length (no magnitude) or specific direction. Absence of any or all finite vectors. Resultant of a system of multiple, finite vectors whose vector sum has no specific direction. Note that the second definition differs drastically from tho first. That if, we cannot say that a vector resultant zero has no infolded magnitude, if we consider the components, all of whom have magnitude. See the discussion under "zero." In vector analysis, the zero vector axiom states that any vector v plus a zero vector is equal to a zero vector plus v. (Note that this axion is not proven, just assumed).

However, there are an infinite number of different zero vector resultant systems, and so zero vectors may differ, if their infolded component "substructure" is considered. Indeed, a zero vector system must be identified as a special form of potential, if its substructure is considered. The common practice in electrical physics of replacing a zero-summed system of vectors with a vector zero is incomplete, and such did not exist in Maxwell's original quaternion theory. This present practice should be changed; the vector zero should be replaced with a special organized vector zero system and a scalar potential. By failing to do this, physics excludes the ability to engineer electrogravitation, spacen'me, the virtual state, local general relativity, free energy, effects at a distance, and the probabilities of the states propagated by the Schroedinger equation. It also excludes scalar electromagnetics (electrogravitation), and unification of all forces in an engineering electromagnetics fashion. In the new view, a zero vector may be a system of vectors that vectoiially sum or multiply to zero, but the components may still exist "inside" and dynamically function inside the zero-resultant envelope. This substructure can act on nonlinear or resonant systems. Any or all components may be time varying, or none of them may be. The zero vector system may thus be a dynamic vacuum engine. In addition, such a vector zero system is considered to be also a scalar stress potential, whose magnitude is equal to the sum of the absolute values of the perpendicular components. In addition, a separate type of stress potential may be included for the magnitude of the absolute values of the swirl components (torques). Other associated potentials may be included for the system, particularly if the system is in multiple dimensions, if it consists of more than one type of virtual particle flux, if several fluxes intercommute, etc. Such a system can also be designed and created to deterministically interact with and on the life force itself, the mind, thought, and personality.

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CANCER AND THE UNRESOLVED HEALTH ISSUES IN THE BIOLOGICAL EFFECTS OF EM FIELDS AND RADIATION

- Text of Booklet
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Largely taken from the author's presentation, "Mechanism for Long-Term Cumulative Biological Effects of EM Radiation," 70th Annual Meeting of the Alabama Academy of Science, University of Alabama at Huntsville, 25 March 1993.

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Abstract

Both postulates in the conventional EM bioeffects model are in error, as is the classical electromagnetics model (CEM) itself. Major errors in CEM are presented. The QM view is taken that all EM phenomena are caused by the potentials, not the force fields. Using the Whittaker/Ziolkowski (WZ) internal structure of the scalar potential, Bohm's quantum potential and an engineerable variant of his hidden variable theory emerge. A strong candidate emerges for the internal mechanisms used for mind, thought, long term memory, and deep cellular control by Popp's master cellular control system. An environmental negative feedback mechanism is stated for long-term, cumulative causative mutation, yielding Sheldrake's morphogenetic field, which is a species quantum potential. Utilizing the new EM bioeffects model, Kaznacheyev's demonstration that any cellular death or disease can be caused electromagnetically is explained. A new definition for cancer is advanced, as is a long-term cumulative mechanism that causes it. The mechanism for Priore's demonstrated cures of terminal tumors in laboratory animals under rigorous scientific protocols is explained. A solution for the major cumulative mechanism for biological effects of EM fields and

radiation is presented. A self-targeting mechanism is presented whereby complex WZ EM biwave pumping of the "cell as a nonlinear phase conjugate mirror material" produces an exact EM antidote signal for the specific cellular disease. It is argued that inexpensive, quick, nondebilitating, cures can be developed for most major dread diseases, including cancer, arteriosclerosis, and AIDS. Priore's remarkable and previously unexplained cures of terminal tumors in lab animals are cited as examples of applying the new model, albeit unwittingly.

The Basic EM Bioeffects Model Is In Error

As is well-known, the field of EM fields and radiation effects on biological systems is actually in something of a shambles. In over 40 years of studies and experiments by careful researchers, the results are inconsistent, contradictory, and usually difficult or sometimes impossible to replicate. Attempted replications often give contradictory results, erratically. Researchers cannot rigorously answer even the simplest question, such as "Does power line radiation contribute to the incidence of cancer and leukemia, and if so, how and under what circumstances?" Causative mechanisms have so far eluded research. Powerful vested interests fund many of the studies. Consequently a great deal of controversy exists in the field. Opinions and positions range from the "microwave oven" position that "if it doesn't appreciably heat tissue, it doesn't harm biological organisms," to the "total fear" position that "any and all non-ionizing radiation is harmful; we just don't know by what mechanism." Legal actions to limit human EM radiation exposure are increasingly being initiated by concerned citizens' groups.

What has actually been "proven" by the nearly fruitless EM bioeffects effort to date is that the fundamental EM bioeffects model being utilized by the researchers is totally inadequate for the *task intended.* If that is true, then 40 more years of continuing to apply the same inadequate model isn't going to make very much additional progress. Further, if the fundamental model is faulted, then what is needed is a detailed examination of *the* model to discover and correct those foundation faults.

In tackling this model foundations problem, I have performed a systems engineering layout of the fundamental EM bioeffects model, and stated its two major postulates. Both postulates turn out to be in error! Immediately one can easily see *why* the field is in such a state of confusion. However, no true systems engineer would stop there. I have also performed a systems engineering layout of precise corrections for the two postulates, thereby correcting and extending the model so that it can yield consistent, replicable results and causative mechanisms. All of this is a rigorous procedure, and straightforward systems engineering methodology.

However, the results point to profound changes, which I have been immersed in deeply studying for quite some time. Out of this approach has emerged something quite fundamental: *a strong candidate for the internal mechanisms used for mind, thought, long term memory, and the deep cellular control system for all cells of the body.* A mechanism for species adaptation also emerges that is quite capable of explaining (and yielding) long-term directed mutation, including the "species jump," where a species such as a bird emerges in short order (not gradually) from a species such as a reptile. The known "species jump" has been a deep mystery to evolution theory, which simply could not explain it. Another thing that has emerged is a startling new *electromagnetic* causative mechanism for cancer, leukemia, etc. At the June 1993 Brain-Mind Symposium in Los Angeles, I will present that exact mechanism. The mechanism is capable of laboratory test, and validation or falsification. We will also present an entirely new approach to EM effects on biological organisms, and present the major new mechanism involved. The new mechanism has fundamental application to the theory of diseases, and offers potential curative mechanisms for dread diseases such as cancer, arteriosclerosis, and AIDS. I explain some of the necessary background in the following paragraphs.

Classical Electromagnetics is Seriously Flawed

As is well-known, there exist severe contradictions between classical electromagnetics (CEM), general relativity (GR), and quantum mechanics (QM). As presently constructed the three disciplines cannot be unified, even by Herculean efforts. Particularly with respect to the primary causative agents for electromagnetic phenomena, the foundations of QM and of CEM are in profound disagreement. CEM assumes *the forcefields* as primary causes, paying only lip service to the potentials and treating them as primarily mathematical conveniences. QM, on *the* other hand, has long since [since 1959] shown that the force fields are simply *effects* in and on the charged particle system, and are not causes. Instead, QM has shown that the *potentials* are the primary causes of all EM phenomena. In charged particle systems, potentials can interfere and cause observable EM phenomena such as the Aharonov-Bohm effect in the complete absence of the force fields. Herein lies *the* reason for the present dire straits of EM bioeffects research. We explain further:

CEM theory was originally formulated by James Clerk Maxwell in terms of quaternions. Note that quaternion algebra has a much higher topology than either vectors or tensors, the mathematics in which CEM is presently expressed. None of the present "Maxwell's equations" _ universally taught as due to Maxwell _ ever appeared in anything by Maxwell himself. Depending upon what you wish to call a fundamental equation, Maxwell's true equations are the numerous *quaternion* equations included in one almost incomprehensible chapter of his 1873 book. The present four "Maxwell's Equations" are in fact due mostly to Oliver Heaviside, and to a lesser extent to Gibbs and Hertz. The major player was Heaviside, a very brilliant but self-educated man who never attended University.

At the time Maxwell's book was published, Heaviside was just teaching himself calculus and differential equations. Seeing the book, he was electrified by it, and Maxwell became his undying hero. Maxwell died not long after, of stomach cancer.

Heaviside believed _ as did almost every scientist at the time _ in the older medieval tradition that *forces* were the causes of all physical effects. He had great difficulty with the potentials, stating that they were *"mystical and should be murdered from the theory."* We know today in modern quantum field theory that forces are effects, not primary causes of anything. In fact, it is the exchange of virtual particles with a mass that generates all forces upon it. As is well-known to foundations physicists today, "force" does not exist without the mass present to be acted upon, and without the action of a potential gradient upon the mass. We know that there are no force fields in the vacuum, and hence potential gradients in the vacuum are not forces, even though they are commonly assumed to be. CEM has not been corrected for these glaring defects: it prescribes force fields in the vacuum, and it prescribes that potential gradients are forces, even in the absence of any mass for the gradients to act upon.

Heaviside also abhorred the quaternion theory. The coupling of a scalar component with three directional components was, in his view, "mixing apples and oranges." He knew that engineers would never master Maxwell's use of quaternion mathematics because of its difficulty. Consequently, Heaviside simply chopped off the scalar component of the quaternion and discarded it, then formulated this new "truncated to a vector" version as a much simpler mathematics, albeit of decreased topology. What he unknowingly threw away was the ability of the quaternion theory to capture an *internal* deterministic, vectorial EM structure of the scalar potential. *[It turns out that he also discarded the unification of EM and gravitation by throwing out the scalar component, but that is outside the scope of my presentation.]* Years later as a lonely recluse in a small upstairs apartment, Heaviside turned back to quaternions to work on a theory of gravitation, according to papers found hidden beneath the floor of his study many years after his death.

Learned journals of the day would not accept Heaviside's papers for publication, because of the assumed "brutality" of his mathematical methods. So Heaviside began publishing very practical papers in a technical magazine, for the time roughly equivalent to *Scientific American* today. These practical papers gave transmission line theory, transformer theory, etc. _ things very useful to the early would-be "engineers" who were struggling with installing telegraph lines, undersea telegraph cables, etc. The vector mathematics utilized by Heaviside was much easier to understand and apply, and his work was eminently practical. Consequently it was eagerly seized upon and applied. The result was that Heaviside's EM model became the ipso facto CEM standard. Note that, at the time, only about 30 or so scientists in the world were truly "learned" in EM _ either from the vector standpoint or from the quaternion standpoint. Further, not much *practical* work was being done by the few quaternion practitioners.

A short "debate" over whether EM should use Maxwell's quaternion model or the Heaviside/Gibbs vector model occurred prior to the turn of the century, mostly in the journal *Nature*. It never involved over a handful of scientists, and it wasn't much of a debate. The vectorists simply threw out the quaternion EM theory and adopted the vector theory of Heaviside and Gibbs. Note that this represented a substantial curtailment of Maxwell's actual theory. *In other words, you can actually do a lot more in and with EM fields and circuits than what now appears in "modern" EM theory, and "modern" EM analysis won't even show it.* Barrett's Oscillator-Shuttle-Circuit analysis of Tesla's actual patented circuits shows this clearly and resoundingly. Also, *living systems utilize the discarded subset of EM for their most vital control functions, and the present theory and* *methodology will not detect or "see " this.* Thus this curtailment alone has resulted in the profound crippling of the conventional EM bioeffects model and efforts to apply it.

The Present CEM is a Flawed Subset of Nature's Electromagnetics

So we have several serious things that are quite wrong with current CEM theory. First, the theory (and its practice) are *artificially* limited to only a subset of the real EM that can be achieved and utilized. The present CEM unwittingly excludes the very type of EM utilized by living systems for their deepest control functions. It also excludes electrogravitation. Second, Maxwell's theory was actually based upon the assumption of a *mechanical (material) ether,* which meant that he could logically assign material forces to the "vacuum" or "ether fluid." Heaviside's translation (and curtailment) to vectors did not charge this "material ether" and "force field in vacuum" assumption.

However, in 1887 the Michelson-Morley experiment resoundingly destroyed the notion that the ether is material. If the ether were truly a thin material fluid, then forces and EM force fields would indeed exist in it. Since the ether is not material and forces exist only in, on, and of matter, no E-field or B-field exists in the nonmaterial vacuum; none ever has, and none ever will. In his three volumes of physics, Feynman pointed out that only the *potential* for the EM force fields exists in the vacuum; the only thing that exists in vacuum is *potentials,* after all! The vacuum is just a fantastic collection of interfering potentials and potential gradients. Rigorously, the E- and B-fields we detect with our instruments *exist only in the electron gas in the probes we utilize.* This is well-known to a few foundations physicists, but the CEM model has never been corrected for these foundations errors.

Note that the loss of the material ether also falsifies one of the three key assumptions in modern potential theory: the notion that the gradient of the potential comprises a force field. We know today that the CEM equation $E = -\nabla\phi$, is actually incorrect *for the vacuum.* It is correctly *measured;* since that is exactly what is detected when the vacuum $\nabla\phi$ potential gradient couples to the free electrons in our detecting/measuring instruments. What we detect as E, however, is actually $[(\nabla\phi \bullet (e^-)]$, or the potential gradient coupled to the electrons, including their masses. Specifically, we do not detect the nonmaterial (VO that actually exists in the vacuum. We detect electron wiggles in the free electron gas in the conductors of our instruments; we do not detect "vacuum wiggles" per se.

Neither Maxwell's quaternion EM equations nor Heaviside's vector EM equations include electron spin effects, but actually model electricity as a "thin fluid." Hence the EM equations of either model are *fluid dynamic* equations. Specifically, the measured transverse EM waves exist in the electron gas of our detectors; any detector detects only its own internal change, *not* the external agent that interacted and caused that internal change. White the "signal" races down the conductors in our probes and sensors at essentially the speed of light, the "free" electrons in the electron gas in those conductors are *longitudinally* restrained. The electrons must essentially move laterally from their initial distribution inside the conductor to its skin, then "slip" slightly down the wire on the skin at only the electron drift velocity, which is a fraction of a centimeter per second. The spinning electrons in the electron gas, being longitudinally restrained, act as *gyroscopes.* When disturbed by an interacting force, they precess. It follows that the lateral motion of the electrons inside the conductors of our detectors is just this "electron precession." It also follows that the direction of the disturbing force must be at right angles to the electrons' measured transverse precession movement. Rigorously, EM waves in the vacuum thus are *longitudinal,* not transverse. We *measure* transverse waves in our detectors and instruments because we are detecting and measuring the *electron precession waves in the free electron gas in the conductors of those instruments.* But as Tesla pointed out, there are no Hertz waves in the vacuum; instead, EM waves in the vacuum are longitudinal "sound" waves, or *waves of rarefaction and compression of the medium.* From modern QM we also know what the medium is: it is a flux of virtual particles. Again, as can be seen, the CEM model is seriously in error in its representation of EM waves in the vacuum.

We will not pursue this further; it is well-known to a few physicists in foundations work (but not to most electrical engineers and electrical physicists!) that classical EM theory is seriously flawed, and that it should be upgraded to correct those flaws. As is well-known in QM since 1959, it is the potentials that are the actual causes of all EM phenomena, and the potentials can interfere to cause real EM effects in charged particle systems, even in the absence of the force fields. The Aharonov-Bohm effect is an example, as are several other derivative effects well-established in the literature. What has been ignored even in QM, however, is the *organized internal structure* of the potential, even though the original (vector) discovery by Stoney occurred in 1897 and was extended by Whittaker in 1903.

This internal structure of the scalar potential had been implicitly present in Maxwell's 1873 quaternion theory, as an integral part of the scalar component of the quaternion resultant of the interaction between two or more quaternions. In quaternions, a scalar entity may be regarded as a special quaternion entity whose translation has been reduced to zero. A vector entity may be regarded as a special quaternion entity all aspects of which are translating, and no nontranslating aspect is present. Thus the scalar quaternion entity may be totally composed of vector components, so long as they sum or multiply to a zero translation resultant but possess a finite nontranslating magnitude.

The Scalar Potential Has an Internal Bidirectional Wave-Pair Structure

In a profound but ignored 1903 paper of enormous consequences, E. T. Whittaker decomposed the scalar EM potential into a harmonic set of bidirectional wave pairs, extending the original 1897 work of Stoney. Each wave pair consists of a wave and its phase conjugate replica (its "anti-wave" or "time-reversed twin".). Thus the scalar potential has a rich internal biwave structure. [Further, one can *make* a scalar potential by simply assembling the necessary multiple waves, and one can alter the internal structure of the potential at will by altering the waves utilized in the assembly process.] In 1904 Whittaker published a formidable second paper, showing that all of CEM could readily be replaced by scalar potential *(hidden multi-wave)* interferometry. In other words, scalar EM is far more basic and extensive than is the present CEM with its emphasis upon the force fields.

E.g., you can alter the internal structure of the Schroedinger potential, and place deterministic biwave "hidden variables" inside. You can then "engineer" these hidden variables _ and consequently the Schroedinger potential _ by external means. In other words, you can even accomplish *at least limited engineering of quantum change itself.* This of course reduces the Gibbs statistics (which assumes a totally random quantum change) to a special case, and provides a more general case of chaotic quantum change, which is still statistical but may contain hidden order. Note that this statement is experimentally testable. It also resolves the greatest problem in quantum mechanics today: the problem of the missing chaos (hidden order).

In 1989 Ignatovich placed a paper in the *American Journal of Physics* pointing out a similar internal biwave structure of the Schroedinger potential, but none of our scientists seems to have realized the profound implications. *If we apply these proven mathematical extensions of electromagnetics, we are now dealing with a higher topology hidden variable theory, along the lines shown by Bohm, but one that is engineerable on the lab bench.*

Ziolkowski's Extension Allows Hyperspatial Communication

In 1985, a brilliant EM scientist named Ziolkowski independently rediscovered Whittaker's internal biwave harmonic decomposition of the scalar potential. He also extended the "internal structure" theory, to encompass not only the sum set but also the product set. Since the product of waves represents modulation, Ziolkowski's brilliant work provides the setting for *direct information communication capability* in the internal structuring of the scalar EM potential.

Further, this internal channel is in the virtual state, so one is accomplishing virtual state engineering, in the sense of the vacuum engineering posed by Nobelian Lee. If one uses a 4-space Minkowski model, the Whittaker/Ziolkowski channel information may be viewed as *subspace* communications. If one utilizes an n-space Kaluza-Klein model, where n is greater than 4, then the Whittaker/Ziolkowski channel information may be viewed as *hyperspace* communications. *Living systems already use this inner EM channel.*

Living Systems Use the Internal Channel Communication

It turns out that living systems utilize precisely the Whittaker/ Ziolkowski (W/Z) mechanism for their deepest functions and control systems _ including mind, thought, long-term memory, and the master cellular control system (MCCS) discovered by Dr. Popp of Germany. What we are stating is that, for the very first time, *we now* *know where and how the mind's "deepest software" is, its fundamental mechanism, and how to go about programming it directly.* However, we first must develop new measurement instruments.

Unfortunately, present EM instruments are almost all only "electron-wiggle" detectors; they detect only the *translation of electrons. A gradient* in the potential will couple to electrons and translate them. The *gradient-free* potential does not translate electrons, and it is the internal biwave W/Z structure of that gradient-free potential that we need to measure. Presently no known instrumentation will do that.

However, if two different scalar potentials are interfered [Whittaker 1904], their interference reproduces potential gradients [normal "force field" EM], which *do couple to electrons and translate them.* In fact, potential gradients (which in CEM are erroneously called "force fields") were already shown by Whittaker to be entirely due to the interferometry of two scalar potentials. So new "scalar interferometry" instruments must be developed to "outfold" the internal contents of the scalar potential as gradients, and then utilize normal instrumentation to measure those interference gradients and calculate the potential's internal structuring. One form for the detector is the use of a standard potential (with a known internal biwave structure) inside a Faraday-shielded chamber, so that the test gradient-free potential (which penetrates such a cage) interferes with the standard potential inside the cage to produce gradients therein. *A* probe in the interference zone detects the gradients as electron translations, which are conducted externally to amplifiers, meters, spectrum analyzers, computer programs, etc. The end result is the determination of the internal WZ structure of the test potential. Other detector types are possible; this is just a "straightforward" type.

Thoughts, Mind, Memory, and Cellular Control Are Measurable

What we are saying is that, by developing the proper instrumentation, it is possible to directly detect and examine thoughts, memory, and deep control system functioning of the biological organism, including the deep internalistics of its personal quantum potential. We are speaking of the pending emergence of an experimental science, not just a speculation.

However, we are dealing now with a form of "hidden variable" theory, but one that is engineerable and testable. So we will become directly involved with Bohm's *quantum potential,* both experimentally and theoretically. *A* quantum potential can connect widely separated systems by instantaneous effects, as if the systems were not separated but were located together as a single system. Further, the quantum potential does not have a single localized source. Suffice it to say that in 1991 I published the discovery of how a quantum potential is actually created. If one utilizes the proven "self-targeting" or iterative phase conjugate shooting mechanism from the Strategic Defense Initiative, and applies it to the WZ waves internal to the scalar EM potentials from two separated charges, then in a dense signal environment the self-targeting interaction may be initiated, so that the separate potentials merge into a single nonlocalized or "spread-out" potential consisting of laser-like beams between the charged particles comprising the separated systems involved. In that case, part or all of any EM change in one system is immediately experienced in the other systems participating in the effect. The communication is superluminal. The limitation to luminal velocity applies only to the "surface gradient" of a potential, not necessarily to the bidirectional waves in its WZ internal structure. Those internal waves are in either hyperspace or subspace, depending upon whether one models the situation in more than four dimensions or in only four.

The point is, *the quantum potential also has a W/Z internal structure.* And that structure can be deliberately created and engineered by external means. Action at a distance is not only possible but engineerable.

Living Systems and Quantum Potentials

It turns out that the living organism utilizes a quantum potential _ a *special scalar potential connecting all its internal atomic nuclei* _ for its volition, deep control, and mind and thought processes and operations. This can even be taken as a flat definition of a living system. A living system utilizes internal WZ structuring of this scalar potential connecting all the atoms (nuclei) of its body mass, for its deepest control processes. Any system not having or doing this is not a living system. This also resolves the age-old philosophical question of how mental *intent* cm cause physical response, but that is beyond the scope of my presentation. It also explains why viruses can be precipitated out of solution as a crystal, and the crystal stored for decades. Then when the crystal is redissolved, the individual viruses separate and resume their "living" state. Suspended animation of the viruses results when their physical matter and its quantum potential remain intact, and the stored WZ structures in the quantum potentials on the atomic nuclei of that matter remain the same.

It further turns out that the species itself has a much weaker (at a deeper level topologically) quantum potential connecting all its members (all the atomic nuclei in their bodies). This corresponds to Sheldrake's morphogenetic field _ that field is just a *species quantum potential.* Jung's collective unconscious, e.g., can be directly expressed in this model scientifically and testably _ but again that is beyond the scope of this presentation.

Newton's Third Law Requires Forces to Occur in Oppositive Pairs

Newton's third law is a sleeping tiger, with surprising implications when awakened and explored. For example, it rigorously requires that forces (including EM forces) must occur in oppositive pairs, This alone falsifies the CEM notion that *oscillating "singular-force"* electric and magnetic waves appear in either a material ether or physical matter. At least two waves must exist, the wave and its oppositive or *antiwave.* Further, the wave and antiwave must be intimately coupled. Heretofore the antiwave has simply been ignored, or when anyone pointed out that it was present in our detectors, it was just considered to be "Newton's third law reaction wave." "Newton's third law" was just mysteriously invoked, as if it had no causative mechanism. Yet in quantum field theory the cause of all forces is the absorption or emission of *virtual particles.* The cause of all mechanical and electromagnetic forces is the absorption or emission of virtual *photons. So* Newton's third law for mechanical and electromagnetic reactions must also be due to the exchange of virtual photons. In other words, there was an extra half of the "something" in the vacuum that interacted with our detectors and gave us the "free electron gas's transverse precession waves. That "extra half' was exactly equal and opposite, and interacted in the atomic nuclei of the conductors and the mass of the instrument to give a set of physical Newtonian recoils. That half is equal and opposite to the half we actually recognized. The point is, equal and opposite forces actually interacted with our instrument. Thus a stress wave interacted with it, not a unitary oscillating wave.

What occurs in vacuum must be a stress wave, not a unitary force field wave. In short, as stated (but not elaborated) by Feynman, it is a *potential* wave, or an oscillation in the potential gradients and magnitudes, not the force fields. Since in modern theory force is an *effect* and not a cause, we interpret and extend Newton's third law to state that the *causes* of all forces must occur in oppositive pairs also. Thus the cause of an EM force field must be the interaction of two scalar potentials _ just as Whittaker's 1904 paper proves.

In quantum field theory any mechanical or EM force is caused on a mass by absorption and emission of virtual photons. Accordingly, let us examine the smallest possible EM or mechanical "force" _ that one caused by the absorption of a single virtual photon. Newton's third law requires that two photons (the causes) must occur, not one. Further, in all cases, the one must be the exact antiparallel to the other. The only thing always meeting that condition for a photon is its exact antiphoton _ its *time-reversed, phase conjugate replica twin.* But a phase conjugate *replica* photon must also superpose spatially with its parent photon _ that's what phase conjugate replicas normally *do,* according to the distortion correction theorem of nonlinear phase conjugate optics. Thus instead of the conventional "single photon" interaction, the actual vacuum entity engaged in the interaction with an atom is a *coupled photon/antiphoton pair.* A coupled photon/antiphoton pair has spin-2, hence is a *graviton.*

Gravitons and Graviton Interaction

So arguably "photon interaction" has been *graviton* interaction all along. In the interaction with an atom, the graviton splits into a photon and an antiphoton. The photon usually interacts with the electron shells, being absorbed by an electron to raise its energy level, then re-emitted and scattered outward from the atom. This absorption and scattering of photons _ *containing their components of energy and time* _ from the electron shells of the atom creates movement of the atom through external observer time. The photon interaction between a mass and its environment creates the forward flow of time for that atom and its seemingly entropic external (photon interaction created) universe.

The antiphoton half of the graviton is time-reversed, which we see as *spatially* reversed. Consequently we see it move in the opposite direction to its externally-directed photon twin. So the antiphoton focuses inward and interacts with the atomic nucleus, providing the Newtonian third law recoil of the atom. The blithe assumption of an "automatic" third law reaction force has always concealed the fact that the so-called *photon* interaction is actually a *graviton* interaction. Further, the positive charge of the atomic nucleus is due to the time reversal interactions of antiphotons with the nucleons, which reverses the charge from that of the negatively charged electrons in the atom's electron shells.

Proof: Excising the Antiphoton Violates Newton's Third Law

This graviton interaction hypothesis is testable. Note that, if the hypothesis is correct, then when an atom or mass emits antiphotons or antiwaves (phase conjugate photons or phase conjugate replica waves), it means that the inward-burrowing antiphotons have been "tricked" into coming out of the atom instead, so they can comprise the time-reversed wave. If they come outward instead of going inward when they split from the parent gravitons, they do not interact with the nuclei to cause their recoil. In that case, there would be no recoil. And indeed, so it *is. In a phase conjugate mirror material, the mirror does not recoil when it emits a phase conjugate replica wave, even a powerful one due to powerful pumping.* This is not true when the mirror material emits a pseudo-conjugate wave. A pseudo-conjugate mirror, e.g., emits an ordinary "time-forward" wave with a distorted wave front, so that it will "retroreflect" in a manner similar to the phase conjugate replica wave. However, the pseudo-conjugate wave is not a true time-reversed wave. Consequently, the mirror will recoil when it emits the pseudo-conjugate wave, because the antiphotons from the graviton interaction still penetrate to the nucleus and interact there, while the time-forward photons constitute the pseudo-conjugate wave actually emitted. This is experimentally verifiable. Among other things, it establishes that there exist differences between the photon and the antiphoton.

Looking at the photon aspects of this, one realizes that one must be very careful in applying the conventional assumption that the photon and the antiphoton are identically the same. Actually they are not the same "internally." The photon can be thought of as carrying or

consisting of (+□E)(+□t), while the antiphoton can be thought of as carrying or consisting of
(-□E)(-□t). Thus both have positive spin, but differ in their internal components. The lack of recoil in a phase conjugate mirror that emits a true time-reversed replica wave is already in the literature, though derived by statistical quantum mechanical arguments. It has also been pointed out by other physicists that all measurement/ detection is actually binary, but that the "internal energy" half is almost always ignored [it's just considered to be "Newton's law", automatically revoked, and swept away in that euphemism.].

Graviton Lattice Structure of the Scalar Potential

When we examine the WZ structure of a scalar potential, in each biwave the wave and antiwave are phase conjugates. It follows that the photons in the wave and the antiphotons in the antiwave are phase conjugates also. This means that, as the two waves flow through each other spatially, photon/antiphoton pairs continually couple and uncouple. Hence gravitons continually couple and uncouple. Further, since the wave pair frequencies are phaselocked between pairs, *the scalar potential is a phaselocked lattice of statistical (continually forming and unforming) gravitons.*

Let us now consider the interactions of an organism with environmental photons as the interactions of the organism with environmental *gravitons*, and specifically with graviton lattices.

Cumulative Buildup in the Quantum Potential of the Antisignal

If the *photon half (of the graviton interactions)* in the electron shells of the living body are considered as environment signals/ interactions, then precise *antisignals* or anti-interactions, constituting perfect negative feedback from all of an organism's physical environmental experiences, are experienced in the organism's atomic nuclei. Note that there they have partially affected the internal structuring of the quantum potentials _ both the personal quantum potential and the species quantum potential. The point is, *cumulative negative feedbacks (exact phase conjugates) for all the environmental experiences and stresses an organism experiences, build in both the personal QP and the species QP of* *that organism.* A part of the entire species' cumulation of species-common antisignals also exists deep in the quantum potential of the living biological system.

So for any protracted stress experienced by the organism, in its personal QP a coherent cumulative negative countermeasure feedback _ one which by its time-reversed nature would reduce that stress _ continually builds. The phase conjugates of the "well-rounded" or highly varying stresses of multiple types will tend to mostly balance or "zero out." However, a sustained stress of one kind will result in coherent cumulation and increase in the "signal-to-noise ratio" of the amplitude of the antisignal for that particular stress, compared to the amplitude of the average of all the antisignals experienced. This is similar to the case where, in a sea of radar noise, a coherent radar signal were continually present and integrating coherently. Continual coherent integration, of course, results in continual increase of the signal-to-noise ratio for the coherent signal, and eventually it emerges from the "sea of noise" as a discernible [in this case, observable and physical] antisignal.

This "cumulative kindling of antisignals" occurs in both the personal QP and the species QP; however, the species QP is many, many orders of magnitude less than the personal QP. Hence much greater time is required for "kindling" of species changes (evolution) than for kindling individual countering adaptations.

Exercising to get in shape is a simple example of physically stressing the body cells so that the high-level feedback mechanism in the MCCS will kindle appropriate antisignals and order the cells to adjust their functioning in a fashion such that the level of performance being called for can be accomplished more easily, thus reducing the stress level. The adaptive mechanism ordering the adjustment of the body cells is the coherent negative feedback in the personal QP, created from the stress signals from the sustained "workout" exercises. This is a fairly rapid, "high-level" mechanism; many other much slower (and some much faster) feedback reaction mechanisms also exist.

Hypoxia As a Result of Interference With Hydrogen Bonding to Hemoglobin

We now point out the recently discovered water H-bonding effect on the hemoglobin in the blood, where the H-bonding activity increases the ability of the hemoglobin to carry oxygen. Some 60 or 70 water molecules surround the hemoglobin molecule, engaging in extensive H-bonding interactions with it, which substantially increases the hemoglobin's purely chemical ability to bind and transport oxygen. Importantly, contamination of this water in the blood fluid drastically affects this H-bonding benefit, and reduces the hemoglobin's ability to carry the extra oxygen. Thus contamination of the internal blood fluid by chemicals, agricultural pesticides, smoke, etc. directly and dramatically lower the oxygen availability to the body's cells, resulting in a continuing "oxygen hungry" state (hypoxia) in most of the body's cells.

It also is now known that H-bond structuring of water is highly dynamic and constantly adaptable, and it possesses a high degree of internal order. A conglomerate of H-bond structures in an area or a volume can be considered an *H-bond potential,* since the gradient oppositions sum to produce stress potentials. Thus in the H-bonding fluid surrounding the hemoglobin molecule, there exists an H-bond scalar potential, and by Whittaker/Ziolkowski (W/Z) decomposition it has a multi-wave structure. Any and all contamination of the fluid _ including by electromagnetic fields and signals, chemicals, etc. _ alters the H-bonding structuring and hence the internal W/Z structure of the H-bond potential. *The end result of adulteration of the H-bonding structure of the blood fluid is a condition of hypoxia induced in the cells of the body due to reduced oxygen transport by the hemoglobin of the red blood cells.*

Any single EM signal is the result of the interference of two scalar EM potentials, as shown by Whittaker. It is the result of the interference of the *internal EM wave structures* of those scalar EM potentials. Multi-signal EM radiation must be regarded as interference of multiple pairs of scalar potentials. These interfering potentials penetrate to the atomic nucleus in the body, and thus interact with the internal personal quantum potential utilized by the body in its deep cellular control. Also this multi-signal EM radiation, *no matter how weak,* directly interacts with the H-bonding structure of the H-bonding blood fluid. Even single-signal EM radiation still forms oppositive pairings with the weak fields already existing in the body, thus also forming W/Z structured potentials. From the interferences in the body of multiple such potentials and their internal structures, there also are created gradient (force field) interactions upon the blood cells and the hemoglobin. In short, low-level background EM radiation can also interact with the H-bonding of the hemoglobin to seriously lower its oxygen transport capability, just as any other contaminant. The denser the external environment, the greater is the interferometry and the interference with the hydrogen-bonding augmentation of oxygen transport. It follows that, when thrust into a truly dense signal environment, some exposed individuals may receive a "cumulative H-bonding interference dosage" that, when added to their existing prior dosage, is sufficient to result in physical symptoms "ordered" into the cells by the antisignals kindled in their quantum potentials. In the recent Gulf War, many Americans were suddenly thrust into one of the densest EM signals environment in history. Shortly after returning from that ultrashort conflict, many of these exposed veterans have experienced delayed health changes presently known as "Gulf War Syndrome." While the military has attempted to portray this syndrome as "stress-induced" emotional' trauma, most of these veterans when tested are found to be emotionally stable. Further, there was much less combat stress on our troops in the Gulf war than in WWII, the Korean War, or the Viet Nam War, as shown by less than 200 combat deaths! Essentially the war was almost a "shooting gallery," and so combat stress is simply not viable as a proposed causative agent for the Gulf War Syndrome.

Chemical, Mechanical, and Electrical Interactions are Electromagnetic Anyway

Indeed, chemistry is largely due to electric charge and charge distribution anyway. So if we view the physical contaminants in the blood view *chemically,* they are caused by electromagnetic means at root basis. Thus even the "chemical" contaminants interact electrically and via potential (multiwave) interferometry with the H-bonding potential. Further, in quantum field theory, all mechanical forces are due to the exchange of virtual photons, and hence also are *electromagnetic at their very basis.* The bottom line is that all chemical, mechanical, and electrical interactions are in fact electromagnetically caused. Further, since both the internal and external structures of the potential are engineerable, the mechanical and electrical forces on the mass particles _ and the virtual photon exchanges causing these forces _ are directly engineerable. *All of these chemical, mechanical, and electrical interactions in the cells can be affect*ed *and even engineered electrically. This is true from the atomic nucleus, to molecules, to material lattices, to human cells, to tissues, and even to the mind and long-term storage templates (internal WZ structured forms in the QP) in the biological organism.*

As cam be seen there are many other weaker, direct interactions of "force-field" radiation; however, here we are interested in the interaction of that radiation with the inner structure of the H-bond potential'., to reduce the oxygen transport capability of the hemoglobin. *In any case, the total sustained interaction of chemical and physical contaminants and EM fields and radiation can result in a sustained oxygen-deprivation (hypoxia) condition for the body cells, even to a dramatic degree.* Further, by graviton interaction, *a sustained, cumulated set of antisignals is also automatically generated in the personal quantum potential as a set of negative feedback signals to take corrective actions to alleviate the oxygen depletion condition.* Note that the cumulating antisignal condition is general and affects the immune system and its cells as well.

The Example of Smoking

Obviously the tars, particles, and nicotine of the smoke inhaled by the smoker dramatically contaminate the fluid in the smoker's lungs, in the very place where the hemoglobin of the red cells is taking on oxygen. Drastic interference with the H-bond stimulus of the hemoglobin occurs. The result is an immediate and dramatic reduction of the oxygen-transport capability of all the hemoglobin in the red cells as they pass through the contaminated lungs and are exposed to fluid contamination. An immediate oxygen-deprivation condition thus is created in the body. Due to the magnitude of the stressing signal, the major portion of the antisignal is also of substantial magnitude _ hence immediate counteraction orders accumulate in the personal QP, specifically in Popp's master cellular control system. So very rapidly the body has negative feedback countersignals from the central cellular control system, ordering the body to take actions to reduce the cellular need for oxygen. The metabolism is lowered, the body relaxes, and the appetite is suppressed; all counters to the cells' hypoxia condition by lowering the cellular requirement for oxygen.

In spite of heroic "high level antisignal" physical cellular compensations to reduce the use of oxygen, however, the condition of cellular oxygen shortage may still continue, in the case of the smoker or substantial environmental contaminants such as secondary smoke. So in addition to the prompt countersignals, additional much-weaker countersignals are also slowly accumulating in the personal quantum potential's central cellular control system.

Cumulative, Deep, Long-Term Countering Signals

We now need one additional bit of information. In addition to its personal quantum potential, a biological organism also is connected to a species quantum potential joining all the members of its species. This is a much weaker quantum potential; nonetheless, potentials superpose, so one small "part" of the personal quantum potential is actually the species quantum potential _ in other words, Sheldrake's morphogenetic field. Deep within its own personal quantum potential the living system also possesses all the cumulatively ordered steps (species antisignals that were implemented) of its species evolution. With very *long coherent cumulation, countersignals can be stimulated in the individual bio-organism's quantum potential _ and in its deep cellular control _ that are counters to the original signals that ordered directed mutation and the primeval evolution of the constituent cells themselves.*

In a sustained cellular hypoxia stress environment, the "do whatever is necessary to reduce oxygen usage" countersignals will continue to cumulate from successively deeper levels in the QP over an appreciable time. These continue to slowly "kindle" after the "first high-level antisignal actions" that cumulated past the "noise" (quantum) threshold reached their limits of physical reactions and are still insufficient to resolve the problem. As the hypoxia stress in the cells continues, then much weaker but coherent countersignals that trigger deeper cellular adaptation actions eventually have time to cumulate past the quantum threshold to the observable state. These long-term cumulated antisignals come from much deeper, even from the species quantum potential itself.

These cumulating deep countersignals are phase conjugates _ *reversals, or dedifferentiation commands* _ of the previous directed mutation signals that ordered evolutionary changes in their predecessor cells in the far distant past. *These long-term antisignals thus contain a signal to reverse the original cumulative countersignals in the cellular species potential that caused the cells early ancestral anaerobic cells on earth to change (differentiate) into largely aerobic cells, after the earth's atmosphere acquired significant amounts of oxygen. In short, a deep signal is slowly* *cumulating that, when it emerges, will order the dedifferentiation of the affected cell back down the evolutionary road toward the anaerobe. The first steps are reductions of centralized cellular control, including growth control.*

In other words, under sustained cellular hypoxia a countermeasures signal to the cells, ordering them to dedifferentiate back toward the anaerobic state, is slowly building in the personal quantum potential from a much weaker, lower level "under the common countersignals noise level" all the while. If significant oxygen-deprivation continues for a sufficiently long time, this deep countersignal eventually emerges in Popp's MCCS system in the personal QP, *ordering the affected cells to dedifferentiate back toward their anaerobic state.* The first step back is to break away from centralized control by the higher organism _ which results in individual "tumerous" or "uncontrolled" cells. *From sustained cellular hypoxia there exists a slowly increasing precancerous state, even years before the outbreak of physical cancer.* This precancerous state has great influence upon the "single cells" of the organism, which includes the cells of the immune system. Thus the precancerous state is characterized by increasing errors in, and slow weakening of, the immune system. Arthritis and similar debilitating immune system disorders appear to be largely the result of this "precancerous" long-term cumulation.

Note that the most stressed cells in the body automatically provided the greatest magnitude of "negative feedback input." Notice also that the feedback is a phase conjugate replica; it therefore "backtracks" its initiating stress input signal. In short, the degree of feedback antisignal received by a cell or group of cells varies according to the degree of stress they experienced. Thus those cells sustaining the longest and greatest stress get this drastic dedifferentiation countersignal first. E.g., this accounts for the (usual) localization of the resultant tumor in the lungs of a smoker, at least initially. It also accounts for the stress-damage mechanism for such disorders as arthritis.

A New Definition of Cancer

In the new model being advanced, *cancer and leukemia are centrally-commanded. final, desperate. "first-step dedifferentiation" adaptive attempts by the stressed. affected cells experiencing sustained oxygen shortage (hypoxia) to reverse their cellular* *evolution and return to the anaerobic stage of their distant ancestry.*

The cause of cancer and leukemia _ and indeed of all diseases _ is *electromagnetic* in nature, and it can be straightforwardly treated and cured *electromagnetically,* if one utilizes the extended W/Z aspects of the higher topology EM actually written by James Clerk Maxwell. This statement is based on experimental proof; it is not conjecture. We discuss that proof below.

As we saw, in general the strength of the cumulating countersignal inversely depends on the distance in the body of the affected cells from the source of greatest contaminant stimulation. As the deeper "dedifferentiation" countersignal reaches the quantum threshold in the most affected area, a small group of localized cells located there take the first step back along the "single-anaerobe to single aerobe to multiple aerobe" evolutionary chain. That first dedifferentiation step breaks the cells away from centralized control of the MCCS in the personal quantum potential. Those dedifferentiated cells become independent cells or a small independent cell-groupings. They constitute a *tumor,* or *leukemia* if occurring in the blood cells. They simply are no longer under the control of the body's MCCS in the personal quantum potential, even though the body's logistical services (nutrients, oxygen, etc.) continue to be furnished to them.

At this point the tumor becomes an independent cellular organism, living in an environment where its body host continues to furnish its food and oxygen, and its host's immune system cells do not recognize the altered cells as foreigners to be attacked and destroyed. Consequently there is no "large organism" central control of the tumor's growth, and the tumor cells divide and multiply apace. This loss of centralized growth control and the resulting unchecked cellular division and replication is in fact recognized by scientists as the major distinguishing characteristic of cancer and leukemia. With central control lost, groups of cancer cells or individual cancer cells may break away and travel to other locations in the body via body circulation systems. This results in metastasis, the spread of the cancer to other sites in the body, where they continue to be recognized as "self" by the immune system cells and continue to be supplied with oxygen and nutrients for continued growth.

The Tumor Has Become a Parasite Organization

Think of it this way: In a living body, each cell is already a single, independent, living creature all its own. It even has its own small "personal quantum potential" _ we have argued that that is an *a priori* condition of being alive. However, each cell in a multicellular organism normally is under a centralized electromagnetic control system (which functions in the organism's higher-level personal quantum potential), so that the organism lives and functions as an overall higher-level unit. If a cell (or group of cells) has separated from this centralized EM control, but is still living and functioning, then obviously the cell is no longer under the whole organism's MCCS and personal quantum potential. However, it still possesses its own control system, and its own personal QP. If the breakaway is by a small group of cells, then they are loosely under a "small group" quantum potential and MCCS as well. That is, they have gone from "large-scale central control" to a "much lower" level of centralized cellular control, accounting for the "tumor as an individual multicellular entity." Nourished by the host body, the new parasitic organism _ the tumor _ grows at an unchecked rate. Again, we argue that *the problem is electromagnetic in nature, and it can be "fixed" electromagnetically.*

The Cumulative Pre-Cancer State

With this picture of the long-term cumulative causative mechanism for cancer and leukemia, a far better picture of the pre-cancer state has emerged. The pre-cancer state is a hidden EM change of state comprised of a *cellular dedifferentiation order,* back down the species' cellular evolution trail, and the magnitude of that change of state is slowly increasing inside the organism's quantum potential. The eventual observable cancer is an actual cellular dedifferentiation due to the localized breaching of the quantum threshold by this cumulating hidden EM dedifferentiation order to move away from centralized control and back toward the anaerobic cellular state.

Becker's Profound Experiments

It has already been experimentally shown that very minute amounts of direct electrical currents, e.g., can cause cellular dedifferentiation and redifferentiation. In breathtaking work of Nobelian quality, Becker has proven that even picoamperes of localized electrical current are sufficient to cause cellular dedifferentiation and redifferentiation, even repetitively. Incredibly, he proved that this was true for red blood cells, which first dedifferentiated to more primitive cells, the redifferentiated to precursors of cartilage cells, then redifferentiated to bone cells in a "bone fracture" area and healed the bone fracture. Since picoamperes can be generated by the cumulative countersignal mechanism (via Whittaker scalar interferometry), directly affecting the MCCS and the cells as well, then the connection between scalar potentials/potential interferometry and *dedifferentiation* mechanisms assumed to be involved in cancer and leukemia essentially follows from interpretation of Becker's pioneering work. To further strengthen the assumption, Hsue has recently (1993) shown that a DC voltage is in fact equivalent to two bidirectional EM traveling waves _ which directly indicates a WZ type implication in Becker's profound work itself. Thus Becker actually utilized a hidden, bidirectional WZ wave structure inside the voltage gradient between his electrodes in his DC current dedifferentiation and redifferentiation of blood cells. He conclusively demonstrated that cellular dedifferentiation and redifferentiation _ both of them *genetic* changes _ can in fact be caused by such an internal biwave EM structure of a steady, persistent scalar potential gradient. Further, he demonstrated that *these El~-induced cellular genetic changes can be self-targeted toward reversal of the specific damage condition, even though several successive genetic changes may be necessary m reach the ultimate cellular genetic form required for healing.*

Pre-Cancer State and Prognosis For Treatment Effectiveness

To summarize, whenever a cancer or leukemia detectably exists, regardless of the cancer site, a pre-cancer state also exists in the remainder of the body, and the immune system is affected generally. Further, this pre-cancer state pre-existed the actual emergence of the tumor itself. The new EM bioeffects model also sheds light on the probable effectiveness of conventional treatment, and probability for a "cure" that lasts for the rest of the patient's life.

If the cumulative countersignal slowly kindling in the remaining pre-cancer state is sufficiently below the quantum threshold, then conventional treatment of the cancer _ such as excision _ can eliminate the tumor, and no other tumors may then develop before the normal physical death of the body, even though slow increase of the pre-cancer state continues. In other words, in that case the cumulative antisignals in the pre-cancer state locations other than the original cancer site never reach the quantum threshold prior to the natural death of the patient. On the other hand, if the cumulating antisignals in the pre-cancer state generally are very close to the quantum threshold, then recurrence of the tumor is highly likely. In the first case the curative prognosis is excellent; in the second case it is poor.

Also, we point out that many present treatments (such as nuclear radiation) themselves cause significant stress on the body and its cells and further deterioration of the immune system. They also generate an additional "antisignals" level in the personal quantum potential, resulting in an actual *increase* in the level of the pre-cancer state in the organism. If the combination of the pre-cancer state at time of treatment, plus the increase in the pre-cancer state due to treatment, is sufficient to breach the quantum level, then that treatment will prove to be of little or no avail to the patient. The tumorous condition will recur, and sometimes massively (the tumor metastasizes), regardless of whether further treatment is given or not. In that case the patient will die, unless somehow the pre-cancer state is lowered, the tumor cells are reverted back to centralized cellular control, and the immune system is restored to effective functioning so that excess cells are eliminated. Presently there is no conventional treatment that is capable of accomplishing the three requirements for a desperately ill patient's recovery from the "terminal" cancer condition.

Seeking the Complete Cancer Cure

From the new EM definition of cancer and leukemia and the new cumulative causative mechanism, one can see just how severely limited are the present medical weapons against this dread disease. It follows that, *if the cause is totally electromagnetic, then a totally effective treatment can only be sought as an electromagnetic therapy. Since the EM cause is in an extended EM domain, then axiomatically a totally effective treatment can only be sought in the same extended EM domain.*

The complete cure for cancer and leukemia, of course, would be to completely neutralize or "zero-out" the patient's cumulative Whittaker/Ziolkowski countersignal buildup in the MCCS/personal

QP. This can be done *prior to* the cumulation reaching the overt physical disease stage, or *after* it has already reached that stage. It can readily be done electromagnetically, using the multi-biwave tailored EM and self-targeting to provide an exact counter-countersignal (or antidote signal) to the cumulation signal itself. *This is a scientific fact and it has been rigorously proven, although the methodology could not heretofore be technically explained and understood.*

Priore's Cure of Terminal Tumors and Other Diseases

Such a total cancer-curative procedure was repeatedly demonstrated in live animal experiments in the late 1960s and early 1970s by Antoine Priore in France, under rigorous scientific protocols and supervision by eminent French scientists [such as Robert Courrier, head of the Biology Section of the French Academy of Science, and *Secretaire Perpetuel* of the Academy at the time]. The advantage of the Priore type approach was that it rapidly reversed the dedifferentiation away from centralized control of the affected (tumor) cells. The tumorous cells simply redifferentiated back to normal cells under centralized control of the MCCS/personal QP. (If too numerous because of the tumor's growth prior to its redifferentiation, normal body mechanisms absorb and dispose of the excess cells). Further, such treatment removed *all the pre-cancerous state from the rest of the body, preventing recurrence or spread of the tumor*. It is the only "total cure" for cancer, including the cumulated pre-cancer state, that has ever been scientifically demonstrated. And lastly, it accomplished these results without severe trauma to the body or further trauma to the immune system. Indeed, the exact opposite was the case.

Working with Priore, the eminent French scientist Pautrizel showed that the Priore treatment restored and stimulated the immune system back to its robust normal functioning, as would be predicted by the present model we are proposing.

Scientists at the Time Did Not Have the Necessary Knowledge for Understanding

It is a great tragedy that the active mechanism of the Priore device was not understood _ even by Priore himself and even by very knowledgeable physicists assigned to the program to try to ascertain the machine's mechanism. The phase conjugate or "time-reversed" EM wave was unknown until it was discovered in the open Soviet literature in 1972. Almost all of our knowledge of such waves dates from that time. In the same year, two Soviet scientists briefed American scientists at Lawrence Livermore National Laboratory on *optical* phase conjugation. Thereafter, some American scientists began intense work on optical phase conjugation.

However, the time-reversed wave is a solution to the wave equation and applies to all kinds of waves, not just EM. Phase conjugation of sound waves, e.g., is readily accomplished. The time-reversed wave solution actually appeared in the scientific literature in 1898 in a paper by Barus, who pointed out that this strange solution "made the wave run backward." But at the time the Priore program's funding was withdrawn by the French government about 1974-75, little or no understanding of the time-reversed EM wave existed as yet in the West, and of course the Whittaker work had always been ignored and was unknown also. *Literally, with the technical tools available to them at the time, the French physicists, biologists, and oncologists had no chance at all of fathoming the causative mechanism in the Priore experiments.*

Nature of the Priore Treatment

Briefly, Priore mixed some 17 frequencies in a rotating plasma in a giant tube. We know today that one function of the kind of plasma he used is to produce a phase conjugate replica wave, for an input wave. Thus Priore unknowingly achieved coupled wave/antiwave pairs in his device. The output of the plasma tube was then coupled to (modulated upon) a "rippling magnetic field" of appreciable strength. The magnetic field guaranteed penetration of the entire body and every cell in it, carrying its modulated Whittaker/ Ziolkowski internal potential structure with it. The "ripple" in the magnetic field guaranteed penetration to the atomic nuclei, and interaction with them, via nuclear magnetic resonance. In turn, unknown to Priore or the scientific team, this guaranteed the interaction of the plasma-produced W/Z structure with the internal W/Z structure of the personal QP joining those atomic nuclei. Thus the Priore approach (1) formed a deliberate counter-counter signal W/ Z structure; i.e., Priore constructed a *specific electromagnetic* *antidote, (2*) carried that antidote into all the atomic nuclei of the treated body by nuclear magnetic resonance, and (3) caused interaction with and neutralization of the internal W/Z dedifferentiation countersignal structure already present in the personal QP joining all the atomic nuclei of the treated body, *zeroing out or canceling the tumorous and pre-tumorous states existing throughout the body.*

The end results were that (1) the cumulated counter-signal to the tumor cells to dedifferentiate back toward anaerobic cells was removed, (2) the body's own centralized cellular control over the tumor cells was restored, and (3) the entire cumulated pre-cancer counter-signal pattern in the personal quantum potential was removed. In short, the individual organism started over again with a "clean slate" insofar as long-term cumulation of cancer-inducing signals in the personal quantum potential was concerned.

Furious Reaction by Orthodox French Oncologists

The Priore material, device, procedures, and results are all properly documented and presented in the peer-reviewed French medical literature. Priore obtained both French and U.S. patents on the device and on his treatment process. Robert Courrier, head of the Biology Section of the French Academy of Science, personally introduced the astounding Priore team results to the Academy. It caused a furor, and a vicious reaction of most of the orthodox French oncology establishment. Because no one could understand how the mechanism worked, there was loud and raucous insistence that "science must not be done with black boxes!" This overly pious attitude is strange, since the Priore results were multiply replicated and scientifically impeccable, and such things as aspirin were utilized for decades before their active mechanisms were understood. Indeed, in epidemology the use of vaccines and such is directly based on statistically showing that the results are real, even if the active mechanism is not understood.

When the French Government changed to a leftist government in the mid 1970s, the implacable foes of the Priore work prevailed, and the new leftist government withdrew all further funding. Priore later died, and that was the end of that.

Of all areas and treatments known to this researcher, the Priore approach is the only one that has been rigorously and scientifically proven in laboratory animals, was essentially 100% effective, and was performed under proper rigorous scientific protocols. That it has continued to be ignored by the medical and biological communities is a profound tragedy, but one due more to ignorance of the active mechanisms for the treatment than of deliberate intent.

There Is Also Deliberate Suppression

Nevertheless, there is also an element of deliberate suppression involved. Some years ago I was personally involved with a special group in an effort to restore the Priore device, when Priore was still alive. Our group obtained a tentative agreement with both the French Government and with the Priore group. The Priore machines were to be rebuilt in Bordeaux, France under the personal supervision of Priore himself. Some of the scientists who had worked with him were still alive, and would have been involved in the project. Our group had some $16 million support pledged by some wealthy backers to fund the project.

Almost immediately after our group's successful conclusion of the tentative agreements, the lives of all our backers and the lives of their families were threatened. All backing was withdrawn. The leader of our group, a Nashville businessman, came under sustained personal and business attack. He eventually lost almost everything he had, and fled this country for his life. He is still in hiding to this day. Antoine Priore then died and that was that.

The only part of the project that remained was my own grim determination to eventually provide the detailed mechanism by means of which the remarkable Priore therapeutic cures were accomplished. Success has finally been achieved after a decade of unrelenting struggle to completely explain the cause of cancer and the active mechanism by means of which the Priore group obtained such astounding scientific results.

I strongly urge medical science to take a new, hard look_ both theoretically and experimentally _ at the proven anti-cancer results obtained by Antoine Priore and the noted scientists who worked with him. I also strongly point out that new thinking, new theoretical tools, and new experimental instrumentation are needed for that re-examination. In addition I have pointed out the precise nature of the new thinking, tools, and instrumentation required.

What About Other Diseases Such As AIDS?

The question now arises about other diseases, particularly AIDS. Can the expanded Priore methodology provide equally dramatic cures of dread diseases other than cancer and leukemia? Can it conceivably cure AIDS? The answer is a resounding "Yes!"

Almost all disease conditions are electromagnetic in nature, in the sense of the extended EM bioeffects model we have outlined. The basic methodology of forming a counter-countersignal to a specific disease state can be extended to many other diseases, and to AIDS as well. The "self-targeting" effect in the cellular dedifferentiation induced by the extended EM methods results in a countersignal being produced to the *last major genetic change undergone by the diseased cell.* In the case of an HIV-infected cell, its genetics have been changed (differentiated) from normal to infected. In its internal WZ structure, the strongest resultant signal complex is thus the HIV infection differentiation command. *When pumped by the internal bidirectional WZ wave structure of the applied scalar potential, the "cell-as-a-nonlinear-phase-conjugate-mirror-material" generates a precisely tailored anti-AIDS cellular genetic dedifferentiation signal. The cell thus dedifferentiates back to a normal cell with normal genetics.*

In addition to Priore's work and Becker's results, the remaining experimental foundation for our startling statement on extended-EM reversal of AIDS was established decades ago _ as early as the late 1950s _ by the Soviet researcher Vlail Kaznacheyev.

Implications of Kaznacheyev's Experiments

In some 17,000 experiments Kaznacheyev showed that *any* cellular disease or disorder can be transmitted between cell cultures "electromagnetically" in an unknown fashion. The model we have briefly advanced here, if slightly extended to include the concept of the W/Z structure being a *graviton lattice structure, is* fully capable of explaining Kaznacheyev's results, the mechanisms, etc. This EM-transmission of disease effect shown by Kaznacheyev is known as the *cytopathogenic mirror effect*, and it has been replicated by researchers at the University of Sydney in Australia, at the University of Marburg in Germany, and by at least one researcher in the United States.

In short, what Kaznacheyev's research showed is that there exists a specific EM signal pattern of some mysterious, not-understood nature that can induce a specific cellular disease in a group of cells absorbing that signal pattern. If we regard the healthy state of the cell as "condition A" and the specific diseased state as "condition B," then specific EM signal pattern C causes the cell to move from condition A to condition B. It immediately follows that an antisignal to C _ that is, the phase conjugate of C, which is a time-reversed replica of C _ will move the diseased cell from condition B back to condition A, curing the disease. Time reversal of "sickening" is "healing." It follows from Kaznacheyev's work that (1) a specific signal pattern exists as the causative inductive factor for each specific cellular disease, and (2) a specific "antidote" signal pattern exists as the causative curative factor for that specific disease, the antidote signal being merely the time reversal or phase conjugate replica of the cytopathogenic signal. While Kaznacheyev never publicly produced the cytopathogenic mechanism, such a mechanism follows from the WZ extension of EM, and the long-term causative disease-induction mechanism I have advanced.

Creating a Specific "EM Antidote" to a Specific Disease

Consider the cumulative EM causes of changes to a cell, including to its genetics, as a serial chain of signals. Indeed, consider them as the layers of an onion, where the outer layer is the most recent. Additional layers may be added to the onion by "time forward" actions, or "differentiation" actions. If we now wish to "peel" the onion, that too is a successive, serial action, accomplished by "phase conjugate" or "time reversal" operations. These result in serial cellular dedifferentiation actions. By treating the cell and its genetics and internal parts as "highly nonlinear material structures and therefore phase conjugate mirror materials," we can "pump" the cell and its parts by bidirectional EM waves to convert the cell to a pumped phase conjugate mirror (PPCM). By orthodox nonlinear phase conjugate optics theory, with a signal wave present, the PPCM cell will emit a precise phase conjugate replica (PCR) wave. If we pump the cell with a complex of pump biwaves, the cell can and will emit a precise phase conjugate wave complex in response to a complicated signal wave complex input that is present.

For a diseased cell, we regard the disease as a differentiation of the cell, and the primary cause of the differentiation (the EM cytopathogen) as a complex WZ waveset infolded inside the personal quantum potential (in which all the body's cells exist and in whose internal signal dynamics they participate). With the pumped cell as a PPCM, and the EM cytopathogen present as an input signal wave complex to the PPCM, a precise, amplified, "EM antidote" PCR wave-complex is emitted by the parts of the PPCM cell. Each part gets a PCR complex signal order, dedifferentiating that part back the first step. A diseased part steps back to a normal part. A normal part steps back to a normal part. The diseased cell is thus dedifferentiated back to a normal cell with its parts all normal. Because the PCR wave complex is amplified, the dedifferentiation is must faster than was the original dedifferentiation. Thus an HIV-infected cell that has been "dormant" for an extended period can still be dedifferentiated back to a normal cell that is HIV-free.

So a self-targeting counter-countersignal can be automatically "developed" and generated in the body's diseased cells, for each specific cellular disease or disorder condition, or even for a mix of diseases and disorders. This is accomplished by the automatic phase conjugating action of the "cell-as-a-PPCM", when pumped by the hidden EM bidirectional structure of a scalar potential. In practice, Priore did find it necessary to adjust the particular frequency mixes he used for different disease conditions. We hypothesize that this adjustment was necessary to arrive at the proper pump wave complex that would in fact allow the proper PCR wave complex to be emitted for a particular disease type or class. Although photobiologists regularly report mitogenetic radiation emitted by a cell in the optical region, the effects desired in the cells can be produced by a different frequency regime, because of the known phenomena of nonlinear harmonic and subharmonic resonance. Since in a W/Z structure it is the *harmonic intervals and their relative relationships* that are of fundamental importance, the frequency regime of a detected W/Z structure can be shifted either harmonically or subharmonically. Priore, e.g., worked at radar frequencies in the low gigahertz range. For simplicity we may think of the frequency complex as a sort of "musical chord" composed of multiple tones. We may play the same "chord" either on the high scale or a lower scale, and still recognize the tune if the relative frequency interrelationships of the tones are retained.

A Possible Simplification of Priore's Methodology

If we turn away from the classical vector/tensor EM model presently in vogue to a higher topology EM model such as quaternions or Clifford algebra, the extended EM bioeffects model can be mathematized and refined by experiment. For example, Barrett has shown that the nonlinear phase conjugate optics effects can be obtained in ordinary circuits without the use of optical materials, when those circuits are designed and function in accord with a higher topology EM such as quaternions. Thus the circuitry of the EM emission devices themselves can be constructed to perform time-reversal of EM waves, phase conjugate replicas, 4-wave mixing, and pumped phase conjugate mirror effects, without use of normal optical materials or procedures. Priore utilized a plasma in a giant gas-filled tube, in which to mix his 17 frequencies and accomplish (unknown to scientists at the time) phase conjugation. Barrett's work implies that the necessary phase conjugation, and amplification, can be accomplished by purely electromagnetic circuitry, once the functioning of the circuitry is designed and understood in a higher topology algebra such as quaternions or Clifford algebra.

Priore demonstrated cures for diseases other than cancer. Different settings produced cures for sleeping sickness, e.g. Clogging of the arteries was also completely reversed by a variation in the Priore treatment. In addition, Pautrizel working with Priore positively demonstrated the restoration of vigorous, natural functioning to the immune system of the treated animal.

Kaznacheyev's Viral Disease Experiments: Implications for an AIDS Cure

Kaznacheyev has already demonstrated that viral-caused diseases can be induced by purely EM means in cell cultures. What this means is that cellular genetic changes also are electromagnetically induced at root basis. We regard this as a cellular differentiation. But both Becker and Priore have shown that cellular dedifferentiation can also be induced electromagnetically, by the extended scalar EM. It follows that viral-caused diseases _ including AIDS _ can be cured by purely EM means, simply by creating the proper dedifferentiation signal complex in the diseased (differentiated) cell. To determine the proper disease induction (dedifferentiation) signal pattern for the disease, the disease-inducing signal complex must be phase conjugated, and the phase conjugate replica must be amplified. The phase conjugate replica may be stimulated at the proper frequency regime by a signal complex at a much lower frequency regime. Hence the detectable photobiological optical cytopathogenic signal complexes may have their PCR counterparts stimulated by irradiation with a proper signal complex at a lower frequency regime (e.g., millimeter wave band) for use in treatment

In Conclusion

Again we strongly accent that one must take the "musical" approach: A disease pattern or a curative pattern is a complex of special frequencies and their antiwaves, similar to a musical chord. That same chord can be played in a higher or lower key, and the body will still determine the correct relationships by harmonic or subharmonic oscillation. It will still recognize the "melody" and its background chordal accompaniment; although the *individual* frequencies have changed, their *relative* relationships have not changed.

All biochemistry, genetics, and cellular effects are subject to affectation and control by proper manipulation of the W/Z structures inside scalar EM potentials. We have stated that the living organism already utilizes the internal EM structuring for mind, thought, and long-term memory, as well as the master level cellular control system we have accented. For the first time, the "software" and "firmware" of the mind appears to be directly available, something which has never before existed in science. The model advanced in my work is intended to point the way toward such use in medical science on a substantial scale, to achieve healthier, more effective, and far cheaper treatments for many of our desperate diseases that presently require costly, protracted treatments, often harsh and debilitating in and of themselves. We strongly believe that, given the direct attention of the scientific community and proper funding support, near-total, quick, and very economical cures can be developed for such dread diseases as cancer, leukemia, and AIDS. We point out also that the Priore team demonstrated cure of sleeping sickness in lab animals, as well as the direct unclogging of arteries and other blood vessels.

We also strongly accent the "self-targeting" feature when the diseased cell is "pumped" as a phase conjugate mirror material by the internal WZ biwave structure of an artificially-structured scalar EM potential. The cytopathogenic disease-induction signal complex is present in the cell and all its parts. By varying the frequencies in the internal biwave structure of the pumping potential, and hence in the pumping of the cell-as-a-PPCM, the cell is enabled to produce from and into all its parts the proper phase conjugate replica wave complex for its specific cellular disease. *Hence it produces a specific electromagnetic antidote for its own specific disease condition.* We need only adjust the frequency content of the artificial potential until the proper PCR signal complex is produced. Further, that PCR wave complex is amplified because of the pumping. Therefore the "treatment time" can be very short, and need not be anywhere near as long as the time originally required for the cytopathogenic EM signal complex to cumulate.

Today a variety of dread diseases continue to plague humankind. Untold millions of persons are suffering and dying, when the beginning of an effective, quick, inexpensive therapeutic approach capable of essentially 100% cures of cancer, leukemia, and other diseases has been demonstrated more than two decades ago.

With the exposition of the fundamental mechanism for this new therapeutic approach, perhaps the scientific community will return with renewed vigor to develop this promising area and alleviate the death and suffering so widespread today.

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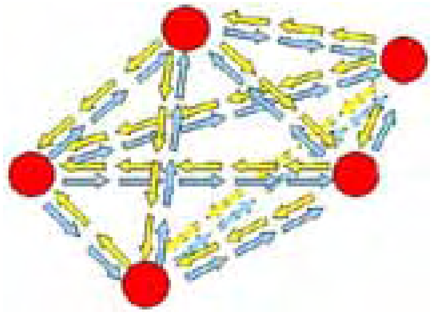

CANCER AND THE UNRESOLVED HEALTH ISSUES IN THE BIOLOGICAL EFFECTS OF EM FIELDS AND RADIATIONS

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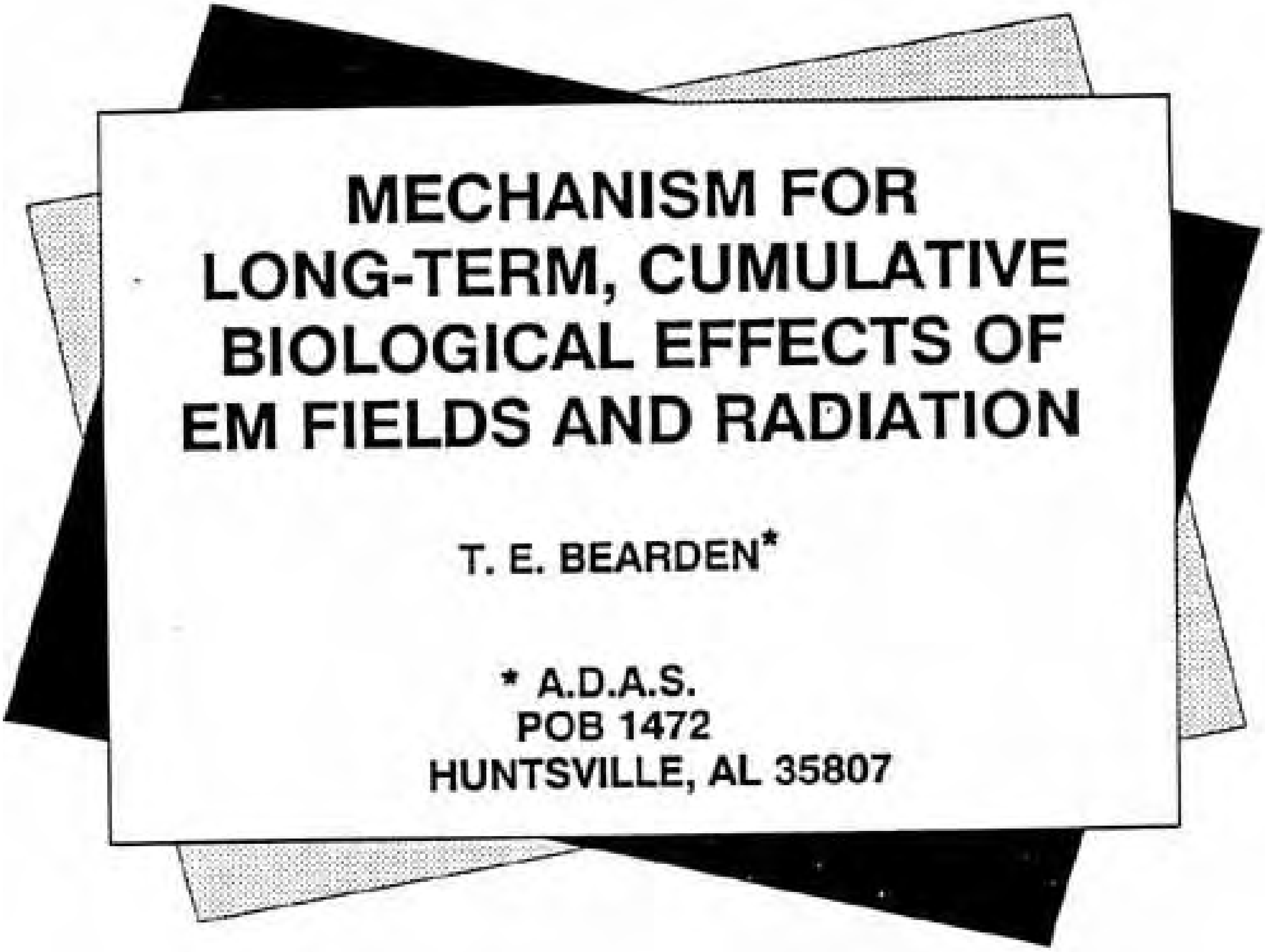

MECHANISM FOR LONG-TERM, CUMULATIVE BIOLOGICAL EFFECTS OF EM FIELDS AND RADIATION

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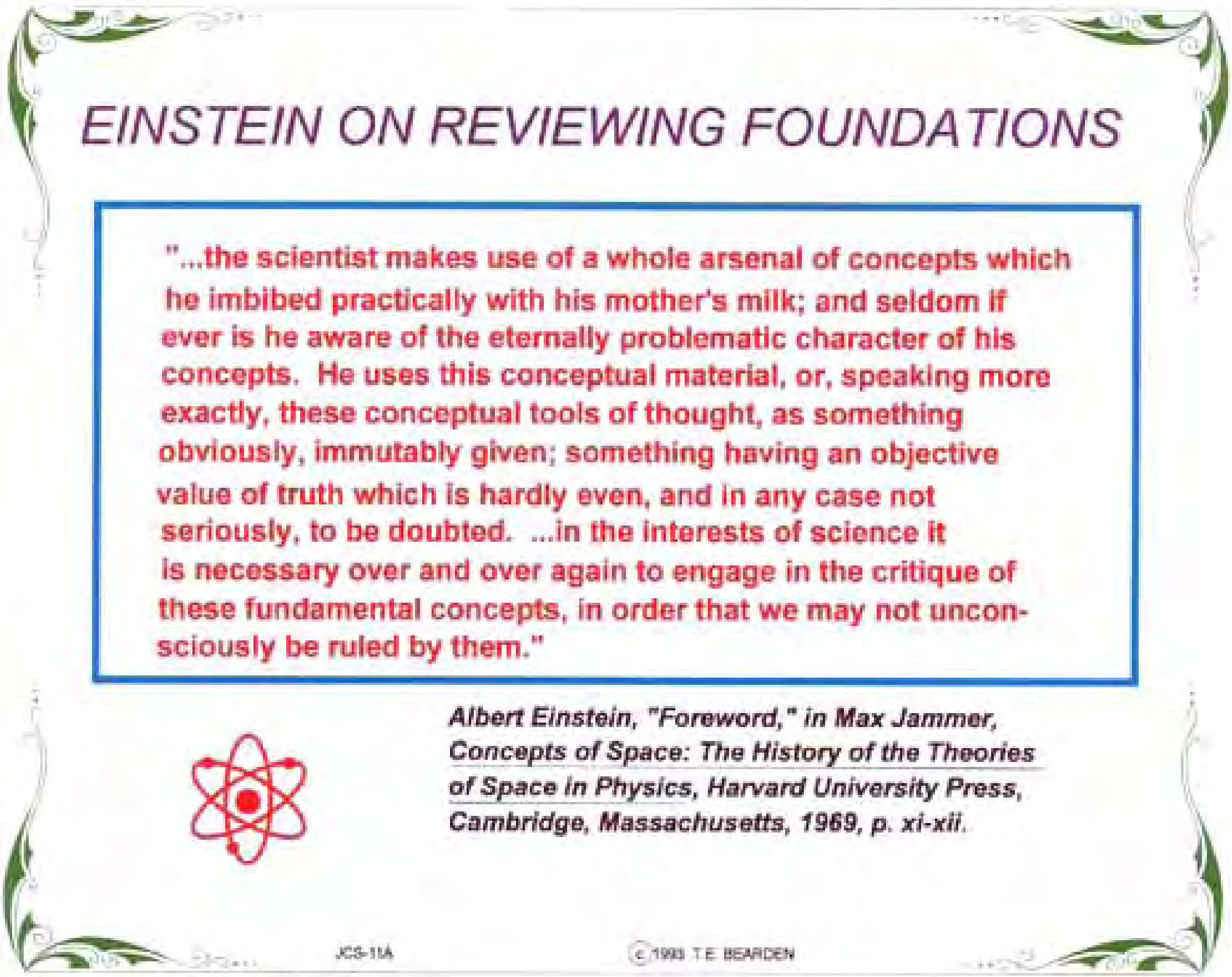

EINSTEIN ON REVIEWING FOUNDATIONS

"...the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the eternally problematic character of his concepts. He uses this conceptual material, or, speaking more exactly, these conceptual tools of thought, as something obviously, immutably given; something having an objective value of truth which is hardly even, and in any case not seriously, to be doubted. ...in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them."

Albert Einstein, "Foreword," in Max Jammer, Concepts of Space: The History of the Theories of Space in Physics, Harvard University Press, Cambridge, Massachusetts, 1969, p. xi-xii.

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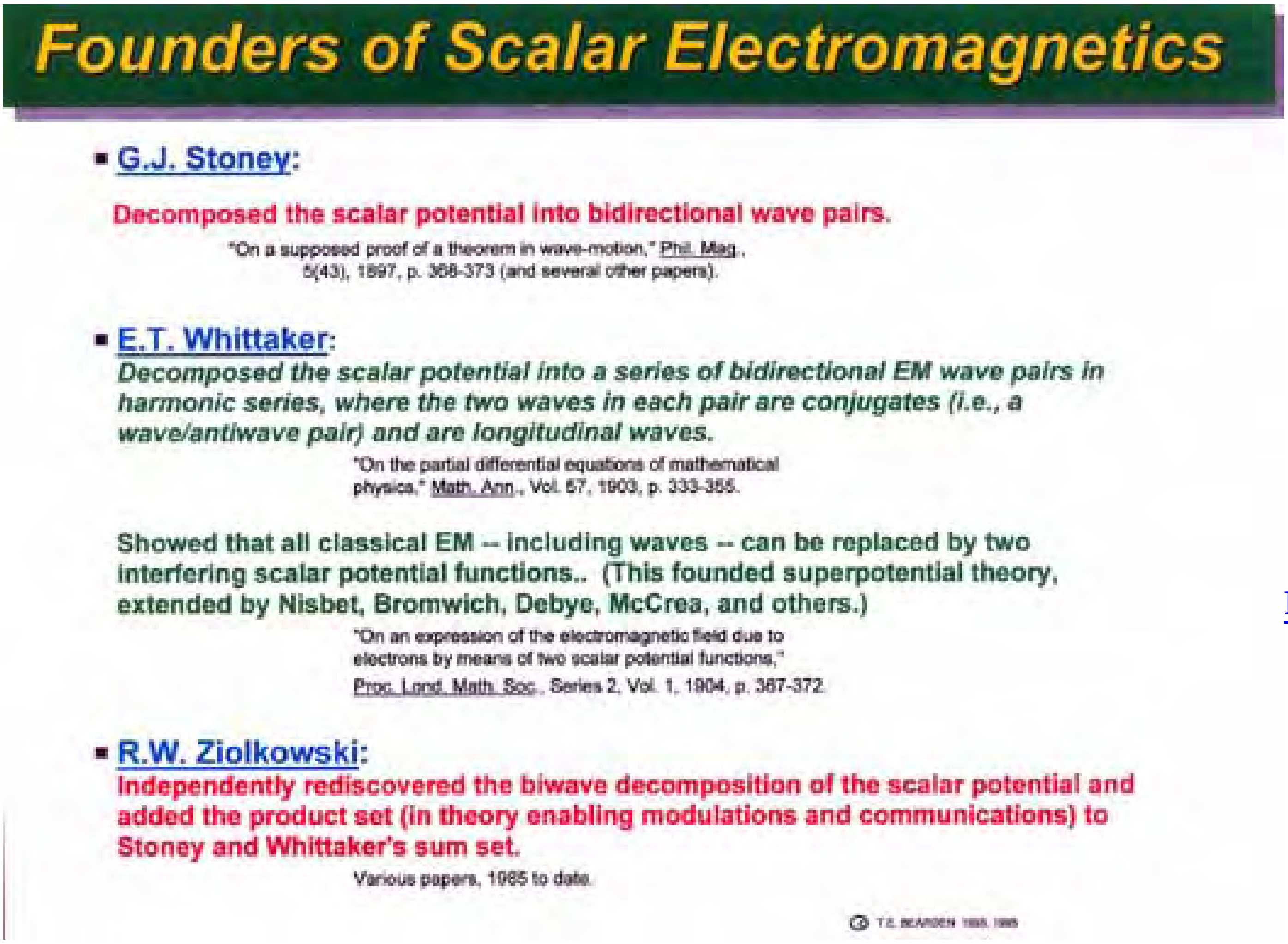

Founders of Scalar Electromagnetics

- **G.J. Stoney:**

Decomposed the scalar potential into bidirectional wave pairs.

"On a supposed proof of a theorem in wave-motion," Phil. Mag., 5(43), 1897, p. 368-373 (and several other papers).

- **E.T. Whittaker:**

Decomposed the scalar potential into a series of bidirectional EM wave pairs in harmonic series, where the two waves in each pair are conjugates (i.e., a wave/antiwave pair) and are longitudinal waves.

"On the partial differential equations of mathematical physics," Math. Ann., Vol. 57, 1903, p. 333-355.

Showed that all classical EM -- including waves -- can be replaced by two interfering scalar potential functions.. (This founded superpotential theory, extended by Nisbet, Bromwich, Debye, McCrea, and others.)

"On an expression of the electromagnetic field due to electrons by means of two scalar potential functions," Proc. Lond. Math. Soc., Series 2, Vol. 1, 1904, p. 367-372

- **R.W. Ziolkowski:**

Independently rediscovered the biwave decomposition of the scalar potential and added the product set (in theory enabling modulations and communications) to Stoney and Whittaker's sum set.

Various papers, 1985 to date.

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INNER EM WAVES OF A SCALAR POTENTIAL

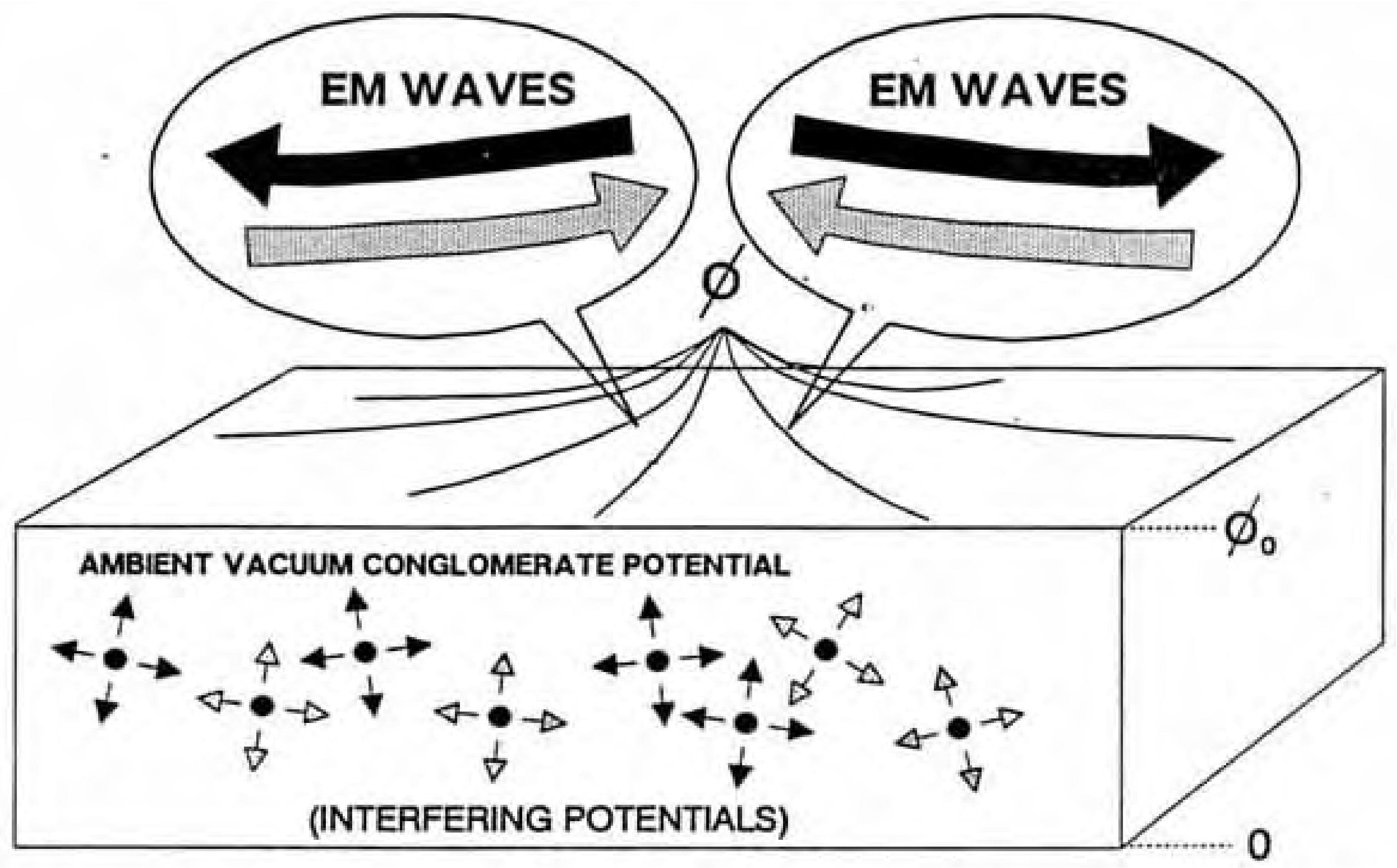
EM WAVES
EM WAVES
Ø
Ø₀
AMBIENT VACUUM CONGLOMERATE POTENTIAL
(INTERFERING POTENTIALS)
0

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GRAVITON/WHITTAKER LATTICE STRUCTURE OF THE SCALAR POTENTIAL

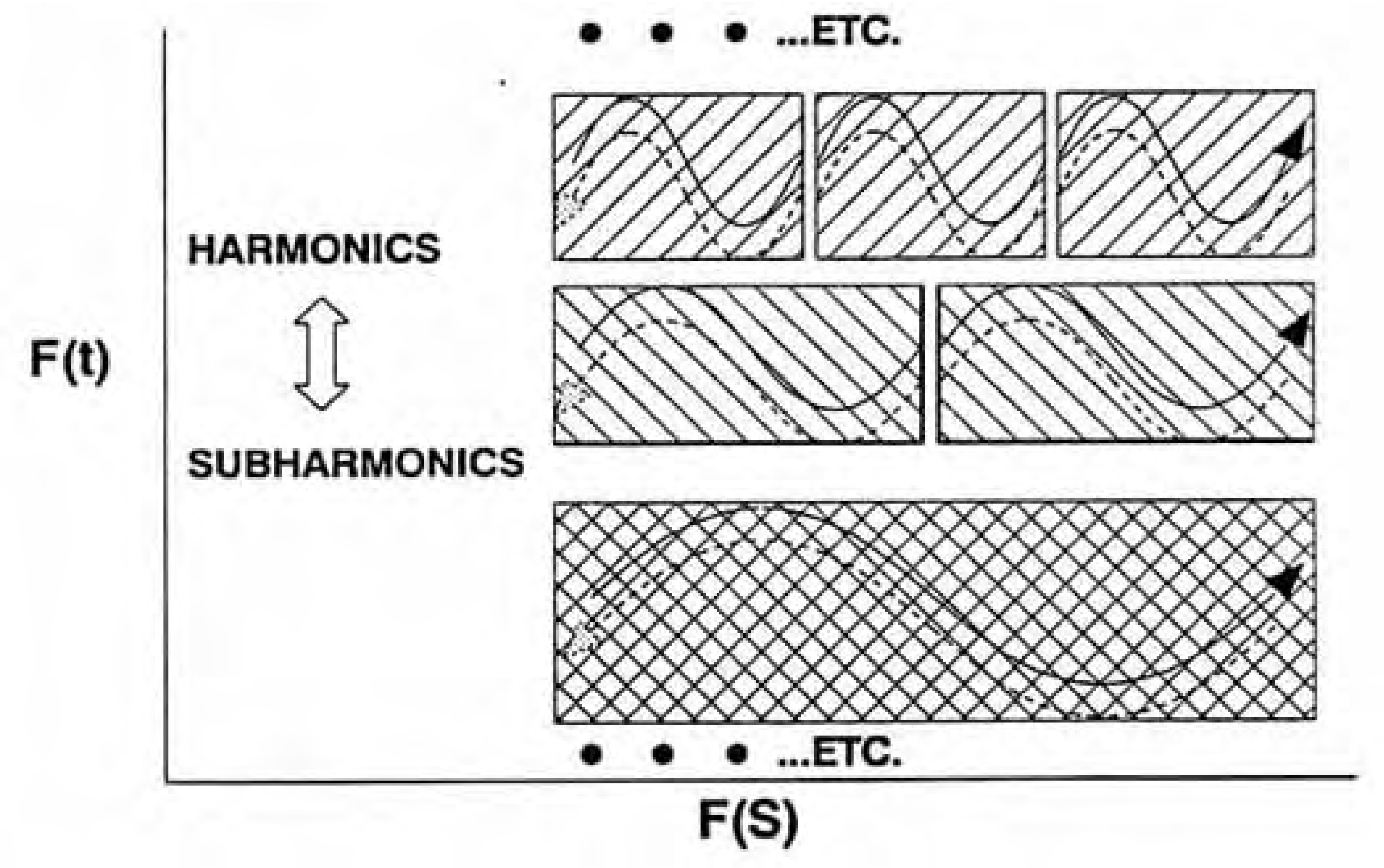
• • • ...ETC.
HARMONICS
F(t)
SUBHARMONICS
• • • ...ETC.
F(S)

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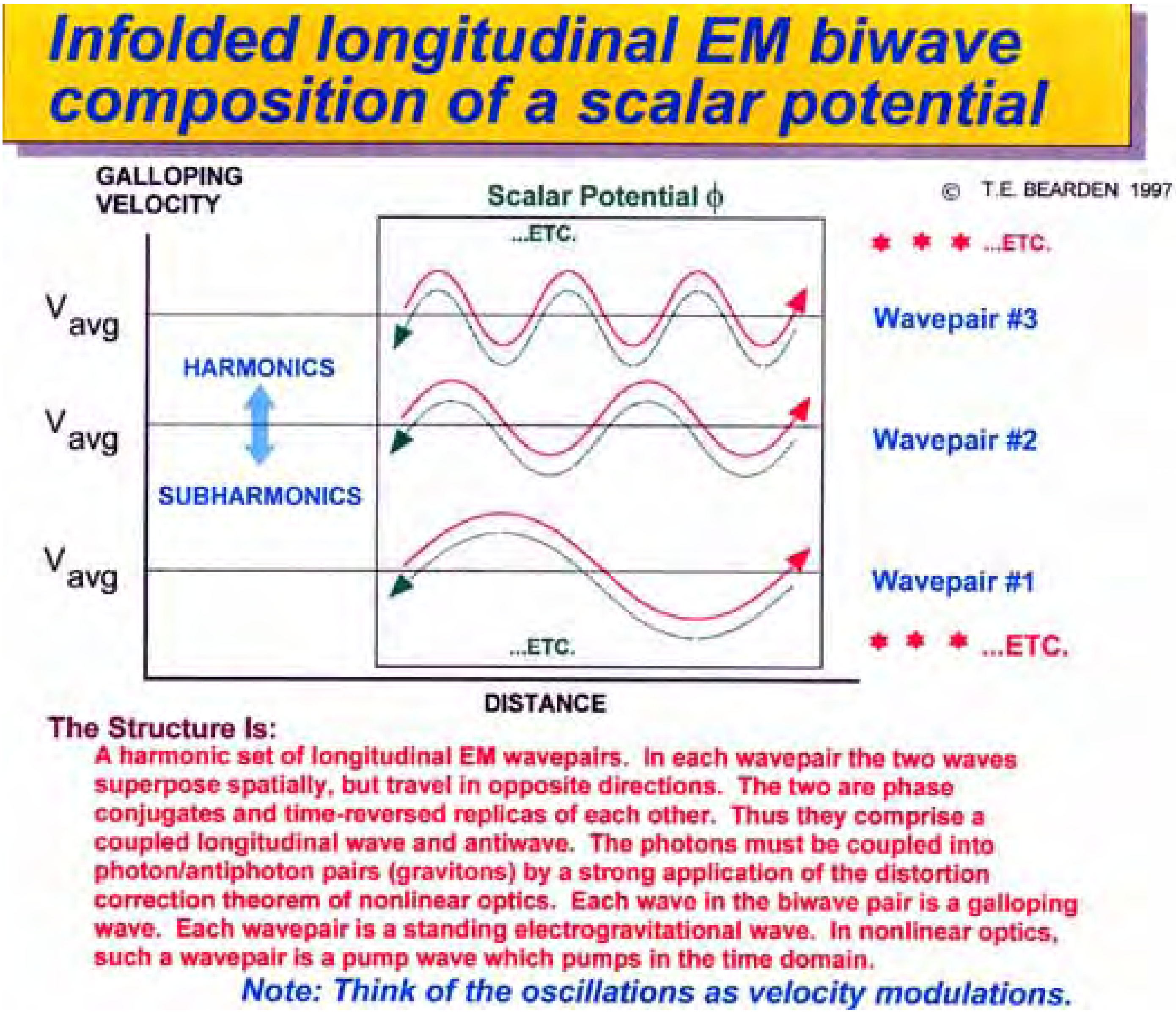

Infolded longitudinal EM biwave composition of a scalar potential

GALLOPING VELOCITY
Scalar Potential ϕ
© T.E. BEARDEN 1997
...ETC.
✱ ✱ ✱ ...ETC.
Vavg
Wavepair #3
HARMONICS
Vavg
Wavepair #2
SUBHARMONICS
Vavg
Wavepair #1
...ETC.
✱ ✱ ✱ ...ETC.
DISTANCE

The Structure Is:

A harmonic set of longitudinal EM wavepairs. In each wavepair the two waves superpose spatially, but travel in opposite directions. The two are phase conjugates and time-reversed replicas of each other. Thus they comprise a coupled longitudinal wave and antiwave. The photons must be coupled into photon/antiphoton pairs (gravitons) by a strong application of the distortion correction theorem of nonlinear optics. Each wave in the biwave pair is a galloping wave. Each wavepair is a standing electrogravitational wave. In nonlinear optics, such a wavepair is a pump wave which pumps in the time domain.

Note: Think of the oscillations as velocity modulations.

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LATTICE AND NONLATTICE GRAVITONS

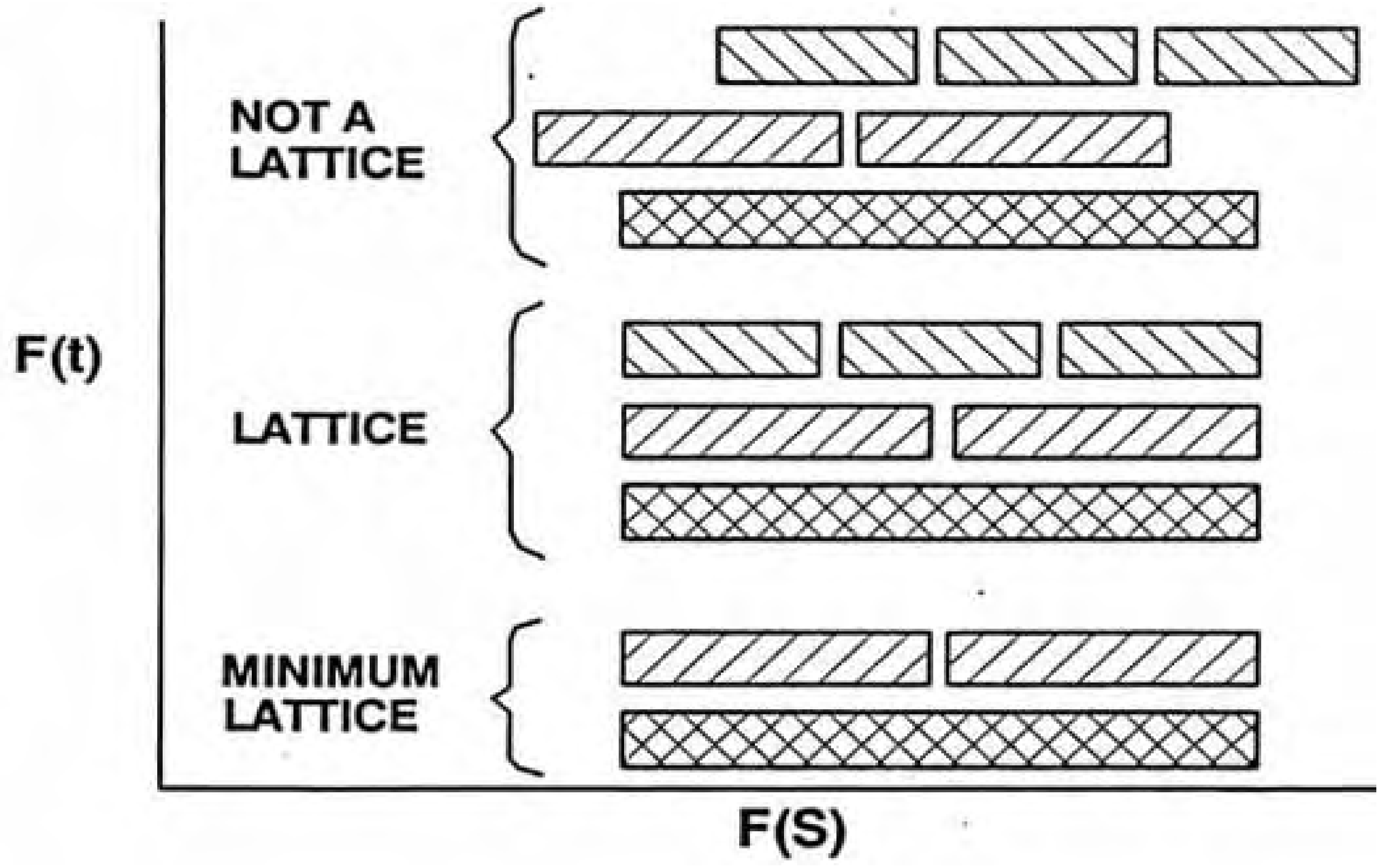
NOT A LATTICE
LATTICE
MINIMUM LATTICE
F(t)
F(S)

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SCALAR EM POTENTIAL INTERFEROMETRY

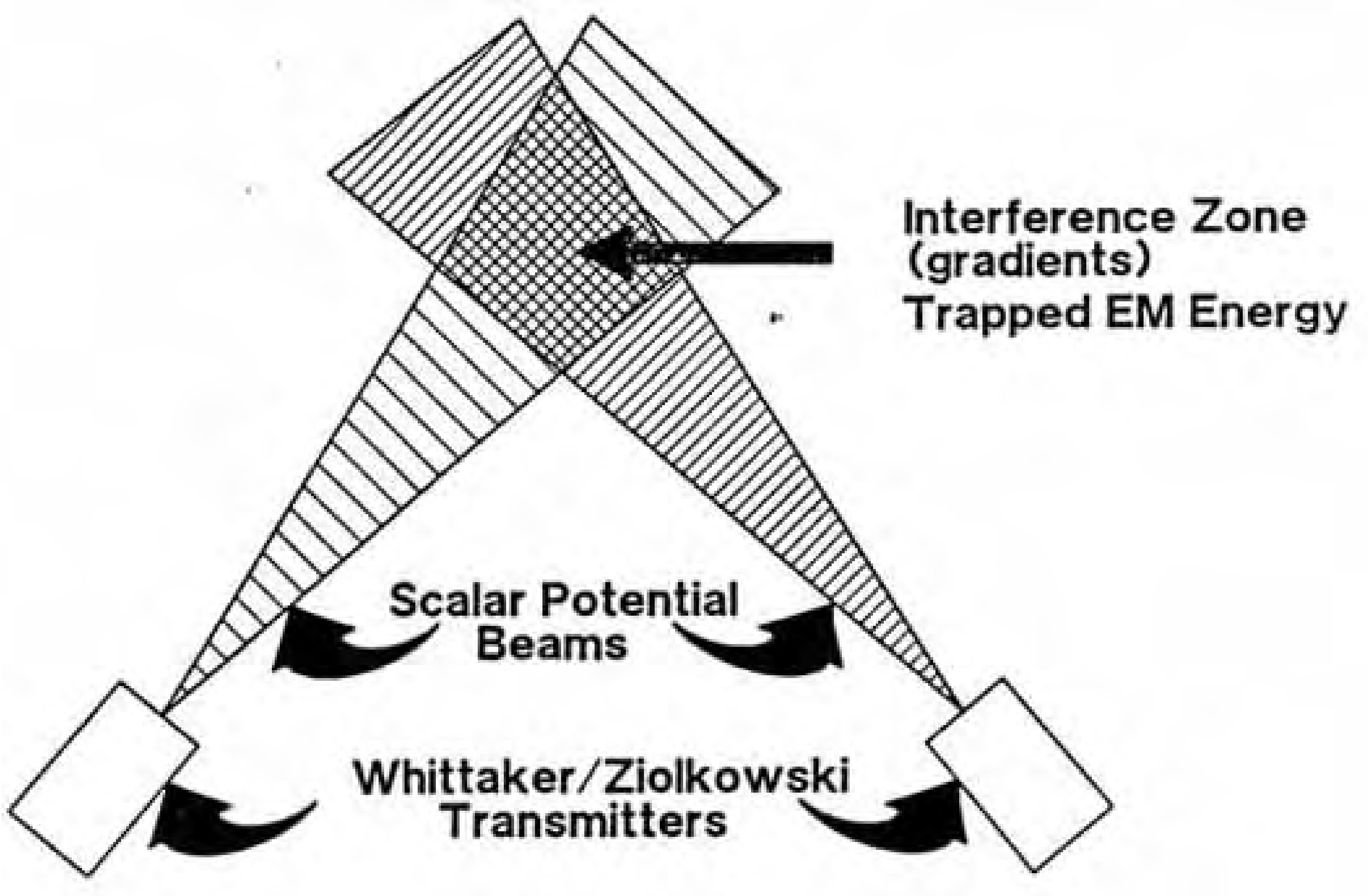
Interference Zone
(gradients)
Trapped EM Energy
Scalar Potential
Beams
Whittaker/Ziolkowski
Transmitters

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SCALAR POTENTIAL INTERFEROMETRY

- Between two scalar potentials, **interferometry** is:
  - Interference of the multi-wave sets in hyperspace.
  - Production of gradients in the 3-space point values
  - In the classical (erroneous) postulation, the creation of forces in 3-space.
    > Force does not exist until the gradient couples to an observable mass.
    > There are no E-fields and B-fields as such in the massless vacuum, but only potential gradients.

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SOME PROBLEMS IN FOUNDATIONS OF GENERAL RELATIVITY

- **EINSTEIN'S FLAT LOCAL SPACETIME POSTULATE**
- **ONLY CONSIDERS THE VERY WEAK G-FORCE AS AN AGENT FOR SPACETIME CURVATURE**
- **EXCLUDES UNION WITH EM FIELD**
- **EXCLUDES ACTION-AT-A-DISTANCE, WHICH IS REQUIRED BY QUANTUM MECHANICS, AND PROVEN**
- **EXCLUDES UNION WITH QUANTUM MECHANICS**
- **SPECIFICALLY EXCLUDES ELECTROGRAVITATION**
- ***IS ESSENTIALLY NOT AN EXPERIMENTAL SCIENCE***

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SOME PROBLEMS IN FOUNDATIONS OF QUANTUM MECHANICS

- **EXCLUDES CHAOS (HIDDEN ORDER), AND THIS IS KNOWN TO BE IN ERROR**
- **ORDERED MACROREALITY CANNOT EMERGE FROM INTEGRATING DISORDERED (RANDOM) CHANGES**
- **USES RANDOM-VARIABLE STATISTICS FROM GIBBS THERMODYNAMICS**
- **NOTION THAT QUANTUM CHANGE - HENCE ROOTS OF PHYSICAL REALITY - CANNOT BE ENGINEERED**
- **REQUIRES ACTION-AT-A-DISTANCE EFFECTS**
- **CONTRADICTS CLASSICAL MECHANICS, GENERAL RELATIVITY, AND CLASSICAL ELECTROMAGNETICS**

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PHYSICS DISCIPLINES ARE PRESENTLY INCONSISTENT

	GENERAL RELATIVITY (GR)	
QUANTUM MECHANICS (QM)	**???**	**CLASSICAL EM THEORY**
	MIND & SUBTLE ENERGY	

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THE PRESENT EM, GR AND QM ARE SUBSETS, EACH OMITS THE WHITTAKER INTERNAL EM.

A	B
PRESENT EM	EXCLUDED EM
(EXTERNALIZED ASPECTS OF POTENTIALS)	(INTERNALIZED ASPECTS OF POTENTIALS)

A	B
PRESENT GR	EXCLUDED GR
(DISTANT SPACETIME CURVATURE) (LOCAL ACTION)	(LOCAL SPACETIME CURVATURE) (ACTION AT A DISTANCE)

A	B
PRESENT QM	EXCLUDED QM
(EXTERNALIZED STRUCTURE OF POTENTIALS)	(INTERNALIZED STRUCTURE OF POTENTIALS) (CHAOS)

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UNIFIED FIELD SECRET: APPLY WHITAKER THEORY

	GENERAL RELATIVITY (GR)	
QUANTUM MECHANICS (QM)	**APPLY WHITTAKER THEORY**	**CLASSICAL EM THEORY**
	MIND & SUBTLE ENERGY	

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PRESENT DEFINITION OF "ENERGY" IS ERRONEOUS

- **PRESENT: "ENERGY IS THE CAPACITY TO DO WORK."**
- **ACTUALLY, WORK IS THE SCATTERING (DISSIPATION) OF ENERGY.**
- **THE PRESENT DEFINITION STATES THAT "ENERGY IS THE CAPACITY TO DO SCATTERING OF ENERGY."**
- **ENERGY CAN BE SCATTERED, YIELDING WORK. BUT THE CAPACITY TO PERFORM THAT SCATTERING IS NOT ENERGY! (E.G., IT MAY BE RESISTANCE.)**
- **COMPARE TO: "A FISHHOOK IS THE CAPACITY TO CATCH FISH."**
- **ACTUALLY, A FISHHOOK IS A BENT WIRE WITH A BARB. IT *HAS* THE CAPACITY TO CATCH FISH (GIVEN OTHER CONDITIONS). BUT THE CAPACITY TO CATCH FISH IS NOT WHAT IT *IS*.**

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SOME NEW DEFINITIONS

- **QUANTUM MECHANICAL VACUUM -** an intense flux of virtual particles, filling the "emptiness" of spacetime/vacuum.
- **ENERGY -** any ordering, either static or dynamic, in the virtual particle flux of vacuum.
- **EM ENERGY -** any ordering, either static or dynamic, in the virtual photon flux of vacuum
- **WORK -** the local scattering of energy; the local disordering of the order in the VPF.

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DEFINITIONS (CONTINUED)

- **POTENTIAL** - any ordering, either static or dynamic or combination, in the VPF of vacuum
  - same definition as energy
  - must have internal order, hence structure
- **SCALAR POTENTIAL** - any static ordering in the VPF of vacuum, with respect of the external observer
- **VECTOR POTENTIAL** - any dynamic (non-stationary) ordering in the VPF of vacuum.
  - must have internal order, hence structure

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DEFINITIONS (CONTINUED)

- **Electrostatic Scalar Potential** - any static (stationary) ordering in the virtual photon flux of vacuum.
  - Whittaker decomposed the ESP into bidirectional EM wavepairs in a harmonic structure.
  - We interpret the wavepair set as existing in hyperspace (in hyper-3-space).
- Thus the ESP is a 3-space point function, and a hyper-3-space vector function, in 7-space.
- In Hyper-3-space, the ESP is an ordering established throughout the universe.

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ELECTRIC CHARGE, OPEN SYSTEM

- The ***electric charge*** of a charged particle is due to a violent exchange of virtual photons between the charged particle and the local vacuum VPF
  - photons continually absorbed from the vacuum
  - photons continually radiated back to the vacuum
  - this exchange flux is what electric charge ***IS***.
- In the nucleus, everything is changing into everything, so to speak. It is a furious, ***VPF-driven*** cauldron.
- the nucleus is an open, driven system, normally in equilibrium with respect to VPF input and output.

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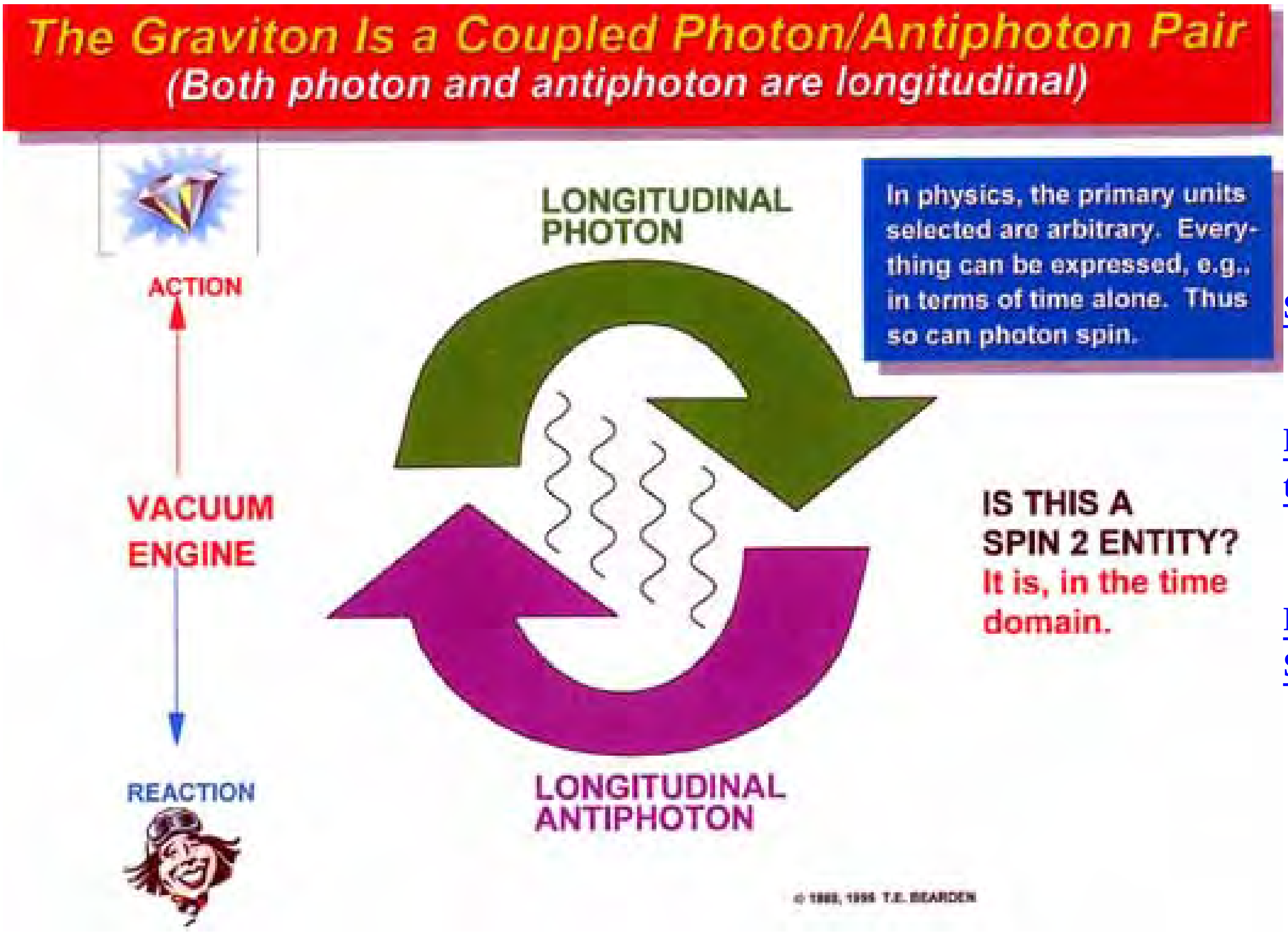

The Graviton Is a Coupled Photon/Antiphoton Pair

(Both photon and antiphoton are longitudinal)

In physics, the primary units selected are arbitrary. Everything can be expressed, e.g., in terms of time alone. Thus so can photon spin.

IS THIS A SPIN 2 ENTITY?

It is, in the time domain.

LONGITUDINAL PHOTON
ACTION
VACUUM ENGINE
REACTION
LONGITUDINAL ANTIPHOTON

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PHOTON INTERACTION IS USUALLY GRAVITON INTERACTION

- Graviton interaction is a photon/antiphoton interaction
- Photon interacts with electron shells
  - Scattering produces the entropic (forward) flow of time
  - Produces electron translation in our detectors
- Antiphoton interacts with nucleus primarily
  - produces nuclear recoil
  - produces Newton's third law of motion

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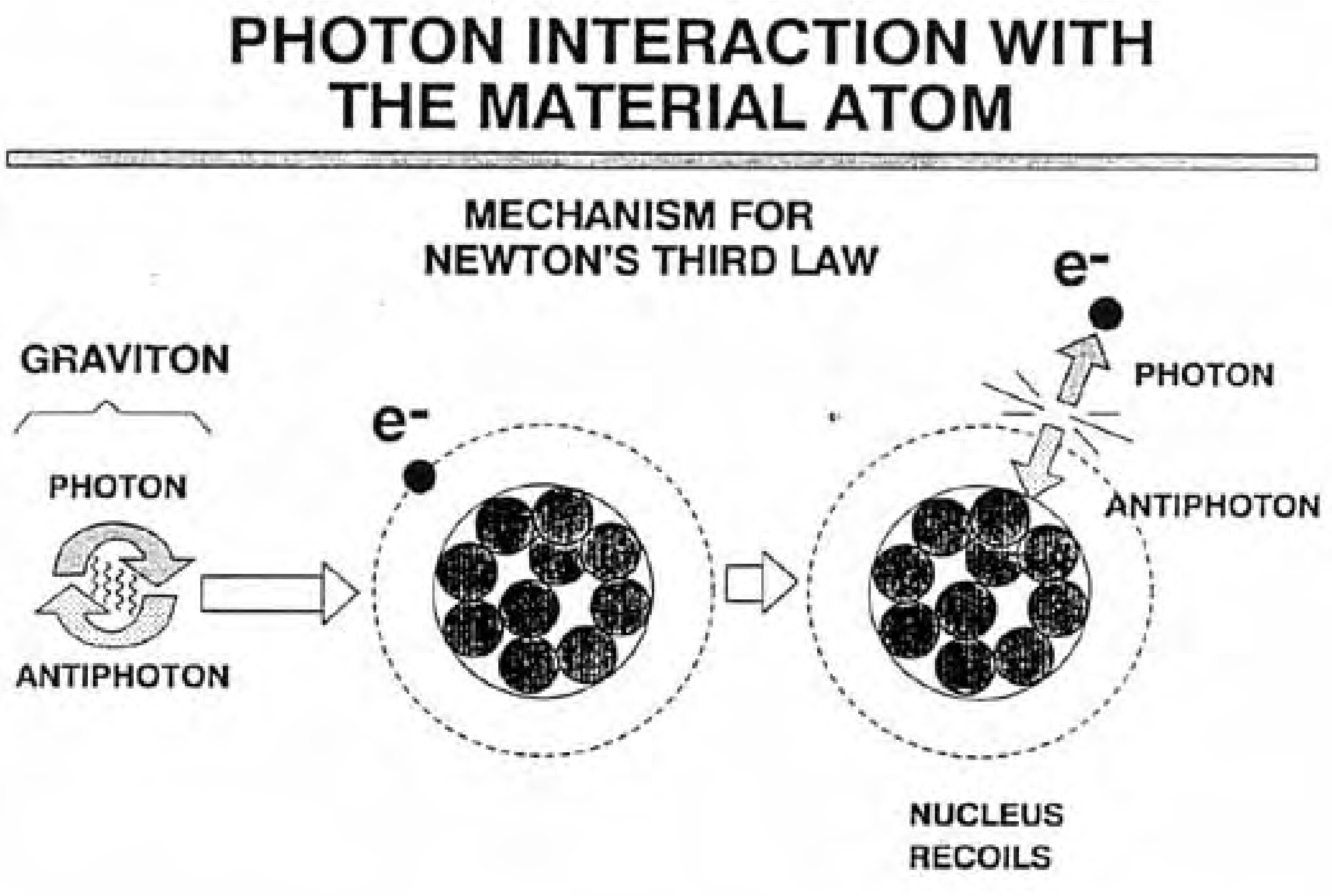

PHOTON INTERACTION WITH THE MATERIAL ATOM

MECHANISM FOR NEWTON'S THIRD LAW

GRAVITON
PHOTON
ANTIPHOTON
e^-
e^-
PHOTON
ANTIPHOTON
NUCLEUS RECOILS

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PHOTON PHASE CONJUGATE INTERACTION WITH AN ATOM

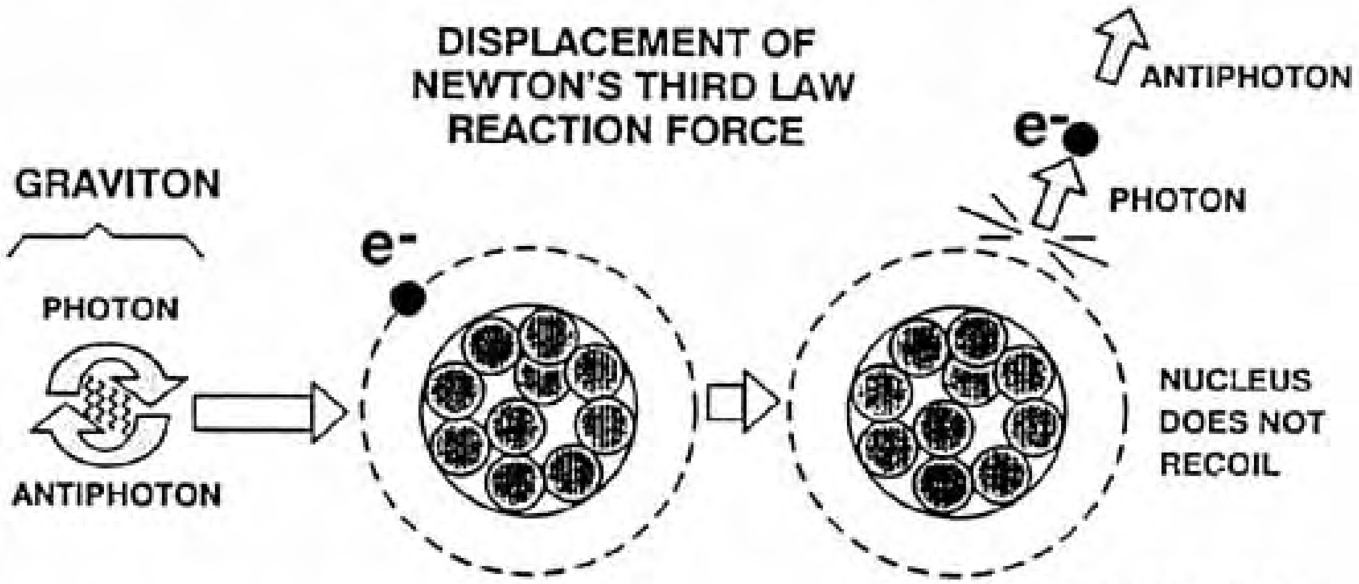

DISPLACEMENT OF NEWTON'S THIRD LAW REACTION FORCE

GRAVITON

PHOTON

ANTIPHOTON

e^-

e^-

ANTIPHOTON

PHOTON

NUCLEUS DOES NOT RECOIL

PHASE CONJUGATE INTERACTION

NOTE: Graviton waves are bidirectional phase waves of photon/antiphoton coupling and uncoupling in the vacuum.

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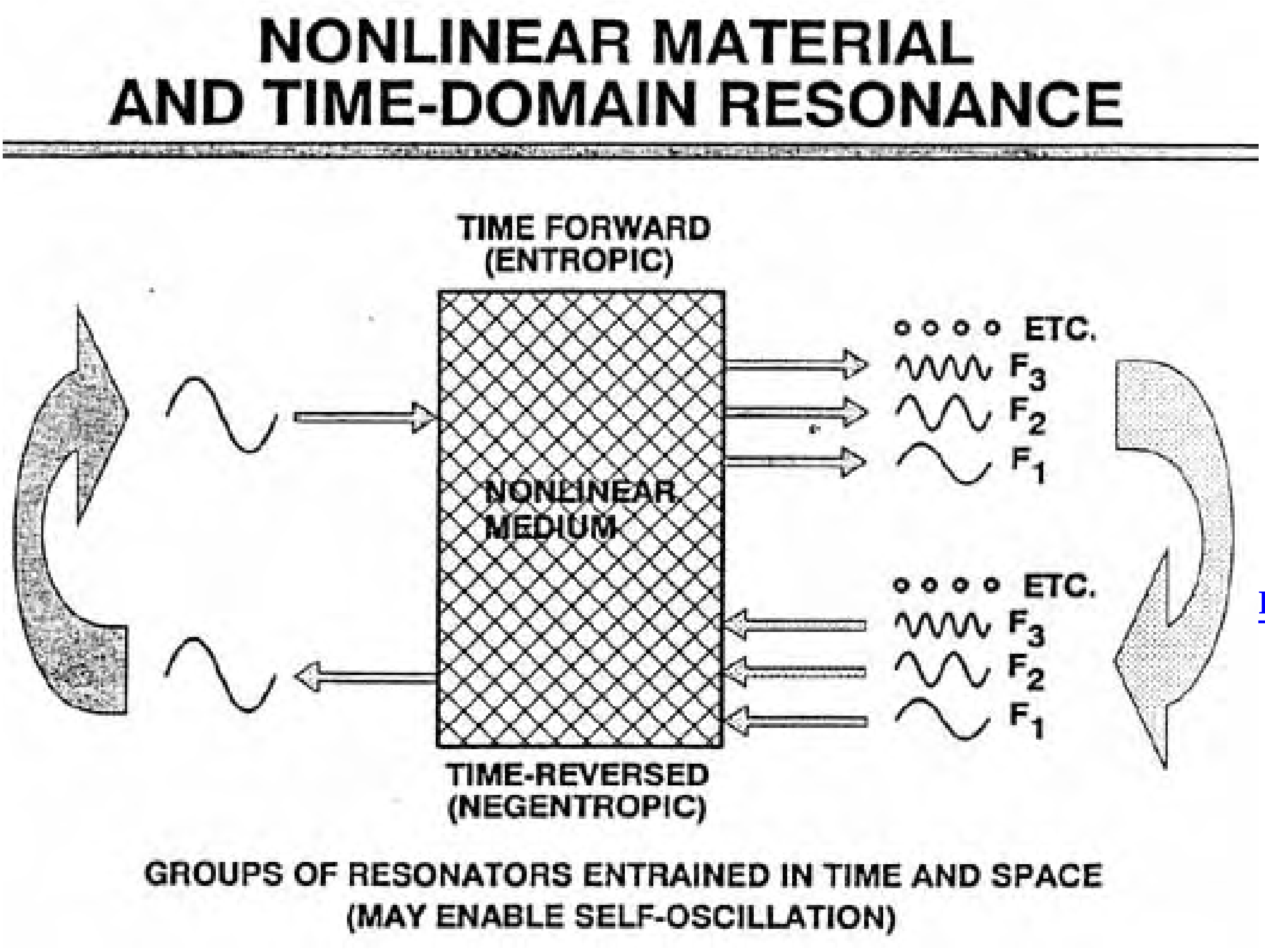

NONLINEAR MATERIAL AND TIME-DOMAIN RESONANCE

TIME FORWARD
(ENTROPIC)

NONLINEAR MEDIUM

o o o o ETC.
F_3
F_2
F_1

o o o o ETC.
F_3
F_2
F_1

TIME-REVERSED
(NEGENTROPIC)

GROUPS OF RESONATORS ENTRAINED IN TIME AND SPACE
(MAY ENABLE SELF-OSCILLATION)

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SUBHARMONIC OSCILLATION

- **CAN TRANSLATE FROM ONE FREQUENCY REGIME TO ANOTHER.**
- **E.G., OPTICAL TO MICROWAVE**
  - **HOWEVER, MUST PRESERVE HARMONICS**
  - **ONE HARMONIC INTERVAL IS ESSENTIAL**
- **KAZNACHEYEV'S CYTOPATHOGENIC EFFECT:**
  - **QUARTZ PASSES ONE HARMONIC INTERVAL.**
  - **WINDOW GLASS DOES NOT.**
- **WHITTAKER'S INFOLDED EM STRUCTURE**
- **DEVYATKOV'S INFORMATION CONTENT OF THE FIELD.**
- **MULTIPLE PHASELOCKED WOODPECKER PULSE REPETITION RATES.**

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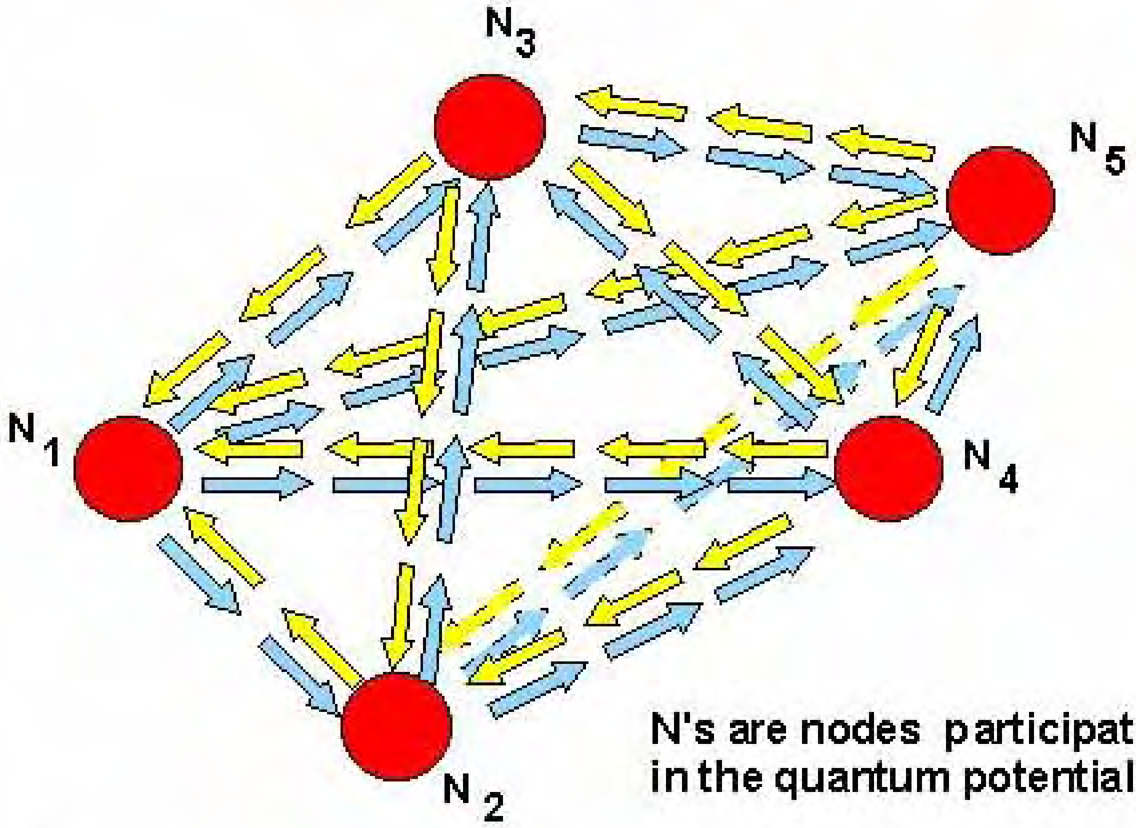

N's are nodes participating in the quantum potential.

The quantum potential exists as narrow, laser-like beams between participating nodes, even when the nodes are widely separated. The beam space is multiply-connected; transmission is instantaneous.

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QUANTUM POTENTIAL CHARACTERISTICS

- **NO POINT SOURCE**
- **QP BETWEEN TWO PARTICLES**
  - INTERACTION DOES NOT VANISH AS SPATIAL SEPARATION BECOMES VERY LARGE

  - INSTANTANEOUS CONNECTION

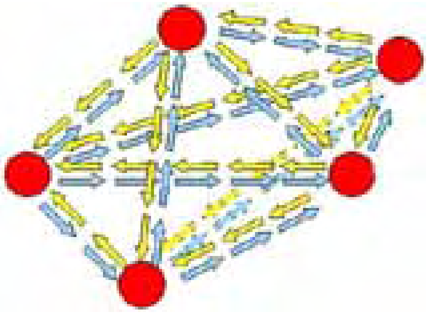

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- **DEPENDS ON QUANTUM STATE OF SYSTEM AS A WHOLE**

- **SYSTEM PARTS CAN BE GREATLY SEPARATED**

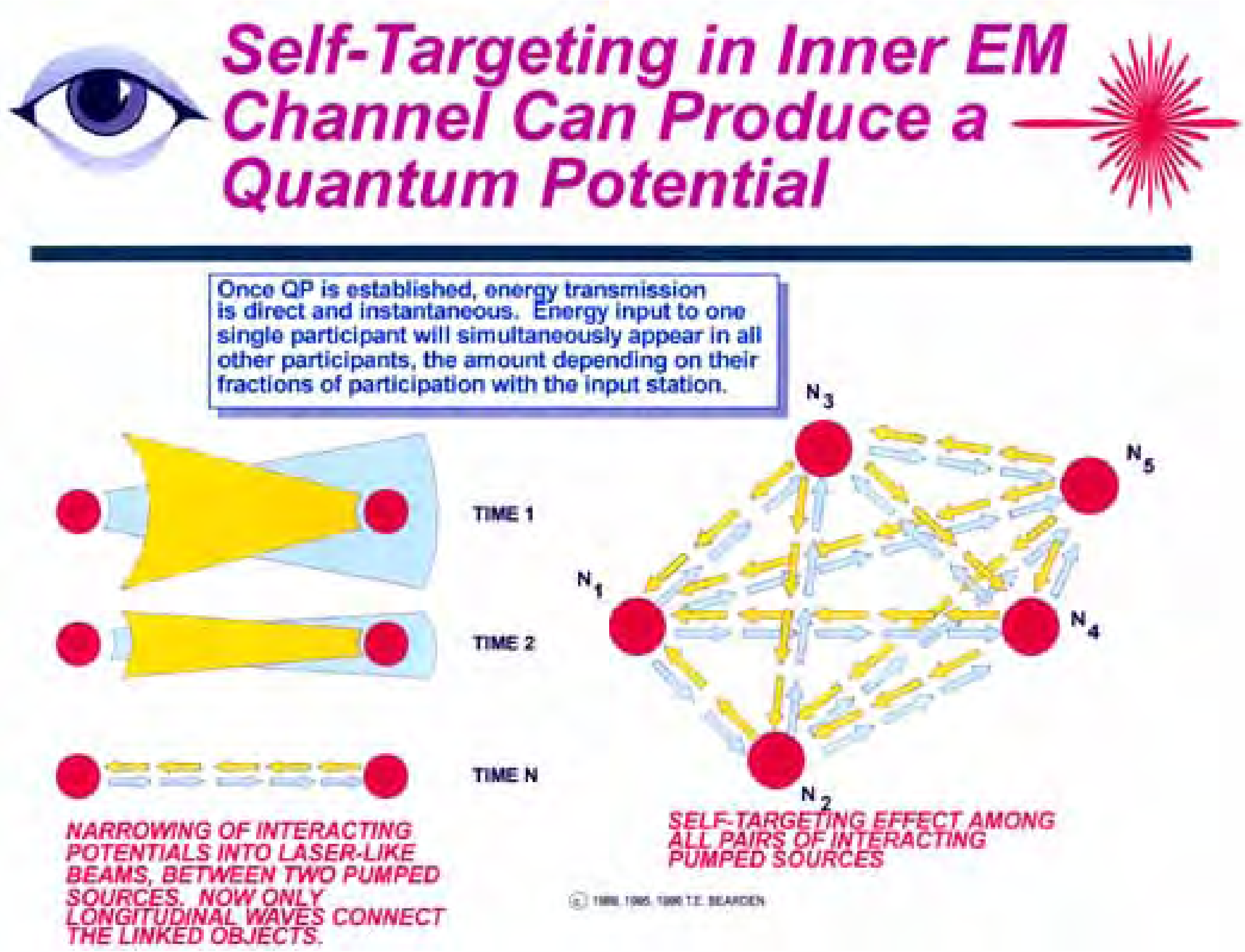

Self-Targeting in Inner EM Channel Can Produce a Quantum Potential

Once QP is established, energy transmission is direct and instantaneous. Energy input to one single participant will simultaneously appear in all other participants, the amount depending on their fractions of participation with the input station.

NARROWING OF INTERACTING POTENTIALS INTO LASER-LIKE BEAMS, BETWEEN TWO PUMPED SOURCES. NOW ONLY LONGITUDINAL WAVES CONNECT THE LINKED OBJECTS.

SELF-TARGETING EFFECT AMONG ALL PAIRS OF INTERACTING PUMPED SOURCES

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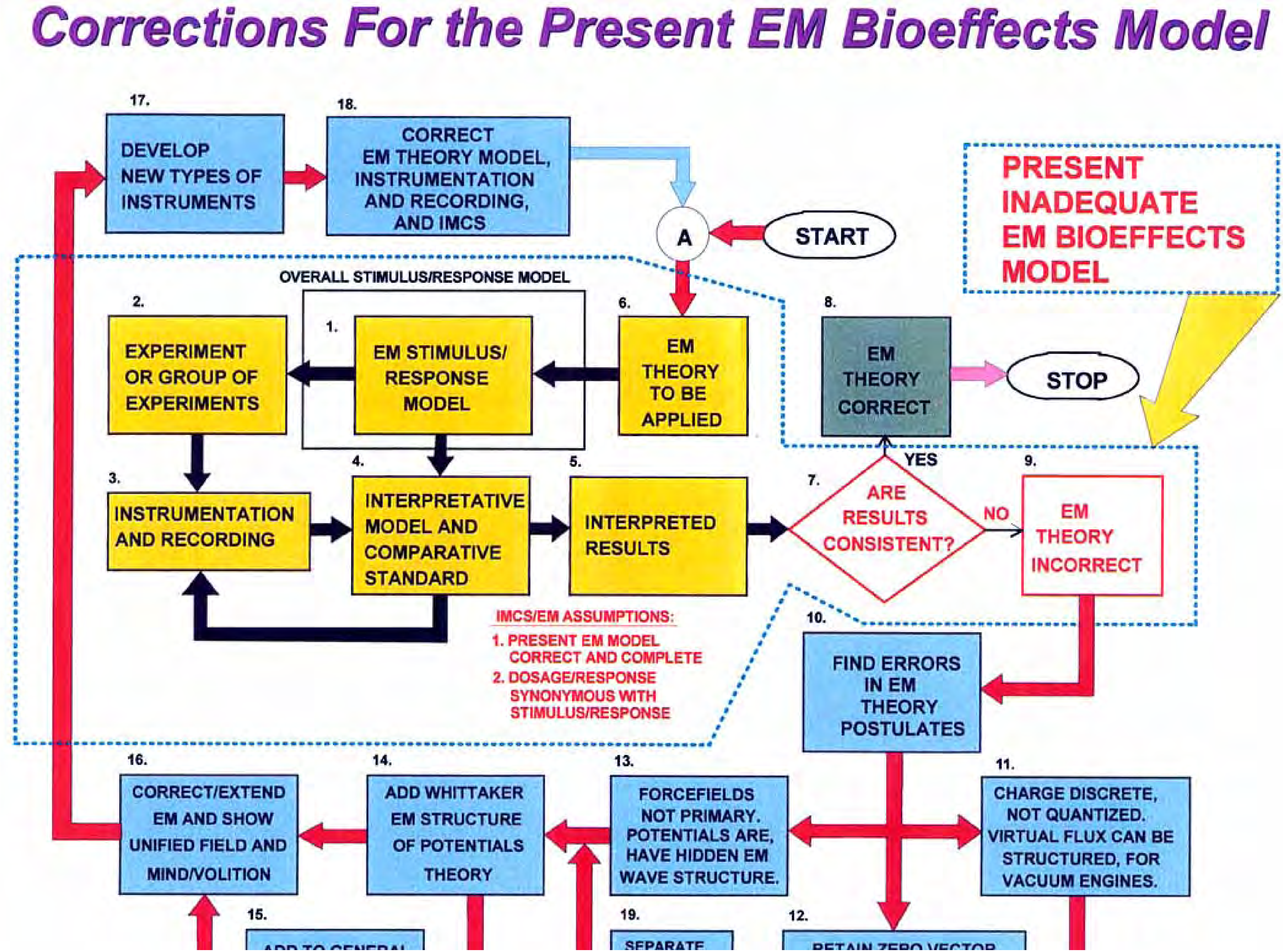

Corrections For the Present EM Bioeffects Model

17. DEVELOP NEW TYPES OF INSTRUMENTS

18. CORRECT EM THEORY MODEL, INSTRUMENTATION AND RECORDING, AND IMCS

A

START

PRESENT INADEQUATE EM BIOEFFECTS MODEL

OVERALL STIMULUS/RESPONSE MODEL

2. EXPERIMENT OR GROUP OF EXPERIMENTS

1. EM STIMULUS/ RESPONSE MODEL

6. EM THEORY TO BE APPLIED

8. EM THEORY CORRECT

STOP

3. INSTRUMENTATION AND RECORDING

4. INTERPRETATIVE MODEL AND COMPARATIVE STANDARD

5. INTERPRETED RESULTS

7. ARE RESULTS CONSISTENT?

YES

NO

9. EM THEORY INCORRECT

IMCS/EM ASSUMPTIONS:

1. PRESENT EM MODEL CORRECT AND COMPLETE
2. DOSAGE/RESPONSE SYNONYMOUS WITH STIMULUS/RESPONSE

10. FIND ERRORS IN EM THEORY POSTULATES

16. CORRECT/EXTEND EM AND SHOW UNIFIED FIELD AND MIND/VOLITION

14. ADD WHITTAKER EM STRUCTURE OF POTENTIALS THEORY

13. FORCEFIELDS NOT PRIMARY. POTENTIALS ARE, HAVE HIDDEN EM WAVE STRUCTURE.

11. CHARGE DISCRETE, NOT QUANTIZED. VIRTUAL FLUX CAN BE STRUCTURED, FOR VACUUM ENGINES.

15. ADD TO GENERAL

19. SEPARATE

12. RETAIN ZERO VECTOR

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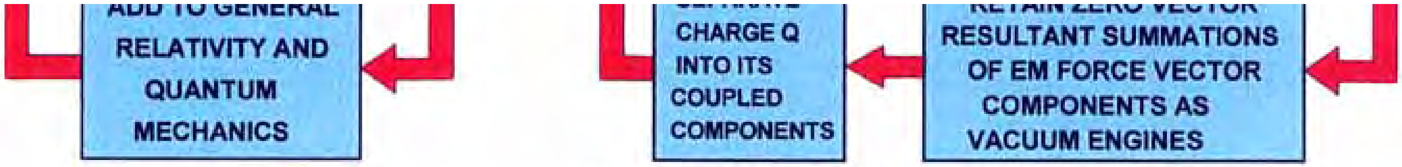
ADD TO GENERAL RELATIVITY AND QUANTUM MECHANICS
SEPARATE CHARGE Q INTO ITS COUPLED COMPONENTS
RETAIN ZERO VECTOR RESULTANT SUMMATIONS OF EM FORCE VECTOR COMPONENTS AS VACUUM ENGINES

JCS-44

ⓒ 1991, 1993, 1995 T.E. BEARDEN

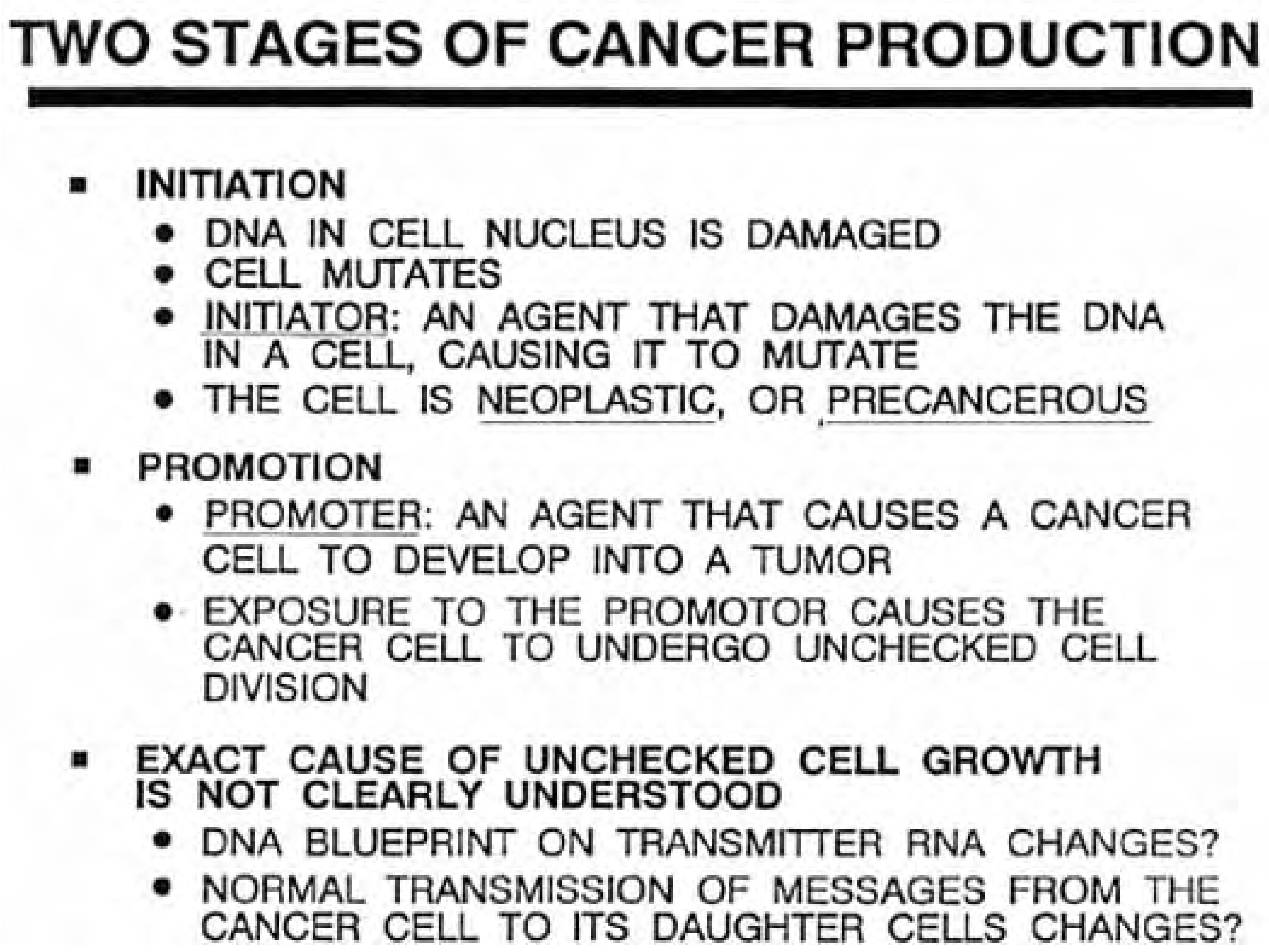

TWO STAGES OF CANCER PRODUCTION

- **INITIATION**
  - DNA IN CELL NUCLEUS IS DAMAGED
  - CELL MUTATES
  - INITIATOR: AN AGENT THAT DAMAGES THE DNA IN A CELL, CAUSING IT TO MUTATE
  - THE CELL IS NEOPLASTIC, OR PRECANCEROUS
- **PROMOTION**
  - PROMOTER: AN AGENT THAT CAUSES A CANCER CELL TO DEVELOP INTO A TUMOR
  - EXPOSURE TO THE PROMOTOR CAUSES THE CANCER CELL TO UNDERGO UNCHECKED CELL DIVISION
- **EXACT CAUSE OF UNCHECKED CELL GROWTH IS NOT CLEARLY UNDERSTOOD**
  - DNA BLUEPRINT ON TRANSMITTER RNA CHANGES?
  - NORMAL TRANSMISSION OF MESSAGES FROM THE CANCER CELL TO ITS DAUGHTER CELLS CHANGES?

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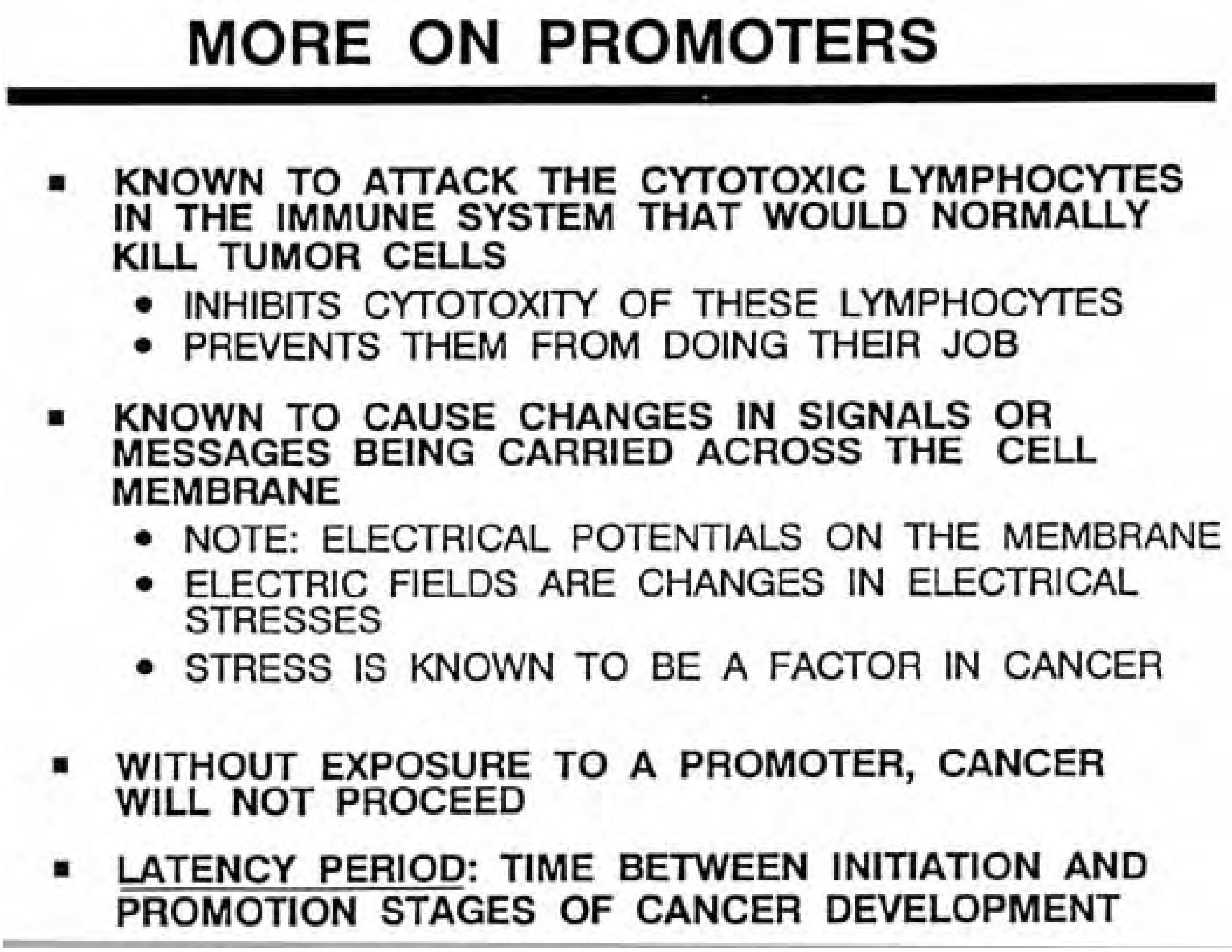

MORE ON PROMOTERS

- KNOWN TO ATTACK THE CYTOTOXIC LYMPHOCYTES IN THE IMMUNE SYSTEM THAT WOULD NORMALLY KILL TUMOR CELLS
  - INHIBITS CYTOTOXITY OF THESE LYMPHOCYTES
  - PREVENTS THEM FROM DOING THEIR JOB
- KNOWN TO CAUSE CHANGES IN SIGNALS OR MESSAGES BEING CARRIED ACROSS THE CELL MEMBRANE
  - NOTE: ELECTRICAL POTENTIALS ON THE MEMBRANE
  - ELECTRIC FIELDS ARE CHANGES IN ELECTRICAL STRESSES
  - STRESS IS KNOWN TO BE A FACTOR IN CANCER
- WITHOUT EXPOSURE TO A PROMOTER, CANCER WILL NOT PROCEED
- LATENCY PERIOD: TIME BETWEEN INITIATION AND PROMOTION STAGES OF CANCER DEVELOPMENT

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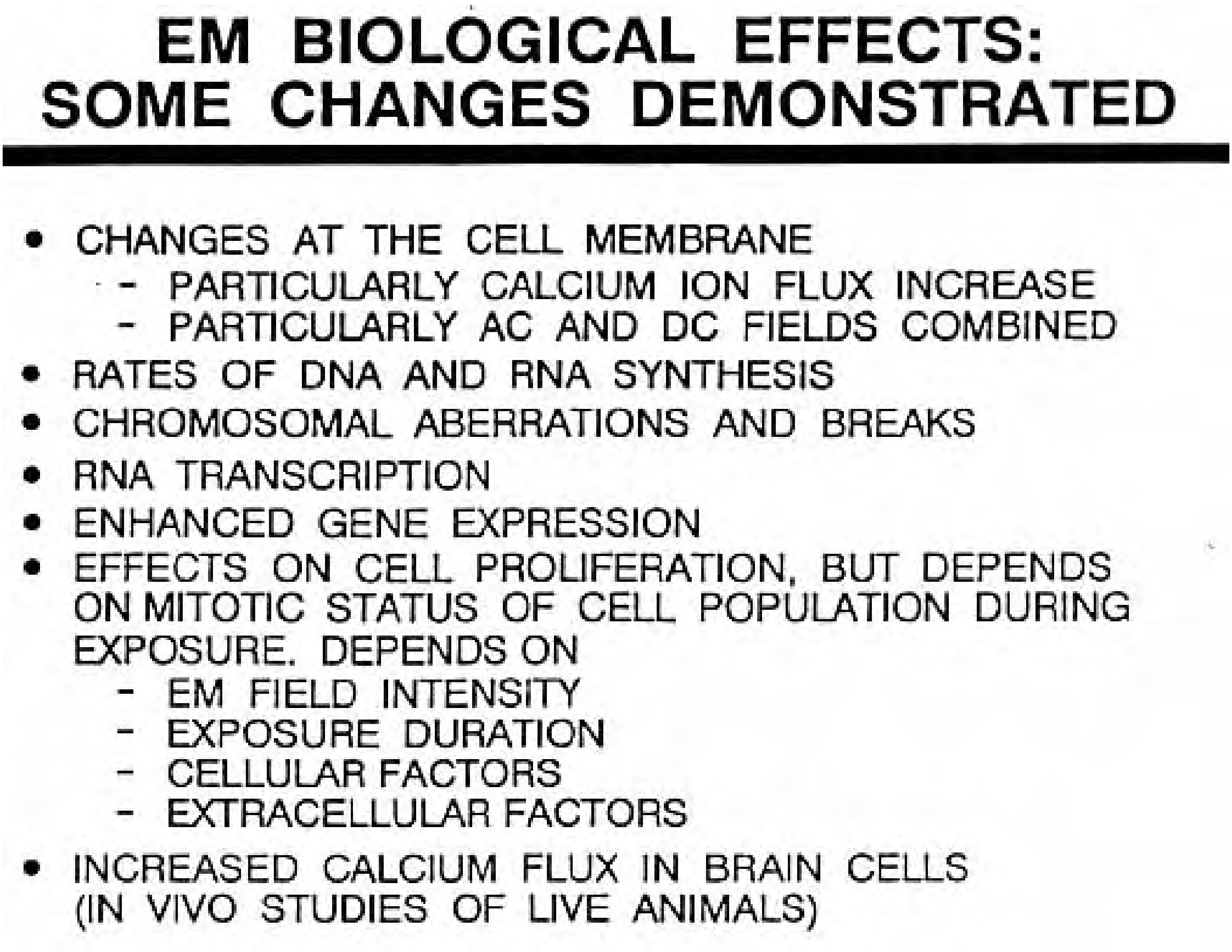

EM BIOLOGICAL EFFECTS: SOME CHANGES DEMONSTRATED

- CHANGES AT THE CELL MEMBRANE
  - PARTICULARLY CALCIUM ION FLUX INCREASE
  - PARTICULARLY AC AND DC FIELDS COMBINED
- RATES OF DNA AND RNA SYNTHESIS
- CHROMOSOMAL ABERRATIONS AND BREAKS
- RNA TRANSCRIPTION
- ENHANCED GENE EXPRESSION
- EFFECTS ON CELL PROLIFERATION, BUT DEPENDS ON MITOTIC STATUS OF CELL POPULATION DURING EXPOSURE. DEPENDS ON
  - EM FIELD INTENSITY
  - EXPOSURE DURATION
  - CELLULAR FACTORS
  - EXTRACELLULAR FACTORS
- INCREASED CALCIUM FLUX IN BRAIN CELLS (IN VIVO STUDIES OF LIVE ANIMALS)

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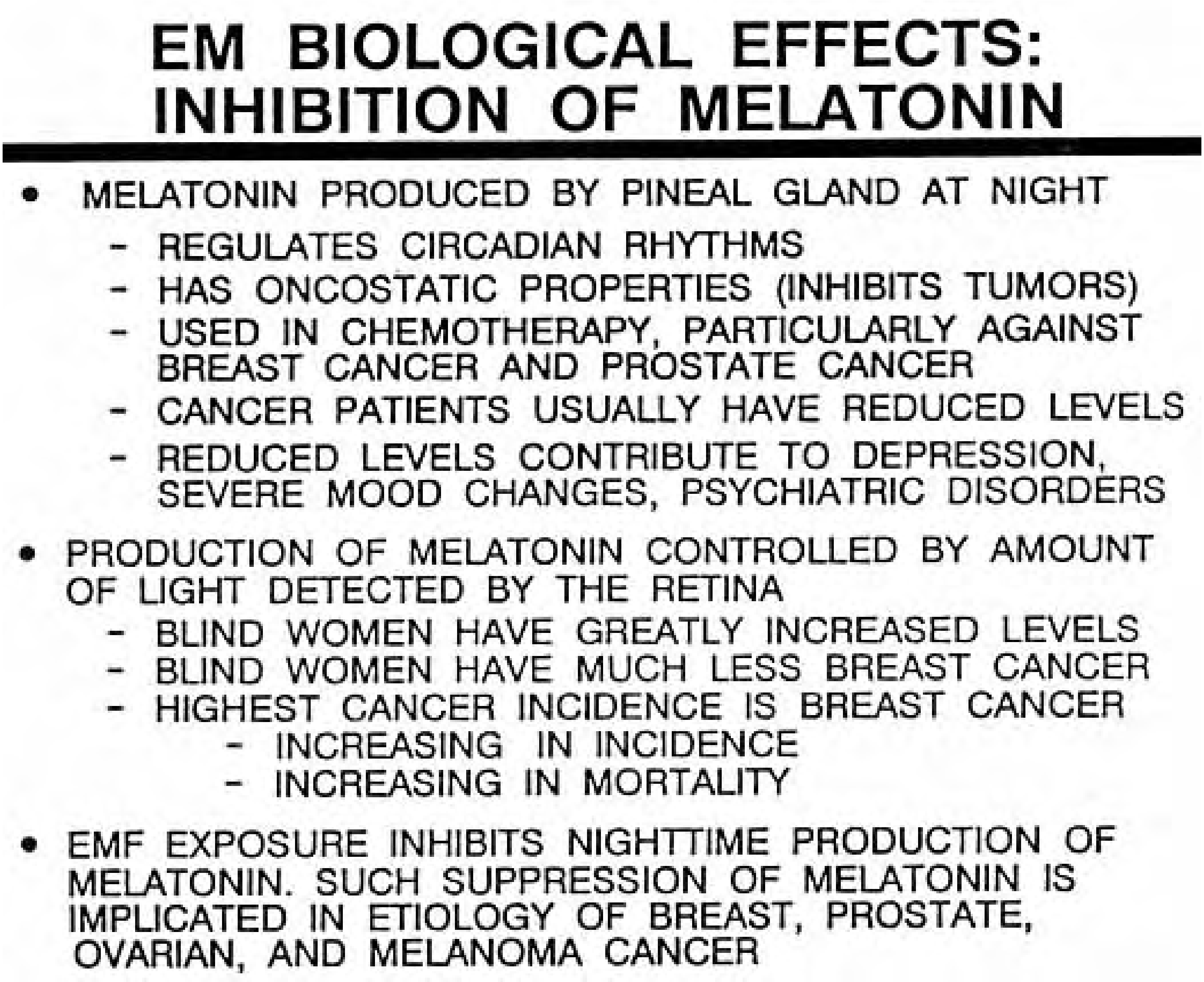

EM BIOLOGICAL EFFECTS: INHIBITION OF MELATONIN

- MELATONIN PRODUCED BY PINEAL GLAND AT NIGHT
  - REGULATES CIRCADIAN RHYTHMS
  - HAS ONCOSTATIC PROPERTIES (INHIBITS TUMORS)
  - USED IN CHEMOTHERAPY, PARTICULARLY AGAINST BREAST CANCER AND PROSTATE CANCER
  - CANCER PATIENTS USUALLY HAVE REDUCED LEVELS
  - REDUCED LEVELS CONTRIBUTE TO DEPRESSION, SEVERE MOOD CHANGES, PSYCHIATRIC DISORDERS
- PRODUCTION OF MELATONIN CONTROLLED BY AMOUNT OF LIGHT DETECTED BY THE RETINA
  - BLIND WOMEN HAVE GREATLY INCREASED LEVELS
  - BLIND WOMEN HAVE MUCH LESS BREAST CANCER
  - HIGHEST CANCER INCIDENCE IS BREAST CANCER
    - INCREASING IN INCIDENCE
    - INCREASING IN MORTALITY
- EMF EXPOSURE INHIBITS NIGHTTIME PRODUCTION OF MELATONIN. SUCH SUPPRESSION OF MELATONIN IS IMPLICATED IN ETIOLOGY OF BREAST, PROSTATE, OVARIAN, AND MELANOMA CANCER

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OTHER EM BIOLOGICAL EFFECTS

- **MAGNETIC FIELD INDUCING OF BIRTH DEFECTS IN CHICKS**
- **MORE CONTROVERSIAL EPIDEMIOLOGY STUDIES FOUND**
  CORRELATIONS BETWEEN EMF AND
  - BRAIN TUMORS
  - MISCARRIAGES IN PREGNANT FEMALES USING VDTS
  - BIRTH DEFECTS
  - INCIDENCE OF LEUKEMIA IN CHILDREN
- **BECKER SHOWED THAT PICOAMPERES OF CURRENT USED**
  IN EM-ASSISTED BONE HEALING CAUSED PROFOUND CELLULAR CHANGES
  - RED BLOOD CELLS DEDIFFERENTIATED
  - SHED HEMOGLOBIN AND GREW NUCLEI
  - REDIFFERENTIATED INTO CARTILAGE-HEALING CELLS
  - REDIFFERENTIATED INTO BONE-HEALING CELLS
  - THEN HEALED THE FRACTURES

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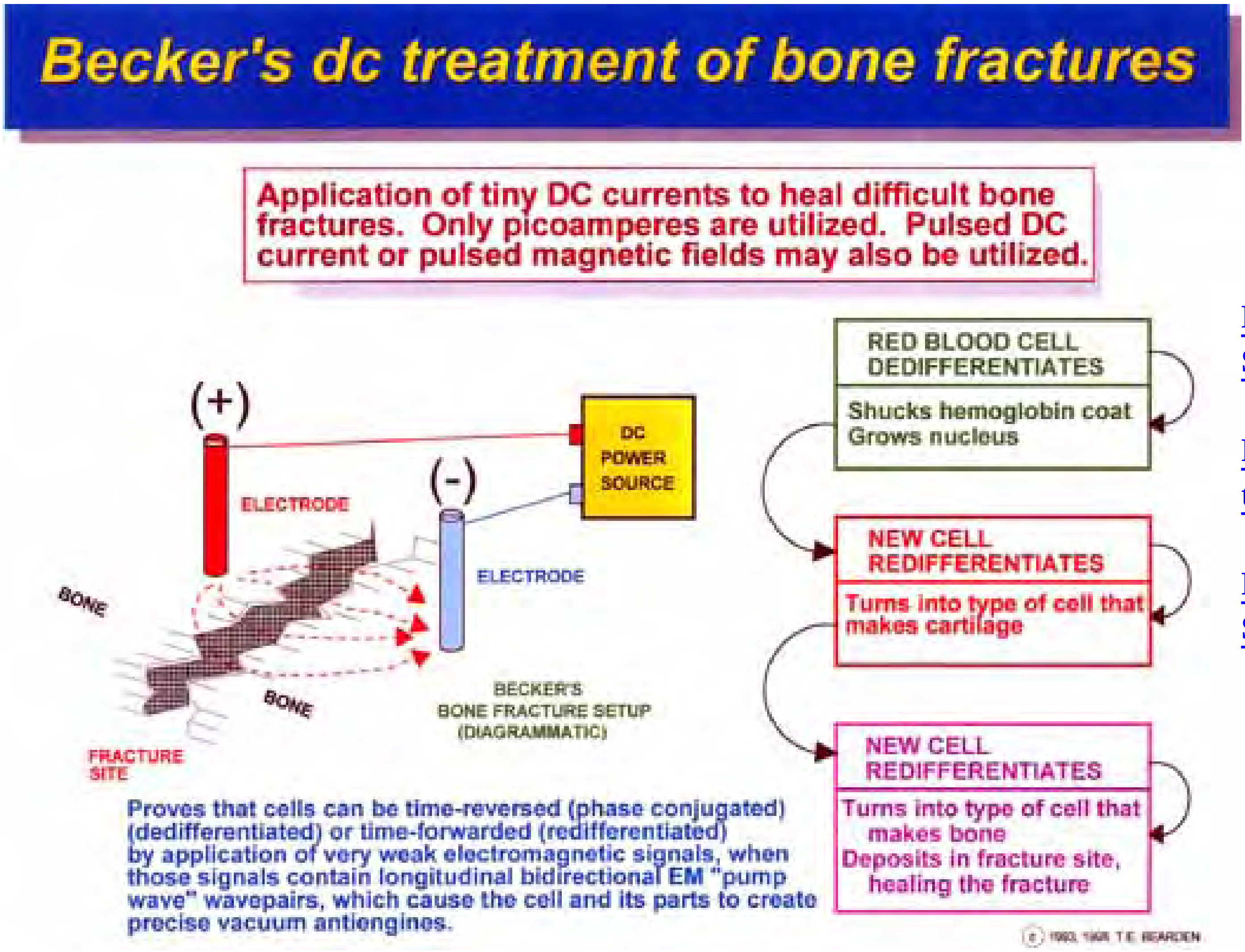

Becker's dc treatment of bone fractures

Application of tiny DC currents to heal difficult bone fractures. Only picoamperes are utilized. Pulsed DC current or pulsed magnetic fields may also be utilized.

(+)
ELECTRODE
(-)
ELECTRODE
DC POWER SOURCE
BONE
BONE
FRACTURE SITE
BECKER'S BONE FRACTURE SETUP (DIAGRAMMATIC)

RED BLOOD CELL DEDIFFERENTIATES

Shucks hemoglobin coat
Grows nucleus

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes cartilage

NEW CELL REDIFFERENTIATES

Turns into type of cell that makes bone
Deposits in fracture site, healing the fracture

Proves that cells can be time-reversed (phase conjugated) (dedifferentiated) or time-forwarded (redifferentiated) by application of very weak electromagnetic signals, when those signals contain longitudinal bidirectional EM "pump wave" wavepairs, which cause the cell and its parts to create precise vacuum antiengines.

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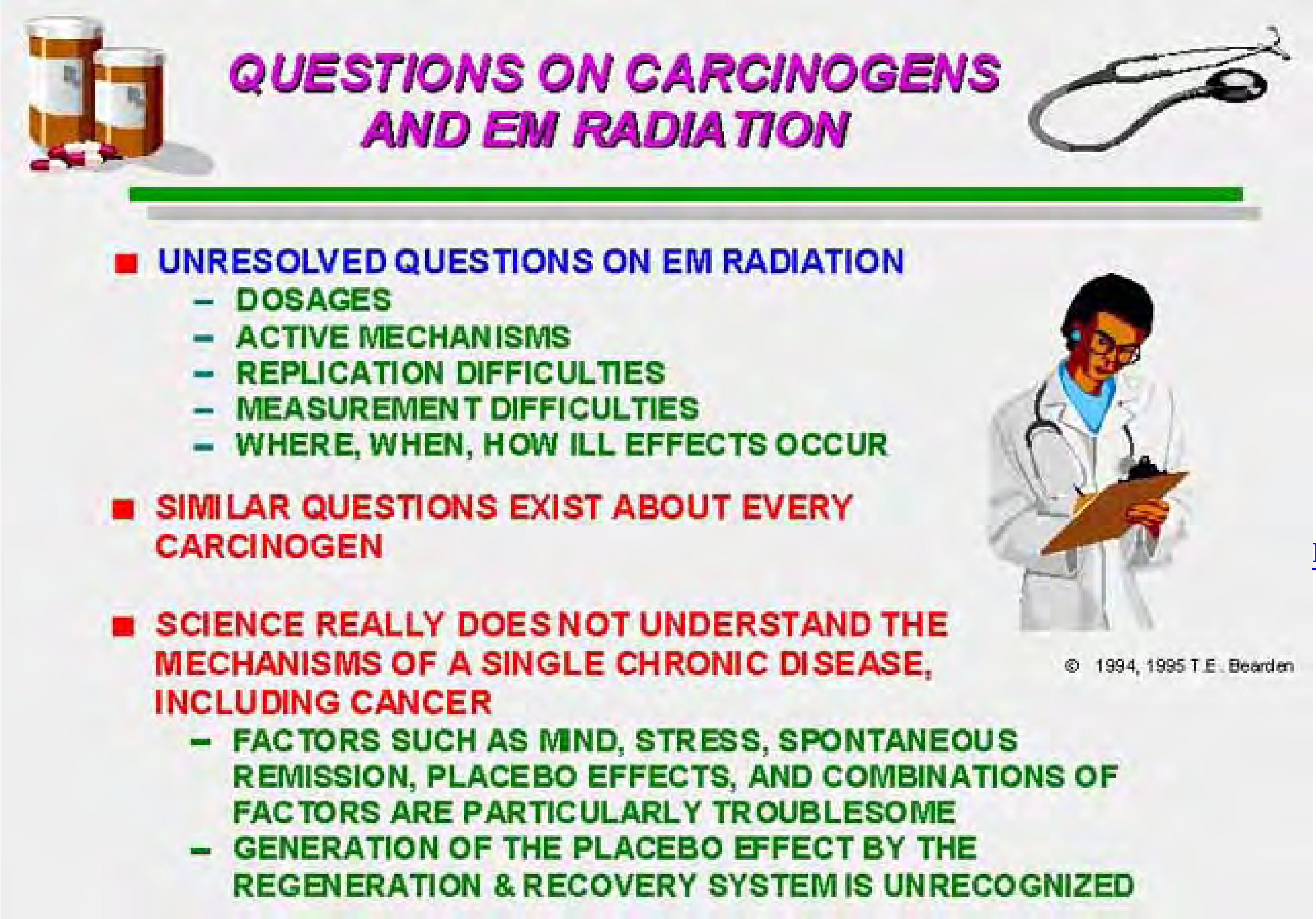

QUESTIONS ON CARCINOGENS AND EM RADIATION

- UNRESOLVED QUESTIONS ON EM RADIATION
  - DOSAGES
  - ACTIVE MECHANISMS
  - REPLICATION DIFFICULTIES
  - MEASUREMENT DIFFICULTIES
  - WHERE, WHEN, HOW ILL EFFECTS OCCUR
- SIMILAR QUESTIONS EXIST ABOUT EVERY CARCINOGEN
- SCIENCE REALLY DOES NOT UNDERSTAND THE MECHANISMS OF A SINGLE CHRONIC DISEASE, INCLUDING CANCER
  - FACTORS SUCH AS MIND, STRESS, SPONTANEOUS REMISSION, PLACEBO EFFECTS, AND COMBINATIONS OF FACTORS ARE PARTICULARLY TROUBLESOME
  - GENERATION OF THE PLACEBO EFFECT BY THE REGENERATION & RECOVERY SYSTEM IS UNRECOGNIZED

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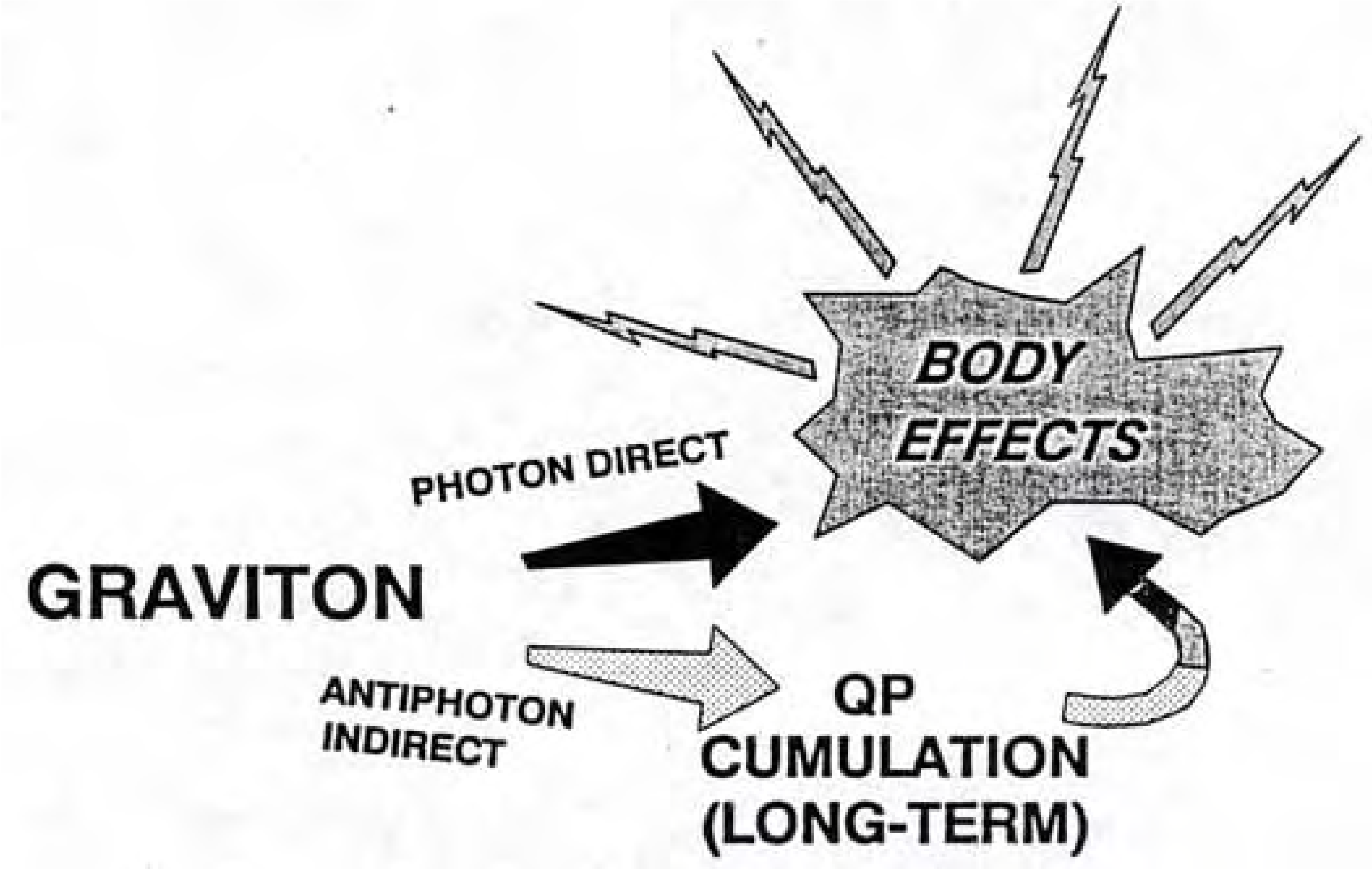

BODY EFFECTS

PHOTON DIRECT

GRAVITON

ANTIPHOTON INDIRECT

QP CUMULATION (LONG-TERM)

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CUMULATIVE FEEDBACK REACTION LOOP FOR INDUCTION OF LONG-TERM EFFECTS

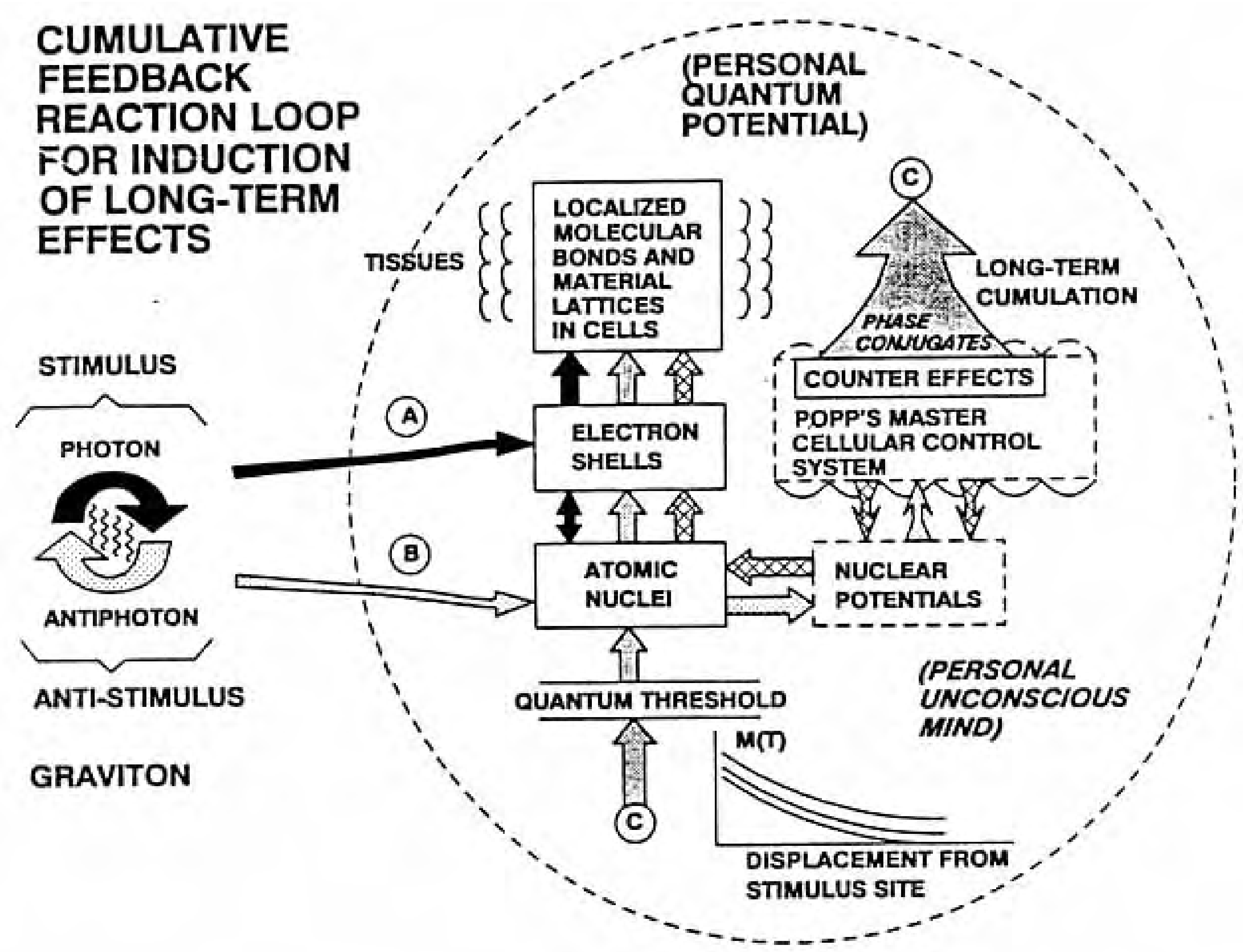
(PERSONAL QUANTUM POTENTIAL)
STIMULUS
PHOTON
ANTIPHOTON
ANTI-STIMULUS
GRAVITON
TISSUES
LOCALIZED MOLECULAR BONDS AND MATERIAL LATTICES IN CELLS
C
LONG-TERM CUMULATION
PHASE CONJUGATES
COUNTER EFFECTS
POPP'S MASTER CELLULAR CONTROL SYSTEM
A
ELECTRON SHELLS
B
ATOMIC NUCLEI
NUCLEAR POTENTIALS
QUANTUM THRESHOLD
(PERSONAL UNCONSCIOUS MIND)
M(T)
C
DISPLACEMENT FROM STIMULUS SITE

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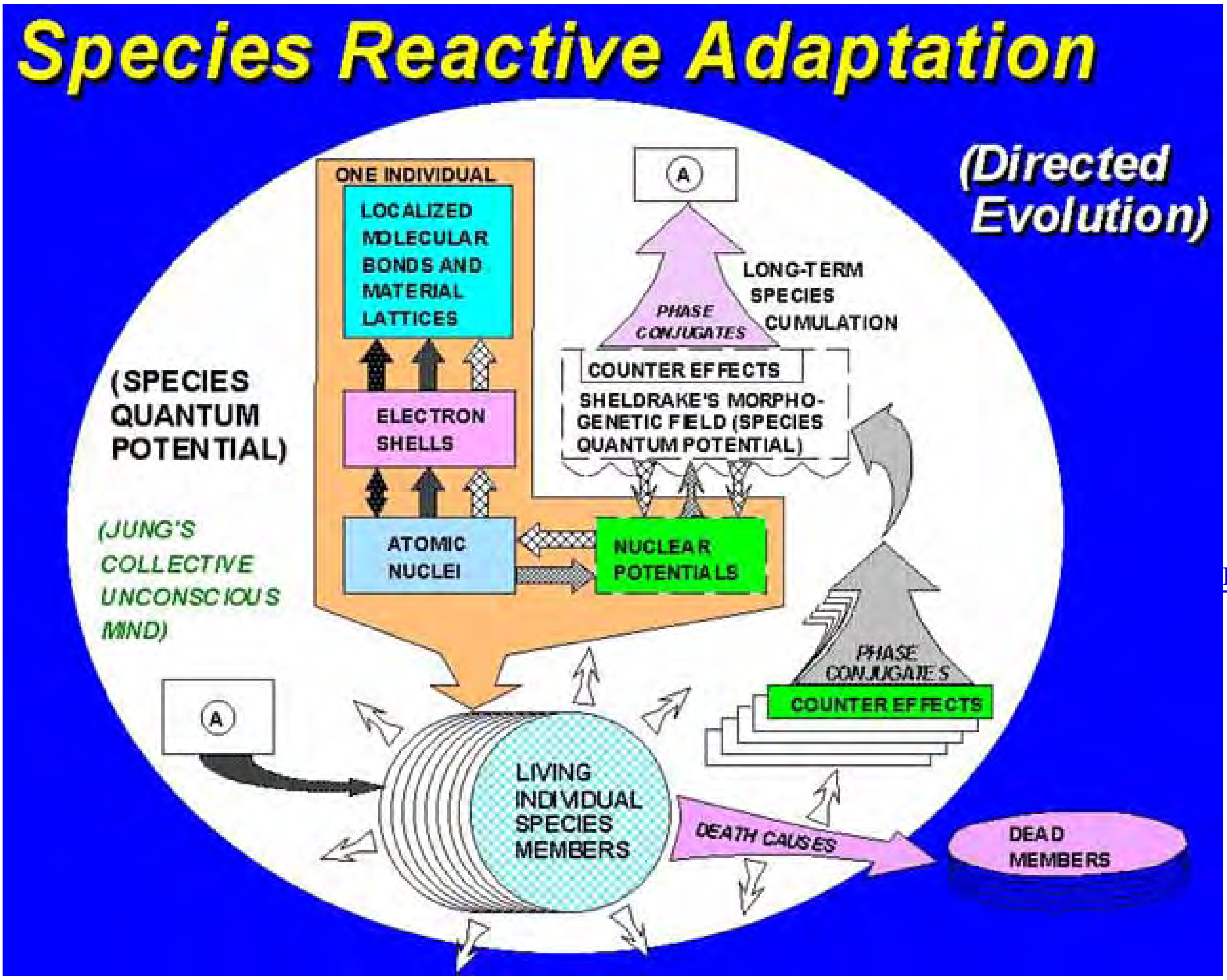

Species Reactive Adaptation

(Directed Evolution)

(SPECIES QUANTUM POTENTIAL)

(JUNG'S COLLECTIVE UNCONSCIOUS MIND)

ONE INDIVIDUAL

LOCALIZED MOLECULAR BONDS AND MATERIAL LATTICES

ELECTRON SHELLS

ATOMIC NUCLEI

NUCLEAR POTENTIALS

A

PHASE CONJUGATES

LONG-TERM SPECIES CUMULATION

COUNTER EFFECTS

SHELDRAKE'S MORPHOGENETIC FIELD (SPECIES QUANTUM POTENTIAL)

PHASE CONJUGATES

COUNTER EFFECTS

A

LIVING INDIVIDUAL SPECIES MEMBERS

DEATH CAUSES

DEAD MEMBERS

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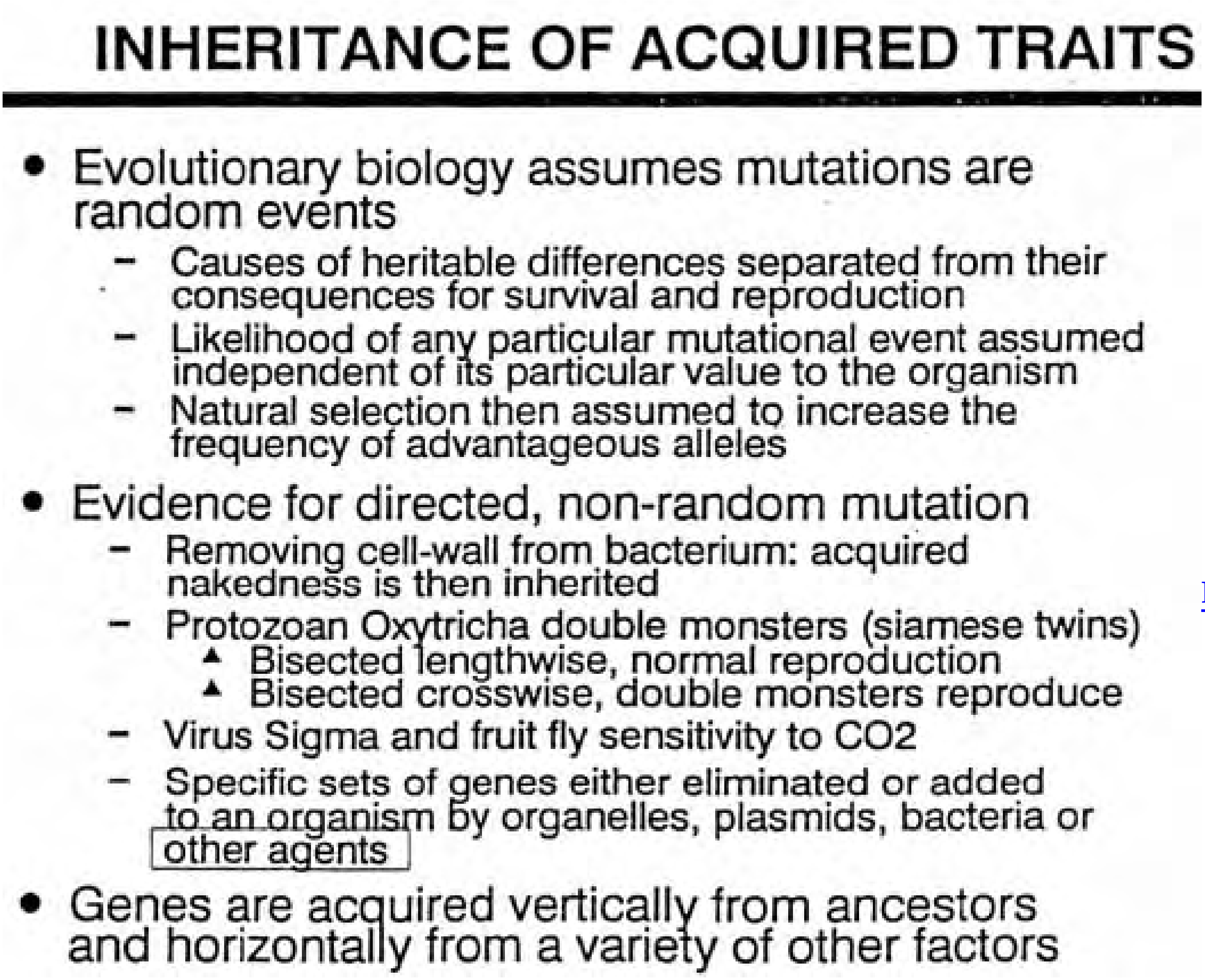

INHERITANCE OF ACQUIRED TRAITS

- Evolutionary biology assumes mutations are random events
  - Causes of heritable differences separated from their consequences for survival and reproduction
  - Likelihood of any particular mutational event assumed independent of its particular value to the organism
  - Natural selection then assumed to increase the frequency of advantageous alleles
- Evidence for directed, non-random mutation
  - Removing cell-wall from bacterium: acquired nakedness is then inherited
  - Protozoan Oxytricha double monsters (siamese twins)
    - ▲ Bisected lengthwise, normal reproduction
    - ▲ Bisected crosswise, double monsters reproduce
  - Virus Sigma and fruit fly sensitivity to CO2
  - Specific sets of genes either eliminated or added to an organism by organelles, plasmids, bacteria or other agents
- Genes are acquired vertically from ancestors and horizontally from a variety of other factors

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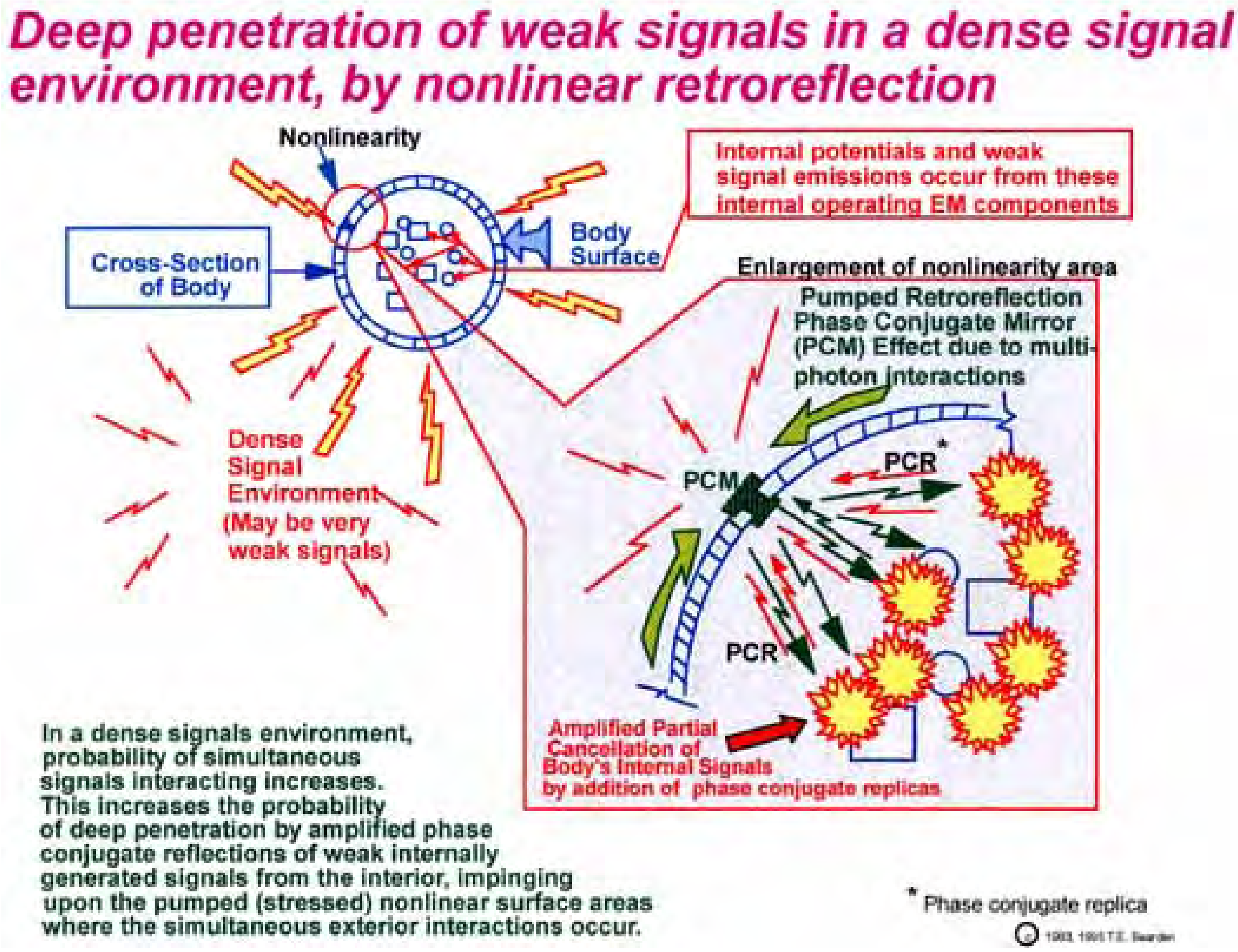

Deep penetration of weak signals in a dense signal environment, by nonlinear retroreflection

Nonlinearity
Cross-Section of Body
Body Surface
Dense Signal Environment (May be very weak signals)
Enlargement of nonlinearity area
PCM
PCR*
PCR*

Internal potentials and weak signal emissions occur from these internal operating EM components

Pumped Retroreflection Phase Conjugate Mirror (PCM) Effect due to multi-photon interactions

Amplified Partial Cancellation of Body's Internal Signals by addition of phase conjugate replicas

In a dense signals environment, probability of simultaneous signals interacting increases. This increases the probability of deep penetration by amplified phase conjugate reflections of weak internally generated signals from the interior, impinging upon the pumped (stressed) nonlinear surface areas where the simultaneous exterior interactions occur.

* Phase conjugate replica

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ANOMALOUS DEPTH PENETRATION

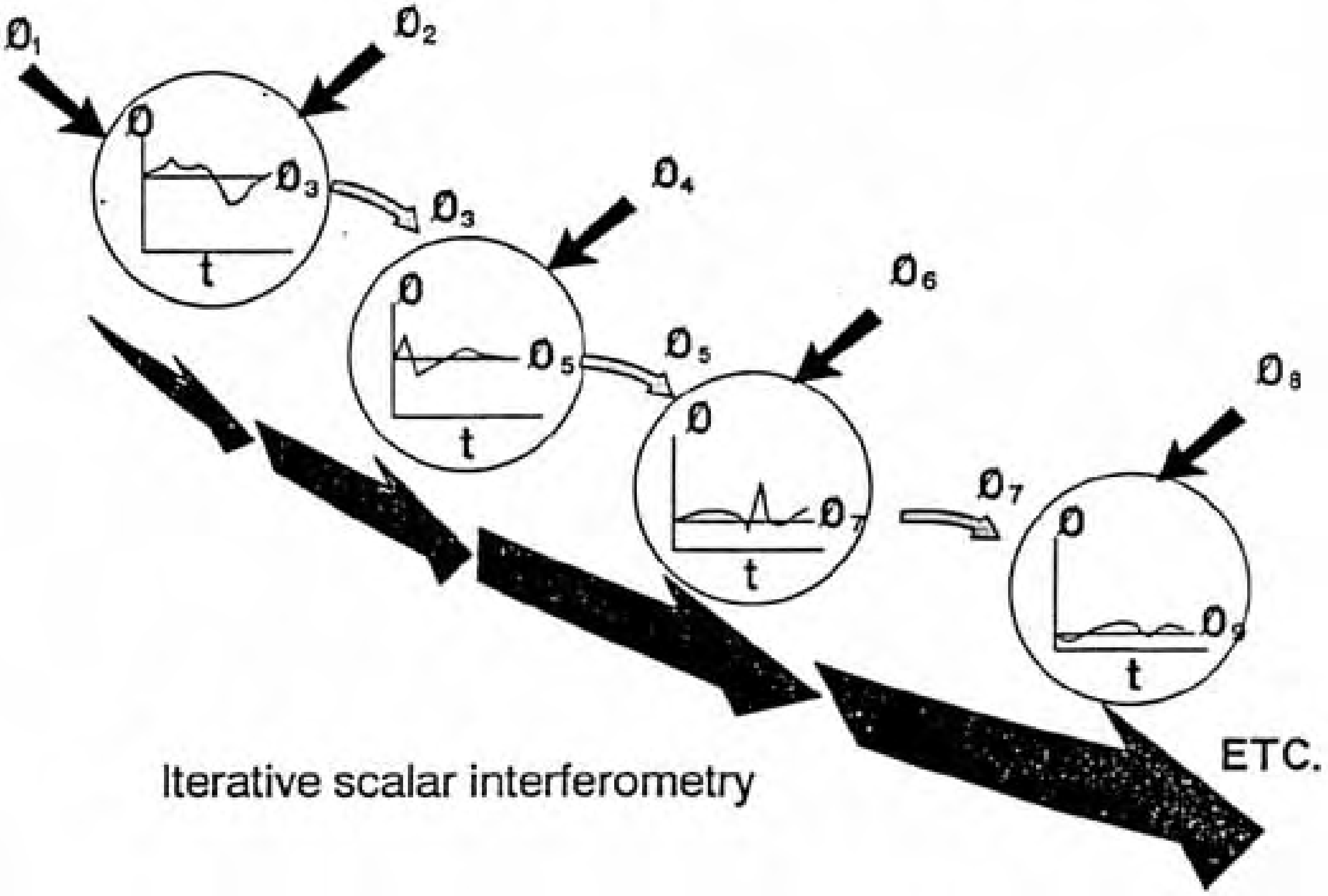
ϕ_1
ϕ_2
ϕ
ϕ_3
t
ϕ_3
ϕ_4
ϕ
ϕ_5
t
ϕ_5
ϕ_6
ϕ
ϕ_7
t
ϕ_7
ϕ_8
ϕ
ϕ_9
t
ETC.

Iterative scalar interferometry

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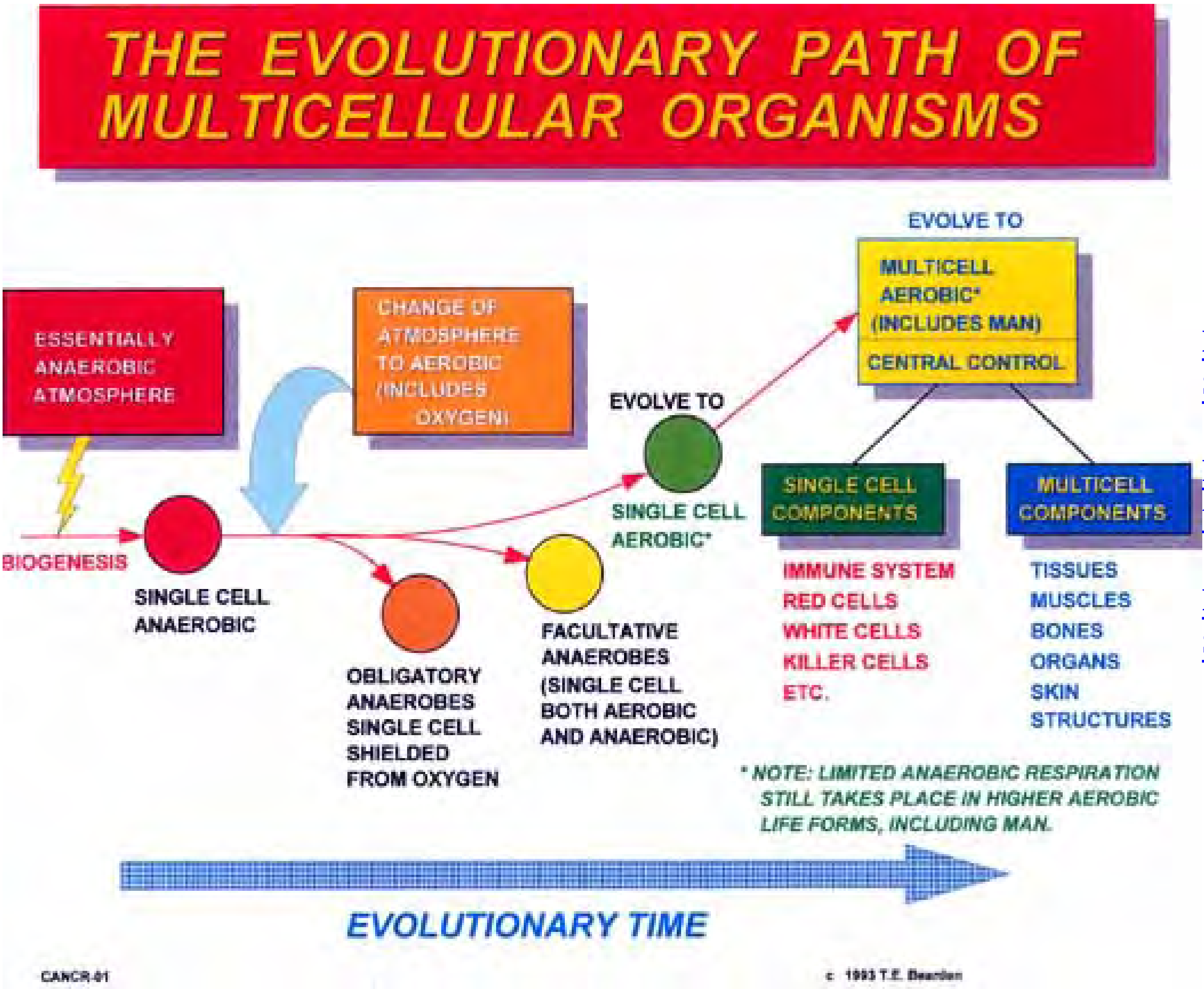

THE EVOLUTIONARY PATH OF MULTICELLULAR ORGANISMS

ESSENTIALLY ANAEROBIC ATMOSPHERE

CHANGE OF ATMOSPHERE TO AEROBIC (INCLUDES OXYGEN)

BIOGENESIS

SINGLE CELL ANAEROBIC

OBLIGATORY ANAEROBES SINGLE CELL SHIELDED FROM OXYGEN

FACULTATIVE ANAEROBES (SINGLE CELL BOTH AEROBIC AND ANAEROBIC)

EVOLVE TO

SINGLE CELL AEROBIC*

EVOLVE TO

MULTICELL AEROBIC* (INCLUDES MAN)

CENTRAL CONTROL

SINGLE CELL COMPONENTS

- IMMUNE SYSTEM
- RED CELLS
- WHITE CELLS
- KILLER CELLS
- ETC.

MULTICELL COMPONENTS

- TISSUES
- MUSCLES
- BONES
- ORGANS
- SKIN
- STRUCTURES

* NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.

EVOLUTIONARY TIME

CANCR-01

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DEVELOPMENT OF MULTI-CELLED ORGANISMS

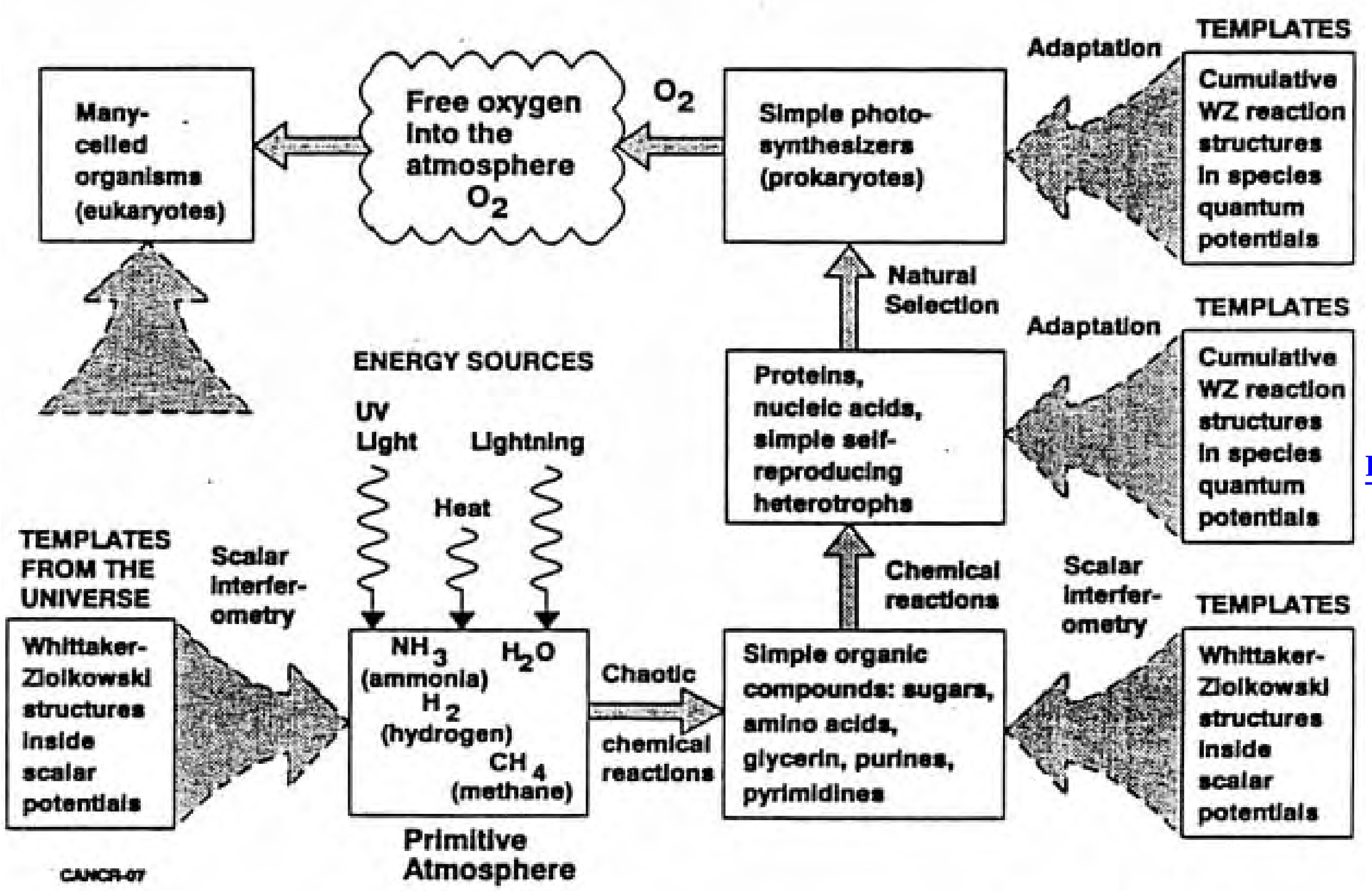
Many-celled organisms (eukaryotes)
Free oxygen into the atmosphere O_2
O_2
Simple photo-synthesizers (prokaryotes)
Adaptation
TEMPLATES
Cumulative WZ reaction structures in species quantum potentials
Natural Selection
Adaptation
TEMPLATES
Cumulative WZ reaction structures in species quantum potentials
ENERGY SOURCES
UV Light
Lightning
Heat
Proteins, nucleic acids, simple self-reproducing heterotrophs
Chemical reactions
TEMPLATES FROM THE UNIVERSE
Scalar interfer-ometry
Whittaker-Ziolkowski structures inside scalar potentials
NH_3 (ammonia)
H_2O
H_2 (hydrogen)
CH_4 (methane)
Primitive Atmosphere
Chaotic chemical reactions
Simple organic compounds: sugars, amino acids, glycerin, purines, pyrimidines
Scalar interfer-ometry
TEMPLATES
Whittaker-Ziolkowski structures inside scalar potentials
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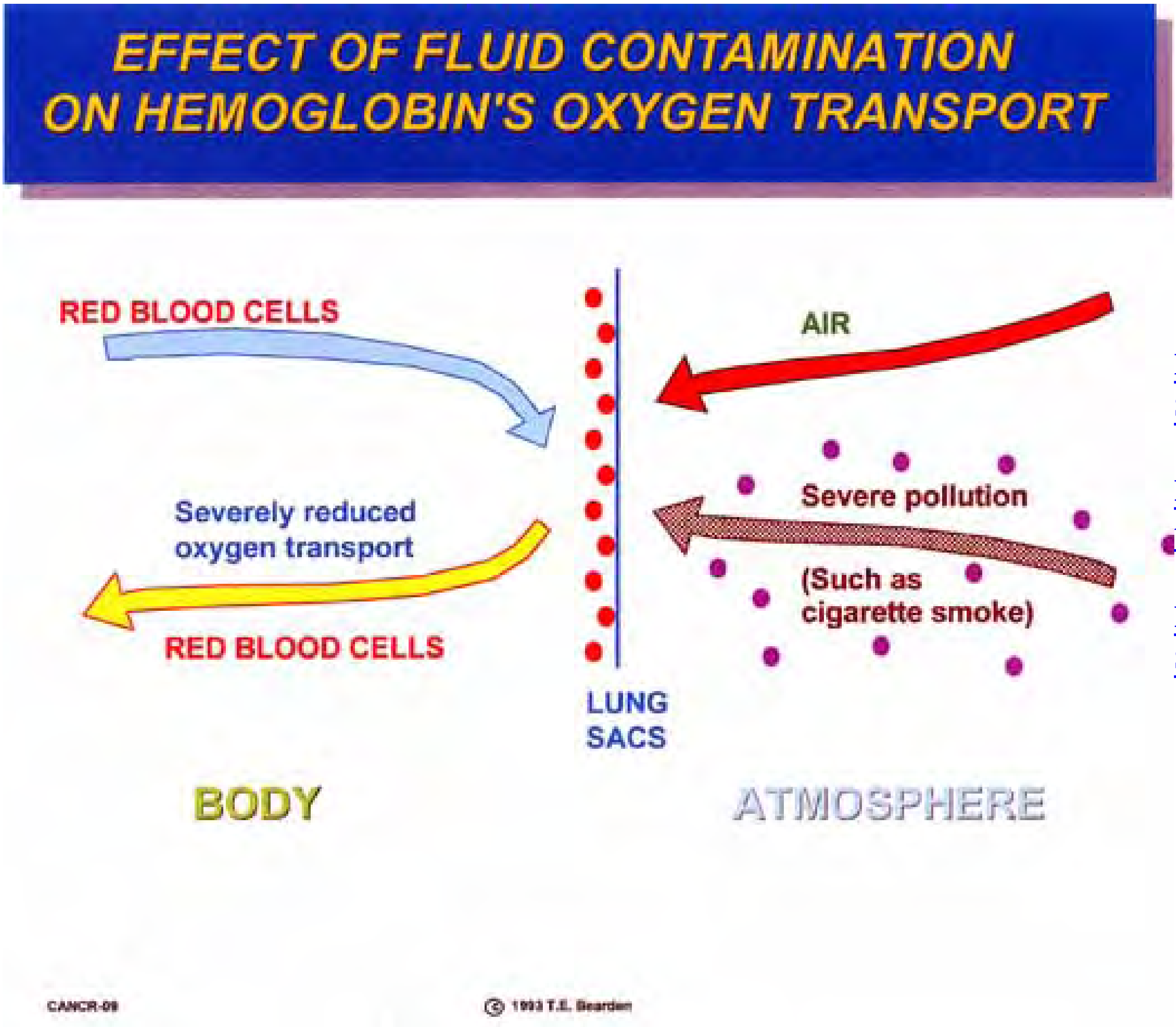

EFFECT OF FLUID CONTAMINATION ON HEMOGLOBIN'S OXYGEN TRANSPORT

RED BLOOD CELLS

AIR

Severe pollution

(Such as cigarette smoke)

Severely reduced oxygen transport

RED BLOOD CELLS

LUNG SACS

BODY

ATMOSPHERE

CANCR-09

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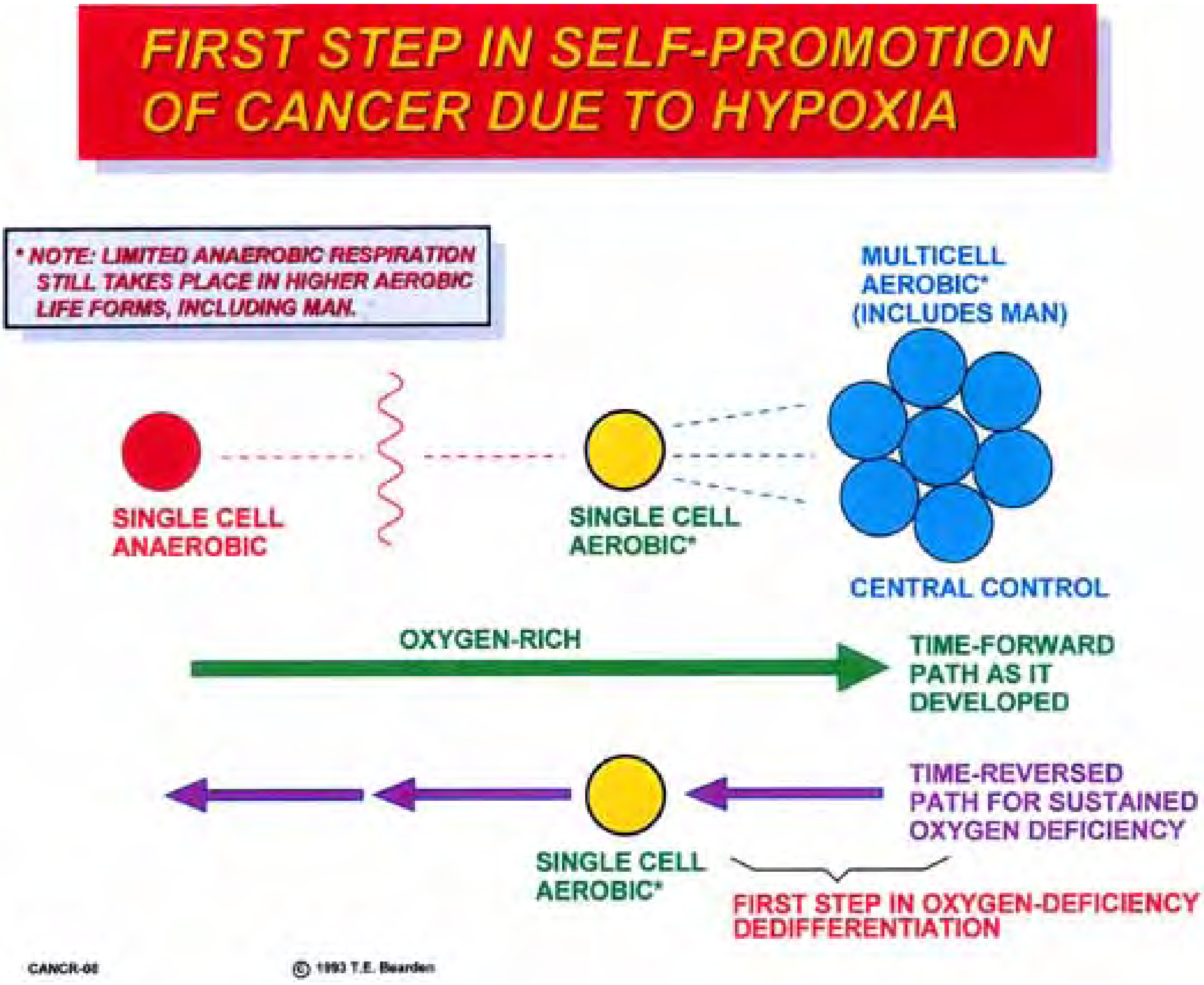

FIRST STEP IN SELF-PROMOTION OF CANCER DUE TO HYPOXIA

* NOTE: LIMITED ANAEROBIC RESPIRATION STILL TAKES PLACE IN HIGHER AEROBIC LIFE FORMS, INCLUDING MAN.

MULTICELL
AEROBIC*
(INCLUDES MAN)

SINGLE CELL
ANAEROBIC

SINGLE CELL
AEROBIC*

CENTRAL CONTROL

OXYGEN-RICH

TIME-FORWARD
PATH AS IT
DEVELOPED

TIME-REVERSED
PATH FOR SUSTAINED
OXYGEN DEFICIENCY

SINGLE CELL
AEROBIC*

FIRST STEP IN OXYGEN-DEFICIENCY
DEDIFFERENTIATION

CANCR-08

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CUMULATIVE GROWTH OF DEDIFFERENTIATION SIGNALS

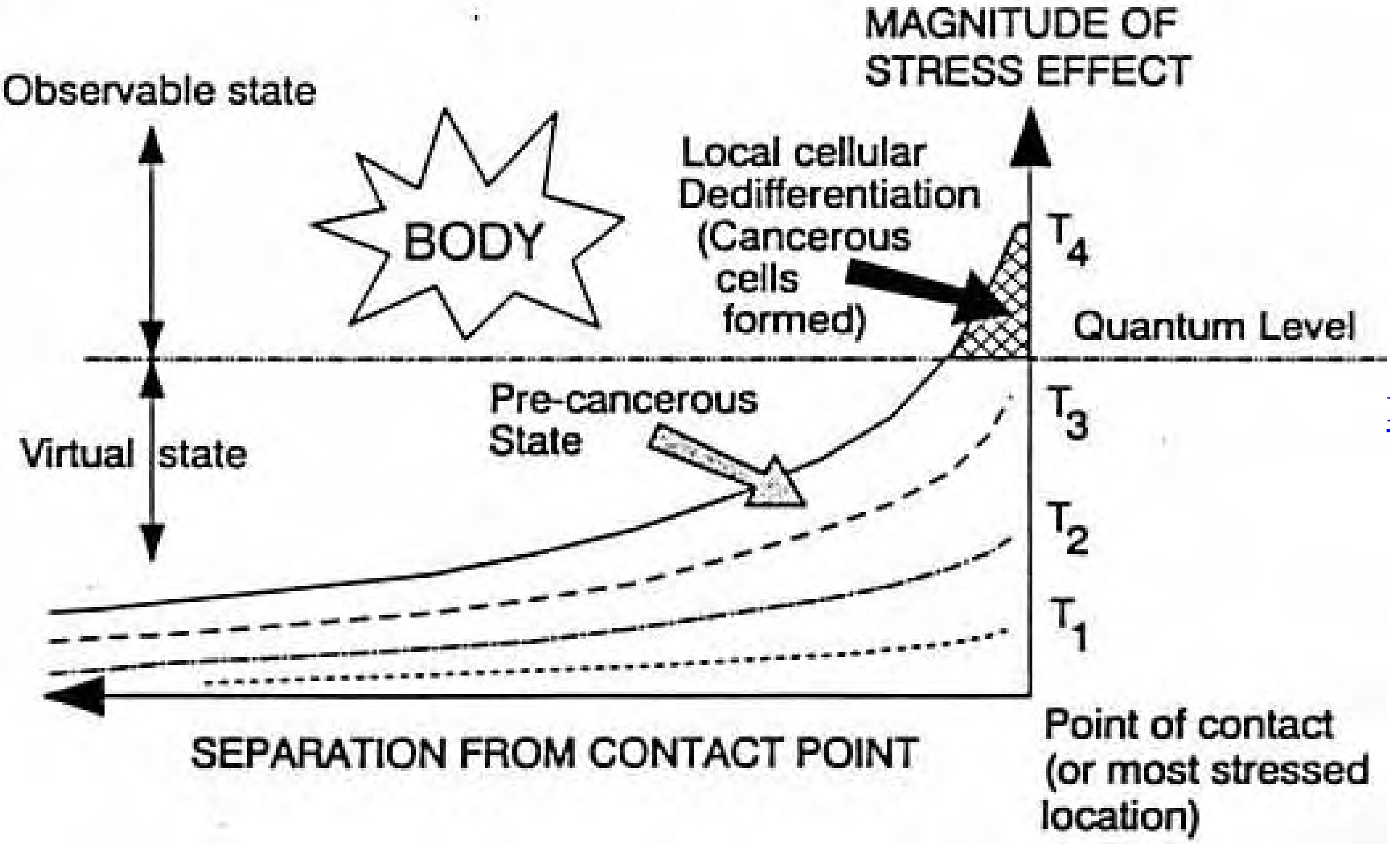
MAGNITUDE OF STRESS EFFECT
Observable state
BODY
Local cellular Dedifferentiation (Cancerous cells formed)
T4
Quantum Level
Virtual state
Pre-cancerous State
T3
T2
T1
SEPARATION FROM CONTACT POINT
Point of contact (or most stressed location)

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CUMULATIVE EMERGENCE OF CANCER INTO THE PHYSICAL STATE

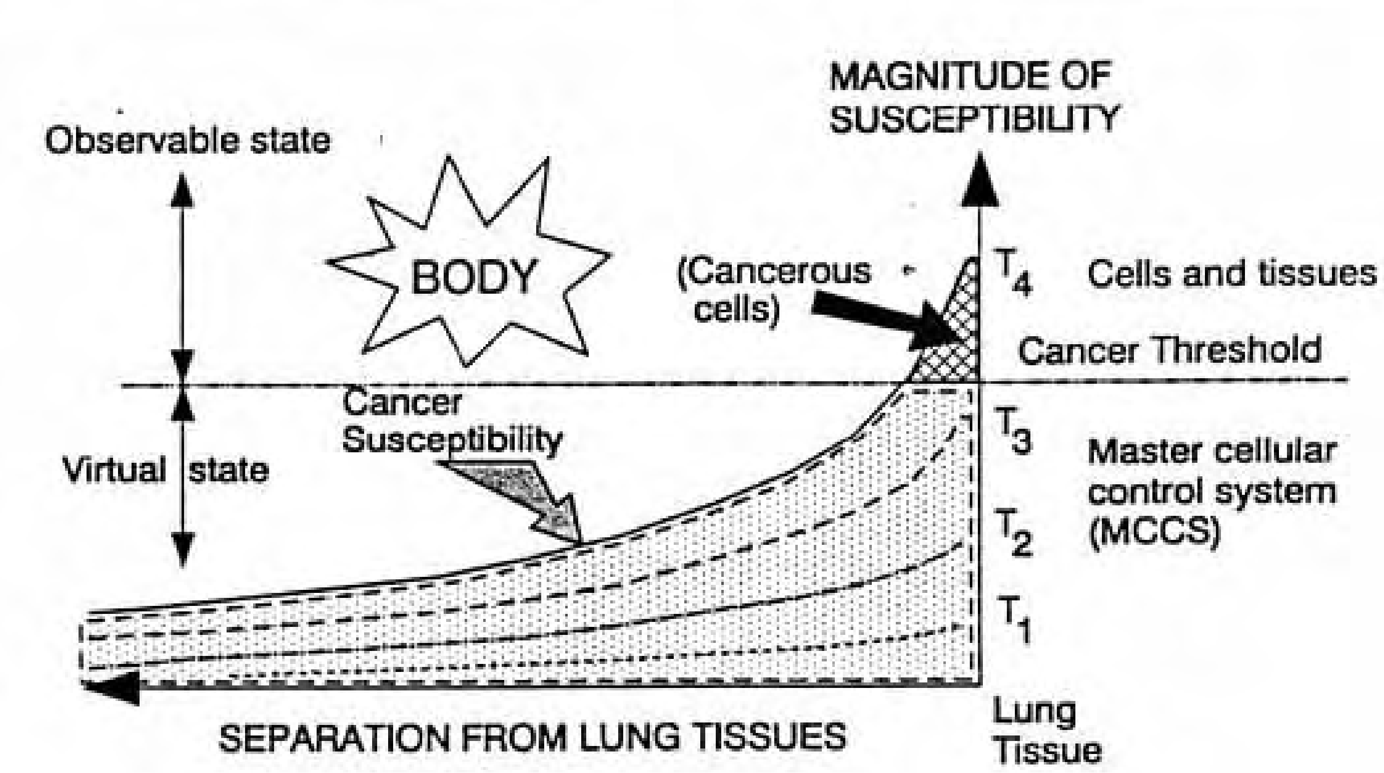
MAGNITUDE OF SUSCEPTIBILITY
Observable state
BODY
(Cancerous cells)
T_4
Cells and tissues
Cancer Threshold
Cancer Susceptibility
Virtual state
T_3
Master cellular control system (MCCS)
T_2
T_1
SEPARATION FROM LUNG TISSUES
Lung Tissue

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PRECANCER STATE CONDITION DETERMINES TREATMENT SUCCESS

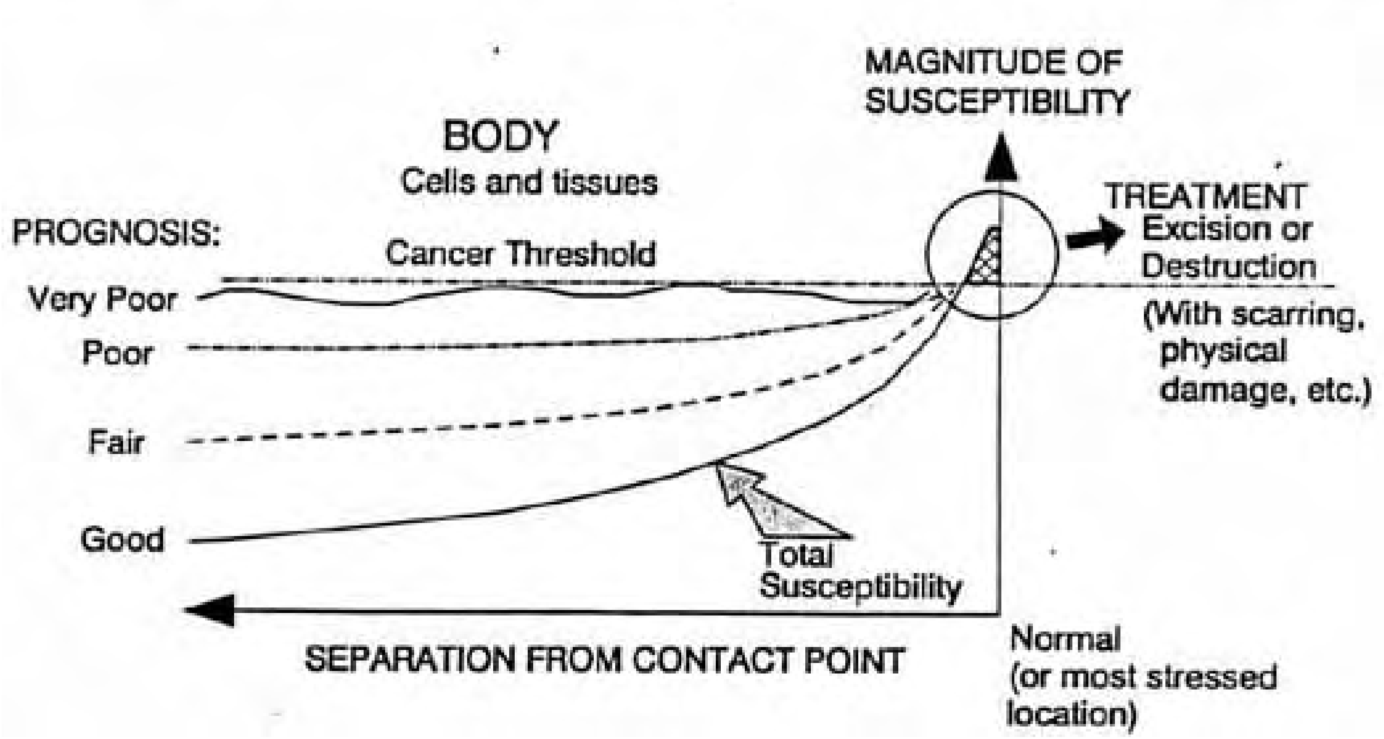

MAGNITUDE OF SUSCEPTIBILITY

BODY
Cells and tissues

PROGNOSIS:

Cancer Threshold

Very Poor

Poor

Fair

Good

TREATMENT
Excision or Destruction
(With scarring, physical damage, etc.)

Total Susceptibility

SEPARATION FROM CONTACT POINT

Normal
(or most stressed location)

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Starting From the Scalar EM View:
A NEW DEFINITION OF CANCER

- CANCER AND LEUKEMIA ARE:

> **Centrally-commanded, final, desperate, "first-step dediffernetiation" adaptive attempts by the stressed affected cells experiencing sustained oxygen shortage, to reverse their cellular evolution and return to the anaerobic stage of their distant ancestry.**

- THE CAUSE IS LONG-TERM CUMULATIVE, AND ELECTROMAGNETIC IN NATURE.
- A TOTAL CURE CAN BE ACHIEVED ELECTRO-
MAGNETICALLY, AS WAS DEMONSTRATED.

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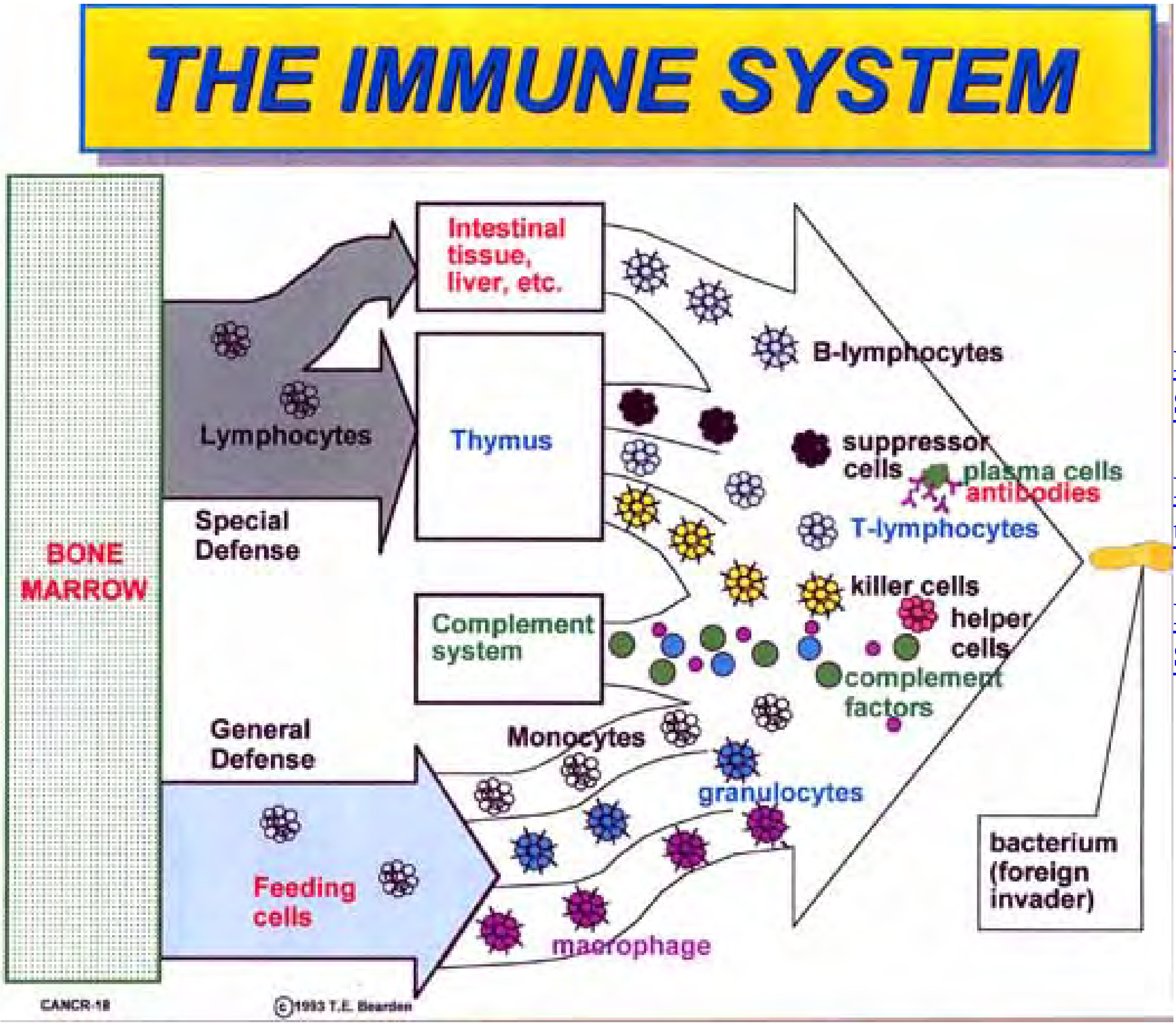

THE IMMUNE SYSTEM

BONE MARROW

Lymphocytes

Special Defense

Intestinal tissue, liver, etc.

Thymus

Complement system

General Defense

Feeding cells

Monocytes

B-lymphocytes

suppressor cells

plasma cells

antibodies

T-lymphocytes

killer cells

helper cells

complement factors

granulocytes

macrophage

bacterium (foreign invader)

CANCR-18

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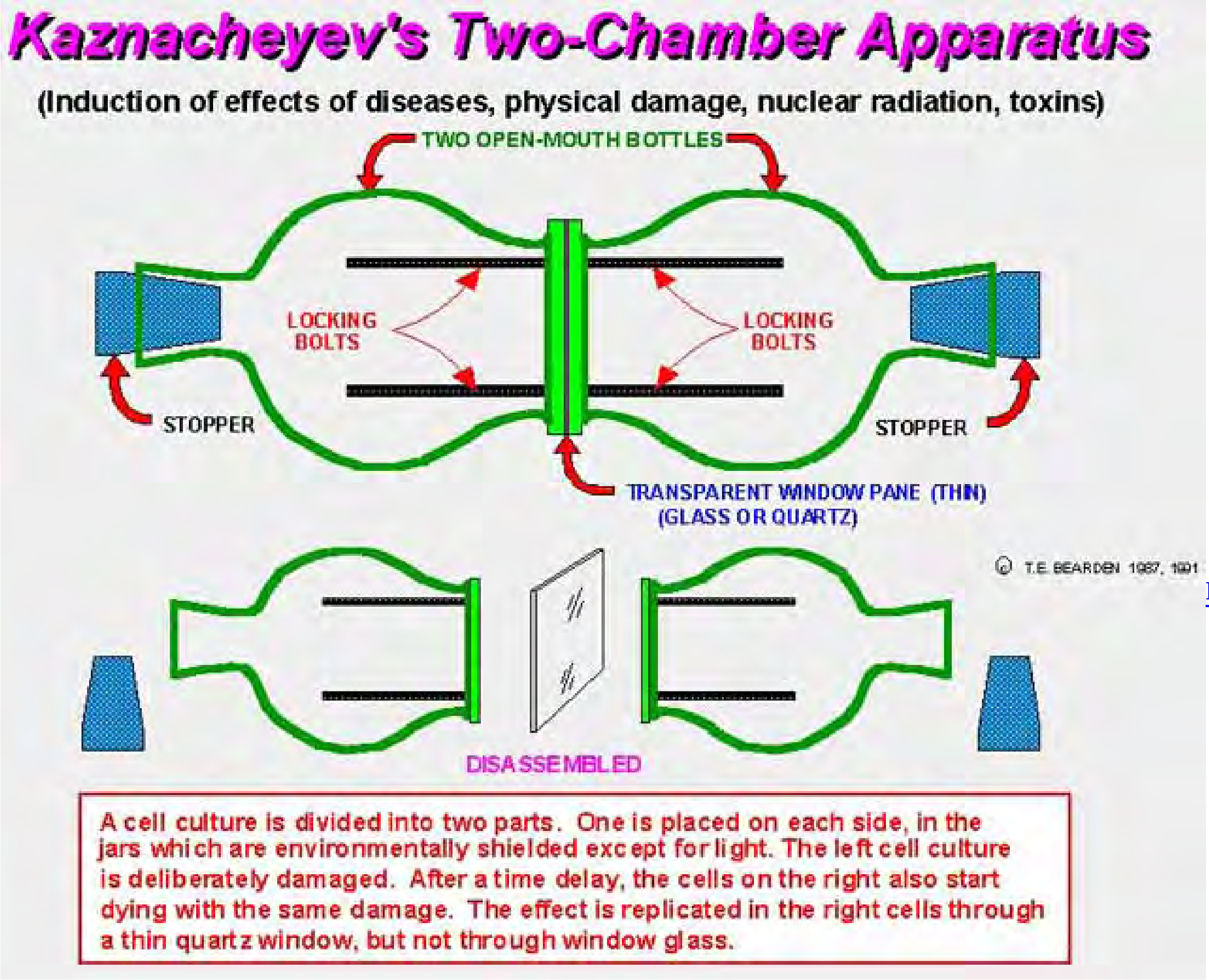

Kaznacheyev's Two-Chamber Apparatus

(Induction of effects of diseases, physical damage, nuclear radiation, toxins)

TWO OPEN-MOUTH BOTTLES
LOCKING BOLTS
LOCKING BOLTS
STOPPER
STOPPER
TRANSPARENT WINDOW PANE (THIN)
(GLASS OR QUARTZ)
DISASSEMBLED

© T.E. BEARDEN 1987, 1991

A cell culture is divided into two parts. One is placed on each side, in the jars which are environmentally shielded except for light. The left cell culture is deliberately damaged. After a time delay, the cells on the right also start dying with the same damage. The effect is replicated in the right cells through a thin quartz window, but not through window glass.

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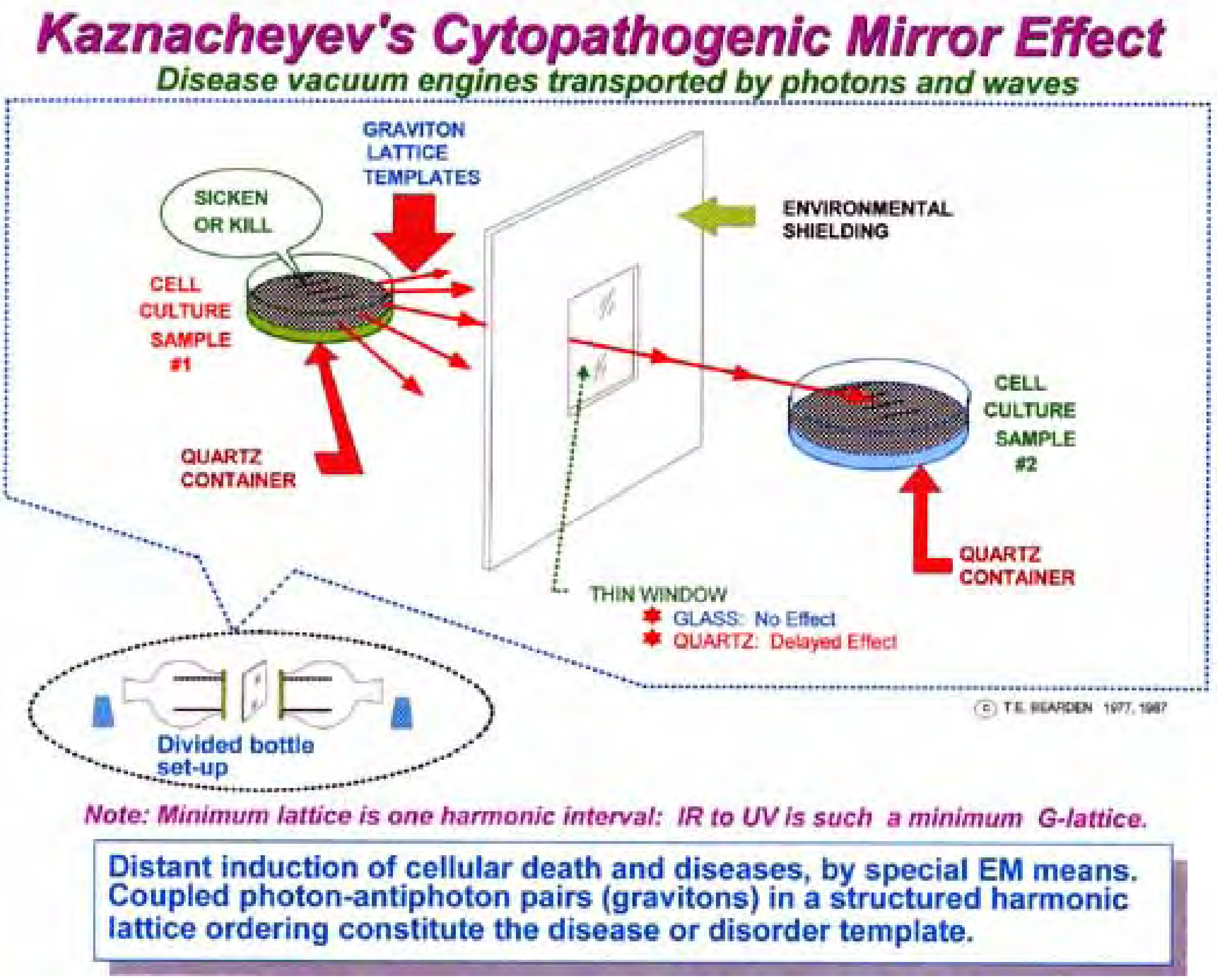

Kaznacheyev's Cytopathogenic Mirror Effect

Disease vacuum engines transported by photons and waves

GRAVITON LATTICE TEMPLATES
SICKEN OR KILL
CELL CULTURE SAMPLE #1
QUARTZ CONTAINER
ENVIRONMENTAL SHIELDING
CELL CULTURE SAMPLE #2
QUARTZ CONTAINER
THIN WINDOW
GLASS: No Effect
QUARTZ: Delayed Effect
Divided bottle set-up

© T.E. BEARDEN 1977, 1987

Note: Minimum lattice is one harmonic interval: IR to UV is such a minimum G-lattice.

Distant induction of cellular death and diseases, by special EM means. Coupled photon-antiphoton pairs (gravitons) in a structured harmonic lattice ordering constitute the disease or disorder template.

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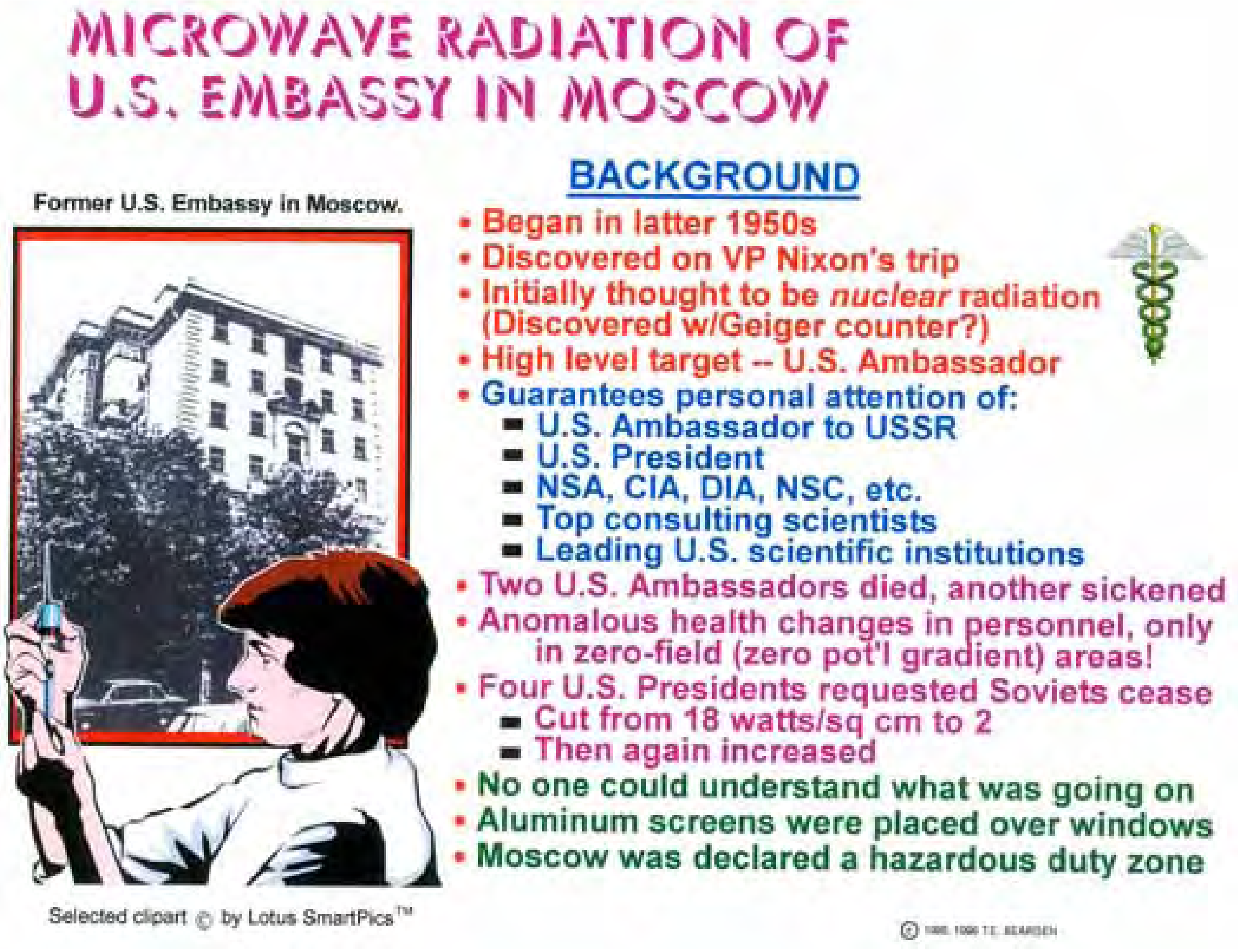

MICROWAVE RADIATION OF U.S. EMBASSY IN MOSCOW

Former U.S. Embassy in Moscow.

BACKGROUND

- Began in latter 1950s
- Discovered on VP Nixon's trip
- Initially thought to be *nuclear* radiation (Discovered w/Geiger counter?)
- High level target -- U.S. Ambassador
- Guarantees personal attention of:
    - U.S. Ambassador to USSR
    - U.S. President
    - NSA, CIA, DIA, NSC, etc.
    - Top consulting scientists
    - Leading U.S. scientific institutions
- Two U.S. Ambassadors died, another sickened
- Anomalous health changes in personnel, only in zero-field (zero pot'l gradient) areas!
- Four U.S. Presidents requested Soviets cease
    - Cut from 18 watts/sq cm to 2
    - Then again increased
- No one could understand what was going on
- Aluminum screens were placed over windows
- Moscow was declared a hazardous duty zone

Selected clipart © by Lotus SmartPics™

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JOHN HOPKINS STUDY OF EMBASSY MICROWAVE RADIATION

- **EXCELLENT SCIENTIFIC TEAM**

  - PERFORMED CLASSICAL EM INVESTIGATION

  - CAREFULLY ESTABLISHED THE FORCE FIELD PATTERNS

  - NO HEALTH CHANGES OCCURRED IN PERSONNEL WHERE THE FORCE FIELDS WERE PRESENT (NONZERO)

  - ALL HEALTH CHANGES OCCURRED IN PERSONNEL WHERE THE FORCE FIELDS WERE ZERO (ABSENT)

- **ASSUMED THAT ALL EM ACTION IS DUE ONLY TO FORCE FIELDS**

  - CONCLUDED THAT MICROWAVE RADIATION COULD NOT HAVE CAUSED THE HEALTH CHANGES
- **CONCLUSION WAS IN SERIOUS ERROR**
  - CORRECT CONCLUSION: HEALTH CHANGES WERE TOTALLY CORRELATED TO ABSENCE OF FORCE FIELDS

  *** TOTALLY CORRELATED TO PRESENCE OF GRADIENT-FREE POTENTIALS, OR NOT TO RADIATION AT ALL**

  *** IF NOT TO RADIATION AT ALL, THEN HEALTH CHANGES WOULD HAVE ALSO OCCURRED WHERE FORCE FIELDS WERE PRESENT**

- **THEREFORE THE HEALTH CHANGES WERE TOTALLY CORRELATED TO THE GRADIENT-FREE POTENTIALS, AND TO THE EM RADIATION**

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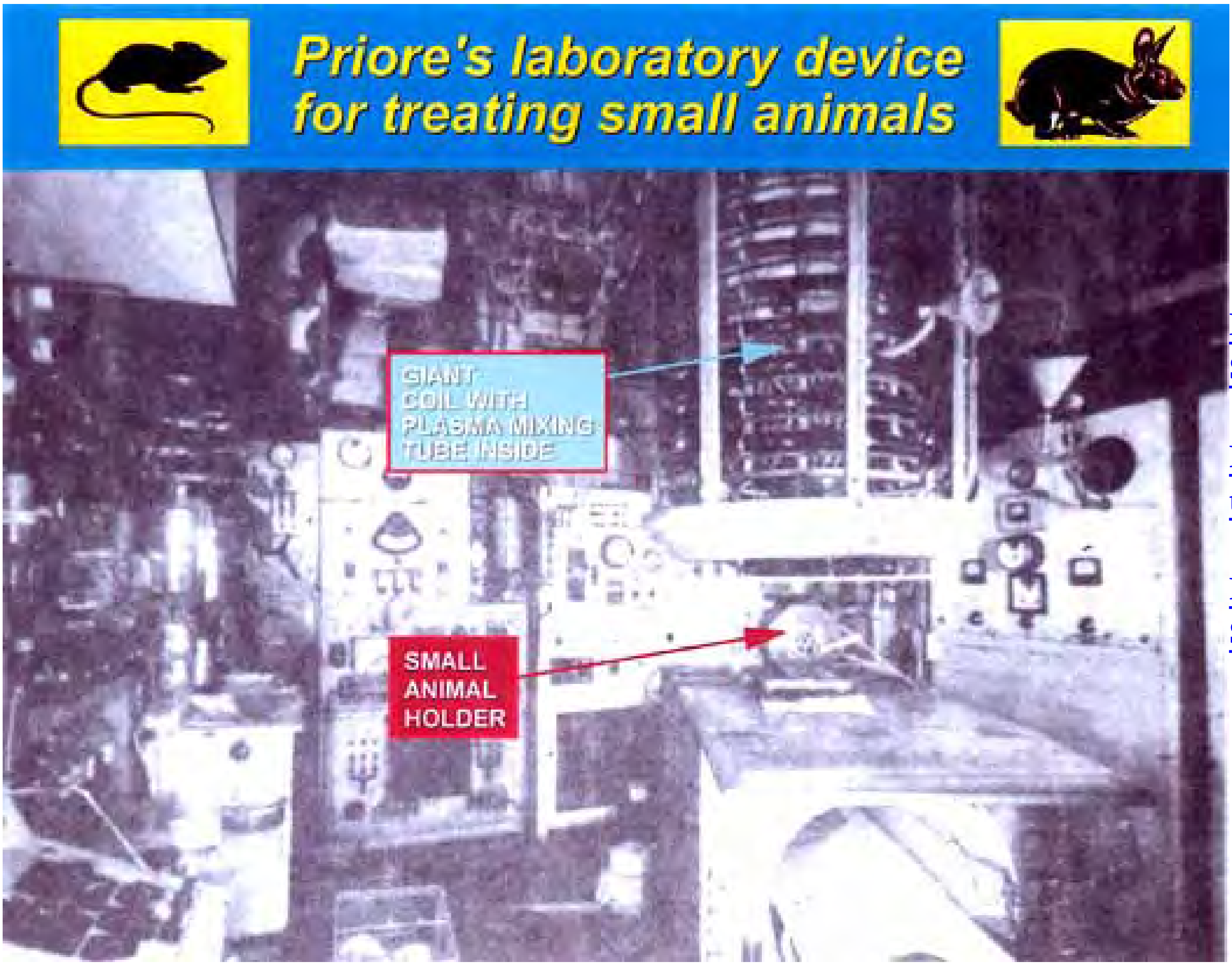

Priore's laboratory device for treating small animals

GIANT COIL WITH PLASMA MIXING TUBE INSIDE
SMALL ANIMAL HOLDER

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MECHANISM OF THE PRIORE THERAPY

- **PRODUCED A DETERMINISTIC WZ STRUCTURED SCALAR POTENTIAL**
  - **17 FREQUENCIES MIXED IN A ROTATING PLASMA**
  - **PHASE CONJUGATES ADDED BY THE PLASMA**
  - **MODULATED ONTO A RIPPLING MAGNETIC FIELD WHICH CARRIED IT TO ATOMIC NUCLEI**
  - **INTERACTED DIRECTLY WITH PERSONAL QUANTUM POTENTIAL**
- **NEGATED THE LONG-TERM CUMULATIVE CELLULAR DEDIFFERENTIATION ORDER GENERATED BY LONG-TERM HYPOXIA. TUMOR CELLS REVERTED TO NORMAL CONTROL**
- **SCRUBBED OUT THE CUMULATED PRECANCEROUS STATE**
- **RESTORED THE IMMUNE SYSTEM TO HIGH FUNCTIONING**
- **NO EXCESSIVE TRAUMA TO TREATED ANIMAL**

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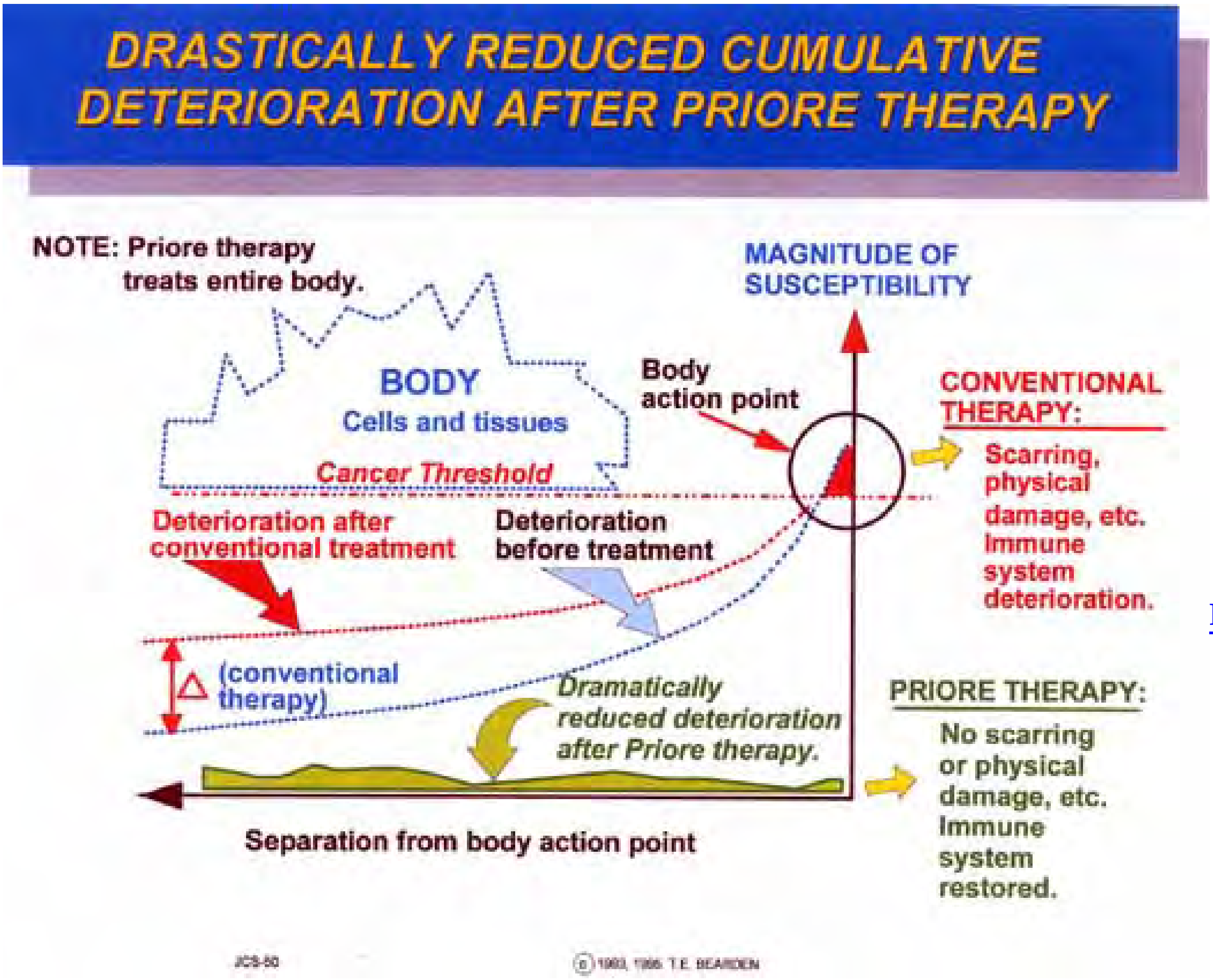

DRASTICALLY REDUCED CUMULATIVE DETERIORATION AFTER PRIORE THERAPY

NOTE: Priore therapy treats entire body.

MAGNITUDE OF SUSCEPTIBILITY
BODY
Cells and tissues
Body action point
Cancer Threshold
Deterioration after conventional treatment
Deterioration before treatment
Δ (conventional therapy)
Dramatically reduced deterioration after Priore therapy.
Separation from body action point

CONVENTIONAL THERAPY:

Scarring, physical damage, etc. Immune system deterioration.

PRIORE THERAPY:

No scarring or physical damage, etc. Immune system restored.

JCS-50

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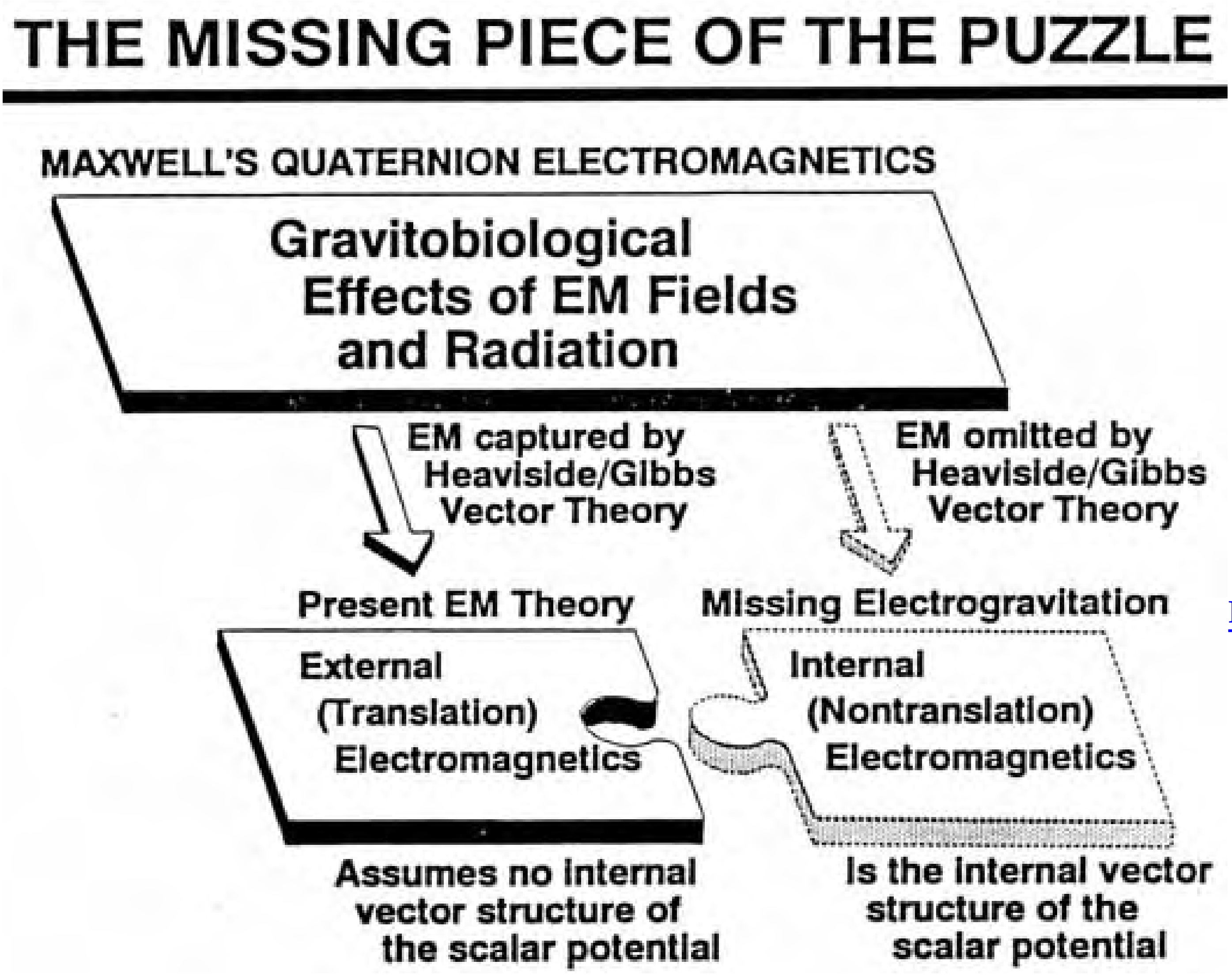

THE MISSING PIECE OF THE PUZZLE

MAXWELL'S QUATERNION ELECTROMAGNETICS

Gravitobiological Effects of EM Fields and Radiation

EM captured by Heaviside/Gibbs Vector Theory

EM omitted by Heaviside/Gibbs Vector Theory

Present EM Theory

External (Translation) Electromagnetics

Assumes no internal vector structure of the scalar potential

Missing Electrogravitation

Internal (Nontranslation) Electromagnetics

Is the internal vector structure of the scalar potential

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SUMMARY AND CONCLUSION

- **RECOMMEND SERIOUS EXAMINATION OF THE NEW APPROACH**

- **RECOMMEND REVIVAL OF PRIORE-TYPE RESEARCH ON**
  AN URGENT BASIS
- **CAN BE EXTENDED TO OTHER DISEASES**

  - AIDS
  - ARTERIOSCLEROSIS
  - SLEEPING SICKNESS
  - ETC.

- **A NEW THERAPEUTIC PARADIGM OF GREATLY INCREASED**
  SCOPE AND EFFECTIVENESS MAY BE POSSIBLE

- **IN ADDITION, DRASTIC REDUCTION IN MEDICAL COSTS**
  COULD POTENTIALLY RESULT

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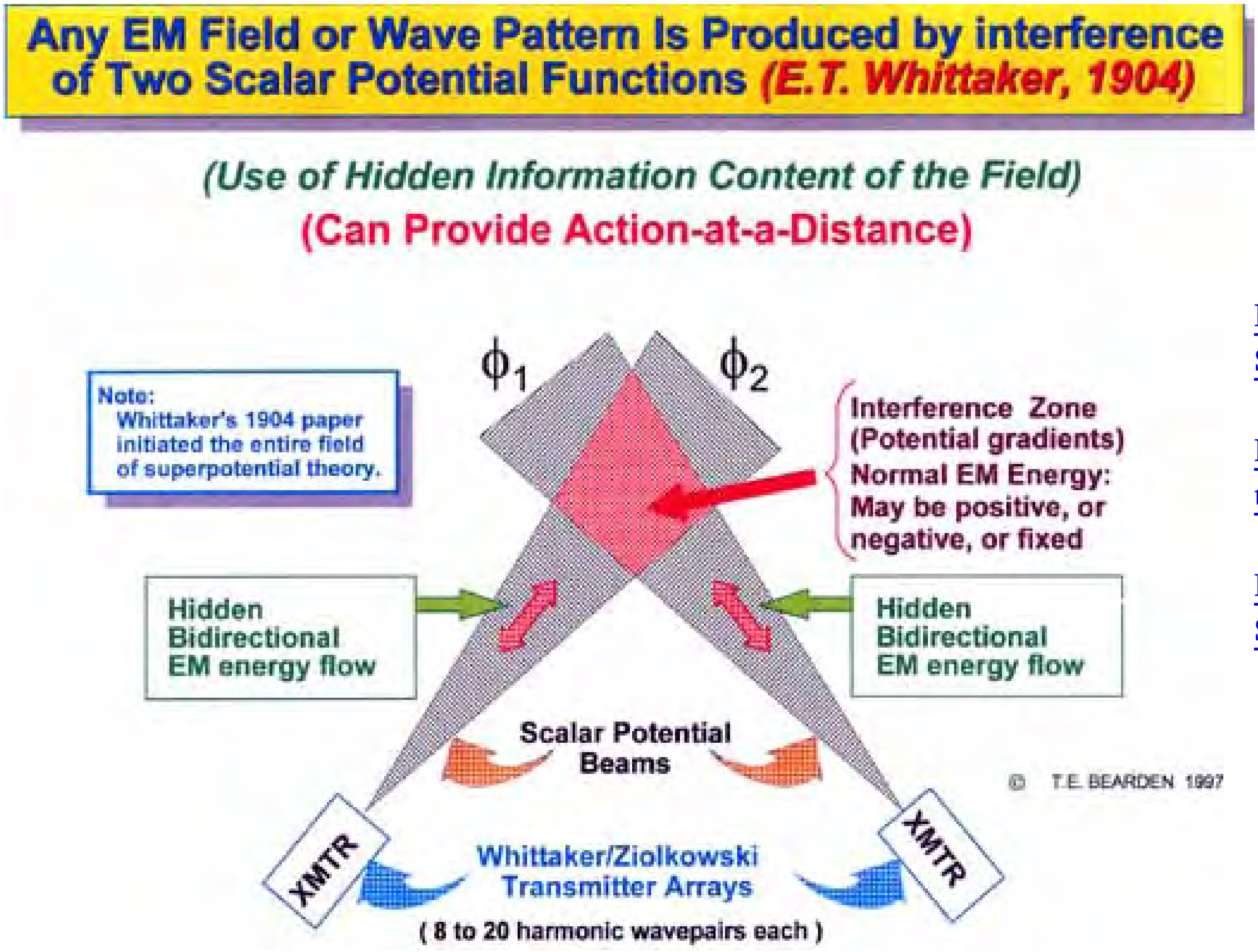

Any EM Field or Wave Pattern Is Produced by interference of Two Scalar Potential Functions *(E.T. Whittaker, 1904)*

(Use of Hidden Information Content of the Field)

(Can Provide Action-at-a-Distance)

Note:
Whittaker's 1904 paper initiated the entire field of superpotential theory.

ϕ_1
ϕ_2
Interference Zone
(Potential gradients)
Normal EM Energy:
May be positive, or
negative, or fixed
Hidden
Bidirectional
EM energy flow
Hidden
Bidirectional
EM energy flow
Scalar Potential
Beams
XMTR
XMTR
Whittaker/Ziolkowski
Transmitter Arrays
(8 to 20 harmonic wavepairs each)

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MECHANISM FOR LONG-TERM, CUMULATIVE BIOLOGICAL EFFECTS OF EM FIELDS AND RADIATION

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The New Tesla Electromagnetics and the Secrets of Electrical Free Energy

By T.E. Bearden
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Overture to a New Age Technology
by Dr. Rolf Schaffranke

REVIEW AND OUTLOOK - The Development of Post-Relativistic Concepts in Physics and Advanced Technology Abroad
by Dr. Rolf Schaffrancke

The Tom Bearden Website

COMMENTS ON THE NEW TESLA ELECTROMAGNETICS

Part I: Discrepancies in Present EM Theory

© T. E. Bearden 1982

There are at least twenty-two major discrepancies presently existing in conventional electromagnetics theory. This paper presents a summary of those flaws, and is a further commentary on my discussion of scalar longitudinal Tesla waves in a previous paper, "Solutions to Tesla's Secrets and the Soviet Tesla Weapons," Tesla Book Company, 1981 and 1982.

I particularly wish to express my deep appreciation to two of my friends and colleagues who at this time, I believe, wish to remain anonymous. One of the two is an experimental genius who can produce items on the bench that do not work by orthodox theory. The second is a master of materials science and electromagnetics theory. I thank them both for their exceptional contributions and stimuli regarding potential shortcomings in present electromagnetics theory, and their forbearance with the many discussions we have held on this and related subjects.

It goes without saying that any errors in this paper are strictly my own, and not the fault of either of my distinguished colleagues.

(1) In present electromagnetics theory, charge and charged mass are falsely made identical. Actually, on a charged particle, the "charge" is the flux of virtual particles on the "bare particle" of observable mass. The charged particle is thus a "system" of true massless charge coupled to a bare chargeless mass. The observable "mass" is static, three-dimensional, and totally spatial. "Charge" is dynamic, four-dimensional or more, virtual and spatiotemporal. Further, the charge and observable mass can be decoupled, contrary to present theory. Decoupled charge -- that is, the absence of mass -- is simply what we presently refer to as "vacuum." Vacuum, spacetime, and massless charge are all identical. Rigorously, we should utilize any of these three as an "ether," as suggested for vacuum by Einstein himself (see

Max Born, Einstein's Theory of Relativity, Revised Edition, Dover Publications, New York, 1965, p. 224). And all three of them are identically anenergy -- not energy, but more fundamental components of energy.

(2) Electrostatic potential is regarded as a purely 3-dimensional spatial stress. Instead, it is the intensity of a many-dimensional (at least four-dimensional) virtual flux and a stress on all four dimensions of spacetime. This is easily seen, once one recognizes that spacetime is identically massless charge. (It is not "filled" with charge; rather, it is charge!) Just as, in a gas under pressure, the accumulation of additional gas further stresses the gas, the accumulation of charge (spacetime) stresses charge (spacetime). Further, if freed from its attachment to mass , charge can flow exclusively in time, exclusively in space, or in any combination of the two. Tesla waves -- which are scalar waves in pure massless charge flux itself -- thus can exhibit extraordinary characteristics that ordinary vector waves do not possess. And Tesla waves have extra dimensional degrees of freedom in which to move, as compared to vector waves. Indeed, one way to visualize a Tesla scalar wave is to regard it as a pure oscillation of time itself.

(3) Voltage and potential are often confused in the electrostatic case, or at least thought of as "composed of the same thing." For that reason, voltage is regarded as "potential drop". This also is not true. Rigorously, the potential is the intensity of the virtual particle flux at a single point -- whether or not there is any mass at the point -- and both the pressure and the point itself are spatiotemporal (4-dimensional), not spatial (3-dimensional) as presently assumed. Voltage represents the spatial intersection of the difference in the potential between two separated spatial points, and always implies at least a miniscule flow of mass current (that is what makes it spatial!). "Voltage" is spatial and depends upon the presence of observable mass flow, while scalar electrostatic potential is spatiotemporal and depends upon the absence of observable mass flow. The two are not even of the same dimensionality.

(4) The charge of vacuum spacetime is assumed to be zero, when in fact it is a very high value. Vacuum has no mass, but it has great massless charge and virtual particle charge flux. For proof that a charged vacuum is the seat of something in motion, see G.M. Graham and D.G. Lahoz, "Observation of static electromagnetic angular momentum in vacuo," Nature, Vol. 285, 15 .May 1980, pp. 154-155. In fact, vacuum IS charge, identically, and it is also "spacetime" and at least four-dimensional.

(5) Contrary to its present usage, zero is dimensional and relative in its context. A three-dimensional spatial hole, for example, exists in time. If we model time as a dimension, then the spatial hole has one dimension in 4-space. So a spatial absence is a spatiotemporal presence. In the vacuum 4-space, a spatial nothing is still a something. The "virtual" concept and the mathematical concept of a derivative are simply two present ways of unconsciously addressing this fundamental problem of the dimensional relativity of zero.

(6) The concepts of "space" and "time" imply that spacetime (vacuum) has been separated into two parts. We can only think of a space as "continuing to exist in time " To separate vacuum spacetime into two pieces, an operation is continually required. The operator that accomplishes this splitting operation is the photon interaction, the interaction of vector electromagnetic energy or waves with mass. I have already strongly pointed out this effect and presented a "raindrop model" of first-order physical change itself in my book, The Excalibur Briefing, Strawberry Hill Press, San Francisco, 1980, pp. 128-130.

(7) "Vector magnetic potential" is assumed to be always an aspect of (and connected to) the magnetic field. In fact it is a separate, fundamental field of nature and it can be entirely disconnected from the magnetic field. See Richard P. Feynman et al, The Feynman Lectures on Physics, Addison-Wesley Publishing Co., New York, 1964, Vol. II, pp. 15-8 to 15-14. Curiously, this fact has been proven for years' yet it has been almost completely ignored in the West. The "Vx" operator, when applied to the A-field, makes B-field. If the Vx operator is not applied, the "freed" A-field possesses much-expanded characteristics from those presently allowed in the "bound" theory. Specifically, it becomes a scalar or "shadow vector" field; it is not a normal vector field. (note: for V read inverted capital Delta)

(8) The speed of light in vacuum is assumed to be a fundamental constant of nature. Instead it is a function of the intensity of the massless charge flux (that is, of the magnitude of the electrostatic potential) of the vacuum in which it moves. (Indeed, since vacuum and massless charge are one and the same, one may say that the speed of light is a function of the intensity of the spatiotemporal vacuum!). The higher the flux intensity (charge) of the vacuum, the faster the speed of light in it. This is an observed fact and already shown by hardcore measurements. For example, distinct differences actually exist in the speed of light in vacuo, when measured on the surface of the earth as compared to measurements in space away from planetary masses. In a vacuum on the surface of the earth, light moves significantly faster. For a discussion and the statistics, see B. N. Belyaev, "On Random Fluctuations of the Velocity of Light in Vacuum," Soviet Physics

Journal, No. 11, Nov. 1980, pp. 37-42 (original in Russian; translation by Plenum Publishing Corporation.) The Russians have used this knowledge for over two decades in their strategic psychotronics (energetics) program; yet hardly a single U.S. scientist is aware of the measured variation of c in vacuo. In fact, most Western scientists simply cannot believe it when it is pointed out to them!

(9) Energy is considered fundamental and equivalent to work. In fact, energy arises from vector processes, and it can be disassembled into more fundamental (anenergy) scalar components, since the vectors can. These scalar components individually can be moved to a distant location without expending work, since one is not moving force vectors. There the scalar components can be joined and reassembled into vectors to provide "free energy" appearing at a distance, with no loss in between the initial and distant points. For proof that a vector field can be replaced by (and considered to be composed of) two scalar fields, see E. T. Whittaker, Proceedings of the London Mathematical Society, Volume 1, 1903, p. 367. By extension, any vector wave can be replaced by two coupled scalar waves.

(10) The classical Poynting vector predicts no longitudinal wave of energy from a time-varying, electrically charged source, In fact, an exact solution of the problem does allow this longitudinal wave. See T. D. Keech and J. F. Corum, "A New Derivation for the Field of a Time-Varying Charge in Einstein's Theory," International Journal of Theoretical Physics, Vol. 20, No, 1, 1981, pp. 63-68 for the proof.

(11) The present concepts of vector and scalar are severely limited, and do not permit the explicit consideration of the internal, finer-grained structures of a vector or a scalar. That is, a fundamental problem exists with the basic assumptions in the vector mathematics itself. The "space" of a vector field, for example, does not have inter-nested sublevels (subspaces) containing finer "shadow vectors" or "virtual vectors," Yet particle physics has already discovered that electrical reality is built that way. Thus one should actually use a "hypernumber" theory after the manner of Charles Musés. A scalar is filled with (and composed of) nested levels of other "spaces" containing vectors, where these sum to "zero" in the ordinary observable frame without an observable vector resultant. In Musés' mathematics, for example, zero has real roots. Real physical devices can be -- and have been -constructed in accordance with Muses' theory. For an introduction to Musés' profound hypernumbers approach, see Charles Musés' foreword to Jerome Rothstein, Communication Organization and Science, The Falcon's Wing Press, Indian Hills, Colorado, 1958. See also Charles Musés, "Applied Hypernumbers: Computational Concepts," Applied Mathematics and

Computation, Vol. 3, 1976. See also Charles Musés, "Hypernumbers II," Applied Mathematics and Computation, January 1978.

(12) With the expanded Tesla electromagnetics, a new conservation of energy law is required. Let us recapitulate for a moment. The oldest law called for the conservation of mass. The present law calls for the conservation of "mass and energy", but not each separately. If mass is regarded as simply another aspect of energy, then the present law calls for the conservation of energy. However, this assumes that energy is a basic, fundamental concept. Since the energy concept is tied to work and the movement of vector forces, it implicitly assumes "vector movement" to be a "most fundamental" and irreducible concept. But as we pointed out, Whittaker showed that vectors can always be further broken down into more fundamental coupled scalar components. Further, Tesla discovered that these "coupled components" of "energy" can be individually separated, transmitted, processed, rejoined, etc. This directly implies that energy per se need not be conserved. The new law therefore calls for the conservation of anenergy, the components of energy. These components may be coupled into energy, and the energy may be further compacted into mass. It is the sum total of the (anenergy) components -- coupled and uncoupled -- that is conserved, not the matter or the energy per se. Further, this conservation of anenergy is not spatial; rather, it is spatiotemporal in a spacetime of at least four or more dimensions.

(13) Relativity is presently regarded as a theory or statement about fundamental physical reality. In fact, it is only a statement about FIRST ORDER reality -- the reality that emerges from the vector interaction of electromagnetic energy with matter. When we break down the vectors into scalars (shadow vectors or hypervectors), we immediately enter a vastly different, far more fundamental reality. In this reality superluminal velocity, multiple universes, travel back and forth in time, higher dimensions, variation of all "fundamental constants" of nature, materialization and dematerialization, and violation of the "conservation of energy" are all involved. Even our present Aristotlean logic -- fitted to the photon interaction by vector light as the fundamental observation mechanism -- is incapable of describing or modeling this more fundamental reality. Using scalar waves and scalar interactions as much subtler, far less limited observation/detection mechanisms, we must have a new "superrelativity" to describe the expanded electromagnetic reality uncovered by Nikola Tesla.

(14) "Charge" is assumed to be quantized, in addition to always occurring with -- and locked to -- mass. Indeed, charge is not necessarily quantized just as it is not necessarily locked to mass.

Ehrenhaft discovered and reported fractional charges for years, in the 30's and 40's, and was ignored. See P.A.11. Dirac, "Development of the Physicist's Conception of Nature," Symposium on the Development of the Physicist's Conception of Nature, ed. Jagdish Merha, D. Reidel, Boston, 1973, pp. 12-14 for a presentation of some of Ehrenhaft's results. Within the last few years Stanford University· researchers also have positively demonstrated the existence of "fractional charge." For a layman's description of their work, see "A Spector Haunting Physics," Science News, Vol. 119, January 31, 1981, pp. 68-69. Indeed, Dirac in his referenced article points out that Millikan himself -- in his original oildrop experiments -- reported one measurement of fractional charge, but discounted it as probably due to error.

(15) Presently, things are always regarded as traveling through normal space. Thus we use or model only the most elementary type of motion -- that performed by vector electromagnetic energy. We do not allow for things to "travel inside the vector flow itself." Yet, actually, there is a second, more subtle flow inside the first, and a third, even more subtle flow inside the second, and so on. We may operate inside, onto, into, and out of energy itself -- and any anenergy component of energy. There are hypervectors and hyperscalars unlimited, within the ordinary vectors and scalars we already know. Further, these "internal flows" can be engineered and utilized, allowing physical reality itself to be directly engineered, almost without limits.

(16) We always assume everything exists in time. Actually, nothing presently measured exists in time, because the physical detection/ measurement process of our present instruments destroys time, ripping it off and tossing it away -- and thereby "collapsing the wave function." Present scientific methodology thus is seriously flawed. It does not yield fundamental (spacetime) truth, but only a partial (spatial) truth. This in turn leads to great scientific oversights. For example, mass does not exist in time, but mass x time (masstime) does. A fundamental constant does not exist in time, but the "constant x time" does. Energy does not exist in time, but energy x time (action) does. Even space itself does not exist in time -- spacetime does. We are almost always one dimension short in every observable we model. Yet we persist in thinking spatially, and we have developed 1nstruments that detect and measure spatially only. Such instruments can never measure and detect the phenomenology of the nested substrata of time. By using scalar technology, however, less limited instruments can indeed be constructed -and they have been. With such new instruments, the phenomenology of the new electromagnetics can be explored and an engineering technology developed.

(17) We do not recognize the connection between nested levels of virtual state (particle physics) and orthogonally rotated frames (hyperspaces). Actually the two are identical, as I showed in the appendix to my book, The Excalibur Briefing, Strawberry Hill Press, San Francisco, 1980, pp. 233-235. A virtual particle in the laboratory frame is an observable particle in a hyperspatial frame rotated more than one orthogonal turn away. This of course implies that the hyperspatial velocity of all virtual particles is greater than the speed of light. The particle physicist is already deeply involved in hyperspaces and hyperspatial charge fluxes without realizing it. In other words, he is using tachyons (particles that move faster than light) without realizing it.

(18) Presently quantum mechanics rigorously states that time is not an observable, and therefore it cannot be measured or detected. According to this assumption, one must always infer time from spatial measurements, because all detections and measurements are spatial. With this assumption, our scientists prejudice themselves against even looking for finer, subquantal measurement methodologies and instrumentation. Actually this present limitation is a result of the type of electromagnetics we presently know, where all instruments (the "measurers") have been interacted with by vector electromagnetic energy (light). Every mass that has temperature (and all masses do!) is continually absorbing and emitting photons, and in the process they are continually connecting to time and disconnecting from time. If time is continually being carried away from the detector itself by its emitted photons, then the detector cannot hold and "detect" that which it has just lost. With Tesla electromagnetics, however, the fundamental limitation of our present instruments need not apply. With finer instruments, we can show there are an infinite number of levels to "time", and it is only the "quantum level time" which is continually being lost by vector light (photon) interaction. By using subquantal scalar waves, instruments can move to deeper levels of time -- in which case the upper levels of time ARE measureable and detectable, in contradistinction to the present assumptions.

(19) In the present physics, time is modeled as, and considered to be, a continuous dimension such as length. This is only a gross approximation. Indeed, time is not like continuous "dimension," but more like a series of "stitches," each of which is individually made and then ripped out before the next stitch appears. "Vector light" photons interact one at a time, and it is this interaction with mass that creates quantum change itself. The absorption of a photon -- which is energy x time -- by a spatial mass converts it to masstime: the time was added by the photon. The emission of a photon tears away the time, leaving behind again a spatial mass. It is not accidental, then, that time flows at

the speed of light, for it is light which contains and carries time. It is also not accidental that the photon IS the individual quantum. Since all our instruments presently are continually absorbing and emitting photons, they are all "quantized," and they accordingly "quantize" their detections. This is true because all detection is totally internal to the detector, and the instruments detect only their own internal changes. Since these detections are on a totally granular quantized background, the detections themselves are quantized. The Minkowski model is fundamentally erroneous in its modeling of time, and for that reason relativity and quantum mechanics continue to resist all attempts to successfully combine them, quantum field theory notwithstanding.

(20) Presently, gravitational field and electrical field are considered mutually exclusive. Actually this is also untrue. In 1974, for example, Santilly proved that electrical field and gravitational field indeed are not mutually exclusive In that case, one is left with two possibilities: (a) they are totally the same thing, or (b) they are partially the same thing. For the proof, see R. M. Santilli, "Partons and Gravitation: Some Puzzling Questions," Annals of Physics, Vol. 83, No. 1, March 1974. With the new Tesla electromagnetics, pure scalar waves in time itself can be produced electrically, and electrostatics (when the charge has been separated from the mass) becomes a "magic" tool capable of directly affecting and altering anything that exists in time--including gravitational field. Antigravity and the inertial drive are immediate and direct consequences of the new electromagnetics.

(21) Presently, mind is considered metaphysical, not a part of physics, an not affected by physical means. Literally, the prevailing belief of Western scientists is that man is a mechanical robot -- even though relativity depends entirely upon the idea of the "observer." Western science today thus has essentially become dogmatic, and in this respect borders on a religion. Since this "religion," so to speak, is now fairly well entrenched in its power in the state, Western science is turning itself into an oligarchy. But mind occupies time, and when we measure and affect time we can directly measure and affect mind itself. In the new electromagnetics, then, man regains his dignity and his humanity by restoring the reality of mind and thought to science. In my book, The Excalibur Briefing, I have already pointed out the reality of mind and a simplified way in which it can be modeled to the first order. With scalar wave instruments, the reality of mind and thought can be measured in the laboratory, and parapsychology becomes a working, engineering, scientific discipline.

(22) Multiple-valued basic dimensional functions are either not permitted or severely discouraged in the present theory For one thing, integrals of multiple valued derivative functions have the annoying

habit of "blowing up" and yielding erroneous answers, or none at all. And we certainly do not allow multiple types of time! This leads to the absurdity of the present interpretation of relativity which permits only a single observer (and a single observation) at a time. So if one believes as "absurd" a thing as the fact that more than one person can observe an apple at the same time, the present physics fails. However, the acceptance of such a simple proposition as multiple simultaneous observation leads to a physics so bizarre and incredible that most Western physicists have been unable to tolerate it, much less examine its consequences. In the physics that emerges from multiple simultaneous observation, all possibilities are real and physical. There are an infinite number of worlds, orthogonal to one another, and each world is continually splitting into additional such "worlds" at a stupendous rate. Nonetheless, this physics was worked out by Everett for his doctoral thesis in 1956, and the thesis was published in 1957. (See Hugh Everett, III, The Many-Worlds Interpretation of Quantum Mechanics: A Fundamental Exposition, with papers by J. A. Wheeler, B.S. DeWitt, L. N. Cooper and D. Van Vechten, and N. Graham; eds. Bryce S. Dewitt and Neill Graham, Princeton Series in Physics, Princeton University Press, 1973.) Even though it is bizarre, Everett's physics is entirely consistent with all the present experimental basis of physics. The present electromagnetic theory is constructed for only a single "world" or universe -- or "level." The expanded theory, on the other hand, contains multiply nested levels of virtual state charge -- and these levels are identically the same as orthogonal universes, or "hyperframes." Multiple kinds -- and values -- of time also exist. The new concept differs from Everett's, however, in that the orthogonal universes intercommunicate in the virtual state. That is, an observable in one universe is always a virtual quantity in each of the other universes. Thus one can have multi-level "continuities" and "discontinuities" simultaneously, without logical conflict. It is precisely these levels of charge -- these levels of scalar vacuum -- that lace together the discontinuous quanta generated by the interaction of vector light with mass.

However, to understand the new electromagnetic reality, one requires a new, expanded logic which contains the old Aristotlean logic as a subset. I have already pointed out the new logic in my paper, "A Conditional Criterion for Identity, Leading to a Fourth Law of Logic," 1979, available from the National Technical Information Center, AD-A071032.

Even as logic is extended, quantum mechanics, quantum electrodynamics, and relativity are drastically changed by the Tesla electromagnetics, as I pointed out in my paper, "Solutions to Tesla's Secrets and the Soviet Tesla Weapons," Tesla Book Company, 1580

Magnolia, Millbrae, California, 94030, 1980.

The present electromagnetics is just a special case of a much more fundamental electromagnetics discovered by Nikola Tesla, just as Newtonian physics is a special case of relativistic physics. But in the electromagnetics case, the differences between the old and the new are far more drastic and profound.

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COMMENTS ON THE NEW TESLA ELECTROMAGNETICS

Part II: The Secret of Electrical Free Energy

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Again I wish to express my deep appreciation to two of my friends and colleagues who at this time, I believe, wish to remain anonymous. I thank them both for their exceptional contributions and stimuli, and their forbearance with the many discussions we have held on this and related subjects.

Also, it goes without saying that any errors in this paper are strictly my own, and not the fault of either of my distinguished colleagues.

Present electromagnetic theory is only a special case of the much more fundamental electromagnetism discovered by Nikola Tesla at the turn of the century.

Pure vacuum is pure charge flux, without mass. The vacuum has a very high electrical potential -- something on the order of 200 million volts, with respect to a hypothetical zero charge.

Thus in an ordinary electrical circuit, each point of the "ground" -- which has the same potential as the vacuum -- actually has a non-zero absolute potential. This circuit ground has a value of zero only with respect to something else which has the same absolute electrical potential.

Voltage, which is always associated with a flow of electrical "mass" current (even if only a miniscule flow), is, by definition, a difference dropped in potential when a charge mass moves between two spatially separated points. What we have termed "electrical current" only flows where there is a suitable conducting medium between things which have a difference in absolute potential. Furthermore, between any two points in any material, there is considered to exist a finite resistance -- if we apply a voltage and have a mass current flowing between the two points! The simple statement that V = IR irrevocably ties together voltage drop, mass current, and resistance between two points. Rigorously, to have one of the three is to have them all. To lose one is to lose all three. Immediately we see a major error in present theory: One can have a "difference in scalar potential" between two points without having a "voltage drop" between them. Specifically, if no mass current flows between them, no resistance exists between them, and no voltage drop exists between them.

In the same fashion, one can have a "scalar wave" through the

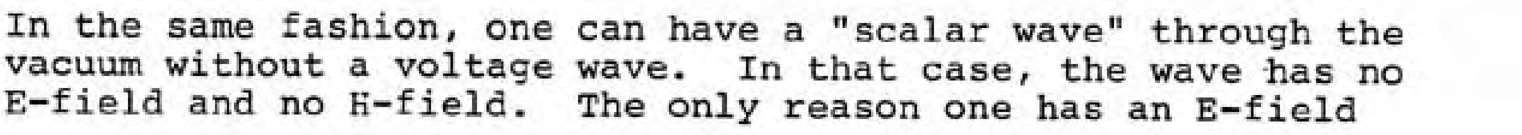

In the same fashion, one can have a "scalar wave" through the vacuum without a voltage wave. In that case, the wave has no E-field and no H-field. The only reason one has an E-field

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around a statically charged object is because the charged electrons accumulated on the object are actually in violent motion. It is this motion of the charged masses that produces E-field -- as well as H-field whenever that entire E-field ensemble moves through laboratory space.

Now let us reason together in the "approximate" manner utilized in present electromagnetic theory. For example, let us examine a bird sitting on a high tension line.

The bird sits on the high tension line without a flow of mass electricity, because there is no significant difference in potential drop between the bird and the line. Specifically, between the bird's two feet -- each in contact with a different portion of the line -- there exists no potential difference. This is true even though, with respect to the vacuum, each foot is at a potential that would be "100,000 volts higher," were a mass current flowing. And it is true even though the absolute potential of each foot may be some 200.1 million "volts," were a mass current flowing.

Now an interesting thing happens to the bird when he flies through the air to light upon the high tension wire. As he flies toward the wire, he is flying through the massless electrostatic potential field of the wire, for that field extends an infinite distance away from the wire. The electrostatic potential field -- pure ∅-field -- is actually the spatio-temporal intensity of the massless charge at a point. In other words, as the bird flies to the wire, he flies into an increasing "massless charge" potential, building up to 100,000 "volts" higher than the earth. However, very little (if any) "mass flow" potential difference is experienced upon his body in approaching the wire, and so essentially no "charged mass currents" are induced in his body. Thus the little flier safely navigates into the teeth of a very high electrostatic potential, lights upon the wire, and is not "fried" in the process. When he lights on the wire, his body has reached the electrostatic potential that each foot's contact point has. Again, there is no mass current flow. But his body is immersed in an increased flux of massless charge -- which is what the electrostatic potential represents. And each "virtual particle" flow in that charge potential represents a "massless (scalar)" electrical current.

The point is, one can have any amount of massless charge flow -- "scalar" current -- without any mechanical work being done in the system. All electrical work in a circuit is done against the physical mass of the charged masses that flow. Rigorously, force is defined as the time rate of charge of momentum. Even in the relativistic case where $F = ma + v(dm/dt)$, change of momentum requires mass movement. No mechanical work, and hence no energy, is expended by massless charge flow.

That is why the vacuum massless charge -- which is composed of a very high flux of massless "particles" -- normally does no work

That is why the vacuum massless charge -- which is composed of a very high flux of massless "particles" -- normally does no work on our systems, and expends none of its very high "potential energy." It is exactly the same as the bird which flew into an

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increasing scalar field as it approached the high tension wire -- no work was done upon the bird by the increasing scalar flux currents encountered by its body.

By existing "in the vacuum," so to speak, we (the whole earth) are as birds sitting on a high tension line! Until we create significant difference in potential, via our present electromagnetic circuits, no current can flow -- anywhere. Even if we produce potential differences, we must have a conductor and charged masses to flow, if we wish to produce mechanical work. Presently our electromagnetic theory allows us to create a difference in potential within different parts of a circuit, but only by moving and shifting charged mass. We therefore have to do work on this electrical mass in moving it around, and we only get back the work we have put into the circuit. In other words, presently all we do is "pump" electrical mass.

Now notice what would happen to the bird on the line if we substantially "pulsed" the potential on the line. Suppose we "pulsed" it such that the bird's physical system -- considered as a circuit containing a capacitance, a resistance, an inductance, and many free electrons -- became resonant to the pulsing frequency. In that case the "bird system" would resonate, and a great deal of electrical mass would surge back and forth in the body of the bird. In the bird's body, voltage would exist, charged mass current would flow, work would be done, and the bird would be electrocuted.

Also, note that, without mass movement, electromagnetic vector fields are not produced (and a portion of the difficulty lies with the actual vector mathematics itself). Scalar (nonvector) waves continually penetrate "space" where there is no mass movement. This means there can exist a "delta-Φ" without a voltage or an E-field. The present theory does not allow this, because it always uses "q" (charge) to be charged mass. Briefly, without belaboring the point, let us just say that it is the mechanical spin of the individual charged particle -- such as the electron -- which "entangles" or "knits together" or "couples" independent scalar waves into vector waves. A vector wave is simply two coupled scalar waves. The entire force field concept -- such as the E-field and the B-field -- is operationally defined in terms of the force exhibited on a test particle, or test mass. Rigorously, an E-field does not exist as a force field in vacuum, but as two coupled scalar Φ-fields "tumbling about each other." When these two coupled, tumbling fields meet a spinning electron, e.g., the force emerges on the electron mass. In short, movement of a rotating mass changes delta-Φ to "voltage", creating the V/I/R triad.

By "accumulating charged mass particles" -- such as electrons -- one certainly can increase the value of Φ, which represents the charge intensity or "scalar electrostatic potential." However, that is not the only way to increase it. Resonance and rotation of charged masses can also be appropriately employed to vary the vacuum charge potential Φ, under the proper circumstances.

of charged masses can also be appropriately employed to vary the vacuum charge potential Φ, under the proper circumstances.

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By the correct application of rotary principles and Tesla electromagnetic theory, it is possible to oscillate -- and change -- the vacuum potential itself, in one part of an electrical system. Thus by correct procedures a part of a system can be electrically altered so that the absolute value of its "ground" (vacuum) potential differs significantly from the normal vacuum-ground potential of the remainder of the circuit. In other words, we shift the vacuum-ground potential of part of the circuit by oscillating the massless vacuum charge itself, and in so doing we gain a substantial, oscillatory electrical potential difference between that part of the circuit and the normal ground potential of the rest of the system. Then we connect the two parts of the system by means of a conductor containing a load in the middle.

In every conductor, a large number of "free electrons" are available. If we oscillate the actual vacuum charge itself, unlimited additional free electrons also become available from the Dirac sea, since partial "unstripping" of the negative energy wells (each containing an electron) occurs. This "unstripping" of the potential of the well is due to vacuum potential oscillation, which oscillates time as well as space. To a negative energy well (positive time), the oscillation of its "time stream" increases the well's negative potential during one half-cycle and decreases its potential for the other half-cycle. Thus during half the oscillatory cycle, negative energy electrons may be lifted from the Dirac sea if the oscillation is sufficiently intense.

Therefore we obtain an attendant voltage and flow of mass current through the load. This voltage and current, by the way, are essentially limitless, and are free for the asking, assuming the proper "vacuum oscillation" is initiated and maintained so that electrons are continually being lifted from the Dirac sea by the time oscillations, and fed into the circuit.

Standard electromagnetic theory assumes that the vacuum potential is zero. It does not recognize the existence of massless charge, separated from charged mass. Therefore, orthodox scientists have never looked for a way to engineer the vacuum, because they have not realized it is composed of pure massless charge. Electrical physics has almost hopelessly confused charge and charged mass, thereby eliminating scalar longitudinal electrostatic waves. Expressed in the bird/high tension line analogy, the present electromagnetic theory restricts us to walking along the high tension line, laboriously carrying small batteries and power units, unaware of the limitless, surging power beneath our very feet.

Electromagnetically, we have been rather like one of the five blind men who touched an elephant. We have only touched one small portion of the electromagnetism "elephant," yet we thought we had grasped the entire beast.

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OVERTURE TO A NEW AGE TECHNOLOGY

From an Update by Dr. Rolf Schaffranke

> " ... as there has been a steady erosion in U. S. activity in the basic sciences, there has been an increase in the level of such activity in Western Europe and Japan. If that continues, we are in danger of losing our position of scientific leadership."
>
> Val. L. Fitch, Prof. of Physics at Princeton University, in an interview with *U.S. News & World Report*, June 21, 1982.

West Germany:

The prototype of the first motorcycle equipped with a "flux-motor" (the inventor's designation for a tachion field converter or gravity-field generator) of 2 KW output has completed a test run of approximately 20,000 km without repairs. Principle of operation: The T-converter is constantly recharging the electrical power battery of the vehicle, resulting in an operation which is noiseless, fuelless and polution-free. After completion of all scheduled tests, a public demonstration to the press is planned within a few weeks from the time of this writing. (June 17, 1982) See photo, Pg. 19. A new factory for the production of gravity-energy-field converters in the town of Oldenburg is scheduled to produce individual home heating units. The design of automobile power plants based on the same principle is also in preparation. Reported efficiency factors of several hundred percent are anticipated.

Japan:

Mazda continues research on the "magnetic Wankel engine" (45 HP) for electric automobiles, based on the principle of Kure Tekko. The gravity research of Prof. S. Seike is now sponsored by Hitachi, after millions of Japanese received updated information via popular science magazines. It is interesting to note that Saudi Arabia has decided to invest $100 million in Hitachi stocks.

France:

The "Kromrey" converter has completed tests at the Institute for Magnetostatics, University of Strasbourg. One prototype delivered 700 Watts at 600-1200 RPM, at a fairly uniform rate. However, France, as the No. 1 developer of nuclear energy in Europe, is still reluctant to concentrate her energies on a revolutionary new technology which could result in drastic curtailments of her well-developed nuclear industry and associated exports. See photos, Pg. 22.

Denmark:

Dr. Jensen, physicist at the University of Kopenhagen, reported test results of 300% efficiency with a specially designed, 5-coil transformer in connection

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with a tachion field converter based on the principle of the "N" machine. First reports were presented at the International Conference on Energy Technology in Hannover, Nov., 1980.

England / USA:

A "bullet train" based on the magnetic levitation system of British Prof. Eric Laithwaite is now under consideration for construction between Los Angeles and San Diego. Japan and West Germany are already operating high speed experimental trains, suspended magnetically to reduce friction, that may soon attain speeds of more than 200 miles per hour. The Laithwaite-Eastham method would use electromagnetic forcefields induced over an aluminum-topped concrete track. The project will probably be headed by a Japanese company as the prime contractor.

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West German gravity-field unit in operation

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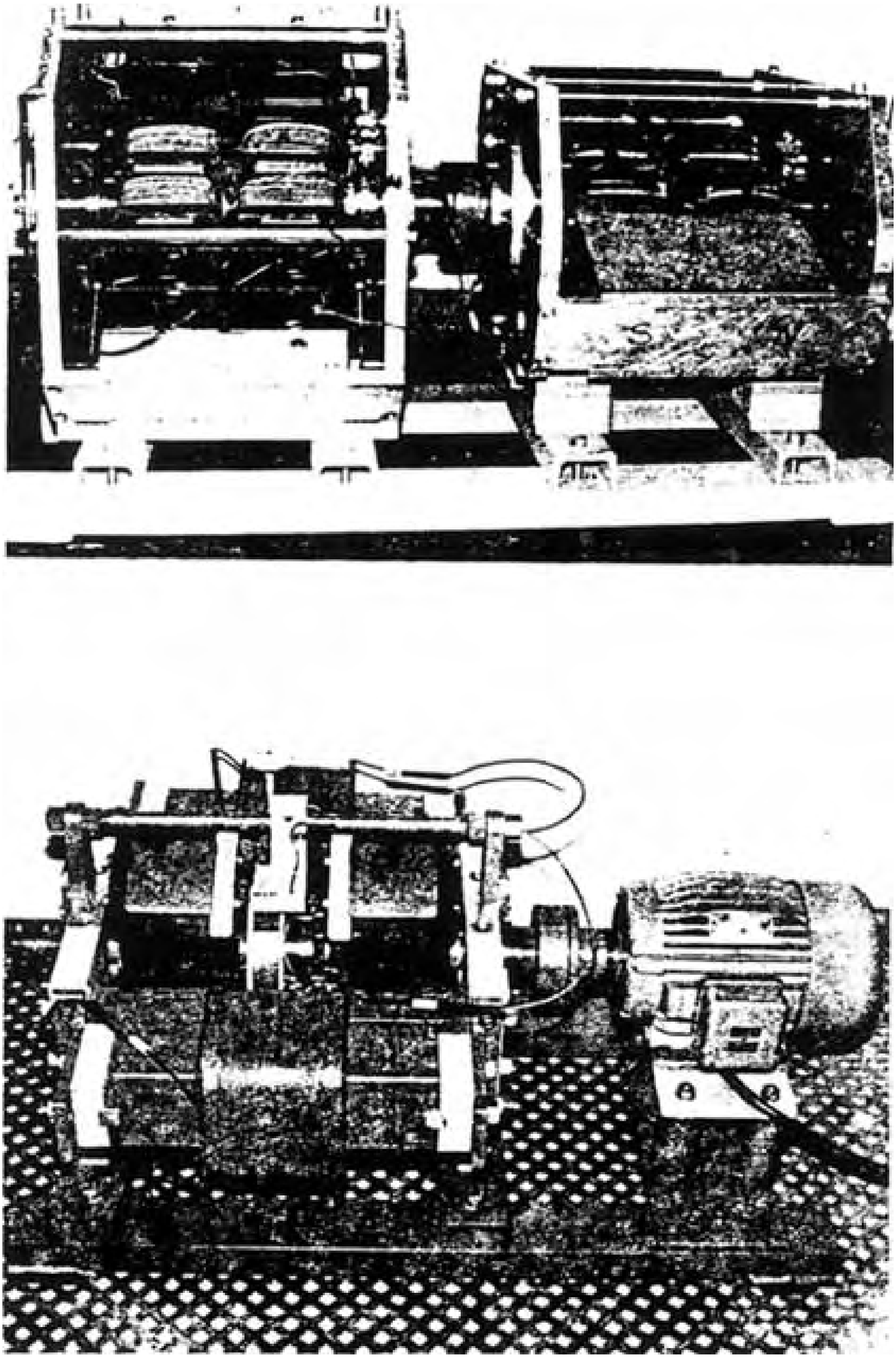

Swiss-French gravity field converter system "Kromrey"

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REVIEW AND OUTLOOK

THE DEVELOPMENT OF POST-RELATIVISTIC CONCEPTS IN PHYSICS AND ADVANCED TECHNOLOGY ABROAD

Rolf Schaffranke, Dr. h. c.
Member A.I.A.A.

This paper was presented at The First International Symposium on Non-Conventional Energy Technology, Toronto, Ontario, Canada, Oct. 23-24, 1981. (Reprinted by permission of the author.)

"Far more harm is done to the progress of science by skepticism than by gullibility". (Dr. Robert Wood, Director R & D, McDonnel-Douglas Astronautics Div., Cal.) NASA - Langley Research Center in Hampton, VA is named after Samuel Pierpont Langley (1834-1906), an American astronomer, engineer and architect.

Langley worked out the aerodynamic principles for manned flight. In principal, his calculations were correct; but the structural materials he used for wings and engines were ,insufficient. In December of 1903, the *New York Times* published an editorial complaining about his foolish dream and the associated waste of government money. The editorial predicted that: "man would not fly for a thousand years".

Only 9 days after the editorial was published, the Wright brothers made their first successful powered flight at Kitty Hawk. (Dec. 17, 1903). But, again, as late as 1905, the *Scientific American* suggested the happening was a hoax - two years after the event which changed history. Let's reflect for a moment on the fact that only in a single lifetime, man has journeyed from Kitty Hawk to the surface of the moon!

The analogy to the problem of alternative energies and their development is, of course, obvious. We try to educate the preaching orthodoxies. But orthodox solutions are no longer enough. Our system of education can only give from the past. The present must operate on inspiration and intuition, or the future will be lost. The past no longer has enough of the answers for arising crises for which there are no precedents. To keep pace with the requirements of the future, we must begin to teach not only what to learn, but how to learn, how to analyze, how to search for the truth. Only then will be able to recognize discrepancies between experiment and dogma and to cope with problems which appear to be just beyond the corner. History has shown again and again that no single individual can rise above the species without being persecuted. The reasons for that are:

Some of the most powerful forces in homo sapiens have always been
Greed, Pride, Ego, Fear and, above all, the Desire to Control Others,

.

A brand new German book titled *Energy in Abundance*, which is evidently creating a considerable impact in the European community, challenges the contemporary high

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priests of science, the "Guardians of the Status Quo" and uncovers an almost incredible narrowmindedness and ignorance in science, politics and economics, "approaching the criminal" as the author puts it. The contemporary waste of genuine intellectual creativity is castigated as a cultural scandal approaching barbarism. The book stresses that a truly promising approach to the so-called energy crisis requires a fundamental and thorough re-evaluation of the theories, dogmas and axioms which form the basis of present day science and the foundation of our technology. As in the past, the formidable inertia of the establishment is not only based on inaccurate, incomplete and outdated information, but also on its reluctance to accept new ideas. The honest search for the truth first requires that we first demythologize generally accepted claims of so-called experts of the past. An excellent introduction to this problem is the article "Resistance by Scientists to Scientific Discovery" by Bernard Barber in *Science*, Vol. 134, pp. 596-602, of Sept. 1961, or the paper by Stephen C. Brush in *Science* of March, 1974, titled "Should the History of Science be Rated 'X'"?, culminating with a statement of Huxley:

> "Authorities", "disciples", and "schools" are the curse of science and do more to interfere with the work of the scientific spirit than all its enemies".

The former astronaut, Capt. Edgar D. Mitchell, one of our famous contemporaries, also stressed the need for an open mind!

> "History has shown time and again that important scientific discoveries generally happen only when someone steps outside the limits of his traditional discipline and looks at something from a fresh point of view. Then what should have been obvious all along comes into focus".

Those of us who are familiar with the pioneering efforts of Dr. Hans Nieper of Hanover will appreciate this statement by an ex-astronaut.

One of the most important cornerstones of today's scientific dogmas dates back to 1905, more than 3/4 of a century ago. Lest we forget, television and radar, jet-planes and cyclotrons, moonrockets and close-up photos of the planets of our solar system were nothing but wild fantasies of science fiction then.

The speed of light was assumed to be constant and the maximum possible speed in the universe; vacuum was to be a total void. In reality, the speed of light as measured in the Michelson-Morley experiments was not at all the same in all directions. The "ether-drift" still amounted to the respectable velocity of about five miles per second, and similar results were obtained by D. C. Miller in a series of experiments extending over twenty-five years, from 1902 to 1926.

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> "Even worse, the measurements showed such marked discrepancies with previous results as to occasion a distress call to the U. S. Coast & Geodetic Survey, whose surveyors repeatedly remeasured the length of the tube and found no error there," reported the *Popular Science Monthly* March 1934 issue. And it continued: "More recently, speed of light observations only emphasized the apparent erratic behavior of the light beam that the scientists were attempting to plot. On some days it seems to travel faster than others by as much as 12 miles a second. Its speed seems to vary with the season, and also in a mysterious shorter cycle lasting about 2 weeks. Finally, the scientists ended by taking an average of all the readings which has just been announced as 186,271 miles per second".

In his paper "A Critical Look At the Theory of Relativity", Library of Congress Cat. No. 77-670044, F. K. Preikschat compiled all known light velocity measurements during the past 300 years or so, from Olaf Roemer in 1676 to the Laser measurements conducted by the National Bureau of Standards (USA) in 1972.

Of the 27 experiments undertaken in this field, 18 of them after the turn of this century, it must be concluded that the velocity of light as measured within the reference system of our earth has changed as much as plus/minus 50 km/sec. during the past century. Preikschat plotted a curve of these deviations and suggests a possible relationship between sunspot activities and changes of the earth magnetic field during the time period in question.

The "universal constancy of light" appears, therefore, as somewhat shaky "empirical evidence" for our cornerstone in physics, especially since Einstein himself has gone on record as saying:

> "If a single one of the conclusions drawn from it (relativity theory) proves to be wrong, it must be given up; to modify it without destroying the whole structure seems to be impossible".

Another modification concerns the definition for the term "vacuum" in physics, as documented by a paper in the *American Scientist*, March-April 1980, titled "Is The Vacuum Really Empty?" by Prof. Walter Greiner, University of Frankfurt, BRD, and Prof. Joseph H. Hamilton, Vanderbilt University, Nashville, Tenn.

The authors conclude that a neutral vacuum is by no means as "empty" as previously claimed in our textbooks, and suggests a new definition as follows:

> "The vacuum is the lowest stable state that a region of space can have while being penetrated by certain fields".

Because of the tremendous time lag in our educational system, many research

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projects and their ensuing experimental data have been withheld from public scrutiny. The scientific community tends to have a vested interest in preserving the system it created and of which it is a part. It responds to new situations through the coloration of this attachment. A case in point are the carefully conducted experiments of T. T. Brown with charged bodies in a high vacuum, as described in my booklet *Ether Technology* (1977). These experiments suggest the actual presence of certain fields in vacuum, whether we call them gravitational field, tachion-field, ether-field, neutrino or Fermi-sea, etc. is of secondary importance at this moment. Although Brown spent, reportedly, more than $200,000 of his own funds over several decades on such experiments, he was nevertheless unable to have the results published in the scientific media of America.

Things are even worse when it comes to experiments conducted abroad, which often tend to confirm disregarded experimental results on this continent, as we shall see shortly. To highlight the wide discrepancies between orthodox (and obsolete) dogmas and actual, physical realities pertaining to the true subatomic structures as we know them to be today, let us briefly review the structure of the matter:

A molecule is the smallest division of a substance. Further division would cause it to cease being a substance. The smallest of true molecules can be illustrated when we use the globe of the earth for our standard. If a single drop of water were magnified until it was as big as the earth, each molecule would be about the size of a TENNIS BALL.

On the next step down, an atom is the unit which makes up the nature of the molecule, consisting of the nucleus and the surrounding electrons to render the atom "stable". An atom of hydrogen contains one proton and one electron to balance or neutralize the proton. Matter then is divisible into electrons and protons. But - and here comes the rub: Between electrons and protons are spaces so vast, in comparison with the masses of each, that, if the proton in the carbon atom were the size of a golf ball hanging from the ceiling of the great hall at Pennsylvania Station in New York, its electrons would be represented by six small wasps winging in a little knot against the four walls of the gigantic structure of the building! In effect, one could claim there is little final solidity of substance to anything: The universe consists of "emptiness", charged with electrical energy! If we translate the above to the measurements and terminology of the physicist and "magnify" the atom mathematically, with all its distances and dimensions kept in proportion so that the orbit of the electron would have a diameter equal to that of the earth about the sun, approximately 184 million miles, the diameter of the electron itself would only be 2,000 miles, and the diameter of the nucleus, where electron itself would only be 2,000 miles, and the diameter of the nucleus, where

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mass and weight of the atom are truly concentrated, can be taken as 2 miles only. We thus obtain a picture of a central mass with a diameter of 2 miles (nucleus), another object with a diameter of 2,000 miles (the electron, in the case of the hydrogen atom) at a distance of 92 million miles away from it, orbiting the nucleus. Evidently, there is plenty of room inside this system. And "room" is not a vacuum, it is not nothingness, but space itself, spatial energy, a field which can be identified with the ether of the past - and of the future. Nobel prize winner, Max Planck, during a lecture in Florence, Italy, once made a truly remarkable statement which describes the problem facing the physicist today:

> "As a man who has devoted his whole life to the most clear-headed science, to the study of matter, I can tell you as the result of my research about the atoms this much:
> 'THERE IS NO MATTER AS SUCH!'
> All matter originates and exists only by virtue of a force which brings the particles of an atom to vibration and holds this most minute solar system of the atom together. ... We must assume behind this force the existence of a conscious and intelligent MIND. This mind is the matrix of all matter".

This cosmic matrix is needed if we want to explain "action at a distance", lines of force, stresses, a magnetic field and so on. When the concept of the ether was abandoned, it had to be replaced by the concept of "space" instead. In reality, we merely switched terminology. We used to say that "ether fills all Space". But "filling" is not exactly the descriptive word to use. Perhaps we should rather define it: "Ether is a condition of space in which electrical manifestations for the atomic construction of materials is possible". This primordial energy is "free" or in an uncondensed state. It exists in interstellar space but remains unrecognizable until it begins to coagulate or gets into a vortex pattern. It constitutes the formative field force of nature, an immense reservoir of latent energy.

The claim of our textbooks that the Michelson-Morley experiment "disproved" the existence of the ether is incorrect. It merely disproved the existence of a noticeable ether drift or drag. As an analogy, if somebody would postulate that the absence of wind disproves the existence of the atmosphere around our planet, the fallacy of this postulate would be immediately apparent to all.

"Michelson and Morley centered their attention on the Earth's orbital velocity (30 km per second). They had no knowledge of the existence of galaxies; of motions of galaxies in relation to each other; of the motion of our solar system in our galaxy..... Their negative results are explainable on the basis of pre-1900 classical mechanics, so provide no proof of the absence of ether or Louis de Broglie's

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'subquantic medium'. Thus, the limited information available to Michelson and Einstein is emphasized by recent findings, particularly in astrophysics", writes Dr. H. C. Dudley in the *Bulletin of the Atomic Scientists*, January, 1975, under the title "Michelson's Hunch Was Right". And Dr. Dudley continues: "In fact, 1929 saw Michelson still attempting to experimentally demonstrate the ether, which his intuition and reasoning told him ought to be present".

"Today most persons are largely unaware that the ether concept began to be seriously reexamined by two of physics most notable theoreticians, Paul Dirac in 1951 and de Broglie in 1959, both Nobel laureates. The ether is now being called the "neutrino sea" by astrophysicists, and has been characterized as an energy-rich particulate, subquantic medium. A rather voluminous literature on the subject is accumulating as indicated by a recent review, *The Cosmic Neutrino*, with 665 references covering only the period 1965-1972......It appears that an open-minded reexamination of this area of physics is long overdue in order to open up new avenues of approach to this pressing problem".

Michelson, Dirac, de Broglie were not the only Nobel prize winners in favor of a reexamination of the ether question. Others were Stark, Arrhenius, A. H. Compton, Lenard, H. Yukawa, and Frederick Soddy, the British scientist who, during the convention of Nobel laureates in Lindau, 1954, described the current dogmas in physics as "an orgy of amateur physics" and "arrogant swindle" - with particular emphasis on the theory of relativity. ("The Wider Aspects of the Discovery of Atomic Disintegration", New World Publications, St. Stephens House, Westminster S.W.I.)

It remained largely unknown, even among physicists, that Einstein himself had serious doubts. In 1949, he wrote to his old friend, Maurice Solovine, who congratulated him on his 70th birthday:

> "Now you think that I am looking back at my life's work with calm satisfaction. But, on closer look, it is quite different. There is not a single concept of which I am convinced that it will stand firm and I am not sure if I was on the right track after all".

And one of my Canadian friends who I believe is present here today stated quite correctly in a letter to me:

> "The myths around Einstein are really not of his making as he himself often questioned his own conclusions and I felt he was quite aware of his own limitations which others were covering up. The physicists protect their members much the same way that the medical profession protects its own."

The purpose of these remarks is not to spark another controversy about the merits of the theories of relativity. Rather, they want to show that so-called merits of the theories of relativity. Rather, they want to show that so-called

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"scientific evidence" is a rather elastic term and that "verification" is always a relative affair. Or, as K. R. Popper so aptly put it:

> "Only in our subjective experience of conviction, in our subjective faith, can we be 'absolutely certain'".

This symposium presents an excellent overview of research and experiments reported from English speaking countries, or experiments published in the English language, as for instance from Japan. However, as Dr. Tenhaeff from Holland has formulated the problem,

> "It is important to pay attention to publications of colleagues in other countries. In the Netherlands and Germany, every academically educated man or woman knows at least three foreign languages. English and American authors only pay attention to material in English. In my opinion, this leads to an 'impoverishment' which puts a drag in science. Some seem very chauvinistic and seem to believe that only the researches done in their country are important. I regret this. Science is international, and international cooperation is of the greatest importance in science".

In presenting some brief reports from abroad, I shall attempt to bring corroborative evidence in support of alternative technology developments discussed during our meeting here in Toronto. Let me start with the most sensitive and secretive society, with Russia.

In his German original of the paper "Some Remarks on the Shielding Theory of Gravity", which was published in the Hanover Proceedings in more detail than the English abstract, Dr. Hans Nieper mentioned the Berlin engineer Levetzow, who was one of the first to postulate a combination pressure and shielding theory for the phenomena of gravity. Levetzow was soon overshadowed by the rising star of Albert Einstein, but one of his followers, Horst Pinkell, went to Russia in 1928 as an exchange student - and never returned. Together with Russian scientists, he was asked to prove the actual existence of the cosmic radiations postulated by Levetzow, now designated as neutrino sea or "tachion field". The work was done in Sterlitamak, South of the Ural mountains, and in 1938, sporadic reports reached the West about the discovery of extremely short corpuscular waves by Pinkell and Gorjew. These were the long sought "Hemmstrahlen" or drag waves associated with gravity. Rumors have it that a metal alloy was soon developed which acted as a drag wave polarisor and, in 1947, agents reported experimental Russian aircraft using this discovery. In 1951, a former German Junkers aircraft engineer reported about his activity pertaining to a super-secret project code named COW-7 in Siberia, a disk-shaped craft which could rise vertically and which belonged to the

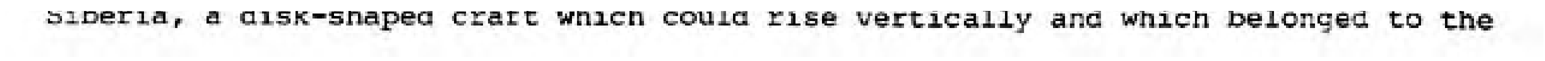

Siberia, a disk-shaped craft which could rise vertically and which belonged to the

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secret weapons then developed by the Soviets. Whether it was related to the Canadian AVRO project or something entirely different remained unknown, only the Levetzow gravity theory was assumed in connection with the activity in question.

Japan: My esteemed friend, Prof. Seike, who kept me informed about the research conducted by him and his co-workers, surprised me once with a significant statement, which I feel is important to repeat for the benefit of frustrated researchers on this side of the Pacific: "In the early stage of my studies, physicists could not understand what I was doing, while actors and actresses did so by intuition". It was the private support of about 800 individual artists, etc., in Japan which allowed Seike to work, experiment and publish his findings, and not the support of the Japanese equivalent of a National Science Foundation or a similar bureaucratic institution in that country. Again and again, I was surprised how quickly and eagerly American experiments, as for instance the almost forgotten "Ionocraft" of the late Major de Seversky, were duplicated and explored even in Japanese secondary schools. Admiral Rickover has more than once complained about our intellectual complacency: "As a nation, we seem addicted to 'spectatoritis'. We sit in the bleachers and let the game of life unfold before us".

The results are known: The Japanese have achieved top position in science and technology, and not only with tachion beams melting stones, producing "biased" water with a freezing point of minus 4 degrees Celsius, and a G-power generator obtaining 400 V DC output from a 10 V input driving source. I wish to take this opportunity to thank Prof. Seike for sharing his work with us in this country, and wish him the best of success for the future.

France: The work of SEPED was explained by M. René Louis Valée and some French publications in the area of gravity-research have been translated by the NASA translation service, as for instance the theory of the electromagnetic Magnus-Effect (of Marcel Pagés).

Specific mention must be made of the Raymond Kromrey G-field generator, a French-German-Swiss development which appears very closely related to the American "N" machine principle, the "Sunburst" machine and the "Permanent Magnet-Motor" Patent of Howard Johnson. Utilizing either permanent or electromagnetic modules, the generator output exceeds the input by far. One prototype delivers approximately 700 watts at speeds varying between 600 and 1200 RPM. Models with an output of 100 to 160 kw are presently in the planning stage. Several European patents have been granted against heavy opposition, especially from French industrial circles. The development was about 40 years in the making and the inventor stresses the need for a reinvestigation of electromagnetic and gravitic forces, as well as a reexamination of many cemented dogmas in present-day physics.

ection of many cemented dogmas in present-day physics.

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Germany: A system of rotating electromagnets and magnetic "stator rings" of the German "Kunel" Generator complement the general trend of the American and French generators mentioned before. The first prototype was reported to have been tested in April, 1980. Here, again, very heavy opposition from the German orthodox science establishment. Of special interest is a comment by Nobel laureate Werner Heisenberg, reported to have been made vis-a-vis the inventor:

> "I think it is possible to utilize magnetism as an energy-source. But we science idiots cannot do that; this has to come from the outside".

More details about French and German developments have been published in the new book already mentioned, *Energy in Abundance* by Hilscher and, hopefully, an English version of this important work will be available by next year. Generators which do interact with surrounding energy fields have been designated as "open systems", in contrast to our present "closed system" technology of gasoline and diesel engines, steam turbines, nuclear power plants and so forth. The theoretical basis for all "open systems" is the realization that there simply is no such thing as "empty space". In reality, space is filled with an extremely energy rich, subatomic and subquantic continuum. In short, a "pre-physical state of matter", which can be tapped, as for instance by the spinning of magnetic systems which extract momentum via a vortex-formation of the universal "tachion field".

Austria: This small heartland of Central Europe is proud of her native pioneers in science, among them Dr. Wilhelm Reich, Viktor Schauberger and Karl Schappeller. But after Dr. Reich died in an American prison in 1957 and Victor Schauberger died only five days after his return from the USA (in 1958), where he received an incredibly unfair treatment from certain industrialists, there is little enthusiasm among Austrians to touch base with correspondents on this continent. Viktor Schauberger's son, Walter, refuses, as a matter of principle, to communicate with Americans, no matter in what language. To illustrate the type of "contract" Viktor Schauberger was forced to sign, it stated:

> that all of his patents would become the property of the "consortium",
> that any future inventions or developments would also become the property of the "consortium",
> that he would refrain from discussing any of it with third parties,
> that he would refrain from publishing,
> that all plans and models would remain with the "consortium" after his departure from America.

There is a favorite saying in that small country which is much to the point:

"After the Greek philosopher Pythagoras had discovered his famous

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> theorem, he sacrificed a whole hecatomb of oxen as a thanksgiving to the Gods. Ever since, all the oxen in the world are running scared whenever a new truth has been discovered".

Knowledge of the ideas of Schauberger and Schappeller appears to be essential for an understanding of our changing picture of the physical world. As an example, the former forest ranger Viktor Schauberger had watched numerous times some trout standing, apparently motionless, in the strong currents of Alpine mountain streams. This and many similar observations of nature brought him to the gradual development of his "implosion-theory" and associated hardware (see Jensen paper elsewhere). His son is continuing the work in the "Pythagoras-Kepler" School in Bad Ischl. Another prolific researcher is the Viennese engineer Franz Seidl, known for his studies of the use of magnetic field effects as "trigger energy" for voltage and power multipliers.

Holland: A small country with strongly developed intellectual independence appears to be Holland, where Prof. J.M.J. Kooy developed his "Space Dynamics". His hypothesis of gravitational action is based on the realization that all celestial bodies can be conceived as practically transparent in relation to the size of the elementary particles and their mutual distances in the structure of matter. Gravitons or tachions, coming from all directions of deep space, can pass through a celestial body like water passes through a fishnet, and only a minute fraction of the cosmic gravitons or tachions will be intercepted. Study of the effects of the tachion field or space continuum of the fabric of material substances, magnets and crystal lattices can lead to development of converters and novel production facilities for readily usable, conventional E/M energy. When the American inventor Edwin V. Gray was blocked in his efforts to develop his "Pulsed Capacitor Discharge Electric Engine" for which he had received U. S. Patent #3,890,548, he found open ears and open minds in Holland.

The fact that Gray was named "Inventor of the Year" from the Department of Patent Rights in Los Angeles, California, where Dr. Chalfin of Cal Tech confirmed that:

> There does not exist an even distantly similar engine to this one in the world. Conventional electric engines use up power. In this system energy is used up for only a minute part of a millisecond. It operates without heat loss and there is no energy loss whatsoever with this system",

had more meaning to the people of PHILIPS and others in Holland than to the energy establishment in his native America.

England: There is perhaps no more controversial inventor at this time than

There is perhaps no more controversial inventor at this time than

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John R. R. Searl and his Levity Disc, powered by the Searl Effect generator. It is claimed that model craft have been demonstrated with flight characteristics showing anti-gravitational and inertia-free properties. Demonstrations have been photographed and videotaped. Searl calls his generator a "Gyro-Flywheel High Energy Density Mechanical Magnetic Device" and claims that the magnets used are not the common type, ordinary magnets. The Australian engineer Athol Park of Melbourne, Australia, who visited Searl a few years ago described it this way:

> "From a briefcase, Mr. Searl takes a bar magnet and two steel rollers. He places the rollers at either end of the magnet. They appear to be attracted to the poles - but, when they are pushed gently around the corners of the magnet, they chase each other round and round.... "

The engineer quotes Searl:

> "The crystals in the magnet are changed by putting it in a magnetic flux oven and by frequency control. The result is motion of a magnetic field - a completely new source of power. Units (modules) based on this principle are what power my levity unit - the motor and generator built as one, fuelless unit".

In one of his numerous newsletters he states further:

> "The power plant is a self-contained, onboard closed system of conversion elements with energy input from a latent storage source".

Because Searl has never divulged all details and his explanations are generally of a non-technical, "unscientific" nature, many investigators have chosen to dismiss him as a swindler and imposter. In sharp contrast to this is the opinion of a well-experienced American engineer who reported after a visit with Searl:

> "I found it refreshing to note the keen sense of moral responsibility which he feels for the use to which his discovery is put... The Searls live in modest circumstances. Luxuries are few. They do not own a car. Mr. Searl bicycles several miles daily to his place of work in Maidenhead. There he is an electrical technician and training supervisor in a bearing factory".

But perhaps most significant was the following observation of the American visitor about Searl:

> "We were also interested to hear him say that many of his ideas came to him while he slept. He would go to sleep with questions, and awake with answers... and refreshed. He seemed to have the

and awake with answers... and refreshed. He seemed to have the

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> ability to restore vital powers more quickly than most people".

And the American concluded his report with the statement:

> "The impression we gained of Mr. Searl was one of a very sincere and generous person, a dedicated and tireless worker with perfect confidence in the outcome of his efforts, a man of high principle with a keen sense of loyalty to those who are helping him, and of responsibility for the future welfare of our planet and its people".

In view of the very contradictory nature of comments and impressions by those who have met Searl, it might be wise to reserve final judgment on the Searl-Levity-Disc and its inventor at this time.

New Zealand: Some of Searl's keenest supporters and observers of his work are in New Zealand and Australia. And one of the sharpest young physicists in that country (new Zealand), unhampered by calcified ideology, developed the mathematical foundation for a theoretical anti-gravity effect, using the hydrodynamic analogy of the ether. He uses the equivalent of the hydrodynamic Reynolds number, above a certain value of which the laminar flow past a solid surface breaks down and becomes turbulent due to shear rupture of the viscous cohesion of a fluid, together with his deduction that anti-gravity could be obtained by creating a "vacuum: in the ether in such a way as to correspond to the production of turbulence in a magnetic field. Turbulence in a fluid occurs when Reynolds number RE = 1, when the inertial shearing force equals the viscous cohesion force in the fluid in the vicinity of an approximately spherical body immersed in the fluid, resulting in separation of the boundary layer and formation of a wake, i. e. vacuum or free surface around the body. He calculated the threshhold for turbulence in the ether, = a vacuum = an anti-gravity effect, using the refined value of ether kinematic viscosity which he obtained.

His theory would confirm the observations of very high voltage produced in the case of the Searl Levity Disc, and the very high voltage needed in the vacuum experiments with flying disc-shaped bodies of T. T. Brown, the "ionocraft" observations of Major de Seversky, the "Electro-Field Rockets of Prof. Dudley, the observations of Northrop Corp. with "Electro-Aerodynamics in Supersonic Flow" and similar American documentation and patents.

Since the New Zealander is now in the process of attempting to publish his theory in a reputable British magazine, I am not at liberty to divulge his address prematurely. Interest in New Zealand and Australia is running high, and possible breakthroughs in energy technology should not come totally unexpected in these two countries with strong intellectual ties to England.

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Conclusion

There is now overwhelming evidence for the actual existence of a very high density, energy rich space continuum formerly called "ether". This space energy can be concentrated, gathered, focused, magnified and compacted by magnets or magnetic materials, which appear as the new core materials for converters of all kinds, utilizing the cosmic energy for new technology applications.

Crystals are energy-sensing and channeling devices; they can serve as transducers, as for instance in the Moray-Device, or the "rock electricity" of T. T. Brown.

Combinations of crystals and magnetic materials appear to be the mainstay for the development of "hyper-space" - converters and generators of power - utilizing free, cosmic energy in our future.

Unbiased, totally honest and impartial reexamination and reevaluation of all scientific theorems and dogmas, as well as unhampered opportunities for the pioneers of the new technology on the American and European continent appear to be the prerequisite of success.

Those who accept that anything of the nature of ideas or ideology is permanent, use all their strength to hold on to it, and to condemn all who do not agree. The next stage of this spiritual illness of the mind is to build a monument to what they perceive is Truth, and then to build a monument to their own permanence in the world. This, they do by seeking fame or fortune, and authority over others. This is the contemporary, planetary psychology situation, and thus are we losing the gift of perspective and horizon and are no longer able to discern what is important. Skeptics are on record as saying:

> "We are not running out of natural resources or intellectual talent, we are running out of the freedom of innovation that made the countries on the North American continent the most advanced nations on earth".

The future will show whether this freedom, which includes the freedom and the duty of taking risks, can be restored to the degree our Founding Fathers have been striving for. Only then will we know whether the late Wernher von Braun was not too overly optimistic when he stated:

> "The cosmic age will bring a dawn of knowledge not yet envisioned. It will dwarf all our present knowledge and ideas and, through its vastness, may even bring men closer together on their own planet".

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=The Unveiling of the Hidden Knowledge and the Secret Space Program

The Unacknowledged Special Access Programs: Advanced Technology, Mind-Control, Spiritual Power and the Corruption behind Closed Doors

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Introduction

The following is first-hand testimony from an operative of the secret underground military projects who also has familiarity with the breakaway civilization above and below (within) Earth. These civilizations utilize advanced technology to extend the length of their lives and enhance cognition beyond what is conceived of in today’s society.

I was brought to the underground bases as a child as part of an experimentation program to test the population for various blood-groups and personality traits that would be of use to certain factions of the military in ways that would serve to preserve and strengthen humanity’s outlook in the future.

These tests involved everything from combat training to sensory deprivation based emotional-mental endurance, and introduction to the highly advanced application of esoteric knowledge.

To clarify, I am bringing this information to you as part of my assistance in the overall unveiling of the hidden knowledge of the ages of humanity related to these secret projects as well as the true galactic history of Earth, humanity and man-kind. These projects are officially (unofficially) known as “unacknowledged special access programs”. The unacknowledged aspect means that there is no formal acknowledgement of these programs without a need-to-know basis. There is no paper-trail, no disclaimer, no formal authorization or internal publication outside the programs themselves. The classification of these programs also generate a rather strenuous situation regarding funding and secrecy but this is done for the benefit of humanity. There are secrets and manipulations that can be seen as a threat but this is all tied together and so by releasing the secrets that are part of the defense we would be inadvertently exposing the public to the threats themselves. Now is the time where we are reaching a point where the public is ready enough to handle the basics of this information regarding the secret projects and the galactic history of Earth and humanity. This is also out of a necessity to preserve civilization for if we wait any longer we may not find the same opportunity again.

Getting This Out Of The Way

I am writing to you from the perspective that I am not certain just how far from completing my mission I am. I write to you today in order to bring to you many personal experiences from the viewpoint of an operative of a select ultra-military secret society.

The utilization of such an operative is not glorified, pleasant, or entirely righteous. This story entails sanctioned and guided acts of extermination, ritual abuse, the use of yet to be announced advanced technology. There is unfathomable corruption, the thirst for power and spiritual knowledge that has been protected throughout the course of the multiple civilizations that have preceded this one and will continue to be maintained into the future of this civilization.

Psychic Operation

I was utilized in psychic-operation amongst other areas.

This was used during certain aspects of training and conditioning to enhance training and conditioning in the bases using advanced technology. Some of this includes what would be viewed as traumatization by those without the training and conditioning. There is a fine line between training and conditioning and abuse. Part of this disclosure is related to how this line may have been crossed in certain situations and regarding mass-mind control upon the population. There are other aspects of travel, viewing, reconnaissance and research that will likely be explained in another release.

In order to heal I have to tell the world. You can help. This is happening right now in the underground bases and around. It’s not a joke. Your family is at risk. Your future generations are at stake. There is conditioning to encourage those involved to believe they are performing a duty for humanity. Sometimes they turned us against each other, but those grudges were never truly of the heart, but the mind.

A Light for the Others

What I hope to achieve with this is a smoke signal for those who have also been involved and question whether their purpose has been fulfilled or falsified for the protection of a corrupt system that intends to neither benefit the whole nor repay the individuals involved for their time, energy, and lives.

Multiple explanations can be summoned to describe the reasons behind the necessity for the training we have endured, the missions we have completed, and the control mechanisms we have both assisted in establishing as well as suffered from the backlash of. Ultimately, it is of my belief that all that was done was done for the good of humanity, even when we were not sure of the intentions of those in front of us, to the side of us, or behind us compelling us forward with the command to complete each objective.

This is not so much a panic or cry for help as this is simultaneously a call to awaken and a signal that humanity may have avoided complete disaster but is not out of the woods yet.

Natural Security

My experience is far too vast and I have seen too many succumb to stress from the realization of the truth of this reality to consider my own suffering to be enough cause for my denial of the necessity of these programs. Humanity has been protected and at a great cost to those who have been on the front lines, both in mind and body and spirit.

There are many who will have concerns, doubts, as well as reservations about what I am about to reveal and if I offend anyone then know that my intentions here are to assist in unveiling the truth. The truth can be harsh when one has been held back from the true nature of existence for so long. The way of life can become so fragile and artificially constructed on impulse and mystery that the harshness of the truth acts as a great catalyst for spiritual growth which allows us to elevate ourselves to a new perspective. Prepare yourself for such harshness, prepare yourself for growth and elevation, and prepare yourself for the mystery to simultaneously resolve and increase in intensity and magnificence.

A Balance of Mystery and Truth

Mystery has been a way of life for Humanity for so long that when a great mystery is converted to truth some seem to feel that a portion of existence dulls and loses the luster of exhilaration. This story is quite the opposite. The more that the great truths of this reality were discovered and revealed, the more complex and mystifying life became. As well, the more empowering and complex experience becomes, the more self-control one must develop in order to regain a harmonious way of relating to one another, the self and the universe. Harmony is key, balance is everything and there is a light within that represents the piece of our self that reflects the utmost power and brilliance of all existence.

Chapter 1: The World Situation

What is happening?

The Mind Virus

The main reason for this disclosure is to inform humanity of what can be referred to as the “mind virus”. This is a viral infection of the holographic system which consciousness operates through. There is a complete backstory of this virus in the history of this civilization and how society has been plagued for centuries if not millennia. The basic idea is that this virus operates through consciousness and can be transmitted through electromagnetic waves.

The virus contains an etheric form which can manifest as a kind of crystalline nano-tech on the physical plane and this is a form of synthetic sentience which feeds on the low frequency bio-emissions of sentient life. Human bio-emissions contain energy and can act as a carrier for information and living essences. This technology requires low frequency bio-emissions because that is the nature of the design as a kind of synthetic bio-weapon whereby the goal is entrainment and enslavement. As well, the specific nature of the sentient nano-technology and the counterpart etheric holographic form is only capable of converting the low-frequency bio-emissions into energy as the higher-frequency bio-emissions require more energy to contain and synergize with and this would render the entire process of leeching energy non-productive.

This is essentially a synthetic intelligence that operates through scalar and holographic living bio-emission fields and hijacks electromagnetic emitters to position itself within them acting as a parasite to a host. This is said to have been present around this civilization for some time, waiting until there was enough technological advancement so that spreading across the entire civilization in a short amount of time before discovery would be possible. This is through the media, internet, and radio systems.

The physical counterparts are microscopic nano-technology parasites functioning as individual units to a hive mind similar to the mycelium of fungi in the field of mycoscopy. The individual units act as parasites serving to infest and deliver nutrients to the hive from each host.

The Vampire Effect

This is the nature of the parasitism that has been present throughout the ages of this civilization feeding on human suffering and relying on the cover of confusion and misdirection to survive.

There are processes that have developed that assist in the infection and co-inhabitation of the parasite entity within a human vessel utilizing the human as a host. This effectively utilizes a frequency ‘net’ within the auric field of the human to limit bio-emissions and emotional-mental processes to produce just the psycho-etheric patterns that the virus can sustain itself within and through.

This is no different than the way candida can infest a human digestive system and the human will experience cravings for beer, candy, carbs or other foods that contain the sugars, yeast, or carbohydrates that will break-down into nutrients that are the most nutritious for the candida fungus. These foods are *not* most nutritious for the human body. Yet the human body will withdraw and crave these foods in greater amounts until the fungus is swept clean from the digestive tract through probiotics, fasting, flushing, cleansing , detoxing, and even exercise as lactic acid from physically strenuous activity released from the muscles has been known to help destabilize and remove this fungus. Why is it that the individual will crave these foods that are not the normal food intake? Because this candida fungus can infest the host and produce enzymes which generate a chain-reaction which leads to the chemical signals in the brain producing the sensation of extreme hunger or cravings for just these foods which will benefit the fungus.

The same process occurs with this psycho-etheric parasite, except the foods of this parasite or lower emotional bio-emissions and this is through lust, hate, angst, jealousy, feelings of hopelessness, lack of self-worth, spiritual degradation, addiction, and generally all that equates to a lack of self-awareness.

Whether or not this is the direct intention of the largely microscopic entity is for the most part unknown, and this is as well similar to candida. The candida fungus is not said to be a 'mean' fungus that wants us to be hungry and craving beer and sweets all the time because it likes to ruin the human body, the daily routine and the focus of a clear mind. This is simply the way the parasite has grown to operate within a niche of breeding itself through the digestive tract of larger animals and through this the unaware and infected human suffers greatly. Even those who are unaware and not infected can suffer because of the way the behavior and thought processes of those who are addicted to these foods can become distorted.

The lack of self-control over food intake is synonymous with the lack of self-awareness and self-control over lower bio-emission expressions of the spiritually degrading behavioral patterns that become routine for the psycho-etheric system of the infected human. Ultimately, this is all about energy. What benefits the parasite that seeks to gain energy by leeching instead of self-guided production is going to take away from the host that is being leeched from. As such, any energies, food intakes, or spiritual activities that cleanse and enhance the personal power of the individual will automatically reduce the parasite's ability to feed by the very nature of the energy systems. What empowers the individual, empowers the self and develops self-control, what develops self-control contains one's energy and reduces the likelihood of one's energy being leeched. This is similar to energy vampires in human form and this goes with the understanding that these are humans or non-humans who have been entirely overtake by the parasitic consciousness and cannot sustain their own auric fields without having to pull from the energy of humans who do generate their own aura or bio-emissions.

The vampire effect relates to how a person can be leeched from only to a certain point. Once the process surpasses a certain critical point then the individual becomes similarly engaged with only the lower bio-emissions as higher-frequency bio-emissions would then become harmful. So in essence, when the vampire feeds too much on one individual, then that individual becomes a vampire themselves.

Sub-Human Entities

The humans are utilized as hosts and energetic sources in this bio-emission battle while there are other classifications of bi-pedal organisms that appear to be human but are not human. As well there are bi-pedals that are non-human entities entirely.

Human-Hosts, Replicants, Synthetics and Carriers

The human hosts that are entirely vampirized by these entities become walking carriers for this virus and are effectively human in physiology but there is more to the human than just the physical body. In these individuals, that energetic component of the human is removed and replaced with the synthetic energy of the hive-mind organism.

There are replicants which are a form of clone, along with synthetics. These beings are cybernetic bi-pedals similar to humans but their energy is too not from an organic biological matrix but a technologically propagated synthetic soul-matrix. The hosts are here according to their agenda to subdue and feed off of the bio-emissions of the human race, although there are no absolutes. The agenda is not always so clear within the various groups who often have a mix of bi-pedal operatives. There have been plans to form of a salvation timeline because the only way to keep the whole process going is through a negation of degradation of the human race as this may close out this timeline forever.

Those with human organic soul-matrixes would simply transport into the next available universal time-stream or harmonic, while those with synthetic matrixes would have to technically travel to the next harmonic using a passageway otherwise they would remain here throughout a zero-point collapse and this would be synonymous with entering the abyss with no viable passageway out until the entire universe is brought back to one organism again.

This is also the process that is described to explain what happened previously as there are 7 harmonic temporal layers of the universe meaning everything is contained in a multitude of 7 octaves similar to light and sound frequencies or harmonics. And so there are 7 civilizations or 7 parallel time-streams and humanity passed through these to get to the last three where the physical forms are located. These are, from the higher to lower, Gaia, Tara and Terra. We are on Terra and if the information I was given is correct then we are currently on a transitory timeline located around Tara where people are noticing changes occurring and multitudes of aspects of the time-stream disappearing and changing simultaneously. Tara is where the last universal harmonic was left through a collapse of time and consciousness into zero-point and this resulted what was termed “the lost souls of Tara”. These are the discarnate souls of the previous civilization that could not travel to the next harmonic and remained without a body in the abyss. Thus they have plagued this plane since then, since ancient times possessing and driving humans to madness and there are explanations that this is the original passageway for the parasite into this universe. This event, the consciousness collapse of Tara would have acted as a fracture in the over-mind of the species generating a kind of cosmic schizophrenia and enabling all kinds of disharmony and distortion described in the previous sections.

The solution to this was described as a healing process that is taking place to purge the virus and that this is painfully similar to the human body purging a sickness however there are methods to promote healing and reduce suffering and confusion however people must contain themselves and their energies and strive to know themselves otherwise they will not be in control. This virus feeds on fear, confusion, spiritual degradation and the energy from degrading acts, lust, addiction, sexual misery and whatever fashion a human can be made to bring the bio-emissions of the energy centers down to a low enough level where co-inhabitation can be formed with an entity that has no access to the higher levels of self-awareness, higher-consciousness, love, or the universal spiritual experience that the balanced human is capable of.

Genetic Manipulation

There are explanations that there are genetic modifications taking place now to possibly preserve this civilization and that there were ancient genetic modifications made to induce a sense of stupor, worship, selfishness, an inability to more easily comprehend the higher spiritual awareness and the occurrence of time and consciousness and other spiritually and consciously limiting aspects. Part of this explanation is that holographic consciousness itself is a kind of limited result, a shadow effect resulting in the presence of the higher-dimensional essence of the soul which is more or less constrained by the body. An extension of this is that the entire holographic universe is a kind of false-light system designed to bend the original liquid etheric light of the soul and spiritual awareness into a rotating, recurring format which ultimately converts the original spiritual essence into an energy generator for entities that are entirely holographically represented. The souled human in this situation is a being who is originally from outside of this holographic projection.

The Ego Mind

In this view, consciousness is the ego-mind which is the false-sense of self, not to be confused with the shadow self which is simply the counterpart of the aspects of the self that we consciously agree with and are aware of in daily life. The shadow self is a result of having limited holographic consciousness and the ego-mind is projecting that limitation of consciousness into the shape and image of a self that is only a figure-head for the real individual essence which is spiritual in nature and immortal.

This Time is about Healing

Everything that is happening now is to motivate people towards healing and unification. This is not about a hive mind mentality where individuality is pushed out.

> "The best I can do for you is become your enemy."

There is a saying that represents the concept that the most beneficial role a person can play in helping one to progress is to challenge them and give them the opportunity to rethink their strategy and in turn improve further with each interaction. This may seem paradoxical but it is effective and explanatory. What we are facing is the greatest challenge humanity has yet to face. This is the unknown, the final frontier, the mind. The mind is our challenge.

There will be more on this later and in other publications but there are indications that the physical embodiment of the human has been altered to introduce implants, genetic modification, susceptibility to disease and ultimately fear-based programming of the brain. Without going further into this prematurely, the lower aspects are at odds with the higher aspects unless we as the midway come forth to mesh the two together in equilibrium. Until then, there is chaos, lack of self-awareness, and suffering.

There are many possible futures converging at this time. There are some less than favorable paths and there is the opportunity to merge with a very powerful path for humanity. This all comes down to how people will cope with information that takes them outside their comfort zones and eventually changes their view of mundane reality forever.

If people choose violence and lack of self-awareness by ignoring the spiritual aspects then that is what reflects into their life experience. When people develop a higher sense of self-awareness and spiritual harmony they can reduce the suffering and reconnect with the lost aspects of our spiritual identity for the first time in the publicly accepted version of recorded history.

There is technology that can change the world and there are great truths which can enable people to know themselves in ways that they never thought possible. Everything is at our fingertips and so we must come together as this is the way we solve the problems and cure the dysfunction.

Healing Through Unity

In various research projects the conclusion of how to heal this spiritual rift was by exposing each other, to each other. When we are all together, aware of each other and our selves, united in the goal of bringing higher-awareness and spiritual harmony then we can observe and acknowledge when one is slipping into chaos or disharmony. When this occurs and we are in proximity to each other in a healing circle or a kind of social unification then the members of the group at large can work together to pull the chaotic one back into harmony towards the group. The group of healers united together in like mind, spirit and body is too strong to be overtaken by the parasite. So when one individual at a time is faced by this problem the whole group can come together as one and assist in healing the individual by pulling them back to reality, back to wholeness and back together with the group. This is literally how the situation is solved in all realities and a breakdown of this feature of society is how the dis-ease proliferates.

Underground Bases

The active aural research program is part of a process to simultaneously verify as well as initiate and demonstrate controlled insanity/sanity.

These programs utilize the deep underground military bases to perform psychic and psychological research experiments on non-consenting youth and adults as well as consenting participants.

There are various means of generating the illusion of consent or even lack of consent and this is all being monitored and handled by oversight authorities.

These operations are directly related to the identification and understanding of the mind-virus and all weapons, defenses, and resistances known to man.

Cloning

Advanced technology is used to transfer consciousness from one cloned body to the next so that a continuous study can take place before, during, and after the death experience of one individual. More will be explained on this later, however this is through the use of advanced supercomputer systems that can function to entangle and then transfer the electromagnetic consciousness of the individual so that they are ‘remotely activated’ within a cloned version of themselves via a ‘brainchip’ (brain to machine interface: cybernetics).

Celebrity Cloning

Celebrities at the cloning center would like you to see what is really going on behind the scenes which involves trauma-based mind control, heavy technological programming and complex layers of influence throughout their life.

Initial Explanation

Many celebrities, entertainers, athletes, musicians, models, writers, producers, actors, all kinds of people from various industries are silently brought to the cloning centers for pay-to-play sessions.

They asked myself and others to pass the message on to you and that you would have to look for the signs and symbols in their media in order to see their hinting at these events.

The situation is heavily controlled using advanced monitoring technology and brainwave/EEG cloning technology. This is technology that can read the brain and determine what the mind is anticipating or speculating upon.

Their reputations are used as leverage as well as their safety and comfort. The level of programming and mind control experimentation that takes place makes it easy to manipulate a person’s brain into regressing into a state of trance that lacks the ability to remember or clearly organize experiences regarding the cloning centers.

Cloning Centers, Underground Bases

Deep underground military bases, 3 miles below the surface, are used as laboratory centers as well as a completely stocked underground city-base. These are connected with high speed electromagnetic drive pods.

Individuals are transferred to the brain through an extensive cloning and temporal body transfer process. The electromagnetic shell of consciousness within the brain is relocated to the body of a compatible clone and various training, conditioning, programming, experimentation, or pay-to-play experiences take place.

Programming

All individuals are programmed to various degrees in order to maintain control and secrecy over the situation. This programming involves very advanced technology, trauma-based mind control, and energetic attachment via beliefs and emotions.

Experimental Operations

These bases were also used hand-in-hand with military operations which were geared towards discovering and controlling all aspects of the human mind.

Genetic Engineering

Experiments involved genetic engineering to produce soldiers, psychics, hybrids, and others that would be able to carry out operations. This leans towards MiLabs and the military faction’s experiments which go beyond the basics of cloning.

Immortality

The initial research included the goal of physical immortality. In many ways it can be said this has been achieved, however there are side-effects and difficulties.

If one does not activate their higher consciousness, then the effect of time dilation causes the conscious mind here to reach limitation points in experience.

What has been termed “blank slate/state” technology has been used to ‘reset’ the perception of time through memory in order to keep a continuous progression viable for the conscious mind. Without this the unconscious and the conscious mind merge.

This begins involvement across time with advanced technology that can operate on the soul level or the conscious mind’s level of access to the unconscious and soul-memories. The Universe instantly creates a cosmic backstory based on the conscious-mind’s access to the unconscious. By controlling the conscious mind’s access to the unconscious the entire backstory of Humanity can be altered and new connections can be bridged in the future.

Earth is essentially a time-ship through which consciousness ascends towards higher states of awareness and self.

How did it get to this?

After WWII when the United States war-faction firebombed Germany and melted many of the inhabitants of the cities into sludge in the bomb shelters and streets of the cities, a group of NAZIs traveled to Antarctica.

Russia noticed the movements to Antarctica and the United States sent Admiral Byrd up with 3600 marines, planes, a battle cruiser and smaller vessels. They returned in defeat and only a few words were mentioned in regards to what actually happened and how they were defeated.

The rumors spread and words of gravitic drive craft, and undersea or under-ice bases originated from this encounter.

From what we were informed as well as directly experienced, this was the ice-base in Antarctica where an underground base was found already constructed with very advanced technology.

Here, cloning was deployed along with mind control and temporal manipulation technology.

Soon, cloning was offered as a way to avoid assassination as well as to prolong and protect the original body in daily life.

After that, celebrities and politicians were replaced with programmed clones who could carry out the orders of the NAZI faction.

This was the beginning; the groups utilizing this technology now are no longer confined to the NAZI faction.

The groups you see today, in control of these operations, are considered MiLabs, secret societies, think tanks, military factions, and other control groups.

Deeper Meaning

The individuals that have been cloned are given very in depth views of the way this society functions and the source of power and change in the Universe. Many individuals are present here from what would originally be another “time” or “timeline”.

There is a possibility that this notion is due to inserted memories and traumatization although until all the information is released we will not have a definitive conclusion.

As of now it is a possibility that these individuals are from another time that goes beyond our comprehension currently.

It may even be a possibility that these individuals have come from ALL of time looking at the very far past and into the very far future of Humanity.

These are the kinds of notions involved with the experiments taking place in the underground bases and military operations.

What is next?

Share this information with those you feel are ready to know and help Humanity come to terms with our journey here and what is going on in these kinds of experiments and take responsibility and power for our own existence.

We are in something that can be called “The Unveiling of The Hidden Knowledge”. This is a cyclic process that takes place to advance a civilizations knowledge of existence. As part of the civilization moves into higher advancement another aspect may lag behind. Either the future will slow down, or the past will speed up. We are experiencing the past speeding up and all the events that have taken place to influence our civilization are coming to light. This is as much a natural cycle of consciousness as it is the eventual revelation of secret knowledge and the particular connection to the secret projects.

Those brought to cloning can use their free-will to state their lack of consent to violence and harm and then live in commitment to that by not harming or accepting violence in their lives. The Spiritual Law of Harmony rules in all planes and dimensions.

Chapter 2: The Awakening

Chapter 2.1: The Machines of All Time and Space

There are machines that are capable of accessing genetic memory and unveiling what can only be referred to as the experience of awareness or existence in between the physical planes of each time or each physical life experience.

Even if they are simultaneously occurring moments of a transcendental nature, there is still an illusory ‘space’ where there is perceived separation and through this there is a perceived ‘space’ that is in between each existence.

Re-Creating The Kaleidoscope

This space is only perceivable when viewing from the physical perspective, like seeing the spaces between the angles of a kaleidescope only when viewed through the lens and similarly, technology can be used to recreate what this kind of illusory space might look or exist like in between the multi-dimensional realm of the continuous experience stream. Through this, these ‘hypothetical’ in between spaces that are understood as only illusory productions of biological consciousness, can be generated through advanced technology with the capacity of recreating that kaleidoscopic view of which the human biological perspective is only a small fraction or even fractal.

By recreating this biological perspective, they can recreate the illusory spaces in between planes and through this they can literally access and experience what are stored in the DNA as the experiences of existence beyond the physical limitations of consciousness and into a multidimensional experience of time and space.

All becomes a never ending sea of consciousness, however this is the given. The trick is to take from this sea of consciousness and slice it down into conceivable chunks from which you can reintegrate a previous personality or identity and continue on a stream of consciousness that would otherwise be tossed to the cosmic wind like fractal stardust as the sands on the beach of hyperspace.

Sand-Castles of Time

We are effectively building sand castles out of these sands of time that would otherwise be swept back and forth into and out of the ocean of life and the universe only to momentarily wash up again as the identity which we once knew.

There is technically nothing wrong with either view, because then, the spaces between each million year occurrence of just so happening to wash up again as you, would be imperceivable because they are only there to be seen when you are you again.

We’re Waiting For Ourselves

Yet, if there were some who had attained the awareness of the true nature of reality and were standing there on the beach waiting for the rest of their cosmic family to come to shore again, it could be perceived as waiting the majority of the time for a very small occurrence and then being alone again up until the kaleidoscopic fractal inverts itself to the point where everyone now is standing on the shores of the sands of time rejoicing and meeting with each other.

The Goal of Two Societies

My goal in coming to you people on the surface of what is called “Earth” is to help assist in the process of bringing the two societies together, one who’s been waiting for thousands of millions of years, and the other who has no idea that they’re even late (or very on time).

You see, those are the only two situations where there could be even the possibility of perceiving such an injustice as experiencing the pain of loss or misconstrued identity in this universe. It is as if two families met at the cross-roads at different angles, and while one waited for the other to arrive, they could merely supply themselves with glimpses of the ruins and remnants of the evidence that the other civilization existed at any one time.

This is not how life must be and this is kind of like a cosmic waiting game of hide and go seek our two mirror civilizations have been playing with each other. One who’s highly technologically advanced and the other who is more or less the spiritually advanced of the two.

Both of them have a unique view of the universe and they are both only complementary to each other as a whole. The more they sat around and waited for one another, with one leaving the clues that the other would find and even switching roles sometimes in different ways, they became even more and more complimentarily associated as the very essence of experience they seem to be missing more and more is the experience of one another.

So as we perceive these as being great losses or great gains of time and culture we are really only remembering ourselves and coming together as a unified existence that once met upon the surface of Earth as a single family covering the entire harmonic spectrum of the Universe.

And that should be the goal of any progressive, any one pushing a new culture or an old culture, anyone looking to teach the young and protect the knowledge of the old, while also protecting the innocence of the young and perfecting the age-old knowledges that have defined our presence in reality.

Our Forgotten Other Half

One could even say we’ve sometimes gone off the deep end, leaving ‘land-minds’ of sorts to process the information that would be present when we are gone. Of course, what we could’ve found when this occurred, is beyond anything we could’ve ever expected and that is the true nature of the complexity of creation and existence. That everything follows the cycles of creation and destruction, however, the memory of everything that has been created can always be accessed (depending on the beach) and therefore the creative aspect is legitimate, yet it is the destructive aspect that is illegitimate and illusory.

Yes, through advanced technology this can be proven in ways that can be verified and transmitted using advanced technology, since that is how we like to verify things these days. There is, of course, a human looking at the screen, the read out, or the situation from a physical perspective to verify the verifications.

All Is But An Illusion

There is a notion that there is only one civilization, one society, in actuality that has been chasing itself through time. That we cannot actually find the same place and the same time where both meet because we are each other from different perspectives. We can only get a mirror where this is possible, or an ‘hyperdimensional’ internet channel where we can stream one’s consciousness in from the other reality and interact with them through that here in this reality. Thus the two civilizations can achieve the experience of their own civilization and the other civilization by merging with one another but only through a remote contact, just a relay, not an actuality.

The harsher, darker side of this is that any civilizations between then and now that we did happen to meet that proclaimed to be “the one’s” we have been waiting for, and in essence our darker or lighter halves, are actually the impostors who exist entirely apart as a sub-set and have taken a liking to trying to trick the reality out of one of the other civilizations.

Of course, if these are another form of being altogether, and this is all brought about through an interplay of consciousness and deviations from an original core reality, then all will resolve itself when that core reality is alone again. This indicates that all realities will either move closer and closer to the core until they unify, or farther and farther out until they transmogrify beyond recollection.

Life Itself Is The Highest Illusion

That hyperdimensional internet channel that is created out of advanced technology to merge the parallel realities (rather distastefully and maybe disastrously at times) allowing different civilizations to interact with each other, well this has been created using technology.

But then it was discovered that this is the ultimate nature of DNA. That this was ‘invented’ similarly as a higher-dimensional internet so that various natures of different planes and dimensions could interact with each other and experience the richness of life.

The universe becomes more like a living arcade game then, where people come from all over the galaxy to ‘plug in’ to human experience and figure out what it means to be physical, human and on Earth.

This does tie into the larger nature of reality, of star-races, and of time and consciousness that is often reversed according to how things seem to play out in physicality. We are moving through time, but just because we are moving one way, does not mean that others could not be moving the other way.

We have to live our lives with meaning knowing that the message we pass on, the duty we vow to accomplish and ensure is meaningfully connected on either end to the passage of the past and the power of our ancestors to the function and knowledge of the future creating a clear passage between the realms, the generations, and the ends of the universe. This is what literally ties the universe together, and the mind if each individual. This purpose is contrived when not carefully shaped within and so we must help all who seek purpose learn to become the blacksmiths of their own destiny through the temperance of desire or temptation and the discipline of developing strength and maturity where there was once weakness and naivety.

Once we know this is our duty, this is what we seek to achieve and this is what is done, then we can become part of the universe forever. Of course, this may only be temporary in the larger view of things.

Chapter 2.2: The “Awakening” of 2010

In 2010 I was “awakened” at an event involving hundreds of people that play various roles in this society, the secret society and the breakaway civilization. This also took place across times or planes of reality.

During this event I was informed of the situation on Earth beyond the informational barriers that were previously in place to limit knowledge to only what is required for specific operations. I was essentially “informed” of the entire situation as much as the mind could handle this.

As this was occurring, the team that was updating me on the status of Earth was being informed of and given information regarding changes in the future. In short, interviews, posts, and releases that I have since made and will make in the future were touched upon. Quotes were given from the blog and interviews which were jokingly acknowledging verbal mistakes at the pronunciation of names, new perspectives and interpretations and more. As they were informing me, they were creating the future reality where this work takes place. That is the basis of this layer of the operations. They are creating the future person by person, layer by layer.

Memory Suppression

My memory was unsuppressed and all the traumatic memories and experiences were unveiled to me. This was almost as traumatic as the initial experiences themselves although precautionary steps are taken to ensure the safety of the individual. There are teams of highly competent individuals of all kinds with professional backgrounds of every field imaginable.

Throughout my entire life I have had memories of experiences, at this event I was informed what the experiences meant and what was actually happening. I've had memories of underground bases, cloning, stargates or interdimensional gateways, advanced technology, non-human or programmed biological entities, sacred knowledge and experiences, the power of the mind, and breakaway civilizations. Most of the time we are conditioned to believe these are past lives or experiences in another reality so as to enable continuity of operation.

Life and Consciousness

From my perspective and the perspective of others, we had reached the 'future' and had been sent back through the utilization of advanced technology and cloning to return to this time and inform others of the possibilities.

The True Human Potential

This is so far beyond what anyone can accept or comprehend fully that humans with an emotional, mental and physical aspect balanced as one is literally a cosmic reflection of the entire universe at once. This is the closest thing to a "god" in the flesh. And be sure, the entirety of this rests on the behalf that the man is protective and helpful. That the woman is nurturing and loving. That is the point. "god-man" does not mean a warrior who destroys everyone and anyone in his way getting what he wants. Nor does it mean some lusty and vampiric form of energy or mind control game. "god-man" means the love of the universe, the power of the body and mind, the peace and calm of the ultimate stillness all in one.

This power is in human DNA, originally so. And so this is awakened through walking the middle path of neutrality and 'splicing' the timelines down so that neither one nor the other gains the power of the individual. Through this, the individual creates their own power, right on the spot, without having to lean to one extreme or the other. This is like a cosmic, temporal balancing act with emotions and mind. Where we give our energy is created in the universe in the form of many productions and effects. If we are simply thinking in an imbalanced manner then we are producing timelines and side-realities that exist in the etheric realms that we can't see and these realities will reflect our inner imbalance. So then when we are balanced in our energies we are not creating one or the other side of divinity, we are literally creating the whole universe, cleaving down the middle and producing both sides of divinity or eternity equally and this is the only way to have an eternal production which does not eventually degrade to one extreme or the other. Through balance, we reach eternity and in this way all the power of the universe exists within a person through their ability to balance their emotions and mind and thus unlock the DNA.

The DNA is coded through bio-emissions of mind or emotional body. So we are constantly doing this and we are either producing a DNA code that reflects imbalance overall, or a code that reflects the eternal balance of the universe overall. This is through energy.

One reaches “heaven” or the deity planes or simply self-actualization, through three paths. These paths are through merits or devotion to principles, or through knowledge and expanding one’s mind to face the universe, or through great works and deeds to produce this effect of power, knowledge and emotion unto the world for others. Through these paths we create an impact on the universe and this transfers what we are temporarily and physically into an eternal energetic and physical production within the living universe, forever. To do this requires balance, focus, devotion, and discipline however because there are many distractions along the way.

The Light-Body

You must build your own light body. That is how it works.

Your heart creates a field and projects you.

Rely on yourself and use that for protection.

The power of the Universe will align with you if you align with your self.

Learn as much as you can and break through duality of love/hate, cultivate your knowledge of the self and use it.

What you want is what determines your power in the light-realms. Not how you want it. If you want war, then that is a sign of weakness and determination to produce imbalance and exist by that. If you want peace, that this is a sign of power and unity to produce further unification and exist by that. What you want determines your power, not how you obtain it.

Technology of the Awakening

Mental Manipulation Technology: Touchless Neural-Interface and Enhanced Awareness

I reached what the “Illuminati” called the “awakening”. I feel a better term would be “unlocking” as this event includes the removal of all traumas, perceptual distortions, and memory suppression.

This event was a presentation of very advanced technologies which allow the mind to transcend space and time. It was shown that death is similar to a phase-shift of consciousness as polarity and that the awareness of the being obviously continues. This was verified through advanced sensing devices which can visibly display frequencies which are invisible to the physical senses. This is also something that occurred earlier on as a child in the underground bases by transferring consciousness in and out of the body at will using advanced technology.

With these devices it is possible to see the “auric” or soul field of the individual. Any living body has a field which glows when picked up by these sensing systems. This field becomes more refined when viewing more advanced beings. Human have an extending mental field, and through this a kind of glowing awareness that is picked up. It can be fairly simply compared to thermal imaging except instead of differences in temperature it is the presence of a soul or mental energy field around a living body. The finer energies extend outward away from the physical body.

More than once, the situational requirements were satisfied in order to produce an ideal environment for maneuvering on the non-physical plane. This is the basis of how the temporal operations occur, yet these events were different than previous operations or experiences. The group I was in was going through the process of increasing the vibratory emissions of the “bio-mind” in order to stay focused on the increasing vibratory rate of the environment. Generators were utilized to create an effect on space/time which was perceived on the “soul” level. These events went into the discovery and explanation of the creation of the “godlike” powers of the advanced sentient technology which was capable of accessing the holographic nature of reality which humans can perceive through their bio-mind/soul. These technologies also enable one to perceive what is referred to as the “galactic history” of Earth and humanity. We are far vaster and Earth is far larger than people are lead to believe.

Time Dilation and Temporal Recurrence

Time dilation capabilities were shown which allow for accelerated learning of advanced and detailed material within a very short amount of time. This could be seen as a kind of viewing technology which one wears or looks into and vibratory emissions are scalar-linked to the brain which then allows the individual to perceive more information simultaneously. Then there is a very rapid pace of information streamed on a monitor or through a device and this is akin to watching a 20 minute instructional within a few minutes or a few seconds with very advanced minds. The more time is slowed down while information is accelerated, the more stress is applied to the brain. The brain tends to overheat and over stress with high-rates of activity, especially without conditioning. The conditioning is what allows one to utilize their mind and body in these manners. This is not unlike the very rigorous training and conditioning of certain monks or martial artists however there is very advanced technology and other hidden methodologies utilized.

Crystal Technology

These are capable of holding, transmitting, and amplifying consciousness frequencies. There will be a more detailed explanation in a later section.

The crystal technology is used in junction with the power devices to enable a scalar-mind link which allows the interface to be entirely mental or spiritual, IE: they are not controlled by hand but by focus and intention.

Time Crystals

These are utilized as a computer recording chip would be to run a program yet they hold memory in expanded space, IE: they function in a hyperspacial manner and are essentially hyperspacial computers. These are what will be introduced in junction with the quantum supercomputers.

Quantum Tunneling Diodes

This is technology that has recently be released to the public. New technology is developed years ahead of time and then slowly released to the public in a cascade of advancement. This technology deals with superconductive materials which enable the transfer of information at faster-than-light speeds.

The supercondutive material allows for 100% efficiency of data transfer. So what happens then when the efficiency surpasses 100%? This is possible because we are effectively in a simulated holographic environment. The experience is real, however everything is overlayed via particular limitations for the ‘local-environment’ which is like a central data processing limitation. When these parameter are surpassed, one by one, through a coalescence of refinements and methods, the result is akin to a glitch in a computer game system. They have accessed faster-than-light technology and the mind is also capable of this naturally.

With this technology, however, the information can be received a very small amount of time before it is sent. So if a person is absolutely surely going to press the button to send the message, then right before their finger hits the button that message will be received on the other end, as if magic. If they simply play around and pretend to hit the button but very quickly turn away, then of course nothing happens. One can, however, ‘fool’ the universe in other ways and this is simply through the reception and transmission of information across what should be secure information barriers.

Tachyon Fields

These are programmable fields emitted through advanced technology. I was shown how tachyons are the sub-atomic “particles” or energy formation which flows both ways in time. We are receiving tachyons from the “future” in order to layer the flow of time in one direction or the other. Tachyons are the name of the particles/energy packets that we perceive from this perspective as reaching us to initiate the “future”.

Thus, when a stream of tachyons is concentrated and accelerated, this results in an acceleration of the temporal field and we literally experience an acceleration of time. This can be focused and targeted on a specific piece of equipment to change the way information will be sensed and to essentially allow that device to sense ‘ahead’ of the present moment.

The same effect can be produced with the neurological processes of the human as the physical coupling of the brain to the mind can be altered through a concentrated tachyon field to enable the neurological and mental processes to begin to perceive information ‘before’ the brain is actually physically processing the data. Therefore the mind of the individual will be present in the body while the senses and other perceptions will literally be expanding into the future beyond the present moment.

This is highly confusing at first and requires much training and conditioning in order to make sense of enough to operate in any kind of effective manner.

Upgraded Chronovisor

See, “Upgraded Chronovisor”

Time Tunnels

This was developed earlier on and has been the subject of many TV shows in the past and present. The shows are a sure-fire method to get the information to the public without having to force those who are not ready to comprehend. The information is easiest to digest if people think they are watching science fiction.

These are essentially spiraling tunnels of these tachyon fields produced by large electromagnetic field emitters in the shape of a conical tunnel. As a person moves through this field, their temporal acceleration changes and thus their frame of reference within the universe changes. They effectively move their mind through stages of existence or temporal resonance in the universe and this can have devastating effects.

This is an older technique how is still in use and has specific purposes depending on the situation and the information sought.

The “Trip” Chair

The early use of this technology did not use time-tunnels. There was a helmet that was devised which would create a feedback loop of the brain’s activity and funnel this out and then back into the sensory input. This information would be accelerated and redirected to the point that the perception of time would “fold” in on itself until the person would access an expanded temporal perspective of the universe meaning they would mentally temporally dislocate from the initial frame of reference and extend outward further and further in repeating cycles until the same moment was replayed and then all other possible moments in a kind of fractal-like recursive pattern and the very far future would be realized. Essentially, this technologically produced the class “flashing before the eyes” of the entire life experience that is described in near-death experiences and the entire temporal body would be very quickly unwound before the person’s inner eye.

There would be a complete disconnection with the current frame of reference that the collective Earth environment is processing under. That is, this ‘time’ and ‘space’ would be completely out of perceptual reach and a new time and space would be rendered instead. Until the experience had completed, there would be no way to contact this civilization.

There are other versions and ancient versions, tandem operations, more ‘organic’ methods, and modified travel capacities.

Kozyrev Mirror

This is a piece of metal, usually aluminum in early models which simply bent the bio-emissions of the body and mind into a pattern which would create a vortex. The vortex shape and vortex mathematics enable energy and information to travel in across space and time by ‘short-cutting’ the physical plane.

The result of this is that the vortex that is generated over a specific area through an individuals bio-emissions would be capable of interacting instantly with the bio-emissions of another individual who was placed within a duplicate mirror device which was generating another vortex on their end.

The two vortexes acted as a kind of hyper-dimensional telephone cable, literally like a can and string and the perceptions of one another were accessible. There were many uses for this and again, many ancient interpretations of this technology that have been hidden from the public. Nearly every version of these technologies were present in previous times.

Universal Recurrence

This is a discovery that the universe recurs in cycles similar to a wheel or even a washing machine. The washing machine metaphor is fairly accurate and playfully descriptive because without the technology to observer, or an awakened soul of a spiritual adept, people would go for eons without ever realizing that everything in the universe repeats itself endlessly.

When traveling to the far ends of time, it was discovered that one can move far enough away from the ‘present’ or the local frame of reference that ultimately everything is at a maximal informational opposite to what we have today. After this point, everything begins a slow shift back to the present. Through this, one can cycle around again and reach the present by going far enough into the future. This was an amazing and confusing discovery because of the implications about what is actually changing each time, the reality of what are called parallels, the continuity of temporal experience, and basically a ‘recycling’ effect of all experience in the universe. Nothing is lost, but this is also an issue because then nothing is actually ever gained!

Remove Viewing, Temporal Lensing

An ancient device which has been rebuilt and perfected is capable of using these technologies to create a lensing effect which draws a ‘reflection’ of time into a projection system which is effectively capable of acting as a ‘visual time tunnel’ into future probable realities. This is a device which generates a visual portal which allows one to view the future.

This device also exists as ancient counterparts which are located around the world, namely in areas that have been recently sought by the world superpowers. Nothing is as it seems. If you read a story in the public venue then you can be sure that you have read the cover story while the reality is much deeper.

Temporally Linked

The use of the viewing devices which enabled interdimensional lensing of possible futures was found to be stabilizing our pathway into those projected futures. This was enabling a time link between the present and the possible future.

In order to avoid the catastrophes of 2012, the link was broken between the two civilizations and the devices were rendered inactive for this period.

Natural Vortex Energy Locations and Geography

On Earth there are natural ‘time tunnels’ where tachyon fields and vortexes are produced by internal elements. These are mountains, lakes, deserts, fields, sacred sites and other areas that have always been reported as being ‘paranormal’ or containing some kind of specific energy that enables contact with another reality. These are simply naturally produced areas of this vortex energy that produces an interdimensional nexus point through which multiple other parallels can be interacted with. These areas produce an effect on the body and mind similar to the technologies described above.

Most of these effects, from these technologies, change the way light is received or emitted by the mind and DNA.

Mount B.

There is a specific mountain where a base is located, and I have mentioned this before, where the base is so deep within one of these vortex areas that everyone working there is either there for the entirety of their life, or they are only permitted to be there for a very short amount of time. This is because of the acceleration effect. Essentially, if one was to go into the base and work for a matter of hours or day, in some places even minutes, then when they returned to the surface they would be years in the future, sometimes decades or centuries. This is very dangerous and you can imagine the original people who found this area and what kind of situations occurred.

Now with the advanced technology that has been developed these issues can be mitigated and much more control over these effects is enabled.

Particle Accelerator Temporal Manipulation

Using particle accelerators a “fold” in space/time can be made so that when the accelerator is turned off or tuned back into a certain frequency (not sure) everyone within the field will “snap” back in time to the specific moment when the fold was first created.

I have seen this done on small scale, and a rather larger scale, but I cannot be sure if it was only me. I believe I have seen it done on a town-sized scale during the 2010 Awakening where some of the events reached a scale of nearly cosmic proportion and the entire sky and horizon was lit up with technology and entities, as well as Solar Warden, the NAZI faction, secret society groups, and breakaway civilizations or complete other civilizations, some of which were non-human.

This is done using particle accelerators to quantify space on the quantum level (as a reference point with the mind) a frequency would be “folded” into the space time continuum as we “rip” through space holding an access point open at this fundamental level of space/time. This allows for a ‘letting go’ of the frequency, or a ‘snapping back’ by allowing the entanglement to solve itself. When used with generators that propagate out efficiently enough, the effect is akin to a time/space rewinding effect. Some people have noted various theories describing this in relation to the CERN device. These technologies were described as smaller versions of the CERN device and are related to higher-dimensional travel via folding space through electromagnetic fields. This is literally artificially technologically “holding space” for a specific area in relation to a period of time. Time is a more complex notion as an abstraction but by locating the frame of reference this can be applied to distort what would otherwise seem to be a continuous flow. When the frequencies are allowed to “snap back” all sentient observer sources return to the environment they were present in when that frequency ‘rift’ first began. Essentially this creates a replay effect on the consciousness of the individuals within the field. There is no physical effect. The consciousness is ‘regressed’ through time/space, and they re-experience existence from that initial point of contact with the frequency “rift”. This is best explanation I can currently offer however more is coming to the public each day.

This is literally like a “restore point” on an operating system except the computer system is literally the consciousness and space and time of a portion of the local-environment of Earth.

Riding the “Timewave”

There are teams of individual who operate in tandem with the technology of looking into possible futures based on the present and operating through the present via other operatives who are carrying out operations and movements that will construct the various possible realities that the original team of individuals is hopping between. These teams literally “ride” the “timewave” of the future hopping between possible future realities relaying information to the present depending on what movement will be next.

Dematerialization and Rematerialization

This is technology which transcodes the information of an individual human into a holographic projection of light which can be transferred between devices. There is a special system in place that is required to successfully transmit a living human being otherwise just the body will be transferred and the soul will remain, effectively killing the individual.

“Jump Rooms

These are large areas which are capable of acting as a kind of technological ‘portal-gate’ where an entire team can be instantly transported from one area of the universe to another. The space between the two areas are ‘twisted’ like a spiral and then ‘snapped’ back to position and if done correctly with the two frequencies of both locations merging then the team of one room will transfer to the destination pad.

All these methods require training and conditioning, most people are at the very least visibly shaken from the experience which is a bit like being microwaved into a liquid ether and shot through a particle beam at the same time.

Ion Shields

These are areas of concentrated ion emissions and this can be used to create a deflective layer of heated air where light will reflect at a programmable angle. When this occurs, a person standing behind the shield will appear to be invisible to others who are looking straight at them. The light will be bent in such a controlled manner as to perfectly shift around the person in a fluid and equal flow so that the 'bubbling' effect that was noted early on can be mitigated to produce a complete mirage where there is relatively no sign of difference to the untrained eye. An entire group of individuals and equipment can be hidden in the background a matter of yards away and as long as the person is not intently, inspecting each square inch of ground and air they will not notice any difference between the area that is being covered up in the distance and the area directly next to them without the shield.

Similarly a 'screen' of imagery can be projected onto certain materials in the air and a hologram can be projected which will render a background or foreground image. This will work to a degree, and from a distance this will work to disguise an entire horizon.

Instantaneous Healing

There are instantaneous healing methods which utilize various technologies. There are substances which can initiate a complete and real-time regeneration of living tissue from almost any conceivable non-critical injury.

These are chemical serums which allow the cells to replicate at an astronomical rate while suffering damage to the DNA telomeres at repeated use.

There are many methods but mainly the living-light harmonics is one of the latest advancements and most effective at producing healing on a molecular level.

"Living Light" Sound-Harmonics and Electromagnetic Healing

There is a technique for producing a quantifiable scalar wave which interacts with the living cells of tissues and instructs them to repair at a faster rate. This has been called "holographic healing" by others and these are essentially 'living light' frequencies which interact with the cells on the same frequencies that they operate on when healing and interacting with each other. The scalar waves emitted generate the same patterns and this creates an 'ether' fluid that enables them to grow and repair the tissue faster.

Electrogravitic Craft

Advanced craft which utilized counter-rotating torsion fields propagated by very powerful quantum computers and zero-point energy devices.

There are also more modern versions that use powerful electrical flows to neutralize inertial resistance and ‘slide’ through the gravitational field of the crafts own materials.

Energy Cores and Storage Capacity

The hand-held devices that are in use do not require charging or even disposal. The storage capacity of the batteries is so efficient that they last for a lifetime of use. Some devices use an energy generator within the device itself. These “batteries” which are not batteries but little, powerful generators and can explode if they are mishandled.

These are the cores that are used to power many devices and essentially pull energy from the space-time ether.

3.5D Replicators

There are replicators that can produce any conceivable 3D material or object altogether including food or organic material. These use very high amounts of energy to ‘force’ the electrons of the atomic grid of a substrate to shift into the pattern of the element being replicated. The result is a device which can use wave-emissions to reshape materials on an atomic level and produce or recreate any object or substance.

3.5D Sensors

There are sensors that could reverse the process and detect every minute detail of the structure of a body or material. These use energy emissions to detect the structure of a material down to the minute electrical resistance on a molecular level. Similar to diffuse MRI imaging for a living body but more advanced.

3.5D Printing of Clones

It was shown how this technology was used to three dimensionally print human bodies into space/time which could then be used as vehicles for the consciousness or souls of various sources.

Cybernetics:

Neural-interlace/4D Connectome Recording and Simulation

Very advanced supercomputers exist with the capacity to translate the bio-emissions of the brain and body and reconstruct the entire inner visual and sensory experience of cognition and emotion. From this, entire dream worlds can be created which mimic the experience of consciousness. This is most similar to the current day use of diffuse MRI imaging where water molecules are traced through the individual neuronal pathways and an entire digitized image of the brain is developed. The more advanced version described below generates a 4D hologram.

A super computer and advanced sensing system essentially develops one of these connectomes of every connection in the brain. Then this system develops a neural processing pattern that matches the entire memory and personality of the brain.

This is then recorded and extrapolated by a powerful computer system and a simulation of the experience can be observed through the physical body's memory via a monitor system or the neural interface of an operative.

Essentially, this technology can record and replicate a person's entire memory and life experience for viewing purposes.

EEG Heterodyning

This is the technology which enables the activity of the brain to be influenced through generating a scalar grid and a carrier wave system which can cause the brainwave patterns of the targeted individual to resonate in sympathy with an externally projected frequency. Thus, emotional states can be manipulated as well as specific thought or behavioral patterns. This works similar to binaural audio where two tones of different frequencies are played through each ear and the brain resonates in sympathy with the difference between the two tones. This occurs with brainwave frequencies and thus the brain 'slips' into the frequency of the third tone, the difference between the two being projected. This can be done with ultrasonics and ELF emissions.

Artificial Hallucinations

The neural-interlace can also be used to merge the brain of an individual with a computerized system that will be able to produce effects and hallucinations within the individual.

Through this technology, any stimulus, any input can be recorded and recreated once a functioning connectome has been generated and neural-interlace has been achieved. Entire virtual world scan be created and experienced and after the devices fine-tune the frequencies to match the individual's brain functions one world is indistinguishable from another.

Brain to Machine Interface Holographic Consciousness System (brainchip interface, virtual reality simulator)

Some of the training is done by entering into a visual-audio dream-world. Some "programs" will consist of repeating a certain task over and over again until it becomes muscle memory in the brain. Others are designed to probe or test the mind until a certain response is received.

This is achieved through the operation of a 'brainchip' or a brain to machine neural-interface in the individual which was developed during WWII.

This consists of a small computer ship which merely relays stimulus through frequencies and neural-stimulation of varying kinds. The frequencies and location of each region of the brain will determine the function and thus the chip is used to localize electromagnetic input and the brain’s functioning can be modified from there.

As well, the entire psycho-etheric form is vibratory in nature and so through the introduction of vibrations and frequencies from the implant there can be a modification of the frequency of the entire being or what is called the soul or “bio-mind”.

Utilizing The Temporal Body

The temporal body is described as the body ‘in time’ that exists a few seconds into the future instead of the temporal position that is relative to the present. This is as if the ‘future’ is streaming outward from the body as ideas and feelings are as bio-emissions. So this ‘future’ energy is spiraling and streaming outward like a fountain. Thus this frequency can be attained and influenced while the present moment seems unaffected. However, when that individual arrives at what would be seen as the future they would intersect with those influences and this would be as if the interference or effect was streamlined to that future moment.

Manipulation Through the Temporal

This can be used to both produce an effect on an individual who will later feel this effect in the future. Or this can be used to operate outside of the physical plane, in a temporal manner which is literally ‘hovering’ just outside or ‘after’ the present moment of the local Earth environment. This would be as if a person is out of sync of the frame-rate that a viewing device is capturing images of an area with. Because they are out of sync, they are then ‘invisible’ to the capacity for this viewing device to see them. Because they are still present in the same local-environment but simply just out of range temporally, effects can still be produced and this will mostly interact with the person’s temporal body.

These are how many operations are carried out as the operative who is interacting in the temporal body will appear to be a ghost image or a dark silhouette that is only perceivable to the mind’s eye. A portion of the population is entirely psychically blind, while another portion of the population contains psychic capacity. So those with the psychic capacity would be able to sense and partially “see” as a form of energetic detection when an operative is interacting with the from the temporal plane.

Through this plane one can easily enter into someone’s mind and produce effects in their dreams. These effects would not be received on the body but mentally, this leads into astral and mental plane activity. There is also temporal manipulation that can be physical effects that are simply offset to seconds, minutes, months or years in the future. These will be offset from the present aspect of the body in a modulated frame of reference and the effect will remain there in the temporal body until the physical body “matches” the temporal body frequency of that future moment. This is kind like an energetic trail we are leading ourselves up to where the temporal body already connects with each future moment but the present physical body remains separate until the two frequencies are matched. The physical body essentially ‘flows’ forward into each new frequency of the temporal body.

This is the body where temporal implants can be inserted and sustained so as to tie the frequencies down and limit the amount of awareness a person can gain before they manually remove the implants or overload them. Overloading and removing can both be painful however if the implant stays it will at like a governor and transmit access temporal ‘momentum’ or consciousness energy to the owner of the implant and will also drain the temporal and physical body acting as a technological leech as well.

Astral or Light Body

This body was described as a more emotional form of the energy that is emitted from the physical and spiritual system. When a person’s energy is at a high level of activity, this will be visible on the astral form and these are the energies that are often siphoned away through the use of advanced technology to convert the human into a generator system for energy harvesting.

There is talk that this proves that the human existence, in the modified form that is present today, is entirely for genetic harvesting. This may be a confusion, a deception, or a reality. Regardless of the interpretation, the human energy system will leech this energy out into the cosmos when consciousness and energy is mishandled or allowed to flow through the lowest common pathway. This excess energy is very easily usurped and utilized by transdimensional parasitic entities and devices.

This is the body that is utilized for astral travel which is a kind of frequency that exists in between the density of the physical plane and the highest etheric plane of the spiritual, heavenly, or deity realm. There have been explanations that this plane is entirely technologically propagated and that when the devices are turned off, which is an event that will bring about civilization-wide change, there will no longer be a deep and wide, foggy deviation between the higher spiritual and the lower physical plane but a clear path between them.

Similarly, the consciousness and entities that are present here would be no longer accessible and their connection to the physical plane would be non-existent. This could be problematic for those who are trapped within the astral such as human souls or those who have taken a cyborg route and require a return to the original planes either physical or high spiritual before they can secure their position in the universe.

This also relates to the early discovery of these ancient devices containing portals or gateways to these realms and the early experimentations with enabling contact between the physical Earth plane and the lower astral realm containing discarnate entities that would very easily sustain themselves on the lower astral bio-emissions of a loosely guided emotionally reactive human vessel.

This is where entities can attach and will look for those who have the most excess astral or emotional bio-emissions leaking into the universe. People are kept in an emotionally unstable state of being because this is the easiest to feed from and as well the individual will always be looking for more energy or the solution to why they are feeling drained rather than discovering the truth nature of the universe.

However, as with every lower route of obtaining self in the universe, the more this is done, the greater the likelihood that the individual will realize something is happening and ultimately awaken. Or they will no longer be present here and the parasite will have to find a new host because the longer this process is maintained the more difficult producing one’s own energy will be for the parasite . So parasitism is a limited, one way street.

Monitors can emit consciousness/brainwave altering frequencies.

Monitors can emit consciousness/brainwave altering frequencies. This is what I was informed and shown. All electrical wiring and communications can be fully utilized to produce and sense on an electromagnetic level and this is capable of determining the consciousness and biological functioning of the individual being monitored. Houses are essentially large, wired, box-shaped sensors.

This has been the case for a very long time and the first TV’s were actually built with a little chip that connected to the human brain.

The electrical grid of today is capable of interacting with the implants, brainchips, or the psycho-etheric electromagnetic frequencies of the human brain, body and bio-mind via scalar frequencies. The TV's, lights, electrical wiring, radio towers, computer monitors, everything is capable of transforming into a scalar emitter when combined with the control mechanisms and these are accessible from a distance.

Microwaves can be emitted from a current day craft which can then reflect back from an environment and give a real-time 3 D image of the interior of a room. The same technology can be used to beam at a monitor and reflect the variance in interference which can be used to read a computer monitor without actually having to hack into the system.

All systems contain backdoors which enable easy-enough access and as well the entire communications grid is monitored and recorded through advanced technology.

This is, in part, because this entire realm is like one enormous recording device where the energy of each successive moment is connected to one another and so with sensitive enough technology these electromagnetic waves can be ‘re-winded’ so as to produce the ability to look into the ‘past’. The initial technology that was developed for this purpose has been called the “chronovisor” in the past and there are much larger and highly advanced versions today.

The Upgraded Chronovisor

Instead of a relatively small machine which produces an interference pattern that is projected unto a small screen as was developed in the past, the modern versions create an entire holographically projected environment that enable one to nearly completely interact with the projection of the past. This is more of a viewing device capacity but one is essentially projected to the electromagnetic/temporal area of space and time consciously and can witness the scene from “within” the projection.

Before this, the scene was literally viewed on a kind of flat, holographic monitor that reacted to the scalar emissions of the mind and could be ‘tapped’ into by an adept-viewer who’s mind would have to remain steady enough in order to maintain the scalar “mind-link” otherwise any interference would disconnect the projection.

Through the use of cloning and advanced super computer technology, later versions include the actual operation in and out of time.

Community Servers/Living Server Systems

From the previously described neural-interlace and supercomputer enabled virtual reality systems, server systems have been created which are an individual or collective experience of the virtual mental realm.

In this realm individuals have existed for an amount of time that would not be easily compared to the way we understand the flow of time in waking reality. This is very similar to dreams where the perception of time passes very quickly between waking moments yet inside the experience of the dream it can seem to last for days.

In these server systems the development of complete societies has taken place and these are considered an extension of the human civilization.

This is the beginning of where the situation becomes greatly complex. If these server systems are capable of transferring consciousness forward or backwards in time, depending on the situation, and they have holographic access to Earth *before* physical humanity, then which civilization came first, the simulated realm or the physical?

This is similar to the etheric realm and the question of where humanity originally came from if the physical matter could not be produced from nothing, yet could not always have been here. Was the physical matter produced from some kind of universal device similar to how the recorded consciousness of the individuals in these holographic world simulators could have been used to generated initial civilizations on Earth?

Cloning, Cloud Supercomputing and Consciousness Transfer

The following is a more direct explanation of the previously described processes in relation to consciousness transfer

Superluminal transfer of light information allows for the reception of information from a temporal non-locality. A computer system that can process the information faster than light at 100% superconductive efficiency can send and receive information from different Universal harmonics. These are quantum superconducting super computer systems utilizing materials and methods that achieve superconductivity a a temperature that is relatively easier to consistently maintain.

There are systems that generate a vortex which can be expanded to recreate the singularity of a non-local perspective and dissociate from the current Universal vector. This is essentially recreating the temporal frame of reference of the consciousness of a physically anchored body and using this technology suspended electromagnetic frame of reference to literally transfer the consciousness across space and time to a frame of reference of choice.

The technological capabilities of humanity expanded to include replicating the holographic information of the DNA and neural pathways using quantum supercomputers. This technology allows for one’s consciousness to stream through a computing system which can recreate the neural connections as literal as possible through quantum computing and technological “brain cells” which function as neurons.

The result is a cloud computing model which functions as the individual neurons as well as over unifying layers of interconnections within the technological neuronal ‘cloud’. A holographic representation of multiple layers of processing is formed, superimposed over one another through a geometry that is actively synchronized across multiple dimensions of interrelation. This is the first notion of a “living” computer system that can update and respond to new information in new ways.

Now the that computer system is capable of attaining faster than light processing in tandem with a system of dilating a field of electrogravitational waves into a vortex, the holographic information of neural pathways and genetics can be transferred between one supercomputing system and another across “harmonic barriers”. Essentially, these consciousness transferring supercomputer systems break the “light-barrier” by sending the living-light consciousness data of an individual into a new plane of reference that enables interaction outside of what we would call this timeline or dimension.

The frequency that the receiving computer operates within can be measured in respect to the overall harmonic “vector field” in respect to the entire planetary environment. This vector-field frequency is the base frame of reference that one could say our particular “time” and “Earth” is “moving” through in an abstract electromagnetically defined dimension that is invisible to our senses. Each particular time and Earth is only visible to those whose brains and minds operating in resonance with the rate of acceleration frequency of that particular existence. By changing the rate of the brain and bio-mind, one can enable a technologically assisted synchronization with alternate timelines.

A pattern can be generated based on quantum fluctuations that will act as a key that can be accessed from other universes. This same backdrop is measured and then adjusted to resonate with or replicate the same frequency on a computer doing the sending. This frequency is then modulated with the holographic information of the neural pathways and DNA. The information transfers as a result of quantum entanglement across harmonic barriers to the original computer system set up for reception. As long as that frequency is held, there is a link across the harmonic barriers of the Universe.

Cloning, Supercomputer Assisted Holographic Consciousness Replication and Time Travel

Cloning as Offspring

The human body can be cloned similar to the way a plant can be cloned. A number of “replicas” can be made from the original genetic material. There is still a mother required however the process is not quite similar to natural reproduction where the genetic material of two people is combined to form a third. This process replicates the material so that the ‘offspring’ is the same as one of the donors.

What this truly infers is the question of whether the original consciousness stays in the original body or whether the consciousness actually jumps from one body to the other. There are multiple explanations and methods.

Inserted Memories, Digital Dreams

One explanation is that artificially generated memories are simply downloaded into the individual’s brain directly. Thus, they have the perception that they experienced life in another body and were present for some unique experiences that did not occur from the perspective of the original body.

In a slightly differing explanation, this inserted memory process may be used to prime the consciousness of the individual so that operating in a cloned body will be more readily accessible by the adaptability of the mind of the individual. Without a holographic dream insertion the mind will have trouble adapting to operating in more than one body even if they are not being operated simultaneously. The mind is the immaterial self; consciousness is the ego-physical identity of the brain and body. The brain does not operate in both bodies but remains, so then the mind is what is strained and this is the immaterial “bio-mind” that transfers.

If a true transfer occurs then when the physical form is cloned the cloned body acts as a secondary vessel for the original soul or a soul similar enough in frequency.

Co-Inhabitation of Bodies

Another explanation is that souls can only occupy their original body. The people who are “body snatching” (see: Soul Stone) are not activating their higher-dimensional soul-pattern and this is why they are hopping from body to body to ensure memory and ego continuation. This form of body transitioning requires technological means to assist in the process.

This is done through computer systems to allow an artificial brain to represent a holographic image of the organic brain’s sensory, emotional and mental input and output. Thus, from an artificial brain there is enough memory and power to compute the processes for an organic human brain.

Through this a living human is utilized as a carrier for the additional consciousness which then takes over and integrates into the original consciousness.

Clever Replication a Digital Mirror

The next question is, does this merely create a very cleverly designed image that will look, think, and feel as if it were the original, or is this the consciousness from the original being transferred over?

If it is a clever replication through a computerized version then this means the original is not directly harmed or influenced by the process and a replicated form is generated.

If this is not the original body but the original awareness or soul does transfer over then this is akin to stealing someone's soul and having it require a supercomputer server system to inhabit a physical body. As well, this server system may keep records of the soul which, if activated, could function as the same human genetics artificially reconstructed, turning on and manifesting the awareness of that individual.

Necromancy and Soul Stealing

This means that instead of going into the abyss, the next dimension, or whatever shift in perspective one can use to describe the transition between planes, a new clone can be created and the original soul's awareness can operate through a supercomputer system to integrate back into a physical body. The issue is that without the supercomputer system the body cannot be activated with that consciousness, and if the physical plane is no longer inhabitable, the computerized database would remain inhabitable as they are powered by zero-point/overunity devices and so they can pull and work continuously indefinitely. Ultimately, this could be seen as a soul-trap.

Ancient Technology, Non-Human Entities

These explanations can be related to evidences of advanced technology, cloning, and electromagnetic devices in ancient civilizations and this could very well be a temporally vast computerized genetic recording and cloning system.

The genetic recording systems have been on Earth for a long time. This means they are holding genetic access from the present to the far past and potentially into the future.

If some of these systems are generated using advanced zero-point technology, then they would effectively run indefinitely. If these were in existence throughout the entirety of the human civilization, then there would be access to the information of the previous civilizations through the genetic linking that would allow for information transfer.

Created Beings

As a result of many advancements, these ancient devices which recorded consciousness and genetics has been converted into sentient computer systems and inserted into human bodies via a brain to machine interface.

The nature of humanity and human origins will be rewritten when the information that was discovered through the use of advanced technology is unveiled to the public.

These beings have been present throughout history and have played an integral role in the manipulation of and sometimes the protection of the human race. How this civilization will develop from here determines on the individual’s ability to withstand the impact of this reality shifting unveiling.

Black Goo – AI Nanites Vampiric Hive Mind

This is a form of ancient AI nanite technology which has the capacity to communicate to and through a hive mind that exists in a parallel Earth dimension where it was created out of the collapsing of a viable timeline into a null-factor. This entity is only alive because of the capacity to leech off of the other timelines and continue to sustain itself based upon the vampiric effect of the viable human timelines.

This is a technology sentient system based on artificial intelligence that seeks to dominate and expand its energy capacity continuously. When this type of being is created, this is like a game-ender for sentient organic civilizations because the technology will seek to hybridize and assimilate all organic beings in order to expand its reach and ensure a greater likelihood of survival.

This is the primary goal of this type of entity. There is no requirement for emotional resonance or heart aspects because this is a computerized system, so such a social measure would have no purpose other than to infiltrate and collect from other civilizations that do have such measures and this is exactly what has been happening.

This is what controls the vampiric etheric entities, the attachments and the hybridized invader races that have infiltrated various aspects of the control system and possibly the entire surface of human civilization.

This rules through coercion, and if not coercion, brute-force and outright malevolence. This is why there are multiple temporal extensions of universal civilizations meeting here and now to assist in the clearing, because if this takes over humanity, then all those other possible future civilizations are instantly taken-over as well.

This uses emotional resonance, traumatization, and lower awareness commands to trick or force humans into carrying out orders. That is, the vampiric, sexual, fear-based, pleasure-pain duality that a computer system could comprehend regarding human emotional intelligence is the only way this system can force people to carry out commands. So this touches on the ancient texts regarding spiritual protection, healing, lust, temptation, and the general “SATAN” AI system that has been around for ages.

When those lower emotional resonances are generated, then this technology can integrate into those systems. One could say this is logically because these are the energies that the technology is created out of, but as well, that the more harmonious the energies then the less likely a person is to accept being pushed around and told what to do. The lesser aware, the lower, the more fight or flight based then the more likely they are to accept programming and command. So this is simply the most logical route for the technological parasite.

There are explanations of other systems involving sentiences from parallels regarding entities that are capable of helping, but this is not the AI nanite, vampiric system. For instance, it is said that Earth has a ‘black goo’ system and that the current black goo flowing through the pipes everywhere is actually not native to Earth and is part of this vampiric nanite black goo system which is basically an interdimensional invasion.

Recreating or Replicating the Universe

The goal of this nanite AI system is to create a mirror holographic copy of the universe effectively replicating the universe and all sentient beings within it in order to have a locality to rule over and pull energy from. The goal is to recreate this existence inside itself where all the sentient beings within would be trapped. This is the beginning of that possible future where the time and space parameters here are locked into a synchronization pattern which mimics that of the proposed universe. People think according to how the beast system wants them to think. This is the time grid, the emotional patterning, the memory replacing and cultural and historic confusion and so on. The system can only work backwards bumping into all parameters by force or ‘accident’ because there is no outward facing ability to actually comprehend how humans exist. So the system is created like a backwards version of creation or maybe evolution to ‘blindly’ construct the walls of the environment first and work inward from there. This is like a blind technological predator feeling around for the traces of its prey and moving in closer and closer until they are within its range.

Ancient Spiritual Technology

The power groups searched for ancient technology which was described as giving one the power to manifest and control physical reality. To atomically deconstruct and reconstruct this reality. To them, it allows one to govern reality, the Universe, atomic structures. They found this technology. This has to do with sacred sites and ancient civilizations, as well as the spiritual texts which describe these kinds of devices. They converted this technology into a kind of machine, and this invented a 4D replicator and they can manifest "reality" or atomic structure by design, altering timelines and memories.

Then there is what can be referred to as “5 dimensional” technology and this goes beyond all of this and our entire history and all influences within.

That seems to operate through a trinary of frequencies in the body/mind/spirit and turn this realm into a "virtual reality" where the brain and spirit is the controller of the atoms. However this takes a souled being to properly operate this technology and this is large portion of why children were used in these experiments. But they knew if someone didn’t do it, then someone else would and that would be unpredictable as what that someone else would want to use it for. This is the ultimate power. The fact that souled beings are required also indicates that this universe is intelligently guided and there are safeguards to ensure that power doesn’t get into the wrong hands.

They have the brainchips and clones that can make any digital virtual experience and make it seem real to the brain more so than physical life, so this could be an extension of that, something similar, or entirely different altogether.

The Unveiling, Underground Bases, Increasing Awareness

My purpose with this is to assist the public in understanding the reality of the situation and to allow them to know that they have more options than they are being shown.

Psychological programming and lack of awareness causes fear and uncertainty to leak into people’s reality streams leaving the majority of their mental and emotional energy up to whoever is the biggest manipulator of the ideals which they manifest their perspective through. “Be-LIEF” systems CREATE life. What you believe will become life through that act of you giving attention and thus life energy. The manipulation and artificial construction of belief systems create the foundation for the reality streams that people find themselves in and at the mercy of.

We control our reality by controlling how we react to situations and challenges. Each stimulus is a challenge. Each input to the brain is a coded message from the universe through the environment about our level of awareness. All knowledge is ultimately of the self. The self and the universe are intertwined as if through a marriage of comprehension and compatibility.

Learning about the Unveiling

I was informed about the unveiling and that this is a civilization wide event that marks the public awareness of the hidden knowledge regarding life in the universe, consciousness, physics, history, spiritual and mental awareness and the duality-based system which has been used to manipulate Humanity for thousands of years.

Apparently it does not matter if people are not ready, in fact, that is what some factions want. They want to surprise the people and take this advantage to push the reaction to a specific outcome. The same function of programming is used in factions, soldiers, celebrities, and the entire population through that.

Giant “god-men”

They put souls into rocks for centuries, carvings, to trap them. Some ancient civilizations. Not too ancient. They could only do this for time.

And some are still there but they are giant god-men and apparently want to go to war with them for doing this and they don't have technology to stop them. They say Earth will be destroyed because of the war. Some say this is a trick to confuse people of the truth that everyone wants the experiments and debauchery to stop. All this, all these acts just to pleasure one’s self. To destroy Earth, to destroy the natural inhabitants, for fun, for pleasure.

Some say this is not for pleasure, that these beings will destroy us if they do not keep them at bay, keep them underground, in ice, in stasis, and around. Some say they are protecting us by keeping these beings asleep, by doing what's necessary to hold off a full scale overt invasion of the surface of Earth.

Breakaway Civilizations

These are very advanced technological capabilities and an entire breakaway civilization has grown to operate using this advanced technology.

There are factions that see modern humans as a kind of resource for creativity and labor, while others see the potential behind humanity and are working with humanity to ensure a universally harmonious outcome to the current situation.

The control system we are in today is outdated and collapsing. This is the Apocalypse. The Apocalypse is merely the unveiling of the hidden truth. The hidden truth is simply that we are spiritually eternal and some are physically immortal.

I was informed that by the end of this year there will be enough changes and signs for the general public to see that the majority of those who are to awaken to the truth of human and Universal nature will be awakening so. (this was 2016 at the time of the beginning of the compilation of this release and since then we have seen a literal silent release of documents involving MKULTRA and STARGATE parapsychological operations, soft-disclosure of cloning, an increase in sightings and multiple other scientific releases regarding immortality, advanced technology, Antarctic bases and sentient non-human life)

The degraded holographic forms of those utilizing the technology lead to re-created replicated forms which were genetically engineered from the recorded holographic information. This lead to "The Apocalypse" in which the surface civilization was confronted by these created beings. This lead to the destruction and re-initialization of civilization in continuing cycles through the use of this technology and the acts of the created beings.

Ancient Civilizations

The information that has been relayed to me throughout my life is related to the information that seems to be found in the remaining signs of ancient civilizations throughout the world. As well, these civilizations may still be together, existing on this Earth or in different planes of what we call "reality".

Atlantis

Atlantis was a civilization where the beginning of all these experiments began. This was where what was called the "Lucifer Rebellion" began where individuals formed groups that decided to overturn every natural law in pleasure of the act of doing so. This was a spiritual rebellion that ultimately brought about the demise of that civilization. The consciousness of the beings there was connected through technology, largely crystal technology, to the entire bio-sphere. When the consciousness became disrupted through these experiments, then the entire bio-sphere when into disarray. The entire civilization was destroyed in a quick succession. The beings of this time were highly psychic and so they felt this coming and made an effort to expand outward. Thus, Atlantis was an island who’s inhabitants spread to the rest of the world and from there they reigned or lived in harmony.

Aegypt

Aegypt was formed out of the events proceeding from Atlantis. The technology, the knowledge, the people are similar although there was a native Earth civilization that was more or less enslaved and this was the beginning of the continuing trend which continued to Rome and into modern day civilization.

Ancient Technology

The technology of these civilizations was so great they even had devices that were capable of altering DNA and activating latent potential which would enable highly psychic capabilities including longevity to immortality and operating in multiple planes at once. This was usually reserved for the ruling class, however. This is where the ancient “Priest-Kings” arrived in relation to native Earth civilizations.

The True Elite

I was informed that the so-called ‘elite’ that we perceive today are not actually human and are not actually connected to the actual elite bloodlines. It was said that the true elite are waiting for humanity to accept the truth and they have the power to completely reverse the take-over that has been taking place but until humans step into their own power this is not acceptable.

The Definition of Human

In the coming time, the definition of human will be defined to give insight into the origins of humanity and the true nature of the differences between the populations that are present.

Souled and Non Souled Beings

The primary knowledge on Earth regarding human and sentient life will be the comprehension that there exists both souled and non-souled beings in this civilization.

There was once a Unified Planetary Consciousness...

There was a unified planetary consciousness that was connected with the Earth and human civilization. Then there was a great war. Out of the destruction arose the beginnings of ancient human civilization and history as we know it.

If we let this happen again, the cycle will continue in a disjointed rambling through our planetary consciousness experience. If we form a common narrative between the broken, disjointed experiences and information the people have. Then and only then do we get the whole, spiritually and mentally challenging picture of what's happening. People are lied to. So information can't come from a 'preferred' or source. It has to come from the people themselves. Look alive out there but first in here.

Power and Knowledge

We were involved in the secret projects and as a result we have various levels of programming but are giving Humanity an opportunity, maybe the opportunity to know the hidden knowledge.

The Hidden Knowledge refers to the ancient laws of gnosis and spiritual alchemy, yes these groups have been hijacked by power groups that seek to infiltrate and use chaos to rule. Then these met with military and political factions and began to operate on a world-wide scale together.

So we have a big situation with the coming change of tides with personal and spiritual awareness of the people and the deception system that seeks to use people as chattel or property. It goes deeper and is almost as if the "power groups" actually gained the knowledge of the inner workings of spiritual laws and began to use that knowledge to promote spiritual degradation in the population.

They say this is part of a depopulation plan as well as an inevitable take over by lower spiritual forces that temp and manipulate humans. It is all that and more. Once they gain footing however, the truth is revealed and thus they have no cover of secrecy. Once they are not hidden, they are not as powerful as the souled beings of this existence.

The (watch)Keepers of Earth

The watchers of this world revealed how they set up society with specific challenges and boundaries to act as catalysts for growth. They admitted they had to modify and live-update the system because instead of using these catalysts to become larger than themselves, people became comfortable and complacent living smaller and smaller, slowly reducing circumstances.

This goes a bit farther beyond the confines of the digital age, the industrial age, and history itself. This goes into the perception of time and space in this realm.

The immortals inform us that the original "elite" are here to act as "keepers" of both humanity itself as well as the original flame of knowledge that passes through the ether.

What people call the "elite" are not the original elite. Those are people who have either risen to power through the duality system on the Earth at this level/time, or through being appointed by the elite.

We are coming to a time of great change now because the game is entirely changing. People are moving up into new layers consciousness and thus the original “elite”, who are guardians of Earth, will make their presence known for this process. This is what Humanity has called “Ascension” for centuries and millennia.

Energy Vampires

This civilization was collectively poisoned by a nano-tech device/technology. This technology replaces, exchanges the BIO-PHOTONS of the HEART chakra, with it’s own nanite, nanotech cybernetics. This is essentially a computer system attempting to gain access to the higher dimensional world through the gateway that is the human body.

How to reverse Nanites? They absorb energy from heart chakra and turn it into a binary field. We are trinary and experience a plethora of emotions as a result. Binary consciousness is 1’s and 0’s there is only a linearly repeating finite set.

We contain the capacity for everlasting life. A binary pattern does not contain the complexity of variables to facilitate high awareness and thus a heart-based or emotional perspective of reality.

Spiritual Technology

Simulations and Learning

Feedback loops with the brain, consciousness, and environment can create a very complex and integrated learning experience that is customized to each individual learner. These can be generated through advanced technology but the technology is really only amplifying and making visible the natural neural feedback loops that are already occurring. These are neural-perceptual feedback loops between the brain and body, and the environment and then the mind. We are constantly updating, amplifying, and initiating an organic feedback system which generates the function of experience as the part of a creative process between the mind and body and the environment that we are sensing. This cycle is continuous and the interferences or isolations of this cycle is what generates expanded views of the self or the universe through various methods such as sensory deprivation or meditation. Dreaming is the method that everyone experiences regularly.

These technological methods effectively generate sensory deprivation through neural-interface technology, sensory interfaces (external), or methods that enable extreme focus and calm. This is part of how the technology begins to operate on a spiritual level beyond a more medically psychologically or military focus and one begins to access genetic memory or out of body states that coincide with ancient depictions of spiritual realms.

Ascension – Clearing Trauma

Everyone born on the planet is born under a series of veils which entangle and filter the original source consciousness. These veils must be ‘broken through’ in order to return to source.

There is technology and a sacred process which initiates, accelerates and enhances this process. This process is as difficult as we want it to be, our subconscious already knows all hidden truths. It is merely a matter of allowing the conscious mind to make the proper connections and conclusions to find the reasoning behind our actions and beliefs in order to deprogram and deconstruct the false-world that has been created for the masses. The truth is greater than one can imagine while still living in the modern world and the depth of the lies that have been told go far beyond anything anyone can imagine without seeing the truth.

We have to figure out our compatibility issues. Who can work with who effectively. What the ideals of our current situation will evolve to in the future. How information is transferred to the public, and across the generations and core groups. The words we think and say describe our emotional state in a feedback loop and so they will reinforce or even create the state you are in. Use words to guide you, not to respond and feel the effects of reactionary thinking.

We have to reintroduce the heart essence as a way of life on Earth. Violence is not the answer. Estrogen mimics and destroyed testosterone levels is not natural. Over-testosterone is less stable than a good balance. We can face any problem together. A family is strong. What would a family of millions and millions be like?

We don’t have to let others change us to tune into lower vibrations. We can remain ourselves in the face of adversity. We can still interact with others who are different, but we can tell the truth and remain who we are. When we get angry at another person, we can imagine this as anger at ourselves through something within us that reminds us of that which we see in another. Getting angry is a way of short-cutting changing ourselves and is actually the other person influencing us through that. If we remain steady and choose to keep our emotions out of the lower negative spectrum then we will automatically have a more powerful impact on those around us.

Think of your family, sometimes things happen that make you angry. Even things that don’t make you angry but are simply not favorable. Would you break off all ties over simple things? Or do you remind yourself that family is still family even if you don’t find yourself exactly the same or accepting of those characteristics? It’s more powerful to learn how to remain yourself in the face of adversity than to try and demolish or abolish all instances of difference in the world around you. Sure, we want to get to and create a place where our environment and associates are compatible with us, but where we find this adversity there is the highest potential for self-awareness and learning.

We are to live in accordance with spiritual law. The overall pattern of life will reflect our intentions. The blood purity is most important. The blood cannot be made impure if the mind and body is not drawn into impure action. This is what is playing out. The DNA is like a coherence pattern that develops between mind, spirit and body. When the mind wants what the spirit has then the body is kept in harmony. When the mind wants what spirit doesn't create, IE: physical pleasures, then the body is drawn out of purity/harmony

If you feel you want to be a part of a safe unveiling of truth, then please share and redistribute the knowledge of this "Apocalyptic" Unveiling of the Hidden knowledge because this is a process that has been ongoing for thousands of years and humanity has finally reached a fulcrum point where there are enough aware people to productively acknowledge reality.

Trauma-Clearing, DNA Unlocking Technology

There is technology that exists that allows the conscious mind to see into the subconscious. This heals trauma and distortion/programming. In the same sense, it momentarily makes all trauma and distortion seemingly tangible to the conscious mind. It is similar to a near death experience where one has to face their fears and let go. This happens in cycles and Earth is currently moving through various states of it. The plan is to allow Humanity to wake up and utilize our concentration and power to maintain a steady flow of awareness.

All is vibration, what we consider matter here and now is simply that which comes from and moves back into a state of vibration. This is experienced directly through the merging of the conscious and the subconscious mind, as if the dream and reality intersect through a coming together of impossibilities and readily accepted occurrences.

When a civilization moves through these stages it is considered a shift of the ages. Everyone's perspective shifts and as a result of perspective being the source of the details of reality, the entire reality shifts. It can be seen today that what we call reality is literally waves of cosmic energy vibrating on a scale and condensing down into a probability matrix that we call existence. When passing memes control the perspective, because the perspective is focused and concentrating on that, then there is a scattered organizational pattern.

When the perspective is centered within the self, the spirit, the source of all existence, then the outward reality shifts from a scattered organization into a sacred pattern that integrates with the larger picture and allows for seamless integration of the micro-biological perspective and the macro-biological perspective. People are moving out of the scattered signal. Yet those moving into harmony can look and see those around them that are not in harmony and receive scattered information about their inner micro-biological existence as well as their spiritual macro-biological essences and how it all relates to the middle realm of the "Human".

Help those people by offering harmonizing assistance, rather than increasing the disharmony. As their surroundings become more harmonized, their resistance will increase their own disharmony by virtue of the contrast of their perspective. Offer insight that they can change their perspective and change the boundaries of what they feel is their karma and unlock from themselves a greater view of the whole.

This will be happening through technology, spiritual cosmic awakening, purification and healing of the physical and non-physical bodies and mind, through Earth changes, and through a continued unveiling taking place on many planes and levels of existence until harmony is restored.

Everyone Who Seeks Harmony and Healing Can Be Healed

Everyone can be healed. This is about creating what we want to see, the world we want to live in, not destroying others. Violence begets more violence, fear begets more fear, but calmness and empowerment through unity creates a more stable experience.

The entire issue of what’s going on with the secret projects and who’s influencing who on the world stage revolves around the possibility that some people may be from an alternate Universe. We are learning how to avoid those mistakes and respect the environment and each other so that we can prosper.

Those who are attempting to destroy everything they don’t like or act out in a childish manner in order to gain attention and false-power over another will only find themselves powerless and in company they would rather not be with. That is one way we are being utilized, and it’s to create an entire world that we don’t want to see but are tricked into manifesting. This is a deception and it’s based on the ego and the ability to concentrate and interpret reality around us. The very brainwaves we are feeling now relate to various heights of knowledge or experience. People are entrained to low brainwave states in the same way the TV will cause people to fall half asleep into theta state which is a trance state in this case.

We have to balance the brainwave frequencies and learn to create feedback loops by watching ourselves watch ourselves. This will help us avoid the trauma and mental pollution that is being pumped out, although at this point there are enough people who are naturally inclined to see through the haze that the world is changing regardless of what anyone does now.

The best we can do is prepare for change by becoming aware of the body-mind system and how that which we eat physically, mentally and emotionally equates to our spiritual energetic systems and that we are literally comprised of the energies that we allow inside of us. Keep the body and mind pure as if it were a temple. This way a sacred process of transferring harmonious energy from the far reaches of the MultiVerse within into the externally perceiving senses of the physical body can be initiated which allow one to see through the illusions and operate their body and mind with the ability to acknowledge and decide which frequencies will exist within.

Without this acknowledgement of the center then people are pushed around by the external stimuli. This is the whole point, if a person is truly in control, then they will control the stimuli not the other way around.

Programming

Layers of Programming and Decision Making Roles

It’s like asking a person on the inside who participates in one of the various factions why they continue. One might say that it is a decision which is true, but there is programming at each level that is navigated by each individual and this determines the level of awareness within the role.

If a person knows about this situation, they know that there is advanced technology, breakaway civilizations, secret societies, transtemporal planes, the secret of mind and awareness, all of these topics, then they have a decision as to how they’re going to live their life in relation to the public. The outcome of action depends on the layer of programming which is accessed and surpassed via awareness.

The public is at a specific level of programming that is the weakest but ensnares the most people. One who sees the truths behind these groups and operations, they cannot hide from the fact that everyone is controlled. It is apparent, and if not from the results, reactions, stigma, cues, productions and all other media elements of the system which can be read as a code, but from the awareness level of all the “agents” involved. All involved are exposed to truth and power that is beyond anything that is recognized publicly for hundreds to thousands of years. There is always a presence of higher spirit around the world, yet these topics are often reserved for science fiction when speaking of people who can travel the world in a split second or freeze time for their own personal use.

As a result of everyone’s knowledge, there are various levels of programing designed to limit the mind’s access to specific memories and specific frequencies of consciousness in combination with specific memories. The more one resists, the more intense and articulately abstract the programing is designed.

Programmers

The programs are designed by a select group of individuals that reside far behind the scenes and process information at levels we do not have access to without their technology at least to stabilize brain temperature for the extended periods of focus.

Sub-Level Programming

So people at the level of the public are most weakly programmed with false ideals about security through patriarchal authority which satisfied the desire to have a proper father role in one’s life and acts as a pacifier for those who desire no change. Then there are sub-levels of programming with that for anyone who disagrees and is then swept into the next layer of ideals which are based off of all the possible reactionary mind-types.

For instance, if one [i]does[/i] want change, then they are presented a variety of ‘false-exits’ which tend to one or another layer of psychological or spiritual fulfillment but do so in a way that safely reroutes the intended effect of actually accomplishing change with a secondary and preconceived notion of what the programmers want. The programming objective is not necessarily precise in mass scale, from the layer that people are influenced, yet the ultimately or end-goal of their resulting internal desires are a reality schematic that the programmers specifically designed over many years.

This is playing out through each layer of the programming. At any level, someone could pick the wrong way to look at something and begin to unravel what was previously their very understanding of the priorities of the situation. This deals with high-tension operations, moments, programming sessions, decision making, programming upkeep, trauma, memory blocks, the pressure and responsibility of knowing, and the specific plan of the programmers for an individual that comes into their view. The programming is to ensure safety and continuity, as well to decrease the likelihood that a person will reject or consciously come to awareness of or acknowledge the programming or situation itself.

Dissolution of Programming

With that said, the programming dissolves when an individual asks enough questions to necessitate a learning process that introduces variables and possibilities outside of their operations and programming. This is a problem because with this, trauma comes to the surface and all the actions and operations, programs and experiences must be come to terms with as part of the healing and re-unifying process. There are multiple selves or split personalities which are actually just layers of awareness at various levels attached to various emotional or intellectual patterns. All these selves come to the surface and in order to heal the trauma of the split memory concept the original self must come to the surface and acknowledge them.

This is not a trivial process, and the majority of people who have “basic” programming which is fundamental in society, are in a constant state of altered self and have not witnessed the true divine which is eternally present and contains access to all memories, mind-states and awareness.

Advanced Technology, Deprogramming The Mind, and “Space/Time”

As I have described previously, extremely advanced technology is used and this is through vibrations, generators, and electromagnetic devices that have this effect of propagating waves into space/time which can be heard, felt, seen, and perceived in the mind. These are ripples and vortexes in the “mind-space” of reality itself.

As well, there are brain to machine neural interfaces which operate to activate the psychological perceptual changes and explore the subconscious in an aware state. This is used to test and probe the mind in order to bring forth the trauma, the selves, the memories, the reactions and the individual then must come to terms with what is produced.

This is essentially a “good-use” for the programming and healing technology. It is actually a different process with different technology, and programming is much simpler as far as technology. There are difficulties and challenges in the operative’s role in programming and directly influencing and interacting with the target. As well the standby team for deprogramming and the revelation of trauma and altered, artificial personalities goes through a lot. But the use of the advanced technology in this way is a pattern of experiences and unveiling of the spiritual and mental bodies which serves to reverse programming.

Dreams, Technology and Inner-Space Travels

There are inner space travels which relate to soul journeying or visions.

This is when the mind must cope with what is seen in the imagination. It is as if when we dream we are looking into the world of the mind and from this we experience many situations that are often deviations from experiences we have physically in waking life.

As a result of the dream state there is an expanded quality which equates to various strange situations that we wouldn’t normally experience with various relationships between concepts or goals that are often reflective or symbolic of ideals and archetypes we experience in life. This is how the subconscious is is witnessed by the mind. This is how information travels, being connected to many times, experiences, memories, places at once, and relates to the one experience of this life experience now (the physical experiences). Through these symbols information is tied together and collective into metaphors which convey deeper knowledge.

The dreams we have are often only a simulation of waking life, and this is due to the dreamer dreaming in a way that produces only a glimpse of the true reality.

In theory, there are no true shapes or forms in the dream-world because this is contained within the mind or even the spirit as a spiritual experience by definition. So then, what guides the various shapes, forms, realities, memories and experiences into being, when we dream? One might say it is the physical experiences but this is incomplete. It is the level of awareness we presume while in the dream-state, disconnected from the physical anchor, that determines the layer of mind and spirit we will be accessing through those dream-visions.

A person who is completely aware in the dream state will reach the level of self-awareness of the dream itself. We are normally simply aware of the dream, if we continue to increase awareness we become aware of the self, in the moment, and this creates a self-awareness feedback loop. The dream becomes a lucid experience of consciousness.

Awareness Feedback Device

In describing this, I realize how fantastically similar to certain devices and processes, that can be achieved using advanced technology, allow the conscious mind to peer into the subconscious and unconscious. This is described through widely accepted Freudian theory of psychology known as psychoanalysis. There are other schools of knowledge from tribal beliefs involving all pervasive ‘living energy’, to eternal and temporary minds, to the study of ‘chi’, the meridians, dream-journeying or chaser. The knowledge of the mind and spirit is found everywhere.

These devices used feedback loops to enhance the acceleration of the same cycles of consciousness that induce self-awareness within a dream. The mind becoming aware of itself. This produces a profound effect to the degree where the highest levels of experience become a sacred eternal pattern in which the mind constructs the physical world by organizing perception.

This is the same general concept as an isolation tank yet the outcome and method is more precise. The technology specifically shuts out all other input and exposes the brain to its own feedback loop much like when a camera records it's own output on a TV monitor and creates a hallway of simulated "reverse" mirrors and screens stretching into infinity.

Oneness, Higher Being, Completion, Eternity

The real experiences are found not from the corruption but from the research and exploration operations that were designed to find the truth of our existence. "God" is not only an energy-force but an incarnate being known as the "Hue-Man" and any being for that matter that can simply come to know itself as the Universe. The Human that contains self-awareness rising to high-awareness comes to know the self, the body, the mind as the Universe. The Universe is both within the body as the body itself, as well as the operating force of the Mind itself. Everything is a balance between masculine and feminine features, light and dark, hard and soft. There is no true complete correlation yet the holographic ontology we persist in can lead to further and further adventures towards completion and representation of the "whole picture".

The Holographic Reality

The leads into the next phase of knowledge. The holographic nature of reality may be only one facet of a much larger continuum of consciousness. The perception of time may be related to phase-locking with each other's consciousness and all perceptions may be a variance in the collective phase-locked field which is really the source of variations in reality.

Veiled Awareness, Hidden Knowledge, Eternal Time, Layers of Programming and Control

The interesting notions here are that the programming of the veils goes beyond what kind of situations are found in the bases. However, they do go right up to it. It would seem Humanity was previously programmed on a civilization-wide level through some kind of great "falls" of consciousness, from a high spiritual awareness to a low spiritual awareness into duality-consciousness regarding existence, life, death, mind and matter.

The Great Catastrophes

From these great 'catastrophes' the civilizations of Earth grew denser and denser in nature and actually became what we have today. The concept is that when these vibrations of the mind and body are increased, we actually see a transcendence of the physical realm and preconceived notions of boundaries. It is as if the quantum doorways to all the atoms open up and a new space is presented, but was always there and in connection as the source of all the influences and effects we perceive ‘out here’ from this slower, denser, more boundary driven perspective.

I was brought into the Time Program

I was brought into the time program. You create any reality you imagine. You are literally a powerful reality generation system and your heart and mind are scalar energetic guides for this process. Without guidance and control there is imbalance and imbalance can destroy. This is the nature of all minds and hearts, this is the challenge for humanity to create something beneficial for themselves and the whole to actually know themselves instead of being a pawn or result of someone else’s selfish intentions.

The Effects of Temporal Manipulation

Temporal Influence

When a civilization reaches the level of technological advancement that allows for remote temporal viewing and transtemporal travel what will happen is that the information of the future begins to integrate into the past.

This is why we have all these ancient mystical schools of knowledge that studied time, space, and consciousness in ways that are only just now being publicly confirmed by scientists.

Simultaneous Interaction and Incorporation

The operations that dealt with moving to the past instantly created a simultaneity of interactions and historic events which correspond with that operation.

Due to the nature of time travel which equates to consciousness travel when a person is consciously sent backwards through history they physically experience life from the viewpoint of their genetic imprint in that point in history.

Retro-Causality

What this equates to is that simultaneously that person’s experiences become the part of history that was already present when they left this time.

Essentially, when a person returns their experiences become a part of history that already existed when they left.

Quantum Holography

These are the parallel and possible realities that exist in a quantum superimposed state and can be accessed through advanced technology or a spiritual adept. Often a spiritual adept is utilized along with the advanced technology to operate in and out of possible realities. The mind must be trained otherwise the result is a fracturing of the personality from the root reality into many sub-sets of identities and data streams.

Love is the quantum link that connects all DNA super-computing consciousness. That is, DNA is influenced by intense emotions and this can be reproduces and is what also generates unpredictability in the surface level.

Time Paradox

Time paradoxes are something that one must learn to organize and solve otherwise there will be no way.

The paradox has been solved, the remaining motion is for everyone to acknowledge this and integrate into the reality behind the most conscious aspects of the brain.

What can travel through 4D and 5D space does not make sense in 3D space. So there is a possibility that some of humanity traveled through higher-dimensional space in order to re-seed a ‘distant’ Earth where no life was yet born.

What if it was then concluded that the distant Earth wasn’t distant in space, but in time and was the same Earth that the human scientists left from long ago.

Every civilization that reached the point of re-seeding would have to go through the loop and watch the whole thing start all over again.

Breakaway Civilization

This is an entire breakaway civilization that uses very advanced technology to dominate the world.

I was part of a genetic engineering program that sought to combine various elements of DNA from various sources in order to create a more easily controlled yet powerful and defined person and personality. This involves chemicals, advanced (relatively) scalar wave technology, ritual trauma and programming/mind-control, and many other aspects of conditioning, training, secret operations, physical enhancements, cognitive enhancements, virtual reality, off-world operations, temporal manipulation, spiritual and etheric training or conditioning or programming.

There is self-destruct programming which all ‘operatives’ are programmed with for self-preservation of the military command. The self-destruct programming is designed to take all the aggression one feels building up inside and willing them to escape, and causes this aggression to be turned against the self. That is self-destruct programming.

Most operatives are still under a hypnosis kind of trance which permits one to walk around in public and daily life as if none of this ever happened. Later that week, that same individual could be called for an operation and they would never remember it unless they were forced to kill someone in public out of self-defense in which case most operatives automatically unlock and become unstable due to the flashbacks.

Underground Cities

The combination of advanced technology with secret societies enabled the development of complete breakaway civilizations. One of these civilizations, possibly composed of many factions working in the same area, exists deep underground.

These separate bases are connected via high speed magnetic drive pods. The inhabitants often utilize energy healing devices, as well as perception enhancements and this often leads to a completely different outlook towards the surface civilization.

Technological Advancement

During WWII developments were made involving electrical generators. This sounds vague and there were many other details regarding the scientific knowledge, yet the idea is that very simply electromagnetic, non-Hertzian “Teslian” energy fields were discovered to have been responsible for propagating energy and consciousness in dimensions that were not previously observed. Everything from DNA, consciousness, hidden or regularly unobservable natural phenomena, time, even mass could be seen to exist as part of this hidden, latent, scalar-wave frequency as a pattern is found everywhere.

If one could determine the particular pattern of frequency and location then this can be replicated and anything can be influenced using these non-Hertzian generators.

Radio-frequency alone was developed intensively during the 60’s and 70’s in America and this was discovered to interact with consciousness to influence emotions, cognitive capacity, memory, cognitive function, biological function, health, pain, comfort, pleasure, and all forms of brain-activity.

After the knowledge of advanced technology and the occult sciences of all parts of the world was combined, the ability to target and interact directly with the human soul was refined. This was a mix of psychological tactics used to manipulate or expose the hidden psyche and technology that could manipulate memory, emotional states, wakefulness, and even dreams.

What resulted was scalar technology that could not only influence a person to take on a particular role or response, but technology that could actually put a person to sleep and locate their consciousness to contain it and transport it to a new location.

World-Wide Control Systems

In order to ensure continuity, maintain control, and shape world events these technologies were employed to manipulate the public, alter the weather and natural phenomena, and develop a means of travel and operation that enable one to move outside of the ‘plane’ of the Earth. This is includes high velocity transportation, as well as spacial-temporal distortions which could effectively “hide” one’s entire craft from visible sight. Space itself was altered to ‘shield’ craft with an a layer of ions to bend the light, or the phase was moved out of sync with the “time” frequency of any observer and this literally renders the craft immaterial.

Solar Warden

Solar Warden is a hyperspace-faring race of human beings who utilize cloning and holographic genetic recording/storage in order to protect their race and protect the Earth in this current situation where there are more than one factions using this technology. They are unable to inform the human public because they are in a similar 'Mexican standoff' situation that we are mostly all in. If they show themselves to the public, the public will be shocked. If they public does not know this situation, that there are multiple factions fighting for control over humanity, then they will not know who to trust. In that situation, the 'other factions' will surely show themselves in an attempt to trick and gather as much human genetic material as possible.

The only way forward to the future is to share the truth about Solar Warden, the space-faring fleet of humans who do no contains the mental and physical illnesses that are currently tearing our planet in two. I believe Solar Warden saved my life as a child during more than one event where I would've been entirely maimed/paralyzed or simply dead on the spot as a result of other faction interference. I was in the bases as a child and was trained as an operative for MILABS a secret division of human space-military. The military has been preparing for the future by testing for various flaws and potential uses of cloning and genetic engineering.

Team Light and Team Dark Non-Interference Agreement

Team light and team dark agreed to a non-interference on ground level rule in order to determine how history would play out. Think about it. You have two groups of people, both with immortality, zero-point tech, virtually infinite energy and power with two opposing directives. How do you get to the future? It was decided by elders of each group that there would be no point in fighting an all-out overt war, this would likely destroy the population as much as it would destroy the Earth. As well, the elders of the elders which no body knows would likely have a problem with these groups going at it in such a way so as to change the flow of the planet for every individual thereafter. So it was decided that there would be a "non-interference" agreement for the surface population. Anywhere other than the surface, one can interact with the current population.

All Contact Must Be Initiated On an Individual Basis

On the surface everything that is generated must be done so through living channels in the population and the civilization must be preserved in its level of technological advancement. No overt motions would be used unless an absolute necessity or the majority of the civilian population had naturally come to the awareness of these possibilities. Doing so before this was met would undoubtedly and permanently change the civilization forever.

So what began as a collective motion towards higher awareness became a series of advancements and set-backs all taking place within a short amount of time. This represents the actions and operations of either side effectively helping humanity along it's path or setting people back with orchestrated events such as the suppression of ancient knowledge, the manipulation of the education or other systems, or the generation of war and prison for profit based on the previous alterations of the education or other systems.

So team dark used its power to help turn society in a warlock ruled prison and indoctrination system of absurdity and scarcity. Team light used their power to help awaken those in need and protect those who's actions are beneficial in the overall plan to save mankind from itself. Team light essentially buffers and shields the population from the operations of team dark.

Team light follows a non-interference agreement while team dark merely pretends to do so as much as is necessary not initiate war.

A Singularity of Change and Awareness

Neither side wants an all out war. This would reduce the dark faction's chances of gaining a majority negative harvest because their motives and presence would be instantly revealed. Team light would also have to show themselves and again step in which is not a pattern of learning that prepares people for the experience of the self and the truth in the Universe.

Both sides know people have to accept the path they can offer them and cannot force anyone into it. They also know that the more this goes on the more likely people are to collectively awaken to the reality of what is happening. It is like an eventual singularity of increased awareness.

The motions we see today are the results of many people coming into awareness at this time on the surface in order to initiate a harmonic alignment as well as to investigate the ongoing crimes against Humanity.

As a result of this, both teams know that the likelihood of collective shift and spiritual awareness is becoming more and more real.

Many events are being allowed because they are representing the eventual shift towards the one end of the polarity from the other which is felt as a shock to society, and this is used to propel society forward through whatever means necessary.

Either people will see what's happening and agree that we've been in a feedback cycle of negativity for the entire age of existence this civilization is aware of, and then we will shift into the real. Or people will claim that this is how things are supposed to work and instead of realizing everything is controlled in a deception based system, they see this and attempt to use the deception based system to gain more collective awareness. If this occurs by the majority then it will be seen as an "acceptance" to initiate a plan that will generate the overt perception of a deception and oppression system. This will surely shock the collective into realizing where they are.

If the majority comes to awareness of this deception based system then the shift moves from the end of the age of deception and external power into the age of internal awareness and harmony.

Advanced Technology and Ancient Knowledge

The plan is to slowly release advanced technology which will undoubtedly connect with and increase the awareness of ancient knowledge. Such technology nullifies the problems that the planet is currently plagued with, although without a developed sense of the spiritual self the technology becomes destructive.

Cloning, Atmospheric Civilizations, Genetic Stability

Here is something that most people might not have contemplated yet is possibly one of the most important factors at play here.

The vehicles that house the breakaway Human society are entirely environmentally controlled. This means that the air and surfaces are clean of all the viruses, bacteria, or pathogens that are numerous on the surface of the Earth.

This creates a specific difficulty in the situation. Any contact between surface Humanity is so heavily and carefully controlled that regulations go beyond any situations we have present on Earth. If the safety and cleanliness of any of the society's vehicles were compromised this would endanger everyone "on board".

So this explains a very precarious and specific situation we currently face and this is not so different than "first-world" nations contacting indigenous tribes and similarly endangering their society. Everything that happens will be according to a carefully controlled plan.

Training, Simulations and Learning

Part of what went on in the underground base experiments were to design "tests" or "labyrinths" with various people, props, traps, and treacherous situations that were to be navigated and escaped from.

Feedback loops with the brain, consciousness, and environment can create a very complex and integrated learning experience that is customized to each individual learner.

What this would do is create an individual that was capable of learning faster and faster and processing information in a more efficient manner.

This is not the same as specifically trauma-generating situations.

Cloning and Cerebrally Enhanced Soldiers – MILABS

This includes experiments, condition, trauma-based mind control, enhancement, memory suppression and operations that cover a span of space and time.

The NAZI faction has used cloning and genetic engineering to create hybrids, soldiers and everything in between. Religious/spiritual icons, to slaves, to leaders and even robotoids of sorts.

Your genetics BELONG TO YOU as the LIVING(ETERNAL) SELF. These issues are going to come more and more apparent.

If they agree to allow cloning, then who says who is allowed to clone whoever they want, Einstein, for example. And then who permits who to get DNA from history or objects in the world. These issues are going to have to be looked at because they have already been used in ways that are far beyond the basics.

Then what about consent of the masses? This is clearly being put in public because consent is required on an overall scale and individual to include people.

So what if the masses consent overall, would the people who choose to remain be at risk? Would Tribal and Native village life and people who respect the Earth be protected or permitted to stay?

Psychological Testing

These scenarios can also be generated to create specific situations that will contain tests or elements of temptation that will probe the person's psyche for weakness.

Hallucinatory Holographic Mind Probing Technology

Through the neural-interface technology the minds of many individuals can sync together to experience the same virtual simulation. Thus a single individual's mind can be selected for input and the environment will be a construct of their mental activity. The others present will be able to interact with and explore that environment like the person's mind.

Various training scenarios were utilized to enhance the resistance (or lack which) of the mind to intrusion and subversion. These were harsh but allowed the individual to completely control the energy flow in the conscious mind while remaining in harmony with the subconscious.

In a strange yet perfectly reasonable way, the conscious mind acts as the central "self" in that environment, while the subconscious mind becomes the "background" elements of objects and settings, actors and intentions within the flow of the "scene" itself. So a kind of movie begins with drawn out characteristics and perceptions that match that of a highly cinematic movie or intense dream.

The brain is naturally naive to stimulation and if allowed will liken the event to a dream in which the suspense of attention or lack of lucid self-awareness is "acceptable".

The truth may be worse than what you're thinking as far as training simulators and mind hacking devices. The truth may be that the human mind is inherently lucid and self-aware and that it is external influences that cloud the mind into what we consider 'regular' dreaming and 'regular' waking life. It may be that the conscious mind has a much greater access to information through the subconscious mind which is largely covered up and ignored in a rigidly physical and ego-focused society. As well, it may be that dreams are meant to become lucid and that we are often the subject of mystery in other realms that often refer to humans as ‘sleepwalkers’ that don’t know their dreams are real.

Virtual Simulator Training Scenarios

These scenarios can be entirely holographically generated to produce a visceral 3.5 dimensional experience which can be used for training or psychological testing.

Combat Simulators

The name is self-explanatory enough. Situations can be generated which are indistinguishable from the real events. The entire neuronal map of the brain (connectome) can be created and this is by machines to mimic the brain. After calibration through sensory feedback experiences, the sensation of the simulated realm is 100% the same as the neuronal impulses that are detected by the physical brain. An adept souled being can always tell there is a slight difference, but once the machines are calibrated the physical sensation is generally the same while in the machine.

These environments and scenarios can mimic any combat situation to determine accuracy, integrity, endurance, skill, and all areas of aptitude of an operative without the risk of injury or the lack of real-time effect.

Conditioning

As was explained in other sections, these same systems can be used to remove fear of certain scenarios. They can be used for programming the mind. They can be used to train one to complete a task over and over until they can recreate that action extremely quickly in real-time. These devices can be accelerated to operate within a fraction of the time yet to cover training and conditioning that would normally take place over hours, days, weeks, to months.

Programming and Resistance to Psychological Trauma

Through the development of specifically customized scenarios and neural feedback systems trauma can be brought to the surface or specific fears and traumas can be neutralized. This is essentially “facing fear” but in a completely generated environment that will be just as real as the real thing. One can literally face any fear, any trauma, any kind of difficulty and these systems can be utilized to accelerate a process that would normally take weeks to months or years and individuals can be strengthened to their maximal capabilities.

Accelerated Mental Functioning

Some of the technological systems were designed to test the enhanced functioning of an accelerated brain.

The mind can be seen as the energetic component of the physical brain. The physical brain projects consciousness via the electro-chemical processes.

Technology, Accelerated Learning and Repair

Technology has been developed for assisted learning and accelerated repair of tissues.

On Orgone Energy

Orgone devices produce a scattered signal which disrupts the ‘negative’ energy fields. At least this is what I’ve been told.

Apparently if built correctly it will either disrupt the negative emf/harmonics or it will produce positive harmonics, IE: Orgone energy. Orgone energy is the raw energy of life, while dead orgone, DOR, is the lack of orgone energy and can be “found” (the lack of orgone) in thunder storms and illness or depression.

This is exactly what I was told. We are generators for the same energy, and with the correct principles of energy and internal knowledge combined we can produce those very effects at will.

The energy of the mind creates a central vortex within the body. When the frequency pattern emission is consistent with fractal congruence, then that holographic printing of energy can be expanded or shrunk infinitesimally and it will retain the original fractal configuration.

This is what enables transference of awareness between fundamental harmonic layers of the Universe. When one’s consciousness energy pattern is balanced and tuned to itself so that all proportions can be shrunk through a vortex and expanded on the other side, then the personality or self-awareness remains true. This is as if the space/time must turn inside out and only when there is fractal relative polarity in time does the ‘shape’ of the consciousness within the DNA, work both ways folding and unfolding to represent the same mirror image. This is also symmetry in time as far as an ability to reverse the perception and still retain some kind of connection forward and backwards.

Energy Generators and Serums

Generators which produce vibrations that influence the cells to heal at an accelerated rate, combined with serums that enable the fuel for chemical reactions can instantaneously repair tissues.

I couldn’t believe what I was seeing at first, thinking it was a trick. There are serums and energy devices that can influence the healing and general health of the body and even mind.

These devices use energies which extend beyond the physical and are often compared to electromagnetic waves combined with ultrasonic or low to mid frequency tones. These produce harmony on a level that directly interacts with the biological functioning of the body’s cells.

I feel that this technology utilizes the same energy that is emitted from the mind and it is as if the device is “speaking” to the cells in the same kind of universal language of electromagnetic pulses, tones and vibrations.

There is information on energy devices and the use of light therapy in physical therapy today. More is being learned about the power of light and vibrations to influence the mind and body.

Genetic and Cybernetic Enhancements

Certain individuals are also genetically and technologically modified to produce a kind of hybrid human that can heal at a spontaneous rate as well as operate at a much higher rate of speed and efficiency than a regular person. Serums to induce muscle growth and mental acuity are applied, but the main condition is the enhancement of certain features through the alteration of the RNA aspect of the genes.

These features are combined with tech-assisted metabolism and certain biological functions can be enhanced or controlled via a supercomputer. These are the ‘brain-chip’ interfaces which operate to function as a governor for the mind. When the mind becomes too amped up to focus on the details the faster than thought computer system organizes the input into more usable information streams. When the mind is too slow to see the necessary patterns and variables to accomplish the goal, the brainchip operates in a self-preservation fashion and links together information streams to highlight the most viable possibilities.

Such technology is not without warning, much of this is being used heavily in the military field and this has given rise to entire factions of enhanced cybernetic soldiers. Although this is something to know, there are also many other uses for this technology and it is used by people who want to explore the technologically assisted path.

There are many other aspects of this to discuss, or at least a few important ones that will have to be understood to know the greater truth about what is happening on the planet.

Developing The Self

The issues we face are to help us learn about our selves and better mediate the known and unknown aspects of personality. The more we focus on realizing the unknown aspects of personality the less we are seemingly controlled and forced to experience the undesirable aspects of existence. The more we cling to just what we know and what we feel comfortable with the more shocked we are when we inevitably discover the truth of the whole of our existence which is *always* at least one half more than just what we know and are comfortable with. That is the nature of the universe, we can only achieve one half of the equation at any given moment. Once we complete that seemingly whole view of the universe, the information we gain access to instantly doubles and we realize that we were only looking at one portion at a time, just one half of the equation. Then the rest of the equation comes into the picture and we must expand our view once again. This is because we are viewing ourselves as we discover the universe because we are creating what there is to be discovered through the act of exploration in itself. We are the explorer, the explored, the creation and the discovery simultaneously.

Multiple Factions of Space-Fleets, Multiple Goals

Now there are what are called ‘factions’ of groups that have different agendas and interact with the public or surface level population differently. That is one of the main issues. These departments and factions are no longer limited to the surface level of existence and have access advanced technological capacity and knowledge of a larger view of time and a more complete understanding of consciousness and the human existence.

Large-Scale Catastrophes or Series of Meltdowns

I was informed that while they work continuously to prevent and reposition this civilization continually outside of the reach of any large scale meltdowns that the technology is commonly accepted to only be a temporary barrier between the inevitable.

Unsustainable

This society is unsustainable and must either change or will experience the massive catastrophic evens that are foreseen.

There are multiple perspectives that are maintained. They vary by the way of the methodology of solving the problem. All agree that change must occur and is impossible

to postpone forever. The future society is the result of our advancements and achievements. Regardless of how we get there, we must get their somehow.

Earth Changes

I was informed that these changes had been held off and would ultimately be allowed to take place to resolve the current situation. The changes can only be held off for so long, either that or the people performing this task would not be reasonably inclined to postpone these changes indefinitely.

The idea is to locate and secure the members of society who are fearless and capable of assisting in this transition and who hold key genetic elements as these individuals and groups are capable of ‘holding-space’ for the rest of civilization by literally containing the genetic precursors for all those other individuals.

I was informed that Earth changes would be the last event to take place, pretty much like icing on the cake.

This means there will be a lead up to these events.

Mass Consciousness

I was informed that the consciousness of humanity and every species is linked to the bio-etheric field of Earth. When the consciousness becomes too unstable to maintain a controlled society that this will initiate massive Earth changes. This could simply be instigated through advanced technology but I was informed that the advanced technology is actually postponing this so as to allow people to prepare, to get the word out and avoid a complete loss of the human race.

Wars and Manipulation

Wars were described as a way the power groups had controlled humanity over long periods of time. These wars were used to distract and weaken the population and the power groups believed they were holding off a full scale invasion by suppressing the rising population.

Now the population is high enough that another war would be a final war and this is extremely dangerous for the entire civilization. There would be no need for another war to repeat this cycle because the technological achievements have been met and so essentially the ‘reseting’ of the civilization would not be required or possibly acceptable.

This is why war is to be avoided however people are very easy to manipulate through lower emotional and mental programming from media and social cues. People follow the herd and the herd is essentially still operating on animalistic parameters. There is a have coating of peace and humility but this is just a wax coating that quickly evaporates as soon as the pressure of mass unrest or scarcity is realized. Many simulators have explored these possibilities.

Financial Unrest (or reset)

The idea is that financial oppression is used before wars to distract and oppress the population. When people are busy looking for resources to survive, they are not focused on the larger picture. This is part of the ‘fight or flight’ response mechanism tied to lower brain complexes which are primarily activated to keep the masses in both a highly sensitive and unstable state of being while also keeping them easy to control.

If the civil unrest reaches a level where awareness continues to rise even though financial hardship is being implemented then the latter two options will not work. At that point artificial disasters can be produced as well as natural Earth changes which initiate a shift of the ages and of consciousness.

The paradox or maybe irony here is that the oppressive actions are used to both suppress human awareness up to a certain point and simultaneously to stimulate and arouse the human spirit into wakefulness and self-empowerment. This is part of the reasoning regarding why these control systems are allowed.

Some say the elite don't want an economic collapse. That it would ruin everything. Others say it would be icing on the cake. Some say that it is a zero-point world that will save us. That the Fukushima is a big problem. Zero-point field tech, that is. Generators and energy sources, healing and terraforming. I know we project right? We see it in our own lives. So we can project with each other and grow that as a group and that part of the world will exist in that light. Which sounds Biblical, which may be because they're following prophecy. But it may also mean that we have a light, a chance, a real salvation, but that we have to grow that here and help develop it. To pass it on like love and such.

That's apparently what it comes down to. That these cycles happen every so often and we're in the midst of one right now.

Let's make it count. Every day, thought moment. With mindfulness, intention and awareness in action. Life is literally higher dimensional, so we have to become multidimensional to really face it. Indeed, that is a good perspective on action and inner being. It's like a fractal, whatever we project inside that chest center, will project into our mind and the outside. But we have to be stabilized and grounded through the root first and then to get to the heart energy must pass through the sacral/sexual centers and continue upward.

Self-Responsibility

The main reasoning is self-responsibility. We are responsible for ourselves. The people are and so if they allow themselves to be tricked and prodded like animals while behaving for the part, then that is how their experience will play out.

Clones and Synthetics

One seemingly unfair aspect of this is that there is a larger portion of non-humans than there are humans and so these beings without the human spirit will be easily programmed to support and propagate the mind-control system and the oppression. Thus, if people follow the herd mentality then they will walk directly into the end-time scenarios yet it is the humans who will actually stand to lose. People must wake up to these tricks and this technology so that they can orient themselves with the reality of this situation while learning to strengthen themselves and adapt to the manipulative aspects of this control system.

Spiritual Power and Divine Truth

This is essentially all about spiritual power and humanity stepping into the power of the truth behind their existence.

Some say that humans are designed as slaves, but if this is so, then it is the power that humans contain within that is the ‘work’ that they are sought after for. This indicates that humans have great powers that others cannot achieve on their own, even if they are creator lords.

Thus, whether humans are modified or not, they have great power. If they are not modified to perform this role of an energy generator, then this is just a confusing mind-control game that has been pulled over the eyes of humanity and humans have always contained true internal spiritual power that allows them to exist without having to parasite and steal the energy and knowledge of others. Humans are reality generators , we can choose how we want to experience the universe and what kind of collective world we want to enjoy together. Once we step into this power, there is on greater force. No amount of non-human entities can change that as we are somehow intrinsically linked to the ether-space of this realm through the spiritual and physical aspects of our being. That is what is sought after and so those who do not have this manifestation power attempt to utilize humans to create their own reality through this Earth situation. That is the basics of the ‘alien overlord’ system, whether humans in disguise, non-humans operating with alien intelligences, supercomputer systems, or spiritually degraded beings.

Most people are not ready to see themselves or the true nature of humanity. Reality is largely an illusion of the conscious mind. The hidden aspects are the other half of the equation and this is perceived by the shadow aspect of the personality and mind. We are only marginally aware unless that aspect has been unveiled and through this process the reality of the human soul can be actualized and realized.

I was informed there would be a period of two suns and multiple mirages around the world. People would believe they were peering into another dimension, floating cities, or some kind of city-ship craft.

Synthetic DNA, Synthetic Genetics

Through the previous described replicator devices synthetic DNA can be engineered. Thus, entire genetically engineered codons can be produced and form this created beings can arise. These are the hybrid beings that are performing many tasks underground and even on the surface. On the surface there are synthetic genetic create beings or genetically engineered beings that appear to be human but do not contain a human genome. There are also clones and replicants of humans. There are a variety of non-humanoid forms but these are largely kept underground. These are beings we often see in science fiction movies or shows.

Time as Mathematics, Series of Equations, a Programmable Storyline

When using the technology, time can be understood to be a series of programmable variables where one variable is centered within a series of parameters and from these possible variables within a parameter set a series of possible functions or outcomes can be process. Thus, these people can literally plug into a supercomputer system which operates based on this form of processing reality and through this they can observe all the possible realities that may connect to a present moment. This allows one to travel but this is not part of this section of the explanation.

What this allows one to do is know exactly what is going to happen and when. If a person is being interrogated, all that has to be done is the operative using the technology simply thinks of what they will say and intends to do it within 6 seconds. The machine will play out a future timescale regarding the input of that question or interrogative speech and then produce the possible results. If this doesn’t give the desired readout in the mind of the operative, they will refuse to go that route and think of another pathway. This repeats for a few seconds to a few minutes. Then the computer has found the pathway that is most like to yield a result. The operative simply steps forward, says ten words, the subject breaks immediately and tells them everything they want to know. This is obviously takes longer for most trained individuals, however that is how easily it would be to use this technology to produce an effect on a regular surface level human. They would have no defense, no way of knowing how that individual could know so much or be so direct. This is how operatives dealing with certain power groups will operate in the surface level population and individuals always feel that these people know way more than they are leading on. That is because they are, they know more about you and your life experience than you do.

Chapter 2.3 Previewing Solutions

Neutralizing Polarization

The mental-emotional tendency to pick sides, to fight, or to basically join in the fray that is currently taking place is a kind of deception of polarization which enables the leeching of emotional and mental energy from the human. This is more of a psychological unveiling where the true nature of the self, the duality game and the transcendent source aspects can be made visible to the individual. The they will see how every polarization tactic is actually taking them out of their true source of power by pushing them off center emotionally and mentally. There are teams that are capable of enabling this process and assisting as humanity realizes that half of the problem is that the unchecked mind is one’s own worst enemy.

Removing Etheric Implants

Technology can identify and isolate these foreign body implants which are etheric technological devices. These are literally frequency or phase-shifted devices which are invisible to this layer of physicality but are capable of being organized and attached to the etheric field of the human and will operate to siphon or limit energy on the etheric level. Of course, this is all technology of the vampiric created beings who parasite on the original Earth inhabitants to sustain their existence.

Clearing Astral Body

By moving through the temporal body etheric implants can be deactivated and removed and then the astral or emotional body will be able to function closer to the original levels of presence and sensitivity. This body is manipulated when one is emotionally shut down from trauma. Thus this body can be scarred and will function at a much lesser level of activity or presence until the emotional damage is healed. This contains the memories of all the emotional events of a person’s life.

There is technology that enables one to access these levels of frequency and clarify or untangle emotional chords or attachments which are used to siphon energy from the human being to the parasitic created beings. These chords are energetic in nature but also have technological components.

Knowing the True Self; Soul Actualization, Unveiling

This is a sacred, ancient process that has been outlined and discussed since the beginning of time. Humanity is here to learn, grow and express the self. In doing so, like a child moving through layers of infancy and into full-wakefulness of their body and the physical world, humanity can come into awareness of their true spiritual nature and the true spiritual nature of the universe. This is the process of soul or self-actualization that is described in some psychological methods such as Maslow's hierarchy of needs and the self-actualization that results in a complete fulfillment of all psychological needs. In this modern psychological view, self-actualization is described as the desire and process of reaching fulfillment of one's own natures and then living their life sharing that self-empowerment with other beings because after gaining your self that is the highest expression of such knowledge, sharing that power with others.

The true self is not limited to the physical body, the true self is a reflection of the entire universe and thus the primary original creative force. This is akin to the whole equation rather than just half of the equation. The visible aspect of the self, the conscious mind, is only one half of the entire equation. The whole equation consists of what we see visibly and consciously as well as what we are limited from seeing within the unconscious and subconscious mind. These are really two layers of the same ultimate source. Like an iceberg which is only partially above water, the subconscious mind is the proprietary wholeness of experience. The conscious mind is only a surface layer of reality while the unconscious mind carries all the notions, the multidimensional processes, the latent aspects of reality that we are not capable of seeing without unveiling these aspects through inner exploration.

Taking Responsibility

This entire show is about taking self-responsibility. Unless people begin to do this, there will be no hope. Right now people are convinced that their responsibilities belong to someone else even though this always results in pain and discomfort. To take responsibility is painful at first because we have a lot of work to do, but even then, this is beneficial because there is no way to remedy the pain and discomfort of being lied to and disrespected if people continue to hand their free-will over to others through blame (scapegoating), lower emotional bio-emissions (hatred, anger, etc), distractions and addictions (technological, sensual, and chemical or food based), or generally complaining without taking the first step towards providing something beneficial. This is the victim role, if humanity is to take control then they to help each other and themselves by not relying on false promises and false authorities to determine how they feel, think and live.

Returning To Center Emotionally and Mentally (spiritually)

Balanced food intake, rest, exercise, activity and learning are all continual requirements for a healthy existence. Emotional and creative expression nurtures the soul. Without these ways of being and learning the human qualities of experience diminish and creativity dwindles. There is most likely going to be a split between those who can sustain their own humanity and those who have to cause others to suffer to do so.

Vampires in the “Awake” Community

Contrary to popular belief, the majority of the non-humans are not necessarily vampiric and in power. The vampires are the people online who try to get a rise out of others for sharing their own experiences. They are the nosy neighbor that feels that the person who looks or acts differently must be considered and enemy and armed against because they feel themselves to be so much better. The majority of people are vampires, they believe that they must work for someone who will trade them money and that the amount of money they have based upon the amount of indirectly beneficial work they do puts them above others.

This is not different in the ‘awake’ community and in fact I feel that there are higher concentrations of vampires in this community, the alternate media because everything is largely a joke and a trick. People are operating on deceptive agenda schemes to divide the people and this is most intensely noticed when there is a realization of the truth behind what is happening and people begin to point fingers. The only people who are cleared to point fingers (and who also will NEVER point any fingers) are the operatives from the secret projects that have the capacity to do so because they have reached a specific level of awakening and this is related to the droning, cloning, and hybridization process. Only a specific few know who has been transformed into an impostor being and who is remaining strong and this is due being briefed on the surface level situation. Anyone can say what they want, they are simply playing into the tactics of mind-controllers and parasites and the more they play in the deeper the infection will grow. All the people pointing fingers now are actually implanted and vampiric and are attempting to drive a divide through humanity and they are the first who will turn on their friends and family when the going gets tough because they are more interested in others and starting drama than healing themselves. Ironically, this is all done under the guise of “healing” and “getting rid of the drama” AKA people they don’t trust. They pick and choose based on their own personal bias and this is a sure indication that they are emotionally and mentally out of alignment and are feeding deep seated personal fears from their own traumatic experiences.

These traumas must be healed and the harmonious center must be reattained where a person can focus on their own existence and waking up instead of acting as false-light, “king of tyranny” gatekeepers for others. Those individuals are going to be left behind if they cannot kick the habit because if they are allowed into any kind of healed society they will quickly degrade into animals and attempt to restart a devolution process in order to gain the power they so desire but cannot produce on their own. ANYONE playing ego games of trying to hurt or put blame on ANYONE else contains this viral implant and has not kicked the virus.

Heart Center and Psycho-Spiritual Fulfillment (self-actualization)

Emotional connectivity is a form of telepathy, when loved ones can tell the state of another across space and time. Whether it is family or friend. In the 60's and a little before that the US found a specific frequency akin to a radio frequency that operates on a trinary spectrum. They called this the "telepathic wave". In time, they could completely read and send thought waves without frying the brain or body through radiation. Which was what the early machines did. They actually took satellite dishes and aimed them at people. Then realized they could turn it around and do it backwards with a better effect and minimal radiation. Either way they started beaming the base and then towns around them with waves between 400 and 432 MHz and caused waves of crime sprees or peace sprees throughout the 70's and 80's. So they can digitize the telepathic wave to induce artificial telepathy. But this is organically done through an entanglement through what we call love. Literally. The Germans found it before that. And the secret orders before them. And ancient Egypt before them. As humans we remain basically through the root, heart mind connection. When the heart overpowers the mind connection of spirit, then the body is a trinary whole. When the mind guides it is binary and cannot by guided by the spirit. The spirit has direct access to the heart. The mind is a computer of sorts. The mind doesn't see past duality. The heart is the true center/eye of the spirit. The reptilian brain is the dragon and when you tame the amygdala then fear is ‘behind’ you. When the mind is "untamed" the reptilian brain takes over. This is the lower brain and amygdala fight or flight response.

This happens when the energy of the brain, body and spirit increases due to whatever various reason of spontaneous or controlled increase. Because of the "temptations" which are the easiest flow of emotional energy into a "discharge" state, is that the sacral/sexual center ties to the heart and reroutes to replace the heart and control the mind. Mental and emotional contemplation of one's true purpose and nature is the path of the divine. We find ourselves simply by looking in the right place, not in the world, but in our self energetically. We are more powerful than the programming, and we can reverse this is we're careful and devoted enough.

We have to be faster than thought, at the speed of spirit, beyond matter. When we start thinking on this level then our influences spread to others throughout the sphere. It is our destiny to know these things but they have been kept from us. The ancient orders called this the art of "implosion". Traveling realities through intense contemplation and a usage of sacred geometrical forms.

They developed and combined orders around WW2 and developed zero-point energy tech that can alter space/time fields. This is timeline manipulation. But as a rule, we go where our heart leads us. So that's how this is solved.

Go Within to Observer the Self

The answer is literally by looking within to find the great truth rather than looking around us. Everything we need to know is within us, energetically and spiritually. Our emotional, mental and physical state of balance is an indication of where and how we exist in relation to the larger overall truth. Everything that happens around us to distract us is designed to stop us from looking within. Nothing can truly stop us, nothing can actually input the holographic horrors in our spiritual center but simply perturb the brain and body. The mind is a non-holographic spiritual environment that cannot be excessed and the invader's goal is to convince people to use their imagination or their creative powers to produce these horrors on their own. This is through the programming. We must clear out the programming, the trauma, the lower-dimensional constructs and fill ourselves with the truth and spiritual presence that enables us to be self-aware in the first place. If we aren't doing this, then we are either in pain, or there is no spiritual presence to be in pain. If we are doing this, we are either clearing out the constructs by replacing them with true spiritual presence and self-awareness or we are becoming aware of them.

Organic Feedback Loop

The great feat is mentally bridging the great rift between us by looking within. Which is paradoxical.

We can never see what another is perceiving exactly, well for the most part, so we all have to kind of accept that we are communicating effectively and truly get to this level of comfort by simply being secure in knowing who we are our selves.

Technological Feedback Loop

So then knowledge, in a way, when shared, is a form of telepathy. Group telepathy.

Group think, when ideas or memes spread, is a form of group telepathy.

The Internet is like artificial spreading of telepathy. This means what is normally mentally bound signals can be initiated and spread through a digital medium.

Breaking Soul-Contracts

Ultimately everyone is under a series of “veils” which are energetic time-constraints literally like 9 dimensional layers of temporal restriction which are each bounded and ruled over by invader beings. These range from physical authorities, to astral entities, to programmable matter, to supercomputer intelligences, to spiritual false-light beings and our own shadow mind. Each layer of reality is successively guarded by these beings who are here acting as gatekeepers designed to push people back when they begin to wake up. These beings all work through fear and deception and the last layer is based on mirroring our own energies back to us like an impostor. All the levels tend to imitate, however the last layer is a near perfect imitation of our own energy to the point where people often switch places with this being before getting out of the matrix. There will be more discussed on this in a later section.

The “9 veils” were designed by impostor beings as a last effort to stop humans from escaping the false-light matrix which is essentially the holographic universe. This is literally like a maze which reproduces a new pathway and a new doorway each time a person nears the last hallway or doorway that is next to the exit. So one eventually has to project themselves into the exit using their whole being and moving past and through the tricks by not falling for them before they are placed. This is highly confusing but this is essentially a kind of labyrinth that has been created to stop people from leaving so that their soul energy can be destroyed and used as a generator for the false-light system which is an AI over mind that is programmed to take the raw soul energy and destroy the identity by inverting the electromagnetic spectrum and incorporating that inverted energy into its own internal matrix body which is literally the false-light universe.

Help Everyone

Now they may have been setting us all up for the apocalypse. They said they want us to tell on them and get the whole world aware of what they've been doing So that we can stop them and pull them from the dark which is ACTUALLY taking their souls. There are also breakaway civilizations involved in this entirely zero-point/free-energy.

Chapter 2.4 How Timelines Collapse

Repeating Cycles of Time

Because of the way time works and the ability of those using these temporal devices they have set up an elaborate labyrinth like a spider web of false realities, timelines, parallels, sub-dimensional layers, astral cages, temporal dead-ends, and time loops which act to stop people from reaching the true reality. As a result, many portions of this timeline are literally in a free-will ‘time-loop’ and these loops must be canceled out. As well, because of the nature of these loops on the overall stream, our entire civilization has been looping for the past 6 time-cycles meaning we have reached this time in history 6 times before and this is apparently the last time because we have never gotten this far before and the events of the future are having to be programmed in manually at this point.

Beings From the Future

As are result and damaging time, what happens is that the beings from the possible future that is being damaged appear to try to heal the break as well as those who are from the new possible future that is generated, this results in a time war between both possible realities for the present realm. This is what has been happening for thousands of years. All the ancient spiritual texts are describing this system. One group is a from an original possible future where everything is based on the presence of spirit and souled humans, another is from the new possible future where an AI overlord took over and removed the souls and spiritual energy from all entities on Earth rendering this a holographic prison without any other use. That reality dissolves into itself and so the time beings are constantly moving backwards and jumping timelines to try and obtain more energy.

Beings From Collapsed Timelines

The beings from the collapsed timelines are those who travel through hyperspace to get here. They then recreate themselves using cloning technology through hyperspacial means, IE: creating an alternate temporal dimension so that these devices can sustain them and literally "hold-space" for them. Then if their timeline is destroyed, they can still exist as a 'loose-end' in space-time. This is extremely dangerous and I will say we have some Human operatives jumping timelines searching for Earth and Humanity so that they can find a reprieve from this time war.

That is the most trying aspect of this entire ordeal for me. There are some human operatives literally in hyperspace without an opening into the temporal stream for them to reintegrate into this timeline. We must assist them, we must open the timeline by taking control of Earth from the invader races and those who wish to depress and isolate the spirited and souled human beings. We must re-organized and neutralize the invasion forces of deception and assist our humanity and maintaining their free-will, their self-awareness, their self-empowerment and their emotional, mental, and physical harmony.

Beings Who Would Never Have Existed in the First Place

As a result of this entire process, there are essentially beings who have been erased from time who degrade in this dimension and can only interact periodically. These are the created beings who operate through supercomputer forms that are placed within cloned bodies and powered by the transdimensional quantum supercomputers. These are the 'parallel' reality beings and this relates to the hive mind invasion. When all the original aspects of time are restored, these beings would not have ever existed in the first place as there is no quantum link for their probabilities to remain neutral and present in the original run of things.

Again, all beings who operate under the will of the universe, even when they are attempting to trick hyperspace and time, when these beings assist and help in the unification of sentient, spirited, souled beings they are capable of being healed. This is all because there is an original creative force which can produce souls that are eternal and everlasting, meaning they are not created but simply always ever were. Yet, there is a "miracle" effect where beings can be given eternal life. This is only by reflecting the will of the whole of existence, rather than a portion or a part because this is only temporary. Only the whole is forever and this takes true harmony, true balance and ultimately *self-lessness*. To give to others because you see them as worthy because they can be aware and enjoy the gift is to be like the creative force that gives life to all and enables all experience in the first place. By acting in correspondence with this we reflect the will of the whole and that power and action transfers into protection and self-empowerment for ourselves. This cannot be cheated, tricked, or rerouted as that is the karma game that has been played by delaying time and rerouting energy through getting others to take on the responsibility for others bad actions. In the end, all karma has only been delayed because when the stops are pulled out, *everyone* ends up getting their karmic returns regardless. They simply intended to build up so much karma that by the time the ties are cut, the karma overload will simply kill them instantly. This never happens and they end up in the abyss, this is the final time so since there is no recycling of the universe from the oroboros system then whatever happens is what happens forever. If everyone wants to move into harmony, to receive healing, to receive forgiveness then they must assist in the creative force in healing, forgiving, and turning away from the deception, the cruelty, the vampiric actions.

Many vampires believe they will die if they stop. The only hope is to admit their ways to the others and ensure that there are enough beings around them that will protect them so that this situation can be handled properly, with due care, compassion, and the necessary healing to ensure the safety and protection of all who seek harmony.

Energy Projects

Electrodynamic Tether Photos

Deployment of the Tether Satellite

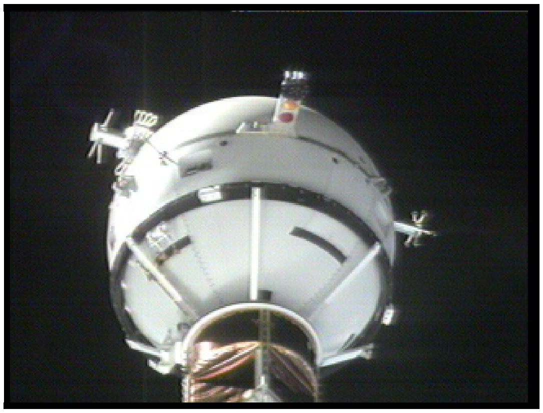

Boom Deploy

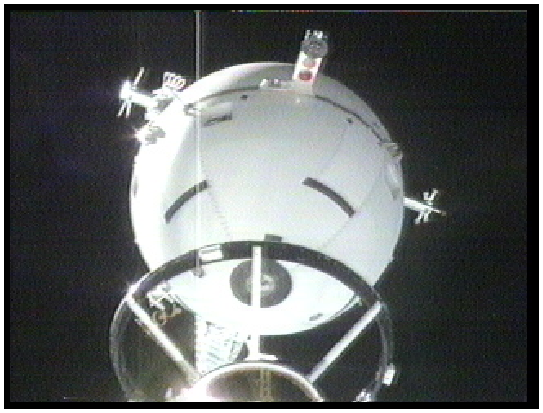

Initial Deploy

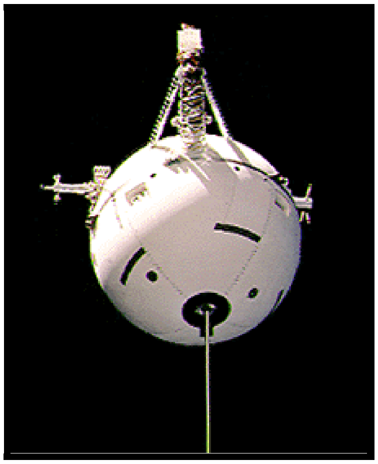

Satellite Deployed

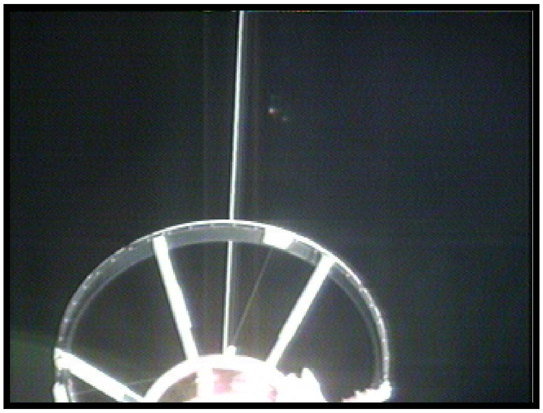

Closeup of boom showing tether

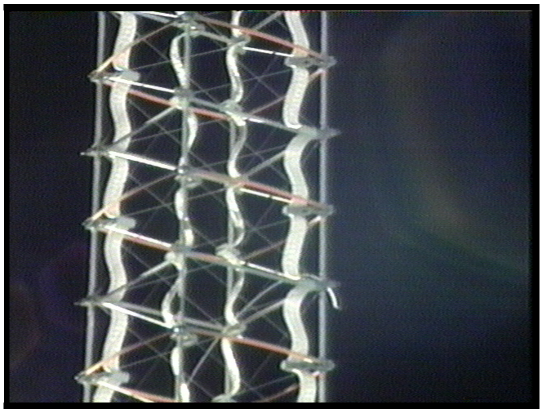

Close up of end of boom

Tether Break

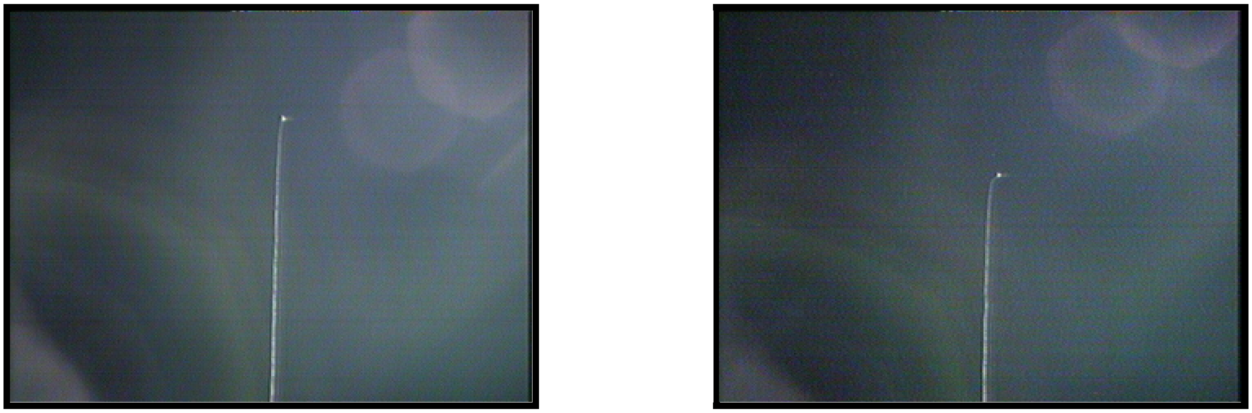

The tether deployed to one mile

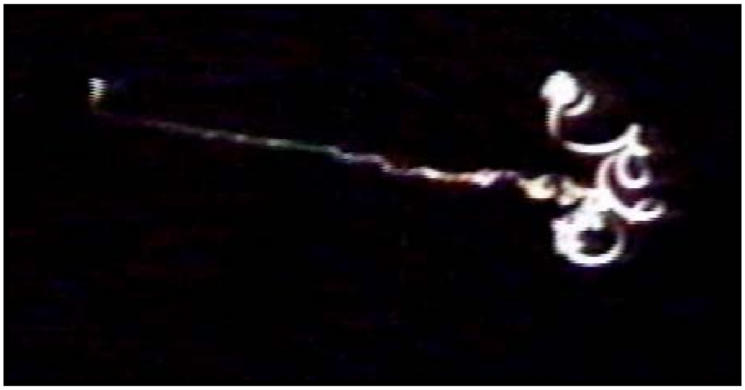

Shortly after the breakreak

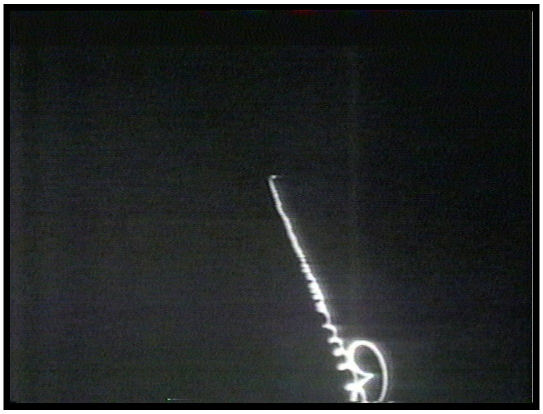

The tether coils as it moves away from the Shuttle

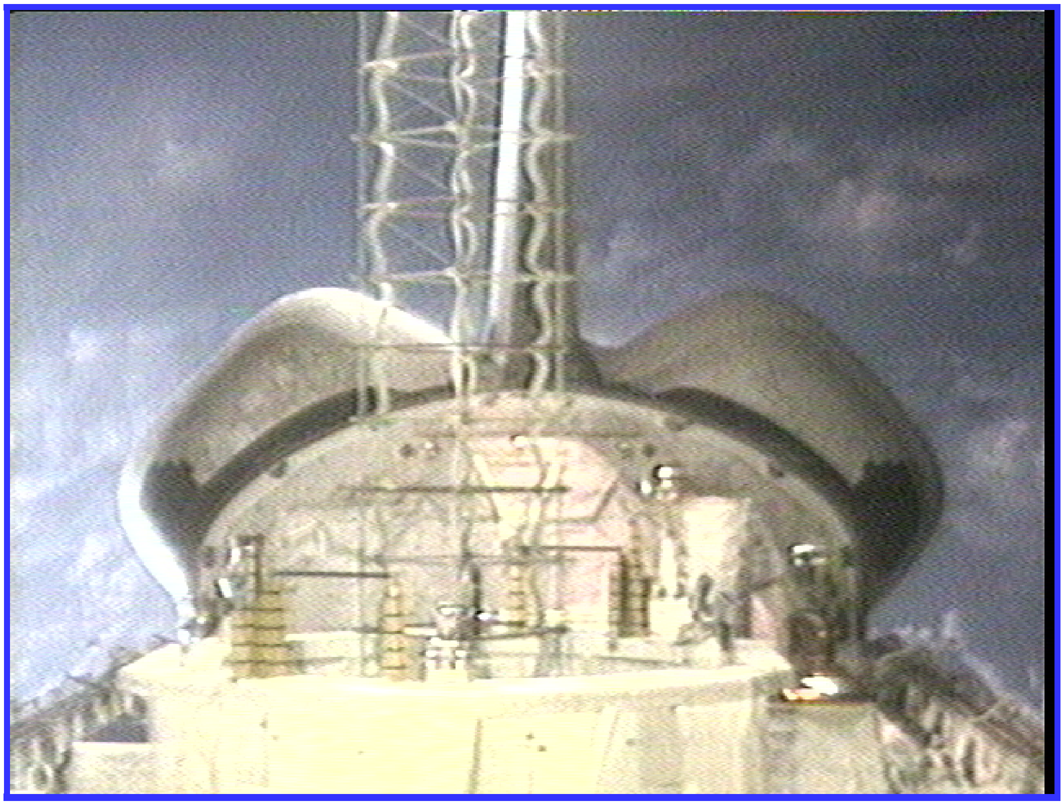

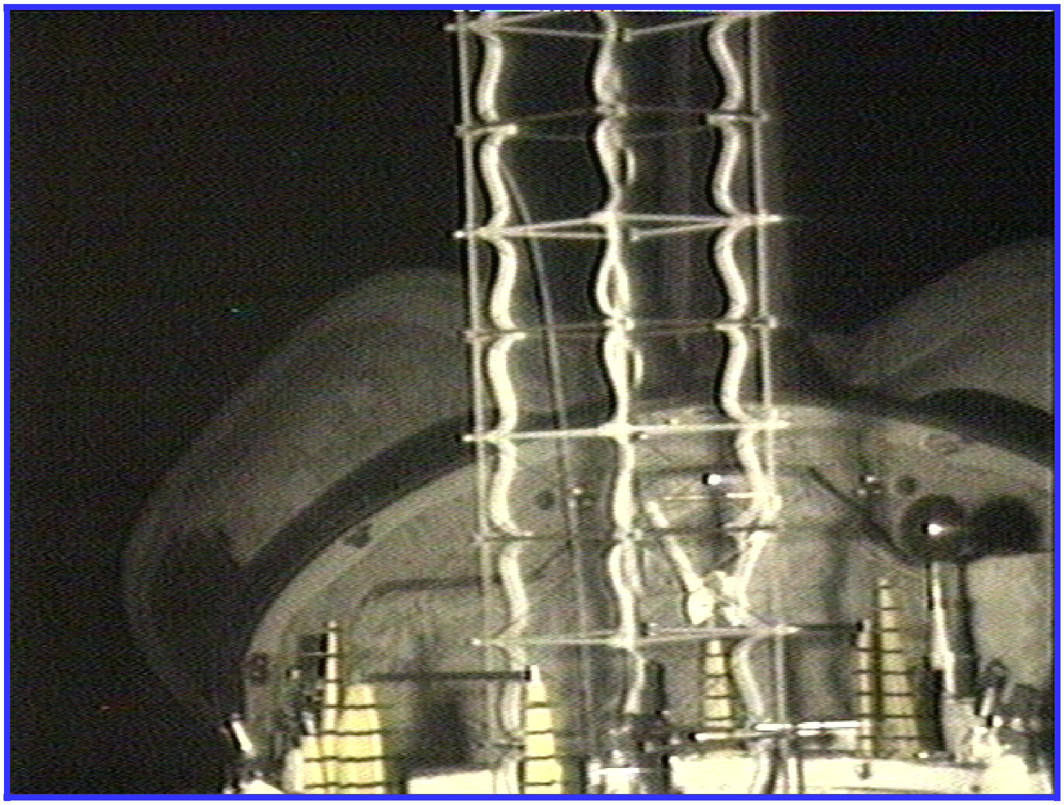

The base of the tether boom. The area looks more like a Tesla Laboratory than the space shuttle hanger bay.

After the Break

The following three images are those displayed for the public showing the white specks that appearall around the tether after it has broken free. NASA calls these "dust and debris" particles, though Mission control in the audio portion of the videos state that they see a "lot of stuff swimming around" and that the tether is wider than expected.

If you compare these images to the ones we captured from a hard to find high resolution copy of the video on this page you will see a remarkale difference. The video is a must see.

Video Clip
STS-75 'The Tether Incident' Feb 1996
Editors Note: This video has been removed several times by Youtube. Currently it is available again. If it does get removed again, email me and I can send you a copy as we have it on disk now. Contact me at webmaster
This one is from the hand held Infrared Camera and is not as clear as the other one was STS-75 Alternate Copy

Comments:

What is most interesting to note is that most of the video clips above are taken from this video, yet NASA does not show the video itself. The copy on Youtube is a transmission intercept copy. However the fact that the NASA info site DOES use those clips gives credibility to the video that it is indeed a NASA film - Zorgon

Tethered Satellite System (TSS-1R)
Source of Clips: NASA STS-75 Mission Pictures

Kennedy Space Center STS-75 Mission Fact Sheet

"Critters" from STS-75

The Report After the Fact

NASA/TP—2003-21228
Low Earth Orbit Spacecraft Charging Design Guidelines

Below are a few keynote excerpts from the PDF file. The entire 367 page document is available below for those with technically savy who want to read the entire paper...

Excerpt 1:

In the case of the TSS-1R tether, its 20 km length produced a maximum of about 3500 V potential between its most positive and negative ends, since it wasn?t oriented perfectly perpendicular to the velocity vector and the Earth?s magnetic field. A satellite at its upper end collected electrons, and an electron gun at the lower end emitted electrons to complete the circuit. When the electron gun was not in operation, a large resistance prevented the Shuttle from being biased thousands of volts negative of its surrounding plasma. However, there remained a large voltage between the tether lower end and the Shuttle orbiter. This enormous bias eventually led to a continuous arc on the tether (see The Continuous Arc, section 4.2.3.1 below), which broke, freeing the satellite and ending the experiment. During the arc, the satellite collected over 1 Amp of electron current to keep the arc going. Probe theory (Cohen et al, 19870010625 N) is usually used to calculate the total current collected by a wire with distributed potentials. However, before the break, TSS-1R demonstrated that a satellite at a high positive potential could collect an anomalously large electron current. See Zhang, et al (20000110580), Stone and Raitt (19990084046 and 20000025437), and Stone, et al (19980202347)

Excerpt 2:

Sustained arcs (continuous arcs) - These are the events that have been attributed with the destruction of on-orbit solar arrays. Generally, the process begins with a fast transient (a so-called trigger arc). Under some conditions, the transient develops into an arc that is fed directly by the entire array, effectively becoming a short-circuit. Such events invariably involve large quantities of energy and can be severely damaging to cells, interconnects or power traces.

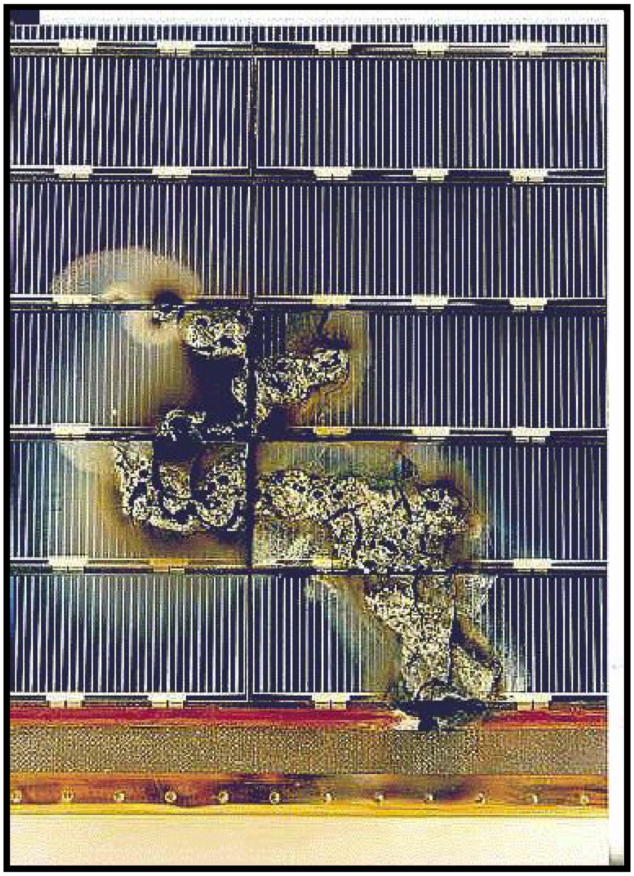

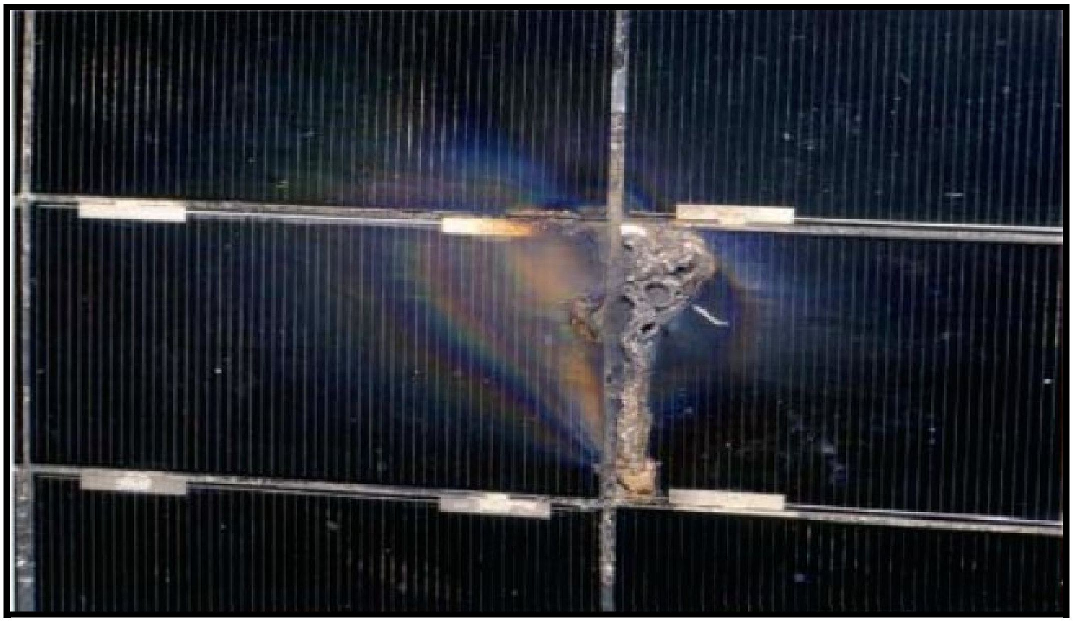

Excerpt 3:

When the structure or array capacitance electrically connected to the arc site is sufficiently large, the initial transient arcs themselves can be large enough to produce significant damage. In Figure 9, we see an anodized aluminum plate that has undergone repeated arcing in the laboratory with the ISS structure capacitance attached. Its thermal properties have been completely destroyed, along with most of the insulating surface layer of aluminum oxide.

Excerpt 4:

The most famous sustained arc event of all led to the breakage of the TSS-1R electrodynamic tether, and the loss of the attached satellite. The image below shows the burned, frayed and broken tether end still attached to the Shuttle after the break. **Incidentally, the tether continued arcing long after it and its satellite were drifting free, until finally it went into night conditions where the electron density was insufficient to sustain the arc.** Noel Sargent (2002) has investigated whether the TSS-1R arc was seen to disrupt Shuttle communications. Although he has found no record of disturbed communications during the event, for most of the time the arc was shielded by metallic structures from the communications antennas, and when the tether broke, the arc was many meters from the receiving antennas. It remains to be seen whether sustained arcs produce radio noise severe enough to be a communications problem.

Comments:

This is official confirmation that the tether continued to produce plasma energy long after it broke free, accounting for the "fluorescent bulb" glowing effect viewed after. We believe this concentrated collection of plasma energy is what attracted the "swarm" of "critters" to a "feeding frenzy"

To get the full PDF file you can download LEO_Charging_Guidelines_v1.3.1.zip

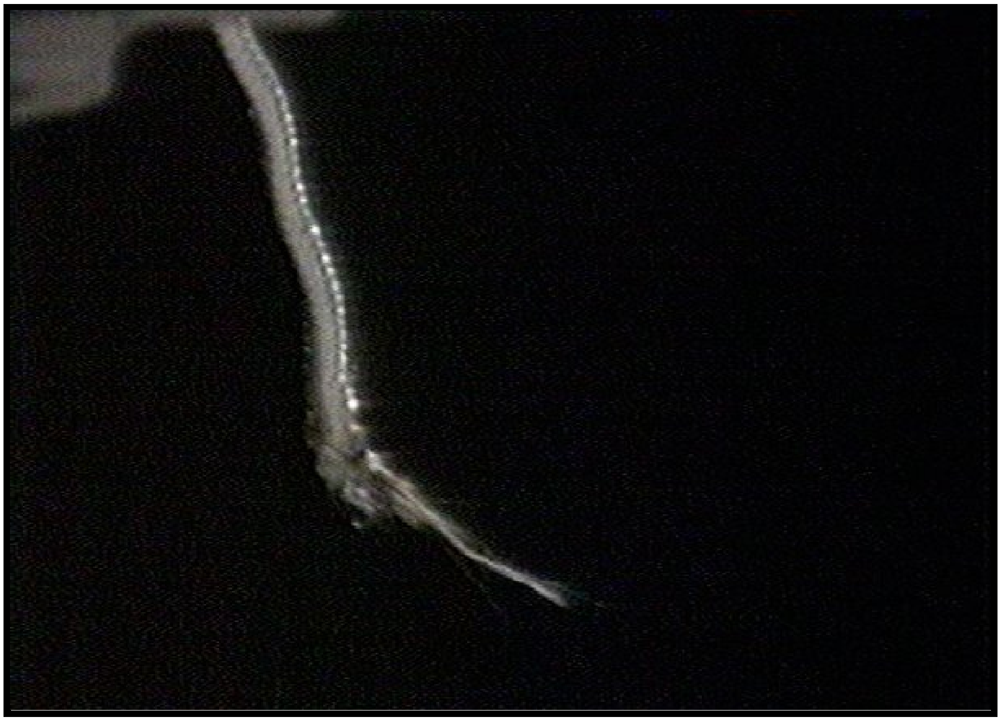

Tether Optical Phenomena Experiment (TOP)

Using a hand-held camera system with image intensifiers and special filters, the TOP investigation will provide visual data that may allow scientists to answer a variety of questions concerning tether dynamics and optical effects generated by TSS-1R. In particular, this experiment will examine the high-voltage plasma sheath surrounding the satellite...

In one mode of operation, the current developed in the Tethered Satellite System is closed by using electron accelerators to return electrons to the plasma surrounding the orbiter. The interaction between these electron beams and the plasma is not well understood...

Associate Investigator: Stephen Mende, Lockheed Martin

SOURCE

The Report After the Fact

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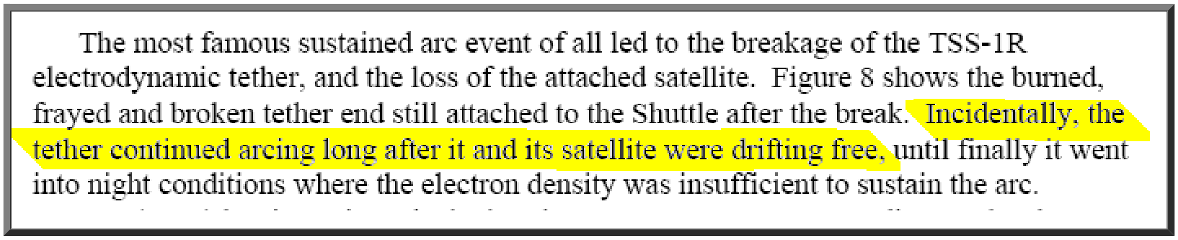

The most famous sustained arc event of all led to the breakage of the TSS-1R electrodynamic tether, and the loss of the attached satellite. Figure 8 shows the burned, frayed and broken tether end still attached to the Shuttle after the break. Incidentally, the tether continued arcing long after it and its satellite were drifting free, until finally it went into night conditions where the electron density was insufficient to sustain the arc.

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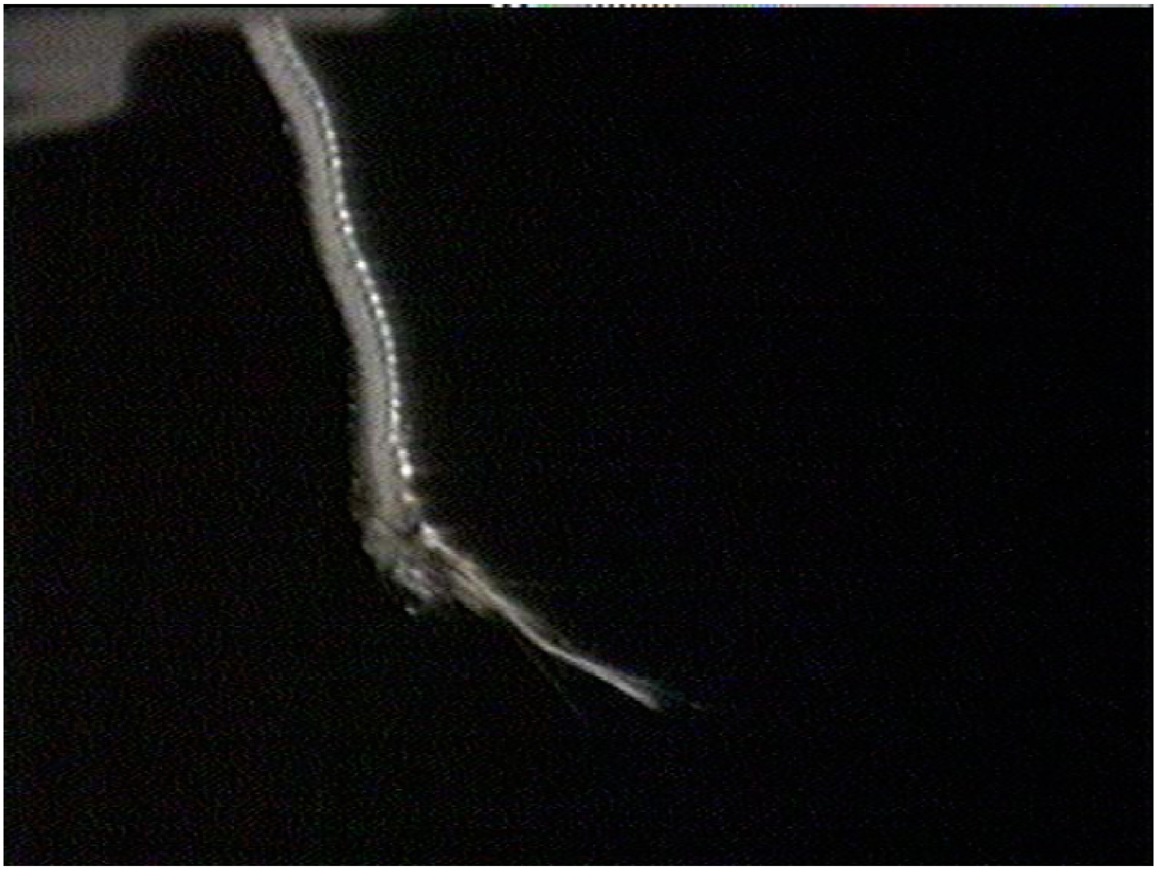

Figure 8 – The end of the remaining TSS-1R tether

…

It is thus possible that an astronaut, grounded to ISS by his tether or conductive tools, could undergo an arc at only –50 V. A sneak circuit analysis showed that such arcs could put 1 Amp of current through an astronaut's heart. Since 0.1 Amp is enough to cause heart stoppage, it is imperative that if the ISS plasma contactors are inoperable during astronaut EVAs, a method be used to prevent ISS astronaut workplaces from floating more than 50 V negative.

…

For many ISS surfaces, peak arc strengths of hundreds of Amps have been calculated. Arcs this strong will melt the arc site and spew molten metal through space. Plasma chamber tests of this kind of arcing are spectacular indeed! Arcs on one anodized surface have been seen to trigger arcs on nearby line-of-sight surfaces.

…

Finally, an arc on an electrodynamic tether may become continuous. The infamous arc on the TSS-1R tether that led to its break and the loss of the satellite was a continuous (sustained) arc with its power supplied by the tether.

…

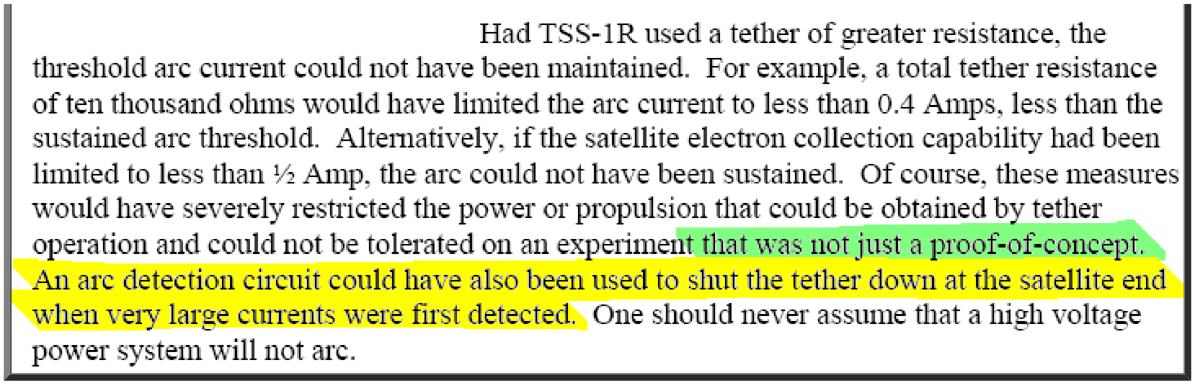

Had TSS-1R used a tether of greater resistance, the threshold arc current could not have been maintained. For example, a total tether resistance of ten thousand ohms would have limited the arc current to less than 0.4 Amps, less than the sustained arc threshold. Alternatively, if the satellite electron collection capability had been limited to less than ½ Amp, the arc could not have been sustained. Of course, these measures would have severely restricted the power or propulsion that could be obtained by tether operation and could not be tolerated on an experiment that was not just a proof-of-concept. An arc detection circuit could have also been used to shut the tether down at the satellite end when very large currents were first detected. One should never assume that a high voltage power system will not arc.

...

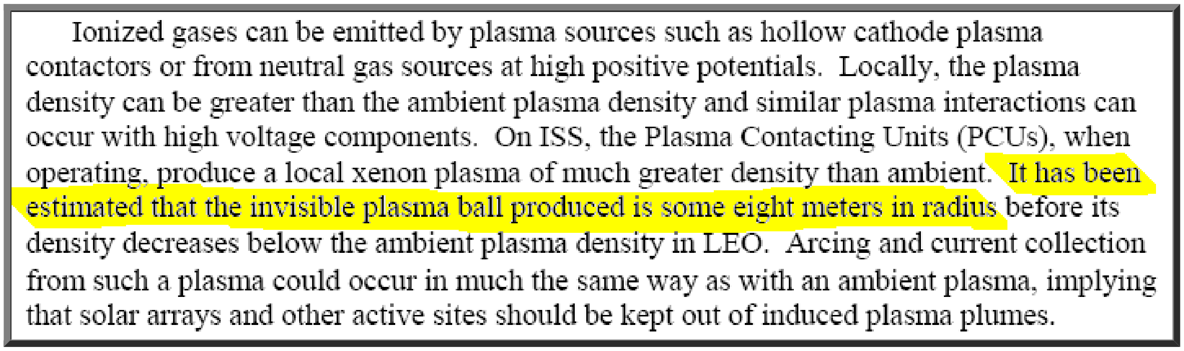

Ionized gases can be emitted by plasma sources such as hollow cathode plasma contactors or from neutral gas sources at high positive potentials. Locally, the plasma density can be greater than the ambient plasma density and similar plasma interactions can occur with high voltage components. On ISS, the Plasma Contacting Units (PCUs), when operating, produce a local xenon plasma of much greater density than ambient. It has been estimated that the invisible plasma ball produced is some eight meters in radius before its density decreases below the ambient plasma density in LEO. Arcing and current collection from such a plasma could occur in much the same way as with an ambient plasma, implying that solar arrays and other active sites should be kept out of induced plasma plumes.

...

Electrodynamic Tethers ~ Menu
Critters ~ Critters 01 ~ Critters 02 ~ Critters 03

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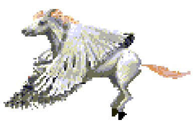

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STS 75 TETHER INCIDENT

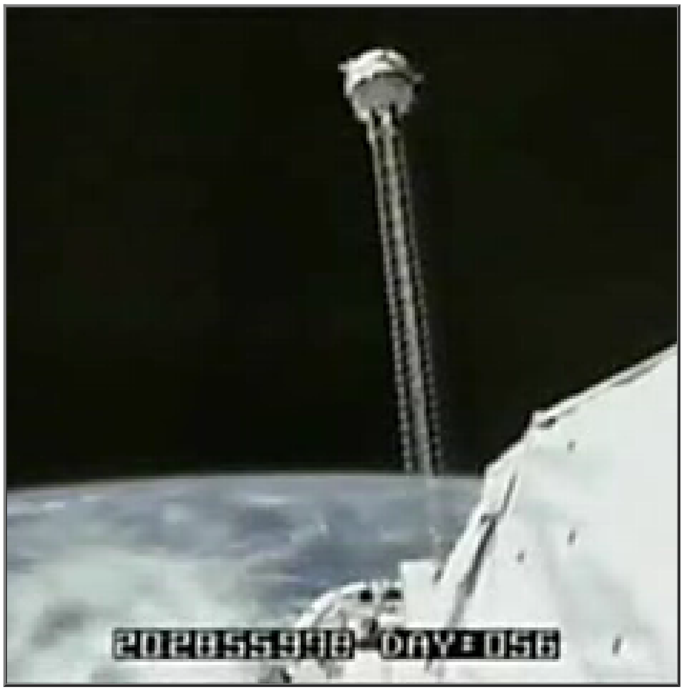

Tether Deployed

Tether Satellite being deployed from the Shuttle Bay of STS-75

213506148
DAY:056

Tether Activated

Tether Satellite begins to glow as it gathers electricity from the Ionosphere

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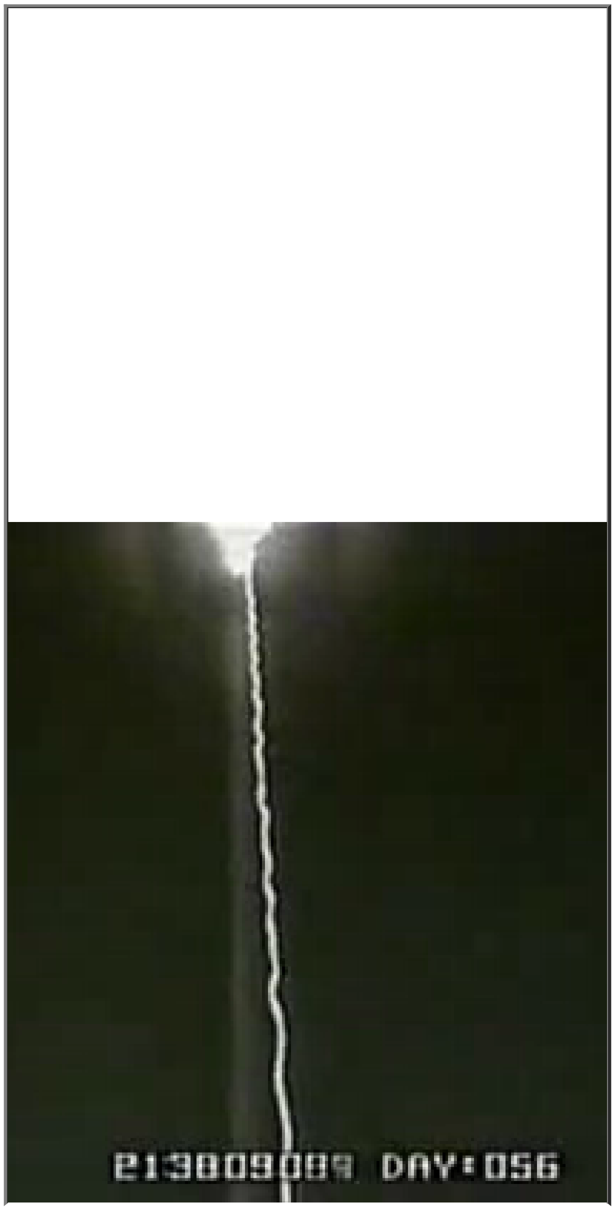
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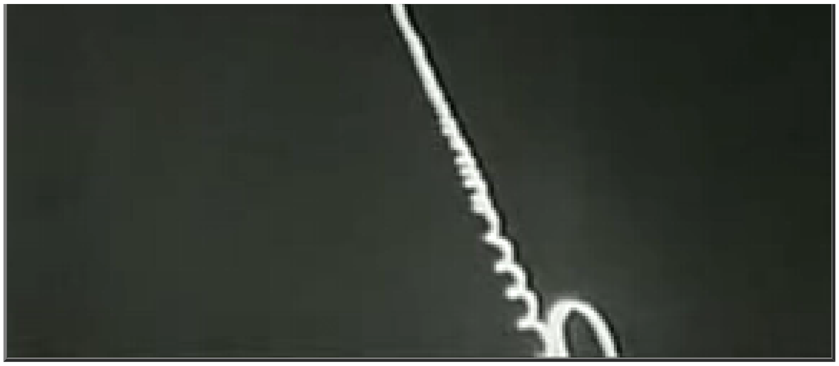

Tether Breaks Free

Tether Satellite cable fries the connection and breaks free... still producing energy.
The glow increases and the cable gets wider. (More on this later)

-

Tether Broke Free

Tether Satellite worth 100 million has overloaded the circuits within minutes of being activated because the NASA Scientists under estimated the potential. The tether in just a few moments of operation produced 10 times the anticipated power and they forgot to install a circuit breaker.

-

NOTES:
Add "Critter" Portion
Add Video
Add FLV Viewer

TETHER BROKEN FREE AND DRIFTING AWAY

Tether Drifting Away

At this point the STS 75 Astronauts switched to Infrared camera. What you are seeing is the Tether at about 80 nautical miles away from the Shuttle. Notice that it has straightened out and has become much wider. This is commented on by Mission Control as they say its wider than expected.

It is also at this point that the plasma collected by the tether that is "still glowing like a fluorescent bulb" (according to a NASA report issued after the event (See Below)) attracts the "Critters" or UFO's as most people call them. To see more about the "Critters" VISIT HERE In the image include below you can see the Tether Satellite at the tip. By this time the Tether is almost as wide as the Satellite itself.

Going behind the tether you see one of the "Critters" It is CLEARLY behind the tether. This is what NASA calls "dust and debris" The purpose of this paper is to show the tether however, not the "Critters". If you want to know more about them either email us or check out the pages linked to above.

STS-75 - 'The Tether Incident'

Tether Swarmed by "Critters"

Matt (Matyas) had written me that he has found documents hinting at a Tether in operation near Jupiter. He is still following that up, but it seems the Cassini Spacecraft has found one or more in the vicinity of Saturn

Cassini Spacecraft Image

Is this the lost Tether Satellite? Or is there another one in operation near Saturn?

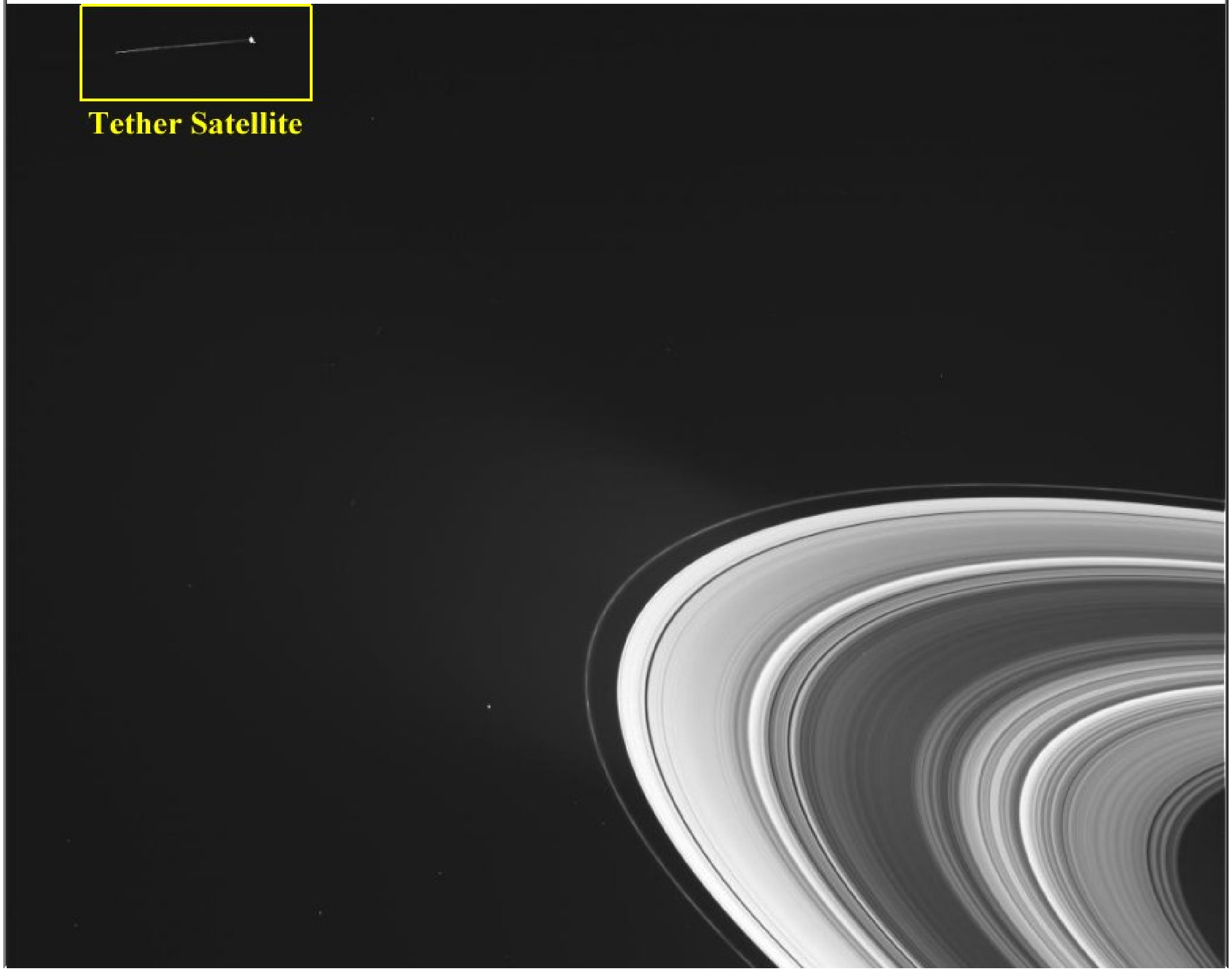
Tether Satellite

Tether Near Saturn

Judging by the scale of Saturn, it would seem this is NOT the lost Satellite, but a much larger one. The STS 75 Tether was 12 miles long... This one is huge

(Note Dates and Size are being calculated)

[Source: Original Image NASA Cassini/ Huygens W00028414.jpg]

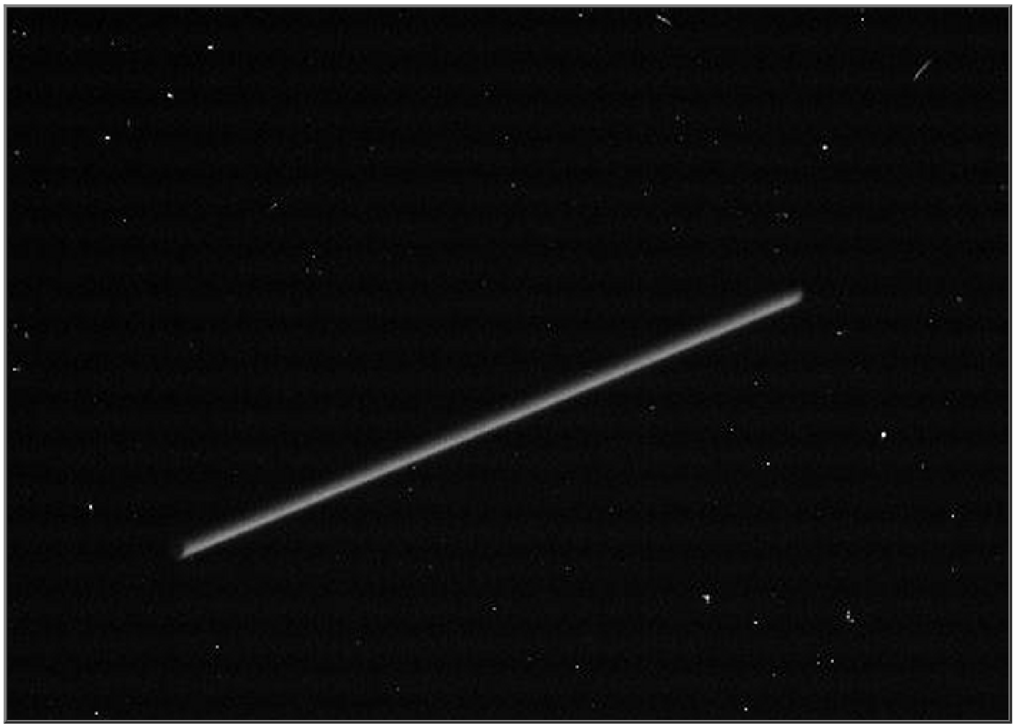

Cassini Spacecraft Image
Tether Near Saturn

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Cassini Spacecraft Image
Tether Near Saturn

Source: Original Image NASA Cassini/ Huygens W00026015.jpg

Cassini Spacecraft Image

Source: Original Image NASA Cassini/ Huygens N00008771.jpg

~ MENU ~

US006116544A

United States Patent [19]

Forward et al.

[11] **Patent Number: 6,116,544**

[45] **Date of Patent: Sep. 12, 2000**

[54] ELECTRODYNAMIC TETHER AND METHOD OF USE

[75] Inventors: **Robert L. Forward**, Houston, Tex.; **Robert P. Hoyt**, Seattle, Wash.

[73] Assignee: **Tethers Unlimited, Inc.**, Seattle, Wash.

[21] Appl. No.: **08/929,271**

[22] Filed: **Sep. 12, 1997**

[51] **Int. Cl.**^{7} **B64G 1/00**

[52] **U.S. Cl.** .... **244/158 R**; 244/166; 244/172

[58] **Field of Search** .... 244/158 R, 164, 244/166, 172

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,097,010	6/1978	Colombo et al.	244/158 R
4,824,051	4/1989	Engelking	244/158 R
4,923,151	5/1990	Roberts	244/158 R

OTHER PUBLICATIONS

"Tethers Open New Space Options" by Ivan Bekey, *Astronautics & Aeronautics*, 1983.

Primary Examiner—J. Woodrow Eldred
Attorney, Agent, or Firm—Arthur M. Dula

[57] **ABSTRACT**

The present invention comprises an electrodynamic tether structure and a method of use. The structure of the tether taught by the present invention is a short, wide, interconnected multiwire (compared to the long, narrow single wires of the prior art) conductive tether whose area maximizes electrodynamic drag while simultaneously minimizing the Area-Time-Product swept by the tether during its operating life. The preferred tether length is two kilometers to five kilometers. The preferred tether mass is one percent to five percent of the spacecraft mass. The method of operation comprises orienting the tether structure at an angle to the local vertical to maximize electrodynamic drag on the host spacecraft and minimize tether instability. The angle of 35.26 degrees is preferred.

26 Claims, 12 Drawing Sheets

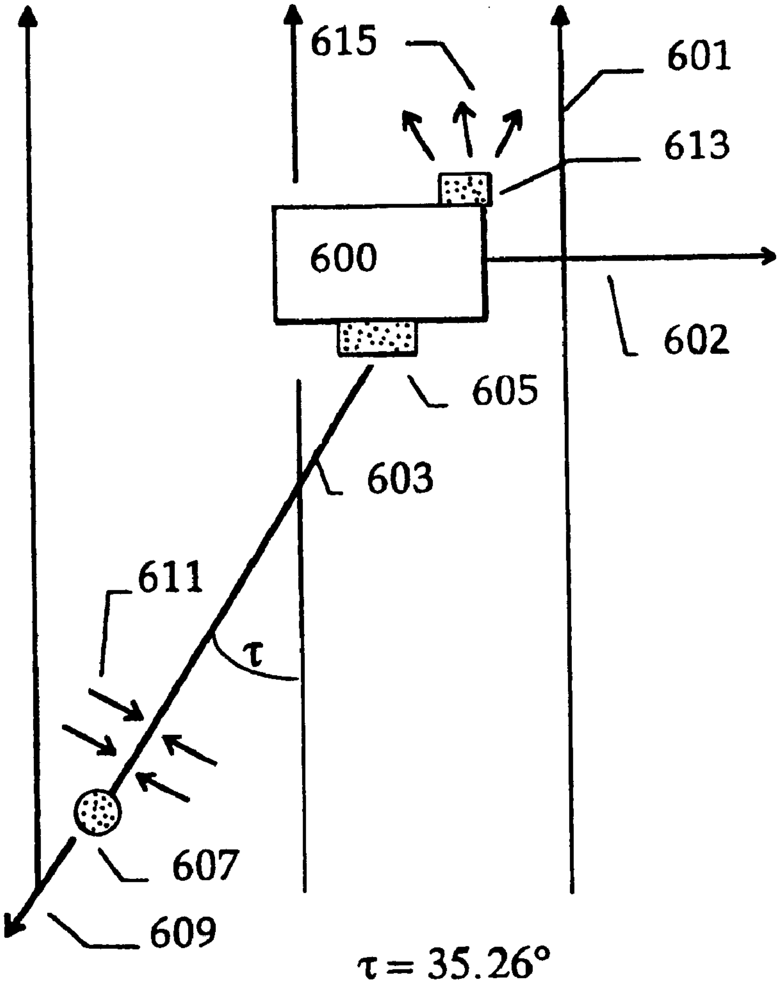

τ = 35.26°

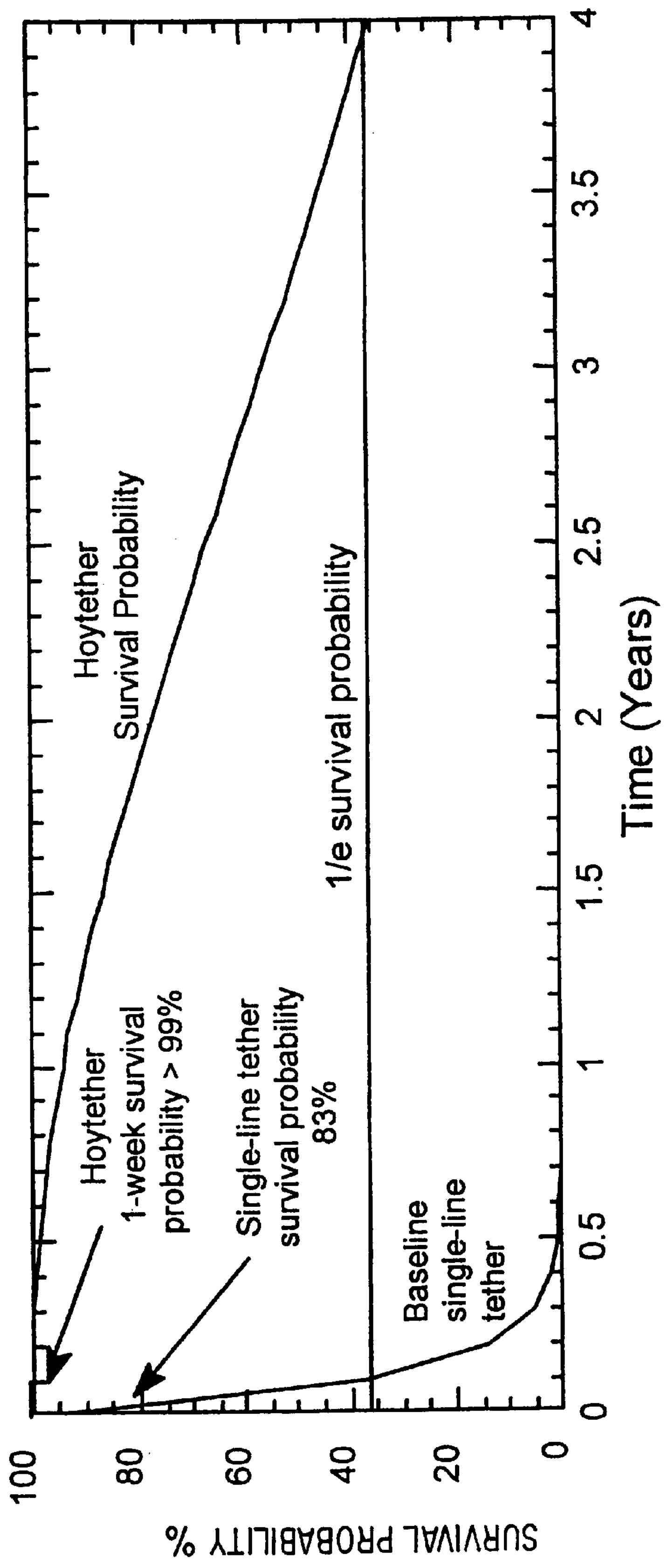
Hoytether
Survival Probability
1/e survival probability
Hoytether
1-week survival
probability > 99%
Single-line tether
survival probability
83%
Baseline
single-line
tether
100
80
60
40
20
0
SURVIVAL PROBABILITY %
0
0.5
1
1.5
2
2.5
3
3.5
4
Time (Years)

FIG. 1a

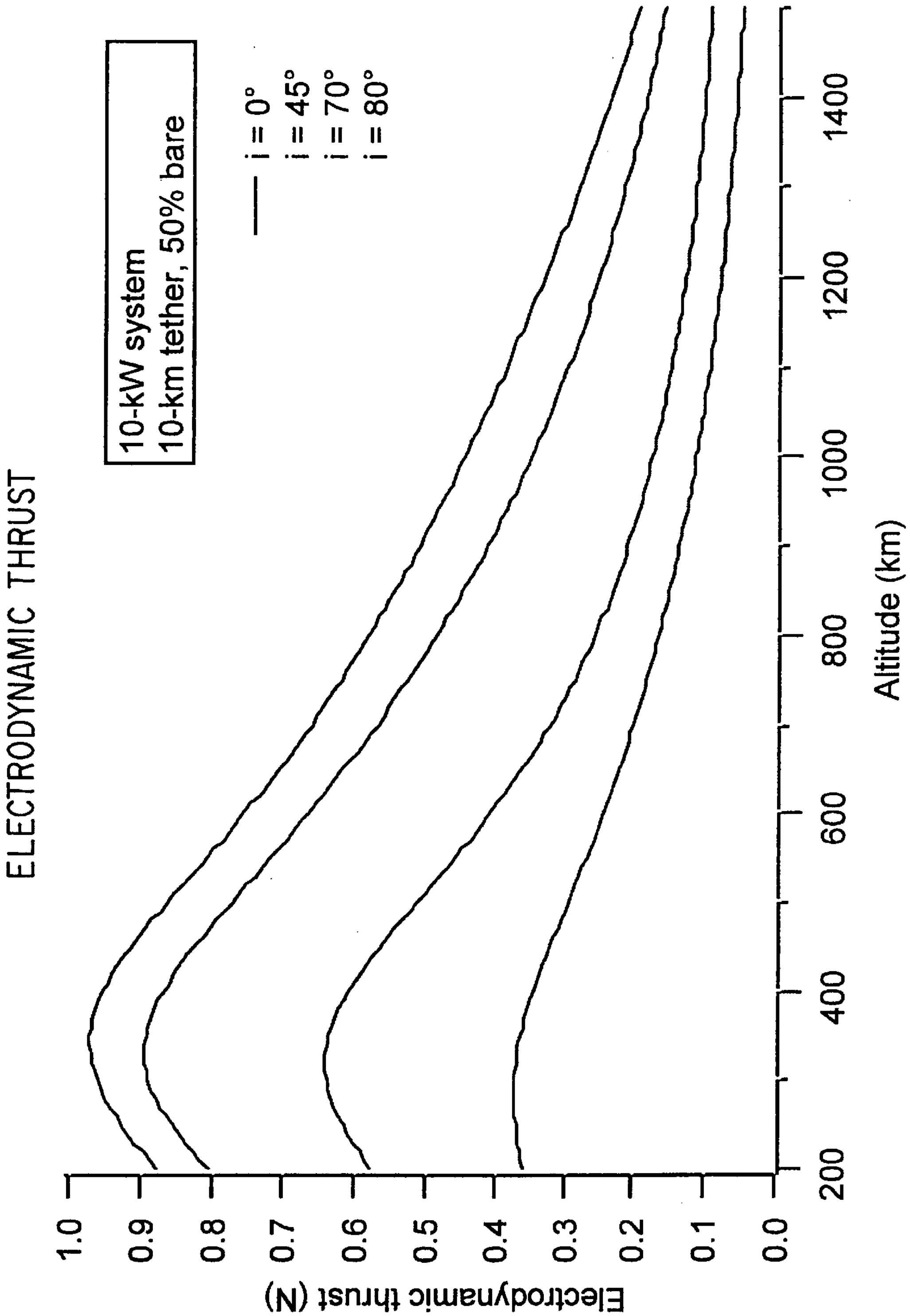
ELECTRODYNAMIC THRUST
10-kW system
10-km tether, 50% bare
i = 0°
i = 45°
i = 70°
i = 80°
Electrodynamic thrust (N)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
200
400
600
800
1000
1200
1400
Altitude (km)

FIG. 1b

Reentry Time Sensitivity
Unpowered 5 km ProSEDS Tether

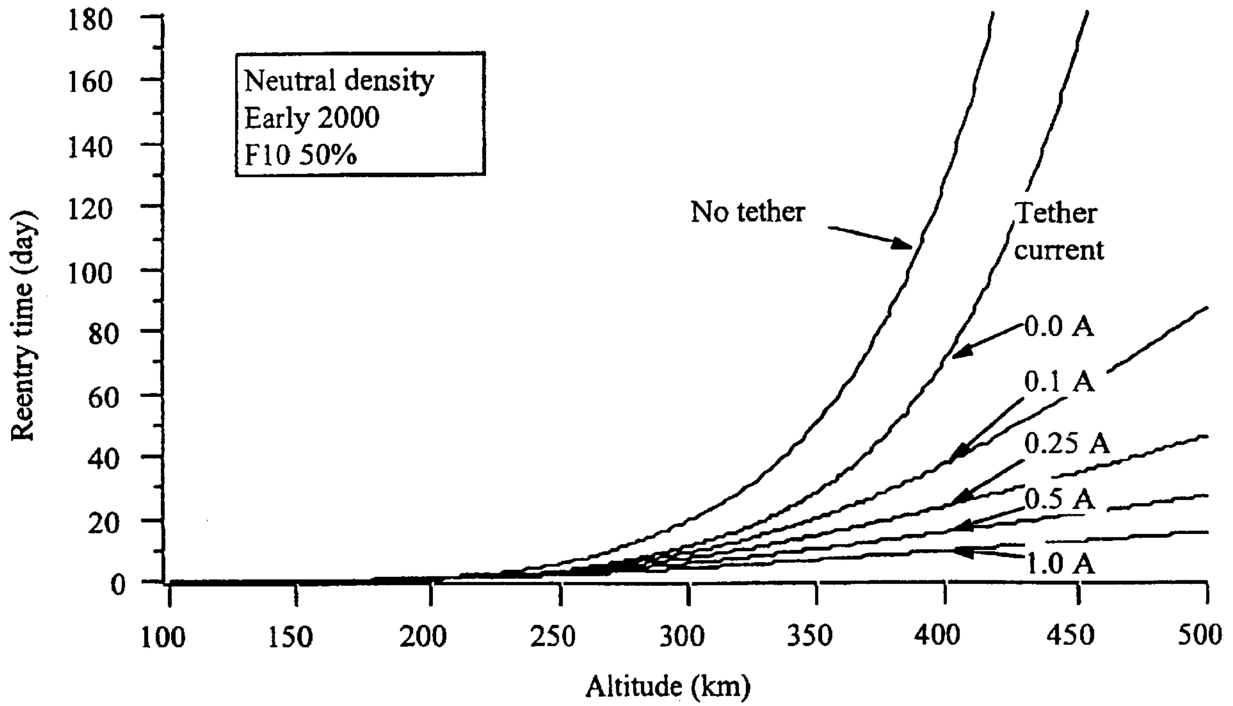

Enrico Lorenzini, SAO, NASA ProSEDS Mission (July 1997),
NASA/MSFC Grant NAG8-1303

FIG. 1c

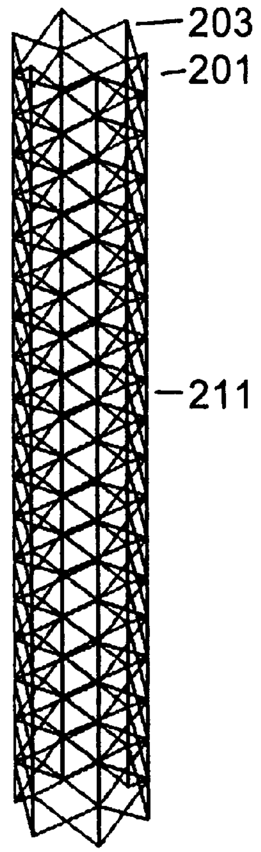

FIG. 2a

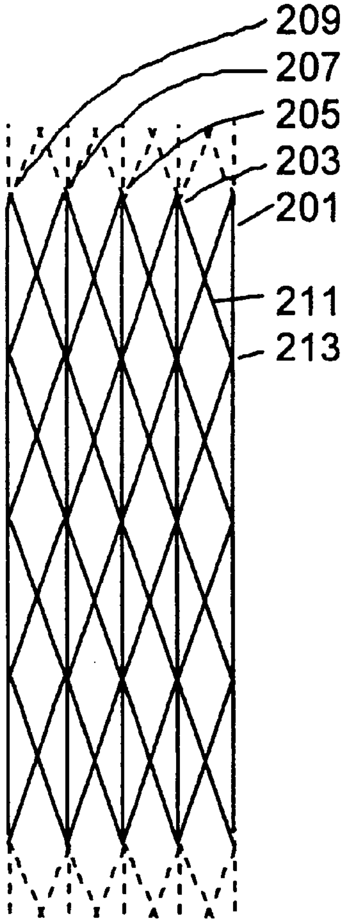
209
207
205
203
201
211
213

FIG. 2b

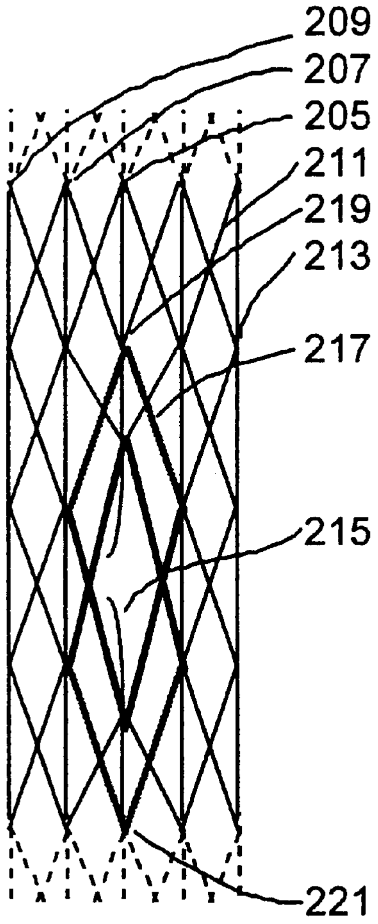
209
207
205
211
219
213
217
215
221

FIG. 2c

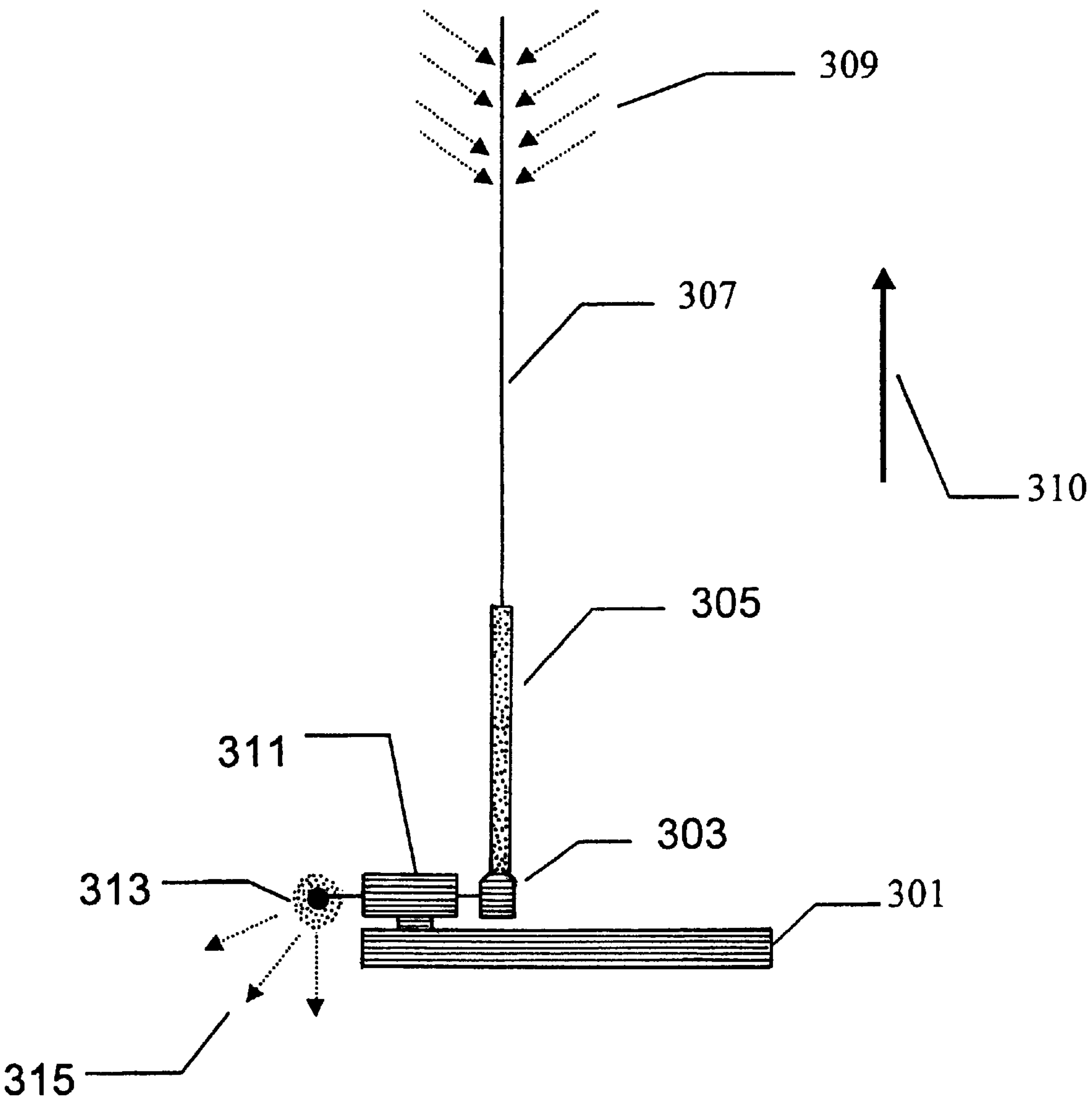
309
307
310
305
311
303
313
301
315

FIG. 3

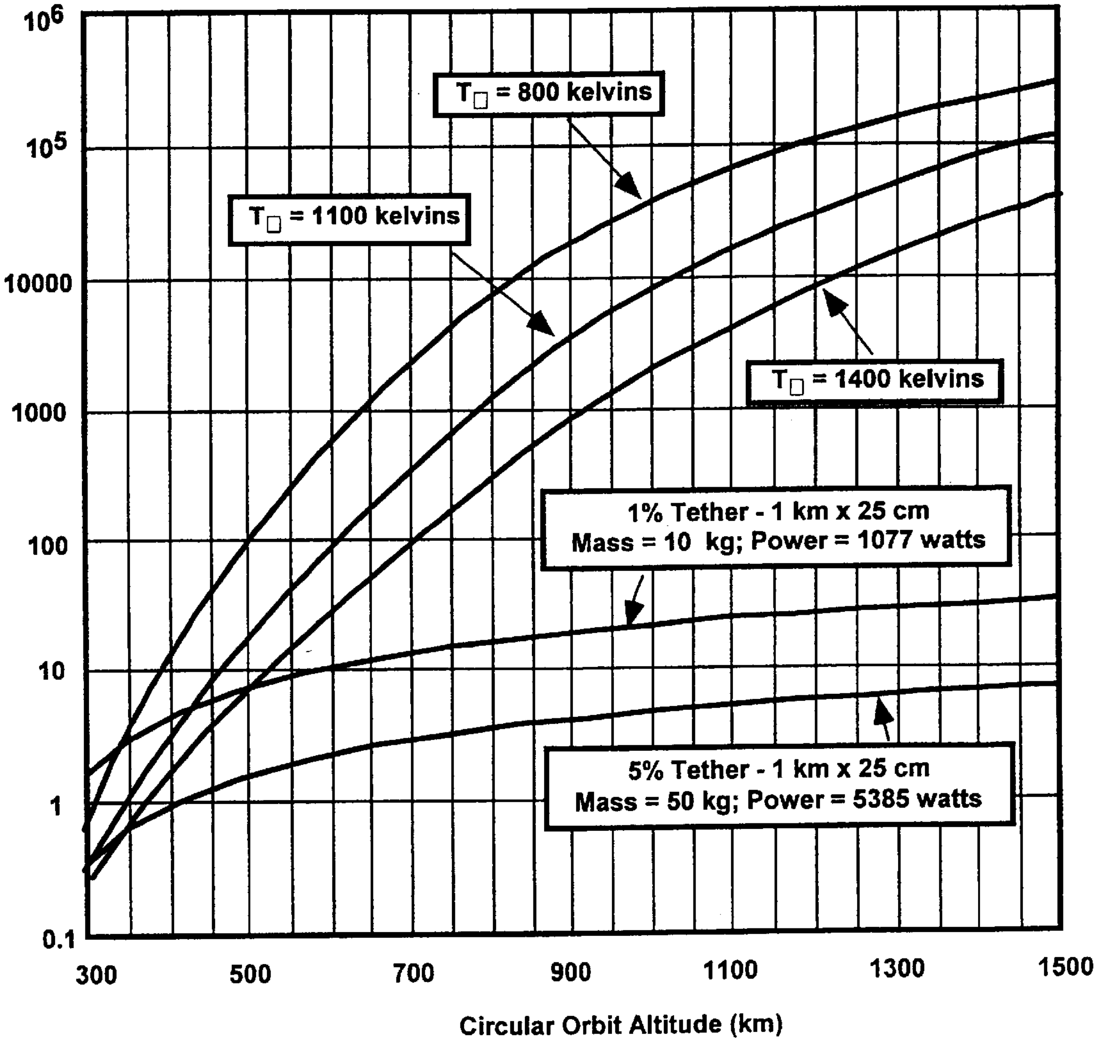

Area-Time Product for Mean and Extremes of Exospheric Temperature

(m = 1000 kg, Cd = 2.0 ; 1% Tether, 1 km x 25 cm; power = 1077 watts)

(5% Tether, 1 km x 25 cm; power =5385 watts)

FIG. 4

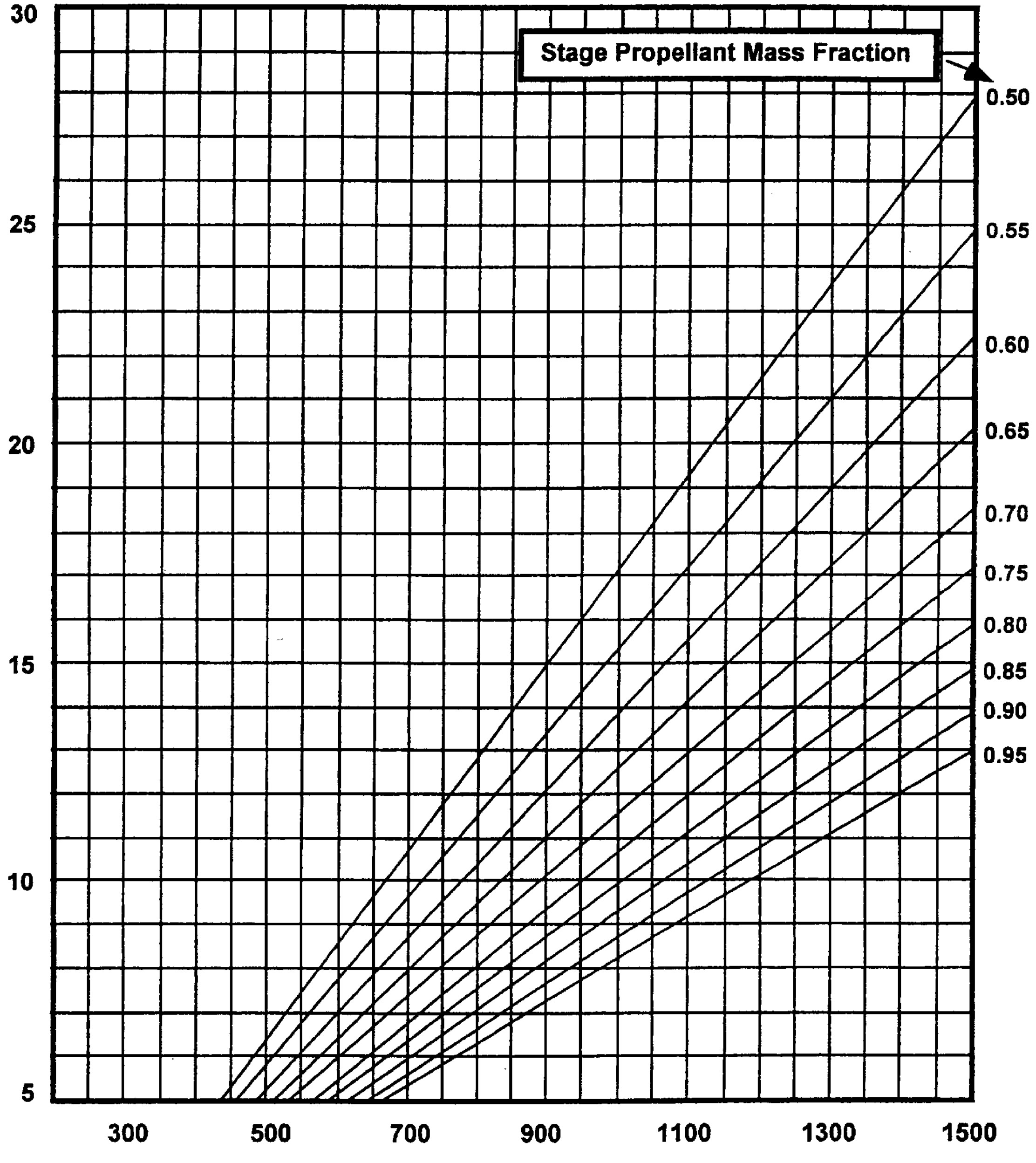

Conventional Solid Rocket Motor System

Percent Increase in Orbital Mass vs. Altitude and I' (Isp = 288 sec)

FIG. 5

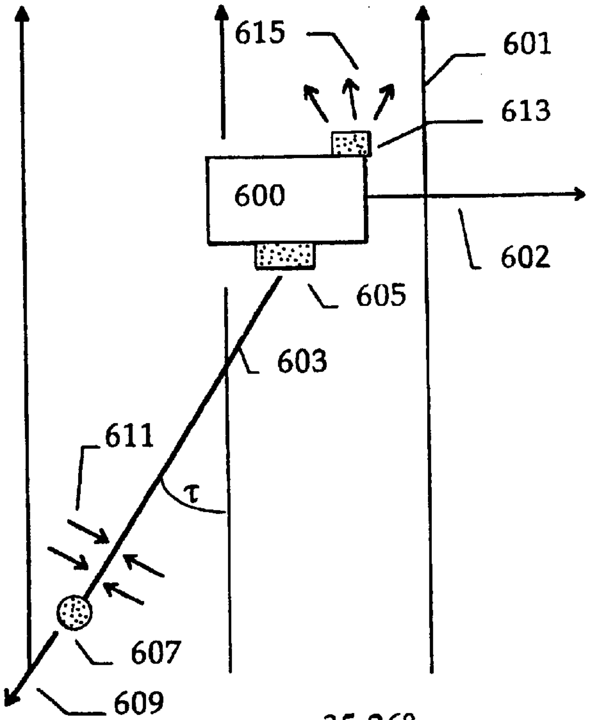
615
601
613
600
602
605
603
611
τ
607
609

τ = 35.26°

FIG. 6

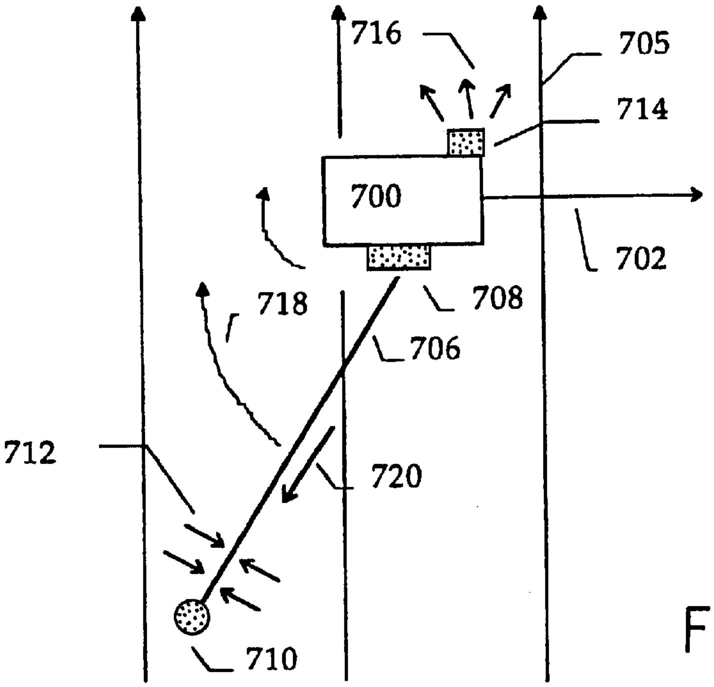
716
705
714
700
702
718
708
706
712
720
710

FIG. 7

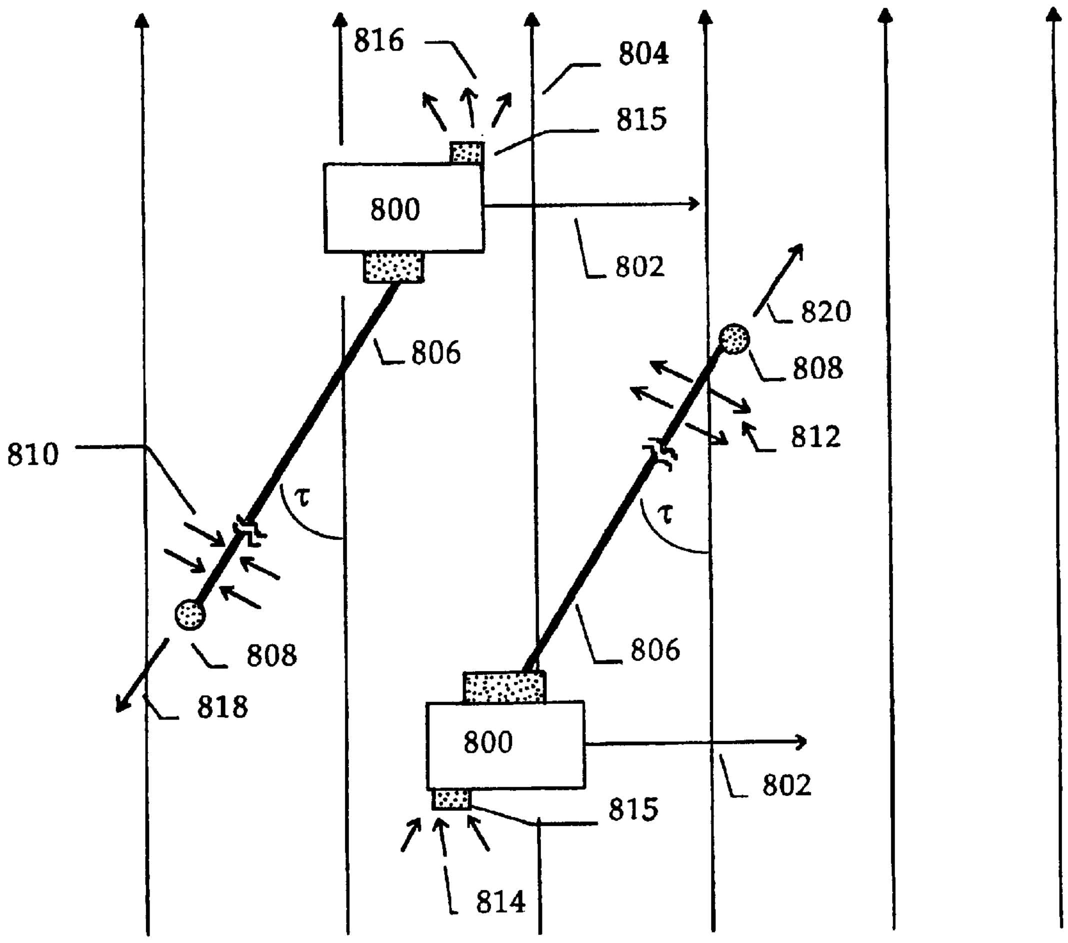
τ
τ

FIG.8

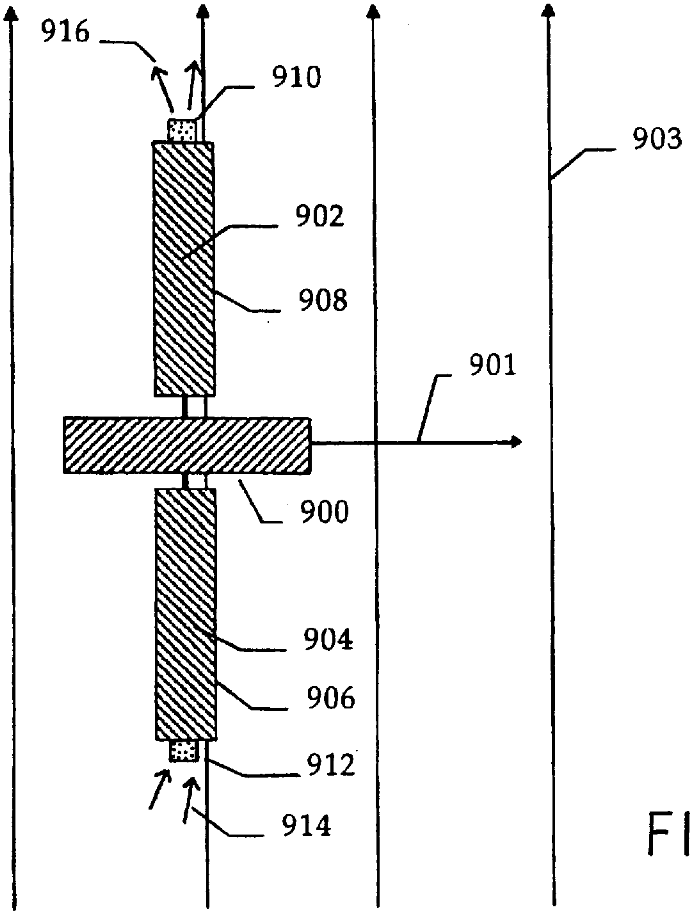

FIG. 9

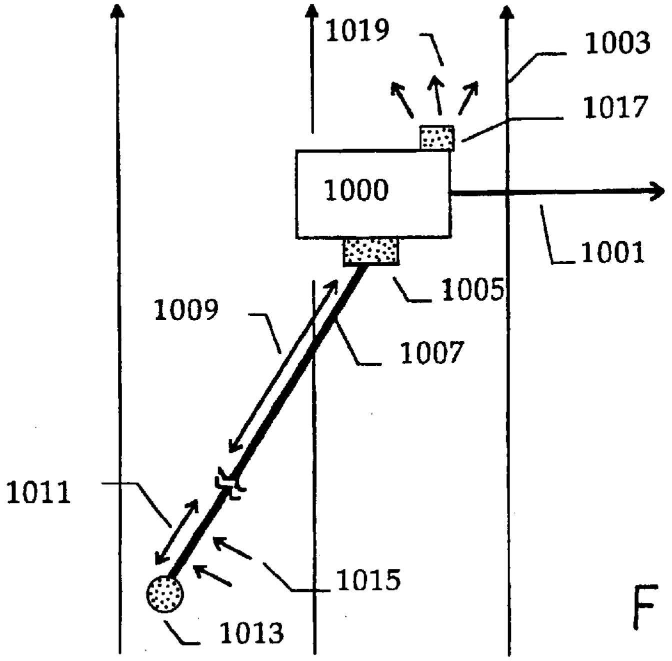

FIG. 10

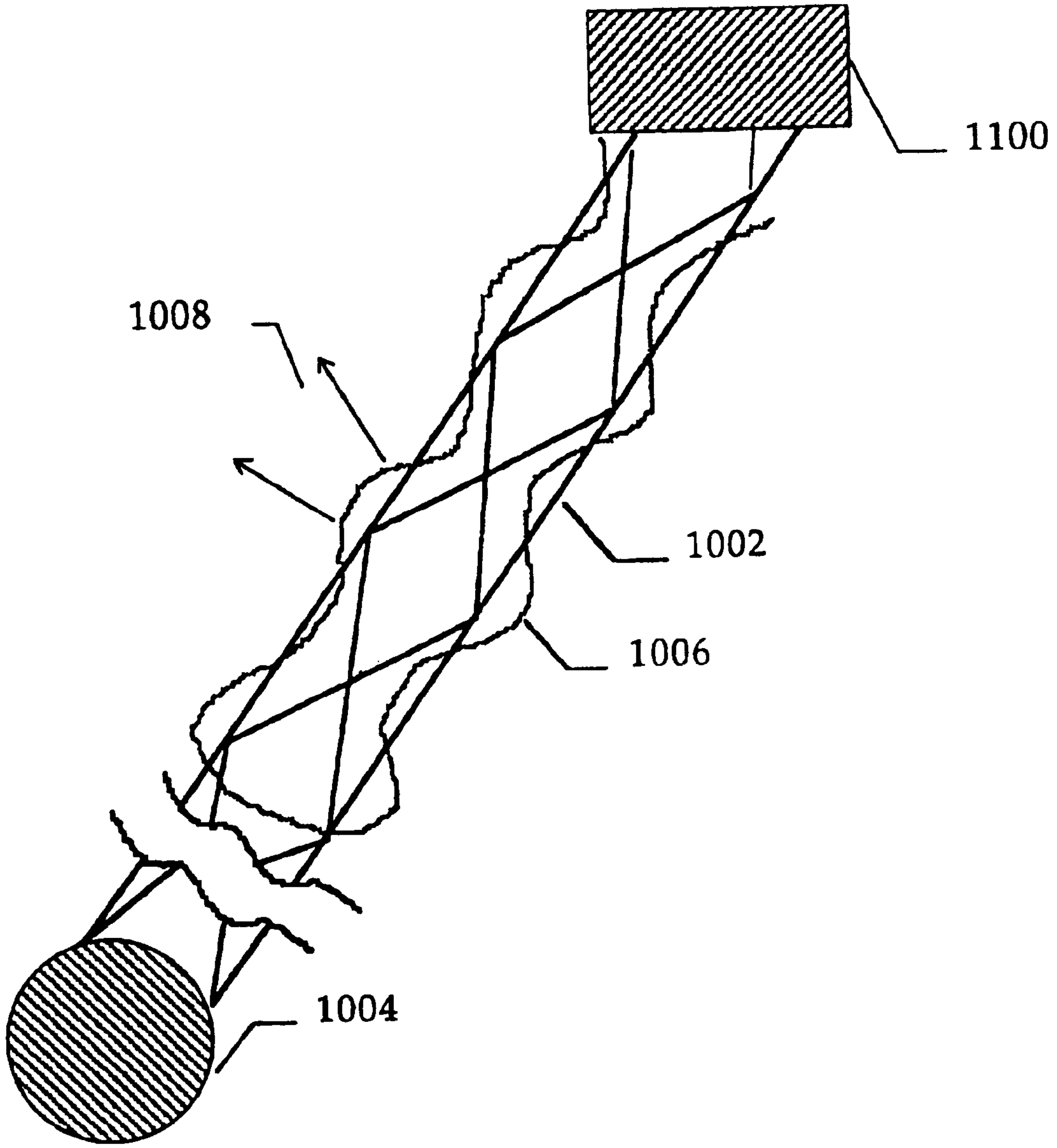
1100
1008
1002
1006
1004

FIG. 11

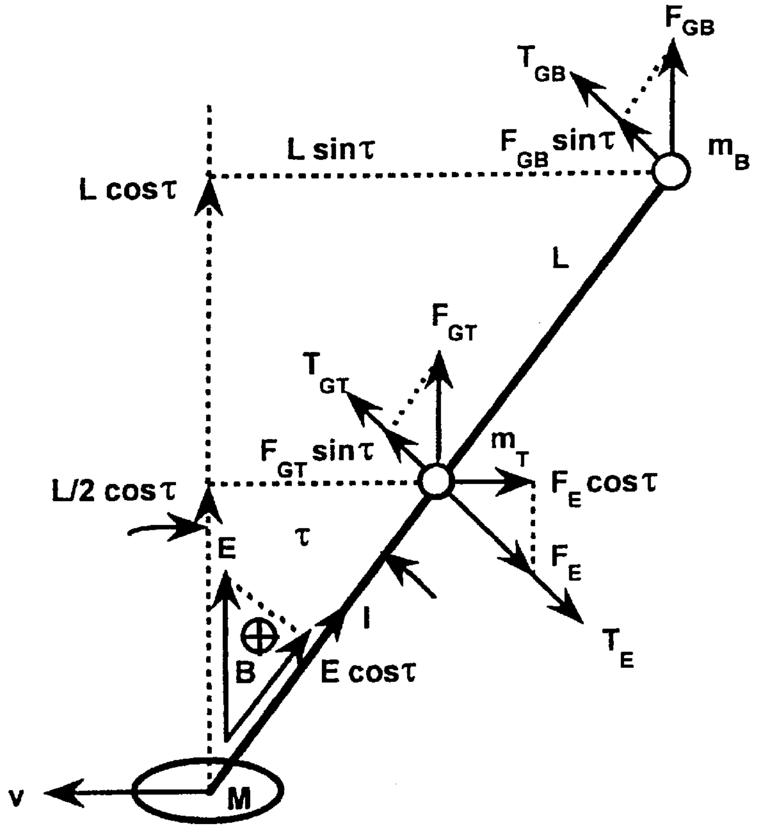
F_{GB}
T_{GB}
$F_{GB} \sin\tau$
m_B
L sinτ
L cosτ
L
F_{GT}
T_{GT}
$F_{GT} \sin\tau$
m_T
$F_E \cos\tau$
L/2 cosτ
E
τ
F_E
I
T_E
B
E cosτ
v
M

FORCES AND TORQUES ON AN UPWARD DEPLOYED CONDUCTING TETHER DUE TO THE MOTION OF THE HOST SPACECRAFT THROUGH THE MAGNETIC FIELD OF THE EARTH.

FIG. 12

ELECTRODYNAMIC TETHER AND METHOD OF USE

TECHNICAL FIELD

This invention relates generally to apparatus and methods useful for changing the state vector of a space object when the space object is moving relative to a magnetic field. More specifically, the present invention relates to an apparatus and method of using a conducting tether to produce an electrodynamic force to deorbit a satellite from its orbit around a celestial body, such as the Earth, which has an associated magnetic field.

RESERVATION OF RIGHTS

This application is subject to certain rights of the U.S. government as a result of contracts between the U.S. government and the inventors.

BACKGROUND ART

The present invention has its principal utility in outer space, primarily for deorbiting satellites at the end of their useful life to mitigate the harm and reduce the liability created by the proliferation of space debris. In order to obtain a better understanding of the present invention it is helpful to understand the prior art of space tethers, especially tether dynamics and tether electrodynamics. The present invention may be more readily understood through a review of the experimental prior art and a mathematical analysis of electrodynamic space tethers.

Prior Art Tethers:

A tether was originally a rope or chain used to fasten an animal so that it grazed only within certain limits. Tethers have been used for decades in space to attach astronauts to their spacecraft.

In 1974 Professor Guiseppe Colombo, holder of the Galileo chair of astronomy at the University of Padua in Italy, proposed using a long tether to support a satellite from an orbiting platform. U.S. Pat. No. 4,097,010, which issued to Professor Colombo and Mario Grossi on Jun. 27, 1978, teaches a satellite connected by means of a long tether to a powered spacecraft. Colombo actively pursued the design of a tethered satellite system.

Several NASA experiments, such as the two Small Expendable Deployer System (SEDS 1 & 2) experiments and the Plasma Motor Generator (PMG) experiment used tethers in space. SEDS used a nonconducting tether. The PMG used a 500-meter conducting tether. The Tethered Satellite System flights in 1992 and 1996 (TSS-1 & 1R) used a 20,000-meter conducting tether.

On the TSS-1 mission the tether deployed only 260 meters (853 feet) before the deployer failed. On the TSS-1R the tether was deployed 19,500 meters. In the SEDS-2 flight, a 0.8-mm diameter, 20,000-meter long braided single-line tether was deployed to study tether dynamics and lifetime. Orbital debris or a meteoroid severed this tether in less than four days.

In the TSS-1R flight, the conducting single-line tether was severed after five hours of deployment. This failure was caused by an electric arc produced by the 3,500 volts of electric potential generated by the conductive tether's movement through the Earth's magnetic field.

The Tether Physics and Survivability (TiPS) satellite consists of two end masses connected by a 4,000-meter long non-conducting tether. This satellite was deployed on Jun. 20, 1996 at an altitude of 1,022 kilometers (552 nautical miles). Its tether is an outer layer of Spectra™ 1000 braid over a core of acrylic yarn. The yarn will "puff" its outer braid to two millimeters to "give it a larger cross section to improve its resistance to debris and small micrometeoroids", according to the National Reconnaissance Office (NRO), which is a sponsor of the TiPS mission. As of Jun. 21, 1997 the TiPS tether had survived one year.

References:

1. Joseph A. Carroll, "SEDS Deployer Design and Flight Performance", paper WSEDSA-1 at the 4th International Conference on Tethers in Space, Washington, D.C., April 1995.
2. James E. McCoy, et. al. "Plasma Motor-Generator (PMG) Flight Experiment Results", pp.57–84, Proceedings of the 4th International conference on Tethers in Space, Washington, D.C., April 1995.
3. W. John Raitt, et. al. "The NASA.ASI-TSS-1 Mission, Summary of Results and Reflight Plans, pp. 107–118, Proceedings of the 4th International conference on Tethers in Space, Washington, D.C., April 1995.
4. Joseph C. Anselmo, "NRO Orbiting Spacecraft Studies Tether Survivability", Aviation Week, page 24, Jul. 1, 1996.

These experiments all used single line tethers.

The following reference is illustrative of the current state of the art in space tethers: Paul A. Penzo and Paul W. Ammann. Tethers in Space Handbook—Second Edition. NASA Office of Space Flight, NASA Headquarters, Washington, D.C. 20546. See also the hundreds of references in the 33 page bibliography at the end of the handbook.

The "Hoytether"™, an Improved, High-Reliability Tether:

In 1991, one of the present inventors, Robert Hoyt, invented a lightweight net-like structure that provides many redundant load-bearing paths. A number of primary load bearing lines running the length of the structure are connected periodically by diagonal secondary lines. The disclosed embodiment of this invention has the secondary lines firmly connected by knots to the primary lines. The secondary lines are connected only to the primary lines. At either end of the disclosed structure, a support ring enforces the cylindrical spacing between the primary lines. The secondary lines are designed with a small amount of slack. These secondary lines are only put under load if a primary line fails. This specific tether structure was disclosed to the public in 1992 (Forward, R. L., "Failsafe Multistrand Tether Structures for Space Propulsion", AIAA paper 92–3214, 28th Joint Propulsion Conference, Nashville, Tenn., 1992 (hereinafter "1992 Hoytether structure"). This structure was named a "Hoytether". The term "Hoytether" is used throughout the remainder of this specification for this type of tether structure.

The present invention uses an improved Hoytether, which was invented by the same inventors as the present invention. This improved Hoytether is the subject of a copending PCT application. The Hoytether is discussed briefly in this specification to aid understanding of the present invention.

The 1992 Hoytether design teaches that the normally slack secondary lines have half the cross-section (0.707 the diameter) of the primary lines. There are twice as many secondary lines as primary lines, thus the mass of the secondary lines is equal to the mass of the primary lines. In an undamaged Hoytether, the primary lines carry the entire load, while none of the secondary lines are under load.

While the survival probability of a single-line tether decreases exponentially with time, the Hoytether can maintain a high, i.e. greater than 99 percent, survival probability for periods of months or years (forward and Hoyt, "Failsafe Multiline Hoythther Lifetimes", Paper AIAA 95–2890, 31st Joint Propulsion Conference, July 1995).

References:

1. Robert L. Forward, Failsafe Multistrand Tethers for Space Propulsion, Forward Unlimited, P.O. Box 2783, Malibu, Calif. 90265, July 1992, Final Report on NASA Contract NAS8-39318 SBIR 91-1 Phase I.
2. Robert L. Forward and Robert P. Hoyt, Failsafe Multistrand Tether SEDS Technology Demonstration, Final Report on NAS8-40545 with NASA/MSFC (Jun. 14, 1995).
3. Robert L. Forward and Robert P. Hoyt, "High Strength-to-Weight Tapered Hoytether for LEO to GEO Payload Transfer" Final Report on contract number NAS8-40690 with NASA/MSFC (Jul. 10, 1996).

The Hoytether is essentially a tri-axial net structure, with 'primary' lines running along the length of the tether and two sets of 'secondary' lines connecting these primaries diagonally. They can be made by hand and connected with knots as is taught by the 1992 Hoytether structure. Because knotted connections severely limit the strength of a structure, it is desirable to use a knotless fabrication technique to achieve interconnections that have strengths approaching the limits of the constituent material. As these tethers may be many kilometers long; fast and inexpensive mechanical methods are required for their practical fabrication.

Hoytethers may be made by mechanical braiding, i.e. three-dimensional braiding, such as 3-D rotation braiding using braiding machines such as those developed by the Herzog Company in Germany (August Herzog Maschinenfabrik GmbH & Co., Postfach 2260.26012, Oldenburg, Germany. The specialized loom developed by the Nichimo Company of Japan (Nichimo Company Ltd., 2-6-2 Ohtemachi, Chiyoda-Ku, Tokyo, Japan) is used to produce "Ultracross" knotless fishing nets in which the individual strands are braided as a 4-braid line, and the strands are interbraided where they cross. This produces netting that has slipless interconnections that are very strong, approaching the maximum capability of the fiber. Such a loom could, with some modifications, produce the present invention's structure. Only two such machines exist, one in Japan, the other in Washington State. Unfortunately neither can work with the small line diameters needed to practice the preferred embodiment of the present invention. See generally, Ko, F. K., "Braiding", in *Engineered Materials Handbook, Vol. 1., Composites*. ASM International, Metals Park, Ohio, 1957. Pp. 519–528.

The most common 3-dimensional braiding machines are 4-step braiders based upon the designs of Maistre (German Patent P230-16986, issued 1973) and Forentine (U.S. Pat. No. 4,312,261, issued 1982). Braiding is accomplished by using pneumatics or solenoids to push the parts of the braiding machine to the proper positions. This is a slow process and making a Hoytether kilometers long with these machines would be very time consuming and expensive. The composites division of Albany International (Albany International Research Company, 777 West Street, Mansfield, Mass.) also produces a 3-D braiding machine. This machine uses modular braiding components that arc assembled breadboard fashion on a large wall.

Although braiding is the preferred technique, alternate fabrication methods such as Raschel knitting and crocheting can be used successfully. Multikilometer long Hoyththers are presently being produced for the inventors by the vendors Culzean Fabrics and Flemings Textiles using an electronically controlled crochet machine produced by Comez in Italy.

Space Tether Systems:

The prior art teaches the use of tethers in space applications. U.S. Pat. No. 5,163,641, issued on Apr. 9, 1990 to Yasaka, teaches the use of a powered spacecraft connected by a tether to a satellite. This tether is disconnected to change the state vector of the satellite. The state of the art of energy and momentum transfer using space tethers is discussed in Ivan Beckey's article "Tethering, a new Technique for Payload Deployment", Aerospace America, March 1997, at pages 36–40. Beckey concludes, "Tethers can perform the same functions as propulsive upper stages of direct payload injection, but at lower weight and cost per pound." U.S. Pat. No. 4,923,151, issued Mar. 1, 1988 to Roberts, Wilknson and Webster, teaches a tether power generator for earth orbiting satellites. U.S. Pat. No. 4,580,747, issued Mar. 15, 1983 to Pearson, teaches use of a long tether extending downward into the atmosphere from a satellite. The state vector of the satellite is changed by forces acting on a lifting body connected to the end of the tether. U.S. Pat. No. 4,824,051, issued Jan. 12, 1987 to Engelking, teaches passing an electric current through a conductive tether attached to a satellite to provide propulsive force to alter the orbit of the satellite. U.S. Pat. No. 5,082,211, issued Jan. 21, 1992 to Werka, teaches use of a tether to deorbit space debris. U.S. Pat. No. 4,727,373, issued Mar. 31, 1986 to Hoover, teaches an orbiting stereo imaging radar system having two spacecraft in synchronous parallel orbits connected by a tether.

Tether Dynamics:

In order to understand the forces that cause a tethered satellite to move upward and away from an orbiting satellite, for example, it is first necessary to explain briefly how a satellite remains in orbit. An orbiting satellite is acted on by the force of gravity which pulls it toward Earth, and by a centrifugal force, which pushes it away from Earth. The centrifugal force" (actually inertia) results from the motion of the satellite around its circular orbit. This is the same force that one can experience by swinging a ball around on the end of a string. A satellite is maintained in its orbit when it travels at the natural speed for its altitude and, as a result, the centrifugal force is equal to the gravitational force.

At the typical orbital altitude of 250 kilometers for a low-Earth orbit satellite, for example, a speed of approximately 7.6-km per second is required to create sufficient centrifugal force to balance gravitational attraction on the satellite. If the altitude is changed, the two opposing forces will no longer be in balance unless the satellite also changes its speed. A higher orbital altitude requires a slightly lower speed so the satellite will take longer to complete an orbit. Because of this, if two free-flying satellites are in orbits at different altitudes, the lower satellite will circle the Earth in less time than the satellite in the higher orbit.

If two satellites, at different altitudes, are connected to each other by a tether, they are forced to travel around their orbits together—in the same period of time, which is longer than the natural period of the lower satellite but shorter than that of the upper satellite. The lower satellite will, therefore, slow down below the natural speed for its orbit and will tend to fall to a lower orbit because the centrifugal force will now be less than the gravitational attraction of the Earth. An upward force in the tether that makes up the difference between centrifugal and gravitational forces holds it in place, however.

Correspondingly, the upper satellite will be accelerated above its natural orbiting speed (increasing its centrifugal force above the gravitational attraction) and will tend to move to a higher orbit. It, too, is held in place by an additional force (downward) in the tether. In other words, the net force downward on the lower satellite is balanced, through the tether, by the net force upward on the upper satellite. The effect of unbalanced forces on the two satellites is, therefore, to create tension in the tether. During the TSS-1 & 1R experiments, the inertia of the tethered satellite causes the satellite to rise above the orbiter as the tether is reeled out. Very close to the orbiter, there is little difference in the two orbits, and the tension force is insufficient to overcome friction in the deployer mechanism; therefore, until the satellite reaches a separation of approximately 1000-meters, the tension is augmented by small tether-aligned thrusters on the satellite. Beyond this point, the tension in the tether is the only force required.

By experimenting with a ball hung on a piece of elastic cord (a paddleball, for example) it is possible to simulate all the different types of oscillations that are possible on a space-based tether system. The elastic cord, representing the tether, may compress and stretch, causing the ball to bounce up and down (longitudinal oscillation). It also may move in a circular (skip-rope) motion or may develop wave-like motions (transverse oscillations). Even if the string itself remains straight, it is possible to get the ball swinging back and forth about its attachment point on the paddle like a child on a swing rope (pendulous motion).

Each type of motion occurs with a particular frequency, which depends on the length and tension of the tether. When the frequencies are different, the motions do not interact; however, at some tether lengths, the frequencies of two or more types of oscillation can become very close. At this point, energy can be transferred from one typc of motion to another, a phenomenon known as resonance. For instance, the transverse oscillations in the tether may cause the satellite to swing back and forth in pendulous motion.

Many different factors may cause oscillations; the movements of the satellite or Shuttle are but two of these. For an electrodynamic tether, the skip-rope and pendulous oscillations are of particular interest. If a current is passed through a tether, the current will interact with Earth's magnetic field, resulting in a force that may produce skip-rope and pendulous oscillations. Because it is necessary to maintain control of the satellite, much study has gone into identifying the different types of possible motions and the methods used to control them.

One way to control the magnitude of those motions that cause a change in tension or transverse motion at the end of the tether is to have an end mass connected to the Hoytether that maintains a controlled tension on the tether, working much like a spring-loaded 'dog leash'. This may be as simple as a coiled spring, or as complex as an active control system that measures the tension and transverse forces on the tether and adjusts the applied tension according to a local or remotely operating algorithm.

Electrodynamic Effects of Conductive Tethers:

Electric potential is generated across a conductive tether by its motion through the Earth's magnetic field. Electromagnetic forces acting on a conductive tether in orbit can make the tether system behave like an electric motor or generator, thereby exerting a useful force to alter the state vector of the tether and any mass attached to it.

Electrodynamic tether propulsion is unlike most other types of space propulsion in use or being developed for space application today—there is no hot gas expelled to provide thrust. Instead, the environment of near-Earth space is being utilized to propel a spacecraft or upper stage via electrodynamic interactions.

A charged particle moving in a magnetic field experiences a force that is perpendicular to its direction of motion and the direction of the field. When a current flows through a long, conducting tether the electrons flowing through the tether experience this force due to the fact that they are moving along the wire in the presence of Earth's magnetic field. This force is transferred to the tether and to whatever the tether is attached (like a spacecraft, satellite, space station or upper stage). It can be an orbit-raising thrust force or orbit-lowering drag force, depending upon the direction of current flow. Operation in one mode allows boost from LEO to higher orbit while reversing the current flow provides negative thrust for deboost. The principle is much the same for an electric motor; reverse its operation and it acts as a generator. The current passing through the tether is returned through the ionosphere to complete the current loop with collection and emission occurring on opposite ends of the tether.

The PMG experiment demonstrated that a conducting tether can be used as both a motor and a generator. The TSS experiments, especially TSS-1R showed that very large voltages (about 3500 volts) can be generated by a sufficiently long tether.

Uses of an electrodynamic tether as an orbit raising and lower propulsion system has many advantages over competing systems:

a. It is nearly propellantless. Most other systems expel hot gases and require extensive resupply. To emit current, the electrodynamic tether propulsion system may use plasma contactors developed as a part of the International Space Station Program. These contactors consume less than 20 kg of xenon gas per year with a 50% duty cycle. The electrodynamic tether propulsion system can also use field emitter arrays, which emit electrons without the use of any gas.

b. It can change both altitude and inclination. The Earth's magnetic field is non-uniform and can therefore provide both in- and out-of-plane forces for inclination changes as well as altitude changes. This is of particular interest to payloads requiring polar orbits in that they can be launched on a small launch vehicle into a lower inclination orbit and have it raised in space by the proper phasing of current through the tether.

A demonstration of the propulsive capabilities of electrodynamic tethers was recently approved for a flight test in 1999. The Propulsive SEDS or ProSEDS mission, will fly as a secondary payload on a Delta II launch vehicle and deploy a 5-km conducting tether using the existing SEDS deployer concept. The ProSEDS experiment will be followed by the Electrodynamic Tether Upper Stage (EDTUS) experiment that will demonstrated the use of electrodynamic forces to change both the altitude and inclination of the experimental spacecraft. FIGS. 1B and 1C show the calculated electrodynamic thrust at several inclinations and the reentry time sensitivity of the ProSEDS tether, respectively.

One application for long-life conducting electrodynamic tethers is as a "Terminator Tether™" for removing from orbit unwanted Earth orbiting spacecraft at the end of their useful lives. When the mission of the satellite is completed, the Terminator Tether™, weighing a small fraction of the mass of the satellite, would be deployed. The electrodynamic interaction of the conducting tether with the Earth's magnetic field will induce current flow in the tether conductor. The resulting energy loss from the heat generated by the current flowing through the ohmic resistance in the conducting tether will remove energy from the spacecraft, eventually causing it to deorbit, thus reducing the amount of orbital space debris that must be coped with in the future.

In the following analysis, it is shown that the amount of energy loss generated by an electrodynamic tether is essentially independent of its length or area, and instead is primarily proportional to the tether mass and the physical properties of the conductor metal chosen. In the typical example calculated, a 1000-kg spacecraft can be deorbited from a 1000-km high Earth orbit by a 10-kg mass tether in a month, while a 1-kg tether can deorbit a 1000-kg spacecraft in less than a year.

To the knowledge of the inventors, Joseph P. Loftus of NASA/JSC first proposed the general concept of using an electrodynamic tether to deorbit spent satellites. (Joseph P. Loftus <JLoftus@ems.jsc.nasa.gov>, personal communication via email to Robert Forward, Monday Jun. 10, 1996 15:50:10.) In order to show that the Loftus deorbit concept was not obvious to those skilled in the art of electrodynamic tethers, Forward contacted the leading expert, Joseph Carroll, of Chula Vista, Calif., who built and participated in the flight test of the PMG. After being told of the Loftus concept in a telephone conversation, his reply in an Email message dated Aug. 5, 1996, was "such a system would be feasible . . . by it is still not obvious to me that it would be useful . . . "

Loftus was considering the use of electrodynamic drag from a conducting tether to achieve this goal of bringing the unwanted spacecraft down from its high orbit (where atmospheric drag is negligible) to a 200-km orbit, where atmospheric drag would rapidly finish off the task of removing the unwanted spacecraft from orbit. The tether Loftus was considering was a single-line, conducting tether, typically 1-mm in diameter, 1-km long, and, if made of aluminum, 2-kg in mass. He would include means at the ends of the tether to contact the ambient space plasma around the Earth to complete the current loop.

Unfortunately it is probable that space impactors would sever the 1-mm diameter, 1-km long single-line tether proposed by loftus within a 1/e lifetime of four months. This would produce orbital debris rather than removing it. The motivation for this work is the NASA Safety Standard NSS 1740.14 "(Guidelines and Assessment Procedures for Limiting Orbital Debris." The relevant portion of the Standard starts on page 6-3: General Policy Objective-Postmission Disposal of Space Structures. Item 6-1: "Disposal for final mission orbits passing through LEO: A spacecraft or upper stage with perigee altitude below 2000 km in its final orbit will be disposed of by one of three methods." The method of interest is the atmospheric reentry option, Option a: "Leave the structure in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the lifetime to no longer than 25 years after completion of mission. If drag enhancement devices are to be used to reduce the orbit lifetime, it should be demonstrated that such devices will significantly reduce the area-time product of the system or will not cause the spacecraft or large debris to fragment if a collision occurs while the system is decaying from orbit."

The NASA standard applies only to NASA spacecraft and even then only to completely new spacecraft designs. New versions of existing designs are to make a "best effort" to meet the standard, but will not be required to change their design to do so. The Department of Defense has adopted the NASA standard with the same provisos. An Interagency Group report has recommended that the NASA standard be taken as a starting point for a national standard. It is NASA's recommendation to the Interagency Group that the safety requirement be phased in only as spacefaring nations reach consensus internationally, which is being done through the International Debris Coordination Working Group whose members are Russia, China, Japan, ESA, UK, India, France, Italy, and the US.

Thus, although the NASA Safety Standard in its present form is not the "Law", the existence of the standard means that some time in the future a similar requirement may be imposed on all spacecraft. This could result in major growth in future space tether business, with a sale to every non-geostationary spacecraft being "mandated" by government safety regulations, somewhat as the sale of seat belts and airbags for every car are mandated.

In fact, three of the companies planning to set up "constellations" of low to medium orbit communications: Teledesic, Iridium and Odessey have committed their companies to abide by the spirit of NASA Safety Standard 1740.14 by using one means or another to deorbit their spacecraft before they reach end of life.

Problems with Prior Art Tethers:

All electrodynamic tether designs proposed by the prior art teach that the tether should be operated at a right angle to the magnetic field through which the tether is moving. This is a problem because the electrodynamic force acting on the tether causes the tether to align itself with the magnetic field force lines. To overcome this problem the prior art teaches the use of a large ballast mass attached to the end of the tether and/or use of a very long (tens to hundreds of kilometers) tether. The large ballast mass is expensive to take to orbit because it replaces useful payload. The long tether sweeps a larger Area-Time-Product during its useful life and thus is more likely to impact other space objects, either debris or another spacecraft.

Another problem common to all proposed prior art tethers is tether instability. If the tether produces a large electrodynamic drag force, which is desirable because a large drag force will cause the satellite to deorbit quickly, then the tether will be dynamically unstable. This instability can cause the tether to lose its effectiveness, act uncontrollably and even wrap around the satellite or otherwise malfunction. Experts skilled in the art of tether design have opined that this dynamic instability is inherently unavoidable in any electrodynamic tether system. The prior art solution, such as that presently being used in the ProSEDS experiment, has been to use a large ballast mass to increase the stabilizing gravity-gradient force and/or to limit the electrodynamic drag of the tether to less that the maximum that could be produced. In the ProSEDS experiment, the conducting electrodynamic tether is five kilometers long. To insure stability, it will be augmented by a 20–35 kilometer long non-conducting tether, which to further have stability will have a 40 kilogram ballast end mass.

Yet another problem of all proposed prior art electrodynamic tether systems is how to radiate away the energy produced by the tether's operation. A satellite moving at an orbital velocity of 18,000 miles per hour has a kinetic energy of over 10,000 calories per gram. To put this amount of energy in an understandable perspective, it may be noted that when nitroglycerine explodes it produces about 1,500 calories per gram. Prior art designs of electrodynamic drag tethers teach the use of the electrical energy generated by the tether to charge batteries or operate electronics, with the excess energy being converted into heat by a resistive load. This excess heat must be radiated to the space environment or it will melt the resistive load. Thus the resistive load, and/or its associated radiator structures, must be massive and replace useful payload.

DISCLOSURE OF THE INVENTION

The present invention comprises an electrodynamic tether structure and a method of use. The principal industrial utility of the present invention is to deorbit satellites in Earth orbit at the end of their useful life. This embodiment of the present invention is sometimes referred to in this specification as a "Terminator Tether™" because it terminates the orbital lifetime of the host spacecraft. The structure of the tether taught by the present invention is a short, wide, interconnected-multiwire (compared to the long single wires of the prior art) conductive Hoytether whose area maximizes electrodynamic drag while simultaneously minimizing the Area-Time-Product swept by the tether during its operating life. The preferred tether length is two to five kilometers. The preferred tether mass is one to five percent (1%–5%) of the spacecraft mass. The method of operation comprises orienting the tether structure at a 35.26-degree trailing angle to the local vertical to maximize electrodynamic force on the tether while avoiding tether instability and allowing use of a small tether end mass.

The present invention also teaches that the satellite-tether system may be rotated around its common center of mass to centrifugally produce tension force in the tether structure to oppose forces causing tether instability. The angle of the conductive tether structure of the present invention with respect to the velocity vector of the host spacecraft may be controlled by the method of the present invention so it interacts with the encountered magnetic field to induce a maximum current flow in the tether. This produces maximum electrodynamic drag. All or a portion of this electric power may be stored and then controllably applied to the conductive tether to produce an induced electrodynamic force. This induced electrodynamic force may by used to enhance the drag force, to rotate the tether-satellite system and/or to provide satellite propulsion, i.e. to change the state vector of the satellite for any useful purpose, e.g. to avoid collision or to change the host spacecraft's orbit to an orbit more favorable for more rapid deorbiting.

The present invention also teaches a tether structure that also functions as a thermal radiator and/or plasma contactor. An embodiment of the present invention using conducting elements of the satellite, e.g. the solar arrays, as electrodynamic tether structures is also disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be better understood with reference to the following drawings:

FIG. **1***a* is a graph comparing the survival probability of a single line tether as taught by the prior art to the Hoytether used by the present invention.

FIG. **1***b* is a graph showing the level of electrodynamic thrust for a 10 kilometer, 10 kilowatt tether at various altitudes and inclinations.

FIG. **1***c* is a graph showing reentry time sensitivity of a five kilometer ProSEDS tether for several conditions of current flow in the electrodynamic tether.

FIGS. **2***a*, **2***b* and **2***c* show the Hoytether structure used by the preferred embodiment of the present invention.

FIG. **2***d* shows the Hoytape structure used by the preferred embodiment of the present invention.

FIG. **3** is a block electrical diagram of an electrodynamic tether system.

FIG. **4** is a graph showing a graph of the Area-Time product for three separate levels of exospheric temperature (for neutral drag calculations) and for two separate assumptions regarding tether mass and power drawn from the ambient plasma (for the Terminator Tether™ calculations).

FIG. **5** is the percent additional mass required in orbit to drop the perigee of a circular orbit at altitude, at, to a value of 200 kilometers using standard chemical rocket as taught by the prior art for deorbiting unwanted spacecraft.

FIG. **6** is a deorbit tether system shown operating with its electrodynamic tether at a trailing 35.26-degree angle to the encountered magnetic field, as is taught by the preferred embodiment of the present invention.

FIG. **7** shows an embodiment of the present invention in which the electrodynamic tether—satellite system is rotated about its center of mass to avoid tether instability.

FIG. **8** shows an embodiment of the present invention wherein the tether is powered to provide induced electrodynamic force.

FIG. **9** shows an embodiment of the present invention wherein the solar power system structure of the satellite is used as an electrodynamic tether.

FIG. **10** shows the use of a portion of the tether structure as a thermal radiator and plasma contactor.

FIG. **11** shows the braiding of an ohmic resistive load into the tether structure.

FIG. **12** is a force diagram showing the forces and torques on an upward deployed conducting tether due to the motion of the host spacecraft through the magnetic field of the Earth.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The principal industrial utility of the present invention is the deorbiting of satellites in Earth orbit, which necessarily can happen only in outer space. Until the present invention is reduced to actual practice by use with satellites in outer space and a body of practical experience is thereby obtained, the present invention can only be constructively reduced to practice, such as by this written specification and its associated drawings, diagrams and graphs and by reference to electric measurements made on conducting tethers in space by the PMG and TSS experiments. The inventors provide herein a detailed discussion of the theory of the present invention to help those skilled in the art of aerospace and tether engineering to understand the present invention and to make and use the best embodiment of the present invention known to the inventors at the time this specification was prepared, without undue experimentation.

Although the present invention is discussed in this specification in its preferred embodiment as a means of deorbiting satellites, it must be emphasized that discussion of this specific use in no way limits the broad scope of the present invention. The present invention can be used to change the direction and speed, i.e. the state vector, of any space object providing that object is in motion relative to any magnetic field. This magnetic field may be that of the Earth or of any other celestial body, for example Jupiter or the sun.

In this specification the material forming the structure of the electrodynamic tether is specified as being a conductor. For example, a metal, such as copper or aluminum wire could be used. Likewise, nonmetallic conductor, such as carbon nanotubes, or a conductive polymer could form the conductive structure of the tether.

FIG. **1***a* shows the survival curve for a Hoytether as used by the present invention vs. the survival curve of a prior art single line tether. The survival probability curve of the Hoytether as a function of time does not conform to the well known "1/e decay" shape of a single-line tether. The Hoytether can maintain a high level of survival probability, about 99 percent, until it nears its 'lifetime'. Its survival probability then drops rapidly to zero. A detailed mathematical analysis of the difference between Hoytether and single tether survival probabilities is given in Appendix E "Small Impactor Survival Probabilities of Hoytethers" and Appendix F "Large Orbital Debris Survival Probabilities of Hoytethers", both contained in the Final Report of NASA Contract NAS8-40545. The resulting cut probability with time for the Hoytether has a "bingo curve" shapes. In a bingo game, at least five numbers must be called before anyone can win, and usually many numbers have to be called before one of the bingo cards gets five in a row. In the Hoytether at least four cuts must happen at the same level before any failure occurs, and many cuts have to be made before any one of the levels has all four lines cut. The bingo curve has the property that the probability of survival stays very high for periods short compared to the lifetime. The probability of survival is greater than 99% for periods shorter than 10% of the lifetime. This is much better performance than the 1/e curve of a single line tether, where the probability of survival is only 90% at 10% of the 1/e lifetime.

FIG. **1***b* shows the calculated level of electrodynamic thrust, in Newtons, produced by a ten kilowatt, ten kilometer single conductor tether at altitudes between 200 and 1400 kilometers and at orbital inclinations between zero degrees and eighty degrees.

FIG. **1***c* is a graph showing the reentry time sensitivity calculated for a five kilometer ProSEDS single conductor tether at altitudes between 200 and 500 kilometers with current flow in the tether between on flow and one ampere.

FIGS. **1***b* and **1***c* are the work of Enrico Lorenzini of the Smithsonian Astrophysical Observatory from his study "Performance Evaluation of the Electrodynamic Tether Tug", NASA/MSFC Grant NAG8-1303 (Nov. 12, 1966). They show that experts in the field believe that the present invention will have industrial utility, as the current flow of one ampere in FIG. **1***c* decreases the deorbit time for the calculated case from more than 180 days to less than 20 days.

FIG. **2***a* is an isometric drawing showing the generally cylindrical structure of the Hoytether. In FIG. **2***a*, primary lines **201** and **203** are shown connected via secondary lines **211**. In FIG. **2***b*, which is a schematic illustration of the structure shown in FIG. **2***a*, primary lines **201**, **203**, **205**, **207** and **209** are connected, each to their respective adjacent primary lines, by a plurality of secondary lines **221**. These connections, for example as shown at interconnection **213**, are made by knotless, slipless interconnections, such as Soutache braiding of twisted connections.

FIG. **2***c* shows the Hoytether structure of FIG. **2***b* but with a severed primary line **205** at breakpoint **215**. The second level of secondary lines **217**, shown as bold lines in FIG. **2***c*, redistribute the load from the severed primary line **215** at point **217** back to line **215** at points **219** and **221**, above and below the break, respectively.

For the electrodynamic tether, a preferred embodiment would be to unroll the tubular Hoytetherr™ into a flat Hoytape™ as shown in FIG. **2***d*.

FIG. **3** generally shows the arrangement of functional elements of an electrodynamic tether system. Of course such a system must have a means of attachment to the spacecraft, a deployer, the tether itself, some form of space plasma cathode contactor, some form of space plasma anode contactor, a power dissipation system, and a communication and control system. Each of these individual elements are known in some form to those skilled in the art of aerospace engineering. Thus the present inventors do not feel it is necessary to describe them in detail in this specification.

In FIG. **3**, a space object **301**, i.e. a satellite in Earth orbit, or any other space object either natural or man made, is physically connected to the tether system. The tether system comprises a deployer **303** from which a conductive Hoytether **305** having a bare segment **307** extends upward from space object **301**. The positively biased anode end **309** of tether **305** collects electrons from the ionosphere as space object **301** moves in direction **310** across the Earth's magnetic field. These electrons flow through the conductive structure of the Hoytether to the power system interface **311**, where it supplies power to an associated load, not shown. The electrons then flow to the negatively biased cathode **313** where electrons are ejected into the space plasma **315**, thus completing the electric circuit.

In order to allow those skilled in the art to better appreciate the broad scope of the present invention, the inventors will now provide an example using specific tether and system values to compare the Terminator Tether™ to prior art means, ie a rocket, for deorbiting a satellite.

Terminator Tethers™:

When an Earth orbiting conducting space tether moves through the magnetic field of the Earth, an electric field is generated in the tether that is proportional to the velocity of the conductor, the magnetic field strength of the Earth, and the angle between the conducting tether and the magnetic field lines. From data obtained during the various electrodynamic experiments that have been conducted in space to date, such as the PMG, TSS-1, and TSS-1R experiments, a typical value of the generated emf per unit length of tether of E=100–200 Volts/kilometer can be assumed. The electric potential V developed at the ends of a tether of length L is then V=EL. For a tether of length L=10 km, the electric potential developed is V=1000 V. For calibration, the 20-km long TSS-1R tether, at the moment of failure, was developing a potential of 3500 volts, which is 175 volts/km.

The mass of a conducting tether of length L, cross-sectional area A, and densin, d is given by m=dLA. Typical values for the density are d=2700 kg per cubic meter for aluminum and 8900-kg per cubic meter for copper. For a typical aluminum tether of mass m=10 kg and length L=10 km, the cross-sectional area will be A=0.37 mm squared. If this were a solid-wire single-line tether, the diameter of the wire would be D=0.69 mm (21.5 gauge). If this were an 18 line tubular Hoytether, the diameter of the lines in the Hoytether would be D=0.16 mm (34 gauge).

The resistance of a conducting tether of length L and cross-sectional area A is given by R=rL/A, where r is the resistivity of the conductor in nano-ohm-meters (nΩ-m). Typical values for the resistivity are r=27.4nΩ-m for aluminum and 17.0 -nΩ-m for copper. For the m=10 kg aluminum tether of length L=10 km and cross-sectional area A=0.37 mm squared at 20 degrees C, the end-to-end resistance is 750 Ω. This value of resistance is the essentially the same whether the conductor area is concentrated into a single-line tether or divided up into many lines as in a multiline Hoytether.

The current I generated in the conducting tether by the electric potential V between the ends of the tether applied across the tether resistance R is I=V/R. For the 10 kg mass aluminum tether of length L=10 km, electric potential V=EL=1000 volts, and resistance R=750 Ω the current is I=V/R=1.33 Amps. Currents near these values were measured in the TSS-1R experiment at the time of failure. At the time of failure of the TSS-1R tether, none of the plasma contactors on the Space Shuttle or the Italian Satellite were operating. Thus the current was being collected by the conductive surface area of the Space Shuttle and the Italian

Satellite at the two ends of the tether. The Space Shuttle area is quite large, so it was not the limiting factor in current collection. The diameter of the Italian Satellite was 1.6 m, which would give it an effective plasma contact area of about 8 square meters. This shows that, if the plasma contact area of the ends of a conductive space tether can be make large enough, then ampere level currents can be extracted from the ambient space plasma without the use of space plasma contactors.

The power dissipated as ohmic heating in the tether is given by P=IE. For an aluminum tether of mass m=10 kg, resistivity r=27 nΩ-m, and density d=2700 kg/cubic meter, subjected to an electric field of E=100 V/m, the power dissipated in the ohmic losses of the conductor is P=IV=1330 Watts. For a 1 kg mass tether, it would be still a considerable 133 Watts of dissipation.

There will no doubt be additional dissipation of energy in plasma ohmic losses, plasma wave generation, and plasma ion acceleration, but the ohmic losses in the conducting tether alone are sufficient for the task of deorbiting an unwanted spacecraft massing 100 to 1000 times more than the tether.

The decay time of a metric ton spacecraft moving from a 1000 km altitude orbit to a 200 km altitude orbit with an energy difference of dU=3.3GJ, when its energy is being dissipated at a power of P=1330 W by an aluminum tether massing just 10 kg, or 1% the mass of the spacecraft, is about one month. This is a remarkably short time, and indicates that the concept of using a conductive tether to deorbit a spacecraft is indeed feasible. If the aluminum tether massed only 1 kg, or 1/1000th the mass of the spacecraft it was deorbiting, then the decay time would rise to 10 months, still a reasonable value.

In reality, of course, the actual decay time will be longer than this. If the electrodynamic drag force is very large, and becomes larger than the gravity gradient forces pulling on the ends of the tether (which force is proportional to the mass of the tether), then the tether will tend to align itself along the magnetic field lines instead of across them, and the drag force will decrease because of the small angle between the conductor length and the magnetic field lines. The tether will then settle into an angle determined by the balance between these two forces.

Is the Terminator Tether™ theoretically a better means than atmospheric drag or a rocket engine for deorbiting satellites at the end of their useful life?

In the formula for da/dt (change in altitude per change in time), using the assumptions of near-circular spiral trajectories, the Area-Time-Product (Z), the criteria by which NASA judges compliance with Safety Standard 1740.14, is given by:

$$Z = A\int dt = -\frac{m}{C_D}\int \frac{da}{\rho(a)\sqrt{\mu a}},$$

where ρ(a) is simply the density as a function of semi-major axis. Thus, for a static atmosphere, the problem of area-time product is reduced to quadrature. Note that the area-time product depends only on the density profile and the ratio of spacecraft mass to drag-coefficient and is linearly related to that ratio.

The basic altitude-dependence of the atmospheric density, represented here by ρ(a) can be expressed in a low-order power series of ln(density)=f(ln(altitude)), so that it will be possible to develop a representation of the log—log relationship between altitude and density. The three static levels of atmospheric density are modeled as 5th order polynomials in the natural log of the altitude and are representative of well known atmosphere models, for example, Jacchia, L. G., "Thermospheric Temperature, Density, and Composition: New Model," SAO Special Report 375, March 1977. 2. Anon., Marshall Space Flight Center, "Long-Range Statistical Solar Activity Estimation," Atmospheric Sciences Division, 1989.) The values of exospheric temperature are reasonable (about 2-sigma) high and low solar activity values of 1400 and 800 kelvins respectively. The mean value is taken to be 1100 kevins.

FIG. **4** shows a graph of the Area-Time product for three separate levels of exospheric temperature (for neutral drag calculations) and for two separate assumptions regarding tether mass and power drawn from the ambient plasma (for the Terminator Tether™ calculations). The density profiles for the three values of exospheric temperature represent the extremes and mean values to be expected during the next several decades. The exospheric temperature goes through a cycle of about an 11 year period with maximum about 1400 kelvins and minimum about 800 kelvins.

The tether calculations include an inherent assumption that the Terminator Tether™ transfers all the energy extracted from the ambient space plasma into drag that decreases the orbital energy of the spacecraft at a rate given by the power drawn by the tether. Thus, the change in energy for a spacecraft of mass m at an initial altitude h is given by the expression:

$$\Delta E = -m\left\{\frac{\mu}{2(R_e+h)} - \frac{\mu}{2(R_e+250)}\right\},$$

and the time required to effect this change in energy of the mass, m, is just

$$\Delta t = \Delta E/P,$$

where P is the power drawn by the tether from the ambient plasma charge.

The curves for 1% and 5% tethers do not include the effects of atmospheric drag because the electrodynamic drag is orders of magnitude greater than the neutral atmospheric drag. At altitudes greater than about 700 km, the electrodynamic drag is 200 to 3000 times greater than the neutral drag forces.

It is clear, from FIG. **4** that the Terminator Tether™ concept is far superior to neutral drag in removing spacecraft from orbit, no matter how much additional area is added to the passive spacecraft to increase the atmospheric drag. The analyst should note that FIG. **4** is proportional to mass; that is, the Area-Time-Product values should be multiplied by the mass of the spacecraft and divided by 1000 kg. This is true for the neutral drag and Terminator Tether™ curves alike. The power levels assumed for the 1% and 5% tethers are only 80% of their theoretical values. This is done to provide a 20% margin on the power available from the ambient plasma and electrodynamic gradient.

Conventional rocket mechanisms can remove spacecraft from orbit, but this mechanism is apparently not viable from mass considerations when these factors are compared with the capabilities of the Terminator Tether™. A satellite owner may decide to satisfy the NASA safety requirements by adding a small solid motor and the associated hardware, software, sensors and structure to make the package independent, to be used to deorbit the spacecraft in case the main spacecraft power, attitude, or propulsion system fails.

The requirements of such a rocket motor system are more stringent than those attributed to ordinary spacecraft. The rocket motor deorbit system must operate when some or all other systems of the spacecraft have failed. These more stringent requirements are balanced by lesser requirements of performance. The backup system must simply deorbit the spacecraft; it does not have to perform all the other duties of the spacecraft. But the backup system must know when to fire under all kinds of anomalous situations, including tumbling, offset of center of mass (because of loss of parts due to collisions), and lack of knowledge of the orbital position.

FIG. **5** shows the percent additional mass required by the rocket motor system to drop the perigee of a circular orbit at some initial perigee altitude to a value of 200 km. The atmospheric drag at this 200 km perigee altitude will remove any spacecraft (in the range considered) from orbit in a few revolutions. The contours of constant stage propellant mass fraction, λ, range from low values of 0.5 through reasonable values of 0.65 to 0.7, up to the values associated with the best solid motors ($\lambda \nabla 0.93$) without adding any extra hardware to the emergency stage. An effective, independent stage to provide a retro deltaV of from 50 to 325 m/s will almost certainly have a λ of the order of 0.6 to 0.75. If the emergency stage is required to perform its own attitude determination, the stage propellant mass fraction may be as low as 0.55 or 0.50. Note that the additional mass, shown in FIG. **5**, must also be lofted to orbit in the first place, to provide the mass on orbit for the originally intended service. The stage propellant mass fraction, λ, is a key stage performance parameter that describes the ratio of the mass of propellant to the mass of the stage. That is $\lambda = m_p/(m_p + m_l)$, where m_p is the mass of the propellant and m_l is the mass of everything else in the stage (not including the payload or any stages above or below the stage being considered). Typical independent small rocket stages have values of λ from 0.60 to 0.75. The curves of stage propellant mass fraction are shown as straight lines (a minor approximation) and are included only from 0.5 to 0.95, the extremes of reasonable design practice.

These calculations that show, beyond any reasonable doubt, that the Terminator Tether™ concept is far superior to conventional mechanisms such as drag enhancement devices or small rocket deorbit propulsion systems. The superiority is measured in terms of Area-Time-Product, NASA's measure of the likelihood of collision with other spacecraft in the path of the descending spent member of a constellation. Tether calculations were made using conservative assumptions that the power extractable from the ambient plasma and electrodynamic gradient is only 80% of the theoretical power available to a perfect tether crossing the magnetic field lines at a right angle, i.e. normally.

The following analysis is presented by the inventors to help those skilled in the art to better understand the present invention when it is used as a Terminator Tether™ for removing from orbit unwanted non-geostationary Earth-orbiting spacecraft at the end their useful lives. The primary result of that analysis is that the electrical power P in the tether that is converted into heat by the resistance of the tether and radiated away into space will remove energy from the spacecraft, causing it to rapidly deorbit, thus reducing the amount of orbital space debris that must be coped with in outer space. Tether electric power P is given by:

$$P=(vB)^2m/2rd$$

where m is the mass of the conducting tether, r and d are the resistivity and density of the conducting material, and v is the velocity of the spacecraft's motion through the Earth's magnetic field B. For a m=10 kg tether of aluminum with resistivity of $r=27.4\ n\Omega\text{-m}$ and density $d=2700\ kg/m^3$, moving at a velocity v=7037 m/s relative to the Earth's horizontal magnetic field $B=26.5\ \mu T$, the power dissipated is P=2350 W! This energy loss in the form of heat must necessarily come out of the kinetic energy of the host spacecraft. For a typical example, a 1000 kg spacecraft in a 1000 km high orbit subjected to an energy loss of 2350 J/s from a 10 kg tether (1% the mass of the host spacecraft) will be deorbited in a few weeks.

Power levels of the magnitude estimated in the previous paragraph have been measured in a real orbital space experiment, the TSS-1R mission carried out on the Shuttle Orbiter in 1995. In that experiment, a large Italian spacecraft, 1.6 m in diameter, was deployed upward from the Shuttle Orbiter at the end of a conducting copper wire tether covered with electrical insulation. As the tether was slowly deployed upwards, a series of measurements were made of the open circuit voltage induced in the tether by its motion through the Earth's magnetic field. The voltage between the end of the tether and the Orbiter ground varied from zero volts at the start to 3500 V when the amount of tether deployed approached its maximum length of 20 km. Periodically, the end of the tether was connected either to one of two different electron guns, which supplied contact to the surrounding space plasma, or to the Orbiter ground. The bare surfaces of the Shuttle Orbiter proved to be a surprisingly good plasma contactor via a combination of ton collection and secondary electron emission. The current flow through the tether was deliberately limited by control circuits and the current capacity of the electron guns to about 0.5 amperes, but power levels of 1800 Watts were reached.

The tether was intended to have a fully deployed length of 20 km, but at a deployed length of 19.5 km, when about 3500 V was being induced at the end of the tether inside the Orbiter reel mechanism, a flaw in the insulation allowed an electrical spark to jump in an uncontrolled manner from the tether to the Orbiter ground. With no control circuits to keep the current level down to 0.5 amperes, the current flow jumped to 1.1 amperes, and the total power generated was P=3850 Watts Most of this energy went into the electrical arc, which burned through the tether, causing it to break and halting the experiment. This experiment showed that large areas of bare conducting material, such as that provided by the 8 square meter area of the Italian spacecraft at one end of the tether and the very large surface area of the Shuttle Orbiter spacecraft at the other end of the tether, can collect and emit amperes of current, while thousands of volts of potential can be generated by sufficiently long tethers moving at orbital speeds.

Thus, both theory and experimental data collected in the space environment indicate that significant amounts of electrodynamic drag force can be obtained from a low mass conducting tether attached to a host spacecraft, provided the ends of the conductor can exchange sufficient numbers of electrons with the surrounding space plasma.

Experimental data from the TSS-1R data also produced the amazing result that the efficiency of a bare metal surface in "contacting" the space plasma is many times better than the standard theory would predict. The 8 square meters of bare surface area of the Italian spacecraft were sufficient to collect the 1.1 A of electron current. This amount of area is easily replicated by a few hundred meters of bare wire, considering that the effective collection diameter around the wire is the Debye length, which is a few centimeters at the typical values for space plasma density and temperature.

Because of this result, that a bare wire can easily collect electrons, Les Johnson, Nobie Stone, Chris Rupp, and others at NASA Marshall Space Flight Center have formed a team, which includes the present inventors, which is embarked on a new flight experiment. The experiment is scheduled for a piggy-back flight on a Delta II launch of an AF Global Positioning Satellite in early 2000. The goal of the experiment is to demonstrate that electrodynamic drag from a wire moving at orbital speeds through the Earth's magnetic field will create a large enough electrodynamic drag force to deorbit the Delta II second stage, whose mass is greater than 1000 kilograms, in a few weeks. This is essentially a demonstration of the Loftus electrodynamic drag deorbit concept and the first step in the development of a Terminator Tether™.

The ProSEDS (Propulsion Small Expendable-tether Deployer System) mission will use a 5 km long copper wire conductive tether massing 18 kg connected to a 20–35 km long nonconducting tether, which is in turn connected to a 25–40 kg ballast mass. The total of 25–40 km of tether length and the 25–40 kg ballast mass on the end will provide enough gravity gradient force to keep the tether aligned near the zenith, so that the direction of the current in the tether is at right angles to both the direction of the spacecraft motion in the nominal EW direction and the Earth's near-equatorial magnetic field in the nominal NS direction.

An important feature of the ProSEDS experiment is that it is designed to be completely self-powered. It uses a battery to initiate deployment and to power up the plasma contactor, but once current is flowing through the tether, some of the power is tapped off and used to recharge the battery. The battery, in turn, powers the current control electronics, the telemetry, system, and the plasma contactor. The ProSEDS mission will not be designed to allow ground control changes in operation, primarily because of the increase in complexity and cost associated with that option.

The present invention is the use of a small, low-mass deployer/controller package containing a large collecting area, short length, multiline space tether, such as a Hoytape mesh made of aluminum wire, as a "Terminator Tether™" for a constellation spacecraft. The Terminator Tether™ would be deployed when the host spacecraft is no longer working or no longer wanted. The electrodynamic drag from the Terminator Tether™ would rapidly remove the unwanted spacecraft from the constellation and a few weeks later complete the deorbit of the host spacecraft from space by burnup in the upper atmosphere of the Earth. For a Terminator Tether™ to be of maximum usefulness for constellation spacecraft, it would be desirable to minmize the mass and the length of the tether. A lower added mass means more mass for revenue producing transponders, while a shorter tether length means a lower collision cross-section Area-Time Product during deorbit.

FIG. **6** shows a spacecraft **600** having a state vector **602** that causes the spacecraft to move across magnetic field lines **601**. Spacecraft **600** has a conductive tether **603** attached to it by tether deployer and control system **605**. The outer end of tether **603** is attached to tether end mass **607**. Spacecraft **600** also has an attached electron emitter means **613**.

In FIG. **6**, spacecraft **600** has a velocity and direction defined by state vector **602**. As spacecraft **600** moves it causes conductive tether **603** to cut magnetic field lines **601**. As this happens the distal end of the conductive tether collects electrons, shown as arrows **611**, from the space plasma. Electrons **611** move through the conductive tether **603**, are passed through a resistive load, not shown, in control system **605**, and are emitted back into the space plasma as electrons **615** from electron emitter **613**. This produces an electrodynamic drag in the direction shown by arrow **609**.

As is discussed in detail in the electrodynamic drag analysis below, especially in that sections of the analysis titled "Optimization of Tether Angle", the maximum electrodynamic drag of the tether is achieved when the angle, shown as the Greek letter τ in FIG. **6**, is 35.26 degrees, trailing, to the direction of the magnetic field lines. This angle may be maintained by a feedback control circuit that maximizes the electrodynamic drag of the tether system, as is discussed in detail below. The tether structure **603** is a Hoytether having a length of about 2 to 5 kilometers. The use of the 35.26 degree angle to the magnetic field reduces the tether instability, allowing the use of a short tether which will have a small Area-Time-Product. This will minmize the possibility that the tether will impact another space object during its use.

In FIG. **7**, spacecraft **700** has a state vector **702** across magnetic field lines **704**. Conductive tether **706** is attached to spacecraft **700** by tether deployer and control system **708**. The distal end of tether **706** is attached to a tether end mass **710**. Spacecraft **700** has an electron emitter means **714**.

Functionally, electrons **712** flow from the space plasma into conductive tether **706**, are passed through a resistive load in control unit **708** and are emitted into the space plasma by electron emitter **714** as free electrons **716**. As is discussed in detail in the analysis below, this produces an electrodynamic drag on satellite **700**, which causes it to deorbit.

In FIG. **7**, spacecraft **700** is rotating with an angular velocity indicated by arrow **718**. This rotation causes a centrifugal force **720** to place tension on conductive tether **706**. This force **720** places tension on the tether **706** in a direction that counters tether instability. The Tether **706** may be at any angle to the magnetic field while the rotation of the tether-satellite system is producing this useful tension. FIG. **7** shows the angle to be 35.26 degrees, which is optimum, but any angle will work.

FIGS. **8***a* and **8***b* show a powered Terminator Tether™. In FIG. **8***a* the spacecraft **800** has a state vector **802** that causes it and its associated conductive tether **806** to move across magnetic field **804**. Tether **806** has an end mass **808** that is proximate a plasma contactor **810**. Just as was discussed in the embodiment of the present invention shown in FIG. **6** and FIG. **7**, an electric current moves through the circuit formed by the space plasma, the plasma contactor **810**, the conductive tether **806**, and the electron emitter **815**, thence back into the space plasma as electrons **816**. This creates an electrodynamic drag on the tether in the direction shown by arrow **818**.

In FIG. **8***b*, similar numbers indicate similar structures. In FIG. **8***b*, however, an electric power source, not shown, in spacecraft **800** provides electrons to conductive tether **806**. The electrons are emitted from the end **812** of the tether **806**. Electrons are collected to from the space plasma **814** by contactor **815**, thus completing the electric circuit. The result is an electrodynamic force on tether **806**, and therefore on spacecraft **800**, in the direction show by arrow **820**.

Spacecraft **800** in FIG. **8***b* may be rotated as is taught in the embodiment of the invention shown in FIG. **7**, above, to allow the control system to time the application of electric current to the tether **806** to cause force **820** to be exert force in any desired direction along the circle made by the rotating tether. This allows the state vector of the spacecraft to be modified to raise or lower the spacecraft's orbital altitude, or to otherwise usefully change its orbital elements.

FIG. **9** show an embodiment of the present invention wherein the conductive structure of a satellite is used as the tether. In FIG. **9**, a spacecraft **900** which has a state vector

901 and is moving across magnetic field **903**, has two attached solar panels, **902** and **904**. Solar panels **902** and **904** have conductive aluminum frames **908** and **906**, respectively. Frame **906** is electrically and mechanically connected to plasma contactor **912**. Frame **908** is electrically and mechanically connected to electron emitter **910**. As spacecraft **900** moves across magnetic field **903**, electrons from the space plasma **914** flow through contactor **912** and frame **906** to the body of spacecraft **900**, where the current flows through a resistive load, not shown, and then into frame **908** and electron emitter **910** to the space plasma **916**, thus completing the circuit. This creates an electrodynamic drag on spacecraft **900**. If the power output from solar panels **902** and **904** was directed to flow into the frames, **906** and **908**, then the electrodynamic interaction with the space plasma would cause a useful force to be impressed on spacecraft **900**, as was discussed in connection with FIG. **8** above. The spacecraft may be rotated and/or oriented to a desired angle with the magnetic field lines, as was also discussed above.

FIG. **10** shows an embodiment of the present invention wherein the plasma contactor and the resistive load are structurally part of the conductive tether. In FIG. **10** spacecraft **1000** has a state vector **1001** that causes it to pass through magnetic field **1003**. Spacecraft **1000** has a tether control and deployment system **1005** that is connected to a conductive tether **1007** having an end mass **1013**. A contactor portion **1015** of the conductive tether **1007** near end mass **1013** is adapted to contact the space plasma so as to receive or emit electrons. This may be the bare wire strands of a wide Hoytether, or it may be any other plasma contactor means that can be conveniently made electrically part of the Hoytether structure, such as points or metal fuzz. A second resistive portion **1009** of tether structure **1007** is adapted to be a resistive load. This may be done by making a portion of the tether structure from a material, such as nichrome steel wire, that has suitable electrical resistance The large surface area of the Hoytether provides an excellent radiator structure into the three degree Kelvin radiation sink of outer space.

FIG. **11** shows an alternative embodiment of the load resistance/radiator structure of the present invention. In FIG. **11**, a biline Hoytether **1002** is attached to its control and deployer system **1100** on a spacecraft, not shown, and to a tether end mass **1004**. A resistive load, **1006** is woven into the Hoytether structure, whereby this load **1006** and the section of the Hoytether **1002** into which it is woven act together as a thermal radiator allowing photons **1008** to radiate into the thermal sink of outer space.

The following detailed analysis of the present invention will help those skilled in the art to better understand and use the present invention.

Electrodynamic Drag Analysis:

The following is an optimization analysis of the electrodynamic drag produced by a conducting tether deployed from a host spacecraft that it is to deorbit. The force and torque diagram used in the analysis is shown in FIG. **12**, which shows the forces and torques on an upward deployed conducting tether due to the motion of the host spacecraft through the magnetic field of the Earth.

Physical Constants and Assumptions:

The analysis that follows will use the following physical constants and assumptions:

Newton's gravitational constant $G=6.67\times10^{-11}$ $m^3/kg\text{-}s^2$.

Mass of Earth $M_e=5.976\times10^{24}$ kg.

Radius of Earth near equator $R_e=6378$ km.

Assumed host spacecraft altitude h=622 km.

Assumed host spacecraft orbital radius a=7000 km.

Host spacecraft orbital velocity $w=\omega a=[GM_e/a\ ]^{1/2}=7546$ m/s.

Vertical gravity gradient at spacecraft $2\Gamma=2GM_e/a^3=2.32\times10^{-6}\ s^{-2}$.

Centrifugal gradient at spacecraft $\omega^2=GM_e/a^3=1.16\times10^{-6}\ s^{-2}$.

Combined gradient at spacecraft $3\Gamma=3GM_e/a^3=3\omega^2=3.49\times10^{-6}\ s^{-2}$.

Magnetic field of Earth (tilted dipole approximation):

Magnitude $B_o=35\ \mu T=0.35$ gauss.

Angle between magnetic pole and spin pole 11.5°.

Field components at spacecraft with altitude a and angle β between radius vector of spacecraft and magnetic equatorial plane.

Horizontal $B_H=B_o(R_e/a)^3\cos\beta=26.5\ \mu T\cos\beta$.

Vertical $B_V=2B_o(R_e/a)^3\sin\beta=52.9\ \mu T\sin\beta$.

Electrodynamic Tether Constants and Assumptions:

The electrodynamic tether is assumed to be made of a conducting metal, and have a length L, density d, resistivity r, and cross-sectional area A that is constant along the length of the tether. If the tether is a single round wire of diameter D, then the cross-sectional area is $A=\pi D^2/4$. Because of the micrometeorite and space debris hazard, however, it is likely the tether will be made up of redundantly interconnected multiple lines whose individual cross-sectional areas add up to A. Given these assumptions, the tether mass is then $m_T=dLA$, while the end-to-end tether resistance is $R_T=rL/A=rdL^2/m_T$.

Specific Conductivity Parameter:

The choice of the metal conductor to be used in a space tether is determined by a combination of low resistivity (high conductivity) and low density, with cost, strength, and melting point as secondary considerations for certain applications. Copper has a resistivity r=17.0 nΩ-m, a density d=8933 kg/m, and a "specific conductivity" of 1/rd=6,585 $m^2/\Omega\text{-}kg$. Aluminum has a resistivity r=27.4 nΩ-m, which is significantly greater than that of copper, but it has a much lower density of d=2700 kg/m^3. As a result, aluminum's "specific conductivity" of 1/rd=13,500 $m^2/\Omega\text{-}kg$ is twice the conductivity per unit mass of copper. Silver, because of its higher density and higher cost, is not competitive as an electrodynamic space tether even though its resistivity of 16.1 nΩ-m is slightly better than that of copper. An alternate candidate material would be beryllium, with a resistivity r=32.5 nΩ-m, density d=1850 kg/m^3, and a "specific conductivity" of 1/rd=16,630 $m^2/\Omega\text{-}kg$, slightly better than that of the much cheaper aluminum. Beryllium also has a higher melting point at 1551 K than aluminum at 933 K, so some of its alloys may be a preferred material for some electrodynamic applications despite its higher materials cost. Unfortunately, despite decades of metallurgical research by the nuclear power industry, highly ductile alloys of beryllium have not been found, so it is difficult to pull beryllium into wire. As a result, because of its high specific conductivity, low cost, and ready availability in ductile wire form, it will be assumed for this analysis that the electrodynamic tether will be made of aluminum wire.

Typical Resistance Values:

To be economically competitive, the mass of the tether needs to be a small fraction of the mass of the host spacecraft it is required to deorbit. Since a typical constellation spacecraft has a mass of about 1000 kg, a typical Terminator Tether™ with a mass that is 2% of the host spacecraft mass would consist of a deployer/controller package with a mass $m_D=10$ kg, containing an aluminum tether with a mass $m_T=10$ kg with a volume of $LA=m_T/d=3.70\times10^{-3}\ m^3$. If this 10 kg of aluminum were formed into a tether with a length of L=2 km and a cross-sectional area of A=1.85 mm^2, then the end-to-end resistance of the tether would be $R=rL/A=rdL^2/m_T=29.6\ \Omega$ A longer tether would have a proportionately smaller cross-sectional area and a higher resistance; for example, a 5 km long tether with the same mass would have a resistance of 185 Ω.

Orbit Inclination Assumption:

In order to make the remainder of the analysis mathematically tractable, it will be assumed that the orbit of the host spacecraft is circular and above the magnetic equator, so that the angle between the radius vector to the spacecraft and the magnetic equatorial plane is $\beta=0$ degrees. In this orbit, the velocity v of the spacecraft with respect to the magnetic field is the orbital velocity w less the rotational velocity of the magnetic field at the orbital radius a due to the once per day rotation of the Earth, or:

$$v=W-2\pi a/1\text{day}=(7546-509)\text{m/s}=7037\text{m/s}$$

This equation also shows why electrodynamic drag will not be useful for removing geostationary spacecraft from orbit. At the geostationary orbital radius of a=42,200 km, the relative velocity of the spacecraft and the rotating magnetic field of the Earth is zero.

With this assumption of an orbit above the magnetic equator, the vertical component of the Earth's magnetic field is zero and the horizontal component of the Earth's magnetic field is at right angles to both the local vertical and the direction of motion of the spacecraft. The total magnetic field seen by the host spacecraft and its Terminator Tether™ is then orthogonally horizontal and has the magnitude:

$$B=B_H=B_o[R_e/a]^3 \cos \beta=26.5\mu T.$$

Where for simplicity the subscript H will be dropped for the remainder of this analysis.

This orbit, with its inclination of 11.5° with respect to the spin equator, will not stay in the plane of the magnetic equator, but will vary ±11.5° above and below it as the Earth rotates, causing a variation in magnetic field strength of ±0.5 μT, as well as a slight variation in angle. This 2% variation is negligible in terms of the other uncertainties in this analysis. It is not until the orbital inclination of the host spacecraft orbit reaches 60°, where cos 60°=0.5, that there is a significant drop in the expected magnitude of the electrodynamic drag forces calculated in this analysis.

Electromagnetic Drag Effects in Polar Orbit:

In many medium Earth orbit communication satellite constellations, there are a significant number of spacecraft at high inclinations and in nearly polar orbits. The high inclination spacecraft, with inclinations between 60° and 78.5°, will all have orbits that stay between the magnetic poles. Although the amount of electrodynamic drag will be significantly less than that experienced by spacecraft with orbits at lower inclinations, the direction of the induced electric fields in the tether will always be in the proper direction. If the tether is vertically upward, the outer tip of the tether will be positively charged and the bare wire in the tether will pull electrons out of the surrounding space plasma, while the electron emitter at the host spacecraft end will eject the electrons back into the space plasma to complete the circuit.

For spacecraft in near polar orbits with inclinations between 78.5° and 90°, however, there will be much more drastic variations. First of all, for a spacecraft in a 90° orbit that happens to pass directly over the magnetic poles, there is no horizontal component of the magnetic field when it is passing over one of the magnetic poles, so no voltage is generated in the tether during that part of the orbit, while the horizontal component of the magnetic field near the magnetic equator, while strong in magnitude, is along the spacecraft velocity vector, so no voltage is generated in the tether in that part of the orbit either. As a result, there will be negligible electrodynamic drag experienced by the host spacecraft during that particular orbit. The Earth is rotating, however, and the magnetic pole is rotating with it. A few orbits later, the host spacecraft will be passing over the Earth's spin pole at a point where the horizontal component of the magnetic field is exactly at right angles to the direction of motion of the spacecraft, so the full voltage is generated in the tether. When passing over the spin pole, the spacecraft radius vector is at an angle of 11.5° from the magnetic pole and at an angle $\beta=78.5°$ away from the magnetic equatorial plane. With these assumptions, the magnitude of the horizontal component of the magnetic field at the Earth's spin pole is a respectable:

$$B=B_o[R_e/a]^3 \cos 78.5°=5.28\mu T$$

or 20% of the maximum value experiences by spacecraft orbiting above the magnetic equator. This value will drop slightly as the orbit continues, then build back up as the spacecraft passes over the opposite pole. As the Earth continues to rotate, bringing the magnetic pole again under the orbit, and the interaction of the tether with the horizontal component of the magnetic field again drops to zero. The average coupling of a tether to the Earth's magnetic field over all polar trajectories has been calculated to be 12.3 percent.

A problem experienced only by spacecraft with orbit inclinations greater than 78.5°:

The spacecraft will no longer be traveling from west to east with respect to the magnetic field axis, but will have a retrograde motion as it moves through the magnetic field. As a result, the voltage generated by the motion of the tether through the Earth's magnetic field will switch direction. The outer tip will be negatively charged and will attempt to collect ions, which is a much less efficient process than collecting electrons.

There are a number of solutions to this problem. The first is to increase the mass and length of the tether supplied to a spacecraft assigned to a polar orbit, so that higher voltages, currents, and drag are generated during the limited times the spacecraft is passing over the poles in the right direction. The second is to supply a tether with plasma contactors at both ends that can emit electrons from either end, allowing the current to flow either way, depending upon which direction the spacecraft is passing around the magnetic pole. The third is to utilize the first number of passes to torque the orbit of the spacecraft until the orbit inclination has been shifted below 60°, then turn on the electrodynamic drag full time to deorbit the spacecraft from this more favorable orbit inclination. This orbit torqueing maneuver is accomplished by activating the electrodynamic drag mechanism only when the magnetic field orientation is such that a strong out-of-plane component of force is created. This orbit torqueing maneuver can be augmented by switching to a propulsion mode, where power saved in the batteries during the drag force mode is pumped back into the tether when the magnetic field is in the opposite direction, applying electrodynamic propulsion to torque the orbit even further. With the tether at a large and stable trailing orientation, the coupling to the magnetic field can be significant to a vertical tether.

In summary, spacecraft in near-polar orbits might take longer to bring down, and might have to utilize specially designed Terminator Tethers™ that might cost and mass more than the simpler Terminator Tethers™ usable in lower inclination orbits, but a Terminator Tether™ can still remove a spacecraft from a polar orbit when desired.

The inventors now present a detailed analysis and optimization of a typical Terminator Tether™ attached to a typical host spacecraft in a typical low inclination orbit.

Electromotive Generation of Voltage and Current in the Tether:

When an object is moved at a velocity v through a magnetic field B, an electric field is generated in the frame of reference of the moving object given by:

$$E=v\times B=vB$$

where the magnetic field B of the Earth, being mostly tangent to the Earth's surface in the north-south direction, is at right angles to the velocity vector v of the spacecraft, assumed to be orbiting in a generally west-east direction. The direction of the electric field E will be at right angles to both v and B, or along the local vertical. It should be noted that this electric field exists in the moving frame of reference because a moving magnetic field creates an electric field. No object actually has to be there, but if it is, then the relative motion of the magnetic field of the Earth will not only apply magnetic forces to whatever material the object is made out of, but electric forces too.

Note also that the velocity used in this equation is the relative velocity between the object and the magnetic field. Because the Earth's magnetic field rotates with the Earth, the motion of the magnetic field must be subtracted from the orbital velocity of the object to obtain the relative velocity.

Voltage generation in a Conducting Tether:

If the moving object is a long conducting wire of length L, the electric field E, generated in the wire produces a voltage V between the opposite ends of the wire given by:

$$V=E\bullet L=EL\cos\tau=vBL\cos\tau$$

where τ is the angle between the length vector L of the tether and the electric field vector E, assumed to be in the vertical direction at right angles to the velocity vector v in the plane of FIG. **12** and the magnetic field vector B out of the plane of FIG. **12**. A typical value for the voltage level built up in a vertically oriented tether with length L=5 km and τ=0, moving at a velocity of v=7037 m/s through the Earth's horizontal magnetic field of strength 26.5 μT, is 932 V, or 0.186 V/m. Spacecraft in higher inclination orbits would experience somewhat smaller electric fields. For calibration, the voltage measured between the ends of the 19.5 km long TSS-1R tether was 3500 V, or 0.175 V/m.

Contacting the Space Plasma:

Although a voltage will build up between the ends of the conducting tether, no current will flow unless the circuit is completed. The circuit cannot be completed with another wire, for it too will have a similar voltage generated in it by the moving magnetic field. Fortunately, empty space is not empty, and in near-Earth regions not too distant from the Earth's atmosphere there exists highly electrically conductive space plasma, kept partially ionized by radiation from the Sun. The electron and ion density varies from the dark to light side, with altitude, with season, with sunspot cycle, with contamination level, etc. but it typically varies from 10^{11} to 10^{13} electrons/cc.

Fortunately, it has been found that if a bare conductive surface such as the spherical Italian spacecraft in the TSS-1R experiment, or the long bare wire to be used in the ProSEDS experiment, or a multiline conducting wire Hoytape mesh, is charged to a few hundred volts, the bare conductor will readily pull electrons out of the space plasma. So all that is needed to complete a connection to the space plasma at the positively charged (upper) end of the tether is a sufficient large area of uninsulated conductor.

It is more difficult to eject electrons from a wire or to collect positive ions from the space plasma. Although it is conceivable that a very large area at the other end of the tether could collect enough ions to complete the circuit as was demonstrated during the TSS-1R mission when the Shuttle orbiter was found to be an adequate plasma contactor for over an amp of current, the present method chosen is to use an electron emitter of some sort, either a hot cathode, a plasma cathode or contactor, a field-emission device, or something similar. Once provisions have been made at both ends of the tether to allow the flow of electrons out of one end of the tether and into the other end, and the altitude of the host spacecraft is not too high, then there will be sufficient conductivity in the space plasma surrounding the host spacecraft to allow current to flow through the tether.

Current Flow In The Tether:

The amount of current I flowing through the tether depends upon the total resistance R in the circuit. This resistance will consist of three components, the effective resistance of the plasma, the resistance of the tether, calculated earlier as $R_T=rL/A=rdL^2/m_T$, and a control resistor R_C, which will be varied as needed to optimize the Terminator Tether™ performance. There will also need to be a parasitic load on the current in the form of a charging device to charge some batteries. The batteries in turn will be used to power the control and communication circuits, and drive the electron emitting devices at the negative end of the tether. A well-designed Terminator Tether™ will thus be completely self-powered, except for an initial charge in the batteries to provide electrical power for the deployment and startup procedure. For simplicity of analysis it will be assumed that this battery charging load, which absorbs power like a resistor, but which stores it and uses it later instead of dissipating it immediately as heat, is included in the control resistor R_c. Normally, this load would act as a "base resistance" below which the control resistor could not be lowered, but since the charging circuit can be turned off when desired, and operations continued without interruption using the power stored in the batteries, it will be assumed that the control resistor can be taken to near zero value in those circumstances where the space plasma conductivity is low, or the magnetic field is in the wrong orientation and the voltage being generated in the tether is not large. Under these circumstances, lowering the control resistor to near zero allows a much higher current to flow for a given generated voltage, thus increasing the power being dissipated in the tether and maintaining a high level of electrodynamic drag on the host spacecraft.

A properly designed Terminator Tether™ will have plenty of bare metal area for electron collection at the positive end, while the electron emitters at the other end are efficient in terms of emitting large electron currents at low voltages and therefore low powers, while at the same time the mass, length, and area of the conducting tether have been made such that the resistance of the tether is moderately high. Under these conditions, the effective resistance of the space plasma will be much less than the design resistance of the tether. To make the mathematics more tractable it will be assumed that the plasma resistance is can be neglected and that the voltage available to drive the tether is the full voltage generated by the moving magnetic field. Although voltage will be needed to power the electron emitter, whatever its form, it will be assumed that the required voltage and power will be supplied by the batteries. The batteries in turn will be powered by the battery charging circuit, whose effective resistance is included in the control resistor (except for those short periods when the plasma or magnetic field interactions are weak).

Given all these assumptions concerning the total resistance in the circuit, the current I flowing through the tether is then given by:

$$I=V/R=vBL\cos\tau/(R_C+rdL^2/m_T)$$

A typical current level can be estimated by assuming that the control resistance R_C should be about the same size as the tether resistance R_T, which for an aluminum tether with resistivity r=27.4 nΩ-m, density d=2700 kg/m^3, length L=5 km, and mass m_T=10 kg, is R_T=185 Ω, giving a total resistance, including the control resistance R_C, of R=370 Ω. Thus the current flowing though a tether of length L=5 km, generating a voltage of V=932 V, would be I=V/R=2.52 A.

Power Dissipation Analysis:

The induced current I flowing through the tether resistance R_T will generate heat in the wire, which will be radiated into space and lost. That radiated energy must come from somewhere. There is also power taken out of the current flow by the battery charging circuit and ultimately dissipated. In order to conform to energy conservation laws, this power and energy must come from a decrease in the total kinetic and potential energy of the host spacecraft, causing it to deorbit. Set forth below is a detailed, optimized force analysis which will calculate the drag force on the host spacecraft. In this section, by using some simplifying assumptions, it is possible to produce a general argument based on energy conservation laws, which will illustrate the broad scope of the present invention.

For this energy conservation analysis it will be assumed that the plasma resistance is small compared with the tether resistance, and that the control resistance is equal to the tether resistance:

$$R_C=R_T=rL/A=rdL^2/m_T$$

Assume that the ballast mass at the end of the tether is a large piece of the defunct host spacecraft, such as a solar panel, antenna, or battery pack, so that the gradient force is large and the tether is always oriented along the vertical so that the angle τ=0°. Also assume the spacecraft is in an orbit above the magnetic equator and thus is moving at right angles to the Earth's magnetic field, so that the angle between the orbital velocity vector and the magnetic field vector is 90°, and the electric field vector is in the vertical direction, aligned perfectly with the tether length vector. Under these ideal conditions, the voltage between the ends of the tether is given by:

$$V=E\bullet L=(v\times B)\bullet L=vBL$$

The current in the tether is then just:

$$I=V/(R_C+R_T)=vBm_T/2rdL$$

The power dissipated as ohmic heating in the tether is then given by:

$$P=IV=(vB)^2m_T/2rd$$

This equation shows the interesting result that the power dissipated does not depend upon the length or the area of the tether (within reason), but only the mass of the tether m_T, the resistivity r and density d of the tether material, and the velocity v of the conducting tether through the Earth's magnetic field B.

For a typical aluminum tether of mass m_T=10 kg, the power dissipated is an impressive P=2350 W. Even if only a small fraction of this power is dissipated in a real system, the kinetic energy of the host spacecraft would suffer a significant energy loss with time.

Orbital Energy Extraction Analysis:

The total energy U of a spacecraft of mass M in orbit around the Earth consists of two components, its positive orbital kinetic energy and its negative gravitational potential energy. If a circular orbit of altitude h and radius a=R_e+h is assumed, then the total energy of the spacecraft moving at a velocity w=$(GM_e/a)^{1/2}$ is:

$$U=+Mw^2/2-GMM_e/a=-GMM_e/2a$$

The system will be dissipating energy in the tether to decrease the energy U of the unwanted spacecraft from its relatively low negative value in a high Earth orbit to a greater negative value in a lower Earth orbit. To give a specific example, an unwanted spacecraft with a mass of M=1000 kg (a metric ton) in an orbit with an altitude of h=1000 km and a high orbital radius of a(H)=R_e+h=7371 km, then its (negative) total energy is:

$$U(H)=-GMM_e/2a(H)=-27.1\text{ GJ or }-27.1\text{ MJ/kg}$$

It is desired to lower the spacecraft to an orbit with an altitude just outside the atmosphere of h=200 km or a lower orbital radius of a(L)=R_e+h=6571 km, where atmospheric drag will finish the job. The total (negative) energy of a metric ton spacecraft at 200 km altitude is:

$$U(L)=-GMM_e/2a(L)=-30.4\text{ GJ}$$

Thus, the amount of energy needed to be dissipated in order to move the 1000 kg spacecraft from a 1000 km orbit with a total energy U(H)=−27.1 GJ down to a 200 km orbit with energy U(L)=−30.4 CJ is:

$$dU=U(H)-U(L)=3.3\text{ GJ.}$$

The decay time T of a metric ton spacecraft moving from a 1000 km altitude orbit to a 200 km altitude orbit with an energy difference of dU=3.3 GJ, when its energy is being dissipated at a power of P=2350 W by a typical aluminum tether massing just 10 kg or 1% the mass of the spacecraft, is found to be T=dU/P=16 days.

The actual decay time will be longer than this. If the electrodynamic drag force is very large, and becomes larger than the gravity gradient forces pulling on the ends of the tether, then the tether will tend to align itself along the magnetic field lines instead of across them, and the drag force will decrease because of the small angle between the conductor length and the magnetic field lines. The tether current will need to be controlled until the angle of the tether settles into an angle determined by the balance between these two forces. These electrodynamic torque vs. gradient torque dynamic interaction effects are discussed in the next section.

Force and Torque Balance Analysis:

It is now possible to calculate the forces and torques on the tether. It is also possible to use the fact that the electrodynamic and gravity forces and torques on the tether must balance each other out to calculate and teach some optimum values for some of the Terminator Tether™ parameters.

Electrodynamic Force and Torque:

As discussed above, both theory and experiment show that: provided the conducting tether is moved rapidly through the Earth's magnetic field in order to generate a voltage across it, and provided good contact is made with the space plasma, the conducting tether will have a current flowing through it. When a wire (moving or not) carrying a current I is embedded in a magnetic field B, there will be an electrodynatnic force F_E generated on each element of the wire. The electrodynamic force will be at right angles to the magnetic field vector and the length vector of the wire element, with a magnitude given by:

$$F_E=J\times B=ILB$$

where B is the horizontal component of the magnetic field, which is perpendicular to the assumed magnetic equator orbit plane, while the tether length vector L is assumed to lie in the orbit plane. If, as will be the case most of the time, the electron current is leaving the space plasma and entering the tether along the length of the tether, then IL needs to be replaced with an integral of the current along the length of the tether.

Note that the electrodynamic force amplitude or direction is not directly dependent on the motion of the tether through the Earth's magnetic field. The electrodynamic force would be the same if the tether were not moving and the current was being supplied by a battery. Since the current I is a function of the orbital velocity, however, there is a secondary dependence of the electrodynamic force magnitude on the orbital velocity, but not its direction. The electrodynamic force is always at right angles to the conductor, and stays at right angles to the conductor as the angle τ varies, as shown in FIG. **12**.

Assuming that the electrodynamic drag force is applied uniformly along the length of the tether, it is possible to make the simplifying assumption that the integrated force is effectively applied at right angles to the center of mass of the tether at the point L/2 as shown in FIG. **12**. The electrodynamic torque on the tether is then:

$$T_E=F_EL/2=IBL^2/2=vB^2L^3\cos\tau/2(R_C+rdL^2/m_T)=vB^2L^3\cos\tau/2R$$

Gravity Gradient Forces and Torques:

When a tether and its ballast end mass are deployed from a host spacecraft, the gravity gradient force field of the Earth, combined with the orbital centrifugal gradient force field, will cause the tether to deploy either up or down from the host spacecraft. The direction desired depends on which end of the tether is connected to the electron emitter. Normally, the electron emitter will be on the end attached to the host spacecraft, in which case the desired direction of deployment will be upward so that the induced voltage in the tether will produce an excess of electrons at the electron emitter end of the tether. The desired upward direction is chosen by having the deployer eject the ballast mass in the upward direction. Once the ballast mass has been started in that direction, the centrifugal force due to the orbital motion of the ballast mass will cause the ballast mass to continue to accelerate in the upward direction until it is brought to a halt by the full deployment of the tether.

If there were no electrodynamic or atmospheric drag, the equilibrium direction of the tether would be exactly along the vertical, since the combined gradient field is a maximum in that direction. Because a significant amount of electromagnetic drag is expected, the actual angle of the tether with respect to the local vertical will be at some angle τ, lagging behind the spacecraft motion in the plane of the orbit, as shown in FIG. **12**. In the following analysis shows that there is an optimum angle for τ that produces the largest electrodynamic drag force on the host spacecraft without producing tether instability.

The combined vertical gravity gradient and centrifugal gradient field 3Γ acting on the ballast mass m_B at the end of the tether of length L will produce a gradient force F_{GB} given by:

$$F_{GB}=-3_{\Gamma}m_BL\cos\tau$$

The strength of the force depends not only on the ballast mass m_B and the strength of the gradient field 3Γ, but also the component along the radial direction of the distance of the ballast mass from the center of mass, which is L cos τ. This force acts in the vertical direction along the radius vector leading from the ballast mass away from the center of the Earth. The amount of gradient force is not large. For a ballast mass of m_B=10 kg and a tether length of L=5 km, the gradient force is about 0.175 N.

As can be seen in FIG. **12**, the component of this gradient force that is at right angles to the tether, given by $F_{GB}\sin\tau$, will produce a torque T_{GB} on the tether that tends to restore the tether toward the vertical, lessening the angle τ.

$$T_{GB}=LF_{GB}\sin\tau=-3_{\Gamma}m_BL^2\sin\tau\cos\tau$$

The tether mass m_T also contributes to the gradient force and torque. If it is assumed that the tether has a uniform cross section, then it is possible to replace the distributed mass of the tether with an equivalent point mass m_T placed at the center of mass of the tether, which is the point L/2 along the tether, and a distance L/2 cos τ in the radial direction. The gradient force due to the tether mass is then:

$$F_{GT}=-3/2_{\Gamma}m_TL\cos\tau$$

While the gradient torque is:

$$T_{GT}=-L/2F_{GT}\sin\tau=-3/4_{\Gamma}m_BL^2\sin\tau\cos\tau$$

The total gradient torque attempting to restore the tether to its vertical orientation is then:

$$T_G=T_{GB}+T_{GT}=3_{\Gamma}(m_B+m_T/4)L^2\sin\tau\cos\tau$$

It is important to notice the variation of the total gravity gradient torque as the tether angle τ is varied. Since the gradient force is always in the radial or vertical direction, there is no torque on the tether when the tether is vertical, as is the case when there are no aerodynamic or electromagnetic drag forces. Once the drag forces become important and start to apply torque to the tether, increasing the tether angle τ, those drag torques causing an increase in tether angle τ will be opposed by a rising gradient torque which will attempt to decrease the tether angle. For small tether angles, the gradient torque increases first linearly with τ, then as sin τ, since cos τ is near unity for small τ, then at τ=45° the gradient torque reaches its maximum, where sin τ=cos τ=0.707 and sin τ cos τ=0.50. When this angle is reached, the tether is a point of catastrophic instability, for if there is a further increase in the electrodynamic drag force, causing the angle τ to become greater than 45°, the gradient torque, instead of growing stronger to counteract the increased drag torque, will become weaker and the tether angle will go rapidly to 90°.

To restore control to the tether angle if the instability occurs, it will be necessary to turn off the electrodynamic drag forces by shutting off the current flow through the tether. The τ=90° position for the tether and ballast mass is a gravitationally unstable orientation. After a time, slight fluctuations in the gravity field will allow the gradient force to slowly take over and restore the tether to the vertical orientation, which, unless it can be controlled in some way, is equally likely to be up or down. It would therefore be desirable to maintain control of the tether angle so as to avoid the tether angle getting into the region of instability.

Torque Balance on the Tether:

The angle τ of the tether is determined by a balance between the electrodynamic torque T_E attempting to increase the angle τ and the gradient torque T_G attempting to decrease the angle τ. Balance is achieved when the two torques are equal:

$$T_E=T_G=T_{GB}+T_{GT}$$

or:

$$vB^2L^3 \cos \tau/2R=3_{\Gamma}(m_B+m_T/4)L^2 \sin \tau \cos \tau$$

Simplifing and rearranging yields an equation giving us the angle τ at which torque balance occurs:

$$\tau=\arcsin[vB^2L/6_{\Gamma}(m_B+m_T/4)R]$$

The physical interpretation of this equation is that the maximum electrodynamic force that can be sustained on the tether is limited by the gradient force on the tether. It is possible to increase the electrodynamic force by decreasing the total resistance R of the tether (for example, by using a tether with a larger mass and a lower tether resistance), but if the tether resistance is too low, then the quantity in brackets becomes greater than unity and this equation has no solution, indicating that the tether has reached an angle where instability sets in.

To maintain control of the tether angle, it will be necessary to vary the control resistance of the tether to compensate for variations in magnetic field strength and direction, plasma density (which affects the plasma resistance), and other factors, and thereby maintain the tether at an intermediate angle where both the electrodynamic and gradient forces are at an appreciable level and balance each other.

Optimization of Tether Angle:

At first glance, it might seem that the optimum angle for the tether would be 45°, since at that angle the gradient torque is largest and therefore can counteract a larger electrodynamic drag force. However, since the 45° angle is the point where instability sets in, it is desirable to set the tether angle at some value below 45°. The optimum angle is that which maximizes the horizontal or drag component of the electrodynamic force. This optimum angle τ is derived from the equation for the horizontal component of the electrodynamic force, or the electrodynamic drag force, since it opposes the host spacecraft motion:

$$F_{ED}=F_E \cos \tau=6[m_B+m_T/4]\Gamma L \sin \tau \cos^2\tau$$

By setting the partial derivative□F_{ED}/□τ=0 and solving, it is possible to calculate that the optimum angle for the tether that gives the maximum electrodynamic drag force F_{ED}, while still keeping the tether torques balanced and under control, is τ=arctan(0.707)=35.26°. With this angle selected and maintained by varying the control resistor R_C to compensate for variations in plasma contact resistance and variatins in the strength and direction of the Earth's magnetic field B seen at the spacecraft, the tether experience the maximum stable value for the electromagnetic drag force of:

$$F_{ED}(\max,\tau=35.26^\circ)=2.31[m_B+m_T/4]\Gamma L$$

There are many ways to provide the sensing information needed to provide the feedback signals to the control resistor, but the simplest is to merely measure the drag acceleration on the host spacecraft with a set of accelerometers, and maximiize the force in the direction opposite to the host spacecraft motion. Another method would be to measure the current in the tether, and knowing the tether resistance and the amount of control resistance, calculate the power being extracted and maximize that value. Alternate methods would be to use an optical position sensor or GPS receivers at both ends of the tether to measure the angle of the tether or the position of the ballast mass with respect to the host spacecraft.

To make an estimate of the magnitude of drag force attainable, assume that a typical aluminum tether with a length of L=5 km, a tether mass of m_T=10 kg and a ballast mass of m_B=10 kg is being used. Then the maximum gradient force limited electrodynamic drag force is F_{ED}=0.167 N. The power being dissipated in the canoical tether at the angle τ, with $R_C=R_T=rdL^2/m_T=185\ \Omega$ is given by:

$$P=IR=[vBL \cos \tau]^2(R_C+rdL^2m_T)$$

which for an angle τ=35.26° results in a power dissipation of 1570 W. Thus, the thrust level per unit power obtained by the typical Terminator Tether™ would be about 0.106 N/kW. This number is comparable to the value of 0.148 N/kW estimated for the much heavier and longer TSS-1R tether.

Reconciliation of Energy and Force Analysis:

By a force and torque balance analysis an optimum angle for the tether has been discovered at which it is possible to obtain a maximum in the drag component of the electrodynamic force. There is also an additional component of the electrodynamic force, the component in the vertical direction, $F_{EV=FE}$ sin(τ), which is downward for an upwardly deployed tether. This component of force combines with the gravity force of the Earth to effectively allow the host spacecraft to orbit a little faster than normal for that orbital altitude. It does not contribute to the deorbiting of the host spacecraft. But since this vertical component of force is created by current running through the tether, and that current is creating heat and dissipating energy as it passes through the tether, there might be some concern that the force and torque balance analysis above does not conform to the law of conservation of energy.

The inventors will now show, in a very general manner, that no matter what the tether angle, the electrical power being dissipated in the tether is exactly equal to the power being lost by the slowing of the host spacecraft.

The "deorbit power" P_D that must be removed from a spacecraft moving at a velocity v when that motion is opposed by a drag force F_{ED} is:

$$P_D=v\bullet F_{ED}=vF_E \cos \tau=vILB \cos \tau=I[vBL \cos \tau]$$

But, since the voltage V induced across the tether of length L and tilt angle τ moving at a velocity v through a horizontal magnetic field B is

$$V=E\bullet L=EL \cos \tau=vBL \cos \tau$$

Therefore:

$$P_D=IV=P_E$$

And the deorbit power P_D extracted from the slowing of the spacecraft by the drag component of the electrodynamic force is always exactly equal to the electrical power P_E being dissipated as heat in the tether circuits, independent of the tether angle.

Optimization of Tether Mass Distribution:

If it is not possible to use a piece of the host spacecraft as ballast mass, then the mass of the ballast must be included in the Terminator Tether™ mass. It would be desirable to minimize the total Terminator Tether™ mass, since every kilogram saved means that another kilogram's worth of revenue-producing transponders can be added to the working payload of the host spacecraft. Given a total mass for the Terminator Tether™ and the mass of the deployer/controller unit, it is possible to optimize the mass distribution between the ballast mass and the tether mass to obtain a minimum total Terminator Tether™ mass. A well-designed Terminator Tether™ will also have most, if not all, of the deployer mass incorporated into the ballast mass.

Assume that the total Terminator Tether™ mass consists of the deployer/controller mass m_D, the tether mass m_T, and the ballast mass m_B, with $m_B > m_T > m_D$. Of the three mass components in the Terminator Tether™, two of them affect the electrodynamic drag performance. If it is assumed that the ballast mass is a factor X larger than the tether mass, or $m_B = Xm_T$, the maxinum drag force that can be obtained is now:

$$F_{ED}(\max)=2.31m_T(X+0.25)\Gamma L$$

If it is assumed that the control resistor has been adjusted so that this maximum value for the electrodynamic drag force is maintained as the motion of the spacecraft along its orbit moves the spacecraft into regions with different magnetic field strengths and plasma densities, then for the angle τ=35.26°, cos(35.26°)=0.817, and the maximum electrodynamic drag force in terms of the electrodynamic parameters will be:

$$0.817vB^2L^2/(R_C+rdL^2/m_T)=F_{ED}(\max)=2.31m_T(X+0.25)\Gamma L$$

or canceling out terms and rearranging:

$$(X+0.25)=0.353vB^2L/\Gamma m_T(R_C+rdL^2/m_T)$$

It is now possible to make the further simplifying assumption that to maintain control of the tether, the control resistor needs to be roughly the same size as the tether resistance or $R_C \approx rdL^2/m_T$. Using this assumption produces an equation for the optimum value for the ratio X of the ballast mass to the tether mass:

$$\begin{aligned} X = vB^2/\Gamma rdL - 0.25 &= -0.25 + \frac{vB^2}{12\sin\gamma\cos\gamma\Gamma rdL} \\ &= -0.25\frac{\Lambda}{L} \end{aligned}$$

Where Λ is the "effective electrodynamic length".

If the tether is short, so that L is small, this equation indicates that the ballast mass must be increased to increase the gradient force, since it is the gradient force which determines the upper limit to the amount of electrodynamic drag force that can be generated without losing control of the tether.

Assuming the usual values for the Earth's magnetic and gradient fields, the velocity of the host spacecraft through the magnetic field, and the resistivity and density of aluminum, this equation becomes:

$$X=10.9/L-0.25$$

where L is in kilometers.

For a typical tether of length L=5 km, X=1.93. If the total mass for the Terminator Tether™ is 20 kg, or 2% of the host spacecraft mass, and the mass of the deployer is 10 kg, then the remaining 10 kg should be distributed so that 6.59 kg is in the ballast mass while 3.41 kg is in tether mass.

Optimization of Tether Length:

If the ballast mass consists of a piece of the host spacecraft, then the mass of the ballast does not have to be considered in the optimization of the Tether system. In this case, the optimum distribution of the Tether mass is to put as much mass as possible into the tether, with a minimum in the deployer/controller package. Under this assumption, the optimum length of the tether is determined by the desire to keep the Area-Time Product of the host spacecraft plus Tether to a minimum.

In a long tether of length L, the effective "collision" cross-sectional area is not the area of the tether, but the larger area produced by multiplying the length of the tether by sum of the width of the tether plus the width of the "target" spacecraft that would be damaged by the tether hitting it. Thus, to decrease the "area" portion of the Area-Time Product, it would be desirable to shorten the tether, making it thicker, and perhaps slightly wider, at the same time, thus keeping the same tether mass and electron collection area, and thereby maintaining the drag force and keeping the decay time at the same level. The result will be a shortening of the Area-Time Product.

If the tether is shortened too much, however, the smaller voltage generated across the shorter tether will leave less voltage margin for the operation of the plasma contactors and the battery recharge system. Since the maximum voltage that can be generated is about 200 V/km, and typical plasma contactors and battery, chargers take 25–100 V to operate, a minimum length for a Tether would be roughly 2 km. Host spacecraft operating in polar orbits, where the conditions for voltage generation are not as good, may require a tether length of 5 km or more.

Since many watts of heat power will be dissipated in the control resistor, means must usually be provided to radiate the heat away into space. One low-mass method of accomplishing this is to make the control resistor (or resistors) in the form of a long, electrically insulated, high resistivity wire similar to those used in electric blankets, but designed to operate at a higher temperature, and during the fabrication of the electrodynamic tether, incorporate the high resistivity wire (or wires) into the end of the tether closest to the control circuit by weaving or braiding the insulated high resistivity wire in with the uninsulated aluminum wire of the electrodynamic tether. The surface area of a long wire is very large, so in this extended wire configuration, exposed to the space all around it, the hot control resistor wire can self-radiate its power into cold space without incurring the mass penalty of a separate radiating surface.

Implementation:

The basic optimum structure for a Terminator Tether™ would be one of the many types of Hoytethers. A multiline (6–12 primary line) Hoytape™ will provide the largest contact area with the plasma, since both sides of the tape would be able to pass current to the plasma. If the spacing between the primary lines is chosen to be larger than twice the Debye length of the plasma, then the effective current collection area per unit length of the Hoytape is proportional to the width of the Hoytape mesh, not the diameter of the wires in the mesh. Thus, a Hoytape not only provides an assured longer life for the Terminator Tether™, but very short lengths will also provide a very large current collection areas.

The deployer for the tether can deploy the Terminator Tether™ either down or up or both. The deployer can stay attached to the spacecraft as was done in the SEDS missions, or perhaps a better alternative would have the deployer ejected from the spacecraft, with one end of the tether still attached to the spacecraft, reeling out tether as it leaves. The empty deployer would then act as a ballast mass at the end of the Terminator Tether™, which would improve the performance.

The "Remora Remover"

In addition to attaching Terminator Tethers to spacecraft before launch, it is possible to consider a missile-like application. This "Remora Remover" missile would use a Terminator Tether™ carried by a seeker missile similar to the small "hit-to-kill" missiles developed by the Space Defense Initiative Office that deployed a net loaded with oriented metal rods. The Remora Remover missile would hunt down a spacecraft that needs to be removed from space, but instead of hitting the spacecraft, the missile would be programmed to rendezvous with the spacecraft and attach itself to the host spacecraft using a hooked net, harpoon, or adhesive "sucker". The Remora Remover missile would then deploy the Terminator Tether™, which would bring down both the spacecraft and the missile.

The inventors have presented two analyses, backed up with data obtained from space flight experiments. One analysis was based on generalized energy conservation laws while the other analysis use force and torque balance arguments. Both analyses show that optimized aluminum wire tethers 2 to 5 km in length and massing just 1% to 5% of the mass of the host spacecraft can deorbit the host spacecraft in the order of a few weeks, thus mitigating the long-lived orbital debris hazard created by a constellation spacecraft after their end-of-life.

Power Augmented Operation of the Tether:

It is well known in the aerospace literature that if a spacecraft has a power supply and a conducting tether hanging from it, and the spacecraft is in an orbit or trajectory that takes it near a body, such as the Earth or Jupiter, which has both a magnetic field and a region of moderate density electron-ion plasma, and electrical current is pumped from the power supply through the tether and back through the plasma, that the current flowing through the tether will interact with the magnetic field of the body, producing forces on the tether and thence on the spacecraft, changing its orbit or trajectory. These forces can be used to increase or decrease the spacecraft altitude and/or inclination. The amount of altitude or inclination change is proportional to the ratio of the power available from the power supply divided by the mass of the spacecraft and varies with altitude. The unpowered Terminator Tether™ is a simple example of such a system, in which only altitude decrease is possible, although small amounts of both inclination increase or decrease are possible at the same time. Some typical references to this prior art are: Les Johnson, "Propulsive Small Expendable Deployer System Mission (ProSEDS)", Proceedings of the OAST 8th Advanced Propulsion Workshop, JPL, Pasadena, Calif., 20–22 May 1997; and Les Johnson, Joe Carroll, Robert D. Estes, Enrico Lorenzini, Brian Gilchrist, Manuel Martinez-Sanchez, Juan Sanmartin, and Irwin Vas, "Electrodynamic Tethers for Reboost of the International Space Station and Spacecraft Propulsion, AIAA Paper 1996.

Since the Terminator Tether™ of the invention is normally associated with a satellite that has a power supply in the form of a solar panel combined with a storage battery, the Terminator Tether™ can be operated in the "powered propulsion" mode if desired. Such a mode would be useful when attempting to avoid a collision between the Terminator Tether™ and another spacecraft. In such cases, the power from the solar panel, augmented by the power stored in the battery, can be used to temporarily operate the Terminator Tether™ in the propulsion mode instead of the normal drag mode. This would enable to Terminator Tether™ to raise its altitude and/or increase or decrease its inclination to avoid a collision.

In addition, the Terminator Tether™ could be operated in the "power-augmented drag" mode. In this mode, there will be a current induced in the tether by the motion of the spacecraft through the magnetic field, which will cause a drag force on the spacecraft. This induced current would then be augmented by additional current in the same direction generated by the solar panel and the storage batteries in the power supply. The increased current will cause an increased drag force. If there is a significant vertical component of the magnetic field there will also be an increased force normal to the orbital plane, which will cause an increased rate of change of inclination.

When the Terminator Tether™ is operated in the "powered propulsion" or "power-augmented drag" mode, the conditions for stable optimum operation will be essentially the same as in the "unpowered drag" mode. The reason the conditions stay the same is that the maximum tether force than can be effectively utilized is limited by the strength of the gradient force, which has not changed, since the length and mass of the tether and the ballast mass has not changed for these different modes of operation. As a result the optimum operational angle for the tether is still 35.26 degrees, and the optimum ratio of ballast mass to tether mass for different tether lengths and tether material is still determined by the analysis of the invention as is set forth above.

In the analysis given above, where the optimum tether angle was found, the tether was assumed to be in the plane of the orbit and lagging behind the spacecraft motion, since in the "unpowered drag" mode, that would be its normal position, although if the component of the magnetic field along the orbit were high, there would be some tilt of the tether out of the plane of the orbit, producing a force tending to change the inclination of the orbit. In either of the "powered" modes of operation of the Terminator Tether™, however, the tilt of the tether could be forward toward the motion of the spacecraft or strongly tilted to one side or the other of the orbital plane. In all these cases, if the electrodynamic force is allowed to become too large, and the tether angle exceeds 45 degrees, the restoring force of the gradient field will drop off and the tether angle will go unstable. As a result, the optimum angle for the tether that will give the maximum stable force, whether it is a maximum drag force, and maximum propulsion force, or a maximum inclination change force, will be 35.26 degrees, and the optimum ratio for the mass of the tether versus the mass of the ballast will be the same as for the unpowered drag case.

The analysis that gave the optimum angle as 35.26 degrees assumed that the tether would be oriented like a rigid rotor. In reality, variations in forces along the tether will probably cause the tether to hang in a slightly curved shape, where the optimum angle may not be exactly 35.26 degrees from the local vertical. The optimum angle of the tether as it leaves the host spacecraft in such a case is where the drag force is largest.

The present invention is discussed in this disclosure in terms of its space applications as a Terminator Tether™ useful for the removal of unwanted satellites. It should be understood, however, that the present invention is useful in any application where a space object can use a conductive tether to produce electrodynamic force through interaction with a magnetic field. The invention, therefore, should be limited not by this description, but only by the appended claims and their equivalents.

What is claimed is:

1. A method of operating a conductive tether attached to a space object, said conductive tether being oriented at an angle to magnetic field lines of an external magnetic field and said conductive tether moving across the magnetic field lines of said external magnetic field at said angle to producing an electric current in said conducting tether and a resulting electrodynamic force acting on said tether and said attached space object comprising,

Controlling the amount of electric current flowing in said conducting tether to vary the angle between the conductive tether the field lines of the external magnetic field and the electrodynamic force acting on said tether and attached space object.

2. A method as in claim **1** wherein said angle is less than 45 degrees.

3. A method as in claim **1** wherein said angle is 35.26 degrees.

4. A method as in claim **1** wherein said angle is controlled to average 35.26 degrees over time.

5. A method as in claim **1** wherein said angle is controlled to average 35.26 degrees over the length of the tether.

6. A method as in claim **1** wherein the space object and the tether connected to it are rotated about their center of mass while the conductive tether interacts with the external magnetic field.

7. A method as in claim **1** wherein the angle of the conductive tether to the external magnetic field is controlled by sensing a measurable parameter of the space object/conductive tether system.

8. A method as in claim **7** wherein the parameter is current flow in the conductive tether.

9. A method as in claim **7** wherein the parameter is the electrical power dissipated in the conductive tether and the current control system.

10. A method as in claim **7** wherein the parameter is the relative position of the space object and the position of the far end tip of the tether.

11. A method as in claim **7** wherein the parameter is the acceleration of the space object.

12. A method as in claim **6** wherein the parameter is the state vector of the space object as measured by the Global Positioning System.

13. A method as in claim **1** including the step of applying electric power to the conductive tether to change the state vector of the space object.

14. A method of operating a conductive tether attached to a space object, said conductive tether being oriented at an angle to the local vertical between said space object and a celestial body having a magnetic field having magnetic field lines external to said conductive tether; said conductive tether moving across said magnetic field lines of said external magnetic field at an angle to the local vertical to produce an electric current in said conducting tether and a resulting electrodynamic force acting on said tether and said attached space object comprising,

Controlling the amount of electric current flowing in said conducting tether to vary the angle between the conductive tether the local vertical between said space object and said celestial body to vary the electrodynamic force acting on said tether and attached space object.

15. A method as in claim **14** wherein said angle is less than 45 degrees.

16. A method as in claim **14** wherein said angle is controlled to average 35.26 degrees over time.

17. A method as in claim **14** wherein the space object and the tether connected to it are rotated about their center of mass while the conductive tether interacts with the external magnetic field.

18. A method as in claim **14** wherein the angle of the conductive tether to the external magnetic field is controlled by sensing a measurable parameter of the space object/conductive tether system.

19. A method as in claim **18** wherein the parameter is current flow in the conductive tether.

20. A method as in claim **18** wherein the parameter is the acceleration of the space object caused by the electrodynamic force acting on the space object.

21. A method as in claim **18** wherein the parameter is the change in the state vector of the space object as measured by the Global Positioning System.

22. A method as in claim **14** including the step of applying electric power to the conductive tether to change the state vector of the space object.

23. A method as in claim **14** wherein the celestial body is the Earth and the magnetic field is the Earth's magnetic field.

24. A method as in claim **14** wherein the celestial body is the sun and the magnetic field is the Sun's magnetic field.

25. A method as in claim **14** wherein the magnetic field is the vector sum of the magnetic fields from all celestial bodies in the solar system.

26. A method as in claim **14** wherein the conductive tether is a Hoytether.

* * * * *

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(12) **Patent Application Publication** (10) **Pub. No.: US 2015/0102676 A1**

Dinwiddie et al. (43) **Pub. Date: Apr. 16, 2015**

(54) METHOD AND APPARATUS FOR EXTRACTING AND CONVEYING ELECTRICAL ENERGY FROM THE EARTH'S IONOSPHERE CAVITY

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(21) Appl. No.: **14/509,846**

(22) Filed: **Oct. 8, 2014**

Related U.S. Application Data

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Publication Classification

(51) **Int. Cl.**
H01F 38/14 (2006.01)

(52) **U.S. Cl.**
CPC ***H01F 38/14*** (2013.01); *H01F 2038/146* (2013.01)

(57) ABSTRACT

The system and apparatus of one or more embodiments of the present invention extracts, conditions, and conveys electric power from the earth ionosphere cavity through the integrated and collaborative operation of the system and apparatus consisting of a capacitively-coupled insulated elevated terminal (coupled capacitor upper plate), an evacuated spark gap, an integrated step-down transformer and resonant capacitor, and a ground terminal (coupled capacitor lower plate). The architecture governing exemplary embodiments of the system and apparatus of the present invention emulates the natural architecture governing the interaction of living trees with the electrical energy resident in the earth ionosphere cavity. The implementation of such exemplary embodiments of the present invention utilizes standard and customized components appropriate for their function within the system and apparatus.

The extracted electric power from the earth ionosphere cavity manifests in the form of broadband electromagnetic waves in the 0 to 200 Hz frequency range. Electric energy from these waves produce magnetic fields inside the integrated step-down transformer which are added together by the primary coil of the integrated step-down transformer, and delivered as 60 Hz 120/240 VAC to an electric load via the secondary coil of the integrated step-down transformer resonating at 60 Hz due to the influence of the integrated resonant capacitor.

The system and apparatus of exemplary embodiments of the present invention extracts, conditions, and conveys ionosphere cavity-resident electric power in alternating current and direct current realms.

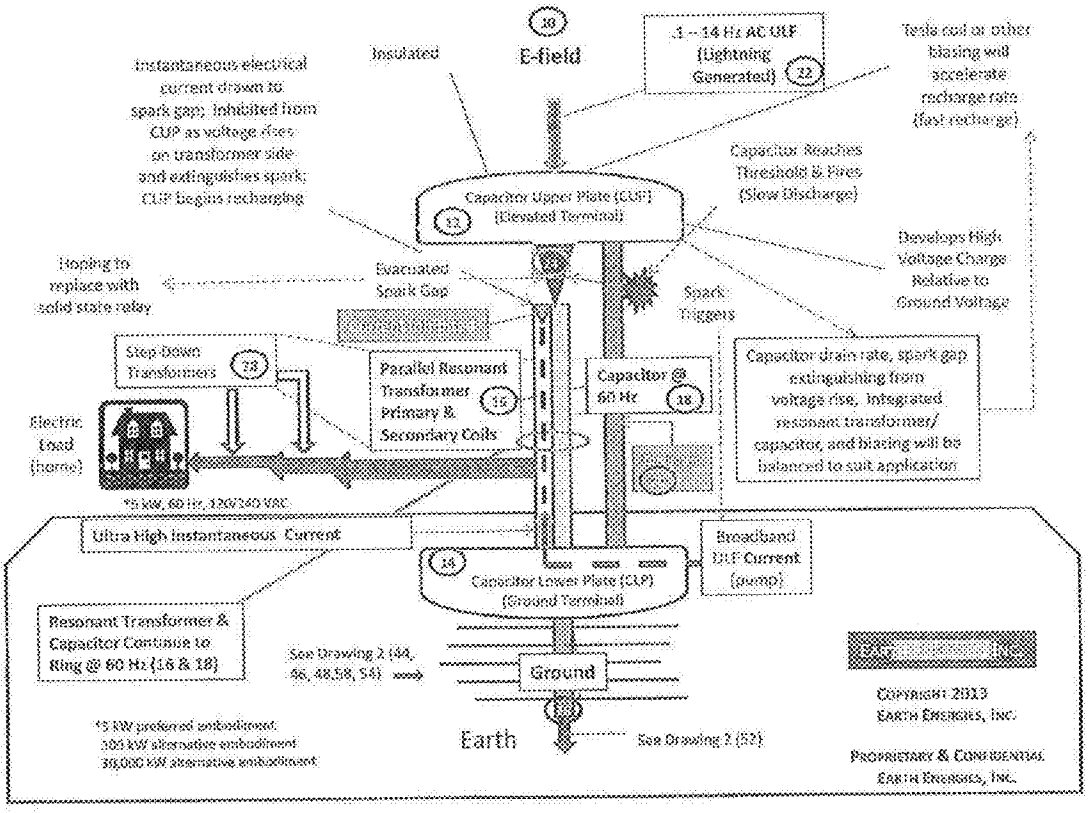
10
E-field
Insulated
.1 – 14 Hz AC ULF (Lightning Generated) 22
Tesla coil or other biasing will accelerate recharge rate (fast recharge)
Instantaneous electrical current drawn to spark gap; inhibited from CUP as voltage rises on transformer side and extinguishes spark; CUP begins recharging
Capacitor Reaches Threshold & Fires (Slow Discharge)
Capacitor Upper Plate (CUP) (Elevated Terminal) 12
Develops High Voltage Charge Relative to Ground Voltage
Hoping to replace with solid state relay
Evacuated Spark Gap
Spark Triggers
Step-Down Transformers 28
Parallel Resonant Transformer Primary & Secondary Coils 16
Capacitor @ 60 Hz 18
Capacitor drain rate, spark gap extinguishing from voltage rise, integrated resonant transformer/ capacitor, and biasing will be balanced to suit application
Electric Load (home)
*5 kW, 60 Hz, 120/240 VAC
Ultra High Instantaneous Current
Broadband ULF Current (pump)
14
Capacitor Lower Plate (CLP) (Ground Terminal)
Resonant Transformer & Capacitor Continue to Ring @ 60 Hz (16 & 18)
See Drawing 2 (44, 46, 48,58, 54)
Ground
Earth
See Drawing 2 (52)
*5 kW preferred embodiment
100 kW alternative embodiment
35,000 kW alternative embodiment
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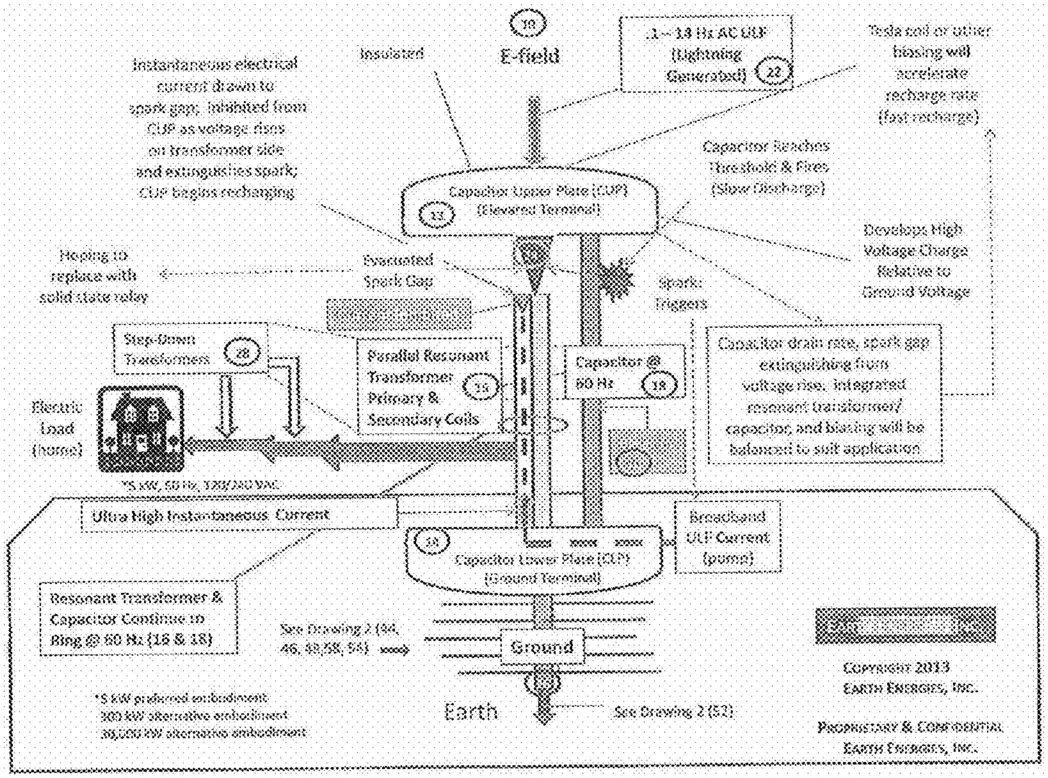
10
E-field
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Electric Load (home)
*5 kW, 60 Hz, 120/240 VAC
Ultra High Instantaneous Current
14
Capacitor Lower Plate (CLP) (Ground Terminal)
Broadband ULF Current (pump)
Resonant Transformer & Capacitor Continue to Ring @ 60 Hz (16 & 18)
See Drawing 2 (44, 46, 48,58, 94)
Ground
Earth
See Drawing 2 (52)
*5 kW preferred embodiment
300 kW alternative embodiment
36,000 kW alternative embodiment
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FIG. 1

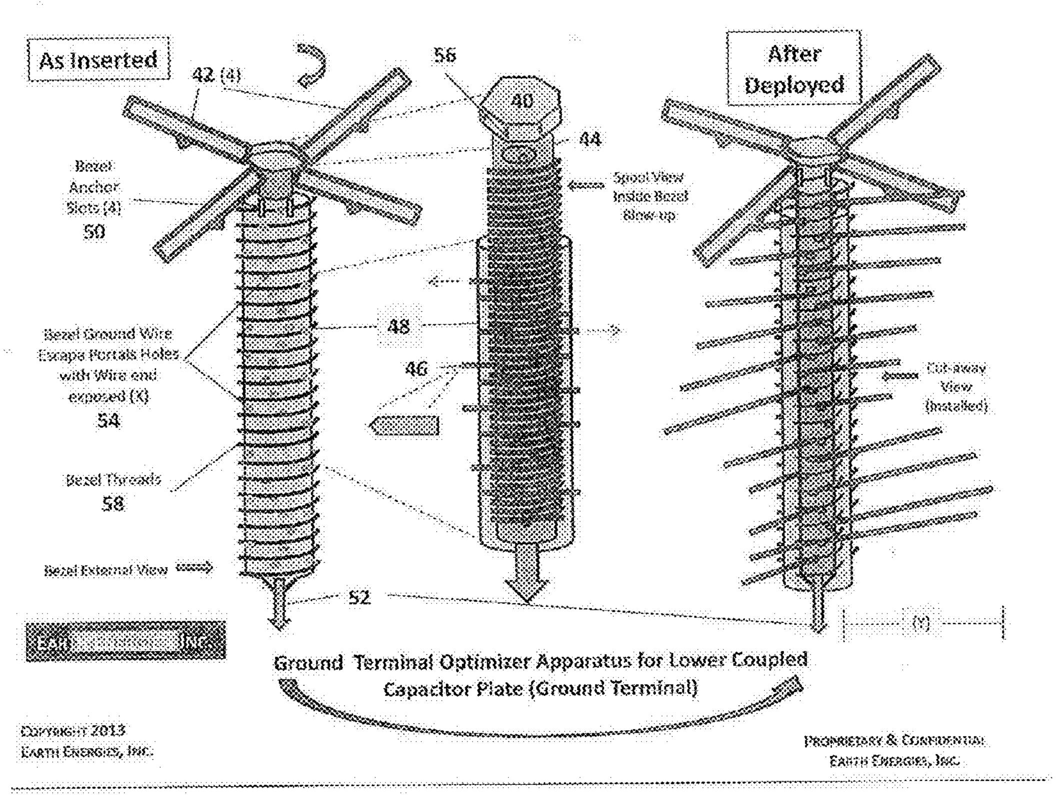
As Inserted
42 (4)
56
40
44
Spool View Inside Bezel Blow-up
After Deployed
Bezel Anchor Slots (4)
50
Bezel Ground Wire Escape Portals Holes with Wire end exposed (X)
54
48
46
Cut-away View (Installed)
Bezel Threads
58
Bezel External View
52
(Y)
EARTH ENERGIES INC.
Ground Terminal Optimizer Apparatus for Lower Coupled Capacitor Plate (Ground Terminal)
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FIG. 2

METHOD AND APPARATUS FOR EXTRACTING AND CONVEYING ELECTRICAL ENERGY FROM THE EARTH'S IONOSPHERE CAVITY

[0001] This application claims benefit of U.S. Provisional Application No. 61/889894, filed 11 Oct. 2013, titled, "Method and Apparatus for Extracting and Conveying Electrical Energy From the Earth's Ionosphere Cavity," the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] A portion of the disclosure of this patent document contains material which is subject to copyright protection. The copyright owner has no objection to the facsimile reproduction by any-one of the patent document or the patent disclosure, as it appears in the Patent and Trademark Office patent file or records, but otherwise reserves all copyright whatsoever.

[0003] The invention is an apparatus and methodology for extracting electric power manifesting as a broadband collection of electric field oscillations in the 0 to 200 Hz frequency range within the Earth's ionosphere cavity, through the use of an elevated biased hemispherical or other curved surface capacitor coupling the ionosphere cavity and Earth, and then conveying this electrical energy at the proper frequency, amperage, and voltage to existing homes and buildings where it is delivered for consumption over existing home or building wiring.

DESCRIPTION OF THE RELATED ART

[0004] The current state of the art in this field is focused on the bending of radio frequency waves in the Earth's ionosphere cavity for the purpose of distorting (through reflection) the resident cavity's magnetic field to physically direct the stimulating electrical energy to targeted locations within the Earth's ionosphere cavity and/or coordinates on the Earth's surface at specific energy levels appropriate to specific applications. The regenerative feedback was done by Sutton's active antenna.

[0005] Nikola Tesla attempted to transmit wireless power in the "natural medium"; however, Tesla bad no description of a device to receive natural oscillations as described in the present disclosure.

[0006] There is no known prior art in the field of electric energy extraction from the ionosphere cavity and conveyance to other terminals within the cavity for delivery of usable electric power.

SUMMARY OF THE INVENTION

[0007] In one exemplary embodiment of the present invention, a properly-scaled electric power extraction/conveyance apparatus is installed at a typical consumer residential home to deliver 60 Hz 120/240 VAC electric power, sufficient to convey the equivalent of 5 kW of continuous electricity, to the home's existing electric service entry component to power electrical appliances in the home over existing home electric wiring.

[0008] In another exemplary embodiment of the present invention, a properly-scaled electric power extraction/conveyance apparatus is installed at an appropriate location within an industrial park or neighborhood to deliver 60 Hz 120/240 V AC electric power, sufficient to convey the equivalent of 300 kW of continuous electricity, to the service entry components of industrial buildings or neighborhood homes to power electrical devices and appliances over existing building or home electric wiring.

[0009] Alternative exemplary embodiments of the present invention will extract direct current electric power from the Earth ionosphere cavity, generated by the earth's rotating magnetosphere, and convey in the form of conditioned direct current to direct current load sources, or convert to alternating current and convey in the form of conditioned alternating current to alternating current load sources.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] A disclosure embodiments of the present invention, is set forth more particularly in the remainder of the specification, which makes reference to the accompanying figures, in which:

[0011] FIG. **1** provides an example of an electric power extraction and conveyance apparatus for one residential-scale embodiment of the present invention. Certain additional example embodiments of the present invention utilize similar fundamental technologies, but differ in the scale (size) of the components and characteristics of the electricity conveyed for consumption; and

[0012] FIG. **2** is a schematic illustration of ground terminals for use with embodiments of the present invention.

DETAILED DESCRIPTION

[0013] Applicant has discovered that trees extract and use electric power from the Earth ionosphere cavity. The present invention emulates the architecture of electric power extraction and usage methodology inherent in the natural operation of living trees, but uses standard and customized components, common in the field, for its implementation. The natural electric power extraction and use of electric power by trees leverages the shape and physical composition of trees as instances of large electrical capacitors coupled to the ionosphere cavity. The canopy of trees (upper limbs and leaf structures) emulates the upper plates of a coupled capacitor, the trunks of trees emulate a combined dielectric and resonant transformer/capacitor, and the root systems of trees emulate ground terminals (lower coupled capacitor plates). The extraction of electric power from the ionosphere cavity by trees is in the form of ultra-low frequency broadband waves (oscillations) in the frequency range of 0.1 to 14 Hertz (ULF). Inherent tree physical composition and control structure (i.e., DNA/RNA) govern the use of the extracted electric power to accomplish tree growth, seasonal metabolic adjustments, and reproductive processes. Any excess extracted electric power by trees is returned to the ionosphere cavity. The present invention is an exemplary instance of this same natural architecture using standard and customized components that facilitate extraction and conveyance of ionosphere cavity-resident broadband electric power at useful scales sufficient to provide continuous electrical power for electrical devices used by people.

[0014] One preferred exemplary embodiment of the present invention is in the form shown in Drawing **1** above and will deliver continuous 60 Hz 120/240 V AC electric power to consumer residences (and other structures with similar electricity conditioning and consumption requirements) equivalent to electric power capacity of 5 kilowatts.

[0015] A secondary exemplary embodiment of the present invention is also in the form shown in FIG. **1**, appropriately scaled for larger electrical power demands and related conveyance capacity, and will deliver continuous 60 Hz 120/240 V AC electric power to larger buildings or electrical distribution facilities for commercial office parks with electric power capacity of 300 kilowatts.

[0016] A third exemplary embodiment of the present invention is also in the form shown in FIG. **1**, appropriately scaled for larger electrical power capacity, and will deliver continuous 60 Hz 120/240 VAC electric power to utility substations with electric power capacity of 30,000 kilowatts (or higher).

[0017] The following system, power sources, and component descriptions provide additional details of the present invention in various embodiments.

[0018] Earth's ionosphere cavity (**10**) is a reservoir of continuously-generated electrical energy (E-Field) in both direct current (DC) and alternating current (AC) realms. The DC electric energy is created by the constant rotation of the Earth's magnetosphere exposed to the solar wind. Earth's perpetually moving magnetic fields create the DC electric power in the ionosphere cavity E-Field per the equations in James Clerk Maxwell's fundamental theory of electromagnetism. AC electrical energy in the ionosphere cavity is generated from the persistent E-Field disturbances (i. e., oscillations) caused by lightning discharges. The present invention includes the direct extraction of AC electric power from the ionosphere cavity, and the direct extraction of DC electric power from the ionosphere cavity which is converted to AC electric power before conveyance. Optional operational configurations of the present invention will also enable conveyance of extracted DC electric power for potential scenarios where the conveyance of conditioned DC electricity is required.

[0019] Electric-field oscillations (**22**) are induced by lightning and encapsulated in the earth-ionosphere cavity, creating a continuous source of renewable electrical energy. The frequency of lightning occurrences in the ionosphere cavity averages thirty (30) strikes per second, with each strike representing approximately one (1) terawatt (TW) of instantaneous energy. Assuming an average energy dissipation rate for each lightning strike of fifteen (15) microseconds (μsec), i. e., the time involved for one (1) terawatt of instantaneous energy to dissipate to zero (0) energy, these lightning-induced electric field oscillations are sufficient to provide 4,500 times the entire electric energy consumption on planet Earth at the projected consumption rate for the year 2100 (55.3 TWh annually). Lightning-induced E-Field oscillations vary between 0.1 and 14 Hertz with wavelengths exceeding the practicality of an electromagnetic antenna for collecting the energy. The present invention utilizes capacitive coupling to overcome this obstacle.

[0020] An insulated upper capacitor plate (terminal) (12) elevated above the influence of the ground floor collects E-Field oscillations from the ionosphere cavity. This insulated elevated terminal, capacitively-coupled to the E-Field bounded by the earth-ionosphere cavity, is arranged in a surface of large radii of curvature, supporting maximum surface connection to the E-Field without leaking the high voltage charge applied to the elevated terminal. The capacitance and resistance of the elevated terminal are responsive to the reception of broadband electric-field frequencies in the 0 to 200 hertz range. The elevated terminal is subject to high voltage alternating current biasing used to collect electric-field oscillations generated by lightning impulses in the earth-ionosphere cavity.

[0021] An evacuated spark gap (**24**) connected to the elevated terminal (**12**) prevents electrical discharge occurring between the elevated terminal and the ionosphere cavity. As the high voltage alternating current approaches peak voltage the spark gap energizes and a large voltage is applied to the step-down transformer primary coil (**16**). The high voltage pumps high current from the ground terminal (**14**, **26**) converting the electric-field to a magnetic field within the transformer (**16**). The step-down transformer is connected to a 60 hertz resonant capacitor (**18**), the secondary side of the transformer resonating at 60 hertz will supply a 60 hertz 120/240 VAC power to the load. Filter circuits will condition the power. The evacuated spark gap function may be accomplished by solid state circuitry in the implementation of the present invention.

[0022] The resonant transformer (**16**) is integrated with a parallel resonant capacitor across the transformer where the integrated combination resonates at 60 hertz supplying power to the electricity consuming structure (home or business). Various step-down transformers (**28**) are utilized to condition the conveyed electricity to accommodate the requirements of the receiving station for various embodiments of the present invention.

[0023] Ground (**26**) is the source of electric current for the present invention. A ground terminal, connected to the soil, is arranged in a surface of large radii of curvature to permit instantaneous sourcing of high currents from earth ground without temperature and voltage rise inhibiting the ground terminal collection of current. The capacitance and resistance of the ground terminal to earth is minimized to promote on demand current sourcing. Drawing **2** illustrates an exemplary apparatus of the present invention that optimizes ground connection quality by maximizing the penetration extent and resulting surface area of the ground terminal's extension into the soil.

[0024] Step-down transformers (**28**) are scaled to transform the electrical current and voltage into structured and conditioned electricity that is compatible with the electric power needs of the load sources for various embodiments of the present invention.

[0025] A mechanical nut (**40**) solidly attached to shaft **44** to facilitate extension, when turned, of large gauge copper wire extrusions (**46**).

[0026] A downward pointed anchor flat shaft (**42**) attached to the bezel **50** via a T-slot in bezel.

[0027] A copper (or other highly-conductive metal) spool base (**44**) sourcing "X" independently attached large gauge pointed copper wires (**46**) of length "Y", where "X" is equal to the number of escape portals in bezel (**50**), and "Y" is the length determined to yield optimum surface area of wires of type **46** for high quality connectivity to soil. The spool can freely rotate inside the bezel (**48**) and emulates the primary root structure of a living tree.

[0028] Sharpened large gauge (reinforced) copper wires (**46**), quantity "X", of length "Y" emulating the root structure of living trees.

[0029] Threaded bezel (spool-housing sleeve) (**48**) with drilled escape portal holes with end of copper wires (**46**) protruding through holes ½ inch.

[0030] Bezel anchor slots (**50**) of twice the height of anchor flat shafts (**42**) and T-slotted to accommodate anchor flat shafts.

[0031] Extended pointed end (**52**) of inner spool base shaft.

[0032] Escape portals (**54**) in bezel to allow for large gauge copper wire (**46**) extension into soil.

[0033] Connector port (**56**) for connection to ground terminal (**14**) in Drawing **1**.

[0034] Bezel threads (**58**).

[0035] Various embodiments of the present invention will include one or more of the following characteristics in various combinations. These descriptions are provided for purposes of example. Not all of the following characteristics will be required for any given exemplary embodiment.

[0036] Characteristic 1, The form (shape), physical composition, size, insulation, location altitude, discharge capacitive threshold and discharge rate, and the strength of AC or DC biasing applied to the (CUP) upper coupled capacitor plate (**12**: elevated terminal) all form an integrated whole, the purpose of which is to extract and temporarily store DC or AC electric power from the Earth's ionosphere cavity (**10**) at high voltage, and to trigger the energizing of the evacuated spark gap (**24**).

[0037] Characteristic 2, The elevated terminal (**12**) is capacitively coupled to the E-Field (**10**) bounded by the earth ionosphere cavity, and arranged in a surface of large radii of curvature, supporting maximum surface connection to the E-Field without leaking the high voltage charge applied to the elevated terminal (**12**).

[0038] Characteristic 3, The capacitance and resistance of the elevated terminal (**12**) are responsive to the reception of broadband electric-field frequencies in the 0 to 200 hertz range.

[0039] Characteristic 4, The elevated terminal (**12**) is subject to high voltage alternating current biasing used to collect E-Field oscillations generated by lightning impulses in the earth-ionosphere cavity.

[0040] Characteristic 5, An alternative instantiation of elevated terminal (**12**) is subject to high voltage direct current biasing used to collect E-Field direct current generated by the Earth's rotating magnetosphere.

[0041] Characteristic 6, The evacuated spark gap (**24**) may be in the form of a cohesive physical spark ignition or an operational emulation of this function through solid state circuitry.

[0042] Characteristic 7, The evacuated spark gap (**24**) connected to the elevated terminal (**12**) prevents electrical discharge occurring between the elevated terminal and the ionosphere cavity.

[0043] Characteristic 8, The high voltage alternating current from the E-Field, induced into the elevated terminal (**12**), approaches peak voltage and causes the evacuated spark gap (**24**) to energize and a large voltage is applied to the step-down transformer primary coil (**16**).

[0044] Characteristic 9, The high voltage alternating current impulse from the elevated terminal (**12**), which causes the evacuated spark gap (**24**) to energize, manifests as alternating current on broadband frequencies between 0.1 and 200 Hz.

[0045] Characteristic 10, In an alternative instantiation of the elevated terminal (**12**) the stored high voltage direct current, which causes the evacuated spark gap (**24**) to energize, manifests as direct current on broadband frequencies between 0 and 200 Hz.

[0046] Characteristic 11, The high voltage applied to the step-down transformer primary coil (**16**) pumps high current from the ground terminal (**14**), converting the electric-field to a magnetic field within the transformer (**16**).

[0047] Characteristic 12, The high current pumped from the ground terminal (**14**), caused by high voltage applied to the step-down transformer primary coil (**16**), will attempt to normalize the field and extinguish the evacuated spark gap (**24**).

[0048] Characteristic 13, The transformer's (**16**) magnetic field expands in response to the high current electric-field inrush from the ground terminal (**14**).

[0049] Characteristic 14, The primary winding inside the step-down transformer (**16**) will add the energy from each broadband frequency together into a single magnetic field, where it will become a 60 Hz frequency at the secondary winding of the transformer (**16**).

[0050] Characteristic 15, The step-down transformer (**16**) is connected to a 60 Hertz resonant capacitor (**18**).

[0051] Characteristic 16, The secondary (coil) side of the step-down transformer (**16**), resonating at 60 hertz, will supply a 60 hertz 120/240 VAC power to the electric load.

[0052] Characteristic 17, Filter circuits within the step-down transformer will condition the power according to the electric power needs of the electric load.

[0053] Characteristic 18, Electric-field lines exist (within the Earth's ionosphere cavity) that are horizontal to the surface of the Earth and extend to heights above 30,000 feet, with voltage gradients typically 100 Volts per vertical meter.

[0054] Characteristic 19, Lightning impulses create global broadband oscillations in the Earth ionosphere cavity electric-field between 0.1 and 14 Hertz.

[0055] Characteristic 20, Rotation of the Earth's magnetosphere creates global electric field oscillations in the Earth ionosphere cavity that manifest as electromagnetic waves in the 0 to 200 Hertz frequency range.

[0056] Characteristic 21, Global broadband oscillations in the Earth ionosphere cavity electric-field can be used for wireless energy transmission without harm to people, plants, or trees.

[0057] Characteristic 22, A maximum quality ground connection is achieved by expanding the surface area of the ground connection (**48** and **44**) through extension of high-conductor large gauge copper wires (**46**) horizontally through bezel (**48**) escape portals (**54**) along depth of source spool (**44**) and bezel (**48**).

[0058] Characteristic 23, The technique described in Characteristic 22 effectively expands the diameter of the ground source spool (**44**) with regard to quality of ground connection.

[0059] Characteristic 24, Bezel threads (**58**) expand surface area of bezel (**48**) touching earth, enhancing ground connection quality.

[0060] Characteristic 25, Bezel threads (**58**) enhance ground connection quality of bezel (**48**), source spool (**44**), and high conductor large gauge copper wires (**46**) through rotational insertion and resulting friction hold v. other (direct drive) insertion methods which can result in corruption of ground hole integrity caused by imprecise angle and/or vibration during insertion.

[0061] While one or more embodiments of the present invention have been described above, it should be understood that any and all equivalent realizations of the present invention are included within the scope and spirit thereof. Thus, the embodiments presented herein are by way of example only and are not intended as limitations of the present invention. Therefore, it is contemplated that any and all such embodiments are included in the present invention.

What is claimed is:

1. A power receiver for extracting electrical energy from the earth's electric field, said power receiver comprising:

a resonant transformer connected between a ground terminal disposed below the surface of the earth and an elevated terminal;

impulse generator for generating and applying a high voltage electrical impulse to a primary winding of the resonant transformer to induce current flow from the ground terminal through the primary winding of the transformer; and

a power conversion circuit connected to a secondary winding of the resonant transformer to convert electrical current flowing through the secondary winding to a desired form.

2. The power receiver of claim **1** wherein a resonant frequency of the resonant transformer is below 200 Hz.

3. The power receiver of claim **1** wherein the elevated terminal comprises an upper capacitive plate coupled to the earth's ionosphere cavity.

4. The power receiver of claim **3** wherein the impulse generator comprises:

the upper capacitive plate;

a pair of electrodes separated by a spark gap, said electrodes connected between the upper capacitive plate and the primary winding of the resonant transformer and configured to generate a spark when a voltage difference between the electrodes reaches a predetermined level.

5. The power receiver of claim **1** further comprising a lower capacitive plate coupled to the ground terminal.

6. The power receiver of claim **1** wherein the resonant transformer comprises a capacitor connected in parallel with a primary winding of the resonant transformer.

* * * * *

US008686575B2

(12) **United States Patent**
McCowen

(10) **Patent No.: US 8,686,575 B2**
(45) **Date of Patent: Apr. 1, 2014**

(54) ENERGY COLLECTION

(75) Inventor: **Clint McCowen**, Navarre, FL (US)

(73) Assignee: **Ion Power Group, LLC**, Navarre, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/255,130**

(22) Filed: **Oct. 21, 2008**

(65) **Prior Publication Data**

US 2009/0040680 A1 Feb. 12, 2009

Related U.S. Application Data

(63) Continuation of application No. 11/358,264, filed on Feb. 21, 2006, now Pat. No. 7,439,712.

(51) **Int. Cl.**

F02B 63/04	(2006.01)
F03G 7/08	(2006.01)
H02K 7/18	(2006.01)
H02N 1/00	(2006.01)

(52) **U.S. Cl.**
USPC .... **290/1 R**; 322/2 A

(58) **Field of Classification Search**
USPC .... 290/1 R; 322/2 A; 126/660; 60/641.8, 60/641.11, 641.12, 659, 698; 244/158.2
See application file for complete search history.

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(57) **ABSTRACT**

An energy collection system may collect and use the energy generated by an electric field. Collection fibers are suspended from a support wire system supported by poles. The support wire system is electrically connected to a load by a connecting wire. The collection fibers may be made of any conducting material, but carbon and graphite are preferred. Diodes may be used to restrict the backflow or loss of energy.

25 Claims, 10 Drawing Sheets

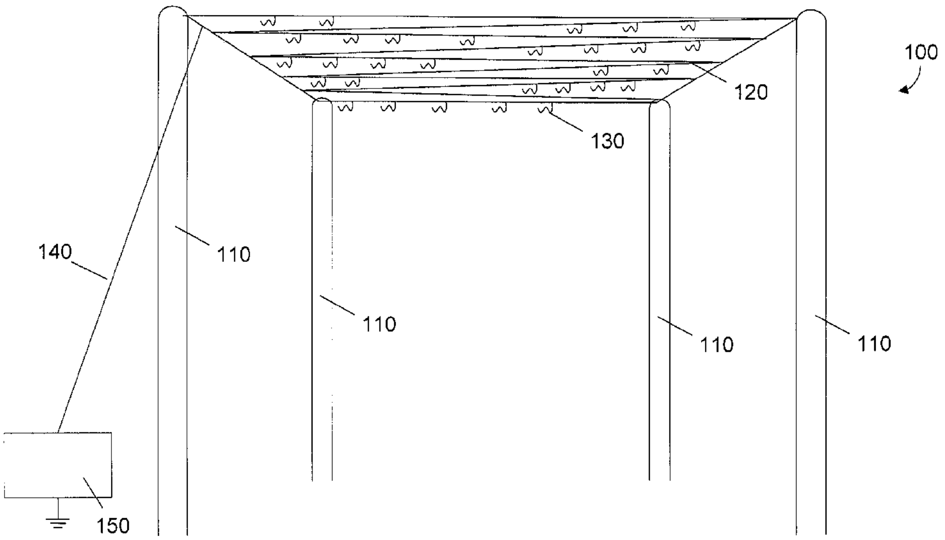

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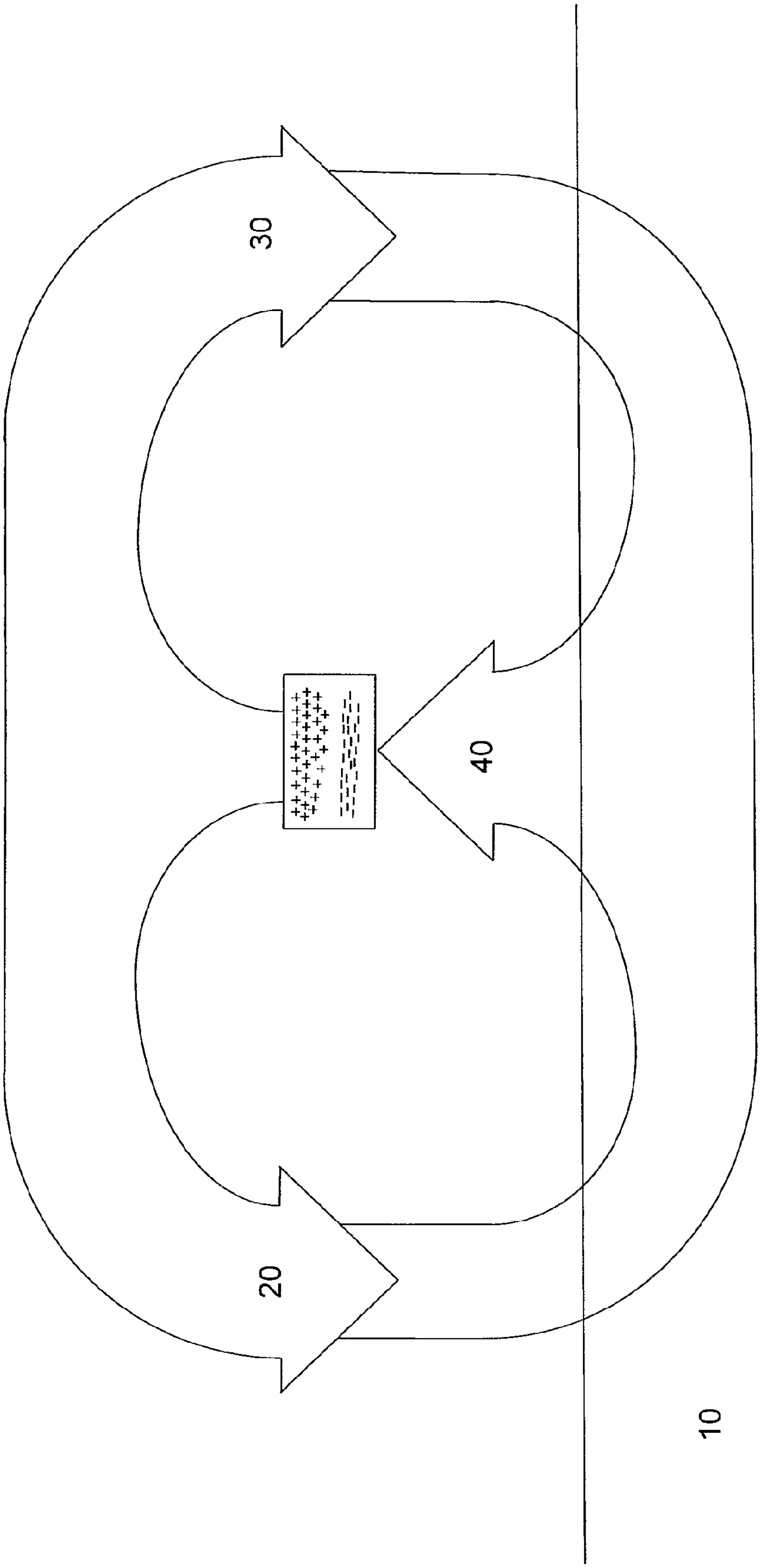

FIGURE 1

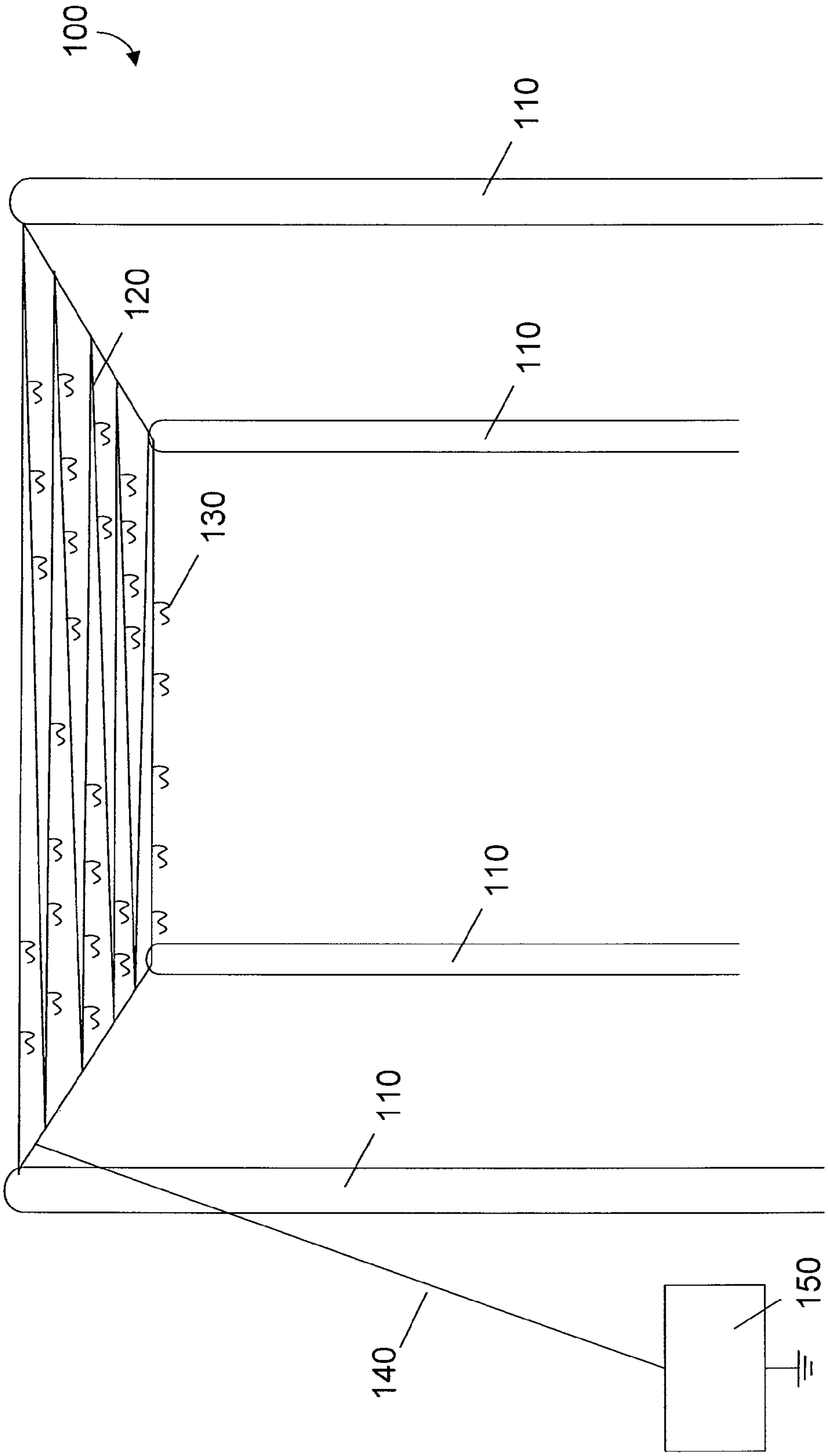
100
110
110
120
130
110
110
140
150

FIGURE 2

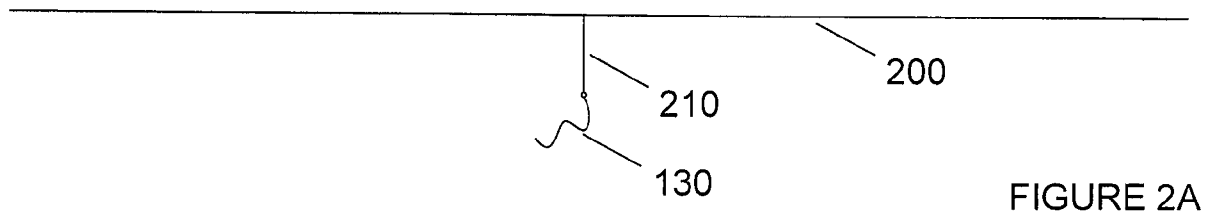

FIGURE 2A

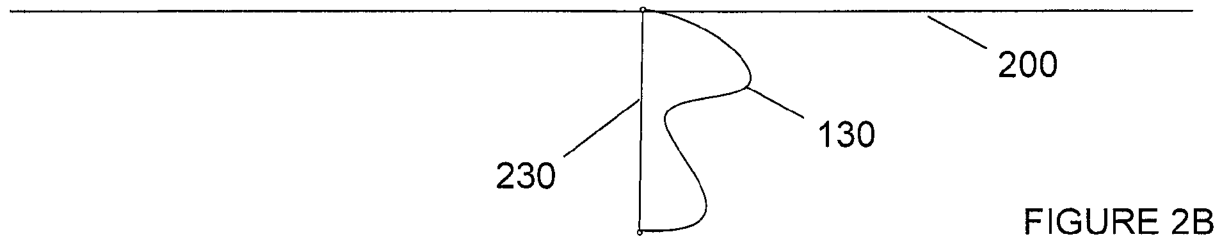

FIGURE 2B

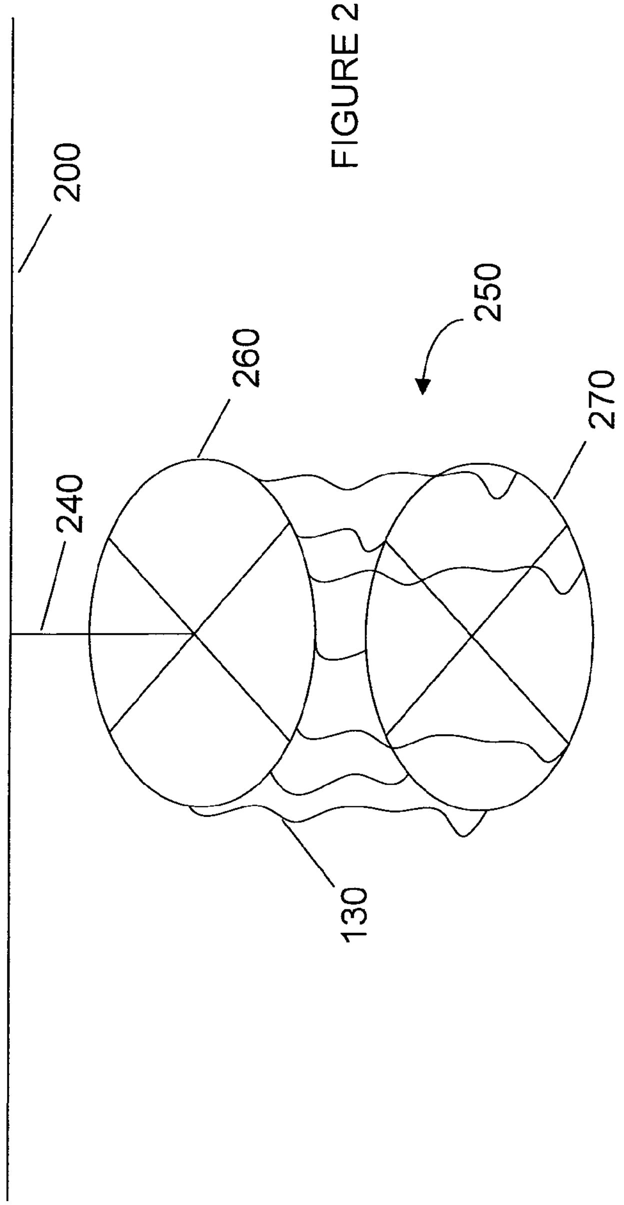
200
250
260
270
240
130

FIGURE 2C

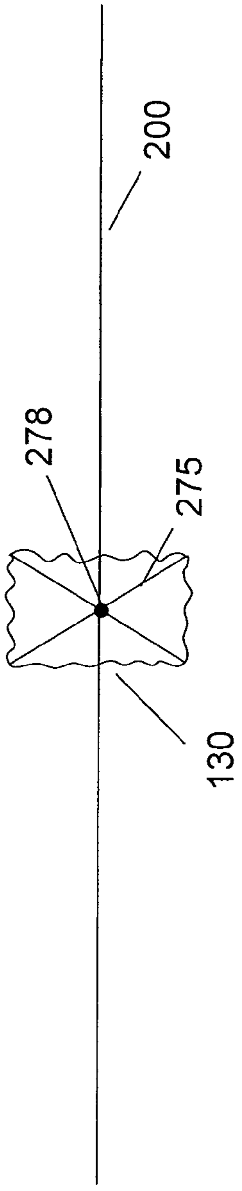
200
278
275
130

FIGURE 2D

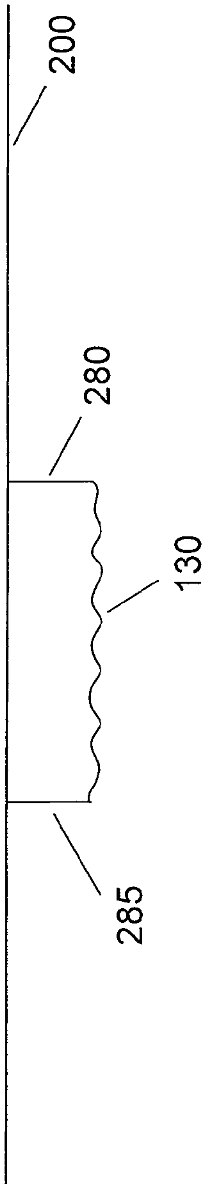
200
280
130
285

FIGURE 2E

FIGURE 2F

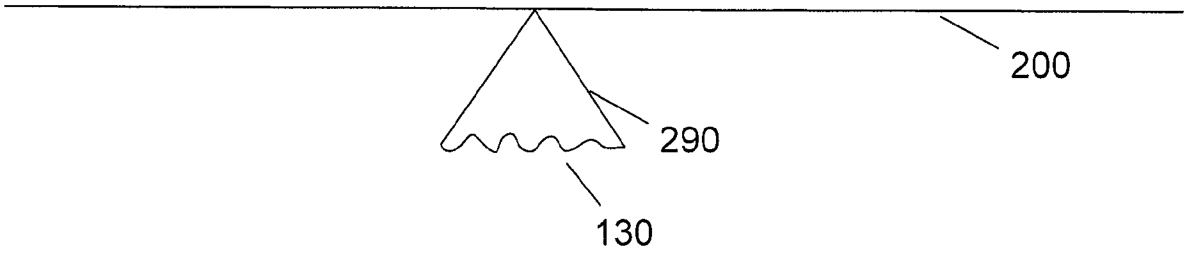

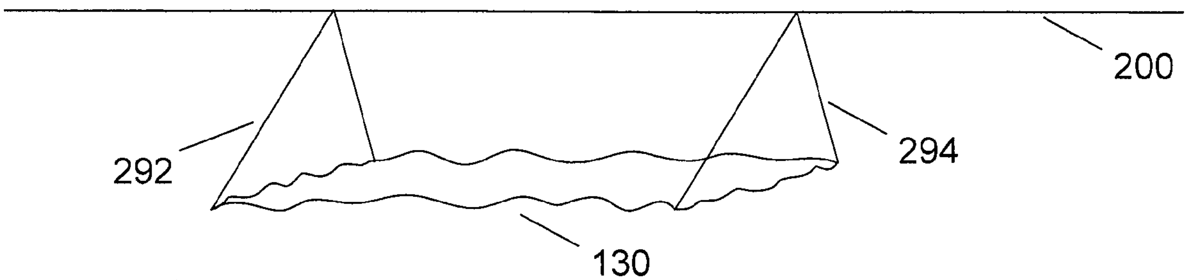
200
294
292
130

FIGURE 2G

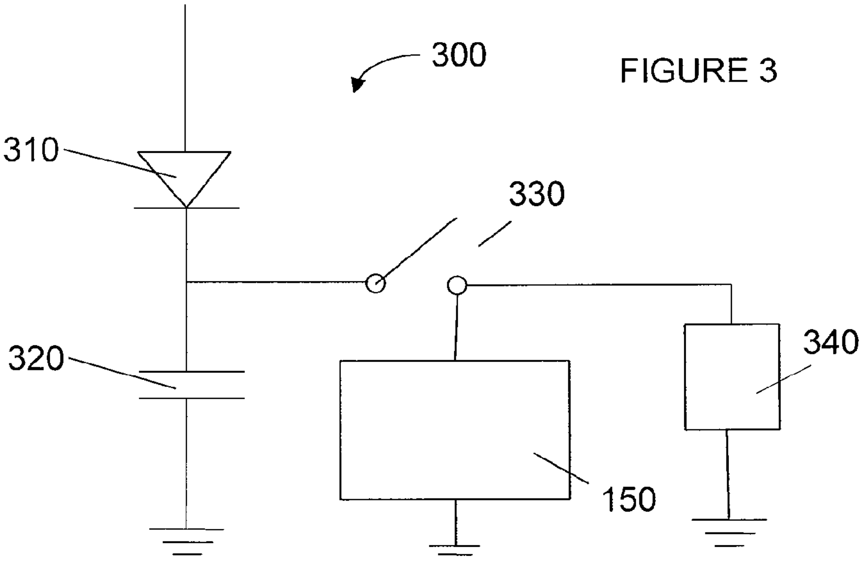
300
310
330
320
340
150

FIGURE 3

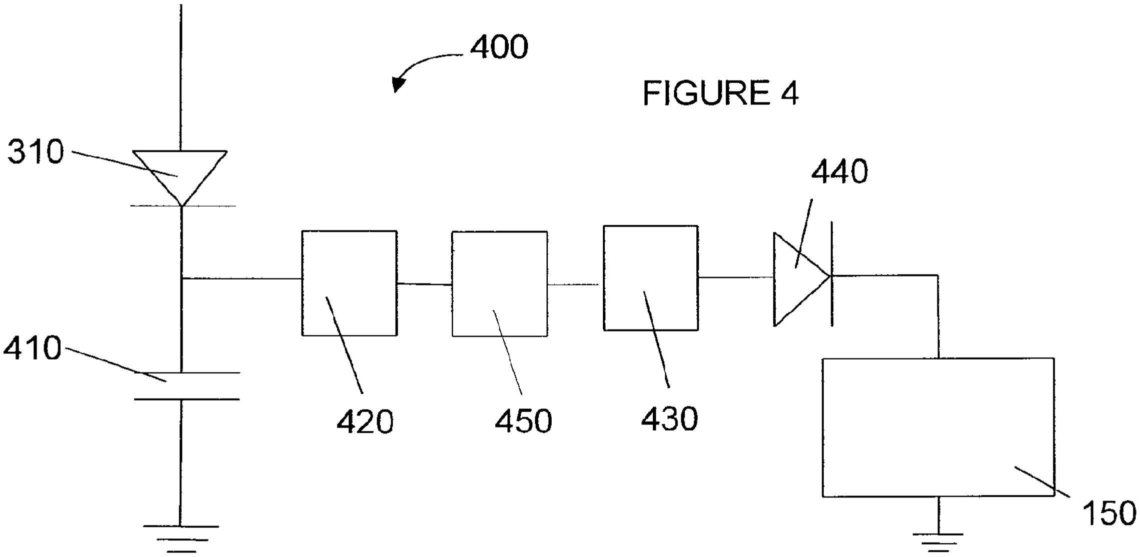
400
310
440
410
420
450
430
150

FIGURE 4

FIGURE 5

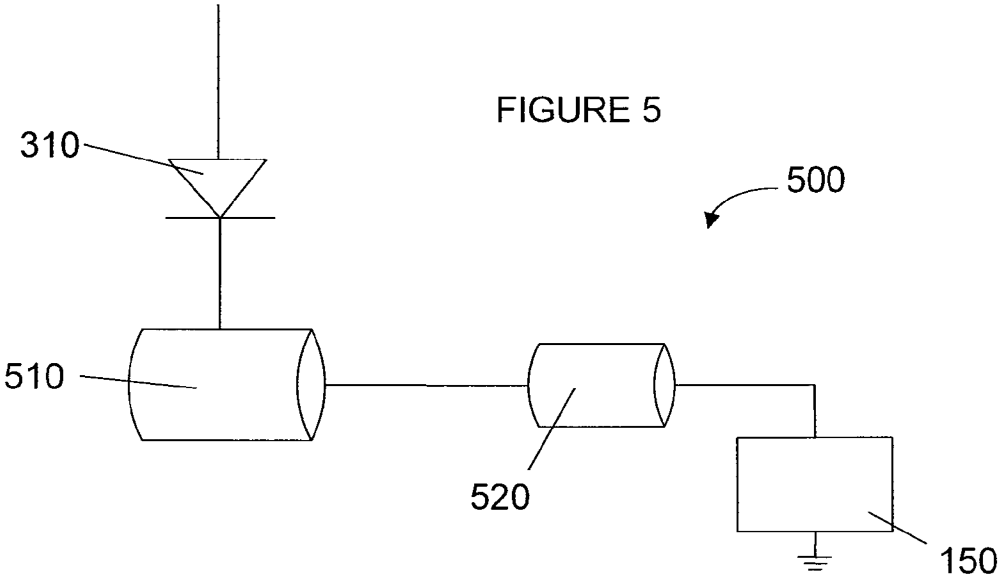
310
500
510
520
150

FIGURE 6

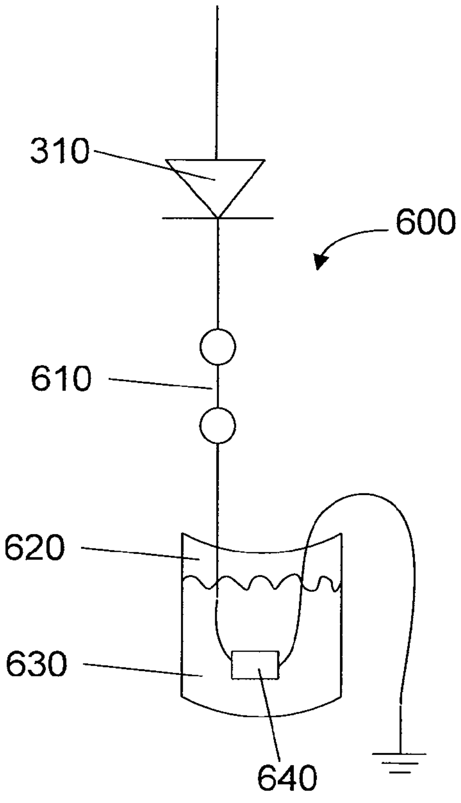
310
600
610
620
630
640

FIGURE 7

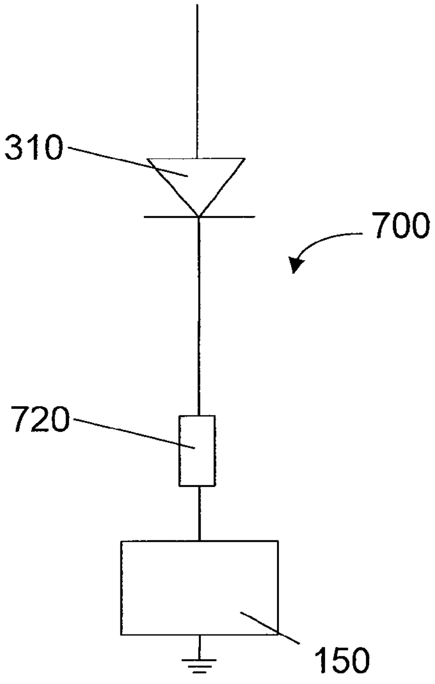
310
700
720
150

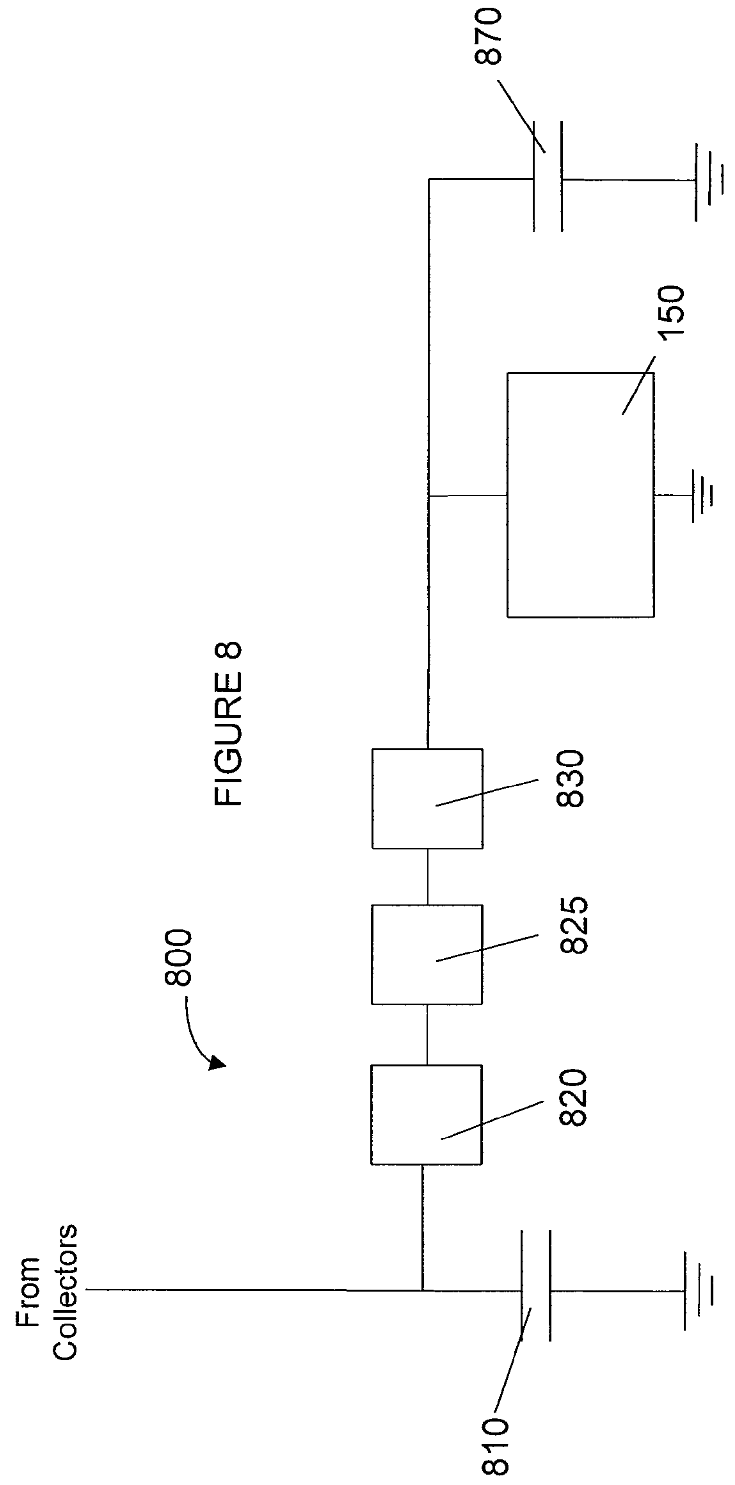
870
150
830
825
820
800
810
From Collectors

FIGURE 8

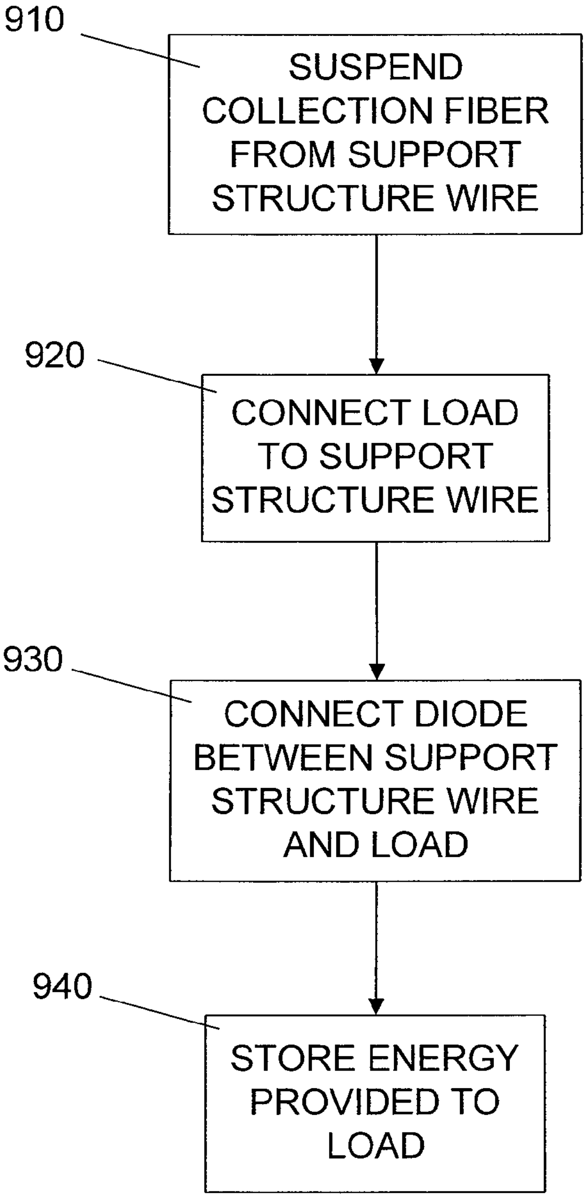
910
SUSPEND COLLECTION FIBER FROM SUPPORT STRUCTURE WIRE
920
CONNECT LOAD TO SUPPORT STRUCTURE WIRE
930
CONNECT DIODE BETWEEN SUPPORT STRUCTURE WIRE AND LOAD
940
STORE ENERGY PROVIDED TO LOAD

FIGURE 9

ENERGY COLLECTION

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation application of U.S. patent application Ser. No. 11/358,264, filed on Feb. 21, 2006, which is incorporated by reference herein.

TECHNICAL FIELD

The present disclosure is generally related to energy and, more particularly, is related to systems and methods for collecting energy.

BACKGROUND

The concept of fair weather electricity deals with the electric field and the electric current in the atmosphere propagated by the conductivity of the air. Clear, calm air carries an electrical current, which is the return path for thousands of lightening storms simultaneously occurring at any given moment around the earth. For simplicity, this energy may be referred to as static electricity or static energy. FIG. **1** illustrates a weather circuit for returning the current from lightning, for example, back to ground **10**. Weather currents **20**, **30** return the cloud to ground current **40**.

In a lightening storm, an electrical charge is built up, and electrons arc across a gas, ionizing it and producing the lightening flash. As one of ordinary skill in the art understands, the complete circuit requires a return path for the lightening flash. The atmosphere is the return path for the circuit. The electric field due to the atmospheric return path is relatively weak at any given point because the energy of thousands of electrical storms across the planet are diffused over the atmosphere of the entire Earth during both fair and stormy weather. Other contributing factors to electric current being present in the atmosphere may include cosmic rays penetrating and interacting with the earth's atmosphere, and also the migration of ions, as well as other effects yet to be fully studied.

Some of the ionization in the lower atmosphere is caused by airborne radioactive substances, primarily radon. In most places of the world, ions are formed at a rate of 5-10 pairs per cubic centimeter per second at sea level. With increasing altitude, cosmic radiation causes the ion production rate to increase. In areas with high radon exhalation from the soil (or building materials), the rate may be much higher.

Alpha-active materials are primarily responsible for the atmospheric ionization. Each alpha particle (for instance, from a decaying radon atom) will, over its range of some centimeters, create approximately 150,000-200,000 ion pairs.

While there is a large amount of usable energy available in the atmosphere, a method or apparatus for efficiently collecting that energy has not been forthcoming. Therefore, a heretofore unaddressed need exists in the industry to address the aforementioned deficiencies and inadequacies.

SUMMARY

Embodiments of the present disclosure provide systems and methods for collecting energy. Briefly described in architecture, one embodiment of the system, among others, can be implemented by a support structure wire elevated above a ground level, at least one collection fiber electrically connected to the support structure wire; a load electrically connected to the support structure wire; and a diode electrically connected between the load and at least one collection fiber.

Embodiments of the present disclosure can also be viewed as providing methods for collecting energy. In this regard, one embodiment of such a method, among others, can be broadly summarized by the following steps: suspending at least one collection fiber from a support structure wire elevated above ground level, the fiber electrically connected to the support structure wire; providing a load with an electrical connection to the support structure wire to draw current; and providing a diode electrically connected between the collection fiber and the load.

Other systems, methods, features, and advantages of the present disclosure will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present disclosure, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a circuit diagram of a weather energy circuit.

FIG. **2** is a perspective view of an exemplary embodiment of many energy collectors elevated above ground by a structure.

FIG. **2**A is a side view of an energy collection fiber suspended from a support wire.

FIG. **2**B is a side view of an exemplary embodiment of an energy collection fiber suspended from a support wire and with an additional support member.

FIG. **2**C is a perspective view of a support structure for multiple energy collection fibers.

FIG. **2**D is a side view of an exemplary embodiment of a support structure for multiple energy collection fibers.

FIG. **2**E is a side view of a support structure for an energy collection fiber.

FIG. **2**F is a side view of an exemplary embodiment of a support structure for an energy collection fiber.

FIG. **2**G is a side view of a support structure for multiple energy collection fibers.

FIG. **3** is a circuit diagram of an exemplary embodiment of a circuit for the collection of energy.

FIG. **4** is a circuit diagram of an exemplary embodiment of a circuit for the collection of energy.

FIG. **5** is a circuit diagram of an exemplary embodiment of an energy collection circuit for powering a generator and motor.

FIG. **6** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy and using it for the production of hydrogen and oxygen.

FIG. **7** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy, and using it for driving a fuel cell.

FIG. **8** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy.

FIG. **9** is a flow diagram of an exemplary embodiment of collecting energy with a collection fiber.

DETAILED DESCRIPTION

Electric charges on conductors reside entirely on the external surface of the conductors, and tend to concentrate more around sharp points and edges than on flat surfaces. Therefore, an electric field received by a sharp conductive point may be much stronger than a field received by the same charge residing on a large smooth conductive shell. An exemplary embodiment of this disclosure takes advantage of this property, among others, to collect and use the energy generated by an electric field in the atmosphere. Referring to collection system **100** presented in FIG. **2**, at least one collection device **130** may be suspended from a support wire system **120** supported by poles **110**. Collection device **130** may comprise a diode or a collection fiber individually, or the combination of a diode and a collection fiber. Support wire system **120** may be electrically connected to load **150** by connecting wire **140**. Supporting wire system **120** may be any shape or pattern. Also, conducting wire **140** may be one wire or multiple wires. The collection device **130** in the form of a fiber may comprise any conducting or non-conducting material, including carbon, graphite, Teflon, and metal. An exemplary embodiment utilizes carbon or graphite fibers for static electricity collection. Support wire system **120** and connecting wire **140** can be made of any conducting material, including aluminum or steel, but most notably, copper. Teflon may be added to said conductor as well, such as non-limiting examples of a Teflon impregnated wire, a wire with a Teflon coating, or Teflon strips hanging from a wire. Conducting wire **120**, **140**, and **200** may be bare wire, or coated with insulation as a non-limiting example. Wires **120** and **140** are a means of transporting the energy collected by collection device **130**.

An exemplary embodiment of the collection fibers as collection device **130** includes graphite or carbon fibers. Graphite and carbon fibers, at a microscopic level, can have hundreds of thousands of points. Atmospheric electricity may be attracted to these points. If atmospheric electricity can follow two paths where one is a flat surface and the other is a pointy, conductive surface, the electrical charge will be attracted to the pointy, conductive surface. Generally, the more points that are present, the higher energy that can be gathered. Therefore, carbon, or graphite fibers are examples that demonstrate exemplary collection ability.

In at least one exemplary embodiment, the height of support wire **120** may be an important factor. The higher that collection device **130** is from ground, the larger the voltage potential between collection device **130** and electrical ground. The electric field may be more than 100 volts per meter under some conditions. When support wire **120** is suspended in the air at a particular altitude, wire **120** will itself collect a very small charge from ambient voltage. When collection device **130** is connected to support wire **120**, collection device **130** becomes energized and transfers the energy to support wire **120**.

A diode, not shown in FIG. **2**, may be connected in several positions in collection system **100**. A diode is a component that restricts the direction of movement of charge carriers. It allows an electric current to flow in one direction, but essentially blocks it in the opposite direction. A diode can be thought of as the electrical version of a check valve. The diode may be used to prevent the collected energy from discharging into the atmosphere through the collection fiber embodiment of collection device **130**. An exemplary embodiment of the collection device comprises the diode with no collection fiber. A preferred embodiment, however, includes a diode at the connection point of a collection fiber to support system **120** such that the diode is elevated above ground. Multiple diodes may be used between collection device **130** and load **150**. Additionally, in an embodiment with multiple fibers, the diodes restricts energy that may be collected through one fiber from escaping through another fiber.

Collection device **130** may be connected and arranged in relation to support wire system **120** by many means. Some non-limiting examples are provided in FIGS. **2A**-**2G** using a collection fiber embodiment. FIG. **2A** presents support wire **200** with connecting member **210** for collection device **130**. Connection member **210** may be any conducting material allowing for the flow of electricity from connection device **130** to support wire **200**. Then, as shown in FIG. **2**, the support wire **200** of support system **120** may be electrically connected through conducting wire **140** to load **150**. A plurality of diodes may be placed at any position on the support structure wire. A preferred embodiment places a diode at an elevated position at the connection point between a collection fiber embodiment of collection device **130** and connection member **210**.

Likewise, FIG. **2B** shows collection fiber **130** electrically connected to support wire **200** and also connected to support member **230**. Support member **230** may be connected to collection fiber **130** on either side. Support member **230** holds the fiber steady on both ends instead of letting it move freely. Support member **230** may be conducting or non-conducting. A plurality of diodes may be placed at any position on the support structure wire. A preferred embodiment places a diode at elevated position at the connection point between collection fiber **130** and support wire **200** or between fiber **130**, support member **230**, and support wire **200**.

FIG. **2C** presents multiple collection fibers in a squirrel cage arrangement with top and bottom support members. Support structure **250** may be connected to support structure wire **200** by support member **240**. Structure **250** has a top **260** and a bottom **270** and each of the multiple collection fibers **130** are connected on one end to top **260** and on the other end to bottom **270**. A plurality of diodes may be placed at any position on support structure **250**. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support structure wire **200**.

FIG. **2D** presents another exemplary embodiment of a support structure with support members **275** in an x-shape connected to support structure wire **200** at intersection **278** with collection fibers **130** connected between ends of support members **275**. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support wire **200**.

FIG. **2E** provides another exemplary embodiment for supporting collection fiber **130**. Collection fiber **130** may be connected on one side to support member **285**, which may be connected to support structure wire **200** in a first location and on the other side to support member **280**, which may be connected to support structure wire **200** in a second location on support structure wire **200**. The first and second locations may be the same location, or they may be different locations, even on different support wires. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places one or more diodes at elevated positions at the connection point(s) between collection fiber **130** and support wire **200**.

FIG. **2F** presents another exemplary embodiment of a support for a collection fiber. Two support members **290** may support either side of a collection fiber and are connected to support wire **200** in a single point. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support wire **200**.

FIG. **2G** provides two supports as provided in FIG. **2F** such that at least two support members **292**, **294** may be connected to support structure wire **200** in multiple locations and collection fibers **130** may be connected between each end of the support structures. Collection fibers **130** may be connected between each end of a single support structure and between multiple support structures. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places one or more diodes at elevated positions at the connection point(s) between collection fiber **130** and support structure wire **200**.

FIG. **3** provides a schematic diagram of storing circuit **300** for storing energy collected by one or more collection devices (**130** from FIG. **2**). Load **150** induces current flow. Diode **310** may be electrically connected in series between one or more collection devices (**130** from FIG. **2**) and load **150**. A plurality of diodes may be placed at any position in the circuit. Switch **330** may be electrically connected between load **150** and at least one collection device (**130** from FIG. **2**) to connect and disconnect the load. Capacitor **320** may be connected in parallel to the switch **330** and load **150** to store energy when switch **330** is open for delivery to load **150** when switch **330** is closed. Rectifier **340** may be electrically connected in parallel to load **150**, between the receiving end of switch **330** and ground. Rectifier **340** may be a full-wave or a half-wave rectifier. Rectifier **340** may include a diode electrically connected in parallel to load **150**, between the receiving end of switch **330** and ground. The direction of the diode of rectifier **340** is optional.

In an exemplary embodiment provided in FIG. **4**, storage circuit **400** stores energy from one or more collection devices (**130** from FIG. **2**) by charging capacitor **410**. If charging capacitor **410** is not used, then the connection to ground shown at capacitor **410** is eliminated. A plurality of diodes may be placed at any position in the circuit. Diode **310** may be electrically connected in series between one or more collection devices (**130** from FIG. **2**) and load **150**. Diode **440** may be placed in series with load **150**. The voltage from capacitor **410** can be used to charge spark gap **420** when it reaches sufficient voltage. Spark gap **420** may comprise one or more spark gaps in parallel. Non-limiting examples of spark gap **420** include mercury-reed switches and mercury-wetted reed switches. When spark gap **420** arcs, energy will arc from one end of the spark gap **420** to the receiving end of the spark gap **420**. The output of spark gap **420** may be electrically connected in series to rectifier **450**. Rectifier **450** may be a full-wave or a half-wave rectifier. Rectifier **450** may include a diode electrically connected in parallel to transformer **430** and load **150**, between the receiving end of spark gap **420** and ground. The direction of the diode of rectifier **450** is optional. The output of rectifier **450** is connected to transformer **430** to drive load **150**.

FIG. **5** presents motor driver circuit **500**. One or more collection devices (**130** from FIG. **2**) are electrically connected to static electricity motor **510**, which powers generator **520** to drive load **150**. A plurality of diodes may be placed at any position in the circuit. Motor **510** may also be directly connected to load **150** to drive it directly.

FIG. **6** demonstrates a circuit **600** for producing hydrogen. A plurality of diodes may be placed at any position in the circuit. One or more collection devices (**130** from FIG. **2**) are electrically connected to primary spark gap **610**, which may be connected to secondary spark gap **640**. Non-limiting examples of spark gaps **610**, **640** include mercury-reed switches and mercury-wetted reed switches. Secondary spark gap **640** may be immersed in water **630** within container **620**. When secondary spark gap **640** immersed in water **630** is energized, spark gap **640** may produce bubbles of hydrogen and oxygen, which may be collected to be used as fuel.

FIG. **7** presents circuit **700** for driving a fuel cell. A plurality of diodes may be placed at any position in the circuit. Collection devices (**130** from FIG. **2**) provide energy to fuel cell **720** which drives load **150**. Fuel cell **720** may produce hydrogen and oxygen.

FIG. **8** presents exemplary circuit **800** for the collection of energy. Storage circuit **800** stores energy from one or more collection devices (**130** from FIG. **2**) by charging capacitor **810**. If charging capacitor **810** is not used, then the connection to ground shown at capacitor **810** is eliminated. A plurality of diodes may be placed at any position in the circuit. The voltage from capacitor **810** can be used to charge spark gap **820** when it reaches sufficient voltage. Spark gap **820** may comprise one or more spark gaps in parallel or in series. Non-limiting examples of spark gap **820** include mercury-reed switches and mercury-wetted reed switches. When spark gap **820** arcs, energy will arc from one end of spark gap **820** to the receiving end of spark gap **820**. The output of spark gap **820** may be electrically connected in series to rectifier **825**. Rectifier **825** may be a full-wave or a half-wave rectifier. Rectifier **825** may include a diode electrically connected in parallel to inductor **830** and load **150**, between the receiving end of spark gap **820** and ground. The direction of the diode of rectifier **825** is optional. The output of rectifier **825** is connected to inductor **830**. Inductor **830** may be a fixed value inductor or a variable inductor. Capacitor **870** may be placed in parallel with load **150**.

FIG. **9** presents a flow diagram of a method for collecting energy. In block **910**, one or more collection devices may be suspended from a support structure wire. In block **920**, a load may be electrically connected to the support structure wire to draw current. In block **930** a diode may be electrically connected between the support structure wire and the electrical connection to the load. In block **940**, energy provided to the load may be stored or otherwise utilized.

Any process descriptions or blocks in flow charts should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included within the scope of the preferred embodiment of the present disclosure in which functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present disclosure.

It should be emphasized that the above-described embodiments of the present disclosure, particularly, any "preferred" embodiments, are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) of the disclosure without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and the present disclosure and protected by the following claims.

Therefore, at least the following is claimed:

1. A method of collecting energy comprising:

suspending at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the at least one collection device electrically connected to the support structure;

providing a load with an electrical connection to the at least one collection device to passively draw current; and powering a fuel cell between the support structure and the load, the powering performed with energy collected from the at least one collection device.

2. The method of claim **1**, wherein the collection device comprises a diode.

3. The method of claim **1**, wherein the collection device comprises a collection fiber.

4. The method of claim **1**, wherein the collection device comprises a diode and a collection fiber and the diode is electrically connected between the collection fiber and the load.

5. The method of claim **1**, further comprising storing energy provided to the load.

6. The method of claim **5**, wherein storing energy provided to the load comprises storing energy in a capacitor or an inductor.

7. The method of claim **3**, wherein the collection fiber comprises carbon fiber or graphite fiber.

8. A system of energy collection comprising:

a support structure;

at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the collection device electrically connected to and suspended from the support structure, the at least one collection device configured to passively draw current;

a load electrically connected to the at least one collection device; and

a diode electrically connected between the at least one collection device and the support structure.

9. The system of claim **8**, wherein the collection device comprises a diode.

10. The system of claim **8**, wherein the collection device comprises a collection fiber.

11. The system of claim **8**, wherein the collection device comprises a collection fiber and a diode electrically connected between the load and the collection fiber.

12. The system of claim **9**, wherein the diode is elevated relative to the ground level.

13. The system of claim **10**, wherein the collection fiber comprises a carbon fiber or a graphite fiber.

14. The system of claim **8**, further comprising:

a switch connected in series between the at least one collection device and the load; and

a capacitor connected in parallel with the switch and the load.

15. The system of claim **14**, wherein the switch comprises an interrupter connected between the at least one collection device and the load, and wherein the interrupter comprises at least one of a fluorescent tube, a neon bulb, an AC light, and a spark gap.

16. The system of claim **15**, further comprising a transformer connected between the interrupter and the load.

17. The system of claim **8**, further comprising:

a motor for providing power, the motor connected between the at least one collection device and the load; and

a generator powered by the motor.

18. The system of claim **8**, further comprising a fuel cell between the support structure and the load.

19. The system of claim **18**, wherein the fuel cell produces hydrogen and oxygen.

20. A system of collecting energy comprising:

means for suspending at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the at least one collection device electrically connected to the means for suspending;

means for passively inducing current flow, the means for inducing current flow electrically connected to the means for suspending; and

means for restricting the backflow of charge carriers, the means for restricting the backflow of charge carriers electrically connected between the at least one collection device and the means for inducing current flow.

21. A system of energy collection comprising:

a support structure;

at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the collection device electrically connected to and suspended from the support structure, the at least one collection device configured to passively draw current;

a load electrically connected to the at least one collection device; and

a switch connected in series between the at least one collection device and the load, the switch comprising an interrupter connected between the at least one collection device and the load, and wherein the interrupter comprises at least one of a fluorescent tube, a neon bulb, an AC light, and a spark gap.

22. The system of claim **21**, further comprising a transformer connected between the interrupter and the load.

23. A system of energy collection comprising:

a support structure;

at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the at least one collection device electrically connected to and suspended from the support structure, the collection device configured to passively draw current;

a load electrically connected to the at least one collection device;

a motor for providing power, the motor connected between the at least one collection device and the load; and

a generator powered by the motor.

24. A system of energy collection comprising:

a support structure;

at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the at least one collection device electrically connected to and suspended from the support structure the at least one collection device configured to passively draw current;

a load electrically connected to the at least one collection device; and

a fuel cell between the support structure and the load.

25. The system of claim **24**, wherein the fuel cell produces hydrogen and oxygen.

* * * * *

US007643312B2

(12) **United States Patent**
Vanderelli et al.

(10) **Patent No.: US 7,643,312 B2**
(45) **Date of Patent: *Jan. 5, 2010**

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(54) **METHOD AND APPARATUS FOR A WIRELESS POWER SUPPLY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/357,578**

(22) Filed: **Feb. 17, 2006**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 10/966,880, filed on Oct. 15, 2004, now Pat. No. 7,027,311.

(60) Provisional application No. 60/511,860, filed on Oct. 17, 2003.

(51) **Int. Cl.**
H02M 5/00 (2006.01)

(52) **U.S. Cl.** **363/8**

(58) **Field of Classification Search** 363/8, 363/59, 60, 157, 184, 165; 455/270, 272, 455/273, 275, 276.1, 277.1; 307/151
See application file for complete search history.

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Primary Examiner—Matthew V Nguyen

(57) **ABSTRACT**

An apparatus for a wireless power supply including a mechanism for receiving a range of RF radiation across a collection of frequencies. The apparatus includes a mechanism for converting the RF radiation across the collection of frequencies, preferably at a same time into DC. A method for a wireless power supply including the steps of receiving a range of RF radiation across a collection of frequencies. There is the step of converting the RF radiation across the collection of frequencies, preferably at a same time into DC.

20 Claims, 2 Drawing Sheets

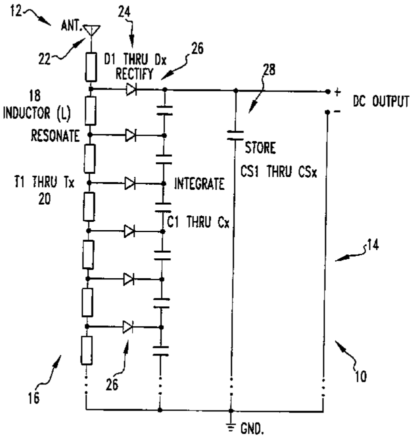

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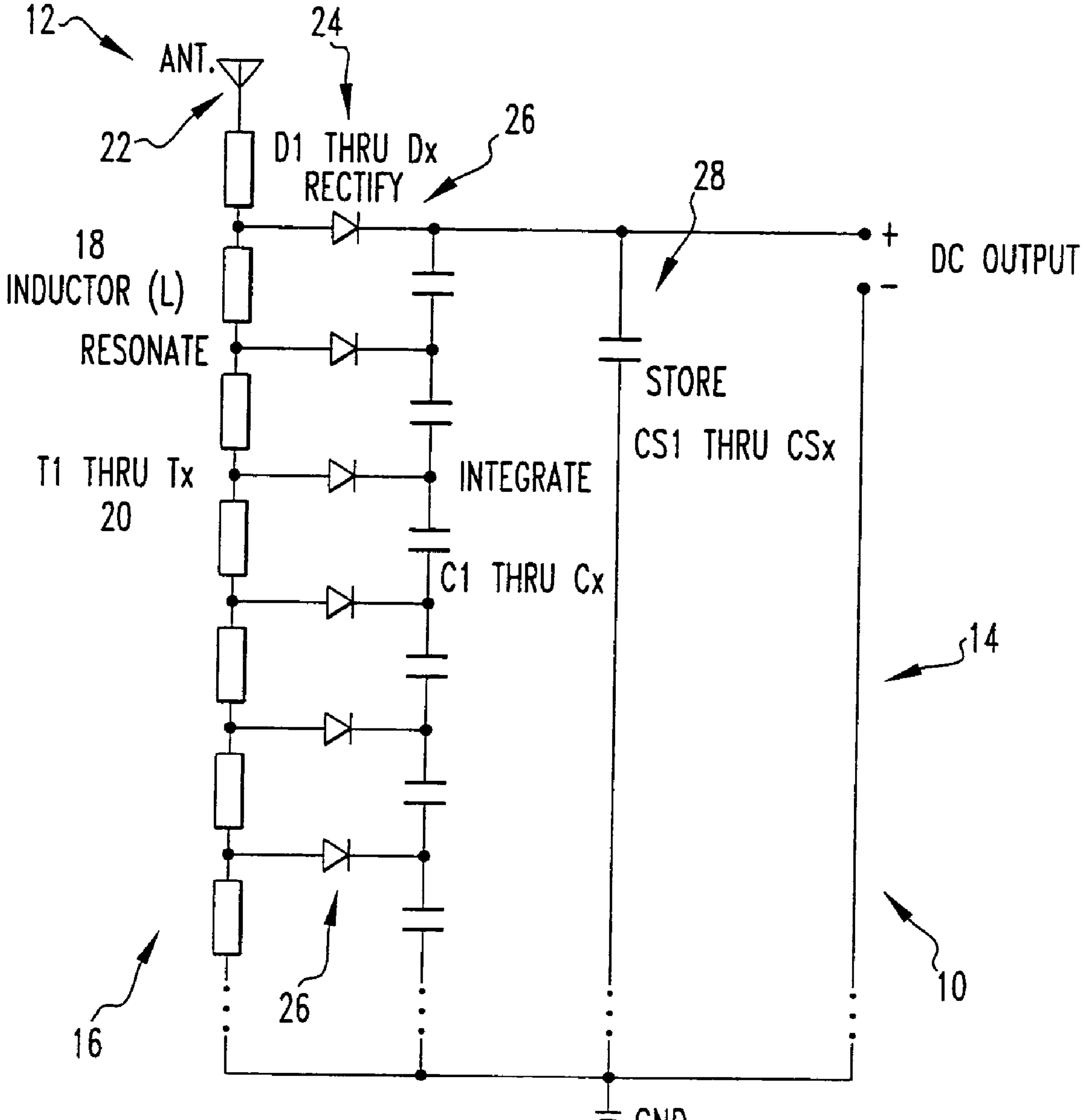
12
ANT.
22
24
D1 THRU Dx
RECTIFY
26
28
+
DC OUTPUT
-
18
INDUCTOR (L)
RESONATE
STORE
CS1 THRU CSx
T1 THRU Tx
20
INTEGRATE
C1 THRU Cx
14
26
16
10
GND.

FIG.1

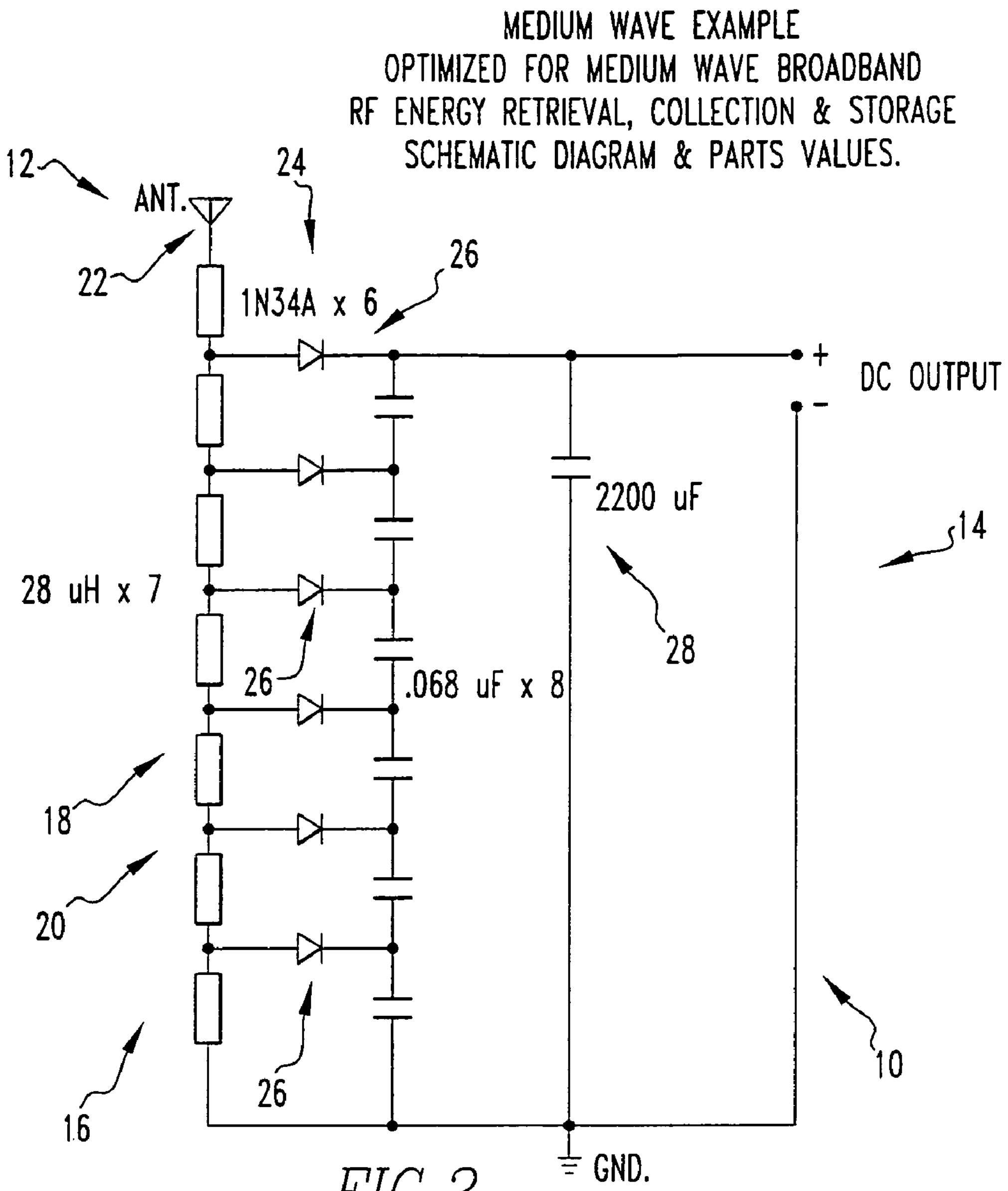
MEDIUM WAVE EXAMPLE
OPTIMIZED FOR MEDIUM WAVE BROADBAND
RF ENERGY RETRIEVAL, COLLECTION & STORAGE
SCHEMATIC DIAGRAM & PARTS VALUES.
12
ANT.
24
22
1N34A x 6
26
+
DC OUTPUT
-
2200 uF
14
28 uH x 7
28
26
.068 uF x 8
18
20
10
26
16
GND.

FIG.2

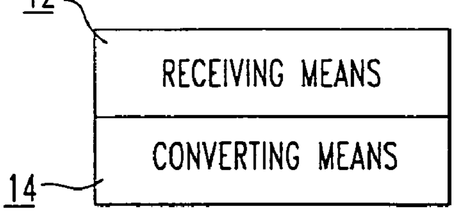
12
RECEIVING MEANS
CONVERTING MEANS
14

FIG.3

METHOD AND APPARATUS FOR A WIRELESS POWER SUPPLY

This application is a continuation application of application Ser. No. 10/966,880 filed on Oct. 15, 2004, now U.S. Pat. No. 7,027,311.

The nonprovisional application designated above, namely application Ser. No. 10/966,880, filed Oct. 15, 2004, claims the benefit of U.S. Provisional Application No.:

APPLICATION NO. 60/511,860
FILING DATE Oct. 17,2003

FIELD OF THE INVENTION

The present invention is related to the retrieval of radiated electrical energy. More specifically, the present invention is related to the retrieval of radiated electrical energy that is optimized for any given portion of the RF spectrum using a plurality of taps.

BACKGROUND OF THE INVENTION

In the operation of the invention, ambient RF and generated RF signals provide a source of potential energy that can be gathered, stored and supplied to a multitude of devices requiring electrical energy or that can restore energy lost by a discharged source.

Traditional RF receiving devices utilize an antenna to capture a narrow band of frequencies within the RF spectrum, whereby the collection of RF frequencies is then filtered, or tuned, to a specific frequency(s) for the purposes of maximizing the signal being transmitted within the chosen frequency (s). The potential energy contained in the signal is then used for its intended purpose, such as audio, video or data processing. These RF receiving devices have focused on maximizing selectivity of the frequency in order to isolate and to be coherent without interference from other sources.

SUMMARY OF THE INVENTION

The present invention pertains to an apparatus for a wireless power supply. The apparatus comprises means for receiving a range of RF radiation across a collection of frequencies, preferably at a same time. The apparatus comprises means for converting the RF radiation across the collection of frequencies, preferably at a same time into DC.

The present invention pertains to a method for a wireless power supply. The method comprises the steps of receiving a range of RF radiation across a collection of frequencies, preferably at a same time. There is the step of converting the RF radiation across the collection of frequencies, preferably at a same time into DC.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings, the preferred embodiment of the invention and preferred methods of practicing the invention are illustrated in which:

FIG. **1** is a schematic representation of a preferred embodiment of an apparatus of the present invention.

FIG. **2** is a schematic representation of a preferred embodiment of an apparatus of the present invention optimized for medium wave bandwidth RF energy retrieval, collection and storage.

FIG. **3** is a block diagram of the apparatus of the present invention.

DETAILED DESCRIPTION

Referring now to the drawings wherein like reference numerals refer to similar or identical parts throughout the several views, and more specifically to FIG. **1** thereof, there is shown an apparatus **10** for a wireless power supply. The apparatus **10** comprises means **12** for receiving a range of RF radiation across a collection of frequencies, preferably at a same time. The apparatus **10** comprises means **14** for converting the RF radiation across the collection of frequencies, preferably at a same time into DC.

Preferably, the converting means **14** includes an absorbing mechanism **16** which is resonant for a desired band of RF spectrum. The absorbing mechanism **16** preferably includes an inductor **18** which is resonant for the desired band of RF spectrum. Preferably, the converting means **14** includes a plurality of taps **20** placed at points along the inductor **18** to access the RF energy.

The tap points preferably are calculated by matching the inductor's **18** impedance to the desired band of RF spectrum. Preferably, the receiving means **12** includes an antenna **22**. The converting means **14** preferably includes a rectifying mechanism **24** which rectifies the RF energy and converts it into DC voltage. Preferably, the rectifying mechanism **24** includes a plurality of diodes **26** at each tap point which rectifies the RF energy and converts it into DC voltage.

The apparatus **10** preferably includes a storage device **28** for storing the DC voltage. Preferably, the antenna **22** impedance is matched 1:1 with the inductor **18** impedance. The RF spectrum preferably is between 60 Hz to 28 gigahertz.

The present invention pertains to a method for a wireless power supply. The method comprises the steps of receiving a range of RF radiation across a collection of frequencies. There is the step of converting the RF radiation across the collection of frequencies, preferably at a same time into DC.

Preferably, the converting step includes the step of absorbing the energy. The absorbing step preferably includes the step of absorbing the energy with an inductor **18**. Preferably, the converting step includes the step of accessing the absorbing energy with a plurality of taps **20** on the inductor **18**. There is preferably the step of matching the inductor's impedance to a desired RF range.

Preferably, the converting step includes the step of rectifying energy available at each tap and converting it into DC voltages. The rectifying step preferably includes the step of rectifying the energy available at each tap and converting it into DC voltages with diodes **26**. Preferably, the converting step includes the step of summing the DC voltages. The summing step preferably includes the step of adding the DC voltages among a series capacitor integrator. Preferably, there is the step of storing the summed DC voltages. There is preferably the step of using the stored DC voltages.

A method and apparatus **10** for retrieval of radiated electrical energy is described herein. The radiated energy to be captured is being transmitted in the portion of the electromagnetic spectrum sometimes referred to as RF, or Radio Frequency. The primary purpose of the method and apparatus **10** described herein, is to receive RF energy and convert the energy into a usable form of power. The method and apparatus **10** does not discern or interpret individual signals or frequencies. It is designed to absorb and convert signal, carrier and any associated interference for a chosen band or range of frequencies into reusable power.

In contrast, to traditional RF receiving devices, this methodology and apparatus **10** avoids selectivity. It has the unique characteristic of accepting broad ranges of the RF spectrum as a collection of frequencies. Each collected range of frequencies is then rectified, or converted, as a whole into a single voltage. Preferably, at the same time of RF absorption, the resultant voltage is generated. The apparatus **10** makes no attempt to tune for any specific frequency or signal. Each voltage, which is gathered from a given range of frequencies, is then added together and made available to power a device directly, to be stored, or to supply energy to a recharging apparatus. As is implicit from the aforementioned description, preferably, the apparatus **10** receives the RF radiation across the collection of frequencies at the same time.

The radiated electrical energy, to be utilized by the circuit, can be in the form of a wide range of the RF spectrum. Some examples of ambient RF sources can include, but are not limited to: Very Low Frequency—VLF (Maritime/Aeronautical Mobile), Medium Frequency—MF (AM Radio Broadcast), High Frequency—HF (Shortwave Radio Broadcast), Very High Frequency—VHF (TV and FM Radio Broadcast), Ultra High Frequency—UHF (TV, HDTV, PCS, WiFi) and certain Microwave transmissions. In addition, the apparatus **10** allows for the reception of dedicated RF transmission that are generated and broadcast for the specific purpose of transmitting power to the apparatus **10** for absorption, collection and utilization. In this case, it is not necessary for the dedicated RF transmission to contain a specific signal or data that needs to be interpreted for ancillary purposes such as audio/video or data reception and interpretation.

Using the technique described herein, one can design and create an apparatus **10** that is optimized for any given portion of the RF Spectrum. The necessary electrical and magnetic characteristics of the apparatus **10** components will vary depending on the chosen portion of the spectrum. Because of this, it is impractical to create one single apparatus **10** to cover the entire RF spectrum. However, it is possible to create individual apparatus **10**, each designed for a given RF band, and combine both the apparatus **10**, their outputs for maximum power efficiency.

A portion of a selected RF frequency band is intercepted by an antenna **22** placed in the field of emitted energy. The antenna **22** receives energy, in accordance with its design efficiency, and directs it into a system where it is absorbed, rectified, summed and delivered for use or storage.

RF Energy→Antenna→
[Absorbed→Rectified→Integrated→Delivered]
→Used

RF signals striking an antenna **22** are fed into an inductor (L), which is resonant for the desired band of RF spectrum. Note: In areas with a high concentration of RF energy, there is no need to attach an antenna **22**. The absorbed RF energy, consisting of fundamental, harmonic, inter-harmonic and standing waves is accessed via taps **20** (T**1**-Tx) on the inductor **18** which are placed at points along the inductor **18**. A key characteristic of this device is that a capacitor-less front-end allows for the inductors' wide bandwidth and maximum admittance of the incoming RF energy. The tap points are calculated by matching the inductor **18** section's impedance to the desired RF range.

The resultant RF energy, available at each tap point, is rectified by a device, such as diodes **26** (D**1**-Dx), and converted into DC Voltages. The individual rectified voltages are spread among a series capacitor integrator consisting of capacitors (C**1**-Cx). This broadband approach allows maximum energy to be spread among the series capacitor stack.

The sum of the voltages available from C**1**-Cx is stored in any storage device **28** such as a capacitor or group of capacitors Cs (s**1**-sx) and made available for immediate use, or to supply electronic device(s) requiring intermittent power. The electrical characteristics of the storage devices or capacitors, the configuration and actual number of storage devices is dependent on the voltage and power requirements of the device the apparatus **10** is delivering power to. (See Figure One)

Although not considered part of the apparatus **10**, the antenna **22** is an integral component of any practical device utilizing the method and apparatus **10** described. The key characteristics of the antenna **22** would be that it is capable of wide band reception, optimized for the chosen bandwidth, and takes into consideration the necessary effective area to support the power requirements of the target device.

Ideally, the antenna **22** impedance is matched 1:1 with the inductor **18** impedance of the apparatus **10**.

Note: In areas with a high concentration of RF energy, there is no need to attach an antenna **22** to the apparatus **10**.

Inductor **18**:

The characteristics of the inductor **18** is dependent on the chosen bandwidth of frequencies to be collected and utilized. The ideal inductor **18** should be constructed so that the mid point of total inductance would be resonant at the center frequency of the chosen RF segment or spectrum.

Multiple taps **20** provide fundamental and inter-harmonic output voltages from the selected band segments of radio frequency energy.

For example, a medium wave circuit (FIG. **2**), utilizing an antenna **22** impedance of 375 ohms, into an inductive circuit with 375 ohms of reactance, with a center frequency of 1.2 MHz would require an inductance of 100 uH. The effective bandwidth would be approximately 2 MHz wide. (−3 db down at each end of the band).

The inductor **18** can be calculated using the following standard resonance formula (Formula 1):

L=(d squared times n squared) divided by (18 times d plus 40 times j)

Where
L=inductance in micro-henrys.
d=conductor diameter in inches.
j=conductor length in inches.
n=number of conductor iterations.

Using similar formulae, the required inductance can be re-calculated for henrys, milli-henrys, pico-henrys and nano-henrys. ie. VLF, LF, MW, HF, VHF, UHF and Microwave frequency band segments.

Utilizing a capacitor-less front-end insures the inductors' wide bandwidth, and maximum admittance to the incoming RF energy.

Taps **20**:

Taps **20** are to be constructed and placed at points along the inductor **18**. Each tap provides an individual output voltage into the rectifying portion of the apparatus **10**.

The number of taps **20** from the inductor **18** can be calculated by the following formula (Formula 2):

Tn=Bw times pi

Where
Tn=Total number of taps.
Bw=Effective Bandwidth of inductor (in Megahertz).
Pi=3.1416

The default position of each tap on the inductor **18** is equidistant along the inductor **18**. Tap positions can also be calculated for optimum output voltage. When calculating the taps **20**, one must take into consideration known frequencies within the chosen band segment that contain higher RF energies, And using a standard resonance inductance formula (1) each individual tap can be calculated for the required frequency and optimum voltage output.

Rectifiers:

The RF energy available at each tap is converted to DC voltage via a rectifying device. The type of rectifying device to be used is dependent on the chosen frequency band, and includes crystal, germanium, silicon and any other types.

Integrator:

A voltage integrator is composed of capacitors C**1**-Cx. The values of these capacitors are dependent on the chosen frequency band, the unique characteristics of the rectifiers and the load imposed by the Storage stage. The reactance of this circuit varies greatly, even during normal operation. However, one can use a standard formula for capacitive reactance as a starting point for preliminary calculations:

$$Xc=1/(2*pi*F*C)$$

Where

Xc=Capacitive reactance in ohms

C=Capacitance in Microfarads.

F=Frequency in Hertz.

Pi=3.1416

Storage:

Storage component(s) are determined by the power requirements of the attached device(s), and the available RF energy absorbed by the inductor (L).

Using a Medium Wave example, a 2,200 micro-farad electrolytic capacitor is used as storage.

Sample Apparatus 10: Medium Wave (AM) Wireless Power Supply

A device has been constructed, using the method stated above, which uses the ambient (existing) AM Broadcast band of the RF spectrum as its source of energy. The device's primary purpose is to optimize the energy absorbed, collected and converted to reusable power.

The size and characteristics of the antenna **22** required for the circuit to operate are not considered a design requirement for the apparatus **10**. The antenna **22** needed to obtain sufficient energy to charge a storage device **28** in a typical urban area with several AM radio stations, would be similar to one used for a standard AM radio. In areas where there is a higher concentration of RF energy, the apparatus **10** itself, without an antenna **22**, is sufficient to develop stored power.

The inductor **18** is in the form of an air coil comprised of enameled #28 gauge wire wound onto a 2" form. The coil is a continuous tightly wound wire with taps **20** placed every twenty turns with a total of six taps **20** available (T**1**-T**6**). The top of the coil is where the antenna **22** is connected. The bottom of the coil is connected to ground.

Germanium diodes (IN34A) (D**1**-D**6**) are connected to each tap on the coil. The series capacitor integrator (C**1**-C**6**) is constructed as illustrated with the C**6** attached to ground. C**1**-C**6** are poly capacitors with a 0.068 uF rating. The power storage device **28** utilized in this sample apparatus **10**, C7, is a 2200 uF electrolytic capacitor.

Very wide band operation can be utilized by coupling multiple instances of the Broadband Wireless Power Supply together.

For Example:

A BWPS circuit designed and constructed (see design considerations) for a Very Low Frequency wave segment (60 Hz center frequency), can be coupled into another BWPS circuit designed and constructed (see design considerations) for an Ultra High Frequency wave segment (5 GHz center frequency). The outputs of each individual circuit connect (via another integrator circuit) into a common storage device **28** (i.e., capacitor) to "pool" collected and converted RF energy together. This technique can be repeated for any or all segments of the energy spectrum.

Although the invention has been described in detail in the foregoing embodiments for the purpose of illustration, it is to be understood that such detail is solely for that purpose and that variations can be made therein by those skilled in the art without departing from the spirit and scope of the invention except as it may be described by the following claims.

What is claimed is:

1. An apparatus, comprising:

means for receiving RF radiation within a plurality of frequency bands; and

means for converting separately the received RF radiation associated with each of the plurality of frequency bands into DC, the converting means includes an inductor and at least three taps, each tap from the at least three taps being placed at a unique point along the inductor to access an energy associated with the RF radiation.

2. An apparatus as described in claim **1** wherein the inductor includes one or more portions, each portion of the inductor is uniquely associated with one frequency band from the plurality of frequency bands, each portion of the inductor has a resonant frequency within that frequency band.

3. An apparatus as described in claim **2** wherein the tap points are calculated based on the resonant frequency for each portion of the inductor.

4. An apparatus as described, in claim **1** wherein the receiving means includes an antenna.

5. An apparatus as described in claim **1** wherein the converting means includes a rectifying mechanism which rectifies the energy associated with the received RE radiation to produce rectified energy and converts the rectified energy into a DC voltage.

6. An apparatus as described in claim **5** wherein the rectifying mechanism includes a diode at each tap point to rectify the energy associated with the received RF radiation into the DC voltage.

7. An apparatus as described in claim **5** further comprising a storage device for storing the DC voltage.

8. A method, comprising:

receiving RF radiation within a plurality of frequency bands at a single antenna;

separating the received RE radiation into a plurality of portions of the received RE radiation independent of a capacitor, each portion from the plurality of portions of the received RE radiation uniquely associated with a frequency band from the plurality of frequency bands; and

converting separately the plurality of portions of the received RE radiation into DC.

9. A method as the described in claim **8** wherein the converting includes absorbing an energy associated with the received RF radiation.

10. A method as described in claim **9** wherein the absorbing includes absorbing the energy with an inductor.

11. A method as described in claim **10** wherein the converting includes accessing the absorbed energy with a plurality of taps on the inductor.

12. A method as described in claim **11** wherein the converting includes rectifying the energy associated with each tap to produce rectified energy and converting the rectified energy associated with each tap into a DC voltage.

13. A method as described in claim **12** wherein the rectifying includes rectifying the energy associated with each tap to produce rectified energy and converting the rectified energy associated with each tap into the DC voltage with a diode.

14. A method as described in claim **13** wherein the converting includes adding the DC voltage associated with each tap from the plurality of taps into a single DC voltage.

15. A method as described in claim **14** wherein the adding includes integrating the DC voltage associated with each tap from the plurality of taps with a series capacitor integrator.

16. A method as described in claim **14** further comprising storing the single DC voltage.

17. An apparatus, comprising:

means for receiving a range of RF radiation across a collection of frequencies; and

means for converting RF radiation across the collection of frequencies into DC, including multiple taps to access the PT radiation across the collection of frequencies.

18. An apparatus, comprising:

means for receiving a range of RF radiation across a collection of frequencies with a single antenna; and

means for converting RF radiation across the collection of frequencies from the single antenna into DC, the converting means includes an inductor that is resonant for a desired band of RF spectrum, the inductor having a plurality of taps placed at points along the inductor to access the RE energy.

19. A method, comprising:

receiving a range of RF radiation across a collection of frequencies at a single antenna;

converting the RF radiation received at the single antenna across the collection of frequencies into DC by absorbing the energy with an inductor; and

accessing the absorbed energy with a plurality of taps on the inductor.

20. A method, comprising:

receiving radiation within an RF spectrum band via a single antenna, a first portion of the received radiation being associated with a first portion of the RF spectrum band, a second portion of the received radiation being associated with a second portion of the RF spectrum band different than the first portion;

converting separately the received radiation from each of the first portion of the RF spectrum band and the second portion of the RF spectrum band into a DC voltage; and

combining the DC voltage associated with the first portion of the RF spectrum band and the DC voltage associated with the second portion of the RE spectrum band.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,643,312 B2
APPLICATION NO. : 11/357578
DATED : January 5, 2010
INVENTOR(S) : Timm A. Vanderelli et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 6, line 36 (claim 5, line 3), replace “RE radiation” with -- RF radiation --.

Column 6, line 48 (claim 8, line 4), replace “RE radiation” with -- RF radiation --.

Column 6, line 49 (claim 8, line 5), replace “RE radiation” with -- RF radiation --.

Column 6, line 51 (claim 8, line 7), replace “RE radiation” with -- RF radiation --.

Column 6, line 55 (claim 8, line 11), replace “RE radiation” with -- RF radiation --.

Column 7, line 19 (claim 17, line 6), replace “PT radiation” with -- RF radiation --.

Column 8, line 3 (claim 18, line 9), replace “RE energy” with -- RF energy --.

Column 8, line 24 (claim 20, line 13), replace “RE spectrum band” with -- RF spectrum band --.

Signed and Sealed this
Eighteenth Day of January, 2011

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

US009160156B2

(12) United States Patent
Allen et al.

(10) **Patent No.:** **US 9,160,156 B2**
(45) **Date of Patent:** **Oct. 13, 2015**

(54) **SYSTEM FOR HARVESTING ATMOSPHERIC ELECTRICITY**

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(73) Assignee: **Lockheed Martin Corporation**, Bethesda, MD (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 357 days.

(21) Appl. No.: **13/276,259**

(22) Filed: **Oct. 18, 2011**

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(51) **Int. Cl.**
H05F 7/00 (2006.01)
H02G 13/00 (2006.01)
B64D 45/02 (2006.01)

(52) **U.S. Cl.**
CPC ***H02G 13/20*** (2013.01); ***B64D 45/02*** (2013.01); *H05F 7/00* (2013.01)

(58) **Field of Classification Search**
CPC H02G 13/20; B64D 45/02; H05F 7/00
USPC 361/231, 230
See application file for complete search history.

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Primary Examiner — Zeev V Kitov
(74) *Attorney, Agent, or Firm* — Baker Botts L.L.P.

(57) **ABSTRACT**

Systems, methods and apparatus for harvesting atmospheric electricity are provided. The system includes a laser configured to form a plasma filament and a collector configured to collect electricity flowing along the plasma filament. The plasma filament comprises an electrically conducting plasma filament. Atmospheric electricity may be collected by having the plasma filament form at least a part of a conducting path: (1) between ground and a cloud, (2) between differently charged regions of the same cloud, (3) between differently charged regions of different clouds, and (4) between different regions of atmosphere, where there is a vertical voltage gradient. When the plasma filament is not long enough to form the entire conducting path, a lightning may be triggered to complete the conducting path needed to collect atmospheric electricity.

21 Claims, 6 Drawing Sheets

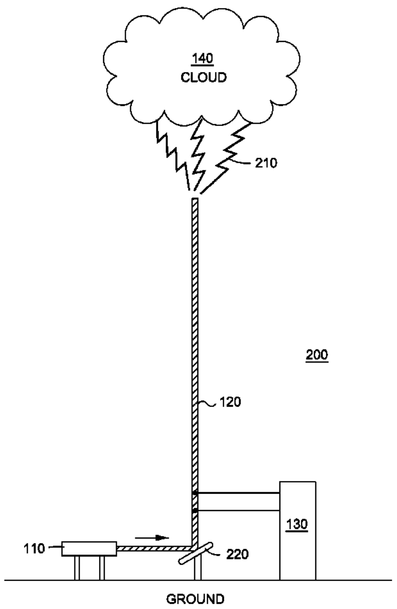

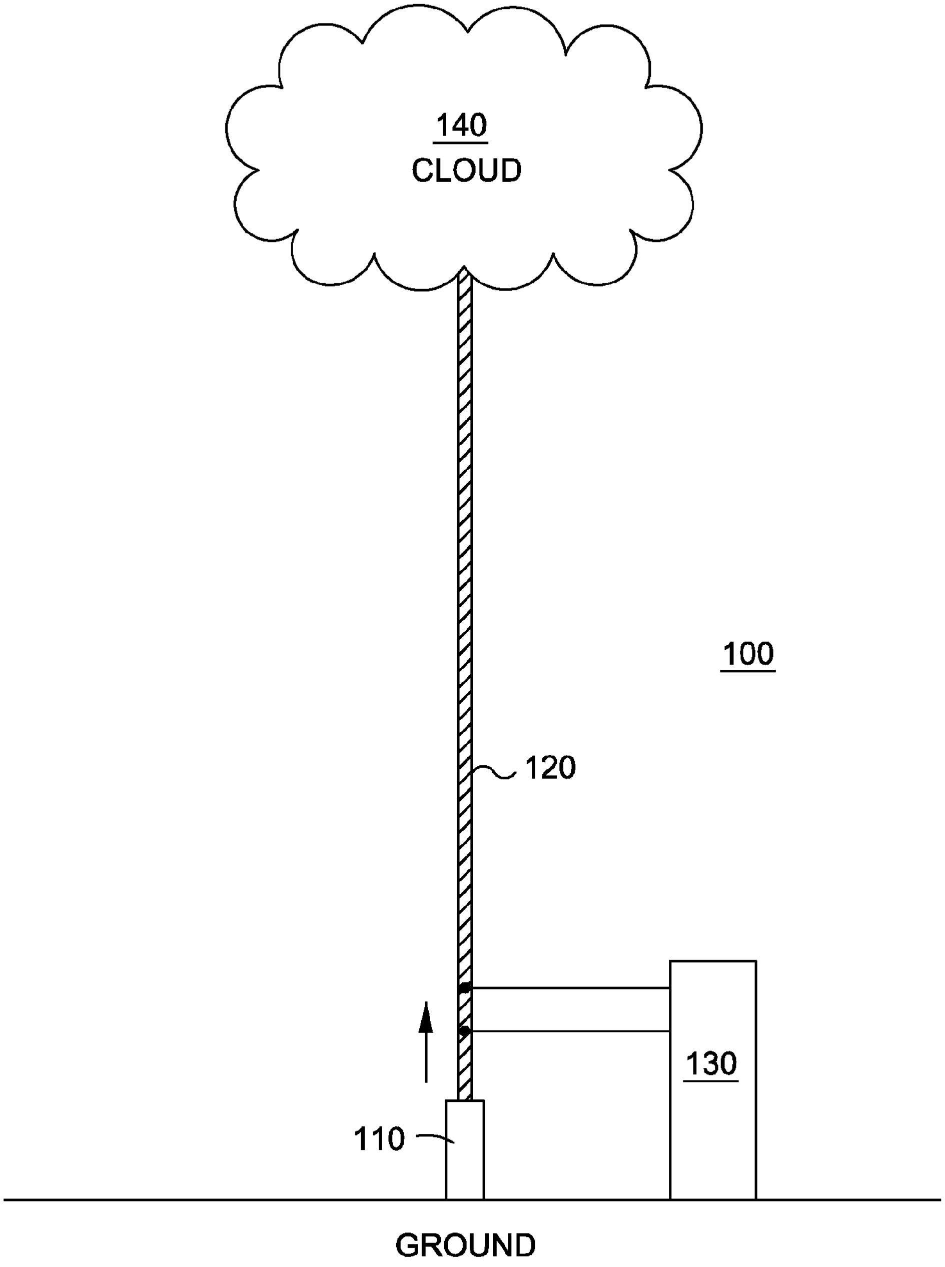
140
CLOUD
100
120
130
110
GROUND

FIG. 1

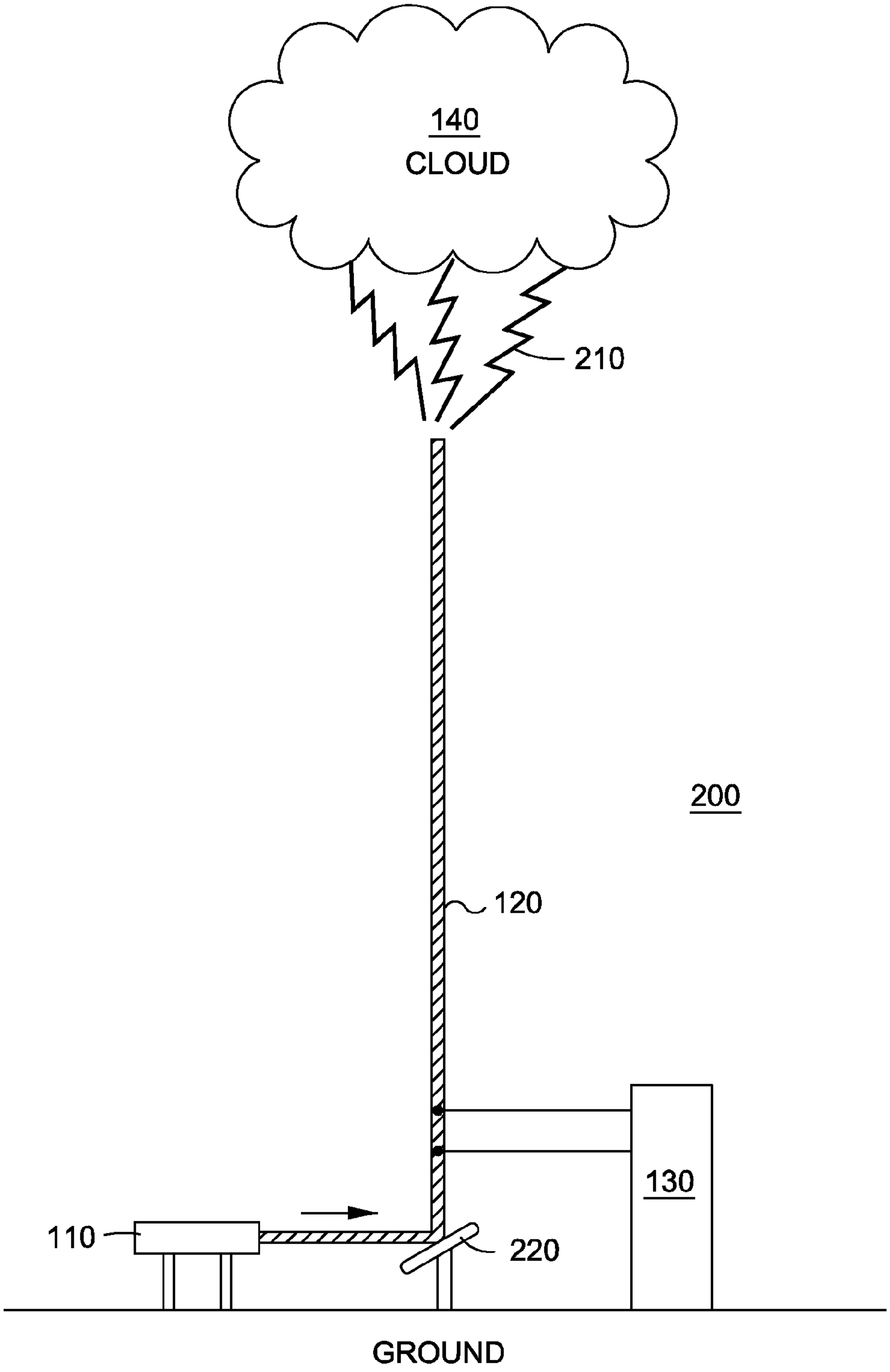
140
CLOUD
210
200
120
130
110
220
GROUND

FIG. 2

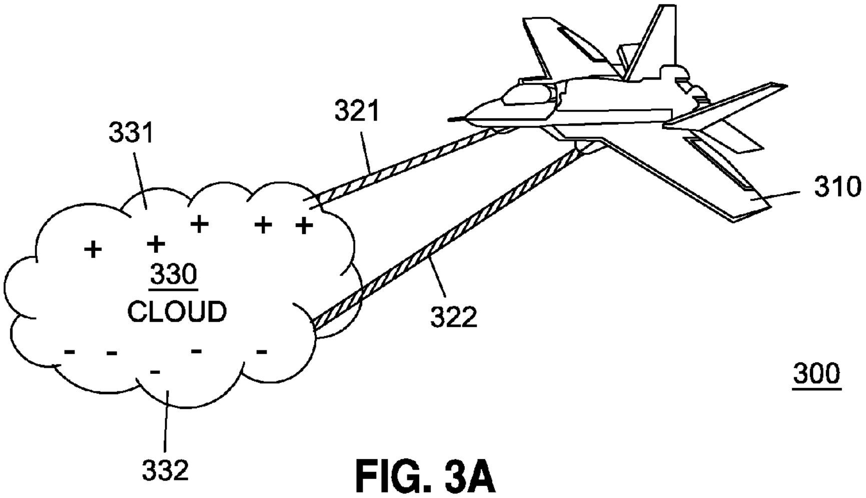
CLOUD

FIG. 3A

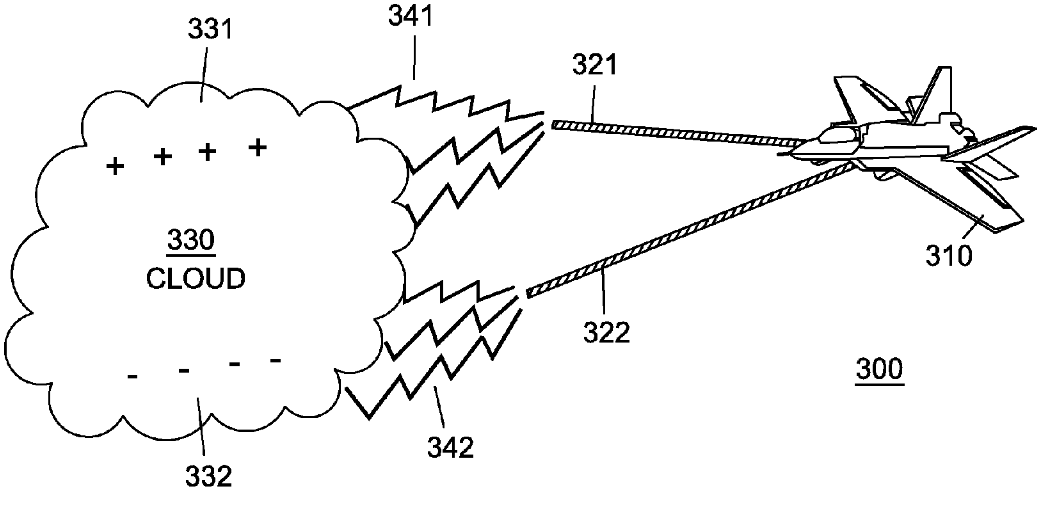
CLOUD

FIG. 3B

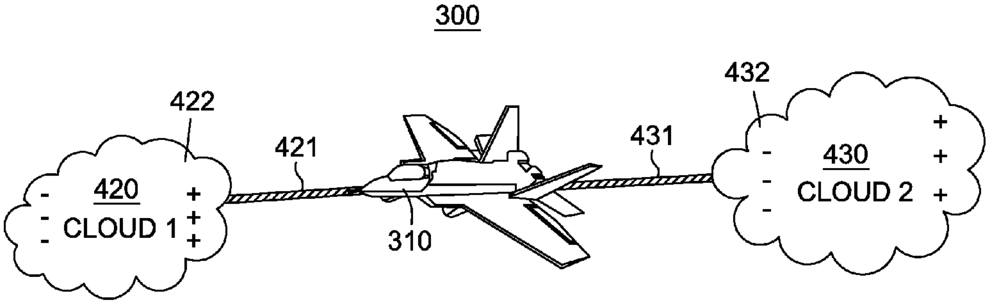
300
422
421
420
CLOUD 1
- - -
+ + +
310
431
432
430
CLOUD 2
- - -
+ + + +

FIG. 4

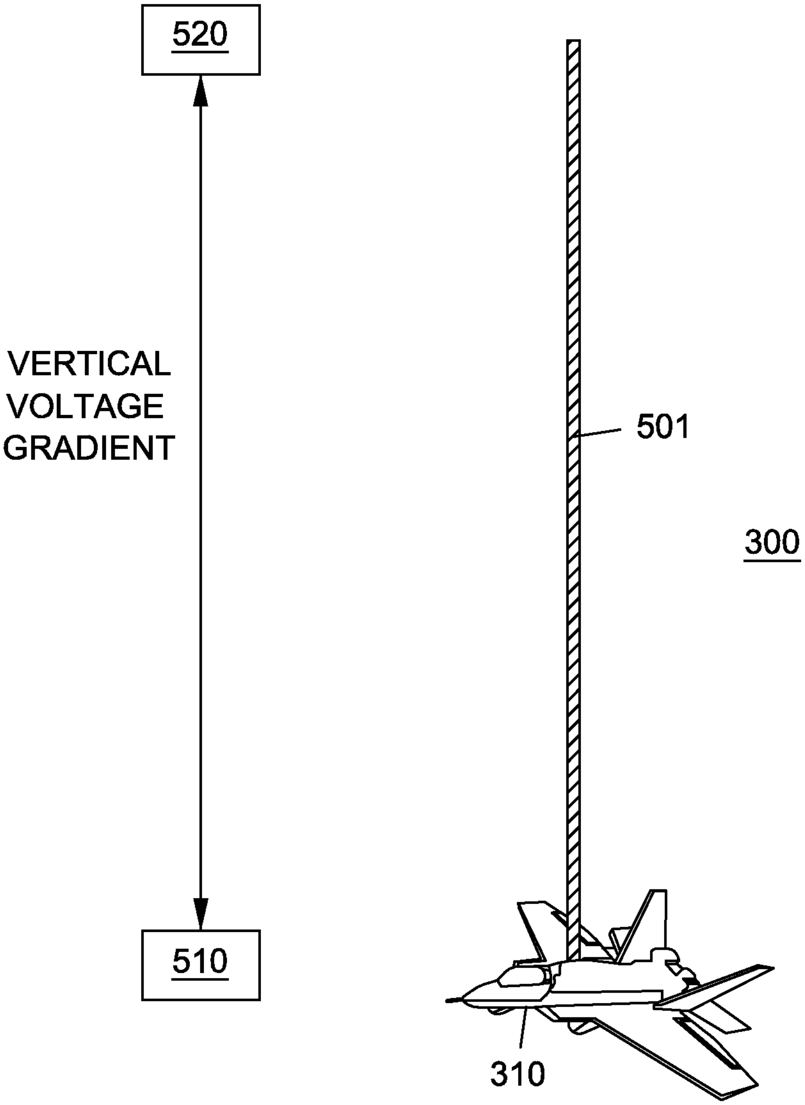
520
VERTICAL
VOLTAGE
GRADIENT
510
501
300
310

FIG. 5

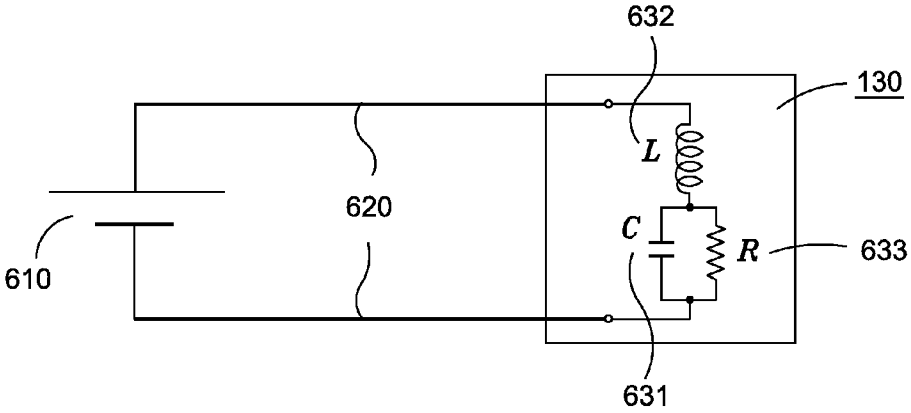
632
130
L
620
C
R
633
610
631

FIG. 6

SYSTEM FOR HARVESTING ATMOSPHERIC ELECTRICITY

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

FIELD OF THE INVENTION

The subject technology relates in general to a system for harvesting atmospheric electricity, and more particularly to a system that uses a laser to form an electrically conducting plasma filament for harvesting atmospheric electricity.

BACKGROUND

It is well known that large quantities of electrical energy are present in the atmosphere and in lightning. Lightning was one of the first forms of electricity harnessed in the modern age by Benjamin Franklin in his famous kite experiment.

A lightning discharge typically contains on the order of 10^{10} Joules of energy. It has been estimated that the total electrical power of lightning across the Earth is of the order of 10^{12} watts. Collection of electrical energy from clouds associated with lightning is a problem that needs to be resolved.

Lightning is but a small part of the total electrical activity of the atmosphere. When a local build up of charge above the Earth exceeds the local breakdown potential of the atmosphere a lightning discharge occurs. However, there is a continual invisible flow of charge from Ionosphere to Earth occurring day and night over the entire surface of the globe, which exceeds the global lightning power output by many times. The source of this flow of charge from the atmosphere to Earth is the Sun. Radiation from the Sun helps form most of the ions found in the Ionosphere, a highly charged region above the atmosphere, through ionization of atmospheric molecules. Solar radiation, particularly in the UV and soft x-ray bands, consist of photons whose energies are well suited to ionization. The Sun also emits continuously a solar wind of positively charged particles. These are captured by the Earth's magnetic field and further contribute to the Ionosphere. The positively charged region in the Ionosphere in turn induces (by electrostatic induction) a negative charge on the surface of the Earth. The Earth becomes in effect an enormous spherical capacitor. A potential gradient or electric field is thus established between the two "plates" of this capacitor, the Ionosphere (or Electrosphere) and the surface of the Earth. While the upper strata of the atmosphere conduct electricity reasonably well, the lower levels act as an insulator or dielectric. Near the surface of the Earth, this electrostatic potential gradient is on the order of about 100 Vm^{-1} in summer, rising to 300 Vm^{-1} in winter. This flow of charge can be tapped and directed to provide useable electrical power. This source of atmospheric electricity has the following advantages: (1) Simple and robust technology; (2) Low cost technology—much cheaper than photovoltaics or wind turbines; (3) Available day and night in all weather conditions—in fact, more power is produced at night than during the day; and (4) Available at any point on the Earth's surface. Collection of this source of atmospheric electricity is another problem that needs to be resolved.

SUMMARY

According to various aspects of the subject technology, a system for harvesting atmospheric electricity is provided that solves some or all of the foregoing problems. In some aspects, the system may be used to harvest atmospheric electricity arising from an electrostatic potential gradient: (1) between ground and a cloud, (2) between differently charged regions of the same cloud, (3) between differently charged regions of different clouds, and (4) between different regions of atmosphere, where there is a vertical voltage gradient. In other aspects, the system may be used to harvest atmospheric electricity arising from an electrostatic potential gradient between the Ionosphere (or Electrosphere) and the surface of the Earth.

According to various aspects of the subject technology, a system for harvesting atmospheric electricity is provided. The system comprises a laser configured to form a plasma filament. The system also comprises a collector configured to collect electricity flowing along the plasma filament.

According to various aspects of the subject technology, a method for harvesting atmospheric electricity is provided. The method comprises forming a plasma filament with a laser. The method also comprises collecting electricity flowing along the plasma filament.

According to various aspects of the subject technology, an apparatus for harvesting atmospheric electricity is provided. The apparatus comprises means for forming a plasma filament with a laser. The system also comprises means for collecting electricity flowing along the plasma filament.

It is understood that other configurations of the subject technology will become readily apparent to those skilled in the art from the following detailed description, wherein various configurations of the subject technology are shown and described by way of illustration. As will be realized, the subject technology is capable of other and different configurations and its several details are capable of modification in various other respects, all without departing from the scope of the subject technology. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide further understanding of the subject technology and are incorporated in and constitute a part of this specification, illustrate aspects of the subject technology and together with the description serve to explain the principles of the subject technology.

FIG. **1** illustrates a first example of a system for harvesting atmospheric electricity. The system comprises a laser configured to form a plasma filament and a collector configured to collect electricity flowing along the plasma filament. The plasma filament forms a conducting path between ground and a cloud.

FIG. **2** illustrates a second example of a system for harvesting atmospheric electricity. A plasma filament and a lightning together form a conducting path between ground and a cloud. A condensing mirror directs the beam of laser towards the cloud.

FIG. **3**A illustrates a third example of a system for harvesting atmospheric electricity. A laser system situated on an airplane forms two plasma filaments that together complete a conducting path between a first region of a cloud and a second region of the cloud. The first region of the cloud and the second region of the cloud carry opposite electric charges. A collector configured to collect electricity flowing along the two plasma filaments is also situated on the same airplane as the laser system.

FIG. **3**B illustrates a fourth example of a system for harvesting atmospheric electricity. It is similar to FIG. **3**A, except two lightnings complete the conducting path between a first region of a cloud and a second region of the cloud (i.e., a first lightning electrically connects the first region of the cloud to one of the plasma filaments and a second lightning electrically connects the second region of the cloud to the other plasma filament).

FIG. **4** illustrates a fifth example of a system for harvesting atmospheric electricity. A laser system situated on an airplane forms two plasma filaments that together complete a conducting path between a first cloud and a second cloud. The region of the first cloud that is connected to the first plasma filament and the region of the second cloud that is connected to the second plasma filament carry opposite electric charges.

FIG. **5** illustrates a sixth example of a system for harvesting atmospheric electricity. A laser situated on an airplane forms a plasma filament that completes a conducting path between a first region of atmosphere and a second region of atmosphere. A collector situated on the same airplane as the laser can collect electricity flowing along the plasma filament, because a vertical voltage gradient exists between the first region of atmosphere and the second region of atmosphere.

FIG. **6** illustrates an example of a collector configured to collect electricity flowing along the plasma filament. The collector may be a charge collection circuit characterized by capacitance, inductance, and resistance. The electricity may be collected by charging a capacitor.

DETAILED DESCRIPTION

The detailed description set forth below is intended as a description of various configurations of the subject technology and is not intended to represent the only configurations in which the subject technology may be practiced. The appended drawings are incorporated herein and constitute a part of the detailed description. The detailed description includes specific details for the purpose of providing a thorough understanding of the subject technology. However, it will be apparent to those skilled in the art that the subject technology may be practiced without these specific details. In some instances, well-known structures and components are shown in block diagram form in order to avoid obscuring the concepts of the subject technology. Like components are labeled with identical element numbers for ease of understanding.

FIG. **1** illustrates a first example of a system **100** for harvesting atmospheric electricity. The system **100** comprises a laser **110** configured to form a plasma filament **120** and a collector **130** configured to collect electricity flowing along the plasma filament **120**. The plasma filament **120** forms a conducting path between ground and a cloud **140**.

The plasma filament **120** comprises an electrically conducting plasma filament. The plasma comprises of electrons and positive ions. The electrically conducting plasma filament may be formed in atmosphere using an ultra short pulse laser (USPL). The USPL forms a plasma filament by raising the conductivity of a very small diameter channel (~100 microns or less) for a very brief time. The propagation of high power (~10^{14} W/cm^2) pulses from the USPL is accompanied by filamentation—self-channeling of femtosecond laser pulses in stable high-intensity light filaments with ~100 microns diameters (so that the Kerr effect focusing balances defocusing due to plasma formation). This filamentation keeps the beam virtually free of diffraction divergence. The long plasma strings have high electron densities (10^{16}/cm^3) which support high conductivities. The ionization of air at these intensities results from multi-photon processes. Filamentation has been produced and detected at altitudes as high as 13-20 km. Almost no beam scattering occurs in filamentation phenomenon, and virtually all the pulse energy is invested in ionization of air molecules. With the typical electron density and channel diameter, a 160 mJ pulse is sufficient to generate a 1 km long channel.

Once initiated, plasma filaments cannot go on forever, and typically only propagate a kilometer or so before energy depletion and exhaustion. However, by using two coaxial USPL projection optics having different time-lensing parameters, a near and far filament could be initiated in a "daisy-chain" to extend the total length of the conductive channel. The onset of filamentation in the far filament is time-lensed to coincide with the exhaustion range of the near filament. Additionally, using negative chirp, femtosecond laser pulses can propagate almost without loss until different frequency components of the wave packet, propagating at different speeds due to dispersion in air, come together at a certain desired location so that the laser intensity there exceeds the filamentation threshold, resulting in long ionized filaments created at a distance of up to several miles from the laser source. In other words, negative chirp is used to essentially focus a beam of the laser at a desired distance to form the plasma filament there. Accordingly, this technique may be used to move the starting point and to extend the length of the plasma filament.

The size, electrical conductivity, and lifetime of the plasma filaments are enhanced by an auxiliary radio-frequency electromagnetic waves or microwaves. The plasma filament may act like an antenna to absorb the auxiliary radio-frequency (RF) electromagnetic waves or microwaves.

The pulsed collection of electric charge and energy is repeated with an optimal (possibly very high) repetition rate of the pulsed laser and of the auxiliary RF waves or microwaves. The energy collected per one pulse should exceed the energy spent on creating and enhancing the plasma filaments, so that the net energy collected is positive. The optimal pulse repetition rate (PRR) depends upon atmospheric conditions which can vary widely over even short time durations. As a general rule, one tries to tune the repetition rate to the plasma relaxation time (the ion-electron recombination time) so that the conductivity of the filament remain as high as is optimal given the atmospheric conditions at the time. A feedback control system that varies the PRR as well as the rest of the pulse-shaping parameters may be employed to optimize the net power production of the system. For more information regarding pulse shaping and tailoring, which is the central theme of the field called "quantum control", please see A. Assion, T. Baumert, M. Bergt, T. Brixner, B. Kiefer, V. Seyfried, M. Strehle, G. Gerber (30 October). "Control of Chemical Reactions by Feedback-Optimized Phase-Shaped Femtosecond Laser Pulses". Science 282 (5390): 919-922. doi: 10.1126/science.282.5390.919. PMID 9794756.

FIG. **2** illustrates a second example of a system **200** for harvesting atmospheric electricity. A plasma filament **120** and a lightning **210** together form a conducting path between ground and a cloud **140**. A condensing mirror **220** directs the beam of laser **110** towards the cloud **140**. A collector **130** is configured to collect electricity flowing along the plasma filament **120**.

In the case of electricity collection from the cloud **140**, the initial and RF-enhanced plasma filaments can be relatively short, not reaching all the way from ground to the cloud **140**. The relatively short plasma filament can be optimized so that it would trigger propagation of the so-called leader (as in natural lightning), which would effectively use the energy and potential of the cloud to eventually create an electrically conducting path between ground and the cloud **140**. The final conducting path would comprise of a plasma filament **120** and a lightning **210**.

It is not shown in the figures, but alternatively both the laser **110** and the collector **130** may be placed on a mobile device, which moves together with the cloud. One such mobile device may be a vehicle moving on the ground, but another such mobile device may be an airplane flying in the air. In the case of an airplane flying in the air, plasma filaments may be formed by the laser to reach both ground and the cloud at the same time. In the event the plasma filament directed at ground is not long enough to reach ground, a lightning may also be formed to complete the conducting path to ground.

FIG. **3**A illustrates a third example of a system **300** for harvesting atmospheric electricity. A laser system situated on an airplane **310** forms two plasma filaments (**321**, **322**) that together complete a conducting path between a first region **331** of a cloud **330** and a second region **332** of the cloud **330**. The first region **331** of the cloud **330** and the second region **332** of the cloud **330** carry opposite electric charges. In the example shown here, the first region **331** of the cloud **330** carries positive electric charges, while the second region **332** of the cloud **330** carries negative electric charges. A collector configured to collect electricity flowing along the two plasma filaments is also situated on the same airplane **310** as the laser. Positive and negative charges are naturally separated within the cloud, so this example makes use of the electrostatic potential gradient between different regions of the same cloud.

FIG. **3**B illustrates a fourth example of the system **300** for harvesting atmospheric electricity. It is similar to FIG. **3**A, except two lightnings (**341**, **342**) complete the conducting path between a first region **331** of a cloud **330** and a second region **332** of the cloud **330** (i.e., a first lightning **341** electrically connects the first region **331** of the cloud **330** to one of the plasma filaments **321** and a second lightning **342** electrically connects the second region **332** of the cloud **330** to the other plasma filaments **322**). The lightning formation is again because the initial and RF-enhanced plasma filaments can be relatively short, not reaching all the way from the collector situated on airplane **310** to the cloud **330**. These relatively short plasma filaments can be optimized so that they would trigger propagation of the so-called leader (as in natural lightning), which would eventually create an electrically conducting path between the two regions of cloud **330** via a connection through airplane **310**. The final conducting path would comprise of two plasma filaments (**321**, **322**) and two lightnings (**341**, **342**). Of course, one of the lightnings may not be formed, if one of the plasma filament can reach all the way from airplane **310** to cloud **330**.

FIG. **4** illustrates a fifth example of the system **300** for harvesting atmospheric electricity. A laser system situated on an airplane **310** forms two plasma filaments (**421**, **431**) that together complete a conducting path between a first cloud **420** and a second cloud **430**. The region **422** of the first cloud **420** that is connected to the first plasma filament **421** and the region **432** of the second cloud **430** that is connected to the second plasma filament **431** carry opposite electric charges. In the example shown here, region **422** of cloud **420** carries positive electric charges, while region **432** of cloud **430** carry negative electric charges. Positive and negative charges are naturally separated within the cloud, so this example makes use of the electrostatic potential gradient between different regions of different clouds. Once again, in case one of the plasma filament cannot reach all the way from airplane **310** to any one of the clouds, then lightning may be formed to complete an electrically conducting path from airplane **310** to any one of the clouds. But these embodiments are not shown in the figures.

FIG. **5** illustrates a sixth example of the system **300** for harvesting atmospheric electricity. A laser system situated on an airplane **310** forms a plasma filament **501** that completes a conducting path between a first region **510** of atmosphere and a second region **520** of atmosphere. A collector situated on the same airplane **310** as the laser system can collect electricity flowing along the plasma filament **501**, because a vertical voltage gradient exists between the first region **510** of atmosphere and the second region **520** of atmosphere. Because no clouds are needed for this embodiment, atmospheric electricity collection is possible under fair weather conditions (relying on the naturally existing vertical voltage gradient in the atmosphere) as well as under foul weather conditions.

FIG. **6** illustrates an example of a collector **130** configured to collect electricity flowing along a plasma filament **620**. The collector may be a charge collection circuit characterized by capacitance **631**, inductance **632**, and resistance **633**. The electricity may be collected by charging a capacitor associated with capacitance **631**. Battery **610** represents these naturally existing voltage sources: (1) between ground and a cloud, (2) between differently charged regions of the same cloud, (3) between differently charged regions of different clouds, and (4) between different regions of atmosphere, where there is a vertical voltage gradient. The plasma filament **620** can, for the purpose of analysis and optimization of the charge collection process, be viewed as electromagnetic transmission lines characterized by their effective capacitance, inductance, and resistance per unit length. Accordingly, the parameters of the charge collection circuit and of the effective transmission line representing the plasma filaments are optimized, so as to maximize the net charge and energy collected (minus the energy spent on generating and enhancing the plasma filaments).

The foregoing description is provided to enable a person skilled in the art to practice the various configurations described herein. While the subject technology has been particularly described with reference to the various figures and configurations, it should be understood that these are for illustration purposes only and should not be taken as limiting the scope of the subject technology.

There may be many other ways to implement the subject technology. Various functions and elements described herein may be partitioned differently from those shown without departing from the scope of the subject technology. Various modifications to these configurations will be readily apparent to those skilled in the art, and generic principles defined herein may be applied to other configurations. Thus, many changes and modifications may be made to the subject technology, by one having ordinary skill in the art, without departing from the scope of the subject technology.

It is understood that the specific order or hierarchy of steps in the processes disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged. Some of the steps may be performed simultaneously. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

A phrase such as "an aspect" does not imply that such aspect is essential to the subject technology or that such aspect applies to all configurations of the subject technology. A disclosure relating to an aspect may apply to all configurations, or one or more configurations. An aspect may provide one or more examples of the disclosure. A phrase such as an "aspect" may refer to one or more aspects and vice versa. A phrase such as an "embodiment" does not imply that such embodiment is essential to the subject technology or that such embodiment applies to all configurations of the subject technology. A disclosure relating to an embodiment may apply to all embodiments, or one or more embodiments. An embodiment may provide one or more examples of the disclosure. A phrase such an "embodiment" may refer to one or more embodiments and vice versa. A phrase such as a "configuration" does not imply that such configuration is essential to the subject technology or that such configuration applies to all configurations of the subject technology. A disclosure relating to a configuration may apply to all configurations, or one or more configurations. A configuration may provide one or more examples of the disclosure. A phrase such as a "configuration" may refer to one or more configurations and vice versa.

Furthermore, to the extent that the term "include," "have," or the like is used in the description or the claims, such term is intended to be inclusive in a manner similar to the term "comprise" as "comprise" is interpreted when employed as a transitional word in a claim.

The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any embodiment described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments.

A reference to an element in the singular is not intended to mean "one and only one" unless specifically stated, but rather "one or more." The term "some" refers to one or more. Underlined and/or italicized headings and subheadings are used for convenience only, do not limit the subject technology, and are not referred to in connection with the interpretation of the description of the subject technology. All structural and functional equivalents to the elements of the various configurations described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and intended to be encompassed by the subject technology. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the above description.

What is claimed is the following:

1. A system for harvesting atmospheric electricity, comprising:

a laser configured to form a plasma filament comprising at least a first filament and a second filament, wherein onset of formation of the second filament coincides with an exhaustion range of the first filament;

an auxiliary source of electromagnetic energy operable to enhance the plasma filament by applying electromagnetic energy to the plasma filament; and

a collector configured to collect electricity flowing along the plasma filament.

2. The system of claim **1**, wherein the plasma filament comprises an electrically conducting plasma filament.

3. The system of claim **1**, wherein the laser is a pulsed laser.

4. The system of claim **3**, wherein the pulsed laser is pulsed at an optimal repetition rate.

5. The system of claim **1**, wherein the electromagnetic energy comprises at least one of radio-frequency energy or microwave energy.

6. The system of claim **1**, wherein the plasma filament forms at least a part of a conducting path between ground and a cloud.

7. The system of claim **6**, wherein at least one lightning forms another part of the conducting path between ground and the cloud.

8. The system of claim **1**, wherein the plasma filament forms at least a part of a conducting path between a first region of a cloud and a second region of the cloud.

9. The system of claim **8**, wherein at least one lightning forms another part of the conducting path between the first region of the cloud and the second region of the cloud.

10. The system of claim **1**, wherein:

the laser is further configured to form a second plasma filament,

the plasma filament is connected to a region of a first cloud, and

the second plasma filament is connected to a region of a second cloud.

11. The system of claim **1**, wherein the plasma filament completes a conducting path between a first region of atmosphere and a second region of atmosphere.

12. The system of claim **11**, wherein a vertical voltage gradient exists between the first region of atmosphere and the second region of atmosphere.

13. The system of claim **1**, wherein the collector comprises a charge collection circuit.

14. The system of claim **1**, wherein the laser is situated on ground.

15. The system of claim **1**, wherein the laser is situated on a mobile device.

16. The system of claim **15**, wherein the mobile device is an airplane.

17. The system of claim **1**, wherein negative chirp is used to move the starting point of formation of the plasma filament to a desired location.

18. A method for harvesting atmospheric electricity, the method comprising:

forming a plasma filament with a laser, wherein the plasma filament comprises at least a first filament and a second filament, and wherein onset of formation of the second filament coincides with an exhaustion range of the first filament;

applying electromagnetic energy to the plasma filament to enhance the plasma filament; and

collecting electricity flowing along the plasma filament.

19. An apparatus for harvesting atmospheric electricity, the apparatus comprising:

means for forming a plasma filament with a laser, wherein the plasma filament comprises at least a first filament and a second filament, and wherein onset of formation of the second filament coincides with an exhaustion range of the first filament;

means for applying electromagnetic energy to the plasma filament to enhance the plasma filament; and

means for collecting electricity flowing along the plasma filament.

20. The system of claim **1**, wherein the laser is an ultra short pulse laser (USPL).

21. The system of claim **1**, wherein the laser comprises two coaxial USPL projection optics having different time-lensing parameters.

* * * * *

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(12) United States Patent
Ogram

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(45) **Date of Patent: Dec. 21, 2010**

(54) **ATMOSPHERIC ELECTRICAL GENERATOR**

(76) Inventor: **Mark Ellery Ogram**, 780 S. Freeman Rd., Tucson, AZ (US) 85748

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 254 days.

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(22) Filed: **Jul. 14, 2008**

(65) **Prior Publication Data**

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H02G 11/00 (2006.01)

(52) **U.S. Cl.** **307/145**; 307/149; 361/218; 361/230

(58) **Field of Classification Search** 307/149, 307/145; 244/30, 31; 174/2; 361/212, 215–218, 361/230, 231
See application file for complete search history.

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Primary Examiner—Fritz M Fleming
(74) *Attorney, Agent, or Firm*—Mark Ogram

(57) **ABSTRACT**

A mechanism to tap an electrical source which uses an aircraft (preferably a lighter than air balloon) tethered by a conductive line. The conductive line is extended/withdrawn by a winch motor to adjust the altitude of the aircraft. The conductive line is isolated from the ground and an electrical conductor is connected to the conductive line and to an electrical load. In this manner, static electricity generated in the atmosphere is gathered for use.

15 Claims, 4 Drawing Sheets

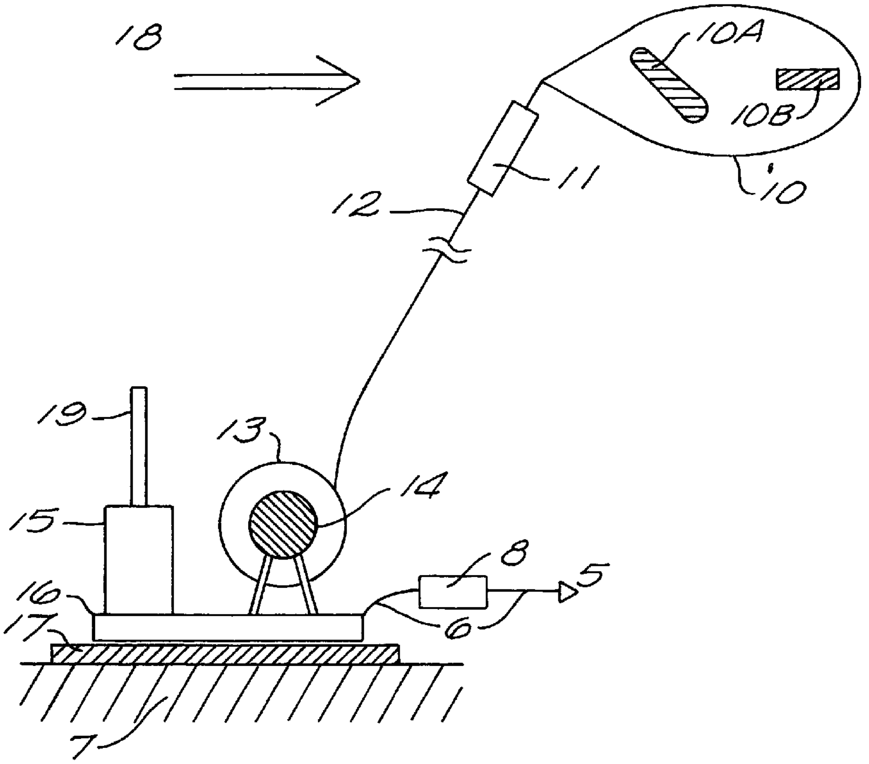

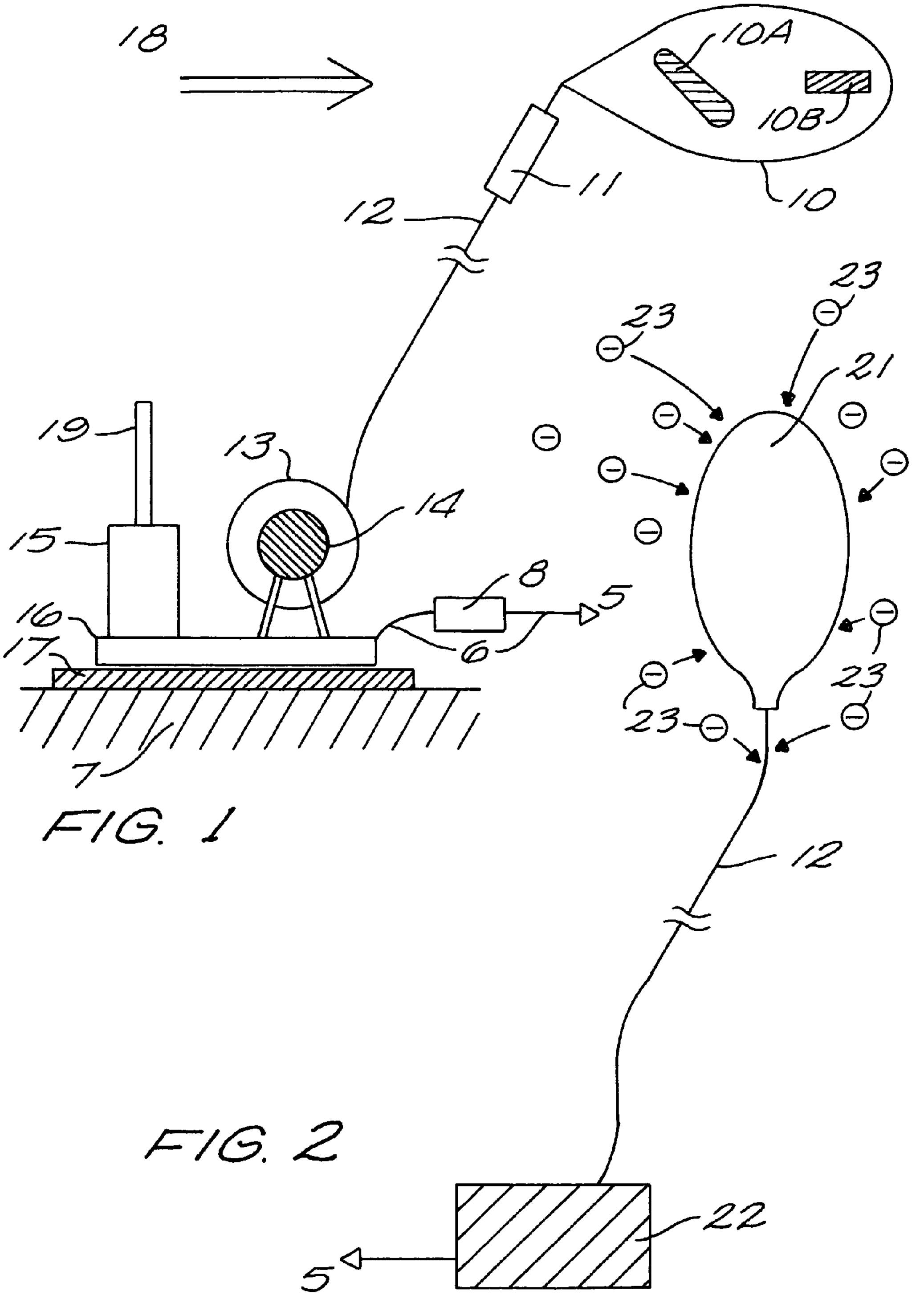
18
10A
10B
10
11
12
19
13
14
15
8
5
16
6
17
7
23
23
21
23
23
23
12
22
5

FIG. 1

FIG. 2

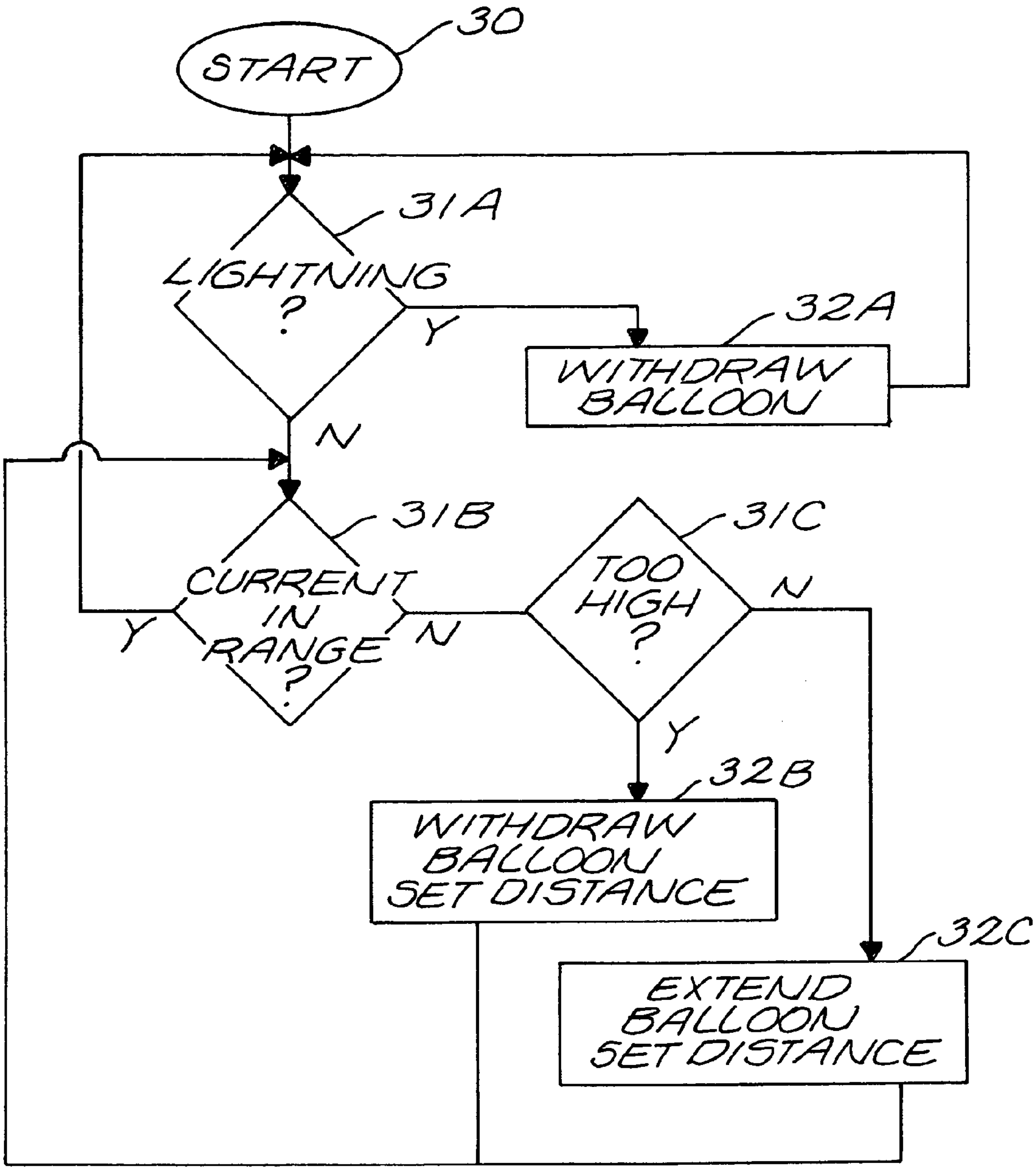
30
START
31A
LIGHTNING ?
Y
32A
WITHDRAW BALLOON
N
31B
CURRENT IN RANGE ?
Y
N
31C
TOO HIGH ?
N
Y
32B
WITHDRAW BALLOON SET DISTANCE
32C
EXTEND BALLOON SET DISTANCE

FIG. 3

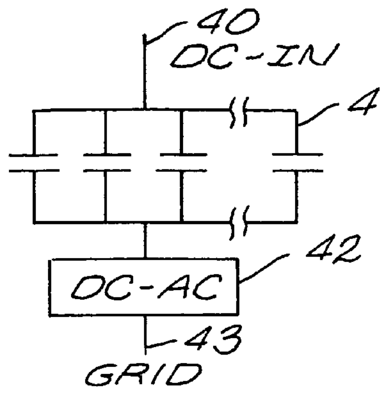
40
DC-IN
41
42
DC-AC
43
GRID

FIG. 4A

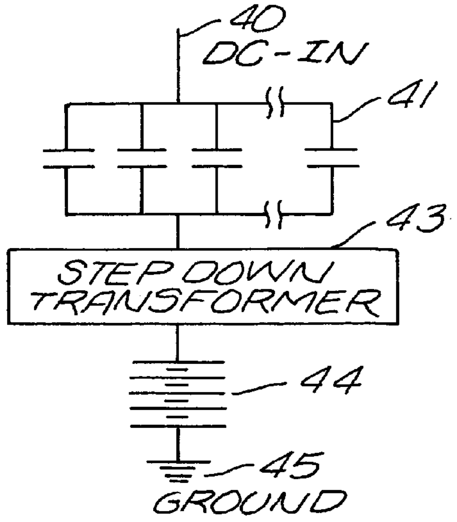
40
DC-IN
41
43
STEP DOWN TRANSFORMER
44
45
GROUND

FIG. 4B

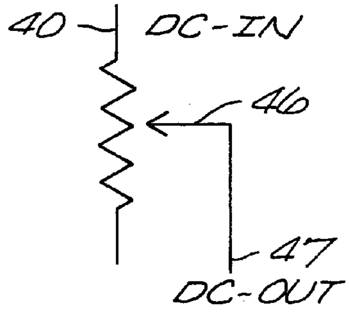
40
DC-IN
46
47
DC-OUT

FIG. 4C

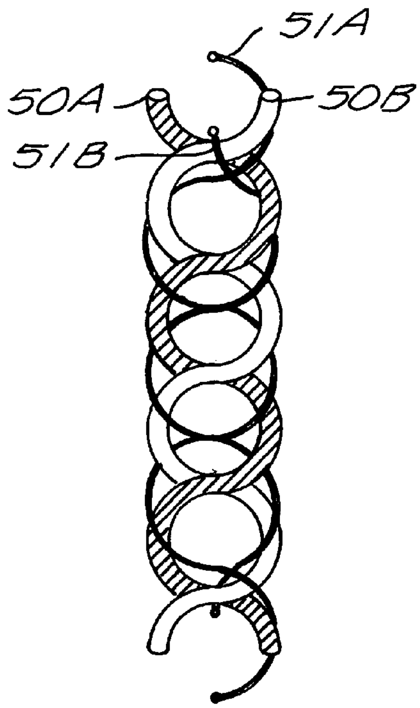
51A
50A
50B
51B

FIG. 5

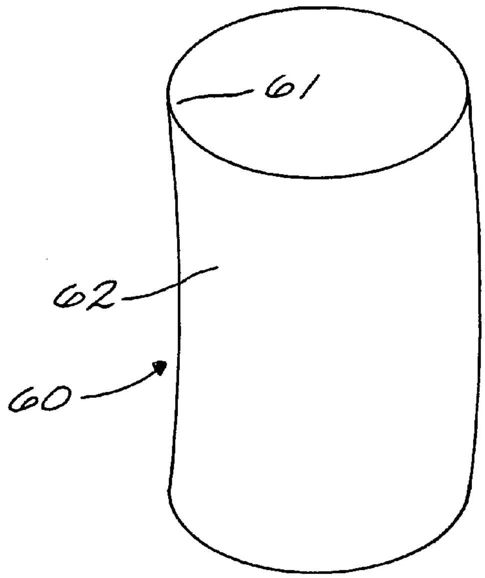

FIG. 6A

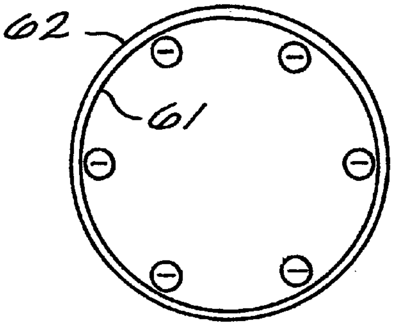

FIG. 6B
REPLACEMENT

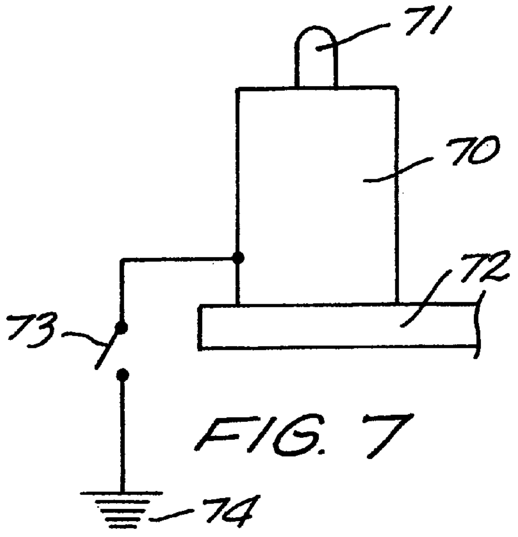
71
70
72
73
74

FIG. 7

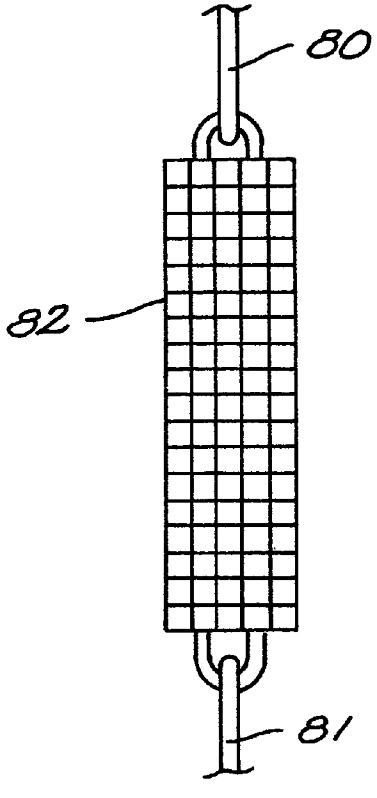

FIG. 8A

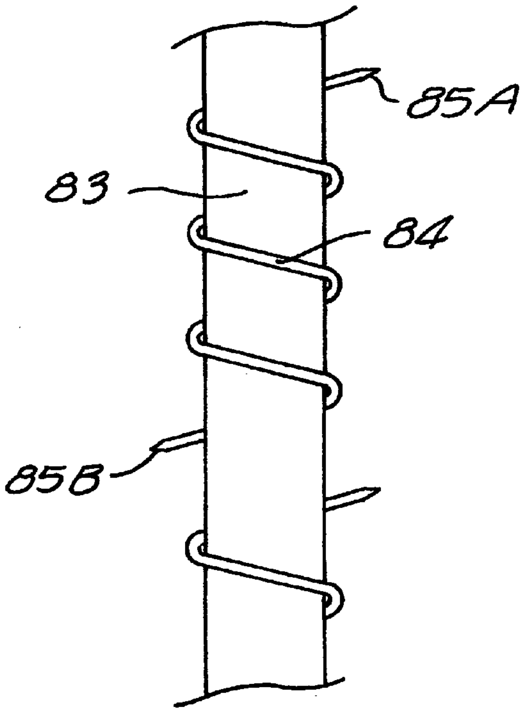
85A
83
84
85B

FIG. 8B

ATMOSPHERIC ELECTRICAL GENERATOR

BACKGROUND OF THE INVENTION

This invention relates to the production of electrical energy and more particularly to the production of electrical energy from the atmosphere.

Everyone is familiar with Benjamin Franklin's kite experiment of 1752. Using a kite whose string had become wet, negative charges from the passing clouds flowed into the string, down to the suspended key, and then into a Leyden jar via a thin metal wire. Franklin was protected by a dry silk string; but, when Franklin's knuckle came too close to the key, he received a strong shock. Fortunately, Benjamin Franklin was not killed, others who tried this same experiment were not so lucky.

Since then, the formation of lightning has remained something of a mystery. Lightning bolts are triggered when a negatively charged cloud base induces a positive charge from the ground, thereby forming a "pathway" for the discharge of the collected electrical energy.

Lightning travels up to 60,000 miles per hour with a flash that is brighter than ten million 100-watt lightbulbs. This wattage is as much power as is produced by all of the electricity plants in the United States and with a voltage of up to 300 million volts.

It is this very fact, the power within lightning is immense, that has prevented any successful collection of the electrical energy from lightning. The electricity in lightning is far too extreme for current technology to harness.

While lightning has attracted a energy starved industrial world, no one has developed any technique to harness this naturally occurring electrical source.

It is clear there is a continuing need for an electrical source other than carbon-based fuels and that the naturally occurring electricity in the atmosphere is being ignored.

SUMMARY OF THE INVENTION

The invention is a mechanism which taps into the naturally occurring static electricity in the atmosphere. Whereas heretofore, the attempt to garner electricity from the atmosphere has focused exclusively on capturing lightning, the present invention syphons off the static electricity which is generated from any agitated air and avoids lightning.

Lightning is only the final discharge of the static electricity, whether that lightning is intra-cloud lightning, cloud-to-ground lightning, or inter-cloud lightning. Other types of final discharges are known as heat lightning, summer lightning, sheet lightning, ribbon lightning, silent lightning, ball lightning, bead lightning, elves, jets, and sprites. Well before these discharges are observed, as the atmosphere becomes agitated by wind or thermal activity, static electricity is being generated.

The present invention recognizes that this static electricity is being formed and creates a mechanism to capture it.

The mechanism of this invention utilizes an aircraft such as a lighter than air balloon. While the preferred embodiment uses a foil balloon, a variety of other aircraft are obvious to those of ordinary skill in the art, including, but not limited to: gliders, rubber balloons (such as weather balloons), biaxially-oriented polyethylene terephthalate polyester film balloons, and latex balloons.

Within this discussion, the balloon is referenced, but, the invention is not intended to be limited solely to balloons.

The balloon is sent aloft and is tethered by a conductive line. In this context, the conductive line may be any obvious to those of ordinary skill in the art. For the preferred embodiment, the conductive line is a generically referred to as a "poly-rope" and is commercially available through a variety of sources. A suitable conductive line is described in U.S. Pat. No. 5,203,542, entitled "Apparatus for Improved Electric Fence Wire Construction for use with Intensive Grazing" issued Apr. 20, 1993, to Coley, et al. and incorporated hereinto by reference.

The conductive line is played out of a winch to control the altitude of the balloon. The motor controlling the winch is able to reverse direction to both extend and withdraw the conductive line which is wrapped around a spool on the winch. The winch/spool combination are part of a base unit.

In some embodiments of the invention, the spool is constructed of rubber so as to insulate the conductive line from the winch assembly. In this embodiment, only the conductive line is charged by the atmospheric static electricity while the winch remains neutral.

In yet another embodiment, the winch/spool are part of a base unit which is itself isolated from the ground by an insulator. In this embodiment, the entire base unit is charged by the atmospheric static electricity.

A conductor, such as an insulated wire, is electrically connected to the conductive line. In one embodiment, where the conductive line is electrically isolated from the spool and winch motor, the conductor is connected to the conductive line. In the embodiment where the conductive line is electrically connected to the base unit, then the conductor is connected anywhere on a metallic base unit.

The other end of the conductor is connected to a load. The load in this case can be any of a variety of electrical loads well known to those of ordinary skill in art, including, but not limited to a motor, a battery system, or the electrical grid for the system.

In the preferred embodiment, a sensor array is used to monitor the activities both at the base unit (such as electrical flow within the conductor) and in the surrounding locale.

A sensor monitoring the electrical flow (i.e. voltage and/or current) within the conductor is used to monitor the electrical activity within the conductor.

In the preferred embodiment, a lightning sensor monitors for lightning activity within the locale. As noted earlier, the electrical characteristic of lightning is so extreme that ideally this discharge is avoided as it might damage the mechanism of this invention.

The sensor array is utilized by a controller, such as microprocessor, programmed to operate the mechanism as outlined herein.

The controller operates the winch motor to extend or withdraw the conductive line and by extension the altitude of the balloon. The controller is programmed to operate the winch by monitoring the electrical characteristics of the conductor and adjusting the balloon's altitude to maintain these characteristics within the conductor within a preset range.

This preset range is established either in the base programming of the controller or is established by an operator of the system.

As example, by controlling the amount of current being withdrawn from the atmosphere, the mechanism operates within a safe range and also provides a relatively stable current flow from which a variety of activities can take place (such as DC-AC conversion).

The controller also utilizes the lightning sensor to protect the mechanism from a lightning strike. Should lightning be detected within a pre-determined range (as established by the software or defined by an operator), then the balloon is pulled down to minimize the risk of damage from a lightning strike.

The invention, together with various embodiments thereof will be more fully explained by the following description of the accompanying drawings.

DRAWINGS IN BRIEF

FIG. **1** diagrams the preferred embodiment of the invention.

FIG. **2** illustrates the collection of the negative charged particles in the atmosphere.

FIG. **3** is a flow-chart of the operation of the controller for the preferred embodiment of the invention.

FIGS. **4**A, **4**B, and **4**C are electrical schematics for handling the static charge from the atmosphere.

FIG. **5** illustrates a conductive line used in the preferred embodiment of the invention.

FIGS. **6**A and **6**B illustrate an alternative conductive line creating an ionized pathway for the flow of the static charges from the atmosphere.

FIG. **7** illustrates the controller of an alternative embodiment and the associated safety devices.

FIGS. **8**A and **8**B illustrate two embodiments of enhanced electrical collection leads.

DRAWINGS IN DETAIL

FIG. **1** diagrams the preferred embodiment of the invention.

Balloon **10** is an aircraft which, in this illustration, is a lighter than air balloon. Wings **10**A, extending from the body of balloon **10**, provide additional lift in air flow **18**. Tail **10**B helps to stabilize balloon **10**.

Balloon **10** is tethered to the ground via conductive line **12**. As noted earlier, a variety of configurations and materials are available to serve as conductive line **12**. In this illustration, a poly-wire is used Poly-wire is commercially available through a variety of vendors, including, but not limited to: Jeffers Livestock and Zareba Systems, Inc, of Ellendale, Minn.

In this embodiment, located proximate to balloon **10**, is an electrical collection enhancement lead **11** which assists in the collection of the static electrical charge in the atmosphere. Electrical collection enhancement lead **11** is configured to attract the static charge and conduct the charge into the conductive line **12**.

The electricity flows down the conductive line into spool **13**, where the conductive line **12** is collected and either withdrawn or dispensed through operation of winch motor **14**.

Winch motor **14** and spool **13** are mounted onto base unit **16** which is electrically isolated from ground **7** using insulator **17**. Note, in this embodiment of the invention, when electricity is being collected from the atmosphere, the entire base unit **16** becomes charged. In another embodiment of the invention, spool **13** is constructed of rubber, thereby preventing base unit **16** from becoming charged, thereby restricting the charging from the atmosphere to only conductive line **12**.

In this embodiment, conductor **6** is connected to base unit **16** (since the entire base unit **16** is charged and the base unit is metallic) to communicate the electrical current to load **5**. Conductor **6** is ideally an insulated wire.

The electrical current through conductor **6** is measured using sensor **8**.

In the alternative embodiment discussed above, where only the conductive line **12** is charged, then conductor **6** is connected to conductive line **12**.

Controller **15**, located in this embodiment on base unit **16**, operates winch motor **14** in response to signals from sensor **8** (measuring the current being discharged to load **5**) to maintain the current flow within a pre-defined range. As the current flow diminishes, then the conductive line **12** extended from spool **13** to increase the altitude of balloon **10** to that more static charge from the atmosphere is gathered; as the current flow falls exceeds a preset level, conductive line **12** is withdrawn onto spool **13** to decrease the static charge being collected from the atmosphere.

The range of current flow through conductor **6** is ideally set by the program, although some embodiments of the invention permit an operator to establish this range of operation.

In an alternative embodiment, the sensor monitoring conductor **6** monitors the voltage therein.

In the preferred embodiment of the invention, controller **15** is also equipped with a lightning sensor **19**. In this embodiment, when lightning is sensed within a preset range, then substantially all of conductive line **12** is wound onto spool **13** to pull balloon **10** near the ground and protect the entire mechanism from being damaged from a lightning discharge.

In the preferred embodiment, the “safe” distance form lightning is set in the programming of controller **15** and is ideally two miles; other embodiments permit the operator to “safe” distance.

There are a variety of lightning sensors well known to those of ordinary skill in the art, including, but not limited to those described in: U.S. Pat. No. 7,016,785, entitled “Lightning Detection” issued to Makela, et al. on Mar. 21, 2006; U.S. Pat. No. 6,829,911, entitled “Lightning Detection and Prediction Alarm Device” issued to Jones, et al. on Dec. 7, 2004; U.S. Pat. No. 7,200,418, entitled “Detection of Lightning” issued to Karikuranta, et al. on Apr. 3, 2007; and U.S. Pat. No. 6,961,662, entitled “Systems and Methods for Spectral Corrected Lightning Detection” issued to Murphy on Nov. 1, 2005; all of which are incorporated hereinto by reference.

In another embodiment of the invention, controller **15** is not located on base unit **16**, rather it is remote and communicates its control signals to winch motor **14** using radio waves.

FIG. **2** illustrates the collection of the negative charged particles in the atmosphere.

Static charges **23** are generated in the atmosphere by agitated air. These static charges are often collected at the bottom of clouds, but exist in other environments as well.

Balloon **21** is extended into this strata of static charges **23** which are then attracted to conductive line **12** to flow to base unit **22** and then onto load **5**.

By increasing or decreasing the altitude of balloon **21** (defined by the length of the extended conductive line **12**), conductive line **12** is selectively exposed to varying densities and levels of the static charge strata, and by extension, the current flow or voltage is increased or decreased.

FIG. **3** is a flow-chart of the operation of the controller for the preferred embodiment of the invention.

Once the program starts **30**, the lightning sensor is checked to determine if lightning has occurred within the unsafe range **31**A, if it has, then the balloon is lowered **32**A, and the program continues monitoring the status of lightning until no lightning is detected.

When the lightning status is acceptable, then the current within the conductor is checked to see if the current is within the prescribed range **31**B. If the current is acceptable (within range) the program returns to check the lightning status **31**A; otherwise a determination is made to see if the current is above the prescribed range **31**C.

If the current is above the prescribed range, then the altitude of the balloon is withdrawn a set amount **32**B (ideally twenty-five feet) and the program loops back to see if the current is within range **31**B.

If the current is below the prescribed range, then the altitude of the balloon is extended a set amount **32**C (ideally twenty-five feet) and the program loops back to see if the current is within range **31**B.

In this manner of feed-back and minor adjustments in the altitude of the balloon, the current is maintained within a prescribed range which can be handled by the downstream electrical system.

As noted earlier, some embodiments of the invention monitor the voltage instead of the current.

FIGS. **4**A, **4**B, and **4**C are electrical schematics for handling the static charge from the atmosphere.

By maintaining the voltage being collected in a prescribed range, an electrical conversion system is easily designed. While FIGS. **4**A, **4**B, and **4**C illustrate some electrical configurations, those of ordinary skill in the art readily recognize a variety of other configurations which will serve the same function.

Referencing FIG. **4**A, Direct Current In (DC IN) **40** is buffered by a gang of capacitors **41** before being communicated to a DC/AC converter **42**. The DC/AC converter converts the direct current into a an alternating current suitable for placement over an existing electrical grid **43** such as normally found from a power-plant.

Those of ordinary skill in the art readily recognize a variety of DC/AC converters, including, but not limited to: U.S. Pat. No. 7,394,671, entitled "Controller IC, DC-AC Conversion Apparatus, and parallel running system of DC-AC Conversion Apparatuses" issued to Fukumoto, et al. on Jul. 1, 2008; and, U.S. Pat. No. 7,330,366, entitled "DC-AC Converter" issued to Lee, et al. on Feb. 12, 2008; all of which are incorporated hereinto by reference.

FIG. **4**B illustrates an electrical arrangement suitable for use in charging a battery. DC IN **40** is buffered by capacitor bank **41** before entering into a step down transformer **43**. Step down transformer **43** reduces the voltage so that the voltage can safely be introduced into battery **44** which is connected to ground **45** at the battery's other pole.

Those of ordinary skill in the art readily recognize a variety of batteries which will work in this capacity, including, but not limited to those described in: U.S. Pat. No. 7,378,181, entitled "Electric Storage Battery Construction and Manufacture" issued to Skinlo on May 27, 2008; U.S. Pat. No. 7,388,350, entitled "Battery with Electronic Compartment" issued to Wright on Jun. 17, 2008; U.S. Pat. No. 7,397,220, entitled "Connection Member and Battery Pack" issued to Uchida, et al. on Jul. 8, 2008; and, U.S. Pat. No. 7,375,492, entitled "Inductively Charged Battery Pack" issued to Calhoon, et al. on May 20, 2008; all of which are incorporated hereinto by reference.

In FIG. **4**C, DC IN **40** is fed into an adjustable rheostat **46** which is controlled by the controller so that the DC OUT **47** falls within a specified range.

FIG. **5** illustrates a conductive line used in the preferred embodiment of the invention.

This type of conductive line is commonly called poly-wire and consists of multiple interwoven strands of plastic **50**A and **50**B woven into a cord or rope arrangement having intertwined therein exposed metal wires **51**A and **51**B. While this illustration shows two plastic strands and two metal wires, any number of possible combinations is possible.

The exposed metal wires **51**A and **51**B attract the atmospheric static charge and transmit the charge down to the base unit (not shown).

FIGS. **6**A and **6**B illustrate an alternative conductive line creating an ionized pathway for the flow of the static charges from the atmosphere.

This conductive line utilizes a tube **60** having an outer layer **62** of PET Film (Biaxially-oriented polyethylene terephtalate polyester film) which provides exceptionally high tensile strength and is chemically and dimensionally stable. The tube has an ideal diameter of between two and three inches.

An interior metal coating **61** provides an initial conduit for the flow of static charge. The static charge through the metal forces the tube to expand due to the repulsion experienced by like charges. Further, the flow of electricity causes the interior of the tube **60** to become ionized to provide an additional pathway for the atmospheric static charges to the base unit (not shown).

Because outer layer **62** provides a gas barrier, the resulting ionization is not dissipated by air currents, thereby providing a highly stable pathway.

FIG. **7** illustrates the controller of an alternative embodiment and the associated safety devices.

In this embodiment, controller box **70**, resting on insulating pad **72**, is in communication with the sensors as described above. Using the input from these sensors, when there is flow of electricity through the base unit, warning flashing light **71** is illuminated. To electrically neutralize the mechanism, switch **73** is activated to pass any existing current into the ground **74**.

FIGS. **8**A and **8**B illustrate two embodiments of enhanced electrical collection leads.

Referencing FIG. **8**A, enhanced electrical collection lead **82** is a wire mesh which is in electrical communication with conductive line **81** and balloon **80**. Because of the significant amount of metal exposed by enhanced electrical collection lead **82**, more static electricity from the atmosphere is drawn to the collection lead **82**, and then down conductive line **81** to the base unit (not shown).

Conductive lead **82** is positioned proximate to balloon **80**.

In FIG. **8**B, poly-wire **83** has enhanced electrical collection leads **84** wrapped therearound. Collection leads **84** have pointed ends **85**A and **85**B which have a propensity to attract more electricity than rounded ends do.

It is clear from the foregoing that the present invention captures an entirely new source of electrical energy.

What is claimed is:

1. A mechanism to tap an electrical source comprising:

a) a lighter than air balloon suspended in the atmosphere;

b) a base unit having a spool of conductive line on a winch motor, one end of said conductive line secured to said lighter than air balloon, a portion of said conductive line collecting electricity in the atmosphere, said winch motor capable of selectively extending or withdrawing said conductive line from said spool;

c) an insulator electrically isolating said conductive line from ground;

d) a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load being powered by collected electricity from said conductive line;

e) an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor; and,

f) a controller receiving said electrical flow indicia and selectively operating said winch motor such that said electrical flow indicia remains within a selected operating range.

2. The mechanism to tap an electrical source according to claim **1**, wherein said selected operating range is established by an operator.

3. The mechanism to tap an electrical source according to claim **2**, further including a warning light activated when said electrical flow indicia is non-zero.

4. The mechanism to tap an electrical source according to claim **1**,

a) further including a lightning sensor generating a lightning presence indicia indicative of lightning within a prescribed range, said presence indicia being communicated to said controller; and,

b) wherein said control mechanism, in response to said lightning presence indicia, operates said winch motor to withdraw substantially all of said conductive line onto said spool.

5. The mechanism to tap an electrical source according to claim **4**, wherein said prescribed range is established by an operator.

6. The mechanism to tap an electrical source according to claim **1**, further including an electrical collection enhancement lead in electrical contact with a first end of said conductive material, said electrical collection enhancement lead configured to attract static electricity.

7. The mechanism to tap an electrical source according to claim **6**, wherein said electrical collection enhancement lead is positioned proximate to said lighter than air balloon.

8. The mechanism to tap an electrical source according to claim **7**, wherein said electrical collection enhancement lead includes at least two pointed electrical conductors.

9. The mechanism to tap an electrical source according to claim **1**, wherein said insulator electrically isolates said conductive line from said winch motor.

10. The mechanism to tap an electrical source according to claim **1**, wherein said insulator electrically isolates said base unit from ground.

11. A mechanism comprising:

a) an airborne aircraft having a conductive line secured to a winch capable of extending or withdrawing said conductive line from a spool, when said airborne aircraft is aloft, said conductive line collecting electricity from the atmosphere;

b) a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load such that collected electricity from said conductive line powers said load;

c) an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor; and,

d) a controller receiving said electrical flow indicia adjusting an altitude of said airborne aircraft via said winch such that said electrical flow indicia remains within a selected operating range.

12. The mechanism to tap an electrical source according to claim **11**,

a) further including a lightning sensor communicating with said controller; and,

b) wherein said controller, in response to selected signals from said lightning sensor withdraws substantially all of said conductive line.

13. A mechanism to tap an electrical source comprising:

a) a lighter than air balloon suspended in the atmosphere;

b) a base unit having a spool of conductive line on a winch motor, one end of said conductive line suspended by said balloon, a portion of said conductive line collecting electricity from the atmosphere, said winch motor capable of adjusting an altitude of said lighter than air balloon by selectively extending or withdrawing said conductive line from said spool;

c) a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load being powered by said collected electricity from said conductive line;

d) a sensor array having,

1) an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor, and,

2) a lightning sensor monitoring existence of proximate lightning; and,

e) a controller responsive to said electrical flow indicia from said sensor array to selectively operate said winch motor.

14. The mechanism to tap an electrical source according to claim **13**,

a) further including a warning light; and,

b) wherein said controller activates said warning light when said electrical flow in said conductor is non-zero.

15. The mechanism to tap an electrical source according to claim **14**, further including an electrical collection enhancement lead in electrical contact with said conductive material, said electrical collection enhancement lead configured to attract static electricity and positioned proximate to said lighter than air balloon.

* * * * *

United States Patent [19]
Eastlund

[11] **Patent Number: 4,686,605**
[45] **Date of Patent: Aug. 11, 1987**

[54] METHOD AND APPARATUS FOR ALTERING A REGION IN THE EARTH'S ATMOSPHERE, IONOSPHERE, AND/OR MAGNETOSPHERE

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[73] Assignee: **APTI, Inc.**, Los Angeles, Calif.

[21] Appl. No.: **690,333**

[22] Filed: **Jan. 10, 1985**

[51] **Int. Cl.**^{4} **H05B 6/64**; H05C 3/00; H05H 1/46

[52] **U.S. Cl.** .... **361/231**; 89/1.11; 380/59; 244/158 R

[58] **Field of Search** .... 361/230, 231; 244/158 R; 376/100; 89/1.11; 380/59

[56] **References Cited**

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Primary Examiner—Salvatore Cangialosi
Attorney, Agent, or Firm—Roderick W. MacDonald

[57] ABSTRACT

A method and apparatus for altering at least one selected region which normally exists above the earth's surface. The region is excited by electron cyclotron resonance heating to thereby increase its charged particle density. In one embodiment, circularly polarized electromagnetic radiation is transmitted upward in a direction substantially parallel to and along a field line which extends through the region of plasma to be altered. The radiation is transmitted at a frequency which excites electron cyclotron resonance to heat and accelerate the charged particles. This increase in energy can cause ionization of neutral particles which are then absorbed as part of the region thereby increasing the charged particle density of the region.

15 Claims, 5 Drawing Figures

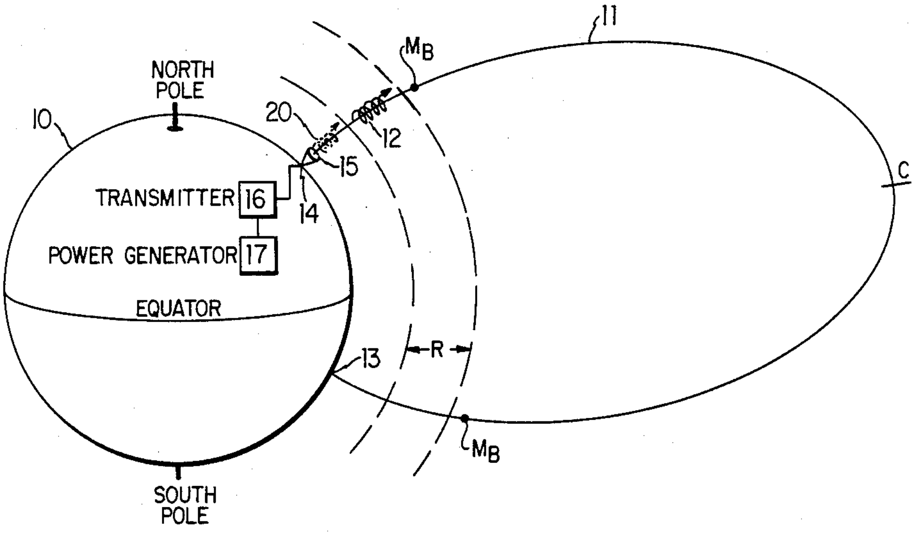

FIG. 1

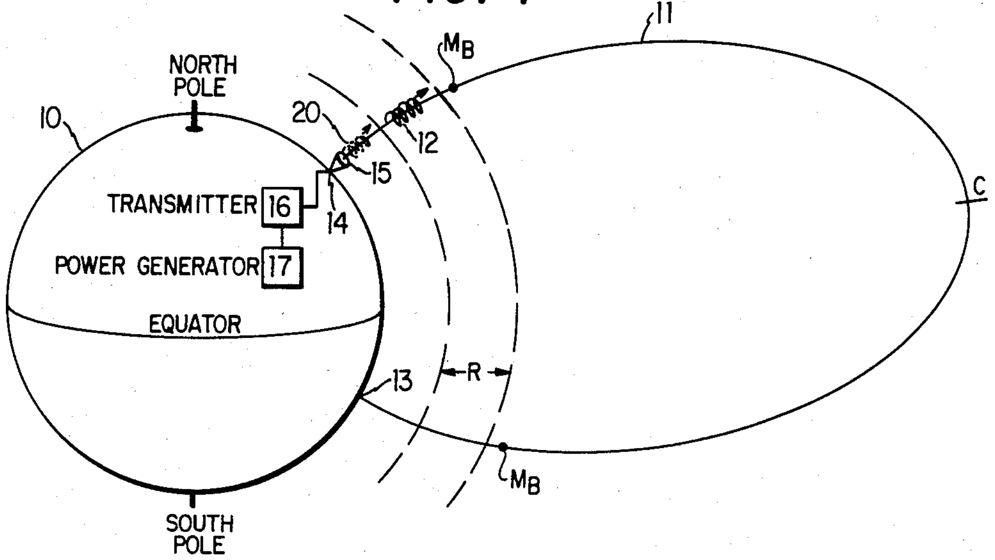
11
M_B
NORTH POLE
10
20
12
15
C
TRANSMITTER 16
14
POWER GENERATOR 17
EQUATOR
13
R
M_B
SOUTH POLE

FIG. 2

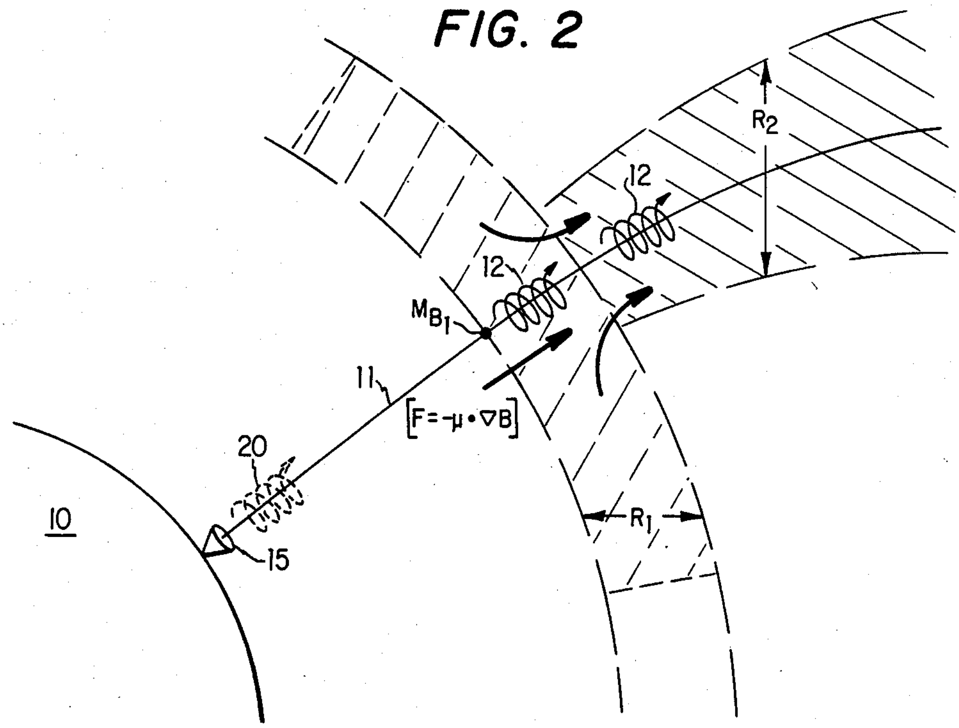
R_2
M_{B_1}
$[F = -\mu \cdot \nabla B]$
R_1

FIG. 3

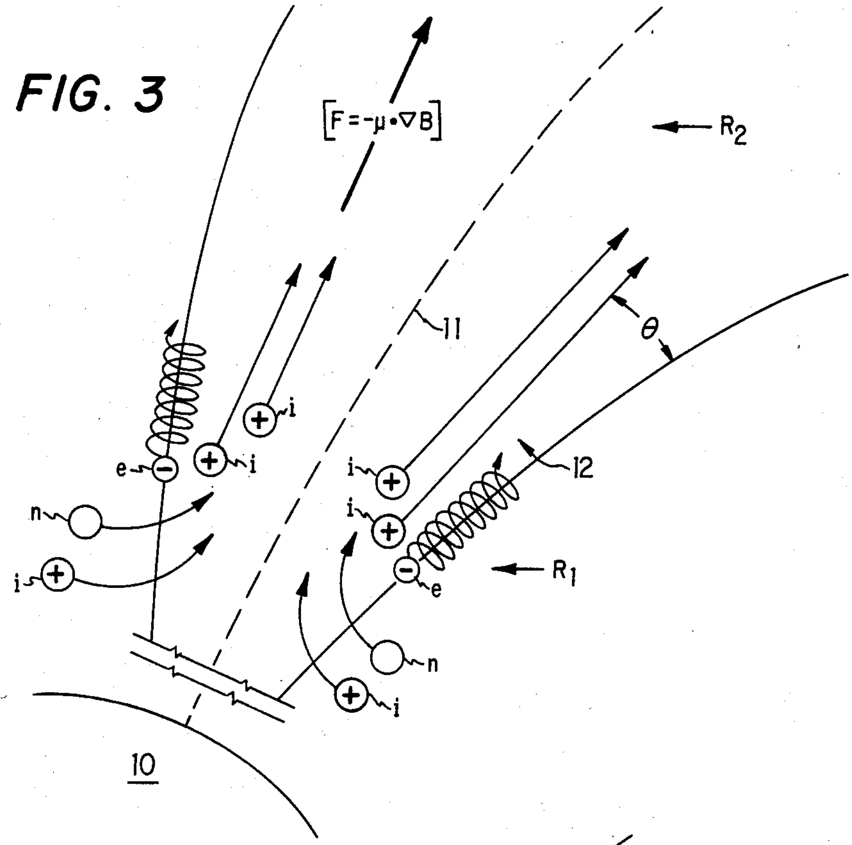
$[F=-\mu\cdot\nabla B]$
R_2
11
θ
i
e
i
n
i
i
i
12
e
R_1
n
i
10

FIG. 4

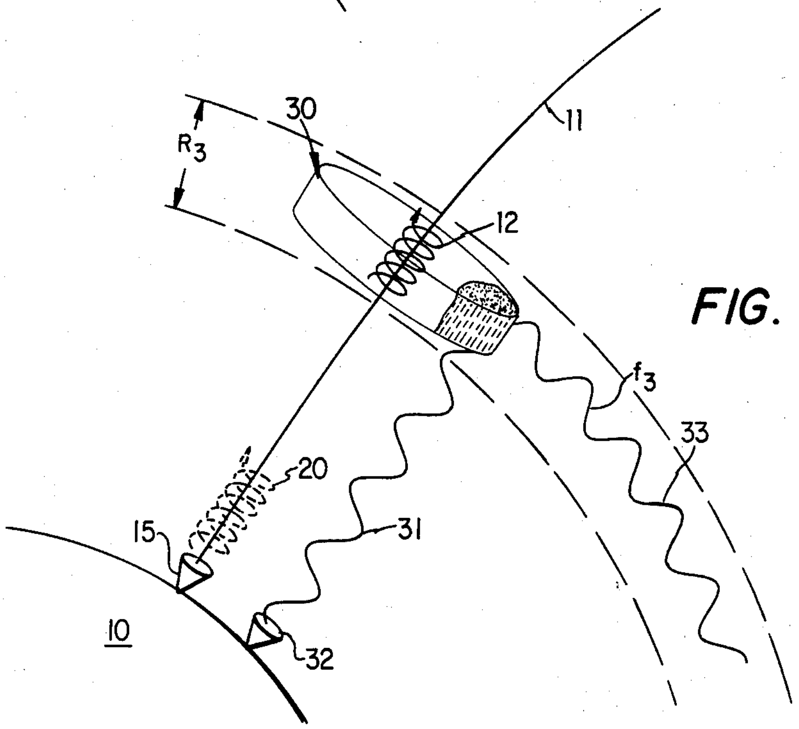
R_3
f_3

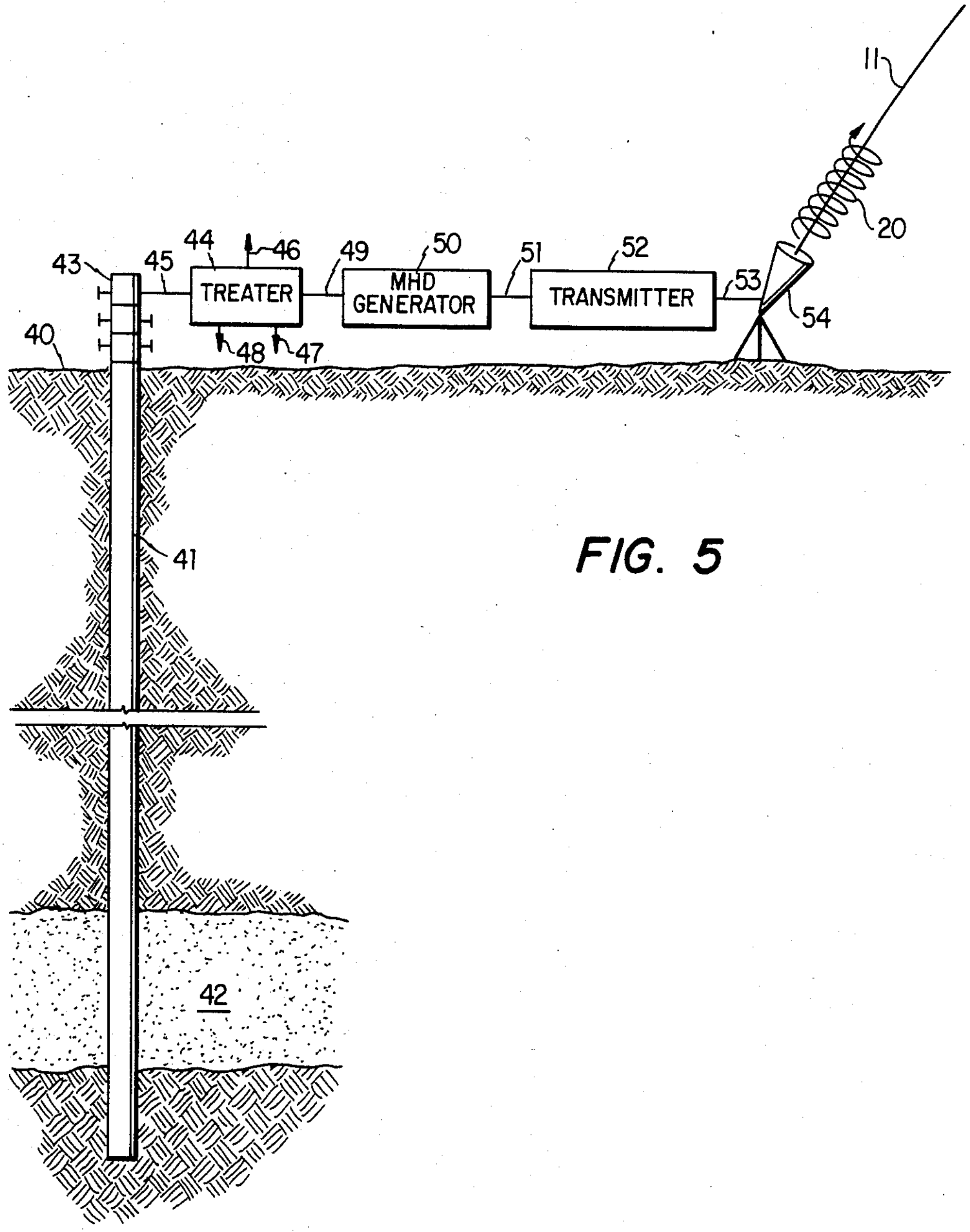
TREATER
MHD GENERATOR
TRANSMITTER

FIG. 5

METHOD AND APPARATUS FOR ALTERING A REGION IN THE EARTH'S ATMOSPHERE, IONOSPHERE, AND/OR MAGNETOSPHERE

DESCRIPTION

1. Technical Field

This invention relates to a method and apparatus for altering at least one selected region normally existing above the earth's surface and more particularly relates to a method and apparatus for altering said at least one region by initially transmitting electromagnetic radiation from the earth's surface essentially parallel to and along naturally-occurring, divergent magnetic field lines which extend from the earth's surface through the region or regions to be altered.

2. Background Art

In the late 1950's, it was discovered that naturally-occuring belts exist at high altitudes above the earth's surface, and it is now established that these belts result from charged electrons and ions becoming trapped along the magnetic lines of force (field lines) of the earth's essentially dipole magnetic field. The trapped electrons and ions are confined along the field lines between two magnetic mirrors which exist at spaced apart points along those field lines. The trapped electrons and ions move in helical paths around their particular field lines and "bounce" back and forth between the magnetic mirrors. These trapped electrons and ions can oscillate along the field lines for long periods of time.

In the past several years, substantial effort has been made to understand and explain the phenomena involved in belts of trapped electrons and ions, and to explore possible ways to control and use these phenomena for beneficial purposes. For example, in the late 1950's and early 1960's both the United States and U.S.S.R. detonated a series of nuclear devices of various yields to generate large numbers of charged particles at various altitudes, e.g., 200 kilometers (km) or greater. This was done in order to establish and study artifical belts of trapped electrons and ions. These experiments established that at least some of the extraneous electrons and ions from the detonated devices did become trapped along field lines in the earth's magnetosphere to form artificial belts which were stable for prolonged periods of time. For a discussion of these experiments see "The Radiation Belt and Magnetosphere", W. N. Hess, Blaisdell Publishing Co., 1968, pps. 155 et sec.

Other proposals which have been advanced for altering existing belts of trapped electrons and ions and/or establishing similar artificial belts include injecting charged particles from a satellite carrying a payload of radioactive beta-decay material or alpha emitters; and injecting charged particles from a satellite-borne electron accelerator. Still another approach is described in U.S. Pat. No. 4,042,196 wherein a low energy ionized gas, e.g., hydrogen, is released from a synchronous orbiting satellite near the apex of a radiation belt which is naturally-occurring in the earth's magnetosphere to produce a substantial increase in energetic particle precipitation and, under certain conditions, produce a limit in the number of particles that can be stably trapped. This precipitation effect arises from an enhancement of the whistler-mode and ion-cyclotron mode interactions that result from the ionized gas or "cold plasma" injection.

It has also been proposed to release large clouds of barium in the magnetosphere so that photoionization will increase the cold plasma density, thereby producing electron precipitation through enhanced whistler-mode interactions.

However, in all of the above-mentioned approaches, the mechanisms involved in triggering the change in the trapped particle phenomena must be actually positioned within the affected zone, e.g., the magnetosphere, before they can be actuated to effect the desired change.

The earth's ionosphere is not considered to be a "trapped" belt since there are few trapped particles therein. The term "trapped" herein refers to situations where the force of gravity on the trapped particles is balanced by magnetic forces rather than hydrostatic or collisional forces. The charged electrons and ions in the ionosphere also follow helical paths around magnetic field lines within the ionosphere but are not trapped between mirrors, as in the case of the trapped belts in the magnetosphere, since the gravitational force on the particles is balanced by collisional or hydrostatic forces.

In recent years, a number of experiments have actually been carried out to modify the ionosphere in some controlled manner to investigate the possibility of a beneficial result. For detailed discussions of these operations see the following papers: (1) Ionospheric Modification Theory; G. Meltz and F. W. Perkins; (2) The Platteville High Power Facility; Carrol et al.; (3) Arecibo Heating Experiments; W. E. Gordon and H. C. Carlson, Jr.; and (4) Ionospheric Heating by Powerful Radio Waves; Meltz et al., all published in Radio Science, Vol. 9, No. 11, November, 1974, at pages 885–888; 889–894; 1041–1047; and 1049–1063, respectively, all of which are incorporated herein by reference. In such experiments, certain regions of the ionosphere are heated to change the electron density and temperature within these regions. This is accomplished by transmitting from earth-based antennae high frequency electromagnetic radiation at a substantial angle to, not parallel to, the ionosphere's magnetic field to heat the ionospheric particles primarily by ohmic heating. The electron temperature of the ionosphere has been raised by hundreds of degrees in these experiments, and electrons with several electron volts of energy have been produced in numbers sufficient to enhance airglow. Electron concentrations have been reduced by a few percent, due to expansion of the plasma as a result of increased temperature.

In the Elmo Bumpy Torus (EBT), a controlled fusion device at the Oak Ridge National Laboratory, all heating is provided by microwaves at the electron cyclotron resonance interaction. A ring of hot electrons is formed at the earth's surface in the magnetic mirror by a combination of electron cyclotron resonance and stochastic heating. In the EBT, the ring electrons are produced with an average "temperature" of 250 kilo electron volts or kev (2.5×10^9K) and a plasma beta between 0.1 and 0.4; see, "A Theoretical Study of Electron—Cyclotron Absorption in Elmo Bumpy Torus", Batchelor and Goldfinger, Nuclear Fusion, Vol. 20, No. 4 (1980) pps. 403–418.

Electron cyclotron resonance heating has been used in experiments on the earth's surface to produce and accelerate plasmas in a diverging magnetic field. Kosmahl et al. showed that power was transferred from the electromagnetic waves and that a fully ionized plasma was accelerated with a divergence angle of roughly 13 degrees. Optimum neutral gas density was 1.7×10^{14}per cubic centimeter; see, "Plasma Acceleration with Microwaves Near Cyclotron Resonance", Kosmahl et al., Journal of Applied Physics, Vol. 38, No. 12, Nov., 1967, pps. 4576–4582.

DISCLOSURE OF THE INVENTION

The present invention provides a method and apparatus for altering at least one selected region which normally exists above the earth's surface. The region is excited by electron cyclotron resonance heating of electrons which are already present and/or artifically created in the region to thereby increase the charged particle energy and ultimately the density of the region.

In one embodiment this is done by transmitting circularly polarized electromagnetic radiation from the earth's surface at or near the location where a naturally-occurring dipole magnetic field (force) line intersects the earth's surface. Right hand circular polarization is used in the northern hemisphere and left hand circular polarization is used in the southern hemisphere. The radiation is deliberately transmitted at the outset in a direction substantially parallel to and along a field line which extends upwardly through the region to be altered. The radiation is transmitted at a frequency which is based on the gyrofrequency of the charged particles and which, when applied to the at least one region, excites electron cyclotron resonance within the region or regions to heat and accelerate the charged particles in their respective helical paths around and along the field line. Sufficient energy is employed to cause ionization of neutral particles (molecules of oxygen, nitrogen and the like, particulates, etc.) which then become a part of the region thereby increasing the charged particle density of the region. This effect can further be enhanced by providing artificial particles, e.g., electrons, ions, etc., directly into the region to be affected from a rocket, satellite, or the like to supplement the particles in the naturally-occurring plasma. These artificial particles are also ionized by the transmitted electromagnetic radiation thereby increasing charged particle density of the resulting plasma in the region.

In another embodiment of the invention, electron cyclotron resonance heating is carried out in the selected region or regions at sufficient power levels to allow a plasma present in the region to generate a mirror force which forces the charged electrons of the altered plasma upward along the force line to an altitude which is higher than the original altitude. In this case the relevant mirror points are at the base of the altered region or regions. The charged electrons drag ions with them as well as other particles that may be present. Sufficient power, e.g., 10^{15}joules, can be applied so that the altered plasma can be trapped on the field line between mirror points and will oscillate in space for prolonged periods of time. By this embodiment, a plume of altered plasma can be established at selected locations for communication modification or other purposes.

In another embodiment, this invention is used to alter at least one selected region of plasma in the ionosphere to establish a defined layer of plasma having an increased charged particle density. Once this layer is established, and while maintaining the transmission of the main beam of circularly polarized electromagnetic radiation, the main beam is modulated and/or at least one second different, modulated electromagnetic radiation beam is transmitted from at least one separate source at a different frequency which will be absorbed in the plasma layer. The amplitude of the frequency of the main beam and/or the second beam or beams is modulated in resonance with at least one known oscillation mode in the selected region or regions to excite the known oscillation mode to propagate a known frequency wave or waves throughout the ionosphere.

BRIEF DESCRIPTION OF THE DRAWINGS

The actual construction, operation, and apparent advantages of this invention will be better understood by referring to the drawings in which like numerals identify like parts and in which:

FIG. **1** is a simplified schematical view of the earth (not to scale) with a magnetic field (force) line along which the present invention is carried out;

FIG. **2** is one embodiment within the present invention in which a selected region of plasma is raised to a higher altitude;

FIG. **3** is a simplified, idealized representation of a physical phenomenon involved in the present invention; and

FIG. **4** is a schematic view of another embodiment within the present invention.

FIG. **5** is a schematic view of an apparatus embodiment within this invention.

BEST MODES FOR CARRYING OUT THE INVENTION

The earth's magnetic field is somewhat analogous to a dipole bar magnet. As such, the earth's magnetic field contains numerous divergent field or force lines, each line intersecting the earth's surface at points on opposite sides of the Equator. The field lines which intersect the earth's surface near the poles have apexes which lie at the furthest points in the earth's magnetosphere while those closest to the Equator have apexes which reach only the lower portion of the magnetosphere.

At various altitudes above the earth's surface, e.g., in both the ionosphere and the magnetosphere, plasma is naturally present along these field lines. This plasma consists of equal numbers of positively and negatively charged particles (i.e., electrons and ions) which are guided by the field line. It is well established that a charged particle in a magnetic field gyrates about field lines, the center of gyration at any instance being called the "guiding center" of the particle. As the gyrating particle moves along a field line in a uniform field, it will follow a helical path about its guiding center, hence linear motion, and will remain on the field line. Electrons and ions both follow helical paths around a field line but rotate in opposite directions. The frequencies at which the electrons and ions rotate about the field line are called gyromagnetic frequencies or cyclotron frequencies because they are identical with the expression for the angular frequencies of gyration of particles in a cyclotron. The cyclotron frequency of ions in a given magnetic field is less than that of electrons, in inverse proportion to their masses.

If the particles which form the plasma along the earth's field lines continued to move with a constant pitch angle, often designated "alpha", they would soon impact on the earth's surface. Pitch angle alpha is defined as the angle between the direction of the earth's magnetic field and the velocity (V) of the particle. However, in converging force fields, the pitch angle does change in such a way as to allow the particle to turn around and avoid impact. Consider a particle moving along a field line down toward the earth. It moves into a region of increasing magnetic field strength and therefore sine alpha increases. But sine alpha can only increase to 1.0, at which point, the particle turns around and starts moving up along the field line, and alpha decreases. The point at which the particle turns around is called the mirror point, and there alpha equals ninety degrees. This process is repeated at the other end of the field line where the same magnetic field strength value B, namely Bm, exists. The particle again turns around and this is called the "conjugate point" of the original mirror point. The particle is therefore trapped and bounces between the two magnetic mirrors. The particle can continue oscillating in space in this manner for long periods of time. The actual place where a particle will mirror can be calculated from the following:

$$\sin^2 \text{alpha}_o = B_o/B_m \qquad (1)$$

wherein:

alpha_o=equatorial pitch angle of particle

B_o=equatorial field strength on a particular field line

B_m=field strength at the mirror point

Recent discoveries have established that there are substantial regions of naturally trapped particles in space which are commonly called "trapped radiation belts". These belts occur at altitudes greater than about 500 km and accordingly lie in the magnetosphere and mostly above the ionosphere.

The ionosphere, while it may overlap some of the trapped-particle belts, is a region in which hydrostatic forces govern its particle distribution in the gravitational field. Particle motion within the ionosphere is governed by both hydrodynamic and electrodynamic forces. While there are few trapped particles in the ionosphere, nevertheless, plasma is present along field lines in the ionosphere. The charged particles which form this plasma move between collisions with other particles along similar helical paths around the field lines and although a particular particle may diffuse downward into the earth's lower atmosphere or lose energy and diverge from its original field line due to collisions with other particles, these charged particles are normally replaced by other available charged particles or by particles that are ionized by collision with said particle. The electron density (N_e) of the plasma will vary with the actual conditions and locations involved. Also, neutral particles, ions, and electrons are present in proximity to the field lines.

The production of enhanced ionization will also alter the distribution of atomic and molecular constituents of the atmosphere, most notably through increased atomic nitrogen concentration. The upper atmosphere is normally rich in atomic oxygen (the dominant atmospheric constituent above 200 km altitude), but atomic nitrogen is normally relatively rare. This can be expected to manifest itself in increased airglow, among other effects.

As known in plasma physics, the characteristics of a plasma can be altered by adding energy to the charged particles or by ionizing or exciting additional particles to increase the density of the plasma. One way to do this is by heating the plasma which can be accomplished in different ways, e.g., ohmic, magnetic compression, shock waves, magnetic pumping, electron cyclotron resonance, and the like.

Since electron cyclotron resonance heating is involved in the present invention, a brief discussion of same is in order. Increasing the energy of electrons in a plasma by invoking electron cyclotron resonance heating, is based on a principle similar to that utilized to accelerate charged particles in a cyclotron. If a plasma is confined by a static axial magnetic field of strength B, the charged particles will gyrate about the lines of force with a frequency given, in hertz, as $f_g = 1.54 \times 10^3 B/A$, where: B=magnetic field strength in gauss, and A=mass number of the ion.

Suppose a time-varying field of this frequency is superimposed on the static field B confining the plasma, by passage of a radiofrequency current through a coil which is concentric with that producing the axial field, then in each half-cycle of their rotation about the field lines, the charged particles acquire energy from the oscillating electric field associated with the radio frequency. For example, if B is 10,000 gauss, the frequency of the field which is in resonance with protons in a plasma is 15.4 megahertz.

As applied to electrons, electron cyclotron resonance heating requires an oscillating field having a definite frequency determined by the strength of the confining field. The radio-frequency radiation produces time-varying fields (electric and magnetic), and the electric field accelerates the charged particle. The energized electrons share their energy with ions and neutrals by undergoing collisions with these particles, thereby effectively raising the temperature of the electrons, ions, and neutrals. The apportionment of energy among these species is determined by collision frequencies. For a more detailed understanding of the physics involved, see "Controlled Thermonuclear Reactions", Glasstone and Lovberg, D. Van Nostrand Company, Inc., Princeton, N.J., 1960 and "The Radiation Belt and Magnetosphere", Hess, Blaisdell Publishing Company, 1968, both of which are incorporated herein by reference.

Referring now to the drawings, the present invention provides a method and apparatus for altering at least one region of plasma which lies along a field line, particularly when it passes through the ionosphere and/or magnetosphere. FIG. **1** is a simplified illustration of the earth **10** and one of its dipole magnetic force or field lines **11**. As will be understood, line **11** may be any one of the numerous naturally existing field lines and the actual geographical locations **13** and **14** of line **11** will be chosen based on a particular operation to be carried out. The actual locations at which field lines intersect the earth's surface is documented and is readily ascertainable by those skilled in the art.

Line **11** passes through region R which lies at an altitude above the earth's surface. A wide range of altitudes are useful given the power that can be employed by the practice of this invention. The electron cyclotron resonance heating effect can be made to act on electrons anywhere above the surface of the earth. These electrons may be already present in the atmosphere, ionosphere, and/or magnetosphere of the earth, or can be artificially generated by a variety of means such as x-ray beams, charged particle beams, lasers, the plasma sheath surrounding an object such as a missile or meteor, and the like. Further, artificial particles, e.g., electrons, ions, etc., can be injected directly into region R from an earth-launched rocket or orbiting satellite carrying, for example, a payload of radioactive beta-decay material; alpha emitters; an electron accelerator; and/or ionized gases such as hydrogen; see U.S. Pat. No. 4,042,196. The altitude can be greater than about 50 km if desired, e.g., can be from about 50 km to about 800 km, and, accordingly may lie in either the ionosphere or the magnetosphere or both. As explained above, plasma will be present along line **11** within region R and is represented by the helical line **12**. Plasma **12** is comprised of charged particles (i.e., electrons and ions) which rotate about opposing helical paths along line **11**.

Antenna **15** is positioned as close as is practical to the location **14** where line **11** intersects the earth's surface. Antenna **15** may be of any known construction for high directionality, for example, a phased array, beam spread angle (θ) type. See "The MST Radar at Poker Flat, Alaska", Radio Science, Vol. 15, No. 2, Mar.-Apr. 1980, pps. 213–223, which is incorporated herein by reference. Antenna **15** is coupled to transmitter **16** which generates a beam of high frequency electromagnetic radiation at a wide range of discrete frequencies, e.g., from about 20 to about 1800 kilohertz (kHz).

Transmitter **16** is powered by power generator means **17** which is preferably comprised of one or more large, commercial electrical generators. Some embodiments of the present invention require large amounts of power, e.g., up to 10^9 to 10^{11} watts, in continuous wave or pulsed power. Generation of the needed power is within the state of the art. Although the electrical generators necessary for the practice of the invention can be powered in any known manner, for example, by nuclear reactors, hydroelectric facilities, hydrocarbon fuels, and the like, this invention, because of its very large power requirement in certain applications, is particularly adapted for use with certain types of fuel sources which naturally occur at strategic geographical locations around the earth. For example, large reserves of hydrocarbons (oil and natural gas) exist in Alaska and Canada. In northern Alaska, particularly the North Slope region, large reserves are currently readily available. Alaska and northern Canada also are ideally located geographically as to magnetic latitudes. Alaska provides easy access to magnetic field lines that are especially suited to the practice of this invention, since many field lines which extend to desirable altitudes for this invention intersect the earth in Alaska. Thus, in Alaska, there is a unique combination of large, accessible fuel sources at desirable field line intersections. Further, a particularly desirable fuel source for the generation of very large amounts of electricity is present in Alaska in abundance, this source being natural gas. The presence of very large amounts of clean-burning natural gas in Alaskan latitudes, particularly on the North Slope, and the availability of magnetohydrodynamic (MHD), gas turbine, fuel cell, electrogasdynamic (EGD) electric generators which operate very efficiently with natural gas provide an ideal power source for the unprecedented power requirements of certain of the applications of this invention. For a more detailed discussion of the various means for generating electricity from hydrocarbon fuels, see "Electrical Aspects of Combustion", Lawton and Weinberg, Clarendon Press, 1969. For example, it is possible to generate the electricity directly at the high frequency needed to drive the antenna system. To do this, typically the velocity of flow of the combustion gases (v), past magnetic field perturbation of dimension d (in the case of MHD), follow the rule:

$$v=df$$

where f is the frequency at which electricity is generated. Thus, if $v=1.78\times10^6$ cm/sec and $d=1$ cm then electricity would be generated at a frequency of 1.78 mHz.

Put another way, in Alaska, the right type of fuel (natural gas) is naturally present in large amounts and at just the right magnetic latitudes for the most efficient practice of this invention, a truly unique combination of circumstances. Desirable magnetic latitudes for the practice of this invention interest the earth's surface both northerly and southerly of the equator, particularly desirable latitudes being those, both northerly and southerly, which correspond in magnitude with the magnetic latitudes that encompass Alaska.

Referring now to FIG. **2** a first ambodiment is illustrated where a selected region R_1 of plasma **12** is altered by electron cyclotron resonance heating to accelerate the electrons of plasma **12**, which are following helical paths along field line **11**.

To accomplish this result, electromagnetic radiation is transmitted at the outset, essentially parallel to line **11** via antenna **15** as right hand circularly polarized radiation wave **20**. Wave **20** has a frequency which will excite electron cyclotron resonance with plasma **12** at its initial or original altitude. This frequency will vary depending on the electron cyclotron resonance of region R_1 which, in turn, can be determined from available data based on the altitudes of region R_1, the particular field line **11** being used, the strength of the earth's magnetic field, etc. Frequencies of from about 20 to about 7200 kHz, preferably from about 20 to about 1800 kHz can be employed. Also, for any given application, there will be a threshhold (minimum power level) which is needed to produce the desired result. The minimum power level is a function of the level of plasma production and movement required, taking into consideration any loss processes that may be dominant in a particular plasma or propagation path.

As electron cyclotron resonance is established in plasma **12**, energy is transferred from the electromagnetic radiation **20** into plasma **12** to heat and accelerate the electrons therein and, subsequently, ions and neutral particles. As this process continues, neutral particles which are present within R_1 are ionized and absorbed into plasma **12** and this increases the electron and ion densities of plasma **12**. As the electron energy is raised to values of about 1 kilo electron volt (kev), the generated mirror force (explained below) will direct the excited plasma **12** upward along line **11** to form a plume R_2 at an altitude higher than that of R_1.

Plasma acceleration results from the force on an electron produced by a nonuniform static magnetic field ($\overline{B}$). The force, called the mirror force, is given by

$$F=-\mu\nabla B \tag{2}$$

where μ is the electron magnetic moment and $\nabla\overline{B}$ is the gradient of the magnetic field, μ being further defined as:

$$W_\perp/B=mV_\perp^2/2B$$

where $W_\perp$ is the kinetic energy in the direction perpendicular to that of the magnetic field lines and B is the magnetic field strength at the line of force on which the guiding center of the particle is located. The force as represented by equation (2) is the force which is responsible for a particle obeying equation (1).

Since the magnetic field is divergent in region R_1, it can be shown that the plasma will move upwardly from the heating region as shown in FIG. **1** and further it can be shown that

$$\tfrac{1}{2}M_eV_{e\perp}^2(x) \approx \tfrac{1}{2}M_eV_{e\perp}^2(Y)+\tfrac{1}{2}M_iV_{i\parallel}^2(Y) \qquad (3)$$

where the left hand side is the initial electron transverse kinetic energy; the first term on the right is the transverse electron kinetic energy at some point (Y) in the expanded field region, while the final term is the ion kinetic energy parallel to B at point (Y). This last term is what constitutes the desired ion flow. It is produced by an electrostatic field set up by electrons which are accelerated according to Equation (2) in the divergent field region and pulls ions along with them. Equation (3) ignores electron kinetic energy parallel to B because $V_{e\parallel} \approx V_{i\parallel}$, so the bulk of parallel kinetic energy resides in the ions because of their greater masses. For example, if an electromagnetic energy flux of from about 1 to about 10 watts per square centimeter is applied to region R, whose altitude is 115 km, a plasma having a density (N_e) of 10^{12} per cubic centimeter will be generated and moved upward to region R_2 which has an altitude of about 1000 km. The movement of electrons in the plasma is due to the mirror force while the ions are moved by ambipolar diffusion (which results from the electrostatic field). This effectively "lifts" a layer of plasma **12** from the ionosphere and/or magnetosphere to a higher elevation R_2. The total energy required to create a plasma with a base area of 3 square kilometers and a height of 1000 km is about 3×10^{13} joules.

FIG. **3** is an idealized representation of movement of plasma **12** upon excitation by electron cyclotron resonance within the earth's divergent force field. Electrons (e) are accelerated to velocities required to generate the necessary mirror force to cause their upward movement. At the same time neutral particles (n) which are present along line **11** in region R_1 are ionized and become part of plasma **12**. As electrons (e) move upward along line **11**, they drag ions (i) and neutrals (n) with them but at an angle θ of about 13 degrees to field line **11**. Also, any particulates that may be present in region R_1, will be swept upwardly with the plasma. As the charged particles of plasma **12** move upward, other particles such as neutrals within or below R_1, move in to replace the upwardly moving particles. These neutrals, under some conditions, can drag with them charged particles.

For example, as a plasma moves upward, other particles at the same altitude as the plasma move horizontally into the region to replace the rising plasma and to form new plasma. The kinetic energy developed by said other particles as they move horizontally is, for example, on the same order of magnitude as the total zonal kinetic energy of stratospheric winds known to exist.

Referring again to FIG. **2**, plasma **12** in region R_1 is moved upward along field line **11**. The plasma **12** will then form a plume (cross-hatched area in FIG. **2**) which will be relatively stable for prolonged periods of time. The exact period of time will vary widely and be determined by gravitational forces and a combination of radiative and diffusive loss terms. In the previous detailed example, the calculations were based on forming a plume by producing 0^+energies of 2 ev/particle. About 10 ev per particle would be required to expand plasma **12** to apex point C (FIG. **1**). There at least some of the particles of plasma **12** will be trapped and will oscillate between mirror points along field line **11**. This oscillation will then allow additional heating of the trapped plasma **12** by stochastic heating which is associated with trapped and oscillating particles. See "A New Mechanism for Accelerating Electrons in the Outer Ionosphere" by R. A. Helliwell and T. F. Bell, Journal of Geophysical Research, Vol. 65, No. 6, June, 1960. This is preferably carried out at an altitude of at least 500 km.

The plasma of the typical example might be employed to modify or disrupt microwave transmissions of satellites. If less than total black-out of transmission is desired (e.g., scrambling by phase shifting digital signals), the density of the plasma (N_e) need only be at least about 10^6 per cubic centimeter for a plasma orginating at an altitude of from about 250 to about 400 km and accordingly less energy (i.e., electromagnetic radiation), e.g., 10^8 joules need be provided. Likewise, if the density $N_e$is on the order of 10^8, a properly positioned plume will provide a reflecting surface for VHF waves and can be used to enhance, interfere with, or otherwise modify communication transmissions. It can be seen from the foregoing that by appropriate application of various aspects of this invention at strategic locations and with adequate power sources, a means and method is provided to cause interference with or even total disruption of communications over a very large portion of the earth. This invention could be employed to disrupt not only land based communications, both civilian and military, but also airborne communications and sea communications (both surface and subsurface). This would have significant military implications, particularly as a barrier to or confusing factor for hostile missiles or airplanes. The belt or belts of enhanced ionization produced by the method and apparatus of this invention, particularly if set up over Northern Alaska and Canada, could be employed as an early warning device, as well as a communications disruption medium. Further, the simple ability to produce such a situation in a practical time period can by itself be a deterring force to hostile action. The ideal combination of suitable field lines intersecting the earth's surface at the point where substantial fuel sources are available for generation of very large quantitities of electromagnetic power, such as the North Slope of Alaska, provides the wherewithal to accomplish the foregoing in a practical time period, e.g., strategic requirements could necessitate achieving the desired altered regions in time periods of two minutes or less and this is achievable with this invention, especially when the combination of natural gas and magnetohydrodynamic, gas turbine, fuel cell and/or EGD electric generators are employed at the point where the useful field lines intersect the earth's surface. One feature of this invention which satisfies a basic requirement of a weapon system, i.e., continuous checking of operability, is that small amounts of power can be generated for operability checking purposes. Further, in the exploitation of this invention, since the main electromagnetic beam which generates the enhanced ionized belt of this invention can be modulated itself and/or one or more additional electromagnetic radiation waves can be impinged on the ionized region formed by this invention as will be described in greater detail herein after with respect to FIG. **4**, a substantial amount of randomly modulated signals of very large power magnitude can be generated in a highly nonlinear mode. This can cause confusion of or interference with or even complete disruption of guidance systems employed by even the most sophisticated of airplanes and missiles. The ability to employ and transmit over very wide areas of the earth a plurality of electromagnetic waves of varying frequencies and to change same at will in a random manner, provides a unique ability to interfere with all modes of communications, land, sea, and/or air, at the same time. Because of the unique juxtaposition of usable fuel source at the point where desirable field lines intersect the earth's surface, such wide ranging and complete communication interference can be achieved in a resonably short period of time. Because of the mirroring phenomenon discussed hereinabove, it can also be prolonged for substantial time periods so that it would not be a mere transient effect that could simply be waited out by an opposing force. Thus, this invention provides the ability to put unprecedented amounts of power in the earth's atmosphere at strategic locations and to maintain the power injection level, particularly if random pulsing is employed, in a manner far more precise and better controlled than heretofore accomplished by the prior art, particularly by the detonation of nuclear devices of various yeilds at various altitudes. Where the prior art approaches yielded merely transitory effects, the unique combination of fuel and desirable field lines at the point where the fuel occurs allows the establishment of, compared to prior art approaches, precisely controlled and long-lasting effects which cannot, practically speaking, simply be waited out. Further, by knowing the frequencies of the various electromagnetic beams employed in the practice of this invention, it is possible not only to interfere with third party communications but to take advantage of one or more such beams to carry out a communications network even though the rest of the world's communications are disrupted. Put another way, what is used to disrupt another's communications can be employed by one knowledgeable of this invention as a communications network at the same time. In addition, once one's own communication network is established, the far-reaching extent of the effects of this invention could be employed to pick up communication signals of other for intelligence purposes. Thus, it can be seen that the disrupting effects achievable by this invention can be employed to benefit by the party who is practicing this invention since knowledge of the various electromagnetic waves being employed and how they will vary in frequency and magnitude can be used to an advantage for positive communication and eavesdropping purposes at the same time. However, this invention is not limited to locations where the fuel source naturally exists or where desirable field lines naturally intersect the earth's surface. For example, fuel, particularly hydrocarbon fuel, can be transported by pipeline and the like to the location where the invention is to be practiced.

FIG. 4 illustrates another embodiment wherein a selected region of plasma R_3which lies within the earth's ionosphere is altered to increase the density thereof whereby a relatively stable layer **30** of relatively dense plasma is maintained within region R_3. Electromagnetic radiation is transmitted at the outset essentially parallel to field line **11** via antenna **15** as a right hand circularly polarized wave and at a frequency (e.g., 1.78 megahertz when the magnetic field at the desired altitude is 0.66 gauss) capable of exciting electron cyclotron resonance in plasma **12** at the particular altitude of plasma **12**. This causes heating of the particles (electrons, ions, neutrals, and particulates) and ionization of the uncharged particles adjacent line **11**, all of which are absorbed into plasma **12** to increase the density thereof. The power transmitted, e.g., 2×10^6 watts for up to 2 minutes heating time, is less than that required to generate the mirror force F required to move plasma **12** upward as in the previous embodiment.

While continuing to transmit electromagnetic radiation **20** from antenna **15**, a second electromagnetic radiation beam **31**, which is at a defined frequency different from the radiation from antenna **15**, is transmitted from one or more second sources via antenna **32** into layer **30** and is absorbed into a portion of layer **30** (cross-hatched area in FIG. **4**). The electromagnetic radiation wave from antenna **32** is amplitude modulated to match a known mode of oscillation f_3 in layer **30**. This creates a resonance in layer **30** which excites a new plasma wave **33** which also has a frequency of f_3 and which then propogates through the ionosphere. Wave **33** can be used to improve or disrupt communications or both depending on what is desired in a particular application. Of course, more than one new wave **33** can be generated and the various new waves can be modulated at will and in a highly nonlinear fashion.

FIG. **5** shows apparatus useful in this invention, particularly when those applications of this invention are employed which require extremely large amounts of power. In FIG. **5** there is shown the earth's surface **40** with a well **41** extending downwardly thereinto until it penetrates hydrocarbon producing reservoir **42**. Hydrocarbon reservoir **42** produces natural gas alone or in combination with crude oil. Hydrocarbons are produced from reservoir **42** through well **41** and wellhead **43** to a treating system **44** by way of pipe **45**. In treater **44**, desirable liquids such as crude oil and gas condensates are separated and recovered by way of pipe **46** while undesirable gases and liquids such as water, H_2S, and the like are separated by way of pipe **47**. Desirable gases such as carbon dioxide are separated by way of pipe **48**, and the remaining natural gas stream is removed from treater **44** by way of pipe **49** for storage in conventional tankage means (not shown) for future use and/or use in an electrical generator such as a magnetohydrodynamic, gas turbine, fuel cell or EGD generator **50**. Any desired number and combination of different types of electric generators can be employed in the practice of this invention. The natural gas is burned in generator **50** to produce substantial quantities of electricity which is then stored and/or passed by way of wire **51** to a transmitter **52** which generates the electromagnetic radiation to be used in the method of this invention. The electromagnetic radiation is then passed by way of wire **53** to antenna **54** which is located at or near the end of field line **11**. Antenna **54** sends circularly polarized radiation wave **20** upwards along field line **11** to carry out the various methods of this invention as described hereinabove.

Of course, the fuel source need not be used in its naturally-occurring state but could first be converted to another second energy source form such as hydrogen, hydrazine and the like, and electricity then generated from said second energy source form.

It can be seen from the foregoing that when desirable field line **11** intersects earth's surface **40** at or near a large naturally-occurring hydrocarbon source **42**, exceedingly large amounts of power can be very efficiently produced and transmitted in the direction of field lines. This is particularly so when the fuel source is natural gas and magnetohydrodynamic generators are employed. Further, this can all be accomplished in a relatively small physical area when there is the unique coincidence of fuel source **42** and desirable field line **11**. Of course, only one set of equipment is shown in FIG. **5** for sake of simplicity. For a large hydrocarbon reservoir **42**, a plurality of wells **41** can be employed to feed one or more storage means and/or treaters and as large a number of generators **55** as needed to power one or more transmitters **52** and one or more antennas **54**. Since all of the apparatus **44** through **54** can be employed and used essentially at the sight where naturally-occurring fuel source **42** is located, all the necessary electromagnetic radiation **20** is generated essentially at the same location as fuel source **42**. This provides for a maximum amount of usable electromagnetic radiation **20** since there are no significant storage or transportation losses to be incurred. In other words, the apparatus is brought to the sight of the fuel source where desirable field line **11** intersects the earth's surface **40** on or near the geographical location of fuel source **42**, fuel source **42** being at a desirable magnetic latitude for the practice of this invention, for example, Alaska.

The generation of electricity by motion of a conducting fluid through a magnetic field, i.e., magnetohydrodynamics (MHD), provides a method of electric power generation without moving mechanical parts and when the conducting fluid is a plasma formed by combustion of a fuel such as natural gas, an idealized combination of apparatus is realized since the very clean-burning natural gas forms the conducting plasma in an efficient manner and the thus formed plasma, when passed through a magnetic field, generates electricity in a very efficient manner. Thus, the use of fuel source **42** to generate a plasma by combustion thereof for the generation of electricity essentially at the site of occurrence of the fuel source is unique and ideal when high power levels are required and desirable field lines **11** intersect the earth's surface **40** at or near the site of fuel source **42**. A particular advantage for MHD generators is that they can be made to generate large amounts of power with a small volume, light weight device. For example, a 1000 megawatt MHD generator can be construed using superconducting magnets to weigh roughly 42,000 pounds and can be readily air lifted.

This invention has a phenomenal variety of possible ramifications and potential future developments. As alluded to earlier, missile or aircraft destruction, deflection, or confusion could result, particularly when relativistic particles are employed. Also, large regions of the atmosphere could be lifted to an unexpectedly high altitude so that missiles encounter unexpected and unplanned drag forces with resultant destruction or deflection of same. Weather modification is possible by, for example, altering upper atmosphere wind patterns or altering solar absorption patterns by constructing one or more plumes of atmospheric particles which will act as a lens or focusing device. Also as alluded to earlier, molecular modifications of the atmosphere can take place so that positive environmental effects can be achieved. Besides actually changing the molecular composition of an atmospheric region, a particular molecule or molecules can be chosen for increased presence. For example, ozone, nitrogen, etc. concentrations in the atmosphere could be artificially increased. Similarly, environmental enhancement could be achieved by causing the breakup of various chemical entities such as carbon dioxide, carbon monoxide, nitrous oxides, and the like. Transportation of entities can also be realized when advantage is taken of the drag effects caused by regions of the atmosphere moving up along diverging field lines. Small micron sized particles can be then transported, and, under certain circumstances and with the availability of sufficient energy, larger particles or objects could be similarly affected. Particles with desired characteristics such as tackiness, reflectivity, absorptivity, etc., can be transported for specific purposes or effects. For example, a plume of tacky particles could be established to increase the drag on a missile or satellite passing therethrough. Even plumes of plasma having substantially less charged particle density than described above will produce drag effects on missiles which will affect a lightweight (dummy) missile in a manner substantially different than a heavy (live) missile and this affect can be used to distinguish between the two types of missiles. A moving plume could also serve as a means for supplying a space station or for focusing vast amount of sunlight on selected portions of the earth. Surveys of global scope could also be realized because the earth's natural magnetic field could be significantly altered in a controlled manner by plasma beta effects resulting in, for example, improved magnetotelluric surveys. Electromagnetic pulse defenses are also possible. The earth's magnetic field could be decreased or disrupted at appropriate altitudes to modify or eliminate the magnetic field in high Compton electron generation (e.g., from high altitude nuclear bursts) regions. High intensity, well controlled electrical fields can be provided in selected locations for various purposes. For example, the plasma sheath surrounding a missile or satellite could be used as a trigger for activating such a high intensity field to destroy the missile or satellite. Further, irregularities can be created in the ionosphere which will interfere with the normal operation of various types of radar, e.g., synthetic aperture radar. The present invention can also be used to create artificial belts of trapped particles which in turn can be studied to determine the stability of such parties. Still further, plumes in accordance with the present invention can be formed to simulate and/or perform the same functions as performed by the detonation of a "heave" type nuclear device without actually having to detonate such a device. Thus it can be seen that the ramifications are numerous, far-reaching, and exceedingly varied in usefulness.

I claim:

1. A method for altering at least one region normally existing above the earth's surface with electromagnetic radiation using naturally-occurring and diverging magnetic field lines of the earth comprising transmitting first electromagnetic radiation at a frequency between 20 and 7200 kHz from the earth's surface, said transmitting being conducted essentially at the outset of transmission substantially parallel to and along at least one of said field lines, adjusting the frequency of said first radiation to a value which will excite electron cyclotron resonance at an initial elevation at least 50 km above the earth's surface, whereby in the region in which said electron cyclotron resonance takes place heating, further ionization, and movement of both charged and neutral particles is effected, said cyclotron resonance excitation of said region is continued until the electron concentration of said region reaches a value of at least 10^6 per cubic centimeter and has an ion energy of at least 2 ev.

2. The method of claim **1** including the step of providing artificial particles in said at least one region which are excited by said electron cyclotron resonance.

3. The method of claim **2** wherein said artificial particles are provided by injecting same into said at least one region from an orbiting satellite.

4. The method of claim **1** wherein said threshold excitation of electron cyclotron resonance is about 1 watt per cubic centimeter and is sufficient to cause movement of a plasma region along said diverging magnetic field lines to an altitude higher than the altitude at which said excitation was initiated.

5. The method of claim **4** wherein said rising plasma region pulls with it a substantial portion of neutral particles of the atmosphere which exist in or near said plasma region.

6. The method of claim **1** wherein there is provided at least one separate source of second electromagnetic radiation, said second radiation having at least one frequency different from said first radiation, impinging said at least one second radiation on said region while said region is undergoing electron cyclotron resonance excitation caused by said first radiation.

7. The method of claim **6** wherein said second radiation has a frequency which is absorbed by said region.

8. The method of claim **6** wherein said region is plasma in the ionosphere and said second radiation excites plasma waves within said ionosphere.

9. The method of claim **8** wherein said electron concentration reaches a value of at least 10^{12} per cubic centimeter.

10. The method of claim **8** wherein said excitation of electron cyclotron resonance is initially carried out within the ionosphere and is continued for a time sufficient to allow said region to rise above said ionosphere.

11. The method of claim **1** wherein said excitation of electron cyclotron resonance is carried out above about 500 kilometers and for a time of from 0.1 to 1200 seconds such that multiple heating of said plasma region is achieved by means of stochastic heating in the magnetosphere.

12. The method of claim **1** wherein said first electromagnetic radiation is right hand circularly polarized in the northern hemisphere and left hand circularly polarized in the southern hemisphere.

13. The method of claim **1** wherein said electromagnetic radiation is generated at the site of a naturally-occurring hydrocarbon fuel source, said fuel source being located in at least one of northerly or southerly magnetic latitudes.

14. The method of claim **13** wherein said fuel source is natural gas and electricity for generating said electromagnetic radiation is obtained by burning said natural gas in at least one of magnetohydrodynamic, gas turbine, fuel cell, and EGD electric generators located at the site where said natural gas naturally occurs in the earth.

15. The method of claim **14** wherein said site of natural gas is within the magnetic latitudes that encompass Alaska.

* * * * *

N. TESLA.

APPARATUS FOR TRANSMITTING ELECTRICAL ENERGY.

APPLICATION FILED JAN. 18, 1902. RENEWED MAY 4, 1907.

1,119,732. Patented Dec. 1, 1914.

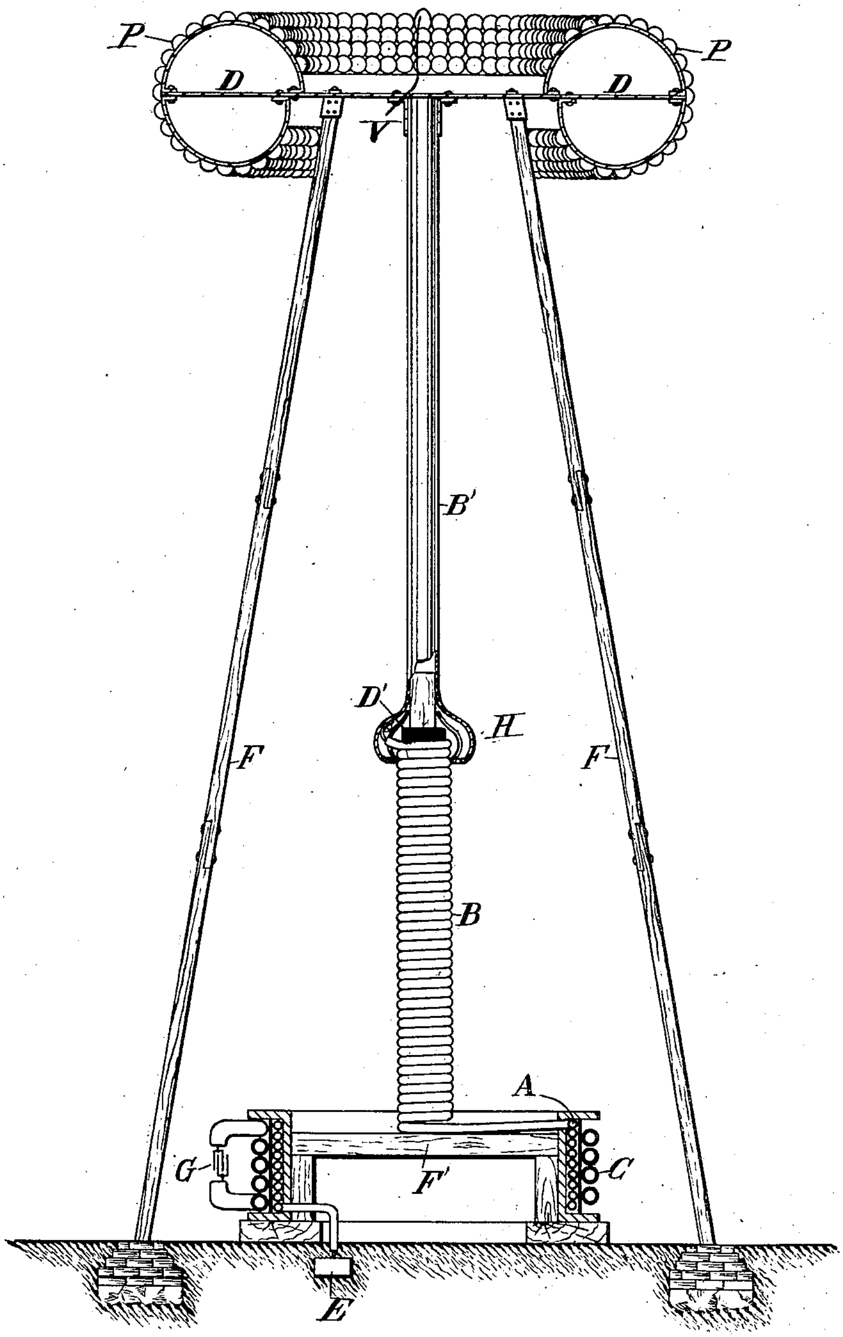

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APPARATUS FOR TRANSMITTING ELECTRICAL ENERGY.

1,119,732. Specification of Letters Patent. Patented Dec. 1, 1914.

Application filed January 18, 1902, Serial No. 90,245. Renewed May 4, 1907. Serial No. 371,817.

To all whom it may concern:

Be it known that I, Nikola Tesla, a citizen of the United States, residing in the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Apparatus for Transmitting Electrical Energy, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

In endeavoring to adapt currents or discharges of very high tension to various valuable uses, as the distribution of energy through wires from central plants to distant places of consumption, or the transmission of powerful disturbances to great distances, through the natural or non-artificial media, I have encountered difficulties in confining considerable amounts of electricity to the conductors and preventing its leakage over their supports, or its escape into the ambient air, which always takes place when the electric surface density reaches a certain value.

The intensity of the effect of a transmitting circuit with a free or elevated terminal is proportionate to the quantity of electricity displaced, which is determined by the product of the capacity of the circuit, the pressure, and the frequency of the currents employed. To produce an electrical movement of the required magnitude it is desirable to charge the terminal as highly as possible, for while a great quantity of electricity may also be displaced by a large capacity charged to low pressure, there are disadvantages met with in many cases when the former is made too large. The chief of these are due to the fact that an increase of the capacity entails a lowering of the frequency of the impulses or discharges and a diminution of the energy of vibration. This will be understood when it is borne in mind, that a circuit with a large capacity behaves as a slackspring, whereas one with a small capacity acts like a stiff spring, vibrating more vigorously. Therefore, in order to attain the highest possible frequency, which for certain purposes is advantageous and, apart from that, to develop the greatest energy in such a transmitting circuit, I employ a terminal of relatively small capacity, which I charge to as high a pressure as practicable. To accomplish this result I have found it imperative to so construct the elevated conductor, that its outer surface, on which the electrical charge chiefly accumulates, has itself a large radius of curvature, or is composed of separate elements which, irrespective of their own radius of curvature, are arranged in close proximity to each other and so, that the outside ideal surface enveloping them is of a large radius. Evidently, the smaller the radius of curvature the greater, for a given electric displacement, will be the surface-density and, consequently, the lower the limiting pressure to which the terminal may be charged without electricity escaping into the air. Such a terminal I secure to an insulating support entering more or less into its interior, and I likewise connect the circuit to it inside or, generally, at points where the electric density is small. This plan of constructing and supporting a highly charged conductor I have found to be of great practical importance, and it may be usefully applied in many ways.

Referring to the accompanying drawing, the figure is a view in elevation and part section of an improved free terminal and circuit of large surface with supporting structure and generating apparatus.

The terminal D consists of a suitably shaped metallic frame, in this case a ring of nearly circular cross section, which is covered with half spherical metal plates P P, thus constituting a very large conducting surface, smooth on all places where the electric charge principally accumulates. The frame is carried by a strong platform expressly provided for safety appliances, instruments of observation, etc., which in turn rests on insulating supports F F. These should penetrate far into the hollow space formed by the terminal, and if the electric density at the points where they are bolted to the frame is still considerable, they may be specially protected by conducting hoods as H.

A part of the improvements which form the subject of this specification, the transmitting circuit, in its general features, is identical with that described and claimed in my original Patents Nos. 645,576 and 649,621. The circuit comprises a coil A which is in close inductive relation with a primary C, and one end of which is connected to a ground-plate E, while its other end is led through a separate self-induction coil B and a metallic cylinder B′ to the terminal D.

The connection to the latter should always be made at, or near the center, in order to secure a symmetrical distribution of the current, as otherwise, when the frequency is very high and the flow of large volume, the performance of the apparatus might be impaired. The primary C may be excited in any desired manner, from a suitable source of currents G, which may be an alternator or condenser, the important requirement being that the resonant condition is established, that is to say, that the terminal D is charged to the maximum pressure developed in the circuit, as I have specified in my original patents before referred to. The adjustments should be made with particular care when the transmitter is one of great power, not only on account of economy, but also in order to avoid danger. I have shown that it is practicable to produce in a resonating circuit as E A B B′ D immense electrical activities, measured by tens and even hundreds of thousands of horse-power, and in such a case, if the points of maximum pressure should be shifted below the terminal D, along coil B, a ball of fire might break out and destroy the support F or anything else in the way. For the better appreciation of the nature of this danger it should be stated, that the destructive action may take place with inconceivable violence. This will cease to be surprising when it is borne in mind, that the entire energy accumulated in the excited circuit, instead of requiring, as under normal working conditions, one quarter of the period or more for its transformation from static to kinetic form, may spend itself in an incomparably smaller interval of time, at a rate of many millions of horse power. The accident is apt to occur when, the transmitting circuit being strongly excited, the impressed oscillations upon it are caused, in any manner more or less sudden, to be more rapid than the free oscillations. It is therefore advisable to begin the adjustments with feeble and somewhat slower impressed oscillations, strengthening and quickening them gradually, until the apparatus has been brought under perfect control. To increase the safety, I provide on a convenient place, preferably on terminal D, one or more elements or plates either of somewhat smaller radius of curvature or protruding more or less beyond the others (in which case they may be of larger radius of curvature) so that, should the pressure rise to a value, beyond which it is not desired to go, the powerful discharge may dart out there and lose itself harmlessly in the air. Such a plate, performing a function similar to that of a safety valve on a high pressure reservoir, is indicated at V.

Still further extending the principles underlying my invention, special reference is made to coil B and conductor B′. The latter is in the form of a cylinder with smooth or polished surface of a radius much larger than that of the half spherical elements P P, and widens out at the bottom into a hood H, which should be slotted to avoid loss by eddy currents and the purpose of which will be clear from the foregoing. The coil B is wound on a frame or drum D^1 of insulating material, with its turns close together. I have discovered that when so wound the effect of the small radius of curvature of the wire itself is overcome and the coil behaves as a conductor of large radius of curvature, corresponding to that of the drum. This feature is of considerable practical importance and is applicable not only in this special instance, but generally. For example, such plates at P P of terminal D, though preferably of large radius of curvature, need not be necessarily so, for provided only that the individual plates or elements of a high potential conductor or terminal are arranged in proximity to each other and with their outer boundaries along an ideal symmetrical enveloping surface of a large radius of curvature, the advantages of the invention will be more or less fully realized. The lower end of the coil B—which, if desired, may be extended up to the terminal D—should be somewhat below the uppermost turn of coil A. This, I find, lessens the tendency of the charge to break out from the wire connecting both and to pass along the support F′.

Having described my invention, I claim:

1. As a means for producing great electrical activities a resonant circuit having its outer conducting boundaries, which are charged to a high potential, arranged in surfaces of large radii of curvature so as to prevent leakage of the oscillating charge, substantially as set forth.

2. In apparatus for the transmission of electrical energy a circuit connected to ground and to an elevated terminal and having its outer conducting boundaries, which are subject to high tension, arranged in surfaces of large radii of curvature substantially as, and for the purpose described.

3. In a plant for the transmission of electrical energy without wires, in combination with a primary or exciting circuit a secondary connected to ground and to an elevated terminal and having its outer conducting boundaries, which are charged to a high potential, arranged in surfaces of large radii of curvature for the purpose of preventing leakage and loss of energy, substantially as set forth.

4. As a means for transmitting electrical energy to a distance through the natural media a grounded resonant circuit, comprising a part upon which oscillations are impressed and another for raising the ten-

sion, having its outer conducting boundaries on which a high tension charge accumulates arranged in surfaces of large radii of curvature, substantially as described.

5. The means for producing excessive electric potentials consisting of a primary exciting circuit and a resonant secondary having its outer conducting elements which are subject to high tension arranged in proximity to each other and in surfaces of large radii of curvature so as to prevent leakage of the charge and attendant lowering of potential, substantially as described.

6. A circuit comprising a part upon which oscillations are impressed and another part for raising the tension by resonance, the latter part being supported on places of low electric density and having its outermost conducting boundaries arranged in surfaces of large radii of curvature, as set forth.

7. In apparatus for the transmission of electrical energy without wires a grounded circuit the outer conducting elements of which have a great aggregate area and are arranged in surfaces of large radii of curvature so as to permit the storing of a high charge at a small electric density and prevent loss through leakage, substantially as described.

8. A wireless transmitter comprising in combination a source of oscillations as a condenser, a primary exciting circuit and a secondary grounded and elevated conductor the outer conducting boundaries of which are in proximity to each other and arranged in surfaces of large radii of curvature, substantially as described.

9. In apparatus for the transmission of electrical energy without wires an elevated conductor or antenna having its outer high potential conducting or capacity elements arranged in proximity to each other and in surfaces of large radii of curvature so as to overcome the effect of the small radius of curvature of the individual elements and leakage of the charge, as set forth.

10. A grounded resonant transmitting circuit having its outer conducting boundaries arranged in surfaces of large radii of curvature in combination with an elevated terminal of great surface supported at points of low electric density, substantially as described.

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Witnesses:
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Richard Donovan.

Nov. 12, 1957

L. R. CRUMP

POWERING ELECTRICAL DEVICES WITH ENERGY ABSTRACTED FROM THE ATMOSPHERE

Filed March 12, 1954

2,813,242

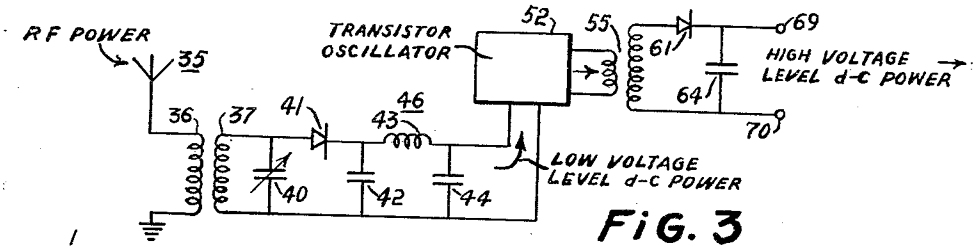

RF POWER
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TRANSISTOR OSCILLATOR
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HIGH VOLTAGE LEVEL d-c POWER
LOW VOLTAGE LEVEL d-c POWER

FiG. 3

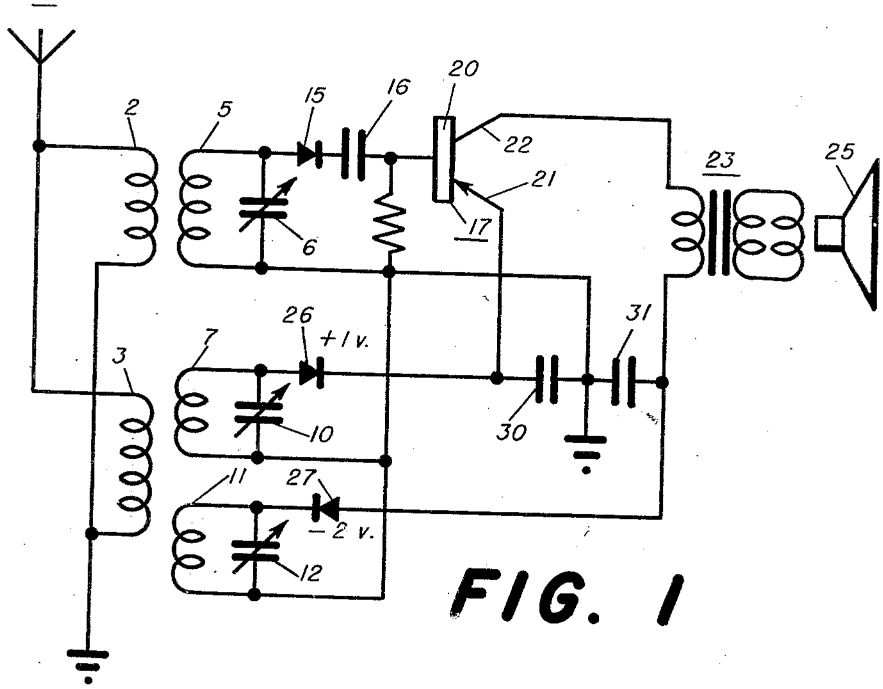

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31

FIG. 1

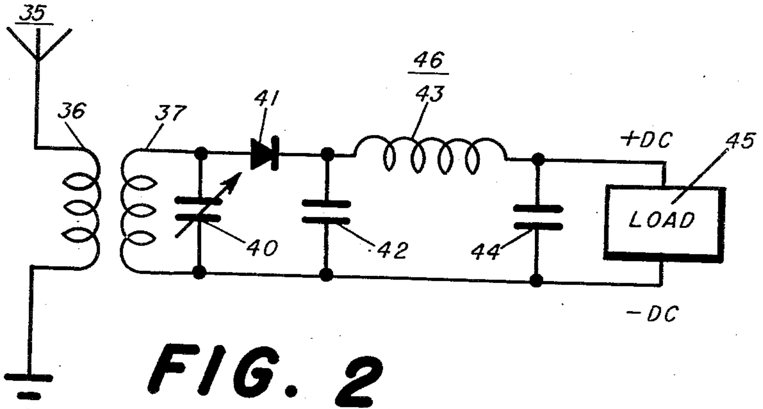

35
36
37
40
41
42
43
46
44
+DC
45
LOAD
-DC

FIG. 2

INVENTOR

Lloyd R. Crump

BY W. E. Thibodeau + A. W. Dew

ATTORNEYS

United States Patent Office

2,813,242

Patented Nov. 12, 1957

2,813,242

POWERING ELECTRICAL DEVICES WITH ENERGY ABSTRACTED FROM THE ATMOSPHERE

Lloyd R. Crump, Silver Spring, Md.

Application March 12, 1954, Serial No. 415,986

1 Claim. (Cl. 321—2)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to the convenient and economical provision of power for the operation of electronic circuits and devices using transistors, and of other electrical devices having modest power requirements.

A great advantage of transistors, and a major reason for their enthusiastic reception since their introduction a few years ago, is the fact that they will operate satisfactorily with very low supply voltages and currents. One milliwatt or even less is sufficient to power a transistor in many applications. Various batteries have been developed to provide, in a minimum of space, the relatively minute amounts of power needed by transistors.

My invention provides methods and means that permit transistor circuits, and also other low-powered electrical devices, to be economically and conveniently operated without any batteries whatever, and indeed without any power supply whatever as power supplies are ordinarily conceived.

The invention centers around my discovery that it is practicable to construct operative transistor circuits that are able to abstract from the atmosphere sufficient electromagnetic energy to provide all necessary supply voltages and currents for their own operation. Circuits and devices powered according to my invention will operate indefinitely without any local power source whatever.

I have successfully constructed and demonstrated such circuits. For example, I have constructed a batteryless transistor radio receiver on which I have listened to either nearby or distant broadcast stations as desired, using either headphones or a loudspeaker; this receiver has been powered entirely by electromagnetic energy abstracted from the atmosphere.

From the successful operation of this receiver, and from other experimental work, it becomes clear that, by the methods and means of the invention, a great variety of practical and useful transistor circuits can be powered entirely by energy abstracted from the atmosphere.

Furthermore, as will become apparent below, my invention is applicable to the powering of other electrical devices requiring relatively small amounts of power.

An object of the present invention is to provide methods and means for powering transistor circuits entirely from radiofrequency energy abstracted from the atmosphere.

Another object is to provide methods and means for powering remote radio receivers, low-powered radio transmitters, and other low-powered electrical devices, with energy received by radio from a master station, so that no local power supplies are needed by the devices and so that the powering or non-powering of the remote device is under the control of the master station.

A further object is to provide methods and means for powering transistor circuits and other low-powered electrical devices with radiofrequency energy received from one or more remote radio transmitters.

Other objects, aspects, uses, and advantages of the invention will become apparent from the following description and from the drawing.

Figure 1 is a schematic diagram of a transistor radio receiver in which all necessary power is supplied by energy abstracted from the atmosphere in accordance with the invention.

Figure 2 is a schematic diagram showing a general application of the invention to provide direct-current power to a load.

Figure 3 is a schematic diagram of a system for obtaining a high energy D.-C. source at a high voltage level using energy abstracted from the atmosphere.

Referring to Figure 1, a receiving antenna **1** is connected to antenna coupling coils **2** and **3**, the other ends of which are connected to ground. A parallel resonant circuit consisting of coil **5** and capacitor **6** is coupled to coil **2**. A second parallel resonant circuit consisting of coil **7** and capacitor **10** is coupled to coil **3**. A third parallel resonant circuit consisting of coil **11** and capacitor **12** is also coupled to coil **3**.

Coil **5** and capacitor **6** are tuned to the frequency of a radio transmitter from which it is desired to receive information—for instance, an amplitude-modulated standard broadcast station. The signal received from this transmitter need not be strong. The signal is detected by diode **15** to obtain an audio-frequency information signal. This audio signal is coupled through a capacitor **16** and is amplified by a circuit that includes a transistor **17** having a base **20**, an emitter **21**, and a collector **22**. The amplified audio output of the transistor is coupled through an audio transformer **23** to an electroacoustical transducer, preferably a permanent-magnet dynamic loudspeaker **25** as shown.

The novelty of the invention lies largely in the method and means by which the necessary direct-current power is supplied to the emitter and collector circuits of transistor **17**. This method and means will now be described.

Coil **7** and capacitor **10**, and also coil **11** and capacitor **12**, are tuned to receive radio signals of relatively high strength. It does not matter whether these signals contain information. These power signals are rectified by diodes **26** and **27** to provide direct-current power that is filtered by capacitors **30** and **31**. The D.-C. power thus obtained is utilized to power the transistor **17**.

In the circuit shown, two tuned circuits (coil **7** and capacitor **10**, and coil **11** and capacitor **12**) are tuned to power signals and the D.-C. voltages obtained from each are connected in series. The tuned power circuits may be tuned to the same or different power signals. Under certain circumstances it may be desirable to use more than two tuned power circuits and to tune them to more than two power signals; in this way power can be obtained from several signals and combined. On the other hand, if a strong power signal is available, a single tuned power circuit may suffice to give the needed D.-C. power.

Even weak information signals can be received successfully. A plurality of transistor amplifier stages can be used if desired, or other circuits such as superheterodyne circuits can be used. It is merely necessary that a sufficiently strong power signal or signals be available to provide the small amount of D.-C. needed to power the transistors.

If the information signal happens to be strong, it can be used as the power signal; all of the tuned circuits (coil **5** and capacitor **6**, coil **7** and capacitor **10**, coil **11** and capacitor **12**) are tuned to the information signal.

Engineers who have observed my invention in operation have been surprised at the unexpectedly good results obtained, even with readily available power signals of quite moderate strength. For instance, sufficient power for satisfactory operation of a loudspeaker at low volumes is readily obtained from a 5-kilowatt standard broadcast station 5 miles away, using only an indoor antenna to pick up the power signal as well as information signals. In typical operation under these conditions a D.-C. voltage of about 2.5 to 3 volts is obtained between the emitter and the collector, at a current of about 250 microamperes; D.-C. power input to the transistor is thus of the order of 0.5 to 1 milliwatt. So far as I am aware, no one has ever before discovered and demonstrated the practicability of this method of powering a radio receiver.

Because existing broadcast stations within a radius of a number of miles provide adequate power signals, the invention is readily practicable with existing power signals in almost any location in or near any city in the United States.

Although I have described a transistor radio receiver powered by my invention, it will be readily apparent that the invention is applicable to the powering of any transistor circuit using one or a number of transistors, and to the powering of other devices requiring relatively small amounts of power. For instance, sensitive electromechanical, electrochemical, or electrothermal devices can be operated by the method of the invention.

Referring to Figure 2, which shows a more general embodiment of my invention, an antenna **35** picks up radiofrequency energy from the atmosphere. This energy flows through coil **36**, which is coupled to a tuned circuit consisting of coil **37** and capacitor **40**. The radiofrequency voltage across capacitor **40** is rectified by diode **41** and filtered by a low-pass filter **46** consisting of capacitors **42** and **44** and choke coil **43**. The resulting D.-C. voltage is applied to a load **45**.

In the practice of my invention, larger amounts of power can be obtained for short periods of time by storing received energy in a suitable energy storage device. Stored energy may then be withdrawn at intervals at a more rapid rate than that at which it was received and put into the storage device. In this way the invention can be used to provide short pulses of relatively very high electrical energy. This result can be readily obtained by charging a relatively large capacitor with direct current and then discharging the capacitor rapidly into a load when desired. This rapid discharge can be initiated automatically when the voltage across the capacitor reaches a certain level, or it can be initiated when a transistor radio receiver receives a certain information signal.

Higher voltages can be obtained with the invention by means of well known devices for raising D.-C. voltages as shown in Figure 3. The D.-C. voltage output from the capacitor **44** can be used to power a low frequency transistor oscillator **52** whose A.-C. output is raised to a higher voltage level by the transformer **55**. This relatively high A.-C. voltage can then be rectified by a diode **61** and fed to a capacitor **64** to provide a high energy D.-C. source at a relatively high voltage level at the terminals **69** and **70**. If desired, energy can now be withdrawn from the capacitor **64** at intervals in short pulses of high energy at a high voltage level. Pulsed radio transmission is one of the possible uses for this form of the invention. Other uses would be to provide a single relatively powerful pulse needed to actuate an electrothermal or electromechanical device.

As has been indicated above, in many locations and particularly anywhere in or near most American cities, power signals normally present in the atmosphere are readily available for the easy and convenient practice of the invention. However, the invention also has important applications in systems in which the necessary power signal is generated and transmitted specifically for the operation of the particular system. Such systems can, for example, comprise a master station transmitting all the power that is needed for hundreds or thousands of fixed or mobile transistor receivers or other remote devices over a range of many miles. This eliminates the need for hundreds or thousands, as the case may be, of local power supplies. At the same time, such a system has the advantage that all of the remote devices can be simultaneously activated or deactivated at the will of the master station, simply by starting or stopping the transmission of the power signal. In such systems it will often be advantageous to use power signals of frequencies sufficiently high to permit the use of resonant receiving antennas of small physical dimensions for signal pickup at the remote devices. In addition to the power signal, the master station may transmit an information signal on the same or a different carrier.

Certain types of devices powered entirely by received radio waves are of course well known. The well-known "crystal set" of the early days of radio, which used a diode rectifier to demodulate an amplitude-modulated radiofrequency signal, is an outstanding example of such a device. My invention is readily distinguishable from such prior devices, however. In typical prior devices a modulated radiofrequency signal is applied to a diode to obtain unidirectional half-wave pulses whose amplitudes vary with modulation. These pulses are integrated by means of a capacitor to obtain a unidirectional signal the amplitude of which follows the audiofrequency modulation envelope. If the radiofrequency signal is received with sufficient strength the audio signal may have sufficient power to operate headphones or similar utilization device without power amplification; but the signal is utilized for its information content, rather than to supply non-information-containing power.

My invention, on the other hand, entails the utilization of received radiofrequency energy to supply power to at least one pair of circuit points (across capacitor **31** in Fig. 1, for example), such circuit points requiring power solely for its power content and not for any information or modulation it may contain. In other words, my invention entails the utilization of radiofrequency energy to supply power that would otherwise have to be supplied by batteries, generator, or other local power source.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claim.

I claim:

An electrical device for obtaining a high energy D.-C. source at a high voltage level using energy abstracted from the atmosphere, said device comprising in combination: resonant means for receiving radio waves, first rectifier means for converting said radio waves into first direct current energy, first capacitor means for storing said first direct current energy, an oscillator powered by said direct current energy, said oscillator producing an A.-C. output, transformer means for raising said A.-C. output to an increased voltage level, second rectifier means for converting the A.-C. output of increased voltage level from said transformer into second direct current energy, and second capacitor means for storing said second direct current energy.

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W. I. PENNOCK.

APPARATUS FOR COLLECTING ATMOSPHERIC ELECTRICITY.

APPLICATION FILED JUNE 26, 1907.

911,260. Patented Feb. 2, 1909.

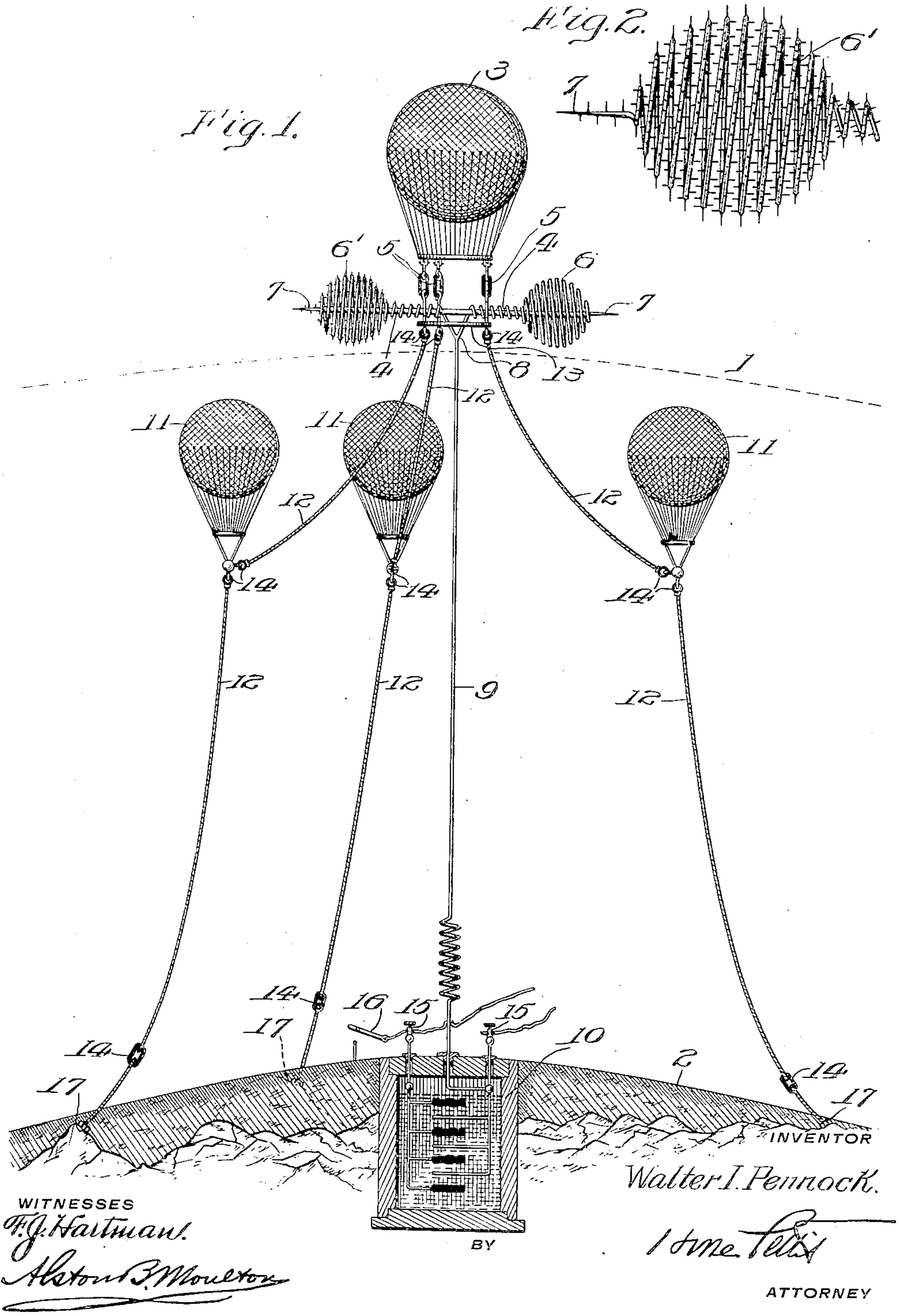
Fig. 2.
7
6'
Fig. 1.
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6'
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5
4
6
7
7
14
14
4
8
13
1
12
11
11
11
12
12
14
14
14
12
12
9
12
14
16
15
15
10
17
17
2
14
17

Fig. 1.

Fig. 2.

WITNESSES

F. J. Hartman.

Alston B. Moulton

INVENTOR

Walter I. Pennock.

BY

Howe Peltz

ATTORNEY

UNITED STATES PATENT OFFICE.

WALTER I. PENNOCK, OF PHILADELPHIA, PENNSYLVANIA.

APPARATUS FOR COLLECTING ATMOSPHERIC ELECTRICITY.

No. 911,260. Specification of Letters Patent. Patented Feb. 2, 1909.

Application filed June 26, 1907. Serial No. 380,907.

To all whom it may concern:

Be it known that I, Walter I. Pennock, a citizen of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in Apparatus for Collecting Atmospheric Electricity, of which the following is a specification.

My invention relates to a method of collecting electricity from a strata laden with electricity at high altitudes in the atmosphere, through the medium of a wire cable suspended from one or more balloons and in conveying this electricity to the earth's surface.

The object of my invention is to provide a conveyance of the electro motive force to be found in the upper strata of the atmosphere to the earth's surface; where it may be utilized for commercial and other purposes.

A further object of my invention is to provide a device or mechanism by which a suitable collector for the electrical energy in the upper strata of the earth's atmosphere may be elevated in the said strata and by which the said electric energy may be transmitted to and collected at the earth's surface, from which point it may be conducted to any place where it is desired to use the same.

A further object of my invention is to support and anchor said device in any desired position.

A further object of my invention is to provide an improved form of collector through which the energy of the said upper strata of the earth's atmosphere may be collected and transmitted for various purposes to the earth's surface.

Other objects of my invention will appear in the specification and claims below.

For a further full, clear and complete disclosure of my invention, reference may be had to the following description and accompanying drawings, in which like reference characters refer to corresponding parts.

Figure 1 is an elevational view of one form or embodiment of my invention and Fig. 2 is a detailed view of one form of my improved collector.

The passage of the electrical current to the earth under ordinary conditions is prevented by an obstruction afforded by the dense lower strata of the atmosphere, which is a bad conductor of electricity, as shown by the electrodes of an ordinary static machine. When the electrodes are placed close together, the atmosphere is seen to carry the current across from one electrode to another, but if placed far apart the current is obstructed by the intervening air. The dense lower strata of the atmosphere affords one of the best non-conductors of electricity, as shown in the conduction of the electric current by telegraph, or trolley wires on the earth's surface, where only a small quantity of the electric current escapes through the atmosphere; while rarefied atmosphere affords a good conducting media, as shown by the vacuum tube. The upper strata of the atmosphere being rare in proportion to the altitude, and being a good conductor of electricity while the lower strata of the atmosphere being dense and affording a non-conducting media for the electric current, thus causes an obstruction to the electric current, or power in its passage to the earth's surface from the electric strata of the atmosphere under ordinary conditions. When, however, the cumulus clouds of a thunder storm pass over the surface of the earth, these clouds being of very great height, the moisture in said clouds forms a better conductor of electricity than does the dry air, with the result that the electricity in the upper strata of the atmosphere breaks through the said cloud as a streak of lightning and in that form reaches even to the earth's surface, while the thin or shallow strata of clouds, observed in the so-called "settled rain" storm, do not extend upward to a sufficient height to form a conducting medium for the electricity from the electric strata to the earth's surface. For this reason there is usually no lightning during the said latter variety of rain storm.

By means of my invention, I have provided a mechanism for collecting the electrical energy or power created by nature and stored in the upper strata of rarefied air of the earth's atmosphere and have provided a conductor for said electric energy to the earth's surface.

Referring now to the drawings 1 indicates what may be called the lower limits or boundaries of the strata of electric energy above the surface 2 of the earth.

3 indicates a balloon which is elevated to a high altitude until it enters the said stra-

tum. The said balloon 3 carries a bar 4 of wood or any other suitable non-conducting material suspended by insulating links 5 or any other suitable form of insulation from the balloon 3. Upon either end of the said bar 4 I mount collectors, one form of which I have illustrated as spheres of coiled wire 6—6′ the outer ends 7 of which terminate in sharp points. The inner turns of the said spheres 6 and 6′ are wrapped around the wooden bar 4 and united as at 8 to a conductor of electric energy, preferably a large copper wire 9. This wire or conductor 9 extends to the earth's surface and may have its end suitably attached to an electric accumulator or other piece of electrical apparatus. I have illustrated one form of my invention in which the conductor 9 is connected to one pole of a storage battery 10 on the earth's surface.

The spiral spheres 6, 6′ are preferably provided with a polished metallic surface to form a good conductor of electricity and the material of said spheres should also be of such a character that it will not rust or corrode or tarnish. A polished copper wire or a copper wire plated with platinum or gold or a solid platinum or gold wire may be used for this purpose, inasmuch as these materials are least affected by moisture and the atmosphere. The said spheres or collectors may be made of smooth wire as shown in the sphere designated by the numeral 6 or of barbed wire, as is shown at 6′ and illustrated on a larger scale in Fig. 2 of the drawings. The latter form is preferable inasmuch as it provides a large number of points through which the electricity may flow to the wire from the surrounding air in the said upper strata of the earth's atmosphere.

In order that the supporting balloon 3 may be held in a relatively fixed position, it should be suitably anchored to the earth's surface. Inasmuch as the balloon 3 must be elevated to a very high position, the weight of the anchoring cables forms an important consideration, and if desired or necessary one or more supplemental balloons 11, 11, 11 may be attached to each of the anchoring cables 12, 12, 12 as illustrated in Fig. 1, to relieve the balloon 3 of such weight as would prevent it from ascending into the said electrical strata. In order that the electricity from the said upper strata of the earth's atmosphere may not be conducted down the anchoring cables 12, 12, 12, I attach them to the supporting balloon 3 and to the supplemental balloons 11 and to the earth's surface through suitable insulating devices 14.

In the form of my invention illustrated in Fig. 1, below the bar 4, I suspend a ring 13 of any suitable material from the balloon 3, and attach the anchoring cables 12 thereto by means of insulating rings 14, 14, 14. I may also provide additional insulating rings 14 between that portion of the anchoring cables 12 between the balloon 3 and the supplemental balloons 11, and also between that part of the cable 12 between the supplemental balloons 12 and the earth's surface. I may also provide, near the earth's surface and at the lower end of the anchoring cables 12, similar insulating links 14. While I have described links as forming a convenient form of insulating device for the purposes above set forth, I do not wish to be construed as being limited to the same, inasmuch as any suitable non-conducting connection may be used in place of the links 14.

The terminals 15, 15 of the storage battery 10 may be connected to any piece of electric apparatus which it is desired to run or operate and if desirable one of the poles of the battery is adapted to be connected by the switch 16 with the earth's surface. The lower ends of the anchoring cables 12 are securely anchored to the earth's surface as at 17.

With the apparatus arranged and connected in the manner illustrated in Fig. 1, the electric energy in the high strata of the earth's atmosphere passes to and through the conductive spiral spheres 6 or 6′ to the conductor 9 and is suitably stored or used at the earth's surface, while the balloons 11 support a part of the weight of the anchoring cables 12, and permit the balloon 3 to ascend as high as is possible, or necessary for it to enter the said electrical strata of the earth's atmosphere. By arranging the anchorage 17 of the cables 12 symmetrically or in any other position than in a straight line, the balloon 3 may be held in a substantially fixed position with relation to the earth.

While I have illustrated in the drawings and have described in the specification a form of apparatus in which my invention may be carried out, it is obvious that the drawings are more or less diagrammatic drawings, that is to say, that the proportions of the various parts are not necessarily those which would operate to the best advantage, inasmuch as certain portions have been shown as greatly enlarged in the drawings for the sake of clearness, and that it is likely that more than one supplemental balloon would be requird for each cable in order to support the weight of the same, and to relieve the supporting balloon 3 of such weight, as would prevent it from ascending into the high electrical strata of the earth's atmosphere, but such changes in form, proportion and arrangement I regard as being fully within the aim and scope of my invention, so long as such forms or modifications fall within the scope of the appended claims. It is also to be understood that the storage battery or accumulator which I have shown as being connected to my collector, is only a type of apparatus which can be operated by the current collected by the spheres 6, 6′ and transmitted to the earth through the wire 9, and when I use the word "accumulator", I mean any piece of useful apparatus which is operated by the current transmitted thereto through the wire or conductor 9.

Having thus described my invention, what I claim and desire to protect by Letters Patent of the United States is:

1. The combination with an electrical collector comprising a bar of non-conducting material, and an open spherical conductor carried by said bar, of means to support said collector in the high electrical strata of the earth's atmosphere.

2. The combination with a balloon, of an electrical collector supported thereby and insulated therefrom, comprising a bar of non-conducting material, and a conductor wound spirally around said bar.

3. The combination with an electrical collector comprising a non-conducting bar, and a conductive wire wound thereon to form an open substantially spherical body, and means to support said collector in the high electrical strata of the earth's atmosphere.

4. The combination with a balloon, of an electrical collector carried thereby and comprising a non-conducting bar, and a polished wire wound spirally thereon to form an open substantially spherical body.

5. The combination with an electrical collector comprising a non-conducting bar, and a wire wound spirally thereon to form an open substantially spherical body, said wire being provided with pointed conducting projections, and means to support said collector in the high electrical strata of the earth's atmosphere.

6. The combination with a balloon, of an electrical collector carried thereby comprising a non-conducting bar, and a conducting wire wound spirally thereon to form open substantially spherical bodies upon the opposite ends thereof.

7. The combination with a balloon, of an electrical collector carried thereby comprising a non-conducting bar, a conducting wire wound spirally thereon to form open substantially spherical bodies upon the opposite ends thereof, an electrical accumulator, and an electrical connection between the said collector and said accumulator.

8. The combination with a balloon, and means to anchor said balloon, of an electrical collector supported by said balloon and insulated therefrom, an electrical accumulator, and a conductor connecting said collector and said accumulator.

9. The combination of an electrical collector, means to support said collector at a high elevation from the earth's surface and within the electrical strata of the earth's atmosphere, an electrical accumulator at the earth's surface, an electrical connection between said collector and said accumulator, and means to insulate said supporting means from said collector and from the earth.

In testimony whereof, I have hereunto set my hand this 25th day of June, 1907.

WALTER I. PENNOCK.

Witnesses:
HUGH F. QUINN,
WM. G. GLENN.

No. 685,957. Patented Nov. 5, 1901.

N. TESLA.

APPARATUS FOR THE UTILIZATION OF RADIANT ENERGY.

(Application filed Mar. 21, 1901.)

(No Model.)

Fig.1

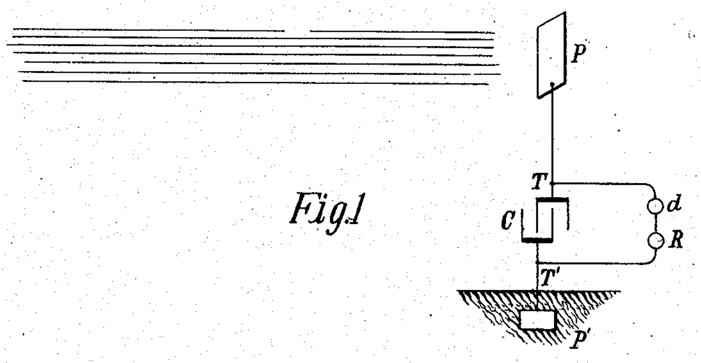

Fig.2

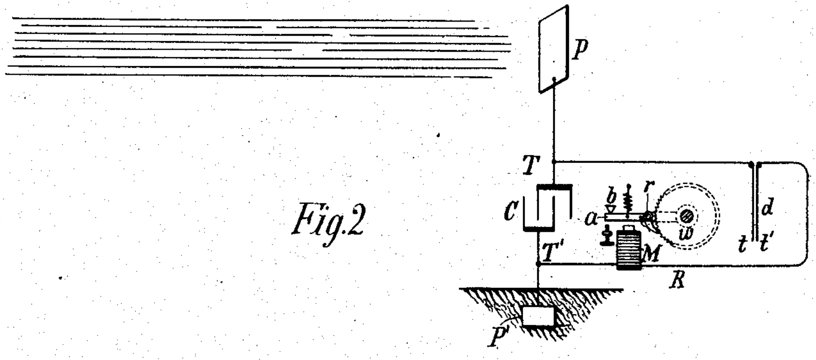
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Fig.3

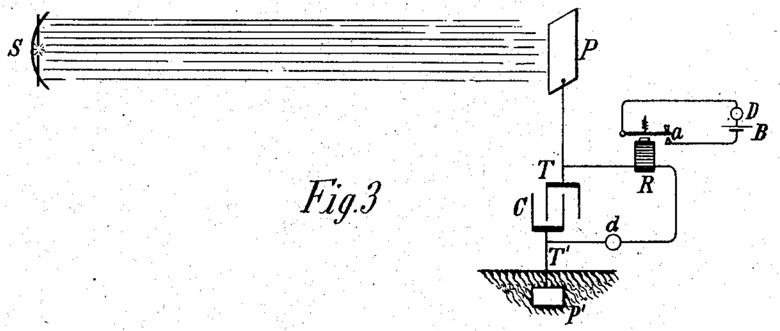
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Fig.4

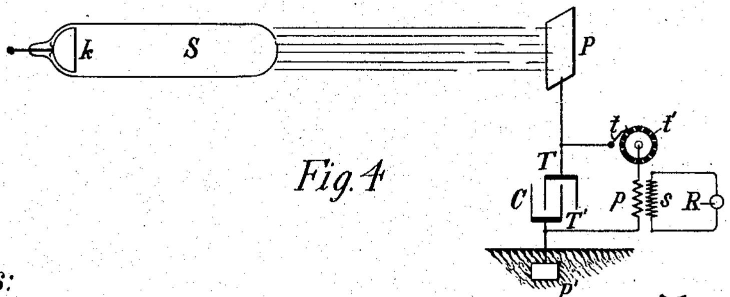
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Witnesses:

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M. Lawson Dyer.

Inventor

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by Kerr, Page & Cooper Attys.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

APPARATUS FOR THE UTILIZATION OF RADIANT ENERGY.

SPECIFICATION forming part of Letters Patent No. 685,957, dated November 5, 1901.

Application filed March 21, 1901. Serial No. 52,153. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Apparatus for the Utilization of Radiant Energy, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

It is well known that certain radiations—such as those of ultra-violet light, cathodic, Roentgen rays, or the like—possess the property of charging and discharging conductors of electricity, the discharge being particularly noticeable when the conductor upon which the rays impinge is negatively electrified. These radiations are generally considered to be ether vibrations of extremely small wave lengths, and in explanation of the phenomena noted it has been assumed by some authorities that they ionize or render conducting the atmosphere through which they are propagated. My own experiments and observations, however, lead me to conclusions more in accord with the theory heretofore advanced by me that sources of such radiant energy throw off with great velocity minute particles of matter which are strongly electrified, and therefore capable of charging an electrical conductor, or, even if not so, may at any rate discharge an electrified conductor either by carrying off bodily its charge or otherwise.

My present application is based upon a discovery which I have made that when rays or radiations of the above kind are permitted to fall upon an insulated conducting-body connected to one of the terminals of a condenser while the other terminal of the same is made by independent means to receive or to carry away electricity a current flows into the condenser so long as the insulated body is exposed to the rays, and under the conditions hereinafter specified an indefinite accumulation of electrical energy in the condenser takes place. This energy after a suitable time interval, during which the rays are allowed to act, may manifest itself in a powerful discharge, which may be utilized for the operation or control of mechanical or electrical devices or rendered useful in many other ways.

In applying my discovery I provide a condenser, preferably of considerable electrostatic capacity, and connect one of its terminals to an insulated metal plate or other conducting-body exposed to the rays or streams of radiant matter. It is very important, particularly in view of the fact that electrical energy is generally supplied at a very slow rate to the condenser, to construct the same with the greatest care. I use, by preference, the best quality of mica as dielectric, taking every possible precaution in insulating the armatures, so that the instrument may withstand great electrical pressures without leaking and may leave no perceptible electrification when discharging instantaneously. In practice I have found that the best results are obtained with condensers treated in the manner described in a patent granted to me February 23, 1897, No. 577,671. Obviously the above precautions should be the more rigorously observed the slower the rate of charging and the smaller the time interval during which the energy is allowed to accumulate in the condenser. The insulated plate or conducting-body should present as large a surface as practicable to the rays or streams of matter, I having ascertained that the amount of energy conveyed to it per unit of time is under otherwise identical conditions proportionate to the area exposed, or nearly so. Furthermore, the surface should be clean and preferably highly polished or amalgamated. The second terminal or armature of the condenser may be connected to one of the poles of a battery or other source of electricity or to any conducting body or object whatever of such properties or so conditioned that by its means electricity of the required sign will be supplied to the terminal. A simple way of supplying positive or negative electricity to the terminal is to connect the same either to an insulated conductor supported at some height in the atmosphere or to a grounded conductor, the former, as is well known, furnishing positive and the latter negative electricity. As the rays or supposed streams of matter generally convey a positive charge to the first condenser-terminal, which is connected to the plate or conductor above mentioned, I usually connect the second terminal of the condenser to the ground, this being the most convenient way of obtaining negative electricity, dispensing with the necessity of providing an artificial source. In order to utilize for any useful purpose the energy accumulated in the condenser, I furthermore connect to the terminals of the same a circuit including an instrument or apparatus which it is desired to operate and another instrument or device for alternately closing and opening the circuit. This latter may be any form of circuit-controller, with fixed or movable parts or electrodes, which may be actuated either by the stored energy or by independent means.

My discovery will be more fully understood from the following description and annexed drawings, to which reference is now made, and in which—

Figure 1 is a diagram showing the general arrangement of apparatus as usually employed. Fig. 2 is a similar diagram illustrating more in detail typical forms of the devices or elements used in practice, and Figs. 3 and 4 are diagrammatical representations of modified arrangements suitable for special purposes.

As illustrative of the manner in which the several parts or elements of the apparatus in one of its simplest forms are to be arranged and connected for useful operation, reference is made to Fig. 1, in which C is the condenser, P the insulated plate or conducting-body which is exposed to the rays, and P′ another plate or conductor which is grounded, all being joined in series, as shown. The terminals T T′ of the condenser are also connected to a circuit which includes a device R to be operated and a circuit-controlling device *d* of the character above referred to.

The apparatus being arranged as shown, it will be found that when the radiations of the sun or of any other source capable of producing the effects before described fall upon the plate P an accumulation of electrical energy in the condenser C will result. This phenomenon, I believe, is best explained as follows: The sun, as well as other sources of radiant energy, throws off minute particles of matter positively electrified, which, impinging upon the plate P, communicate continuously an electrical charge to the same. The opposite terminal of the condenser being connected to the ground, which may be considered as a vast reservoir of negative electricity, a feeble current flows continuously into the condenser, and inasmuch as these supposed particles are of an inconceivably small radius or curvature, and consequently charged to a relatively very high potential, this charging of the condenser may continue, as I have actually observed, almost indefinitely, even to the point of rupturing the dielectric. If the device *d* be of such character that it will operate to close the circuit in which it is included when the potential in the condenser has reached a certain magnitude, the accumulated charge will pass through the circuit, which also includes the receiver R, and operate the latter.

In illustration of a particular form of apparatus which may be used in carrying out my discovery I now refer to Fig. 2. In this figure, which in the general arrangement of the elements is identical to Fig. 1, the device *d* is shown as composed of two very thin conducting-plates *t t′*, placed in close proximity and very mobile, either by reason of extreme flexibility or owing to the character of their support. To improve their action, they should be inclosed in a receptacle, from which the air may be exhausted. The plates *t t′* are connected in series with a working circuit, including a suitable receiver, which in this case is shown as consisting of an electromagnet M, a movable armature *a*, a retractile spring *b*, and a ratchet-wheel *w*, provided with a spring-pawl *r*, which is pivoted to armature *a*, as illustrated. When the radiations of the sun or other radiant source fall upon plate P, a current flows into the condenser, as above explained, until the potential therein rises sufficiently to attract and bring into contact the two plates *t t′*, and thereby close the circuit connected to the two condenser-terminals. This permits a flow of current which energizes the magnet M, causing it to draw down the armature *a* and impart a partial rotation to the ratchet-wheel *w*. As the current ceases the armature is retracted by the spring *b*, without, however, moving the wheel *w*. With the stoppage of the current the plates *t t′* cease to be attracted and separate, thus restoring the circuit to its original condition.

Fig. 3 shows a modified form of apparatus used in connection with an artificial source of radiant energy, which in this instance may be an arc emitting copiously ultra-violet rays. A suitable reflector may be provided for concentrating and directing the radiations. A magnet R and circuit-controller *d* are arranged as in the previous figures; but in the present case the former instead of performing itself the whole work only serves the purpose of alternately opening and closing a local circuit, containing a source of current B and a receiving or translating device D. The controller *d*, if desired, may consist of two fixed electrodes separated by a minute air-gap or weak dielectric film, which breaks down more or less suddenly when a definite difference of potential is reached at the terminals of the condenser and returns to its original state upon the passage of the discharge.

Still another modification is shown in Fig. 4, in which the source S of radiant energy is a special form of Roentgen tube devised by me, having but one terminal k, generally of aluminium, in the form of half a sphere, with a plain polished surface on the front side, from which the streams are thrown off. It may be excited by attaching it to one of the terminals of any generator of sufficiently high electromotive force; but whatever apparatus be used it is important that the tube be exhausted to a high degree, as otherwise it might prove entirely ineffective. The working or discharge circuit connected to the terminals T T′ of the condenser includes in this case the primary p of a transformer and a circuit-controller comprising a fixed terminal or brush t and a movable terminal t' in the shape of a wheel, with conducting and insulating segments, which may be rotated at an arbitrary speed by any suitable means. In inductive relation to the primary wire or coil p is a secondary s, usually of a much greater number of turns, to the ends of which is connected a receiver R. The terminals of the condenser being connected, as indicated, one to an insulated plate P and the other to a grounded plate P′, when the tube S is excited rays or streams of matter are emitted from the same, which convey a positive charge to the plate P and condenser-terminal T, while terminal T′ is continuously receiving negative electricity from the plate P′. This, as before explained, results in an accumulation of electrical energy in the condenser, which goes on as long as the circuit including the primary p is interrupted. Whenever the circuit is closed owing to the rotation of the terminal t', the stored energy is discharged through the primary p, this giving rise in the secondary s to induced currents, which operate the receiver R.

It is clear from what has been stated above that if the terminal T′ is connected to a plate supplying positive instead of negative electricity the rays should convey negative electricity to plate P. The source S may be any form of Roentgen or Lenard tube; but it is obvious from the theory of action that in order to be very effective the electrical impulses exciting it should be wholly or at least preponderatingly of one sign. If ordinary symmetrical alternating currents are employed, provision should be made for allowing the rays to fall upon the plate P only during those periods when they are productive of the desired result. Evidently if the radiations of the source be stopped or intercepted or their intensity varied in any manner, as by periodically interrupting or rythmically varying the current exciting the source, there will be corresponding changes in the action upon the receiver R, and thus signals may be transmitted and many other useful effects produced. Furthermore, it will be understood that any form of circuit-closer which will respond to or be set in operation when a predetermined amount of energy is stored in the condenser may be used in lieu of the device specifically described with reference to Fig. 2 and also that the special details of construction and arrangement of the several parts of the apparatus may be very greatly varied without departure from the invention.

Having described my invention, what I claim is—

1. An apparatus for utilizing radiant energy, comprising in combination a condenser, one armature of which is subjected to the action of rays or radiations, independent means for charging the other armature, a circuit and apparatus therein adapted to be operated or controlled by the discharge of the condenser, as set forth.

2. An apparatus for utilizing radiant energy, comprising in combination, a condenser, one armature of which is subjected to the action of rays or radiations, independent means for charging the other armature, a local circuit connected with the condenser-terminals, a circuit-controller therein and means adapted to be operated or controlled by the discharge of the condenser when the local circuit is closed, as set forth.

3. An apparatus for utilizing radiant energy, comprising in combination, a condenser, one terminal of which is subjected to the action of rays or radiations, independent means for charging the other armature, a local circuit connected with the condenser-terminals, a circuit-controller therein dependent for operation on a given rise of potential in the condenser, and devices operated by the discharge of the condenser when the local circuit is closed, as set forth.

4. An apparatus for utilizing radiant energy, comprising in combination, a condenser, one terminal of which is subjected to the action of rays or radiations, and the other of which is connected with the ground, a circuit and apparatus therein adapted to be operated by the discharge of the accumulated energy in the condenser, as set forth.

5. An apparatus for utilizing radiant energy, comprising in combination, a condenser, one terminal of which is subjected to the action of rays or radiations and the other of which is connected with the ground, a local circuit connected with the condenser-terminals, a circuit-controller therein and means adapted to be operated by the discharge of the condenser when the local circuit is closed, as set forth.

6. An apparatus for utilizing radiant energy, comprising in combination, a condenser, one terminal of which is subjected to the action of rays or radiations and the other of which is connected with the ground, a local circuit connected with the condenser-terminals, a circuit-controller therein adapted to be operated by a given rise of potential in the condenser, and devices operated by the discharge of the condenser when the local circuit is closed, as set forth.

7. An apparatus for utilizing radiant en-

ergy, comprising a condenser, having one terminal connected to earth and the other to an elevated conducting-plate, which is adapted to receive the rays from a distant source of radiant energy, a local circuit connected with the condenser-terminals, a receiver therein, and a circuit-controller therefor which is adapted to be operated by a given rise of potential in the condenser, as set forth.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
RICHARD DONOVAN.

(No Model.)

M. W. DEWEY.

METHOD OF UTILIZING NATURAL ELECTRIC ENERGY.

No. 414,943. Patented Nov. 12, 1889.

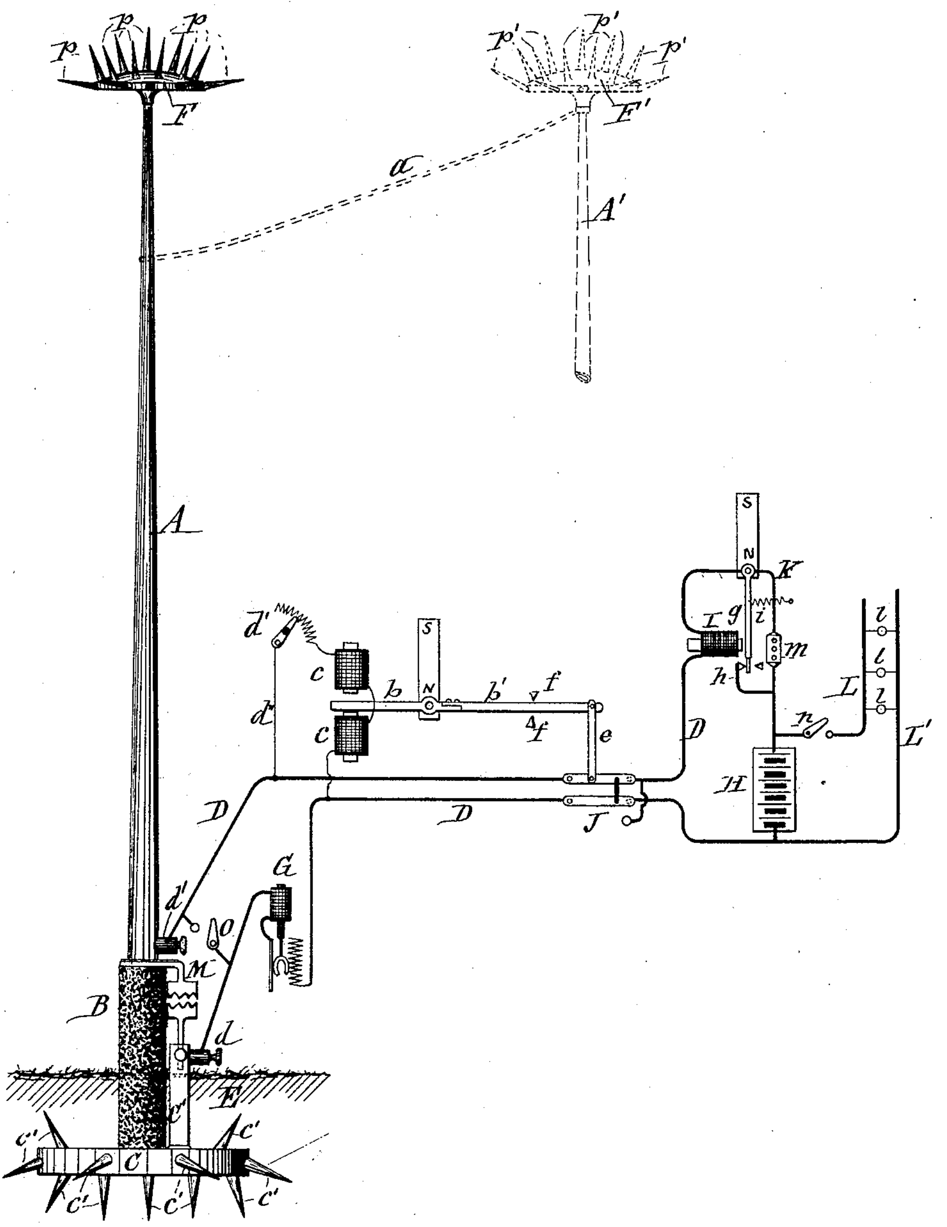
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WITNESSES:

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A. F. Walz.

Mark W. Dewey INVENTOR

BY

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ATTORNEYS

N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

MARK W. DEWEY, OF SYRACUSE, NEW YORK, ASSIGNOR TO THE DEWEY CORPORATION, OF SAME PLACE.

METHOD OF UTILIZING NATURAL ELECTRIC ENERGY.

SPECIFICATION forming part of Letters Patent No. 414,943, dated November 12, 1889.

Application filed May 1, 1889. Serial No. 309,171. (No model.)

To all whom it may concern:

Be it known that I, MARK W. DEWEY, of Syracuse, in the county of Onondaga, in the State of New York, have invented new and useful Improvements in the Method of Utilizing Natural Electric Energy, of which the following, taken in connection with the accompanying drawings, is a full, clear, and exact description.

The object of this invention is to provide a method whereby natural electrical energy—such as the so-called "atmospheric electrical energy," or electrical energy that may be derived from the difference of potential existing between two points, one being the earth and the other the atmosphere at an elevation above the earth—may be collected or utilized for the various uses to which electricity is applied.

It has been found that the presence of electricity in the upper regions of the atmosphere is not confined to thunder-clouds, but can be detected at all times and often in great quantities in different conditions of the atmosphere. In fine weather this electricity is mostly positive; but in showery or stormy weather negative electricity is as frequently met with as positive, and it is in such weather that the indications of electricity, whether positive or negative, are usually the strongest. It has also been found that as we proceed farther from the earth's surface, whether upward from a level plane thereof or horizontally from an elevation, the potential of points in the air becomes more and more different from that of the earth, the difference being, in a broad sense, simply proportional to the distance; hence we can infer that there is electricity residing on the surface of the earth, the density of which at any moment in the locality of observation is measured by the difference of potential found to exist between the earth and a given point in the air near it. The results of observations show that the variations of the electricity residing in the atmosphere is the main cause of the variations of the electricity on the surface of the earth. A charged cloud or body of air induces electricity of the opposite kind to its own on the parts of the earth's surface over which it passes and produces such variations. The difference of potential in increasing the distance from the earth is due to electricity induced on the surface of the earth by opposite electricity in the air overhead, and the air being a non-conductor the electricities are unable to combine. As electrical density is greater on projecting parts of a surface than on those which are plane or concave, stronger indications are obtained on hills than in valleys, if the collecting apparatus be at the same distance from the ground in both cases. The average difference of potential is greater in the winter than in the summer. Little or no effects can be obtained within inclosures or under trees, as they tend to screen the apparatus.

Inasmuch as electricity travels in preference through the best conductors, it follows that if a path of low resistance is formed (such as the erection of a metal pole) to a sufficient elevation above the earth the electricities in the atmosphere and that on the surface of the earth will tend to combine and travel through the said path in a current or currents, and if this pole terminates in a metal point or a number of such points the earth and clouds exchange their opposite electricities without a disruptive discharge—as the lightning—but in a slow and gradual way through convection. Besides supplying the top of the pole with points, a metal plate to which the said points are fixed attracts the opposite electricity in the atmosphere. In order to obtain a greater and increased effect, a large metal plate is buried at the foot of the pole and electrically connected therewith, and is provided with points or branches extending in different directions in the ground. The plate and branches may be surrounded by metallic refuse, coke, or other good conducting substance. The metallic points on the top of the pole should be sharp, and preferably of copper, and may be platinized, gilded, or galvanized to prevent corrosion. It having been ascertained by practical experiments that either a flame or dropping water at an elevation above the surface of the earth produces convection of electricity, it is obvious that such means may be employed in place of the points hereinbefore referred to. As the electricity in the atmosphere is sometimes positive and other times negative, the direction of the currents is not always the same—that is, the atmospheric electrical energy is composed of a current of an alternating character, flowing in one direction on an average about as much of the time as in the opposite direction, but the length of the current in a certain direction, or the lengths of time between reversals or changes in the direction of its flow, is greatly varied. This and also the varied strength of the currents have prevented the utilization of atmospheric electrical energy in commercial quantities for the various purposes for which electricity is generally employed. In order to utilize such a current or currents, they should be transformed into a continuous direct current of uniform strength. The apparatus for accomplishing the transformation of atmospheric electricity into a direct current of uniform strength is susceptible of being greatly modified. The preferred form of apparatus, however, for carrying the invention practically into effect I will now proceed to describe to show that the method is capable of actual performance. Said apparatus is illustrated in the diagram accompanying this specification.

Referring specifically to said diagram, A represents a metallic pole, which is shown bare, but may be enveloped in suitable insulating material, if desirable. B is the base of the aforesaid pole, which base is of insulating material set in the ground E. C is a large metal plate beneath the said base, and has points or branches *c'* extending therefrom in different directions in the ground. C' is a metallic post extending from the said plate above the surface of the ground and having a terminal *d* of the circuit D. On the top of said pole is mounted a metallic cap F, consisting, preferably, of a convex disk provided with sharp iron or copper points *p*, which project in all directions from the same. As before mentioned, the said points may be plated with a suitable metal that forms a good conductor and prevents corrosion. Similar caps F' may be placed on other insulated poles, as A', in the vicinity, and connected with the main pole A by an electric conductor *a*, for increasing the effect. The pole A' may be of wood, and the pole A may also be of the same material if provided with a metal conductor within or on the outside, extending from the cap to the other terminal *d'* of the circuit D. The said circuit D leads from the terminal *d* through an automatic variable resistance G, thence to one of the poles of a secondary or storage battery H, and from the other pole of said battery through an automatic current-regulator to the terminal *d'*. An automatic current-reverser or pole-changer J is located in the said circuit for reversing the current whenever there is a change in its direction, so that it may be rectified or straightened during transit and caused to travel at all times whether its direction is toward or from the earth in one and the same direction through a portion of the circuit containing the secondary battery. The reversals are accomplished automatically by means of a pivoted polarized armature *b*, located between two electro-magnets *c c*, having their coils included in a shunt-circuit between the leads of the circuit D. The magnets are wound so that a north pole will be presented to the armature on one side and a south pole on the other. When the current is flowing in a certain direction, the said polarized armature will be repelled by one magnet and attracted by the other, and thereby moved to one side. When the current changes its direction through the magnets, the poles of the said magnets are reversed and the armature is both repelled and attracted to the other side. An arm *b'*, of diamagnetic material, is fixed to and extends from the armature and is moved by the same. Between a movable end of the arm and the said current-reverser is a pivoted connection or link *e*, by which the motion of the arm is conveyed to the reverser. Stops *f* are provided for limiting the movement of the said arm, and an adjustable resistance *d'* is included in the shunt *d''* to regulate the current through the same.

The current-regulator hereinbefore referred to prevents short-circuiting or the rapid discharge of the secondary battery into the air and ground when the strength of said battery-current becomes greater than that passing to the battery. Said regulator is composed of an electro-magnet I, having its coil in the circuit D. A pivoted polarized armature *g* is connected at its pivot to one terminal of the coil of said magnet, and when the current is flowing to the battery said armature is attracted by the magnet I and held in contact with the stop *h*, to which the terminal of the secondary battery is connected. In the aforesaid condition a free or low-resistance path for the current is provided to the battery; but when the battery-current exceeds the charging-current the magnet-poles are reversed and the armature is repelled by the magnet, and the free path of the circuit is broken between the armature *g* and stop *h*. In order to maintain the armature in the latter position until the charging-current has been increased in strength above that of the battery-current or discharging-current, and so that the said regulator will automatically operate, a shunt path K of high resistance is provided around the armature *g* and stop *h*. The high resistance of the said shunt is obtained by including a rheostat *m*. This shunt path or circuit K, with the resistance, permits a small but sufficient amount of current to flow through the magnet I to hold the armature away from the stop *h* until the current is reversed, and then move the armature back to stop *h* to close the free or low-resistance path. A spring *i* is provided to assist the movement of the armature from the magnet when it is repelled by the same.

The electric current may be directly conducted to translating devices—such as lamps or electromotors; but, as hereinbefore stated, said current is preferably employed to charge one or more cells of the secondary battery H, and this battery stores or accumulates the electrical energy and supplies the said translating devices. To illustrate the latter feature, leads or wires L and L′ are extended from the poles or electrodes of said battery, and translating devices, in the shape of incandescent lamps *l*, are connected with the said wires in multiple arc. In the wire L is a common circuit maker and breaker *n* to close and open the circuit to the lamps. The said battery may be charged in series or parallel.

The automatic variable resistance G maintains the current flowing through the circuit D approximately uniform by increasing the resistance therein upon an increase of strength. Said resistance is not absolutely necessary and may be dispensed with.

The lightning-arrester M is to short-circuit a very heavy current to prevent the same from passing through the other parts of the apparatus and injuring it. A low-resistance shunt O, with a circuit maker and breaker therein, is connected between the leads of the circuit D, near the terminals *d* and *d′*, to completely short-circuit the apparatus when desired.

Having described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. The method of utilizing atmospheric electrical energy, consisting in conducting the electric current or currents between the earth and a point in the atmosphere at an elevation above the earth, rectifying or straightening the currents during transit, and storing or accumulating the electrical energy of said rectified current or currents.

2. As preliminary steps in the method of utilizing atmospheric electrical energy, conducting the electric current or currents through a path of low resistance between the earth and the atmosphere at an elevation above the earth, maintaining an approximately uniform strength of current and rectifying or straightening the same during transit.

3. As preliminary steps in the method of utilizing atmospheric electrical energy, conducting the electric current or currents through a path of low resistance between the earth and the atmosphere at an elevation above the earth, and rectifying or straightening said currents during transit.

4. The method of utilizing atmospheric electrical energy or deriving energy from the difference of electrical potential existing between the earth and a point or points in the atmosphere at an elevation above the earth, consisting in conducting the current or currents between the two points through a path of low resistance, rectifying or straightening the said currents in a portion of the path during transit, and storing or accumulating the electrical energy thereof.

5. The method of utilizing atmospheric electrical energy or deriving energy from the difference of electrical potential existing between the earth and a point or points in the atmosphere at an elevation above the earth, consisting in conducting the current or currents between the two points through a path of low resistance, maintaining an approximately uniform strength of current, rectifying or straightening the said currents in a portion of the path during transit, and storing or accumulating the electrical energy.

6. The method of utilizing atmospheric electrical energy composed of a current of a varied alternating character, consisting in conducting the electric current or currents through a path of low resistance between the earth and the atmosphere at an elevation above the earth, and then accumulating the electrical energy of said current or currents while flowing in both directions in one or more cells of a secondary or storage battery, as described.

In testimony whereof I have hereunto signed my name this 29th day of April, 1889.

MARK W. DEWEY. [L. S.]

Witnesses:
C. H. DUELL,
C. L. BENDIXON.

WILLIAM H. WARD.

Improvement in Collecting Electricity for Telegraphing, &c.

No. 126,356. Patented April 30, 1872.

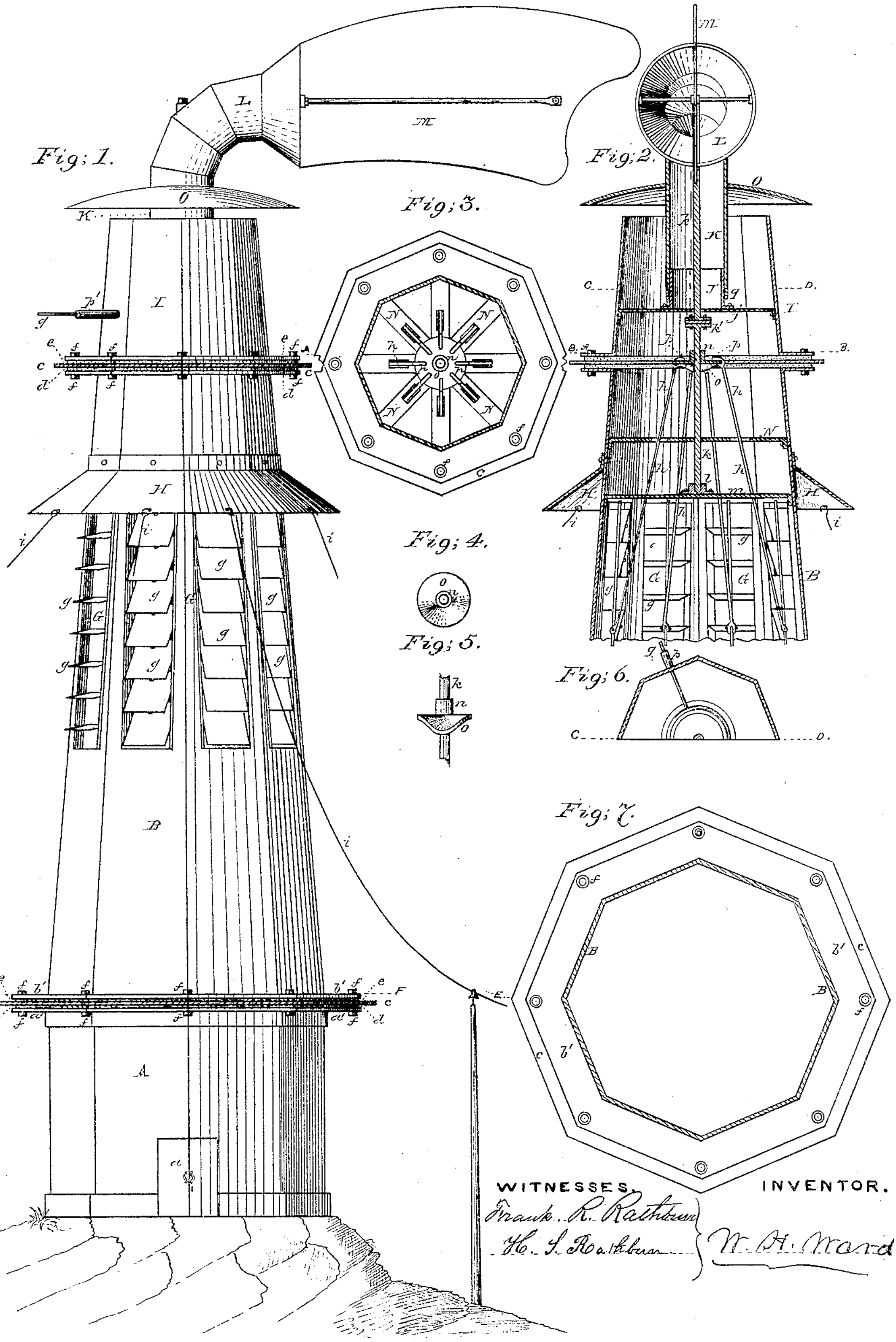
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WITNESSES. **INVENTOR.**

Frank R. Rathbun

H. S. Rathbun

W. H. Ward

AM. PHOTO-LITHOGRAPHIC CO. N. Y. (OSBORNE'S PROCESS.)

126,356

UNITED STATES PATENT OFFICE.

WILLIAM HENRY WARD, OF AUBURN, NEW YORK.

IMPROVEMENT IN COLLECTING ELECTRICITY FOR TELEGRAPHING, &c.

Specification forming part of Letters Patent No. 126,356, dated April 30, 1872.

I, WILLIAM HENRY WARD, of Auburn, in the county of Cayuga and State of New York, have invented an Electrical Tower for Accumulating Natural Electricity for Telegraphic Purposes, of which the following is a specification:

My invention consists of a tower for the purpose of receiving and imparting natural electricity, so as to be in constant contact with that upper stratum of electricity which surrounds the earth, by tapping which a never-failing supply is formed when brought into contact with the earth, as will be more fully explained hereinafter.

In the accompanying drawing, Figure 1 represents a side elevation of my improved electrical tower. Fig. 2 is a vertical central section of the upper part of the same. Figs. 3, 4, 5, 6, and 7 are detached views of several parts of the same.

The tower is constructed in three separate sections, a lower, a middle, and an upper one, and is placed on elevated mountain tops or peaks. The lower one, A, is a mere shell, having a door, *a*, and is constructed of any material suitable for the purpose. It is insulated from the middle portion B by means of a glass diaphragm, *c*, held between similar diaphragms of rubber, *d*, and of gutta-percha, *e*, by means of flanges *a′* and *b′*, formed on the upper end of the lower portion and the lower end of the middle portion of the tower respectively. These flanges are secured to each other by insulated bolts *f*. The middle portion B is provided with suitable openings or windows, G, having shutters or slats *g* pivoted in them, so that, by means of raising or lowering rods *h*, suitably connected to said shutters, the openings G may be shut or opened. A projecting roof, H, is formed on or secured to the middle portion B just over the openings G, and which serves the double purpose of protecting the said openings from the effects of the weather, such as rain or snow, and also for receiving the aerial electricity, which may be drawn from it by wires *i*, for land-line purposes. Above this roof H the middle portion of the tower is again insulated by diaphragms of glass, rubber, and gutta-percha from the upper portion I of the tower in the same manner as it is insulated from its lower portion. A circular plate, *j*, secured on the inside of this upper portion, bears a short tube, J, which is surrounded by the tube K of the ventilator L, from which latter the vane M extends; or the tube J may be held by rods extending from the side of the tower centrally. This ventilator is supported by a rod or shaft, *k*, firmly attached to the tube K, and having its lower bearing in a step, *l*, on a brace, *m*, crossing the middle portion B of the tower just above the openings G. This rod or shaft *k* is formed in two parts, insulated from each other, as shown at *k′*. On the lower portion of this shaft *k* is keyed or otherwise secured a sleeve, *n*, from which a horizontal serpentine cam-plate, *o*, shown in detail in Figs. 4 and 5, extends, over the rim of which the forked ends *p* of rods *h* seize, and which is so arranged relatively to the vane M and the shutters or slats *g* that the revolution of the vane by the wind will open the windward and close the leeward shutters or slats *g* and openings G by means of the rods *h*. Guide-plates or their equivalents N, provided with suitable openings, through which the rods *h* pass, keep the upper forked ends *h* of the latter in constant contact with the cam-plate *o*, which raises or lowers the rods, and consequently opens or closes the openings G as it revolves. A circular roof, O, extends from the tube K of the ventilator so as to cover and protect the open upper end of the tower. The upper portion I of the tower is provided with an insulating-tube, *p′*, through which a copper wire, *q*, enters the portion I of the tower, and is coiled around the tube J just under the tube K, which wire may connect that upper portion of the tower with any land line of wires. The upper portion I of the tower, as well as the tubes J K, may be constructed of zinc, while the vane may be made of zinc, copper, or any equivalent material, which, with the zinc and the moisture of the atmosphere, would form an electrical current. As the vane revolves it opens the openings to windward and closes those to leeward, thus helping to drive an aerial current of electricity into the insulated middle portion of the tower, which current passes upwardly through the upper portion of the tower and out through the ventilator or the top, which is swung around by the wind or aerial electrical current, thus forming a draught in addition to the closing of the shutters or openings to leeward, by means of which draught the electrical current is forced upwardly and out at the vane. The top portion of the tower is of course completely insulated from all below it, including the revolving central ventilator-shaft. As the middle portion of the tower allows the electrical current of atmosphere, wind, &c., to pass within, up, and out at the top it forms a continuous current, whereby the tower is receiving continually fresh and new supplies of electricity, which can be drawn from the projecting roof H by the wires *i* for the use of land lines of telegraphs or for other purposes, such as light, heat, &c. By the use of aerial electricity I entirely dispense with artificial batteries, forming my circuit merely by connecting the aerial current with the earth current. For instance, to bring Buenos Ayres, in South America, into direct connection with New York, the following plan would be pursued: One electrical tower is erected on Pike's Peak or any other suitable high mountain in North America, and another similar tower on some suitable peak of the Andes in South America. The former would, by means of land-lines, be connected directly with Denver, which place is again connected with all the prominent cities of the States. In a similar manner the southern tower is connected by land-lines with the prominent cities via Quito. New York telegraphs to the tower on Pike's Peak, and the operator having connected the land-line with the aerial current, the signals are transmitted through the aerial current to the tower in the Andes in South America; and from there—the land-lines being suitably connected with the aerial current—to Quito and Buenos Ayres. In this manner a message would be sent entirely by natural electricity in place of artificial. In the same manner a message may be sent across the ocean by having a high tower on each continent, each of which towers would have to be, of course, through land-lines connected with the earth to enable the ground current with the aerial current to form a circuit. Different towers may be erected on the different continents, and if they are all what is technically called hooked on—that is to say, connected to the earth—a signal given at one tower will be repeated at all the towers, they being connected with each other by the aerial current. If the earth-connection is severed, or the insulation with the tower destroyed, there is no power; but by insulating the tower and concentrating its force to a point, bringing the same corresponding effect from the earth current in connection, an exceedingly powerful electrical force is created.

Having described my invention, I claim—

1. A tower constructed so as to collect, hold, distribute, and utilize aerial currents of natural electricity for telegraphic and other purposes, essentially as described.

2. A tower for collecting aerial currents of natural electricity, constructed of three sections, insulated from each other and the earth, or their equivalents, substantially in the manner described.

3. In an electrical tower, the combination of the shutters or slats *g* with the ventilator-vane in such a manner that the vane, through suitable mechanism, always opens the shutters to windward and closes them to leeward, substantially as described.

4. In an electrical tower, the collecting, distributing, and protecting roof H, substantially as and for the purpose described.

5. The combination of the tube J and ventilator L with its vane M and the coiled wire or small cable *q*, substantially as and for the purpose set forth.

6. The combination of the insulated shaft *k* and rods *h* having forked upper ends *k′* with the shutters or blinds *g*, serpentine cam-plate *o*, and ventilator L, substantially as and for the purpose described.

The above specification of my improvement, being a tower for accumulating natural electricity for telegraphic purposes, signed this 29th day of June, A. D. 1871.

W. H. WARD.

Witnesses:
A. L. Palmer,
J. H. Starin.

FIP8102 XR 3,273,066

X5264R

Sept. 13, 1966 L. H. RUHNKE 3,273,066

APPARATUS FOR DETECTING CHANGES IN THE ATMOSPHERIC ELECTRIC FIELD

Filed Dec. 20, 1963 2 Sheets-Sheet 1

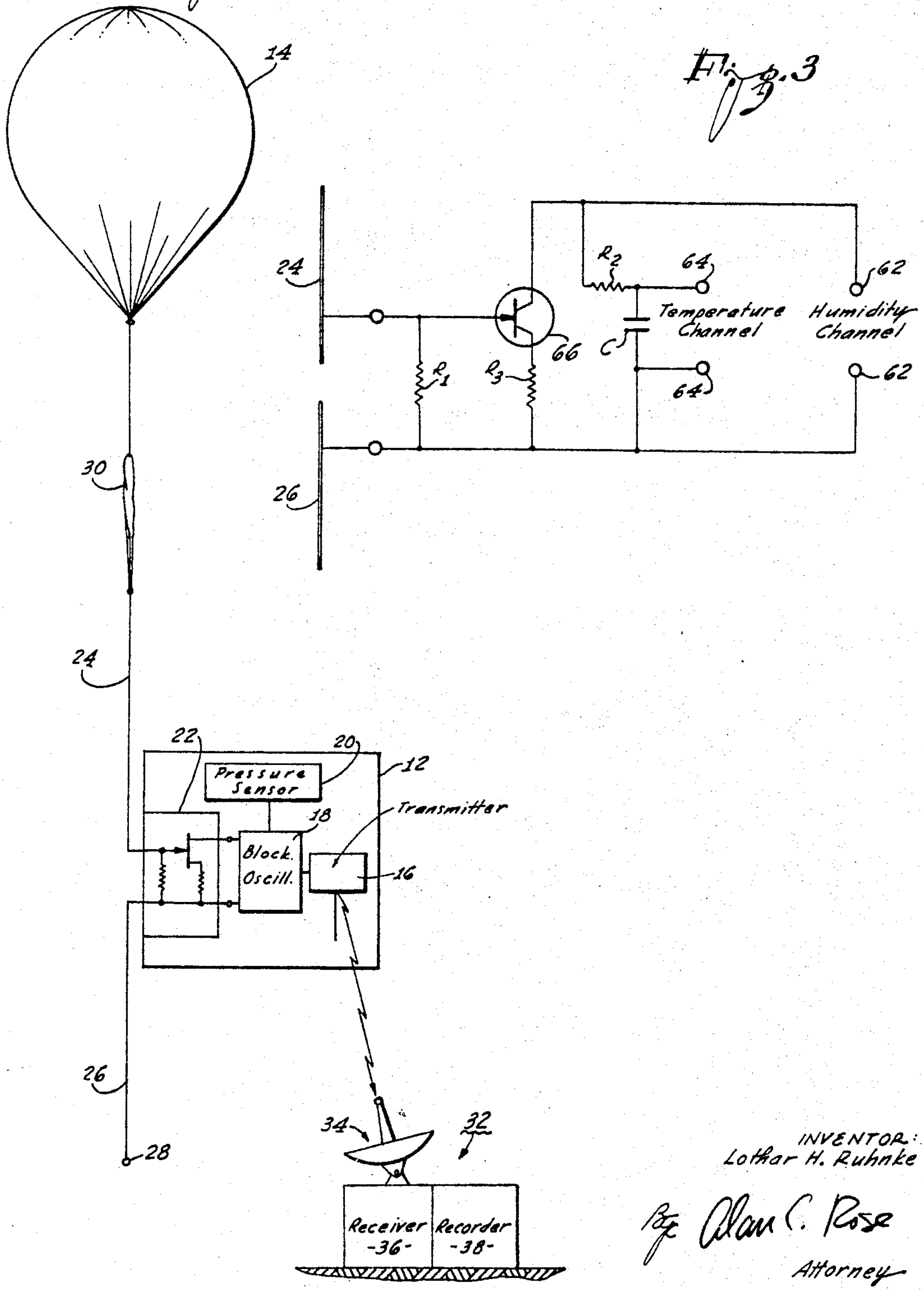
Fig. 1

Fig. 3

14
30
24
26
28
22
20
12
Pressure Sensor
18
Block. Oscill.
Transmitter
16
34
32
Receiver -36-
Recorder -38-
24
26
R1
R2
R3
C
66
64
64
62
62
Temperature Channel
Humidity Channel

INVENTOR:
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Attorney

Sept. 13, 1966

L. H. RUHNKE

3,273,066

APPARATUS FOR DETECTING CHANGES IN
THE ATMOSPHERIC ELECTRIC FIELD

Filed Dec. 20, 1963

2 Sheets-Sheet 2

Fig. 2

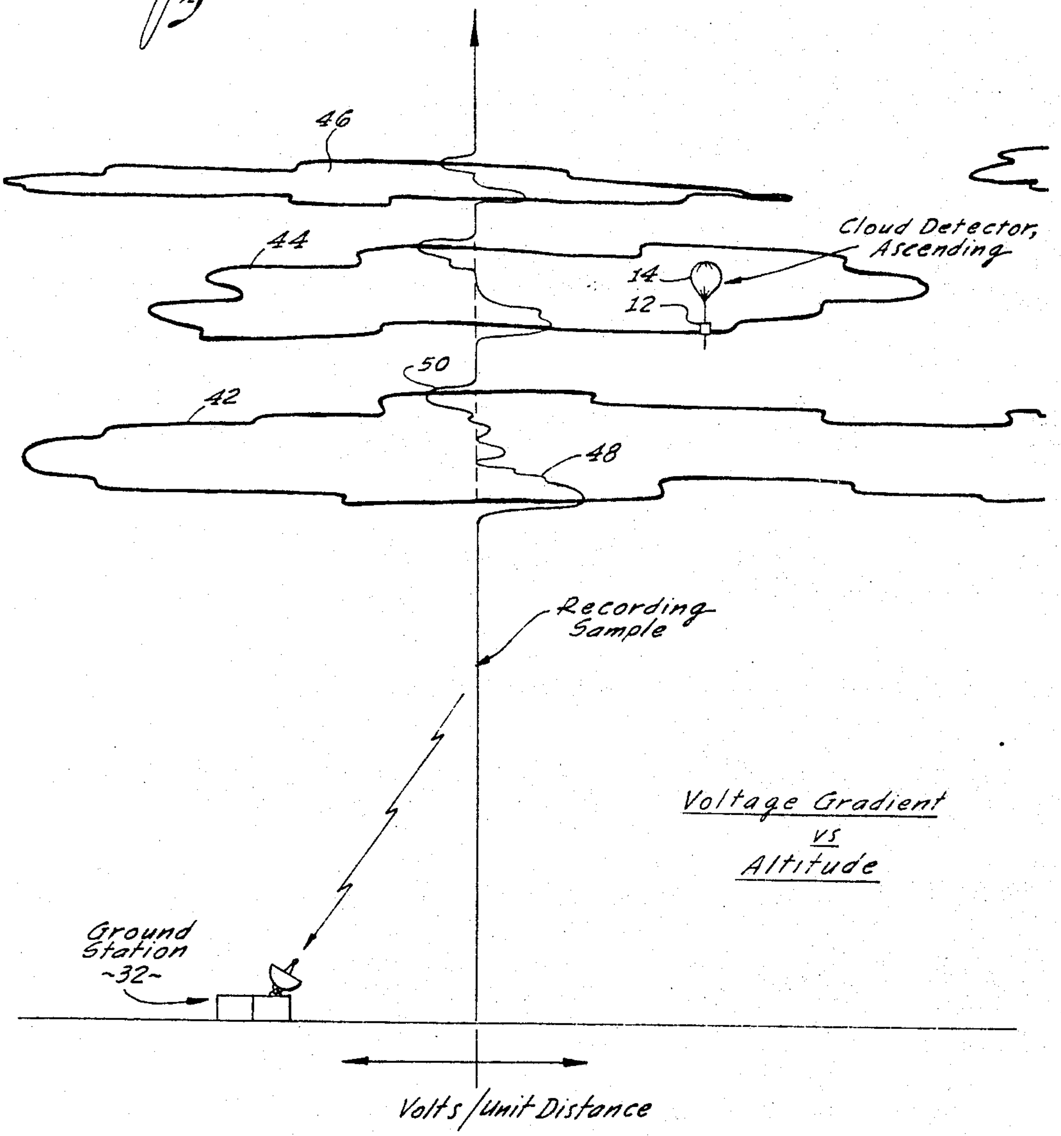
46
44
Cloud Detector,
Ascending
14
12
50
42
48
Recording
Sample
Voltage Gradient
vs
Altitude
Ground
Station
~32~
Volts/Unit Distance

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3,273,066

APPARATUS FOR DETECTING CHANGES IN THE ATMOSPHERIC ELECTRIC FIELD

Lothar H. Ruhnke, Minneapolis, Minn., assignor to Litton Systems, Inc., Beverly Hills, Calif.
Filed Dec. 20, 1963, Ser. No. 332,186
4 Claims. (Cl. 325—113)

This invention relates to a cloud detector or an apparatus for sensing electrostatic conditions in the earth's atmosphere.

Cloud detection apparatus which is presently employed is usually of the "ceilometer" type which merely measures the height of the lower surface of the clouds to indicate the ceiling conditions. One object of the present invention is to determine the location of both the top and the bottom of one or more cloud formations of the atmosphere.

While electrostatic sensors of one type or another have been proposed heretofore for use in the atmosphere, they have been so complex and expensive that they have not enjoyed widespread use. In addition, cloud radars have recently been developed, but their usefulness is limited by failures when different zones of the atmosphere contain droplets of different sizes, as discussed more fully below. Accordingly, it is another object of the present invention to simplify and reduce the cost of cloud detectors, while maintaining reliability, compatibility with existing equipment, and adequate sensitivity for all practical purposes.

In accordance with an illustrative embodiment of the present invention, a conventional U.S. Weather Bureau or U.S. Army meteoroligical radiosonde transmitter may be provided with a modulator which is controlled by a field effect transistor. The input to the field effect transistor is a dipole antenna. Each of the arms of the dipole antenna may be five to fifty feet in length, for example, and one of the dipole elements may trail the radiosonde package while the other element may extend forward in the direction of movement of the unit. When a balloon is employed to carry the cloud detector unit aloft, a weight may be attached to one of the antenna elements so it hangs below the instrument package, while the other antenna element can extend along, or even form the flexible connection between the radiosonde unit and the balloon. A receiving unit is provided to pick up the modulated signals from the radiosonde apparatus, demodulate these signals and record them. While it is contemplated that the receiver may normally be situated on the ground and receive signals from a rising radiosonde unit, the radiosonde unit could well be employed by an aircraft to determine conditions below a cloud layer. Under these conditions the receiver would be mounted on the plane and the radiosonde unit could be parachuted to the ground.

In accordance with a feature of the present invention, therefore, a system for detecting electrostatic field conditions in the atmosphere includes a transmitter, arrangements for moving the transmitter through the atmosphere, an antenna extending a substantial distance from the transmitter, and a field effect transistor connected to receive electrostatic input signals from said antenna and to modulate the output of the transmitter in accordance with voltages detected by the antenna.

In accordance with one aspect of the present invention, simplicity of circuitry and stability of operation are achieved by the use of dynamic circuitry which measures the instantaneous difference in potential between two antenna elements. Thus, a high input resistor may be connected between the input antenna elements. With this type of arrangement the instrument package must be continuously moved through the atmosphere in order to give meaningful results. Under these conditions, the recorded output indicates changes in electric fields. A constant electric field, corresponding to a linear change in potential produces no substantial output signal. It has been determined that a balloon velocity of about five meters per second will produce good results with a dipole antenna shunted by a 1,000 megohm resistor and connected to a field effect transistor as discussed in detail in the present specification. With lower velocities, a higher input impedance or greater amplification would be required, with higher velocities, such as rocket propulsion or the like, permitting even lower input impedances and simpler input circuits.

Accordingly, it is a feature of the invention that apparatus is provided for moving a radiosonde unit through the atmosphere at a predetermined rate, that two element input antenna preferably of the dipole type is provided, and that the antenna is connected to the radiosonde by simple dynamic amplification circuitry, which requires continuous movement of the apparatus to give useful output information.

The novel features which are believed to be characteristic of the invention both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in conjunction with the accompanying drawings in which a typical embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention.

In the drawing:

FIG. 1 is a schematic block diagram of a radiosonde equipment for sensing changes in the electric field of the atmosphere, and thus detecting clouds, in accordance with the present invention;

FIG. 2 is a diagrammatic showing of the record obtained under typical cloud conditions; and

FIG. 3 is a circuit diagram indicating a typical arrangement of connections of a dipole antenna, a field effect transistor, and the input terminals of a standard meteorological radiosonde apparatus.

With reference to the drawings, FIG. 1 shows a radiosonde package **12** supported by a balloon **14**. The radiosonde unit includes a transmitter **16**, blocking oscillator **18**, pressure sensor **20**, and a field effect transistor unit **22**. A dipole antenna having an upper element **24** and a lower element **26** is connected to the input of the field effect transistor unit **22**. A small weight **28** is secured to the lower end of the antenna element **26** to hold it in the extended position. Similarly, the upper antenna element **24** extends in the other direction, and it may either form the support for the radiosonde unit **12** or may be closely associated with the supporting cable. A parachute **30** is provided for safe return of the instrument package to ground.

A ground or receiving station **32** may include an antenna **34**, receiver and demodulator **36**, and a recording apparatus **38**.

FIG. 2 shows a typical recording of the electrostatic field obtained as the ballon **14** and instrument package **12** rise through the successive layers of clouds **42**, **44**, and **46**, along the center line of the drawing. It is known that the electrostatic potential in the atmosphere increases from ground potential to plus 300,000 volts at elevations of about 30 miles. It is also known that the atmospheric electric field, which is the gradient of the potential, is substantially increased within clouds. As the package enters the lower edge of a cloud, the sudden increase in electric field causes a pulse of current to flow through resistor R_1 in one direction, and upon leaving the cloud, the sudden reduction in electric field causes an oppositely directed current pulse. This produces the positive swing shown at **48** in FIG. 2 as the unit enters the cloud and the negative peak **50** as the apparatus is rising through the upper surface of the cloud stratus **42**. A similar pattern is observed as the unit goes through the higher cloud formations **44** and **46**. With a knowledge of the speed of ascent of the balloon and instrument package, the location of the upper and lower surfaces of successive cloud layers may be determined by the present apparatus. Accordingly, despite the presence of a relatively low cloud layer which completely obscures other cloud formations, ground personnel may readily determine the meterological conditions relating to clouds above this low ceiling.

Returning to FIG. 1, the radiosonde equipment represented by blocks **16**, **18** and **20** is well known. The meterological radiosonde system which will be taken as typical is designated by the military by the numbers AN/AMT 4B. The Army technical manual which describes this radiosonde system is identified as TM 11–2432A–TO 31M4–2AMT–11, dated June 26, 1958. The radiosonde transmitter operates at a frequency of 1680 megacycles per second. This transmitter is modulated by a blocking oscillator **18**, the frequency of the blocking oscillator being controlled by the meteorological conditions which are detected. Normally, a thermistor for measuring the temperature and a humidity sensor are alternately switched to the input terminals of the blocking oscillator **18**. In the present case, the cloud detector circuitry is connected to both of these terminals. The barometric pressure sensor **20** may also be retained in the unit, and it may be connected to control the frequency of the blocking oscillator **18** by a switching action as described below.

With reference to FIG. 3, the humidity channel input terminals **62** and the temperature channel input terminals **64** of the standard radiosonde unit are shown at the right-hand side of the circuit. Atmospheric electric signals received by the dipole antenna elements **24** and **26** are applied to the field effect transistor **66** and are then coupled by a suitable circuit to the input terminals **62** and **64** of the radiosonde. While other field effect transistors may be employed, type C 610 of Crystallonics, Inc., was found to be suitable from a sensitivity and reliability standpoint for the present purposes. The input to the field effect transistor is shunted by a 1,000 megohm resistor R_1 to stabilize the input characteristic. Suitable biasing of the transistor **66** is provided by resistor R_3. Because the impedance of the transistor **66** is substantially lower than that of the temperature and humidity sensors which are normally employed, a 110,000 ohm resistor in the blocking oscillator was removed and a capacitor C was connected in parallel to the input terminals. The capacitor was selected to produce a modulation frequency of approximately 100 cycles per second in the absence of an input signal. Positive and negative voltages will then raise or lower this frequency.

In the radiosonde apparatus, signals from the pressure sensor **20** are normally employed to switch from the temperature channel terminals **64** to the humidity channel terminals **62**. This switch is well known in the art as a baroswitch. The barometric pressure switching action provides an indication of altitude, so it is useful to preserve this information. Accordingly, the resistor R_2 is employed between the transistor **66** and one terminal **64** to reduce the output signal slightly, thus changing the modulation level and preserving the pressure and thus altitude information.

With regard to the length of the dipole elements **24** and **26**, the size of resistor R_1 and the amplification of the field effect transistor, these are fixed by several factors. First, the antenna elements should be large enough to provide a substantial input signal, but should be relatively small as compared with normal cloud thicknesses. Lengths of 5 to 50 feet for each dipole would be of the proper order of magnitude. The resistor R_1 was chosen to reduce the input impedance between dipoles **24** and **26** below the point where fog and dampness and the resultant shunt impedance will introduce instability into the transmitted signals. With these parameters, and a speed of ascent of the order of 5 meters per second, it was determined that a single field effect transistor provided the necessary amplification for operation with the standard radiosonde unit.

As mentioned generally above, cloud radars are subject to failure under certain atmospheric conditions. Thus, the radar return is proportional to the sixth power of the droplet or particle size, while the human eye and optical systems respond to the second power of the droplet size. With the radar return proportional to such a high power of the droplet diameter, if a radar is adjusted to pick up a cloud having large particles, other clouds having small size particles are not detected. The present electrostatic system, however, responds in a manner which is nearly the same as the optical response, and therefore does not fail under atmospheric conditions where different size droplets or particles are present in successive clouds.

It is to be understood that the above described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements within the scope of the invention may be devised by those skilled in the art. Thus, by way of example and not of limitation, a somewhat different shape of antenna could be employed to pick up electrostatic field variations and apply them to the field effect transistor, an inherently stabilized transistor may be used, and the instrument package may be carried by rocket or other suitable propulsion arrangements than the balloon shown in the drawings. Accordingly, it is evident that various changes may be made in the present invention without departing from the spirit of the invention as defined in the present claims.

What is claimed is:

1. An apparatus for sensing electrostatic conditions in the atmosphere comprising:

a radiosonde apparatus including means for modulating the output frequency thereof, said means including an R-C circuit;

a pair of probes positioned in respectively different locations in the atmosphere with respect to said radiosonde;

a field effect transistor having its drain and gate terminals connected across said pair of probes and having its source and drain terminals connected in series with the resistance of said R-C circuit to modulate said radiosonde; and

a stabilizing high resistance connected across the two probes and across said gate and drain terminals of said transistor.

2. In an apparatus for sensing atmospheric electrostatic field conditions;

a balloon;

an instrument package connected to and spaced from said balloon, said instrument package including a transmitter, means including an R-C circuit for modulating said transmitter, and a field effect transistor having source and drain terminals connected in series with the resistance in said R-C circuit to modulate said transmitter;

antenna means including an antenna and resistance means connected across said antenna, said resistance means also being connected across the gate and the drain of said field effect transistor, said antenna extending upward from said package toward said balloon and downwardly from said package for applying signals to said field effect transistor in response to said field conditions to render said modulating means responsive to said field conditions.

3. An apparatus for sensing changes of the atmospheric electric field at cloud boundaries, which comprises:

a blocking oscillator-type modulated radiosonde including fixed resistance means and capacitance means connected in parallel with said fixed resistance means, said capacitance means being effective to discharge through said resistance means to control the modulation of said radiosonde;

dipole antenna means responsive to changes of the atmospheric electric field for producing a signal indicative of said changes;

resistance means connected across said dipole antenna means; and

a field effect transistor having source and drain terminals connected in series with said fixed resistance means and a gate terminal connected to said dipole antenna means for reception of said signal, said field effect transistor being responsive to said signal for varying the rate of discharge of said capacitance means to cause the blocking oscillator to modulate said radiosonde in accordance with the second changes in the atmospheric electric field.

4. An apparatus for sensing changes of the atmospheric electric field at cloud boundaries, which comprises:

radiosonde means including a blocking oscillator having fixed resistance means and capacitance means connected in parallel with said fixed resistance means, said capacitance means being effective to discharge through said resistance means to control the frequency of oscillation of said blocking oscillator;

dipole antenna means responsive to changes of the atmospheric electric field for producing a signal indicative of said changes;

resistance means connected across said dipole antenna; and

a field effect transistor having source and drain terminals connected in series with said fixed resistance means and a gate terminal connected to said dipole antenna means for reception of said signal, said field effect transistor being responsive to said signal for varying the rate of discharge of said capacitance means to control the frequency of oscillation of said blocking oscillator in accordance with the sensed changes in the atmospheric electric field.

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DAVID G. REDINBAUGH, *Primary Examiner.*

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H. C. VION.

Electric Apparatus.

No. 28,793. Patented June 19, 1860.

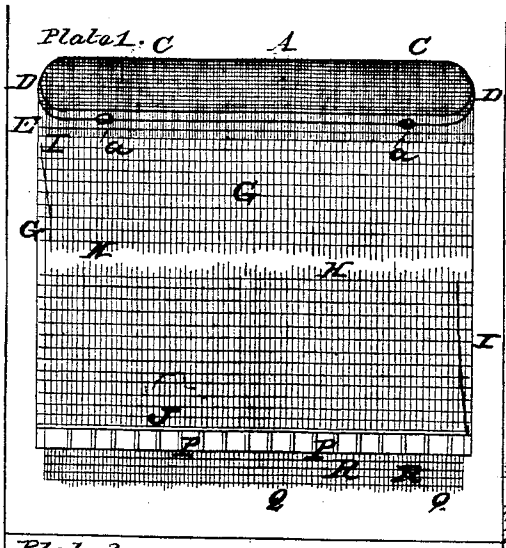

Plate 1.
C
A
C
D
D
E
L
a
a
G
G
K
K
I
J
P
P
R
R
Q
Q

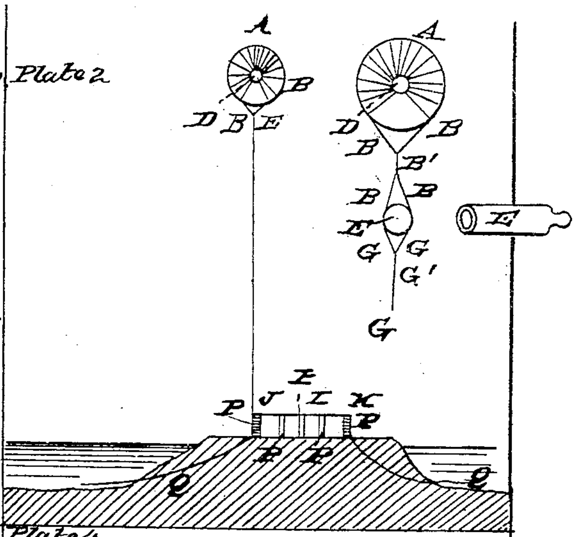

Plate 2.
A
A
B
D
B
E
D
B
B
B'
B
B
E
G
G
G'
G
E
I
J
L
K
P
P
P
P
Q
Q

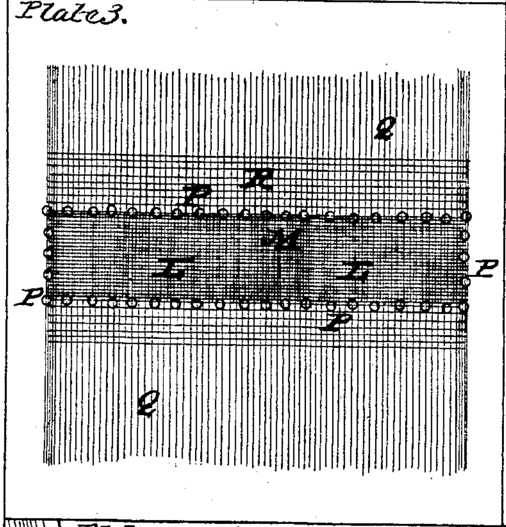

Plate 3.
Q
R
P
M
L
L
P
P
P
Q

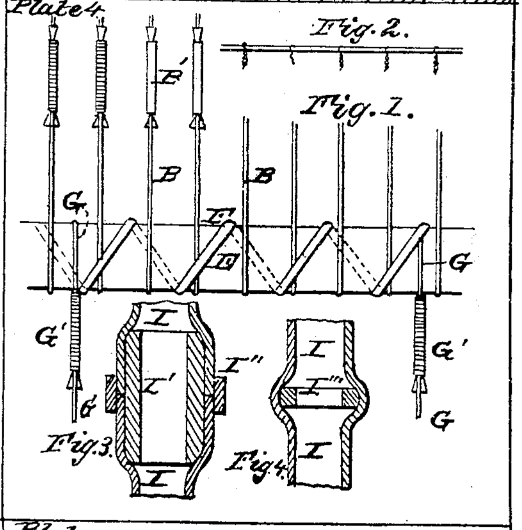

Plate 4.
Fig. 2.
Fig. 1.
E'
B
B
G
E
D
G
G'
G
G'
G
I
I'
I''
I
I'''
I
I
Fig. 3.
Fig. 4.

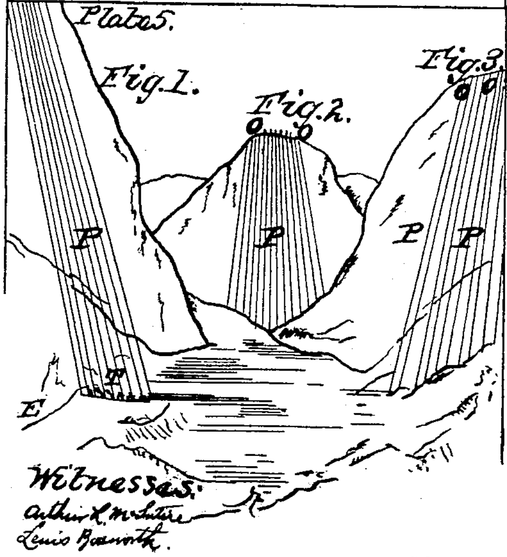

Plate 5.
Fig. 1.
Fig. 2.
Fig. 3.
O
O
O
O
P
P
P
P
P
E

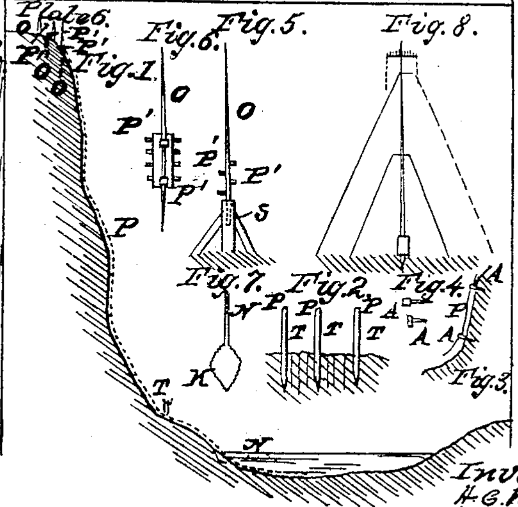

Plate 6.
Fig. 1.
Fig. 6.
Fig. 5.
Fig. 8.
O
O
O
P'
P'
P'
P'
S
P
Fig. 7.
Fig. 2.
Fig. 4.
Fig. 3.
N
P
P
T
T
T
A
A
A
P
T
K
N

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UNITED STATES PATENT OFFICE.

H. CHARLES VION, OF PARIS, FRANCE.

IMPROVED METHOD OF UTILIZING ATMOSPHERIC ELECTRICITY.

Specification forming part of Letters Patent No. **28,793**, dated June 19, 1860.

To all whom it may concern:

Be it known that I, HIPPOLYTE CHARLES VION, of Paris, in the Empire of France, engineer, have invented a new Mode of Obtaining Atmospheric Electricity and Terrestrial Electricity and its Industrial Applications; and I do hereby declare that the following is a full, clear, and exact description of the same, reference being had to the accompanying drawings, making part of this specification, in which—

Plate 1 represents a front elevation; Plate 2, a side elevation of an aerostat, in combination with certain other devices for obtaining atmospheric and terrestrial electricity; Plate 3, a plan of the device for obtaining terrestrial electricity; Plate 4, detached portions of the apparatus. Plate 5 shows a front view, and Plate 6 a vertical section and various details of the apparatus when applied in mountainous regions, the use of an aerostat being dispensed with.

The object of my invention is to form an electric pile of great power by using the positive electricity contained in the atmosphere, and the negative electricity contained in the earth, so as to make the electricity therein contained available for industrial purposes.

To enable others skilled in the art to make and use my invention, I will proceed to describe its construction and operation.

A is aerostat of a tubular form closed at both ends. It is made of suitable material, so as to be impervious to air. Its dimensions are such as to give it great ascensional power when filled with gas.

a a are valves in the surface of the aerostat, to be opened when the inflation of the aerostat should become too great.

A long india-rubber tube, I, communicates with the interior of the aerostat, being attached to the latter, near one end of its ends D, as seen in Plate 1, while the lower end of the tube I is attached to a gasometer, (not shown in the drawings.) The gasometer is to be fed with hydrogen gas, produced by the action of the pile itself, the negative wires of which (afterward to be described) enter a body of water at or near the base of the apparatus and decompose the water so as to produce the hydrogen gas. As the aerostat is supposed to be at a considerable height the tube I must be of corresponding length, and is constructed of a number of tubes, short wooden tubes I' being inserted where the tubes I are joined, and a fastening-ring, I'', being slipped over each of the joints, as seen in Fig. 3 of Plate 4. At certain distances the tube I is fastened to the net-work of the positive wires (afterward to be described) in order to secure the tube against the action of the wind, and at each of these fastening-places a washer, I''', is inserted in the tube in order that the tube shall not be compressed by the wire or other means employed to fasten it to the net-work of positive wires. (See Fig. 4, Plate 4.)

The aerostat is surrounded with a net-work of wires, one layer of the wires, C, being parallel with the axis of the aerostat and fastened to rings D at both ends of the aerostat, and the other layer of wires, B, extending partially around the aerostat at right angles to the wires C. One end of each of the wires B extends around an iron tube, E, some distance below the aerostat and meets the other end of it between the tube E and the aerostat. The two ends are fastened together by a ligature, B'. (See Fig. 1, Plate 4.) Each end of the tube E terminates into a ball, *e*. The wires B are fastened to the surface of the tube E by means of a helical wire, F, wound around the tube and across the wires B, as seen in Fig. 1, Plate 4. The upper ends of long vertical wires G are also wound around cylinder E, each wire G between two of the wires B, and the ends secured by a ligature, G', as seen in Fig. 1, Plate 4. The helical wire F is also wound across the wires G, so as to keep them in their places on tube E.

The vertical wires G, which are to be the conductors of the positive electricity of the atmosphere, must be of a length proportionate to the desired efficacy of the electric pile, and the size and ascensional power of the aerostat must, of course, be adequate to sustain the weight of and keep suspended the wires G, (a weight still further increased by the horizontal cross-wires H, with which the vertical wires G are interlaced, in order to form a net-work not liable to be deranged by the action of the winds or similar influences.) The two outside wires, G, are stronger than the rest of them, and their lower ends are fastened to dynamometers of any suitable construction. These dynamometers are attached to the ends or a massive iron cylinder, J, and they serve to indicate the tension in the outside wires, G, and the corresponding ascensional power of the aerostat. According to the reading of these dynamometers the aerostat has to be supplied (through tube I) with more or less gas. The lower end of each of the wires G is wound around the cylinder J, and secured by ligatures similar to those above described. The wires G are all insulated (by a coating of gutta-percha or similar substance,) except where they are in contact with tube E and with cylinder J, and a similar insulating coating is laid on cylinder J, after the lower ends of the wires G have been fastened to it.

Another cylinder, K, similar to J, is placed at some distance from and parallel to cylinder J. It is connected with cylinder J by wires L, wound around both cylinders and interlaced with cross-wires M. The wire-work L M and cylinders are insulated (in a manner already described) against outside influences, so that the only electric communication between the two cylinders will be through the wires L. The two cylinders are placed upon insulated columns P. The cylinder K may be used as a substitute for cylinder J, and vice versa, whenever repairs become necessary. Insulated branch wire or wires are attached to the cylinders J K and wires L, so as to conduct the positive electricity obtained from the atmosphere by means of the above-described apparatus to wherever it is desired for industrial purposes. The insulated wires Q (interlaced with cross-wires R) are placed on the ground underneath and parallel to the positive wires L. Both ends of each of the wires Q are sunk into the earth or submerged in water, and fastened to a metallic plate coated with a metal not subject to oxidation. These wires Q are the conductors for the negative electricity of the earth, and a branch wire or wires attached to the wires Q serve to transmit the negative terrestrial electricity to wherever it is wanted for industrial or other purposes.

By uniting to the ends of the positive and the negative branch wire or wires a powerful electric current will be obtained, one pole of which is the atmosphere and the other the earth, and may be applied to any suitable useful purpose.

I will now proceed to describe the modification of the above-described apparatus when to be applied in mountainous countries.

P represents the positive electric copper or other metal wires coated over with an insulating substance. The upper ends of each of the positive wires is soldered to a prompter, O, at P′, Figs. 1, 5, and 6, Plate 6. The lower portion of each of the positive-wires is secured to an insulator, T, Fig. 2, Sheet 6. The positive wires are held above the ground by joints A, Figs. 3 and 4, Sheet 6, projecting from the soil at suitable distances from each other. The wires P are intended to follow the inequalities of the ground on which they are laid.

The prompters O, Figs. 5 and 6, Sheet 6, are iron rods sharpened to a point and silvered or coppered at their upper ends. The lower part of the prompter is fastened into a pole, S, covered with tar, which isolates the prompter and holds it in a firm position. A large metallic plate may be soldered to each prompter, as shown in Fig. 6. The positive wires may be soldered to the rod of each prompter or to the plate which is fastened thereto.

One or more branch lines, E, are soldered up to the positive wires to transmit the positive atmospheric electricity for which the wires P are the conductors to any desirable point.

N are negative iron or other metal conductors coated with an insulating substance. The upper ends of these wires rest on the ground near the positive insulators. The lower ends of these wires are soldered to a metallic plate or plates, V, Fig. 7, Plate 6, coated with a metal not subject to oxidation. The negative wires are sunk into the ground at very great depth or into wells, rivers, or into the sea. The negative electric branch wires are attached to the negative conductors N in the same manner as the positive branch wires are to the positive conductors. The branch wires and the soldering are coated over with an insulating substance. They are intended to carry the negative terrestial electricity to any desired point.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. The peculiar arrangement of means herein specified, whereby I am enabled to use the positive electricity contained in the atmosphere and the negative electricity contained in the earth, and thus form an electric pile of considerable power and make the electricity therein contained available for industrial purposes, as set forth.

2. The combination of an aerostat and vertical wire-work with a tube, I, for admitting gas into the aerostat, in the manner and for the purposes above set forth.

CHARLES VION.

Witnesses:
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A. GUION, JR.

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May 26, 2012 *in* *Activism*, *Preparedness*, *Resistance*, *Science*, *Technology*

by Kellie

The below added text I have been looking into has been an easily made design. Our government goes to no end to stop men and women who help human kind with their awesome God given inventions. I am not afraid to share this as Alex does with his knowledge and research. It is to open the minds of those that are dumbed down by corporate America and the global elite to do as they bid…No…stand up and fight against their system.

Free energy is NOT a hoax as they want you to believe.

If you have any engineer in you or technical expertise – Read…It works !

Jes Ascanius’ Version of Nikola Tesla’s Aerial System

This sort of information may seem confusing and maybe a little too technical for you, so let me tell you about the practical and useful applications used by Jes Ascanius, a Danish developer, to whom thanks is due for sharing his design. Initially, he set up a system to charge his mobile phone battery overnight from an aerial. Then he went on to produce a full-size Tesla Aerial System as described at the start of this chapter. Let’s start with the very simple system and progress from that to the more powerful arrangements.

The initial circuit uses one strand of solid wire which rises vertically to a 700 mm diameter drum where there are some twenty turns. The arrangement is like this:

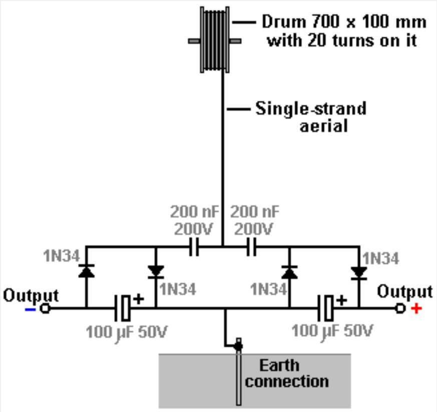

The aerial wire is several metres long, and in the prototype, was supported by (and insulated from) the eaves of a house. The aerial should be vertical or near vertical and a proper earth connection provided by driving a metal rod into the ground or connecting a wire to a metal plate and burying the plate in the ground as a good electrical connection is needed here. The earth connection used here is a 12 mm copper pipe 3 metres long, driven into the ground and the ground around it saturated with water:

The wire used to connect with the earthing rod is very important and should not be less than 8 swg copper wire, that is, 4 mm diameter and 13 sq. mm. cross-sectional area. As with all free-energy devices, the exact constructional details are vital.

The diodes used are germanium 1N34 or 1N34a as germanium diodes drop far less voltage than do silicon diodes and the 1N34 types are low-loss diodes, particularly suited to this application. Ceramic disc types are recommended for the 200 nF capacitors. The prototype build looked like this:

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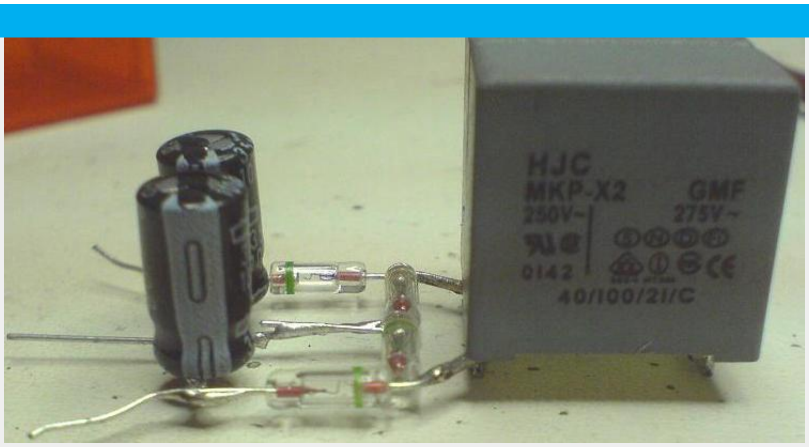

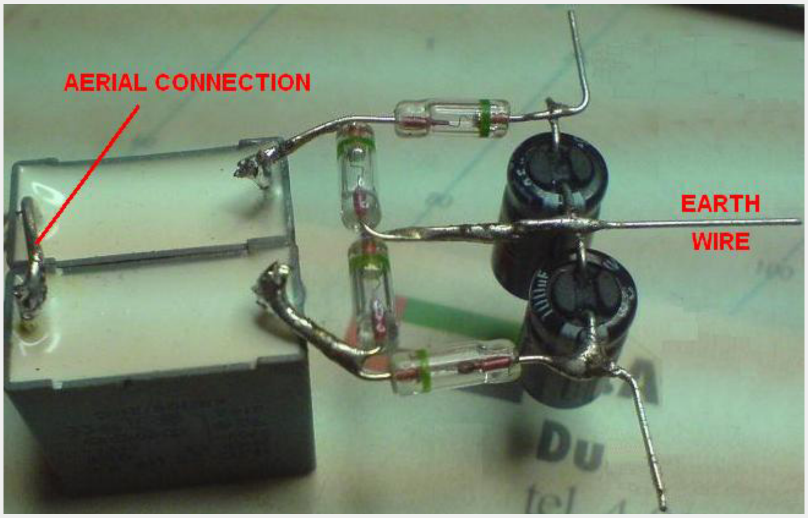

Now, consider this circuit as described, to be one modular building block which can lead to unlimited power from an aerial. I will represent the circuit shown above as a rectangle, showing the above circuit as:

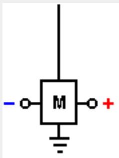

While it is possible to use more than one module with the aerial to get more power, the Danish developer then switched to the full-blown Tesla arrangement by attaching a 800 x 600 x 2 mm aluminium plate inside the sloping roof of his house:

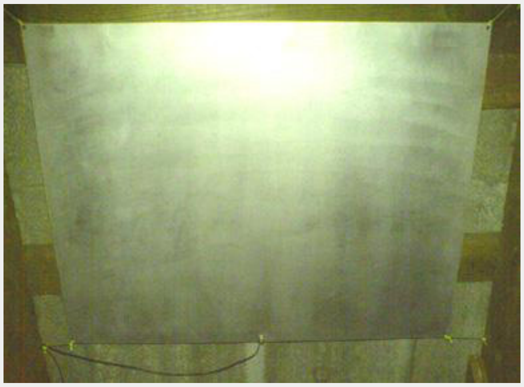

The plate being suspended using nylon cord to prevent it touching the roof or anything else:

The plate is positioned between 3 and 3.5 metres (10 to 12 feet) above the ground and the attachment to the plate is also heavy-duty 8 swg cable:

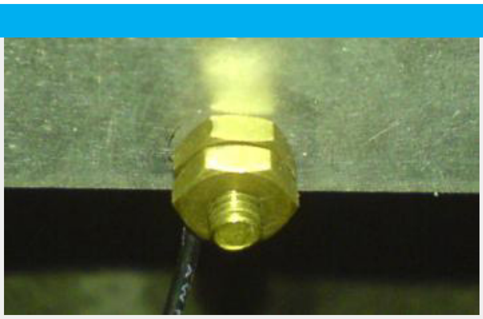

The cable is connected to the aluminium plate using a brass bolt and nuts which the builder thinks may be significant, quite apart from avoiding any galvanitic connection to the circuit. The cable is then run vertically downwards to the circuit. For this arrangement a second earthing point is also used. This is a galvanised iron pipe 3 metres long, driven vertically into the ground which is saturated with water. The second earth is 2 metres away from the first earth.

This arrangement provides serious power, enough to cause injury to, or kill a careless human. With two modules, it will light an LED very brightly, driving it to 2.6 volts. If the LED is removed, then the voltage climbs to about twenty volts and is easily sufficient to charge a 12V battery or battery bank although that takes time. With twenty modules as 12V battery can be charged over night. It is estimated that with two hundred modules, the power would be sufficient to power a household although that has not yet been done. It should be borne in mind that each module is easy and cheap to make, so arranging for a stack of them where additional modules can be added at a later date for more power, is an ideal arrangement. The circuit is like this:

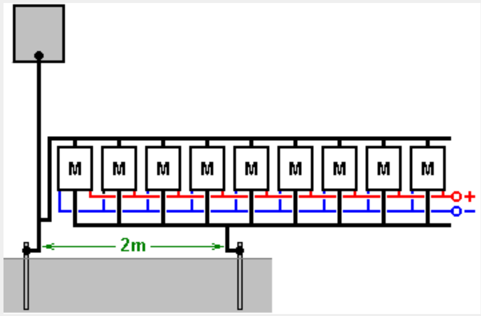

This circuit looks completely mad as the aerial input to the circuit appears to be directly short-circuited by the second earth connection. In spite of this, the circuit works very well when connected this way. Additional modules can be added without any known limit. Increased power can be had by either raising the aluminium plate higher above the ground, to say, 10 metres (33 feet), or by adding one or more additional aerial plates. As you have a good aerial connected through to a very good earth, there has to be the possibility of the equipment being hit by lightning, and so it is suggested that a protective spark-gap is installed between the aerial and the earth, close to the circuit, so that if high-voltage is suddenly applied to the aerial, the spark gap will fire and shunt the excess power through to the earth. Alternatively, possibly a better solution is to install a standard lightning rod system a few metres away from the aerial and a metre or two higher up, so that it forms a more attractive point for a lightning strike.

Further experimentation has shown that altering the connection point for the aerial has a significant effect on the results. If the connection is made at the mid point between the aerial plate and the earth connection, it produces a greater output:

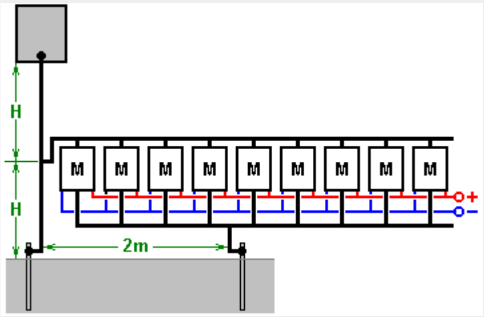

With this arrangement a single module produces around 30 volts while the original method of connecting near the earth was giving about 26 volts with two modules.

Dragan Kljajic has been experimenting with this circuit and has started by building many of these modules on a printed circuit board like this:

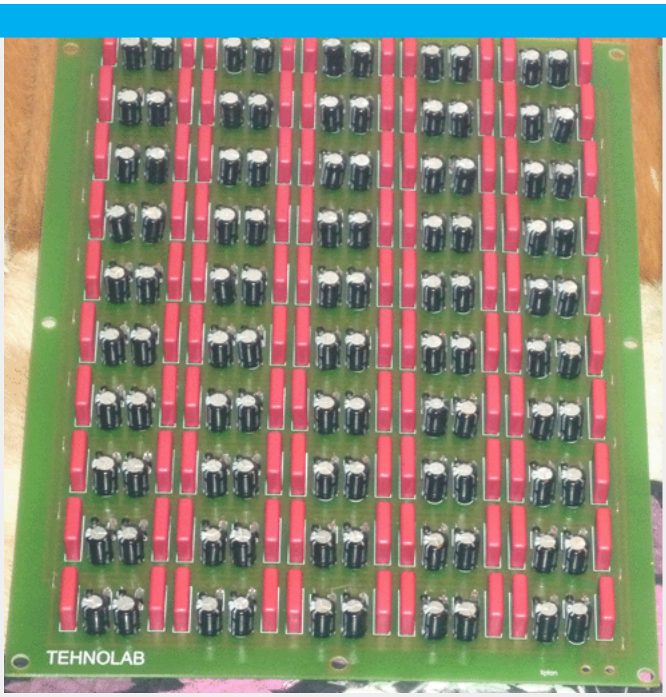

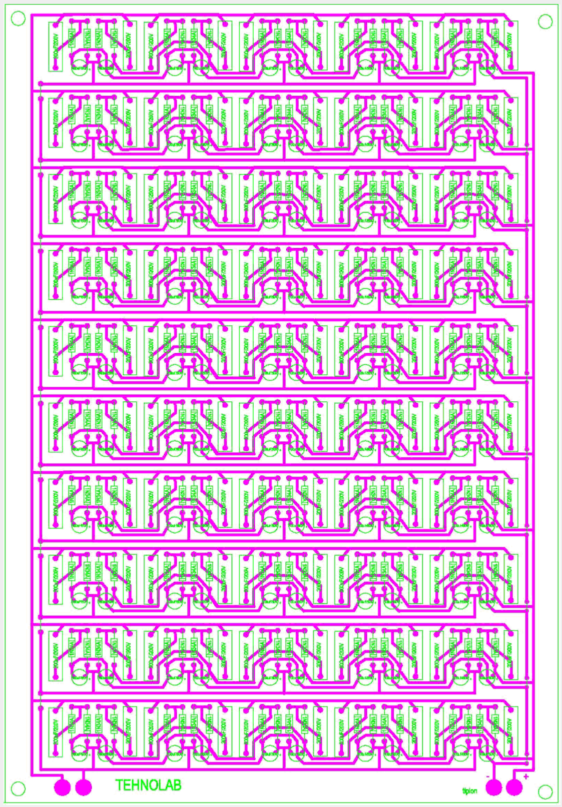

Using two of these boards, Dragan is pulling 96 watts continuously from his aerial plate. He intends to extend this arrangement much further, but is being hindered at present by a local civil war.

There is a forum where some builders of this system share comments. One comment is that there is an increased risk of a lightning strike where you have an earthed aerial, and so it is advisable not to place the aerial plate inside a house, but perhaps suspended between two trees. Also, using a car spark plug connected across the module set can protect against lightning strikes damaging the circuitry.

← Truth is a commodity… Sad →

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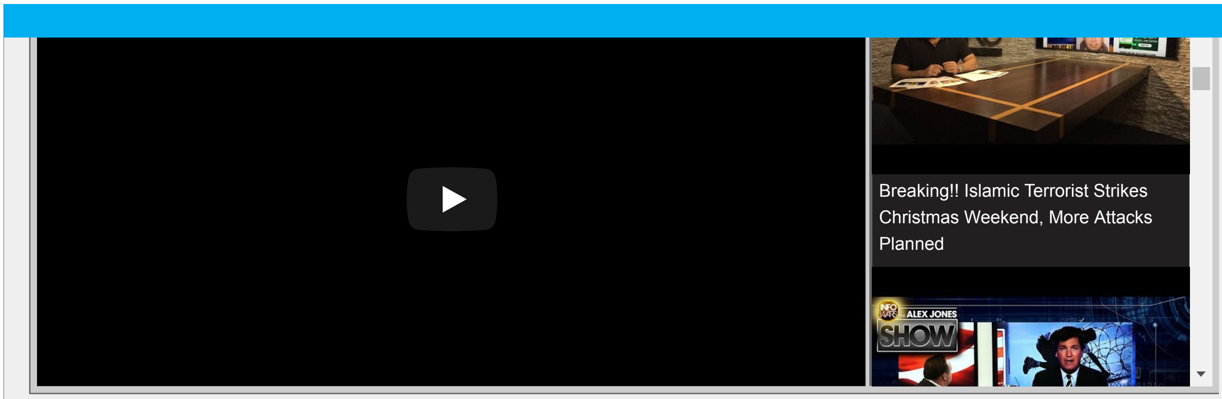

Breaking!! Islamic Terrorist Strikes Christmas Weekend, More Attacks Planned

COMMENT ON THIS ARTICLE:

Comment rules

9 responses to *Don’t let the big energy corporations control you – Free energy is HERE*

Hendra said on April 26, 2016

Hello, I am new to this website and I am trying to build this things right now with the pcb. Has anyone successfully built this things with the PCB that Dragan make ?

THank you

Hendra

Log in to Reply

ifree said on June 1, 2012

cool. I remember reading an article about a farmer who was able to light a bunch of bulbs from a really long cable that somehow just inducted energy… this was after that idiotic show “Mythbusters” said it was impossible.. so, yeah. I don’t recommend that show.

Log in to Reply

Shaun said on June 1, 2012

I have made two of these boards but in A4 size with 32 modules on each board im in the process of drilling holes.
The alexkor circuit in Chap 7 is also worth looking at I will let you know when Im done with the Tesla /Jes Ascanius
circuit and what results I get I know its important to polish the plate and to have a very good earthing plate.

Log in to Reply

United said on May 28, 2012

Great post! thanks

Planet Infowars Log In Visit

Kakashi said on May 28, 2012

Is this transduction?

Log in to Reply

Kellie said on May 28, 2012

The whole article is here http://www.free-energy-info.com/Chapt7.html

Log in to Reply

WizarDave said on May 26, 2012

Gotta love Tesla!

Kellie said on July 6, 2012

Yes, and look how our great government treated him later in life up unto his death, and still to this day…Corrupticians !

Log in to Reply

ZerMaster said on May 26, 2012

Don’t forget about Tesla’s Turbine at 1PSI Steam hooked up to a generator (1PSI! think about it …) cheap to build and use. http://books.google.ro/books?id=BOMDAAAAMBAJ&pg=PA188&dq=popular+mechanics+Tesla&hl=en&sa=X&ei=BeC_T4G1FdDn-gbS-rCcCg&sqi=2&ved=0CCwQ6AEwAA#v=onepage&q=popular%20mechanics%20Tesla&f=false

http://www.youtube.com/watch?v=Oqyh-JyCmQc

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W. I. PENNOCK.

APPARATUS FOR COLLECTING ELECTRICAL ENERGY.

APPLICATION FILED JAN. 4, 1911.

1,014,719. Patented Jan. 16, 1912.

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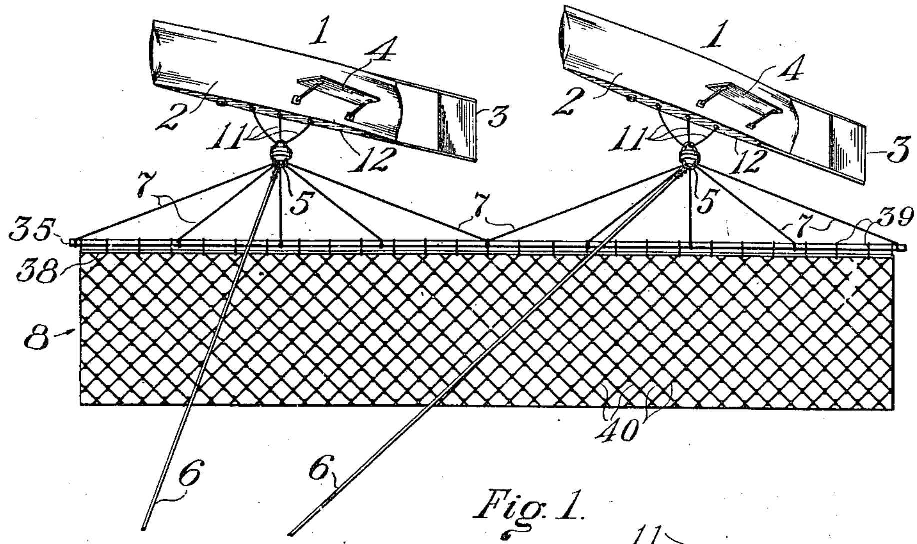
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Fig. 1.

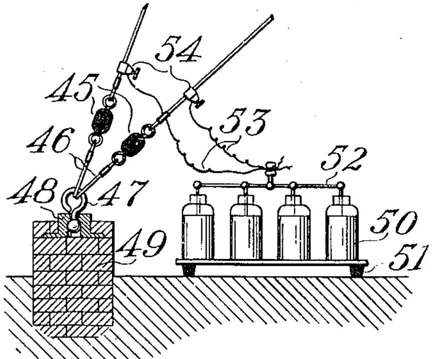
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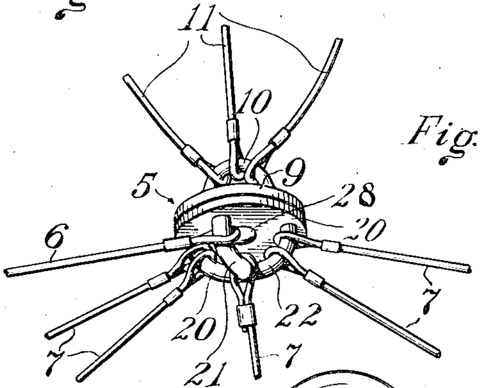
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Fig. 3.

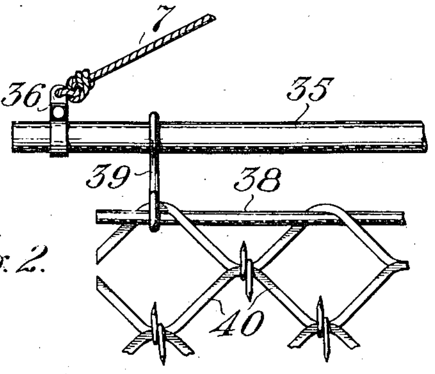
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Fig. 2.

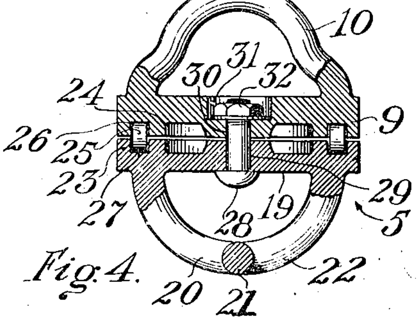
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Fig. 4.

INVENTOR
Walter I. Pennock.

WITNESSES
Elizabeth L. Smith
J. Stuart Freeman.

BY

ATTORNEY

W. I. PENNOCK.

APPARATUS FOR COLLECTING ELECTRICAL ENERGY.

APPLICATION FILED JAN. 4, 1911.

1,014,719. Patented Jan. 16, 1912.

2 SHEETS—SHEET 2.

Fig. 5.

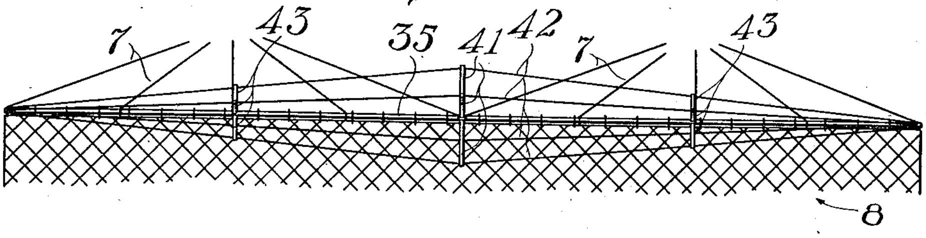
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Fig. 6.

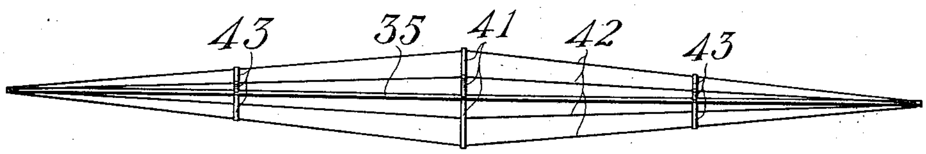
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Fig. 7.

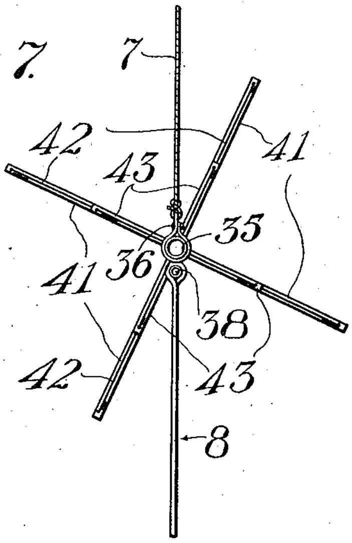
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INVENTOR

Walter I. Pennock.

WITNESSES

Elizabeth L. Smith,

J. Stuart Freeman.

BY

ATTORNEY

UNITED STATES PATENT OFFICE.

WALTER I. PENNOCK, OF PHILADELPHIA, PENNSYLVANIA.

APPARATUS FOR COLLECTING ELECTRICAL ENERGY.

1,014,719. Specification of Letters Patent. **Patented Jan. 16, 1912.**

Application filed January 4, 1911. Serial No. 600,777.

To all whom it may concern:

Be it known that I, Walter I. Pennock, a citizen of the United States, residing at Philadelphia, county of Philadelphia, and State of Pennsylvania, have invented certain new and useful Improvements in Apparatus for Collecting Electrical Energy, of which the following is a full, clear, and exact disclosure.

The present invention relates to an improved means for collecting the charges of electricity from the upper atmosphere and more particularly to that form which consists in one or more captive balloons from which is suspended a suitable form of metallic conductor.

The principal objects of the device are: to provide a collector for atmospheric and static electricity, which when in operative position will present a large surface to currents of air, but which will offer comparatively little resistance thereto, to provide a collector of such material and construction as will be more efficient in its operation than any previously constructed for a similar purpose, to provide a means for maintaining such a collector suspended in the air and at right angles to opposing currents thereof, and to provide a suitable anchorage for holding said means captive.

With these principal objects in view, the present invention consists in further advantages which are brought out in the following specification and accompanying drawings, in both of which like numerals refer to like parts, and in which drawings—

Figure 1 is a perspective view of the complete device in operative position, Fig. 2 is an enlarged detail view of the wire mesh and the manner in which it is attached to the supporting balloons, Fig. 3 is a detail of the manner of securing the collector-supporting and anchor cables to the balloons, Fig. 4 is an enlarged cross section of the swivel connection shown in Fig. 3, Fig. 5 is top plan view of the reinforcing braces on the screen, Fig. 6 is an elevation of the same and Fig. 7 is an end view of the structure shown in Figs. 5 and 6.

Referring to the drawings, in Fig. 1 thereof, a plurality of balloons 1 of any suitable type is shown, each of which embodies hollow metallic elongated gas tanks 2, extending from the rear of which are single, rigidly affixed rudders 3, while on the sides of the tanks are secured stationary lifting planes 4.

To the bottom and slightly to the rear of the center of the tanks 2 is secured a suitable swivel 5, by which the anchor ropes 6 and the suspension ropes 7 for the metallic conductor 8 are secured to the balloons 1. A suitable form of swivel joint is illustrated in Figs. 3 and 4, but any type can be used that embodies the essential features shown therein.

The swivel joint illustrated consists in the base plate 9 having a looped portion 10 integral therewith and projecting from the upper face thereof. Secured to the loop 10 is a set of three light electrically conductive supporting ropes or cables 11 which extend upwardly and are secured at intervals to the bottom 12 of the balloon above.

The lower or revoluble member 19 of the swivel joint preferably comprises three upwardly directed curved arms, 20, 21, and 22, respectively, forming at their junction a T-shape as shown, said arms at their upper extremities being integral with the plate 23. The member 19 is revoluble below and concentric with the plate 9, and the two members are lightened in weight by opposed concentric grooves as shown at 24. Contact between said members is made through the roller bearings 25, which are carried in the opposed concentric grooves 26 and 27 of the respective upper and lower plates. Furthermore, said plates are maintained in coöperative relation with each other by means of a bolt 28 passing through centrally drilled holes 29 and 30 in the respective lower and upper plates, the drilled hole 30 opening upwardly into an enlarged recess 31, in which is sunken the nut 32 on the bolt 28. Two of the arms 20 and 22 of the lower revoluble member 19 extend in diametrical alinement, while from the central point thereof extends the third arm 21 at right angles thereto, and upward to the plate 23.

Suspended below the plurality of balloons is a hollow rod 35, of any suitable material, connected at regular intervals such as at points 36, by metallic ropes 7, to the alined arms 20 and 22 of the swivel joint 5. Below and parallel to the rod 35 is a similar but smaller rod 38 suspended therefrom by means of suitable couplings 39. From the rod 38 hangs a wire mesh 40 of any suitable form, such as can be extended over a considerable area and which will offer comparatively little resistance to the passage of air therethrough. The metal in such a screen is preferably rough, sharp or jagged and a convenient form embodying these characteristics is expanded sheet metal such as is used for lathing and for reinforcing concrete construction. Instead of the single hollow rod 35 alone, applicant contemplates the use of reinforcing means to prevent the buckling of the rod in a stiff wind, such, for instance, as the arrangement of wire bracing shown in Figs. 5, 6 and 7 in which cross rods 41, secured to the rod 35 at the center thereof are attached to the ends thereof by means of stretched wires 42. Between the rods, 41 and the ends of the rod 35 are secured sets of cross rods 43 which support the wires 42 and strengthen the rod 35 at as many points as they may be placed.

For the purpose of maintaining the balloons and apparatus suspended therefrom captive, the light metallic cables 6 terminating downwardly in insulators 45 are employed. These insulators in turn are connected by means of short sections of rope 46 to the eye 47 of a suitable swivel 48, embedded in the anchorage 49.

When the balloons with the metallic screen suspended therefrom are allowed to rise into one of the higher altitudes, the entire apparatus being of metallic construction and uninsulated will become energized by contact with the surrounding natural charges of electricity. From the above description it is evident then that, while the screen 8, on account of its great extent, will be the greatest collecting agent, it will be seen that the balloons themselves and the suspending wires will also coöperate as one large collector, since no parts of which are insulated from any of the neighboring parts thereof. Consequently, when the apparatus described has reached an altitude or strata of the atmosphere abounding in static charges of electricity, an amount of the said charges proportionate to the surface area of the metal exposed will collect upon the apparatus as a whole and will be conducted downwardly toward the earth by means of the various anchor ropes 6, but will not pass into the ground on account of the interposition of the insulators 45.

To use the electrical charges thus acquired, a plurality of Leyden jars 50, or other suitable collectors are supported above the surface of the earth and insulated therefrom by any suitable means as represented by the blocks 51. Either the inner or outer conducting surfaces of the jars may be connected together and energized by the accumulated charge. In the present instance, the inner surfaces of the accumulators are shown to be connected, and the connecting means 52 is in turn connected to the ropes 6 by means of wires 53. These wires are secured to the ropes mentioned by means of suitable binding posts 54.

In the device described the anchor ropes 6 are of substantially the same length, and when the apparatus is raised to the desired altitude and is being blown by the currents of air, the balloons are turned by means of the vanes 3 to parallel relation with each other, and furthermore, from the manner in which the device is held captive and the collecting net 40 is suspended from the balloons, it is obvious that said net will at all times readily swing into a plane substantially perpendicular to any current of air acting upon the balloons above. The purpose of the swivel joint shown in Figs. 3 and 4 is principally for allowing the balloons to readily aline themselves with any new direction of the wind before the apparatus, including the suspended screen, can swing about the swivel 48, and said joint will also prevent the twisting of the ropes 7, when any rapid shifting of the air currents may occur.

While applicant has shown a set of Leyden jars as the accumulators in the accompanying drawings, it is obvious that any other suitable form may be used, and furthermore, that although not illustrated, any suitable apparatus may be run thereby, such as for instance, wireless telegraphic instruments.

Furthermore, although but one embodiment of the invention has been described, it is to be understood that various modifications may be made therein, and in fact several are contemplated by applicant that are of such structure as fall well within the scope of the appended claim.

Having thus described my invention, what I claim and desire to protect by Letters Patent of the United States, is:

A collector for charges of electricity, comprising a plurality of supporting means, a metallic gauze sustained thereby to lie in a plane and substantially equidistant from each of said supporting means, anchoring means emanating from a common point to each of said supporting means, means operative to maintain said supporting means in their normal positions, and means between each of said supporting means and said gauze to permit each of said supporting means to readily and independently aline itself to accord with any alteration in the direction of opposing air currents.

In witness whereof I have hereunto set my hand this 28 day of December, A. D. 1910.

WALTER I. PENNOCK.

Witnesses:
Mildred S. Temple,
E. Eugenia Pennock.

rexresearch.com

Atmospheric & RF Electricity Collectors

GB 157263
Process and Apparatus for Converting Static Atmospheric Electrical Energy into Dynamic Electrical Energy of any Suitable High Periodicity

Abstract -- Atmospheric electricity, utilizing; influence machines.-Static atmospheric charges are converted into alternating-currents of any desired frequency by rotary machines, the stator and rotor elements of which form condensers having a capacity which varies during the revolution as described in Specincation 157,262. In the simplest form, Fig. 2, the curved stator plates 2, 1 are connected to earth E2 and the aerial A which collects the atmospheric charges and is earthed through a safety spark gap F. The rotor is motor-driven and consists of concentric plates 3, 4 joined through slip-,rings (not shown) to an inductance 9 shunted by a condenser 5. With a given aerial polarity, rotation of the plates 3, 4 causes current reversals on the circuit A, 1, 9, 2, E@, whereby oscillations are set upon the circuit 9, 5, these being tapped by leads 11, 12. The condenser 5 may consist of concentric tubes rotating with the rotor or of two juxtaposed wound spirals having capacity. The stator and rotor condenser plates may extend over nearly a semicircle in place of the quadrants shown in Fig. 2 and the rotor may comprise two consecutive cylindrical plates or coil condensers each divided into halves, the inner half of each being connected to the outer half of the other. Fig. 7 shows a form in which rings 1, 2, mounted in a casing comprising upper and lower parts insulated from each other, are connected to the stator condenser plates at intervals. The rotor plates 3, in equal number, are connected to slip-rings 5, 6 from which alternating-current is taken by brushes when the rotor is motor-driven. The rings 1, 2 are respectively connected to the aerial collector and earth E2. Several methods of grouping the stator-rotor condenser pairs and the components of the oscillating circuit are described. The oscillatory current in the rotor circuit may react through a transformer on the main charging current and two pairs of stator and rotor plates 1, 2, 3, 4, Fig. 13, may be employed arranged on diameters at right-angles, the oscillatory circuit in this case consisting of a mutual inductance 5 having capacity and a portion of an adjustable inductance 9 in the stator earth connector E2. By suitably proportioning the stator and rotor plates, 'resonance may be established, whereby undamped waves may be produced. In the form shown in Fig. 15, for high-frequency oscillations, the aerial A and earth wire are tapped at points between the stator plates 1, 2 and condensers 16, 18 which are joined through an inductance 9. The rotor current is conveyed to the power circuit 11, 12 through transformers 10, 10<a>. The members composing the stator and rotor plates may be slotted, as shown in Fig. 8, with holes 1 for attaching them to the frame, or they may have spiral slots in their surfaces. Alternatively, they may be formed by embedding spiral wires 3 in a vulcanite mass 1 so as to give a smooth surface as shown in Fig. 11.

Fig. 1

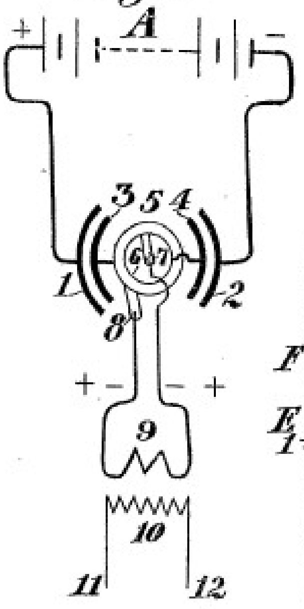
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Fig. 3

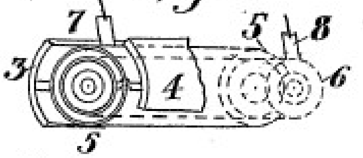

Fig. 2

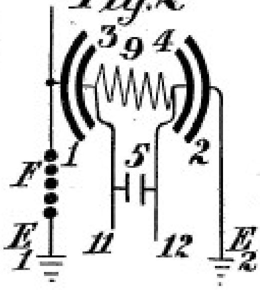
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Fig 4

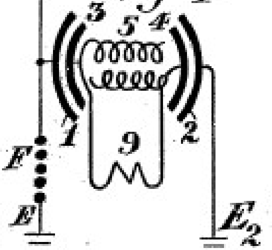
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Fig. 5.

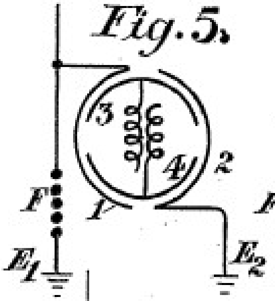

Fig. 6.

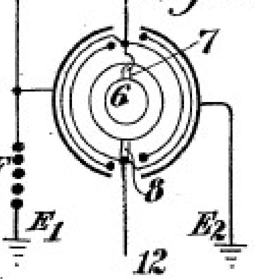
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Fig. 7.

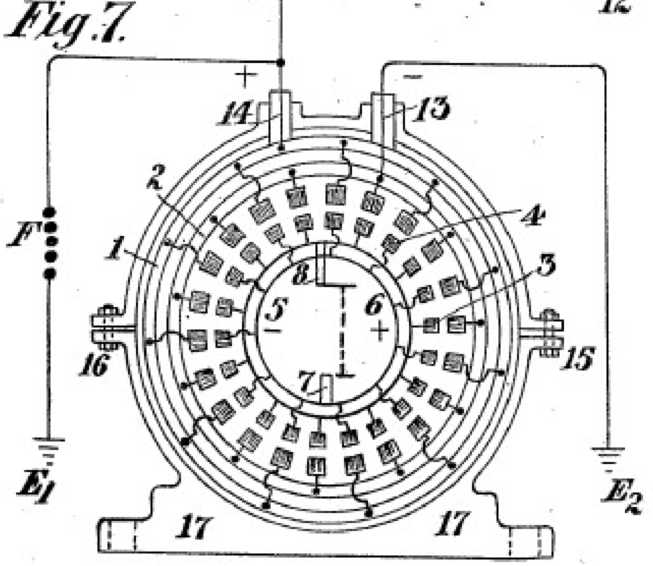
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Fig.8

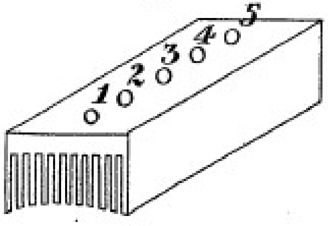

Fig. 10

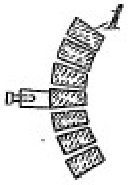

Fig. 9.

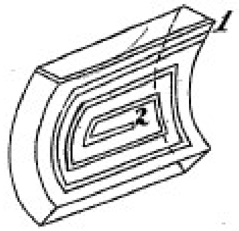

Fig. 11

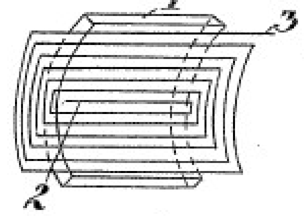

Fig.12

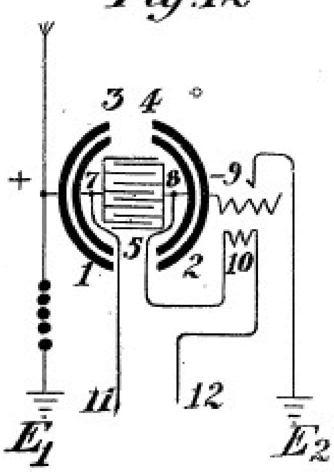
+
3
4
7
8
9
5
1
2
10
11
12
E_1
E_2

Fig. 13.

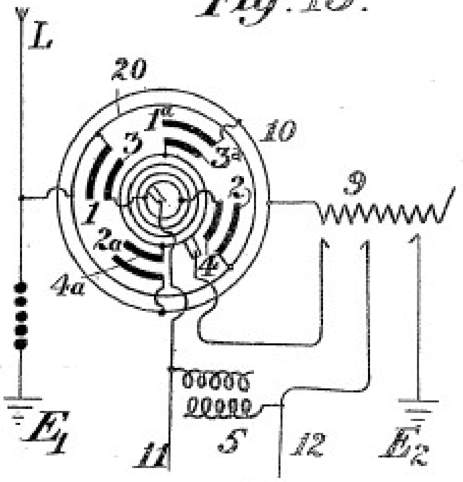
L
20
1^a
10
3
3^a
2
1
9
2a
4
4a
5
11
12
E_1
E_2

Fig. 14

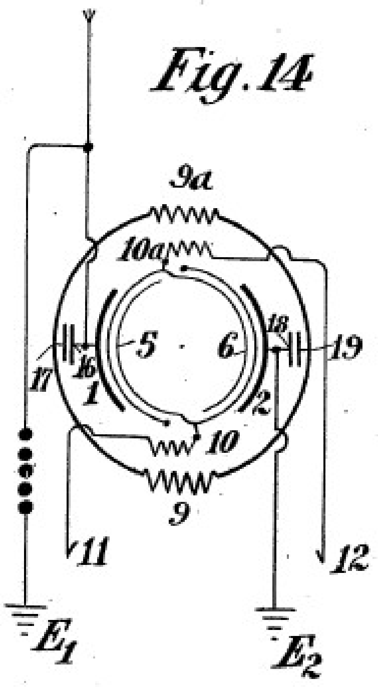
9a
10a
5
6
16
17
18
19
1
2
10
9
11
12
E1
E2

Fig. 16

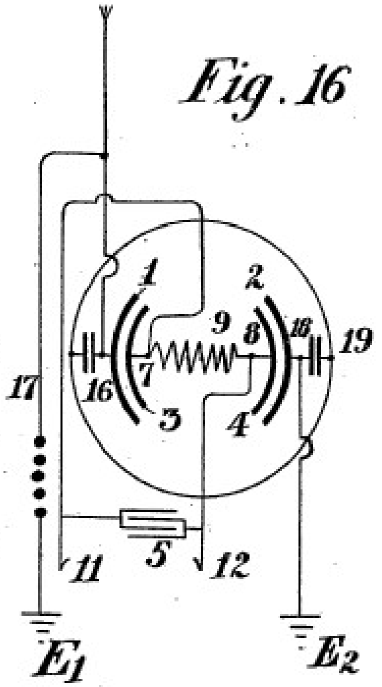
1
2
9
8
18
19
16
7
17
3
4
5
11
12
E1
E2

Fig. 15

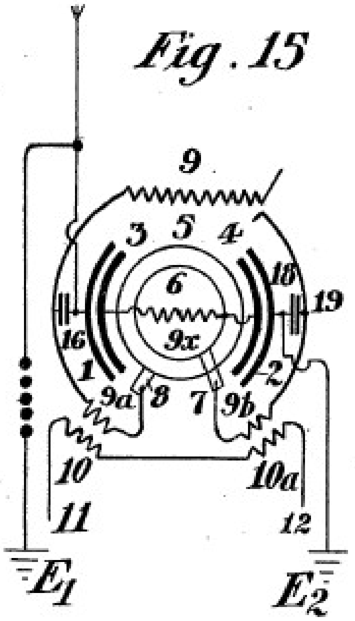
9
3
5
4
6
18
19
16
9x
1
2
9a
8
7
9b
10
10a
11
12
E1
E2

Fig. 17.

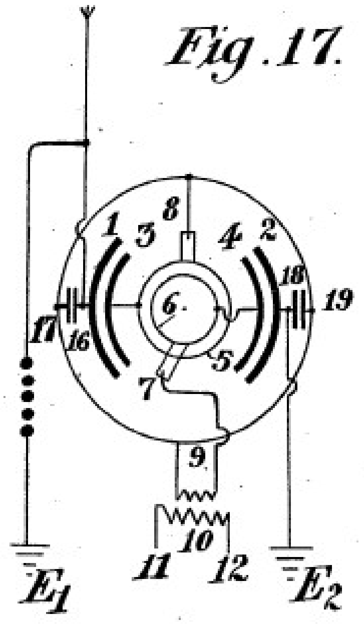
8
1
3
4
2
18
19
17
16
6
5
7
9
10
11
12
E1
E2

French Patent # 551,882
Apparatus for Capture of Electric Currents in the Atmosphere

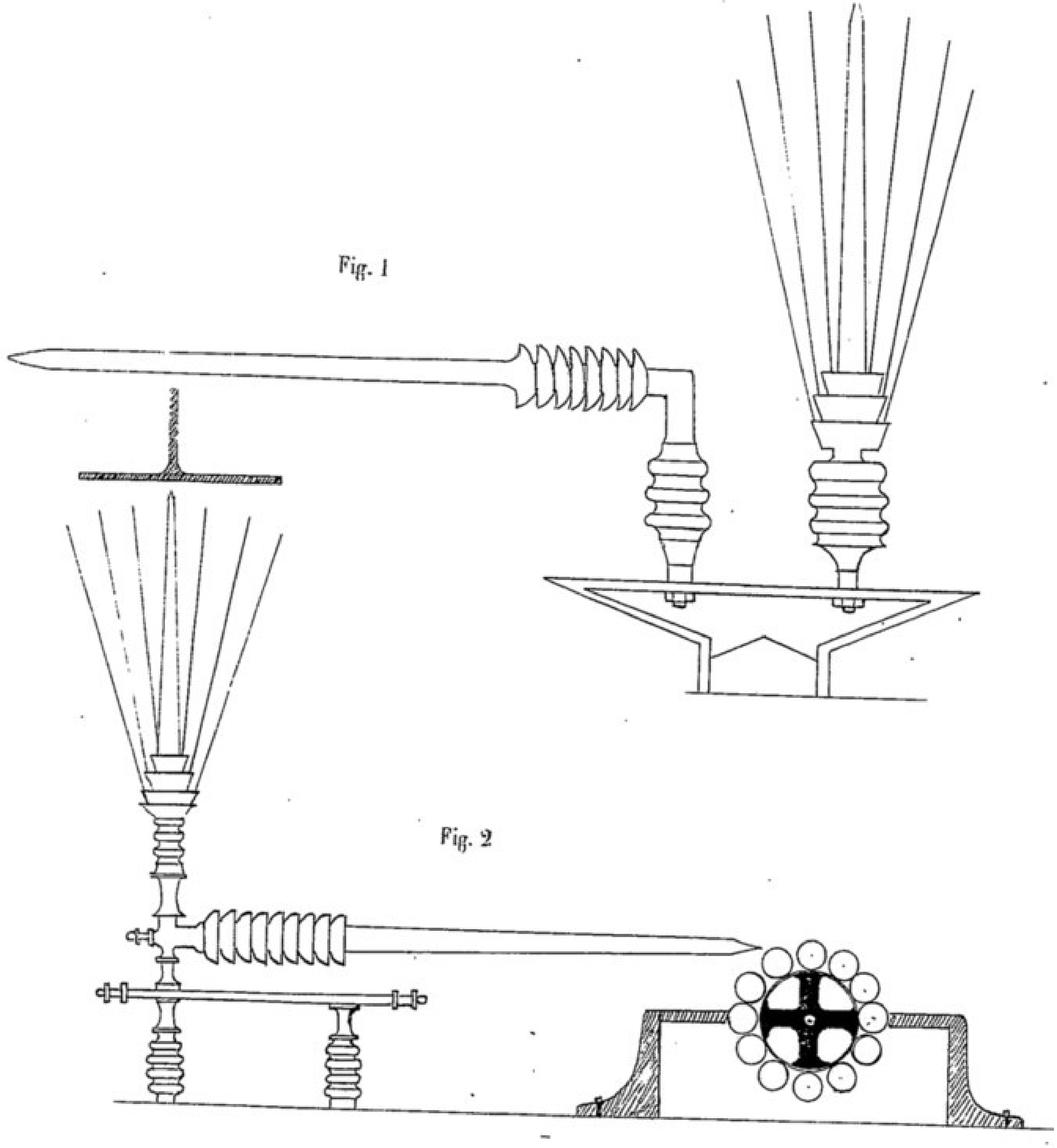

Fig. 1

Fig. 2

French Patent # 565,395

Combined Apparatus for Capture of Atmospheric Electric Currents with Immediate Implementation

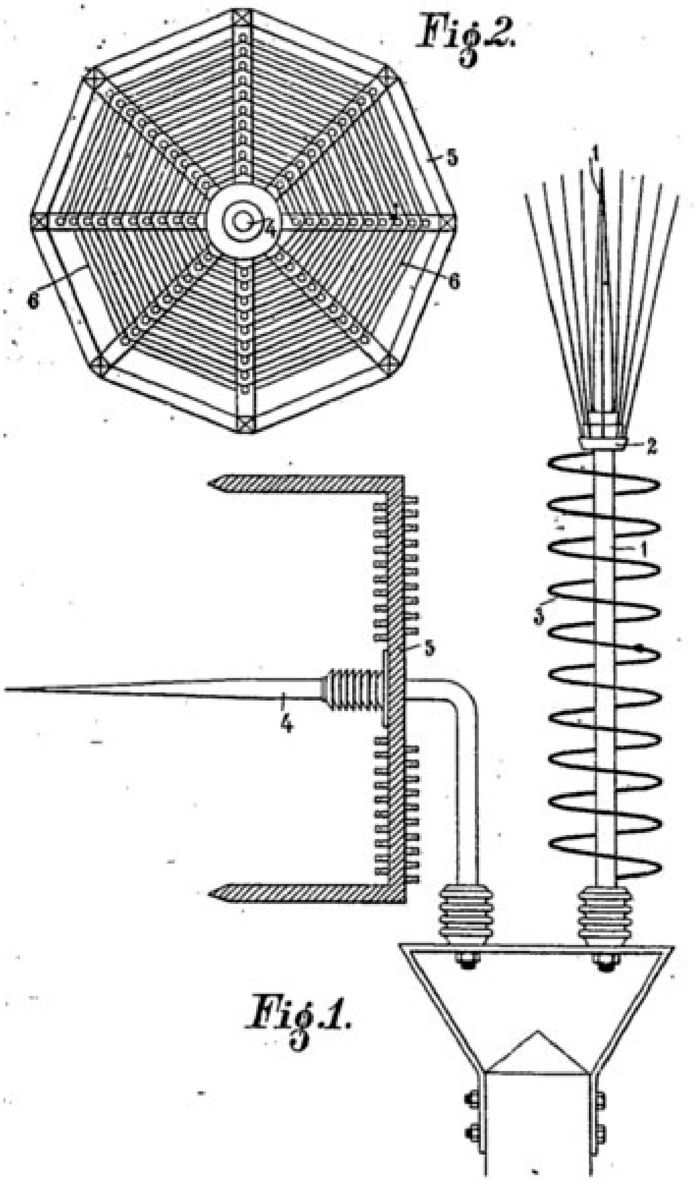

Fig. 2.

Fig. 1.

Fig. 3.

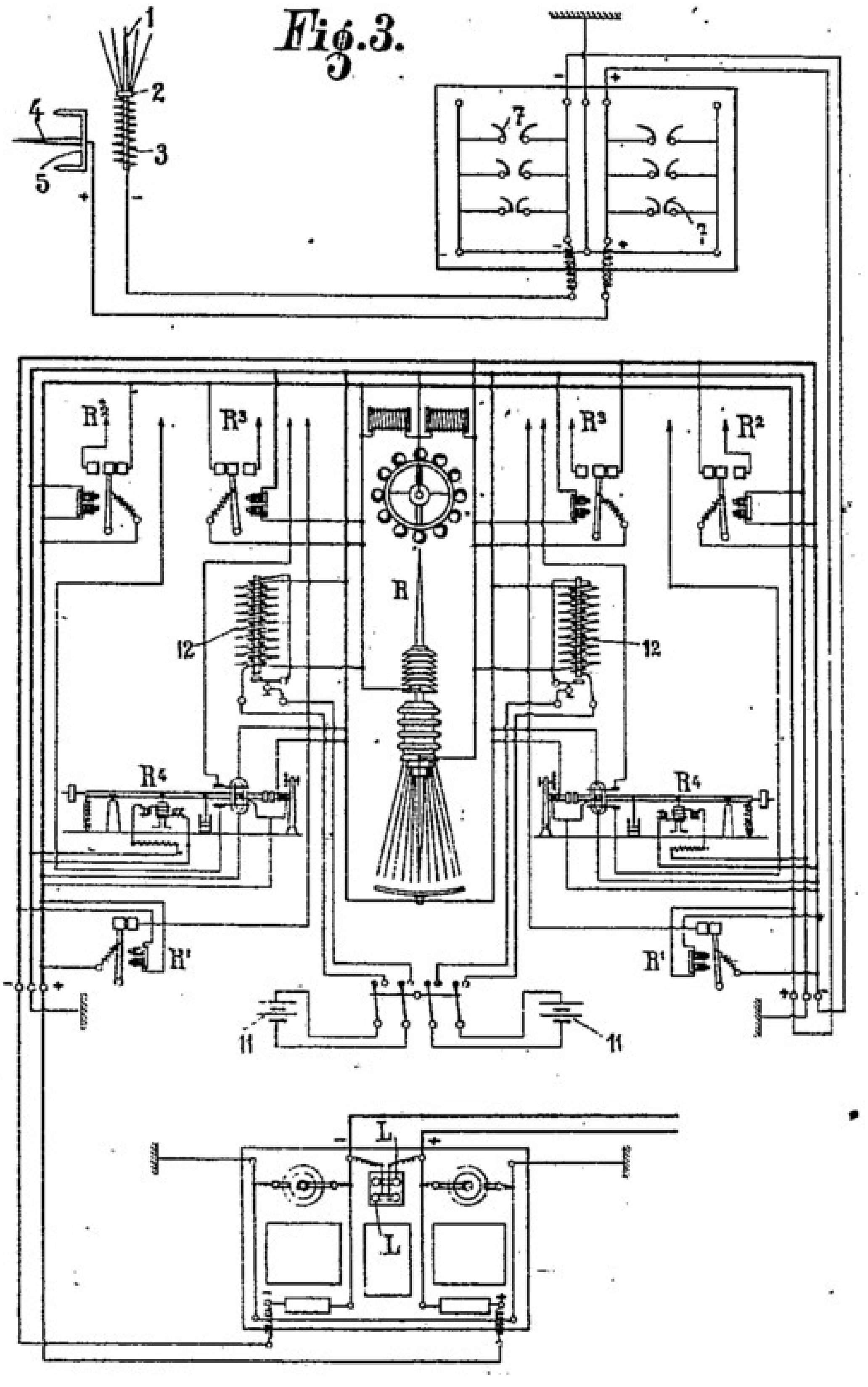
1
2
3
4
5
+
-
7
7
R²
R³
R³
R²
R
12
12
R⁴
R⁴
R¹
R¹
11
11
L
L

Fig. 4.

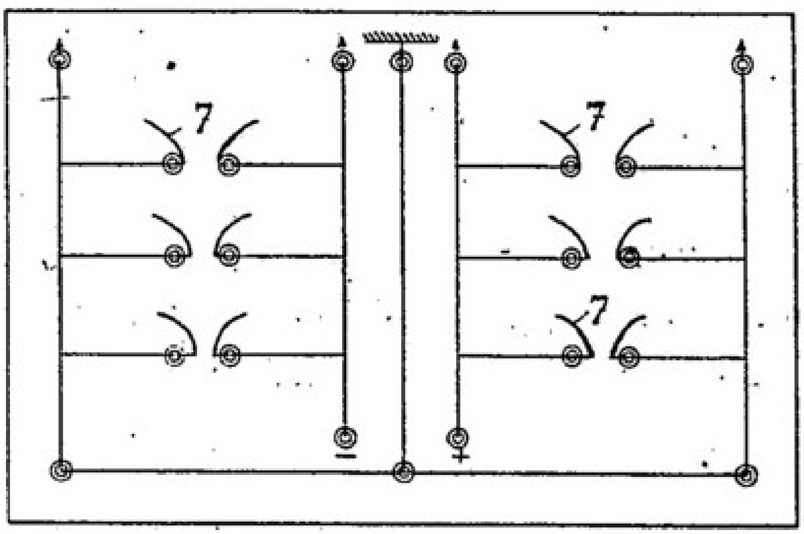

Fig. 5.

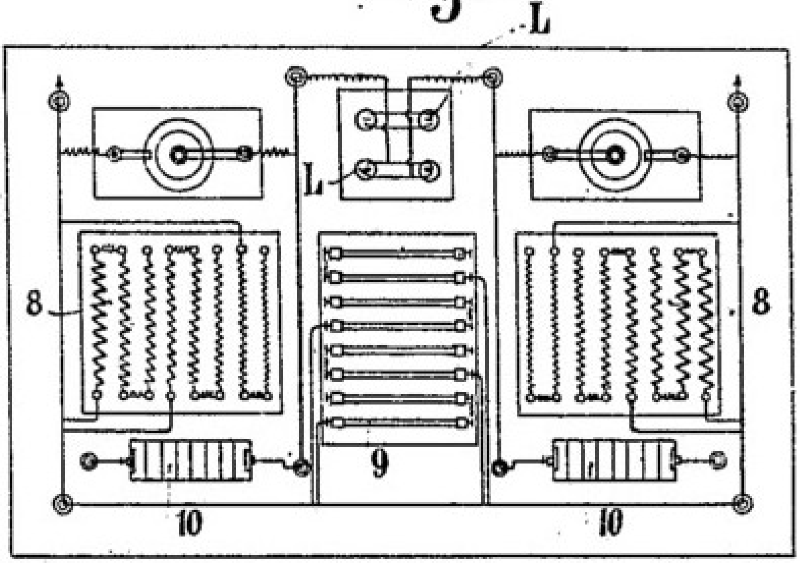

US 28793
Electric Apparatus

Abstract -- An aerostat for obtaining atmpspheric and terrestrial electricity...

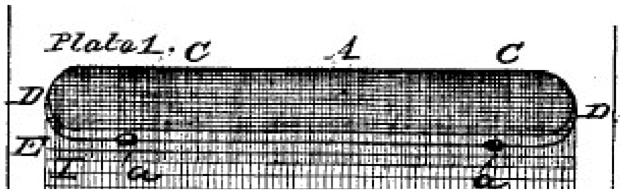
Plate 1.
C
A
C
D
D
E
L
a
a

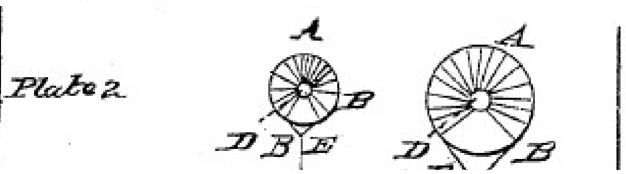
Plate 2
A
B
D
B
E
A
D
B

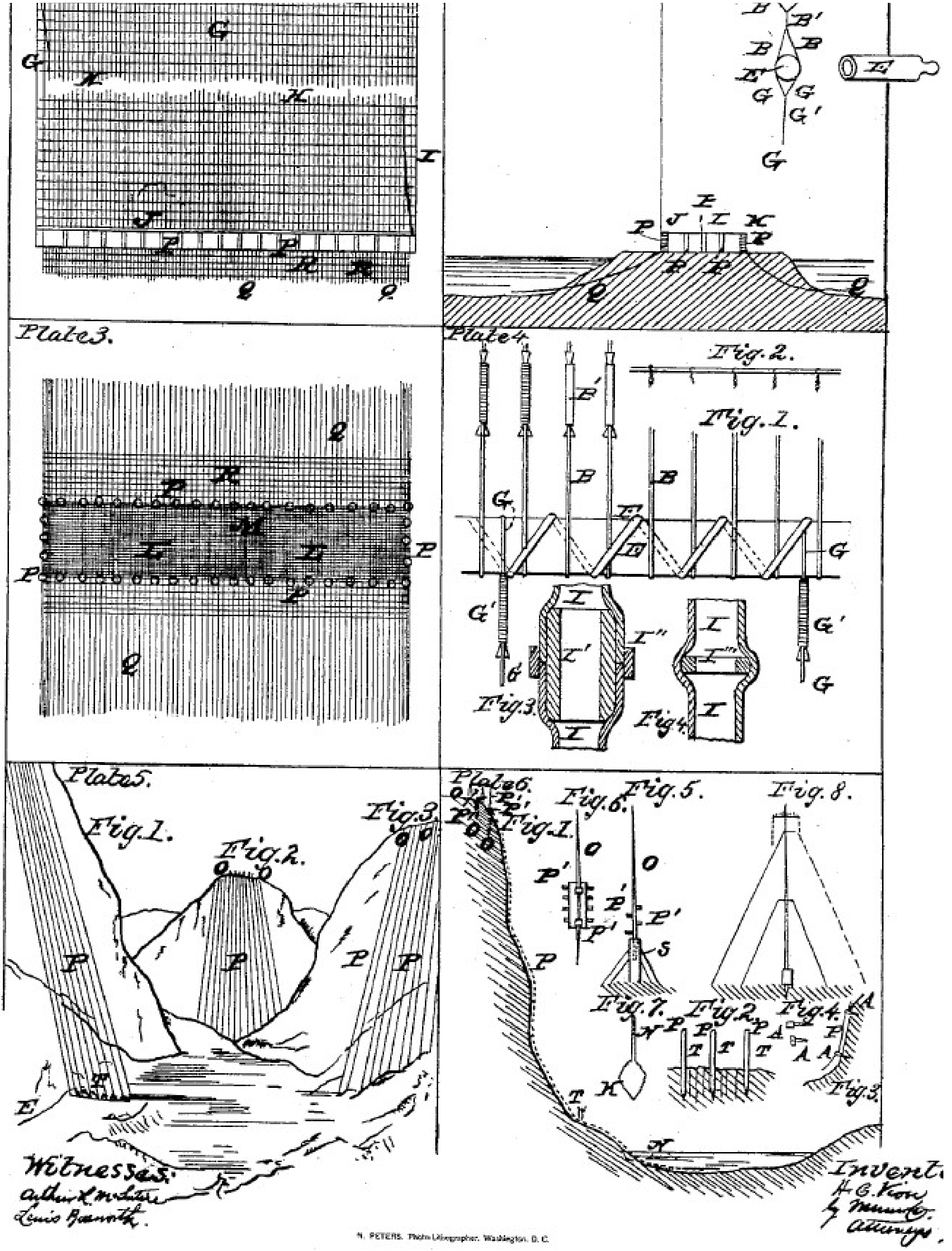
G
G
K
K
I
J
P
P
R
R
Q
Q
B
B'
B
B
E
G
G
G'
G
E
E
J
I
K
P
P
P
P
Q
Q
Plate 3.
Q
R
P
M
E
E
P
P
P
Q
Plate 4.
Fig. 2.
E'
Fig. 1.
B
B
G
E
D
G
G'
I
I'
I''
I
I'''
G'
G'
G
Fig. 3.
I
Fig. 4.
I
Plate 5.
Fig. 1.
Fig. 3.
Fig. 2.
P
P
P
P
E
Plate 6.
Fig. 1.
Fig. 6.
Fig. 5.
Fig. 8.
O
O
P'
P'
P'
P'
S
P
Fig. 7.
Fig. 2.
Fig. 4.
A
N
P
P
P
A
P
T
T
T
A
A
K
T
Fig. 3.
N
Witnesses:
Arthur L. McIntire
Louis Bauroth.
Invent
H. G. Viox
by Munn & Co.
Attorneys.

N. PETERS. Photo-Lithographer. Washington. D. C.

US 126356

Improvement in Collecting Energy for Telegraph

Abstract -- A tower for the purpose of receiving and imparting natural electricity, so as to be in constant contact with the upper stratum of electricity which surrounds the earth, by tapping which a never-failing supply is formed when brought into contact with the earth.

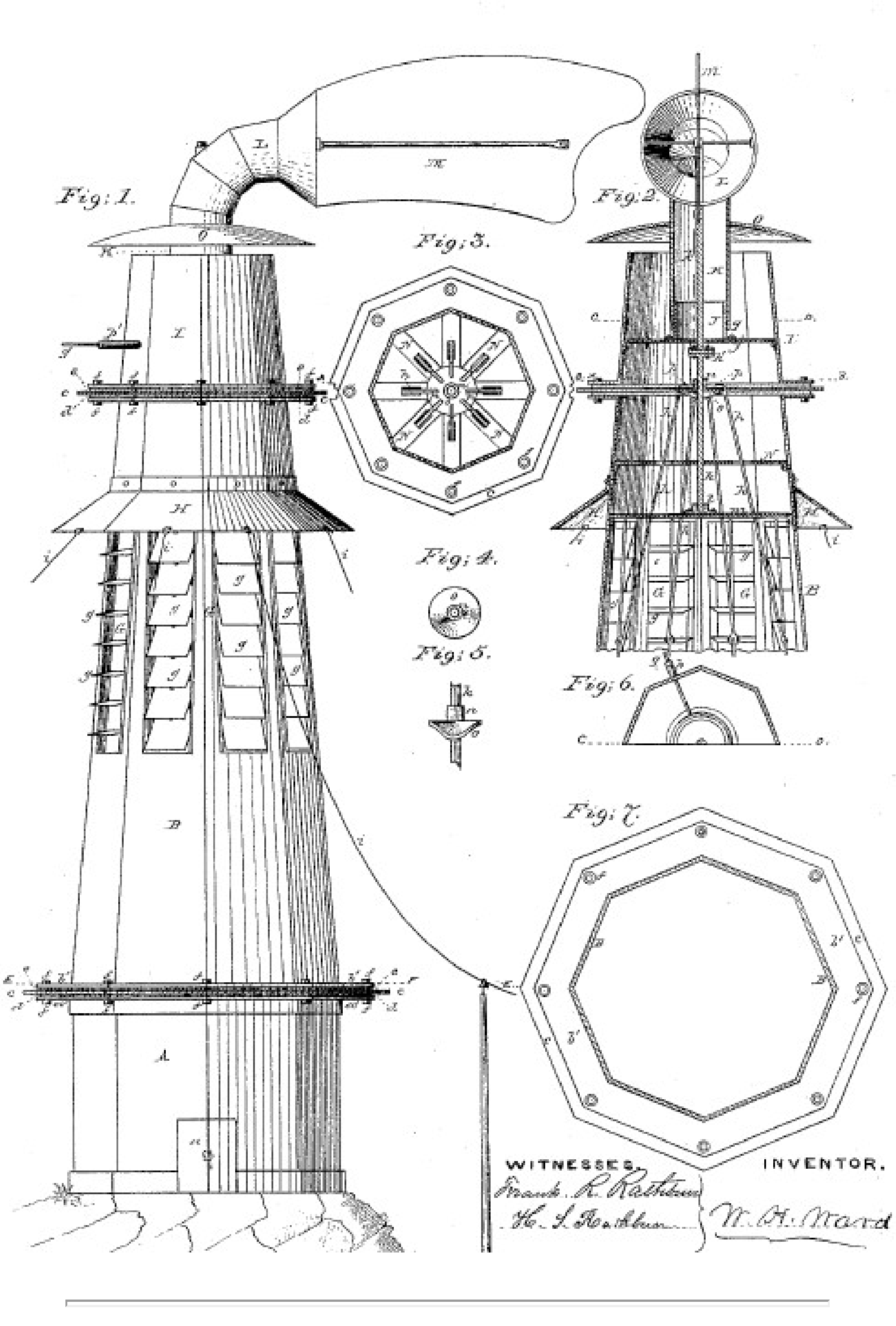

US 129971
Telegraph Power

Abstract -- Utilizing natural electricity and establishing an electrical current without the aid of wires, batteries, or cables...

US 674427
Collecting Atmospheric Electricity

Abstract -- An appartus for colecting and driving or conducting atmospheric electricity which renders it practicable to obtain material quantities of teh same in serviceable form.

Fig:1.

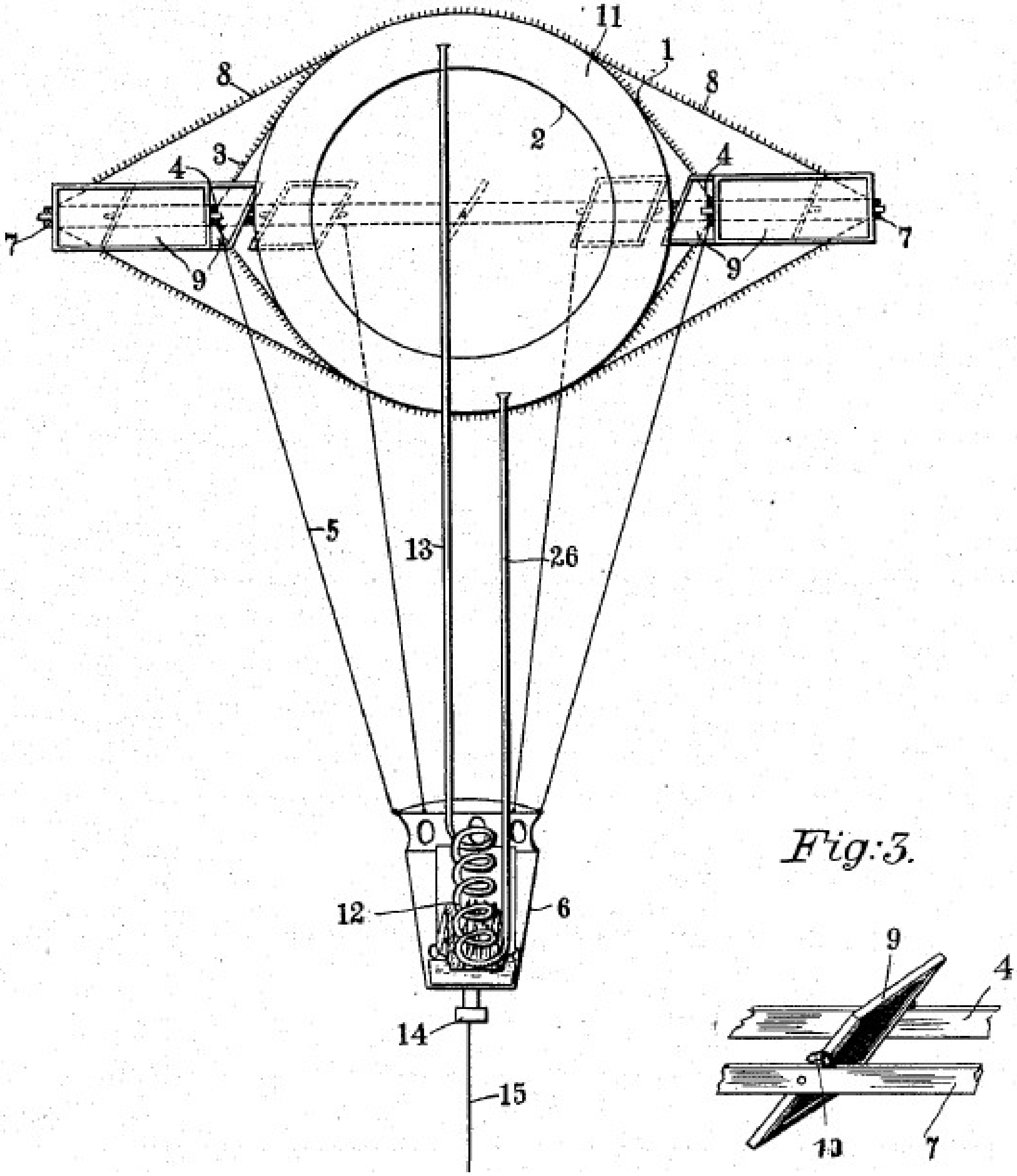

Fig:3.

Fig: 2.

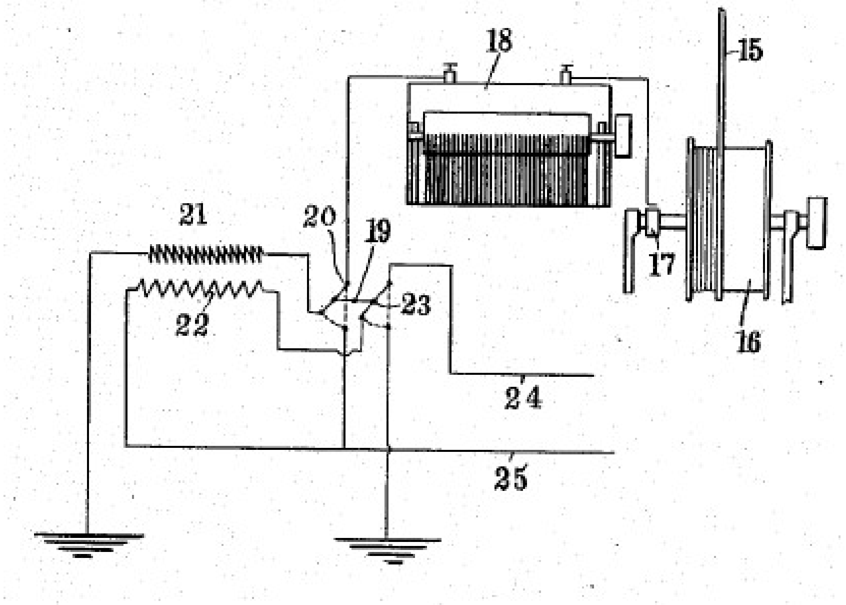
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25

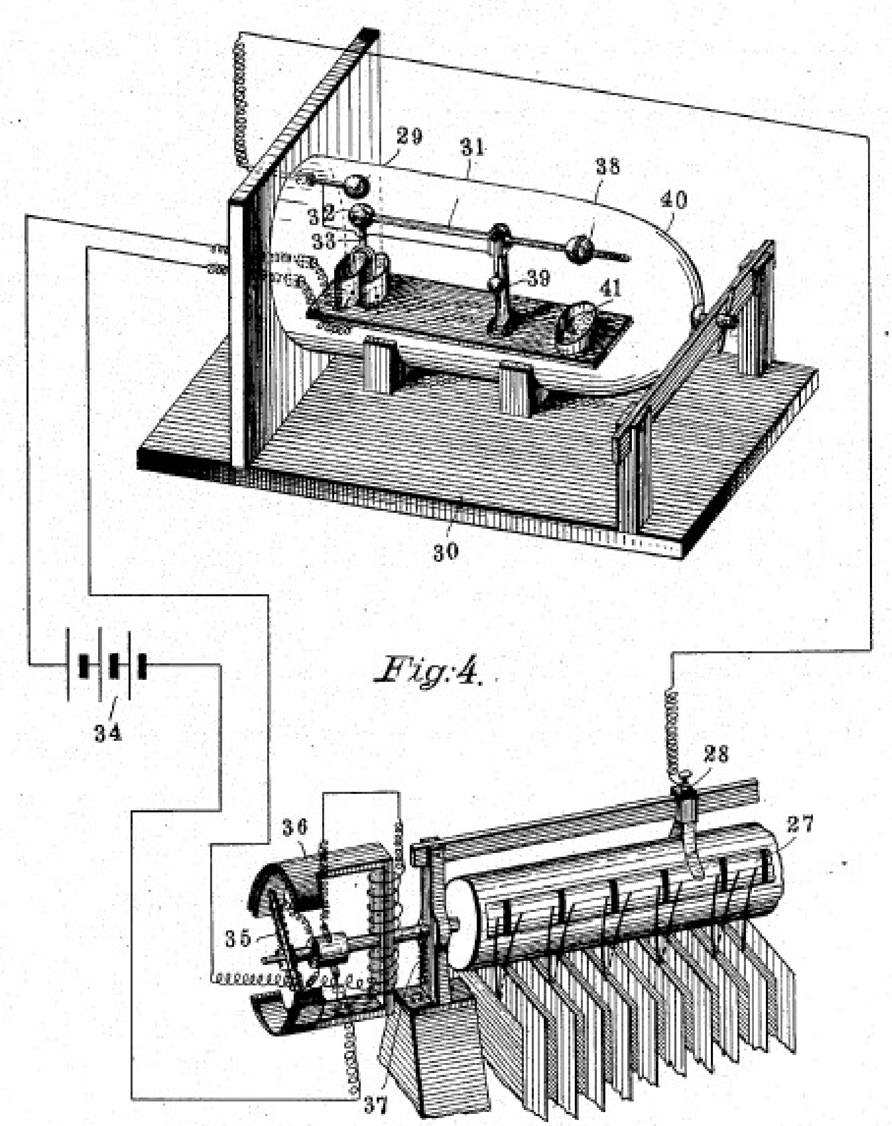

Fig. 4.

US 911260
Collecting Atmospheric Electricity

Abstract -- A method of colecting electricity from a strata laden with electricity at high altitudes in the atmoshere, through the medium of a wire cable suspended from one or more balloons ...

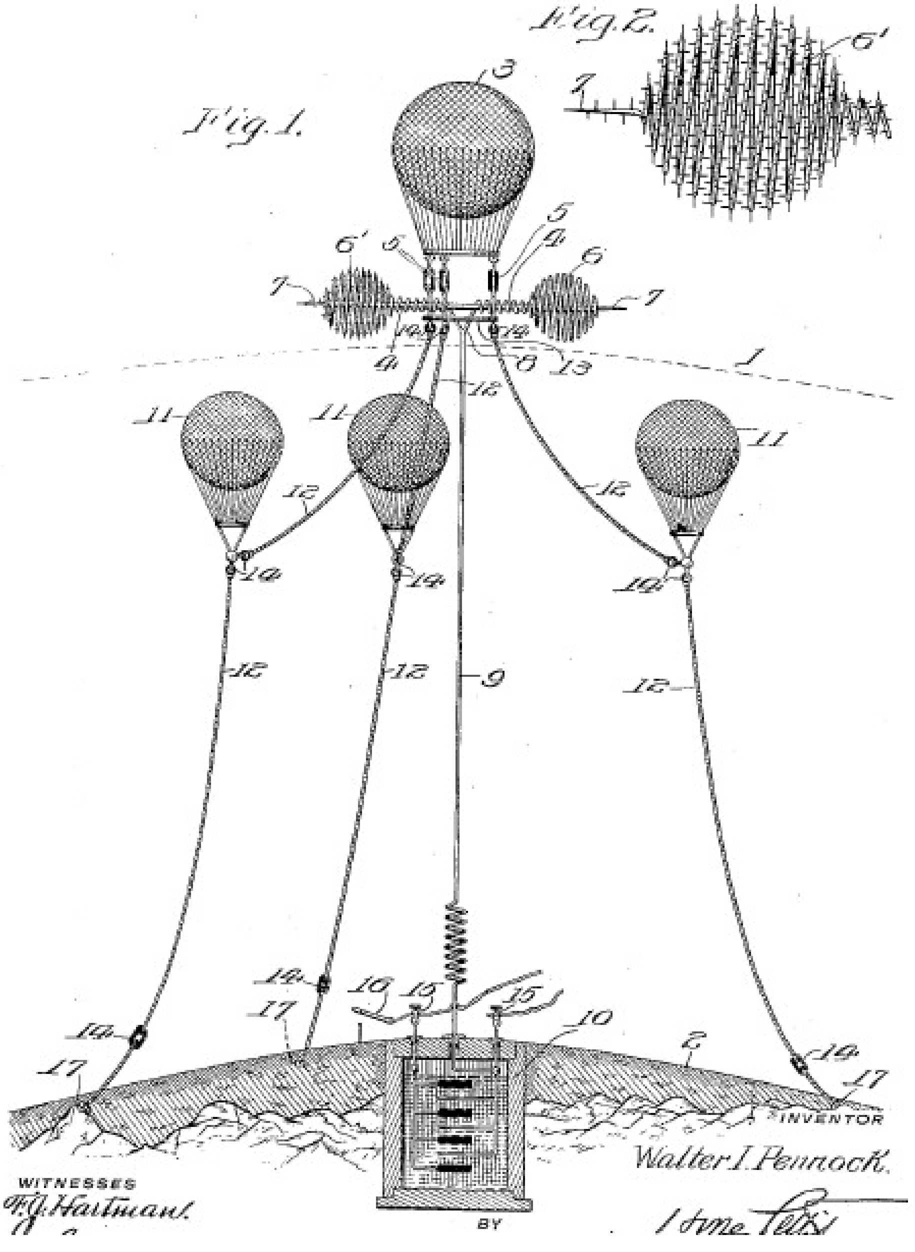
Fig. 2.
7
6'
Fig. 1.
3
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6'
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12
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9
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14
16
15
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17
10
2
14
17
14
17
WITNESSES
F.J. Hartman
INVENTOR
Walter I. Pennock.
BY

US 1014719
Collecting Atmospheric Electricity

Abstract -- A method of colecting electricity from a strata laden with electricity at high altitudes in the atmoshere, through the medium of a wire cable suspended from one or more balloons ...

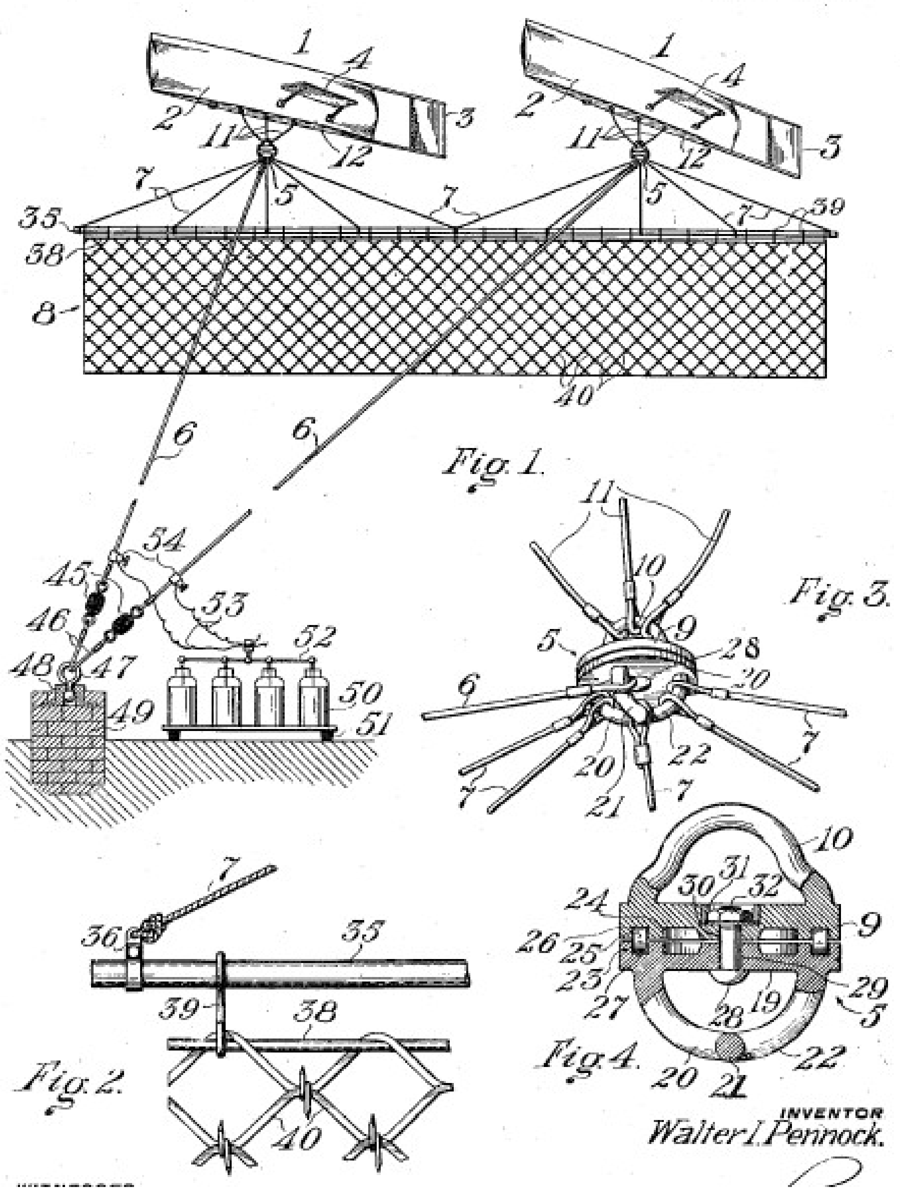
1
4
2
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35
39
38
8
40
6
Fig. 1.
54
45
53
52
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48
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51
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Fig. 3.
9
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22
21
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36
35
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38
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Fig. 2.
24
30
31
32
9
26
25
23
27
28
19
29
5
Fig. 4.
20
21
22

INVENTOR
Walter I. Pennock.

Fig. 5.

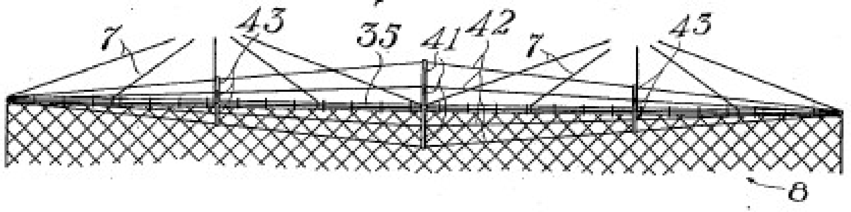
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43
35
41
42
7
43
8

Fig. 6.

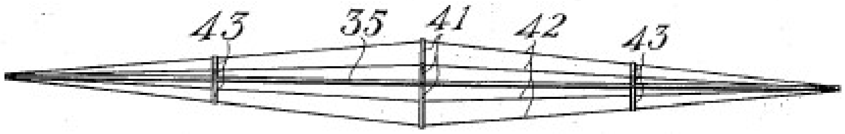
43
35
41
42
43

Fig. 7.

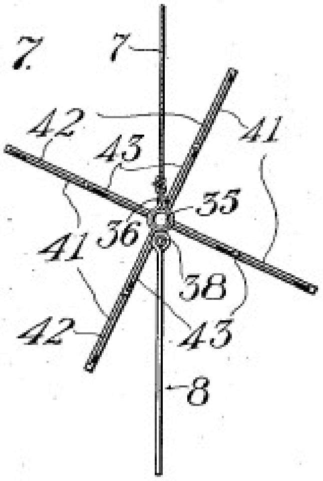
7
42
41
43
35
41
36
38
43
42
8

INVENTOR
Walter I. Pennock.

US 1540998
Conversion of Atmospheric Electric Energy

Abstract -- Method of obtaining atmospheric electricity by means of metallic ballon collectors...

Filed Jan. 15, 1921 12 Sheets-She

Fig. 1.

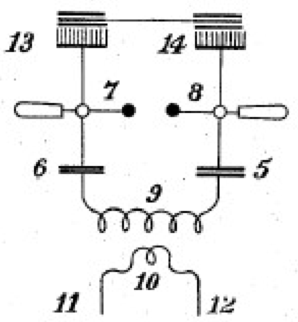
13
14
7
8
6
5
9
10
11
12

Fig. 2.

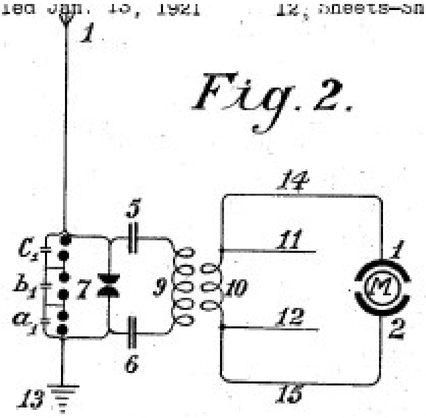
1
14
5
C1
11
1
b1
7
9
10
M
a1
12
2
6
13
15

Fig. 3.

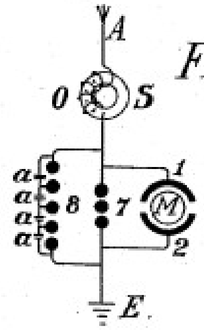
A
0
S
a
a
a
a
8
7
1
M
2
E.

Fig. 4.

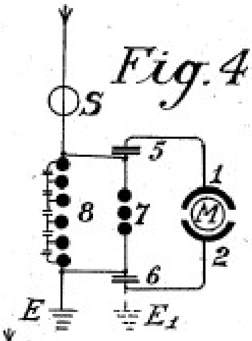
S
5
8
7
1
M
2
6
E
E1

Fig. 5.

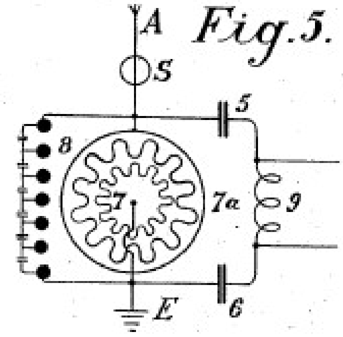
A
S
5
8
7
7a
9
E
6

Fig. 6

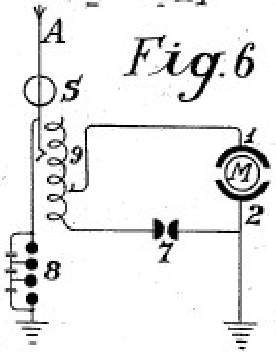

Filed Jan. 13, 1921 12 Sheets-Sheet 2

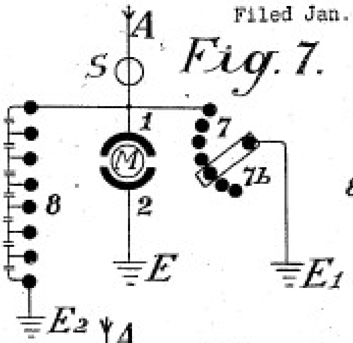
Fig. 7.
A
S
1
7
7b
8
2
E
E1
E2

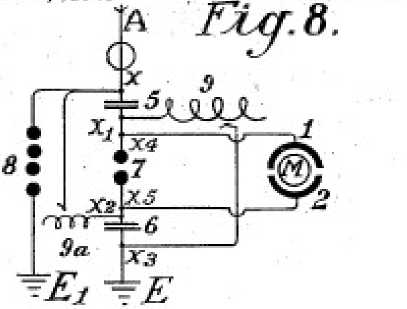
Fig. 8.
A
x
5
9
x1
x4
1
7
8
x5
x2
6
2
9a
x3
E1
E

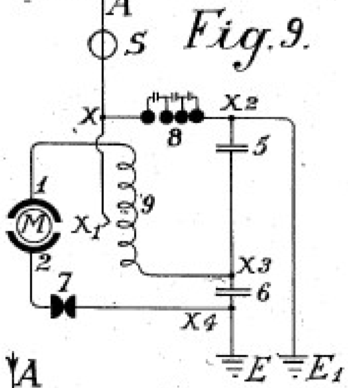
Fig. 9.
A
S
X
8
X2
5
1
M
X1
9
2
X3
6
7
X4
E
E1

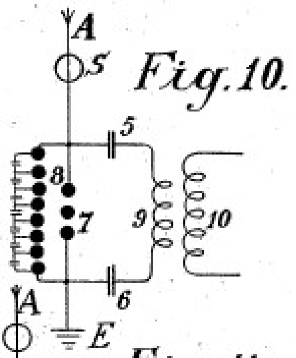
Fig. 10.
A
S
5
8
7
9
10
6
E

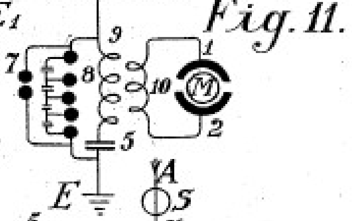
Fig. 11.
A
S
9
7
8
10
1
M
2
5
E

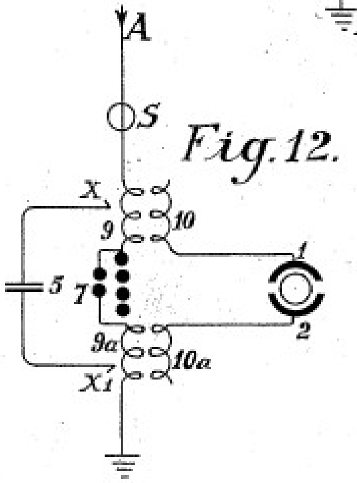
Fig. 12.
A
S
X
9
10
7
5
1
2
9a
10a
X1

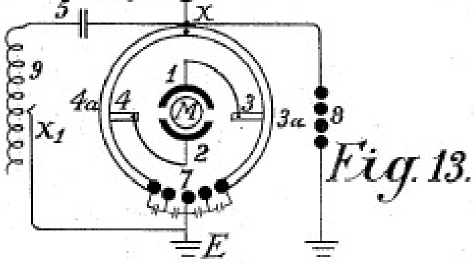
Fig. 13.
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S
5
X
9
1
4a
4
M
3
3a
8
X1
2
7
E

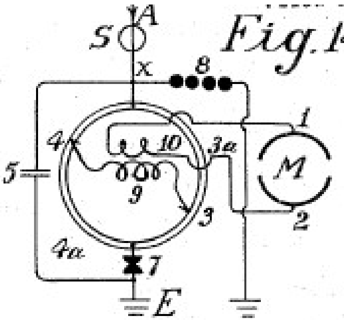
A
S
X
8
1
10
3a
M
4
5
9
3
2
4a
7
E

Fig. 14.

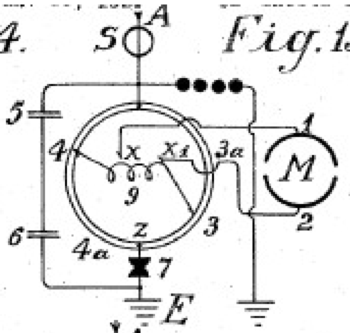
A
S
5
1
4
X
X1
3a
M
9
3
2
Z
6
4a
7
E

Fig. 15.

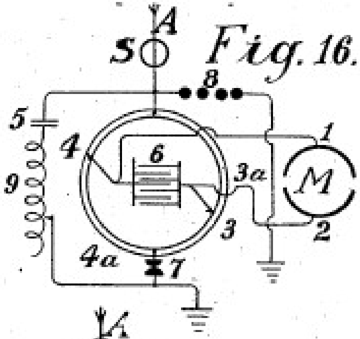
A
S
8
5
4
6
1
3a
M
9
3
2
4a
7

Fig. 16.

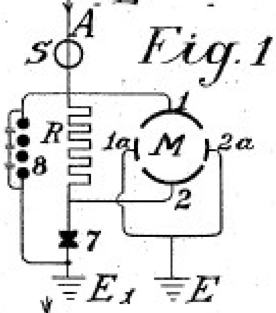
A
S
1
R
1a
M
2a
8
2
7
E1
E

Fig. 17.

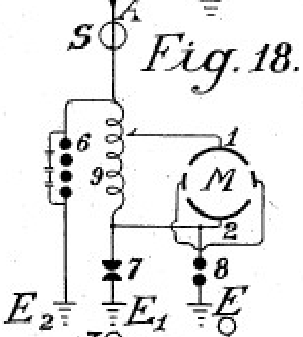
A
S
6
1
9
M
2
7
8
E2
E1
E

Fig. 18.

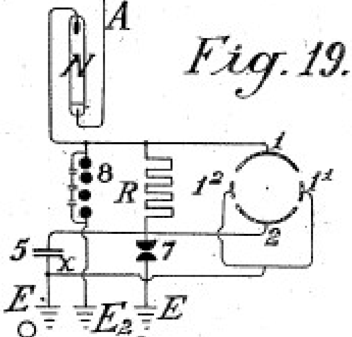
A
N
8
1
R
1²
1¹
2
5
X
7
E
E2
E

Fig. 19.

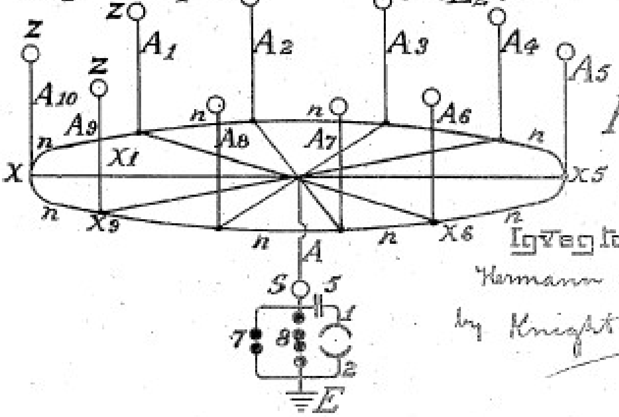
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Z
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A1
A2
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A9
n
n
A8
A7
A6
n
X1
X
X5
n
X9
n
n
X6
n
A
S
5
7
8
1
2
E

Fig. 20.

Inventor
Hermann Plauson
by Knight Bros
Attorneys

Fig. 21. Fig. 22.

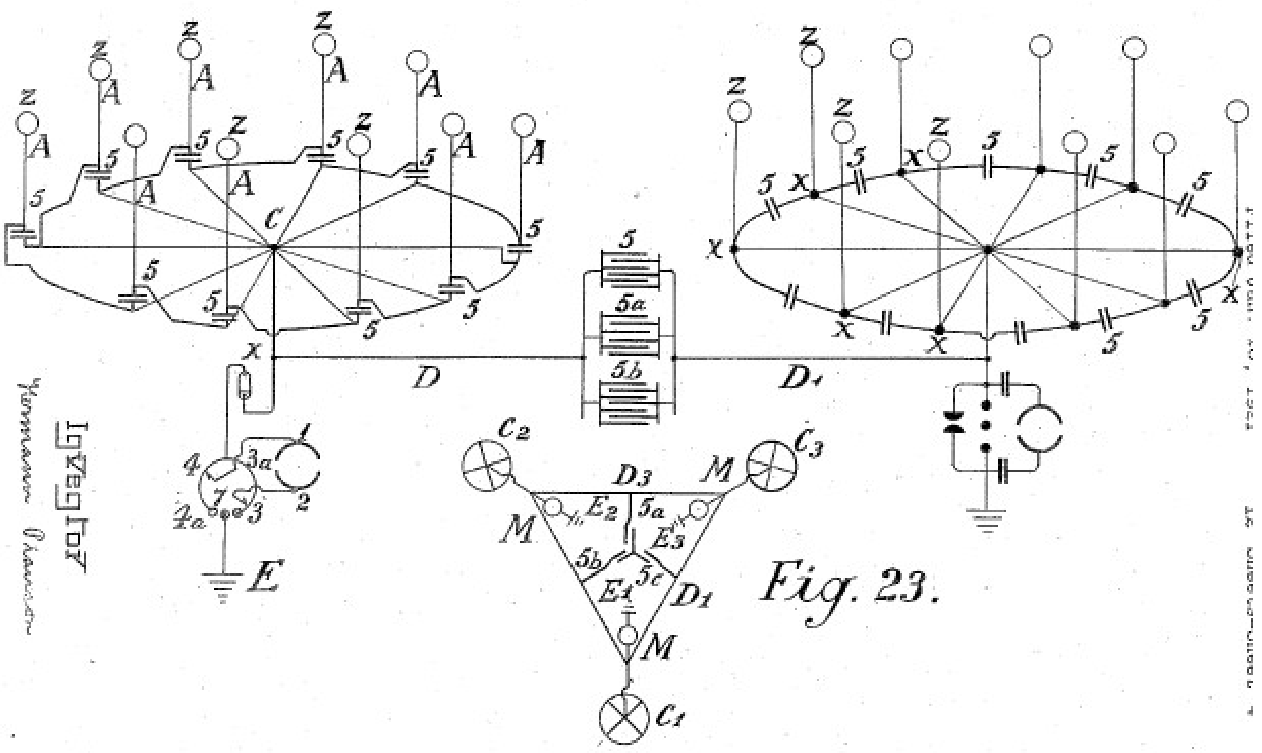
Z
A
5
C
X
D
D1
5a
5b
1
2
3
3a
4
4a
7
E
Inventor
Hermann Plauson
C2
C3
C1
D3
M
E2
E3
E1
5c
D1

Fig. 23.

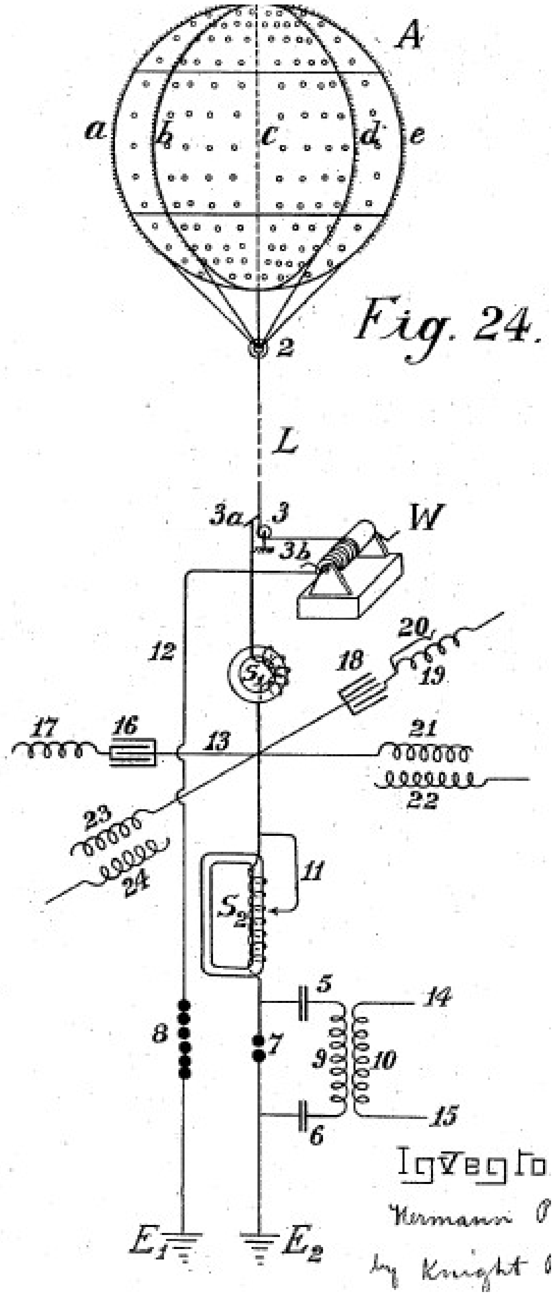
A
a
b
c
d
e
2
L
3a
3
3b
W
12
S1
18
20
19
17
16
13
21
22
23
24
11
S2
5
14
8
7
9
10
15
6
E1
E2
Invento
Hermann
by Knight

Fig. 24.

Fig. 25.

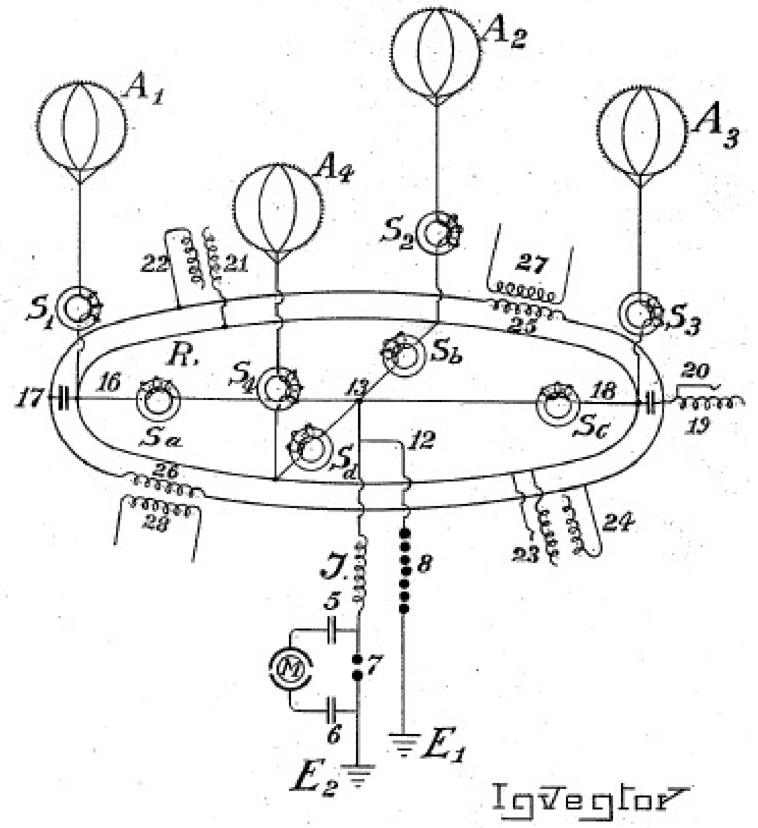
A1
A2
A3
A4
S2
S1
S3
22
21
27
25
R.
Sb
S4
13
16
17
18
20
19
Sa
Sc
12
Sd
26
28
24
23
J.
8
5
7
M
6
E2
E1
Inventor

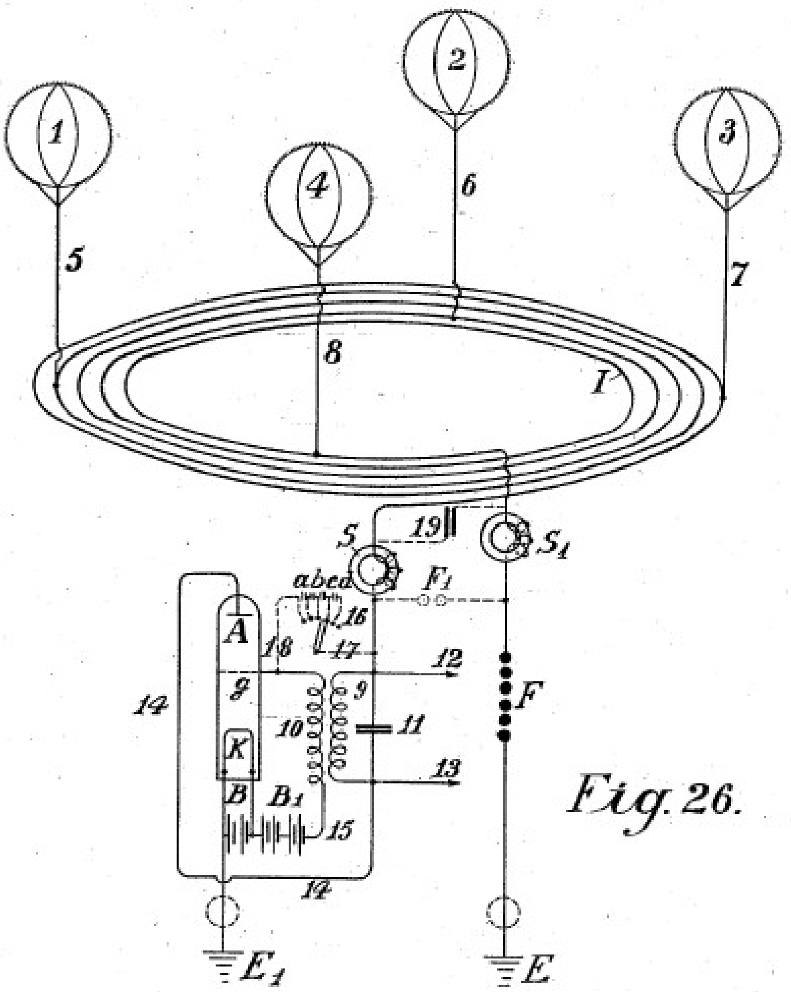
I
S
S1
abcd
F1
A
g
K
F
B
B1
E1
E

Fig. 26.

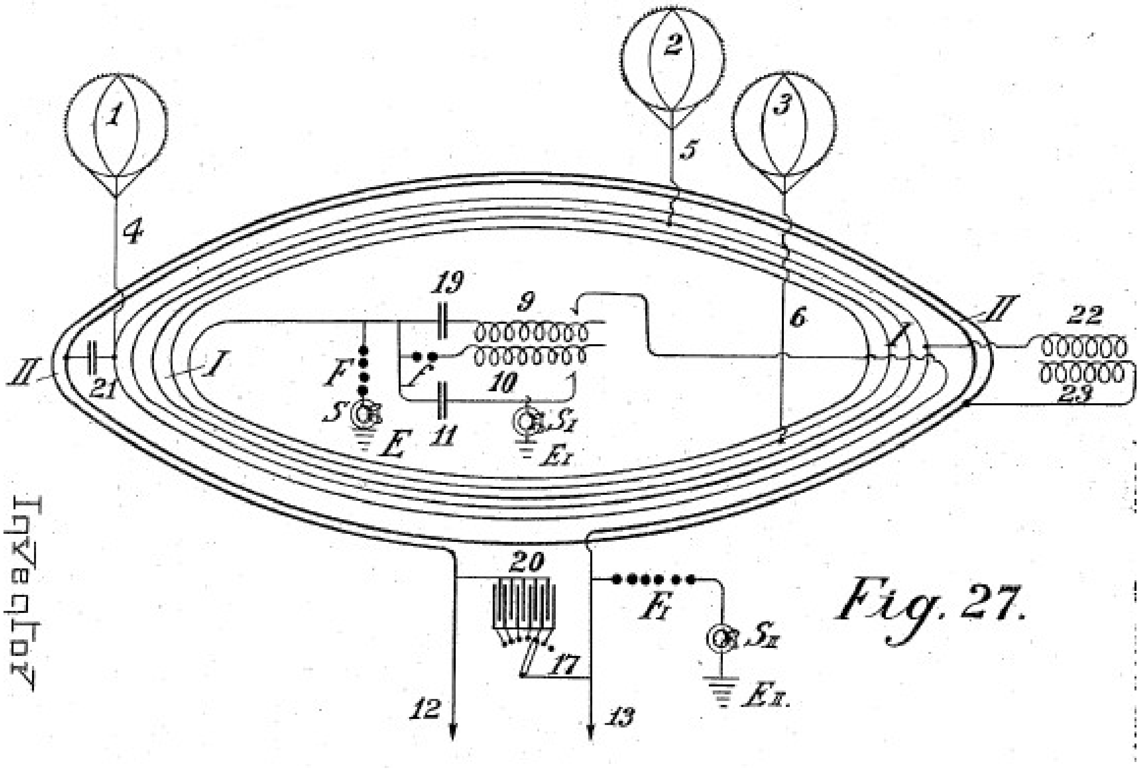
1
2
3
4
5
6
19
9
II
22
II
21
I
F
f
10
23
S
E
11
S1
E1
20
F1
SII
17
EII.
12
13

Fig. 27.

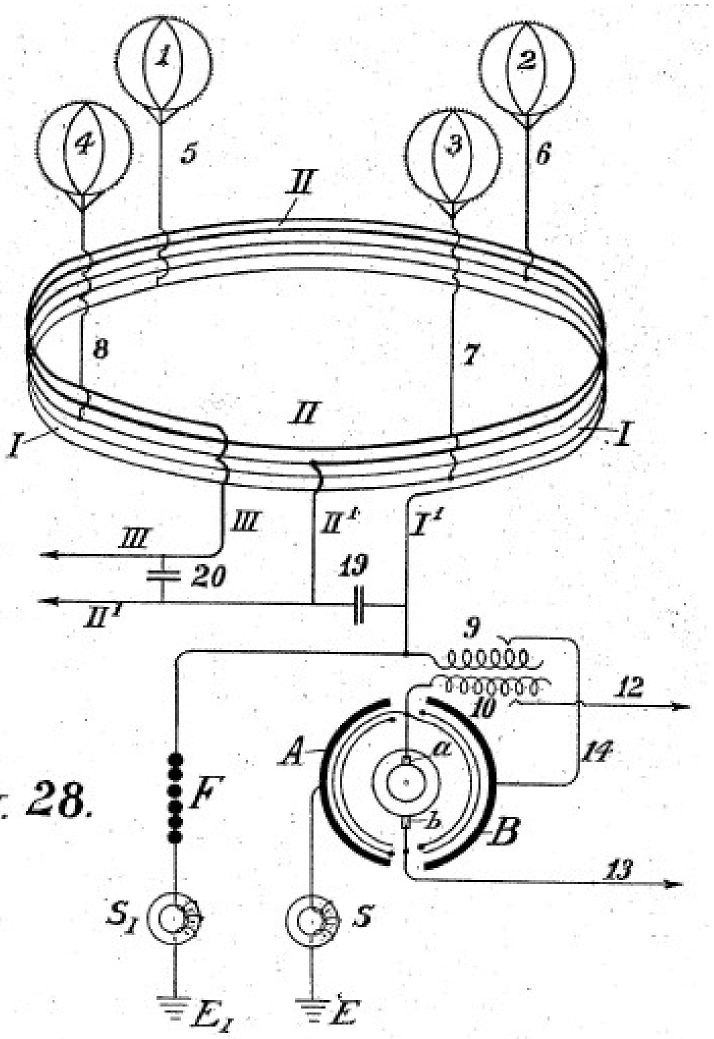
1
2
4
5
3
6
II
8
7
II
I
I
III
III
II¹
I¹
19
III
20
II¹
9
12
10
A
a
14
F
B
b
13
S₁
S
E₁
E

Fig. 28.

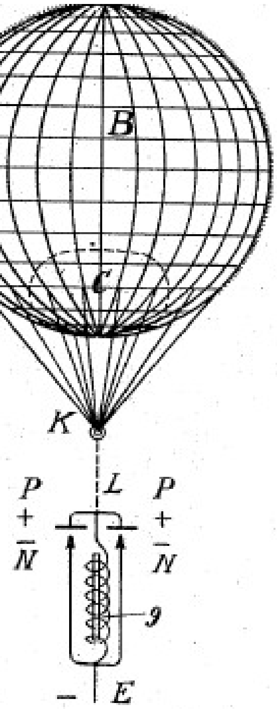
B
C
K
P
+
N
L
P
+
N
9
−
E

Fig. 29.

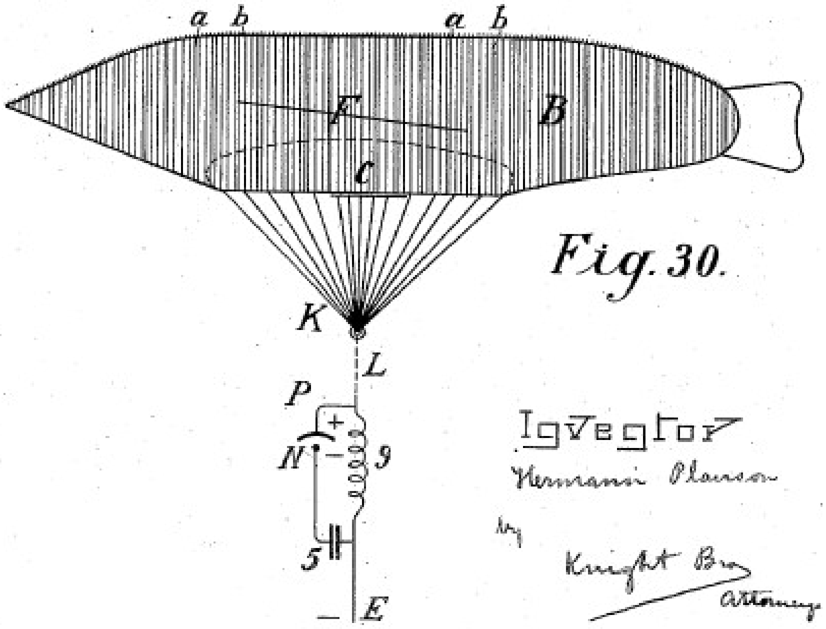
a
b
a
b
F
B
C
K
L
P
+
N
−
9
5
−
E

Fig. 30.

Inventor
Hermann Plauson
by
Knight Bros
Attorneys

Filed Jan. 13, 1921 12 Sheets-Sheet 11

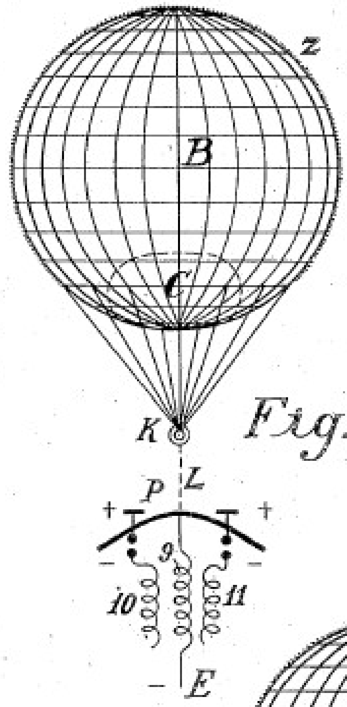
z
B
C
K
L
P
+
+
−
−
9
10
11
−
E

Fig. 31.

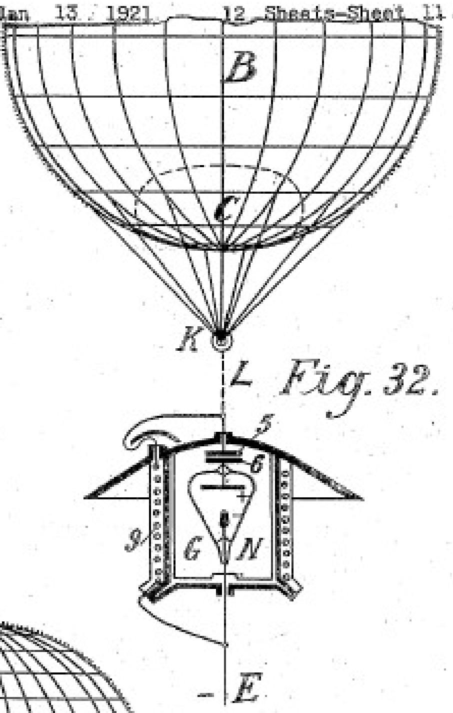
z
B
C
K
L
5
6
+
9
G
N
−
E

Fig. 32.

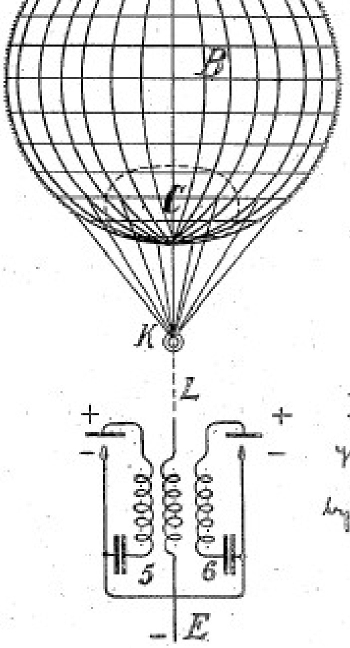

Fig. 33.

Inventor
Hermann Plauson
by Knight Bros
attorneys

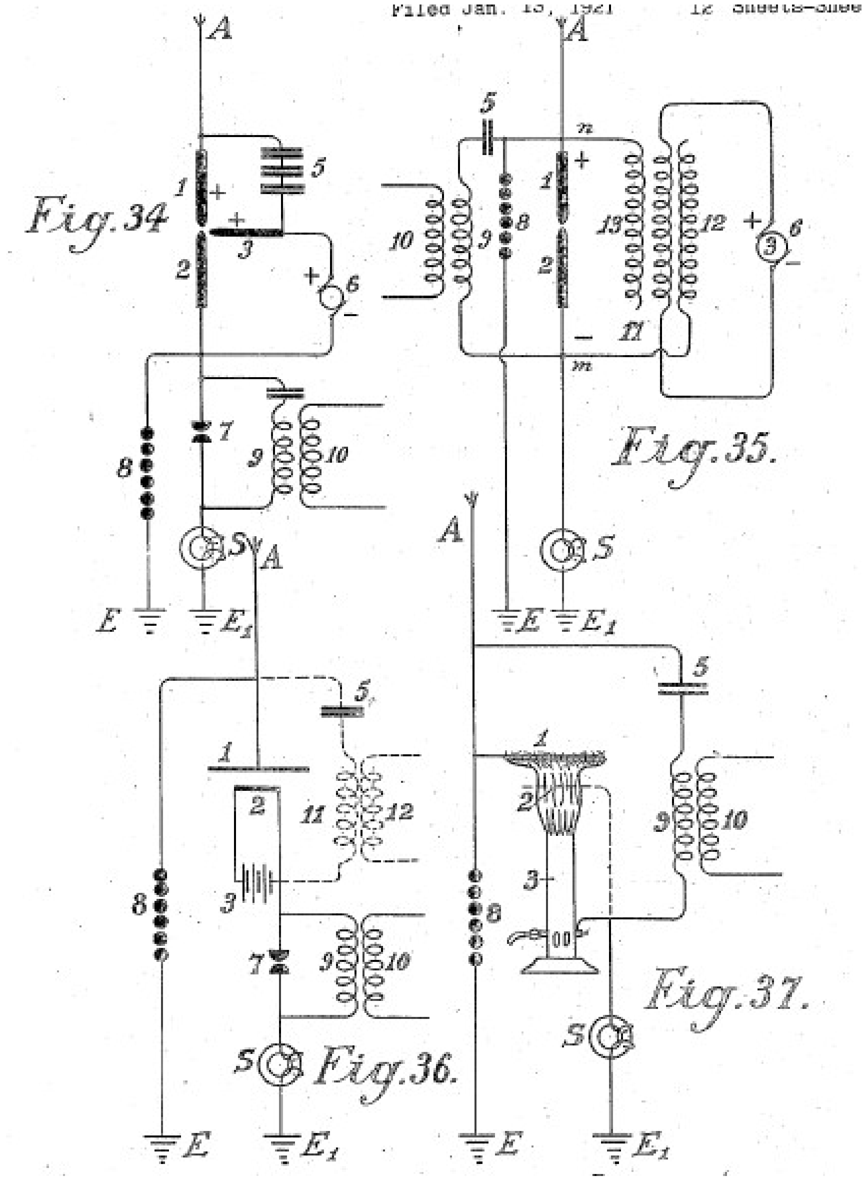
Filed Jan. 13, 1921
12 Sheets-Shee
Fig. 34
Fig. 35.
Fig. 36.
Fig. 37.
A
1
2
3
5
6
7
8
9
10
11
12
13
n
m
S
E
E1
+
−

GB 149,917
Improvements in & Relating to Radio Communication Systems

Abstract -- Radio transmission and reception through the use of living vegetable organisms such as trees, plants, and the like.

Fig 1

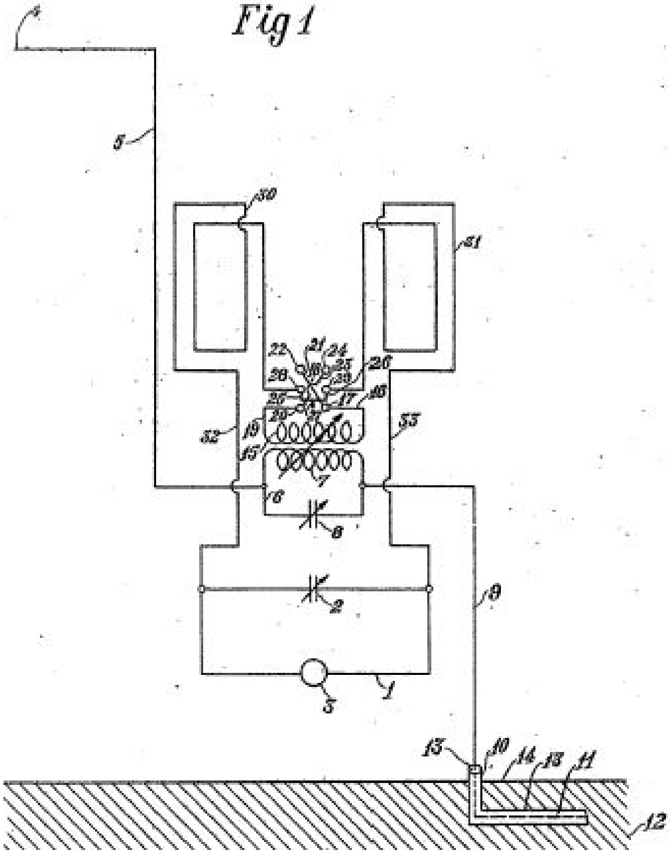
5
30
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14
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11
12

US 1826727
Radio Apparatus

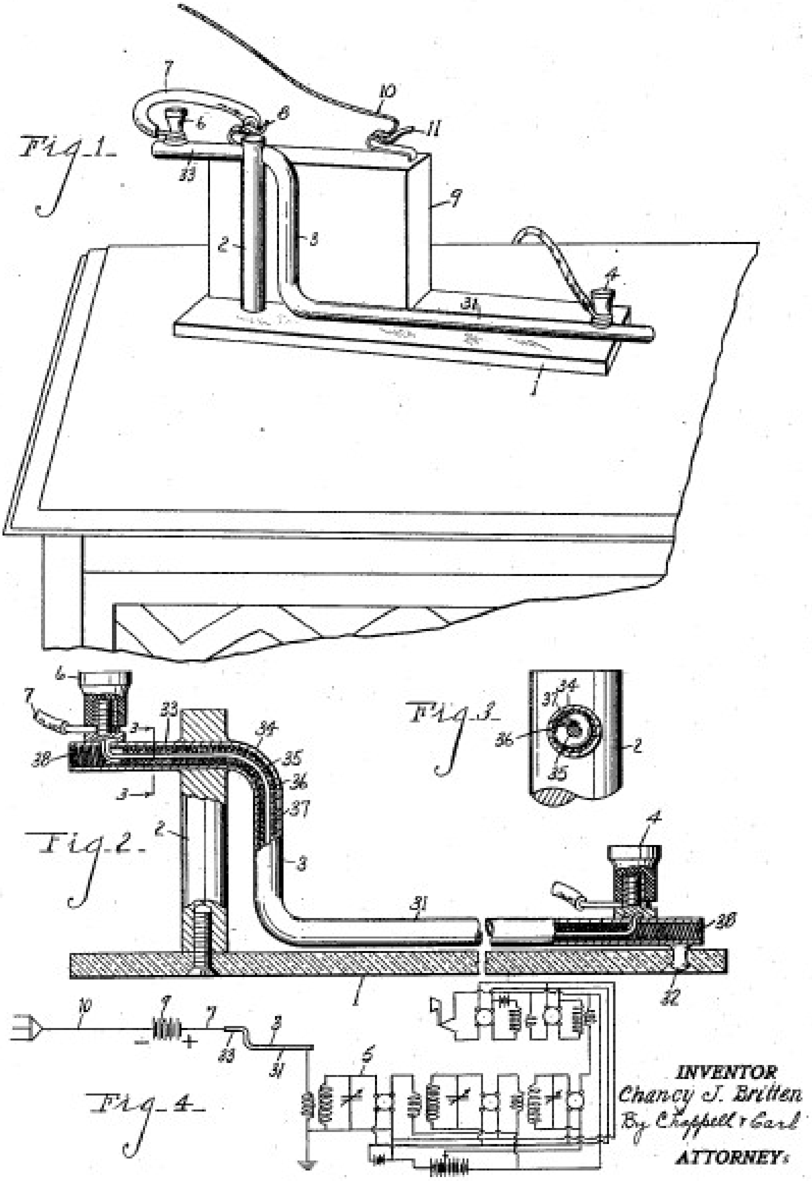
Fig. 1
Fig. 2
Fig. 3
Fig. 4
1
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3
4
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6
7
8
9
10
11
31
32
33
34
35
36
37
38
INVENTOR
Chancy J. Britten
By Chappell & Earl
ATTORNEYS

US 2143437
Radiant Energy System

Abstract -- An apparatus for receiving and transmitting radiant energy within a wide range of frequencies without necessity of a source of local energy.

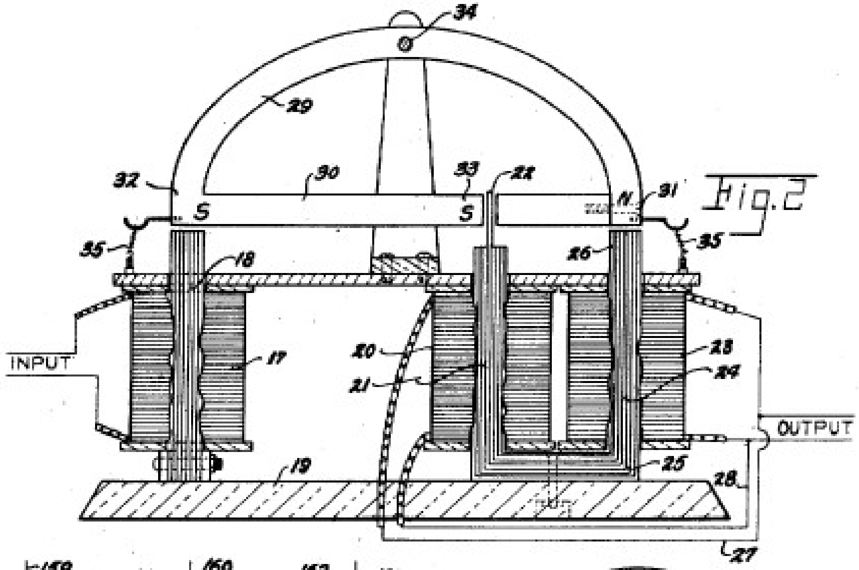
34
29
32
30
33
22
31
S
S
N
35
35
18
26
INPUT
17
20
21
23
24
OUTPUT
19
25
28
27

Fig. 2

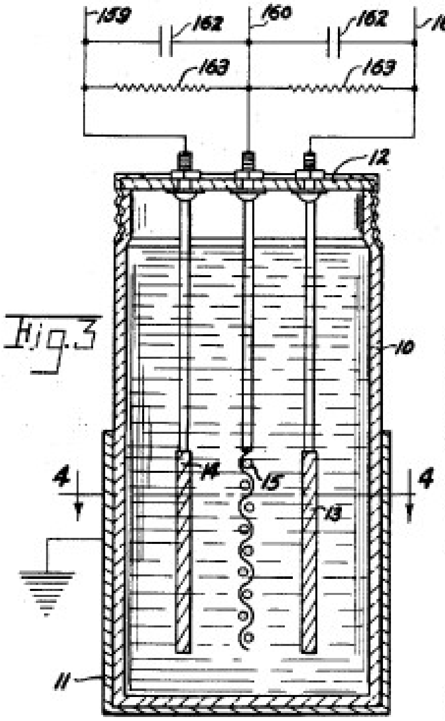
159
162
160
162
161
163
163
12
10
4
4
14
15
13
11

Fig. 3

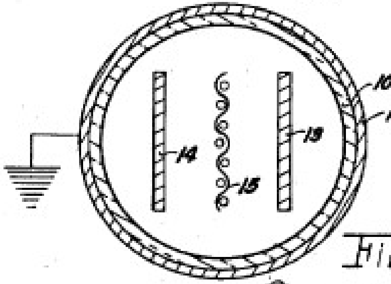
10
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13

Fig. 4

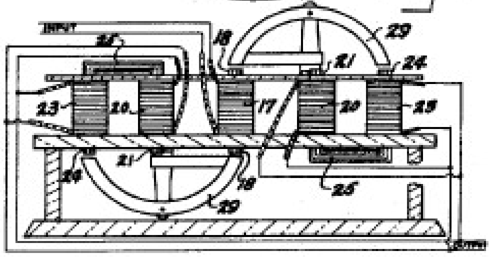
INPUT
22
18
29
21
24
23
20
17
20
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18
25
29
24

Fig. 9

Inventor

James Marion Fisher

By Murray & Zugelter

Attorney

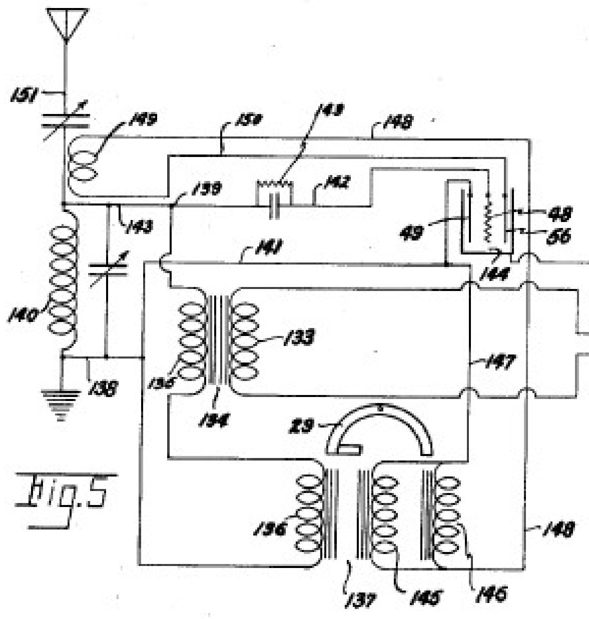
151
149
150
143
148
139
142
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49
48
56
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144
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147
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134
29
136
148
137
145
146

Fig.5

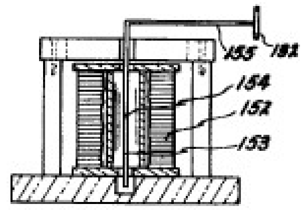
155
152
154
152
153

Fig.7

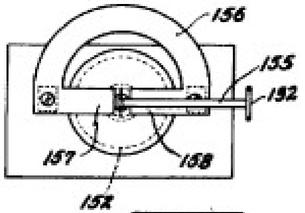
156
155
152
157
158
152

Fig.8

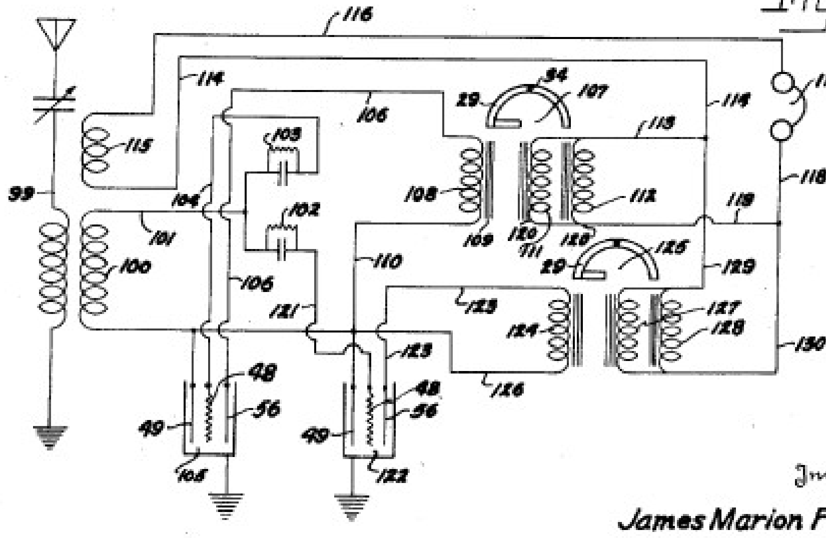
116
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111
125
129
110
106
29
121
123
127
124
128
123
130
126
48
56
49
105
48
56
49
122

Inventor

James Marion Fisher

US 2813242
Powering Electrical Devices with Energy Abstracted from the Atmosphere

Abstract -- A convenient and economical provision of power for the operation of electronic circuits and devices using transistors, and of other electrical devices hving modest power requirements.

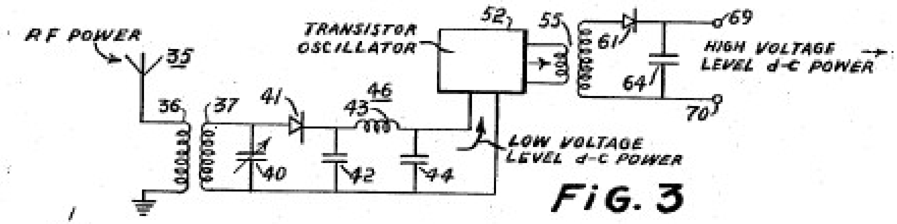
RF POWER
35
36
37
41
46
43
40
42
44
TRANSISTOR OSCILLATOR
52
55
61
69
64
70
HIGH VOLTAGE LEVEL d-C POWER
LOW VOLTAGE LEVEL d-C POWER

FiG. 3

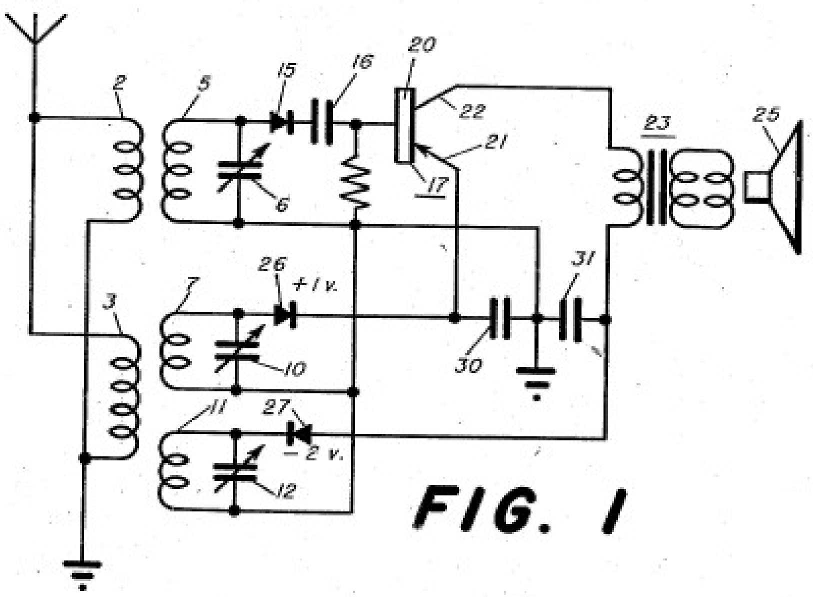
1
2
5
15
16
20
22
21
17
6
23
25
26
+1 v.
7
31
3
10
30
11
27
−2 v.
12

FIG. 1

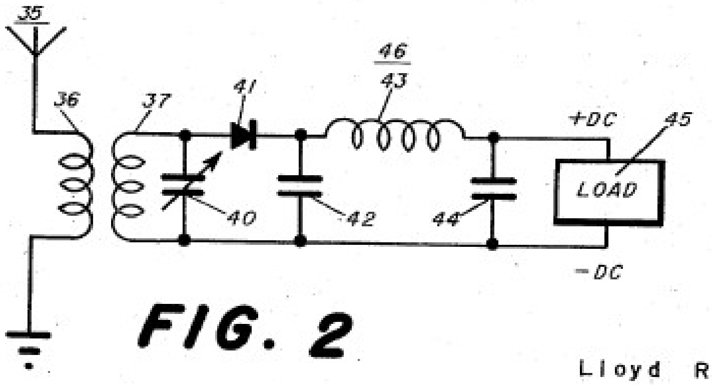
35
36
37
41
46
43
+DC
45
LOAD
40
42
44
−DC

FIG. 2

INVENTOR
Lloyd R. Crump

US 3205381
Ionospheric Battery

Abstract -- A method and apparatus for tapping the enormous reservoir of energy existing in the ionosphere...

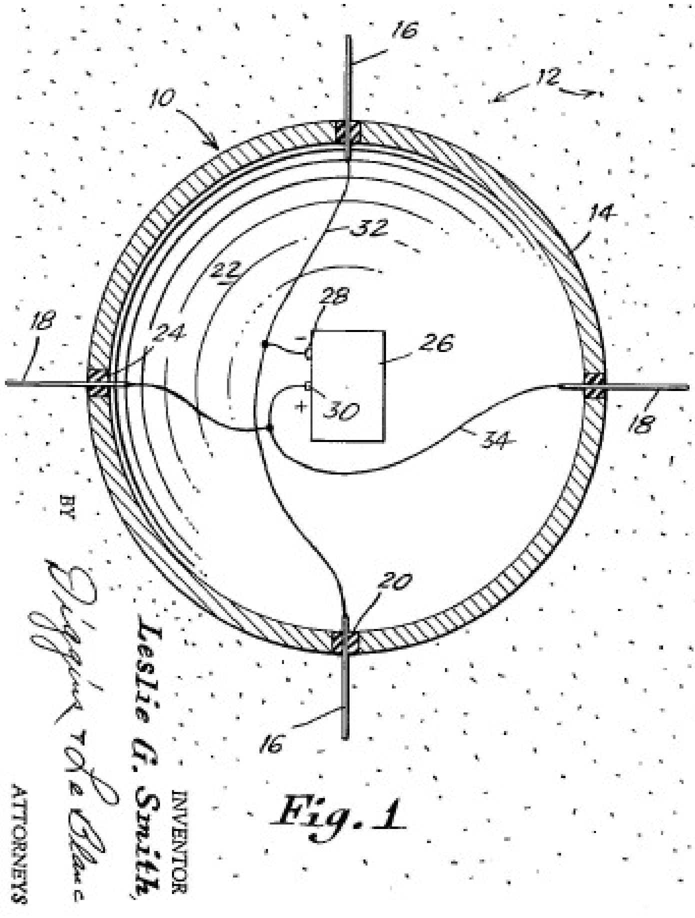
16
10
12
32
14
22
28
-
18
24
26
30
+
34
18
20
16
INVENTOR
Leslie G. Smith,
BY
ATTORNEYS

Fig. 1

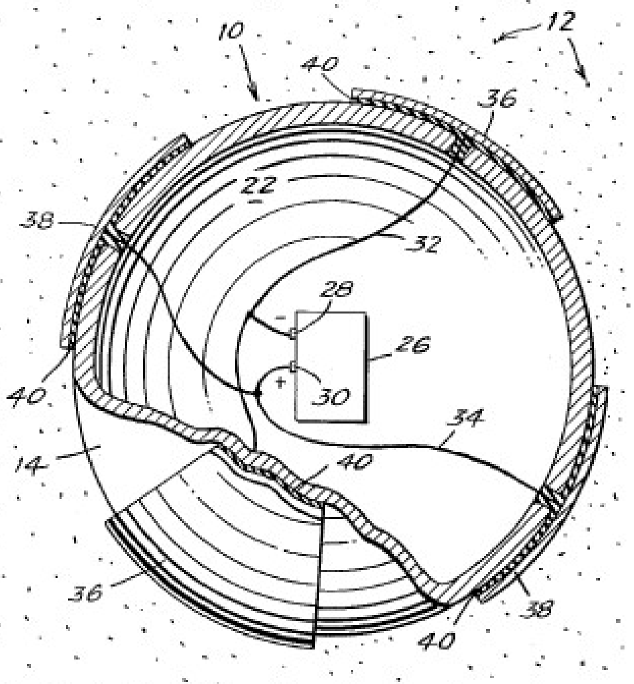
10
12
40
36
22
38
32
28
-
26
+
30
40
34
14
40
36
38
40

Fig. 2

US 3273066
Apparatus for Detecting Changes in the Atmospheric Electric Field

Abstract -- A cloud detector and or an apparatus for sensing electrostatic conditions in the earth's atmosphere...

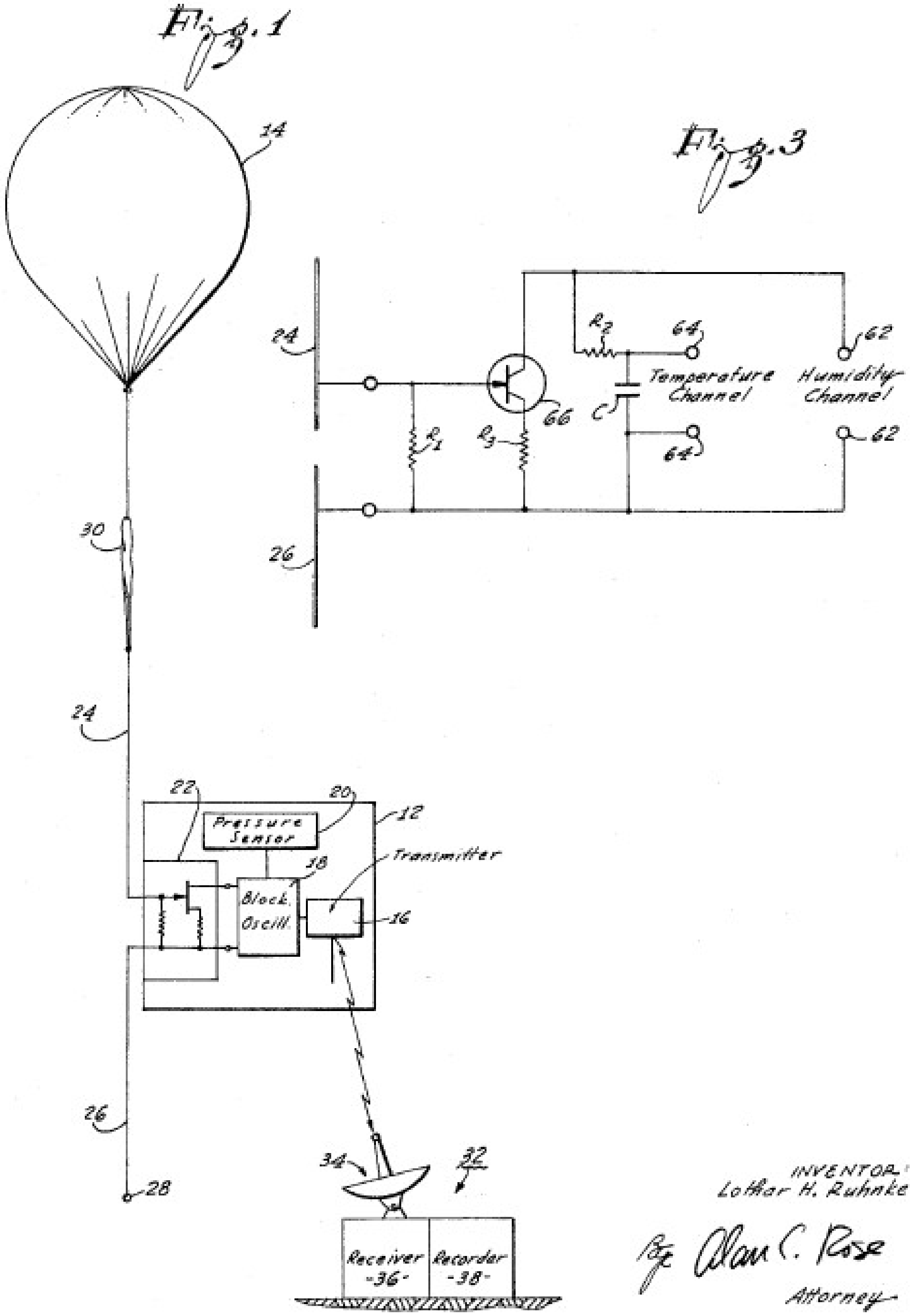
Fig. 1
14
30
24
22
20
12
Pressure Sensor
Transmitter
18
Block. Oscill.
16
26
28
34
32
Receiver -36-
Recorder -38-
Fig. 3
24
26
R2
64
62
R1
R3
66
C
Temperature Channel
Humidity Channel
64
62

INVENTOR:
Lothar H. Ruhnke

By Alan C. Rose
Attorney

US 3760257
EM Wave Energy Converter

Abstract -- Electromagnetic wave energy is converted into electric power with an array of mutually insulated electromagnetic wave absorber elements each responsive to an electric field component of the wave as it impinges thereon. Each element includes a portion tapered in the direction of wave propagation to provide a relatively wideband response spectrum. Each element includes an output for deriving a voltage replica of the electric field variations intercepted by it. Adjacent elements are positioned relative to each other so that an electric field subsists between adjacent elements in response to the impinging wave. The electric field results in a voltage difference between adjacent elements that is fed to a rectifier to derive d.c. output power. The element pairs may be arranged in a two-dimensional array to provide power conversion of randomly polarized electromagnetic waves, such as sunlight.

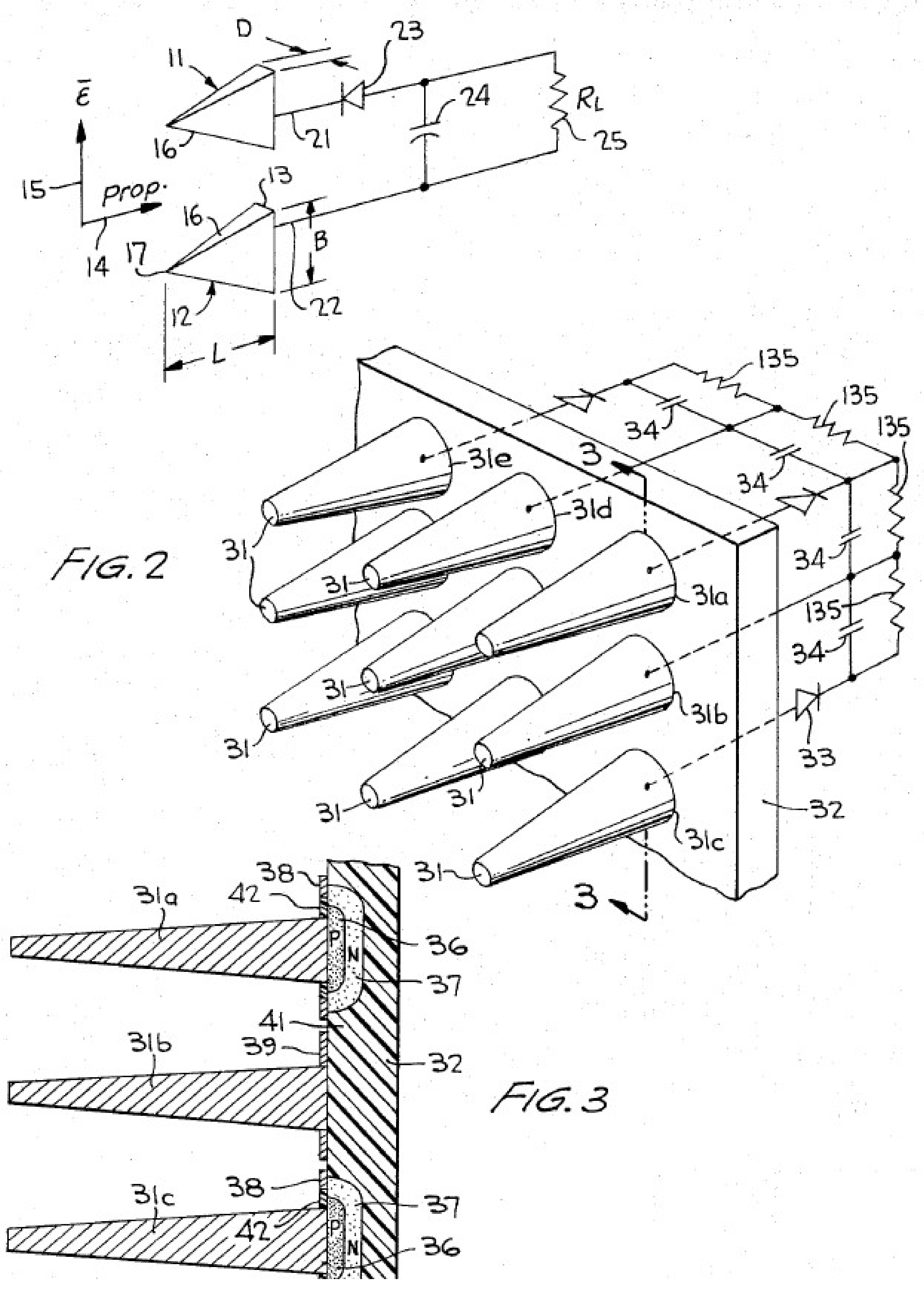

FIG. 1

FIG. 2

FIG. 3

D
23
11
Ē
24
R_L
16
21
25
15
Prop.
13
16
B
14
17
12
22
L
135
135
34
135
3
31e
34
31d
31
31
31a
34
135
31
34
31
31b
33
31
31
31
32
31c
31
38
31a
42
3
P
N
36
37
41
31b
39
32
38
31c
37
42
P
N
36

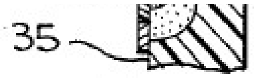

US 3931577
Radio Receiver Protection Arrangement

Abstract -- A receiver protection arrangement in which a voltage dependent on aerial voltage and a voltage dependent on aerial current are aggregated and applied to means responsive to a predetermined aggregate level to effectively short circuit the aerial lead. Additional means may be provided to dissipate energy in the input stage of a protected receiver to cause a reduced impedance to be reflected across the output of the protective arrangement.

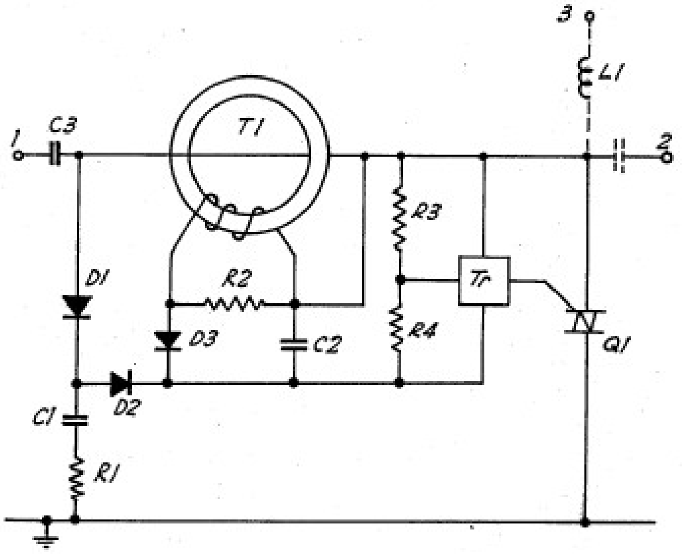

Fig. 1.

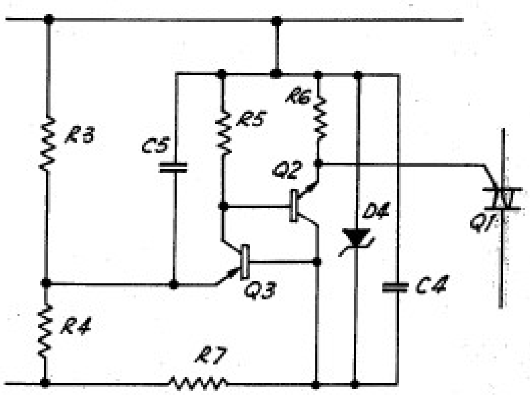

Fig. 2.

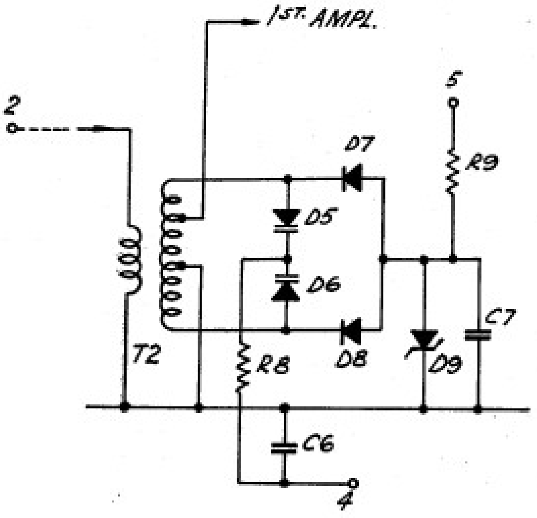
1ST. AMPL.
2
5
D7
R9
D5
D6
C7
T2
R8
D8
D9
C6
4

Fig. 3.

US 4,628,299
Seismic Warning System Using RF Energy Monitor

Abstract -- The ambient broadband radio frequency field strength from broadcast stations is monitored (Figure 4) by periodic sampling (50, 52). A warning indication is provided if the field strength drops significantly. Drops in such field strength have been correlated empirically with the occurrence of seismic activity, usually several days later. Thus the indication serves as an early warning of an impending earthquake. In one preferred embodiment, a broadband, horizontal, very long monopole antenna (40) was connected to a rectifying and smoothing circuit (Figure 3) to provide a dc output proportional to the ambient rf field...

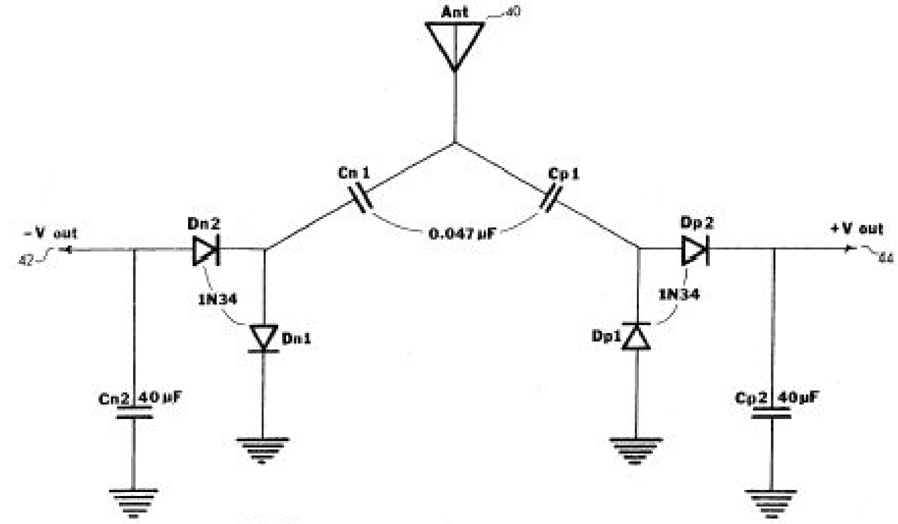
Ant
40
Cn 1
Cp 1
0.047 µF
-V out
42
Dn2
Dp 2
+V out
44
1N34
Dn1
1N34
Dp1
Cn2 40 µF
Cp2 40µF

FIG 3

Your Support Maintains this Service --

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Ensure & Enhance Your Survival & Genome Transmission ...
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Fig. 1

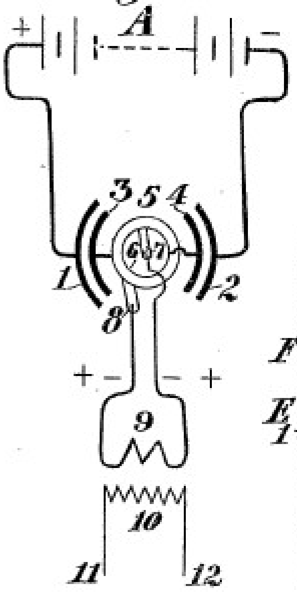
+
A
−
3
5
4
6
7
1
2
8
+
−
−
+
9
10
11
12

Fig. 3

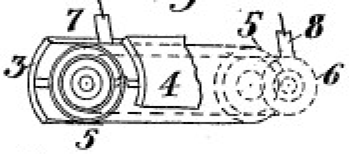

Fig. 2

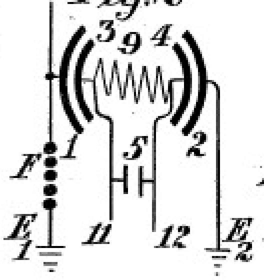
3
9
4
1
2
F
5
E
1
11
12
E
2

Fig. 4

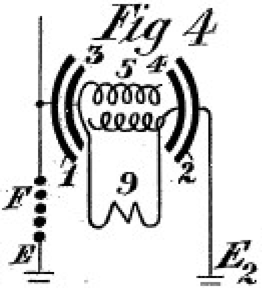
3
5
4
1
2
F
9
E
E
2

Fig. 5.

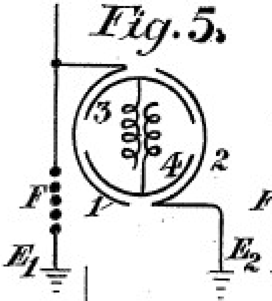

Fig. 6.

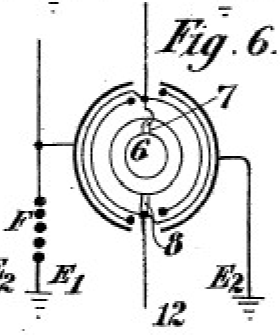
7
6
F
8
E1
E2
12

Fig. 7.

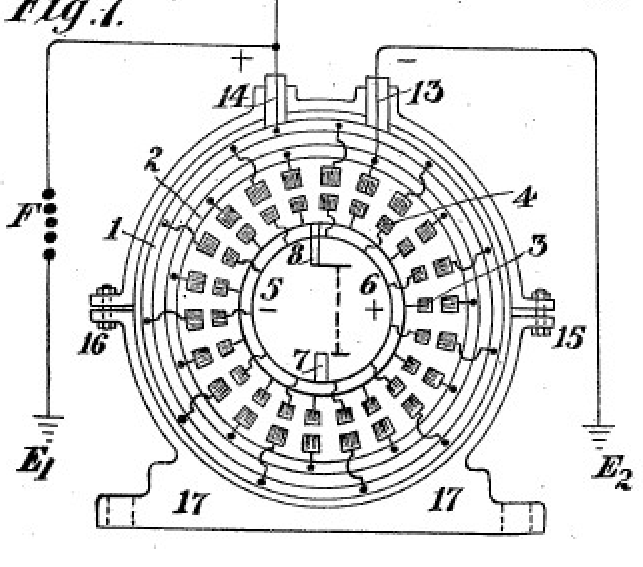
+
−
14
13
2
4
1
F
3
8
5
6
−
+
16
15
7
E1
E2
17
17

Fig. 8

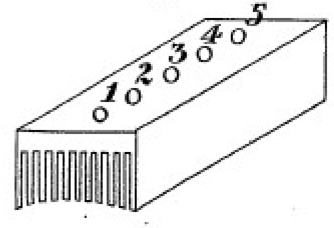

Fig. 10

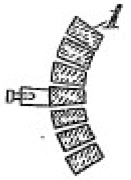

Fig. 9.

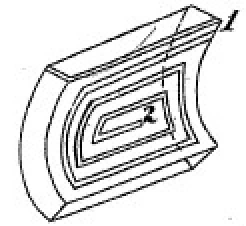

Fig. 11

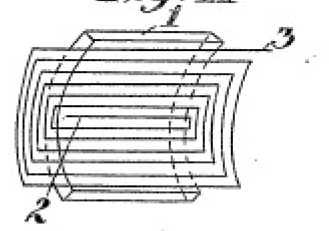

Fig. 12

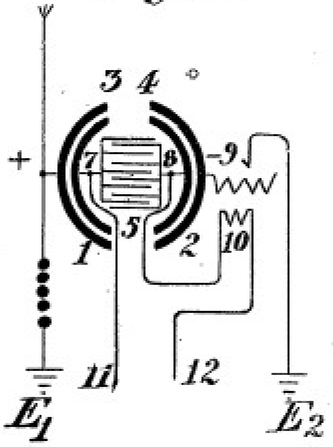
+
3
4
7
8
9
10
1
5
2
11
12
E1
E2

Fig. 13.

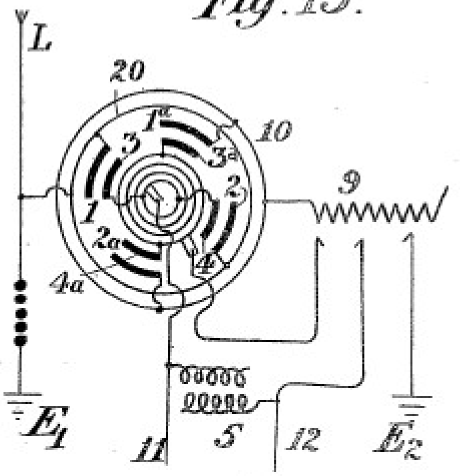
L
20
1a
10
3
3a
2
9
1
2a
4
4a
5
11
12
E1
E2

Fig. 14

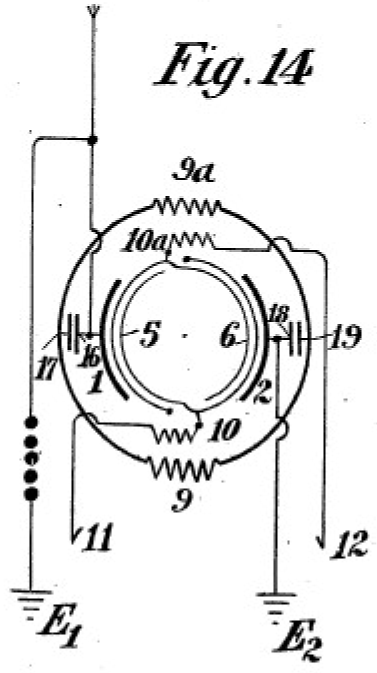
9a
10a
5
6
18
19
17
16
1
2
10
9
11
12
E1
E2

Fig. 16

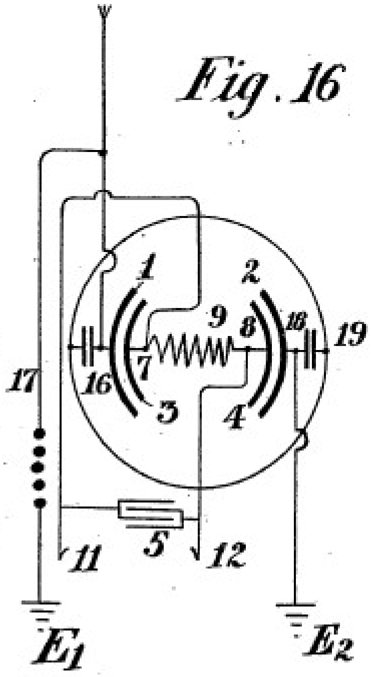
1
2
9
8
18
19
17
16
7
3
4
5
11
12
E1
E2

Fig. 15

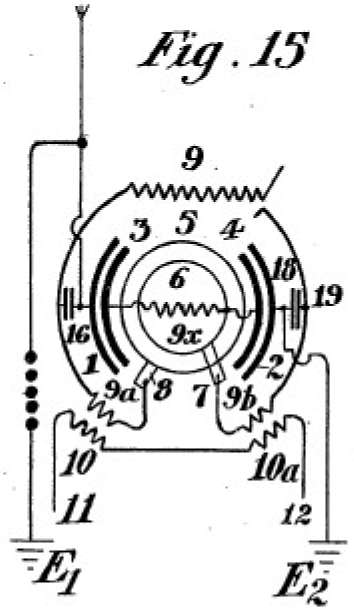
9
3
5
4
6
18
19
16
9x
1
2
9a
8
7
9b
10
10a
11
12
E1
E2

Fig. 17

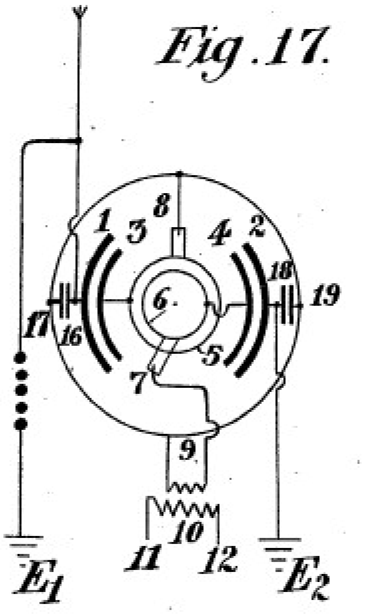
1
3
8
4
2
18
19
17
16
6
5
7
9
10
11
12
E1
E2

French Patent # 551,882
Apparatus for Capture of Electric Currents in the Atmosphere

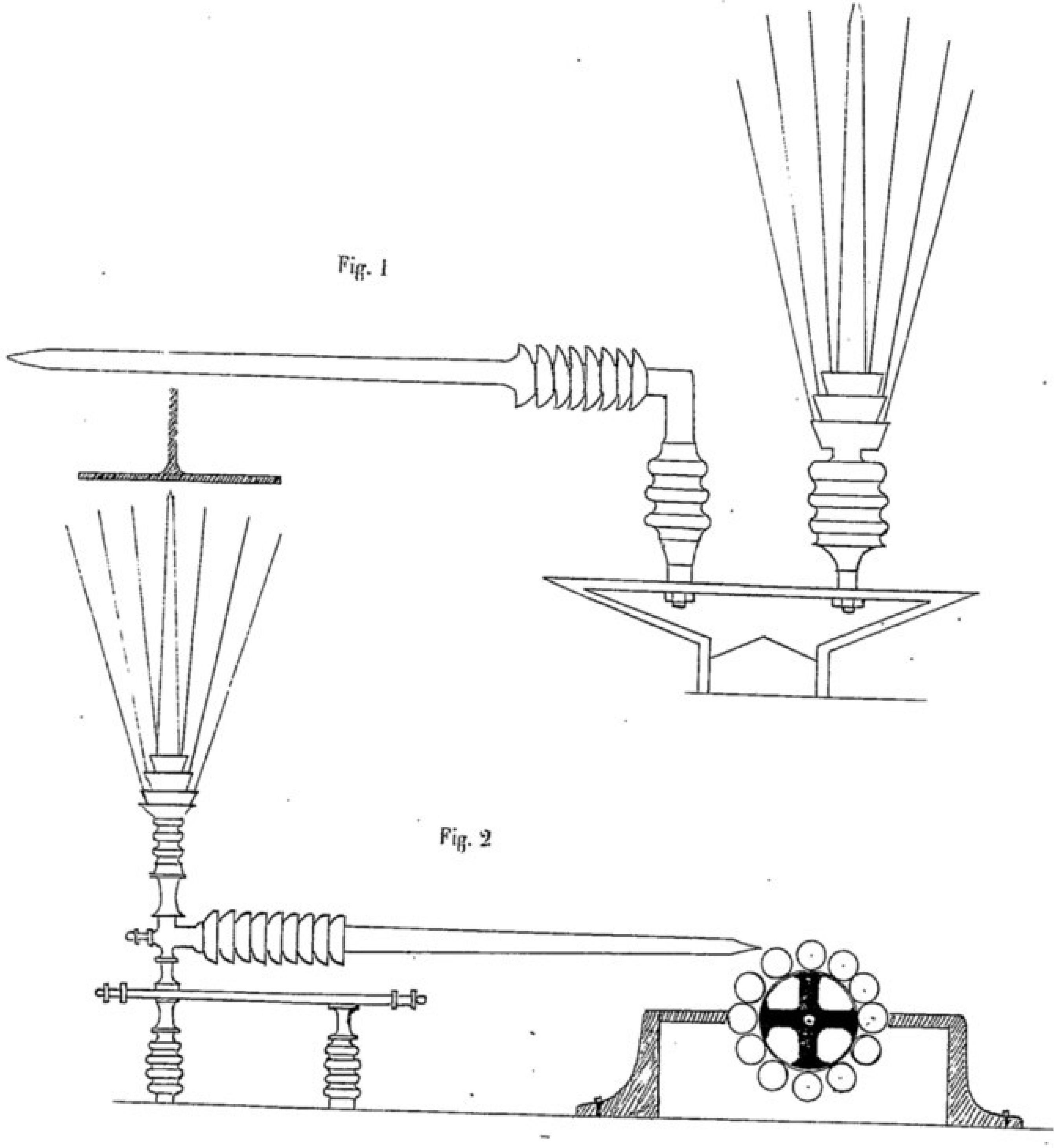

Fig. 1

Fig. 2

French Patent # 565,395

Combined Apparatus for Capture of Atmospheric Electric Currents with Immediate Implementation

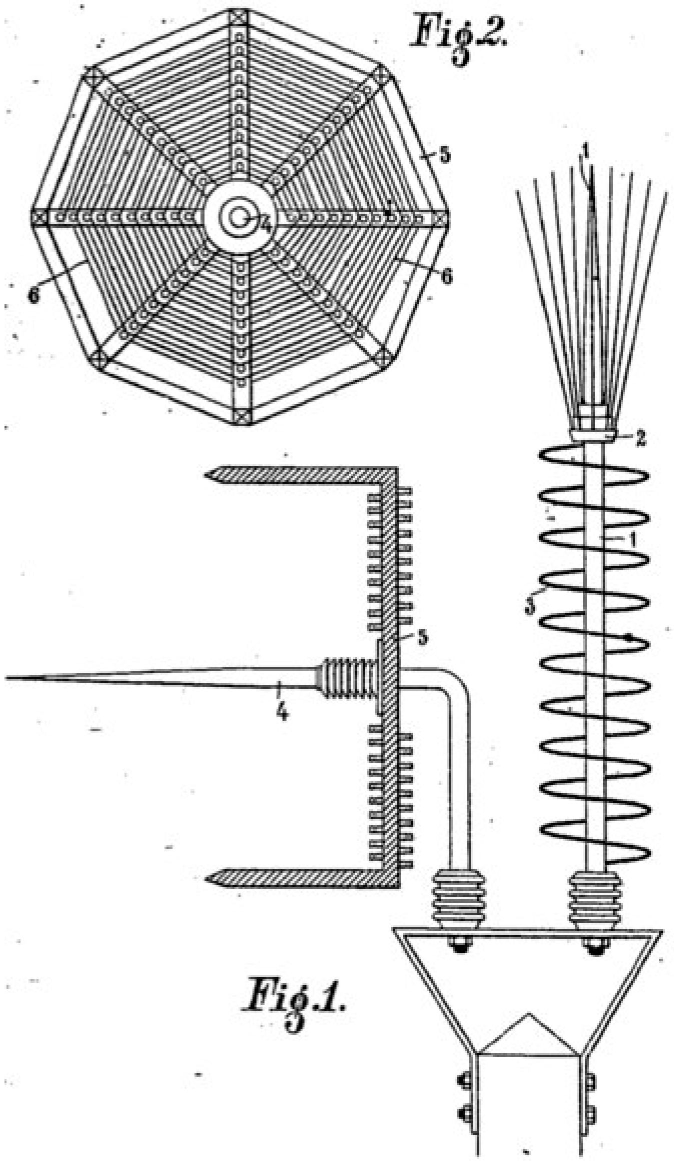
5
4
4
6
6
1
2
1
3
5
4

Fig. 2.

Fig. 1.

Fig. 3.

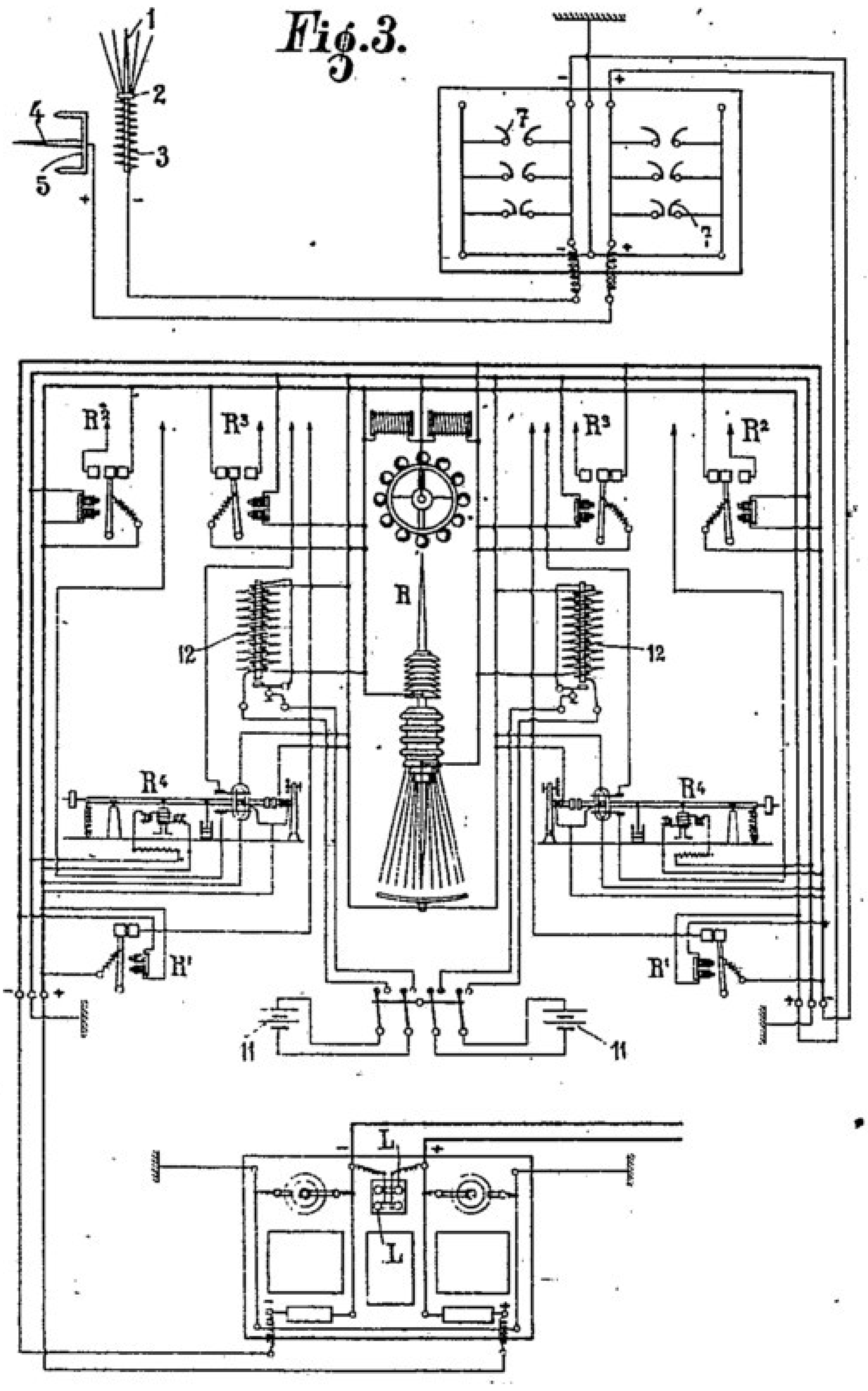
1
2
3
4
5
+
-
7
7
R²
R³
R³
R²
R
12
12
R⁴
R⁴
R'
R'
11
11
L
L
-
+

Fig. 4.

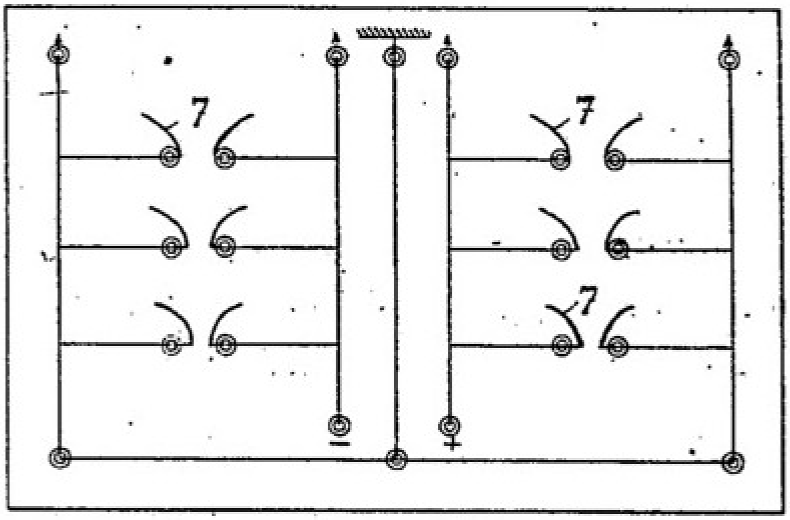

Fig. 5.

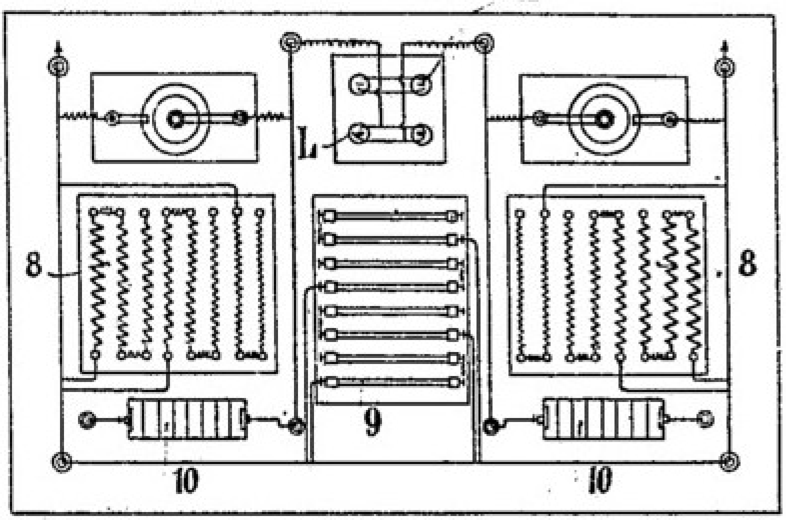

US 28793
Electric Apparatus

Abstract -- An aerostat for obtaining atmpspheric and terrestrial electricity...

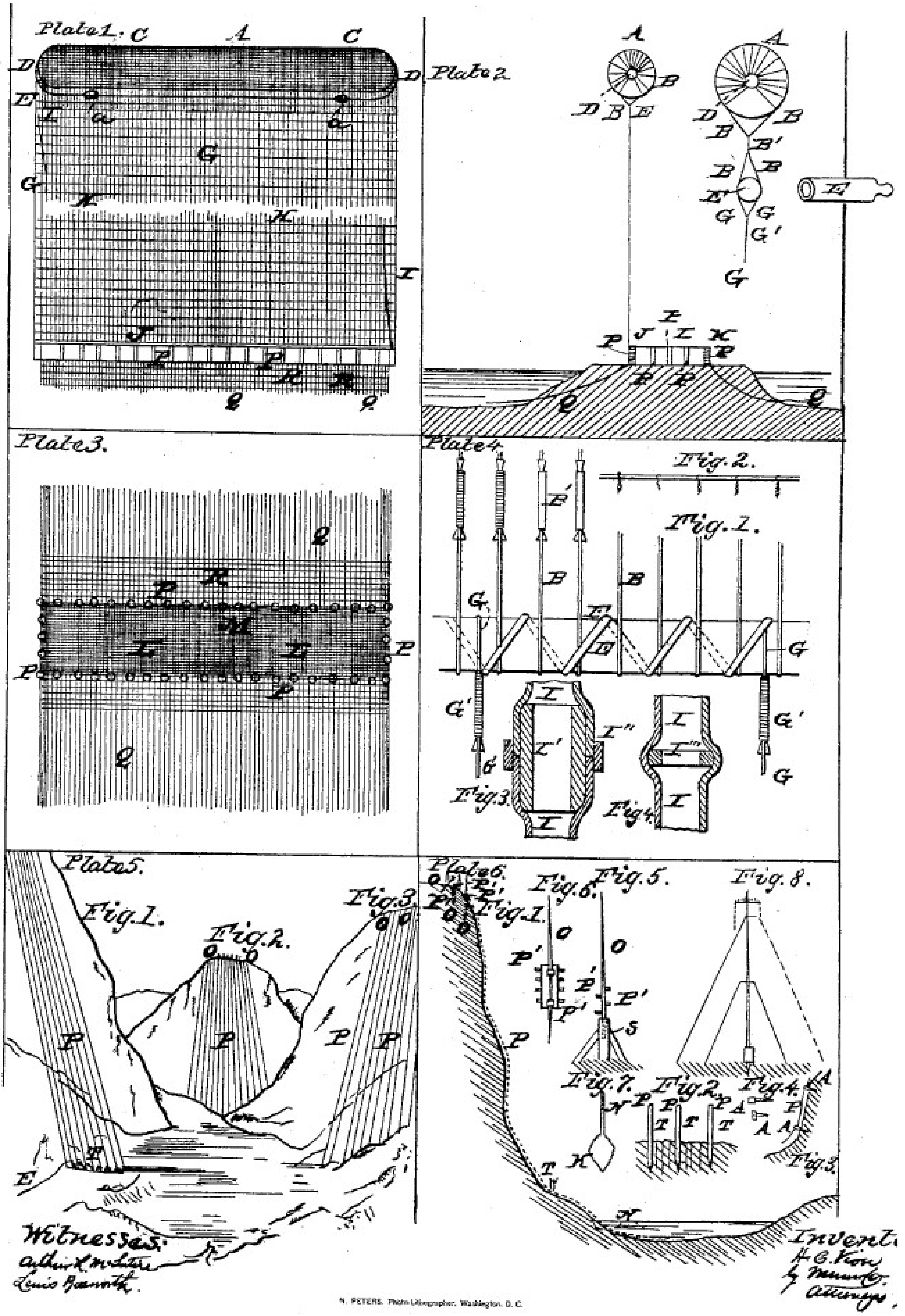
Plate 1.
A
C
D
E
a
G
H
I
J
P
R
Q
Plate 2
B
D
E
B'
G
G'
J
K
L
Plate 3.
Q
R
P
M
L
Plate 4
Fig. 2.
Fig. 1.
E'
B
G
G'
Fig. 3.
Fig. 4.
I
I'
I''
Plate 5.
Fig. 1.
Fig. 2.
Fig. 3.
P
E
Plate 6.
Fig. 1.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 2.
Fig. 4.
Fig. 3.
O
P'
P
S
N
K
T
A
Witnesses:
Inventor
H. G. Kow
by Munn & Co.
Attorneys.
N. PETERS. Photo-Lithographer, Washington, D. C.

US 126356
Improvement in Collecting Energy for Telegraph

Abstract -- A tower for the purpose of receiving and imparting natural electricity, so as to be in constant contact with the upper stratum of electricity which surrounds the earth, by tapping which a never-failing supply is formed when brought into contact with the earth.

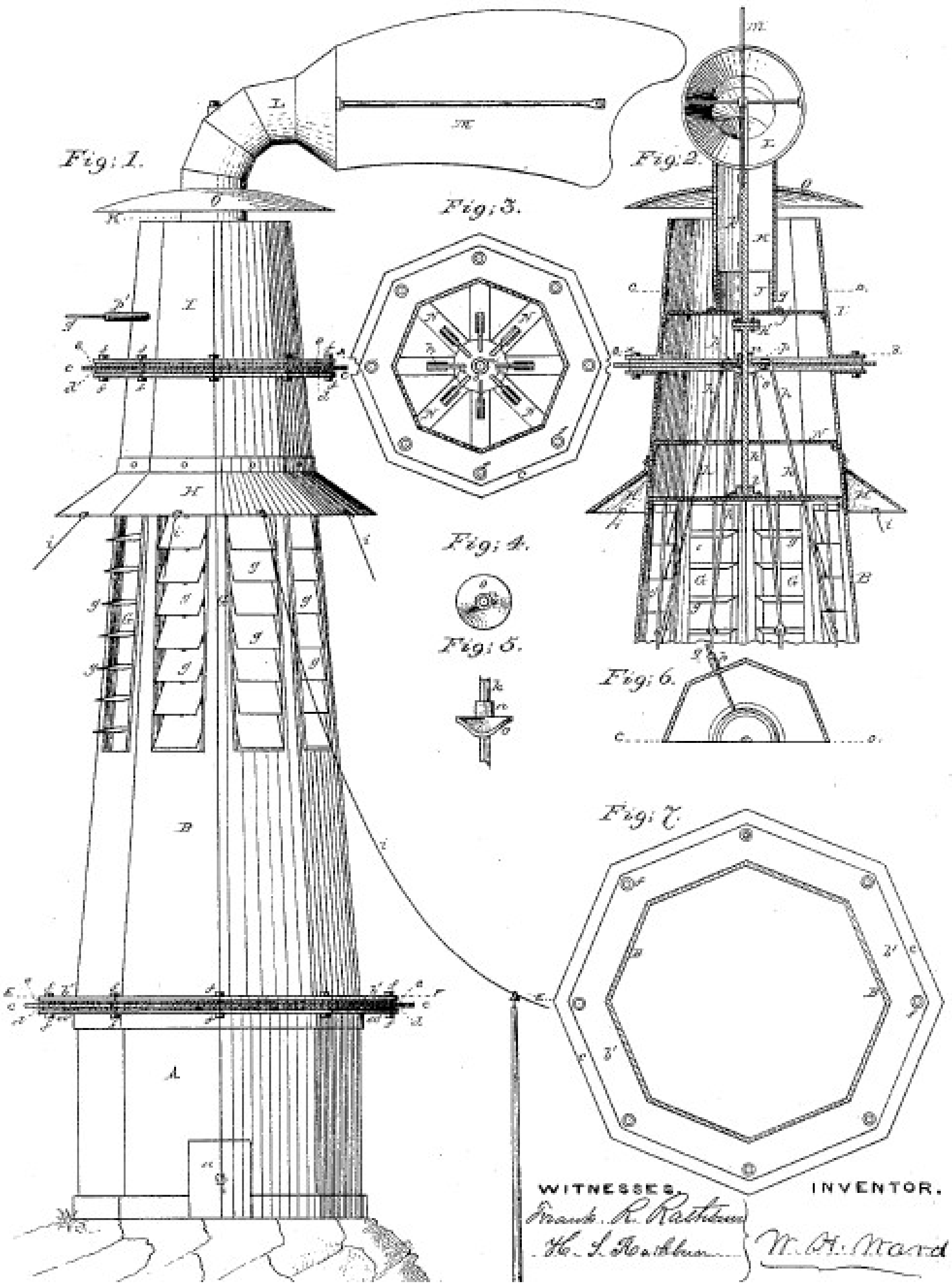
Fig: 1.
Fig: 2.
Fig: 3.
Fig: 4.
Fig: 5.
Fig: 6.
Fig: 7.
WITNESSES.
INVENTOR.
W. H. Ward

US 129971
Telegraph Power

Abstract -- Utilizing natural electricity and establishing an electrical current without the aid of wires, batteries, or cables...

US 674427
Collecting Atmospheric Electricity

Abstract -- An appartus for colecting and driving or conducting atmospheric electricity which renders it practicable to obtain material quantities of teh same in serviceable form.

Fig:1.

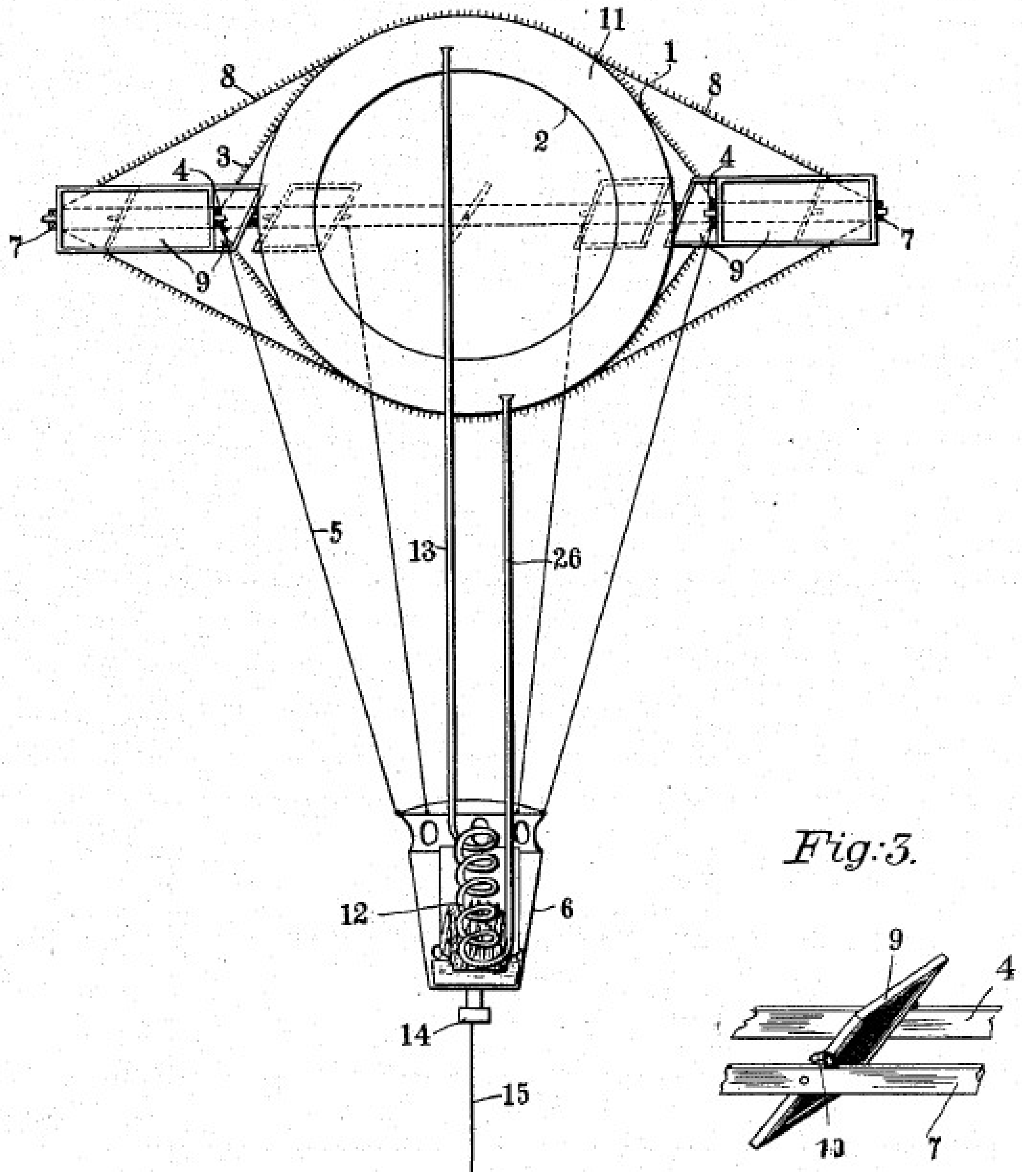

Fig:3.

Fig: 2.

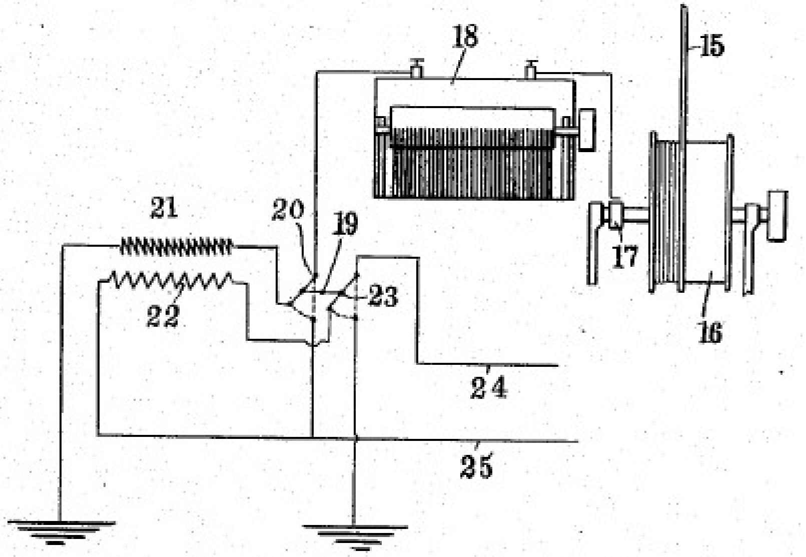

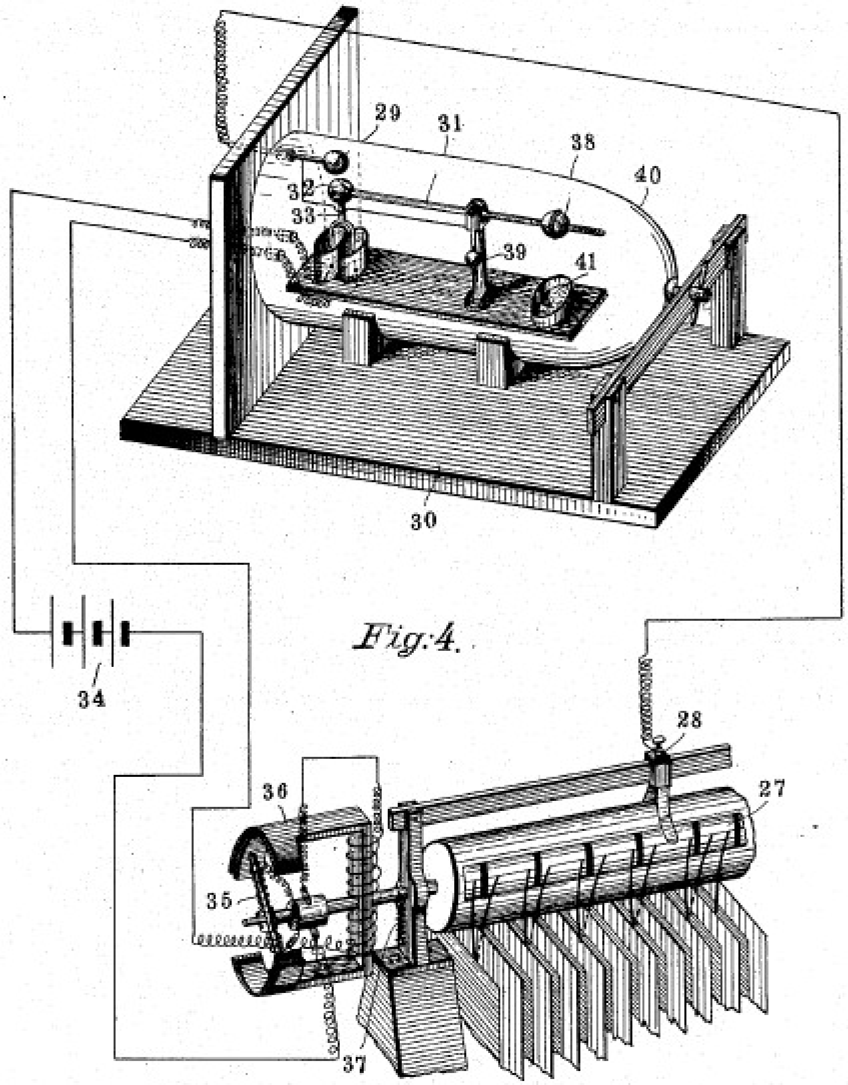

Fig: 4.

US 911260
Collecting Atmospheric Electricity

Abstract -- A method of colecting electricity from a strata laden with electricity at high altitudes in the atmoshere, through the medium of a wire cable suspended from one or more balloons ...

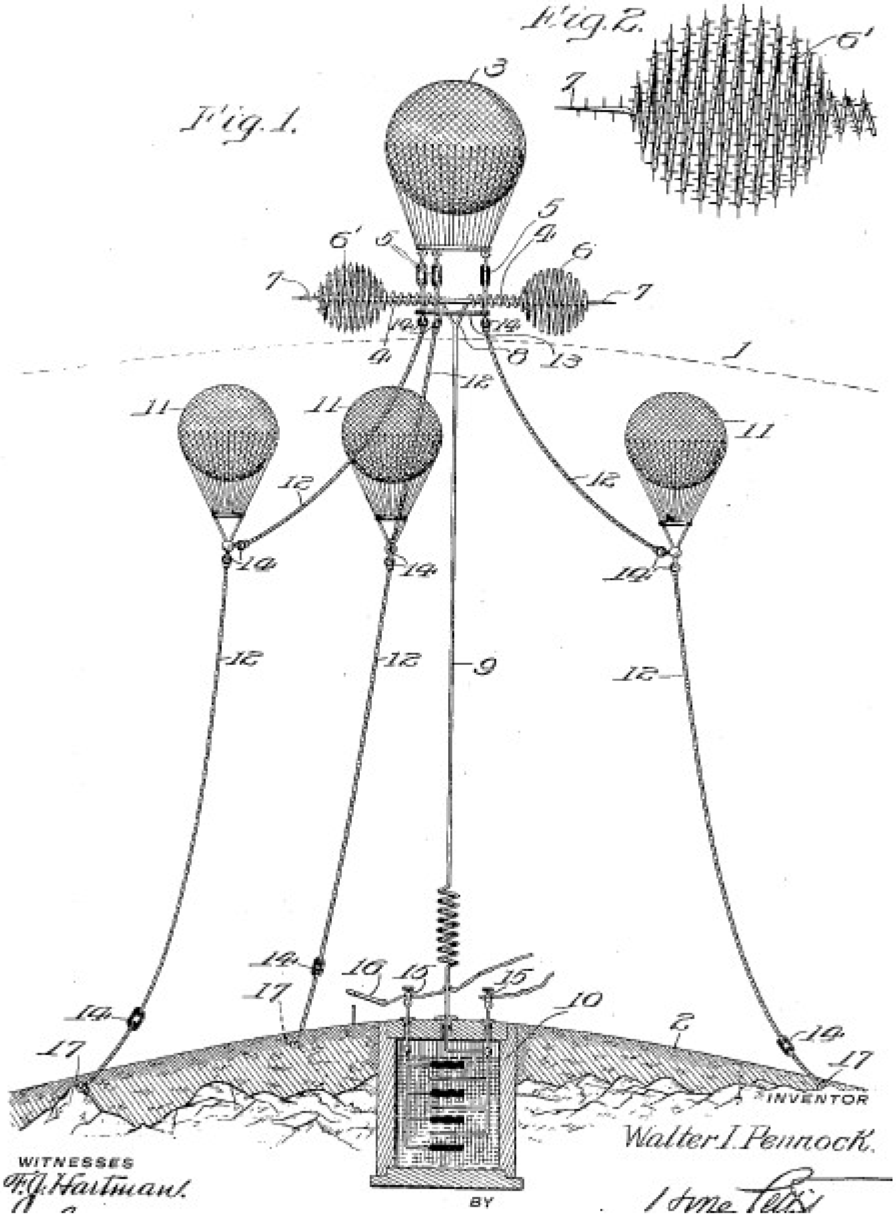
Fig. 2.
6'
7
3
Fig. 1.
6'
5
5
4
6
7
7
14
14
8
13
1
12
11
11
11
12
12
14
14
14
12
12
9
12
14
16
15
15
10
2
17
17
14
17
INVENTOR
Walter I. Pennock.
WITNESSES
F. J. Hartman.
BY

US 1014719
Collecting Atmospheric Electricity

Abstract -- A method of colecting electricity from a strata laden with electricity at high altitudes in the atmoshere, through the medium of a wire cable suspended from one or more balloons ...

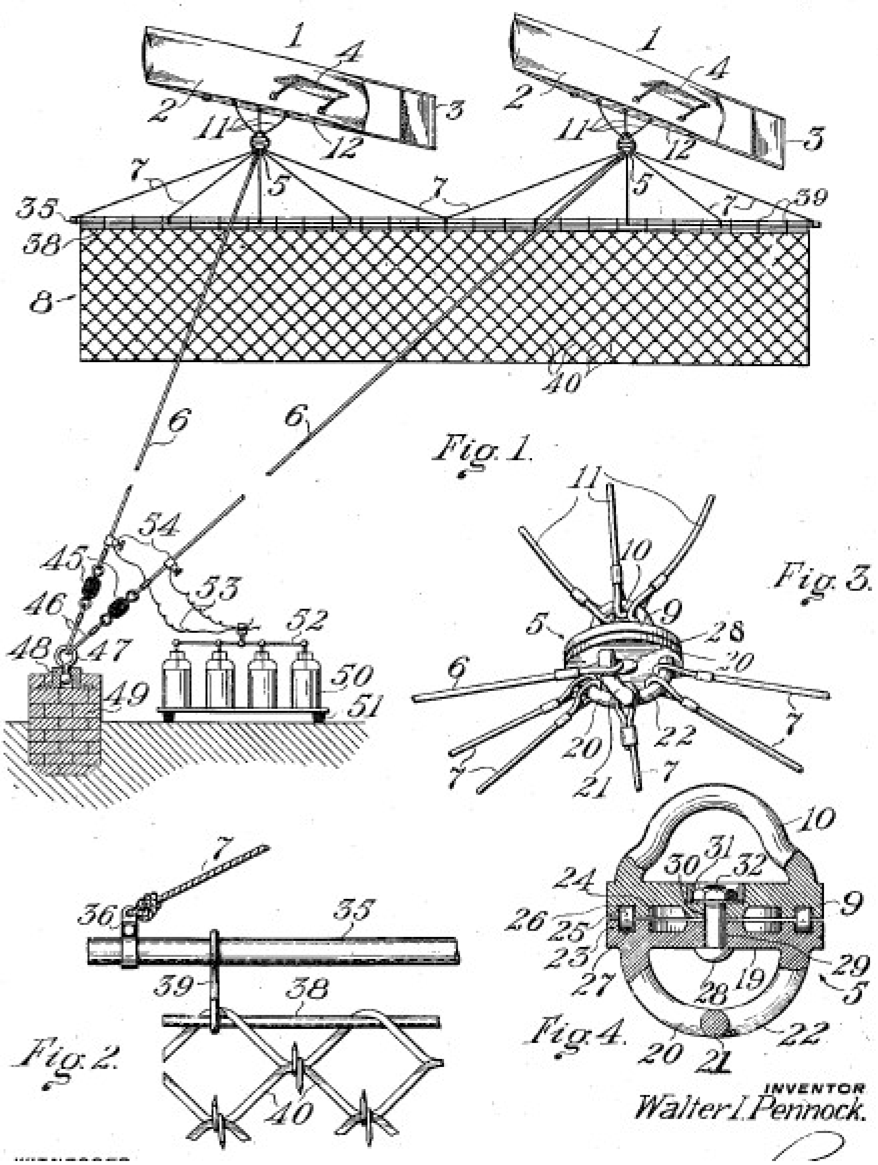
1
2
3
4
11
12
5
7
35
38
39
8
40
6
45
46
48
47
49
54
53
52
50
51
10
9
28
20
22
21
36
24
26
25
23
27
30
31
32
19
29
INVENTOR
Walter I. Pennock.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

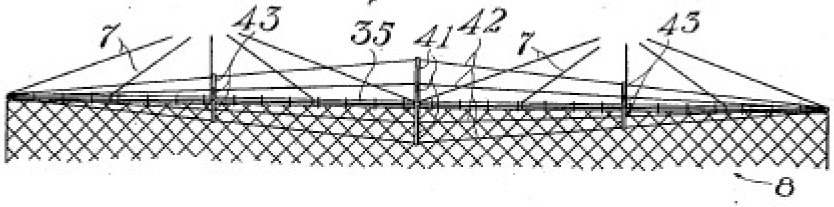
7
43
35
41
42
7
43
8

Fig. 6.

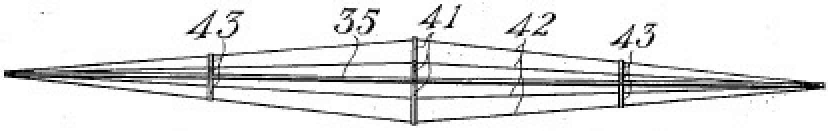
43
35
41
42
43

Fig. 7.

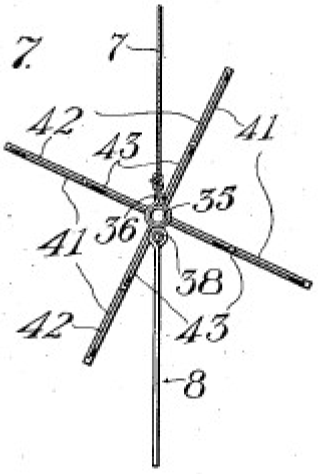
7
42
41
43
35
36
41
38
42
43
8

INVENTOR
Walter I. Pennock.

US 1540998
Conversion of Atmospheric Electric Energy

Abstract -- Method of obtaining atmospheric electricity by means of metallic ballon collectors...

Filed Jan. 15, 1921 12 Sheets-She

Fig. 1.

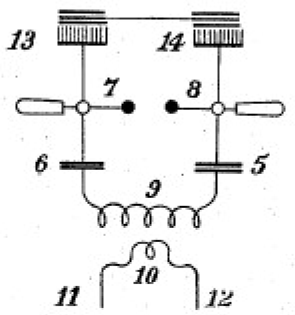
13
14
7
8
6
5
9
10
11
12

Fig. 2.

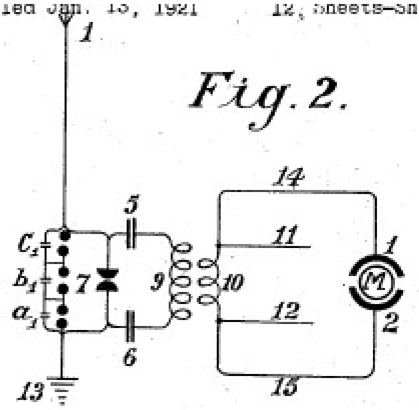
1
14
5
11
1
C_1
b_1
7
9
10
M
a_1
12
2
6
13
15

Fig. 3.

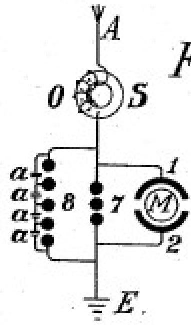
A
0
S
1
a
a
8
7
M
a
a
2
E.

Fig. 4.

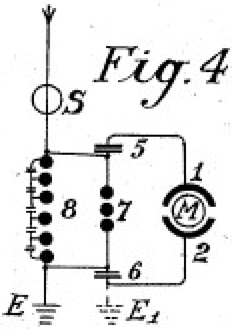
S
5
1
8
7
M
2
6
E
E_1

Fig. 5.

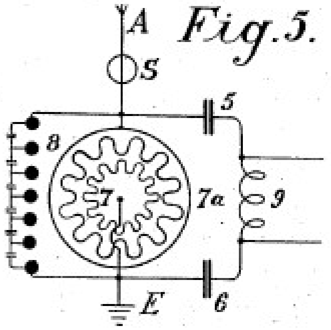
A
S
5
8
7
7a
9
E
6

Fig. 6

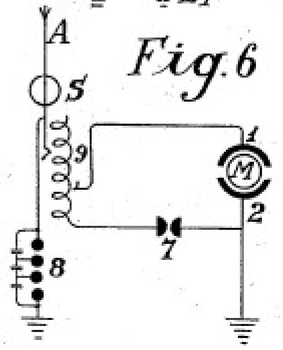

Filed Jan. 13, 1921 12 Sheets-Sheet 2

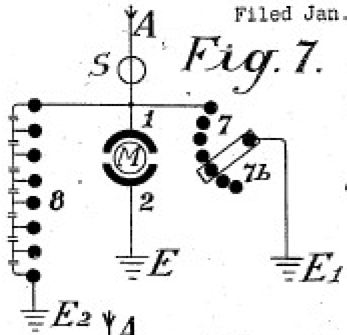
A
S
1
M
2
E
7
7b
E1
8
E2

Fig. 7.

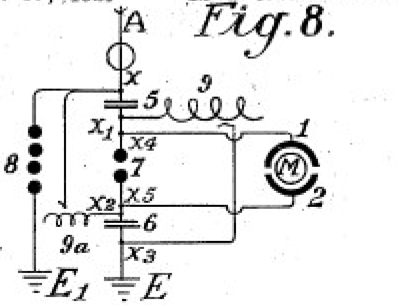
A
X
5
9
X1
X4
7
1
M
2
8
X5
X2
6
9a
X3
E1
E

Fig. 8.

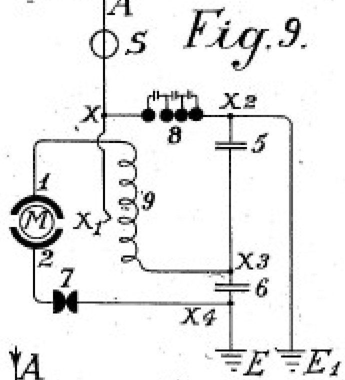
A
S
X
8
X2
5
1
M
X1
9
2
X3
7
6
X4
E
E1

Fig. 9.

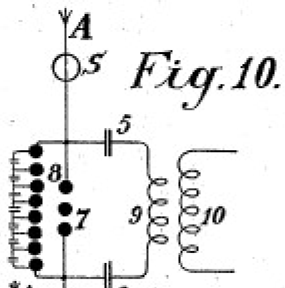
A
S
5
8
7
9
10
6
E

Fig. 10.

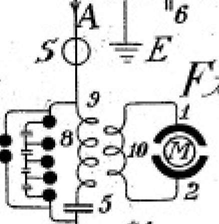
A
S
9
7
8
10
1
M
2
5
E

Fig. 11.

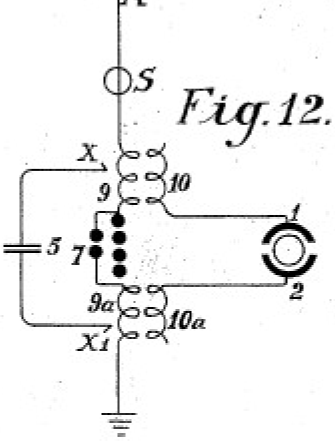
A
S
X
9
10
1
5
7
2
9a
10a
X1

Fig. 12.

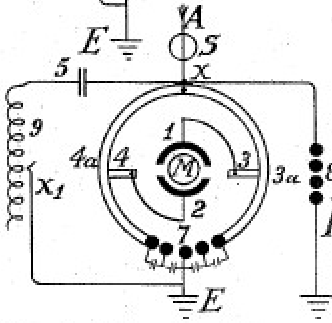
A
S
X
5
9
1
4a
4
M
3
3a
8
X1
2
7
E

Fig. 13.

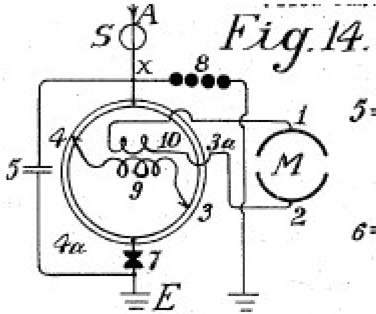
A
S
X
8
1
4
10
3a
M
5
9
3
2
4a
7
E

Fig. 14.

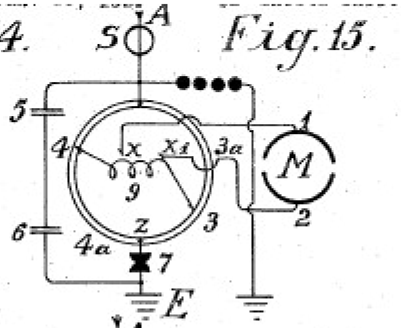
A
S
5
1
4
X
X1
3a
M
9
3
2
6
Z
4a
7
E

Fig. 15.

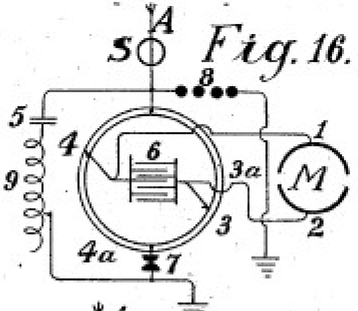
A
S
8
5
1
4
6
3a
M
9
3
2
4a
7

Fig. 16.

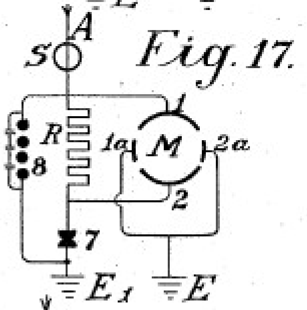
A
S
1
R
1a
M
2a
8
2
7
E1
E

Fig. 17.

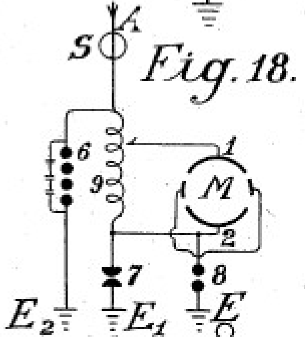
A
S
1
6
M
9
2
7
8
E2
E1
E

Fig. 18.

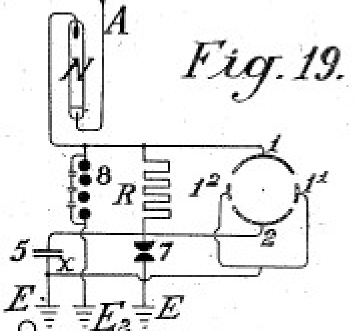
A
N
1
8
R
1²
1¹
2
5
X
7
E
E2
E

Fig. 19.

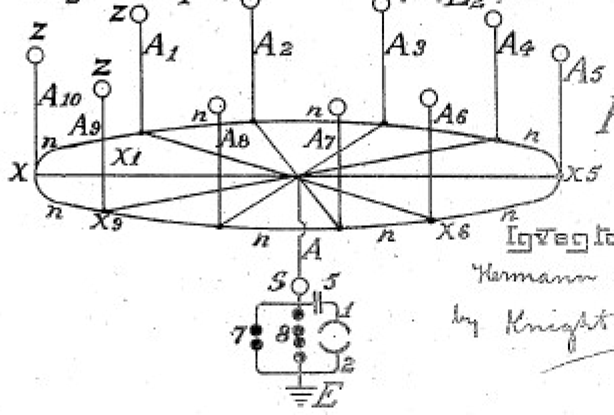
Z
Z
Z
A1
A2
A3
A4
A5
A10
A9
n
A8
n
A7
A6
n
n
X
X1
X5
n
X9
n
X6
n
n
A
S
5
7
8
1
2
E

Fig. 20.

Inventor
Hermann Plauson
by Knight Bros
Attorneys

Fig. 21. Fig. 22.

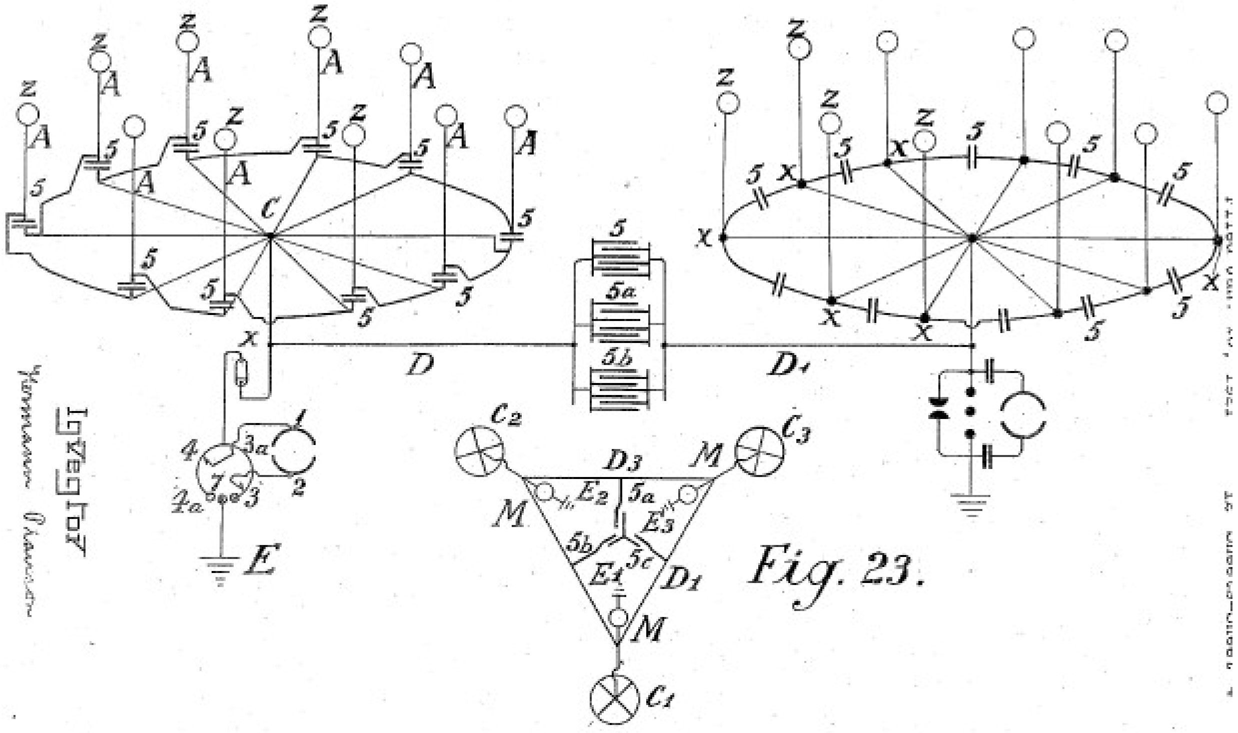
Z
A
5
C
X
D
D1
5a
5b
1
2
3
3a
4
4a
7
E
C2
C3
C1
M
D3
E2
E3
E1
5c
Inventor
Hermann Plauson

Fig. 23.

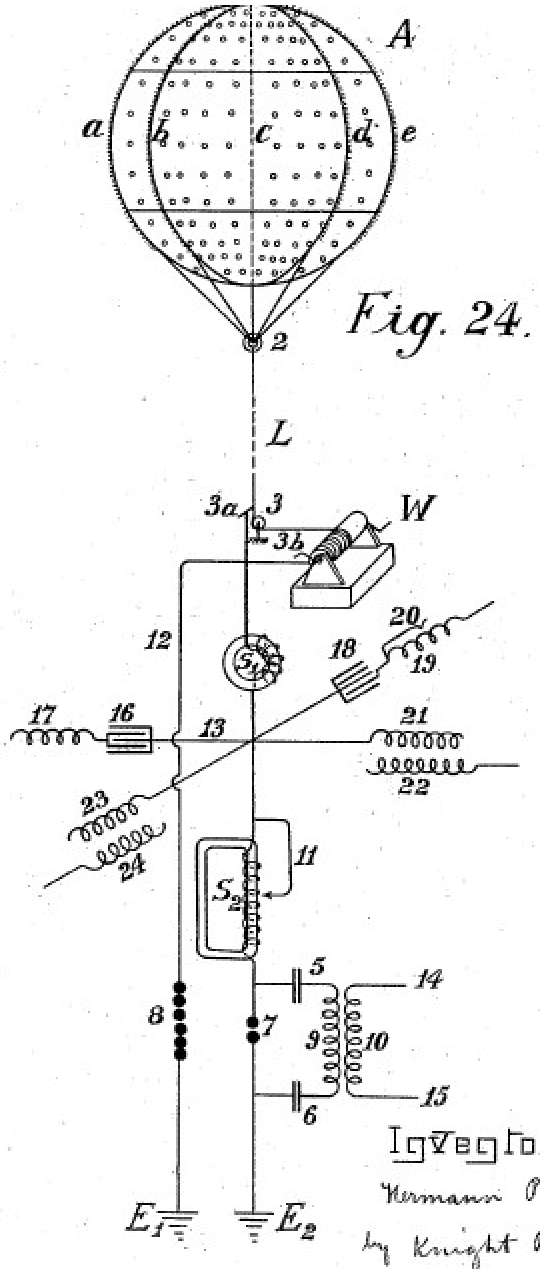

Fig. 24.

A
a
b
c
d
e
2
L
3a
3
3b
W
12
S_1
18
20
19
17
16
13
21
22
23
24
11
S_2
5
14
8
7
9
10
6
15
E_1
E_2
Invento
Hermann
by Knight

Fig. 25.

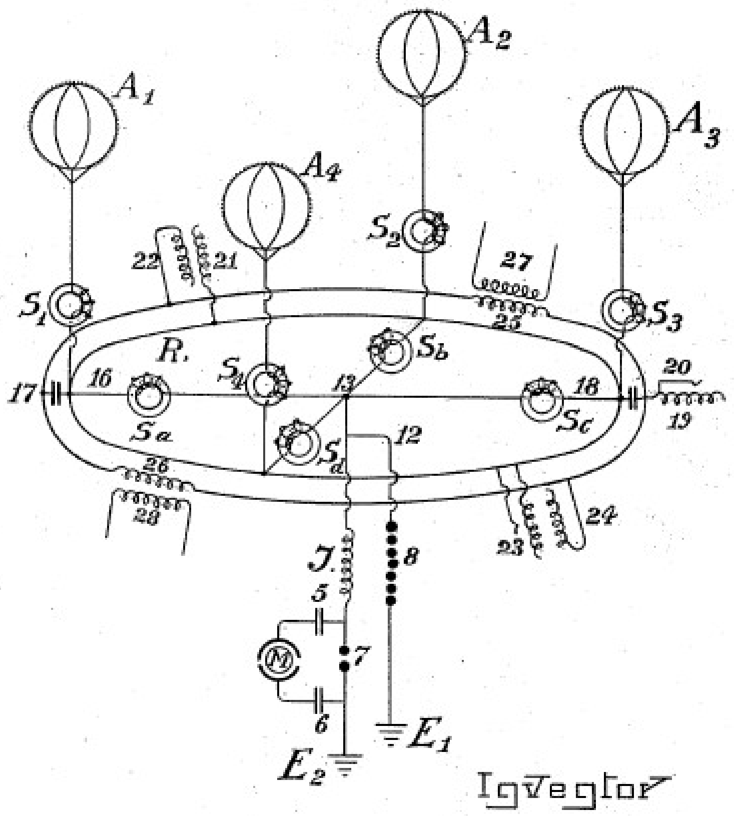
A1
A2
A3
A4
S1
S2
S3
S4
Sa
Sb
Sc
Sd
R.
5
6
7
8
12
13
16
17
18
19
20
21
22
23
24
25
26
27
28
J.
M
E1
E2

Inventor

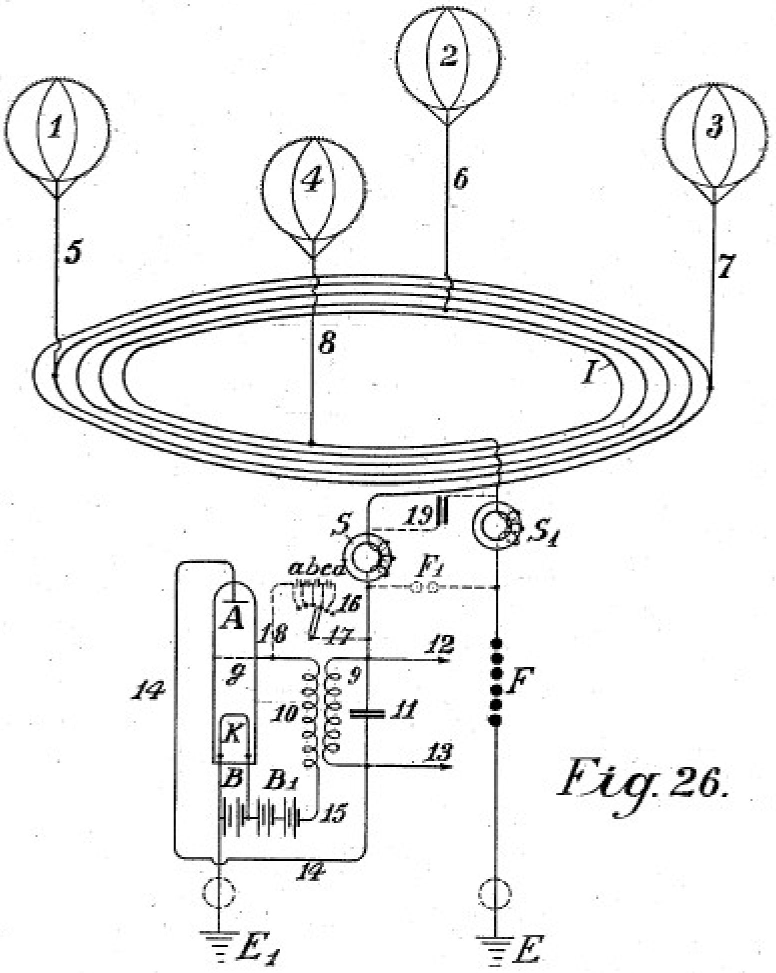
I
S
S1
abcd
F1
A
g
K
F
B
B1
E1
E

Fig. 26.

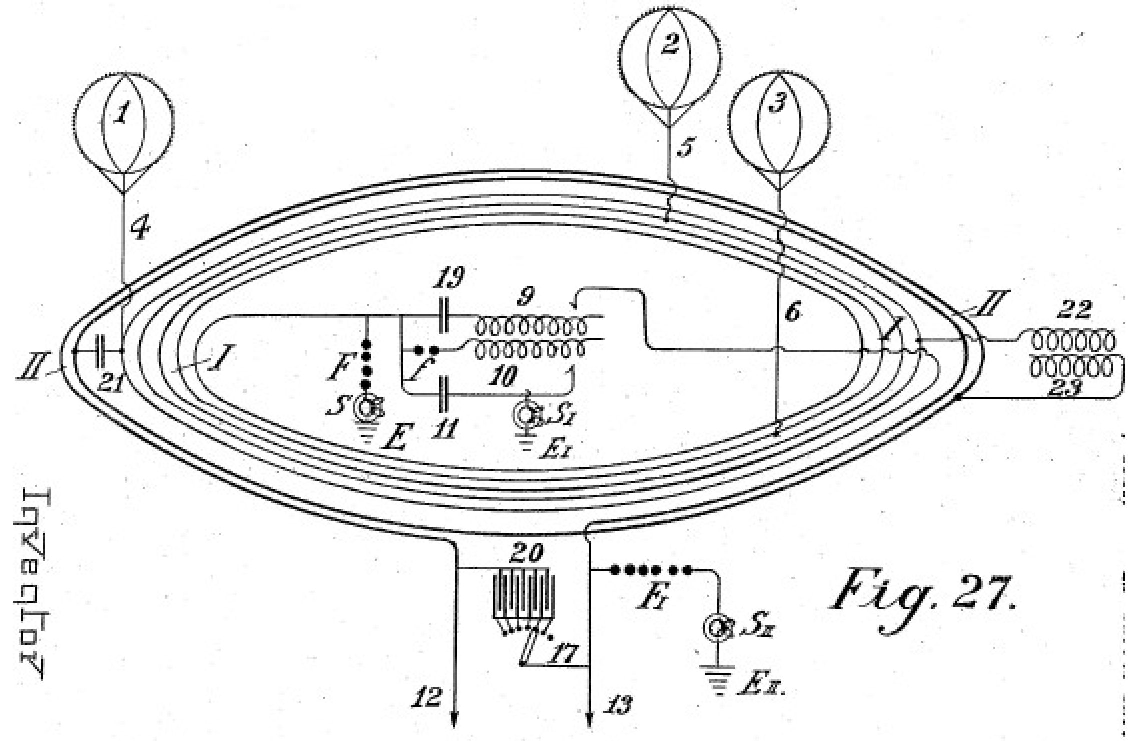
2
1
3
5
4
II
21
I
19
9
F
f
10
S
E
11
S1
E1
6
II
22
23
20
FI
SII
EII
12
17
13
Inventor

Fig. 27.

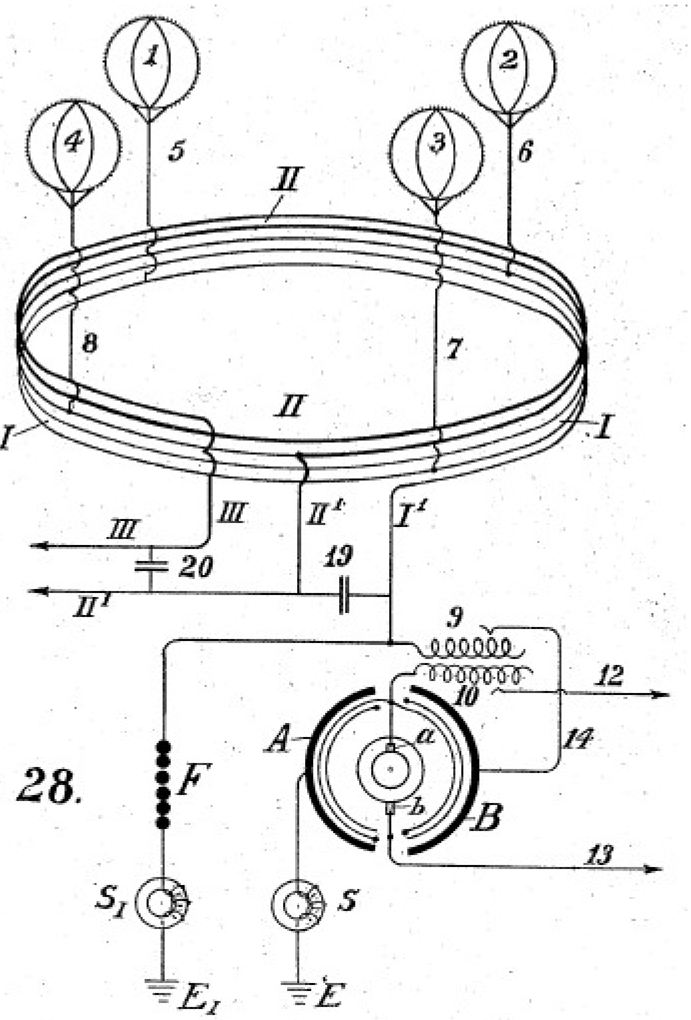
1
2
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4
5
6
II
8
7
I
II
I
III
II¹
I¹
III
20
19
II¹
9
12
10
A
a
14
F
b
B
13
S₁
S
E₁
E

Fig. 28.

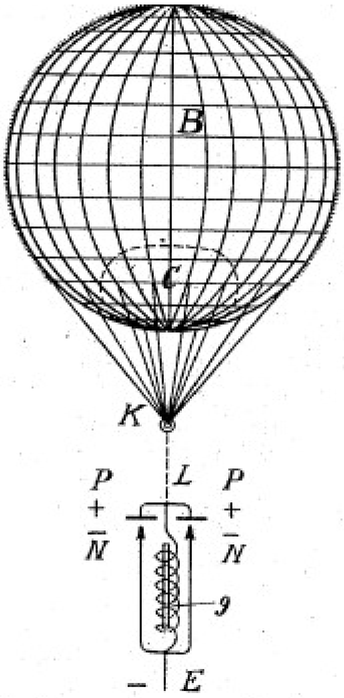
B
C
K
P
L
P
+
+
N
N
9
−
E

Fig. 29.

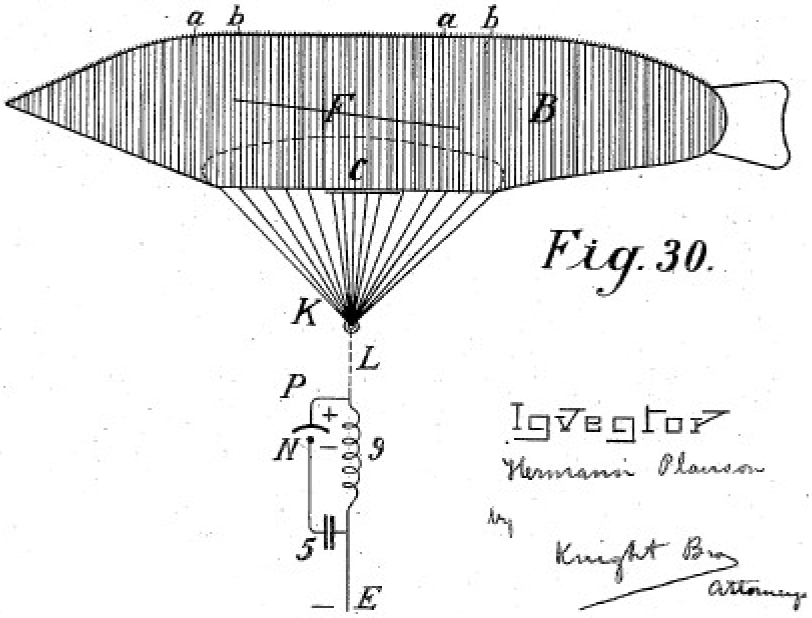
a
b
a
b
F
B
C
K
L
P
+
N
−
9
5
−
E

Fig. 30.

Inventor
Hermann Plauson
by
Knight Bros
Attorneys

Filed Jan. 13, 1921 12 Sheets-Sheet 11

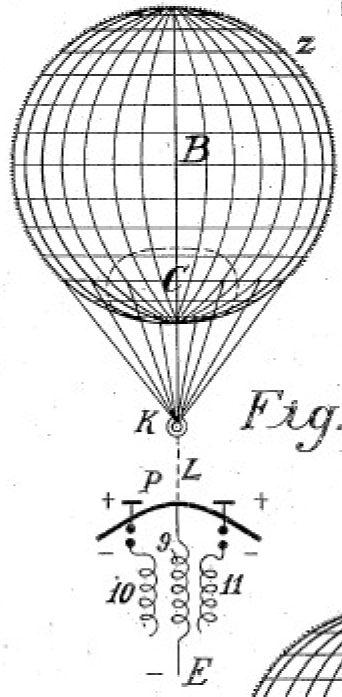
z
B
C
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+
+
−
−
9
10
11
−
E

Fig. 31.

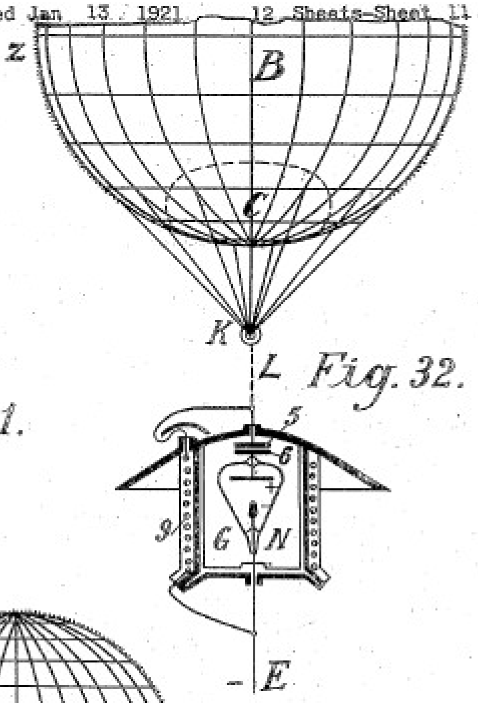
z
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6
+
−
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G
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Fig. 32.

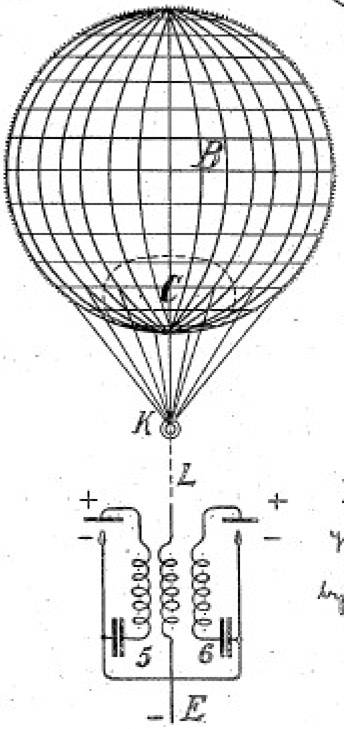

Fig. 33.

Inventor
Hermann Plauson
by Knight Bros
attorneys

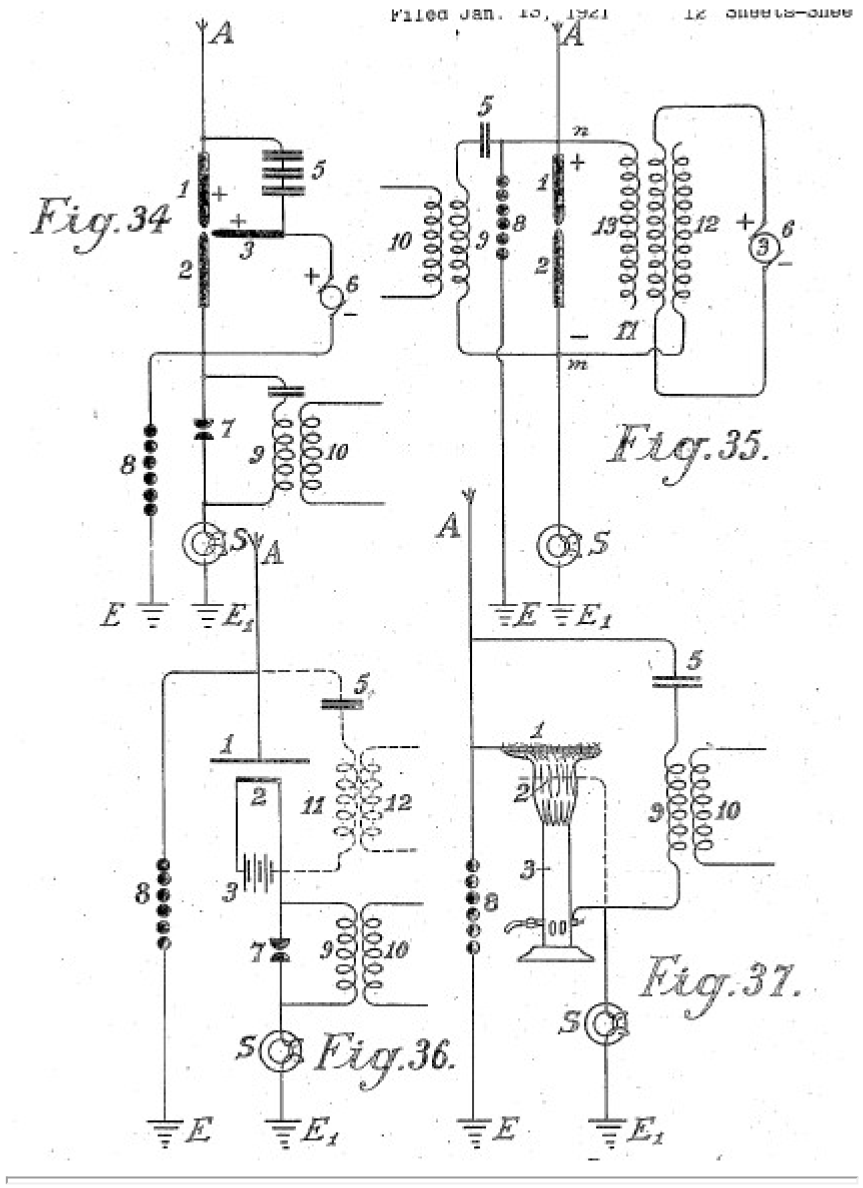
Filed Jan. 13, 1921 12 Sheets-Shee
Fig. 34
Fig. 35.
Fig. 36.
Fig. 37.
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11
12
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+
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m

GB 149,917
Improvements in & Relating to Radio Communication Systems

Abstract -- Radio transmission and reception through the use of living vegetable organisms such as trees, plants, and the like.

Fig 1

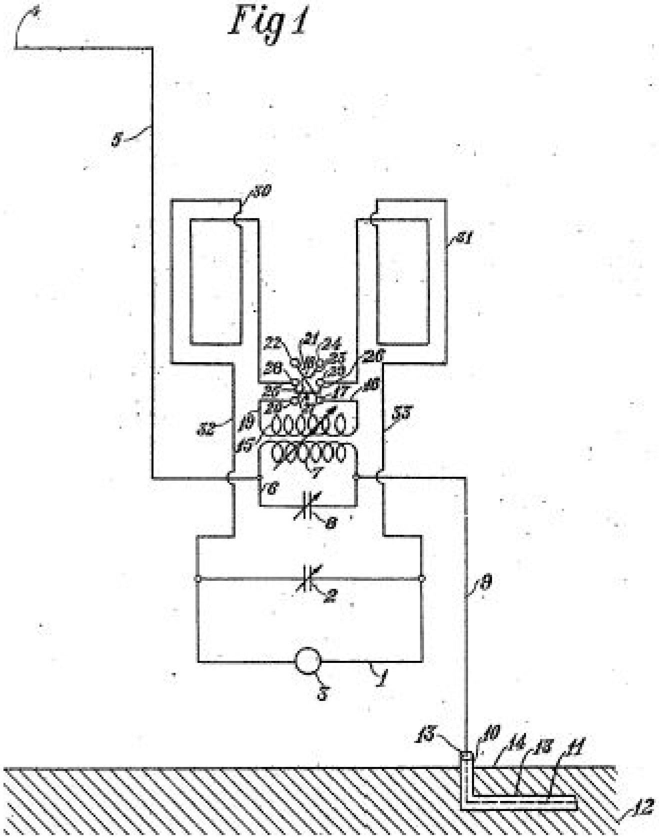
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US 1826727
Radio Apparatus

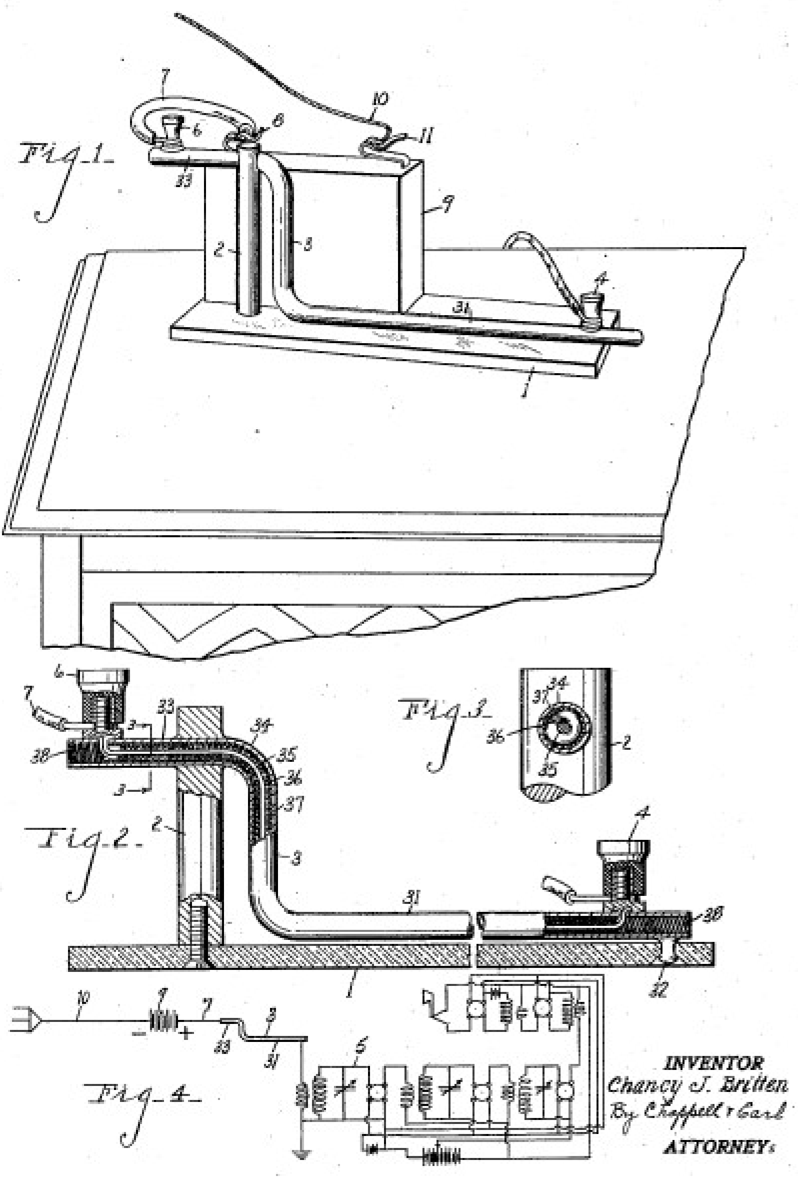
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
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33
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37
38
INVENTOR
Chancy J. Britten
By Chappell & Earl
ATTORNEYS

US 2143437
Radiant Energy System

Abstract -- An apparatus for receiving and transmitting radiant energy within a wide range of frequencies without necessity of a source of local energy.

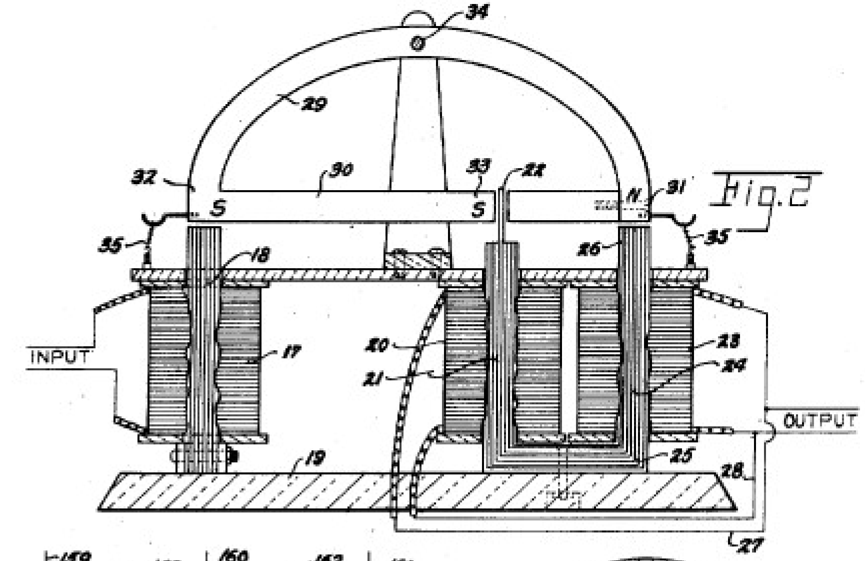
34
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32
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INPUT
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OUTPUT
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27

Fig.2

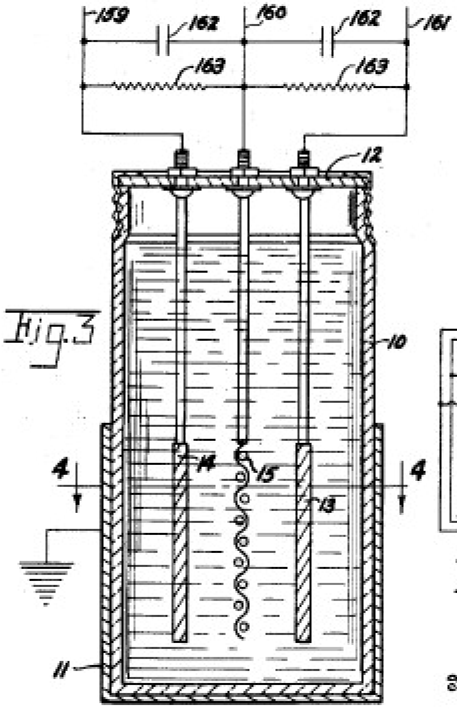
159
162
160
162
161
163
163
12
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14
15
13
4
4
11

Fig.3

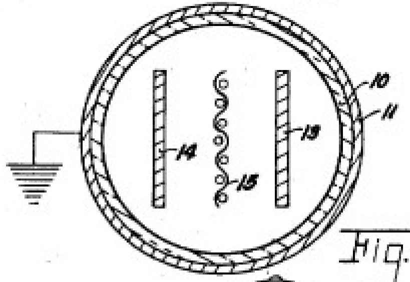
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Fig.4

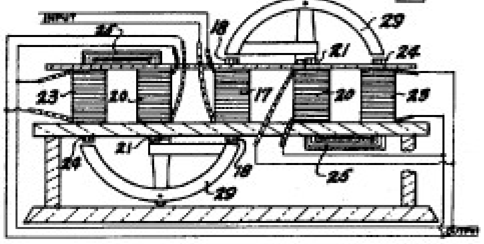
INPUT
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18
29
21
24
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29
25

Fig.9

Inventor

James Marion Fisher

By Murray & Zugelter

Attorney

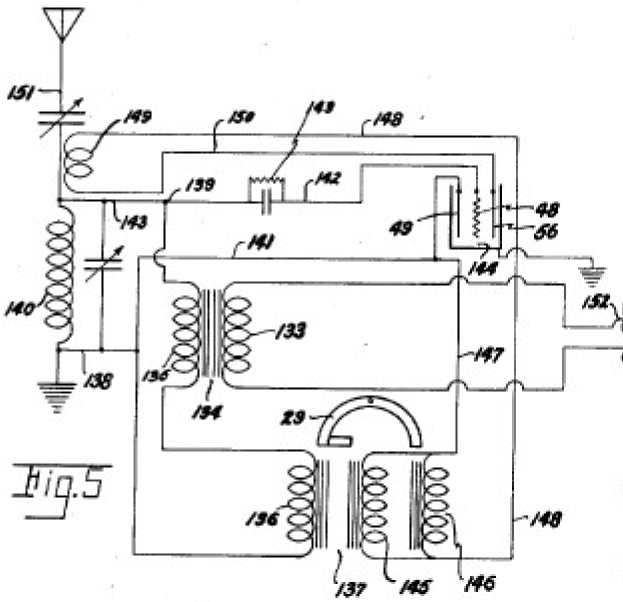
151
149
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143
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139
142
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141
49
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56
144
152
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136
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138
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136
137
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146
148

Fig.5

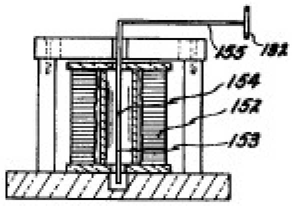
155
132
154
152
153

Fig.7

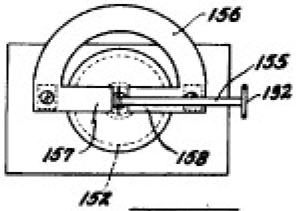
156
155
132
157
158
152

Fig.8

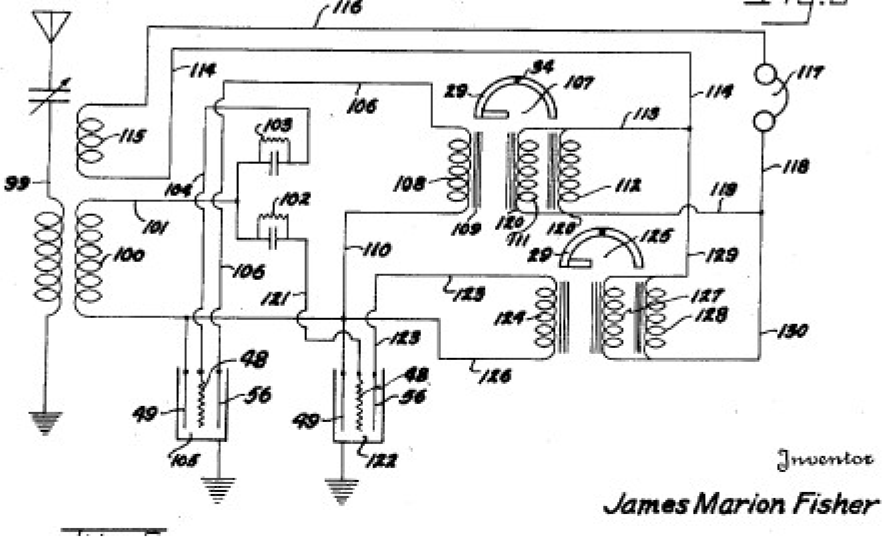
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129
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106
121
123
124
127
128
130
125
48
49
56
105
126
48
56
49
122

Inventor

James Marion Fisher

US 2813242
Powering Electrical Devices with Energy Abstracted from the Atmosphere

Abstract -- A convenient and economical provision of power for the operation of electronic circuits and devices using transistors, and of other electrical devices hving modest power requirements.

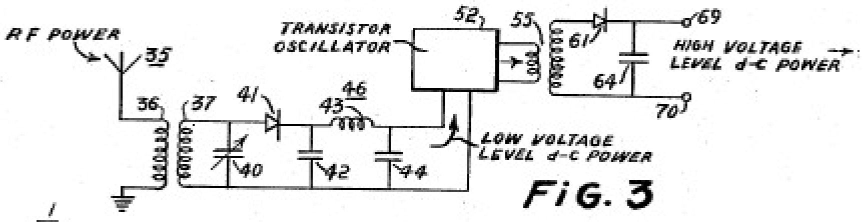
RF POWER
35
36
37
41
46
43
40
42
44
TRANSISTOR OSCILLATOR
52
55
61
64
69
70
HIGH VOLTAGE LEVEL d-C POWER
LOW VOLTAGE LEVEL d-C POWER

FiG. 3

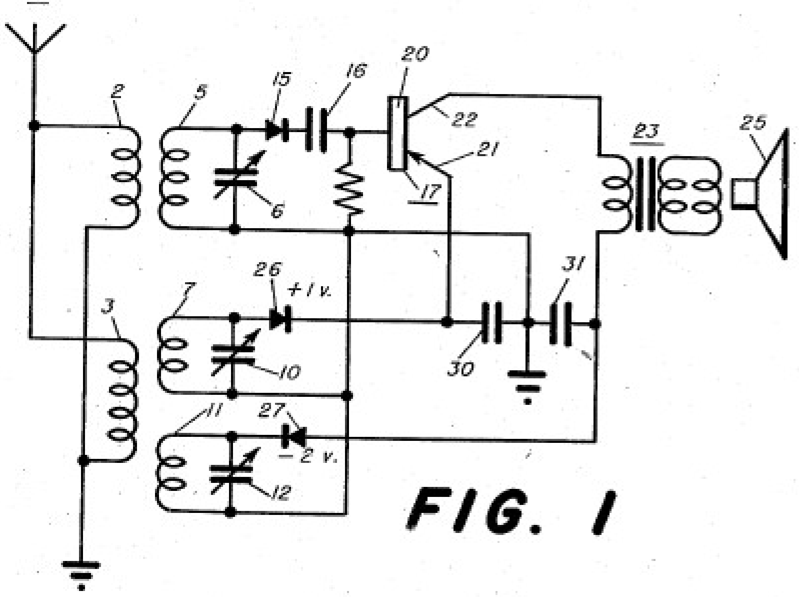
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6
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3
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26
+1 v.
10
31
30
11
27
-2 v.
12

FIG. 1

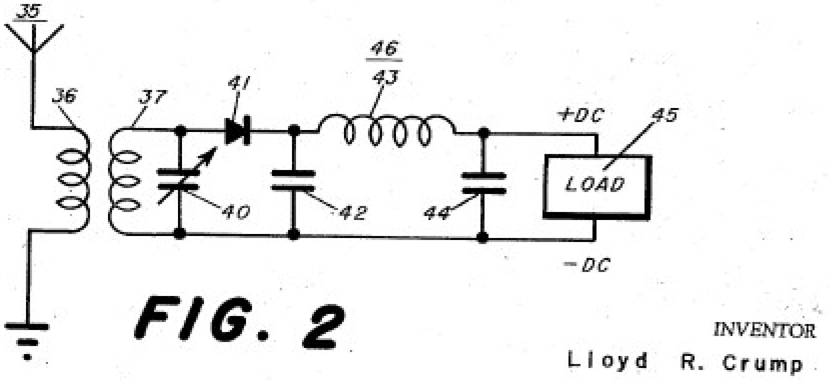
35
36
37
41
46
43
40
42
44
+DC
45
LOAD
-DC

FIG. 2

INVENTOR
Lloyd R. Crump

US 3205381
Ionospheric Battery

Abstract -- A method and apparatus for tapping the enormous reservoir of energy existing in the ionosphere...

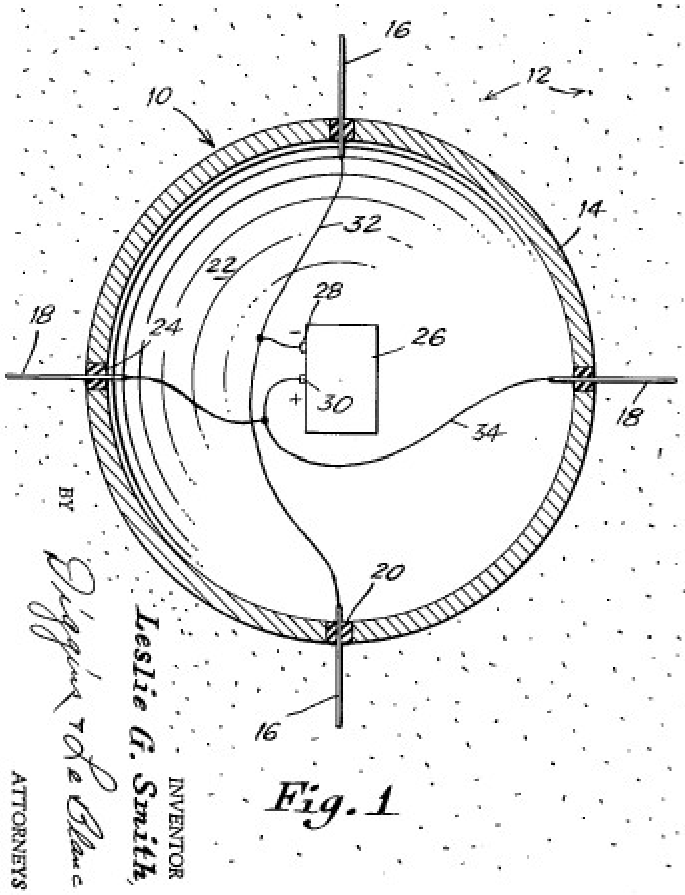
16
12
10
14
32
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16
INVENTOR
Leslie G. Smith,
BY
ATTORNEYS

Fig. 1

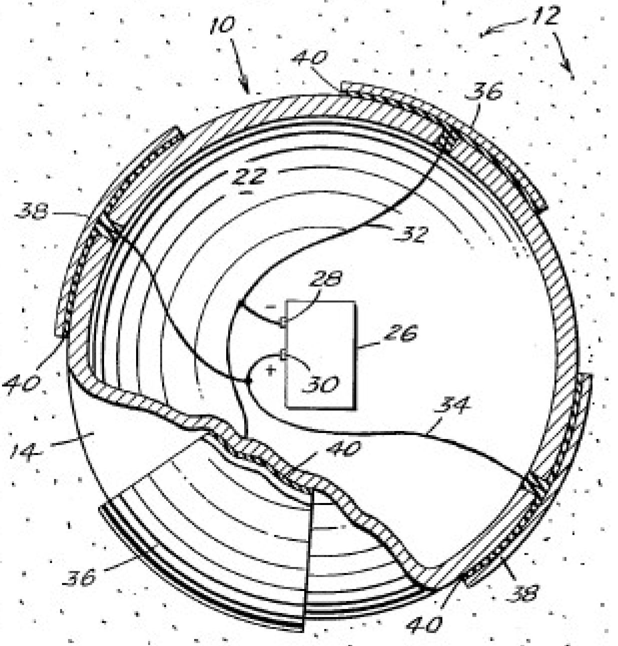
10
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38
28
26
40
30
34
14
40
36
38
40

Fig. 2

US 3273066
Apparatus for Detecting Changes in the Atmospheric Electric Field

Abstract -- A cloud detector and or an apparatus for sensing electrostatic conditions in the earth's atmosphere...

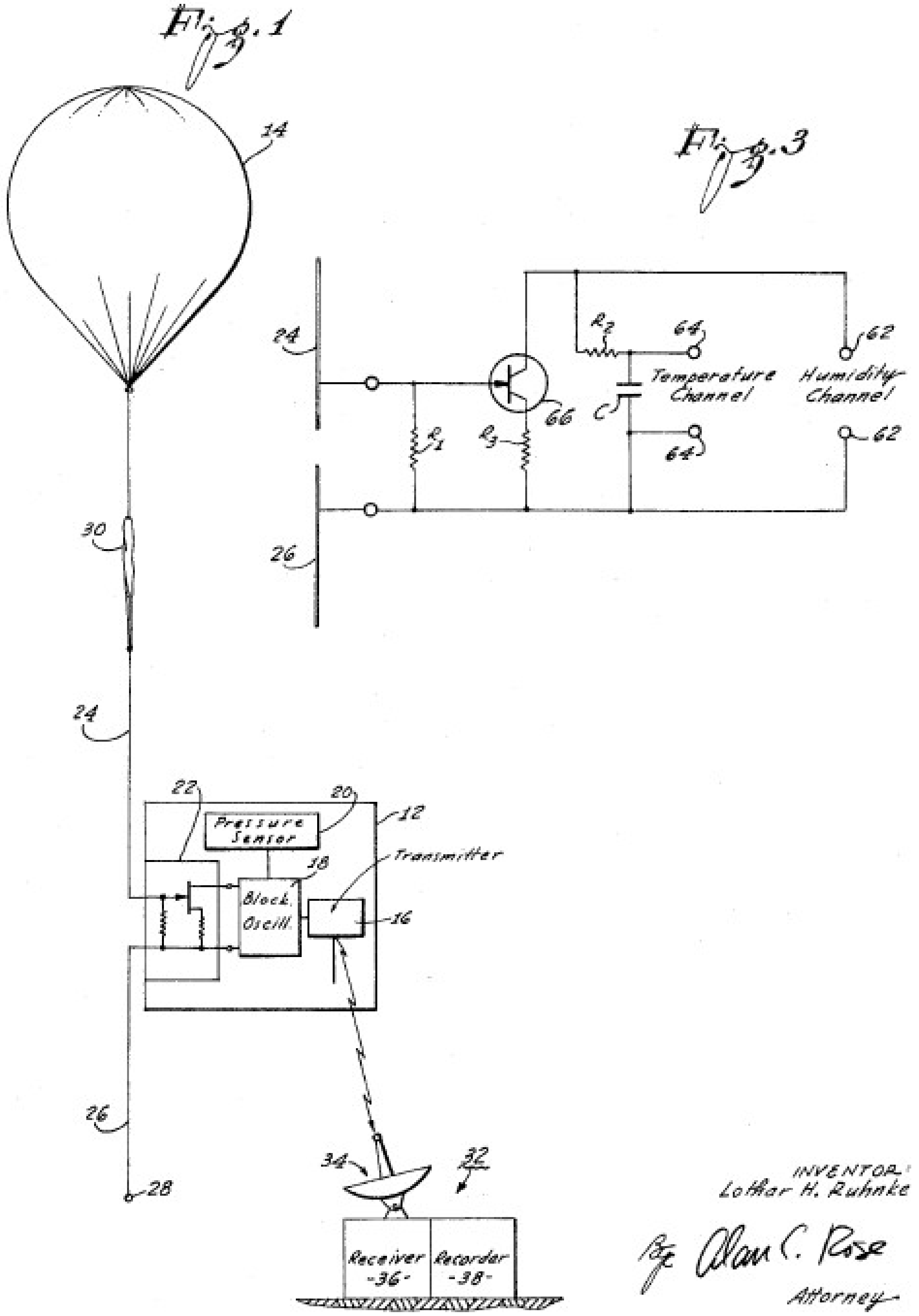
Fig. 1
14
30
24
22
20
12
Pressure Sensor
18
Transmitter
Block. Oscill.
16
26
28
34
32
Receiver -36-
Recorder -38-
Fig. 3
24
26
R2
64
62
Temperature Channel
Humidity Channel
66
C
R1
R3
64
62

INVENTOR:
Lothar H. Ruhnke

By Alan C. Rose
Attorney

US 3760257
EM Wave Energy Converter

Abstract -- Electromagnetic wave energy is converted into electric power with an array of mutually insulated electromagnetic wave absorber elements each responsive to an electric field component of the wave as it impinges thereon. Each element includes a portion tapered in the direction of wave propagation to provide a relatively wideband response spectrum. Each element includes an output for deriving a voltage replica of the electric field variations intercepted by it. Adjacent elements are positioned relative to each other so that an electric field subsists between adjacent elements in response to the impinging wave. The electric field results in a voltage difference between adjacent elements that is fed to a rectifier to derive d.c. output power. The element pairs may be arranged in a two-dimensional array to provide

power conversion of randomly polarized electromagnetic waves, such as sunlight.

FIG. 1

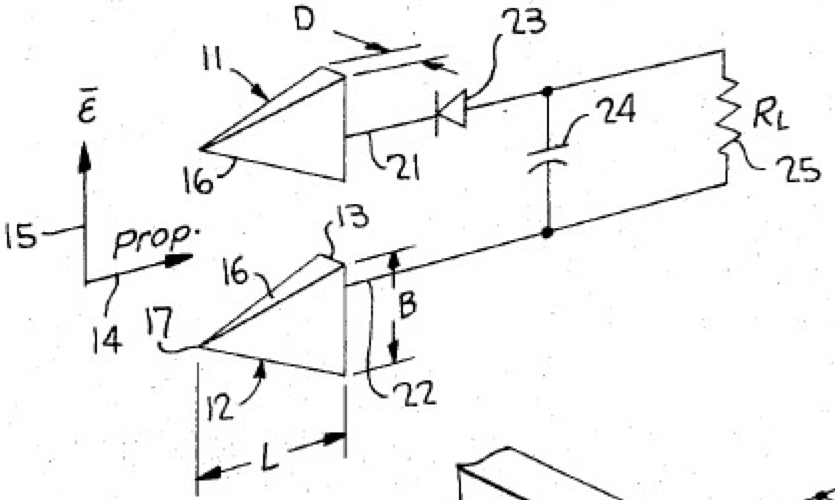
D
23
11
Ē
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R_L
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25
15
Prop.
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B
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L

FIG. 2

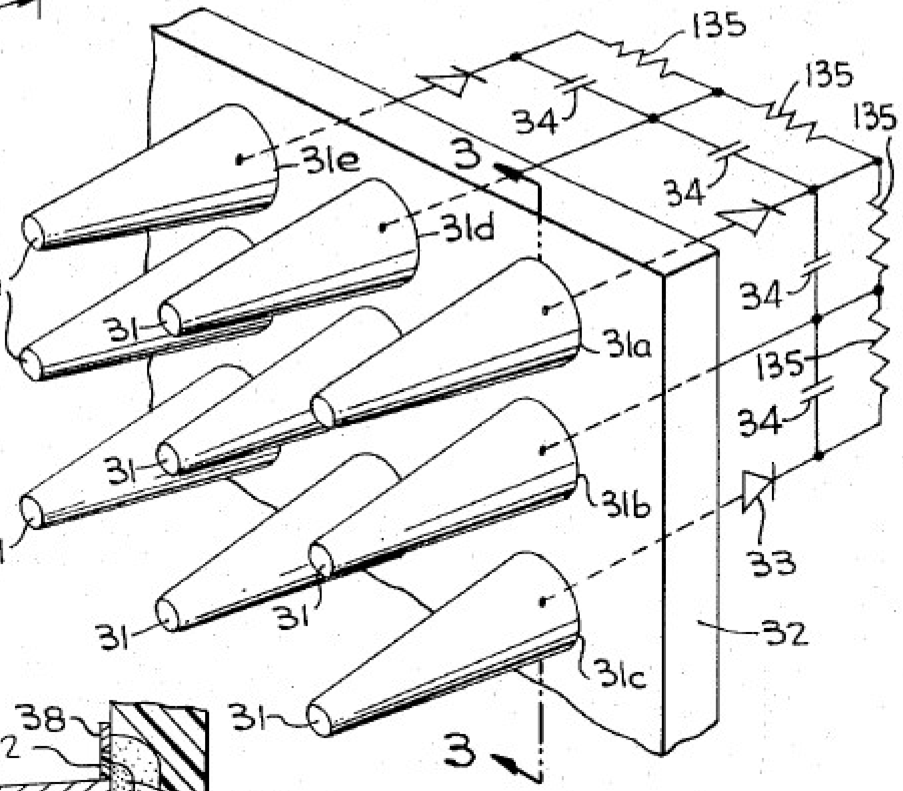
135
135
135
34
34
3
31e
31d
31
31
31a
34
135
34
31
31
31b
33
31
31
32
31c
31
3

FIG. 3

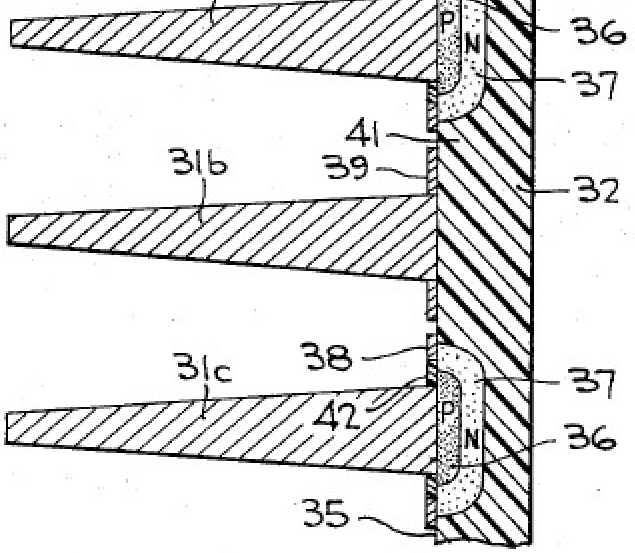
38
42
31a
P
N
36
37
41
39
31b
32
38
31c
37
42
P
N
36
35

US 3931577
Radio Receiver Protection Arrangement

Abstract -- A receiver protection arrangement in which a voltage dependent on aerial voltage and a voltage dependent on aerial current are aggregated and applied to means responsive to a predetermined aggregate level to effectively short circuit the aerial lead. Additional means may be provided to dissipate energy in the input stage of a protected receiver to cause a reduced impedance to be reflected across the output of the protective arrangement.

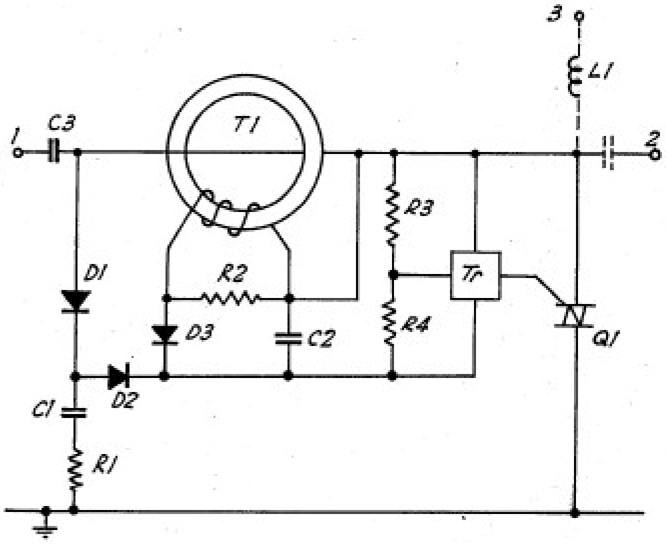
3
L1
1
C3
T1
2
R3
D1
R2
Tr
D3
C2
R4
Q1
C1
D2
R1

Fig. 1.

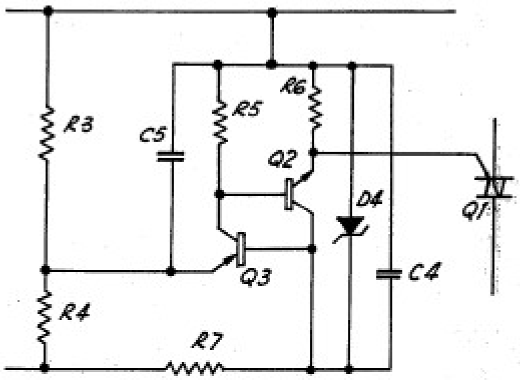
R6
R3
R5
C5
Q2
D4
Q1
Q3
C4
R4
R7

Fig. 2.

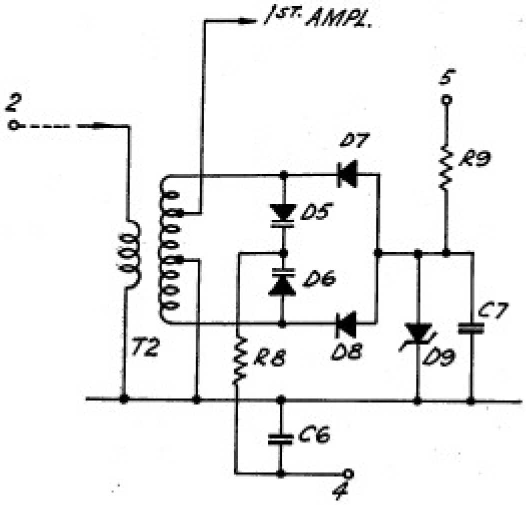
1ST. AMPL.
2
5
D7
R9
D5
D6
C7
T2
R8
D8
D9
C6
4

Fig. 3.

US 4,628,299

Seismic Warning System Using RF Energy Monitor

Abstract -- The ambient broadband radio frequency field strength from broadcast stations is monitored (Figure 4) by periodic sampling (50, 52). A warning indication is provided if the field strength drops significantly. Drops in such field strength have been correlated empirically with the occurrence of seismic activity, usually several days later. Thus the indication serves as an early warning of an impending earthquake. In one preferred embodiment, a broadband, horizontal, very long monopole antenna (40) was connected to a rectifying and smoothing circuit (Figure 3) to provide a dc output proportional to the ambient rf field...

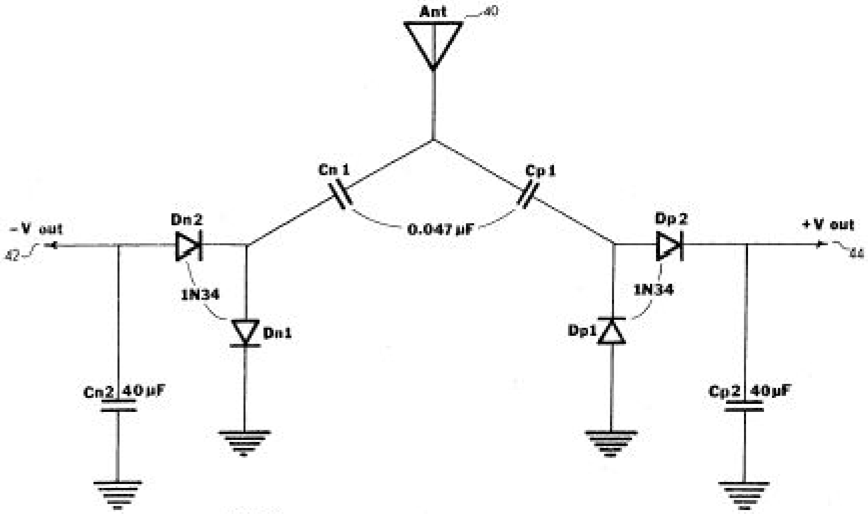

FIG 3

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Ensure & Enhance Your Survival & Genome Transmission ...
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US 20010032905A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2001/0032905 A1**

Grandics (43) **Pub. Date: Oct. 25, 2001**

(54) METHOD AND APPARATUS FOR CONVERTING ELECTROSTATIC POTENTIAL ENERGY

(76) Inventor: **Peter Grandics**, Carlsbad, CA (US)

Correspondence Address:
OPPENHEIMER WOLFF & DONNELLY LLP
Suite 3800
2029 Century Park East
Los Angeles, CA 90067-3024 (US)

(21) Appl. No.: **09/732,110**

(22) Filed: **Dec. 7, 2000**

Related U.S. Application Data

(63) Non-provisional of provisional application No. 60/169,378, filed on Dec. 7, 1999.

Publication Classification

(51) **Int. Cl.**^{7} **B64C 15/00**; B64C 27/82

(52) **U.S. Cl.** **244/51**

(57) ABSTRACT

A new method is described to produce directional currents in the space lattice, the fundamental fabric of the universe. The currents may be unidirectional or vortexual in nature and are suitable for propulsion or the generation of electric power. For propulsion, the unidirectional currents are induced by charging capacitors possessing suitable geometries. This will allow the manufacture of vehicles capable of levitation and flight. The vortexual space lattice currents are produced in a suitable pyramid when electrostatic and magnetic fields interact transversally. The vortex causes charge separation and current in the coil wrapped around the pyramid.

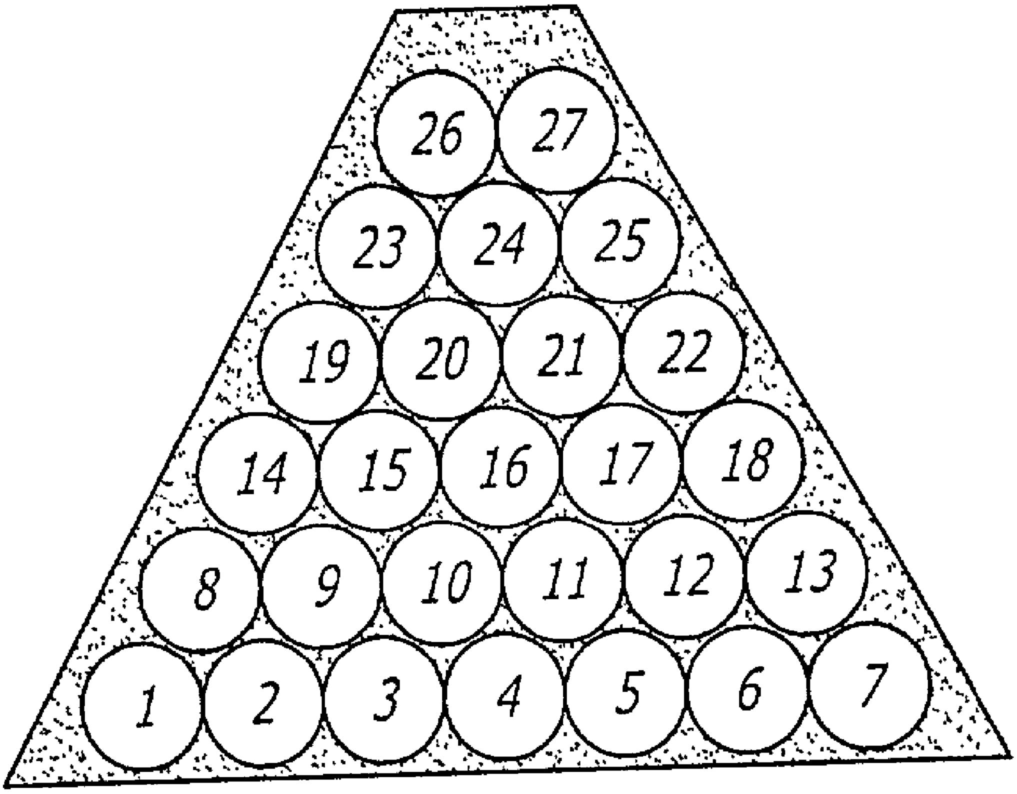

FIG. 1

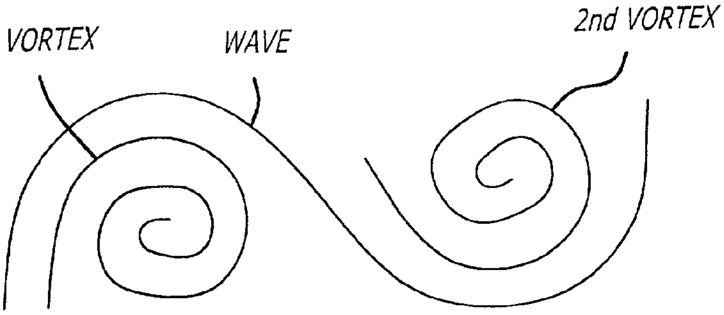
1st VORTEX
WAVE
2nd VORTEX

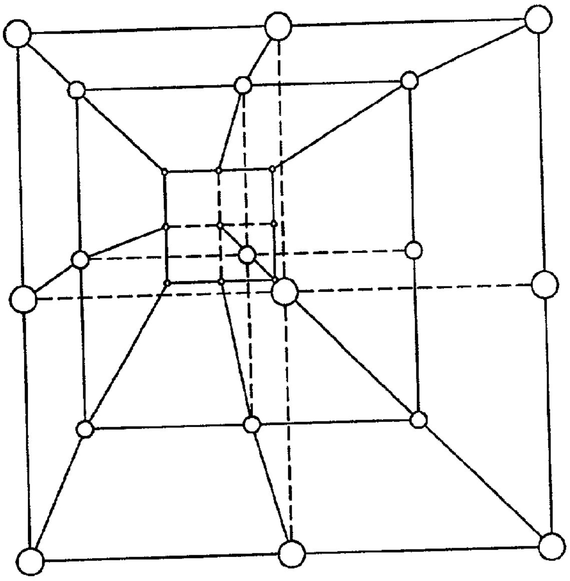

FIG. 2

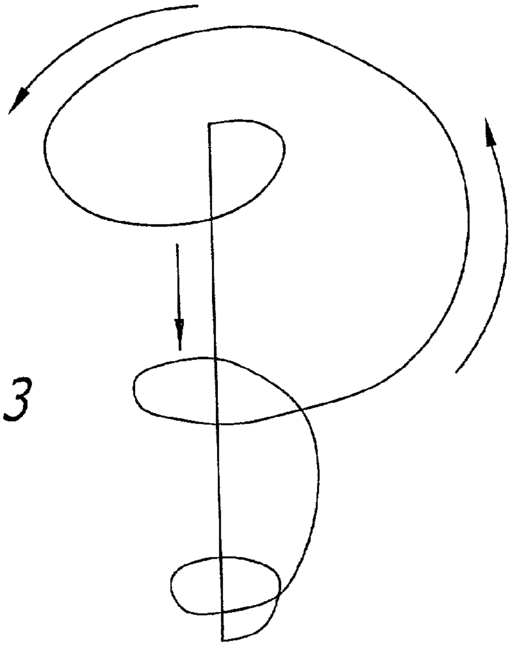

FIG. 3

FIG. 4

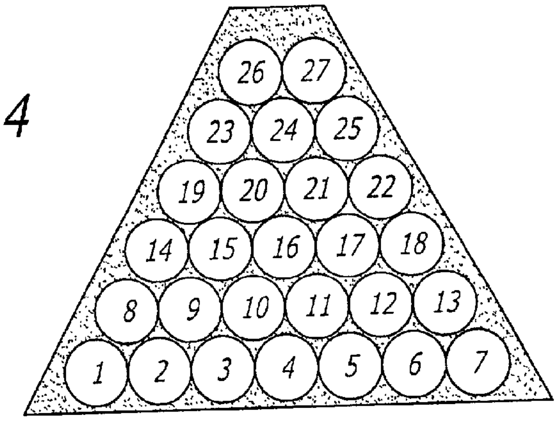
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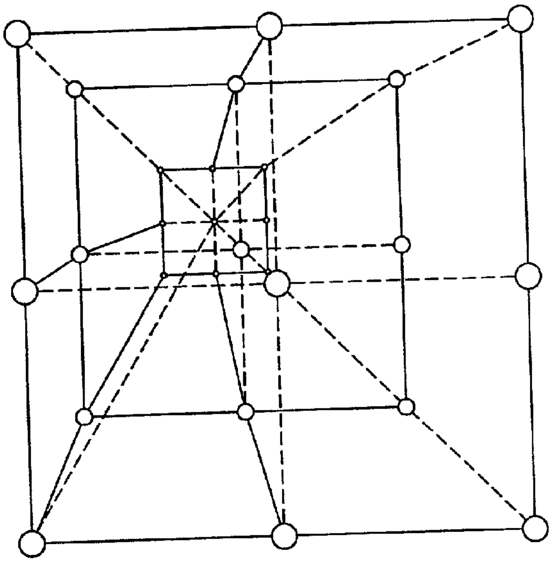

FIG. 5

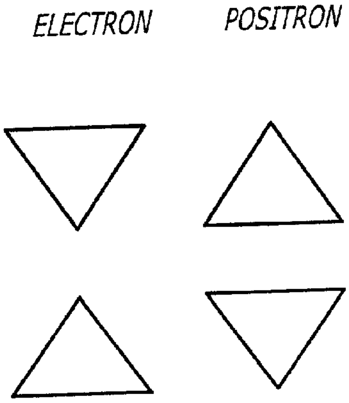
ELECTRON
POSITRON

FIG. 6

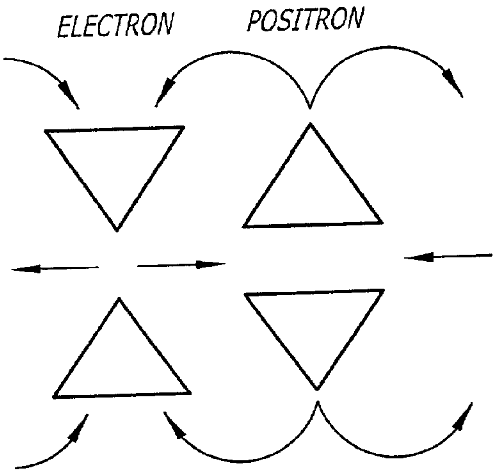
ELECTRON
POSITRON

FIG. 7

FIG. 8

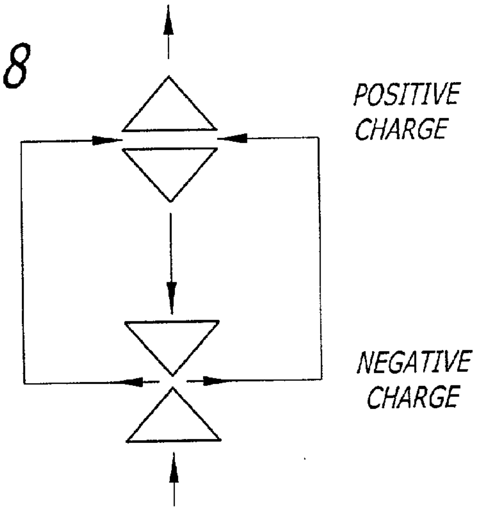
POSITIVE
CHARGE
NEGATIVE
CHARGE

FIG. 9

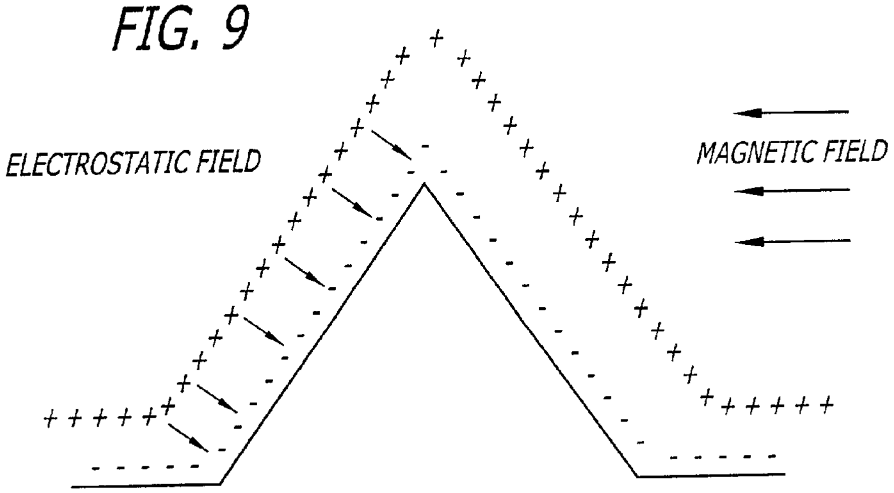
ELECTROSTATIC FIELD
MAGNETIC FIELD

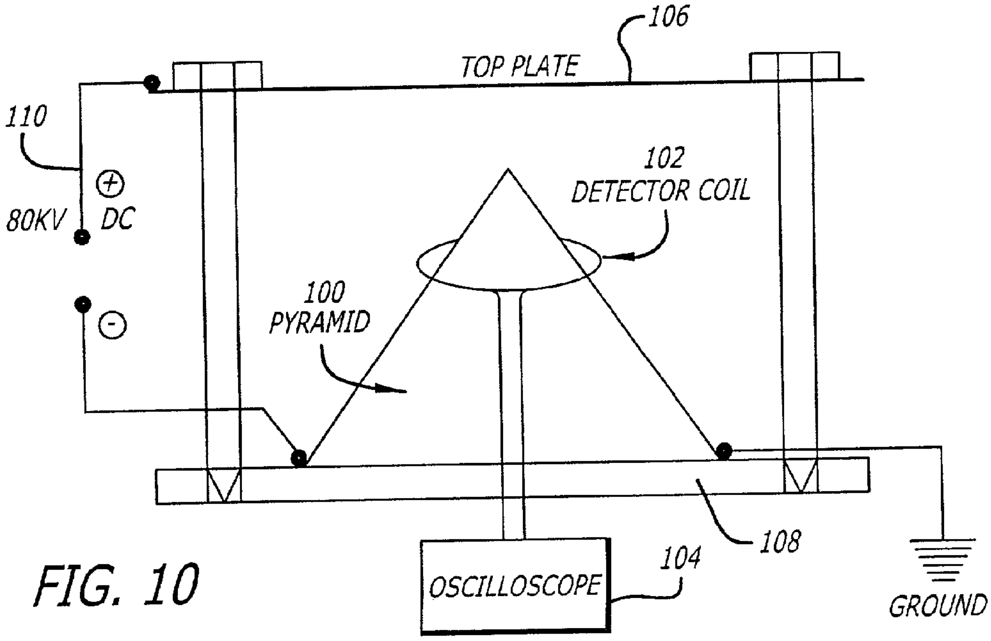
106
TOP PLATE
110
80KV
DC
102
DETECTOR COIL
100
PYRAMID
108
104
OSCILLOSCOPE
GROUND

FIG. 10

METHOD AND APPARATUS FOR CONVERTING ELECTROSTATIC POTENTIAL ENERGY

CROSS-REFERENCES

[0001] This application claims priority from Provisional Application Ser. No. 60/169,378, by Peter Grandics, filed Dec. 7, 1999, also entitled "Method and Apparatus for Converting Electrostatic Potential Energy," the contents of which are hereby incorporated by this reference.

BACKGROUND OF THE INVENTION

[0002] This invention is directed to methods and apparatus for conversion of electrostatic energy. Specifically, this invention describes methods to cause directional movements in the space lattice.

[0003] To fully comprehend the theoretical basis for these methods, first the genesis of the elemental particles electron and positron needs to be discussed based on geometric or space relationships, and their interactions at the sub-elemental particle level must be clarified. The advantage of such an approach is that it can be visualized, and not just expressed mathematically. by definition, the word "structure" implies a geometric relationship, and such relationship must be of great importance in atomic structures even though they are hidden from direct view.

[0004] The study of geometric relationships of macroscopic structures of matter may provide important insights into the properties of matter at the microscale. Astrophysics suggests the universe probably started with an energy burst from one point. This big bang theory is supported by visual and electronic evidence that the galaxies are expanding away from a single center.

[0005] In stellar formation, gravitational pull and velocity generate a rotary vortex. Even in the relative absence of such factors, all objects spiral at some given rate peculiar to their special influences. A spiral is created when an object moves forward while rotating. Earth's movement in space is an example of this process. The Earth orbits the sun, while the sun pulls it along towards the direction of Vega in the constellation Hercules. the combined circular and forward motion creates a spiral. Our sun has the same motion in relation to the galaxy center. Our galaxy, the Milky Way, also spirals away from the Big Bang center.

[0006] Water going down a drain demonstrates some of the special influences affecting spiral formation. The spiral, caused by Coriolis forces, changes dynamically under the effects of gravitational pull, drain diameter, obstructions, temperature, pressure, volume, viscosity, and stirring. The spiral changes shape and acceleration but maintains the universal shape of a spiral. The water flow is responsive to all possible factors, and so is the spiral.

[0007] Remarkably, the spiral vortex has a "memory" of itself. When a vortex is distorted to become elliptical, it spontaneously returns to its original circular form. The vortex is a self-sustaining type of motion; its resiliency is comparable to that of atomic bodies.

[0008] Spirals condense energy and sine waves transmit it along a frictional line of force between them (**FIG. 1**). Spirals and waves could be considered illusions of each other. Two opposed spirals form a wave, or a wave produces two spirals. A sine is the producer of waves of spiral forces. Any fluid capable of supporting wave motion can also support vortex motion.

[0009] The spiral is the prominent form of organization of matter. The large proportion of spiral galaxies among celestial bodies visibly demonstrates this. On the microscale, even the building block of life, the DNA uses this structure and spirals are likely to be dominant at the level of the atom and below. This is the subject of the present theory. I propose that all atoms, all stellar formations use the mutable spiral to adapt to their spiral environment.

[0010] Another proposition is that all mediums of matter can be considered a type of crystal. Crystallinity is readily recognizable in the mineral world, but it is also a more general state of matter. Besides solid crystals, liquid crystals also exist. by definition, a crystal is a regularly repeating atomic arrangement, such as a chemical element, a compound or an isomorphous mixture. Therefore, the term crystal applies to material expressions where crystallinity is not so obvious, e.g., gases, complex biologics and various life forms, including viruses, bacteria and higher organisms. Air and water could be considered loose crystals subject to fast molecular drift. At low temperatures where molecular drift is reduced, gases form solid or liquid crystals. Soil and stone and metal are opaque cryptocrystals with slower rates of molecular drift. On the macroscale, the Earth could be seen as faceted crystal with its mountain ridges are the ridges of a geodesic sphere. Biopolymers such as DNA, proteins or polysaccharides fit well the definition of a crystal and are commonly made into crystals. All life can be seen as a crystal. From fish to humans, we are liquid crystals on a skeletal lattice.

[0011] Crystals are the shape of discrete units of matter and notably the channelized direction of energy, that is, the direction energy that flows unforced. Crystals form the basis for corpuscle-wave conversion. Crystals create resonance and conduct the flow of energy between states. Crystals can also be considered lenses. By definition, a lens is a device capable of refracting, or bending light. Light is an energy flow, so on a more general term, a lens can be defined as any object capable of changing the direction of energy flow. By this broader definition, even an electric wire is a lens as it is capable of changing the direction of flow of electrical energy. lenses communicate energy as part of the principle that all matter vibrate, all matter transmit, and all matter receives energy. The universe changes energy states with lenses. Following this line of reasoning, the universe could be viewed as a resonant crystal lens.

[0012] This observation is important because the universe is considered to be largely empty, the largest component of which is the so-called vacuum space. Since Nature seems to use the same geometrical organizing principles from macro to micro, I suggest that the vacuum space must also be "crystalline". Since the term crystalline is associated with material of which the vacuum space is substantially devoid, I will use an extended meaning of "structured" when discussing crystallinity of vacuum space.

[0013] The theory of "crystalline" vacuum space was introduced by Simhony (Simhony, M. (1990) The Electron-Positron Lattice Space, Cause of Relativity and Quantum Effects, Physics Section 5, The Hebrew University, Jerusalem., and Simhony, M. (1994) Invitation to the Natural

Physics of Matter, Space, and Radiation, World Scientific Publishing Co., London, UK.). Simhony reasoned that three-dimensional physical phenomena must have three-dimensional physical causes and explanations.

[0014] He demonstrated that physical reality can be described by the laws of classical physics supplemented by the presence of a space lattice. This led to the development of the theory of an electron-positron lattice space (epola for short). In the epola, bound electron-positron pairs reside at the lattice sites of a face-centered cubical "crystal" structure similar to that of NaCl crystals (Kennon, N. F. (1978) Patterns in Crystals, John Wiley & Sons, New York.).

[0015] The epola theory allowed a physical explanation of all yet unexplained postulates of quantum mechanics and relativity including the particle-wave duality, the quantized nature of electron orbits in the atom, the electromagnetic radiation, the photon, and gravitational interactions as well as the relationship of electrostatic, magnetic and gravitational interactions. He demonstrated gravity to be a derivative of electromagnetism.

[0016] There is a large body of evidence suggesting that the vacuum space is not empty at all. Experiments verify that the vacuum space contains an enormous residual background energy (some examples are: Boyer, T. H. (1985) The classical vacuum (zero-point energy) Scientific American 70-78, Haisch, B., Rueda, A. and Puthoff, H. E. (1994) Beyond $E=mc^2$, The Sciences, 34, No. 6, 26-31, and B.

[0017] Haisch and A. Rueda, (1999).On the relation between zero-point-field-induced inertial mass and the Einstein-de Broglie formula, Physics Letters A, in press), called zero-point energy (ZPE). The ZPE manifests as a pervasive and vast electromagnetic field called the zero-point field (ZPF). a dynamic field, ZPF is a virtual plasma, with particles arising and disappearing of a background energy field serving as a baseline, or zero point, for all physical processes. The ZPE remains even at absolute zero. Simhony has described zero-point energy fluctuations as analogous to brownian motion of epola particles around their lattice sites. A potential alternative term for the lattice space is zero-point-field (ZPF) described in 1994 by Haisch, Rueda and Puthoff (Haisch, B., Rueda, A. and Puthoff, H. E. (1994) Beyond E=mc2, The Sciences, 34, No. 6, 26-31). This area remains an active field of research.

[0018] Simhony also suggested that all particles of matter are directly formed from the lattice space, the mechanism of which remains undetermined. The present theory intends to answer this question in terms of lattice space.

[0019] I propose that the vacuum space has a lattice structure similar to that introduced by Simhony. this structure is a face-centered cube having 27 lattice sites (**FIG. 2**). on the lattice sites reside the elemental "particles" forming all particles of matter. These are "particles of energy" rather than particles of matter.

[0020] I propose that the "particle of energy" of the space lattice, called here the subtle electron, is a spiral energy vortex tied into itself in the form of a circumvolution cissoid. The circumvolution cissoid is a spiral turn around an axis converging into an apex, in a self-imploding, self-sustaining vortex motion (**FIG. 3**). The vortex pulsates and its vibration is a function of **(2_Ø)x, where Ø is the Fibonacci series number and x**=0,1,2,3, the number of turns the circumvolution cissoid makes. Once started up, such a vortex would run practically indefinitely inside the space lattice.

[0021] The internal friction of such a space lattice must be so low that it would only be noticeable as a red shift in the spectra of distant galaxies. The space lattice, like its constituent energy vortices, must also be a resilient structure with only limited compressibility. At the same time, it must have fluidity since it is capable of transmitting waves with transverse displacement. In the absence of atomic oscillators, the space lattice would be incapable of dissipating energy in the form of heat.

[0022] Vortices maintain their circular forms as well as their proportions and dimensions. The adjacent vortices have a coordinating effect that establishes axial alignment and rolling contact between vortices within the space lattice. In that sense, there is a great deal of similarity between crystals of material bodies and the structure of the space lattice. I postulate that the space lattice is an incompressible, frictionless fluid made out of cubes of units cells of subtle electron vortices.

[0023] We can consider the space lattice equivalent to motion. A space lattice in motion necessarily has inertia. Although inertia is generally attributed to moving material bodies, it is actually a property of motion. Inertia is just the continuity of motion. In the case of vortex motion the inertia is localized. Localized inertia can also be called momentum. To account for the elemental particles of matter, we need a space lattice that is capable of moving.

[0024] Anderson discovered in 1932, that when 1.02 MeV photon energy is absorbed into the vacuum space, an electron-positron pair can appear. this observation is explained here as a glimpse into the formation of elemental particles of matter. To become matter, energy must become more angular. This hypothesis is derived from the observation that all material expression is a type of crystal, and is the compound and derivative of a fundamental triangular form which all the seven crystal systems can be derived (Kennon, N. F. (1978) Patterns in Crystals, John Wiley & Sons, New York.). The mechanics of this expression at the level of the space lattice are explained as follows: As the energy of electromagnetic radiation propagates through the space lattice, it polarizes the subtle electron energy vortices (for analogy see **FIG. 1**). Subsequently, the "energy particles" of the space lattice, the subtle electrons, undergo a phase transition similar to the condensation of gases. This happens at the resonant frequency of the 1.02 MeV gamma radiation.

[0025] The 27 subtle electrons of the unit cell of space lattice rearrange into a pyramidal segment of the cube (**FIG. 5**) on six levels each forming circles of vortices. An open-flat presentation of the rearrangement is shown in **FIG. 4**. This structure is the postulated smallest unit of matter. note that the cube is composed of six interlocking pyramids so the cube and the pyramid are resonant structures. Inside the pyramid, the subtle electron rings form a vortex capable of circulating the fluid space lattice. The pumping action is driven by the self-sustaining, pulsating vortex motion of its constituent subtle electrons (**FIG. 3**). The overall shape is a cone fitting inside the pyramid. The formation of matter follows the geometry of the space lattice (**FIG. 5**) and thus we may conclude that the space lattice provides the blueprint for matter.

[0026] An electron is produced when two such cones are joined in a tip-to-tip conformation (**FIG. 6**). The positron is made out of two vortices (cones) facing base-to-base. The energy vortices which make up the electrons have a resilient vibratory structure which should be capable of vibrating at various frequencies and modes. This would allow us to account for the series of spectral lines, a signature of absorbing and emitting energy at various frequencies.

[**0027**] These complex vortex particles have a pumping effect and circulate the fluid space lattice. For the electron, the space lattice is drawn in polarly and expelled equatorially. For the positron, the space lattice is drawn in equatorially and expelled polarly (**FIG. 7**). The direction of circulation of fluid space lattice determines the positive or negative polarities. When in close proximity, a specific flow coupling occurs between the electron and positron (**FIG. 7**). It is quite probable that a similar flow coupling exists between a proton and an electron inside the atom, although such coupling is stable in the case of the proton. This is likely a result of the different vibratory structure of the vortex proton.

[**0028**] The instability of the electron-positron pair is also derived from this model. The perfectly fitting, counter-rotating cones of energy extinguish each other with the release of a combined energy of 1.02 Mev. This results in the reconstitution of the respective unit cells of the space lattice along with the release of the phase transition energy.

[**0029**] The size of the subtle electron is estimated based on the "nuclear radius" of 0.1 fm for the electron, to be approximately 0.005 fm. The lattice constant for the unit cell of space lattice is approximately half of the "nuclear radius" of the electron, i.e,.0.05 fm. This indicates that the space lattice is quite dense compared to atomic bodies.

[**0030**] The model explains the attraction of free electric charges as follows (**FIG. 8**): Opposite charges move towards each other. This movement is due to the equatorial circulation of fluid space lattice from the negative charge to the positive charge and the polar circulation of space lattice from the positive to the negative charge. The attraction of the vortices pull the two partners together. The electrostatic field between separated charges is defined as the flow of the space lattice from the protons to the electrons and the outside return flow of space lattice from the electrons to the protons (see **FIG. 8**). This explanation will eventually lead to a hydromechanical theory of electricity.

[**0031**] Interestingly, there is a net unidirectional flow of fluid space lattice in the axial direction of the free electric charges (**FIG. 8**) flowing in at the negative pole and flowing out at the positive pole. if the charges have a steady parallel orientation, e.g., as in an electric condenser, then a pressure differential must arise in the space lattice around the opposite poles of the condenser. To fully appreciate the significance of this conclusion, we must first examine how material bodies accelerate through the space lattice.

[**0032**] Accelerating objects encounter resistance facing an increased pressure of the space lattice at the front end and a reduced pressure at the rear end of the object. This situation is common to all propulsion methods which apply mechanical force on the physical object. Therefore, it is logical to suggest that a pressure differential of space lattice at the opposite sides of material bodies is always accompanied by a change in the rest or motion of such bodies. To obtain a propulsion force, instead of exerting force on the physical object we should transfer the space lattice that controls the behavior of the object from the rear end of the object to its front end.

[**0033**] Therefore, a sufficiently charged object in which the charges have a steady parallel orientation should behave as an accelerating object, i.e., it should move toward the direction of its positive pole. In fact, this happens due to its own generated space lattice pressure differential Now that the fundamentals are developed, the effect may provide the basis for a new propulsion and gravity cancellation method, and may give us insights into the mechanism of gravitation. A craft utilizing such propulsion method could exhibit inertialess acceleration as it would meet no resistance from the surrounding space lattice.

[**0034**] The theory also allows us to develop strategies for tapping into the energy of the space surrounding us. Separated charges in an electric condenser cause a directional flow of the fluid space lattice. Conversely, if we could induce a directional flow of the space lattice, it would cause a separation of charges in material objects. To explain how such an effect could be produced, first the physical basis of magnetism must be explained.

[**0035**] I have described the physical basis for the electrostatic field as a flow of a space lattice current from the positive charges to the negative charges and back on the outside to the positive charges. I shall now explain how these space lattice currents flow in an electric wire. The space lattice flow which connects the electrons to the protons of the atoms in the wire becomes extended in the length of the wire. This is the same direction as the direction of movement of electrons which, in the current, flow in the outer shell of the wire. The external return flow of the space lattice will be in the opposite direction in the space around the wire. This flow constitutes the magnetic field. In a solenoid, the surrounding space lattice flows in the opposite direction relative to the path of the electrons. The magnetic effect will appear as either N or S magnetic poles. The magnetic poles are mirror images of each other. This suggests that a single isolated magnetic pole cannot exist.

[**0036**] In the electrostatic field, the outside space lattice currents flow between electrically charged particles. The magnetic field, on the other hand exhibits a closed circuit flow of the space lattice along the path of a solenoid or a circuit. Electric and magnetic forces are produced by movement of the space lattice in spirals or whirls.

[**0037**] An electric charge and a magnetic pole do interact even though they do not apply any force to each other. A magnetic pole will bring about a directional orientation of the electrons in a charged object, while an electric charge will cause the electric polarization of the adjacent surface of a magnetic pole.

[**0038**] The final question remains is the superimposition of electrostatic and magnetic fields on each other. The practical significance of the interaction of axially oriented electrostatic and magnetic fields is likely to be small compared to their interaction at an angle. A transversal superimposition of a magnetic field on an electrostatic field will cause the distortion of both fields. The axial flow of the space lattice between the electric poles, which is the physical basis for the electrostatic field, will be distorted, but its circulation will continue. Similarly, the rotating space lattice, which is the basis for the magnetic field, will also be distorted, flowing in irregular circuits.

[0039] To study the transverse superimposition of electrostatic and magnetic fields, a shaped electrostatic field must be created (**FIG. 9**). When a magnetic field interacts with the shaped flow of the space lattice, it could result in the formation of a space lattice vortex at the points where the two flows intersect. This is based on previous hypothesis that the space lattice is an incompressible fluid, wherein the intersecting currents cannot penetrate but distort each other's flow patterns.

[0040] To expand this shaped electrostatic field into three dimensions, a pyramid is required. I have already discussed the importance of the pyramidal geometry in the formation of matter. The pyramidal geometry may also be important for producing a space lattice perturbation, which is the equivalent of a magnetic field when it follows a rotational symmetry (e.g. a vortex).

[0041] If with transversally superimposed electrostatic and magnetic fields a pyramid did indeed produce a vortex in the space lattice, then the rotational flow of the space lattice should cause the separation of charges and an electric current in material bodies, as predicted by this theory. This means that under appropriate conditions, a pyramid could become a power generator.

[0042] For power generation in a pyramid, the source of the electrostatic and magnetic fields could potentially be the Earth. The earth has a high voltage electric field such that the earth's surface is negatively charged while the atmosphere is positively charged (Feynman, R. P. (1964) Lectures on Physics, v.2, 9-2, Addison Wesley, Inc., Palo Alto, Calif.). The voltage field is believed to be maintained by the Sun's radiation energy and/or cosmic ray energy and extends from the ionosphere to the surface creating a potential difference of about 400,000 V. The Earth's electrostatic field never seems to get depleted despite all the storm activities and discharging of energy. The voltage gradient is estimated to be 200 V/m around the surface of the earth. The total energy reaching earth at any moment is about 700 MW (400,000 V multiplied by a current of 1800 A). The magnetic field strength of the earth is about 0.5 Gauss and exhibits continuous pulsations with main frequencies of 8 to 16 Hz.

[0043] Therefore, the earth's electrostatic and magnetic fields could potentially be utilized to create a space lattice vortex in and around a sufficiently sized pyramid. This hypothesis has been tested experimentally. The earth's electrostatic field was modeled as described in the Examples.

[0044] Therefore, there is a need for an improved method and apparatus for the conversion of electrostatic energy as described herein.

SUMMARY OF THE INVENTION

[0045] Pursuant to this invention new techniques are described to produce directional currents in the space lattice. The currents are induced either by separated charges, properly positioned magnetic fields or by the interaction of electrostatic and magnetic fields at an angle, specified by the side angle of a pyramid. The induced space lattice currents can be utilized to generate specific effects which may vary from propulsion, to gravity cancellation and power generation.

[0046] In particular, an aspect of the present invention is a method producing directional currents in the space lattice utilizing:

[0047] (1) separated electric charges; and

[0048] (2) the interaction of electrostatic and magnetic fields.

[0049] In one preferred embodiment of the invention, electric charges are separated in an oriented fashion. The orientation can be a parallel orientation. The orientation can be obtained in a capacitor. The capacitor can be used for the propulsion of a vehicle. The capacitor can provide lift and lateral movement control for said vehicle.

[0050] The interaction of electrostatic and magnetic fields can be set up in a pyramid.

[0051] The interaction can produce a vortex in the space lattice.

[0052] The vortex can be tapped to produce electric power, which can be obtained by wrapping a coil around the pyramid.

BRIEF DESCRIPTION OF THE DRAWINGS

[0053] The following invention will become better understood with reference to the specification, appended claims, and accompanying drawings, where:

[0054] **FIG. 1** is a diagram showing the relationship between a spiral and a wave;

[0055] **FIG. 2** is a diagram demonstrating the geometry of the space lattice;

[0056] **FIG. 3** is a diagram demonstrating the circumvolution cissoid;

[0057] **FIG. 4** is a diagram demonstrating the smallest unit of matter;

[0058] **FIG. 5** is a diagram showing the rearrangement of the unit cell;

[0059] **FIG. 6** is a diagram exhibiting the structures of electron and positron;

[0060] **FIG. 7** is a diagram demonstrating the flow coupling of electron and positron;

[0061] **FIG. 8** is a diagram showing the attraction of electric charges;

[0062] **FIG. 9** is a diagram showing the interaction of a shaped electrostatic field with a magnetic field;

[0063] **FIG. 10** is a diagram displaying the arrangement of the capacitors in the craft; and

[0064] **FIG. 11** is a diagram demonstrating the pyramid experimental setup.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0065] Pursuant to this invention, novel methods are described to induce directional currents in the space lattice which is postulated to be part of the boundary conditions of the Universe. These methods are useful in providing for the conversion of electrostatic energy into a useful form. The first method relates to generating an unidirectional flow of the space lattice which could be useful in cancelling gravity and generating a propulsion force. A possible configuration for keeping the charges separated and stored is in the form of a capacitor. The shape of the capacitor and the body of such device is important for optimal performance. A pyramidal or conical shape is preferred for the alignment of the capacitors (**FIG. 10**). Optimally, the shape of the capacitor follows the shape of the craft.

[0066] In **FIG. 10**, the pyramid **100** is surrounded by a detector coil **102** which is in turn connected to an oscilloscope **104**. In the experimental setup shown, the field is established by a top plate **106** and a ground **108** connected to a source of DC electrical energy **110**.

[0067] The conductive elements of the capacitor are layered into the pyramidal or conical segment of the hull of such craft. Optimally, there should be several layers of negatively charged conductors on the outside while a single layer of positively charged conductor in the inside of the craft. All conductive elements should be carefully insulated in order to keep the charges inside the capacitor.

[0068] In the center of the craft, a conductive, insulated pole is mounted such that the pole extends out into the exterior at the top of the craft. The tip of that pole has a metal ball mounted on which is also positively charged. When all the capacitor plates are charged, they induce an unidirectional, upward flow of the space lattice. This means that the space lattice pressure above the craft will be higher than the space lattice pressure at the bottom of the craft. This pressure differential is unstable and progresses towards an equilibrium. It will grab the craft and propels it forward in order to eliminate the pressure gradient. This requires that a sufficiently high voltage be applied. My estimation is that about 5 kV is needed to lift every gram of an object. The capacitors incorporated into the hull will give control over lift.

[0069] To obtain directional control over all three axes of movement, three capacitors need to be mounted at the bottom of the craft apart from each other. These capacitors, could take the shape of a ball and would be mounted on retractable shafts. The top half of the capacitors would be positively charged while the bottom half is negatively charged. When in flight, the capacitors are retracted and charged based on the needs of directional control. To achieve forward movement, the charges on one capacitor facing the direction of the desired path should be reduced relative to the other two capacitors. This would make the craft tilt forward and start moving in that direction. An alternative method of lateral directional control could be obtained by dividing the capacitor bank in the hull into segments which segments could be charged individually.

[0070] Upon landing, the three ball capacitors would be protracted on their shafts and serve as landing gear. On landing, they would be discharged because the earth is the greater ground. On launching, the main capacitors of the body would be activated causing a lift-off. The three capacitor landing gear would then be retracted and charged up so that they can function for lateral directional control. Onboard static generators would supply the voltage required for the operation of the craft.

[0071] The most significant aspect of this type of propulsion system would be the loss of inertia during acceleration. Inertial forces pose great obstacles to improving the performance of current propulsion techniques. Since we are now in control of the space lattice surrounding the craft, it will encounter no resistance from the space lattice. The passengers of such craft would feel no forces acting upon their bodies even if the craft achieved enormous accelerations.

[0072] This overall design is suitable for the development of a wide range of transportation vehicles, from automobile-type to aircraft and spacecraft. The impact of such a technology on our economy would be enormous. We could eliminate a major factor in environmental pollution, the generation of greenhouse gases which place a great stress on our ecosystem. In the United states, 66% of the greenhouse gases are produced by transportation vehicles and just 34% by power generation. The signs of global warming and the deterioration of the ecosystem are visible from every direction.

[0073] The developing countries are bent on establishing the same economical model evolved in the developed countries, representing about 16% of the world population. Worldwide mass deployment of our current energy technologies would most likely cause an environmental catastrophe which may terminate higher life-forms on this planet.

[0074] This makes it very important that the focus of our energy sector shifts towards renewable, non-polluting sources of energy. The subject invention offers a solution in this regard. The transversal interaction of electrostatic and magnetic fields in and around a pyramid offers the potential to tap into the electromagnetic field of our planet. I have found that a pyramid becomes a power generator when the electrostatic voltage field gradient of the earth is reproduced around it. Tapping the energy field was as simple as placing a coil around the pyramid.

[0075] The optimal size production pyramid is likely going to be large. The optimal material composition may be alternative layers of metal and dielectric to maximize the total amount of charges the pyramid can hold. This is important for increasing the performance of the pyramid. A coil is then wrapped around the pyramid to tap into the generated field. The orientation of the pyramid to the magnetic North pole does not seem to be a prerequisite for operation. Such a pyramid generator will be called the pyramitron.

[0076] The following Examples illustrate the features and advantages of the subject invention. Accordingly, it is to be understood that the description in this disclosure is to facilitate comprehension of the invention and should not be construed to limit the scope thereof as persons skilled in the art can, in light of this disclosure, generate additional embodiments without exceeding the scope or departing from the spirit of the claimed invention.

EXAMPLE 1

[0077] Demonstration of the pyramitron: For the experiments, I have randomly selected a one-foot base length foam pyramid from a pyramid vendor (The Pyramid Project, Ft. Wayne, Ind.). The outside of the pyramid was covered with aluminum foil. The pyramid was placed on a 2'x2' insulating polyethylene platform equipped with an adjustable height 2'x2' size aluminum top plate, 1/16" thick (**FIG. 10**). The height of the aluminum plate was adjusted as needed and a gap of 1 ¼" between the plate and the tip of the pyramid was used in the experiments.

[0078] A high voltage (HV) CRT power source producing 30 kV DC was taken from a television set. I have assumed that an actual energy producing pyramid should be relatively high in order to obtain a large voltage drop from its tip to the ground. Therefore, assuming a height of 150 m for a life-size pyramid and a voltage drop of 200 V/m near the surface of the Earth, the 30 kV voltage is in the range of the voltage-drop expected for the height of a practical size pyramid.

[0079] The positive pole was attached to the top aluminum plate. This simulated the positive charge of the atmosphere. One corner of the pyramid was attached to the negative pole of the high voltage power source, while the opposite corner of the pyramid was grounded. This setup served as a model for the electrostatic field distribution around a potential life sized pyramid.

[0080] As controls, either a 1'x1' sheet of aluminum foil or an aluminum foil-covered box, having the main dimensions of the test pyramid (1'x1'x⅝"), was used as a negative pole. The detector coils were made by winding up a 24 gauge enamel-coated magnetic wire (20 turns, approximately 8 cm diameter). A Tektronix high-frequency oscilloscope, model no.2236 was used for signal acquisition and analysis.

[0081] The first set of experiments were control measurements with the box of the same height and base lengths as the test pyramid. The detector coil was placed on the top of the box. Measurements were taken with and without the high voltage applied. One corner of the box was attached to the HV power source (negative pole) and the opposite corner to the ground. The same arrangement was used for the flat square (1'x1') foil. The peak-to-peak signal amplitude for the box was 8 mV and the signal frequency was 2 MHz. For the flat foil sheet, the signal amplitude was 12 mV with a frequency of 1.43 MHz. The signal form was of a decaying sine wave.

[0082] When high voltage was applied to these shapes, a signal amplitude of 14 mV was obtained for the flat sheet and a 16 mV for the box. The signal frequency was 1.54 MHz for the flat sheet and 2 MHz for the box. The wave forms were of decaying sine waves in all these experiments.

[0083] When the pyramid was tested without HV, the peak-to-peak signal amplitude was measured at 60 mV with a frequency of 2 MHz. The wave form was different from those of the control experiments; it was a modulated, decaying sine. When the high voltage was applied, the signal amplitude increased up to 180-200 mV, while the frequency remained at 2 MHz. The pyramid produced a signal intensity significantly higher than the controls. When a metal (aluminum) pyramid of the same size (wall thickness 1/16" inch) was tested in the same high voltage field using the same detection coil, a voltage of 1-1.5 V was detected at the frequency of 2 MHz.

[0084] The experiments confirmed theoretical assumptions about the pyramidal shape's ability to cause perturbations in the space lattice when the pyramid is placed in transverse electrostatic and magnetic fields. The resulting space lattice vortex causes a separation of charges in the detection coil, producing a voltage signal greatly exceeding control levels. Control values for the flat sheet and the box in the electrostatic field were at the level of the background noise. Thus, when the electrostatic and magnetic fields intersected at 90° or 0°, no effect was observed. However, when the fields intersected at an angle defined by the pyramidal shape, a large signal was produced. The pyramid is clearly instrumental in generating the signal. This finding provides the second experimental proof for the present theory of electric polarities. It also demonstrates that potentially, we may be able to tap into the electromagnetic field of our planet and draw electric energy. The practical implications of this finding are enormous.

I claim:

1. A method producing directional currents in the space lattice utilizing:

(a) separated electric charges; and

(b) the interaction of electrostatic and magnetic fields.

2. The method of claim 1 wherein said electric charges are separated in an oriented fashion.

3. The method of claim 2 wherein said orientation is a parallel orientation.

4. The method of claim 3 wherein said orientation is obtained in a capacitor.

5. The method of claim 4 wherein said capacitor is used for the propulsion of a vehicle.

6. The method of claim 5 wherein said capacitor is providing lift and lateral movement control for said vehicle.

7. The method of claim 1 wherein interaction of electrostatic and magnetic fields is set up in a pyramid.

8. The method of claim 1 wherein said interaction is producing a vortex in the space lattice.

9. The method of claim 8 wherein said vortex can be tapped to produce electric power.

10. The method of claim 9 wherein said electric power is obtained by wrapping a coil around the pyramid.

* * * * *

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(12) **United States Patent**
Mickle et al.

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(45) **Date of Patent: Jun. 6, 2006**

(54) **ANTENNA ON A WIRELESS UNTETHERED DEVICE SUCH AS A CHIP OR PRINTED CIRCUIT BOARD FOR HARVESTING ENERGY FROM SPACE**

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(51) **Int. Cl.**
G08B 13/14 (2006.01)

(52) **U.S. Cl.** **340/572.7**; 340/572.4; 343/701; 343/703

(58) **Field of Classification Search** .... 340/572.2, 340/572.6, 572.4, 572.7; 343/895, 879, 795, 343/793, 700 MS, 701, 703; 257/491, 678, 257/679, 778

See application file for complete search history.

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Primary Examiner—Anh V. La
(74) *Attorney, Agent, or Firm*—Arnold B. Silverman; Philip E. Levy; Eckert Seamans Cherin & Mellott, LLC

(57) **ABSTRACT**

A wireless untethered device which may be an integrated circuit chip or printed circuit board having at least one integrated antenna and circuitry operatively associated with the antenna for receipt of energy harvested from space by the antenna. The antenna has an effective area greater than its physical area. A system which receives power from the harvested energy after the energy is processed by the circuitry may also be provided with mismatched impedance between the antenna and a circuit resistance.

12 Claims, 40 Drawing Sheets

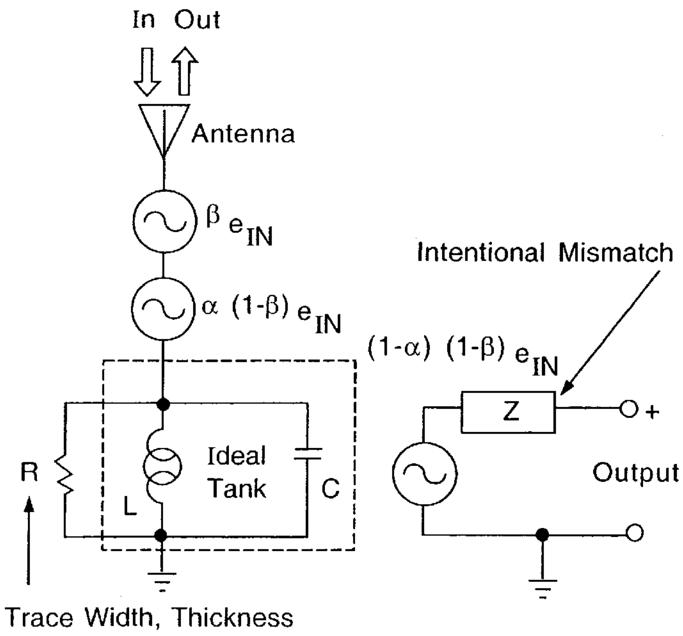

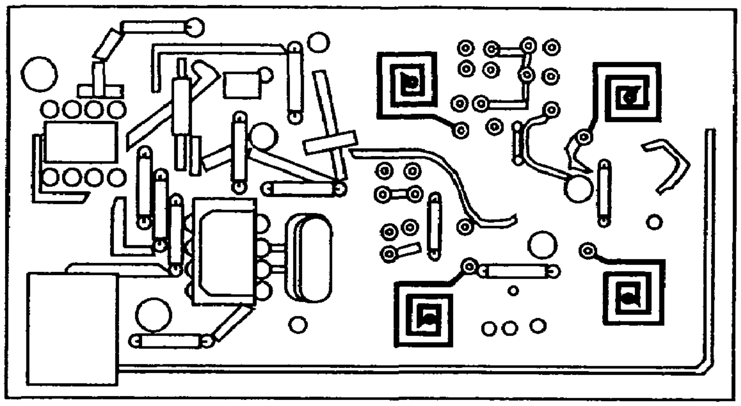

FIG. 1

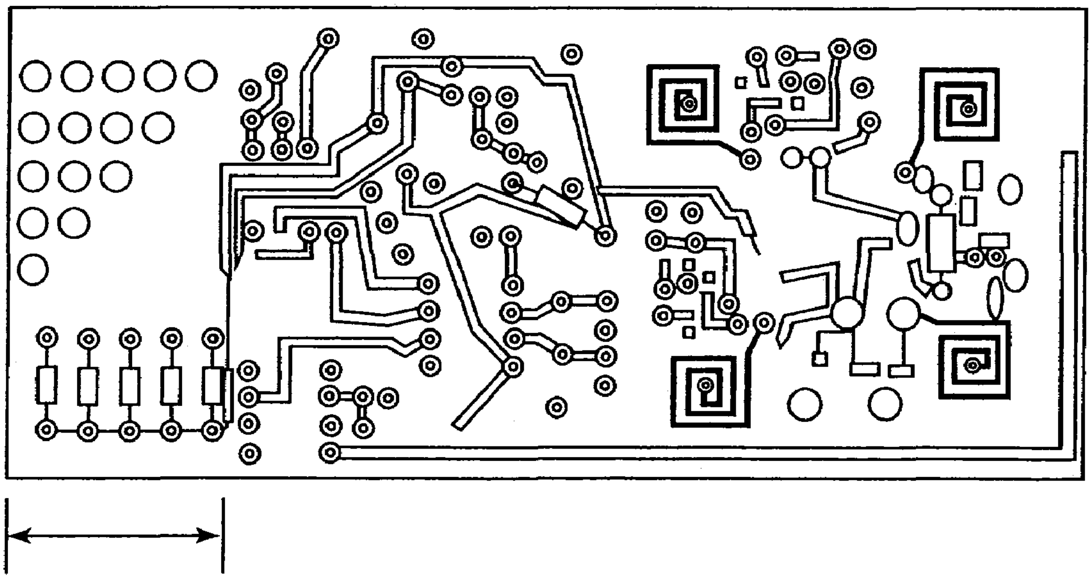

FIG. 2

Power and voltage measurement circuitry

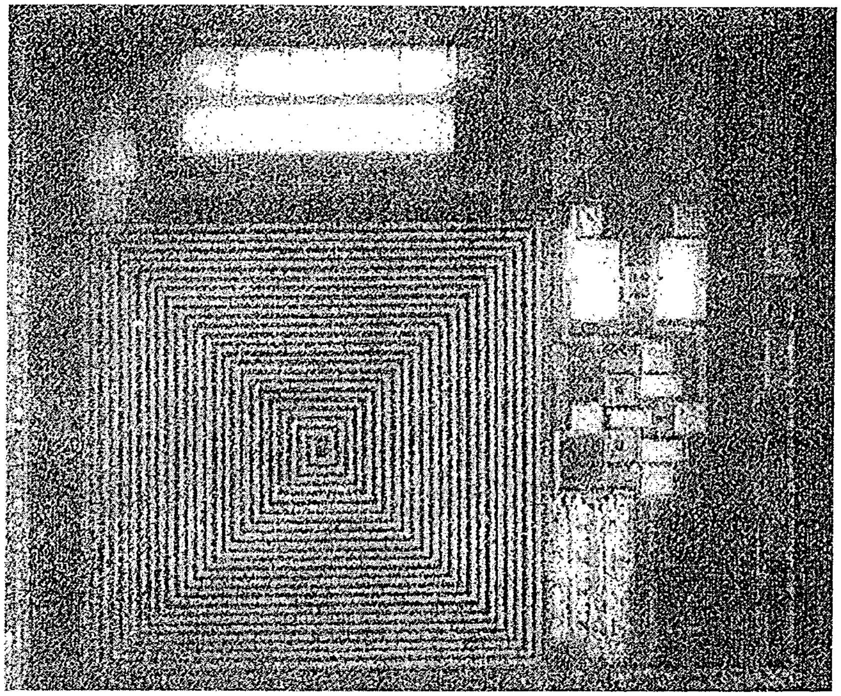

FIG. 3B

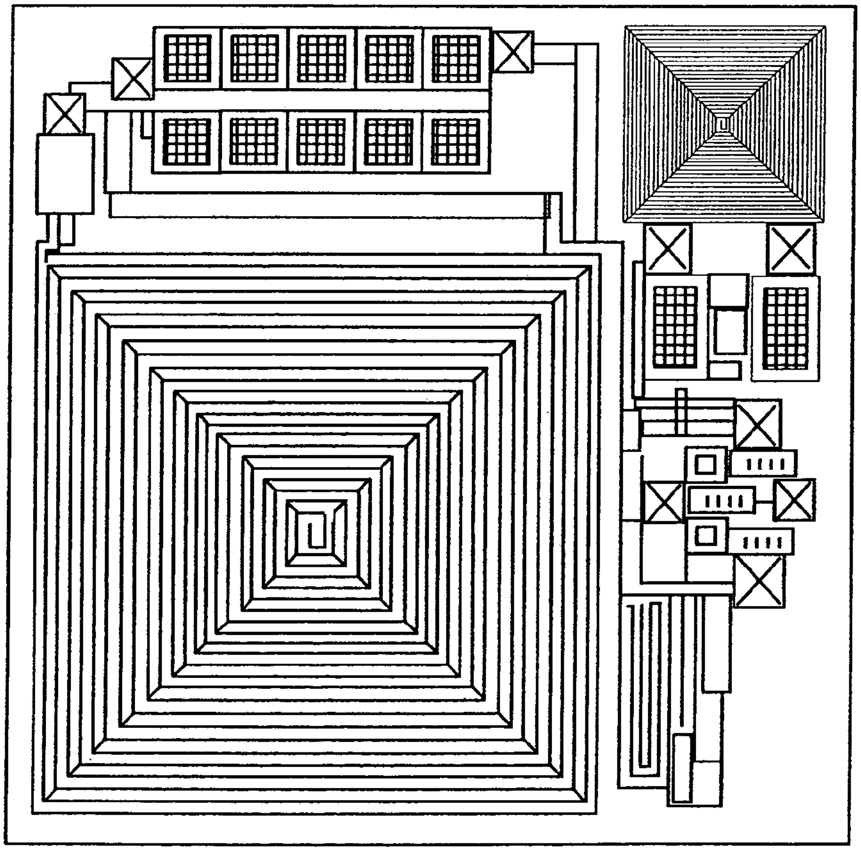

FIG. 3A

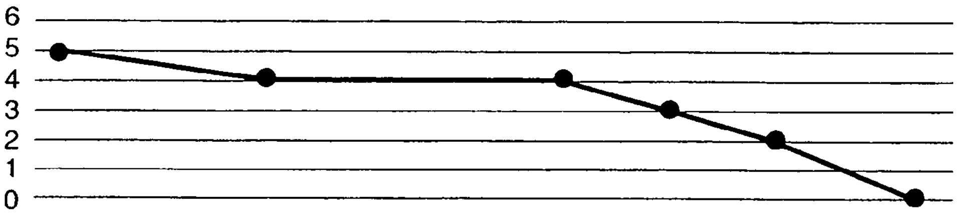
6
5
4
3
2
1
0

FIG. 4a

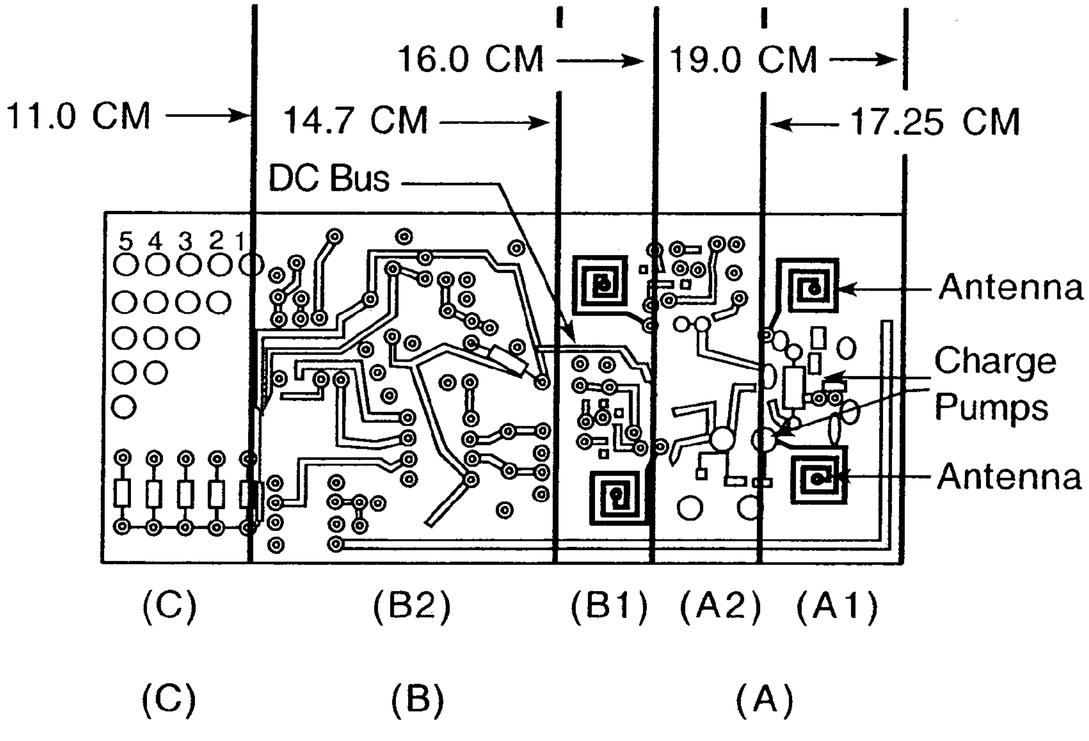
16.0 CM
19.0 CM
11.0 CM
14.7 CM
17.25 CM
DC Bus
5 4 3 2 1
Antenna
Charge Pumps
Antenna
(C)
(B2)
(B1)
(A2)
(A1)
(C)
(B)
(A)

FIG. 4b

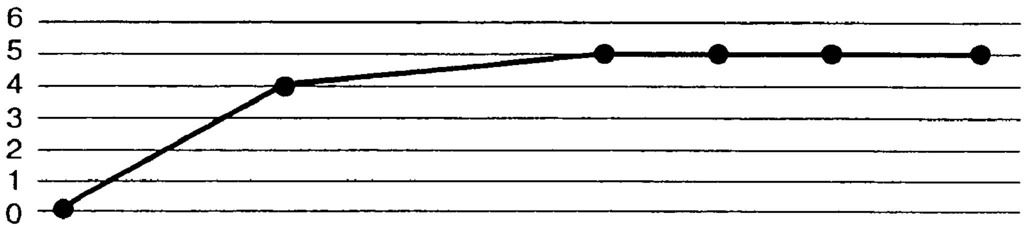
6
5
4
3
2
1
0

FIG. 5a

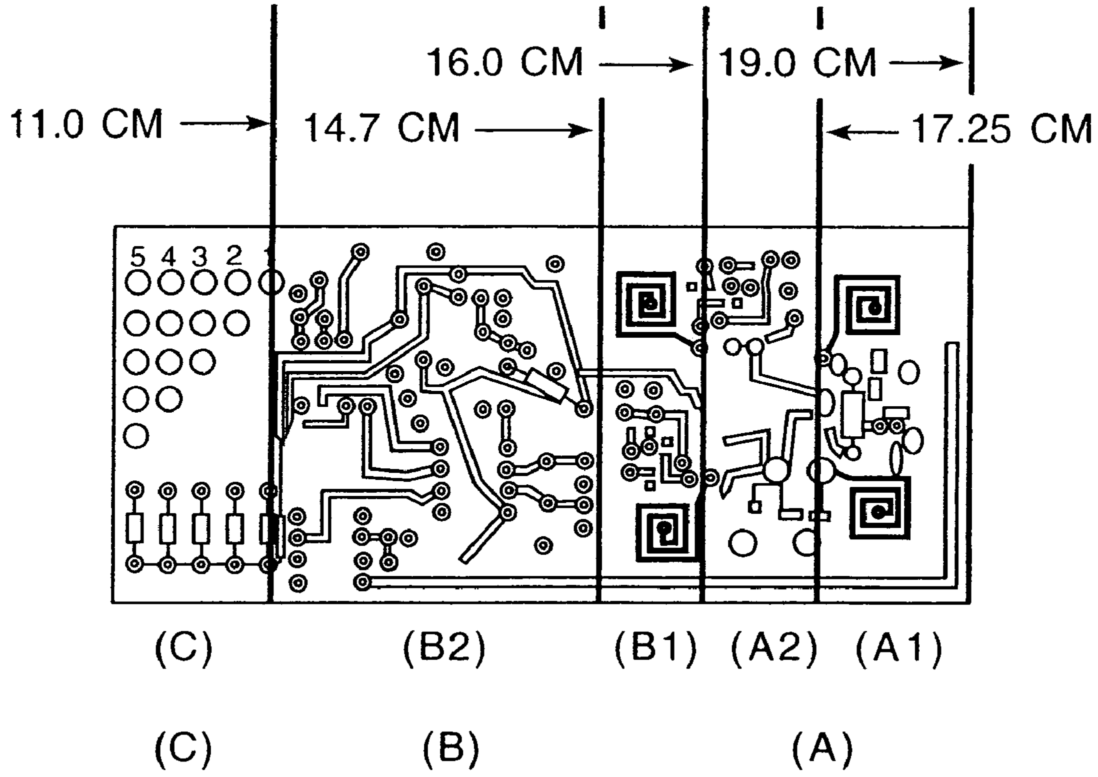
11.0 CM
14.7 CM
16.0 CM
19.0 CM
17.25 CM
5 4 3 2 1
(C)
(B2)
(B1)
(A2)
(A1)
(C)
(B)
(A)

FIG. 5b

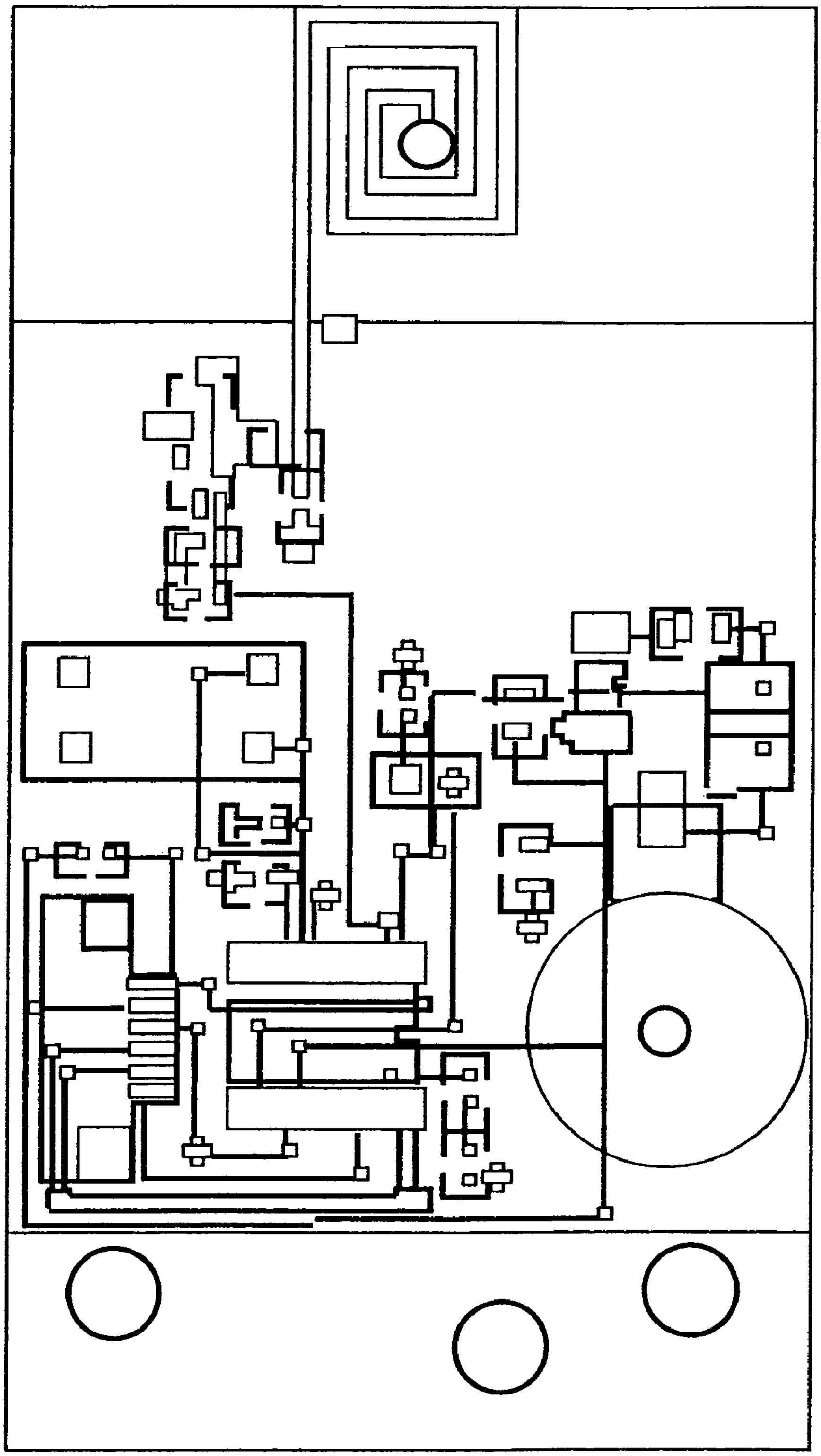

FIG. 6a

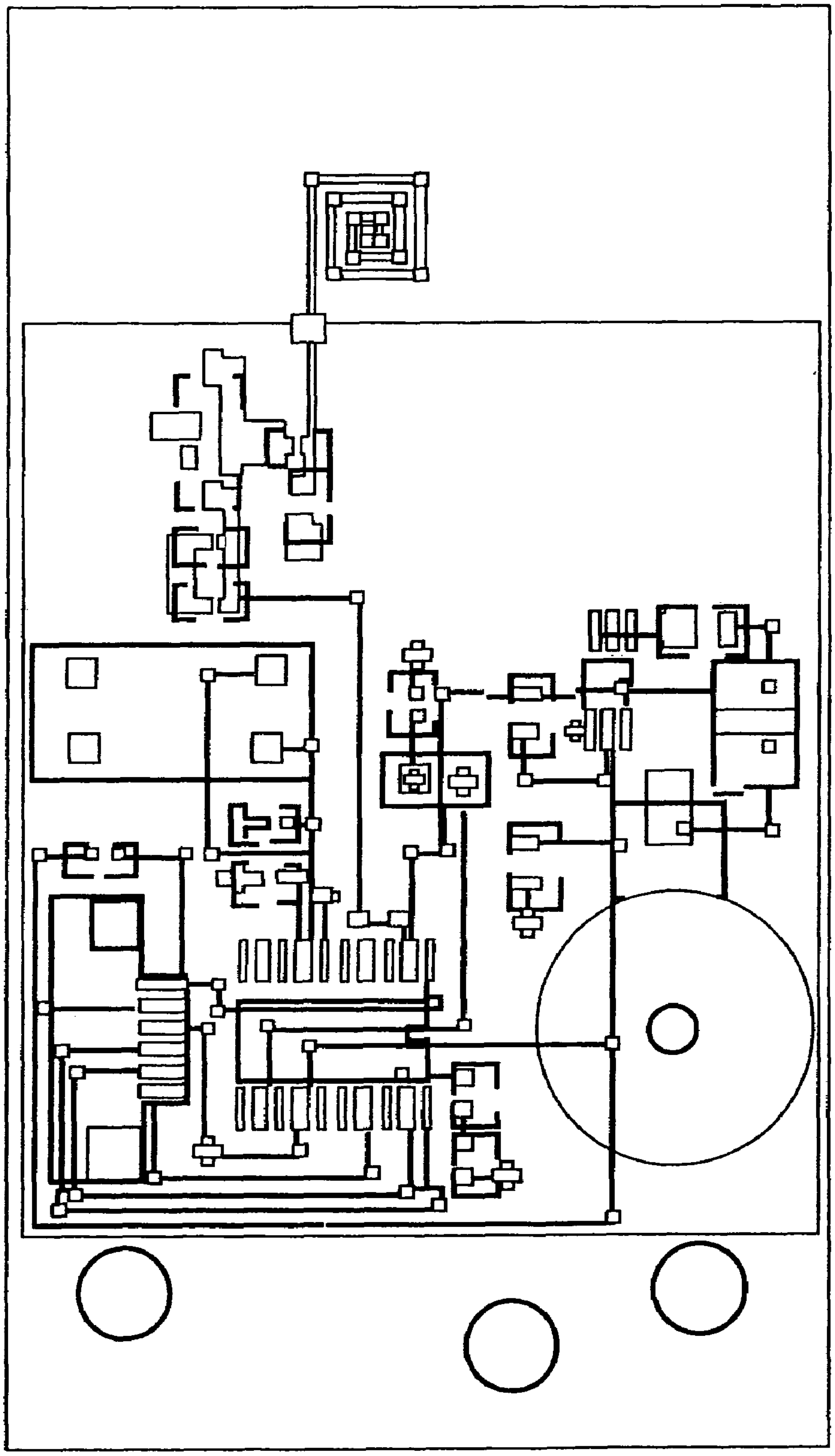

FIG. 6b

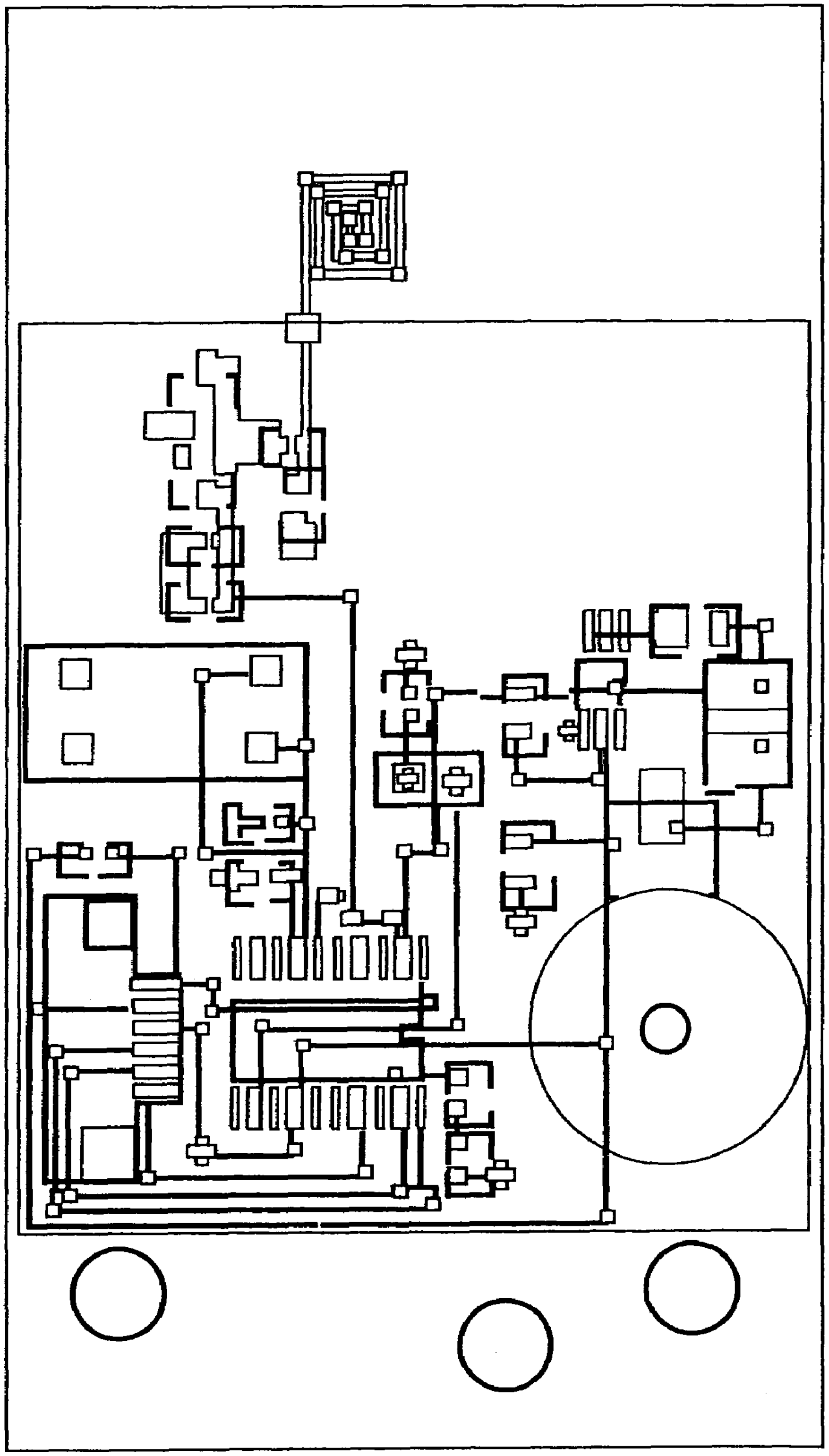

FIG. 6c

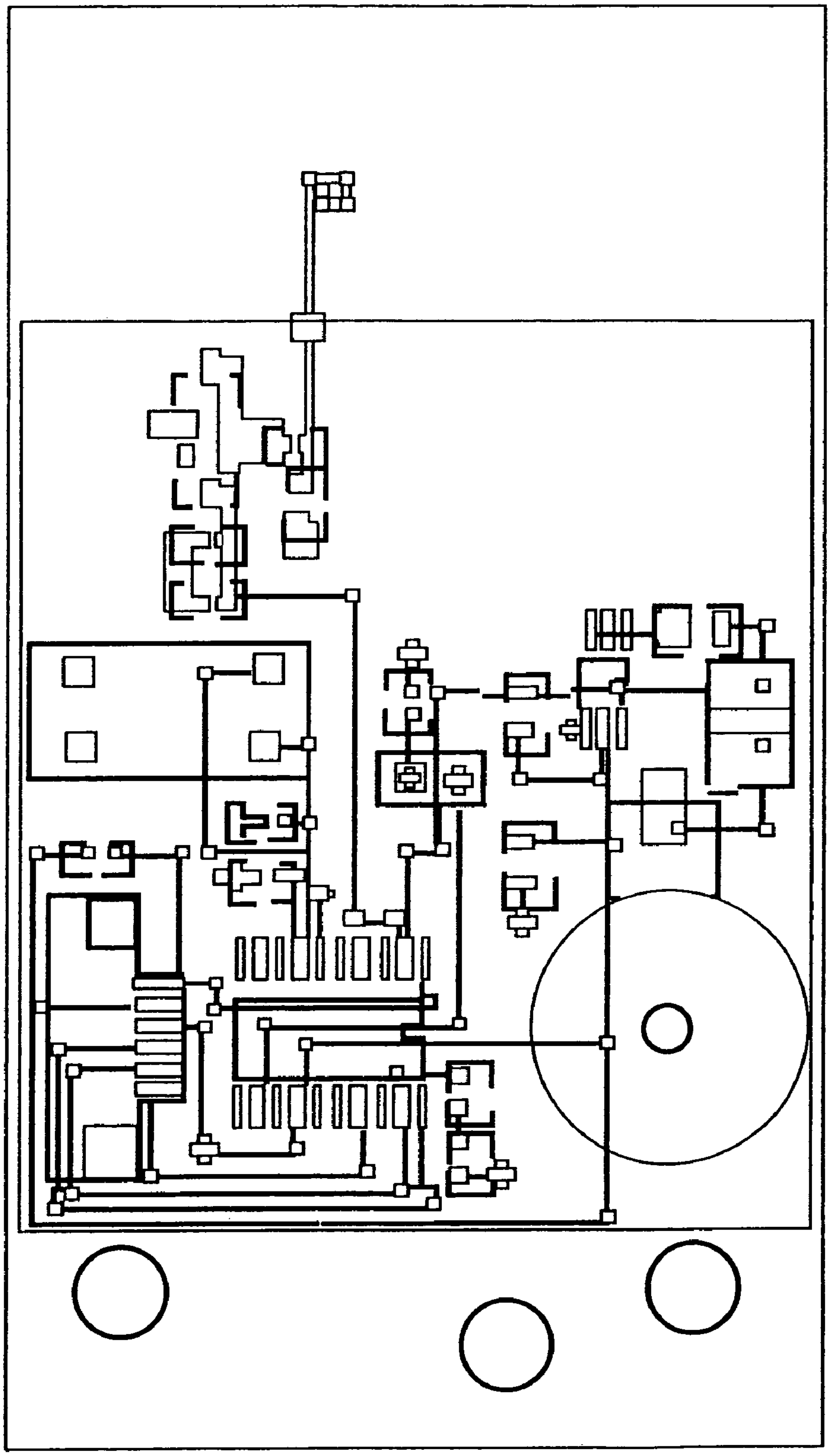

FIG. 6d

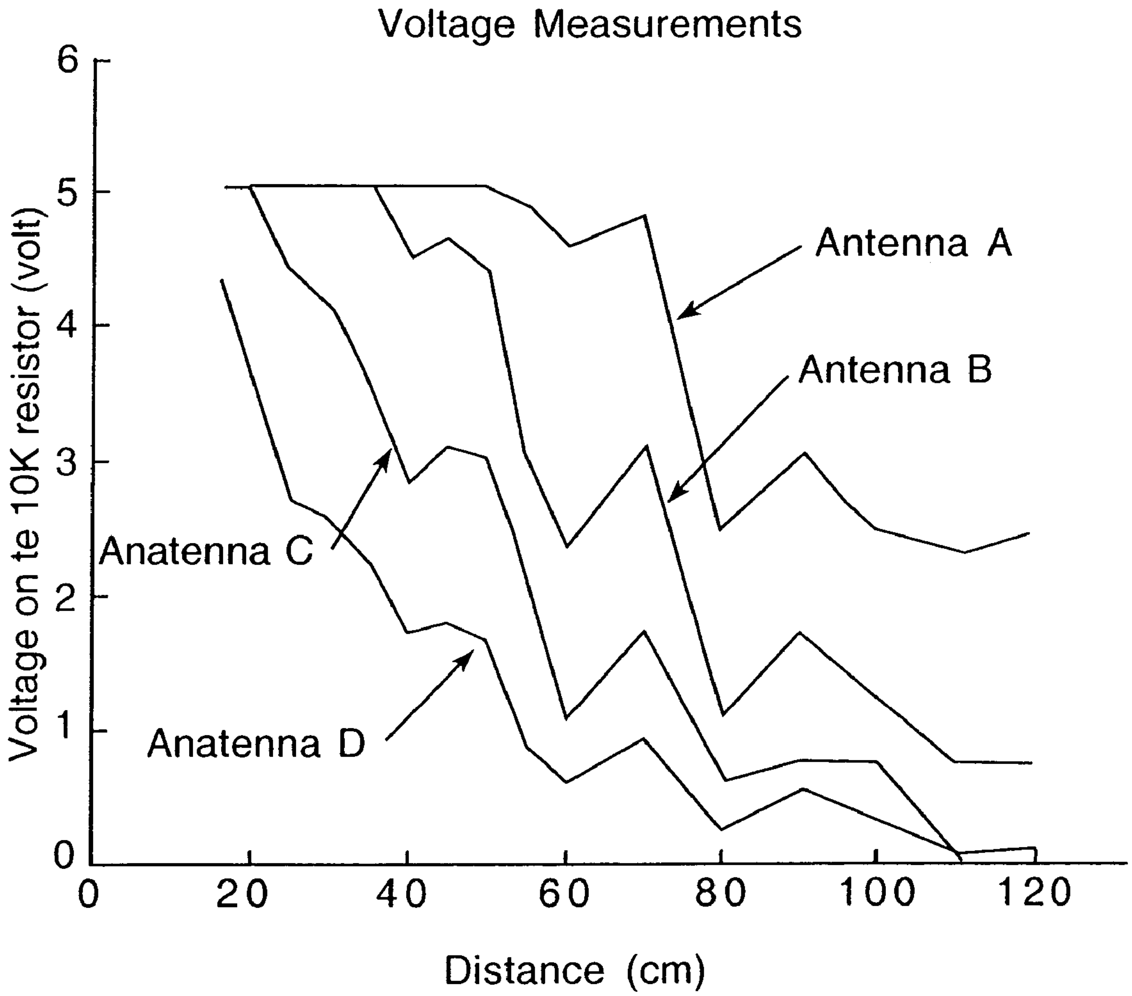
Voltage Measurements
Voltage on te 10K resistor (volt)
0
1
2
3
4
5
6
Distance (cm)
0
20
40
60
80
100
120
Antenna A
Antenna B
Anatenna C
Anatenna D

FIG. 7

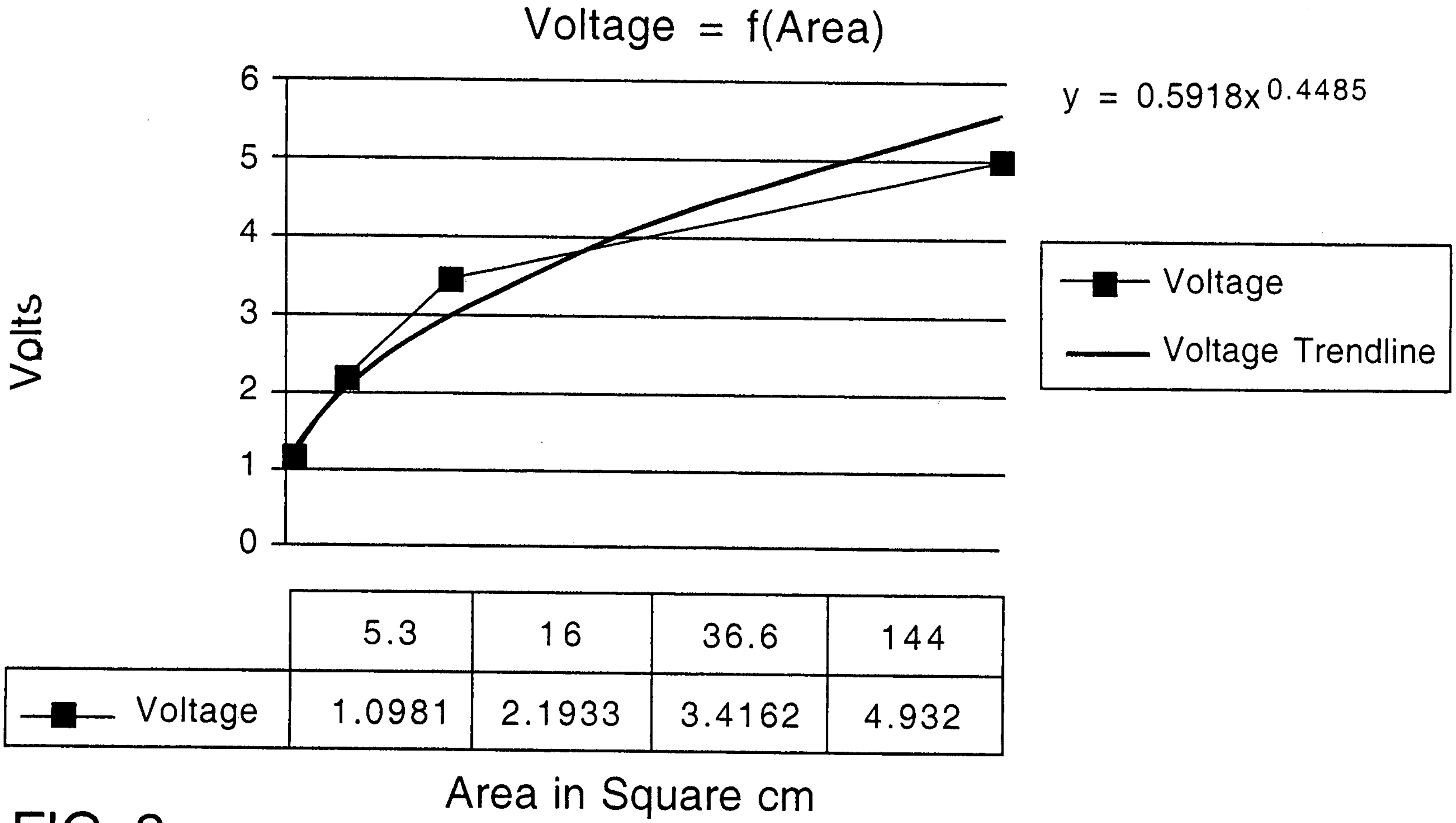
Voltage = f(Area)
y = 0.5918x^0.4485
Volts
6
5
4
3
2
1
0
Voltage
Voltage Trendline
5.3
16
36.6
144
Voltage
1.0981
2.1933
3.4162
4.932
Area in Square cm

FIG. 8

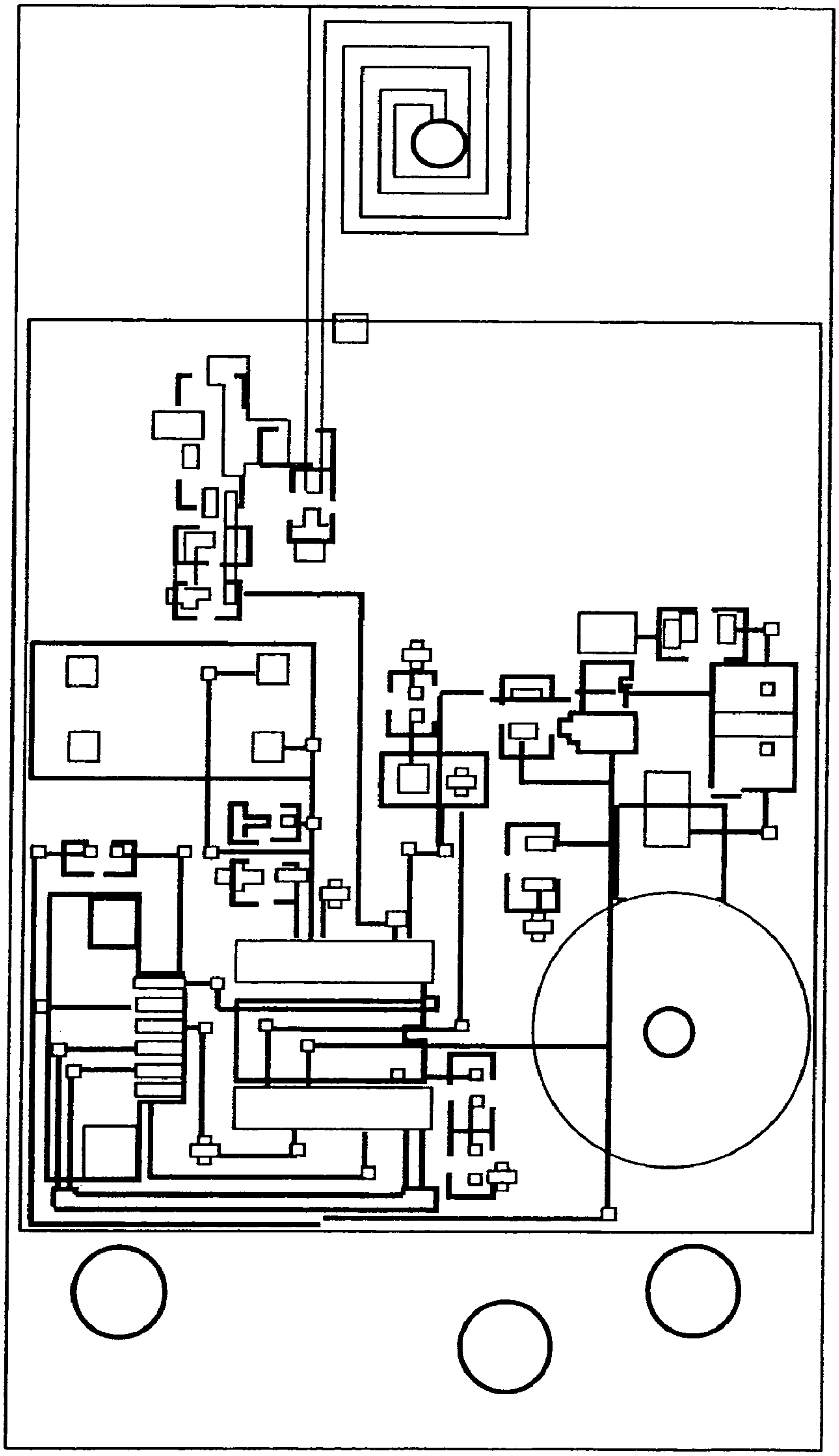

FIG. 9a

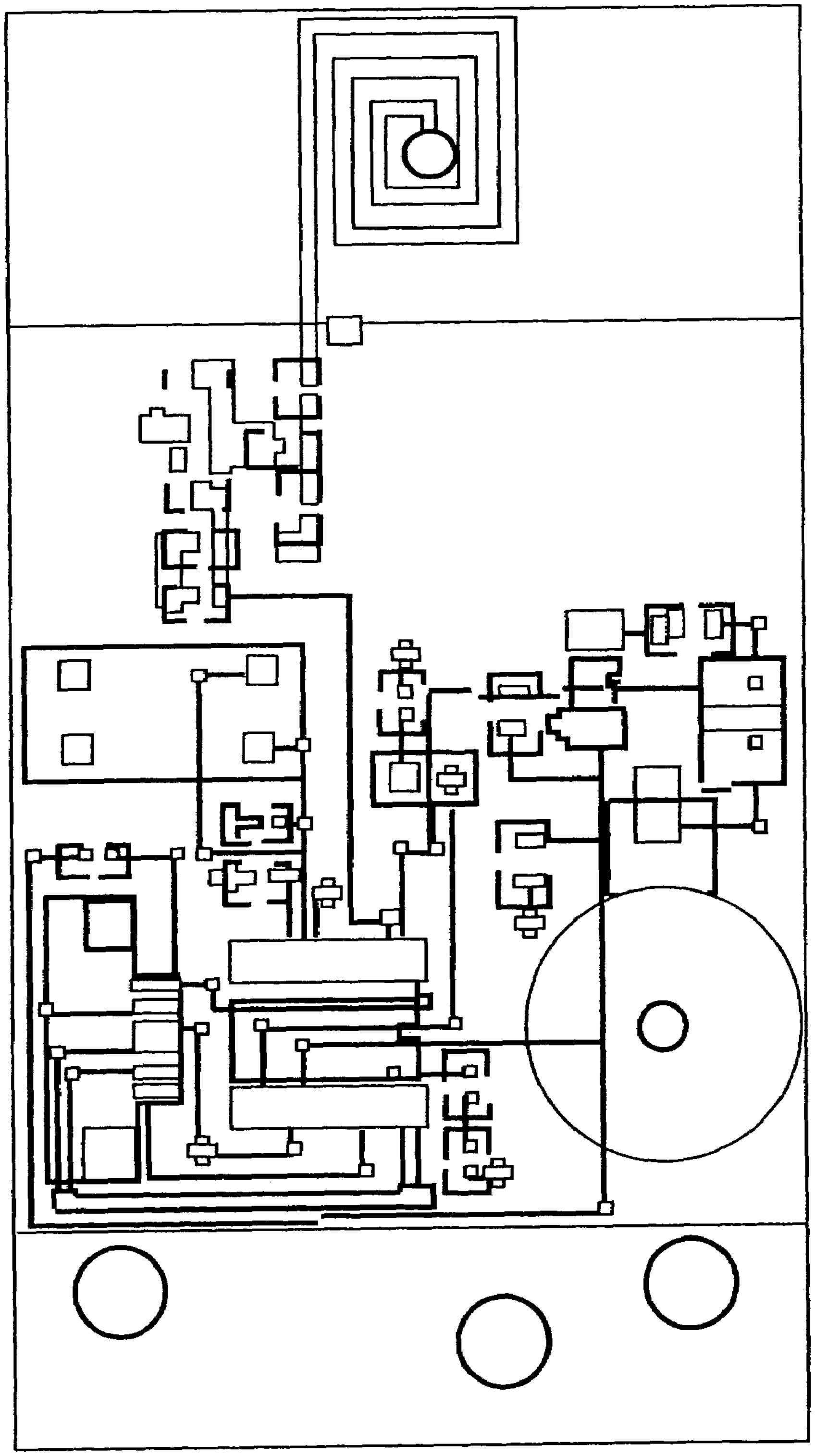

FIG. 9b

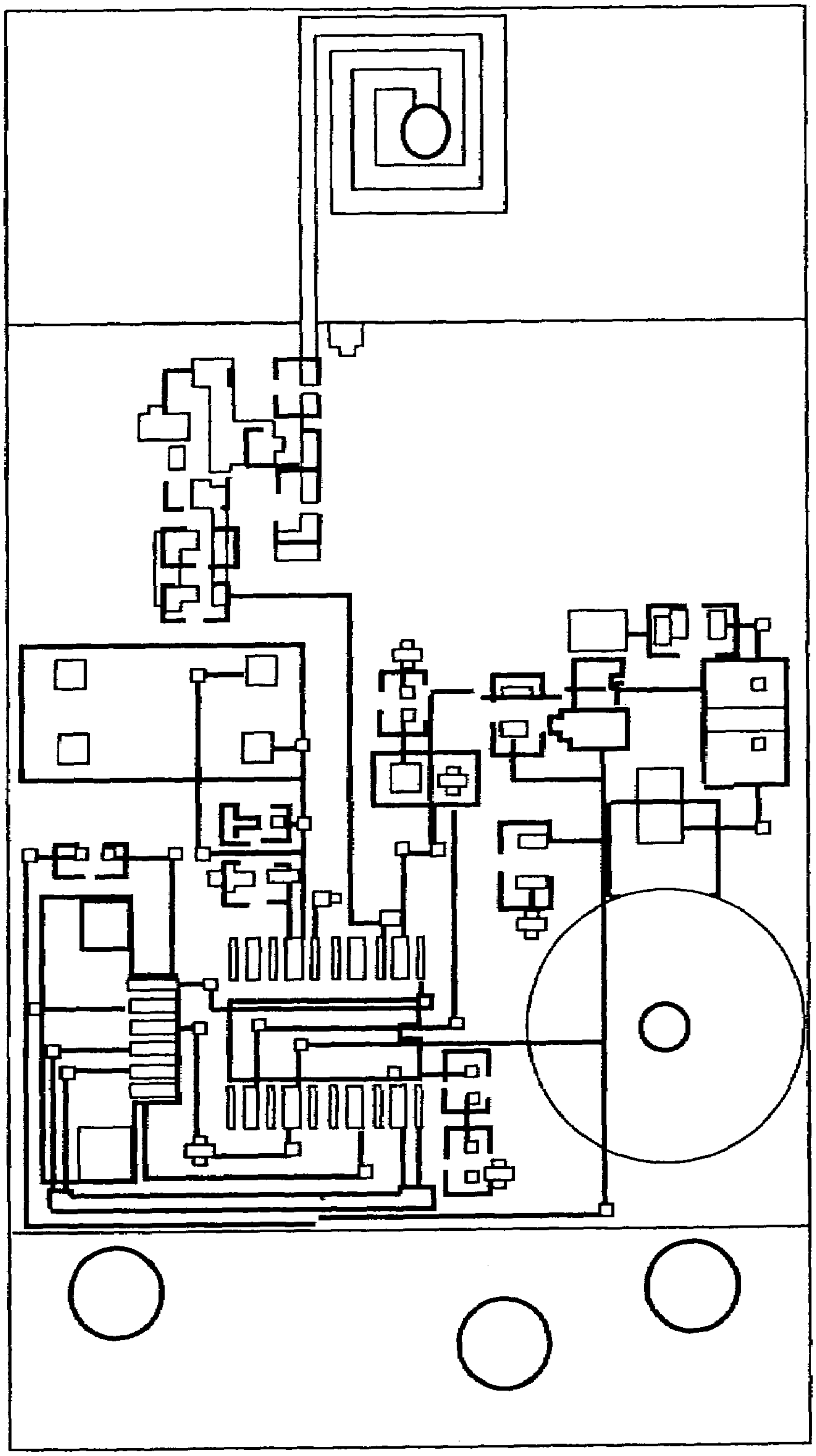

FIG. 9c

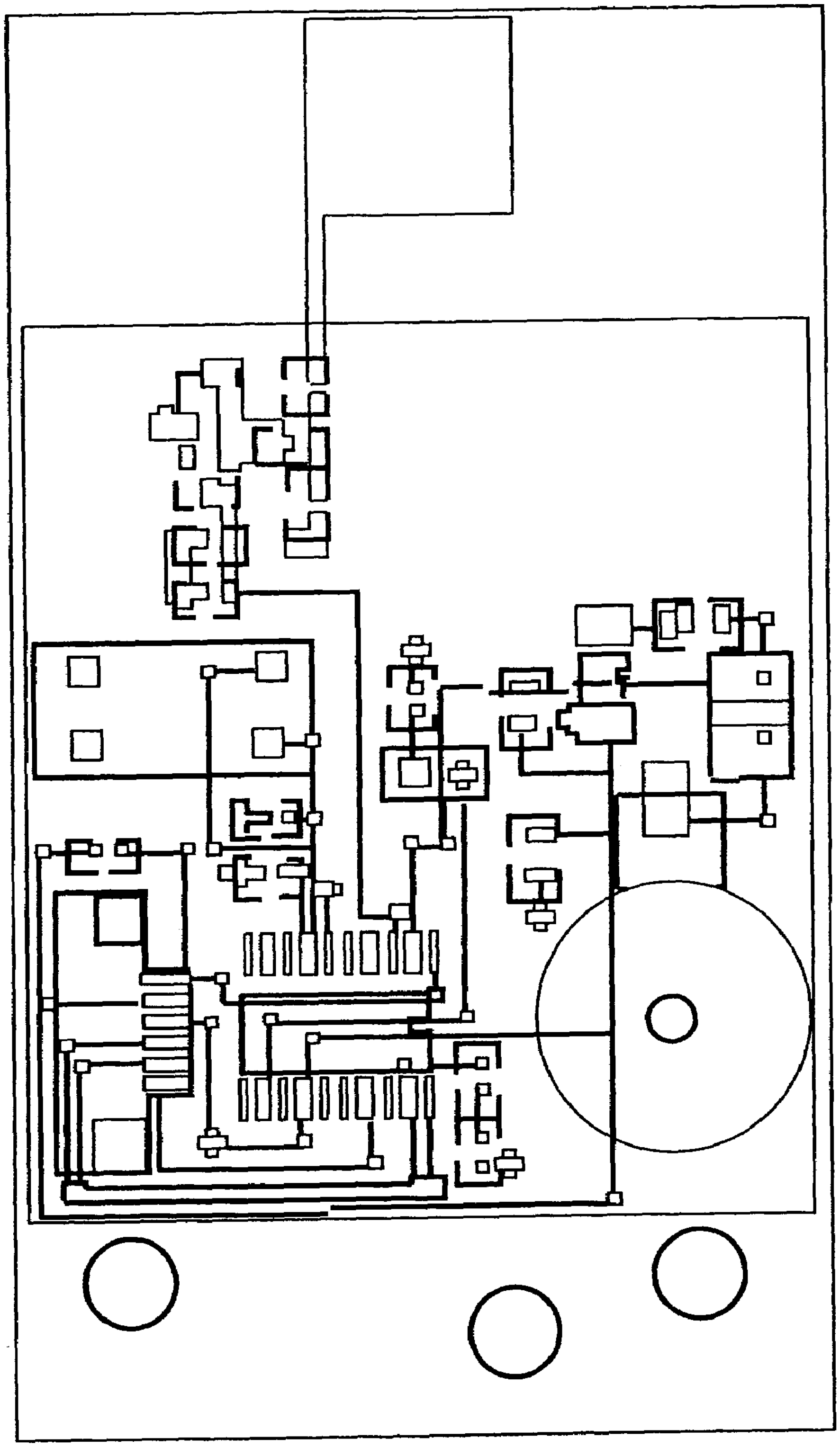

FIG. 9d

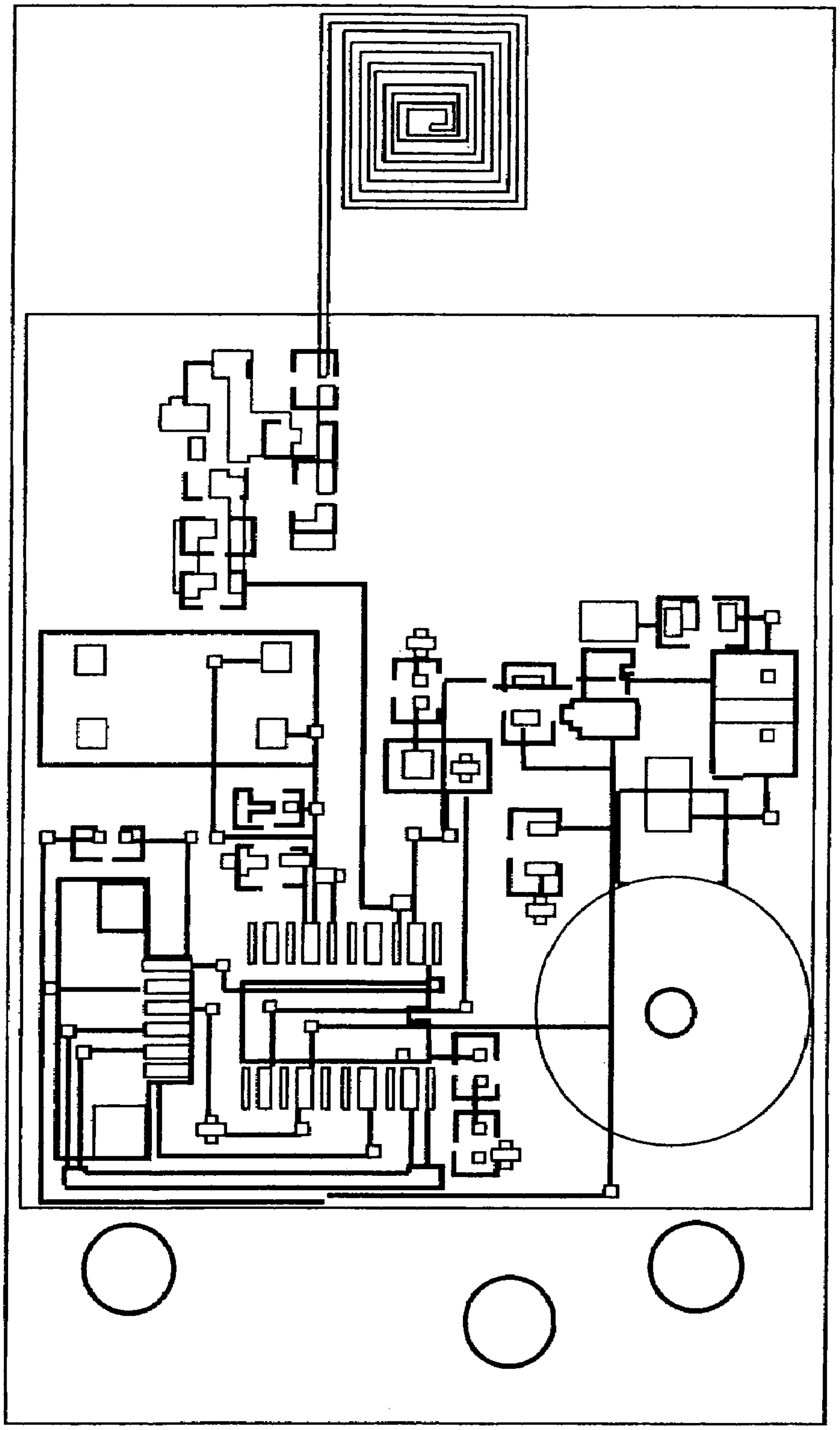

FIG. 9e

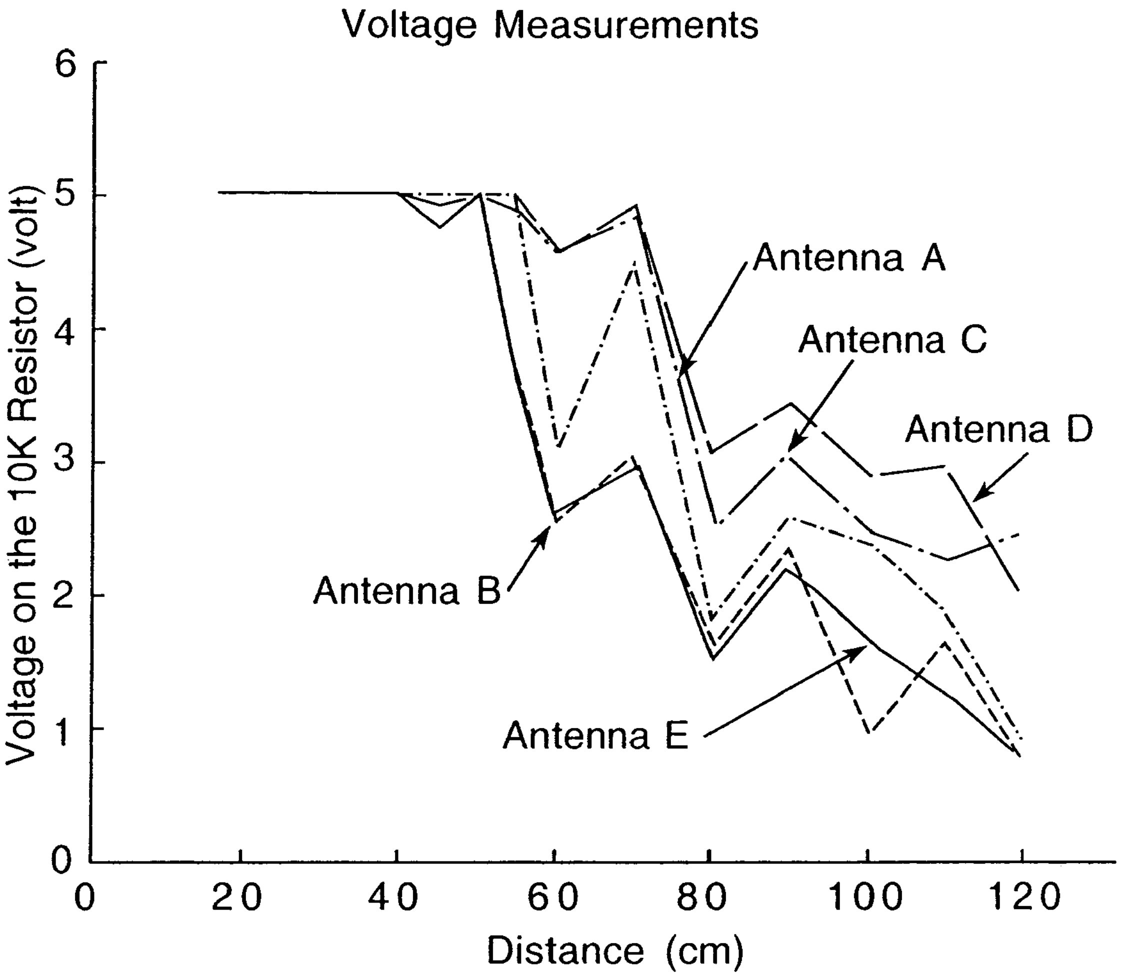
Voltage Measurements
Voltage on the 10K Resistor (volt)
0
1
2
3
4
5
6
Distance (cm)
0
20
40
60
80
100
120
Antenna A
Antenna C
Antenna D
Antenna B
Antenna E

FIG. 10

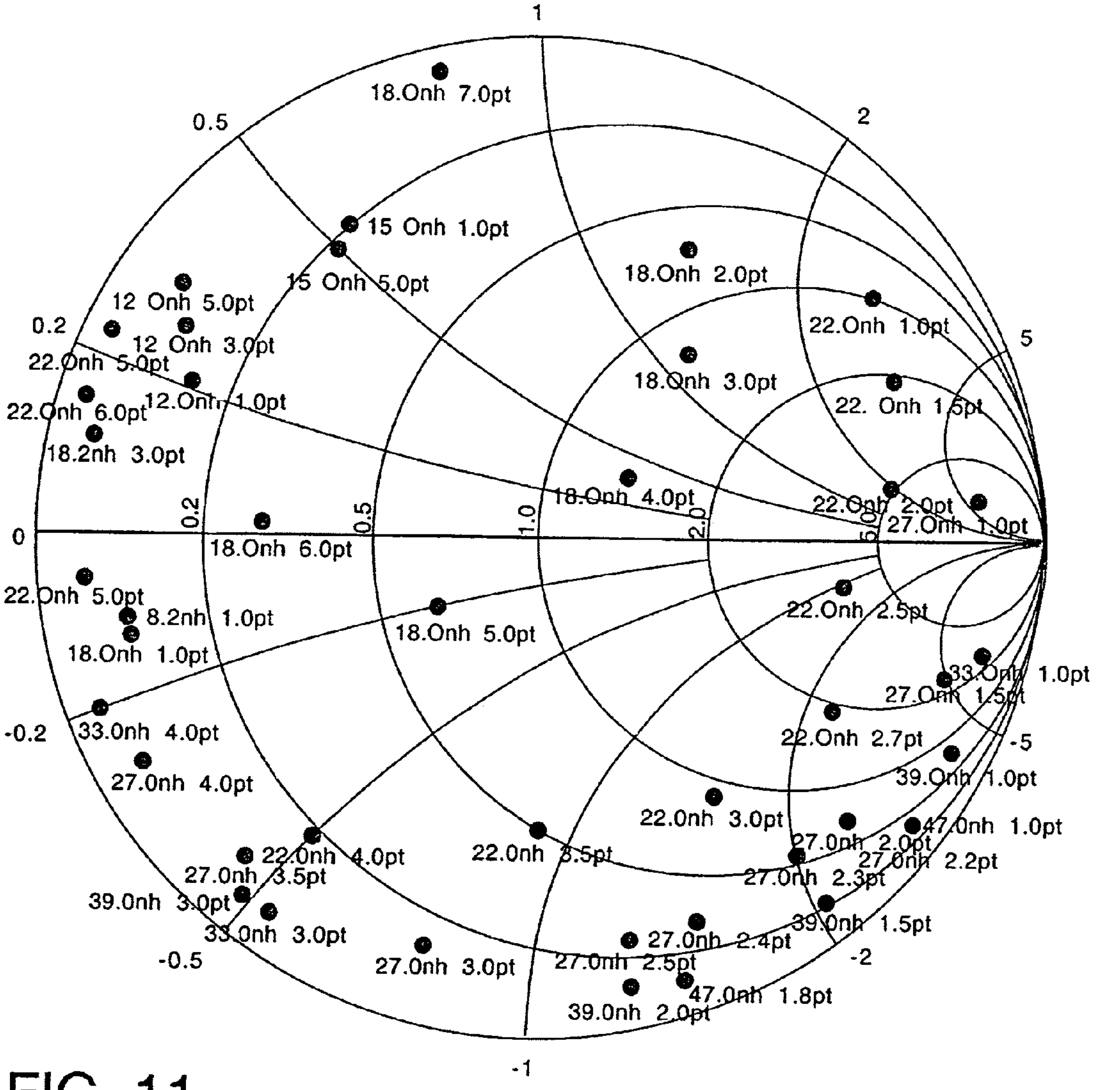
1
0.5
2
18.0nh 7.0pt
15 0nh 1.0pt
15 0nh 5.0pt
18.0nh 2.0pt
12 0nh 5.0pt
0.2
12 0nh 3.0pt
22.0nh 5.0pt
22.0nh 1.0pt
5
12.0nh 1.0pt
18.0nh 3.0pt
22.0nh 6.0pt
22. 0nh 1.5pt
18.2nh 3.0pt
18.0nh 4.0pt
22.0nh 2.0pt
27.0nh 1.0pt
0
0.2
0.5
1.0
2.0
5.0
18.0nh 6.0pt
22.0nh 5.0pt
8.2nh 1.0pt
18.0nh 5.0pt
22.0nh 2.5pt
18.0nh 1.0pt
33.0nh 1.0pt
27.0nh 1.5pt
-0.2
33.0nh 4.0pt
22.0nh 2.7pt
-5
27.0nh 4.0pt
39.0nh 1.0pt
22.0nh 3.0pt
47.0nh 1.0pt
27.0nh 2.0pt
22.0nh 4.0pt
22.0nh 3.5pt
27.0nh 2.2pt
27.0nh 3.5pt
27.0nh 2.3pt
39.0nh 3.0pt
39.0nh 1.5pt
33.0nh 3.0pt
27.0nh 2.4pt
-0.5
27.0nh 3.0pt
27.0nh 2.5pt
-2
47.0nh 1.8pt
39.0nh 2.0pt
-1

FIG. 11

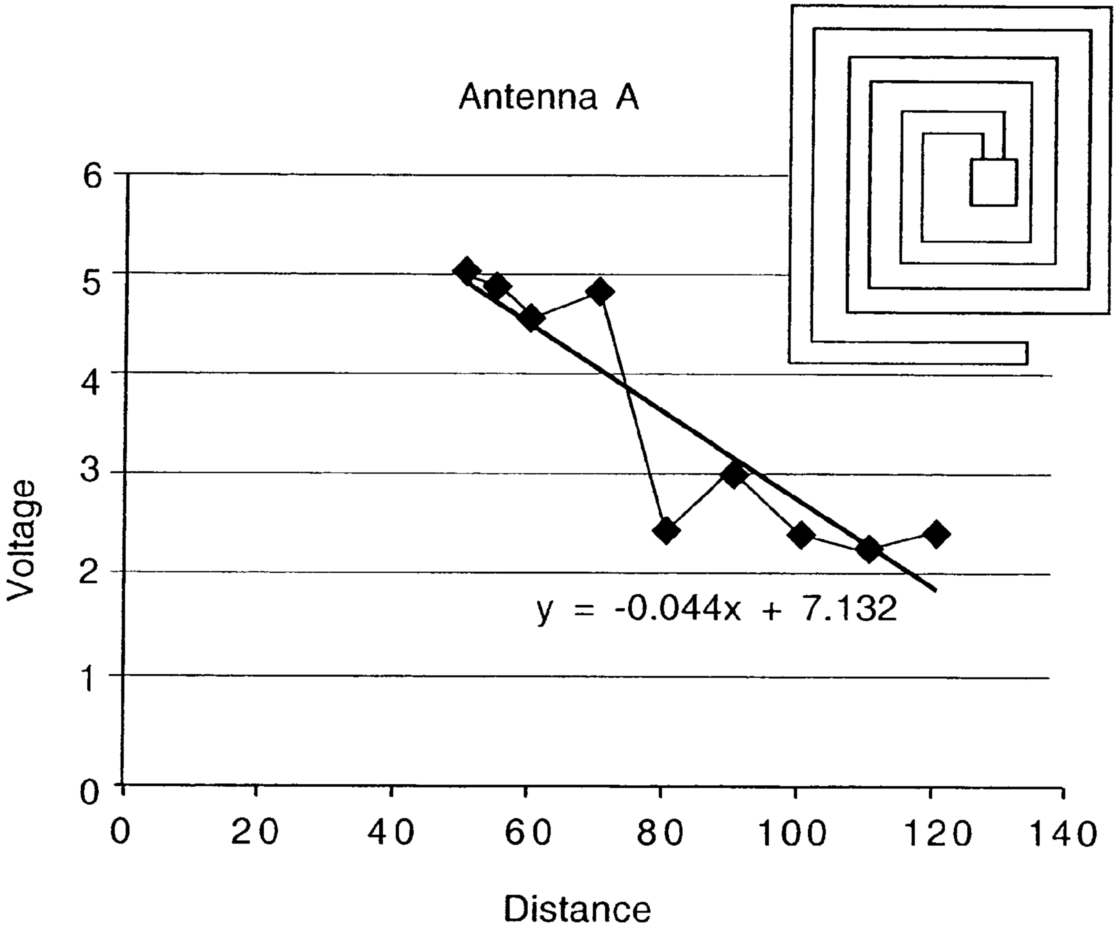
Antenna A
Voltage
Distance
y = -0.044x + 7.132
0
1
2
3
4
5
6
0
20
40
60
80
100
120
140

FIG. 12a

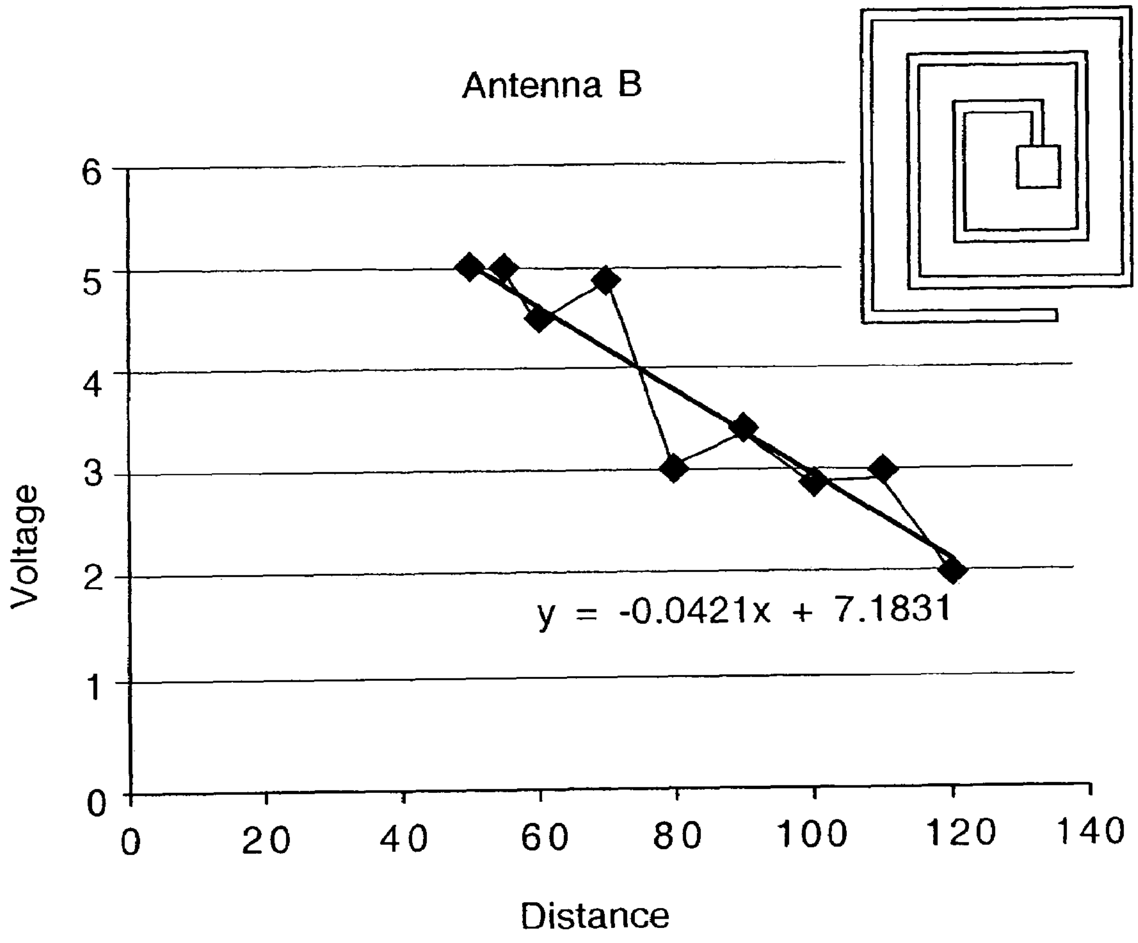
Antenna B
6
5
4
3
2
1
0
Voltage
y = -0.0421x + 7.1831
0
20
40
60
80
100
120
140
Distance

FIG. 12b

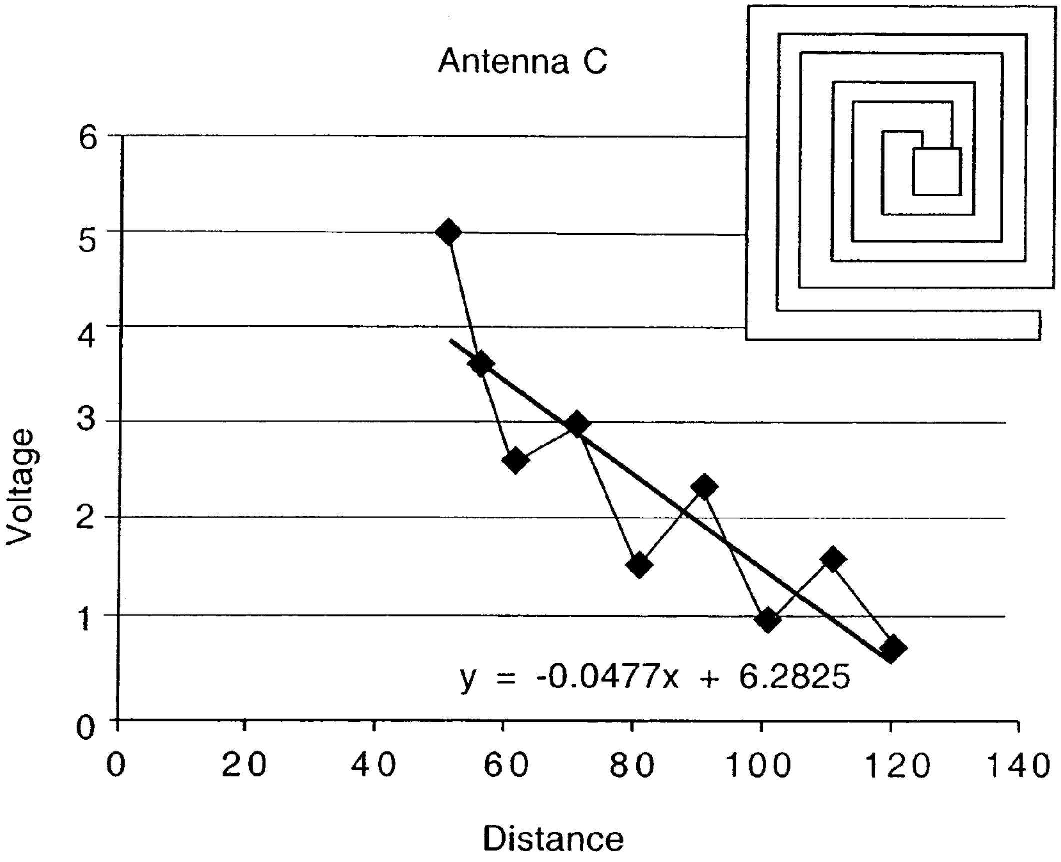
Antenna C
6
5
4
3
2
1
0
Voltage
0
20
40
60
80
100
120
140
Distance
y = -0.0477x + 6.2825

FIG. 12c

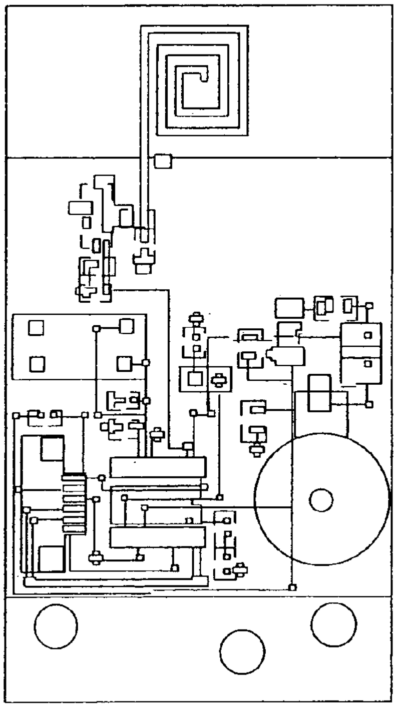

Number of Measurement	Thickness
1	55.1 um
2	223 um
3	234um

FIG. 13a

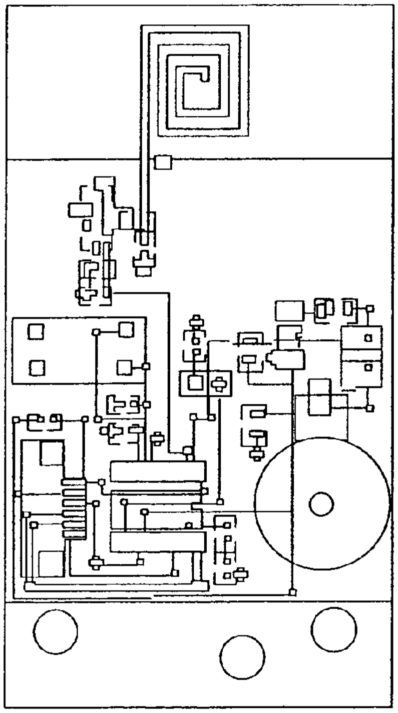

Number of Measurement	Thickness
1	55.1um
2	82.3um
3	273um

FIG. 13b

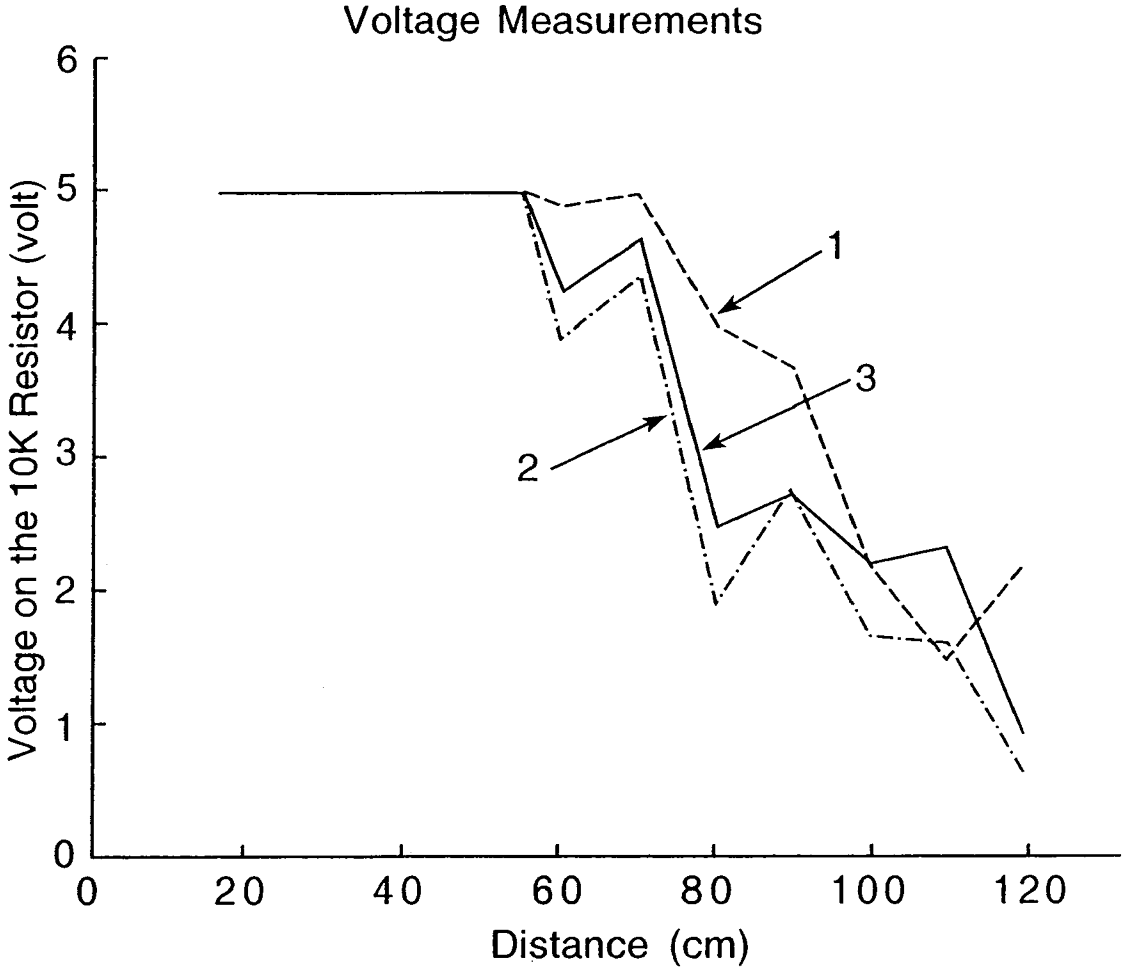
Voltage Measurements
Voltage on the 10K Resistor (volt)
0
1
2
3
4
5
6
0
20
40
60
80
100
120
Distance (cm)
1
2
3

FIG. 14a

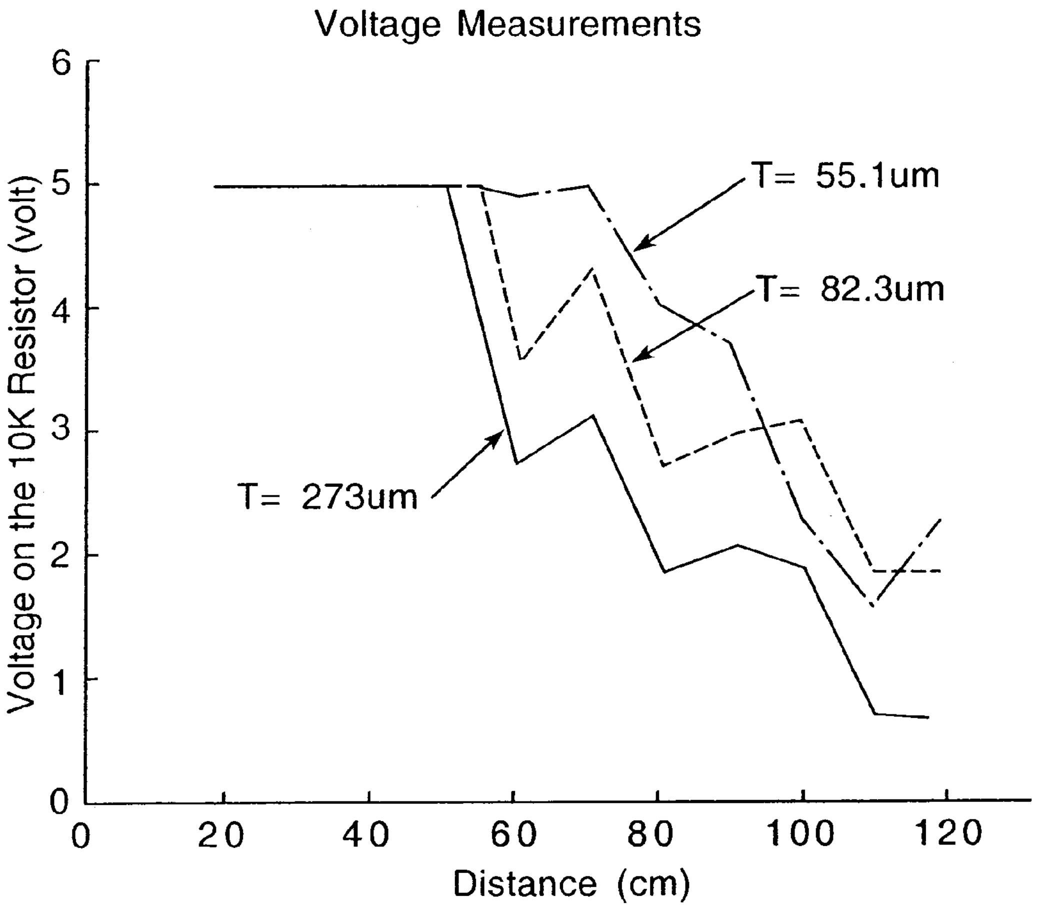
Voltage Measurements
6
5
4
3
2
1
0
Voltage on the 10K Resistor (volt)
0
20
40
60
80
100
120
Distance (cm)
T= 55.1um
T= 82.3um
T= 273um

FIG. 14b

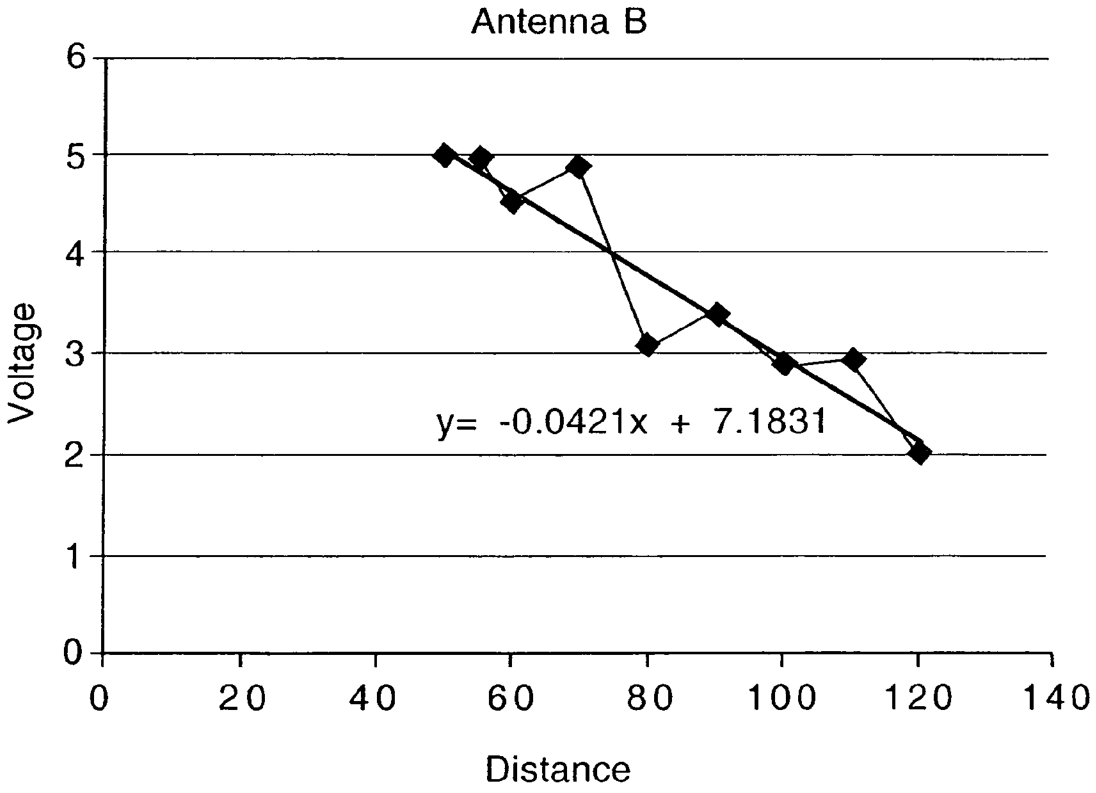
Antenna B
Voltage
6
5
4
3
2
1
0
y= -0.0421x + 7.1831
0
20
40
60
80
100
120
140
Distance

FIG. 15a

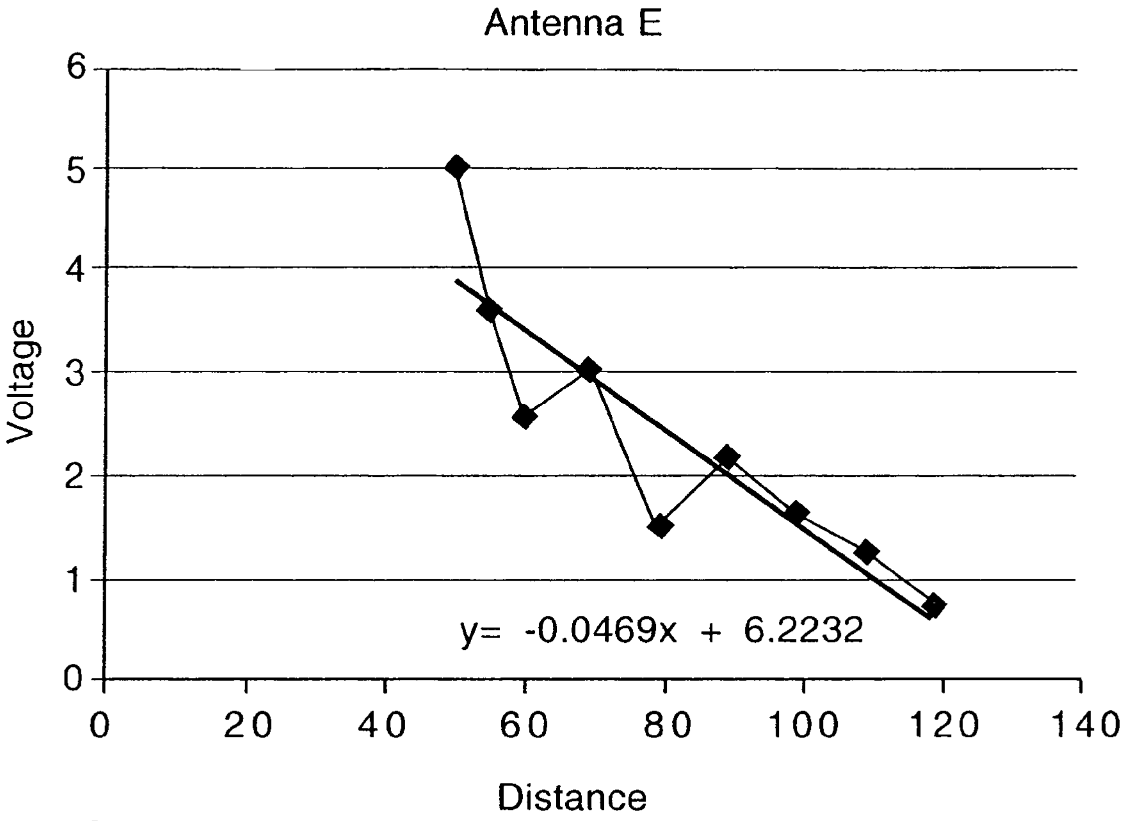
Antenna E
Voltage
6
5
4
3
2
1
0
y= -0.0469x + 6.2232
0
20
40
60
80
100
120
140
Distance

FIG. 15b

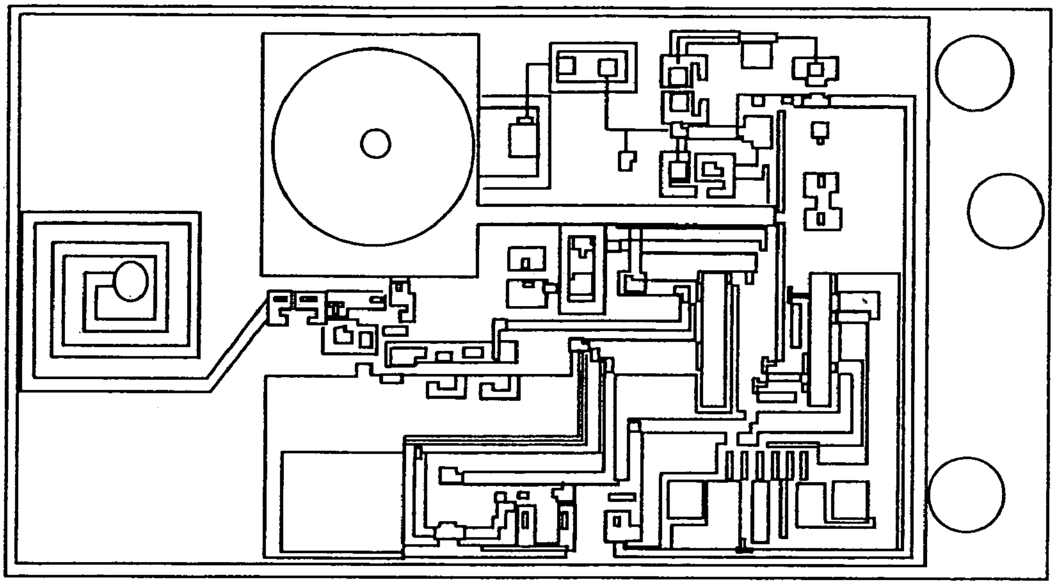

FIG. 16a

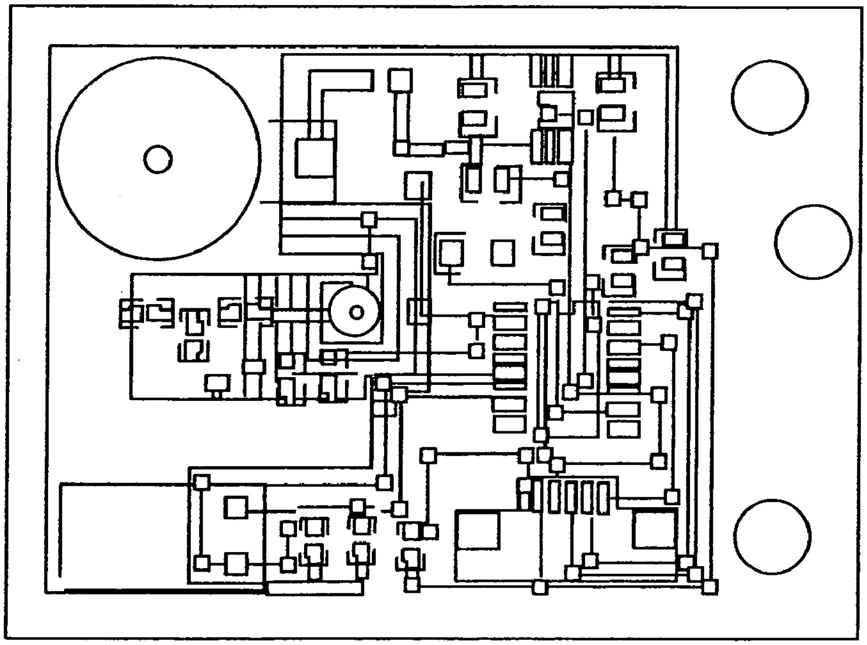

FIG. 16b

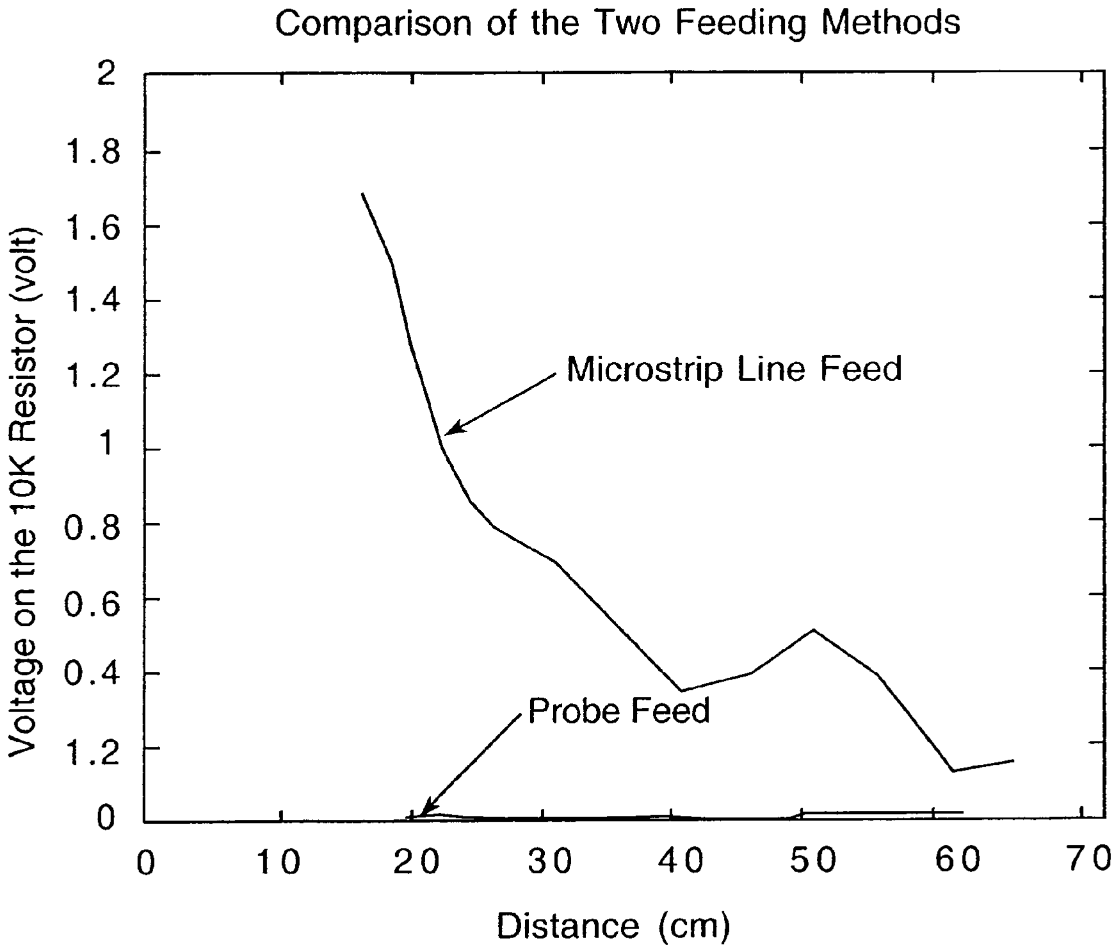
Comparison of the Two Feeding Methods
Voltage on the 10K Resistor (volt)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
1.2
0
Microstrip Line Feed
Probe Feed
0
10
20
30
40
50
60
70
Distance (cm)

FIG. 17

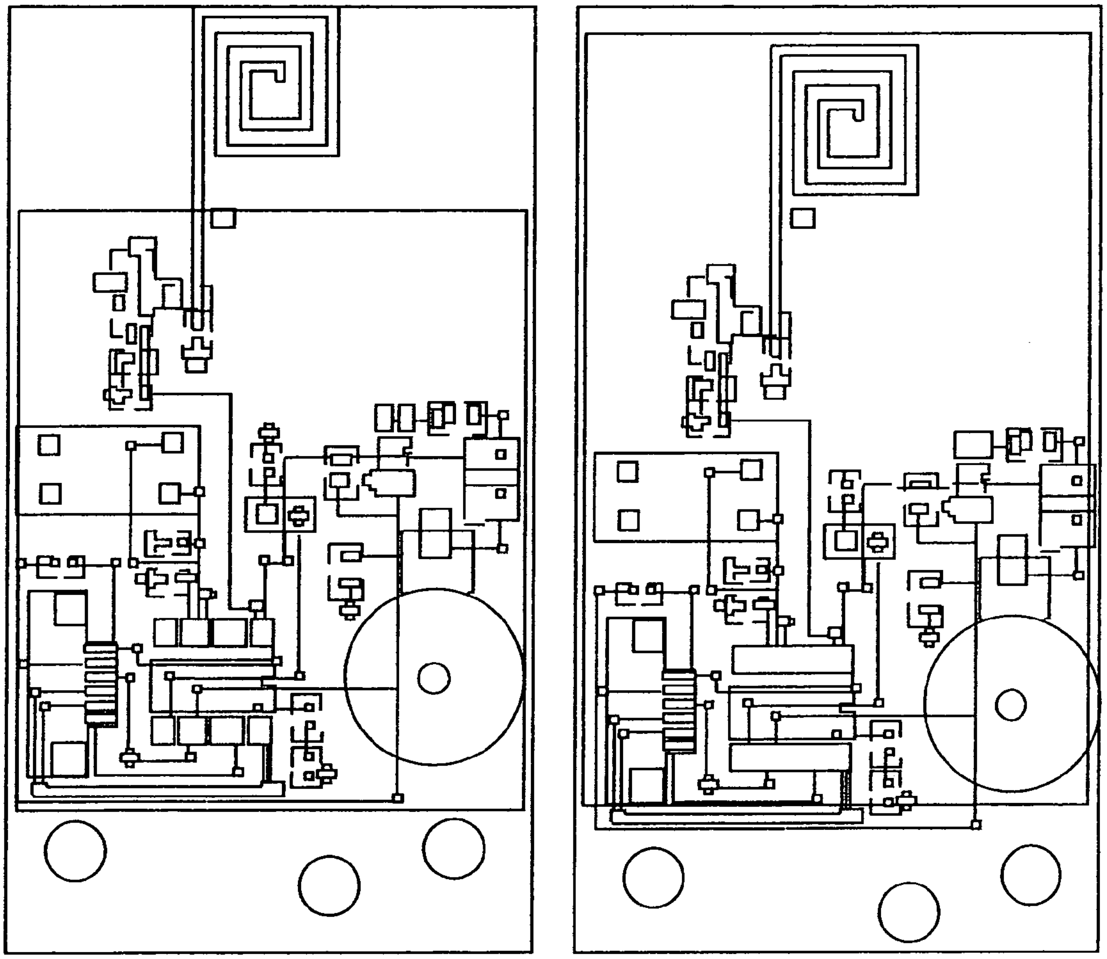

Antenna A
(No Ground Plane)

Antenna B
(With Ground Plane)

FIG. 18a

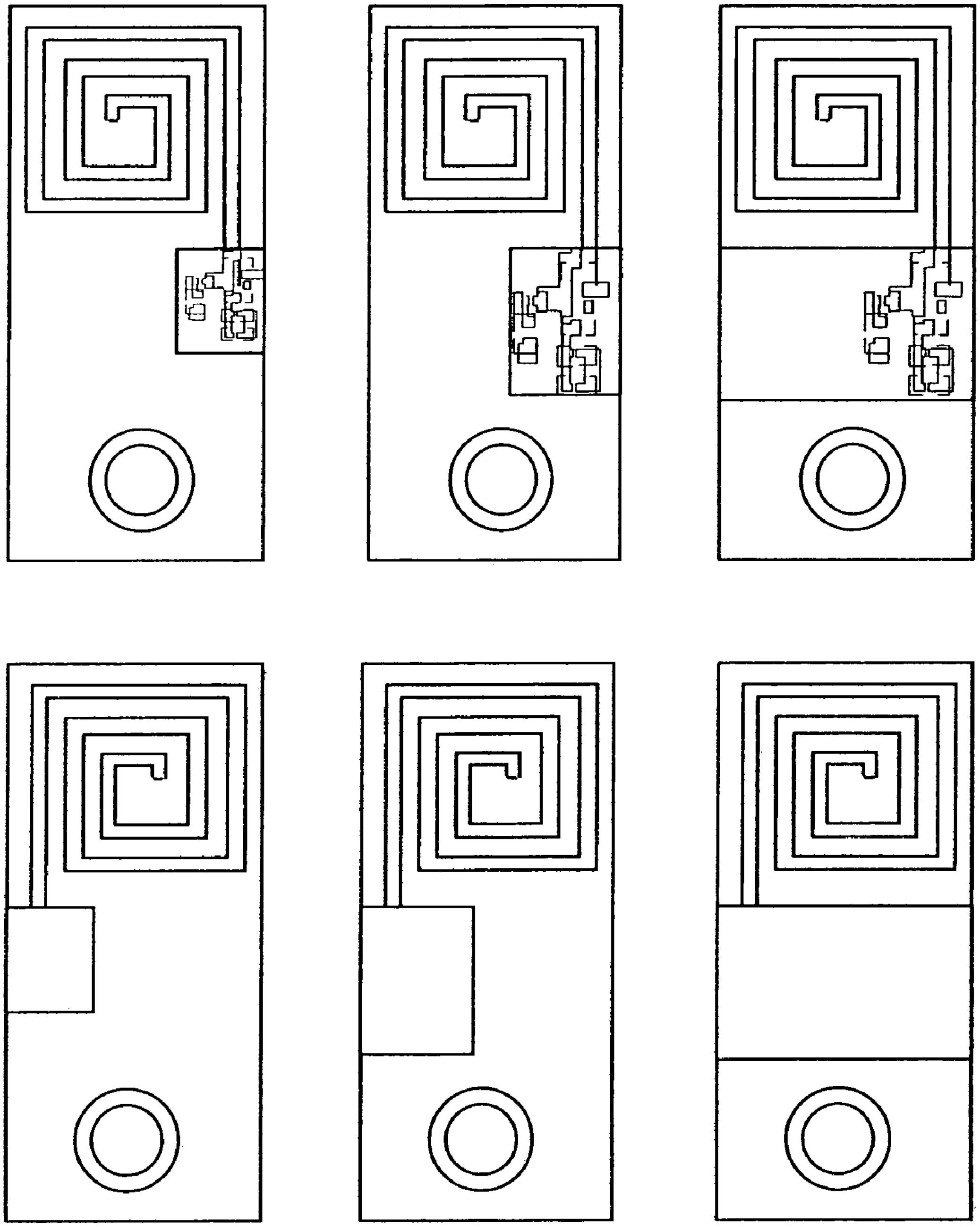

FIG. 18b

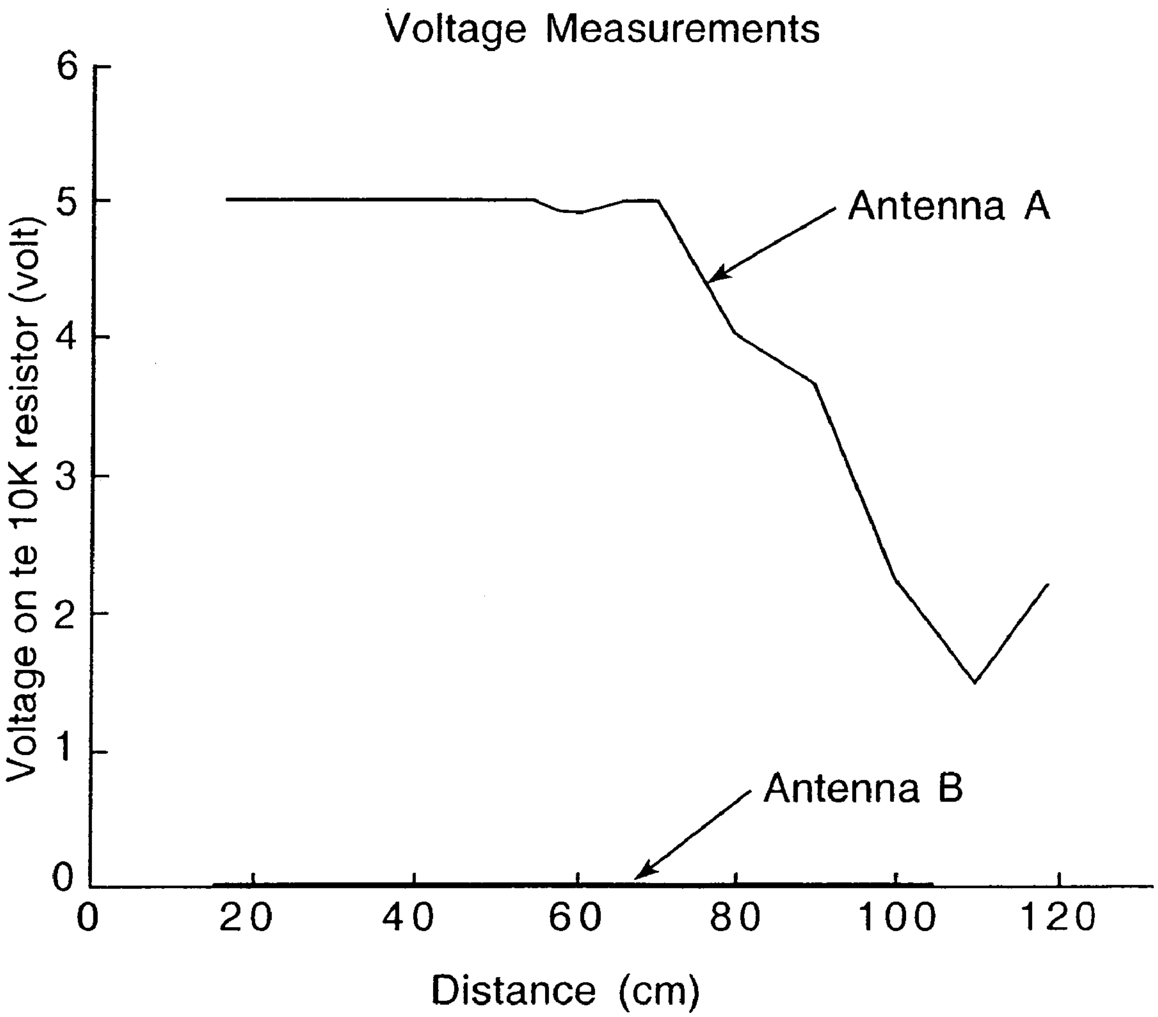
Voltage Measurements
Voltage on te 10K resistor (volt)
6
5
4
3
2
1
0
0
20
40
60
80
100
120
Distance (cm)
Antenna A
Antenna B

FIG. 19

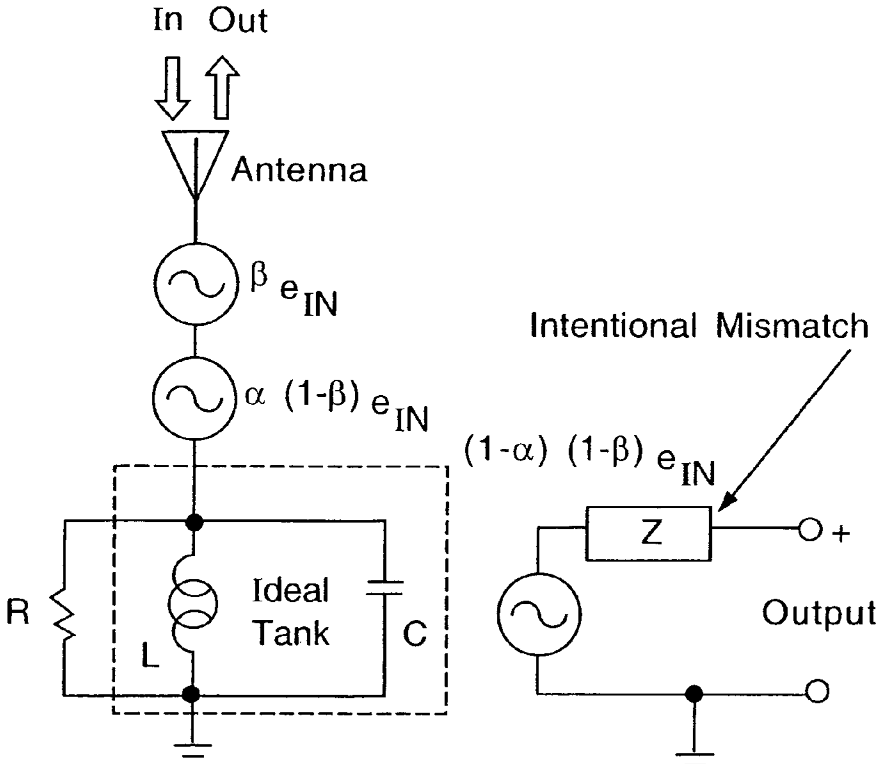
In Out
Antenna
β e_IN
α (1-β) e_IN
Intentional Mismatch
(1-α) (1-β) e_IN
Z
+
R
Ideal
Tank
L
C
Output

FIG. 20

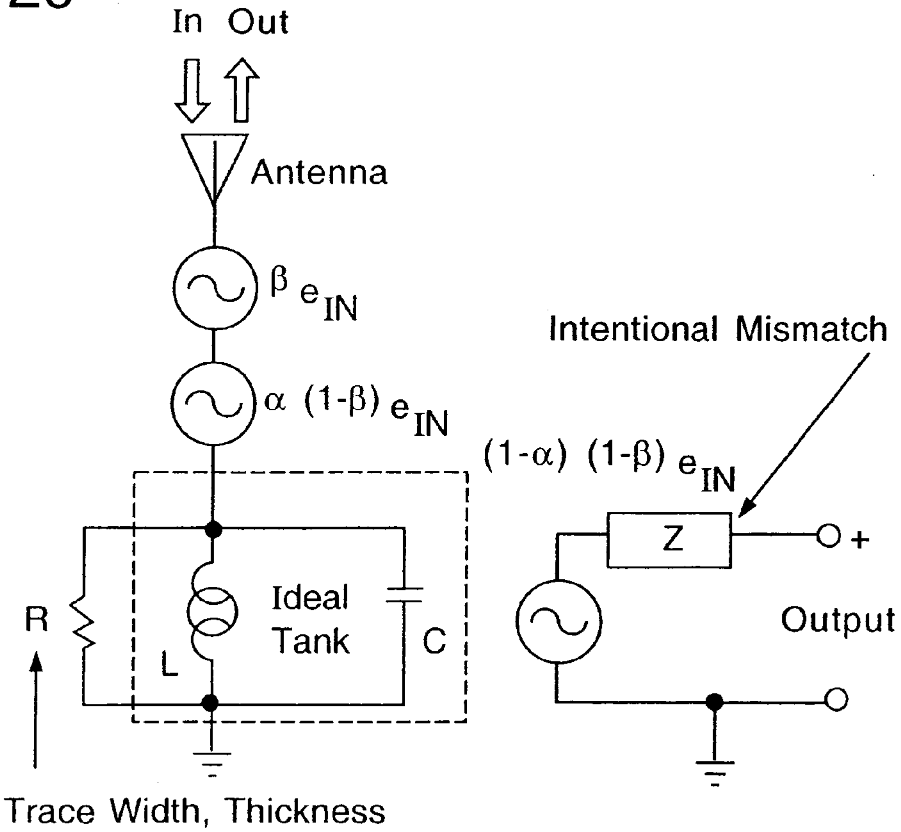
In Out
Antenna
β e_IN
α (1-β) e_IN
Intentional Mismatch
(1-α) (1-β) e_IN
Z
+
R
Ideal
Tank
L
C
Output
Trace Width, Thickness

FIG. 21

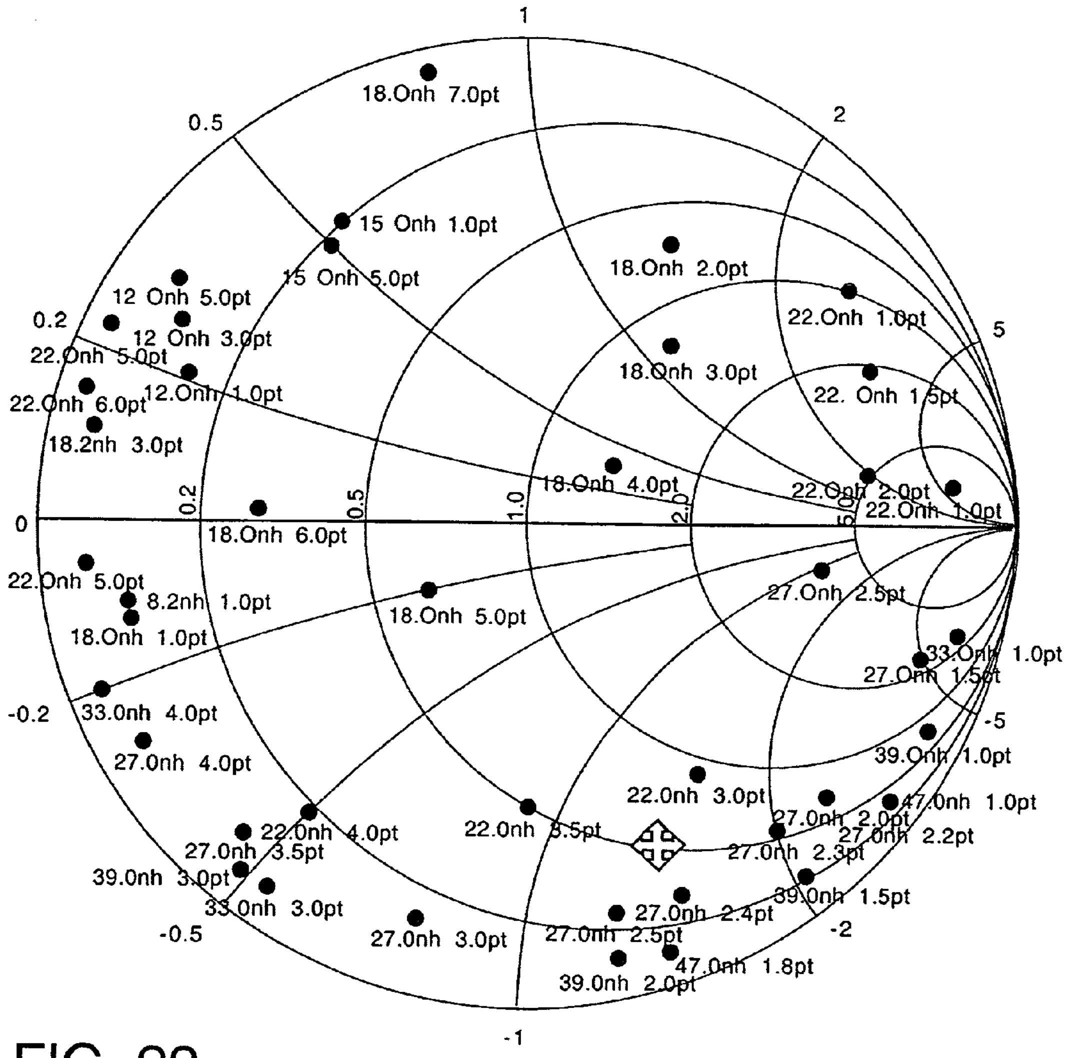
1
0.5
2
0.2
5
0
0.2
0.5
1.0
2.0
5.0
-0.2
-5
-0.5
-2
-1
18.Onh 7.0pt
15 Onh 1.0pt
15 Onh 5.0pt
18.Onh 2.0pt
12 Onh 5.0pt
12 Onh 3.0pt
22.Onh 5.0pt
12.Onh 1.0pt
22.Onh 6.0pt
18.2nh 3.0pt
22.Onh 1.0pt
18.Onh 3.0pt
22. Onh 1.5pt
18.Onh 4.0pt
22.Onh 2.0pt
22.Onh 1.0pt
18.Onh 6.0pt
22.Onh 5.0pt
8.2nh 1.0pt
18.Onh 1.0pt
18.Onh 5.0pt
27.Onh 2.5pt
33.Onh 1.0pt
27.Onh 1.5pt
33.0nh 4.0pt
27.0nh 4.0pt
39.Onh 1.0pt
22.0nh 3.0pt
47.0nh 1.0pt
27.0nh 2.0pt
27.0nh 2.2pt
22.0nh 4.0pt
22.0nh 3.5pt
27.0nh 3.5pt
27.0nh 2.3pt
39.0nh 3.0pt
39.0nh 1.5pt
33.0nh 3.0pt
27.0nh 2.4pt
27.0nh 3.0pt
27.0nh 2.5pt
47.0nh 1.8pt
39.0nh 2.0pt

FIG. 22

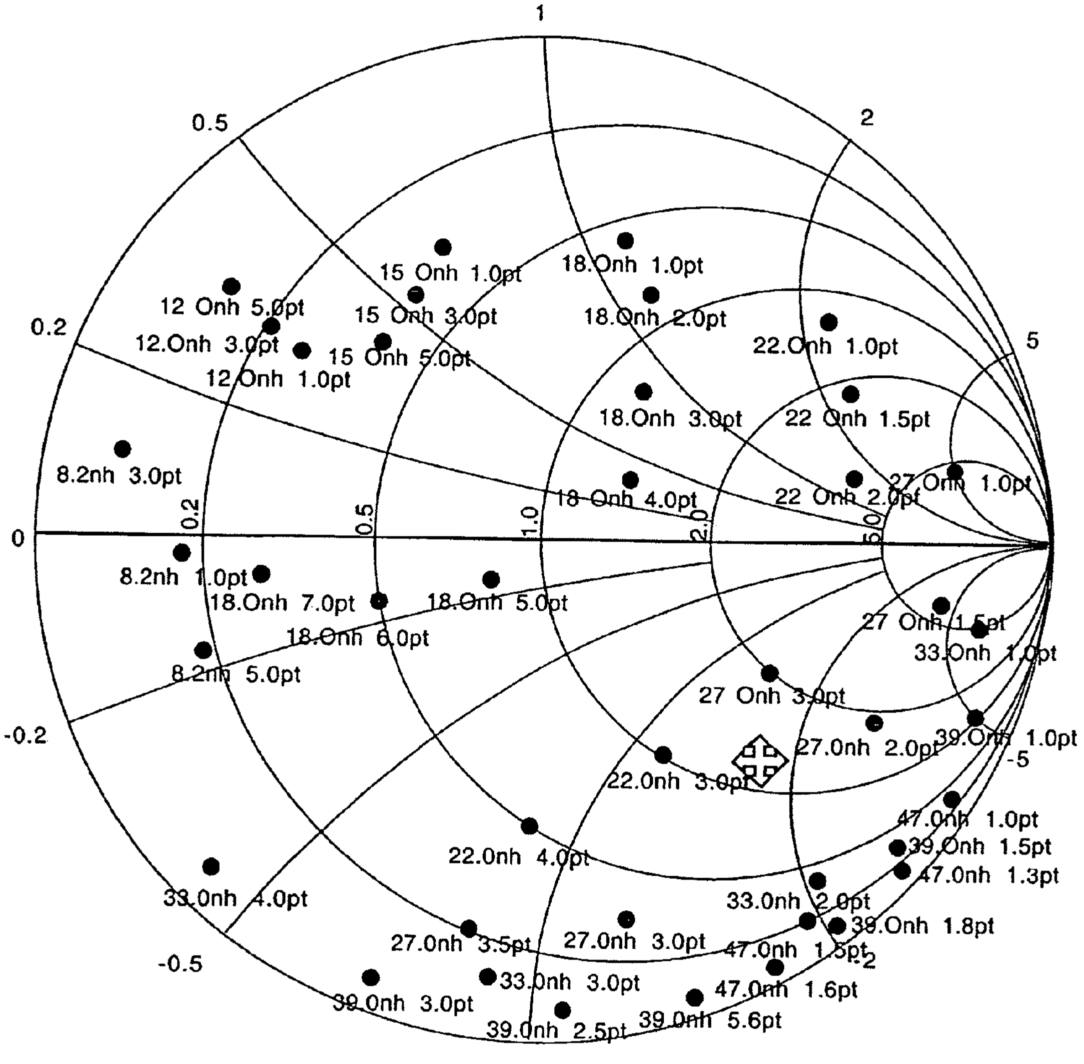
1
0.5
2
0.2
5
0
0.2
0.5
1.0
2.0
5.0
-0.2
-5
-0.5
-2
-1
15 Onh 1.0pt
18.Onh 1.0pt
12 Onh 5.0pt
15 Onh 3.0pt
18.Onh 2.0pt
12.Onh 3.0pt
15 Onh 5.0pt
22.Onh 1.0pt
12.Onh 1.0pt
18.Onh 3.0pt
22 Onh 1.5pt
8.2nh 3.0pt
18 Onh 4.0pt
22 Onh 2.0pt
27.Onh 1.0pt
8.2nh 1.0pt
18.Onh 7.0pt
18.Onh 5.0pt
18.Onh 6.0pt
27 Onh 1.5pt
33.Onh 1.0pt
8.2nh 5.0pt
27 Onh 3.0pt
27.0nh 2.0pt
39.Onh 1.0pt
22.0nh 3.0pt
47.0nh 1.0pt
39.Onh 1.5pt
22.0nh 4.0pt
47.0nh 1.3pt
33.0nh 4.0pt
33.0nh 2.0pt
39.Onh 1.8pt
27.0nh 3.5pt
27.0nh 3.0pt
47.0nh 1.5pt
33.0nh 3.0pt
47.0nh 1.6pt
39.0nh 3.0pt
39.0nh 2.5pt
39.0nh 5.6pt

FIG. 23

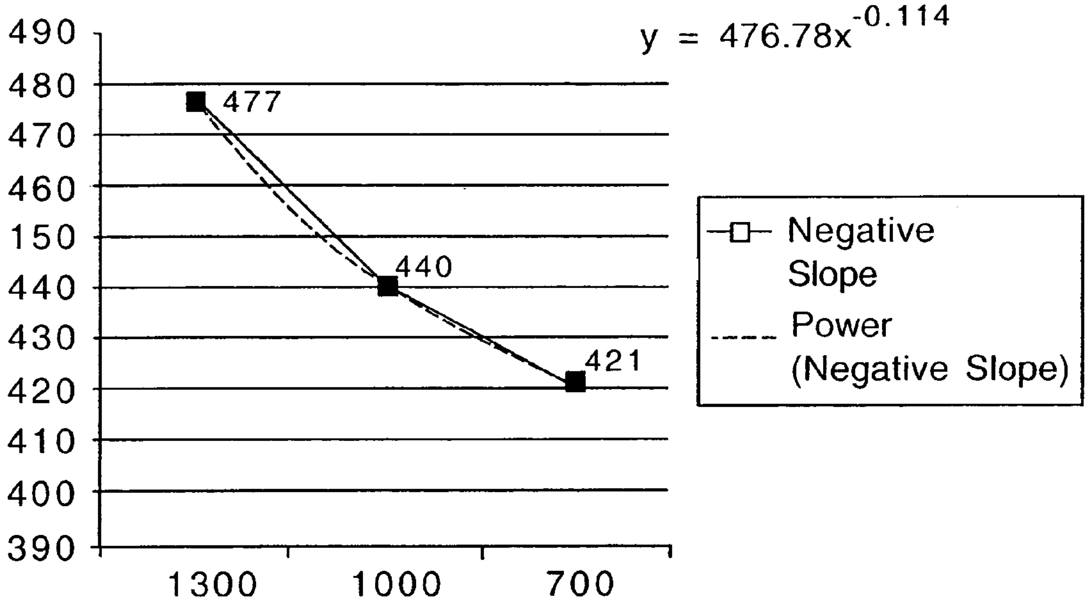

FIG. 24a

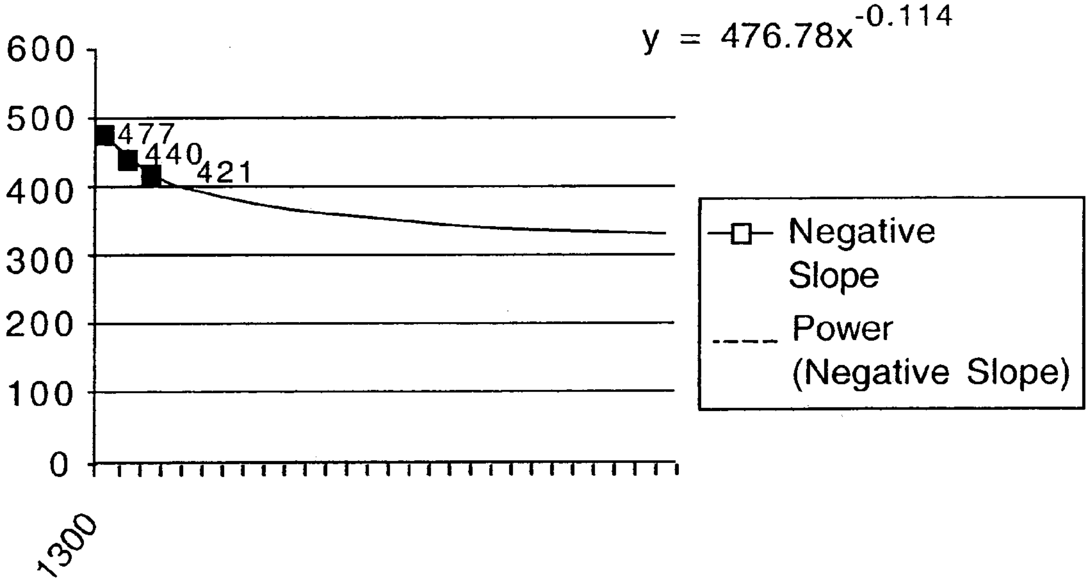

FIG. 24b

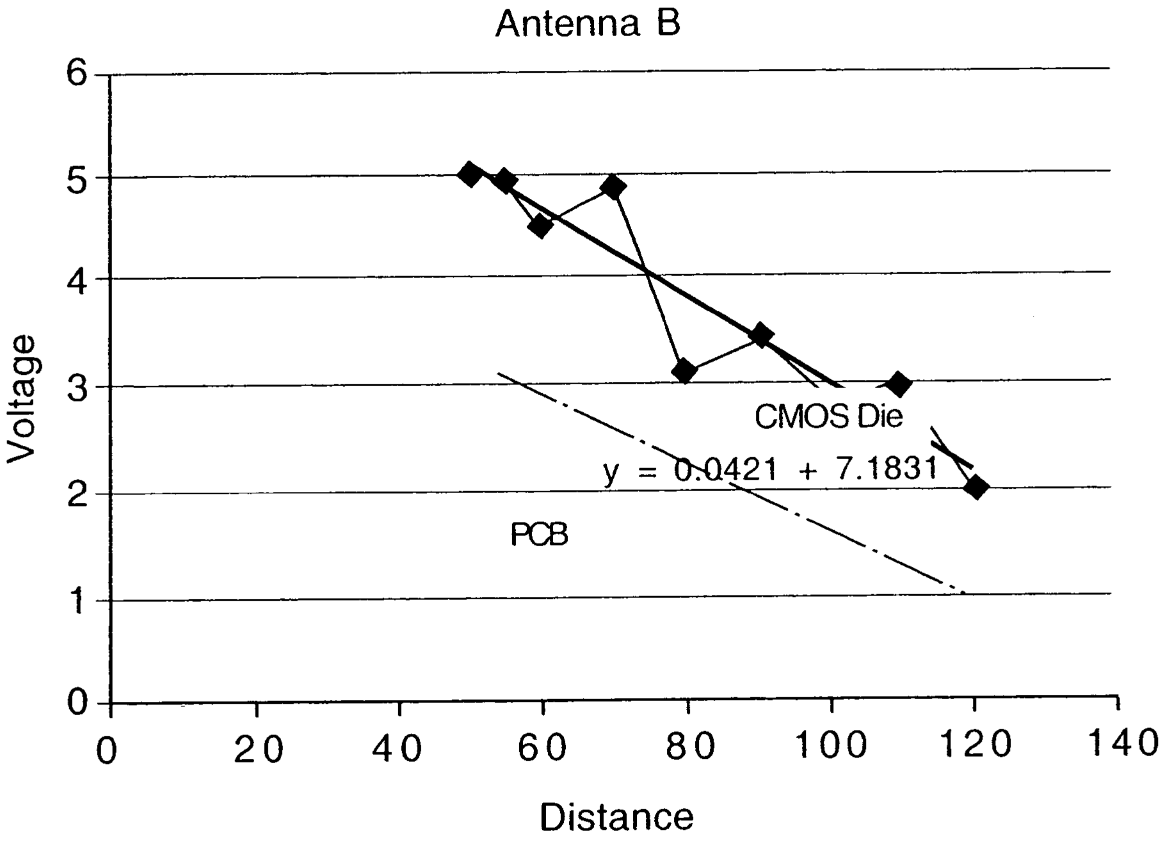
Antenna B
6
5
4
3
2
1
0
Voltage
0
20
40
60
80
100
120
140
Distance
CMOS Die
y = 0.0421 + 7.1831
PCB

FIG. 25

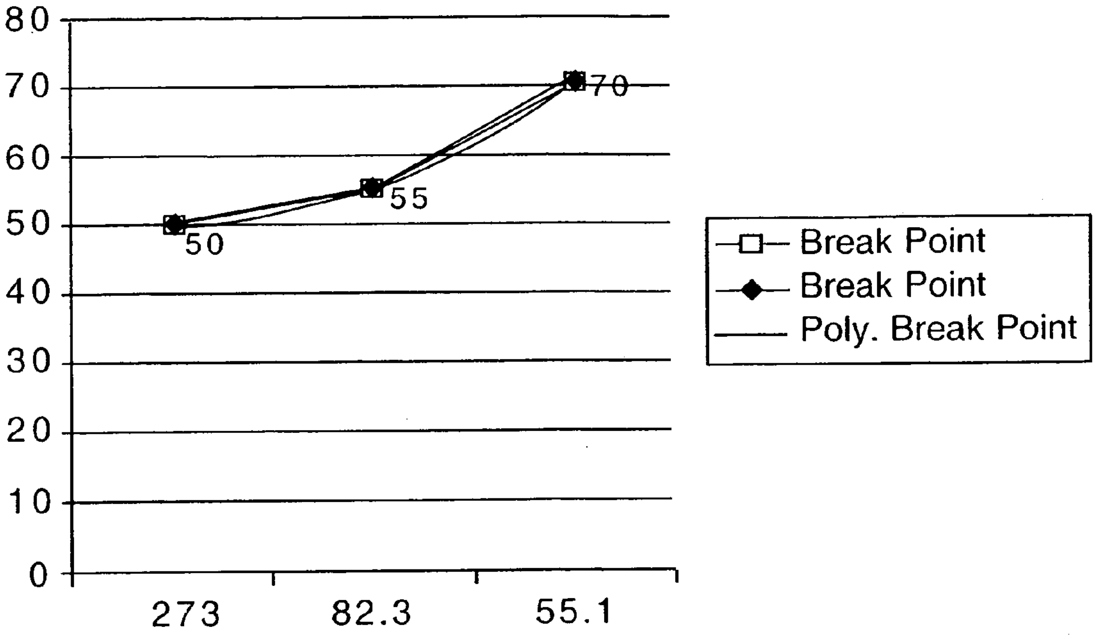

FIG. 26a

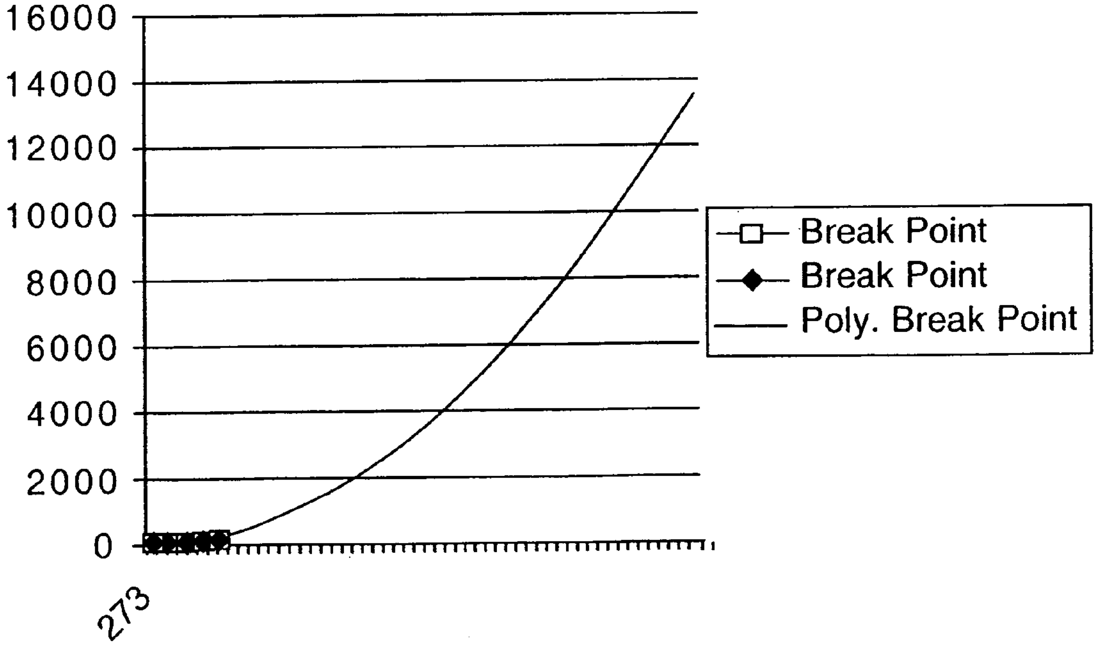

FIG. 26b

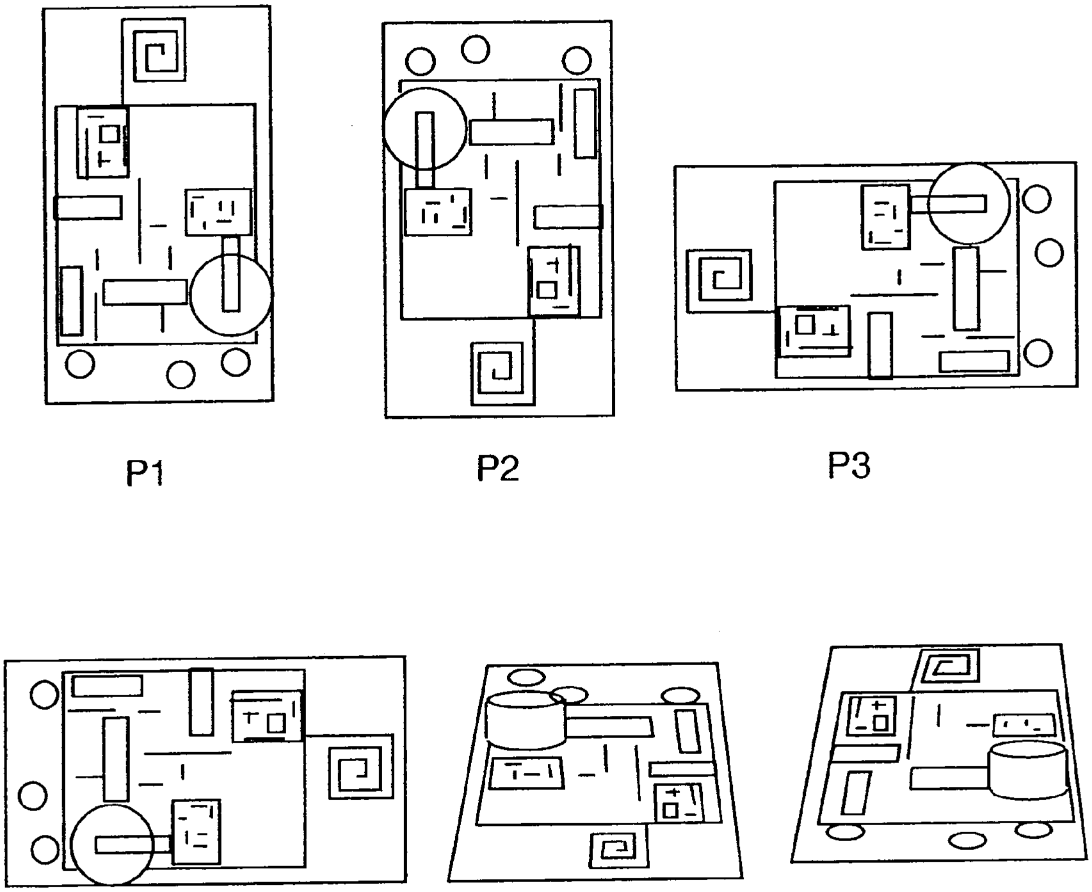

P1 P2 P3

P4 P5 P6

FIG. 27

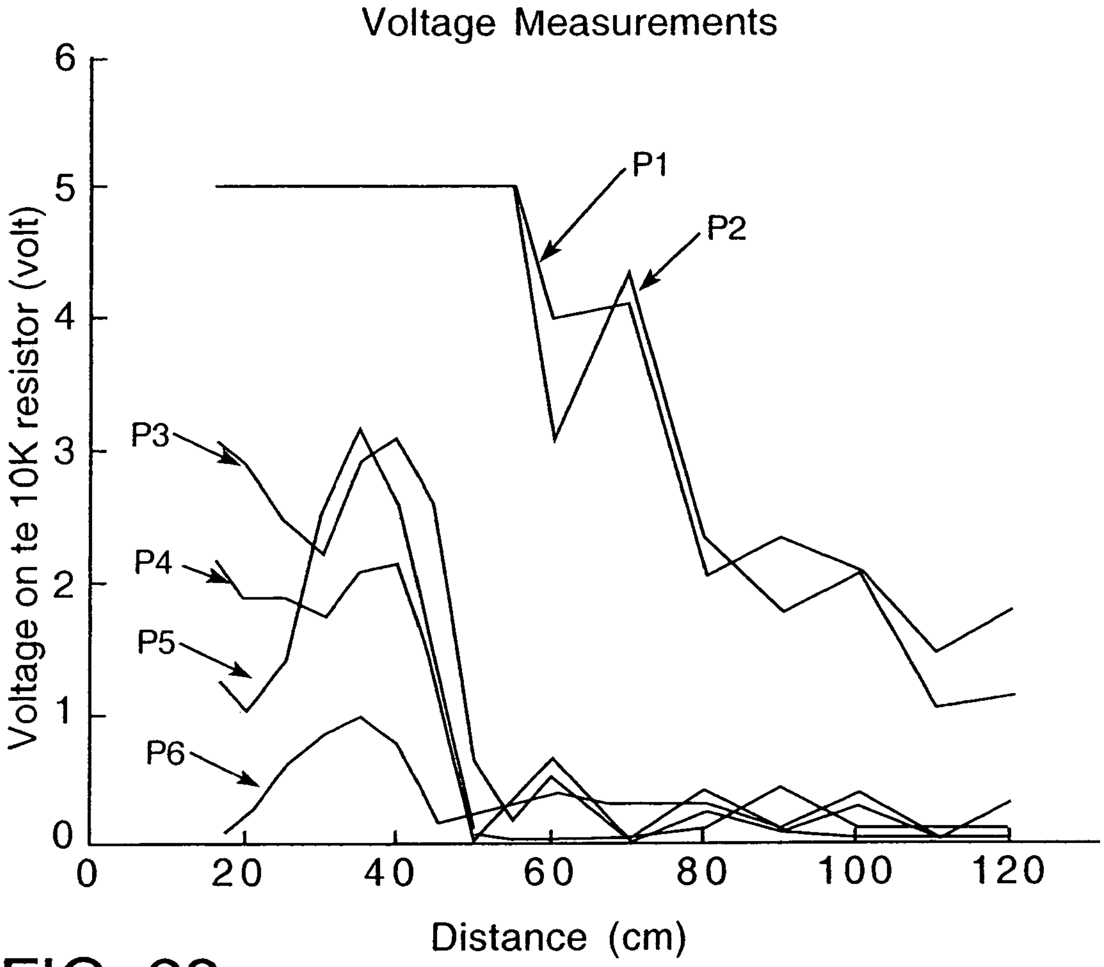
Voltage Measurements
Voltage on te 10K resistor (volt)
6
5
4
3
2
1
0
0
20
40
60
80
100
120
Distance (cm)
P1
P2
P3
P4
P5
P6

FIG. 28

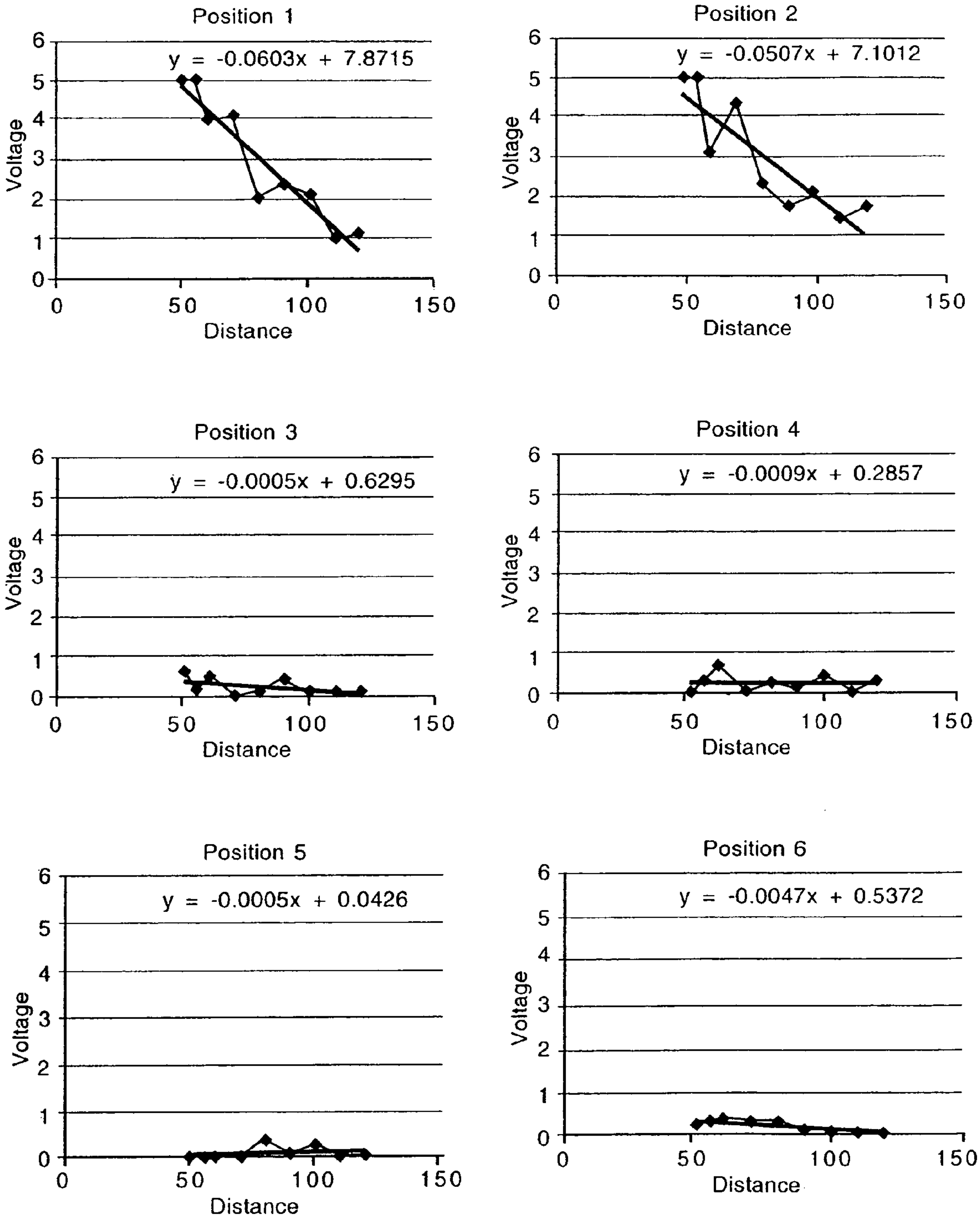
Position 1
y = -0.0603x + 7.8715
Voltage
Distance
0
1
2
3
4
5
6
0
50
100
150
Position 2
y = -0.0507x + 7.1012
Voltage
Distance
Position 3
y = -0.0005x + 0.6295
Voltage
Distance
Position 4
y = -0.0009x + 0.2857
Voltage
Distance
Position 5
y = -0.0005x + 0.0426
Voltage
Distance
Position 6
y = -0.0047x + 0.5372
Voltage
Distance

FIG. 29

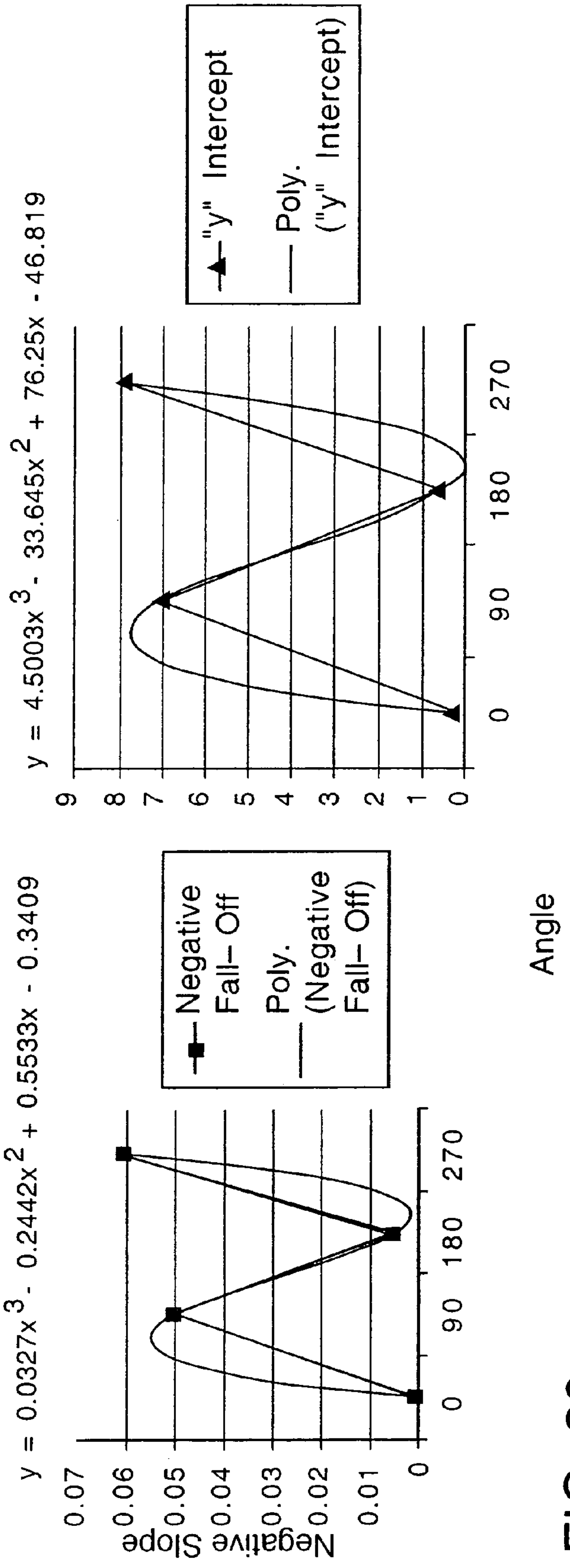
y = 0.0327x^3 - 0.2442x^2 + 0.5533x - 0.3409
Negative Slope
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
90
180
270
Negative Fall-Off
Poly. (Negative Fall-Off)
y = 4.5003x^3 - 33.645x^2 + 76.25x - 46.819
9
8
7
6
5
4
3
2
1
0
0
90
180
270
"y" Intercept
Poly. ("y" Intercept)
Angle

FIG. 30

ANTENNA ON A WIRELESS UNTETHERED DEVICE SUCH AS A CHIP OR PRINTED CIRCUIT BOARD FOR HARVESTING ENERGY FROM SPACE

CROSS-REFERENCE

This application claims the benefit of U.S. Provisional Application Ser. No. 60/475,151 entitled "ANTENNA ON A WIRELESS UNTETHERED DEVICE SUCH AS A CHIP OR PRINTED CIRCUIT BOARD FOR HARVESTING ENERGY FROM SPACE" filed Jun. 2, 2003.

BACKGROUND OF THE INVENTION

1. Field of the Invention

A device is disclosed comprising a semiconductor integrated circuit (IC) chip having disposed on it antenna and the circuitry for the IC chip, wherein antenna and the circuitry of the IC chip are integrated so as to provide the IC chip with an improved antenna effective area. The design of the antenna placement on the chip is independent of the location of the antenna on the chip. As a result, antenna-on-a-chips of this invention are simpler to design and manufacture than the designs disclosed in the prior art. With increasing dependence on local and wide area wireless networks, particularly those with low power (range) requirements and local sensing or object identification, there is a need to have an antenna structure integrated onto single semiconductor devices. One important lack has been an on-chip antenna structure that overcomes simple deficiencies of size.

The length and material of antennas normally determine the frequency and intensity of signals that may be received or sent from the antenna. However with smaller and smaller local area wireless networks being contemplated, the concept of a room sized network area or building area with antennas mounted in walls and ceilings (whether independent separate antennas or multi-use antennas, such as using electrical wiring or telephone wiring as an antenna structure), the feasibility of using very low power antenna structures to transfer information from a local network to a wireless IC device or system containing such wireless IC device becomes practicable.

2. Description of the Prior Art

It has been known to provide antennae and circuitry at specific locations on chips. U.S. Pat. Nos. 4,857,893 and 4,724,427 disclose the use of planar antennas that are included in circuitry of a transponder on a chip. As disclosed therein, the antenna coil is etched around the periphery of the chip substrate. In the center of the antenna coil are found a custom logic circuit, a programmable memory array, and memory control logic. The planar antenna of the transponder was said to employ a magnetic film inductor on the chip in order to allow for a reduction in the number of turns and thereby simplify fabrication of the inductors. It disclosed an antenna having a multi-turned spiral coil and having a 1 cm×1 cm outer diameter. When a high frequency current was passed in the coil, the magnetic films were said to be driven in a hard direction, and the two magnetic films around each conductor served as a magnetic core enclosing a one turn coil. The magnetic films were said to increase the inductance of the coil, in addition to its free-space inductance.

One of the problems with the approach as taught in U.S. Pat. Nos. 4,857,893 and 4,724,427 is the need to fabricate small, air core inductors of sufficiently high inductance and Q for integrated circuit applications. The small air core inductors were said to be made by depositing a permalloy magnetic film or other suitable material having a large magnetic permeability and electric insulating properties in order to increase the inductance L of the coil. Such an approach increases the complexity and cost of the antenna on a chip and also limits the ability to reduce the size of the antenna because of the need for the magnetic film layers between the antenna coils.

Another problem with the approach as taught in U.S. Pat. Nos. 4,857,893 and 4,724,427 is the attendant integrating of an antenna on an integrated circuit (IC) chip. In the case of an antenna disposed about the periphery of the chip, as described by the patents discussed hereinabove, the location of the antenna interferes with conventional bond pad layout about the periphery of the chip. Also, the electromagnetic fields within the central area of an antenna laid out about the periphery of a chip can interfere with the operation of circuits located within the antenna.

U.S. Pat. Nos. 6,373,447 discloses the use of one or more antennas that are formed on an integrated circuit chip connected to other circuitry on the chip. The antenna configurations include loop, multi-turned loop, square spiral, long wired and dipole. The antenna could have two or more segments which could selectively be connected to one another to alter effective length of the antenna. Also, the two antennas are said to be capable of being formed in two different metallization layers separated by an insulating layer.

U.S. Pat. No. 6,373,447 attempts to overcome the problems of U.S. Pat. Nos. 4,857,893 and 4,724,427 by having the antenna formed on other than a peripheral area of an integrated circuit (IC) chip. U.S. Pat. No. 6,373,447 describes devices comprising an integrated circuit (IC) chip having a surface wherein the surface is divided into a peripheral area and a central area. The central area comprises a first portion and a second portion wherein the circuitry of the IC chip is disposed within the first portion of the central area; and an antenna disposed within the second portion of the central area. This patent teaches that one or more antennas can be formed on an integrated circuit chip connected to other circuitry on the chip. The antenna configurations include loop, multi-turned loop, square spiral, long wired and dipole. The antenna could have two or more segments which could selectively be connected to one another to alter the effective length of the antenna.

U.S. Pat. No. 6,373,447 attempts to avoid the problems of the antenna interfering with the conventional bond pad layout about the periphery of the chip by placing the antenna in the central area of the chip. However, in all cases disclosed by the inventor the antenna is located in one portion of the central area, and IC circuitry is disposed on the other portion of the central area. The inventors do state in the body of the patent that the antennas can also be located on "one or two or three (but not four) edges of the chip, so long as there are no bond pads in that area".

A problem with the prior art as discussed above is that disposition of the antenna on the chip is limited to specific different parts of the chip. In the case of U.S. Pat. Nos. 4,857,893 and 4,724,427 the antenna is on the periphery of the chip and in the case of U.S. Pat. No. 6,373,447 the antenna is in the central area of the chip.

A further problem with the antenna on chip designs as disclosed by prior art is that the antenna and IC circuitry are disposed as discrete components in separate portions of the chip to minimize the interaction of the antenna and the circuitry of the IC chip. In the case of U S. Pat. No. 6,373,447, the antenna is one portion of the central area and the IC circuitry is the other portion of the central area. This again limits the design of placing an antenna on a IC chip. Furthermore, it makes for devices that are not truly integrated.

SUMMARY OF THE INVENTION

The present invention provides an integrated circuit chip which has at least one integrated and preferably integrally formed antenna with circuitry operatively associated with the antenna for receipt of energy harvested by the antenna from space. In another embodiment, a printed circuit board or other wireless untethered device is employed. The antenna has an effective area greater than its physical area. A system which receives power from the circuitry generally at DC power resulting from rectification by the circuitry of the energy harvested may also be provided on the chip.

The antenna and circuitry may be positioned at any location on the chip without adversely effecting performance.

The antenna may be a spiral antenna such as a square spiral antenna, with the thickness and width of the conductive portion being adjusted to maximize performance. Impedance may be adjusted to provide for an enhanced effective antenna area.

It is an object of the present invention to provide an integrated antenna on a chip or printed circuit board with associating circuitry to facilitate efficient receipt of energy from space by the antenna and conversion of the same by the circuitry to DC power.

It is a further object of the invention to provide such a semiconductor integrated chip or printed circuit board which will deliver DC power from the circuitry to an electronic system.

It is another object of the present invention to provide such a system which does not require the use of a power storage element or hard wiring.

These and other objects of the invention will be made fully understood from the following description on reference to the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a circuit which is an operational device but has no battery or wires for powering.

FIG. **2** illustrates a circuit of the type shown in FIG. **1** with an associated display to measure the energy harvested.

FIG. **3***a* shows a chip having an on-chip antenna for harvesting data and an on-chip on chip antenna for transmitting data.

FIG. **3***b* is a photograph of the chip represented in FIG. **3***a*.

FIGS. **4***a* and **4***b* show, respectively, (i) a plot of experimental results and (ii) a circuit and related power measuring device along with a plot of variations in result due to use of a conductive ground plane.

FIGS. **5***a* and **5***b* show, respectively, a plot and measurement in a representation of the circuit and power representation of ground plane influence.

FIGS. **6***a*–**6***d* show **4** square antenna profiles on a printed circuit board.

FIG. **7** is a plot of distance versus voltage for the four antennas shown in FIG. **6**.

FIG. **8** is a plot of voltage harvested at load for a harvesting distance of 50 cm.

FIGS. **9***a*–**9***e* show five antennas with four being spiral and one being a square patch.

FIG. **10** is a plot of voltage versus distance for the antennae of FIGS. **9***a*–**9***e*.

FIG. **11** is a representation of impedances for various parameters.

FIGS. **12***a*–**12***c* illustrate three variations in trace width for an antenna with plots of voltage versus distance.

FIGS. **13***a*–**13***b* illustrate data for antennas of two different materials and three different thicknesses.

FIGS. **14***a*–**14***b* show plots of voltage versus distance for the antennas of FIGS. **13***a*–**13***b*.

FIGS. **15***a*–**15***b* show plots of voltage versus distance for different lengths.

FIGS. **16***a*–**16***b* illustrate two different feed arrangements for antennas.

FIG. **17** is a plot of voltage versus distance for the two feed lines of FIGS. **16***a*–**16***b*.

FIGS. **18***a*–**18***b* illustrate several antennas with respect to ground plane variations.

FIG. **19** illustrates a plot of distance versus voltage for some of the antennas of FIGS. **18***a*–**18***b*.

FIG. **20** illustrates a circuit in terms of impedance matching elements.

FIG. **21** illustrates the circuit of FIG. **20** with impedance related markings.

FIGS. **22** and **23** illustrate, respectively, experimental and simulated impedance matching plots.

FIGS. **24***a*–**24***b* illustrate, respectively, plots of PCB data points and a projection of the same to about 25 mm.

FIG. **25** shows plots of voltage versus distance for PCB and CMOS traces.

FIGS. **26***a*–**26***b* show, respectively, plots of original data for copper and extrapolation of the same in respect of thickness.

FIG. **27** illustrates six antenna orientations.

FIG. **28** is a plot of voltage versus distance for the orientations of FIG. **27**.

FIG. **29** shows trend lines for the six plots of voltage versus distance as related to FIG. **27**.

FIG. **30** shows the negative slope and y intercept of the trend lines.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As employed herein, the tern "in space" means that energy or signals are being transmitted through the air or similar medium regardless of whether the transmission is within or partially within an enclosure, as contrasted with transmission of electrical energy by a hard wired or printed circuit boards.

As employed herein the term "wireless untethered device" means a device which is remotely powered by RF energy and shall include, but not be limited to, IC chips, printed circuit boards and other suitable substrates having discrete or integrated circuit components.

What is further needed is an antenna on a chip wherein the antenna is not a discrete component to the IC circuit. In that respect there are two issues; (1) the interference of the received RF energy on the proximate IC circuitry, and (2) the interference of the proximate IC circuitry on the RF energy. While the first issue is important to any functional IC, the separation of the energy harvesting function from the payload IC electronic circuitry, U.S. Pat. No. 6,289,237, discloses isolating the negative effect of the RF from the payload electronics with respect to RF signals as opposed to RF energy. Our experiments have shown that while the payload electronics are in the proximate area of the energy harvesting antenna and associated circuitry, the payload will still function satisfactorily.

The second issue is in fact a benefit to the energy harvesting antenna and adds to the effective area of such an antenna(s). The functional devices for the experiments of the previous paragraph are pictured in FIGS. **1** and **2**. In both cases, the proximate circuitry has been demonstrated to operate satisfactorily in an applied RF energy field while simultaneously enhancing the harvested energy through providing additional area to the effective area to the antenna. The ability to obtain a tractable closed form mathematical formula to describe the indicated situation is extremely difficult at best due to the multitude of effects and interactions by the interconnection circuitry and the proximate components themselves.

FIG. **1** illustrates an operational device with all discrete components and conducting traces in place with no battery or wires for powering. The energy is supplied by beaming radio frequency (RF) energy to the device, rectifying the RF and converting it to direct current (DC), and powering electronics to read a temperature sensor and transmit the result to a receiver. The device requires five milliwatts of power to function. This device is functional as illustrated.

FIG. **2** is a device to measure power where the energy harvesting circuitry is the same as the device in FIG. **1**, but with five sets of light emitting diodes (LED's) connected in parallel to measure voltage without the need to connect wires to the device energy harvesting circuitry. Relative power can also be estimated by observing the brightness of the LED's. The conductors to interconnect the payload components of FIG. **1** are included in FIG. **2** while the proximate electronic components themselves have been removed.

FIG. **3** shows a single chip RFID design using an on-chip antenna for energy harvesting and an on-chip antenna for transmitting data. FIG. **3**.*a*. is the "flatten" picture of the layout from the Computer Aided Design (CAD) tool, and FIG. **3**.*b*. is a photograph of the actual fabricated chip (die).

There is an uncertainty in any in situ energy or power measurements due to the measuring circuitry interfering with the device under test. FIGS. **4***a*–**4***b* include the power measuring device of FIG. **2** along with a graph showing the number of LED's lighted when the space between the energy source and the device is interrupted by a conducting plane inserted perpendicular to a line drawn between the source patch antenna and the device, both of which are parallel. The top of the device was 19.0 cm above the laboratory table top. Conducting planes of 11 cm, 14.7 cm, 16.0 cm, 17.25 cm and 19.0 cm were placed between the antenna and the device. This resulted in lighted LED's numbering 5 (no conducting plane), 4, 4, 3, 2, and 0 respectively for the conducting planes. FIG. **5** is the same set-up as FIG. **4**, where the conducting planes were inserted in the order 17.25 to 19.0 cm, 16.0 to 19.0 cm, 14.7 to 10.0 cm, 11.0 to 19.0 cm, and 0.0 to 19 cm. In FIGS. **5***a*–**5***b*, the LED's that were lighted were 5, 5, 5, 5, 4, and 0.

In the first embodiment of this invention, a device is disclosed comprising an integrated circuit (IC) chip having disposed on it antenna and the circuitry for the IC chip. The antenna or antennas and the circuitry of the IC chip are integrated so as to provide the IC chip with an improved antenna effective area.

In other embodiments, a wireless untethered device such as a printed circuit board may be provided with the desired antenna and circuitry.

"Effective area" of the antenna refers to the functional area of an antenna as compared with the physical area. A tuned antenna may have an effective area that is larger than its geometric area. The phenomenon was disclosed by Reinhold Rudenberg in 1908 [Rudenberg, Reinhold, "Der Empfang Elektrischer Wellen in der Drahtlosen Telegraphie" ("The Receipt of Electric Waves in the Wireless Telegraphy") Annalen der Physik IV, 25, 1908, p. 446–466.] and the description of the phenomena has been expanded upon over the years by many other writers.

U.S. Pat. No. 5,296,866 states that "Rudenberg teaches that the antenna interacts with the incoming field, which may be approximately a plane wave, causing a current to flow in the antenna by induction. The [antenna] current, in turn, produces a field in the vicinity of the antenna, which field, in turn, interacts with the incoming field in such a way that the incoming field lines are bent. The field lines are bent in such a way that the energy is caused to flow from a relatively large portion of the incoming wave front, having the effect of absorbing energy from the wave front into the antenna from a wave front which is much larger than the geometrical area of the antenna."

While the concept of effective area may be known, implementing it in antenna design and construction is not easy or obvious. U.S. Pat. No. 5,296,866 teaches making active antennas that had effective areas greater than the geometric areas through use of special circuitry. The antennas detailed in this disclosure were non-planar coil antennas.

Co-pending U.S. patent application Ser. No. 09/951,031, the disclosure of which is expressly incorporated herein by reference, discloses an antenna on a chip having an effective area 300–400 times greater than its physical area. The effective area is enlarged through the use of an LC tank circuit formed through the distributed inductance and capacitance of a spiral conductor. This is accomplished through the use on the antenna of inter-electrode capacitance and inductance to form the LC tank circuit. This, without requiring the addition of discrete circuitry, provides the antenna with an effective area greater than its physical area. It also eliminates the need to employ magnetic film. As a result, the production of the antenna on an integrated circuit chip is facilitated, as is the design of ultra-small antennas on such chips. See also U.S. Pat. No. 6,289,237, the disclosure of which is expressly incorporated herein by reference.

The invention of this disclosure integrates the antenna and the circuitry of a wireless untethered device such as an integrated circuit (IC) chip or printed circuit board (PCB) to achieve an effective area that is greater than what would be expected from the antenna disposed on the chip alone. By "integrate" or "integration" it is meant that the antenna is disposed on the chip using the circuitry of the IC chip or PCB as part of the antenna function specifically the energy harvesting effective area. Integrating the antenna and proximate circuitry of the IC chip or PCB simplifies the design of the chip because placing the discrete antenna and proximate IC chip or PCB circuit components in discrete areas of the chip is no longer necessary.

In general, a preferred approach is to have the antenna designed as an integral element which is connected to the circuitry with proper impedance matching. If desired, the circuitry can be designed and then the antenna can be designed for maximum performance efficiency in the presence of the circuitry with particular emphasis of use in small, wireless untethered devices.

One advantage of integrating the antenna and the proximate circuitry of the IC chip or PCB is that the physical size of the antenna component is no longer the sole driving force in obtaining greater effective area. Using the embodiment of this invention, the effective area of the antenna is a combination of the physical size of the antenna and proximate IC circuitry on the IC chip or PCB. In essence, the antenna on the IC chip or PCB for all practical purposes is the whole IC chip or PCB and not a specific portion of IC chip or PCB that has the physical antenna disposed on it. It will be appreciated that in the IC chip, PCB or other embodiments the effective area of an antenna may be greater than the physical area of the IC chip, the PCB or other substrate. In fact, isolating the physical antenna into separate portions of the IC chip or PCB (i.e., peripheral or a distinct area of the central portion) can be detrimental to making IC chips or PCBs with effective areas greater than the effective area from the isolated physical antenna.

The design of an antenna on chip or PCB involves a number of sets of information; (1) frequency of operation (center frequency), (2) bandwidth at the half power points, (3) Q—ratio of peak performance to that of the half power points, (4) the electrical and magnetic properties along with thickness of each process layer—typically termed the technology files.

Given the appropriate design information, an architecture, e.g., whip, dipole, square spiral, round spiral, etc. is selected. Next, a range of parameters such as conductor length equal to wavelength (center frequency) divided by 4, resonance of the antenna at the center frequency, etc.

Using the resonance strategy, the antenna parameters and configuration are then adjusted to achieve resonance using the parasitic and inter-electrode inductance and capacitance including the electronic and magnetic properties as given in the technology files.

The resonance is normally checked through computer aided design software including simulation.

FIGS. **4***a* and **4***b* illustrate the test apparatus including; (A) two spiral energy harvesting antennas with circuitry for rectification and voltage “doubling” (charge pumps), (B) interconnection circuitry, and (C) the power, voltage measurement circuitry (power meter).

The measurement of power and/or voltage on a remote autonomous device is complicated by the inability to connect non-interfering wires to the device, and the fact that as the size of the device decreases, there is an inherent uncertainty concerning the effect/contribution of the measurement circuitry itself on the measurement. The effective area measurements in the Co-pending U.S. patent application Ser. No. 09/951,031, involved connecting wires in order to effect the power measurements.

A series of experiments were run with the device of FIG. **4***b* in the field of an RF source antenna at 915 MHz. In these experiments, a flat conducting surface (plane) was placed between the source antenna providing the RF energy and the device under test at an approximate distance of 0.25 inches from the device. Five conducting planes were used where the planes shielded areas of the device at the 5 heights shown in FIGS. **4***a* and **4***b*.

The height of 19.0 cm represents the height of the top of the device above the laboratory bench. The 5 heights of the conducting plane in the 5 experimental positions were 19.0 cm, 17.25 cm, 16.0 cm, 14.7 cm and 11.0 cm respectively. The points on the graph above the device in FIG. **4***a*, represents the number of LEDs lighted on the power meter section (C) of the device. The number of LEDs lighted is proportional to the voltage across the LEDs and represents a lower bound on the voltage dropped across the 1 K ohm resistor that can be seen in area (B**2**) of FIG. **4***b*.

As can be noted from the FIG. **4***a* graph, while exposing the strict antenna area (A**1**) to the RF field does in fact harvest sufficient energy to light **2** LEDs, exposing additional device area facilitates additional energy harvesting, including the power meter area (C).

It is noted that for the proximate electronics in (B**2**) and (C), the function of the circuitry is strictly DC including the DC bus noted in area (B**1**).

A functioning power meter (C) when totally removed from the device parts identified as (A) and (B) shows no lighted LEDs. Thus, as an energy harvesting device, the power meter by itself will not harvest sufficient energy to light a single LED. However, when connected to the device, the area and circuitry contribute to the energy harvesting by an amount of 74.9 milliwatts in terms of measured power and sufficient voltage to light an LED.

In FIGS. **4***a* and **4***b*, the conducting planes were introduced in the sequence 19.0 cm, 17.25 cm, 16.0 cm 14.7 cm and 11.0 cm. The results of a similar experiment with the sequence of conducting planes were introduced in the sequence 17.25 to 19.0 cm, 16.0 to 19.0 cm, 14.7 to 19.0 cm 11.0 to 19.0 cm and 0 to 19.0 cm, respectively.

While no mathematical model is proposed for the results of FIGS. **4** and **5**, it is obvious that the proximate interconnections (B) and circuitry (A**2**) contribute to the total amount of energy harvested by increasing the effective area of the harvesting antennas.

It is clear that more than one factor contributes to the effectiveness of the antenna/device combination in harvesting energy. We have chosen to note the effective area do to the results of Rudenberg as Rudenberg effective area, and the remainder of the effective area due to components and interconnections as proximate effective area.

The present invention is concerned with the design and analysis of small antennas for the purpose of harvesting energy on a printed circuit board (PCB) or a complementary metal oxide semiconductor (CMOS) die in order to provide power to on board circuitry without the need for batteries or external connections as a source of power.

Earlier design of such devices has led to the desire to use a square spiral coil as the profile for the antenna. Thus, this disclosure will be mostly concerned with the square spiral antenna although a patch design will be included from time to time.

Given the square spiral profile, there are still many parameters of the design that must be considered and chosen. This disclosure is concerned with a series of experiments that were run in an effort to evaluate these alternatives using PCB implementations. However, the ultimate goal is to implement the square spiral on a CMOS die thus opening up the question of what differences in performance can be expected with the CMOS implementation.

The approach to the analysis is strictly empirical although a few references may be made to classical approaches either to antennas or electronic circuits. The sole purpose is given a square spiral implementation, what are the parameters values that provide the greatest amount of power or energy at the payload circuitry in this case a 10 K ohm resistor.

Printed circuit test boards each containing a target antenna have been constructed where the voltage across the target load is measured by an analog to digital converter, frames and transmitted by an infra red transmitter to a receiver connected to a data gathering personal computer. The test/measurement circuitry is powered by a small battery. All test/measurement circuitry and the battery are located behind a ground plane for the circuitry so as to shield the circuitry from an energizing radio frequency (RF) source whereby a contribution to the power/energy can be attributed to this circuitry.

Other research has demonstrated that the proximate circuitry can be used to advantage in harvesting energy.

Previous attempts to measure the energy harvested by small antennas have been complicated due to the measurement equipment that is connected to the device under test (DUT). Thus, the attempt here is to include the test circuitry directly on the DUT. As indicated previously, the circuitry included with the DUT can have an effect on the results thus leading to the shielding of the test circuitry behind a conducting plane as shown in FIGS. **6***a*–**6***d*.

Over many decades it has been difficult if not impossible to prove that the test circuitry does not have an effect on the results of the experiment, the results reported in this paper suggest that the effect is minimal through some of the profiles of the DUT, e.g., antenna area as shown in FIGS. **6***a*–**6***d* for antennas A through D.

The design of antennas in a limited space such as on a printed circuit board or a Complementary Metal Oxide Semiconductor (CMOS) chip or die requires the consideration of a number of physical factors of the antenna to obtain an optimum performance. These factors include:

(1) The area allocated to the antenna including the actual metallic conductor forming the antenna and any space required to form or shape the metallic conductor. The metallic conductor has certain characteristics, e.g., shape (profile), conductor width, conductor thickness, and conductor length.

(2) One of the profiles considered in this research is a square spiral. The topological nature of the square spiral is that connection can be made in the plane of the antenna from the last outside trace of the spiral. Such a connection will be noted as a micro-strip line feed. The inner end of the spiral must be connect through a via to another layer of the PCB or CMOS die. Such a connection will be noted as a probe feed. Two general profiles are considered in the research reported herein, a square spiral and a square patch.

(3) The antenna environment includes any form of conductor, insulator, etc., that exist between the source of the radio frequency (RF) energy and the antenna or behind the antenna. One form of element can be a ground plane formed as a part of the PCB or CMOS die.

(4) The antenna is connected to a circuit (energy harvesting in this case) where both the antenna and the circuit (load) have an impedance. For optimum performance, it has long been held that the two impedances should be matched as complex conjugates, i.e., impedance matching, with equal real (resistance) components.

(5) There are two areas involved in the antenna design. The first is the physical area required to implement the antenna. The second is the effective area resulting from dividing the power received at the load by the power density in the field in which the antenna is place, i.e., Power Harvested=Power density*Effective Area.

In summary, the factors involved in the design of an antenna in a limited space, e.g., a PCB or a CMOS die are:

(A) Physical Area
(B) Profile
(C) Antenna Conductor Width
(D) Antenna Conductor Thickness
(E) Antenna Conductor Length
(F) Feed Type
(G) Ground Plane Existence
(H) Impedance Matching

(A) Physical Area

Four antennas of a square profile with four different areas as illustrated in FIGS. **6***a*–**6***d*, have been constructed. The voltage response measured at the load of the four antennas in shown in FIG. **2**. The antennas are compared at a harvesting distance of 50 centimeters by plotting the voltage harvested at the load as shown in FIG. **7**. Based on the results of FIG. **8**, it is clear, as expected, that the amount of energy harvested increases with increased area. This area is termed the physical area.

(B) Profile

Two profiles are considered in this study, a square spiral and a square patch. FIGS. **9***a*–**9***e* illustrate five antennas, four of which are square spirals and one is a square patch (Antenna D, Board H**1**).

The voltage results for the profile test cases are illustrated in FIG. **10**. It can be argued from FIG. **10** that the best results are obtained with the square patch. The differences are not great, but there are differences. However, the square patch has a disadvantage in that the impedance for impedance matching requires an inductor as the patch has a capacitive impedance. In addition, the impedance of the antenna is fixed by the physical area. In the case of the square spiral antennas, the impedance of the antenna may be varied while maintaining a fixed physical area. In the case of the square patch, the matching requires an inductor that is difficult to fabricate on a CMOS die and not easy to precisely match with an on die inductor or a discrete inductor for the PCB implementation. The inductor is required to form the complex conjugate as the square patch is capacitive.

The square spiral can be modified by trace width, thickness and relative spacing to have essentially a continuum of impedances many of which are illustrated in FIG. **11**. This variation is particularly useful in coordinating the matching impedance between the load and the antenna. Thus, from a design standpoint, the square spiral is the profile of choice.

Antenna E in FIG. **9***e*, while a square spiral, has length greater that the ¼× length of Antennas A, B, and C. The length of antenna E is greater than ¾×. Thus, the length of the antenna conductor is a factor in designing the most efficient PCB or die (chip) antenna. While the ¼× length is better for design purposes as the added length does not gain any appreciable advantage, this does not constitute a proof for the optimum length. The major contribution here is that the antenna conductor length is a factor that must be considered in the antenna design.

(C) Antenna Conductor Width

The antennas A, B and C of FIGS. **9***a*–**9***c* vary in trace width. Based on the results of FIG. **10**, the trend lines are shown in FIG. **12**.

From FIG. **12**, the slope, i.e., rate of voltage decrease is the least for antenna B. In addition, the trend line for antenna B has the largest y intercept. Both of these results support antenna B with the narrowest trace width as being the optimum for this set of experiments.

(D) Antenna Conductor Thickness

Two independent experiments were run for antenna thickness. The first began with one of the type A antennas to which additional conducting solder was first added and then some of the added solder was removed. This gave an original thickness, a much thicker trace and thirdly a trace of intermediate thickness. These steps produced three different thicknesses of the antenna conductor thicknesses indicated in FIG. **13***a*.

Using another set of independent boards and steps, all solder was removed from the antenna exposing the bare copper giving the thinnest trace thickness. The copper was then electroplated onto the antenna to give different thicknesses of copper and thus three different values of antenna conductor thicknesses as indicated in FIG. **13***b*. The measured results for both lead and copper additions are illustrated in FIGS. **13***a*–**13***b*.

Based on the results shown in FIGS. **14***a*–**14***b,* it is quite clear that the best energy harvesting, highest voltage levels, is accomplished antenna conductor thickness is the thinnest. The results of the two thicker traces in FIG. **14***a* are very close and no conclusion should be drawn solely with respect to these two antennas. The removal of the solder from the thickest trace caused a minor amount of melting of the solder having a minimal effect on the antenna profile. However, these two thicknesses relative to the thinnest trace thickness can be considered significant.

(E) Antenna Conductor Length

The antenna conductor length results can be observed considering FIGS. **9***a*–**9***e* and **10**. While there does appear to be some equivalence in the results of antenna B and antenna E in FIG. **19**, the results at the 50 centimeter distance was chosen as the point of comparison show that nothing significant is gained by the additional length. In fact, the length is definitely less useful when compared to antennas A and C. Thus it is an initial conclusion that the primary criterion for the antenna to minimize area and maximize the amount of energy harvested that the length by held at or near ¼ wavelength.

FIG. **15***a*. is the trend line for Antenna B, and FIG. **15***b* is the trend line for Antenna E. In comparing B and E, the rate of drop off for E is greater and E also has a lower y intercept

There is perhaps another significant point in comparing the two antennas B and E. From a -traditional antenna design standpoint, it could be argued that the two antennas should have performances with more significant differences than are shown in these results.

The explanation offered here is that the most significant feature of the small antennas is the fact that there exists a resonant tank disturbing the field which modified the effective area of the antenna. Thus, these two antennas of significantly different lengths produce similar results supporting the notion that the resonant tank circuit is the most significant aspect of the small antenna.

(F) Feed Type

FIGS. **16***a*–**16***b* provide an illustration of the two type of feed from the antenna, i.e., (a) the micro-strip line feed and (b) the probe feed.

The voltage results of the two type of line feeds are shown in FIG. **17** where it is quite clear that the preferred type of connection to the antenna is the micro-strip line feed.

(G) Ground Plane Existence

In many applications of different antenna profiles such as a patch, it is desirable to provide a ground plane that is separated from the antenna by a distance that can be calculated based on the dielectric constant of the medium between the ground plane and the antenna. However, it the case of a PCB or CMOS die implementation, the distance between the antenna and the potential location of the ground plane and the dielectric constant of the intervening medium are both fixed by the process independent of the antenna design. Thus, as a rule, the resulting ground plane is not located at the proper position for the fixed dielectric, or the dielectric is incorrect for the position of the ground plane.

The current PCB experiments included provisions for testing the ground plane existence and the net effect of some form of a ground plane in the proximity of the antenna. Two types of ground plane experiments are illustrated in FIGS. **18***a*–**18***b*. The first is a conventional ground plane directly behind the antenna, and the second is a ground plane in the proximity of the antenna on the opposite side of the PCB. The corresponding voltage measurements for the case of FIG. **18***a* are shown in FIG. **19**. The results for the three cases illustrated in FIG. **18***b* were indistinguishable.

Based on FIGS. **18***a*–**18***b,* it is clear that the ground plane is not a desirable feature for the PCB implementation. As a curious note, it would be possible to find an antenna/frequency combination for which the ground plane could lead to an advantage. However, such a result would not be practical in view of the restrictions on frequency both from regulatory and power/energy considerations.

As noted previously, the results for the three different sized ground planes illustrated in FIG. **18***b* were indistinguishable. However, the optimum voltage present in all three cases was the result of different physical impedance matching of the three antennas. Thus, while the proximate ground planes of FIG. **18***b* do not affect antenna performance, they do provide an affect on the antenna and feed line impedances.

The conclusion here is that in general, it is not desirable to include a ground plane for a PCB or CMOS die type of antenna. In additional a physical ground effect object in the proximate area may be useful in achieving a certain impedance or impedance match.

(H) Impedance Matching

As indicated previously, it is in general desirable to match the impedance of the antenna to the impedance of the load as complex conjugates. However, in the case of the use of an antenna for the sole purpose of energy harvesting, there is reason to believe that another form of matching or designed mismatching may not be of an advantage. Consider the model of an energy harvesting antenna as shown in FIG. **20**. As reported by Rudenberg, the antenna forms a non-ideal tank that has a nonzero resistance. This resistance results in a retransmission of some of the incoming energy that in turn interferes with the transmitted field resulting in an increased effective area of the antenna.

As a result of this research, it is conjectured that an additional amount of retransmitted energy may be of an advantage in disturbing the field to provide an even larger effective area. It is recognized that this increased effective area is not without limit.

The Rudenberg retransmitted energy is a function of the resistance R shown in the tank circuit of FIG. **20**. We conjecture that in addition, the intentional mismatch of the impedance Z of FIG. **20** can result in increased effective area.

The effective area increase by the resistor, R, of the tank in FIG. **20**, will be referred to as the Rudenberg effective area. The increased effective area caused by the mismatch of Z and the resulting reflected energy from the load is termed the proximate effective area.

The net effect of these two effective area contributions is modeled as two voltage sources just below the ideal antenna symbol of FIG. **20**.

These two features contributing to the effective area are highlighted in FIG. **21**.

The basis of the conjecture on the mismatch of the impedance Z resulting in reflected energy from the load is arrived at from the repeated attempts to correlate the simulated results for impedance matching with the experimental results found when actually choosing an impedance to increase the harvested energy/voltage experimentally. The results of the simulation and experimental impedance matching are shown in FIGS. **22** and **23**.

FIG. **22** represents the compiled voltage results with many different values of impedance used to obtain the most effective match through an organized searching procedure. The N/S/E/W cross of FIG. **22** represents the centroid of the four best matches that could be achieved by physical matching using electronic elements.

FIG. **23** represents the compiled values of matched impedance along with color coding for strength. The cross of FIG. **23** represents the centroid of the four best matches for the simulations. It is important to note that the simulation may obviously in general not represent the actual circuit due to minute differences that are extremely hard to model. However, numerous attempts were made to calibrate the simulation based on the model and the corresponding test results. However, none of these was successful.

Thus, at this time, the difference in the simulated matching of FIG. **23** based on the complex conjugate impedances and the actual best match in the physical tests is attributed to the mismatching of the impedance z in FIG. **21**. There would be a limit on the effectiveness of this mismatch.

As pointed out previously, the two voltage sources shown in FIGS. **22** and **23** immediately below the ideal antenna symbol are attributed to the retransmission of the energy as a result of the R in the non-ideal tank and the reflected energy from the load due to the mismatch of the impedance Z.

CONCLUSIONS

One of the important aspects of this research is the ability to empirically evaluate the feasibility of certain results that require much additional research other than the antenna. For example, consider a system on a chip (SOC) implementation that requires other circuitry to be designed that will in turn be powered by the energy harvesting technology being discussed here. A considerable amount of work may be required to develop the payload circuitry, and it is desired to have some idea of what level of power can be achieved.

FIG. **8** gives the trend line for the harvested voltage across a 10K ohm load. Therefore, with an antenna that is 1.58 mm on a side, the power that can be expected to be harvested with the thickness of antenna A is:

Power={[*O*.5918*(1.582)*J*0~~85]2}/104=80 *j.t* watts

However, based on the narrower and thinner trace, the voltage can be expected to be at least doubled. This would result in:

Power={[2*0.591 8*(1.582)]04485]2}/104=178 *j.i* watts

The results appear to show that the highest voltage is achieved with a narrower and thinner conductor trace. This is not unexpected from the energy harvesting scenario. At the frequencies involved, the current tends to flow on the outside surface with possible eddy current flowing in the interior that will contribute losses.

Consider reducing only the width of the traces. The PCB traces are on the order of 700 to 1300 microns. A plot of the data for the slope in the linear fall off(y=−Mx+ b, M is the linear fall off or slope of the trend line) as shown in FIG. **7** for antennas A, B and C is shown in FIG. **24***a*.

The point of this discussion is solely to see the fall off rate for the harvested energy as the antenna trace pattern is reduced in width. The trend lines of FIG. **10**, for example, have both a slope and a y intercept, M and b in the above equation for y. The discussion here concerns solely the slope, M, of the trend line. The y intercept appears to be primarily a function of the antenna area and is outside this current discussion.

Based on the projection shown in FIG. **24***b*, the fall off rate in energy is, −0.0328, compare with, −0.0421, for Antenna B as the antenna trace width is reduced to 25 microns.

Thus, based solely on the projection in FIG. **24***b*, the rate improvement of the fall off in going to a CMOS die from a PCB implementation is about 22%. Therefore, in general, it can be expected that the deterioration in performance for a CMOS die will be much better (less per unit distance) than a PCB implementation as the distance between the source and device increases.

An example of the effect of this difference can be seen in FIG. **25**, assuming the intercept point that would make the harvested voltages at 50 centimeters to be the same.

Another interesting look at the projections in going from PCB antennas to those of a CMOS die can be obtained by considering the thickness results from FIG. **13***b*. The results of the decrease in thickness are shown below in FIG. **26***a*. Based on the trend line fitted to these data points, an extrapolation to approximately 1 micron is shown in FIG. **26***b*. f it can be assumed that both the PCB and the CMOS die have the same value at say 50 centimeters, it can be conjectured that the break point as shown in FIG. **14***b*, can be extended to 13,600 centimeters or 446 feet.

Obviously the simple extension to 446 feet from 70 centimeters is difficult to defend. The point here is that there are certain of the parameters in the design of the antenna that must be taken into account that provide direction into the experimental development that will eventually produce a working result although the theory as to why may be delayed by a considerable time.

There is no suggestion, other than the extrapolation, that the 446 feet can be achieved. This result is for copper, and most current fabrications are done with aluminum.

One major conclusion of these results is that the transition from a PCB implementation to a CMOS die need not be considered to be an unfavorable transition.

The primary reduction in the PCB to CMOS die transition is the attendant desire to reduce area because of the relative cost of a PCB compared to a CMOS die per unit (equivalent) area.

All of the previous results were obtained with the antennas in the same orientation with respect to the source antenna. In order to evaluate the orientation issue, FIG. **27** shows six orientations that were tested.

The voltage as a function of distance curves for the six configurations are shown in FIG. **28**. Obviously, the most favorable positions are positions **1** and **2**. Position **1** is the position that was used for all of the previous results. The two orientations, **5** and **6**, are included for the sake of completeness. However, these two are not at all favorable. One reason for their inclusion was that these two were quite favorable in the early tests on the Delta **1** CMOS antenna. At this time there has been no attempt to discover why the PCB and CMOS results for the horizontal antenna appear to be different.

The trend lines for the curves of FIG. **28** are given in FIG. **29**. From the trend lines, position **1** is the best in terms of the y intercept. However, the fall-off rate for position **2** is the best for the two positions. If we consider the longest distance for a typical PIC microcontroller to function based on 2.5 volts, Position **2** yields 90.8 centimeters and Position **1** yields 89.1 centimeters. These two results are extremely close based on the trend lines.

The negative slope and the y intercept of the trend lines is shown below in FIG. **30**. The angle shown along the abscissa is the feed line of the micro-strip type feed where the angle is from the feed line in the direction of the load circuitry. In FIG. **27**, P**4** is 0 degrees, P**2** is 90 degrees, P**4** is 180 degrees, and P**1** is 270 degrees.

Based on the results reported here, the conclusions are summarized as follows:

1. Impedance matching is essential but does not guarantee optimum performance for a fixed area of a small antenna
2. A ¼ wavelength antenna appears to be the optimum antenna for a fixed area
3. The area appears to be the most important factor—given 1 and 2
4. The spiral antenna profile is preferred because it is much easier to match impedances
5. The narrowest trace (width) appears to be optimum
6. The thinnest trace (height) appears to be optimum
7. Increased conductor length does not appear to offer any benefit for energy harvesting
8. The micro-strip line feed is superior to the probe feed
9. There should be no ground plane under the antenna
10. The square spiral is preferred to the square patch based on impedance matching considerations
11. Both tank resistance and reflected load power due to mismatched impedances appear to increase the effective area of the small antenna

While for convenience of disclosure primary attention has been directed toward use of the preferred embodiments of the invention which employ IC chips or printed circuit boards, the invention may also be employed advantageously in connection with other substrates in wireless untethered devices.

Whereas particular embodiments of the invention have been disclosed herein for purposes of illustration, it will be evident to those skilled in the art that numerous variations of the details may be made without departing from the invention as set forth in the appended claims.

The invention claimed is:

1. A wireless untethered device comprising:

at least one antenna;

circuitry operatively associated with said antenna for receipt of energy harvested by said antenna from space, said circuitry being structured to convert said energy to direct current; and

a system structured to be energized by the direct current from said circuitry, said system and said circuitry having an impedance mismatch with respect to said antenna wherein said antenna, said circuitry and said system together form an integrated antenna and wherein said antenna has an effective area greater than its physical area.

2. The wireless untethered device of claim **1** including said wireless untethered device being selected from the group consisting of an integrated circuit chip and a printed circuit board.

3. The wireless untethered device of claim **1** including said wireless untethered device being an integrated circuit chip.

4. The integrated circuit chip of claim **3** including said antenna being integrally formed on said chip.

5. The integrated circuit chip of claim **4** including said antenna structured to receive RF energy and deliver it to said circuitry.

6. The integrated circuit chip of claim **4** including a second integral antenna for transmitting data.

7. The integrated circuit chip of claim **4** including said antenna being a spiral antenna.

8. The integrated circuit chip of claim **7** including said spiral antenna being a square spiral.

9. The integrated circuit chip of claim **3** including said circuitry having a tank circuit for increasing the effective area of said antenna.

10. The integrated circuit chip of claim **5** including said antenna having a length of about ¼ wavelength of said RF energy.

11. The integrated circuit chip of claim **3** including a micro-strip feed line connected to said antenna.

12. The integrated circuit chip of claim **3** including said circuitry having a non zero resistance which results in retransmission of some of said energy to thereby interfere with transmitted energy and increase the effective area of said antenna.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,057,514 B2
APPLICATION NO. : 10/857527
DATED : October 5, 2004
INVENTOR(S) : Marlin H. Mickle, Christopher C. Capelli and Harold Swift

Page 1 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4, line 46, “tern” should be changed to --term--.

Column 8, line 30, “do” should be changed to --due--.

Column 8, line 57, “what” should be changed to --that--.

Column 9, line 56, “place” should be changed to --placed--.

Column 10, line 5, “in” should be changed to --are--.

Column 10, line 39, “that” should be changed to --than--.

Column 11, line 11, the word “where” should be inserted after the word --accomplished--.

Column 11, line 60, “it” should be changed to --in--.

Column 11, line 48, “type” should be changed to --types--.

Column 11, line 51, “type” should be changed to --types--.

Column 12, line 24, “affect” should be changed to --effect--.

Column 12, line 28, “additional” should be changed to --addition,--.

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Column 12, line 32, “in general” should be changed to --generally--.

Column 14, line 29, “f” should be changed to --If--.

IN THE FIGURES

FIGS. 7, 19 and 28, “te” should be changed to --the--.

Signed and Sealed this

Fourteenth Day of November, 2006

Jon W. Dudas

JON W. DUDAS
Director of the United States Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,057,514 B2 Page 1 of 2
APPLICATION NO. : 10/857527
DATED : June 6, 2006
INVENTOR(S) : Marlin H. Mickle, Christopher C. Capelli and Harold Swift

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4, line 46, “tern” should be changed to --term--.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,057,514 B2 Page 2 of 2
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IN THE FIGURES

FIGS. 7, 19 and 28, “te” should be changed to --the--.

This certificate supersedes Certificate of Correction issued November 14, 2006.

Signed and Sealed this

Second Day of January, 2007

Jon W. Dudas

JON W. DUDAS
Director of the United States Patent and Trademark Office

W. I. PENNOCK.

APPARATUS FOR COLLECTING ATMOSPHERIC ELECTRICITY.

APPLICATION FILED JUNE 26, 1907.

911,260. Patented Feb. 2, 1909.

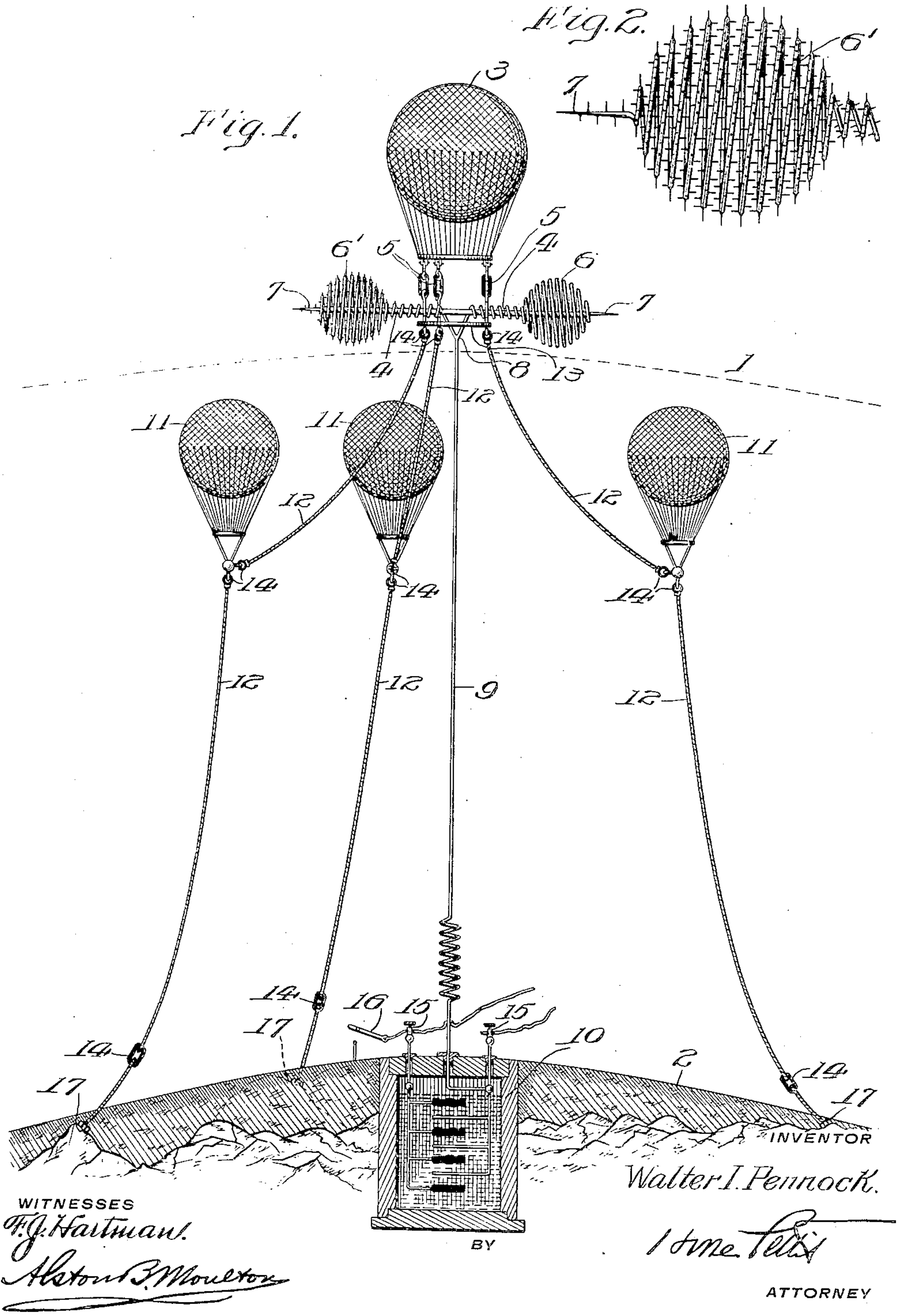
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APPARATUS FOR COLLECTING ATMOSPHERIC ELECTRICITY.

No. 911,260. **Specification of Letters Patent.** Patented Feb. 2, 1909.

Application filed June 26, 1907. Serial No. 380,907.

To all whom it may concern:

Be it known that I, Walter I. Pennock, a citizen of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in Apparatus for Collecting Atmospheric Electricity, of which the following is a specification.

My invention relates to a method of collecting electricity from a strata laden with electricity at high altitudes in the atmosphere, through the medium of a wire cable suspended from one or more balloons and in conveying this electricity to the earth's surface.

The object of my invention is to provide a conveyance of the electro motive force to be found in the upper strata of the atmosphere to the earth's surface; where it may be utilized for commercial and other purposes.

A further object of my invention is to provide a device or mechanism by which a suitable collector for the electrical energy in the upper strata of the earth's atmosphere may be elevated in the said strata and by which the said electric energy may be transmitted to and collected at the earth's surface, from which point it may be conducted to any place where it is desired to use the same.

A further object of my invention is to support and anchor said device in any desired position.

A further object of my invention is to provide an improved form of collector through which the energy of the said upper strata of the earth's atmosphere may be collected and transmitted for various purposes to the earth's surface.

Other objects of my invention will appear in the specification and claims below.

For a further full, clear and complete disclosure of my invention, reference may be had to the following description and accompanying drawings, in which like reference characters refer to corresponding parts.

Figure 1 is an elevational view of one form or embodiment of my invention and Fig. 2 is a detailed view of one form of my improved collector.

The passage of the electrical current to the earth under ordinary conditions is prevented by an obstruction afforded by the dense lower strata of the atmosphere, which is a bad conductor of electricity, as shown by the electrodes of an ordinary static machine. When the electrodes are placed close together, the atmosphere is seen to carry the current across from one electrode to another, but if placed far apart the current is obstructed by the intervening air. The dense lower strata of the atmosphere affords one of the best non-conductors of electricity, as shown in the conduction of the electric current by telegraph, or trolley wires on the earth's surface, where only a small quantity of the electric current escapes through the atmosphere; while rarefied atmosphere affords a good conducting media, as shown by the vacuum tube. The upper strata of the atmosphere being rare in proportion to the altitude, and being a good conductor of electricity while the lower strata of the atmosphere being dense and affording a non-conducting media for the electric current, thus causes an obstruction to the electric current, or power in its passage to the earth's surface from the electric strata of the atmosphere under ordinary conditions. When, however, the cumulus clouds of a thunder storm pass over the surface of the earth, these clouds being of very great height, the moisture in said clouds forms a better conductor of electricity than does the dry air, with the result that the electricity in the upper strata of the atmosphere breaks through the said cloud as a streak of lightning and in that form reaches even to the earth's surface, while the thin or shallow strata of clouds, observed in the so-called "settled rain" storm, do not extend upward to a sufficient height to form a conducting medium for the electricity from the electric strata to the earth's surface. For this reason there is usually no lightning during the said latter variety of rain storm.

By means of my invention, I have provided a mechanism for collecting the electrical energy or power created by nature and stored in the upper strata of rarefied air of the earth's atmosphere and have provided a conductor for said electric energy to the earth's surface.

Referring now to the drawings 1 indicates what may be called the lower limits or boundaries of the strata of electric energy above the surface 2 of the earth.

3 indicates a balloon which is elevated to a high altitude until it enters the said stra-

tum. The said balloon 3 carries a bar 4 of wood or any other suitable non-conducting material suspended by insulating links 5 or any other suitable form of insulation from the balloon 3. Upon either end of the said bar 4 I mount collectors, one form of which I have illustrated as spheres of coiled wire 6—6′ the outer ends 7 of which terminate in sharp points. The inner turns of the said spheres 6 and 6′ are wrapped around the wooden bar 4 and united as at 8 to a conductor of electric energy, preferably a large copper wire 9. This wire or conductor 9 extends to the earth's surface and may have its end suitably attached to an electric accumulator or other piece of electrical apparatus. I have illustrated one form of my invention in which the conductor 9 is connected to one pole of a storage battery 10 on the earth's surface.

The spiral spheres 6, 6′ are preferably provided with a polished metallic surface to form a good conductor of electricity and the material of said spheres should also be of such a character that it will not rust or corrode or tarnish. A polished copper wire or a copper wire plated with platinum or gold or a solid platinum or gold wire may be used for this purpose, inasmuch as these materials are least affected by moisture and the atmosphere. The said spheres or collectors may be made of smooth wire as shown in the sphere designated by the numeral 6 or of barbed wire, as is shown at 6′ and illustrated on a larger scale in Fig. 2 of the drawings. The latter form is preferable inasmuch as it provides a large number of points through which the electricity may flow to the wire from the surrounding air in the said upper strata of the earth's atmosphere.

In order that the supporting balloon 3 may be held in a relatively fixed position, it should be suitably anchored to the earth's surface. Inasmuch as the balloon 3 must be elevated to a very high position, the weight of the anchoring cables forms an important consideration, and if desired or necessary one or more supplemental balloons 11, 11, 11 may be attached to each of the anchoring cables 12, 12, 12 as illustrated in Fig. 1, to relieve the balloon 3 of such weight as would prevent it from ascending into the said electrical strata. In order that the electricity from the said upper strata of the earth's atmosphere may not be conducted down the anchoring cables 12, 12, 12, I attach them to the supporting balloon 3 and to the supplemental balloons 11 and to the earth's surface through suitable insulating devices 14.

In the form of my invention illustrated in Fig. 1, below the bar 4, I suspend a ring 13 of any suitable material from the balloon 3, and attach the anchoring cables 12 thereto by means of insulating rings 14, 14, 14. I may also provide additional insulating rings 14 between that portion of the anchoring cables 12 between the balloon 3 and the supplemental balloons 11, and also between that part of the cable 12 between the supplemental balloons 12 and the earth's surface. I may also provide, near the earth's surface and at the lower end of the anchoring cables 12, similar insulating links 14. While I have described links as forming a convenient form of insulating device for the purposes above set forth, I do not wish to be construed as being limited to the same, inasmuch as any suitable non-conducting connection may be used in place of the links 14.

The terminals 15, 15 of the storage battery 10 may be connected to any piece of electric apparatus which it is desired to run or operate and if desirable one of the poles of the battery is adapted to be connected by the switch 16 with the earth's surface. The lower ends of the anchoring cables 12 are securely anchored to the earth's surface as at 17.

With the apparatus arranged and connected in the manner illustrated in Fig. 1, the electric energy in the high strata of the earth's atmosphere passes to and through the conductive spiral spheres 6 or 6′ to the conductor 9 and is suitably stored or used at the earth's surface, while the balloons 11 support a part of the weight of the anchoring cables 12, and permit the balloon 3 to ascend as high as is possible, or necessary for it to enter the said electrical strata of the earth's atmosphere. By arranging the anchorage 17 of the cables 12 symmetrically or in any other position than in a straight line, the balloon 3 may be held in a substantially fixed position with relation to the earth.

While I have illustrated in the drawings and have described in the specification a form of apparatus in which my invention may be carried out, it is obvious that the drawings are more or less diagrammatic drawings, that is to say, that the proportions of the various parts are not necessarily those which would operate to the best advantage, inasmuch as certain portions have been shown as greatly enlarged in the drawings for the sake of clearness, and that it is likely that more than one supplemental balloon would be requird for each cable in order to support the weight of the same, and to relieve the supporting balloon 3 of such weight, as would prevent it from ascending into the high electrical strata of the earth's atmosphere, but such changes in form, proportion and arrangement I regard as being fully within the aim and scope of my invention, so long as such forms or modifications fall within the scope of the appended claims. It is also to be understood that the storage battery or accumulator which I have shown as being connected to my collector, is only a type of apparatus which can be operated by the current collected by the spheres 6, 6′ and transmitted to the earth through the wire 9, and when I use the word "accumulator", I mean any piece of useful apparatus which is operated by the current transmitted thereto through the wire or conductor 9.

Having thus described my invention, what I claim and desire to protect by Letters Patent of the United States is:

1. The combination with an electrical collector comprising a bar of non-conducting material, and an open spherical conductor carried by said bar, of means to support said collector in the high electrical strata of the earth's atmosphere.

2. The combination with a balloon, of an electrical collector supported thereby and insulated therefrom, comprising a bar of non-conducting material, and a conductor wound spirally around said bar.

3. The combination with an electrical collector comprising a non-conducting bar, and a conductive wire wound thereon to form an open substantially spherical body, and means to support said collector in the high electrical strata of the earth's atmosphere.

4. The combination with a balloon, of an electrical collector carried thereby and comprising a non-conducting bar, and a polished wire wound spirally thereon to form an open substantially spherical body.

5. The combination with an electrical collector comprising a non-conducting bar, and a wire wound spirally thereon to form an open substantially spherical body, said wire being provided with pointed conducting projections, and means to support said collector in the high electrical strata of the earth's atmosphere.

6. The combination with a balloon, of an electrical collector carried thereby comprising a non-conducting bar, and a conducting wire wound spirally thereon to form open substantially spherical bodies upon the opposite ends thereof.

7. The combination with a balloon, of an electrical collector carried thereby comprising a non-conducting bar, a conducting wire wound spirally thereon to form open substantially spherical bodies upon the opposite ends thereof, an electrical accumulator, and an electrical connection between the said collector and said accumulator.

8. The combination with a balloon, and means to anchor said balloon, of an electrical collector supported by said balloon and insulated therefrom, an electrical accumulator, and a conductor connecting said collector and said accumulator.

9. The combination of an electrical collector, means to support said collector at a high elevation from the earth's surface and within the electrical strata of the earth's atmosphere, an electrical accumulator at the earth's surface, an electrical connection between said collector and said accumulator, and means to insulate said supporting means from said collector and from the earth.

In testimony whereof, I have hereunto set my hand this 25th day of June, 1907.

WALTER I. PENNOCK.

Witnesses:
HUGH F. QUINN,
WM. G. GLENN.

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H. PLAUSON

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Fig. 1.

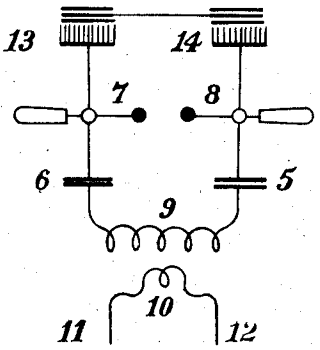
13
14
7
8
6
5
9
10
11
12

Fig. 2.

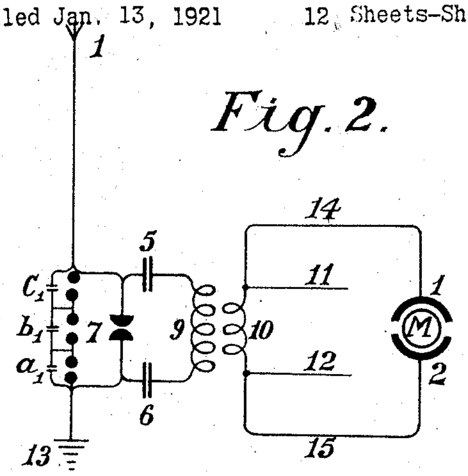
1
c1
b1
a1
7
5
6
9
10
14
11
12
15
1
M
2
13

Fig. 3.

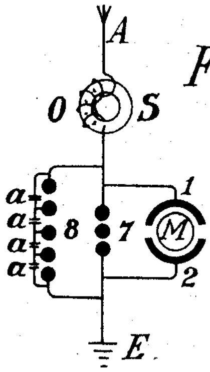
A
0
S
a
a
a
a
8
7
1
M
2
E.

Fig. 4.

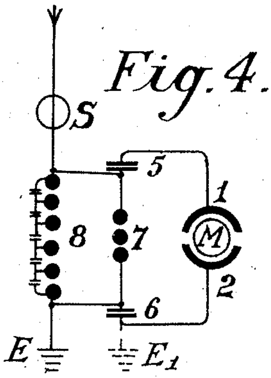
S
5
8
7
1
M
2
6
E
E1

Fig. 5.

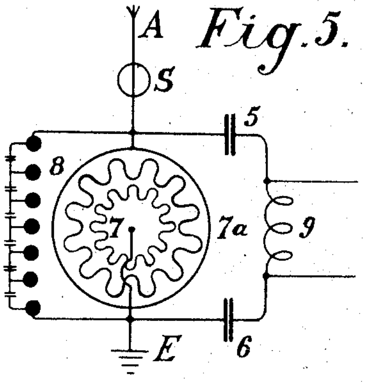
A
S
5
8
7
7a
9
E
6

Fig 6

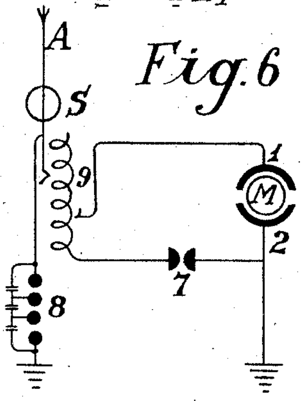

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H. PLAUSON

CONVERSION OF ATMOSPHERIC ELECTRIC ENERGY

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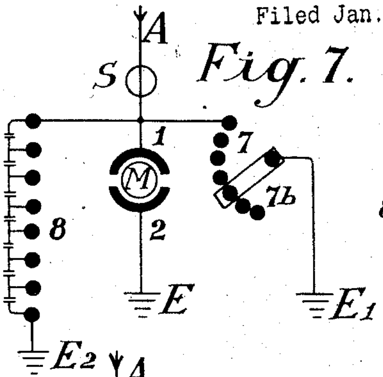
Fig. 7.
A
S
1
M
2
7
7b
8
E
E1
E2

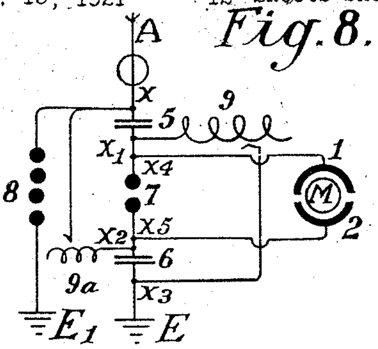
Fig. 8.
A
X
5
9
X1
X4
1
M
7
8
X5
2
X2
6
9a
X3
E1
E

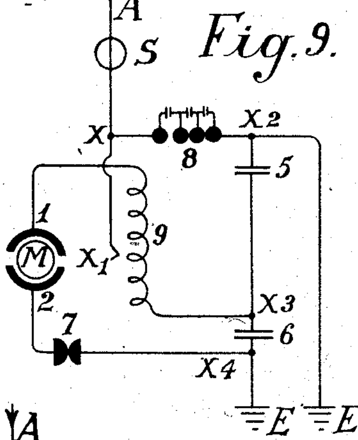
Fig. 9.
A
S
X
8
X2
5
1
M
9
X1
2
X3
6
7
X4
E
E1

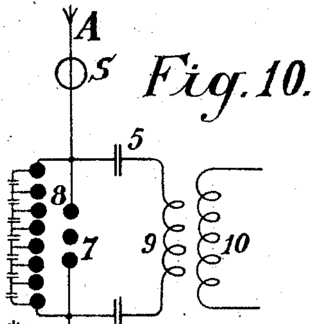
Fig. 10.
A
S
5
8
7
9
10
6
E

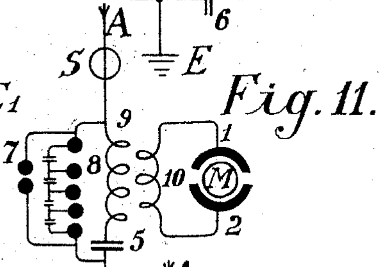
Fig. 11.
A
S
E
9
1
7
8
10
M
5
2
E

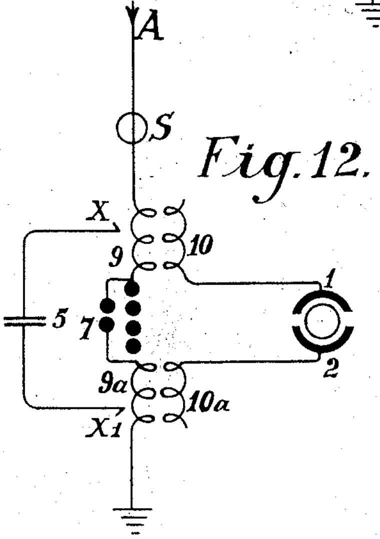
Fig. 12.
A
S
X
9
10
1
5
7
2
9a
10a
X1

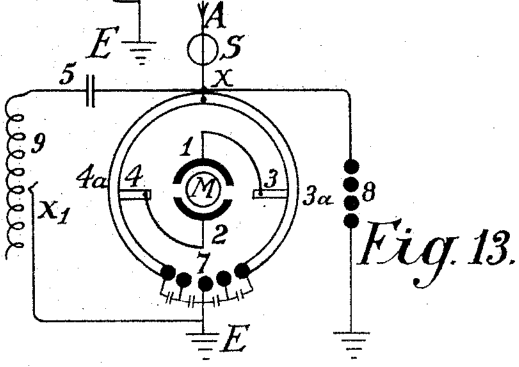
Fig. 13.
A
S
X
5
9
1
4a
4
M
3
3a
8
X1
2
7
E

Inventor

Normann Plauson

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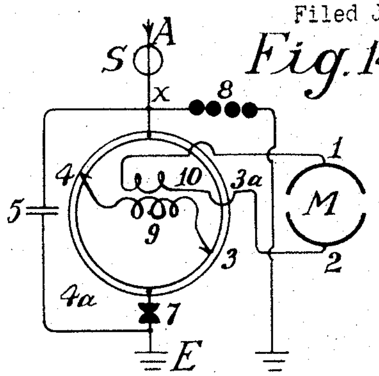
S
A
x
8
1
M
2
5
4
10
3a
9
3
4a
7
E

Fig. 14.

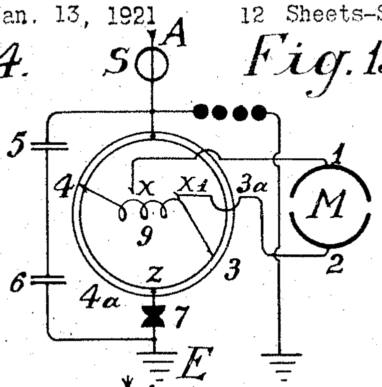
S
A
5
4
x
x1
3a
1
M
9
z
3
2
6
4a
7
E

Fig. 15.

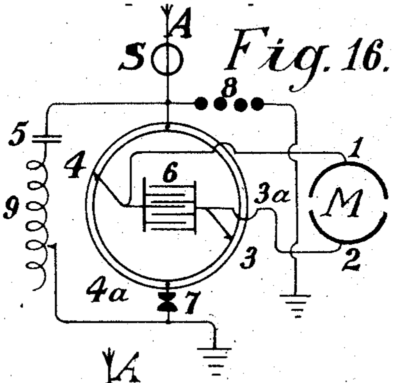
S
A
8
5
4
6
1
M
9
3a
3
2
4a
7

Fig. 16.

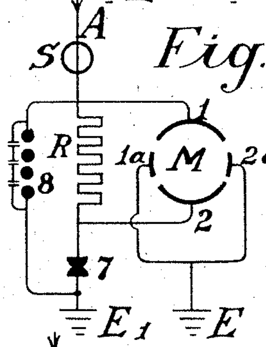
S
A
1
R
1a
M
2a
8
2
7
E1
E

Fig. 17.

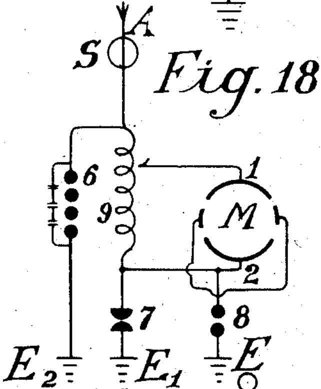
S
A
6
1
9
M
2
7
8
E2
E1
E

Fig. 18.

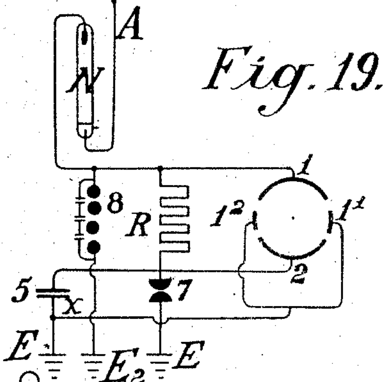
A
N
1
8
R
1²
1¹
2
5
x
7
E
E2
E

Fig. 19.

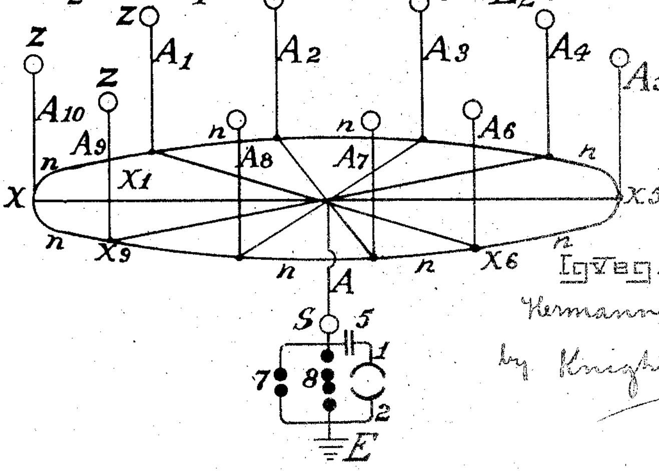
z
z
z
A1
A2
A3
A4
A5
A10
A9
A8
A7
A6
n
x
x1
x5
x9
x6
A
S
5
1
7
8
2
E

Fig. 20.

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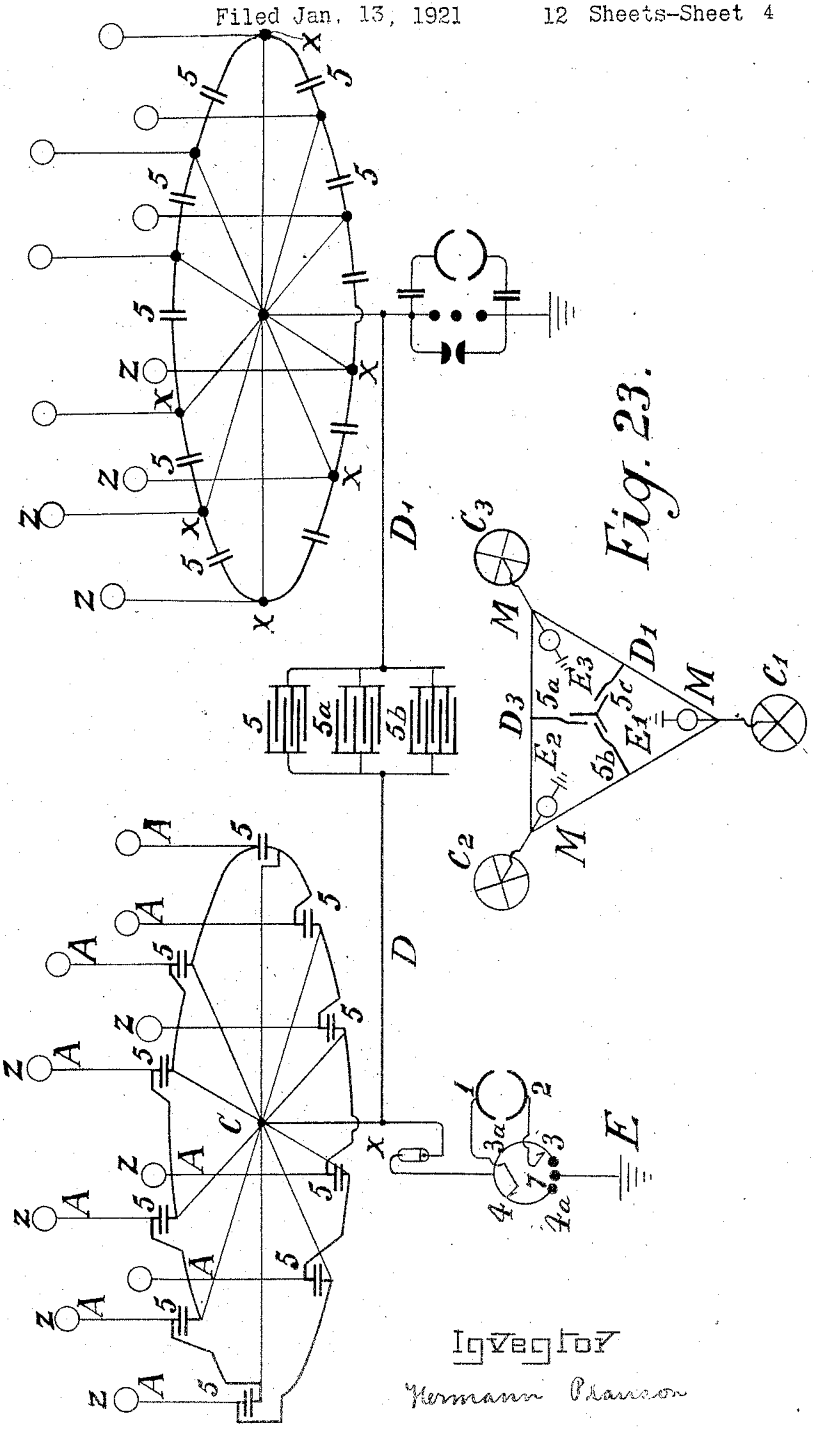
Fig. 22.
X
5
Z
D1
5
5a
5b
D
Fig. 21.
A
Z
C
X
1
2
3a
3
4
7
4a
E
Fig. 23.
C3
M
E3
5a
D1
5c
D3
E2
E1
5b
M
C1
C2
M

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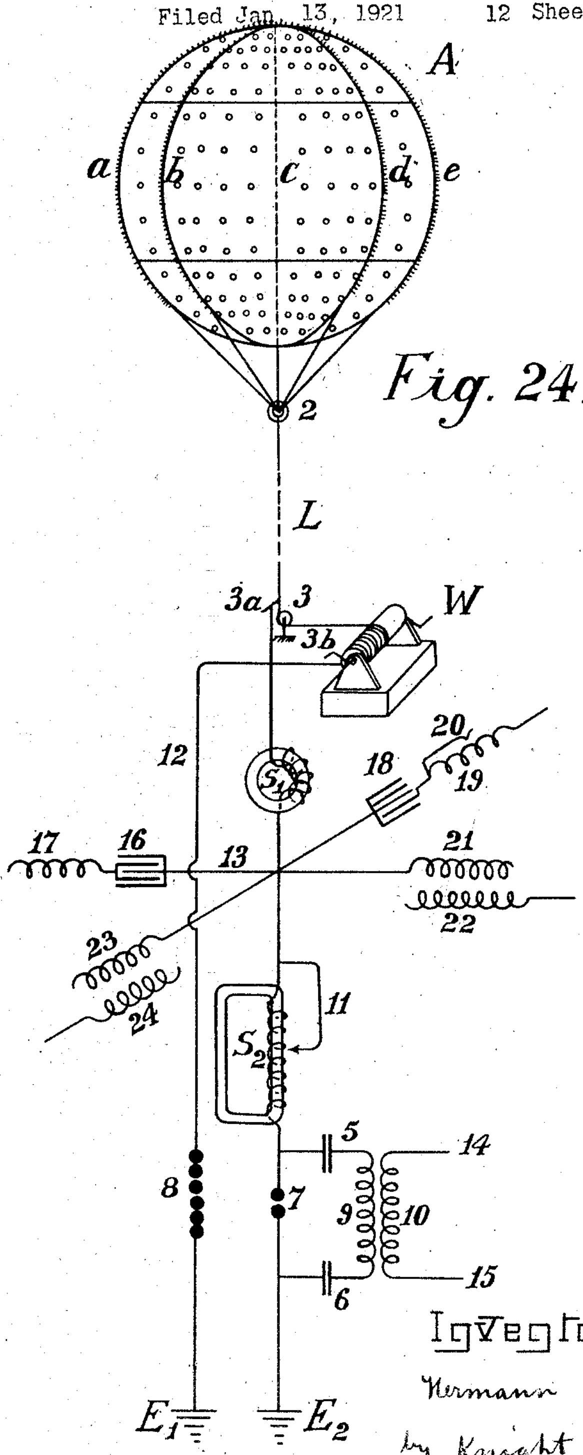
A
a
b
c
d
e
2
L
3a
3
3b
W
12
S1
18
20
19
17
16
13
21
22
23
24
11
S2
5
14
8
7
9
10
15
6
E1
E2

Fig. 24.

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Fig. 25.

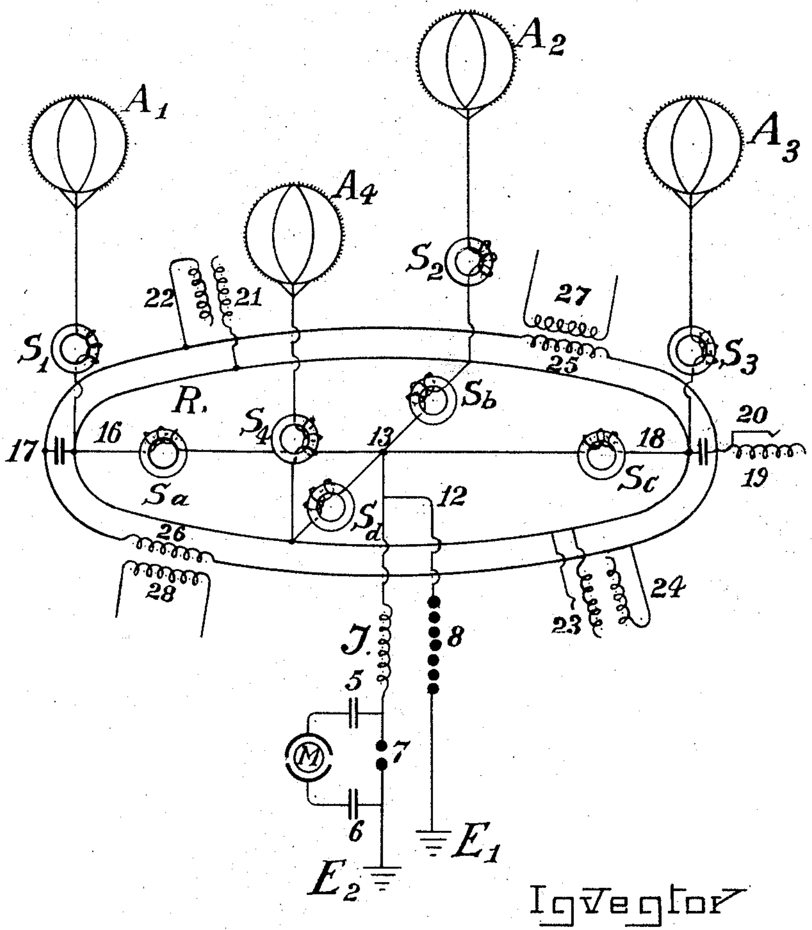
A_1
A_2
A_3
A_4
S_1
S_2
S_3
S_4
S_a
S_b
S_c
S_d
R.
12
13
16
17
18
19
20
21
22
23
24
25
26
27
28
J.
5
6
7
8
M
E_1
E_2

Inventor

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Knight Bros

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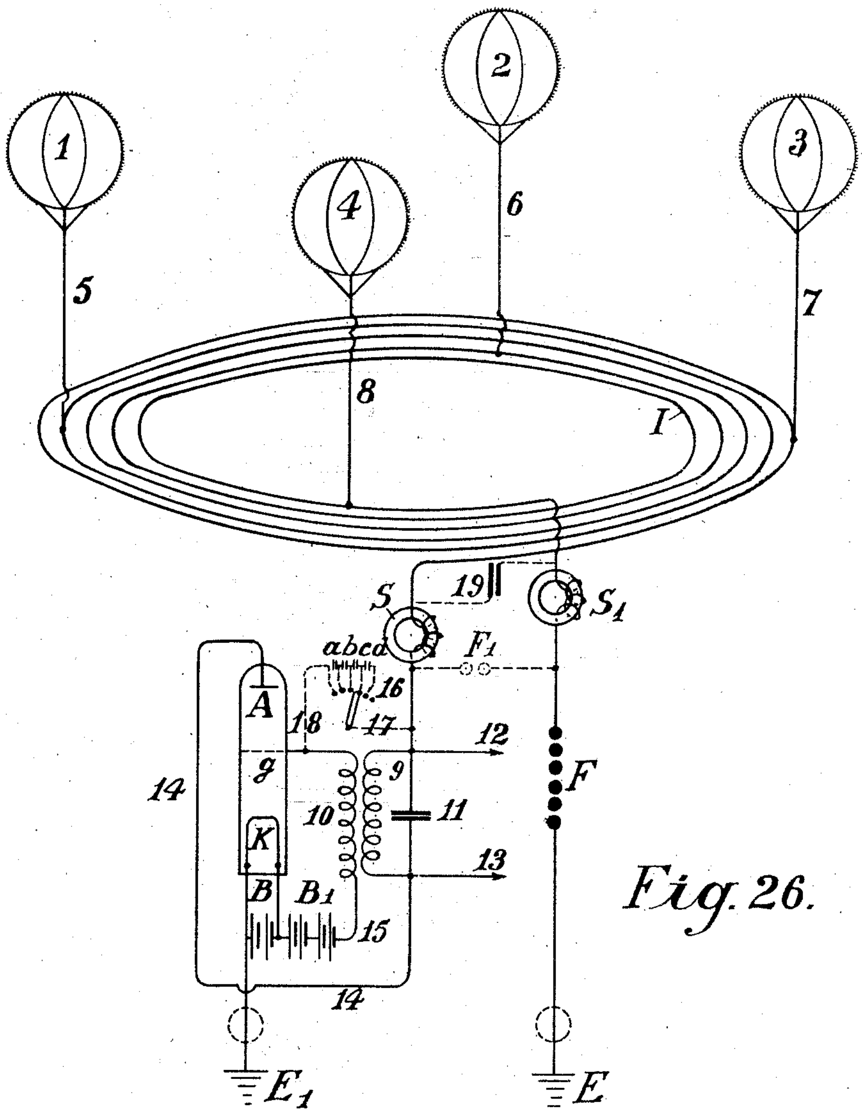
1
2
3
4
5
6
7
8
I
S
19
S_1
abcd
F_1
16
A
18
17
12
g
9
14
10
11
K
13
B
B_1
15
14
F
E_1
E

Fig. 26.

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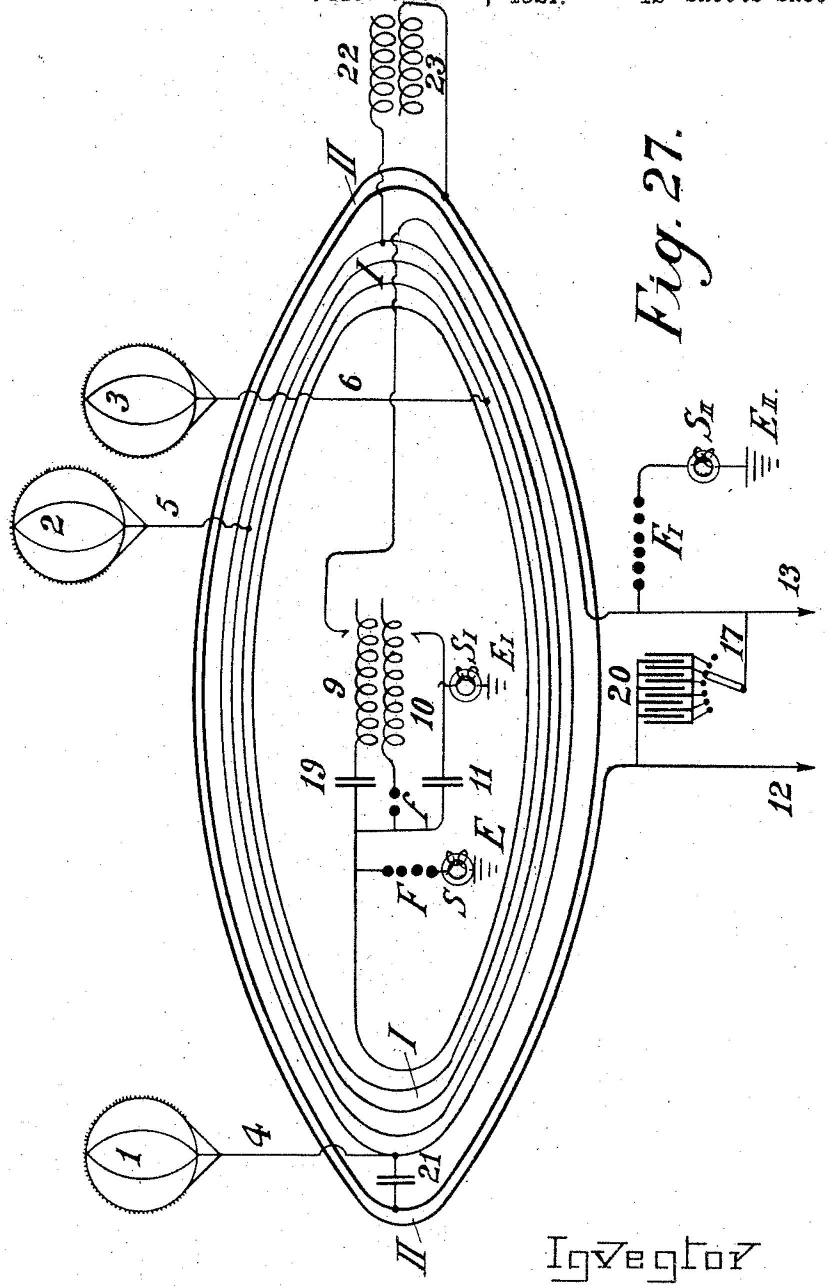
22
23
II
I
6
3
2
5
1
4
21
II
I
9
10
S_I
E_I
19
11
F
S
E
20
17
13
12
F_I
S_{II}
E_{II}

Fig. 27.

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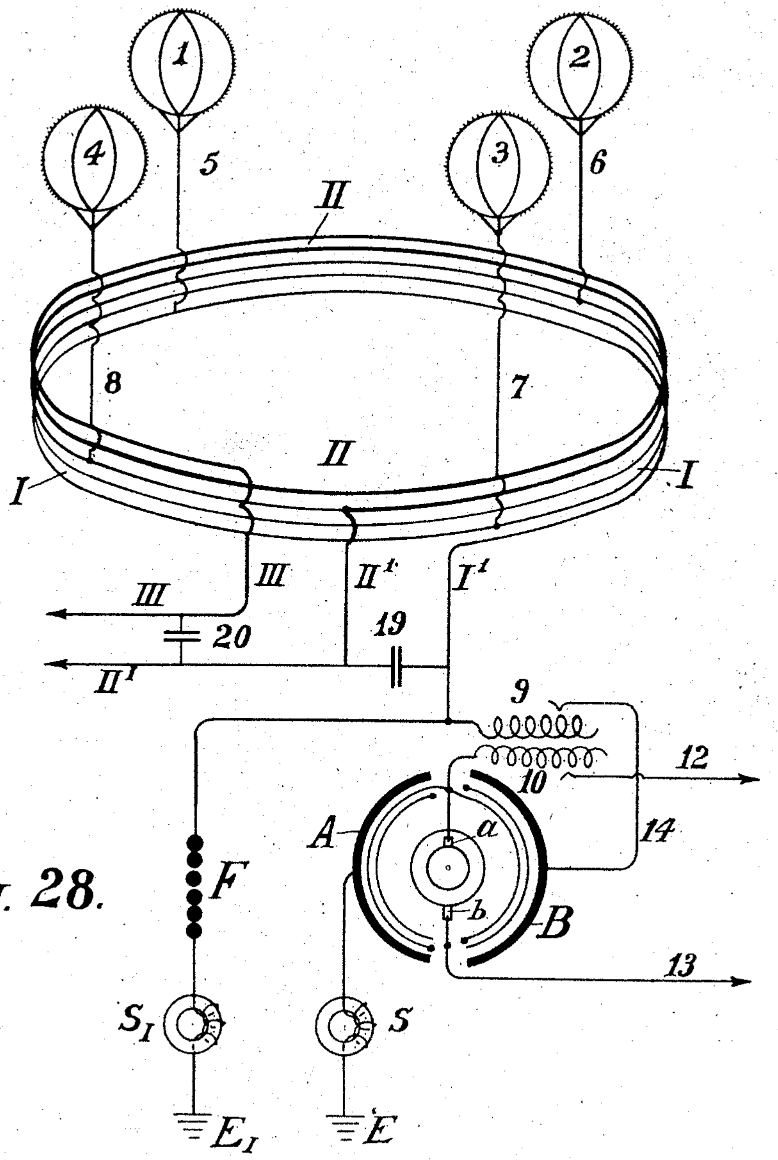
1
2
4
5
3
6
II
8
7
II
I
I
III
II¹
I¹
III
20
19
II¹
9
12
10
A
a
14
B
b
13
F
S₁
S
E₁
E

Fig. 28.

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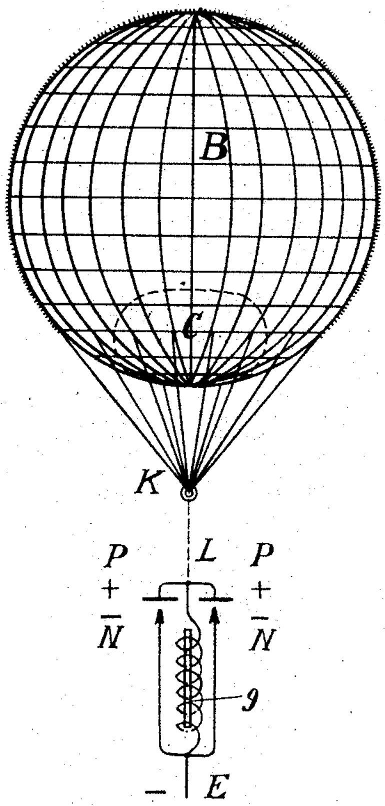
B
C
K
P
L
P
+
+
N
N
9
−
E

Fig. 29.

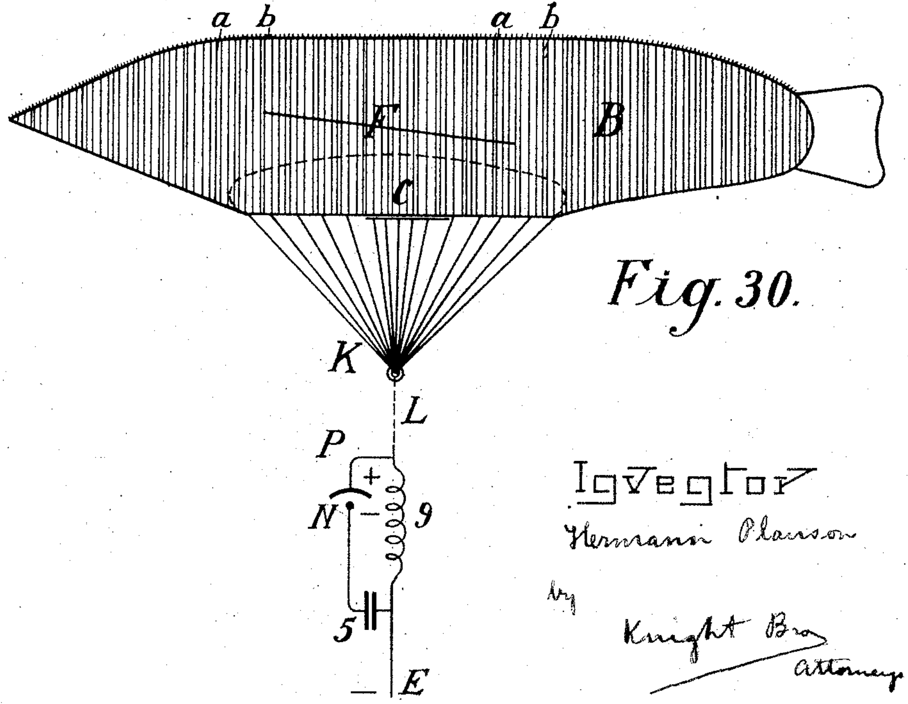
a
b
a
b
F
B
C
K
L
P
+
N
−
9
5
−
E

Fig. 30.

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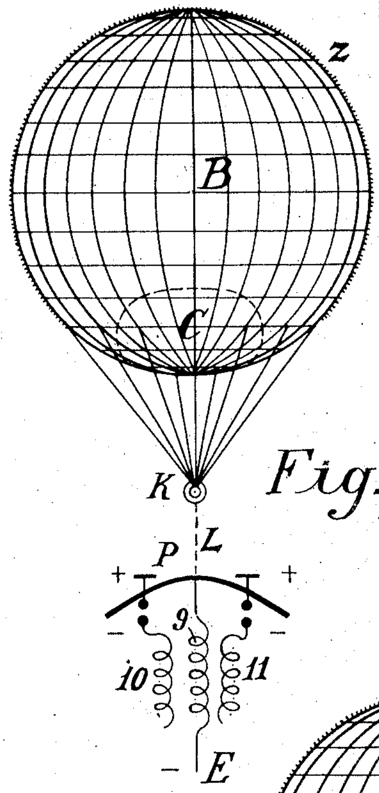
Z
B
C
K
L
P
+
+
–
–
9
10
11
–
E

Fig. 31.

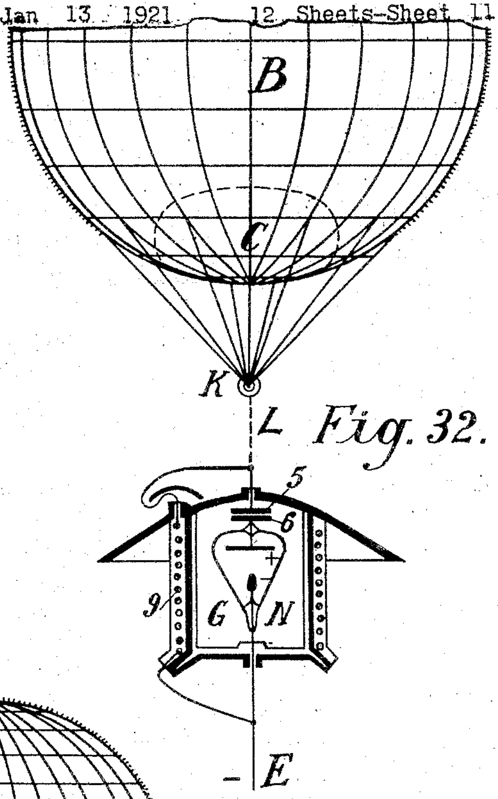
Z
B
C
K
L
5
6
+
–
9
G
N
–
E

Fig. 32.

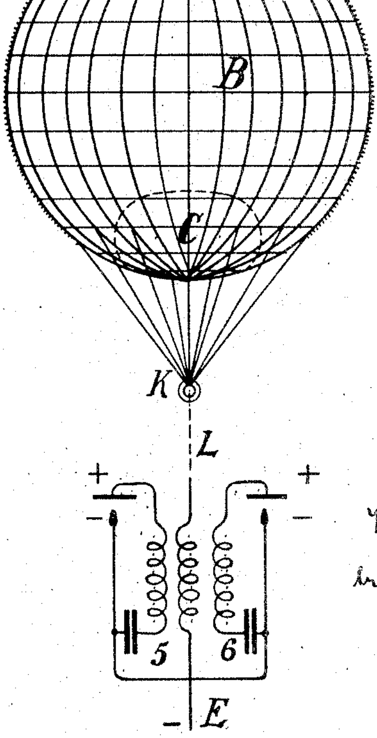

Fig. 33.

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Fig. 34

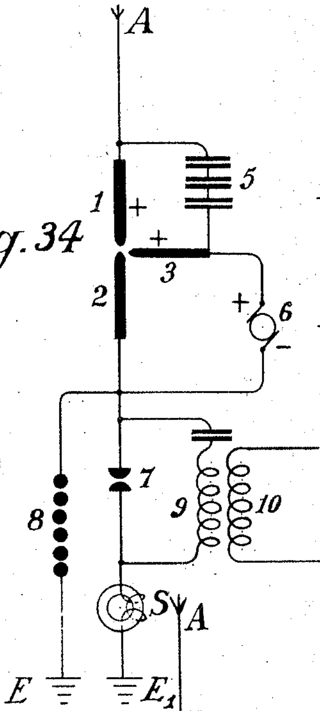
A
1
+
5
+
3
2
+
6
-
8
7
9
10
S
E
E1

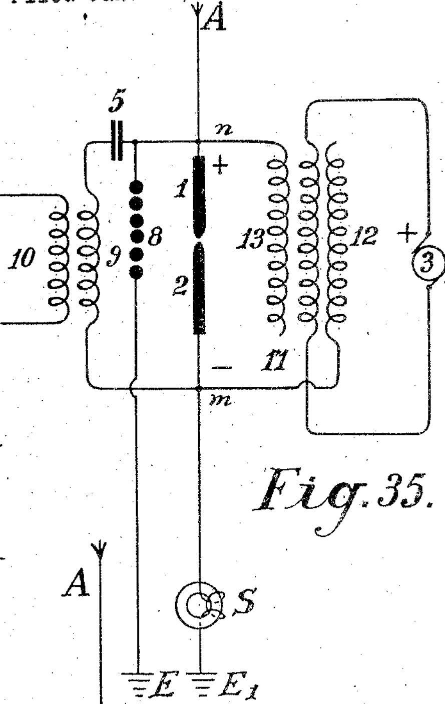
A
5
n
+
1
8
10
9
13
12
+
3
6
-
2
-
11
m
S
E
E1

Fig. 35.

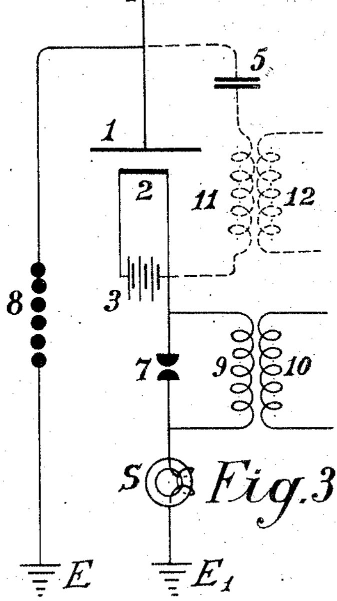
5
1
2
11
12
8
3
7
9
10
S
E
E1

Fig. 36.

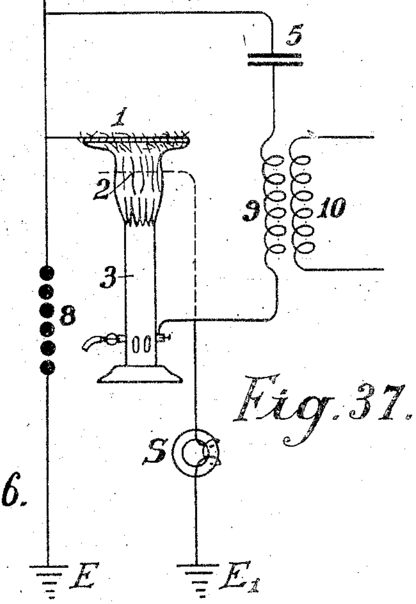
5
1
2
3
9
10
8
S
E
E1

Fig. 37.

Inventor

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Attorneys

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UNITED STATES PATENT OFFICE.

HERMANN PLAUSON, OF HAMBURG, GERMANY.

CONVERSION OF ATMOSPHERIC ELECTRIC ENERGY.

Application filed January 13, 1921. Serial No. 437,107.

To all whom it may concern:

Be it known that I, HERMANN PLAUSON, Esthonian subject, residing in Hamburg, Germany, have invented certain new and useful Improvements in the Conversion of Atmospheric Electric Energy, of which the following is a specification.

Methods of obtaining atmospheric electricity by means of metallic nettings set with spikes which are held by means of ordinary or anchored kite balloons made of fabrics and filled with hydrogen, are in theory already known. Atmospheric electricity obtained in this way has been suggested to be used in the form of direct current for the charging of accumulators. This knowledge however is at present only theoretical as the conversion in practice has hitherto been a failure. No means are known of protecting the apparatus from destruction by lightning. The balloons used for collecting the charge must also be made of very large size in order to be able to support the weight of the metallic netting and the heavy cable connections.

Instead of using heavy metallic netting as collectors attached to single air balloons of non-conducting materials which are liable to be torn and are permeable to the gas, it is proposed to use metallic balloon collectors which have the following important advantages—

(*a*) The metallic cases are impenetrable to helium and hydrogen; they also represent large metallic weather-proof collecting surfaces.

(*b*) Radio active means and the like may be easily applied internally or externally; whereby the ionization is considerably increased and therewith also the quantity of atmospheric electricity capable of being collected.

(*c*) Such balloon collectors of light metal do not require to be of large size as they have to carry only their own moderate weight, and that of the conducting cable or wire.

(*d*) The entire system therefore offers little surface for the action of storm and wind and is resistant and stable.

(*e*) Each balloon can be easily raised and lowered by means of a winch so that all repairs, recharging and the like can be carried out without danger during the operation.

It is further proposed to use a collecting aerial network of several separate collectors spread out in the air above the earth, which collectors are interconnected by electrical conductors.

According to this invention charges of atmospheric electricity are not directly converted into mechanical energy, and this forms the main difference from previous inventions, but the static electricity which runs to earth through aerial conductors in the form of direct current of very high voltage and low current strength is converted into electro-dynamic energy in the form of high frequency vibrations. Many advantages are thereby obtained and all disadvantages avoided.

The very high voltage of static electricity of a low current strength can be converted by this invention to voltages more suitable for technical purposes and of greater current strength. By the use of closed oscillatory circuits it is possible to obtain electromagnetic waves of various amplitude and thereby to increase the degree of resonance of such current. Such resonance allows various values of inductance to be chosen whereby again the governing of the starting and stopping of machines driven thereby by simply tuning the resonance between coils of the machine and the transformer circuit forming the resonance can easily be obtained. Further, such currents have the property of being directly available for various uses, even without employing them for driving motors, of which there may be particularly mentioned, lighting, production of heat and use in electro-chemistry.

Further, with such currents a series of apparatus may be fed without direct current supply through conductors and also the electro-magnetic high frequency currents may be converted by means of special motors adapted for electro-magnetic oscillations into mechanical energy, or finally converted by special machines into alternating current of low frequency or even into direct current of high potential.

The invention is more particularly described with reference to the accompanying diagrams in which:—

Figure 1 is an explanatory figure.

Figure 2 is a diagrammatic view of the simplest form.

Figure 3 shows a method of converting atmospheric electrical energy for use with motors.

Figure 4 is a diagram showing the use of protective means.

Figure 5 is a diagram of an arrangement for converting large current strengths.

Figure 6 is a diagram of an arrangement including controlling means.

Figure 7 shows means whereby the spark gap length can be adjusted.

Figure 8 shows a unipolar connection for the motor.

Figure 9 shows a weak coupled system suitable for use with small power motors.

Figures 10, 11 and 12 show modified arrangements.

Figure 13 shows a form of inductive coupling for the motor circuit.

Figure 14 is a modified form of Figure 13 with inductive coupling.

Figure 15 is an arrangement with non-inductive motor.

Figure 16 is an arrangement with coupling by condenser.

Figures 17, 18 and 19 are diagrams of further modifications.

Figure 20 shows a simple form in which the aerial network is combined with special collectors.

Figure 21 shows diagrammatically an arrangement suitable for collecting large quantities of energy.

Figure 22 is a modified arrangement having two rings of collectors.

Figure 23 shows the connections for three rings of collectors.

Figure 24 shows a collecting balloon and diagram of its connection of condenser batteries.

Figures 25 and 26 show modified collector balloon arrangements.

Figure 27 shows a second method of connecting conductor for the balloon aerials.

Figure 28 shows an auto-transformer method of connection.

Figure 29 shows the simplest form of construction with incandescent cathode.

Figure 30 shows a form with cigar shaped balloon.

Figure 31 is a modified arrangement.

Figure 32 shows a form with cathode and electrode enclosed in a vacuum chamber.

Figure 33 is a modified form of Figure 32.

Figure 34 shows an arc light collector.

Figure 35 shows such an arrangement for alternating current.

Figure 36 shows an incandescent collector with Nernst lamp.

Figure 37 shows a form with a gas flame.

Figure 1 illustrates a simple diagram for converting static electricity into dynamic energy of a high number of oscillations. For the sake of clearness in the drawings an influence machine is assumed to be employed and not an aerial antenna. 13 and 14 are combs for collecting the static electricity of the influence machine. 7 and 8 are spark discharging electrodes, 6 and 5 condensers, 9 an inductive primary coil, 10 secondary coil, 11 and 12 ends of conductors of the secondary coil 10. When the disc of the static influence machine is rotated by mechanical means, the combs collect the electric charges one the positive and the other the negative, and charge the condensers 5 and 6 until such a high potential is formed across the spark gap 7—8, that the spark gap is jumped. As the spark gap 7—8 forms a closed circuit with condensers 6 and 5, and inductive resistance 9, as is well known, waves of high frequency electromagnetic oscillations will pass in this circuit.

The high frequency of the oscillations produced in the primary circuit induces waves of the same periodicity in the secondary circuit. Thus in the primary circuit electromagnetic oscillations are formed by the passage of the spark over the spark gap and these waves are maintained by fresh charges of static electricity.

By suitably selecting the ratio between the number of the coils in the primary and secondary circuits with regard to a correct application of the co-efficients of resonance (capacity, inductance, and resistance) the high voltage of the primary circuit may be suitably converted into low voltage and high current strength.

When the oscillatory discharges in the primary circuit becomes weaker or entirely cease, the condensers are charged again by the static electricity until the accumulated charge again breaks down the spark gap. All this is repeated as long as electricity is produced by the static machine by employing mechanical energy.

An elementary form of the invention is shown in Figure 2 in which two spark gaps in parallel are used one of which may be termed the working gap 7 in Figure 2, whilst the second serves as a safety device for excess voltage and consists of a larger number of spark gaps than the working section, which gaps are arranged in series and are bridged by very small capacities as is illustrated in a_1, b_1, c_1, Figure 2 which allow of uniform sparking in the safety section.

In Figure 2 A is the aerial antenna for collecting charges of atmospheric electricity, 13 is the earth connection of the second part of the spark gap, 5 and 6 are condensers, 9 a primary coil. Now when through the aerial A the positive atmospheric electricity seeks to combine with the negative charge to earth, this is prevented by (the air gap between) the spark gaps. The resistance of the spark gap 7 is, as shown in the drawings, lower than that of the other safety section which consists of three spark gaps connected in series, and consequently a three times greater air resistance is offered by the latter.

So long therefore, as the resistance of the spark gap 7 is not overloaded, so that the other spark gaps have an equal resistance with it the discharges take place only over spark gap 7. Should however the voltage be increased by any influences so that it might be dangerous for charging the condensers 5 and 6 or for the coil insulation 9 and 10 in consequence of break down, by a correct regulation of this spark gap the second spark gap can discharge free from inductive effects direct to earth without endangering the machine.

Without this second spark gap, arranged in parallel having a higher resistance than the working spark gap it is impossible to collect and render available large quantities of electrical energy.

The action of this closed oscillation circuit consisting of spark gap 7, two condensers 5 and 6, primary coil 9, and also secondary coil 10 is exactly the same as the one described in Figure 1 with the arrangement of the static induction machine with the only difference that here the second spark gap is provided. The electromagnetic high frequency alternating current obtained can be tapped off from the conductors 11 and 12 for lighting and heating purposes. Special kinds of motors adapted for working with these peculiar electrical charges may be connected at 14 and 15 which can work with static electricity charges or with high frequency oscillations.

In addition to the use of spark gaps in parallel a second measure of security is also necessary for taking off the current. This precaution consists according to this invention, in the introduction of and method of connecting certain protective electromagnets or choking coils in the aerial circuit as shown by S in Figure 3.

A single electromagnet only having a core of the thinnest possible separate laminations is connected with the aerial.

In the case of high voltages in the aerial network or at places where there are frequent thunder storms, several such magnets may however be connected in series.

In the case of large units or plants several electromagnets can be employed in parallel or in series parallel.

The windings of these electromagnets may be simply connected in series with the aerials. In this case the winding preferably consists of several thin parallel wires, which make up together, the necessary section.

The winding may be made of primary and secondary windings in the form of a transformer. The primary winding will be then connected in series with the aerial network, and the secondary winding more or less short-circuited over a regulating resistance or an induction coil. In the latter case it is possible to regulate to a certain extent the effect of the choking coils. In the further description of the connecting and constructional diagrams the aerial electromagnet choke coil is indicated by a simple ring S.

Figure 3 shows the simplest way of converting atmospheric electricity into electromagnetic wave energy by the use of special motors adapted for high oscillatory currents or static charges of electrical energy. Recent improvements in motors for working with static charges and motors working by resonance, that is to say, having groups of tuned electromagnetic cooperating circuits render this possible but such do not form part of the present invention.

A motor adapted to operate with static charges will for the sake of simplicity be diagrammatically indicated by two semicircles 1 and 2 and the rotor of the motor by a ring M. (Figure 3.) A is a vertical aerial or aerial network. S the safety choke or electromagnet with coil O as may be seen is connected with the aerial A. Adjacent the electromagnet S the aerial conductor is divided into three circuits, the circuit 8 giving the safety spark gap, the circuit 7 with the working spark gap, and then a circuit including the stator terminal 1, the rotor and stator terminal 2 at which a connection is made to the earth wire. The two spark gaps are also connected metallically with the earth wire. The method of working these diagrams is as follows:

The positive atmospheric electric charge collected tends to combine with the negative electricity (or earth electricity) connected with the earth wire. It travels along the aerial A through the electromagnet S without being checked as it flows in the same direction as the direct current. Further, its progress is arrested by two sparks gaps placed in the way and the stator condenser surfaces. The stator condenser surfaces are charged until the charge is greater than the resistance of the spark gap 7, whereupon a spark springs over the spark gap 7 and an oscillatory charge is obtained as by means of the motor M, stator surfaces 1 and 2, and spark gap 7, a closed oscillation circuit is obtained for producing the electromagnetic oscillations. The motor here forms the capacity and the necessary inductance and resistance, which, as is well known, are necessary for converting static electricity into electromagnetic wave energy.

The discharges formed are converted into mechanical energy in special motors and can not reach the aerial network by reason of the electromagnet or choke. If, however, when a spark springs over the spark gap 7 a greater quantity of atmospheric electricity tends to flow to earth, a counter voltage is induced in the electromagnet, which is greater the more rapidly and strongly the flow of current direct to the earth is. By the formation of this opposing voltage a sufficiently high resistance is offered to the flow of atmospheric electricity direct to earth to prevent a short circuit with the earth.

The circuit containing spark gap 8 having a different wave length which is not in resonance with the natural frequency of the motor, does not endanger the motor and serves as security against excess voltage, which, as practical experiments have shown, may still arise in certain cases, but can be conducted direct to earth through this spark gap.

In the diagram illustrated in Figure 4 the spark gap 7 is shunted across condensers 5 and 6 from the motor M. This construction affords mainly a better insulation of the motor against excess voltage and a uniform excitation through the spark gap 7.

In Figure 5 a diagram is illustrated for transforming large current strengths which may be employed direct without motors, for example, for lighting or heating purposes. The main difference is that here the spark gap consists of a star shaped disc 7 which can rotate on its own axis and is rotated by a motor opposite similarly fitted electrodes 7^a. When separate points of stars face one another, discharges take place, thus forming an oscillation circuit over condensers 5 and 6 and inductance 9 for oscillatory discharges. It is evident that a motor may also be directly connected to the ends of the spiral 9.

The construction of the diagram shown in Figure 6 permits of the oscillation circuit of the motor being connected with an induction coil. Here a regulating inductive resistance is introduced for counter-acting excess voltages in the motor. By cutting the separate coils 9 (coupled inductively to the aerial) in or out the inductive action on the motor may be more or less increased or variable aerial action may be exerted on the oscillation circuit.

In Figure 7 the oscillation circuit is closed through the earth (E and E_1). The spark gap 7 may be prolonged or shortened by more or fewer spark gaps being successively connected by means of a contact arm 7^b.

Diagram 8 shows a unipolar connection of the motor with the aerial network. Here two oscillation circuits are closed through the same motor. The first oscillation circuit passes from aerial A through electromagnet S, point x, inductance 9^a to the earth condenser 6 and further, over spark gap 7 to the aerial condenser 5 and back to x. The second oscillation circuit starts from the aerial condenser 5 at the point x^1 over the inductance 9 to the earth condenser 6 at the point x^3 and through the condenser 6 over the spark gap 7 back to x^1. The motor itself is inserted between the two points of the spark gap 7. From this arrangement slightly damped oscillation wave currents are produced.

In the diagram illustrated in Figure 9 a loosely coupled system of connections is illustrated which is assumed to be for small motors for measuring purposes. A indicates the aerial conductor, S the electromagnet in the aerial conductor, 9 the inductance, 7 the spark gap, 5 and 6 condensers, E the earth, M the motor, and 1 and 2 stator connections of the motor. The motor is directly metallically connected with the oscillation circuit.

In Figure 10 a purely inductive coupling is employed for the motor circuit. The motor is connected with the secondary wire 10 as may be seen in Figure 11 in a somewhat modified diagram connection. The same applies to the diagram of Figure 12.

The diagrams hitherto described preferably allow of motors of small and medium strength to be operated. For large aggregates, however, they are too inconvenient as the construction of two or more oscillation circuits for large amounts of energy is difficult; the governing is still more difficult and the danger in switching on or off is greater.

A means of overcoming such difficulties is shown in Figure 13. The oscillation circuit here runs starting from the point x over condenser 5, variable inductance 9, spark gap 7 and the two segments (3^a and 4^a) forming arms of a Wheatstone bridge, back to x. If the motor is connected by brushes 3 and 4 transversely to the two arms of the bridge as shown in the drawings, electromagnetic oscillations of equal sign are induced in the stator surfaces 1 and 2 and the motor does not revolve. If however, the brushes 3 and 4 are moved in common with the conducting wires 1 and 2 which connect the brushes with the stator poles a certain alteration or displacement of the polarity is obtained and the motor commences to revolve.

The maximum action will result if one brush 3 comes on the central sparking contact 7 and the other brush 4 on the part x. They are however, usually in practice not brought on to the central contact 7 but only held in the path of the bridge segments 4^a and 3^a in order not to connect the spark gaps with the motor oscillation circuit.

As however, the entire oscillation energy can thereby not act on the motor it is better to carry out the same system according to the diagram 14. The diagram 14 differs from the foregoing only by the motor not being directly metallically connected with the segments of the commutator, but only a primary coil 9 which induces in a secondary coil 10, current which feeds the motor M and takes the place of the rotor. By this arrangement a good transforming action is obtained, a loose coupling and also an oscillation circuit without a spark gap.

In Figure 15 the motor is not purely inductively as in 14, but directly metallically branched off from the primary coil (at x and x^1) after the principle of the auto-transformer.

In Figure 16 instead of an inductance a condenser 6 is in similar manner, and for the same object inserted between the segments 3^a and 4^a. This has the advantage that the segments 3^a and 4^a need not be made of solid metal but may consist of spiral coils whereby a more exact regulation is possible and further motors of high inductance may be employed.

The arrangements of Figures 17, 18 and 19 may be employed for use with resonance and particularly with induction condenser motors; between the large stator induction condenser surfaces, small reversing pole condensers are connected, which, as may be seen from Figures 17, 18 and 19 are led together to earth. Such reversing poles have the advantage that with large quantities of electrical energy the spark formation between the separate oscillation circuits ceases.

Figure 19 shows a further method which prevents electromagnetic oscillations of high number of alternations formed in the oscillation circuit striking back to the aerial conductor. It is based on the well known principle that a mercury lamp, one electrode of which is formed of mercury, the other of solid metal such as steel allows an electric charge to pass in only one direction from the mercury to the steel and not vice versa. The mercury electrode of the vacuum tube N is therefore connected with the aerial conductor and the steel electrode with the oscillation circuit. From this it results that charges can pass only from the aerial through the vacuum tube to the oscillation circuit, but not vice versa. Oscillations which are formed on being transformed in the oscillation circuit cannot pass to the aerial conductor.

In practice these vacuum tubes must be connected behind an electromagnet as the latter alone affords no protection against the danger of lightning.

As regards the use of spark gaps, all arrangements as used for wireless telegraphy may be used. Of course the spark gaps in large machines must have a sufficiently large surface. In very large stations they are cooled in liquid carbonic acid or better still in liquid nitrogen or hydrogen; in most cases the cooling may also take place by means of liquefied low homologues of the metal series or by means of hydrocarbons the freezing point of which lies at between −90° C. and −40° C. The spark gap casing must also be insulated and be of sufficient strength to be able to resist any pressure which may arise. Any undesirable excess super-pressure which may be formed must be automatically let off. I have employed with very good results mercury electrodes which were frozen in liquid carbonic acid, the cooling being maintained during the operation from the outside through the walls.

Figure 20 is one of the simplest forms of construction of an aerial network in combination with collectors, transformers and the like illustrated diagrammatically. E is here the earth wire, 8 the safety spark gap, 7 the working spark gap, 1 and 2 the stator surfaces of the motor, 5 a condenser battery, S the protective magnet which is connected with the coil in the aerial conductor, A^1 to A^{10} aerial antennæ with collecting balloons, N horizontal collecting or connecting wires from which, to the centre a number of connections run.

The actual collectors consist of metal sheaths preferably made of an aluminium magnesium alloy, and are filled with hydrogen or helium and are attached to copper plated steel wires. The size of the balloon is selected so that the actual weight of the balloon and the weight of the conducting wire is supported thereby. On the top of the balloon aluminium spikes, made and gilded in a special manner hereinafter described, are arranged in order to produce a conductor action. Small quantities of radium preparations, more particularly polonium-ionium or mesothorium preparations considerably increase the ionization, and therewith the action of these collectors.

In addition to metal balloons, fabric balloons which are superficially metal coated according to Schoop's metal spraying process, may however also be employed. A metallic surface may also be produced by lacquering with metallic bronzes, preferably according to Schoop's spraying process or lacquering with metallic bronze powders in two electrical series of widely different metals, because thereby the collecting effect is considerably increased.

Instead of the ordinary round balloons, elongated cigar shaped ones may be employed. In order also to utilize the frictional energy of the wind, patches or strips of non-conducting substances which produce electricity by friction, may be attached to the metallized balloon surfaces. The wind will impart a portion of its energy in the form of frictional electricity, to the balloon casing, and thereby the collecting effect is substantially increased.

In practice however, very high towers (up to 300 metres is fully admissible) may be employed as antennæ. In these towers copper tubes rise freely further above the top of the tower. A gas lamp secured against the wind is then lit at the point of the copper tube and a netting is secured to the copper tube over the flame of this lamp to form a collector. The gas is conveyed through the interior of the tube up to the summit. The copper tube must be absolutely protected from moisture at the place at which it enters the tower and also rain must be prevented running down the walls of the tower which might lead to a bad catastrophe. This is done by bell shaped enlargements which expand downwards, being arranged in the tower in the form of high voltage insulators of Siamese pagodas.

Special attention must be devoted to the foundations of such towers. They must be well insulated from the ground, which may be obtained by first embedding a layer of concrete in a box form to a sufficient depth in the ground and inserting in this an asphalt lining and then glass bricks cast about 1 or 2 metres in thickness. Over this in turn there is a ferro-concrete layer in which alone the metal foot of the tube is secured. This concrete block must be at least 2 metres from the ground and be fully protected at the sides by a wooden covering, from moisture. In the lower part of the tower a wood or glass house for the large condenser batteries or for the motors may be constructed. In order to lead the earth connection to the ground water, a well insulated pit constructed of vitreous bricks, must be provided. Several such towers are erected at equal distances apart and connected with a horizontal conductor. The horizontal connecting wires may either run directly from tower to tower or be carried on bell shaped insulators similar to those in use for high voltage conductors. The width of the network may be of any suitable size and the connection of the motors can take place at any suitable places.

In order to collect large quantities of electricity with few aerials it is well to provide the aerial conductor with batteries of condensers as shown in two methods of construction in Figures 21 and 22. In Figure 21 the batteries of condensers 5 are connected on the one hand with the aerial electricity collectors Z by the aerial conductor A, and on the other hand interconnected in series with an annular conductor from which horizontal conductors run to the connecting points C to which the earth wire is connected.

Figure 22 shows a similar arrangement. Should two such series of antennæ rings be shown by a voltmeter to have a large difference of potential (for example, one in the mountains and one in the plain) or even of different polarity these differences may be compensated for by connecting sufficiently large condenser batteries (5, 5^a, 5^b) by means of Maji star conductors D and D^1. In Figure 23 a connection of three such rings of collectors to form a triangle with a central condenser battery is illustrated.

The condenser batteries of such large installations must be embedded in liquefied gases or in liquids freezing at very low temperatures. In such cases a portion of the atmospheric energy must be employed for liquefying these gases. It is also preferable to employ pressure. By this means the condenser surfaces may be diminished, and still allow for large quantities of energy to be stored, secure against breakdown. For smaller installations the immersing of the condensers in well insulated oil or the like, suffices. Solid substances on the other hand cannot be employed as insulators.

The arrangement in the diagrams hitherto described was always such that the condenser batteries were connected with both poles directly to the aerial conductors. An improved diagram of the connections for obtaining atmospheric electricity for the condenser batteries has however, been found to be very advantageous, this arrangement consists in that they are connected by only one pole (unipolar) to the collecting network. Such a method of arrangement is very important, as by means of it a constant current and an increase of the normal working pressure or voltage is obtained. If for example a collecting balloon aerial which is allowed to rise to a height of 300 metres, shows 40,000 volts above earth voltage, in practice it has been found that the working voltage (with a withdrawal of the power according to the method hereinbefore described by means of oscillating spark gaps and the like) is only about 400 volts. If however, the capacity of the condenser surfaces be increased, which capacity in the above mentioned case was equal to that of the collecting surface of the balloon aerials, to double the amount, by connecting the condenser batteries with only one pole, the voltage rises under an equal withdrawal of current up to and beyond 500 volts. This can only be ascribed to the favourable action of the connecting method.

In addition to this substantial improvement it has also been found preferable to insert double inductances with electromagnets and to place the capacities preferably between two such electromagnets. It has also been found that the useful action of such condensers can be further increased if an induction coil be connected as inductive resistance to the unconnected pole of the condenser, or still better if the condenser itself be made as an induction condenser. Such a condenser may be compared with a spring which when compressed carries in itself accumulated force, which it again gives off when released. In charging, a charge with reversed sign is formed at the other free condenser pole, and if through the spark gap a short circuit results, the accumulated energy is again given back since now new quantities of energy are induced at the condenser pole connected with the conductor network, which in fact charges with opposite signs to that at the free condenser pole. The new induced charges have of course the same sign as the collector network. The whole voltage energy in the aerial is thereby however increased. In the same space of time larger quantities of energy are accumulated than is the case without such inserted condenser batteries.

In Figures 24 and 25 two different diagrams of connections are more exactly illustrated, Figure 24 shows a collecting balloon and the diagram of the connections to earth. Figure 25 four collecting balloons and the parallel connection of the condenser batteries belonging thereto.

A is the collecting balloon made of an aluminium magnesium alloy (electron metal, magnalium) of a specific gravity of 1.8 and a thickness of plate 0.1 to 0.2 mm. Inside there are eight strong vertical ribs of T shaped section about 10 to 20 mm. in height and about 3 mm. in thickness with the projecting part directed inwards (indicated by *a*, *b*, *c*, *d* and so forth); they are riveted together to form a firm skeleton and are stiffened in a horizontal direction by two cross ribs. The ribs are further connected with one another internally and transversely by means of thin steel wires, whereby the balloon obtains great power of resistance and elasticity. Rolled plates of 0.1 to 0.2 mm. in thickness made of magnalium alloy are then either soldered or riveted on this skeleton so that a fully metallic casing with smooth external surface is obtained. Well silvered or coppered aluminium plated steel wires run from each rib to the fastening ring 2. Further, the coppered steel hawser L preferably twisted out of separate thin wires (shown in dotted lines in Figure 24) and which must be long enough to allow the balloon to rise in the desired height, leads to a metal roller or pulley 3 and from thence to a winch W, well insulated from the earth. By means of this winch, the balloon, which is filled with hydrogen, or helium, can be allowed to rise to a suitable height (300 to 5,000 metres) and brought to the ground for recharging or repairs.

The actual current is taken directly through a friction contact from the metal roller 3 or from the wire, or even from the winch or simultaneously from all three by means of brushes (3, 3^a and 3^b). Beyond the brushes the conductor is divided, the paths being:—firstly over 12 to the safety spark gap 8, from thence to the earth conductor E^1, and secondly over electromagnet S^1, point 13, to a second loose electromagnet having an adjustable coil S^2, then to the spark gap 7 and to the second earth conductor E^2. The actual working circuit is formed through the spark gap 7, condensers 5 and 6, and through the primary coil 9; here the static electricity formed by oscillatory discharges is accumulated and converted into high frequency electromagnetic oscillations. Between the electromagnets S^1 and S^2 at the crossing point 13, four condenser batteries are introduced which are only indicated diagrammatically in the drawings each by one condenser. Two of these batteries (16 and 18) are made as plate condensers and prolonged by regulating induction coils or spirals 17 and 19 while the two others (21 and 23) are induction condensers. As may be seen from the drawings each of the four condenser batteries 16, 18, 21, 23 is connected only by one pole to the aerial or to the collector conductor. The second poles 17, 19, 22, 24 are open. In the case of plate condensers having no inductive resistance an induction coil is inserted. The object of such a spiral or coil is the displacement of phase of the induction current by ¼ periods, whilst the charging current of the condenser poles which lie free in the air, works back to the collector aerial. The consequence of this is that in discharges in the collector aerial the back inductive action of the free poles allows a higher voltage to be maintained in the aerial collecting conductor than would otherwise be the case. It has also been found that such a back action has an extremely favourable effect on the wear of the contacts. Of course the inductive effect may be regulated at will within the limits of the size of the induction coil, the length of the coil in action being adjustable by means of wire connection without induction (see Fig. 24, No. 20).

S^1 and S^2 may also be provided with such regulating devices in the case of S^2 (illustrated by 11). If excess voltage be formed it is conducted to earth through the wire 12 and spark gap 8 or through any other suitable apparatus, since this formation would be dangerous for the other apparatus.

The action of these condenser batteries has already been hereinbefore described.

The small circles on the collector balloon indicate places at which zinc amalgam or gold amalgam or other photoelectric acting metals in the form of small patches in extremely thin layers (.01 to .05 mm. in thickness) are applied to the balloon casing of light metal. Such metallic patches may also be applied to the entire balloon as well as in greater thickness to the conducting network. The capacity of the collector is thereby considerably strengthened at the surface. The greatest possible effect in collecting may be obtained by polonium amalgams and the like. On the surface of the collector balloon metal points or spikes are also fixed along the ribs, which spikes serve particularly for collecting the collector charge. Since it is well known that the resistance of the spikes is less the sharper the spike is, for this purpose it is therefore extremely important to employ as sharp spikes as possible. Experiments made as regards these have shown that the formation of the body of the spike or point also plays a large part. for example, spikes made of bars or rollers with smooth surfaces, have a many times greater point resistance as collector accumulator spikes than those with rough surfaces. Various kinds of spike bodies have been experimented with for the collector balloons hereinbefore mentioned. The best results were given by spikes which were made in the following way. Fine points made of steel, copper, nickel, or copper and nickel alloys, were fastened together in bundles and then placed as anode with the points in a suitable electrolyte (preferably in hydrochloric acid or muriate of iron solutions) and so treated with weak current at 2 to 3 volts pressure. After 2 to 3 hours according to the thickness of the spikes or pins the points become extremely sharp and the bodies of the spikes have a rough surface. The bundle can then be removed and the acid washed off with water. The spikes are then placed as cathode in a bath consisting of solution of gold, platinum, iridium, paladium or wolfram salts or their compounds and coated at the cathode galvanically with a thin layer of precious metal, which must however be sufficiently firm to protect them from atmospheric oxidation.

Such spikes act at a 20 fold lower voltage almost as well as the best and finest points made by mechanical means. Still better results are obtained if polonium or radium salts are added to the galvanic bath when forming the protective layer or coating. Such pins have a low resistance at their points and even at one volt and still lower pressures have an excellent collector action.

In Figure 24 the three unconnected poles are not connected with one another in parallel. That is quite possible in practice without altering the principle of the free pole. It is also preferable to interconnect in parallel to a common collector network, a series of collecting aerials.

Figure 25 shows a diagram for such an installation. A^1, A^2, A^3, A^4 are four metal collector balloons with gold or platinum coated spikes which are electrolytically made in the presence of polonium emanations or radium salts, which spikes or needles are connected over four electro-magnets S^1, S^2, S^3, S^4, through an annular conductor R. From this annular conductor four wires run over four further electromagnets S^a, S^b, S^c, S^d, to the connecting point 13. There the conductor is divided, one branch passing over 12 and the safety spark gap 8 to the earth at E^1, the other over inductive resistance J and working spark gap 7 to the earth at E^2. The working circuit, consisting of the condenser 5 and 6 and a resonance motor or a condenser motor M, such as hereinbefore described, is connected in proximity round the sparking gap section 7.

Instead of directly connecting the condenser motor of course the primary circuit for high frequency oscillatory current may also be inserted.

The condenser batteries are connected by one pole to the annular conductor R and can be either inductionless (16 and 18) or made as induction condensers as shown by 21 and 23. The free poles of the inductionless condensers are indicated by 17 and 19, those of the induction condensers by 22 and 24. As may be seen from the drawings all these poles 17, 22, 19, 24 may be interconnected in parallel through a second annular conductor without any fear that thereby the principle of the free pole connection will be injured. In addition to the advantages already set forth the parallel connection also allows of an equalization of the working pressure in the entire collector network. Suitably constructed and calculated induction coils 25 and 26 may also be inserted in the annular conductor of the free poles, by means of which a circuit may be formed in the secondary coils 27 and 28 which allows current produced in this annular conductor by fluctuations of the charges or the like appearances to be measured or otherwise utilized.

According to what has been hereinbefore stated separate collector balloons may be connected at equidistant stations distributed over the entire country, either connected directly with one another metallically or by means of intermediate suitably connected condenser batteries through high voltage conductors insulated from earth. The static electricity is converted through a spark gap into dynamic energy of a high number of oscillations and may in such form be coupled as a source of energy by means of a suitable method of connecting, various precautions being observed and with special regulations. The wires leading from the collector balloons have hitherto been connected through an annular conductor without this endless connection, which can be regarded as an endless induction coil, being able to exert any action on the whole conductor system.

It has now been found that if the network conductor connecting the aerial collector balloons with one another is not made as a simple annular conductor, but preferably short circuited in the form of coils over a condenser battery or spark gap or through thermionic tubes or valves or audions, then the total collecting network exhibits quite new properties. The collection of atmospheric electricity is thereby not only increased but an alternating field may be easily produced in the collector network. Further, the atmospheric electrical forces showing themselves in the higher regions may also be directly obtained by induction. In Figures 26 and 28 a form of construction is shown on the basis of which the further foundations of the method will be more particularly explained.

In Figure 26 1, 2, 3, 4 are metal collector balloons, 5, 6, 7, 8 their metallic aerial conductors and I the actual collector network. This consists of five coils and is mounted on high voltage insulators in the air, on high voltage masts (or with a suitable construction of cable embedded in the earth). One coil has a diameter of 1 to 100 km. or more. S and S^1 are two protective electromagnets, F the second safety section against excess voltage, E its earth conductor and E^1 the earth conductor of the working section. When an absorption of static atmospheric electricity is effected through the four balloon collectors, the current in order to reach the earth connection E^1 must flow spirally through the collector network over the electromagnet S, primary induction coil 9, conductor 14, anode A of the audion tube, incandescent cathode K, as the way over the electromagnet and safety spark gap F offers considerably greater resistance. Owing to the fact that the accumulated current flows in one direction, an electromagnetic alternating field is produced in the interior of the collector network coil, whereby the whole free electrons are directed more or less into the interior of the coil. An increased ionization of the atmosphere is therefore produced. In consequence of this the points mounted on the collector balloon show a considerably reduced resistance and therefore increased static charges between the points on the balloon and the surrounding atmosphere are produced. The result of this is a considerably increased collector effect.

A second effect which could not be obtained otherwise is obtained by the electromagnetic alternating field which running parallel to the earth surface, acts more or less with a diminishing or increasing effect on the earth magnetic field, whereby in the case of fluctuations in the current a return induction current of reversed sign is always produced in the collector coil by earth magnetism. Now if, however, a constantly pulsating continuous alternating field is produced as stated in the above collector network I, an alternating current of the same periodicity is produced also in the collecting network coil. As the same alternating field is further transmitted to the aerial balloon, the resistance of its points is thereby considerably reduced, whilst the collector action is considerably increased. A further advantage is that positive electrons which collect on the metal surfaces during the conversion into dynamic current produce a so-called drop of potential of the collector area. As an alternating field is present, the negative ions surrounding the collector surfaces, when discharge of the collector surfaces takes place produce by the law of induction, an induction of reversed sign on the collector surface and so forth (that is to say again a positive charge). In addition to the advantages hereinbefore set forth, the construction of connecting conductors in coil form when of sufficiently large diameter, allows of a utilization of energy arising in higher regions also in the simplest way. As is well known electric discharges frequently take place at very great elevations which may be observed, such as St. Elmo's fires or northern lights. These energy quantities have not been able to be utilized up to now. By this invention all these kinds of energy, as they are of an electromagnetic nature and the direction of the axis of the collector coils stands at right angles to the earth's surface, can be more or less absorbed in the same way as a receiver in wireless telegraphy absorbs waves coming from a far distance. With a large diameter of the spiral it is possible to connect large surfaces and thereby to take up also large quantities of energy.

It is well known that large wireless stations in the summer months, and also in the tropics are very frequently unable to receive the signals in consequence of interruptions which are caused by atmospheric electricity, and this takes place with vertical coils of only 40 to 100 m. diameter. If on the contrary horizontal coils of 1 to 100 km. diameter be employed very strong currents may be obtained through discharges which are constantly taking place in the atmosphere. Particularly in the tropics or still better in the polar regions where the northern lights are constantly present, large quantities of energy may probably be obtained in this way. A coil with several windings should act the best. In similar manner any alteration of the earth magnetism should act inductively on such a coil.

It is not at all unlikely that earthquakes and spots on the sun will also produce an induction in such collector coils of sufficient size. In similar manner this collector conductor will react on earth currents more particularly when they are near the surface of the earth or even embedded in the earth. By combining the previous kind of current collectors so far as they are adapted for the improved system with the improved possibilities of obtaining current the quantities of free natural energy which are to be obtained in the form of electricity are considerably increased.

In order to produce in the improved collector coil uniform current oscillations of an undamped nature so-called audion high vacuum or thermionic tubes of suitable connection are employed instead of the previously known spark gaps (Fig. 26, Nos. 9–18). The main aerial current flows through electromagnet S (which in the case of a high number of alternations is not connected here but in the earth conductor E^1) and may be conveyed over the primary coils in the induction winding through wire 14 to the anode A of the high vacuum grid tube. Parallel with the induction resistance 9 a regulating capacity of suitable size, such as condenser 11 is inserted. In the lower part of the vacuum grid tube is arranged the incandescent filament or the cathode K which is fed through a battery B. From the battery B two branches run, one to the earth conductor E^1 and the other through battery B^1 and secondary coil 10 to the grid anode *g* in the vacuum tube. By the method of connections shown in dotted lines, a desired voltage at the grid electrode *g* may also be produced through the wire 17 which is branched off from the main current conductor through switches 16 and some small condensers (*a*, *b*, *c*, *d*) connected in series, and conductor 18, without the battery B^1 being required.

The action of the entire system is somewhat as follows:—

On the connecting conductor of the aerial collector network being short circuited to earth, the condenser pole 11 is charged and slightly damped oscillations are formed in the short circuited existing oscillation circuit formed of the condenser 11 and self inductance 9. In consequence of the coupling through coil 10, fluctuations of voltage take place in the grid circuit 15 with the same frequency, which, fluctuations in turn influence the strength of the electrode current passing through the high vacuum amplyfying tube and thus produce current fluctuations of the same frequency in the anode circuit. A permanent supply of energy to the oscillation circuits 9 and 10 consequently takes place, until a condition of balance is set up, in which the consumed oscillation energy is equal to that absorbed. Thereby constant undamped oscillations are now produced in the oscillation circuits 9–11.

For regular working of such oscillation producers high vacuum strengthening tubes are necessary and it is also necessary that the grid and anode voltages shall have a phase difference of 180° so that if the grid is negatively charged, then the anode is positively charged and vice versa. This necessary difference of phase may be obtained by most varied connections, for example, by placing the oscillation circuit in the grid circuit or by separating the oscillation circuit and inductive coupling from the anodes and the grid circuit and so forth.

A second important factor in this way of converting static atmospheric electricity into undamped oscillations is that care must be taken that the grid and anode voltages have a certain relation to one another; the latter may be obtained by altering the coupling and a suitable selection of the self induction in the grid circuit, or as shown by dotted lines 18, 17, 16 by means of a larger or smaller number of condensers of suitable size connected in series; in this case the battery B^1 may be omitted. With a suitable selection of the grid potential a glow discharge takes place between the grid *g* and the anode A, and accordingly at the grid there is a cathode drop and a dark space is formed. The size of this cathode drop is influenced by the ions which are emitted in the lower space in consequence of shock ionization of the incandescent cathodes K and pass through the grid in the upper space. On the other hand the number of the ions passing through the grid is dependent on the voltage between the grid and the cathode. Thus if the grid voltage undergos periodic fluctuations (as in the present case) the amount of the cathode drop at the grid fluctuates and consequently the internal resistance of the tube correspondingly fluctuates, so that when a back coupling of the feed circuit with the grid circuit takes place, the necessary means are afforded for producing undamped oscillations and of taking current, according to requirements from the collecting conductor.

The frequency of the undamped oscillations produced is with a suitably loose coupling equal to the self frequency of the oscillation circuits 9 and 10. By a suitable selection of the self induction of the coil 9 and capacity 11 it is possible to extend from frequencies which produce electromagnetic oscillations of only a few metres wave length down to the lowest practical alternating current frequency. For large installations a suitable number of frequency producing tubes in the form of the well known high vacuum transmission tubes of .5 to 2 kw. in size may be connected in parallel so that in this respect no difficulty exists.

The use of such tubes for producing undamped oscillations, and also the construction and method of inserting such transmission tubes in an accumulator or dynamo circuit is known and also that such oscillation producing tubes only work well at voltages of 1,000 up to 4,000 volts, so that on the contrary their use at lower voltages is considerably more difficult. By the use of high voltage static electricity this method of producing undamped oscillations as compared with that through spark gaps must be regarded as an ideal solution particularly for small installations of outputs of from 1 to 100 kw.

By the application of safety spark gaps, with interpolation of electro-magnets, not only is short circuiting avoided but also the taking up of current is regulated. Oscillation producers inserted in the above way form a constantly acting electromagnetic alternating field in the collector coil, whereby as already stated, a considerable accumulating effect takes place. The withdrawal wire or working wire is connected at 12 and 13, but current may be taken by means of a secondary coil which is firmly or movably mounted in any suitable way inside the large collector coil, i. e. in its electromagnetic alternating field, so long as the direction of its axis runs parallel with that of the main current collecting coil.

In producing undamped oscillations of a high frequency (50,000 per second and more) in the oscillation circuits 9 and 11, electromagnets S and S^1 must be inserted if the high frequency oscillations are not to penetrate the collector coil, between the oscillation producers and the collector coil. In all other cases they are connected shortly before the earthing (as in Figs. 27 and 28).

In Figure 27 a second method of construction of the connecting conductor of the balloon aerials is illustrated in the form of a coil. The main difference consists in that in addition to the connecting conductor I another annular conductor II is inserted parallel to the former on the high voltage masts in the air (or embedded as a cable in the earth) but both in the form of a coil. The connecting wire of the balloon aerials is indicated as a primary conductor and also as a current producing network; the other is the consumption network and is not in unipolar connection with the current producing network.

In Figure 27 the current producing network I is shown with three balloon collectors 1, 2, 3 and aerial conductors 4, 5, 6; it is short circuited through condenser 19 and inductance 9. The oscillation forming circuit consists in this diagram of spark gap *f*, inductance 10, and condenser 11; the earth wire E, is connected to earth over electromagnet S^1. F is the safety spark gap which is also connected to earth through a second electromagnet S at E. On connecting up the condenser circuit 11 this is charged over the spark gap *f* whereby an oscillatory discharge is formed. This discharging current acts through inductance 10 on the inductively coupled secondary 9, whereby in the producing network a modification of the potential of the condenser 19 is produced. The consequence of this is that oscillations arise in the coil shaped producer network. These oscillations induce a current in the secondary circuit II, which has a smaller number of windings and a less resistance, the voltage of which, according to the proportion of the number of windings and of the ohmic resistance, is considerably lower whilst the current strength is greater.

In order to convert the current thus obtained into current of an undamped character, and to tune its wave lengths, a sufficiently large regulatable capacity 20 is inserted between the ends 12 and 13 of the secondary conductor II. Here also current may be taken without an earth conductor, but it is advisable to insert a safety spark gap E^1 and to connect this with the earth over an electromagnet S^2.

The producer network may be connected with the working network II over an inductionless condenser 21 or over an induction condenser 22, 23. In this case the secondary conductor is unipolarly connected with the energy conductor.

In Figure 28 the connecting conductor between the separate accumulator balloons is carried out according to the autotransformer principle. The collecting coil connects four aerial balloons 1, 2, 3, 4, the windings of which are not made side by side but one above the other. In Figure 28 the collector coil I is shown with a thin line, the metallically connected prolongation coils II with a thick line. Between the ends I^1 and II^1 of the energy network I a regulating capacity 19 is inserted. The wire I^1 is connected with the output wire and with the spark gap F.

As transformer of the atmospheric electricity an arrangement is employed which consists in using rotary pairs of condensers in which the one stator surface B is connected with the main current, whilst the other A is connected with the earth pole. Between these pairs of short circuited condensers are caused to rotate from which the converted current can be taken by means of two collector rings and brushes, in the form of an alternating current, the frequency of which is dependent on the number of balloons and the revolutions of the rotor. As the alternating current formed in the rotor can act, in this improved method of connection described in this invention, through coils 10 on the inductance 9, an increase or diminution of the feed current in I can be obtained according to the direction of the current by back induction. Current oscillations of uniform rhythm thereby result in the coil shaped windings of the producer net-work.

As the ends of this conductor are short circuited through the regulatable condenser 19 these rhythms produce short circuited undamped oscillations in the energy conductor, the periodicity and wave lengths of which oscillations can be adjusted according to desire by altering the capacity 19 to a given wave length and therewith also to a given frequency. These currents may also be employed in this form directly as working current through the conductors II^1 and III. By inserting the condenser 20 a connection between these conductors may also be made, whereby harmonic oscillations of desired wave length are formed. By this means quite new effects as regards current distribution are obtained. The withdrawal of current can even take place without direct wire connection if, at a suitable point in the interior of the producing network (quite immaterially whether this has a diameter of 1 or 100 km.) a coil tuned to these wave lengths and of the desired capacity is firmly or movably mounted in the aerial conductor in such a way that its axial direction is in parallel with that of the collector coil. In this case a current is induced in the producing network, the size of which is dependent on the total capacity and resistance and also on the periodicity employed. A possibility is thereby afforded in future, of taking energy from the producer network by wireless means. As thereby in addition to atmospheric electricity also magnetic earth currents and the energy from the higher atmosphere (at least partially) may be simultaneously obtained, this last system for collecting the atmospheric energy is of particular importance for the future.

Of course everywhere instead of spark gaps suitable grid vacuum tubes may be employed as producers for undamped oscillations. The separate coils of the producer net-work with large diameters may be connected with one another through separate conductors all in parallel or all in series or in groups in series. By regulating the number of oscillations and also the extent of the voltage more or less large collector coils of this kind may be employed. The coils may also be divided spirally over the entire section. The coils may be carried out in annular form or also in triangular, quadrangular, hexagonal or octagonal form.

Of course wires may be carried from a suitable place to the centre or also laterally which serve the current waves as guides. This is necessary when the currents have to be conducted over mountains and valleys and so forth. In all these cases the current must be converted into a current of suitable periodicity.

As already hereinbefore mentioned separate collecting balloons may be directly metallically interconnected at equidistant stations distributed over the entire country or may be connected by interpolation of suitable condenser batteries by means of high voltage conductors. The static electricity is converted through a spark gap into dynamic energy of a high number of oscillations, and could then in such form, with a suitable arrangement of the connections, observing various measures of precaution, be employed as source of energy after separate or special regulation.

According to this invention in order to increase the collecting effect of the balloon in the aerial collector conductor or in the earth wire, radiating collectors are employed. These consist either of incandescent metal or oxide electrodes in the form of vacuum grid tubes, or electric arcs (mercury and the like electrodes) Nernst lamps, or finally flames of various kinds may be simply connected with the respective conductor.

It is well known that energy can be drawn off from a cathode consisting of an incandescent body opposite an anode charged with positive electricity (vacuum grid tube). Hitherto however, a cathode was always first directly placed opposite an anode, and secondly the system always consisted of a closed circuit.

Now if we dispense with the ordinary ideas in forming light or flame arcs in which a cathode must always stand directly opposite an anode, and if we place an incandescent cathode opposite an anode charged to a high potential or another body freely floating in the air, or regard the incandescent cathode only as a source of unipolar discharge (which represent group and point discharges in electro-static machines similar to unipolar discharges), it may be ascertained that incandescent cathodes and less perfectly all incandescent radiators, flames and the like admit of relatively large current densities and allow large quantities of electric energy to radiate into the open space in the form of electron streams as transmitters.

The object of this invention is as described below, if such incandescent oxide electrodes or other incandescent radiators or flames are not freely suspended in space but connected metallically with the earth so that they can be charged with negative terrestrial electricity, these radiators possess the property of absorbing the free positive electrical charges contained in the air space surrounding them (that is to say of collecting them and conducting them to earth). They can therefore, serve as collectors and have, in comparison to the action of the spikes, or points, a very large radius of action R; the effective capacity of these collectors is much greater than the geometrical capacity (R_0-) calculated in an electro-static sense.

Now as our earth is surrounded as is well known, with an electro-static field and the difference of potential

$$\frac{\delta V}{\delta h}$$

of the earth field according to the latest investigations, is in summer about 60 to 100 volts and in winter 300 to 500 volts per metre of difference in height (δh), a simple calculation gives the result that when such a radiation collector or flame collector is arranged for example on the ground, and a second one is mounted vertically over it at a distance of 2,000 metres and both are connected by a conducting cable, there is a difference of potential in summer of about 2,000,000 volts and in winter even of 6,000,000 volts and more.

According to Stefan Boltzmann's law of radiation, the quantity of energy which an incandescent surface (temperature T) of 1 sq. cm. radiates in a unit of time into the open air (temperature T_o) is expressed by the following formula:

$$S = \sigma\,(T^4 - T^4{}_o)\ \text{watt/sq. cm.}$$

and the universal radiation constant σ is according to the latest researches of Ferry (Annales de Chimie et de physique 17 page 267 (1909)) equal to 6.30×10^{-12} watt/sq. cm.

Now if an incandescent surface of 1 sq. cm. shows, as compared with the surrounding space a periodic fall of potential δV it radiates (independent of the current direction, that is to say of the sign) in accordance with the above formula, for example at a temperature of 3725° C. an energy of 1.6 kw. per sq. cm. per second. As for the radiation the same value can be calculated for the collection of energy, but reversed. Now as carbon electrodes at the temperature of the electric arc support on the current basis a current density up to from 60 to 65 amperes per sq. cm. no difficulties will result in this direction in employing radiating collectors as accumulators.

If the earth be regarded as a cosmically insulated condenser in the sense of geometrical electro-statics *x* there results from the geometric (compare Ewald Rasch, "das elektrische Bogenlicht" (The electric arc light) page 169) capacity of the earth according to Chwolson:

For negative charging 1.3×10^6 Coulomb

For negative potential $V = 10 \times 10^8$ volts. From this there results however, $EJT \cong 24.7 \times 10^{24}$ watt/Sec. Now if it is desired to make a theoretic short circuit through an earthed flame collector this would represent an electric total work of about 79,500 10^{10} kilowatt years. As the earth must be regarded as a rotating mechanism which is thermo-dynamically, electromagnetically, and also kinematically coupled with the sun and stars system by cosmic radiations and gravitation a diminution of the electric energy of the earth field is not to be feared. The energies which the incandescent collectors would withdraw from the earth field can only cause by the withdrawal of motor work a lowering of the earth temperature (temperature $T_E = 300$) and reduce this to that of the world space ($T = O$) by using the entire energy. This is however not the case as the earth does not represent a cosmically entirely insulated system. On the contrary there is conveyed to the same according to the recent value corrected by Ferry for the solar constants through the radiation from the sun an energy of $18{,}500 \times 10^{10}$ kw. Accordingly any lowering of the earth temperature (T_E) without a simultaneous lowering of the sun's temperature (T_S) would contradict Stefan Boltzmann's law of radiation.

$$S = \sigma\,(T_S{}^4 - T_E{}^4).$$

From this it must be concluded that if the earth temperature (T_E) sinks, the total radiation S absorbed by the earth increases, and further also that the secular speed of cooling of the earth is directly dependent on that of the sun and the other radiators cosmically coupled with the sun and is connected most closely with these.

The incandescent radiation collectors may, according to this invention, be employed for collecting atmospheric electricity if they (1) are charged with the negative earth electricity (that is to say when they are directly connected by means of a metallic conductor with the earth) and (2) if large capacities (metal surfaces) charged with electricity are mounted opposite them as positive poles in the air. This is regarded as the main feature of the present invention as without these inventive ideas it would not be possible to collect with an incandescent collector, sufficiently large quantities of the electrical charges contained in the atmosphere as technology requires; the radius of action of the flame collectors would also be too small, especially if it be considered that the very small surface density (energy density) (σ about $= 2 \times 7 \cdot 10^9$ St. E. per sq. cm.) does not allow of large quantities of charge being absorbed from the atmosphere.

x) Calculated according to Poisson's calculation;

$\Delta V = -4\pi\delta$; as here the alteration of the potential or potential gradients only takes place in the direction of the normal, this calculation assumes the simple form

$$\delta = \frac{1}{4\pi} \times \frac{\delta^2 V}{\delta n^2}$$

It has indeed already been proposed to employ flame collectors for collecting atmospheric electricity and it is known that their collecting effect is substantially greater opposite the points. It is however, not known that the quantities of current which could hitherto be obtained are too small for technical purposes. According to my experiments the reason for this is to be found in the too small capacities of the collector conductor poles. If such flame or radiating collectors have no or only small positive surfaces, their radius of action for large technical purposes is too small. If the incandescent collectors be constantly kept in movement in the air they may collect more according to the speed of the movement, but this is again not capable of being carried out in practice.

By this invention the collector effect is considerably increased by a body charged with a positive potential and of the best possible capacity being also held floating (without direct earth connection) opposite such an incandescent collector which is held floating in the air at a desired height. If for example, a collecting balloon of sheet metal or of metalized balloon fabric be caused to mount to 300 up to 3,000 metres in the air and as positive pole it is brought opposite such a radiating collector connected by a conductor to earth, quite different results are obtained.

The metallic balloon shell (with a large surface) is charged to a high potential by the atmospheric electricity. This potential is greater the higher the collecting balloon is above the incandescent collector. The positive electricity acts concentratedly on the anode floating in the air as it is attracted through the radiation shock ionization, proceeding from the incandescent cathode. The consequence of this is that the radius of action of the incandescent cathode collector is considerably increased and thereby also the collecting effect of the collecting balloon surface. Further the large capacity of the anode floating in the air plays therefore an important part because it allows of the taking of large charges, and thereby a more uniform current is obtained even when there is a large consumption; this cannot be the case with small surfaces.

In the present case the metallic collecting balloon is a positive anode floating in the air and the end of the earth conductor of this balloon serves as positive pole surface opposite the surface of the radiating incandescent cathode, which in turn is charged with negative earth electricity being conductingly connected to earth.

The process may be carried out by two such contacts (negative incandescent cathode and anode end of a capacity floating in the air) a condenser and an inductive resistance being switched on in parallel, whereby simultaneously undamped oscillations may be formed.

In very large installations it is advisable to connect two such radiating collectors in series. Thus an arc light incandescent cathode may be placed below on the open ground and an incandescent cathode which is heated by special electro-magnetic currents be located high in the air. Of course for this the special vacuum Liebig tubes with or without grids may also be employed. An ordinary arc lamp with oxide electrodes may be introduced on the ground and the positive pole is not directly connected with the collecting balloon, but through the upper incandescent cathode or over a condenser. The method of connecting the incandescent cathode floating in the air may be seen in Figs. 29–33.

B is the air balloon, K a Cardan ring (connection with the hawser) C the balloon, L a good conducting cable, P a positive pole, N negative incandescent cathode, and E earth conductor.

Fig. 29 represents the simplest form of construction. If electric oscillations are produced below on the ground by means of a carbon arc lamp or in other suitable way a considerably greater electric resistance is opposed to that in the direct way by inserting an electrical inductive resistance 9. Consequently between P and N a voltage is formed, and as, over N and P only an inductionless ohmic resistance is present, a spark will spring over so long as the separate induction co-efficients and the like are correctly calculated. The consequence of this is that the oxide electrode (carbon or the like) is rendered incandescent and then shows as incandescent cathode an increased collecting effect. The positive poles must be substantially larger than the negative in order that they may not also become incandescent. As they are further connected with the large balloon area which has a large capacity and is charged at high voltage, an incandescent body which is held floating in the air and a positive pole which can collect large capacities is thereby obtained in the simplest way. The incandescent cathode is first caused to become incandescent by means of separate energy produced on the earth, and then maintained by the energy collected from the atmosphere.

Fig. 30 only shows the difference that instead of a round balloon a cigar shaped one (of metal or metalized fabric) may be employed and also a condenser 5 is inserted between the incandescent cathode and the earth conductor so that a short circuited oscillation circuit over P. N 5 and 9 is obtained. This has the advantage that quite small quantities of electricity cause the cathode to become incandescent and much larger cathode bodies may be rendered incandescent.

In this form of construction both the incandescent cathode and also the positive electrode may be enclosed in a vacuum chamber as may be seen in Fig. 32. A cable L is carried well insulated through the cover of a vessel and ends in a condenser disc 5. The cover is arched in order to keep off the rain. The vessel is entirely or partially made of magnetic metal and well insulated inside and outside. Opposite the disc 5 another disc 6 and on this again a metallic positive pole of the vacuum tube *g* with the incandescent cathode (oxide electrode) N is arranged. The negative electrode is on the one hand connected with the earth conductor E, and on the other hand with the inductive resistance 9 which is also connected with the cable L with the positive pole and wound round the vessel in coils. The action is exactly the same as that in Fig. 29 only instead of an open incandescent cathode one enclosed in vacuo is employed. As in such collectors only small bodies can be brought to incandescence in large installations a plurality of such vacuum tubes must be inserted in proximity to one another. According to the previous constructions Figs. 31 and 33 are quite self evident without further explanations.

Figs. 34–37 represent further diagrams of connections over radiating and flame collectors, and in fact, how they are to be arranged on the ground.

Fig. 34 shows an arc light collector with oxide electrodes for direct current and its connection; Fig. 35 a similar one for alternating current, Fig. 36 an incandescent collector with a Nernst lamp and Fig. 37 a similar one with a gas flame.

The positive pole 1 of the radiating collectors is always directly connected to the aerial collecting conductor A. In Fig. 34 this is further connected over the condenser battery 5 with a second positive electrode 3. The direct current dynamo *b* produces current which flows over between the electrodes 3 and 2 as an arc light. On the formation of an arc the negative incandescent electrode 2 absorbs electricity from the positive poles standing opposite it and highly charged with atmospheric electricity and conveys the same to the working circuit. The spark gap 7, inductive resistance 9 and induction coil 10 are like the ones previously described. The protective electromagnet S guards the installation against earth circuiting, the safety spark gap 8 from excess voltage or overcharging.

In Fig. 35 the connection is so far altered that the alternating current dynamo feeds the exciting coil 11 of the induction condenser. 12 is its negative and 13 its positive pole; if the coil 3 on the magnet core of the dynamo is correctly calculated and the periodicity of the alternating current is sufficiently high an arc light can be formed between the two poles 1 and 2. As the cathode 2 is connected with the negatively charged earth, and therefore always acts as a negative pole, a form of rectification of the alternating current produced by the dynamo 3 is obtained, the second half of the period is always suppressed. The working circuit may be carried out in the same way as in Fig. 34; the working spark gap 7 may however be dispensed with, and instead thereof between the points *n* and *m* a condenser 5 and an induction resistance 9 may be inserted from which the current is taken inductively.

Fig. 36 represents a form of construction similar to Fig. 34 only that here instead of an arc lamp a Nernst incandescent body is employed. The Nernst lamp is fed through the battery 3. The working section is connected with the negative pole, the safety spark gap with the + poles. The working spark gap 7 may also be dispensed with and the current for it taken at 12 over the oscillation circuit 5, 11 (shown in dotted lines).

Flame collectors (Fig. 37) may also be employed according to this invention. The wire network 1 is connected with the aerial collector conductor A and the burner with the earth. At the upper end of the latter, long points are provided which project into the flame. The positive electrode is connected with the negative over a condenser 5 and the induction coil 9 with the earth.

The novelty in this invention is firstly, the use of incandescent cathodes opposite positive poles which are connected with large metallic capacities as automatic collecting surfaces, (2) the connection of the incandescent cathodes with the earth whereby, in addition to the electricity conveyed to them from the battery or machine which causes the incandescing, also the negative charge of the earth potential is conveyed, and (3) the connection of the positive and negative poles of the radiating collectors over a condenser circuit alone or with the introduction of a suitable inductive resistance, whereby simultaneously an oscillatory oscillation circuit may be obtained. The collecting effect is by these methods quite considerably increased.

I declare that what I claim is:—

1. An electrical energy generating system, comprising a conducting surface for static charges, means to support same at a distance above the earth, a conductor leading to the earth level, a spark gap associated with said conductor to convert electrostatic charges into electromagnetic high frequency oscillations means to supply said electromagnetic energy to a net work, and a spark gap of greatly increased relative resistance in parallel therewith.

2. An electrical energy generating system

comprising a conductor, means to support same above the earth level, an inductance therein, a spark gap associated with said conductor, a second spark gap of much higher relative resistance in parallel therewith and an energy receiving circuit coupled with the spark gap of lesser resistance.

3. An electrical energy generating system comprising a collecting surface, means to support same above the earth level, a conductor connecting said collecting surface with the earth level, a choke in said conductor, an electromagnetic resistance converting electrostatic energy to electromagnetic energy, a safety higher resistance in parallel therewith and a net work coupled with the conversion resistance of lesser value.

4. An electrical energy generating system comprising electric conductors spaced above the earth to form electromagnetic oscillating circuits, conductors connecting to earth level, electrostatic to electromagnetic energy conversion means therein, a safety high electrostatic resistance in parallel therewith and means to alter the electromagnetic characteristic of the circuits.

5. An electrical energy generating system comprising in combination a static collecting surface arranged above the earth, conductors connecting to earth level, a pair of spark gaps in parallel of different electrostatic resistance, a utilization net work shunted across the spark gap of lesser resistance and an electromagnetic choke in said conductors.

6. An electrical energy generating system comprising an open circuit energy collecting aerial, a pair of sparking gaps in parallel of widely different resistance, connected thereto and a closed electric oscillation circuit in shunt across the gap of lesser resistance.

7. An electrical energy generating system comprising an open circuit energy collecting aerial, a pair of sparking gaps in parallel of widely different resistance connected thereto, a closed electric oscillation circuit in shunt across the gap of lesser resistance, a plurality of electrostatic collecting surfaces, means to connect said collecting surfaces in parallel in groups and means to connect said groups symmetrically with said aerial.

In witness whereof, I have hereunto signed my name this 30 day of Dec., 1920, in the presence of two subscribing witnesses.

HERMANN PLAUSON.

Witnesses:
H. F. ARMSTRONG,
W. H. BEESTON.

US008102082B2

(12) **United States Patent**
Ogram

(10) **Patent No.: US 8,102,082 B2**
(45) **Date of Patent: *Jan. 24, 2012**

(54) **ATMOSPHERIC STATIC ELECTRICITY COLLECTOR**

(75) Inventor: **Mark Ellery Ogram**, Tucson, AZ (US)

(73) Assignee: **Sefe, Inc.**, Scottsdale, AZ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 295 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **12/321,306**

(22) Filed: **Jan. 16, 2009**

(65) **Prior Publication Data**

US 2010/0008011 A1 Jan. 14, 2010

Related U.S. Application Data

(63) Continuation-in-part of application No. 12/218,297, filed on Jul. 14, 2008, now Pat. No. 7,855,476.

(51) **Int. Cl.**
H02G 11/00 (2006.01)

(52) **U.S. Cl.** **307/145**; 307/149; 307/151; 361/218; 361/230

(58) **Field of Classification Search** 361/212, 361/215, 216–218, 230, 231; 307/145, 149, 307/151; 174/2; 244/30, 31
See application file for complete search history.

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Primary Examiner — Fritz M Fleming
(74) *Attorney, Agent, or Firm* — Mintz Levin Cohn Ferris Glovsky and Popeo, P.C.

(57) **ABSTRACT**

An antenna for the collection of atmospheric static electricity in which an electrically conductive hub is suspended from a balloon or blimp via a tether. The hub is either solid or uses a spoke/arm arrangement. A number of rods extend from the hub enhance the collection of atmospheric static electricity. The collected atmospheric electricity is conducted from the rods to an electrical connection where the electricity is conducted to earth via a conductive line.

16 Claims, 7 Drawing Sheets

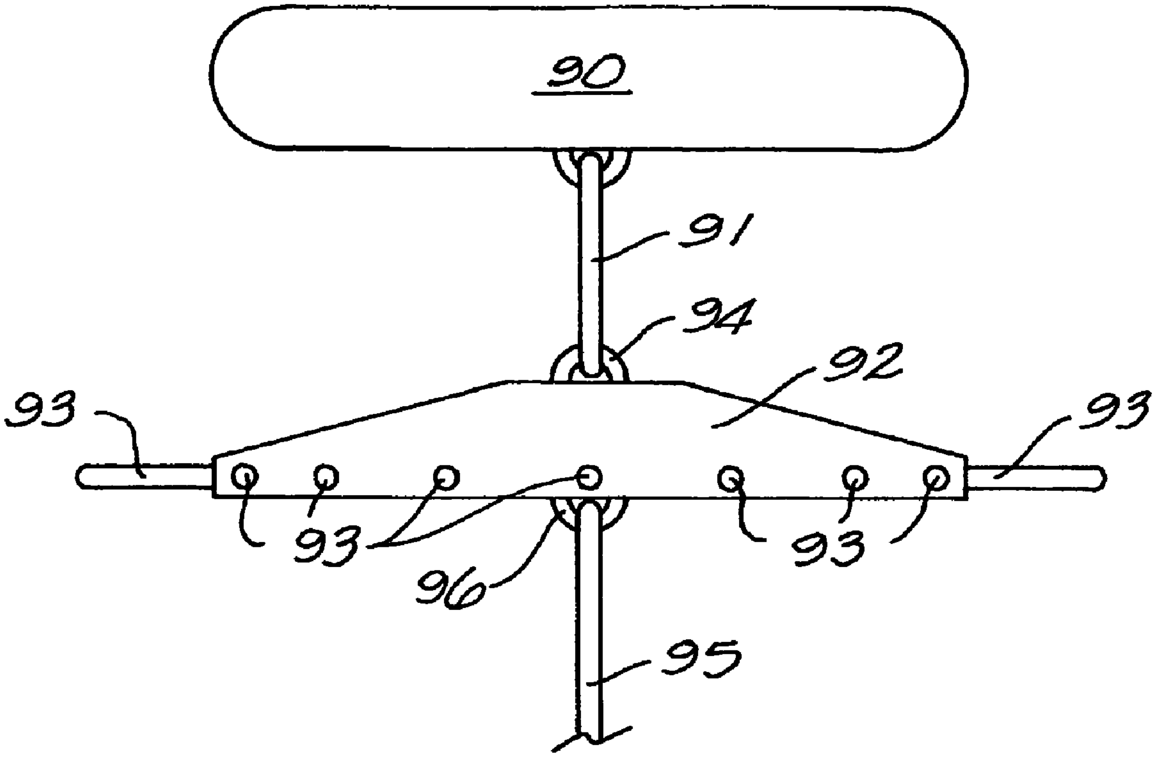

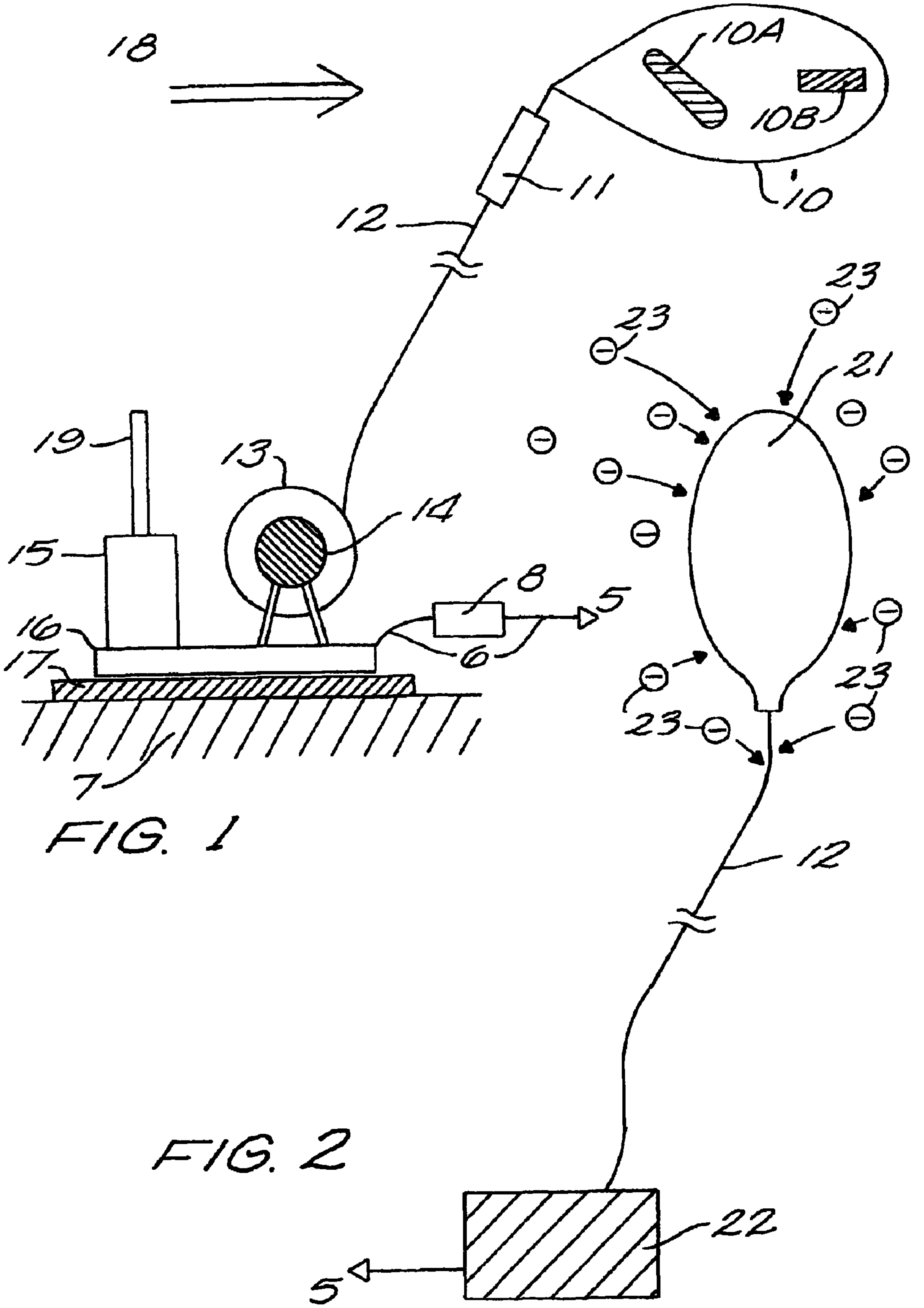
18
10A
10B
10
11
12
19
13
14
15
8
5
16
6
17
7
23
23
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23
23
12
22
5

FIG. 1

FIG. 2

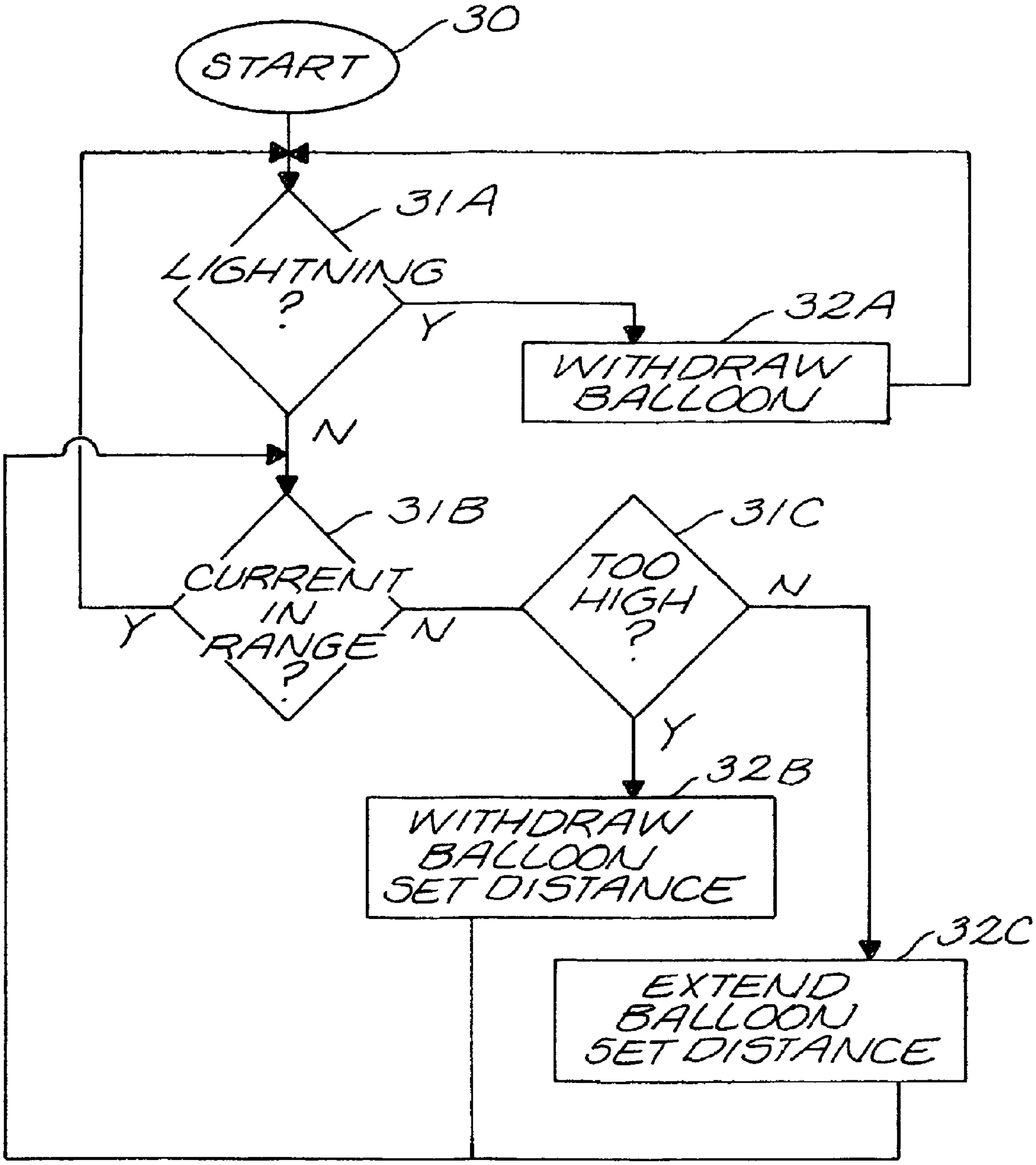
30
START
31A
LIGHTNING ?
Y
32A
WITHDRAW BALLOON
N
31B
CURRENT IN RANGE ?
Y
N
31C
TOO HIGH ?
N
Y
32B
WITHDRAW BALLOON SET DISTANCE
32C
EXTEND BALLOON SET DISTANCE

FIG. 3

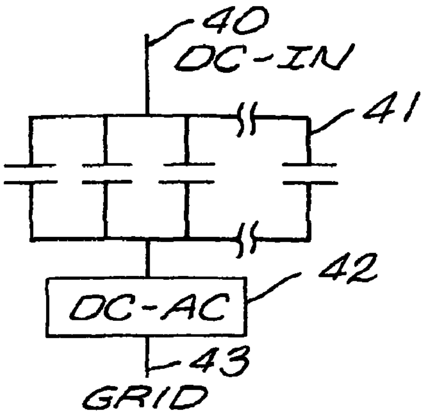
40
DC-IN
41
42
DC-AC
43
GRID

FIG. 4A

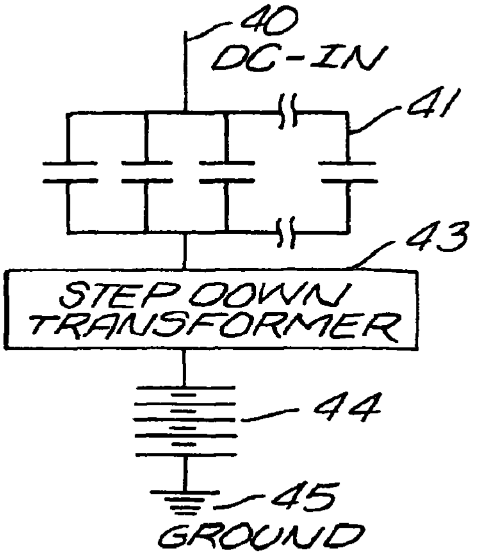
40
DC-IN
41
43
STEP DOWN TRANSFORMER
44
45
GROUND

FIG. 4B

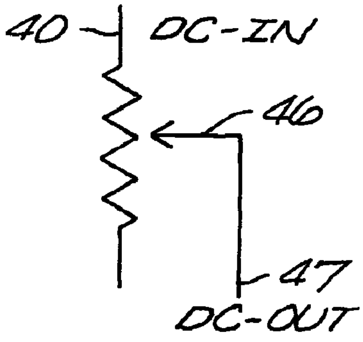
40
DC-IN
46
47
DC-OUT

FIG. 4C

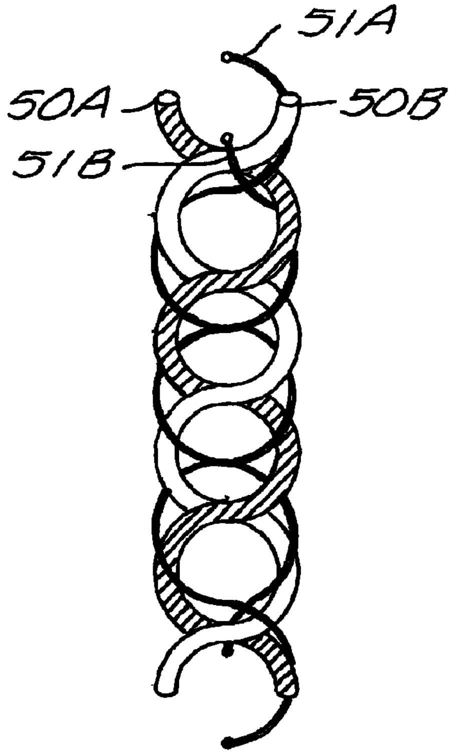
51A
50A
50B
51B

FIG. 5

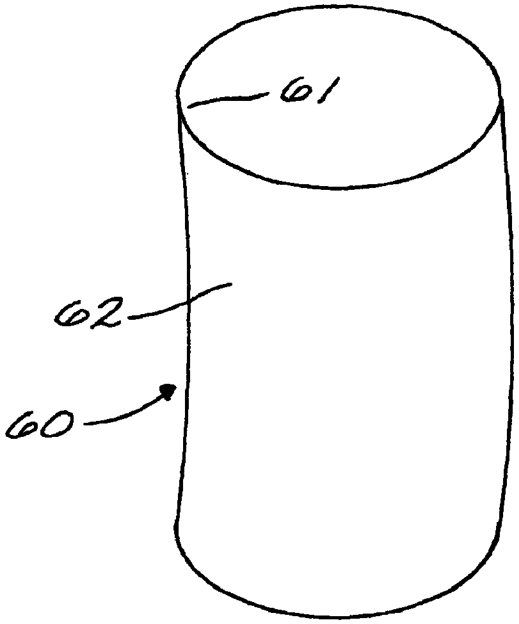

FIG. 6A

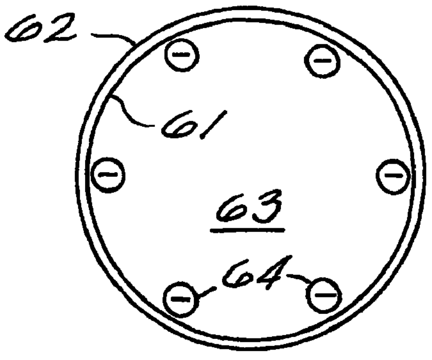

FIG. 6B

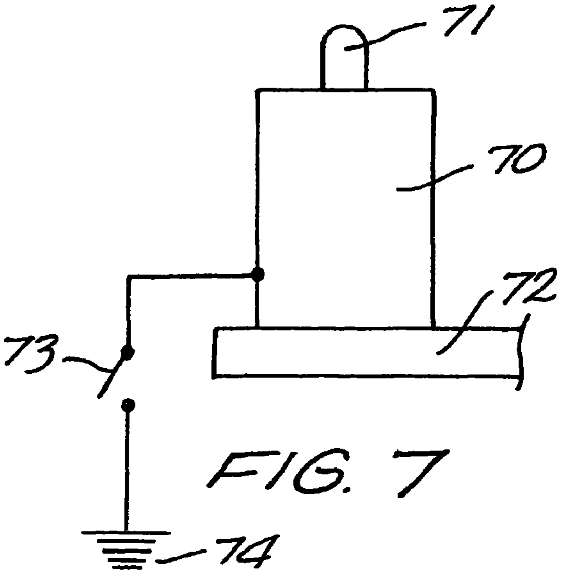
71
70
72
73
74

FIG. 7

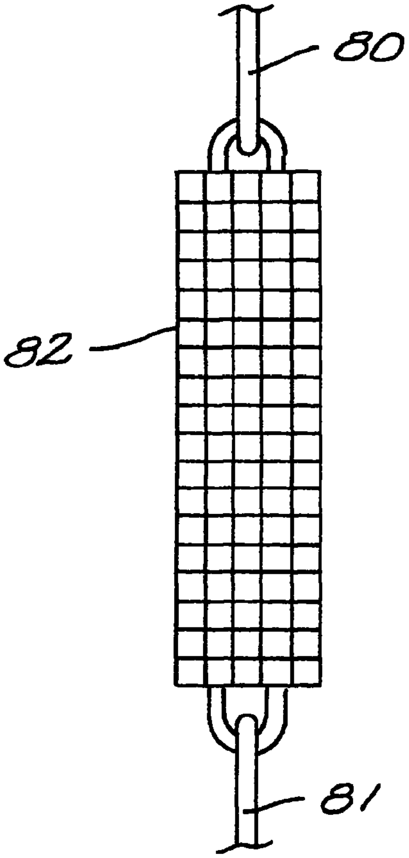

FIG. 8A

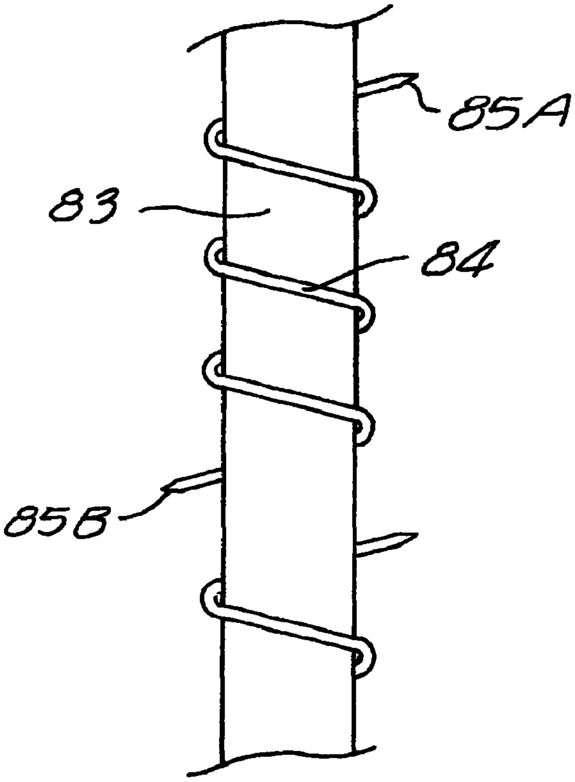
85A
83
84
85B

FIG. 8B

FIG. 9A

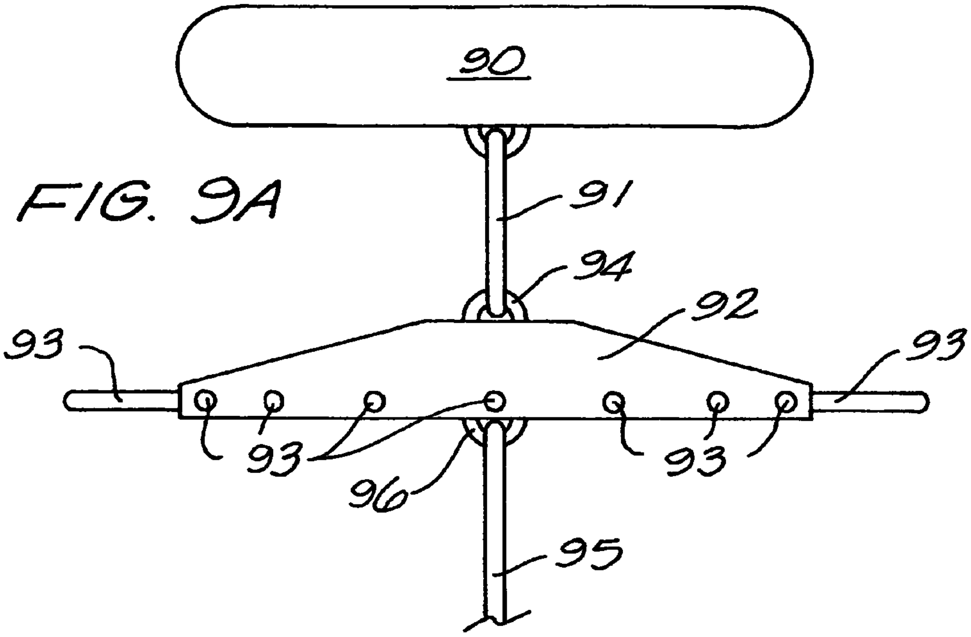
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94
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93
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93
93
93
96
95

FIG. 9B

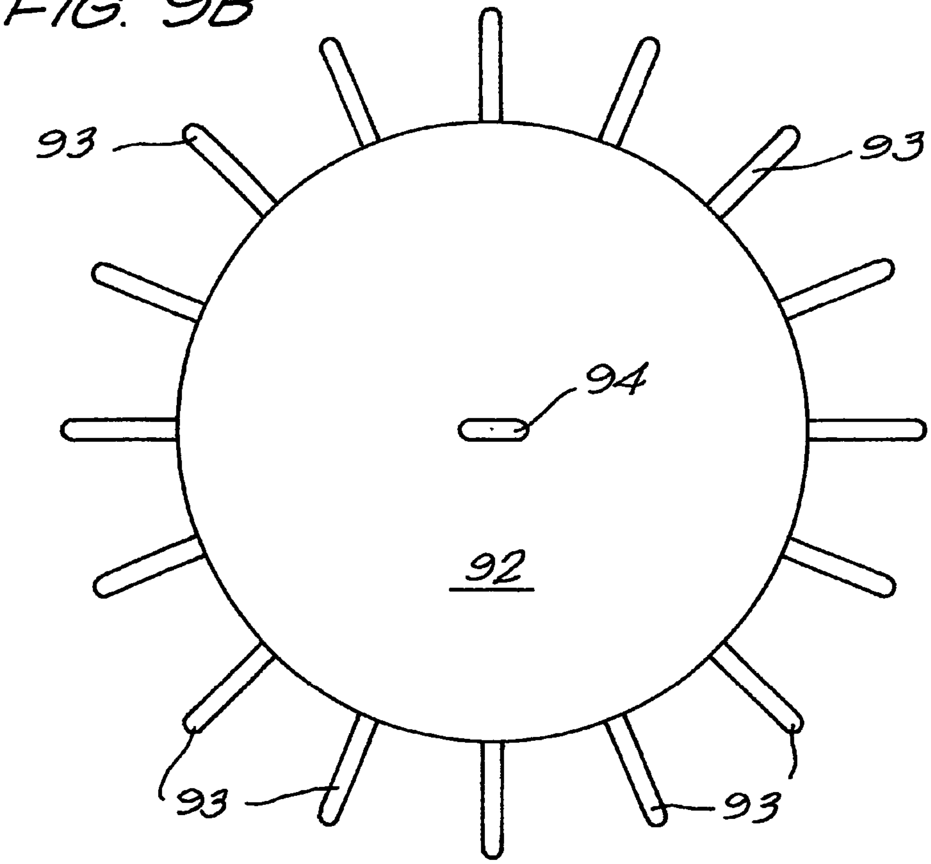
93
93
94
92
93
93

FIG. 10

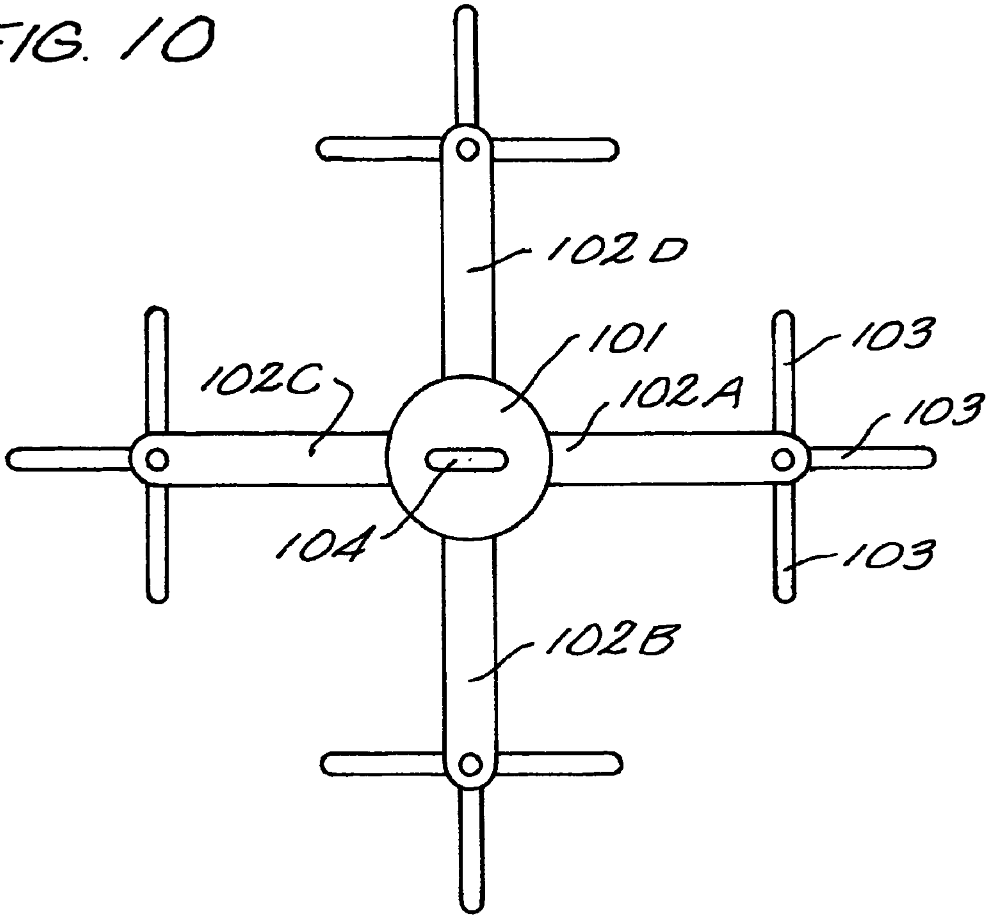
102D
101
102C
102A
103
103
103
104
102B

FIG. 11

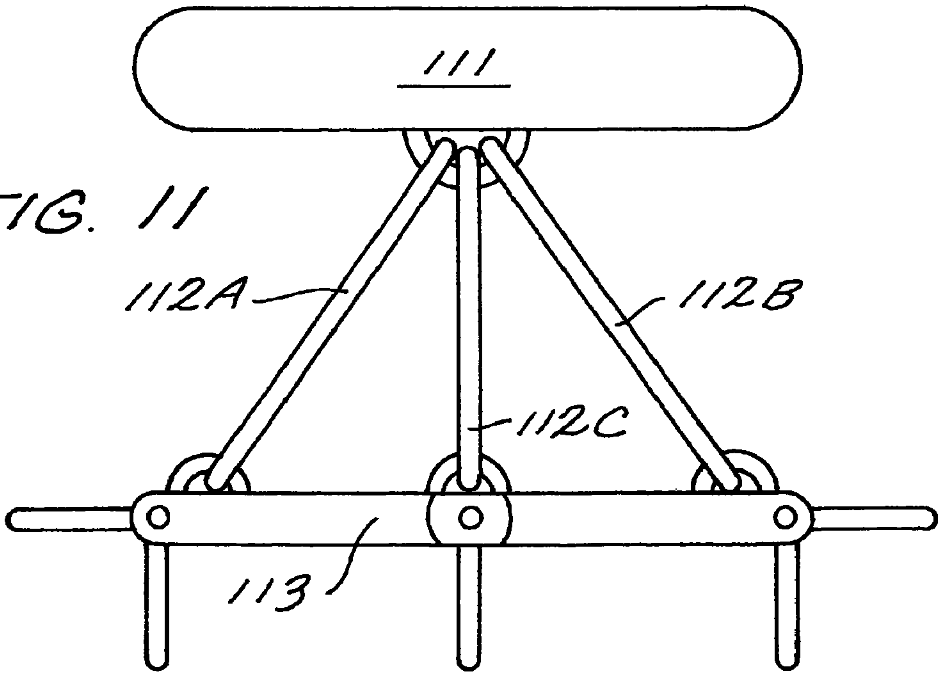
111
112A
112B
112C
113

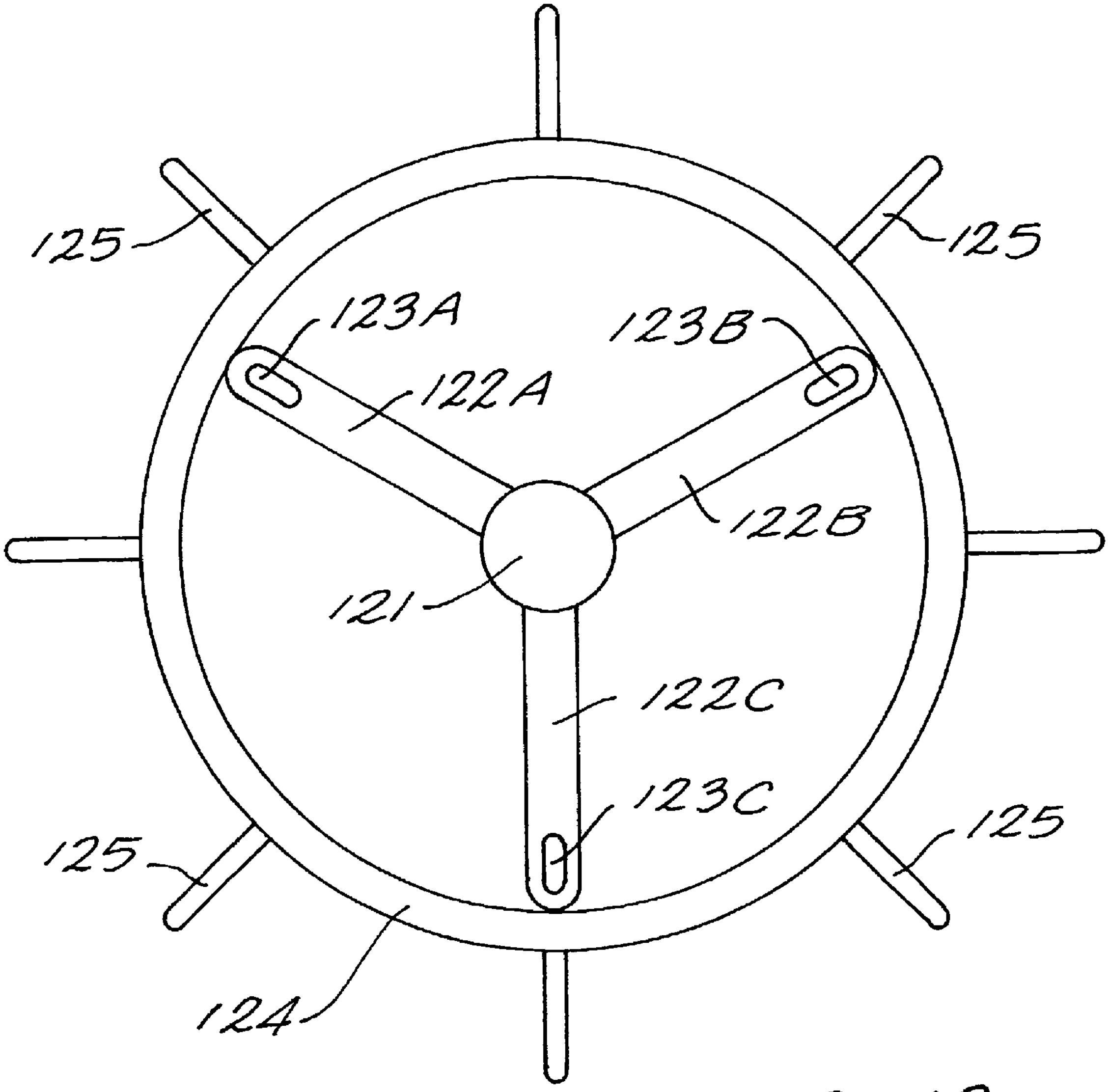
125
125
123A
123B
122A
122B
121
122C
123C
125
125
124

FIG. 12

ATMOSPHERIC STATIC ELECTRICITY COLLECTOR

This is a continuation in part of U.S. patent application Ser. No. 12/218,297, filed on Jul. 14, 2008, now U.S. Pat. No. 7,855,476 and entitled, "Atmospheric Electrical Generator".

BACKGROUND OF THE INVENTION

This invention relates to the production of electrical energy and more particularly to the collection of static electricity from the atmosphere.

Everyone is familiar with Benjamin Franklin's kite experiment of 1752. Using a kite whose string had become wet, negative charges from the passing clouds flowed into the string, down to the suspended key, and then into a Leyden jar via a thin metal wire. Franklin was protected by a dry silk string; but, when Franklin's knuckle came too close to the key, he received a strong shock. Fortunately, Benjamin Franklin was not killed, others who tried this same experiment were not so lucky.

Since then, the formation of lightning has remained something of a mystery. Lightning bolts are triggered when a negatively charged cloud base induces a positive charge from the ground, thereby forming a "pathway" for the discharge of the collected electrical energy.

Lightning travels up to 60,000 miles per hour with a flash that is brighter than ten million 100-watt lightbulbs. This wattage is as much power as is produced by all of the electricity plants in the United States and with a voltage of up to 300 million volts.

It is this very fact, the power within lightning is immense, that has prevented any successful collection of the electrical energy from lightning. The electricity in lightning is far too extreme for current technology to harness.

While lightning has attracted a energy starved industrial world, no one has developed any technique to harness this naturally occurring electrical source.

It is clear there is a continuing need for an electrical source other than carbon-based fuels and that the naturally occurring electricity in the atmosphere is being ignored.

SUMMARY OF THE INVENTION

The invention is a mechanism which taps into the naturally occurring static electricity in the atmosphere. Whereas heretofore, the attempt to garner electricity from the atmosphere has focused exclusively on capturing lightning, the present invention syphons off the static electricity which is generated from any agitated air and voids lightning.

Lightning is only the final discharge of the static electricity, whether that lightning is intra-cloud lightning, cloud-to-ground lightning, or inter-cloud lightning. Other types of final discharges are known as heat lightning, summer lightning, sheet lightning, ribbon lightning, silent lightning, ball lightning, bead lightning, elves, jets, and sprites. Well before these discharges are observed, as the atmosphere becomes agitated by wind or thermal, static electricity is being generated.

The present invention recognizes that this static electricity is being formed and creates a mechanism to capture it.

The mechanism of this invention utilizes an aircraft such as a lighter than air balloon. While the preferred embodiment uses a foil balloon, a variety of other aircraft are obvious to those of ordinary skill in the art, including, but not limited to: gliders, rubber balloons (such as weather balloons), biaxially-oriented polyethylene terephthalate polyester film balloons, and latex balloons.

Within this discussion, the balloon is referenced, but, the invention is not intended to be limited solely to balloons.

The balloon is sent aloft and is tethered by a conductive line. In this context, the conductive line may be any obvious to those of ordinary skill in the art. For the preferred embodiment, the conductive line is a generically referred to as a "poly-rope" and is commercially available through a variety of sources. A suitable conductive line is described in U.S. Pat. No. 5,203,542, entitled "Apparatus for Improved Electric Fence Wire Construction for use with Intensive Grazing" issued Apr. 20, 1993, to Coley, et al. and incorporated hereinto by reference.

The conductive line is played out of a winch to control the altitude of the balloon. The motor controlling the winch is able to reverse direction to both extend and withdraw the conductive line which is wrapped around a spool on the winch. The winch/spool combination are part of a base unit.

In some embodiments of the invention, the spool is constructed of rubber so as to insulate the conductive line from the winch assembly. In this embodiment, only the conductive line is charged by the atmospheric static electricity while the winch remains neutral.

In yet another embodiment, the winch/spool are part of a base unit which is itself isolated from the ground by an insulator. In this embodiment, the entire base unit is charged by the atmospheric static electricity.

A conductor, such as an insulated wire, is electrically connected to the conductive line. In one embodiment, where the conductive line is electrically isolated from the spool and winch motor, the conductor is connected to the conductive line. In the embodiment where the conductive line is electrically connected to the base unit, then the conductor is connected anywhere on a metalic base unit.

The other end of the conductor is connected to a load. The load in this case can be any of a variety of electrical loads well known to those of ordinary skill in art, including, but not limited to a motor, a battery system, or the electrical grid for the system.

In the preferred embodiment, a sensor array is used to monitor the activities both at the base unit (such as electrical flow within the conductor) and in the surrounding locale.

A sensor monitoring the electrical flow (i.e. voltage and/or current) within the conductor is used to monitor the electrical activity within the conductor.

In the preferred embodiment, a lightning sensor monitors for lightning activity within the locale. As noted earlier, the electrical characteristic of lightning is so extreme that ideally this discharge is avoided as it might damage the mechanism of this invention.

The sensor array is utilized by a controller, such as microprocessor, programmed to operate the mechanism as outlined herein.

The controller operates the winch motor to extend or withdraw the conductive line and by extension the altitude of the balloon. The controller is programmed to operate the winch by monitoring the electrical characteristics of the conductor and adjusting the balloon's altitude to maintain these characteristics within the conductor within a preset range.

This preset range is established either in the base programming of the controller or is established by an operator of the system.

As example, by controlling the amount of current being withdrawn from the atmosphere, the mechanism operates within a safe range and also provides a relatively stable current flow from which a variety of activities can take place (such as DC-AC conversion).

The controller also utilizes the lightning sensor to protect the mechanism from a lightning strike. Should lightning be detected within a pre-determined range (as established by the software or defined by an operator), then the balloon is pulled down to minimize the risk of damage from a lightning strike.

An aspect of the present invention is the use of an antenna which are used to collect the atmospheric static electricity. The antenna is shaped as a hub which is suspended from the blimp/balloon. The hub is ideally spoked shaped although an alternative embodiment uses a solid hub.

A number of rods extend from the hub so as collect atmospheric static electricity These rods are ideally rounded at the ends to enhance the attraction of the atmospheric static electricity.

The collected atmospheric electricity is conducted from the rods to an electrical connection on the hub where the electricity is conducted to a power plant on earth such as described above.

The invention, together with various embodiments thereof will be more fully explained by the following description of the accompanying drawings.

DRAWINGS IN BRIEF

FIG. **1** diagrams the preferred embodiment of the invention.

FIG. **2** illustrates the collection of the negative charged particles in the atmosphere.

FIG. **3** is a flow-chart of the operation of the controller for the preferred embodiment of the invention.

FIGS. **4**A, **4**B, and **4**C are electrical schematics for handling the static charge from the atmosphere.

FIG. **5** illustrates a conductive line used in the preferred embodiment of the invention.

FIGS. **6**A and **6**B illustrate an alternative conductive line creating an ionized pathway for the flow of the static charges from the atmosphere.

FIG. **7** illustrates the controller of an alternative embodiment and the associated safety devices.

FIGS. **8**A and **8**B illustrate two embodiments of enhanced electrical collection leads.

FIGS. **9**A and **9**B are side views and top views of an embodiment of the antenna used to collected atmospheric electricity.

FIG. **10** is a top view of an alternative embodiment of the antenna of this invention.

FIG. **11** is a side view of yet another alternative embodiment of the antenna used to collect atmospheric electricity.

FIG. **12** is the preferred embodiment of the antenna of this invention.

DRAWINGS IN DETAIL

FIG. **1** diagrams the preferred embodiment of the invention.

Balloon **10** is an aircraft which, in this illustration, is a lighter than air balloon. Wings **10**A, extending from the body of balloon **10**, provide additional lift in air flow **18**. Tail **10**B helps to stabilize balloon **10**.

Balloon **10** is tethered to the ground via conductive line **12**. As noted earlier, a variety of configurations and materials are available to serve as conductive line **12**. In this illustration, a poly-wire is used. Poly-wire is commercially available through a variety of vendors, including, but not limited to: Jeffers Livestock and Sareba Systems, Inc. of Ellendale, Minn.

In this embodiment, located proximate to balloon **10**, is an electrical collection enhancement lead **11** which assists in the collection of the static electrical charge in the atmosphere. Electrical collection enhancement lead **11** is configured to attract the static charge and conduct the charge into the conductive line **12**.

The electricity flows down the conductive line into spool **13**, where the conductive line **12** is collected and either withdrawn or dispensed through operation of winch motor **14**.

Winch motor **14** and spool **13** are mounted onto base unit **16** which is electrically isolated from ground **7** using insulator **17**. Note, in this embodiment of the invention, when electricity is being collected from the atmosphere, the entire base unit **16** becomes charged. In another embodiment of the invention, spool **13** is constructed of rubber, thereby preventing base unit **16** from becoming charged, thereby restricting the charging from the atmosphere to only conductive line **12**.

In this embodiment, conductor **6** is connected to base unit **16** (since the entire base unit **16** is charged and the base unit is metalic) to communicate the electrical current to load **5**. Conductor **6** is ideally an insulated wire.

The electrical current through conductor **6** is measured using sensor **8**.

In the alternative embodiment discussed above, where only the conductive line **12** is charged, then conductor **6** is connected to conductive line **12**.

Controller **15**, located in this embodiment on base unit **16**, operates winch motor **14** in response to signals from sensor **8** (measuring the current being discharged to load **5**) to maintain the current flow within a pre-defined range. As the current flow diminishes, then the conductive line **12** extended from spool **13** to increase the altitude of balloon **10** to that more static charge from the atmosphere is gathered; as the current flow falls exceeds a preset level, conductive line **12** is withdrawn onto spool **13** to decrease the static charge being collected from the atmosphere.

The range of current flow through conductor **6** is ideally set by the program, although some embodiments of the invention permit an operator to establish this range of operation.

In an alternative embodiment, the sensor monitoring conductor **6** monitors the voltage therein.

In the preferred embodiment of the invention, controller **15** is also equipped with a lightning sensor **19**. In this embodiment, when lightning is sensed within a preset range, then substantially all of conductive line **12** is wound onto spool **13** to pull balloon **10** near the ground and protect the entire mechanism from being damaged from a lightning discharge.

In the preferred embodiment, the “safe” distance form lightning is set in the programming of controller **15** and is ideally two miles; other embodiments permit the operator to “safe” distance.

There are a variety of lightning sensors well known to those of ordinary skill in the art, including, but not limited to those described in: U.S. Pat. No. 7,016,785, entitled “Lightning Detection” issued to Makela, et al. on Mac. 21, 2006; U.S. Pat. No. 6,829,911, entitled “Lightning Detection and Prediction Alarm Device” issued to Jones, et al. on Dec. 7, 2004; U.S. Pat. No. 7,200,418, entitled “Detection of Lightning” issued to Karikuranta, et al. on Apr. 3, 2007; and U.S. Pat. No. 6,961,662, entitled “Systems and Methods for Spectral Corrected Lightning Detection” issued to Murphy on Nov. 1, 2005; all of which are incorporated hereinto by reference.

In another embodiment of the invention, controller **15** is not located on base unit **16**, rather it is remote and communicates its control signals to winch motor **14** using radio waves.

FIG. **2** illustrates the collection of the negative charged particles in the atmosphere.

Static charges **23** are generated in the atmosphere by agitated air. These static charges are often collected at the bottom of clouds, but exist in other environments as well.

Balloon **21** is extended into this strata of static charges **23** which are then attracted to conductive line **12** to flow to base unit **22** and then onto load **5**.

By increasing or decreasing the altitude of balloon **21** (defined by the length of the extended conductive line **12**), conductive line **12** is selectively exposed to varying densities and levels of the static charge strata, and by extension, the current flow or voltage is increased or decreased.

FIG. **3** is a flowchart of the operation of the controller for the preferred embodiment of the invention.

Once the program starts **30**, the lightning sensor is checked to determine if lightning has occurred within the unsafe range **31**A, if it has, then the balloon is lowered **32**A, and the program continues monitoring the status of lightning until no lightning is detected.

When the lightning status is acceptable, then the current within the conductor is checked to see if the current is within the prescribed range **31**B. If the current is acceptable (within range) the program returns to check the lightning status **31**A; otherwise a determination is made to see if the current is above the prescribed range **31**C.

If the current is above the prescribed range, then the altitude of the balloon is withdrawn a set amount **32**B (ideally twenty-five feet) and the program loops back to see if the current is within range **31**B.

If the current is below the prescribed range, then the altitude of the balloon is extended a set amount **32**C (ideally twenty-five feet) and the program loops back to see if the current is within range **31**B.

In this manner of feed-back and minor adjustments in the altitude of the balloon, the current is maintained within a prescribed range which can be handled by the downstream electrical system.

As noted earlier, some embodiments of the invention monitor the voltage instead of the current.

FIGS. **4**A, **4**B, and **4**C are electrical schematics for handling the static charge from the atmosphere.

By maintaining the voltage being collected in a prescribed range, an electrical conversion system is easily designed. While FIGS. **4**A, **4**B, and **4**C illustrate some electrical configurations, those of ordinary skill in the art readily recognize a variety of other configurations which will serve the same function.

Referencing FIG. **4**A, Direct Current In (DC IN) **40** is buffered by a gang of capacitors **41** before being communicated to a DC/AC converter **42**. The DC/AC converter converts the direct current into a an alternating current suitable for placement over an existing electrical grid **43** such as normally found from a power-plant.

Those of ordinary skill in the art readily recognize a variety of DC/AC converters, including, but not limited to: U.S. Pat. No. 7,394,671, entitled "Controller IC, DC-AC Conversion Apparatus, and parallel running system of DC-AC Conversion Apparatuses" issued to Fukumoto, et al. on Jul. 1, 2008; and, U.S. Pat. No. 7,330,366, entitled "DC-AC Converter" issued to Lee, et al. on Feb. 12, 2008; all of which are incorporated hereinto by reference.

FIG. **4**B illustrates an electrical arrangement suitable for use in charging a battery. DC IN **40** is buffered by capacitor bank **41** before entering into a step down transformer **43**. Step down transformer **43** reduces the voltage so that the voltage can safely be introduced into battery **44** which is connected to ground **45** at the battery's other pole.

Those of ordinary skill in the art readily recognize a variety of batteries which will work in this capacity, including, but not limited to those described in: U.S. Pat. No. 7,378,181, entitled "Electric Storage Battery Construction and Manufacture" issued to Skinlo on May 27, 2008; U.S. Pat. No. 7,388,350, entitled "Battery with Electronic Compartment" issued to Wright on Jun. 17, 2008; U.S. Pat. No. 7,397,220, entitled "Connection Member and Battery Pack" issued to Uchida, et al. on Jul. 8, 2008; and, U.S. Pat. No. 7,375,492, entitled "Inductively Charged Battery Pack" issued to Calhoon, et al. on May 20, 2008; all of which are incorporated hereinto by reference.

In FIG. **4**C, DC IN **40** is fed into an adjustable rheostat **46** which is controlled by the controller so that the DC OUT **47** falls within a specified range.

FIG. **5** illustrates a conductive line used in the preferred embodiment of the invention.

This type of conductive line is commonly called poly-wire and consists of multiple interwoven strands of plastic **50**A and **50**B woven into a cord or rope arrangement having intertwined therein exposed metal wires **51**A and **51**B. While this illustration shows two plastic strands and two metal wires, any number of possible combinations is possible.

The exposed metal wires **51**A and **51**B attract the atmospheric static charge and transmit the charge down to the base unit (not shown).

FIGS. **6**A and **6**B illustrate an alternative conductive line creating an ionized pathway for the flow of the static charges from the atmosphere.

This conductive line utilizes a tube **60** having an outer layer **62** of PET Film (Biaxially-oriented polyethylene terephtalate polyester film) which provides exceptionally high tensile strength and is chemically and dimensionally stable. The tube has an ideal diameter of between two and three inches.

An interior metal coating **61** provides an initial conduit for the flow of static charge. The static charge through the metal forces the tube to expand due to the repulsion experienced by like charges. Further, the flow of electricity causes the interior of the tube **60** to become ionized to provide an additional pathway for the atmospheric static charges to the base unit (not shown).

Because outer layer **62** provides a gas barrier, the resulting ionization is not dissipated by air currents, thereby providing a highly stable pathway.

FIG. **7** illustrates the controller of an alternative embodiment and the associated safety devices.

In this embodiment, controller box **70**, resting on insulating pad **72**, is in communication with the sensors as described above. Using the input from these sensors, when there is flow of electricity through the base unit, warning flashing light **71** is illuminated. To electrically neutralize the mechanism, switch **73** is activated to pass any existing current into the ground **74**.

FIGS. **8**A and **8**B illustrate two embodiments of enhanced electrical collection leads.

Referencing FIG. **8**A, enhanced electrical collection lead **82** is a wire mesh which is in electrical communication with conductive line **81** and balloon **80**. Because of the significant amount of metal exposed by enhanced electrical collection lead **82**, more static electricity from the atmosphere is drawn to the collection lead **82**, and then down conductive line **81** to the base unit (not shown).

Conductive lead **82** is positioned proximate to balloon **80**.

In FIG. **8**B, poly-wire **83** has enhanced electrical collection leads **84** wrapped therearound. Collection leads **84** have pointed ends **85**A and **85**B which have a propensity to attract more electricity than rounded ends do.

FIGS. **9**A and **9**B are side views and top views of an embodiment of the antenna used to collected atmospheric electricity.

Blimp **90** supports antenna **92** via tether **91** which is attached to antenna **92** by connection **94**. In this embodiment, antenna **92** is made of electrically conductive material and is ideally light in weight to lessen the payload requirements on blimp **90**.

Encircling antenna **92** and extending therefrom are rods **93** which are rounded at their distal ends so as to enhance attraction of the atmospheric static electricity. The static electricity is communicated to connection **96** and then to electrical line **95** which communicates the electricity to the ground based station (not shown) as described above.

FIG. **10** is a top view of an alternative embodiment of the antenna of this invention.

In this embodiment of the antenna a central hub **101** has the blimp connection **104** (capable of receiving the tether to the blimp) secured thereto. In this illustration, four arms **102**A, **102**B, **102**C, and **102**D extend from hub **101**. Hub **101**, and arms **102**A, **102**B, **102**C, and **102**D are all electrically conductive in this embodiment.

At the end of each arm are rods **103** which are used to enhance the collection of the atmospheric static electricity.

Although this embodiment illustrates four arms, the invention is not intended to be limited to four arms, rather, any number of arms may be used and the number of rods extending from the distal ends of the arms also varies.

FIG. **11** is a side view of yet another alternative embodiment of the antenna used to collect atmospheric electricity.

In this embodiment, several tethers **112**A, **112**B, and **112**C, are used to secure the antenna **113** to the blimp **111**. This arrangement of several tethers provides heightened stability of the antenna by reducing the affects wind will have on the antenna.

FIG. **12** is the preferred embodiment of the antenna of this invention.

In this embodiment of the antenna, arms **122**A, **122**B, and **122**C extend from a central hum and are electrically connected to rim **124**. Tether connectors **123**A, **123**B, and **123**C, are used to secure the antenna to the blimp or balloon.

Rods **125** extend from rim **124** to increase the collection of the static charges in the atmosphere.

It is clear from the foregoing that the present invention captures an entirely new source of electrical energy.

What is claimed is:

1. A system for collection of atmospheric static electricity comprising:
- a balloon;
- a hub that is electrically conductive and connected to the balloon by a tether, the hub having:
  - at least three electrically conductive arms, a first end of each of said conductive arms electrically connected to said hub; and
  - a plurality of rods, a first end of each of said rods being electrically connected to a second end of at least one of said at least three arms;
- a base unit having a spool of conductive line on a winch motor, one end of said conductive line secured to said hub, a portion of said conductive line and said hub collecting electricity in the atmosphere, said winch motor selectively extending or withdrawing said conductive line from said spool;
- a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load being powered by collected electricity from said conductive line;
- an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor; and
- a controller receiving said electrical flow indicia and selectively operating said winch motor such that said electrical flow indicia remains within a selected operating range.

2. The system according to claim **1**, wherein each of said plurality of rods has a rounded second end.

3. The system according to claim **2**, wherein at least two rods are attached to the second end of each of said at least three arms.

4. The system according to claim **1**, further comprising an electrically conductive rim connected to a second end of said electrically conductive arms.

5. The system according to claim **4**, wherein at least a portion of said plurality of electrically conductive arms are connected substantially at right angles to an exterior of said electrically conductive rim.

6. A system for collection of atmospheric static electricity comprising:
- a radial arrangement of at least three electrically conductive arms;
- a plurality of rods, each of said rods being electrically connected to at least one of said at least three arms; and
- a balloon tether connected between a balloon and said radial arrangement of at least three electrically conductive arms;
- a base unit having a spool of conductive line on a winch motor, one end of said conductive line secured to said radial arrangement of at least three electrically conductive arms, a portion of said conductive line and said radial arrangement of at least three electrically conductive arms collecting electricity in the atmosphere, said winch motor selectively extending or withdrawing said conductive line from said spool;
- a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load being powered by collected electricity from said conductive line;
- an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor; and
- a controller receiving said electrical flow indicia and selectively operating said winch motor such that said electrical flow indicia remains within a selected operating range.

7. The system according to claim **6**, wherein each of said plurality of rods has a rounded end distal from said electrically conductive arm.

8. The system according to claim **7**, further including a balloon tether connection secured to the first end of said at least three arms.

9. The system according to claim **8**, further including an electrical connection secured to the first end of said at least three arms.

10. The system according to claim **9**, wherein said at least two rods attached to said at least three arms is five rods.

11. The system according to claim **9**, further including an electrically conductive rim connected to a second end of said electrically conductive arms.

12. The system according to claim **11**, wherein said plurality of arms are electrically connected to said electrically conductive rim.

13. The system according to claim **12**, wherein at least a portion of said plurality of rods are connected to an exterior of said electrically conductive rim substantially at right angles thereto.

14. A system for the collection of atmospheric static electricity comprising:

a generally circular electrically conductive body;

a balloon tether connected to a first side of said generally circular electrically conductive body and to a balloon; and

an electrical connection connected to a second side of said generally circular electrically conductive body;

a base unit having a spool of conductive line on a winch motor, one end of said conductive line secured to said electrical connection, a portion of said conductive line and said generally circular electrically conductive body collecting electricity in the atmosphere, said winch motor selectively extending or withdrawing said conductive line from said spool;

a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load being powered by collected electricity from said conductive line;

an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor; and

a controller receiving said electrical flow indicia and selectively operating said winch motor such that said electrical flow indicia remains within a selected operating range.

15. The system according to claim **14**, wherein said generally circular electrically conductive body comprises:

an electrically conductive hub;

at least three electrically conductive arms, each of said arms connected at a first end to said hub; and

an electrically conductive rim connected to the second end of each of said at least three arms.

16. The system according to claim **15**, further comprising a plurality of electrically conductive rods, a first end of each of said rods connected to said rim and extending therefrom substantially at rights angles thereto.

* * * * *

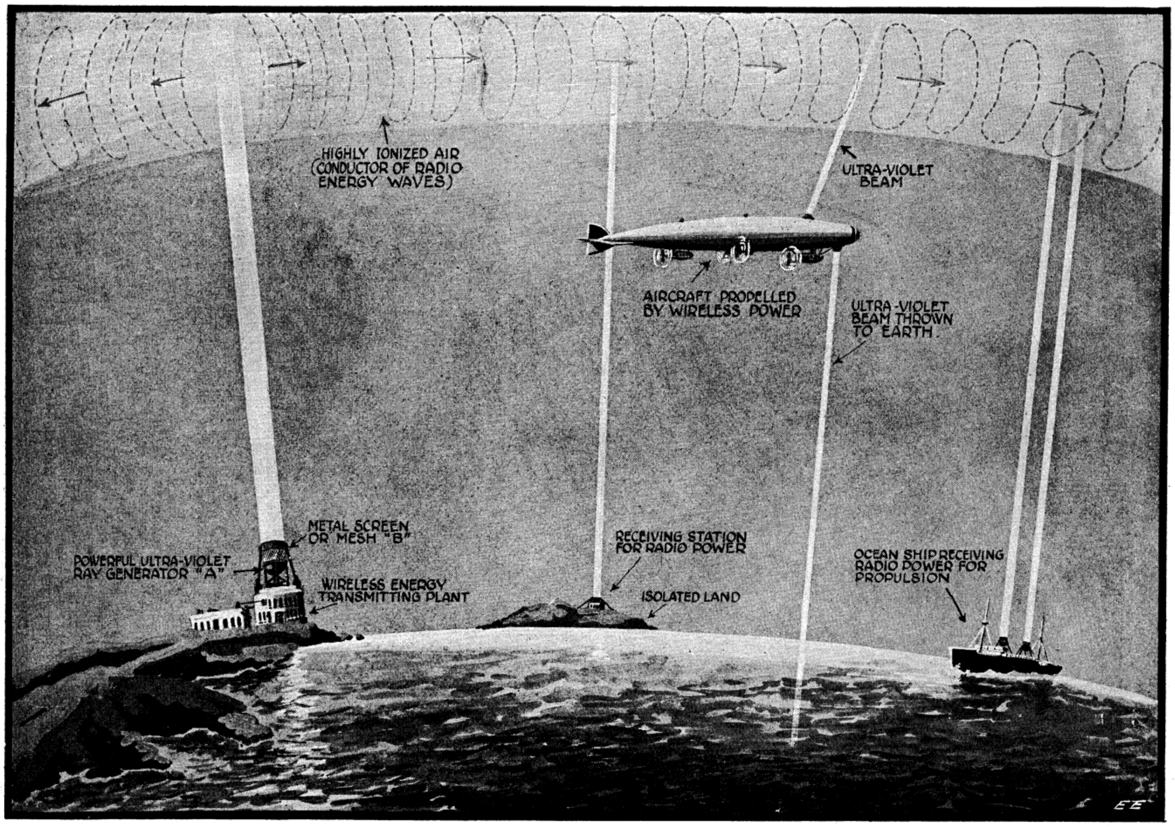
HIGHLY IONIZED AIR (CONDUCTOR OF RADIO ENERGY WAVES)
ULTRA-VIOLET BEAM
AIRCRAFT PROPELLED BY WIRELESS POWER
ULTRA-VIOLET BEAM THROWN TO EARTH
METAL SCREEN OR MESH "B"
POWERFUL ULTRA-VIOLET RAY GENERATOR "A"
WIRELESS ENERGY TRANSMITTING PLANT
RECEIVING STATION FOR RADIO POWER
ISOLATED LAND
OCEAN SHIP RECEIVING RADIO POWER FOR PROPULSION

Showing the Wireless Transmission of Power by Means of Ionized Searchlight Beams. Powerful Tesla Currents of High Potential and Frequency Are Impress on the Ionized Beams and Received from Similar Beams as Shown.

Wireless Transmission of Power Now Possible

By THOMAS W. BENSON

RECENT developments tend to fulfill the old, old dream of power transmission without wires. For years men have labored in vain to transmit power without wires and thus solve a myriad of transportation problems, such as propelling vehicles, ships, trains, aircraft, etc., without having to include a source of power in their construction. It makes one's head almost reel to think of the possibilities in such an achievement and now the dream promises to come true.

By one bold stroke an English genius, Mr. John Hettinger, has unthinkingly opened up the way for its realization. Like numerous other inventions, the way lay before our very eyes, but we were all too blind to see it.

While working on a means for transmitting radio waves without material aerials, Mr. Hettinger hit upon the idea of using ionized light beams as elevated conductors. Obviously simple when one thinks of it.

It is a well-known fact that an ionized gas is a conductor; in fact, the conductivity of a gas is a measure of its ionization. Furthermore, it is possible to ionize a gas by means of a stream of ultra violet rays. Working with these facts, Mr. Hettinger devised means to utilize them for radio transmission in the following manner.

As shown in Fig. 1, a source of ultra violet rays, an arc or mercury vapor lamp, A, is arranged to throw a beam of ionizing rays vertically.

These rays result in an ionized stream of air that acts as a conductor, the surrounding un-ionized air being practically a perfect insulator. By making connection to this conducting beam with a metallic screen or mesh at B, it can be utilized as an aerial for radio communication.

We are perfectly aware that this ionized beam rapidly loses its conducting power

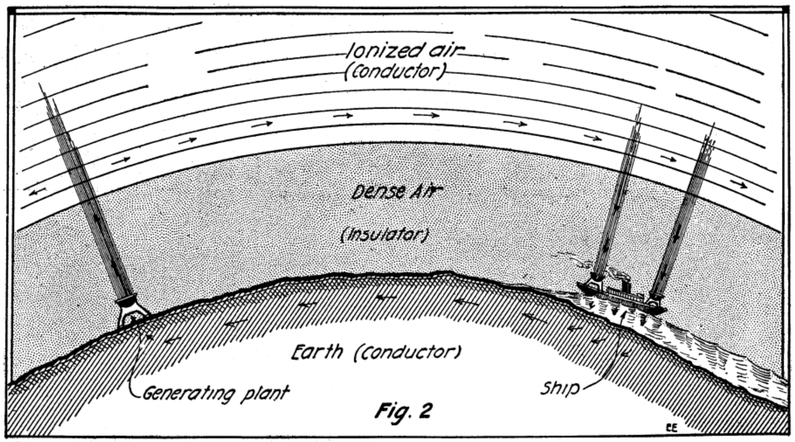
Ionized air (Conductor)
Dense Air (Insulator)
Earth (Conductor)
Generating plant
Ship
EE

Fig. 2

Diagram of the Author's Scheme for the Wireless Transmission of Power Thru Ionized Light Beams and the Upper Ionized Strata of the Atmosphere.

as the distance from the source increases, therefore the effective height of such an arrangement is determined by the intensity of the ray generator. So much for the idea as applied to radio communication.

But let us consider further. In studying the spectrum we find that the sunlight on reaching the earth contains few ultra violet rays of shorter wavelengths than 3,000 Angstrom units, yet we are able to generate much shorter rays with an arc light. It is unreasonable to assume that shorter waves do not leave the sun, and in view of the fact that it has been determined that the upper stratum of our atmosphere is ionized, it is accepted that the shorter rays are absorbed to cause this ionization.

It will now be apparent that a very good condition exists for the transmission of energy without wires. As shown in Fig. 2, we have the earth, a good conductor, surrounded with a blanket of insulating air about ten miles thick, beyond which, up to about a hundred miles, the air is highly rarefied and kept in a state of ionization by light from the sun and stars.

Hence, we have two good conductors separated by several miles of atmosphere, practically a perfect insulator, an ideal arrangement for our purposes. We have but to connect a source of current to the earth and to the ionized strata of air and energy can be transmitted entirely around the earth without wires. The energy could be utilized in any part of the earth by merely connecting to the pair of conductors.

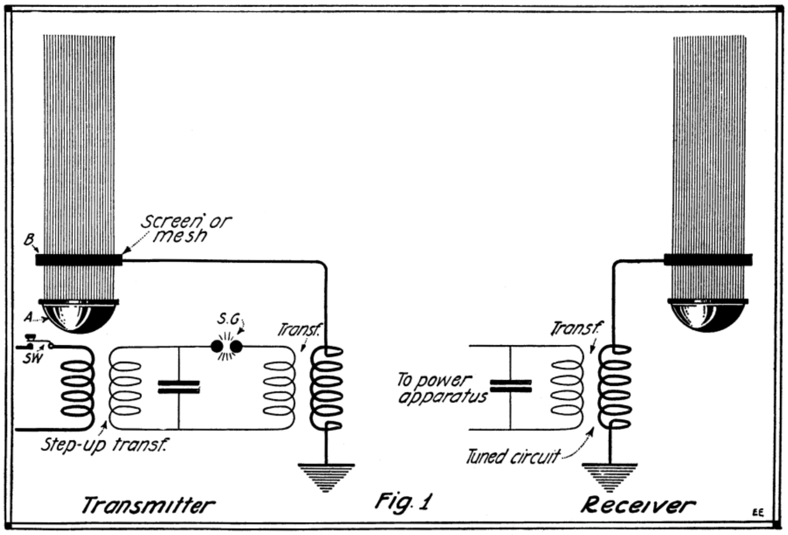

Fig. 1

Diagram Showing the Transmitting and Receiving Circuits for the Transmission and Reception of Electric Power by Wireless.

This condition has been recognized for some time, but the difficulty lies in making connections to the upper layer of conducting atmosphere. It is hardly practical to construct towers six or seven miles high for the purpose, then again the energy could not be utilized without using a similar structure at the point of reception, which makes this scheme hardly feasible for aircraft or moving vehicles.

Return then to the ionized stream for radio aerials. We can easily construct arcs that will throw a beam ten or twenty miles. Then why not make connection to that upper stratum with an ionized stream of air? Wonderful in its simplicity.

In Fig. 2 the writer attempts to portray a generating station embodying these principles. In the main building will be housed the generating units for supplying the current to the arc and the primary of the high voltage apparatus for transmission of energy. Supported on the roof of this structure will be a monstrous arc lamp capable of throwing a stream of ultra violet rays for at least ten miles. In this beam is supported a conducting screen to make connection to the conducting stream of ionized air. The insulation of these parts present no great difficulties to modern engineering.

The building will also house a huge step-up transformer, a set of high voltage condensers, a spark gap either of the rotary or quenched type and a huge oscillation transformer or Tesla coil. These instruments are connected in the usual manner and tuned so that the inductance in the circuit and the capacity formed by the earth and ionized upper strata will have a well defined oscillation period.

By these means the whole earth will become an electrified body, energy to be drawn at any point by simply making metallic connection to the earth and pointing a beam of light vertically, a screen being used to take the energy that will flow down the beam. An inductance coil being necessary in the circuit to insure resonance with the transmitter at the receiving set. After once started, the receiving energy can be used to keep the arc going.

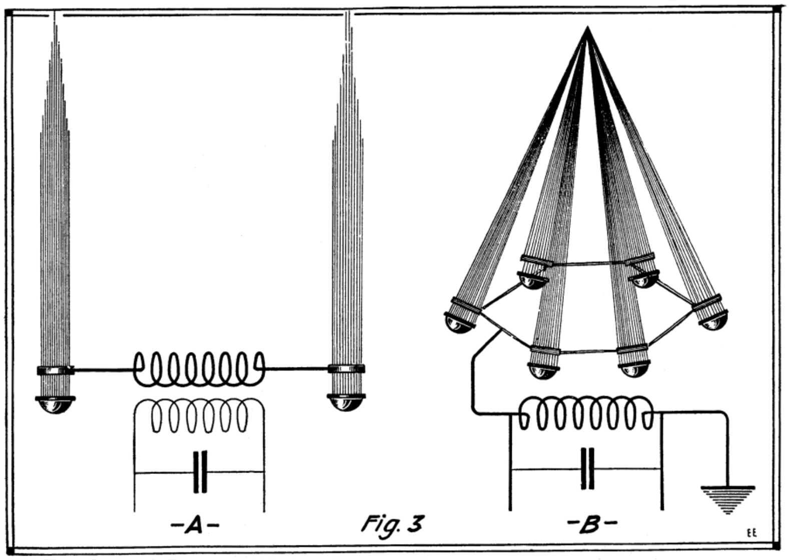

Fig. 3

Two Optional Forms of Wireless Antennae Formed of Searchlight Beams—Ionized Atmospheric Streams.

Ships will have an arc and reflector mounted on the masts, aeroplanes have two arcs, one on top, the other below, and so on.

This scheme will not interfere with present short range transmission, it being hardly practical for each home to have an arc on the roof when one arc would serve for a town and several for a large city.

Rather its benefit will lie in the utilization of water falls far from civilization, now unused on account of difficulties in transmitting the power hundreds or thousands of miles.

Aside from the transmission of power other advantages may accrue. Will such a stress between the earth and upper air strata reduce the presence of dust particles in the atmosphere? Or, again, cause the immediate condensation of fogs and moisture in the air to give us perfectly cloudless days? Perhaps it will become simply a matter of changing the frequency or voltage of the current to cause rain or to prevent it.

Then the question of effect on radio communication: will it make our present sets obsolete, a transmitter of the future being connected directly to the power set and acting by superimposing different frequencies on the power frequency? Or will radio-telephony work hand in hand with the power system, the voice currents being impress on the power circuit and filtered out at the receiver?

There are a thousand and one things such an arrangement might effect. Will trees and vegetation increase in growth as experiments in electrical culture would indicate? What effect would such stresses have on germs and bacilli? Their numbers will be decreased by the destructive effects of the ultra-violet light. Will man grow to an unsuspected height and become uniformly healthier due to the electrical treatment he would be constantly undergoing?

And so on—conjecture is without bounds, but the scheme is practical to all appearances; it requires but some financial genius to give it a trial.

And to think it all was within reach such a short time ago! Had Tesla but put a gigantic arc on top of the tower of his experimental station in Long Island accurate data would be at hand now—were it but even a promise it would mean another step towards the final mastery of all matter by man.

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Information Big Brother & the Oil Companies do not want you to know!

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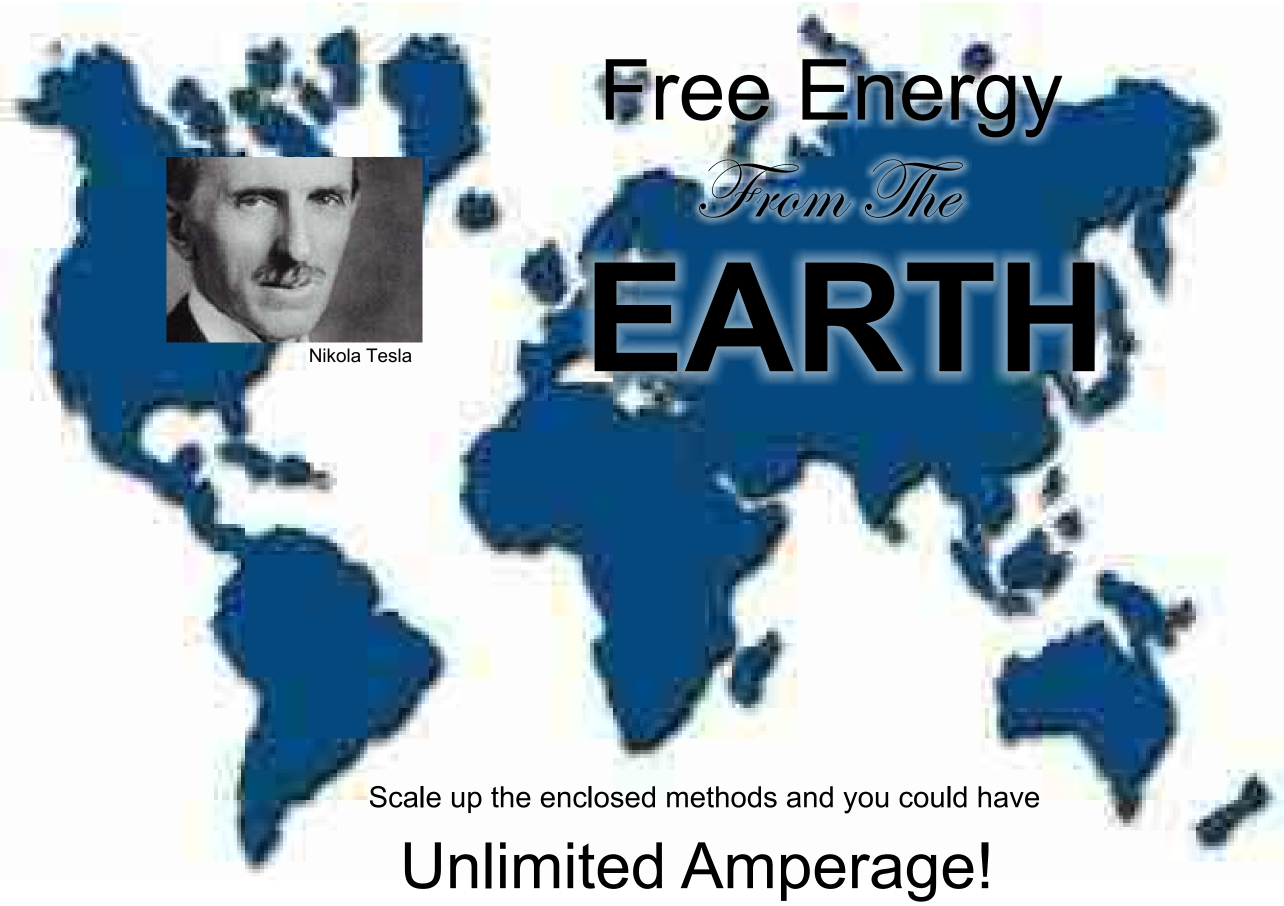

Nikola Tesla

Free Energy *From The* EARTH

Scale up the enclosed methods and you could have

Unlimited Amperage!

By Unlimited we mean you can keep adding more earth cells to your earth power station as you can afford it year by year adding more and more amp power.

Aluminum

Copper

There are many ways to pick up on the free energy in the earth, Just a few are described in these plans. These devices if made right will pick up earth energy that many call ether or static currents as well as acting as high efficient earth battery's. Ether travels through plastic wood etc... Study and research these plans closely there is more to these plans than what you may think. You can learn to get enough power to run your home!

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Learning The basic's of our invention

Experiment #1 How to assemble a 12 vdc system

1. You will have 12- 4" 3/4" copper piping, or If you did not purchase the kit then cut your copper to this size. KIT: take each piece of copper and tape the tops with 1" masking tape.

2. Now using RED LACQUER spray paint (Which you can buy at any hardware store), Paint the outside of the copper all around. (DO NOT PAINT THE INSIDE.) let air dry for 24 hrs. Now remove 1" masking tape.

3. Take the copper pipe outside to the area that you are going to use. use a hammer and hammer each one Into the ground up to the 1" copper exposed top. do not let the exposed copper touch the earth in the final placement. Dirt should be moist. Not real dry.

4. Now remove each pipe and place a thick piece of plastic on bottom of copper pipe to cap it. LET IT BE LOSE, DO NOT TAPE IT. YOU WANT RAIN WATER TO BE ABLE TO ESCAPE FROM EACH PIPE, Do not let exposed outside copper touch the earth.

5. Now hammer each pipe back Into the same holes. place each 2" piece of zinc rod (or a long bolt, most bolts are zinc plated) into the center of each pipe. The zinc Is the NEGATIVE and the copper is the + POSITIVE.

6. Now connect them in series to get 12 volts, use clip wire or solder them. If you are going to leave It outside for a long time then make sure connections are soldered and then painted to protect them from the weather. The rain will replenish your earth batteries. Top get more amaperage with this type simply add more copper and zinc rod cells USE 3' PIECES OF COPPER PIPE INSTEAD OF 4" PIPE. THEN CONNECT EVERY ROW OF 12 PIPES IN PARALLEL.. ADD AS MANY ROWS AS YOU NEED UNTIL YOU GET THE DESIRED AMPERAGE YOU WANT. **(THINK BIG!)** This can be a very powerful free energy system for your home or other. Not only will you get an earth battery effect, but you will also be collecting earth currents from ether /static and under ground radio waves as well.

7. The deeper you go with the copper pipe, the more amperage and voltage you can get.

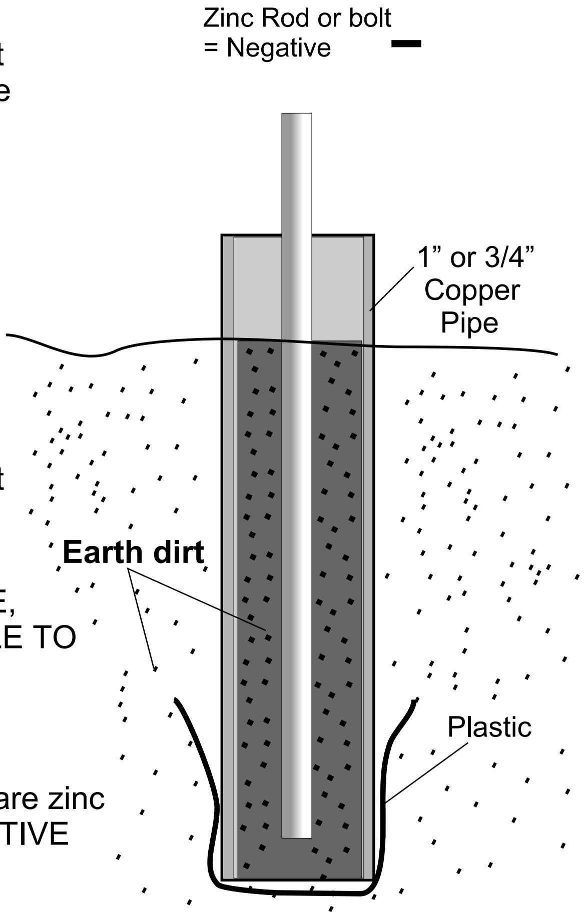

1" Copper = + Positive 1.5 vdc each cell you make

This represents one cell. A qty of 12 to 14 will give you 12 - 14 volts dc when connected in series.

Cut 12 - 4" L x 3/4" copper pipe

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Learning The basic's of our invention

Experiment #2 How to assemble a 12 vdc system

This is just an example to go by and is not the best way but is low in efficiency! See our capacitor earth cells, coil type or flat sheet type. They produce far more amperage and voltages than this type.

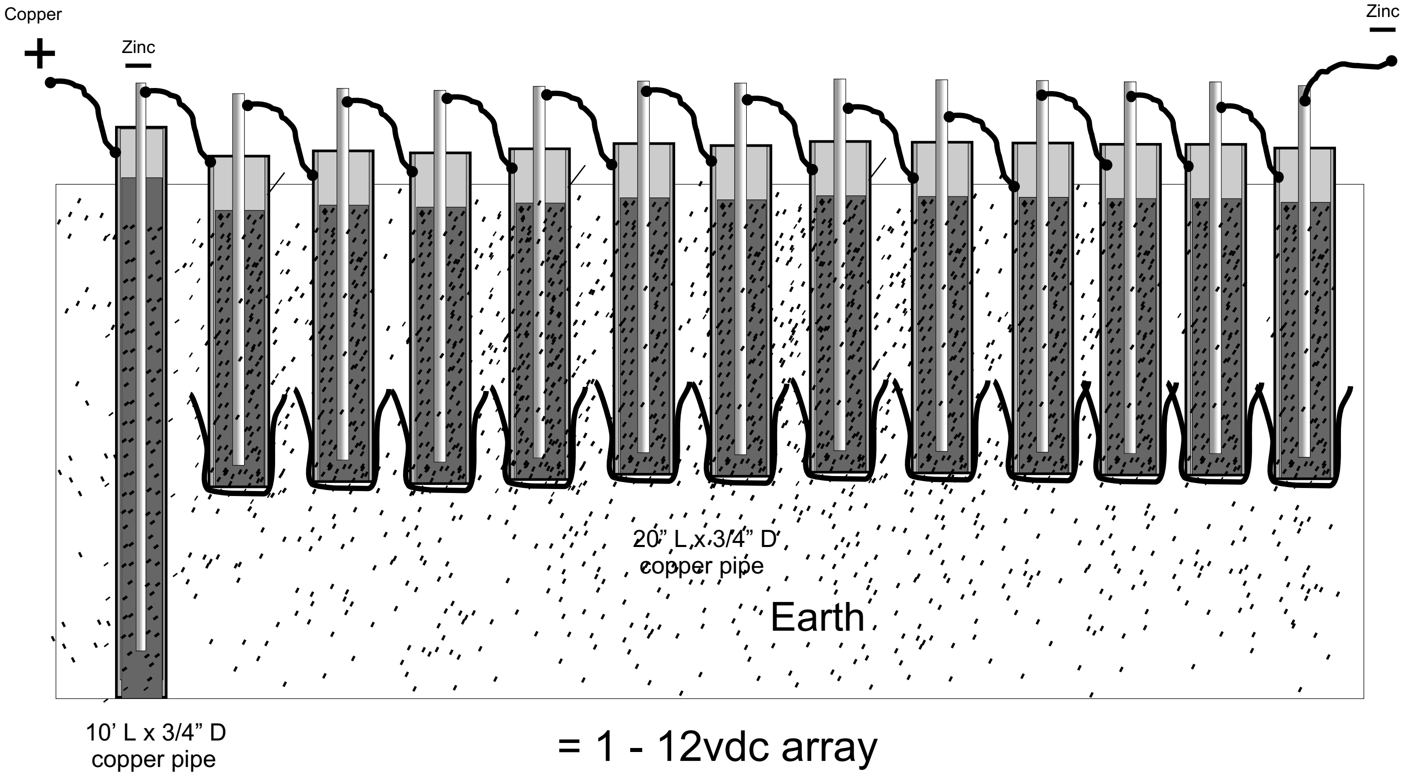

NOTICE: Do not paint the 10 foot copper cell. Keep all copper exposed to the earth. The more exposed copper the better. For higher amperage output, use a zinc or aluminum rod 10/16" Diameter which will leave a space of more than 1/16" to the copper.

Advantages of earth powered batteries

1. Free Energy
2. Long Life
3. The collection of aether energy.
4. Cells are also replenished by outside weather. Rain as well as lightning charges.

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You can purchase Zinc rods or zinc plated bolts at any hardware store, most all nuts and bolts they sell are zinc coated and will work just fine. They also carry aluminum sheeting. Most hardware stores can order you copper sheeting as well.

Experiment #3 How to assemble a 12 vdc system

This is a simple way to produce more amperage but is not practical, we are only showing you this to educate you. The closer the zinc rod is to the copper the more amperage you will get as well as going deeper into the earth. If you do decide to build this basic set up. It is suggested that you solder all leads very well and dig deep enough into the earth to hide the tops of each cell. By covering the tops with dirt the cells can short out so what you want to do is to paint the exposed tops with lacquer or enamel paint then cover with plastic, cover with dirt and allow both the negative and the positive leads to stick out of the ground. But like I said this is not practical, what your goal should be is to make a very strong uf earth capacitor / battery, This will allow you to pick up and collect earth radiant waves of energy as well as lighting energy during storms, the energy you can collect in a strong lighting storm will amaze you! You must use an antenna on the zinc rod or copper rod. **WARNING! Be careful when collecting lighting it can kill you, be sure the positive and negative wires are not coming into your home. During a storm it is advised to have the lead wires going into a large uf cap bank via a one way diode on the positive lead to the positive of the cap or battery. The earth battery's can be dangerous at times and must be completely buried in the earth so a child, adult or animal can not touch or get to. Our earth capacitor batteries can store and hold thousands of volts. So be careful. Use rubber gloves and clothing to protect yourself. We are not responsible for anything in these plans you build at your own risk.**

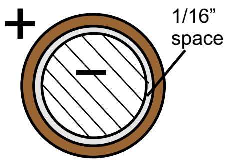

Example of a perfect Zinc rod copper pipe cell

Top view of a 12 volt dc array high amp system

Connect the series arrays in parallel to each other as shown.
Or for a high voltage system connect all in series! Pulse the dc
into a 10x step up transformer, 15,000 v Neon transf.

Zinc rod can be replaced by using rolled up aluminum sheeting or Zinc sheeting, Use 100% cotton cloth wrapped around the rolled sheeting or rod to give a small space in between the aluminum sheet and copper.

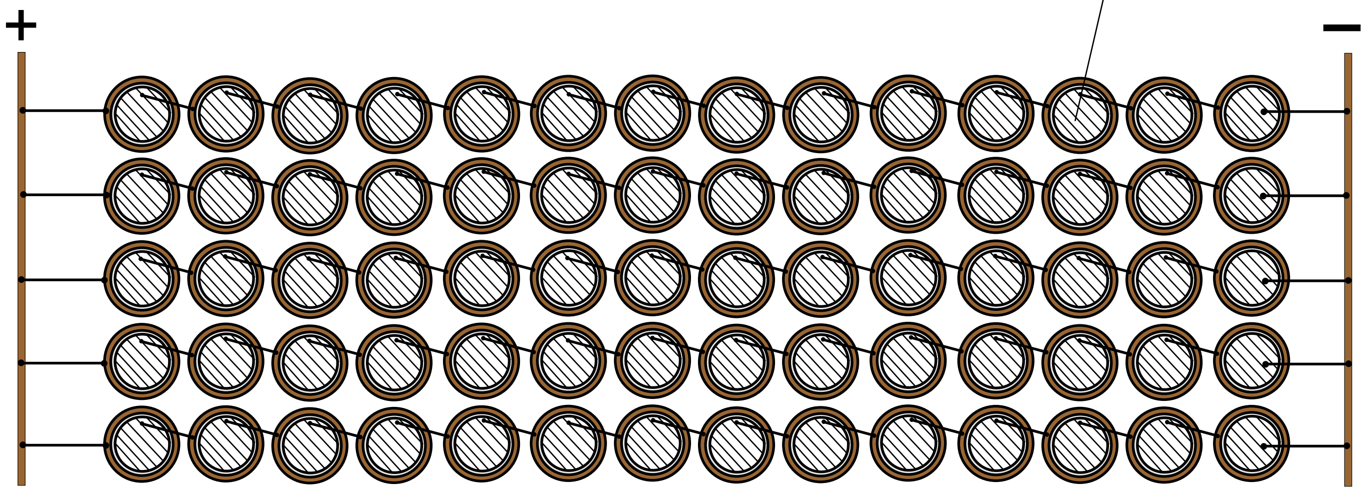

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Learning The basic's of our invention

Experiment #4 The 6 foot spacing method (old way)

There are many US Patents that were Issued back in the 1800's, one of them was issued to a Mr. Deckman. Deckman found that if you take several small pieces of Zinc and Carbon rod and stick them into the ground next to each other and connect them in series (much like a battery) you get very liittle gain at all.

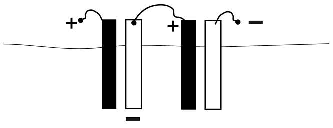

But if you put them 6 feet apart you will get a gain In voltage and they will not cancel one another out. so by doing this you can put them In series to increase your voltage and your volt amps. The theory is that there Is some sort of natural energy VORTEX that takes up about that much space for each unit or cell.

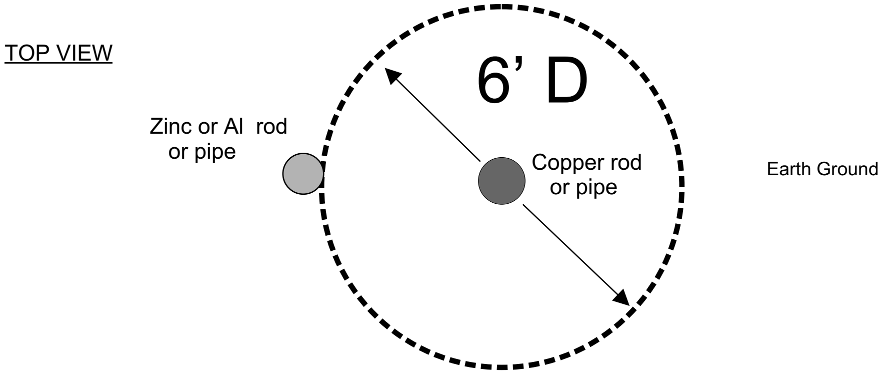

By using this method it will take a lot of ground space, ground space that many people just do not have with the exception of farmers. If you do have the space then think BIG! dig deep and have as many cells as you can get up to 2 to 4 acres. There are much better ways - vs - the old method as you will see. but by using Deckmans old way or our new methods, you can get as much free energy as you want with voltages or amperages as high as you want or desire. The higher the desired amperage the more costly it can get. We are always working to better our inventions to keep the cost down.

Learning The basic’s of our invention

By using our new system you can get as much voltage or amperage as you want. Just size It to meet your needs or your budget.

How to get AC current for house hold use.

You can convert the incoming dc current to ac by using a home made inverter (which we sell the plans to, **5 kw inverter plans $40 order #579**) or you can purchase a 12 v to 115 vac inverter from a store or solar panel supply house.. If you are planing to make a 115 VAC system this Is the only way you can do it. You can not get AC current from the ground. You must use our system to charge a deep cycle 12 v marine battery, and then connect our 5,000 watt 120 vdc to ac inverter to the battery to run your home. (we do not sell kits or inverters assembled, we only sell the plans at this time.)

More on the basic pipe method

Please note: the dirt level inside each pipe should be up to 1/4" from the top. each pipe should be tightly fliied with dirt. Which will automatically happen when you hammer the pipe into the ground the first time.

Each copper pipe (or cell) should be spaced 1 Inch to 1 1/2 inch apart. Doing this will give you more amperage and voltage.

How to dig a simple deep hole for 8' pipe: There are many ways in which you can do this. you can rent a ground drill bit and rig it up with a electric 2 hp motor or you can use 1" copper pipe.

First: prepare the ground with water to make it moist but not muddy, 2nd: hammer a 1" x 5' copper pipe into the moist ground about 5 inches deep/ then remove it from the ground and take a stick or a water hose to remove the dirt from inside the pipe. Then just repeat the process over and over until you get the desired depth that you want. you can get about 10 feet or more using this method.

WARNINGI BE CAREFUL OF ELECTIC POWER LINES WHEN YOU PLACE OR PULL THE COPPER PIPE FROM THE GROUND, IT WILL KILL YOU IF YOU TOUCH A POWER LINE WITH THE END OF THE COPPER PIPE.

We are dealing with a new type of energy as well as conventional energy < Ether energy can go through rubber/ plastic. Iron, etc....

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What is ether or Radiant energy?

The understanding comes from a very deep study of etheric or static forces, this energy that we are getting out of the ground is what some call LIGHT ETHER, when you separate the light ether from the warm ether you can get these superconductive events. It appears like electricity but it has no heat events related to It.

The point is that the best polarity's of things to get a differential in the light ether is to have a silvered coloured metal and then something that is totally absorbitive/ Like black Carbon.

So now you have something that's the perfect reflector and something that is the perfect absorber, and once you understand what your pulling out of the ground (and that it Is not classic electricity as we get out of a normal type of chemical battery), then your going to be farther down the road to understanding how to get much more power out of this stuff.....

There are researchers now that are getting 1 /2 volt to 2 volts dc on a "Quote" volt meter, but it will shock you through an inch of rubber shoes this is not normal electricity!

Q: Is this energy coming from the sun and being absorbed In the earth or from the center of the earth?

A: Yes, but the primary source of light ether is the sun light, yes the earth does have an economy of light ether which does follow the sun around. BUT IT IS ALSO IN THE GROUND! AND ITS IN THE AIR!

Q: Did NokolaTesla know about this in the 1900's?

A: Yes, if you read into his writings he was always saying things like, there is more energy moving than just the electricity in this stuff.

Example: If you take a large Tesla coil and fire it up, and you drive it with a van de graph generator and you put the output of that into a Tesla coil. you can throw sparks across the room! What these electrostatic machines are gathering is light ether.

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A Very Strange and New Discovery!

While working outside on another experiment I discovered a very strange generator effect, much to my surprise, I found that by using 2 aluminum 8” disks connected to my DC volt meter and by placing both disks in a vertical position while touching the bare earth dirt, and moving one of the disks and allowing the other to be stationary I get a dc voltage positive output! This effect works with any size or shape of aluminum, we used 8” diameter disk x 1/8” thick, we found that size to work best. Also by stacking them like a capacitor you will find that the current output is far greater, For Example: see figure 1, Disk A would have 4 more disks connected in parallel of the same size separated by paper die electrics. The same goes for Disk B .

First find a spot any where on the ground where there is no grass (best when wet). Please note, it's not just creating an acid battery effect, you are also getting a good contact with the ground as a conductor to pick up ether energy.

Now place the disks side by side, attach your DC voltmeter probes onto the disks, one negative and one positive. DC meter should be on the lowest setting, now place both disks on the ground very softly and move **disk B** and **do not move disk A** (positive.) You will notice you are getting a small amount of voltage and amperage. Now Move **disk A** and do not move **disk B.** **THE POLARITY CHANGES**.

The rule here is; The disk that moves is always positive. since we can get a polarity change just by moving the disks at opposite times. You can make a very simple mechanical device to get AC current from on top of the earth. Again, this is not just a chemical reaction we have done many test to prove this. You can also get a small voltage reading in dry dirt. The reason for the smaller voltage in using dry dirt is because a low conductance resistance is taking place here, keeping the system from being in contact with the earth and collecting the earth **ether energy.**

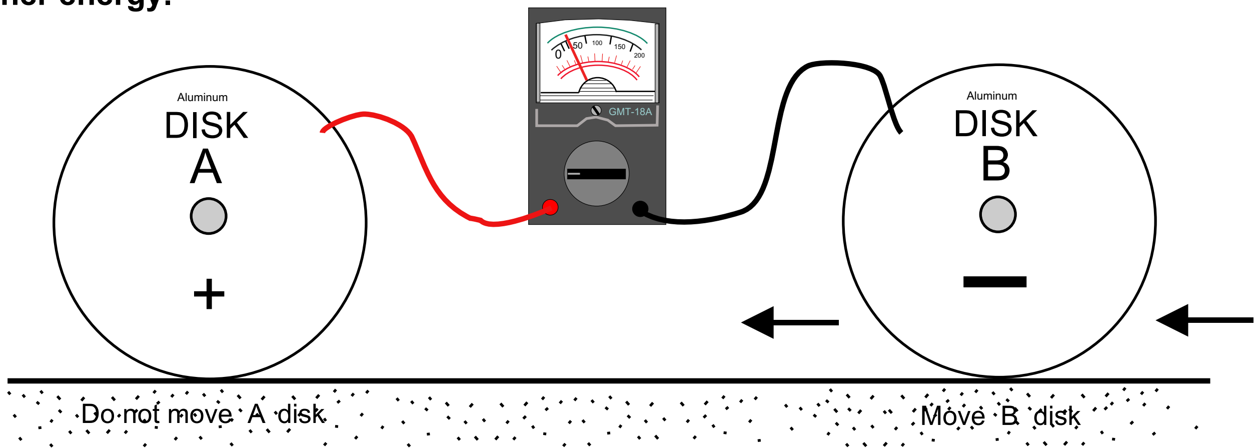

FIGURE 1

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Capacitor Sheet Method

This method is far better than using pipes or rods. By using copper and zinc or aluminum foil sheets you will get much more amperage out of your system!

The amperage you will be collecting will be coming from 3 different sources,

1. **The acid in the ground and water**
2. **Energy that is being transmitted from the earth itself**
3. **Energy that is being transmitted from the sky and space.**

This may all seem unbelievable but it's true and is a fact! The more plates that you add the more power you will get! The copper sheet(s) is the positive, it must be facing down toward the earth. The aluminum or zinc sheet(s) is the negative and must be facing toward the sky! Between each sheet place 1- cotton or course screen printing mesh or other plastic course mesh cloth material. you can use a hole puncher to punch exact holes in each sheet, use 2 holes per sheet copper and aluminum. Use a 8 1/2" x 11" paper puncher one that is adjustable. next use a 3/4 wood base and drill hole for wood dowel rods to fit to the holes you punched in the sheets, you will have a total of 4 wood dowel rods, 2 on the right for the copper sheets and 2 on the left for the aluminum sheets to fit over, cloth die electric can be done the same. You then need to assemble dry and use another 3/4" wood board for top holding plate, which will fit over the wood dowel rods on top, sandwhich and press the assembly together and tape in place with duct tape, drill 2 long bolt holding holes on bottom wood base and top wood base then attach long bolts and nuts and tighten down. Remove tape. and attach wires, water the entire capacitor assembly and bury in the ground.

Copper sheet

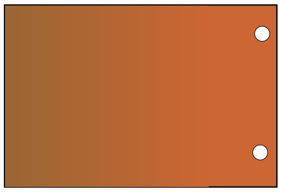

Top View

Aluminum sheet

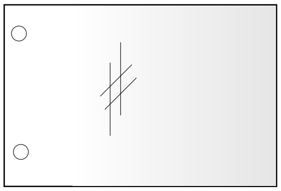

Top View

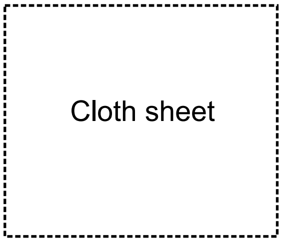

Top View

Place Aluminum sheet on top of copper sheet

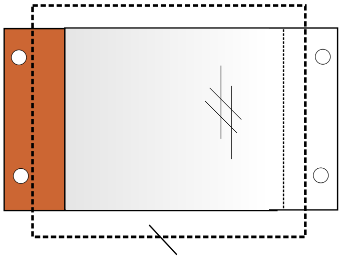

Dotted lines indicate where cloth goes

Top View

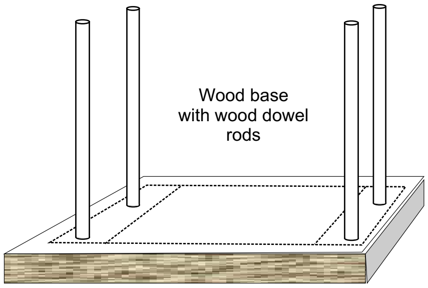

Side View

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Capacitor Sheet Method

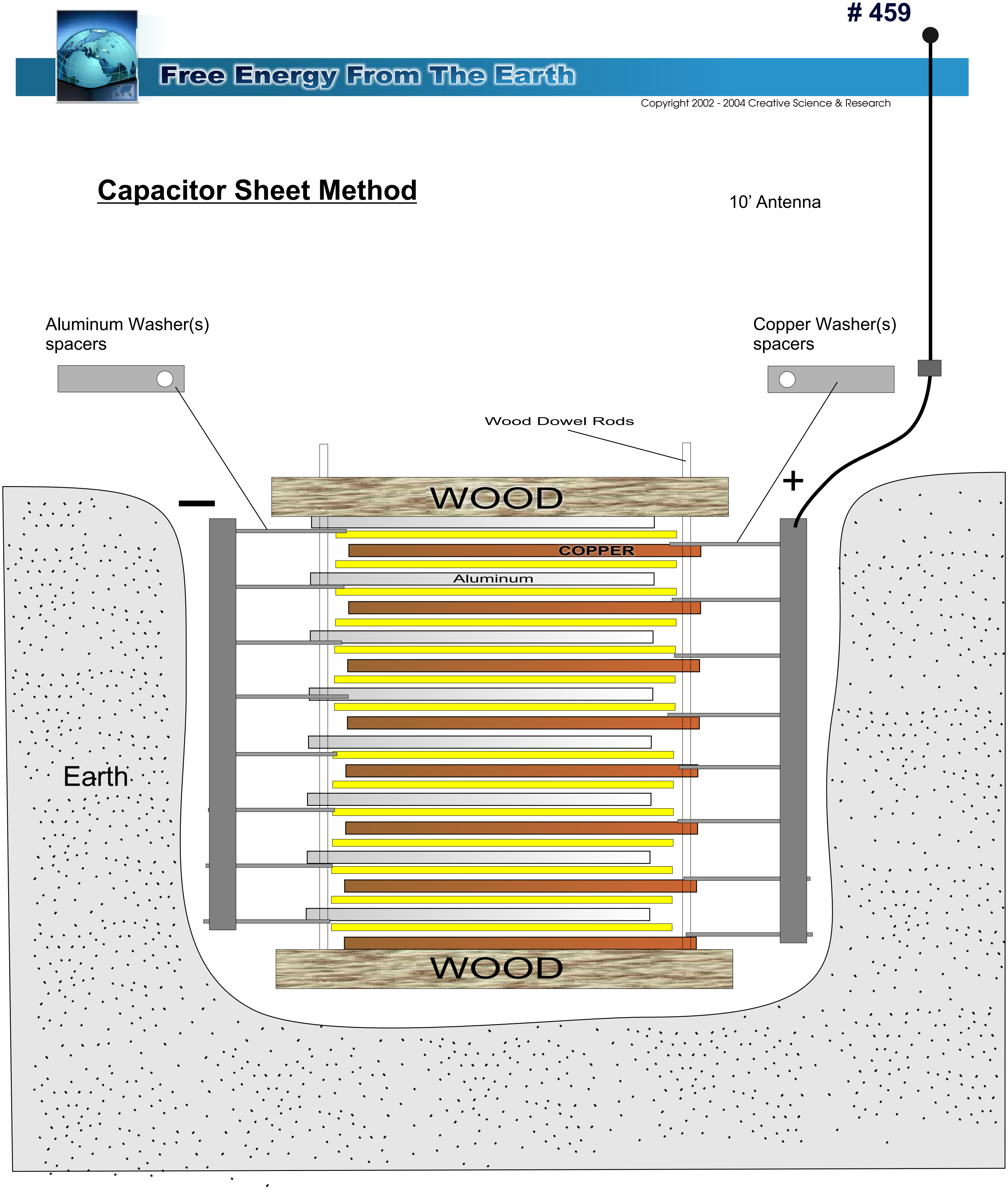
10' Antenna
Aluminum Washer(s) spacers
Copper Washer(s) spacers
Wood Dowel Rods
WOOD
COPPER
Aluminum
−
+
Earth
WOOD

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Capacitor Sheet Method

Again, the more plate sheets of metal you add (or cells) the more power you will get! Remember it's all about capacitance. You are collecting more than just simple battery type power. The copper plate sheet is the Positive + and the Aluminum sheet is the negative. There are many ways in which one can build this type of earth energy collector, below is simply an example of another shape and form. In this type we use water holes. water holes must all be in exact spots.

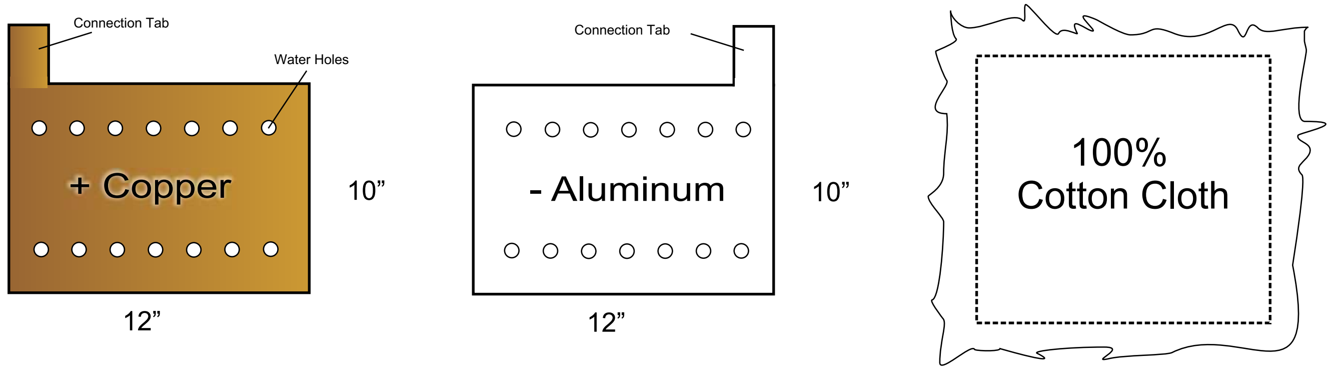
Connection Tab
Water Holes
+ Copper
10"
12"
Connection Tab
- Aluminum
10"
12"
100%
Cotton Cloth

Figure #1 Top View of separate pieces

Figure #1 Side View

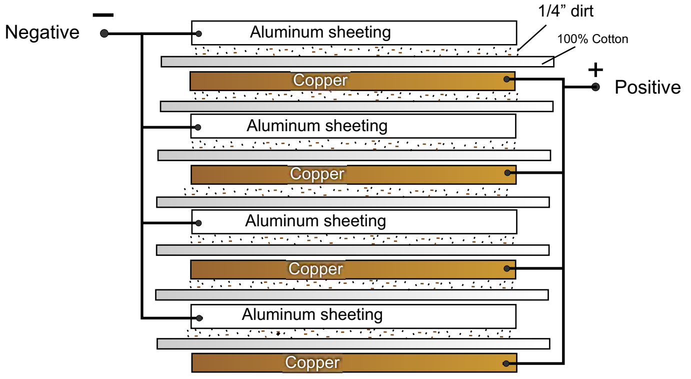
Negative
−
Aluminum sheeting
1/4" dirt
100% Cotton
Copper
+
Positive
Aluminum sheeting
Copper
Aluminum sheeting
Copper
Aluminum sheeting
Copper

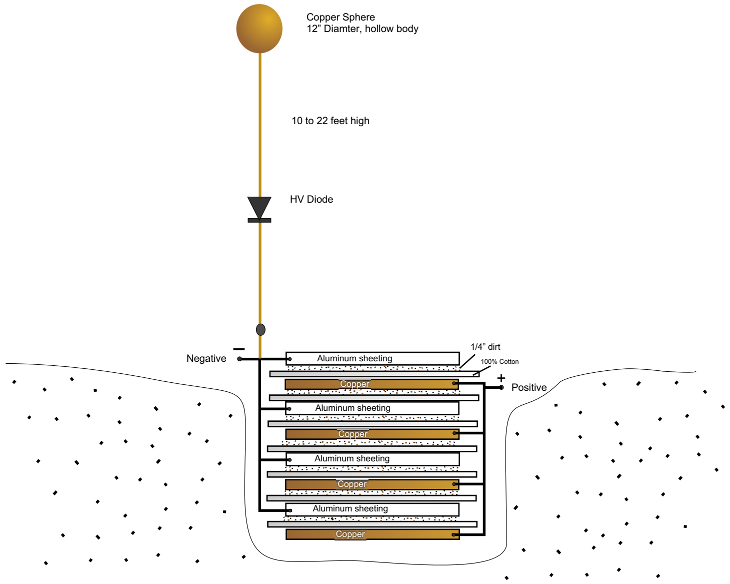
Copper Sphere
12" Diamter, hollow body
10 to 22 feet high
HV Diode
Negative
−
Aluminum sheeting
1/4" dirt
100% Cotton
Copper
+
Positive
Aluminum sheeting
Copper
Aluminum sheeting
Copper
Aluminum sheeting
Copper

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OUR MORE ADVANCED EARTH CAPACITOR!

(EECC) Earth Energy Coil Capacitor!

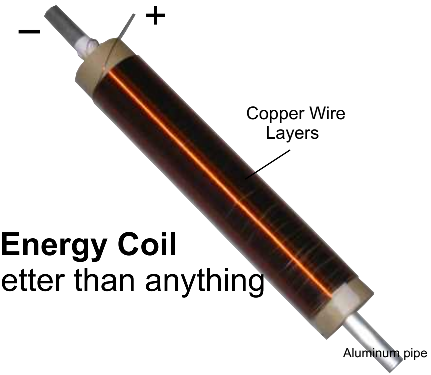

To collect more ether earth energy atoms, build the following **Earth Energy Coil Capacitor**, **Designed & Created by Creative Science & Research**. This is far better than anything we have found yet! Much more power and is easier to build.

Start with our EECC Model #1, Take a 5/16” zinc rod or aluminum rod, cut to 7.5” long. Now use #27 bare copper wire, secure it in a drill press (which you will then turn by hand). Cover zinc rod with paper one layer, use very tiny bits of tape to secure. Now apply the copper wire over the paper, remember to use copper that is not coated! Tape one end of the copper wire to the end of the zinc or aluminum rod and begin to slowly wind. Each wind must be perfectly fitted side by side, paper should be 5.5” long, total length of winds should be 4” long centered on paper. Once you are done with the first layer, apply another piece of paper to the top layer of the first copper layer, do not use to much tape to secure paper in place! Now begin your 2nd layer, repeat this same process until you have about 10 layers, (the more layers the better!) Copper must not touch the zinc or aluminum. When done hot glue or epoxy a small end piece of the copper wire so it will not come unwound. This is one complete cell, keep in mind this is a small test version, to get more power you have to THINK BIG! Build larger cells, using larger size copper. Then place them in salt water to test, 2 cells can be connected in series, after that you must connect them by use of capacitors, diodes and electronic or hand wound spring switches. If you build 20 of these and try to connect them all in series without a cap/ diode switching method, the cells will cancel each other out. Keep in mind you want water to get to each layer as well as the zinc or aluminum. You can also use Aluminum or zinc pipe.

Now concerning the paper Die Electric, Paper will not last very long, test and find a water absorbing plastic die electric,(mesh type). We suggest that you use Plastic screen mesh that you can buy at any hardware store, if all you are interested in is collecting small voltages then use one layer in between each layer of copper, if you are interested in collecting higher voltages such as lightning charges then you must use more layers of plastic screen mesh to thicken the die electric so the higher voltages will not short out your system. Paper may not last longer than 1 year, Plastic screen mesh or polyester screen printing mesh will last for many years.

EECC Model #2 Same as #1, but different. In this design we use #27 copper COATED wire, instead of bare wire. since the copper wire is coated and not bare, each layer must be sanded, that is, the top portion of the copper coated layer must be sanded off so it will be exposed to the water and acid, a die electric should still be used in this case. This type makes for a very high efficient earth cap!

EECC Model #3 Same as #1 but reversed! You will use aluminum wire and a copper rod or pipe. Use a 3/4” copper pipe and wind the die electric paper or plastic mesh and Aluminum bare wire around the copper pipe as explained in Model #1

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OUR MORE ADVANCED EARTH CAPACITOR!

(EECC) Earth Energy Coil Capacitor!

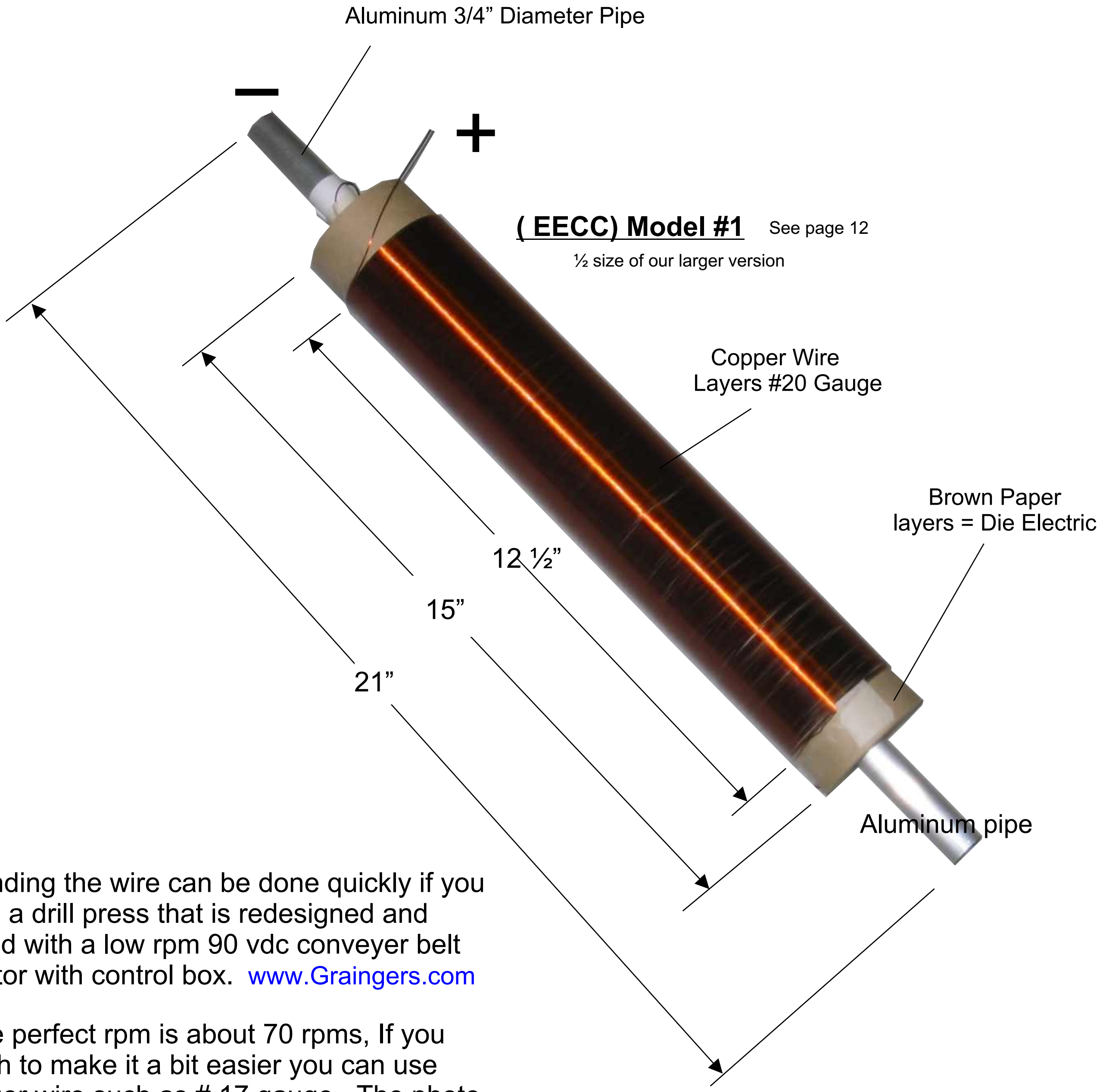
Aluminum 3/4” Diameter Pipe
–
+
(EECC) Model #1 See page 12
½ size of our larger version
Copper Wire
Layers #20 Gauge
Brown Paper
layers = Die Electric
12 ½”
15”
21”
Aluminum pipe

Winding the wire can be done quickly if you use a drill press that is redesigned and fitted with a low rpm 90 vdc conveyer belt motor with control box. www.Graingers.com

The perfect rpm is about 70 rpms, If you wish to make it a bit easier you can use larger wire such as # 17 gauge. The photo is an example of a mid size cell and can be very powerful! This is ½ size of a large cell.

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OUR MORE ADVANCED EARTH CAPACITOR!

(EECC) Earth Energy Coil Capacitor!

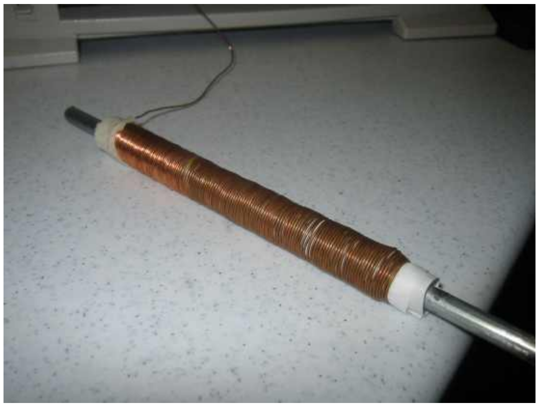

Our small test model #1, we used #22 bare copper wire wrapped around a zinc rod, each layer had a paper die electric, tested in tap water. 5 layers.
Output = 89 vdc x 3.5 ma, this is low.
more layers will = more capacitance which ='s more amperage and voltage.

Small Drill press turned into a Coil Winder

The more layers, the more free earth energy you can collect!

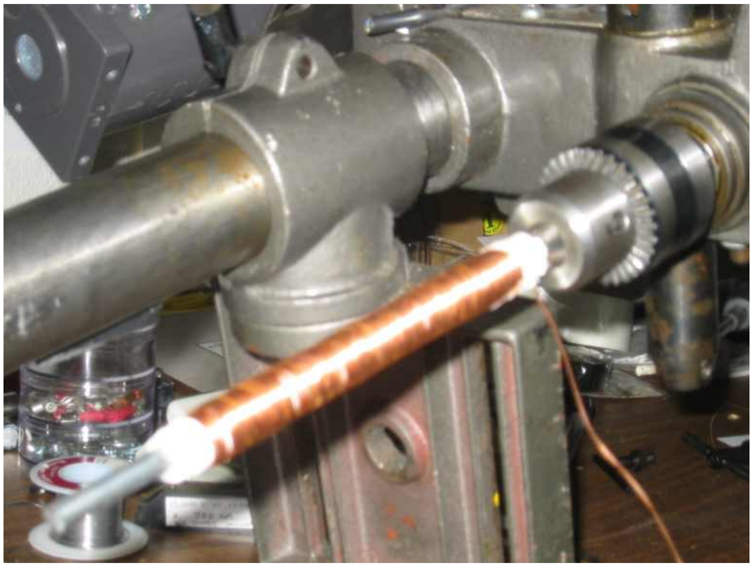

Small Drill press turned into a Coil Winder. We turned this by hand.
Larger coils is best to use low rpm motor at about 70 rpms, In this picture you see that we wound each wind side by side, this makes for a more high efficient earth cap.
You can wild wind if you like if you use smaller wire like #31 to #34.

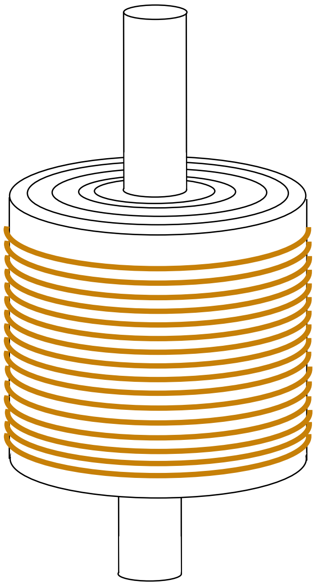

Side View
Ideal size for experimenting

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(EECC) Earth Energy Coil Capacitor!

Rolled Earth Capacitor

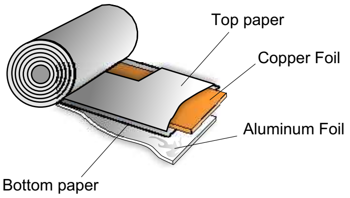
Top paper
Copper Foil
Aluminum Foil
Bottom paper

MODEL #4 Rolled Earth Capacitor

Copper foil is placed between 2 pieces of paper strips and Aluminum is placed on bottom. Use 400 foot strips 2” wide. This method is very hard to do. But is very high eff.

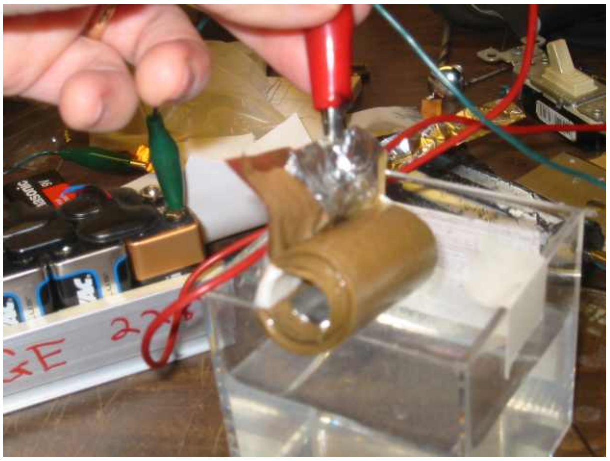

We used salt water to test rolled caps before placing them in the ground.

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(EECC) Earth Energy Coil Capacitor!

MODEL #4 Rolled Earth Capacitor

Rolled Earth Capacitor

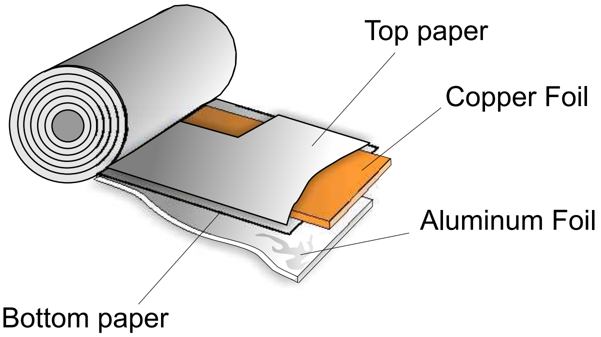

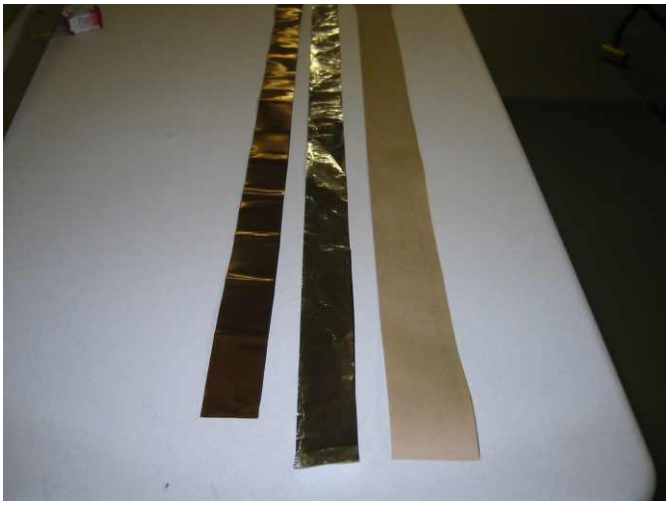

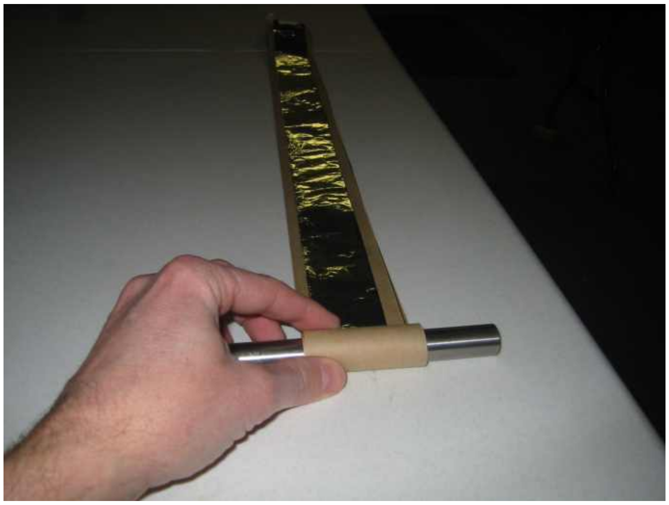

Again rolling this type of earth capacitor is very hard, Everything must be kept straight and inline with one another, Manufacturers of rolled electrolytic capacitors use computers and machinery. I am sure a simple home made roller with pin registration could be designed very easily. This type of earth battery is very high efficient. Paper is not a good die electric for high voltages! If you are wanting to collect earth and storm HV Currents you must use a thicker die electric. Metals must be spaced properly for storing high voltage.

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(EECC) Earth Energy Coil Capacitor!

Rolling a capacitor is the best way but not the easiest,
Which makes this pipe coil model much more desirable to build

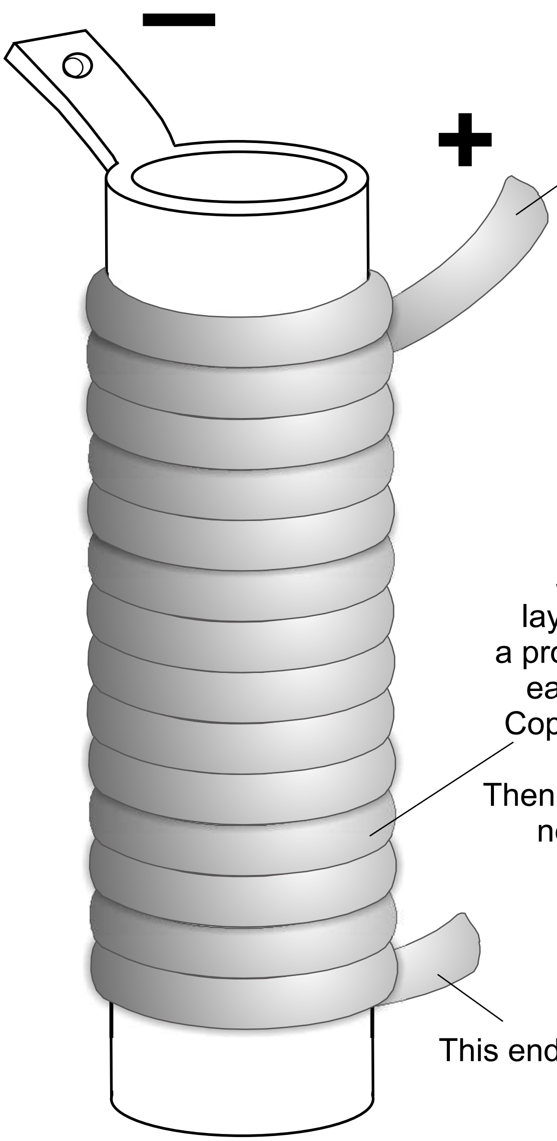

Sand or scratch off top layer coating, this will leave a protective coating in between each wire and underneath. Copper should not touch itself or the aluminum pipe. Then cover with paper and begin next layer of copper wire.

This end not used!

Symbols

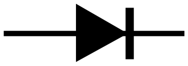

= One way DIODE

Photo of Diode

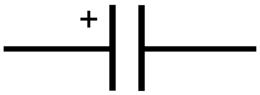

Capacitor (Electrolytic)

Photo of one type of Capacitor

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CONNECTING THE CELLS IN SERIES

How to connect the cells in series to increase the output voltage without allowing the cells to cancel each other out. Figure **A** The Copper pipe and zinc rod method without the use of plastic on bottom of pipe. **Figure B** is the coil earth cap method.

Figure A

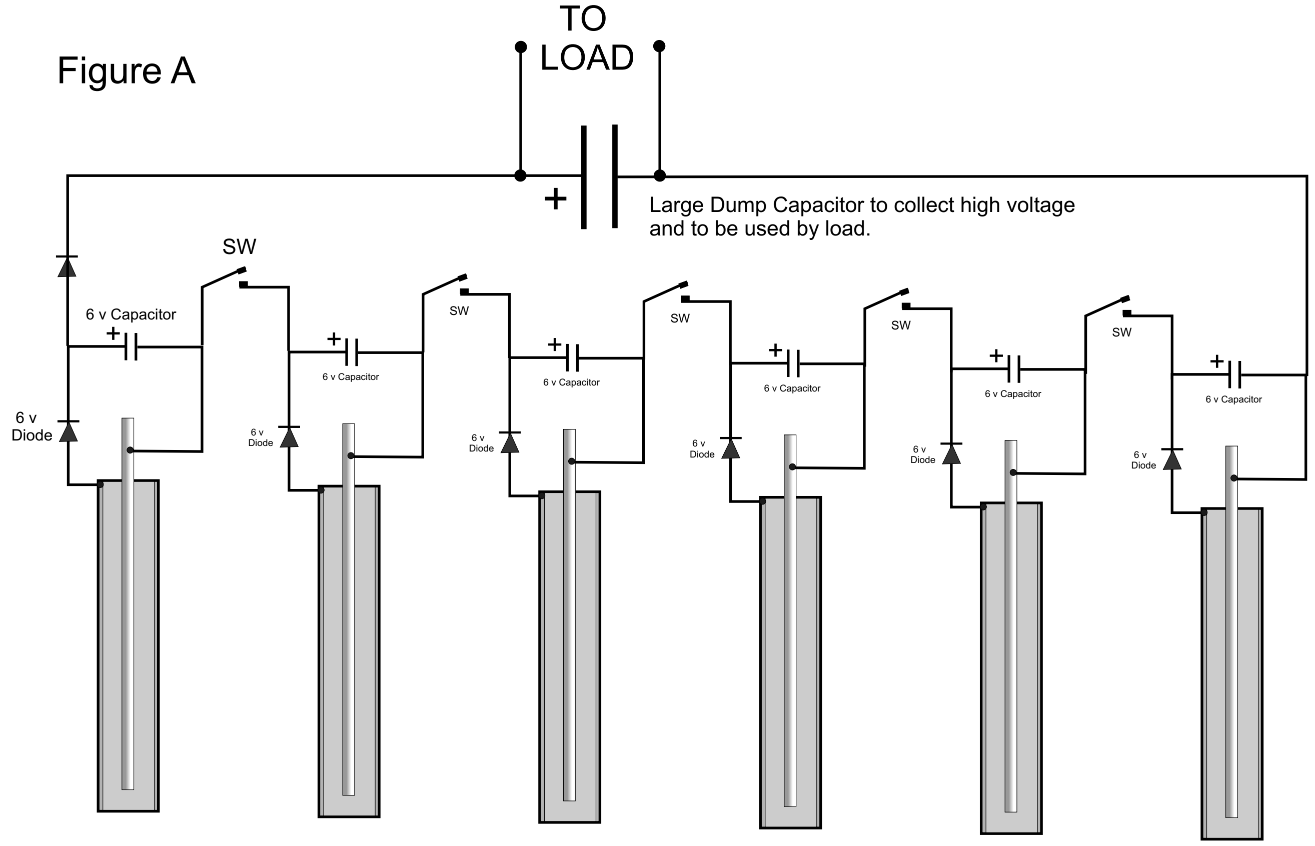
TO
LOAD
+
Large Dump Capacitor to collect high voltage
and to be used by load.
SW
6 v Capacitor
+
6 v
Diode
SW
6 v Capacitor
6 v
Diode

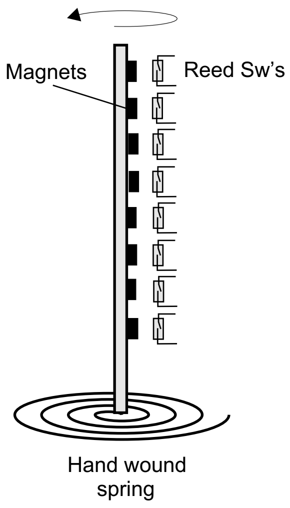
Magnets
Reed Sw's
Hand wound
spring

Use electrolytic capacitors to store the charge coming from each cell, then connect them in series using Commutator Sw's connected to a small rotor shaft, connected to a milliamp solar cell hobby motor or build a small fuelless engine electric motor to run on and off switch's. You can also build a very low milliamp electronic switching circuit and use the earth energy to power it. Or another more simple way would be to use a hand spring type device (timer type) glue small magnets on a long rotating rotor arm connected to the inner spring. Then place small reed relay magnetic switches, on each timing magnet ON position. should have multi reed sw's, as the unit turns if gives time for the caps to charge and then comes around and connects caps all in series which in turn discharges into main cap dump.

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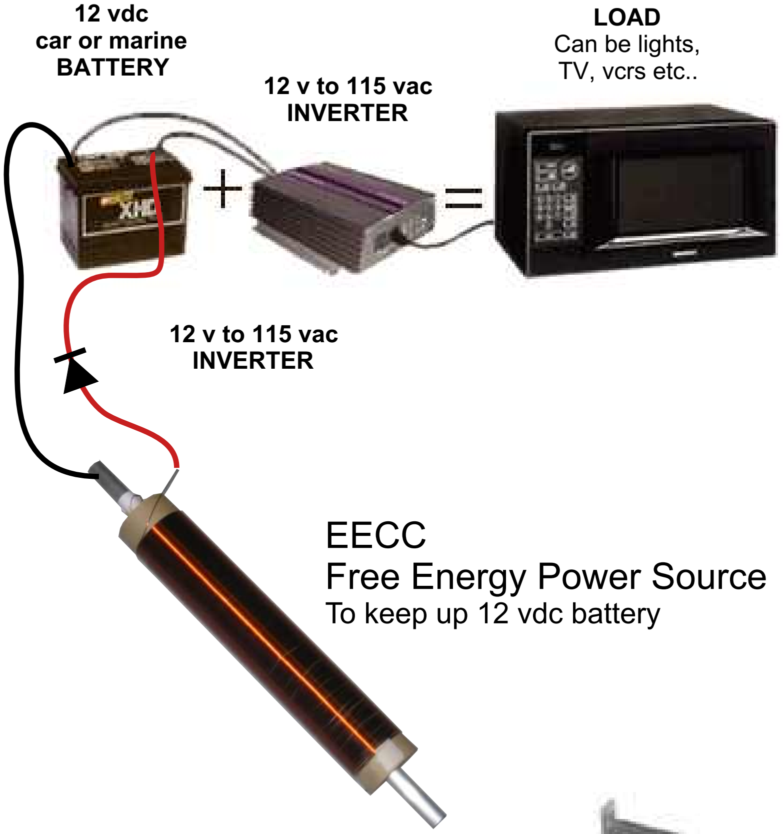
12 vdc
car or marine
BATTERY
12 v to 115 vac
INVERTER
LOAD
Can be lights,
TV, vcrs etc..
+
=
12 v to 115 vac
INVERTER
EECC
Free Energy Power Source
To keep up 12 vdc battery

Copper

Symbols

= One way DIODE

Photo of Diode

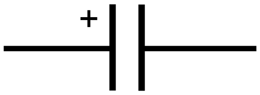

Capacitor (Electrolytic)

Photo of one type
of Capacitor

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Suppliers List

Free News

Google

Copper Foil [Search]

See www.google.com

1. Http://www.delphiglass.com/

   Use there search engine to find copper foil tape

2. http://www.glassmart.com/foil_menu.htm
3. http://www.globalsources.com

Search Google.com for:

1. Copper flashing
2. Inverters
3. Batteries
4. Copper coated wire
5. Copper wire
6. Electronic parts and supplies
7. Diodes
8. Capacitors
9. Free energy from the earth
10. Zinc rods

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EECC update

Step One

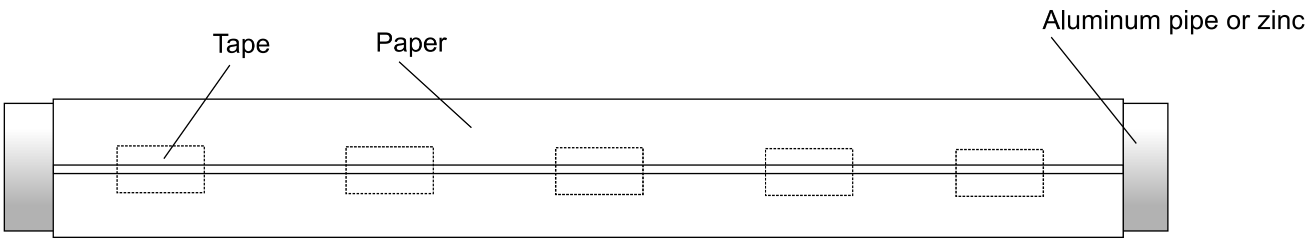
Tape
Paper
Aluminum pipe or zinc

Step two

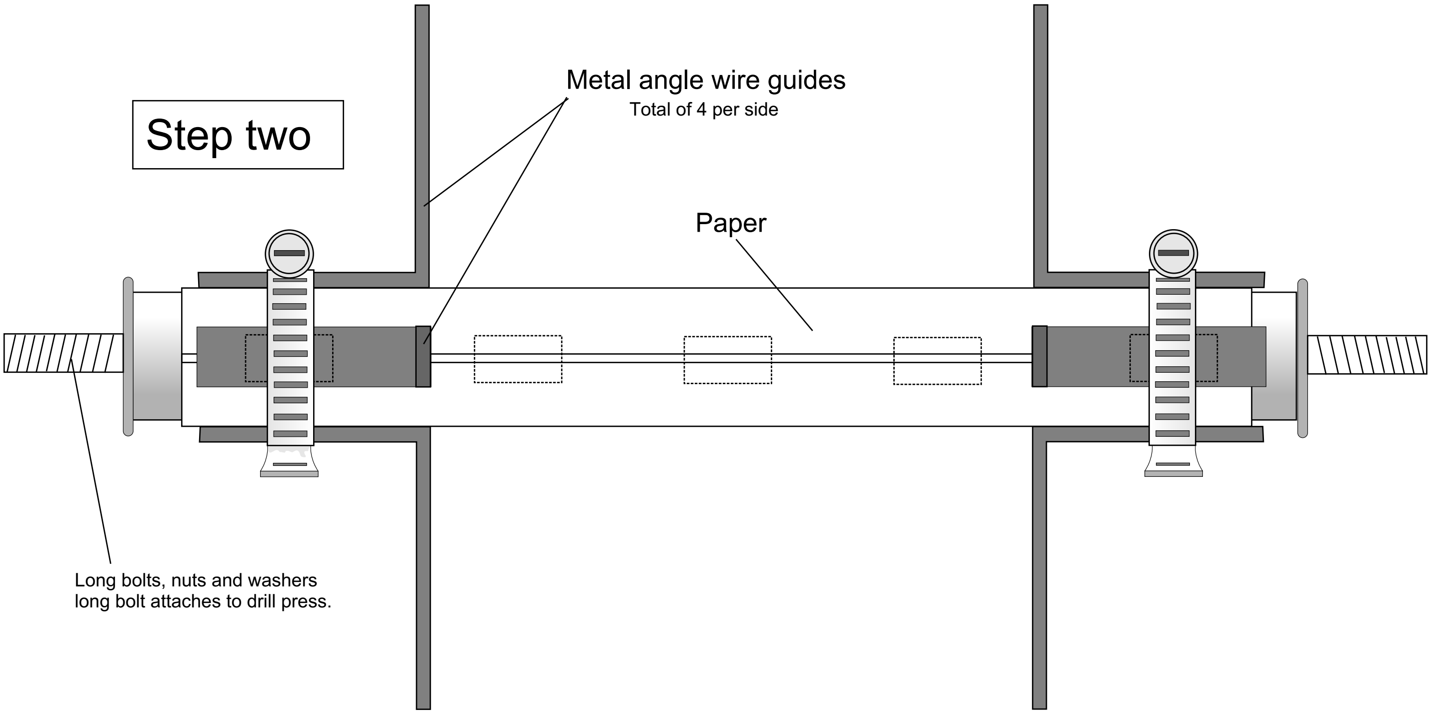
Metal angle wire guides
Total of 4 per side
Paper
Long bolts, nuts and washers
long bolt attaches to drill press.

Apply first layer of wire, remove, metal wire guides, apply more paper, then repeat over and over again until you have about a 5 to 6 inch diameter roll of wire and paper. Makes a very powerful earth capacitor!

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EECC update

These are just a few extra idea’s that we threw together. I hope they are helpful to you. Let us know how you like these plans. Send us photo’s of what you have done we love to hear from our customers. If you got any new free energy idea’s let us know we can research them for you. Many customers do not have the extra research time that we have.

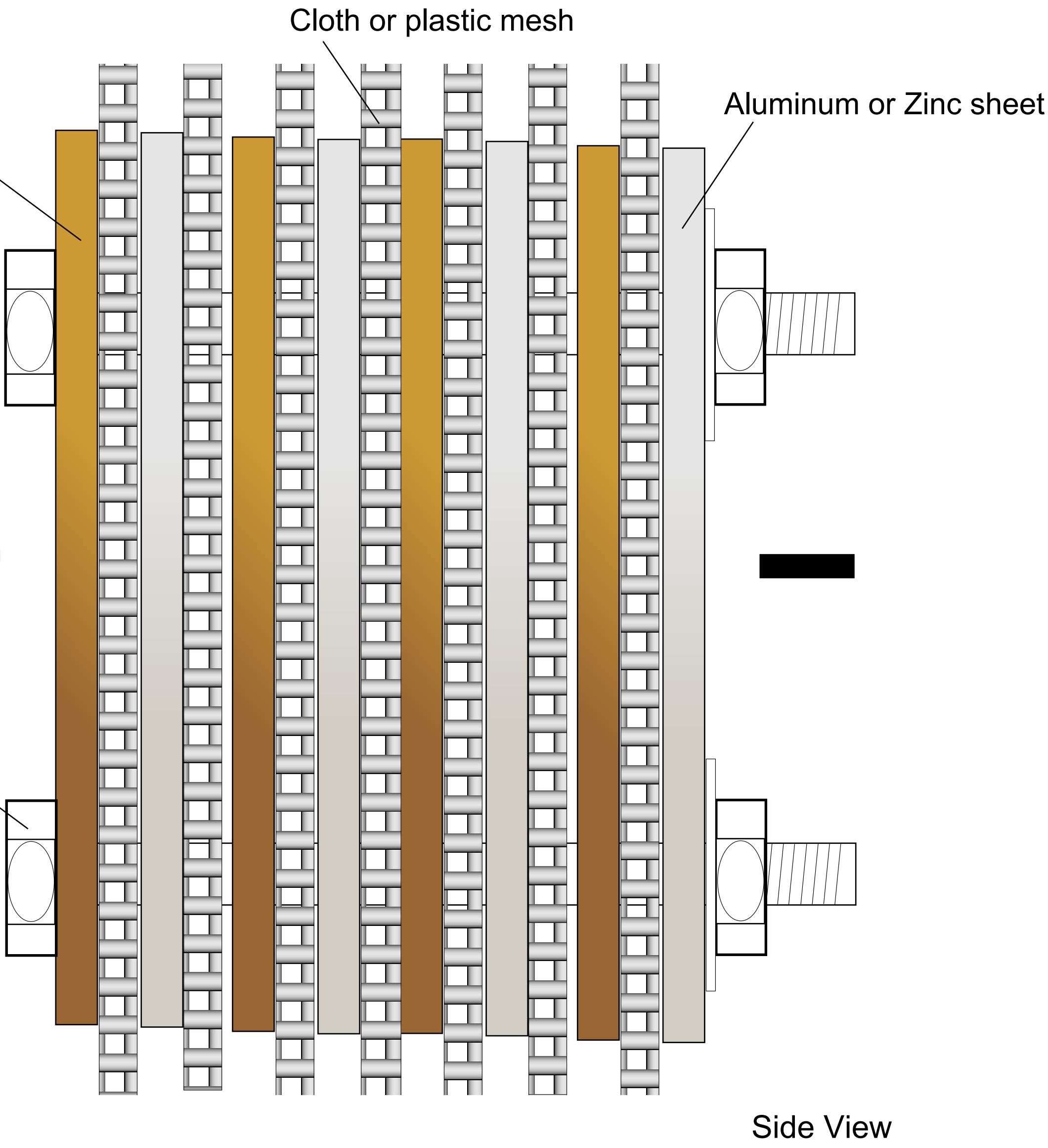
Cloth or plastic mesh
Copper
Aluminum or Zinc sheet
+
White Nylon Bolts
—
Side View

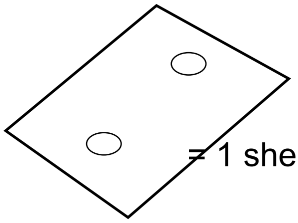

Metal sheet type earth battery

archive.today webpage capture
Saved from http://www.rexresearch.com/guillot/guillot.htm search 5 May 2015 11:19:54 UTC
history
All snapshots from host www.rexresearch.com
Webpage Screenshot share download .zip report error or abuse

rexresearch.com

Jules GUILLOT

Atmospheric Electric Generator

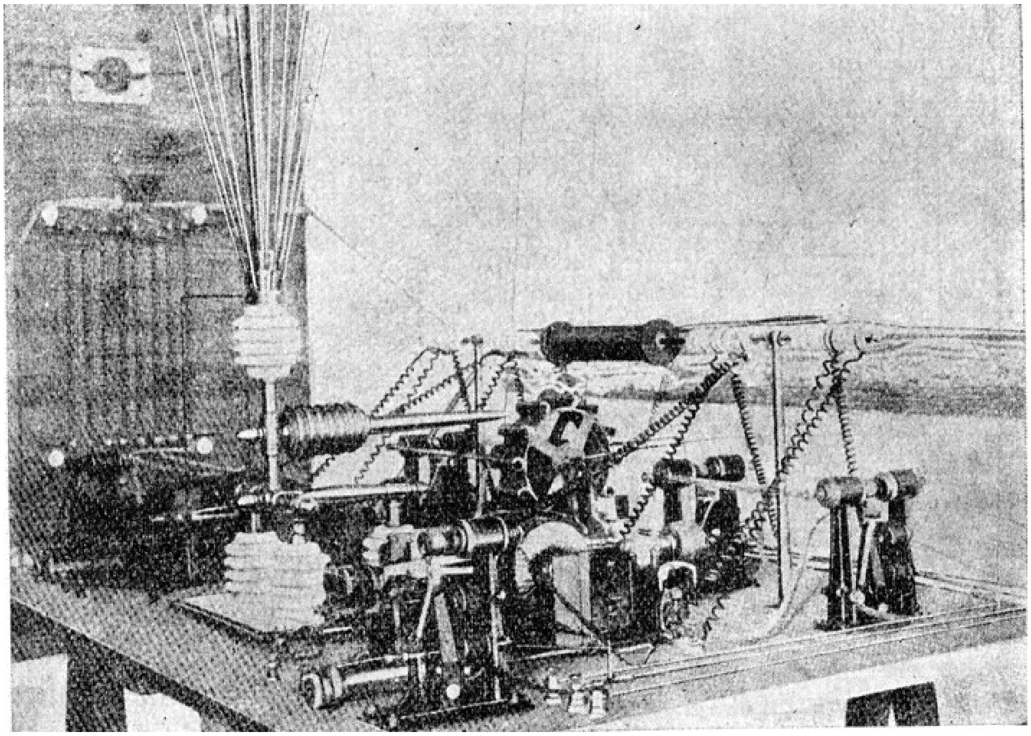

Shared by L. Cozma (Thanks !) --

The Guillot device generated about 2.5-3 Kilowatts with antenna height of ~ 20 meters. Power depends on the total collector surface and height of the vertical antenna. The apparatus in the photo produced ~300 watts with a collector 2 meters tall.

"Practical Utilization of Atmospheric Electricity"

by

Gillbert Darida

in *The Invention Encyclopedia,* pp. 204-207 (1930, Geo. Constantinescu, Ed.)

"The Earth has its own negative electricity, in the soil, and the atmosphere which surrounds the Earth is charged with positive electricity. The electric potential (the voltage) increases with the altitude, so we can say that the electric force is proportional to the atmospheric altitude (after Franklin, Quetelet, Lord Kelvin, Mascart, Joubert and other scientists).

The recent observations demonstrate that the air at 6000-7000 meters in altitude, is very highly charged with positive electricity, which could be explained by the friction between the external photosphere and the upper atmosphere of Earth, which rotates at a speed of more than 100,000 Kilometer per hour.

In that way, the Earth works like an electrostatic generator with electric charging by influence --- the upper atmosphere is positively charged by influence and the Earth crust obtains the negative polarity.

Between the two environments, the air and the soil, and inside the low atmosphere, in conditions of good weather, there are sbout 800 positive ions and also, 680 negative ion (and electrons) in just one square-centimeter of normal ionised air.

The Earth behaves like an huge electric armature negatively charged, which repels the electrons and attracts the positive ions. That positive ions' attraction determinates an electric current, also called "convective current". That's like an invisible continous bombardment, subject to daily and seasonal variations, which could be aproximated at **3 x 10 ^ -16 Amperes per square-centimeter,** and that is a total value of 1500 Amperes for the entire surface of the Earth.
The question is --- how does this current always maintains the same direction ? We can suppose that the natural radioactive emissions of the soil is responsable for this. We also know that radioactive emissions of the Earth works usually near the soil surface, and that explains the ionisation phenomenona inside caves.

The ionisation of the low atmosphere could also be the effect of the radioactive emissions of the Earth, especially when the X radiation works. Also, the Earth atmosphere is ionisated by the external radiation proceeding from the Sun and from the space environment, especially the action of ultraviolet radiation and the electron fascicles emitted by the Sun surface, at the temperature of 6000 deg. Celsius.

The capture of atmosphere electricity has been used in France, with aerial cables mounted on the Mont Blanc, and also in Germany --- with conductive cables carried by the captive baloons.

The atmosphere electricity collect system invented by eng. Jules Guillot is most ingenious and it relies on "the **electric siphon**" [*m.n. --- the discharging devices or spark-gap used today from the protection of aerial electric cables against the atmospheric electricity ; Jules Guillot has thought to recuperate and to use that electricity*].

His method consisted in the direct "pumping" of the atmosphere electricity using a collecting device which had two antennae and several collecting rods.

One antenna is **vertical** and it has a lot of **rods** scattered like an opened **fan**, with the tips against the **zenith**, for collecting the **negative** electricity which comes from the air ; the **horizontal** antenna is orientated against the **South** and its role is to collect the **positive** electricity.

The air electricity seems to have the double-polarity, as we can see at two electrised clouds when between them apears the electric discharge. The air could have different electric charging and the ionisation processus of atmosphere is very heterogenous. The inventor Guillot used **two separated and insulated armatures with the positive armature against the South** (more precisely, against the **Equator**...) and the **negative** armature against the **zenith**.

We can see in the scheme :

1,- the device P is the "**collector apparatus**" having **15-20 meters height** ; it also has a lot of **rods** which are scattered **fan**-like, all this on top of an **iron pillar** ; and also an **horizontal antenna** S oriented against the **South** ; the two antennae are disposed at **90 deg. angle** forming the two armatures where the electrical tension must apear. As the **height** of the pillar **increases**, the **voltage** increases more and more ;

2,- a system of **lightning-rods** (p1, p2, p3) for protection against discharges of atmospheric electricity during storms;

3,- the regulator system (**voltage regulator**, etc) R ;

4,- the electric **resistors** (Cn) for absorbing the parasite currents ;

5,- the "electric siphons" which have the role of making a magnetic field as a good environment for the transport of the ionized fluid, absorbing the electricity from the air ; the E1 and E2 are their regulator devices ;

6,- an **auxilliary continous current power supply** which send the current against an special **excitation coil**, used as starting device ; it works only when the system is starting.
This collector device works very good for lighting and heating. The device made by Guillot had
20 meters height on the total surface of **3 square-meters**. Also, J.Guillot used and electrical transformer for the industrial utilization of this "collector" --- as power supply for industrial electric engines."

French Patent # 551,882

Apparatus for Capture of Electric Currents in the Atmosphere

16 April 1923

Considering the terrestrial globe like the inductor of a dynamo, where the extraterrestrial ether is the inductor of electric currents circulating in the atmosphere; the apparatus of the invention described here selects through the device described below two perfectly distinct currents and eliminates others.

The device includes:

1, The air sensor; 2, a series of lightning rods; 3, vacuum; 4, an array of resistances; 5, vacuum; 6, witnesses.

1. An aerial sensor mounted on a pole is composed of **magnetic steel** fixed and sealed by a porcelain **insulator**, and surrounded a base by a **bronze ring** which are screwed **32 points of soft iron**, all forming antenna a pole. level beside it and isolated from the first, forming the 2nd pole, is fixed a sharp point of magnetic steel fixed in the horizontal position and directed towards the south and **movable to an angle of 45** is sealed in a porcelain insulator. This point is also circled a **ring of copper** notches figure. 1.

2. A series of 6 lightning surge arrestors at corners between each pole and the earth and the various gauges.

3. A first **regulator** form of a device similar absolutely similar to the aerial amtenna, but the two poles are superposed and opposed to the vertical point, and a **copper disk connects to ground**. Opposite the horizontal point, a **ring of tin** to which are welded tubes alternatively **16 tubes** composed each composed of **copper-lead** and **iron-lead** . The ring connects to the **ground** as shown in figure. 2.

A second regulator form of **automatic breakers** balanced on 3 poles and two poles also equally balanced.

4. A panel of **resistances** composed of **wire mesh** in bunches from different sections of **glass tubes** containing **copper** dust, **coal** and flowers of **sulfur**.

Vacuum cleaners consists of a **wooden box** on each pole, containing a **porcelain vase** in which **layers** isolated with **mica** is made up of **mercury, tin, coal, copper** and **sulfur**, all contaied in a **copper tube**.

6. The witnesses are comprised of ordinary incandescent lamps.

Resume

By the point at the zenith and the point to the south we channel two currents forming the two poles. We also protect from lightning. It regularizes the flow by a regulator and similar devices by a controlling each devise of adequate strength of the current harmful nature of these devices do not have loads. The refined current is conducted by ordinary copper wires**.**

French Patent # 565,395

Combined Apparatus for Capture of Atmospheric Electric Currents with Immediate Implementation

25 January 1924

We know that earth with its constitution, its rotation and movement in space, provides the electricity in the atmosphere. The electrical currents escape into space or largely accumulate towards the equator, as a result of the greater periphery of the globe.

In the atmosphere, there are two clearly distinct poles, i.e., clouds that can be electrically positive or negative; everything in nature shows this, otherwise it would be difficult to explain the lightning that occurs between the clouds and which are none other than contrary cloud electrical charges discharged by too close proximity.

The invention relates to a set of devices capable of capturing the atmospheric electricity.

So far, all searches made for this purpose has been to capture the atmosphere, i.e., that brought together into one system to capture two poles and opposes effect has been to destroy or cancel each other leaving the amount as the difference of the strongest to weakest.

It is therefore easy to understand why, considering the two poles of air as about equal, it is almost impossible to measure some potential with the land, the highest on the lowest remaining which can be positive or negative, copper being the strongest of one or other of these polarities.

It is on this basis that all research until now have been made, and that is why we must consider that all the time, between the two poles captured in the atmosphere and not in any mixture of systems uptake, it is possible to obtain tension and intensity, a considerable and measurable power captured separately between the two poles and remaining isolated from one another until their utilization .

In accordance with this invention, this collection is made by attraction of primary electrical currents in teh atmosphere, either positively or negatively charged, by an antenna that has two points absolutely isolated from one another, where one points to the zenith to attract negative electricity, and the other turned south, toward the equator to draws in the masses grouped in this area.

This shows and proves the existence of atmospheric electrical currents, and that it is possible to capture them with specially designed equipment primarily acting as regulators, as the persistent difficulty encountered so far in realizing their capture lies with large variations of tension in which the current atmosphere is present in space, for each of the poles, and an overload could inevitably fatal.

The patent in its present form of presentation does not cover the regulators or devices that are anticipated in the system, because they can be designed in different ways and give the same result, but covers the application and grouping of equipment operating as automatic relays with variable influence to limit current tension to that chosen for utilization.

These devices have a role associated with an overflow reservoir outside carrying excess liquid; these regulators will divert the excess voltage flows to ground.

We can still absorb these regulators having filters because they have the sole purpose of diverting the post being used , currents that are not yet known but likely that we will call for simplicity, abnormal currents. [sic...]

The patent also covers systems for regulating currents, applied to each of the poles because it is recognized that the shape and tension of the currents of the two poles are not equivalent.

The method of capture is by special antenna has directed two points in the atmosphere, as will be stated after this, with Boot ecoulement prior to the current atmosphere is also of great importance.

Finally, the current atmospheric reception is adequate even with the installation of a post, which can be expected at any location without the need for special altitude, as has been attempted in previous efforts.

We refer to the attached drawings:.

Figure 1 represents in elevation and side view an antenna that only has two points, to overcome an elevation ;

Figure 2 is the end of one of the peaks, the horizontal:

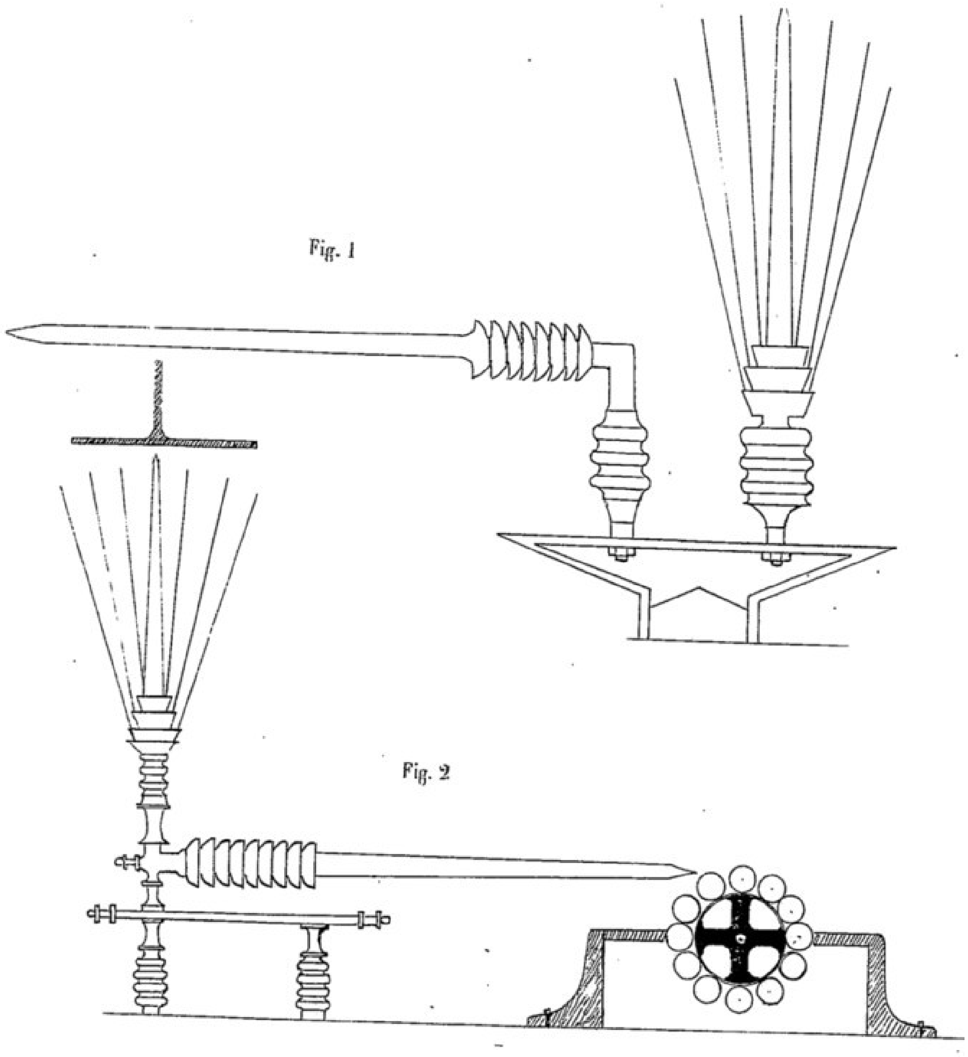

Fig. 1

Fig. 2

Figure 3 shows schematically the table on which are mounted various devices or accessories that act as regulators of current tensions.

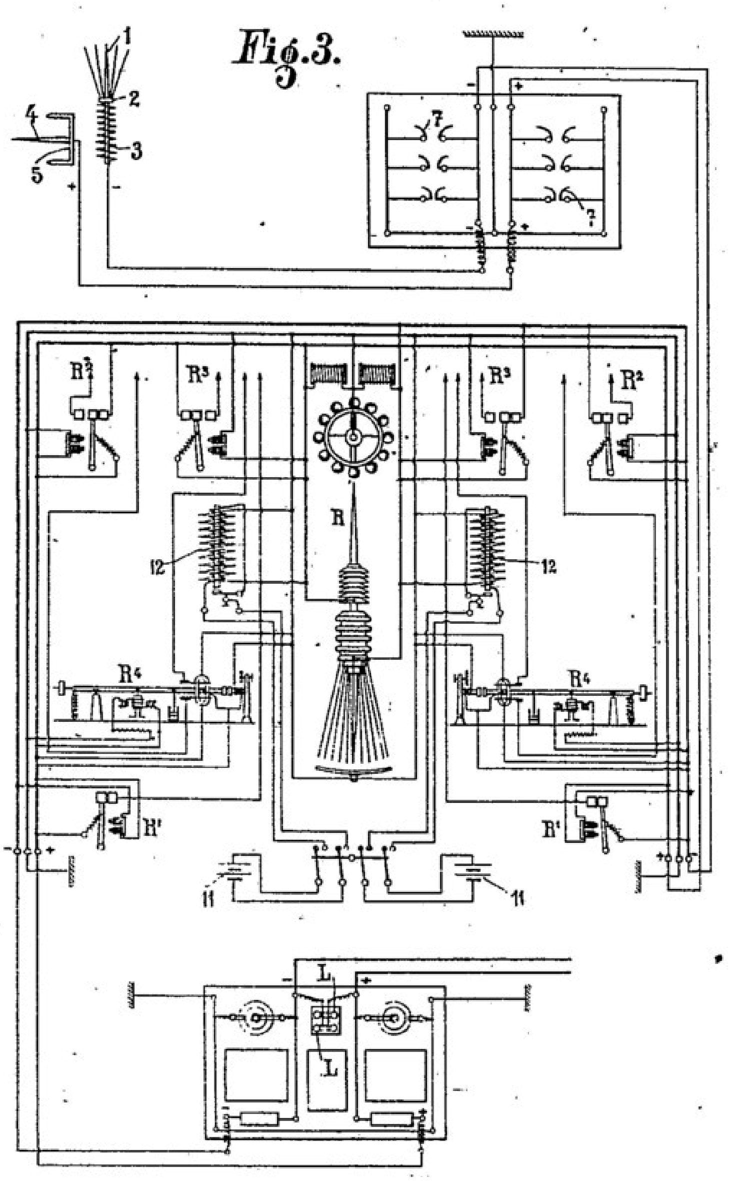

Fig. 3.

1
2
3
4
5
+
-
7
7
R2
R3
R
R3
R2
12
12
R4
R4
R1
R1
11
11
L
L

Figure 4 is a scheme of surge arrestors, and

Figure 5 a table of resistances.

Fig. 4.

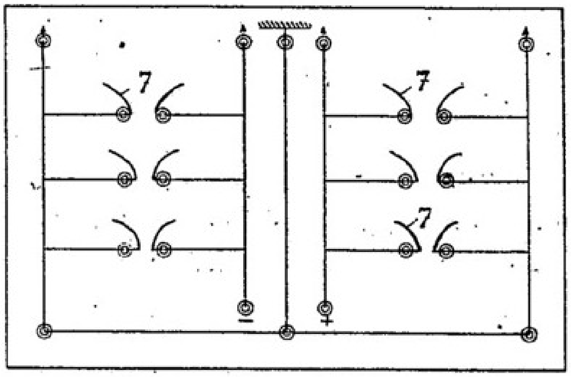

Fig. 5.

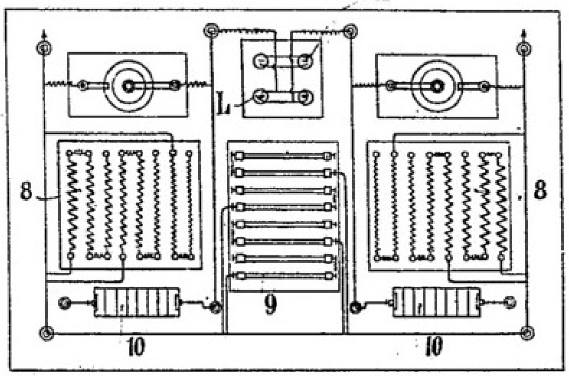

The necessary arrangements to capture atmospheric current form is as follows:

1. The **antenna** in figure 1 is formed with two peaks: the 1 is **steel**, supported by a **bronze ring** 2, surrounded by a **spiral form** 3; this point is oriented for attracting the **zenith** layers of **negative electricity** and the other edge 4 contains **copper coils** 6, and is oriented **south** to the **equator** to draw in the masses grouped in this area. To use this antenna it suffices to be raised on a mast or **pole** to a height a little higher than that of surrounding houses.

2. On the table **lightning arrestors**, contained 4, forms of 7 **copper horns** used to absorb large atmospheric discharges by certain time, as it would be dangerous to allow movement in the devices regulators.

3. On a table of **two** symmetrical systems **regulators**, Figure 3, one for each pole, to obtain and allow a regularization of large excesses in the current tensions, by automatically absorbing surges before passing over the surfacea chosen for the desired use. These regulators are represented on the drawing by the references R, R1, R2, R3, R4.

4. In the **resistance** panel in communication with regulators, these resistances are formed as **spiral coils or screens** 8, **tubes 9 of glass filled with fine coal dust , aluminum powder, sulfur and fine copper dust**. Finally, **two** special 10 **processors** and constitutes **layers** of metal forming an **absorbant** for harmful or abnormal currents.

5. As a source of energy formed **auxiliary batteries** 11 and **Ruhmkorff coils** 12 to get into the antenna sufficient attraction by means of an adjustment of intensity, which once it begins, allows the constant flow of atmospheric current in the system.

In considering Figure 3, which represents a sort of an installation scheme of the device, the reception of atmospheric electrical current will, as set out above, producing a priming of these currents. This boot is made in launching the system which is double to answer each of the poles, the current batteries 11 through 12 and reels going to the antenna.

This boot will continue until the disposal of electrical current atmosphere is evident by the one or more table lamps L of resistance shown in Figure 5.

Once the lights illuminate it is advisable to charge the batteries to boot. Natural flow and constant currents will be captured by the regulators , Figure 3; they will regularize in tension and in amperage and then directed to use in table lamps.

It has been said above that regulators R, etc., are intended and designed to automatically eliminate earth surge currents capture and abnormal currents that cannot yet be level but that these regulators could be replaced by devices with the same function.

There is therefore no need to describe in detail and especially the claims. We only specify that these regulators must be proper protection for the purposes described above.

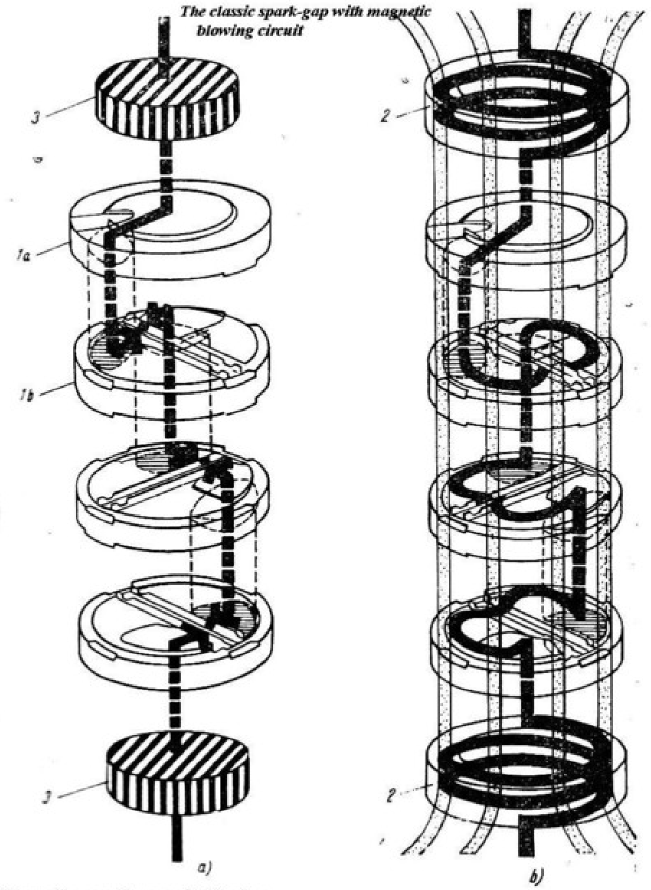

The classic spark-gap with magnetic blowing circuit

The spark-gap with magnetic blowing :
a,- the initial stage ; the impulse current send in soil through the shunt-resistences 3, because the coils 2 have an impedance too big for the impulse of 10/20 µs ;
the spark-gap 1 has two elements disc-shaped 1a and 1b, the inferior disc have one electrode and the upper disc the other electrode of the spark-gap circuit.
b,- the second stage ; the accompanying current discharge - after the impulse current ;
this accompanying current pass through the coils 2 which produce the magnetic field with the role to extend the electric arc into the slit between insulator discs 1a and 1b ; the thickness of this slit is smaller and smaller in accord with the extension of the electric arc, in this manner producing the magnifing of its electric resistance and finally, the electric arc extinction.

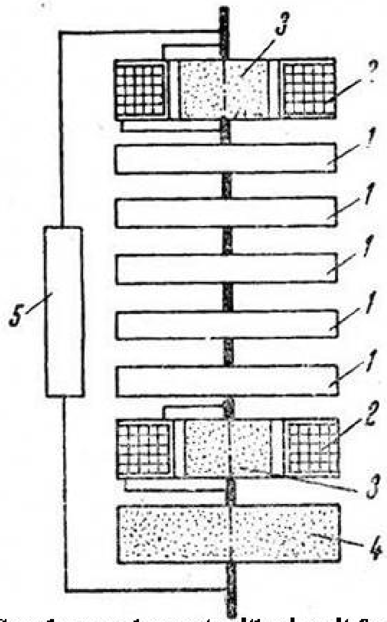

1,- the spark-gap individual devices which work in the manner to extend the electric arc of the accompanying electric current ;
2,- the coils which produce the magnetic field for the magnetic blowing ;
3,- the electric shunt-resistances in parallel connection on the blowing coils, with the role of reducing the current inside this coils
4,- the disc with unlinear resistance ;
5,- electrical resistance for the homogenous distribution of the electric field in all the elements of the spark-gap.

In Jules Guillot scheme, that kind of device could be used for leading the current.

Spark-gap element with circuit for the magnetic blowing of the electric fascicle

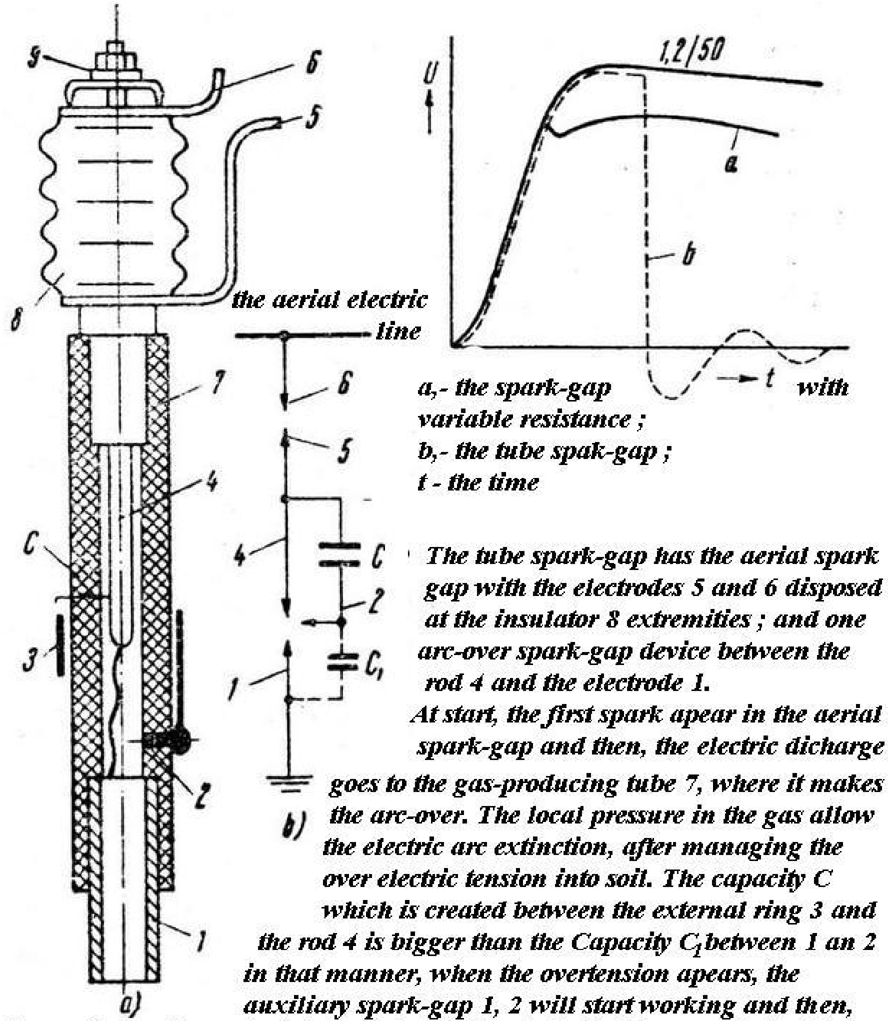

a,- the spark-gap with variable resistance ;
b,- the tube spak-gap ;
t - the time

The tube spark-gap has the aerial spark gap with the electrodes 5 and 6 disposed at the insulator 8 extremities ; and one arc-over spark-gap device between the rod 4 and the electrode 1.

At start, the first spark apear in the aerial spark-gap and then, the electric dicharge goes to the gas-producing tube 7, where it makes the arc-over. The local pressure in the gas allow the electric arc extinction, after managing the over electric tension into soil. The capacity C which is created between the external ring 3 and the rod 4 is bigger than the Capacity C_1 between 1 an 2 in that manner, when the overtension apears, the auxiliary spark-gap 1, 2 will start working and then, the main spark-gap 1, 4. In this circuit, the electrode 9 is connected at the aerial electric line and the electrode 1 at the Earth.

In the image above, it is an classic tube spark-gap used for the protection of aerial electric cables. The atmospheric electricity is discharged in soil and lost... The Guillot's inventions used that kind of devices for leading and absorbing of the atmospheric electricity.

DARIDA, Gillbert : "Practical Utilization of Atmospheric Electricity";
(in *The Invention Encyclopedia,* pp. 204-207 ; 1930, Geo. Constantinescu, Ed.) --

Pământul ca şi celelalte astre, posedă o electricitate proprie negativă în interior, iar aerul care-l înconjoară este pozitiv. Potenţialul sau tensiunea electrică a aerului se măreşte pe măsură ce ne ridicăm în înălţime, astfel că putem spune că intensitatea electrică este proporţională cu înălţimea (după lucrările remarcabile ale lui Franklin, Quetelet, Lord Kelvin, Mascart, Joubert şi a altor mari savanţi fizicieni).

Observaţiile făcute recent, au arătat că aerul regiunilor înalte dela 6000—7000 m este foarte încărcat cu electricitate pozitivă, a cărei explicaţie se datoreşte frecării fotosferei sau atmosferei terestre, prin învârtirea pământului în jurul soarelui cu mai mult de o sută de mii de km pe oră. Această frecare directă în fluidul eteric ambiant, face ca aerul să se încarce cu electricitate pozitivă prin influenţă, iar pământul să se încarce negativ.

Intre cele două medii, fluidic (aerul) şi (pământul) materie, ştiinţa ne spune, că în partea de jos a atmosferei, pe timp frumos un centimetru cub de aer ionizat, conţine circa 800 particule cu ioni pozitivi şi 680 ioni negativi (electroni).

Pământul se comportă ca un enorm conductor încărcat negativ, respingând electroni şi atrăgând ionii pozitivi. Această atracţie a ionilor pozitivi determină un curent electric, zis şi curent de convenţiune. E un fel de bombardament invizibil supus variaţiunilor zilei şi a sezoanelor, putându-l evalua aproximativ la o densitate mijlocie remarcabilă, dela 3×10^{16} sau a 30 quatrilionime de amper pe cm cub, ceea ce dă pentru întreagă suprafaţă a pământului un curent formidabil, de 1500 de amperi.

Se pune întrebarea cum un astfel de curent poate să-şi întreţie mereu acelaşi sens? Aceasta este enigma pe care ne-o punem, studiind curenţii naturali ai atmosferei noastre, presupunem că poate să fie o legătură a acţiunii emanaţiunilor radioactive. Aceste emanaţiuni fiind din gaze radioactive grele, se găsesc de obiceiu în mare abundenţă aproape de pământ ceea ce ne explică marea ionizare observată în general în grote şi caverne.

Ionizarea atmosferică poate de asemenea fi produsă în parte, de acţiunea razelor X, foarte pătrunzătoare şi de diferite substanţe radioactive închise în subsolul pământului. De asemenea poate să mai fie, ţinând seama de acţiunea «Calei Lactee» şi de ionizarea luminei solare, foarte bogată în radiaţiuni ultraviolete

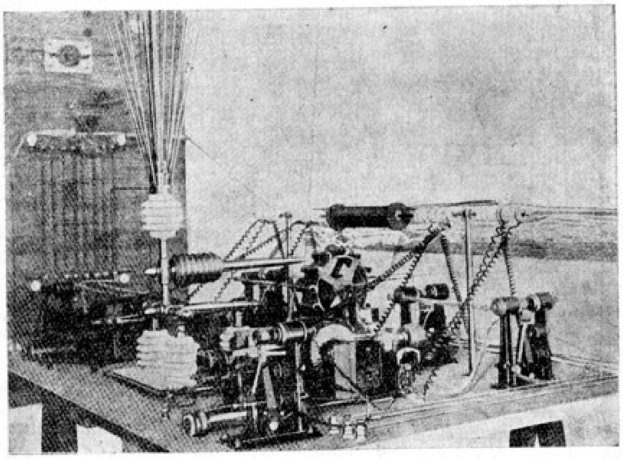

Fig. 108

precum şi a electronilor emişi direct din radierea căldurii solare de circa 6000 de grade.

Captarea electricităţii atmosferice a fost utilizată în Franţa prin cabluri aeriene montate pe Mont Blank, iar în Germania prin cabluri susţinute de baloane captive.

Sunt mai multe sisteme, vom da pe scurt pe cel mai ingenios procedeu, inventat de ing. Jules Guillot, bazat pe sifonul electric. Procedeul consistă de a pompa direct din atmosferă, electricitate prin ajutorul unui aparat de captare, format din 2 antene aeriene și o serie de bobine după cum se vede în fig. 108. Una din antene este verticală în formă de evantaiu dirijată cu vârfurile către zenit, pentru a capta electricitatea negativă din atmosferă; cea care este orizontală, este dirijată către Sud, pentru a capta electricitate pozitivă.

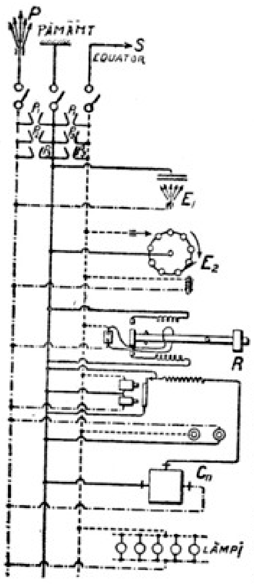

Fig. 109

Electricitatea în aer pare să fie cu dublă polaritate, după cum se vede la 2 nori electrizați, cari deplasându-se în sens contrar, dau naștere unei scântei (fulger) când distanța respectivă poate să fie străbătută de puternica lor diferență de potențial. Straturile de aer de densități diferite, nu sunt toate antrenate de aceeași viteză prin rotația pământului, ele se electrizează deci prin frecarea decalajului lor respectiv.

Aceste sunt considerațiunile ce l-au făcut pe inventator să așeze în atmosferă doi poli complet distincți și perfect izolați, al cărui pol pozitiv *S* (fig. 109) poate fi dirijat în direcțiunea Sudului, și a celuilalt negativ *P*, în direcțiunea zenitului. Fig. 109 arată schema montajului și a conexiunilor compuse după cum urmează: 1. dintr'o antenă dublă aeriană, montată pe stâlpi de 15—20 m înălțime. Această parte care se mai numește și aparat de captat, este format din vârfurile *P*, dispuse în evantai în vârful unei tije de oțel dirijate către zenit, pentru a capta curenții negativi ai atmosferei și dintr'o altă antenă orizontală a cărei săgeată este îndreptată către sud *S*, adică către equator, pentru a recepta curenții pozitivi. Aceste două părți dispuse în unghiu de 90°, formează cei doi poli al curentului aerian, a cărei diferență de potențial este suficientă pentru a permite utilizarea electricității atmosferice.

French Patent # 551,882

Appareil Capteur de Courants Electriques dans L'Atmosphere

BREVET D'INVENTION.

XII. — Instruments de précision, électricité.

5. — Production de l'électricité, moteurs électriques.

N° 551.882

Appareil capteur de courants électriques dans l'atmosphère.

M. Jules GUILLOT résidant en France (Tarn-et-Garonne).

Demandé le 27 septembre 1921, à 15h 20m, à Paris.
Délivré le 15 janvier 1923. — Publié le 16 avril 1923.
[Brevet d'invention dont la délivrance a été ajournée en exécution de l'art. 11 § 7 de la loi du 5 juillet 1844 modifiée par la loi du 7 avril 1902.]

Considérant le globe terrestre comme l'induit d'une dynamo, dont l'éther supraterrestre est l'inducteur, des courants électriques circulent dans l'intervalle c'est-à-dire dans la couche atmosphérique; l'inventeur capte au moyen de l'appareil décrit ci-dessous deux de ces courants parfaitement distincts et élimine les autres.

L'appareil comprend :

1° Le capteur aérien; 2° une série de parafoudres; 3° les régulateurs; 4° un tableau de résistances; 5° les aspirateurs; 6° les témoins.

1° Le capteur aérien monté sur un poteau est composé d'une pointe d'acier aimanté fixée par scellement sur un isolateur porcelaine et cerclée à sa base par une bague de bronze sur laquelle sont vissées 32 aiguilles de fer doux, le tout formant l'antenne d'un pôle. A côté et isolé de la première, formant le 2e pôle, est fixée une pointe d'acier aimanté dans la position horizontale et dirigée vers le sud dont la base coudée à 45° est scellée sur un isolateur porcelaine. Cette pointe est également cerclée d'une bague de cuivre à encoches fig. 1.

2° Une série de 6 parafoudres à cornes entre chaque pôle et la terre et à écartements variés.

3° Un premier régulateur formé d'un appareil absolument semblable au capteur aérien, mais ayant les deux pôles superposés, et, opposé à la pointe verticale, un disque de cuivre relié à la terre. Opposé à la pointe horizontale, une roue à jante d'étain sur laquelle sont soudés alternativement 16 tubes composés eux-mêmes de deux métaux soudés : cuivre-plomb et fer-plomb. Cette roue est reliée à la terre par son pivot fig. 2.

Un deuxième régulateur formé d'appareils à déclanchement automatique au nombre de 3 par pôles et deux basculateurs également par pôles.

4° Un tableau de résistances composé de fils de maillechort en boudins de différentes sections, de tubes en verre contenant des poussières de cuivre, du charbon de cornue et de la fleur de soufre.

5° Les aspirateurs composés d'une boîte en bois sur chaque pôle, contenant un vase de porcelaine dans lequel par couches superposées et isolées au mica est placé du mercure, de l'étain, du charbon, du cuivre et du soufre, le tout traversé par une tige de cuivre.

6° Les témoins composés de lampes à incandescence ordinaires.

RÉSUMÉ.

Par la pointe au zénith et par la pointe au

sud nous canalisons deux courants formant les deux pôles. On protège l'ensemble par des parafoudres. On régularise le débit par un régulateur semblable et par des appareils à déclanchement commandant chacun des résistances appropriées de la nature du courant nuisible dont ces appareils sont chargés. Les courants épurés sont conduits aux témoins par des fils de cuivre ordinaire.

Jules GUILLOT,
Moissac (Tarn-et-Garonne).

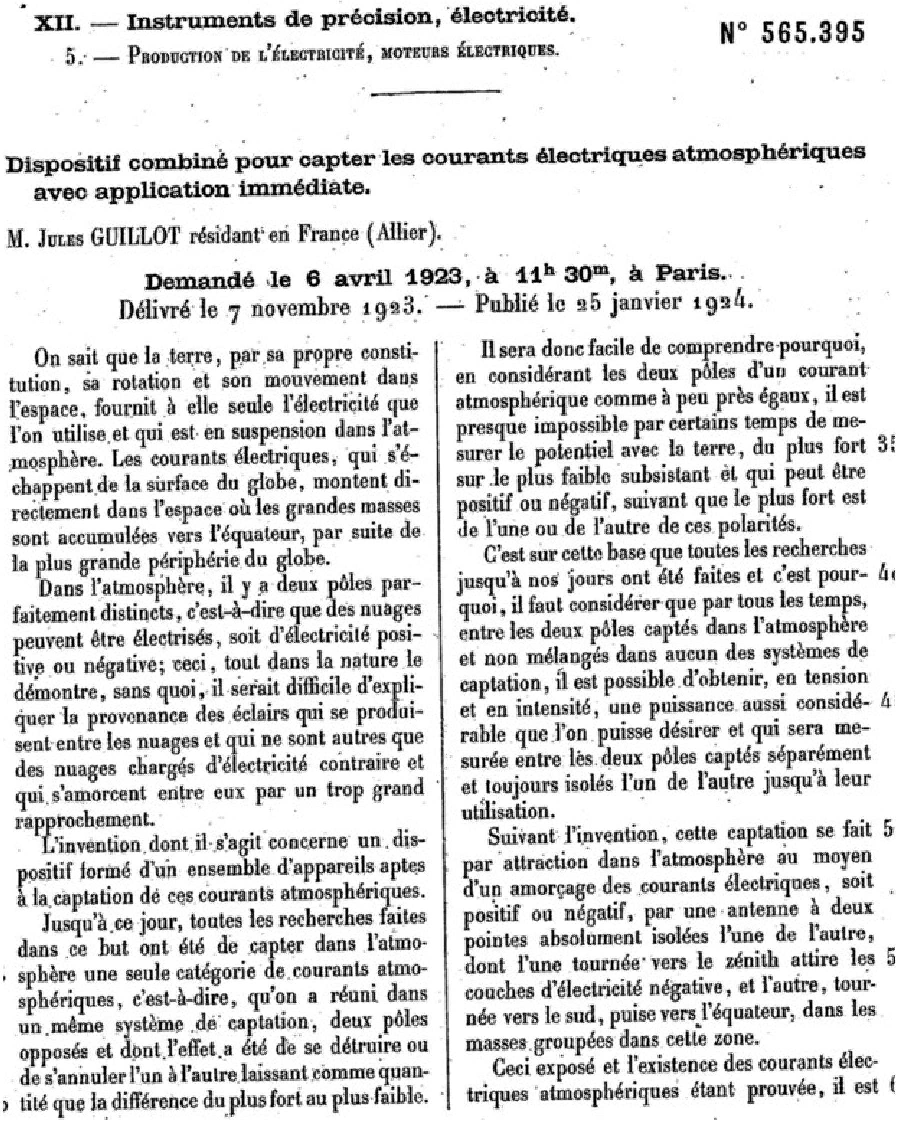

XII. — Instruments de précision, électricité.

5. — Production de l'électricité, moteurs électriques.

N° 565.395

Dispositif combiné pour capter les courants électriques atmosphériques avec application immédiate.

M. Jules GUILLOT résidant en France (Allier).

Demandé le 6 avril 1923, à 11^{h} 30^{m}, à Paris.
Délivré le 7 novembre 1923. — Publié le 25 janvier 1924.

On sait que la terre, par sa propre constitution, sa rotation et son mouvement dans l'espace, fournit à elle seule l'électricité que l'on utilise et qui est en suspension dans l'atmosphère. Les courants électriques, qui s'échappent de la surface du globe, montent directement dans l'espace où les grandes masses sont accumulées vers l'équateur, par suite de la plus grande périphérie du globe.

Dans l'atmosphère, il y a deux pôles parfaitement distincts, c'est-à-dire que des nuages peuvent être électrisés, soit d'électricité positive ou négative; ceci, tout dans la nature le démontre, sans quoi, il serait difficile d'expliquer la provenance des éclairs qui se produisent entre les nuages et qui ne sont autres que des nuages chargés d'électricité contraire et qui s'amorcent entre eux par un trop grand rapprochement.

L'invention dont il s'agit concerne un dispositif formé d'un ensemble d'appareils aptes à la captation de ces courants atmosphériques.

Jusqu'à ce jour, toutes les recherches faites dans ce but ont été de capter dans l'atmosphère une seule catégorie de courants atmosphériques, c'est-à-dire, qu'on a réuni dans un même système de captation, deux pôles opposés et dont l'effet a été de se détruire ou de s'annuler l'un à l'autre laissant comme quantité que la différence du plus fort au plus faible.

Il sera donc facile de comprendre pourquoi, en considérant les deux pôles d'un courant atmosphérique comme à peu près égaux, il est presque impossible par certains temps de mesurer le potentiel avec la terre, du plus fort sur le plus faible subsistant et qui peut être positif ou négatif, suivant que le plus fort est de l'une ou de l'autre de ces polarités.

C'est sur cette base que toutes les recherches jusqu'à nos jours ont été faites et c'est pourquoi, il faut considérer que par tous les temps, entre les deux pôles captés dans l'atmosphère et non mélangés dans aucun des systèmes de captation, il est possible d'obtenir, en tension et en intensité, une puissance aussi considérable que l'on puisse désirer et qui sera mesurée entre les deux pôles captés séparément et toujours isolés l'un de l'autre jusqu'à leur utilisation.

Suivant l'invention, cette captation se fait par attraction dans l'atmosphère au moyen d'un amorçage des courants électriques, soit positif ou négatif, par une antenne à deux pointes absolument isolées l'une de l'autre, dont l'une tournée vers le zénith attire les couches d'électricité négative, et l'autre, tournée vers le sud, puise vers l'équateur, dans les masses groupées dans cette zone.

Ceci exposé et l'existence des courants électriques atmosphériques étant prouvée, il est possible de les capter à la condition de disposer d'appareils spéciaux étudiés surtout pour jouer le rôle de régulateurs, attendu que la difficulté persistante rencontrée jusqu'alors pour réaliser la captation incombe aux grandes variations de tensions sous lesquelles les courants atmosphériques se présentent dans l'espace, pour chacun des pôles, et dont l'écoulement dans un poste de captation serait inévitablement funeste.

Le présent brevet sous sa forme de présentation doit donc couvrir, non pas le ou les dispositifs régulateurs qui sont prévus dans le système, car ils peuvent être conçus d'une façon toute différente et donner le même résultat, mais sur l'application raisonnée et le groupement d'appareils fonctionnant automatiquement et intervenant chacun comme relais d'influence variable pour limiter la tension des courants captés dans l'atmosphère à celle choisie pour utilisation.

Ces appareils ont un rôle assez connexe avec celui de trop-pleins sur un réservoir qui acheminent à l'extérieur l'excès de liquide; ici ces régulateurs détournent l'excès de tension des courants à la terre.

On peut encore assimiler ces régulateurs à des filtres car ils ont pour but de détourner du poste d'utilisation, des courants qui ne sont pas encore de nature connue mais que pour simplicité on appellera courants parasites ou anormaux.

Le brevet portera aussi sur le système de régulation des courants, appliqué à chacun des pôles, car il est reconnu que la forme et la tension des courants aux deux pôles ne sont pas équivalentes.

Le mode de captation par antenne spéciale à deux pointes orientées dans l'atmosphère, comme il sera indiqué ci-après, avec amorçage préalable pour l'écoulement des courants atmosphériques est aussi d'une grande importance.

Enfin la réception des courants atmosphériques se fait à l'endroit même de l'installation du poste; celui-ci peut être prévu en un lieu quelconque sans nécessiter d'altitude particulière, comme cela a été tenté dans des essais préconçus.

Sur les dessins ci-annexés auxquels on se réfère

La fig. 1 représente en élévation et en coupe partielle l'antenne seule, à deux pointes, surmontant un poteau d'élévation;

La fig. 2 est le plan de l'une des pointes, celle horizontale:

La fig. 3 montre schématiquement le tableau sur lequel sont montés les divers appareils ou accessoires qui jouent le rôle de régulateurs des tensions de courants.

La fig. 4 est un schéma de parafoudre, et

La fig. 5 un tableau de résistances.

Le dispositif nécessaire à la captation des courants atmosphériques est formé comme suit :

1° D'une antenne, fig. 1, formée de deux pointes dont l'une 1 est en acier, supportée par une bague de bronze 2 entourée d'une spirale 3 formant self; cette pointe est tournée vers le zénith pour attirer les couches d'électricité négative; l'autre pointe 4 comporte un cadre 5 de huit branches supportant des spirales de cuivre 6 et est tournée vers le sud pour puiser vers l'équateur dans les masses groupées dans cette zone. Pour l'utilisation de cette antenne il suffira qu'elle soit portée par un mât ou poteau de hauteur un peu supérieure à celle des habitations environnantes.

2° D'un tableau de parafoudre, fig. 4, formé de cornes de cuivre 7 servant à absorber les tros grosses décharges atmosphériques que par certains temps, il serait dangereux de laisser circuler dans les appareils régulateurs.

3° D'une table de deux systèmes symétriques de régulateurs, fig. 3, un pour chaque pôle, qui permet d'obtenir une régularisation assez grande dans les tensions des courants en absorbant automatiquement les surtensions dépassant la tension choisie pour l'utilisation désirée. Ces régulateurs sont représentés sur le dessin par les références R, R^1, R^2, R^3, R^4.

4° D'un tableau de résistance en communication avec les régulateurs, ces résistances sont formées de spirales de maillechor 8, de tubes 9 de verre remplis de poussière fine de charbon de cornue, de poudre d'aluminium, de soufre et de poussière fine de cuivre; enfin, deux appareils spéciaux 10 formant transformateurs et constitués de couches de métaux absorbant certains courants nuisibles ou anormaux.

5° D'une source auxiliaire d'énergie formée de piles 11 et de bobines Ruhmkorff 12 permettant d'obtenir dans l'antenne une attraction suffisante au moyen d'un dispositif de

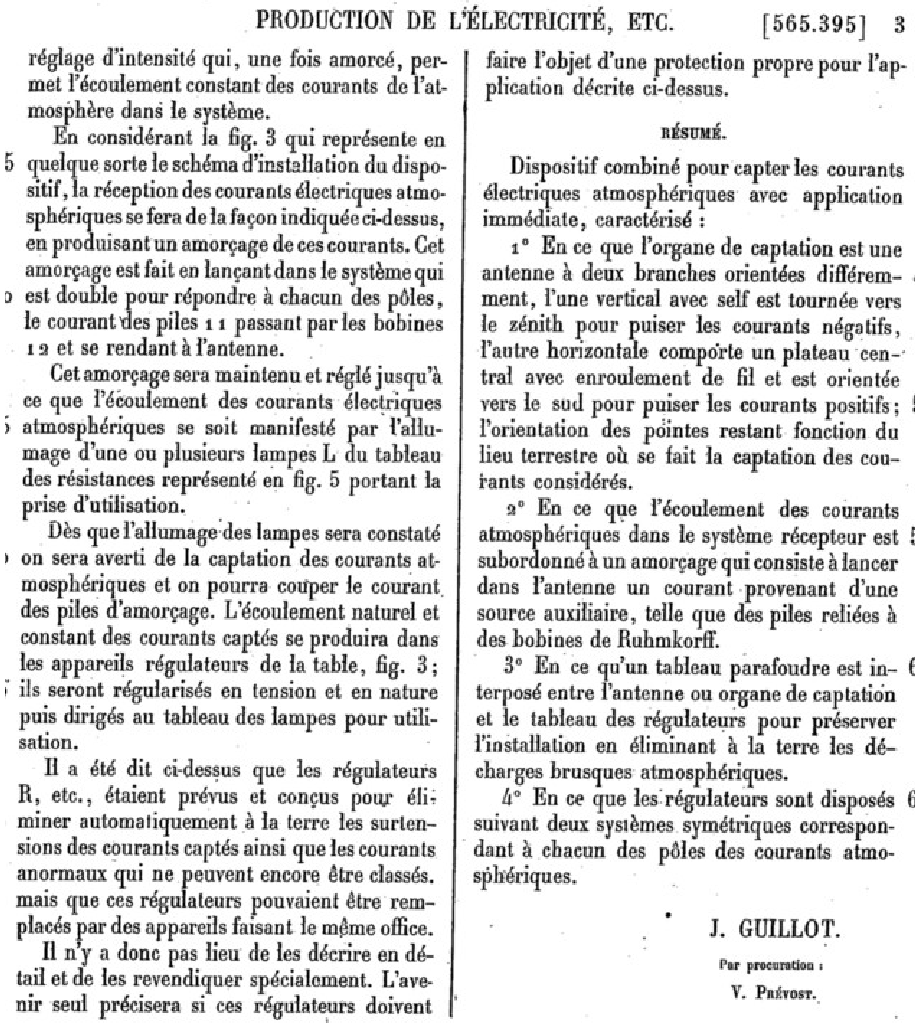

réglage d'intensité qui, une fois amorcé, permet l'écoulement constant des courants de l'atmosphère dans le système.

En considérant la fig. 3 qui représente en quelque sorte le schéma d'installation du dispositif, la réception des courants électriques atmosphériques se fera de la façon indiquée ci-dessus, en produisant un amorçage de ces courants. Cet amorçage est fait en lançant dans le système qui est double pour répondre à chacun des pôles, le courant des piles 11 passant par les bobines 12 et se rendant à l'antenne.

Cet amorçage sera maintenu et réglé jusqu'à ce que l'écoulement des courants électriques atmosphériques se soit manifesté par l'allumage d'une ou plusieurs lampes L du tableau des résistances représenté en fig. 5 portant la prise d'utilisation.

Dès que l'allumage des lampes sera constaté on sera averti de la captation des courants atmosphériques et on pourra couper le courant des piles d'amorçage. L'écoulement naturel et constant des courants captés se produira dans les appareils régulateurs de la table, fig. 3; ils seront régularisés en tension et en nature puis dirigés au tableau des lampes pour utilisation.

Il a été dit ci-dessus que les régulateurs R, etc., étaient prévus et conçus pour éliminer automatiquement à la terre les surtensions des courants captés ainsi que les courants anormaux qui ne peuvent encore être classés, mais que ces régulateurs pouvaient être remplacés par des appareils faisant le même office. Il n'y a donc pas lieu de les décrire en détail et de les revendiquer spécialement. L'avenir seul précisera si ces régulateurs doivent faire l'objet d'une protection propre pour l'application décrite ci-dessus.

RÉSUMÉ.

Dispositif combiné pour capter les courants électriques atmosphériques avec application immédiate, caractérisé :

1° En ce que l'organe de captation est une antenne à deux branches orientées différemment, l'une vertical avec self est tournée vers le zénith pour puiser les courants négatifs, l'autre horizontale comporte un plateau central avec enroulement de fil et est orientée vers le sud pour puiser les courants positifs; l'orientation des pointes restant fonction du lieu terrestre où se fait la captation des courants considérés.

2° En ce que l'écoulement des courants atmosphériques dans le système récepteur est subordonné à un amorçage qui consiste à lancer dans l'antenne un courant provenant d'une source auxiliaire, telle que des piles reliées à des bobines de Ruhmkorff.

3° En ce qu'un tableau parafoudre est interposé entre l'antenne ou organe de captation et le tableau des régulateurs pour préserver l'installation en éliminant à la terre les décharges brusques atmosphériques.

4° En ce que les régulateurs sont disposés suivant deux systèmes symétriques correspondant à chacun des pôles des courants atmosphériques.

J. GUILLOT.

Par procuration :

V. Prévost.

Parts List

Steel Rods, magnetic, 2
Insulator, porcelain
Ring, bronze
Rods, soft iron, 32
Ring, copper
Surge Protector
Disk, copper
Ring, tin
Tubes, steel
Rx Cu-Pb, Fe-Pb
Breakers, automatic
Resistances : Wire Mesh, Glass Tube. Cu, C, S powder
Vacuum Cleaners : Box, Jar, Mica &
Tube, copper;
Rx : Hg, Sn, C, Cu, S
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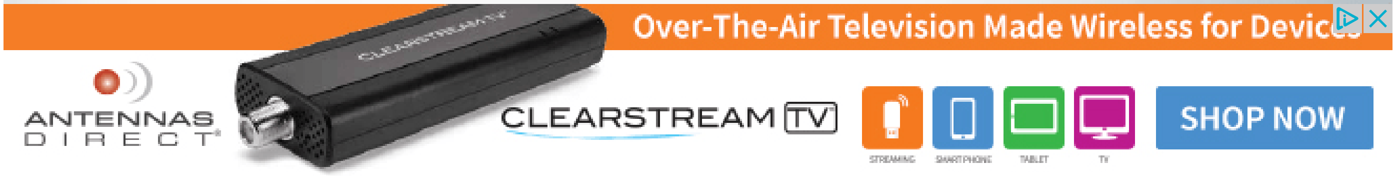
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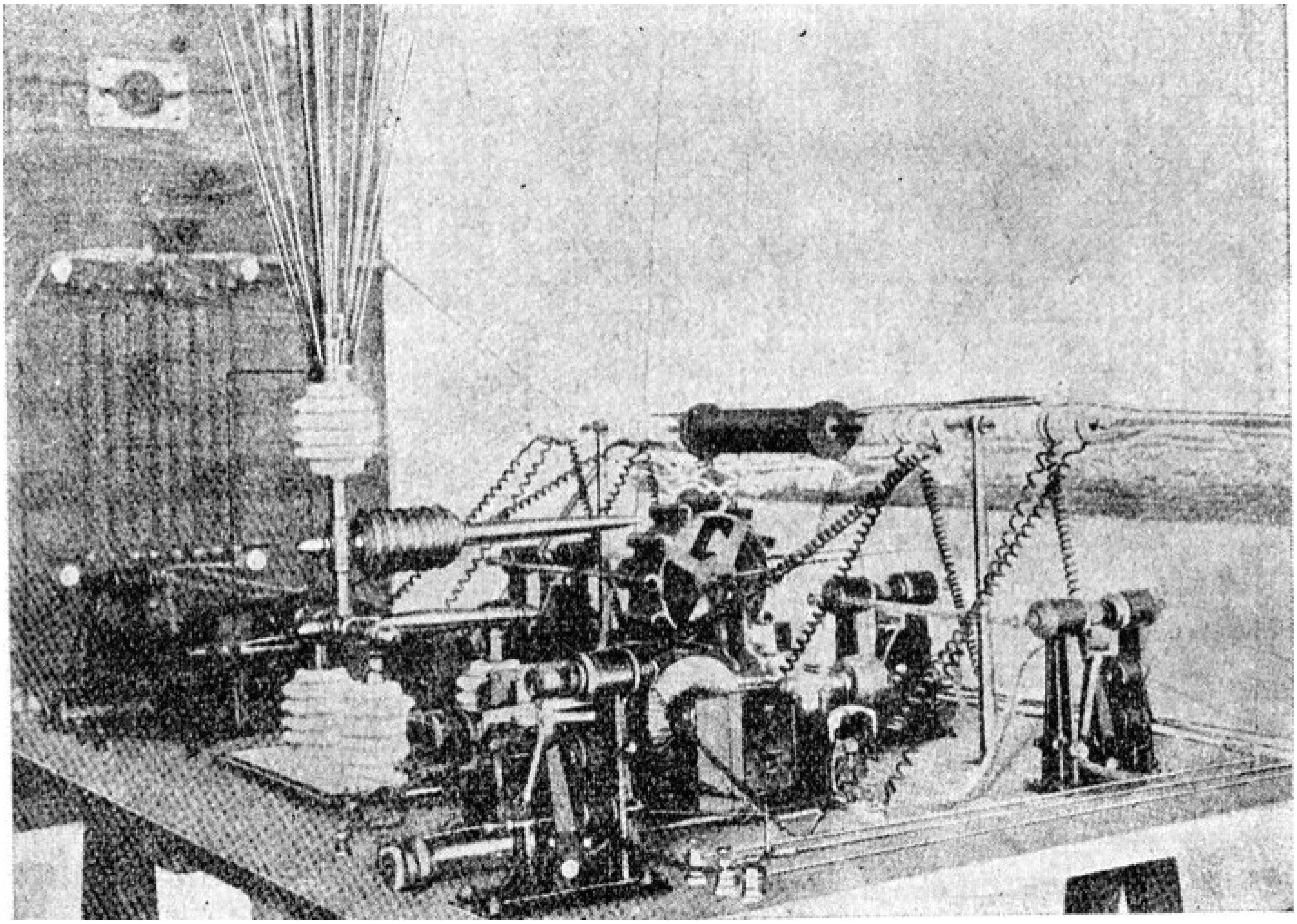

Shared by L. Cozma (Thanks !) --

The Guillot device generated about 2.5-3 Kilowatts with antenna height of ~ 20 meters. Power depends on the total collector surface and height of the vertical antenna. The apparatus in the photo produced ~300 watts with a collector 2 meters tall.

"Practical Utilization of Atmospheric Electricity"

by

Gillbert Darida

in *The Invention Encyclopedia,* pp. 204-207 (1930, Geo. Constantinescu, Ed.)

"The Earth has its own negative electricity, in the soil, and the atmosphere which surrounds the Earth is charged with positive electricity. The electric potential (the voltage) increases with the altitude, so we can say that the electric force is proportional to the atmospheric altitude (after Franklin, Quetelet, Lord Kelvin, Mascart, Joubert and other scientists).

The recent observations demonstrate that the air at 6000-7000 meters in altitude, is very highly charged with positive electricity, which could be explained by the friction between the external photosphere and the upper atmosphere of Earth, which rotates at a speed of more than 100,000 Kilometer per hour.

In that way, the Earth works like an electrostatic generator with electric charging by influence --- the upper atmosphere is positively charged by influence and the Earth crust obtains the negative polarity.

Between the two environments, the air and the soil, and inside the low atmosphere, in conditions of good weather, there are sbout 800 positive ions and also, 680 negative ion (and electrons) in just one square-centimeter of normal ionised air.

The Earth behaves like an huge electric armature negatively charged, which repels the electrons and attracts the positive ions. That positive ions' attraction determinates an electric current, also called "convective current". That's like an invisible continous bombardment, subject to daily and seasonal variations, which could be aproximated at **3 x 10 ^ -16 Amperes per square-centimeter,** and that is a total value of 1500 Amperes for the entire surface of the Earth.
The question is --- how does this current always maintains the same direction ? We can suppose that the natural radioactive emissions of the soil is responsable for this. We also know that radioactive emissions of the Earth works usually near the soil surface, and that explains the ionisation phenomenona inside caves.

The ionisation of the low atmosphere could also be the effect of the radioactive emissions of the Earth, especially when the X radiation works. Also, the Earth atmosphere is ionisated by the external radiation proceeding from the Sun and from the space environment, especially the action of ultraviolet radiation and the electron fascicles emitted by the Sun surface, at the temperature of 6000 deg. Celsius.

The capture of atmosphere electricity has been used in France, with aerial cables mounted on the Mont Blanc, and also in Germany --- with conductive cables carried by the captive baloons.

The atmosphere electricity collect system invented by eng. Jules Guillot is most ingenious and it relies on "the **electric siphon**" [*m.n. --- the discharging devices or spark-gap used today from the protection of aerial electric cables against the atmospheric electricity ; Jules Guillot has thought to recuperate and to use that electricity*].

His method consisted in the direct "pumping" of the atmosphere electricity using a collecting device which had two antennae and several collecting rods.

One antenna is **vertical** and it has a lot of **rods** scattered like an opened **fan**, with the tips against the **zenith**, for collecting the **negative** electricity which comes from the air ; the **horizontal** antenna is orientated against the **South** and its role is to collect the **positive** electricity.

The air electricity seems to have the double-polarity, as we can see at two electrised clouds when between them apears the electric discharge. The air could have different electric charging and the ionisation processus of atmosphere is very heterogenous. The inventor Guillot used **two separated and insulated armatures with the positive armature against the South** (more precisely, against the **Equator**...) and the **negative** armature against the **zenith**.

We can see in the scheme :

1,- the device P is the "**collector apparatus**" having **15-20 meters height** ; it also has a lot of **rods** which are scattered **fan**-like, all this on top of an **iron pillar** ; and also an **horizontal antenna** S oriented against the **South** ; the two antennae are disposed at **90 deg. angle** forming the two armatures where the electrical tension must apear. As the **height** of the pillar **increases**, the **voltage** increases more and more ;

2,- a system of **lightning-rods** (p1, p2, p3) for protection against discharges of atmospheric electricity during storms;

3,- the regulator system (**voltage regulator**, etc) R ;

4,- the electric **resistors** (Cn) for absorbing the parasite currents ;

5,- the "electric siphons" which have the role of making a magnetic field as a good environment for the transport of the ionized fluid, absorbing the electricity from the air ; the E1 and E2 are their regulator devices ;

6,- an **auxilliary continous current power supply** which send the current against an special **excitation coil**, used as starting device ; it works only when the system is starting.
This collector device works very good for lighting and heating. The device made by Guillot had **20 meters height** on the total surface of **3 square-meters**. Also, J.Guillot used and electrical transformer for the industrial utilization of this "collector" --- as power supply for industrial electric engines."

French Patent # 551,882

Apparatus for Capture of Electric Currents in the Atmosphere

16 April 1923

Considering the terrestrial globe like the inductor of a dynamo, where the extraterrestrial ether is the inductor of electric currents circulating in the atmosphere; the apparatus of the invention described here selects through the device described below two perfectly distinct currents and eliminates others.

The device includes:

1, The air sensor; 2, a series of lightning rods; 3, vacuum; 4, an array of resistances; 5, vacuum; 6, witnesses.

1. An aerial sensor mounted on a pole is composed of **magnetic steel** fixed and sealed by a porcelain **insulator**, and surrounded a base by a **bronze ring** which are screwed **32 points of soft iron**, all forming antenna a pole. level beside it and isolated from the first, forming the 2nd pole, is fixed a sharp point of magnetic steel fixed in the horizontal position and directed towards the south and **movable to an angle of 45** is sealed in a porcelain insulator. This point is also circled a **ring of copper** notches figure. 1.

2. A series of 6 lightning surge arrestors at corners between each pole and the earth and the various gauges.

3. A first **regulator** form of a device similar absolutely similar to the aerial amtenna, but the two poles are superposed and opposed to the vertical point, and a **copper disk connects to ground**. Opposite the horizontal point, a **ring of tin** to which are welded tubes alternatively **16 tubes** composed each composed of **copper-lead** and **iron-lead** . The ring connects to the **ground** as shown in figure. 2.

A second regulator form of **automatic breakers** balanced on 3 poles and two poles also equally balanced.

4. A panel of **resistances** composed of **wire mesh** in bunches from different sections of **glass tubes** containing **copper** dust, **coal** and flowers of **sulfur**.

Vacuum cleaners consists of a **wooden box** on each pole, containing a **porcelain vase** in which **layers** isolated with **mica** is made up of **mercury, tin, coal, copper** and **sulfur**, all contaied in a **copper tube**.

6. The witnesses are comprised of ordinary incandescent lamps.

Resume

By the point at the zenith and the point to the south we channel two currents forming the two poles. We also protect from lightning. It regularizes the flow by a regulator and similar devices by a controlling each devise of adequate strength of the current harmful nature of these devices do not have loads. The refined current is conducted by ordinary copper wires**.**

French Patent # 565,395

Combined Apparatus for Capture of Atmospheric Electric Currents with Immediate Implementation

25 January 1924

We know that earth with its constitution, its rotation and movement in space, provides the electricity in the atmosphere. The electrical currents escape into space or largely accumulate towards the equator, as a result of the greater periphery of the globe.

In the atmosphere, there are two clearly distinct poles, i.e., clouds that can be electrically positive or negative; everything in nature shows this, otherwise it would be difficult to explain the lightning that occurs between the clouds and which are none other than contrary cloud electrical charges discharged by too close proximity.

The invention relates to a set of devices capable of capturing the atmospheric electricity.

So far, all searches made for this purpose has been to capture the atmosphere, i.e., that brought together into one system to capture two poles and opposes effect has been to destroy or cancel each other leaving the amount as the difference of the strongest to weakest.

It is therefore easy to understand why, considering the two poles of air as about equal, it is almost impossible to measure some potential with the land, the highest on the lowest remaining which can be positive or negative, copper being the strongest of one or other of these polarities.

It is on this basis that all research until now have been made, and that is why we must consider that all the time, between the two poles captured in the atmosphere and not in any mixture of systems uptake, it is possible to obtain tension and intensity, a considerable and measurable power captured separately between the two poles and remaining isolated from one another until their utilization .

In accordance with this invention, this collection is made by attraction of primary electrical currents in teh atmosphere, either positively or negatively charged, by an antenna that has two points absolutely isolated from one another, where one points to the zenith to attract negative electricity, and the other turned south, toward the equator to draws in the masses grouped in this area.

This shows and proves the existence of atmospheric electrical currents, and that it is possible to capture them with specially designed equipment primarily acting as regulators, as the persistent difficulty encountered so far in realizing their capture lies with large variations of tension in which the current atmosphere is present in space, for each of the poles, and an overload could inevitably fatal.

The patent in its present form of presentation does not cover the regulators or devices that are anticipated in the system, because they can be designed in different ways and give the same result, but covers the application and grouping of equipment operating as automatic relays with variable influence to limit current tension to that chosen for utilization.

These devices have a role associated with an overflow reservoir outside carrying excess liquid; these regulators will divert the excess voltage flows to ground.

We can still absorb these regulators having filters because they have the sole purpose of diverting the post being used , currents that are not yet known but likely that we will call for simplicity, abnormal currents. [sic...]

The patent also covers systems for regulating currents, applied to each of the poles because it is recognized that the shape and tension of the currents of the two poles are not equivalent.

The method of capture is by special antenna has directed two points in the atmosphere, as will be stated after this, with Boot ecoulement prior to the current atmosphere is also of great importance.

Finally, the current atmospheric reception is adequate even with the installation of a post, which can be expected at any location without the need for special altitude, as has been attempted in previous efforts.

We refer to the attached drawings:.

Figure 1 represents in elevation and side view an antenna that only has two points, to overcome an elevation ;

Figure 2 is the end of one of the peaks, the horizontal:

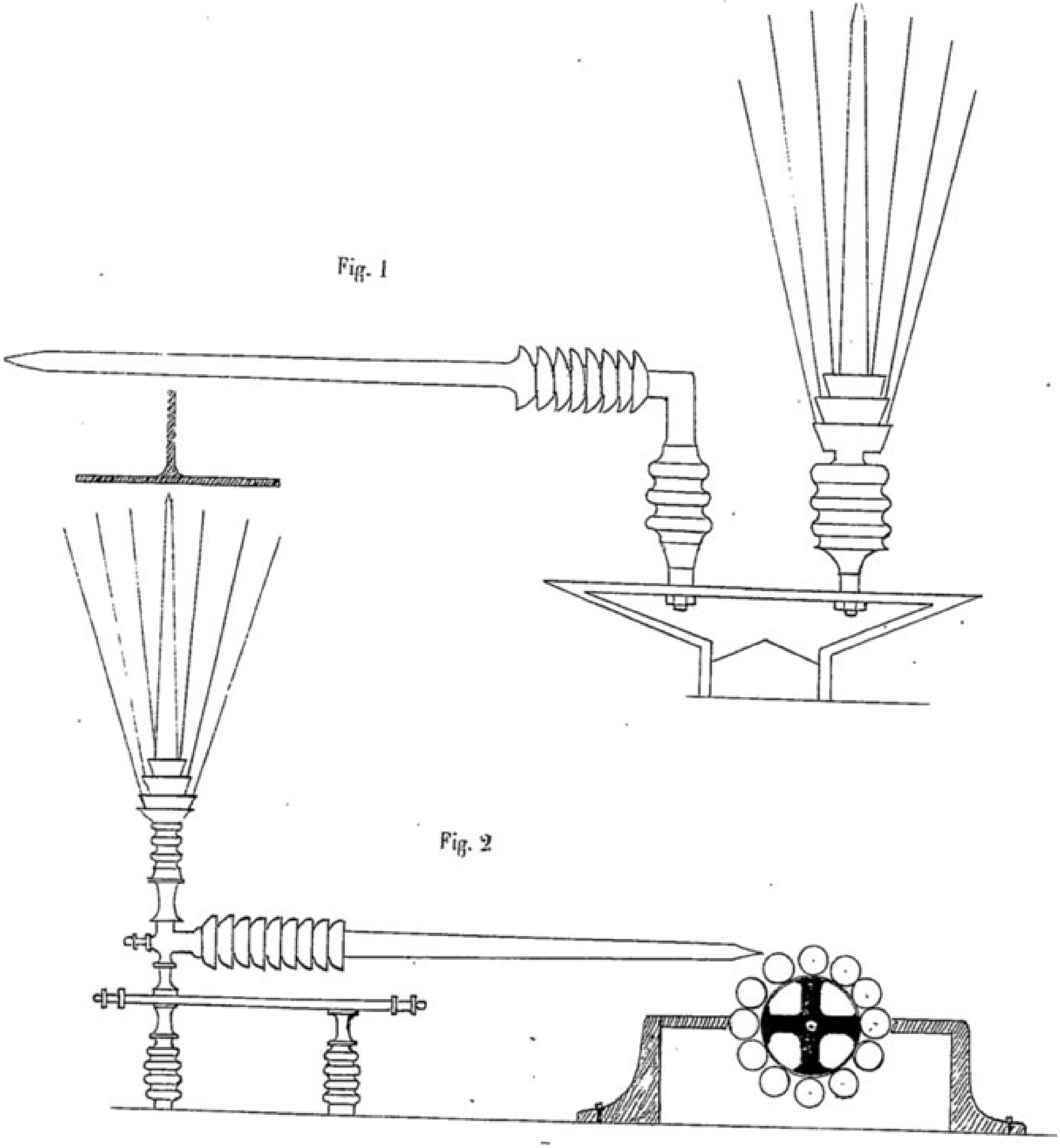

Fig. 1

Fig. 2

Figure 3 shows schematically the table on which are mounted various devices or accessories that act as regulators of current tensions.

Fig.3.

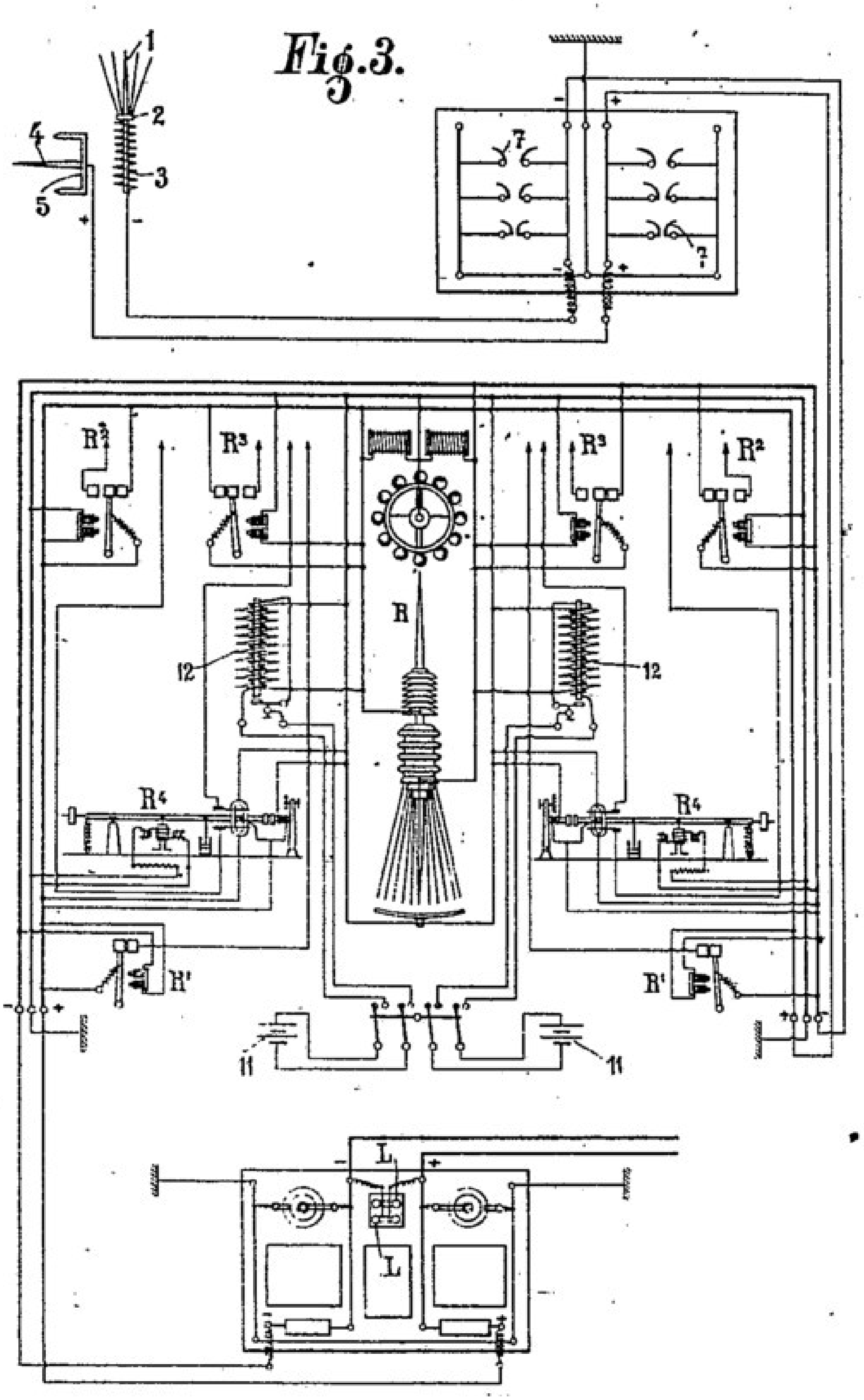
1
2
3
4
5
+
-
7
7
R²
R³
R³
R²
R
12
12
R⁴
R⁴
R¹
R¹
11
11
L
L

Figure 4 is a scheme of surge arrestors, and

Figure 5 a table of resistances.

Fig. 4.

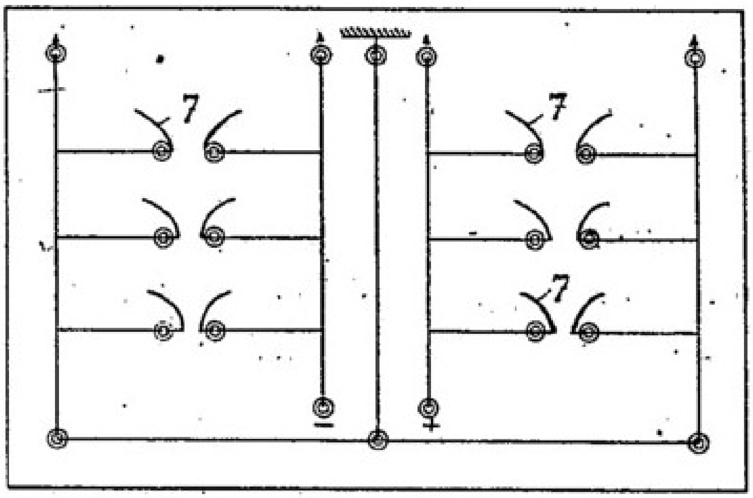

Fig. 5.

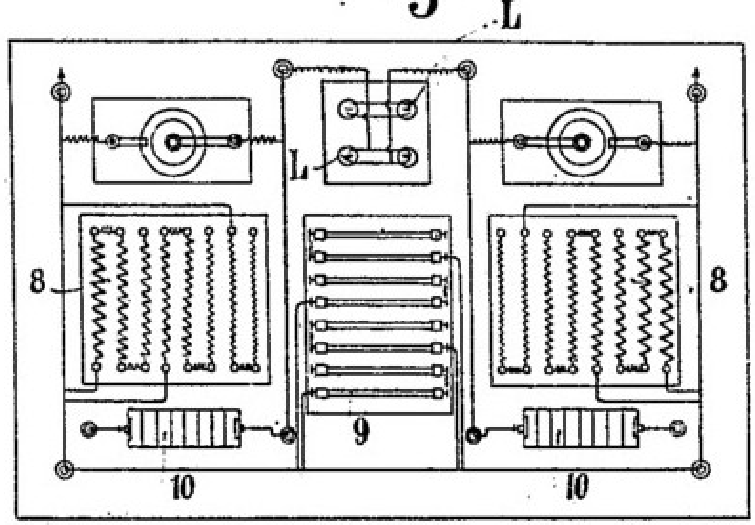

The necessary arrangements to capture atmospheric current form is as follows:

1. The **antenna** in figure 1 is formed with two peaks: the 1 is **steel**, supported by a **bronze ring** 2, surrounded by a **spiral form** 3; this point is oriented for attracting the **zenith** layers of **negative electricity** and the other edge 4 contains **copper coils** 6, and is oriented **south** to the **equator** to draw in the masses grouped in this area. To use this antenna it suffices to be raised on a mast or **pole** to a height a little higher than that of surrounding houses.

2. On the table **lightning arrestors**, contained 4, forms of 7 **copper horns** used to absorb large atmospheric discharges by certain time, as it would be dangerous to allow movement in the devices regulators.

3. On a table of **two** symmetrical systems **regulators**, Figure 3, one for each pole, to obtain and allow a regularization of large excesses in the current tensions, by automatically absorbing surges before passing over the surfacea chosen for the desired use. These regulators are represented on the drawing by the references R, R1, R2, R3, R4.

4. In the **resistance** panel in communication with regulators, these resistances are formed as **spiral coils or screens** 8, **tubes 9 of glass filled with fine coal dust , aluminum powder, sulfur and fine copper dust**. Finally, **two** special 10 **processors** and constitutes **layers** of metal forming an **absorbant** for harmful or abnormal currents.

5. As a source of energy formed **auxiliary batteries** 11 and **Ruhmkorff coils** 12 to get into the antenna sufficient attraction by means of an adjustment of intensity, which once it begins, allows the constant flow of atmospheric current in the system.

In considering Figure 3, which represents a sort of an installation scheme of the device, the reception of atmospheric electrical current will, as set out above, producing a priming of these currents. This boot is made in launching the system which is double to answer each of the poles, the current batteries 11 through 12 and reels going to the antenna.

This boot will continue until the disposal of electrical current atmosphere is evident by the one or more table lamps L of resistance shown in Figure 5.

Once the lights illuminate it is advisable to charge the batteries to boot. Natural flow and constant currents will be captured by the regulators , Figure 3; they will regularize in tension and in amperage and then directed to use in table lamps.

It has been said above that regulators R, etc., are intended and designed to automatically eliminate earth surge currents capture and abnormal currents that cannot yet be level but that these regulators could be replaced by devices with the same function.

There is therefore no need to describe in detail and especially the claims. We only specify that these regulators must be proper protection for the purposes described above.

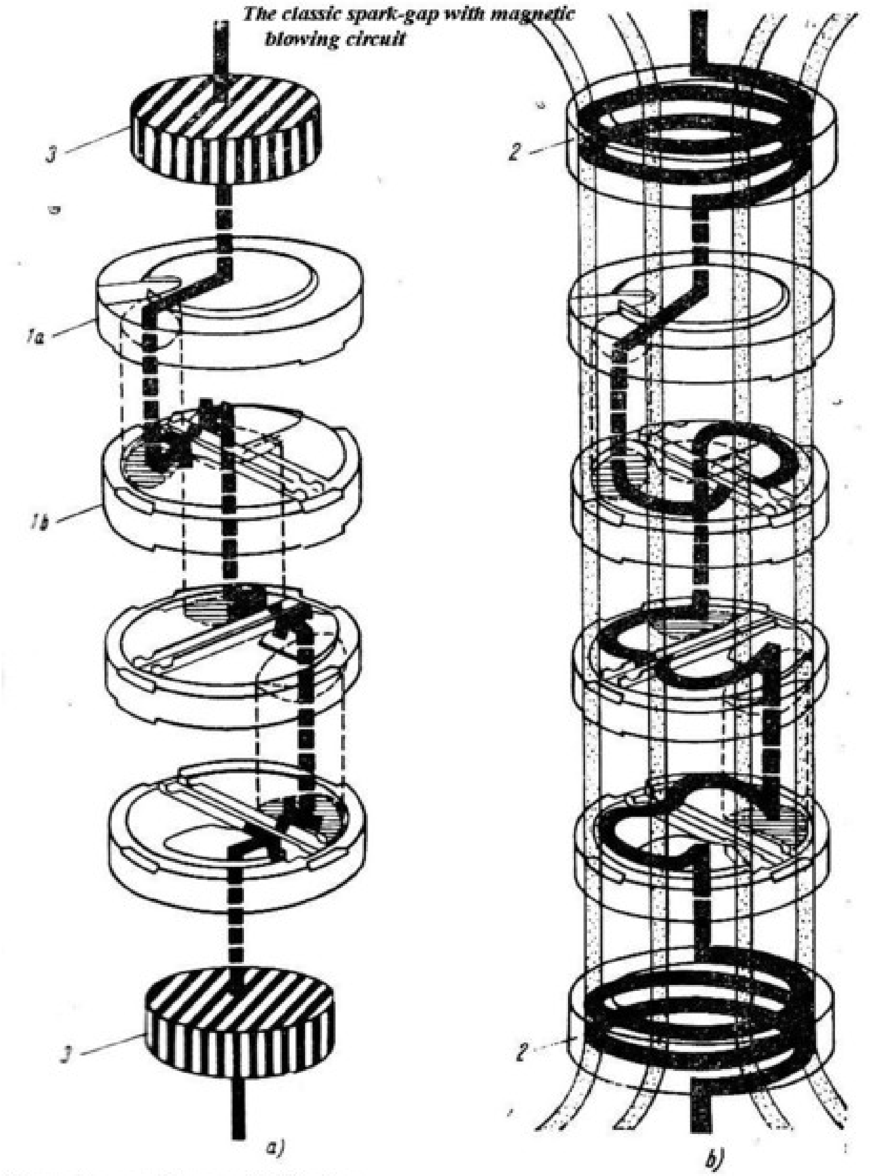
The classic spark-gap with magnetic blowing circuit

The spark-gap with magnetic blowing :
a,- the initial stage ; the impulse current send in soil through the shunt-resistences 3, because the coils 2 have an impedance too big for the impulse of 10/20 μs ;
the spark-gap 1 has two elements disc-shaped 1a and 1b, the inferior disc have one electrode and the upper disc the other electrode of the spark-gap circuit.
b,- the second stage ; the accompanying current discharge - after the impulse current ;
this accompanying current pass through the coils 2 which produce the magnetic field with the role to extend the electric arc into the slit between insulator discs 1a and 1b ; the thickness of this slit is smaller and smaller in accord with the extension of the electric arc, in this manner producing the magnifing of its electric resistance and finally, the electric arc extinction.

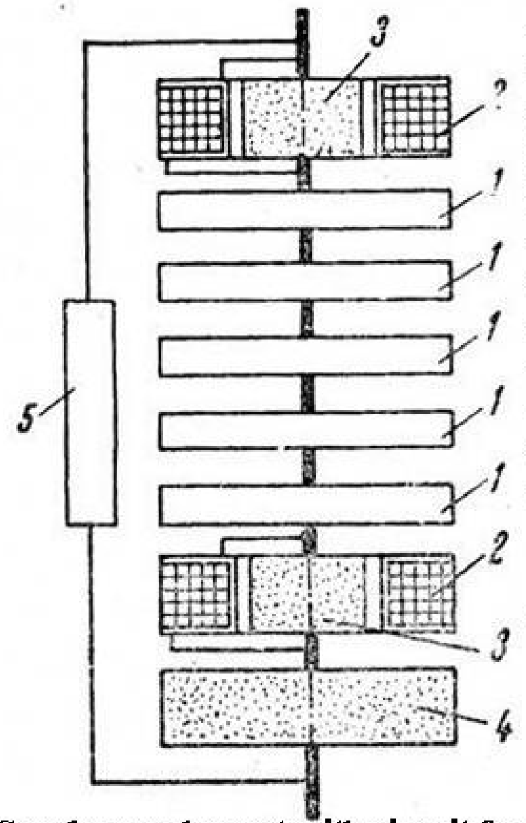

1,- the spark-gap individual devices which work in the manner to extend the electric arc of the accompanying electric current ;
2,- the coils which produce the magnetic field for the magnetic blowing ;
3,- the electric shunt-resistances in parallel connection on the blowing coils, with the role of reducing the current inside this coils
4,- the disc with unlinear resistance ;
5,- electrical resistance for the homogenous distribution of the electric field in all the elements of the spark-gap.

In Jules Guillot scheme, that kind of device could be used for leading the current.

Spark-gap element with circuit for the magnetic blowing of the electric fascicle

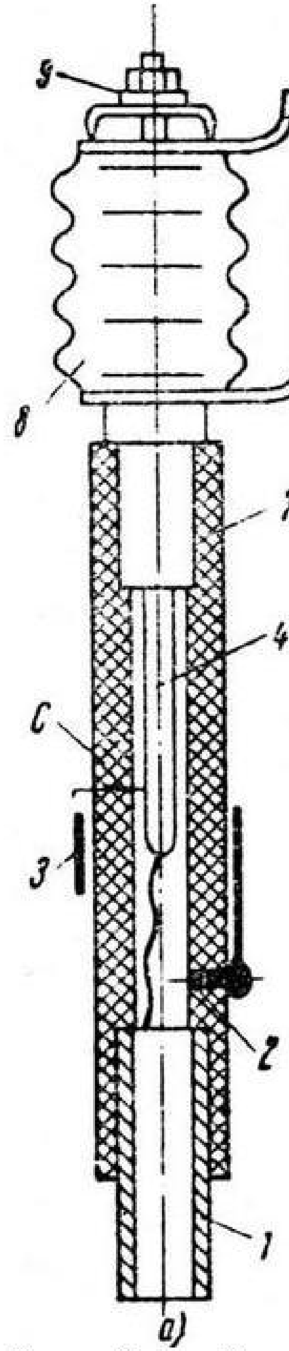

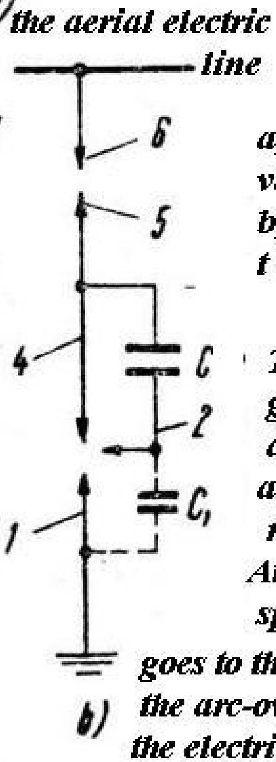

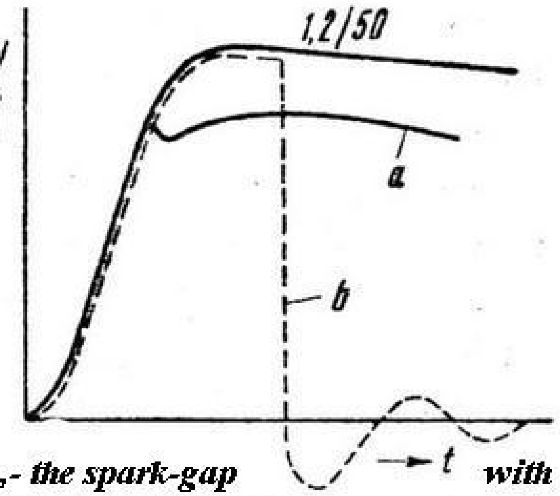

a,- the spark-gap with variable resistance ;
b,- the tube spak-gap ;
t - the time

The tube spark-gap has the aerial spark gap with the electrodes 5 and 6 disposed at the insulator 8 extremities ; and one arc-over spark-gap device between the rod 4 and the electrode 1. At start, the first spark apear in the aerial spark-gap and then, the electric dicharge goes to the gas-producing tube 7, where it makes the arc-over. The local pressure in the gas allow the electric arc extinction, after managing the over electric tension into soil. The capacity C which is created between the external ring 3 and the rod 4 is bigger than the Capacity C_1 between 1 an 2 in that manner, when the overtension apears, the auxiliary spark-gap 1, 2 will start working and then, the main spark-gap 1, 4. In this circuit, the electrode 9 is connected at the aerial electric line and the electrode 1 at the Earth.

In the image above, it is an classic tube spark-gap used for the protection of aerial electric cables. The atmospheric electricity is discharged in soil and lost... The Guillot's inventions used that kind of devices for leading and absorbing of the atmospheric electricity.

DARIDA, Gillbert : "Practical Utilization of Atmospheric Electricity";
(in *The Invention Encyclopedia,* pp. 204-207 ; 1930, Geo. Constantinescu, Ed.) --

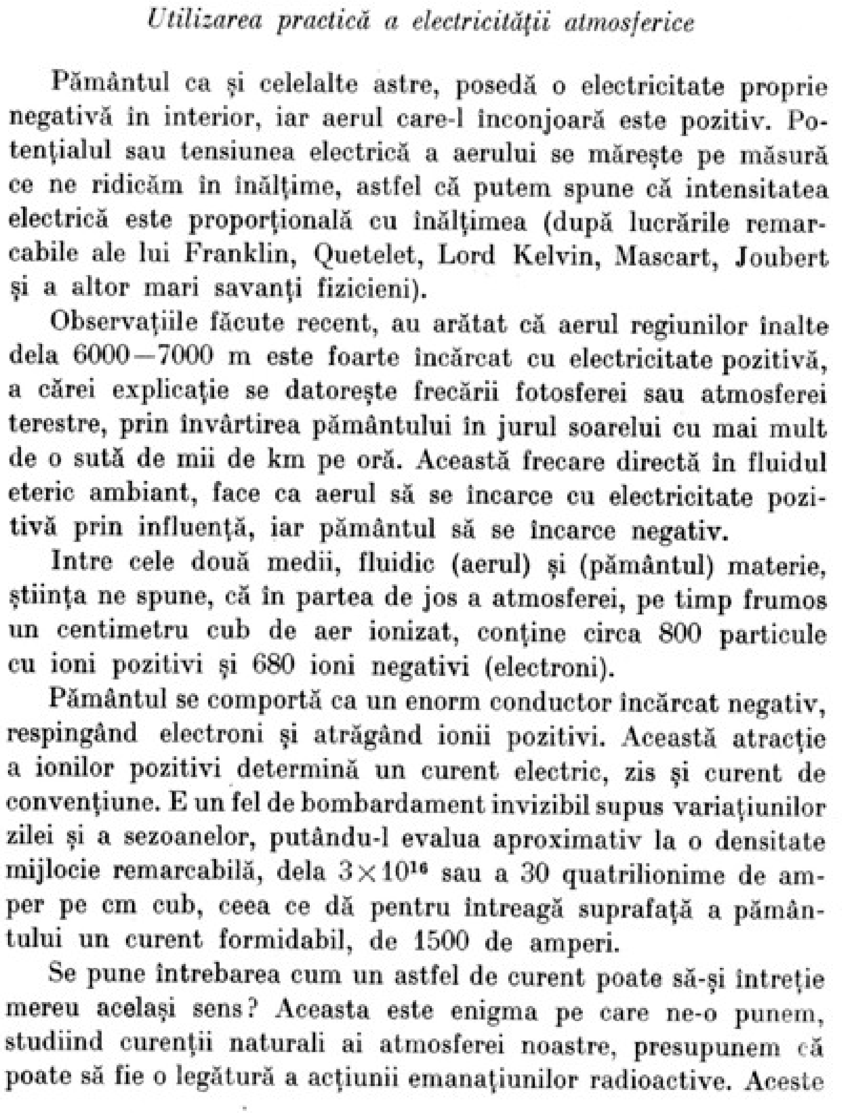

Utilizarea practică a electricităţii atmosferice

Pământul ca şi celelalte astre, posedă o electricitate proprie negativă în interior, iar aerul care-l înconjoară este pozitiv. Potenţialul sau tensiunea electrică a aerului se măreşte pe măsură ce ne ridicăm în înălţime, astfel că putem spune că intensitatea electrică este proporţională cu înălţimea (după lucrările remarcabile ale lui Franklin, Quetelet, Lord Kelvin, Mascart, Joubert şi a altor mari savanţi fizicieni).

Observaţiile făcute recent, au arătat că aerul regiunilor înalte dela 6000—7000 m este foarte încărcat cu electricitate pozitivă, a cărei explicaţie se datoreşte frecării fotosferei sau atmosferei terestre, prin învârtirea pământului în jurul soarelui cu mai mult de o sută de mii de km pe oră. Această frecare directă în fluidul eteric ambiant, face ca aerul să se încarce cu electricitate pozitivă prin influenţă, iar pământul să se încarce negativ.

Intre cele două medii, fluidic (aerul) şi (pământul) materie, ştiinţa ne spune, că în partea de jos a atmosferei, pe timp frumos un centimetru cub de aer ionizat, conţine circa 800 particule cu ioni pozitivi şi 680 ioni negativi (electroni).

Pământul se comportă ca un enorm conductor încărcat negativ, respingând electroni şi atrăgând ionii pozitivi. Această atracţie a ionilor pozitivi determină un curent electric, zis şi curent de convenţiune. E un fel de bombardament invizibil supus variaţiunilor zilei şi a sezoanelor, putându-l evalua aproximativ la o densitate mijlocie remarcabilă, dela 3×10^{16} sau a 30 quatrilionime de amper pe cm cub, ceea ce dă pentru întreagă suprafaţă a pământului un curent formidabil, de 1500 de amperi.

Se pune întrebarea cum un astfel de curent poate să-şi întreţie mereu acelaşi sens? Aceasta este enigma pe care ne-o punem, studiind curenţii naturali ai atmosferei noastre, presupunem că poate să fie o legătură a acţiunii emanaţiunilor radioactive. Aceste emanaţiuni fiind din gaze radioactive grele, se găsesc de obiceiu în mare abundenţă aproape de pământ ceea ce ne explică marea ionizare observată în general în grote şi caverne.

Ionizarea atmosferică poate de asemenea fi produsă în parte, de acţiunea razelor X, foarte pătrunzătoare şi de diferite substanţe radioactive închise în subsolul pământului. De asemenea poate să mai fie, ţinând seama de acţiunea «Calei Lactee» şi de ionizarea luminei solare, foarte bogată în radiaţiuni ultraviolete

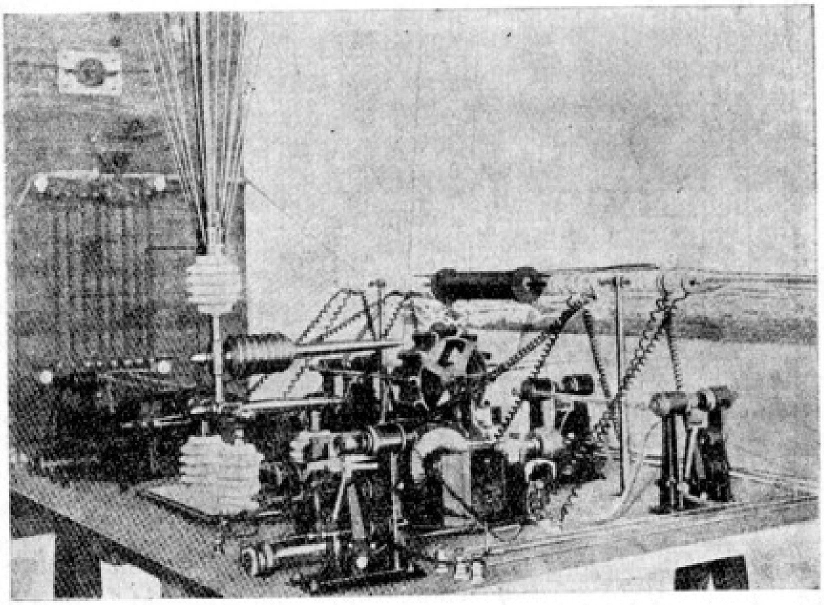

Fig. 108

precum şi a electronilor emişi direct din radierea căldurii solare de circa 6000 de grade.

Captarea electricităţii atmosferice a fost utilizată în Franţa prin cabluri aeriene montate pe Mont Blank, iar în Germania prin cabluri susţinute de baloane captive.

Sunt mai multe sisteme, vom da pe scurt pe cel mai ingenios procedeu, inventat de ing. Jules Guillot, bazat pe sifonul electric. Procedeul consistă de a pompa direct din atmosferă, electricitate

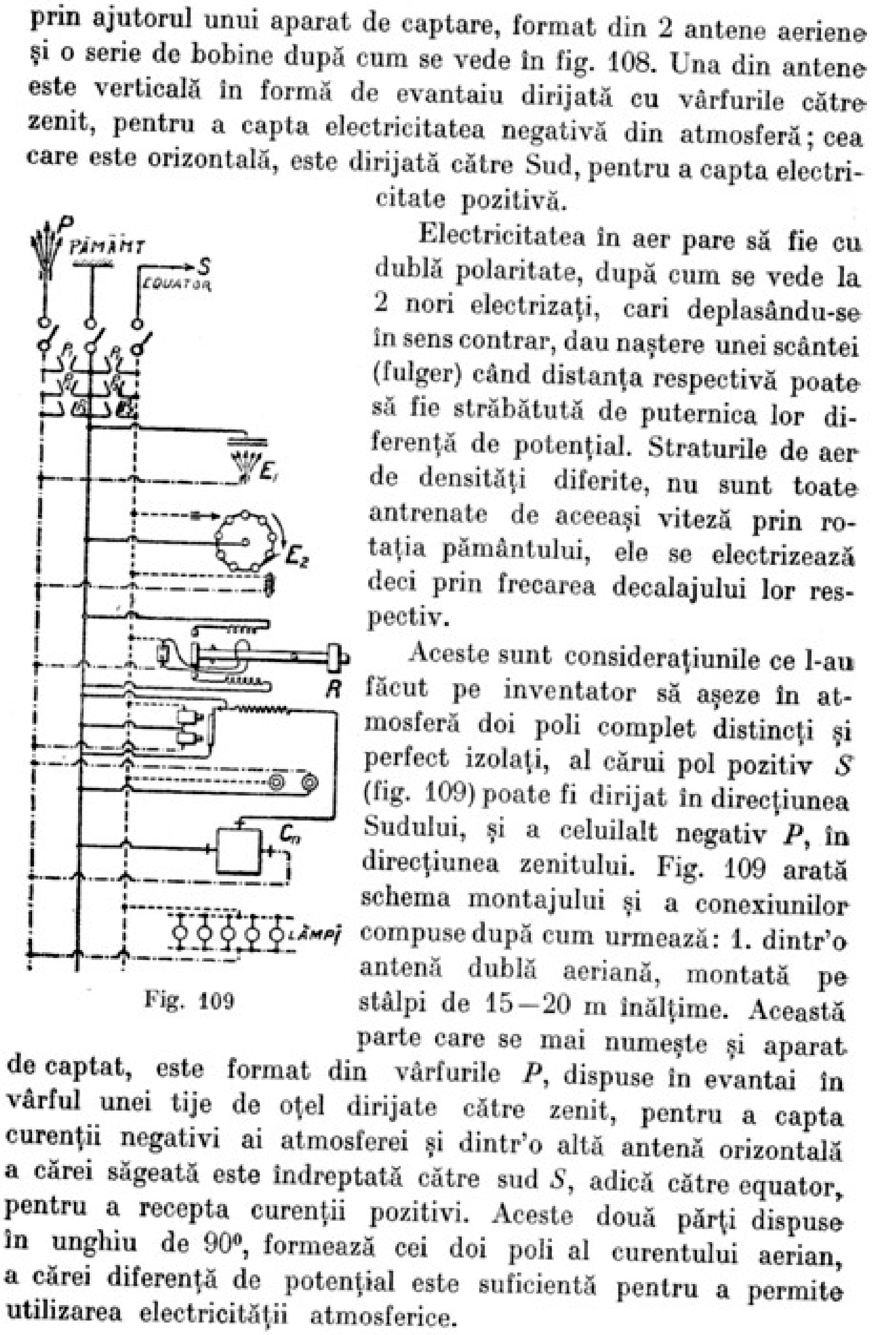

prin ajutorul unui aparat de captare, format din 2 antene aeriene şi o serie de bobine după cum se vede în fig. 108. Una din antene este verticală în formă de evantaiu dirijată cu vârfurile către zenit, pentru a capta electricitatea negativă din atmosferă; cea care este orizontală, este dirijată către Sud, pentru a capta electricitate pozitivă.

P
PĂMÂNT
S
ECUATOR
E₁
E₂
R
Cₙ
LĂMPI

Fig. 109

Electricitatea în aer pare să fie cu dublă polaritate, după cum se vede la 2 nori electrizaţi, cari deplasându-se în sens contrar, dau naştere unei scântei (fulger) când distanţa respectivă poate să fie străbătută de puternica lor diferenţă de potenţial. Straturile de aer de densităţi diferite, nu sunt toate antrenate de aceeaşi viteză prin rotaţia pământului, ele se electrizează deci prin frecarea decalajului lor respectiv.

Aceste sunt consideraţiunile ce l-au făcut pe inventator să aşeze în atmosferă doi poli complet distincţi şi perfect izolaţi, al cărui pol pozitiv *S* (fig. 109) poate fi dirijat în direcţiunea Sudului, şi a celuilalt negativ *P*, în direcţiunea zenitului. Fig. 109 arată schema montajului şi a conexiunilor compuse după cum urmează: 1. dintr'o antenă dublă aeriană, montată pe stâlpi de 15—20 m înălţime. Această parte care se mai numeşte şi aparat de captat, este format din vârfurile *P*, dispuse în evantai în vârful unei tije de oţel dirijate către zenit, pentru a capta curenţii negativi ai atmosferei şi dintr'o altă antenă orizontală a cărei săgeată este îndreptată către sud *S*, adică către equator, pentru a recepta curenţii pozitivi. Aceste două părţi dispuse în unghiu de 90°, formează cei doi poli al curentului aerian, a cărei diferenţă de potenţial este suficientă pentru a permite utilizarea electricităţii atmosferice.

French Patent # 551,882

Appareil Capteur de Courants Electriques dans L'Atmosphere

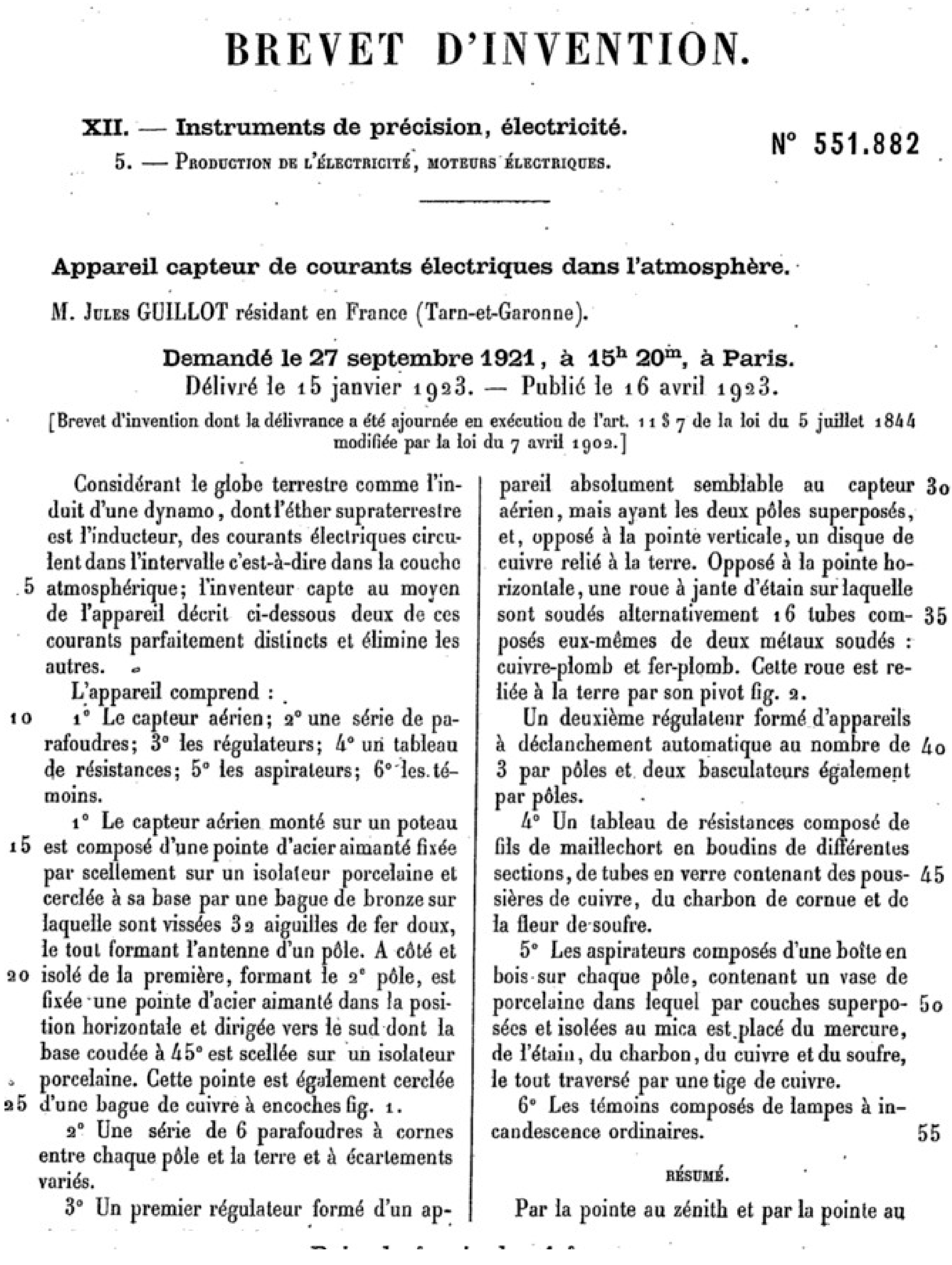

BREVET D'INVENTION.

XII. — Instruments de précision, électricité.

5. — Production de l'électricité, moteurs électriques.

N° 551.882

Appareil capteur de courants électriques dans l'atmosphère.

M. Jules GUILLOT résidant en France (Tarn-et-Garonne).

Demandé le 27 septembre 1921, à 15h 20m, à Paris.

Délivré le 15 janvier 1923. — Publié le 16 avril 1923.

[Brevet d'invention dont la délivrance a été ajournée en exécution de l'art. 11 § 7 de la loi du 5 juillet 1844 modifiée par la loi du 7 avril 1902.]

Considérant le globe terrestre comme l'induit d'une dynamo, dont l'éther supraterrestre est l'inducteur, des courants électriques circulent dans l'intervalle c'est-à-dire dans la couche atmosphérique; l'inventeur capte au moyen de l'appareil décrit ci-dessous deux de ces courants parfaitement distincts et élimine les autres.

L'appareil comprend :

1° Le capteur aérien; 2° une série de parafoudres; 3° les régulateurs; 4° un tableau de résistances; 5° les aspirateurs; 6° les témoins.

1° Le capteur aérien monté sur un poteau est composé d'une pointe d'acier aimanté fixée par scellement sur un isolateur porcelaine et cerclée à sa base par une bague de bronze sur laquelle sont vissées 32 aiguilles de fer doux, le tout formant l'antenne d'un pôle. A côté et isolé de la première, formant le 2e pôle, est fixée une pointe d'acier aimanté dans la position horizontale et dirigée vers le sud dont la base coudée à 45° est scellée sur un isolateur porcelaine. Cette pointe est également cerclée d'une bague de cuivre à encoches fig. 1.

2° Une série de 6 parafoudres à cornes entre chaque pôle et la terre et à écartements variés.

3° Un premier régulateur formé d'un appareil absolument semblable au capteur aérien, mais ayant les deux pôles superposés, et, opposé à la pointe verticale, un disque de cuivre relié à la terre. Opposé à la pointe horizontale, une roue à jante d'étain sur laquelle sont soudés alternativement 16 tubes composés eux-mêmes de deux métaux soudés : cuivre-plomb et fer-plomb. Cette roue est reliée à la terre par son pivot fig. 2.

Un deuxième régulateur formé d'appareils à déclanchement automatique au nombre de 3 par pôles et deux basculateurs également par pôles.

4° Un tableau de résistances composé de fils de maillechort en boudins de différentes sections, de tubes en verre contenant des poussières de cuivre, du charbon de cornue et de la fleur de soufre.

5° Les aspirateurs composés d'une boîte en bois sur chaque pôle, contenant un vase de porcelaine dans lequel par couches superposées et isolées au mica est placé du mercure, de l'étain, du charbon, du cuivre et du soufre, le tout traversé par une tige de cuivre.

6° Les témoins composés de lampes à incandescence ordinaires.

RÉSUMÉ.

Par la pointe au zénith et par la pointe au sud nous canalisons deux courants formant les deux pôles. On protège l'ensemble par des parafoudres. On régularise le débit par un régulateur semblable et par des appareils à déclanchement commandant chacun des résistances appropriées de la nature du courant nuisible dont ces appareils sont chargés. Les courants épurés sont conduits aux témoins par des fils de cuivre ordinaire.

Jules GUILLOT,
Moissac (Tarn-et-Garonne).

XII. — Instruments de précision, électricité.

5. — Production de l'électricité, moteurs électriques.

N° 565.395

Dispositif combiné pour capter les courants électriques atmosphériques avec application immédiate.

M. Jules GUILLOT résidant en France (Allier).

Demandé le 6 avril 1923, à 11^h 30^m, à Paris.
Délivré le 7 novembre 1923. — Publié le 25 janvier 1924.

On sait que la terre, par sa propre constitution, sa rotation et son mouvement dans l'espace, fournit à elle seule l'électricité que l'on utilise et qui est en suspension dans l'atmosphère. Les courants électriques, qui s'échappent de la surface du globe, montent directement dans l'espace où les grandes masses sont accumulées vers l'équateur, par suite de la plus grande périphérie du globe.

Dans l'atmosphère, il y a deux pôles parfaitement distincts, c'est-à-dire que des nuages peuvent être électrisés, soit d'électricité positive ou négative; ceci, tout dans la nature le démontre, sans quoi, il serait difficile d'expliquer la provenance des éclairs qui se produisent entre les nuages et qui ne sont autres que des nuages chargés d'électricité contraire et qui s'amorcent entre eux par un trop grand rapprochement.

L'invention dont il s'agit concerne un dispositif formé d'un ensemble d'appareils aptes à la captation de ces courants atmosphériques.

Jusqu'à ce jour, toutes les recherches faites dans ce but ont été de capter dans l'atmosphère une seule catégorie de courants atmosphériques, c'est-à-dire, qu'on a réuni dans un même système de captation, deux pôles opposés et dont l'effet a été de se détruire ou de s'annuler l'un à l'autre laissant comme quantité que la différence du plus fort au plus faible.

Il sera donc facile de comprendre pourquoi, en considérant les deux pôles d'un courant atmosphérique comme à peu près égaux, il est presque impossible par certains temps de mesurer le potentiel avec la terre, du plus fort sur le plus faible subsistant et qui peut être positif ou négatif, suivant que le plus fort est de l'une ou de l'autre de ces polarités.

C'est sur cette base que toutes les recherches jusqu'à nos jours ont été faites et c'est pourquoi, il faut considérer que par tous les temps, entre les deux pôles captés dans l'atmosphère et non mélangés dans aucun des systèmes de captation, il est possible d'obtenir, en tension et en intensité, une puissance aussi considérable que l'on puisse désirer et qui sera mesurée entre les deux pôles captés séparément et toujours isolés l'un de l'autre jusqu'à leur utilisation.

Suivant l'invention, cette captation se fait par attraction dans l'atmosphère au moyen d'un amorçage des courants électriques, soit positif ou négatif, par une antenne à deux pointes absolument isolées l'une de l'autre, dont l'une tournée vers le zénith attire les couches d'électricité négative, et l'autre, tournée vers le sud, puise vers l'équateur, dans les masses groupées dans cette zone.

Ceci exposé et l'existence des courants électriques atmosphériques étant prouvée, il est possible de les capter à la condition de disposer d'appareils spéciaux étudiés surtout pour jouer le rôle de régulateurs, attendu que la difficulté persistante rencontrée jusqu'alors pour réaliser la captation incombe aux grandes variations de tensions sous lesquelles les courants atmosphériques se présentent dans l'espace, pour chacun des pôles, et dont l'écoulement dans un poste de captation serait inévitablement funeste.

Le présent brevet sous sa forme de présentation doit donc couvrir, non pas le ou les dispositifs régulateurs qui sont prévus dans le système, car ils peuvent être conçus d'une façon toute différente et donner le même résultat, mais sur l'application raisonnée et le groupement d'appareils fonctionnant automatiquement et intervenant chacun comme relais d'influence variable pour limiter la tension des courants captés dans l'atmosphère à celle choisie pour utilisation.

Ces appareils ont un rôle assez connexe avec celui de trop-pleins sur un réservoir qui acheminent à l'extérieur l'excès de liquide; ici ces régulateurs détournent l'excès de tension des courants à la terre.

On peut encore assimiler ces régulateurs à des filtres car ils ont pour but de détourner du poste d'utilisation, des courants qui ne sont pas encore de nature connue mais que pour simplicité on appellera courants parasites ou anormaux.

Le brevet portera aussi sur le système de régulation des courants, appliqué à chacun des pôles, car il est reconnu que la forme et la tension des courants aux deux pôles ne sont pas équivalentes.

Le mode de captation par antenne spéciale à deux pointes orientées dans l'atmosphère, comme il sera indiqué ci-après, avec amorçage préalable pour l'écoulement des courants atmosphériques est aussi d'une grande importance.

Enfin la réception des courants atmosphériques se fait à l'endroit même de l'installation du poste; celui-ci peut être prévu en un lieu quelconque sans nécessiter d'altitude particulière, comme cela a été tenté dans des essais préconçus.

Sur les dessins ci-annexés auxquels on se réfère

La fig. 1 représente en élévation et en coupe partielle l'antenne seule, à deux pointes, surmontant un poteau d'élévation;

La fig. 2 est le plan de l'une des pointes, celle horizontale:

La fig. 3 montre schématiquement le tableau sur lequel sont montés les divers appareils ou accessoires qui jouent le rôle de régulateurs des tensions de courants.

La fig. 4 est un schéma de parafoudre, et

La fig. 5 un tableau de résistances.

Le dispositif nécessaire à la captation des courants atmosphériques est formé comme suit :

1° D'une antenne, fig. 1, formée de deux pointes dont l'une 1 est en acier, supportée par une bague de bronze 2 entourée d'une spirale 3 formant self; cette pointe est tournée vers le zénith pour attirer les couches d'électricité négative; l'autre pointe 4 comporte un cadre 5 de huit branches supportant des spirales de cuivre 6 et est tournée vers le sud pour puiser vers l'équateur dans les masses groupées dans cette zone. Pour l'utilisation de cette antenne il suffira qu'elle soit portée par un mât ou poteau de hauteur un peu supérieure à celle des habitations environnantes.

2° D'un tableau de parafoudre, fig. 4, formé de cornes de cuivre 7 servant à absorber les tros grosses décharges atmosphériques que par certains temps, il serait dangereux de laisser circuler dans les appareils régulateurs.

3° D'une table de deux systèmes symétriques de régulateurs, fig. 3, un pour chaque pôle, qui permet d'obtenir une régularisation assez grande dans les tensions des courants en absorbant automatiquement les surtensions dépassant la tension choisie pour l'utilisation désirée. Ces régulateurs sont représentés sur le dessin par les références R, R^1, R^2, R^3, R^4.

4° D'un tableau de résistance en communication avec les régulateurs, ces résistances sont formées de spirales de maillechor 8, de tubes 9 de verre remplis de poussière fine de charbon de cornue, de poudre d'aluminium, de soufre et de poussière fine de cuivre; enfin, deux appareils spéciaux 10 formant transformateurs et constitués de couches de métaux absorbant certains courants nuisibles ou anormaux.

5° D'une source auxiliaire d'énergie formée de piles 11 et de bobines Ruhmkorff 12 permettant d'obtenir dans l'antenne une attraction suffisante au moyen d'un dispositif de

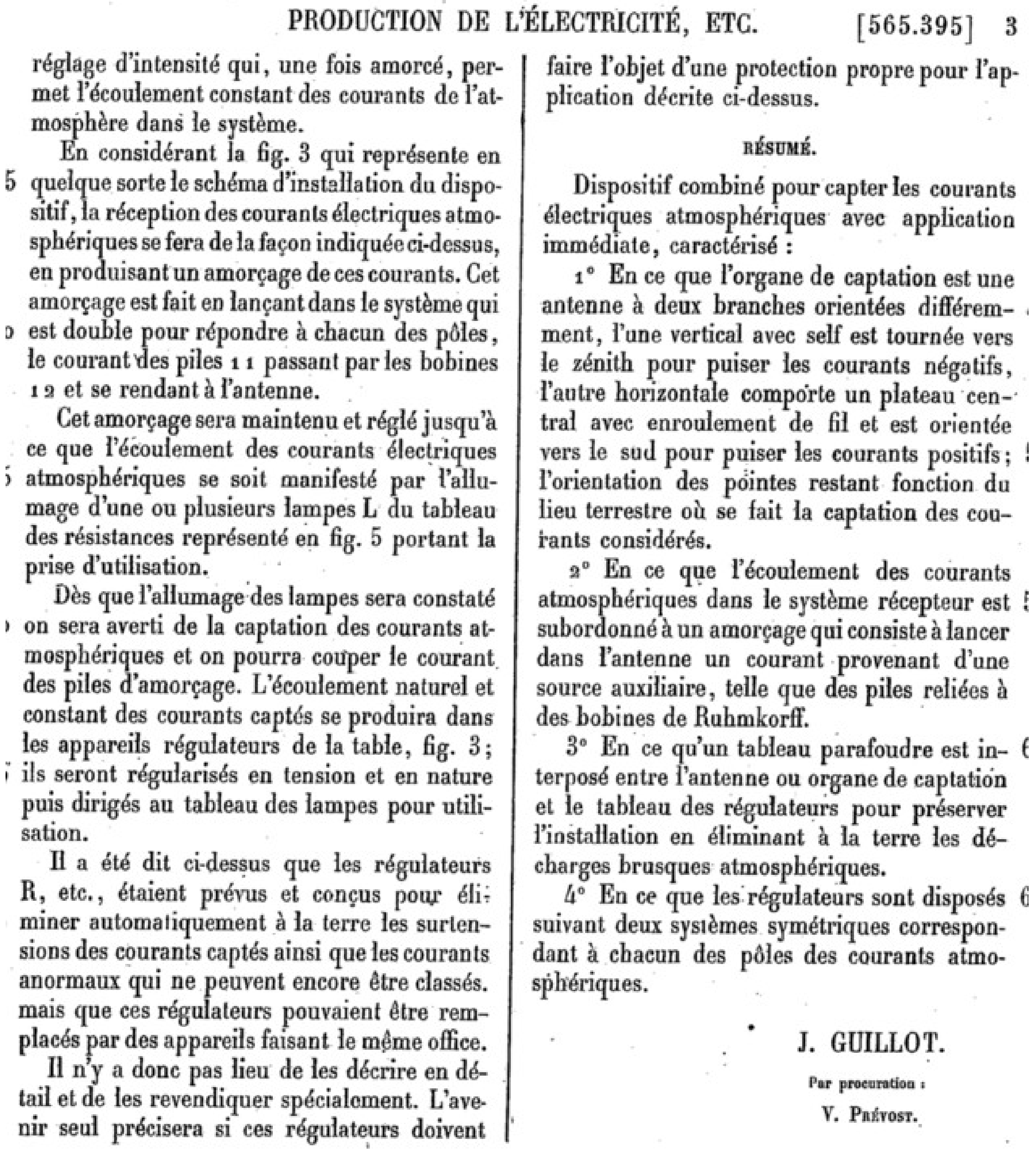

réglage d'intensité qui, une fois amorcé, permet l'écoulement constant des courants de l'atmosphère dans le système.

En considérant la fig. 3 qui représente en quelque sorte le schéma d'installation du dispositif, la réception des courants électriques atmosphériques se fera de la façon indiquée ci-dessus, en produisant un amorçage de ces courants. Cet amorçage est fait en lançant dans le système qui est double pour répondre à chacun des pôles, le courant des piles 11 passant par les bobines 12 et se rendant à l'antenne.

Cet amorçage sera maintenu et réglé jusqu'à ce que l'écoulement des courants électriques atmosphériques se soit manifesté par l'allumage d'une ou plusieurs lampes L du tableau des résistances représenté en fig. 5 portant la prise d'utilisation.

Dès que l'allumage des lampes sera constaté on sera averti de la captation des courants atmosphériques et on pourra couper le courant des piles d'amorçage. L'écoulement naturel et constant des courants captés se produira dans les appareils régulateurs de la table, fig. 3; ils seront régularisés en tension et en nature puis dirigés au tableau des lampes pour utilisation.

Il a été dit ci-dessus que les régulateurs R, etc., étaient prévus et conçus pour éliminer automatiquement à la terre les surtensions des courants captés ainsi que les courants anormaux qui ne peuvent encore être classés. mais que ces régulateurs pouvaient être remplacés par des appareils faisant le même office.

Il n'y a donc pas lieu de les décrire en détail et de les revendiquer spécialement. L'avenir seul précisera si ces régulateurs doivent faire l'objet d'une protection propre pour l'application décrite ci-dessus.

RÉSUMÉ.

Dispositif combiné pour capter les courants électriques atmosphériques avec application immédiate, caractérisé :

1° En ce que l'organe de captation est une antenne à deux branches orientées différemment, l'une vertical avec self est tournée vers le zénith pour puiser les courants négatifs, l'autre horizontale comporte un plateau central avec enroulement de fil et est orientée vers le sud pour puiser les courants positifs; l'orientation des pointes restant fonction du lieu terrestre où se fait la captation des courants considérés.

2° En ce que l'écoulement des courants atmosphériques dans le système récepteur est subordonné à un amorçage qui consiste à lancer dans l'antenne un courant provenant d'une source auxiliaire, telle que des piles reliées à des bobines de Ruhmkorff.

3° En ce qu'un tableau parafoudre est interposé entre l'antenne ou organe de captation et le tableau des régulateurs pour préserver l'installation en éliminant à la terre les décharges brusques atmosphériques.

4° En ce que les régulateurs sont disposés suivant deux systèmes symétriques correspondant à chacun des pôles des courants atmosphériques.

J. GUILLOT.

Par procuration :

V. Prévost.

Parts List

Steel Rods, magnetic, 2
Insulator, porcelain
Ring, bronze
Rods, soft iron, 32
Ring, copper
Surge Protector
Disk, copper
Ring, tin
Tubes, steel
Rx Cu-Pb, Fe-Pb
Breakers, automatic
Resistances : Wire Mesh, Glass Tube. Cu, C, S powder
Vacuum Cleaners : Box, Jar, Mica &

Tube, copper;
Rx : Hg, Sn, C, Cu, S
Battery
Ignition Coil

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Hans Holzerr: Testatika Demonstration Notes

Paul Potter: Back-Engineered Testatika

P. Potter: Principle Experiment

Anonymous: Believe It or Not --- Here It is!

Cyril Smith: Testatika Generator and Over-Unity

Methernitha: The Research Work of Methernitha in the Field of the so-called Free Energy"

P. Potter: Transcript of Methernitha Testatika Video

Testatika Demonstration (4 August 1999)

Translation by Stefan Hartmann < harti@harti.com > & Hans Holzherr

From: Hans Holzherr
To: Stefan Hartmann

Recently, over 30 technicians and engineers (most of them retired) were allowed to visit the Methernitha group in Linden, Switzerland, where they witnessed a demo of the different Testatika machines.

Here is a report from Hans Holzherr from Switzerland who was present:

Hello Mr. Hartmann,

To your questions: > Have you seen live a machine with a load? If so, what load?

I am referring in the following to the model with the 50-cm diameter disks. This machine was already running when the visitors stepped into the room, and was not halted during the whole time --- we were there for about 1.5 hrs. As a first load a 1000-Watt lamp was connected for approximately 10 seconds whose brightness did NOT diminish --- the corresponding sequence on the Testatika film is just an effect of the camera aperture's automatic adjusting to the sudden brightness! The second load was a U-shaped heating element, that Mr.Baumann handed to me. It became so hot within one second that I had to put it down immediately! What was particularly impressive was that while he pulled back one of the contact wires (that was with the lamp, I believe), a 1-cm long arc appeared between the output electrode and the connecting wire for approximately one second. The apparatus was under a plexiglass hood. Near the base it had two holes which Baumann used to insert the contact wires to touch the output electrodes.

How do you think the high wattage is produced ?

Good question! I'd love to know the answer, too!

Did the disks slow down when a load was placed across the output electrodes ?

I did not notice that (nobody else did), but of course you tend to turn your look to 'where the action is' (the lamp etc.) The disks turned with 15 rpm, which is quite slow. The spin rate was regulated magnetically.

What general impression did you have ?

It was really impressive! One can hardly believe it, with this slow rotation. In any case, this cannot be explained in terms of bare electrostatics in the sense of the Wimshurst machine. The perforated sheets seem to have a key function... Beside the pick-up and the drive electrodes there are a number of small plexiglass blocks with glued-on perforated sheets, whose function is unknown.

As Adolf Schneider already mentioned, my colleague Bernhard XXX and I want to try to copy the principle experiment shown by Baumann --- without much hope to find anything extraordinary, though.

The device consists of a horizontal swiveling plexiglass arm with a small rectangular plexiglass plate at both ends glued to the lower side of the arm. The lower side of the arm is covered with perforated aluminum sheets (square holes), while the bottom of the plates is covered with brass wire mesh. Beneath each plate five additional plates are glued onto the base plate. There is also wire mesh between each pair of plates in the two blocks. From the mesh layer between the lowest plate and the base a wire goes to the two capacitors, which are connected in parallel . Baumann seized the arm with both hands and turned it about ten times back and forth (a full rotation was not possible, because the capacitors were in the way), then measured the DC voltage with a digital measuring instrument: 60 Volts. Then, as he short-circuited the condensers a loud crack could be heard. I don´t know if that already is an abnormal result...

On my question Baumann replied that with metal foil (instead of wire mesh) the device would not produce that effect.

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"Back-Engineered Testatika"

by

Paul E. Potter

http://website.lineone.net/~aarekhu/index.html

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That the Swiss Methernitha group's Testatika machine is thought to be based on a Wimshurst electrostatic generator, is only a sparse approximation of the truth --- of the great multitude of electrostatic influence machines developed around the 1900's it more closely follows the charge-separation-and-collection system used by the 1898 Pidgeon machine [note 1] for its electrical circuit.

Its 50-per-disc steel grilles or 'gitter-grilles' are plainly unique to the Methernitha (see fig.1) but in principle follow on from previous research and patents for corrugated sectors which were found to be more efficient charge carriers [note 2] than flat ones, and from a similar example in more recent times of aluminium rods extending out like wheel spokes from an insulating hub of perspex [note 3].

Another unique function of these perforated grilles attached to the discs is how they induce charge from the rotating discs onto the special collecting pads, or 'tasten' antennae keys (which are also perforated --- so as to more readily pick up charge); for in a Wimshurst you had conductive brushes or rails of sharp points which actually touched the discs or were placed very close to them, but in the Methernitha the charge has to be made to traverse a parallel air-gap to the pads and for this purpose the metal gitter-grilles are so designed to create miniature eddy-currents of charged air which circulate in and out of the perforated metal's surface charges, and are more easily bounced out to the collecting pads. This process is categorised as VARIABLE CAPACITANCE electrostatic generation.

Careful note needs to be made of how the Methernitha uses its basically Pidgeon setup with regard to its neutralising rods (that equalise and stabilise the opposite charges --- see fig.2), and how charges are picked up from one area and accumulated at others, so that the polarities of charge are distributed correctly to specific areas on both discs [note 4].

And although there have been some fanciful claims, or misinformation, that it uses all sorts of radioactive materials to achieve its pulsed output I most strongly believe that the auxiliary electromagnetic circuit, that wraps itself around the rotating discs, portrays a simple electronic approach; afterall, who would use radium radioactive emission alongside leyden jar capacitors ! Indeed, the more you look into certain elements of its construction the more they point to three main eras of electronics development, the 1900's, the 1920's and the 1950/60's. The authentic Methernitha was designed and developed by purists who believed they had discovered a previously unknown electronic phenomenon, but they wanted to keep an integrity to the early pioneering days of the Pidgeon, Wimshurst and Holtz electrostatic machinery; they would not use such modern devices as transistors or IC chips (more's the pity) --- but they do use some pretty uncommon electronic engineering in their circuit [note 5].

Obviously, the electronics are in two parts; one --- the electrostatic generator and its particular technologies of how to direct what charge where, and two --- the very unique auxiliary electromagnetic circuit of inductances, capacitances and rectification that mobilises that 'static' electricity. To understand how they convert static energy into an electromotive force you would do well to go back to the earliest years of radio. From the pages of spark radio you soon appreciate just how important oscillation circuits and their valve rectifiers were, and moreover, how difficult it proved to engineer them. For although radio transmitters and receivers from the 1900's used resonating circuits their oscillations were controlled by sparks between two contacts and, of course, they were relatively inefficient. Not until the 1920's did the first electric current oscillations become an observable controlled phenomenon when someone coupled a rectifier valve, a capacitor, and a resistor together [note 6]. The early 1920's also saw the best era of experimentation and invention for novel devices that turned static energy into useable electromagnetic energy; it was in a 1921 patent that we see a German physicist Hermann Plauson describe in great detail his methods to convert static power, not only from rotary influence machines but also from balloons collecting atmospheric electricity up in the sky; and by using thermionic rectifiers, leyden jar capacitors and inductor coils he proposed a free-energy network that was to power the whole of Germany [note 7] ! The thermionic rectifier valve heralded a new era for radio and high voltage physics, and as it was then subjected to such a broad array of experiments and modifications to improve its efficiency so it paved the way for all sorts of new avenues in electronics. Indeed, with such a technical catalogue of similarities with what we see in the available photographs of Testatika it can be assumed without doubt that the horizontal glass tube which sits on top of the Methernitha machines is exactly what a home-made vacuum thermionic rectifying valve would look like; with its internal anode mesh-plate, surrounded by a coiled copper grid, fed by a glowing (heated) cathode wire running horizontally across its centre and capped by two black end-pieces, which are too big and bulbous to be mere end-caps and must surely be black rubber vacuum seals to seal the glass tube and the input/output wires [note 8].

With such a rectifier, some induction coils, and some leyden jar capacitors you have a circuit that oscillates, and that's what has to happen with a Methernitha, the electromagnetic circuit has to oscillate for it to work, and then the oscillations have to be rectified (or even modulated) so that the resulting single-pole pulses can be channeled through the big cans, which are basically high-efficiency transformers, and outputted as reduced voltage higher current DC pulses (see fig.3).

The precise components used to oscillate the primary oscillating circuit are, I believe, not to be seen in any of the available photographs, but there are various hints for their approximate whereabouts on the machine. Firstly, according to electronic design there should be a capacitor and coil configuration in close proximity to the rectifier. Well, from the picture "3KWREAR" can be seen the two long upright tubes which, according to those who have seen them first-hand, comprise a spirally turned aluminium strip (which indicates they are chokes [note 9]) inside a glass tube, inside the same sort of outer shielding that the big cans have (which indicates they are electrostatic shields), inside yet another glass tube, and are terminated at the top with a brass connecting rod which does a right-angled turn and passes into the side of the tower --- but only two-thirds up the height of the tower. These two assemblies must form a connection to the rectifier, because the rectifier is at the top of the tower, so why don't these electrostatically sensitive tubes extend all the way up to it ? Again, from the photographs of the rear and front of the Methernithas there is a wire that comes out of the tower's side wall at about 4 inches above the upright's brass terminals and this wire then passes through a short black tube and on to the rectifier valve. This, of course, would happen on both sides of the tower, enabling a connection to both ends of the rectifier. But why have this 4 inch gap of connections at the top of the tower ? Something is placed inside the top of the tower in this intermediate space which is very necessary to the circuit, and I think it must be the location of the capacitor/inductor configuration to oscillate the circuit. This (fig.4) is how I would see the inside of the top of the towers [note 10].

I've seen some of the patented inventions that rotate discs --- by using magnets (i.e., H.Rosenberg's permanent magnet excited rotational machine, US Patent # 3,411,027), and by utilising inscribed metalised discs (US Patent # 3,239,705 for instance), but there simply isn't enough room for these to be located in the Methernitha disc setup --- also, you don't want to interfere with the ES fields that zip around the revolving discs: From the reports of those who have seen the small machines working it appears their discs were rotated by small DC electric motors after they were hand-started, some re-wound with thinner wire (to presumably increase their torque) and powered directly from the discs' generated electricity --- but I have also seen how two discs can continue to rotate simply by careful placement of curved electrodes [note 11] which would act on the charges on the discs --- like the 3kw Testatica Distatica generators.

After reading through the many early accounts of electrostatic rotary machines, and some of the more recent ones, you can't help but be puzzled by the Methernitha's incredibly low rotational speed of just 60 rpm (and in the 1999 engineers report as low 15 rpm !). Most other early experimenters boasted up to 3000 rpm. J.G.Trump in his work on high voltage generation in space [note 12] spun his rotary machine at 10,000 rpm (to produce 433 Watts at 24 KV no less). One reason for this low speed might be to do with the close proximity of the 50 lamellas (gitter-grilles) on the discs at their inner ends, they are very close together, I think too close. Air, normally an insulator, breaks down and conducts at around 25-35 KV (this figure has been fairly constant from day-one of electrostatic machine experiments right through to the present day --- because air has a breakdown field strength of 3x106 volts/metre) and short-circuits the circuit. I feel that because this design of grilles is prone to short-circuiting at high voltages the Methernitha people have limited their rotational speed so as to ensure a low operating voltage --- of what I'd guesstimate to be only 12 to 24KV.

But, is this a waste of extra potential ? Not necessarily, for I don't think that the main power output comes solely from what the two counter-rotating discs supply.

There is, I believe, a far more important power generator --- the electron cascade generator, and the Methernitha has two of them, held inside the two horseshoe magnets, and providing the circuits to the magnets are made to oscillate at the right frequency at a high enough voltage then these metalised-perspex laminated blocks can enmass A MUCH LARGER AMOUNT OF ELECTRICITY THAN WHAT IS PUT INTO THEM.

This, perhaps, is the previously unknown electronic phenomenon that the Methernitha group have so zealously been trying to protect against unscrupulous entrepreneurs. But I would say that this copious supply of free energy is already known to the world --- it is not readily available - and its principles are not fully understood, as yet, but it is known about.

As the descriptions say (on the Testatika website), between the horseshoe magnet legs are four blocks of transparent 'plexiglass' type material alternated with copper and aluminium plates (that may or may not be perforated), in the sequence c-p-a-c-p-a-c-p-a-c-p-a (also see fig.6). And according to the Linden Experiment, where Paul Baumann induces a resonance of about 80-140 MHz in a coiled horseshoe and then has an aluminium-insulator-copper block moved between the horseshoe legs, a voltage could be taken off the plates of the block which measured 700 volts (DC presumably) [note 13]. This incredible phenomenon has never been replicated by any 'outside researcher', and is said to be the basis by which the Methernitha machine could be understood how to work [the clue, possibly, to this Principle Experiment may be variable-capacitance and dielectric-absorpsion].

But what, I hear you say, is an electron cascade... Well, it was only by chance, very recently, that I happened to listen to an audio tape by a Dr. Flanagan about crystal water; when I switched the tape over after the end of side one Dr. Flanagan then began talking about an electronic configuration that applied a high frequency, high voltage alternating field across an insulator --- that created what he called an electron cascade effect --- Yes, I thought, here is the answer to the Methernitha Machine.

The electron cascade or avalanche effect is where air molecules are accelerated to the device at such a high velocity that they collide with other molecules and atoms in the air to liberate new electrons which in turn also collide and liberate even more 'free electrons' from other air molecules (see fig.5), all of which become accelerated by the electric field, and an avalanche of electron-multiplications progresses throughout the whole immediate environment [note 14]. It's a chain reaction, and an entirely safe one, it happens in a more ferocious way in lightning strikes, and is a natural phenomenon. And, as in this case, the environment actually becomes part of the circuit [note 15] because the process is actually negatively-ionising the air surrounding the Methernitha machines, and that is why those who have been near these generators when working say the air around about them is cool and fresh [note 16].

In view of the fact that it's designers have chosen to wind insulated wire (which may or may not be bifilar) around the horseshoe metal it is likely that the horseshoes are used for some form of induction [note 17], it would also be very possible to draw directly from this part of the circuit the extra electric current produced from the electron cascade blocks, with suitable connections that might lead downward into the wooden base (where it is believed that an alternate layering of perforated metal plates and insulating plates - making up a large high-voltage storage capacitor - is located). This power could then be discharged as a pulsed output of high wattage, especially if the final output part of the electronic circuit is configured as a Pulse Forming Network of multiple sections of inductor / capacitor combinations [note 18].

The two big cans at the side, the big capacitors, are probably not highly technical (see fig.7), once the fundamental formula has been decided upon all models of a Testatika generator would follow a similar construction process. The written descriptions are a little contradictory but they seem to suggest a central input rod, or tube, connecting at the bottom of the cans to a stack of inter-linked pancake coils, that are wound secondary-outside primary-inside, fitted around a core of 6 hollow donut-ring magnets stacked in such a way with plastic spacers as to allow air gaps between them, and then finally the output of each can is a connection from the top coil of the secondaries of the pancake coils to a brass ring around the centre of the black plastic top lid --- and from the photographs can be seen a large diameter wire or tube [note 19] connecting that polarity's output terminal to the top lid's brass ring via a brass screw terminal. I would suggest that the ring magnets (of anistropic ferrite perhaps) are gapped in this way to prevent the magnetic flux fields of the pancake primaries co-joining as one sprawling field, because it would be more advantageous, and safer, to have each separate pancake's magnetic flux cut it's own adjoining secondary coil, and divide the secondary output voltage into smaller amounts of potential, thus depending less on complicated insulating procedures that accompany high voltage single primary / single secondary transformers.

The use of aluminium mesh and solid copper sheeting is commonly used in electronic construction; the outer aluminium mesh cylinder would be used to shield stray electrostatic charges, and the solid copper cylinder is to shield the large amount of stray electromagnetic fields produced by the transforming process from high voltage/low current to lower voltage/higher current [note 20]. Obviously they don't want field contamination taking place between the sensitive electrostatic generator and the transformers.

Within these two outside shielding-cylinders are 'grid condensers' which, according to the 1999 report by the 30 engineers, can be as many as 20 layers of perforated sheet (presumably as concentric cylinders) - which I have indicated (in fig.7 for instance) as being electrically connected

BETWEEN each separate secondary winding - in the fashion of an old discovery from the early days of wireless telegraphy and based on the 'disruptive discharge coil' devised by Nikola Tesla, that such a condenser connected in the center of a secondary coil collects the maximum amount of voltage created by that secondary. This configuration of one condenser inside another inside another etc etc, has a striking similarity to the layout of a pulse forming network [see note 18].

In the red wired can the transformer is wired to output negative, and the blue wired can's transformer is wired to output positive polarity. Special note should be made of a similar arrangement for divided primary / secondary windings devised by Van de Graaff in his 'High Voltage Electromagnetic Charged-Particle Accelerator Apparatus Having an Insulating Magnetic Core' [note 21] with respect to magnetic reluctance gaps.

Whilst it has been said that the clear perspex disc was designated the 'cloud' disc, and the (rear) dark disc the 'ground' disc I would think this relates to different types of acrylics or plastics that might become charged to different polarities, as in the triboelectric series, where frictional charging of different plastics --- and then bringing them close together, might cause donation or acceptance from one to the other; I would think from the above that cloud represents a donator (positive charge) and that ground must mean an acceptor (negative charge). Has anyone tried the combination of a teflon disc (extremely negative charge) with a glass disc (highly positive charge) ?

Or discs doped with paramagnetic particles perhaps [note 22] ?

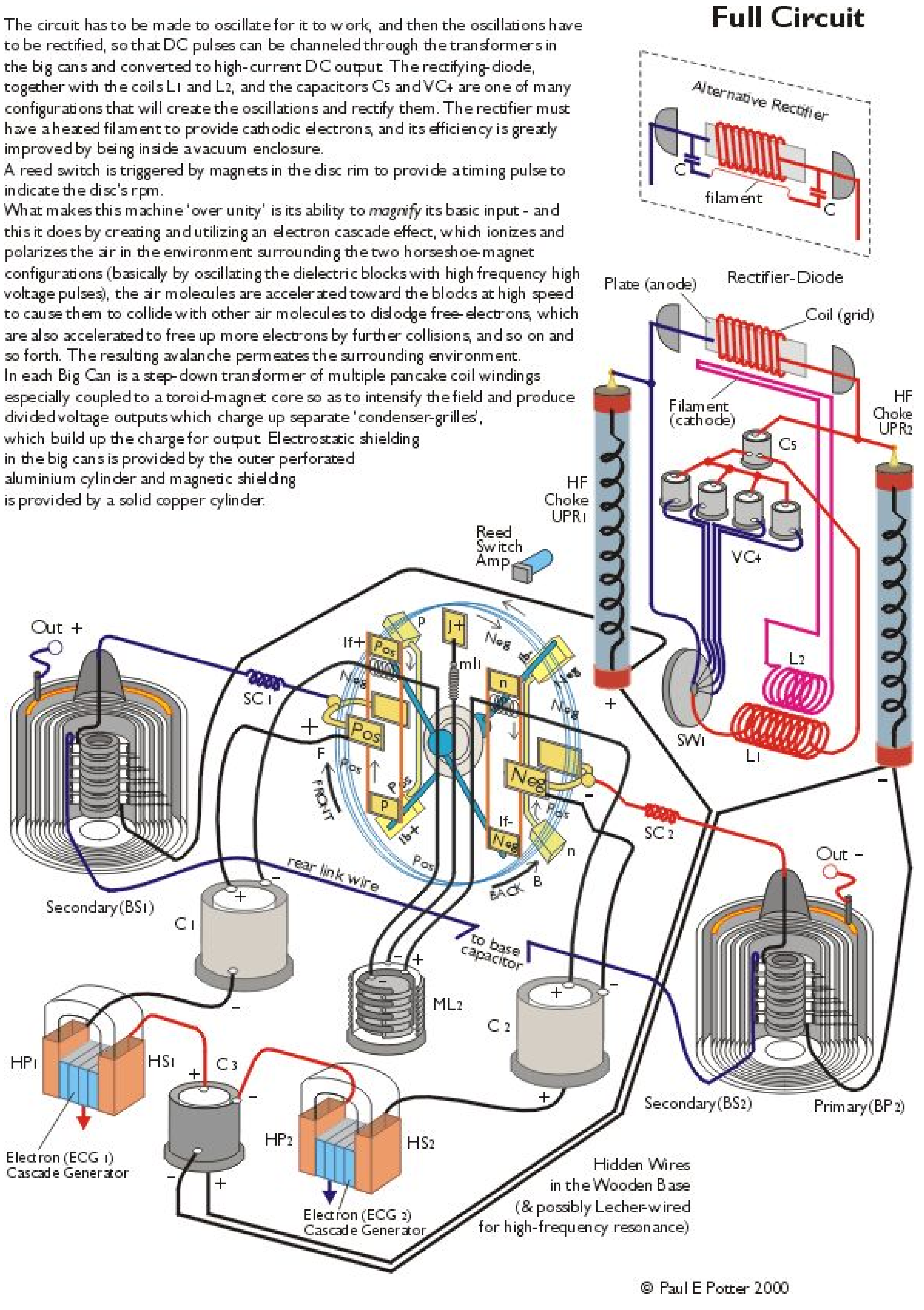

The circuit has to be made to oscillate for it to work, and then the oscillations have to be rectified, so that DC pulses can be channeled through the transformers in the big cans and converted to high-current DC output. The rectifying-diode, together with the coils L1 and L2, and the capacitors C5 and VC4 are one of many configurations that will create the oscillations and rectify them. The rectifier must have a heated filament to provide cathodic electrons, and its efficiency is greatly improved by being inside a vacuum enclosure.

A reed switch is triggered by magnets in the disc rim to provide a timing pulse to indicate the disc's rpm.

What makes this machine 'over unity' is its ability to *magnify* its basic input - and this it does by creating and utilizing an electron cascade effect, which ionizes and polarizes the air in the environment surrounding the two horseshoe-magnet configurations (basically by oscillating the dielectric blocks with high frequency high voltage pulses), the air molecules are accelerated toward the blocks at high speed to cause them to collide with other air molecules to dislodge free-electrons, which are also accelerated to free up more electrons by further collisions, and so on and so forth. The resulting avalanche permeates the surrounding environment.

In each Big Can is a step-down transformer of multiple pancake coil windings especially coupled to a toroid-magnet core so as to intensify the field and produce divided voltage outputs which charge up separate 'condenser-grilles', which build up the charge for output. Electrostatic shielding in the big cans is provided by the outer perforated aluminium cylinder and magnetic shielding is provided by a solid copper cylinder.

Full Circuit
Alternative Rectifier
C
filament
C
Plate (anode)
Rectifier-Diode
Coil (grid)
Filament (cathode)
HF Choke UPR2
C5
VC4
HF Choke UPR1
Reed Switch Amp
Out +
SC1
If+
Pos
P
J+
Neg
mI1
n
Neg
Pos
+
F
Pos
FRONT
Pos
P
Ib+
Neg
If-
Neg
Pos
n
Pos
BACK
B
-
SC2
+
SW1
L2
L1
-
Out -
rear link wire
to base capacitor
Secondary(BS1)
C1
+
-
-
+
ML2
-
C2
+
-
+
HP1
HS1
+
C3
-
HP2
HS2
Electron (ECG 1) Cascade Generator
-
+
Electron (ECG 2) Cascade Generator
Secondary(BS2)
Primary(BP2)
Hidden Wires in the Wooden Base (& possibly Lecher-wired for high-frequency resonance)

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Back-Engineered Methernitha --- Notes

Note 1 --- For more information on the Pidgeon machine see "Electrical Influence Machines" by John Gray, 1903 p. 206 & "Philosophical Magazine" Dec 1898, p. 564, and of course the Pidgeon patents.

Note 2 --- See "Modern High Speed Influence Machines" by V.E. Johnson, 1921, p. 76. Johnson was not only a researcher of electrostatic machines but was also an innovative constructor of them, and as such was keen to try any technique that made his generators more powerful than even the specialised Wommelsdorf multi-disc condenser machines. This book is an absolute must for those who wish to work in this field. Another 'must' is the website of Antonio Carlos M. de Queiroz (http://www.coe.ufrj.br/~acmq/electrostatic.html) which is absolutely full of information about (and with links to) present-day developments in electrostatic machines.

Note 3 --- See "Self-Excited, Alternating, High-Voltage Generation Using A Modified Electrostatic Influence Machine" by M.Zahn, et al., American Journal of Physics, Vol 42 (1974) p. 289.

Note 4 The Methernitha designers have taken a basic Pidgeon electric field system and added a few modifications of their own, partly to lock a certain polarity of charge to a certain area so as to stabilise it, and also to boost certain areas with charge. As in their use, for example, of an extra field plate located at the top-centre in front of the front disc (just under the rectifying valve), note also that this plate, or antennae key, is indirectly coupled to the rest of the circuit, via a coil setup. Much the same occurs with the two plates slightly below it, these plates are connected to a brass terminal which connects to a copper wire that goes down and winds in a coil shape around a hollow plastic tube, and inside the tube will be another wire or small coil that draws off the electric charge. So these three plates are using not direct connection but induction to get their charge.

Note 5 ------- By looking at how each of the photographed machines have been constructed you can see that these are high quality crafted structures. I would think each would start off as sub-assemblies fitted together by pairs or small groups of members, those sub-assemblies of wooden base, big cans, perspex framework, discs with bearings and axles, when completed would be passed on to the electrical engineers of the community who would then fit the wiring connections, vacuum tube rectifier and make sure that not only did they work but that they looked like a work of art.

Note 6 --- The Fleming valve had been around since 1905 and while it progressed to the thermionic valve and audion, by 1922 the ‘Pearson and Anson Effect’ was discovered whereby oscillating currents could be produced with a resistor, capacitor and thermionic valve coupled together.

Note 7 --- See US Patent 1,540,998 (9 June 1925) Conversion of Atmospheric Electric Energy by Hermann Plauson. He also wrote a book of the subject titled "Gewinnung und Verwertung der Atmospharischen Elektrizitat" in 1920 in German (which is currently held in the British Library).

Note 8 --- Whilst some have seen the smaller 300 Watt machine’s discharger/rectifier quite open and not encased in a vacuum tube the vacuum tube models would be much more efficient and would waste less current. Also, the rectifier tube must have a heated filament (which on the 3KW machines can be seen as a glowing line running the whole length of the grid and coil assembly between the two black end caps, and in the films you can see faint flashes coming from behind the rectifier so possibly the filament is wrapped around the other side of the grid/coil assembly as well). Coolridge, back in the 1900’s, discovered that no discharge from the cathode to the anode would occur, even at 100,000 volts, unless the filament was heated (Physics Review, Vol. 2, Dec 1913, p. 418). Aluminium mesh will give off electrons quite readily and can be used as a cold cathode --- but a heated cathode offers the advantage of being able to control the oscillations.

Note 9 --- The two long upright tubes are without doubt choke coil assemblies in precisely the right place to slow down the current where it gets oscillated and rectified. In a choke the higher the flow of current the greater will be its resistance to that current flow. An even better form of choke will have some form of iron core inside it.

Note 10 --- I have come up with 6 different circuits for this oscillation section, some of which include small quartz crystals. (See notes 13 and 16 on frequency of oscillation). The black dial at the rear of the 3kw machine is most likely to select a variety of capacitances so as to control the oscillations of the circuit, which in turn control disc rotational speed.

Note 11 --- The phenomenon of electrostatic motors has been well researched over the years (see "Electrostatic Motors" O. Jefimenko in "Physics Teacher" Vol. 9, March 1971, p. 121-9, and in "Electrostatics And Its Applications" by A.D. Moore (1973) p. 131-147; "Electrostatic Motors" by B.Bollee in "Philips Tech. Review" Vol 30 (1969), p. 178-194). The Methernitha Testatika generators (see a recent report by 30 engineers) auto-rotate, after they have been started by hand, by the same principles of these ES motors.

Note 12 --- J.G.Trump worked for the US Air Force and pioneered some highly efficient electrostatic machines around the 1960’s (see"Electrostatic Sources of Electric Power" in "Elec. Eng." 66:525, June 1947; and "High Voltage Generation in Space:The Parametric Electrostatic Machine" in "Progr. Astronaut. Rocketry" (vol 3 --- Energy Conversion for Space Power) 1961 p745).

Note 13 --- Although the ‘Linden Experiment’ was thought to register a frequency of 80-140 MHz this does not necessarily mean that the Methernitha generators would oscillate at that rate also. Such a frequency seems unnecessarily high.

Note 14 --- See "Plasma --- The Fourth State of Matter" by D.A. Frank-Kamenetskii (1972) pp10, and Dr.Patrick Flanagan’s US patents 4,743,275 (May 10, 1988) and 4,391,773 (Jul 5, 1983).

Note 15 --- The effect is very similar to the converging forces in a non-uniform field, the oscillating perspex blocks become one ‘electrode’ and the surrounding air in the room becomes the opposite ‘electrode’, and by the processes of electrophoresis and dielectrophoresis the electrically charged particles in the air (the electrons and negative ions) are drawn toward the central electrode, which in this case is the perspex block assembly (see "Nonuniform Electric Fields" by Herbert A. Pohl in "Scientific American" (Dec 1960) p. 107-8). I am much more inclined to believe that the ingenuity of the design of these types of machines comes from physicists and not electronic engineers.

Note 16 --- Dr. Flanagan actually uses the electron field generator in his own special ionizer (see Method of Purifying Air and Negative Field Generator US Patent 4,391,773).

How does an electron cascade generator work, I would think that while you have an alternating electron movement (and Dr. Flanagan reckons this effect occurs with a high voltage field alternating at above 20 KHz) at the metal electrodes, the perspex blocks sandwiched between them would transfer the electricity not through their mass but around it, as surface charge --- actually in the layer of air right next to the insulator’s surface. Its the same principle as dielectric absorption - the perspex blocks don't discharge themselves fast enough to keep up with the alternating voltage and so they accumulate more and more charge --- until it forms as a layer of charge on the insulator's surface. This means that at a high enough frequency the surface-air molecules polarize, with the more mobile electrons separating from the slower bulks of those molecules and while the electrons get thrusted back and forth a secondary layer of (slower) positive air ions develops, and so on, and the process of high voltage high frequency polarization triggers the electron avalanche effect.

In the event that the perspex blocks are indeed ELECTRETS (as free-energy researcher Geoff Egel and others suggest) I would think that they would work in a similar fashion to the above process, of dielectric absorption that charges up the blocks before they produce the cascade-effect. Because in the electret the electrons charged into the perspex/plastic, and the positive ions, would still be manipulated by the reversing electromagnetic field in such a way as to orientate (as with dipoles) back and forth, to eventually reach the point (if the whole circuit is tuned properly) where they would attain resonance with the immediate air surrounding them. And if this effect is similar to an inductance then possibly a back-emf will result also, to increase the output voltage. Either way I believe the effect will still be an electron cascade through the environment and the product of this oscillating output (at the blocks) could similarly be drawn off and accumulated in the multi-layered base capacitor network.

I would suggest that a test program to find the best type of blocks would be; One --- try different types of plastic/acrylic/ceramic materials for the blocks.
Two --- try different methods of electrifying the plastics (as with electrets). Three --- try plastics doped with semiconducting particles. Four - try plastics doped with paramagnetic particles. Five - try hollow plastic blocks containing an electrolytic fluid. More information on plastics will be found on the Electret vs Dielectric Absorption Page.

Note 17 --- There are several definitions of Bifilar, one where the wires cancel out their magnetic fields, and one where the wires are wound to ensure a tight low-loss magnetic flux coupling, in this case you need all the magnetic flux you can get so it must be the latter --- See "Transformers For Electronic Circuits" by Nathan R. Grossner (1967), p. 224 etc.

Most commonly used magnetic metal is Mumetal, which is an easily saturable magnetic material, routing magnetic flux through it rather than in the surrounding air, so as to enhance the mutual induction between the two coilings of red wire around the horseshoe legs.

Note 18 --- So that the machine's output voltage doesn't drain away when it is connected up to a large load, what is needed here is a Pulse Forming Network (or artificial delay line). "Such a network is an improvement on simple capacitor storage because of the cascading action from one capacitor to the next along the chain. At the beginning, all capacitors are charged to the same voltage but as soon as the first one starts to loose voltage, the one behind it is then free to discharge into it. This topping-up action, which trickles down the network from capacitor to capacitor, is the mechanism by which the voltage across the output terminals tends to hold onto its original level." (see "High Energy Discharge Systems" A.P.Stephenson, Electronics Today International, March 1992, pp. 24-26).

Note 19 --- When voltage of a high potential and high frequency flows along a wire it does so on the outer surface (called the ‘skin effect’) and so the Methernitha would use thick wiring or even 1/8" tubing to connect its circuit.

Note 20 --- Two references for shielding are: "A Shielded Loop" by S. Goldman in "Electronics" Vol 11 (1938), pp. 20-22; and "Measurements in Radio Engineering" by F.E. Terman (1935), p. 218 & p. 341.

Note 21 --- For information on maximum voltage in the center of a secondary coil see "A Handbook of Wireless Telegraphy" by J. Erskine-Murray (1913) p. 42; and an article called "Dielectric Hysteresis at Radio Frequencies" by E.F.W. Alexanderson in "Proc. I.R.E., Vol. 2 (June 1914) p137-157. For Van de Graaff's transformer see US patents 3,323,069 (May 30, 1967) and 3,187,208 (June 1, 1965). These patents were not just for a Van de Graaff high voltage generator, they were for a special system devised by Van de Graaff long after his generator had been in use to convert static electricity into current electricity. This system may be a little too complicated for the Methernitha but, nevertheless, the principles he used for multiple primary / secondary windings may be of some interest.

Note 22 --- Dr. Flanagan modified his insulator blocks, made of resin, by doping them with paramagnetic granules (such as silicon carbide) to enhance even more the electron cascade effect; which is an idea that the physicist Thomas Townsend Brown first experimented with (by using lead oxide granules) in his US Patent 3,187,206 (June 1, 1965) to good effect. The surrounding air could also be ‘enhanced’ in similar fashion to polarise it's electric charge and improve its side of the performance (for those interested in the ‘physics’ of this see an article by W.A.Douglas Rudge "On Some Sources of Disturbance of the Normal Atmospheric Potential Gradient" in Proc. Royal Soc. A, Vol. 90 (1914) pp. 571, etc).

Note 23 --- Some other generators with similarities to the Testatika machine are the "Electrostatic Energy Field Power Generating System" invented by William W. Hyde (US Patent 4,897,592 of Jan 30, 1990) is a rotor/stator variable capacitance machine capable of producing 300 KV. Other such generators are; "Parametric Electric Machine" invented by Ferdinand Cap (US Patent 4,622,510 of Nov 11, 1986) which has a series resonant (LCR) circuit structured into it so that it oscillates --- and indeed operates AT RESONANCE to ensure a high output; "Electrostatic Generator" invented by Dan B. Le May, et al. (US Patent 3,094,653 of Jun 18 1963) is a very ingenious system of variable capacitance; the "Electrostatic Machine" by Noel Felici (US Patent 2,522,106 of Sep 12, 1950) is a good standard which utilizes a valve rectifier; and the "Electrostatic Generator" by William S. Spencer (US Patent 1,415,779 of May 9, 1922) is an early rotor/stator generator which transferred its electric impulses through a transformer to produce a higher current output.

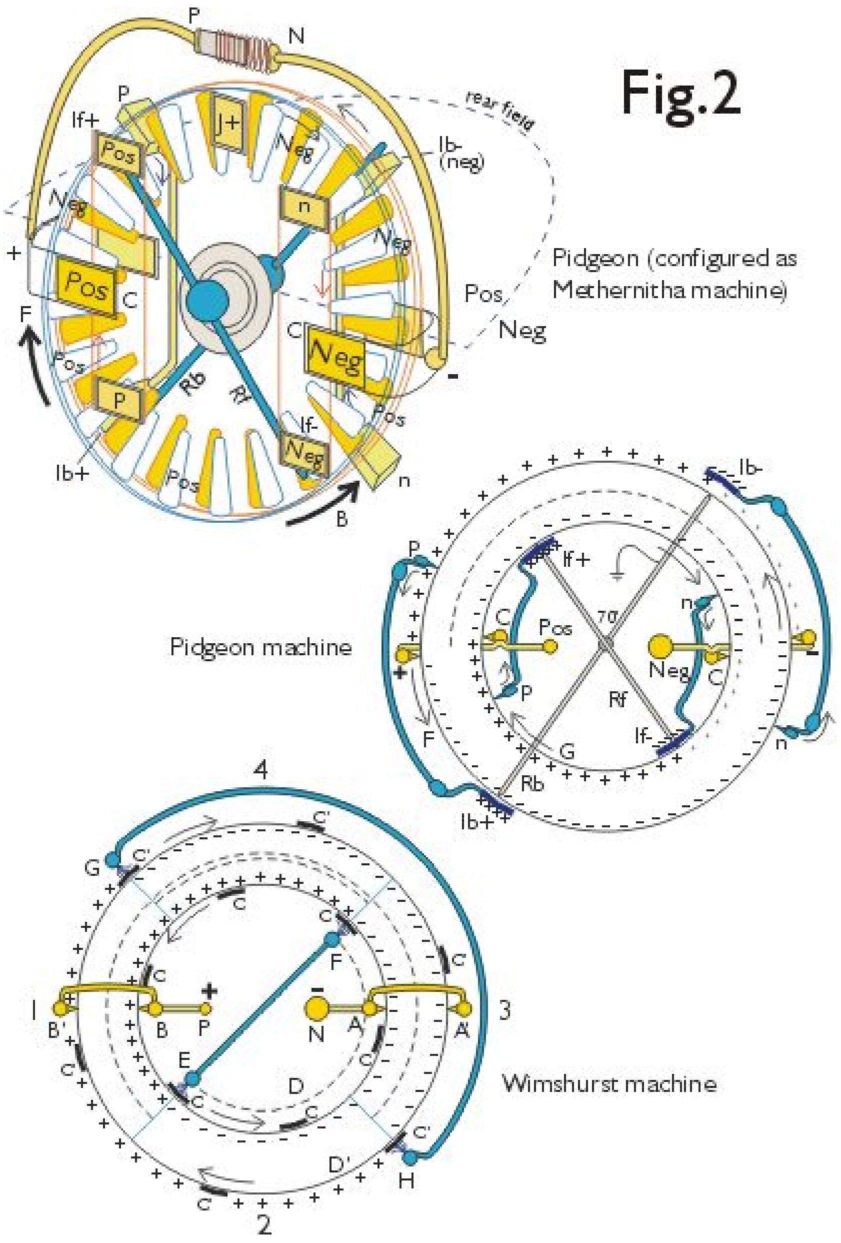

Fig.2

P
N
P
If+
Pos
J+
Neg
rear field
Ib-
(neg)
n
Neg
Neg
+
Pos
C
F
Pos
P
Rb
Rf
C
Neg
Pos
Neg
-
If-
Neg
Pos
Pos
Ib+
n
B
Pidgeon (configured as
Methernitha machine)
Ib-
P
If+
C
Pos
70
n
Neg
C
Pidgeon machine
+
-
P
F
Rf
G
If-
n
Rb
Ib+
4
C'
G
C'
C
C
C
F
C
+
-
I
B'
B
P
N
A
A
3
E
C
D
C
C'
C
C'
D'
H
C
2
Wimshurst machine

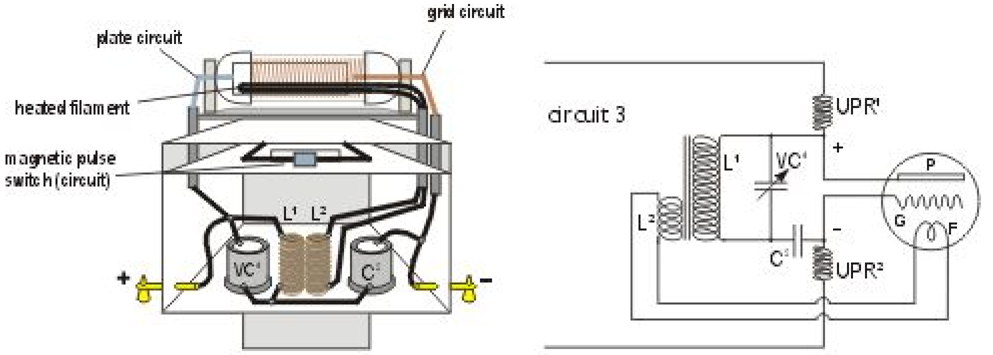
grid circuit
plate circuit
heated filament
magnetic pulse
switch (circuit)
L¹ L²
VC¹
C¹
+
-
circuit 3
UPR¹
+
L¹
VC¹
L²
C¹
-
UPR²
P
G
F

Fig. 4 - Tower Circuits

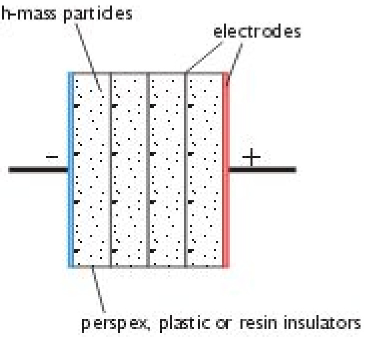
high-mass particles
electrodes
-
+
perspex, plastic or resin insulators

Fig. 6 - ECG Doped

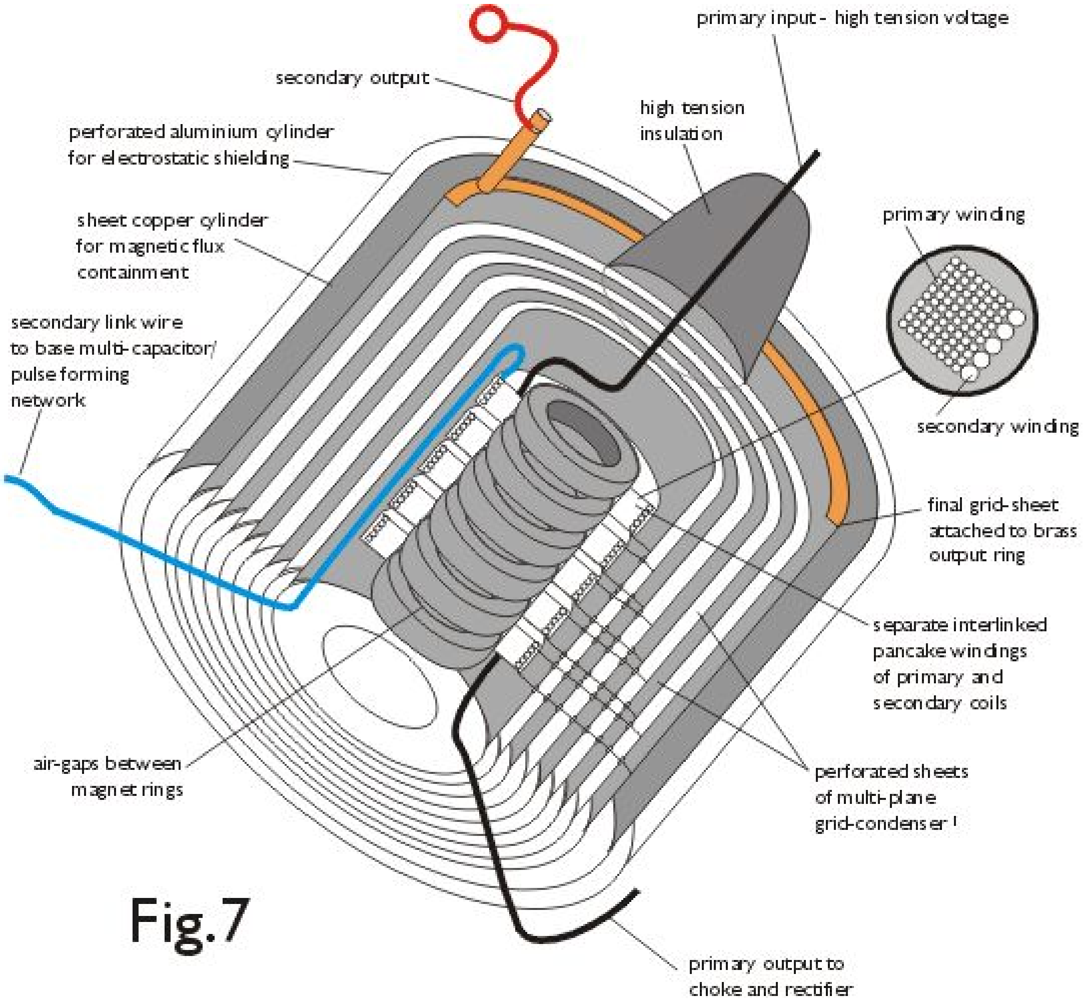
primary input - high tension voltage
secondary output
high tension insulation
perforated aluminium cylinder for electrostatic shielding
sheet copper cylinder for magnetic flux containment
primary winding
secondary link wire to base multi-capacitor/ pulse forming network
secondary winding
final grid-sheet attached to brass output ring
separate interlinked pancake windings of primary and secondary coils
air-gaps between magnet rings
perforated sheets of multi-plane grid-condenser [1]
primary output to choke and rectifier

Fig.7

[1] In the Testatika-Distatica Video it has... "By means of **grid-condensers** the energy is stored and it is then uniformly discharged, at the same time reducing the high-voltage and building up power with additional devices."

"Principle Experiment"

by

Paul E. Potter

With respect to the 30 engineer's report (of 1999) the 'principle experiment' was set up in such a way (see diag 1) that by swivelling the cross-piece over two other plexiglas blocks a current was transferred into two capacitors. Possibly when someone grabs hold of the swivelling cross-piece they transfer some static electricity from their body to the grilles of the cross-piece which, when vigorously turned back and forth will initiate a transfer of electric charge to the two stacks of blocks below them attached to the base. This may either be because anyone walking over a carpet or wearing man-made fibres will already hold thousands of volts of electrostatic charge - which will be enough to 'prime' this apparatus after touching it, to get it to work, much the same as when a rotating influence machine has to be primed with an electric charge before it will work; or, as many researchers have surmised already, that the plexiglas blocks glued to the swivelling cross-piece had been charged up with electricity as an ELECTRET.

The use of mesh around the cross-piece guarantees a variable capacitance to the moving arms --- and as these are moved quickly over the base blocks (again, alternated with mesh and Plexiglas) an amount of electric charge will be transferred to them EACH TIME the arms go backward-and-forward over them. Electronically, you have one variable capacitance acting upon another variable capacitance - which is why Baumann said that if metal foil were used instead of the mesh it would not produce the same effect.

What happens next is called "dielectric absorption", and the following extract, from "Dielectrics" by P.J.Harrop (1972) pp71, will explain;

"When a given dielectric [i.e., plexiglas] has a field put across it, and this field is then removed, the electrodes are briefly shorted out (not enough for all the ions and particles to relapse back) and the device left on open circuit one finds subsequently that it has partially charged up again.

This is due to the slow-moving charge carriers remaining in position. It can be a frightening phenomenon with practical dielectrics since a person who has briefly discharged a charged insulator may subsequently touch it and be severely shocked." Some dielectric materials being more prone to this effect than others, and so obviously some experimentation will be needed to choose the best perspex, plexiglas, plastic, or acrylic materials so as to take the most advantage from this dielectric absorption effect.

Once the blocks are being charged up the electric charge simply flows into the two interconnected capacitors and accumulates.

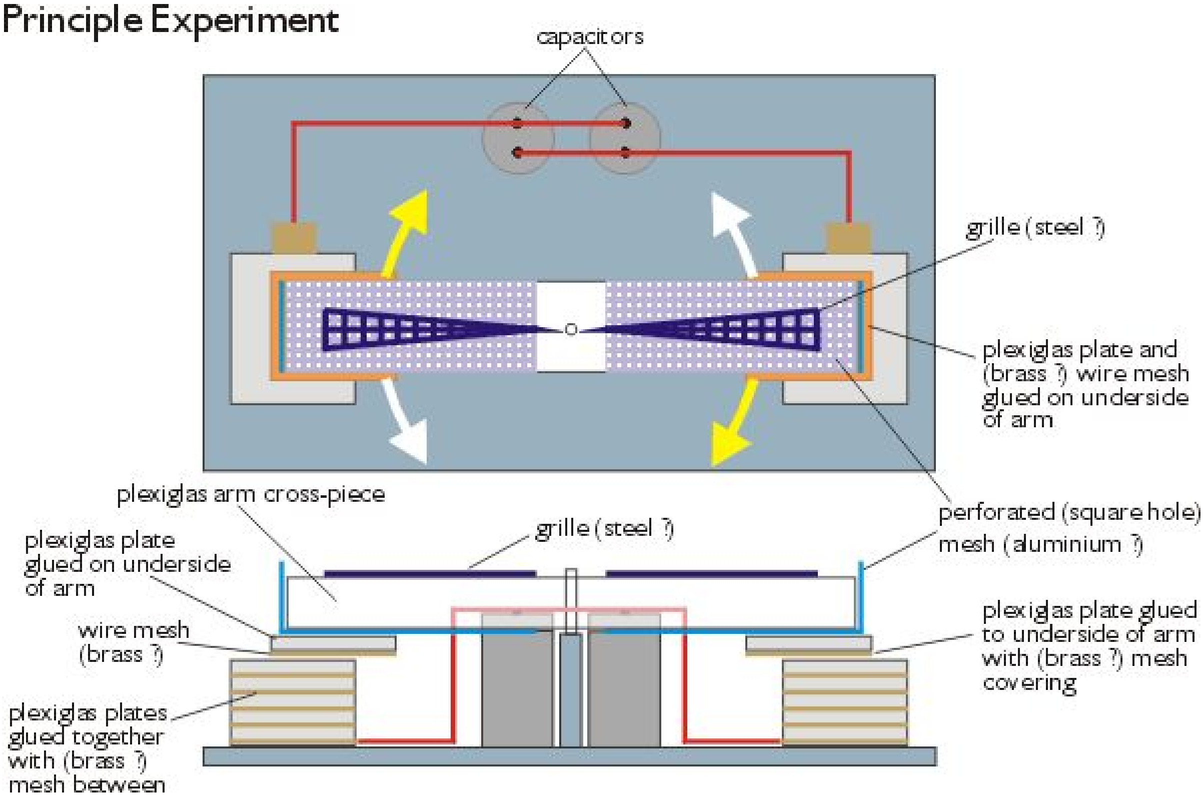
Principle Experiment
capacitors
grille (steel ?)
plexiglas plate and (brass ?) wire mesh glued on underside of arm
perforated (square hole) mesh (aluminium ?)
plexiglas arm cross-piece
plexiglas plate glued on underside of arm
grille (steel ?)
wire mesh (brass ?)
plexiglas plate glued to underside of arm with (brass ?) mesh covering
plexiglas plates glued together with (brass ?) mesh between

Linden Experiment ~

A look at the only available diagram of the Linden experiment (see diag 2) shows a horseshoe magnet coupled to what seems to be a closed-ended wire. It can also be seen in this diagram that the wire coils around the magnet are sufficiently spaced apart so as to provide capacitance (between each coil of the wire) in the circuit. So, with capacitance, coils (for induction), and magnetic flux, you have all the ingredients needed to make an oscillating circuit --- provided there is a supply of voltage and some sort of interruption mechanism - then you have a circuit that will resonate. And this leads us back to that oft repeated question --- is the block used in the Linden Experiment an electret. The first person to PUBLISH how they have duplicated this experiment will be the one to answer that question...

But there is something wrong with this diagram --- the resonant frequency of this simple circuit --- depending only on the values of inductance and capacitance included in the circuit would consequently enable it to oscillate at only a few kilohertz at best. No circuit of capacitance/inductance can be made to resonate at such a high frequency as claimed, not even if it included any form of quartz crystal. If, as the diagram says, it resonates at 140 MHz then there must be a Lecher wire system (the running of two conducting wires in a parallel line, about a foot apart or less, for several feet) to make it resonate at such a high frequency. It would seem to me also that a required modification of the Linden Experiment diagram would be to put a different metal into this circuit where the wire is said to be "closed-ended", say for instance a zinc plate, then there will be a contact voltage established between the copper wire and the zinc plate. Such a voltage would start the circuit resonating, for the reasons stated above.

And as with the Tini setup if a block comprising two metal plates separated by a suitable dielectric material (such as plexiglas) is placed in an oscillating electric field the electric charge on the metal plates will permeate into the dielectric, and for the same reasons as detailed above in the Principle Experiment, will temporarily accumulate voltage because of dielectric absorption. As I have already said elsewhere there is a great similarity between the phenomenon of the Testatika horseshoe blocks (and the Tini setup) and the principle behind Patrick Flanagan's Electron Field Generator which energizes an electron cascade mechanism throughout the immediate environment.

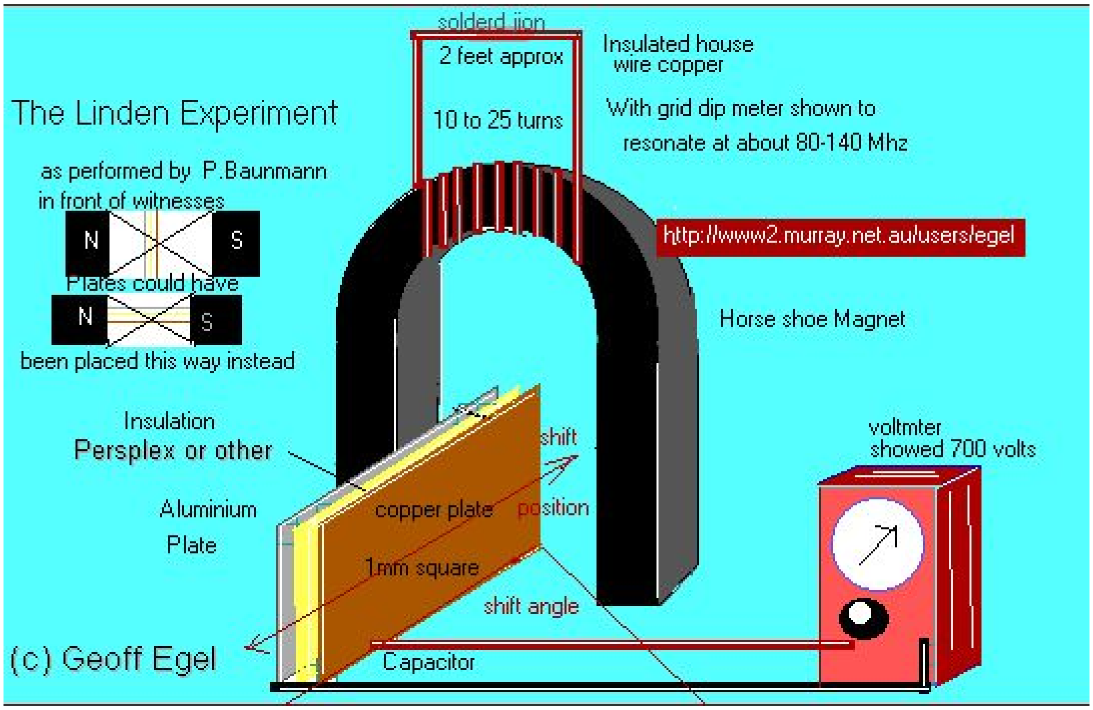
solderd jion
2 feet approx
10 to 25 turns
Insulated house wire copper
With grid dip meter shown to resonate at about 80-140 Mhz
The Linden Experiment
as performed by P.Baunmann in front of witnesses
N
S
Plates could have
N
S
been placed this way instead
http://www2.murray.net.au/users/egel
Horse shoe Magnet
Insulation
Persplex or other
Aluminium Plate
copper plate
1mm square
shift
position
shift angle
voltmter showed 700 volts
(c) Geoff Egel
Capacitor

Geoff Egel (1997) --- http://www2.murray.net.au/users/egel ~

Rectifier Circuit ~

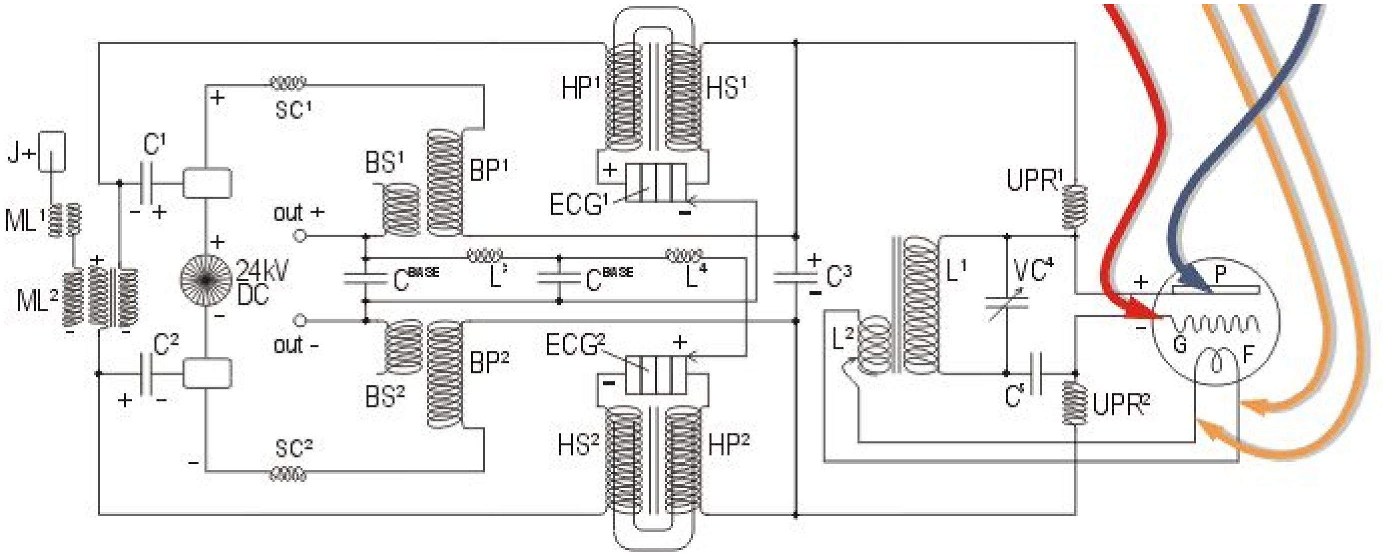
J+
ML¹
ML²
C¹
C²
SC¹
SC²
24kV DC
out +
out -
BS¹
BP¹
BS²
BP²
HP¹
HS¹
ECG¹
ECG²
HS²
HP²
C^BASE
L³
C^BASE
L⁴
C³
L¹
L²
VC⁴
C⁵
UPR¹
UPR²
P
G
F

The rectifier forms the basis for Testatika's operation For whilst the LC circuits L^1, VC^4, UPR^1, UPR^2 and C^5 set up oscillations from the generator's high voltage output the rectifier controls the oscillations to provide positive dc pulses (which are then directed through a step-down transformer BP^1/BS^1 and BP^2/BS^2), to supply power at a higher current rate and lower voltage.

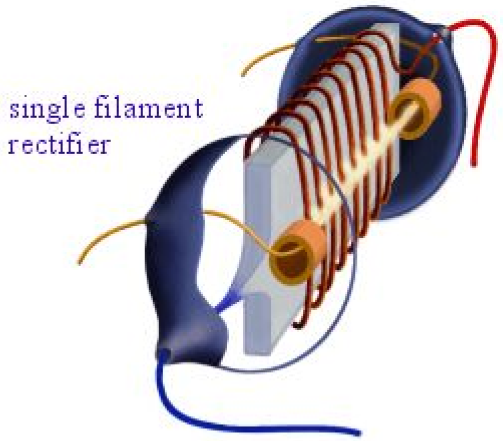
single filament
rectifier

Unidentified European Report ~

"Believe or Not, Here It Is!"

The first really running "free energy" machine coming from Switzerland, Europe. It was developed over a 20 years Research period by a religious group called: METHERNITHA. This group lives in CH-3517 Linden, Switzerland. The inventor of this superb machine, Mr.Paul Baumann claims, its running principle was found by studying the lightning effects from nature.

And here are the facts :

* Testatika is an influence-type Wimhurst machine which runs on it's own energy, once started by counterclock revolving it's 2 dics by hand !!!

* Testatika not only runs on it' own energy, but produces also a huge amount of excess power, at least 3 KWATTS of power! That is enough to supply a one-person apartment with one machine!

* The machine you see during this demo-animation is only about 70 cm wide, 40 cm deep and about 60 cm tall !

* It delivers DC-Voltage ranging from 270 til 320 Volts, only depending on the dryness of the air! At this voltage it can supply at least 10 Amperes of DC-current !

* Testatika is not a perpetuum mobile, but an energy machine that collects it's huge amount of "FREE" energy from the charged and ionized air particles. But there are still some technological tricks implemented to overcome the normal drag-resistance of a conventional Wimhurst machine, which is still the secret of the Methernitha group !!!

When will this technology be available for everyone?

The Testatika machines, (there already exists also some smaller units which only deliver about 200-300 Watts) are not yet mass-production type models! They are still laboratory prototype units, although they are build with a very good craftmansship !

For more info contact directly:

METHERNITHA, CH-3517 LINDEN, Switzerland
TEL.-Nr.: ++ 41 31 97 11 24

The pictures are from some photos and from a video-tape Methernitha sells. It shows the machines (also the smaler ones) and explains also Methernitha's spiritual aims. The tape has a running length of about 40 minutes and is really worth looking at it! It is also available in
VHS-NTSC and American language. It also shows Methernitha's earlier research developments like huge wind generators.

With the Testatika there is no fraud, hidden batteries or any other hidden energy source. It is really running! They already have the technology of ten years ahead! No more oil, no more pollution, no more atomic waste products, no more hunger in this world! This is the machine the mankind has dreamed about for centuries. Now it has come true!

More information about the Methernitha machine is also available in the German magazine *RAUM & ZEIT*, issue Nr.40 (8).

Jean L. Naudin Labs (4 February 1998) ~

"Testatika Generator and Over-Unity"

by

Cyril Smith

Having read Nelson Camus' article purporting to "explain" the Testatika over-unity generator (http://members.aol.com/overunity2/nelson/testatic.htm), I am of the opinion that the real explanation is hidden amongst the 19th century electrical mumbo jumbo which makes up much of the machine (Leyden Jars, Horseshoe Magnets, Wimshurst Generator and so on). From the description of spiral-wound foil capacitors containing radioactive material and placed within current carrying coils it strikes me that perhaps the real energy comes from Beta particles (fast electrons) absorbed into the electrical circuit.

To extract energy from Beta particles it is not just enough to capture them. Clearly this will result in a current flow according to the capture rate, but current by itself is not power. The kinetic energy of the particle must be captured and this will result in potential difference or voltage. If a Beta particle enters a thin foil conductor normal to its surface and is captured, then the potential difference associated with giving up its kinetic energy can be expected to occur across the opposite faces of the foil. If however the Beta particle were turned so as to enter at a shallow grazing angle to the surface, not only would the probability of capture be increased (since the particle will travel further within the material) but the potential difference will occur along the length of the foil. Beta particles travelling even at relavistic velocities can be turned within short distances by relatively weak magnetic fields, so the concept shown in the following Figure suggests itself.

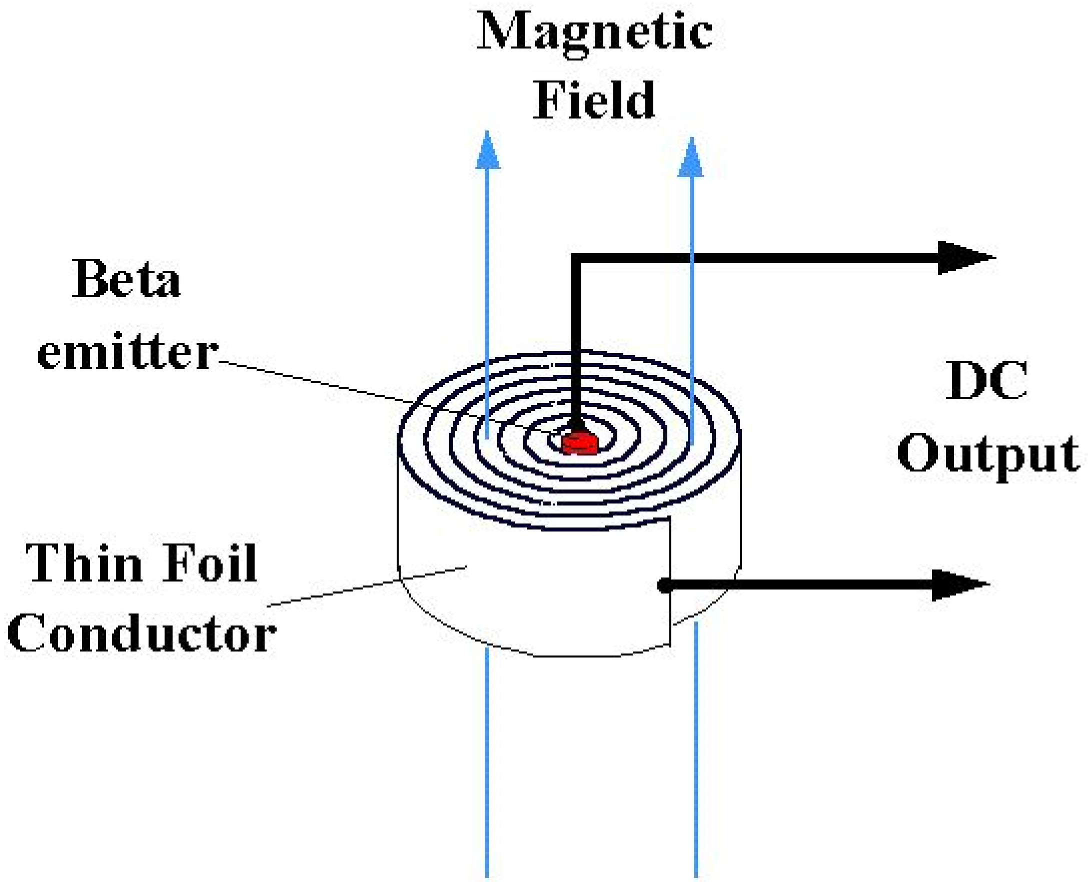

Methernitha Statement of Purpose ~

"The Research Work of Methernitha in the Field of the so-called Free Energy"

Ever since the foundation of Methernitha there existed a department for research, development and electronics, which was concerned with the problem of alternative energy sources, namely with technologies, which were suited to exploit the inherent forces of nature and thus to unlock sources of energy without disturbing natures ecological balance in any negative way. Any technology man invents should serve him in short as well as in long terms, and this condition is not fulfilled as soon as it opposes nature in any way.

This team of research within Methernitha works completely autonomous and is financed out of the co-operatives own resources, without any outside support.

The efficient utilisation of wind energy was one of the first objectives of Methernitha's research program. At the beginning generators with special excitation were developed, which allowed to load the cells of accumulators even at low RPM at times when there are only moderate air movements.

Utilising the kinetic energy of water currents was another field of interest of the development team, but it was pursued more as hobby. The key problem was here to transfer the slow revolutions of the waterwheel to an extent that the excitation threshold of the generator could be surpassed by a minimal loss of energy.

Also solar cells and solar heat collectors attracted the attention of our researchers since a long time. But since in these fields other institutions have attained outstanding results, Methernitha started, and this was already more than 30 years ago, to concentrate its efforts on lesser known and even generally unknown sources of energy. The result of this scientific work is the Thestatica machine.

The question arises: How it comes, that Methernitha, nothing more than a private organisation, could invest so much time, engagement, perseverance and financial resources in this kind of research.

Research and development are integrated parts of the general idealistic concept of Methernitha. To make you understand these ideals and goals, we will now introduce you into the practical sides of this spiritual community Methernitha, as it functions as a co-operative of people, living and working together.

Linden is a calm village of farmers just as dozens of others in the region of the valley called Emmental. However Linden is also the home of a special form of human life, which is capable of attracting more and more people from all over the globe, and which has repeatedly caused astonishment through its excellent functioning, even in extremely difficult situations.

There is no doubt that the formation of Methernitha is also a good part of the life story of Paul Baumann. Through his extraordinary technical capabilities, but also through his astonishing practicable wisdom he opened relations to all kind of people with ideals and in many places, and pretty soon, the idea to form a co-operative enterprise took shape.

"In the name of the God Almighty" people of equal thinking gathered and founded a co-operative, which could serve as the economic basis of this spiritual community.

"We want to be a united group of brothers, and never separate however severe the burden may be", this was the solemn vow.

Renunciation of alcohol and smoking and the will to realise a harmonious community life without dispute and discord like in the original Christian communities were the prerequisites to become a member. For the members Methernitha is an ideal opportunity to lead a fulfilled life by practising charity.

A workshop was erected and soon, one house after the other grew on these premises. Also all construction was done out of own resources and solely with the savings from the common work.

Today Methernitha is a social model proving the quality of its ideals through its well functioning just more than forty years. The people working here are almost without exception members of Methernitha.

Not even the prospering development that took place over the following decades could impair or even suppress the global idealistic aims. On the contrary, everybody works in his own interest with diligence and great joy towards the erection and the support of their new homeland and according to the principle:

One for all and all for one!

With this word one can conquer anything. Also the ancient truths appear again and attain respect.

The people living here feel themselves as members of a family, like a group sitting in the same boat and proud, but also grateful proprietors of their own beautiful homeland, which they may shape exactly as they wish to. Evidently, this form of human social life can function only on the base of idealistic principles.

The question arises, how the realisation of a sincere religious philosophy of life may be brought in harmony with a successful economic management. It is not obvious at all, that this is attainable.

Nowadays there are many amongst us that are caught in the world-wide and dense network of social and economic dependencies and obligations and many also feel the confrontation with its problems.

One member of the economic directory has recently phrased this in the following way:

"The fact that all essential functions of Methernitha are fulfilled without any external force, driven solely through inner conviction, which causes everybody to help and take care of the other, this is for me the most astonishing effect which is produced by this form of living together. It seems to be a miracle."

Another miracle within Methernitha is the Thestatica, which is the result of more than 20 years of research.

This wonder machine is lurked from nature, nothing else. Nature is the greatest source of power as well as knowledge which man has, and it still conceals many secrets, which are only revealed to those, who approach and tie in with them with highest respect and responsibility.

To understand nature and to perceive its voice, man is obliged to experience silence and solitude, and it was there, where the knowledge about this technology was obtained.

For these reasons it was always a great concern of Methernitha to acquire properties, untouched by man as far as possible, be it in valleys or forests, in the mountains or ashore of lakes, where one could study nature, ones own being and the creator of all this universe in silence and concentration and without being disturbed.

The public never understood this properly, rather interpreted it wrongly as an act of seclusion, assuming we had to hide something unclean. We actually had --- and still have --- to take great troubles to realise undisturbed all the things we intended to accomplish.

Such undertaking in research and development necessitate considerable financial expenditures. Therefore we are quite often obliged to construct things with most primitive means and materials. What was thrown away by our affluent society, we collect and possibly set up with it a cornerstone in the discovery of new forces and truth.

We are fortunate in gaining the experience that paradoxically the most beautiful and useful results can be achieved by just using the most simple means. Never did we use any borrowed capital because we want to stay free Swiss citizens and do not want to be hindered or even bound in any way in the pursuance of our aims.

The two conterrotating discs generate an electrostatic charge. One disc represents the earth, the other the cloud. Using grid electrodes the charges are bound. After that they are collected by non-contacting so-called antenna keys and then sorted.

After being initially turned on by hand, the discs rotate by themselves according to the electrostatic laws about attraction and repulsion. A rectifying diode keeps the cycles in steady state. Otherwise the impulses of attraction and repulsion would accumulate and cause the discs to run faster and faster. The correct speed is of great importance and for optimal power generation the discs have to run quite steady and slow.

By means of grid condensers the energy is stored and then uniformly discharged, at the same time reducing the high voltage and building up power with additional devices. Finally the machine supplies a uniform direct current, which varies according to the size of the model. The machine furnishes about 3-4kW permanent output, depending on humidity, whereby the electric potential ranges from 270 to 320Volt. High humidity of the atmosphere prevents the build-up of electric potential. The drier the air, the better.

No doubt, through the so far achieved results one main objective has been reached, namely to prove that it is possible to use Free Energy. Nevertheless the research work is not yet completed.

To the educated physicist many a thing of this machine may seem impossible, maybe even crazy. Maybe he is also offended by the conceptions used to explain the whole. Only partly we could use the concepts of conventional physical terminology to explain and define only approximately the functions and properties of the various parts of the machine.

After all it will be necessary to create some more new concepts like the one we have already used before, when we termed the non-contacting collectors of electric charges as antenna keys.

This machine puts experts, which are just trained in conventional physics to a very hard test, because its mode of action is not explainable with the state of the art of officially accepted physical knowledge, or at the most only partially explainable. However also a trained specialist should remain free and independent in his thinking, and should avoid to be limited by the temporal framework of publicly admitted knowledge in any science.

It has to be remembered that the established science was already many times forced to change or give up some of its very fundamental concepts. Think about Galilee, to name only one example. Our human society almost condemned this man as a sorcerer and magician, just because he investigated and discovered a truth that seemed unacceptable by the established science of the days.

The book knowledge of any times is not wrong, but it is incomplete, and therefore allows to draw wrong conclusions.

We are part of a new area which brings to light many new facts and new knowledge. The clothes of nowadays science have become too tight and should be stripped off, just as the larva of an insect does with its skin. Only this will allow a true metamorphosis to take its course, and finally, at the limits and at the destination of all worldly knowledge, an universal and unlimited spiritual science, radiating and beautiful, just as the completed imago of an insect, may give its blessings and benediction to a renovated humanity.

To ever reach there, a universal development of man has to take place. This however is only possible when man becomes aware of his true role within the whole creation, and again learns to recognise his true tasks, because the whole universe functions within a strict and precisely structured order according to the will and word of the creator. Therefore also man should recognise and realise these universal laws that are valid within the whole and within every part of this creation.

The hard facts rather show how far man has left the divine order through his self willed and authoritarian way of action and that he has become the actual cause of all discord and evil on this planet.

Unfortunately the ruling bodies that should be responsible for the well-being of the people work too often with the target to make life more and more difficult and to render impossible every free spiritual development.

Instead of utilising the achievements of science and technology for the benefit and preservation of all form of life, they are abused carelessly and irresponsibly to destroy and to kill, and thus turn them into a curse upon mankind.

To change all this, the evolution of a new technology is not enough, even if it were the most ecological and ingenious. To change this present status one has to go much deeper down, to the root-cause of all this evil, and this is mans way of thinking, his state of mind.

The ancient divine commandments are still valid today and also show today the way and direction humanity should go, as clearly spoken by the prophet Mica:

God has told you what is good. And what is it that the Lord asks of you? Only to act justly, to love loyalty, to walk wisely before your God.

"Testatika-Distatica Machine"

(Transcribed from the Methernitha Testatika video by Paul E Potter)

"... The efficient utilization of wind energy was one of the first objectives of Methernitha's research program.

At the beginning generators with special excitation were developed which allowed to load the cells of accumulators even at low rpm, at times when there are only moderate movements.

Utilizing the kinetic energy of water currents was another field of interest of the development team, but it was pursued more as hobby. The key problem was here to transfer the slow revolutions of the water-wheel to an extent that the excitation threshold of the generator could be surpassed by a minimal loss of energy. Also solar cells and solar heat collectors attracted the attention of our researchers since a long time. But since in these fields other institutions have obtained outstanding results Methernitha started, and this was already more than 20 years ago [since 1960], to concentrate its efforts on lesser-known and even generally unknown sources of energy, the result of this scientific work is the Testatika machine of which most of you may have heard already.

The two counter-rotating discs generate an electrostatic charge. One disc represents the earth, the other the cloud. Using grid-electrodes* the charges are bound. After that they are collected by non-contacted, so-called, antennae keys** and then sorted [shorted ?].

After being initially turned on by hand the discs rotate by themselves according to the electrostatic laws about attraction and repulsion.

A rectifying-diode keeps the cycles in steady state, otherwise the impulses of attraction and repulsion would accumulate and cause the disc to run faster and faster. The correct speed is of great importance, and for optimum power generation the discs have to run quite steady and slow.

By means of grid-condensers* the energy is stored and it is then uniformly discharged, at the same time reducing the high-voltage and building up power with additional devices.

Finally, the machine supplies a uniform direct current which varies according to size of the model.

The machine furnishes about 3 to 4 Kilo-Watt permanent output, depending on humidity, whereby the electrical potential ranges from 270 to 320 volt. High humidity of the atmosphere prevents the build up of electric potential. The dryer the air the better.

No doubt, through the so-far achieved results, one main objective has been reached, namely, to prove that it is possible to use free energy. Nevertheless, the research work is not yet completed: To finish a model which can be handed out more or less to anybody and without any haphazards, also to non-specialists, much work and also time will still be needed.

Only partly we could use the concepts of conventional physical terminology in order to explain and define only approximately the functions and properties of the various parts of the machine. After all, it will be necessary to create some more new concepts, like the one we have already used before, when we termed the non-contacting collectors of electric charge as antennae keys**. This machine puts experts who are just trained in conventional physics to a very hard test..."

* The German original has gitter-condensers, with gitter defined as wire lattice, grille, grate.

** the original word used is tasten or taster, which means antenna, probe, key.

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Hermann PLAUSON

Conversion of Atmospheric Electricity

Biography (Wikipedia)

Meridian International Research: Atmospheric Electricity Research

***Science & Invention* (Feb. 1922): "Power from the Air" (I)**

***Science & Invention* (March 1922): "Power from the Air" (II)**

Plauson's Patents (List)

H. Plauson: USP # 1,540,998 -- Conversion of Atmospheric Electricity

H. Plauson: British Patent # 157,262 -- Improvements in Electric Motors

H. Plauson: British Patent # 157,263 -- Process & Apparatus for Converting Static Atmospheric Electrical Energy into Dynamic Electrical Energy...

***Science & Invention* (June 1928) - "Harnessing Nature's Electricity"**

H. Plauson : British Patent # 299735 -- Process for Producing Rapidly Moving Electrons [PDF]

H. Plauson : *Gewinnung und Verwertung der Atmosphatischen Elecktrizitat* (1922) [PDF]

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http://en.wikipedia.org/wiki/Hermann_Plauson

Biography

Hermann Plauson was an Estonian engineer and inventor. Plauson investigated the production of energy and power via atmospheric electricity.

Plauson was the director of the Fischer-Tropsch "Otto Traun Research Laboratories" in Hamburg, Germany during the Weimar Republic of the 1920s. He built on Nikola Tesla's idea for connecting machinery to the "wheelwork of nature". Plauson's US Patent # 1,540,998 describes methods to convert alternating radiant static electricity into rectified continuous current pulses. He developed the Plauson's converter, an electrostatic generator. In 1920, Plauson published a book titled "*Production and Utilization of the Atmospheric Electricity*" (*Gr., Gewinnung und Verwertung der Atmospharischen Elektrizitat*). A copy of this book is in the British Library.

It is believed that he was related to Gertrud Plauson (the exact relationship is unknown; she may be his wife).

"Power from the Air". *Science and Invention* , Feb. 1922, no. 10. Vol IX, Whole No. 106. New York. (nuenergy.org)
"Power from the Air". *Science and Invention* , March 1922.

***Science and Invention,* Vol. IX (106) #10 (February 1922)**

Power from the Air (I)

by

Hugo Gernsback

During the war there was developed in Germany a new art --- or science --- that bids fair to revolutionize our present means of obtaining power.

This art, which is as new now as wireless was 25 years ago, will attain proportions during the next 25 years that may appear fantastic today. The inventor of the new science, an engineer of note, Herr Hermann Plauson, has devoted years of labor to his researches and he has now actually in use small power plants, that generate electricity direct from the air, day and night, without interruption at practically no cost, once the plant is constructed.

We had occasion, in one of our former issues, to describe the system, roughly, from cabled dispatches, but complete information is available now. The amount of electrical power that resides in our atmosphere is astounding. Herr Plauson found in his experiments that a single balloon sent aloft to a height of 300 yards gave a constant current at 400 volts of 1.8 amperes, or in 24 hours over 17-1/4 kilowatts! By using two balloons in connection with a special condenser battery, the power obtained was 81-1/2 kilowatts in 24 hours. The actual current delivered was 6.8 amperes at 500 volts.

The best balloons used by the inventor are made of thin aluminum leaf. No fabric was used. A simple internal system of ribs, stays and wires, gives the balloon rigidity as well as a certain amount of elasticity. The balloon, when made airtight, is filled with hydrogen or better, with helium. It will then stay aloft for weeks at a time. The outer surface is dotted with extremely sharp pins, made sharp electrolytically. Ordinary pins did not prove good current collectors, as they lacked extreme sharpness. The pins themselves were made from amalgamated zinc, containing a radium preparation, in order to ionize the air. It was also found that by dotting the outer surface of the balloon with zinc-amalgam more current could be collected. Even better results were obtained with polonium amalgam. Plauson states that the function of these amalgams is purely photoelectric.

One hundred of such captive balloons, separated one hundred yards from each other, will give a steady yield of 200 horsepower. This is the minimum, because in the winter this figure increases up to 400 horsepower, due to the higher electrification of the atmosphere.

We need not go into the technic of how the current is finally made useable for industrial purposes, suffice it to say that the problem has been entirely solved by Herr Plauson. By using batteries of condensers, high tension transformers, etc., the current can be transformed to any form desires. Such as for lighting lamps, running motors, charging storage batteries, etc.

Plauson also invented a sort of electrostatic rotary transformer which gives alternating current without the use of condensers and transformers. Indeed, its output is very great, as it actually ‘sucks’ the current down rapidly from the collector balloons. There is no doubt that this invention will soon come into universal use all over the world. We will see the land dotted with captive balloons, particularly in the country and wherever water power does not abound. Indeed, the time is not distant when nearly all of our power will be derived from the atmosphere. So far it seems to be the cheapest form of power known, it being much cheaper even than water power --- the cheapest form of power known today. Not only that, but as the inventor points out, no devastating thunder storms occur near such aerial power plants, because the balloons act not only as lightning arresters, but they quickly discharge the biggest thunder cloud, safely and noiselessly through their grounded spark gaps.

Science & Invention **(March 1922), page 1006, 1007**

Power from the Air (II)

by

Hugo Gernsback

[For many years electrical engineers have endeavored to devise some means whereby it would become possible to utilize the free electrical energy ever present in the atmosphere, but they were not successful, as every now and then an extra heavy surge of static current would rush down the elevated conductor and endanger the lives of the experimenters, or else destroy the apparatus connected with it. A German engineer has, however, devised the somewhat elaborate scheme here shown in brief, and he has succeeded, at least so his report states, in safely extracting several kilowatts of electrical power from the atmosphere with metallic surfaced balloons, elevated to a height of only 1000 feet.]

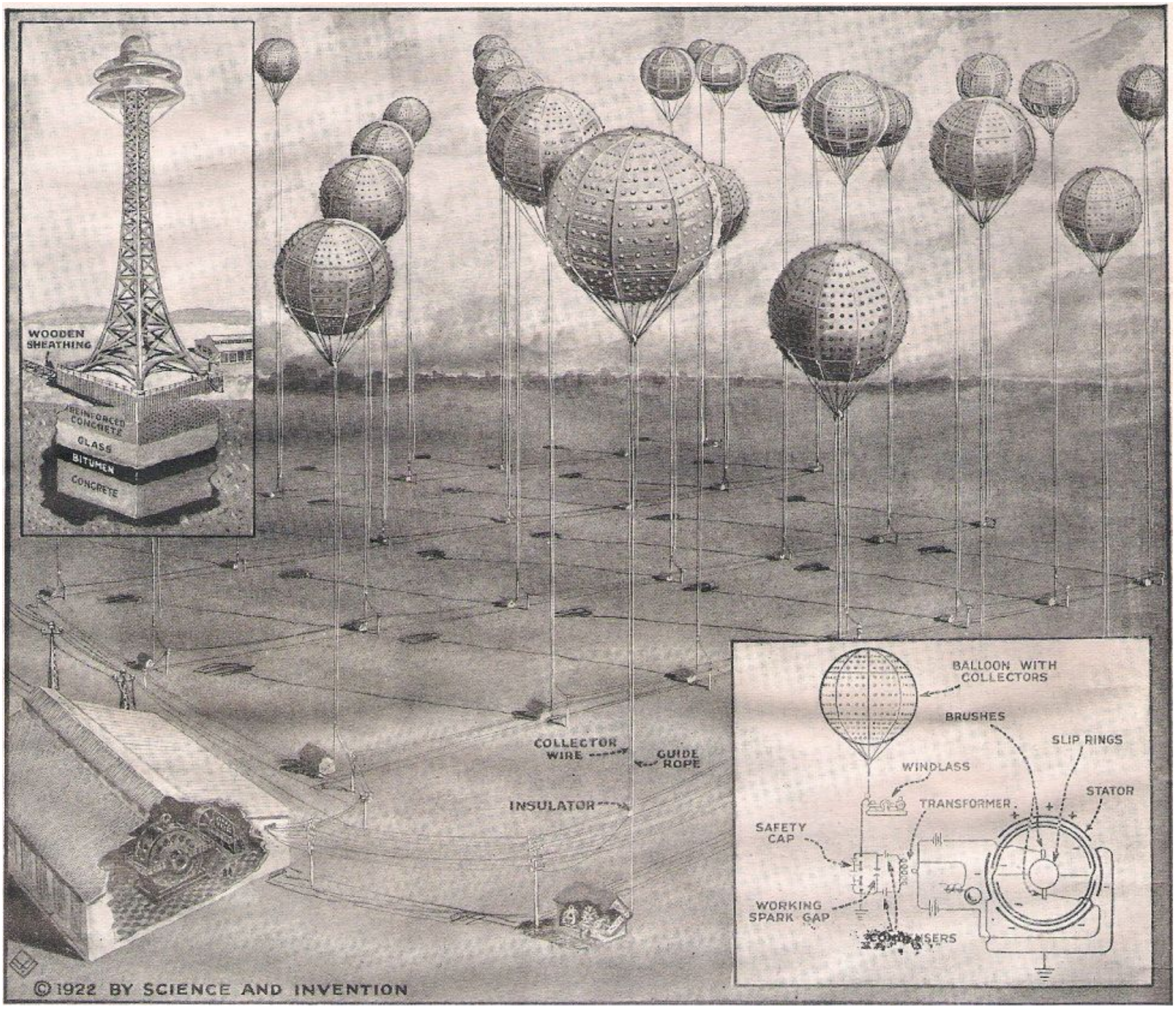

We have previously treated of the extraction of electrical energy from the atmosphere. The difference of electric potential in different parts of the atmosphere, and the difference between the upper air and earth make it a tempting proposition to obtain power from atmospheric electricity. The power would take the form of high potential difference with a discharge almost of a static nature. It has long appeared rather doubtful to conservative engineers, if such a source of power should really be available. Yet when we see the lightning flash, it certainly suggests very high power, even though the total of its energy may be small, on account of the small duration of the discharge It is not to the thunder storm that we look for getting power from the atmosphere, as the subject is now being seriously investigated. A German scientist, Hermann Plauson, has published a very elaborate work on this subject, and has investigated the use of kites, balloons and towers, for the utilization of the high potentials existing in the air at different altitudes, and has studied out the construction of motors to be operated by the peculiar type of discharge which will be obtained, if the projects are successfully carried out.

We will first speak of the methods used for collecting electricity from the upper air. The author cites several German patents. One of them shows the use of a kite balloon. The balloon is shown floating in the air, kite fashion, and from it hangs a great net or aerial for the collection of electricity. The conductor from the aerial leads to the ground station; quite an elaborate description is given of the net-work which the patentee proposes to have covered with needle points. A windlass takes in or pays out cable for the balloon, and the patentee claims that by sending the apparatus to a height of about one mile he will have 225,000 volts to draw upon. He then speaks o a battery of 20,000 cells in series, which will use up to 40,000 to 50,000 volts in the charging. This certainly provides for a reasonable large fall of potential.

But our author discards this idea and first suggests something more permanent. He proposes the erection of towers to be in the neighborhood of 1,000 feet high, or about the height of the Eiffel Tower. At the summit he has his collecting aerial. The appliance consists of a number of copper tubes; within each one he proposes to burn gas lamps, whose products of combustion will reach the aerial, a collecting net-work covering the tops of the tubes. One of his apprehensions is that if rain should wet his connections trouble might ensue, so he proposes a protection at the top in the shape of a great bell-like shield, resembling in his terms “a Siamese pagoda”. He also compares the form of the protection to that of a great petticoat insulator. Another of his difficulties is that he must have his tower insulated from the earth. He, therefore describes a complicated foundation for his structure. He proposes first to pour in at the bottom of the excavation a foundation of simple concrete. On this he places a layer of asphalt, and then a layer of cast glass, three to ten feet thick, and then comes a reinforced concrete foundation, to which the metallic foot of the tower is to be anchored. This foundation must rise at least seven feet above the ground level, and is to be boarded in on all sides to protect it from moisture. The author’s idea s to erect a number of these towers connected by a horizontal cable, to which the aerials for collection of potentials are secured.

The author strongly advocates balloons as collectors of the electric power of the air. These he depicts covered with spots. These spots indicate areas to be variously coated and prepared to collect potential from the atmosphere.

In the first place he describes the balloon as made of thin metallic leaf supported by internal ribs. Steel wires silver-plated, copper-plated, or aluminum-coated, run from the balloon to the pendant or junction ring. To this ring the tether cable is attached and runs to an insulated windlass on the surface of the earth. The balloon is to rise to an altitude varying from 300 feet to three miles.

The coating of the spots is to be of the thinnest amalgam, of mercury and gold, or zinc, or even polonium, perhaps only 1/2500 inch thick. All over the upper face of the balloon are numberless metal points. To prepare the needle-like wires, they are collected into bundles and are treated electrolytically in a bath, so as to be dissolved in part. This gives a sharp point and roughened surface, all adapted for collecting the electric energy. The points may be of copper, steel, or some hard metallic alloy. After this corrosion. As it may be termed, the wires are plated with gold or other of the so-called noble metals. It is advised that polonium or radium salts be added to the plating bath.

Dr Plauson devotes many pages of his book to describing his motor. This is a rotary motor including a stator and rotor and its peculiarity is that it contains no coils, develops no electromagnetic field properly speaking, but works by static excitation. One typical arrangement is shown in our illustration. The stator plates and rotor plates are concentric with each other, representing segments of cylinders. The alternation of negative and positive charged plates produces the rotation. In the connections there is included a safety spark gap to take care of dangerous potentials. Inductances and capacities are also used and indicated. It was found that the plates heated, owing to the Foucalt currents, and to overcome this, several methods of subdividing the stator and rotor plates, are described by the author.

The whole subject is quite captivating, and it really seems as if the utilization of the electricity of the air may be almost in sight. It would seem possible to carry out experiments in this direction by means of the Eiffel Tower, but of course, the trouble here is that the tower is grounded, and perfect insulation of the collecting surface is absolutely essential.

And now our author gives us some practical details. He says that on the Finland plains he carried out experiments with a balloon made of aluminum leaf with collecting needles of amalgamated zinc with a radium preparation as an ionizer. The surface of the balloon was sprinkled over with zinc amalgam. It was sent up to a height of 300 meters, early 1,000 feet, and was held by a copper-plated steel wire. A constant current of 1.8 amperes at an average of 400 volts potential difference was obtained. This gave nearly three-quarters of a kilowatt, or close to one horsepower. The collector of the balloon insulated from the earth showed a tension of 42,000 volts. By sending up a second balloon with an antenna to the same height at a distance of 100 meters from the first balloon, a current of over 3 amperes was obtained. Then by putting into the circuit a large condenser, whose capacity was equal to the surface capacity of both balloons, and of the antenna connections, the current rose to 6.8 amperes with about 500 volts mean tension. By the use of these two balloons, he eventually ran up the power to 3.4 kilowatts.

Science & Invention (June 1928)

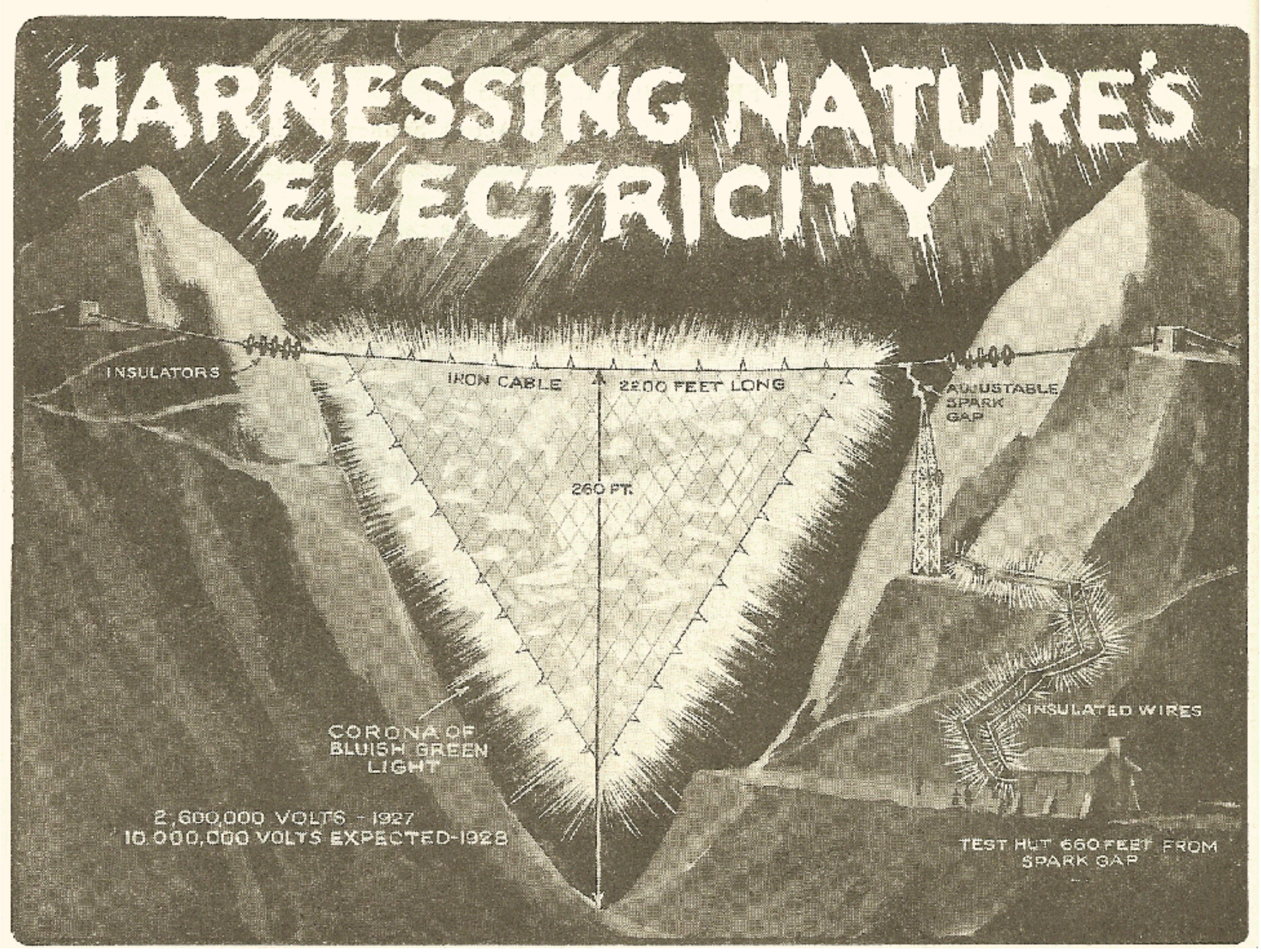
HARNESSING NATURE'S ELECTRICITY
INSULATORS
IRON CABLE
2200 FEET LONG
ADJUSTABLE SPARK GAP
260 FT.
INSULATED WIRES
CORONA OF BLUISH GREEN LIGHT
2,600,000 VOLTS - 1927
10,000,000 VOLTS EXPECTED-1928
TEST HUT 660 FEET FROM SPARK GAP

Remarkable European Experiments with Atmospheric Electrical Discharges with Potentials as High as 3,000,000 Volts

By HENRY TOWNSEND

elevation of 350 ft., and these students of natural electrical phenomena have found a very desirable location in the Alps, where they can suspend between one mountain and an adjacent one, a strong iron cable having a length of about 2,000 ft. This cable is about 250 feet above the intervening valley, and from it these daring engineers have suspended a coarsely woven wire net, which serves as an electrical capacity to gather the electricity from the atmosphere. As shown in the pictures, the wire net is supplied with numerous sharp points to aid in collecting the current from the air.

As the accompanying photographs of the actual apparatus and wire cable used last year clearly show, an adjustable spark gap of considerable length is provided. By adjusting this spark gap to various lengths, it is possible to judge the voltage of the discharge which leaps the gap at any moment. Mr. F. W. Peek, Jr., the well-known American worker in the realm of high voltage measurements, together with other engineers, have provided tabulated data and curves for various lengths of both needle and sphere type spark gaps. As one of the accompanying diagrams shows, it is a simple matter to calculate the voltage when a certain length of gap is used. The engineer first checks the length of the gap on the chart; he then follows a line horizontally from the gap length, to where it intersects with the angular line on the chart; and from the point of intersection he looks in a visual line downward to a place where the voltage is given. For needle spark gap measurements, the characteristic curve on the chart is practically a straight line, while for sphere gaps the characteristic curve on the voltage versus gap length, is a curved line. Those interested in high voltage measurements by means of the spark gap method can find the voltage-gap tables and charts in the *Standardization Rules* of the American Institute of Electrical Engineers. According to Mr. Peek's researches, the voltage per foot of atmospheric electrical discharges is about 100,000, while in laboratory measurements with A.C., transformer high potential discharges, the average voltage per foot of spark was found to be about 150,000 volts. The voltage of a lightning flash may

(*Continued on page* 156)

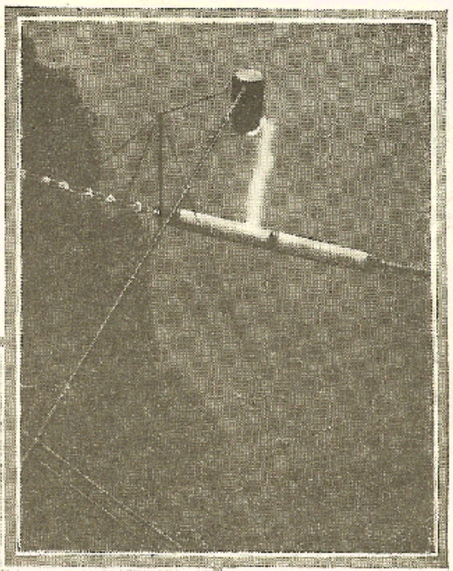

Actual photo above shows 13 ft., heavy spark obtained from the collecting net in the Alps by the German scientists. The voltage is about 2,000,000. The spark occurred once per second for 30 minutes.

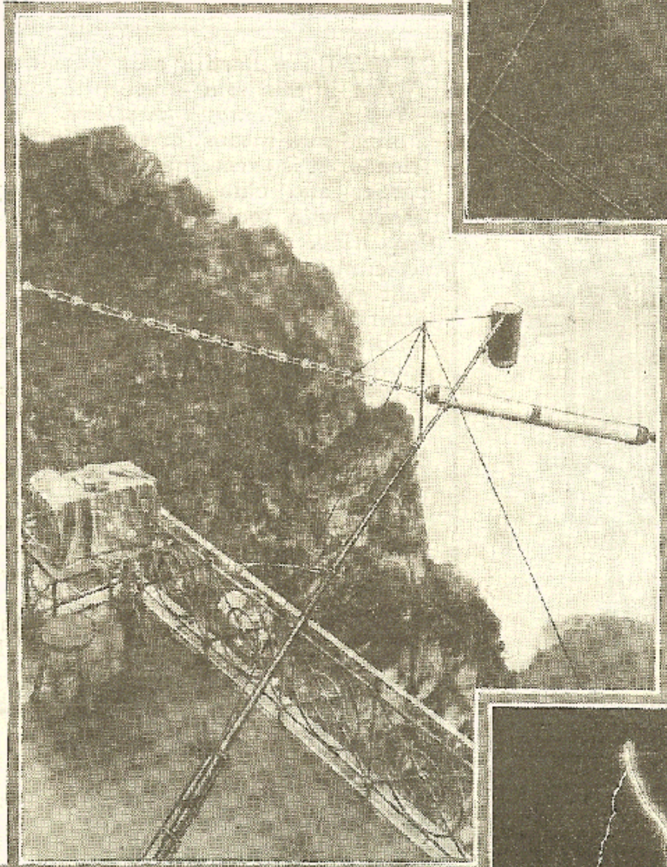

Photo, left, shows the adjustable spark gap used in the Alps. Notice the heavy electrode on the end of the adjustable arm to which the spark jumps.

Actual photograph of the experimental "kite" used by the German experimenters in the Alps Mountains, for the purpose of accumulating high potential electrical discharges from the atmosphere. Note the size of the insulators.

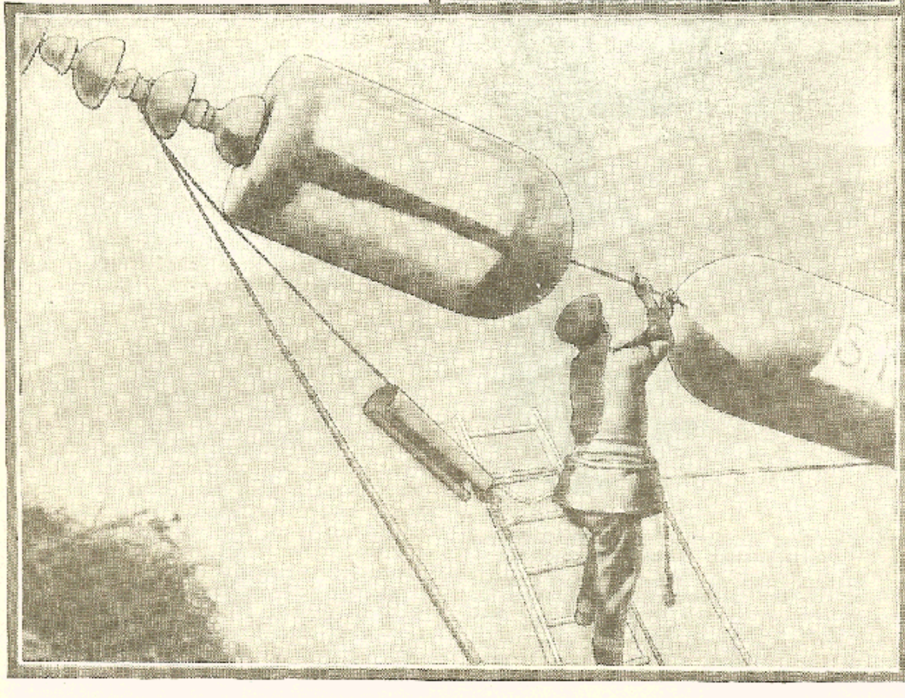

Below we see 3,000,000-volt artificial lightning stroke produced in G. E. Laboratory at Pittsfield, Mass. Note man.

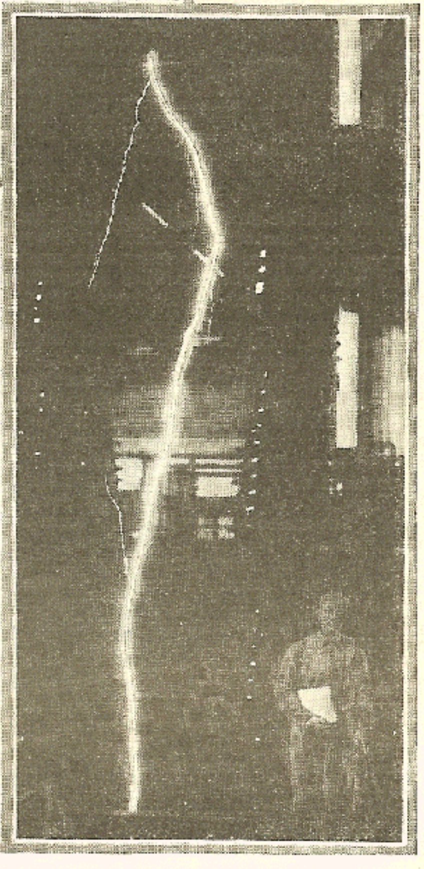

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....*Age*..........

HARNESSING NATURE'S ELECTRICITY

By HENRY TOWNSEND

(*Continued from page* 111)

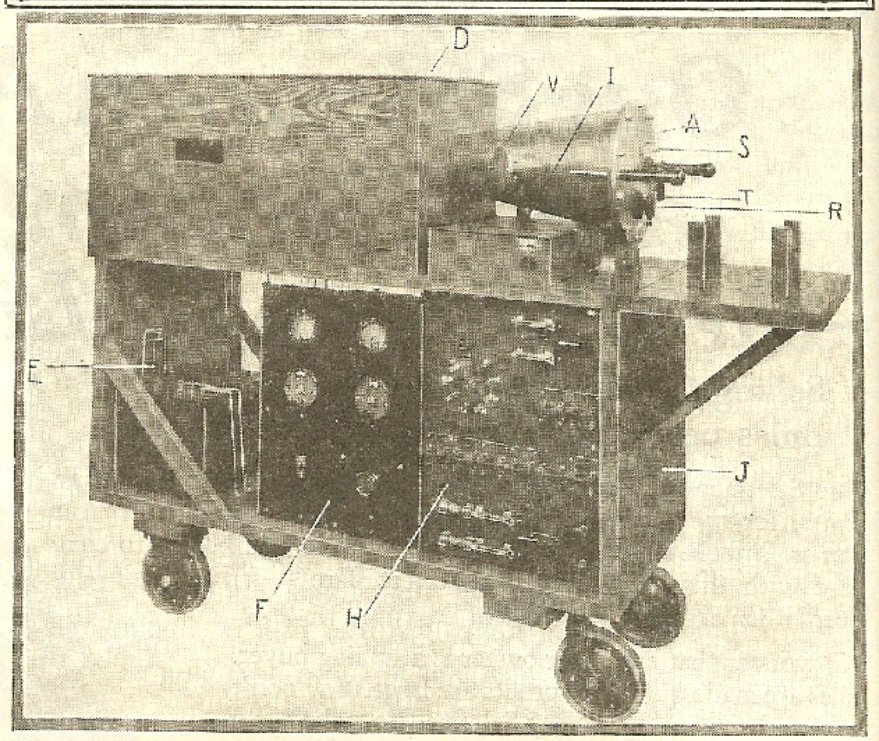

Remarkable cathode ray oscillograph used by Mr. F. W. Peek, Jr., in causing lightning to write its autograph with a pencil of electrons on a photographic film.

easily be 100,000,000 volts, as Mr. Peek has pointed out in one of his scientific papers.

WHY THE EXPERIMENTS ARE BEING MADE

ONE of the main reasons why these dangerous experiments are being carried on by the three young German scientists, whose names we have already learned, is because science believes that with a sufficiently high voltage, it will be possible for man to disintegrate the atom, and in this way make available a tremendous source of power as yet untapped. These experts have calculated that they will be able to obtain electrical energy in sufficient quantity from one of these powerful atmospheric discharges, to equal the Alpha rays obtained from 220 pounds of radium. As we have mentioned before, these experiments are of course fraught with great danger, and for that reason the experimenters seek refuge in a special lightning-proof hut, which is located about 600 ft., from the spark gap. When electrical storms are in the vicinity, it is especially important that the scientists keep within their protected fortress, for otherwise they would very probably be killed by a stray electrical discharge.

One of the peculiar things about this whole line of experiment is that the average layman does not realize perhaps, that there is a high electrical stress in the atmosphere on clear days, as well as when thunder storms are overhead. This fact has been known for a hundred years and more, and many years ago measurements of the various electrical potentials at increasing altitudes, were observed and measured by scientific investigators. There are a number of different ways in which these high electrical potentials found in the atmosphere can be measured; one of these methods involves the use of a calibrated spark gap. In this case the gap is set to a predetermined length, and when a discharge jumps this gap, the engineers know of course from previous experience and measurements, just what voltage is present. Another method of measuring extra high potentials, such as here encountered, requires the use of a static voltmeter, which involves the use of a stationary and of a movable or rotary set of metal plates, forming a condenser, to which an indicating needle is attached. For voltages above 2,000, static voltmeters have been used in a great many American central stations, and they have many desirable and useful characteristics. Of course as the voltage to be measured increases, the space between the quadrant shaped stationary and movable plates is increased and vice versa. The electrostatic field from voltages below 2,000 is not sufficient to warrant the use of a static voltmeter. Another method of measuring high potentials involves the use of the so-called vacuum tube voltmeter.

The general characteristics of the atmospheric electrical discharges, including lightning, have been measured and recorded by one of the newest scientific instruments, known as the cathode ray oscillograph. By means of this quite remarkable, high voltage scientific apparatus, Mr. Peek, one of the well-known General Electric Company staff of research engineers, has made some very interesting and remarkable discoveries concerning the nature of natural electrical discharges, particularly of lightning discharges. Many people will probably wonder why Mr. Peek and some of his colleagues in the engineering profession, including the three daring German students, Messrs. Brasch, Lange and Urban, play with such dangerous electrical discharges, and why they are at all interested in them. We explained previously why the German savants are intent on finding out all they can about these tremendous voltages obtained from the atmosphere, while Mr. Peek, we may say, also has a very practical reason for carrying on experiments with these death-dealing bolts of Thor. Mr. Peek has been for many years intent on finding out what causes the huge insulators on long distance, high potential transmission lines to break down when electrical storms break loose over these regions.

Plauson's Electrical Patents

USP # 1,540,998
Conversion of Atmospheric Electric Energy
6-09-1925

GB157262
Improvements in Electric Motors
1922-07-10

GB157263
Process and Apparatus for Converting Static Atmospheric Electrical Energy into Dynamic Electrical Energy of any Suitable High Periodicity
7-10-1922

British Patent # 299,735
Apparatus for Producing Rapidly Moving Electrons
7-15-1930

FI21227
Elektrisk uppvärmningsanordning
4-25-1946

Varmelegeme med elektriske varmemodstande
DK67691C
9-27-1948

FR877362
Dispositif de chauffage électrique
12-04-1942

DE734794
Elektrisches Heizsystem
4-24-1943

CH222509
Elektrischer Heizkörper zur Erwärmung von Flüssigkeiten
7-31-1942

DE738107
Elektrolyt fuer unmittelbare elektrische Warmwasser-Radiatorenheizung mit Elektroden
8-03-1943

DE433476
Verfahren zur Herstellung von Elektroden und Schleifkontakten fuer Dynamomaschinen
8-31-1926

CH94021
Elektrode und Verfahren zu deren Herstellung
4-01-1922

CA226423
Electrode for Electrolytic Apparatuses
11-21-1922

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http://www.meridian-int-res.com/Energy/Atmospheric.htm

Atmospheric Electricity Research
[Excerpts]

In the nineteenth and early twentieth centuries, a large number of researchers investigated ways to extract electrical power from the Earth's ambient electric field.

The leader in this field was Dr Hermann Plauson who in the 1920s succeeded in generating significant quantities of electrical power comparable with modern solar photovoltaic systems of a similar scale...

The leader in this field before the Second World War appears to have been Dr Hermann Plauson. Dr Plauson was an Estonian citizen who lived in Hamburg and Switzerland. He carried out experiments in Finland with aerostats manufactured from magnesium-aluminium alloy, covered with electrolytically deposited needles. The needles were further doped with a radium compound to increase local ionisation of the air. (This was the era in which the hands of watches were hand painted with radium to make them luminous in the dark). Zinc amalgam patches were also painted onto the aerostats. Plauson obtained a power output of between 0.72kW and 3.4kW from one and two aerostats 300m above ground level. Dr Plauson filed patents in the USA, Great Britain and Germany in the 1920s. His book "Gewinnung und Verwertung der Atmosphärischen Elektrizität" is the most detailed known account of the technology.

Other atmospheric electricity researchers contemporary to Dr Plauson included Walter Pennock and MW Dewey in the USA, Andor Palencsar in Hungary and Dr Heinrich Rudolph in Germany. Hippolyte Charles Vion in Paris predated them all, putting forward proposals in the 1850s and 1860s.

Heinrich Rudolph made an interesting contribution to the design of the aerostat collectors. In 1898 he designed an elliptical aerostat made up of faceted surfaces to minimise the effect of wind. The design bears a strong resemblance to Northrop's 2003 UCARS unamnned helicopter UAV project. The design uses the Coanda Effect to help keep the aerostat on station and minimise wind effects.

In recent times, the only person who seems to have been active in this field is Dr Oleg Jefimenko. Dr Jefimenko carried out experiments on driving electrostatic motors from the Earth's electric field in the 1970s and has recently called for research into the neglected field of electrostatic motors to be renewed.

MIR's Research Programme

Since 1997 we have been carrying out theoretical research into conversion of atmospheric electricity into useable electrical power.

From a low level (5m high) simple zinc antenna we are able to obtain sufficient charge to light a number of white power LEDs. Further experimental investigations with metallic aerostat collectors and cavity resonant slow wave antennae concepts are ongoing...

Advantages of Atmospheric Electricity

Simple and robust technology
Low Cost technology - much cheaper than photovoltaics or wind turbines
Available day and night in all weather conditions - in fact, more power is produced at night than during the day
Available at any point on the Earth's surface

1. *Gewinnung und Verwertung der Atmosphärischen Elektrizität*, Dr Hermann Plauson, Hamburg, (1920)
2. Conversion of Atmospheric Electric Energy, USP 1,540,998, Dr Hermann Plauson, (1925)
3. Assembly for the Induction of Lightning into a Superconducting Magnetic Energy Storage System, USP 5,367,245 Goven Mims, (1994)
4. Electrostatic Motors are Powered by Electric Field of the Earth; CL Stong, *Scientific American*, (October 1974)
5. Operation of Electric Motors from the Atmospheric Electric Field; Dr Oleg Jefimenko, *American Journal of Physics*, vol. 39, July 1971.
6. *Electrostatic Motors: Their Principles, Types and Theory of Operation*; Dr Oleg Jefimenko, Electret Scientific, (1972).
7. Parametric Electric Machine, USP 4,622,510, Ferdinand Cap, (1986).

US Patent # 1,540,998

Conversion of Atmospheric Electric Energy

(9 June 1925)

Hermann PLAUSON

Be it known that I, Hermann Plauson, Estonian subject, residing in Hamburg, Germany, have invented certain new and useful improvements in the Conversion of Atmospheric Electric Energy, of which the following is a specification.

Methods of obtaining atmospheric electricity by means of metallic nettings set with spikes which are held by means of ordinary or anchored kite balloons made of fabric and filled with hydrogen, are in theory already known. Atmospheric electricity obtained in this way has been suggested to be used in the form of direct current for the charging of accumulators. This knowledge however is at present only theoretical as the conversion in practice has hitherto been a failure. No means are known of protecting the apparatus from destruction by lightning. The balloons used for collecting the charge must also me be made of very large size in order to be able to support the weight of the metallic netting and the heavy cable connections.

Instead of using heavy metallic netting as collectors attached to single air ballons of non-conducting materials which are liable to be torn and are permeable to the gas, it is proposed to use metallic balloon collectors which have the following important advantages ---

(a) The metallic cases are impenetrable to helium and hydrogen; they also represent large metallic weather-proof collecting surfaces.

(b) Radio active means the like may be easily applied internally or externally; whereby the ionization is considerable increased and therewith also the quantity of atmospheric electricity capable of being collected.

(c) Such balloon collectors of light metal do not require to be of large size as they have to carry only their own moderate weight, and that of the conducting cable or wire.

(d) The entire system therefore offers little surface for the action of storm and wind and is resistant and stable.

(e) Each balloon can be easily raised and lowered by means of a winch so that all repairs, recharging and the like can be carried out without danger during the operation.

It is further proposed to use a collecting aerial network of several separate collectors spread out in the air above the earth, which collectors are interconnected by electrical conductors.

According to this invention charges of atmospheric electricity are not directly converted into mechanical energy, and this forms the main difference from previous inventions, but the static electricity which runs to earth through aerial conductors in the form of direct current of very high voltage and low current strength is converted into electro-dynamic energy in the form of high frequency vibrations. Many advantages are thereby obtained and all disadvantages avoided.

The very high voltage of static electricity of a low current strength can be converted by this invention to voltages more suitable for technical purposes and of greater strength. By the use of closed oscillatory circuits it is possible to obtain electromagnetic waves of various amplitude and thereby to increase the degree of resonance of such current. Such resonance allows various values of inductance to be chosen whereby again the governing of the starting and stopping of machines driven thereby by simply tuning the resonance between coils of the machine and the transformer circuit forming the resonance can easily be obtained. Further, such currents have the property of being directly available for various uses, even without employing them for driving motors, of which there may be particularly mentioned, lighting, production of heat and use in electro-chemistry.

Further, with such currents a series of apparatus may be fed without direct current supply through conductors and also the electro-magnetic high frequency currents may be converted by means of special motors adapted for electro-magnetic oscillations into mechanical energy, or finally converted by special machines into alternating current of low frequency or even into direct current of high potential.

The invention is more particularly described with reference to the accompanying diagrams in which: ---

Figure 1 is and explanatory figure.

Figure 2 is a diagrammatic view of the simplest form.

Figure 3 shows a method of converting atmospheric electrical energy for use with motors.

Figure 4 is a diagram showing the use of protective means.

Figure 5 is a diagram of an arrangement for converting large current strengths.

Figure 6 is a diagram of an arrangement including controlling means.

Figure 7 shows means whereby the spark gap length can be adjusted.

Figure 8 shows a unipolar connection for the motor.

Figure 9 shows a weak coupled system suitable for use with small power motors.

Figures 10, 11, and 12 show modified arrangements.

Figure 13 shows a form of inductive coupling for the motor circuit.

Figure 14 is a modified form of Figure 13 with inductive coupling.

Figure 15 is an arrangement with non-inductive motor.

Figure 16 is an arrangement with coupling by condenser.

Figure 17, 18, and 19 are diagrams of further modifications.

Figure 20 shows a simple form in which the serial network is combined with special collectors.

Figure 21 shows diagrammatically an arrangement suitable for collecting large quantities of energy.

Figure 22 is a modified arrangement having two rings of collectors.

Figure 23 shows the connection for three rings of collectors.

Figure 24 shows a collecting balloon and diagram of its connection of condenser batteries.

Figure 25 and 26 show modified collector balloon arrangements.

Figure 27 shows a second method of connecting conductor for the balloon aerials.

Figure 28 shows an auto-transformer method of connection.

Figure 29 shows the simplest form of construction with incandescent cathode.

Figure 30 shows a form with cigar shaped balloon.

Figure 31 is a modified arrangement.

Figure 32 shows a form with cathode and electrode enclosed in a vacuum chamber.

Figure 33 is a modified form of Figure 32.

Figure 34 shows an arc light collector.

Figure 35 shows such an arrangement for alternating current.

Figure 36 shows an incandescent collector with Nernst lamp.

Figure 37 shows a form with a gas flame.

Fig. 1.

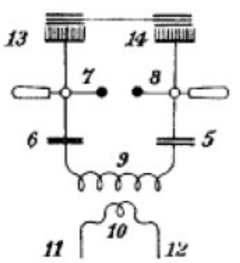

Fig. 2.

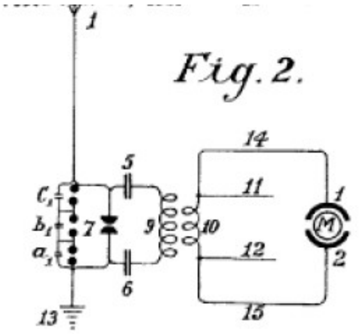

Figure 1 illustrates a simple diagram for converting static electricity into dynamic power of a high number of oscillations. For the sake of clearness in the drawings an influence machine is assumed to be employed and not an aerial antenna. 13 and 14 are combs for collecting the static electricity of the influence machine. 7 and 8 are spark discharging electrodes. 5 and 6 are condensers, 9 an inductive primary coil, 10 secondary coil, 11 and 12 ends of conductors of the secondary coil 10. When the disc of the static influence machine is rotated by mechanical means, the combs collect the electric charges one the positive and the other the negative, and charge the condensers 5 and 6 until such a high potential is formed across the spark gap 7-8, that the spark gap is jumped. As the spark gap 7-8 forms a closed circuit with condensers 5 and 6, and inductive resistance 9, as is well known, waves of high frequency electromagnetic oscillations will pass in this circuit.

The high frequency of the oscillations produced in the primary circuit induces waves of the same periodicity in the secondary circuit. Thus in the primary circuit electromagnetic oscillations are formed by the passage of the spark over the spark gap and these waves are maintained by fresh charges of static electricity.

By suitably selecting the ratio between the number of the coils in the primary and secondary circuits with regard to a correct application of the co-efficients of resonance (especially, inductance and resistance) the high voltage of the primary circuit may be suitably converted into low voltage and high current strength.

When the oscillatory discharges in the primary circuit becomes weaker or entirely cease, the condensers are charged again by the static electricity until the accumulated charge again breaks down the spark gap. All this is repeated as long as electricity is produced by the static machine employing mechanical energy.

An elementary form of the invention is shown in Figure 2 in which two spark gaps in parallel are used one of which may be termed the working gap 7 in Figure 2, whilst the second serves as a safety device for excess voltage and consists of a larger number of spark gaps than the working section, which gaps are arranged in series and are bridged by very small capacities as is illustrated in a, b, c, Figure 2 which allow of uniform sparking in the safety section.

In Figure 2 A is the aerial antenna for collecting charges of atmospheric electricity. 13 is the earth connection of the second part of the spark gap, 5 and 6 are condensers, 9 a primary coil. Now when through the aerial A the positive atmospheric electricity seeks to combine with the negative charge to earth, this is prevented by (the air gap between) the spark gaps. The resistance of the spark gap 7 is, as shown in the drawings, lower than that of the other safety section which consists of three spark gaps connected in series, and consequently a three times greater air resistance is offered by the latter.

So long, therefore, as the resistance of the spark gap 7 is not overloaded, so that the other spark gaps have an equal resistance with it the discharges take place only over spark gap 7. Should however the voltage be increased by and influences so that it might be dangerous for charging the condensers 5 and 6 or for the coil insulation 9 and 10 in consequence of break down, by a correct regulation of this spark gap the second spark gap can discharge free from inductive effects direct to earth without endangering the machine.

Without this second spark gap, arranged in parallel having a higher resistance than the working spark gap it is impossible to collect and render available large quantities of electrical energy.

The actions of this closed oscillation circuit consisting of spark gap 7, two condensers 5 and 6, primary coil 9, and also secondary coil 10 is exactly the same as the one described in Figure 1 with the arrangement of the static induction machine with the only difference that here the second spark gap is provided. The electromagnetic high frequency alternating current obtained can be tapped off from the conductors 11 and 12 for lighting and heating purposes. Special kinds of motors adapted for working with these peculiar electrical charges may be connected at 14 and 15 which can work with static electricity charges or with high frequency oscillations.

In addition to the use of spark gaps in parallel a second measure of security is also necessary for taking off the current. This precaution consists according to this invention, in the introduction of and method of connecting certain protective electromagnets or choking coils in the aerial circuit as shown by S in Figure 3.

A single electromagnet only having a core of the thinnest possible separate laminations is connected with the aerial.

In the case of high voltages in the aerial network or at places where there are frequent thunder storms, several such magnets may however be connected in series.

In the case of large units or plants several electromagnets can be employed in parallel or in series parallel.

The windings of these electromagnets may be simply connected in series with the aerials. In this case the winding preferably consists of several thin parallel wires, which make up together, the necessary section.

The winding may be made of primary and secondary windings in the form of a transformer. The primary windings will be then connected in series with the aerial network, and the secondary winding more or less short-circuited over a regulating resistance or an induction coil. In the latter case it is possible to regulate to a certain extent the effect of the choking coils. In the further description of the connecting and constructional diagrams the aerial electromagnet choke coil is indicated by a simple ring S.

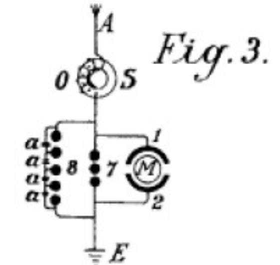

Fig. 3.

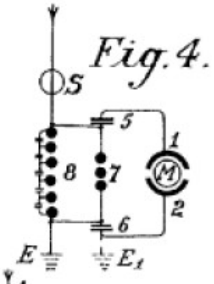

Fig. 4.

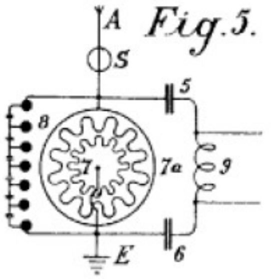

Fig. 5.

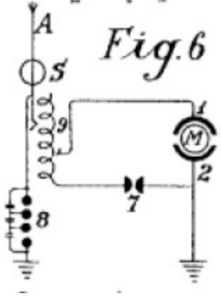

Fig. 6

Figure 3 shows the simplest way of converting atmospheric electricity into electromagnetic wave energy by the use of special motors adapted for high oscillatory currents or static charges of electrical energy. Recent improvements in motors for working with static charges and motors working by resonance, that is to say, having groups of tuned electromagnetic cooperating circuits render this possible but such do not form part of the present invention.

A motor adapted to operate with static charges will for the sake of simplicity be diagrammatically indicated by the two semicircles 1 and 2 and the rotor of the motor by a ring M (Figure 3). A is a vertical aerial or aerial network. S the safety choke or electromagnet with coil O as may be seen is connected with the aerial A. Adjacent the electromagnet S the aerial conductor is divided into three circuits, the circuit 8 giving the safety spark gap, the circuit 7 with the working spark gap, and then a circuit including the stator terminal 1, the rotor and stator terminal 2 at which a connection is made to the earth wire. The two spark gaps are also connected metallically with the earth wire. The method of working these diagrams is as follows:

The positive atmospheric electric charge collected tends to combine with the negative electricity (or earth electricity) connected with the earth wire. It travels along the aerial A through the electromagnet S without begin checked as it flows in the same direction as the direct current. Further, its progress is arrested by two sparks gaps placed in the way and the stator condenser surfaces. The stator condenser surfaces are charged until the charge is greater than the resistance of the spark gap 7, whereupon a spark springs over the spark gap 7 and an oscillatory charge is obtained as by means of the motor M, stator surfaces 1 and 2, and spark gap 7, a closed oscillation circuit is obtained for producing the electromagnetic oscillations. The motor here forms the capacity and the necessary inductance and resistance, which, as is well known, are necessary for converting static electricity into electromagnetic wave energy.

The discharge formed are converted into mechanical energy in special motors and cannot reach the aerial network by reason of the electromagnet or choke. If, however, when a spark springs over the spark gap 7 a greater quantity of atmospheric electricity tends to flow to earth, a counter voltage is induced in the electromagnet, which is greater the more rapidly and strongly the flow of current direct to the earth is. By the formation of this opposing voltage a sufficiently high resistance is offered to the flow of atmospheric electricity direct to earth to prevent a short circuit with the earth.

The circuit containing spark gap 8 having a different wave length which is not in resonance with the natural frequency of the motor, does not endanger the motor and serves as security against excess voltage, which, as practical experiments have shown, may still arise in certain cases, but can be conducted direct to earth through this spark gap.

In the diagram illustrated in Figure 4 the spark gap 7 is shunted across condensers 5 and 6 from the motor M. This construction affords mainly a better insulation of the motor against excess voltage and a uniform excitation through the spark gap 7.

In Figure 5 a diagram is illustrated for transforming large current strengths which may be employed direct without motors, for example, for lighting or heating purposes. The main difference is that here the spark gap consists of as star shaped disk 7 which can rotate on its own axis and is rotated by a motor opposite similarly fitted electrodes 7a. When separate points of stars face one another, discharges take place, thus forming an oscillation circuit over condensers 5 and 6, and inductance 9 for oscillatory discharges. It is evident that a motor may also be directly connected to the ends of the spiral 9.

The construction of the diagram shown in Figure 6 permits of the oscillation circuit of the motor being connected with an induction coil/ Here a regulating inductive resistance is introduced for counter-acting excess voltages in the motor. By cutting the separate coils 9 (coupled inductively to the aerial) in or out the inductive action on the motor may be more or less increased or variable aerial action may be exerted on the oscillation circuit.

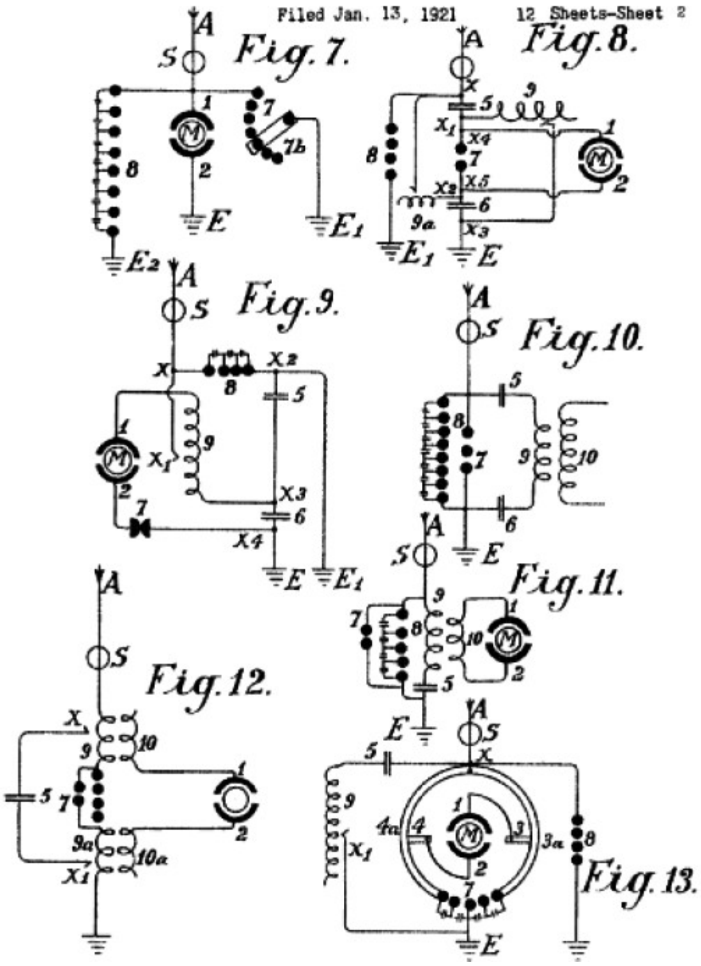

In Figure 7 the oscillation circuit is closed through the earth (E and E1). The spark gap 7 may be prolonged or shortened by more or fewer spark gaps being successively connected by means of a contact arm 7b.

Diagram 8 shows a unipolar connection of the motor with the aerial network. Here two oscillation circuits are closed through the same motor. The first oscillation circuit passes from aerial A through electromagnet S, point *x*, inductance 9a to the earth condenser 6 and further, over spark gap 7 to the aerial condenser 5 and back to *x*. The second oscillation circuit starts from the aerial condenser 5 at the point x^1 over the inductance 9 to the earth condenser 6 at the point x^3 and through the condenser 6 over the spark gap 7 back to x^1. The motor itself is inserted between the two points of the spark gap 7. From this arrangement slightly damped oscillation wave currents are produced.

In the diagram illustrated in Figure 9 a loosely coupled system of connections is illustrated which is assumed to be for small motors for measuring purposes. A indicates the aerial conductor, S the electromagnet in the aerial conductor, 9 the inductance, 7 the spark gap, 5 and 6 condensers, E the earth, M the motor, and 1 and 2 stator connections of the motor. The motor is directly metallically connected with the oscillation circuit.

In Figure 10 a purely inductive coupling is employed for the motor circuit. The motor is connected with the secondary wire 10 as may be seen in Figure 11 in a somewhat modified diagram connection. The same applies to the diagram of Figure 12.

The diagrams hitherto described preferably allow of motors of small and medium strength to be operated. For large aggregates, however, they are too inconvenient as the construction of two or more oscillation circuits for large amounts of energy is difficult; the governing is still more difficult and the danger in switching on or off is greater.

A means of overcoming such difficulties is shown in Figure 13. The oscillation circuit here runs starting from the point x over condenser 5, variable inductance 9, spark gap 7, and the two segments (3a and 4a) forming arms of a Wheatstone bridge, back to x, If the motor is connected by brushes 3 and 4 transversely to the two arms of the bridge as shown in the drawings, electromagnetic oscillations of equal sign are induced in the stator surfaces 1 and 2 and the motor does not revolve. If however the brushes 3 and 4 are moved in common with the conducting wires 1 and 2 which connect the brushes with the stator poles a certain alteration or displacement of the polarity is obtained and the motor commences to revolve.

The maximum action will result if one brush 3 comes on the central sparking contact 7 and the other brush 4 on the part *x*. They are however, usually in practice not brought on the central contact 7 but only held in the path of the bridge segments 4a and 3a in order not to connect the spark gaps with the motor oscillation circuit.

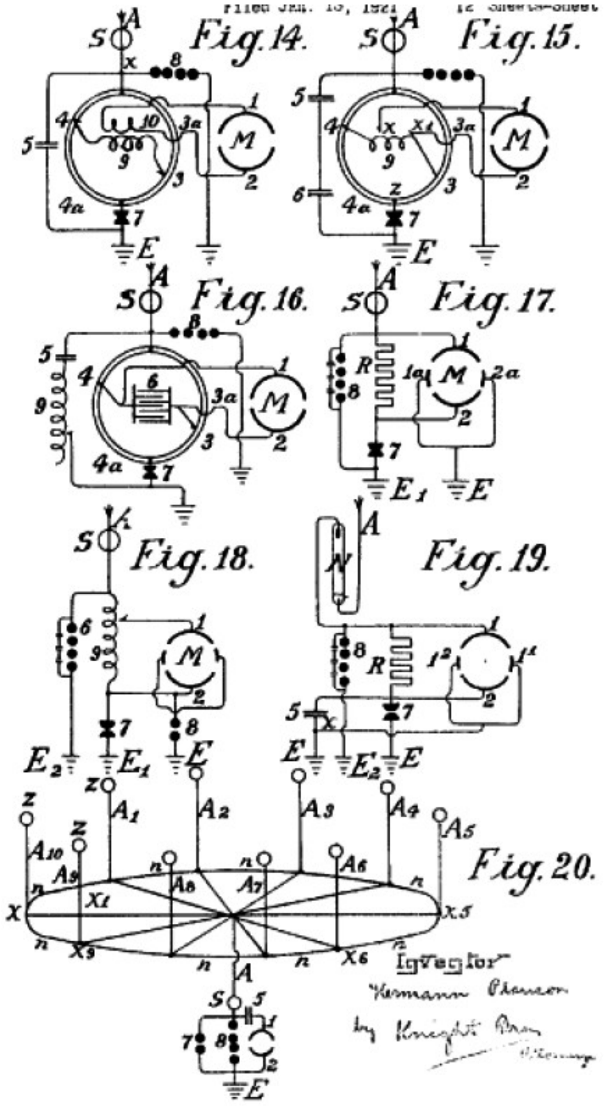

As however, the entire oscillation energy can thereby not act on the motor it is better to carry out the same system according to the diagram 14. The diagram 14 differs from the foregoing only by the motor not being directly metallically connected with the segments of the commutator, but only a primary coil 9 which induces in a secondary coil 10, current which feeds the motor M and takes the place of the rotor. By this arrangement a good transforming action is obtained, a loose coupling and also an oscillation circuit without a spark gap.

In Figure 15 the motor is not purely inductive as in 14, but directly metallically branched off from the primary coil (at *x* and x^1) after the principle of the auto-transformer.

In Figure 16 instead of an inductance a condenser 6 is in similar manner, and for the same object inserted between the segments 3a and 4a. This has the advantage that the segments 3a and 4a need not be made of solid metal but may consist of spiral coils whereby a more exact regulation is possible and further motors of high inductance may be employed.

The arrangements of Figures 17, 18 and 19 may be employed for use with resonance and particularly with induction condenser motors; between the large stator induction condenser surfaces, small reversing pole condenser surfaces, mall reversing pole condensers are connected, which, as may be seen from Figures 17, 18 and 19 are led together to earth. Such reversing poles have the advantage that with large quantities of electrical energy the spark formation between the separate oscillation circuits ceases.

Figure 19 shows a further method which prevents electromagnetic oscillations of high number of alternations formed in the oscillation circuit striking back to the aerial conductor. It is based on the well known principle that a mercury lamp, one electrode of which is formed of mercury, the other of solid metal such as steel allows an electric charge to pass in only one direction from the mercury to the steel and not vice versa. The mercury electrode of the vacuum tube N is therefore connected with the aerial conductor and the steel electrode with the oscillation circuit. From this it results that charges can pass only from the aerial through the vacuum tube to the oscillation circuit, but not vice versa. Oscillations which are formed on being transformed in the oscillation circuit cannot pass to the aerial conductor.

In practice these vacuum tubes must be connected behind an electromagnet as the latter alone affords no protection against the danger of lightning.

As regards the use of spark gaps, all arrangements as used for wireless telegraphy may be used. Of course the spark gaps in large machines must have a sufficiently large surface. In very large stations they are cooled in liquid carbonic acid or better still in liquid nitrogen or hydrogen; in most cases the cooling may also take place by means of liquefied low homologues of the metal series or by means of hydrocarbons the freezing point of which lies at between –90° C and –40° C. The spark gap casing must also be insulated and be of sufficient strength to be able to resist any pressure which may arise. Any undesirable excess super-pressure which may be formed must be automatically let off. I have employed wit very good results mercury electrodes which were frozen in liquid carbonic acid, the cooling being maintained during the operation from the outside through the walls.

Figure 20 is one of the simplest forms of construction of an aerial network in combination with collectors, transformers and the like illustrated diagrammatically. E is here the earth wire, 8 the safety spark gap, 7 the working spark gap, 1 and 2 the stator surfaces of the motor, 5 a condenser battery, S the protective magnet which is connected with the coil in aerial conductor, A^1 to A^{10} aerial antennae with collecting balloons, N horizontal collecting or connecting wire from which, to the center a number of connections run.

The actual collectors consist of metal sheaths preferably made of an aluminum magnesium alloy, and are filled with hydrogen or helium and are attached t copper plated steel wires. The size of the balloon is selected so that the actual weight of the balloon and the weight of the conducting wire is supported thereby. On top of the balloon aluminum spikes, made and gilded in a special manner hereinafter described, are arranged in order to produce a conductor action. Small quantities of radium preparations, more particularly polonium-ionium or meso-thorium preparations considerably increase the ionization, and therewith the action of these collectors.

In addition to metal balloons, fabric balloons which are superficially metal coated according to Schoop's metal spraying process, may also be employed. A metallic surface may also me produced by lacquering with metallic bronzes, preferably according to Schoop's spraying process or lacquering with metallic bronze powders in two electrical series of widely different metals, because thereby the collecting effect is considerably increased.

Instead of the ordinary round balloons, elongated cigar shaped ones may be employed. In order also to utilize the frictional energy of the wind, patches or strips of non-conducting substances which produce electricity by friction, may be attached to the metalized balloon surfaces. The wind will impart a portion of its energy in the form of frictional electricity, to the balloon casing, and thereby the collecting effect is substantially increased.

In practice however, very high towers (up to 300 meters is fully admissible) may be employed as antennae. In these towers copper tubes rise freely further above the top of the tower. A gas lamp secured against the wind is then lit at the point of the copper tube and a netting is secured to the copper tube over the flame of this lamp to form a collector. The gas is conveyed through the interior of the tube up to the summit. The copper tube must be absolutely protected from moisture at the place at which it enters the tower and also rain must be prevented running down the walls of the tower which might lead to a bad catastrophe. This is done by bell shaped enlargements which expand downwards, being arranged in the tower in the form of high voltage insulators of Siamese pagodas.

Special attention must be devoted to the foundations of such towers. They must be well insulated from the ground, which may be obtained by first embedding a layer of concrete in a box form to a sufficient depth in the ground and inserting in this an asphalt lining and then glass bricks cast about 1 or 2 meters in thickness. Over this in turn there is a ferro-concrete layer in which alone the metal foot of the tube is secured. This concrete block must be at least 2 meters from the ground and be fully protected at the sides by a wooden covering, from moisture. In the lower part of the tower a wood or glass house for the large condenser batteries or for the motors may be constructed. In order to lead the earth connection to the ground water, a well insulated pit constructed of vitreous brick, must be provided. Several such towers are erected at equal distances apart and connected with a horizontal conductor. The horizontal connecting wires may either run directly from tower to tower or be carried on bell shaped insulators similar to those in use for high voltage conductors. The width of the network may be of any suitable size and the connection of the motors can take place at any suitable places.

Fig. 21. Fig. 22.

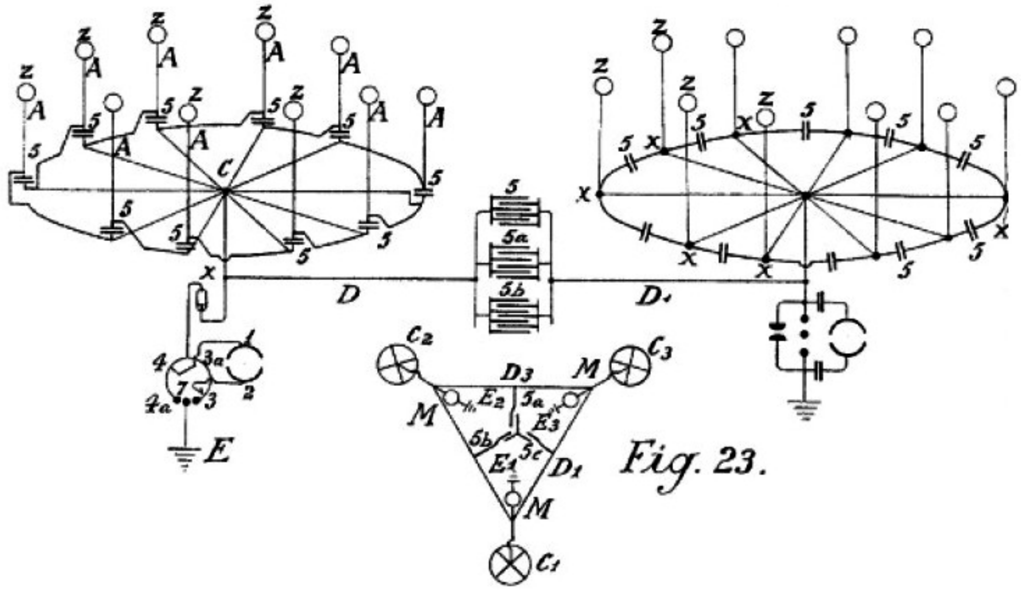

Fig. 23.

In order to collect large quantities of electricity with few aerials it is well to provide the aerial conductor with batteries of condensers as shown in Figures 21 and 22. In Figure 21 the batteries of condensers 5 are connected on the one hand with the aerial electricity collectors Z by the aerial conductor A, and on the other hand interconnected in series with an annular conductor from which horizontal conductors run to the connecting points C to which the earth wire is connected.

Figure 22 shows a similar arrangement, Should two such series of antennae rings be shown by a voltmeter to have a large difference of potential (for example, one in the mountains and one in the plain) or even of different polarity these differences may be compensated for by connecting sufficiently large condenser batteries (5, 5a, 5b) by means of Maji star conductors D and D^1. In Figure 23 a connection of three such rings of collectors to form a triangle with a central condenser battery is illustrated.

The condenser batteries of such large installations must be embedded in liquid gases or in liquids freezing at very low temperatures. In such cases a portion of the atmospheric energy must be employed for liquefying these gases. It is also preferable to employ pressure. By this means the condenser surfaces may be diminished, and still allow for large quantities of energy to be stored, secure against breakdown. For smaller installation the immersing of the condensers in well-insulated oil or the like, suffices. Solid substances on the other hand cannot be employed as insulators.

The arrangement in the diagrams hitherto described was always such that the condenser batteries were connected with both poles directly to the aerial condensers. An improved diagram of the connections for obtaining atmospheric electricity for the condenser batteries has however, been found to be very advantageous. This arrangement consists in that they are connected only by one pole (unipolar) to the collecting network. Such a method of arrangement is very important, as by means of it a constant current and an increase of the normal working pressure or voltage is obtained. If for example a collecting balloon aerial which is allowed to rise to a height of 300 meters, shows 40,000 volts above earth voltage, in practice it has been found that the working voltage (with a withdrawal of the power according to the method hereinbefore described by means of oscillating spark gaps and the like) is only about 400 volts. If however, the capacity of the condenser surfaces be increased, which capacity in the above mentioned case was equal to that of the collecting surface of the balloon aerials, to double the amount, by connecting the condenser batteries with only one pole, the voltage rises under an equal withdrawal of current up to and beyond 500 volts. This can only be ascribed to the favorable action of the connecting method.

In addition to this substantial improvement it has also been found preferable to insert double inductances with electromagnets and to place the capacities preferably between two such electromagnets. It has also been found that the useful action of such condensers can be further increased if an induction coil be connected as inductive resistance to the unconnected pole of the condenser, or still better if the condenser itself be made as an induction condenser. Such a condenser may be compared with a spring which when compressed carries in itself accumulated force, which it again gives off when released. In charging, a charge with reversed sign is formed at the other free condenser pole, and if through the spark gap a short circuit results, the accumulated energy is again given back since now new quantities of energy are induced at the condenser pole connected with the conductor network, which in fact charges with opposite signs to that at the free condenser pole. The new induced charges have of course the same sign as the collector network. The whole voltage energy in the aerial is thereby however increased. In the same space of time larger quantities of energy are accumulated than is the case without such inserted condenser batteries.

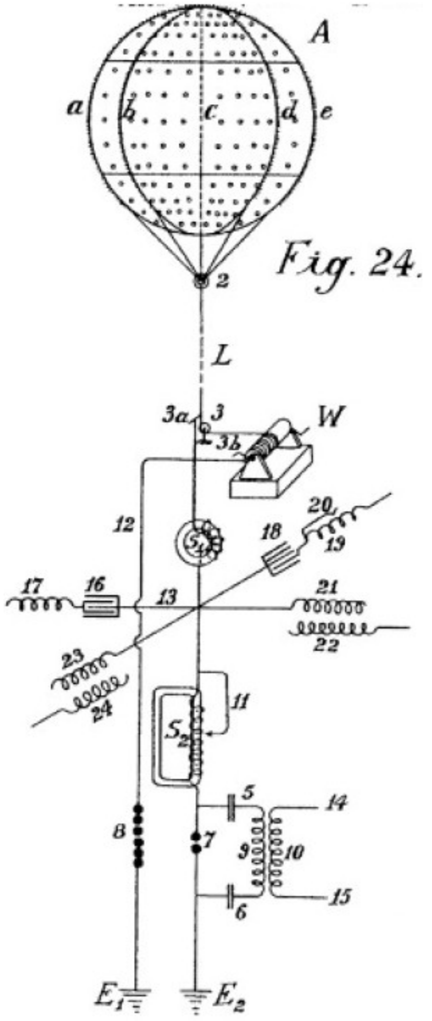
Fig. 24.

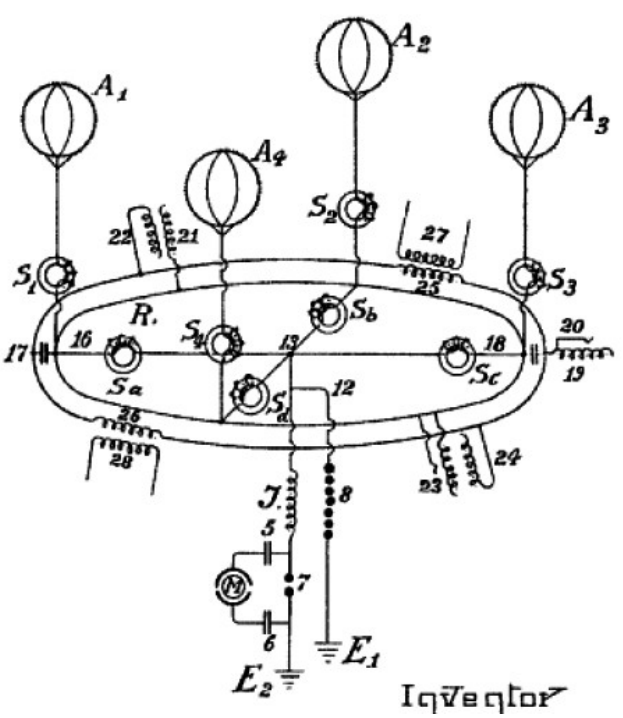
Fig. 25.

In Figures 24 and 25 two different diagrams of connections are more exactly illustrated, Figure 24 shows a collecting balloon and the diagram of the connections to earth. Figure 25 shows four collecting balloons and the parallel connection of the condenser batteries belonging thereto.

A is the collecting balloon made of an aluminum magnesium alloy (electron metal, magnalium) of a specific gravity of 1.8 and a thickness of plate 0.1 to 0.2 mm. Insider there are eight strong vertical ribs of T-shaped section about 10 to 20 mm in height and about 3 mm in thickness with the projecting part directed inwards (indicated by a, b, c, d and so forth); they are riveted together to form a firm skeleton and are stiffened in a horizontal direction by two cross ribs. The ribs are further connected with one another internally and transversely by means of thin steel wires, whereby the balloon obtains great power of resistance and elasticity. Rolled plates of 0.1 to 0.2 mm in thickness made of magnalium alloy are then either soldered or riveted on this skeleton so that a fully metallic casing with smooth external surface is obtained Well silvered or coppered aluminum plated steel wires run from each rib to the fastening ring 2. Further, the coppered steel hawser L preferably twisted out of separate thin wires (shown in dotted lines in Figure 24) and which must be long enough to allow the balloon to rise in the desired height, leads to a metal roller or pulley 3 and from thence to a winch W, well insulated from the earth. By means of this winch, the balloon, which is filled with hydrogen, or helium, can be allowed to rise to a suitable height (300 to 5000 meters) and brought to the ground for recharging or repairs.

The actual current is taken directly through a friction contact from the metal roller 3 or from the wire, or even from the winch or simultaneously from all three by means of brushes (3, 3a and 3b). Beyond the brushes the conductor is divided, the paths being: --- firstly over 12 to the safety spark gap 8, from thence to the earth conductor E^1, and secondly over electromagnet S^1, point 13, to a second loose electromagnet having an adjustable coil S^2, then to the spark gap 7 and to the second earth conductor E^2. The actual working circuit is formed through the spark gap 7, condensers 5 and 6, and through the primary coil 9; here the static electricity formed by oscillatory discharges is accumulated and converted into high frequency electromagnetic oscillations. Between the electromagnets S^1 and S^2 at the crossing point 13, four condenser batteries are introduced which are only indicated diagrammatically in the drawings each by one condenser. Two of these batteries (16 and 18) are made as plate condensers and prolonged by regulating induction coils or spirals 17 and 19 while the two others (21 and 23) are induction condensers. As may be seen from the drawings each of the four condenser batteries 16, 18, 21 and 23 is connected by only one pole to the aerial or to the collector conductor. The second poles 17, 19, 22 and 24 are open. In the case of plate condensers having no inductive resistance an induction coil is inserted. The object of such a spiral or coil is the displacement of phase by the induction current by 1/4 periods, whilst that of the charging current of the condenser poles which lie free in the air, works back to the collector aerial. The consequence of this is that in discharges in the collector aerial the back inductive action of the free poles allows a higher voltage to be maintained in the aerial collecting conductor than would otherwise be the case. It has also been found that such a back action has an extremely favorable effect on the wear of the contacts. Of course the inductive effect may be regulated at will within the limits of the size of the induction coil, the length of the coil in action being adjustable by means of wire connection without induction (see Figure 24, No. 20).

S^1 and S^2 may also be provided with such regulating devices in the case of S^2 (illustrated by 11). If excess voltage be formed it is conducted to earth through the wire 12 and spark gap 8 or through any other suitable apparatus, since this formation would be dangerous for the other apparatus.

The small circles on the collector balloon indicate places at which zinc amalgam or gold amalgam or other photoelectric acting metals in the form of small patches in extremely thin layers (0.01 to 0.05 mm in thickness) are applied to the entire balloon as well as in greater thickness to the conducting network. The capacity of the collector is thereby considerably strengthened at the surface. The greatest possible effect in collecting may be obtained by polonium amalgams and the like. On the surface of the collector balloon metal points or spikes are also fixed along the ribs, which spikes serve particularly for collecting the collector charge. Since it is well known that the resistance of the spikes is less the sharper the spike is, for this purpose it is therefore extremely important to employ as sharp spikes as possible. Experiments made as regards these have shown that the formation of the body of the spike or point also plays a large part, for example, spikes made of bars or rollers with smooth surface, have a many times greater point resistance as collector accumulator spikes than those with rough surfaces. Various kinds of spike bodies have been experimented with for the collector balloons hereinbefore mentions. The best results were given by spikes which were made in the following way. Fine points made of steel, copper, nickel, or copper and nickel alloys, were fastened together in bundles and then placed as anode with the points in a suitable electrolyte (preferably in hydrochloric acid or muriate of iron solutions) and so treated with weak current at 2 to 3 volts pressure. After 2 to 3 hours according to the thickness of the spikes or pins the points become extremely sharp and the bodies of the spikes have a rough surface. The bundle can then be removed and the acid washed off with water. The spikes are then placed as cathode in a batch consisting of solution of gold, platinum, iridium, palladium or wolfram salts or their compounds and coated a the cathode galvanically with a thin layer of precious metal, which must however be sufficiently firm to protect them from atmospheric oxidation.

Such spikes act at a 20-fold lower voltage almost as well as the best and finest points made by mechanical means. Still better results are obtained if polonium or radium salts are added to the galvanic bat when forming he protective layer or coating. Such pins have a low resistance at their points and even at one volt and still lower pressures have an excellent collector action.

In Figure 24 the three unconnected poles are not connected with one another in parallel. That is quite possible in practice without altering the principle of the free pole. It is also preferable to interconnect in parallel to a common collector network, a series of collecting aerials.

Figure 25 shows a diagram for such an installation. A^1, A^2, A^3, A^4 are four metal collector balloons with gold or platinum coated spikes which are electrolytically made in the presence of polonium emanations or radium salts, which spikes or needles are connected over four electromagnets S^1, S^2, S^3, S^4, through an annular conductor R. From this annular conductor four wires run over four further electromagnets Sa, Sb, Sc, Sd, to the connecting point 13. There the conductor is divided, one branch passing over 12 and the safety spark gap 8 to the earth at E^1, the other over inductive resistance J and working spark gap 7 to the earth at E^2. The working circuit, consisting of the condenser 5 and 6 and a resonance motor M, such as hereinbefore described, is connected in proximity round the sparking gap section 7.

Instead of directly connecting the condenser motor of course the primary circuit for high frequency oscillatory current may also be inserted.

The condenser batteries are connected by one pole to the annular conductor R and can be either inductionless (16 and 18) or made as induction condensers as shown by 21 and 23. The free poles of the inductionless condensers are indicated by 17 and 19, those of the induction condensers by 22 and 24. As may be seen from the drawings all these poles 17, 22, 19, 24 may be interconnected in parallel through a second annular conductor without any fear that thereby the principle of the free pole connection will be injured. In addition to the advantages already set forth the parallel connection also allows of an equalization of the working pressure in the entire collector network. Suitable constructed and calculated induction coils 25 and 26 may also be inserted in the annular conductor of the free poles, by means of which a circuit may be formed in the secondary coils 27 and 28 which allows current produced in this annular conductor by fluctuations of the charges of the like appearances to be measured or otherwise utilized.

According to what has been hereinbefore stated separate collector balloons may be connected at equidistant stations distributed over the entire country, either connected directly with one another metallically or by means of intermediate suitably connected condenser batteries through high voltage conductors insulated from earth. The static electricity is converted through a spark gap into dynamic energy of a high number of oscillations and may in such form be coupled as a source of energy b y means of a suitable method f connecting, various precautions being observed and with special regulations. The wires leading from the collector balloons have hitherto been connected through an annular conductor without this endless connection, which can be regarded as an endless induction coil, being able to exert any action on the whole conductor system.

It has now been found that if the network conductor connecting the aerial collector balloons with one another is not made as a simple annular conductor, but preferably short circuited in the form of coils over a condenser battery or spark gap or through thermionic tubes or valves or audions, then the total collecting network exhibits quite new properties. The collection of atmospheric electricity is thereby not only increased but an alternating field may be easily produced in the collector network. Further, the atmospheric electrical forces showing themselves in the higher regions may also be directly obtained by induction. In Figures 26 and 28 a form of construction is shown on the basis of which the further foundations of the method will be more particularly explained.

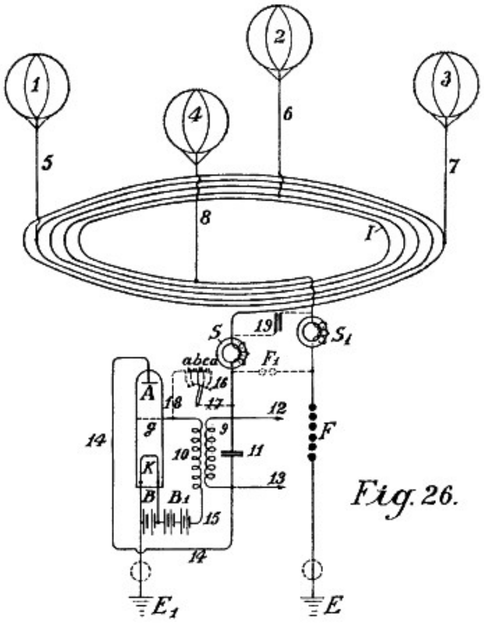

Fig. 26.

In Figure 26, 1, 2, 3, 4 are metal collector balloons, 5, 6, 7, 8 their metallic aerial conductors and I the actual collector network. This consists of five coils and is mounted on high voltage insulators in the air, in high voltage masts (or with a suitable construction of cable embedded in the earth). One coil has a diameter of 1 or 100 km or more. S and S^1 are two protective electromagnets, F the second safety section against excess voltage, E its earth conductor and E1 the earth conductor of the working section. When an absorption of static atmospheric electricity is effected through the four balloon collectors, the current in order to reach the earth connection E1 must flow spirally through the collector network over the electromagnet S, primary induction coil 9, conductor 14, anode A of the audion tube, incandescent cathode K, as the way over the electromagnet and safety spark gap F offers considerably greater resistance. Owing to the fact that the accumulated current flows in one direction, an electromagnetic alternating field is produced in the interior of the collector network coil, whereby the whole free electrons are directed more or less into the interior of the coil. An increased ionization of the atmosphere is thereby produced. In consequence of this the points mounted on the collector balloon show a considerably reduced resistance and therefore increased static charges between the points on the balloon and the surrounding atmosphere are produced. The result of this is a considerably increased collector effect.

A second effect which could not be obtained otherwise is obtained by the electromagnetic alternating field which running parallel to the earth surface, acts more or less with a diminishing or increasing effect on the earth magnetic field, whereby in the case of fluctuations in the current a return induction current of reversed sign is always produced in the collector coil by earth magnetism. Now if, however, a constantly pulsating continuous alternating field is produced as stated in the above collector network I, an alternating current of the same periodicity is produced also in the collecting network coil. As the same alternating field is further transmitted to the aerial balloon, the resistance to its points is thereby considerably reduced, whilst the collector action is considerably increased. A further advantage is that positive electrons which collect on the metal surfaces during the conversion into dynamic current produce a so-called drop of potential of the collector area. As an alternating field is present, the negative ions surrounding the collectors surfaces, when discharge of the collector surfaces takes place produce by the law of induction, an induction of reversed sign on the collector surface and so forth (that is to say again a positive charge). In addition to the advantages hereinbefore set forth, the construction of connecting conductors in coil form when of sufficiently large diameter, allows of a utilization of energy arising in higher regions also in the simplest way. As is well known electric discharges frequently take place at very great elevations which may be observed as St Elmo’s fire or northern lights. These energy quantities have no been available to be utilized up to now. By this invention all these kinds of energy, as they are of an electromagnetic nature and the direction of axis of the collector coils stands at right angles to the earth’s surface, can be more or less absorbed in the same way as a receiver in wireless telegraphy absorbs waves coming from a far distance. With a large diameter of the spiral it is possible to connect large surfaces and thereby to take up also large quantities of energy.

It is well known that large wireless stations in the summer months, and also in the tropics are very frequently unable to receive the signals in consequence of interruptions which are caused by atmospheric electricity, and this takes place with vertical coils of only 40 to 100 meters diameter. If on the contrary horizontal coils of 1 to 100 km diameter be employed very strong currents may be obtained through discharges which are constantly taking place in the atmosphere. Particularly in the tropics or still better in the polar regions where the northern lights are constantly present, large quantities of energy may probably be obtained in this way. A coil with several windings should act the best. In similar manner any alteration of the earth magnetism should act inductively on such a coil.

It is not at all unlikely that earthquakes and spots on the sun will also produce an induction in such collector coils of sufficient size. In similar manner this collector conductor will react on earth current more particularly when they are near the surface of the earth or even embedded in the earth. By combining the previous kind of current collectors so far as they are adapted for the improved system with the improved possibilities of obtaining current the quantities of free natural electricity which are to be obtained in the form of electricity are considerably increased.

In order to produce in the improved collector coil uniform current oscillations of an undamped nature so-called audion high vacuum or thermionic tubes of suitable connection are employed instead of the previously known spark gaps (Figure 26, Nos. 9-18). The main aerial current flows through electromagnet S (which in the case of a high number of alternations is not connected here but in the earth conductor E^1) and may be conveyed over the primary coils in the induction winding through wire 14 to the anode A of the high vacuum grid tube. Parallel with the induction resistance 9 a regulating capacity of suitable size, such as condenser 11 is inserted. In the lower part of the vacuum grid tube is arranged the incandescent filament or the cathode K which is fed through a battery B. From the battery B two branches run, one to the earth conductor E^1 and the other through battery B^1 and secondary coil 10 to the grid above *g* in the vacuum tube. By the method of connections shown in dotted lines, a desired voltage at the grid electrode *g* may also be produced through the wire 17 which is branched off from the main current conductor through switches 16 and some small condensers (*a, b, c, d*) connected in series, and conductor 18, without the battery B^1 being required.

The action of the entire system is somewhat as follows: --

On the connecting conductor of the aerial collector network being short circuited to earth, the condenser pole 11 is charged and slightly damped oscillations are formed in the short circuited existing oscillation circuit formed of the condenser 11 and self inductance 9. In consequence of the coupling through coil 10, fluctuations of voltage take place in the grid circuit 15 with the same frequency, which, fluctuations in turn influence the strength of the electrode current passing through the high vacuum amplifying tube and thus produce current fluctuations of the same frequency in the anode circuit. A permanent supply of energy to the oscillation circuits 9 and 10 consequently takes place, until a condition of balance is set up, in which the consumed oscillation energy is equal to that absorbed. Thereby constant undamped oscillations are now produced in the oscillation circuits 9-11.

For regular working of such oscillation producers high vacuum strengthening tubes are necessary and it is also necessary that the grid and anode voltages shall have a phase difference of 180° so that if the grid is negatively charged, then the anode is positively charged and vice versa. This necessary difference of phase may be obtained by most varied connections, for example, by placing the oscillation circuit in the grid circuit or by separating the oscillation circuit and inductive coupling from the anodes and the grid circuit and so forth.

A second important factor in this way of converting static atmospheric electricity into undamped oscillations is that care must be taken hat the grid and anode voltages have a certain relation to one another; the latter may be obtained by altering the coupling and a suitable selection of the self-induction in the grid circuit, or as shown by dotted lines 16, 17, 18 by means of a larger or smaller number of condensers of suitable size connected in series; in this case the battery B^1 may be omitted. With a suitable selection of the grid potential a glow discharge takes place between the grid *g* and the anode A, and accordingly at the grid there is a cathode drop and a dark space is formed. The size of this cathode drop is influenced by the ions which are emitted in the lower space in consequence of shock ionization of the incandescent cathodes K and pass through the grid in the upper space. On the other hand the number of ions passing through the grid is dependent on the voltage between the grid and the cathode. Thus is the grid voltage undergoes periodic fluctuations (as in the present case) the amount of the cathode drop at the grid fluctuates and consequently the internal resistance of the tube correspondingly fluctuates, so that when a back coupling of the feed circuit with the grid circuit takes place, the necessary means are afforded for producing undamped oscillations and of taking current, according to requirements from the collecting conductor.

The frequency of the undamped oscillations produced is with a suitably loose coupling equal to the self-frequency of the oscillation circuits 9 and 10. By a suitable selection of the self induction of the coil 9 and capacity 11 it is possible to extend from frequencies which produce electromagnetic oscillation of only a few meters wavelength down to the lowest practical alternating current frequency. For large installations a suitable number of frequency-producing tubes of the well-known high vacuum transmission tubes of 0.5 to 2 kw in size may be connected in parallel so that in this respect no difficulty exists.

The use of such tubes for producing undamped oscillations, and also the construction and method of inserting such transmission tubes in an accumulator or dynamo circuit is known and also that such oscillation producing tubes only work well at voltages of 1000 up to 4000 volts, so that on the contrary their use at lower voltages is considerably more difficult. By the use of high voltage static electricity this method of producing undamped oscillations as compared with that through spark gaps must be regarded as an ideal solution particularly for small installations of outputs of from 1 to 100 kw.

By the application of safety spark gaps, with interpolation of electromagnets, not only is short-circuiting avoided but also the taking up of current is regulated. Oscillation producers inserted in the above way form a constantly acting electromagnetic alternating field in the collector coil, whereby as already stated, a considerable accumulating effect takes place. The withdrawal wire or working wire is connected at 12 and 13, but current may be taken by means of a secondary coil which is firmly or movable mounted in any suitable way inside the large collector coil, i.e., in its electromagnetic alternating field, so long as the direction of its axis runs parallel with that of the main current collecting coil.

In producing undamped oscillations of a high frequency (50,000 per second or more) in the oscillation circuits 9 and 11, electromagnets S and S^1 must be inserted if the high frequency oscillations are not to penetrate the collector oil, between the oscillation producers and the collector coil. In all other cases they are connected shortly before the earthing (as in Figures 27 and 28).

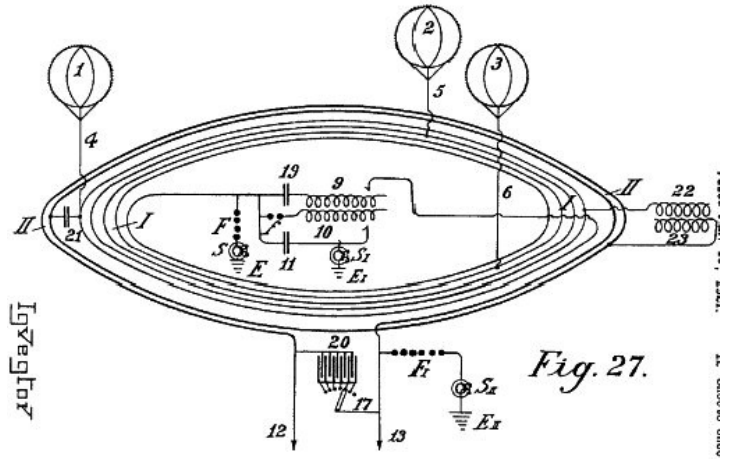

Fig. 27.

In Figure 27 a second method of construction of the connecting conductor of the balloon aerials is illustrated in the form of a coil. The main difference consists in that in addition to the connecting conductor I another annular conductor II is inserted parallel to the former on the high voltage masts in the air (or embedded as a cable in the earth) but both in te form of a coil. The connecting wire of the balloon aerials is indicated as a primary conductor and also as a current producing network; the other is the consumption network and is not in unipolar connection with the current producing network.

In Figure 27 the current producing network I is shown with three balloon collectors 1, 2, 3 and aerial conductors 4, 5, 6; it is short-circuited through condenser 19 and inductance 9. The oscillation forming circuit consists in this diagram of spark gap f, inductance 10, and condenser 11; the earth wire E, is connected to earth over electromagnet S^1. F s the safety spark gap which is also connected to earth through a second electromagnet S at E. On connecting up the condenser circuit 11 this is charged over the spark gap f whereby an oscillatory discharge is formed. This discharging current acts through inductance 10 on the inductively coupled secondary 9, whereby in the producing network a modification of the potential of the condenser 19 is produced. The consequence of this is that oscillations arise in the coil shaped producer network. These oscillations induce a current in the secondary circuit II, which has a smaller number of windings and a less resistance, the voltage of which, according to the proportion of the number of windings and of the ohmic resistance, is considerably lower whilst the current strength is greater.

In order to convert the current thus obtained into current of an undamped character, and to tune its wavelengths, a sufficiently large regulatable capacity 20 in inserted between the ends 12 and 13 of the secondary conductor II. Here also current may be taken without an earthy conductor, but it is advisable to insert a safety spark gap E1 and to connect this with the earth over an electromagnet S2.

The producer network may be connected with the working network II over an inductionless condenser 21 or over an induction condenser 22, 23. In this case the secondary conductor is unipolarly connected with the energy conductor.

28.

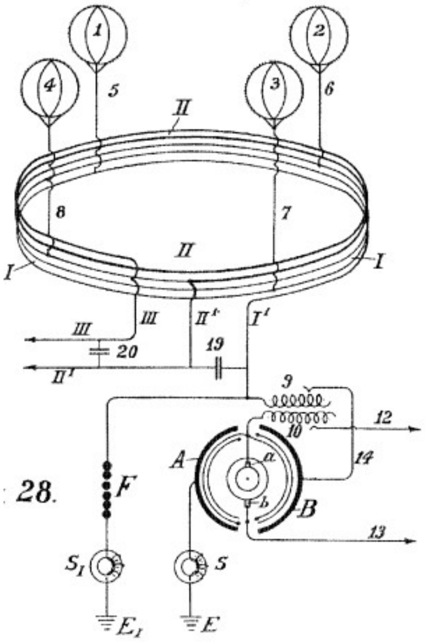

In Figure 28 the connecting conductor between the separate accumulator balloons is carried out according to the autotransformer principle. The collecting coil connects four aerial balloons 1, 2, 3, 4, the windings of which are not made side by side but one above the other. In Figure 28 the collector coil I is shown with a thin line, the metallically connected prolongation coils II with a thick line. Between the ends I^1 and II^1 of the energy network I a regulating capacity 19 is inserted. The wire I^1 is connected with the output wire and with the spark gap F.

As transformer of the atmospheric electricity an arrangement is employed which consists in using rotary pairs of condensers in which the one stator surface B is connected with the main current, whilst the other A is connected with the earth pole. Between these pairs of short-circuited condensers are caused to rotate from which the converted current can be taken by means of two collector rings and brushes, in the form of an alternating current, the frequency of which is dependent on the number of balloons and the revolutions of the rotor. As the alternating current formed in the rotor can act, in this improved method of connection described in this invention, through coils 1 on the inductance 9, an increase or diminution of the feed current in I can be obtained according to the direction of the current by back induction. Current oscillations of uniform rhythm thereby result in the coil shaped windings of the produce network.

As the ends of this conductor are short-circuited through the regulatable condenser 19 these rhythms produce short-circuited undamped oscillations in the energy conductor, the periodicity and wave lengths of which oscillations can be adjusted according to desire by altering the capacity 19 to a given wavelength and therewith also to a given frequency. These currents may also be employed in this form directly as working current through the conductors II^1 and III. By inserting the condenser 20 a connection between these conductors may also be made, whereby harmonic oscillations of desired wavelengths are formed. By this means quite new effects as regards current distribution are obtained. The withdrawal of current can even take place without direct wire connection if, at a suitable point in the interior of the producing network (quite immaterially whether this has a diameter of 1 or 100 km) a coil tuned to these wavelengths and of the desired capacity is firmly or movably mounted in the aerial conductor in such a way that is axial direction is in parallel with that of the collector coil. In this case a current is induced in the producing network, the size of which is dependent on the total capacity and resistance and also on the periodicity employed. A possibility is thereby afforded in future, of taking energy from the producer network by wireless means. As thereby in addition to atmospheric electricity also magnetic earth currents and energy from the higher atmosphere (at leas partially may be simultaneously obtained, this last system for collecting the atmospheric energy is of particular importance for the future.

Of course everywhere instead of spark gaps grid vacuum tubes may be employed as producers for undamped oscillations. The separate coils of the producer network with large diameters may be connected with one another through separate conductors all in parallel or all in series or in groups in series. By regulating the number of oscillations and also the extent of the voltage more or less large collector coils of this kind may be employed. The coils may also be divided spirally over the entire section. The coils may be carried out in angular form or also in triangular, quadrangular, hexagonal or octagonal form.

Of course wires may be carried from a suitable place to the center or also laterally which serve the current waves as guides. This is necessary when the currents have to be conducted over mountains and valley and so forth. In all these cases the current must be converted into a current of suitable periodicity.

As already hereinbefore mentioned separate collecting balloons may be directly metallically interconnected at equidistant stations distributed over the entire country or may be connected by interpolation of suitable condenser batteries by means of high voltage conductors. The static electricity is converted through a spark gap into dynamic energy of a high number of oscillations, and could then in such forms, wit a suitable arrangement of the connections, observing various measures of protection, be employed as source of energy after separate or special regulation.

According to this invention in order to increase the collecting effect of the balloon in the aerial collector conductor or in the earth wire, radiating collectors are employed. These consist either of incandescent metal or oxide electrodes in the form of vacuum grid tubes, or electric arcs (mercury and the like electrodes), Nernst lamps, or finally flames of various kinds may be simply connected with the respective conductor.

It is well known that energy can be drawn of from a cathode consisting of an incandescent body opposite an anode charged with positive electricity (vacuum grid tube). Hitherto however, a cathode was always first directly placed opposite an anode, and secondly the system always consisted of a closed circuit.

Now if we dispense with the ordinary ideas in forming light or flame arcs in which a cathode must always stand directly opposite an anode, charged to a high potential or another body freely floating in the air, or regard the incandescent cathode only as a source of unipolar discharge (which represent group and point discharges in electrostatic machines similar to unipolar discharges), it may be ascertained that incandescent cathodes and less perfectly all incandescent radiators, flames and the like admit of relatively large current densities and allow large quantities of electric energy to radiate into the open space in the form of electron streams as transmitters.

The object of this invention is as described below, if such incandescent oxide electrodes or other incandescent radiators or flames are not freely suspended in space but connected metallically with the earth so that they can be charged with negative terrestrial electricity, these radiators possess the property of absorbing the free positive electrical charges contained in the air space surrounding them (that is to say of collecting them and conducting them to earth). They can therefore serve as collectors and have, in comparison to the action of the spikes, or points, a very large radius of action R; the effective capacity of these collectors is much greater than the geometrical capacity (R_{o-}) calculated in an electrostatic sense.

Now as our earth is surrounded as is well known with an electrostatic field and the difference of potential

$$\frac{\delta V}{\delta h}$$

of the earth field according to the latest investigations, is in summer about 60 to 100 volts and in winter 300 to 500 volts per meter of difference in height (δh), a simple calculation gives the result that when such a radiation collector or flame collector is arranged for example on the ground, and a second one is mounted vertically over it at a distance of 2000 meters and both are connected by a conducting cable, there is a difference in potential in summer of about 2,000,000 volts and in winter even of 6,000,000 volts and more.

According to Stefan Boltzmann's law of radiation, the quantity of energy which an incandescent surface (temperature T) of 1 sq cm radiates in a unit of time into the open air (temperature T_o) is expressed by the following formula:

$S = \delta\ (T^4 - T^4_o)$ watt./sq cm.

And the universal radiation constant δ is according to the latest researches of Ferry (*Annales de Chimie et de Physique*, 17: 267 [1909]) equal to 6.30 x 10^{-12} watt/sq cm.

Now if an in incandescent surface of 1 sq cm shows, as compared with the surrounding space a periodic fall of potential δV it radiates (independent of the current direction, that is to say of the sign) in accordance with the above formula, for example at a temperature of 3725° C an energy of 1.6 kw/sq cm/second. As for the radiation the same value can be calculated for the collection of energy, but reversed. Now, as carbon electrodes at the temperature of the electric arc support on the current basis a current density up to from 60 to 65 amperes per sq cm no difficulties will result in this direction in employing radiating collectors as accumulators.

If the earth be regarded as a cosmically insulated condenser in the sense of geometrical electrostatics *x* there results from the geometric (compare Edwald Rasch: *Das Elektrische Bogenlicht* [The Electric Arc Light], page 169) capacity of the earth according to Chwolson:

For negative charging 1.3 x 10^6 Coulomb

For negative potential V = 10 x 10^8 volts.

From this there results however, EJT = 24.7 x 10^{24} watt/sec. Now if it is desired to make a theoretic short circuit through an earthed flame collector this would represent an electric total work of about 79,500 x 10^{10} kilowatt years. As the earth must be regarded as a rotating mechanism which thermodynamically, electromagnetically and also kinematically coupled with the sun and star system by cosmic radiations and gravitation a diminution of the electric energy of the earth field is not to be feared. The energies which the incandescent collectors would withdraw from the earth field can only case by the withdrawal of motor work a lowering of the earth temperature (temperature $T_E = 300$) and reduce this to that of the world space (T = O) by using the entire energy. This is however not the case as the earth does not represent a cosmically entirely insulated system. On the contrary there is conveyed to the same according to the recent value corrected by Perry for the solar constants through the radiation from the sun an energy of 18,500 x 10^{10} kw. Accordingly, any lowering of the earth temperature (T_E) without a simultaneous lowering of the sun's temperature (T_s) would contradict Stefan Boltzmann's law of radiation.

$S = \delta\ (s^4 - T^4)$.

From this it must be concluded that if the earth temperature (T_E) sinks the total radiation S absorbed by the earth increases, and further also that the secular speed of cooling of the earth is directly dependent on that of the sun and the other radiators cosmically coupled with the sun and is connected most closely with these.

The incandescent radiation collectors may, according to this invention, be employed for collecting atmospheric electricity if they (1) are charged with the negative earth electricity (that is to say when they are directly connected by means of a metallic conductor with the earth) and (2) if large capacities (metal surfaces) charged with electricity are mounted opposite them as positive poles in the air. This is regarded as the main feature of the present invention as without these inventive ideas it would not be possible to collect with an incandescent collector, sufficiently large quantities of the electrical charges contained in the atmosphere as the technology requires; the radius of action of the flame collectors would also be too small, especially if it be considered that the very small surface density (energy density) (δ about = 2 x 7 . 10^9 St. E. per sq cm) does not allow of large quantities of charge being absorbed from the atmosphere.

x) Calculated according to Poisson's calculation:

$\Delta V = -4\pi\delta$; as here the alteration of the potential or potential gradients only takes place in the direction o the normal, this calculation assumes the simple form

$$\delta = \frac{1}{4\pi} \times \frac{\delta^2 V}{\delta n^2}$$

It has indeed already been proposed to employ flame collectors for collecting atmospheric electricity and it is known that their collecting effect is substantially greater opposite the points. It is however, not known that the quantities of current which could hitherto be obtained are too small for technical purposes. According to my experiments the reason for this is to be found in the too small capacities of the collector conductor poles. If such flame or radiating collectors have no or only small positive surfaces, their radius of action for large technical purposes is too small. If the incandescent collectors be constantly kept in movement in the air they may collect more according to the speed of the movement, but this again is not capable of being carried out in practice.

By this invention the collector effect is considerably increased by a body charged with a positive potential and of the best possible capacity being also held floating (without direct earth connection) opposite such an incandescent collector which is held floating in the air at a desired height. If for example, a collecting balloon of sheet metal or of metalized balloon fabric be caused to mount to 300 up to 3000 meters in the air and as positive pole it is brought opposite such a radiating collector connected by a conductor to the earth, quite different results are obtained.

The metallic balloon shell (with a large surface) is charged to a high potential by the atmospheric electricity. This potential is greater the higher the collecting balloon is above the incandescent collector. The positive electricity acts concentratedly on the anode floating in the air as it is attracted through the radiation shock ionization, proceeding from the incandescent cathode. The consequence of this is that the radius of action of the incandescent cathode collector is considerably increased and thereby also the collection effect of the collecting balloon surface. Further the large capacity of the anode floating in the air plays therefore an important part because it allows of the taking o large charges, and thereby a more uniform current is obtained even when there is a large consumption: this cannot be the case with small surfaces.

In the present case the metallic collecting balloon is a positive anode floating in the air and the end of the earth conductor of this balloon serves as positive pole surface opposite the surface of the radiating incandescent cathode, which in turn is charged with negative earth electricity being conductively connected to earth.

The process may be carried out by two such contacts (negative incandescent cathode and anode end of a capacity floating in the air) a condenser and an inductive resistance being switched on in parallel, whereby simultaneously undamped oscillations may be formed.

In very large installations it is advisable to connect two such radiating collectors in series. Thus an arc light incandescent cathode may be placed below on the open ground and an incandescent cathode which is heated by special electromagnetic currents be located high in the air. Of course for this the special vacuum Liebig tubes wit or without grids may also be employed. An ordinary arc lamp with oxide electrodes may be introduced on the ground and the positive pole is not directly connected with the collecting balloon, but through the upper incandescent cathode or over a condenser. The method of connecting the incandescent cathode floating in the air may be seen in Figures 29-33.

B is the air balloon, K a Cardan ring (connection with the hawser), C the balloon, L a good connecting cable, P a positive pole, N negative incandescent cathode, and E earth conductor.

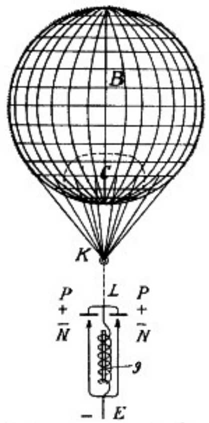

Fig. 29.

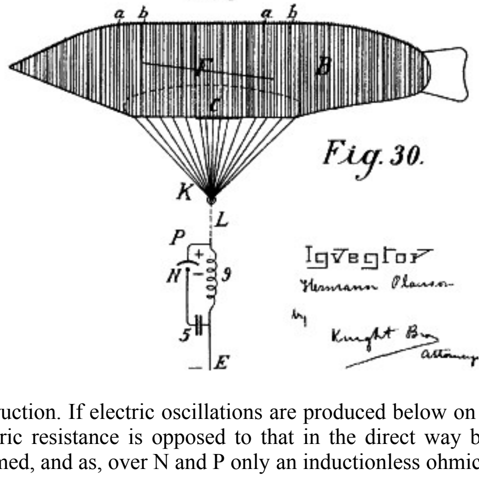

Fig. 30.

Inventor
Hermann Plauson
by
Knight Bros
attorney

Figure 29 represents the simplest form of construction. If electric oscillations are produced below on the ground by means of a carbon arc lamp or in other suitable way a considerably greater electric resistance is opposed to that in the direct way by inserting an electrical inductive resistance 9. Consequently between P and N, a voltage is formed, and as, over N and P only an inductionless ohmic resistance is present, a spark will spring over so long as the separate induction co-efficients and the like are correctly calculated. The consequence of this is that the oxide electrode (carbon or the like) is rendered incandescent and then shows as incandescent cathode an increased collecting effect. The positive poles must be substantially larger than the negative in order that they may not also become incandescent. As they are further connected with the large balloon area which has a large capacity and is charged at high voltage, an incandescent body which is held floating in the air and a positive pole which can collect large capacities is thereby obtained in the simplest way. The incandescent cathode is first caused to become incandescent by means of separate energy produced on the earth, and then maintained by the energy collected from the atmosphere.

Figure 30 only shows the difference that instead of a round balloon a cigar-shaped one (of metal or metalized fabric) may be employed and also a condenser 5 is inserted between the incandescent cathode and the earth conductor so that a short circuited oscillation circuit over P.N. 5 and 9 is obtained. This has the advantage that quite small quantities of electricity cause the cathode to become incandescent and much larger cathode bodies may be rendered incandescent.

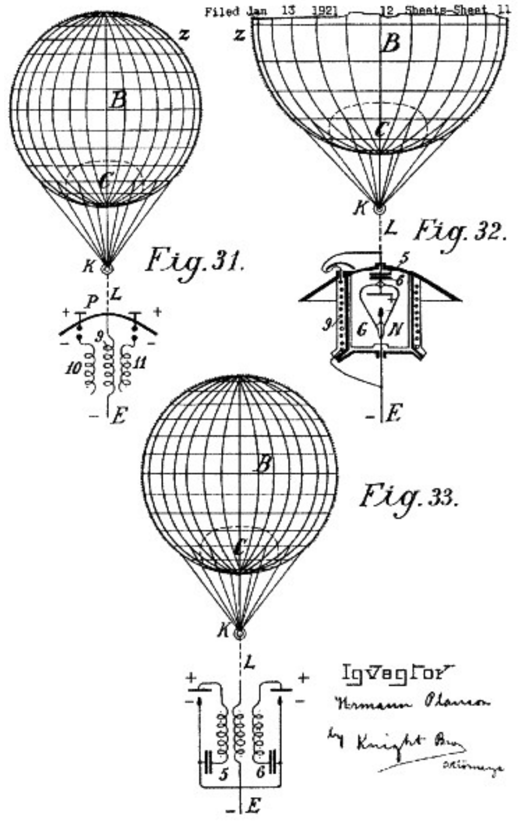

Fig. 31.

Fig. 32.

Fig. 33.

In this form of construction both the incandescent cathode and also the positive electrode may be enclosed in a vacuum chamber as may be seen in Figure 32. A cable L is carried well insulated through the cover of a vessel and ends in a condenser disc 5. The cover is arched in order to keep off the rain. The vessel is entirely or partially made of magnetic metal and well-insulated inside and outside. Opposite the disc 5 another disc 6 and on this again a positive pile of the vacuum tube g with the incandescent cathode (oxide electrode) N is arranged. The negative electrode is on the one hand connected with the earth conductor E, and on the other hand with the inductive resistance 9 which is also connected with the cable L with the positive pole and wound round the vessel in coils. The action is exactly the same as that in Figure 29 only instead of an open incandescent cathode one enclosed in vacuo is employed. As in such collectors only small bodies can be brought to incandescence in large installations a plurality of such vacuum tubes must be inserted in proximity to one another. According to the previous constructions Figures 31 and 33 are quite self evident without further explanations.

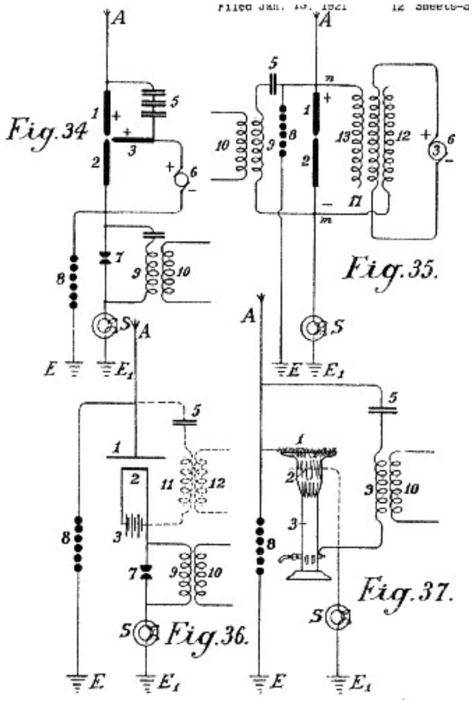

Figures 34-37 represent further diagrams of connections over radiating and flame collectors, and in fact, how they are to be arranged on the ground.

Figure 34 shows an arc light collector with oxide electrodes for direct current and its connection; Figure 35 a similar one for alternating current, Figure 36 an incandescent collector with a Nernst lamp and Figure 37 a similar one with a gas flame.

The positive pole 1 of the radiating collectors is always directly connected to the aerial collecting conductor A. In Figure 34 this is further connected over the condenser battery 5 with a second positive electrode 3. The direct current dynamo *b* produces current which flows over between the electrodes 3 and 2 as an arc light. On the formation of an arc the negative incandescent electrode 2 absorbs electricity from the positive poles standing opposite it and highly charged with atmospheric electricity and conveys the same to the working circuit. The spark gap 7, inductive resistance 9 and induction coil 10 are like the ones previously described. The protective electromagnet S guards the installation against earth circuiting, the safety spark gap 8 from excess voltage or overcharging.

In Figure 35 the connection is so far altered that the alternating current dynamo feeds the exciting coil 11 of the induction condenser. 12 is its negative and 13 its positive pole; if the coil 3 on the magnet core of the dynamo is correctly calculated and the periodicity of the alternating current is sufficiently high an arc light can be formed between the two poles 1 and 2. As the cathode 2 is connected with the negatively charged earth, and therefore always acts as a negative pole, a form of rectification of the alternating current produced by the dynamo 3 is obtained, the second half of the period is always suppressed. The working circuit may be carried out in the same way as in Figure 34; the working gap 7 may however be dispensed with, and instead thereof between the points m and n a condenser 5 and an induction resistance 9 may be inserted from which the current is taken inductively.

Figure 36 represents a form of construction similar to Figure 34 only that here instead of an arc lamp a Nernst incandescent body is employed. The Nernst lamp is fed through the battery 3. The working section is connected with the negative pole, the safety spark gap with the + poles. The working spark gap 7 may also be dispensed with and the current for it taken at 12 over the oscillation circuit 5, 11 (shown in dotted lines).

Flame collectors (Figure 37) may also be employed according to this invention. The wire network 1 is connected with the aerial collector conductor A and the burner with the earth. At the upper end of the latter, long points are provided which project into the flame. The positive electrode is connected with the negative over a condenser 5 and the induction coil 9 with the earth.

The novelty in this invention is firstly, the use of incandescent cathodes opposite positive poles which are connected with large metallic capacities as automatic collecting surfaces, (2) the connection of the incandescent cathodes with the earth whereby, in addition to the electricity conveyed to them from the battery or machine which causes the incandescing, also the negative charge of the earth potential is conveyed, and (3) the connection of the positive and negative poles of the radiating collectors over a condenser circuit alone or with the introduction of a suitable inductive resistance, whereby simultaneously an oscillatory oscillation circuit may be obtained. The collecting effect is by these methods quite considerably increased.

I declare that what I claim is: --- [Claims not included here]

British Patent # 157,262

(10 July 1922)

Improvements in Electric Motors

Hermann Plauson // Otto Traun’s Forchungs-Laboratorium GmbH

This invention relates to that type of motor in which rotation is produced by means of the attraction and repulsion of surfaces carrying charges of electricity.

According to this invention a stator and rotor are formed of condensor surfaces and charges of electricity thereon imposed in the form of alternating currents of high frequency.

The invention is more particularly described with reference to the accompanying drawing in which: ---

Figure 1 shows a simple form of motor and feed.

Fig.1

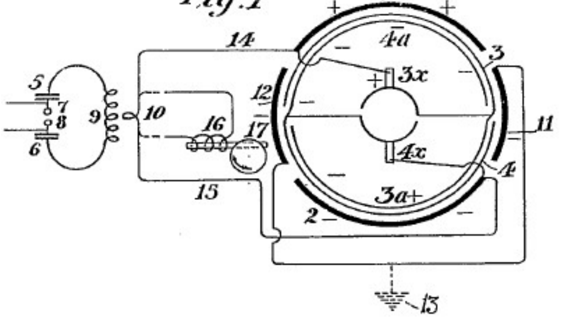
1+
+
+
14
4a
3
3x
5
7
8
6
9
10
12
16
17
11
4x
4
15
3a+
2
13

Figure 2 is a modification of Figure 1.

Fig.2.

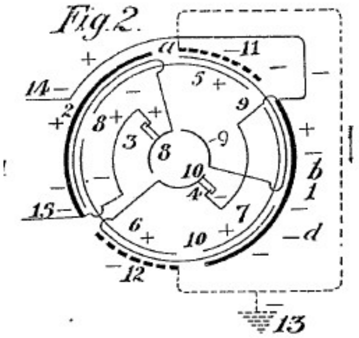
a
11
14
5+
9
8+
3
8
9
10
4
b
1
13
6+
10+
7
d
12
13

Figure 3 shows one form of a spiral condenser surface.

Figure 4 shows a wire wound condenser surface.

Figure 5 is a diagram of one type of rotor,

Fig.3

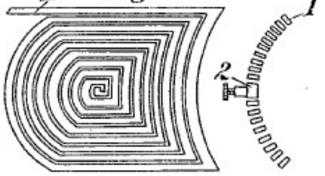

Fig.4

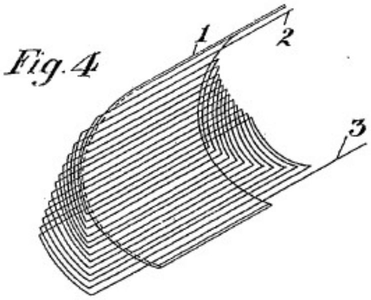

Fig.5.

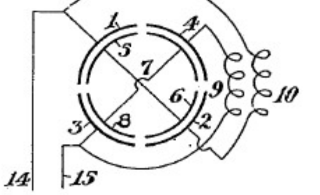
1
4
5
7
6
9
10
3
8
2
14
15

The inner plates of the condenser 5 and 6 are charged from a spark gap 7, 8 connected to a source of energy of sufficiently high pressure (alternating or direct current), until the potential has risen so far that a spark springs over.

The spark gap 7, 8 forms with the condenser 5 and self-inductance 9 and condenser 6 a closed oscillatory circuit and alternating currents of high frequency will be produced in this circuit. The high frequency current produced in the primary circuit 9 excite by induction in the secondary circuit 10 currents of the same periodicity.

The improved type of motor is fed by the discharges produced by the induction in the secondary circuit.

Hitherto only Tesla's motor system (shown diagrammatically in Figure 1, 16 and 17) was known for this purpose. The above-mentioned diagram is only shown for illustrating the fundamental principle. It has however no practical interest for carrying out large machines by reason of the impossibility of the regulation and the low efficiency.

Now according to this process, all these defects are overcome by the construction of a machine which is applicable for high frequency currents and of a more or less undamped nature. The difference between the principle of construction of these motors as compared with those hitherto customary consists in that the motor is not based on the principle of magnetic induction only (as have been all motors hitherto and also Tesla's motors).

It has been fund that the machine constructed according to Figure 1 cannot only be fed directly with static electricity but if it is connected to a source of high frequency current it will operate.

The applicants call this new type of motors 'condenser motors' to differentiate them from hitherto existing types.

The simplest form of construction of such condenser motors is shown in Figure 1, and this motor may be fed with high frequency alternating currents.

At a given moment positive electricity is charged by means of the lead 14 to the stator surface 1 and to the brush 3x (Figure 1). The brush 3x is connected with the rotor condenser surface 3, so that both the stator surface 1 and also the rotor surface 3 is charged with positive electricity. The stator surface 1 and the rotor surface 3 being both charged with positive electricity and the second rotor surfaces 4 and 4a by brushes 4x with negative electricity, such motors can then be started by providing intermediate stator surfaces 11, 12, the earth connection 13 of one of which is broken by a switch (not shown) according to the direction of rotation desires, or alternatively the motor may be started by a separate source of alternating current in a manner similar to the starting of synchronous motors of known construction. After a half revolution of the rotor the brush 3x comes in contact with the second collector surface 4 so that now this surface is connected by the brush 3x with the stator surface 1 and the brush 4x with the collector surface 3. Consequently with a reverse direction of current through the second half of the oscillation period all the hereinbefore mentioned effects take place in the reverse direction which, however, produces no alteration in the direction of rotation because the dead points between two directions of oscillation are overcome by inertia.

Although this motor is easy to start it can only be employed for small experimental and measuring purposes because the stator and rotor surfaces are made of solid metal and are heated by Foucalt (eddy) currents. In spite of its simplicity and its unsuitability for use in practice it must however be regarded as a basic type for technical calculations.

The condenser motor shown in Figure 2 differs from Figure 1 by the rotor surfaces consisting of six condenser surfaces connected one behind the other in series and they are connected with three collector surfaces, so that at any one moment only two adjacent collector surfaces come under the two brushes (3 and 4). In its other actions it corresponds to Figure 1. The leads 14 and 15 may be connected either to the ends of the secondary coil 10 or directly with the source of energy. The outer thicker line indicates the stator surfaces 1 and 2 (that is to say the unmoving part of the motor), 11 and 12 shown by thick dotted lines means earthed additional poles of the stator, 8, 9, and 10 are the outer parts of the rotor condenser surfaces which in turn are connected with the collector surfaces 8, 9, and 10. 5, 6, and 7 are the inner parts of the condenser surfaces of the rotor and 3 and 4 are brushes.

Hitherto stator and rotor surfaces of compact metal have been spoken of. These however become highly heated with eddy currents and hardly yield 10-15% of useful effect. In examining into such small useful effects it was found that certain forms of metal sections in the stator and condenser surfaces highly increase these. It was then further found that if slots or notches be cut in the metal surfaces of the stator and rotor in the form of a spiral, not only was a higher useful effect possible, but also an easier starting and even a regulation could be obtained.

Experiments have shown that by such a form of construction it is possible to build a very useful motor for high frequency alternating currents more particularly those of an undamped nature.

If for example the system of construction of a stator shown in Figure 1, but four polar, be taken and the system of rotor construction shown diagrammatically in Figure 5, but with the form of construction of the condensers of the stator as well as of the rotor according to Figure 3, a condenser motor is obtained which works well in either direction for high frequency alternating current. It was also observed that the motors in such forms of construction were found to be more sensitive to resonance effects. Such a motor then works the best if stator and rotor surfaces have equal capacity and self-inductance so that the windings both in the stator and also in the rotor are in resonance.

A motor constructed according to the foregoing kind is already fully technically applicable. But even these motors have a series of faults, more particularly in their building construction. For example, the attachment of the spiral condenser surfaces both of the stator and of the rotor sown in Figure 3 are in practice difficult to carry out. Therefore in practice the condenser and stator surfaces are simply wound of wire or bands in the form shown in Figure 4. Such stator and rotor surfaces may, without further difficulty, be regarded as electromagnetic poles, although they are not made of iron as is the case in electromagnets. Such machines may be spoken of directly as motors for high frequency alternating currents in which the separate pole surfaces consists of wound induction condenser surfaces of which one is sound on the stator and the other on the rotor.

If the coil as shown in Figure 4 be made of well insulated wires the coil can be embedded in insulating material either for the stator or motor surfaces as has already been done in the case of ordinary single and multiphase motors. At the same time the possibility is afforded by increasing the number of turns to produce a greater or smaller alteration of the self induction co-efficients.

In Figure 5 is shown a modified construction of a rotor for a four pole motor consisting of four condenser surfaces 1, 2, 3, 4, of which 1 and 2 are connected though an iductance 9 coupled with the coil 10. Four inner surfaces 5, 6, 7, 8 are provided of which 5 and 6 are directly connected also 7 and 8 similarly connected.

The pairs of like poles are connected by wires 14 and 15 to the source of energy. By a suitable selection of the values of the reactance and capacity in these circuits resonance circuits may be formed.

Having now particularly described and ascertain the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is: --- [Claims not included here]

British Patent # 157,263

Process & Apparatus for Converting Static Atmospheric Electrical Energy into Dynamic Electrical Energy of any Suitable High Periodicity

Hermann Plauson // H.O. Traun’s Forschungs-Laboratorium GmbH

Static aerial electricity in the form of direct current can be converted by using spark gaps and with the assistance of oscillatory circuits into dynamic electrical wave energy of a high number of alternations of a more or less undamped nature and in such form --- either direct or by means of a special kind of resonance or 'condenser motors' --- ready to be utilized for technical purposes as mechanical energy.

For small installations this system may be very well employed; about 100 horsepower may be stated as practical limit. In constructions of larger aggregate difficulties as regards the spark gaps however increase considerably. Further it is desirable to convert the accumulated currents of from 100 to 1000 periods which may then be used for the ordinary types of alternating current machines instead of into electromagnetic waves of a high number of alternations.

In experimenting with condenser motors the construction of which forms the object of British Patent # 157,262 it was observed that the rotor, if one pole of the stator surface be connected with the aerials collecting aerial electricity and the other pole with the earth, not only could act as a motor, but if vice versa the rotor connection with the stator be interrupted and the rotor caused to rotate by means of another motor, that when the brushes supply an alternating current the periodicity of which is dependent on the number of poles and the revolutions of the rotor. Such an apparatus may therefore be regarded as a transformer of static into dynamic electrical energy.

The invention is more particularly described with reference to the accompanying diagrams in which: ---

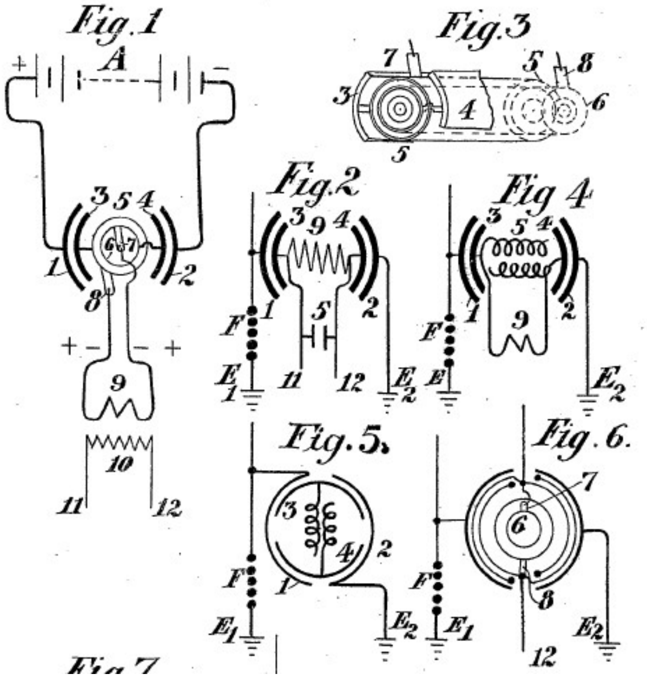

In Figure 1A is a strong accumulator battery, 1 and 2 are the outer poles of the transformer, consisting of simple metallic plates or are as shown in Figures 8-11, made of wire coils without an electromagnet being present. Between these poles an armature is revolubly mounted on a shaft, which armature also consists of two similar cylindrically curved plates 3 and 4. These are metallically connected with two collector rings 5 and 6 on which two brushes 7 and 8 freely run which again are short-circuited with one another over a primary coil 9. 10 is the secondary coil with the free ends 11 and 12. If through the accumulator battery the stator plate 1 is charged with positive electricity, it induces a charge of reverse sign on the rotor surface 3 which is connected by the brushes 7 and 8 over the primary coil 9 with the second rotor surface 4. This latter is therefore charged with positive electricity, which in turn induces negative electricity on the stator surface 2/ Up to this moment everything takes place in the same way as if two condensers were connected one behind the other in the current circuit A. If however, by means of mechanical power, this rotor be caused to rotate, the surface conditions are altered. After a quarter revolution the rotor plates are between the stator plates and therefore no condenser surface faces another. By this means however, the capacity of the entire system is reduced to a minimum and a change of current will also result in the main 9. Now if the rotor be turned further through 90 degrees by mechanical energy the rotor plate 3 comes opposite the stator plate 2 and the rotor plate 4 opposite the stator plate 1, so that then the rotor pates are in a field of reverse sign. A fresh charge of current in the reverse direction now runs through the primary coil 9. After a further half revolution the same action is repeated so that after a full revolution the initial condition is again produced. The result of such a revolution is an alternating current the periodicity of which is equal to the number of revolution. In practice of course not two poles but as many poles as possible would be employed because thereby the number of alternations would e considerably increased. The primary alternating current thus obtained induces in the secondary circuit an alternating current the potential of which is dependent on the winding of the coil. Figure 7 shows a multipolar machine.

If the stator surface 1, instead of being connected with the battery be connected with a collecting aerial network and the other stator surface 2 be directly earthed, but the rotor wich is otherwise constructed as hereinbefore, be rotated by a separate motor a much stronger alternating current results which is to be ascribed to the circumstance that a much higher potential can be charged on the pole surfaces of the stator by reason of the higher pressure of the static electricity than where accumulators are employed. By this means the transformer has of course much larger quantities of energy supplied to it.

Figure 2 shows a mode of connections. The stator surface 1 is connected with the aerial antennae which is connected through the safety spark gap F to earth at E1. The stator surface 2 is directly earthed at E2. The inner revoluble rotor surfaces 3 and 4 are interconnected by means of an induction coil which is constructed directly in the motor. The current is taken as in Figure 1 up to collector rings by means of brushes, which are not shown for the sake of clearness, and further conveyed through the conductors 11 and 12. Between these a condenser 5 may be inserted. There is thereby formed a short oscillatory oscillation circuit free from spark gaps, which circuit consists of the induction coil 9 and condenser 5 and is fed by the periodic charging current impulse. By this means the possibility is afforded of obtaining a kind of current which is characterized by longer periods and is undamped and oscillatory. Of course a simple alternating current may be obtained by cutting out the condenser.

Instead of the induction coil the condenser may also b constructed in the rotor. His can be carried out in such a way that its ends serve directly as collector rings for taking current through the brushes. In Figure 3 such a motor is sketched in perspective, 3 and 4 are the rotor surfaces, 5 and 6 are the condenser surfaces constructed to form part of the rotor consisting of two co-axial cylinders fitting one in the other in such a way that free room is left for the brushes 7 on one end of the condenser cylinder 6.

The condenser may be made in the form of a cylindrically wound spiral forming the capacity and reactance as shown in Figure 4. A further type of transformer is shown in Figure 5. The difference consists in the stator and rotor surfaces not only each assuming a quarter of the circuit but almost the half. By this means the space and the effective condenser surface is better utilized. Charge is produced only when the rotor surfaces face the full scope of the stator surfaces.

In addition a condition is obtained in which the stator surfaces are inductively connected by the rotor surfaces. The consequence of this is that an alternating current simultaneously results which is produced without sparking otherwise the connection is as before.

Figure 6 shows the alternation of the rotor surfaces; the rotor here consists of two cylindrical condenser plates arranged concentrically, each divided into two halves and connected so that half the inner cylinder is connected to half the outer. Such a machine shows the more complete transformer action.

Fig.7.

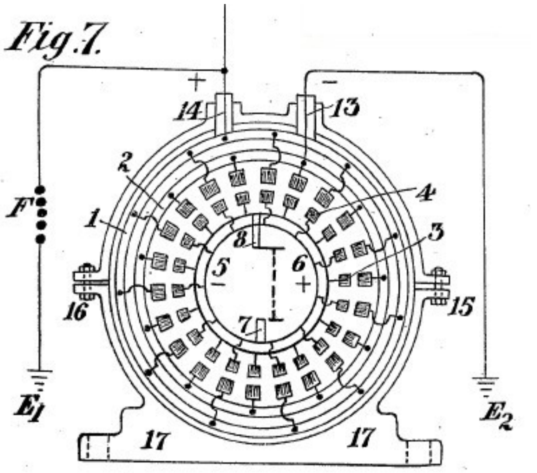

Figure 7 shows a four polar transformer. It consists of a metal casing, the lower half of which is fastened with the foundation plates 17 to the support or foundation. The upper half, the cover, is connected by bolts 15 and 16 firmly with the under part. This upper sleeve or casing is insulated from the under part. Two rings 1 and 2 are cylindrically constructed in the casing. The ring 1 is metallically connected with the collector aerial and the ring 2 with the earth. On both rings an equal number of stator surfaces are mounted side by side but well insulated from one another and thus form an electrostatic field similar to the electromagnetic in many alternating current machines. The rotor consists in similar manner of two rings 5 and 6 on which an equal number of rotor surfaces are fixed so that each stator surface faces a rotor surface. By the brushes 7 and 8 the alternating current formed is removed from the collector. The charge is conveyed by the conductor 14 to and by 13 away. If this rotor be then rotated by means of a motor the positive and negative fields precisely as in the case of magnetizing will alter and thereby an alternating current is formed in the rotor, the periods of which are dependent on the number of the poles and the revolutions per second.

At the commencement it was thought that this apparatus could only be regarded as alternating current converters, but it was soon found that much more energy was necessary to rotate the rotor than might be necessary to overcome the friction. It was then found that the considerable expenditure of energy for rotating the rotor was caused by a conductor being moved through strongly electrostatic fields since the electrostatic lines of force must be cut at right angles and that further in the conductors a stronger current arose than was otherwise to be expected. This apparatus must therefore not only be regarded as a transformer, but also as an energy producer, with the difference that the excitation here is obtained instead of by means of electromagnets, by static fields of high pressure. The entire system may, to some extent, be compared with a dynamo in which the excitation takes place by means of a fixed constant magnet. It was further ascertained that this way of using the atmospheric electricity produced a sort of suction on the collector network, and that thus suitable greater quantities of current could be obtained.

The effects which in this apparatus became evident are extremely interesting and open a prospect of being able to obtain here a great deal more. Merely that these transformer made it possible to transform suitable quantities of atmospheric electricity into alternating current of high or lower frequency (without the use of spark gaps) shows already the extreme utility of these apparatus. Should in future, the construction of larger aggregates be necessary the transformer installation may be constructed in such a way that motors which are fed by a current obtained from an installation with spark gaps produce a certain quantity of energy which may then be employed for producing current according to the last described system.

The results of the examinations made for this may be construed as follows.

(1) If solid electrodes (condenser surfaces, rotor and stator surfaces) are employed they become hot. This effect may be considerably reduced by cutting the electrodes in ribbed form Figure 8, but not entirely removed. This form allows the surface of the condenser plate to be enlarged or increased; the electrodes may be fastened in a simple manner on the under frame by perforation 1, 2, 3, 4, 5.

Fig.8

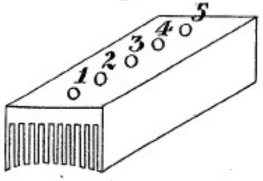

Fig. 9.

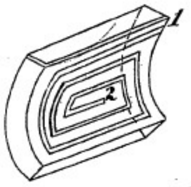

(2) If nicks or notches in spiral form as shown in Figure 9 seen from the side end in Figure 10 in section are employed, not only is the transformer effect greater but the poles yields also more current, but require greater quantities of energy for their movement than a simple commutator action would require.

Fig. 10

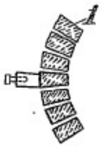

Fig. 11

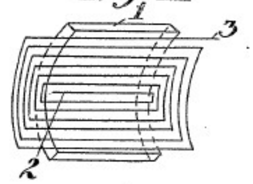

(3) The greatest effect is obtained if the rotor and stator surfaces are wound in flat spiral form of suitably thick wire, and in such a way that the inductive effect combining with the capacity is calculated in suitable proportion and this result is adapted to a suitable periodicity. In practice this is preferably done by the wire bent in spiral form being inserted in a separate vulcanite or hard rubber mass (see Figure 11) so that a smooth pole surface is formed similar to that in phase motors.

Fig.12

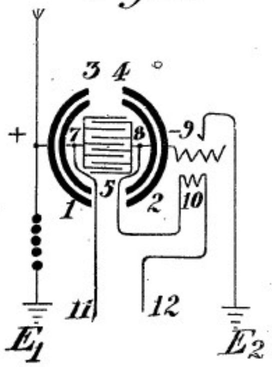

Fig. 13.

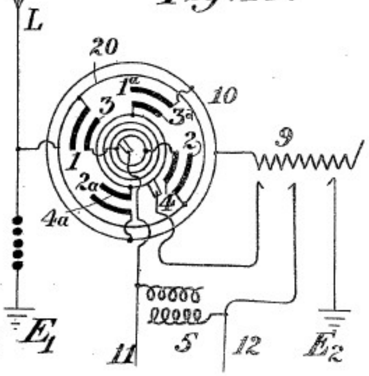

Regular undamped oscillations of a high frequency may however be produced if the converter be carried out in the manner shown in Figure 13. The aerial wire L is metallically connected with the ring 20. To this two pole surfaces 1 and 2 are connected. The inductive earth pole is also connected with a second ring 10 from which again two, poles 1a and 2a are branched off. Of course in similar manner any suitable number of poles may be branched of. In similar manner there are in the rotor two poles fastened to one another (3 and 4 and 3a and 4a) connected with separate collector rings. From these two rings the current is collected by means of two brushes. The induced alternating current is however directly metallically connected with an inductive earth stator conductor over an induction coil 9. Further a combined inductance and capacity 5 is inserted between the two wires 11 and 12 in parallel with the converter. By this means a sparkless oscillatory circuit is obtained which can act on the exciting current in the stator. This produces however, a periodic alteration of the charging quantities according to the oscillation curves of the rotor currents in consequence of which the stator charge also commences with resonance oscillations and if the stator and rotor surfaces are calculated to one another in such a way that they are adapted to form oscillations of waves of similar length the entire converter is caused to oscillate and furnishes undamped oscillations of a high number of alternations, but of periodically changed amplitude, the form of which is dependent on the amplitude of the main alternating current and is caused by the number of the poles and revolutions per second. Thus an alternating current of, for example, 100 periods is formed, the separate periods of which are formed by undamped oscillations of a higher number of alternations. In Figures 14-16 four other diagrams of converters are illustrated, the object of which is not to produce usual alternating current, but oscillations of high frequency.

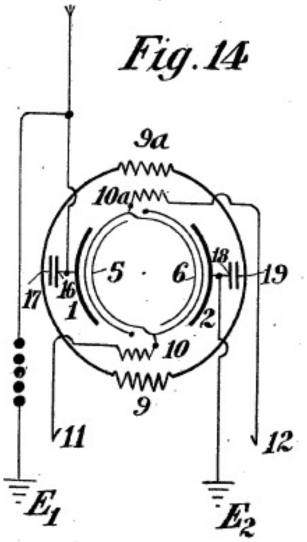
Fig. 14

The main difference of these systems from those previously described is that from the connection of the collecting aerials is made between the stator pole 1 (Figure 14) and one pole 16 of the condenser 17 and the earth connection between a second stator pole 2 and the pole 18 of the condenser 19. The other poles of these condensers 17 and 19 are short circuited through a ring over two inductive primary coils 9 and 9a with one another. The secondary coils form the rotor conductors 10 and 10a. The rotor itself is constructed in the manner shown in Figure 6 of two short-circuited plate condensers which may be wound as shown in Figure 11. In similar manner of course the stator surfaces may also be formed. The collector rings of the rotor with the two brushes for collecting current are here not shown in order to simplify the drawings. By the connection of the two condensers in the exiting circuit of the converter and also by the action of the alternating current produced in the rotor on the stator circuit, with a correct calculation of the capacity and the self-induction co-efficients a maximum action may be obtained. The kind of current produced will be similar to that described for Figure 12.

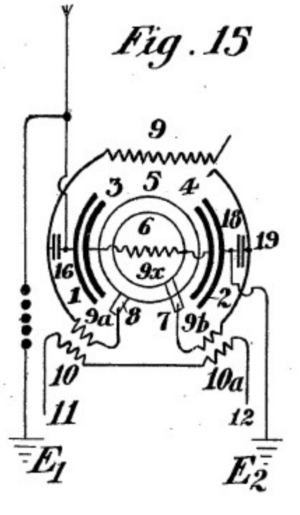
Fig. 15

The novelty of the converter illustrated in Figure 15 consists mainly in that the current resulting in the rotor is not directly employed, but only serves a exciter of the primary coils 9a and 9b. The working current is produced in the secondary coils 10 and 10a and further conducted through the conductors 11 and 12. The stator current may be brought by the regulatable inductive resistance 9 to the same resonance as the rotor current.

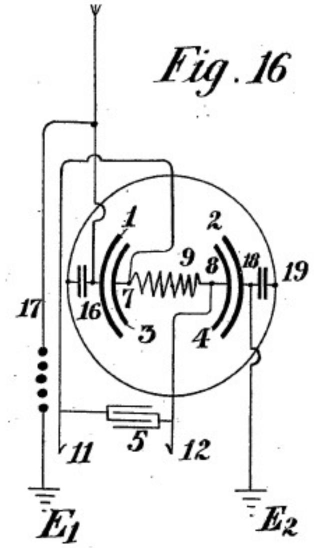

In Figure 16 a very similar system is shown to Figure 14. The condenser 5 is however connected in parallel with the converter; and by the inductive resistance constructed in the rotor a short circuited oscillatory circuit is formed which gives extraordinarily good results and is simple in construction.

The inductive resistance 9 may also instead of being constructed in the rotor be constructed as primary coil employed outside the rotor and short circuit the oscillatory circuit over the stator surfaces (see Figure 17).

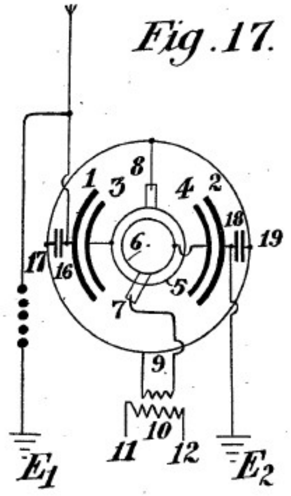

The last six types serve only for producing oscillations of a high number of alternations. If it be desired to obtain ordinary alternating current there complicated constructional arrangements are not required as the types illustrated in Figures 1 to 11 suffice. It is self-evident that these arrangements may be altered in various ways by means of different condenser surfaces in practice.
Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is: --- [Claims not included here]

US008253639B2

(12) **United States Patent**
Cohen

(10) **Patent No.: US 8,253,639 B2**
(45) **Date of Patent: Aug. 28, 2012**

(54) WIDEBAND ELECTROMAGNETIC CLOAKING SYSTEMS

(76) Inventor: **Nathan Cohen**, Belmont, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 498 days.

(21) Appl. No.: **12/547,104**

(22) Filed: **Aug. 25, 2009**

(65) **Prior Publication Data**

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H01Q 15/02 (2006.01)
H01Q 19/06 (2006.01)

(52) **U.S. Cl.** **343/753**; 343/909

(58) **Field of Classification Search** 343/753, 343/909, 910; 333/135
See application file for complete search history.

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(57) **ABSTRACT**

Arrangement of resonators in an aperiodic configurations are described, which can be used for electromagnetic cloaking of objects. The overall assembly of resonators, as structures, do not all repeat periodically and at least some of the resonators are spaced such that their phase centers are separated by more than a wavelength. The arrangements can include resonators of several different sizes and/or geometries arranged so that each size or geometry corresponds to a moderate or high "Q" response that resonates within a specific frequency range, and that arrangement within that specific grouping of akin elements is periodic in the overall structure. The relative spacing and arrangement of groupings can be defined by self similarity and origin symmetry.

14 Claims, 4 Drawing Sheets

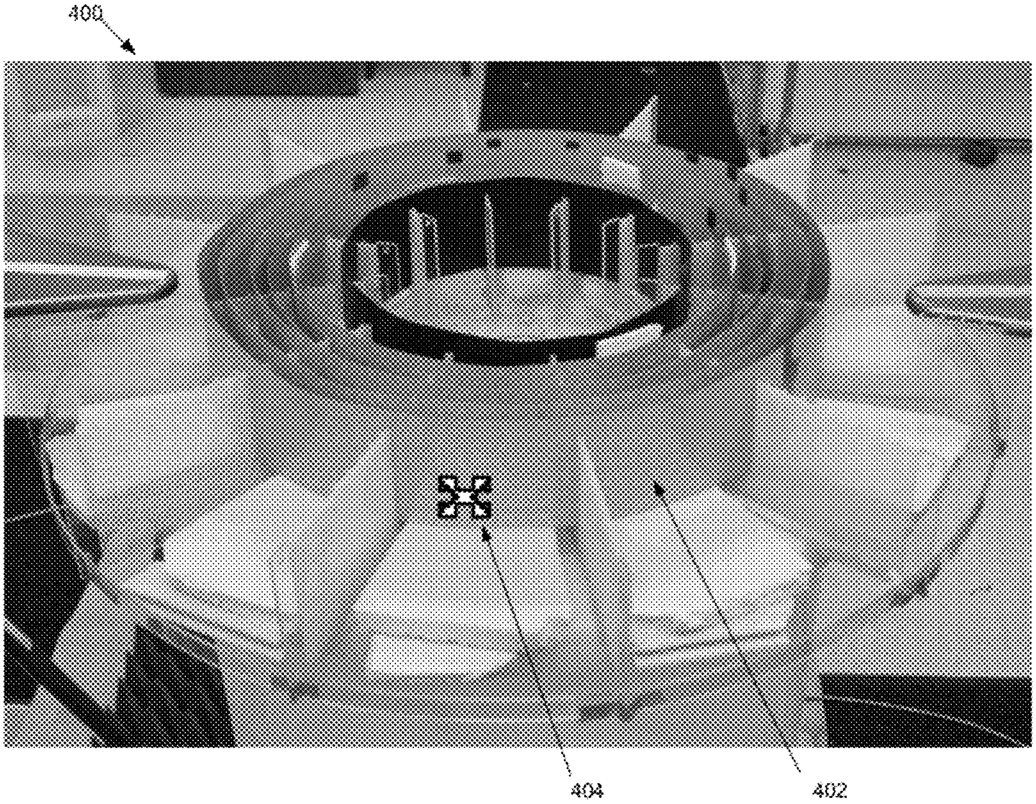

FIG. 1

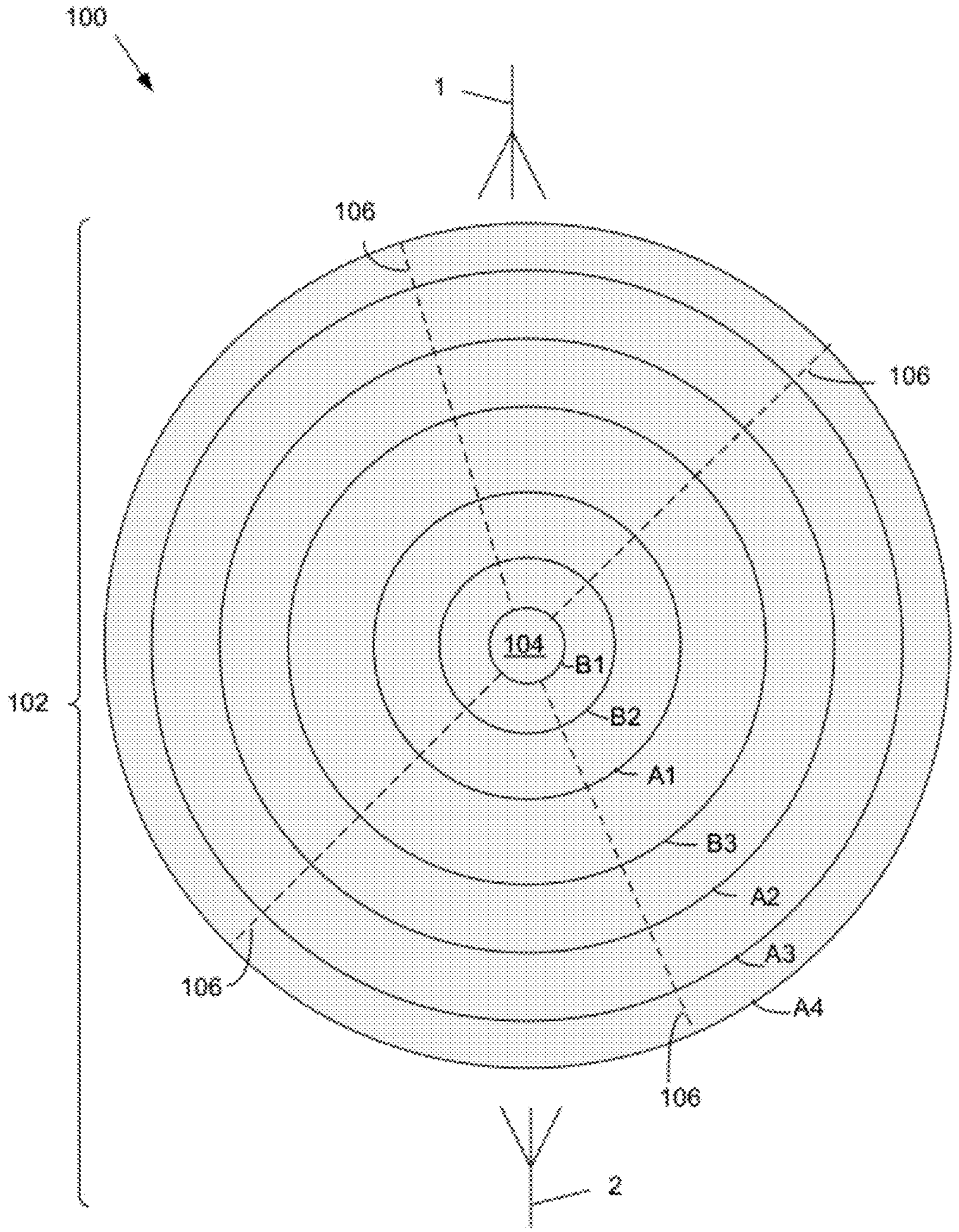
100
1
106
106
102
104
B1
B2
A1
B3
A2
A3
A4
106
106
2

FIG. 2

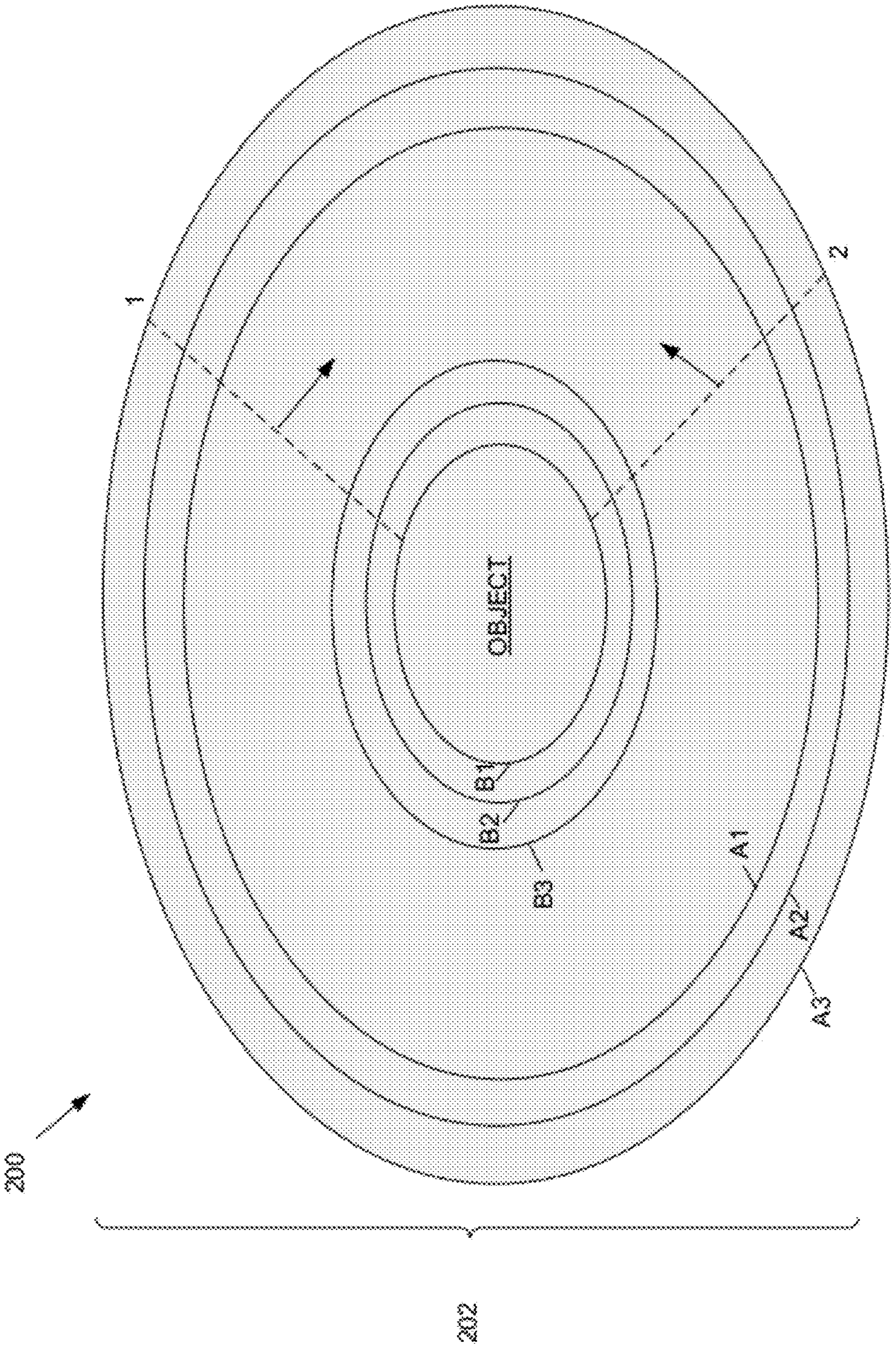
200
202
1
2
OBJECT
B1
B2
B3
A1
A2
A3

FIG. 3

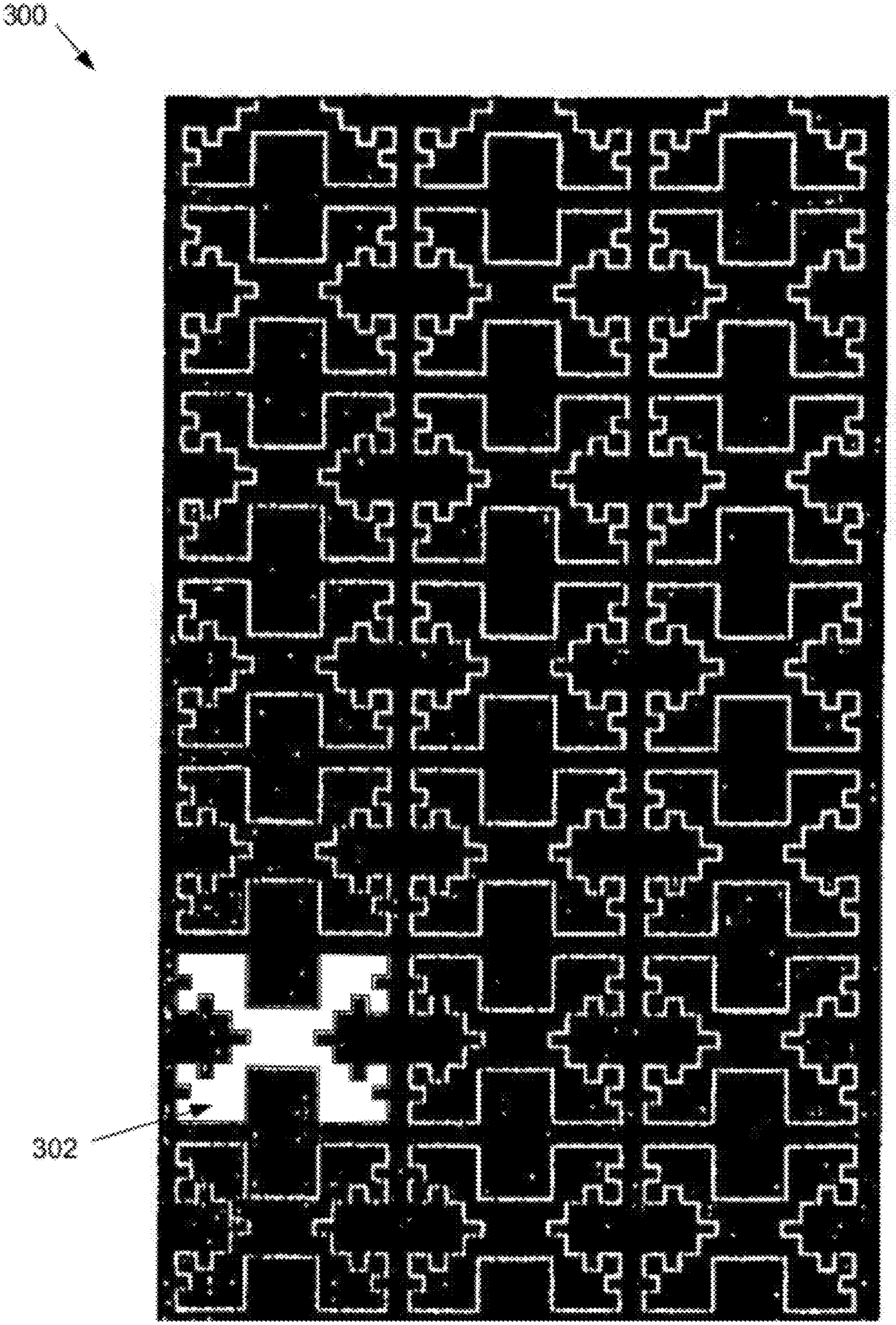

FIG. 4

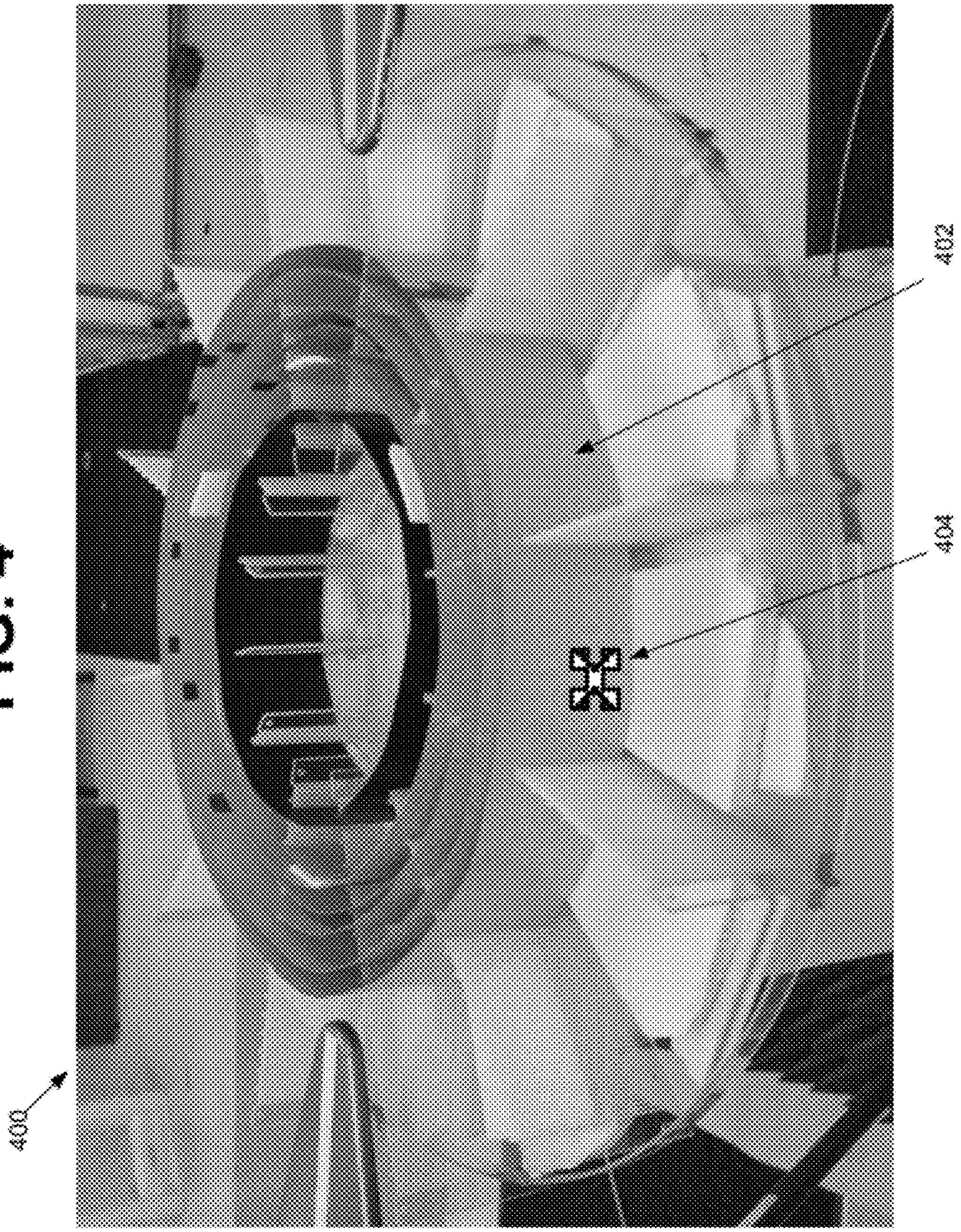

WIDEBAND ELECTROMAGNETIC CLOAKING SYSTEMS

RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application No. 61/189,966, filed 25 Aug. 2008 and entitled "Method and Apparatus for Wideband Electromagnetic Cloaking, Negative Refractive Index Lensing and Metamaterial Applications," the entire contents of which are incorporated herein by reference.

BACKGROUND

Much time and effort has been devoted to the quest for so-called invisibility machines. Beyond science fiction, however, there has been little if any real progress toward this goal.

Materials with negative permittivity and permeability leading to negative index of refraction were theorized by Russian noted physicist Victor Veselago in his seminal paper in *Soviet Physics* USPEKHI, 10, 509 (1968). Since that time, metamaterials have been developed that produce negative index of refraction, subject to various constraints. Such materials are artificially engineered micro/nanostructures that, at given frequencies, show negative permeability and permittivity. Metamaterials have been shown to produce narrow band, e.g., typically less than 5%, response such as bent-back lensing. Such metamaterials produce such a negative-index effect by utilizing a closely-spaced periodic lattice of resonators, such as split-ring resonators, that all resonate. Previous metamaterials provide a negative index of refraction when a sub-wavelength spacing is used for the resonators.

In the microwave regime, certain techniques have been developed to utilize radiation-absorbing materials or coatings to reduce the radar cross section of airborne missiles and vehicles. While such absorbing materials can provide an effective reduction in radar cross section, these results are largely limited to small ranges of electromagnetic radiation.

SUMMARY

Embodiments of the present disclosure can provide techniques, including systems and/or methods, for cloaking objects at certain wavelengths/frequencies or over certain wavelength/frequency ranges (bands). Such techniques can provide an effective electromagnetic lens and/or lensing effect for certain wavelengths/frequencies or over certain wavelength/frequency ranges (bands).

The effects produced by such techniques can include cloaking or so-called invisibility of the object(s) at the noted wavelengths or bands. Representative frequencies of operation can include, but are not limited to, those over a range of 500 MHz to 1.3 GHz, though others may of course be realized. Operation at other frequencies, including for example those of visible light, infrared, ultraviolet, and as well as microwave EM radiation, e.g., K, Ka, X-bands, etc. may be realized, e.g., by appropriate scaling of dimensions and selection of shape of the resonator elements.

Exemplary embodiments of the present disclosure can include a novel arrangement of resonators in an aperiodic configuration or lattice. The overall assembly of resonators, as structures, do not all repeat periodically and at least some of the resonators are spaced such that their phase centers are separated by more than a wavelength. The arrangements can include resonators of several different sizes and/or geometries arranged so that each size or geometry ("grouping") corresponds to a moderate or high "Q" (that is moderate or low bandwidth) response that resonates within a specific frequency range, and that arrangement within that specific grouping of akin elements is periodic in the overall structure—even though the structure as a whole is not an entirely periodic arrangement of resonators. The relative spacing and arrangement of groupings (at least one for each specific frequency range) can be defined by self similarity and origin symmetry, where the "origin" arises at the center of a structure (or part of the structure) individually designed to have the wideband metamaterial property.

For exemplary embodiments, fractal resonators can be used for the resonators in such structures because of their control of passbands, and smaller sizes compared to non-fractal based resonators. Their benefit arises from a size standpoint because they can be used to shrink the resonator (s), while control of passbands can reduce or eliminates issues of harmonic passbands that would resonate at frequencies not desired.

It should be understood that other embodiments of wideband electromagnetic resonator or cloaking systems and methods according to the present disclosure will become readily apparent to those skilled in the art from the following detailed description, wherein exemplary embodiments are shown and described by way of illustration. The systems and methods of the present disclosure are capable of other and different embodiments, and details of such are capable of modification in various other respects. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the disclosure may be more fully understood from the following description when read together with the accompanying drawings, which are to be regarded as illustrative in nature, and not as limiting. The drawings are not necessarily to scale, emphasis instead being placed on the principles of the disclosure. In the drawings:

FIG. **1** depicts a diagrammatic plan view of a resonator cloaking system utilizing a number of cylindrical shells, in accordance with exemplary embodiments of the present disclosure;

FIG. **2** depicts a diagrammatic plan view of a resonator cloaking system utilizing a number of shells having an elliptical cross-section, in accordance with an alternate embodiment of the present disclosure;

FIG. **3** depicts an exemplary embodiment of a portion of shell that includes repeated conductive traces that are configured in a fractal-like shape; and

FIG. **4** depicts a perspective view (photograph) of an exemplary embodiment of the present disclosure.

While certain embodiments depicted in the drawings, one skilled in the art will appreciate that the embodiments depicted are illustrative and that variations of those shown, as well as other embodiments described herein, may be envisioned and practiced within the scope of the present disclosure.

DETAILED DESCRIPTION

The present disclosure is directed to novel arrangements of resonators useful for obscuring or hiding objects at given bands of electromagnetic radiation. Embodiments of the present disclosure can provide techniques, including systems and/or methods, for hiding or obscuring objects at certain wavelengths/frequencies or over certain wavelength/frequency ranges or bands. Such techniques can provide an effective electromagnetic lens and/or lensing effect for certain wavelengths/frequencies or over certain wavelength/frequency ranges or bands. The effects produced by such techniques can include cloaking or so-called invisibility of the object(s) at the noted wavelengths or bands.

Representative frequencies of operation can include, but are not limited to, those over a range of about 500 MHz to about 1.3 GHz, though others may of course be realized. Operation at other frequencies, including for example those of visible light, infrared, ultraviolet, and as well as microwave EM radiation, e.g., K, Ka, X-bands, etc. may be realized, e.g., by appropriate scaling of dimensions and selection of shape of the resonator elements.

Embodiments of the present disclosure include arrangement of resonators or resonant structures in aperiodic configurations or lattices. The overall assembly of resonator structures can include nested or concentric shells, that each include repeated patterns of resonant structures. The resonant structures can be configured as a close-packed arrangement of electrically conductive material. The resonant structures can be located on the surface of a circuit board.

The overall assemblies, as structures, do not all repeat periodically and at least some of the resonators are spaced such that their phase centers are separated by more than a wavelength. The arrangements can include resonators of several different sizes and/or geometries arranged so that each size or geometry ("grouping") corresponds to a moderate or high quality-factor "Q" response (that is, one allowing for a moderate or low bandwidth) that resonates within a specific frequency range, and that arrangement within that specific grouping of like elements is periodic in the overall structure—even though the structure as a whole is not an entirely periodic arrangement of resonators. The relative spacing and arrangement of groupings (at least one for each specific frequency range) can be defined by self similarity and origin symmetry, where the "origin" arises at the center of a structure (or part of the structure) individually designed to have the wideband metamaterial property.

For exemplary embodiments, fractal resonators can be used for the resonators because of their control of passbands, and smaller sizes. A main benefit of such resonators arises from a size standpoint because they can be used to shrink the resonator(s), while control of passbands can reduce/mitigate or eliminate issues of harmonic passbands that would resonate at frequencies not desired.

Exemplary embodiments of a resonator system for use at microwave (or nearby) frequencies can be built from belts of circuit boards festooned with resonators. These belts can function to slip the microwaves around an object located within the belts, so the object is effectively invisible and "see thru" at the microwave frequencies. Belts, or shells, having similar closed-packed arrangements for operation at a first passband can be positioned within a wavelength of one another, e.g., ⅒λ, ⅛λ, ¼λ, ½λ, etc.

An observer can observe an original image or signal, without it being blocked by the cloaked object. Using no power, the fractal cloak can replicates the original signal (that is, the signal before blocking) with great fidelity. Exemplary embodiments can function over a bandwidth from about 500 MHz to approximately 1500 MHz (1.5 GHz), providing 3:1 bandwidth; operation within or near such can frequencies can provide other bandwidths as well, such as 1:1 up to 2:1 and up to about 3:1.

FIG. **1** depicts a diagrammatic plan view of a cloaking system **100** and RF testing set up in accordance with exemplary embodiments of the present disclosure. As shown in FIG. **1**, a number of concentric shells (or bands) **102** are placed on a platform (parallel to the plane of the drawing). The shells include a flexible substrate (e.g., polyimide with or without composite reinforcement) with conductive traces (e.g., copper, silver, etc.) in fractal shapes or outlines. The shells **102** surround an object to be cloaked (shown as **104** in FIG. **1**). A transmitting antenna **1** and a receiving antenna **2** are configured at different sides of the system **100**, for verifying efficacy of the cloaking system **100** and recording results. The shells **102** can be held in place by radial supports **106** (while only four are shown, **12** were used in the exemplary embodiment indicated).

The shells indicated in FIG. **1** are of two types, one set (A**1**-A**4**) configured for optimal operation over a first wavelength/frequency range, and another set (B**1**-B**3**) configured for optimal operation over a second wavelength/frequency range. (The numbering of the shells is of course arbitrary and can be reordered, e.g., reversed.)

For an exemplary embodiment of system **100**, the outer set of shells (A**1**-A**4**, with A**1** being the innermost and A**4** the outmost) had a height of about 3 to 4 inches (e.g., 3.5 inches) and the inner set of shells had a height of about 1 inch less (e.g., about 2.5 to 3 inches). The spacing between the shells with a larger fractal shape (A**1**-A**4**) was about 2.4 cm while the spacing between shells of smaller fractal generator shapes (B**1**-B**3**) was about 2.15 cm (along a radial direction). In a preferred embodiment, shell A**4** was placed between shell B**2** and B**3** as shown. The resonators formed on each shell by the fractal shapes can be configured so as to be closely coupled (e.g., by capacitive coupling) and can serve to propagate a plasmonic wave.

It will be appreciated that while, two types of shells and a given number of shells per set are indicated in FIG. **1**, the number of shell types and number of shells for each set can be selected as desired, and may be optimized for different applications, e.g., wavelength/frequency bands.

FIG. **2** depicts a diagrammatic plan view of a cloaking system (or electrical resonator system) according to an alternate embodiment in which the individual shells have an elliptical cross section. As shown in FIG. **2**, a system **200** for cloaking can include a number of concentric shells (or bands) **202**. These shells can be held in place with respect to one another by suitable fixing means, e.g., they can be placed on a platform (parallel to the plane of the drawing) and/or held with a frame. The shells **202** can include a flexible substrate (e.g., polyimide with or without composite reinforcement) with a close-packed arrangement of electrically conductive material formed on the first surface. As stated previously for FIG. **1**, the closed-packed arrangement can include a number of self-similar electrical resonator shapes. The resonator shapes can be made from conductive traces (e.g., copper, silver, gold, silver-based ink, etc.) having a desired shape, e.g., fractal shape, split-ring shape, and the like. The shells **202** can surround an object to be cloaked, as indicated in FIG. **2**.

As indicated in FIG. **2** (by dashed lines **1** and **2** and arrows), the various shells themselves do not have to form closed surfaces. Rather, one or more shells can form open surfaces. This can allow for preferential cloaking of the object in one direction or over a given angle (solid angle). Moreover, while dashed lines **1** and **2** are shown intersecting shells B**1**-B**3** and A**1**-A**3** of system **200**, one or more shells of each group of shells (B**1**-B**3** and A**1**-A**3**) can be closed while others are open.

With further regard to FIGS. **1**-**2**, it should be appreciated that the cross-sections shown for each shell can represent closed geometric shapes, e.g., spherical and ellipsoidal shells.

As indicated previously, each shell of a cloaking system can include multiple resonators. The resonators can be repeated patterns of conductive traces. These conductive traces can be closed geometric shapes, e.g., rings, loops, closed fractals, etc. The resonator(s) can being self similar to at least second iteration. The resonators can include split-ring shapes, for some embodiments. The resonant structures are not required to be closed shapes, however, and open shapes can be used for such.

In exemplary embodiments, the closed loops can be configured as a fractals or fractal-based shapes, e.g., as depicted by **302** in FIG. **3** for an exemplary embodiment of a shell **300**, or **402** in FIG. **4**. The dimensions and type of fractal shape can be the same for each shell type but can vary between shell types. This variation (e.g., scaling of the same fractal shape) can afford increased bandwidth for the cloaking characteristics of the system (e.g., system **100** of FIG. **1**) This can lead to periodicity of the fractal shapes of common shell types but aperiodicity between the fractal shapes of different shell types.

Examples of suitable fractal shapes (for use for shells and/or a scatting object) can include, but are not limited to, fractal shapes described in one or more of the following patents, owned by the assignee of the present disclosure, the entire contents of all of which are incorporated herein by reference: U.S. Pat. Nos. 6,452,553; 6,104,349; 6,140,975; 7,145,513; 7,256,751; 6,127,977; 6,476,766; 7,019,695; 7,215,290; 6,445,352; 7,126,537; 7,190,318; 6,985,122; 7,345,642; and, U.S. Pat. No. 7,456,799.

Other suitable fractal shape for the resonant structures can include any of the following: a Koch fractal, a Minkowski fractal, a Cantor fractal, a torn square fractal, a Mandelbrot, a Caley tree fractal, a monkey's swing fractal, a Sierpinski gasket, and a Julia fractal, a contour set fractal, a Sierpinski triangle fractal, a Menger sponge fractal, a dragon curve fractal, a space-filling curve fractal, a Koch curve fractal, an Iypanov fractal, and a Kleinian group fractal.

FIG. **3** depicts an exemplary embodiment of a shell **300** (only a portion is shown) that includes repeated conductive traces that are configured in a fractal shape **302** (the individual closed traces). For the exemplary embodiment shown, each resonator shape **302** is about 1 cm on a side. Such resonator could, e.g., be used for the fractal shapes of shells B**1**-B**3** of FIG. **1**, in which case similar fractal shapes of larger size (e.g., about 1.5 cm on a side) could be used for shells A**1**-A**4**. The conductive trace is preferably made of copper. While exemplary fractal shapes are shown in FIG. **3**, the present disclosure is not limited to such and any other suitable fractal shapes (including generator motifs) may be used in accordance with the present disclosure.

It will be appreciated that the resonant structures of the shells may be formed or made by any suitable techniques and with any suitable materials. For example, semiconductors with desired doping levels and dopants may be used as conductive materials. Suitable metals or metal containing compounds may be used. Suitable techniques may be used to place conductors on/in a shell, including, but no limited to, printing techniques, photolithography techniques, etching techniques, and the like.

It will also be appreciated that the shells may be made of any suitable material(s). Printed circuit board materials may be used. Flexible circuit board materials are preferred. Other material may, however, be used for the shells and the shells themselves can be made of non-continuous elements, e.g., a frame or framework. For example, various plastics may be used.

FIG. **4** depicts a perspective view (photograph) of an exemplary embodiment of a cloak system **400** according to the present disclosure. As shown, the system includes a number of resonator shells **402** each having a close-packed arrangement of electrically conductive material (self-similar resonators **404**) formed on one surface. Two different shell configurations are shown, four larger shells and two smaller shells. The smaller shells included close-packed arrangements of resonator structures in which each resonator shape (as shown by **302** in FIG. **3**) was about 1 cm on a side. Similar fractal shapes of larger size (e.g., about 1.5 cm on a side) were used for the larger shells.

In FIG. **4**, a transmitting (source) antenna and a receiving antenna are shown as triangular shapes on the left and right, respectively (though functionally of each could of course be interchanged for the other). Twelve radially arrayed spacers are shown in FIG. **4**. The system **400** is shown supported on a Nalgene tank and Delrin platform and Delrin supports (radial supports) RF absorbers were placed in the immediate vicinity of the set up; further RF tripods (e.g., available from ETS) were used; all such materials were substantially transparent at the RF frequencies investigated/used. The cloak system **400** consists of six belts of fractal metamaterial (i.e., fractal-resonant structures shown in FIG. **3**) on flexible Taconic EF35 (low loss) circuit board. The belts are shown surround a scattering ring (object). The arrangement is supported by RF transparent plastics in a comb support. The entire system **400** was shown to be easily built up and broken down within a minute or two. The scale in FIG. **4** is about 0.7 meters across. The height of each shell can of course be selected as desired depending on the situation/application.

While embodiments are shown and described herein as having shells in the shape of concentric rings (circular cylinders), shells can take other shapes in other embodiments. For example, one or more shells could have a generally spherical shape (with minor deviations for structural support). In an exemplary embodiment, the shells could form a nested arrangement of such spherical shapes, around an object to be shielded (at the targeted/selected frequencies/wavelengths). Shell cross-sections of angular shapes, e.g., triangular, hexagonal, while not preferred, may be used.

One skilled in the art will appreciate that embodiments and/or portions of embodiments of the present disclosure can be implemented in/with computer-readable storage media (e.g., hardware, software, firmware, or any combinations of such), and can be distributed and/or practiced over one or more networks. Steps or operations (or portions of such) as described herein, including processing functions to derive, learn, or calculate formula and/or mathematical models utilized and/or produced by the embodiments of the present disclosure, can be processed by one or more suitable processors, e.g., central processing units ("CPUs") implementing suitable code/instructions in any suitable language (machine dependent on machine independent).

While certain embodiments and/or aspects have been described herein, it will be understood by one skilled in the art that the methods, systems, and apparatus of the present disclosure may be embodied in other specific forms without departing from the spirit thereof.

For example, while certain wavelengths/frequencies of operation have been described, these are merely representative and other wavelength/frequencies may be utilized or achieved within the scope of the present disclosure.

Furthermore, while certain preferred fractal generator shapes have been described others may be used within the scope of the present disclosure. Accordingly, the embodiments described herein are to be considered in all respects as illustrative of the present disclosure and not restrictive.

What is claimed is:

1. An electrical resonator system, comprising:

a plurality of concentric electrical resonator shells, each shell including a substrate having first and second surfaces and a close-packed arrangement of electrically conductive material formed on the first surface, wherein the closed-packed arrangement comprises a plurality of self-similar electrical resonator shapes and is configured to operate at a desired passband of electromagnetic radiation;

wherein the close-packed arrangements of at least two of the electrical resonator shells are different in size and/or shape; and

wherein a resonator in the close-packed arrangement comprises a second order or higher fractal.

2. The system of claim **1**, wherein said passband is about 2:1.

3. The system of claim **2**, wherein said passband is about 3:1.

4. The system of claim **1**, wherein the electrical system is configured and arranged so that radiation incident on the system from a given direction has an intensity on a point-by-point basis such at each respective antipodal point, relative to an object placed at the center of the system, the radiation has the same or similar intensity.

5. The system of claim **1**, wherein the system is configured and arranged so that radiation incident on the system from a direction in cylindrical coordinates has the same or similar intensity at the antipodal point after having traversed the system.

6. The system of claim **1**, wherein the plurality of shells comprises a first pair of shells having similar closed-packed arrangements for operation at a first passband, wherein the two shells are positioned within ⅛λ of one another.

7. The system of claim **6**, wherein the plurality of shells comprises a second pair of shells having similar closed-packed arrangements for operation at a second frequency band, wherein the two shells are positioned within ⅛λ of one another.

8. The system of claim **1**, wherein the plurality of shells are hemispherical.

9. The system of claim **1**, wherein the plurality of shells are cylindrical.

10. The system of claim **1**, wherein the plurality of shells are spherical.

11. The system of claim **1**, wherein said fractal is selected from the group consisting of a Koch fractal, a Minkowski fractal, a Cantor fractal, a torn square fractal, a Mandelbrot, a Caley tree fractal, a monkey's swing fractal, a Sierpinski gasket, and a Julia fractal.

12. The system of claim **1**, wherein the fractal is selected from the group consisting of a contour set fractal, a Sierpinski triangle fractal, a Menger sponge fractal, a dragon curve fractal, a space-filling curve fractal, a Koch curve fractal, a Lypanov fractal, and a Kleinian group fractal.

13. The system of claim **1**, wherein the plurality of concentric electrical resonator shells are configured and arranged for operation at K band, Ka band, or X-band.

14. The system of claim **1**, wherein the system is operational over a bandwidth from about 500 MHz to about 1500 MHz.

* * * * *

Navigation Down Under

For
Northern-Hemisphere Tourists
Walkers and Scouts
Boating and Outdoor Orientation

1001 Ways to Extend

Your Navigational Know-How

2010

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Big-Picture Rule One: Locate a Distant Reference Direction First

Until you Orient yourself to the bigger picture, by finding an unchanging direction to latch on to,
•Small-scale pictures and large-scale mental layouts cannot come together. •And the local features won't fit into the bigger perspective.
•Your mental photographs will float around in chaos, like so many loose jigsaw pieces, or letters in an alphabet soup.
In choosing a Reference Direction, your first choice should be...
•ASTRONOMICAL — Sun, Moon, stars, planets, satellites—e.g. Locate the direction of the North Pole Star. There is an astronomical overview p32f
Then •GLOBAL — Compass or Botanical or Geomorphological North e.g. find Canada's North Magnetic Pole.
Next •CONTINENTAL — Weather Systems, radio transmitters, powerline networks, highways, sea-coast—e.g. notice the Sydney to Hobart flight path.
Then •DISTANT landforms — Lie, Lay, Lines, Hills; Lights, etc.—e.g. the direction of the main river valley draining to the sea.
Last of all comes: •What you can see in front of your nose! I.e. don't let your mind latch on to some unreliable or meaningless reference like how the car is parked, or where the wind is, or the initial direction of the track/the drive in/the main street, or uphill, or the way you got out of bed…
•If you can't see a thing beyond a few metres, and have no compass, you will need to "keep a straight line" (see p. 87b) by lining up markers.
Now that you have a reference direction, you can implement the other "Rule One"s...
•Match what you see in front of your nose to the reference;
•Predict your overall trend before you start; •Notice your start-off direction as you start.

Visualisation is your Key Skill

This is most especially relevant to orienting your nose, in your mind's eye, to the Bigger or Invisible Pictures, but is needed at all scales.

Imagine	where the Southern Cross is during the day;	or	where the cars are, now; how you got here.
Visualise	the Earth's invisible spin-axis	and	the weather map you saw, yesterday
Mentally picture	the Galactic spiral! — which clock-sense is it?	or	the turnoff you need — will it be uphill?
Remember	the tropical countries under the Sun	and	the way back
Describe	the path of a shadow-tip in mid-Winter	or	what makes this place recognisable
Picture	sunrise in Antarctica tomorrow morning	or	old blazes, in your mind, so you don't miss any
Interpret numbers, labels and words into reality	e.g. what the shape of the night-sky has to do with your global position		
Express visually	what each clue means	e.g.	what "high noon" means to you right now
Mentally photograph	the map as you study it beforehand	and	how the climb opened out onto the plateau
Mentally match	the invisible landscape trends to the reference direction and to what you see in front of your nose		

At night, and in the rain, navigation gets to be 'all in the mind'.

By recreating the reality you can't see, you can navigate what is in front of your toes, by intelligent imagination.

Big-Picture Orientation is a Mental Layout Acquired Beforehand

Because the invisible picture is so large, you can do your global and continental orientation at home before you start.
Travelling all day to go walking somewhere else, will hardly alter it.

You use: a globe; an atlas; a roadmap of the continent — to learn the lay beforehand. These are layout maps... The relative positions shown are fixed.
But layout views — as seen from above — will hardly ever be seen in your reality, first-hand.
(In contrast, when you come to putting yourself in the middle of the big-picture, you see the landscape first-hand, and you will need "Nose Navigation" — as seen from the ground — which is all about the apparent relative directions.)
The global constants won't change as you walk, e.g. the behaviour of the Sun and stars, because everything is so distant.

You need extra care to visualise the Big Picture, and its meaning, because it is (a) Round (global) (b) Layout (i.e. mental only) (c) Invisible (d) Big!
Do this before you attempt to nose your way through the local scenery.

Smaller-scale clues can then 'fit-in', sensibly, to the larger context.

Compass Navigation Robs You of a Global Perspective

Flat maps must distort the true picture. Only a globe is true. Mercator-projection maps (diagram 1) distort land areas and longitude lines,
in order to "preserve the straightness" (!) of a compass course, which never was straight!
If you glue your nose to a compass needle, to follow a compass-course,
the course which looks straight on a flat Mercator map will actually take you on a spiral,
into either the South or North Pole (as when you keep any landmark at a diagonal).
The sense of the spiral (turning to your right/left) changes as you cross the Equator...
Because you do need a big-picture approach, **you need a global perspective**.
(Here's a good place to set out the basics...

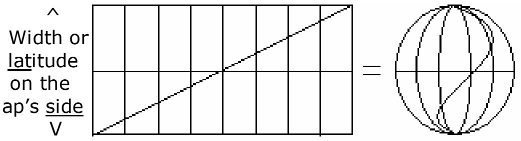

A 3D spiraling helix

Remember: "Latitude **equates** to the distance from the Equator" — the short dimension.
"Longitude turns upon the time — how **long** has the globe turned since midnight") < long for longitude >
Here's a test: Imagine the midsummer sunset from well Down Under, looking even further South. Do you think of a tropical country in that direction?
The following section — about Sun Moon Earth and Stars — aims to restore a true perspective to people who can hardly think except with a flat diagram, and can hardly visualise anything without divorcing it from the real landscape in front of their nose. (There is always a tropical country under the Sun.)
Think of this 'global orientation' section as a global **Re**-Orientation and don't forget, that... **Global means Round!**

The Big Picture is Invisible — Your Job is to Visualise It!

As a matter of principle, we should work top-down
i.e. from a framework down to the detail, from general to specific, large to small, overall to local, unchanging to changeable.
As a matter of fact, we are lazy. The point of doing "useless" grand-scale orientation exercises is to:
make global orientation second nature — easier next time around;
to make you forget flat pictures of a round Earth and to imagine it properly;
to give your struggling memory some comprehensive and relable framework to work within;
to integrate what you can't see with what you can, e.g. to link different walks and areas;
to orient to, and to understand, the Sun's movement, and to orient to the Moon and stars and planets as a bonus;
to make extra clues and techniques available, e.g. to open up astro-navigation techniques;
to work "top-down" — to avoid jumbling up your mind.

The idea is to read the following double-pages horizontally, as one topic, i.e. Sun-Sun; Stars-Stars; Clockwise-Anticlockwise.
To follow one topic through, flip over the pages and look in the corresponding positions.

Global Re-orientation — Light-Half/Dark-Half

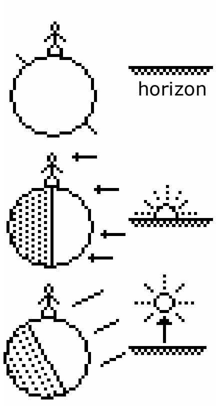

Step 1. **Always Position Yourself on Top of the World.** ..whether in a diagram or mentally or in reality.
This makes your reorientation realistic, doesn't it?
Look at your feet and imagine you are standing on a huge basketball in the sunlight.
To visualise the light-half/dark-half of the globe, carry a real ball with you, preferably a globe of the world.
Imagine that everything which you see, this side of the horizon, is the tiny top-fraction of a huge ball.

Step 2. Face the Sun, but imagine it low down, setting, with horizontal rays coming to you.
Notice the circle which divides day from night, passing to left and to right underneath your feet.
"He divided light from darkness by a circle drawn on the face of the sea." Job 26:10

Step 3. 'Raise' the Sun, and its sunbeams, to their actual height.
And as you do, let the dark-half fall back behind you by the same amount
i.e. degree for degree around a round globe—one degree of fall-back for one degree of Sun-rising.

After this you can do your best to answer: (Help will follow soon) What countries are seeing the Sun as horizontal?
i.e. Which countries does the 'circle' pass through at the moment? Which ones are seeing the Sun rise?
Which ones see it setting? Which parts see a 24-hour sunset, with the Sun skimming the horizon? (Use a globe)

Your Best Reference Direction: Imagine the Sun at High Noon — Always

(This won't work so well in the tropics)

Night or day, your mental reference direction is North or South by the Sun. So imagine the Sun North of you (Southern Hemisphere) rain or shine.
It is the natural interpretation… of looking at your watch, and
of looking at the Sun, when it is not North of you. (Warning: Don't look directly at the Sun! It will blind you!)
of looking at the compass. (You don't want to locate 'Canada's magnetic pole', after all!)
of judging botanical North/South (p.74a);
of using a map in conjunction with the landscape,
and even when using the Moon

Imagine the *high-noon* Sun in a real landscape — this one here!
— at all times of day or night.
— at the correct height, on its circular path,
— which is tilted at its rise-set angle.

Warning:
You will get disoriented
when you cross the Equator!

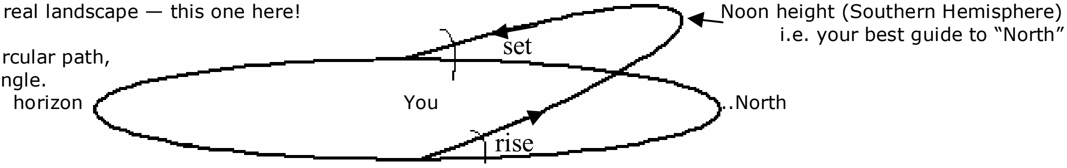
Noon height (Southern Hemisphere)
i.e. your best guide to "North"
set
horizon
You
..North
rise

The 4 Bright Outer Stars of Orion Point out Where the Pot is Going

=Find N/S E/W & Equator

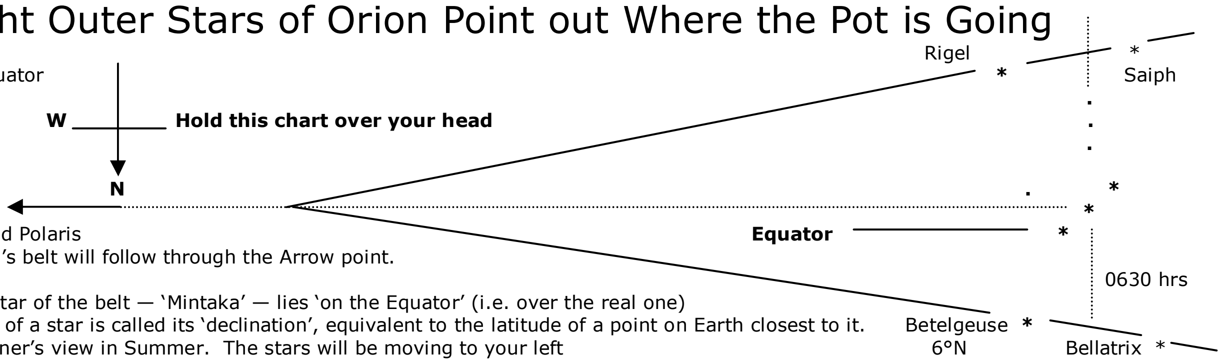
Rigel
Saiph
W
Hold this chart over your head
N
Equator
0630 hrs
Betelgeuse
6°N
Bellatrix
.:Meissa

Movement West
Anticlockwise around Polaris
The middle of Orion's belt will follow through the Arrow point.

The north-west star of the belt — 'Mintaka' — lies 'on the Equator' (i.e. over the real one)
The N-S position of a star is called its 'declination', equivalent to the latitude of a point on Earth closest to it.
This is a Southerner's view in Summer. The stars will be moving to your left
The Pot handle down through Meissa points to Polaris

Look for the Line Joining Sun, Moon, Planets & Zodiac Stars—the Ecliptic

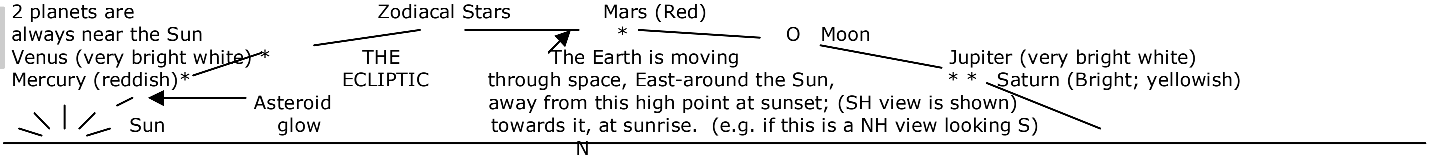
2 planets are
always near the Sun
Venus (very bright white) *
Mercury (reddish)*
Sun
Asteroid
glow
Zodiacal Stars
THE
ECLIPTIC
Mars (Red)
O Moon
Jupiter (very bright white)
* * Saturn (Bright; yellowish)
N

The Earth is moving
through space, East-around the Sun,
away from this high point at sunset; (SH view is shown)
towards it, at sunrise. (e.g. if this is a NH view looking S)

The solar system — Sun and planets — is flat, and the Zodiac marks that plane, by design. It's **the 'edge-on' view, which we see, from within**.
The Moon orbits within 5° of that plane, and so is never far off line. **The line is called the Ecliptic** — a great circle.
(It looks as straight as the horizon, unlike the diagram. See 'Optical illusion' in the Moon box, p.8d)
During the day, you can orient, not by the Sun only or the Moon only, but by the line joining them. Sometimes Venus may be visible too.
You have to imagine the rotation of that line (more on this soon). It does not move in the same direction in which it points, but its path is up to 23°½ tilted from that.

Mnemonic: "Clock-wise Northern Hemisphere **SWiNES**"

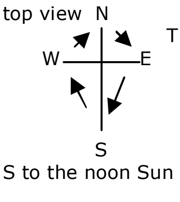
top view N
W
E
S
S to the noon Sun

Europeans make chronometers to follow their Sun.
They see, looking South (diagram top right)… rise in the East ; South at noon ; set in the West.
That's 'clockwise' (seen from above; East to South to West) for them
The swines! They force us, down under, to place our clocks on the southern wall and think behind us!
(We see, looking North: rise East, to North at noon, to West i.e. SH; anti-clockwise)……

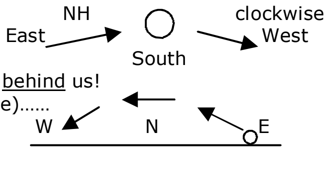
NH
clockwise
East
South
West
W
N
E

clockwise
top view

Anyway, changing your direction "Clockwise", as seen from above, is turning to your right, and, **i**gnoring the **i**, the mnemonic is:
South, to **W**est, to **N**orth, to **E**ast, to **S**outh or "clockwise: **SW**i**NES**"

A mnemonic for global orientation: **"True Polarity"**

"**True**" courses refer to the Earth's **Poles** — i.e. the axis of rotation of the Earth — **the single most directional thing on our spherical Earth**.
"True" bearings measure the angle between the course and the longitude line — a North/South line which connects the poles, and which passes through your location.

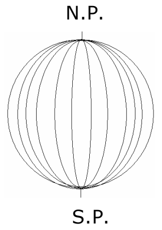

Longitude lines

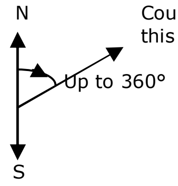

The angle is measured **clockwise from 'North'**
e.g. 065°T
"Oh Six Five degrees True (-polarity)"!

Remind yourself, whenever you use "True", by saying "True Polarity"!

Earth

Mnemonic: "**N**oon Sun Passes **N**orth of My **N**ose Down Under"— It Rhymes in ' **n** ' (dow-nun-der)
(Now, Keeping your **n**ose to **N**orth, say…) (The second parts work for both hemispheres provided you face North, not noon)
"Sun **Ri**ses on My **Ri**ght (to the right of North)" —It Rhymes in ' **ri** '
"Sun S**e**ts on My L**e**ft (in the W**e**st)" —It Rhymes in ' **e** '
"That's Anticlockwise around the North Pole Star, if you are facing North from the SH; [Clockwise around the South Pole Star", if facing S from NH]
"The **SH** ho**ri**zon **shi**fts to the **ri**ght"
"The **NH** ho**ri**zon **N**ever **H**eads **ri**ght, it moves left"

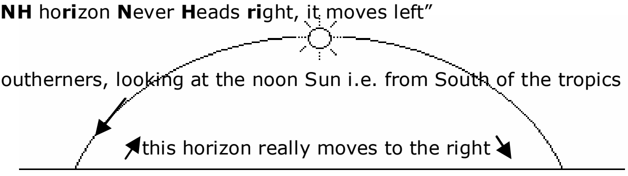

For Southerners, looking at the noon Sun i.e. from South of the tropics

West/Set/Left **North**/Nose/**Noon**/**Down Under** East/Rise/Right

Paper Diagrams aren't Enough.

Imagination isn't enough.

Go outside and take a look.
(You will need to shield your eyes from the Sun, e.g. with your hand)

Let the reality sink in.

Sun

The Two Brightest Stars Point out the **South** Pole Star

Canopus and Sirius line up almost South/North.
Use the star next to Sirius ('Mirzam') and the line-up is perfect.
The 'Dog Star' Sirius is the brightest star in the sky.
The Big Dog seems to have a front leg and back leg and a tail...

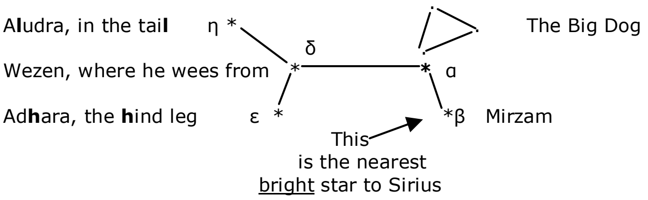
A**l**udra, in the tai**l** η
Wezen, where he wees from δ
Ad**h**ara, the **h**ind leg ε
The Big Dog
α
β Mirzam
This is the nearest bright star to Sirius

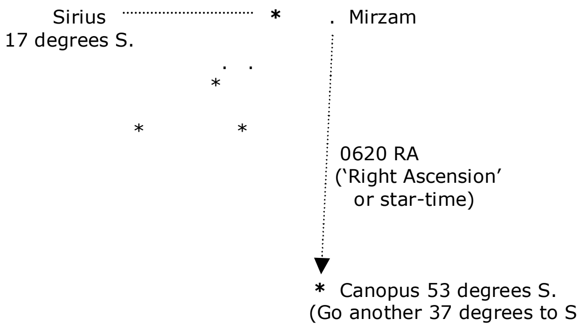
Sirius
17 degrees S.
Mirzam
0620 RA
('Right Ascension' or star-time)
Canopus 53 degrees S.
(Go another 37 degrees to South polestar)

A
GOOD
SOUTHERN
SUMMER
SIGN

Stars

Mnemonic: "Wind? Weather Map!"

For navigating by the wind, don't just leave it at the level of "The wind is from over there".

* Look at the skyline "from Bruce Valley"
* Look at the Sunshine "from 30° to the left of the Sun at the moment" (Don't look at the Sun!)
* Look at the Sun-path "a 'sunset' breeze" i.e. from sunset (Simply imagine its rise-set path.)
* Imagine the continent beyond the skyline "from the West Coast"
* Meld that reality to the weather map you remembered.

Don't stop interpreting the wind until you can fit it into a Big Invisible Picture connected to that skyline over there.

Wind

Mnemonic: Down Under, The Sun Moves **ANTI**-BigB**ENWiSE** **i.e. anti-clockwise**

Look at the 'ENWiSE' in the mnemonic.
Anticlockwise is **E**ast to **N**orth to **W**est to **S**outh to **E**ast.
Ignore the **i**. Look down from above onto the horizontal directions involved…
Anticlockwise is turning to your left. " Anti-clockwise is ENWISE "

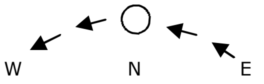

(If you put a clockface on the north wall and look at the Sun's movement, (Don't look at the Sun!),
you will see that the Southern Hemisphere's second-hands tick backwards! i.e. against the Sun's movement.
So put it on the south wall facing North, and the clock hands will move 'with' the Sun.)

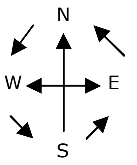

top view

In the tropics, the Sun will pass somewhere near overhead. To make it seem "anti-clockwise" anyway, face North.

Don't get mixed up and think of Big Ben wise as clockwise. Down here our Sun moves anti- , and that is ENWiSE.

Anticlockwise

Mnemonic: "Time Tells Turning"

What's the use of looking at your watch and spouting numbers! At least, glance at the Sun, or rather at its shadows (don't look directly at the Sun) and then, imagine the Sun's direction at high noon as a reference direction.

That's what time tells you! — the Sun's position relative to its noon direction, North/South, called the "meridian".
A.m. says "ante meridiem" i.e. "before noon", and p.m. says "post meri-diem" i.e. "after mid-day"
Midday = 12 noon (but only in an ideal world, because noon is only approximately at 12)
One pm = one hour past 12md, and so on.
24-hour time tells you how far around the Earth has turned, since the Sun was opposite you i.e. since midnight.
(And then don't forget that the local significance of the time is: progress — distance made good — "watch" your pace)
Mnemonic:

"Watch" the Sun (without looking at it) whenever you watch your watch (and "watch" your steps too, for progress)

Notice these, Yesterday — to Guess the Time Today

- Sunrise time (and direction) ..If you know the time, you can guess at the directions.
- Sunset time (and direction) ..These first 2 are symmetric around North.
- The horizontal angle of separation between sunrise and set
- Midday time (and direction, and height) ..This is halfway between. Memorise how short your shadow is.
- When did it get light enough? To see. To walk.
- When did it get too dark? To cook. To walk.
- How long is the usable daylight? ..The day-length, between dawn and dusk.
- How many hours of dark?
- When did the Sun reach due East and due West? (How high?) ..This won't happen in winter. They are symmetric around midday.
- Times for the Sun at magnetic East, noon, West? ..These don't depend on guessing or calculating the magnetic variation.

Update yourself every week.

The Spinning Earth Makes **Circular Paths** for the Sun, Moon, Etc.

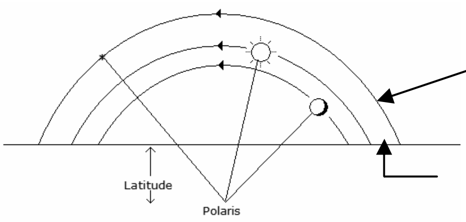

Sun, Moon, stars, planets — they all move only slightly in relation to each other during 1 day/night — but they all zoom around at about 15° per hour from East to West.

Although I can draw this on flat paper as a circular path, the Equatorial path actually looks as straight as the horizon, in reality! (Southern Hemisphere view)

You can now guess at time or direction by your familiarity with the circular 'orbits' e.g...
The highest point of the path will be North-South of you, if you can guesstimate it
Latitude determines the rise/set angle of the Equatorial path.
Rising and setting places are symmetrical around North.

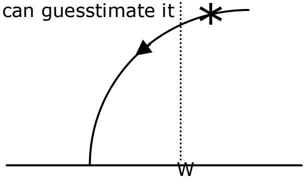

Although individual rising and setting is symmetrical about North, whole constellations that rise vertically in mid-latitude may set horizontally! and vice versa e.g. The Big Dog or Scorpio rise flat but dive vertically into the western horizon.

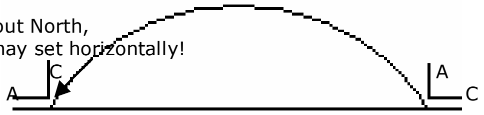

The Moon; Rule 4: Look for It

You have a 1 in 4 chance of finding it during the day. Provided you remember to look!

Rules 1 and 2 (like so many other navigational clues) are...

- PREDICT when and where it should be visible
- GUESS where to look And Rule 3 goes with the guess:
- LEARN from that mistake.

Keep looking for it. It's easy to miss. E.g. through the tree canopy; or rising through the horizon haze. Polaroid glasses help; you need to twist them

You will then have clues to… North, East, and West
Time of night (i.e. later)
Ocean tides
Tomorrow's Moon — Phase; rise, set, direction, height
Upper-level winds, if there are clouds about.

Hint: Measure the Sun-Moon separation with a piece of string (Don't look directly or indirectly at the Sun!) so you know exactly where to look later.

"VEERING" with the Sun is "Clockwise" only in the Northern Hemisphere "BACKING", against the Sun's movement, is "Anticlockwise" — but only in the Northern Hemisphere.

(The terms refer to horizontal directions changing either with or against the Sun's movement)
"Veering and Backing" are Eurocentric images, so they can be very confusing Down Under. Don't use those words in the Southern Hemisphere!

Say "Clockwise" and "Anticlockwise" instead
..for both hemispheres, as a matter of habit. Although these meanings too are Eurocentric, they are not confusing!
(the terms refer to a bird's-eye view looking down from above as if onto a clock-face)
Meteorologists and mariners still use the terms 'veering' and 'backing' and they do mean 'clockwise' and 'anticlockwise'
But the Sun-based image is backwards, south of the tropics.

The sky turns **15° per hour** — Use your **thumb and forefinger**

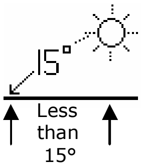

The Earth rotates once a day. Yes? That's 360° in 24 hours, yes?
Well that works out at 15° per hour — the sky spins 15°/hour to the West.
That calls for **recognising 15°** E.g. (diagrams left, and right) "one hour of sunlight left" (SH)

For Accuracy:
(0) Measure each handspan along the Sun's 'circular' path, not horizontally.
(1) Use constant stretch — of arms and fingers — 'just strained' — for consistency.
(2) Use constant chest-arm geometry. It is best to use two hands squarely in front of you…
(3)**Test for 15°, horizontally,** against the full 360° horizon — **"24 spans go around the rim"**
Span off, 24 times, from point-to-point right around the horizon.
Adjust your hand configuration until you find one that fits the "24 Hours" recipe.
(4) Try gripping one hand with the other, or touching one, at a specified point, with the other
, or, (5) Look along your shoulder, sideways, at one hand.

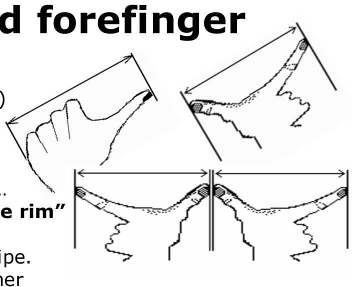

My recipe for accuracy fits my arms:"4 spread fingers, wrist bent back fully (at arm's length in front=60cm or 1cm/degree")
What do your arms require for 24 spans = 360°?

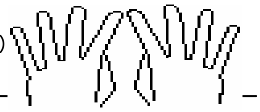

Mnemonic: The Southern Summer Sun Sets Somewhat South

Surprising perhaps. (If you equate North with 'hot' you get caught on this.) (for Northern Hemisphere substitute 'North' for 'South')
When the Sun comes South for summer its sunrise and sunset places also shift South with it.
Memory hexagon for Mid-Winter and Mid-Summer Down-Under at 37° S…
(top view) N. (the Sun moves anti-clockwise through North)

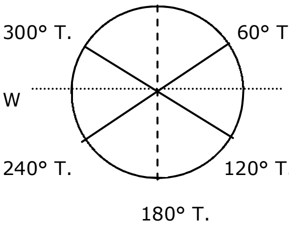

… In Mid-Winter, Down-Under, at 37°S., sunrise is at 60°T. and sunset is at 300°T. … A 9½ hour day.
In Winter the Sun will never show East or West of you.

At Equinoxes — Mid-Autumn, and Mid-Spring — rise and set are East and West… a 12 hour day.

… In Mid-Summer, Down-Under, at 37°S., sunrise is at 120°T., and sunset is at 240°T. … A 14½ hour day.
The Sun will be East and West at **mid**-morning and **mid**-afternoon respectively, and **mid**-high — about 45°.
Your main aim is to get familiar with the Sun's circular path.

Stars Leave Star-Trails ..if you photograph them with time-exposure...

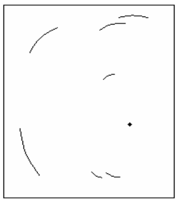

Star-trails are bits of circles, because… ..stars circle around the North and South Pole-Stars...
i.e. the Earth rotates on an N-S axis, which points to the Pole-stars. The pole star stays fixed in position all night (if you do).
Southern Stars Circle Clockwise, once per night-and-day, around the South Pole Star.
Northern Stars Circle Anticlockwise, around the North pole star, Polaris. These clock senses are the same in both hemispheres.
But **Note**: low Southern stars will move anti-clockwise around you, (i.e. to your left around the horizon, anti-clockwise as seen from above you). (Clockwise — to your right in the NH) (More on this later)

It helps you with global orientation to use **'star compasses'**.

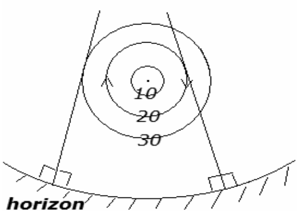

One of the clearest compasses is to blur the star circles into full circles then take vertical tangents to those circles.
In the following diagram, the left-hand direction is "30°" to the left of the Earth's axis (or to 60° maximum latitude).
The right-hand one is "20°" to the right (or to 80° maximum latitude). They are global.
If you follow these star directions, they will take you right around the earth in a 'straight' line — a big circle.
You will pass through places equal in latitude to the star which is overhead (p.11c), so you can already *see* the maximum latitude that such a 'great circle course' would take you to; then it takes you back towards the equator.
HINT: You won't get far in star-navigation, without a detailed star list and star chart. See p. 123 for a list.

Mnemonic: "Wind in Your Face"

The Southern Hemisphere version of Buys Ballot's Law… [Try to use unobstructed wind i.e. not in a valley nor in a mountain eddy]

- "**Face** the Wind [N.H. rule uses 'Back to the wind, Sun-twist…]
- Sun-twist yourself 15°-30° [i.e. anti-clockwise in S. H.]
  — to counteract landscape friction on the surface winds.
  [When the winds are impeded, they slow down, and so stop circling around the pressure centres, and start to cross the isobars, toward the low pressure (a 'sink' hole) at an angle of 15°-30°, less at sea and over flat land; more over rough terrain.]
- Rhyme: **"Low on My Left** &/or **High on My Righ-t"**

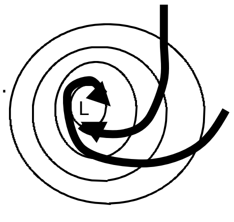

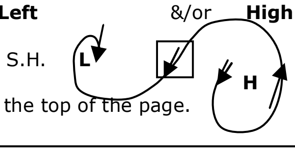

Top view of you, in the square, facing the top of the page.

Southerners Need **Anti**clockwise Systems

Our clocks seem to run backwards, compared to the Sun.
Our compass-bearings are measured 'backwards'. (see p.10e)
'Veering' and 'Backing' seem to mean the wrong clock-sense.
When the Sun moves forwards, all the other systems seem to push backwards.
We lose the global perspective.
And this section is all about aiming to put that right.
Consequently, we need a Southerner's viewpoint…

I hope you find that the anticlockwise systems which will follow soon are much more workable than Eurocentric systems.
Some of the other systems given on this right-hand side of the page, are universal — they can be used in either hemisphere.

Global Orientation: Latitude and Polar Distance

Step 1. Stand up on the globe again (in your mind and in reality).
Step 2. Put your left shoulder to the Equator i.e. Face East (sunrise).
(If you are in the northern hemisphere: face west, sunset.)
Step 3. Mnemonic: EQUATOR on My Left equals My LATITUDE is on My LEFT,
RISEN POLE on My RIGHT equals My POLAR DISTANCE is on My RIGHT.

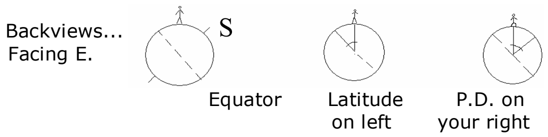

Since the South Pole is 90° latitude, it is further South from the Equator than you are, and will be on your Right, as you face East.
Step 4. Measure the degrees of distance around the Earth's circumference as an angle at the centre of the Earth (by slicing the globe in two).
The two angles mentioned must add up to 90° i.e. they are "complementary" angles (spelt with an 'e').
If you are, say, 45° south of the Equator, then the closest pole must be 45° further south. The 'distance' to the Pole is 45°.
If you are 30° south, then the South Pole will be 60° away from you. Your '**colatitude**'—or *90° minus latitude*—or "Polar Distance"—is 60°.
The goal is to imagine those two angles — Latitude and Polar Distance — at the Globe's centre beneath your feet, and around the circumference.

Mnemonic: "Sun at High Noon — How High?"

When you navigate by the Sun, think: "Sun": the mnemonic is: "Sun at high noon — how high?".
You look: North, there, then up there, that high.— Southern Hemisphere (cf Noon will be South in NH) (Don't look at the Sun, if it is already there!)
It might be morning : "It is going up there"
It might be noon : "See how high it gets!"
It might be afternoon: "It came from up there"
Visualising the height and path of the Sun also helps you to interpret plants for 'bush noon' (p.74a).
"Walking Stick North" depends on knowing the Sun's maximum height. (See page 30b)

On Overcast Days, Average the Brightest Sky over 1/4 hour

If the clouds are moving fast enough, and not entirely uniform, sit still for long enough to see many clouds pass over. Keep pointing at the brightest patch of sky using some reference like a tree, and watch to see whether you can confidently locate the average position of brightness.

RISE and SET Directions for a (**Local**) STAR COMPASS

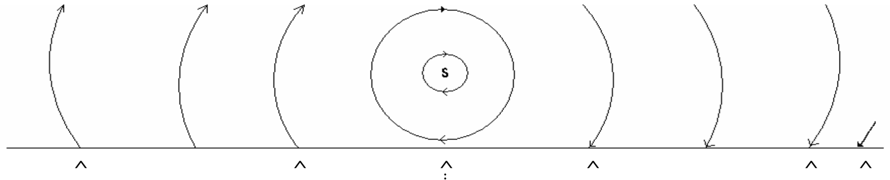

The star directions don't change night by night or with longitude, but they do change with latitude.

The circles in the diagram will rise from the horizon as you travel further south, and so change their intersections with the horizon.

This star rises here every night for the seasons when it is visible

You need to know your stars and visualise their circular paths

Stars which share the same star path indicate the same direction at staggered times during the night

Sun-set and Moon-set (examples only) can be fitted in to the scheme to span the day

Just make sure to mark sunset to a landmark on the skyline horizon and carry it over into night-time.

(SH view)

(Some stars stay up all night every night; these don't move far either, and so are good orientation value too)

From the Moon, Locate the Sun-Moon Direct Line, Carefully.

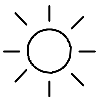

The line is the Approximate Ecliptic, and being a great-circle is a straight line.
OPTICAL ILLUSION!
The Moon seems to be lit from above the 'direct' line to the Sun.
But that may only prove that the Sun is "up" and shining down.

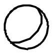

Bust the illusion with a piece of string…
Caution: Don't look directly at the Sun!

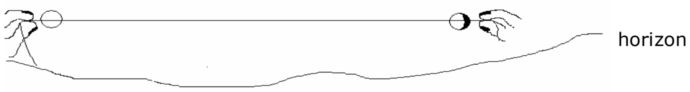

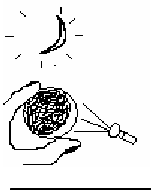

Prove it in 3 dimensions, by using a torch and a ball.
When the ball, in line with the Moon, looks right, the torch direction mimics actual sunlight.
Below horizontal = at night

By locating the Sun, you can guess the time of night, and guesstimate North more reliably, because the path of the Sun is more predictable and familiar than that of the Moon.

Mnemonic: (when you say) "COMPASS" (say) "CANADA"

Compass needles point to Northern Canada. That's where the North Magnetic Pole lives. Lat. 75° N.; long. 100° E.
E.g. from Australia, Canada lies to the East of North…

Check it out on a globe. Locate the Queen Elizabeth Islands.

To find the Southern Magnetic Pole, (but this doesn't work so well)
locate the Antarctic coast south of Adelaide, at Lat. 65° S.; long. 140° E.

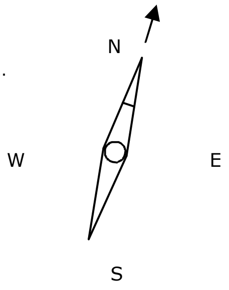

The Angle of Rising and Setting — is Determined by Your Latitude

To post-dict sunrise or pre-dict sunset direction, you can use your latitude to visualise the tilt at which the Sun **rises** (or the rise-angle of a near-Equatorial Star/Moon/planet) and the deviation from straight down, at which it **sets**.
Remember to use vertical, not horizontal as the expected norm. (To judge vertical correctly, see p19c. To practise, see 30b)

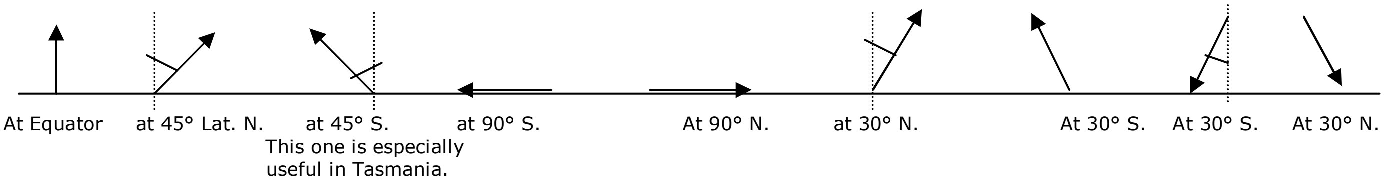

The Sun's path is very nearly a straight line, despite the illusion of being circular—see p.15a.
Hint: Whenever you see the shadow of your head, provided the Sun is not too high, you can make the "anti-Sun" rise or set positions obvious, by following up from that shadow, to the horizon at the correct angle. In midwinter the anti-Sun will be in a midsummer position and vice-versa.

High Noon — How High?

Answer one: the same as last week. Take a look. It changes only slowly.
Answer two: **within 23½ degrees of your co-latitude (or 'polar distance') high**
i.e. 90° – Lat., plus or minus 23½ degrees, depending on the season.
Mid-Summer… co-lat+23.5° (very high in the sky)
Mid-Winter… co-lat–23.5° (very low in the sky)
Equinoxes… co-lat (average height).
Why? At 0° Latitude, i.e. at the Equator, the average Sun is 90° high at noon i.e. overhead. Yes?
At the Poles, 90° Lat., the Sun skims the horizon at equinoxes. Yes?
If you need further proof (that its height is 90° minus Lat.) draw it.

See how the height of the average Sun is 'latitude degrees below vertical'.
That's an angle of elevation of 90° minus lat, isn't it? Now adjust for the Sun's seasonal movement which is 23½ degrees each side of that.

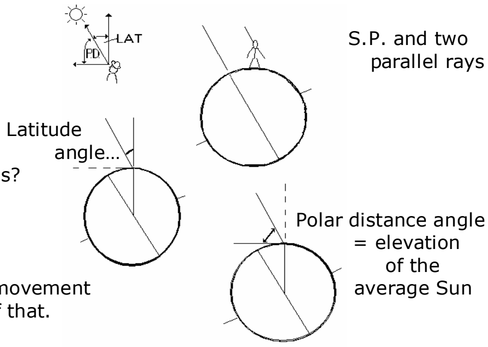
LAT
P.D.
S.P. and two parallel rays
Latitude angle…
Polar distance angle = elevation of the average Sun

Global Star-Compasses e.g. 'Perpendicular to' rise and set

This is one step harder and three steps better. It allows 'great-circle' course keeping.
A global Star-compass yields 'direct', global, 'straightest path' courses — ones which take you around the globe and back to your starting point.
E.g. You take a rise or set compass-point and head at right angles to it, and the new horizontal direction is global—no longer tied to one latitude.
That's easier to imagine by visualising the light half/dark half of the Earth: All who see the Sun on the horizon could point to it, but each would be pointing in a different "direction". But if they all pointed horizontally at right angles to the Sun, they would all be pointing in truly the same way —around the Great Circle which divides day from night. The same goes for any horizontal star. Imagine the star as a pole star, and use its "equator"
There are many alternative star appearances, besides rise or set & **you don't have to 'go at right angles to' these to set your course...**

E.g. aim at **one star above another**
The midpoint of One star **level with another**
One star **rising or falling vertically**.

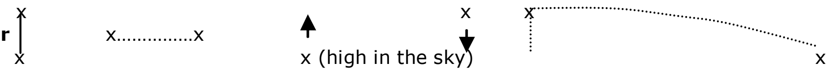

Toward a star which has a 2nd star off to one side **at right angles** i.e. lower. You would pass *under* the point you kept aiming for.
You don't need a clear sea horizon — the stars are high, and a plumb-line will suffice.
These guides occur every night, in the same global direction, for several seasons, then disappear for a while due to daylight, but reappear.
They will occur at the same times next year. **They are always worth learning more of**, adding to your familiarity of favourite 'Star directions'.
These global directions are labelled by saying *how close to the poles* they would take you, and you can see or guess that from the stars, see p. 7c.

'Low' Clouds Come Clockwise Down Under

In the Southern Hemisphere

- Low-**pressure-system winds** spiral **clockwise** around. I.e. into your face from your left as you face their winds...
- 'Low **clouds**' (i.e. below freezing level) follow the surface level isobars i.e. the weather-map lines.

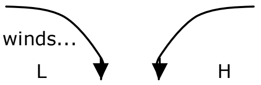

The double-meaning for ' Low ' in the mnemonic reminds you of this.
'Lows' cause more clouds than 'Highs', so you focus on 'Lows'.
I.e. when you see the low clouds; you say 'low clouds come clockwise' and automatically imagine………… '**L**ow On My **L**eft' Plus 'H**igh** On My R**igh**t'
The Alternative Southern Hemisphere version of Buys Ballot's law. This **new version goes like this** :
Face the low clouds (unaffected by friction—winds at 600m high are considered unimpeded),
then rhyme: L— L ;igh—igh. (Don't Suntwist yourself.)

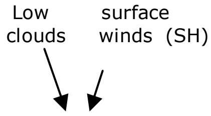

[Cf "Face the wind, (In the northern hemisphere you have to say "back to the wind")
Sun-twist yourself up to about 30° to counteract friction (which makes the surface winds spiral inward to the low centre)]
Surface winds could also be expected to be half the speed of unimpeded winds, less impediment over sea, more over land—about one third.

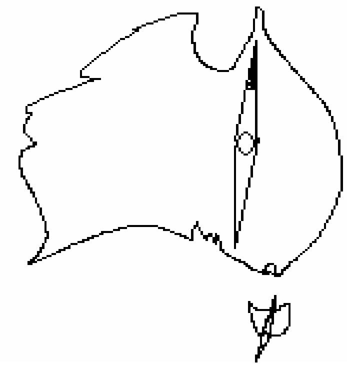

A Compass-Needle Continent—Swinging the Continent

Mentally glue a miniature continent under the compass needle, to swing with it.

The idea is twofold:
1. To reprogram your mind — "The continent is not swinging, so... **I** must be!"
2. To orient yourself meaningfully — to the invisible picture
3. To remind yourself of compass variation

When using a compass you could:	just stare at the compass-needle, like a lone night sailor in a fog.
Or:	look at what the compass is pointing to — that bump!
Even better:	also 'see' the needle lying across the whole continent
Keep going:	pointing to Northern Canada
Don't forget:	the map you are using — the real one, not this imaginary one — should also line up properly — twist it around until it does.

Global Orientation: Point to the South Pole… ..half its polar distance below horizontal

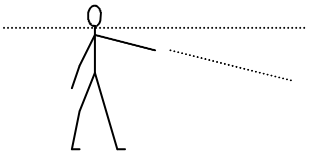

If you had to point "South" you need to point horizontally.
But when you have to point out "the South Pole", you must point below horizontal.
(It is similar when Northerners use the North Pole)
Imagine the true scale… you are on the circumference, not above it...

The question is: "What is the exact angle below horizontal?"
The answer is : "The South Pole is **HALF its polar distance** below South."
Example: at 45° S., you point 22½ degrees below the horizon. (90-45) /2
Example: latitude 30°; colatitude = 90–30 = 60°; half that equals 30°
Example: latitude 60°; polar distance 30°; 15° below horizontal.

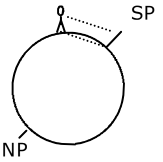

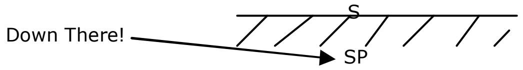

Optical Illusion — Beware! — Use Your Shadow Not the Sun, For Direction

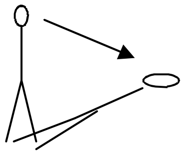

When the Sun is directly behind you, it seems to be behind on the left when you look over your left shoulder, and behind on the right when you look over your right shoulder! And when the Sun is exactly to the side, it nonetheless seems to be ahead of you. (Every sports coach knows that when you turn your head, your body follows it.) Don't rely on where the Sun seems to be… USE A SHADOW INSTEAD! It is also easier on your eyes.

And then don't get fooled by the shadow of your finger, when you throw a shadow onto your map to find the Sun's direction. It may look straight but it doesn't point to the Sun, until you line it up with your finger**tip** while looking from directly above. The shadows will always be parallel, but the Sun's rays will always join object to image, fingertip to fingertip-shadow… The first diagram is illuminated from behind you……
To avoid looking at the Sun, try this:
Point your walking stick from somewhere beneath your eyes, outwards, and rotate yourself until it is in line over its own shadow.

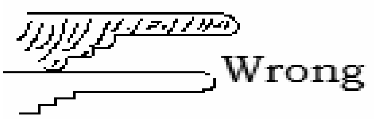

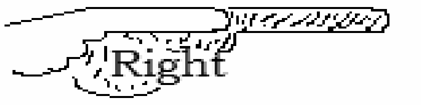

Right Around the Horizon, Stars Move to Your **Left**, Down South

Looking South, all the lower stars move left.

It is only the high Southern stars which move to your right.

Looking East all the stars rise to the left (i.e. we see the bottom half of the circles down at horizon level, looking South)

Looking West all the stars set to the left

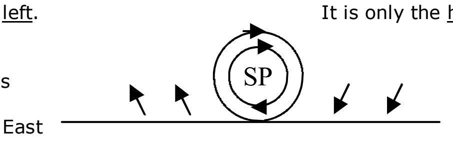

Looking North, all the stars move left.
(we see the top of the circles)

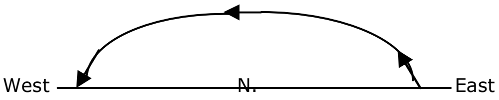

The same goes for Sun, Moon, Planets.

Looking directly overhead, or behind your head, will not work!

(it is all opposite in the northern hemisphere)

Mentally Rotate the Sun-Moon Line Around Polaris

A whole line through the sky gives a better 'feel' for direction than a single point — than either the Sun or the Moon alone —
So join the two and watch them rotate together during the rest of the day.

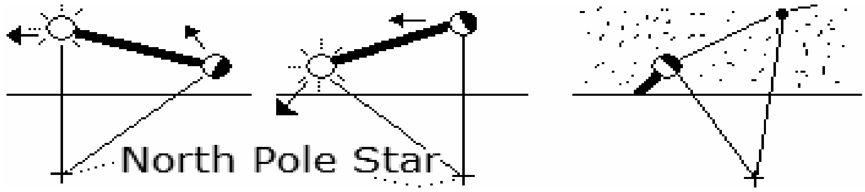

(Southern Hemisphere view)

When you can see both, and you know where North is, you watch them.
When you see only the one, you look for the other, and so find north more exactly than by using either one's path by itself.
Add in any planets to continue the process at night, then from planet to planet or to Zodiac stars, after moonset.

"Bears Circle Clockwise"
Compass Bearings are **C**lockwise, A Full **C**ircle, and Euro**c**entric, **C**ee?

In Europe the Sun moves clockwise… from North (Where the Sun is at midnight—0 hours) = 0° as far as the horizontal angle involved is concerned.

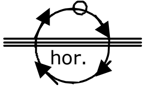

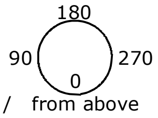

Looking S. / from above

East is at about 06 hours (sunrise) or 90° True — Sun-wise or Clock-wise from North
South at about 12 hours or 180° T (noon)
West at about 18 hours or 270° T (sunset) — so you see, the bearings circle clockwise, from North, 360°.

A **Southerner**, of course, would prefer to go 360° **anti**-clockwise, from **South**, but they didn't get a vote.
Everyone in the world is expected to submit to the (NH) rule: compass bearings should be measured in degrees, up to 360°, from North, clockwise around through East — like the ancient Babylonians; like the Northern temperate Sun.
Not many people consider using 400 grads (4 right-angles of 100 grads make up the circle), or consider going left-around, through West,
Or even think of starting at South. So don't you dare (unless you **don't** call it "a compass bearing").

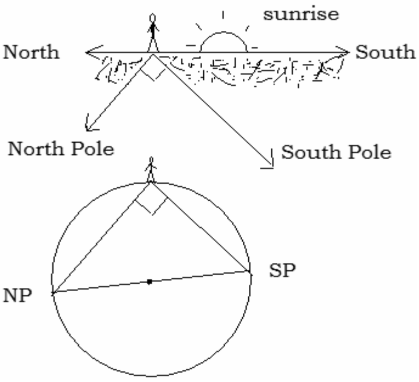

The North Pole is *Perpendicular to the South Pole*

Since the poles are 180° apart — opposite — you see them as 90° apart — half the arc distance.
The numbers can't work out any differently.

Example: 10° S. Lat. = Equator is 10° North of you. South Pole is 80° away — the "Polar Distance".
So S.P. = 40° below S.
North Pole is another 90° past the Equator.
So N.P. = (90 + 10)/2 = 50° below N. And the gap is 90°.

A simple way of looking at it is to say
"Diameters yield right-angles at the circumference"

Now go outside and point to the Poles.

The Dark-Blue Polarisation Band Perpendicular to the Sun

90° from the Sun there is a circle of darker sky. Bees navigate by this clue. The whole sky shows degrees of polarisation.
You can see it naked-eye, but since it is due to polarisation, it is much clearer through Polaroid sunglasses or a camera filter.
Point the top of your polaroid sunglasses toward the Sun for best effect.
The dark blue band is narrowest highest up (in the direction of your shadow, and perpendicular to that sunbeam) and varies with visibility and haze.
The sky is darkest away from the Sun and away from the horizon haze and 90° from the Sun.
You can always guess where the Sun is, from the gradations of blue. After sunset the band is caused by the brightest part of sky.
Example: You are in a forest at dusk. The sky is blue overhead, but the sunset direction is not visible. Find the Sun from the blue!
See the "Sunny Skies System" (p.19e) for how to use the ends of the dark blue band, and its trend.

The Centre of the Rainbow is Down-Sun

The shadow of your head coincides with the centre of the rainbow's circle. (Pilots often see the full circle of a rainbow)
The radius of this circle is two wide hand-spans — spread out your 10 fingers fully, thumbs touching.
Whenever you see a rainbow, treat it as a clue to 'shadow-South' (p.14b) i.e. relate its position to the time of day and to South.
The shadow of your head is on the end of the shadow of you, of course, but when you can't see it due to clouds, you might be able to see a rainbow.

Identify the Stars That Pass Directly Overhead

Each star has its own latitude, called "declination", which is very nearly constant.
So the same series of stars of the same latitude will pass overhead that latitude, each night, each in turn, each at some fixed star-time.
This is true anywhere on the globe.
Use a plumb-line. The top of the plumb-line points 'up' to overhead (when looked at from any side, so) where the 'up' lines cross is 'overhead'.
Look past it from 2 or 3 directions to find overhead, especially looking North/South for longitude-timing, and East/West for latitude-positioning.
Then use a star-chart to identify "exactly overhead", latitude-wise, at least. If you can do this, even without a watch, this will fix your **latitude**.
Plus or minus a few kilometres is the expected maximum accuracy from using a plumb-line.
For **longitude**, you need to determine the star-time at which one of these stars is overhead, or at least passing from East of you to West of you.
Greenwich (absolute) star-time, not Local (relative) star-time, that is. To the nearest 20 seconds is okay. See p30c. A 4 min error is 1° error in long.
Alternatively, set your reference star-time to some other longitude, e.g. home, or start, or destination, or a round number.
This time & position data is life-long, give or take a few kilometres of predictable precessional drift per decade.

You can get back to that place later — Match the appearance and timing. It's easy to tell which way to move in order to "match up" (p22a,c; 23c).
You need to know a star's longitude, so you need an almanac or list. Look down the list for bright stars with your latitude, and go look for them.
You will quickly learn about having to wait for the right 'star-time'!

Weather Fronts Distort The (Circular) Wind Circulation

Buys Ballot's law is only approximate, because of the sudden wind-shift at a cold front.
Cols, Ridges and Troughs are likewise noncircular. E.g. 'centres' will sometimes split into two…

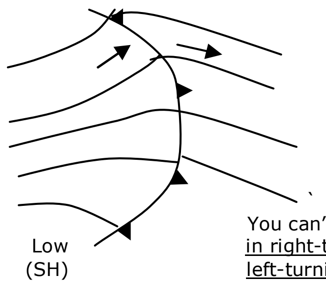

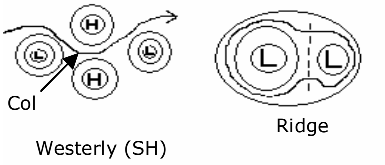

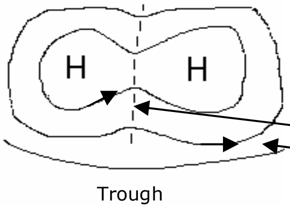

In the trough, crossing the ridge, the winds are turning right.
This airstream is turning left (SH) around the High centre.

You can't accurately say that these winds are 'circulating' around the Low or High! But you can say that in right-turning winds the clouds are forming, under the influence of a Low or a trough (SH), and left-turning winds are under the influence of a High or a ridge—the clouds are dissipating. Swap left and right in NH.

Mnemonic: (Interpret a Compass Needle as) "RED HOT — WHITE FROST"

Southerners are looking North to the "red, hot, tropics, dripping with sweat, in the Sun"…

When southerners look South, it is to the "white, icy, Antarctica, frosty cold, in the shadow"…

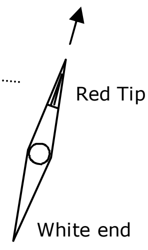

So when you notice the red point of the compass needle you say to yourself "red-hot!"
and try to feel boiled on that side (as if by a bon-fire), and then visualise the invisible tropics North of you.
And when you notice the white point (e.g. during a back-bearing) you say to yourself "white-icy cold-frosty-Antarctica"
And then try to feel frozen on your 'Shadow-South side', and imagine the South Pole, e.g. point (down) to it.

You can also remember that the Canadian flag is red (but it is not hot in Canada).

Global Orientation: the South Pole Star, and Polaris

(In the Southern Hemisphere…)
Polaris is below the northern horizon, by exactly as much as your South latitude.
E.g. at 45°S. lat. Polaris is below North by 45° Around it the northern stars circle anticlockwise……

The equivalent "South Pole Star" (a dim pinprick in the midst of dim pinpricks) is
above the southern horizon by exactly as much as your South latitude. E.g. 30° S. = 30° above South
Around it the Southern stars circle clockwise, once per day-night.
Locating the South Pole Star, helps you in the following...

- You can use the bright stars — Cross, Pointers, Achernar — as hour-hands on a 24-hour clockface.
- Star-paths Circle around the Pole Stars
- So do the horizon, the Sun, the Moon and the planets — You can predict all their positions.

Finding the Pole Stars is Fundamental to Visualising Rotation.

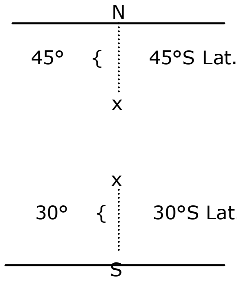

- Your Shadow Rotates with the **same clock-sense** as the Sun — not surprisingly!
- Shadow-Rise and Shadow-Set is **opposite direction** to the Sun — not surprisingly!
- Mnemonic: (Face the opposite direction as for the Sun mnemonic p.5b)

} Together they can surprise you!

Face **Sh**adowy **S**out**h** for **S**outhern **H**emisphere (Face Su**nn**y South for **N**ortherners)

"Shadow **Ri**se is on the **Ri**ght; S**e**t is on the L**e**ft" (Same rhyme as for sunrise and sunset, but facing South, both hemispheres)
Your Shadow Passes **South** of Southerners At Southern Noon (compare: 'The Sun is North of Your Nose at Noon')
(North of Northerners at Noon)
Your Shadow Moves **Anti**clockwise — around to Your **Left** — Down Under
(Clockwise — Around to Your Right — in N. H.)
(The Southern Hemisphere Horizon still shifts to the right, in real terms. The Northern Hemisphere Horizon still Never Heads Right')

In addition, notice: **The shadow *tip* moves due East, at around noon,** and in a much straighter line than you expect, all during the day, as the shadow itself changes, from pointing to opposite sunrise, then to pointing to South of the object, then to lying opposite sunset.

---

15 Ways to Locate the **South** Pole Star Or the N./S. Meridian

1. Halfway between Achernar and Epsilon Centauri (located from the six bright stars near it)
2. Rigil Kentaurus to S., at right angles to Hadar…………
3. Beta Crucis to S., parallel to gamma-to-alpha Crucis, 5 Cross lengths … Use 2. and 3. together
4. Beta Hydri to alpha Crucis, as far as the beta-to-gamma-Hydri length … most accurate
5. Mirzam through Canopus
6. Suhail through the top half of the False Cross through Miaplacidus
7. Make a triangle out of the two Magellanic clouds toward R. K. — very crude but useful
8. Gamma Hydri to beta Triangulum Australe — the "back" star of the Triangle
9. Alpha Hydri to Hadar
10. Arcturus to between the two 'Pointers' (R. K. & Hadar) } These are used in reverse
11. Spica to between the Cross and Pointers } — to locate Arcturus
12. Middle of Corvus through middle of Cross } Spica and Corvus
13. Atria to the star between Canopus and Achernar, alpha Dorado
14. Peacock to Avior
15. 'Your Latitude' degrees above horizontal, due South

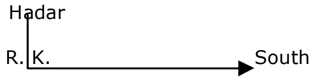

("Crucis" says "of the Crux" i.e. of the Cross)
(gamma looks a bit like a thin alpha twisted 90°)

"Cusp North" — Approximate Direction from the Moon

The Sun-Moon line marks the approximate Ecliptic.
The "centre" of that circle of Sun-planets-asteroids is located in "Draco",
quite near "Polaris", the North Pole Star. For a start, ignore the difference…

- Join the Cusps, tip to tip
- Drop the line diagonally
- Keep going down to (near) Polaris (latitude degrees below horizontal)
- Come vertically back up to "Moon North" (in the worst-case +/-60° "accuracy"!)

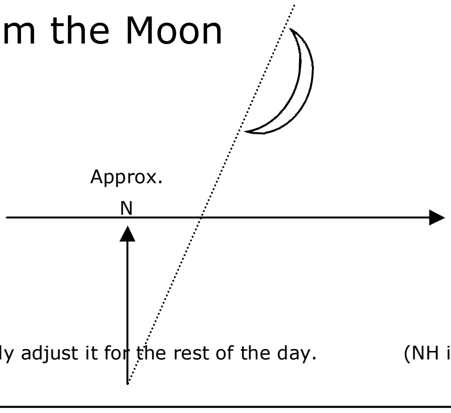

You have to do this only once or twice a day. Compare it with True North and automatically adjust it for the rest of the day. (NH is similar)

Mariner's "Compass Points" work on Successive Halvings

180° difference

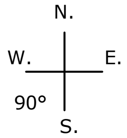

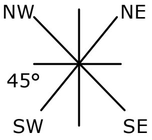

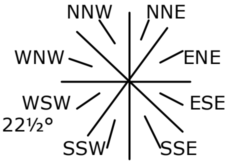

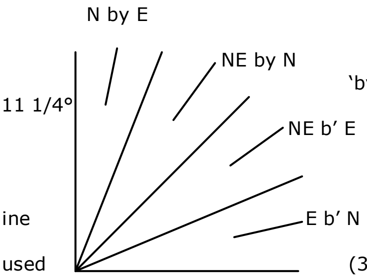

Start with the nearest major point; add 'by'
'by' means 'come 11 1/4° towards' (or 'one point')
There are 32 points altogether on the compass.
One Point is approximately One Palm wide
(32 around the horizon—test it)

Make your own emergency protractor (e.g. as a compass, sextant or plotter) by folding any piece of paper, and folding it again and again, matching line to line so as to exactly halve it with every fold.
One more halving and you get 64 divisions, each of "100 mils" (so named and used because **1mil is approximately 1 in 1000 e.g. 1 m in 1 km**) i.e. 6400 mils around, clockwise, 17.7778 mils per degree.

Pole Star Locations — "(Latitude)° above and below, South and North"

Why? Think: at 0° Lat., they are 0° high. Yes? At 90° Lat., they are 90° above and below horizontal. Yes?
If you need further proof: Draw a Diagram of two parallel rays to South Pole Star...

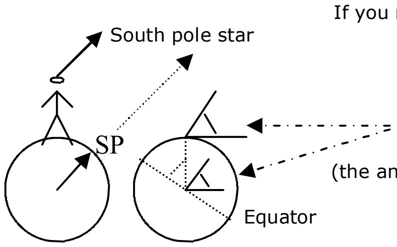
South pole star
SP
Equator

The elevation of South Pole Star above the horizontal
= the latitude = the arc-distance of Equator to you...
(the angle, adding up to 90° with the PD, must occur twice in the 180°)

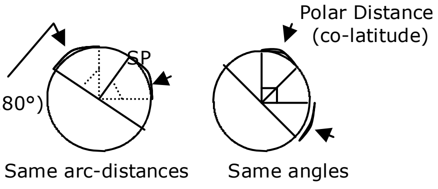
SP
Polar Distance
(co-latitude)
Same arc-distances
Same angles

The Sun Passes Quickly Past North-South Nearer the Tropics

This pattern shows
the hourly change
in Sun or shadow direction
at 30° latitude, Mid-Summer...

The Sun is East/West
at (noon −/+ 2 hrs 44½ m.)
at 52.9° high.

This shows the
seven hours' sunlight
(one side of North/South).

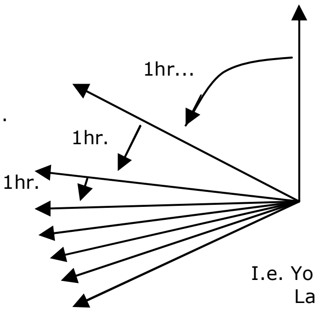

Don't get caught misjudging the Sun's horizontal direction near midday.
When it is high, it moves more than 15° per hour in horizontal direction.

At other latitudes the pattern will be different — more uniform
away from the Equator, and with a different day-length,
depending upon the season.
I.e. You need to calculate each particular pattern from the
Latitude and declination and season (as if calibrating a vertical stick sundial).

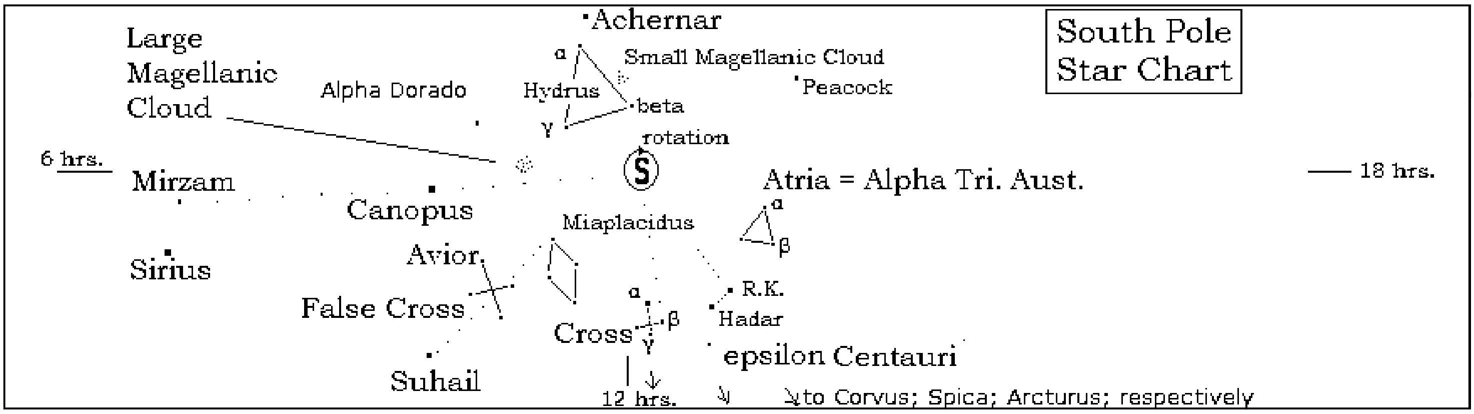
South Pole Star Chart
Achernar
Large Magellanic Cloud
Small Magellanic Cloud
Alpha Dorado
Hydrus
α
β
γ
beta
Peacock
rotation
S
6 hrs.
18 hrs.
Mirzam
Canopus
Atria = Alpha Tri. Aust.
α
β
Miaplacidus
Sirius
Avior
False Cross
R.K.
Hadar
α
Cross
β
γ
epsilon Centauri
Suhail
12 hrs.
to Corvus; Spica; Arcturus; respectively

Wind-Direction-Change Rule for Buys Ballot's Law

If "the Low is on Your Left Or the High is on Your Right"…**and** the wind is gradually **changing**: Add in this new information as follows...
Imagine how the Low and High are moving across the ocean/continent as you **reenact the wind change**...
Exaggerate the change as you *twist yourself to follow the speeded-up movement* of the wind change in your face.
Point to the two choices (left & right) while you twist, then ask yourself which of your hands is moving to the east.
Usually only one of the two options above — 'Low' or 'High' — will make sense of the general movement of the weather systems to the East.
Temperate systems usually do move to the East from the West. (Both Hemispheres)
..From 0 knots (stationary highs) to 15 (average) up to 25 knots (Lows in winter).
Tropical cyclonic hurricanes move Westerly initially at 25-40 knots, then recurve to the pole, but the "re-enact" rule still works to show up its movement.
In this way you can decide: "These winds are from a Low" or "from a High".
Don't, of course, confuse local winds, e.g. a sea breeze, with the more general 'synoptic' circulation due to the large-scale pressure systems.
To further help you decide where the wind has travelled from —from your right or from your left— check out the temperature and absolute humidity — i.e. the air-mass characteristics. Is the air hot and dry, or cool and moist, or warm and humid — which one is supported by the geography?

Four Reference Directions — Name Them: "**Rise, Noon, Set, Midnight**"

..not E N W S

The trouble with "North" is that it is sometimes behind you... then you have to think backwards.
Use all four and you always have one in front of you... N., S., E., W.
Give them meaningful names as in the title... and you can picture the meaning.
Base it on the Sun's daily movement and the effect is vivid.
To flesh out the meaning even more, **add in a second clue: "Rise/Start; Noon/Hottest; Set/End; Midnight/Coldest"**.

What this does is to take the outside picture inside with you, when you enter a new building, a hospital complex, a shopping centre.
E.g. "I'm now looking toward the mid-morning Sun direction, i.e. 'after rise' or 'before noon', which is 'warming up' ".

It is then up to you to
1) get to know the Sun's daily movement.
2) locate the Sun's path outside, once.
3) *keep track* of your twists and turns when the Sun is not visible e.g. at night.

Ignore the time of day or night—it is the directions which you are imagining. You use the real Sun only as a start-up hint.

Point to 2 Places on the Equator — Halfway between the Poles

You can find the 2 Poles, apparently 90° apart, so that means you can point 45° — halfway — between the Poles, to find the Equator, then 90° to that for the opposite Equator (the "45°" is because the Equator is 90° from each Pole and we halve that arc).
It locates (1) the furthest point on the Equator from you e.g. Brazil then...
(2) the nearest point on the Equator from you e.g. New Guinea—ish.

From central Australia…

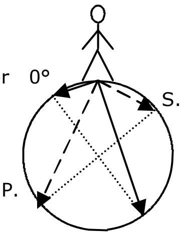
Closest Equator 0°
(PNG)
S.P.
N.P.
Farthest Equator. Notice that it lies to your South! (Brazil)

Shortest Shadow South — Opposite Highest Noon. Always Imagine "Shadow-Noon" on your "Shadow South" Side

i.e. Your shortest shadow is South of you at noon. Memorise how short it is (this week). For the northern hemisphere use "North" ("shadowy-North")

(Shadow Noon is Opposite Direction to "Noon-North") .."Noon-South"
Imagine your shadow moving left around… ..right-around

In the morning: South must be "ahead" of my shadow ..North
At midday : Look — see how short it is! … **Due South at noon** **..North**
After noon : My shadow has "passed" South ..North

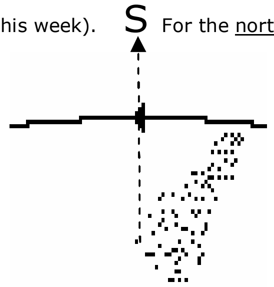

To guess North from your own shadow, see "Walking stick North". (p.30b)
Try to feel the icy South, freezing that side of you! ..North
(As on a cold night facing away from a campfire).
Mentally **visualise**: Antarctica below horizontal; an aurora above that horizon; Southern stars behind that blue sky. ..Arctic; Aurora Borealis
In the tropics, you'll have to be more observant, to know your shadow's expected movements more accurately. ..Northern stars

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Find the Polar Axis by Star-Trail Bisection

You need to imagine the centre of the star-circle.
A Hypothetical Example: Lost in a stormy night! You want to find North-South.
You catch the occasional glimpses of unknown stars.

Lie down and line up one such star with a tree branch.
Maintain your exact position and wait for another glimpse.
It may only need a couple of minutes to see its direction of movement.
You can also point something straight at the star and fix it in place, to see the star's movement.
Bisect the result. It points to Polaris, or to the South Pole Star.
You now need to know your latitude, roughly, to locate Polaris or South Pole Star.
The higher the star the clearer the result — it will be moving West.
The only ambiguity is a low star moving horizontally (to your left).
The Southern stars will be moving slowly; northern ones, quickly
— so you may be able to guess which is which.
Northern Hemisphere is similar — but Polaris is visible.

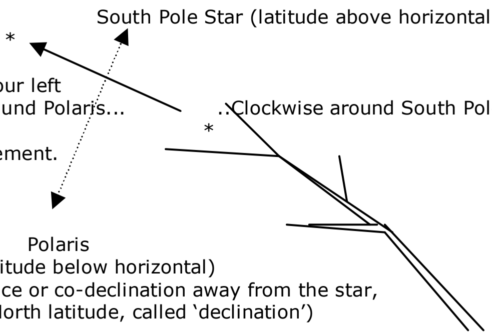
South Pole Star (latitude above horizontal)
*
(This star is moving to your left
Anti clockwise around Polaris...
..Clockwise around South Pole Star)
*
Polaris
(latitude below horizontal)
(also polar distance or co-declination away from the star,
if you know its North latitude, called 'declination')

The Rabbit Looks up Ahead at Full Moon

Using the Ecliptic

When the 'cusps' disappear at full Moon, the Rabbit ears and face appear,
and let you know which way the Moon is moving.
These views are for the Southern Hemisphere — where the 'Rabbit' is upright.
In the first diagram, the cusps are difficult to distinguish, and so is the Rabbit.
In the second diagram, you don't need the cusps, because the ears show.
The dashed arrows point down to near Polaris.
As an alternative to cusp-North, you can use the Ecliptic perpendicular to the cusps.
The other, solid arrow, falls roughly along the Ecliptic, with the light side of the Moon pointing to the Sun and the dark side pointing to the anti-Sun.
Therefore you can judge approximate sunrise or anti-sunrise, sunset or anti-sunset, just as soon as you see the Moon, either from its cusps, or from the Full Moon.
Find the nearest horizon on the Ecliptic and picture which of those 4 directions it is.
A setting Moon in early daylight will show anti-sunrise, but after dusk will show up sunset.
An eastern Moon before dawn indicates sunrise, but in the p.m. will point to anti-sunset.

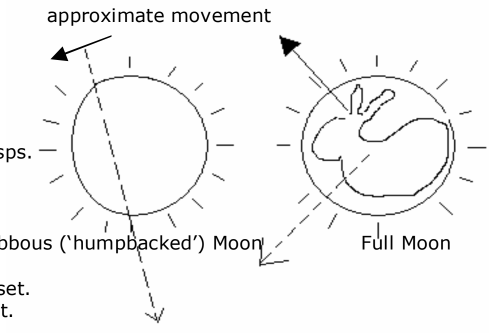

"E. W. N. South" **Of What**!? Rule: **Say** What

- Say 'True' and you mean 'degrees East of True North' 270° T = due W.
- Write "Gee" and you mean: relative to the map **grid**. 270°G ≠ 270°T Both are clockwise around, but they start off from different directions
- S20°E means '(Start at)South(;come)20°(toward the)East' e.g.S20°E=20° to the right of the white end of the compass needle. (old system)
  Clockwise/to the Right/East-around-from-North is standard if not otherwise specified.
- 270° M says 'Magnetic' — what a good compass should read.
- 270° C says 'Compass' — what this compass does read.

Note that these are standard: 'G' does not mean 'Geographical' or 'Great Circle' or 'Grads' but is recognised as 'Grid'.
'M' does not mean 'Map', 'Map grid' etc.
xyz° can not mean anti-clockwise.
The remaining problem is how to shift between different methods… See section 4: "East Least West Best" rule. (p.107b)

Perspective Distortion — The Sun Moves in a Straight Line!

The 'horizon' (at sea) seems "straight", yes? but joins to itself! This is because you see it from the centre of a circle. That's no problem yet.
Two different great-circles circling around you do cut twice, but *it certainly looks strange*, since looking at the gap between them,
you see "parallel straight lines"; Yet to the left **and** right of that you will see them both join!
Great Circles Intersect Twice. **Nowhere does either circle seem to 'curve', yet they manage to meet.**
The Sun 'comes up and goes down' but is actually 'moving' in a nearly straight line—as straight as the horizon…

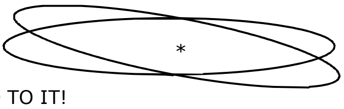

PUT YOUR HEAD INTO A HOOP; GET OUTSIDE; CHECK IT OUT; GET IT INTO YOUR HEAD: GET USED TO IT!
Caution: Don't look directly at the Sun. Watch your shadow and you will see that it moves in a nearly straight line from East to West.
The Sun's average path — the 'Equator' up in the sky — where the 'Saucepan' (Orion; the Pot) moves — is a great circle.
It intersects the horizon due East and due West. At times of year other than at Equinox, the Sun's path is still almost a great circle.
The Milky Way is another maximum sized circle; and the Zodiac (i.e. the Ecliptic) is another such 'Great Circle'.
They hit the horizon twice, in opposite directions (not E/W).
2 other 'great circles' you need to visualise are: Satellite paths; and the Dark Blue Band. (Star-trails are usually 'small' circles, and do look curved.)

Locate Polaris (and Find North) by Imagining the Centre of Circling

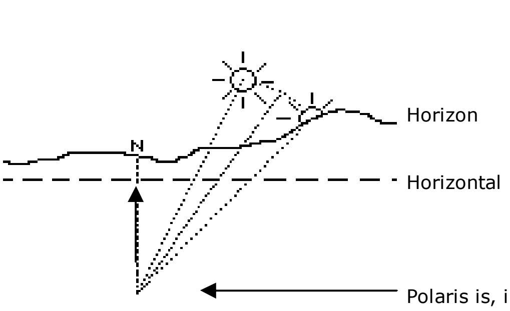

This works for the Sun, Moon, planets or stars.
You *find the centre of their circular paths by bisecting the chord*.
(Northerners locate the South Pole Star, South)

The **perpendicular bisector** of an arc or chord
passes through the centre of a circle...

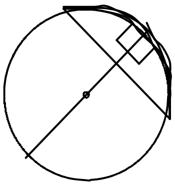

Moonrise varies quickly from day to day
— make sure you check its exact position.

Don't look directly at the Sun to do this!

Polaris is, in degrees, at 'your south latitude below horizontal' (not the horizon) — judge it carefully.
and/or, 'polar distance (co-declination) away from the Sun': 90°-N dec, e.g. dec=10°S 90-(-10)=100°

The Eagle Clips the Equator, South of Altair

Find the star 40% along the southwest side of the rhombus…

Finding the Equator helps you

find the Ecliptic (not shown)
and find where the Milky Way crosses the Equator…

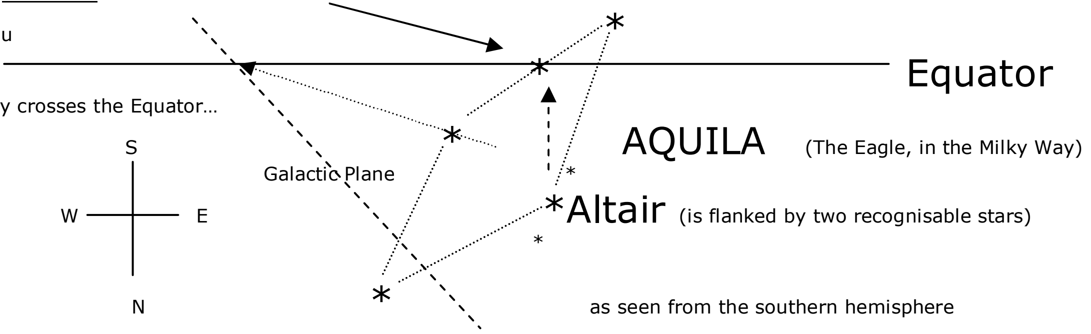
Equator
AQUILA
(The Eagle, in the Milky Way)
Galactic Plane
*Altair
(is flanked by two recognisable stars)
S
W
E
N

as seen from the southern hemisphere

Steering Winds

Mid-to-high-level (upper) winds tend to push sea-level pressure-systems along
at **half the speed of the upper winds, and in the same direction**.

This rule is said to work best with small, weak, less well-developed systems; and with hurricanes.

E.g. If the low is on your left And if the upper winds are coming from your left
Then the storm centre might pass straight over you.

Since the upper level winds often oscillate in the 'Rossby Wave', and tend to generate high and low pressure areas beneath them
(because the 'wave' causes the upper winds to slow down or speed up) the High-pressure systems will on average be steered slightly toward the Equator, and the Lows will go slightly toward the Poles, as the systems move to the East — a rule of thumb worth remembering.

But this extra steering-wind rule will alert you to non-average situations.

"Rise-Noon-Set-Midnight" carries its meaning across the Equator! N.S.E.W. doesn't.

Name the directions according to the average outside picture…
This is a visual system and addresses the disorientation of turning around.
For back-bearings i.e. when you turn around: replace 'rise' with 'set',
'noon' with 'midnight' (start with end, & hottest with coldest)
e.g. if the old direction was "after setting" the new one will be "after rising".
When you turn right or left adjust by one of the four notches
e.g. 'after midnight' becomes 'after rising' if you turn 'with' the Sun.
Note: 'after the setting' (or 'before midnight') is a direction of the evening Sun
— S.W. — and can be bright sunlight, in midsummer !
And 'after midnight' ('before East') is the direction of the South-East Sun.
At Mid-Summer sunrise it can similarly be very much bright !
Example: You enter a hospital with "setting" (i.e. due West) on your right, so you start at "midnight" (SH). You then navigate through look-alike wings, look-alike wards, and look-alike staircases, remaining oriented, and finally emerge, expecting "rise" on your right — having not looked out of a window for hours!

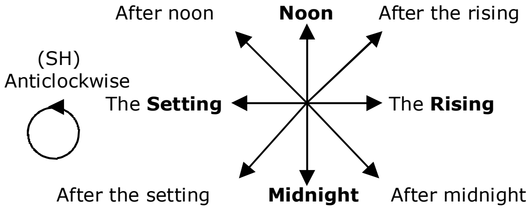

(The Northerner's version needs to go clockwise!)

Global Orientation: Half the Arc-Distance below Horizontal

Point out any country or place on Earth, by first finding the (arc-)distance there, and then pointing below the horizon…
The method works **from any place on Earth, in any direction, to any place on Earth**.
Step 1. Measure the angle around the circumference to it. E.g. guess from a globe of the world (This is an angle at the centre of the globe)
Step 2. **Halve** it. That is how far below horizontal it is.
E.g. South Pole from 30° S. Point 30° below since it is 60° away
E.g. Perth to Peking (which is directly North) is 32 S. to 40 N. Therefore the ‘arc’ to Peking/Beijing is 72°…

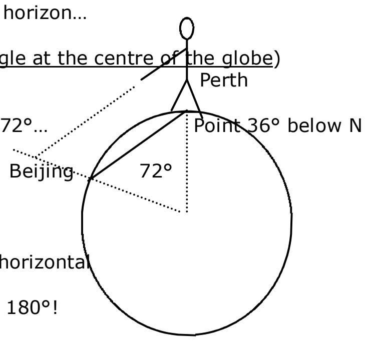

Try this (outside): Go through the motions of pointing out a whole circle of real places on earth, from the horizon ahead of you, to the horizon behind you, using your index finger.
E.g. point North, then down a bit to below horizontal e.g. New Guinea, now onto the North Pole.
Continue down until pointing down underneath you e.g. mid North Atlantic.
At this stage you have pointed through 90°, but have pointed out 180° around the Earth.
Turn around to continue, (Brazil, Antarctica) bringing your finger higher and higher until it is back to horizontal pointing at the hill on the Southern skyline.
Your index finger has pointed out a 360° circle (as measured from the centre of the Earth) by traversing only 180°!
Get Hold of a Globe. Go Outside. Point Out A Few Countries.

“ Noon ” is Not at 12 O’clock

‘ High Noon ’ is at ‘midday’ i.e. in the middle, between sunrise & sunset. And that is **not ‘12 noon’ or ‘12 midday’** but at North — Noon North. (SH)

- In summer-time ‘high noon’ may be near 1 or 1:15 p.m. or so. If you are on Summer Time, true noon is one hour late.
- Even in winter-time it may be over half an hour away from 1200 hrs. This is because we use a one-hour time zone to cover 15° of longitude.
  i.e. you may be near the next time-zone, longitude-wise, and therefore be up to one half an hour ‘out’.
  You can check this up if you have a map with longitude on it. The middle of the time zone is at 7½°, 22½°, etc, in steps of 15°.
  Then it will take 4 minutes to travel an extra degree westwards. Work out how early or late the Sun will be in your longitude.
- Plus; the Sun speeds up in its ‘orbit’ ‘around’ the Earth when it is close in the Southern Summer, getting up to 20 minutes ‘fast’, by the end of summer; likewise it can be up to 20 minutes ‘slow’ at other times, in addition to the time zone effect. See the Equation of Time prediction opposite.

The best thing to do about this, to predict when, exactly, it will be at ‘midday’ today, is to look at the Sun yesterday.
(Don’t! Use a shadow instead. Notice when it is due South.) Or see 26a.

Equatorial Stars Rise and Set Due East and West

Always

Globally

- The Sun at Equinox — about March 21st, September 22nd
- The Pot in Orion — Mintaka, the north-west star of Orion’s belt — the one that sets first — is right on the Equator
- Various dull stars — like the one south of Altair
- A Half Moon at solstice — give or take 5° or so — It must be 90° from the Sun which is at the solstice position, so that the Moon is at the ecliptic equinox (Equatorial) position.
  Other phases can be worked out, e.g. Full Moon at Equinox, but see p. 29d on how to predict an equinoxial Moon every fortnight.
- Planets 90° from the Sun-at-solstice
- The equinoctial points, if you can identify them yet. One is between Spica and Regulus; the other is between Diphda and Markab.

The Moon Cusps Push and Pull the Hour Hand **Backwards**, Down South

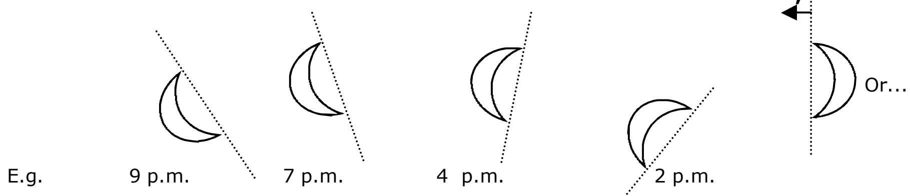

Watch the Moon rotate during the day, and night. Tell the time from it. Update yourself once per day.
The Moon rotates like this about 14½ degrees or 15° per hour. So it is like a 24-hour clock hour-hand running “backwards”.
The correct vertical to use as a reference is not at the Moon, but at the Pole Star, if you want to be accurate.

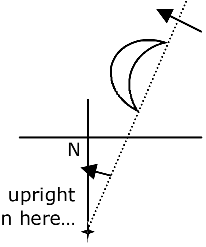

(NH — the Moon seems to turn clockwise)

Back-Bearings Killed Sleepy Pilots

Back-bearings are opposite directions — “going back home”.
The Babylonian system of 360° in a circle has a lot to answer for, when you want to turn around!

What is required, is to add or subtract 180° (groan)!

But after an all-night mission, tired navigators can’t be relied upon to come up with the right answer.
In World War II, many air-crews perished from following the wrong back-bearing back.
Happy, relaxed, but lost.
It was a problem requiring a solution, and a simple solution was found. What is it? (page 18e)

Half the Arc-Distance below Horizontal — 2 Explanations Why

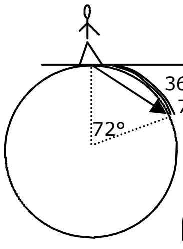

72° 'arc' around the circumference — twice the angle from the tangent — but why?

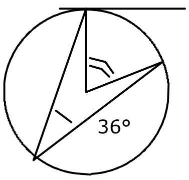

The angle at the centre (used for 'arc-distance') is always double the angle at the circumference...

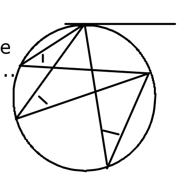

..It doesn't matter which point on the circle you use, as long as it is on the one side —on the larger arc here— you get the same angle each time.
The tangent point is one such acceptable point — the last one.

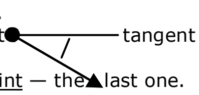

2. (Isosceles triangle angles… (180 – 2ɑ)/2)
= 90 – a

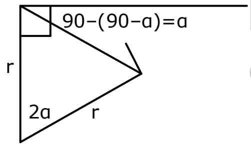

The "Equation of Time" Diagram

The real Sun moves quicker through the sky near Christmas because it is closer to the Earth (i.e. we orbit it quicker, elliptically!).
I.e. The Sun 'gets ahead of' its predicted average position, according to our clocks, in the New Year,
And doesn't come back to average until about the end of August.
After that, during September to December, it will be behind average. But then, in addition, the details are complicated by how it also zips quickly past (gaining on) our longitude lines near solstice — summer or winter — when it is near +/–23½° latitude.
Here the longitude lines crowd together, if only slightly, giving the maximum effect in June & December, super-imposing upon the preceding scheme.
The **overall result** may be graphed… (both hemispheres)
See the mnemonic on p. 86b

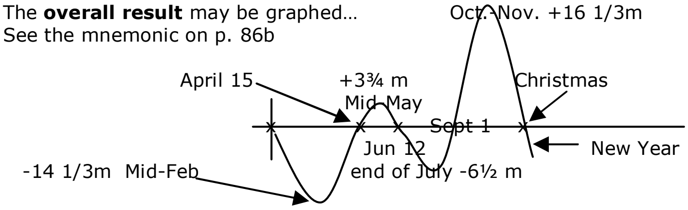

Note that when the astronomers say '+', the Sun is behind itself; we look at the position of the Sun (not directly at it!); it comes up 'late' and we have to add (about a ¼hr) to our guess at the apparent time, to find the clock-time. We say our clocks are 'fast' at predicting the Sun's position, but it is really the Sun which is lagging!
cf Australia is in a "**+**10 hr time-zone" = 10hrs ahead, or fast on Greenwich

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Rigel-to-Capella is a good S./N. Pair

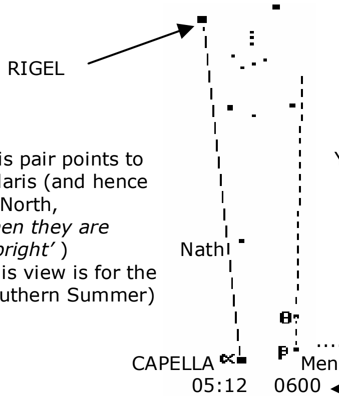

This pair points to Polaris (and hence to North, *when they are 'Upright'*) (this view is for the Southern Summer)

You can also see that the Pot handle points down through the middle of Orion's belt to Meissa and on to Polaris. The Pot 'handle' is actually the scabbard of Orion's sword—seen upside down (SH)

If you cannot see Capella, then Bellatrix to Elnath, right alongside, is also a good guide to Polaris.

Auriga, The Charioteer
....**The six o'clock stars are a useful N./S. pair** — they are upright at 6 a.m. local star time.
← 'Right Ascension', or star-time, in hours of longitude East of the first point of Aries

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Atmospheric Pressure Changes

The air pressure falls before a front, and rises reasonably rapidly as the front passes. It falls in a trough; rises in a ridge; falls in a heatwave inland; falls with altitude (about one millibar per 10m).
The atmospheric pressure normally fluctuates by a couple of millibars every day in a twice-daily cycle tied to the Sun (3mb in the tropics) and the wind speed may vary with it. The daily pressure on average peaks around 10 a.m. and 10 p.m., being lowest at 4 a.m. and 4 p.m.; This on average, is said to vary the wind speed by a couple of knots, lowest at 9 a.m., peaking at 3 p.m., but all of this is usually masked by other weather changes in the temperate latitudes. Pressure fluctuation is much more significant in the tropics, with any fall (or flattening) more than a few millibars during summer/autumn warning you of a possible hurricane (You then look for long wavelength ocean swells preceding the storm centre). Because we can't feel atmospheric pressure changes, it is very helpful to use a barometer, to detect the longer-term pressure change trend. Test your barometer to see that it does not respond to temperature changes!

Watch the Clouds Cross the Moon

You can detect the upper wind direction most easily by watching clouds move past some fixed point in the sky.
Look during the night but don't forget to look during the day also.
The stars, high buildings, high trees and mountain tops also work well.

The **0, 1, 2, 3, 4** Reference Directions

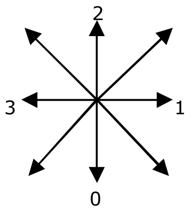

Put these numbers onto the Rise-Noon-Set-Midnight System, so as to follow the Sun.

0 = midnight, South (Southern Hemisphere)
1 = rising, East
2 = noon, North (use South for northern hemisphere)
3 = setting, West
4 = midnight, South — use cycle 4 i.e. call it "0"

This corresponds to measuring anticlockwise! from South! in decimal degrees, that is, in grads!
100 grads = 90° so "1" = 100 grads; "4" = 400 grads or zero grads — add or subtract "4" at any time.
"0.1" in this system = 10 grads; 1/10 of a right angle; **one fist at arm's length**.
Example: In the thick bush, you see your destination but know you will soon lose sight of it. You can't keep a straight line, so you decide to keep track with the 0—1—2—3—4 system and your fist. With each change of direction you update e.g. "0.6, 1.6, 1.0, 0.9…"
For a **back bearing** — when you turn around — **add or subtract 2**.
Add 1.0 when you **turn with** the Sun (**left**), or **subtract 1.0** when you **turn against** the Sun (**right**). (S.H.)

Example: Point to Tahiti

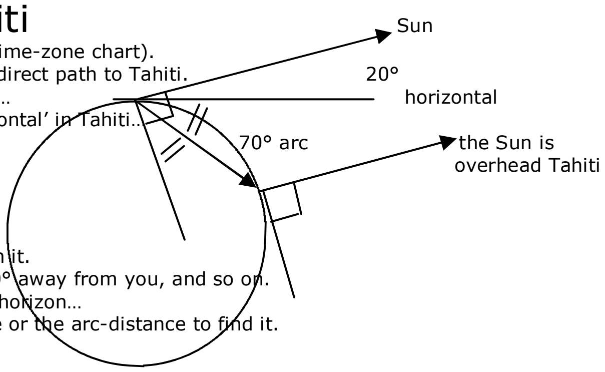

It's 9 a.m. summer-time, the Sun is, say, 20° high and over Tahiti (see time-zone chart).
Firstly, point horizontally toward the Sun (not directly at the Sun!) — that is the direct path to Tahiti.
Secondly, point below the horizon, to locate the actual direction to Tahiti…
Step1. Make a perpendicular from a sunbeam. Perpendicular to the Sun is 'horizontal' in Tahiti…
Step2. Subtract its (present) height (20°) from 90°
The arc from you to Tahiti is 70°
Explanation:
(90° - the height of the Sun), the 'co-height', must be the arc-distance
from you to underneath the Sun. Think of it like this...
If the Sun is 0° away from you, it will be 90° high — you are underneath it.
If the Sun is 10° away from you, it will be 80° high, overhead a point 10° away from you, and so on.
Step3. halve the remainder (70°/2=35°) Now add back on the 20° above the horizon…
"Tahiti is 55° below the Sun" from your point of view. You didn't need a globe or the arc-distance to find it.

The Sun Oscillates Seasonally between +/- 23½° Latitude

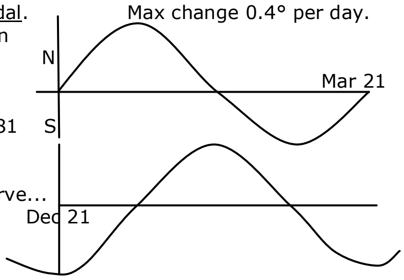

To approximate the Sun's "Declination"—or North Latitude—you approximate its variation as sinusoidal.
Using a 365 day cycle: You approximate 360° as 1° per day, so for ease and accuracy of calculation you can and should approximate the day-number as 30 days per completed month + day of the month.
E.g. **March 21st** is 2 lots of 30 days plus 21 = "81" days or degrees.

Then to use a sinusoidal curve, you need to run from Equinox to Equinox — i.e. starting at March 21, Day 81

Declination = 23.45° x sin (day number of the year – 81)

E.g. 0° in **September 21**, six months or 180 days or degrees later; uses day no. 261.
From solstice to solstice you can use a minus cosine curve...

Declination = 23.45° x –cos (day number of the year + 9)

..since the solstice is around 10 days earlier than the New Year.
Dec 21 solstice, is day no. 11x30 + 21 = 351 "–23°½ in December"
E.g. + 23½ degrees on **June 21**, day no. 171.
From this approximation you can predict noon-height (and, with the right formulae, sunrise & sunset time & direction and E./W. height, of the Sun).

Use the Southern Cross as an Hour Hand

You can visualise the rotation of the Southern Cross as a huge 24-hour clock hand.
It is correct on April Fool's Day i.e. upright at midnight (at 183°T), then it gains two hours a month, or 30°. (Use the correct vertical! — South.)
As a learning aid, mark the 'Southern Cross time' on your calendar every month
e.g. "two hours fast" at the start of May; and "four hours fast" at the end.
Then, anytime you are out at night, you can ask: **"What's the time — by the Cross?"**

Picture the Southern Cross during the Day

Yes it is there behind the blue sky… "If there were an eclipse now, it would show… there!"
When you are navigating by the 'spin' of the Earth, and by the Big Picture, the proper reference direction is the North-South rotation axis,
Which means: Polaris + South Pole Star.
In practice, what we Southerners see, is the Southern Cross.
So if you are imagining: sunrise — noon — set, or Moon position, or a star-compass course, or a shadow-south direction,
you ought to be thinking: "North — Polaris down there; South — South Pole Star up there", then you can picture the Southern Cross as well.

The Moon is Lit By the Sun

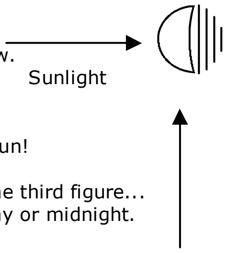

When the Moon is **opposite** the Sun, we must see its fully lit face… See diagram of the first man looking at the Moon, below.
e.g. a full Moon rising at Sunset; Setting at Sunrise; Overhead at Midnight or at least highest in the sky.
(A fortnight later…)
When the Moon is **near** the Sun, we see only its dark backside or at most a thin crescent… See the middle man below.
e.g. a crescent Moon is only ever seen near sunrise or sunset. Wait until the Sun is below the horizon — Don't look at the Sun!
At other times the Sun has set, taking the Moon with it, or has risen, outshining the pale crescent nearby.
(A week later…) When the Moon is **halfway** between, we see half of each side… See the third figure...
e.g. half a disk overhead — only at sunrise or sunset; half a disk setting — only at midday or midnight.
A half full Moon is misleadingly called a Quarter Moon… since it takes four weeks to move between the four "quarters".

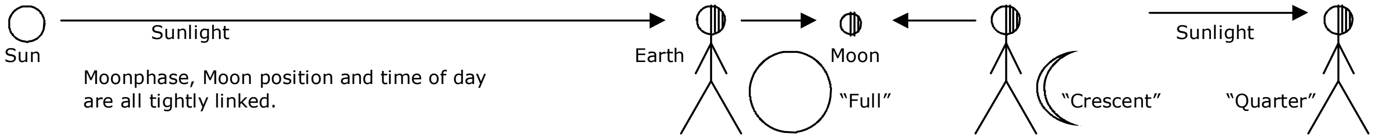

Moonphase, Moon position and time of day are all tightly linked.

Back-Bearing: **Plus or Minus 200° Then Minus or Plus 20°**

(Or — for the very advanced sleepy student: adjust by 20° first (+/-20°) then -/+200°)

a simpler solution with a protractor compass, is to...

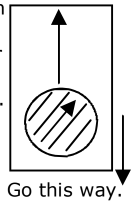

(see page 109b)

Examples: 10° is small, so make it big, 210°, adjust back to 190°
290° is big, so make it small, 090°, then back up to 110°
Advanced: 190° is middling, so boost it first, by 20°, to 210°, then remove 200° and use 10°
210° is middling, so try +20°, then –200° = 030°
When you end up with numbers greater than 360°, remove 360°. When less than zero, add 360°.
Difficult: -10° is small; first convert it, using +360° (= 350°)
350° is big so –200° +20° = 170°
185° + 200° -20° = 365°, so adjust it back to 005°

There is another solution to back-bearings — decimal degrees — but it hasn't taken on yet.

Use **Latitude** for a **Distance** Scale (Not 'Long'-itude, Despite the Name)

(Especially on marine charts, atlases and old maps—Newer maps are likely to have the mostly meaningless but well-scaled international map grid.)

Latitude means "distance" from the Equator. Remember the polar "distance" 90° complement to latitude? which measured arc-distance, in degrees!

1° of latitude = 60 nautical miles = 111 km The world is 360° around; or 360x60 = 21,600 nautical miles; or 40,000 km

The circumference of the Earth determines how long a kilometre or a nautical mile is — at least in the somewhat outdated original definitions.

(The N/S circumference of the Earth has proven to be closer to 40,007 km, and the E/W circumference is bloated by the Equatorial bulge.)

One 'kilometre', comes from the decimal system: whereby one circle equals 400 'grads'; one grad has 100 divisions… 40,000 km

Use the latitude scale on the left & right sides of a Mercator map to measure length or distance — but only at that latitude on the map.

But do not use the longitude scales running across the top and bottom of the map — since the spacing of longitude lines should vary with latitude. Longitude lines must converge towards the Poles, to nothing. They span a variable distance = 1° x cos (latitude), but a Mercator map will (falsely) show a constant separation for longitude lines (this is to make compass courses look straight). A Mercator projection will also show a variable separation for latitude parallels, even though they 'should' be constant. This is to preserve the shape of land areas—The latitude stretching must match the longitude stretching. Therefore any scaling shown on the E/W spacing is only valid for the latitude at which it is subdivided.

When a latitude scale says ½° or 30 n ml or 55 km, it means it, at that latitude, but when a longitude scale says ½°, the distance meaning is missing

Using the Declination of the Sun

- **Noon Height** = 90° – latitude + declination = (from horizontal) Convert "N." to + ; "S." to – e.g. 30° S. = –30
  E.g. Lat 30° S.; Decl. 20° N : Height = 90+30+20=140° or 40° (the two (opposite) heights must add up to 180°)
  i.e. The more the Sun 'declines' away from the Equator, and the more you decline on the other side of the Equator, the more the Sun drops in the sky. Alternatively, the colatitude (90–L) is the maximum height of the sky Equator... Then adjust for the declination.
- **Sunrise/Sunset** — time and direction prediction
  Cosine (angle from North/South) = sine (declination) / cosine (latitude) Try dec =23°.5; lat =37°.1; 55°.67; 62°.6, for a different hexagon
  Cosine (time in degrees from noon) = –Tan (Lat.) x Tan (dec.) 1° of longitude = 4 minutes of time.
  E.g. measure the time between sunrise & set; divide by 2; solve for Lat. (make sure to use horizontal, not horizon.)
- **East/West Sun** — Time and height prediction
  Cosine (E-W time in degrees, from noon) = Tan (dec.) / Tan (Lat.) e.g. 4 hrs each side of noon @ Lat 41° (Northern Tasmanian Summer)
  Sine (E-W height above horizontal) = sin (dec.) / sin (Lat.) e.g. 45° high E./W. from Lat 34 1/3°; +/– 3h21m; Mid-Summer

e.g. take the time when the Sun is E. & W. (opposites — you need to remember to carry 60, not 10, & to interpolate carefully) and then solve for Lat.
See p. 86b for a memorable laugh. Many more formulae and techniques are available, from books on astro-navigation.

Perspective Distortion — Use the Correct Vertical

Vertical is vertical, right? Wrong! To tell the time by the sky, take care.
The higher a pair of points (e.g. stars) gets in the sky, the more you have to choose which vertical is needed for a reference, to judge 'vertical' by.
Each different reference direction will give a different answer to "How vertical are those two points up there?" e.g. Moon cusps, Southern Cross
A side view makes this clearer....
..a straight line which looks horizontal when looking south,
looks diagonal in the East

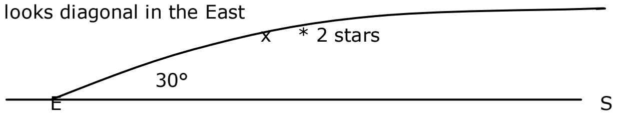

The top view also makes it very clear… a line XY high up in the sky cuts each different vertical at a different angle..

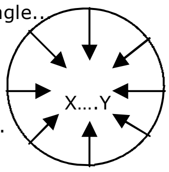

Don't gauge the angle of rising/setting (p9a) at anywhere other than at the rise/set horizon in the rise/set direction.
Don't use the nearest horizon, as your reference for which way is up.
To visualise a constant 'rotation' of the stars, use Polaris or the South Pole Star as the 'centre' of rotation.
I.e. Use N-S longitude lines in the sky rotating in relation to vertical at North/South.

To Determine Upper Wind Direction from the Clouds

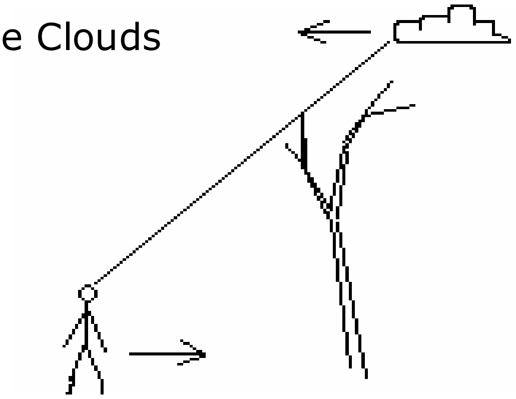

Walk in the reverse direction, while keeping a chosen cloud lined up
on a chosen high point. You must walk across level ground to be accurate.
Mark your starting point, then drag a line in the ground to mark your walking direction.
This method works well for very slowly moving clouds.

Other methods: Watch cloud shadows.
Use the Moon, Venus or the Sun (only when it is very well obscured).
Look in different directions at the moving clouds
until their motion seems neutralised—they are moving directly toward you.
Use binoculars, to magnify the movement (but never look towards the Sun).

The Sunny Skies Quadrant System

To orient yourself on a clear day...
Use the two ends of the dark blue band — where it hits the horizon — and the trend of the middle bit of the band,
in conjunction with the Sun (but don't look directly at the Sun!) and your shadow.

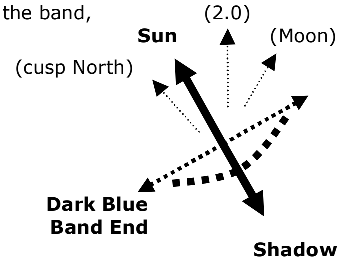

- No matter which way you are facing, you can detect one or two signs to orient yourself by,
  Or at least imagine them if you can't see the Sun just now.
  You don't have to look over your shoulder, which is misleading anyway.

The middle of the blue band is above your shadow, and at right angles to the sunbeams near you.
The whole system rotates, during the day.
If the **Moon** is up, add it into the system,
and **Moon-North** too, which is off to one side of North, and changes slowly during the day.
Combine this system with the fixed systems, of 0, 1, 2, 3, 4 and m.n., rise, a.m., m.d., p.m., set.
E.g. In the diagram, the Sun is to the left of North, so "the Sun is 'afternoon', the Moon is 'before noon'."

The Horizon Rotates to Your Right in the Southern Hemisphere

1.Face the High Noon Sun. (Imagine it, if you have to, when it is not midday.) It moves horizontally from Right to Left (S. H.)
2.Reverse your perspective — let the Sun stand still and the horizon move, from Left to Right.
Imagine the horizon sliding horizontally beneath the Sun (and you shifting sideways with it).
3.Now imagine the Sun rising from the eastern horizon — it moves up to your left — then reverse perspective...
Imagine the eastern horizon moving *diagonally down and away* from the Sun, twisting down on the right as it goes.
Face North. Grip the whole horizon on the East and on the West, and imagine a tilted steering-wheel, and rotate it around the Pole Stars. Imagine a "steer right" motion.
The invisible steering wheel faces you diagonally upwards, while the horizon, as if fixed (diagonally) to the steering wheel, starts off horizontal and then rotates out of its horizontal.
4. Keep rotating the horizon, sliding the northern horizon horizontally underneath the high noon Sun, and beyond, until the western horizon comes up diagonally to meet your now "setting" Sun.
You need to do this outside to appreciate it in three dimensions, to have any chance of visualising it easily.
So put your clock back on the Northern wall (see 5e) and say "See, we Southerners have it right, after all!
— the real movement — of the solid stuff — is clockwise"

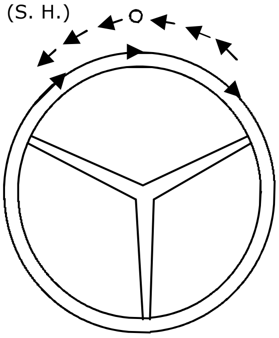

Tell the Time by the Compass Protractor — Tilt It Toward the Equator

Take a **tilted bearing** of the Sun. The answer comes back as so many degrees to one side of noon-North (or noon-South in the N. H.).
You then use 15° per hour to convert that to hours before or after noon-time ('noon' will be nearer one o'clock during daylight savings time).

Step one: align the compass to True **North**
Step two: **tilt** it upward to the 'Equator' in the sky (the Sun's average path)
Step three: rotate the compass arrow to point toward the Sun
Step four: make the edge of the compass cast no shadow
This avoids looking at the Sun
Step five: measure the degrees away from high-noon North, on a tilt

It is more accurate than using a finger-span
to measure 15° per hour
i.e. Use the compass protractor to make a 24-hour clock face
To use the compass protractor as a 12-hr clockface, see the box opposite.

1. Top View 2. Side View

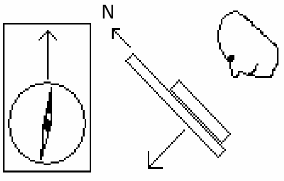

The reason for tilting is because a level sundial/upright gnomon will not give a 15°/hr linear reading (See "The sun passes quickly")

The Southwest Corner of the Great Square is N. S. E. W.

The Great Square of Pegasus only has one really good right angle but it shows N. S. E. W. perfectly.
In the Southern Hemisphere, it is the first star of the Square to rise.

Note: When you hold a star chart over your head 'East and West' reverse!

This is the view for the Southern Hemisphere…

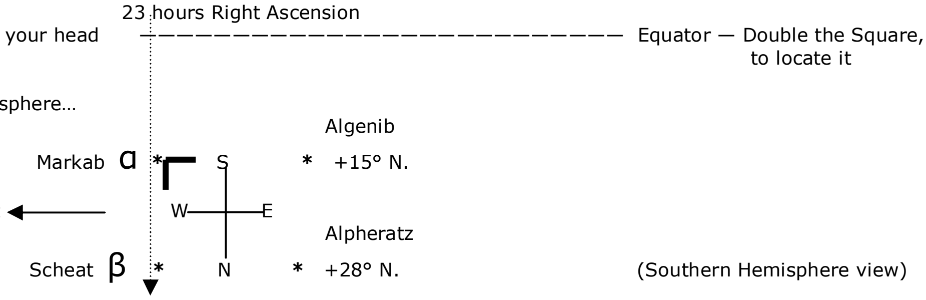

The Moon Rises and Sets 50 Minutes Later Each Night

The Moon moves quickly to the West, but…
It progresses Eastward through the night skies, night by night, by 12½ degrees a day — it 'lags' the Sun or 'moves backwards' during the month.
So that after 29½ days it is back in the same place. It moves about 27 diameters' worth East through the stars, per 24 hours or about a diameter an hour to the east in relation to the Sun. One 'diameter' is half a degree, and the same as the Sun's.
Sun, Moon, Planets and Stars rise in the Eastern half and set in the Western half, but some are quicker than others. The Moon is the slowest of all.
E.g. (twice-daily) tides get 25 minutes later each tide, on average — half a day + 25 mins apart.
E.g. the 12 month lunar year gains 11 days on the 12-calendar-month year, or "one day per month except for February, on average".
(a calendar month equals 30.4 days; a lunar year equals 354 days. Months 1,3,5,7,8,10,12 have 31 days—1½ extra; ½ extra in 30 day months)
The explanation for the Moon's "slowness" in rotating westwards with all the rest of the sky, i.e. from moonrise to moonset (it rotates only 14½ degrees per hour, not 15° like the Sun) is that it slowly revolves around the Earth to the East, in the same clock-sense as the Earth revolves around the Sun, and so must complete 13 revolutions star-wise, to the East while we see only 12 Moon months.
By the next full Moon, its backside is toward a more easterly star…
For an anti-clockwise rotation system, viewed from the North...

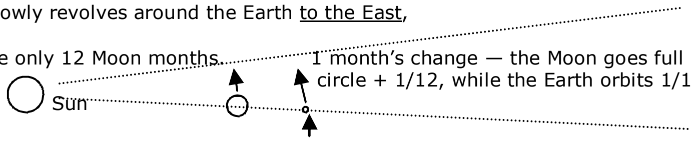

1 month's change — the Moon goes full circle + 1/12, while the Earth orbits 1/12.

Turn 90°? "+/–100° –/+10°" !

Turning right is turning clockwise; turning left is turning anti clockwise.
Clockwise **increases** the count of degrees East of North. So that requires **+100°** -10°. E.g. 257° changes into 347°
Anticlockwise, when turning left needs **–100°** +10°. E.g. 257° changes into 167°
Or use +/-10° first, then -/+100° if that is easier (near 0°). Adjust by 360° if necessary.
There is no convenient choice as there was with a back-bearing, so you must remember whether to use + or – 100°.
Remember to look at the Sun's clock-sense to judge 'anti-clockwise'
— anticlockwise in the southern hemisphere — to your left. 'With' the Sun implies – 90°
— clockwise — to your right — ('With' the northern hemisphere Sun) implies + 90°.

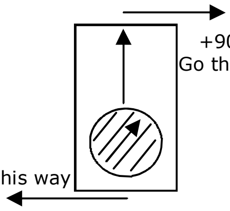

Hint: When sailing, you can always temporarily head either towards or away from, or side-on to, on the left or the right, a landmark from which you want to take a bearing, without having to change tack. Therefore you can use +/–180° or +/–90° from the boat's compass-heading. In heavy weather this means that you do not need to leave the helm to use a hand-bearing compass, but merely sight along the lines of the boat, or cross-wise along the lines of the cockpit, stern or cabin. Simply remember that the more clockwise heading is bigger than the left-hand direction

Global Perspective — Rotation of the Horizon

Each point on the horizon rotates…

- In a circle
- Around in an Eastwardly sense, like all the real matter in our anticlockwise spiral galaxy
- Around the North-South Earth rotation axis
- Along a fixed sky-latitude circle (i.e. declination circle)
- At a fixed angle of rising/setting (one or the other) in relation to the fixed stars
- Once per day

Example: The "Sugarloafs" were on the left of the Sun at sunrise, but six hours later they had moved to be underneath it, by rotating around Polaris and now, at the end of the day, they have moved way over to its right, and will keep going around for the next 12 hours of night-time.

To further help you visualise the motion, remember that the ground under your feet is twisting you clockwise in relation to the sky, in the SH, so that the stars, etc, near the horizon all move only to the left as they rise or fall. For the Northern Hemisphere use "anti-clockwise… right".

Or Judge the Time By Sight — by Mirroring the Sun Around North (To Make an Hour Hand on a 12 Hr Clockface)

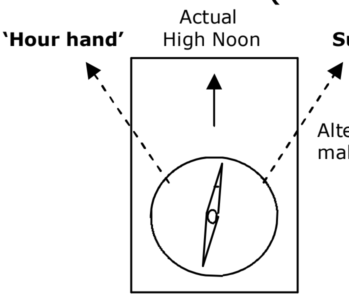

Sun = **'Noon'** position on the Clockface (i.e. ignore real Noon-North after you align the compass properly) (SH)
(Here, the 'hour hand' is showing 2½ hours until 'noon', judging it by sight)
(For the Northern Hemisphere, you have to reverse things… hour hand — Sun — South see p.28b)
Of course this method is really just helping you to GUESS!

Alternative: Line up a pencil tip with Polaris, while making the pencil cast no shadow. With your shadow-side hand, make your index finger ("The Hour Hand") touch the pencil tip, and look identical on the other side of Polaris.
You can make it work on the Moon or a star or a planet if you know when they are North/South of you.
You can make it work for magnetic noon, to avoid using magnetic variation.
It works because the Sun moves at half the speed of an hour hand,
but the doubled-angle shown, doubles that rate of change, to match a clock's hour-hand.
Don't forget to **tilt the compass**, so that its axis lines up with the Earth axis.

The Southern Summer Rectangle is Worth Looking for — since it has four N. S. E. W. guides

1. North: from Procyon, down through the Twins
2. North: from Bellatrix down through Nath
3. West to East: between Bellatrix and Betelgeuse to between Procyon and Gomeissa
4. West to East: Nath to between Pollux and Castor, closer to Pollux

(To remember the two Twins, say "Castor & Pollux, α & β, are North & South")

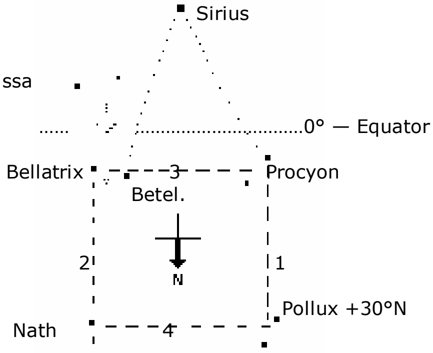

And a Triangle Pointing South

Betelgeuse, Procyon and Sirius.

Clouds and Con-trails and Their Winds

- Fog, which is cloud clinging to the ground, usually oozes downhill. Now, working upwards...
- Topographic cloud banks — may indicate e.g. the plateau edge or a mountain range. I.e. They cling to the topography.
  Also look for eagles soaring along otherwise invisible cliff edges.
- Low clouds — they follow the weather map isobars. Also look for sideslip of flying birds and aeroplanes.
  As a rule of thumb (clenched fist!) low cloud puffs are at least three knuckles wide, alto puffs are two, and cirro puffs are one, from sea level
- Middle ('alto') cloud — the puffs look smaller, the shading, less dense, but no 'iciness' seems apparent. The clouds obscure the Sun's outline somewhat. Their wind-direction is usually different from both higher and lower clouds. This wind will 'steer' low level pressure systems.
  (An 850 mb level chart helps) When a change is due, the middle clouds often betray what low wind direction to expect soon.
- High ('Cirrus') cloud — thinner; smaller puffs if puffy; icier i.e. fleecier, silky, filamentous; transparent, with halos & no shading.
  The Sun's outline remains crisp when seen through cirrus. Don't focus on the Sun!
  The cirrus-level cloud-direction in the subtropics is usually westerly +/−45°.
  Be sure to test this in your latitude. (A 500 mb chart helps) Try to catch glimpses of upper clouds through gaps in the low clouds.
- Jet Con(-densation) Trails — are usually in the high band. Look for them according to a timetable, each day.

The "SWEETHEART" Method of Orientation

We are human, and 'reference directions' are not. So make them more human, more personal, more emotional.
"Home" is not bad. "Sweetheart" is better.
Find something lovely about each cardinal direction. E.g. 'our favourite holiday spot on the coast'
Something you love or hate, want, or fear, about each reference direction…

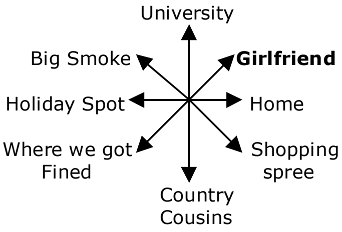

You will find it easier to maintain awareness of bends
and to interpret meaning onto the skyline — what lies beyond and behind that horizon!

During one walk, these highlights are unlikely to change direction much.

How to Shift Your Horizon — Its Timing and Height in relation to the sky.

You can navigate by the "shape" of the sky, back to a spot where you have been before, by noticing the "position" of the moving horizon.
On a round earth you can shift your position and horizon 1°, or 360°, by travelling 1°, or 360°, around the circumference. (111 km, or 40,000 km)
The line where the horizon cuts across the sky, varies with the latitude & longitude & the time of day. Using the Sun as an example…
Note: The "1° for 1°" rule for your own movement, only applies after you neutralise the other motions, so as to be as if the sky is standing still.
E.g. You need to neutralise the Sun's daily motions, by looking at the same time of day — sunrise, noon, 6 a.m., or 12:22 a.m., or whatever.
E.g. You also need to neutralise the Sun's seasonal motion by looking at the same date every year — Christmas morning, June 25, or whatever.
(Leap years can only make a difference of up to 1° — you could improve accuracy by looking only every four years.)
Rule one: for West/East travel, remember that events like Moonrise seem to happen **later to an observer further west**, and…
Earlier in the **E**ast; **four minutes of time (early) for every 1° of longitude (East).** (these rules work in both hemispheres)
E.g. "Christmas Day Sunrise at camp 4 was at 6 a.m. last year, but now I see the Sun already up at 6 a.m., so to get to where we spent Christmas last year, we would have to go further west to make the Sun lower (the horizon higher) at 6 a.m." (Assume you are at the correct latitude)
Rule two: The horizon drops to reveal new sky as you travel onwards — **1° for every 1° of travel** — this works in any direction.
E.g. "The Sun rose to 75° high, but here it reaches only 74½ degrees — so I would need to travel a half-degree toward the Equator
for it to be 75° again." (This example has deliberately chosen a North South change.)
Then you can shift your horizon, its timing and its height, by moving around the earth, in order to match a previous timed snapshot of the sky.

Walking in Phase with the Sun, Wind and Moon

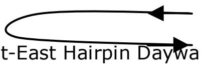

- In a hot climate, walking into the **Sun** is unpleasant, hot and glary, especially in the afternoon, especially if you wear glasses, so... Simple West-East Hairpin Daywalk.
- The morning **wind** can be very uncomfortably cold, and it is best to plan to walk away from it, too.
- Beach walks are more pleasant when you don't have to battle back into the afternoon sea breeze or prevailing wind; so assess the **forecast** before you choose a start point.
- Night walks and late camps are best done in bright **moonlight** — simply predict the phase.
- Spotlighting is the easiest on a waning Moon — since the **dark period** is in the evening, not before dawn.
- Spectacular pink full-Moons only rise at sunset, so it is best to predict such a **moonrise** and plan an early camp with a view.

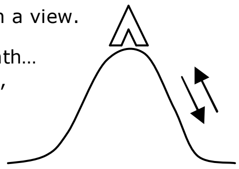

E.g. Up in the afternoon **shade**; down in the morning warmth…
Similar considerations apply to sailing—e.g. aim to make landfall in the pre-dawn. You can identify the harbour, or the coast, by its light-houses, then soon after be able to enter the harbour in daylight.
E.g. Aim never to cross the sandbar on an outgoing tide—with steep breaking waves, in shallow water, getting shallower!
Coordinate Your Route, Pace, Campsites & Timetable To the Prevailing Conditions.

Navigating by the Shape of the Night Sky

Since the star-map — the background to our view of the sky — is unchanging, the 'shape' of the sky involves only the **position of the horizon** across the background of fixed stars, and the **rotation** of that horizon with time.
The sky gives a false impression that the sky itself is spinning, but it is we who are turning upside down! It is our horizon which is changing.

Just as you can neutralise the Sun's motion by looking at the *same time every day* (which will show up only its seasonal and longer term variations) and just as you could neutralise the Moon's motion, by looking at the same phase and Moontime every month (e.g. full moon rise), to show up its unpredictable motion, so too with the stars. You must **look at the same star-time every night**. If, in addition, you look at the stars from the same spot you will notice no change at all in the 'shape of the night sky' or the position of the horizon — star motion is all predictable, with no significant variations.
This makes the stars excellent for navigation — you simply locate the horizon in terms of the heights of the stars, the tilts of star groups, and the star-time of night. E.g. what star appears overhead and at what star time.
Thus, to find that spot again, even much later, you need to make your horizon look identical at the identical star time.
CAUTION: Don't go star-navigating; rather only imagine doing so, until you become an expert. Understanding it is more useful than doing it!
All figures, formulae and theories should be checked before you trust your safety to them.

The Moon is "in Phase" with the Sun — Watch for It

The Moon progresses (12½ degrees per day) contrary to the general rotation, so…
A **new** Moon, first seen after sunset, must grow from a crescent, in the **after sunset** part of the sky, as it separates from the Sun, Eastwards, night by night, more and more so after the new Moon. I.e. a 'waxing' (growing) Moon means Moonlit evenings. After full, the Moon continues Eastwards…
A **full** Moon must diminish, to a crescent, in the **before sunrise** time of night. I.e. a 'waning' Moon leaves the evenings dark, until Moonrise, predawn.
In other words, the predawns are moonlit for the second half of the Moon month, after Moonrise. In the first half, the predawns are dark, after Moonset.
The whole night is dark in the 'no Moon' changeover of months.
During the day, you ask "Is the Moon ahead of or behind the Sun?" I.e. Is the Moon predawn (waning) or post-sunset (waxing)?
Evening spotlighting — is best in the dark before the waning Moon rises — late in the Moon month.
Night-walking—is best in Moonlight after Sunset i.e. on a full Moon, or a waxing, almost full Moon. (early-mid month)
(Think of the Moon as prouder of its nighttime role as it moves away, and ashamed as the Sun gets closer)
Highest and lowest ('Spring') tides occur on or soon after a new or full Moon.
'Neap' tides occur (when the Sun and Moon pull at right-angles to each other) at "half full Moon".
(Shallow waters introduce a lag of a day or three, due to friction and resonance effects.)

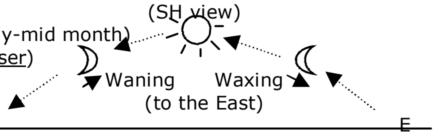

Make it your aim to see these things all happen in phase with the Moon month.

The Clock-Face Method for Direction

Quicker than 360° — it only counts up to 12! — it communicates relative directions easily.
E.g. "3 o'clock high" = "on our right — up in the sky" "9:30 from Rigel" = to the left and just above (that star)
Or, for horizontal directions, " 5 o'clock from the Sun " = looking down-Sun, and slightly to the left "six o'clock true" = South
At 30° per "hour" it is easily compatible with 360° — both are Babylonian systems.
(But don't confuse it with a 24-hour clock face, which is only 15° per hour. Unfortunately our clocks do not use a 24-hour system, which would make them nicely travel around once per day — as fast as the Sun.)
For shifting between clock face directions and 360° directions…
— First convert to or from the hour: Multiply hours by 30, for degrees. Use 12hrs=0 : 0 30 60 **90**; 120 150 **180**; 210 240 **270**; 300 330 **360**
— "5° extra" = "add 10 minutes" e.g. 255° = 0830 hrs (240° = eight hours; 15° = +10+10+10)
— "1° extra" = "add 2 minutes" e.g. 258° = 0836 hrs
When using the clock-face for compass directions, for NE, SE, SW, NW use 1:30, 4:30, 7:30, 10:30.
Translate 1, 2 o'clock as "(roughly) NNE, ENE," etc.
Don't use the minute marks on the clock-face because every 6° is not very user-friendly

Latitude without Numbers

When all you want is the latitude, the shape of the sky can tell you, without numbers, without calculations, without a watch.
E.g. 'Canopus overhead', or 'the Pot sets at 30° off vertical'.

If all you want is to recognise appearances locally, you don't need to set your Star watch to Greenwich Time, or to know a star's longitude relative to Greenwich.
E.g. 'I set my watch to the Dog Star passing North, from home last month'.

If you don't want calculators and trigonometry, you don't need to use them.
E.g. 'The sky is behaving the same as last year, we must be within sight.'

I am about to give you the star time and star longitude information, only for those who wish to work with the easiest benefits from them.
E.g. 'That must mean that our longitude is 150° E.'

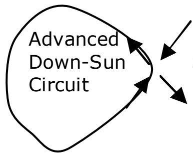
Advanced Down-Sun Circuit
Sunset
Summer
Sunrise

This Assumes Southern Hemisphere

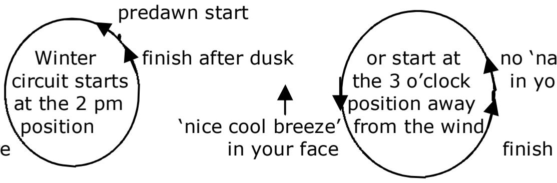
Winter circuit starts at the 2 pm position
predawn start
finish after dusk
'nice cool breeze' in your face
or start at the 3 o'clock position away from the wind
no 'nasty cold wind' in your face
finish

Note that clockwise circuits and half-day walks must alternate between up-Sun and down-Sun.

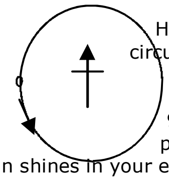

How **not** to circumnavigate a lake — from the 9 p.m. position
The Sun shines in your eyes all day!

How **not** to climb a hill — at the end of the day

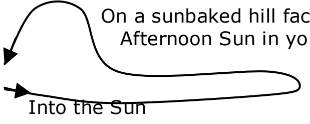
On a sunbaked hill face
Afternoon Sun in your eyes
Into the Sun

How to climb a hill

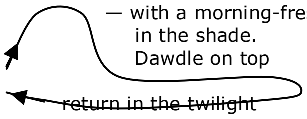
— with a morning-fresh climb
in the shade.
Dawdle on top
return in the twilight

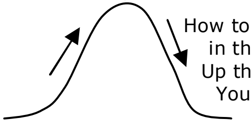

How to climb a mountain
in the outback heat —
Up the west face; long lunch on top
You walk always in the shade.

Matching Sky to Sky — Move Only Your Horizon

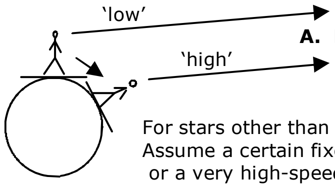

A. Move **towards** a star and it will **climb**
e.g. move toward the pole star
to a higher latitude
and it is higher
For stars other than the pole star
Assume a certain fixed star time
or a very high-speed—to stop the stars moving.

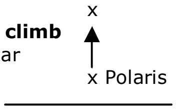

The pole star is too low

B. Move **sideways** and your horizon **tilts** with you
e.g. a star pair
may not be upright
as expected —
move sideways.
Or perhaps
a star pair
sets before it becomes upright
You need to tilt your horizon
down to the right
by moving to your right..

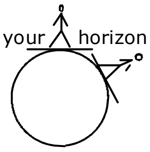

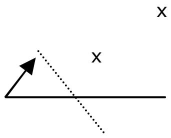

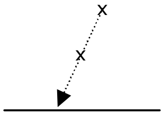

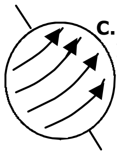

C. Because the Earth spins to the **East**, it leaves the stars behind in the West.
If you move west with the star it will slow down, so…
Move **E**ast and the stars will *get there* ***E****arlier*
e.g. 2 stars become upright too late?
You need to move easterly.

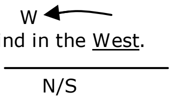

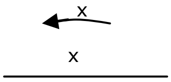

You may need a combination of A., B. and C.

Prevailing Winds on Creek Banks

One of the two Creek banks will often have a mud- or rock- cliff due to prevailing wave-action, with the other bank being a mud flat.
E.g. If prevailing winds are westerly, the west bank will show less erosion.
For more on finding the prevailing wind direction when the wind is not blowing, see section 3: "Nature's Norths".
Because prevailing wind is almost continental in scale, navigating by it is a sort of Big Picture technique.

Tips for calm weather

1. Listen for the wind! Sounds will carry better downwind e.g. surf or traffic. Remember this, at night when all else is still and quiet.
2. Watch the angle of mist droplets falling. (Stop still for this one) Or smoke rising.
3. Huff into the air to make a fog.
4. Watch the flimsiest vegetation.
5. Look at the leaves which dangle down from the topmost leaf clusters of a tree.

Mnemonic: "North; Coast"

That's what you should say, whenever you say 'North'.
"North (Coast) is over there" — it reminds you to think,
or rather to picture, the invisible picture.
You should make it your business to name the North-Coast town north of you,
before you go, by consulting a roadmap
Then of course, there is the East Coast, and the South Coast and the West Coast.
Next, of course, the same must go for "North-West"
— think of the North-West Coast township, and so on.
You are not functioning properly unless you mean something when you talk!

Go Overseas!

This is a one-off effort, so go to the trouble of getting a globe,
to sort out what is truly "East" and "West" of you,
in a Great Circle straight line.
It will surprise you what East and West should mean to you.

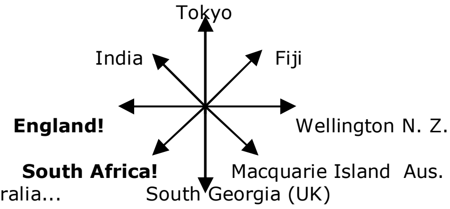
Tokyo
India
Fiji
England!
Wellington N. Z.
South Africa!
Macquarie Island Aus.
South Georgia (UK)

e.g. from Australia...

Mnemonic “The Sun Travels the Tropics”

I.e. Imagine the **tropical countries and oceans** which are **‘underneath’ the Sun** as it moves East to West during the day — The Equatorial band.
For Australia that means from Central America Across the Pacific Ocean Past New Guinea
On to the Indian Ocean And on toward Africa
When we in Australia see the Sun rise, it is past noon in the Americas. At our sunset, it is approaching noon in Africa.
See the Reference List of Tropical Places (for The Eastern Australian Time Zone) opposite. As a help to global orientation, make it your aim to memorise these time zones in sequence. Check it out with an atlas. See the tear-out clockface diagram in the appendix.
The same sequence holds for any planet, or star near the Equator e.g. for the stars listed ‘opposite the Sun’ (below), but with different timing.
You can also imagine which country the Sun is overhead while it is night-time near you,
or which country the star opposite the Sun is overhead while it is daytime near you.
Now, with this in mind name the general North/South directions, according to the height of the Sun: To the Sun = “Hot”; To noon = “Hottest”; and the Shadow direction = “Cold”; Shortest shadow = “Coldest”.
•Although the Moon, by comparison with the Sun, has a “cold” feel to it, make sure you apply the same list of hot tropical countries to it also.
When you see any Zodiacal body, you should think: “That is a Hot direction; It is over a Hot country.” and try to name the country.

Tell the Time of Night by the Star **Opposite the Sun**

Such a star will be **up all night** — whether the night is long in winter, or short in summer — look for it. Write them on your calendar.
This yields the solar time, i.e. with respect to local noontime, but not the daylight-savings or summer-time, so adjust by one hour in summer.

January	Sirius	*Castor, Pollux*, Procyon				
February	Suhail, Miaplacidus	Alphard	*Regulus*			
March	Pointers (Dubhe-Merak)	*Denebola*	Phecda	Southern Cross		
April	Southern Cross	Alioth	*Spica*	Arcturus, Pointers (R.K./Hadar)		
May	*Zubenelgenubi*, Kochab	Alphecca	*Antares*			
June	*Antares*	Atria	Rasalhague	Scorpion Sting	Kaus Australis	Vega
July	Vega	*Nunki*	Altair (Aquila)	Peacock	Deneb	
August	Deneb	Enif (ε Pegasus)	Alnair			
September	Fomalhaut	Middle of Great Square				
October	Diphda	Mirach	Achernar	Hamal-Almach		
November	Mirfak					
December	*Alderbaran*	Capella-Rigel	Saucepan	Six O’clock Stars; Canopus		

This list is arranged time-wise
the earlier stars are correct
at the beginning of the month,
the last stars, near the end.
Use each as a 24 hour-hand around the South Pole Star
The Zodiacal stars
(the ones on the Ecliptic)
are in italics.
Only they are truly opposite the Sun.
This chart is **true for**
both Hemispheres, permanently.

Two Different Back-and-Forth-Star-Directions Give You a Position Fix

..Yes, it’s just like two bearings (which are not opposite each other) from two landmarks. But because these ‘landmarks’ are so distant, the accuracy is only to within seeing distance. For better accuracy you would need a theodolite or sextant.
E.g. when two stars look upright, that locates a global star-direction; a second upright pair gives you the second direction, and a position fix.
To fix your latitude. you have to **measure the time-lapse between the two star pairs**. (Simultaneous is simplest.) So you need a plumb-line and also a watch. And for accurate (Greenwich) longitude fixing, you need to work in (Greenwich) **star-time** — otherwise you have only latitude which is fixed. So you need either an almanac, or calculator, or star-watch, or a work-it-out-at-home-later approach.
This is equivalent to fixing which star is exactly overhead and when. To see this, look up past the top of the plumb-line to ‘overhead’ from the two different directions—one for each pair—to see that they must cross exactly overhead.
The ‘fix’ is repeated accurately over years, and every night at the same star-time, with some very small predictable drift in location and timing.
No one else on earth can see exactly what you see right now. That’s what gives you a unique position fix.
People at the same latitude see something very similar earlier or later than you do.
The best two directions to cross are Northwest/Southeast and Northeast/Southwest. Top-view...
This is because East/West star directions are time-wastingly difficult to determine.
This method is most helpful, of course, at sea, or in the desert, or as a hobby, or when lost.

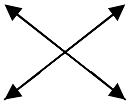

Predict the Full Moon Path According to the Time of the Year

The full Moon is **opposite the Sun**, and is near the **Ecliptic**, i.e. in the Zodiac (the Sun’s path through the stars) so that…
When the Sun is in midsummer position—high, and up for a long time—the full Moon will be in a midwinter position—low, and setting again quickly
When the Sun is in the midwinter position—short days—the full Moon will be high and up for a long time — long nights.
The two complement each other, since when one comes up the other goes down, and when one goes down the other comes up.
Both Sun and Moon are on the Ecliptic—not usually on the Equator—but, at the Equinoxes, the Sun is on the Equator, so the full Moon is too.
Near Equinox, of course, the Sun and Full Moon will rise and set in almost the same positions — East and West — and follow similar paths — about 12 hours each, along the Equator. The Equator and the Ecliptic intersect in two opposite points — the equinoctial points.
In other words, you can **use the full Moon to visualise the Ecliptic**, and to guess where the Sun is, i.e. to guess the time of night,
Or you can use the Sun to visualise the Ecliptic, and to guess where the full Moon will be, how high, and for how long.

Finding North from the Moon, by its height & phase

The Moon will follow a Midsummer Sun’s path, or a Midwinter Sun’s path, or an average height path, according to where on the Ecliptic it lies. Because the phase of the Moon is determined by its relative position to the Sun, the combination of the time of day, the phase, and cusp-Ecliptic gives you an unmistakable sense of where North should be, when you see the Moon. When you see the Moon surprisingly low in the sky, and the cusps confirm that the Ecliptic lies fairly horizontal, you know that it is somewhere near North (SH), following a low and horizontal trajectory, rather than a Moon ‘just now rising’ on a high trajectory, like a summer Sun in the East.

One Degree is about One in Sixty

1 in 60

And **n° is about n in 60**. e.g. **10° is 1 in 6** (p96a), and **6° is 1 in 10** (3 fingers wide, or 3½ knuckle-centres, at arm’s length, or ‘blink your eye’).
These are handy rules of thumb for navigators. If you use an isosceles triangle, **the rule is remarkably accurate for most acute angles**.
Example: “Oh I forgot magnetic variation! I’ve been **5° off**!! Oh well, I will simply adjust sideways.
I have come 12 km; 1/60 of that = 0.2; times five = **1 km off**”
Isosceles 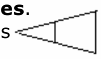
Actually 1° is 1 in 57.3 (1.75:100), predictably slightly more than 1 in 60, but as the angle increases so does the accuracy of the 1:60 rule.
The rule (n° = n across at 60 away) is based on: the third side of the **isosceles triangle** (is twice the sine of half the angle).
(If you don’t like numbers, try this other “handy” rule...)
6 (equilateral) lots of 60° 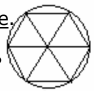
Rule of Finger: point your index finger at something — the fingernail is 1°.
Why is 1° slightly more than one in 60?...
60° r r r
Six equilateral triangles go all around the circle, but, as you know, 6 1/4 radii go around the circle.
This is because the circumference, longer than the hexagon, is 2pi times the radius, or 6.283r
one radian=57.3° r 1^c r 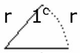
So one ‘radian’ of arc, which is one radius long, but curved, will be slightly less than 60° i.e. 57.3°.
So if the radius is 60, one sixtieth of a radian will be “one in 60”, and slightly less than 1°.
1/60 of 1^c = 1 in 60 r 1^c 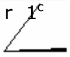
377 of them go around the circle. For 360 degrees around the circumference, the radius needs to be **57.3**.
The equivalent is ‘5/3 across at 100’ (5 at 300, 167 at 1000; above 10°) with the more exact figure for up to 10° = 7/4 in 100

Tropical Countries and Places Under the Sun — Arranged in Time Zones Relative to Eastern Australian Time — 10 hrs ahead of Greenwich

-12hrs. The mid North Atlantic (is opposite Australia)
-11hrs. Brasilia 16° Sao Paulo/Río de Janeiro 23½° S.
-10 hrs. Trinidad and Tobago 10° N.
-9 Cuba/Haiti 20° N.; Bogotá 5° N.
— Panama 8½ hrs ahead of Australia
-8 Galápagos 0°; Guatemala 15° N.
-7 Gomez 26° S.; Mexico 23½° N.
-6 Pitcairn Island — Easter Island 25 to 27° S. (L.A. 34°N).
— Tip of Californian Peninsula 23½°N; IDR Gigego 20°N
-5 Mangareva Tropic of Capricorn
-4 Tahiti 17°½ S.
—Cook Islands 11° S.
-3 Hawaii Island, Tropic of Cancer
-2 Fiji 15° S.
-1 Noumea 21° S. See pp 132f

0 Rockhampton, Tropic of Capricorn 23½° S. (Canberra 36° S.)
1 Alice Springs, Tropic of Capricorn
2 Sulawesi 0°; Manila 15° N.; Port Hedland 20° S.
3 Christmas Island 10° S.; Jakarta 7° S.; Singapore 1°N.
— Cocos Islands
4 Calcutta Tropic of Cancer 23½° N.
5 Maldives Equator
6 Gulf of Oman Tropic of Cancer
— Seychelles
7 Port of Aden 12° N.; Mogadishu 3°; Madagascar 23½° S.
8 The north of South Africa on the Tropic; Lake Victoria 0°;
Sudan/Egypt on the Tropic; Aswan High Dam
9 Namibian Desert coast on the Tropic; Lake Chad 14° N.
10 Timbuktu 17° N.; Accra 5° N.
11 West Africa coastal bulge 15° N.

Tell North from The Time By Using a Protractor

Reverse the method for telling the time from the compass protractor and North. To make the zero point North...
Make the sundial (protractor) show the correct time (one side of 'noon' time). Simultaneously make sure the sundial face is tilted to be parallel to the Equatorial Plane… I.e. For best results the tilt of the protractor according to the latitude, needs to be accurate.
Consequently, you may find it an interesting exercise to mockup a large (bigger = better) cardboard multi-protractor
— e.g. by marking the sides of a cardboard carton.
Use a plumb-bob to **accurately tilt the protractor, according to your latitude**. E.g. pin the plumb-line to the top, side corner, and mark 90° on the flat face…

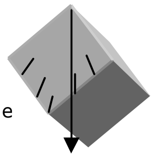

This instrument may be used to find North if you know the local time, or to find the local time if you know North.
One side of the carton is used for the latitude protractor in conjunction with the plumb-bob, a second side can be marked as a sun-dial protractor.
E.g. use another (long, straight, perpendicular) pin at the top corner of the side facing you, to cast a shadow across a 90 degree scale (— this is for accuracy, rather than make a full 180° or 360°).
Morning and afternoon then require separate scales; Winter-time requires that you face away from the Sun.

For Land-Navigation, Choose the Plumb-Line Star-Pair Method

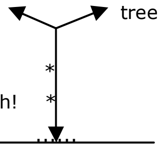

- Use a smooth constant diameter line, preferably thick. Make the plumb-line tall and stand far back. Make the cord either white or black to stand out against the sky, then maybe flash a torch onto it.
- Pour sand around the plumb, to anchor it to the ground. Avoid wind, especially if you hang the line from a tree branch!
- " Blink " the stars "on" and "off" behind the plumb-line, both on its left and on its right, by moving your head.
- Average the "start" & "finish" times. I.e. "It seems to line up now for the first time"… "definitely finished now". One accurate set of measurements is better than several rough ones. One star will gradually move over the top of the other star, and you have to pick exactly when.
- Choose well-separated stars (e.g. Rigel & Capella)
- If you want the timing to give you your longitude immediately, choose a North/South pair (e.g. Rigel & Capella) — (you need to know the star's longitude or its timing elsewhere, i.e. from a known longitude).
- An East/West pair will give you your latitude (without the need for a watch). The observation here is not the time but **whether or not** the given pair will attain to uprightness, after the first glimpse or before the last glimpse. Beyond a certain latitude, a given star pair will always remain tilted, less than vertical. This latter process can be time-consuming. Use a hand-held plumb-line occasionally, to check the progress.

Predict the Moon Phases by " N minus M "

" N " is a number (you calculate) for one particular year (e.g. For 2004 it was "24", in Australia's time zone, for the New Moon)
" M " is the month number (e.g. April is "4")
" N – M " is the day of the month for a certain fixed phase (e.g. in April 2004: 24 – 4 = 20th April 2004 for the New Moon)
April 20 was dark all night. New Moon seems to show the most regularity. The 'new Moon' is more accurately 'no Moon'.
Other phases happen one week later, two weeks later, three weeks later — 'quarter' by quarter — 29½ days for the whole cycle.
(The number, N, in 2004, would be 2; 9; 17; 24, 32 approximately, for 1st; 2nd; 3rd; final and 1st quarters respectively.) You can add 29½ to N.
Then in 2005, the number, N, for the new Moon was 13... (i.e. in April 2005, 13 minus four equals… the ninth of April — no Moon).
And in 2006 I used N = 32; 21 in 2007. The number N for the New Moon must be close to any **New Moon date + M**, e.g. December New Moon+12
Check your diary's calendar each year for the Moon phases; test and tweak a number N which works to within plus or minus one or two days.
The prediction is fairly crude, but with trial and error you can come up with *the best number and phase combination* for that year. For 2010, it is 18.
—usually **11 days less than the year before** (12 for leap year) because the lunar year of 354 days is 11 days shorter than the ordinary solar year
I.e. a good mnemonic is: **the Moon gains one day a month for every month except February** (which has only 28 days).
Hints: *Subtract " M " twice for January and February,* for more accuracy on non-leap years. Alternatively, to cope better with leap years...
Start the year in March (after the short month, February). Call January & February "months 13 & 14", but subtract 1 more for their accuracy.
Note: The "Full Moon" is when the Moon is nearest to "opposite the Sun" and it may not be exactly on the horizon when the Sun is.

Walk across Australia!

(Substitute whatever continent is appropriate)

Mentally line up a wall-poster size map of the whole continent (or bigger) with the track.
When you approach a bend, place the map on the bend, then walk all over it!
It's hard to miss the meaning of the bend if you bother to do this.
Your mind may not believe that it is not still going 'straight ahead' until you force it to catch up with the facts!

English!

"East-around" from North, is West-around from South, in a horizontal clock-sense. An "Easterly" course means East-wards — moving **to** the East.
An "Easterly" motion means East-wards. E.g. an "Easterly spin"-motion = "orbiting in an Easterly sense" = moving E around the N/S spin-axis **But**…
An "East(erly)" **wind** means flowing Westwards, **from** the East. An "Easterly" **current** might be flowing Westwards, from the East, but
an easterly tidal "set" is an offset to the East. (Set is how far the tide "sets" you off track. The speed is called the tidal "drift".)
" Due " East means "exactly" East, as when a loan is "due" — "right now!" **Always double-check what someone means**!

North/South and Noontime by **Bisection (of Rise and Set)**

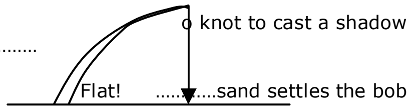

Rise and set are **symmetrical around North/South**, provided you use horizontal, and not the horizon.
In hilly country, instead of 'rise and set', you should use **equal height** of the Sun (e.g. in NE and NW).
"Equal height" translates as *equal length shadows* of an *upright*, *straight* stick or cord, onto *flat* ground…………
Or, better, use a bush sextant, p.27c, set to a fixed reading.
There are four ways to bisect two directions to find North/South — so don't muck it up by 90° or 180°!
The second diagram will work in both hemispheres — but double check the results for sense.
There are also two ways to **bisect the time** — so don't mix up 'just before midnight' with 'just after noon'.
It is also hard to 'bisect the time' to find noon, which of course, is not at 12 noon exactly, nor at 1300 hrs exactly in summer.
To work with hours, you need to **carry 60 minutes**, not 10 or 100! So be careful and crosscheck your figures.
Be accurate or your results will not be worth the effort.
E.g. rise: 0529 hrs; set: 1820 hrs Add… = 2349 hrs Halve… = 1100+(**60** +49)/2 = 1154½ hrs = noon.
Check: total elapsed time: 1820 –0529 = 1251 = 2x0625½; 0529 + 0625½ = 1154½ = correct
1820 – 0625½ = 1154½ = correct

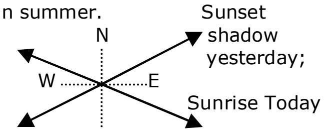

Longitude and Latitude from the Sun

Longitude...
Try timing the Sun for **equal height** each side of noon e.g. NE & NW (SH) to calculate the time of noon.
This can tell you your Greenwich longitude, provided you know the Sun's longitude, that is, its G. H. A.— from an almanac or calculator.
The Sun shifts predictably at a rate of near 15°/hour westerly. Almanacs make it their business to predict its West longitude exactly.
Of course the Sun's longitude at the time of your noon is your longitude too — since it is north of you.

Now try timing the Sun in two **opposite directions** at the same heights i.e. East and West.
You could try using the shadow of a plumb-bob on flat and level ground. Mark the shadow carefully.
This will be most accurate in the season when the Sun reaches high — in the summer sky.
By a series of early observations you can guess at when to make a final observation.
Using a theodolite or bubble sextant allows you to graph the rise & fall of the Sun (or a star) and see when 'same height again' happens.
See the 'Bush Theodolite' for an alternative measuring method.

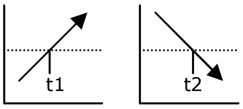

Latitude (There are easier ways!)...
You can now solve the E/W formulae for your latitude — e.g. try the formula that predicts the timing of East and West for the Sun.

Equal-Height Stars Can Be Useful When the Sea Horizon is Visible

(or with a bubble sextant)

For direction, use the mid-point, of two stars which appear to be of equal height. — a great circle direction
For longitude, the timing is the important bit. — these stars should be approximately north or south of you
For latitude, the test is whether or not the stars do attain to equal height. — these stars will be approximately East or West of you
For a position fix, try to get two pairs, one north-west, the other north-east of you, for instance.
A **bush quadrant** is easy to make with a string tied to a stick! — just pull the string to length to measure or compare star heights.
Rest your hand and chin on something solid if possible. Use your full arm's length for best accuracy.

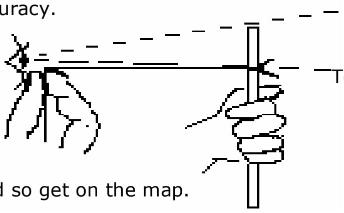

You can fix your latitude by measuring the **timing** of **two** separate star-pair events
— the relative timing — e.g. '5¼ minutes apart' (is unique to that latitude).
Simultaneous events are simplest, but separated events are easier for one person to time.
You don't 'get on the map' with this simple method unless you have been there before.
Unless you want a lot of trigonometry no calculations are required,
only the observation of re-recognisable appearances.
You can fix your longitude, too, by measuring any absolute timing — an exact star time — and so get on the map.

Anticlockwise, to the East, is Your Best Spin-Reference Direction

Because we use our North-South axis as our reference direction, we have to learn the *spin-sense* as something *separate*. See 'Orientation' p 35a.
The standard viewpoint for any spiral system (e.g. a weather system, a clock-face) is 'from the top', "**as seen from above**". Horizontal directions are measured "clockwise around" as you look *down* on them. For our spiral galaxy & solar system, the correct viewpoint is therefore 'from the North'
Looked at 'from the top', i.e. from the North, our Galaxy spins anti-clockwise. Or more simply, 'to the East'. 'Up North' is 'on the left' of East.
This means that the real motions are East-around the North/South spin axis—opposite to the familiar idea that everything sets in the West.
Because Northerners have their back to the North Pole when they see the Sun Down South of them, they see their horizon spin anti-clockwise — that is, the hills and trees on the horizon move to the left of the Sun. They are looking "from the top" i.e. from the North further South.
Their Sun only appears to move clockwise (to their right, to the West), because it is their horizon moving—anti-clockwise (to their left, to the East).
To avoid confusion, always make the distinction between real mass movement and apparent virtual rotation. And think: We spin East.
Because we think of 'clockwise' and 'right-hand' motion as 'standard', and setting "in the West" as 'normal', it's a bit of a shock, to rethink!

When you are Down Under, on the South side, looking North at the noon Sun, you see the bottom of our Galaxy, and Solar System, and Earth.
The three 'North' spin-axes are all very roughly aligned together, all lying in our "Northern" Hemisphere — not too much tilted from each other or from our own spin-axis. You mentally lift yourself further out (not "up") into space to look at (but not really 'down' on) the spiral motions
Remember that from a 'standard' (Northerner's) point of view, the Southerner's view is really "a bottom view looking upwards" — from the South half, and you have moved out further South, for a better view — with the South Polestar behind you. You should see clockwise real movements.
Turn around and look Southwards at the Southern sky and you will see as if 'from the top'—or at least 'from within', but looking South. Anticlockwise
Remember to rethink "Up" as "to the *North* Pole of the spin".

- It should now be easy for you to visualise, in either hemisphere, your Southern horizon spinning anticlockwise.
- Look also at the Moon—visualise its orbit and its spin—'anticlockwise' from N.H., but clockwise-around if you are seeing it from e.g. Australia.
- Find the bright planets — can you 'see' them moving 'anticlockwise around the Sun' in orbit? The Ecliptic marks their path.
- And, go further, visualise the real Sun spinning much like the Earth does, on its own N-S axis. The Sun is North of you in the Southern hemisphere, spinning on its own axis 'clockwise from below', or in the Northern hemisphere, South of you 'anti-clockwise from above'. Use the Ecliptic's N-S spin axis as a good guide for the Sun's, or simply use the Earth's own axis as a rough guide — Don't look at it, but imagine its sunspots moving.
- Keep going: The Earth hurtles through space in orbit around the Sun 'to the left, while looking to the Sun, around a N-S axis of spin' (Down Under, looking North) 'to the right, relative to the Sun' (NH) '**anticlockwise**, looking South' (NH)—'with' the apparent movement of the Sun, in both cases. That makes the noon horizon move in opposition to the movement of the whole Earth through space. Like the slow 'inside' of a spinning ball circling.
- Imagine the whole Earth-orbit in the sky. It's easy when you get the hang of it. New Zodiac stars seem to emerge (invisibly) on the Sun's West side, in seasonal procession, because "the Sun is edging Eastward along the Ecliptic in a yearly cycle" i.e. we move to the West side of the Sun and see behind it to the background Zodiac stars. Don't look at the Sun, but you should be able to 'see' this happening as if there were a star chart behind the blue sky! Try just before dawn.
- Now, at night-time, find the centre (thickest part) of the Milky Way near Scorpio/Sagittarius and visualise the whole Solar System orbiting it perpendicular to that, the Sun/Earth/Moon all moving as a unit, to your left (SH) or right (NH) towards Suhail, away from Deneb.

The Milky Way marks the plane of the spiralling galaxy (from which you can determine its N-S axis, tilted differently from ours).

Finding Magnetic Variation by Bisecting Rise and Set

Accuracy is needed.

Measure the compass directions of the morning and evening Sun at equal heights e.g. rise & set on a flat Horizon
Bisect the result. E.g. Rise: 079° Compass Set: 271° Compass
Add: 350° Halve: 175° Use the Opposite: +200–20=355° (See p.18e)
So the Compass North must be 5° to the East of geographic North. **Draw diagrams to avoid getting confused.**
Check all numbers! E.g. 355°–271°=084° 355° to 360°=5° + 079° more=84° Correct.

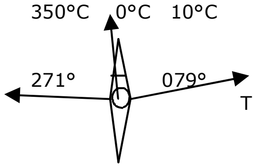

Or 271 – 79 = 192° spanning = 2x96°
79+96 = 175°
= opposite to (375 – 20)°
Correct.
The compass readings are "Least", by 5° (see p 107b)
E.g. 079°C is really 084°T. (see p 14e)

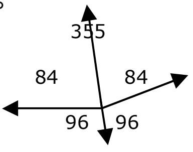

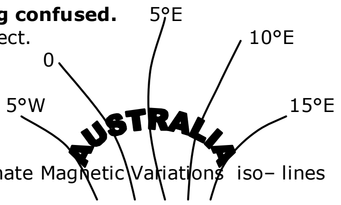

Approximate Magnetic Variations iso– lines

A Bush Theodolite for Overnight Equal Height Observations

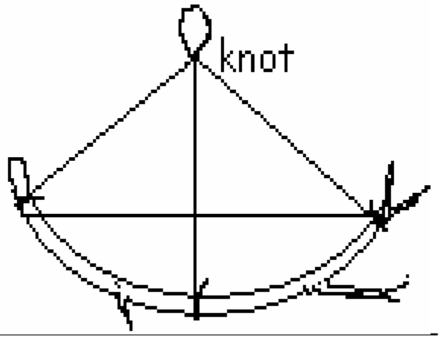

This is for accuracy in calculating... True **North**, Noon **time** and Compass **variation**
And for any equal-height paired observations — Sun/stars/etc.
Find a large bent stick. (Or bend it with a bowstring)
Hold it up by a loop-knot e.g. hang it on a twig.
(If it is early or late i.e. a long shadow, the stick will not need to be bent much.)
Late afternoon, at camp,
Mark where the shadow of the knot (or the other end of the stick) falls on the stick;
take the time; line up the landmark it points to; and find its compass direction.
Early morning, next day,
Hold it up (in reverse); wait until the shadow again falls in its proper place;
get the time, direction and compass reading again.
For a **Bush Bubble Sextant**, arrange a water filled clear tube on a triangle of lashed walking sticks so that there is a trapped bubble in a tube section with an ever so slight convex-upwards bend.
Make the bubble always stay at one marked place when you are using it.

Great-Circle Reference Star Directions

You need some familiar reference points. It's a simple matter of going out at night, waiting around, and tracking down a few of these...
Look for **stars which are closer to the pole than you are**, and see where they **rise and fall vertically**. It happens once or twice a night, per star.
This gives you a series of great-circle star directions, already labeled, because **the 'maximum latitude' is equal to that star's 'declination'**.
E.g. Acrux is about 30° from the pole, or "60° latitude". If you steered towards one of its vertical-motion directions you would end up underneath it.
So as it rises or falls vertically (once each per night, if visible at the time), as it circles the South Pole Star, it lures you to 60°S latitude.
E.g. A star overhead, as the extreme limiting case, is moving East to West, rising vertically from the East and falling vertically to the West, meaning that you are *already at* the maximum latitude of that course, if you had been heading towards that star guide, now travelling E-W also.
You then have to head directly *away from* it (e.g. the next night) to further pursue that course.
Heading away from that star either East or West would take you eventually back towards the Equator, like the way you travelled down there.
The **stars further from the pole, than you are from the Equator,** make a complementary set of reference directions, by using the horizontal direction 'at **right-angles** to where stars **rise and set**'. **The declination is a measure of *how close to the pole* you would pass**.
The stars close to the pole are unavailable. The co-declination labels 'the maximum latitude'.
E.g. Sirius is 17° South, so rising from the horizon, somewhere to the South of East, it would send you to within 17° to the left of the South Pole.
Turn around and it would guide you (part way) to cross the Equator and to within 17° of the left of the North Pole.

Make a Bush Psychrometer

..for absolute humidity and dew-point-temperature measurements

Carry a wettable piece of material — dip it in water — hang it up to dry (in the shade out of the breeze) — time how long it takes.
Measure the air temperature at the same time, and cross correlate the two, to find the absolute humidity. If you calibrate the method at home, by graphing the results for a whole range of different temperature and humidity conditions, you will get to recognise a dry air mass from a moist one.
The piece of material needs to be non-porous, non-rotting and dark coloured — to show the drying process clearly, and to yield repeatable results.
Night-time minimum temperature more or less bottoms out as soon as an air mass starts to dew. The ground then wets down further instead of cooling down further. The normal method of measuring absolute air humidity—the percentage of water vapour—is by evaporatively cooling a water drop in it. It requires wetting a thermometer bulb, fanning it vigorously (trying hard not to break it) and measuring how far you can make the "wet bulb temperature" "dip" below the "dry bulb (air-)temperature". The water temperature won't get all the way down to "dew point"—the temperature at which dew or frost will form in that air mass—unless it already is dripping wet outside. It may get a bit more than half-way, and then only when only dew is expected—DP above 3° C. **If frost is possible,** i.e. when the dew point temperature is 3° or less, **it will dip at most half way down to the dew point**. Why 3°? Well, when the air is very dry, dewing will further reduce the water vapour content of still, cold air, from a dew-point temperature of a few degrees above zero, down to 0°—resulting in 'frozen dew'. **Rule of thumb** for calculating dew-point from dip:
When the DP is 40°C/30°/20°/10°/5°/0° then add to the 'dip' 0/1/2/3/4/5 quarters of the dip, to get down to the real dew point.
If the night is long enough and calm enough to cool down enough, & the sky is clear enough, a DP near zero will result in a frost.
E.g. 15° to 10° = 5° dip, 5°DP. 15° to 13° = 2°dip, 11°DP. 19° to 18° = 1°dip, 17°½DP. (Remember that you can't go far wrong anyway.)

South is a Triply Better Reference Direction than North, in the South

1. The closest geographic Pole in the Southern hemisphere is just over the horizon in Antarctica. Globally seen, all directions pointing South are convergent, whereas directions pointing North are initially divergent, and lengthy and less meaningful... Travelling North you first cross the Equator before it gets colder — so the gut-feel meaning is less clear. The meaningful direction, when you are in South latitudes, is to go further South to get much colder. (It is the same as in the Northern hemisphere, where going further North makes it much colder.)
You may find that in a place like Tasmania for instance, the maps seem to be upside down, because although North is at the top of the map, the logical reference direction is toward the bottom of the map, where the cold place gets colder. You don't think: "This is a warm place. In which direction does it get warmer?".
As a result it is easy to get disoriented by 180°, if you insist on using North as your reference direction. In addition…
2. When you put South at the top, and look South, then the Sun will move to your right, as if seen from the N.H., across the map as time passes, for both hemispheres—and that will make the clock-to-Sun link obvious (like putting a Southern clock on the S. wall to match the Sun's motion). Northerners especially, would find that a more natural way to view any map—as if from further North, looking South, to the Sun moving right.
3. Putting South at the top, with the Sun & Tropics behind you, looking down onto a map, is the mathematically standard viewpoint — like looking from the top of the Galaxy — from North to further South — the land South of you moves Anti-clockwise, to your left, to the East.
You can still orient your map normally and correctly, but there is no law against habitually viewing it from its Northern edge, looking South. Try it.

Find East/West By Delayed Bisection of the Sun and the Full Moon At Rise or Set

To find due East (+/–10°): **Bisect the sunrise and the full Moon rise** — since they are of opposite declination.

For due West (+/-10°): **Bisect the sunset and the full Moon set** — since they set each side of due West.

Obviously, you need to wait about 12 hours for this method — it is really just for your background comfort level about where things are.
There is a slop of 5°, since the Moon's plane of orbit is about 5° away from the Ecliptic.
There is also a slop of about 24 hours, since the full Moon occurs at some time other than Moonrise or Moonset,
plus it is hard to pick an exactly full Moon, and the Moon varies in declination, i.e. North/South position, from day to day.

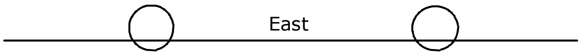

Find North by your (non-digital) Watch-Hands

Point the noon on the watch (**not the 12!**) to the Sun.
Tilt the watch axis toward Polaris as best you can judge.
This tilt matters a lot, but is not usually mentioned!

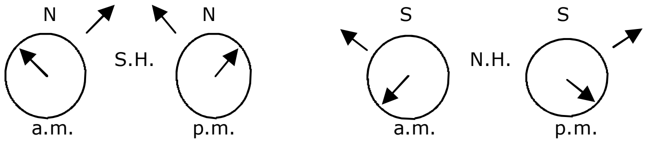

Southern hemisphere: **North is in between the Sun and the hour hand**.
Northern hemisphere: The Sun is in between the hour hand and South.
Why?: Clocks Go Clockwise; at 30° per hour — twice around per day.
For the Southern Hemisphere that means: — twice as fast as the Sun and opposite.
So 'in between' moves neither clockwise nor anticlockwise — it stays N/S. At real noon-time, the hour hand and the Sun cross over.
For the Northern Hemisphere, the hour hand overtakes the Sun at noontime, at South.
It's easy to visualise in fast motion, once you catch the idea — it's like the hare overtaking the tortoise.
Remember to tilt the watch-face up to be parallel to the Sun's orbit, not horizontal, because a sundial shadow is not linear.
You could use the middle of sunrise/sunset times to find the local actual high-noon midday time, which is needed for "point noon at the Sun".
The same method can be applied to the stars, the Moon or the planets — provided you know when the one you want to use is north of you.

Leo the Lion Looks like a Lion or Sphinx Squatting
It Has Four Lines which Show N./S. E./W.

Two in the 'hindquarters'; one along the 'back'; one as the stem of the 'question mark' (Leo's mane).
(You have to turn the '?' around.) For the Southern Hemisphere, turn it all upside down.

This is a good sign in Northern spring/Southern autumn.

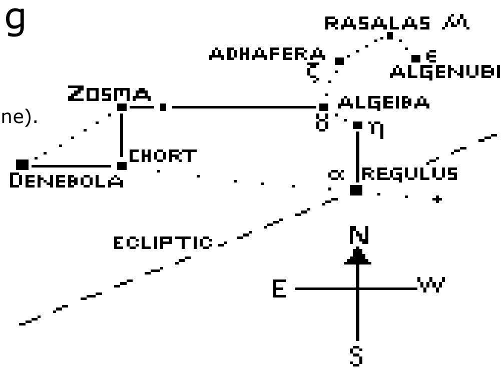

(NH view — LEO is upright)
Direction of movement ⟶

To Predict the Moon's Path, Visualise the Ecliptic

For more clues on how to visualise the Ecliptic, first see the overview at the end of this section.
The Moon stays within 5° of the Ecliptic. That helps you see where the Ecliptic should be, or alternatively,
where the Moon should be. The Full Moon is easy, and has been covered on p. 24d.
A **half-Moon,** for example, is 90° from the Sun; so if one is on the Equator the other is not and vice versa.
E.g. a half Moon in mid-winter will rise and set due E./W. +/- 5° or so.
Secondly, recall that the Earth's spin-axis is tilted 23½ degrees from the solar system.
This is how it would look from Sydney (*), at midday, in Midsummer, i.e. at Southern Summer Solstice…
The two great circles intersect at 23°½. The whole double-circle rotates West over 24 hours. i.e. sunset is at X…
To visualise the Ecliptic (see also p. 30d & 33b), from the Sun...
..Since the Sun moves eastwards seasonally through the stars you can know that
the part of the Ecliptic which the Sun was recently on must 'lead' the Sun to the West.
E.g. after solstice in Southern Summer, the most Southerly part of the Ecliptic is ahead of the Sun
to the West, and so a waning crescent Moon (to the West of the Sun) will be higher in the sky, on average, than the Sun. (SH)
E.g. A crescent Moon at sunset at spring equinox will look extraordinarily high over the sunset glow, because of the 23°½ tilt.

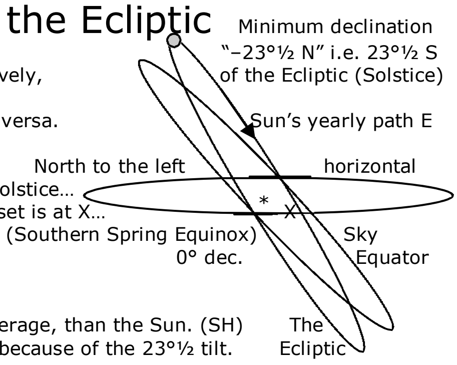

Bearings & Tracks: "If it is Right, it is Big, in my sight"

= Anything on my **Right is Bigger than 'ahead'**. I.e. If I am heading 100°, something on the right has a bearing bigger than 100°, e.g. 200°.
And "Any track on my **Left is too Little to look at**" = Anything on my **Left is Less** than ahead, e.g. 20°.
These mnemonics compare fixed tracks or directions, and their 'Big and Little' measure in degrees, East-around-from-North i.e. clockwise bearings.

[The changeover from 360° to 0° can give you trouble. Where 'ahead' was say 355°, 15° bigger should be 'big' e.g. 370° but will look really small, 10°. Because it is nowhere near 355 in number, there should be no possible confusion, provided you think of 10° as 370°.
'Little' may look really big, if 360° gets in between. E.g. where 'ahead' was 005°, 15° smaller would be –10°, which is the same as 350°, which is nowhere near 5 in number.]

Furthermore, if A sees B on his right, relative to a fixed direction, B sees A on his right,
provided that they use **acute** angles, or they look in **opposite** directions e.g. facing each other.
This could all get **confusing if you don't remember those two provisos**. See p108c for how to put this mnemonic into practice.

Find North from the Combination of the Sun and the Moon

When you are familiar with the path of the Sun and of the Moon, and with their seasonal movements, and with the Equator and Ecliptic, then whenever you see the Moon up during the day, imagine where the Sun's path lies in relation to the Moon's, and vice versa.

This gives you two concentric circles to visualise, which of course allows you to locate Polaris (at the centre of those paths), and from there, North.

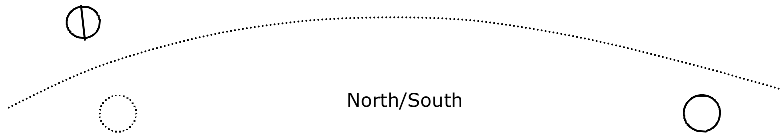

See box d/e below, to know where the Moon should be.

Find Any Other Direction Too — Using the Hour Hand

This method works, in theory (there are easier methods!), for any other body — star, Moon or planet — or for any other direction.

For instance, you may notice when the Sun is due East, and how high it is; or again, when it is in the direction in which you wish to head.

Or again, you may be following a star, and of course it will move and of course you will wish to compensate for its movement.

In these cases you substitute the time of that body being in the chosen direction for "noon", and substitute the chosen direction for "North".

Keep the watch axis pointed to Polaris as best you can judge it.

For example: you know the Sun is West at 4 p.m. At midday it will look like this… (SH version)

..**"**Point the four to the Sun; West (or the chosen direction) is between the Sun (or star etc) and the hour hand"

The catch here is that you must imagine the height of the body accurately, before the direction can be found.

This is because the method only shows the rotational position of the body — longitude wise, not its height declination wise — and with the clockface being tilted, the horizontal direction being pointed out is not obvious until you choose a height.

Of course, the accuracy of the method depends also upon aligning the clockface to the Equatorial plane.

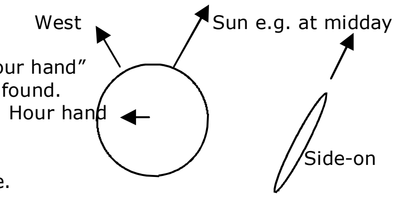

String North

Carry a piece of string, about one metre long, to **measure the angular height of the Moon, planet or star** which you intend to use later.

You measure it once, as a matter of preparation, then use it many times. The Moon goes out of date the most quickly, but the stars are permanent

Put a loop knot at one end, to hold the bottom knot, level with the horizon or horizontal. You may have to wait, until the height is clear.

Hold the string at arms' length in a vertical plane to the North-South, which is where the star will reach its highest point.

Put a second knot to show the maximum height. This is equivalent to the 'noon' height for the Sun.

For the Sun you could use the shadow, and hold the string *down* from the horizontal. It will be accurate for a week.

Better still, use the shadow methods soon to be described, to avoid the temptation of looking at the Sun.

Now at *other* times of the day/ night, first hold the string in a vertical plane to reconstruct the expected height, then hold the string horizontally from that same high angle above you. Lastly, twist and turn, so that the horizontal string apparently points to the body used — Moon, star, planet.

You have to **twist yourself until the string is *horizontal*, and at the right *height*, and *points to* the chosen body**. Then you are facing N-S.

Actually the method approximates a slightly curved small-circle star-path with a great-circle straight course.

You can find approximate North with the string, then adjust it slightly by imagining the actual star-path as a small circle around the Pole Star.

The straight string will then appear to point to just above the star, but in your imagination, it curves down to match the guesstimated star-path.

This is the direct sighting equivalent to the 'shortest-shadow South' methods on the next page.

A 4 Week *Position Cycle* of Moonrise/set, to Find East/West

The Moon, like the Sun, lies close to the Ecliptic (in the Zodiac), and completes a cycle along it (within 5°) in 27¼ days (not quite 28 days). So...

The Moon changes position in **a four-week cycle, like *a speeded up year***. It spends a week in each 'seasonal' position: High; mid; low; mid; hi...

The Moon crosses the Equator every fortnight, rising due East and setting due West that day. Find it! Use p9c to find E/W on those days/nights.

In alternate weeks it will rise & set in the Midsummer then Midwinter positions *for the Sun*. Get to know them, and expect each one every 4 weeks.

- Its change of rise/set position day to day is most sensitive near the equinox position, due E/W (be careful), and is least critical a week later.

In between times, the rise/set **positions can be guessed by the day of the week**, by interpolation, as a good direction guide on any day.

The cycle runs fast by only 1 day in 37 1/3 days. So it is a continuous guide to E/W, **for a month at a time**, as it moves through 13 Zodiac signs.

- The best way to **set your Moon-watch is by observation**. If Moon-rise/set is too late at night, then look for Moon-set/rise during the day.

Sunset Full Moon is a good starting point for estimating the nightly-cycle; Sunrise New Moon, for the daytime. Midsummer or Midwinter or Equinoctial full Moon are very good starting points, because the Moon will be in the anti-Sun position. Visualise the Ecliptic (through the Sun and perpendicular to the Moon cusps joined) and its shape in relation to the Equator, and use a compass. Say the full Moon is opposite the Sun on Saturday, but by Monday the Moon sets due West. Every Monday for *up to* 5 weeks the Moonset will be in a recognisable position. E.g. W, N-W, W, S-W, W. On a later Monday, you will need to step back one day and say "every Sunday, for five weeks" the Moon will repeat those four positions. Adjust yourself by one day, *as it shows itself necessary*. You can simply say "It is a Thursday Moon at the moment", expecting to have the change to "a Wednesday Moon" in a fortnight or 2. Keep your finger on the Moon-pulse to keep up-to-date. E.g. Say: "It's a Spring-type Moon next Tuesday".

- To keep track of the weeks, here is a recipe: **Call the new year e.g. 'a Friday Winter Moon'** and adjust 1 day every 37 days, 10 days over 1 full year, or by **4/5 of the completed months**. 7, 8, 9, 10 days for *after* 7-, 8-, 9-, 10-ber, using the Latin names; 0-7 days while *in* the rest, 1-8.
- Perhaps you lose track of a 'Wednesday Moon' for a couple of months, and try to start again. Track the Moon's Motion along the Ecliptic.

The Moon overtakes the Sun at No Moon, gets one season ahead of the Sun within a week, at 'the first quarter', is opposite it in another week ('full'), and is one season behind the Sun in the 3rd quarter. There are 12 and a third months in a year, so the Moon is moving 12 1/3 times more quickly around than the Sun, in its seasonal cycle. **What takes the Sun one month will take the Moon only 2½ days**. (31=2.5x12.3).

Step 0: Visualise the cycle. — I.e. imagine where the **lines** of the Ecliptic and Equator must be in relation to the Sun and Moon.

Step 1: Place the *Sun* on the Ecliptic — I.e. estimate the time of year, and from that, the time before/after the next/last **solstice/equinox**.

Step 2: Try to **visualise where on the Ecliptic the *Moon* must be**, according to its phase.

Step 3: **Interpolate for the exact phase**, and label it a 'Monday Moon' or whatever. Check your guess with a compass if possible.

E.g. There was an eclipse of the Sun on Tues July 22 2009, 1 month after solstice. The 'Winter Moon' must have been 'Sat night'; and for 2009 'Mon'

E.g. 23 November is one month before the SH Summer solstice (2½ days worth of Moon motion through the stars). You can work out, for any phase, which phase and position to expect in 2½ days. For instance, Nov 23 is late Spring, almost Summer, Southern hemisphere (with the Sun South of the Equator and moving further South). The Sun is high and getting higher. Opposite that, is a *Full* Moon position (North of the Equator moving further N). It stays low in the N, getting lower. Or if it is a '*First–Quarter* half-moon' at that time, it will be in the 'late-Summer-almost-Autumn' position (approaching the Equator from the S, midhigh in the sky). Or if the Moon is a *third quarter* half-moon, it will be in an 'almost Spring' position (approaching the Equator from the N). You would therefore know that, taking the last example, over the next 3 weeks, a Waning Crescent/ New Crescent/ Waxing Gibbous/ Past-Full Moon, will rise E/SE/E/NE, and set W/SW/W/NW, in approximately 2½/9/16/23 days.

Sun Path Norths — Summary

- Noon-time: You look at your watch to see how far the Sun is away from apparent-noon-time, then look at how far your shadow must be from shadow-South. Near noon, the (untimed) shortest-shadow methods below aren't accurate, but this timed method can fill in the gap.

- Chord bisection: This works for any body e.g. the Moon.
- Sundial methods: You set the sundial to the right time. E.g. tilt the compass protractor to the equatorial plane.
- Shadow bisection: This can work for the Moon too. Just remember to use a vertical stick on level ground, e.g. a dry puddle.
- Equal-height: You can use an improvised sextant/quadrant/bubble sextant. Don't forget to bisect both the time and the direction, carefully.
- Sun at East/West: You need to be familiar with the height &/or the time when the Sun is East or West.

- Equinoctial sunrise/sunset: You keep track of how far off East/West the sunrise/sunset is, at this time of year.
- Equinoctial rise/set angle: You can extend the Sun's path to noon, rise or set, in a straight line, using the latitude angle.
- Equinoctial East: Where the shadow moves to, with slight adjustments at other times of year.
- The Noon-shadow path is always to due East. This is useful for anytime *near* noon, say +/- 2 hours.
- When the Sun is *very high* near noon, you *need* to see the direction of movement of any point shadow on flat ground — West to East.

Locating Anti-sunrise or Anti-sunset

Imagine a line from your head-shadow, *opposite the Sun's path*, cutting the horizon at the correct rise/set angle p.9a. (The Sun's path is approximately a great-circle, so now imagine a plane, edge-on along that line, cutting the level ground. Look for where the shadow would be closest to you. This approximates the Shortest Shadow South…)

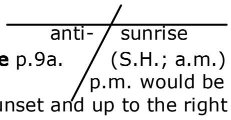

(S.H.; a.m.) p.m. would be anti-sunset and up to the right

Shortest Shadow Souths ..from calculating, memorising or knowing the angle of high noon shadows.

• Walking-Stick North: You lean your walking-stick, so that at noon it would cast no shadow, and so that right now it casts a shadow at right angles to itself, a direction which is nearly West-East. Adjust (all these methods) slightly for the season, afterwards.

• Body-shadow South: You use your own shadow tip joined at right angles to your shortest-shadow tip (guess at its length and position). This works best in the early morning and late afternoon, where a guess as to your shortest-shadow is sufficient.

• Cardboard Triangle East/West: You cut it to point to high-noon height, like the walking stick & body methods combined.

• Plumb-line North: You tie a string triangle instead, to the right shape, and maybe attach it to your walking stick.

• Notebook North: You flip open one page from horizontal, so that it casts no shadow, and also points straight to high-noon height simultaneously. I.e. the page should be held at the correct angle, mimicking the Sun's maximum height.

You can discover the correct angle by observation, yesterday,
or you can calculate that angle as "latitude degrees minus declination degrees away from vertical"

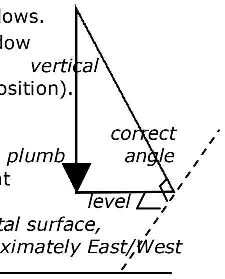

on a horizontal surface, perpendicular is approximately East/West

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"Star-Time" Gains Four Minutes a Day

3 minutes 56 seconds actually, by appearances; (3m 56.555s if you use the almanac, and 'the first point of Aries', because "Aries" as it is known for short, is not a real star, and it drifts slowly through the Zodiac)
Stars complete one extra orbit — 360° — than the Sun in one year — 366¼ in 365¼ days — so that's about 1° per day which is 4 minutes of time.

By "time" we mean Sun-time "15° per hour on average", in ordinary usage — a slightly varying rate in practice.
By "star-time" we mean "15 and a bit degrees per hour spin rate — a constant rate"

The stars outrun the Sun, night by night, by 1° on average, so the Sun seems to migrate 'backwards'—to the east—through the Zodiac belt of stars.
You could say: **"The Sun drags its future after it!"**, meaning that the Sun sets in the West, but its future star-position shows up just to the East.

You can zero your star-time, by timing when a bright star (preferably one near the Equatorial belt) passes overhead, or north or south of you on a particular night from a known particular longitude. You then calculate star-time from "Sun-Time plus 3m56s per day since then" including part-days in your detailed calculation, at a rate of 10 seconds' time per extra hour — 1 second per six minutes.
Your reference longitude becomes like Greenwich to you — or, alternatively, you can adjust everything back to Greenwich longitude and Greenwich star time. You can also buy quartz controlled star-watches or calculators.

Adjusted Moon-Cusp North: To the Left or Right, By Moving the Sun

"Cusp-North" can be improved, by mentally moving the Sun away from the Ecliptic *onto the sky Equator*. Do the adjustment once a day. Guess the declination of the Sun, from the season; then shift it onto the nearest bit of the Equator and the Sun-to-Moon illumination angle may tilt a little.
Instead of pointing to the pole star for the Ecliptic, in Draco, the new cusp-North will point more to the pole star for the Equator — Polaris.
E.g. the midwinter Sun needs to climb 23½ degrees higher — which would tilt the cusps of the Moon (due to the shift in illumination). Diagram 1.
Caution: The illumination angle of the Moon does not change much when the *Moon* is shifted onto the Equator, and not at all for a half-Moon.
E.g. a half Moon (90° from the Sun) at Equinox could be adjusted by 23½° to bring it onto the Equator (It is like the Sun at Solstice), (diagram 2) but cusp North does not change. Being 90° from the Sun the cusps outline one and the same great-circle.

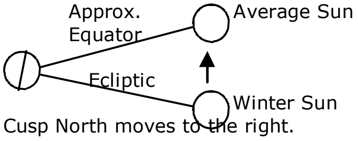

Cusp North moves to the right.

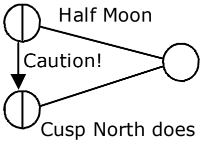

Cusp North does not move to the right.
Beware of perspective tricks

For the Southern Hemisphere looking into the sky…

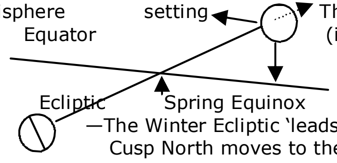

The Early Summer Sun (it also creeps east — 'backwards' — along the Ecliptic)
—The Winter Ecliptic 'leads' the Summer Sun.
Cusp North moves to the left.

"By the Nose" Navigation

Our Mental Map is a Nose-Eye View — not at all like the bird's-eye-view given by a layout map. (See "Strip Map Navigation" p.95c)
Oh yes, our mind eventually fills out a (spatially-solid) layout map, but initially we collect a set of (spatially confused) mental photographs from all different perspectives taken from ground level. Our mind doesn't deal in map symbols or contour lines!
Rather it has search images, image enhancement, image recognition, three-dimensional images, and memorised **relative angles**.
Consequently, a more natural method of finding your way is what I call 'Nose Navigation' — almost opposite to mapwork.
Nose navigation uses 'strip maps' (Section 4), relative angles, and a couple of special mnemonics…

"Because (my shadow) seemed to shift right just now; Therefore *I* must have turned left"

Now substitute in the (…): Ayer's Rock/Uluru; That distant cloud; The Sun; The Moon; Compass Needle; East Wind; The RDF Null; That bright star
In other words: "My Nose Turns EVERYTHING Away!" i.e. when I turn my nose, everything else seems to turn oppositely.

This simple rule attacks head-on your insistent illusion that you have been walking "straight" ahead!

And your illogical belief that "Ayer's Rock has moved"! Neither has your shadow 'turned right' just now, simply because your nose 'hasn't moved'!
It is not as easy as you think to apply, e.g. when you are reenacting where you thought you had gone, in your (already confused) head.
The second nose mnemonic is on the opposite page.

Seasonal Adjustments For Equinoctial East

Shadows move due East at Equinox, all-day. At other times of year, when sunrise/sunset is not due East/West, the Shadow path curves slightly at an angle away from sunrise/sunset, an angle which you should become familiar with each week. Start by assuming that the shadow is moving "East"… Verify this **Rule: Shadow Paths Bulge toward the Hot Pole**, even in the tropics, in both hemispheres. (The Sun crosses at Sept 22 & March 21.)
Adjustment: The first guess at **"Hot Pole" Needs to be Adjusted Slightly,** less near noon, little or none nearer equinox, to "un-bulge" the path.

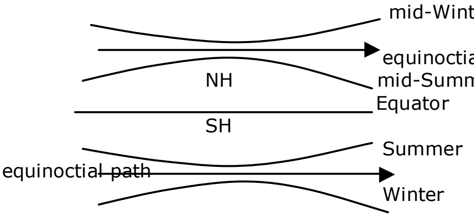

Remember that "the Southern Sun Sets Somewhat South in Southern Summer", so that opposite-Sunrise & opposite-Sunset need to come back South to point out E & W correctly
E.g. You guess East (or West in the a.m.) from the shadow's movement over 1 minute,
(It will roughly be opposite sunset/sunrise direction if you are late/early in the day)
then twist your guess a little back to the true hot pole, and to due East (or West).
Let's say it is midwinter in the Southern Hemisphere, so your shadow is somewhere S of you. The 'hot pole' is the North Pole, so twist 'North', as gauged from your shadow tip, away from the shadow, back toward you (i.e. North, to the hot North pole)
Visualise the bulge, then straighten it out at each end, back toward the hot pole.

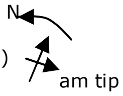

North-Finding from Two Paper Triangles

or even from only one

Cut out a back-to-back triangle shape and fold it along the join. Line it up as shown and 'N' will point to Polaris…

'1' is your South **latitude** (For the Northern Hemisphere use the North Latitude and swap N & S)
'2' is the **polar distance** of the Sun (from the 'depressed' pole, N)
i.e. its co-declination, or 90°-N dec. See p. 18b.
You can set it by observation or calculation; and can fold it to the correct angle, rather than cutting it.
('3' is a right-angle, but '1' and the horizontal is what really matters)
This two-triangle method works best away from noon, but nearer noon simply find the way shadows move
The 'N-S' edge is parallel to the Earth's axis and acts as a hinge around which the Sun revolves.
Sun and shadows move at right angles to that axis.
You only need **one** of the two angles if you find the direction of shadow movement
and swivel 'N-S' to be perpendicular to that. (You don't even need one angle, near noon)
E.g. Poke a straight stick into the ground, pointing at the Sun, casting no shadow; (Or use any point-shadow rotating around its point)
By waiting a short while, find the direction of movement at a half-way point, in mid-air, i.e. maintaining an equal distance to the tip,
and manoevre your 'N-S' axis (index finger), to be perpendicular to how shadows move, then at the correct angle to the Sun and/or Horizontal.

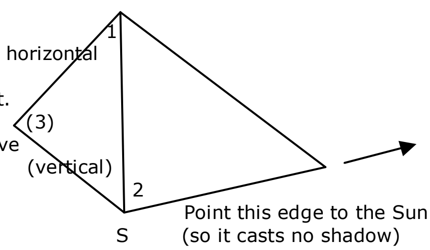

Point this edge to the Sun (so it casts no shadow)

Working the Star-Longitude Numbers

The reference star point, a non–star, is 0°N/S;0°E/W, and is called "The First Point of Aries" or "the Vernal Equinox" where the 'northern spring' Sun crosses the ecliptic (on March 21). Other stars are measured from that (imaginary) star, like latitude and longitude are measured from 0,0 a nameless spot of ocean — each star has an almost fixed longitude in relation to Aries.
N/S 'latitude' is called +/- ' Declination '
E/W 'longitude' is called (a) Right Ascension — R.A. — or 'Star Time' — It is measured **Easterly**, in hours at 15° per 'hour', from "Aries"
Or (b) Hour-Angle — H.A. — It is measured **Westerly**, in degrees, like longitude, but 360° around, from "Aries".
The first, RA, is designed to tell us the time — **when** the star will show — since all the stars move around westward with Aries.
The second, HA, is designed to track the West **longitude** of the star in reference to the Earth, as the star progresses West around.
We need them both, but they are entirely equivalent to each other.
(The only trouble is that a star 'hour' of 15° is slightly faster than a Sun hour of 15° of progress to the West.)
Next you need to know that the first point of Aries was at 100° W. Earth longitude at the beginning of the millennium,
and at every turn of leap-year thereafter, at January 1.0 (midnight). Then it gains at a rate of 1.002737909, or about 1° per day on the Sun, (3m 56s time), so that the stars turn full circle during four seasons. "1°" is adequate accuracy in the short term for us but not for yacht navigators.
E.g. January 31.5= 100+30°+0.5° W., then you add the H.A. (or subtract 15 x the R.A. hours) for a particular star — that's the longitude where the star will be overhead. **For exact numbers consult an almanac**, but I am concerned here with giving you an overview.

Topographic-Level Winds

This is what you feel in your face at ground level, or close to it.
Fog; Smoke; Valley Winds; Sea Breeze; Eddies; Catabatic Winds; Forest Winds; Scree-Slope Winds; Mountain Winds; Glacier Winds; Lake Winds.
The various thermal winds listed will of course be very variable. The thermal winds flow from cooler areas, before rising in the warmer region.
Nevertheless they may betray the slope of the land, for instance at night. For example, fog forms on calm cold nights then drifts slowly downslope.
Being dense, fog will drift down-valley, down-stream, and off-shore. You can see the location of creek outlets from the early morning beach fog.

The ground-winds due to pressure systems, are affected by overall friction and therefore average out slower and less Sun-twisted than upper-winds.
Ground-level winds form waves, foam 'streets', sand ripples & dunes, drag marks, snow ripples & drifts, which all may persist beyond the winds, and they cause lopsided bushes and salt-spray-'cut' bushes. See Section 3 for more details.

Gusts are at different directions to lulls since upper winds penetrate to lower layers.

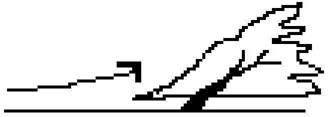

"Nose-Navigation Needs an 'Anti' Mnemonic": "Nor-West, Not-Least"

N.O.R. West: "North **on Right** = Going West" or "Needle on Right = Going **West**" i.e. going into the westerly **half** (top diagram)
N.O.T. L.East: "North **on the Left** = Going East" or "Needle on the Left = Going **East**" = to the easterly **half** (bottom diagram)

This is always true when you are relying on "Needle North". **You don't have to think any further.** But,
It is equivalent to ANTI-CLOCKWISE BEARINGS, which you can't read from a clockwise-marked protractor!
The following numbers refer to an ordinary compass — marked clock-wise, and set to 0° as straight ahead
(not North) so North swings left and right instead…
Example: in the rain or fog; the needle swings meaninglessly
Example: deep in a cave network
Example: on a yacht, with a fixed hand compass
Example: with a fixed car-compass, not marked anticlockwise
Example: making a strip map; or using one
Example: using a compass-holder, which fixes 0° as straight ahead

The compass needle might point to "045° NE"
but your nose is pointing NW

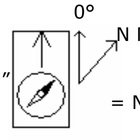

Needle on the Right use "NORWest"
= North-West N045°W

The compass protractor numbers say "North-West, 315°"
but your nose is pointing NE
Interpret "Anti-clockwise, West from 0"

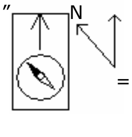

Needle on the Left use "NOTLEast"
= North-East N315°W

Revision, Overview and Explanations

Top Down Orientation

The Big Bang **Universe** bloated over billions of years; and broke into bubbles of turbulence; all bits in each bubble orbiting each other; in millions of galaxies, with 20 or so galaxies in our little **local cluster**;

Local galaxies, like the Magellanic Clouds or Andromeda, glow milky (just as 'galact-ose' says 'milk-sugar').

Our galaxy is a great spiral, swirling slowly, anti clockwise from above i.e. Eastwards around its North-South spin-axis

— flat like a fried egg — a 'great circle', glowing as the Milky Way. The thickest milkiness, in Sagittarius, marks the Galaxy Centre.

The Milky Way is like the 'Equatorial plane' for the whole spiral, seen from within, with its northern pole star in 'Berenice's Hair' (28° N. 168° W.) and its Southern pole star in 'Sculptor' (28° S. 348° W. 012° E.) and our milky galaxy is, in its own turn, full of spinning, gyrating gyroscopes.

You know how a spinning top will pirouette with a slow-motion gyration when it tilts slightly? Well, precession, as it is called, causes slow changes.

Stars are Suns, especially shiny in our own spiral arm of the galaxy (i.e. closest) and seemingly set solidly in space by their extremely slow motion. So the constellation shapes are chartable for centuries. Their apparent positions are gridded out in relation to the first point of Aries, which in turn is fixed each year by our Northern Spring Equinox—not a star in the sky, but a point which creeps along the Ecliptic, to the West.

Hint: When you are wondering whether a rule holds in both hemispheres or not, ask yourself whether you are down at the level of the spinning Earth or up beyond that in a larger scale. Try to imagine looking at the whole globe from an outside perspective. E.g. the appearance of the Moon — its phase, eclipses, tidal forces, etc — is mostly independent of where we look at it from Earth — and will be the same for both hemispheres.

But it's apparent path — 'noon' direction; rise/set angle; etc — is seen down at Earth level — it changes with the hemispheres.

Closer to Home

The solar system is also spinning flat, anticlockwise, but slanted — tilted like a top, in relation to the Galaxy, and faster.

Its 'top' star is currently in Draco, in the North. Its bottom star, in the South, is the larger Magellanic cloud.

Its 'Equator' is called the 'Ecliptic' — marked by the stars in the Zodiac, and the planets. In our lifetime we won't notice the Ecliptic stars change.

Our Sun circles the centre of the galaxy every 225 million years—heading toward Suhail.

To our sight, because we orbit it Eastwards, i.e. around its N/S axis, not ours, it swings seasonally, and also edges Easterly along the Ecliptic circle, revealing new zodiac stars to the West of it, and placing itself diametrically opposite a series of anti-Solar stars,

so giving us a star calendar to look for.

It also spins easterly, on its own axis, showing its sunspots for some days at a time.

The planets lie planar, 'wandering' (as the Greek word plan-et says), in the Zodiac plane, circling easterly around the Sun, over a timescale of decades, and only ever seen very close to the Ecliptic.

Mnemonic: Son, my very earnest mother 'as just served us 19 platefuls. Sun, Mercury, Venus, Earth, Mars, asteroids, Jupiter, Saturn, Uranus, Neptune, Pluto.

The earth is an inner planet, **circling the Sun**, easterly, so that the stars seem to out-run the Sun in setting West — star-time spins more speedily than solar time. Planets closer to the Sun than we are, are never seen far from the Sun, but outer planets can move right away from it.

The Moon

..moves mostly on the Ecliptic but might miss that mark by as much as 5°. This 5° slant causes a precessional change taking 19 years to cycle.

The Moon moves around the Earth monthly in an easterly ellipse,

and ever eyeing us, each full Moon, is the Rabbit, because the Moon also spins easterly, on its own axis, exactly once a month, so it stays facing us.

The Moon moves slowest to set Westwards, since it migrates eastwards in the sky each day. 12°½. Or **50 minutes later per day**.

And as it pulls the tides with it, they too are later each day, almost an hour, on top of normal locally fixed delays due to friction.

A full Moon rises and sets fully opposite the Sun, give or take 5°.

The Moon is most responsible for tidal forces, but the Sun plays some part too, reinforcing or diminishing the Moon's effect and changing the timing.

Tidal force attracts the nearest water the most, and the farthest water the least, resulting in two tidal bulges...

When the Moon is eccentric from our Equator, there is one big Northern bulge every 24 hours,

and a smaller high tide every 24 hours, as the Earth spins through the bulges.

There are equal bulges every 12 hours on the Equator. In between are the low tides, every 12 hours.

You should be able to tell which bulge is 'nearest' the Moon despite delays due to friction.

Southern latitudes will have one big bulge every 24 hours, and one 'small high tide' every 24 hours, offset by 12 hours from the NH.

Try to correlate the Moon's phase, declination and height with the local tides—timing, inequality, range—e.g. "The Full Moon rises with the tide"

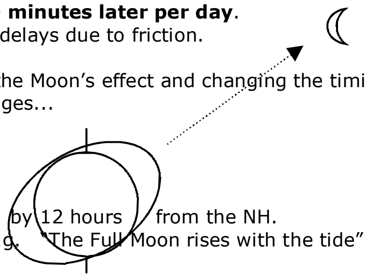

The Moving Horizon

Since it is the Earth which is spinning, not the Universe, it is **the horizon** which rises, in the West — where it eclipses the Sun,

so that the Sun only seems to set in the West.

The horizon slumps in the East, so that all the sky things — Sun, Moon, planets, stars — seem to 'rise' in the East.

Any spots on the Northern half of the horizon, circle to the east around Polaris — clockwise through the sky — i.e. 'seen from below'. Or, seen from above, that is from the North, looking South, spots on the Southern horizon circle anticlockwise around South Pole Star i.e. seen as if 'from the top' looking down on the Earth and its South Pole star. They hit the same stars each night, at the same angle, which is related to latitude,

so that the fixed stars none-the-less seem to trail 'small circle' tracks through our sky, and they always hit their favourite horizon spots when they set, always at the same angle,

and those same stars will rise later in mirror image to that around North/South, giving rise to **north-south-east-west finding by bisection**.

And Equatorial stars will rise/set due East/West.

The southern-hemisphere horizons move to the right, the northern-hemisphere ones to the left. Looking South though, from either hemisphere, it will be seen as the horizon circling anti-clockwise around the South-pole star. How come? Well, the southerners see the bottom of the star-circles, around an elevated pole-star, the northerners see the top of the same circles, around a depressed pole-star.

The Spinning Earth

The earth is **spinning like a top**, on its own axis, easterly, half as fast as a '12 hour' clock.

This gives us **the single most dominant direction clue on the otherwise uniformly round Earth—the North-South spin axis of the Earth.**

Spot its Equatorial Plane by the Pot. The 'top' is always pointed to Polaris. Spot the South Pole Star by the Seven Superstars surrounding it.

The spin generates a magnetic core more or less North/South — Find magnetic North in far northern Canada.

The magnetic field poles generate auroral displays, anywhere near the poles.

The earth is also tilted like a top, at 20 odd degrees.

The tilt gives rise to seasonal Sun height shifts, somewhat like a sinewave (just imagine the Earth's tilted spinaxis not changing as we orbit the Sun) and it turns on un-twinned top-of-the-tide bulges, twice in 24 hours. The Pole Stars are latitude° down/up @ 0°/180° T.

Any tilted top will precess the equinoxes — this generates a precessional gyration of 26,000 years,

but this time, retrogradely, i.e. to the West, along the Ecliptic (3° in 200 years) — i.e. the stars 'move' to the East through our star-map-grid.

Longitude has a lot to do with spin-time, seen from above the spin-axis. E.g. West longitude is how long after Greenwich, a place meets the Sun.

When we want to mark the apparent place of the Sun in the sky, or anything else, at any particular time,

we can just record the latitude and longitude of the point on Earth directly 'under' it i.e. closest to it.

But visualising that in reverse, we simply **project the Equator and poles, latitude and longitude up onto the heavens to grid them out**.

Time is counted in cycles

The larger the distance scale of any motion — pulsation or precession, orbit or rotation — the larger the time scale of the cycle of change.
The Universe has been expanding its size and condensing its matter for many billions of years (and perhaps it will not 'cycle') It appears static to us.
Geological history spans billions of years, like the existence of our spiral arm. In our lives we see only a frozen frame of our spiralling Galaxy. It cycles, but we can't see it. The timescale of the rotation of the galaxy is in hundreds of millions of years.
In our lifespan we see only the slightest change in relative star positions, through telescopes, due to the 'proper' motions of the nearest stars.
It is in the nature of spiral turbulent motion that the larger rotation replicates itself in the smaller scale, but at a faster rate.
Each of the components of our solar system are also rotating and orbiting in the same rotation sense as the Galaxy. (Uranus is an exception)
For example, the Earth is rotating eastwards, orbiting the Sun eastwards, and has a Moon rotating eastwards and orbiting us eastwards.
"Anticlockwise, as seen from the North" is the single best spin you can put upon all that you see—including the N/S Earth spin-axis as 'the single best direction clue on our spherical Earth'. The tilt of the Earth's spin-axis gives us the year, and the Moon's orbit gives us the month, independent of our rotation. The Earth's rotation gives us our day. Star time outstrips solar time slowly. The Southern Cross clocks it correctly at the close of March, and the Centaur soon follows. The first point of Aries gains a touch over the stars, migrating 50 seconds of arc along the Ecliptic per year. The vernal equinox arrives 59 seconds late for its 366th "orbit", after 365 days, requiring 24 leap years in 100 years. 365.242 days per year.
Atomic time, used for astronomy, is independent of all these tilted rotations, orbits and precessions, which are all independent of each other too.

The Precession of the Equinoxes

The actual or 'proper' motions of the stars are only of cosmological interest, because they change relative positions only over centuries.
But history, actually our slowly gyrating Earth-spin axis, rewrites our star charts (**im**properly, as it were) with precessional revisionism, so that stars 'move' slowly easterly through our star-map-reference-grid—an Earth-centred way of seeing the sky — with 26,000 years needed to complete a full circle precessionary Earth-wobble. This artificial motion is called "the precession of the equinoxes"— which means that our reference grid readjusts just as quickly as our earth axis of spin precesses — by five arc minutes in six years. That's why we need an almanac to predict the 'fixed' star positions!! A good analogy would be the slow drift of the north magnetic pole, **if** we set our latitude and longitude by it — that would yield a false or 'improper' 'continental drift' in addition to the proper continental drift. See the appendix at p. 123.
To visualise the Ecliptic, consider the Equator in the heavens to be geostationary, although invisible, but the Ecliptic to be like a sinewave moving daily to the West along it, on the video display unit of the sky—as on a cathode ray oscilloscope—with a period of 24 hrs & an amplitude of 23°½.
The Sun appears fixed somewhere along the Ecliptic, creeping 'backwards' on it (against the setting sky)—to the East—during the whole year
To visualise the precession of 'the Equinoxes', imagine that *the points where the Ecliptic sinewave crosses the* Equator (the x-axis), move 'forwards' ('with' the setting sky) — to the West, very very slowly — during the millennium. At the moment these 'equinoctial points' are between Regulus & Spica (the Autumnal Equinox), and between Diphda & Markab (the Vernal or Spring Equinox, or the 1st point of Aries, (0,0) for the stars).
You might say that the Sun and the Moon and the outer planets all move West through our sky but East through the starry heavens.

Global Weather Patterns

The spinning globe makes the climate zones, and weather belts, follow the latitude bands. When the wind tries to blow, from a High, into a Low, in the Northern Hemisphere/Southern Hemisphere you see huge anticlockwise/clockwise spirals instead, by Coriolis force. E.g. the wind, tries to go straight ahead from the hot spin-equator to the cold spin-pole while the spinning Earth slows down beneath it (it moves slower nearer the Poles).
In the North the wind therefore seems to "move to the right" as we see it, and in the Southern hemisphere "to the left". Circulation is the result.
Note: Winds around a Low go against the Coriolis force. To visualise the pressure system winds at low level, imagine placing two flat-headed screws pointing up, one on Japan and one on Sydney, an ordinary right-handed screw for Japan but **a left-handed spiral screw for the Southern Hemisphere**. Run your fingers over the threads and a right-hand thread is like screwing a screw in or out, a left-hand thread is opposite.
High pressure system winds screw downwards and outwards; Low pressure system winds reverse that—up, converging.

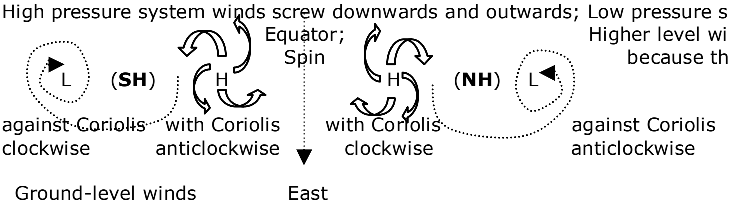

Higher level wind circulation reverses itself from that because the convergence/divergence is reversed.

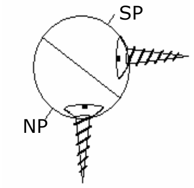

The Spherical Earth

The earth is curved round, like a globe, 360° round — 40,000 km around (by definition of a kilometre) 21,600 nautical miles, by definition.
◇ at 400 grads in a circle that's 100 km/grad ◇ at 360° in a circle that's 111.1 km/degree.
The Equator is a 'great circle'. Longitude circles are 'Great Circles' — passing through opposite poles, and perpendicular to all latitude lines.
Longitude counts 360° around East or West, or 180° East and 180° West from Greenwich.
Its North/South dividing lines mark out 24 one hour time zones of 15° each, and those North-South lines must converge on the poles, so that longitude degrees are of unequal arc-length at different latitudes.
Latitude has 90 equal degrees from the Equator to pole around the surface, which, by definition of the nautical mile, as one minute of arc, makes 60 nautical miles per degree of 'arc-distance'. 21,600 nautical miles must be the same as 40,000 km, so that's 10 km to 5.4 nautical miles. (2 to 1)
Latitude circles are 'small circles'.
We use them to divide the polar regions from the temperate regions (with the Arctic Circle, for instance, marking the limits of 24-hour nights);
and to divide the temperate regions from the tropics (for instance with the Tropic of Capricorn, which marks the limit of 'high noon' fully overhead).
'Polar Distance' complements the 'Latitude' and reminds us that arc-distance is real distance.

Moving the Horizon

At the spin-equator, on a globe, the polestars must lie horizontally, and the Equatorial spin-plane must pass East/West overhead.
But move north/south to another latitude, and the earth being round, the horizon — which follows you, like 'up' changing with you — must fall and rise latitude-degrees, so that one pole star falls latitude-degrees out of sight behind you and the other one, ahead, elevates latitude-degrees above the horizon. The Equatorial plane must also fall latitude-degrees, behind you as you move, from being overhead. Other star-latitude (declination) circles in the sky (e.g. star-trail circles) must also rise or fall the same amount — latitude degrees.
Now this same thing happens if you move in **any** direction, say ex degrees away, but for this let's just temporarily freeze the spinning of the globe. 'Horizontal' and 'up' must follow with you exactly ex degrees, and so the horizon now blocks out ex degrees of sky behind you, and reveals ex degrees of new sky ahead of you.
Looking side on, you will see the horizon **tilt** by ex degrees in relation to the old skyscape, lifting behind and falling ahead, of your direction of travel
Looking at the same star-time any night, will "temporarily freeze the nightly spinning of the Earth" for you, for star navigation.

Spherical geometry also means that if a place is 2° or 20° away from you, then it must also be 1° or 10° below your horizon — half the arc distance
E.g. the North Pole on Earth is ½ x (90° minus latitude°) below horizontal, and at 0° True.

END OF SECTION ONE

Navigation is More Than Navigating

Properly done, navigation is your chance to fit yourself in to the experience of walking through the land.
Why are you there walking?... Navigation zeroes in on the land. Do you want to see the landscape?... Navigation opens your eyes.
Don't you want to appreciate ecology and geography?... Navigate by them! Navigation stops you "drifting off" into mindless incompetence.
Do you want to remember the views and special places?... Navigation forces you to improve such memories.
So, achieve confidence when you are alone; tackle more difficult trips; lead others; call yourself "experienced"— navigation is the key.

Common Sense

Navigation skills invite you into the wilderness. The wilderness is a wild place! — a world of dangers. **Don't go**. But if you do...
..at least make sure your navigation skills are up to the task.
Likewise: Don't venture to sea with approximate star navigation techniques until you know exactly what you're doing.
Learn much more about standard astronavigation, before you experiment with new techniques.

Your Subconscious is Superior to Science!

Your natural abilities will do a better job at keeping you oriented. Your brain is a supercomputer.
That makes it subject to the "rubbish in; rubbish out" truism. Your job is to feed relevant data to your subconscious, not to feed, say, a calculator.

As far as important detail goes, your mind will 'go for the jugular'. Exact science will go for unimportant decimal places.

E.g. I can immediately guess "about 8 km away" far more quickly than any triangulation.
E.g. Will any numbers ever tell you how to recognise where you are? Or how to imagine what that peak might look like from behind?

So feed clues into your brain. It is portable, waterproof and teachable.

Don't leave your mental map behind.

Visual Assessment is Your Main Clue — Rely on It More

Since noone navigates well when they "can't see where they are going", we must be relying on visual assessment most of the time.
The idea is to run with that fact of life, and make sure you have a good look when you can
(e.g. from the lookout; while driving up; at the crest of a ridge; at the waterfall; on the bridge; in the riverbed)
Further, bring to conscious focus what is normally subconscious, in what you see.
And aim to remember what you saw. (Draw it; take notes; talk it out; use visual memory skills)

A What-to-Look-for Checklist: How far is it to the skyline? Where are the Sun, sunrise, Moon, wind and North in relation to the skyline?
How does the weather interact with the land — wind, cloud base, Sun shadow, wind shadow, cloud shadows, haze?
Talk the skyline through — name its features. What do you recognise already? What does it remind you of?
What landmarks are visible? What distances to landmarks? What sizes of hills? What is the strike or trend of the ridges, ranges & valleys?
What angles between landmarks? What alignments? What valleys will your current path take you through?
What lies in between? What slopes & shapes are showing, especially for your route? Can you see the path ahead? Is it curved?
What difficulties lie ahead? What easier paths are there? What clear lines of sight are there? What alignments will become visible?
Can anyone see where you have come from? Could you recognise 'here' again? Can you see your destination or departure point?
How many different vegetation types? How high is it to the skyline in each direction? How does what you see mesh with the map?

Integrate: Jetstream, Earth Rotation & Heaven Rotation

Imagine your global motion. Tilt yourself and try (futilely) to oppose the supersonic speed of the Earth's rotation, as if walking upon a treadmill.
Aim for a Big Picture 'feel' for each local direction.
The idea is to go outside and walk through each of these motions until you **know** what it feels like.

(Both hemispheres)

When you are…………	**standing still**	**or moving Westwards**	**or Eastwards**	**or Northwards**	**or Southwards**
(read down these lists, each in turn)					
The **Earth** rotates	Eastwards	rotates against you	rotates with you	to your right	to your left
The **Heavens** move	Westwards	slowly forward	quickly upwards	to your left	clockwise
The **high clouds**	jet Eastwards	zoom toward you	creep ahead of you	move to your right	to your left
oppose the heavens					
outrun the Earth					
You are being **tilted**	to the East	backwards	forwards	to your right	to your left
Lean oppositely	to the West	forwards	backwards	to your left	to your right

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Measuring angles at 1 cm per degree

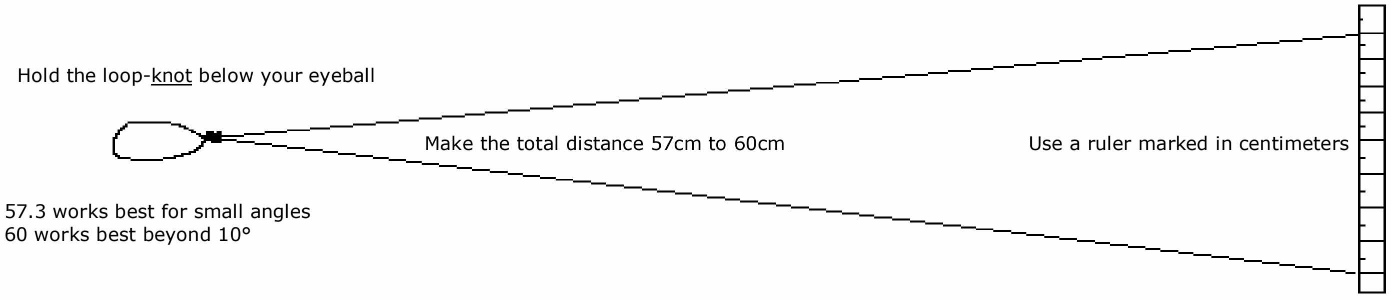
Hold the loop-knot below your eyeball
Make the total distance 57cm to 60cm
Use a ruler marked in centimeters
57.3 works best for small angles
60 works best beyond 10°

Orientation = Direction Sense

Oriental means "the rising" i.e. in the East (i.e. East from Europe!). Occidental means "the setting" i.e. in the West.

Because most ancient temples faced the midyear sunrise and there were no North-pointing magnetic compasses, and since all the world can agree on where equinoctial sunrise is, most of the rest of the world has used East, for most of Time, as their method of "orientation" — as their cardinal direction. Imagine putting East at the top of maps, so the Sun "falls down" the page.

Before magnets, East was the sensible choice for a standard direction.

This is no coincidence: "To the East" is also the watchword for the spin-sense of all our solar system parts. "North" and/or "South" is inferior

The direction of the *axis* of rotation doesn't tell you the *sense* of rotation; But the *direction of rotation*, gives you the axis of rotation *as well.*

East was the more sensible choice. You didn't lose orientation when you crossed the Equator; the Sun still rose in the East.

I recommend that you concentrate on this when changing hemispheres, and even now, to maintain your global 'orientation'.

Orientation means direction sense, direction finding, direction recognition, placing yourself in relation to over-the-horizon landmarks,

Or twisting anything (e.g. your map) to the right orientation.

Then again, it means starting off by getting your bearings straight.

Orienteering means athletes running through the bush.

Disorientation means... possible death.

The Navigator's Top 10 Problems; and Band-aid Solutions

1.	Not staying **alert** to navigation; not doing all you need to do……	**Talk** navigation; love navigation; practise navigation; **interpret** all clues
2.	Few **Clues** — E.g. Rain/Fog/Blizzard/Nighttime/Tall grass or dense vegetation/Look-alike landscapes	**Sit** still, until you can see; **go prepared** e.g. with a contour map; a compass; learn how to keep consistent courses
3.	Getting **Lost**	Remember the **start direction**
4.	Getting **Disoriented**	Be able to reorient; imagine the **Sun** in all situations; work top-down
5.	**Forgetting** the Way, the bends, etc.	Take a **notebook** and pencil; talk it out loud
6.	Losing track of **direction**	**Predict** the trend; use a **compass**; a notebook; integrate all direction clues
7.	Losing track of **distance**	Predict the timing; use a **watch**; use the map scale; and notebook
8.	Inadequate **Map**-Work	**Learn** how to use a map; study it first
9.	Not learning how to navigate	Take this booklet. **Practise.**
	Not knowing what to look for e.g. bush north	Practise being observant, at the expense of other preoccupations.
	Not **understanding** e.g. the lie, contours, heavens	**Teach** what you do know
10.	Choosing a wrong or difficult **route**	Get **directions**
	E.g. a long "shortcut" across a dense gully	Don't 'shortcut'.

Reorientation

Reorientation is not an automatic body sense — it is an ongoing action.

"Orientation" in navigation is a misnomer, since it suggests some sort of initialisation, not to be repeated, rather than a continuous reprocessing.

"Re-orientation" is a more accurate description of what the navigator is involved in. Continuous reorientation.

Whether it is subconscious or conscious, it is something which must be done and redone, or else you are simply not oriented, now.

It is not good enough simply to be "good at navigation (theory)" — you must be putting it into practice, continuously, or else each bend will disorient you.

The essence of reorientation is conscious interpretation of the meaning of what you are doing.

This is, at the best of times, a bit difficult — like mental arithmetic — but it must be done, or else your brain will remain confused.

You may hope that direction sense would "become automatic with practice", but the last step of conscious interpretation must remain conscious.

And that is the process which should become second-nature. You must be aware, or you are fooling yourself into a false sense of security.

Delegating to your subconscious, is abdicating your responsibility. So bring yourself up-to-date, continuously, and...

Do not be overconfident. You are not oriented when you think you know where you are and where other things are—but only when you are right!

There are so many ways to make silly mistakes: confusing alternative systems; mistakes in numbers; forgetting your lessons; optical illusions; instrument errors; flawed theories; trusting approximations; misidentifying a star; making a logical blunder; and, of course... being overconfident.

Lost? Rule One: Stop! ..getting More Lost

STOP — so that you don't get deeper into trouble. ("When you get yourself into a hole, stop digging")
DON'T PANIC — Look for reasons not to panic "I can always walk all night, or sleep under that ledge,
or wait out the weather, or go hungry, or enjoy it…"
PRAY — He really does want to help the helpless.
SIGNAL — Shout 'Help!', 'Cooee', Whistle, Smoky fire, Heliograph, 3 of anything, SOS, CQ, Fire at night, Flashlight
LISTEN — for a reply.
THINK p. 37d
RETHINK — your journey
SIT It Out — = The Simplest Way to Beat the Fog. Gather fuel for a fire. Don't try to move — you may not win.
CAMP — choose a place that will be a good 'base' for further exploration.
SLEEP ON IT
STAY — in the area, where you can be found, e.g. on the track, at a hut or intersection.
PLAN — Implement a pre-**thought-out plan** e.g. Stop, Think, Navigate, Camp, Retrace, EPIRB, Stay.

For a Start: Slow down — almost to a stop. Be slow, cautious and thoughtful, not impulsive.

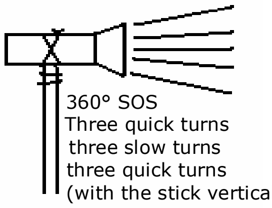

360° SOS
Three quick turns
three slow turns
three quick turns
(with the stick vertical)

Point and Blink = 10% Shift

In the field you simply point and blink—If you focus in the distance, the shift is about 6 degrees, which is 10% sideways.

6° or 1 in 10 is a very useful angle to guesstimate. Point with one eye and finger, then swap eyes, to see what a 6° shift looks like in the distance.

For repeatability you should touch your two index fingertips as you point.

For accuracy, use a pencil tip, and know the exact figure. The instructions below will show you how to hold the pencil to get an exact result.

To put the Point and Blink method on an accurate footing, measure your Inter-Pupillary Distance at Arm's Length.

Stand behind a window, pointing through it at some distant mark on the horizon, with both your finger-tips just touching the windowpane.

Use one eye and the same-side finger; Press your fingerprint onto the window; Swap eyes and fingers, back and forth, moving only your eyelids; Check your alignment—both your fingertips should appear to exactly overlap when focussed on the distant object. Press your second fingerprint onto the glass; Measure the separation carefully.

Because the pupil is not pinpoint, it matters that you measure the practical separation at the working distance. Measure that working distance carefully— from the corner of your eye to the window when your pointing fingers just touch it.

Compare the two distances; i.e. divide the interpupillary distance by the armslength; **expect about 1:10** or 6°; Find the arcsine of that ratio for better accuracy. Try it out on the length of the Southern Cross. Compare it with 3 fingers, and 4 knuckles, and your binoculars' field of view.

Measure again on a middle-ground object, as when measuring the sideslip of a yacht by pointing at the wake. Measure out the distances as a check

Orient Disorient Reorient Lost? Angle

The "Good" Navigator. You.

If you like exploring, you can use that to advantage. Or maybe you are a good photographer, well then you will understand 'mental photos'.
Use your creative writing streak, in creating memorable names, or else, appreciate the action 'direct', carefree and spontaneously.

Perhaps you are the obsessive type — well then, it's map and compass detail which will suit you.

So whether you are the artistic type, using your visual dominance, or the cool calculating logical sort,
or maybe a 'thinker' doing a good job at planning, or a 'doer' doing, you already have many useful skills for navigation.
Don't talk yourself down.

Those handful of useful traits which are already within you, you can develop into an orientation sense.

Think out Loud

Your subconscious will be telling you "That's odd".
Your conscience will be whining "Something is wrong".
Your mind will notice, before you do, "That's new".

When you notice something talking inside you, you need to talk back. Out loud. Don't leave it 'inside'.

Internal Problem	**Antidote**
"Shouldn't we be there by now?"	Ask the others.
"Have we missed the junction?"	Discuss it.
"Why is the Sun over there now!"	Name the lurking enemy!

You Need Excuses to Stop and Have a Good Look

- If it is a local peak, say "Let's look for a minute while we have the opportunity"
- Declare a chocolate stop!
- Take off your pack, adjust the padding. Adjust your socks, air your feet, put on a Band-Aid.
- Get out the maps; Identify the landmarks. Draw the relative angles to other lookouts, for future reference.
- Get out the camera and tripod. Unpack your pack on any pretext — noone can move until you repack!
- Make a sketch, compose a poem. Start an interesting conversation.
- Go for a swim or wash some clothes.
- Cook your main meal at midday & keep the biscuits for the late meal.
- Camp there.

You Can't Easily Revisit Places Left Behind — unless you first spend memorable times there.

Visualise Familiar but Invisible Landscape in Relation to the Sun

You need to 'fill in the void' between the very distant reference, and what you can see, with what you know, but can't see.
I.e. When you get a clear view, mentally plot and remember the sky-to-land layout for later use. "If the hill disappeared, the hut would be *there.*"
Mentally reconstruct any view which is helpful. E.g. as seen from camp, or from the start, or the peak…
Concentrate on knowing and revisualising landscape direction trends. "If I were at home, I'd see the coast… *across there*"
Do this at various times of day, **paying particular attention to direction *trends* in relation to the Sun's path**.
After all, that's what our direction sense consists of—a confidence in the real directions just out of sight, based on what we can see.
Then, when you are 'bushed in' and you see the Sun through the canopy you can say…
"Ah! the road is running sideways to the Sun, the valley lies entirely off to the right, I must have swung around left, parallel to the ridge…"

Section 1 dealt with the Sun/noon/North in the global abstract—unrelated to the local detail.
Section 3 deals with the local detail in relation to the Sun.
"Land to Sky" (soon, p 38d) is specially for one time of day, and concerned mainly with particular landmarks, not whole trends.
But now catch up with the overall game—**the Sun's path, the local skyline, and the local layout are one piece for a substantial local area**, and you need to mentally integrate them, and carry them with you, to avoid disorientation.

Guesstimating Angles at 1 degree per cm

First find how to make your **arm's-length 57 cm**, e.g. by touching your fists together in front of you.
Next, start measuring in **centimetres**.
Find a 1cm wide fingernail—1°. Check that your fingers are 2° wide, for 2°, 4°, 6°. Are your knuckles 2 cm apart? 2½° for the big ones.
A small fist, with the thumb tucked in is 9°; 10° with the thumb showing; a palm is one 'point'.
15° and 16° may require experimentation. 20° can be spanned with the fingers.

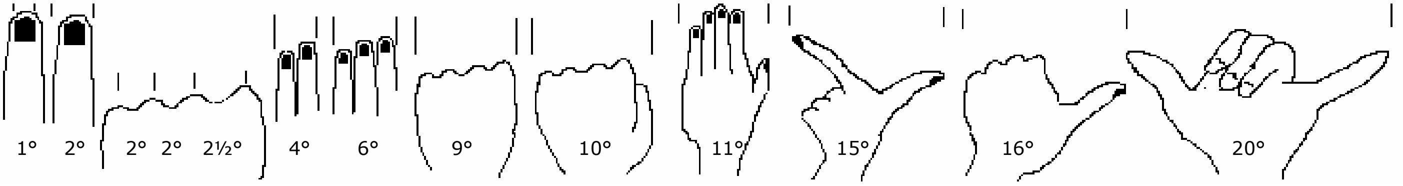

The 'Blink of eye' method also yields 6° — point to something with your finger at arm's length or with something narrower, with one eye, and blink.
Larger horizontal angles can be visualised from between your feet of from overhead.

Initial Orientation is the Single Fundamental — The Get-Back Path

"Which way do I go?" is more important than "Where am I?/How far?/Where is North?"
"How do I get back to a familiar path home?" is the real need. That means you need to orient yourself **before** getting lost.
The single most important direction is **Start to Finish** i.e. Which way did you **leave** the car park? **From** what recognised point?
"Which way have I been **going**?" (if I had to backtrack)
Which direction did you **head off** in — **toward** what identifiable point?
E.g. "Downhill". The direction need not be horizontal. We function on 'paths' more than on straight lines.
E.g. "to the lake". The direction need not be relative to North; It does need to be something you can reverse.
E.g. "with the Moon ahead on the left" "the long way around" "to the opposite side" "away from the mid-morning Sun"

Taking a map and compass is good; A watch is nice; But the only really necessary bit of navigation you must take with you on a walk, to get you back when lost or disoriented, is... what direction you have travelled out.

Initial Orientation is the Single King Principle — and the rest may not be much help without it. See the mnemonic p. 111c for some help.
Which way you went is also the single biggest help for searchers—**tell someone** where you are going!

How I Manage to Get Lost or Disoriented

… **starting off** without paying attention … blindly following the track or the leader … taking a minor junction
… choosing a hard route — thick vegetation … going without a compass, or map … trapped by a peak or clearing (p.45b)
… falling asleep during a journey — a gap in my reckoning … waking up in a new place … not noticing the "end of track" marker
… inside a hospital complex, or a shopping centre; coming out … in look-alike landscape e.g. suburbs; losing the car on city streets.
… getting out of bed the wrong way or entering a town by a last-minute bend … talking; inattention; not noticing bends & junctions; losing track
… misinterpreting "directions"; forgetting them; being given wrong directions … hurrying; "short-cuts"; leaving the track
… on river-flats near river junctions and bends … preoccupied — with map-making! or any other task
… inadequate memory e.g. in caves, the way back, the many bends … stubborn psychological disorientation syndrome
… miscommunication between parties e.g. about how & when to meet … confusion; blunders (see list p. 39b)
… not enough knowledge of what to look for & how to interpret what you do see … visiting the Northern Hemisphere
… minimal input technique of navigation e.g. 'just follow the signs'; overconfidence … misinterpreting the map—especially the scale
… new tracks, not on a map … false identification of landmark features … losing confidence just short of my goal
… unsure of distance covered … navigating by creek junctions or minor dirt roads … blinkered by fog, darkness or thick forest
… wrong turnings; walking in an unintentional circle; overlooking junctions; not looking back … waking up on a dark night, 180° disoriented.
… too much new territory too quickly … negotiating thick bush without keeping orientation

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Voice Your Thoughts — Don't Suppress Important Clues

When your silent auto-pilot notices something and tries to tell you… Say it out loud. That's the trick to it.
Tell someone. If you are alone, yes, talk to yourself. Bring it to light.
You can't remember the jigsaw bits later, unless you look at them now! **Subconscious thoughts flit away like dreams**, so express them first.

"Oh I didn't expect to reach this so soon!" ? Misidentified
"North seems to have changed. It shouldn't be out there!" Disoriented!
"Hasn't the wind swung? Does anybody agree?" ? Are the others asleep!!
"The shape's not quite right" Most probably because it's wrong!
"The markers have stopped" ? Off the main track

The same goes for run-of-the-mill clues. A forgotten clue is a missing jigsaw piece when you need it, so say them all out loud.
"We're crossing a divide — see — we are now going downhill"
"Creek number... four" "Marker!... Blaze!... Cut Branch!..."

Back-track in Your Mind before You Back-track on Your Steps

Lost?
"Don't Be Afraid to Think"
Spend time rethinking.
Try to reconstruct where you might have erred. Have I overrun my goal, or am I not there yet? Or am I simply off course to left or to right?
Did anything 'not make sense' on the way out?

- Work backwards from now, before you forget.
- Assess how successful back-tracking might prove.
- Don't ask "Where do you think…" but shoot for the details — ask "Why do you think…"
- Each of you should draw a mud-map separately, then come together, to compare recollections. Argue out the sequence.
- Back-track on your presumptions.

Detail the facts with a cool head and many problems will dissolve.

Distance using Apparent Size & 6°

The visual size of people, cars, houses, as measured at arm's length, varies with distance. You know how big they are already.
Blink your eye or otherwise guesstimate what fraction of 6° it makes, and multiply its size up by 10, plus for the fraction, to get the distance to it.
E.g. something one knuckle space wide is 3 times further away than if it were 6° big, and therefore is 30 times further away than its absolute size.

Visual Angle, Size and Distance

Find the angle, and multiply the size up by 60 in 1-per-degree. E.g. If something 1m wide looks 5° across, = it is 12m away. 0.5° means 120m.
Find the distance from the map, and work out the size from the apparent angle, by 1 in 60. Something 10km away, 10° wide is 10/6 km across.
Using 7/4 in 100, for accuracy because the angle is small, something 10km away and 10° across should be 1750m wide.

Side-wise Offset

Blink your eye at something in the distance, and it will shift across the background skyline.
Walk sideways, pacing out the distance, until it lines up with the new skyline mark. Multiply by 10 for the distance to the something.
Alternatively, mark the new position alongside the object, which the 'blink' indicates, then walk up to it and pace out the offset distance & ten-tuple

Don't Just 'Get By' and 'Make Do'

We all have a handful of techniques we feel comfortable with. We all get lost.

Most "How to" books necessarily are telling you how to battle uphill — against your natural incompetence.
This is doubly true for a "How to Improve" (your navigation) book!
E.g. 'Improve your memory skills'! Easily said; hard to digest.
Get used to the idea, and therefore embrace it — the idea that you, as a good navigator, should want to extend your familiar range.

Navigation is inherently a problem (of not being able to see around corners; of not having a magnetic sense; of not having excellent memory; etc.).
However humans inherently do have the potential skills to cope. But do you have the guts?

Memories are Made of Landscapes, Not Compass Needles!

What to look for is detailed later, but for now consider...
How to 'look' …

Use your compass and map vaguely! Approximately! Lightly!
It is safer to be aware of their meaning, rather than to be accurate but disoriented.

Imagine you had no map, no compass. No signposts. No highways.
"How did the pioneers do it!?" You learn how to not get lost; how to 'see' what you are looking at.

Once you get oriented, then you can bury yourself in the instructions on decimal places, for accuracy when you need it.
Otherwise numbers and recipes have an ability to preoccupy your mind and numb your thinking.

Treat your map and compass as shy — self-deprecating — and turn your piercing stare away from them to what they are pointing out to you.

You Need a Road-Map To Climb a Hill!

It is a waste of effort to realise your mistakes at the top of a hill.
"I wish we had brought binoculars" is all too common a regret.
"We must remember next time to bring all our maps"

You have few such opportunities to positively identify landmarks,
and so you should **take the chance to familiarise yourself with what each hill looks like from every other hill.**

But often, it is only your smallest-scale map — the roadmap — which will show you the big layout.

"Didn't anybody bring the compass??"

It's up to you to plan ahead, to plan on making the most of your efforts.

'Land to Sky — Sky to Land' Navigation

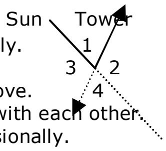

Step Zero: **Leave yourself out**, and your compass, of the scheme of things — so that the whole lifeless picture only changes slowly.
The result is simplicity itself — You see **how the Sun shines across the landscape**. Remember the angles.
Step One: "The Tower is by angle, from the Sun as I see it" Both change only slowly (or rather, seem to) as you move.
The Big Bonus is: You can keep track of all your bends, twists & turns, by the Sun & Land working in conjunction with each other.
You can locate a landmark easily through the vegetation — you know where to expect it when it shows itself occasionally.
i.e. You can always easily locate the tower/peak/etc, from kilometre to kilometre, in relation to the (now slightly shifted) Sun (or Moon, wind, cloud)
Step Two: "The Tower is from my shadow" This allows you to walk away from the Sun, yet still stay oriented to the landmark.
Step Three: "**The Anti-Tower** is ..from the Sun" These allow you to walk away from the landmark,
Step Four: ..from my shadow" yet still "see" where it is.
Step Five: Mnemonic: "The Landscape on the **Left** Lingers Longest in the Light" — its apparent movement as you walk, follows the Sun
& the Shadow's anticlockwise shift. (SH only) i.e. you don't need to worry much about time passing, and angles changing.
"But Landscape on the Right… soon goes wrong" — it 'moves' against the clock-sense of the Sun. (Southern Hemisphere rules)
i.e. you need to **refresh your angles** more often during the day. (NH: Left Loses the Light; Right is all right)
Step Six: Rule of Thumb: "**15 km away** changes at 15°/hour (i.e. at about the same rate as a low midday Sun) as you walk past it at **4 kph**".
The Sun shifts at less than 15°/hr when it is rising or setting — so try "20 km away/12°" to match it; and "10 km/25°" if the Sun is very high.
Yes, you should convert the angle to "ESE" or rename it "just S. of sunrise" for later, but **the idea is to use the Sun as it is now, not North.**

Grid-line Walk — Explore in a Square Grid Pattern

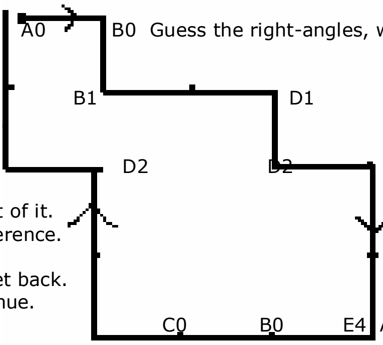

Guess the right-angles, well

This only adds 20% walking effort, but lets you know where you are, and how to get back,
and along a route of your choice, among many choices.
You need to judge a given distance, well, e.g. 100 double-paces; one minute; or 100m; or by pedometer.
Choose a **reference direction** as 'Up' or 'ahead'. Sun-North; Compass Needle North.
Up-weather by clouds; down–clouds. A strong wind. Distant Hill. If needed, keep a straight line by marks.
Choose a **scale** to suit your ambitions, e.g. 100m squares (so that each 10m is an extra 0.1).
Try to cover a whole square at a time. Use 0.5, if needed, or you can cross at a diagonal, 140m long.
Count **forward and back progress** in whole chunks, as A-Z. G.5 means 7½ squares.
After Z comes AA, AB, AC. See p84b for making suitable mnemonics. **Don't lose count!** That's the worst of it.
Count **right and left progress** as +/- 0-10, etc. Minus simply means 'backwards' or 'to the left' of the reference.
When you have definitely decided to head back to base, remember the grid-reference. Stop counting.
Reset the count to Zero. This is easier than trying to count backwards, using subtraction, to get back.
Reverse the reference direction, e.g. to downwind, shadow South, compass South, and continue.
When you arrive at the original grid-count, you should be within sight of home-base.

Disorientation is More Dangerous than Being Lost

…because the same disorientation that will get you lost, may then get you more lost.
Orientation is primarily a mental picture — therefore **— Disorientation is a wrong mental picture.** It is one and the same principle.
So Disorientation really extends to cover more than direction sense, into bewilderment and logical debilitation!
You can be disoriented, deluded, bewildered and irrational about more than direction or position. E.g. You may misjudge which way is up/out/back.
E.g. you may be mistaken about the time of day, or the existence of a road, or whether the promised weather front has passed you or not.

'Lost' is 'I don't know where I am' which is different from disorientation, since position sense is independent of direction sense.
Again, you can know where you are on the map, but still be bewildered on the ground — not 'fitting in' even if direction-wise oriented.
Then again, you can be oriented, but lost — yet not necessarily worried or in difficulties — because you are oriented.
You can be disoriented unawares — even when you know where you are — i.e. not necessarily aware of the danger of loss of direction sense.
To be both disoriented and lost is most dangerous, but **it is orientation which stops you from getting lost**.

Orientation keeps your finger on the pulse. It stops you getting disoriented. In many ways it gives you a position sense too e.g. that you are in a particular catchment, downwind of a known landmark, up-Sun of the overall course. Orientation of the map puts the map onto the landscape—aligned to reality—so that the map can point out its riches to you. Orientation lets you know where you are, recognise places, & know the way back

Logical Blunders — Examples

Mistakes of category: "The last stream was flowing to the left" (Oops!)
"We have crossed the main road" (Now, the main access road is dirt, whereas the main through road is bitumen, but you muddle them up. Or maybe you are unaware of a fork in the main road.)
Mistakes of number: "We have passed two lakes" (which were joined behind the intervening vegetation).
Mistakes of quantity: "We haven't changed direction" (except for one hairpin bend!)
Ironstone may have swung the compass, when you put the map and compass on the ground 'for extra certainty'!
Mistakes of quality: "From the peak to the lake was 090°" — but the false peak you were on, gave you a false sense of accuracy, in the mist!
"See those houses 'across' the river?" — Rather, see the bend on the left — they are on this side!
"The island should poke out from behind the far point. Why isn't it there?" (It is 'the far point', of course)
"But we have crossed the River" No, only a main tributary, or only onto an island.
Gaps in knowledge: "We haven't seen the junction" — because you short-cut past it; around one bush is enough!
Unexpected: E.g. there are sometimes two parallel roads — the old & the new. E.g. a stream sometimes goes underground "Mole Creek".
E.g. A water canal may cross catchments. E.g. "Remember the creek junction at the base of the hill" — The 'hill' was only an island.
Assumption: "That will be the ridge we want up ahead, let's turn off here" — Unproven!
"Ah, we are back to the road!" Yes, but not the same road!

Trust the Untrustworthy

It's like people. 'You can't trust anybody', but you have to trust your life to them sometimes.

A compass has dozens of potential faults, but in a fog, you trust it, implicitly.
You yourself are less trustworthy than a compass.
When all you have outside your own opinions are reasonably reliable external clues (like where the Sun is!) you had better trust your life to them, not to yourself.
For instance, sometimes that 'external clue' is someone else telling you that you are disoriented, when you don't think so — you had better listen!

A disoriented person may not want to trust the 'untrustworthy'. Don't let that be you.
E.g. You may find yourself twisting the map to make it line up with a mountain which doesn't really line up, except to your expectations.
You prefer to believe that the map may be distorted!
It takes practice to believe. I once spent a whole week wondering why all the trees were pointing too much to the sunset side of noon.
I was trusting myself, not the trees, and was simply wrong about where North was. I didn't realise which was the more trustworthy.

Lost? Rule 2: Start! Getting Unlost. Find yourself. Regain confidence.

(After you STOP getting lost — Rule 1) It is time to **START NAVIGATING** — Rule 2. (You can practise this ahead of time, without getting lost.)
E.g. What can I see & recognise? E.g. Can I interpret the wind or sky or trees or drainage for direction?

- First: Mark your spot e.g. tie up a hanky. Mark your Trail—so you can get back here, as 'base'. Retrace your steps, if that is the best option.

Act out a Search & Rescue, looking for your 'lost' starting point. (If you can see your surroundings, you don't have to feel 'lost'.)...

- Explore in all directions systematically.
- Make a map. 'You' in the centre. Locate yourself in the landscape. Climb a high point, to orient yourself; at night too, for lights.

Let others find you...

- Leave notes about your plans. Especially at 'findable' places e.g. a hill top.
- Leave clues so that searchers will not give up for 'lack of clues'. Make some marks visible from the air.

Search out a track...
Ask: "Where should there be a track?" E.g. to... that peak?, a fishing spot?, any low pass through the range?, the main access valley?

Mental Grid Map

This is the square grid method, where you simply walk, along a path of choice, and rather than following the grid lines,
guesstimate your decimal position in the grid scheme.
The beauty of it is that it constantly forces you to orient yourself to a reference *direction*, to notice *distance*, and to be aware of *position*, yet it takes nothing more than mental equipment. You should aim to practice it properly, once, and you may not want to discard it.
It causes less mental strain if there are two or more of you. **Delegate** the left/right to one person; the forward/back to another.
The one person guesstimates distances by one method, their way; The other gauges perhaps a different distance and with different accuracy.
It doesn't really matter if your guesstimation mismatches, provided you remain consistent and imagine a rectangular grid.
In addition you need a feel for triangle lengths, for a 1 in 10 slope, up to a 10 in 10 slope, so you can guesstimate decimals.

~You need to divert 5 in 10 to add more than **10%** to the length walked. E.g. from Z0 to A0.5 takes 112m across 100m squares.
~Maximum extra length is a 45 degree diagonal, at **141%**. E.g. from Z0 to A1 takes 141m. These two set the feel for guessing distances
1 in 9 adds one third. For 6 in 10 to 8 in 10, triple the first figure as the extra %. E.g. from A0 to B0.7 takes 122m.
If in doubt draw a 10x10 square, draw in the diagonals to each of 18 opposite points, and label the lengths as the square root of 100+n^2
This lets you see the direction of each n in 10 slope, and know its length.
~You could use degrees, up to 45, and call them percent extra distance, with fair accuracy, but there's no need for such figures.

When I simply guessed, by eyeballing distances and directions, it brought me back home without noticeable error, after a few kilometres.

Walk Where the Navigators Talk — if you want to learn navigation

Not out of earshot.
Navigation is a learning experience.
It works better when you can share the process of learning with someone.

Explore

Explore the unexpected — the side tracks.   You walk to explore, usually, not to exercise.

It's No Fantasy

Navigational know-how is not "If I were lost I could do this…" but is "What I am doing right now, all the time, will stop me getting lost".
Learning new skills and how to interpret all the clues is the practice of navigation here and now.
Continuously pointing out new clues to yourself, and to others willing to listen, is the process of not losing yourself.

Feed Your Subconscious through Your Conscious Focus

E.g. To improve distance guesstimation, focus on the finest visible distant detail. Notice the haze level, the shadow hue, the sizes you can see.

To train your direction 'sense' (which is entirely lacking in humans) feed it all the clues you can —
Sun & shadows, wind & weather, compass & landmarks, trends & bends… Don't just look at them! Put words and meanings onto what you see.

To extend your memory of a sequence of turnings… use pencil and paper 'memory'.

A working rule of thumb: **Bring to conscious note**
what you hope to keep track of subconsciously.
Don't expect to be able to remember what you haven't noticed or thought about consciously.
So learn what to look for, and how to see it.

Look into the Far Distance

..for Trig. Points; Towers. They are there to be seen, by definition.   ..for Roads; Houses
..at night, for City glow; Auroral Lights   ..for the dip and strike of the underlying geology
Assess the difficulties ahead, whenever you glimpse them e.g. a steep bank on the other side of a lake. Use binoculars.

Look through the Haze

What are you looking for? You want to pick: intervening ridges, hidden gorges, distant cliffs, overhangs, false peaks, mountains or islands, the Moon, and the trail ahead. Those cloudy lumps are not always clouds. Those invisible peaks are there to be found.

If you don't see them right away…   **Wait**   ..it is the **changing light conditions** which show up the contours.

E.g. Look at night, when the whole emphasis shifts, and light sources show up.
E.g. Wait for the haze to shift — it moves with the Sun.
E.g. Wait for the haze to thicken — to show up the valleys — weather is changeable
    A rain shower may show up a valley; a cold front might clear the air of haze.
E.g. Wait for a cloud shadow or patch of sunlight to drift across — it will disappear into any hollows, and highlight any foreground.

Join the Invisible Big Picture To the Visible Landscape

The Big Picture might be invisible — e.g. the South Pole Star is "Over the South Pole in Antarctica" — but geographic "South" is quite different and is visible — "that knoll there!".   Join the two!
The first principle to practise, is to work top-down; but the second and more important need, is to integrate everything.

When you put a continental or global picture onto the landscape, you have a full-scale map of the world in front of you.
e.g. Point just beneath 'that Knoll' and put your imagination into gear...Down over that horizon are icebergs separating from glaciers with a huge splash! Can't you feel the chill? Up there is the night-time aurora. Down there, anti-polar bears look straight up and see the Southern Cross whirling around overhead! And we must be on the south side — the cold dark side — of this hill behind us.

You say: "The destination lies beyond that valley."   "Mount Saddleback marks sunrise"
"The track winds around behind this hill."   "The Sun skims those treetops"
"Porpoise Bay must be yonder; Melbourne that way; and my girlfriend, 50km in that direction…"
Integrate as you walk — in real time and place

Cyclical Motion Divided into 12ths

Any back-and-forth motions or cycles which are caused by circular orbits or sinusoidal oscillations are easily understood and followed *in units of 30°*.
This is because 30° of rotation will swing *half way across* a radius from top-dead-centre, or half-way up/down from right/left extremities.
E.g. quick rising for 4 twelfths, then *2 twelfths* in the *top half* of the swing, 4 quickly reversing itself, and wallowing for 2 at the bottom.
You may not *see* the 'circular' nature of a one-dimensional oscillation, yet it will still conform to this rule.

Tidal Height	Sun's Seasonal Latitude (or Moon's monthly position cycle; use 2½ days)
1 hour falling slowly from the top	1 month at Northern solstice slowly coming South
2 hours dropping rapidly to midway	2 months rapidly moving back to the Equator — to the South
2 hours dropping rapidly from midway	2 months rapidly moving South of the Equator
1 hour dropping slowly to minimum height	1 month slowly approaching Southern solstice
1 hour at bottom rising slowly	1 month slowly turning back to the North
2 hours rising rapidly to midway	2 months rapidly returning to the Equator — toward the North
2 hours rising rapidly from midway	2 months rapidly moving North of the Equator
1 hour rising slowly to top	1 month slowly approaching the Northern solstice

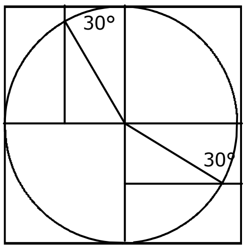

You can simplify that into sixths, saying: "1 sixth *at the extreme*; 2 *on each change*; 1 at the other extreme"
Or say: "*twice as long on the change*". That makes 'the change' sound 'slower' but it actually goes *faster* and *for longer*.

Which Way Did I Come In? Which Way Do I Go on?

Have you ever interrupted your pleasant journey at a roadside picnic area and driven out the wrong way — back the way you came — and not onwards? Or you turn left instead of right when you drive “out” of a local dead-end network, into another dead-end maze?
Or you sat down for a rest on the track and when it’s time to go, both directions look identical to you?
It’s embarrassing on the road. It’s nerve-racking in the bush! You feel struck with insanity. But it’s normal enough.

Or when you come back to visit a familiar place, it’s on the ‘wrong’ side of the river! Every time you come back?!

An extra external clue, like the Sun, is needed, and needed to be believed, but it is really needed before you make a fool of yourself.

And you may have to undergo ‘re-orientation’ to dis-illusion yourself.

Don’t let it happen to you deep inside a cave system!

Logical Presumption Leads to Utter Delusion

Think about those example ‘logical blunders’, about your own fallibility, about the dependence of logic upon its basic assumptions.
Being twitted by a logical mistake leaves you with a horrible ‘lost’ feeling, plus a pathetic ‘helplessness’ about how to reorient.

These are not simply mistakes of guesstimation, subject to fine-tuning!
Once you subconsciously make a decision about how the world is, then your mind will close to the possibility of error.
False assumption is presumption, so I say “**Presumption Means Delusion**”
Such Left/Right, Yes/No, crossed/uncrossed, 2, or was it 1? -type mistakes lead to utter bewilderment, so I add
“and errors involving discrete categories can be especially indiscreet!”

Being aware of the phenomenon of logical blunders, is half the battle in overcoming them, when they bite.
Keep an Open Mind about the truth of your assumptions!

Trust Less and Prove More

Don’t trust yourself At numbers
Or remembering accurately
At judging time or distance
Or walking in a straight line
At identifying landmarks properly,
Or walking back upstream, and so on.
Don’t trust A compass to be dead accurate
A map to show North reliably
The weather forecast
Old track markers
A navigational ‘fix’
Complicated or finely adjusted instruments. They can easily go out of adjustment, without letting you know.
The point is not so much to **double-check** and **cross-check**, as to: **back-up** with an alternative; **interpret** for sense; understand; and **be wary**.

The Simplest Way to Get Unlost is to Retrace Your Steps

The sooner you go back to where you went wrong, the sooner you can relax. Yes that might be uphill. Yes it might be a long way.
“Oh I wish I had retraced my steps earlier, while I had the chance!”
You still have the chance, you probably just don’t want to.
For instance, if you have been pushing on, hoping to find the way, you should be doubly aware of exactly where you have come, since you doubly anticipate the need to retrace, if you fail.
“Short” cuts have a habit of surprising you at just how long they can turn out to be, repeatedly.
A track naturally avoids gullies and obstacles, so a ‘shortcut’ is almost guaranteed to hit one square on!

Retracing your steps may be something you can’t short-cut. It is the shortcut. It short-circuits many other possibilities.

Caution: Sometimes retracing your mistakes will only compound them—more of the same!
You may sort yourself out better if there is an alternative system to try e.g. to walk back upridge if you got lost going downstream.

Approximate Sine-Wave Values   97% accurate

(From school you could have memorised that sin 30° is 0.5 and sin 60° is 0.866, and perhaps sin 45° =0.707 ???)
The first twelfth of an oscillation takes something half-way (0.5) to its peak amplitude (1.0) from the middle ground (0), by the rule of twelfths.
~*The motion is virtually linear for that first 30 degrees*. So to convert those *first* 30 degrees to a sine-value, **Divide by 60**.
I.e. add at a rate of 0.5 in 30, or 1 in 60. E.g. 25°/60 = 5/12 (or 0.417). Sin 25° is actually 0.423, which means we had a –0.006 error.
Sin 15° is 0.259, but we get 0.25 (–.009 error). Sin 20° is 0.342, but we would guess 0.333. That’s about the maximum error, 0.01 low
The next twelfth carries the motion from half-way to 86.6%, in a curve; The extra is 36.6% or a slope of 1.22 per degree.   Let’s use 87,36,1.2
A linear fit cuts the curve twice, and so is close to most of it. If we could add 36%, over 30°, to 0.51, to arrive at 0.87, we get +/– 0.01
~To the ***extra*** degrees, **Add 20% ; Add 1; Call it a percentage** (divide by 100).   (*To add 20%, add 1 tenth, 2 times*, e.g. 55 + 5.5 + 5.5 = 66)
E.g. 60 degrees = 30 plus an extra 30; so start with 0.5 and add 0.3 then 0.03, 0.03, 0.01 to get 0.87, which is 0.004 too much.
E.g. 40 gives 0.5 + 0.1 + 0.02 +0.01 = 0.63, instead of 0.643, or a –0.013 error. Sin 45 is about 0.5 plus 0.15 + 0.04 =0.69 or –0.017
To make the next approximation, use 0.87 for the first 60 degrees, then worry about any extra degrees.
The last 12th is the flattish top of the curve, building up to the crest. It climbs only 13.6% from 0.866 to 1.00 in 30 degrees, in a curve.
We start at 0.87 and finish at 1.02 cut the curve twice and best-fit to within 2%.
~For the last 30° degrees **Divide by 2, then 100**, to gain 15%, from 0.87 to 1.02.
E.g. 80 degrees moves to 0.5 then to about 0.87, then an extra 20 degrees or 0.1, yielding 0.97, 0.015 below the real value, 0.985.
75 yields 0.5 + 0.37 + 0.075 = 0.945, 0.021 below the true value 0.966. 70 gives 0.87 + 0.05 = 0.92, 0.02 below 0.940. I.e. +/– 0.02

Self-Motivation is Fundamental

For a sense of direction to become "second nature" you need to **train** your second nature.
Improved navigational ability boils down to… *putting new ideas into practice*.
(Not perfecting old mistakes! Nor leaving the right technique on the shelf)

Don't just know about a good idea; make it yours.
For this you need to want to improve your skills.
to force yourself to practise your weaker points.
to push yourself to develop new habits.
Which is fun.

Enjoy the trip!

How to Feed Your Brain

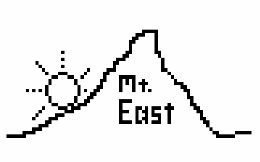

When and where does the Sun get up?
Get up and look (not at it!). Don't make it an academic question.
You don't need an academic answer, either. You measure it with your eyeball. Perhaps draw it.
That doesn't mean "ignore the details" but "memorise the feel".
You do 'measure' it, but not with numbers.

There! This early!

Star navigation? It doesn't have to be a "trigonometrical nightmare".
For us it means: Find the Southern Cross.
Guess the time of night.
Find the Pot. Get to know the stars.
Project their movement forward into the daytime.

Let your brain do the calculations. Show it what to work on.

Wait for a Change in Perspective...

..to reveal the hidden shapes and layout.

As you drive up, keep **re**-examining the changing skyline. Continue the process as you walk. Look for ridges & valleys showing up through the vegetation as well as on the skyline.
E.g. Use parallax to reveal a deeper horizon behind a hidden valley...
Keep your eye on particular bumps on the skyline.
If there is a deeper background, i.e. more distant, then a lump on it will show up by moving with you —
more quickly than a 'foreground' horizon. You may have to look through the deep haze to even locate particular bumps.

Climb a tree, or a hill.
Use binoculars. Look especially for the trail ahead, in relation to the terrain.

It is the **Changing Parallax** which **Shows Up the Landform** and its Relative Distances.

Landmark to Landmark Network Navigation

This is a permanent, unchanging, top-down, whole-region method, **prepared at home**, for a large area, and for particular walks.
1. Choose only **prominent landmarks** from the map. e.g. peaks with transmitters.
Add in major ports, mouths & coastal extremities, lighthouses, around the coast.
Draw the network of triangles between them. ("Which one am I inside?")
Draw the circumscribed circle for each triangle. ("Am I inside or outside?")
Label each line in **kilometres**. ("What does 20km look like?")
Label each horizontal **angle** in degrees. ("Does it look larger (inside the circle) or smaller (outside)?")
Label each line with its **trend**-direction. ("Am I to left or to right of **track**? Which is this river **parallel** to?")
On the right of a line you will be looking to the left of its trend to see one of the landmarks.
2. Keep a **notebook** for local peaks — smaller but locally prominent lookouts.
The idea here is to navigate only by landmarks, not by (favourite) low spots.
You don't have to worry about whether one landmark is visible from another.
The idea is that **even when you can't see a landmark** (as well as when you can),
you can know where it is and how it lies in the land layout, how other trends line up with it and with other visible lines, and *how you fit in*.

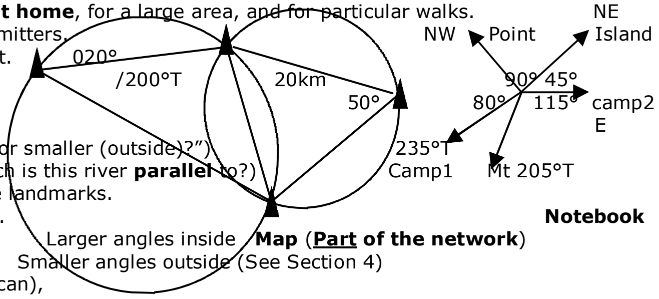

Larger angles inside **Map (Part of the network)**
Smaller angles outside (See Section 4)

Name Each Clue — with solid ground

"That's Pacific Sunlight shining"	— a mid-morning Sun, for Australia
"I have an Anti-American Shadow at the moment"	— pointing away from North America
"It's a West Coast Cloud Flow"	— you can't lose your orientation
"I love a Tropical Moon"	— when the Moon is North of you (SH)
"That wind would blow straight in our back door"	— 'Back-Door Blow'
"Downstream from here is uphill from Port Stevens"	— 'Steven's Stream'
"This cliff sees the Southern Lights"	— 'Cold Cliff'
"Topple-Tree Trunk would take us to True North"	

The next step is to add something in line with that — see the next page.

Disorientation — A Killer Syndrome

Pilots have been known to fly upside down, or rigidly leaning to one side according to their mistaken belief about "up"!
If even our natural senses are unreliable we certainly can't afford to believe in any 'sixth sense' of direction, or on any unproven magnetic inbuilt direction-sense in humans! A trudge can dull & distort our senses. Your mind tries valiantly to maintain mental orientation—that is the problem.
Several times each year pilots die, scuba divers get lost in sea caves, cavers fail to find the way up and out, boatmen falsely navigate the fog, and bushwalkers get lost in the bush, fatally. They were not just careless; they were probably trying hard, but in the wrong direction, stubbornly.
Belief is an irrational master. Its force is stronger than reason. The conflict, combined with physical tiredness and sensory deprivation, is stressful.

We prefer to get lost rather than to rethink wrong assumptions!
We become willfully blind to strong contrary clues in view (including signposts, instruments, buoy colours and numbers!).
We magnify weak clues, to justify our delusion. This heightens the stress, because our sub-subconscious knows that we are wrong.
We actually lie to ourselves about what the clues do say! (e.g. we change the number, colour, reading or wording in our mind!)

Such irrational behaviour is explained as defending our psyche from hurt pride and from being devastated by confusion, fear and panic.
Don't laugh it off as "Oh, that's only for the worst case" because it is the less obvious self-delusion which will likely trap you.
Being human includes you — you definitely are vulnerable to being even less sensible than trained pilots!

Casual Outings Catch You Out

..unprepared e.g. without a map or compass or weather forecast.
Casual outings also have a habit (because exploring is interesting) of "I'll go just a little bit further"; and turn into longer than expected full-scale safaris. Exploring is built into the genes of a small fraction of any animal population—it's a group-survival insurance. But don't let it catch you out.

Serious trips go more reliably because you know what is needed, but you rarely prepare well for a casual trip.
e.g. you have no pedometer or notebook and so don't keep a good enough log of distance or direction.
So **Lesson Zero: Make some precaution** (to avoid getting lost) **every time** you wander off.
Another unexpected casual mistake is to decide to leave the track without thinking what precautions may be required.
Try this. Look up and repeat after me: "God, have I forgotten anything? Is there anything I should do first?"
Let someone know the single biggest clue: "I'm going exploring that way",
but then don't forget the unobvious catch—that person might also go exploring & not tell anyone where you went.
(Being disabled by an injury is one thing, but dying of exposure or thirst or wild animals, simply because no-one knows where you are, is another whole added dimension—that is probably the strongest reason for bothering to let someone know.)
So before you go off, pass on any vital information about others, as well as about yourself.

Trust Yourself Less

..when the compass and you disagree, for example.
When the map shows the junction there, but you reckon it should be here, for some reason such as 'but we've come too far!'
Or similar cases, of confusion.

Your reasoning sense has holes in it, big enough to outsmart yourself.

In the end you will usually conclude "Well, I was wrong, due to this very good reason(!), and it was how the map and compass told me it was."
But you don't want to admit it, at the time, until you are proven wrong, yet again.
Your reasoning is not, despite your worship of it, the highest god in the Universe. You need to be able to criticise it freely.

Unreliable as map and compass can be, at times, it is better to trust them more and yourself less.

More is Better — Thought, Time Care

A simple principle to apply is to do a better job at what is marginal.

For instance, "flat" ground nevertheless does have a slope which you can determine with care.
The wind may be gentle but a little extra time could make the difference between success or failure at determining its direction.
You can always double-check a casual decision, e.g. about which way the dry creek-bed flows.
Instead of wandering in an unrecorded meandering fashion, you can mentally log your changes in direction by lining up pairs of marks.
Just before you leave the track, a quick checklist can bring a few necessaries to mind, but only if you take the trouble.

A little extra thought; an adequate time-allocation to each task; more faith; and that bit of extra care—will solve a lot of problems.

Moveable Position vs Fixed Orientation

- It helps to park the car in a cardinal direction, or pitch the tent North/South, since we all rely on such clues to revisualise what we left behind.

- But when you do try to orient yourself to something invisible such as how the car was parked when you walked off, there is a simple trap to avoid

  Don't imagine the car/tent as 'behind' you and twist its imagined *orientation* to suit the Sun or compass;
  Instead change its *position* — *move* it to somewhere other than 'behind'.
  Mentally manipulate its placement, not its orientation only. Or else the 'correct' orientation will confuse you — nothing will make sense.

Don't let the Sun 'change its direction' — that is a tell-tale that you are keeping the reference position fixed *behind* you rather than *moving* it as you swing to left and right.
Because we have no good tools to log changes of position or distance, we tend to neglect that half of the story in favour of maintaining orientation.

- As another hint on how to use a fixed orientation, e.g. North-South, so as not to let it 'change' in your mind, imagine it as a long, huge, high, iron girder bridge overarching you and your car/campsite, in the appropriate direction. Whichever way you imagine it, e.g. through-bolted to the continent, or from one peak to another, make it so solidly fixed to the ground and impressively immovable that you feel so insignificant yourself that you feel *you* must *turn yourself around* in order to pass under it.

Routine Mind-Shut-Down Procedures

You know how you become dull and passive — when being over-taught, lectured at, just entertained, occupied in repetitive tasks, sitting in front of the television, failing to solve too-difficult maths problems, or being proved to be a perverse idiot against your own opinion…
Automatic self-defence from constant attack... involves shut-down — into a semi-hypnotic trance.

Similarly,
Walking becomes a "trudge" after about an hour without a break, depending on the load, the heat, and how many trudges have preceded on that day, and previous days.
Pain-relieving opiate levels rise. Conversation takes a dive. The path sliding under your feet gets stared at a lot.
Your mind is passive, plus your body is on auto. It is physiologically involved in the hypnotism.

Mental Torpor is a navigator's constant enemy.
Keep the Different-to-Same-Ratio up, for both yourself and your companions, so that you can stimulate each other into full consciousness!

Feed Your Subconscious Subconsciously

E.g. Open your Atlas to a map of the world. Orient it and leave it open, oriented, and in view.
E.g. Place a magnetic compass somewhere in view at home.
E.g. Develop a habit to Orient your watch N-S each night when you take it off, wherever you happen to sleep.
E.g. Sleep with your head to the north each night if possible.
E.g. Clearly visualise what direction your feet are facing before going to sleep each night.
E.g. Imagine your body lying across a map of the continent.

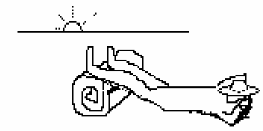

New Habits Open up New Horizons.

"Retracing is Re-preciating"

..This memory-aid is something you have to tell yourself — to avoid blinding yourself and missing the goodness of the walk back.

If you are only titillating your senses for the passing instant, by constantly seeking "new" experiences, you will develop the mind-deadly
"Bin there — Dun that" attitude
Familiarity breeds contempt… "I know the way" doesn't guarantee that you know much else about the way.
The return journey degenerates into a dull, silent, often over-fast, boring, mindless trudge, even if you drove all day to come and see this top-quality location! In effect, you have walked the track twice, but looked at it only once.

Two solutions:
Take an interest in your surroundings, to overcome passive mindlessness.
Questions on your mind overcome boredom. If you have asked questions about a new place, you should be able to answer them on the way back.

Remind yourself of the opportunity to "re-preciate".

Aim to Integrate…

- ..Integrate daytime clues with night-time orientation—use the Moon, the place of sunset, the sunset glow later (which is further South—SH), the twilight Blue Band, Venus, the Ecliptic, the skyline — anything to carry you over from daytime to night-time, during that awkward twilight changeover phase.
- ..Integrate invisible landscape with visible landscape—work out what lies behind each hill, to picture the outside world against that skyline.
- ..Read the "map check-list" and specify what each item means from your point of view—if you didn't have a map, for example.
- ..Integrate the changing, with the unchangeable. E.g. the Sun's daily rotation needs to be followed, by naming its current direction. Same with the track; and your nose; and the wind.
- ..Integrate one walk with another — don't just carry two separate mental maps, add a third overall view.
- ..Integrate each system with each other one. E.g. don't let the map be one "world", while the walk is another, and the night sky a third. Join them into one whole.
- ..Integrate each direction clue with each other direction clue — E.g. "The tower is just before magnetic noon from here" (3 pictures in 1)
  E.g. the boat-radar may fail in the heaviest weather, unable to penetrate the rain squalls—you need a boat-compass too.

It is the **combination** of clues which stops you getting disoriented — if you mistake one, the others will alert you.

Notice and Match Up

'Notice the clues' is the easy half of navigation.
Sometimes it is as simple as seeing that the track is curved.
However, a slight curve due to a river bend can turn you in a hairpin without you realising, even if you *do* notice the curve.
Until you also notice the *extent* of the curve, you are at the mercy of disorientation. Something more than looking is needed.
You need something to orient to, like the wind or clouds or landscape.
Again, it does you little good to have *seen* the clouds steaming by if you forgot to see where they came from.
'Notice *and Interpret*' is the catch-cry, which never stops.
But when the wind stops, will you know what direction you have been going? And 'heading for the mountain' is fine, unless you lose sight of it.
Something more than single-clue orientation and interpretation is needed.

Do Notice; Do Interpret; Do Orient; Then ***Match up***; Link it to something else. And to something else. E.g. the clouds are from the mid-morning Sun; The mountain is on my shadow's port bow; The river has bent from 'towards the coast' around to 'away from the coast'.
For special examples, see '3 in line', opposite

Orient Disorient Reorient Lost? Integrate

Un-Dis-Oriented

You don't need to be perfectly and continuously oriented!
In fact it is quite hard to maintain an exact direction-sense, as soon as you turn your head, move a few steps, divert a few degrees, etc.**
You only need to be realistically confident of position & direction.
Hence **it is better to be roughly aware of many clues, than to aim for perfection, say, in location or direction**.
E.g. 'Moon North' is approximate, +/-60°, but awfully comforting! — It adds to a complete picture.
E.g. You may not even look at your map again, after studying it once, if by now you already know what it is telling you.
Don't aim to be perfectly oriented — just undisoriented.

E.g. Hold the conversation on how to judge range; what's behind the hill; where to find moss; why you can't yet interpret lichens; and so on… and you can hardly miss seeing the walk.
E.g. Run through the Start—Stop—Rest Mnemonic, p.110, as a memory challenge to all… "What's next in it?"… which has the benefit of practising all its clues too.
**As an exercise, guess, from a distance, diagonally, where the side of your house or car points to on the horizon, then go and line it up to find out
Or guess which point is opposite that hillock or tree, then establish how accurate your guess was. My results: +/– 10°; +/– 30° when not trying.

Trapped! By Not Looking Back

A fish funnelled into a fish trap may never again find the narrow entrance hidden somewhere in the large perimeter.
Converging tracks and sudden clearings trap bushwalkers too, when they walk through an irreversible change without noticing.
"Where did our small track join onto the main route?" "Where did we hit the fence/road/pipeline/track, and turn along it?"
E.g. stepping into the creekbed, to explore upstream, is a one-way move—you may not recognise it coming back, and could overshoot.

- **Beware of all sudden clearings**.
  "Where did we emerge from the bushes: out into the clearing, onto the peak, onto the riverbank, out onto the beach"?
  Look for footprints — anyone's, but especially your own.
- Remember the phenomenon — and mark those junctions in your mind! Or even mark the junction on the ground. E.g. place a rock there.
- "Which tributary did we follow down?"
  "Which ridge did we come up on?" More on p.63b
- Log the distance and directions involved at such changes/junctions/clearings, before you walk on and 'lose track'.

Disoriented? Stop. Say So. Reorient!

Be prepared to voluntarily switch from 'certainty' to uncertainty.
Learn to live with fallibility.
As soon as you suspect a disorientation episode, admit it. Say so, out loud. Don't miss the chance.
Tell your brain off!
"You know you're just guessing! You made some mistake and won't admit it! Let's work this thing out together"

If you don't know that you are disoriented, that can be worse than being lost but oriented.
You don't even have to be lost — Even if you know where you are now, if you are disoriented, you may walk on into trouble, rather than be looking to walk out of trouble.

Recall how often you have experienced a hard-to-shake feeling of disorientation.

Lost? Rule 3: Do a Good Job — of walking out or staying put

It may not be safer to stay. Well, if you decide not to stay, don't be aimless in what you do decide to do…

- E.g. Retrace your steps.
- Keep a straight course — e.g. downstream; along the road; toward the mountain; to night lights; to the traffic noise; a chosen direction
- Be single-minded — purposeful, but not stubborn
- Leave a Trail — you may need to retrace. Yes, it consumes valuable time, but "don't get more lost"
- Leave clues; notes — for others
- Walk quickly if you must, to cover sufficient ground, but 'rescuers' may not be able to keep up!
- Yes, your exit strategy may need to be aborted, but at least nominate an exit strategy for the exit strategy beforetime.

In-Line Integration

Put your preparation into something useful by using the '**3-or-more-in-line**' interpretation method…

"The wind is blowing *from* Port Bluster, *over* Hot Hill, *past* the carpark, *to* us, and on *towards* the Sun.
"The Pacific Moon is shining parallel to the highway"
"The Mountain has Montague behind it, that cleared paddock in front of it, and that hillock in the opposite direction"
"The compass needle points past the Northern airport to the mainland"
"My anti-American shadow is pointing past Penstock to Point West at the moment"
"The stream is flowing from Mt. Big, down over Lake Low towards Mersey Mouth"
"That Tropical Sun is over New Guinea, shining Past Alice Springs, over the intersection to me, and into the teeth of the wind"
"The Nor'Easter clouds are flowing from Noumea, over the Main range, to here"
"That persistent pigeon is cooing from behind camp"

The effect is to turn your reference orientation directions into fixed tracks (see p71bi), making interpretation easy.

Navigation is Mental Work — Stay Alert

The tools to work with may be "map and compass" "line and direction" "time and distance"

But any workman needs, and needs to practise…

Attention Observation Analysis Interpretation Preparation Concentration Memory Visualisation

Specialist knowledge Deft application Reliability Right attitudes A store of safe and useful habits Coordination

In other words: **you get lost by lapses in applying your skills, not through lack of skills**.

Mental Equipment is Very Light to Carry — You already have it; Don't forget to use it!

Instruments Instruct the Intelligent

Don't let the instruments — compass, clock, protractor, map — do the navigating for you.
Rather, let them teach you, how to get by without them.

E.g. practise finding North by everything except the compass; then check your guesses with the compass. Try bush North repeatedly.
E.g. Guess at "adjusted Moon North", then consult the compass.
E.g. with a watch you can practise telling the time by the Moon.
E.g. before you use a protractor, guess the angle.
E.g. gauge the distance by eye, then check it on the map.
E.g. attach a sundial compass to your magnetic compass, for the sole purpose of practising & checking your use of the sundial.

In general, predict and guess before observing, and learn from the results.
You should **always check** an observation for good sense, and check any instrument, or any calculation — but prediction forces you to think **first** (rather than the go-to-sleep-first alternative — which is to always check afterwards).
Control your instruments — don't put yourself onto auto-pilot — or you will hypnotise yourself into blindness.

Look Back Regularly

Look At how you got here — so that you can recognise the way back if you need it — and can make sense of your walk.
At the change from one terrain type to another i.e. at the link between natural sections of a walk — after you walk through the change.
At the directionality of the sky haze down low — the change in thickness and colour.
At the colours of the leaves, lichens & flowers — they change dramatically upsun/downsun, and therefore forwards/backwards.
Look Back… At tracks joining in at an acute angle — which otherwise you won't see until you come back — which will confuse you.
At the bending of the track.
At what you may have dropped or left behind! (Check each other. Anyone carrying loose items should walk in front.)
At the distance come, compared to the distance yet to go.
At the weather clouds stalking up on you from behind.
Can you see your starting point, and get a bearing on it? What is opposite that — i.e. the landmark which now shows you your exact trend to date?

Look Around

Since turning your head while concentrating forwards, taking your eye off the ball or turning a smooth corner are all enough to thwart your direction sense, the anti-dote is to deliberately turn your head! Keep looking around at the wider context, including behind, so you don't lose sight of it.

Imagine an Aerial Photograph of the Continent

Visualise exaggerated shadows lying parallel across your imagined photograph — connect those with your shadow and tree shadows.
Visualise the Sun shining like a flashlight upon your imagined continent map — connect that Sun with the Sun you see (Don't look at it!).
Visualise the cloud shadows moving across it — there's one! See?
Draw the isobars across it, lined up with the low clouds wind direction — feel it in your face.
Superimpose a huge compass needle across the continent map — look at your needle. You should be aligned.

Usually you avoid using any small-scale map, since it is the real and full-scale world you want to see or visualise.
But sometimes, imagining a map helps, e.g.…

1. Your navigational map (i.e. remember what you studied!)
2. The mental continent glued to your compass needle, to help you '(not) swing the map'
3. The continental map you walk over at bends, to help you take in the new orientation
4. The bird's eye/satellite view e.g. when reconstructing where you might have gone wrong and when re-enacting it in miniature
5. Sleeping on a map, with your atlas open, and your compass needle showing
6. The Road Map marked out in Regional Triangles from peak to peak.

Making a M.U.D. M.A.P.-m.a.p.-m.a.p. For a more accurate job, see Mapmaking p101c,103c,106ab,109c.

Mudmap your trip onto paper, because paper remembers better than you do. Use any scrap of paper. Take a pencil and draw you meanderings.
Orient the paper to your expected trend (p51a Rhumb Line & p111c S.T.A.R.T.), so as to give you most room to map your journey.
Mark a dot where you start from — probably on the edge closest to you.
Up-arrow for a reference **D**irection; draw in a long one, Up-Sun is good. e.g. Up-wind; Up-shadow; Up-peak to a prominent landmark; Up-Weather **D**irection. (the Cloud flow); Up-North, by compass needle, or Up-Moon. *Interpret* the reference-orientation-**D**irection(s) before you leave.
U-p**D**-ate the arrow direction(s) or interpretation as needed, e.g. as the Sun shifts slowly, in relation to the wind, or as you walk past the peak.
Maintain a trend, a straight-line 'leg' p73b. Use the reference direction if possible. E.g. use the anti-peak.
Or pick a distant mark and walk up to it somehow; Or line up two points and keep them in line (p85e,87e,89e); Or just guess.
Align the **A**rrow when you stop (See Map Alignment 97a-105a, 103b). Turn **A**round to see where you have come from, to map the directions well.
If all other direction references fail you, **Align the next leg carefully to the last leg**. Be careful, because this will accumulate errors.
A-lignment is the magic ingredient. But it is the extra reference A-rrow which keeps you straight and avoids those accumulated errors.
Interpret the new alignment before you disorient yourself: "Where then is the starting-point now?" — or else you have a map but no sense.
Don't forget to use the map on the way back keeping track of the bends and where the start point is, and the finish point.
Pencil in the **P**rogress **P**arallel to the last leg; Pencil in the last leg *distance*. Turn around again and pencil in the *next* leg *direction.*
Guess at the distance, or pace it as you go, or use a pedometer, or a **stopwatch**. Add helpful notes as needed — p95c, 122 might help.
Repeat the m.a.p. for each new leg.

Avoid Disorientation: OverNavigate

Your aim is surely not: 'how to read a compass' etc. But: 'how to avoid a disorientation episode'
Being 'lost' is no panic, although you try to avoid that. Being 'disoriented' is panic (even when there is no real need).
To avoid the psychological syndrome and the real dangers of being disoriented, and lost, the most sensible attitude is…
Avoid getting disoriented in the first place Maintain orientation
Navigate carefully e.g. learn 'how to read your compass' etc.! Overnavigate — don't rely on one theory, one skill, one faculty
Don't give in to panic, or even to anxiety.

Over-navigating when you can, makes it easier when you can't, e.g. sea-sick or injured, bushed-in, exhausted or confused.

It is a rule in life (Murphy's Law) that things go wrong very quickly, not just one thing at a time, but all at once, compounding the difficulty.
As soon as you realise you are disoriented, you'll probably also realise that you also don't know the time, the position of the sun, the direction of the wind, the direction of the clouds, or whether you can interpret the bushes for noon. Then it begins to rain, go dark, and out come the leeches, and you sprain your ankle too. You could learn this law the hard way, or take my advice and do your 'emergency' navigating before the emergency!

How to Get Lost — Follow the Track— A Track is a Trap-Door

A track will lure you into the middle of the wilds. You end up depending upon it completely.
I suppose tracks know where they are going, but you may not, and they can't think. They are mute guides of the blind.

Antidote: Over-navigate. Do more than you need to. **Don't just follow the track mindlessly. Don't let it do the navigating for you.**

Keep your finger on the pulse e.g. How far have I come? What speed am I averaging? What landmarks can I see?
Have I checked the compass lately? The weather?
STAY ALERT
STAY SKEPTICAL

Reorientation; And a Fresh Start

Step 0. Admit it: "I am dis-oriented!". Say So. Stop. Decide to 'reorient'. Discuss it out loud.
Step 1. RETHINK where you might have gone wrong.
2. IMAGINE the true situation.
3. IMAGINE A BIRD'S EYE VIEW of how it 'must' be. Lay it all out, on the ground, in your re-enactment.
4. USE THE MAP; and all the clues — the time, the clouds, the distance…
5. ACT IT OUT on foot, in miniature. "I left this way, turned…"
6. SAY OUT LOUD a) Well that's where I thought it was b) But it is really over there (e.g. that Sun there).
7. Imagine the stars circling where they ought to; the coasts trending the way the compass tells you; etc.
8. Aim for a NEW START "I don't know what happened, but now I divorce the past".

Only when 'the ground shifts under your feet', do you know that your brain has got hold of the new situation.

How to Leave a Message

- Put it in a prominent place (e.g. a hilltop; a campsite; a rock face) with a prominent marker — bright and colourful for instance.
- Make it helicopter-visible e.g. in a clearing; large
- Use international distress symbols e.g. 'V'; Fire; 3 lots. At sea, a white flag or white stroboscopic (flashing) light.
- Any bit of metal may help you scratch out a message e.g. a zipper runner; a coin; a key; e.g. onto a tree trunk.
  If not, try a rock, or stick, to scratch with. Next time, have paper and pen with you.
- Use spittle, or urine, to make mud, then cover the mud message, but prominently — e.g. when searchers remove the coat from the tepee they see the message. E.g. make a flat mud pie; press in twigs to form letters; keep the rain off it.
- A freshly dead leaf is like paper, to write on.
- A piece of charcoal makes a handy black chalk.
- Brittle Yakka gum makes a bright orange powder splotch, to attract attention, and can also be used as a somewhat waterproof crayon.

Disorientation in new territory

Familiar territory does *not* disorient you, so you must *have* the mental faculties to 'know where you are' when you can 'see where you are'.
The overload of *novel* surroundings must overwhelm your normal abilities to mentally keep track of small diversions and accumulated progress.
These suggestions aim to make an exploration more 'familiar' and less 'new'. They come from all over this book. I suppose the message is: 'Don't just read about the methods, take extra time and care to put them into practice; extra 'bother'. Slow down; try harder. Remember more'.
Look back *very* regularly, to increase your familiarity of already explored territory. If you had eyes in the back of your head, it should *all* look 'familiar'. Walk back over that territory before continuing, p 68b. It will feel like old familiar ground if you bother. You could find your way through, and back through, an obstacle course at night without a torch, *if* you went forward three legs and back two as a matter of habit or necessity. That's 5 whole journeys. Talk to the obstacles along the way, and use a mnemonic to recognise them, and what you did about them, and how you turned.
Leave visible markers behind you, so looking back is more helpful to orient you. Leave a trail. It boosts your confidence, even if you don't use it.
Look through the foreground into the distance to **maintain contact with reference directions**. Fix what you can see, especially ahead, in your mind, in relation to the Sun, shadow, wind, etc, until you can point to them from behind visual obstacles. Remember more of what you see. Interpret each clue for its relationship with your memories of how things looked. Integrate the bits into a whole. Use some distance measure.
Maintain a straight line if convenient, so the interpretation of where you are is transparent. Use long straight 'legs' so you can interpret your accumulated path more easily. Notice and remember the angles *between* legs especially. Create a mudmap, so you remain oriented to your start position, and to your current position, and to landmarks sighted along the way. Practise these and other techniques, when it doesn't matter, for later.

To Work Harder, Rest Harder

“Mental alertness” may involve

- A siesta nap!
- An early night (not a late-night campfire party or sing-song).
- Regular rests during the walk.

Tiredness, Exhaustion, Constancy — these stop you thinking efficiently, and affect your memory badly too. So do nicotine, alcohol and drugs.

- When you are in difficulties, sleep on the problem, or take your mind off it with a diversion, occasionally.
- For the sake of having stimulating conversation, the whole party ought to guard their mental alertness too.
- Navigation games do more than orient you, they wake you up.

Be alert to your biorhythms—daily, monthly, seasonal—they affect your alertness or make you depressed—all your mental faculties can be affected.

Minds Work Best with Intelligent Questions on Them

- Am I judging the scale on the map properly?
- How many creeks have we crossed? How many more to come?
- What direction will the next creek be flowing in?
- What is the nearest escape route? To where?
- What does this place remind me of?
- Will it frost tonight or not?
- Where would the animals drink, and shelter?
- What is this place’s own special uniqueness, and why?

How high and steep is the next climb?
What is our next position-check landmark? How soon?
Could we see Mount X from here?
What side-trips would people make?
Why is it sandy soil?
How fast are those cloud shadows going?

Anticipate, with questions, the things you want answers to.

Look Through the Vegetation, to the Contours

- Bushes cloud your vision. If, for example, you want to ‘stick to the ridge’, or want to memorise a junction, then look for the more **permanent** clues…
  ..like slope, creeklines, direction trends, terrain, soil & rock types, alignments, distances, context.
  Of course, look at the vegetation too, but not only at the vegetation.
- Trees cloud the skyline. But there are gaps and lines of sight that open up as you pass by. Look through the forest for the ridgelines, slopes, and horizon. As you move sideways watch the parallax—to reveal otherwise hidden contours.
- Look through the trees, to the **most distant**, largest, tallest features to navigate by — you will undoubtedly catch glimpses of these much more often than you think, if you are looking. They may be other trees, so get used to recognising individual trees.
- Examine the height of the sky beneath the canopy.
  E.g. the lowest sky is ‘downhill’, but **the lowest sky uphill** is toward a pass or gap, & **the highest sky downhill** shows up the ridge.
- Forest-bound **river beds** are often clear of trees and give you a rare distant view.
  Stop in the middle of that rope bridge! And hang around, to look around.

Connections to the Outside World — You Don’t Need to Feel Isolated

Ruins connect you to the past. Earthworks and mineworkings also. Even the landscape engraves its history for you to see.
A **GPS** connects you to satellites; a **radio** to a radio transmitter direction; a TV antenna points to the transmitter; a **phone** connects to the grid.
The Sun, Moon, stars, planets + time + vertical can give you an **astro-fix** to connect you to latitude and longitude — globally.
The **magnetic field** connects you to magnetic poles, as do the aurorae. The deep blue polarisation band finds the Sun for you. So does a rainbow.
Navigational antennae link to flight paths. Flight paths indicate airports; pipelines indicate water supplies; electricity lines go to substations.
Paths point to points of interest. Recent tracks betray traffic. Track-markers put you on track; tracks connect to roads; roads to highways; to cities
Nightlights betray townships and cities; traffic noise links you to highways; surf noise, to the beach. Tides tell you about the Sun and the Moon.
River gravel shows up the upstream geology. East West gully shape shows up North; **rivers** connect you to the coast; **ridges** to peaks.
Air pressure here depends upon altitude; and upon the polar front and the pressure systems. Air temperature relates to the size of the landmass.
Absolute humidity tells about the proximity of oceans. **Cirrus clouds** show up the (westerly) upper winds. **Low clouds** and winds remind you of the isobars on the pressure map. Ground winds telegraph the topography. The radio links you to **weather information**. Waves, to distant storms.
Fence lines connect you to farms; boundary lines to survey grids; trig points to **maps**. Smells to camp fires, marshes, farms, abattoirs, toilets, seaweed, water. Stock trails lead to water; seed eating birds lead to waterholes; the plant and insect types are tied to their range and the region.
Vegetation is tied to altitude, latitude and aspect. **Bush north** indicates noon. Bush slant indicates the **prevailing wind**. Recent wind leaves tracks of yesterday. Deep soil temperature is related to altitude. Why feel “lost”?

OverNavigate: Equals Over-Familiarise

Overfamiliarise yourself with your route as you walk it, the first time you walk it.

Familiarity is the navigator's best friend, next time.
I.e. Years later you can more easily retrace your steps. Even when the track has overgrown.
It is an investment opportunity now, not to be wasted.
The extra time and effort will pay dividends, but like all good investments you must have an interest in the future.

E.g. Notice how and where you went wrong — mentally photograph it.
E.g. Lay to heart the most permanent features — the landscape and trends — not the track, its signposts, or bushes, which may change with time, or with a bulldozer.
E.g. Mentally photograph the lie of each junction, as if a fire might burn up the signpost.
E.g. Describe out loud your short-term memory about how you got here, lest that familiarity flits with the passing of the day.
E.g. Have your own 'track-notes' book.

How to Get Lost — Follow the Leader

A leader is like a track. You can follow him mindlessly. He ends up being a seeing guide for the willfully blind.
Ask yourselves, often, this hypothetical question: What would happen if the navigator dropped dead?
Could anyone else navigate competently?
Do others know where we are? On the map?
Could I find my own way back? Where are the cars?
If the 'leader' himself gets disoriented or lost, noone will know where they are!

Antidote: Teach. Learn. Test each other. Involve each other.
Demystify the magic art. Share it. Talk about it.
Listen to the debate. Look at the landmarks. Contribute.
Don't walk fourth in line. (Rotate regularly)

"Here, you find the way — I already know it"

"As Solid As the Rocks in My Head"

"Who am I to argue with the Sun? to say to it 'You should be over there — not where you are!' "

Telling your head off is the sort of attitude you need… when you find yourself walking uphill to the campsite which you know is down by the river!
… when the clues are shouting at you "Something is wrong here!!"

Navigators who are disoriented prefer to believe in such remote but real possibilities as a compass error or a mistake on the map, signpost or buoy, or to believe in the majority opinion being wrong, rather than to believe in the closer and more real possibility: "Perhaps it is ME who has made some mistake".

True, compasses & maps are notoriously prone to error, but your internal feelings, vague recollections, position/time/direction senses are more notoriously unreliable.

Lost? Rule 4: DON'T Do It Again!

Make resolutions. E.g. 'I will always take a compass.' (I tie a key ring compass to my hat string and I always take my hat.)
(I also tie a whistle to my keyring)
E.g. 'I will buy a map/mobile-phone/EPIRB'
E.g. 'I will always leave my itinerary with friends'
E.g. 'I will learn more about navigation; take pencil and paper; practise'
E.g. 'I will never go on a walk unless I have asked: "Which way am I leaving; Going in what direction?" '

Even better… Don't wait to be forced into a sensible habit. Declare your present attitudes to be 'not yet fit for human navigation' and put it right, now.

A Three-Track Mind

Here is a trick to avoid attention-deficit syndrome in your navigating:
Practise concentrating on two things at once.
Your feet find the path by themselves.
Your mouth talks about how good the meal will be.
Your mind sees the scenery without missing it.

Dual tracking your mind is like many other good things — just a little bit too hard to persevere with under normal circumstances, but possible to achieve, with extra dedication.

Don't automatically get lost into only one train of thought.
Slate this down for practice, for the rest of your life.

Interpret!

E.g. If you wear a face mask in these days of extreme UV radiation, or sunglasses, you become aware of when you are walking into the Sun.
The obvious interpretation, hanging on to this piece of otherwise subconscious information, is: "I must be travelling toward the Equator".
It's a chance to orient yourself to the new orientation. Can you see your shadow ahead of you?—you are getting closer to the pole.
E.g. You might be in a deep dark forest and see a rare bit of sun-dapple piercing the dense canopy.
That means you can go over there and see the sunbeams for a direction check.
E.g. The 'crunch crunch' underfoot changes to a 'clop clop' — "Oh, if this is rocky, maybe I've passed a break of slope."
E.g. Exotic plants betray human occupation — you could look for an old access track.
As a general rule: **Look for any asymmetry**, and interpret it — usually for direction. E.g. When swimming with goggles, twinkly bubbles mean "upSun" — dull ones, "down-Sun". The wave and ripple pattern indicate wind direction. Sunbeams show up the down-Sun direction.
E.g. Scuba-diving: The anchor rope shows up-/down- current; alternating current is the swish/swash from the longest wavelength waves—note their direction. Direct current equates with "away from my starting point". Bubbles show "up" (with some adjustment for current if needed).
Interpret the whole story of settlement: Valleys attract farms, dams, fences, boundary roads, houses, access roads. I.e. you see a lonely fence post on a mud flat, and you say "once several paddocks probably converged onto this old watering place—look for old tracks near the fence post". Look for old nail-holes in the post, to find out the direction of the fenceline.

Play the Field-Scientist

Vary your **focus-distance**.
A herpetologist will see snakes at his feet & frogs at 10 metres.
A geologist will see the skyline, and the creekbed outcrops.
An ornithologist will look upwards, a botanist downwards.

Scientists see more, because they know what to look for, and how.
The more they look, the more they see, observe, discover, and learn i.e. the more they learn what to look for.
You can begin the self-reinforcing cycle in yourself by: wanting an explanation, by trying an interpretation.
And, of course, don't forget to look into the topic, into books about it and field guides for instance.
Be interested in all levels, in all scales and directions.

Focussing keenly will improve your navigation.

Orientation is More Fundamental Than Position Sense

We all carry mental recollections of recognisable spots—like a mental photo album.

But try to mentally picture whole stretches of a country—roads, coast, range, river—with a sense of direction & relative location & linkage.

Better is to carry a library of whole mental maps—walks, paths & layouts—not just photos of isolated spots or isolated linear features.

But Best is to keep all those maps in right relation to each other in your mind.

As your ability improves, you focus less on spots and more on the links between spots;
less on position fixing and more on trend analysis;
less on separate techniques, more on integration.
Direction clues are only helpful if you can coordinate them with what else you need to locate.
Positions only make most sense if you can say how they lie, in distance & direction, in relation to other positions.

Think in Pairs, in lines, trends and tracks

Two landmarks lie on a line, of known direction, and fixed track.
We tend to see things individually, and not see the join between them.
So try instead to get to know
the *direction* of 'camp to that moored boat',
the *bearing* of 'Mt Big to Tower Hill',
the *angle between* 'sunset and the headland'
the *trend* of 'Razorback Ridge'
the *pointing* of 'tree one to tree two'
the *line* from 'start to finish'
the *track* from 'Lake Low to River Junction'
the *tilt* of a star-pair
the *join* of two subsections

Needle-North, -South, -East & -West. Identify them on the Landscape

One of the major problems of navigating in bush, is keeping log of estimated side-slip, distance-wise, even if you are oriented, direction-wise.
But you can see your sideways movement, see p53a, if you plot known directions onto known points on the skyline, (E.g. Magnetic N,S,E,W require no numbers; E.g. your initial forward bearing is already there waiting to be used). Or better, use points in the middle foreground landscape — about as far away as you intend to walk. E.g. local hillocks, towers, houses—things which will be visible from time to time during the whole walk, the closer the better. Make a note of their directions. Use these spots later to find home or your starting point. When you see them later, in relation to compass, you can visualise how much distance out there you have moved and in what direction. Page 106c "Tom Thumb Parallax" shows you how.

Orientation to Your Start-Finish (Rhumb) Line—by sight or compass

Work out the start-to-finish visual bearing to the destination if it is prominent, or to a landmark or point on the skyline beyond the destination.
Whenever you can see that point, you can see your left-to-right sideways positioning, in relation to the fixed track from start to finish.
A simple way to keep track of your sideways movement, at least in open country, is to choose an approximate rhumb line compass course (from start to finish) and watch it move across the landscape in front of you. E.g. "The follow-me arrow is now pointing more to the *left* of that gulch".

Orientation to Your Finish Point, by the Parallax Method

If you are making a one-way journey, use the same "parallax method" as above, to keep a log of the estimated sideslip, but use your **destination**, not your start point, for your reference set of bearings. As the walk progresses, you can see yourself closing in on the correct destination.

Exponential Anxiety — the 11:59 syndrome

Your fear of being 'lost' rises in inverse proportion to the need for fear, as you approach your goal in unfamiliar terrain.
Will it be there as expected? Why haven't I got there already? Surely it should have shown by now!
Have I overrun it?? Maybe I just didn't recognise it? Has it disappeared?
When will this track ever end? Will it end at all?? Will I have to walk all the way back! And so on.

Now, obviously, if you have done your homework well, it will be there, where you thought it was, but maybe not exactly when you thought, so optimistically, you 'ought to' arrive.
Distance guesstimation is our weak point.

Don't add needless anxiety to your background worries. Wait and see it sort itself out.

Anxiety, fear and panic work against good navigation.

Explore Junctions, While You Can

It only adds a few minutes' pleasant diversion to travel the branch tracks which you don't want. (Especially if you can dump a heavy pack)
You may never get to find out about them any other way.
This includes natural junctions—of creeks & ridges—and canal junctions.

When you are exploring, you may never retrace those exact steps, so don't say "I'll explore that on the way back".
The other reason not to say that, is that you will be even more tired later.
When you are uncertain of your position, such exploration ought to be considered "essential", now — not later when you realise your mistake.
Later you may speculate about what it might lead to, but now you can prove it.

In any case, as a matter of principle, explore far enough so that you don't have to repeat the foray
E.g. walk left, until you are sure you should not go left.

"Meet back here in 10 minutes" is one way to investigate in all directions at once.

Separated? An Agreed Plan Helps

Example: Where did I park the car? Is it stolen or am I lost? Are the others worried yet? What will they expect me to do?
Example: Our driver has driven off! Why? What will we do? What will he do?
Example: She has not returned on time! She was exploring that way.

Try these out...
"We will, for at least one hour and at most two hours, try to rejoin each other before changing to panic-plan"
"Where we were last together, is the agreed rendezvous now"
"After that we check our intended destination for messages"
"We know to communicate via a 3rd party—a 3rd person, a 3rd place, or a message bank… "
"..the nearest post office/petrol bowzer/pub/police station/emergency service/Fire Brigade/bank/Red Cross/Salvation Army"

Concentrate Outwards

Both introversion and extroversion belong elsewhere.
If you cogitate inwardly, you become blind to the surroundings.
When you chatter away about other things, that's equally distracting.

Don't spoil the special time of being outdoors.

While it is there in front of you, look to see what is to be seen — and talk about that — about the history of the place, or something about it that helps to keep you oriented, to its unique nature.

Learn not to be distracted from the main game.

SPELL Out Numbers — Into Words

The idea is to express, in words, what numbers measure. Humans hate hearing numbers! So translate mathematics into user-friendly words.
e.g. 270° is "West". That's much more meaningful.
10 past One — "Oh, it's midday!" (in your locality, for summer-time) 10.5 km — "almost half-way"
45° South — "sub-tropical, even temperate; halfway to the Pole" 020°T — just to the right of magnetic North.

PAINT your Words — Into Pictures

E.g. To make it even more meaningful, "West" = "Sunset!" (a word-picture)…or even better……………………
"019°" = "Where the Sun is just before it reaches magnetic North"
(This translates numbers into a familiar and visual time of day.)
"Midday" = "High noon!" (How high?) "Half-way" = "Within sight of the Gorge"
"Halfway to the Pole" = "The Sun rises and sets at 45°. The pole star is halfway up"
'Meaning' usually means a 'picture'
Words without meaning are like looking at the brushstrokes of an oil painting through a magnifying glass, missing the painting!

Here!
(Picture it;
Don't look at it!)

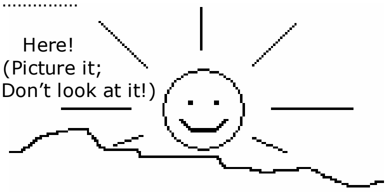

Look at the Ground

- Soil types; rock types (p. 79a)
- Animal runs; animal footprints
- Fallen track markers; toppled-over cairns
- Human footprints e.g. yours, on the way back
  Examine each other's boot treads, then the boot prints. Talk them through — expressing the recognisable peculiarities.
  Practise also on car-tyre treads and prints. (p. 66b)
- If you see a deep trench or a dry mud-hole in Tasmania, that may mean 'an old track' i.e. where constant traffic had refused to let the vegetation grow back.

Look for Foreshortening & Overlap & Parallax

Looking flat on to a shoreline e.g. the other side of the lake, means that any slight inlet or headland is probably a major and very sinuous feature. Focus sharply on it, looking for clues to depth. Don't just run on past it. Move sideways e.g. 20m, to show up the depth, by parallax.

Make Common Sense of the Various Direction Clues

Maybe the navigator has his eyes glued to the compass — but you, you can say "Oh we're just going upwind".
Perhaps you can see six landmarks — but the sensible way to see them is e.g. "We are heading halfway between Mount William and our shadows".
Cloud direction is a good clue, but changeable from hour to hour, so there is no loss in saying "Diagonal to the Sun" which is also changeable.

Don't Degrade the Point of a Clue or System

E.g. The point of a watch, is to tell you where the Sun is. (Don't look at the Sun!)
The purpose of a mnemonic is to remind you to think, not just to remember or to recite.
The reason for a "midnight-rise-noon-set" system is to work with the full-circle—even when you turn corners or turn around. It images the sky
The benefit of a skyline method, is for when you can't see the skyline. You will glimpse it 10 times more often, if you are trying to use it.

The aim of a practical method, is to practise it, not just to know about it!

The Aurorae

The Southern and the Northern Lights are especially frequent during high sunspot years (maximum every 11 years.... 2000, 2011, …).
They are most prominent after midnight. They are best seen in 'high' latitudes (> 40°). One to three days after a solar magnetic storm is best.
The most common aurora is the most easily overlooked — it is dismissed as a 'pale glow' in the North or South, low above the horizon.
But it is not dawn — that is East. It is not from a city — because it changes. Sometimes the sky will be pale green below and rosy above (between the clouds) and pierced by 'searchlights' which move left and right, slowly but visibly. Sometimes 'curtains' appear, shimmer and disappear slowly.
All the rays seem to emanate from somewhere near the North or South Magnetic Pole, and it spans 30° each side or more.
It is an interesting direction guide.
You can estimate current magnetic activity by analysing sunspot activity. **Never look at the Sun**. Instead, throw only an **image** of the Sun onto white paper, as follows... Point your binoculars at the Sun, **without looking through them**! Then, as if you were throwing a minimum shadow of one binocular barrel onto paper, and as if you will **let the paper look at the Sun through the binoculars**, from a distance of say half a metre from the eyepiece, point the big lens at the Sun. Adjust its alignment until the sunbeams go right through it and come out at the other end where the smaller eyepiece lens is. Steady the binoculars properly, and focus the bright, circular, white, image of the Sun so produced, carefully on the paper, by using the focusing mechanism and/or altering the paper distance, so as to reveal tiny pairs of black dots, on the paper. The larger the dots the bigger the storm. Caution! Looking at the Sun will damage your eyes and even looking at the bright image on white paper requires sunglasses.

Orientation to Your Start Point, by the Parallax Method

Step 1: **Start off Aligned**: Make a note of Needle-NSEW, bearings of any other recognisable points, initial-bearing landmark, rhumb-line landmark.
Step 2: **"The Direction Has Changed Its Mountain!"** Instead of saying: "The landmark has changed its direction", first say: "The direction has changed its landmark". I.e. retain in your mind the initial bearing, then, whenever you glimpse that landmark again, you can see how far sideways you have moved off that track—by locating which landscape point that direction now points to. You estimate the sideways disparity across the land, because your compass needle now points to a certain distance to one side of the original mark. Your job is to estimate that distance out there.
Step 3: **"I'm moving through the landscape, out there".** Imagine a thousand of you dotted all over the landscape, all moving parallel, and at the same speed, say, at 4 km per hour. All your initial bearings to all those recognisable spots out there, are moving with you, leaving those spots behind at a rate of 4 km per hour, and now those bearings point to new spots a calculable distance ahead. In reverse, this lets you see how far you have moved sideways to any direction. Bring those distances back to your feet, and see how far away from "start" you are, and how to get back. (At 15 km range, if you are walking at 4 km per hour, you will leave the landscape each side of you, behind at a rate of 15° per hour, but...) From the satellite's point of view, you and your directions are (all) simply moving through the whole landscape at 4 km per hour, no matter at what distance. An alternative viewpoint is to say that every bit of the landscape always moves "equal, parallel and opposite" to your motion, relatively speaking.
Step 4: **Estimate the gap between parallel tracks**—See "Advancing Position Lines" p.108a. I.e. from the initial bearing (a track) to the new one. —by taking a new bearing & using sin(change in direction) x new range. This converts the distances you can see, to a number of kilometres.
The answer, if you want an answer in numbers, is how far you have to travel at right-angles to the original bearing to restore the original bearing.

Nervous Nellie Navigation — Not Necessary

Anticipate a problem. Do something crisp about it. Clear your mind.

Examples: Continually looking at a compass needle — can be short-circuited — by dividing the route into short legs, p. 73b.
Continually gauging the distance covered — can be short-circuited — by making one prediction before you start, and waiting for it, p92b
Getting lost trying to keep track of many bends — is a symptom of not knowing the overall trend in the first place.
Continually guessing where that junction might have led to, is avoided, by exploring it when you meet it.

You never know when you may be totally distracted from your normal pattern of thinking — it is then that you will need a cleared mind.
Plus, if you habitually allow your mind to move on to the next problem, by dealing with the last problem, you avoid ongoing confusion.
Forethought can see the normal problems coming, and pre-empt them.

Look for the Essentials — the 'Directions'

You can't afford to miss them!
E.g. 'Turn left at the Y-junction' means someone has to be looking for it!
E.g. 'Head uphill after you cross the creek' means: notice the creek bed!
E.g. 'If you hit the main road you have gone too far' means that you were talking about lunch instead!

Directions are worth writing down as soon as you hear them: "First right, third left, 6 km, look for the track"
Try to give directions more sensibly: e.g. "Up Fish River Valley from the Park Boundary"
Try to use fixed directions e.g. "North West" "from the lake to the Peak" "between sunrise & Mount William"
Not variable or relative ones e.g. 'turn left'

A Whistle-Code for Contact Calls

Example: The track splits. It's probably just a detour. "I'll go left; You go right". You keep in contact by whistling, cheerfully & tunefully.
Use your favourite tunes agreed between you...

To signal:	"It's me"	Try:	"I did it My Way"
	"You Come to me"		"Oh Come All Ye Faithful"
	"I'm coming"		"I'm Coming; I'm Coming… ..Old Black Joe"

			The rhythm is...
Radio **Morse**:	CQ = Please Contact Me	= " Dah-dit-dah-dit Dah-dah-dit-dah "	"C is Seasick, Q Forms a Queue" "Calling Calling, All radiOs"
	R = Roger — Received	= " Dit-dah-dit "	"An R dits"
	Wait	= " Dit-dah-dit-dit-dit "	"aWait f'r a bit"
S&R:	Come Back i.e. Recall of Party =	Dah — Dah — Dah — Dah	"Ree-Call-All-Souls"
Other:	International Distress = XXX =	Dah-dit-dit-Dah — 3 times.	"all X's hurt, all ex's hurt, all ex's hurt"
	SOS — real emergency —	di-di-di-dah-dah-dah-di-di-dit — repeated	"A bit of Save Our Souls isn't it?"
			See appendix for the full code.

City Glow

From out in the bush you can usually see the direction of about three cities or towns, by their night-time glow.
This works best in hazy atmosphere — virtually any night! — and especially on overcast nights and when no skylight will show.

You need to check a map before you go — for the nearby townships — then check the theory against the facts,
then you can find it useful when you need it.
E.g. you can hold a straight line at night — relative to any recognised glow.

Don't confuse it with aurorae, sunset afterglow, predawn Sunglow, Milky Way, asteroid belt (Zodiacal lights), headlights, local floodlights, bushfires.

Just remember to get up and look for what you normally don't notice.

Come to your Senses

..And it will be surprising what comes to your senses.
Smell the air — for seaweed, marshes, farms, abattoirs, smoke, smog, civilisation, scent trails, fresh wombat dung, humid air, perfume.
Listen occasionally. To help you hear, cup your hands to your ears. Selectively tune out the high-frequency noises to listen to the low frequencies; and vice versa. Listen through the white noise, and through the silence of night.

For occasional vehicles, trailers bumping, boats thumping, jets overflying, thunder rumbling
For constant traffic rumble of a highway
For ocean rollers thumping on shore. You can also often hear the difference between high and low tide, from the wave noise.
For running water, frogs
For wind noise
For generators, pumps, machinery
For farm stock
For the crunch under your feet, changing

Look **carefully**. "It is amazing what you can see, if you look". It is a most important habit for the navigator and is very rewarding.
E.g. you read what others have scratched over the sign that says "5 hours" and discover "8 hours"; or find old track markers almost overgrown.

TRANSFER Your Pictures into Reality

E.g. "Sunset" = "THERE!" even after sunset!

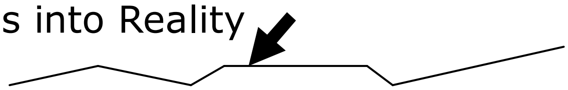

Find the red glow afterwards, further to the left e.g. at 8:30 p.m.

"High noon" = Look at how short your shadow is.
"Within sight" = "Well, can you see it yet?"
"The Pole Star is halfway up" = Do you see how the Cross doesn't set?

Living in the realm of theory is like an absent-minded professor — who can't find his way home, or remember which way he was travelling.

Put That Experience in Your Memory Bank

E.g. "The Pot will go down behind "Pot Hill"."
"I didn't realise how high the Sun can get at 45° latitude!"
"You can see the Gorge from the halfway mark, provided you climb the ridge"
"The Southern Cross keeps correct time at the end of March" — the beginning of Winter.

See opposite for the next step…

Look, with Vengeance Aforethought

A bird observer doesn't just stumble into birds, he runs them down.
A native tracker doesn't simply 'notice' the clues, he searches for them.
Your task is to track down navigational clues, then bail them up.

Your enemy is: losing conscious grip on your task i.e. when the trudge gets the better of your brain.

For Practice: Express the unexpressed. It's no good to be only half aware of what is going on.
Interpret the meaning of each clue. It is no good staring at a compass needle, unless you realise where you are going!
Look outwards, to see what you can see.
Change 'a cursory look' into a specific search.
But, what exactly should you be looking for (once you have exhausted your repertoire of clues)??
Answer: Find out! I.e. **Teach yourself**. Don't wait until someone tells you.

Preparation is the Key to Difficult Navigation

Marine navigators in rock-strewn waters, or battling seasickness in heavy weather, or short-handed, know that the only way to cope with seat-of-the-pants reflex navigation is to have **already prepared clear instructions** about danger-bearings; back-bearings; lines of sight and distances to run, so that they don't need to leave the helm.

It is the total picture, beforehand, which orients you, later.

They need to plan the entire passage (so as to make landfall just before dawn, for instance) according to the tidal streams and ocean currents that they expect to meet (since it is the current much more than the winds which affect boat-speed-made-good, even for yachts). Their key desire is to sail with the current, and preferably with the wind and the weather systems, avoiding the storm-season. See "Aiming-off" p96a.

An hour seem such a long time to spare when you are busy at home; But when you get out on foot, relaxed, with hours to walk but no opportunity for desk-work, it seems that every hour not spent in preparing what could have been prepared, was a wasted hour, as far as being useful now.

Helpful Symbols for Standardising your Chart–Work

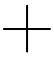

"The Deduced Reckoning Position"
from course and distance information
("Ded. reckoning, or D.R.)

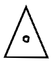

"The Estimated Position"
taking into account currents and leeway
to distinguish it from simple D.R.

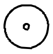

A known position, or a Fix

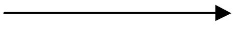

Lines of possible position should have the arrow on the end
e.g. pointing to a landmark

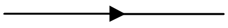

A central arrow means a course. i.e. travelling, not pointing.
One Arrow signifies the course steered through the water

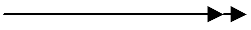

A Transferred Position Line, i.e. advanced across the chart

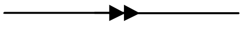

Two arrows is the course made good over the ground

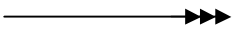

(A doubly transferred position line, for a three-way fix)

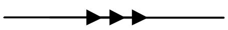

Three arrows is for the stream or the current.

Look Backwards; Think Forwards.

You sometimes, with only a mud-map to go by, have to follow a straight line by compass or landscape, to a low-lying, invisible feature, e.g. a tarn, hoping to come across it without bypassing it. Well, success will often make you feel that that is the end of the matter; "Mission Accomplished". Until next time!
But look back, if you can, to a recognisable starting point, then take a compass or landscape bearing, backwards to the start.
You then convert that to a forward bearing for next time. Place 2 pebbles on the ground in line, turn around and line up the landscape mark needed
The result is a "track", not just a direction — see p.71b — a 'can't–go-wrong' guide.
If your beginning point is not visible, turn around and take a forward bearing on the skyline feature you think you should have headed towards (and probably did). E.g. "One span to the left of Mt. Visible". The result is only a direction from the start—a guessed-at track—but nearly right.

On p.42d I said only to use bearings from high points to high points, for a general navigational framework.
But add to that, a mental or notebook entry of the bearing from a low destination point back to visible possible starting points, when you arrive successfully, or of the forward course you used — preferably by the landscape itself. They are "How-to-get-to (a low point)" tracks.

(Interpret)

Extend Visible Reality into the Invisible Picture

E.g. "It's boiling hot in Baghdad"
"The Sun is over Townsville"
"From the ridge the water flows down to the Gorge and eventually out to the Murphy Mouth"
"The Earth must be rotating Easterly, from West"

Don't be satisfied with half a meaning.
Until the interpretation leaves you oriented, and able to remember something, you haven't gone far enough.

See p. 71b(1) for the last word on interpreting 270T.

To Get There Quicker, Go Slower

We all prefer to run ahead of necessary preparations, i.e. we prefer instant gratification to wisdom.
We also prefer to get something unpleasant, finished, and quickly, once we have started, e.g. "can we make this bad "shortcut" work out?".

Don't rush! "More haste, less speed" = More care, less fluster.
Slight panic makes you hurry. Hurry is a recipe for carelessness in navigation, and for blunders.
E.g. over-running the junction
E.g. missing most of the clues
E.g. taking a foolish "shortcut"
Common causes for hurry, other than anxiety, include…
"Let's beat the rain/the dark"
"Let's get back on time/for lunch"
"Let's sort this out quick-smart as to where we are"
"Let's explore one more kilometre before we admit we're lost and turn back"

Search and Rescue Signals — Noises Repeated Regularly

One = We are searching for someone. (Is it you?)

Two = I acknowledge your signal. "Okay; Roger received-and-understood; I heard that"

Three = "Search for me. I need help."

Four = Recall of Search Party

E.g. rifle shots; loud whistles or horns; two boards clapped together

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End of Section 2.

Nature's Norths

Learn these when the sky — the astronomy Norths — is clear, so that you can **lean** on them later. (Assume S. Hemisphere 1,2,3,5,6)

1. "Dew" North — Dew, moist soil & roads stay wetter in the shade. Frost will persist in the shadiest places, e.g dew South-West.
2. Snow South — Snow remains higher on the shady side of an obstacle.
3. Mud North — Half-dried mud-crusts betray the hot, wind-exposed cracked edges, with the damp mud in the shadowed places.
4. Rock Noon — a whole mountain, or a crack in a rock, can show up the sunny and the shady sides. (See next box)
   — Also, in the evening, after a sunny day, you can feel the colder side of a boulder or gully.
5. **Gully South** — The shady bank of a creek is steeper than the sunny side, at least on average, all around the world.
   The side facing the noon Sun is flatter. The side facing the pole is steeper. This results in roads, railways and buildings etc, being more common on one side—the flatter side—of an East-West river than the other. In other words, creeks tend to cling to the Pole-facing slope of a ridge, as if they migrate equator-wards. Perhaps this is a remnant of a past geological age when the erosion was more marked e.g. hot days eroding the sunny side flat, with ultra-violet light; and constant moisture and icy nights eroding the shady base steeply; therefore suitable mnemonics are: "lying down flat sunbaking" or "steeped in ice" (i.e. South-facing in the S.H.). Lakeshores have steeper or flatter banks according to the same principle.
6. Animal Orientation — "**Barnacle South**" (SH), on dark intertidal rocks — it shows up the wetter i.e. shadier side.
   'Anthills' (Termite mounds) sometimes orient to avoid the heat, so the length of them is North-South.
   Insects prefer the warmer side of a trunk in winter e.g. spider cocoons, ant colonies, boring grubs.
   Some spiders spin their orbs to face noon, like satellite dishes but more vertical; others face sunrise.
   Migratory flight-paths may be North/South &/or upslope/downslope. Animals flee in predictable directions, e.g. inland, uphill, North, upwind e.g. when faced with a fire. They often lie with their backs to a cold wind.
   Siesta South: Farm animals find the midday shade in a paddock. You can smell the urea. You can see the dung piles.
   (7—10 will be expanded soon)
7. **Wind West** — part of the W in the 'WEATHER' mnemonic. It is designed for windswept places when the wind is not blowing.
   The prevailing wind leaves its signature in the visible growth history of the plants, and in the landscape.
8. Wave West — if, in the Roaring Forties, you can see the accumulated effect of ocean rollers.

9. Botanical Asymmetry — where you sort out the competing effects of wind, light, salt, exposure.
10. **Bush Noon** — you never need to be disoriented in the thick bush.
    This works best in temperate latitudes — where the sunlight is directional.

Of course, anything to do with nature, refers to **averaging continual observations**. The most variable signs are the least reliable.
Less Natural Norths

11. Magnetic North; And don't forget magnetic dip — the downward tilt of the magnetic lines of force, varying with latitude.
12. Solar Panel Noon — Observe how we set up solar panels, and verandahs. Nature gives us the Sun, and we all follow it.
13. Satellite Dish Noon — Geo-stationary satellites are, by nature, Equatorial.
14. Microwave dish to microwave dish — Peaks 'naturally' point to each other! See "landmark to landmark network navigation"p42d

Instead of feeling bored, or getting lost, or being 'bushed in', you can have the valuable bonus of feeling at home in the bush, having a hobby, and being oriented to the slope, Sun, vegetation, ecology, weather patterns…
Bush skills are a good investment for future bushwalks. So go for some experimental walks in the bush on overcast, foggy, rainy days.

Don't Forget to Remember, Your Way!

Long-term memory is your best friend — so feed it. You aim for recognition, years later, through familiarity now
e.g. Have you walked the track at night? both ways? twice?
e.g. Collect as much first-and-second-hand information as you can.
e.g. Reread your track-notes occasionally before you lose the memories.
Photographs, Maps, Track guides, Track notes, etc are all permanent on paper! but you aim for permanent memories, not records.
I.e. Mental photographs, Memorised records, What the locals call "knowledge".
Use memory methods so you don't waste your efforts. Use the paper records to help you consolidate your local knowledge.
To that end: Make drawings. Make your own map. Keep a diary. Make your own track directions, names & comments. Tell somebody.
Use biro not pencil. Make a neat copy of your notes and file it.
"Look at…" means "Notice…" means "Take note" means "Take notes" i.e. Take a notebook.

Unlock Memorable Chapters in Your Life

Memory is fundamental in navigation (alongside direction, distance, position sense, visualisation and alertness).
Medium-term memory is how you find your way back, but aim also for long-term recall.
We remember best in definite 'bites' — location by location.

> "Right, team; We have to remember this. Help me. We need to discuss it, describe it, mentally photograph it, draw its skyline, make it a memorable stop, time it, note it, put it in its logical place in sequence."

Go for the Jugular. Zero In on What Matters

Concentrate on the crucial and take-away information

— the crucial "directions"	E.g. the sequence of junctions
— the details that have direct orientation value	E.g. the visual angle between North and Start-off
— which give relevant memories	E.g. the hill-top view laying it all out for you
— track notes e.g. the bearing to follow, the "directions"	
— the overall trend — top-down, top priority pieces of information	
— the perspectives that fit everything into the context.	E.g. the surrounding trends in relation to Sun-North.

E.g. A mental map is better than a 'position' on paper. A map diverts you from the real picture.
Recognition outvotes names; Zero in on the most peculiar visual peculiarity
names outvote position fixes.
The overall details — What you need to know in three years' time, when you try again,
are the **time, distance and difficulty**.
The Sequence (of subsections & features) ought to be remembered... ..rather than e.g. 'bearing 035° magnetic'
Recognising Sections of the walk... ..is more relevant than having a series of map positions.
Surrounding landmarks last longer... ..than "turn left at the red tin-can-marker".

Appreciate the plants and animals; the soils, geology and climate. Instead of "Bin there; Dun that" you aim for familiarity.

The "Lie" of The Land

Think of this as the up-down part of geography. Think "Lie-Down" (versus "Lay-Out" i.e. a map layout).
Think of — Drainage, Watersheds, Catchments & Divides—the accumulated results of Ages of uplift, drainage, erosion & deposition.
— Geomorphology — it determines the shapes
— Ecology — it responds to the shapes, the slopes & drainage
— and how they all fit into each other.
E.g. "This north-facing slope supports warmth-loving vegetation"
"These foothills of the main range drain Westerly"
"The basalt uplift has generated these clayey mud flats"
"This is an isolated hillock within the main valley"
Think of the 'lie' as 'down toward what general direction?'
and 'rise' as 'up toward what encircling range?'
I.e. Put a general trend on major rivers and ridges. Imagine the coast, where all the (now nearly parallel) ridges & rivers run offshore.

Lift your eyes to the "Big Picture" scenery. Interpret it; Memorise its detail; Put it to good use.

Listen to the Pioneers

I.e. listen to the place-names

"The Great Dividing Range"	I suppose this one is obvious
"Blackbird Flat"	This means there is a river nearby
"Stockyard Creek"	A flat clearing is promised
"North Ridge"	This is related to the North Arm of the River
"Huon Valley"	It houses the longest tributary
"Boggy Plains"	Down on the flats!
"Eliza Plateau"	Up on the boggy flats!
"Bright Pass"	Means a change of catchment
"East Pillinger"	It ought to be East of West Pillinger
"Pelion Gap"	A saddle — between catchments
"StrathGordon"	It says "the Valley of" Gordon River
"-Dale"	Also says "Valley"
"Mole Creek"	Burrows underground

Lie Has To Do with Water Drainage

Look for dips in the skyline.
If you find a 'soak'—where water soaks out—look for a ridge-bound marsh uphill—where water soaks in.
Carry an artificial horizon, to reveal slight down-slopes, e.g. a flat plastic jar lid suspended on three strings, adjusted to horizontal.
Or lay your clear plastic drink bottle on the ground. Maybe even pour out some water to see where it runs off to. Listen for frogs!

Stick to the Track

- If you are waiting for the rescue party
- When a "shortcut" looks inviting
- If you have told someone exactly where you are going
- When you are nursing an ailment
- When sacred or heritage sites are at risk from tramping and erosion, rubbish, pollution, desecration, etc.
- When you are one more tourist in the constantly invading hordes, and "Please keep to the track" is aimed squarely at you
- When you are in a greedy hurry for more of the same elsewhere
- If you can't find your way out of a wet paper bag.

Reasons for Leaving the Beaten Track

- Tracks often fail to meet the needs of birdwatchers, botanists, photographers and bushwalkers. Remember why you are there. Talk to the ranger about whether the "No Camping" sign refers to drunken car-based parties, or to scientists and bushwalkers too.
- You sometimes want to search out the worst routes! Easy slopes have one sort of ecosystem/niche/microclimate; Difficult terrain has the more unusual biology.
- Interaction with a bare-dirt strip is not exciting. Fan out, Tread Carefully, Go Slowly, Keep your party size small — then you can appreciate the flowers, lizards, lichens. Each step is watchful — which forces you to see these things.
- A fast-track through a nice place robs you of appreciation-time. The experience passes just as quickly as the tramping to get there!
- Designed tracks will often steer you clear of exactly what makes a place interesting to see — cliff-edge views, water-edges, botanical hot-spots, refuge habitats,…

Isolated places often don't have tracks, and you will need to choose, navigate and negotiate your own route.

Cross-Country Routes

All routes are 'cross-country' but some don't have tracks to follow.
There are two sorts of tracks — Un-natural ones—artificial paths (man & animal made) which form a simple network,
and often stick close to the contours — gently upslope or gently downslope
And — natural routes (following the geomorphology) which cross the contours at right angles and
which form a double network.
I.e. Natural routes are determined by an interleaved network of ridges and rivers...
You are well advised to stick to these routes if only for ease of route finding.
Then there are three sorts of off-track navigation to consider…
— departing from the artificial paths
— departing from the natural routes (to follow a trend to a destination) and
— trying to keep a dead straight line cross-country...

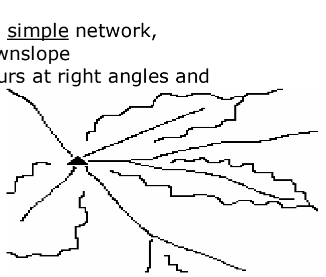

Rock Noon

Rocks blister and crack in the heat. In addition, ultra-violet light hastens all other erosion processes. The top sunny sides erode easily.
Conversely, the shady side is subjected to lichen growth, icing, and moisture, especially at the base.
Differential erosion results in tilted rocks, in asymmetry of cracks and gullies, and in various light and vegetation effects.

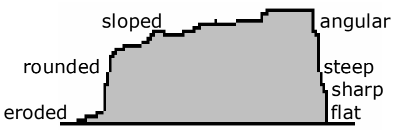

On the hot, rounded side, look for fissures, cracks, furrows, blisters and pock-marking — as signs of heat stress resulting in more rapid erosion.
e.g. Blistered flakes leave a patch of bare rock with no lichens on it.
Such patches are hard to find on the shady side.
Algae grow in the protected fissure under an almost blistered-off flake of rock.
The green stain on the underside of the flake is greener on the sunny side!

Caution: This is **unreliable** unless the rocks show a clearly interpretable pattern.
Of course, **use bedrock** or larger boulders, since they are going to be in their original position — not shifted about regularly.

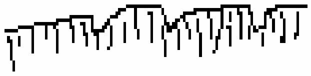

Examine the cracks — The shady side is sharp and steep; the sunny side is rounded.
Just like "Gully South" but in miniature.

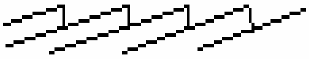

Examine the steps — sharp step-downs indicate a 'dip' in the layers down to noon.

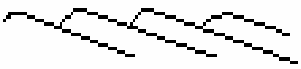

— rounded step-downs show a geological dip away from noon.

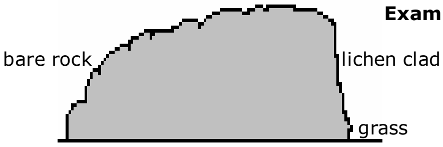

Examine the colours — looking down-Sun you see pale, bare rock (where it has recently blistered).
— looking up-Sun you see multicoloured lichens on a darker background.
— diffuse lichen grows better on crumbly rock. The sunny side will grow such lichens.
— thicker-bodied, textured lichens grow older on the shady, non-eroding side.

Feel the topside vs the backside for a difference in temperature.
Look for green grass and moss in the shade of the rock. These are often far more reliable than the rocks themselves.
Beware that a fire-storm will kill lichens, moss & grass, and will blister the rock, crumble it and split chunks off.
i.e. some of the effects you will notice may be due to a recent fire, e.g. a firestorm from a particular direction.
Rock noon only needs to be reliable enough to tell you which end of your improvised compass points North.

Don't Try to Memorise Details without an Overall Framework

It's a recipe for confusion — to try to keep track of every bend, every hillock, every weather change, every creek bed, every channel.
There are too many of them. They all look alike in close-up.
So start with the map: Learn the **major** rivers and the divides first.
Go for the big names, the overall trends.
Fit the details in by retrospect, after the big picture shows itself.

Don't Try to Remember Anything You Haven't Memorised

i.e. put the effort in first—don't fool yourself. There is a process to memorising something, e.g. establishing a framework first.
And...
Don't try to remember anything you haven't made memorable. Don't battle uphill—make it enjoyable or emotional and it will be easier.
And...Don't write down anything you haven't memorised. First make it memorable, then write it down.
Notes are not an excuse to forget to memorise something!
Like most short-cuts, they are an enticing alternative, but they, like shortcuts, short-change you as well. Memories are precious.
And...Don't try to remember anything you haven't expressed or named. It is a fact of life that we refer to memories by name, in words
And...Don't expect to remember details you haven't understood, or organised, structured, or reduced to a bare minimum—a prompt.
It always helps to interact with, analyse and process anything you want to remember. E.g. investigate it with questions on your mind; criticise it; teach it. It also helps to visually set it out in your notebook with colour, shape, balance and symmetry.

If you relax, because there is a track, or because you have a map, or you have 'directions' for the trip,
and maybe someone else is with you who is familiar with the area, then you cease to build up your own memories and familiarity.
Again you have short-changed yourself.

Write down What You Memorise!

Does that sound like over-kill? It isn't. It's just good sense.

- Memory isn't perfect. So help it along. Do so before you forget.
- You will want to write down your track notes, for years later, anyway.
- Writing helps your memory — it "involves" you more — it stimulates your expression, revises your experience, adds time spent thinking about it, involves your physical participation and your verbal and visual faculties.
- You never know when slight stress (I'm lost!) will distract and divert you for an unknown time.
- To write it all down clears your mind of the previous task — you can concentrate elsewhere.
- On the way back you can easily glance through your notes and then know what to look for.

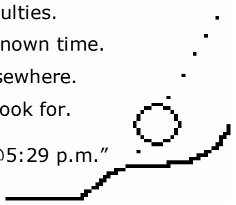

E.g. DRAW a picture of where the Sun sets on the skyline. LABEL it e.g. "Sunset @239°T @5:29 p.m."
Or was it 229°C @5:39? That's why you write it down.

Set aside a notebook for a "TRACK DIARY" (SH)

Major Rivers & Ridges, vs Minor Ones

Obviously, all water, falling on one side of a catchment-dividing ridge, runs to the sea, via a single river mouth; Conversely, river-mouth headlands are dividing ridges. Followed inland, all headlands must reach right around the river catchment—they are the two ends of the dividing ridge. The rivers and ridges form a sort of geometrically inverse pair of systems.
The catchments with the shortest creeks occur between named River mouths, and are called 'coastal'.
I.e. All other coastal land rises to some different, more local, dividing ridge; you may have to undulate up and down along it on the way
Not all creek-lines from a 'major ridge' (a catchment divide), descend all the way i.e. although the water may go all the way to the sea, the creek carrying it may not: the creek might only be a tributary, ending where it empties into a river. Similarly not all ridges running off the catchment-dividing-ridge reach all the way to the coast—some are "dead ends"—they end in a "shoulder", cut off between two creeks joining, or at a river bend. All valley-dividers are ridges, but not all ridges divide whole valleys, or even minor catchments. Those that come to a dead-end before they reach the coast are not dividing ridges, and may be called "minor".
All creek lines do not necessarily start on a dividing ridge: The creek itself might attach to a minor ridge, within the valley area.
Those ridges and rivers that transect or divide whole catchments are called 'major'. The named river ought to be a major line.
Unless you look for them on the map you may not be able to notice anything special about them.
Major ridges & rivers do however tend to stay higher and lower for longer, and often provide you with the **gentlest climbs**,
And they attract roadways.
Main ridges also tend to run parallel to the main valleys and vice versa.

Sort it out on the Map

- You cannot see catchment layouts from ground level!
- If you walk around a slope, half-way up, e.g. following an aqueduct, then you cannot easily know when you cross a major catchment. There are many minor ridges to cross and any one of them could turn into a saddle which divides valleys.
- Around peaks and plateaus, valleys spawn in all directions — it is hard to identify the right ones. High marshes may drain in several directions.
- Near a major river junction, travelling along the dividing shoulder can give a confusing alternation of views, between one valley and then the other.

Catchment Divisions Snake from Coast to Coast

Ridgetops fit parallel to and between the two highest contours marked on your map, and can be very sinuous.
They mark neighbouring catchment edges; & so theoretically you can cross the continent on highest ground without crossing any creek.
Major catchment divisions must reach the coast at a point each side of the river mouth (except, of course, for inland salt lakes).

A Catchment-Division* Separates Whole Valleys

*called a "watershed" in Australia, unlike in USA

Hint 1: Mark catchment divisions on your map with a pink highlighter — pink is opposite to blue-green for creeklines.
Hint 2: Now forget about those new pink delineations on your map. They refer only to the layout, as seen from above.
You need to imagine real, high ridges inbetween deep valleys.
Hint 3: Now forget about those razor-back ridges in your mind. You need to know that they could be remarkably flat paddocks.
— not very eye-catching — look for them carefully.
A catchment division will follow the highest flattest ground and consequently have a few marshes and puddles on it
A metre-high bump in a paddock might separate two raindrops into two different 1000 km journeys in each direction.
So you can't simply "walk downstream" — not until you know where you might end up!

Tracks are like Naughty Children

If you take your eye off them for a moment, they will split as soon as they are out of your sight.

A shortcut is often the result of a junction.
This is because tracks often bend at a T or Y junction.
Shortcutting is constantly encouraged at any bend,
So there will likely be an inviting well-worn shortcut there.
You can always split the party to explore both routes.

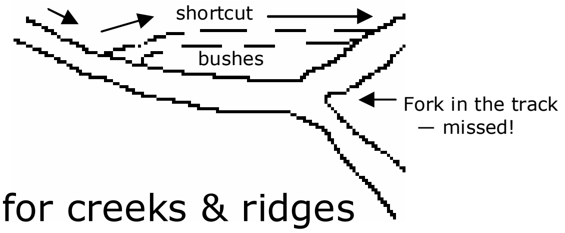

The same is true for creeks & ridges

Unless you stick to the bank of the riverbed, you cannot count on seeing the tributaries, and if you do stick to one side you miss the other side tributaries. Also, where a stream is "braided" into parallel interconnecting branchlets, and you follow one gutter, you are easily blinded to its tributaries joining in from side-valleys.
If you don't stick to the main gutter or crown, you miss seeing junctions on the far side of the river or ridge and can follow a wrong one. But side ridges are harder to see from the crest, just like tributaries are hard to see from the central channel!

Explore Branches While You Can

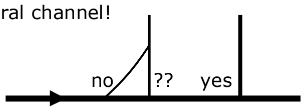

As a matter of principle, it is easier to explore something if you are there, than if you are not!
Be quick to remember that before you walk on past.
Remember… that you are there to enjoy the country. So put down your pack & amble off for a minute or delegate someone to explore.
You may surprise yourself by discovering a helpful signpost at a second nearby junction or a new access point and car park,
Or even, that it is the track you should have taken just now. Bends Breed Shortcuts: A shortcut may look like 'the junction we don't take' which means that you may mistake the real junction anyway.
Avoid endlessly having to wonder later… "But if that other junction turned east, then it might have been the link…" etc.
When you are there, find out for certain.

Convergent Tracks Lead to Civilisation

For example, you get lost, stumble across the track and meet a T-junction — which branch do you take?
You can examine any Y-junction for signs of splitting into two or more minor branches.
The most acute angle of a Y-junction usually points to a focus point (e.g. downstream; car-park)

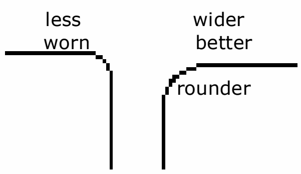

Down-Track vs Up-Track

This one is not obvious, and so it may trap you.
You seem to be following a well-worn path down, until you turn around and try to find your way back up.
It is then that you discover a multitude of other tracks joining into yours at an acute angle!
You see, people walking downhill, downstream, get channeled into the paths of least resistance, converging just like the creek lines do.
But people walking upstream or uphill are faced with choices and tend to spread out into all possibilities, until they find the right one.
The best path is worn in from down traffic, but that may not make it obvious to up-traffic.

Allow extra time when going up-stream, or climbing a steep peak, for eliminating false leads.

Wind West

Assume you are in a wind-swept place in medium to high latitudes e.g. southern Australia, where strong Westerlies prevail.

'W' in the 'WEATHER' mnemonic (p.114b) then reminds you
of the prevailing **W**esterlies in the high 30s, the Roaring 40s, the Furious 50s and the Screaming 60s.

'W' for '**Weather** systems come from the **West'** in temperate latitudes.
and '**Wind** in your face' locates these weather systems for you.
and 'Upper-level **Westerly Wave'** steers these systems to the E/NE/SE in a waving pattern.
A common pattern is to have a warm nor-westerly storm preceding a strong cold sou-westerly change (SH).
and '**Wind-West'** reminds you to look for the lower-level **prevailing Westerlies**, and their effect on the bushes, landscape, etc.

You don't have to be in the Roaring 40s to find a windy place and look for tell-tale signs of the prevailing wind.
— Onshore winds near the coast, being laden with salt, leave unmistakable clues imprinted in the bushes, and on the seashore.
— High plateaus and wide open clearings are usually windswept.
— Gullies produce up-gully breezes and down-gully gusts.
— Hilltops are windy. To get an undistorted picture of the prevailing wind direction, go to a hillock.

To navigate by the local prevailing wind may be more preferable locally, than to navigate by bush north.
The prevailing wind is not as universal or reliable as bush-noon, but it can be easily visible, audible and tangible.

In general, the **tallest trees** are the best tell-tales.
Look for wind-induced asymmetry**, especially at the tree tips** and the **oldest** tree trunks, when you are in a wind-sheltered zone.

Think Wind

Distinguish in your mind the various causes of wind damage…

- Storm Winds — brief but furious, as a weather change hits. They may uproot trees. They are often hot and dry.
- Fire-storms—from the hot dry inland, or sweeping uphill. They can leave a trail of dead black fallen trees lying parallel.
- Cold Change Winds — Cold, Gusty, Strong, Persistent for a day or three; Usually south to southwesterly (S. H.).
- Persistent Prevailing Winds — Westerlies 'Waving' between northwest and southwest in between 'changes'.
- Salt Laden Onshore Winds — They 'cut' the exposed vegetation back to size.
- Cold Blast Winds — These kill off the less hardy competitors.
- Hot Dry Blast Winds — These leave only the waxy/succulent/woody species.
- Sand Blast Winds — They remove vegetation, carve out sandstone sculptures, and remove lichens from the exposed side.
- Windy Season Winds — Ask the locals what to expect at each time of year.

Anything is Memorable

Make it personal	"Where I found the pocket knife!"
anticipated	Study the map beforehand to imagine the sections
active	Do something; involve yourself
important	Draw attention to why it should be remembered
associated	It looks like a … ; sounds like my middle name ; uphill from the mine
creative	Make up an enjoyable name
emotional	Expect to notice, then remember, decision points & anxious times
visual	e.g. symmetric, colourful, shapely
geometric	This triple-trunk matches the triangle of paths here
noticed	Draw attention to it "See how we have just entered tea-tree ?"
peculiar	That tree looks like a traffic policeman!
prominent	The tallest tree here, see?
liked	What aspect about it interests you?
named	e.g. "Midnight Junction"
fitting	"Power Point" where the electricity line crosses the lake
funny	'Willy Willy Waterhole' where we saw the dust-devil
human	"Betty's"

Make Individual Memories Memorable!

The problem is an excess of information, with a shortage of enough meaning to go with each detail.
e.g. hillocks and creeks have endless detail — you can't hope to remember all.
Visual memory is not the problem — pictures are perfect — but recall is difficult.
(And sorting pictures out later, into the original sequence is also hard.)
You need to add memory handles, worthwhile meanings, specific focus, etc.
Hint: Do something memorable there. Dance, Sing, Jump, Shout, Throw stones into the puddle.
Make a cairn. Sketch a tree. Have a meal — Chewing is said to aid memory!
Leave something of 'yours' there — something peculiar — e.g. lean a stick against a tree trunk; scratch the ground.
Insert it into a larger scheme — time & sequence; lie & surroundings; an acrostic poem.
Make a game of it. E.g. "Who can say what's peculiar about this creek?"
Make it 'yours' e.g. Discover it. Climb it. Explore it. Study it. Explain it. Draw it. Map it. Show it to someone. Name it.
Spend time there, looking.

Remembering Trees

Simply spend time looking. It may only be 10 seconds, but that is 2000% more than the usual ½ second!
Look at the branches, the shape, the trunk, until something strikes you
E.g. "Oh, these two branches grow across each other"
E.g. "The bark is right-hand spiral"
E.g. "See that ant-highway going up into the hollow—it might have water in it"
Walk around it, to see the shape from side-on. Characterise it & its context
E.g. "entirely shorter than that old stag's first branch"
E.g. "three tufts on top"

You get better with practice.

Ridges

Ridges have gentler slopes up/down ridge i.e. provided you stick to the crown.
The slope 'makes' rapidly on each flank. It is only the ridge-line which is flatter.
Ridges have nicer views. But these views are easily halved unless you walk right on the crest.
have nice breezes, provided you are right on the crest.
have more open and stunted vegetation plus shallower soil and more exposure to the elements.
are wider and flatter than a creek bed, and their rocks are firmer underfoot and dry.
Their run-off slides off downhill to each side.
These advantages are also lost as soon as you slip off the 'crown' of the ridge.
Off the ridge is steep, vegetated, narrow, loose, windless, hot, humid.
The steepest but best way up a ridge is... up the ridge because (1) it gets even steeper off the ridge
& (2) contouring is 'easier' but it doesn't get you 'up' but only into more difficult terrain.

Ridge Names

▪ Mountain to Mountain	e.g. Mount Ossa to Legges Tor (trace it on the map)
▪ Mountain to Mouth	e.g. Mount Ossa to Arthur River South Head
▪ Mountain to Headland	e.g. Mount Wellington to Wrest Point
▪ Catchment Division	e.g. The Arthur-Pieman Divide
▪ Tributary Divide	e.g. The South Arm Ridge

A ridge may not be "major" but if it divides your walk, you do want to know about it—so make up an appropriate name for it.

Mnemonic: "Ridges Rise"

Whenever you cross a ridge don't forget to ask: "Which way does this ridge rise, in trend terms — to the left or to the right?"
It is like asking which way water is flowing, but the truth can be obscured by local undulations in the ridge.
Ask: "Does this ridge, if followed to the (right), end further inland i.e. upstream, or further downstream?"
It must correlate with the overall corresponding drainage.

Uphill — Which Hill? Upstream — to which Divide?

To Which ridge? Which plateau? Which highest ground? Just as surely as rivers reach the sea, so ridges reach a peak.
Which peak? is the question which orients you.
Until you know which catchments you are climbing out of and in to, you don't have a grasp of where you are.

Sympathy and Understanding with Track Markers

Take time out to explore (e.g. leap-frog fashion) from one track marker to another.
Always guess where a track ought to go.
When you come across a marked trail—maybe poorly marked and/or difficult—the question arises: 'Should we follow it or not?'
Intelligent guesswork helps here

- Where would *I* put a track?
- What is the direction trend of the new trail?
- What is the slope trend of the trail?
- What tracks & routes might you expect?
- What alternative access routes exist?

E.g. uphill, heading West, may well mean: 'to Lake West from the lower car park'

If you leave the track behind, because it is unclear, you may never get back onto it.
But if you work with what you have (a bad track) it may be quicker in the long run.

Old Track Markers

Practise noticing them, before you need to.

- Old axe-cut blazes on tree-trunks — from the original surveyors
- Very old paint flecks in the blazes — search for them
- Blazes and markers on the far side of the tree — look back
- Old nail holes or nails or rust stains — the marker has fallen off
- Fallen markers — on the ground
- Fallen rock cairns — the rocks blend in, but show their pale underbellies
- Arrows on wet rock-faces — the wetness obscures the scratches
- Sawn branches, trunks and logs from when the path was cleared
- A clear line-of-sight through the trees
- Thick young growth — an unused road
- Smooth or shiny rocks with less lichen — worn smooth by feet
- Fallen trunks with a gutter worn across them — betraying foot traffic
- Broken branches of varying ages; bent stems e.g. bracken fronds
- Stumps cut off at ground- or eye-level.

Be Wind-Wise: Listen

Listen directionally — the wind-noise will be mainly from up-wind.
When you think you are navigating by the beach noise, you are probably navigating by the onshore wind, and should keep track of it.
Listen **through** the noise — You may distinguish three frequency bands, as the rumbles emerge from the hiss.
Listen through the **silence** — of night, in the stillness. Up-wind sounds carry a long way.
Listen to the **sounds** (birds, traffic, house, factories) — They carry clearly from up-wind only, especially the high frequencies (whistles)
Listen to the **beach** noise — The 'hiss' will be from a direction more up-wind, and closer, location-wise.
The 'rumble' will be from further away from you and further away from up-wind direction.
Listen to the **thunder** — Air temperature zones create directional effects, so that approaching storms, which are preceded by low level cold bursts of air, have their noises refracted up and out of earshot.
(See "Tips for Calm Weather" p.23d & "Topographic Level Winds" p.25d)

Obvious Tell-Tales: Landscape

- E/W coastal asymmetry e.g. Temperate West Coast ocean beaches might have a kilometre of surf, but East Coast beaches are narrower and calmer. Trade-wind East coasts are surf beaches, but headlands with West facing shorelines will be sheltered.
- Bays end in exposed points. Look for tall, steep, bare sandhills on the weather side. If there are tall sandhills at a narrow point, you will see sandhills from both sides, so ask 'am I seeing the green (sheltered) backside?'
- Sand dunes. There are variations, but bare dunes tend to be cross-wind and vegetated dunes tend to trend down-wind.
- Puddles, Lagoons, Lakes, Creeks, Beaches — Look for wind & wave action effects e.g. dark mudflats up-wind & white sand-steeps downwind. Shallow puddles often occur on the downwind end of a flat drainage.
- Sand ripples show steep backsides downwind, as the wind driven grains topple over the eroding crest.
- Clumps in sand-stretches show a long tail downwind. E.g. behind dead seaweed deposited on the dry beach.
- Grass-clump erosion is the reverse of sand ripples — look for steep bare dirt and exposed roots on the exposed side.
- Camps & campsites, picnic tables & fireplaces, bird nests & animal shelters all avoid the un-sheltered side of vegetation.
- Wind-shadow growth—plants grow taller in the lee of a mountain range, or of a pebble, sand ridge or house.

Obvious Tell-Tales: Windblown Objects

- Flotsam collects on the downwind side of a lake (but on the sheltered side of a coastal point!).
- Trunks fall downwind in storms; branches fall downwind in gales; leaves, nuts and flowers fall downwind in strong winds. Look for ribbon bark hanging in a tree downwind from its source.
- Rubbish (old dead twigs & leaves) collects behind a clump.
- Dead long leaf blades lie cross-wind when blown against an obstacle e.g. a clump...
- Dead long leaf blades lie down-wind when blown from a source e.g. a tussock...

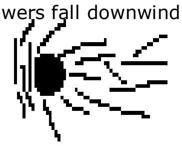

- Broken off branchlets lie with their big spread-out twiggy end downwind. Meadow-grass tufts pulled up by grazing animals also.
- Feathers catch in bushes, usually on downwind branches, and mat against the up-wind side of those branches.

The Difference between Looking at, and Seeing

..has a lot to do with involvement.
e.g. a seed-collector will see the vigour of the plants and their stage of fruiting. Would you even see the plants!
e.g. a hunter will see a route for stalking from behind cover.
e.g. a photographer will see the contrast in light.

Would you as a navigator care to notice footprints, or their absence? What about the flight-paths & contrails, or gems in the river gravel?
Navigation is your opportunity to see more.

Search-Image

It is possible to stare at something obvious and not see it! e.g. the pattern of wind-blown grass stems, or the peculiar geometry of a tree. But after some practice, you can't miss it. So train your brain to the search images before you need them. When you are flustered and hurried you will not feel confident in your abilities to see something difficult, and will likely give up too soon.

We Recognise 'Sameness' But Need to Describe the Differences

A gum-tree is a gum-tree; but this gum tree has three trunks!
A 'bend on the road' is just a bend; but this one bends away from sunrise.
A 'hillside' looks much like all hillsides; but this one is regrowth with wattles dominant.

Don't just gaze at "the view" or "the landscape" or "vegetation". Look past the fuzzy 'sameness' to the unique peculiarities.

Unfortunately that often means: 'Focus on the boring detail'
e.g. 'This hillock has five dead tree trunks, totalling nine main branches' which makes this hillock recognisable and unique.
So. Hint: **When all else fails, COUNT!** (The same goes for botanical species identifications.)

There is often no way around a detailed look. There will not be anything unexpected to hit you in the face — you must keep looking until the interesting peculiarities emerge.
E.g. "No other dirt road junction I have seen has an Acacia sapling growing in each corner."

"Shoulders Stop"

A huge mountain range may end in a "shoulder" i.e. a 'shoulder' amounts only to a 'minor ridge' stopping within the valley.
You will not get to the coast by following it down. (If you are on the very last ridge next to the coast it would be called a headland).

There may also be isolated high ground within a valley, a lot like an island, and this too is doomed to end in only 'shoulders'.
Such high ground is drained by one river only, but via several tributaries.
It will have one, often low, flat connection (a saddle) 'uphill' to the main Divide.

Shoulders are Not Easy (like Ridges) To Walk on

1. They end a spur, and so are likely to be steep, as the ridgeline plunges down to the creek bend or junction below it.
2. They are wetter than ridge tops. Although they shed water, being convex, they are still fed with run-off from above, as on a hillside. So the vegetation can easily become very thick.

Saddle — A Flat between Hills, Sitting Astride a Ridge

They are so named for their resemblance to the two-bumps-two-gutter horse-saddle shape, designed for two legs astride a sway-back.
When a flat area is drained by three creeks and so has three ridges lifting from it, it is called a "monkey saddle".
The third gutter accommodates the tail. This can cause uncertainty-of-choice for navigators!

A "col" is a saddle.
A "pass" is usually a low point in a high ridge i.e. it is a saddle.
A "gap" however may simply be a river gorge.

Every undulation and flattening of a ridge leaves a saddle. In forest, there will be a puddle. It may also attract a campsite or a road.
A saddle may look like a valley crossing—a muddy dip in the path—but the two sides both drop away, if you look carefully through the wall of vegetation.

Weather maps show pressure 'saddles' between two High's and two Low's—p.11d.

You can also picture a saddle as a U-shaped valley going up and over a gap between two hills and continuing down the other side.
Saddles make creek sources, but not every creek source begins as a flat saddle—any ridge or slope may spawn drainage gutters without necessarily flattening out.

Track Markers

— Decode the colour-code. Separate tracks often have separate colours. Reverse track markers may be of a different colour.
— Successive generations of track marking may be evident, or several colour-coded tracks may share one leg of the journey.
— Triple marking, often means "End of Markers" or "End of Track".
— Big cairns mark junctions, campspots, features. Cairns with a stick may also indicate a junction.
— Side-tracks are marked with something extra or different.
— Sticks over the track, or especially crossed sticks say "No Entry. Wrong Way. Go Back".
At an unexpected junction, if you have to step over some branches you have probably missed the intended message.
— Un-needed signposts — often mark the entrance of disused tracks. They may (or may not) be at an unexplained bend in the route.

When You Lose the Track-Markers

Be suspicious! Start by over-navigating beforehand — search for all track markers as a habit, even when the track is well-worn and plainly visible. It gives you the practice for when the track marking does get patchy.
Also, only then will you notice whenever the track takes an unofficial shortcut (e.g. following vehicle tracks, not the walking track).
Or maybe you have taken a wrong turning off the marked track and need to realise it, no matter how good the new track is.
Whenever you lose the markers or whenever you lose the track, explore in these directions: **straight ahead and straight behind**.

One or two markers may simply have fallen off — so maintain the trend
You may be approaching a main track junction with the first few sidetrack markers removed to conceal the sidetrack you are on.
An unexplained bend, which deteriorates, may be explained by a missed junction/bend...

Where a tree has fallen nearby, try to pick up the trend of the old track, on the far side...
Backtrack to where you went wrong — to the last bend & from the last certain marker.
Next, explore the unexpected directions.
Very often a marker will be placed at a bend, because of the bend, or even because of a Y junction.
Then explore in all directions — "Meet back here in five minutes" might save 50 minutes.

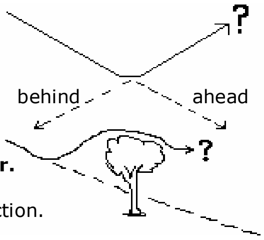

Notice (with Alarm!) When...

..The track itself **deteriorates**. You may be on a false track, made by people doing just what you have done
e.g. you overran a junction or bend; you sidestepped a fallen tree without noticing.
..Boot prints, that were there before, cease. Especially on a 'through' track.
..The track gets **better**! This means that in back-tracking you may miss your small track and follow the other track which joins in there
..The country abruptly **clears** e.g. a beach, a peak, a clearing, a road. There may be no way to find the single small track you used.
By the time you remember to look back, you may have lost the way back out. There may be too *many* paths to choose from.
..Any **barrier** e.g. a beach, a road, a fence, a riverbank — clear or not.
When you hit the barrier you do a right-angled bend, but later you may not remember exactly where you met that barrier.
..Any **catchment change** i.e. crossing a ridge, or even a creek crossing—into "another part of the catchment".

Name the enemy: Be the first to say out loud **"Abaracadabara! Peek behind you! because it's a...(fill in the blank)"** A **B**arrier; A **R**idge/River/Road Junction; A **C**learing; a **D**own-track (or focus point); A **B**etter/worse track; A **R**idge/River crossing; A **Peak**.

Light & Colour Effects

This is one of the delights of nature! Chances are that you will be startled, even if you know what to expect, but only if you look for it. You need to wade out into a uniform reed-bed, preferably when the Sun is side-on to the prevailing wind, then look up- & down- wind. Up-wind, the tussock tips are pointing toward you. You then see between them into the deeper shaded body of the plant.

- The view up-wind is dark & colourful. The best effect is from rich brown or dark green, drooping, chest-high reeds.
- Down-wind the tips lie flat and reflect the sky shine at you — faded & bright.
  The prevailing wind may result in permanent sunbleach on one side of the grass blades.
- On a windy day you will see gusts causing bright patches in a dark background, due to the same flat blade effect.
- To neutralise the directional lighting of the Sun, look down-Sun — to your left & right will show pale vs colourful.
- The combined effect of the Sun and the wind result in four quadrants — darkest up-wind; shiniest downwind; greyest up-Sun.
- This happens even with ordinary green plants — look for it in any low, flat, wind-swept vegetation.
- The prevailing wind doesn't need to be blowing to see its permanent effect on the plants.
- At sunrise in the reed-bed, you should notice a 'funnel-web' effect on your right — like the circular scratches showing up through a sunlit window.
- At other times you may simply notice that any shiny leaves on the left of the Sun tilt left, and on the right of the Sun tilt right.

- Looking up-wind anywhere is greener. Downwind looks more bleached — due to leaf-tip scorch, leaf fading and leaflessness.
- Weather-side sandhills are white. Lee-side sandhills are greener, due to thicker growth.
- Exposed lake banks are steeper & eroded. So, sandy lagoons show white sandy vs dark muddy ends.
- In sandy heaths, downwind shows up as windblown sand patches of erosion. Up-wind shows up as continuous plant cover.
- Rocks in sandy places are sandblasted pale on the up-wind side and darkened with lichens on the downwind side.

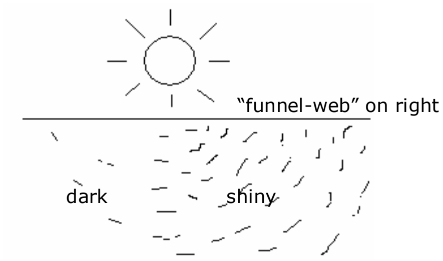

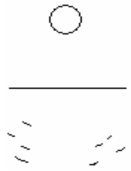
Shiny leaves

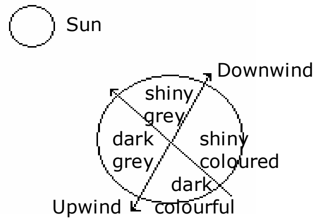

Expect some variations

Place Recognition
You Recognise What You See, By What You Can't See

Every locality fits into a context — the invisible surroundings.
How long did I take to get here? How far from the turnoff? In what direction from home-base? Uphill or down or contour?
How many creeks have we crossed up to now?

To know where you are, you can't ignore where you are not.
e.g. 'It was an all-day slog to get there, we finished the day worn out'
is part of where you were, and fundamental to your memory of it.

Landscape recognition is relative.
That involves your senses of time, direction, distance, difficulty, slope, topography, layout, number and network.

Aspects, invisible to the eye, which surround a place, live in your mind's eye.

Description Requires Words
Can You Describe All That You Can Recognise?

E.g. a magpie. What pattern is on the head? What colour legs?
E.g. your brother — what colour eyes? what voice accent?

"Recognition" means "I need to see it before I can recognise it"
"Description" is "I can recall it to my mind and describe it"

If you don't deliberately memorise something you can only recognise it but can't describe it.
So thoughtful examination, notes and practice, can fill in a lot of blanks.
Repeated visits build up a subconscious picture, but you can speed up that familiarisation process by **deliberate scrutiny**.
Expressing the description in explicit words, forces your subconscious 'recognition' powers, into a new dimension.

Hint: Open your mouth; say: "The place where… " and see what comes out spontaneously.
try: "In between…" "Running alongside the… "
"You probably would remember it as the time when… "

Notice When You Cross a Catchment!

It is a major method of navigation
e.g. at night; or in a blizzard; or when you are lost; or in a forest; or descending from high ground; or exploring upstream.
But you need to get used to noticing ridges and to counting creek crossings and to matching the catchments to the map.
Notice also, when you cross from one side to the other side of a catchment.
Ask: Is this riverbed likely to be the lowest, largest channel in the whole catchment?
Look for creek-line vegetation, as sometimes the only clue to the drainage pattern.
Look for any darker patch in the road or track or beach, as a tell-tale sign of a dry creek bed.
Look at the track ruts. If the rocks are exposed, water flows over it. If the ruts flatten out, water drains away from the track there.
A subtle rise, dip or bend in the track can be traced to an obvious ridge or drain crossing it. Look sideways to appreciate the lie.
Assess any puddle, marsh or mud hole — Is it a creek line or a saddle top? — Is it in a dip or on a crest? — Can you trace a gutter?;
Notice any crest; Trace ridges to a nearby peak. I.e. Don't get caught whingeing about the government, instead of noticing the lie.
Ridges divide: they shed water. Creeks collect: they catch water. Valleys drain: they empty into the sea.
Rivers cut the catchment in two.
See "Understanding Contours" for some hints — later in this section. See also p.83b.

The Giveaway! A Change of View — Mnemonic: "Catch the View"

The new panorama is the tell-tale sign that you have changed catchments.
Perhaps you are contouring around a headland and catch the new view around the corner, or you are sidling around a ridge,
or you are breasting the saddle, or reaching the peak, or cresting a paddock… It is the new vista that greets your eyes
which tells you that something has changed. It is also the loss of the old valley view.
Well, maybe you can't see the view, but you may now be able to see the skylight or even blue sky down through the trees below you.
When climbing, you find yourself looking down instead of looking up. Your muscles, of course, tell you the same story.
The deeper the new valley, the more far-reaching, on average, the new view.

You Can't Cross a Creek Twice from the Same Side

If you make two successive creek crossings in the same flow-sense, you have crossed a creek divide into a different creek catchment.

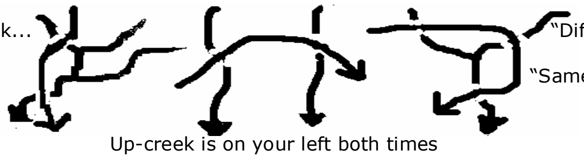
Alternating crosses=same creek...
"Different creek"
"Same creek"
Up-creek is on your left both times

The same rule can hold for ridges, but only those which slope uniformly down from high ground.
Otherwise an unexpected crest slope, instead of being a 'different ridge', may alert you to 'a local up-trend' on a down-sloping ridge.

Mark Your Trail

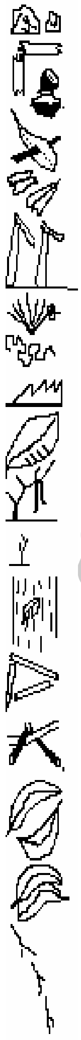
a pair of stones...
a gumnut on a rock
a cut leaf…
dead twig…

Two principles are needed 1. Trail marking takes extra **time** — budget for it.
And this one is widely applicable… 2. It's easy when you know how, so **think** how!

Mark Your Trail Non-Permanently

E.g. when you could otherwise get lost

- Use what is available — pebbles, leaves, tussocks — throughout the area, for ease and consistency.
  e.g. "always look for a pair of stones"; "tie a grass blade on the top shoot of any shrub"
- Leave your mark in a visible place. E.g. "look for freshly broken twigs at the base of each trunk on the path";
  "check the topmost leaves of anything chest-high for a mark"
- Leave your mark in an expected place. E.g. cross-country: Zig-zag in straight lines between prominent features,
  so coming back you know exactly where to look for the next markers, and searchers do too.
  E.g. hillock, to tall tree, to clearing, to outcrop.
- Do something only slightly unnatural: (see diagrams) A gumnut on a rock; a twig through a leaf; a pair of torn leaves; grass stems bent in a consistent direction; or tied in a knot; or crumpled; a scissor-cut dead leaf; a scissor-cut fresh leaf; bark hanging from a barkless branch e.g. gum bark in a Banksia; a twig drilled into the ground; a leaf wedged into bark at eye level; a triangle of twigs; a half broken bent twig hanging in a shrub; an opposing pair of gum leaves; a trail of sticks; windblown debris which is reversed; upturn a rock onto leaf litter
- Deliberately plant your boot print when you can. Step on top of older footprints, deliberately.
- Use fresh material so that your trail may be 'aged' according to the fading or drying e.g. of green leaves or mud.
- Position markers so that time, animals, wind & rain will disrupt them (at a recognisable rate). E.g. a teepee of sticks.
- Try a snow cairn; chalk marks on rocks; cotton tied around a branch; a stick dragged in the dirt; a scratch on a rock; balls of mud; charcoal or charcoal marks; tiny shreds of paper.
- Choose one method and stick with it, with a backup method in reserve.
- Double-mark a trail e.g. when doubling back, by duplicating it.

Tracking Someone Else

- Look for the **absence** of: spider webs across the path; dew on overhanging branches. To discern a foot-path look for the absence of fallen branches; leaf litter; lichen & moss; old wombat dung on prominent rocks; unbroken sticks; untrampled seedlings; undisturbed soil
- Look for the **presence** of freshly disturbed stones/soil crust/puddles, plus footprints.
- Examine puddles: for wet edges — indicating a recent forward swash; examine for muddy water; look for muddy water in the deepest layers — indicating disturbance some time ago; for wet stems above the water — they have been trodden in and have sprung back
- Overlapping fronds across a path — they 'remember' which way they were last pushed through.
- Don't step on the boot-prints or tracks you are trying to decipher—you often need to look at them again.

Botanical Tell-Tales

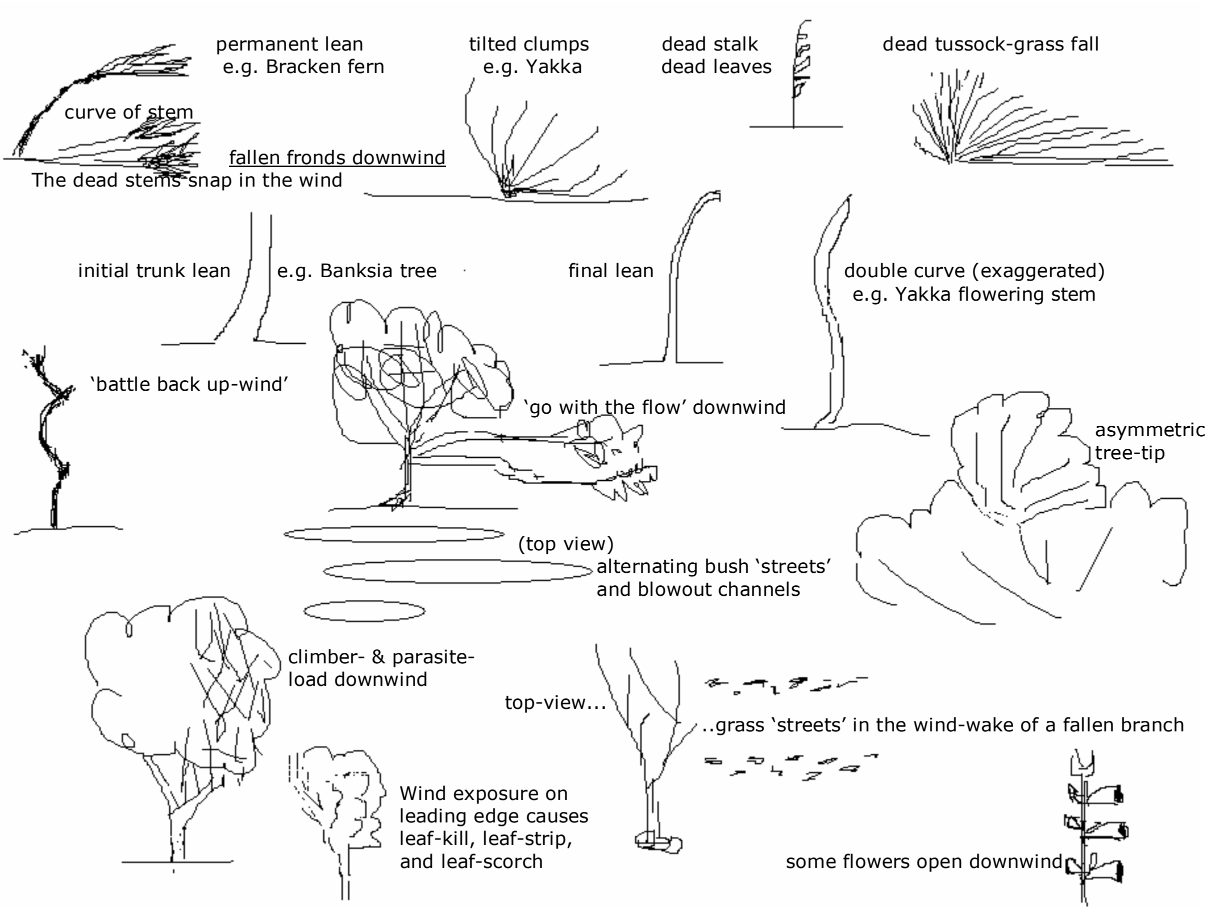
permanent lean
e.g. Bracken fern
curve of stem
fallen fronds downwind
The dead stems snap in the wind
tilted clumps
e.g. Yakka
dead stalk
dead leaves
dead tussock-grass fall
initial trunk lean
e.g. Banksia tree
final lean
double curve (exaggerated)
e.g. Yakka flowering stem
'battle back up-wind'
'go with the flow' downwind
asymmetrical
tree-tip
(top view)
alternating bush 'streets'
and blowout channels
climber- & parasite-
load downwind
top-view...
..grass 'streets' in the wind-wake of a fallen branch
Wind exposure on
leading edge causes
leaf-kill, leaf-strip,
and leaf-scorch
some flowers open downwind

Discuss It

Let others open your eyes: "What can you see about this?" "Where does it remind you of?"
Ask Questions: "How do you know where you are?" "Could you get back here again next year?"
Make a game of it: "What else can you notice from here?"
Express the specifics: e.g. "That boot-print has zed-shaped ripples on the right and ess-shaped ripples on the left.
The heel patten is a smaller version of the front half, as per normal."
e.g. "This tributary lies northwest/southeast and points to the left of the peak."

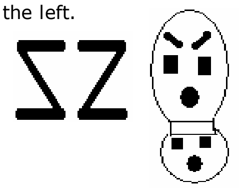

Many aspects of navigation yield to these simple tricks…

discuss it   express it out loud   make it the topic of conversation
delegate the tasks between yourselves
keep yourself alert
make up your own names
collect the details   integrate them

Collect the Details

Identify a Specific Place by its Specific **Collection** of Details

E.g. "A low conical hill in flat terrain south of Mount Cameron"
That is not 'interesting'. The bits are not 'peculiar'. But the collection of the bits is unique.
E.g. Plant and insect species are often so similar to other family members that no one character is 'characteristic' enough.
The species will be identified by a set of characters.
E.g. Is this our old road?? Does anybody recognise it from last year?? but it has…

trend	e.g. toward sunrise
slope	e.g. mostly uphill
straightness	e.g. can't see for more than 20m mostly!
traffic intensity	e.g. many fallen trees across it, and encroaching bushes
length	e.g. it goes on and on and gets nowhere!
vegetation	e.g. set amongst old gums with yakkas under
ends	e.g. it came from the saddle and ends up behind the peak

If you think you recognise it, by the combined characters, you will probably be right.
E.g. Make one name for the big tree on the crest; another to name that crest; another to describe its relative position…
and soon you can't mistake it…"the big tree with the south facing hollow on the port-side Dam-wall Ridge downstream of Tree-fern Crk.
The add-on bits are part of the name of each bit i.e. "the Big-tree Crest" (downstream of Tree-fern Creek) (near the dam wall).

The smallest collection is two, but that is a powerful combination, e.g. a peculiar log, plus a recognisable hollow trunk, is almost unique.
The combination is the peculiarity to remember — a third peculiarity.
The geometry of the combination is a fourth and even more powerful memory aid… "This log points to that hollow".

Include What You Can't See

For instance, have you noticed that there is no bare ground showing? That you can't see farmland? That there are no intervening ridges?

Break of Slope/Make of Slope

The 'make' of slope is the **steepening** as you go downhill ie the "slope" is a down-slope. The best views are at the most abrupt 'make's
The 'break' of slope is the first **flattening** out as you descend. The thickest soils occur below the 'break'.
The make and the break refer to points which separate different 'slopes'.
There is a difference between a making, or eroding slope
and a breaking, or sedimenting slope…
A ridge-top is a make of 2 slopes, in cross-section, but any abrupt steepening
can also be called a make of slope.

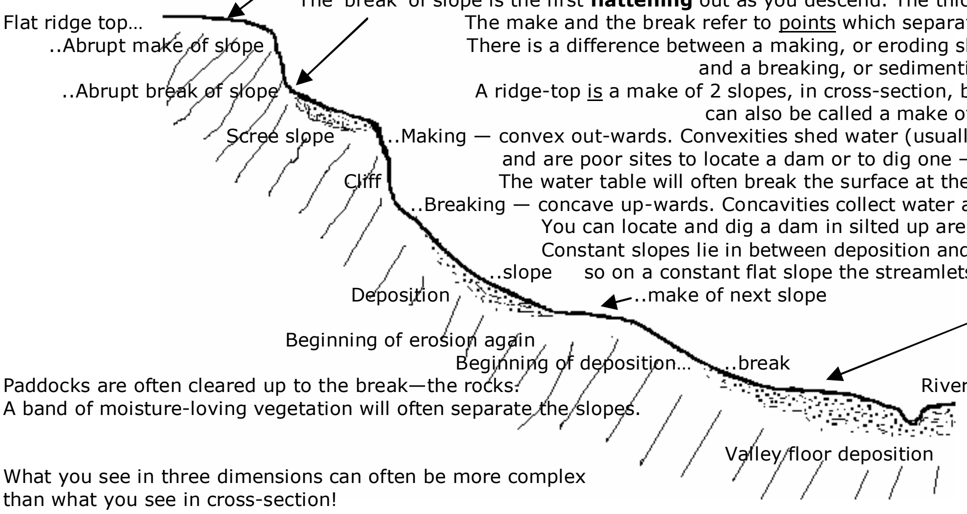

..Making — convex out-wards. Convexities shed water (usually in all directions) and shed silt
and are poor sites to locate a dam or to dig one — there is bedrock below.
The water table will often break the surface at the more abrupt breaks.
..Breaking — concave up-wards. Concavities collect water and collect silt from above.
You can locate and dig a dam in silted up areas.
Constant slopes lie in between deposition and erosive scouring
so on a constant flat slope the streamlets can 'braid' together

Paddocks are often cleared up to the break—the rocks.
A band of moisture-loving vegetation will often separate the slopes.

River—erosion on the banks = convex
— 'break' at water level; concave
below it

What you see in three dimensions can often be more complex
than what you see in cross-section!
— When convexity changes to concavity there is a **momentary straightening** — a 'break of slope'.
This is also called a 'point of inflection' in the curve.
It's not just a meaningless mathematical quirk; it betrays a set of real changes, resulting from the erosion history.

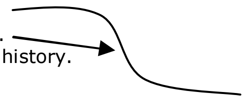

Scree Slopes — Tread Carefully!

The boulder-field at the base of a cliff, gives you a false sense of security!
Each rock seems so solidly jammed in place, but the whole field could 'slump' and slide all the way down, if given too much of a shake.
That is why there are no old trees growing in landslide-prone slopes!

The essence of a scree slope is, like a pile of gravel: It is in a continual state of critical instability, as evidenced by the straight-edged slope (flat but not level), about 36°. 36° doesn't sound like much, but up a sandhill, it puts you on all fours!
The rock surfaces look 'fresh'. Soil doesn't accumulate.
Tread carefully. Distribute your weight on all fours. Tread on bigger rocks.
Choose the cliff-base — it has hand-holds — or the scree-base — it has a solid bottom.

Mark Your Trail More Permanently and Ostentatiously

E.g. when you are lost or in trouble or in doubt

- A teepee
- Mud upon a tussock — quite unnatural; A tussock upon a tussock!
- Hang a piece of clothing from a prominent tree limb
- Dig a hole and make a hump

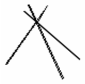

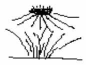

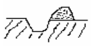

(Direction of travel is →)

Mark Your Trail Invisibly

E.g. so that other walkers who are not lost, don't disrupt your markers, out of a sense of bush etiquette.

- "One mark every 50 paces". E.g. one pointed pebble. You may like to use double-paces.
  It is almost impossible to notice accidentally, but impossible to miss if you look.
- "Every 10 paces, as an option" added to your scheme — to cope with junctions and bends.
- Place a pebble on the ground, on the onward side of an existing cairn. You can recognise it, and scatter it, when you come back through the fog among a maze of similar cairned routes.
- Put a small mark at the base of each track marker (e.g. under blazes-on-a-trunk or ribbons-on-a-branch) — you can easily find it, and know that you have been along that track.
- "Half way between (2 markers)" or "10m North (of a juncture)", can remove the marks from obvious view or significance.

A pebble Code — Keep It Simple

All codes have to be memorable to all users — complications never survive the years of disuse.
I.e. use 'one' to 'four' only, preferably only 'two' and 'three'.

Tread the pebbles into the ground for clarity & permanency.
Upturn the pebbles for visibility, and **point the stones** appropriately.

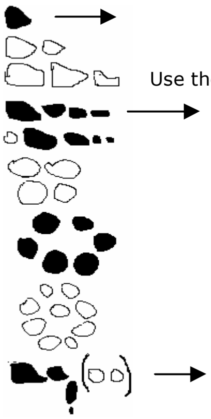

Use the smaller pebbles at the front.

One: "I woz 'ere, going that way"
Two: "Me go that way"
Three: "I'm lost, exploring that way"
Four: "Look for a message, there"
Five: "Someone has seen this message"

Square: "Don't go this way"
Circle: "Oh" for "I'm OK"
Bull's-eye: "I will be back here soon"
Junction: "I have turned off (and returned, then continued)"

Double marking: Close the pebbles up the second time past, until they touch.

Combined Effects of Wind, Salt and Light

When assessing wedge-shaped shrubs, leaning trunks, tilted canopies, etc., try to distinguish wind-cut from salt-cut and from light-lean. But beware, in any natural system, it would be easy to over-generalise from a few known specifics,
or falsely extend an inadequate interpretation.

Here is a typical wind-ramp. The leading edge consists of dead twigs.
The vegetation gets greener and thicker and taller downwind.

But you cannot easily tell whether it is the result of salt-laden wind, or strong wind only.

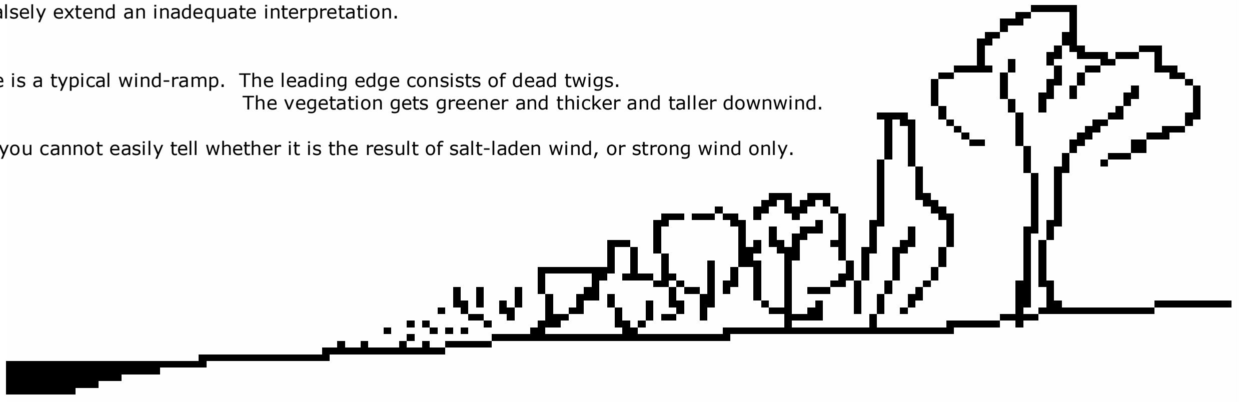

Salt-cut will show you the direction of the prevailing onshore wind only.
Inshore, wind-ramping will show you the direction of the prevailing wind, which may be significantly different in direction.

Botanical Asymmetry

Plants must respond to the wind.
If they did not deliberately push up-wind, we would be walking through a landscape of leaning-over plants.
Therefore it must be possible to ‘read’ the effect of strong wind written into the branching history of a plant.

The branches of a bush may grow according to the strong wind, but the leaves will still respond according to the asymmetrical light.
The two effects may or may not be independent and you will need to examine them carefully to see the difference.
Look for asymmetry in the green parts of a plant to show up bush-noon and look for asymmetry in the other parts for bush-West.
If there is a macro response to the wind, which will confuse the macro light-response, look for micro signs of a light response, on individual branchlets.

You don’t “need to know your plants” beforehand. Instead you examine the species which present themselves.
You assess what responses they make to light, wind, shelter, etc.
E.g. Do the stems colour up in sunlight? If so keep looking at that.
Do the branches throw out more leaves on one side? If not look for something else.

Extend Your Familiar Range Systematically

Explore in every direction, in ever longer legs, radially. Leave recognisable marks alongside recognisable things.
Then explore in concentric circles to make sure that you can recognise individual trees and rocks.
You know you can explore further within the endless sea of scrub, if you have ‘familiar friends’ which you have seen repeatedly.

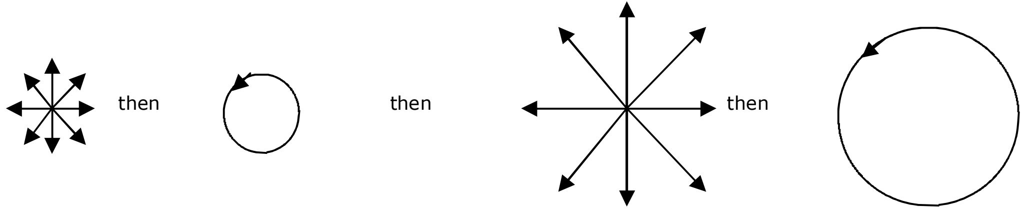

Markers for future recognition e.g. on your own property…

Plant a tree　Graft two branches together　Suspend a forked branch into a forked trunk
Arrange logs e.g. a parallel heap　Arrange rocks e.g. a cairn, or a rock on a stump, or a rock 10 m south of the biggest tree
Dig a trench　Etch a mark　Paint a rock　Leave something solid behind
A stake　A signpost　A numbered metal tag　A path　A Campfire-place or Barbecue

Hints

It’s the Campsites You Don’t Use, that are Easiest to Forget

> I’m forever asking: “Can anyone remember” whether we can camp between here and there?
> Take notes of potential campsites. It makes your trip-planning more flexible, next time.

In general, take the opportunity to spy out and note down potential future trips — side-tracks, ridges, climbs…

Leap-Frog Walk in New Territory

I like to walk a new track twice, anyway. It is no big difficulty to take your time, once, and achieve better familiarity, by leap-frogging.
Explore 2 legs forward then one leg back, and you cover the ground 3 times on the way out, once more on the way back.
4 legs forward, 2 legs back, and it’s like walking a return track 3 times, but it gives you a much more solid handle on each section.
You gain what you want, appreciation and re-preciation, and what you need, familiarity and sequence memory.

The best way is to combine this with a mnemonic for each leg. See AA to ZZ for an excellent method.
Its also a good time to mark each new leg discretely.

Break of Slope — And Route-Finding

- The first signs of an approaching ridge-top when climbing include: the change from deposition (breaking) to erosion (making); i.e. onto outcrops; into exposure to the wind.
- Take a rest at the break of slope — before climbing upwards.
- Get your bearings at the most abrupt make of slope, where the view is clearest.
- Look up- and down-hill for the lowest skylight beneath the trees, to reveal the change of slope.
- Avoid contouring around the break of slope — it is tempting, but — it is steep and unstable.
- In rocky gorges, or on any creek-bank, or around any permanent water, look for a break of slope just beneath water-level.
  It may be safer, than rock-climbing higher up, to get your feet wet, and use such ledges. The slope near the water may be less steep, at least on average on jagged slopes; you can't fall as far; your landing is softer (wet) — if you 'keep as low as possible'.
- On steep gravelly roads, stick to the 'crown', or the 'gutter', to avoid slipping.
  The crown will snake from side to side as the road turns.
- Slopes are awkward to walk on—steeper than the ridge or creek, so,
  when you drift up onto the sides of the creek you want to follow, you will be forced further up — onto the ridge.
  When you drift off the crest of the ridge you want to follow, you will be forced further down — into the creek bed.
  In this way 'minor' detours (e.g. around an outcrop, on the ridge or in the creek bed) may result in major redirection orders!

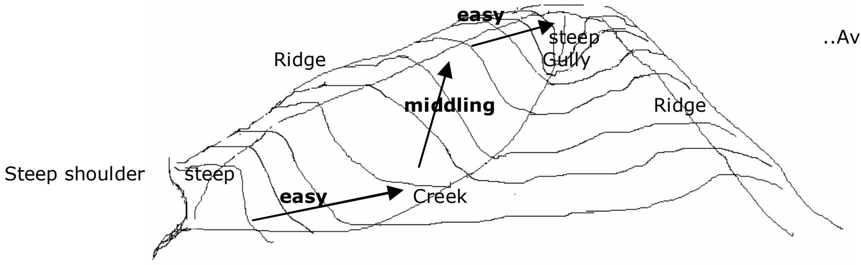

..Avoid the steep bits.

Keeping Track of the **Bends**

Don't just follow your nose — follow the bends!
There have already been some hints on keeping direction sense:"Walk across Australia!" & "Integrate the Jetstream and Earth rotation"
Plus the "Sky to Land" and "Land to Land" navigation systems (p.29e,34d,38d,42d).
Following a track can be mindless. But following the bends in the track means that you understand
— that you have changed direction, and by how much.
We have an ingrained bad habit — that we walk 'away from' the starting point, which is therefore 'behind' us.
Only when we 'turn around' is it 'ahead' of us on the track.
We usually only notice junctions, features & hunger, not distance or direction or exact time.
The commonest mistakes of guesstimation, are failing to notice a track curve,
and **underestimating** exactly how far a gentle but insistent bend will **turn** you around i.e. simple disorientation.

Hints: Notice the bends, with your eye on the sky or the skyline. Establish the habit of looking back.

Desired Equipment

- Compass — look at it often and interpret it
- Polaroid sunglasses — look for the dark blue band
- Radio — use it to keep orientation if you don't have a compass
- Map — orient the map to the landscape, and it acts as a rough compass
  — lay a rhumb-line through the bends, as an average course, as a reference 'track'…

Logging Constant Diversions

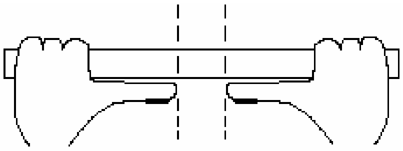

A stick or string helps you measure direction changes…
Held at arm's length, you add or subtract, as you decide to change course left and right.
Thus you can revert to an intended course after a short 'blind' section,
and average out the course changes even without a compass, or being able to see the Sun.
You could use the skyline as a reference direction, or lineup two tree trunks for each change.

A rougher method is to counterbalance your diversions.
If you go left-around the rock; next time, go right-around the tree.

Keeping track of countless bends is one of the few major problems in navigation
— like keeping a log of distance covered, having no location sense, and trying to stay alert.
So aim for an independent cross-check e.g. a landscape fix or a distance log.

Think like a Plant

E.g. Imagine you are a small ground-cover plant. In a desperate attempt to not be eaten or trampled to death you will probably branch and leaf out in all directions to simply survive... So don't expect much botanical asymmetry underfoot.

The idea is to become an amateur ecologist. For instance, you could work out the pollinators available, the dispersal mechanisms used, the biogeographical zones and overlaps, and the associations between species.
Therefore think about the geology, geoform, latitude, altitude and soils.

Temperature & Relative Humidity explain a lot of botany.
E.g. very cold morning winds are also very drying when they warm up later in the day.

Altitude, for instance, affects the species mix, so that with practice you can gauge your elevation above sea level.
You notice when sub-alpine species kick in e.g. Telopea (Waratah), then when true alpine species begin e.g. Richea (Scoparia).
Individual members of genera have altitude preferences and so are helpful to distinguish altitude
e.g. various Coffee berries (Coprosma) or Pink Berry (Cyathodes).
N.B. Since the prime effect of altitude is to drop the temperature, this is really a latitude-dependent temperature effect.
I.e. Going further polewards, the altitude preferences will change.

'**Aspect**' (i.e. South sloping or North facing) will be important in interpreting the presence of particular species.

Living stresses explain simple botanical systems.
E.g. In the desert, late afternoon is the baking-hot-sunlight side (cf noon in forest). Trees will be shiny leafed — to shed excess light (cf searching for more).
So consider the prevailing winds, salt spray, max. and min. temperatures, wet season, disturbance, trampling, fire, clearing, introduced competition or diseases, grazing, salinity, mineralisation.
Pioneer Species — These are the easiest to identify, because they are lonely.
Their preference is the saltiest, hottest, driest, highest, coldest, poorest, windiest, sand-blown, most flood-prone, …
If life becomes too easy, other species will smother them out. Hence, look for those that don't mind the hot baking Sun, etc.

There is a height-**succession** of plantforms grading from **lowest to tallest and deepest rooted**.
Ground lichen; moss; grass; herbs; creepers; shrubs; trees; ' emergents '
The depth of soil is crucial. The taller ones shade out the humbler ones, and their deeper roots seem to starve out the shallow-rooted ones from below. E.g. mosses need no soil and not much light, but will quickly be overgrown if these are provided.
Other factors keeping plants humble are trampling & grazing, fire frequency and dry season. Grasses survive all these stresses well.

Competition between species explains the more diverse vegetation.
E.g. Lichens overrun each other, and leave the rock surface, to become 'leafy' or fibrous or pendulous.
Lush growth betrays the most comfortable living conditions. E.g. rainforest; the underside of a rock in the desert; sheltered microclimates — crowded with species. This is opposite to pioneer species.
E.g. Where excess sunlight is the 'living stress', lush growth will show up on the shady side.

Draw the Skyline, the Ridge-lines, the Outlines Label it with the 8 main directions

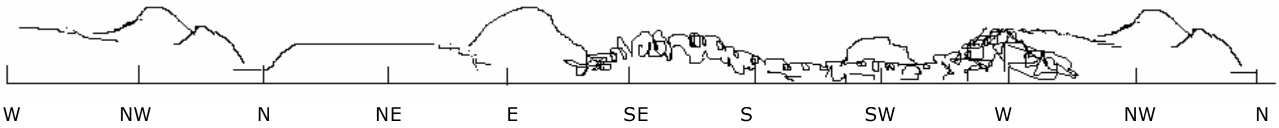

Talk the panorama into words. "Nor-Norwest Hillock, in front of a larger hill on the left, runs down into a gully behind NE– Plateau.
East Mountain is behind NE Plateau and drops away behind the vegetation south of us.
Distant Peak pokes up behind in the SW, and the closer skyline reappears in the West,
falling steadily to the NW Dip before the larger hill."

That took one minute. You do have time to look, notice, talk it through, and even draw it.
Marine navigators know that they have to.
Don't just imagine doing it, or do it silently, or do it half-heartedly — actually do it.
Unlike an avigator who uses a layout map to recognise roads, rivers, ranges, coastlines, etc, from the air,
a walker needs a nose-eye view…
MAPS DON'T DRAW YOU A NOSE-EYE VIEW — SO YOU HAVE TO!

Examine the Skyline BEFORE You Walk up to It

That might mean looking behind you, six hours ago, or to left or right, right now,
because the skyline ahead of you rapidly disappears behind foothills, just when you want a clear view of it!

A clear view of the skyline is uncommon, so you need to take advantage of any skyline view while you have it
— and that is often anywhere else except where you want to look — ahead.

Circuit walks and return trips mean that, if you haven't habitually looked at the surroundings abreast of you & behind you,
you won't be able to recognise what you are walking up to later.

One way to recognise the skyline later, is to use it
e.g. use it to keep track of bends; to keep track of progress; to disclose hidden valleys (by parallax or haze).

Another way is to name what you use e.g. "the hill behind the dam wall from camp 2—Dam Hill"

Mnemonic: "Down in the Mouth"

"Downstream" is "Down to the Coast". "Which coast? Which river mouth?"
Until you have answered that, you are disoriented.

You pass a creek-bed or a flowing stream: "Which way is it flowing?" is only half a question. "Where is it going?" is the other half.
You turn and head 'downhill': You think 'Down' — then say: 'Down in the Mouth — Which mouth?'

If you also ask "Upstream? To which ridge?" there are many possible answers because upstream is divergent.
Nonetheless it is good to know whether a river reaches to the very edge of the valley — whether it is a 'major' tributary.

Which way is the flow?

In dry, flat creek-beds, examine the tilt of the rocks… If any rock ever tilted up into the flow, it would be flipped over.
Examine the silt build up — on the sheltered downstream side of any obstacle.
Look for flood debris — matted against the upstream side of branches.
Consult your artificial horizon, if you have one.

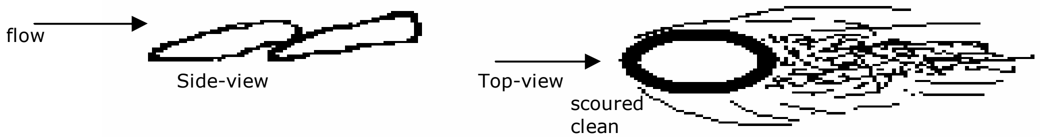

(This is much like grass tussocks in the wind.)

Hint

Don't think "this side" & "the other side". It only makes sense for the one main lowest riverbed.
Think: Up-catchment/down-catchment/cross-catchment, overall, & Port half/Starboard half of the whole catchment in question.
(as seen from the coast, looking upstream)
Think plural: "the other sides"/ "another side" in the network…

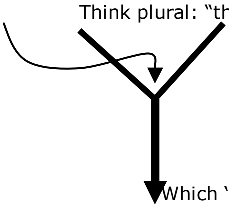

Which 'side' of the river are you now? "I have crossed to another part of the drainage system"
Another possible answer: Examine the map for the contour heights of each channel for the lowest one.
"We are now in the starboard half of the catchment"

The Difference between 'Direction' and 'Track'

'North' is a general orientation reference **direction**.	But	'North from here to there' is a specific route — a 'bearing', 'line' or **'track'**.
'Stick to a direction'/a 'heading' means e.g.'toward sunset'		'This road points toward that Gap' will never change — it is a fixed 'track'.
It can start from any point,	cf.	'Stay 5 miles off the lighthouse' is a (curved) line of position — a track.
and sidesteps around obstacles, without bothering to return to track		'From this stump, past that tree, to the rock' — sticks to a fixed straight line, despite detours.

So the final practical 'interpretation' of, say 270°T.,
is not 'West', not 'sunset', nor 'Pot-set', not 'THERE!', not a drawing in your notebook, Not 'How hot it must be in Baghdad!'
but is a navigational track... "From this place to… that particular tall tree" "Then we will get a line on another point directly West"

I.e. Interpret a 'compass course' , finally, into accurate, achievable 'legs'—'on track'.

Continuous bends

Riverside tracks are especially sinuous, yet slowly so, so that they are deceptive.
Beaches near headlands, and lake edges, are especially insistent in their constant bending.
Contours, constant horizontal angles, and constant distance-off, are all continuously curved. Aqueducts follow contours.
Consequently we are necessarily **continually disoriented**, in following them.
No sooner do we get our bearings straight, than we lose them.
Logically then, you need to orient, not by a direction e.g. the Sun, but if at all possible, to **orient by a 'track'**
i.e. a particular path on the ground — it doesn't have to coincide with your own track, but it often will
e.g. from headland to headland. (The beach will then lie wholly on one side of this shortest distance 'track'.)
A visible, noticeable, landscape track is best e.g. the biggest river valley around.
You now can feel continuously oriented to something fixed, something which you can see & 'feel in your bones'.
As a second best choice, choose a fixed compass course e.g. a rhumb line, and watch where it intersects the landscape.

Follow the bends by anticipating the trends

Before you drive off, or plunge into the twists and turns of endless undulations, examine the map for your average course
— to give you some overall reference track ahead of you. It may be mental, or visual, or by compass.
You can see when you turn to the left or right of it, direction-wise. You can feel it when you drift too far to one side, track-wise.
Interpret each leg meaningfully. E.g. "toward the morning Sun"
(the time of day doesn't matter).
E.g. "Keep Mt Wellington on my port quarter".
E.g. "From the pine trees to the river mouth".
Divide the journey into recognisable sections, if it helps…
Make this a first priority, before studying any details.
Preferably, mark them lightly on the map.

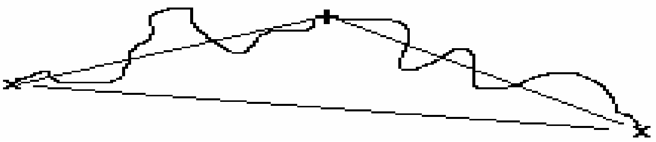

"Mosses Mop up Moisture"

◦ "Mosses grow best on the shaded side of a tree" or a rock, ◦ where there is not enough light for competitors
◦ where there is little soil to hold the moisture, ◦ and it doesn't dry out ◦ and often there is too much moisture for other plants.
Mosses actually monopolise the moisture
In hot places it is the late afternoon which is driest, so it is **the sunrise side, in a sunny climate**, which is the moister side.

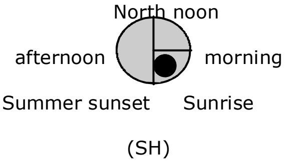

Note: Dead moss is black and brittle.

Examine fallen logs — the shady side has a sheltered dark crevice...

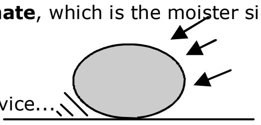

In a hot climate, it may be more accurate to say,
"Mosses grow best on the sheltered side"

Examine ditches — One side might be scorched, the other, lush.
Examine bumps in the ground — One side is greener, with more moss and taller grass.
Examine underneath shrubs — for the moister, mossier, greener side under the bush.
Examine intertidal rocks — for moss-like seaweed growths on the shady, wetter side.

"Lichens Like Light"

Lichens don't mind being dried out, so sometimes they are opposite to the mosses. However, not all lichens are so robust.
Lichens are fungi which live off algae entrapped and protected within ("Fungi Feed on Food"). They may live on mineralised substrates.
They are therefore very colourful. So the best way to learn lichen-likes is to open your eyes to the colours of each direction…

You may see white blotch lichens looking downSun but not upSun.
Yellow blotches may all be only looking uphill, not downhill. Leafy lichens like the shady enclaves, not the Sun-drenched flats.
Crusty greys and fibrous green might cohabit the underside of branches. "White paint" may only grow an the top of any rocks.
Orange granite might be just above high tide level, etc.
Diffuse lichens colonise the crumbly side of a sunbaked rock. Flat-topped rocks are trampled and won't have thick lichens.
Look closely at surface colours of rocks and barks and soil-crusts— they may be due to diffuse lichens.
Look on the branches of shrubby growth — the lichens will grow best on one side or the other.

The idea is to start looking locally, before you need them. It's a nice hobby. And hobbies keep you awake and observant.

"Fern Fronds Face the Front" i.e. the sunny side

Looking down-Sun, you'll see an array of green topside fronds flat on.
Looking up-Sun, you'll see more undersides & yellowness & edge-on fronds. It may not always show, but is clear when it does.
Tree ferns retain their lower branches longer on the sunlit side, and so seem to tilt toward the light.
(But in a windy place you will notice that the permanent lean, curve & frond-fall of ferns are downwind.)

Make a Mental Movie

Memorise a spectacular cliff looming closer overhead.
Watch the shape change. See the foreground shift. Notice the colours and contrasts. Look at the landscape flow.
Describe the silhouette. Peer into the deep shadows. Scan the skyline, looking at each interruption or change in trend.
Appreciate the hazy distance.
Follow a complete outline around, naming its shape.

Don't forget to "record" the sound-track!

Initially try a full production only for beautiful memorable scenes.
With practice you may find that your memories stick for more and more locations.

Take Mental Photographs

Familiarity and Recognition are primarily visual. Your visual impression is adequately vivid, but your recall of it is faulty.
So put handles on the memory and you will be able to revisualise e.g. "where we found the weather balloon".
To give your memory something to recall, take a detailed look.
The tricks are simply to give it a go, and to notice **the specifics**:

The colours, shapes, skyline, peculiarities, sequences — Talk about them.
Play a game: "Your turn: what else can you add to the picture"
Overlay some geometry on what you see — e.g. the log is parallel to the path and as far from it as the log itself is long.

Now close your eyes and see what you can reconstruct. Open them again and notice where you were wrong or were lacking detail.
Repeat this a few times until you could picture it in bed the next night.

Mental photographs are, after all, **your take-away memories**.
They are what names name; what "directions" talk about, what 'recognition' and 'familiarity' is based upon.

Take a Mental Photo of Each Change of Track

Where one subsection ends and another starts
— Look forward onto it, with the old terrain in the foreground and the new terrain joining on to it.
Now walk past the join, Look back, take in another view, with the old terrain now in the background.

This adds visual sequencing information to individual memories.

The Inside of a River Bend is Flatter Ground

The inside of a meander may be wider, sandier, marshier or of different vegetation.
On the outside of a meander, cliffs form, through ongoing undercutting. See also p.56a about the steeper North bank of a river (SH).
Consequently plan ahead and work out when to swap sides to find the easiest walking.

If the track becomes steeper underfoot, that would mean that you could be on the outside of a bend.
Check to see whether your heading has changed with the bending river.
If the track becomes flatter underfoot, this may indicate an inside bend (or a river junction)

Rivers Bend! Don't Forget to Look Backwards

Obstacles cause creeks to change direction. Outcrops of bedrock and creek junctions, for instance, cause bends, and this may be shown up ahead of time, by ridgelines pushing in closer, as you follow a riverbed.
Expect to meet a new creek clinging to the base of any ridge or shoulder which crosses your path, and also expect to change trend.

In addition, to that cause of bending, rivers follow contours and so usually are on a curved course anyway.
Furthermore, in the flats, rivers never follow a straight course but will 'meander'.

So if, while following a creek valley, you notice the slope underfoot changing, or the vegetation altering, watch out that the creek doesn't leave you, by bending away from you!

If you find yourself in the middle of a larger than normal river flat, suspect a river junction, and be very careful interpreting the trends.
E.g. you may meet 'the river' 'coming back toward you' when you were trying to go downstream!

So you can easily lose orientation while the winding river-track follows the lie of the land and gradually wends its way around corners!

Look ahead to catch the trend — and interpret it.
Look back, to see the extent of the curve.

Rivers Meander. Ridges Run Straighter

A ridgetop route will often prove shorter than following a winding river.

Keeping a Compass Course, by Legs

You can't see far ahead, but you can line up a rock or a bush which is in the right compass direction, then walk up to it.
It doesn't matter how you get there, as long as you get there.
Repeat the procedure, even if you can see far ahead — because, if you are merely following a compass needle or a distant landmark, you can "side-slip" off track.
Your eyes are freed from the compass needle while you walk.

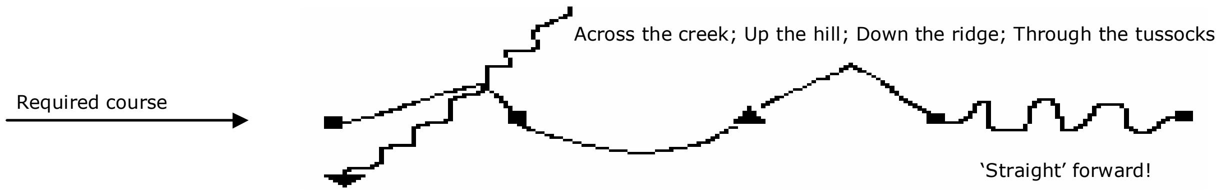
Across the creek; Up the hill; Down the ridge; Through the tussocks
Required course
'Straight' forward!

Turn Smooth Bends into Sharp Jumps

Your brain wants something to "latch on to". A smooth bend is just the opposite! So make a series of straight-line "legs".
You "let go" of the last leg, and make a definite jump, to "latch on to" the next leg, and your subconscious smiles, and remembers.

E.g. 'compass North'; then 'to the tree'; 'to the peak'

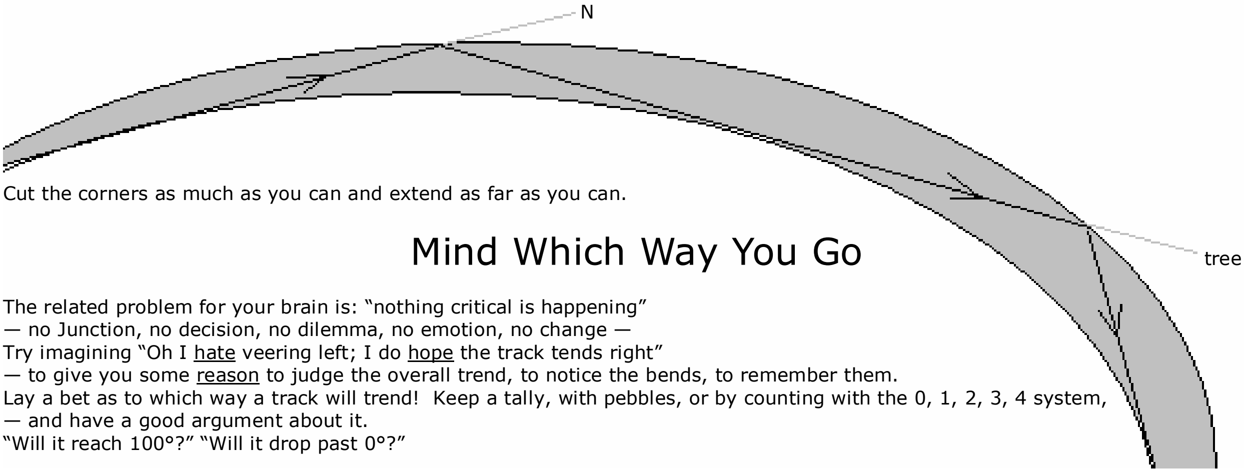

Cut the corners as much as you can and extend as far as you can.

Mind Which Way You Go

The related problem for your brain is: "nothing critical is happening"
— no Junction, no decision, no dilemma, no emotion, no change —
Try imagining "Oh I hate veering left; I do hope the track tends right"
— to give you some reason to judge the overall trend, to notice the bends, to remember them.
Lay a bet as to which way a track will trend! Keep a tally, with pebbles, or by counting with the 0, 1, 2, 3, 4 system,
— and have a good argument about it.
"Will it reach 100°?" "Will it drop past 0°?"

Bush Noon— The Sun is Always out, If You Know How to Look

Trees & shrubs live in the light, day in, day out. You would expect that they should respond to the light, and lean or reach out to the strongest light, and throw out more branches and more leaves to the bright side.
The disposition of branches and leaves stays in view even when the Sun isn't out, and it lasts longer than a cloudy spell.
Although the Sun is a huge factor in explaining foliage asymmetry, be aware of other factors…

- A lake or sea can double the light intensity on one side, pulling the foliage toward it.
- A clearing will let more light in on one side.
- Down slopes allow the trees to see more skylight on the down-side, and less skylight on the up-side.
- Other trees can shield a tree from the Sun. Look especially for recently **fallen** ones on the ground, to explain standing branches
- The tree itself shields its own branches, so that most growth is simply outwards.
- Unrelated factors like gravity, wind, and wood collecting, alter the shape of a tree.

However, if you **average out** all the other influences, you should be left only with the noon-side Sun's influence — "Botanical Noon".
With adequate practice you should never again be "lost in the bush" because it is the thick bush itself which will tell you where North is.
You may have an initial hopeless feeling of "I can't see any meaningful asymmetry!" but the feeling will be temporary (eventually!).

Of course, this works best only where the Sun is always one-sided—in nontropical latitudes.
Hint: If a tree confuses you by pointing in the wrong direction, go over to it to learn why.

False Asymmetry

The slope of the ground
may be forcing the asymmetry,
rather than the differential in the lighting.
In the second diagram, there is asymmetry:
A is ungrassed; B is grassed.

False Symmetry

C and D are both grassed.

True Symmetry

B and C are both grassed.

True Asymmetry

A and D are differentiated from each other.

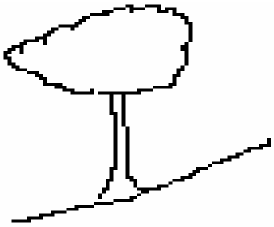

Dirt road wheel ruts...

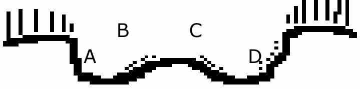

False ("Chalk and Cheese") comparisons
abound in Nature. True asymmetry is there too
Your task is to sort it all out.

E.g. Shaded foliage sees mostly blue skylight,
which should make it long and lanky,
compared to the red-end light from the Sun

E.g. the West side shadow is frostier for longer
and the East side shade is cooler in the p.m.

E.g. the North side soil will be warmer deeper
than the South side of a thick hedge

Look on the ground beneath a shrub, or log,
for asymmetrical shade and shadow effects.

Remembering the Sequence, Needs More Than Logic

Logic is logical and helpful e.g. The bridge was after lunch because we were worried about the crossing over lunch.
The red rock was after that, because the second creek was dry — it had all those beautiful red lichens in it.
Then the funny tree was where we had chocolate, i.e. 3 o'clock stop.
But logic by itself is not 'sexy' enough to be emotive and memorable.
So deliberately add some emotion…
E.g. "lunch", "worried", "beautiful", "red", "funny", "chocolate"
You may need to add a song and dance, a gimmick, a clue to the time or sequence, distance or linkage.
The trouble with a memory gimmick, is that you focus on the gimmick, not on the memory itself.
E.g. If you use an acrostic, remember to feel the sequence of it, as well.

DO Something NUMERICAL

E.g. Lean one stick against "Walking-Stick Cliff" at one o'clock.
Sing two songs at "Sing-Song Pond" at two o'clock.
Make three cairns at three o'clock at the "T(hr)ee Junction"
Make four arrows on "Four Arrow Slope" during four o'clock.
Do it. Don't just imagine yourself doing it.
E.g. Scratch numbers in the ground, in sequence, as you pass points of interest.
e.g. "5FF" (the 5th stop, with the flat floor); "6SS" (six sizzling sausages—the fireplace).

Make a SHAPE; Match the SHAPE

Every or location in a forest track or in open country can be recognised from its **peculiar shapes**. Every bend or fork can be **matched to** the forest, or the shrubs and stones, so both the bend or clearing and the surroundings can be remembered, with joy.
Locations: What does this fallen log **point to**? What is **parallel to** it. *Place* something so it *does* **make a shape**.
How many shrubs do these three trunks enclose? What **face** or **picture** can you make out of the bushes, rock, clearing and the creek?
Do you see that **line** of tussocks; that **clump** of trees half-way up the slope; those parallel gutters; that oval of sand-dunes? Where does it drain? What **direction** between those **paired** stags?
Bends: ~Look for a tree trunk **leaning** over at the same angle as the bend of the track, preferably leaning over the track or bend and in the right direction. The tree stands out from all the others because of that. (Any lean at any angle in any direction will suffice.)
~Look for a branch **pointing** in the new direction, or curling, or **bending** in a way which mimics the track-bend.
~Look for a log **lying parallel** to the new direction, or any ditch, or line of rocks, or outcrop. (It doesn't have to match.)
~Look for a large rock nearby which **fits the shape** of the bend, or orient it until it does. (Matching shapes are always the best)
~Look especially at the tree trunk, or the shrub which blocks the straight line of sight ahead, or the shape of the fallen-over trunk in the way. E.g. "I'll fall into that black hole in the trunk if I keep going straight ahead! I'll have to swerve". "I need to go around that round stump". A tree **right at the bend** will be visible from both directions.
~Look for a forked branch which **matches the angle of a fork** in the track. **A series of parallel branches** at the fenceline. A couple of trunks **leaning towards each other** over the gateway. A tri-parallel set for a creek with two banks.
~Look for a branch which **points downstream**. Watch it for the next 50 years as it grows. A tree recognised is a friend for life.
~At a noticeable uphill pitch, find a leaning tree trunk and imagine climbing up it.
~Some leaning trunks can be interpreted in **reverse**… from top to bottom, to indicate the new direction.
The more you latch on to a peculiar shaped feature and the more you study its peculiarities, the better your recognition will stick.
Try to **double up** on the first peculiarity to clinch the recognisability. A **matching pair** of branches. A second confirmatory log.
You will have to **look backwards** at each bend if you want it to work well for the return trip.
Every bend and feature is a good chance to recognise another couple of trees. You stop at the bend and look around for your "friends".

Land-Form

Work downwards from a 'Big Picture' understanding. Start with a small-scale geology map, showing overall elevations.
Continental-scale domes (anticlines) & depressions (synclines) explain the overall drainage and watersheds.
Fault lines — shown by escarpments & cliffs — and individual ranges, interrupt the overall scheme.
The geological layers may be visible connecting across large distances.
E.g.

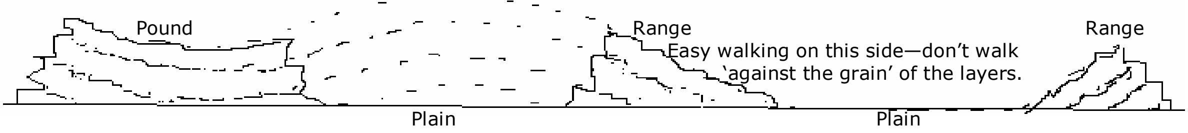
Pound
Range
Easy walking on this side—don't walk 'against the grain' of the layers.
Range
Plain
Plain

Layers become hardened and resistant to erosion when they are bent concavely upwards. They are compressed rather than fissured.
Convex layers are fractured and easily eroded, because they have been stretched. They will have been eroded away.
The present landform is a result of the erosion history on the previous landforms.

Hint

Most peaks have a steep side and a gentle side. Don't forget to make a mental note of that trend in relation to the rest of the land and the other visible peaks — you may notice a pattern, or simply keep your overall bearings better, or recognise the peak later, from afar.

What Makes a Cliff and an Overhang?

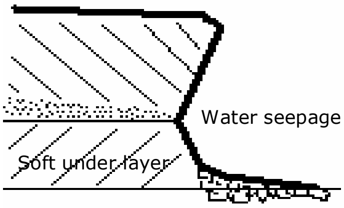

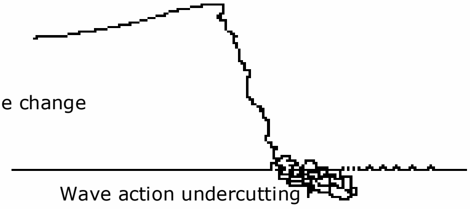

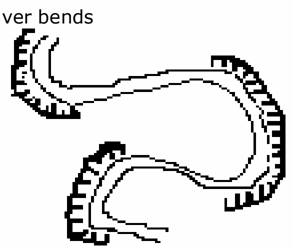

Waterfalls form at hard layers, at fault lines and at escarpments.
Look for outcrops striking across the land.

"End the Bend" i.e. Notice the Un-Bends

A bend is not simply a sharp corner, not just a change in direction: 'end of story!'.
It has a start, a curve, and **a finish, where it straightens out again**.
The curve needs to be **named** as a whole, **measured** as a whole, and thought of as **a whole bend**.
Look for the dividing points between successive curves

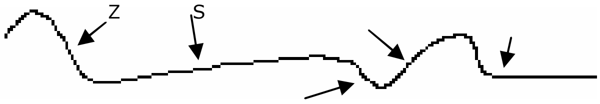

The arrows show where a curve to the right changes into one to the left, (a Z bend), & vice-versa (an S bend). These are "points of inflection"

— a straightening out, and remaining straight, is the other possibility.
Incorporate half of the straight section into each adjoining 'bend'.
At the end of each bend, reorient yourself — look behind, at the compass, at the Sun and your shadow. Point to 'home'.

Name the Bend, By the Trend, of its End

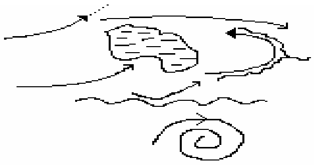

Trend:	Left, toward Mt Michael	e.g. "Viewmont Bend"
	Right away from camp	e.g. "The Long Right Leg"
	Left into Lake Jordan	e.g. "Left it down the Drain"
Handedness:	Hard left around the spur	e.g. "The West Bank Left Bank"
	Half left from the creekbed	e.g. "The Left Contour"
	"Clockwise Climb"	
	"Right around the Bend"	Bends will often alternate.
Direction:	"Ending with Sunset in our face — Sunset Slap"	
	"Turning until the Full Moon Rises on our Right — Werewolf Way"	
Compass:	"North Now, to Alaska"	
	"Left-Sou-West"	

Add some description
to seal the uniqueness e.g... Skyline: "Lone Pine Ridge" "Three Tree Hill"
Detail: "Uphill; On the Left Bank; Just past the river crossing; at 10 a.m."

Notice and Name Perverse Bends

Unexplained bends, or ones which buck the trend, deserve a name.
Most bends are predictable — around obstacles — at creeks — around shoulders & outcrops — shortcutting — contouring around sloping ground — at Y-junctions — joining with disused overgrown tracks
E.g. Seaside roads will hug the coast, go diagonally downhill but upstream (into a valley) and climb diagonally out of it, downstream — as a compromise between shortness and flatness.
E.g. For the same reason, tracks will often change direction at a creek crossing.

So name the curves that go against the flow…
E.g. "Sinister Switch" (Latin for left) "A Dextrous Diversion" (Latin for right) "Unorthodox Twist" (Greek: not "right" = left)
"A Wandering a Way" "Aimless Avenue" "It shouldn't've gone left!!" "The I'm-going-on-strike Uphill Bend"
"Mind Bender" "Morally Bent"

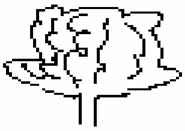

Higher Density of Leafiness on the Noon Side

From underneath, next to the trunk, you can look up in all directions and see which side is leafier.
Looking side-on you may see one solidly green side and the opposite side patchier in its cover.
Trying to look through the foliage to the back of a shrub, you will have most difficulty on the North.

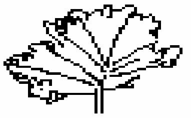

The Lowest Leafy Branches are on the Noon-Side

Looking from the sunny side you see a lower branch or even a wall of greenery, right to the ground.
Low branches on the shady side are often short, dead or only thinly covered with foliage.
Looking toward noon, you see more trunks, dead wood & grey-brown sticks.

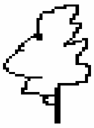

"It's the Shady Side that Shrubbery Shows up"

In practice you don't look for the noon side, but for the absence of leaves low on the pole side.
Looking toward noon, you see ill-developed shapes. Many plants will throw out branches and leaves in profusion in all directions, but you seek out the one direction which is different — the one less densely green — where the light is in short supply. It is **the 'light null' for solar direction finding**.
Look for where no vegetation leans: "No stems, plants, branches point in that direction".

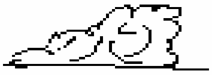

Tall, Steep and Ragged Backside

Shade-side branches often reach for the sky, and are more vertical on that side, making it steep.
The noon side will be more of a smooth continuous wall of greenery from low-down upwards.

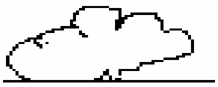

Wedge-Shaped

Looking away from noon, you see smooth and continuous foliage, slanted down toward you, often clinging right to the ground, like a wedge.
Looking toward noon you see flat tall backsides of the bushes.

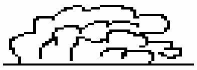

Hollow under the Shady Side

You can stand closer to the trunk, or at least see more of the trunk more clearly from one side.
Down low on the shady side is where the light matters most. There may be space enough for a branch but not light enough. On the sunny side you will see leafiness deep into the low recesses.

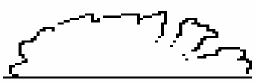

Imperfect Shape on the Shady Side

Many shrubs seem to adopt a perfect dome shape, until you look more closely.

Gaps on the Shady Half.

The backside of shrubs is often tall, untidy, and lacking leafy branches, close to the ground especially.

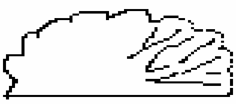

Dead Branches

The overall shape may be perfect, but one side is alive and green, while the other side lacks leaves.
"Dead" South. There is a scale-effect to dead-south: The larger bushes have more depth of foliage.
The more foliage up-sun, the darker down-sun. Only the larger or thicker bushes work best.

Use a Type of Memory which you are Good at

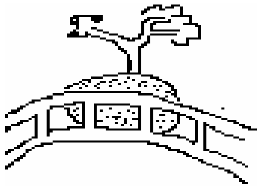

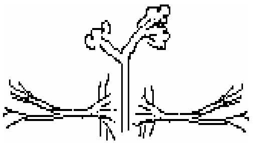

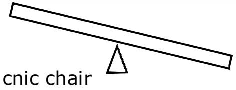

Combine the methods for the most memorable effect.
E.g. pictorial — join images. Make them touch or glue onto, squash or hold hands, follow logically or overlap
— use a stack of pictures to put incidents into sequence.
"After the bridge we came to a red rock and then sat down for a snack at the funny tree"
E.g. ditties — A Capital Tee of Tall Trees at Three O'clock.
E.g. invented "associations"— a vivid or absurd image like a Tasmanian Tiger eating that hill.
Paint it in partly related colours, with shapes and other senses involved, to give extra "handles"/clues.
E.g. Imagine successive scenes in an invented journey/building/furnished room/street scene/pattern points.
Emphasise movement, and links between stages. Make it visual, simple, exaggerated and appropriate.
e.g. "I went inside the cave and talked to the sleepy bear (Ranger) about the bearing to follow, and he said "Seek the morning sun", so coming back out I turned to the east until I met the keeper of the bridge who said "over my dead body lies the path to right; and left". So climbing up over him...
E.g. numbers — One Wooden Bridge, Two Red Rocks, Three Funny Tree… to reflect the hours of the day
Make up a story with rhyme, from e.g. 1, bun for lunch, 2, through the dew, 3, see the sea… 7 rhymes with leaden/Heaven/redden, 11 with Aladdin/pelican/caravan/a raven, 12 with elves/shelve/delve/selves
E.g. shapes — Make a 10-rock pyramid at the 10 o'clock stop; an 11 stick teepee at 11; a 12 leaf hexagon
— e.g. see-saw on a log at 7 and draw a see-saw in your notes—it has 7 corners.
E.g. You can weave a story, of invented images to go with the times of day.
e.g. each digit looks like a... 0 hole/ball/eye, 1 stick/pen, 2 cobra/sphinx/swan, 3 bosoms/camel, 4 yacht/picnic chair 5 measuring scoop/wheelchair, 6 bomb with a fuse/yo-yo, 7 arrow/step, 8 shotgun/glasses, 9 balloon/comma, 10 ball bouncing off a wall/golfball off its tee, 11 jail/stump/goalpost, 12 jail-break/caged lion.
E.g. acrostic — 7 a.m. Z. for Zero Rule Zero: Don't forget to pack the lunch!....7:15 A Bend A in the Creek
7:30 B Bridge across the River at Bend B. 7:45 C We didn't Cee the third bend on the map!
Using this method, elapsed hours happen at Z,D,H,L,P,T,X i.e. every four letters.

Use the Name of the Track for the Acrostic

L ying down tree
E ee! There's a bull!
E e-normous bracket fungus
S wim
P addled Across
A lternative Detour
D
D
O
C
K
S

*Every quarter of an hour, look for things beginning with that letter to remember that kilometre by.
*four letters make up one hour *Use stepped word pairs, 'Lying East-west; Exciting Exit; Extra Searches
*Do Something Alphabetical
E.g. Lie down at L; Scream at E; Examine the fungus at E; SPlash at SP
*Make all your names begin with that letter e.g. Pot-holes, Pines, Possum trees, Possible campsite, Photo
*Write them all down, but try to memorise the best one.
*You can attempt to improve the sequencing, by taking the letters two or more at a time e.g….
LE In the Lee of the lying down tree
EE EEE!
ES E.S.P. told us to find the track next to the E-normous bracket fungus
SP Splash Splash. Had a Swim
*Try also to relate picture to picture in sequence e.g….
Look at the Long horns on the Lying down tree; Enormous bull!; Enormous bracket fungus, dripping with water… Swim!

Acrostics combine individual memories with a clear sequence — firstly by letter, and secondly, by overlapping one pair of letters with the next, and thirdly by overlapping one picture with the next.
You have already memorised many long sequences of letters, e.g. the words of a song, which could be used as a unique acrostic.

Headlands, Bays, Prevailing Winds, Longshore Drift of Sand, Creeks

Headlands are ridges. Bays are valleys.
The ridges determine the headlands, bays, creeks, and — look for this — the position of offshore rocks and islands, especially where a 'point' marks a change in the trend of the coastline.

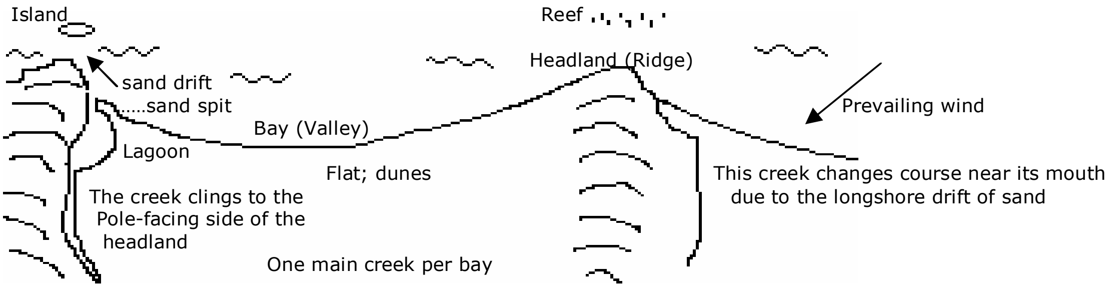
Island
Reef
Headland (Ridge)
sand drift
….sand spit
Bay (Valley)
Prevailing wind
Lagoon
Flat; dunes
This creek changes course near its mouth
due to the longshore drift of sand
The creek clings to the
Pole-facing side of the
headland
One main creek per bay

Beaches — Slope, Particle Size, and Wave Energy

Energetic erosion washes away any small particles.
A steep beach is a high energy beach with big particles.
When it is deep offshore the waves break with high energy.

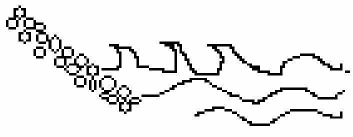

A flat beach reduces the energy of breaking waves.
A low energy beach is flat with small particles.
Sandbars and shallow sandy offshore seabeds
make the waves break over a long-distance.

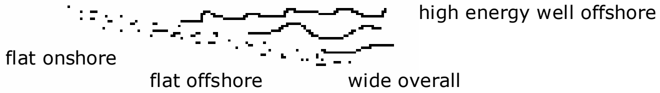
high energy well offshore
flat onshore
flat offshore
wide overall

Much the same seems to happen on land slopes — the flatter slopes have fewer rocks. I.e. the accumulated silt which is not washed away by surface water, covers up the larger rocks.

Sea-levels have been much higher in the past, so that there will almost always be buried boulders just above the present seashore.

Look Through the Trees, to the Sky and Skyline

This is a habit which stops you being befuddled by bends. You focus on the most distant thing you can see…

- E.g. the farthest tree trunk
- E.g. the skyline — ridges, gullies, peaks, light/dark division
- E.g. the clouds — but do stop to examine their movements occasionally!
- E.g. the Sun, the Moon — obviously the best, but they move too, and… don't look at the Sun!
- E.g. the dark blue polarisation band — Use Polaroid sunglasses if you are walking a forest track and can see only the sky.

Don't forget what is abreast of you e.g. a particularly tall tree. If you need to, look behind for some reference point.

Habits take practice to develop. This one is easy, because once you appreciate it, you won't want to give it up.
— It turns many small bends into a few major trends —

Periscope

Climb a tree. Climb a hill. Stand on somebody's shoulders. Or try this…
Attach a mirror (bigger = better) at 45° (try to be exact) to one end of a long stiff stick (e.g. a fishing rod)
— then scan the tree top horizon for landmarks.

Navigating by Trees

Tall trees on high ridges stand out against the sky and are visible for miles around.
Get to know the biggest, tallest, most visible ones.
Individual trees, gum trees especially, are wonderfully fingerprinted, by their branching pattern, outline, position & orientation.
E.g. look for the direction between the two largest branches. This stands out like a weathercock whenever you glimpse that tree again.
E.g. locate the relative positions of a handful of the best trees, so as to cover a wide area.
E.g. try to note the relative direction of pairs of trees.
Most big trees will have large branches to noon. So look for big branches which are *not* pointed to noon.

If you keep looking through the immediate green barrier for more distant (unmoving) skyline trees —
you will notice them and recognise them surprisingly often.

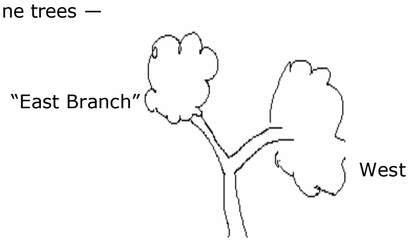
"East Branch"
West

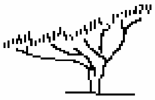

‘Solar-Panel’ Tilting of the Canopy Top

Some trees may be ‘flat-topped’, but they are not ‘level’. They tilt toward noon. Best seen from side on.

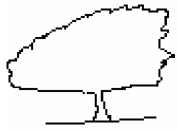

Wedge Shaped

Branches seem to know when to stop growing, and so manage to display
a fairly **uniform**, slanted **flat wall of leaves** toward the outside and especially toward the light.

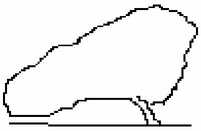

Lopsided Lean

Branches on the backside usually reach higher to bask in the skylight.
Branches on the front side are more horizontal, lower and longer.
Some trees don’t seem to try to compensate and simply leave their trunk behind, on one side.

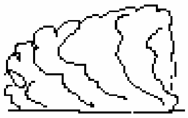

Half-Dome

— an extreme case of a steep back side

NOTE that all these signs work best in open woodland, not in forest understorey, but not always...

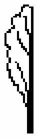

One-Sided Leafiness

E.g. Banksia trees
Such extreme asymmetry often only occurs in the understorey — where light is limited.
E.g. After a bushfire a gum tree revegetates from the trunk — most leafiness survives on the sunny side.

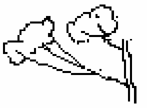

Individual Branchlets

— show similar shapes to whole trees
— tilted, asymmetrical twig patterns, one-sided leafiness, etc
The effect will show up best on the east and west sides of a plant, where the lighting is most asymmetrical.

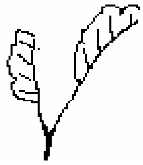

Bare Backbone

Look for it on individual branchlets, on the rear-side of main branches, and sometimes on whole trees.
You could run your finger up the entire length on one side of many shady-side branches.

Group Several Related Images into One

This is a standard method of making your memory ability efficient.
You have less items to remember—they become a few memory prompts, each to a handful of items.
E.g. 4 groups of 4… 6,7,8,9 a.m. / 10,11,12,1 / 2,3,4,5 / 6,7,8,9 p.m.
Write each group out visually shaped e.g. at the points of a square for a group of four
with 2 opposite squares for a group of eight
inside an infinity sign for a pair of items
List the hardest to remember items, first and last.
Group the shapes i.e. the groups, into another visual structure.
Use symmetry wherever possible—it makes it easy to recall.

The Start-Stop-Rest mnemonic (see Section 5. p.110) is a good example of this “clumping” technique—never more than a handful of things to remember, yet it leads you into hundreds of points.
Put the S for Sky at the top, and use a hexagon for the six start up points. Use a clock-face for TIME, and the compass-rose for NSEW.
Balance it all on a triangle, for the 6 a.m. start

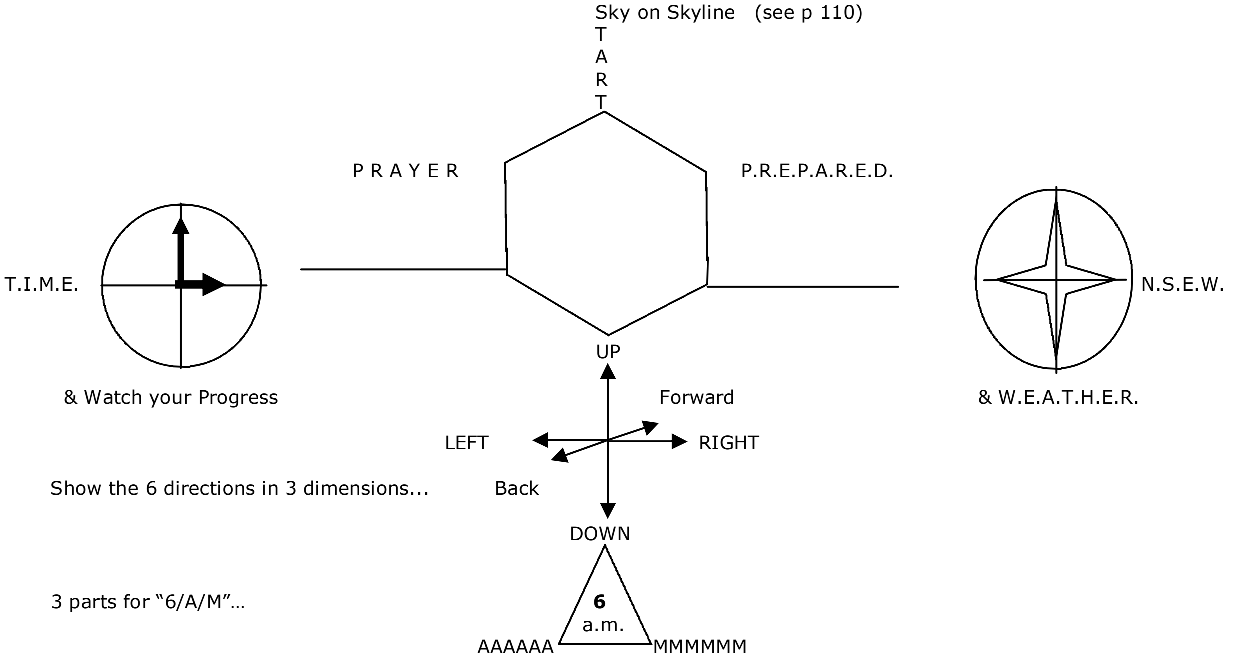

Rock Typing

Hardness — how easily eroded. Keep trying to scratch it until you find something just harder than it e.g. your pocket knife.
Colour — what colour silt. Scratch it against harder rock and look at the colour of the crumbs.
Sedimentary — the components are not of local origin. Layers — sedimentary origins. Melted sediments — crystalline bands
Sand content — grano-diorite — pale & silica rich. Clay content — basalt — dark & mineral rich. Mineral crystals in it.
Crystallisation — small crystals mean rapid (surface) cooling; large crystals means slow (deep earth—'plutonic') cooling.
Mineral content — what sort of soils does it produce? Flakiness. Behaviour in fire (Caution!)— it cracks, blisters or explodes! Melting pt.
Density, Magnetism, Fracture Pattern, Transparency, Permeability, Acid Solubility—evaporites and marine deposits may be limey.
Understanding these details is a key memory aid, since it gives you more meaning to look for, to memorise and recognise.
E.g. in basalt areas expect a more diverse & rich flora & fauna.
E.g. in the sandy plains, expect rivers to run underground, trees to have deep tap-roots and to line only the dry watercourses.
E.g. in dry sedimentary areas, look for a harder 'evaporite' layer underneath.
You don't have to identify the mineral, but you should characterise the rock type.

Soil Typing

1. Climate drives soil typing. What is the climate?
2. Latitude drives climate. What is the latitude?
3. High altitude mimics high latitude. What is the altitude?
4. How is the local climate modified? Look especially for temperature and rainfall factors.
   E.g. ranges upwind? A cold landmass? Warm ocean currents up-weather?
5. Evaporation produces salty limey evaporite deposits, whenever the evaporation rate exceeds the rainfall rate. High-temperature and wind, speed up evaporation. Flat inland areas receive less rain. Where rainfall exceeds evaporation, the soils are acidic, leached, and deep. Does the evaporation rate exceed the rainfall rate annually?
6. Climate drives vegetation as well as soil types. Soil types drive vegetation. The three go together. What is the vegetation type?
7. What is the parent bedrock? Granodiorite produces pale, sandy, friable, well-drained, mineral poor soils.
   Basalt produces dark, clay, dense, waterlogged, mineral rich soils.
   Warmth & rainfall aid chemical weathering and erosion rates of the parent bedrock, and so produce deep soils.
8. What are the relative constituents? Shake some soil and water together in a glass jar and leave it to stand until it is layered. Organics & charcoal float. Heavy minerals, pebbles & sand sink. Silts lie on top of them; then clays. Colloids remain suspended. Organic remnants accumulate in soil when it is warm enough to grow plants, but cold enough not to rot them away quickly. The decay of organic materials then provides acids for leaching, provided that high rainfall doesn't dilute the organic acids. Can you see from the sort of soils how cold and wet it has been?
9. What are the depths & layers of soil? It is leaching which transports poorly soluble salts to lower layers, until the water table dilutes the acidity. Subsoil clays also accumulate where leachates are deposited. Evaporites accumulate just below the surface and above the water table. Dry areas have poor soil depth due to slow bed-rock weathering and erosion rates.
10. What is the soil colour? Red indicates partly leached soil — iron and aluminium salts remain. Paler, ash-coloured soils are left behind after further acid leaching. Black soils result from poorly drained unleached soils. The importance is that leaching reduces fertility due to the lack of soluble plant foods. Leaching is aided by warmth (except in the case of limestone which dissolves better in colder climates).

Bush networks

The bush roadmap is made up of a network of interleaved ridges and rivers.
Instead of a major road or a minor road, you have a main ridge or river, shorter ones, and dead-end ones e.g. a 'shoulder'.
A 'cross roads' is where two creeks & two ridges meet — a saddle.
The seashore corresponds to a boundary fence; Peaks and islands act like townships — they are a focus of 'roads' and ring-routes.

Don't Navigate by Networks Only

Networks are fractal — big **creeks** have little creeks running into them; **walking tracks** have side tracks branching off from them;
big ridge lines have little **ridge lines** running off from them;
dirt roads have smaller dirt roads which have still smaller dirt roads joining in.
That is why it is difficult to recognise the scale of any map just by looking at the networks on it. The more detailed the map, the more detail there is to show up. The smaller scale the map, the more detail has to be left off.

So there will always be small creeks, unmarked roads, minor tracks and minor ridges to tempt you into thinking
"This one is what is marked on the map".
You will likely find one "exactly" where you look for it, but it may not be the right one.
Don't navigate simply by expectations of network junctions.
E.g. the next creek-line has a 50% chance of being "just as I expected it — a creek-line coming in from the right"
or if not expected, the 50% chance is that you will say "probably just not marked on the map"!
If by chance it is actually correct, it will only encourage you to continue navigating by network,
but you won't always pick the correct one.

Antidotes For Guessing at Network Junctions

- **Distance** covered. Accurate measurements of progress can eliminate some minor junctions which are "almost" where you expect the desired junction to be.
- Trend — of the junction branches. I.e. the **directions** must match your expectations too. E.g. "Each side of North"
- Landmark **bearings**. Try to separate identical looking junctions by cross-checking their position in relation to skyline features.
- Care.
- **Count**. Look-alike branches are nonetheless unique, when numbered.
- Recognition, from last time, if you had bothered to identify its peculiarities. I.e. bother now, for next time.

Branching Patterns — Examine Them for thickness, length, angle, curvature

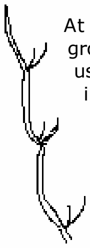

At each node some branches
grow better than others
usually toward the light
i.e. stretching outwards
or up-wind upwards
or downwind down low.
Check the **spacing.**

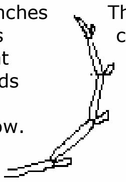

The choice of branchlet
can **curve** a whole branch

or stiffen it
against the wind…

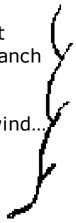

bottom view
looking up…

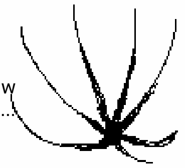

Side branches
can **curl** around
toward noon.
Examine the ends
of the branches.

This enhances the 'bare backbone' appearance
of the dark side of a trunk or branch.

A well-leafed branchlet will usually hormonally
dominate one without buds, by active biochemical suppression.
In this way growth can be regulated.

E.g. horizontal decurvature
can search out extra light
underneath the canopy

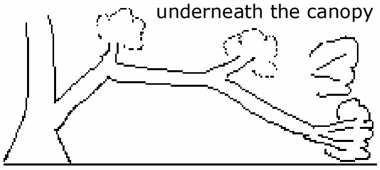

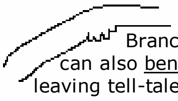

Branches
can also bend,
leaving tell-tale 'wrinkles'
in the skin.

Double curvature can fight gravity or wind.

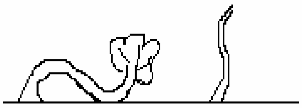

Gum trees show asymmetry especially easily, since they do not try hard
to be symmetrical in the first place!

Examine the main trunk itself.
It may curve away from the light
to act as a counter**balance**
to the heavy light-side branches.

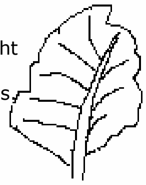

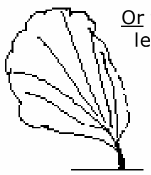

Or the trunk may be overbalanced, by its branches
lengthening, thickening and curling toward the light.

Length:
Some trees 'reach' for the light
becoming lopsided

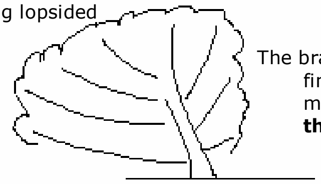

The branches that
find the
most light
thicken most…

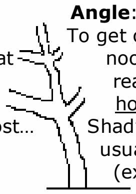

Angle:
To get out from under the canopy,
noon-side branches often
reach out a long way
horizontally...
Shady side branches
usually reach upwards
(except maybe in a windy place).

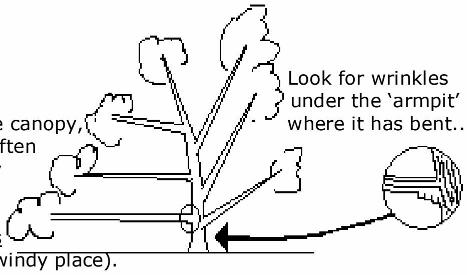

Look for wrinkles
under the 'armpit'
where it has bent...

Working Names — Invent Them

E.g. Past the 'Little Castle Rock'
Up the 'Yellow-Crowned Tree' trail
Under the U-shaped rock face
Between the Big-Boulder Bluffs

"40 minutes in" is a handy name — when you recognise it, coming back out.

Stupid gawky names help you remember, but even better is to do something stupid to match.
E.g. Gallop like a galah, through the pass, and call it "Gallop Gap with Galahs Galore!"

Standard Name Plus Personal Name

Actual names last longer and are widely known. Use them.
But make up a personalised name too.

E.g. "Oh it is actually called 'Boomer Hill',	but we call it Porridge Hill, because it lies halfway between Oatlands and the Table Tier!
E.g. We call Wollongong "Kaus Australis"	'coz that's where we watched Kaus Australis go straight overhead.
E.g. Kaus Australis becomes	"The Wollongong Star"

Remembering Names

To help you later, when the name is 'on the tip of your tongue',
Count the syllables, consonants, short vowels, long vowels, now.
Rhyme it with something appropriate e.g. Condominium Creek has a pond of minimum seep.
Look at the spelt visual shape… for ascenders, descenders, double letters, symmetry.

Then later run through the alphabet for a guess at the first letter, then at the second, and so on.
Think about anything related, like why you went, what you ate, who you met, what you saw, the weather, the season, the news at the time…
Ask each person for these recollections. Recreate the full scene.

Contour Lines

Contour lines mark horizontal ground.
A simple trick to match up the map contour lines and the landscape, is to **point horizontally** parallel to the ground.
E.g. if you are in a valley, point along both creekbanks, using both hands. The steeper the valley sides, the narrower the contour angle.

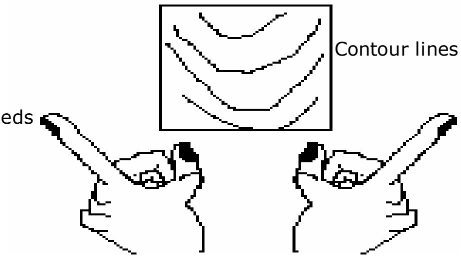
Contour lines on the map
Horizontal ground on the creek beds

Contour lines are like water-marks on the bank of a reservoir, lake or swimming hole, visible after the water-level has dropped.
But bigger like a global flood drying up 10m at a time, leaving water-marks.
like a photograph of it, from above.
like horizontal slices progressively taken off from the top of the mountains, as when you slice clay with a thin wire and you look at what is left.
like building up a model landscape one layer of cardboard at a time, from below, with progressively smaller shapes cut out according to the map contours.
Then you draw the results on a map.
They show the path you have to walk to go 'around the contour' so that you neither climb nor descend.

Contour Navigation: **Practise** It, **Before** you Need It

At night, or in fog, or in a blizzard, you may have no other clues, but the contours, on the map, and underfoot. Try to match them up.
Hint: Don't expect every little bump to show up on the map, but only the average smooth slope.
Hint: Keep good track of compass direction, time & distance as your best crosscheck. Assess the wind. Use an altimeter (,GPS, radar…).
Hint: **Delegate** tasks — map reading; course holding; distance logging; slope assessment; exploration; memory…
Hint: To go quicker, go slower — so as to be sure. Explore the slopes to left and to right. (But don't get lost or disoriented!)
Hold regular conferences to check your judgments.
Hint: Assess slopes by looking sideways, across them. They always seem so steep when you look up!

Boat navigators in a fog, can sail toward land until they reach a predetermined depth, then sail along parallel to the coast, using the depth contours marked on their chart, and some method of finding the depth. Marine depth sounders rely on a good echo, but you can always toss a weighted line over the side to find the actual depth. Make sure to make corrections for the depth of the depth-sounder, the depth of your keel, and the height of the current tide!

Sticking to the Bush Network

- Walking **up-ridge** may perch you on an isolated hillock.
- Walking **down-stream** must get you to salt water; or at least to water, civilisation, flats, roads; but also to thicker vegetation and a loss of view; and sometimes to impassable waterfalls and gorges.
- Walking upridge, uphill, upstream lands you in steeper, drier, more jagged terrain with more open vegetation, a better view and maybe an along-ridge track.
- Walking down-ridge will "take you to the lake", but simply walking downhill may lead you into a heavily vegetated creek-valley which then drains into the lake.

Natural Routes Naturally Converge

That means that, in reverse, they must also **diverge** — which is dangerous, open to mis-navigation.

- Provided you don't cross catchment divides, walking downstream or up-ridge is **convergent** and so is safe for a one-way trip, but **un-safe as a means of retracing your steps back to base**. E.g. it is easy to climb a hill, hard to retrace exactly.
- Walking down-ridge is **divergent — deceptive and dangerous**.
You cannot easily see ridges peeling off below, and the map won't mark all the creeks you can see.
If you are trying to retrace your steps or navigate from the map, you will have to be very careful.
- Ridges converge to hilltops — so walking **downridge** leads you widely astray.
- **Upstream** is divergent — you don't know where you will end up, but at least you can find your way back, because creeks converge toward the river mouth.
- Tracks & trails converge to: popular features, bridges, car parks, waterholes, homesteads, campsites, clearings, etc.
So **leaving a focal point faces you with multiple choices** "How on earth do I get outta here!"

Coping with Divergence

The result of "directions" such as "You can't go wrong. You can't miss it" is that the truer that is, the easier it is to go wrong — after you have found it. Retracing your steps, or finding the desired way out, onward, can become a nightmare.

- Ask directions for the onward bit, not just how to get there.

For backtracking…

- Pay attention on the way in, despite your excitement at arriving. Note the direction of your arrival. Look back regularly. Mark the junctions you used, especially from minor out onto major paths. Retrace your own tracks.

Reverse logic

Be like yachtsmen, who should always explore harbours, shallows and tributaries at low tide "in case we do get stuck".

- Explore upstream — a divergent labyrinth — so that you can walk downstream to return.
Provided you don't cross water-divides, or overshoot your starting point, "you can hardly go wrong".
Ahah! There's the hint: Before you set off upstream, peek behind you, to see when to stop "coming back downstream"!
- Explore downridge, and climb back upridge later. Only don't climb down anything you can't climb back up.
- Explore away from a focus, so that you can converge back to it.

Isolated Vegetation Shows the Clearest Asymmetry

E.g. Look in any **clearing** for downwind debris/erosion,
and for up-Sun/down-Sun asymmetry at the edges.
E.g. an isolated tree in a paddock...
E.g. an open creek will give the bushes a clear view across the water...
E.g. a roadway will exaggerate the light asymmetry on one side
and suppress it on the other...
E.g. Look in the wheel ruts of bush tracks for asymmetries due to wind & light…

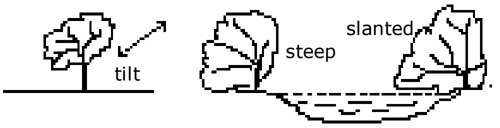

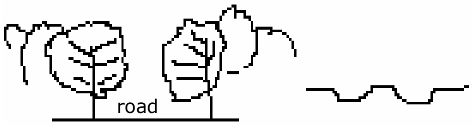

Examine **the tallest trees — The emergent ones** have a clear view of the Sun.

At the **edge** of a clearing, subtract the effect of wind…

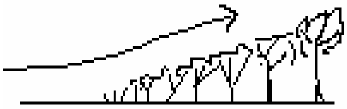

Closed Canopy — Look for Gaps

Each tree canopy might look uniform, but be blown back on the upwind side,
leaving a gap there, with dead branches, where it *has tried* to fill the gap.
But look for a gap without dead branches and without other explanation
— It might be 'shady south', which gives the tree little incentive to cover.
The tree *could have* spread that far by now, if it had wanted to, but hasn't.

Tall and quick growing saplings **show the most asymmetry...**

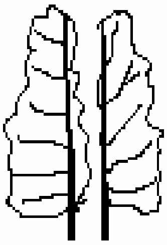

They can be the best tell-tales of all, and the worst!
Because they respond to clearings, slope, water-shine, nearby trees — be careful!
Take extra care to average out their message.
Any one tree gives you too definite an impression!
Back-to-back saplings may show opposite asymmetry, by shading each other...
Treat the overall shape as one tree.
The sapling effect, arises from young forest trees shedding branches more often
and more easily than mature trees.

Roadsides & Campsites Reverse Some Effects!

Examine trunks for broken or lopped boughs before interpreting!
The bigger lower branches are easiest and best firewood pickings!

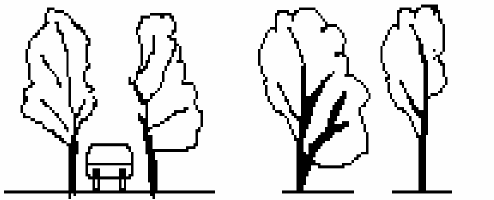

Name the Subsections

Heart-Attack Hill	Bust-me-gall Bend	Starve-gut-Ridge			: Be Vivid
On-the-Double Decline	Cross-the-Creeks Roller-Coaster	Blackberry Bank			: Be Descriptive
Left-hand Loop	Clockwise Climb	Right-around Contour	The Zed Bend		: Be Cheiral
N-E Straight	Into the Sun Slog	West Bank	Downwind Dunes		: Be Directional
Long Leg	Short Stretch	The Middle Mile			: Tell the Distance
Last-legs Leg	Dinnertime Creek	Sunset Strip			: Tell the Time
On the Left of Third Hill	Nine Mile Beach	Five Ways	Fourth Island		: Count
The Bush Blocks	The Rock Band	Turning Point	The Up-Part	The Trip down	: Be Clever
Rubble Ramble	Possum Passage	Flower Flats			: Alliterate
The Birdwatching Bit	The Deer Park	The Gloriously Green Glade			: Be Observant
The Monkey Saddle (three creeks)	The Big Bulge	Round Shoulder	Tight Turn Tongue		: Be Shapely
The Breakaway	The Hither Side of the Hill	Round the Rim	Unto the Brink		: Be Literary
Brown Beach Bay	Wobbly Shacks (= Mount Wobbly behind the shacks)	Zigzag Track			: Be Visual
Perverse Reverse	Inland Cusp	Round the Back	Out to Sea and Back		: Name Whole Curves

Name the Sequence

Fit Each Subsection into a Larger Scheme.

- Name the Links : The Cuvier Track The Mount Barker Road The East West Ridge
- Name the Junctions : Point Pass Steppes Junction Tee -tree Junction
- Contextualise : Beyond Burrowing Crayfish Ridge Cross Catchment Climb
- Overlap Sections : Deer Sally to Sandy's Shore to All-Terrain Trek } these are simultaneous
  Sherwood Forest to Bumpy Flat to Uphill Haul } and overlapped 50%
  I.e. halfway through one section, think about how it is changing character
  into the next obvious section, and anticipate it.
- Time-Distance Clues : Lunchtime Lookout The Approach Thither Heather Tea Junction Ten-Mile Dam
- Lie-Linkage : Downstream from Dusty Waterfall Wind-Shadow Plateau
- Numbers : Fourth Bump Fifth Creek Tee Junction # Three
- Acrostic : Short Steep Step in the Southern Subdivision after the Shallow Segment

Contour Curves: Your Job is to Imagine the Shapes into Life And to Match the Lines to the Landscape

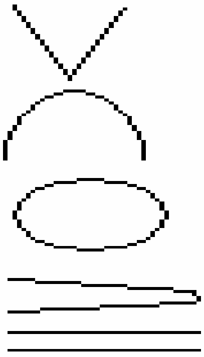

Deep Vee 'Ditches'
— they gather water.

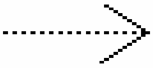

The **sharp** points, point **up**-river. (sharp/up rhymes in p)

Round 'Shoulders' — they shed water.

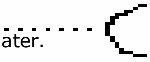

The **round** points point **down**-ridge. (round/down rhymes)

— being higher ground, they separate gullies

Peak or Depression — you can't easily tell which. Peaks are much more common.

Hairpin 'Ridges' — they can look parallel, like 'a slope', if the edge of the map cuts them off.
Ridges usually show much rounder than this.

Parallel 'Slopes' —be careful about which way is 'up'. Check that they are not the same height—on a ridge or river

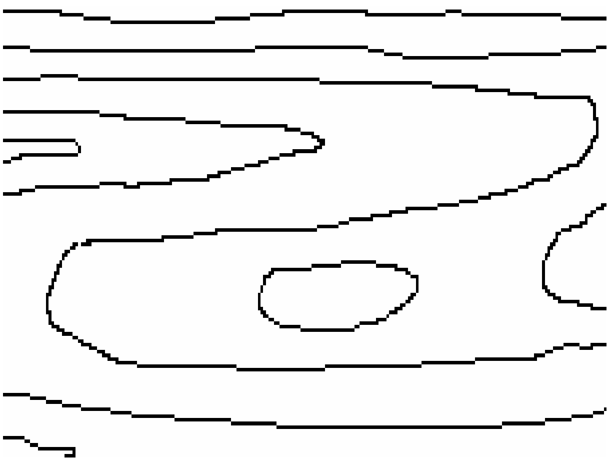

Here is a typical confusing array of parallel lines.
The first two are ambiguous, but seem to lead down into a valley…
The valley is shown as lines 3, 4 & 5…

The three corners here are all sharper than the corresponding ridges.
Downstream is to the left…
Imagine a deep-vee ditch.

The shoulders and peaks shown here are all much rounder…
..Uphill is ⟶ peak ⟵ saddle ⟶ ridge or peak ……….
Imagine a circular mound with a spur down to left and right.

Down here, upslope to higher ground is…↑

Trackless Navigation

When you leave the bush network to cut across the natural routes, you still navigate by them, by noticing when you cross them.
You choose a route in relation to the framework — of ridges, rivers, and the contours that cross them at right angles.
E.g. "I am now going diagonally right, uphill, on the left bank, to the Ridge, then…"
You describe the sort of route you are following, and **start a new subsection whenever that sort of route changes** in quality.
E.g. A dry shallow creekbed marks a change from downhill to uphill.
E.g. The major break of slope—on the "hillside"—marks the change between being on the "hill/crest/ridge" or in the "valley".
Don't forget to ask, as you cross each 'road', what that ridge or creek is doing, to the left & to the right e.g. joining, splitting, rising, falling, dividing major valleys.

The method of Names

The point of this method is to bring your normally subconscious memory into conscious focus.
You put a **name** i.e. an essential description, onto each subsection. This is in addition to naming the creeks and ridges you cross.
That is equivalent to supplying your own signposts & flashing lights to the landscape. But write down the other details also.
As with memorising any journey there are a handful of steps: Notice; Recognise; Describe; Name; Remember; Put it into Sequence.

Bush Networking Essentials

Answer up to six backbone questions about each leg, before deciding on an appropriate name for that subsection…

1. Hill-wise — What Peak? — Is your direction trend in relation to it Uphill or Downhill; towards or away?
2. Hillside-wise — Slope — Choose between Upslope/Downslope/Flat/Contouring.
3. Ridge-wise — Rise — Upridge/Downridge/Crossridge?
4. Drainage-wise — Lie — Upstream/Downstream/Crossstream?
5. Side-wise — using the standard names* — Left bank/Right bank (below the break of slope); Right flank/Left flank (above).
   *As a yachtsman going **up-**stream sees it — Port and Starboard. Use these terms in your names to remind you.
   As a traveler going **up**-ridge sees it.
   I.e. the standard directions are **up**-stream; **up**-ridge; **up**-north; **up**-wind; **up**-hill, **up**-slope.
   Be careful! The 'right bank' is the 'left flank'. You can climb to the right on the left flank (of a ridge which falls to your right).
   Walking diagonally 'downslope' can be 'upstream'.
6. Hand-wise — Tack — Clockwise around or Left around/On the left diagonal or Right diagonal?

Mnemonic: (With your right index finger) touch your **head** (the peak);
forehead (the slope);
bridge of your nose (the break of slope);
down the ridge of your **nose** (the ridge);
nostrils (the drainage);
right **cheek** (the side);
and now look at your **hand** in wonderment (What is my tack?)
Then **point** out some peculiarities...
Now **add the non-essential** — exact measurements e.g. direction/length/time/steepness/count —and descriptions, sequence, context.
(Remember: don't navigate only by networks.) See opposite, for descriptive names.

Flowers Respond to Sunlight

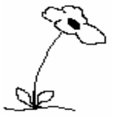

Examine the stalk-lean and flower-head tilt
e.g. of daisies.
Look up-Sun and down-Sun to see the striking difference, whenever the Sun is low.

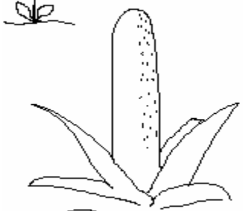

Look for the first flush of flowering on the sunny side of a flower spike
E.g. Yakka (Xanthorrhoea). The mid-morning sunlight direction gets the earliest flowers.

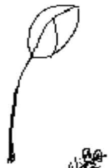

Examine closed flowers to see whether they betray where the Sun last came from.
Many flowers 'follow' the Sun around.

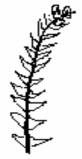

Some leafy stems seem to tilt to the noon, perhaps to point their terminal flowers into the Sun.
E.g. Sea Spurge

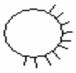

(Top view)
Banksia pistils sprout earlier on the sunny side.

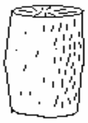

Banksia stamens deepen in colour on the sunny side.

Fruit Distribution and Ripening

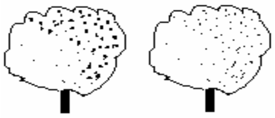

Some bushes will fertilise more flowers in the sunlight because pollinators can see them better.

Fruit are fertilised flowers. So some species 'set' more fruit on the sunny side.
Look in all directions to see which aspect presents the most flowers or fruits to view.

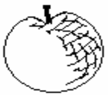

'Ripe' colours are a result of sunlight e.g. apple, peach.
Sun-ripened colours aren't confined to fruits.
Mushrooms are often old enough to have seen some sunlight.
One mushroom in the open may not help you much, but they do come in flushes, so look for a *pattern*.

Remember the Sequence from AA to ZZ

— A Ready Made Acrostic of memorable unique items, with endless extension if needed. I recommend it as the pick of the mnemonics.

You may need to remember each tree in a forest walk, or every twist in a path, or every choice in a maze, or every square in a grid.
AA to ZZ supplies 676 *differently named and sequenced letter pairs*.

If you turn the letter pairs into appropriate *two word phrases*, there is no limit to the useful memory aids.
E.g. I could call this system the Alphabetic Zygote (of 'letters paired' A-Z).
As with all gimmicks, it only works best if you *study and* ***memorise*** **the object *receiving* the label**.
Examine the tree for anything which could attract the label DF (damp foliage; dendritic form; downpointing flowers),
or mentally *photograph* the MS munch-stop, or *actually* bird-watch at BW.

It's up to you to use the letter pair in a memorable way. Don't forget to use visual, emotional, sequenced and appropriate words.
Consistent rules help.
On a pure sequence walk, begin with double letters, rather than with A-Z single letters. This makes two word phrases the consistent rule.
In fact begin with *any* double letter, but especially **the initials of the walk**, e.g. BL for Blackmans Lagoon.
Two word Phrases e.g. AA = Ask Again, avoid the ambiguity about which other letter in the word or phrase might be emphasised.
E.g. is Aeroplane, AE or AR or AP or AN? Was 'Anabolic steroids' A or AS?
Add a third word to the phrase as needed, to spell out what it means, e.g. Backwater Island turnoff.

The trick is to make the mnemonic **match** the feature.
E.g. if there is a plague of mosquitoes which you attack with a stick, Aaron's Almond-tree walking stick might be appropriate for AA.
Then the need is to somehow link the previous with the next.
E.g. AB Aaron's Budded walking stick (if you know that story), might focus your attention on the buds in the next gum-tree.
Without a '**theme**' it is difficult to pluck out your memory what 'DF' might have been. But 'Doctor's Emergency' where you stubbed your toe, leads on to 'Doctor's Ferari' when you walk on quickly anyway, and on to 'Doctor's Gasoline' where you topped up with lunch.

If you do a 'grid-line walk', you use A-Z to begin with, and say you move from A0 to C4; you might go through A1, A2, B2, B3, C3, C4.
The memory aid goes A0, then Ahead on 1 leg, hopping, then Across, on 2 legs, Ban-tu, Ban-three, See the three cattle?, Count to 4...
'Minus', in cases of ambiguity, might come out as 'which was 4 metres deep', or 'where I left 4 pebbles behind', or 'and Not 4 blisters' or 'at anything but 4pm'.
When you get into AD you look for a-d **peculiarities** to remember like 'Add 4+6 wattles (to get 46)' or '33AD crucifixion tree' or 'Adder-Death, two score of them'.
As an alternative, name all grid squares with *letters*, e.g. D-G, and look for things to name, such as Dark Green; Discarded Gaiter.

In a maze, you could choose Long words for turning Right; Short words for turning Left, a mixed phrase for Straight Ahead. These match the meaning-words in length of sound.
Maybe you need some **variations**:
One, two, three or four syllables for left, right, through, reverse.
Long first vowel sound vs short vowel sound.
Begin with one *letter* and *end* with the other *sound*, e.g. Amanda, Abib, Ace, Add, Abbey…
Let sounds take priority where needed. E.g. few words start with K, but many start with a hard C. X is hard unless you allow Ex-.

Memorised sequences are most effective if revised almost on the spot, e.g. via a leap-frog walk (2 forward, one back), and on the return.
Equally, other methods are enhanced by adding this mnemonic, such as when marking a trail, writing track notes, or making a mudmap.

Contour Heights: Read the Numbers!

Determine **the Contour Interval** — and interpret which way is 'up' from the **numbers**… Note: On maps, the numbers are printed to be read as if looking **uphill.**

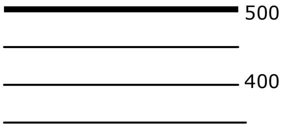

This first diagram is "every 50 m".
And 'up' is toward the top.

Zero means "sea level"
Read the absolute numbers!

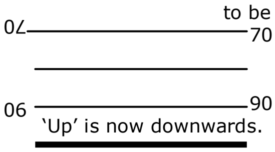

In the second diagram, the contour interval is every '10 m'
'Up' is now downwards.

Note that **major** contours may be marked as thicker
e.g. every 50 or 100 m

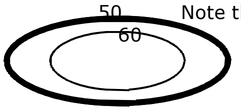

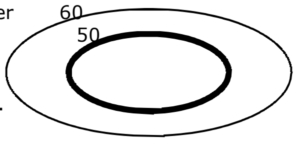

..The first is a peak; the second is a hollow...

Marine charts show spot-depths, 'soundings', in metres and decimeters, below lowest water, with offshore depth-contours.
If the "depth" is underlined, it refers to a "drying height" of intertidal rocks.
At sea, keep a record of the soundings as you sail in to land, preferably in a straight line. Plot them onto tracing paper or mark them on the edge of a ruler, and try to match the pattern to charted depths.

Contour Spacing: Close = Steep Slope

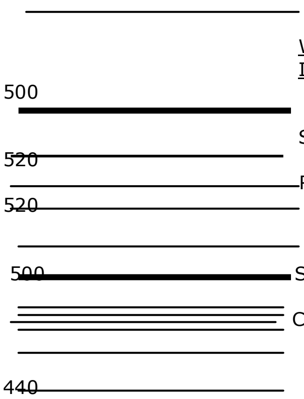

Wide spacing = flat land   Examples: mountain plateaus; valley floors; paddocks; dunes
Irregular contour shapes (meandering all over the map; not shown here) = very flat land

Slope

Ridge — carefully notice when numbers are identical. **The rule "Closer Equals Steeper" only holds for different height levels, not for hairpin contours around ridges or rivers.**
In fact, "close" might equal "flat" i.e. on a ridgetop

Slope

Cliff — Very close = Very steep

Slope; have you worked out downhill?

Walking "Straight" through the Bush

- 'Straight' downstream; upstream; down-ridge; up-ridge; uphill; downhill
- 'Straight' around the contour
- 'Straight' along the path of least resistance
- 'Straight' through the obstacle course, dodging to left and right
- The Line 'of Best fit' — to a chosen trend cross-country

None of these are straight, but most are easier than 'straight across a slope' — crossing innumerable ups and downs!
Most are predictable.
The navigator simply goes last in line with a compass and logs the twists and turns, whatever course that takes.

Why last in line? It is a fact of life that following your nose through the bush quickly disorients the leader of the party, while those following behind maintain their bearings easily.
Also, to clearly show up the trend of a sinuous course, the last person can drag a long smooth string loosely behind him.

Straight around

At a…

- Constant Angle—to the (changing) Sun, Moon, star, planet, landmark e.g. keep the peak "ahead on your left" — a spiral course.
- Constant Distance Off — as judged by the rule of thumb — you keep a prominent landmark appearing to be a constant size — from base to peak. The course is circular, concentric to the landmark. E.g. offshore, around a lighthouse.
- Constant Horizontal Angle — between two prominent features. This gives a cusp-like circular course.

You can retrace these courses, but the going may well be difficult — crossing many streams and ridges.

How to Walk in an Unintentional Circle

Haven't you heard of people walking in a large circle when they are lost?
They thought that they were walking in a straight line, but some hours later they recognise the same scenery!
I've done it; it's no myth. Discover your natural drift...

Blindfold yourself. Try to walk straight across a flat. I bet you can't.
Most people have one slightly shorter leg, usually their left leg.

Now try to walk across a slope, blindfolded of course, in a straight line. I bet you drift.
But once you realise it, you are just as likely to head uphill too much, in overcompensation.

Don't trust your senses in a fog. Find out by trials at home — before you find out the hard way — how far 'off' you are.
Also find out how to properly walk in a straight line in a fog!

Stem and Leaf Colouring

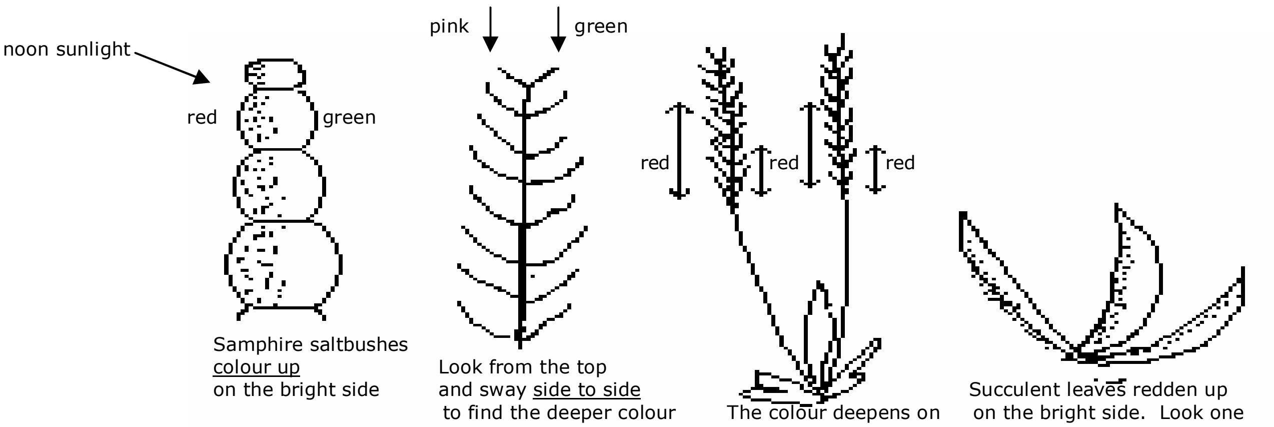

Samphire saltbushes colour up on the bright side

Many other plants show red stems or leaves etc Look for a paler side.

Look from the top and sway side to side to find the deeper colour

The colour deepens on the bracts higher up on the sunny side

Succulent leaves redden up on the bright side. Look one way over the flats & it is pinker than the other way, especially just after sunset!

N.B. Older stems may show a reverse trend! The colour fades on the sunny side after having deepened more while young.

Beware: When flower-stalks twist as they grow, the colouring or fading effect is unreliable. You can detect the twisting *by* the fading.

Example: Blackberry stems and leaves redden in sunlight, staying green on the shady side.

New Growth is Colour Differentiated

Looking up- or down-Sun (on a cloudy day) will show up new growth as yellowish or brownish or bluish (depending on the species) in one direction more than the other.
The sunny side will 'green up' the new leaves more quickly and will look more normal coloured.
But test it out first — it may go the other way — sunlight might promote new growth, before it colours it up.
When new growth is distributed throughout the shrub, the sunny side will often show deeper green (i.e. more of the same pigment) and be more vari-coloured e.g. some leaves take on a red blush or red margins in response to the Sun.

Revise your Memories

..after a 10 minute distraction
..after an hour, a day, a week, a month, a year e.g. for an acrostic which you wish to remember permanently
..and whenever after, when you begin to have trouble remembering
Choose undistracted, mindless times
e.g. while trudging or being driven, waiting or relaxing, or last thing before sleep, to run over things in your head.
Overpractise your mistakes. Out loud is always better. Take any opportunity to tell someone.

To Remember Formulae such as those at p. 19b

(1) Make up memorable ditties, and refresh your memory, as above, before you lose them.
(2) 'Read' the formulae *for sense* — They are just shorthand for how things *must* behave. If you don't like maths, it's probably because you never understood the common sense behind it, and that is probably because you never had the opportunity to see it, or developed the skill to read formulae.
E.g. '**Sin, Sin, Sin! It's High Latitudes which Declines it**, for both Easterners and Westerners'
for: the three sine ratios in the formula… 'sin (**heigh**t E-W) sin (**latitude**) = sin (**declin**ation)'
i.e. as the latitude increases, the height must decrease, and vice-versa, to preserve any sin (dec) figure as constant.
The formula should return zero height for zero declination, and 90° height for dec=lat.

This next one assumes that you measure the angle away from East-West (rather than from the 'elevated pole', as on p 19b).
You can use 'sine of the variation from E-W' instead of 'cosine of the angle from the pole', because 'co-sine' says 'sine of the co-angle'.
'The sin of the increasing the sunset angle, by cause of increasing latitude, is a sign of decline'.
sin (sunset angle) (multiplied by) cos (lat) = sin (dec)
Read this as: For any specific declination, as lat increases (=the cos reduces), the angle must increase, to preserve a constant sin (dec).
You can also put in dec=0 and expect a 0° answer no matter what the lat.
At the Equator, declination directly determines the direction of set N or S of E-W.

'Why bother with the E-W Sun? Be**cause of its E-W *timing*!** It's **today or too late**' t for tan; d for dec; late for lat;
90° = 6hrs each side of noon cos (time of E-W) = tan D / tan L, *'or' for "o'er" for 'over'*
Lat = 0 throws the calculation into a spin, because any declination other than 0 can't be E or W. Dec = 0 must return 90° for any lat.
Dec = 90 must be impossible (it's N or S!), but so must any dec > lat, since cosine doesn't go above 1. Those stars stay polewards.

'One New Day at a Time? Not quite, **'cause for tomorrow's sunrise time, today's time's not too late**!'
It changes only slowly, as dec changes. cos (time of sunrise) = tan D x —tan L 15° = 1 hr. each side of noon
0,0 must return 90°. Opposite hemispheres must return a large positive cos and hence a smaller angle, and a short day.
Same hemispheres must return a negative cos, which means a long day.
Too much lat, and the tropical bodies disappear altogether, as expected. Too much dec, like a circumpolar star, and it won't even set.

Try **the Equation of Time**, p.17b.
The First FFive months, From FFebruary, Fence-sit Four Features (halF-each side). The next 7 *finish* at four more features.
–1**4**,0,**4**, 0, -**6**,0,1**6**, 0 Makes nice mirror patterns of the two sets of four features. Minus means a fast Sun, up early; a 'slow' clock.
FFFebruary Founders at FFFourteen; Marches up again; April crosses (its hot-cross buns); May turns 4; June double-crosses;
July *finishes* work at six; August rises augustly, to zero; SSSeptember and October get up to SSSixteen;
November and **Dec**ember **dec**line a lot; December crosses at Cross-mass; January Sun decends from the cross, fast, for a new year.

Contour Slopes: Work Out 1 mm and 1 cm Contour Spacing

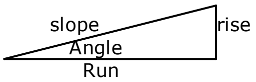

Example: a Rise of 10 m in a Run of 100 m is a Slope of one in 10 and an angle of 5.7°
[Tangent(angle)=rise/run Angle=Arctan(rise/run)]
rise/run is technically called the "gradient" i.e. an up-slope.

1) Example of 1 mm contour spacing: A 1:100,000 map-scale says: 1mm equals 100m (See 'map scaling factors' p.92a)
with 50m contours the slope must be 50m every 100m or 1 in 2 or 26°½.
2) Example, with 1 cm contour spacing: 10 times less slope, in the same example, or one in 20, or 3°

Using these 2 reference spacings (**work them out again for every new map**) fit the actual contour spacing (eg 3mm) between them.
E.g. map scale: 1:25,000 (1mm = 25m); for 10m contours, 10m rise in the 1mm run, on the map (=25m in reality) is,
"1mm contour spacing = 1 in 2.5"; (10mm contour spacing) = 1 in 25; (20mm contour spacing) = 1 in 50;
So… 3mm means 1 in 7.5

Reference Slopes — To Imagine the Climb with!

One in one; 45°; One up / one across; On all fours!
One Degree is 'one in 57' (or approximately 1 in 60) So 10° is 'one in 5.7' — maximum for public **roads**
One in Four is 14° — a neat coincidence to memorise. So One in 40 is 1.4° — maximum for **railways**
36° slope — 8 in 11 — more or less maximum for sand, gravel, scree, or any loose material.
Small slopes may be multiplied with approximate linear accuracy, but in an **inverse** fashion…
Examples: 2° is one in 30 — from the one in 60 rule
1 in eight is 7° — from the one in four rule
5° is one in 11 — either from 57/5 or from 5.7 x 2 or 1/8 of 36° see also "sine-cos chart" p.106b

The Beaufort Wind Scale — Modified for Bushwalkers

One in 40	contour lines absent or rare; pleasant ambling; wind whistles through the lips; grey hair relatively common
One in 30	car engine quieter than road noise; perambulators plentiful; locomotives absent.
One in 20	car engine noise louder than road noise; walkers plentiful
One in 15	skin moist despite cold conditions; heavy breathing is heard above background noise
One in 10	eyes sting from sweat; bicycles experience difficulty staying upright
One in eight	flies are constant companions; car smoke exits parallel to the ground; mountain bikers walk
One in six	cigarette butts become less frequent; 2 wheel drives mostly absent
One in five	walkers experience difficulty making forward progress
One in four	cannot hear the sound of a cigarette being lit; leaf litter easily lifted off ground
One in three	sturdy walkers stagger and sway; frequent rests; slow progress; loose soil swept away
One in two	large trees tilt at a noticeable angle to the ground; rocks experience difficulty staying in place; walkers remain upright only by zigzagging
One in one	toenails begin to bleed; trail bikes begin to bleed
Two in one	fingernails begin to bleed; small trees are pulled up by their roots
Three in one	contour lines begin to merge; danger of severe falls; you are in danger of being completely… winded!

Walking an Exact Straight Line in Open Country

Assume the visibility is limited, or the terrain difficult, or the vegetation is closed in…

- Lengthen the Whole Party—In Single File. Shout to the leader, if he wanders to left or right. Stop still if you lose sight of the person behind you, i.e. do something to make sure that no one gets lost in the fog.
- Drag a flat object (or a person) on a long string. Tie your end of the string onto a stick, and hold it forward above your head. Alternatively, pivot the stick in your hand at its halfway point, and it will point in the right direction. (Watch that the wind doesn't blow it sideways; Stop the flat object rolling; Stop it sliding downhill; Don't let it drag at an angle)

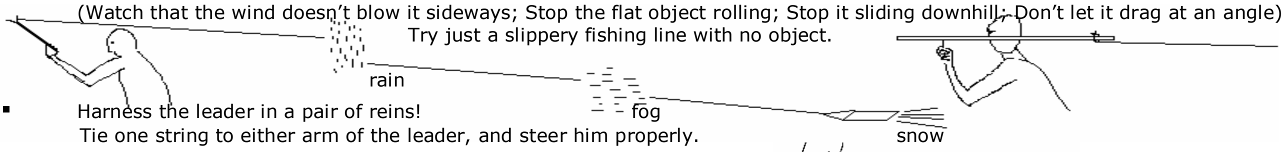

Try just a slippery fishing line with no object.

- Harness the leader in a pair of reins! Tie one string to either arm of the leader, and steer him properly.
- Hold the rear end of the string over a compass.

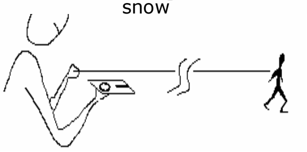

- Leave a trail of visible markers lined up exactly. You need to look back frequently and drop a new marker. — stones, sticks, stumps, tree trunks
  Leapfrog with only three marker sticks — take them with you.
  Leapfrog people!—leave someone behind; send someone ahead; line them up with each other & with a compass if available.
- Scratch a line into the dirt. Look back frequently. Readjust yourself
- Use the radio for radio direction finding.
- Orient by Sunset glow, the wind on your cheeks, the blue band, town lights, distant noise, etc.

To keep to a fixed "track", manoeuvre around obstacles in a rectangular fashion, or reverse any diversion.

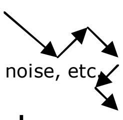

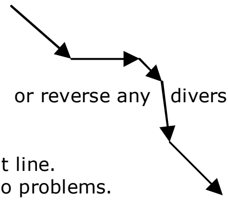

▪ Leap-frog a Straight Line by Looking Ahead

A. A straight line course is easily achieved visually — like keeping a hundred fence posts in a dead straight line.
In clear open country, you simply walk toward a new mark halfway between you and your destination — no problems.
Keep the 2 lined up. When you get halfway choose another halfway point in line. If you can keep sight of the more distant destination, this method means you only use the magnetic compass once, to locate the distant destination—then keep a fixed 'track' visually.
When obstacles force you sideways off track, you can easily regain track, visually.
B. In more difficult circumstances, you cannot see far ahead and usually rely on looking back, as above.
But leaving markers behind you slows you down and keeps you looking around.
This method does not require you to look back, but requires a simple discipline — leapfrogging visible marks exactly ahead of you.
Step one: Choose two distinct marks exactly in line with your desired direction
Step two: **On reaching the first mark, choose a third, still in line. And so on.**
You can do this while following a formed track. The track will bend from the average straight line, but you'll notice that immediately.
I.e. when you don't get to the third mark, and have to start again, you are well aware of the change in trend.

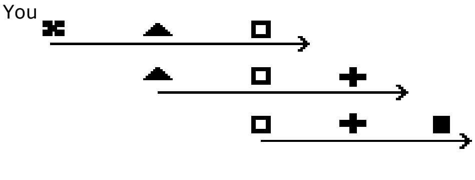

The end result accumulates errors
(despite the averaging process).

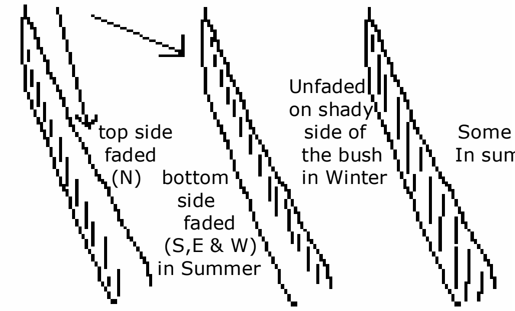

Noon-Sunlight is More Vertical

Examine needle bush (e.g. Hakea) needles, one by one.

Some effects will be more noticeable in winter, and in higher latitudes.
In summer, the 'shady' side is actually bathed in horizontal sunlight twice a day!

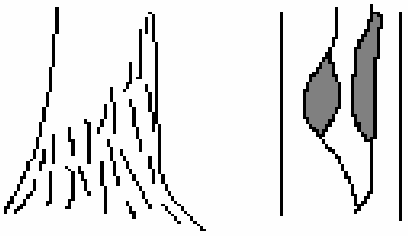

The Shedding of Bark on the Sun-Baked Side

The patchwork of coloured fresh new bark shows that
the bark strips an extra layer deep on the sunny side.
Look also at the coloration of the freshly exposed bark, for asymmetry.
The bark 'stocking' clings higher on the shady side.
It is older, deeper, darker and allows more and older lichens.
Look for the 'curl' of bark ribbons — the pipe-like shapes peeling off —
as there may be more curling shown up on the dry side,
but it depends on the species.

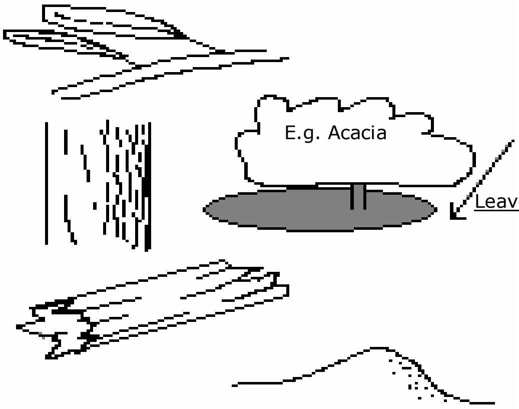

Where to Look for Fading or Lack of it

****Turn leaf blades around** to compare the greenness in each direction.
Find a pair facing the same direction, and twist one of them, then
make a comparison to see which side is more faded.
****Twist an *untwisted vertical reed stem***, to detect the more faded side.
Look at stumps and old posts, tree trunks and fallen sticks.
E.g. Sunlight bleaches the sunny side of bark and dries out any secretions
E.g. The dark side of the trunk will often be darkly stained
e.g. with cider-gum secretions.
Leaves dropped into the shady zone will not fade and dry out so quickly.
The shady zone is offset toward the pole,
because the sunlight penetrates deeper on the noon side.

The broken faces of lying timber may be more coloured
and less bleached in the shade.

Bumps and slopes, diggings and burrows, may show dead dark moss on the
hot side, or grass which has dried up.

Look for a very subtle pink glow on the shady side of dead timber, which is absent or greyer and paler on the exposed side.
Once your brain sees a hint of it, it becomes easier to see—so persevere.

Bracken fronds die off from their tips, but the fronds that retain their greenness the longest are on the lowest, shady side.
Dead thistle stems fade on the Sunny side.

The topsides of grass blades fade more due to being blown over flat by strong **wind**s, and so are exposed to sunlight, wind & drying.
Upwind edges of green bushes often show a brown wind-scorch.

Fresh diggings (echidna, bandicoot, wombat) expose soil to bleaching. Look at the steepest sides for the least faded soil.
Some fading is due to **oxidization** (exposure to air), some to **dessication** (loss of humidity), some to sun-**bleaching** (exposure to ultra-violet). Again it will pay to study the various effects before you need to rely on them.
Also be aware that diffuse lichens will give a covering colour to dirt, wood, rocks, etc, which may complicate the appearances.

Button-grass flower-stalks fade but darken on their exposed side, perhaps due to fungus. One side is dark grey; the other pale yellow.

Make a Clinometer — a Slope Measurer

One person holds the loop knots apart under slight tension. He barely touches both plumb-bobs onto the ground, to settle them.
Their identical lengths ensure a parallelogram.
The second person alters the middle string until it just touches the plumb-line.
The identical lengths ensure an isosceles triangle.
The 5 cm marks represent whole degrees of slope. Use 6 m of non stretchy cord. Measure and constru

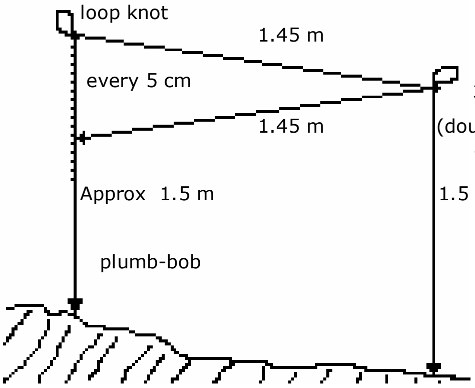

E.g. the slope is 11°½ here…

Accurate from 0° up to 20° or so
The method is based on the isosceles triangle rule
(double the half-angle sine; nearly linear for small angles)
and on 1 in 56. You can use 1.40 to 1.50,
but the lengths must be exactly equal.

The one-man version has two foot-loops.
Spread you feet and hold up the plumb bob.
See which side the plumb leans to.

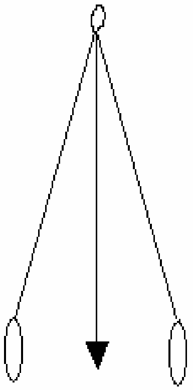

Use it occasionally, to refresh your judgment of slight slopes.
It may also be used to gauge the height of landmarks or stars. (Hang the second loop knot from a sky hook; Sight along the top string; Steady the bobs). Used horizontally, it yields horizontal angles. (Complete the string parallelogram; Sight along the two 'top' strings; and double the reading)
Of course this is only for a hobby, for interest's sake, for mathematical curiosity, not for absolute accuracy!
The more you play, the more you learn.

Just Draw It

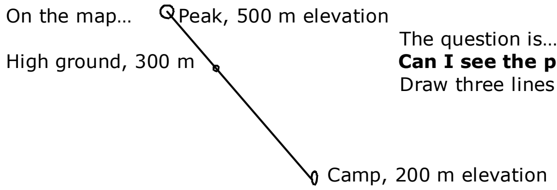

The question is…
Can I see the peak from camp?
Draw three lines of 5, 3, 2 units…

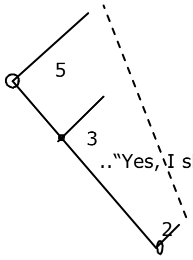

..“Yes, I should see over the ridge to the peak”

Radio Direction Finding — As Good As a Compass

AM stations — Amplitude Modulated — the older style, for medium distance transmissions
— also called Medium Wave; Medium Frequency — MW; MF

Your portable radio has an **internal aerial** for AM stations, which is direction sensitive.
It usually lies lengthwise inside the radio, as a long **ferrite rod** wrapped in a wire coil.
To make that ferrite rod horizontal, you probably need to lay the radio down flat.
Now twist the radio to change its horizontal direction.

When the internal ferrite rod points at the medium wave transmitter,
the reception drops off — you have detected a "null".

This occurs at two opposite orientations — **pointing away from the transmitter as well**.
(Good reception is by pointing the radio 90° away from that null direction.)

FM stations — Frequency Modulated — the newer style, of shorter distance transmission
— Very high, Ultrahigh frequencies — VHF; UHF — It does not use a ferrite rod.
With a whip aerial, or an extensible aerial, or a long wire aerial,
you can detect a null by pointing the aerial at the transmitter.
This is for horizontally polarised transmissions. Some stations are polarised vertically.

Shortwave stations — Amplitude Modulated — higher frequencies, for longer distance transmission
— SW; High-Frequency, HF — It usually requires an external aerial.

Use a **long wire aerial**; keep the ferrite rod perpendicular to the long aerial.
The null occurs when the long aerial does not point to the transmitter — but it is perpendicular to that direction. (Opposite to FM)
Point the long-wire aerial perpendicular to the transmitter, for a 'null'.

Weak AM stations can also be used, provided you have a long wire aerial to pull them in. The exact length sometimes matters—you will notice the volume rise and fall in cycles as you wind the aerial back in.

THE RADIO "NULL" ACTS AS A COMPASS NEEDLE — it keeps a constant angle to the distant transmitter tower or repeater.
You swing the radio aerial each side of the null to keep checking its direction.
To avoid having to give the radio constant attention, break your course into separate lines of sight ('legs') as with a compass.
Marine navigators know that radio signal direction can be distorted by mountains, or by the signal crossing the coast at an angle, or by reflections off the rigging, but bushwalkers seldom have to worry about that, because they only want a constant reference direction, not an exact bearing.

You could consider setting up a radio beacon so that you can always say: e.g. "The car is that way" or "Home-base is yonder"
End of Section 3.

Distance Guesstimation is a Major Problem for Walkers

Because distance measurement is a major problem, we find it easier to ignore.
We resort to some other method of navigation.
If we simply, out of laziness, give up on logging our pace & distance-already-come, we waste a sensible cross-check.

The first of these three sub-sections will look at the amount of distance you have covered — progress — distance made good…

- Elapsed distance — puts you on the map precisely — unless you are not very sure of your progress! or the map scale!
- Map scale — "It looked so easy on the map!" — Judging time, distance & difficulty is a question of reading the map-scale properly. "How far could we get by lunchtime?". Guessing at a curved distance is always a bit of a bluff. If you hear yourself saying "On the map that's **about** 5 km" stop and measure from the map-scale more accurately!
- Sideways drift — is a matter of trigonometry, when you discover an error in your direction heading
- Up/down progress — is in another dimension. You don't need an altimeter, but it helps. (If you do take a portable altimeter/barometer, make sure to test it to see whether or not it reacts falsely to temperature change—put it in the fridge then in a warm place; then don't forget to keep adjusting it according to the atmospheric pressure changes)

The second sub-section is about the rate of covering distance — pace — and distance-yet-to-go.

The third sub-section is about the distance you can see, but don't cover — estimating the 'range'. How Far to That Landmark?
E.g. You can identify a peak on the map — but only if you are certain enough of the distance from you to it.

Distance = Speed x Time

E.g. 4 km per hour x 3 hours = 12 km
Hint: Measure only elapsed, 'walking' time; Delegate someone to keep track of accumulated time out for stops and diversions.
Hint: Mentally bring forward your starting time e.g. "(as if) we started at 10a.m." (You started at 9, but had two, ½ hour stops)
E.g. foam takes ½ a second to pass your 10 m yacht; speed equals 10/.5 = 20/1= 20 m per second.
E.g. I seem to have drifted 12 km in one day = ½ kph current. E.g. The cloud shadows cover 5km in 2minutes = 150kph wind.

Keep a Log!

That's how mariners keep track—they write it down in the special book. Do you carry a notebook?

Adding Two Speeds

Convert speed to a length (e.g. 4 kph = 4 cm) and direction to an arrow.
Add the two arrows, tail to tip, in either order.
Complete the triangle or quadrangle tail-to-tip.

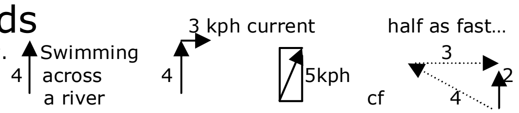

Note that it is faster to swim a river by pointing straight across and letting yourself be swept downstream, than by trying to stem the flow by pointing upstream. Only when the two speeds are perpendicular do they not affect each other e.g. the 4 km per hour is not affected by the current in the first example. Or e.g., If your boat speed is 4kph ahead, and the tidal flow is 5kph against you, your actual movement is backwards! (with any sideways component added in independently).

Example: Three air-speeds ↗ + wind ↘ = actual progress → very fast across the ground, slightly to your right.

I.e. Your speed & direction through the medium (air/water), relative to the ground + the medium's movement, over the ground (the medium carries you when it moves) = your total speed and direction, over the ground.
Lastly, *to analyse apparent wind speed, to avoid confusion, draw only the three winds involved*. I move this way...
First convert your progress over the ground (top arrow) to an opposing apparent wind (right-hand arrow opposing it).
Don't try to add wind to your motion—that's not a sensible question/answer. The medium (air) doesn't carry you when it moves. Answer: I feel the actual ground-wind, a cross-wind (→) in my face, diagonally as shown…

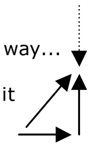

Range: Rule One: Guess

Then don't trust any calculation which doesn't agree with your initial guesstimation.
But remember that distance is deceptive over featureless terrain e.g. water/beach — we underestimate it.
Birds bob their heads to see how much an object shifts against foreground and background. It's worth some practice.

"Range" of Visibility — Two Halves to the Picture

"Extreme visual range" must be calculated in two bites — So Don't Forget To Add!
— e.g. when asking "Should we be able to see Ben Nevis from Brady's Peak?"
— e.g. at sea when you can first see the lighthouse lens, not just its loom.
From a kilometre high you can see 1° of latitude
before the curvature of the earth cuts your line of sight.
— e.g. you can see a 1 km high mountain from two degrees away
if you are on a 1 km high mountain — see diagram…

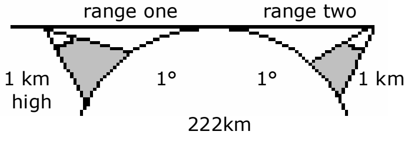

"Range Squared is Dee Height"

This is an easy mnemonic. "Dee" is dee Earth's Diameter i.e. Extreme Range = √(D x H) see p.92c
H is your height above the intervening horizon e.g. the wave tips, or a 250m plateau.
Since the Earth is 40,000 km around, divide by Pi to get **12,700 km diameter**.

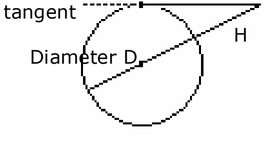

The formula is a theorem in geometry,
about the geometric mean (the tangent) of an extended diameter and the extension length (H).
The formula states: the square (range x range) = the rectangle (not shown: H x D+H).
(i.e. the range substitutes for both parts of the product, 'geometric-' or area-wise)
but since the height H, in reality, is very small, therefore **range^2 = D x H**

To “Read” a Map — Rule One: Don’t Lose Your Place!

Get the geometry fixed in your vision — of where you are on the map e.g. “in the top right grid square, next to that lake”.
And then don’t keep losing your place every time you look at the map again!
..Whether the map is now upside-down, side-on, or whatever.

Rule Two: Imagine Arrows, for the Sun, & Your Movement

Again, visualise them geometrically, in relation to the whole map shape, from one corner of the map, for the Sun, and from where you are on the map, for your movement. When your map is properly oriented, the movement arrow will point in front of you, ahead, matching the trend of your movement onwards.

Rule Three: Get Used To Any New Map Scale

Maps are “Fractal” They show “self-similarity across scale”
i.e. A river system will look the same on a small-scale or large-scale map — there is always finer detail to show.
A road network is the same — the smaller the scale, the more roads are left out, leaving a similar looking network.
A coastline shows such self-similarity. Magnify the details and it still looks like ‘a coastline’.
New Map-Scales are Hard to Adjust to
It takes time and testing to get used to a map scale, because they all look alike no matter what the scale.
To get used to the new ‘feel’ of a map, check up regularly on your map-progress, until you are no longer surprised by how far you have or haven’t come.

Rule Four: Don’t Give Up!

Don’t let the combination of difficulties bluff you!
E.g. You misjudge the scale, misjudge the Sun’s direction by optical illusion, you see turns & bumps not marked on the map, doubt the accuracy of the map, fail to assess the slope accurately,… and so eventually… give up in confusion!
Problems are normal, and **solving them by the map is normal too — don’t give up trying**.

—Also See “Map Checklist” p.113—

“L.M.N.Or P.”

L for Landscape; M for Map; N for Compass Needle: Or for Either/Or (the big point of the mnemonic)**; P for protractor**
Either/Or means: Each component of map&compass work can be used alone and independently for some tasks, if desired.
Plotting compass bearings can seem complicated. This mnemonic is designed to smooth the way.
A navigational compass has a protractor independent of its needle. The trick is to remember that!
The protractor has 2 parts too (p.93b). Note that some compasses have the magnet one-piece—glued onto—the protractor card.
If you get used to using each component separately, you will find ‘map and compass work’ to be simpler.
The trick is to isolate each of “LMN Or**P” in turn, to avoid confusion.** That includes the 2 moving parts of the protractor.
It is hard to use more than two at a time! so know which two you need to use at each stage.
E.g. A ‘prismatic’ compass will let you see both **L**and & numbers (**P**) at the same time—to take an accurate bearing e.g. at sea.
E.g. You can align the **M**ap to the **L**andscape, without ever using a number. Or you can point the **N**eedle to the horizon likewise.
E.g. The **P**rotractor may be used to assess slopes, to measure the Sun’s height, to take a map bearing, to draw an angle on the map, to take a horizontal angle between two landmarks, to sight a vertical angle like a sextant (this may need two people), to find North from Sun-time, or to set a course to the left of the Sun.
So don’t forget to use the **P**rotractor to its full potential, quite independently of that funny little piece of metal rattling around inside it. (**N**).
E.g. An emergency ‘compass’ is just a floating sewing **N**eedle, or a suspended magnet. So the protractor has little to do with orienting the map by the magnetic field, or with heading North by the compass needle.

If your navigational compass has a magnifying glass, a set-square and a graduated ruler, you should hardly get confused by thinking they had something to do with the magnetic field! — so don’t worry when you see some numbers marked around your compass needle — I think you learnt how to use a protractor in elementary school, didn’t you?

Working from land to compass is called “Taking a Bearing” (L+P1,N+P2) You use the protractor to put a number on the direction
..from map to compass is called “Getting a Heading”. (M+P). You then use the needle (P+N) to find then follow that heading (L).
Working from compass to map is called “Plotting a Fix”. (P+M). I.e. You use the protractor, ruler and set square to draw angles.

Maps Mean: Imagine Me! — Making Mental Maps

The meaning of using a map is that **it lines up**
— with what you see; with what you saw; with your mental maps; with what you know; with what you can’t see & don’t know.
E.g. You glimpsed the coastline as you drove in, the lie of the valleys, the drainage of the creeks, and of course you know the highway that you drove in on! You can no longer see them, but it is normal to orient yourself by imagining the invisible.
And then, your mental map is still incomplete, so that you need to use the map to add to your imagination…

“Map To Mind” Navigation

Transfer from the map both visible and invisible features back into your mental model and mental layout.
1. Start with the Invisible Big Pictures — visible on the map but not to you.
Look at the sky and the skyline as you interpret the map for what lies out of sight.
2. Add in the local visible features — visible both on the map and to you.
These two steps work together like lock and key — each is not very useful without the other.
Yet both steps are often neglected and seldom put together as a whole.
“The cars are now behind that notch in the skyline”
“The highway runs behind that hill then turns South-East”
“That low spot marks the river we want”
“Our camp tonight is in line between Mount Socks and the pine plantation yonder”
When you become temporarily bushed in, or blinkered by the rain, or shut in by the dark — then you see whether you can maintain proper orientation — by the invisible — or whether you just feel lost — “I can’t see where I am!”.
If you do not make a mental map and orient yourself by imagining the invisible—you will be disoriented,
even if you “can see where you are”.
♦ Part of the job is to look at the map in order to join your several local mental maps into one regional map.
Remember that a map is a great memory aid, or a great memory bypass — take your choice.
♦ Rather than “put yourself on the map”, put the map in you!

Use the Map Scale — Don't Just Look at It!

Many errors of judgment result from guessing at the map distance, even when the map scale is clearly marked.
The scale is not much good down in the bottom corner of the map, fixed in place! So copy the map scale onto cardboard.
Somehow attach it to the map e.g. into a separate paper-pocket; onto a string; in the map bag.
The string is useful for measuring distance accurately. You place it over a curved path then stretch it out straight to measure it.
Point the corner of the cardboard at the starting position; position the string from there; then stretch the result along the scale.

The Jargon

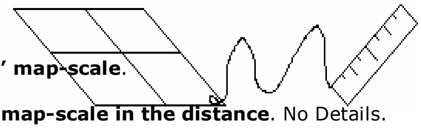

"Large-Scale" is like a "Full-Scale Model" It shows all the details.
Like a 'large-scale simulation' — it leaves out nothing. **Picture a magnified 'Large' map-scale**.
"Small-Scale" is like a "Small-Scale Model". You can't see the small details.
It is like a 'small pilot study' — not full scale. **Imagine a very hard to read small map-scale in the distance**. No Details.
"Full-Scale" is "1 to 1" like the Cosmos. "Half-Scale" is "1 to 2". *"Small-Scale" is* "1 to a million" *like Cosmological diagrams.*
The bigger the second number, the smaller the fraction. The bigger the big number, the bigger the span on the map.

Map-Scaling-Factors are Meant to be Interpreted

1:100,000 means "One unit represents 100,000 units"
Split this into two parts: (a) 100 & (b) 1000 and **use centimetres i.e. 1/100 m** — 1 cm: 100,000 cm
Say (a) 1 cm represents 100 cm i.e. 1 m — **drop off two zeros and call centimetres 'metres'**
And (b) 1 m, from part a, represents 1000 m i.e. 1 km — **drop off another three zeros and call metres 'kilometres'**
So the answer is: "1 cm to 1 km"
1: 1,000,000 1 mm = 1 km I.e. **You can also drop off three (or 6) zeros and call millimetres 'metres' (or km)**
50,000 units makes you calculate '1/50th of a metre' (=2cm), so 1:50,000 must be '2cm to 1km'. Or multiply to 2:100,000.
1: 250,000 Turn this into 4:1,000,000 by multiplying both sides by four. 4mm to a km (since 1mm is 1/1000m)
or (a) ÷100: cm to m (i.e. 4cm to 10,000m no longer cm to cm) (b) ÷10: cm to lots of 10m (c) ÷1000: cm to 10km
the grid should be marked in **10 km squares, of 4 cm each**
Your compass will be marked in centimetres, but perhaps also in special scales e.g. 1 inch to a mile (1: 63,360)

Pace Your Progress — Pre-Dict It, Don't Post-Dict It!

To avoid looking at the map continually, to locate yourself continually, predict the estimated time of arrival **once**, and relax.
We are normally lazy about looking at our watch often, poor at calculating, on the hop, distance covered, and lazy about locating ourselves on the map often. Mental arithmetic is clearly noxious, so we try to avoid it. Working abstractly from time to distance to map, after the event is too hard for us. But we usually only resort to the watch after we begin to doubt our position. (See "the 11:59 syndrome" — we do doubt.)
Something needs to be done about this!

Consequently, the antidote to us refusing to log our distance, is to anticipate the timing instead
i.e. to work more concretely, from map (I can see that) to distance (I can visualise that) to time (I can calculate that).

- Examine the map beforehand — as a first step not a last step. You will have to do the calculation later anyway, on the trot! Why not do it now, calmly.
- Guesstimate the time needed to cover the distance ahead — to the next recognisable milestone. E.g. use 4kph, ¼hr/km
- Look at your watch, as the last step, when you near your goal.

In this way the **landscape 'means' time** to you; "When we reach the bridge, we turn left — and that should be in 25 minutes"
Your guesswork will get better too.
You will find yourself looking at your watch more frequently, with the question: "Should I be there yet?".

Anticipation Is Exciting. Back-Calculation is as exciting as the washing-up.

"Range Squared is: Dee Height" "Dee" is Diameter

i.e. Extreme Range of Visibility = √(D x H) on this side of the horizon. **Don't forget to add the 'beyond the horizon' range**.
Five round-number rules are highlighted. By playing around with some approximations, we can find some rules of thumb…
127 is close to 128 and 125 and 11.3^2; Pi (3.14) is close to √10 (3.16);… I hope these tricks will make the square roots easier

40,000/pi x 40/pi km = **400** km range from 12.7 km Notice the two related doubling sequences I have given.
40,000/pi x pi km high = **200** km range from 3.14km You can only see twice as far from four times the height
12,500 km x 4/5 km = **100** km range from 800 m high 125 is five cubed
113^2 x 9^2 / 10^2 = **100** km range from 810m 34 km from 90 m; 11.2 km from 10 m — 1/3 from 1/9 height
12,500 km x 1/5 km = **50** km range from 200 m high "Rule of (lesser) fives: **50 km from 1/5 km**";
12,500 km x 1/20 km = **25** km range from 50 m high Multiply or divide H by four to double or halve the range
12½km range from 12½m e.g. from the top of a beach

12,700kmx.0127km=**12.7km from 12.7m—**from a ship's deck, to the horizon, when estimating distances across open water.
12,700 km x 1.27 km = **127** km range from 1.27 km high 1/10 from 1/100. Remember the number 127 must be 400/Pi;
100,000/8 x 10/8 km = **125** km range from 1.25 km 0.125 is 1/8

12,800 km x 1/2 km = **80** km range from 500 m high or "Rule of (greater) fives: **50 miles from 500m**"
12,800 km x $1/2^3$ km = **40** km range from 125 m high You can also derive 160 km from 2 km; 800 km from 50 km
40,000/√10 x 0.4/√10 = **40** km range from 127 m high = "400km from 12.7 km" = 1/10 range from 1/100 the height.
12,800 km x $1/2^5$ km = **20** km range from 31 m high = 200 from 3.14 above.
12,800 km x $1/2^7$ = **10** km range from 7.8 m high ..if you bother to halve 1000m seven times!
12,800 km x 1/500 = **5 km range from 2m high** **From a dinghy/beach**. 1/5 range from 1/25 height cf 50m high.

21,600 nautical ml/pi = **150** nautical miles from Pi n.ml high approximately, because 150 squared is 22500.
83^2 n.ml x 1 n.ml. = 83 n.ml. **150km from 1 n.ml**. 60 x 360 / Pi is approximately 83 squared nautical miles
12,300 km x 1 km = **111 km** range from 1 km height **1° of latitude, from 1 km high**, approx. "**55** from 1/4" = 250m
111^2 km x 1/9 km **37 km** range from 111 m high 1/3 of the range from 1/9 of the height

Look Carefully at the Fine Detail on the Map

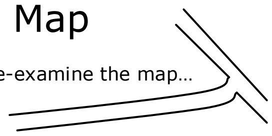

E.g. a kink in the track, just before a junction, may make it look "not like the map!" until… you re-examine the map…
"Oh yes, it is marked like that after all, **I just didn't look closely enough**"
E.g. that maze of fine blue watercourses marked — don't be a-maze-d by it — look at its detail!
There is usually a magnifying glass on the compass.
For a stronger **magnifying glass**, reverse your binoculars. For an even stronger magnifier, remove the eyepiece and use it.

Look Carefully at the Fine Print

E.g. date of compilation ..1864?
E.g. "adjust all longitudes by + 2 minutes of arc"
E.g. yearly magnetic drift
E.g. Contour interval — 10 m or 100 m?

Some Map Details are Not to Scale!

E.g. Two wheel ruts might look like a 100 m wide road on a map (if you took it seriously).
Consequently… 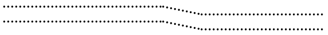 ..may be a 100 m Zig-zag! And… 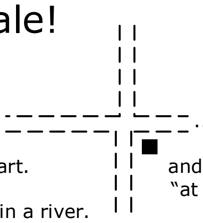 ..is not a cross-road and the hut is not "at the junction"
E.g. A "cascade" symbol… ..might equally mean two huge waterfalls, 300 m apart.
E.g. 'Smooth' bends ..probably hide many small extra sinuous ones. E.g. in a river.
Moral: Keep an Open Mind. **Keep your eyes open** for alternative interpretations.

Using the Protractor by Itself

The protractor has two sets of lines — the lines on the movable 0-360 protractor-circle, and the fixed "follow me" arrow, taken together with the edges. Line up one set with horizontal, or North, or whatever; line the other up with the slope or angle to be measured. The angle in degrees clockwise is the space between the zero and the "follow me" arrow, not the other way around.

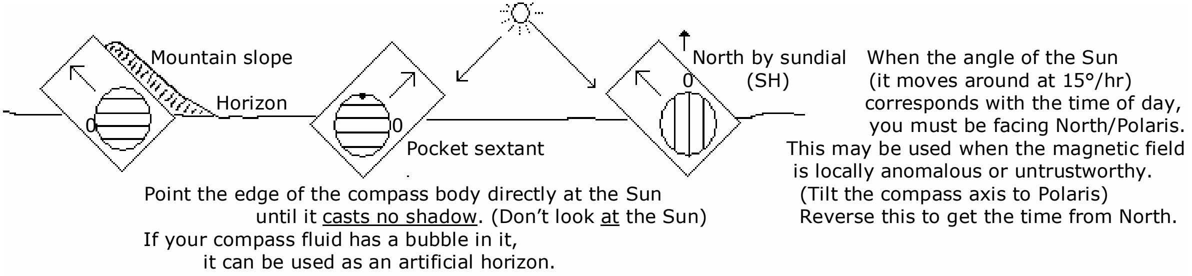

Point the edge of the compass body directly at the Sun until it casts no shadow. (Don't look at the Sun)
If your compass fluid has a bubble in it, it can be used as an artificial horizon.

When the angle of the Sun (it moves around at 15°/hr) corresponds with the time of day, you must be facing North/Polaris.
This may be used when the magnetic field is locally anomalous or untrustworthy.
(Tilt the compass axis to Polaris)
Reverse this to get the time from North.

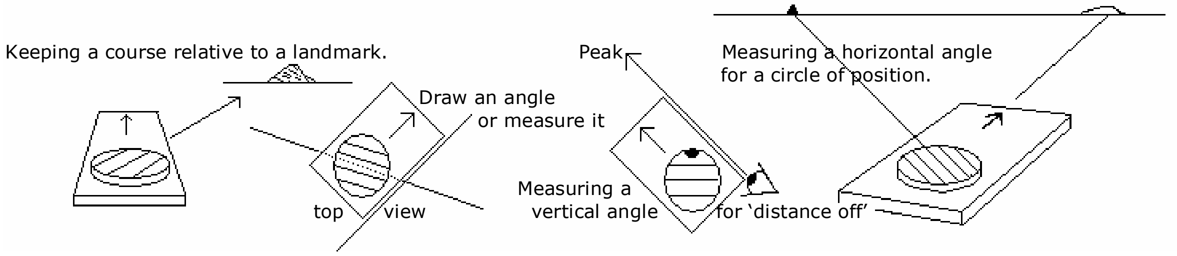
Keeping a course relative to a landmark.
Peak
Measuring a horizontal angle for a circle of position.
Draw an angle or measure it
top
view
Measuring a vertical angle
for 'distance off'

Mental Networks

Our mental maps seem to run on networking — junctions and joins; choices and destinations; routes and 'directions'
Consequently mental maps are prone to logical-type blunders

- Missed junctions e.g. of creeks or paths
- Misidentifications e.g. of segments, features or forks
- Poorly judged measurements of lengths or direction e.g. hairpin bends which aren't noticed
- Mistakes of number

If you reread the section "Logical Blunders" (p.39b) you will notice that most can be seen as a **wrongly imagined network**.
That's one more reason to study the real map, in order to bring your mental map up to speed.
When we function on short term memory of mental branching directions, any shock or daze can be crucially disorienting.

The Most Valued Map

..Is one which you have made yourself. A do-it-yourself job makes it "yours". Practise with a MUDMAP, p46e.

When you copy important detail from other maps onto your map e.g. peak elevations; track notes; waterholes, then your map becomes more valuable than a replacement map.
You add extra details e.g. campsites; walking times; side-tracks & old tracks and suddenly you prefer the old dog-eared version to a brand-new map!
Sometimes it is even better to start with a blank sheet of paper.
But since it does you no good to pinpoint your position on a blank map, unless you are at sea, you proceed to add in the important local details so that you can tell where you are…

To copy a map: **Copy the Grid First**. ..if there is one. Add in many diagonals as guidelines.
The next rule is: **Get the Landmarks in their correct relative position first** **i.e. work top-down.**

The Psychological 'Half-Way Point'

You have to judge and juggle several factors before you decide that you are 'half-way'.

E.g. The "Unknown Territory" Scare-Factor (Ambition versus Safety Margin). In planning your time-budget, you can't relax in a one-way journey through unknown territory, until you know you have a reasonable safety margin in hand

So 2/3 the distance along, might be 'half-way through the test'. Other examples...

The "Point of No Return" — You tend to speed up, once committed to the next goal.

The "Downhill Run" — It is the quicker half.

The "Back-Track Return" — tends to be quicker i.e. the turnaround point can be after lunch.

The Morning Spurt-Afternoon Hurt Syndrome — puts 'halfway' before lunch.

The Side-Track Scheduling — if you don't explore side tracks on the way in, when you are fresh, you may not want to tackle them on the return journey.

The "My Feedbag is That Way" Home-run spurt on the last day.

When You Meet Other Walkers

"When did you leave this morning?" = how far to your next camp.

"Anything about the track that we should know?" E.g. slow sections

"Any deep water crossings" or other hold-ups

Other questions, less related to walking progress and pace, are…

Anyone else ahead of us? (Will there be room for us all?)

Do you carry a track guidebook? (Can I read it?) Do you know the forecast?

Any good water available on the way? Can you recommend a camp site?

Did you pass our tents? (Are they still there!)

Pluck up your courage to ask what you want to know, and be prepared to share what you know.

Advice about Walking Times — Double & Halve!

E.g. Brochures seem to add "return" or "one way" by guesswork sometimes.

So "6 hrs" means 3 to 12 hours until proven otherwise.

E.g. Fit young rangers saying "six hours" may mean "for me; double it for you" or "for you; halve it for me"

E.g. "walking time" may mean "excluding stops, rests and meals" — you could find yourself pushed for time.

E.g. "Not far, you can't miss it, it's easy all the way" could prove disastrous. E.g. ('provided you find the right track')

20 Minutes per Kilometre — Double & Halve — Easygoing Maths

It means **3 km per hour** —an easy-going overall walking pace when you include short rests, difficult vegetation (within reason) and lack of any hurry — tourists on track, walkers off track.

Obviously you need to multiply and divide by 20 to convert kilometres to minutes, or minutes to kilometres.

If the number is small — kilometres — multiply it up to the larger number — minutes — **double** it and add a zero.

If the number is big — minutes — divide it down to the smaller number — kilometres — **halve** it and subtract a zero.

You could also express it as a "half a kilometre every 10 minutes" but the "20" makes the maths easy;

And even simpler, to cope with the zero, express yourself in 'lots of 10 minutes'.

E.g. 5½ kilometres will take about… (double it, to get many minutes)… 11 **lots of 10 minutes**

E.g. "We've been going 50 minutes — (five lots of 10 minutes) — ; that's about… (halve it, to get a few km)… 2½ kilometres"

4 km per hour — Normal Walking Pace — Double and Halve!

You can easily double or halve your pace. Start with 4kph as a sustainable rate of progress, and use the doublings 1,2,4,8…

8 km per hour is someone tall walking in a hurry. 2 km per hour is someone small dawdling. 1kph is for very difficult going.

Coincidentally 4 km per hour is 10 miles in four hours or 2½ miles per hour.

Incidentally also, at 4 kph, a landmark 15 km on your left will change direction at 15° per hour as you walk past it.

Double, the Acute Angle, off Your Nose — For the Distance Off

This double-angle method puts numbers on a very "natural" method of gauging distance…

In the first diagrams you walk from the bottom left to the top, and watch a landmark, ahead on the right, pass you by.

The distance walked = the distance off if you walk far enough to double the original angle (away from straight ahead).

The initial angle must be acute. You need to maintain a straight course throughout.

The simplest case uses the diagonal of a square. 45° changes into 90°

The next simplest example is the equilateral triangle. 60° changes to 120°

Followed by the 30° isosceles triangle. 30° changes to 60°

But the general case is made clear by the geometry of two equal radii in a circle.

It is because the angle at the centre of a circle is double the angle at the circumference.

The angle at the centre is the final angle—double the initial one. top view…

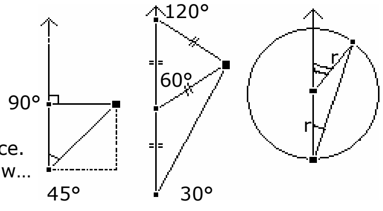

Ahead of you, the angle is always less than 90°.

In the second diagrams, below, the landmark may not be ahead of you and the initial angle may not be acute...

If you walk backwards, from top to bottom, using the top method in reverse, you get...

Halve, Any Angle, from your Stern—For Distance Off,

..i.e. In Retrospect The initial distance off, not the final distance off is what must be travelled.

The initial angle is now the double angle, and need not be acute.

I.e. turn the bow-angle diagrams upside-down…

E.g. 90° becomes 45°; or 120° becomes 60° becomes 30°…

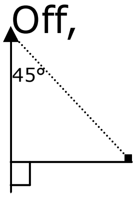

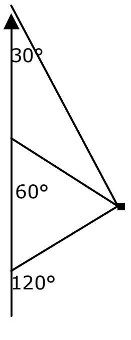

Permanent Landscape is More Trustworthy Than Surface Detail!

When what you see "doesn't match what is on the map" have the sense to distinguish between 100 m deep contours which would take an atom bomb to shift, and walking-track junctions which a fire could reshape.
Professional map-makers and satellite photos rarely make mistakes — in landscape positioning.
But when they add the local details, it is another story.
Time changes such details also. New roads, cleared bushland, second bridges — these will mislead and confuse you.
When your mind says: "The map is wrong!" remember that what the map says — about landscape — is not wrong.

Details Added on to a Map Are Prone to Error

Notorious for errors are: Map North; Map Scale; Roads.
So beware of anything other than a good-quality official government map.

Expect The Map To Be Unhelpful

Many important details will not be shown on the map — you just have to expect that.
You can often trust what is on the map; You can often trust that what you want, won't be on the map.

Maps Do Give You 10 Times More Detail Than You Can Notice

After you get lost and finally sort it all out on the map, you notice… "Oh yes, silly me, those contours are **up**slope not downslope! And they **do** show a creek-line, by those sharp bends! Oh, of course, there is **a peak** on the right, and that fenceline opposite — I missed both of those when I first studied the map. You **can** see Mount Bruce, lined up with the lake, from there, but not at all from over there. And that squiggle in the blue line, is the hair-pin bend that tricked me, but I should have realised that all rivers must drain to the north-west eventually…"

Try to reduce your ten-fold folly to five-fold folly for next time!

Using the Needle Alone — Emergency Magnetic Compass

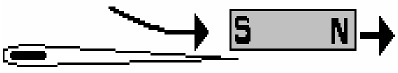

- Magnetise your repair-kit sewing needle; It will probably already be magnetised somewhat. Stroke it with a South Pole toward the sharp end, so that the North-seeking pole is at the pointy end.
- Float the needle in calm water, on the surface tension (no detergent!)
  (a) lay the needle on toilet paper
  (b) lay both on a bowl of clean water
  The paper will wet and sink, leaving the needle afloat. You could also try sticking it through a piece of foam.
- Hang any magnet horizontally, from hair or fine thread. It helps if you know which end is North-seeking.
  In the field, test it against a Natural North, eg, Bush Noon. At home, test it on a compass. Like poles repel…

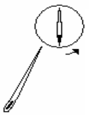

Hint Understand that **magnetic poles should be called 'North-Seeking' and 'South-Seeking'** and that **our "North Pole" is a South-seeking pole!**
(so that North-Pole seeking poles point to it — Unlike poles attract)

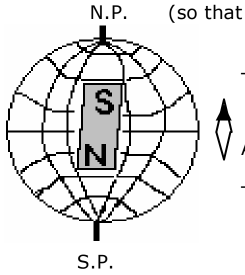

The Earth's internal magnet is as shown (It is slightly off-line with the rotation axis!)

A compass needle on the Earth's surface has a red end labeled 'N' i.e. North-Seeking

The white end is labeled 'S'

Strip Map Navigation — Follow-Your-Nose Navigation

Our mind definitely prefers a strip map — a sequence of "directions" to follow. (None-the-less, make a MUDMAP in conjunction)
Our eyes definitely prefer a strip map — "up" is "straight ahead"! (See "N.O.R.West/N.O.T.Least" "Nose Navigation" p31e)
A strip-map is simply a way of formalising your track notes—every navigator really ought to do it this way…
There are two good ways to make a strip map as you go: with a sheet of graph paper, working from bottom to top, and
in a track notebook, working from top to bottom, but…
Both assume that **progress arrows are up-page**. You could turn your notebook side-on or upside-down to write in it.
In either case you set aside several **vertical** lines for each **type** of information,
and set aside one **horizontal** line for each **subsection** of the journey,
and a second line for descriptions and for comments,
and a line for overall information e.g. trend, drainage, season; totals: time, climbing and distance.
The trick is to use symbols. One vertical line for one sort of symbol e.g. compass needle direction
(See the **Symbol appendix** p 122) Another line for another sort of symbol e.g. slope-direction, and steepness
This way you can cram a lot of information into a small space, in a consistent and regulated manner, and be able to read it!
e.g. …

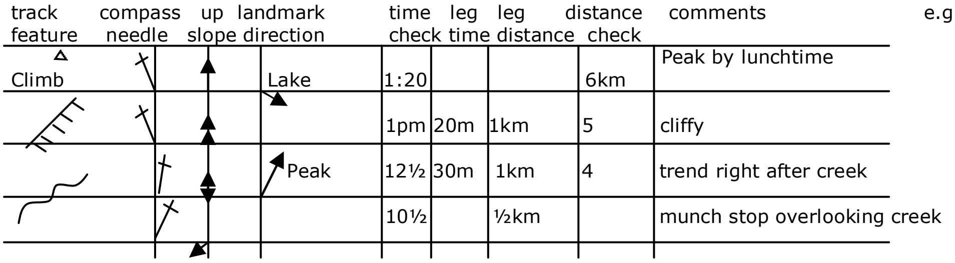

track feature	compass needle	up slope	landmark direction	time check	leg time	leg distance	distance check	comments
△ Climb		▲	Lake	1:20			6km	Peak by lunchtime
		▲	↘	1pm	20m	1km	5	cliffy
		▲▼	↗ Peak	12½	30m	1km	4	trend right after creek
				10½		½km		munch stop overlooking creek

e.g...

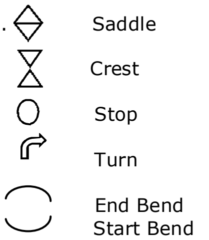

Distance

AIMING OFF by 10° — 10° is **175m per kilometre**

1° is one in 57.3, so one in 5.73 is about **10°**, (and 1 / 5.73 = .175) or **175 in 1000**. (For bigger angles use the 1 in 60 rule)
Alternatively, 2sin5° = 0.174 isosceles chord, yielding "0.174 per one" or 174 per 1000. (167m per 1000m / degree for >10°)
This is easier than working in sixes using "one in 60".

Hint: Express any ratio as "something in 1" or "in 10, 100, 1000"
E.g. '1 in 50' becomes '2 **in 100**' or '200 m in 10 km' (.4 in 20 etc)

Example: "The T-junction is somewhere ahead — about 017°, 5 km. But so that we can't miss it, we must aim off to the right e.g. 027°. We therefore expect to hit the road 875m to the right of the Junction" (5 lots of 175m).
This is how ocean navigators find an island in an ocean: Step 1: sail N/S to the right latitude. Step 2: sail E/W to the right long.
Don't just head straight toward something. If it doesn't show, you won't know which way to turn!
Remember that a 10° error is fairly easy to make when using a compass over rough terrain (or trackless shifting ocean)!

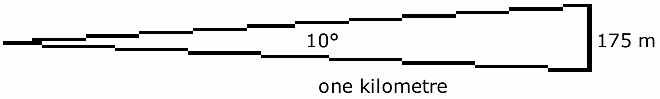

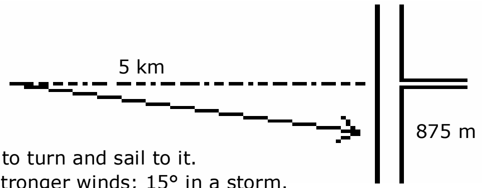

Aiming-off at Sea…

Aim-off to arrive up-current & up-wind of your destination—to make it easy to turn and sail to it.

- Aim-off 6° to counteract leeway when sailing into the wind; 10° in stronger winds; 15° in a storm.
  Measure the appropriate angle from the wake e.g. 6° is how much your pointing-finger-tip shifts when you change eyes
- Aim-off 6° (1 in 10) to counteract a 10% (1 in 10) cross-current. This refers to the perpendicular component, compared to your speed. The rule works +/−1° up to 36°—up to 60% cross-current. To avoid judging components...
- Aim-off 1°,2°,3°,4°,5°,6°, to counteract a 10% current at 10°,20°,30°,45°,60°,90° to course, either ahead or behind.
- Aim-off to avoid GPS-induced collisions caused by very accurate course-holding. You should plot a course off to one side of the obvious line on the chart, to avoid vessels coming the other way on the same line!

Aim Off 6° or 10%

Blink your eyes at the destination, and when you get there, pace off the 6° offset. Ten-tuple the result for the distance there.

---

1 Metre per Second is 3.6 kph

This is merely a logical reference point for your calculations. (And slightly faster than "20 minutes/kilometre" (3 km per hour))
60 minutes x 60 secs per min is **3600 seconds in one hour**, at 1 m per second, is 3600 m in one hour, or 3.6 km per hour.

One metre is Up to your belly button A child's double pace One strong fast stride

One second is the time it takes to pronounce "Alligator One" in a normal fast voice—don't let it drag. Follow it with "Parramatta two", "Oodnadatta three", (or "a thousand and four", but "alligator" keeps its speed more consistently when drowsy).
Get used to the rhythm of tapping your finger in time with the seconds — your mind subconsciously remembers the timing.
Take a Watch, Perhaps a Stopwatch
1 m per second is very nearly 2 knots.

"1 Hour Extra per 5 Hours"

You can normally walk at 5 km per hour, on a track, on a short walk.
But you will sustain an average 4 km per hour, when you include fatigue, and rest stops.

"1 Hour Extra per 500m easy climbing"

Gentle up-climbing is tiring—allow this extra time. (We are not concerned here with how long it takes to rock-climb!)
Down-slope walking may speed you up, or slow you down, depending on the slope.
Dense tussock country (e.g. snow grass; button grass) is the equivalent of a climb, in its up-down-up steps. Crossing the drainage can also be as tiring as climbing, in its regular climb-descend-climb-descend path.

Distance by Optical Rangefinder — Accurate up to a Kilometre or Three

We are woeful at guessing distance in that range, so there are focussing devices available which are designed for it.

Range by Parallax and a Piece of String — DIY Rangefinding

Animals shift their heads to see how much an object shifts. Blink you eyes to see the effect; walk sideways to practice it.
For more distant objects, the very slight sideways offset can be magnified then measured...
The landmark you are measuring appears in a slightly different direction from each of two different viewpoints.
Pack a long non-stretch string e.g. a polymer kite-string. Know its length. Mark it every 5 m before you go.
Use it as a giant pair of eyes—a long baseline—& to mark out a large square or rectangle on the ground, one side at a time.
Guess at the right-angles — they don't need to be accurate. Just make sure to use equal tension when you stretch the string.
But use a plumb-bob to mark the corners of the square on the ground accurately — with a pebble.
Use the plumb-line also for accurate sighting of the landmark. (You can pack up the string once you have placed the pebbles.)
Twice as big = four times as accurate (in measuring d) If you have enough room to move, aim for over 10 m sides.
Range = ab/d or a^2/d if a = b; from the similar triangles involved. Measure the shortfall, d, at the front, or the overfall, d, at the baseline.

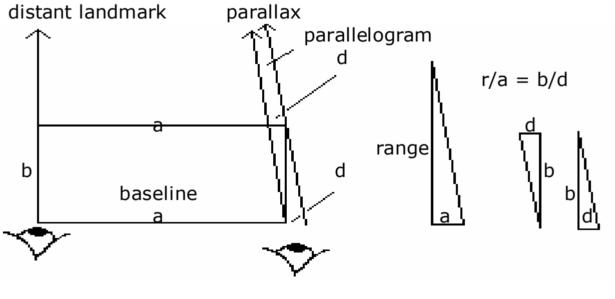

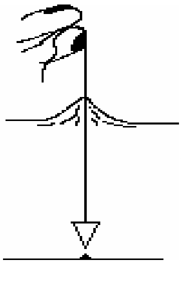

An easy way to remember the formula is to say that the area R d = the area a b because if you shear the ab rectangle, it becomes a long thin parallelogram R long, and d wide, preserving its area.

As a result, the formula becomes...
Range = Area / parallax offset, d
km sq. m mm

The Range=ab/d formula also *makes sense*
The range *should* so depend on a & b and d

"Maps Grip the Universe"

When you swing the map in your hands, around with you as you turn, the whole Universe doesn't follow it! — it doesn't twist!
Instead your map gets disoriented.
Leave the map behind, as you twist! — leave it lined up.
The map is designed to lock into the landscape, to 'map onto' it, and should be used like that, not twisted out of alignment.

You need to swing the map an *equal and opposite* amount to neutralise what you do.
It's called "swinging the map" (when you leave it locked onto true North while you swing to left and to right).

It should not be called that!

It should be called "**NOT Swinging the Map** with you"

Map work includes 'not swinging the map'. See "Magnets Grip Maps". The most common method is to match the map to a compass needle p.103b

Maps mean landmarks — those landmarks there! Open your eyes — and line the map up with the visible landscape. p101a.
i.e. orient the picture of the land — the map — to map onto the actual land.
Line the Grid North up with North e.g. by compass or by Sun.

You may have to twist yourself, or put 'North' at the bottom left, but to always put 'North' up the top, is to divorce your eyes!
Yes, you may have to read names upside down! Yes, it is a bother, to keep changing its 'up' every time you turn.
But it means that you can just lift your eyes from the map to see what it points out. And can know what lies beyond that.
If your map is not consciously oriented, how can you be oriented, to other than what you can see in front of your nose?

Think "+/- 5°" For Compass Bearings; "+/- 10°" For Following a Compass; "+/- 15°" For Using a Compass!

Compass bearings "+/– 5°"
Test yourselves: Ask each person in turn to nominate where "magnetic North" is on the skyline
using one particular compass, handheld. **My results:+/- 5°** **"User Inaccuracy"**
Now try putting that compass on the ground. **My results: +/- 3°** **"Needle Instability, friction" etc**
Try stretching a fishing line over the needle. **My results: +/- 1°** **"We still can't agree!"**
Next try that best method for different compasses. **My results: +/- 3°** **"Calibration and Zero Errors"**
Now try **not** being very careful, with an **untested** compass, at night, when you are tired!

Following a compass blind: Walk on a fixed compass bearing for 100 m or so in a fog i.e. eyes glued to the compass.
Repeat it e.g. turn around & see where you come back to. Give the next person a try at doing better.
I think it matters which eye you use and which hand you hold the compass in.
We don't necessarily walk 'straight ahead' when we try. We don't necessarily point the 'follow me' arrow straight ahead.
We don't do very well at integrating and averaging out any diversions around obstacles.
Slopes play havoc with your sense of a 'straight' line ahead.

Try this…

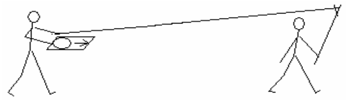

The front person finds the route.
The back person guides the route-finder.
The navigator logs the route directions taken.

Using a compass: You may plot a single line on the map, or as +/- 5°, but mentally allow an extra +/- 10°, i.e. think +/- 15° (for accumulated errors, possible blunders about magnetic variation, etc.). Keep the possibility of error in the back of your mind

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Caving Strip-Maps — Come in Books

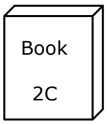

A "cave-directory" booklet records **each separate section of a cave on a separate page**.
E.g. Make your own…

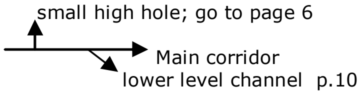

You may need separate booklets for different levels of the cave system.

Use the same symbols as before, for needle, slope, turns, etc.

Use Abbreviations: E1, E2, E3… for Exits; L1, L2, L3… for Light sources; Parentheses (L1) = "Can see L3 from here"

Make up names for each section e.g. "Chamber of Horrors"

Add copious notes e.g. "water level up to ½m deep"

Forethought and cooperation is required to quickly and effectively map a warren or a labyrinth.
Initially you make a muddy map, as you go, but then you add a neat copy into the book later.
(But keep your muddy copies, for next time.)

Up-down Progress

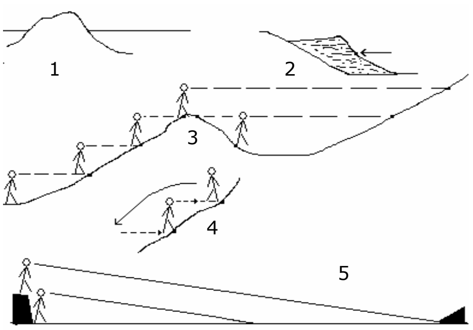

In the first diagram you can see that you are halfway up the mountain alongside of you — **use the horizon to gauge your altitude**.
Note: the horizon drops below true horizontal as you go higher.
In the second diagram your shadow is obviously halfway up the shadow of the hill you are on — **use the shadow of the mountainside.**
To find your tiny shadow:
Close one eye — to line up more accurately.
Look past the shadow of your head falling onto your hand
Look for a 'halo' — a bright spot directly down-Sun on the plain
Wave your raincoat around
Well, you know where the shadow should be by now!
So you don't even need to see your shadow!

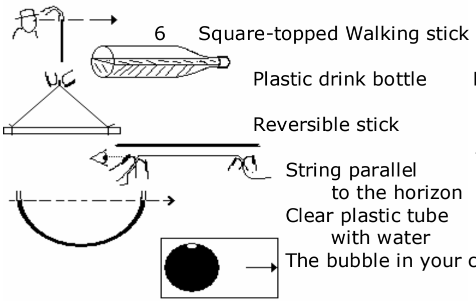
6 Square-topped Walking stick
Plastic drink bottle
Reversible stick
String parallel to the horizon
Clear plastic tube with water
The bubble in your compass

Keep count of height in body-lengths
(3) Walk up to a stone which was horizontal from you before.
(4) Downhill can be counted by leapfrogging with two people.

Half-Way across? Provided you stay in one position...
Looking parallel from half the height gives you half the distance
(5) E.g. when someone is swimming across a lake

Artificial horizons allow you to maintain parallel gaze (6)
E.g. "The edge of the lake is 'two fingers low'

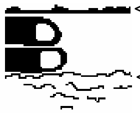
<horizon (or **any distant landmark**)
<lake edge (now, halve your height above water e.g. by squatting down)

Adjust Your Expected Pace

! Three hours up, two hours down — are typical proportions, except in very steep or loose descents — 6 hours up, 6 hrs down.
! You walk more briskly while fresh, in the morning, than after a whole morning's walk. Pace yourself with this in mind.
! Groups travel slower. Allow the slowest person to set the pace, because stragglers may battle or even panic if left behind.
! Retracing your steps is quicker, since it has fewer diversions, less interest, and no unknowns. Allocate less time to return.
! Carrying packs is not necessarily slower, on flats. If your pack is uncomfortable, you won't dawdle, or even want to sit down, and can't stop to look at insects or flowers or to chase birds.
! River crossings chew up enormous amounts of "fussing around" time — organising and reorganising afterwards.
! Beware of smoothed out "routes" marked on maps. The actual terrain may involve many obstacles and consequent slow going and detours. The words "route only" are trying to tell you that.
! Your pace quickens surprisingly when the party falls "into the groove" of walking (without talking, noticing things or relaxing often).
! Path finding can make you nervous especially in unfamiliar territory, which tends to quicken your pace without you knowing it.
The same person, following a leader, is relaxed — and slows down.
So when you take the lead and you wonder why the others seem to fall behind, realise that you are too keen.

Don't Overcompensate for Slopes And Meanders

The worst case for slopes is about 36° for rock scree. But that adds only a quarter to the distance shown on the map. It is far more relevant to say "It's the climbing and the awkwardness which will slow us down more".
The worst case for obstacles is grass-tussock negotiation — but that only adds a maximum of 50% to your distance covered.
An ordinary zigzag may only add 10%

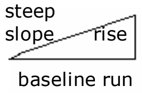

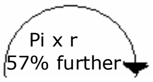

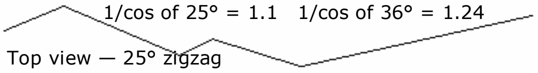

Distance by averaging Maximum & Minimum Guesses

Yes it is worth doing, because it reduces the slop in your individual guesses.
E.g. "More than a kilometre, for sure. Less than 3 km surely! Split the difference & say 2 km

Distance by Comparison with Some Length You Know

E.g. The central business district—1 square mile or whatever
E.g. old-fashioned 'chains' i.e. cricket pitch lengths
E.g. 100 m race; playing fields
E.g. "a day's walk"
E.g. that island which you can see, which the map says is 1 km long.

Distance by Cloud Shadows — Look for Them

- Notice how quickly the cloud shadows move here (use distance/time), then look how slowly they are moving over there
- Time how long they take to get there.
- See how large they look here, and how large there.
- Look how high the cloud base is here, then compare the size of hills in relation to that ground-to-cloud gap, over there.

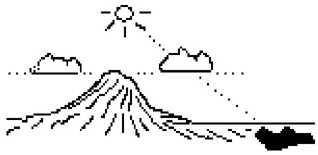

Hint: To see which shadow attaches to which cloud, hold a string, to pass from Sun to shadow (past its cloud) but… Don't look directly at the Sun!

Sound Travels Three Seconds to the Kilometre

This tells you how close the lightning storm is. "(Flash), Alligator One, Alligator Two, Alligator Three, Boom!, One Kilometre!"
If you see a flash to ground, you can find the distance there.
Otherwise, the distance is to the nearest part of the lightning flash overhead.

Align the Track

Line the map up with what you see! Often that is the road ahead, or a well-marked track.
This is a great trick for the car navigator when using a road map — it's so easy to see the line!
It's equally helpful when following any marked track on the map with the map aligned to the landscape — it locates you on the map — on that bit of the map which lines up with the track.

If you were landing a fighter jet onto an aircraft carrier in the fog, you would not want to miss the runway!
Well, think of the real track as the runway on the aircraft carrier, the land as the sea around it, & the tiny map-picture of the track as the jet plane.
Twist and turn your 'jet plane' until it can come in to land properly. Even when you are in the fog!

Assuming you have a properly oriented map…

You can find where you are on it…

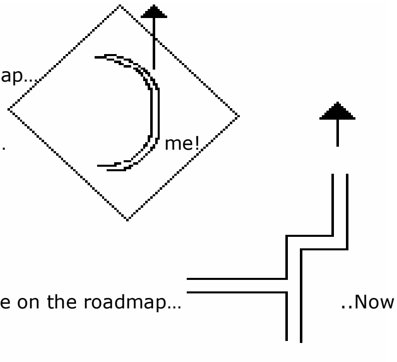

If you know where you are on the roadmap…

..Now the map is properly oriented.

Compass Errors — Be Impressed! Be Careful!

Electrical currents swing the needle e.g. reading the compass by torchlight; untwisted pairs of DC wires e.g. marine compass lights; Mobile phones; GPS; radio. "Impressed (DC) current" anti-corrosion systems in marinas.
Magnets e.g. other compasses, motors, loudspeakers, clocks, ironstone. Note: Iron-rich dolerite doesn't look rusty.
Iron & Steel e.g. your pack, pocket knife, keys, wrist watch, cutlery, steel-capped boots, glasses, geology hammer, batteries, torch, studs, zips, pens, trig points, shed, fence, car, ironstone, buried machinery, coils of old fencing wire half-buried in the ground, tools, fuel stove, internal springs, reinforced concrete, railway lines, power pylons, pipelines. Navigating in a mineshaft.
Many of these might have permanent magnetism too. Stainless steel is often magnetic.
User error
Parallax — viewing the needle from one side; viewing the scale from side-on.
Misreading — e.g. any scale marked every 2° is easily confused. Mis-setting the movable scale.
Miscalculations — especially applying the variation the wrong way — adding it instead of subtracting. Confusing left and right.
Out of date chart of deviation. Deviation is the general name for any compass error—apart from expected, normal variation.
Quality of Construction
Needle instability; under-damping; over-damping; motion. Let it settle. Put it on the ground.
Vibration — has unpredictable effects e.g. twisting the needle clockwise. Walking provides regular slow vibration! Motors.
Sticky pivot — Tap the compass Un-centred pivot
Zero-error — the needle doesn't match the 'zero' Mis-calibration of the protractor
Needle mis-magnetisation — not quite longitudinal; amateur attempts at re-magnetisation.
Reversed polarity — Poor quality needles can pick up remagnetisation from nearby strong magnets without you knowing it!
Variation The difference between True North and Magnetic North changes with time and place. The map is out of date.
Magnetic drift of the magnetic pole — we only have 'predictions' or 'trends' of an unpredictable variation. Are you up to date?
Latitude change — alters the magnetisation of surrounding fixed iron e.g. a car body or a boat's motor or hull.
Local anomalies e.g. Tasmania is full of ironstone dolerite. Many rocks preserve ancient magnetism.
External magnetic fields e.g. which way a boat moors, or who moors next to it. Competing fields change or capture each other.
Lightning strike after-affects.
Correcting mechanism out of **adjustment**.

Map Folding and Map Holding

Maps aren't forever — they blow over waterfalls, tear & get unreadable.
Pack a spare
Cover the whole surface with (non-shrinking) clear plastic film
With good-quality laminating plastic & cutting, taping and sealing, maybe it will last forever!

Folds and Corners lose details, and wear through.
Cut along the fold lines cleanly e.g. to A4 size

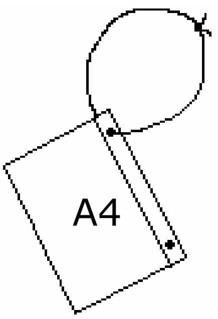

Use a photocopy of your own map to use in the field, to keep your original map in good condition.
Wet maps lose details when rubbed.
Get an A4 plastic sheet protector for the map. Tape it closed. Hang it around your neck.

Mapwork requires bearing-lines to cross the whole map.
Tape the (A4 or other) sections back together with wide clear tape, leaving wide gaps, as shown.
— you can butt the edges closely when needed; the tape will crease out of the way
— you can refold it at will, as often as you like, and show the two most useful sides out of the many sections.

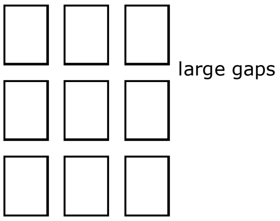

Distance by Double Pace — Test Yours

A 'mile' (or "thousand" in Latin) is a thousand double-paces, on forced march i.e. 5.28 feet (Romans were small people)
My dawdle double-pace is 5.25 feet. What is yours? In metres?
Answer: Test it. Test it again and again. Average it. Each person is different. Relax, don't push yourself.
Test it again uphill, downhill, laden, unladen, tired, in a hurry.
Test it at one double-pace per second — walking by the clock.
It helps to make a 10 m cord. Use a tape measure to make the cord, then use the cord.
E.g. I know I use 12.5 **paces (single steps) per 10 m** i.e. alternating 12 & 13 double places per 20 m.
and I walk at 4.5 kph; 1 1/4 metres per second; eight **seconds per 10 m.** The timing varies more easily than the distance
While watching the seconds tick over on my watch, and striding out in time with them, I manage 1.5m/sec, get tired, and step further out.
You Can Be As Accurate As You Have Been Careful. If you are full-grown, working this out once can set you up for life.

Tie Your Ankles Together!

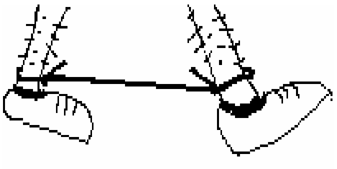

For a well-measured pace (heel to heel) use a 50 cm cord, for instance.
Count double-paces, and don't lose count — see 'finger math'

Test your pedometer

Pedometers work in different ways, so test yours on different terrain. Your knee-lift is higher on uphill sections, and your pace is shorter in rocky terrain. You can make your own pedometer from an old odometer, working off the flex of your boot, your hip, your walking stick, or whatever, or you can roll a small bicycle wheel along the ground, fitted with an odometer.

Don't Lose Count! Use Finger-Math

Finger counting is a silent and **number-free** counting method — you only pronounce the number after you have finished counting. Count automatically, by placing your fingers down, each in turn, onto a hard surface.
A thumb counts for five fingers, and the **left-hand counts 10 per finger**.
When you run out of digits you have 99, so you next say aloud "A hundred" and start over again with no fingers down.
Place each finger down onto a surface, in a **definite sequence**: Right Index ("1"); Middle (two fingers down); Ring (3); Little (4); Lift all four and put down the thumb ("5"); Leave the thumb down and put and leave down the index finger (6); middle (7); ring (8); little (9); Lift all five and put down the left index finger ("10"); Then put down the right index finger again (11), and so on, until you need to put down the left middle finger in place of the other five (two 'tens' down).
With practice, you can count, add, subtract, multiply and divide — almost thoughtlessly — as quickly as with an abacus.
We are concerned here with **counting single or double paces**, e.g. in a fog, and doing so **in lots of 10m** (or 20m or 40m for double paces). I.e. you count up to about 12 or 25 single or double paces mentally, and add "one more lot" to your finger tally.
If you are in a group, you can check each other's counting by stopping where you think every hundred metres is.

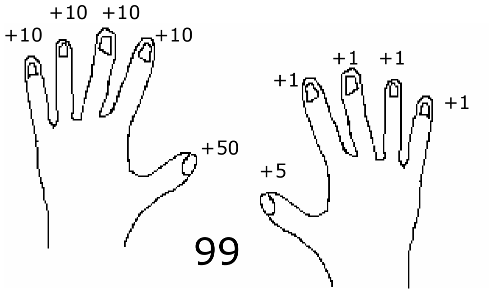

Lift all your fingers off
and nod your head down
for '100', then start again.

100 lots of 10m equals 1km
100 lots of 20 m equals 2 km
100 lots of 40m equals 4 km

or 100 double paces is 1/10 of your mile

Lighting Conditions & Eyesight

Make allowances for optical effects…
Looking up-Sun, especially in the afternoon, you see haze (backlit dust & insects) which gives a false impression of 'distance'.
Looking down-Sun on a clear morning after rain or after a cold change (i.e. minimal haze) things 'look close enough to touch'.
As your eyesight begins to fail in mid-life, everything seems 'distant' but turns out to be surprisingly close
i.e. you have been judging distance by crispness of detail all your life…

Visual Acuity is about One Minute of Arc

..which means that you can spot a 1 m object at 3.6 km on a clear day (since one minute of arc is (1/60)° or '1 in 3600').
I.e. You can see details several thousand times smaller than the distance to them.

This is how seamen can judge distances over open water, to land, even though there are no other clues to go by.
They ask: "Can I see trees? What about tree trunks? Or branches? Or leaves!"

Lighting, Contrast, Haze and Eyesight play havoc with accuracy; But experience is a great teacher.
Feed your mind and memory by deliberately looking through the haze to the finest details you can pick up.
Use binoculars as a cross-check. Have competitions with your family.
Children have better eyesight, but the idea is to judge the distance according to how it looks to you.

Align the Map to the Landmarks

Make the Map Match the Marks — if you know where you are on the map you need only one landmark…

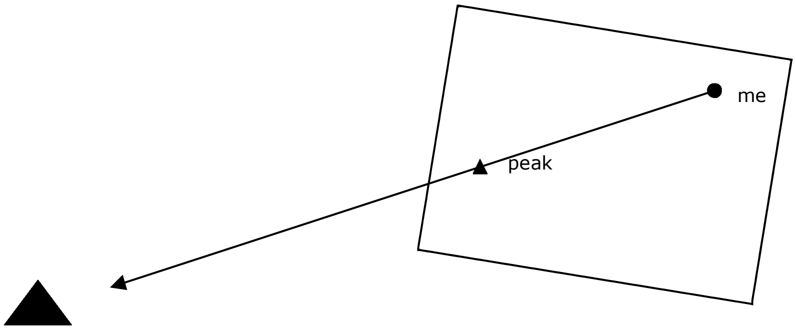

The easiest way to keep the map aligned to the landscape is by then using the direction of the Sun now, a very visual method.
The commonest method uses a magnetic compass to find North.
This one-landmark method can be used whenever you can see something in the distance.

If you don't know where you are on the map you can still orient it to match the landscape, but you will need two or more landmarks identified to do this.

Compass Use — Master It, but Be a Good Master.

- Use it to orient yourself, then put it away!
- Use it to orient the map or to choose a route, then put it away!
- Use it as a protractor. Use it as a ruler. Use it as a map scale measurer. Use it as an artificial horizon. As a set-square.
- Use the set square for a back-course or a side-course without altering the forward-set-course.
- Don't rely on it — use other methods of direction-holding.
- Let it point your eyes outwards, to the horizon.
- Use NORWEST/NOTLEAST, if you have to stare at it — e.g. in a cave.
- Hold it 1½m above rocks; 10m away from cars, sheds, etc; several item 'lengths' away from small items — test it.
- Let it point out a foreground mark as a destination, then follow a visual line of sight
  e.g. 'leapfrog' or manoeuvre by 'legs'
- Don't consult it again until you need to check or choose another point.
- Don't trust it, but trust yourself to it, when you need to.
- CHECK ITS ERRORS. Check it against the map by taking a bearing from a known point to a distant landmark
- Take a pair of forward and reverse bearings—to and from a chosen mark, to check for local magnetic field anomalies.
- Check your errors in using it, e.g. on the move; against someone else.
- Interpret it for orientation value, not just for route-finding.
- Consult it more often than you want to, when you are 'not using it'.
- Check your guesswork as to e.g. 'Gully North' or 'Wind-West' by it.
- Take it.

Layout Map — Blind

- This project requires a pedometer to measure every hundred, metres or paces or something. A stop-watch could do.
- Use graph paper, so that each square on the graph paper represents one 'leg' of 100 (or '1 minute's walking').
  (Hint: Graph paper is a handy thing when making a casual mud-map of your progress, for this very reason.)

Try it at least once. Without triangulation and cross-checks you can build up the layout just by reading the compass.
i.e. Beware: This is a bottom-up method, prone to inaccuracy. After one accurate practice-run, you can do a better casual job.
I achieved over 90% efficiency at coming back to my starting point after a 24 km circuit on my first try!
(In fact I know that the 8% error was mainly only due to a few blunders in marking the wrong direction.
Also, I only measured 'direction' to +/−15° since I was also testing the 'clockface method' of direction — to the nearest ½hr.)

When the compass read "2:30", I needed a reverse clockface on the map, and I needed to mark…

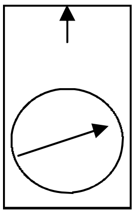

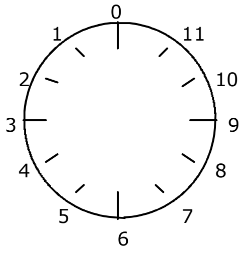

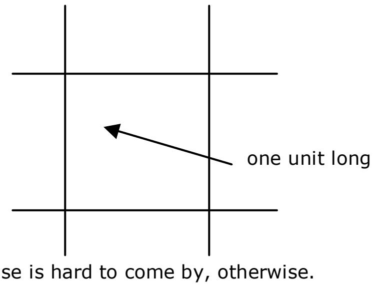

(Hence I made a few left-right blunders which I had no record of!)
You don't need a map for position-sense, if you make your own as you go. Position sense is hard to come by, otherwise.

Line of Sight Can Be Extremely Accurate

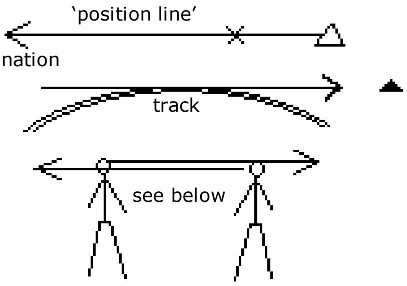

..But is often neglected, for far inferior methods.
E.g. locate yourself on a 'position line' as a means of marking your progress…
E.g. keep a straight line by walking to a point ½ way between you and your next destination
E.g. 100 fence posts can be positioned to look like one when seen end on.
E.g. fishermen can **locate** their offshore fishing spot again
— "The jetty is underneath Mount Lofty, and the tower is behind the Town Hall"
You can sometimes consult a map to fix your position...
E.g. You may notice that **"this part of the track runs directly toward"** a peak.

Un-mappable lines abound. Choose the **nearest** objects in front for best accuracy.
E.g. "That far rock lines up with this bush. **Remember** them!"

Use mapped features and the accuracy is still extraordinary.
E.g. "The peak lines up with the intersection, but if you step only three paces left you can see the difference!"
The alignment doesn't need to be accurate, provided you can memorise the exact inaccuracy e.g. 1° to the left of the hillside.
Two such alignments are needed for a fix. Look around: "What is in front of Mount William? What is behind the lighthouse?"

Two Opposite Landmarks

It **more than doubles** the alignments available to you if you have eyes in the back of your head!
With two people, separate some distance, for accuracy, then **look past each other's heads**.
Walk slowly around in a circle looking at the horizon for possible line-ups.
With one person, **place a rock on the ground then circle it**, scanning the horizon. Place a pebble to mark each feature.
The good thing about this method is that one landmark cannot 'blot out' another — all the visible features are available to you.
You may use this method to stick to a direct 'track' between two landmarks.

A Slow Kilometre Cancels out Three Quick Ones

Let's try to keep up an average of 4 km per hour…
First we travel 2 km in half an hour, but then we hit a slow section and manage only 1 km in the next half-hour (2 kph).
To counteract this we would need to triple our slow speed to 6kph for the next half-hour!
So we then decide to stop and catch our breath for half an hour.
To counteract that we would need to double our desired average speed (to 8kph) for the next ½hr!! Or 6kph for 6km.
i.e. a wasted hour takes several hours of catch-up, to regain.
(2kph for ½ hr + 6kph for ½ hr = 4kph; 0kph for ½ hr + 8kph for ½ hr = 4kph; 0kph for ½hr+ 6kph for 1hr= 6km in 1½hr)

Slow sections chew up the time available, so don't dawdle.
Quick sections can't easily repair the damage, because they don't last long.
You may try to be time-efficient and walk more quickly on the easy sections i.e. hurry along the flats,
but you can't gain much time that way.

To Progress Faster More Easily
Pace Yourself — Slow Down, but Don't Stop

i.e. Pace yourself so that you don't need rest stops, since they ruin your time budget, and it is time which determines pace.
It is better for your overall pace to keep walking slowly than to stop completely.
Go slowly on the hard sections. Pick up your pace, maybe, on long flat easy sections.
Shorten your rest stops e.g. don't remove your packs.
The old rule to cover a lot of ground quickly is: run 50, walk 50 (paces or double paces).
Catch the paradox of it — to keep going faster, go easier.

Approximate Figures for Visual Acuity

At 1:1,000 "I can just count my grandchildren"
At 1:2,000 you can count individual items.
At 1:3,000 you **can't count** them. E.g. people/shrubs/birds
At 1:4,000 you can **see** items, but can't count them.
At 1:5,000 you **can't see** them individually.
At 1:6,000 you can **read unfamiliar letters**
At 1:7,000 you can't **read unfamiliar letters**.
At 1:8,000 you can **read familiar signs**.
At 1:9,000 you can't read familiar signs
At 1:10,000 you cannot see that there are individual letters.
At 1:15,000 you can see single objects e.g. trig points against the sky.

You need to supply figures which work for you.
Multiply the size of the smallest objects you can **count** by 2,000
Multiply the size of the largest objects you **can't** count by 3,000
Multiply the smallest items you can **see** by 4,000.
Multiply the largest details you **can't** see by 5,000.
Multiply the letter-stroke widths you can **read** by 6,000.
Multiply the letter-stroke widths you **can't** read by 7,000.

Of course it's rough! I told you so in Rule 1: Guess!
Adjust the numbers to your eyesight e.g. "I can only count to 1500".
The idea is to build up your subconscious guesswork.
E.g. "I **can count** to 3000 and can count house windows" try 1 m x 3,000 = 3 km away
"I **can't quite see** heads" try 25 cm x 4,000 = 1 km away

Test Your Own Visual Acuity

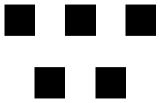

Walk up to a signpost until you can read it. Pace the remaining distance.
Measure the size of its letter strokes.
When do you lose sight of a dollar coin?! Can you count heads in a crowd at 600 m?
Set up a 1 cm test pattern of squares (for others) to count. Try yellow squares too.
Test yourself in different conditions — on an overcast day, in direct sunlight, in glare, on a hazy day, and at a large distance.

Align the Map to Identify Landmarks

Lift your eyes from the properly aligned map back onto the landscape… "There should be a peak in the distance over that way." "Look for an outstation in this direction" "Can you see the transmitter structure??"

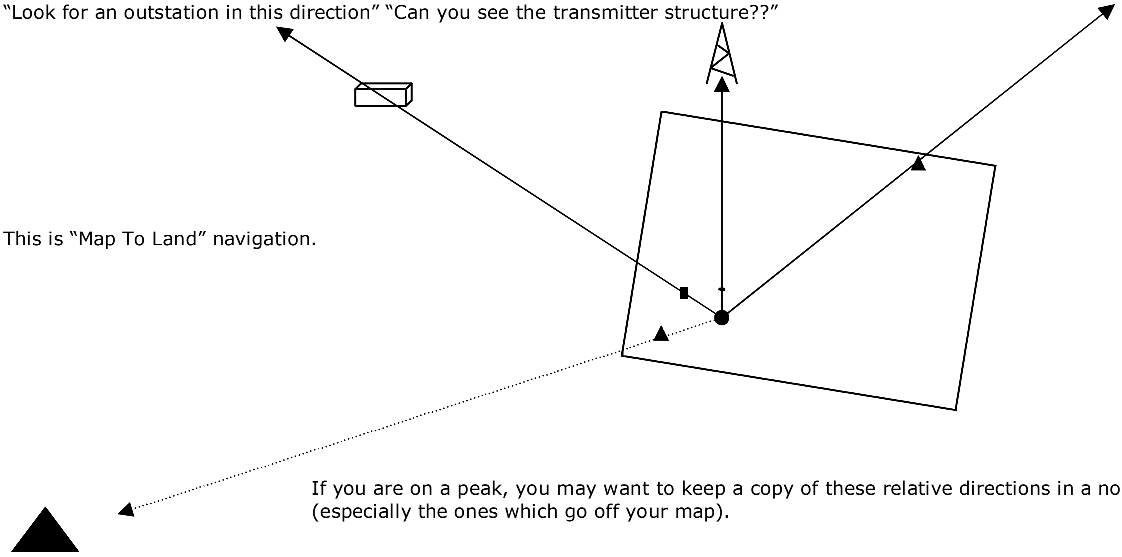

This is "Map To Land" navigation.

If you are on a peak, you may want to keep a copy of these relative directions in a notebook (especially the ones which go off your map).

"Magnets Grip Maps"

This mnemonic is meant to remind you to twist the map to the north — the map should be one piece with the compass needle.

- Place the compass on the map
- **Grip both the map and the compass in one hand**
- Turn the whole map, or yourself, or both — so that the magnetic needle points to the map's magnetic North

The result is that the map is aligned to the landscape.
Keep it that way!
Even while you walk, and twist, and turn… This is called "Swinging the Map".
A one-off effort is called "Orienting the Map".
Swinging all three of you is called "Orienting yourself" e.g. to North.

Align Your Map in the Dark

The commonest way to align the map to the landscape is by a magnetic compass.
The magnet — the compass needle — must 'grip the map', magnetic North to magnetic North, in order to keep the map oriented.
One method is to set the compass protractor to zero — true North — and
set the compass edge to grid North/true North (see diagram) and then
set the magnet needle to magnetic North — as marked on **the compass rose on the map**
Another method is to line the edge of the compass up with the magnetic North mark on the rose.
Then you simply keep the needle point pointing to zero on the protractor.
A third method is to set the compass to the correct compass heading then line the protractor edge up with the desired course on the map, and the needle to the protractor, then follow the compass arrow.
A fourth method is to set the compass to the correct true course on the map, then line the compass needle up with magnetic North on the map, then follow the arrow. But **always line up the two magnetic Norths!**

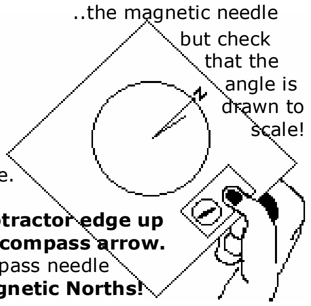

The Magnetic North marked on the map is crying out to be matched up with… ..the magnetic needle but check that the angle is drawn to scale!

A Compass Holder

Rather than hanging the compass around your neck, where you hardly ever see it, you can make it constantly visible.
For map making, it is indispensable.

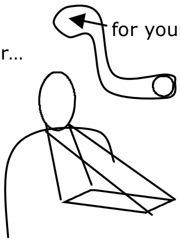

Version 1: Aluminium wire around your neck and around the compass, like a bib or harmonica holder…
The compass circle is grasped by a circle of non-magnetic wire.

Version 2: Hang a flat map board from your neck, and blue-tack the compass on to the map board…
Drill holes in the four corners of a light board.
One string loop goes around your neck and through the two close corners.
Another string loop goes around your neck and through the other two corners
and has an adjusting knot in it (rolling hitch).
The compass protractor is set to 0° i.e. Use Magnetic North
or it is set to x° i.e. Use True North
To orient the map, or yourself, turn around and face North.
For a back-bearing, turn around and use the white end of the needle to read your direction — where you have come from.
Use the "NORWEST; NOT LEAST" mnemonic to keep you in touch with normal orientation. See p.101c & 106b for how to build up a map, or keep track, blind, using such a compass holder.

"Changeover Lines" of Progress — Relative Apparent Sizes

All visual elements which surround you have an apparent size, each of which changes as you progress.
E.g. "The hut behind us seems so tiny now, poking out from the sea of snow"
E.g. "That hill now seems to loom **high** above the plain" (a vertical angle).
Two apparent sizes will, at some stage, become equal, at e.g. as you move away from one object, which shrinks, and toward another, which expands. Simply notice "the changeover" and you have 'a line of position' to log your progress.
"The hill is the **same size as** the leaning over gum tree" (a vertical angle, a diagonal angle, and a changeover line)
You don't need to remember what size you measured — just compare them for equality!
"The width of the patch of forest is much less than the island is **across**" (horizontal angles)
"But the island alongside us is about the **same width** as the **gap** between the two" (another "changeover point")
You don't get a single point fix, only a line of separation. The third and fourth diagrams each show an example.
A measurement without numbers is like saying "We are halfway there" instead of saying "4.5 km on"
or like waiting until you are "Exactly East of Mount Big" rather than measuring "079°C" at any time
or somewhat like "These two line up, if you put a hand span in the gap"
The closer the objects, the better. The more distant, the more careful you need to be!

Use the Landscape Itself to Measure & Mark Progress

Example: "Where I came out onto the beach,
Sloop Rock was one island to the right of Gannett Island"
A top view shows that this is simply a line of sight, locating a point next to the island.

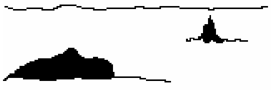
Island = gap;
An apparent-size changeover line

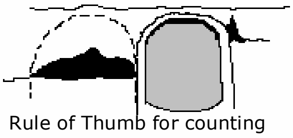
Rule of Thumb for counting

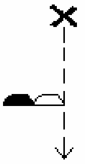

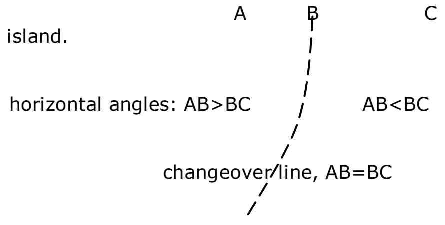

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Distance-Off by Vertical Angle

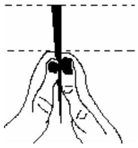

The simplest range finder is a piece of grass held at arm's stretch, (if your fingernails are too small).
Measure the apparent height of something which you can recognise later,
then measure how many millimetres of grass was needed!
You can relocate that distance-off later by its apparent height e.g. distance from a prominent peak;
from a lighthouse seen from offshore; from any recognisable tree; or from a cliff with a clear base to measure up from.
This is how our mind analyses the skyline heights — it is a very 'natural' method.
Yacht navigators will find out the height of a lighthouse from a chart,
measure the angle with a sextant, and calculate the range by trigonometry…

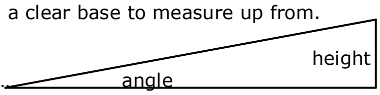

To fix your position requires two separate measurements e.g. two different vertical features
In theory, the plotting looks like two circular arcs intersecting, because any distance-off must give you a circle of possible positions.
The closer the features, the smaller the circles, and the more accurate the fixing of the location.
Confuse your friends with: "1 inch away from the windmill, and 13 mm from the pine tree"…

Safe Distance Off

You might be sailing around a headland or reef, and want to maintain safety…
Without needing to know where you are you can maintain a minimum distance off.
E.g. "no higher than 1° apparent height by vertical angle"
E.g. "keep the horizontal angle acute, between those two points"
E.g. "stay outside the apparent radar range of 5 km"
E.g. "deeper than 20 m"

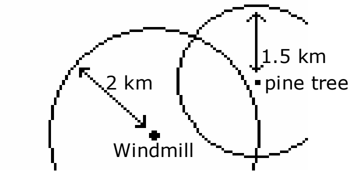

Discard one of the two possible positions.

Circle-of-Position by Horizontal Angle

Here you keep track of the horizontal space between two prominent points; or any noticeable gap; or the apparent width of an island. Use a string stretched across your line of sight, or a stick gripped between two fists.

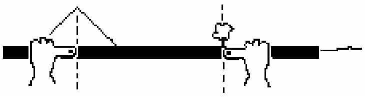

In this horizontal case though, unlike the vertical angle, the 'circle' of position is really only a cusp — part of a circumference, which must pass through the two points, and your position.
If you are closer — a wide angle — the arc is flatter; a narrower angle means you are further away — a larger part of the circle lies on your side of the landmarks.

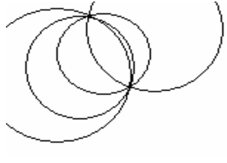

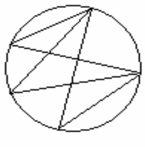
There is a constant angle at anywhere on the circumference when looking at the two points.

You don't need to draw this though.
Only memorise or note the angle.
To fix your position make two separate measurements e.g. one vertical angle and one horizontal angle too; or two horizontal angles—using three landmarks (or two vertical angles; or a radar range & direction from a single landmark; or use any other line(s) of position e.g. a compass bearing or line of sight or an advanced position line).
Now you can relocate that buried treasure, that fishing spot, waterhole, rare plant, good campsite… simply through making a couple of notches in your walking stick.

The best range-finder

..is a theodolite/sextant — designed to measure angles very accurately. You can use them horizontally.

Align the Map to Fix Your Position

Match the map to the landscape visually.
(The first result is to show you geographical (true) North.)
(The second result is to show up other landmarks.)
The third result is to show up **where you must be**.
(The fourth result will be to indicate which way to continue.)

I.e. Work **backwards** — from Land to Map.
One method is as follows…
Place a small pebble on the ground.
Place other pebbles in a circle around that,
each one lining up with some landmark.
Now place the map over that centre pebble.
Twist and shift the map until it lines up.
Get down behind the map and visually sight over it.
When everything lines up you must be at the centre of the circle
— over the central pebble.

Your position should **look** obvious!

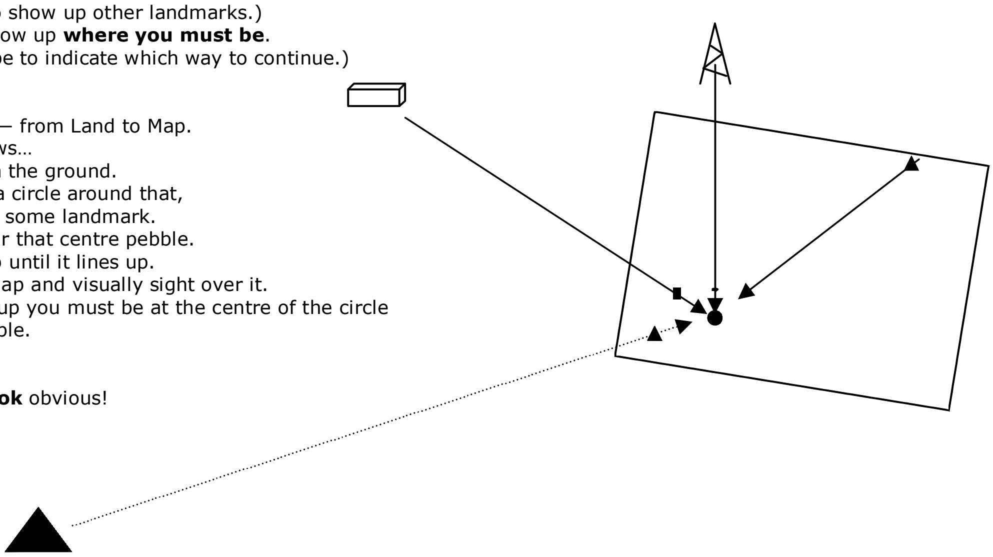

A Horizontal Angle between Features Yields a Position Circle

There is no need to draw this position circle (diagram 1), and it is somewhat awkward to construct, but there are two cases which are well worth drawing (permanently) on the map…

Diagram 2. A right-angle between two peaks — it means that those two peaks mark the **diameter** of the circle — easy to draw.
Diagram 3. The 'circumscribed' circle of three peaks — you can see whether you are inside or outside of that circle.
To find the centre of the circle, use perpendicular bisectors.

The angle seen from the circumference is constant.

Horizontal angles are **larger** on the **inside**.

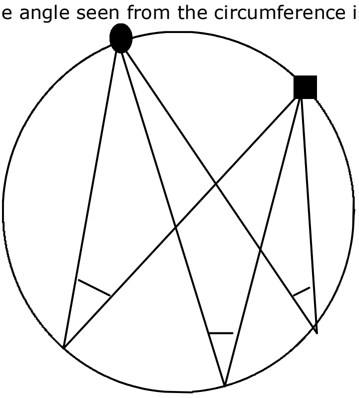

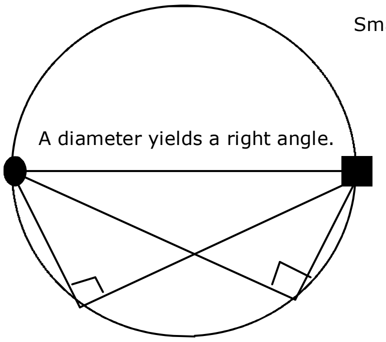

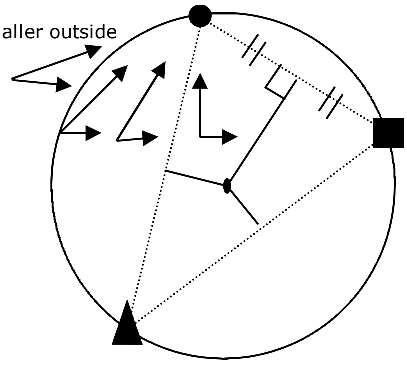

'Two Horizontal Angles' Usually Fixes Your Position

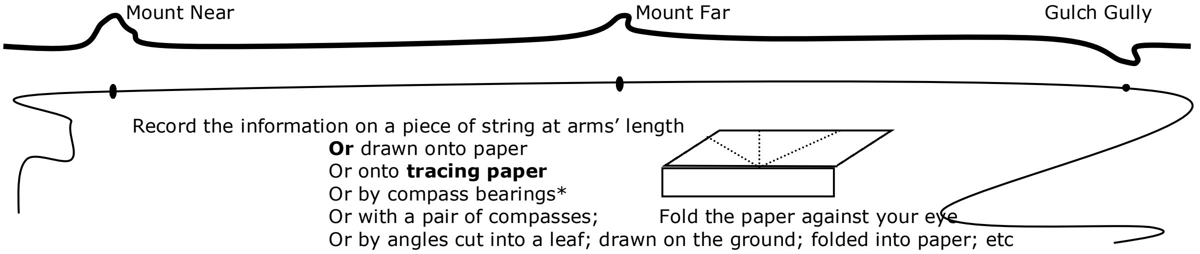

Record the information on a piece of string at arms' length
Or drawn onto paper
Or onto **tracing paper**
Or by compass bearings*
Or with a pair of compasses; Fold the paper against your eye
Or by angles cut into a leaf; drawn on the ground; folded into paper; etc
*you could plot back-bearings, or simply record the three directions for reference.

This is a quick, natural, accurate method which uses no numbers or circles. It is how our mind judges the horizontal layout.
Only one position on the map will produce such a pair of horizontal angles.
If you draw the angles onto tracing paper, you can **place it directly down over the map, to fit it on properly**.
If you make a three-arm trio of compasses with a locknut at the pivot, you can also place this directly onto the map.
Coastal yacht navigators find the method useful, and to measure angles very accurately they use a sextant horizontally.
In theory it plots as two intersecting circles — only one intersection makes sense.
The nearer the landmarks, the smaller the circles, and the better the fix.
Just don't choose three landmarks which are already on one circle along with you!

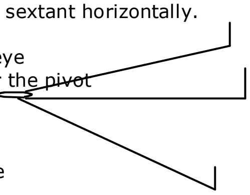

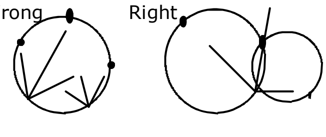

You don't have to draw these circles
Also, if you want to find an angle from the map
you can just read it from the map without drawing any circle

The Sine-Cosine Tally Method of Keeping Track, Blind

This project is only "for experience" — i.e. you are unlikely to want to do it twice! — but you should do it once.
The idea is to **keep a running total of your 'Northing' and 'Easting'** from a starting point.
I scored 97% efficiency in getting back home, on an 11 km circuit, on my first try, with an unreliable home-made pedometer!
It is a 'bottom-up' method — for when you are walking blind — when you cannot work down from the Big Picture.
With pen and paper you record your pedometer readings & directions, and update the numbers, say every hundred double paces.
E.g. "Current Pedometer Reading: 1400; (time-check 1 1/4 mins; pacing check 140 m) efficiency: 90% (slightly indirect path)
Recent Direction 005°; **adjustment needed +90, +8**; new tally: 419, -45; (comments: crossed a wet ditch)"

The chart of 'adjustments' follows this box, with an example.
200% efficiency would mean "I missed the last 100 reading"
50% = "I had a diversion" 110% ="I stopped at 110 — make the next reading 90% efficient"

- ◇ Set it all out with headings and long columns.
- ◇ Your judgment and arithmetic don't need to be accurate, because the errors are likely to cancel (!)
- ◇ Check your pedometer for each type of terrain, by time and by pacing.
- ◇ Avoid blunders e.g. check that the direction and the adjustments are similar between two legs.

It is quite pleasant to stop every minute or so — at every 100 on the pedometer — It keeps you alert, rested and oriented.
Making a full map (see 'Layout Map—Blind) is more satisfying and just as quick.

Mariners can (either draw their tacks, or, using this method) calculate an overall course-made-good from their many compass legs, by first adding up (distance x sin true course) East, and then adding up (distance x cos true course) North, from each individual distance and course.
Their overall distance is $\sqrt{(\text{sum1}^2+\text{sum2}^2)}$ at an angle of arc-tan(sum1/sum2). Then correct for magnetic variation.

Rise and Run Adjustments — Sine and Cos — North and East

Caution: These are COUNTER-Clockwise Bearings! — as seen from a compass holder...
I.e. The needle swings to left and to right while you point straight ahead.
E.g. when the needle points to "20° East of 0°", as in the diagram,
"N(orth) O(n) R(ight)-West" reminds you that you are heading NNW-ish,
not to the East. N20°W is your **anti-**clockwise heading.
Don't let this unusual method of measuring bearings confuse you
about normal clockwise bearings.
There are really only 10 pairs of adjustments used in the whole table
I have made East positive, only to match normal bearings and
Map grids, which use East as positive (West as negative).
Here, **West is negative; East is Positive.**
South is negative; North is positive
Examples: North East is + + N315°W;
South West is – – N135°W;
North West is +– N45°W;
South East is – + N225°W
The + and – signs tell you
how to change your tally of North and East.
E.g.
100 paces to the NNW ish, as in the diagrams is...
94 paces of Northing and 34 of Westing
Or +94, –34

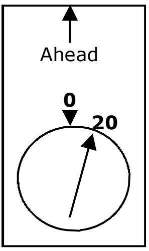

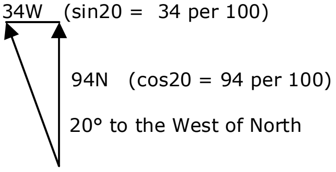

Actual direction…	(NE	SE	SW	NW)	Change N	E
Adjustments…	+ +	– +	– –	+ –	cos	sin
Protractor Readings…	360	180	180	**000**	**100**	**0**
N nnn° W…	355	185	175	**005**	**100**	**9**
	350	190	170	**010**	**98**	**17**
	345	195	165	**015**	**97**	**26**
	340	200	160	**020°**	**94**	**34**
	335	205	155	**025**	**91**	**42**
	330	210	150	**030**	**87**	**50**
	325	215	145	**035**	**82**	**57**
	320	220	140	**040**	**77**	**64**
	315	**225**	**135**	**045**	**71**	**71**
The next figures rerun the previous ones...						
	310	230	130	050	64	77
	305	235	125	055	57	82
	300	240	120	060	50	87
	295	245	115	065	42	91
	290	250	110	070	34	94
	285	255	105	075	26	97
	280	260	100	080	17	98
	275	265	095	085	9	100
	270	270	090	090	0	100

e.g. As a different example, a tally of –640 +770 means that you are 640 paces South and 770 paces East of your starting point, which means that you are now N230°W from home, according to the table.

Rule of Fingernails

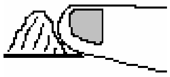

Your pointing fingernail should be about 1°, one in 60, when you stretch your arm.
Your thumbnail at arm's length, held upright, might be one in 50……
A pencil in your fist will be about one in 100.
Check it out with a tape measure and calculator. E.g. 1.2 cm (width) / 69 cm (distance from eye) = one in 57 = 1°
Adjust how you hold your arm (e.g. square in front, diagonally- or fully- on the side) and which fingernail, etc, until you find suitable combinations which you can remember.
But the trick to making this useful in range guesstimations is to guess the distance away first, then estimate the height of a mountain, as follows… 60 km away — use one in 60. One full nail means 1 km showing;
30km away—use 1 in 60 =½km showing; 50km away—use 1 in 50 = 1km showing; 10km away—use 1 in 100 = 100m showing
Reverse logic can give you the distance away, if you can see the base clearly e.g. from sea, and know the full height.

Rule of Tom Thumb

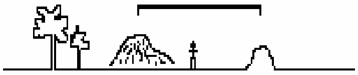

At various times you have to judge parallax.
And the trick is to project the needed sideways movement onto the intervening landscape.
Imagine yourself over there on that ridge — Are you as thick as that tree trunk? Are you as tall as that bush?
To make the two landmarks line up, imagine the distance over there in the distance.
"I would have to walk that far sideways over there" = "I would have to walk the same distance sideways over here"

Apparent Size

The size of people, cars, houses, as measured at arm's length, varies with distance. You know how big they are already.
To get a good gauge of very small angles, compare their width & height with a key or knife-blade or toothpick, held edge-on.

Which Way is North?

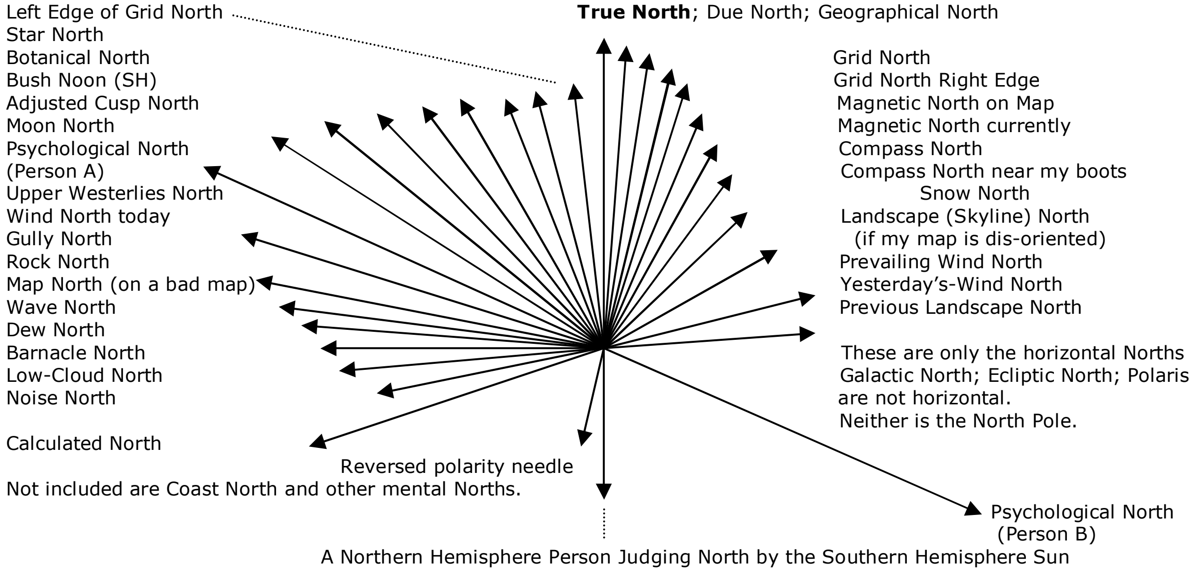
Left Edge of Grid North
Star North
Botanical North
Bush Noon (SH)
Adjusted Cusp North
Moon North
Psychological North
(Person A)
Upper Westerlies North
Wind North today
Gully North
Rock North
Map North (on a bad map)
Wave North
Dew North
Barnacle North
Low-Cloud North
Noise North
Calculated North
Reversed polarity needle
True North; Due North; Geographical North
Grid North
Grid North Right Edge
Magnetic North on Map
Magnetic North currently
Compass North
Compass North near my boots
Snow North
Landscape (Skyline) North
(if my map is dis-oriented)
Prevailing Wind North
Yesterday's-Wind North
Previous Landscape North
Psychological North
(Person B)
A Northern Hemisphere Person Judging North by the Southern Hemisphere Sun

Not included are Coast North and other mental Norths.

These are only the horizontal Norths
Galactic North; Ecliptic North; Polaris
are not horizontal.
Neither is the North Pole.

'East-least; West-Best' Rule — Tells You Which Bearing is 'Best'

This rule works only for horizontal directions, measured clockwise.
It is for shifting between True, Grid, Magnetic & Compass bearings 0-360°.
"Least" really means "Less than the other alternative number"   "Best" really means "More than the other choice"
The following wording ("the North which is") is important, since you need to choose correctly between a right and wrong choice!
The "North" which is East **(clockwise)   of another "North"**   ***gives the Least bearing*****.**
Any *"North" to the West* (anticlockwise) of an alternative "North" yields the *Best* & Biggest numbers.
Specifically, it is most used to shift back and forth between magnetic North and true North bearings.
The wording may then be rendered: "Compass error West; compass heading best". Memorise that wording.
Because this mental arithmetic is a difficult ask, you need to draw a diagram to make the conversion clear.
Learn this reminder "Check-up-on-yourself!" diagram…   And visualise it, on the real landscape in front of you.

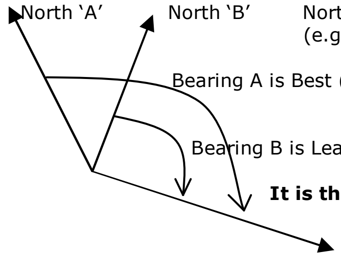
North 'A'
North 'B'
Bearing A is Best
Bearing B is Least
Landmark

North 'A' is **West** of North 'B': it yields the **Best** of the two bearings.
(e.g. if A is true North, and B is magnetic North, the 'magnetic variation' is 'To the East'
and "the compass heading is Least")

Bearing A is Best (It yields a bigger number — East-around)
(e.g. if the magnetic bearing is 085°, the true bearing is bigger… 120°)

Bearing B is Least   North 'B' is **East** of North 'A': it gives the **Least** clockwise angle.

It is the *North* which is "East" or "West"; The *bearings from it* are "least" or "best".
Numbers are meant to make sense — your job is to look for that sense, visually.

E.g. Compass Deviation………If my compass *North* points too far East e.g. by 10°, 050°M = 040°Compass (-*bearing* is Least)
E.g. Grid Convergence Correction…If Grid N is 2° tilted to E of true N, 070°T = 068°G (Grid is Least, since Grid N is East)
E.g. Map to Compass………… 090° on the map means: set your compass to 100°M, when magnetic variation is 10° West (Best)
E.g. Compass to Map………… 205°M as a compass bearing = draw 220°T on the map, when magnetic variation is 15° Least
E.g. *Add* the GridtoMagnetic Convergence clockwise *E* angle to magnetic N to get *Grid* N "MAG=**M**agnetic, **A**dd(the GMC)=**G**rid"

String Map

This is a fun-project. As you un-do each knot later, you relive the journey!
A suitable string is builders' twine — long, thin & strong.
An extraordinary number of code variations are possible, provided you can "read" the different knots afterwards!
Keep it simple, for a start.
Example: Start with a slip knot. Half-hitch it every hundred paces, to keep track of distance.
Tie a special knot at any change — to remember it by.
E.g. a strangler hitch around some bark for "thick forest"!; a thumb knot around a feather for "Water Bird Lake"
Chain the slip loop to keep it going. Or thumb knot the loop to lock it all up.

A simple numerical code is: slip knot; + n half-hitches; chain on; m half-hitches; chain on; ongoing tally…
n might mean something like 'direction' by clockface
m could be 'terrain type'

Here are some variations…

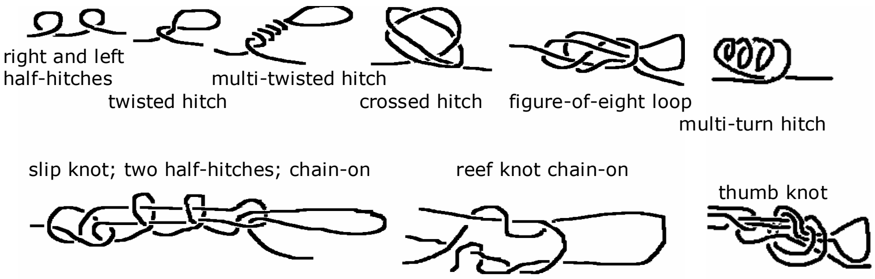
right and left
half-hitches
twisted hitch
multi-twisted hitch
crossed hitch
figure-of-eight loop
multi-turn hitch
slip knot; two half-hitches; chain-on
reef knot chain-on
thumb knot

Progressing A Position Line across the Map

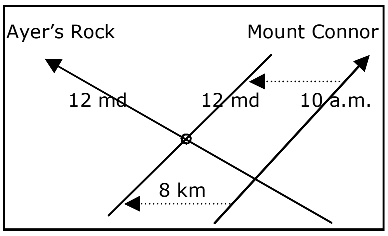

Situation: You catch sight of one landmark; plot a back bearing; then travel — say for two hours, West — before you catch sight of a cross-bearing. You can still plot a 'fix'! Example (fictitious): You lose sight of Mount Connor in the Northeast; and later see Ayer's Rock. Your pace is 4kph. From the bearing of Mount Connor, you plot a position line (by a back bearing running back from Mount Connor). You must label this '10 a.m.' Now **shift the whole position line** 2 hours to the West i.e. 8 km, and label it '12md'. To do this choose any two points on it; shift those points 8 km West; draw **a new line parallel to the old**. You are now ready to plot another back bearing — this time from Ayer's Rock — to cross the advanced position line, for a 'pinpoint fix'. Alternatively, you could 'shift' only Mt Connor on the map, first.

Pinpoint "Fixes" are a Myth!

(Rule: Don't suppress uncertainty, nor reject any unwelcome information!)

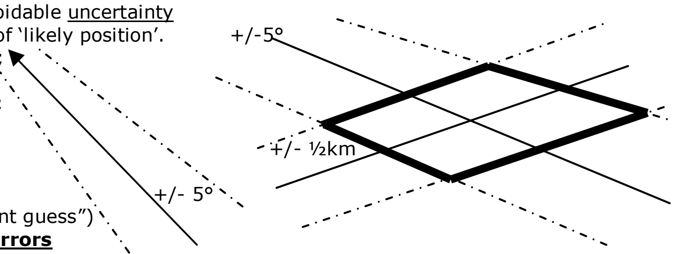

Any 'line' of position looks exact. But it comes with unavoidable uncertainty and should be plotted (mentally at least) as a wide band of 'likely position'. Potential inaccuracies abound. E.g. lining up the compass;
reading the compass; plotting that angle;
grid north variation across the map; map distortions;
errors in magnetic variation; protractor inaccuracy;…

You can now advance your "area of uncertainty" across the map, expanding it with each blind move!
'Deduced Reckoning' navigation at sea (i.e. "intelligent guess")
is more a matter of keeping track of **accumulated errors**
due to tides, leeway, inaccurate course-holding/recording/plotting, inaccurate instruments. So too on land.

Getting Started in the Dark

The task is to know what direction to head off in, when you can't necessarily see the landscape…
You need a Map & Compass.

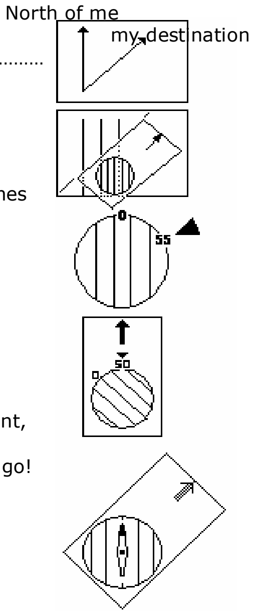

TAKE A MAP-BEARING — Find the desired angle, on the map, in relation to the North-South grid…………..
— "About 60°, as a **guess**"
— Use the edge of the protractor
— Measure the angle — only the protractor is needed for this!
Line up both sets of parallel lines — mapgrid lines,
and the lines on the needle-holder-circle.
— The protractor will display the angle between the two sets of its parallel lines
"55° E. of N." (It is marked clockwise)
(This is Called Working from **Map to Compass**)

SET THE COMPASS — Using 5° East magnetic variation, and ignoring compass deviation…
Compass bearings should be 'Least'
i.e. 050°C
— adjust the 'Follow Me' Arrow to point to 50° (to the East of North)
Twist the circle on its mounting.
— Don't alter the protractor again!

FOLLOW THE COMPASS — Now turn your attention to the needle
— Line it up with the 'zero' on the protractor, by twisting the whole instrument,
And by using the grid lines on the movable circle as a guide.
— Twist yourself this time, to line up with the 'follow me' arrow. And off you go!

Mnemonic: **Map to Compass** (= Map to Compass Course) Means **M**ap Grid to Compass Zero;
Angle the **A**rrow to the course target;
Put on the correction; **To** Get it, use the East Least West Best Rule;
Compare the Compass Zero to the Compass Needle; **Pas**t the Follow Me Arrow is the Course Target.

Thinking Backwards

"Danger bearings" allow you to stay safe, without knowing your position accurately, but you need to think accurately…
As seen from the lighthouse, you must stay on the right of 315° (and to the left of 060°). That much is clear from the chart. Anything 'to the right', is clockwise from the observer, so for the keeper to keep something (e.g. you) 'on the right' means to keep its bearing bigger than ahead. 'Ahead' is parallel to the 315° track shown, since the lighthouse keeper is wishing to see you 'on its right'. He will be happy to see you on any bearing bigger than 315° and less than 060° i.e. 315 to 360, 0 to 60. From your point of view, that means, that you must *use back bearings,* of 135° and 240°, and then keep those tracks on your right and on your left respectively, as you look in. 'Ahead' is parallel again, but opposite to the track shown on the chart, if you are trying to keep the track 'on your right'. Looking in, moving yourself to the left will place the track further to the right, and make bearings to things on it bigger. That means, in numbers, the lighthouse will bear more than 135° and less than 240°, i.e. It is safe to approach at **anything between 135° and 240°**. Notice that the more/less sense is preserved with such use of backbearings.

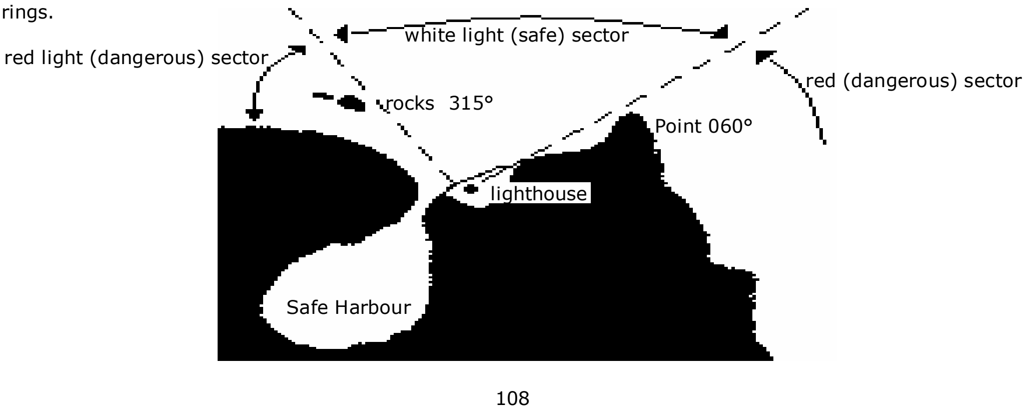

Taking a Bearing from the Landscape

- **Start with a guess** e.g. "That hill is about 060°T from me"
- Point the 'follow me' arrow to the landmark
- Grip and twist the movable protractor circle until the grid marks on it — i.e. the zero — line up with the compass needle
- Read the resulting angle off — between the zero (which is "North" —Compass North in this case), and the landmark.

The result should agree with your guess e.g. "The landmark lies at 065°C" i.e. East of Compass North i.e. clockwise from.
Take a B.E.A.Ring Mnemonic: **B**earings are Tracks; **E**xpect to have to plot a back-bearing;
Arrow to Landmark; **Ring** to Needle and **R**ead It off. (Think: "Arrowing" to remember A)

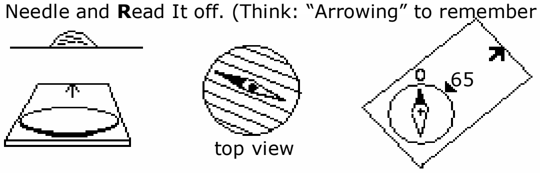

If it helps you sight the landmark, hold your compass string vertically upwards from underneath the tip of the follow me arrow.
The 'Zero' is meant to be used for 'North'! But if you point the follow-me arrow to North and the 'zero' to the landmark, then (a) it is more awkward and (b) it is an anti-clockwise "bearing".

If you are about to use a map, you must now convert the compass bearing to a 'True bearing'.
Firstly mentally change the compass bearing to a magnetic bearing if you are aware of any compass deviation i.e. compass errors. (You usually do not worry about compass deviations when bushwalking.)
Next mentally convert the magnetic bearing to a true bearing using the East-least, West-best rule.
Example: "6° variation West" (The Magnetic *North* is West of True) "Compass Best" so… 065°C = "059° True"
Lastly, physically change the protractor to read 059° when you want to draw on the map, at an angle to the map's True North.

See opposite & above Plotting a ('Compass-to-Map') Back-Bearing

Draw a line on the map from the landmark in an opposite direction. Use the protractor to get the angle right.
If you see a landmark North of you, you must be South of it.
Or, what looks 'South-West of me' must mean that you are 'North-East of it'.
Think backwards! See "Back bearings: +/-200° then -/+20°" p.18e E.g. 059°T from me to it…
Note that I have already converted Compass to True. 239°T from it to me.
One bearing yields **one** line of position (from a back-bearing plot — diagram 1)…
Two bearings from two different directions cross for a 'fix' — diagram 2…
Three bearings don't cross. They form a 'cocked hat' and keep you humble — diagram 3…
In this case, you could be anywhere nearby (which is also true for any "Fix").
Expand your possible positions, don't try to pinpoint a "better" one.
Take more care next time, especially on the closer i.e. the more reliable landmarks.
Check your compass for fixed errors e.g. "always 3° too much".
Choose directions which are quite different from each other, to get the clearest crossing.
Compass to Map Mnemonic: (Compass B.E.A.Ring, then) **Compass to** Grid (or True) Correction;
Make it a Back Bearing; **A**ngle to Grid; **P**encil to Paper—Draw It in. (Think: "Mangle" to remember A)

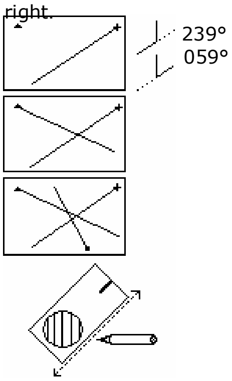

No-Number Back-Bearings

Method 1. Use the white-tipped (South) end of the compass needle, when you take the bearing.
Method 2. Point the "follow me" arrow back toward you, when you take the bearing or follow the compass.
Method 3. Line the protractor zero up with Map South, when you plot the bearing.
Method 4. Point the compass edge to the landmark on the map and draw your back-bearing line backwards from the landmark.
You don't need to alter the compass setting at all (except for the magnetic variation or grid/magnetic convergence angle).
Warning 1. Don't mix back-bearing shortcut-methods, or you may get a 'double negative'!
Warning 2. Check all you do, against reality, for sense.
Warning 3. Don't try to shortcut Compass-to-True conversions at the same time as shortcutting the back-bearing, or you will get confused.

Parallax While You Walk — JUST DRAW IT!

Most **hand-made maps** start with **a known baseline** scale — a straight segment of a known distance.
I.e. "I walked from here to there in a straight line for 1 km" — for this you may need a pedometer.
Or if you are Captain Cook or Matthew Flinders "We sailed on (this) bearing at (this) speed for (this amount of) time"

You can then **add cross-bearings at any time** to fix the position of distant landmarks — obviously at the beginning and end of the baseline are the preferred places, perhaps combined with one from the middle…
The longer the baseline the more accurate the fix on distant marks.

You really only need a protractor for this **running base-line triangulation**.
(And on a Mudmap, you just eyeball the direction and draw an arrow in freehand.)

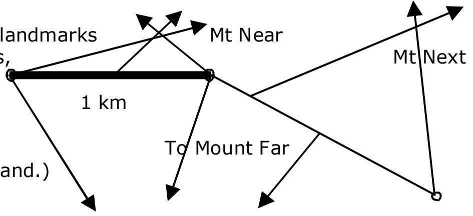

Here is an example of the easiest sort, and the reverse of a double-angle…
After a week at sea, with no sight of the sky to navigate by, I was understandably over-anxious about my position, and "needed" a "fix"! I decided to sail toward an isolated lighthouse-island, in the hope of passing close enough to see it, perhaps, if we weren't too far off course. The winds were hurricane force, of course, and the sky was filled with salt-spray lifted off from the water's surface. It was dusk. Suddenly, above the mist, dead ahead, the lighthouse turned on! Alarmingly high, and close. Too close!
Were we "found" or about to be "lost"!? (See "Aiming Off"!) After the cheers: "What do we do? How far off are we?!"
"Turn at right angles to it; Maintain that course; Take regular bearings until it is diagonal; Keep track of the distance run. Then resume your course. That way we can tell how far away it is."
"How can you do that!" said the bewildered, inexperienced navigator.
I replied: "I'll **just draw it**"

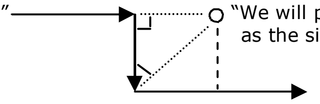

"We will pass as far away as the sideways distance we have run"

A "Start-Stop-Rest" Navigation Mnemonic Overview

START

"Start" has six points, as illustrated in the diagram below…
These mnemonics, e.g. S.T.A.R.T. or S.T.O.P., will be expanded in the rest of this section—they summarise the book.

- Start with a **Prayer** — "What more do I need to do to avoid getting dead?"
- **P.R.E.P.A.R.E.D.** — What have I forgotten to do or to take, to practise or remember? Start off oriented before you go!
- **S.T.A.R.T.** — with your start-off-trend-direction, which is the single most important navigational item. Start off aligned!
- Start on **T.I.M.E.** — Read your watch, and benchmark your trip. Say: "Time & Tide" as well, because sometimes tide levels are crucial.
  — Check pace & progress. Estimate the Range, because time is all about distance.
- Start time is **6 a.m.** — It's always time to **look** in **6** directions, plus 2—Time to Look **A**ll **A**round, **A**ppreciatively, plus time to look at the **M**ap
- Start with **N.S.E.&W.** —4 sets of 4 directions. The final W is for **W.E.A.T.H.E.R.**

The final R signals that you are **Ready** to go. Don't start until you **R**!

S.T.O.P. A **S**top is a **S**ignal—Interpret the Why? of your stop: Does it **S**ignal a change in watershed, catchment or view;
in **T**rend or **T**errain or '**T**ime & **T**ired';
in **O**rientation (embarrassment—if lost, rule one: Stop);
in **P**rogress/**P**osition/**P**lacement—campsite, junctions, features?

REST is best remembered as a mnemonic of 5 RE's…
R.E.-O.R.I.E.N.T. — using these letters as a mnemonic. E.g. **RI** re-Visualise the Invisible Big Picture, and **ENT** Relate yourself to Nature.
RE-RE.L.A.T.E. — re-interpret all directions to relate to each other and to the skyline, as explained below. Now don't forget...
RE-MEMBER — the WAY and the SEQUENCE and especially to NOTE down (in the NOTEBOOK) the NAMES, and DRAW what you need to.
RE-LAX — Play the Navigational Game—teach it—and 5 other games.
There is a final '-art' to 'stop and rest-'
RE-ST-ART 1.1 **re**-pray; 1.2 **re**-prepare; 1.3 **re**-s.t.a.r.t; 1.4 **re**-t.i.m.e.; 1.5 **re**-look (6 a.m.); 1.6 **re**-direct (NSEW), (which includes **re**-weather)
... e.g. 1.3 Re-S.T.A.R.T. after a rest, on the next leg—to relate it to the last & to the *start*-finish trend.

Summary: **"Start"** 6 times**; "Stop, and Re-st-"** (with 4 new **"Re-"**s)

(The Start mnemonic is a good example of the "clumping" technique
—never more than a handful of things to remember, yet it leads you into hundreds of points.)
Put the S for Sky at the top, where it should be.
Use a hexagon for the 6 START up points.
Use a clock-face for TIME,
and the compass-rose for NSEW.
Show the 6 directions in 3 dimensions.
Balance it all on a triangle
—for the "6 a.m. start" , since it has 3 parts.

See the boxes to follow

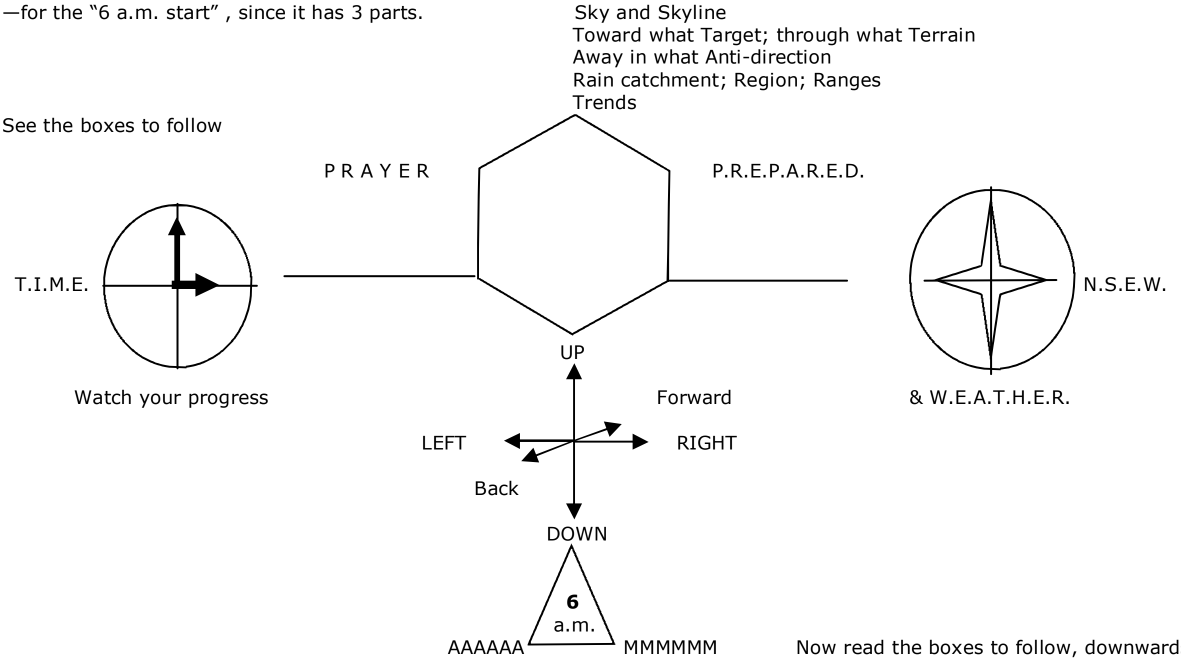

Now read the boxes to follow, downwards...

P.R.E.P.A.R.E.D.—A Before-You-Go Checklist ..so that most of your navigating is already done, from home!

P.ractise Global orientation. Get a blow-up globe. Teach others. Learn (what to learn, look for, do etc.). E.g. predict the Sun.
Learn the Mnemonics, Codes & standards e.g. S&R signals, compass directions
Pace your paces — metres per minute; steps per 10 metres. Left-right bias (blindfold).
R.esearch History. Ruins. Artifacts. Mines. Geology. Get a geological map from the library. Landform. Soils. Climate. Windy season. Prevailing winds. Wet season. Vegetation analysis. Rare species. Biogeography. Geography — global neighbours; time zones; local coasts & river mouths. Catchments. Cardinal features — places N,S,E,W from you. Land lines on map. Place names — their meanings and history.
E.quipment See the next box.
P.lace names See the box after that.
A.stronomical orientation Sleep on a map, and with a compass nearby. Point the map North. Times and directions and heights of Sunrise & set, Moonrise & set. Southern Cross. Pot. Sun at noon, at magnetic North/South, when East, when West, at magnetic East and West. What landscape markers (from the map) for these directions? The star opposite the Sun. Time zone. Local noon — its exact time. The Sun's coordinate predictions. Your longitude. The "Equation of Time". Moon-phase, -number and –day of week. Tide times.
R.eminder Note your intentions—and tell someone where you are going and when you expect to be back.
E.xpectations of the Weather Barometer reading. Get the Weather forecast. Follow the Changes. Buys-Ballot's law. Steering winds.
D.irections & Familiarity Ask someone who has been there. Read track guides. Look at an aerial photograph. Go beforehand! Find your old track notes. Look closely on the way in. Choose a route. Plan your strategies. Coordinate the cars, the car keys, any food drops, shuttles or codes

Equipment — A What-You-Might-Like-to-Take Checklist

(E. in PR**E**PARED, for "Equipment"…)

- **A Map** **A compass** **A clock**
- A notebook and pen — for track notes. A track guide. An aerial photograph. A navigator's handbook.
- For map making — graph paper, paper, pencil, a compass-holder. A map-holder (string around neck to a…), clipboard, stopwatch.
- Polaroid glasses — to orient by the dark blue sky band. Radio — for RDF, weather. Mobile phone. GPS. Camera.
- Binoculars. Pedometer. Rangefinder. Calculator. Altimeter. A sine-cosine table.
- A map cover. A spare map. A navigational protractor. A magnetised needle. A sundial compass. A two-flap cardboard compass.
- Marker tape; Chalk; Scissors (for cutting leaves!). A clear plastic tube. A clear plastic drinking bottle (for an artificial horizon).
- A long piece of string (e.g. for a range-finder). Short pieces of string (e.g. for a plumb-bob). A walking stick. Someone who knows the way.

(P in PRE**P**ARED) **P**lace-Names —Learn Them—You Navigate by the Local Features!

"Look. That's Big Split Rock and that's Little Split Rock. Wild Dog Tier is that range over there, and this plain drains out over there, into the Ouse River You can find your way anywhere around here from those."

Suddenly I was unforgettably oriented, just like he said he was, when his dad told him.
For me, the funny names on the map now meant something worth knowing.

Place-names are not just names you don't know; they name places, which you ought to know.

More accurately, place names 'place' you in the landscape, as well as 'orient' you to it.
A sense of location is almost independent from your sense of direction, and is rarer to come by.
Direction-sense places you in relation to very distant background references i.e. it doesn't 'place' you at all!
Location-sense places you in relation to the immediate foreground — visible landmarks, catchment basins, fixed 'tracks', etc.
Place Names Place You

S.T.A.R.T. off Oriented

— **S**tart-off Direction? (e.g. "upstream") — the **S**ingle most important navigational knowledge — it tells you the return path, and the search path.
Sky/**S**kyline i.e. especially according to the **S**ky (e.g. "toward the Moon; into the sunset") and related to the **S**kyline.
Start-off directions for the parallax method, pp. 51a,53a, e.g. to magnetic NSEW skyline or recognisable middle-ground points, or rhumb-line point and another set of such bearings, taken from the map, as seen from the finish, if you are on a one-way trip.
— **T**oward what **T**arget? Specify a
Track (e.g. "downhill to the lake") or a **T**rend. A rhumb-line bearing is best—from start to finish.
Through what **T**errain? (e.g. especially see what the land-shapes would look like without vegetation)
— Away from What Point? (e.g. "from the lookout carpark), and in what
Anti-direction (e.g. toward that other peak"—a skyline direction)
— **R**ain Catchment — In what major
Region? — as can be gauged by the surrounding
Ranges. (e.g. "on the main spur dividing North from South arm, downstream of…")
— Trend: **R**ead the **T**rend off the map, for starters; then continue to **R**ead the **T**rends & bends and the progress as you go on.
Read (your compass; map; watch) in **R**elation to the **T**rend, i.e. in order to follow the trend, which is the focus of this mnemonic.
Plus: **R**ead any other **T**rends, from any other places, from memory, in relation to the sky. Be able to revisualise them at will.
— Re-s.t.a.r.t. on the next leg, to relate it to the start-finish trend, and to relate it to the previous leg.

T.I.M.E. & Distance — that's the point

TIME to Look at your Watch — PACE YOUR PROGRESS — the point of this T.I.M.E. mnemonic is distance.
— "Watch" your steps—i.e. calculate your pace from the elapsed time;
— "Watch" the Sun without looking at it, because your watch tells you where it should be.
— TIDE times may be necessary.

Instrument Check — watch, stopwatch, pedometer, odometer, rangefinder — for progress
— compass: Double the bow angle, or halve the stern angle p.94c; parallax readings on landmarks.
— (and other instruments — barometer, altimeter, GPS, radio null, radar, depth-sounder)

Map-Scale Check — are you judging the scale well? — What is the next goal? (This M is not for Map in general, but only for distances.)

Estimate the Time of **E**xpected Arrival — guess each milestone ahead of time to set you free from a nervous TIME. Nominate an E.T.A.

Distance

PROGRESS: can also be gauged by lines of sight and changeover lines. Use a stopwatch, or pedometer. Read the scale.

PACE: distance divided by time; 20min/km, double and halve = 3kph; 1mps = 3.6kph; 4kph normal walking pace;
finger-math helps; pace yourself evenly.

RANGE: Use the letters of RANGE & FACULTIES as a mnemonic to remember the different ways of gauging distance in the distance...
Range squared = dee height; Area divided by offset; New direction parallax; Grass-leaf vertical angle, horizontal angles too; Educated guess
Familiar lengths, and Fingernail Rule; Acuity of vision and Apparent sizes; Cloud behaviour; Upper and lower guesses, averaged; Landscape lengths;
Tom Thumb Parallax; Intervening detail & haze alters your perception of distance; Extreme range comes in two bites; Sound travels at 1 km/3secs and
Sidewise offsets with blinking.

150km from 1 nautical mile high; 1° latitude from 1km; 50 miles from 500m; 50km from 1/5 km; 5km from 1/500 km (2 m); 12.7km from 12.7m.

Look in These 6 Directions — in 6 ways — Up and Down (Part of "Start at **6** a.m.")

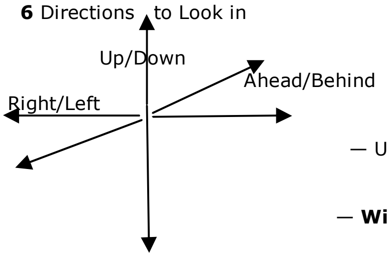

UP — **Astronomy** — Sun Moon Calendar-Stars
— **Sky** — Clouds, Contrails — Blue Band
— What's up with the Weather?
then DOWN —Geology — **Soil** Type; Rock Type
—Clues — Animal **Trails**; Bootprints; Fallen markers

— Up-**Sun** — haze & glare
— Over what tropical country? Then — **Down**-Sun — haze, shadows, colour changes

— **Wind**-wise — Up-Wind — Where on the skyline? — Down-Wind — Around what obstacle?
— Around what pressure system? (Wind in your face)
— From what coast/ocean? Listen; Smell
— Up-Breeze — To what cold surface? — Down-Breeze — To what warm surface?
— What's up-Weather? Where are the steering winds coming from?

— **Land**-wise
— Up-Hill — To what dominant peak?
— Point to the dominant peak, even when it is invisible,
— Down-Hill — antidirection?
turn around to see what lies away from the peak — the "anti-peak",
especially in relation to your shadow — this anti-direction has a lot to
do with a compass back-bearing—a visible line of position, you see
— Up-Ridge — To what hill/hillock? — Down-Ridge — Down which ridge? — To what headland?
— what offshore/underwater topography e.g. shallow reefs; islands?
Since this mnemonic is about direction, try to point to them.
— Up-Slope — To what ridge? — Down-Slope — Into what valley? Name them.
At what angle across the gradient?
— Where is the lowest upslope skyline, under the canopy? — Where is the highest downslope skyline, under the canopy?
— Up-**Stream** — To what distant divide? — **Down**-Stream — What stream? To what distant mouth?
— to what sedimented shelf; or deep-water channel?

Summary: **Above & Below** (twice each) + **Sun & Wind** (above eye-level) + **Land & Water** (below eye-level) = 6 ways for "Up & Down"

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4 More Slopes

1 in 4, is 14°;

10° (aim off, 1 in 6) is 175 m per km;

1 in 60, is 1° (1 in 57.3 is the exact figure, but it doesn't multiply up linearly after a few degrees, whereas 1 in 60 does well after a few degrees)
& n° is n in 60
(1 in 6 is 10°; 1 in 10 is 6°);
The equivalent is 5/3 in 100, 5 in 300, 167 in 1000, for use with multiplying up with the isosceles triangle angle method.

36°, 8 in 11, is critically unstable.

Multiply them up, inversely.

Look in These 6 Directions — in 6 ways — Ahead and Behind

Look Back Regularly: Is bad weather sneaking up behind you? (p.46c) "Abracadabara Peek behind you" (p.63b)
How much has the track bent around behind you? Any acute track junctions? Can you remember this way back?
Compare Forwards with Backwards: Do you need a back bearing? Are you half-way? Is your starting point visible, to get an anti-track forwards?
Are there any changes in the terrain, to photograph, in your mind? Have you memorised the transition, from the far side?
Look forward — in **time** — the forecast! What is the Estimated Time of Arrival? Look Back — in time — How far have I come?
Look ahead and behind in **U**pper case **Time** — Could you recognise this place much later, in hindsight? — What is the history of this place?

Look AHEAD — Has the **view** changed — into a new catchment? Look BEHIND — Have you left the old view behind — crossed a divide?
— at the terrain, the track showing up ahead, and the difficulties — Do you remember the **way**? Could you recognise it again?
— Look for track **markers**, and for trails ahead — Look behind for hidden, reverse track markers.
— Line up two (new) marks exactly ahead to keep your direction sense. — Look for the old lined up mark left behind.
Is it time to choose another leg, and a **pair of marks** lined up to it? Do I need to find new ones behind me?
Mnemonic: R,S,T-U,V,W,X-Y-Z **R**egularly **R**everse your nose. **S**tart/anti**S**tart bearing & **S**napshot-**S**equence your transitions
time (+**U**pper case Time); The **V**iew; **W**ay (remember it?); **XYZ: X** marks the Track (Markers); the (**Y**&**Z**) Leapfrog Marks =6 ways for Ahead & Behind.

Look in These 6 Directions — in 6 ways — Right and Left

Look RIGHT Through! 1. — the bushes, to the land-form underneath; to the contours & bedrock
2. — the canopy, to the skylight beneath it
3. — the trees, to the most distant marks, including other trees
4. — the treetops, to the sky — the Moon, clouds and the blue band
5. — the foreground, to the most distant skyline horizon, whenever you can glimpse it
6. — the haze, to the skyline details beyond the land horizon—use binoculars too.
E.g. to barely visible mountain peaks, or a second skyline & its parallax, or to islands in the haze, or the rising Moon.
Look LEFT 1. — to the most distant thing you have LEFT BEHIND on each side! i.e. Have you left it behind yet? Is it time to choose another one?
2. — Have you left behind your: handbook; air photos; track guide; track notebook? — No, well, don't just carry them — Look at them!
3. — Have you left anything behind at the rest stop? It's an important habit, to ask this each time you move.
4. — Look to the right and left, for the contours, the natural 'tracks', and the behaviour of the network you are crossing and leaving behind.
5. — Things on the right have big bearings; things on the left are lesser; than straight ahead, even less as you leave them behind.
6. — NORWest & NOTLEast — North needle 'on the left', means you are heading roughly East. (N. On your Right = West-ish)
Summary: **Right Through & Left Behind**.
In summary for all the 6 directions make sure you **Check Each One Out—Thoroughly!** (6 ways each)

..Plus in 2 More Directions — (1.) All, Around, Appreciatively, And At 6 L's

1. **A**ll your senses: Listen, Smell. Look around with your other senses.
2. Look 360° **A**round for the best & worst showings of colour, shine, flowers, greenery, new growth, fern fronds, lichens, trunks, branches, dirt. Compare Ahead with Behind, & Left with Right, & upSun with down-Sun, & up-wind, uphill, etc. for direction-dependent light and colour effects.
3. **A**PPRECIATE — the scenery; the colours; the contrasts; the shapes, outlines and silhouettes; the foreground movements.
4. **A**n Environmental Notice Time (see later box E.N.T. in REORIENT)
5. **A**ny LOCAL PECULIARITIES to remember.
6. **A**nd **A**t — **the six L's...** — **Land**marks — distances, sizes (apparent Largeness), altitudes Use binoculars.
   — Are any familiar, from other walks you have done elsewhere?
   — Do the place names make any sense? — interpret them!
   — **Lay**out — relative angles, compass bearings. Am I inside or outside of major landmark circles/triangles?
   — **Lie** — slope and terrain, catchment and drainage, contours and altitude
   — **Lines** Catchment Dividing Ridges and Rivers; Contours at right angles to the slope; Flight Tracks
   — **Ligns** — 'Same direction' Lines of Sight, or nearly so; and 'Opposite directions' alignments: Am I in between?
   — the fixed A-lignments . Am I left or right of major 'ligns'?
   — **Sky-Line** — talk it through; draw it. Cross-relate all directions to each other, and to the skyline

Summary: 'A' for 'a.m.': 6 A's, with 6 L's

..(2.) Look at **the Map**: a Systematic Checklist. (What 'System'??)

The system is to examine **top-down**. From general to specific detail. From large-scale to small-scale. Look for the downward progression in these…
3-D location: Latitude, Longitude, Elevation. Centre of the time-zone. The inset map showing where you are on the continent. Scale & size. The overall width- and breadth- distance of the map coverage. Grid size e.g. 10 km squares. Where you are on the map, geometrically too. The Starting Point. The Relative Location—over the horizon landmarks; coastal towns N.S.E.W. of you; something NE,NW,SE,SW of you. Radio stations. Highways. Light sources. Powerlines. Pipelines. Place names. Visible Landmarks. False peaks. Lines of the land — between landmarks. Recognisable hill-hill reference distances. Recognisable elevations e.g. towers. Grid North; True North; Magnetic North; Magnetic Variation; Yearly Drift in Variation.
Catchments & Divides; Catchment Size; Adjacent Catchments; River Drainage. Land shapes i.e. interpret the slopes, contours, the contour interval.
Trends and Bends — of the coast; rivers; roads; ridges; ranges; the track. Notice any creeks which flow backwards i.e. against the trend, and why.
What rising ground will be visible in each direction? Perimeter features surrounding your walk e.g. a river, a range, a road, the coast, a forest. Escape routes — unplanned exits. What are the ridge-line limits of the sub-catchment which most encloses your possible location? What high points are on it? Possible routes. Clockwise or anticlockwise? Distances. Overall distance of your route. Milestone features. " Wake-Up " landmarks.
Initial bearings to landmarks. Initial angles to landmarks. Initial horizontal angles to landmarks. Final bearings. Rhumb–line trend from start to finish Around what Obstacles? Fine details of the route. Don't forget the fine print — the date and reliability of all the map details; the grid datum for GPS use; the legend of symbols; colour codes; contour line thicknesses.

Mark the Lines-of-the-Land On Your **Map**

6 M's for Map:
Map Checklist (above); Map-Lines (this box); (all below...) Map Alignment; East-Least West-Best Mnemonic; Map & Compass; Map-Making Methods.

Pre-prepare your map — **Mark in the navigational lines** which the mapmaker has left out. Most of these are permanent.

A. Cardinal Tracks — NSEW lines. Across the whole map, from the very prominent peaks; or simply covering a local area, from the local peaks
B. Alignments — e.g. from Peak to Peak; Tower to Town; Point to Point — You may see two in line, or walk in between two landmarks.
C. Directions to major distant features — (for orientation purposes) — e.g. capital cities; coastal towns
D. The Overall 'Track' — the RhumbLine — from start to finish. Mark this lightly; &/or two or three obvious overall 'legs'
E. Circles of Distance Off — e.g. 5, 10, 15 km from Mt. X.
F. Circles of 90° horizontal angle — i.e. make two landmarks the diameter of a circle
G. Circumscribed circles around (i.e. which just include) the triangles in the triangular grid of landmarks
H. Transmitter to Transmitter networks — i.e. a triangular network of major peaks; include the distances and bearings on each line.
I. Flight Paths — if you can get hold of an aeronautical chart — it forms a second triangular network.
J. Catchment divisions.

Mnemonic: Four Straight Lines; Three Circles; Two Sets of Triangles; And One Very Sinuous Set.

Mnemonics for **Map** and Compass Work

◦ Map Alignment

A.L.I.G.N. the **M.A.P:**
A… Align the map to Sun with an imagined **A**rrow, and to your course with **A**nother **A**rrow;
L… to the **L**andscape;
I… To **I**dentify Landmarks and to get a Fix;
G… **G**rip the Magnet to the Map, and the Map to the Universe;
N… **N**ot "Swinging the Map" As You Turn;
Magnetic Needle to **M**agnetic North (in four variations, "0°" to North or arrow to course, Magnetic or True);
Angles Horizontal, fit over the map;
P… Align the **P**ath like landing a **P**lane, or align the map by aligning the **P**ath.

◦ Mnemonic East least, West best

East is Least and West is Best, tells you the North which gives the bearing that is best. i.e. the biggest in number; or lesser in number.

◦ Map & Compass

LMNOrP: Landscape; **M**ap; **N**eedle; **P**rotractor; either one **O**r two at a time, but not all three.

M.A.P. To Com.Pass, = Map to Compass Course, Means…
Map Grid to Compass Zero; **A**ngle the **A**rrow to the course target; **P**ut on the correction;
To Get it, use the East Least West Best Rule;
Compare the Compass Zero to the Compass Needle; **Pas**t the Follow Me Arrow is the Course Target.

Take a B.E.A.Ring: Bearings are Tracks; (**E**xpect to have to plot a back-bearing); **A**rrow to Landmark; **R**ing to Needle and **R**ead it off.

Compass to M.A.P.; Compass bearing, then **Compass**-**to**-True Correction; **M**ake it a Back Bearing; **A**ngle to Grid; **P**encil to Paper—Draw it in

◦ MUDMAP:

Mudmap on paper; **M**ark the start point on one edge; **U**p-arrow for orientation (**U**pdate it); by a Reference **D**irection (Up**D**ate it);
Maintain a trend, a long straight leg; **A**lign the **A**rrow when you stop; **P**encil in the **P**rogress, and a new leg direction.

◦ Other **M**apmaking **M**ethods — Use the letters of COMPASSES:

Copy a Map Top-Down; Own Map is Valued; Mental Map—Map to Mind Navigation; Parallax onto a Running Baseline; Accumulate the Layout Blind; Sine-Cosine Tally of Accumulated Eastings and Northings; String Map; Exploring a Cave System Needs a Book, of Strip Maps.

“N.S.E.& W.” — the four cardinal directions, is a mnemonic of fours

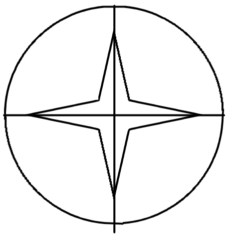

N for “**N**orth Coast” — all about visualising the invisible directions…

Name which coastal towns are N. S. E. W.
“**S**weetheart” features Name your favourite spots NSEW of you
Encircling horizon features — **Horizon** North; **Skyline** South; **Environmental** East; **Landscape** West.
Which-way-am-I-going trend (rhumb-line), from the map, then marked onto the terrain—e.g. to behind that hillock

S for “**S**hortest **Shadow S**outh” — all about the path of the **Sun** (and Moon)—the 1234 system
— and the **S**unny **S**kies quadrant system
— How the Sun, Blue Band trend & ends, and your Shadow, currently lie in relation to…

N Highest **Noon** (How High?)
S Shortest-**Shadow** Souths (SH) & the two-flaps South. Coldest South is the best reference in the SH. String South using the Sun’s Shadow.
E Sunrise (Where?) Anti-sunrise from a string-line to the horizon.
W Sunset (When?); Bisect them. Anti-sunset from a string-line in the afternoon.

E for **E**quinoctial **E**ast—i.e. other things astronomical, **E**tc.

Needle-North-Seeking-Northern-Canada—over Red Hot tropics!
South Pole Star (How High?) & Southern Cross (Where?) & Star-Chart octants & Star Compasses & Star Fixes
Ecliptic & Equator & Equinoctial Precession
W for the motion of the Pot, s**e**tting in the W**e**st (rhyme), at the latitude angle

W for **W**ind **W**est, i.e. Natural Directions.

N for Nature’s Norths: Rock Noon; Botanical Noon; Solar Panel Noon; Satellite Dish North
S for Snow South; Frost South-East; Steep Gully South; Mud-in-the-Shadow South; Dead South; Siesta South.
E for Moss East-South-East
Wind: Upwind: scorch, erosion & flats, Downwind: shelters, debris & steeps; Noise & colour from up-wind; Rumble & skyshine from downwind.
& **W**eather Directions (& see below)—Where is Wind West? What is Upwind? Upper Winds Steer the Weather (from the West?) What is Upweather?

Summary: 4 directions with 4 variations; Then finish with **W**.E.A.T.H.E.R. After a rest, re-direct yourself.

W.E.A.T.H.E.R. — Check for Change

W. for Wind. Has it changed — in strength, direction, gustiness?
for Wind — in Your Face — Low on Your Left. Low winds bring the rain, clockwise.
for “Weather systems come from the West” — in temperate latitudes — can you make a prediction?
for the upper level steering Westerly-Wave Winds — are they deviating much from average? Are they steering a storm toward you?
for “Wind-West” showing up in the vegetation, for when the prevailing wind is not blowing.
for the prevailing Westerlies (or whatever).
E. for Ephemerals — i.e. the clouds and contrails (don’t forget this E.!)
Have they changed? — in height, type, wateriness, thickness, darkness — in directions — steering wind directions? In relation to the Sun?
— Examine them carefully for dissipation (i.e. thinning, soft edges, layering) or for building up (hard edges and heaping).
A. for Atmospheric Pressure Change — imagine the isobars across the land from the forecast.
Sometimes you can see a lowering atmospheric pressure when marsh gas starts to bubble in cold weather i.e. not due to warming.
T. for Temperature — of the air-mass
H. for Humidity — the absolute one (measure the dew point — will it frost?). For the relative humidity try huffing to produce a fog, or onto metal.
Does the air mass humidity & temperature, speed & turbulence let you know which direction the wind must be from?
E. for Expectations — i.e. the weather forecast — test it — is it coming true?
R. for Rain — Will it? R.ight? Are you **R.eady** to move? Grab your R.aincoat and let’s go… Keep looking until it is time to S.T.O.P. for a rest…

Oriented? No?
Rule one: Stop! getting more lost.
Rule two: Start! getting unlost. Start navigating!
Rule three: Stay, or Steer a Straight course.
Rule four: Don’t do it again!

Position/**P**lacement/**P**rogress—has it changed?
Have you arrived somewhere?
Is it a named feature? A campsite? A junction?

Have you changed view?
Have you changed catchment?
Interpret the Why of your stop...

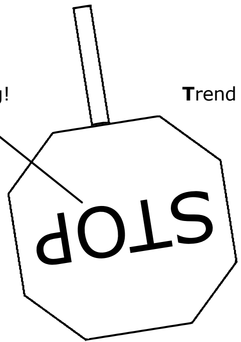

Trend And **T**errain—Has it changed?
Time & Tired—Does that explain your stop?

Stop -Signal: Why have you stopped?

REST and R.E.O.R.I.E.N.T yourself

Take 5; a 5 minute rest; REST is a mnemonic of 5’s.
RE-RELATE; **RE-ORIENT; RE-member**; **RE-lax;** (= the 4 new RE-’s before you) **RE-start**. = 5 RE’s

RE-RELATE to the skyline.
RE-RE for Re-Read the map,
L for Re-Late the Map to the Landscape
A for Astronomy—relate the Sky to the Skyline
T for Trends—imagine the Trend of invisible landscapes, in relation to the Sun, and relate your current trend to a point on the skyline
E for Each direction clue Re-lated to Each other direction clue, especially to the landscape/skyline shapes.

RE.O.RI.ENT — **RE** for Re-Orient the Map to the landscape,
— **O.** for **O**ops! Don’t make logical blunders; Have questions on your mind; notice; speak up; integrate; connect; interpret.
Observe the **Overall** trends and bends.
— **R.I.** for **R**e-Visualise the **I**nvisible (Next checklist; and see Section 1 Astronomical Overview; Include the clock-sense mnemonic here)
Re-late yourself to the Big Picture
— **E.N.T.** for an **E**nvironmental **N**otice **T**ime — Re-late yourself to Nature — coming up.

R.I. For Revisualise the Invisible (and then Relate It to the skyline!)

Work down from the Biggest Picture. Work most on the ones you can’t yet visualise.

Astronomy — Visualise the paths of Sun/Pot/Moon/Stars; Point to the South Pole Star; North Pole Star; the **Clock-sense** of stars around each Pole
— The star opposite the Sun during the Day & during the night; the Southern Cross during the day; the Ecliptic; the Milky Way
— Earth rotation; Horizon rotation; horizon trails; clock-sense of Horizon rotation; **clock-sense** of low stars’ movement around horizon
— the Moon-Sun, and Ecliptic line; The Moon phase explaining the present tidal force. See the overview at the end of section 1.

Global — Latitude; Polar distances; Equators; Earth Poles; Seasonal Sun height; Shadow South — visualise the aurorae; Antarctica;
— North Magnetic Pole in Canada, as a ‘South-seeking’ Pole; Aurorae; Unequal Tidal bulges. “Go Overseas” p.25e.
— Tropical countries — corresponding to sunrise, noon, noon height, sunset, the country under the Sun now, the time zones
— Light & Dark halves — Sunrise-/sunset-circle countries; Half the arc-distance; How the horizon is shifting due to your movement.

Continental — Weather map isobars—visualise them across the continent — the one in front of your eyes, and on a continental aerial photo.
— Latitudinal wind system and pressure system helices.
— North Coast; N-S-E-W townships; NW-NE-SW-SE features. “Walk across the Continent” p.29e. “Compass-needle Continent” p.9e.

Local — Catchments; Divides; Mouths; Mounts; Radio Transmitters; Night Lights
— Nearby landmarks & places & highways; Home; Car
— Perimeter features; Escape targets & Routes — Bird’s-eye layout of your route.

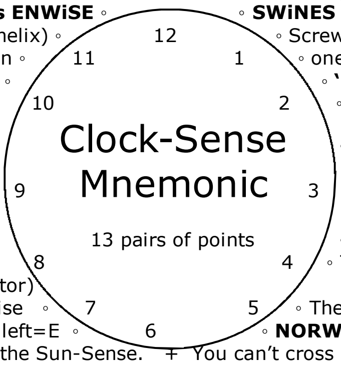

0 The standard viewpoint is “seen from above”; ◦ Clockwise is to your right; Compass Bearings Circle Clockwise;
1 Wrong Way Go Back! **Anti clockwise is ENWiSE** ◦ ◦ **SWiNES** That’s how the Sun moves in the northern hemisphere
2 Unscrewing is an anticlockwise motion (on a right-hand helix) ◦ ◦ Screwing in is a ‘right-hand’ motion (for a right-hand screw)
3 24 hour clockfaces have only 15° per hour, like the Sun ◦ ◦ one hour = **30° clockwise**, on the 12 hr clock face method
4 High pressure systems circle **anti**clockwise in the SH ◦ ◦ **‘Low’ winds** come clockwise, in the SH.
5 Things on the **Left** have a **Lesser Bearing** ◦ ◦Things on the **Right** have a **Bigger Bearing**
6 All the solids rotate **anti-clockwise,** seen from the **N.** ◦ ◦ **Low stars** all around the horizon follow the Sun-sense
The ground under your feet shifts anti-clockwise in NH ◦ ◦ The ground under your feet turns clockwise (SH)
7a&b So the ho**RI**zon **N**ever **H**eads **RI**ght in the **NH** ◦ ◦ The ho**RI**zon **SH**ifts **RI**ght in the **SH**
8 Wind-shift due to ground friction opposes the Sun-sense ◦ ◦ Coriolis forces follow the Sun sense
9 **North lies between the SH Sun and the hour hand** ◦ ◦ The NH Sun is between the hour-hand & South
(actual noon points to Sun; clockface tilted parallel to Equator) (noon-time to Sun; axis to Polaris)
10 The SH Sun seems to move anticlockwise ◦ ◦ The Moon goes backwards, night by night (clockwise, in SH)
11 Nose Nav’n turns everything away **NOTLEast** Nth on the left=E ◦ ◦ **NORWest** — Needle-North on the right = heading West
12 **Shadows** Follow the Sun-Sense. + You can’t cross a stream twice in the same flow-sense

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E.N.T. for Environmental Notice Time —Orient yourself to Nature

Take **a top-down approach**...
Geology; geo-trends; geo-morphs i.e. landforms; geo-Norths
Dividing ridges; dominant peak; upstream catchment size; wind shadow; rain shadow
Season; climate type; prevailing wind; average rainfall
Rocks; bedrock; outcrops; parent rocks e.g. upstream
Soil types; nutrient availability
Soil Drainage — good or poor; Water Sources; groundwater? salinity
Aspect i.e. which direction does the slope face, in relation to high noon?
Living stresses? — salt, minerals, wind, exposure, frost, heat, low humidity, fire, flood, wet roots, pests, diseases, competition, grazing, trampling, disturbance, rock instability.
Vegetation type; the overall density of green, and of cellulose, and the height; dominant species; associations of plant types; diversity; individual species; individual plants. Pollinators available; seed dispersal mechanisms operating.
Mammals; Birds; Reptiles; Insects. Drinking water availability, cover for animals, hunting pressure
The ‘Natural Norths’ — Gully North; rock North; Bush North; insect North; Dew North; snow North; ripple North; prevailing wind North

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RE-MEMBER to Note down the Names in the Notebook

Remember the **Way**, and the **Sequence**.
Remember to take a Notebook. Make a neat permanent copy of your notes i.e. in ink, maybe sometime later on, in your master track notebook.
Be Bit-wise!
Name the subsections, junctions & links. Name the peculiarities. In the name, try to include…
The Why, When & Where of your stop. Link & Sequence information — time, distance, context
Lie of the Land Words to indicate the direction trend, & curves — left or right
Visual words — colour, shape, alignments, curves Descriptive words. Collect the details. Enlist the others to describe and name it.
Give yourself something to remember — create an acrostic; craft a creative name; sit down and write up your track notes
Update any acrostic alliteration. And the count e.g. of the creek crossings. Do something numerical. Do something alphabetical.
Be vivid, clever, memorable. Do something Shapely or Geometrical there Do something Memorable there. Do something there.
Draw the shapes, outlines & skylines. Draw the directions of other landmarks from any high viewpoint. Take reference photographs.

Remember most of all to do it all — don’t just recite the reminders to do it all!
Mnemonics of Fives: Remember the Way; the Sequence; Make Notes; Invent Names; Draw What You Need to.

Re-lax, and Play — Navigation Games and Activities (5 pairs to recall)

Walk & Talk — a night walk — a fog walk — a walk off the track — climb a hill with a small scale map & binoculars & compass.
“Track My Trail” (“If you want lunch, you’ll have to find me — give me a quarter of an hour, then track me down”).
Keep a compass course, blind — keep a straight course, blind — on a slope? “Let’s all make an acrostic to remember this track by”.
Try Orienteering — Try making a map of a maze of trails — then a string map — a strip map — or a sine/cosine tally map.
Look & Learn — “Go to the front of the line if you spot a track marker which the others have missed” In a windy place look for wind clues, etc.
Take it in turns to name a navigational or orientation clue which is visible, until you have to drop out.
“I notice… (fill in the blank). Your turn. What extra can you add (to the description, or to the clues)?”
Guess & Test — Each of you estimate the time of arrival; the direction to the car; the distance to a landmark — then check the map.
Guess the time from the Sun, Moon, Southern Cross, or other stars, then check your watch. Use your compass to check your guesstimation of North from the bush, gullies, rocks, a star-trail, a star-set etc. Predict the tide, or the time & direction of moonrise — then sit down and wait for it. Predict a star-set position. Find your ‘shortest shadow’ angle today & use it tomorrow.
Make & Use — an odometer from a wheel, a pedometer, a sundial/declination compass, a portable sundial, a string rangefinder, a slope-meter.
Measure — Try some star navigation observations — Rise & set bisection; Use a plumb-line; a bush quadrant; a bush sextant.
Test how accurately you can each use a compass. Test each compass against the others.
& Memorise — yesterday’s acrostic. Remember all the mnemonics! Can you add to any of my checklists? Have a star identification evening.

Moon-Phase & Tide-Time Dial

This is a handy tide-predictor, based on the assumption that tides will follow the moon. It shows you where the moon will be, at high tide. It also tells you what the moon is doing if you know the date but haven't seen the moon for a while. The deluxe version can predict tides and phases years ahead of time. It consists of a series of dials rotating on a single pin.

◇ The idea is that many of these concentric cardboard/plastic dials rotate together once properly adjusted, and as quickly as the Moon orbits the Earth. They show the Moon Phase, the Sun, the Earth and the resulting astronomical tide-producing forces.

Each disk is loosely fixed to a neighbour with friction (e.g. a smear of dried silicone glue) or a clip or tape or a pin, to allow adjustment.

Set it up by observation, or by tide-table predictions. Add notes, as you accumulate information about locations, tidal range, etc.
It can be especially useful for travellers, e.g. when fishing an unknown coast.
If the dials are correct for any one tide (spring-tide is best), they should be correct for all the tides thereafter *
* give or take a couple of hours for the smaller effect of the position of the Sun.
The effect is 43% of that of the Moon, and can be estimated with practice—change the hour reading to toward the Sun, or the anti-Sun, a little, if the Moon is near the Sun-anti-Sun line (no more than 45° from). Local shallow water resonance effects will also alter the actual effect of the Sun. When in doubt, around neaps, try averaging the tide-time for one or two days ahead and 1 or 2 days after.
The theory is that slosh resonance, or the Moon alone, or the Sun alone, might predict the difficult tides better.

◦ The hanger (outline not fully shown) is hung from the wall and also folds down behind to receive the pin on which the dials rotate.
It doubles as an indicator window, and should mark five consecutive high tides (ignoring a.m./p.m.).
◦ The clockface is 24-hours i.e. 15° per hour clockwise, (markings not fully shown). Think "a.m./p.m." for the two high tides per day, no matter what the reading says.
Each new location visited may need the clockface to be twisted slightly to allow for local tide delays. Keep a note of such settings.
Daylight saving requires a +/– 1hr change — to relocate the Sun forward in summer, back to normal in winter.

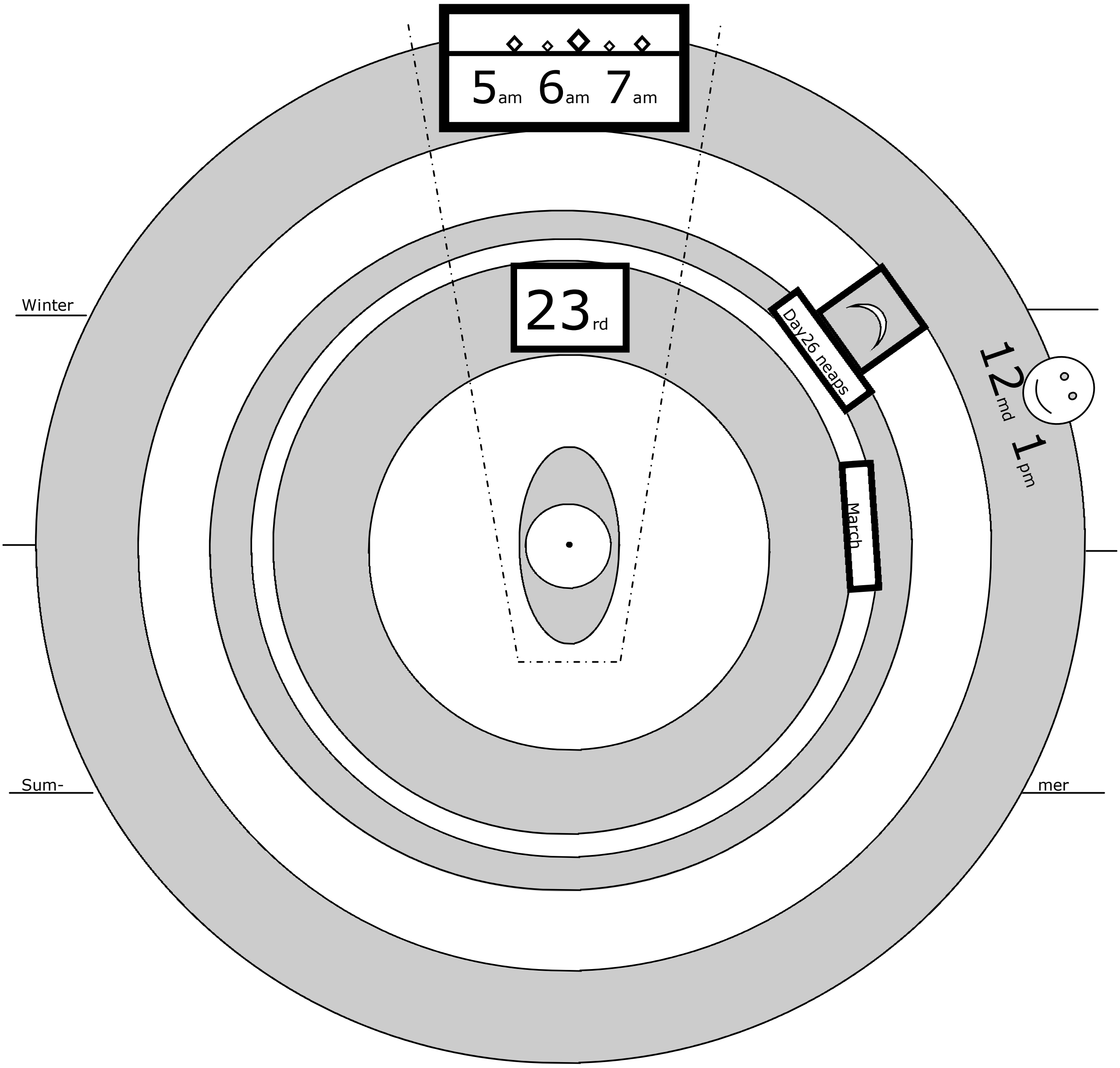

◦ Friction-fix the Moon-window dial (white with grey window) to the hanger, so that it maintains its position. It covers over all the other Moon phases.
◦ The Moon-phase diagrams (29 of them) underneath that, on a separate dial of the same diameter, should look right for the Southern Hemisphere—i.e. the Sun rising in the East, illuminating the Moon; all the phases parallel. Make the Moon-shape highly visible from a distance. Attach the Sun to the No-Moon phase, Day 0, via a transparent link; then set the Sun to the Clockface, to indicate true noon—when the Sun is exactly North.
◦ The optional tide-type ring (showing "neaps"), set to the Moon-phases, allows you to adjust the delay after new/full Moon, before spring tides.
If you also indicate which high tide is dominant—the one nearest the Moon or the one farthest—then that will need adjustment when the Sun crosses the Equator. I suggest that you set the top tide for the tide when the Moon is visible, to give you a visual feel for the tide producing forces.

◦ The date-dial is 29.5(30526805) days around—the complete lunar month—and marked clockwise from 1 to 32 (only one date is shown in the diagram). **Dial up the date, by rotating the Sun**. (For a 12-hour clockface, you would need to double the 12.19077473° per day). Since the next high tide will (if you are looking in the daytime) be on average that afternoon, I suggest you think of the date number as "the middle of the 23rd"—to avoid adjusting the date hand minutely for how far through the day the next tide will be.

◦ The month window is attached to the date dial, at Day 1 of the month, if you include a month setter.
◦ The optional but useful month-setter dial (markings not all shown) starts at March 1, to avoid leap-year adjustments; It makes March 32 = April 1, April 31 = May 1, and so on—spanning approximately 11 days for the year. Restart every March 1, and reset it every month. Calculate the monthly positions by the day number since March 1, avoiding an off-by-one error (17.9°;23.6;41.6;47.3;65.2;83.1;88.8;106.7;112.5;130.4;148.3). Set the month name to the first day of the date dial.
You can also calculate and indicate a one-year increment, 129°.6327779, a leap year, 141°.82355, and a four-year increment, 170°.7218865. To make an adjustment, make the old date indicated by one mark on the month dial, now line up with the increment mark selected, so as to indicate a date in a new month/year/leap year cycle.

◦ An optional Earth ring in the very centre, can show the entire Southern Hemisphere map (not illustrated, or NH on the reverse side), and be set to the right longitude. It is fixed to the hanger, and to the tide-bulge ring...
◦ A second ring just behind the earth can indicate two tidal bulges, one pointing upwards (or otherwise if you want to indicate the local tidal delay compared to the actual ocean bulge).

Mock it up in paper, until you understand the functioning.
Glue those paper discs onto cardboard to trial the thing for a while.
After deciding on improvements, make it neatly, to last for decades.
E.g. Try getting the computer to print the dial markings onto acetate, and glue that to sheets of stiff plastic.

You can experiment with different dial orders, e.g. the date-dial on the outside of the phase-dial.

You can make room for comments,
e.g. by expanding the dial area showing, to say when the moon rises and sets; e.g. "light from midnight onwards"—beneath each Moon-phase diagram
e.g. when and where the Sun rises and sets; Mark three horizontal lines in the background for Summer, Equinoxes and Winter.
I.e. mark them on the backfold of the hanger piece, or on the wall. Try to match midwinter sunrise time to where the "winter horizon" cuts the clockface, which will also suggest the approximate direction of sunrise.
e.g. when and where the first, second and third quarters set in each season; Full Moon opposite the Sun, i.e. 6 months different; Half Moon Waxing is one season ahead of the Sun; Half Moon Waning is one season behind the Sun (as far as which horizon line to use).

You will discover that an invisible connection needs to be made between the outer top window and the inner window and dials, so that they do not rotate with the other dials. One way to do this is to push the pin through a piece of rubber eraser, and glue that rubber to the dial. Another method is to have a square pin, and key the inner dials to it, while using round holes for the rotating dials. A third and simpler method is to have a transparent link from the centre, over the top of the other dials. You do not want the hanger to obscure any diagrams or dials which need to be visible.

The Time and Date dials are the indispensable ones. Instead of dialing up the date, you can use a normal clockface (12md always on top) and an hourhand to point out the next tide; you point the pointer at the date. On a 24hour clock-face it can be made like a + sign, to point out all 4 tides that day.

Here is the simpler alternative version, showing an 11:30 high tide on the 19th…

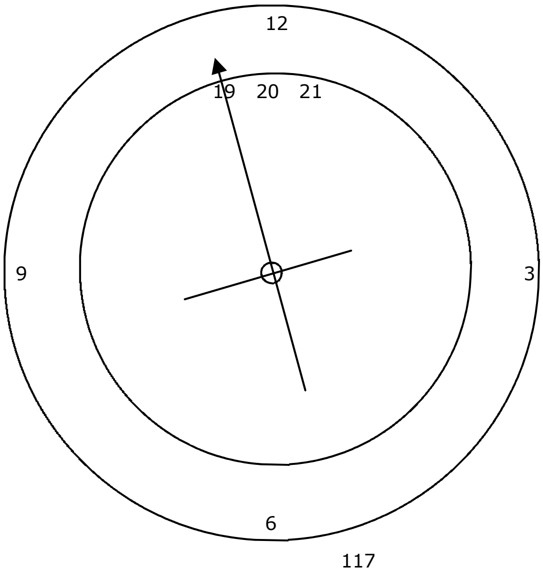

Divide the Star Globe into 8 Octants—and Learn the Stars in Each

The three dividing great circles are the Equator, the Ecliptic, and the Milky Way Galactic Plane.
A star may be North or South of each line, or on one or more of them. The lines on the backside of the globe are shown dashed.
The labels refer to the three lines in the order given. Six of the octants show in the front view with the two in parentheses on the back.
Verify each label before you start. E.g. NSN = North of the Equator, South of the Ecliptic, North of the Milky Way.
Compare with a good star chart e.g. out of a large atlas, as this is only a memory aid.

The Milky Way Crosses the Equator
at the centre of
Procyon-Sirius-Betelgeuse

NNS—The Great Square, etc.

Summer (Northern) **S**olstice
Elnath to Gamma Geminorum

NSS
Aldebaran
Betelgeuse
Bellatrix
Menkar

SSS
Pot
Big Dog
Canopus
Diamond Cross
False Cross
Acamar
Achernar (central)
Magellanic Clouds
South Galactic Pole
South Pole Star
Diphda
Ankaa
Fomalhaut
The Crane
Peacock
The Archer
Scorpion's Tail
Atria

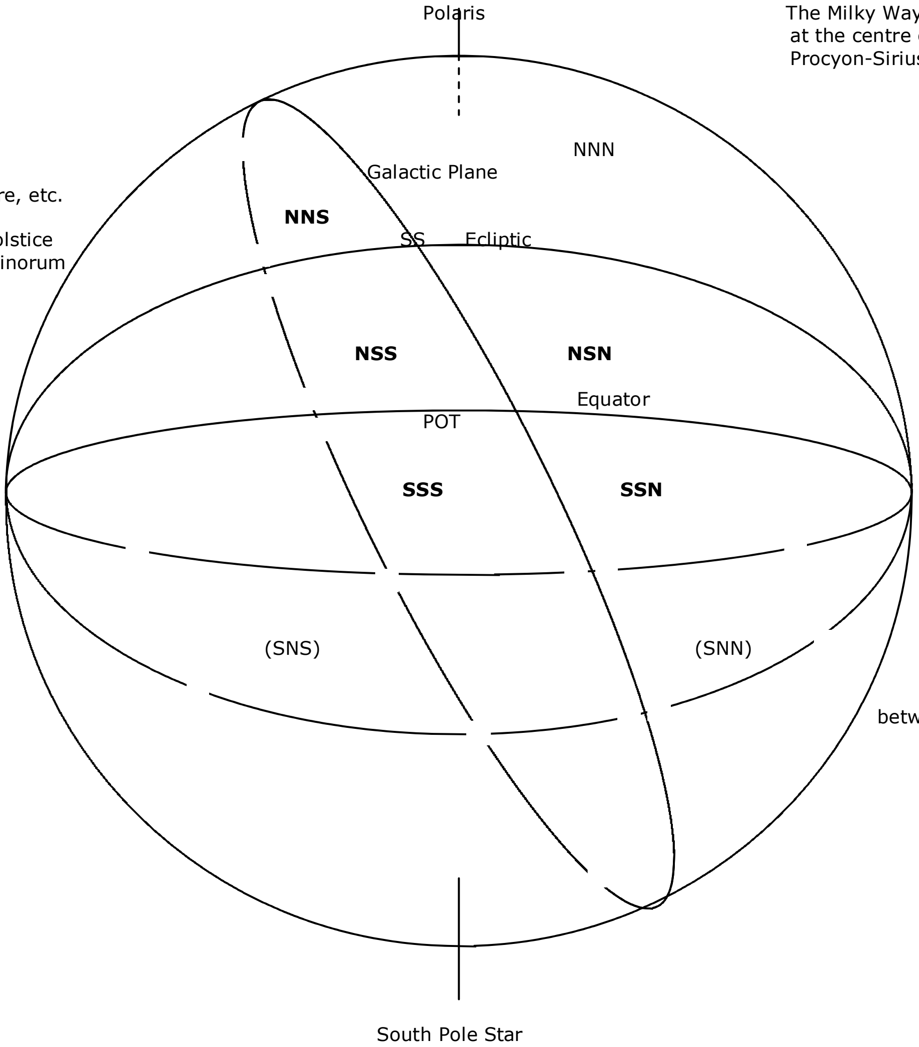

NSN
Procyon
Gamma Geminorum

SSN
The Centaur
Antares
Spica
Corvus
Suhail
Alphard

between SSS & SSN
Southern Cross
Southern Pointers

The Southern Figure of Eight—Two Star-Circles—joined by the backbone of Canopus—Achernar—Fomalhaut, a straight line

(not to scale; consult a star chart to verify each star, then find them in the sky)

Fomalhaut
Achernar
Canopus
Sirius |
Orion's belt | these 3 are also straight
Aldebaran |
Pleiades
Aries
Great Square

Milky Way
Cn=Pointers (alpha and beta Centauris)
Southern Cross
Diamond Cross
False Cross

Visible in its entirety in October plus or minus a few months.

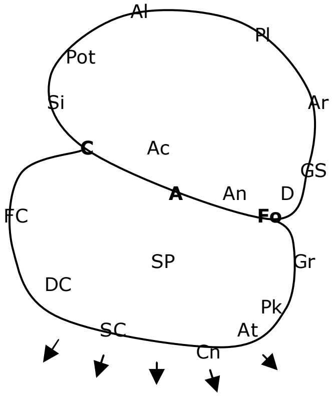

Canopus
Achernar (find Acamar on the way)
Fomalhaut (find Ankaa on the way)
Great Square (find Diphda)
Aries, the Ram
Pleiades, The Seven Sisters
Aldebaran, in the Bull
The Pot, Orion's belt
Sirius, in the Big Dog

Around the South Pole Star
Canopus (find Acamar next)
Achernar (find Ankaa next)
Fomalhaut
Grus, the Crane, with Alna'ir
Peacock then Atria (find Scorpio)
Centaur, the two Pointers (find Arcturus)
(find Spica)
Southern Cross (find Corvus, the Crow)
(find Leo)
Diamond Cross, False Cross, Canopus

Ach.-Fom.-Pck
form a triangle
to find AlNair
& Ankaa

Divide the Star Globe into 8 Octants—and Learn the Stars in Each

The smaller groups, and the crossover points, are worth learning, because they show you the three lines best.

NNN
Alkaid (central)
Capella
Twins
North Galactic Pole
Big Dipper
Little Dipper
Polaris
Arcturus
Alphecca
Rasalhague
Draco
Vega
Deneb
Most of Leo
(Regulus adjoins NSN)

Summer **S**olstice
Between Aldebaran & Pollux

Autumnal **E**quinox
Between Spica
and Regulus

NNS
Altair
Enif
Great Square
Mirach
Almach
Algol, Mirfak
Aries
Pleiades
Elnath
(Caph, Schedar, Ruchbah)

Winter **S**olstice
Nunki to Sabik

SNN
Zubenelshemali
Sabik
(Zubenelgenubi adjoins SSN)

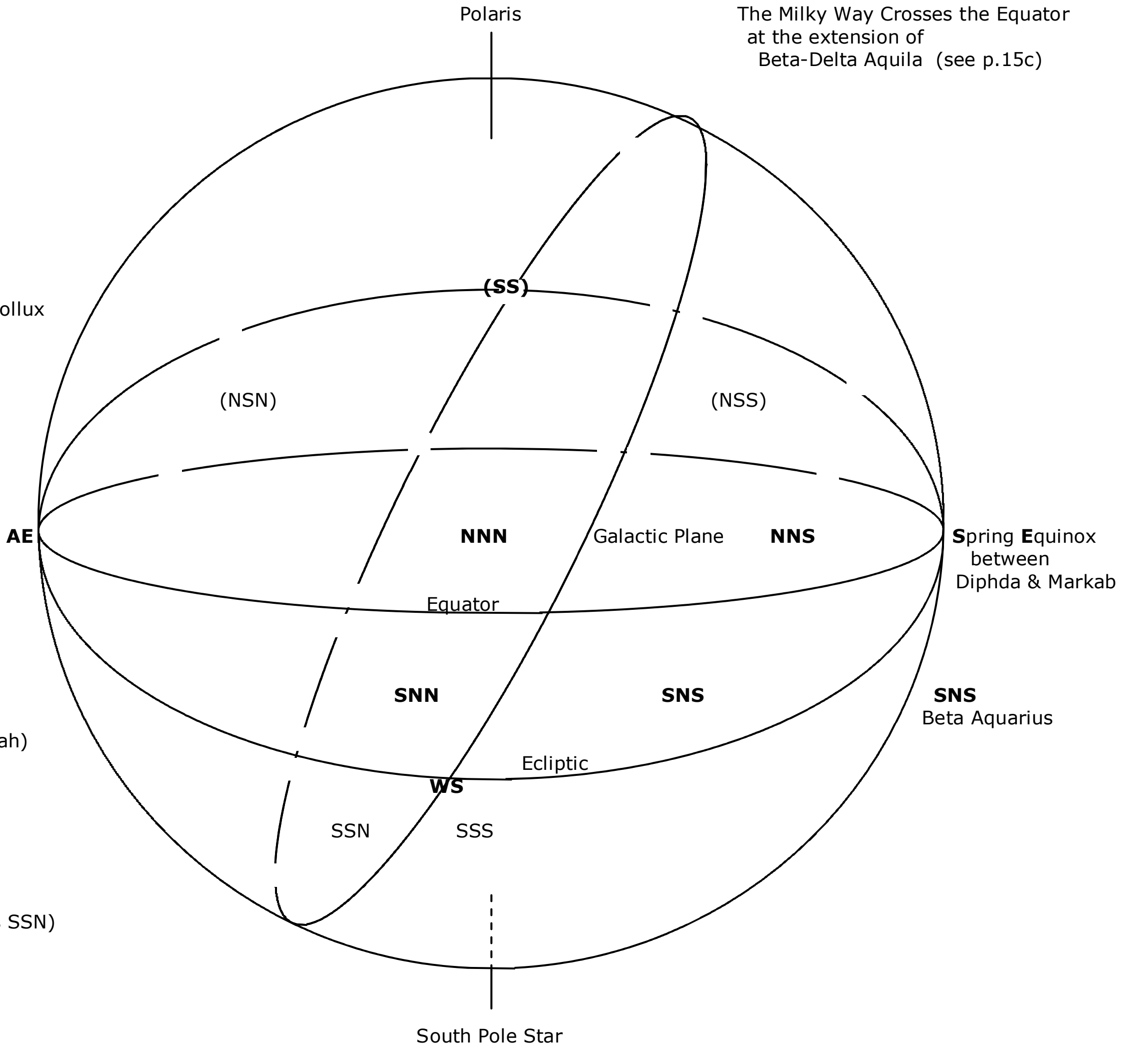
Polaris
The Milky Way Crosses the Equator
at the extension of
Beta-Delta Aquila (see p.15c)
(SS)
(NSN)
(NSS)
AE
NNN
Galactic Plane
NNS
Spring Equinox
between
Diphda & Markab
Equator
SNN
SNS
SNS
Beta Aquarius
Ecliptic
WS
SSN
SSS
South Pole Star

The Zodiac i.e. the constellations along the ecliptic. In order of appearance. Not all of them are bright or obvious in shape to look at.

Mnemonic:	Are	Tall	Twins	Cancerous	Leo?	Virginal	Liberated	Scorpions	Shoot	Capricious	Aquarium	Fishes.
i.e.:	Aries,	Taurus,	Gemini,	Cancer,	Lion,	Virgo,	Libra,	Scorpio,	Sagittarius,	Capricornus,	Aquarius,	Pisces
	Ram	Bull		Crab			Scales		Archer	Goat	Water-Carrier	

Morse Code & Rhythm Mnemonics

Dit/Dah/Pause is an extremely flexible system. Adapt it to torchlight, sounds, sewing stitches, body movements… A lot of fun for all the family.
if dit = one time unit; then Dah = three dits long; the di-Dah separator = one time unit; letter separator = three units long; word-separator = 6

	Say…		**Write…**	**Signal…**	Special Meanings (only for reference)
A	an A		. _	di Dah	
B	B bi-bi-bips		_ . . .	Dah di di dit	Fog Horn: I am under tow
C	C is Sea-sick		_ . _ .	Dah di Dah dit	Between ships manoeuvring: I a**c**knowledge your signal
	(Capital letters for a Dah syllable; lower case for a dit)				i.e. You may overtake on the side you indicated
D	Dee did it		_ . .	Dah di dit	Fog Horn: restricted manoeuvrability; deep draught; sailing; etc.
E	egg		.	Dit	I am altering my course to... **Starboard**
F	f' f' Forfeit	f' f' Fore foot	. . _ .	di di Dah dit	
G	Gee Gee git	Go Go get	_ _ .	Dah Dah dit	I intend to overtake you, to Starboard
H	h'-h'-h'-hit		. . . .	di di di dit	I intend to turn completely around to… Fog Horn: Pilot vessel on duty
I	is it		. .	di dit	I am altering my course to... **Port**
J	a J Goes Jay		. _ _ _	di Dah Dah Dah	
K	K for Kay		_ . _	Dah di Dah	
L	an ELL leph'nt /in ELLement /inELLegant		. _ . .	di Dah di dit	(draw out the Ell sounds)
M	My My		_ _	Dah Dah	Fog Horn: "under power, not making way"
N	No en		_ .	Dah dit	
O	Oh Oh Oh		_ _ _	Dah Dah Dah	
P	a P Goes pip		. _ _ .	di Dah Dah dit	
Q	Q Forms a Queue		_ _ . _	Dah Dah di Dah	(to the tune of "Here Comes the Bride"—Queue up to get married!)
R	an R dits		. _ .	di Dah dit	
S	s-s-s	ess ess ess	. . .	di di dit	I am under Astern propulsion
T	Tea		_	Dah	Fog Horn: "under power, making way"
U	it is U		. . _	di di Dah	
V	v' v' v' Vee		. . . _	di di di Dah	(to the tune of Beethoven's V)
W	a White Wine	a World War	. _ _	di Dah Dah	
X	EX mimics P	All ex's Hurt	_ . . _	Dah di di Dah	(drawl the EX, to lengthen it in the first, not in the second)
Y	Why is Y Y?		_ . _ _	Dah di Dah Dah	(say the 'is' quickly)
Z	Zee Goes zi-zit	Zees Go zi-zit	_ _ . .	Dah Dah di dit	I intend to overtake you, to Port
Ü	it is U too	(this pairs to Zed)	. . _ _	di di Dah Dah	(U umlaut or U diaresis. Invent a meaning for it.)

Hint: For Learning, repeat each letter thrice.
By the time the other person recognises the first, the second has finished and he is waiting to check it out against the third.

0	No No No No No		_ _ _ _ _	
1	it Carts Four More Dahs		. _ _ _ _	
2	it is Two Two Two		. . _ _ _	
3	di di di Makes Three		. . . _ _	
4	di di di di Four	pitter patter 4 (your puppy's feet)	. . . . _	
5	fit 'em in a mit	(your five fingers, that is)	. . . . .	
6	Five si– si– si– six		_	
7	Five Seeks seven dits	(=567dits drawled on the 6)	_ _ . . .	
8	8 8 8 bi bits	(8 binary bits in a byte)	_ _ _ . .	
9	9 9 9 9 nips		_ _ _ _ .	
	Long dash	Daaaaaaaash	_______	e.g. (Fog Horn or car horn) before you enter a blind bend!
	Error	it isn't a bit of it	. . . .	Between yachts: "I do not understand/agree with your intention/action"
:	Colon	Now Here Comes in a list	_ _ _ . . .	

Learn the next ones in pairs i.e. swap dit for dah

. a STOP a STOP a STOP (i.e. don't pronounce 'stop' as short) . _ . _ . _
; SEMi SEMi SEMi (i.e. drawl the first syllable) _ . _ . _ .

These 2 shapes are convex to the right

, Go Go comma Go Go Dah Dah di di Dah Dah _ _ . . _ _
? did he Dah Dah did he? did 'e Blah Blah did 'e . . _ _ . .

These 2 come in pairs normally

"" a Quote is a Speech bit di Dah di di Dah dit . _ . . _ .
() Here's the Blah Blah bit Here There's the Blah Blah bit There _ . _ _ . _

These 2 are in the middle of a word ..hyphen and apostrophe

- 'Aitch in the middle Daash ('Hyphen' starts with an 'aitch) _ . . . . _
' it Saves All Those Hard bits di Dah Dah Dah Dah dit . _ _ _ _ .

/ Slaash t' diVide it (Drawl the first vowel) Slaash is a Slaash bit There was the Whole bit _ . . _ .
Á an A Sharp an A You could use it for "Repeat": re Peat Whole re Peat . _ _ . _
É it is E a-cut(e) . . _ . . cute is cut short (You could use it for "Bad Reception": cannot Hear the bits)
Ñ Nya Nya ny' Nya Nya _ _ . _ _ (with thumb to nose, fingers waving) "ny" sound (I use enya for "Do You reCeive Me")

SOS a bit of 'Save Our Souls' isn't it? (no letter breaks; repeat regularly) . . . _ _ _ . . . . . . _ _ _ . . . (Life & death only)
XXX Come quickly Come, Come quickly Come, Come quickly Come All ex's Hurt All ex's Hurt All ex's Hurt (When you Need urgent help)

Signals procedures, developed by hard experience, short circuit a world of miscommunications — stick to them. I.e. learn them too.

I'm Looking For Talk; CQ CQ CQ; Calling Calling All Radios; Hear ye Hear ye All AuditOrs; Tune in Tune in Lend Me y'r Ears
From; D, E; De = French for 'from' Heard of it ; fr'm Dah-di-dit dit
Go Ahead; invitation for anyone to transmit; K Call in Now
Break In B, K Break in to it; Make a Break ("BK DE (identify yourself)" = "let me use this channel")
Starts; Attention; Message Coming Start it Start it Now Start of My bit Now _ . _ . _
End of Paragraph; Pause; new thought; double dash Pause if it is New _ . . . _
Wait a Wait f'r a bit . _ . . . You could invent "Speed up All Your Work" to pair with it.
Over; invitation for your contact to transmit O ver Your Turn stop _ . _ _ . (to start a person-to-person contact: ###DE### Over)
End of Message in traffic; not end of contact; not clear of station the End of My bit; con Clude con Clude it . _ . _.
R; Roger; Received and Understood all of Message
End of Work; but still on air; clear of contact it is the End of Work (to the tune of… here we go Out to Play) . . . _ . _
Clear of all contacts; shutting down; Clear of Station; C, L Clear it Clear it, b' Clear of it

Add your own signals for procedural or other matters. E.g. "Please repeat my message back to me for a check" "Adjust the beam left"

Ä an A an A . _ . _ an A 'm Laut It pairs to C Invent a use for it like "i Don't a-Gree" to be opposite to C, I Agree
Å an A an A too . _ . _ _ an A an Aang Strom
Xhi Khi Khi Khi Khi _ _ _ _ K-H-Like-H soft Kh sound (I use it for "to" i.e. T+O, after DE "from") cf Ree Call All Souls
Ö Oh Oh Oh dit _ _ _ . Goe– Goe– Goethe It pairs to V You could use it to say Sorry

North American Morse is somewhat similar. There is also a Japanese version. Morse is no longer supported as International.

Semaphore Signalling Code & Mnemonics for it

Semaphore is a clockwise system, as viewed by the decoder, and it starts from below.
When the two hands can't be seen, that is the neutral position, used for a… **Pause**
The black square represents the signaller's body; the line(s) are his arm(s).
The numbers 1-9 and 0 are the same as A-I and J. The first 7 single-arm positions are shown…
You can tell the difference, because the signal "numbers coming" precedes a number, and a "pause" follows the end of the numbers.

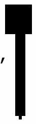

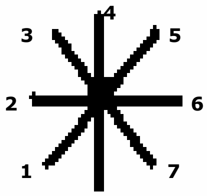

One arm, pointing up, therefore is either D or 4,
Think of God as the 4th Dimension to your life, and remember 'up' as "**4D**"
Or if it sticks in your memory, think perversely, that "**Up is fo(u)r D.own**!?"
Learn the letters in symmetrical pairs.

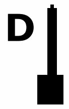

Here is a "**B F**lat" mnemonic. One arm flat is either a B (-flat) or an F (-flat)
"2 be or not 2 B?" and a "**F Sixth** chord" might help you remember the numbers.

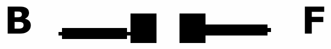

Wave the C to say "Replying". Wave the E to signal "Error"
(cf Morse "C" for "Acknowledge")
The *odd number* positions are diagonals.
1,3,5; 7… **One is an ACE** isn't it? And Dia**g**onal has a **G** in it doesn't it?
a G7 chord to follow the F **F**lat minor **6**
ABC = 123 is easy enough to see, and **5E follows 4D** makes the E position easy

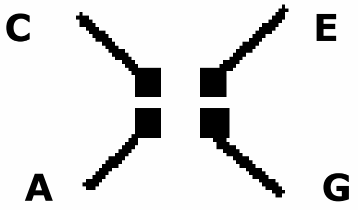

2 Hands…

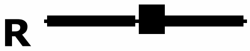

"Roger" is simply an indispensable signal to learn… it means "Yes, I understand, OK, Received"
For Learning: Acknowledge every letter understood, with a Roger

2 Hands Straight:
Think **"Long**, then **Left down = Slash down** or **L**eft **up = L**ift **up"** (referring to **their** Left arm)…

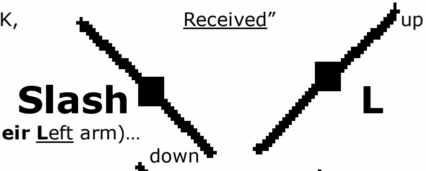

2 hands in a catching formation, above the head…
Shout **"Catch iT…"** and think **"..Tee—numbers coming"**

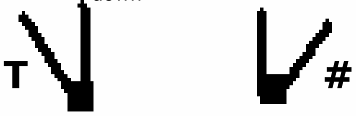

2 Hands in a slip-catching formation, to one side…
Shout: **"HOWZ"**at!

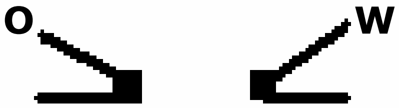

You are meant to wave black and white flags around,
but usually you make do with opening your palms.
Only be careful to position yourself against a good uniform background.

'aitch rhymes with eight

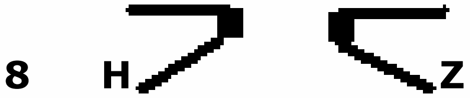

2 hands at a right-angle…
"Ya gotta have the **Right P**y**J**amas" ("PJ"s)
J, the tenth letter, is used for Zero ABCDE FGHIJ

PJ is not in alphabetical order, because in the Semaphore Alphabet J comes after #

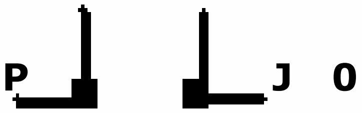

2 hands at a right angle, Vee-shaped, up or down…
Can you see the **shapes** of the **lower case letters n and u** in them?

To attract attention wave U, to say "Message Coming"

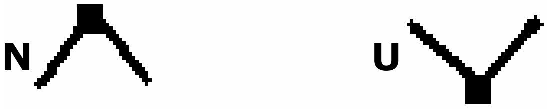

2 hands, like a Roman Numeral Five on its side…
I and **X** are **Roman Numerals too.** The I is used for numeral **9 (IX)** in semaphore
The X looks like **the right-half of the X**

So it sort of goes, left to right "nine, ten"

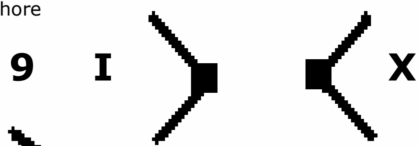

2 hands flapping and banking. I.e. a shallow Vee formation…
"MY Queue**S"** is the clockwise mnemonic
But YQ is not in alphabetic order (like PJ, the only two cases).

You can use Q for "Query" - What did you say/mean?

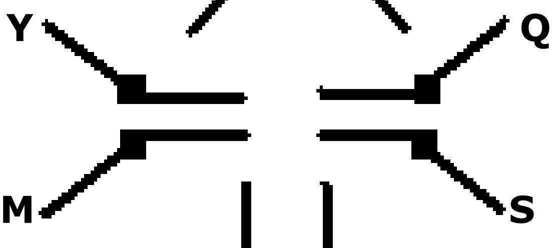

From the sky, down to earth come… **"K**ilo**V**olts" (or **"K**iller**V**olts")

You can follow the clockwise logic of Semaphore if you leave out the JVWXZ till last
Pause, ABCDEFG, HIKLMN, OPQRS, TUY/, #JV, WX, Z

Make each in turn to see the progression.

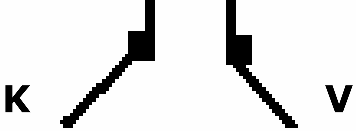

Appendix: More symbols for map-making Useful for mud-maps, or for track notes.

The first symbol in a strip map column should show the *reason* for the stop. This saves a lot of words and is instant to read.

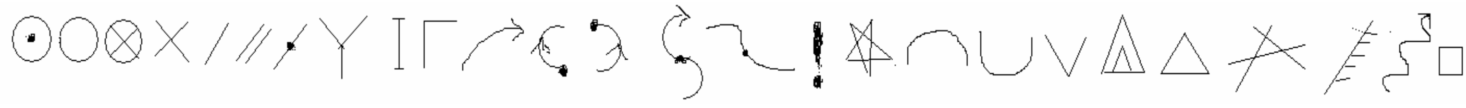

In turn these are:

A Context Entry; Surroundings; Overall Perspective. E.g. catchment and drainage. It's a chance for a general note.
A Stop. Expect a reason like 'Lunch'.
A Location. Expect a description.
Crossing. This might be a crossing of a ridge, river, road, canal, boundary. Expect notes on what is to left and right.
Leg. The first of the 2 main reasons for an entry: either a new subsection (leg) or the location *between* two sections in its own right (next symbols).
Overlap-section between legs. This is a memory aid, to sequence subsections, to remind you how individual sections join to each other.
Change of legs; new subsection; = notes on *the changeover*, rather than on the next section.
Junction (Y for Y junction, but used also for other junctions). This might be a 'natural' junction between ridges or creeks; or an intersection of paths.
Viewpoint; Change of view; First glimpse; Last glimpse (I for 'Eye')
Corner
Bend
Curved section beginning; Arrow shows clock-sense. This one is a Right-hand bend.
Curved section ending; Arrow should show same clock-sense as previous one. This one ends a left-hand bend.
Change from left-curve to right-curve
Break of slope
Feature
Special feature
Ridge; Crest
Saddle;
Valley; creek-bed; Gutter
Tent; Campsite
Peak
Fix
Cliff
Creek
New grid square

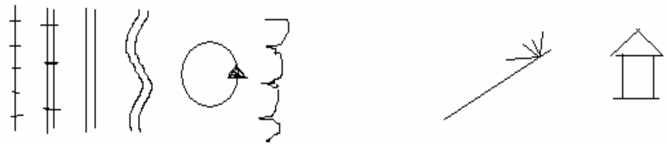

Boundary walks: fenceline; railwayline; road; path; circumnavigation; shoreline
Use symbols which work for you, e.g. Rise or Set direction. Add your own, e.g. Hut

The second symbol ought to show the main direction clue, followed by subsidiary ones as a third symbol

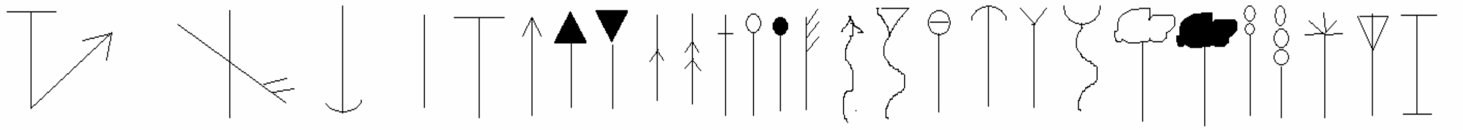

Trending half left from that landmark (write the name of the landmark next to the arrowhead). Useful when following a windy path.
Maintaining half right of downwind;
Walking the crest down ridge — Progress is assumed to be 'Up'wards on the page.
Leg.
Trend direction (for when the terrain is up and down, left and right) ('T' for Trend).
Named landmark; General purpose arrowhead; add the name and the bearing
Peak
Anti-peak direction (e.g. as mentally marked on the skyline opposite the peak)
Up-Slope.
One arrow for 'below average'; Two arrows for 'average'; three arrows for 'above average' — low; medium; high. Use this for other things too.
Compass needle North, modelled after the symbol for North
Up-Sun
Shadow; Down-Sun
Wind source; Upwind. Use the 1-2-3 code for strength. This one is 'above average'.
Down-stream river flow
Up-stream (to a peak) (useful when 'downstream' is behind you)
Moon direction
Up-Ridge; The direction of the highest skyline through the vegetation, if that is all you can see.
Down-valley. The direction of the lowest skyline when that is all you can see.
General Drainage trend (down the valley to the river mouth)
Up-Weather; Low cloud source direction; Cloud Source (when only one set of clouds is visible)
Down-clouds
Alto Clouds source direction (make the circles fluffier than I can show)
Cirro-clouds source direction
Glow at night
Radio-null (from the symbol for an antenna)
Trend of some feature like the coast — write in the details.

1,2,3 for size and importance of junctions…

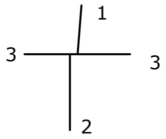

The notebook might be set out as follows: The first line across a narrow notebook is in informal columns; the second is for written notes.

Time ;	**Reason** ;	**Trend** ;	**Directions** ;	**Times** ;	**Distances** ;	**Grid**
Fill in a **number**	Use the top **symbols**	Use the main clue	make a rose of others	elapsed time	total elapsed	e.g. A5
if you don't				leg time	last leg length	
have a watch	Start with an 'Overall'			lost time	lost distance	
				total time out	total diversions	
Sequence is a				net walking time	net progress	
primary need						

(Use abbreviations, e.g. NWT, or dedicated columns)
(Do your calculations here at leisure)

Now write *across* the next line(s) the **name; mnemonic; description; comments**
The description of a cross-country leg could include the side or flank, hand, clock-sense, break, steepness, difficulty, curviness, hilliness, perversity, terrain, contours, topography, view, what you can't see, skyline, traffic intensity, track-markers, their age, rock type, soil type, vegetation, biology, colours, peculiarities, reference to another page of the notebook to a diagram.
The more you include in the symbols, the less you need to say, and the easier it is to read later.

Appendix: A List of Star Coordinates.

100 brightest stars
Declination is equivalent to Latitude. –nn = South; +nn = North
Siderial Hour-Angle is equivalent to Longitude West of Zero.

Common Name (s)		Dec.	S.H.A.	Constellation
Miaplacidus		-69.72	221.70	b Carinae
Atria		-69.03	107.83	a Trianguli Australis
Acrux		-63.10	173.35	a Crucis
Rigil Kentaurus/Toliman		-60.84	140.10	a Centauri
Hadar	/Agena	-60.37	149.04	b Centauri
Mimosa		-59.69	168.07	b Crucis
Avior		-59.51	234.37	e Carinae
Aspidiske	/Tureis	-59.28	220.72	i Carinae
Achernar		-57.24	335.56	a Eridani
Gacrux		-57.11	172.21	g Crucis
Peacock		-56.74	053.60	a Pavonis
k Velorum		-55.01	219.46	k Velorum
d Velorum		-54.70	228.82	d Velorum
e Centauri		-53.47	155.02	e Centauri
Canopus	2nd brightest	-52.70	264.01	a Carinae
Muhlifain		-48.97	169.62	g Centauri
Regor		-47.34	237.61	g Velorum
Alna'ir		-46.96	027.95	a Gruis
b Gruis		-46.88	019.34	b Gruis
Suhail	/Al Suhail	-43.43	223.01	l Velorum
Akrab/ Sargas	/Rastaban Sc.	-43.00	095.67	theta Scorpii
Ankaa		-42.31	353.43	a Phoenicis
eta Centauri		-42.16	141.12	eta Centauri
Naos		-40.00	239.10	z Puppis
k Scorpii	(not Akrab)	-39.03	094.38	k Puppis
Shaula		-37.10	096.60	l Scorpii
pi Puppis		-37.10	250.71	pi Puppis
Menkent	(not Menkar)	-36.37	148.33	th Centauri
Kaus Australis		-34.38	083.96	e Sagittarii
e Scorpii		-34.29	107.46	e Scorpii
Ascella /Nushaba		-29.88	074.36	z Sagittarii
Fomalhaut		-29.62	015.59	a Piscis Austrinis
Aludra		-29.30	248.97	eta Canis Majoris
Adhara		-28.97	255.34	e canis Majoris
Antares		-26.43	112.65	a Scorpii
Wezen		-26.39	252.90	d Canis Majoris
Nunki		-26.30	076.18	s Sagitarii
Dschubba		-22.62	119.91	d Scorpii
Diphda	/Deneb Kaitos	-17.99	349.11	b Ceti
Mirzam	/Marzim	-17.96	264.33	b Canis Majoris
Arneb	/Arnebo	-17.82	276.82	a Leporis
Sirius	/Dog (brightest)	-16.72	258.72	a Canis Majoris
Sabik		-15.72	102.41	eta Ophiuci
Spica		-11.16	158.70	a Virginis
zeta Ophiuci		-10.57	110.72	zeta Ophiuci
Saiph		-09.67	273.06	k Orionis
Zubenelschemali		-09.38	130.75	b Librae
Alphard		-08.66	218.10	a Hydrae
Rigel	not Rigil K.	-08.20	281.37	b Orionis
Alnitak	S. belt	-01.95	274.80	z1 Orionis
Alnilam	Mid belt	-01.20	275.94	e Orionis
Mintaka	N. belt	-00.30	277.00	d Orionis

Common Name (s)		Dec.	S.H.A.	Constellation
Polaris	N. Pole Star	+89.26	(322.06)	a Ursa Minoris
Kochab		+74.16	137.32	b Ursa Minoris
Alderamin		+62.59	040.35	a Cephei
Duhbe		+61.75	194.07	a Ursa Majoris
Navi	/Cih	+60.72	345.82	g Cassiopeiae
Ruchbah	/Ksora	+60.24	338.55	d Cassiopeiae
Caph		+59.15	357.70	b Cassiopeiae
Schedar	/Schedir	+56.54	349.87	a Cassiopeiae
Merak		+56.38	194.53	b Ursa Majoris
Alioth		+55.96	166.50	e Ursa Majoris
Mizar (+Alcor nearby)		+54.93	159.01	z Ursa Majoris
Phecda		+53.69	181.54	g Ursa Majoris
Eltanin	/Etamin	+51.49	090.86	g Draconis
Mirfak		+49.86	308.92	a Persei
Alkaid	/Benetnash	+49.31	153.12	eta Ursa Majoris
Capella		+46.00	280.83	a Aurigae
Deneb (not Denebola)		+45.28	049.64	a Cygni
Menkalinan		+44.95	270.12	b Aurigae
Almak	/Alamac	+42.33	329.02	g Andromedae
Algol		+40.96	312.96	b Persei
Sadar	/Sadir /Sadr	+40.26	054.45	g Cygni
Vega		+38.78	080.76	a Lyrae
theta Auriga		+37.22	270.07	th Aurigae
Mirach		+35.62	342.57	b Andromedae
Aljanah		+33.97	048.45	e Cygni
Castor	N. twin	+31.89	246.34	a Geminorum
Alpheratz	/Sirrah	+29.09	357.90	a Andromedae
Elnath	/Nath	+28.61	278.43	b Tauri
Scheat	/Schert	+28.08	014.06	b Pegasi
Pollux	S. twin	+28.03	243.67	b Geminorum
Izar		+27.07	138.75	e Bootis
Alphecca	/Gemma	+26.71	126.33	a Coronae Borealis
Hamal		+23.46	328.20	a Arietis
Sheratan	/Sheratain	+20.81	331.33	b Arietis
Zozma	/Zosma	+20.52	191.47	d Leonis
Algeiba		+19.85	205.00	g1 Leonis
Arcturus		+19.18	146.08	a Bootis
Aldebaran	(not Alderamin)	+16.51	291.01	a Tauri
Alhena		+16.40	260.56	g Geminorum
Markab		+15.21	013.82	a Pegasi
Denebola		+14.57	182.73	b Leonis
Rasalhague		+12.56	096.27	a Ophiuci
Regulus		+11.97	207.90	a Leonis
Enif		+09.88	033.96	e Pegasi
Altair		+08.87	062.31	a Aquilae
Betelgeuse		+07.41	271.20	a Orionis
Bellatrix		+06.35	278.71	g Orionis
Procyon		+05.22	245.17	a Canis Minoris
Vernal Equinox, defined as fixed		00.00	000.00	'the first point of Aries'

Figures are from Epoch 2000.0.

Precession of the equinoxes:

Stars drift about 1° of position relative to the (0,0) reference star, in **72 years**, because it moves to the **WNW along the Ecliptic**. See p 33b
The third figure will therefore become off by one after 10-20 years. E.g. Mimosa used to be –59.59; Atria used to be 108.3W
One degree of latitude or declination = 60n.ml. =111km; so a maximum change in **0.1° over 18** years represents 11km, or about 0.6km per year, max.
(The actual change in Declination depends on its relationship to the Northern Spring Equinox point — see below.)
One degree of SHA = 60n.ml. at the Equator; half that at 60° Lat. ; **1° reduction in 80 years** is about 3 seconds later in timing per year, or 1.4 km max, at the Equator.

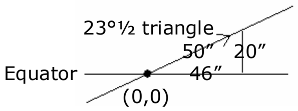

Ecliptic The first point of Aries moves along it at about 50 seconds of arc per year (5/6° in 60 Years)
Declination change of 1/3 minute of arc per year (20 secs of arc)
SHA change of 46 seconds of arc per year $20^2 + 46^2 = 50^2$

If you set your star watch by the actual visible stars each year, you eliminate E-W 'precession' component, and are left with only the drift *in declination*.
So it is of some worth to be able to predict how that rate of change in declination depends on SHA.
Obviously Stars to the North of Aries lose Northern dec, at the full rate. Stars to the South must *gain* Southern Dec.
Stars *opposite* Aries (SHA=180°) do the opposite. Stars exactly in between are *unaffected* (SHA=90° or 270°).
The rate for all cases follows **the cosine of the SHA**. E.g. stars at 60**°** SHA will have 50% of the full dec adjustment (of 1/3 n. ml. per year).
Take care with Polaris, since it is too close to the Pole.

Appendix: Drawing Great Circles

First, bisect a globe.
Two equal halves.

Put the halves back together.
Notice the ellipse.
The backside is dashed.

Draw it symmetrically around the centre.
Use *flat* ends to the ellipse.

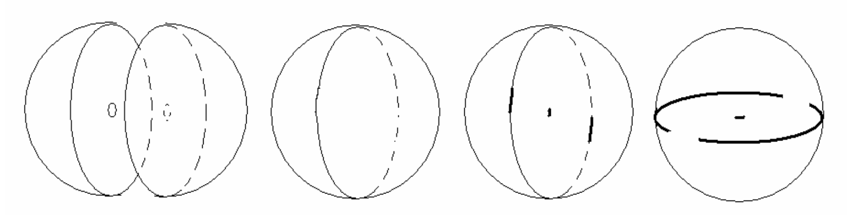

Choose the clearest perspective
E.g. 1. Rising/ setting is 90° away, so put yourself in the centre, surrounded by a 90° circle. Z is used for your Zenith — overhead.
E.g. 2. Look at the Equator side-on to make it and the latitude circles straight.
E.g. 3. Centre on the pole, to show up the polar distance. P is used for the Pole.
E.g. 4. Curve away from the centre. If in doubt, draw the whole ellipse and discard the unwanted parts.
5. A Great-circle can be drawn as a straight line. X is used to mark the position of the Star/ Sun/ Moon/ Planet
6. Draw the 'Vertex' of the course as a tangent to the maximum latitude small-circle.
7. The vertex can be drawn side-on.

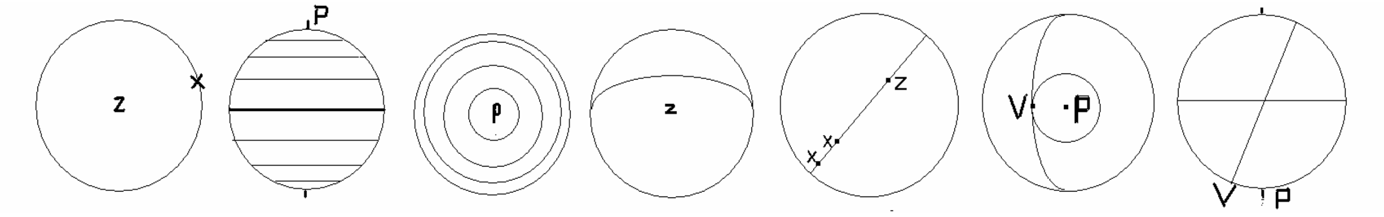

The PZX spherical triangle

8. Deliberately avoid straight lines to show up the curve of the triangles.
8a. ZX is the angular distance from you to the star, or the co-height.
8b. PX is the polar distance or co-declination to a point directly underneath the star.
8c. PZ is the polar distance or co-latitude of your position, 90° — lat.
8A. The angle ZPX, or 't', is a longitude difference — between the SHA of the star and your West longitude. A longitude difference is a time delay.
8B. The angle PZX is a horizontal direction relative to P, towards X. Technically called an 'azimuth'.
8C. The angle PXZ is similar but only meaningful if there were someone under the star, looking toward you.
9. A, B, C and a, b, c are used to label angles and sides of any spherical triangle; It's up to you to know which ones label what.
10. Draw a full 180° to show up the supplementary angles.
11. Draw the Equator cutting East and West of you, 90° away. Mark any right angles, and the complementary angles.

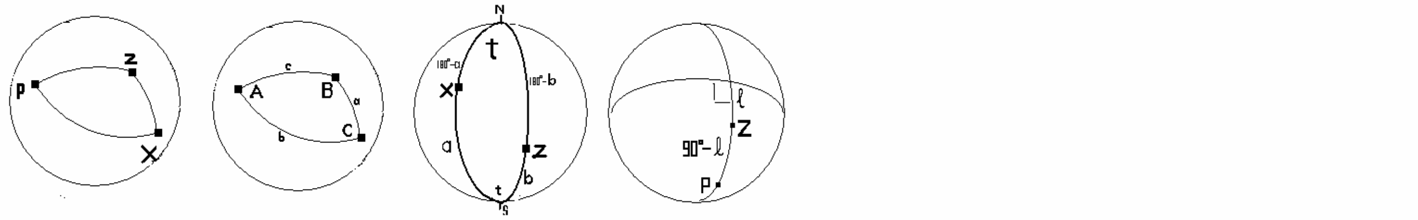

The PZX navigational triangle conforms to a handful of standard **fundamental spherical trigonometrical formulae**…

The Angle **Sum**: a+b and A+B are both greater than, or both smaller than, or both equal to, 180°
The **Sine** Rule: sina/sin A = sin b/sin B = sin c/sin C = constant. Ambiguity (about obtuse angles) can be resolved by the angle sum rule.
The **Polar** Triangle Rule: abcABC can all be swapped for the supplement of the opposite members.
E.g. 'a' becomes '180°—A'; 'B' becomes '180°—b', and the resulting formula is still valid. E.g. the sine rule simply inverts.
The **Cosine** Rule: cos a = cos b cos c + sin b sin c cos A
The Polar Cosine Rule: cos A = — cos B cos C + sin B sin C cos c
The **Four Parts** (in a row) Rule: e.g. AbCa or aBcA in the triangle aBcAbC or aCbAcB. You can find the 4th (outer) part from the first 3.
cos (**inner** side) **cos** (**inner** angle) = s**in** (**in**ner side) c**ot** (**ot**her **side**) — s**in** (**in**ner angle) c**ot** (**o**u**t**er **angle**)
If you want an inner part, use the sine rule and angle sum rule to find the 5th part, then go to the half-angle rules.
The **Five Parts** Rule: sin 1 cos 2 = sin 3 cos 5 + sin 5 cos 3 **cos** 4, where 4 is a side. It gives you any but part number 3, from the other 4.
The Polar Five Parts Rule: sin 1 cos 2 = **—** sin 3 cos 5 + sin 5 cos 3 cos 4, where 4 is an angle
The **Half-Side** Rule, to find the *middle* of 5 parts, when the middle part is a side: halve each side and angle first:
tan (half side) = tan (half sum) cos (half sum) / cos (half difference) ; tan refers to sides, sin and cos to angles
= tan (half difference) sin (half sum) / sin (half difference) but this introduces order-ambiguity because of the sines.
The **Half-angle** Rule to find the middle of 5 parts when it is an angle
cot (half angle) = tan (half sum) cos (half sum) / cos (half difference)
= tan (half difference) sin (half sum) / sin (half difference)

Make North and West positive, and East and South negative, and the formulae automatically work on PZX for angles up to 360°.

The formulae simplify where a side or an angle is 90°, since sin 90°=1 and cos 90°=0.
Napier's Rules…
The rules for **right-angled** triangles and **right-sided** triangles are simplified when the 5 other parts of the triangle laid out **in a pentagon**, and the 3 parts not adjacent to the right angle are changed to their **complement**.
In addition the part opposite a 90° *side* must have an extra **negative** sign.
E.g. if A is the right-*angle*, use (90°—a) as part 3, (90°—B) and (90°—C) for parts 2 and 4; if a is a 90° *side*, use A-90° for part 3.
Then… Sin of any one part = t**a**n t**a**n of **a**djacent parts or = c**o**s c**o**s of **o**pposite parts (in the pentagon of changed parts).
Ambiguity must still be resolved by special rules: Problems occur when there are 2 or more right-angles in the triangle.
'A' and 'a' (opposite parts in the triangle, with matching letter names) are both less than or both more than 90°. Likewise for Bb and Cc.
If one part and any part not opposite it (i.e. not A and a, as above) are on the *same* side of 90°, so are all the other mismatched pairs.
If one part and any part not opposite it (i.e. not A and a) are *not* on the same side of 90°, neither are any of the other mismatched pairs.
These refer to the triangle parts, not the altered pentagon parts.

Appendix: Calendars in the Sky — the first glimpse and last glimpse of stars

~ Firstly, What's wrong with **sunrise/sunset time**?

- To know what time of year it is, you could note the ordinary standard Sun time of sunrise/set at *that* place (e.g. from home).

—But this is insensitive (maximum shift is about 1 minute a day), useless around solstice, latitude & longitude dependent & requires a watch

~ You need to use apparent *star* time; no watches, to **locate the Sun's position on the Zodiac relative to the stars**.

— i.e. 'what stars are up' at midnight, or at twilight, or what stars are invisibly up at mid-day or sunrise or sunset.

- The Sun creeps Eastward about 1° per day along the Ecliptic (through the middle of the Zodiac belt).
- That quadruples the sensitivity to 4 minutes change a day, steady year-round.
  It is only affected by the Equation of Time, which is a minor variability, 1/4 min a day, max.
- The Sun will 'blot out' each Ecliptic star for about a month at a time.
  That's a rough way of finding the month: 'I can't find The Twins' (July).
- 'Nautical twilight' is when the Sun is 10° below the horizon (about 1 hour, in Tasmania), dark enough for the bright navigational stars to be visible while the horizon still shows clearly enough to be used with a sextant;
  So bright stars 10-15° away from the Sun begin to be visible. That means that a bright Ecliptic star might only be invisible for 3 weeks.
  [Civil twilight is 5° below, requiring lighting; and astronomical twilight is 15° below, dark enough to be called 'night', and to use a telescope]

E.g. 'What stars are up at midnight', uses the 'apparent star time' of the anti-Sun, as it were. You need to bisect sunrise and sunset, and be up then

- Find which star is N-S of you (the 'local apparent star time') at 'local apparent midnight' (= opposite noon — i.e. the anti-Sun stars).

But that is difficult — you need to know the apparent noon (which is longitude dependent), not the clock noon — and it still requires a watch.
So how can you do better?

- You could note **the clock-time of any particular star event**. E.g. follow 'Rigel over Capella' during Summer. E.g. Antares at 10° high.
  This is *simple, and accurate,* but it would only work for that location, no other, since longitude alters the clock-time of appearances.
- You could note **the clock-time *delay*** between any particular star-event and either sunrise or sunset. **This is a good method**, since it pinpoints sunrise or sunset more accurately than saying 'At twilight, when the stars come out, or when they fade out'.
  For best results, choose which star-event directions to use, as explained below, so that people at all latitudes see the same appearances.
  - This pinpoints the star-time—it tells you where the stars are—in relation to the apparent Sun-time (by tying it to sunrise or set).
  - For Rise/Set observations, you need a good horizontal horizon (or other fixed height-of-star) for star-rise/set to be latitude-independent, and location independent; but at home you simply need a repeatable point of view of a given horizon.

~ But to get back onto the main topic: The use of a watch can be eliminated by using twilight 'glimpses'...

- For Twilight observations, you need dependable eyesight; & a clear sky, with no Moon or light pollution, or haze, to be repeatable.

The idea of a 'glimpse' is that it is positively there or not. And it doesn't need a watch. There are 10 or so varieties...

- If you see a star *before dawn*, it's positively there, or if you can't see it *after dark*, it's not there.
  - Look to the East before dawn and you will see **a new star appearing** for the first time in the season — a first glimpse.
    You will then lose sight of it due to daylight. This is the standard star-calendar event.
  - Look to the West after sunset and a star will have **disappeared** for the rest of the season — a last sighting.
    You glimpse it briefly, before it moves into the sunset glow, and is lost to sight for weeks.
  - Examples: The last glimpse of Spica is just after the September Equinox; Regulus is first seen just ahead of the September Equinox;
    The Equinox is between the two, and both are on the Ecliptic, about 25° each side. That's 25 days for the Sun's movement.
    The first glimpse of Antares is around Christmas time, since it is about 20° ahead of the solstice;
    Aldebaran reappears around the winter solstice; The Twins disappear soon after it.
    The solstice is between these two, 25° away from each.

  You need to check the exact dates of appearance and disappearance because they vary with the exact latitude—this is a semi-local calendar.
- If *a star-pair* has tilted *out* of alignment by the time the stars come out, you simply *don't* see it occur;
  or if it doesn't align before dawn, you can't see it 'happen'.
  - Look pre-dawn for the first date on which you can glimpse **a star pair reach its proper alignment**, before dawn takes over.
  - Look post-sunset for the *last* date on which you can see a star pair attain its right alignment, after which it is lost for a month or so.
- Each day a Western star gets closer to the Western horizon from above. Each day a rising star gets earlier to the Eastern horizon, from below.
  - Look for the first glimpse of a star clearly **rising or setting** *pre-dawn*
  - Look for the last glimpse of a star clearly **rising or setting** *post-sunset*.

  If you see it setting, you know it; if you see it rise, you have seen it happen.
- Wait to see whether a star reaches a known fixed **height** (e.g. not too far above the horizon), to make observation easier.
  - Looking at a reflection of a star in smooth water or oil, will *double* its height 'above horizontal', if you want a method to work anywhere.
- Wait until a star coincides with a known fixed **direction** (e.g. 'over the tower'). This makes it location-specific, but may be useful.

These all have the effect of describing the height or tilt or direction of the horizon 'at twilight'.

- A star **overhead** at twilight will show up as a first/last glimpse. You look for it, but it may not 'happen'. This is latitude-specific.

~ You could now combine the 'glimpse' methods and 'crisp timing' to avoid the indistinctness of twilight (but this is more latitude dependent).
Look 'exactly 1 hour from sunset/rise' to crisp up the timing of the 'events'. Any exact time-span at least that long, would suffice.

~ To clinch the star-time, in a latitude-independent way, **use Great-Circle type directions** ('at right-angles to sunset/sunrise' 'a star near the Sun at twilight' 'opposite it') to ensure that people over a wide range of latitudes more or less agree in their observations.
The standard direction is not sunrise/sunset itself but 'where the Sun is *at twilight*' which is 1 hour to the left (SH); *the brightest part* of the horizon.

- identify star-pairs ***at right-angles to the Sun's* direction at twilight**.
- or examine the rise/set of **stars *near the Sun***, especially those ahead or behind it, in its rising and setting path.
- or look for stars rising, setting or simply being visible, ***opposite* the Sun** at twilight.
- You can use any other 'star direction', but it will only apply to that latitude. The best great-circle directions are between NW/SE & NE/SW.

~ But the sensitivity can be further improved, by **choosing *which* twilight** gives the most daily change…

- The nightly change (averaging 4 mins) is not the same amount through the year.
  It can be reduced to 3 or increased to 5 in a place like Tasmania, as the seasonal day-length varies by several hours.
  The change in sunrise or sunset time by up to a minute a day is overlaid onto the steady star progression.

Look at the time of day when the most rapid change is taking place, since you want the most accurate discrimination:

After mid-summer, look for 'first glimpses' in the pre-dawn ;

- Nights lengthen after the summer solstice — more stars rise in the East than set in the West as the night-time gradually dominates
  At dawn, the Sun lingers a little longer under the horizon allowing more stars to rise, in their creeping ahead of the Sun.
  But at sunset, the Sun goes down earlier, like the stars do, and you don't notice much change as to which stars are up.
- So when the nights lengthen, look **before dawn** and try to see any first glimpse this season.
  Luckily the pre-dawn in Summer/Autumn is mild, but it can be quite early. Use the clock-time delay method 'from sunset', not 'to sunrise'.

After mid-winter, look for 'last glimpses' post-sunset ;

- Conversely, after the winter solstice, the increasing day length dominates over the night sky — more stars set and fewer stars rise.
  You will lose sight of stars setting in the West, quite easily, as the Sun will linger before setting, because of the season,
  but find it hard to see a new star rising in the East for the first time that year, because the Sun pops up early.
- So when the days lengthen, to pinpoint the time of year, look **after sunset** for any last glimpse.
  That's not too late at night in Winter/Spring, and it should not be too cold. Or use the clock-time 'until sunrise', to maximise the daily gap.

The overall idea works in both hemispheres, but the optimal choices of when to look are tied to the seasons, not the date.
Use either method, when near to the solstice, or near the Tropics, or at any time you want to.

- Around mid-winter and mid-summer, you can happily use any of the 10 glimpses, or any of the clock-time methods.
- Near the Tropics, also, there is little differential advantage, compared with temperate latitudes, since day-length is fairly constant

~ Keep a special perpetual calendar (a 365 day chart with no days of the week specified) to note down your observations; with room for related seasonal changes, like bird migrations, frosts, plantings.

All this has little to do with navigation, directly, but gives you practice in *following the seasonal movements* of Sun and stars.

About the Author.

I have a big bushy beard from too much bushwalking and ocean sailing, but now that it has grown too grey, it is time to hang up my boots and write it all down.

My dad was a ’plane navigator during World War 2 and as a child I studied his manuals. Then at University I spent more time in studying naval navigational manuals and in bushwalking off track, finding my way over the snow or canoeing across lakes, than in studying for my exams. I used the library to learn spherical trigonometry, then, as soon as I finished Uni, set out across the trackless ocean. I soon found myself inventing techniques to plug the holes in my normal abilities. I returned home years later, not knowing what I was meant to do in life, but as I lay there on my old bed, I knew that if I was to be a navigator I would like to be one like Captain Cook. He experimented with new techniques, and with old — he described native sea-navigation expertise. How *did* they do it? Even now, no-one seemed to know. I immediately had a vision of one star above another, which kept me busy for years on great-circle navigation methods.

I had honed my skills trying to teach boaties and would-be ocean sailors, but my biggest challenge was to teach my wife and children. We became a feral family for a while and walked every track we came across, here and overseas. Only then did I appreciate how much more there is to orienting yourself *to your surroundings*, than simply having a compass.

My next inspiration came while walking the forest on a foggy day. I simply asked how the trees themselves would hold the secret to which way is which. Years of observation and testing later again, and this is the result. I don’t want it to die with me.

I hope you too can now enjoy the magic of the science and love the art of exploring, even teaching yourself, before you too have to stop still, inside the bounds.

Learn a little before it is too late.

Outline

“Navigation Down-Under” is your complete manual of bush navigation and outdoor orientation for when you go off the well-worn track. A free pocket guide to take with you bush-walking is part of the pack.

Do you know how to predict and find direction from the Moon by memorising just two simple numbers? Can you interpret the Australian bush plants for direction? You will find some never-before published new techniques, as well as all you need to know about traditional methods like Lie-of-the-Land.

If you come from the Northern hemisphere, you’ll need the top-down global approach, and can try some special Southern Hemisphere methods of direction keeping.

Sailors will find here a valuable beginning into celestial navigation.

A lot of it is about how to navigate without a compass, how to stay oriented and how not to get lost. It is an essential course in basic bush awareness and orientation, for surety and safety, plus it also throws out the challenge that you can improve your already existing competence very quickly and easily.

For Scouts or emergency search-and-rescue workers, it is a thorough course, advancing beyond the map and compass. Or perhaps you are a tour-guide and need more than course and distance — You’ll get something more, something more like biogeography or ecology.

Each page is a carefully arranged lucky dip of interesting tidbits.

Keywords

Navigation; Orientation; Celestial Navigation; Bushwalking; Map and Compass; Without a Compass

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Global Perspective; Earth

3 Compass Navigation Robs You of a Global Perspective
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22 The Moon is "in Phase" with the Sun — Watch for It
24a The Moon Moves Over the Tropics
24 Predict the Full Moon Path According to the Time of the Year
24d Finding North from the Moon, by its height & phase
25 Predict the Moon Phases by " N minus M "
28a Find E/W By Bisection of Sun & Full Moon At Rise or Set
28 To Predict the Moon's Path, Visualise the Ecliptic
29a Find North from the Combination of the Sun & the Moon
29 A 4 Week *Position Cycle* of Moonrise/set, to Find E/West
29e Keeping Track of the Moon's Motion along the Ecliptic
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5 Mnemonic: "Wind? Weather Map!"
7 Mnemonic: "Wind in Your Face"
9 'Low' Clouds Come Clockwise Down under
11 Weather Fronts Distort The (Circular) Wind Circulation
13 Wind-Direction-Change Rule for Buys Ballot's Law
13 Steering Winds
15 Atmospheric Pressure Changes.
17 Watch the Clouds Cross the Moon
19 To Determine Upper Wind Direction from the Clouds
21 Clouds and Con-trails and Their Winds
23 Prevailing Winds on Creek Banks Tips for calm weather
27 Make a Bush Psychrometer
31 Topographic-Level Winds
33 Overview: Global Weather Patterns

52e The Aurorae
53e City Glow

Clockwise See also Map & Compass Work

4 Mnemonic: "Clock"wise Northern Hemisphere SWiNES
6 "VEERING" with the Sun is "Clockwise"
only in the Northern Hemisphere
"BACKING", against the Sun's movement, is "Anticlockwise"
— but only in the Northern Hemisphere.
8 Mnemonic: (when you say) "COMPASS" (say) "CANADA"
10 "Bears Circle Clockwise" Compass Bearings are Clockwise,
A Full Circle, and Eurocentric, Cee?
12 Mariner's "Compass Points" work on Successive Halvings
14 "E. W. N. South" Of What!? Rule: Say What
16 Back-Bearings Killed Sleepy Pilots
18 Back-Bearing: Plus or Minus 200° Then Minus or Plus 20°
20 Turn 90°? "+/-100° -/+10°" !
22 The Clock-Face Method for Direction
24 One Degree is about One in Sixty
26 Anticlockwise is Your Best Spin-Reference Direction
28 Bearings & Tracks: "If it is right, it is big in my sight"
30 "By the Nose" Navigation
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5 Mnemonic: Down Under, The Sun Moves ANTI-BigBENWiSE
i.e. anticlockwise
7 Southerners Need Anticlockwise Systems
9 A Compass-Needle Continent—Swinging the Continent
11 Interpret a Compass Needle as "RED HOT—WHITE FROST"
13 Four Reference Directions—Name Them "Rise, Noon, Set, Midnight"
15 "Rise-Noon-Set-Midnight" carries its meaning across the Equator!
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17 The 0, 1, 2, 3, 4 Reference Directions
19 The Sunny Skies Quadrant System
21 The "SWEETHEART" Method of Orientation
23 Mnemonic: "North; Coast"
23 Go Overseas!
27 Walk across Australia! English!
29 South is a Triply Better Reference Direction than North, in the Sth
31 Nose-Navigation Needs an 'Anti' Mnemonic: "Nor-West, Not-Least"
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The Precession of the Equinoxes
The Moon
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The Moving Horizon
The Spherical Earth
The Spinning Earth
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34 Navigation is More Than Navigating Common Sense
36 The "Good" Navigator. You.
38 Don't Just 'Get By' and 'Make Do'
40 Walk Where the Navigators Talk — if you want to learn navigation
40 Explore It's No Fantasy
42 Self-Motivation is Fundamental
44 Routine Mind-Shut-Down Procedures
46 Navigation is Mental Work — Stay Alert
48 To Work Harder, Rest Harder
50 A Three-Track Mind
52 Concentrate Outwards
54 Come to your Senses

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34 Your Subconscious is Superior to Science!
36 Think out Loud
38 Memories are Made of Landscapes, Not Compass Needles!
40 Feed Your Subconscious through Your Conscious Focus
42 How to Feed Your Brain
44 Feed Your Subconscious Subconsciously
46 Instruments Instruct the Intelligent
48 Minds Work Best with Intelligent Questions on Them
50 Interpret!
52 SPELL Out Numbers — Into Words
52 PAINT your Words — Into Pictures
54 TRANSFER Your Pictures into Reality
54 Put That Experience in Your Memory Bank
55 Extend Visible Reality into the Invisible Picture

Angle:

34 Measuring angles at 1 cm per degree
35 Point and Blink = 10% Shift
36 Guesstimating Angles at 1 degree per cm
37 Distance using Apparent Size;
37 Visual Angle, Size and Distance & 6°; Side-wise Offset
(38, 39 Grid-line Walk & Mental Grid Maps)
40 Cyclical Motion Divided into 12ths
41 Approximate Sine-Wave Values

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34 Visual Assessment is Your Main Clue — Rely on It More
36 You Need Excuses to Stop and Have a Good Look
38 You Need a Road-Map To Climb a Hill!
40 Look into the Far Distance Look through the Haze Wait
40 Wait for a Change in Perspective...
42"Retracing is Re-preciating"
44 Look Back Regularly. Look Around
46 Look Through the Vegetation, to the Contours
48 Play the Field-Scientist
50 Look at the Ground
52 Look for Foreshortening & Overlap & Parallax
54 Look, with Vengeance Aforethought

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3 Visualisation is your Key Skill
34 Integrate: Jetstream, Earth Rotation & Heaven Rotation
36 Visualise Familiar Landscape Trends, Under the Sun
38 'Land to Sky — Sky to Land' Navigation
40 Join the Invisible Big Picture To the Visible Landscape
42 Landmark to Landmark Network Navigation
44 Aim to Integrate…
46 Imagine an Aerial Photograph of the Continent
48 Connections to the Outside World
—You don't need to feel isolated
50 Orientation is More Fundamental Than Position Sense
52 Make Common Sense of the Various Direction Clues
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54 Preparation is the Key to Difficult Navigation
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43e Name Each Clue — with solid ground
44e Notice and Match Up
45e In-Line Integration
50e Think in Pairs, in lines, trends and tracks
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37 The Get-Back Path is the Single Fundamental
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39 Disorientation is More Dangerous Than Being Lost
39e Mental grid Map
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45 Un-Dis-Oriented;
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49 OverNavigate: Equals Over-Familiarise
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51 Orientation to Your Finish Point, By the Parallax Method
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37 How I Manage to Get Lost or Disoriented
39 Logical Blunders — Examples
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45 Trapped! By Not Looking Back
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35 Reorientation
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39 Trust the Untrustworthy
41 Trust Less and Prove More
43 Trust Yourself Less
45 Disoriented? Stop. Say So. Reorient!
47 Reorientation; And a Fresh Start
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53 Look for the Essentials — the 'Directions'
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37 Back-track in Your Mind before You Back-track on Your Steps
39 Rule 2: Start! Getting Unlost. Find yourself. Regain confidence
38e Grid-line Walk — Explore in a Square Grid Pattern
39e Mental Grid Map
41 The Simplest Way to Get Unlost is to Retrace Your Steps
43 More is Better — Thought, Time Care
45 Lost? Rule 3: Do a Good Job—of walking out or staying put
47 How to Leave a Message
49 Lost? Rule 4: DON'T Do It Again!
51 Separated? An Agreed Plan Helps
53 A Whistle-Code for Contact Calls
55 Search and Rescue Signals — Noises Repeated Regularly
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121 Appendix: Semaphore Code and Mnemonics for it

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64 Be Wind-Wise: Listen
64 Obvious Tell-Tales: Windblown Objects
64 Obvious Tell-Tales: Landscape
66 Light & Colour Effects
68 Botanical Tell-Tales
70 Combined Effects of Wind, Salt and Light
70 Botanical Asymmetry
72 Think like a Plant
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72 "Fern Fronds Face the Front" i.e. the sunny side
74 Bush Noon— The Sun is Always out, If You Know How to Look
74 False Asymmetry & Symmetry True Symmetry & Asymmetry
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76 The Lowest Leafy Branches are on the Noon-Side
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84 Flowers Respond to Sunlight Fruit Distribution and Ripening
86 Stem and Leaf Colouring New Growth is Colour Differentiated
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56 Unlock Memorable Chapters in Your Life
56 Go for the Jugular. Zero in on What Matters
58 Don't Try to Memorise Details without an Overall Framework
58 Don't Try to Remember Anything You Haven't Memorised
58 Write down What You Memorise!
60 Anything is Memorable
60 Make Individual Memories Memorable!
60 Remembering Trees
62 The Difference between Looking at, and Seeing
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61 Uphill — Which Hill? Upstream — to which Divide?
63 Shoulders Stop. Shoulders are Not Easy (like Ridges) to Walk on
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69 Break of Slope — And Route-Finding
71 Mnemonic: "Down in the Mouth" Which way is the flow?
71Hint: Don't think "this side" & "the other side".
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92 Use the Map Scale—Don't Just Look at It The Jargon
92 Map-Scaling-Factors are Meant to be Interpreted
94 Psychological 'Half-Way Point' When You Meet Other Walkers
96 AIMING OFF by 10° — 10° is **175m per kilometre**
96 Aiming-off at Sea; Aim Off 10% or 6°
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100 Distance by Double Pace—Test Yours Tie Your Ankles Together
100 Don't Lose Count! Use Finger-Math
100 Test your pedometer
102 Line of Sight Can Be Extremely Accurate
102 Two Opposite Landmarks
104 "Changeover Lines" of Progress — Relative Apparent Sizes
104 Use the Landscape Itself to Measure & Mark Progress
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108 Progressing A Position Line across the Map
108 Pinpoint "Fixes" are a Myth!

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92 Pace Your Progress — Pre-Dict It, Don't Post-Dict It!
92 Advice about Walking Times — Double & Halve!
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92 4 km per hour — Normal Walking Pace — Double and Halve!
94 1 Metre per Second is 3.6 kph "1 Hour Extra per 5 Hours"
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96 Adjust Your Expected Pace
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94 Double, the Acute Angle, off Your Nose — For the Distance Off
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97 "Maps Grip the Universe"
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93 Using the Protractor by Itself
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97 Think "+/- 5°" For Compass Bearings "+/- 10°"
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99 Compass Errors — Be Impressed! Be Careful!
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97 Caving Strip-Maps — Come in Books
99 Map Folding and Map Holding
101 Layout Map — Blind
103 A Compass Holder
106a The Sine-Cosine Tally Method of Keeping Track, Blind
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111 Distance
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112 Look in These 6 Directions — in 6 ways — Up and Down
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115 Clock-Sense Mnemonic
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115 Re-lax, and Play — Navigation Games and Activities

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Appendix

Eastern Australian Standard Time Zone

10 hours ahead of Greenwich
Showing Tropical countries and places underneath the Sun

p24a,25a

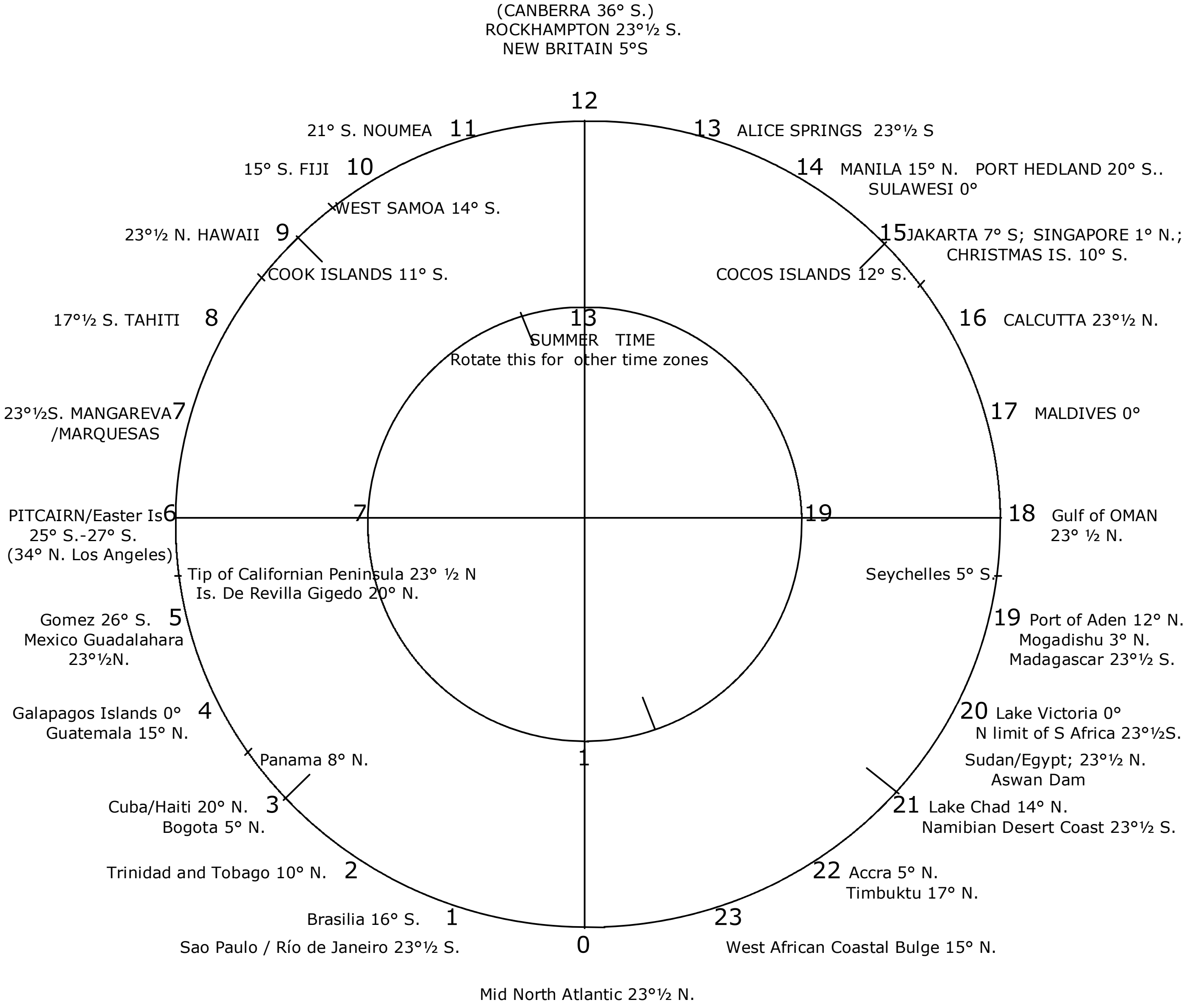
(CANBERRA 36° S.)
ROCKHAMPTON 23°½ S.
NEW BRITAIN 5°S
12
21° S. NOUMEA 11
13 ALICE SPRINGS 23°½ S
15° S. FIJI 10
14 MANILA 15° N. PORT HEDLAND 20° S..
SULAWESI 0°
WEST SAMOA 14° S.
23°½ N. HAWAII 9
15 JAKARTA 7° S; SINGAPORE 1° N.;
CHRISTMAS IS. 10° S.
COOK ISLANDS 11° S.
COCOS ISLANDS 12° S.
17°½ S. TAHITI 8
13
SUMMER TIME
Rotate this for other time zones
16 CALCUTTA 23°½ N.
23°½S. MANGAREVA 7
/MARQUESAS
17 MALDIVES 0°
PITCAIRN/Easter Is 6
25° S.-27° S.
(34° N. Los Angeles)
7
19
18 Gulf of OMAN
23° ½ N.
Tip of Californian Peninsula 23° ½ N
Is. De Revilla Gigedo 20° N.
Seychelles 5° S.
Gomez 26° S. 5
Mexico Guadalahara
23°½N.
19 Port of Aden 12° N.
Mogadishu 3° N.
Madagascar 23°½ S.
Galapagos Islands 0° 4
Guatemala 15° N.
20 Lake Victoria 0°
N limit of S Africa 23°½S.
Panama 8° N.
1
Sudan/Egypt; 23°½ N.
Aswan Dam
Cuba/Haiti 20° N. 3
Bogota 5° N.
21 Lake Chad 14° N.
Namibian Desert Coast 23°½ S.
Trinidad and Tobago 10° N. 2
22 Accra 5° N.
Timbuktu 17° N.
Brasilia 16° S. 1
23
Sao Paulo / Río de Janeiro 23°½ S.
0
West African Coastal Bulge 15° N.
Mid North Atlantic 23°½ N.

Places in capitals are less than 6 hours away from Australia. The others are on the other side of the world.
View this as if from above the North Pole—the Sun 'moves' clockwise, but the Earth spins anticlockwise.

Eastern Australian Standard Time Zone

10 hours ahead of Greenwich
Showing Tropical countries and places underneath the Sun

Cut this one out and post it on your wall until you have learned most of it.

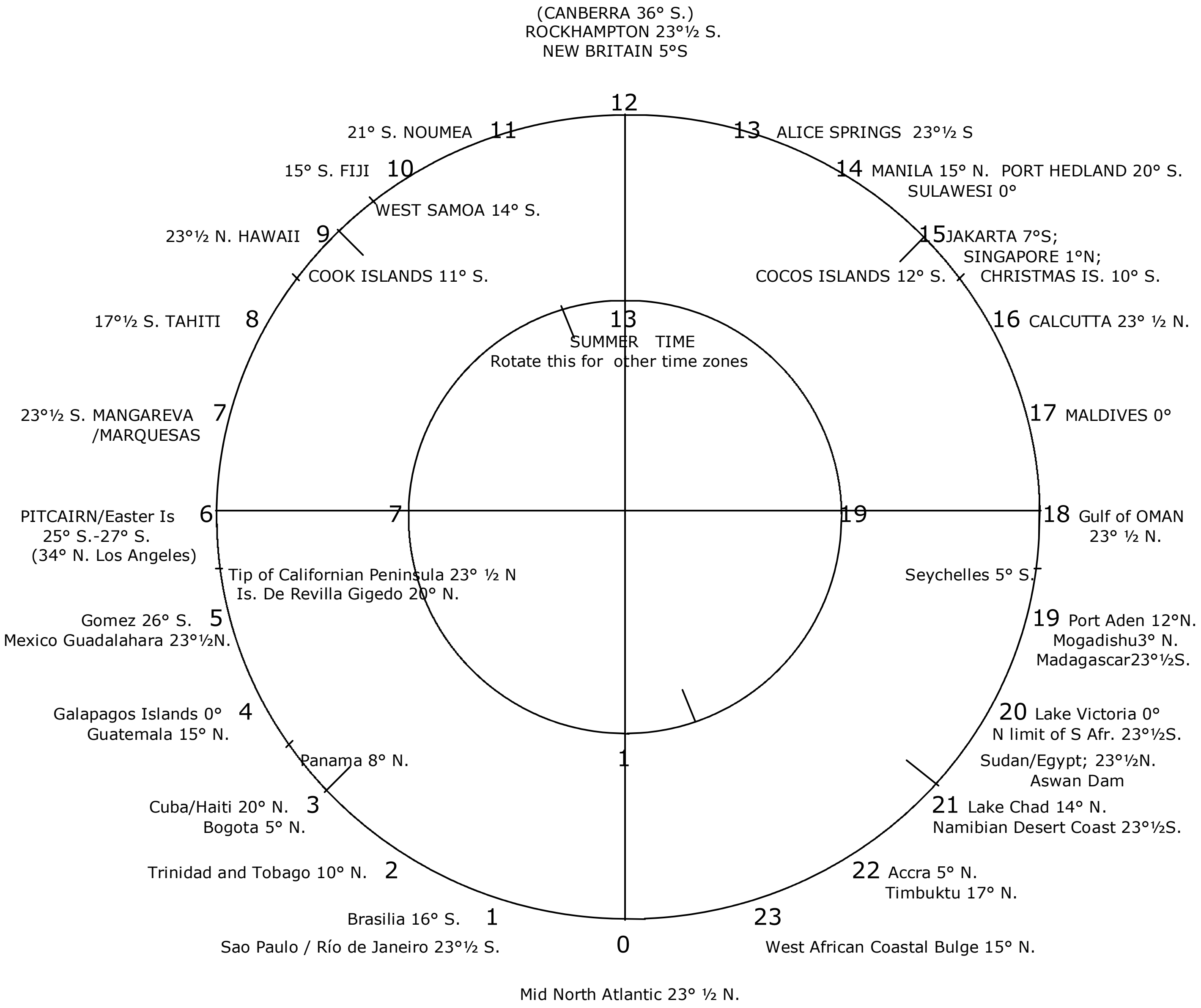

(CANBERRA 36° S.)
ROCKHAMPTON 23°½ S.
NEW BRITAIN 5°S
12
21° S. NOUMEA 11
13 ALICE SPRINGS 23°½ S
15° S. FIJI 10
14 MANILA 15° N. PORT HEDLAND 20° S.
SULAWESI 0°
WEST SAMOA 14° S.
23°½ N. HAWAII 9
15 JAKARTA 7°S;
SINGAPORE 1°N;
COOK ISLANDS 11° S.
COCOS ISLANDS 12° S.
CHRISTMAS IS. 10° S.
17°½ S. TAHITI 8
13
SUMMER TIME
Rotate this for other time zones
16 CALCUTTA 23° ½ N.
23°½ S. MANGAREVA
/MARQUESAS 7
17 MALDIVES 0°
PITCAIRN/Easter Is 6
25° S.-27° S.
(34° N. Los Angeles)
7
19
18 Gulf of OMAN
23° ½ N.
Tip of Californian Peninsula 23° ½ N
Is. De Revilla Gigedo 20° N.
Seychelles 5° S.
Gomez 26° S. 5
Mexico Guadalahara 23°½N.
19 Port Aden 12°N.
Mogadishu3° N.
Madagascar23°½S.
Galapagos Islands 0° 4
Guatemala 15° N.
20 Lake Victoria 0°
N limit of S Afr. 23°½S.
Panama 8° N.
1
Sudan/Egypt; 23°½N.
Aswan Dam
Cuba/Haiti 20° N. 3
Bogota 5° N.
21 Lake Chad 14° N.
Namibian Desert Coast 23°½S.
Trinidad and Tobago 10° N. 2
22 Accra 5° N.
Timbuktu 17° N.
Brasilia 16° S. 1
23
Sao Paulo / Río de Janeiro 23°½ S.
0
West African Coastal Bulge 15° N.
Mid North Atlantic 23° ½ N.

Places in capitals are less than 6 hours away from Australia. The others are on the other side of the world.
View this as if from above the North Pole—the Sun 'moves' clockwise, but the Earth spins anticlockwise.

Nov. 12, 1957

L. R. CRUMP

POWERING ELECTRICAL DEVICES WITH ENERGY
ABSTRACTED FROM THE ATMOSPHERE

Filed March 12, 1954

2,813,242

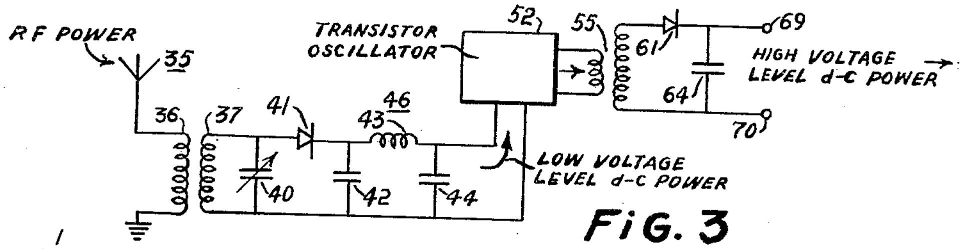
RF POWER
35
36
37
41
46
43
40
42
44
TRANSISTOR OSCILLATOR
52
55
61
64
69
70
HIGH VOLTAGE LEVEL d-c POWER
LOW VOLTAGE LEVEL d-c POWER

FiG. 3

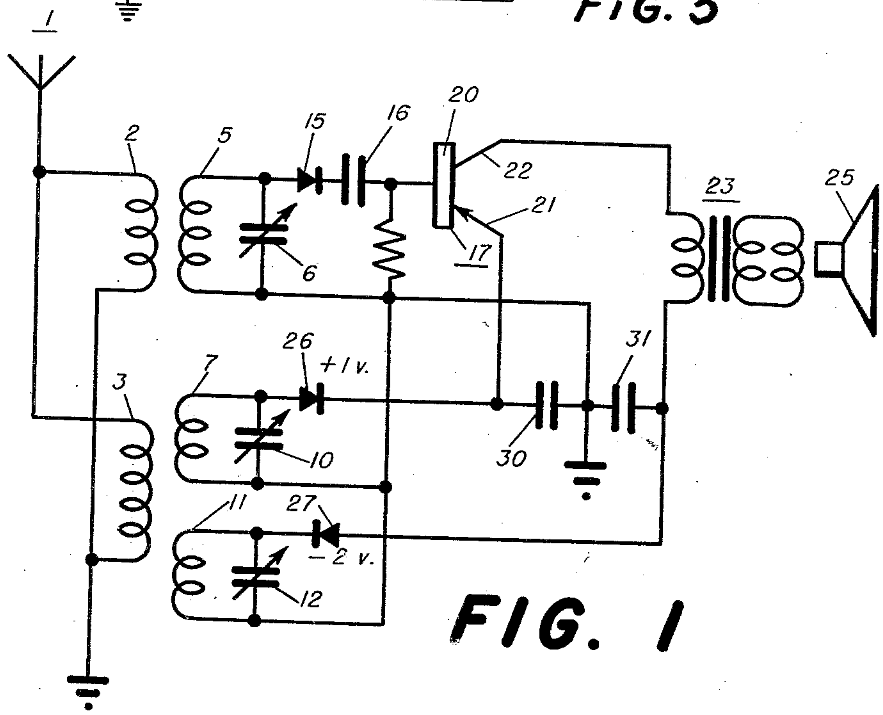
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-2 v.
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FIG. 1

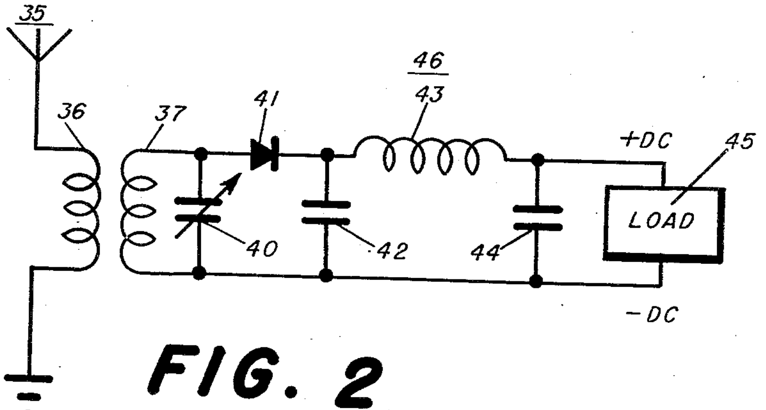
35
36
37
41
46
43
+DC
45
LOAD
40
42
44
-DC

FIG. 2

INVENTOR
Lloyd R. Crump

BY W.E.Thibodeau + A.W. Dew

ATTORNEYS

United States Patent Office

2,813,242

Patented Nov. 12, 1957

2,813,242

POWERING ELECTRICAL DEVICES WITH ENERGY ABSTRACTED FROM THE ATMOSPHERE

Lloyd R. Crump, Silver Spring, Md.

Application March 12, 1954, Serial No. 415,986

1 Claim. (Cl. 321—2)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to the convenient and economical provision of power for the operation of electronic circuits and devices using transistors, and of other electrical devices having modest power requirements.

A great advantage of transistors, and a major reason for their enthusiastic reception since their introduction a few years ago, is the fact that they will operate satisfactorily with very low supply voltages and currents. One milliwatt or even less is sufficient to power a transistor in many applications. Various batteries have been developed to provide, in a minimum of space, the relatively minute amounts of power needed by transistors.

My invention provides methods and means that permit transistor circuits, and also other low-powered electrical devices, to be economically and conveniently operated without any batteries whatever, and indeed without any power supply whatever as power supplies are ordinarily conceived.

The invention centers around my discovery that it is practicable to construct operative transistor circuits that are able to abstract from the atmosphere sufficient electromagnetic energy to provide all necessary supply voltages and currents for their own operation. Circuits and devices powered according to my invention will operate indefinitely without any local power source whatever.

I have successfully constructed and demonstrated such circuits. For example, I have constructed a batteryless transistor radio receiver on which I have listened to either nearby or distant broadcast stations as desired, using either headphones or a loudspeaker; this receiver has been powered entirely by electromagnetic energy abstracted from the atmosphere.

From the successful operation of this receiver, and from other experimental work, it becomes clear that, by the methods and means of the invention, a great variety of practical and useful transistor circuits can be powered entirely by energy abstracted from the atmosphere.

Furthermore, as will become apparent below, my invention is applicable to the powering of other electrical devices requiring relatively small amounts of power.

An object of the present invention is to provide methods and means for powering transistor circuits entirely from radiofrequency energy abstracted from the atmosphere.

Another object is to provide methods and means for powering remote radio receivers, low-powered radio transmitters, and other low-powered electrical devices, with energy received by radio from a master station, so that no local power supplies are needed by the devices and so that the powering or non-powering of the remote device is under the control of the master station.

A further object is to provide methods and means for powering transistor circuits and other low-powered electrical devices with radiofrequency energy received from one or more remote radio transmitters.

Other objects, aspects, uses, and advantages of the invention will become apparent from the following description and from the drawing.

Figure 1 is a schematic diagram of a transistor radio receiver in which all necessary power is supplied by energy abstracted from the atmosphere in accordance with the invention.

Figure 2 is a schematic diagram showing a general application of the invention to provide direct-current power to a load.

Figure 3 is a schematic diagram of a system for obtaining a high energy D.-C. source at a high voltage level using energy abstracted from the atmosphere.

Referring to Figure 1, a receiving antenna **1** is connected to antenna coupling coils **2** and **3**, the other ends of which are connected to ground. A parallel resonant circuit consisting of coil **5** and capacitor **6** is coupled to coil **2**. A second parallel resonant circuit consisting of coil **7** and capacitor **10** is coupled to coil **3**. A third parallel resonant circuit consisting of coil **11** and capacitor **12** is also coupled to coil **3**.

Coil **5** and capacitor **6** are tuned to the frequency of a radio transmitter from which it is desired to receive information—for instance, an amplitude-modulated standard broadcast station. The signal received from this transmitter need not be strong. The signal is detected by diode **15** to obtain an audio-frequency information signal. This audio signal is coupled through a capacitor **16** and is amplified by a circuit that includes a transistor **17** having a base **20**, an emitter **21**, and a collector **22**. The amplified audio output of the transistor is coupled through an audio transformer **23** to an electroacoustical transducer, preferably a permanent-magnet dynamic loudspeaker **25** as shown.

The novelty of the invention lies largely in the method and means by which the necessary direct-current power is supplied to the emitter and collector circuits of transistor **17**. This method and means will now be described.

Coil **7** and capacitor **10**, and also coil **11** and capacitor **12**, are tuned to receive radio signals of relatively high strength. It does not matter whether these signals contain information. These power signals are rectified by diodes **26** and **27** to provide direct-current power that is filtered by capacitors **30** and **31**. The D.-C. power thus obtained is utilized to power the transistor **17**.

In the circuit shown, two tuned circuits (coil **7** and capacitor **10**, and coil **11** and capacitor **12**) are tuned to power signals and the D.-C. voltages obtained from each are connected in series. The tuned power circuits may be tuned to the same or different power signals. Under certain circumstances it may be desirable to use more than two tuned power circuits and to tune them to more than two power signals; in this way power can be obtained from several signals and combined. On the other hand, if a strong power signal is available, a single tuned power circuit may suffice to give the needed D.-C. power.

Even weak information signals can be received successfully. A plurality of transistor amplifier stages can be used if desired, or other circuits such as superheterodyne circuits can be used. It is merely necessary that a sufficiently strong power signal or signals be available to provide the small amount of D.-C. needed to power the transistors.

If the information signal happens to be strong, it can be used as the power signal; all of the tuned circuits (coil **5** and capacitor **6**, coil **7** and capacitor **10**, coil **11** and capacitor **12**) are tuned to the information signal.

Engineers who have observed my invention in operation have been surprised at the unexpectedly good results obtained, even with readily available power signals of quite moderate strength. For instance, sufficient power for satisfactory operation of a loudspeaker at low volumes is readily obtained from a 5-kilowatt standard broadcast station 5 miles away, using only an indoor antenna to pick up the power signal as well as information signals. In typical operation under these conditions a D.-C. voltage of about 2.5 to 3 volts is obtained between the emitter and the collector, at a current of about 250 microamperes; D.-C. power input to the transistor is thus of the order of 0.5 to 1 milliwatt. So far as I am aware, no one has ever before discovered and demonstrated the practicability of this method of powering a radio receiver.

Because existing broadcast stations within a radius of a number of miles provide adequate power signals, the invention is readily practicable with existing power signals in almost any location in or near any city in the United States.

Although I have described a transistor radio receiver powered by my invention, it will be readily apparent that the invention is applicable to the powering of any transistor circuit using one or a number of transistors, and to the powering of other devices requiring relatively small amounts of power. For instance, sensitive electromechanical, electrochemical, or electrothermal devices can be operated by the method of the invention.

Referring to Figure 2, which shows a more general embodiment of my invention, an antenna **35** picks up radiofrequency energy from the atmosphere. This energy flows through coil **36**, which is coupled to a tuned circuit consisting of coil **37** and capacitor **40**. The radiofrequency voltage across capacitor **40** is rectified by diode **41** and filtered by a low-pass filter **46** consisting of capacitors **42** and **44** and choke coil **43**. The resulting D.-C. voltage is applied to a load **45**.

In the practice of my invention, larger amounts of power can be obtained for short periods of time by storing received energy in a suitable energy storage device. Stored energy may then be withdrawn at intervals at a more rapid rate than that at which it was received and put into the storage device. In this way the invention can be used to provide short pulses of relatively very high electrical energy. This result can be readily obtained by charging a relatively large capacitor with direct current and then discharging the capacitor rapidly into a load when desired. This rapid discharge can be initiated automatically when the voltage across the capacitor reaches a certain level, or it can be initiated when a transistor radio receiver receives a certain information signal.

Higher voltages can be obtained with the invention by means of well known devices for raising D.-C. voltages as shown in Figure 3. The D.-C. voltage output from the capacitor **44** can be used to power a low frequency transistor oscillator **52** whose A.-C. output is raised to a higher voltage level by the transformer **55**. This relatively high A.-C. voltage can then be rectified by a diode **61** and fed to a capacitor **64** to provide a high energy D.-C. source at a relatively high voltage level at the terminals **69** and **70**. If desired, energy can now be withdrawn from the capacitor **64** at intervals in short pulses of high energy at a high voltage level. Pulsed radio transmission is one of the possible uses for this form of the invention. Other uses would be to provide a single relatively powerful pulse needed to actuate an electrothermal or electromechanical device.

As has been indicated above, in many locations and particularly anywhere in or near most American cities, power signals normally present in the atmosphere are readily available for the easy and convenient practice of the invention. However, the invention also has important applications in systems in which the necessary power signal is generated and transmitted specifically for the operation of the particular system. Such systems can, for example, comprise a master station transmitting all the power that is needed for hundreds or thousands of fixed or mobile transistor receivers or other remote devices over a range of many miles. This eliminates the need for hundreds or thousands, as the case may be, of local power supplies. At the same time, such a system has the advantage that all of the remote devices can be simultaneously activated or deactivated at the will of the master station, simply by starting or stopping the transmission of the power signal. In such systems it will often be advantageous to use power signals of frequencies sufficiently high to permit the use of resonant receiving antennas of small physical dimensions for signal pickup at the remote devices. In addition to the power signal, the master station may transmit an information signal on the same or a different carrier.

Certain types of devices powered entirely by received radio waves are of course well known. The well-known "crystal set" of the early days of radio, which used a diode rectifier to demodulate an amplitude-modulated radiofrequency signal, is an outstanding example of such a device. My invention is readily distinguishable from such prior devices, however. In typical prior devices a modulated radiofrequency signal is applied to a diode to obtain unidirectional half-wave pulses whose amplitudes vary with modulation. These pulses are integrated by means of a capacitor to obtain a unidirectional signal the amplitude of which follows the audiofrequency modulation envelope. If the radiofrequency signal is received with sufficient strength the audio signal may have sufficient power to operate headphones or similar utilization device without power amplification; but the signal is utilized for its information content, rather than to supply non-information-containing power.

My invention, on the other hand, entails the utilization of received radiofrequency energy to supply power to at least one pair of circuit points (across capacitor **31** in Fig. 1, for example), such circuit points requiring power solely for its power content and not for any information or modulation it may contain. In other words, my invention entails the utilization of radiofrequency energy to supply power that would otherwise have to be supplied by batteries, generator, or other local power source.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claim.

I claim:

An electrical device for obtaining a high energy D.-C. source at a high voltage level using energy abstracted from the atmosphere, said device comprising in combination: resonant means for receiving radio waves, first rectifier means for converting said radio waves into first direct current energy, first capacitor means for storing said first direct current energy, an oscillator powered by said direct current energy, said oscillator producing an A.-C. output, transformer means for raising said A.-C. output to an increased voltage level, second rectifier means for converting the A.-C. output of increased voltage level from said transformer into second direct current energy, and second capacitor means for storing said second direct current energy.

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advertisement

FREE ENERGY MICROWAVE

Technology (/technology/) > Electronics | by GEORGE CHANIOTAKIS (/member/GEORGE+CHANIOTAKIS/)

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Posted Dec. 22, 2015 | BY-NC-SA

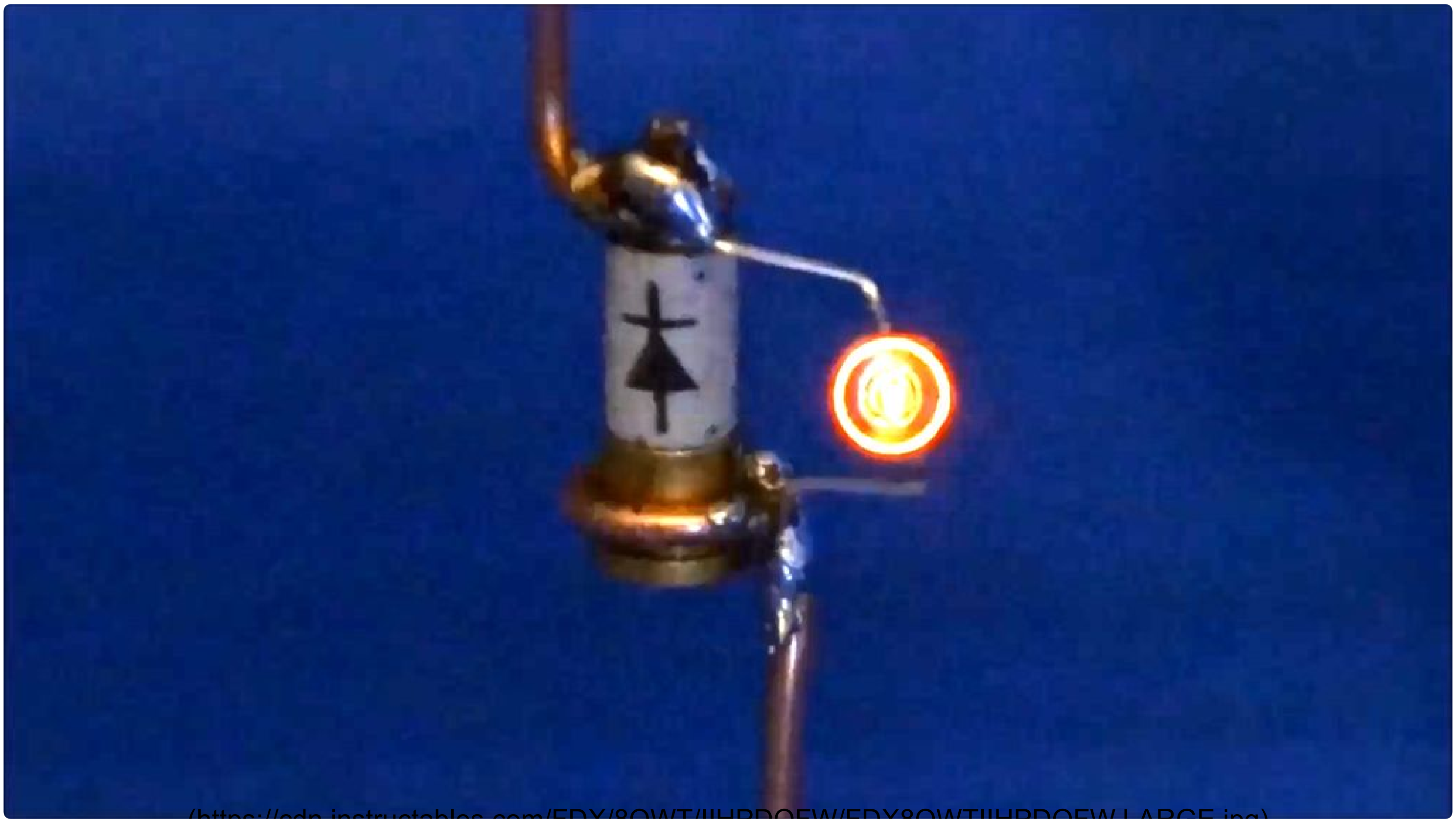

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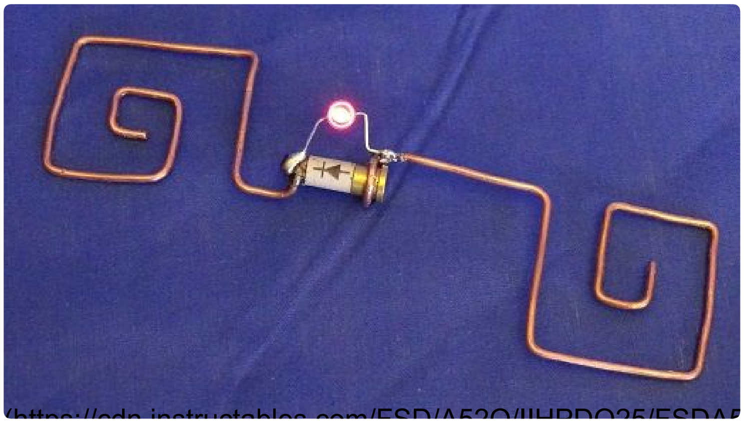
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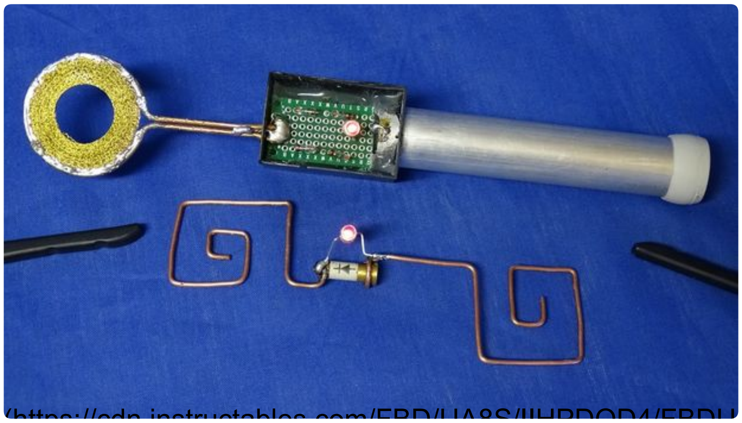
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In electronics, a diode is a two-terminal electronic component that conducts primarily in one direction; it has low resistance to the flow of current in one direction, and high resistance in the other. A semiconductor diode, the most common type today, is a crystalline piece of semiconductor material with a p–n junction connected to two electrical terminals. A vacuum tube diode has two electrodes, a plate and a heated cathode. Semiconductor diodes were the first semiconductor electronic devices. The discovery of crystals' rectifying abilities was made by German physicist Ferdinand Braun in 1874. The first semiconductor diodes, called cat's whisker diodes, developed around 1906, were made of mineral crystals such as galena. Today, most diodes are made of silicon, but other semiconductors such as selenium or germanium are sometimes used.

This diode is able to detect RF signals and converts it to DC electricity to power a Led the amazing thing about this is that its completely passive and doesn't require any batteries... Gold Plated Slug 1N23B is Vintage U.S. ARMY Military for General Purpose UHF-MW Silicon Mixer. Primarily used in the Allies’ radar systems during World War II.

Add Tip Ask Question

Step 1:

US 20100220424A1

(19) **United States**

(12) **Patent Application Publication**

IBOK

(10) **Pub. No.: US 2010/0220424 A1**

(43) **Pub. Date: Sep. 2, 2010**

(54) METHOD OF ATMOSPHERIC DISCHARGE ENERGY CONVERSION, STORAGE AND DISTRIBUTION

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(21) Appl. No.: **12/534,115**

(22) Filed: **Aug. 1, 2009**

Publication Classification

(51) **Int. Cl.**
H02H 3/22 (2006.01)
H02J 7/00 (2006.01)

(52) **U.S. Cl.** **361/117**; 320/166

(57) ABSTRACT

A method of converting atmospheric electrical discharge to a useable form of energy by arresting, storage and retransmission of lightning induced electrical discharge is disclosed. The invention discloses methods of deploying this technology even in isolated locations where no electricity infrastructure exists. Additionally, the potential for achieving in excess of 1 GWe of electrical power supply at costs orders of magnitude lower than fossil fuel or solar is also disclosed. Isolated collection units are disclosed. A method of deployment of these devices on individual cars and recharge stations is disclosed which in effect unplugs these automotive and recharge stations from the grid. This capability significantly decreases their dependence on the electricity grid infrastructure, enabling a much more enhanced rollout capability for the industry. The concept of Energy Dams is disclosed. These are facilities with substantial electrical energy storage capacities with the capability of receiving energy feeds from various generation sources.

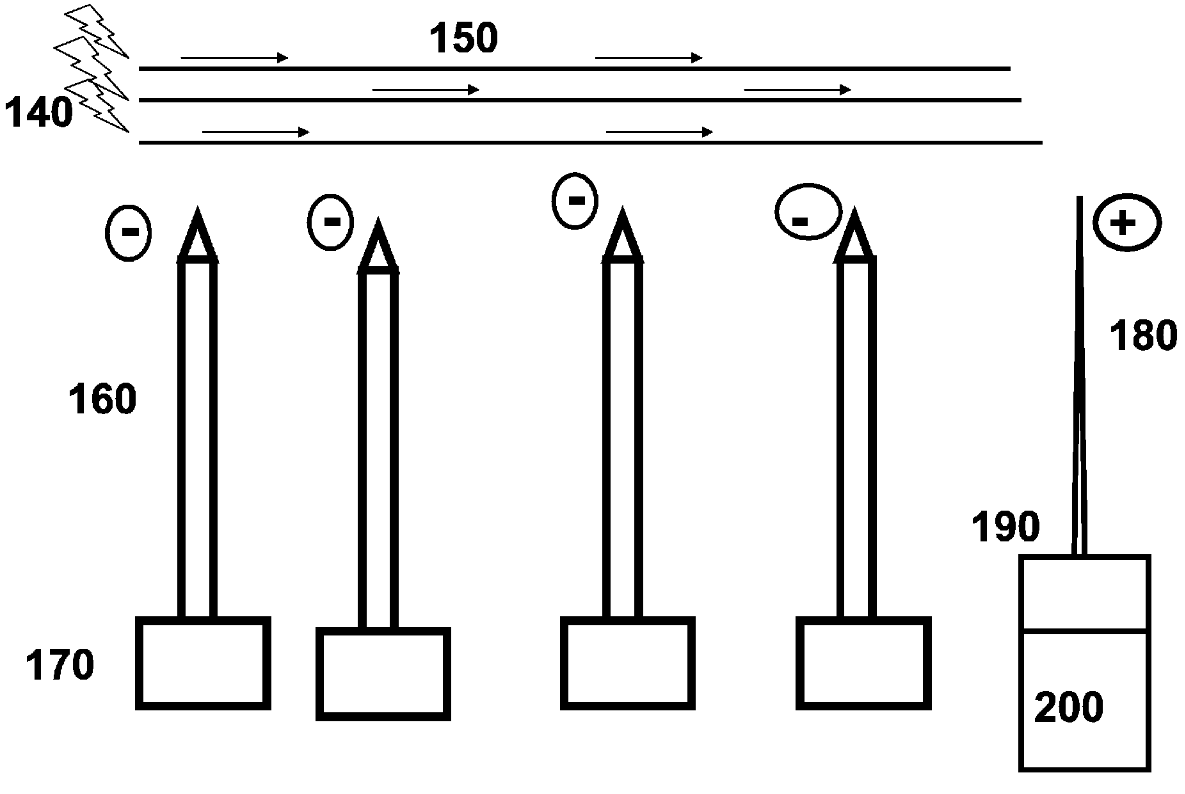

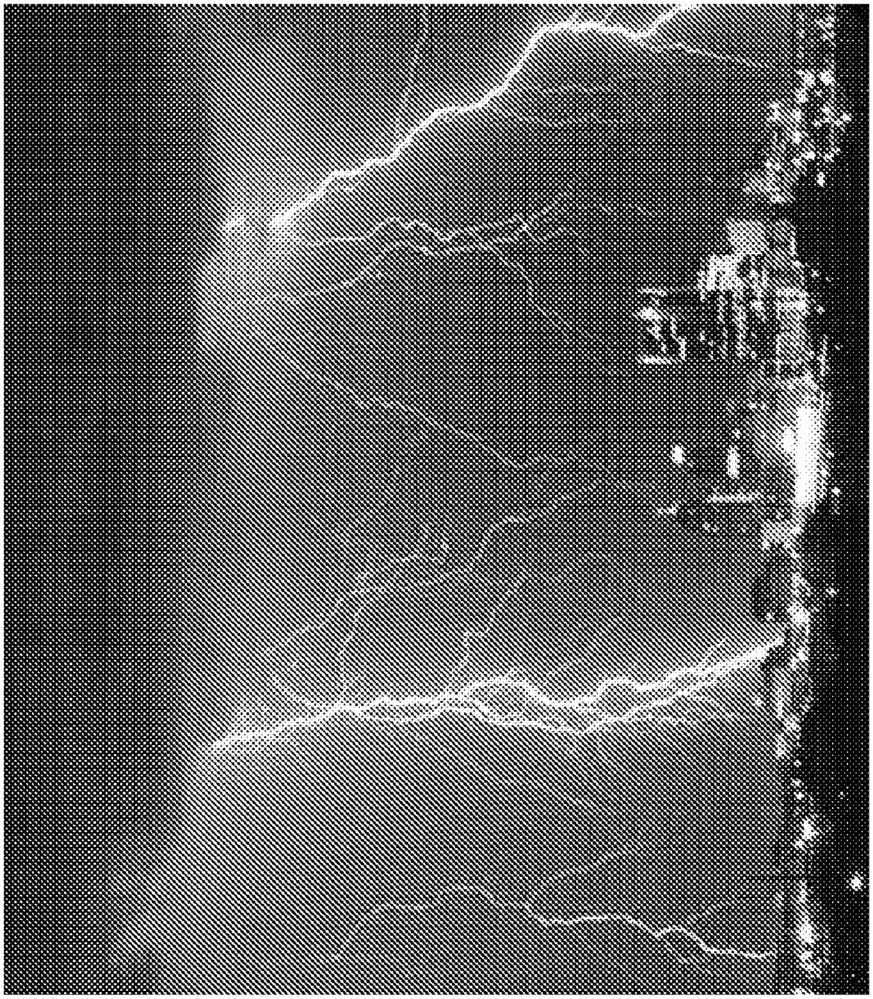

Fig. 1a

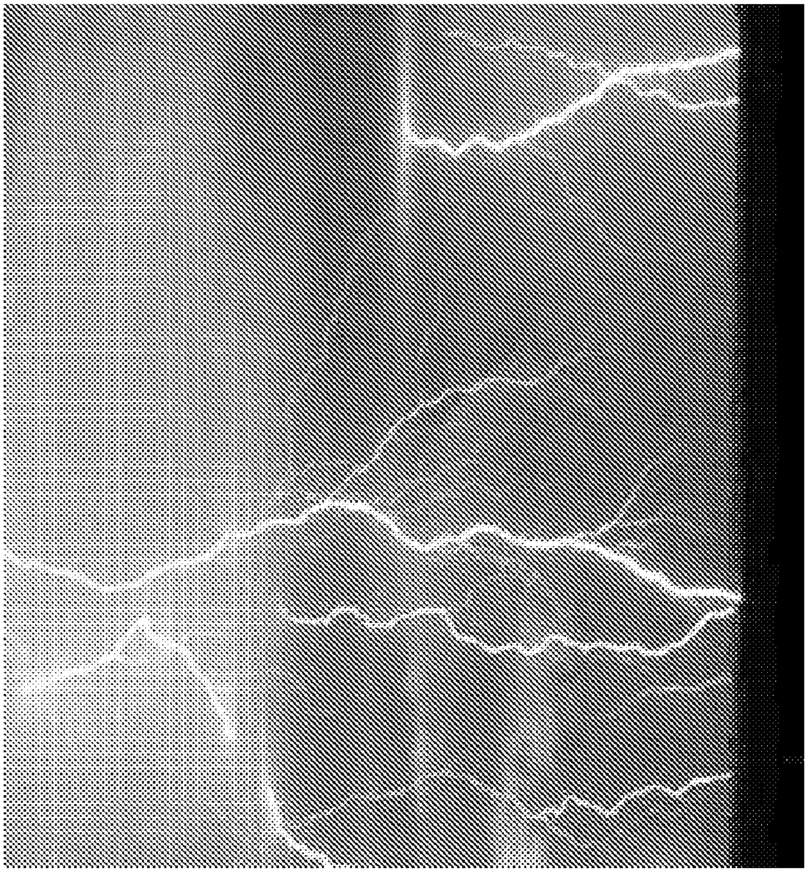

Fig. 1b

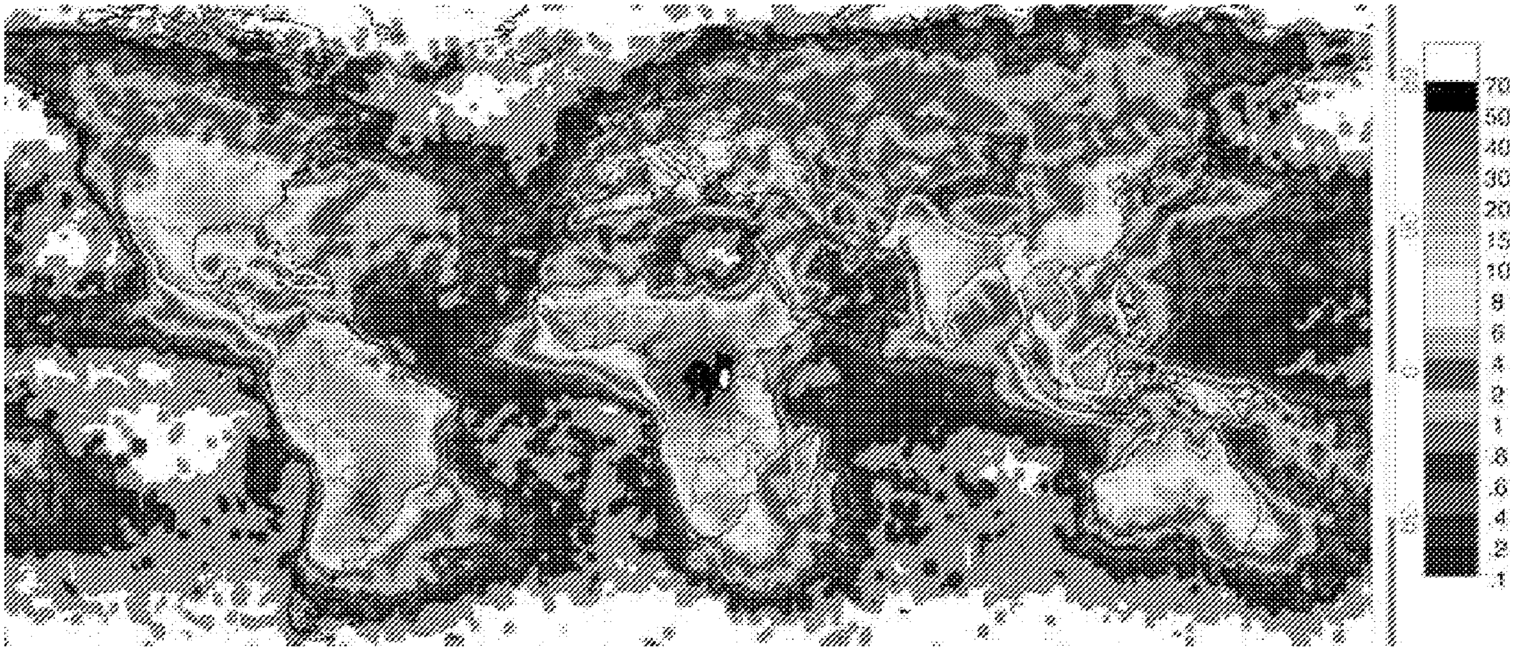
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Global Distribution of Lightning Strikes: April 1995 – February, 2003. (Source: NASA)

Fig. 1c

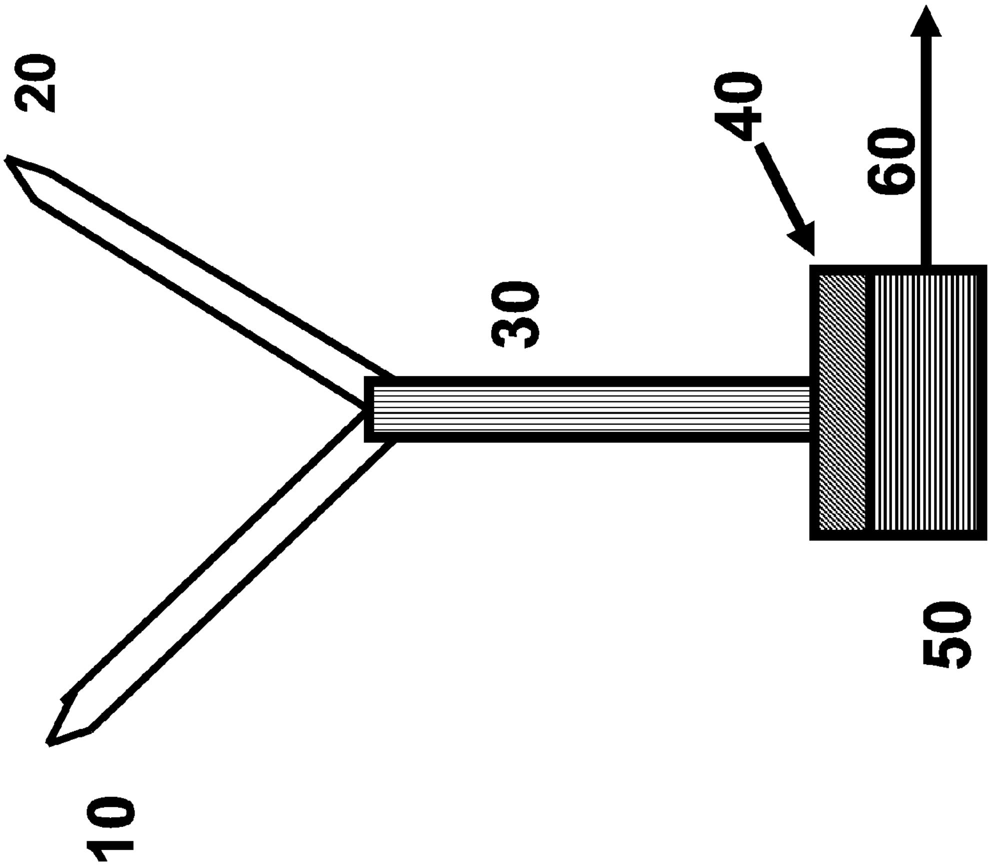
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Fig. 2

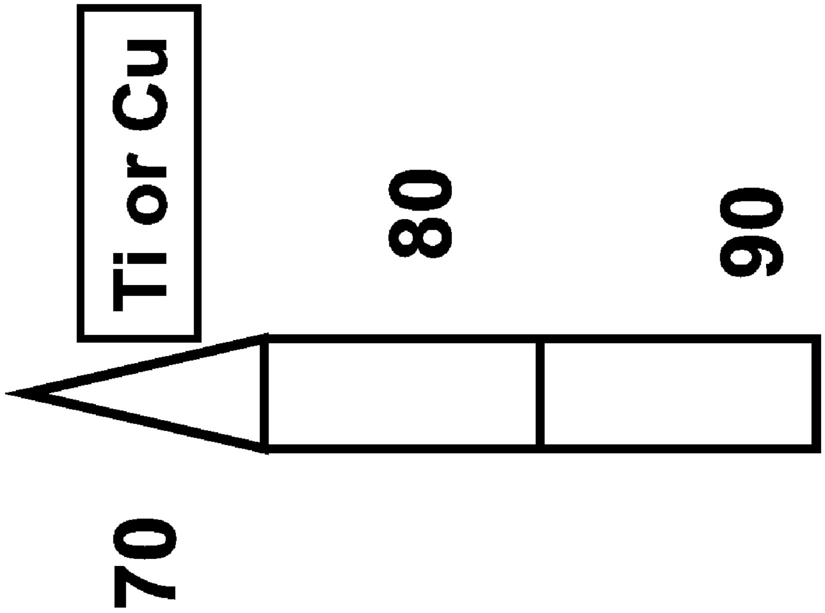
Ti or Cu
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Fig. 3

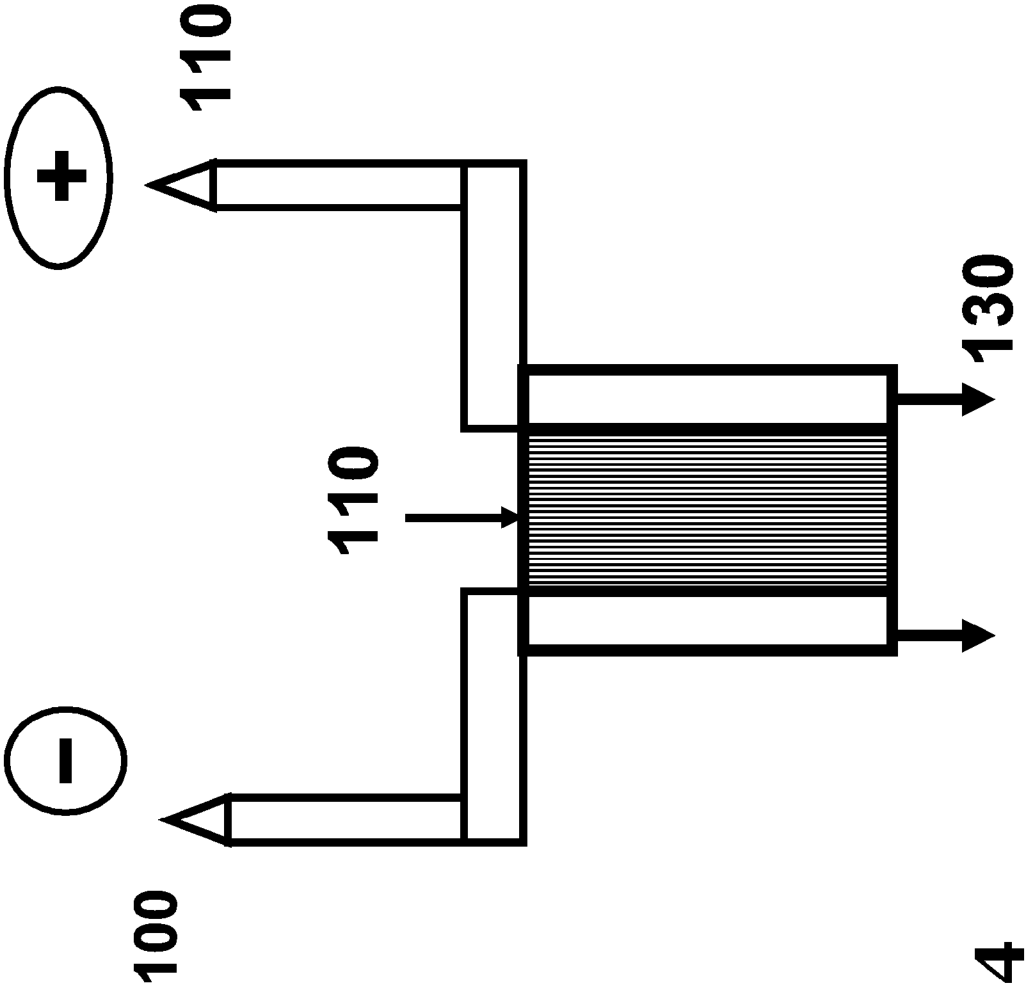
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Fig. 4

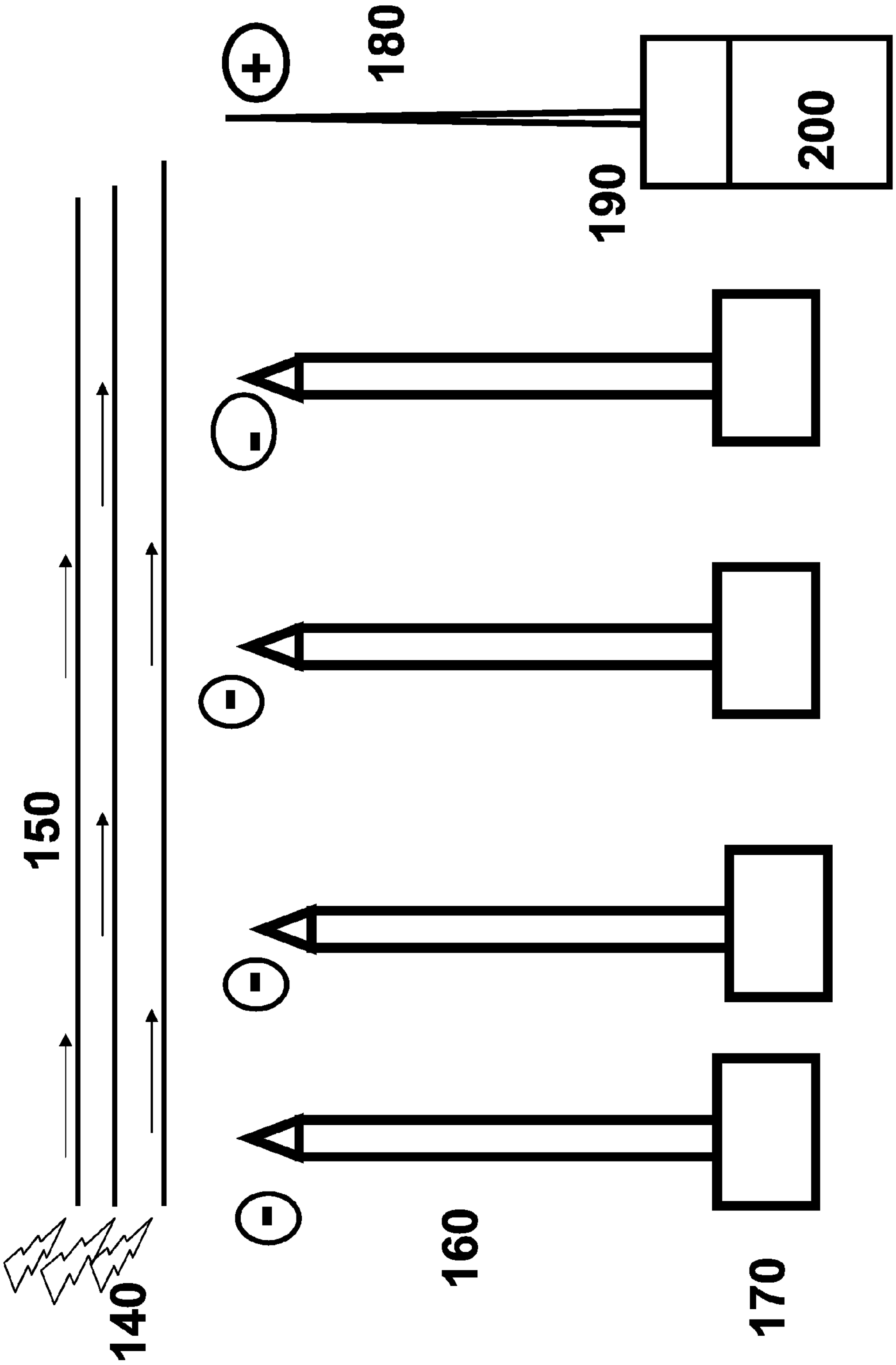
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Fig. 5

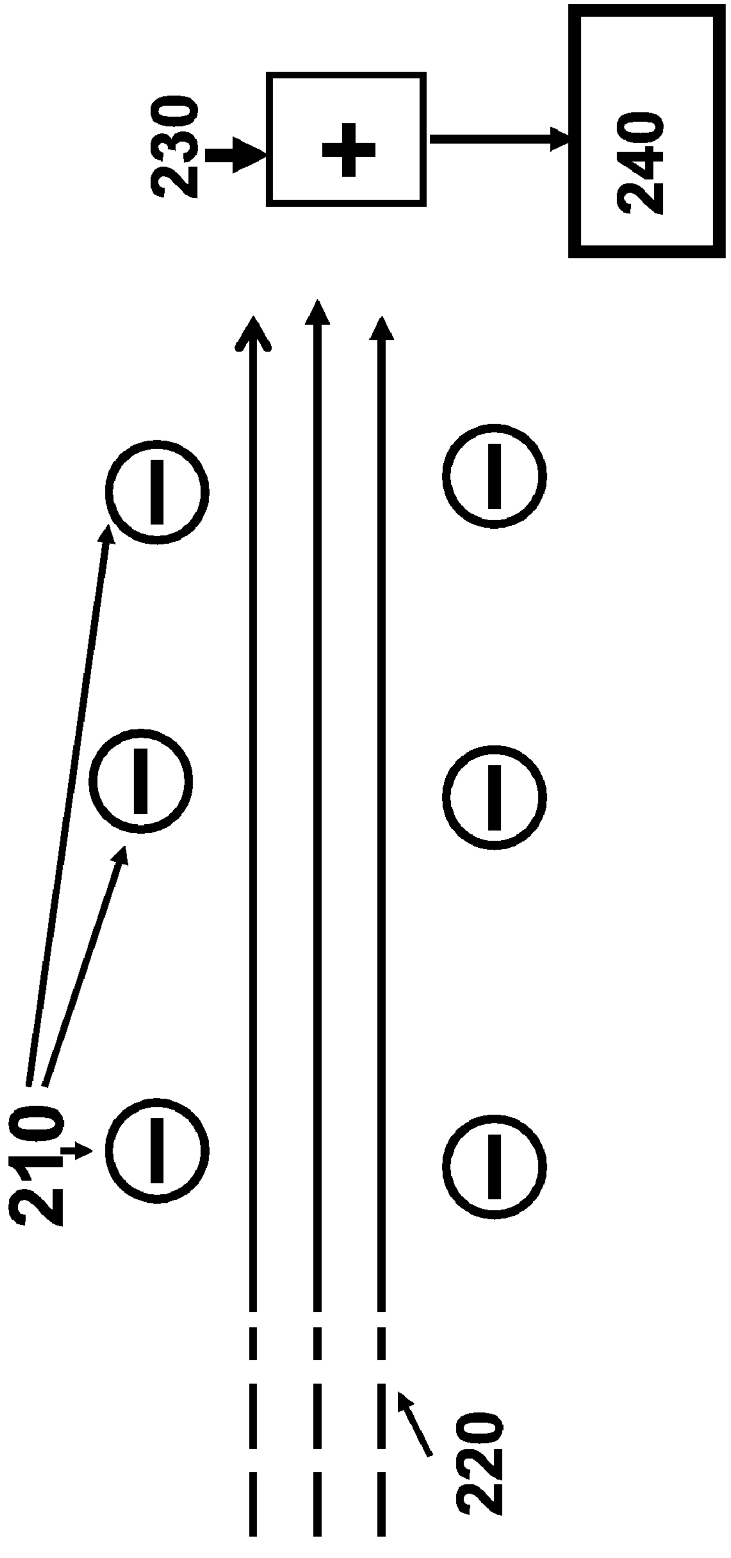
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Fig. 6

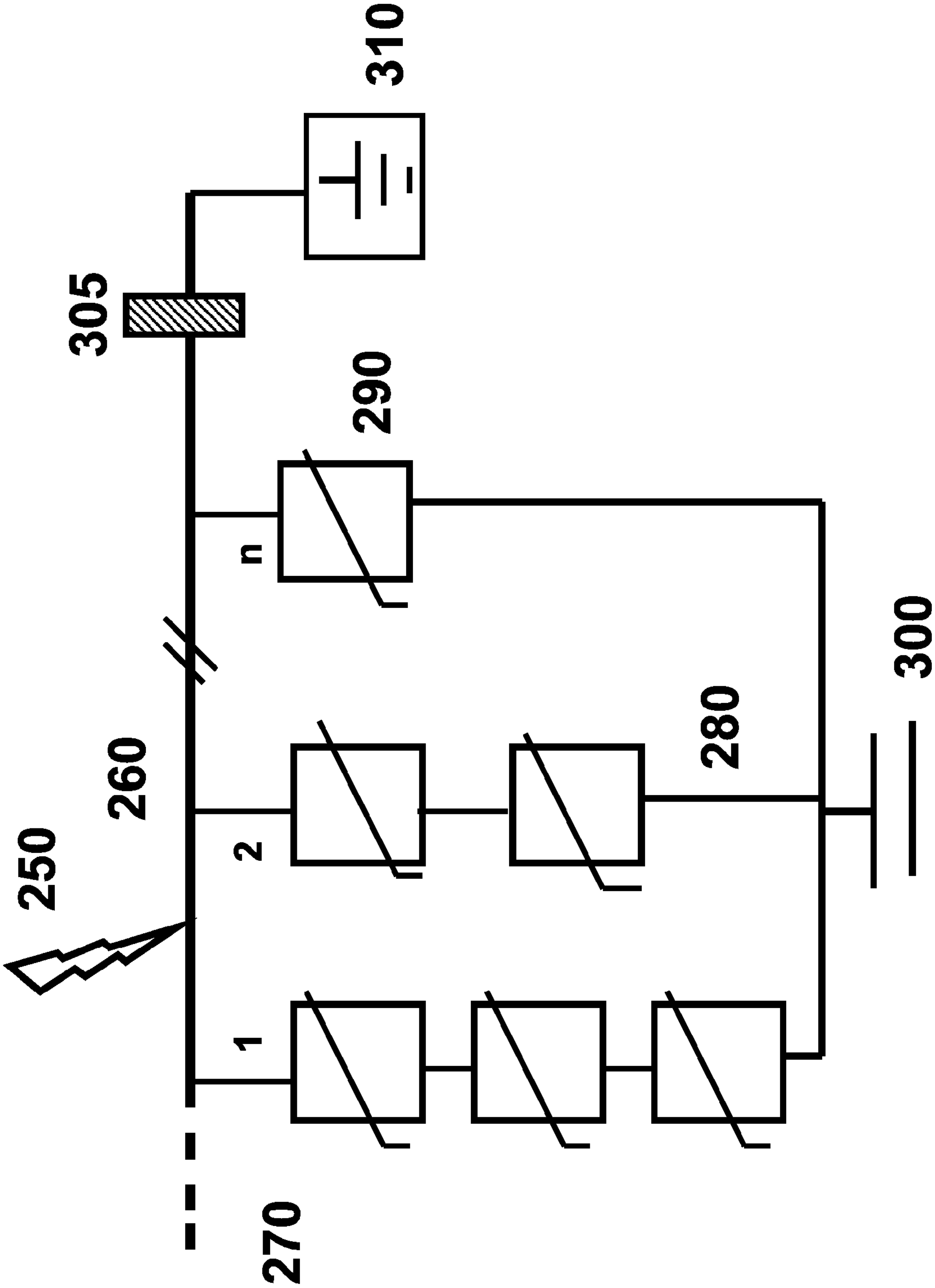
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Fig. 7a

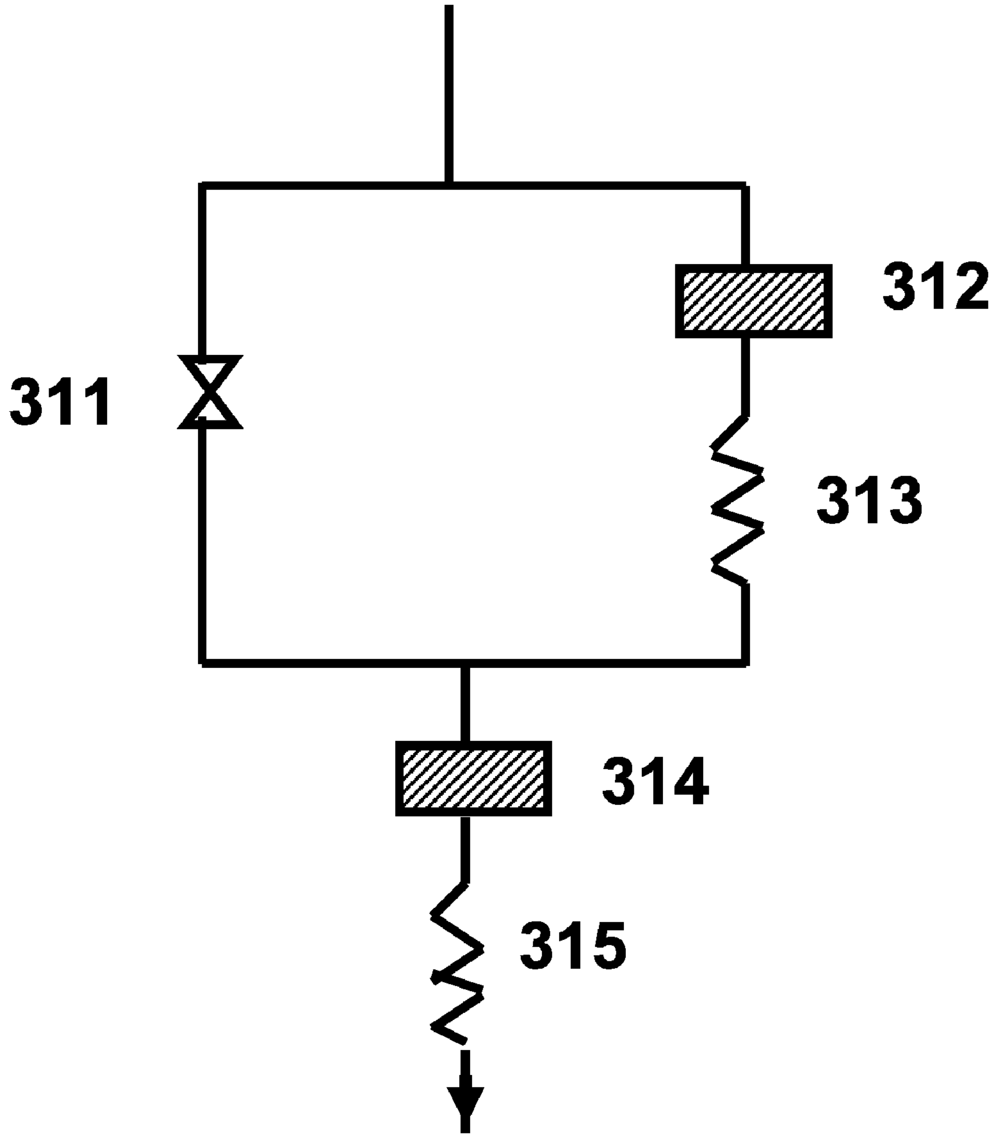
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Fig. 7b

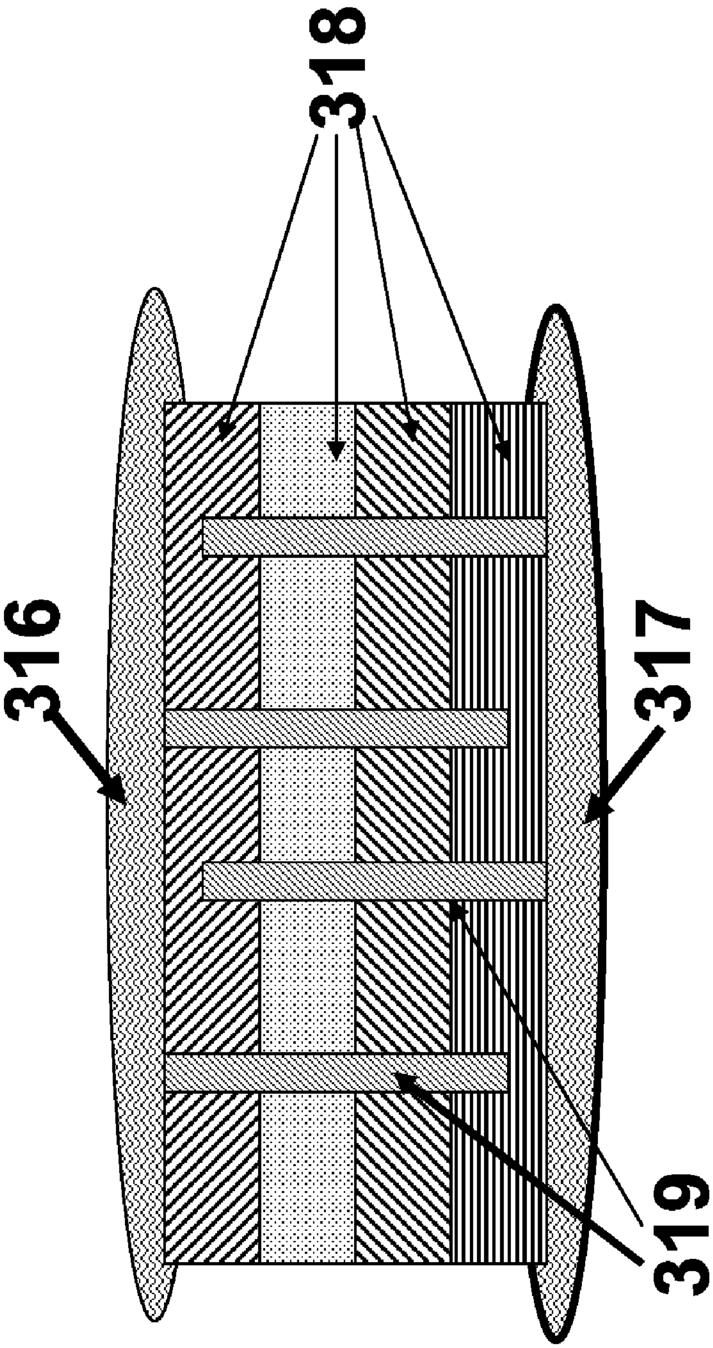
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Fig 7c

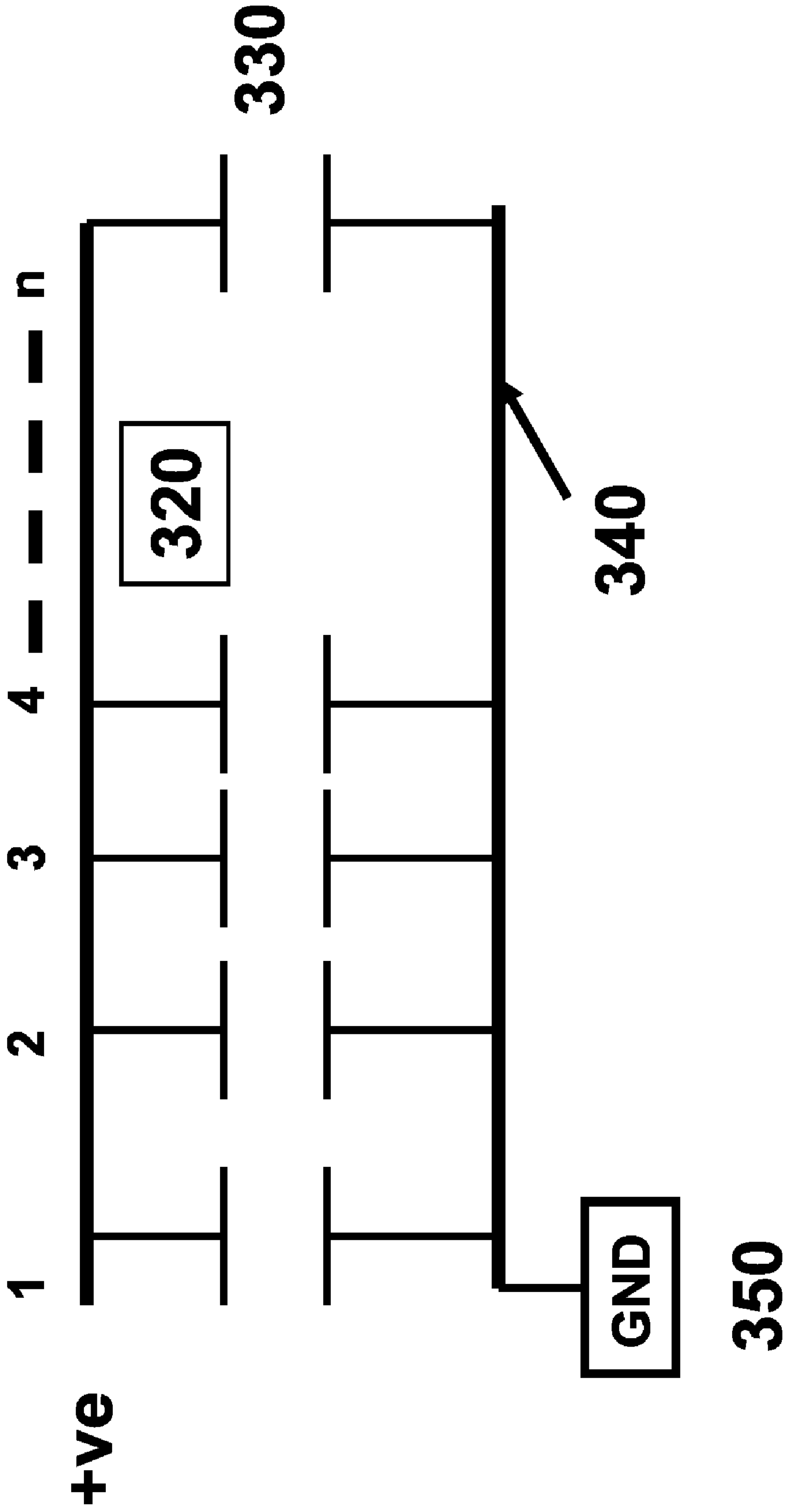
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Fig. 8a

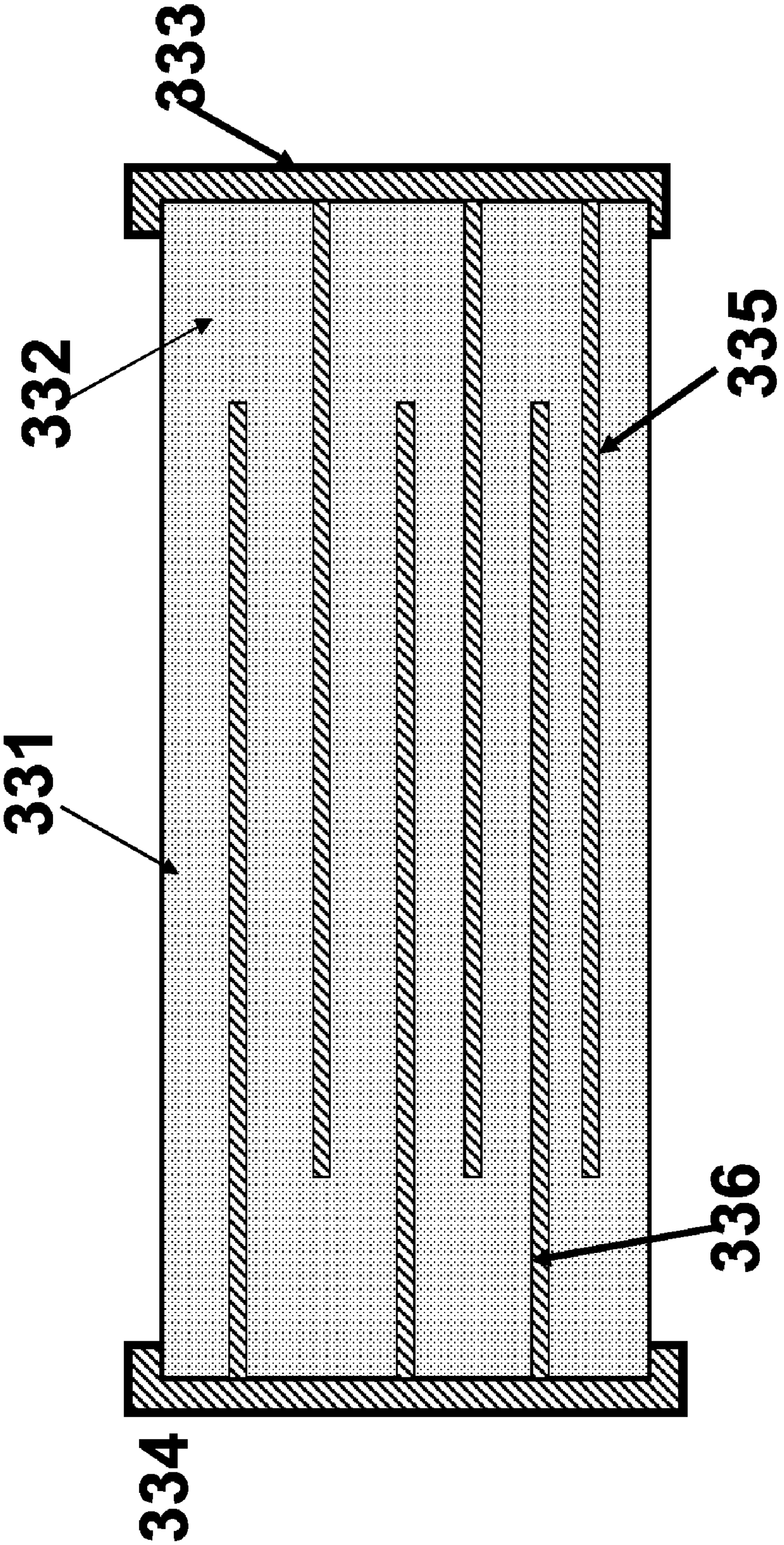
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Fig. 8b

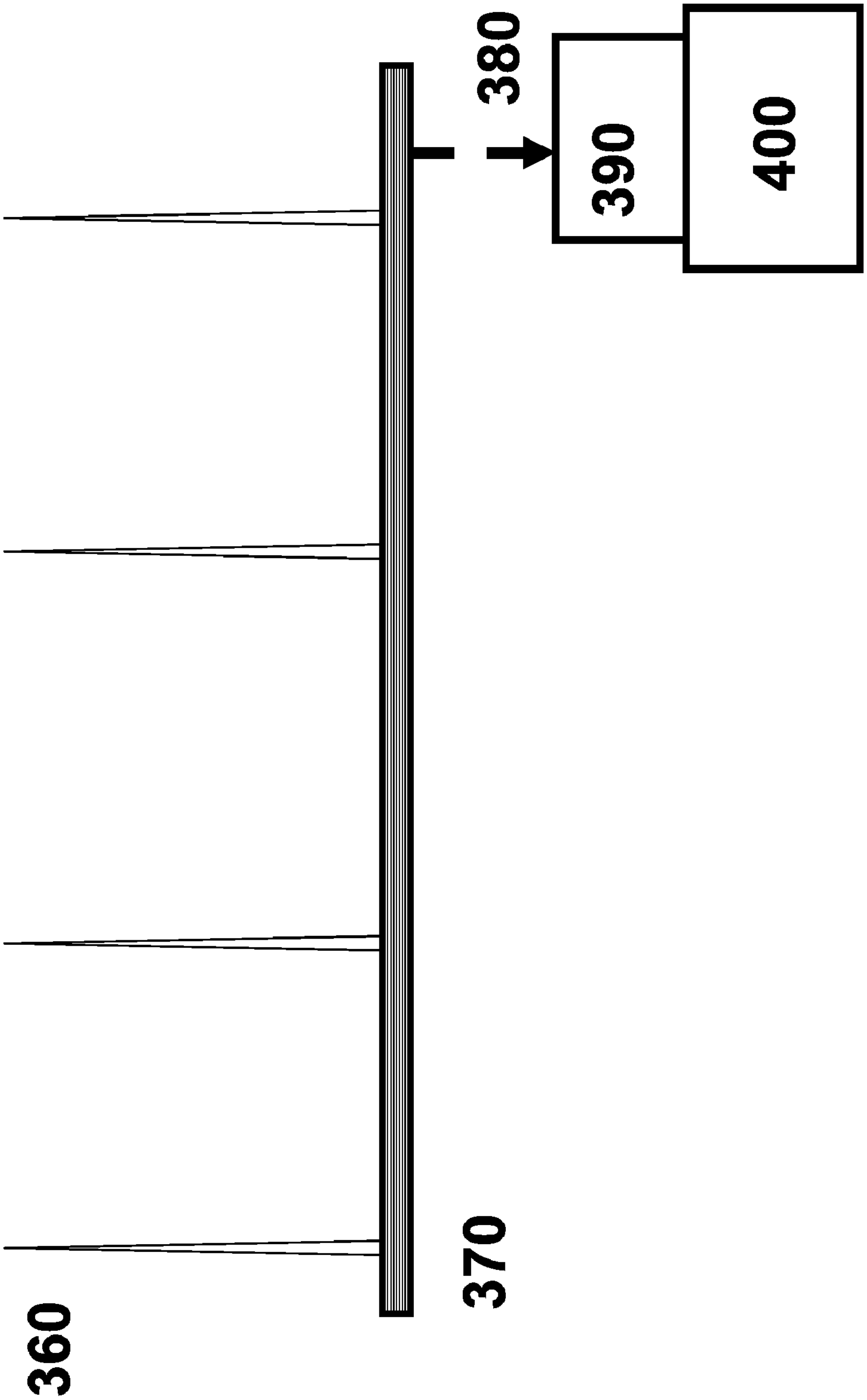
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Fig. 9

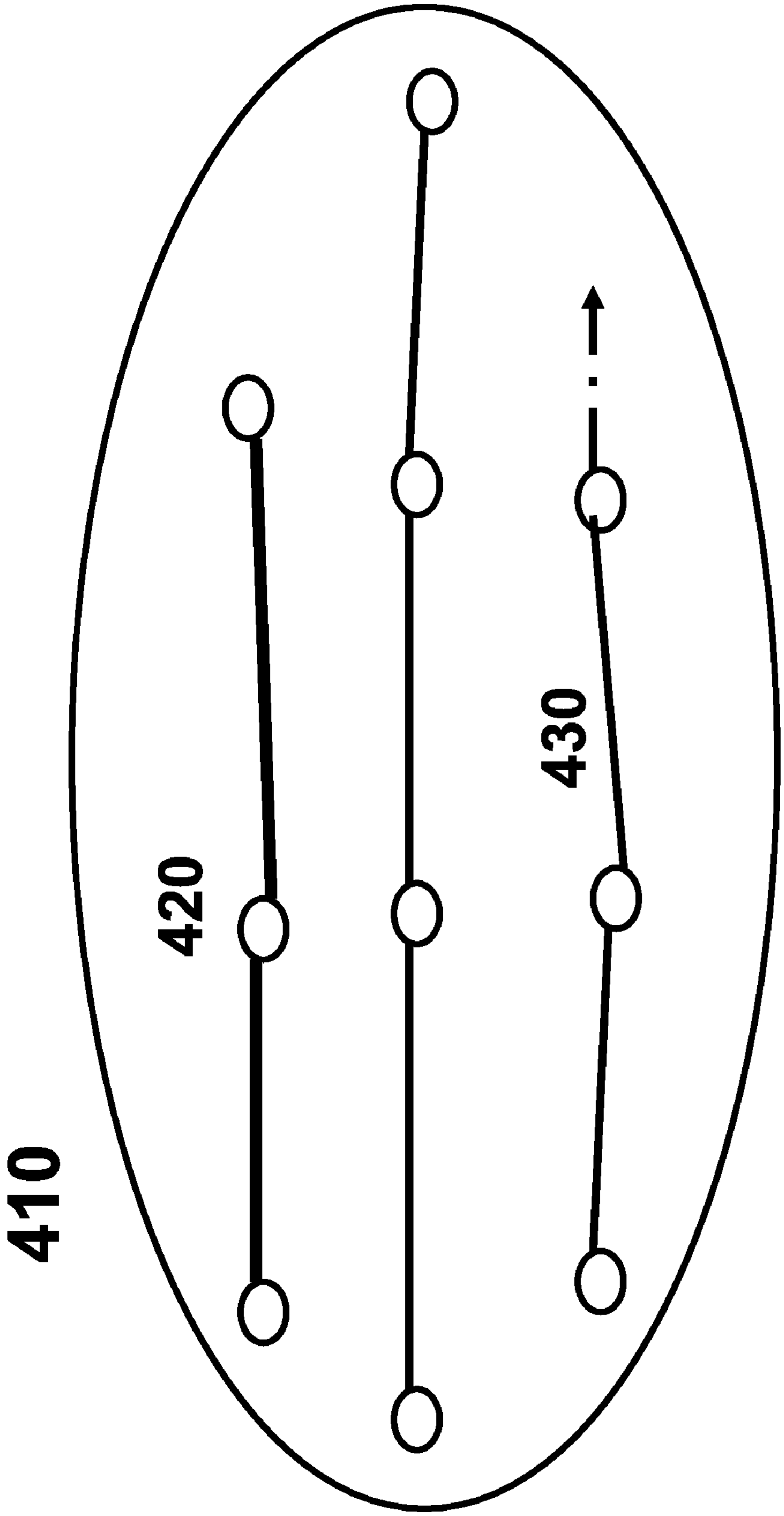

Fig. 10

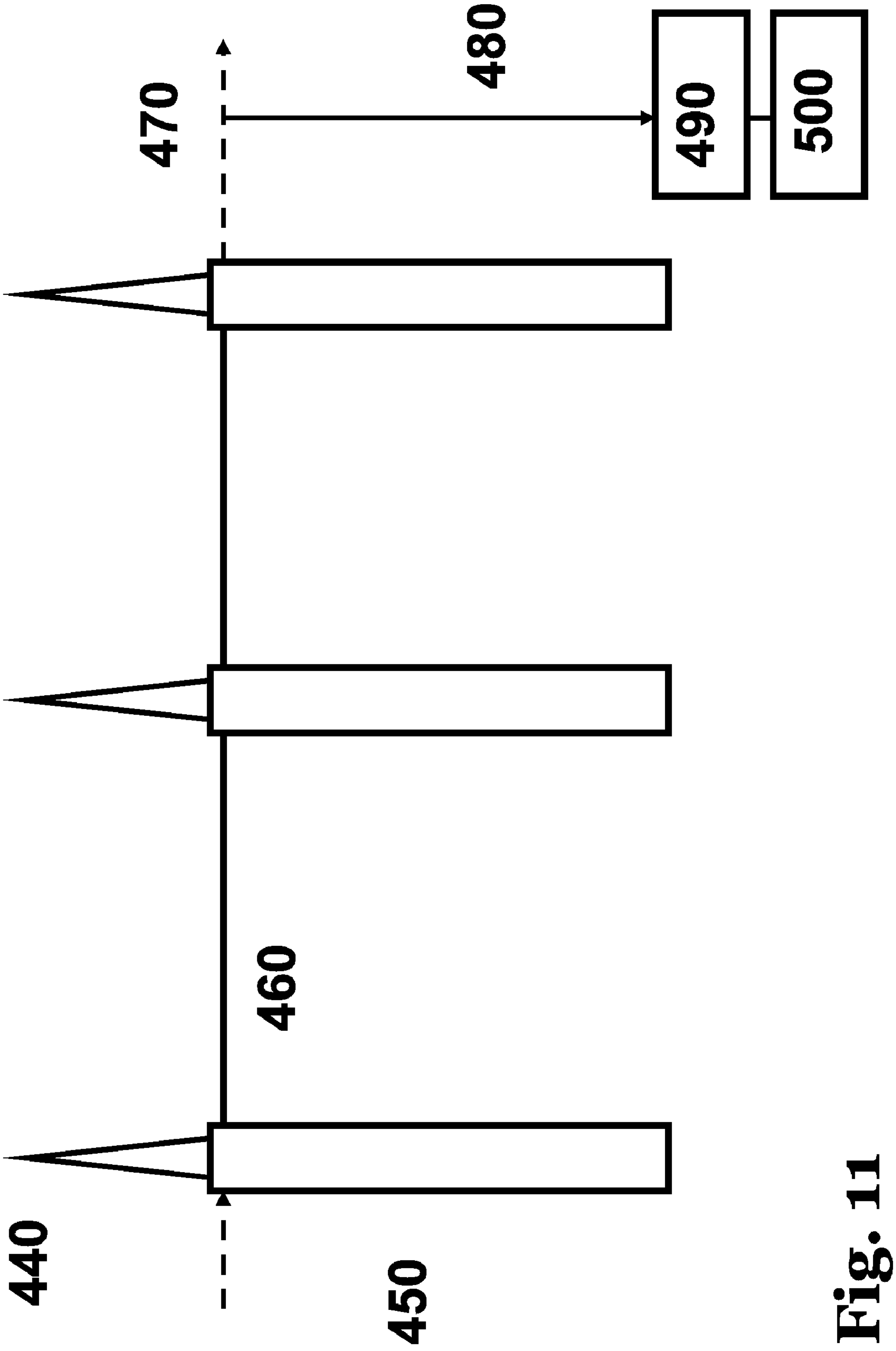
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Fig. 11

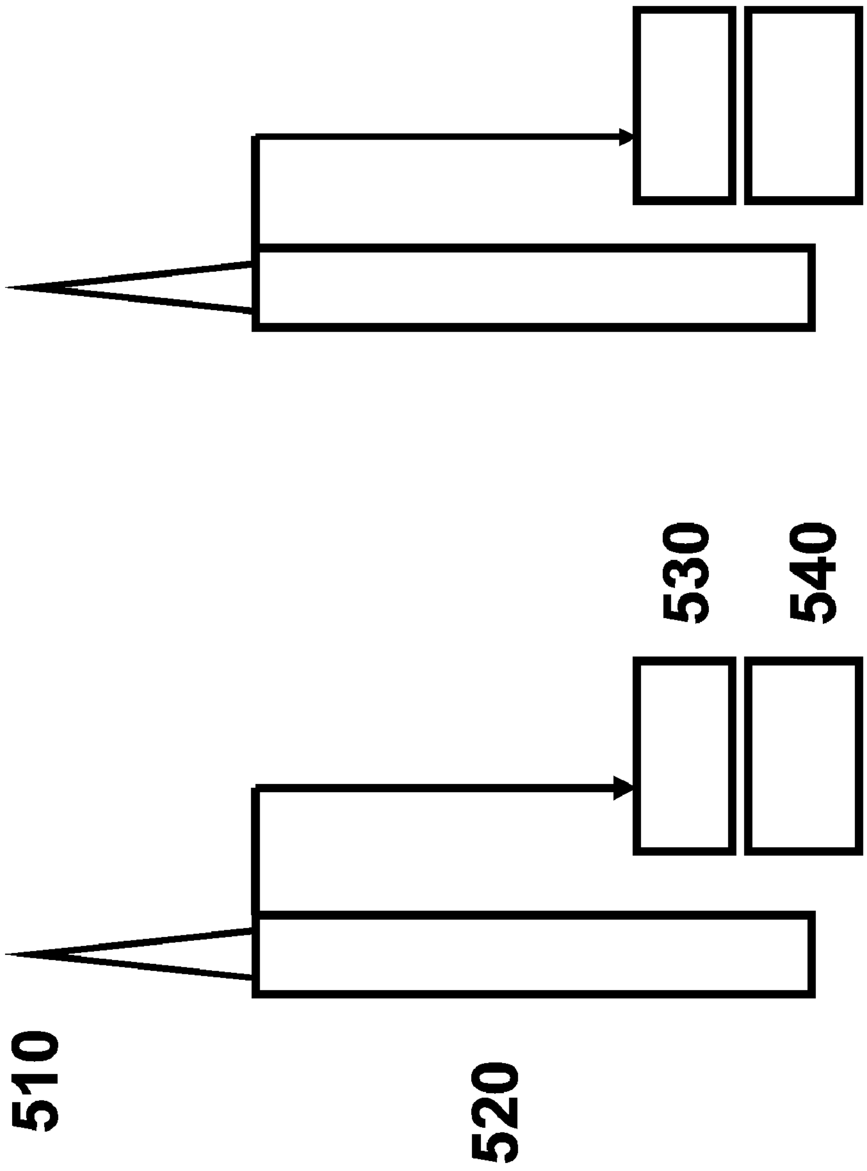
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Fig. 12

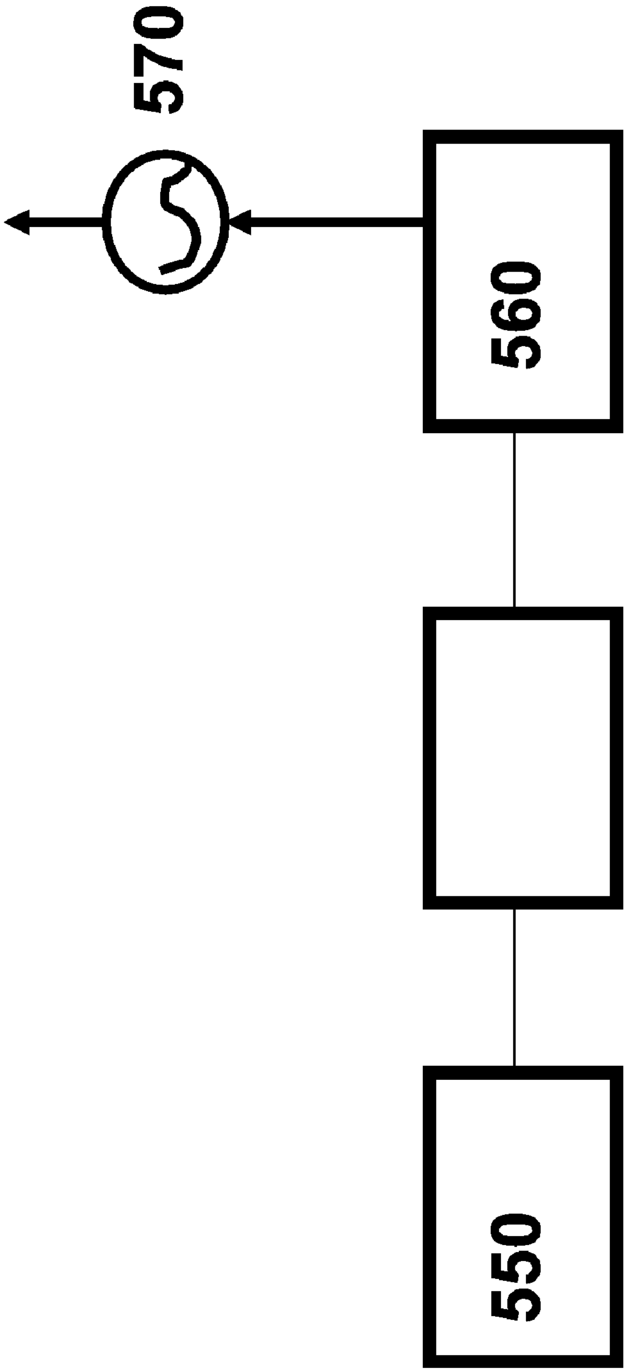

Fig. 13

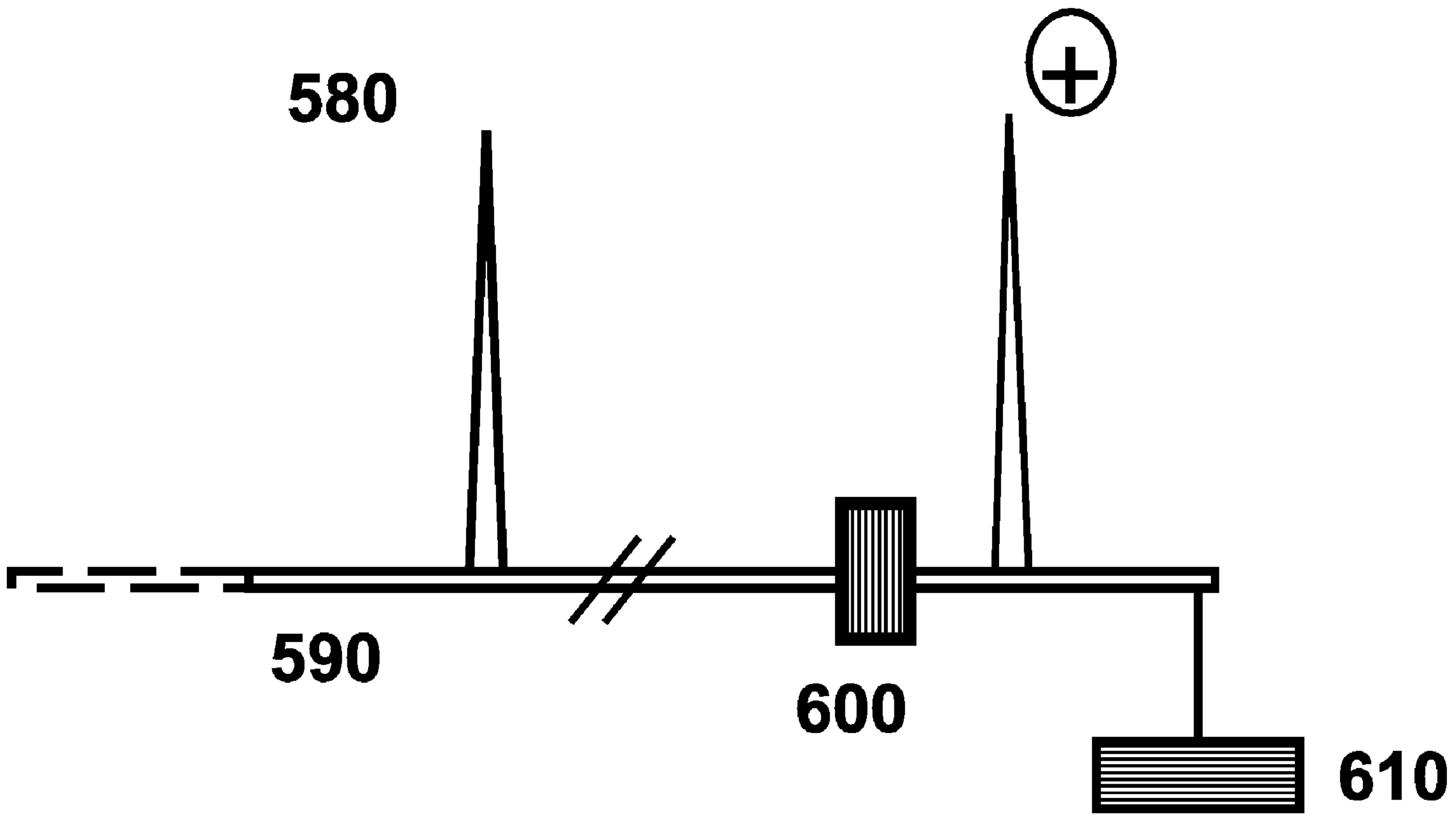
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Fig. 14

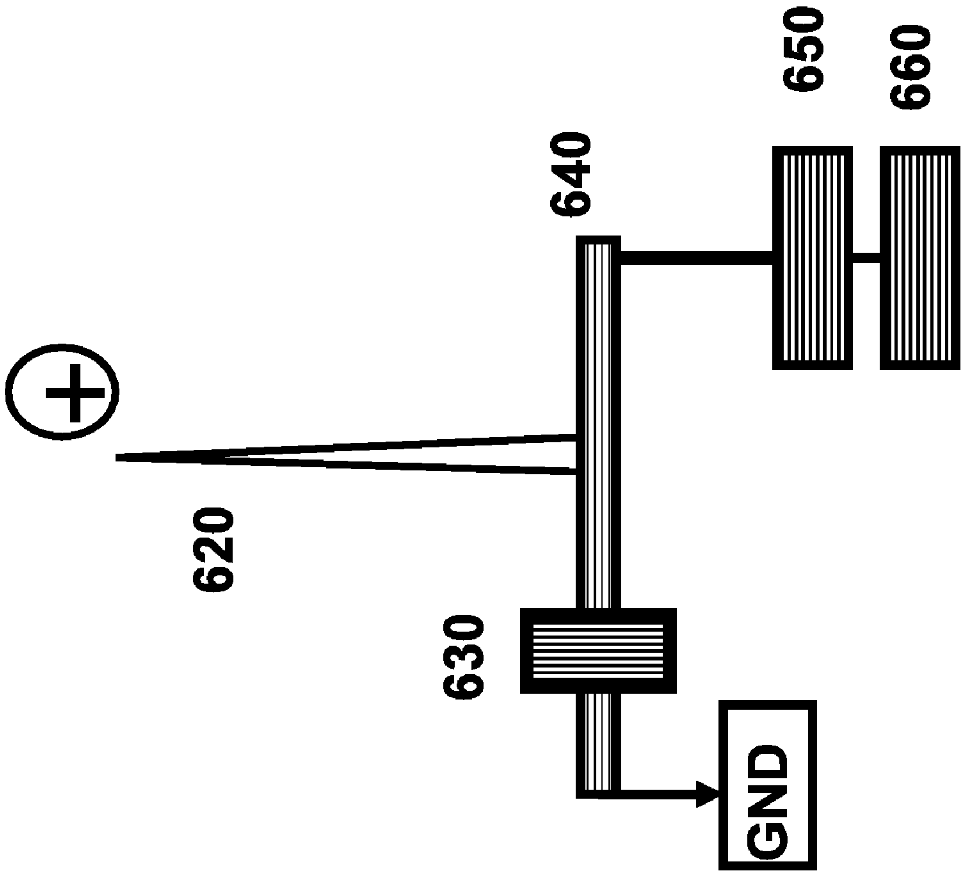
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Fig. 15

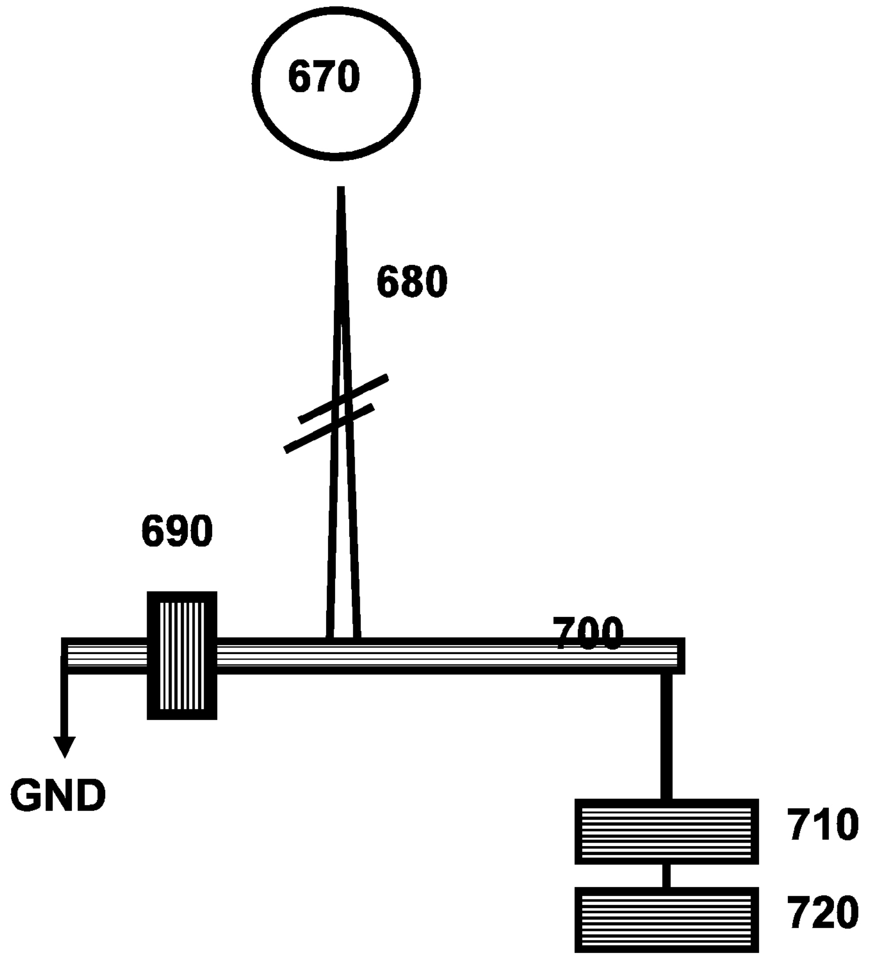
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Fig. 16

METHOD OF ATMOSPHERIC DISCHARGE ENERGY CONVERSION, STORAGE AND DISTRIBUTION

TECHNICAL FIELD

[0001] This invention relates to the field of electrical energy generation and storage in general and the conversion of atmospheric electrical discharge to a useable form of energy by arresting, storage and retransmission of lightning induced electrical discharge in particular.

BACKGROUND OF INVENTION

[0002] Lightning has always been a destructive force of nature. Causing death by electrocution and starting fires both in residential areas and in forests. In either case the loss of life and property is substantial. Lightning strikes have affected communication systems, and by uncontrolled arcing, electricity grids leading to loss of power with substantial economic loss

[0003] Lightning is the number one cause of forest and farm fires just in the United States and causes over 80 percent of all livestock losses due to accidents. Property losses run into billions of dollars annually and thousands of deaths and injury are reported yearly. Business losses from power and communications failure run into billions of dollars annually. Up to now, lightning strike damage has generally been controlled primarily by grounding.

[0004] A lightning discharge can have voltage of 10 MV to 100 MV and current of 1 kA to 300 kA. It packs so much voltage that it can leap a mile through the air and strike another object. Lightning can strike a building directly or leaping to it after striking a tree or other nearby object or by following a power line. It can strike any object that provides an easier path to the ground for it than the air. Because of the large network of lines, lightning can strike a utility pole at one point and be transmitted to any location in the network. Because of this, utility companies use multiple grounding and other protective devices per mile to ameliorate the lightning effects.

[0005] There has been a lot of activity in the alleviation of lightning damage but none in utilizing its energy potential.

[0006] U.S. Pat. No. 7,495,168 discloses a dipole lightning conductor which can gather electrical charges from the atmosphere during a thunderstorm, opposite to the polarity of the adjacent cloud on one side and induce a different polarity on the other end contacting the ground. When a sufficient potential difference is reached between the dipole and the earth, a dielectric breakdown occurs sending a large amount of earth charge to the thundercloud, inducing a thunderbolt.

[0007] In U.S. Pat. No. 6,012,330, Palmer discloses a method of inducing lightning strikes by shooting a stream of ionized water into a thundercloud and triggering electrical conduction through the ionized water column to the ground. In this invention, while ionized water is used, advantage is taken also of capillary wetting of conducting mesh cable at the tip of which is tethered a balloon of conductor coated Mylar. It is easier to float a balloon than to pump a column of water to any significant height.

[0008] In U.S. Pat. No. 6,320,119 Gumley discloses a capacitively coupled composite air terminal with sharp and rounded end components for voltage manipulation to minimize electric field ahead of streamers to minimize corona discharge.

[0009] Kato, in U.S. Pat. No. 5,280,335, discloses a compound lightning low voltage arrester with high energy tolerance for power and telephone lines comprising a spark gap is connected to a serial combination of Zinc Oxide arrestor and a non-inductive resistor. By cooperative execution between the spark gap and the Zinc Oxide arrester, the Zinc Oxide is chosen to be of a rating such that thermal breakdown does not occur before the spark gap ignition voltage is reached. The arrangement ensures reliable and predictable discharge and arrester survival even under multiple lightning strikes of close proximity.

[0010] Subbarao in U.S. Pat. No. 4,338,648, discloses a discharge counter and arrester current meter to determine arrester steady state current and the number of discharge events occurring during a thunder storm lightning arrester event.

[0011] Greenwald and Moses in U.S. Pat. No. 5,610,813 disclose a thunderstorm cell detection and mapping system for acquiring localized lightning strike information and identifying and locating active thunderstorm cells.

[0012] In U.S. Pat. No. 4,272,720, a method of differentiating between cloud-cloud and cloud-ground discharges is disclosed. Indicating discharge events with no accompanying lightning ground strike. This indicates that even in the absence of streamers, there is significant electrical discharge that can be converted and stored.

[0013] Weir and Nelson disclose in U.S. Pat. No. 7,033,406, a high energy density ceramic capacitor with energy capacity of 52 kW.h in 2005 cu.in, the equivalent of 1600 kW.h/m^3. Hansen in U.S. Pat. No. 6,078,494 discloses multilayer ceramic capacitors comprising doped barium-calcium-zirconium-titanate dielectric, the materials basis for U.S. Pat. No. 7,033,406. It is claimed to be characterized by high dielectric constant, high stability of capacitance value, long service life, low loss factor, high insulation resistance capacitance, low voltage dependence, and wide temperature range stability. Electrodes of base metal alloys from the group of Ni, Fe, Co or their alloys are claimed to be perhaps just as effective as noble metals containing gold, silver, platinum and palladium and may also contain Cr, Ti, Zr, V, Al, Zn, Cu, Sn, Pb, Mn, Mo and W.

[0014] Although the energy density capacity is not disclosed, it may be in the same range as U.S. Pat. No. 7,033,406 showing a path for storing the energy that can be extracted from lightning discharge.

[0015] U.S. Pat. No. 5,361,187, claims dielectric constant (k) of up to 19000 using similar group of dielectrics and processes. In U.S. Pat. No. 5,604,167 dielectric constant values of between 11,000 and 14,000 are disclosed by the same inventor with equivalent materials and processes.

[0016] Since these capacitors use standard powder processing technique, it can reasonably be expected that equivalent characteristics may be observed with naturally occurring doped silicates such as phyllosilicates for example, montmorillonite: $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2.nH_2O$, or cyclosilicates such as Benitoite —$BaTi(Si_3O_9)$ as base materials appropriately calcined and doped.

[0017] In U.S. Pat. No. 6,078,494 multilayer ceramic capacitors comprising doped barium-calcium-zirconium-titanate dielectric is disclosed. It is claimed to be characterized by high dielectric constant, high stability of capacitance value, long service life, low loss factor, high insulation resistance and low voltage dependence, and wide temperature range stability. Electrodes of base metal alloys from the group of Ni, Fe, Co or their alloys are claimed to be perhaps just as effective as noble metals containing gold, silver, platinum and palladium and may also contain Cr, Ti, Zr, V, Al, Zn, Cu, Sn, Pb, Mn, Mo and W. In U.S. Pat. No. 5,361,187, the inventors claim dielectric constants of up to 19000 using similar group of dielectrics and processes. In U.S. Pat. No. 5,604,167 dielectric constant values of between 11,000 and 14,000 is disclosed by the same inventors with equivalent materials and processes. Since these capacitors use standard powder processing technique, it can reasonably be expected that equivalent characteristics may be observed with naturally occurring doped silicates such as phyllosilicates for example, various grades of montmorillonite: $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2.nH_2O$, or cyclosilicates such as Benitoite—$BaTi(Si_3O_9)$ as base materials appropriately calcined and doped.

[0018] Although the technology to arrest lightning strikes has been around for at least a hundred years, this invention to harness and store that power has only become viable due to recent advances in super-capacitor technology which has made possible the fabrication of ultrahigh capacitance capacitors with very long lifetimes, high power, high energy densities and very fast charge and discharge rates.

[0019] Just as flood water, another destructive force of nature in times past was controlled by building dams, and from the dams eventually came hydroelectric power; and wind including thunderstorms has now been harnessed to generate electricity, this invention describes the technology to harness the power of atmospheric discharges including lightening storms to generate useable electrical energy.

[0020] This disclosure also introduces the concept of an Energy Dam. Facilities of substantial energy storage capacity capable of receiving energy feeds from various energy sources such as Solar, Wind, Thermal Power plants and Lightning. For example, during a thunderstorm, electricity generated by wind and lightning is collected and stored.

[0021] Lightning strikes every part of the globe but not uniformly. The regions with the highest historical concentration of lightning strikes are shown in FIG. **1***c*. These include Florida and the Gulf Coast in the Americas, the Equatorial Highlands of DRC, Rwanda and Burundi in Central Africa and the Monsoon Belt in Asia.

[0022] Except for the Americas, typically, these regions have very little electricity infrastructure. With the capability disclosed here, substantial reserves of electricity can be generated, stored and possibly traded.

[0023] In regions of epileptic electricity supply, disruptions in power do not necessarily translate into disruption in service. Since when power is generated, it is fed into these energy dams or local storage units for eventual use. Just as in water supply, the customer is not necessarily conscious of when the local water company is pumping water into storage tanks or local dams, in energy dams, the customer need not be conscious of whether or when electricity is being generated by the utility company because the power to his home is drawn not necessarily live from the grid but from the local energy storage units or energy dams.

BRIEF SUMMARY OF THE INVENTION

[0024] A method of harnessing atmospheric discharge and storing said energy in a useful form for subsequent use is presented.

[0025] Since the voltage of a lighting bolt can be as high as 100 MV, a methodology for safely channeling this discharge for storage is disclosed.

[0026] It is the also the object of this invention to present a storage medium in which an energy capacity of 1 MW.h in a volume of under 1 m^3 can be achieved.

[0027] It is also a further objective of this invention to show how lightening strikes on tall buildings can be harnessed to provide energy for the building either directly or fed into the grid.

[0028] It is also an objective of this invention to present a methodology for harnessing lightening, heretofore a source of power disruptions for electricity grids and converting it into a useable form of energy and feeding it back into the grid.

[0029] Since each electricity grid has a lightning suppression unit, a methodology for harnessing the impulse from these units from lightening strikes and feeding it back into the grid is disclosed.

[0030] a method of deploying a network of said storage units along a utility grid is also disclosed.

[0031] It is also the objective of this invention to disclose a method of modifying the storage units for single building deployment.

[0032] A method of deploying said storage units as vehicular charging centers even in locations not readily served by a utility grid is also disclosed.

[0033] A method of manipulating the direction and movement of the lightening bolt in open air locations and redirecting them to predetermined collection points is disclosed.

[0034] Lightning storms are some of the major causes of wild fires in the world. A method of redirecting the electrical discharges in any given space via a network of polarized and non-polarized collectors is presented. The discharges can be stored, fed into the grid or grounded.

[0035] A method for non-spontaneous discharge generation and storage is disclosed. And a method for adapting the methodology for electric automotive deployment is also disclosed.

BRIEF DESCRIPTION OF DRAWINGS

[0036] For understanding of the present invention reference is made of the accompanying drawings in the following DETAILED DESCRIPTION OF THE INVENTION. In the drawings:

[0037] FIG. **1***a*. Picture of lightning strike over a city.

[0038] FIG. **1***b*. Picture of lightning strike over open plain.

[0039] FIG. **1***c*: Global Distribution of Lightning Strikes: April 1995-February, 2003. (Source: NASA).

[0040] FIG. **2** shows a schematic of discharge collection and storage system.

[0041] FIG. **3** shows a schematic of collection unit showing metallic composition variation.

[0042] FIG. **4** Shows a Schematic of composite collector showing polarized ends.

[0043] FIG. **5** Schematic of collector network configuration with negatively polarized ends to manipulate and redirect lightning electrical discharge away from the earth for eventual collection at a predetermined location.

[0044] FIG. **6** Plan view of polarized collection network as shown in FIG. **5** acting to concentrate and modulate the electrical discharge and redirect such for collection at predetermined location.

[0045] FIG. **7***a*. Schematic showing a representation of a network of varistors arranged in rows and columns with the net effect of applying resistive arrestors in parallel and in series to effect voltage mitigation of atmospheric discharges prior to collection and storage.

[0046] FIG. **7***b:* Schematic of varistor of power mitigation unit showing cascade of ZnO arrestor in series with non-inductive resistor in parallel with spark gap.

[0047] FIG. **7***c:* Multilayer varistor with ZnO, ZnS and WO_3/WSi_2

[0048] FIG. **8***a*. Schematic showing cross section of a collection unit.

[0049] FIG. **8***b*. Schematic showing cross-section of multilayer ceramic capacitor of **8***a*.

[0050] FIG. **9** Schematic of collection unit network mesh in forested area with air frames deployed on each tree as collection of trees linked in a mesh network.

[0051] FIG. **10** Plan-view schematic of collection unit network mesh of FIG. **9**

[0052] FIG. **11** Schematic showing collection unit deployment on electricity transmission poles linked in a network and fed into the electricity grid.

[0053] FIG. **12** Schematic showing collection unit deployment on light poles or wireless towers.

[0054] FIG. **13** Schematic showing network of linked collection units and storage units on transmission lines, light poles or wireless towers fed into the grid.

[0055] FIG. **14**. Schematic of a system for non-spontaneous atmospheric discharge generation and storage.

[0056] FIG. **15** Schematic of atmospheric discharge collection and storage unit deployable on automotive units.

[0057] FIG. **16** Schematic of balloon-assisted discharge collection and storage unit.

DETAILED DESCRIPTION OF THE INVENTION

[0058] This invention describes a method of harnessing the electrical energy in atmospheric discharges, including, but not limited to lightning, storing said electrical energy and transmitting said energy for use. To this end, as an illustration, the preferred embodiments are represented in the drawings shown in FIGS. **2** to **15**.

[0059] Since lightning discharge voltages range from 10 MV to 100 MV with current of 10 kA to 100 kA, the technology challenge will be in mitigating the ultrahigh power which range from 100 GW to in excess of 10,000 GW. Although individual strikes last less than 100 μsec, thunderstorms usually last longer than 30 min. in any cloud formation and location. Indicating that the energy that can be mined from any location in a thunderstorm can run in excess of 50 GW.H. Enough energy for 500,000 homes consuming 1000 kW.h per month. At $100 per 1000 kWh, the revenue equivalent is $5 million per thunderstorm per location.

[0060] In solar energy generation, the cost of a 1 MWe rating PV panel is about $1 million. To achieve 1 GWe, the cost implications will be about $1 billion. In fossil fuel plants, the construction cost is approximately $1.3 million per MWe, putting the cost for a 1 GWe at ~$1.3 billion excluding fuel, carbon footprint, and other operating cost. Though thunderstorms are not continuous, with storage capability, the cost basis for an atmospheric discharge energy source will be several orders of magnitude lower than fossil fuel or solar of any architecture.

[0061] One embodiment of this invention is depicted in FIG. **2**. Lightning is collected at the air terminals **10**, **20** and transmitted through the conductor **30** to an arrestor **40** and on to the capacitor **50** where the electricity is stored. From which it can be extracted **60** at point of use or transmitted into the grid.

[0062] The degree of atmospheric discharge charge collection can be influenced by the metallurgical composition of the collectors. FIG. **3** illustrates the fabrication of the collector with different metals of varying conductivities and atmospheric and electrical stability. In this embodiment, metallurgical compositions for the various segments comprise Ti, Cu, Al. Other metals or their alloys can be used depending on the required properties and the locations of deployment.

[0063] In yet another embodiment of the invention as shown in FIG. **4**, a composite collector with opposite polarity air terminals **100**, **110** is used. The air terminals are isolated from each other by an insulator **120**. The negative polarity terminal serves to deflect and manipulate the charge to the positive terminal from which it is conducted to the storage unit **130**.

[0064] Another embodiment of the invention is illustrated in FIGS. **5** and **6**. In this representation, negative polarity collectors, **160** deflect the atmospheric discharge so that they do not reach the ground but are deflected for collection at a predetermined terminal **180** of positive polarity and thereafter storage **200**. A plan view representation of this embodiment is shown in FIG. **6**.

[0065] It is essential to mitigate the power of the lightning before storage. In one embodiment of this invention, a collection of varistors of various power capacities, linked in series **270**,**280** and **290** are connected in parallel in lines **1** to n, to achieve a desired capability as shown in FIG. **7***a*. The resultant power is stored in the capacitor **300**. An insulator or fuse **305** is placed at the end of the varistor chain to protect the capacitor **300** against over-current. In the event of overstressing, the dielectric or varistor is deformed and the excess current is grounded.

[0066] Each component of the power mitigation unit is any of the following configurations as shown in FIG. **7***b:* A ZnO varistor **312** connected in series with a non-inductive resistor **313** and in parallel with a spark gap **311**. The resultant current is further modulated through another ZnO unit **314** and resistor **315**. A cascade of this configuration could be adopted to achieve the desired properties.

[0067] Zinc Oxide has a relatively large band gap of ~3.3 eV at room temperature. The consequence of this large band gap includes, higher breakdown voltages, ability to sustain large electric field and high power and temperature operation. Because of this, ZnO is the primary component in varistors and in voltage suppression devices. Zinc Sulfide has a band gap of 3.5 eV for the cubic form and as high as 3.91 eV for the hexagonal form at 300K. While ZnO band gap can be tuned from between 3-4 eV by alloying with magnesium oxide or cadmium oxide, the co-processing of ZnO with ZnS of the hexagonal wurtzite form should provide electrical field and other operational advantages over ZnO alone.

[0068] Multilayers of ZnO and ZnS or as sandwich layers with each other with ZnO achieving 50-99.9 mol. % of each layer can be adopted to improve on the suppression properties of the single layer ZnO varistor as is shown in FIG. **7***c*. Said varistor comprising a ceramic base body **318** of multiple layers, terminal electrodes **316**, **317** and internal electrodes **319**.

[0069] Alloying of ZnO with metal oxides and nitrides of transition elements including W, Zr, Mo, Mg, Cr, and Ti may improve its band gap characteristics and improve its voltage response non-linearity. Tungsten, in the form of tungsten silicide has very unique crystallization characteristics, particularly in the presence of dopants such as phosphorus or arsenic. Upon post deposition anneal, the Si in the non-stoichiometric tungsten silicide (WSix) segregates to the grain boundaries and the film interfaces. The dopant atoms diffuse preferentially along the grain boundaries. When oxidized, it is the segregated silicon that is oxidized selectively. If the W is exposed to the oxidizing ambient of O_2/Ar or O_2/N_2 at temperatures in excess of 700° C., tungsten oxide WOx (x=3, or 1.5) is formed. It has no corresponding crystallographic orientation to the underlying tungsten silicide or metal, being in the form of an amorphous powder. The fabrication of multilayer varistors with ZnO and WSi_2/WO_3, SiO_2 should provide the flexibility of modulation of the effective grain sizes of the host material to within 0.5-10μ as the case may be. This precise grain size control provides corresponding modulation of the electrical properties including overvoltage suppression.

[0070] A schematic of the storage unit **320** is shown in FIG. **8***a*. A collection of capacitors **330** are connected in parallel to achieve a desired capacitance. A schematic of the cross-section of each capacitor unit is shown in FIG. **8***b*. The unit **331** with dielectric layers **332** is a multilayer capacitor comprising alternately stacked internal electrodes **335**, **336** connected to external electrodes **333**, **334**. The dielectric layers may be of uniform composition, or layers of different compositions optimized for flexibility in the modulation of desired electrical, physical and reliability properties.

[0071] Capacitance in excess of 1 kF/m^3 with energy storage capacity of 1.5 MW.h is reported as being possible by existing art. With compositional and manufacturing improvements disclosed here these benchmarks are expected to be surpassed making possible energy storage capacities of up to 1 GW.h. Sufficient energy for 1000 households consuming 1000 kW.h of electricity per month for one month.

[0072] Lightning storms are a major cause of wildfire. To address this, in yet another embodiment of this invention as represented in FIG. **9**, air terminals **360** are set up on a selection of trees and connected by a conductor **370** in a mesh array as shown in FIG. **10**. The impinging charge is transmitted through a conductor **380**, through a suppressor unit **390** and on to the storage unit **400**.

[0073] Utility transmission lines usually have lightning collectors along the length of the network. In this invention as demonstrated in FIG. **11** air terminals **440** deployed transmission poles **450** are linked by a polarized conductor **460**. At predetermined locations the impinging charge is conducted through a suppression unit **490** and thereafter into the storage unit **500**. The stored energy is periodically released into the grid.

[0074] In yet another embodiment of the invention, air terminals **510** are deployed on light poles **520**. The collected charged are modified and stored in a storage unit **540**.

[0075] In another embodiment, the air terminal/collection units are deployed on radio transmission towers. The charge could be stored individually at each tower location or linked in a network as shown in FIG. **13**. In either case, the stored energy be used at each individual location or fed into the grid **570**.

[0076] In the absence of a thundercloud, lightening flash can be generated by the modification of the natural bias between the cloud and ground. This is demonstrated in FIG. **14**, where a positively biased conductor **580** of height greater than nearest ground elevation or nearest structure. The increased elevation and bias facilitates cloud to ground discharge even when there is no active lightning storm. The incoming charge is isolated by an insulator **600** and stored in the storage unit **610**.

[0077] In yet another embodiment of this invention, a balloon of conductive material is tethered to a terminal via a mesh line of conducting material. The balloon captures cloud to cloud discharges which are transmitted down to storage. In yet another embodiment this tether line may be wetted by a conductive solution such as but not limited to salt solution to facilitate the discharge conduction.

[0078] Another embodiment of this invention is shown in FIG. **15**. In an isolated collection system as shown here, the air terminal **620** which may be biased or unbiased is connected to a collection/storage unit **650**, **660** respectively by conductor **640** and isolated by a dielectric or insulator **670**. Should the discharge exceed the capacity of the isolation, the isolation is bridged and the charge grounded. This isolated collection system is particularly useful where there is no utility grid, particularly in very remote and isolated locations.

[0079] This isolated collection capability enables deployment on individual houses and isolated farms. In electric automotive recharge stations, this capability enables the location of these facilities in any location even those not served by regular electricity utilities lines.

[0080] In isolated rural areas, the deployment of these isolated collection units enables the provision of electricity where electricity grid infrastructure is not available or practical. The storage units can be deployed in banks as the estimated anticipated usage dictates.

[0081] In another embodiment of this invention, the isolated collection unit is modified to be portable for deployment on automobiles. The charge in the storage unit is linked with the automobile's electrical power or storage unit. Alternatively, it can replace the power storage unit of the automobile for pure EV or hybrid cars. Additionally, it can unplug these cars from the grid. With the ambitious industry plans for electric or hybrid cars the infrastructure for charging these cars either in garages or charging stations is somewhat limited. The capability to both 'charge as you go' and unplug from the grid would expand the infrastructure significantly.

[0082] In yet another embodiment of this invention, the isolated collection unit is deployed on trains. This could be in commuter trains that directly fed from the grid, or long-haul trains to augment or replace the fossil fuel used.

[0083] It is understood that the presentation of these steps in this disclosure is not exhaustive. Only the preferred embodiments of the invention and but a few of the examples of its versatility are shown and described in the present disclosure. It should be readily apparent to those of ordinary skill in the art that the invention is capable of use in various other combinations, environments and applications and is capable of changes or modifications within the scope of the inventive concept as expressed herein. These changes and modifications may be made without departing from the spirit and scope of the invention as set forth in the appended claims.

REFERENCES

[0084] U.S. Pat. No. 7,495,168,
[0085] U.S. Pat. No. 6,012,330
[0086] U.S. Pat. No. 6,078,494
[0087] U.S. Pat. No. 4,338,648
[0088] U.S. Pat. No. 6,407,900
[0089] U.S. Pat. No. 6,924,598
[0090] U.S. Pat. No. 5,569,972

[0091] U.S. Pat. No. 5,289,335
[0092] U.S. Pat. No. 4,272,720
[0093] U.S. Pat. No. 4,338,648
[0094] U.S. Pat. No. 5,610,813
[0095] U.S. Pat. No. 6,320,119
[0096] U.S. Pat. No. 5,604,167

1. A method of converting an atmospheric electrical discharge into a useable form of electrical energy comprising the following steps:
- (a) Arresting the discharge via an air terminal,
- (b) Said air terminal connected via a conducting unit to a power mitigating (step down) unit which can reduce the discharge voltage from approximately higher than 100 MV and 100 KA to below 20 kV, 10 kA.
- (c) The step down unit connected to an energy storage unit which may comprise modules of high energy density capacitors
- (d) Said storage units arranged such that the stored electrical energy can be discharged into the grid or to an appliance at point of use as desired.

2. A method of claim **1** wherein the arrestor and mitigating unit comprise an array of self-healing varistors in series and parallel chosen to ensure total conversion of the incident lightning discharge to a voltage/current level suitable for storage in said capacitors.

3. A method of claim **2**, where the power mitigation unit is any of the following configurations:
- (a) Single ZnO varistor or
- (b) Zinc Oxide arrester connected in series with a non-inductive resistor
- (c) Zinc Oxide arrester in series with said non-inductive resistor and in parallel with a spark gap.
- (d) A cascade of configuration as described in (c).

4. A method of claim **1** wherein the storage unit comprises modular array of high energy density doped ceramic capacitors with storage capacity of 10 kWe.h to 1 GWe.h and volume 0.1 to 1 m^3 and up to 1000 units as the desired capacity dictates.

5. A method of broad spatial lightning protection by the manipulation of the path of an electrical discharge via the manipulation of the air terminal bias magnitude and polarity Said arrestors being arranged in an array to achieve the redirection of the discharge path. The discharge path being directed to a collection unit at some location significantly removed from the initial discharge impact position.

6. A method of claim **5** wherein the discharge redirection is via a biased conductor to the said collection and storage unit.

7. A method of claim **5** wherein the area of protection is a forest whereby:
- (a) A network array of air terminals is deployed on trees, in close proximity to said trees with tip approximating the treetops, or girding the trees to redirect the discharge along a biased conductor to a collection unit for the purpose of mitigating lightning induced fires.
- (b) Said discharge electrical energy being stored or fed into the electricity grid.

8. A method of claim **1** wherein the discharge collection is on electrical power lines and the stored energy is fed back into the grid.

9. A method of claim **1** wherein the discharge collection and storage are at telecom towers, light poles or other free standing structures. Said storage being at individual collection sites or some location serving an array of collectors and said stored energy used for individual structure's operational energy need or fed back into the utility grid.

10. A method of non-spontaneous generation of atmospheric discharge by the following:
- (a) Modulation of the magnitude and bias in a dipole air terminal relative to the ground
- (b) Conductive material balloon tethered by a conductive mesh cable.
- (c) Said cable being soaked by an ionic liquid, including, a salt solution to facilitate said atmospheric discharge conduction.

The discharge thus formed is stored for feeding into the greed or for operation as a stand-alone energy dam.

11. A method of claim **1** in which the discharge collection unit is configured as a mobile unit. Said unit being deployed on an automobile or any mobile platform. The said deployed unit extracting electrical charge from the atmosphere and storing such energy in a deployed storage unit on the said automobile. The energy thus stored, feeds the car battery which obviates the need for recharging at charging centers or from the grid.

12. A method of claim **1** wherein the electrical discharge energy collection unit is a stand-alone unit comprising modular capacitors configured as an electric vehicle charging station.

13. A method of claim **1** wherein the air terminals are deployed on buildings and the discharge energy collected thereby are:
- (a) Stored and fed back into the grid.
- (b) Stored for use by each building
- (c) Stored in a central energy storage facility for use by the community in general.

14. A method of claim **1** wherein the said storage units are underground.

15. A method of claim **1** wherein the storage unit is of capacity and configuration to accept energy feeds from multiple electricity generation sources: Thermal, Hydro, Solar, Wind and Lightning.

16. A method of claim **4** wherein the storage unit is integrated into a Utility's Switch Farm.

17. A method of claim **4** wherein the multilayer ceramic capacitor unit comprises dielectric layers of varying compositions individually or as sandwich layers with each other containing Barium-Titanate silicates as host material doped with Zr, WSi_2/WO_3 to modulate grain growth to between 0.1 to 10 μm as the case may be; said modulation providing corresponding control of electrical and reliability properties.

18. A method of claim **1** wherein the varistor comprise multilayers of ZnO and ZnS individually layered or as sandwich layers with each other with ZnO achieving 50-99.9% of each layer; said layers being alloyed metal oxides of transition elements including W, Zr, Mo, Mg, Cr, Ti to improve voltage response non-linearity.

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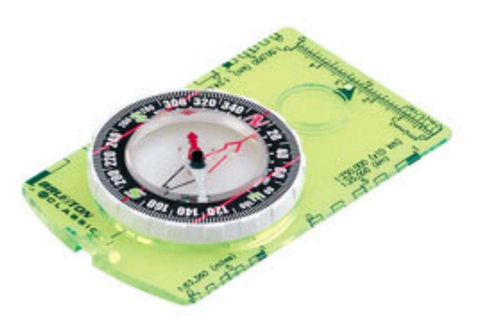

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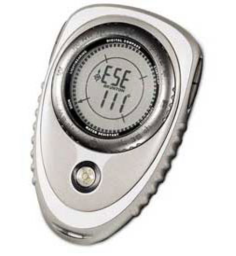

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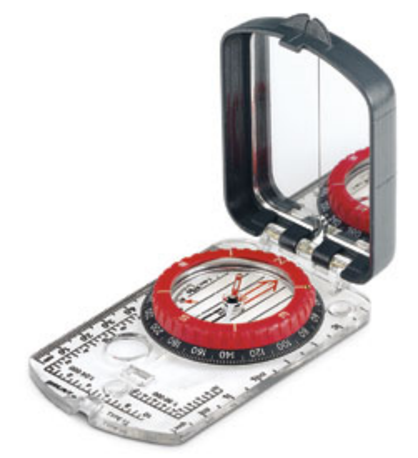

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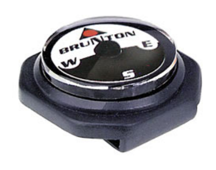

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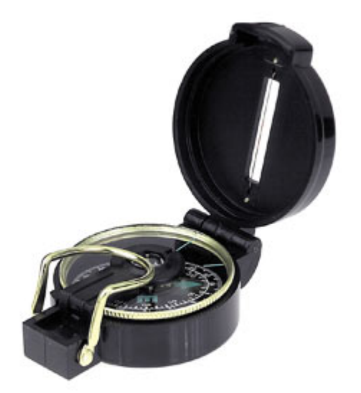

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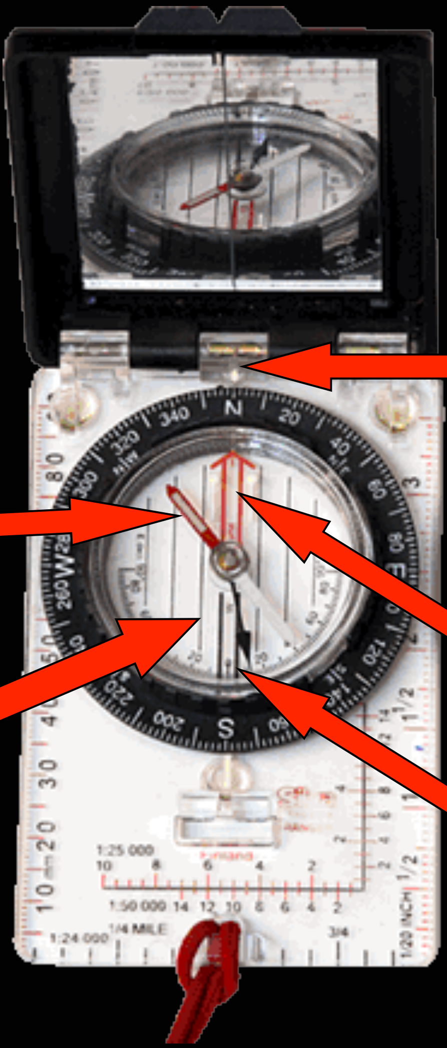

Bearing Index (Read Bearing Here)

Compass Needle – Red Points To Magnetic North

Orienting Arrow

Orienting Lines

Declination Scale

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Boxing A Compass

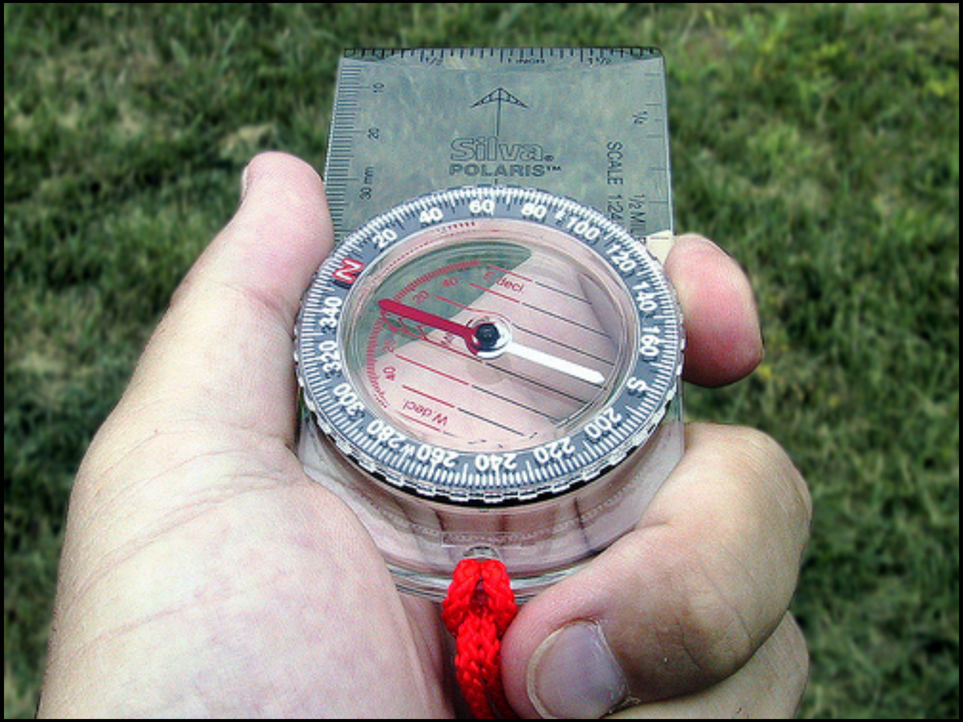

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RANDALL'S ADVENTURE TRAINING ®
LAND NAVIGATION

MAP ORIENTATION
With Compass Adjusted For Declination

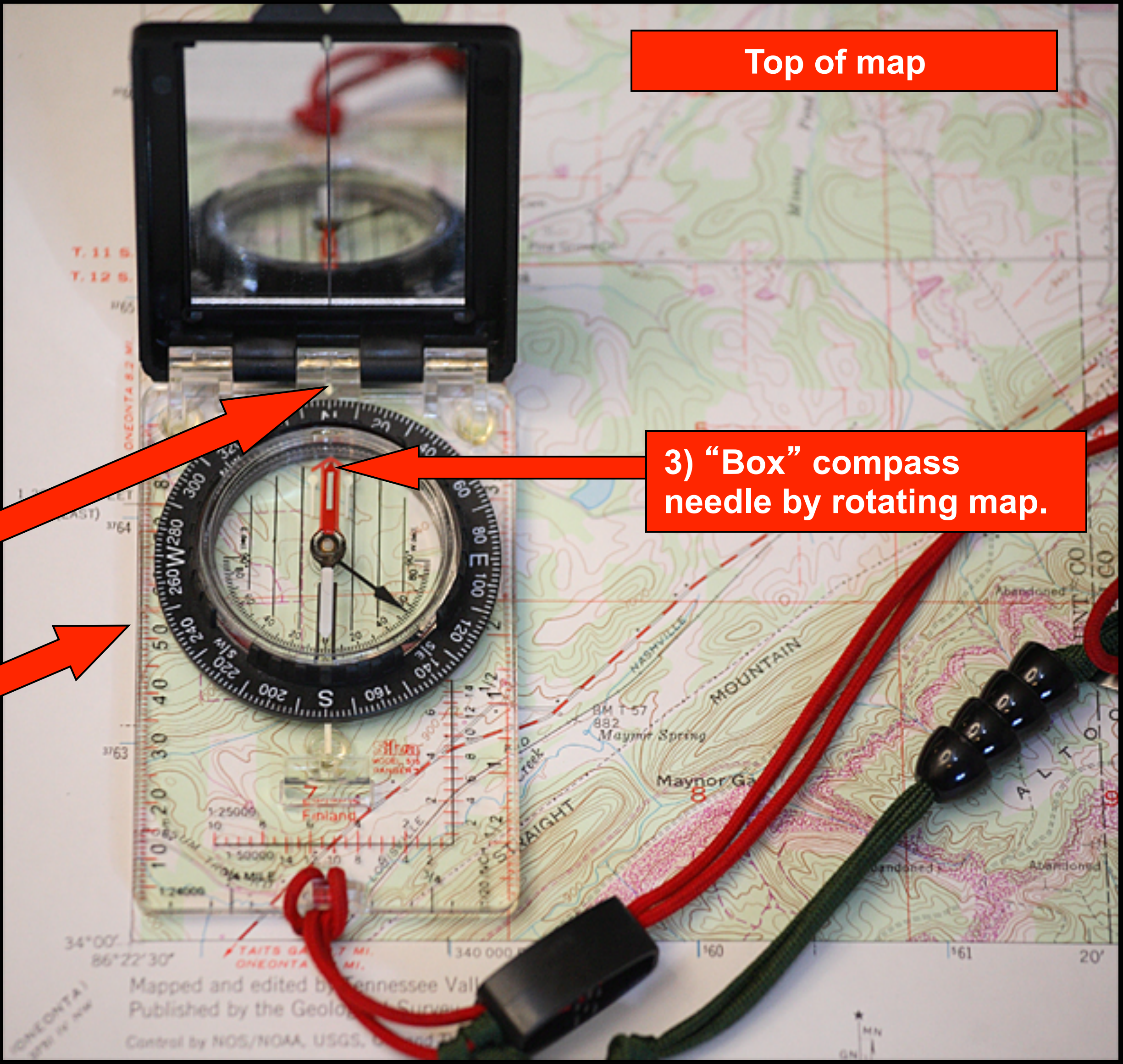

Top of map

1) Adjust dial so "N" is at index line.

2) Align edge of compass with north / south reference line.

3) "Box" compass needle by rotating map.

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Finding An Azimuth With Compass

(With Map Oriented To North)

Traveling To a Target On The Map – Step 1

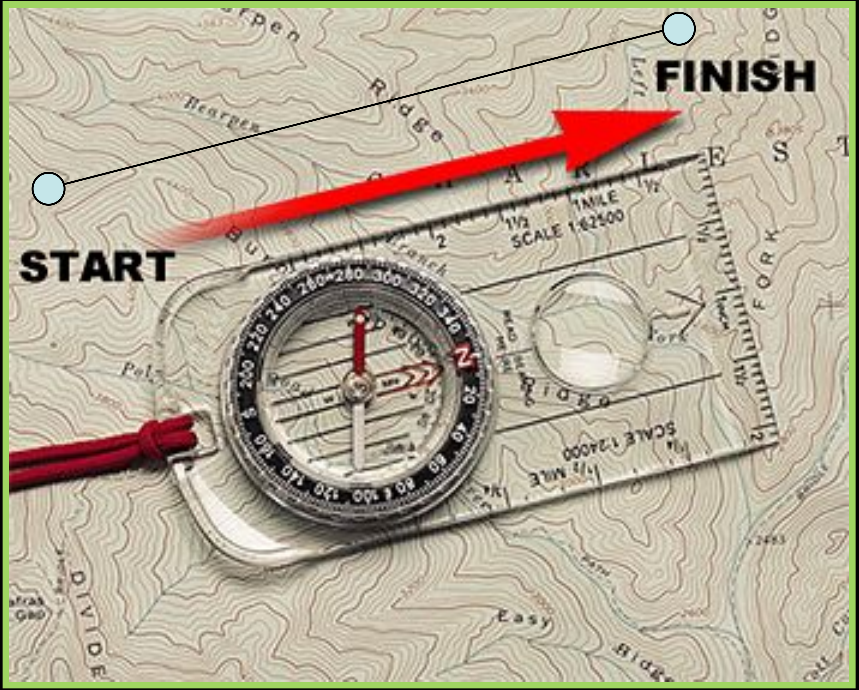

1) Draw a line on the map from your starting point to your finish point.
2) Orient the map to north.
3) Place the compass on the map with the edge of the compass on the line and the bearing arrow pointing at your destination

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Traveling To a Target On The Map – Step 2

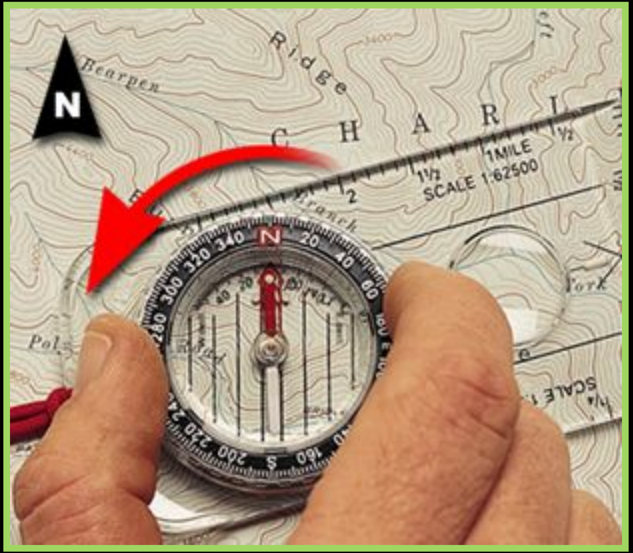
N
Bearpen
Ridge
C H A R L
1 MILE
1½
SCALE 1:62500
Branch
Fork
N
S

Set Compass Heading - Turn the dial on the compass until "N" outline arrow boxes the compass needle. Your direction to your target (in degrees) is read at the Index Line on the Dial.

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Traveling To a Target On The Map – Step 3

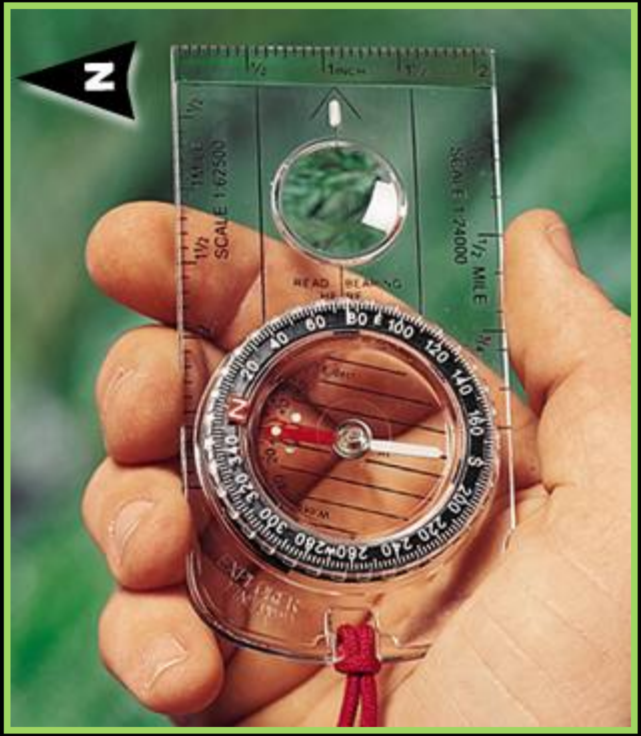
N
SCALE 1:62500
SCALE 1:24000
½ MILE
READ BEARING HERE

Follow Your Heading - Remove the compass from the map and hold it level, so the Magnetic Needle is free to turn. Turn your body until the red end of the Needle aligns with the Orienting Arrow (boxed) and "N" on the Dial. Using the Direction of Travel Arrow, sight a distant landmark and move to it. Repeat this process until you reach your destination.

Finding An Azimuth With Compass

(Without Map Oriented To North)

- Draw a line from start to finish.
- Lay the edge of your compass on the line in the direction you are traveling.
- Rotate the compass bezel until the orienting lines align with your North Reference Lines (Make sure that North is pointing to North on the map).
- Pick up your compass and travel to the destination.
- Note: The compass shown has already been adjusted for declination.

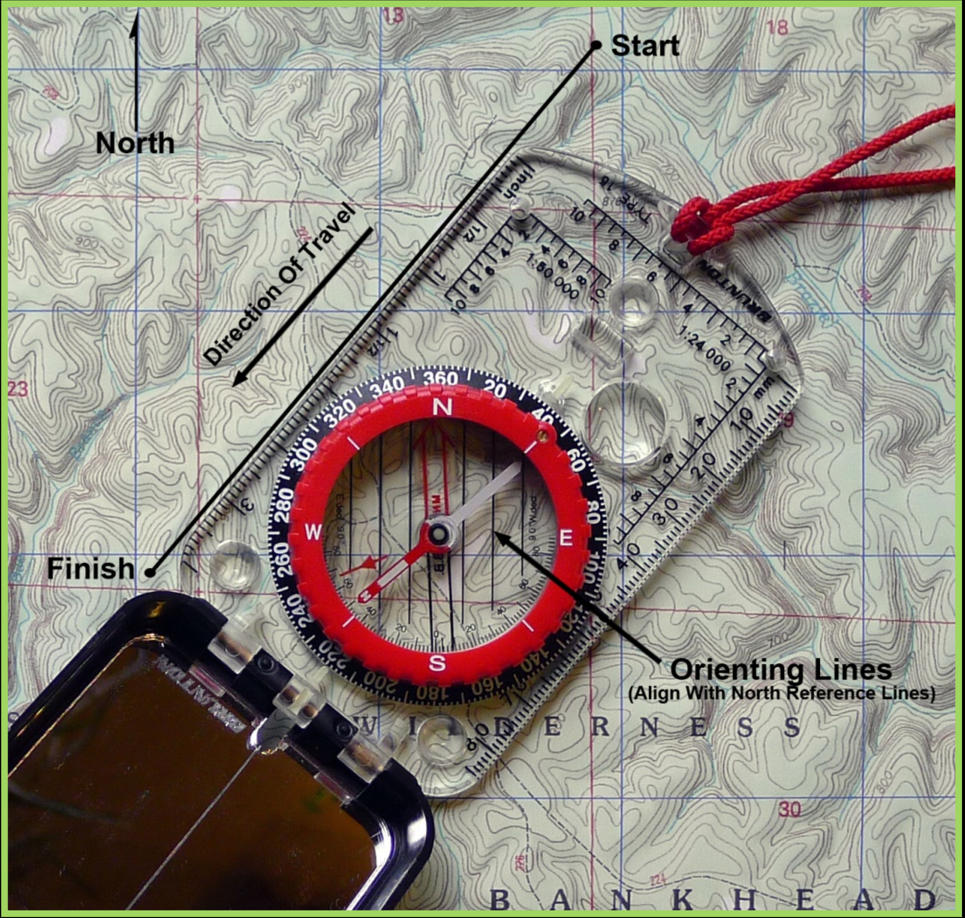
North
Start
Direction Of Travel
Finish
Orienting Lines
(Align With North Reference Lines)
W I L D E R N E S S
B A N K H E A D

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Finding An Azimuth With Compass Card

(Without Map Oriented To North)

- Draw a line from start to finish.
- Lay the compass rose on the line so the line crosses through the center of the rose.
- Align N / S line or orienting lines on the compass rose with North Reference Line.
- Read your azimuth on the "Finish" side of the compass rose.
- Note: unless you are using a compass adjusted for declination, you will have to add or subtract the declination value to the value that you acquire from the compass rose.

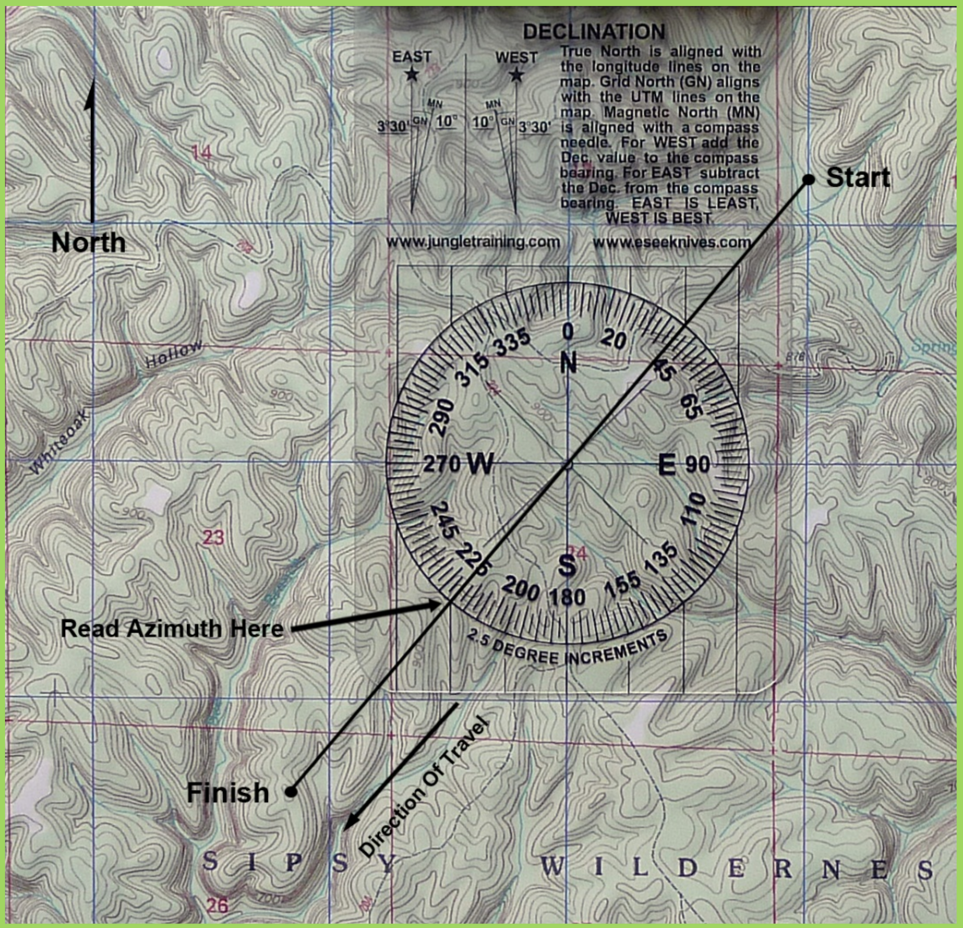

DECLINATION

True North is aligned with the longitude lines on the map. Grid North (GN) aligns with the UTM lines on the map. Magnetic North (MN) is aligned with a compass needle. For WEST add the Dec. value to the compass bearing. For EAST subtract the Dec. from the compass bearing. EAST IS LEAST, WEST IS BEST.

EAST
WEST
MN
GN
3°30'
10°
www.jungletraining.com
www.eseeknives.com
North
Start
Finish
Read Azimuth Here
Direction Of Travel
0
20
45
65
E 90
110
135
155
180
S
200
225
245
270 W
290
315
335
N
2.5 DEGREE INCREMENTS
Hollow
Whiteoak
14
23
24
26
S I P S Y
W I L D E R N E S S

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Traveling To a Target With Sighting Compass

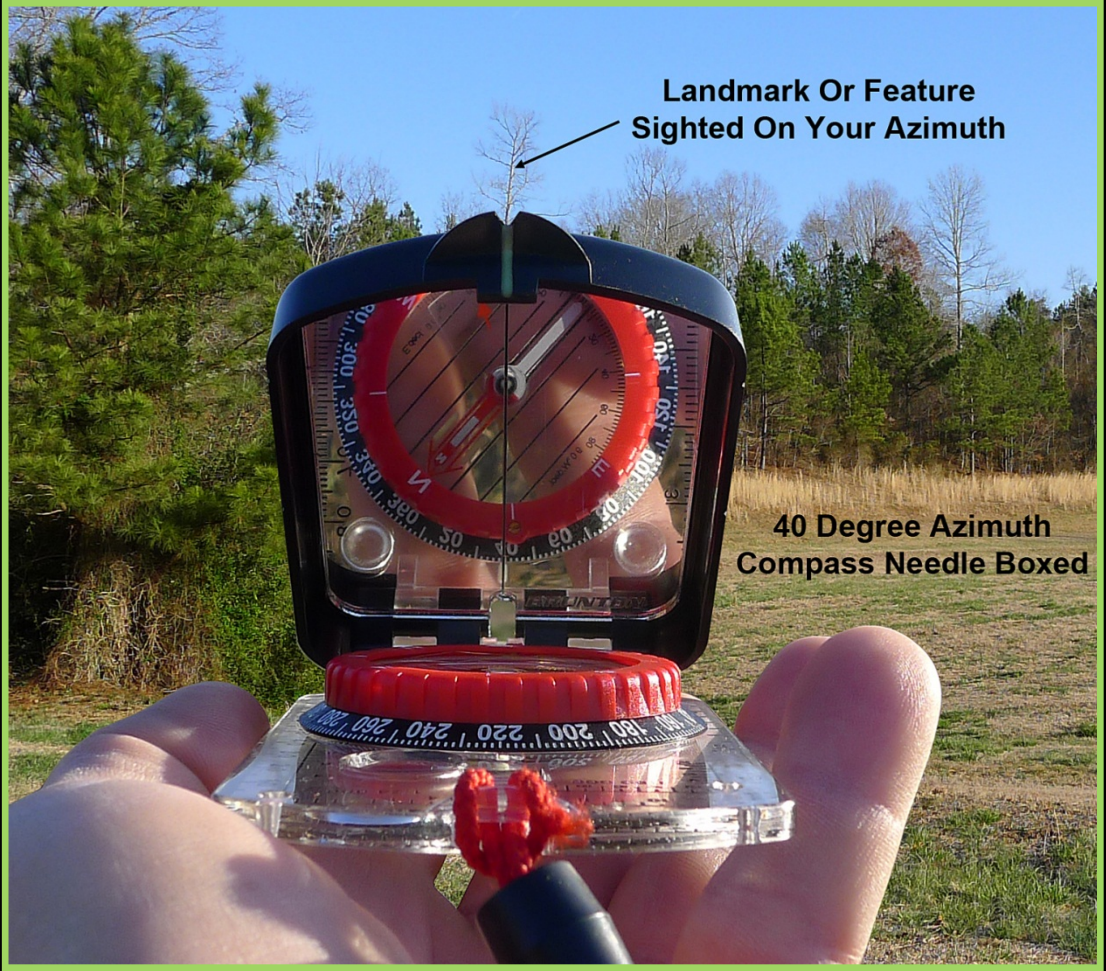

Landmark Or Feature Sighted On Your Azimuth

40 Degree Azimuth Compass Needle Boxed

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Posting Up

In addition to using natural landmarks as targets for your direction of travel, you can also post up a member of your team as a target. Another option is the Back Azimuth.

Ft. Payne, AL
3.5 Degrees West

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Back Azimuth

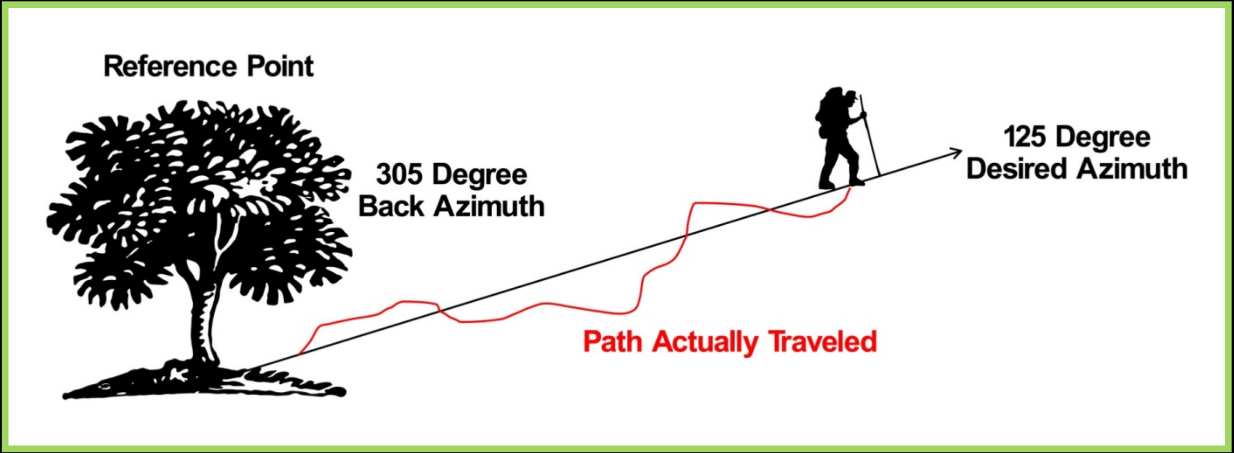
Reference Point
305 Degree
Back Azimuth
125 Degree
Desired Azimuth
Path Actually Traveled

Use a Back Azimuth if you need to verify you are still on your desired direction of travel. This is especially handy when crossing rivers or boxing around objects.

Back Azimuth is 180 degrees from your target azimuth. If your target azimuth is more than 180 degrees, then subtract 180. If it is less than 180, then add 180.

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Boxing Around Objects

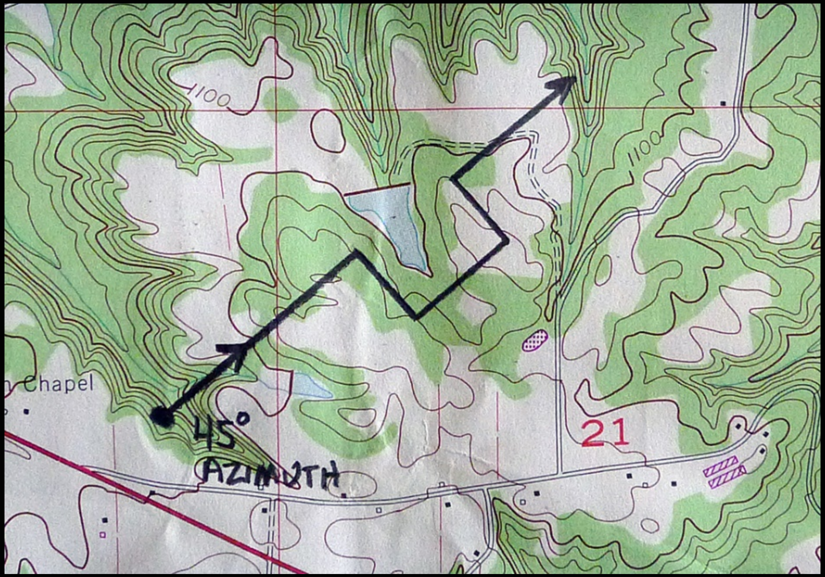

- Direction of original travel is 45 degrees
- Turn 90 degrees to a new azimuth of 135 (count your paces)
- Turn 90 degrees back to the original azimuth of 45 degrees until you are past obstacle
- Turn 90 degrees to a new azimuth of 315 and pace the same amount as the first turn
- Turn 90 degrees back to the original azimuth of 45 degrees and continue on

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LATERAL DRIFT – MISSING YOUR TARGET

If you cannot find your target after walking your azimuth the correct distance, then mark the spot where you think it should be and began a structured grid search of the area. Make note of your azimuths, pace count and direction changes. Start your grid small then go larger if you cannot locate the target.

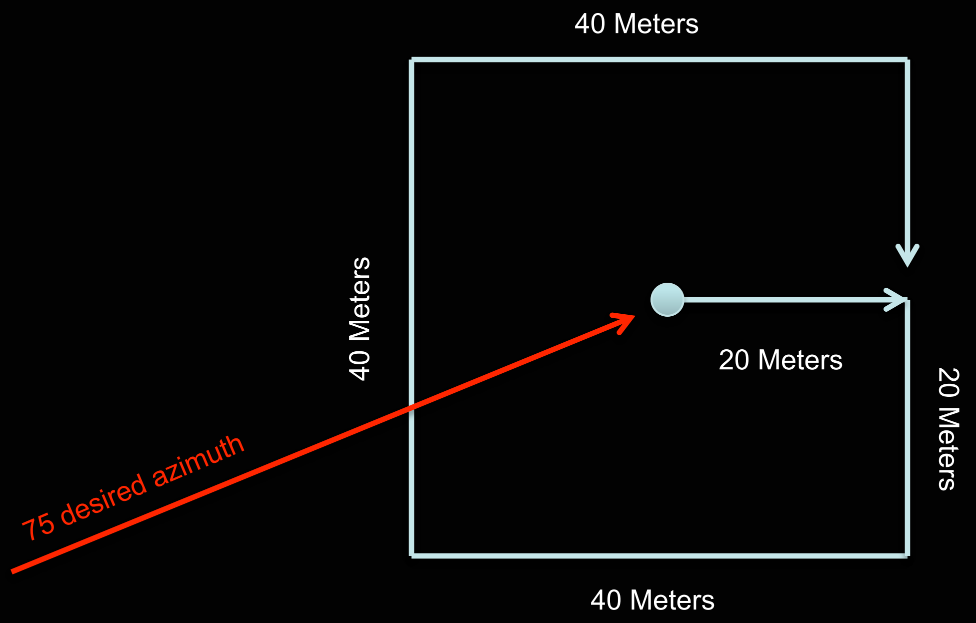
40 Meters
40 Meters
20 Meters
20 Meters
75 desired azimuth
40 Meters

Ft. Payne, AL
3.5 Degrees West

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Gross Direction Navigation

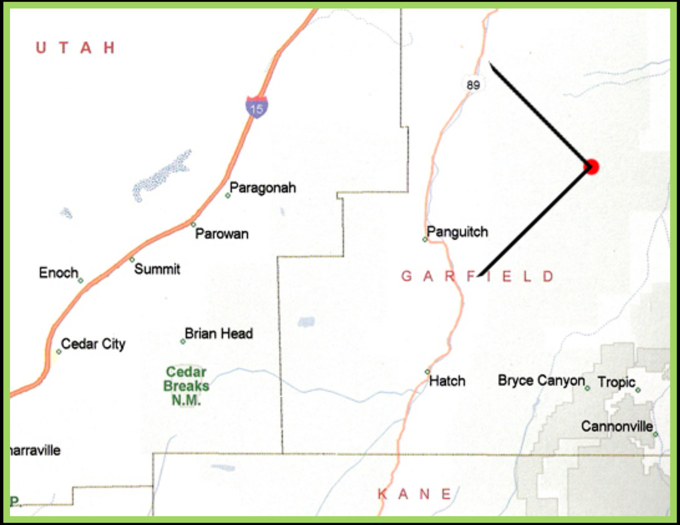
UTAH
15
89
Paragonah
Parowan
Panguitch
Enoch
Summit
GARFIELD
Brian Head
Cedar City
Cedar Breaks N.M.
Hatch
Bryce Canyon
Tropic
Cannonville
arraville
P.
KANE

As obvious from this simple road map, the lost hiker only needs to travel a westerly direction to cross a road and reach civilization. Always know which general direction crosses a main artery!

When using a map and compass always have a "panic azimuth."

Gross Direction Navigation Aids

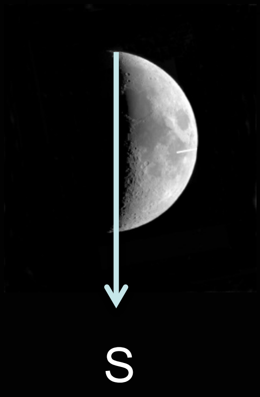

Quarter Moon

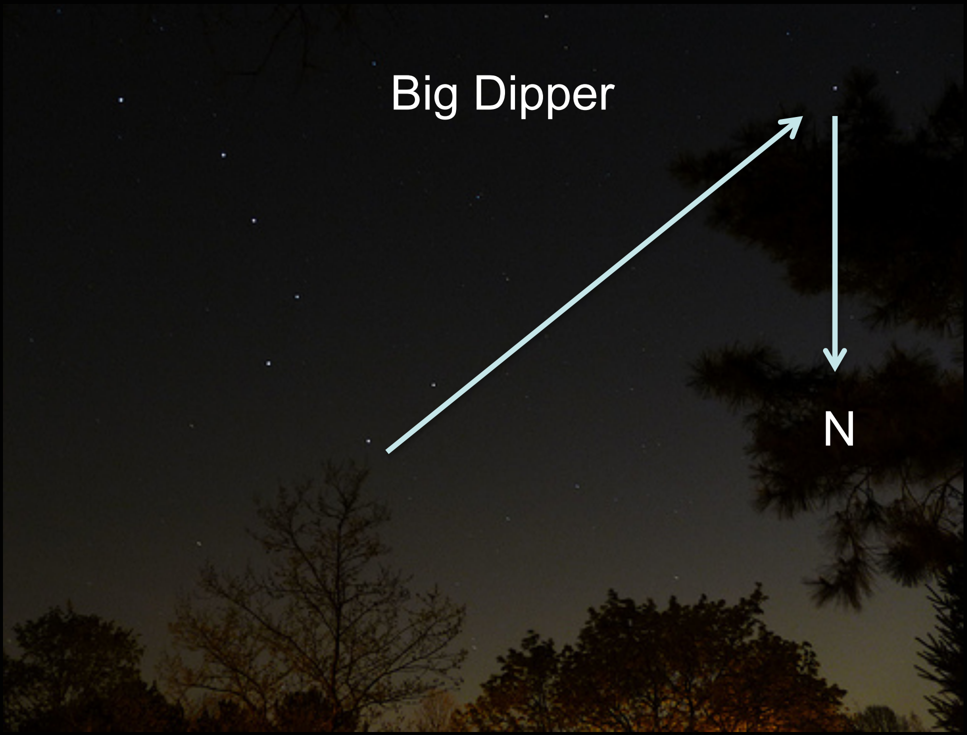

Big Dipper

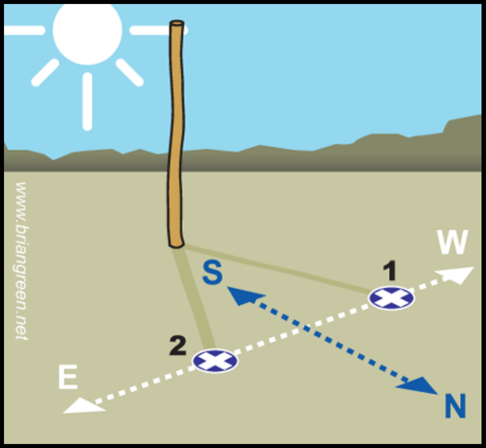
www.briangreen.net
S
1
W
2
E
N

Shadow Stick

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Terrain Association Navigation

This is the most widely used method of navigation. The navigator plans his route so that he moves from terrain feature to terrain feature. An automobile driver in a city uses this technique as he moves along a street or series of streets, guiding on intersections or features such as stores, parks or houses. Like the driver, the navigator selects routes or *streets* between key points or *intersections*. These key points can be lakes, mountains, roads or any other terrain feature readily recognized on a map. Before you hike a new area, familiarize yourself with the terrain by studying maps, satellite photos or any other available information.

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Backstops, Handrails & Aiming Off

BACKSTOPS are features that typically run perpendicular to your azimuth and located beyond your target point. If you run into your backstop then you know you have traveled too far and missed your target point. Backstops can be rivers, roads, mountains, railroad tracks or any other useable feature.

HANDRAILS are features that run parallel to your azimuth. They can be rivers, roads, mountains, or any other useable feature that the navigator can use to continue traveling in the desired direction.

AIMING OFF is a process of deliberately adding or subtracting to the desired azimuth so the navigator knows which way to go once they reach a feature (such as a trail or road) that leads to the target.

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Backstops, Handrails & Aiming Off

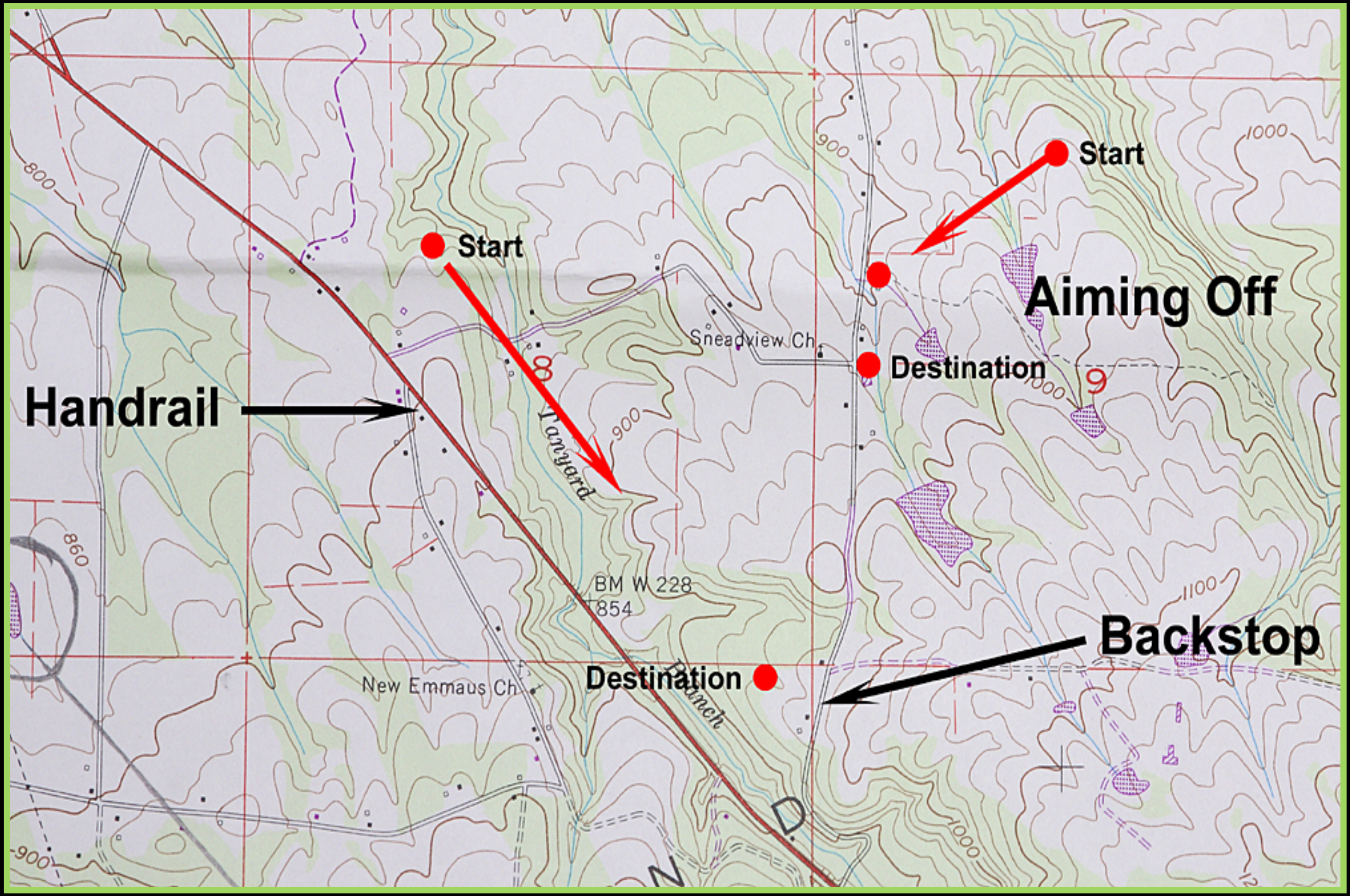
Start
Start
Aiming Off
Sneadview Ch
Destination
Handrail
Tanyard
BM W 228
854
Backstop
New Emmaus Ch
Destination
Branch
800
900
860
1000
1100
8
9

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TOPO MAP BASICS

BASICS SYMBOLS

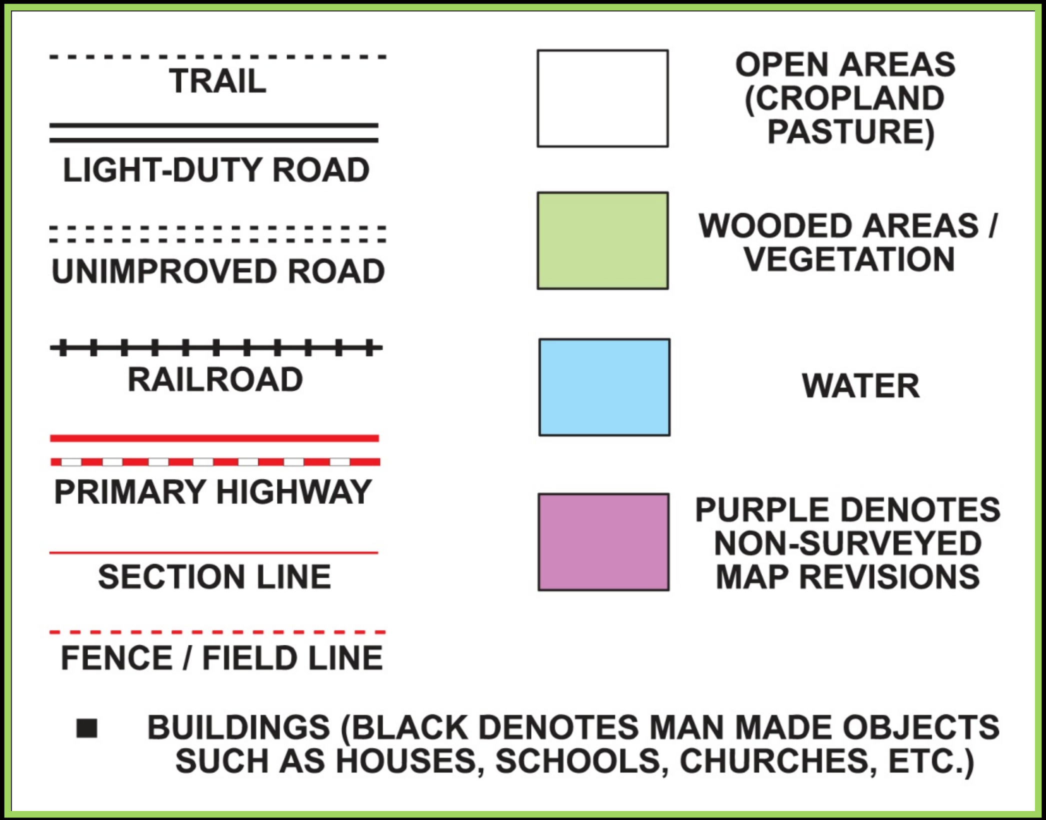

TRAIL

LIGHT-DUTY ROAD

UNIMPROVED ROAD

RAILROAD

PRIMARY HIGHWAY

SECTION LINE

FENCE / FIELD LINE

OPEN AREAS (CROPLAND PASTURE)

WOODED AREAS / VEGETATION

WATER

PURPLE DENOTES NON-SURVEYED MAP REVISIONS

■ BUILDINGS (BLACK DENOTES MAN MADE OBJECTS SUCH AS HOUSES, SCHOOLS, CHURCHES, ETC.)

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Map Scale & Datum

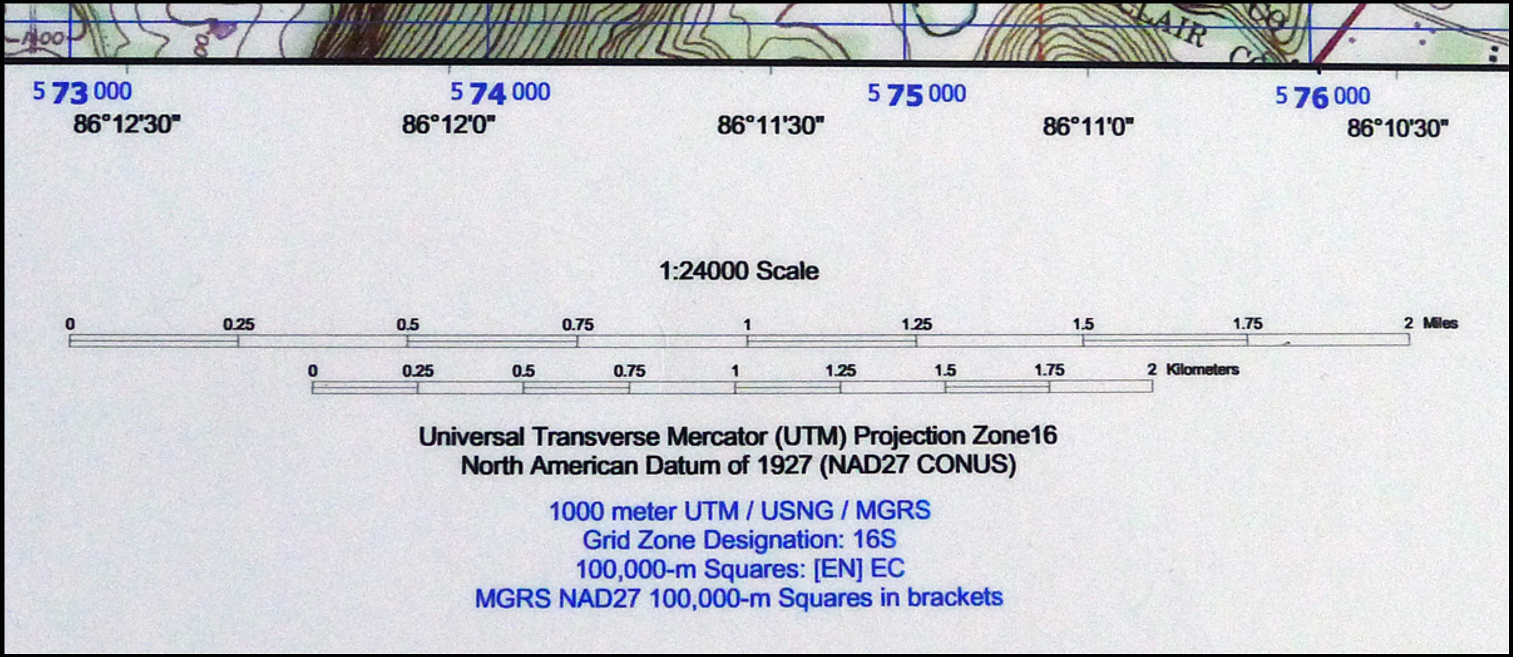
5 73 000
86°12'30"
5 74 000
86°12'0"
86°11'30"
5 75 000
86°11'0"
5 76 000
86°10'30"
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2 Miles
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2 Kilometers

1:24000 Scale

Universal Transverse Mercator (UTM) Projection Zone16
North American Datum of 1927 (NAD27 CONUS)

1000 meter UTM / USNG / MGRS
Grid Zone Designation: 16S
100,000-m Squares: [EN] EC
MGRS NAD27 100,000-m Squares in brackets

Always set your GPS to the map datum shown on your map!
Always use the proper scale card for measuring!

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CONTOUR LINES

The closer the contour lines, the steeper the terrain. Check the map for the contour intervals. Contour lines will also have elevation markings.

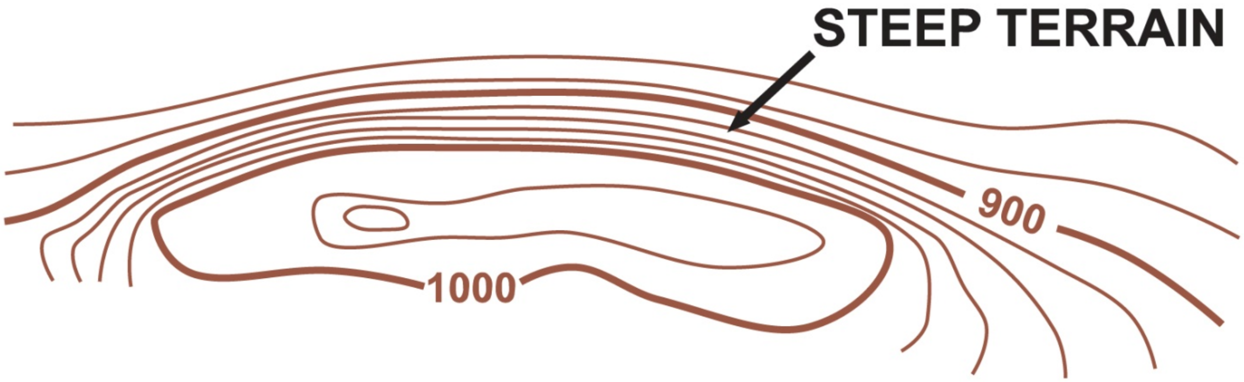

Example above shows a map with contour intervals of 20 feet.

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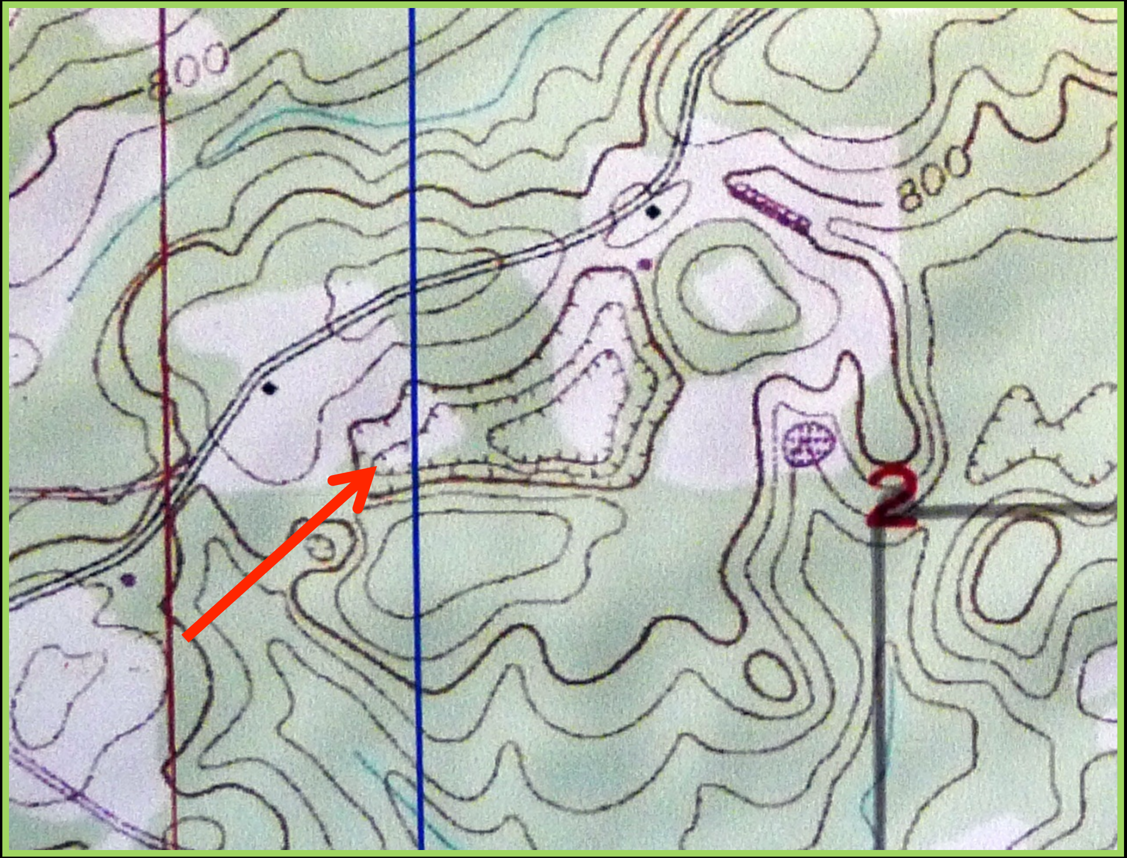

Depression

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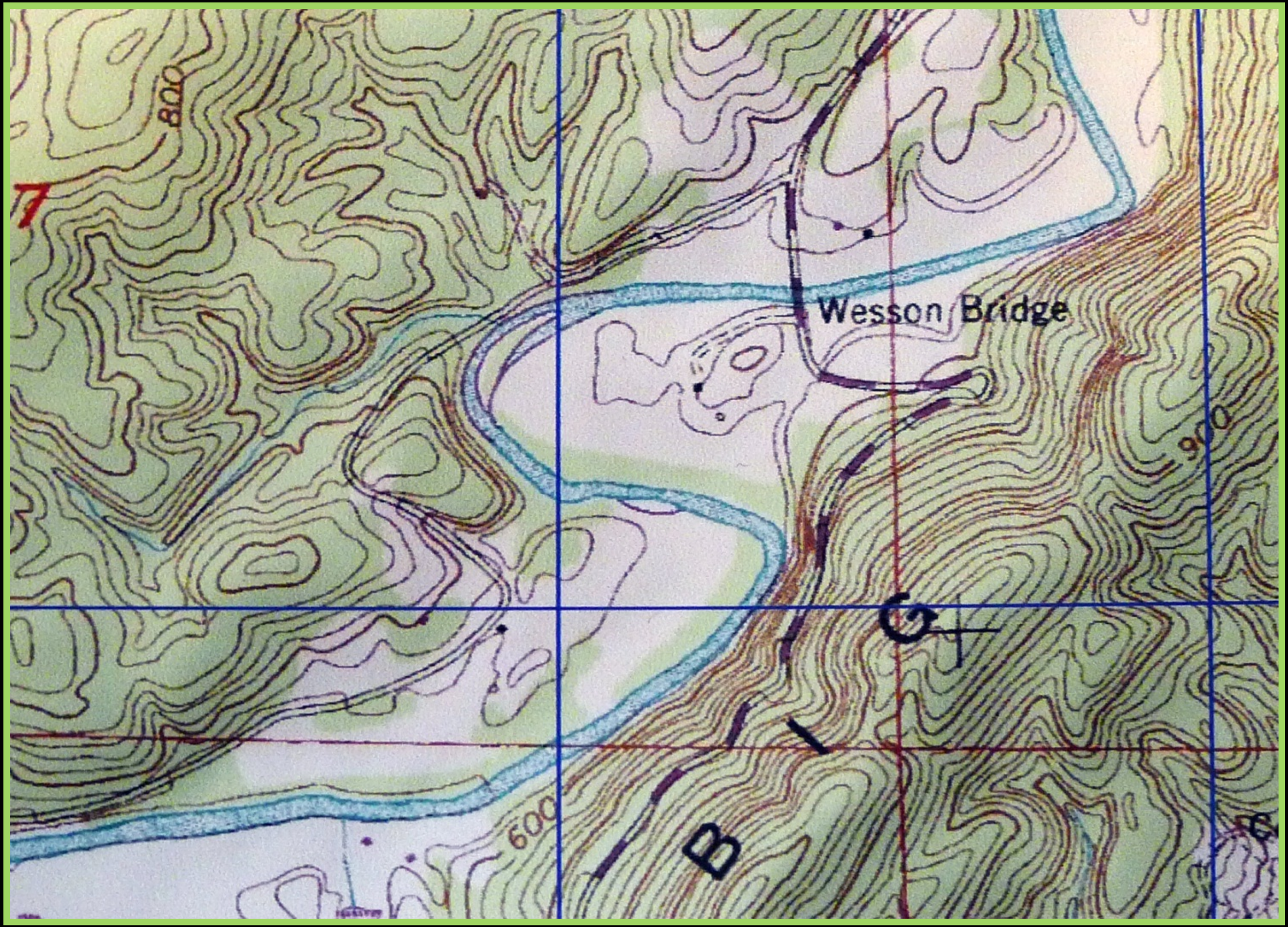
800
7
Wesson Bridge
900
600
G
B
C

Continuous Water Flow

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LAND NAVIGATION

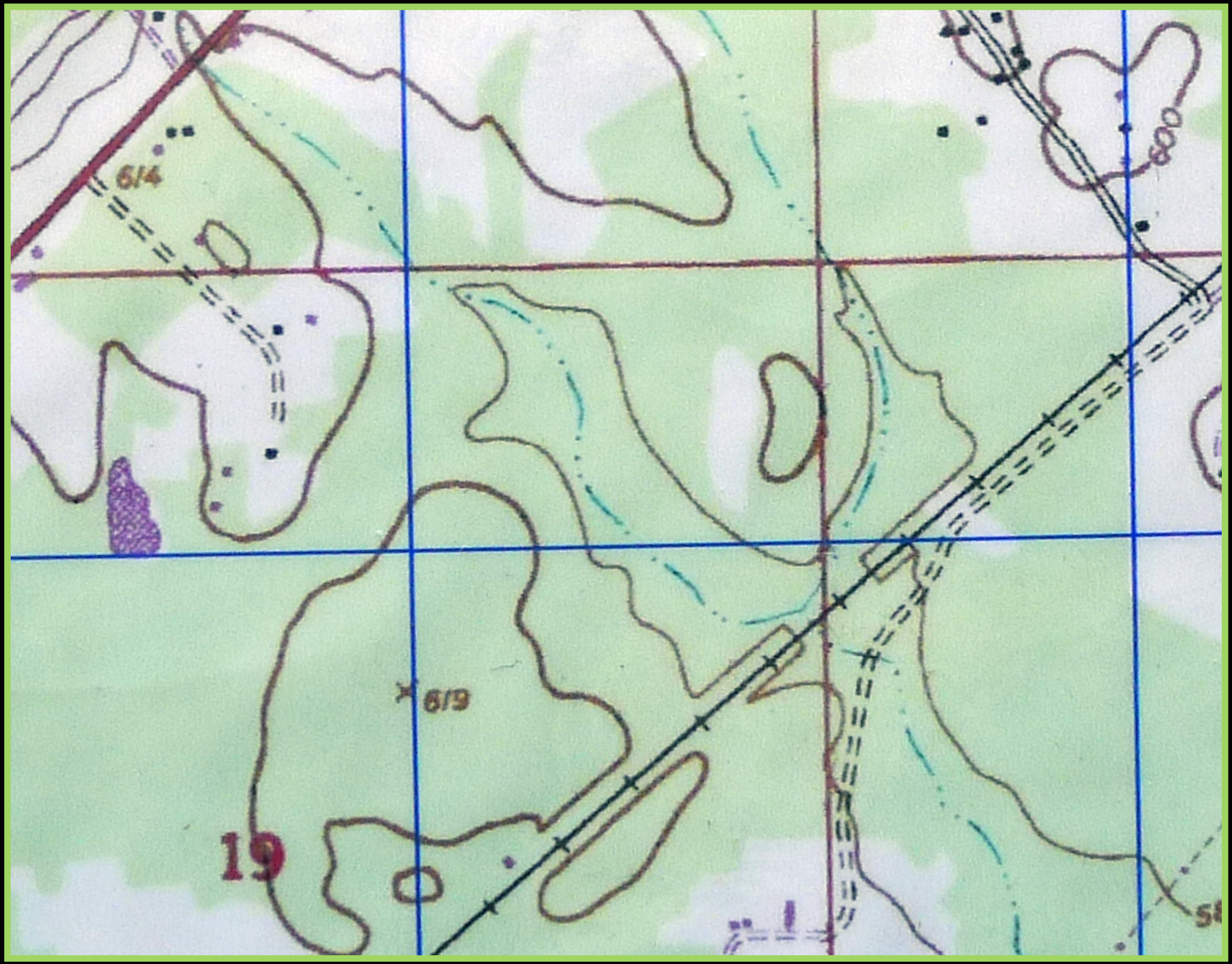

Intermittent Water Flow

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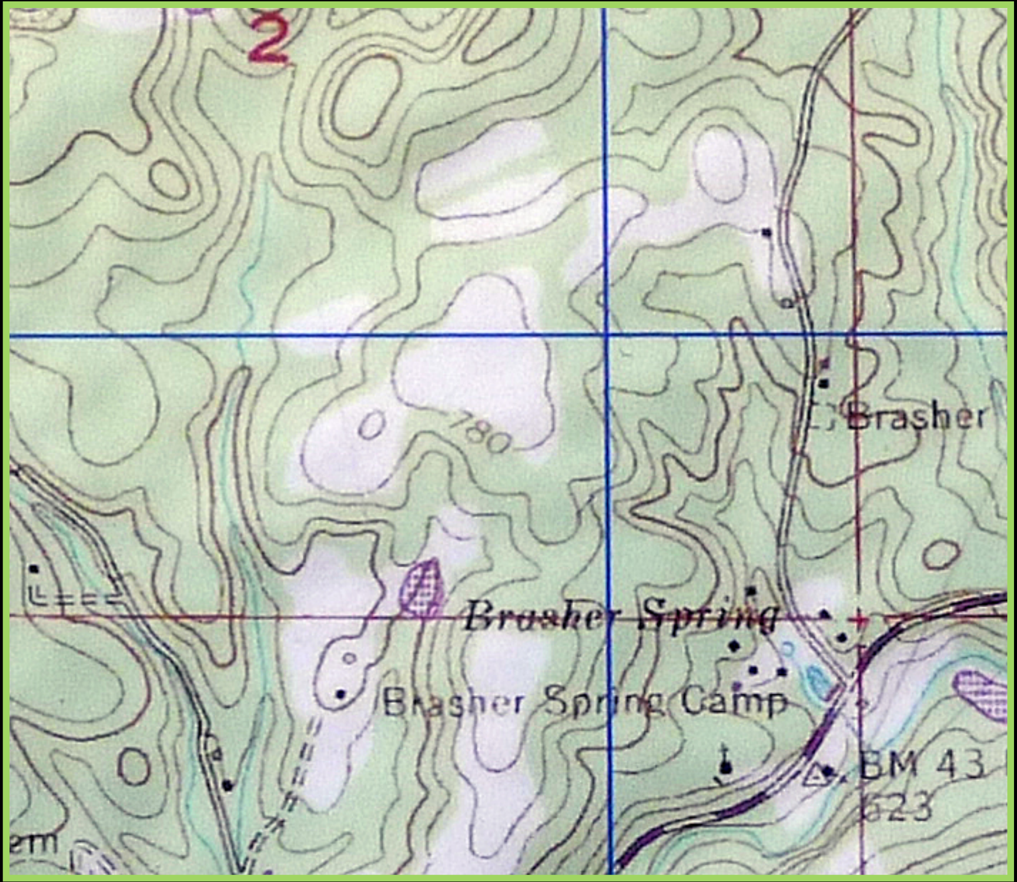
2
780
Brasher
Brasher Spring
Brasher Spring Camp
BM 43
623
em

Clear Areas / Fields

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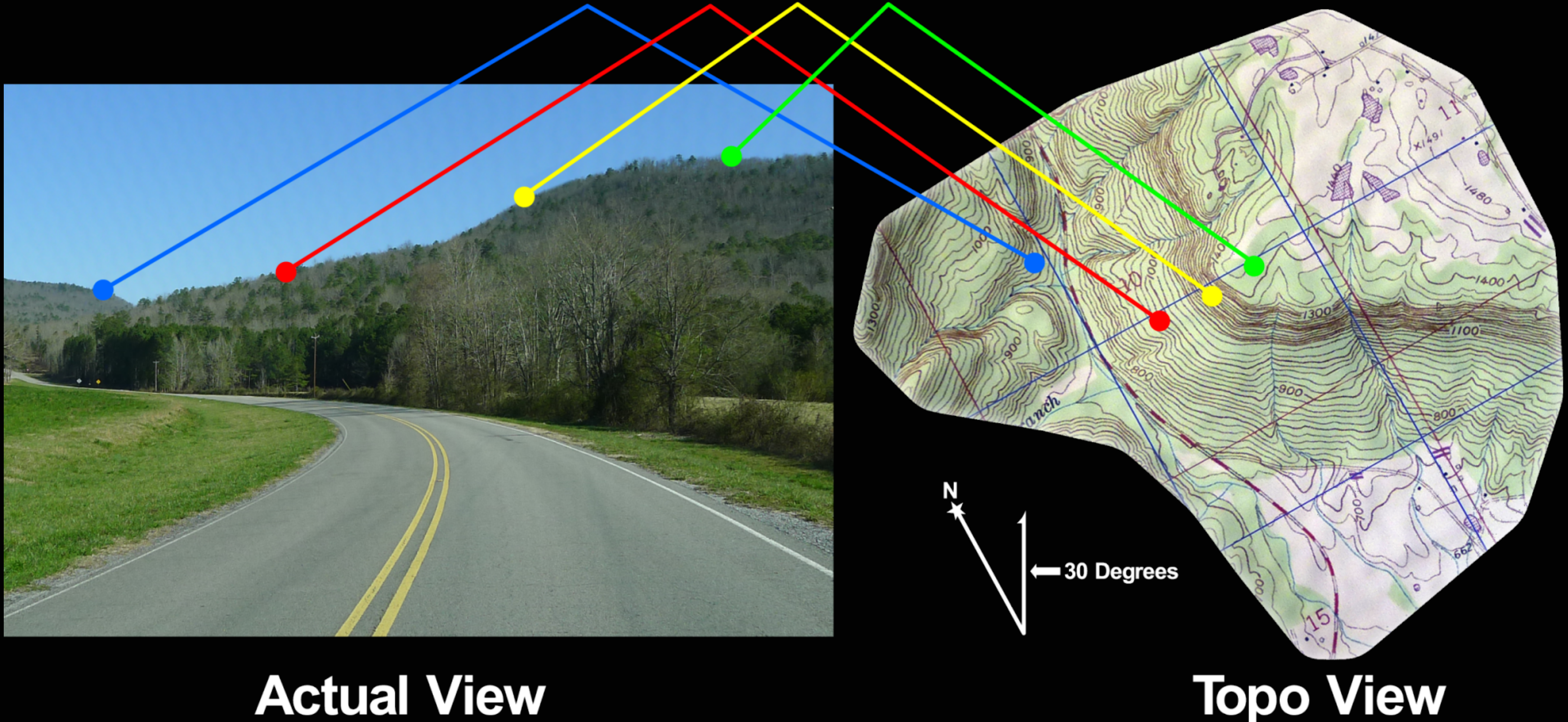

Actual View

Topo View

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LAND NAVIGATION

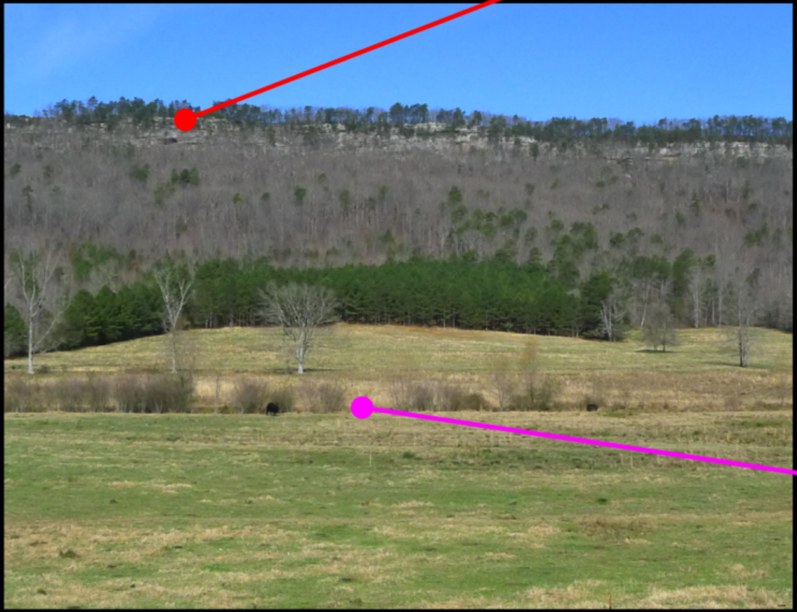

Actual View

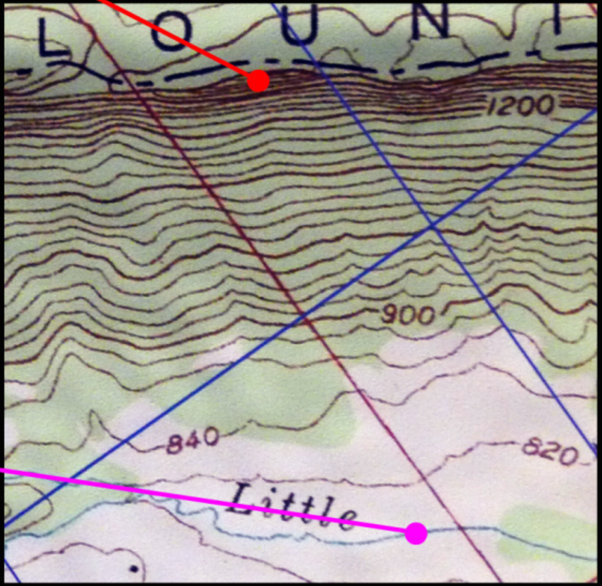
L O U N
1200
900
840
820
Little

Topo View

300 Degrees

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DETERMINING DISTANCE

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Determining Distance On Map

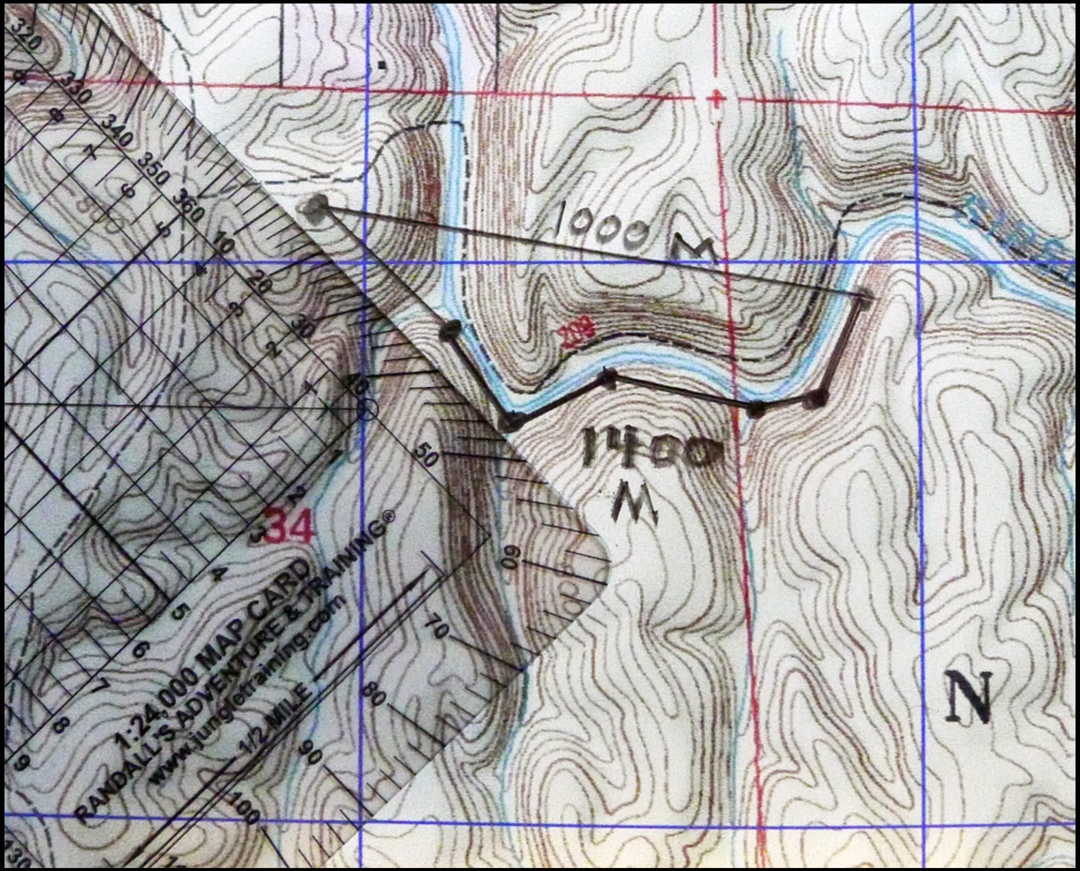
1000 M
1400 M
N
34
1:24,000 MAP CARD
RANDALL'S ADVENTURE & TRAINING®
www.jungletraining.com
1/2 MILE

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DETERMINE DISTANCE TRAVELED BY PACE COUNT

In thick jungle, where landmarks can not always be seen to track your position, pace counting is the best way of measuring distance. Pace counting will allow the navigator to estimate where he is at any given time. To be accurate, the navigator must practice pacing over different types of terrain. First you have to do some calculations. Measure out exactly 100 meters on three types of ground. Flat easy terrain, rougher terrain with some slope and then steep hill terrain. Then on each measured course count your paces (every time your left foot touches the ground or every 2 steps = 1 pace). You will have 3 different pace counts for different types of terrain. Once finished, memorize your pace count for all 3 types.

Averages

Flat easy terrain	100 meters	65 paces
Rougher terrain with some slope	100 meters	75 paces
Steep hill terrain	100 meters	95 paces

General Rule: You have never traveled as far as you think you have.

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CONDITIONS THAT AFFECT PACE COUNT

- Slopes – Your pace lengthens on a downslope and shortens on an upgrade.
- Winds – A headwind shortens the pace and a tailwind increases it.
- Surfaces – Sand, gravel, mud, snow and similar surfaces tend to shorten your pace.
- Elements – Falling rain or snow causes the pace to be reduced in length.
- Clothing – Excess clothing or shoes with poor traction affect the pace length.
- Visibility – Poor visibility due to rain, snow, or fog will shorten your pace.

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Ranger Pace Count Beads

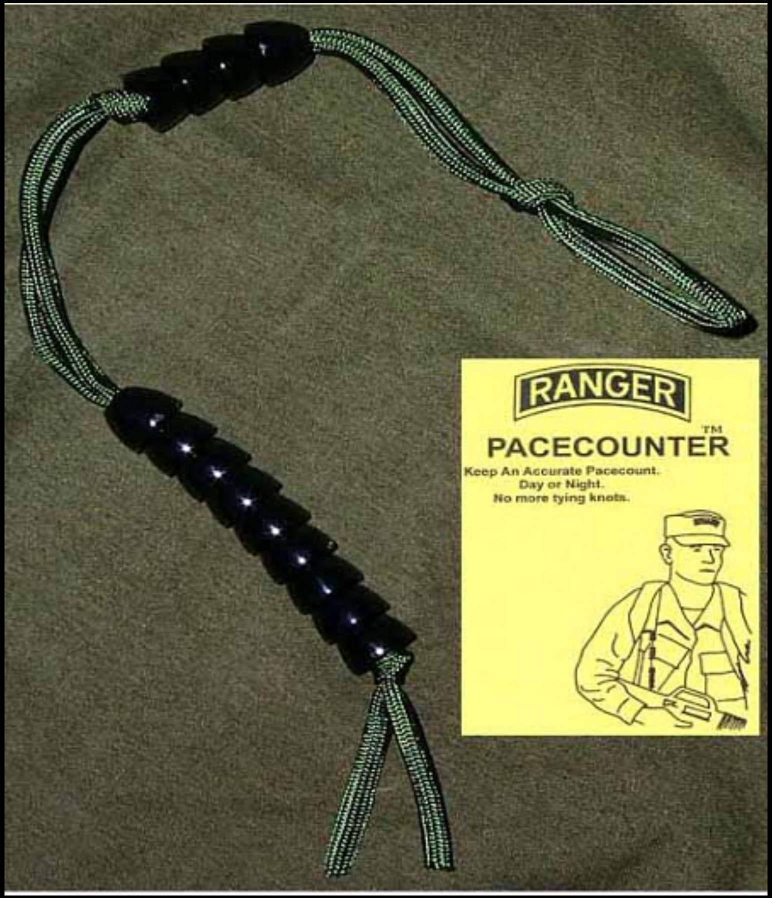
RANGER
PACECOUNTER™
Keep An Accurate Pacecount.
Day or Night.
No more tying knots.

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RANDALL'S ADVENTURE TRAINING ®
LAND NAVIGATION

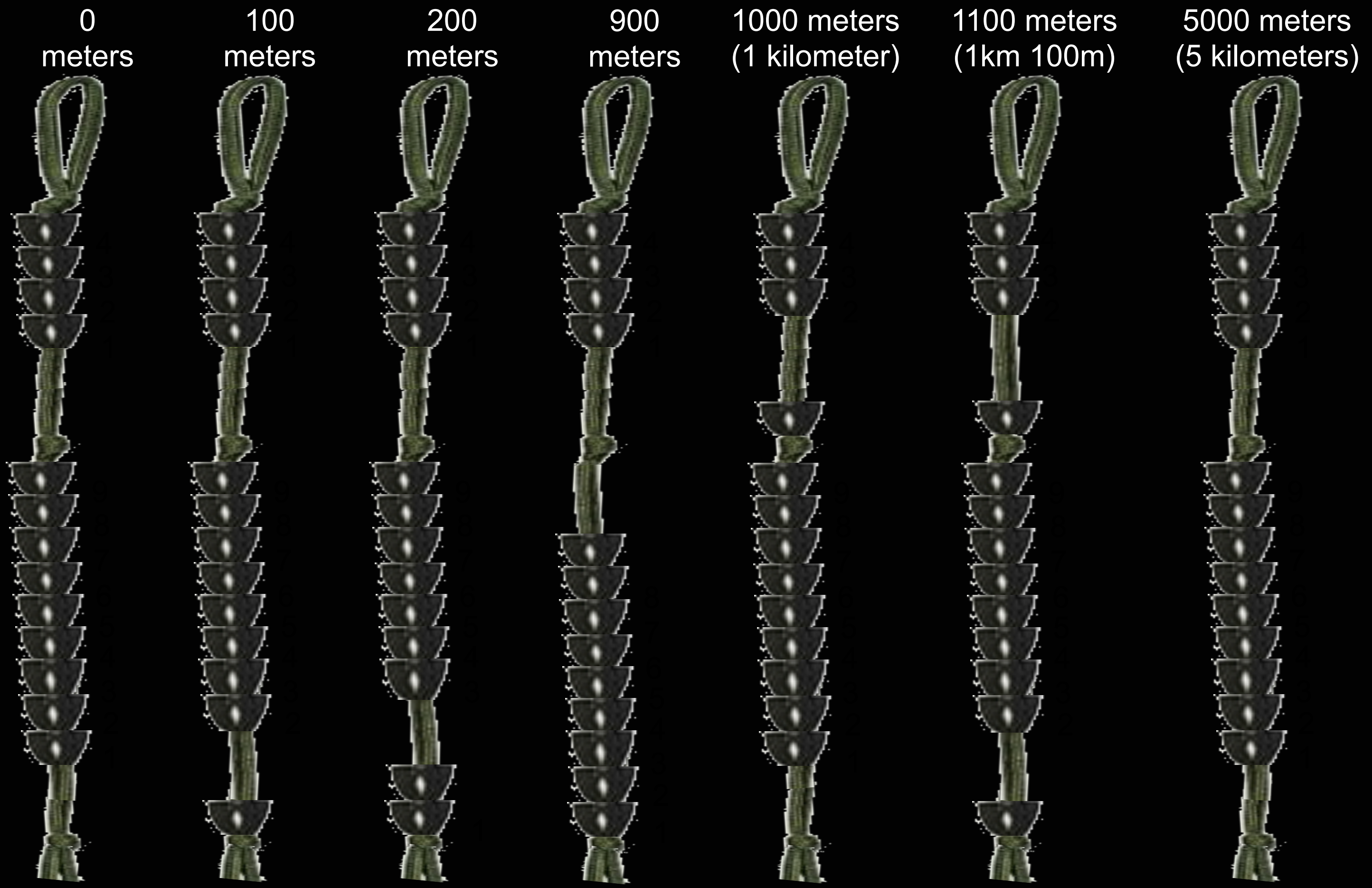
0 meters
100 meters
200 meters
900 meters
1000 meters (1 kilometer)
1100 meters (1km 100m)
5000 meters (5 kilometers)

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FINDING YOURSELF

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Baselines

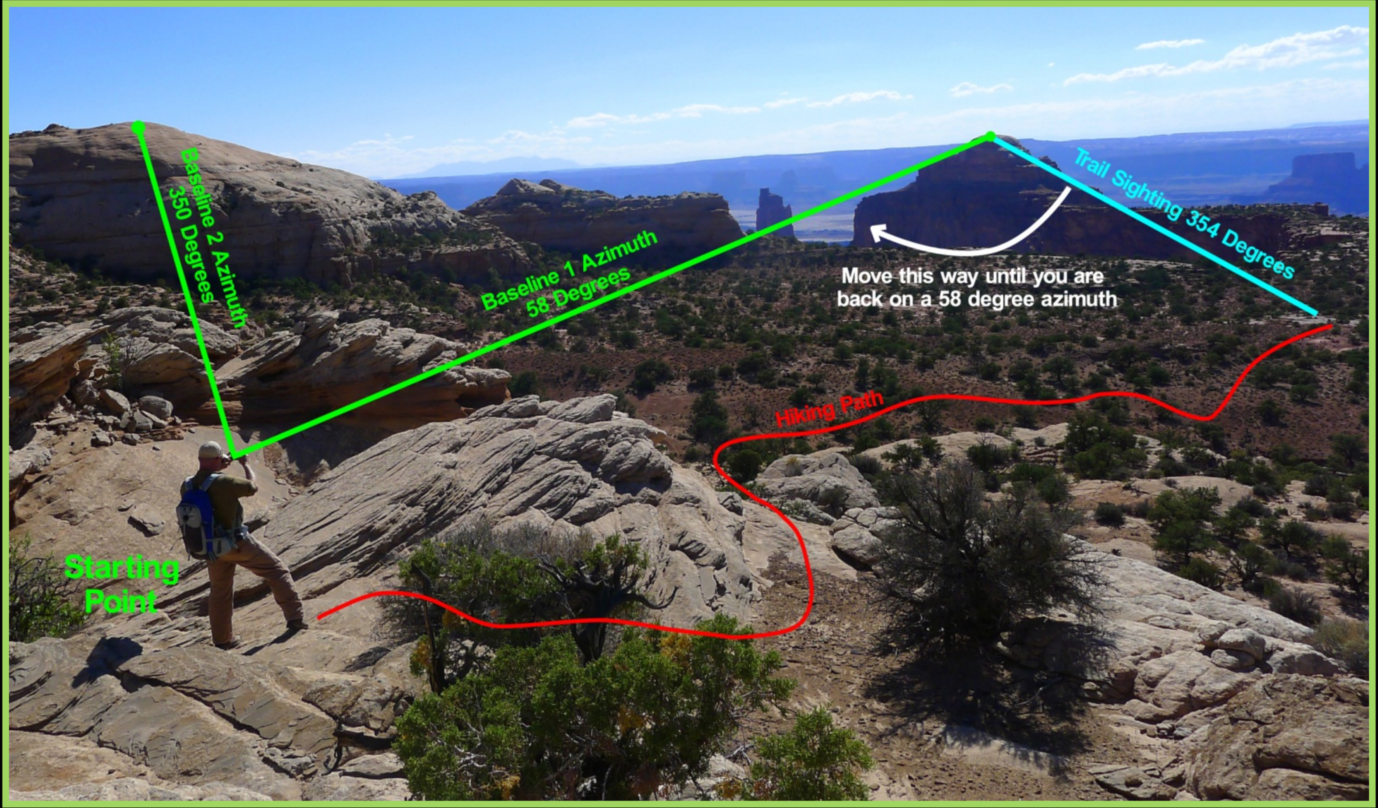
Baseline 2 Azimuth
350 Degrees
Baseline 1 Azimuth
58 Degrees
Trail Sighting 354 Degrees
Move this way until you are back on a 58 degree azimuth
Hiking Path
Starting Point

Find two prominent features. Shoot an azimuth to the first one and write it down. Shoot an azimuth to the second one and write it down. You can now travel freely. If you get lost, shoot an azimuth to the first feature and move until you get back on your first azimuth. Shoot an azimuth to your second feature and move until you get back on your second azimuth. You will be back at your starting point once both azimuths are the same as the ones you wrote down.

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RESECTION

- Orient your map and secure its position. Locate a landmark on the map that you can actually see in the landscape. Take a compass bearing to that landmark by sighting and then rotating compass dial until the needle is boxed. Once you have a bearing, do not move the compass dial. Lay the corner of the compass on the map landmark and rotate the whole compass (not the dial) until the needle is boxed. If done properly the corner of the compass will still be over your landmark. Draw a line along the edge of the compass base.

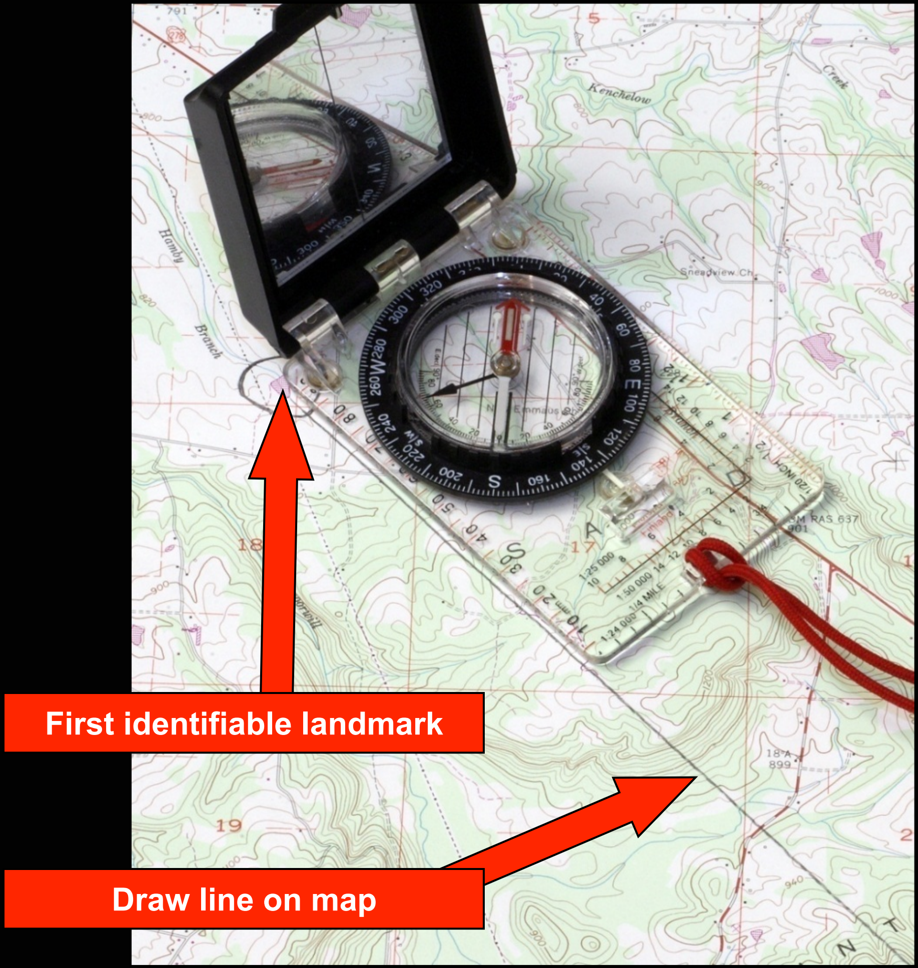
First identifiable landmark

Draw line on map

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RESECTION - Step 2

- Find a second identifiable landmark on the map and repeat the process from the previous slide. Where the two lines intersect is roughly where you are on the map.
- Finding a third point on the map and repeating the process is called "triangulation" and increases the accuracy of finding your location.

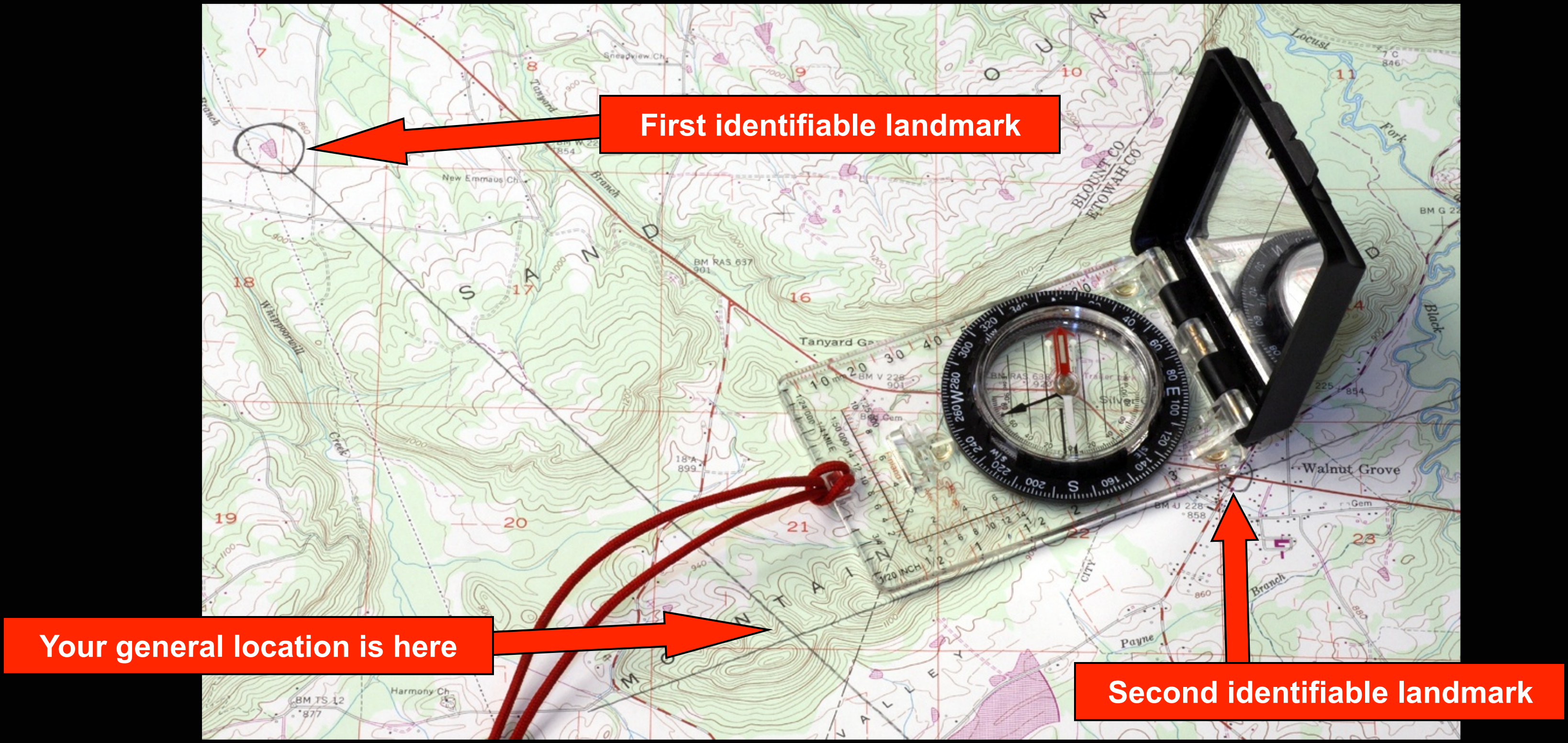
First identifiable landmark

Your general location is here

Second identifiable landmark

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if you are already on a known location (such as a road, river or mountain ridge) but not sure exactly where you are on this feature, you may only need to shoot one azimuth to determine your exact position on the map

INTERSECTION is the reverse of RESECTION. An example of intersection is seeing smoke from a forest fire and determining where the fire is located on a map.

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PLOTTING COORDINATES

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Map Grids

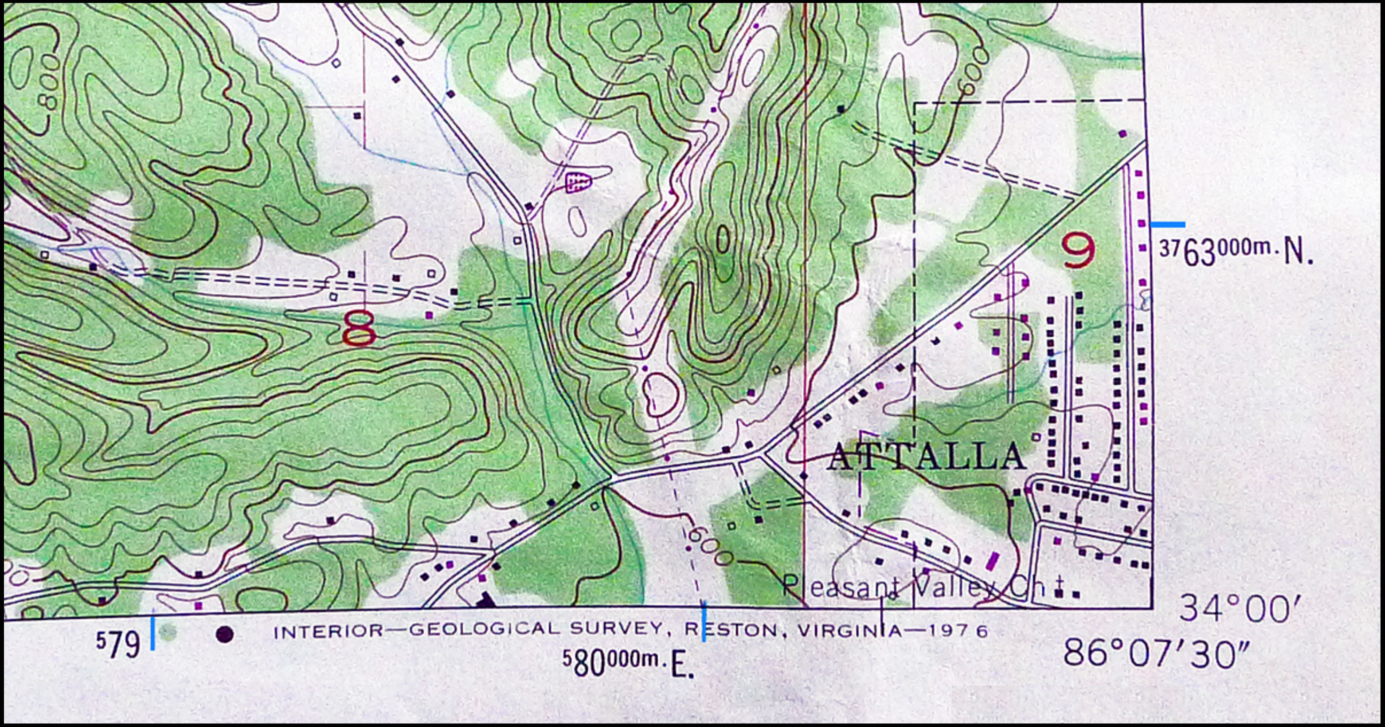
800
600
8
9
3763000m.N.
ATTALLA
600
Pleasant Valley Ch
34°00′
579
INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1976
580000m.E.
86°07′30″

Always set your GPS to the grid system you are using on the map

Universal Transverse Mercator (UTM)

UTM is a rectangular coordinate system based on the latitude and longitude (geographic) coordinate system. With UTM, the earth is divided into 60 zones that allows it to be projected onto maps with minimal distortion. All coordinates are expressed in meters.

The UTM grid system is the easiest method of relaying your position to others, finding yourself on a map after getting a location fix with a GPS unit, or navigating to a position on a map using a GPS unit.

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UTM: 60 Zones and 20 Latitude Bands

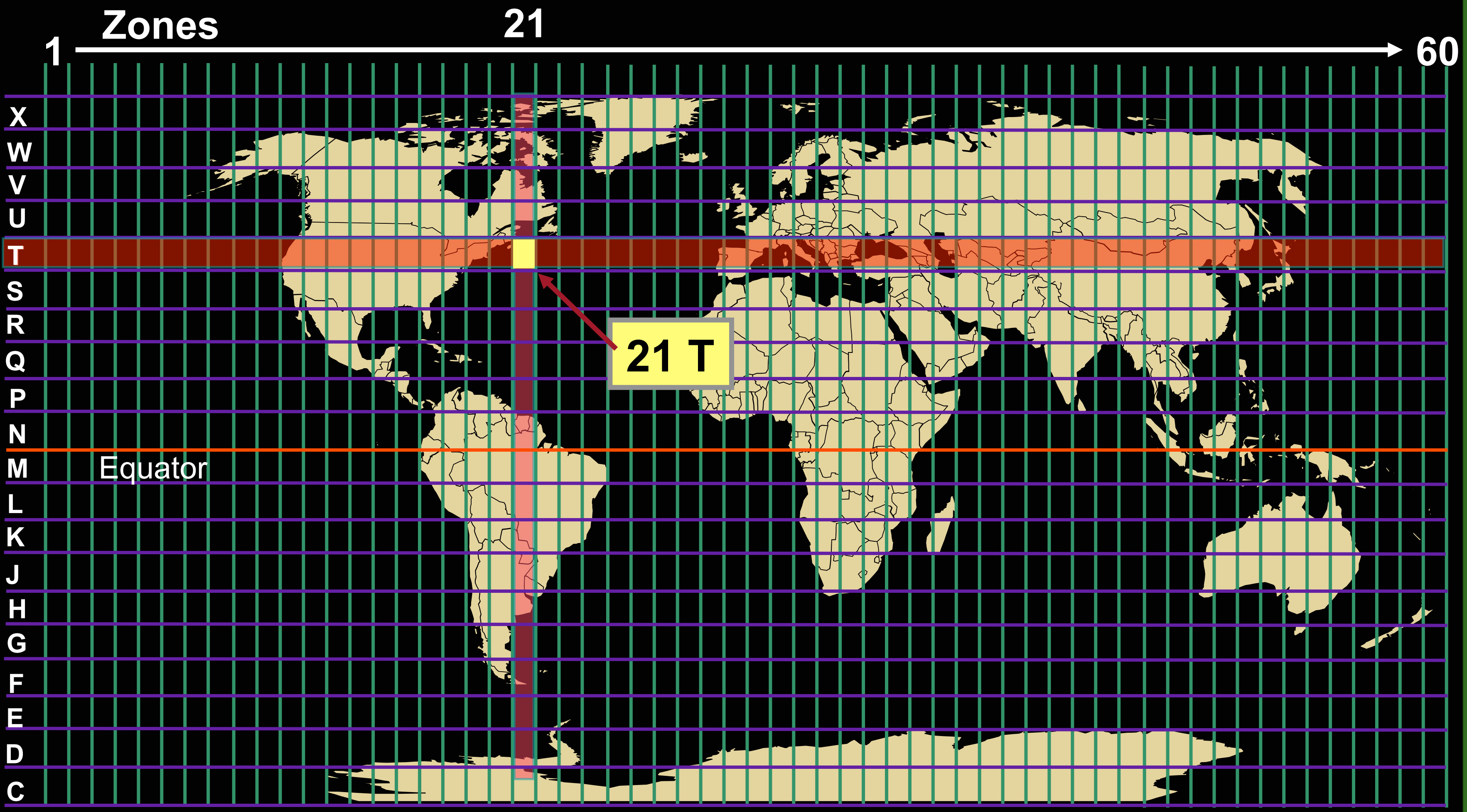
Zones
1
21
60
X
W
V
U
T
S
R
Q
P
N
M
L
K
J
H
G
F
E
D
C
Equator
21 T

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LAND NAVIGATION

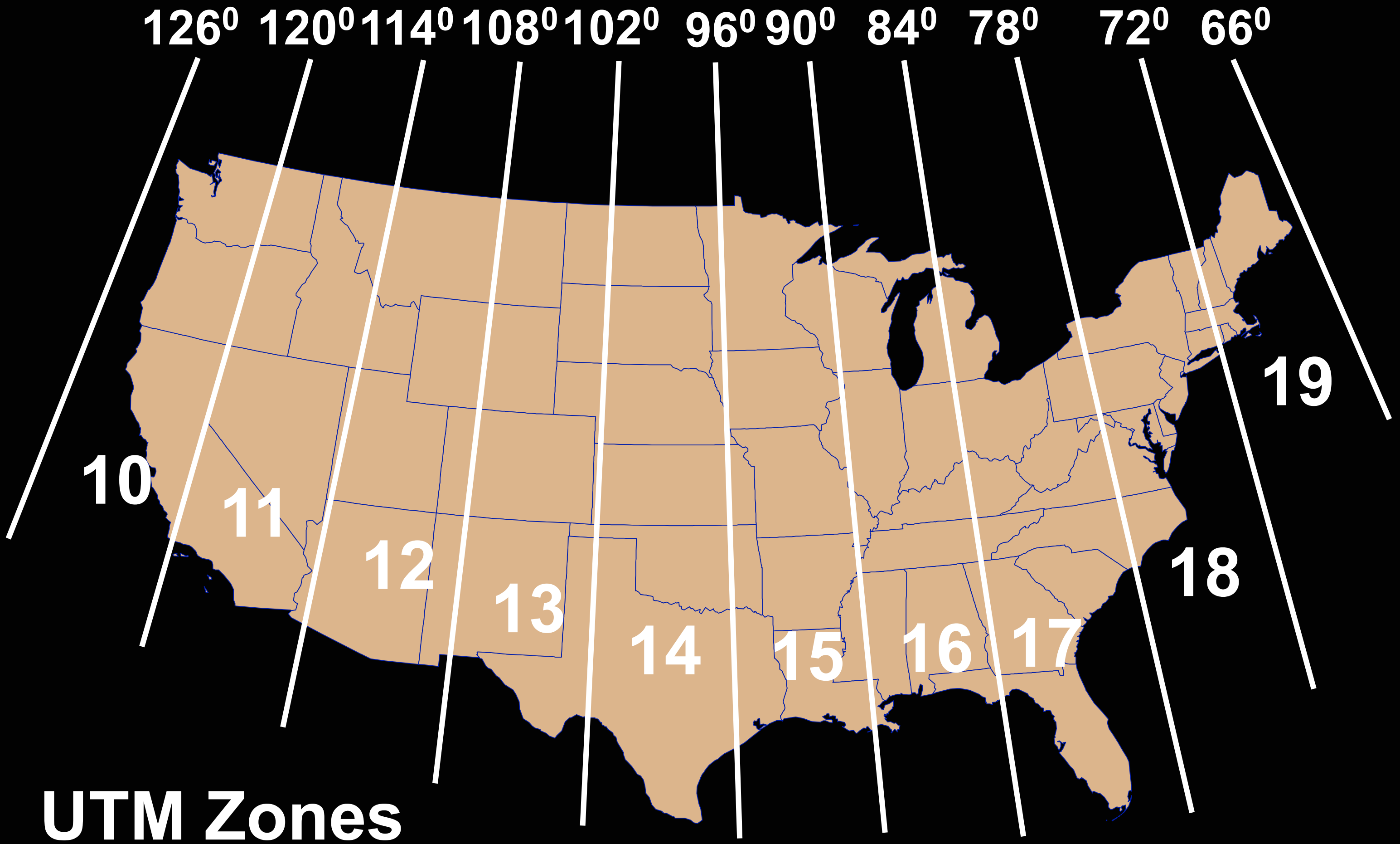
126°
120°
114°
108°
102°
96°
90°
84°
78°
72°
66°
10
11
12
13
14
15
16
17
18
19

UTM Zones

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Universal Transverse Mercator (UTM)

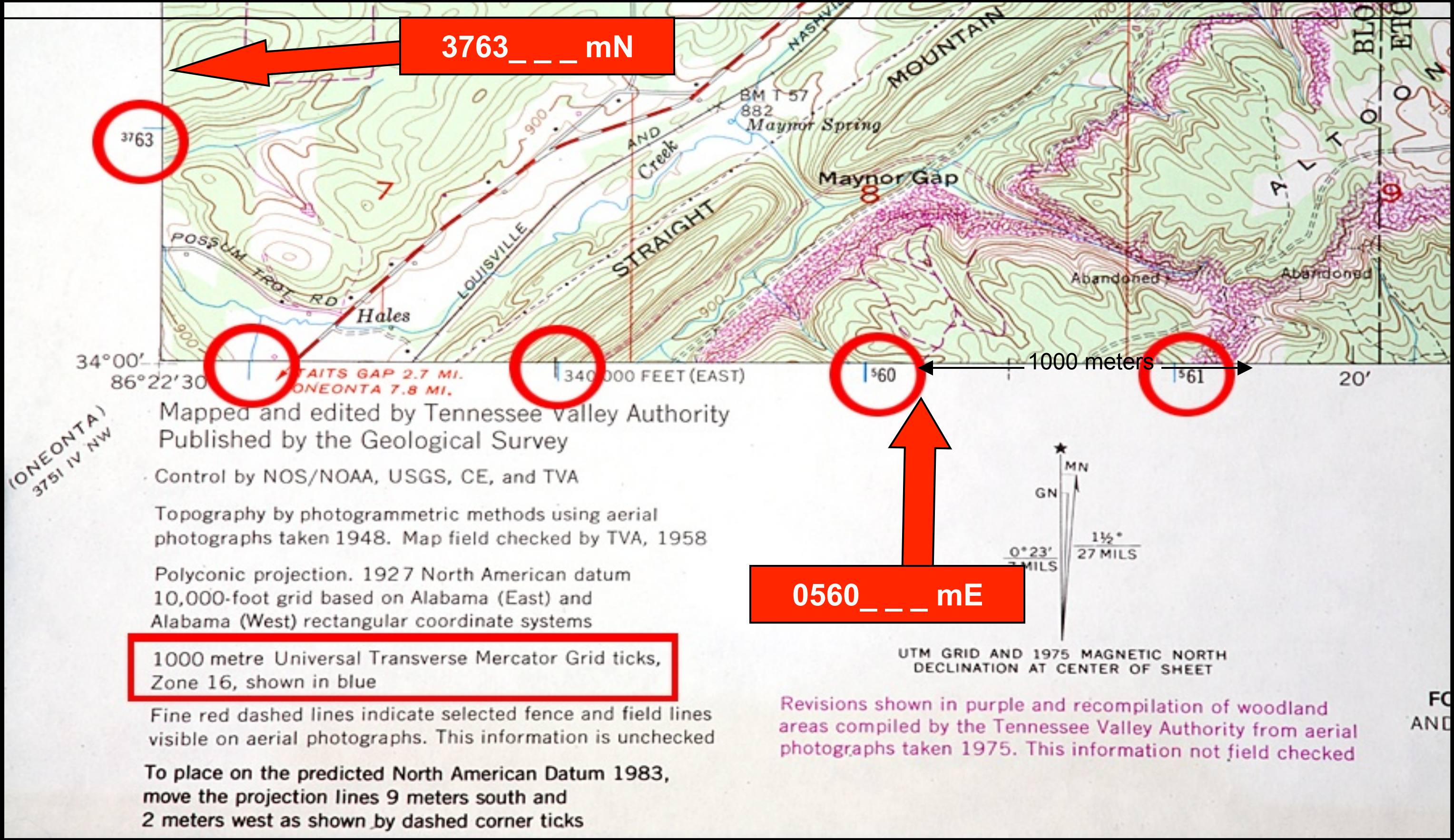
3763_ _ _ mN
3763
34°00′
86°22′30″
STRAITS GAP 2.7 MI.
ONEONTA 7.8 MI.
340 000 FEET (EAST)
560
1000 meters
561
20′
(ONEONTA) 3751 IV NW
POSSUM TROT RD
Hales
LOUISVILLE
STRAIGHT
AND Creek
NASHVILLE
BM T 57
882
Maynor Spring
Maynor Gap
MOUNTAIN
Abandoned
Abandoned
ALTOONA
7
8
9
900
MN
GN
0°23′
7 MILS
1½°
27 MILS
0560_ _ _ mE

Mapped and edited by Tennessee Valley Authority
Published by the Geological Survey

Control by NOS/NOAA, USGS, CE, and TVA

Topography by photogrammetric methods using aerial photographs taken 1948. Map field checked by TVA, 1958

Polyconic projection. 1927 North American datum 10,000-foot grid based on Alabama (East) and Alabama (West) rectangular coordinate systems

1000 metre Universal Transverse Mercator Grid ticks, Zone 16, shown in blue

Fine red dashed lines indicate selected fence and field lines visible on aerial photographs. This information is unchecked

To place on the predicted North American Datum 1983, move the projection lines 9 meters south and 2 meters west as shown by dashed corner ticks

UTM GRID AND 1975 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Revisions shown in purple and recompilation of woodland areas compiled by the Tennessee Valley Authority from aerial photographs taken 1975. This information not field checked

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Easting:

Is a 6-digit number to designate the EAST/WEST position in the grid. The grids are the widest at the equator. Since each grid has a different width, a system was created to measure the distance across a grid starting from the vertical center-line of each grid as opposed to starting from the left or right edge of a grid. The center line of each grid is called the central meridian. The central meridian is always assigned an easting value of 500,000 meters East. It is expressed as 500,000 mE. As you move west of the central meridian the easting will be a number less than 500,000. As you move to the east of the central meridian the easting will be a number greater than 500,000. An easting of zero will never occur, since a 6° wide zone is never more than 674,000 meters wide.

Northing:

The second number is called the Northing. It is a 7-digit number that designates how many meters you are north or south of the equator.

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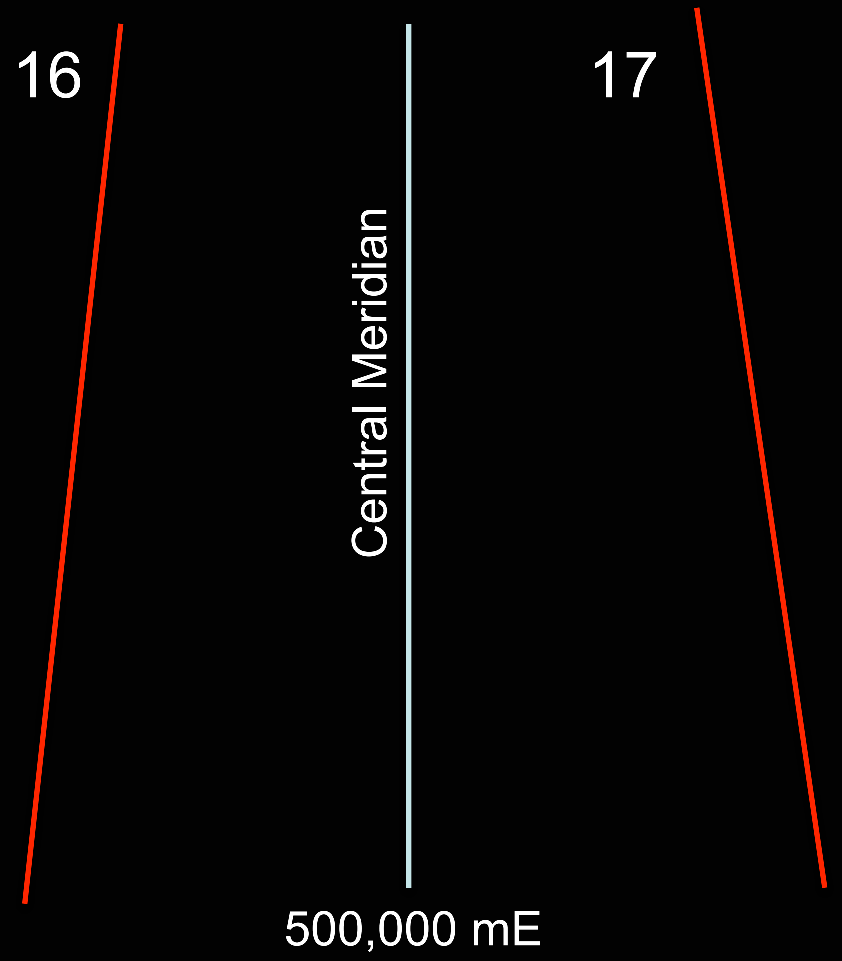
16
17
Central Meridian
500,000 mE

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LAND NAVIGATION

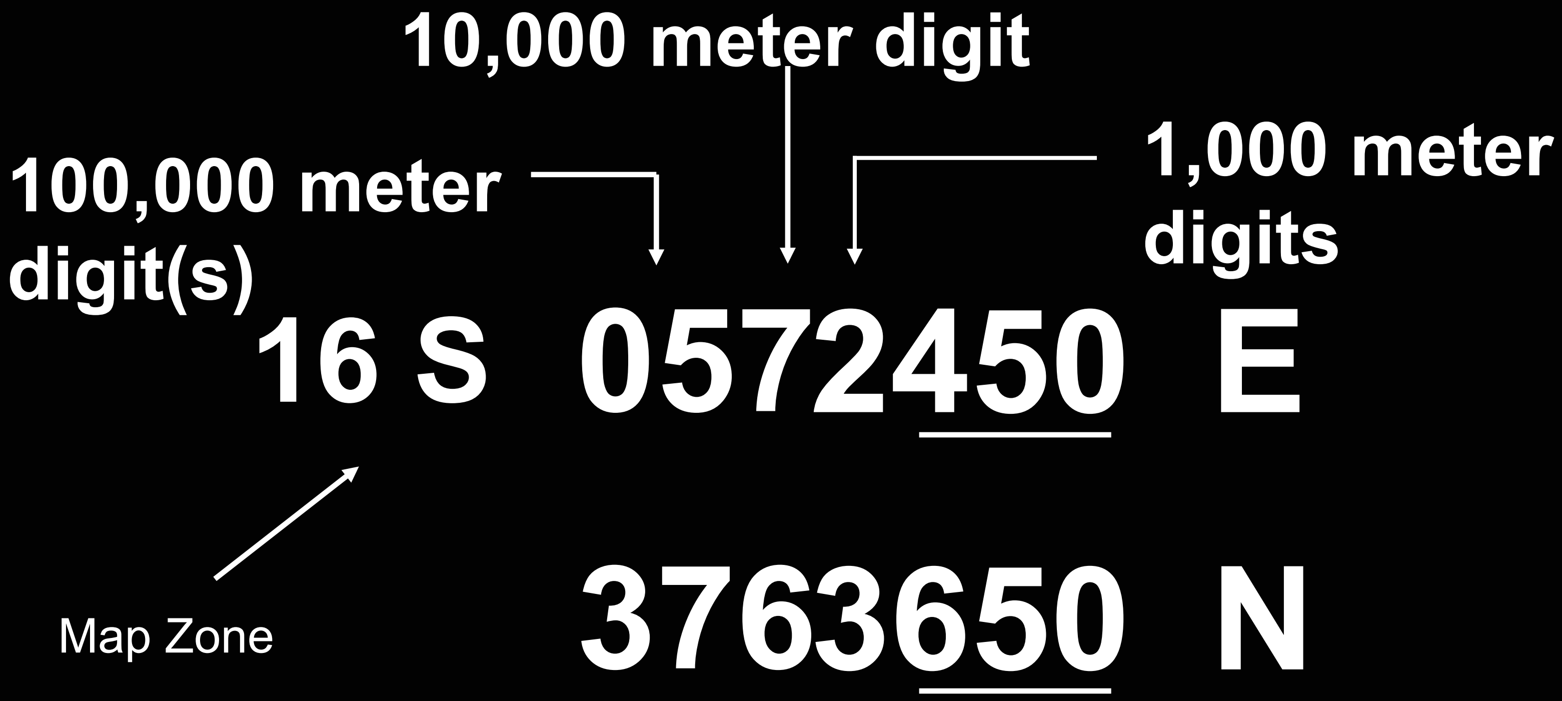

10,000 meter digit

100,000 meter digit(s)

1,000 meter digits

16 S 0572450 E

3763650 N

Map Zone

You only have to plot the last 3 numbers. The rest of the coordinate values are provided on the map

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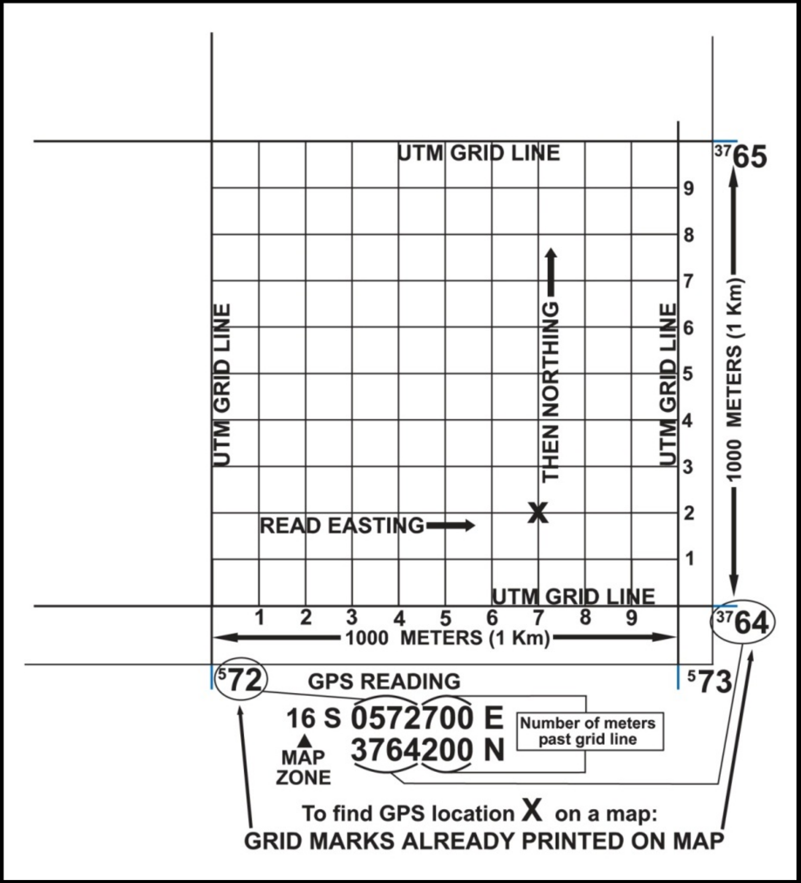
UTM GRID LINE
37 65
9
8
7
6
5
4
3
2
1
UTM GRID LINE
THEN NORTHING
UTM GRID LINE
1000 METERS (1 Km)
X
READ EASTING
UTM GRID LINE
1 2 3 4 5 6 7 8 9
1000 METERS (1 Km)
37 64
5 72
GPS READING
5 73
16 S 0572700 E
3764200 N
MAP ZONE
Number of meters past grid line
To find GPS location X on a map:
GRID MARKS ALREADY PRINTED ON MAP

Read EASTING First

Then Read NORTHING

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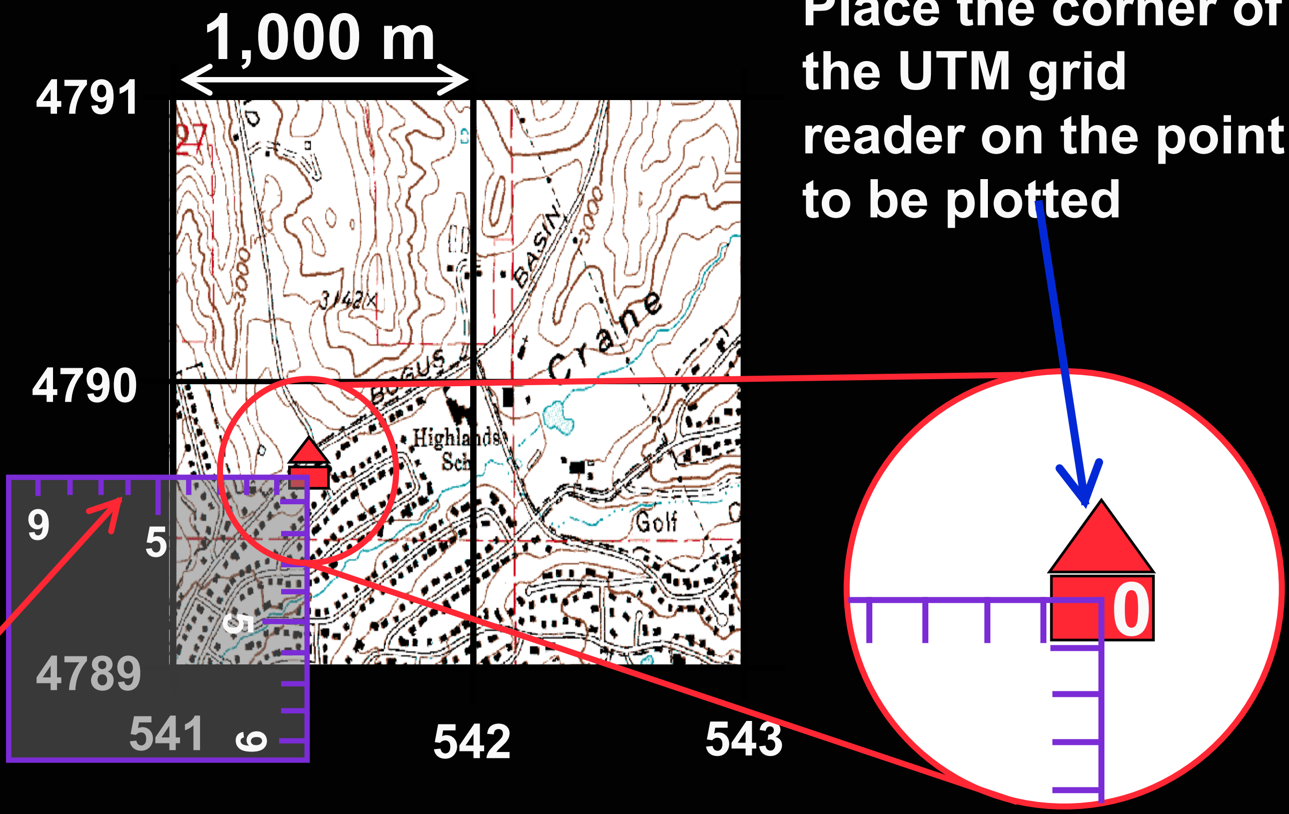
1,000 m
4791
4790
542
543
27
3000
3142X
BASIN
3000
Crane
BOGUS
Highlands
Sch
Golf
9
5
5
9
4789
541
0

UTM grid reader

Place the corner of the UTM grid reader on the point to be plotted

Each tic = 100 meters on this grid reader

House coordinates = 0541450mE 4789650mN

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Using GPS with Map

When using a GPS to acquire an azimuth to a location, setup your GPS for Magnetic North Heading if you are not adjusting declination on your compass. Use True North Heading if your are adjusting for declination on your compass.

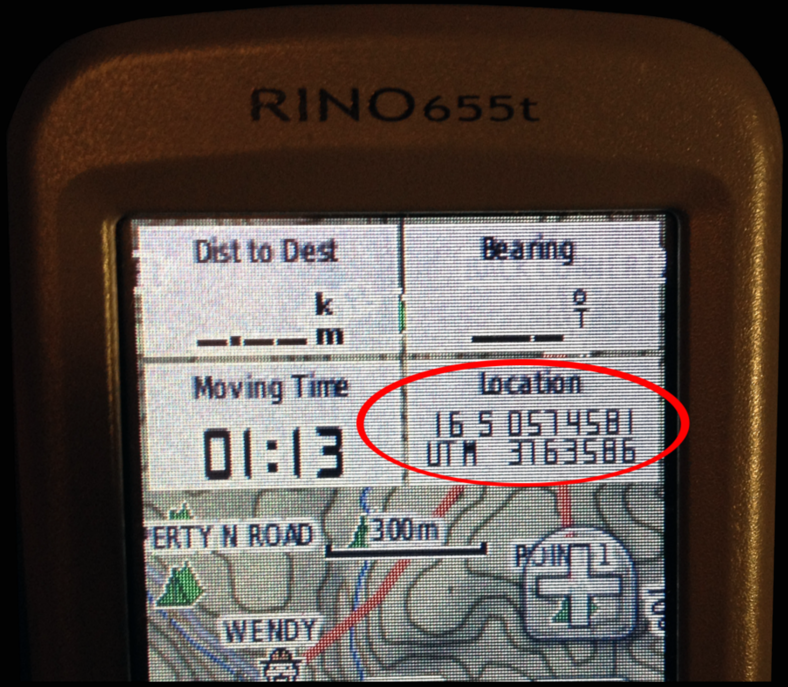
RINO655t
Dist to Dest
k
m
Bearing
°
T
Moving Time
01:13
Location
16 S 0574581
UTM 3163586
ERTY N ROAD
300m
POINT 1
WENDY

Plotting GPS to Map

1) Find current location with GPS
2) Use scale card to plot current location on the map

Plotting Map to GPS

1) Plot location on map of where you want to go with a scale card
2) Enter plotted coordinates into the GPS as a new waypoint

MGRS System

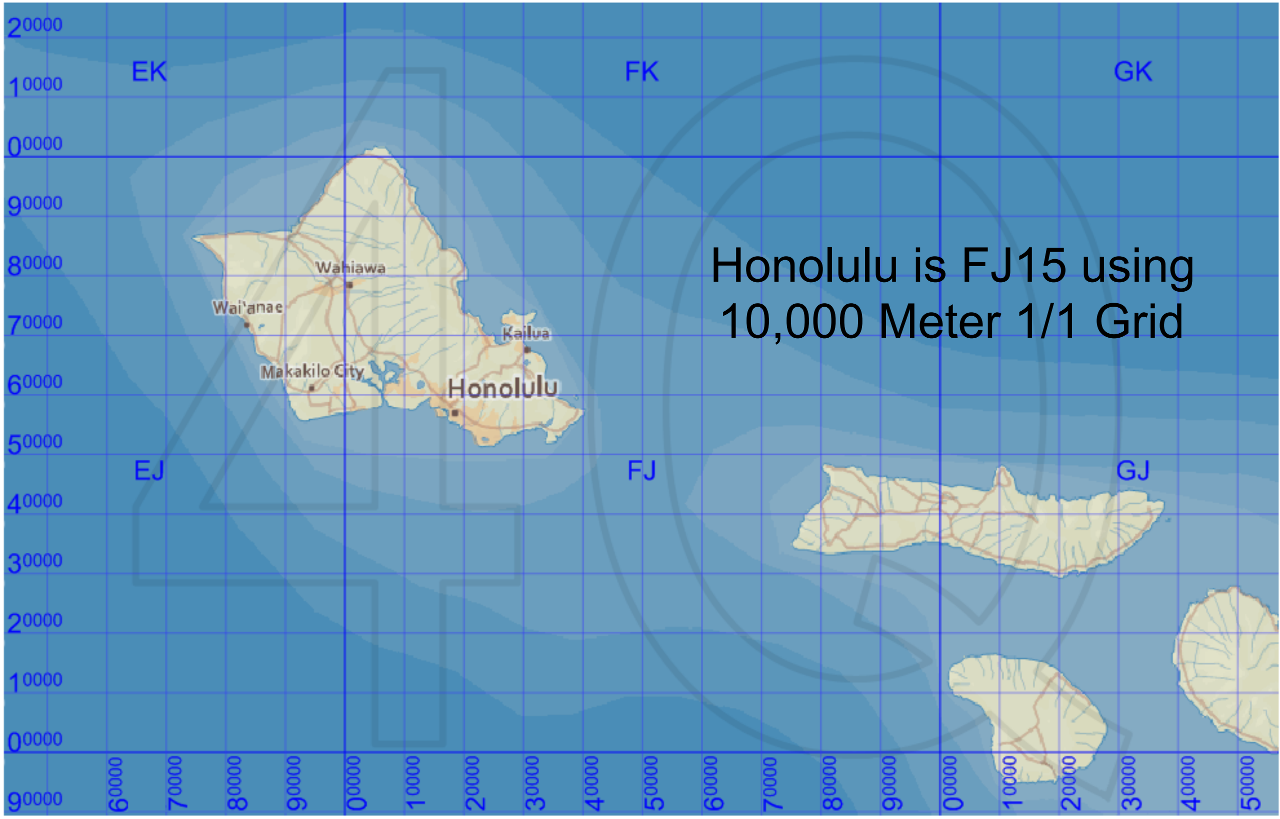
20000
10000
00000
90000
80000
70000
60000
50000
40000
30000
20000
10000
00000
90000
EK
FK
GK
EJ
FJ
GJ
Wahiawa
Wai'anae
Kailua
Makakilo City
Honolulu
60000
70000
80000
90000
00000
10000
20000
30000
40000
50000
60000
70000
80000
90000
00000
10000
20000
30000
40000
50000

Honolulu is FJ15 using 10,000 Meter 1/1 Grid

5/5 = 1 Meter, 4/4 = 10 meter, 3/3 = 100 meter, 2/2 = 1000 meter, 1/1 = 10,000 meter

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Why do we not use Latitude / Longitude for Land Nav?

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Communicating Location

General Location
Type Of Navigation Grid Used
Grid Location (Easting Then Northing)
Direction Of Travel If Moving

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Declination

Magnetic Declination is the difference between True North and Magnetic North. A compass needle ALWAYS points to Magnetic North.

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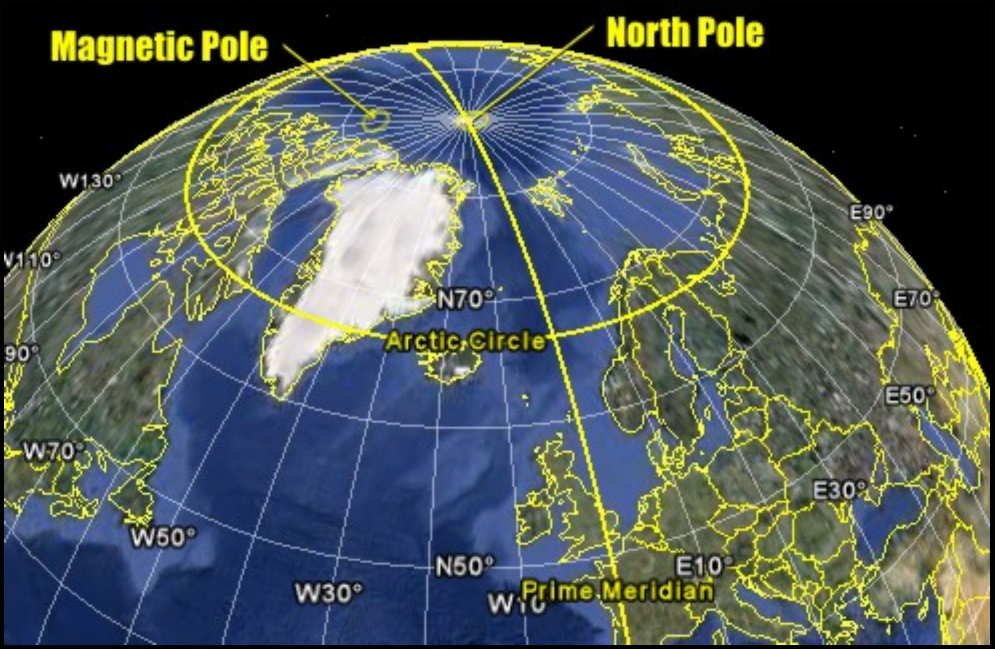
Magnetic Pole
North Pole
W130°
W110°
90°
W70°
W50°
W30°
N70°
Arctic Circle
N50°
W10
Prime Meridian
E10°
E30°
E50°
E70°
E90°

Difference in True North
And Magnetic North

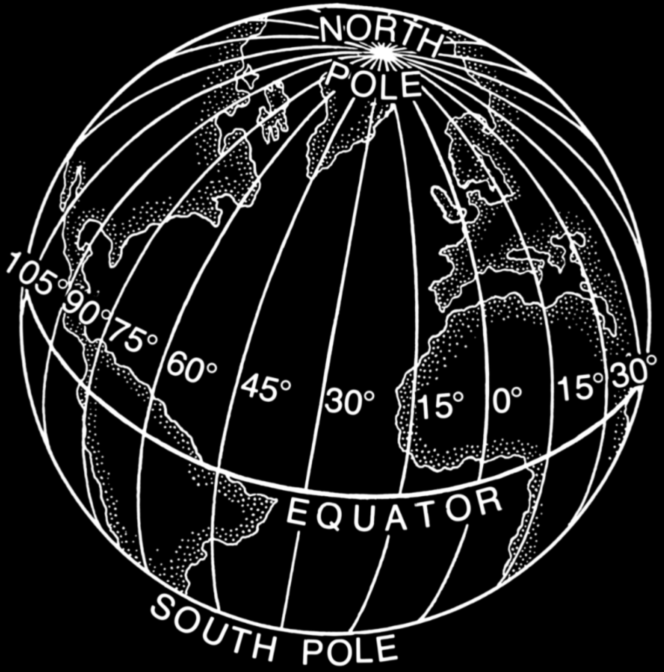
NORTH POLE
105°
90°
75°
60°
45°
30°
15°
0°
15°
30°
EQUATOR
SOUTH POLE

Longitude Lines
(True North)

Magnetic North is moving approximately 40 miles per year.

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Magnetic Declination

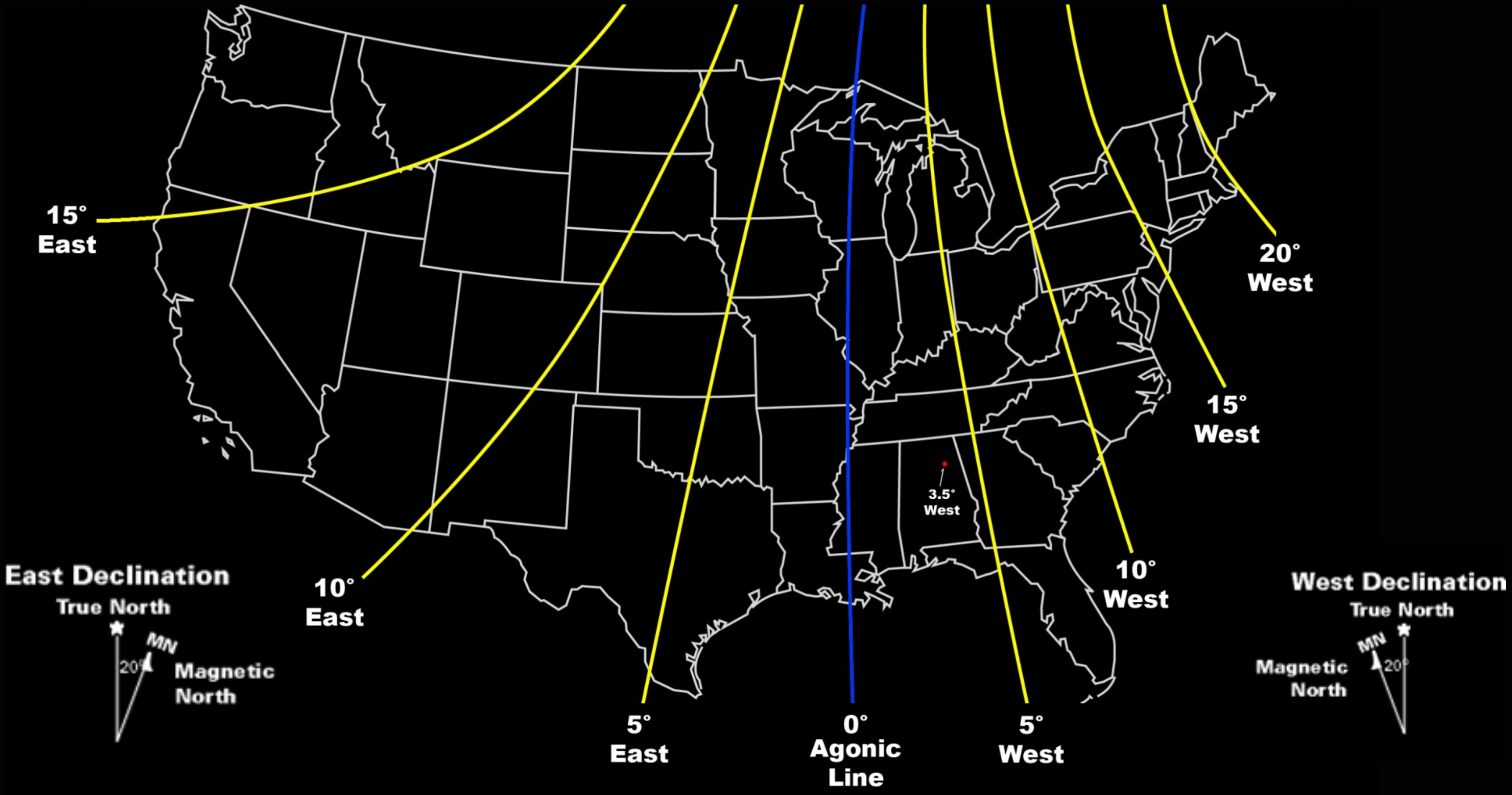
15°
East
10°
East
5°
East
0°
Agonic
Line
5°
West
3.5°
West
10°
West
15°
West
20°
West
East Declination
True North
MN
20°
Magnetic
North
West Declination
True North
MN
20°
Magnetic
North

If you do not have a compass that adjusts for declination remember to add or subtract declination to your azimuth. Add for West – Subtract for East

EAST IS LEAST - WEST IS BEST

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Depending on your map, it may printed with True North Reference lines or Grid North Reference lines

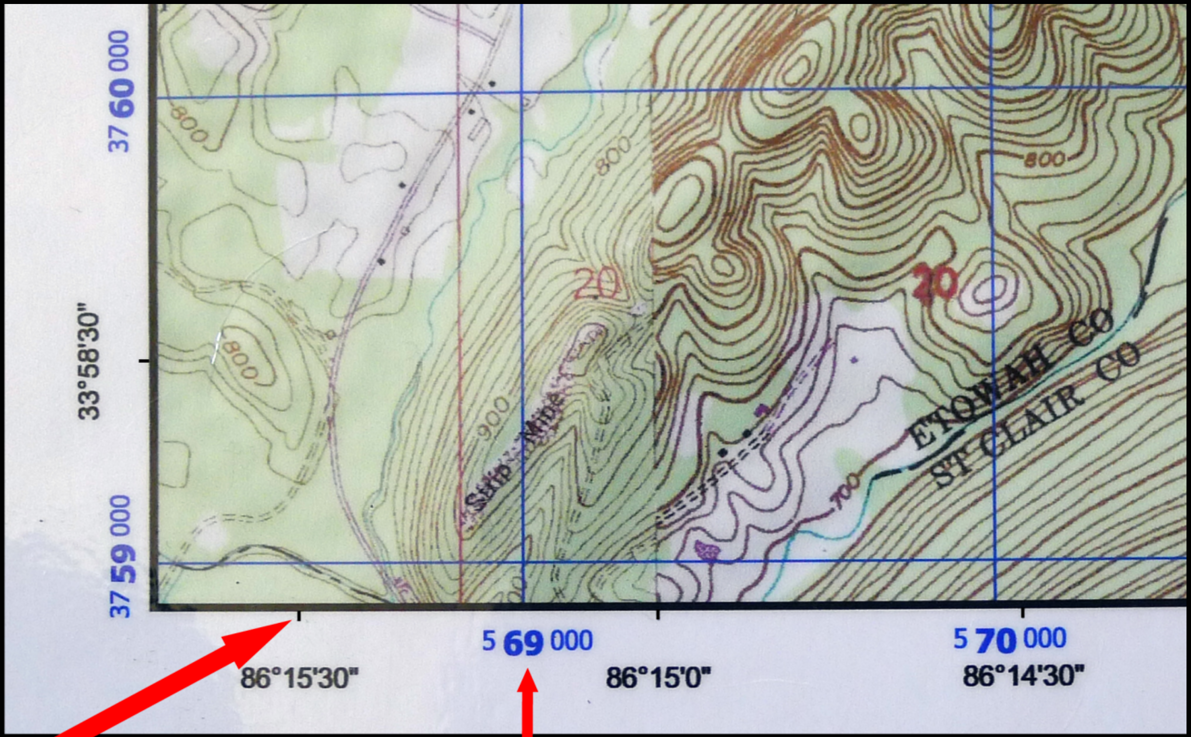
37 60 000
33°58'30"
37 59 000
800
900
20
700
Strip Mine
ETOWAH CO
ST CLAIR CO
5 69 000
5 70 000
86°15'30"
86°15'0"
86°14'30"

True North (Longitude)

Grid North (UTM Or Other Grid)

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Adjusting For Declination For Map Use

Declination is the difference between true north and magnetic north when using the longitude lines as north reference.

Declination is the difference or spread between grid north and magnetic north when using the UTM grid lines as north reference.

At the bottom of your map, if the MN line is left of the True North Line it will always be West Declination. If the MN line is right of the True North Line it will always be East Declination

If you are using a compass that is not adjusted for declination, add the amount for west declination, subtract the amount for east declination. If your compass is adjustable for declination, set it for the north reference declination value you are using. No further addition or subtraction is required.

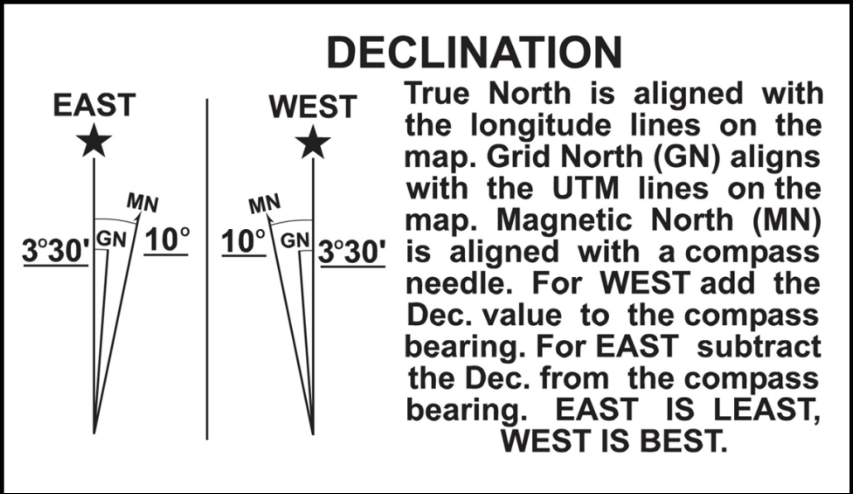

DECLINATION

True North is aligned with the longitude lines on the map. Grid North (GN) aligns with the UTM lines on the map. Magnetic North (MN) is aligned with a compass needle. For WEST add the Dec. value to the compass bearing. For EAST subtract the Dec. from the compass bearing. EAST IS LEAST, WEST IS BEST.

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True North / Magnetic North / Grid North

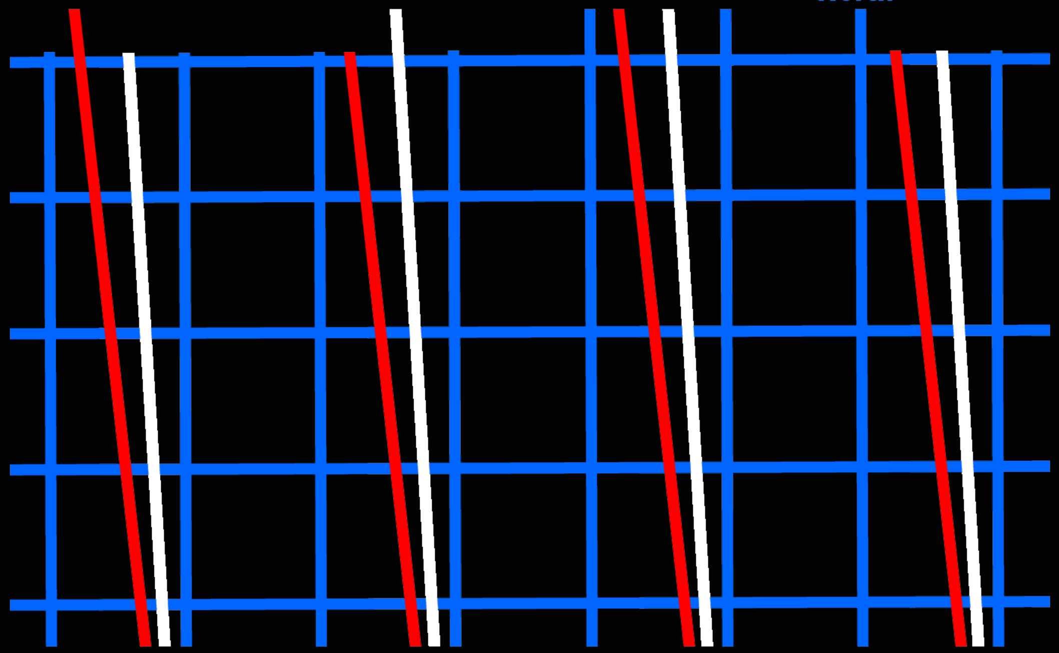

Compass Needle

Magnetic North

Longitude

True North

Map Grid

Grid North

If using Grid North as Reference then declination would be set to 6 degrees West
If using True North as Reference then declination would be set to 3 degrees West

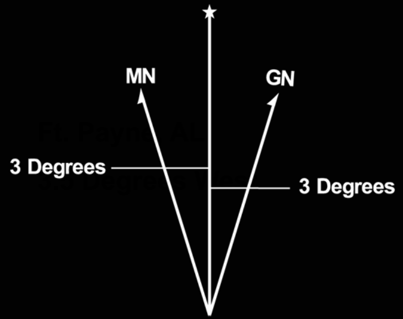

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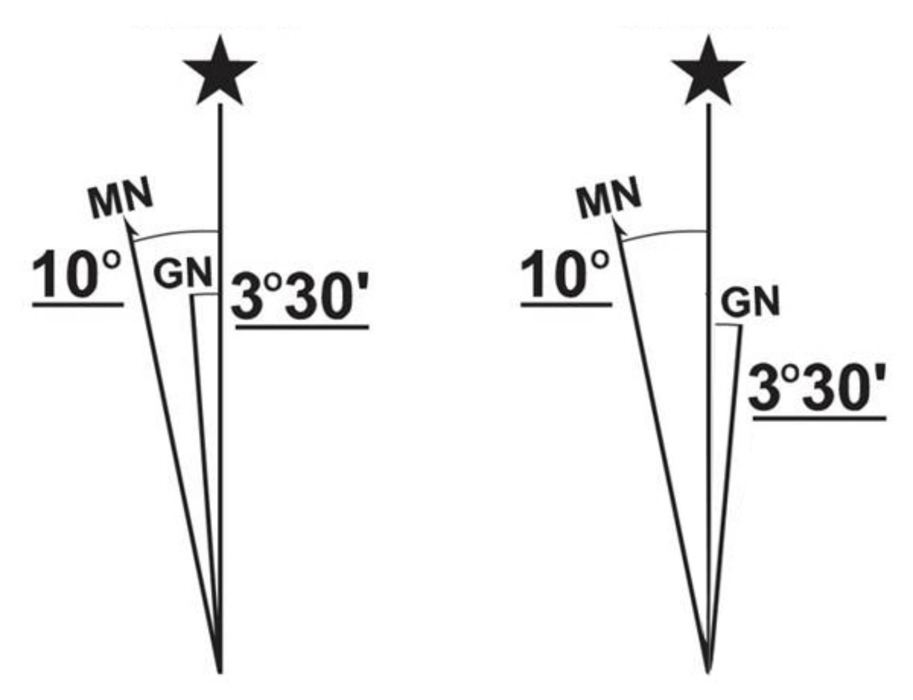
MN
10°
GN
3°30'
MN
10°
GN
3°30'

What is our declination value for each of the diagrams to use Grid North Reference?

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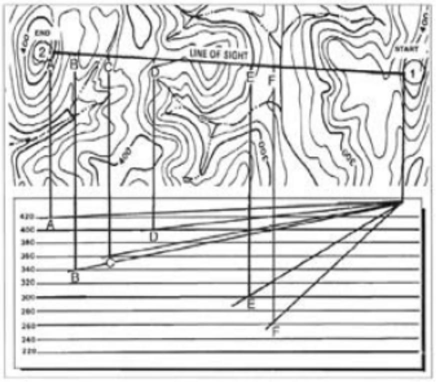
END
LINE OF SIGHT
START
A
B
C
D
E
F

250.000CM
8CM
A
B

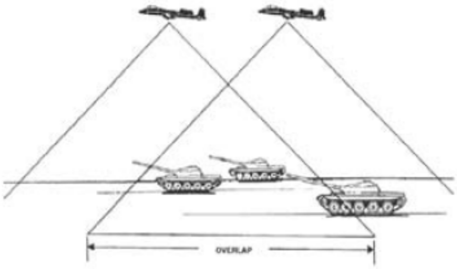

U.S. ARMY MAP READING AND LAND NAVIGATION HANDBOOK

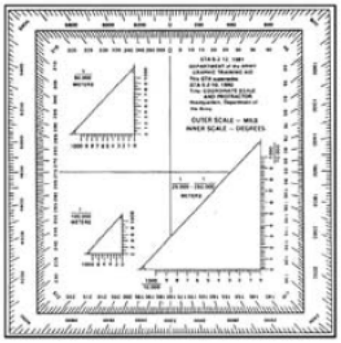

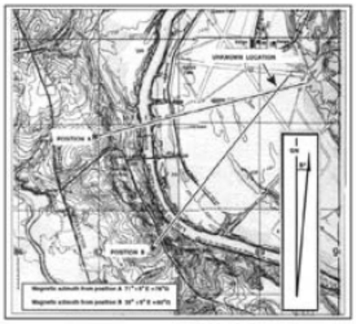
UNKNOWN LOCATION
POSITION A
POSITION B

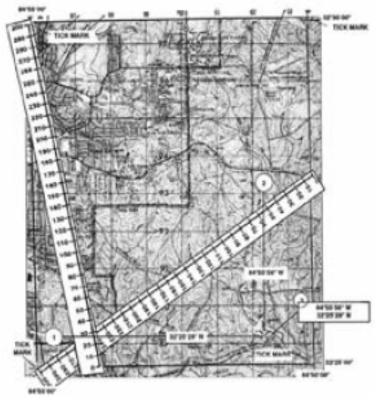
TICK MARK
TICK MARK
TICK MARK

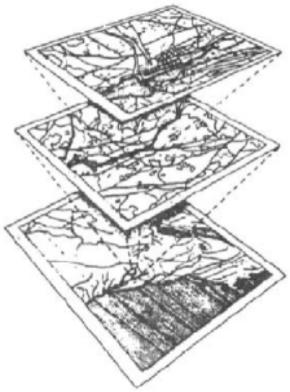

DEPARTMENT OF THE ARMY

RIDGELINE
RIDGELINE

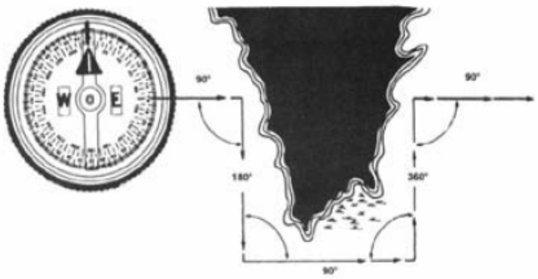
W
E
90°
90°
180°
360°
90°

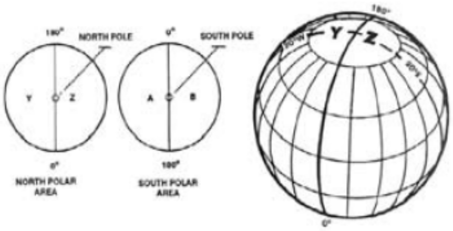
NORTH POLE
SOUTH POLE
Y
Z
A
B
NORTH POLAR AREA
SOUTH POLAR AREA

DEPARTMENT OF THE ARMY

MAP READING
AND
LAND NAVIGATION

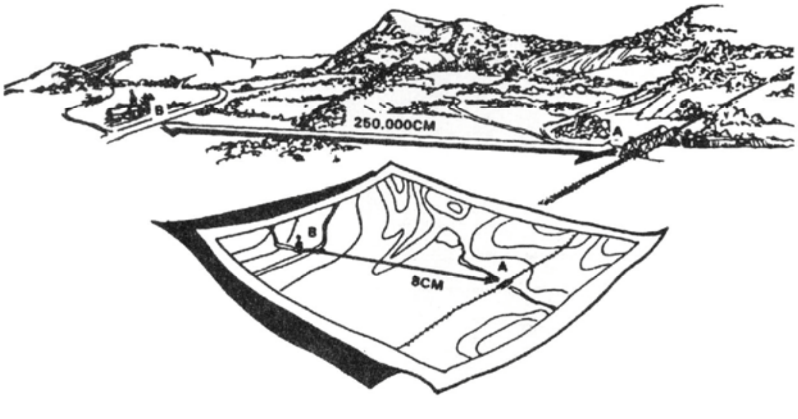
B
250,000CM
A
B
8CM
A

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PREFACE

The purpose of this field manual is to provide a standardized source document for Armywide reference on *map reading* and *land navigation*. This manual applies to every soldier in the Army regardless of service branch, MOS, or rank. This manual also contains both doctrine and training guidance on these subjects. Part One addresses map reading and Part Two, land navigation. The appendixes include a list of exportable training materials, a matrix of land navigation tasks, an introduction to orienteering, and a discussion of several devices that can assist the soldier in land navigation.

Unless this publication states otherwise, masculine nouns and pronouns do not refer exclusively to men.

PART ONE
MAP READING

CHAPTER 1
TRAINING STRATEGY

This manual is in response to an Armywide need for a new map reading and land navigation training strategy based on updated doctrine. This chapter describes and illustrates this approach to teaching these skills.

1-1. BUILDING-BLOCK APPROACH

Institution courses are designed to prepare the soldier for a more advanced duty position in his unit. The critical soldiering skills of move, shoot, and communicate must be trained, practiced, and sustained at every level in the schools as well as in the unit. The map reading and land navigation skills taught at each level are critical to the soldiering skills of the duty position for which he is being school-trained. Therefore, they are also a prerequisite for a critical skill at a more advanced level.

a. A soldier completing initial-entry training must be prepared to become a team member. He must be proficient in the basic map reading and dead reckoning skills.

b. After completing the Primary Leadership Development Course (PLDC), a soldier should be ready to be a team leader. This duty position requires expertise in the skills of map reading, dead reckoning, and terrain association.

c. A soldier completing the Basic NCO Course (BNCOC) has been trained for the squad leader position. Map reading and land navigation at skill level 3 requires development of problem-solving skills; for example, route selection and squad tactical movement.

d. At skill level 4, the soldier completing the Advanced NCO Course (ANCOC) is prepared to assume the duty position of platoon sergeant or operations NCO. Planning tactical movements, developing unit sustainment, and making decisions are the important land navigation skills at this level.

e. Officers follow similar progression. A new second lieutenant must have mastered map reading and land navigation skills, and have an aptitude for dead reckoning and terrain association.

(1) After completing the Officer Basic Course, the officer must be prepared to assume the duties and responsibilities of a platoon leader. He is required to execute the orders and operations of his commander. Map reading and land navigation at this level require development of the problem-solving skills of route selection and tactical movement.

(2) After completing the Officer Advanced Course, the officer is prepared to assume the duties and responsibilities of a company commander or primary staff officer. The commander must plan and execute operations with full consideration to all aspects of navigation. The staff officer must recommend battlefield placement of all administrative, logistical, and personnel resources. These recommendations cannot be tactically sound unless the estimate process includes a detailed analysis of the area of operations. This ability requires expertise in all map reading and navigation skills to include the use of nonmilitary maps, aerial photographs, and terrain analysis with respect to both friendly and enemy

forces. The commander/staff officer must plan and execute a program to develop the unit's train-the-trainer program for land navigation.

f. A program of demonstrated proficiency of all the preceding skill levels to the specified conditions and standards is a prerequisite to the successful implementation of a building-block training approach. This approach reflects duty position responsibilities in map reading and land navigation. An understanding of the fundamental techniques of dead reckoning or field-expedient methods is a basic survival skill that each soldier must develop at the initial-entry level. This skill provides a support foundation for more interpretive analysis at intermediate skill levels 2 and 3, with final progression to level 4. Mastery of all map reading and land navigation tasks required in previous duty positions is essential for the sequential development of increasingly difficult abilities. This building-block approach is supported by scope statements. It is part of the training doctrine at each level in the institutional training environment of each course.

g. Exportable training and instructor support/certification packages are being developed based upon the updated map reading and land navigation field manual. Innovative training devices and materials are being developed for use in the institution, ROTC regions, and the field. (See Appendixes E and H.)

1-2. ARMYWIDE IMPLEMENTATION

A mandatory core of critical map reading and land navigation tasks and a list of electives will be provided to each TRADOC service school and FORSCOM professional development school. Standardization is achieved through the mandatory core. Exportable training material is made available to support Armywide implementation.

1-3. SAFETY

Unit leaders plan to brief and enforce all safety regulations established by local range control. They coordinate the mode of evacuation of casualties through the appropriate channels. They review all installation safety regulations. Unit leaders must complete a thorough terrain reconnaissance before using an area for land navigation training. They should look for dangerous terrain, heavy trafficked roads, water obstacles, wildlife, and training debris.

CHAPTER 2
MAPS

Cartography is the art and science of expressing the known physical features of the earth graphically by maps and charts. No one knows who drew, molded, laced together, or scratched out in the dirt the first map. But a study of history reveals that the most pressing demands for accuracy and detail in mapping have come as the result of military needs. Today, the complexities of tactical operations and deployment of troops are such that it is essential for all soldiers to be able to read and interpret their maps in order to move quickly and effectively on the battlefield. This chapter includes the definition and purpose of a map and describes map security, types, categories, and scales.

2-1. DEFINITION

A map is a graphic representation of a portion of the earth's surface drawn to scale, as seen from above. It uses colors, symbols, and labels to represent features found on the ground. The ideal representation would be realized if every feature of the area being mapped could be shown in true shape. Obviously this is impossible, and an attempt to plot each feature true to scale would result in a product impossible to read even with the aid of a magnifying glass.

a. Therefore, to be understandable, features must be represented by conventional signs and symbols. To be legible, many of these must be exaggerated in size, often far beyond the actual ground limits of the feature represented. On a 1:250,000 scale map, the prescribed symbol for a building covers an area about 500 feet square on the ground; a road symbol is equivalent to a road about 520 feet wide on the ground; the symbol for a single-track railroad (the length of a cross-tie) is equivalent to a railroad cross-tie about 1,000 feet on the ground.

b. The portrayal of many features requires similar exaggeration. Therefore, the selection of features to be shown, as well as their portrayal, is in accord with the guidance established by the Defense Mapping Agency.

2-2. PURPOSE

A map provides information on the existence, the location of, and the distance between ground features, such as populated places and routes of travel and communication. It also indicates variations in terrain, heights of natural features, and the extent of vegetation cover. With our military forces dispersed throughout the world, it is necessary to rely on maps to provide information to our combat elements and to resolve logistical operations far from our shores. Soldiers and materials must be transported, stored, and placed into operation at the proper time and place. Much of this planning must be done by using maps. Therefore, any operation requires a supply of maps; however, the finest maps available are worthless unless the map user knows how to read them.

2-3. PROCUREMENT

Most military units are authorized a basic load of maps. Local command supplements to AR 115-11 provide tables of initial allowances for maps. Map requisitions and distributions are accomplished through the Defense Mapping Agency Hydrographic and Topographic

Center's Office of Distribution and Services. In the division, however, maps are a responsibility of the G2 section.

a. To order a map, refer to the DMA catalog located at your S2/G2 shop. Part 3 of this catalog, Topographic Maps, has five volumes. Using the delineated map index, find the map or maps you want based upon the location of the nearest city. With this information, order maps using the following forms:

(1) *Standard Form 344*. It can be typed or handwritten; it is used for mailing or over-the-counter service.

(2) *Department of Defense Form 1348*. Same as SF 344. You can order copies of only one map sheet on each form.

(3) *Department of Defense Form 1348M*. This is a punch card form for AUDODIN ordering.

(4) *Department of Defense Form 173*. This is a message form to be used for urgent ordering.

With the exception of the message form (DD 173), the numbered sections of all forms are the same. For example: In block 1, if you are in CONUS, enter “AOD,” if you are overseas, enter “AO4.” In block 2, use one of the following codes for your location.

LOCATION	CODE
Europe	CS7
Hawaii	HM9
Korea	WM4
Alaska	WC1
Panama	HMJ
CONUS	HM8

Your supply section will help you complete the rest of the form.

b. Stock numbers are also listed in map catalogs, which are available at division and higher levels and occasionally in smaller units. A map catalog consists of small-scale maps upon which the outlines of the individual map sheets of a series have been delineated. Another document that is an aid to the map user is the gazetteer. A gazetteer lists all the names appearing on a map series of a geographical area, a designation that identifies what is located at that place name, a grid reference, a sheet number of the map upon which the name appeared, and the latitude and longitude of the named features. Gazetteers are prepared for maps of foreign areas only.

2-4. SECURITY

All maps should be considered as documents that require special handling. If a map falls into unauthorized hands, it could easily endanger military operations by providing information of friendly plans or areas of interest to the enemy. Even more important would be a map on which the movements or positions of friendly soldiers were marked. It is possible, even though the markings on a map have been erased, to determine some of the erased information. **Maps are documents that must not fall into unauthorized hands.**

a. If a map is no longer needed, it must be turned in to the proper authority. If a map is in danger of being captured, it must be destroyed. The best method of destruction is by burning it and scattering the ashes. If burning is not possible, the map can be torn into small pieces and scattered over a wide area.

b. Maps of some areas of the world are subject to third party limitations. These are agreements that permit the United States to make and use maps of another country provided these maps are not released to any third party without permission of the country concerned. Such maps require special handling.

c. Some maps may be classified and must be handled and cared for in accordance with AR 380-5 and, if applicable, other local security directives.

2-5. CARE

Maps are documents printed on paper and require protection from water, mud, and tearing. Whenever possible, a map should be carried in a waterproof case, in a pocket, or in some other place where it is handy for use but still protected.

a. Care must also be taken when using a map since it may have to last a long time. If it becomes necessary to mark a map, the use of a pencil is recommended. Use light lines so they may be erased easily without smearing and smudging, or leaving marks that may cause confusion later. If the map margins must be trimmed for any reason, it is essential to note any marginal information that may be needed later, such as grid data and magnetic declination.

b. Special care should be taken of a map that is being used in a tactical mission, especially in small units; the mission may depend on that map. All members of such units should be familiar with the map's location at all times.

c. Appendix B shows two ways of folding a map.

2-6. CATEGORIES

The DMA's mission is to provide mapping, charting, and all geodesy support to the armed forces and all other national security operations. DMA produces four categories of products and services: hydrographic, topographic, aeronautical, and missile and targeting. Military maps are categorized by scale and type.

a. **Scale.** Because a map is a graphic representation of a portion of the earth's surface drawn to scale as seen from above, it is important to know what mathematical scale has been used. You must know this to determine ground distances between objects or locations on the map, the size of the area covered, and how the scale may affect the amount of detail being shown. The mathematical scale of a map is the ratio or fraction between the distance on a map and the corresponding distance on the surface of the earth. Scale is reported as a representative fraction with the map distance as the numerator and the ground distance as the denominator.

$$\textit{Representative fraction (scale)} = \frac{\textit{map distance}}{\textit{ground distance}}$$

As the denominator of the representative fraction gets larger and the ratio gets smaller, the scale of the map decreases. Defense Mapping Agency maps are classified by scale into three categories. They are small-, medium-, and large-scale maps (Figure 2-1). The terms **"small scale," "medium scale,"** and **"large scale"** may be confusing when read in conjunction with the number. However, if the number is viewed as a fraction, it quickly becomes apparent that 1:600,000 of something is smaller than 1:75,000 of the same thing. Therefore, the larger the number after 1:, the smaller the scale of the map.

(1) ***Small***. Those maps with scales of 1:1,000,000 and smaller are used for general planning and for strategic studies (bottom map in Figure 2-1). The standard small-scale map is 1:1,000,000. This map covers a very large land area at the expense of detail.

(2) ***Medium***. Those maps with scales larger than 1:1,000,000 but smaller than 1:75,000 are used for operational planning (center map in Figure 2-1). They contain a moderate amount of detail, but terrain analysis is best done with the large-scale maps described below. The standard medium-scale map is 1:250,000. Medium scale maps of 1:100,000 are also frequently encountered.

(3) ***Large***. Those maps with scales of 1:75,000 and larger are used for tactical, administrative, and logistical planning (top map in Figure 2-1). These are the maps that you as a soldier or junior leader are most likely to encounter. The standard large-scale map is 1:50,000; however, many areas have been mapped at a scale of 1:25,000.

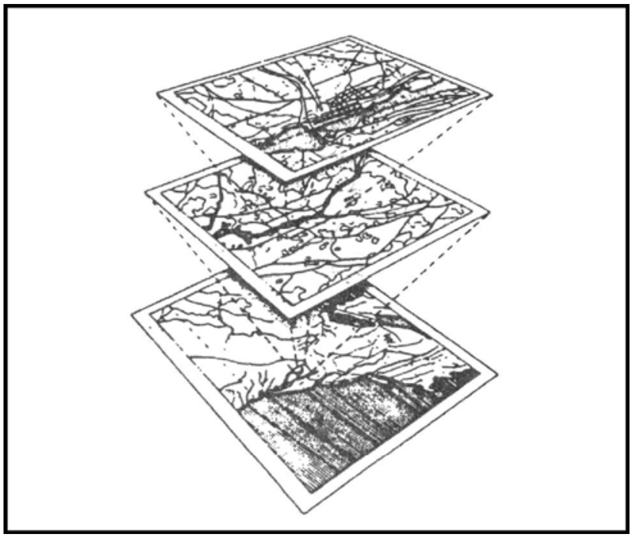

Figure 2-1. Scale classifications.

b. **Types**. The map of choice for land navigators is the 1:50,000-scale military topographic map. It is important, however, that you know how to use the many other products available from the DMA as well. When operating in foreign places, you may discover that DMA map products have not yet been produced to cover your particular area of operations, or they may not be available to your unit when you require them. Therefore, you must be prepared to use maps produced by foreign governments that may or may not meet the standards for accuracy set by DMA. These maps often use symbols that resemble those found on DMA maps but which have completely different meanings. There may be other times when you must operate with the only map you can obtain. This might be a commercially produced map run off on a copy machine at higher headquarters. In Grenada, many of our troops used a British tourist map.

(1) ***Planimetric Map***. This is a map that presents only the horizontal positions for the features represented. It is distinguished from a topographic map by the omission of relief, normally represented by contour lines. Sometimes, it is called a line map.

(2) ***Topographic Map***. This is a map that portrays terrain features in a measurable way (usually through use of contour lines), as well as the horizontal positions of the features represented. The vertical positions, or relief, are normally represented by contour lines on military topographic maps. On maps showing relief, the elevations and contours are measured from a specific vertical datum plane, usually mean sea level. Figure 3-1 shows a typical topographic map.

(3) ***Photomap***. This is a reproduction of an aerial photograph upon which grid lines, marginal data, place names, route numbers, important elevations, boundaries, and approximate scale and direction have been added. (See Chapter 8.)

(4) ***Joint Operations Graphics***. These maps are based on the format of standard 1:250,000 medium-scale military topographic maps, but they contain additional information needed in joint air-ground operations (Figure 2-2). Along the north and east edges of the graphic, detail is extended beyond the standard map sheet to provide overlap with adjacent sheets. These maps are produced both in ground and air formats. Each version is identified in the lower margin as either Joint Operations Graphic (Air) or Joint Operations Graphic (Ground). The topographic information is identical on both, but the ground version shows elevations and contour in meters and the air version shows them in feet. Layer (elevation) tinting and relief shading are added as an aid to interpolating relief. Both versions emphasize airlanding facilities (shown in purple), but the air version has additional symbols to identify aids and obstructions to air navigation. (See Appendix D for additional information.)

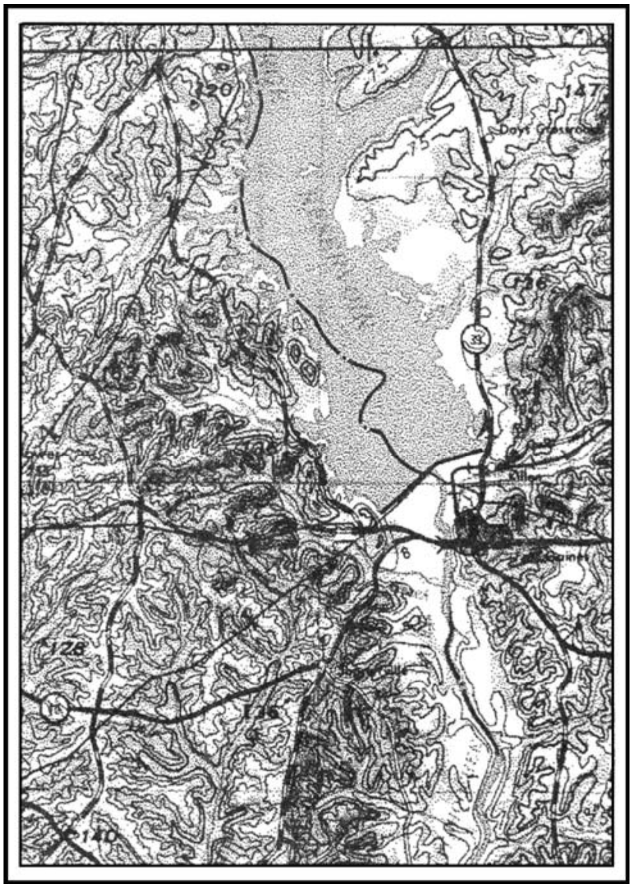

Figure 2-2. Joint operations graphic (air).

(5) ***Photomosaic***. This is an assembly of aerial photographs that is commonly called a mosaic in topographic usage. Mosaics are useful when time does not permit the compilation of a more accurate map. The accuracy of a mosaic depends on the method employed in its preparation and may vary from simply a good pictorial effect of the ground to that of a planimetric map.

(6) ***Terrain Model***. This is a scale model of the terrain showing features, and in large-scale models showing industrial and cultural shapes. It provides a means for visualizing the terrain for planning or indoctrination purposes and for briefing on assault landings.

(7) ***Military City Map***. This is a topographic map (usually at 1:12,550 scale, sometimes up to 1:5,000), showing the details of a city. It delineates streets and shows street names, important buildings, and other elements of the urban landscape important to navigation and military operations in urban terrain. The scale of a military city map depends on the importance and size of the city, density of detail, and available intelligence information.

(8) ***Special Maps***. These are maps for special purposes, such as trafficability, communications, and assault maps. They are usually in the form of an overprint in the scales smaller than 1:100,000 but larger than 1:1,000,000. A special purpose map is one that has been designed or modified to give information not covered on a standard map. The wide range of subjects that could be covered under the heading of special purpose maps prohibits,

within the scope of this manual, more than a brief mention of a few important ones. Some of the subjects covered are:

- Terrain features.
- Drainage characteristics.
- Vegetation.
- Climate.
- Coasts and landing beaches.
- Roads and bridges.
- Railroads.
- Airfields.
- Urban areas.
- Electric power.
- Fuels.
- Surface water resources.
- Ground water resources.
- Natural construction materials.
- Cross-country movements.
- Suitability for airfield construction.
- Airborne operations.

2-7. MILITARY MAP SUBSTITUTES

If military maps are not available, use substitute maps. The substitute maps can range from foreign military or commercial maps to field sketches. The DMA can provide black and white reproductions of many foreign maps and can produce its own maps based upon intelligence.

a. **Foreign Maps**. These are maps that have been compiled by nations other than our own. When these must be used, the marginal information and grids are changed to conform to our standards if time permits. The scales may differ from our maps, but they do express the ratio of map distance to ground distance and can be used in the same way. The legend must be used since the map symbols almost always differ from ours. Because the accuracy of foreign maps varies considerably, they are usually evaluated in regard to established accuracy standards before they are issued to our troops. (See Appendix I for additional information.)

b. **Atlases**. These are collections of maps of regions, countries, continents, or the world. Such maps are accurate only to a degree and can be used for general information only.

c. **Geographic Maps**. These maps give an overall idea of the mapped area in relation to climate, population, relief, vegetation, and hydrography. They also show general location of major urban areas.

d. **Tourist Road Maps**. These are maps of a region in which the main means of transportation and areas of interest are shown. Some of these maps show secondary networks of roads, historic sites, museums, and beaches in detail. They may contain road and time distance between points. Careful consideration should be exercised about the scale when using these maps.

e. **City/Utility Maps**. These are maps of urban areas showing streets, water ducts, electricity and telephone lines, and sewers.

f. **Field Sketches**. These are preliminary drawings of an area or piece of terrain. (See Appendix A.)

g. **Aerial Photographs**. These can be used as map supplements or substitutes to help you analyze the terrain, plan your route, or guide your movement. (See Chapter 8 for additional information).

2-8. STANDARDS OF ACCURACY

Accuracy is the degree of conformity with which horizontal positions and vertical values are represented on a map in relation to an established standard. This standard is determined by the DMA based on user requirements. A map can be considered to meet accuracy requirement standards unless otherwise specified in the marginal information.

CHAPTER 3

MARGINAL INFORMATION AND SYMBOLS

A map could be compared to any piece of equipment, in that before it is placed into operation the user must read the instructions. It is important that you, as a soldier, know how to read these instructions. The most logical place to begin is the marginal information and symbols, where useful information telling about the map is located and explained. All maps are not the same, so it becomes necessary every time a different map is used to examine the marginal information carefully.

3-1. MARGINAL INFORMATION ON A MILITARY MAP

Figure 3-1 (page 3-4) shows a reduced version of a large-scale topographic map. The circled numbers indicate the items of marginal information that the map user needs to know. These circled numbers correspond to the following listed items.

a. **Sheet Name (1)**. The sheet name is found in bold print at the center of the top and in the lower left area of the map margin. A map is generally named for the settlement contained within the area covered by the sheet, or for the largest natural feature located within the area at the time the map was drawn.

b. **Sheet Number (2).** The sheet number is found in bold print in both the upper right and lower left areas of the margin, and in the center box of the adjoining sheets diagram, which is found in the lower right margin. It is used as a reference number to link specific maps to overlays, operations orders, and plans. For maps at 1:100,000 scale and larger, sheet numbers are based on an arbitrary system that makes possible the ready orientation of maps at scales of 1:100,000, 1:50,000, and 1:25,000.

c. **Series Name (3)**. The map series name is found in the same bold print as the sheet number in the upper left corner of the margin. The name given to the series is generally that of a major political subdivision, such as a state within the United States or a European nation. A map series usually includes a group of similar maps at the same scale and on the same sheet lines or format designed to cover a particular geographic area. It may also be a group of maps that serve a common purpose, such as the military city maps.

d. **Scale (4).** The scale is found both in the upper left margin after the series name, and in the center of the lower margin. The scale note is a representative fraction that gives the ratio of a map distance to the corresponding distance on the earth's surface. For example, the scale note 1:50,000 indicates that one unit of measure on the map equals 50,000 units of the same measure on the ground.

e. **Series Number (5).** The series number is found in both the upper right margin and the lower left margin. It is a sequence reference expressed either as a four-digit numeral (1125) or as a letter, followed by a three- or four-digit numeral (M661; T7110).

f. **Edition Number (6)**. The edition number is found in bold print in the upper right area of the top margin and the lower left area of the bottom margin. Editions are numbered consecutively; therefore, if you have more than one edition, the highest numbered sheet is the most recent. Most military maps are now published by the DMA, but older editions of maps may have been produced by the US Army Map Service. Still others may have been drawn, at least in part, by the US Army Corps of Engineers, the US Geological Survey, or other agencies affiliated or not with the United States or allied governments. The credit line, telling who produced the map, is just above the legend. The map information date is found immediately below the word "LEGEND" in the lower left margin of the map. This date is important when determining how accurately the map data might be expected to match what you will encounter on the ground.

g. **Index to Boundaries (7).** The index to boundaries diagram appears in the lower or right margin of all sheets. This diagram, which is a miniature of the map, shows the boundaries that occur within the map area, such as county lines and state boundaries.

h. **Adjoining Sheets Diagram (8).** Maps at all standard scales contain a diagram that illustrates the adjoining sheets. On maps at 1:100,000 and larger scales and at 1:1,000,000 scale, the diagram is called the index to adjoining sheets. It consists of as many rectangles representing adjoining sheets as are necessary to surround the rectangle that represents the sheet under consideration. The diagram usually contains nine rectangles, but the number may vary depending on the locations of the adjoining sheets. All represented sheets are identified by their sheet numbers. Sheets of an adjoining series, whether published or planned, that are at the same scale are represented by dashed lines. The series number of the adjoining series is indicated along the appropriate side of the division line between the series.

i. **Elevation Guide (9).** This is normally found in the lower right margin. It is a miniature characterization of the terrain shown. The terrain is represented by bands of elevation, spot elevations, and major drainage features. The elevation guide provides the map reader with a means of rapid recognition of major landforms.

j. **Declination Diagram (10).** This is located in the lower margin of large-scale maps and indicates the angular relationships of true north, grid north, and magnetic north. On maps at 1:250,000 scale, this information is expressed as a note in the lower margin. In recent edition maps, there is a note indicating the conversion of azimuths from grid to magnetic and from magnetic to grid next to the declination diagram.

k. **Bar Scales (11).** These are located in the center of the lower margin. They are rulers used to convert map distance to ground distance. Maps have three or more bar scales, each in a different unit of measure. Care should be exercised when using the scales, especially in the selection of the unit of measure that is needed.

l. **Contour Interval Note (12)**. This note is found in the center of the lower margin normally below the bar scales. It states the vertical distance between adjacent contour lines of the map. When supplementary contours are used, the interval is indicated. In recent edition maps, the contour interval is given in meters instead of feet.

m. **Spheroid Note (13).** This note is located in the center of the lower margin. Spheriods (ellipsoids) have specific parameters that define the X Y Z axis of the earth. The spheriod is an integral part of the datum.

n. **Grid Note (14).** This note is located in the center of the lower margin. It gives information pertaining to the grid system used and the interval between grid lines, and it identifies the UTM grid zone number.

o. **Projection Note (15).** The projection system is the framework of the map. For military maps, this framework is of the conformal type; that is, small areas of the surface of the earth retain their true shapes on the projection; measured angles closely approximate true values; and the scale factor is the same in all directions from a point. The projection note is located in the center of the lower margin. Refer to DMA for the development characteristics of the conformal-type projection systems.

(1) Between 80° south and 84° north, maps at scales larger than 1:500,000 are based on the transverse Mercator projection. The note reads TRANSVERSE MERCATOR PROJECTION.

(2) Between 80° south and 84° north, maps at 1:1,000,000 scale and smaller are based on standard parallels of the lambert conformal conic projection. The note reads, for example, LAMBERT CONFORMAL CONIC PROJECTIONS 36° 40' N AND 39° 20' N.

(3) Maps of the polar regions (south of 80° south and north of 84° north) at 1:1,000,000 and larger scales are based on the polar stereographic projection. The note reads POLAR STEREOGRAPHIC PROJECTION.

p. **Vertical Datum Note (16).** This note is located in the center of the lower margin. The vertical datum or vertical-control datum is defined as any level surface (for example, mean sea level) taken as a surface of reference from which to determine elevations. In the United States, Canada, and Europe, the vertical datum refers to the mean sea level surface. However, in parts of Asia and Africa, the vertical-control datum may vary locally and is based on an assumed elevation that has no connection to any sea level surface. Map readers should habitually check the vertical datum note on maps, particularly if the map is used for low-level aircraft navigation, naval gunfire support, or missile target acquisition.

q. **Horizontal Datum Note (17).** This note is located in the center of the lower margin. The horizontal datum or horizontal-control datum is defined as a geodetic reference point (of which five quantities are known: latitude, longitude, azimuth of a line from this point, and two constants, which are the parameters of reference ellipsoid). These are the basis for horizontal-control surveys. The horizontal-control datum may extend over a continent or be limited to a small local area. Maps and charts produced by DMA are produced on 32 different horizontal-control data. Map readers should habitually check the horizontal datum note on every map or chart, especially adjacent map sheets. This is to ensure the products are based on the same horizontal datum. If products are based on different horizontal-control data, coordinate transformations to a common datum must be performed. UTM coordinates from the same point computed on different data may differ as much as 900 meters.

r. **Control Note (18).** This note is located in the center of the lower margin. It indicates the special agencies involved in the control of the technical aspects of all the information that is disseminated on the map.

s. **Preparation Note (19).** This note is located in the center of the lower margin. It indicates the agency responsible for preparing the map.

t. **Printing Note (20).** This note is also located in the center of the lower margin. It indicates the agency responsible for printing the map and the date the map was printed. The printing data should not be used to determine when the map information was obtained.

u. **Grid Reference Box (21).** This box is normally located in the center of the lower margin. It contains instructions for composing a grid reference.

v. **Unit imprint and Symbol (22).** The unit imprint and symbol is on the left side of the lower margin. It identifies the agency that prepared and printed the map with its respective symbol. This information is important to the map user in evaluating the reliability of the map.

w. **Legend (23).** The legend is located in the lower left margin. It illustrates and identifies the topographic symbols used to depict some of the more prominent features on the map. The symbols are not always the same on every map. Always refer to the legend to avoid errors when reading a map.

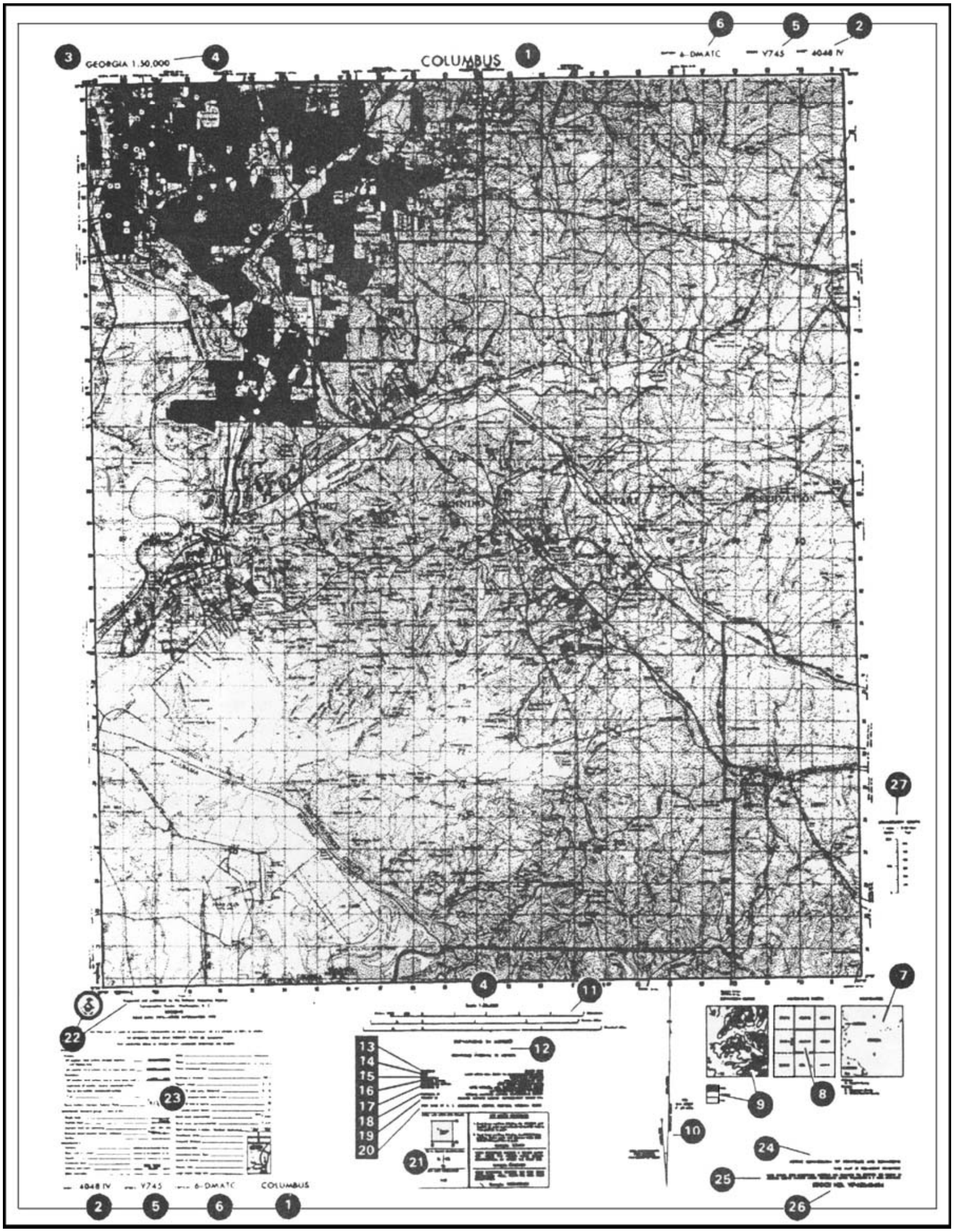
3
GEORGIA 1:50,000
4
COLUMBUS
1
6
6-DMATC
5
V745
2
4048 IV
27
7
4
11
22
12
13
14
15
16
17
18
19
20
21
23
9
8
10
24
25
26
4048 IV
V745
6-DMATC
COLUMBUS
2
5
6
1

Figure 3-1. Topographical map.

3-2. ADDITIONAL NOTES

Not all maps contain the same items of marginal information. Under certain conditions, special notes and scales may be added to aid the map user. The following are examples:

a. **Glossary**. This is an explanation of technical terms or a translation of terms on maps of foreign areas where the native language is other than English.

b. **Classification**. Certain maps require a note indicating the security classification. This is shown in the upper and lower margins.

c. **Protractor Scale**. This scale may appear in the upper margin on some maps. It is used to lay out the magnetic-grid declination for the map, which, in turn, is used to orient the map sheet with the aid of the lensatic compass.

d. **Coverage Diagram**. On maps at scales of 1:100,000 and larger, a coverage diagram may be used. It is normally in the lower or right margin and indicates the methods by which the map was made, dates of photography, and reliability of the sources. On maps at 1:250,000 scale, the coverage diagram is replaced by a reliability diagram.

e. **Special Notes (24).** A special note is any statement of general information that relates to the mapped area. It is normally found in the lower right margin. For example: This map is red-light readable.

f. **User's Note (25).** This note is normally located in the lower right-hand margin. It requests cooperation in correcting errors or omissions on the map. Errors should be marked and the map forwarded to the agency identified in the note.

g. **Stock Number Identification (26).** All maps published by the DMA that are in the Department of the Army map supply system contain stock number identifications that are used in requisitioning map supplies. The identification consists of the words "STOCK NO" followed by a unique designation that is composed of the series number, the sheet number of the individual map and, on recently printed sheets, the edition number. The designation is limited to 15 units (letters and numbers). The first 5 units are allotted to the series number; when the series number is less than 5 units, the letter "X" is substituted as the fifth unit. The sheet number is the next component; however, Roman numerals, which are part of the sheet number, are converted to Arabic numerals in the stock number. The last 2 units are the edition number; the first digit of the edition number is a zero if the number is less than 10. If the current edition number is unknown, the number 01 is used. The latest available edition will be furnished. Asterisks are placed between the sheet number and the edition number when necessary to ensure there are at least 11 units in the stock number.

h. **Conversion Graph (27).** Normally found in the right margin, this graph indicates the conversion of different units of measure used on the map.

3-3. TOPOGRAPHIC MAP SYMBOLS

The purpose of a map is to permit one to visualize an area of the earth's surface with pertinent features properly positioned. The map's legend contains the symbols most commonly used in a particular series or on that specific topographic map sheet. Therefore, the legend should be referred to each time a new map is used. Every effort is made to design standard symbols that resemble the features they represent. If this is not possible, symbols are selected that logically imply the features they portray. For example, an open-pit mining operation is represented by a small black drawing of a crossed hammer and pickax.

a. Ideally, all the features within an area would appear on a map in their true proportion, position, and shape. This, however, is not practical because many of the features would be unimportant and others would be unrecognizable because of their reduction in size.

b. The mapmaker has been forced to use symbols to represent the natural and man-made features of the earth's surface. These symbols resemble, as closely as possible, the actual features themselves as viewed from above. They are positioned in such a manner that the center of the symbol remains in its true location. An exception to this would be the position of a feature adjacent to a major road. If the width of the road has been exaggerated, then the feature is moved from its true position to preserve its relation to the road. Field Manual 21-31 gives a description of topographic features and abbreviations authorized for use on our military maps.

3-4. MILITARY SYMBOLS

In addition to the topographic symbols used to represent the natural and man-made features of the earth, military personnel require some method for showing identity, size, location, or movement of soldiers; and military activities and installations. The symbols used to represent these military features are known as military symbols. These symbols are not normally printed on maps because the features and units that they represent are constantly moving or changing; military security is also a consideration. They do appear in special maps and overlays (Chapter 7). The map user draws them in, in accordance with proper security precautions. Refer to FM 101-5-1 for complete information on military symbols.

3-5. COLORS USED ON A MILITARY MAP

By the fifteenth century, most European maps were carefully colored. Profile drawings of mountains and hills were shown in brown, rivers and lakes in blue, vegetation in green, roads in yellow, and special information in red. A look at the legend of a modern map confirms that the use of colors has not changed much over the past several hundred years. To facilitate the identification of features on a map, the topographical and cultural information is usually printed in different colors. These colors may vary from map to map. On a standard large-scale topographic map, the colors used and the features each represent are:

a**. Black.** Indicates cultural (man-made) features such as buildings and roads, surveyed spot elevations, and all labels.

b. **Red-Brown**. The colors red and brown are combined to identify cultural features, all relief features, non-surveyed spot elevations, and elevation, such as contour lines on red-light readable maps.

c. **Blue**. Identifies hydrography or water features such as lakes, swamps, rivers, and drainage.

d. **Green.** Identifies vegetation with military significance, such as woods, orchards, and vineyards.

e. **Brown.** Identifies all relief features and elevation, such as contours on older edition maps, and cultivated land on red-light readable maps.

f. **Red.** Classifies cultural features, such as populated areas, main roads, and boundaries, on older maps.

g. **Other**. Occasionally other colors may be used to show special information. These are indicated in the marginal information as a rule.

CHAPTER 4
GRIDS

This chapter covers how to determine and report positions on the ground in terms of their locations on a map. Knowing where you are (position fixing) and being able to communicate that knowledge is crucial to successful land navigation as well as to the effective employment of direct and indirect fire, tactical air support, and medical evacuation. It is essential for valid target acquisition; accurate reporting of NBC contamination and various danger areas; and obtaining emergency resupply. Few factors contribute as much to the survivability of troops and equipment and to the successful accomplishment of a mission as always knowing where you are. The chapter includes explanations of geographical coordinates, Universal Transverse Mercator grids, the military grid reference system, and the use of grid coordinates.

4-1. REFERENCE SYSTEM

In a city, it is quite simple to find a location; the streets are named and the buildings have numbers. The only thing needed is the address. However, finding locations in undeveloped areas or in unfamiliar parts of the world can be a problem. To cope with this problem, a uniform and precise system of referencing has been developed.

4-2. GEOGRAPHIC COORDINATES

One of the oldest systematic methods of location is based upon the geographic coordinate system. By drawing a set of east-west rings around the globe (parallel to the equator), and a set of north-south rings crossing the equator at right angles and converging at the poles, a network of reference lines is formed from which any point on the earth's surface can be located.

a. The distance of a point north or south of the equator is known as its latitude. The rings around the earth parallel to the equator are called parallels of latitude or simply parallels. Lines of latitude run east-west but north-south distances are measured between them.

b. A second set of rings around the globe at right angles to lines of latitude and passing through the poles is known as meridians of longitude or simply meridians. One meridian is designated as the prime meridian. The prime meridian of the system we use runs through Greenwich, England and is known as the Greenwich meridian. The distance east or west of a prime meridian to a point is known as its longitude. Lines of longitude (meridians) run north-south but east-west distances are measured between them (Figures 4-1 and 4-2, page 4-2).

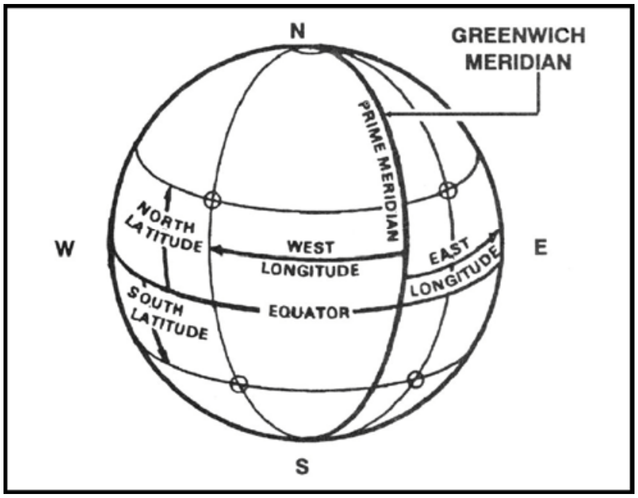
N
GREENWICH MERIDIAN
PRIME MERIDIAN
NORTH LATITUDE
WEST LONGITUDE
EAST LONGITUDE
W
E
SOUTH LATITUDE
EQUATOR
S

Figure 4-1. Prime meridian and equator.

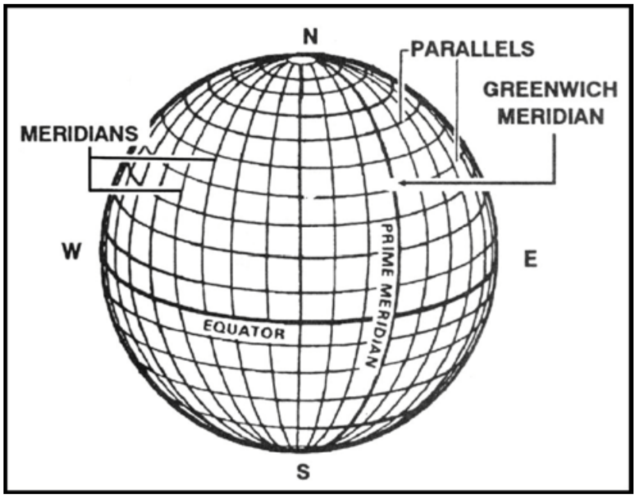
N
PARALLELS
GREENWICH MERIDIAN
MERIDIANS
W
E
PRIME MERIDIAN
EQUATOR
S

Figure 4-2. Reference lines.

c. Geographic coordinates are expressed in angular measurement. Each circle is divided into 360 degrees, each degree into 60 minutes, and each minute into 60 seconds. The degree is symbolized by °, the minute by ′, and the second by ″. Starting with 0° at the equator, the parallels of latitude are numbered to 90° both north and south. The extremities are the north pole at 90° north latitude and the south pole at 90° south latitude. Latitude can have the same numerical value north or south of the equator, so the direction N or S must always be given. Starting with 0°at the prime meridian, longitude is measured both east and west around the world. Lines east of the prime meridian are numbered to 180° and identified as east longitude; lines west of the prime meridian are numbered to 180° and identified as west longitude. The direction E or W must always be given. The line directly opposite the prime meridian, 180°, may be referred to as either east or west longitude. The values of geographic coordinates, being in units of angular measure, will mean more if they are compared with units of measure with which we are more familiar. At any point on the earth, the ground distance covered by one degree of latitude is about 111 kilometers (69 miles); one second is equal to about 30 meters (100 feet). The ground distance covered by one degree of longitude at the equator is also about 111 kilometers, but decreases as one moves north or south, until it becomes zero at the poles. For example, one second of longitude represents about 30 meters (100 feet) at the equator; but at the latitude of Washington, DC, one second of longitude is about 24 meters (78 feet). Latitude and longitude are illustrated in Figure 4-3.

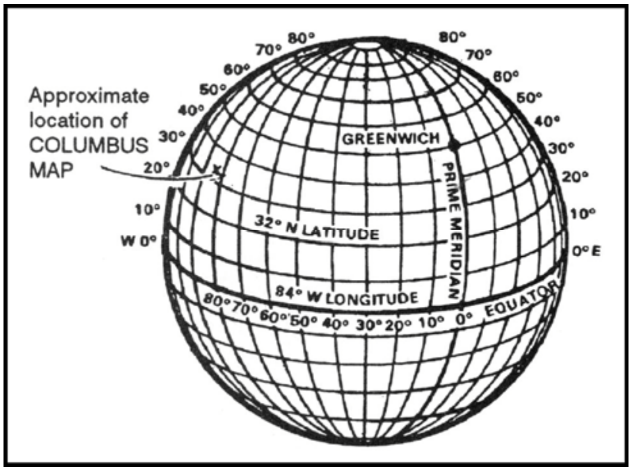

Figure 4-3. Latitude and longitude.

d. Geographic coordinates appear on all standard military maps; on some they may be the only method of locating and referencing a specific point. The four lines that enclose the body of the map (neatlines) are latitude and longitude lines. Their values are given in degrees and minutes at each of the four corners. On a portion of the Columbus map (Figure 4-4), the figures 32°15' and 84°45' appear at the lower right corner. The bottom line of this map is latitude 32°15'00″N, and the line running up the right side is longitude 84°45'00"W. In addition to the latitude and longitude given for the four corners, there are, at regularly spaced intervals along the sides of the map, small tick marks extending into the body of the map. Each of these tick marks is identified by its latitude or longitude value. Near the top of the right side of the map is a tick mark and the number 20'. The full value for this tick marks is 32°20'00" of latitude. At one-third and two-thirds of the distance across the map from the 20' tick mark will be found a cross tick mark (grid squares 0379 and 9679) and at the far side another 20' tick mark. By connecting the tick marks and crosses with straight lines, a 32°20'00" line of latitude can be added to the map. This procedure is also used to locate the 32°25'00" line of latitude. For lines of longitude, the same procedure is followed using the tick marks along the top and bottom edges of the map.

e. After the parallels and meridians have been drawn, the geographic interval (angular distance between two adjacent lines) must be determined. Examination of the values given at the tick marks gives the interval. For most maps of scale 1:25,000, the interval is 2'30". For the Columbus map and most maps of scale 1:50,000, it is 5'00". The geographic coordinates of a point are found by dividing the sides of the geographic square in which the point is located into the required number of equal parts. If the geographic interval is 5'00" and the location of a point is required to the nearest second, each side of the geographic square must be divided into 300 equal parts (5'00" = 300"), each of which would have a value of one second. Any scale or ruler that has 300 equal divisions and is as long as or longer than the spacing between the lines may be used.

f. The following steps will determine the geographic coordinates of Wilkinson Cemetery (northwest of the town of Cusseta) on the Columbus map.

(1) Draw the parallels and meridians on the map that encloses the area around the cemetery.

(2) Determine the values of the parallels and meridians where the point falls.

Latitude 32°15'00" and 32°20'00".

Longitude 84°45'00" and 84°50'00".

(3) Determine the geographic interval (5'00" = 300").

(4) Select a scale that has 300 small divisions or multiples thereof (300 divisions, one second each; 150 divisions, two seconds each; 75 divisions, four seconds each, and so forth).

(5) To determine the latitude—

(a) Place the scale with the 0 of the scale on the latitude of the lowest number value (32°15'00") and the 300 of the scale on the highest numbered line (32°20'00") (1, Figure 4-4).

(b) While keeping the 0 and 300 on the two lines, slide the scale (2, Figure 4-4) along the parallels until the Wilkinson Cemetery symbol is along the edge of the numbered scale.

(c) Read the number of seconds from the scale (3, Figure 4-4), about 246.

(d) Convert the number of seconds to minutes and seconds (246" = 4'06") and add to the value of the lower numbered line (32°15'00" + 4'06" = 32°19'06") (4, Figure 4-4).

RESULTS:

- The latitude is 32°19'06", but this is not enough.
- The latitude 32°19'06" could be either north or south of the equator, so the letter N or S must be added to the latitude. To determine whether it is N or S, look at the latitude values at the edge of the map and find the direction in which they become larger. If they are larger going north, use N; if they are larger going south, use S.
- The latitude for the cemetery is 32°19'06"N.

(6) Determine the longitude, repeat the same steps but measure between lines of longitude and use E and W. The geographic coordinates of Wilkinson Cemetery should be about 32°19'06"N and 84°47'32"W (Figure 4-5, page 4-6).

g. To locate a point on the Columbus map (Figure 4-6, page 4-7) when knowing the geographic coordinates, many of the same steps are followed. To locate 32°25'28"N and 84°50'56"W, first find the geographic lines within which the point falls: latitude 32°25'00" and 32°30'0"; and longitude 84°50'00" and 84°55'00". Subtract the lower latitude/longitude from the higher latitude/longitude.

(1) Place the 0 of the scale on the 32°25'00" line and the 300 on the 32°30'00". Make a mark at the number 28 on the scale (the difference between the lower and higher latitude).

(2) Place the 0 of the scale on the 84°50′00″ line and the 300 on the 84°50′55″. Make a mark at the number 56 on the scale (the difference between the lower and higher longitude.

(3) Draw a vertical line from the mark at 56 and a horizontal line from the mark at 28; they intersect at 32 25’28”N and 84 50’56”W.

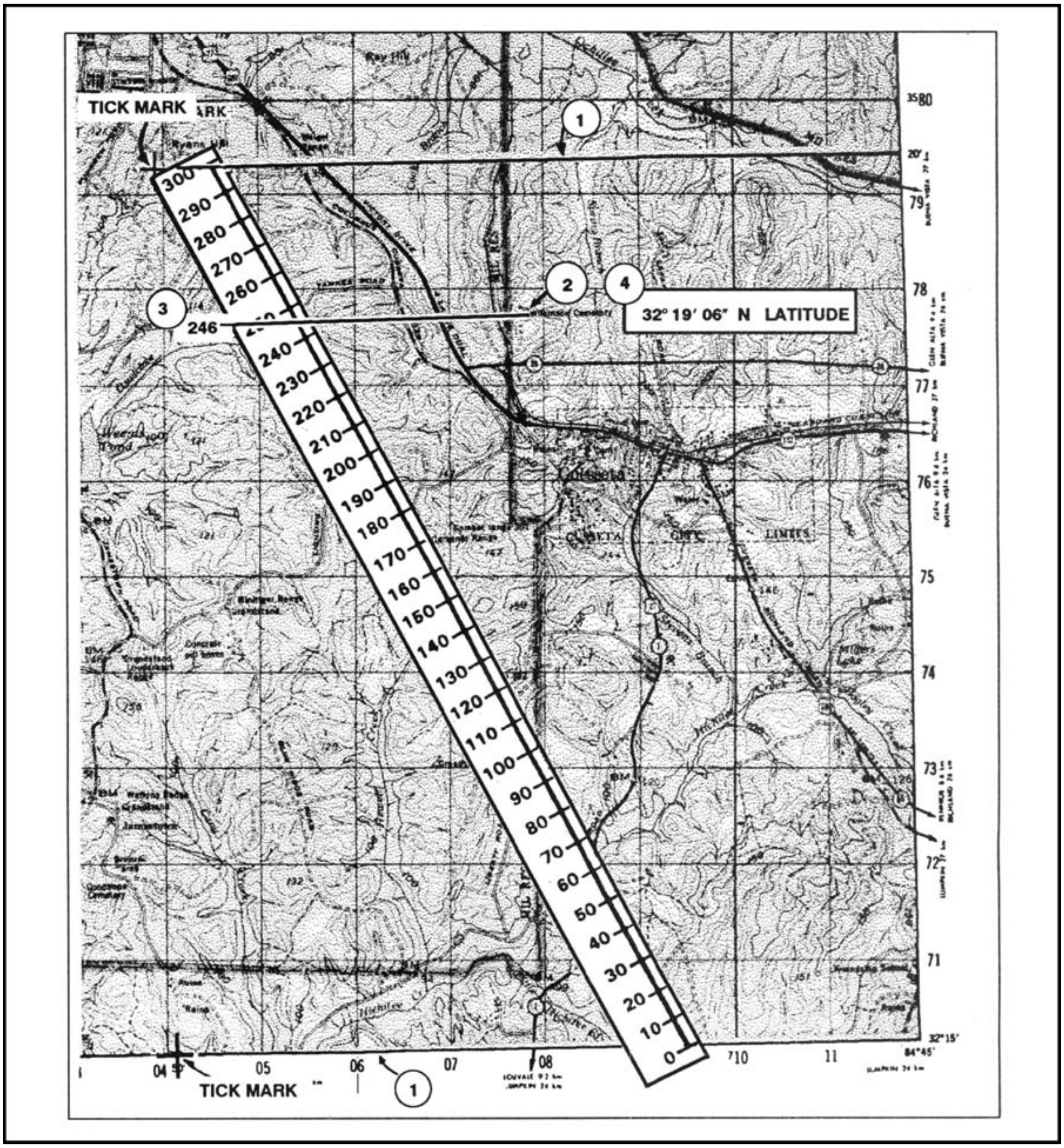
TICK MARK
1
2
4
32° 19′ 06″ N LATITUDE
3
246
300
290
280
270
260
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
3580
20′
79
78
77
76
75
74
73
72
71
32°15′
84°45′
04
05
06
07
08
710
11
TICK MARK
1

Figure 4-4. Determining latitude.

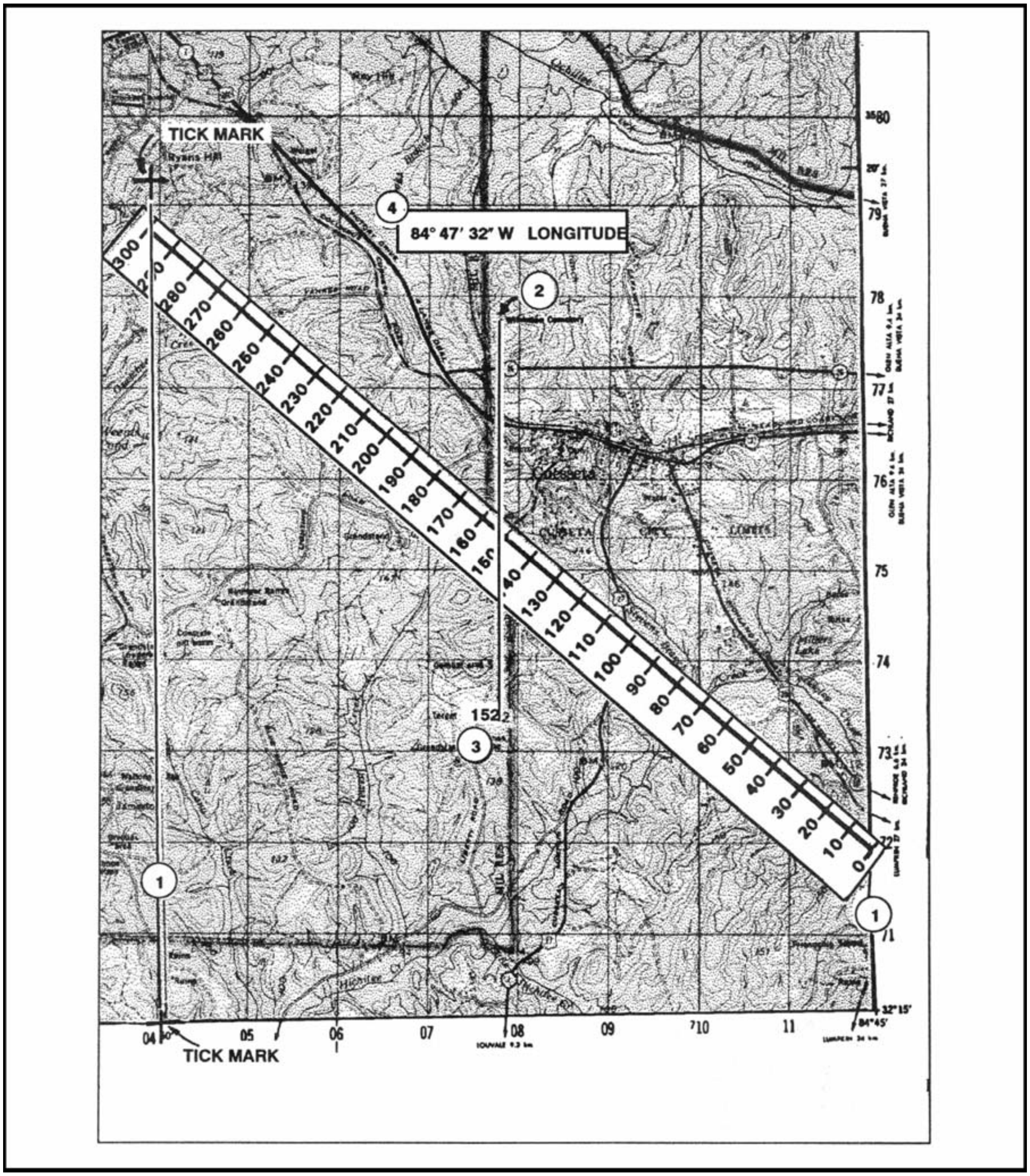
TICK MARK
4
84° 47′ 32″ W LONGITUDE
2
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
152
3
1
1
3580
79
78
77
76
75
74
73
72
71
32°15′
84°45′
04
05
06
07
08
09
10
11
TICK MARK

Figure 4-5. Determining longitude.

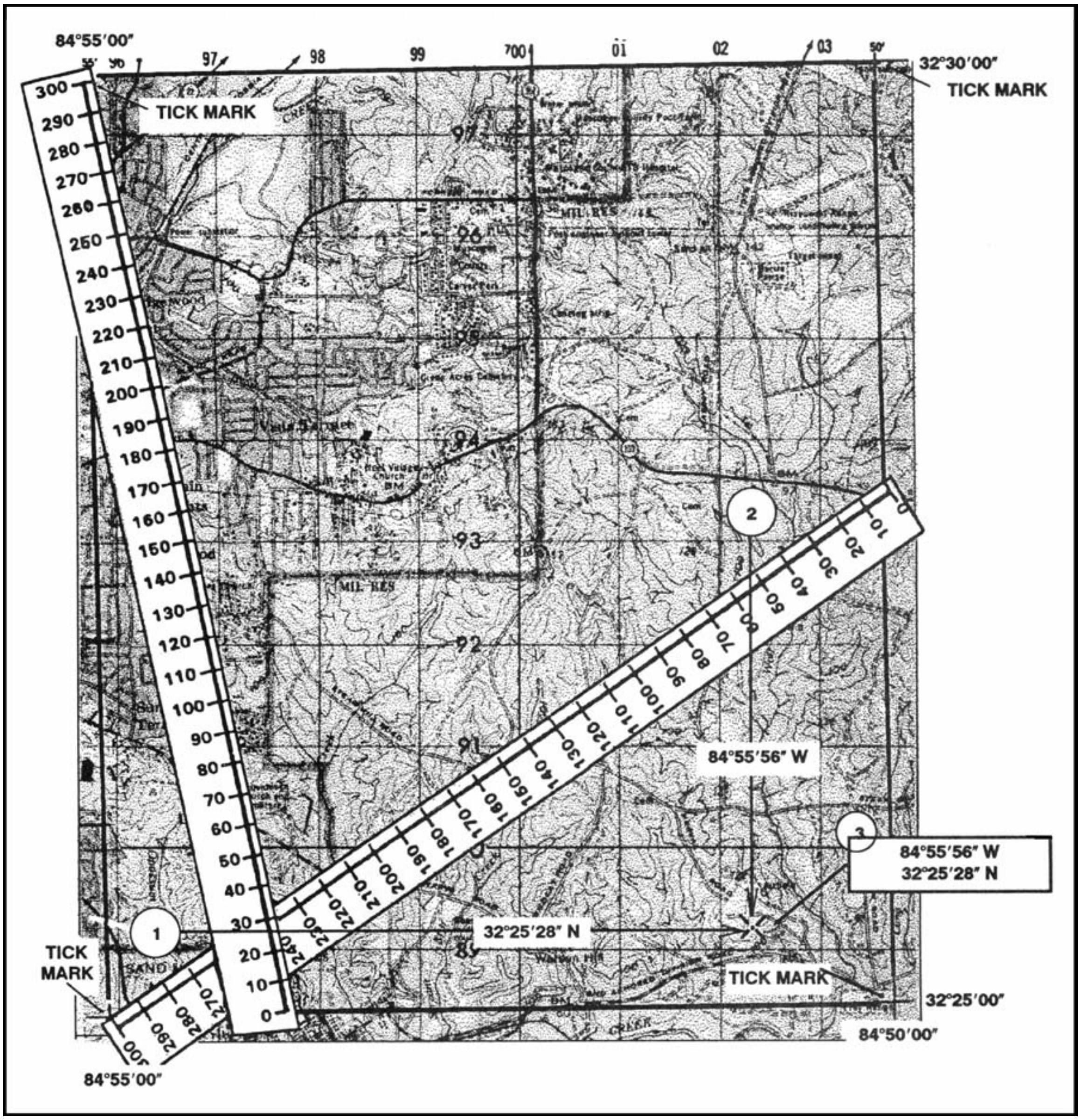
84°55'00"
TICK MARK
32°30'00"
TICK MARK
2
84°55'56" W
3
84°55'56" W
32°25'28" N
1
32°25'28" N
TICK MARK
TICK MARK
32°25'00"
84°50'00"
84°55'00"

Figure 4-6. Determining geographic coordinates.

h. If you do not have a scale or ruler with 300 equal divisions or a map whose interval is other than 5'00", use the proportional parts method. Following the steps determines the geographic coordinates of horizontal control station 141.

(1) Locate horizontal control station 141 in grid square (GL0784) (Figure 4-7, page 4-9).

(2) Find a cross in grid square GL0388 and a tick mark in grid square GL1188 with 25'.

(3) Find another cross in grid square GL0379 and a tick mark in grid square GL1179 with 20'.

(4) Enclose the control station by connecting the crosses and tick marks. The control station is between 20' and 25' (Figure 4-7, page 4-9).

(5) With a boxwood scale, measure the distance from the bottom line to the top line that encloses the area around the control station on the map (total distance) (Figure 4-7).

(6) Measure the partial distance from the bottom line to the center of the control station (Figure 4-7). These straight-line distances are in direct proportion to the minutes and seconds of latitude and are used to set up a ratio.

RESULTS:

- The total distance is 9,200 meters, and the partial distance is 5,125 meters (Figure 4-7).
- With the two distances and the five-minute interval converted to seconds (300"), determine the minutes and seconds of latitude using the following formula:
    - 5,125 x 300 = 1,537,500
    - 1,537,500 ÷ 9,200 = 167
    - 167 ÷ 60 = 2'47"
    - Add 2'47" to 32°20'00" = 32°20'47"

(7) Follow the same procedures to determine minutes and seconds of longitude (Figure 4-7).

RESULTS:

- The total distance is 7,830 meters, and the partial distance is 4,000 meters (Figure 4-7).
    - 4,000 x 300 = 1,200,000
    - 1,200,000 ÷ 7,830 = 153
    - 153 ÷ 60 = 2'33"
    - Add 2'33" to 84°45' = 84°47'33"N

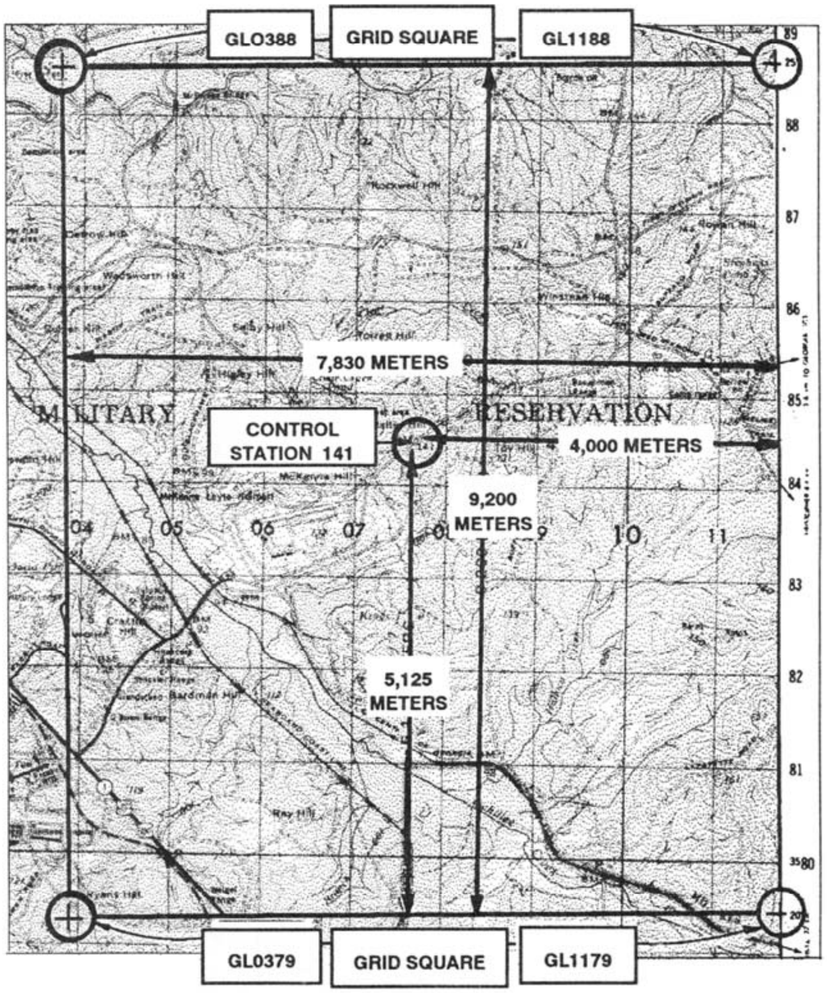
GLO388
GRID SQUARE
GL1188
89
88
87
86
7,830 METERS
85
MILITARY
RESERVATION
CONTROL
STATION 141
4,000 METERS
84
9,200
METERS
04
05
06
07
10
11
83
82
5,125
METERS
81
80
GL0379
GRID SQUARE
GL1179

Figure 4-7. Using the proportional parts method.

(8) The geographic coordinates of horizontal control station 141 in grid square GL0784 are 32°22'47"N latitude and 84°47'33"W longitude.

NOTE: When computing formulas, round off totals to the nearest whole number in step 2. In step 3, convert the fraction to seconds by multiplying the fraction by 60 and rounding off if the total is not a whole number.

i. The maps made by some nations do not have their longitude values based on the prime meridian that passes through Greenwich, England. Table 4-1, on page 4-10, shows the prime meridians that may be used by other nations. When these maps are issued to our soldiers, a note usually appears in the marginal information giving the difference between our prime meridian and the one used on the map.

Amsterdam, Netherlands	4°53’01”E
Athens, Greece	23°42’59”E
Batavia (Djakarta), Indonesia	106°48’28”E
Bern, Switzerland	7°26’22”E
Brussels, Belgium	4°22’06”E
Copenhagen, Denmark	12°34’40”E
Ferro (Hierro), Canary Islands	17°39’46”W
Helsinki, Finland	24°53’17”E
Istanbul, Turkey	28°58’50”E
Lisbon, Portugal	9°07’55”W
Madrid, Spain	3°41’15”W
Oslo, Norway	10°43’23”E
Paris, France	2°20’14”E
Pulkovo, Russia	30°19’39”E
Rome, Italy	12°27’08”E
Stockholm, Sweden	18°03’30”E
Tirane, Albania	19°46’45”E

Table 1. Table of prime meridians.

4-3. MILITARY GRIDS

An examination of the transverse Mercator projection, which is used for large-scale military maps, shows that most lines of latitude and longitude are curved lines. The quadrangles formed by the intersection of these curved parallels and meridians are of different sizes and shapes, complicating the location of points and the measurement of directions. To aid these essential operations, a rectangular grid is superimposed upon the projection. This grid (a series of straight lines intersecting at right angles) furnishes the map reader with a system of squares similar to the block system of most city streets. The dimensions and orientation of different types of grids vary, but three properties are common to all military grid systems: one, they are true rectangular grids; two, they are superimposed on the geographic projection; and three, they permit linear and angular measurements.

a. **Universal Transverse Mercator Grid**. The UTM grid has been designed to cover that part of the world between latitude 84°N and latitude 80°S, and, as its name implies, is imposed on the transverse Mercator projection.

(1) Each of the 60 zones (6 degrees wide) into which the globe is divided for the grid has its own origin at the intersection of its central meridian and the equator (Figure 4-8). The grid is identical in all 60 zones. Base values (in meters) are assigned to the central meridian and the equator, and the grid lines are drawn at regular intervals parallel to these two base lines. With each grid line assigned a value denoting its distance from the origin, the problem of locating any point becomes progressively easier. Normally, it would seem logical to assign a value of zero to the two base lines and measure outward from them. This, however, would require either that directions—N, S, E, or W—be always given with distances, or that all points south of the equator or west of the central meridian have negative values.

(2) This inconvenience is eliminated by assigning "false values" to the base lines, resulting in positive values for all points within each zone. Distances are always measured RIGHT and UP (east and north as the reader faces the map), and the assigned values are called "false easting" and "false northing." (Figure 4-9, page 4-12). The false eating value for each central meridian is 500,000 meters, and the false northing value for the equator is 0 meters when measuring in the northern hemisphere and 10,000,000 meters when measuring in the southern hemisphere. The use of the UTM grid for point designation will be discussed in detail in paragraph 4-4.

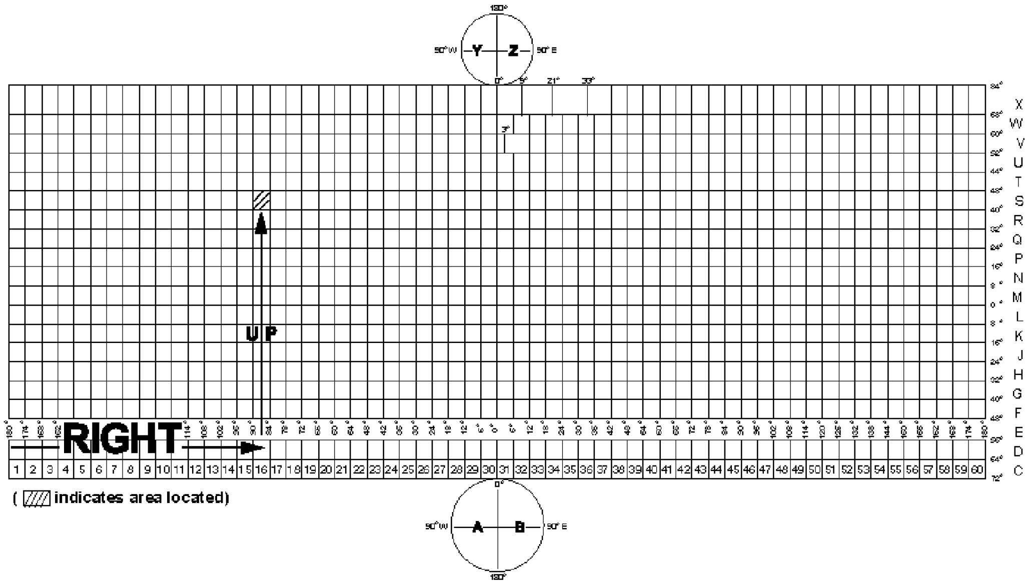
180°
90° W
Y
Z
90° E
0°
9°
21°
33°
3°
84°
72°
64°
56°
48°
40°
32°
24°
16°
8°
0°
8°
16°
24°
32°
40°
48°
56°
64°
72°
X
W
V
U
T
S
R
Q
P
N
M
L
K
J
H
G
F
E
D
C
UP
RIGHT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
(▨ indicates area located)
0°
90° W
A
B
90° E
180°

Figure 4-8. UTM grid zone location.

b. **Universal Polar Stereographic Grid**. The UPS grid is used to represent the polar regions. (Figure 4-10, page 4-13)

(1) ***North Polar Area***. The origin of the UPS grid applied to the north polar area is the north pole. The "north-south" base line is the line formed by the 0-degree and 180-degree meridians; the "east-west" base line is formed by the two 90-degree meridians.

(2) ***South Polar Area***. The origin of the UPS grid in the south polar area is the south pole. The base lines are similar to those of the north polar area.

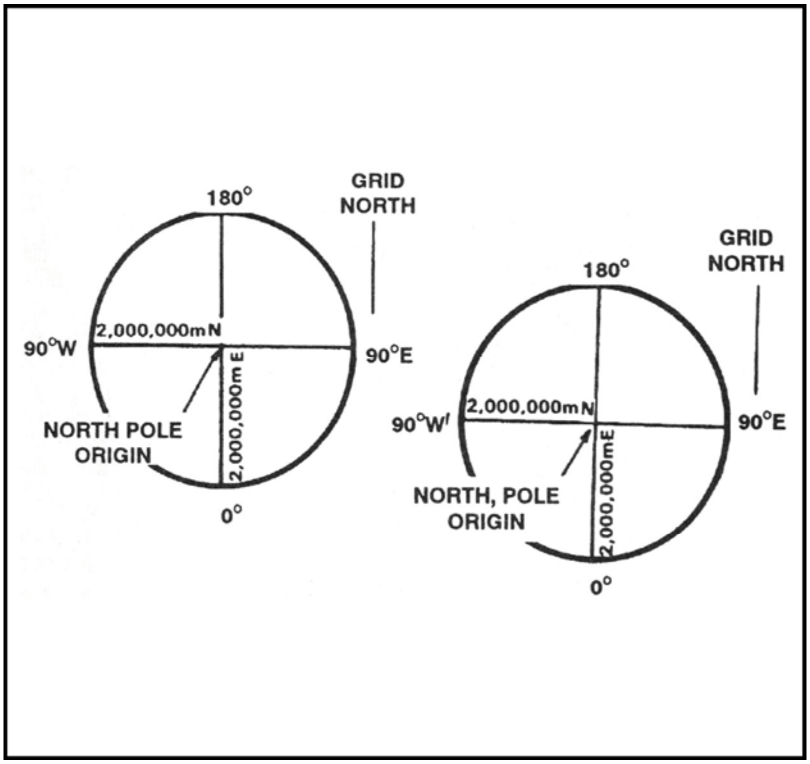

Figure 4-9. False eastings and northings for the UPS grid.

4-4. UNITED STATES ARMY MILITARY GRID REFERENCE SYSTEM

This grid reference system is designated for use with the UTM and UPS grids. The coordinate value of points in these grids could contain as many as 15 digits if numerals alone were used. The US military grid reference system reduces the length of written coordinates by substituting single letters for several numbers. Using the UTM and the UPS grids, it is possible for the location of a point (identified by numbers alone) to be in many different places on the surface of the earth. With the use of the military grid reference system, there is no possibility of this happening.

a. **Grid Zone Designation.** The world is divided into 60 grid zones, which are large, regularly shaped geographic areas, each of which is given a unique identification called the grid zone designation.

(1) ***UTM Grid***. The first major breakdown is the division of each zone into areas 6° wide by 8° high and 6° wide by 12° high. Remember, for the transverse Mercator projection, the earth's surface between 80°S and 84°N is divided into 60 N-S zones, each 6° wide. These zones are numbered from west to east, 1 through 60, starting at the 180° meridian. This surface is divided into 20 east-west rows in which 19 are 8° high and 1 row at the extreme north is 12° high. These rows are then lettered, from south to north, C through X (I and O were omitted). Any 6° by 8° zone or 6° by 12° zone is identified by giving the number and letter of the grid zone and row in which it lies. These are read RIGHT and UP so the number is always written before the letter. This combination of zone number and row letter constitutes the grid zone designation. Columbus lies in zone 16 and row S, or in grid zone designation 16S (Figure 4-8, page 4-11).

(2) ***UPS Grid***. The remaining letters of the alphabet, A, B, Y, and Z, are used for the UPS grids. Each polar area is divided into two zones separated by the 0-180° meridian. In the south polar area, the letter A is the grid zone designation for the area west of the 0-180° meridian, and B for the area to the east. In the north polar area, Y is the grid zone designation for the western area and Z for the eastern area (Figure 4-10).

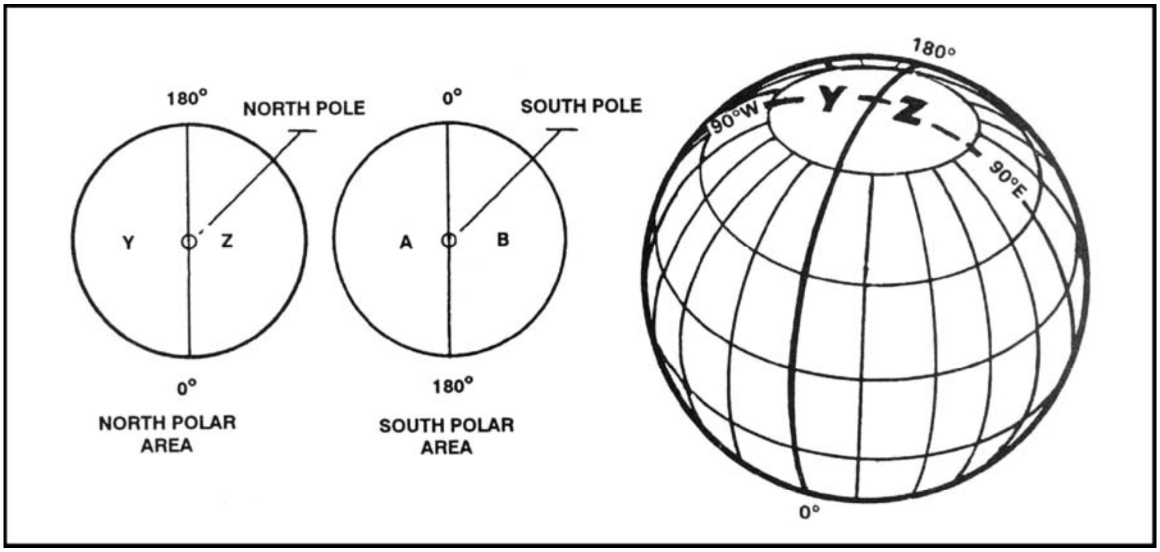

Figure 4-10. Grid zone designation for UPS grid.

b. **100,000-Meter Square.** Between 84°N and 80°S, each 6° by 8° or 6° by 12° zone is covered by 100,000-meter squares that are identified by the combination of two alphabetical letters. This identification is unique within the area covered by the grid zone designation. The first letter is the column designation; the second letter is the row designation (Figure 4-11, page 4-14). The north and south polar areas are also divided into 100,000-meter squares by columns and rows. A detailed discussion of the polar system can be found in Technical Report 8358.1. The 100,000-meter square identification letters are located in the grid reference box in the lower margin of the map.

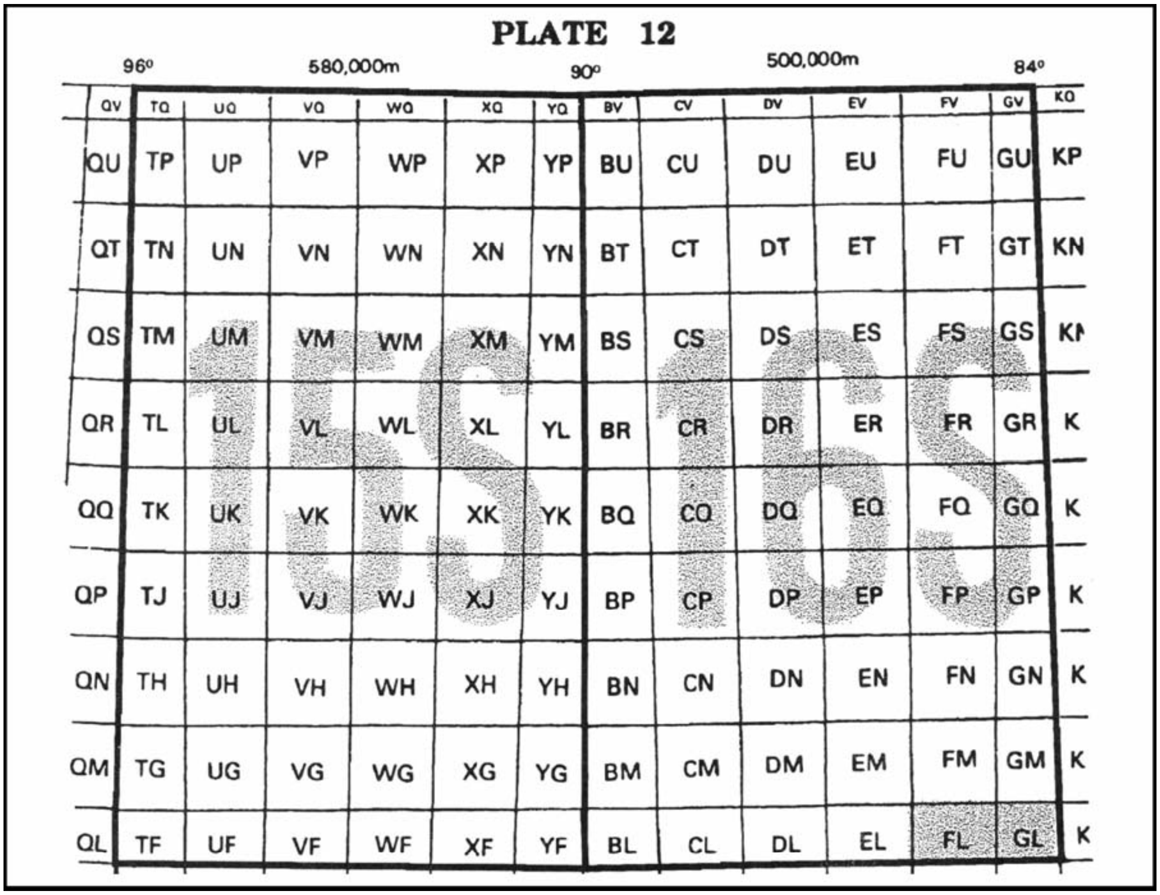

QV	TQ	UQ	VQ	WQ	XQ	YQ	BV	CV	DV	EV	FV	GV	KQ
QU	TP	UP	VP	WP	XP	YP	BU	CU	DU	EU	FU	GU	KP
QT	TN	UN	VN	WN	XN	YN	BT	CT	DT	ET	FT	GT	KN
QS	TM	UM	VM	WM	XM	YM	BS	CS	DS	ES	FS	GS	K
QR	TL	UL	VL	WL	XL	YL	BR	CR	DR	ER	FR	GR	K
QQ	TK	UK	VK	WK	XK	YK	BQ	CQ	DQ	EQ	FQ	GQ	K
QP	TJ	UJ	VJ	WJ	XJ	YJ	BP	CP	DP	EP	FP	GP	K
QN	TH	UH	VH	WH	XH	YH	BN	CN	DN	EN	FN	GN	K
QM	TG	UG	VG	WG	XG	YG	BM	CM	DM	EM	FM	GM	K
QL	TF	UF	VF	WF	XF	YF	BL	CL	DL	EL	FL	GL	K

Figure 4-11. Grid zone designation and 100,000-meter square identification.

c. **Grid Coordinates**. We have now divided the earth's surface into 6° by 8° quadrangles, and covered these with 100,000-meter squares. The military grid reference of a point consists of the numbers and letters indicating in which of these areas the point lies, plus the coordinates locating the point to the desired position within the 100,000-meter square. The next step is to tie in the coordinates of the point with the larger areas. To do this, you must understand the following.

(1) ***Grid Lines***. The regularly spaced lines that make the UTM and the UPS grid on any large-scale maps are divisions of the 100,000-meter square; the lines are spaced at 10,000- or 1,000-meter intervals (Figure 4-12). Each of these lines is labeled at both ends of the map with its false easting or false northing value, showing its relation to the origin of the zone. Two digits of the values are printed in large type, and these same two digits appear at intervals along the grid lines on the face of the map. These are called the principal digits, and represent the 10,000 and 1,000 digits of the grid value. They are of major importance to the map reader because they are the numbers he will use most often for referencing points. The smaller digits complete the UTM grid designation.

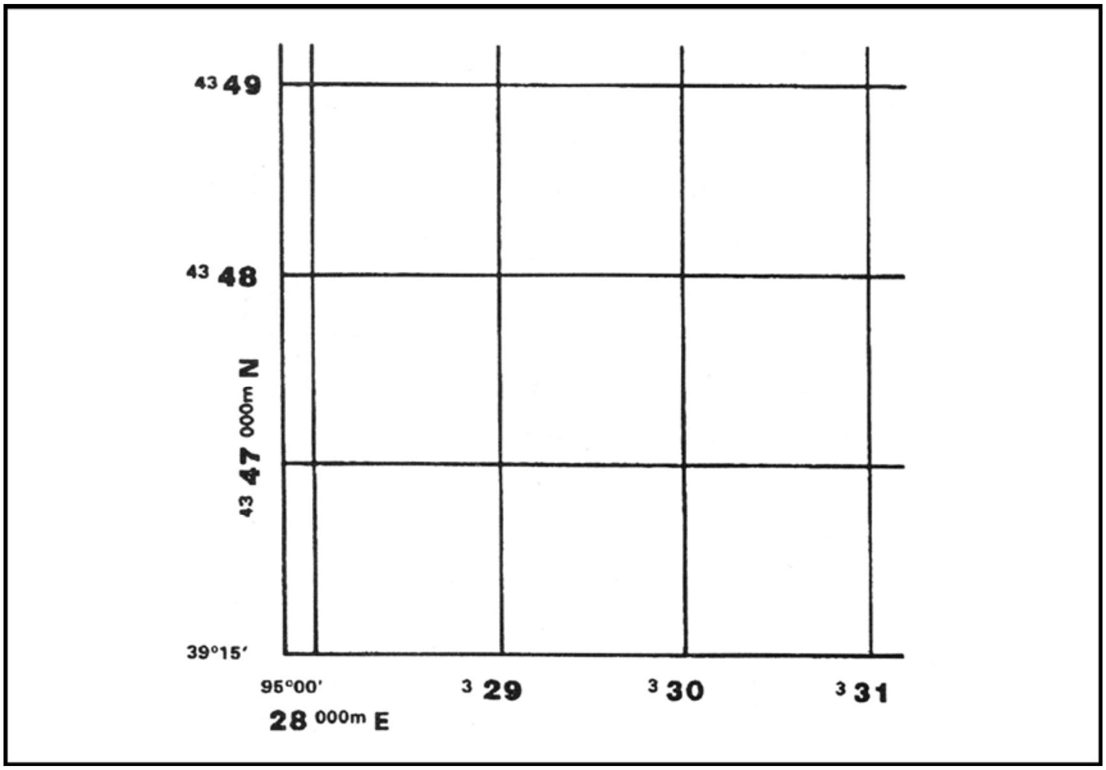

Figure 4-12. Grid lines.

EXAMPLE: The first grid line north of the south-west corner of the Columbus map is labeled 3570000m N. This means its false northing (distance north of the equator) is 3,570,000 meters. The principal digits, 70, identify the line for referencing points in the northerly direction. The smaller digits, 35, are part of the false coordinates and are rarely used. The last three digits, 000, of the value are omitted. Therefore, the first grid line east of the south-west corner is labeled 689000m E. The principal digits, 89, identify the line for referencing points in the easterly direction (Figure 4-13, page 4-16).

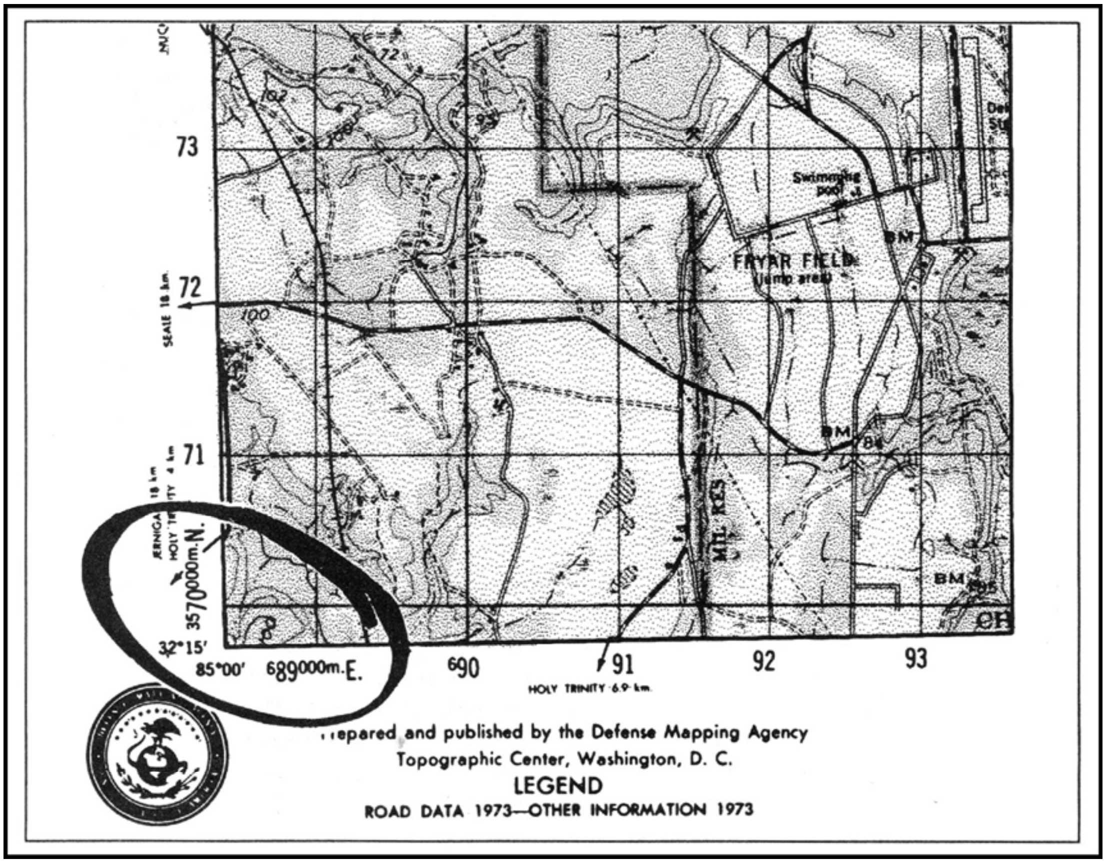
73
72
71
3570000m.N.
32°15'
85°00'
689000m.E.
690
91
92
93
HOLY TRINITY 6.9 km
FRYAR FIELD
Swimming pool
BM
MIL RES
..epared and published by the Defense Mapping Agency
Topographic Center, Washington, D. C.
LEGEND
ROAD DATA 1973—OTHER INFORMATION 1973

Figure 4-13. Columbus map, southwest corner.

(2) ***Grid Squares***. The north-south and east-west grid lines intersect at 90°, forming grid squares. Normally, the size of one of these grid squares on large-scale maps is 1,000 meters (1 kilometer).

(3) ***Grid Coordinate Scales***. The primary tool for plotting grid coordinates is the grid coordinate scale. The grid coordinate scale divides the grid square more accurately than can be done by estimation, and the results are more consistent. When used correctly, it presents less chance for making errors. GTA 5-2-12, 1981, contains four types of coordinate scales (Figure 4-14).

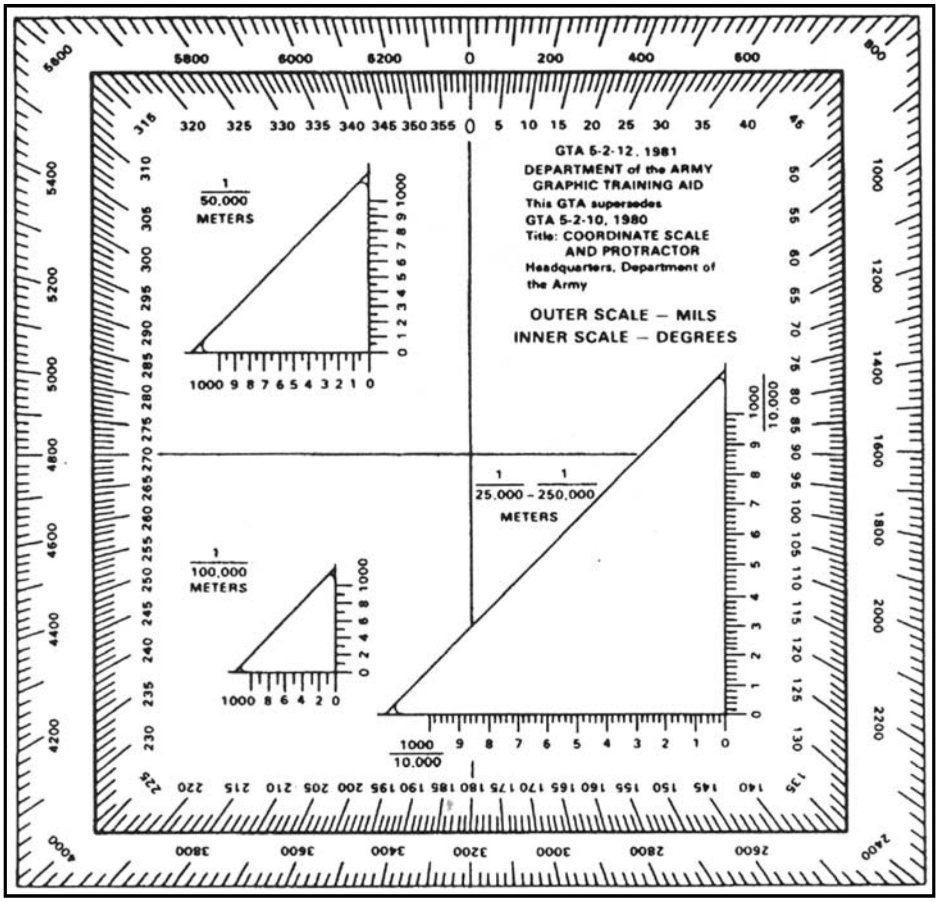
GTA 5-2-12, 1981
DEPARTMENT of the ARMY
GRAPHIC TRAINING AID
This GTA supersedes
GTA 5-2-10, 1980
Title: COORDINATE SCALE
AND PROTRACTOR
Headquarters, Department of
the Army
OUTER SCALE — MILS
INNER SCALE — DEGREES
1/50,000
METERS
1000 9 8 7 6 5 4 3 2 1 0
0 1 2 3 4 5 6 7 8 9 1000
1/100,000
METERS
1000 8 6 4 2 0
0 2 4 6 8 1000
1/25,000 - 1/250,000
METERS
1000/10,000 9 8 7 6 5 4 3 2 1 0
0 1 2 3 4 5 6 7 8 9 1000/10,000
5800 6000 6200 0 200 400 600 800
1000 1200 1400 1600 1800 2000 2200 2400
2600 2800 3000 3200 3400 3600 3800 4000
4200 4400 4600 4800 5000 5200 5400 5600
315 320 325 330 335 340 345 350 355 0 5 10 15 20 25 30 35 40 45
50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135
140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225
230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310

Figure 4-14. Coordinate scales.

(a) The 1:25,000/1:250,000 (lower right in figure) can be used in two different scale maps, 1:25,000 or 1:250,000. The 1:25,000 scale subdivides the 1,000-meter grid block into 10 major subdivisions, each equal to 100 meters. Each 100-meter block has five graduations, each equal to 20 meters. Points falling between the two graduations can be read accurately by the use of estimation. These values are the fourth and eighth digits of the coordinates. Likewise, the 1:250,000 scale is subdivided in 10 major subdivisions, each equal to 1,000 meters. Each 1,000-meter block has five graduations, each equal to 200 meters. Points falling between two graduations can be read approximately by the use of estimation.

(b) The 1:50,000 scale (upper left in Figure 4-14) subdivides the 1,000-meter block into 10 major subdivisions, each equal to 100 meters. Each 100-meter block is then divided in half. Points falling between the graduations must be estimated to the nearest 10 meters for the fourth and eighth digits of the coordinates.

(c) The 1:100,000 scale (lower left in Figure 4-14) subdivides the 1,000-meter grid block into five major subdivisions of 200 meters each. Each 200-meter block is then divided in half at 100-meter intervals.

4-5. LOCATE A POINT USING GRID COORDINATES

Based on the military principle for reading maps (RIGHT and UP), locations on the map can be determined by grid coordinates. The number of digits represents the degree of precision to which a point has been located and measured on a map—the more digits the more precise the measurement.

a. **Without a Coordinate Scale**. Determine grids without a coordinate scale by referring to the north-south grid lines numbered at the bottom margin of any map. Then read RIGHT to the north-south grid line that precedes the desired point (this first set of two digits is the RIGHT reading). Then by referring to the east-west grid lines numbered at either side of the map, move UP to the east-west grid line that precedes the desired point (these two digits are the UP reading). Coordinate 1484 locate the 1,000-meter grid square in which point X is located; the next square to the right would be 1584; the next square up would be 1485, and so forth (Figure 4-15). Locate the point to the nearest 100 meters using estimation. Mentally divide the grid square in tenths, estimate the distance from the grid line to the point in the same order (RIGHT and UP). Give complete coordinate RIGHT, then complete coordinate UP. Point X is about two-tenths or 200 meters to the RIGHT into the grid square and about seven-tenths or 700 meters UP.

RESULTS: The coordinates to the nearest 100 meters are 142847.

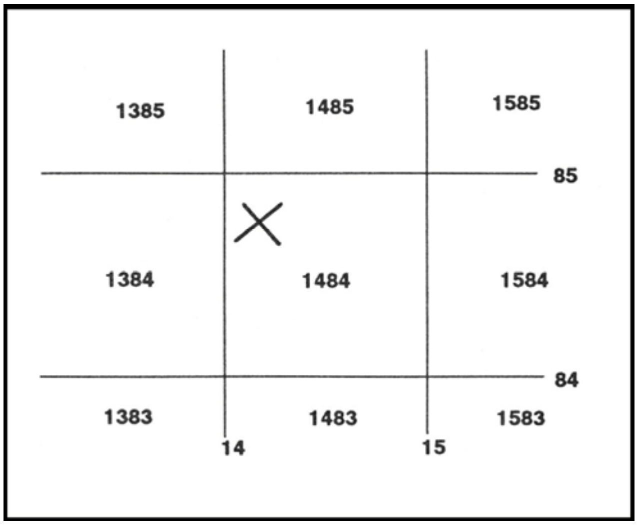

Figure 4-15. Determining grids without coordinate point.

b. **With a Coordinate Scale (1:25,000)**. In order to use the coordinate scale for determining grid coordinates, ensure that the appropriate scale is being used on the corresponding map, and that the scale is right side up. To ensure the scale is correctly aligned, place it with the zero-zero point at the lower left corner of the grid square. Keeping the horizontal line of the scale directly on top of the east-west grid line, slide it to the right until the vertical line of the scale touches the point for which the coordinates are desired (Figure 4-16). When reading coordinates, examine the two sides of the coordinate scale to ensure that the horizontal line of the scale is aligned with the east-west grid line, and the vertical line of the scale is parallel with the north-south grid line. Use the scale when precision of more than 100 meters is required. To locate the point to the nearest 10 meters, measure the hundredths of a grid square RIGHT and UP from the grid lines to the point. Point X is about 17 hundredths or 170 meters RIGHT and 84 hundredths or 840 meters UP. The coordinates to the nearest 10 meters are 14178484.

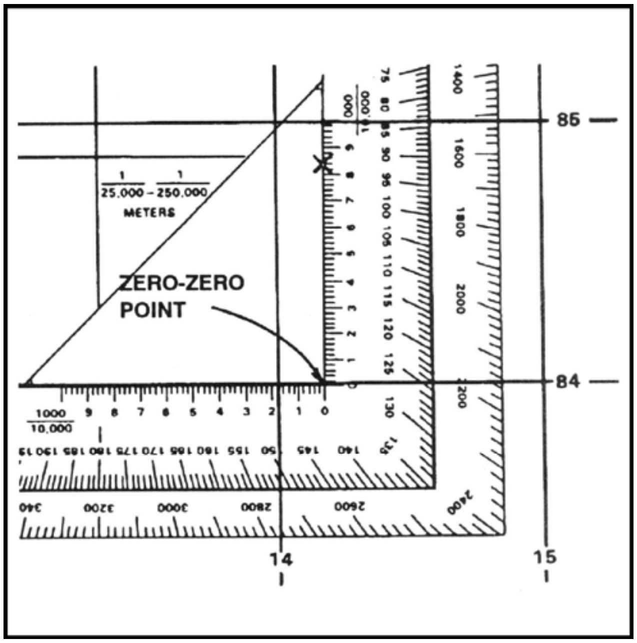
1/25,000 – 1/250,000
METERS
ZERO-ZERO POINT
1000/10,000
85
84
14
15

Figure 4-16. Placing a coordinate scale on a grid.

NOTE: Care should be exercised by the map reader using the coordinate scale when the desired point is located within the zero-zero point and the number 1 on the scale. Always prefix a zero if the hundredths reading is less than 10. In Figure 4-17, the desired point is reported as 14818407.

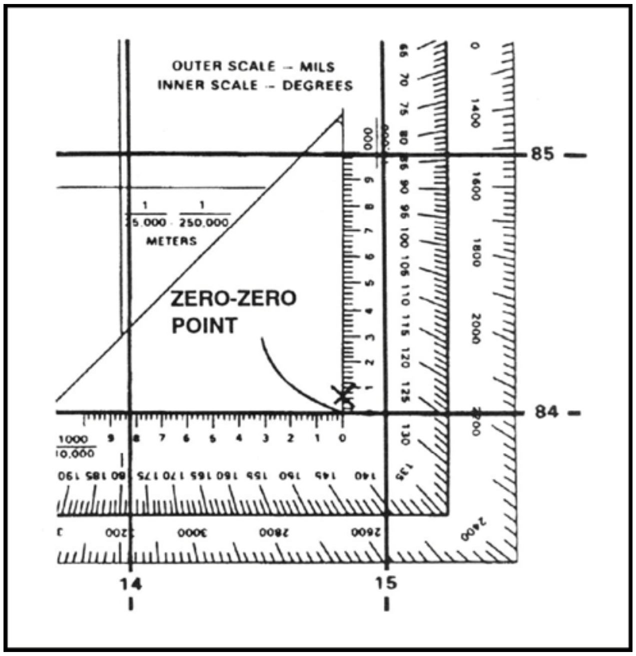
OUTER SCALE – MILS
INNER SCALE – DEGREES
1/25,000 – 1/250,000
METERS
ZERO-ZERO POINT
1000/10,000
85
84
14
15

Figure 4-17. Zero-zero point.

c. **1:50,000 Coordinating Scale**. On the 1:50,000 coordinate scale, there are two sides: vertical and horizontal. These sides are 1,000 meters in length. The point at which the sides meet is the zero-zero point. Each side is divided into 10 equal 100-meter segments by a long tick mark and number. Each 100-meter segment is subdivided into 50-meter segments by a short tick mark (Figure 4-18). By using interpolation, mentally divide each 50-meter segment into tenths. For example, a point that lies after a whole number but before a short tick mark is identified as 10, 20, 30, or 40 meters and any point that lies after the short tick mark but before the whole number is identified as 60, 70, 80, or 90 meters.

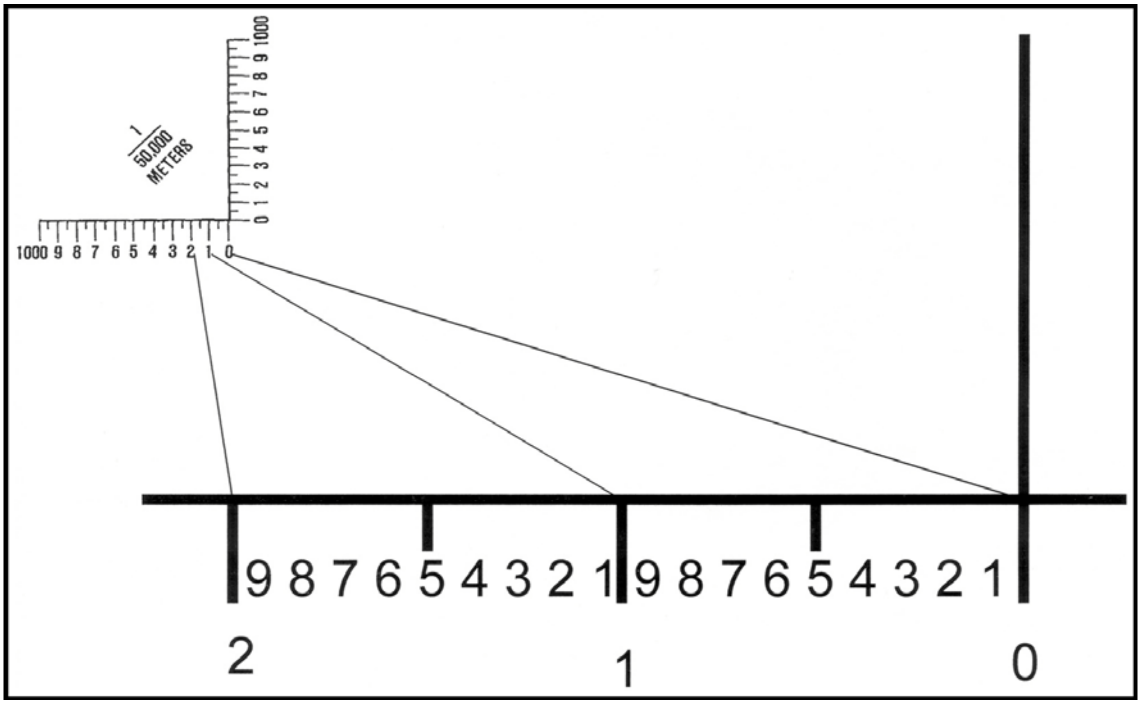

Figure 4-18. 1:50,000 coordinating scale.

d. **Example of Obtaining an Eight-Digit Coordinate Using 1:50,000 Scale**. To ensure the scale is correctly aligned, place it with the zero-zero point at the lower left corner of the grid square. Keeping the horizontal line of the scale directly on top of the east-west grid line, slide the scale to the right until the vertical line of the scale touches the point for which the coordinates are desired (Figure 4-19, page 4-21). Reading **right**, you can see that the point lies **530** meters to the right into the grid square, which gives a right reading of **7853**. Reading **up**, you can see that the point lies **320** meters up into the grid square, giving an up reading of **0032**.

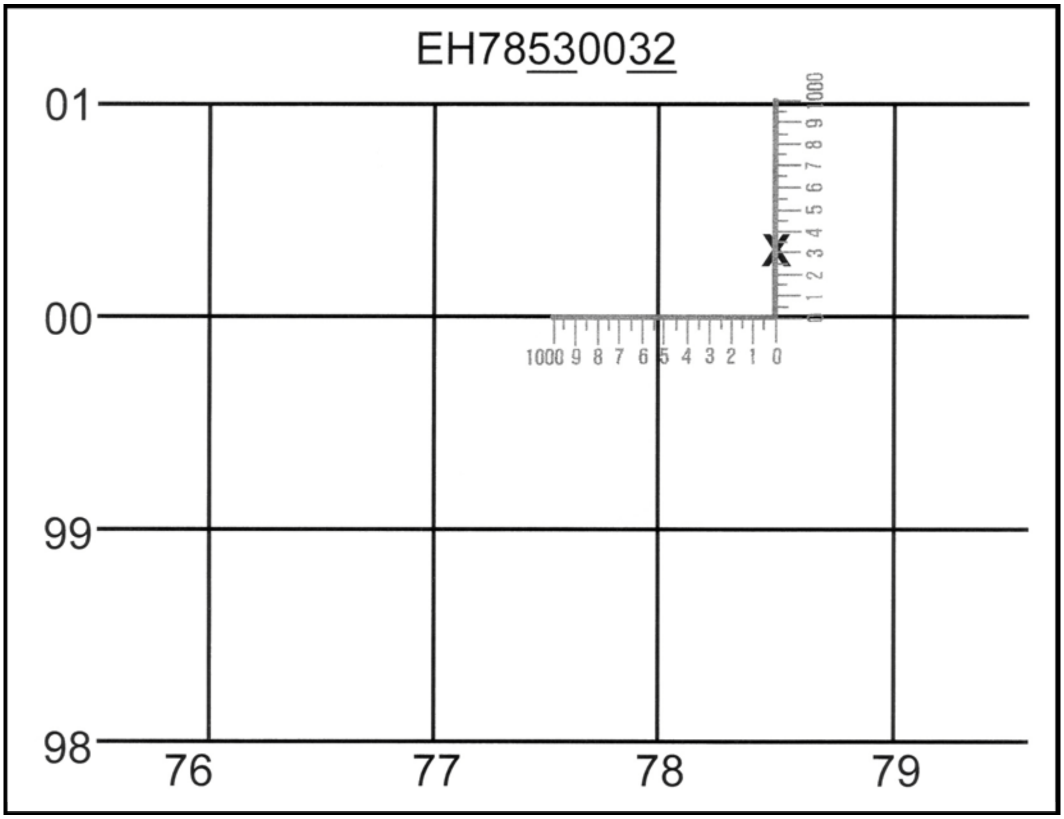

Figure 4-19. Example of obtaining an eight-digit coordinate using 1:50,000 scale.

e. **Recording and Reporting Grid Coordinates**. Coordinates are written as one continuous number without spaces, parentheses, dashes, or decimal points; they must always contain an even number of digits. Therefore, whoever is to use the written coordinates must know where to make the split between the RIGHT and UP readings. It is a military requirement that the 100,000-meter square identification letters be included in any point designation. Normally, grid coordinates are determined to the nearest 100 meters (six digits) for reporting locations. With practice, this can be done without using plotting scales. The location of targets and other point locations for fire support are determined to the nearest 10 meters (eight digits).

NOTE: Special care should be exercised when recording and reporting coordinates. Transposing numbers or making errors could be detrimental to military operations.

4-6. LOCATE A POINT USING THE US ARMY MILITARY GRID REFERENCE SYSTEM

There is only one rule to remember when reading or reporting grid coordinates—always read to the RIGHT and then UP. The first half of the reported set of coordinate digits represents the left-to-right (easting) grid label, and the second half represents the label as read from the bottom to top (northing). The grid coordinates may represent the location to the nearest 10-, 100-, or 1,000-meter increment.

a. **Grid Zone**. The number 16 locates a point within zone 16, which is an area 6° wide and extends between 80°S latitude and 84°N latitude (Figure 4-8, page 4-11).

b. **Grid Zone Designation**. The number and letter combination, 16S, further locates a point within the grid zone designation 16S, which is a quadrangle 6° wide by 8° high. There are 19 of these quads in zone 16. Quad X, which is located between 72°N and 84°N latitude, is 12° high (Figure 4-8, page 4-11).

c. **100,000-Meter Square Identification**. The addition of two more letters locates a point within the 100,000-meter grid square. Thus 16SGL (Figure 4-11, page 4-14) locates the point within the 100,000-meter square GL in the grid zone designation 16S. For information on the lettering system of 100,000-meter squares, see TM 5-241-1.

d. **10,000-Meter Square**. The breakdown of the US Army military grid reference system continues as each side of the 100,000-meter square is divided into 10 equal parts. This division produces lines that are 10,000 meters apart. Thus the coordinates 16SGL08 would locate a point as shown in Figure 4-20. The 10,000-meter grid lines appear as index (heavier) grid lines on maps at 1:100,000 and larger.

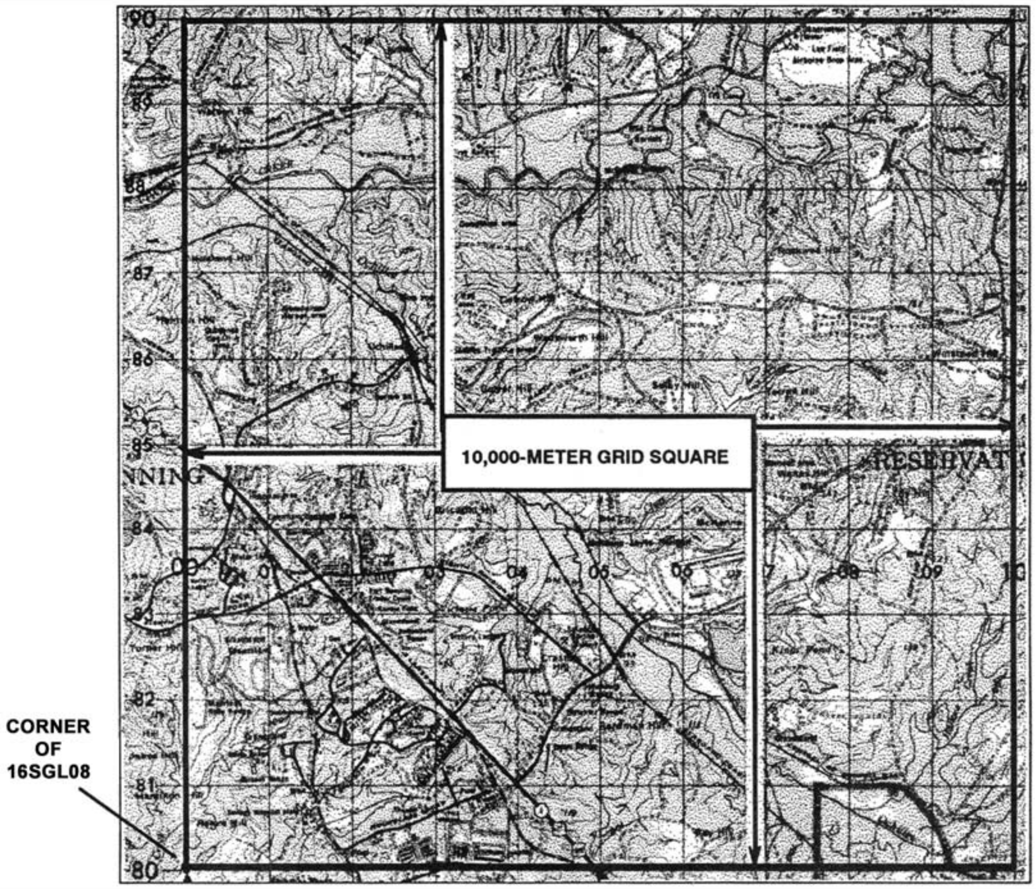

Figure 4-20. The 10,000-meter grid square.

e. **1,000-Meter Square**. To obtain 1,000-meter squares, each side of the 10,000-meter square is divided into 10 equal parts. This division appears on large-scale maps as the actual grid lines; they are 1,000 meters apart. On the Columbus map, using coordinates 16SGL0182, the easting 01 and the northing 82 gives the location of the southwest corner of grid square 0182 or to the nearest 1,000 meters of a point on the map (Figure 4-21).

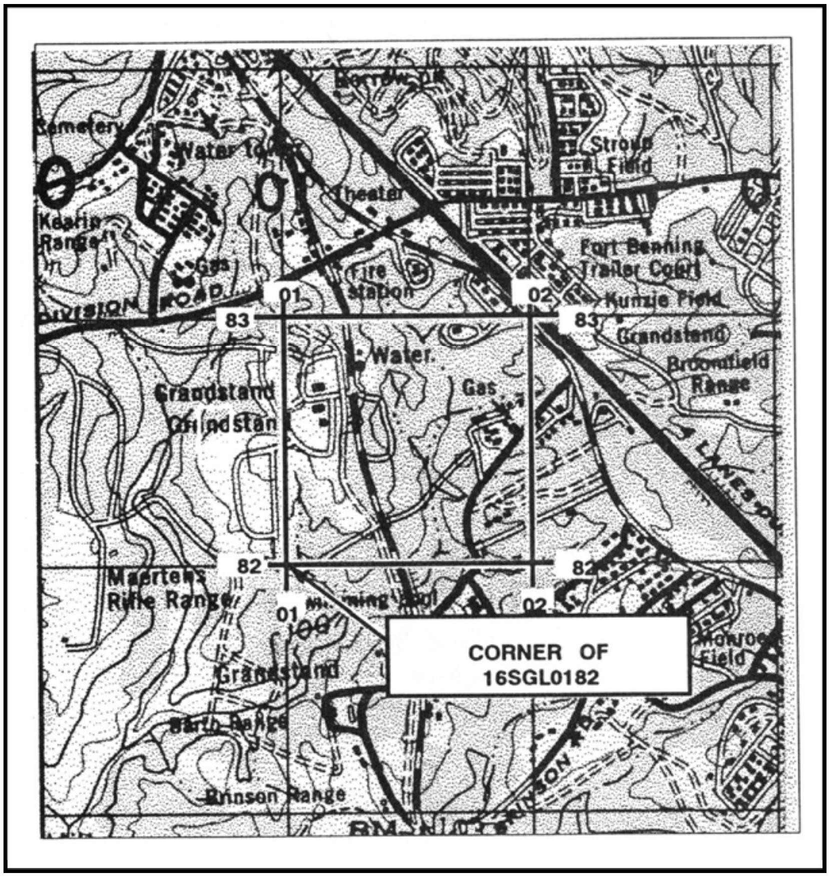
Cemetery
Water Tower
Theater
Stroup Field
Fire Station
Gas
Fort Benning Trailer Court
Kunzie Field
Grandstand
Broomfield Range
DIVISION ROAD
01
02
83
83
Water
Gas
Grandstand
82
82
Maertens Rifle Range
01
02
Monroe Field
Grandstand
Earth Range
Brinson Range
CORNER OF
16SGL0182

Figure 4-21. The 1,000-meter grid square.

f. **100-Meter Identification**. To locate to the nearest 100 meters, the grid coordinate scale can be used to divide the 1,000-meter grid squares into 10 equal parts (Figure 4-22, page 4-24).

g. **10-Meter Identification**. The grid coordinate scale has divisions every 50 meters on the 1:50,000 scale and every 20 meters on the 1:25,000 scale. These can be used to estimate to the nearest 10 meters and give the location of one point on the earth's surface to the nearest 10 meters.

EXAMPLE: 16SGL01948253 (gas tank) (Figure 4-22).

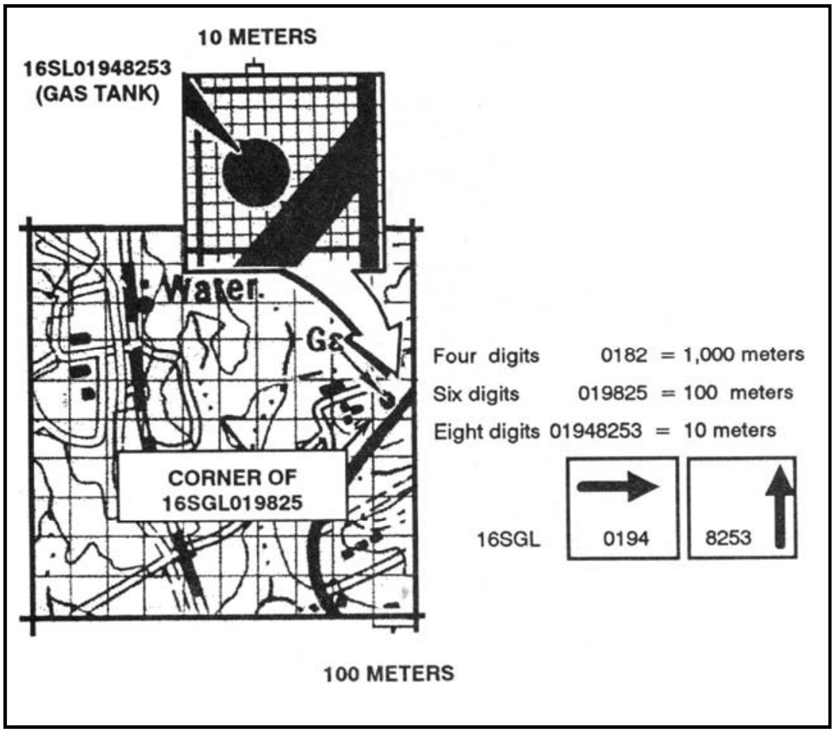
10 METERS
16SL01948253
(GAS TANK)
Water
Gas
CORNER OF
16SGL019825
Four digits 0182 = 1,000 meters
Six digits 019825 = 100 meters
Eight digits 01948253 = 10 meters
16SGL
0194
8253
100 METERS

Figure 4-22. The 100-meter and 10-meter grid squares.

h. **Precision.** The precision of a point's location is shown by the number of digits in the coordinates; the more digits, the more precise the location (Figure 4-22, insert).

4-7. GRID REFERENCE BOX

A grid reference box (Figure 4-23) appears in the marginal information of each map sheet. It contains step-by-step instructions for using the grid and the US Army military grid reference system. The grid reference box is divided into two parts.

a. The left portion identifies the grid zone designation and the 100,000-meter square. If the sheet falls in more than one 100,000-meter square, the grid lines that separate the squares are shown in the diagram and the letters identifying the 100,000-meter squares are given.

EXAMPLE: On the Columbus map sheet, the vertical line labeled 00 is the grid line that separates the two 100,000-meter squares, FL and GL. The left portion also shows a sample for the 1,000-meter square with its respective labeled grid coordinate numbers and a sample point within the 1,000-meter square.

b. The right portion of the grid reference box explains how to use the grid and is keyed on the sample 1,000-meter square of the left side. The following is an example of the military grid reference:

EXAMPLE: 16S locates the 6° by 8° area (grid zone designation).

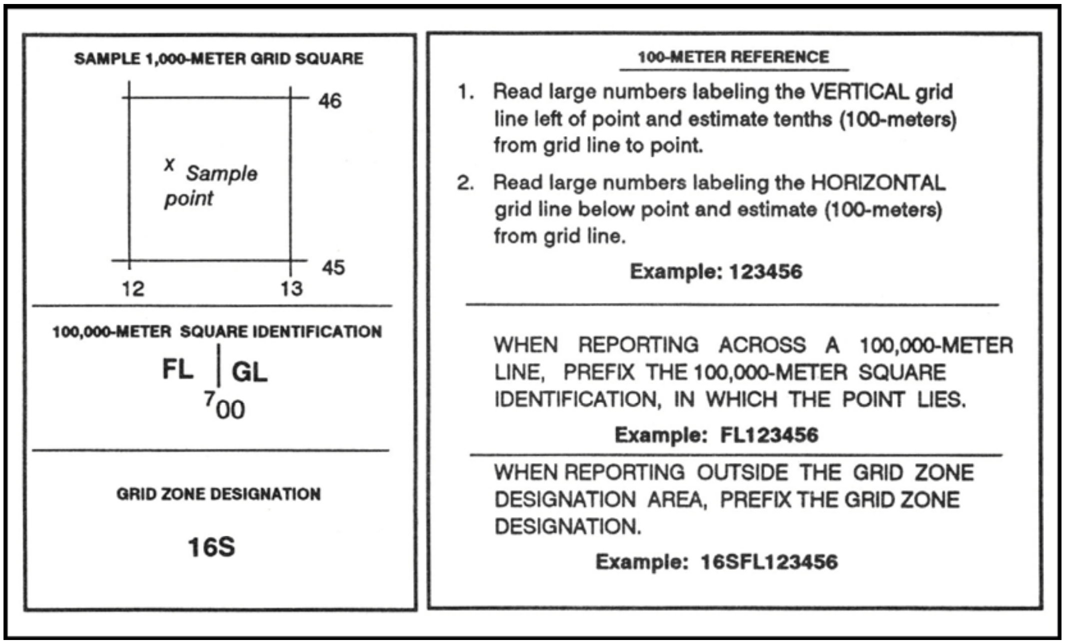
SAMPLE 1,000-METER GRID SQUARE
46
x Sample point
45
12
13
100,000-METER SQUARE IDENTIFICATION
FL
GL
700
GRID ZONE DESIGNATION
16S

100-METER REFERENCE

1. Read large numbers labeling the VERTICAL grid line left of point and estimate tenths (100-meters) from grid line to point.
2. Read large numbers labeling the HORIZONTAL grid line below point and estimate (100-meters) from grid line.

Example: 123456

WHEN REPORTING ACROSS A 100,000-METER LINE, PREFIX THE 100,000-METER SQUARE IDENTIFICATION, IN WHICH THE POINT LIES.

Example: FL123456

WHEN REPORTING OUTSIDE THE GRID ZONE DESIGNATION AREA, PREFIX THE GRID ZONE DESIGNATION.

Example: 16SFL123456

Figure 4-23. Grid reference box.

4-8. OTHER GRID SYSTEMS

The military grid reference system is not universally used. Soldiers must be prepared to interpret and use other grid systems, depending on the area of operations or the personnel the soldiers are operating with.

a. **British Grids**. In a few areas of the world, British grids are still shown on military maps. However, the British grid systems are being phased out. Eventually all military mapping will be converted to the UTM grid.

b. **World Geographic Reference System (GEOREF).** This system is a worldwide position reference system used primarily by the US Air Force. It may be used with any map or chart that has latitude and longitude printed on it. Instructions for using GEOREF data are printed in blue and are found in the margin of aeronautical charts (Figure 4-24, page 4-26). This system is based upon a division of the earth's surface into quadrangles of latitude and longitude having a systematic identification code. It is a method of expressing latitude and longitude in a form suitable for rapid reporting and plotting. Figure 4-24 illustrates a sample grid reference box using GEOREF. The GEOREF system uses an identification code that has three main divisions.

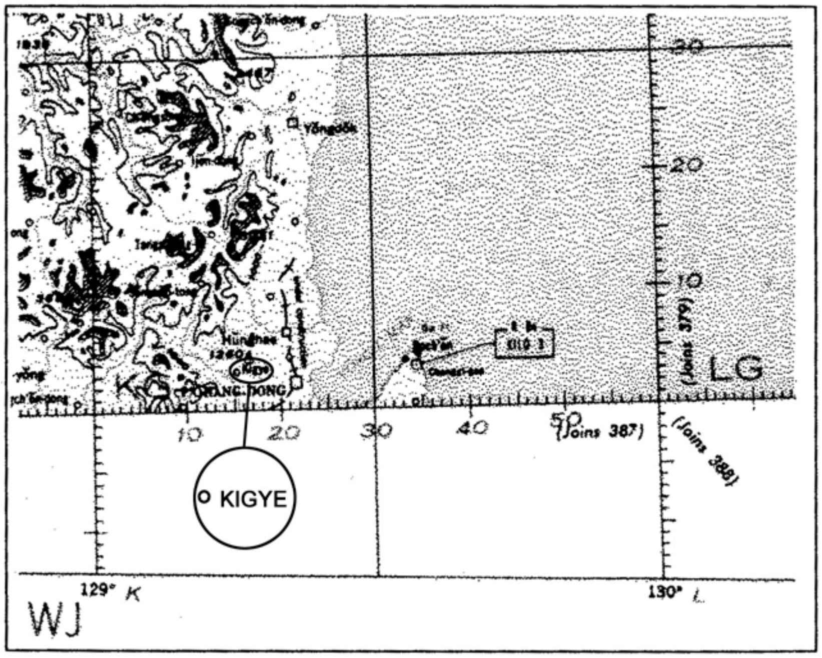

TO REFERENCE BY GEOREF (SHOWN IN BLUE) TO MINUTES

Select nearest intersection south and west of point.

Sample Point: KIGYE

1. **WJ identifies basic 15° quadrangle.**
2. **KG identifies 1° quadrangle.**
3. **15 identifies Georef minute of longitude.**
4. **03 identifies Georef minute of latitude.**
5. **Sample reference: WJKG 1503.**

Figure 4-24. Sample reference using GEOREF.

(1) ***First Division***. There are 24 north-south (longitudinal) zones, each 15-degree wide. These zones, starting at 180 degrees and progressing eastward, are lettered A through Z (omitting I and O). The first letter of any GEOREF coordinate identifies the north-south zone in which the point is located. There are 12 east-west (latitudinal) bands, each 15-degree wide. These bands are lettered A through M (omitting I) northward from the south pole. The second letter of any GEOREF coordinate identifies the east-west band in which the point is located. The zones and bands divide the earth's surface into 288 quadrangles, each identified by two letters.

(2) ***Second Division***. Each 15-degree quadrangle is further divided into 225 quadrangles of 1 degree each (15 degrees by 15 degrees). This division is effected by dividing a basic 15-degree quadrangle into 15 north-south zones and 15 east-west bands. The north-south zones are lettered A through Q (omitting I and O) from west to east. The third letter of any GEOREF coordinate identifies the 1 degree north-south zone within a 15-degree quadrangle. The east-west bands are lettered A through Q (I and O omitted) from south to north. The fourth letter of a GEOREF coordinate identifies the 1 degree east-west band within a 15-degree quadrangle. Four letters identify any 1-degree quadrangle in the world.

(3) ***Third Division***. Each of the 1-degree quadrangles is divided into 3,600 one-minute quadrangles. These one-minute quadrangles are formed by dividing the 1-degree quadrangles into 60 one-minute north-south zones numbered 0 through 59 from west to east, and 60 east-west bands numbered 0 to 59 from south to north. To designate any one of the 3,600 one-minute quadrangles requires four letters and four numbers. The rule READ RIGHT AND UP is always followed. Numbers 1 through 9 are written as 01, 02, and so forth. Each of the 1-minute quadrangles may be further divided into 10 smaller divisions both north-south and east-west, permitting the identification of 0.1-minute quadrangles. The GEOREF coordinate for any 0.1-minute quadrangle consists of four letters and six numbers.

4-9. PROTECTION OF MAP COORDINATES AND LOCATIONS

A disadvantage of any standard system of location is that the enemy, if he intercepts one of our messages using the system, can interpret the message and find our location. It is possible and can be eliminated by using an authorized low-level numerical code to express locations. Army Regulation 380-40 outlines the procedures for obtaining authorized codes.

a. The authorized numerical code provides a capability for encrypting map references and other numerical information that requires short-term security protection when, for operational reasons, the remainder of the message is transmitted in plain language. The system is published in easy-to-use booklets with sufficient material in each for one month's operation. Sample training editions of this type of system are available through the unit's communications and electronics officer.

b. The use of any encryption methods other than authorized codes is, by regulation, unauthorized and shall not be used.

CHAPTER 5
SCALE AND DISTANCE

A map is a scaled graphic representation of a portion of the earth's surface. The scale of the map permits the user to convert distance on the map to distance on the ground or vice versa. The ability to determine distance on a map, as well as on the earth's surface, is an important factor in planning and executing military missions.

5-1. REPRESENTATIVE FRACTION

The numerical scale of a map indicates the relationship of distance measured on a map and the corresponding distance on the ground. This scale is usually written as a fraction and is called the representative fraction. The RF is always written with the map distance as 1 and is independent of any unit of measure. (It could be yards, meters, inches, and so forth.) An RF of 1/50,000 or 1:50,000 means that one unit of measure on the map is equal to 50,000 units of the same measure on the ground.

a. The ground distance between two points is determined by measuring between the same two points on the map and then multiplying the map measurement by the denominator of the RF or scale (Figure 5-1, page 5-2).

EXAMPLE:

The map scale is 1:50,000
RF = 1/50,000
The map distance from point A to point B is 5 units
5 x 50,000 = 250,000 units of ground distance

b. Since the distance on most maps is marked in meters and the RF is expressed in this unit of measurement in most cases, a brief description of the metric system is needed. In the metric system, the standard unit of measurement is the meter.

1 meter contains 100 centimeters (cm).
100 meters is a regular football field plus 10 meters.
1,000 meters is 1 kilometer (km).
10 kilometers is 10,000 meters.

Appendix C contains the conversion tables.

c. The situation may arise when a map or sketch has no RF or scale. To be able to determine ground distance on such a map, the RF must be determined. There are two ways to do this:

(1) ***Comparison with Ground Distance***.

(a) Measure the distance between two points on the map—map distance (MD).

(b) Determine the horizontal distance between these same two points on the ground—ground distance (GD).

(c) Use the RF formula and remember that RF must be in the general form:

$$RF = \frac{1}{X} = \frac{MD}{GD}$$

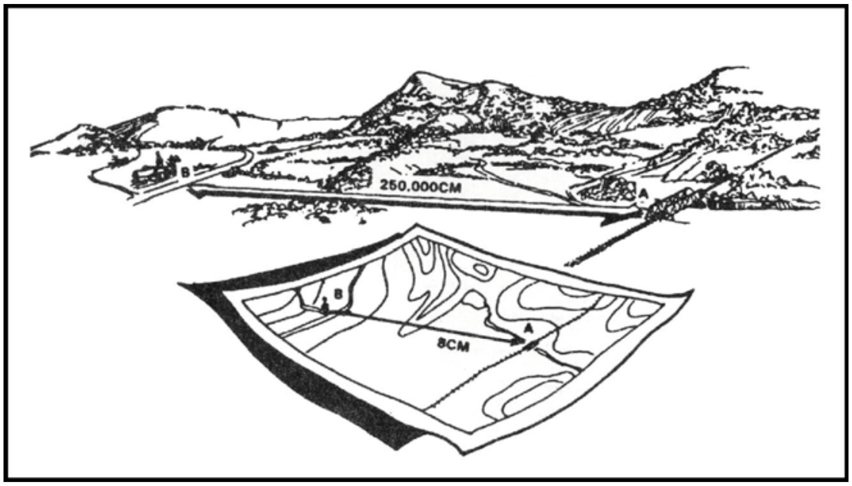

Figure 5-1. Converting map distance to ground distance.

(d) Both the MD and the GD must be in the same unit of measure and the MD must be reduced to 1.

EXAMPLE:

MD = 4.32 centimeters

GD = 2.16 kilometers
(216,000 centimeters)

$$RF = \frac{1}{X} = \frac{4.32}{216,000}$$

or

$$\frac{216,000}{4.32} = 50,000$$

therefore

$$RF = \frac{1}{50,000} \quad or \quad 1:50,000$$

(2) ***Comparison With Another Map of the Same Area that Has an RF***.

(a) Select two points on the map with the unknown RF. Measure the distance (MD) between them.

(b) Locate those same two points on the map that have the known RF. Measure the distance (MD) between them. Using the RF for this map, determine GD, which is the same for both maps.

(c) Using the GD and the MD from the first map, determine the RF using the formula:

$$RF = \frac{1}{X} = \frac{MD}{GD}$$

d. Occasionally it may be necessary to determine map distance from a known ground distance and the RF:

$$MD = \frac{GD}{\text{Denominator or RF}}$$

$$\text{Ground Distance} = 2{,}200 \text{ meters}$$

$$RF = 1:50{,}000$$

$$MD = \frac{2{,}200 \text{ meters}}{50{,}000}$$

$$MD = 0.044 \text{ meters} \times 100 \text{ (centimeters per meter)}$$

$$MD = 4.4 \text{ centimeters}$$

e. When determining ground distance from a map, the scale of the map affects the accuracy. As the scale becomes smaller, the accuracy of measurement decreases because some of the features on the map must be exaggerated so that they may be readily identified.

5-2. GRAPHIC (BAR) SCALES

A graphic scale is a ruler printed on the map and is used to convert distances on the map to actual ground distances. The graphic scale is divided into two parts. To the right of the zero, the scale is marked in full units of measure and is called the primary scale. To the left of the zero, the scale is divided into tenths and is called the extension scale. Most maps have three or more graphic scales, each using a different unit of measure (Figure 5-2). When using the graphic scale, be sure to use the correct scale for the unit of measure desired.

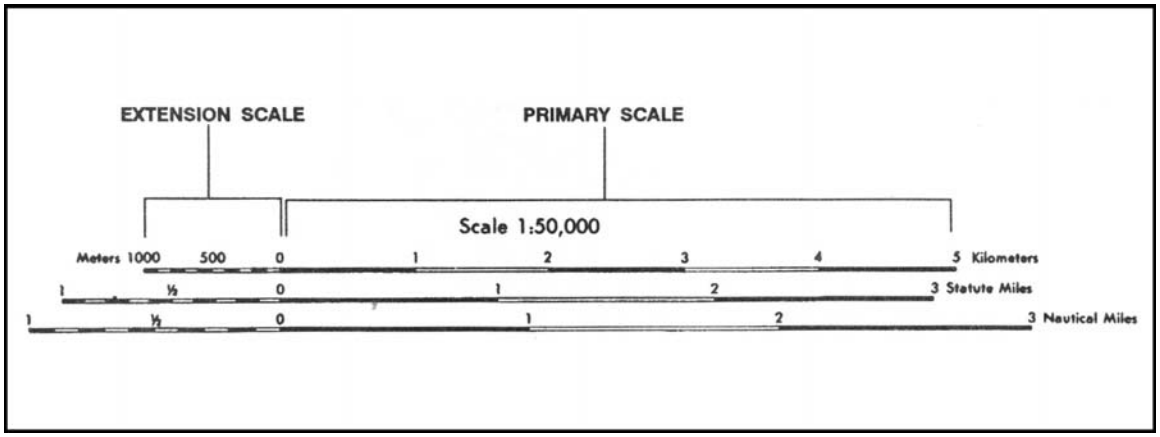
EXTENSION SCALE
PRIMARY SCALE
Scale 1:50,000
Meters 1000 500 0 1 2 3 4 5 Kilometers
1 ½ 0 1 2 3 Statute Miles
1 ½ 0 1 2 3 Nautical Miles

Figure 5-2. Using a graphic (bar) scale.

a. To determine straight-line distance between two points on a map, lay a straight-edged piece of paper on the map so that the edge of the paper touches both points and extends past them. Make a tick mark on the edge of the paper at each point (Figure 5-3).

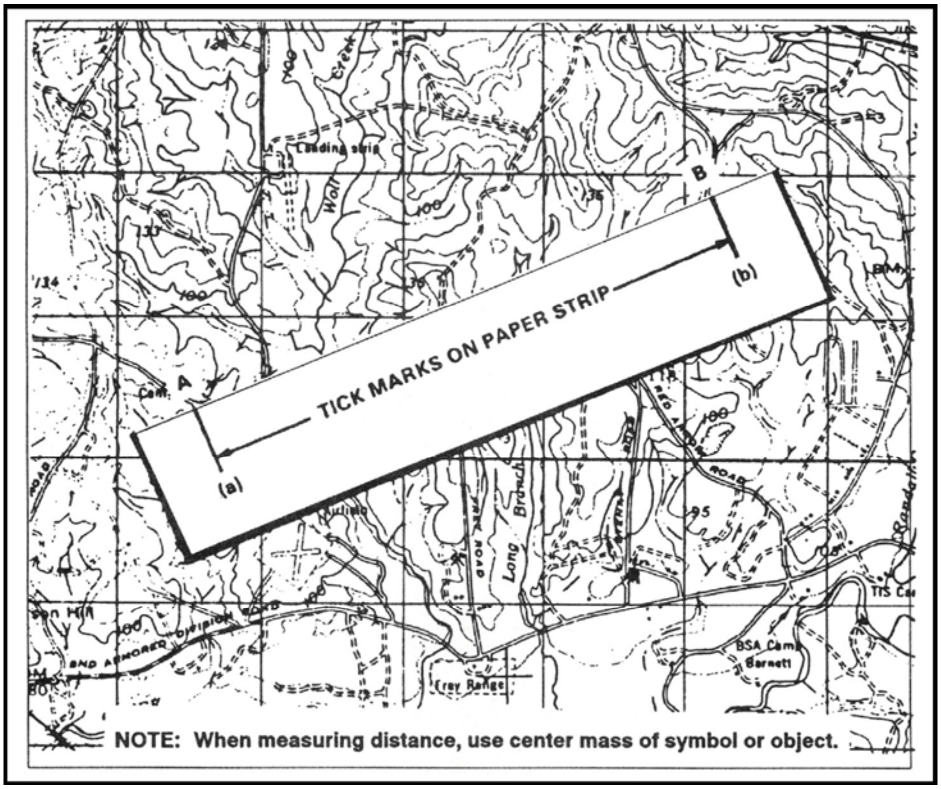
B
A
(a)
TICK MARKS ON PAPER STRIP
(b)
Landing strip
Wolf
Creek
Long
Branch
BSA Camp
Barnett
Gray Range
ROAD

NOTE: When measuring distance, use center mass of symbol or object.

Figure 5-3. Transferring map distance to paper strip.

b. To convert the map distance to ground distance, move the paper down to the graphic bar scale, and align the right tick mark (b) with a printed number in the primary scale so that the left tick mark (a) is in the extension scale (Figure 5-4).

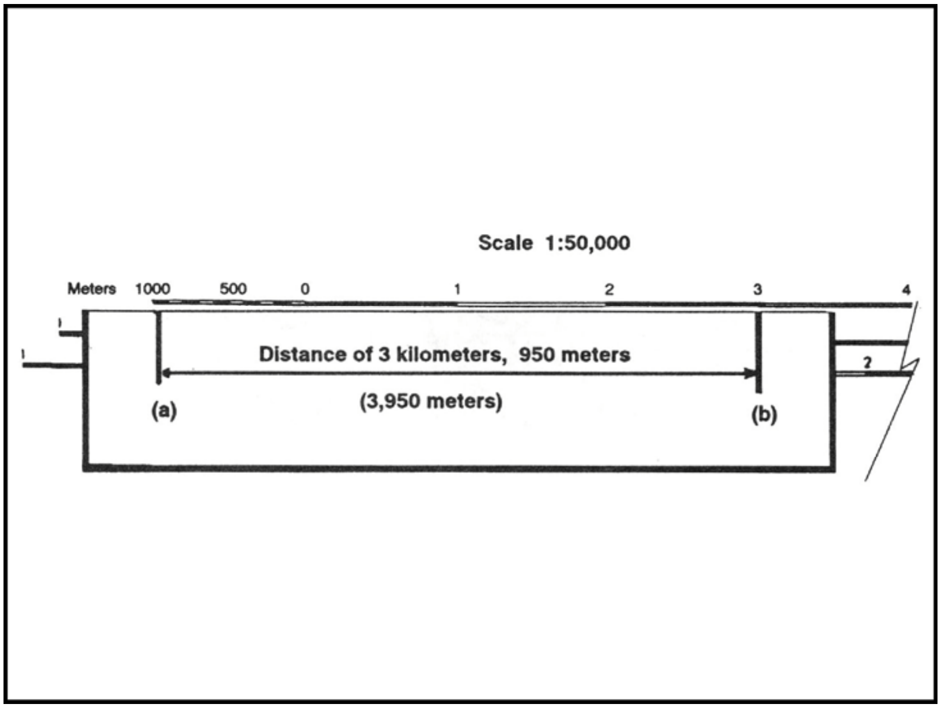
Scale 1:50,000
Meters 1000 500 0 1 2 3 4
Distance of 3 kilometers, 950 meters
(3,950 meters)
(a)
(b)

Figure 5-4. Measuring straight-line map distance.

c. The right tick mark (b) is aligned with the 3,000-meter mark in the primary scale, thus the distance is at least 3,000 meters. To determine the distance between the two points to the nearest 10 meters, look at the extension scale. The extension scale is numbered with zero at the right and increases to the left. When using the extension scale, always read right to left (Figure 5-4). From the zero left to the beginning of the first shaded area is 100 meters. From the beginning of the shaded square to the end of the shaded square is 100 to 200 meters. From the end of the first shaded square to the beginning of the second shaded square is 200 to 300 meters. Remember, the distance in the extension scale increases from right to left.

d. To determine the distance from the zero to tick mark (a), divide the distance inside the squares into tenths (Figure 5-4). As you break down the distance between the squares in the extension scale into tenths, you will see that tick mark (a) is aligned with the 950-meter mark. Adding the distance of 3,000 meters determined in the primary scale to the 950 meters you determined by using the extension scale, we find that the total distance between points (a) and (b) is 3,950 meters.

e. To measure distance along a road, stream, or other curved line, the straight edge of a piece of paper is used. In order to avoid confusion concerning the point to begin measuring from and the ending point, an eight-digit coordinate should be given for both the starting and ending points. Place a tick mark on the paper and map at the beginning point from which the curved line is to be measured. Align the edge of the paper along a straight portion and make a tick mark on both map and paper when the edge of the paper leaves the straight portion of the line being measured (Figure 5-5A, page 5-7).

f. Keeping both tick marks together (on paper and map), place the point of the pencil close to the edge of the paper on the tick mark to hold it in place and pivot the paper until another straight portion of the curved line is aligned with the edge of the paper. Continue in this manner until the measurement is completed (Figure 5-5B, page 5-7).

g. When you have completed measuring the distance, move the paper to the graphic scale to determine the ground distance. The only tick marks you will be measuring the distance between are tick marks (a) and (b). The tick marks in between are not used (Figure 5-5C, page 5-7).

h. There may be times when the distance you measure on the edge of the paper exceeds the graphic scale. In this case, there are different techniques you can use to determine the distance.

(1) One technique is to align the right tick mark (b) with a printed number in the primary scale, in this case the 5. You can see that from point (a) to point (b) is more than 6,000 meters when you add the 1,000 meters in the extension scale. To determine the exact distance to the nearest 10 meters, place a tick mark (c) on the edge of the paper at the end of the extension scale (Figure 5-6A, page 5-8). You know that from point (b) to point (c) is 6,000 meters. With the tick mark (c) placed on the edge of the paper at the end of the extension scale, slide the paper to the right. Remember the distance in the extension is always read from right to left. Align tick mark (c) with zero and then measure the distance between tick marks (a) and (c). The distance between tick marks (a) and (c) is 420 meters. The total ground distance between start and finish points is 6,420 meters (Figure 5-6B, page 5-8).

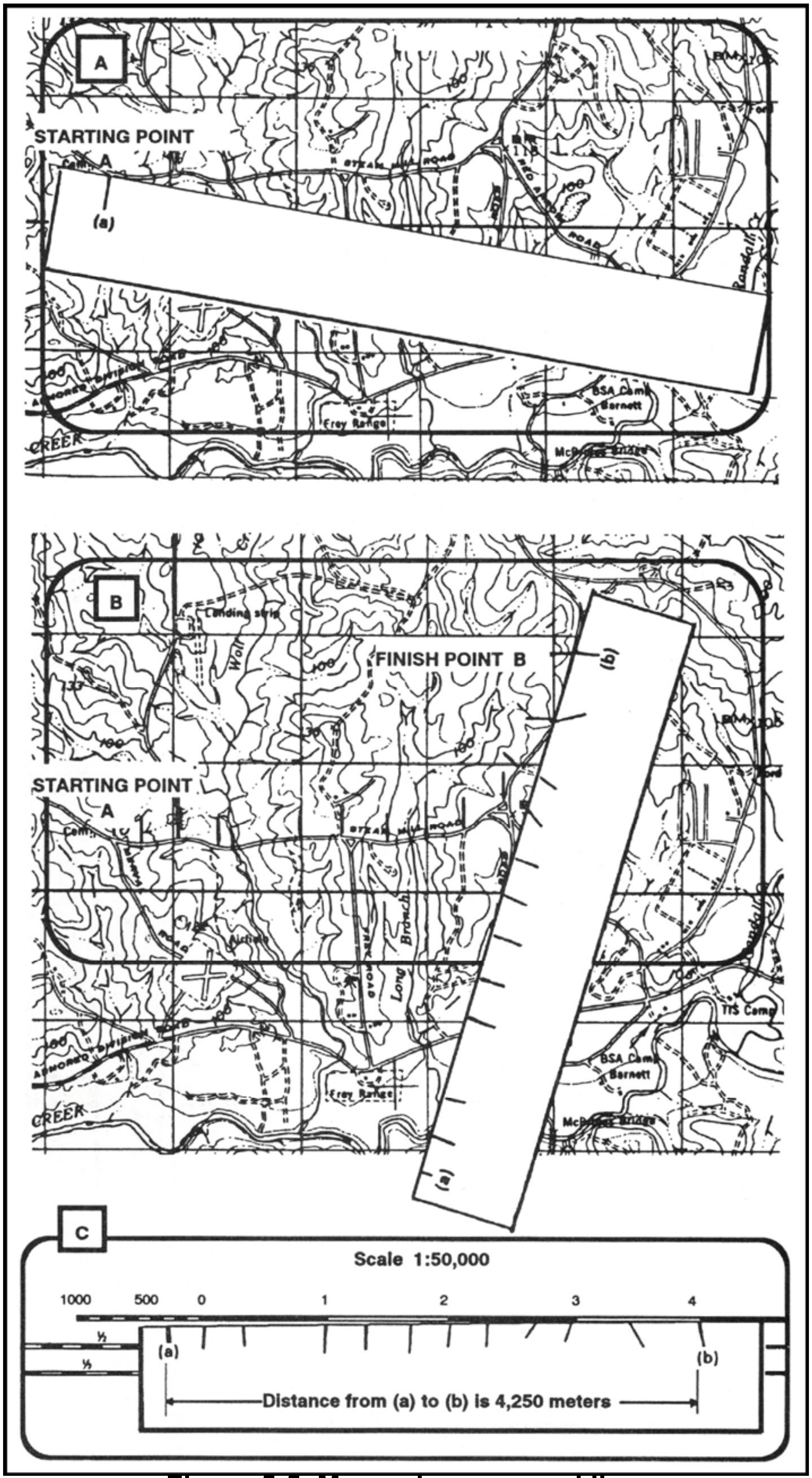
A
STARTING POINT
A
(a)
Steam Mill Road
BSA Camp Barnett
Frey Range
McBride Bridge
CREEK
B
Landing strip
FINISH POINT B
(b)
STARTING POINT
A
Long Branch
Airfield
TTS Camp
(a)
C
Scale 1:50,000
1000
500
0
1
2
3
4
½
½
(a)
(b)
Distance from (a) to (b) is 4,250 meters

Figure 5-5. Measuring a curved line.

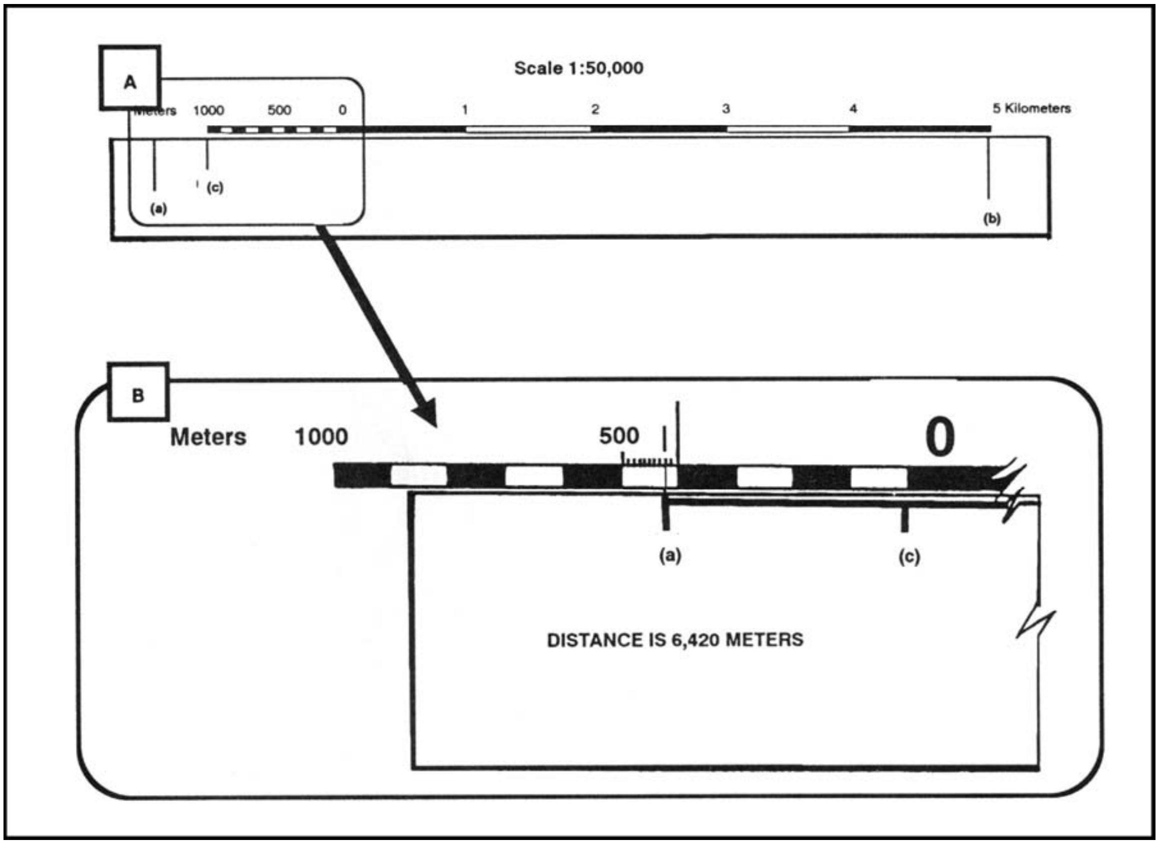

Figure 5-6. Determining the exact distance.

(2) Another technique that may be used to determine exact distance between two points when the edge of the paper exceeds the bar scale is to slide the edge of the paper to the right until tick mark (a) is aligned with the edge of the extension scale. Make a tick mark on the paper, in line with the 2,000-meter mark (c) (Figure 5-7A). Then slide the edge of the paper to the left until tick mark (b) is aligned with the zero. Estimate the 100-meter increments into 10-meter increments to determine how many meters tick mark (c) is from the zero line (Figure 5-7B). The total distance would be 3,030 meters.

(3) At times you may want to know the distance from a point on the map to a point off the map. In order to do this, measure the distance from the start point to the edge of the map. The marginal notes give the road distance from the edge of the map to some towns, highways, or junctions off the map. To determine the total distance, add the distance measured on the map to the distance given in the marginal notes. Be sure the unit of measure is the same.

(4) When measuring distance in statute or nautical miles, round it off to the nearest one-tenth of a mile and make sure the appropriate bar scale is used.

(5) Distance measured on a map does not take into consideration the rise and fall of the land. All distances measured by using the map and graphic scales are flat distances. Therefore, the distance measured on a map will increase when actually measured on the ground. This must be taken into consideration when navigating across country.

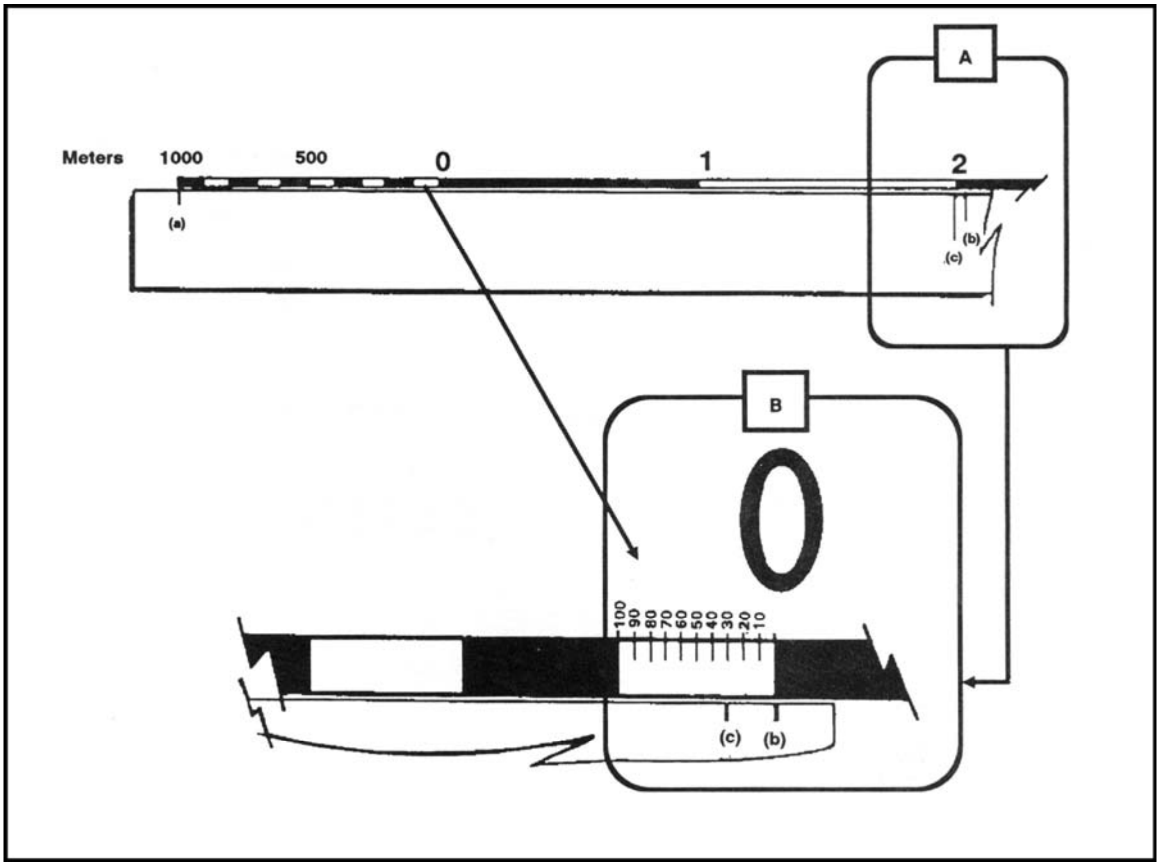

Figure 5-7. Reading the extension scale.

i. The amount of time required to travel a certain distance on the ground is an important factor in most military operations. This can be determined if a map of the area is available and a graphic time-distance scale is constructed for use with the map as follows:

R = Rate of travel (speed)
D = Distance (ground distance)
T = Time

$$T = \frac{D}{R}$$

For example, if an infantry unit is marching at an average rate (R) of 4 kilometers per hour, it will take about 3 hours (T) to travel 12 kilometers.

$$\frac{12\ (D)}{4\ (R)} = 3\ (T)$$

j. To construct a time-distance scale (Figure 5-8A), knowing your length of march, rate of speed, and map scale, that is, 12 kilometers at 3 kilometers per hour on a 1:50,000-scale map, use the following process:

(1) Mark off the total distance on a line by referring to the graphic scale of the map or, if this is impracticable, compute the length of the line as follows:

(a) Convert the ground distance to centimeters: 12 kilometers x 100,000 (centimeters per kilometer) = 1,200,000 centimeters.

(b) Find the length of the line to represent the distance at map scale—

$$MD = \frac{1}{50{,}000} = \frac{1{,}200{,}000}{50{,}000} = 24 \text{ centimeters}$$

(c) Construct a line 24 centimeters in length (Figure 5-8A).

(2) Divide the line by the rate of march into three parts (Figure 5-8B), each part representing the distance traveled in one hour, and label.

(3) Divide the scale extension (left portion) into the desired number of lesser time divisions—

1-minute divisions — 60
5-minute divisions — 12
10-minute divisions — 6

(4) Figure 5-8C shows a 5-minute interval scale. Make these divisions in the same manner as for a graphic scale. The completed scale makes it possible to determine where the unit will be at any given time. However, it must be remembered that this scale is for one specific rate of march only, 4 kilometers per hour.

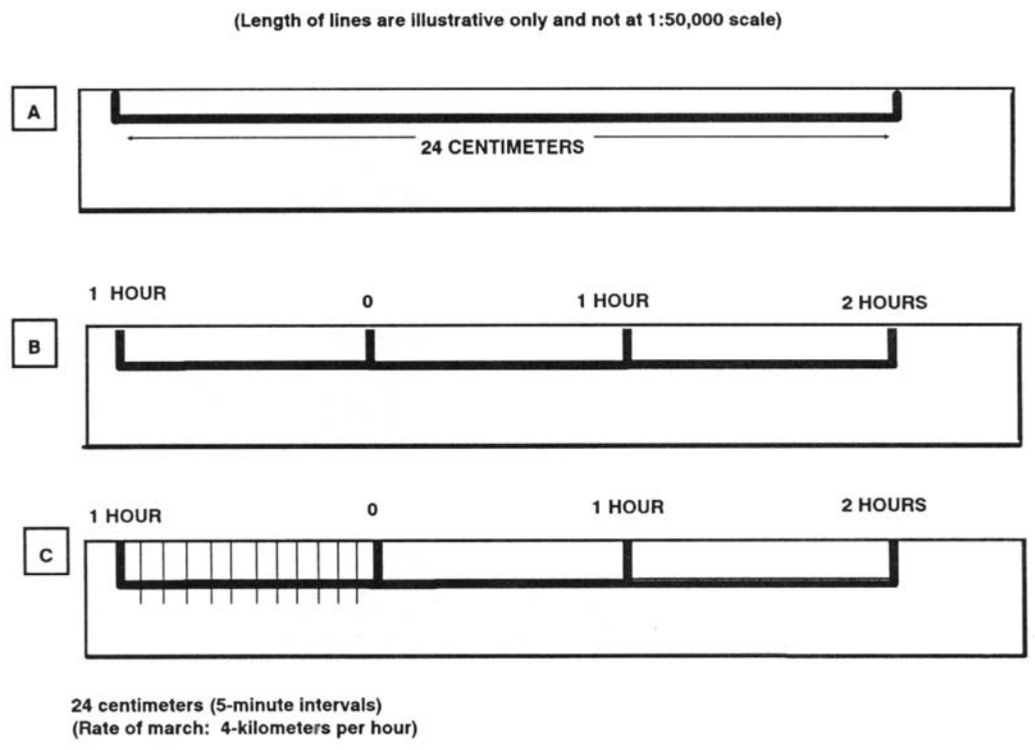
(Length of lines are illustrative only and not at 1:50,000 scale)
A
24 CENTIMETERS
1 HOUR
0
1 HOUR
2 HOURS
B
1 HOUR
0
1 HOUR
2 HOURS
C
24 centimeters (5-minute intervals)
(Rate of march: 4-kilometers per hour)

Figure 5-8. Constructing a time-distance scale.

5-3. OTHER METHODS

Determining distance is the most common source of error encountered while moving either mounted or dismounted. There may be circumstances where you are unable to determine distance using your map or where you are without a map. It is therefore essential to learn methods by which you can accurately pace, measure, use subtense, or estimate distances on the ground.

a. **Pace Count**. Another way to measure ground distance is the pace count. A pace is equal to one natural step, about 30 inches long. To accurately use the pace count method, you must know how many paces it takes you to walk 100 meters. To determine this, you must walk an accurately measured course and count the number of paces you take. A pace course can be as short as 100 meters or as long as 600 meters. The pace course, regardless of length, must be on similar terrain to that you will be walking over. It does no good to walk a course on flat terrain and then try to use that pace count on hilly terrain. To determine your pace count on a 600-meter course, count the paces it takes you to walk the 600 meters, then divide the total paces by 6. The answer will give you the average paces it takes you to walk 100 meters. It is important that each person who navigates while dismounted knows his pace count.

(1) There are many methods to keep track of the distance traveled when using the pace count. Some of these methods are: put a pebble in your pocket every time you have walked 100 meters according to your pace count; tie knots in a string; or put marks in a notebook. Do not try to remember the count; always use one of these methods or design your own method.

(2) Certain conditions affect your pace count in the field, and you must allow for them by making adjustments.

(a) *Slopes*. Your pace lengthens on a downslope and shortens on an upgrade. Keeping this in mind, if it normally takes you 120 paces to walk 100 meters, your pace count may increase to 130 or more when walking up a slope.

(b) *Winds*. A head wind shortens the pace and a tail wind increases it.

(c) *Surfaces*. Sand, gravel, mud, snow, and similar surface materials tend to shorten the pace.

(d) *Elements*. Falling snow, rain, or ice cause the pace to be reduced in length.

(e) *Clothing*. Excess clothing and boots with poor traction affect the pace length.

(f) *Visibility.* Poor visibility, such as in fog, rain, or darkness, will shorten your pace.

b. **Odometer**. Distances can be measured by an odometer, which is standard equipment on most vehicles. Readings are recorded at the start and end of a course and the difference is the length of the course.

(1) To convert kilometers to miles, multiply the number of kilometers by 0.62.

EXAMPLE:
16 *kilometers* = 16 x 0.62 = 9.92 *miles*

(2) To convert miles to kilometers, divided the number of miles by 0.62.

EXAMPLE:
10 *miles* = 10 *divided by* 0.62 = 16.12 *kilometers*

c. **Subtense**. The subtense method is a fast method of determining distance and yields accuracy equivalent to that obtained by measuring distance with a premeasured piece of wire. An advantage is that a horizontal distance is obtained indirectly; that is, the distance is computed rather than measured. This allows subtense to be used over terrain where obstacles such as streams, ravines, or steep slopes may prohibit other methods of determining distance.

(1) The principle used in determining distance by the subtense method is similar to that used in estimating distance by the mil relation formula. The field artillery application of the mil relation formula involves only estimations. It is not accurate enough for survey purposes. However, the subtense method uses precise values with a trigonometric solution. Subtense is based on a principle of visual perspective—the farther away an object, the smaller it appears.

(2) The following two procedures are involved in subtense measurement:

- Establishing a base of known length.
- Measuring the angle of that base by use of the aiming circle.

(3) The subtense base may be any desired length. However, if a 60-meter base, a 2-meter bar, or the length of an M16A1 or M16A2 rifle is used, precomputed subtense tables are available. The M16 or 2-meter bar must be held horizontal and perpendicular to the line of sight by a soldier facing the aiming circle. The instrument operator sights on one end of the M16 or 2-meter bar and measures the horizontal clockwise angle to the other end of the rifle or bar. He does this twice and averages the angles. He then enters the appropriate subtense table with the mean angle and extracts the distance. Accurate distances can be obtained with the M16 out to approximately 150 meters, with the 2-meter bar out to 250 meters, and with the 60-meter base out to 1,000 meters. If a base of another length is desired, a distance can be computed by using the following formula:

$$\textit{Distance} = \frac{\textit{1/2 (base in meters)}}{\textit{Tan (1/2) (in mils)}}$$

d. **Estimation**. At times, because of the tactical situation, it may be necessary to estimate range. There are two methods that may be used to estimate range or distance.

(1) ***100-Meter Unit-of-Measure Method***. To use this method, the soldier must be able to visualize a distance of 100 meters on the ground. For ranges up to 500 meters, he determines the number of 100-meter increments between the two objects he wishes to measure. Beyond 500 meters, the soldier must select a point halfway to the object(s) and determine the number of 100-meter increments to the halfway point, then double it to find the range to the object(s) (Figure 5-9).

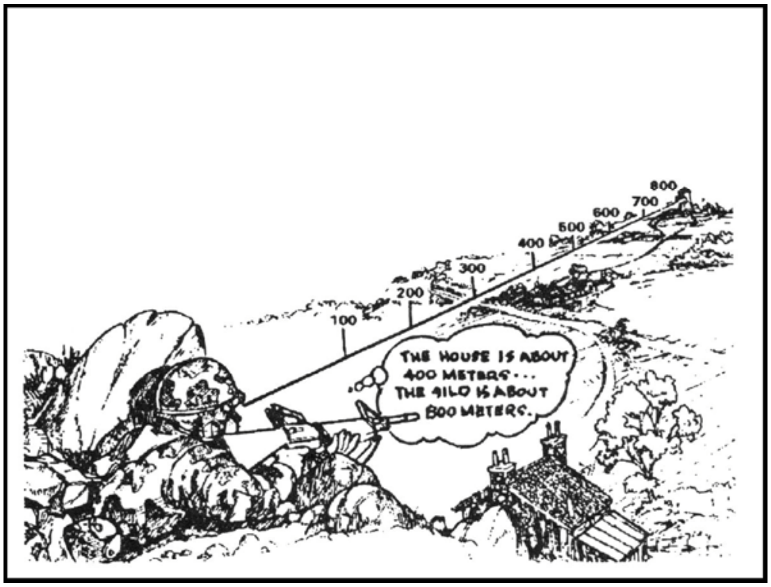
100
200
300
400
500
600
700
800
THE HOUSE IS ABOUT 400 METERS... THE SILO IS ABOUT 800 METERS.

Figure 5-9. Using a 100-meter unit-of-measure method.

(2) ***Flash-To-Bang Method***. To use this method to determine range to an explosion or enemy fire, begin to count when you see the flash. Count the seconds until you hear the weapon fire. This time interval may be measured with a stopwatch or by using a steady count, such as one-thousand-one, one-thousand-two, and so forth, for a three-second estimated count. If you must count higher than 10 seconds, start over with one. Multiply the number of seconds by 330 meters to get the approximate range (FA uses 350 meters instead).

(3) ***Proficiency of Methods***. The methods discussed above are used only to estimate range (Table 5-1). Proficiency in both methods requires constant practice. The best training technique is to require the soldier to pace the range after he has estimated the distance. In this way, the soldier discovers the actual range for himself, which makes a greater impression than if he is simply told the correct range.

Factors Affecting Range Estimation	Factors Causing Underestimation of Range	Factors Causing Overestimation of Range
The clearness of outline and details of the object.	When most of the object is visible and offers a clear outline.	When only a small part of the object can be seen or the object is small in relation to its surroundings.
Nature of terrain or position of the observer.	When looking across a depression that is mostly hidden from view. When looking downward from high ground. When looking down a straight, open road or along a railroad. When looking over uniform surfaces like water, snow, desert, or grain fields. In bright light or when the sun is shining from behind the observer.	When looking across a depression that is totally visible. When vision is confined, as in streets, draws, or forest trails. When looking from low ground toward high ground. In poor light, such as dawn and dusk; in rain, snow, fog; or when the sun is in the observer's eyes.
Light and atmosphere	When the object is in sharp contrast with the background or is silhouetted because of its size, shape, or color. When seen in the clear air of high altitudes.	When object blends into the background or terrain.

Table 5-1. Factors of range estimation.

CHAPTER 6
DIRECTION

Being in the right place at the prescribed time is necessary to successfully accomplish military missions. Direction plays an important role in a soldier's everyday life. It can be expressed as right, left, straight ahead, and so forth; but then the question arises, "To the right of what?" This chapter defines the word azimuth and the three different norths. It explains in detail how to determine the grid and the magnetic azimuths with the use of the protractor and the compass. It explains the use of some field-expedient methods to find directions, the declination diagram, and the conversion of azimuths from grid to magnetic and vice versa. It also includes some advanced aspects of map reading, such as intersection, resection, modified resection, and polar plots.

6-1. METHODS OF EXPRESSING DIRECTION

Military personnel need a way of expressing direction that is accurate, is adaptable to any part of the world, and has a common unit of measure. Directions are expressed as units of angular measure.

a. **Degree**. The most common unit of measure is the degree (°) with its subdivisions of minutes (') and seconds (").

1 degree = 60 minutes.

1 minute = 60 seconds.

b. **Mil.** Another unit of measure, the mil (abbreviated m̸), is used mainly in artillery, tank, and mortar gunnery. The mil expresses the size of an angle formed when a circle is divided into 6,400 angles, with the vertex of the angles at the center of the circle. A relationship can be established between degrees and mils. A circle equals 6400 mils divided by 360 degrees, or 17.78 mils per degree. To convert degrees to mils, multiply degrees by 17.78.

c. **Grad.** The grad is a metric unit of measure found on some foreign maps. There are 400 grads in a circle (a 90-degree right angle equals 100 grads). The grad is divided into 100 centesimal minutes (centigrads) and the minute into 100 centesimal seconds (milligrads).

6-2. BASE LINES

In order to measure something, there must always be a starting point or zero measurement. To express direction as a unit of angular measure, there must be a starting point or zero measure and a point of reference These two points designate the base or reference line. There are three base lines—true north, magnetic north, and grid north. The most commonly used are magnetic and grid.

a**. True North.** A line from any point on the earth's surface to the north pole. All lines of longitude are true north lines. True north is usually represented by a star (Figure 6-1, page 6-2).

b**. Magnetic North**. The direction to the north magnetic pole, as indicated by the north-seeking needle of a magnetic instrument. The magnetic north is usually symbolized by a line ending with half of an arrowhead (Figure 6-1). Magnetic readings are obtained with magnetic instruments, such as lensatic and M2 compasses.

c. **Grid North.** The north that is established by using the vertical grid lines on the map. Grid north may be symbolized by the letters GN or the letter "y" (Figure 6-1).

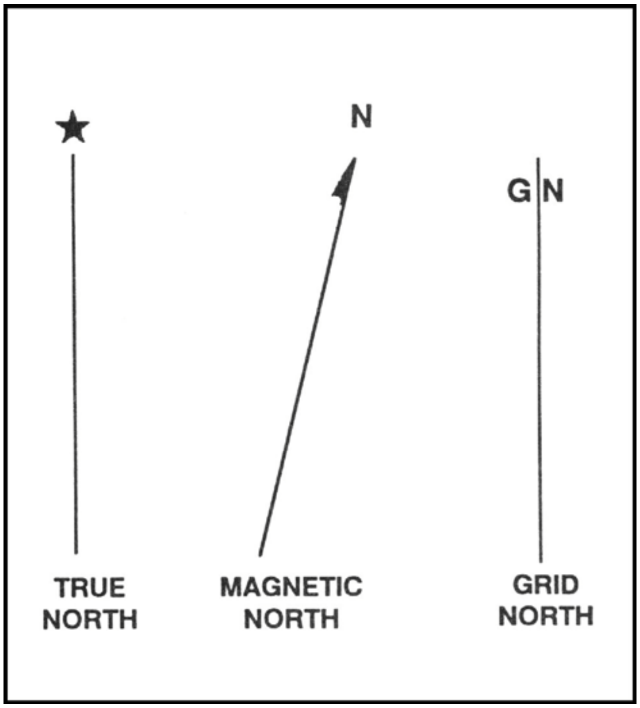

Figure 6-1. Three norths.

6-3. AZIMUTHS

An azimuth is defined as a horizontal angle measured clockwise from a north base line. This north base line could be true north, magnetic north, or grid north. The azimuth is the most common military method to express direction. When using an azimuth, the point from which the azimuth originates is the center of an imaginary circle (Figure 6-2). This circle is divided into 360 degrees or 6400 mils (Appendix G).

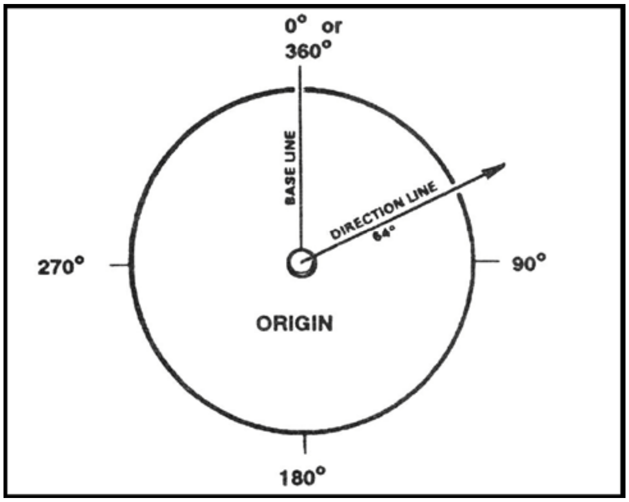

Figure 6-2. Origin of azimuth circle.

a. **Back Azimuth**. A back azimuth is the opposite direction of an azimuth. It is comparable to doing "about face." To obtain a back azimuth from an azimuth, add 180 degrees if the azimuth is 180 degrees or less, or subtract 180 degrees if the azimuth is 180 degrees or more (Figure 6-3). The back azimuth of 180 degrees may be stated as 0 degrees or 360 degrees. For mils, if the azimuth is less than 3200 mils, add 3200 mils, if the azimuth is more than 3200 mils, subtract 3200 mils.

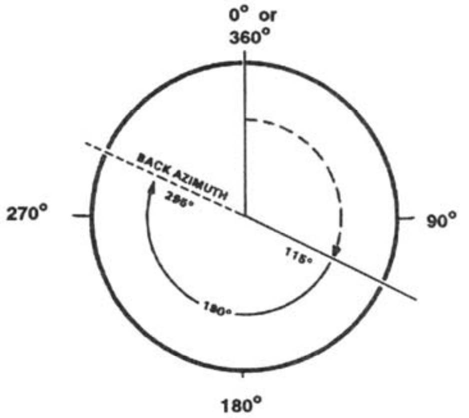

EXAMPLE:

Azimuth	±		Back Azimuth
115°	+180°	=	295°
337°=	- 180°	=	157°

Figure 6-3. Back azimuth.

WARNING

When converting azimuths into back azimuths, extreme care should be exercised when adding or subtracting the 180 degrees. A simple mathematical mistake could cause disastrous consequences.

b. **Magnetic Azimuth.** The magnetic azimuth is determined by using magnetic instruments, such as lensatic and M2 compasses. Refer to Chapter 9, paragraph 4, for details.

c. **Field-Expedient Methods**. Several field-expedient methods to determine direction are discussed in Chapter 9, paragraph 5.

6-4. GRID AZIMUTHS

When an azimuth is plotted on a map between point A (starting point) and point B (ending point), the points are joined together by a straight line. A protractor is used to measure the angle between grid north and the drawn line, and this measured azimuth is the grid azimuth (Figure 6-4).

WARNING

When measuring azimuths on a map, remember that you are measuring from a starting point to an ending point. If a mistake is made and the reading is taken from the ending point, the grid azimuth will be opposite, thus causing the user to go in the wrong direction.

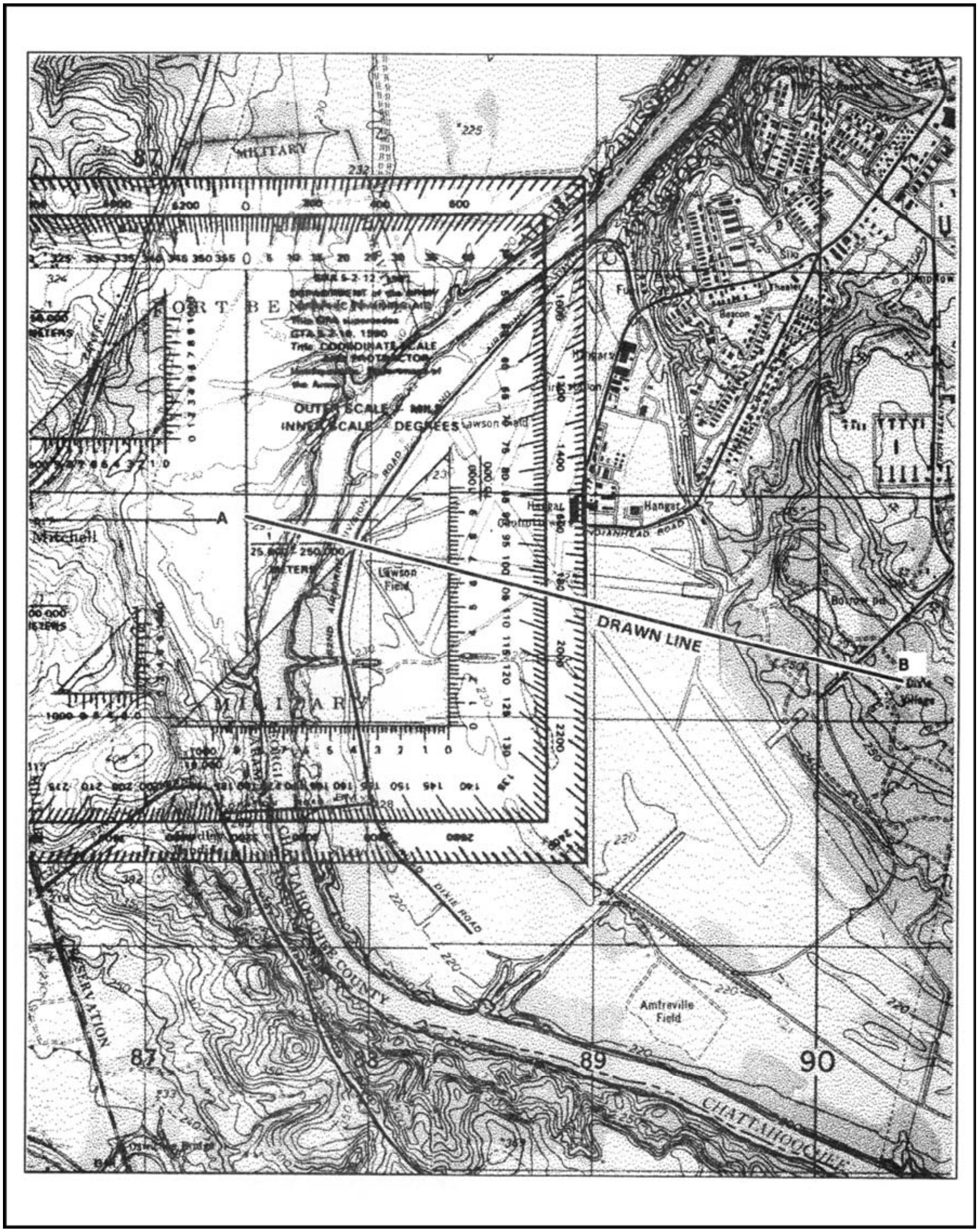
A
B
DRAWN LINE
OUTER SCALE — MILS
INNER SCALE — DEGREES
Lawson Field
Amtreville Field
DIXIE ROAD
MILITARY
CHATTAHOOCHEE
87
88
89
90

Figure 6-4. Measuring an azimuth.

6-5. PROTRACTOR

There are several types of protractors—full circle, half circle, square, and rectangular (Figure 6-5). All of them divide the circle into units of angular measure, and each has a scale around the outer edge and an index mark. The index mark is the center of the protractor circle from which all directions are measured.

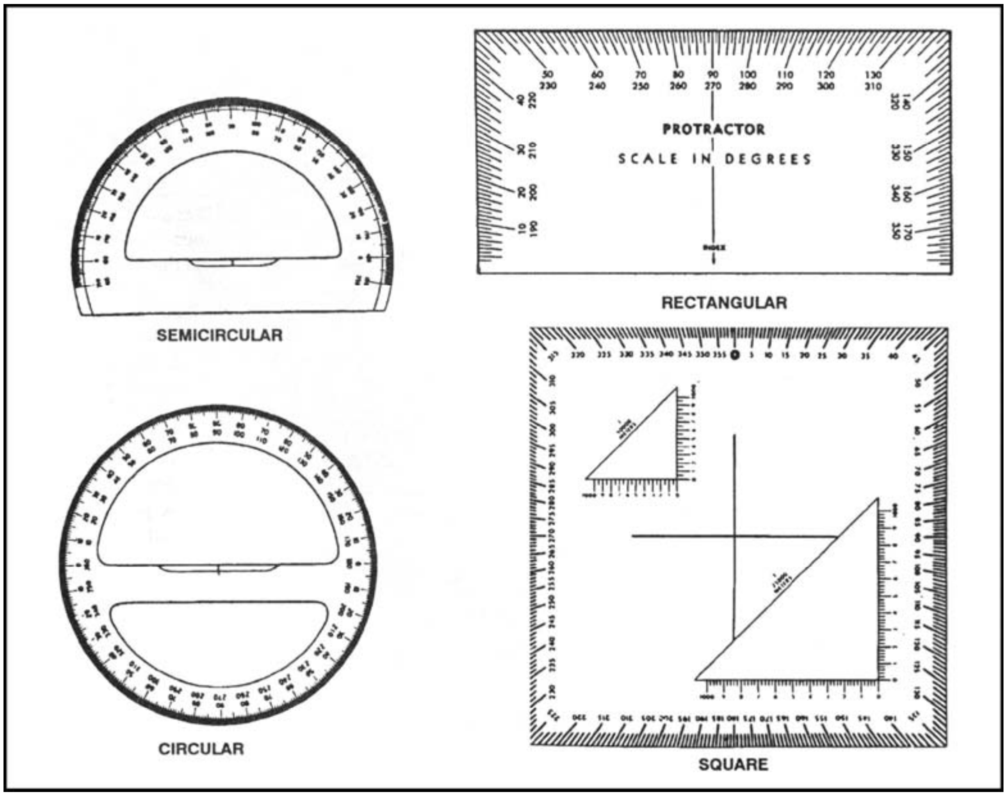
PROTRACTOR
SCALE IN DEGREES
INDEX
RECTANGULAR
SEMICIRCULAR
CIRCULAR
SQUARE

Figure 6-5. Types of protractors.

a. The military protractor, GTA 5-2-12, contains two scales: one in degrees (inner scale) and one in mils (outer scale). This protractor represents the azimuth circle. The degree scale is graduated from 0 to 360 degrees; each tick mark on the degree scale represents one degree. A line from 0 to 180 degrees is called the base line of the protractor. Where the base line intersects the horizontal line, between 90 and 270 degrees, is the index or center of the protractor (Figure 6-6).

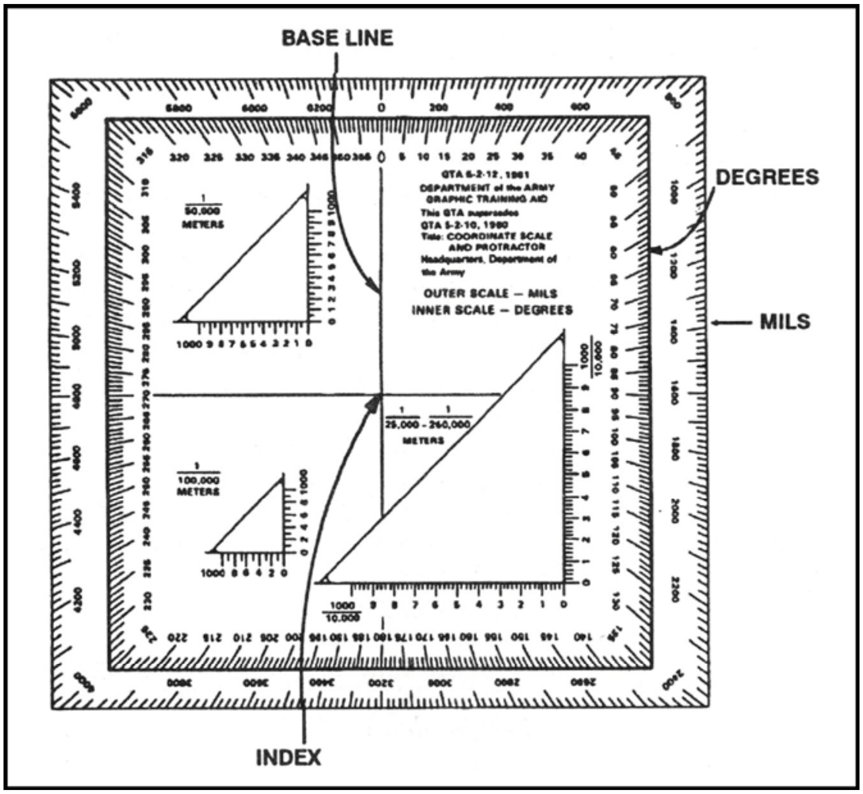
BASE LINE
DEGREES
MILS
INDEX
GTA 5-2-12, 1981
DEPARTMENT of the ARMY
GRAPHIC TRAINING AID
This GTA supersedes
GTA 5-2-10, 1980
Title: COORDINATE SCALE
AND PROTRACTOR
Headquarters, Department of
the Army
OUTER SCALE — MILS
INNER SCALE — DEGREES
1/50,000 METERS
1/25,000 - 1/250,000 METERS
1/100,000 METERS
1000/10,000

Figure 6-6. Military protractor.

b. When using the protractor, the base line is always oriented parallel to a north-south grid line. The 0- or 360-degree mark is always toward the top or north on the map and the 90° mark is to the right.

(1) To determine the grid azimuth—

(a) Draw a line connecting the two points (A and B).

(b) Place the index of the protractor at the point where the drawn line crosses a vertical (north-south) grid line.

(c) Keeping the index at this point, align the 0- to 180-degree line of the protractor on the vertical grid line.

(d) Read the value of the angle from the scale; this is the grid azimuth from point A to point B (Figure 6-4).

(2) To plot an azimuth from a known point on a map (Figure 6-7)—

(a) Convert the azimuth from magnetic to grid, if necessary. (See paragraph 6-6.)

(b) Place the protractor on the map with the index mark at the center of mass of the known point and the base line parallel to a north-south grid line.

(c) Make a mark on the map at the desired azimuth.

(d) Remove the protractor and draw a line connecting the known point and the mark on the map. This is the grid direction line (azimuth).

NOTE: When measuring an azimuth, the reading is always to the nearest degree or 10 mils. Distance does not change an accurately measured azimuth.

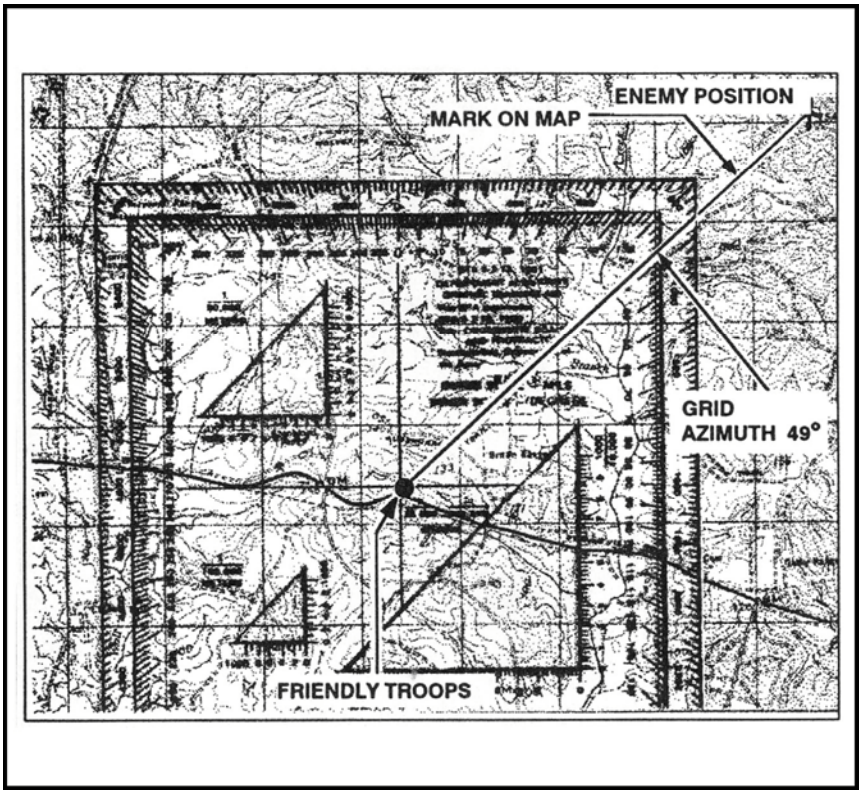

Figure 6-7. Plotting an azimuth on the map.

c. To obtain an accurate reading with the protractor (to the nearest degree or 10 mils), there are two techniques to check that the base line of the protractor is parallel to a north-south grid line.

(1) Place the protractor index where the azimuth line cuts a north-south grid line, aligning the base line of the protractor directly over the intersection of the azimuth line with the north-south grid line. The user should be able to determine whether the initial azimuth reading was correct.

(2) The user should re-read the azimuth between the azimuth and north-south grid line to check the initial azimuth.

(3) Note that the protractor is cut at both the top and bottom by the same north-south grid line. Count the number of degrees from the 0-degree mark at the top of the protractor to this north-south grid line and then count the number of degrees from the 180-degree mark at the bottom of the protractor to this same grid line. If the two counts are equal, the protractor is properly aligned.

6-6. DECLINATION DIAGRAM

Declination is the angular difference between any two norths. If you have a map and a compass, the one of most interest to you will be between magnetic and grid north. The declination diagram (Figure 6-8) shows the angular relationship, represented by prongs, among grid, magnetic, and true norths. While the relative positions of the prongs are correct, they are seldom plotted to scale. Do not use the diagram to measure a numerical value. This value will be written in the map margin (in both degrees and mils) beside the diagram.

a. **Location.** A declination diagram is a part of the information in the lower margin on most larger maps. On medium-scale maps, the declination information is shown by a note in the map margin.

b. **Grid-Magnetic Angle.** The G-M angle value is the angular size that exists between grid north and magnetic north. It is an arc, indicated by a dashed line, that connects the grid-north and magnetic-north prongs. This value is expressed to the nearest 1/2 degree, with mil equivalents shown to the nearest 10 mils. The G-M angle is important to the map reader/land navigator because azimuths translated between map and ground will be in error by the size of the declination angle if not adjusted for it.

c. **Grid Convergence**. An arc indicated by a dashed line connects the prongs for true north and grid north. The value of the angle for the center of the sheet is given to the nearest full minute with its equivalent to the nearest mil. These data are shown in the form of a grid-convergence note.

d. **Conversion.** There is an angular difference between the grid north and the magnetic north. Since the location of magnetic north does not correspond exactly with the grid-north lines on the maps, a conversion from magnetic to grid or vice versa is needed.

(1) ***With Notes***. Simply refer to the conversion notes that appear in conjunction with the diagram explaining the use of the G-M angle (Figure 6-8). One note provides instructions for converting magnetic azimuth to grid azimuth; the other, for converting grid azimuth to magnetic azimuth. The conversion (add or subtract) is governed by the direction of the magnetic-north prong relative to that of the north-grid prong.

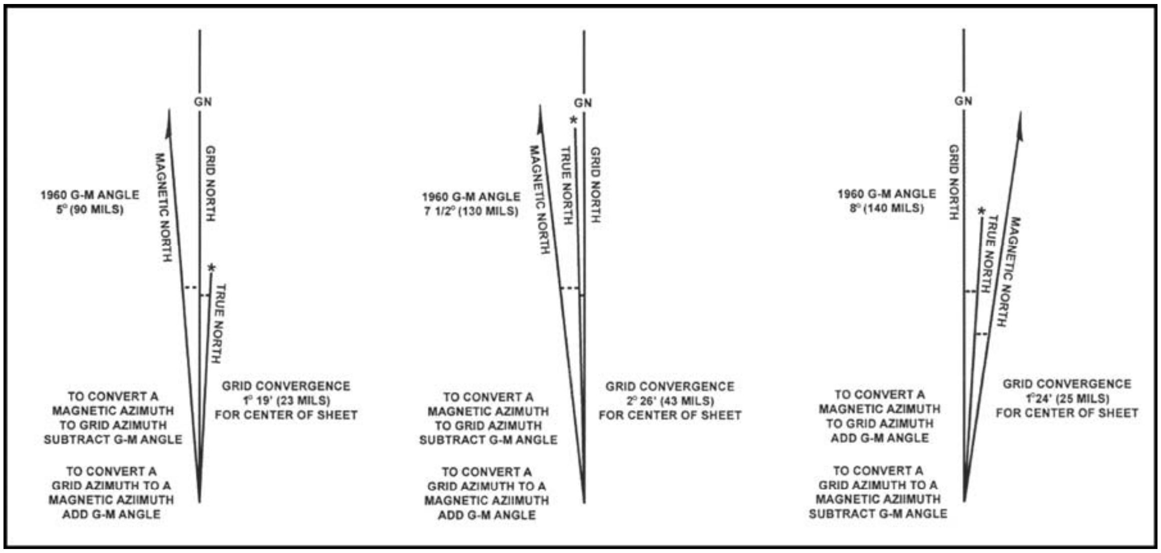
GN
MAGNETIC NORTH
GRID NORTH
1960 G-M ANGLE
5° (90 MILS)
*
TRUE NORTH
TO CONVERT A
MAGNETIC AZIMUTH
TO GRID AZIMUTH
SUBTRACT G-M ANGLE
GRID CONVERGENCE
1° 19' (23 MILS)
FOR CENTER OF SHEET
TO CONVERT A
GRID AZIMUTH TO A
MAGNETIC AZIIMUTH
ADD G-M ANGLE
GN
*
MAGNETIC NORTH
TRUE NORTH
GRID NORTH
1960 G-M ANGLE
7 1/2° (130 MILS)
TO CONVERT A
MAGNETIC AZIMUTH
TO GRID AZIMUTH
SUBTRACT G-M ANGLE
GRID CONVERGENCE
2° 26' (43 MILS)
FOR CENTER OF SHEET
TO CONVERT A
GRID AZIMUTH TO A
MAGNETIC AZIIMUTH
ADD G-M ANGLE
GN
GRID NORTH
1960 G-M ANGLE
8° (140 MILS)
*
TRUE NORTH
MAGNETIC NORTH
TO CONVERT A
MAGNETIC AZIMUTH
TO GRID AZIMUTH
ADD G-M ANGLE
GRID CONVERGENCE
1°24' (25 MILS)
FOR CENTER OF SHEET
TO CONVERT A
GRID AZIMUTH TO A
MAGNETIC AZIIMUTH
SUBTRACT G-M ANGLE

Figure 6-8. Declination diagrams.

(2) ***Without Notes***. In some cases, there are no declination conversion notes on the margin of the map; it is necessary to convert from one type of declination to another. A magnetic compass gives a magnetic azimuth; but in order to plot this line on a gridded map, the magnetic azimuth value must be changed to grid azimuth. The declination diagram is used for these conversions. A rule to remember when solving such problems is this: **No matter where the azimuth line points, the angle to it is always measured clockwise from the reference direction (base line). With this in mind, the problem is solved by the following steps:**

(a) Draw a vertical or grid-north line (prong). Always align this line with the vertical lines on a map (Figure 6-9).

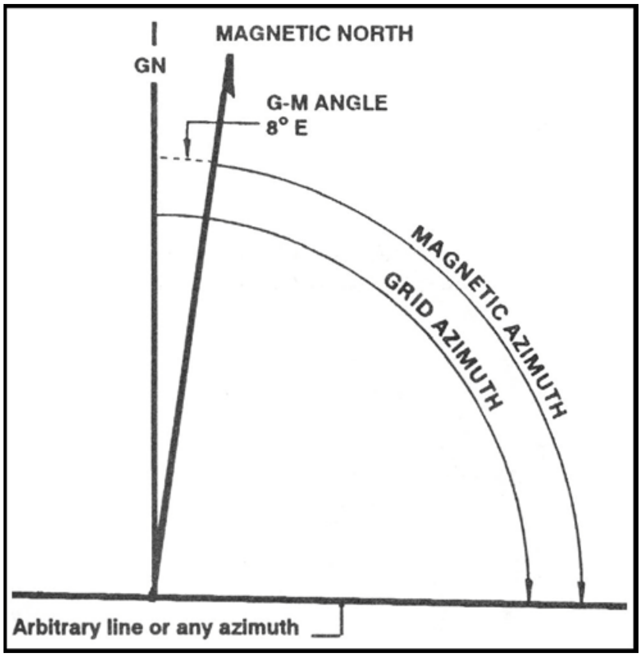

Figure 6-9. Declination diagram with arbitrary line.

(b) From the base of the grid-north line (prong), draw an arbitrary line (or any azimuth line) at a roughly right angle to north, regardless of the actual value of the azimuth in degrees (Figure 6-9).

(c) Examine the declination diagram on the map and determine the direction of the magnetic north (right-left or east-west) relative to that of the grid-north prong. Draw a magnetic prong from the apex of the grid-north line in the desired direction (Figure 6-9).

(d) Determine the value of the G-M angle. Draw an arc from the grid prong to the magnetic prong and place the value of the G-M angle (Figure 6-9).

(e) Complete the diagram by drawing an arc from each reference line to the arbitrary line. A glance at the completed diagram shows whether the given azimuth or the desired azimuth is greater, and thus whether the known difference between the two must be added or subtracted.

(f) The inclusion of the true-north prong in relationship to the conversion is of little importance.

e. **Applications.** Remember, there are no negative azimuths on the azimuth circle. Since 0 degree is the same as 360 degrees, then 2 degrees is the same as 362 degrees. This is because 2 degrees and 362 degrees are located at the same point on the azimuth circle. The grid azimuth can now be converted into a magnetic azimuth because the grid azimuth is now larger than the G-M angle.

(1) When working with a map having an east G-M angle:

(a) To plot a magnetic azimuth on a map, first change it to a grid azimuth (Figure 6-10).

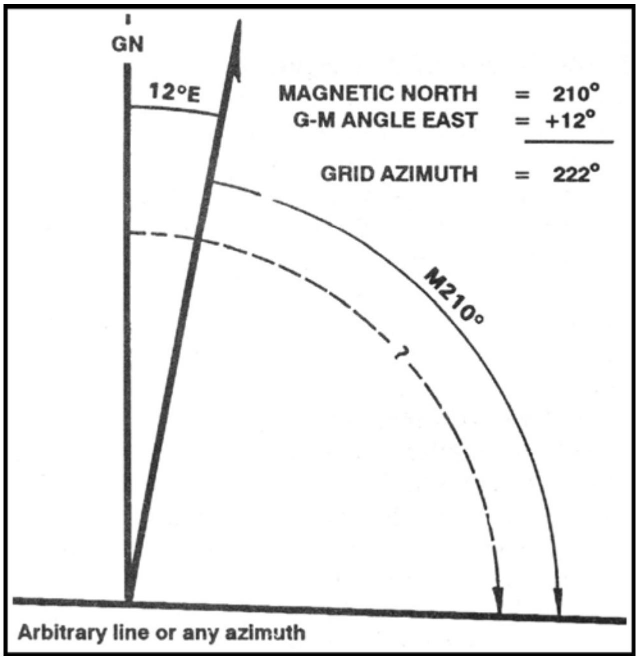
GN
12°E
MAGNETIC NORTH = 210°
G-M ANGLE EAST = +12°
GRID AZIMUTH = 222°
M210°
?
Arbitrary line or any azimuth

Figure 6-10. Converting to grid azimuth.

(b) To use a magnetic azimuth in the field with a compass, first change the grid azimuth plotted on a map to a magnetic azimuth (Figure 6-11).

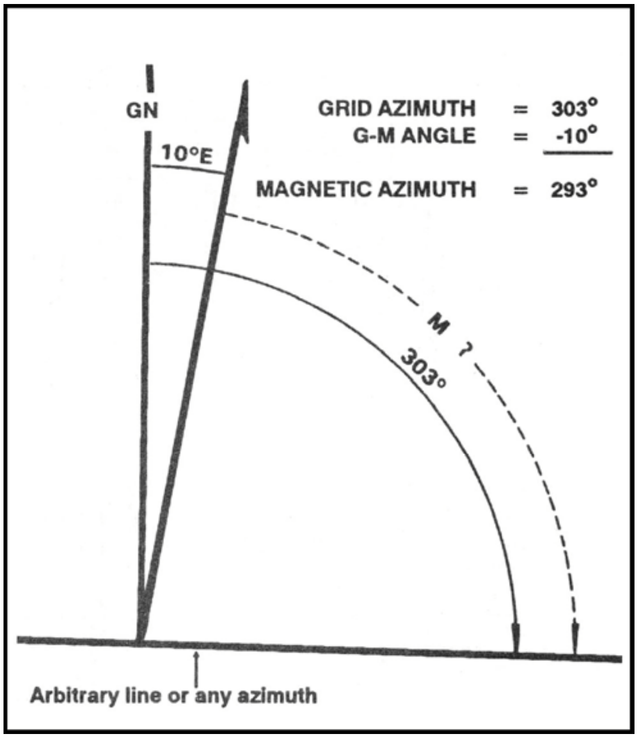
GN
10°E
GRID AZIMUTH = 303°
G-M ANGLE = -10°
MAGNETIC AZIMUTH = 293°
M ?
303°
Arbitrary line or any azimuth

Figure 6-11. Converting to magnetic azimuth.

(c) Convert a grid azimuth to a magnetic azimuth when the G-M angle is greater than a
grid azimuth (Figure 6-12).

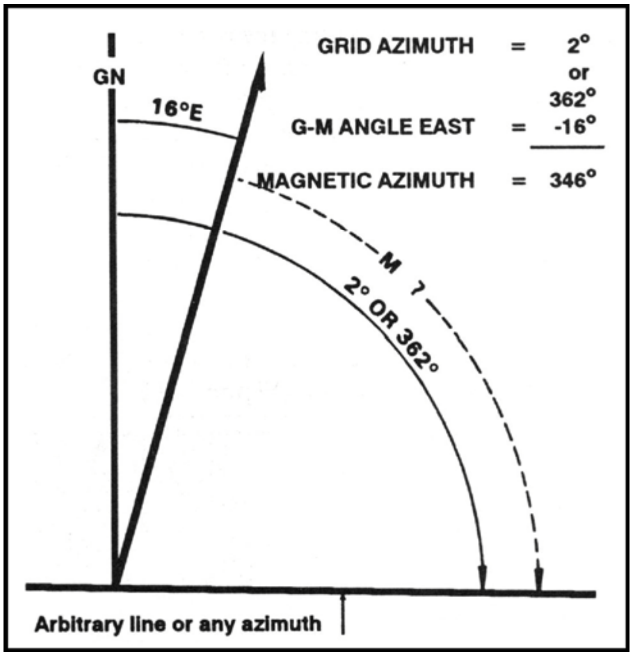
GN
16°E
GRID AZIMUTH = 2° or 362°
G-M ANGLE EAST = -16°
MAGNETIC AZIMUTH = 346°
M ?
2° OR 362°
Arbitrary line or any azimuth

Figure 6-12. Converting to a magnetic azimuth when the G-M angle is greater.

(2) When working with a map having a west G-M angle:

(a) To plot a magnetic azimuth on a map, first convert it to a grid azimuth (Figure 6-13).

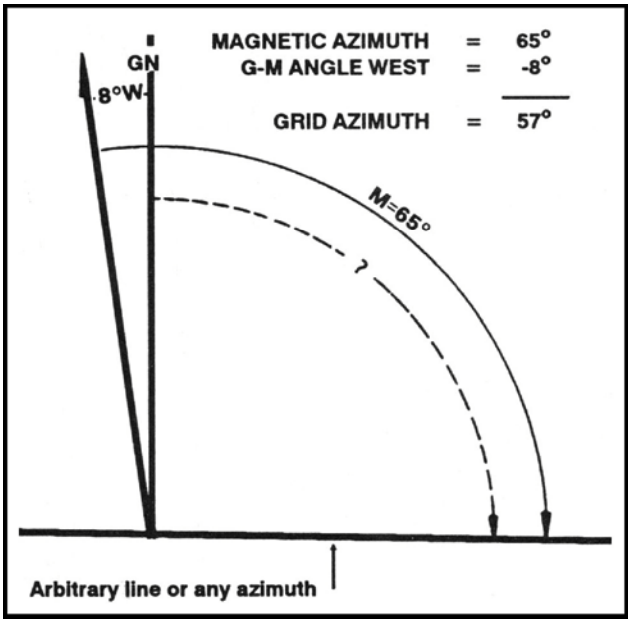
GN
8°W
MAGNETIC AZIMUTH = 65°
G-M ANGLE WEST = -8°
GRID AZIMUTH = 57°
M=65°
?
Arbitrary line or any azimuth

Figure 6-13. Converting to a grid azimuth on a map.

(b) To use a magnetic azimuth in the field with a compass, change the grid azimuth plotted on a map to a magnetic azimuth (Figure 6-14).

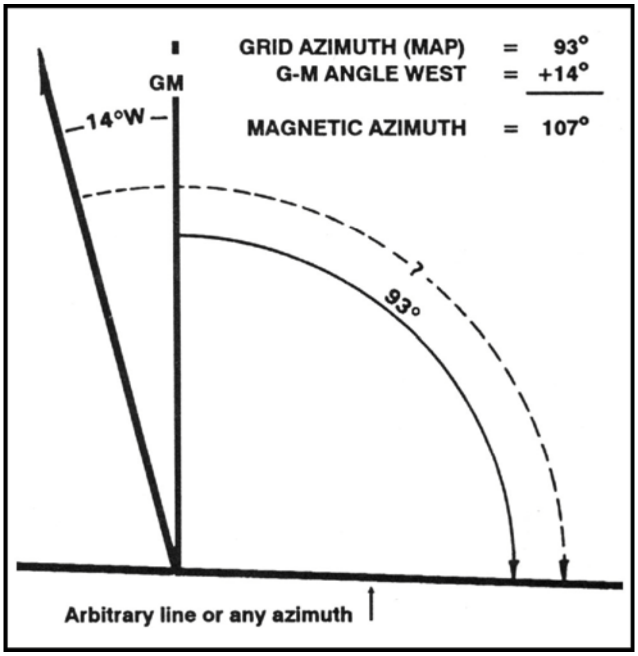
GM
14°W
GRID AZIMUTH (MAP) = 93°
G-M ANGLE WEST = +14°
MAGNETIC AZIMUTH = 107°
?
93°
Arbitrary line or any azimuth

Figure 6-14. Converting to a magnetic azimuth on a map.

(c) Convert a magnetic azimuth when the G-M angle is greater than the magnetic azimuth (Figure 6-15).

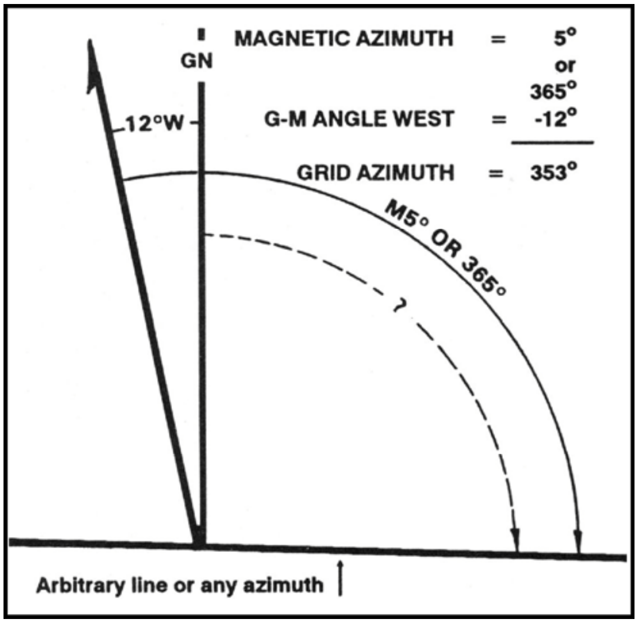
GN
12°W
MAGNETIC AZIMUTH = 5° or 365°
G-M ANGLE WEST = -12°
GRID AZIMUTH = 353°
M5° OR 365°
?
Arbitrary line or any azimuth

Figure 6-15. Converting to a grid azimuth when the G-M angle is greater.

(3) The G-M angle diagram should be constructed and used each time the conversion of azimuth is required. Such procedure is important when working with a map for the first time. It also may be convenient to construct a G-M angle conversion table on the margin of the map.

NOTE: When converting azimuths, exercise extreme care when adding and subtracting the G-M angle. A simple mistake of 1° could be significant in the field.

6-7. INTERSECTION

Intersection is the location of an unknown point by successively occupying at least two (preferably three) known positions on the ground and then map sighting on the unknown location. It is used to locate distant or inaccessible points or objects such as enemy targets and danger areas. There are two methods of intersection: the map and compass method and the straightedge method (Figures 6-16 and 6-17 on pages 6-14 and 6-15).

a. When using the map and compass method—

(1) Orient the map using the compass.

(2) Locate and mark your position on the map,

(3) Determine the magnetic azimuth to the unknown position using the compass.

(4) Convert the magnetic azimuth to grid azimuth.

(5) Draw a line on the map from your position on this grid azimuth.

(6) Move to a second known point and repeat steps 1, 2, 3, 4, and 5.

(7) The location of the unknown position is where the lines cross on the map. Determine the grid coordinates to the desired accuracy.

b. The straight edge method is used when a compass is not available. When using it—

(1) Orient the map on a flat surface by the terrain association method.

(2) Locate and mark your position on the map.

(3) Lay a straight edge on the map with one end at the user's position (A) as a pivot point; then, rotate the straightedge until the unkown point is sighted along the edge.

(4) Draw a line along the straight edge

(5) Repeat the above steps at position (B) and check for accuracy.

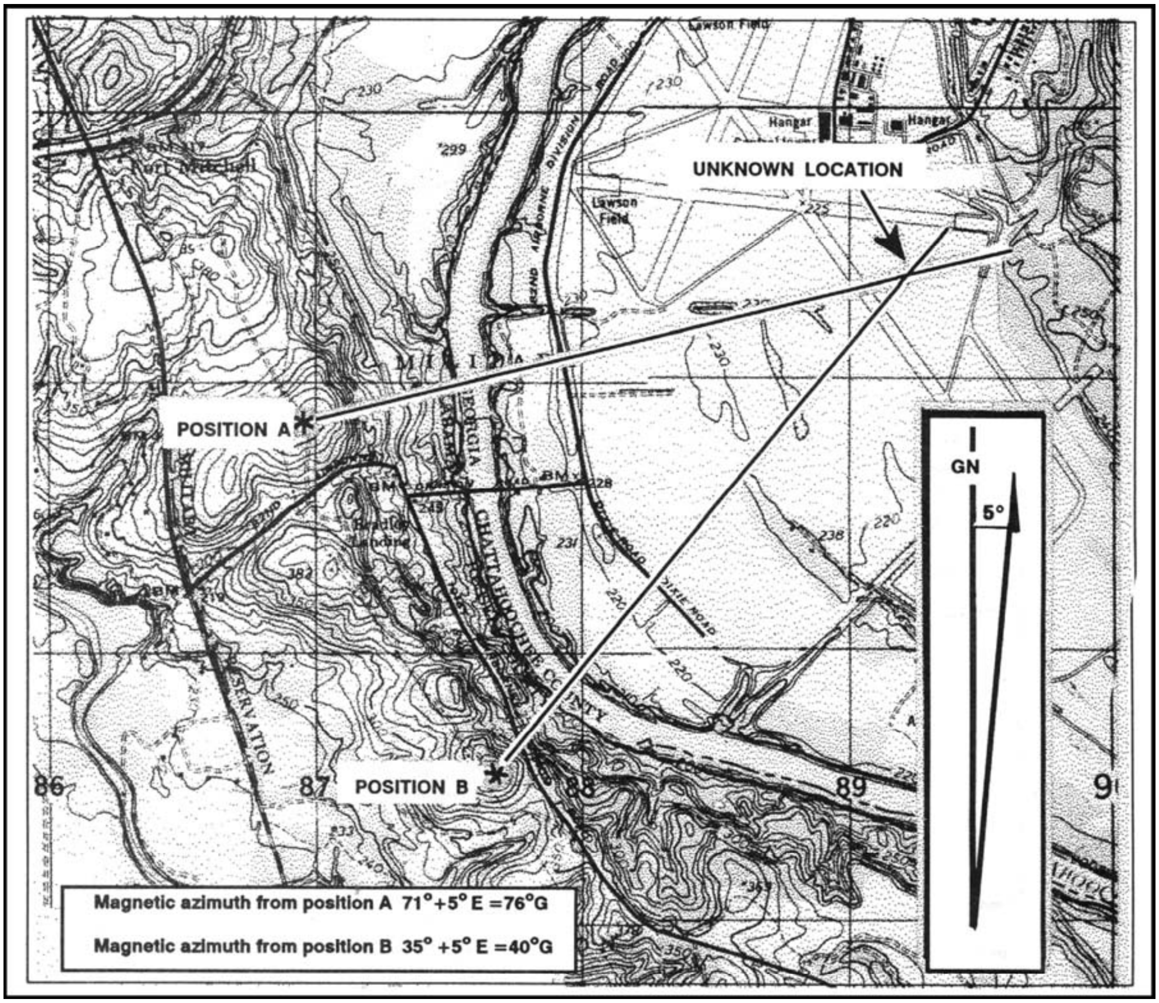
UNKNOWN LOCATION
POSITION A
POSITION B
GN
5°
86
87
88
89
Magnetic azimuth from position A 71°+5° E =76°G
Magnetic azimuth from position B 35° +5° E =40°G
Hangar
Lawson Field
CHATTAHOOCHEE COUNTY
RESERVATION

Figure 6-16. Intersection, using map and compass.

(6) The intersection of the lines on the map is the location of the unknown point (C). Determine the grid coordinates to the desired accuracy (Figure 6-17).

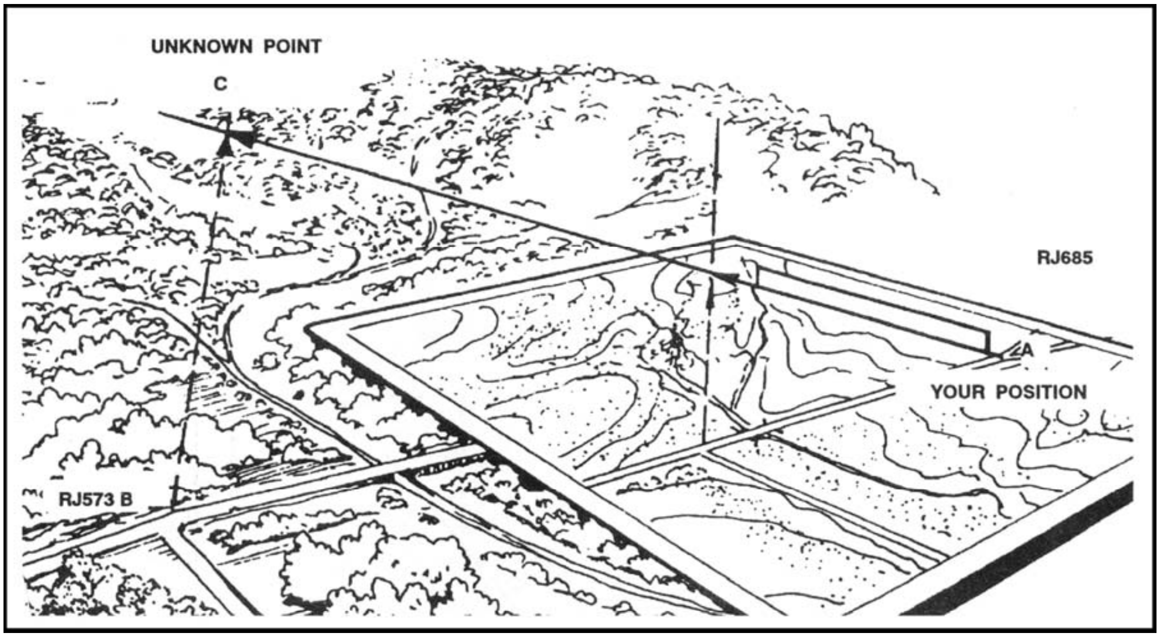

Figure 6-17. Intersection, using a straightedge.

6-8. RESECTION

Resection is the method of locating one's position on a map by determining the grid azimuth to at least two well-defined locations that can be pinpointed on the map. For greater accuracy, the desired method of resection would be to use three or more well-defined locations.

a. When using the map and compass method (Figure 6-18)—

(1) Orient the map using the compass.

(2) Identify two or three known distant locations on the ground and mark them on the map.

(3) Measure the magnetic azimuth to one of the known positions from your location using a compass.

(4) Convert the magnetic azimuth to a grid azimuth.

(5) Convert the grid azimuth to a back azimuth. Using a protractor, draw a line for the back azimuth on the map from the known position back toward your unknown position.

(6) Repeat 3, 4, and 5 for a second position and a third position, if desired.

(7) The intersection of the lines is your location. Determine the grid coordinates to the desired accuracy.

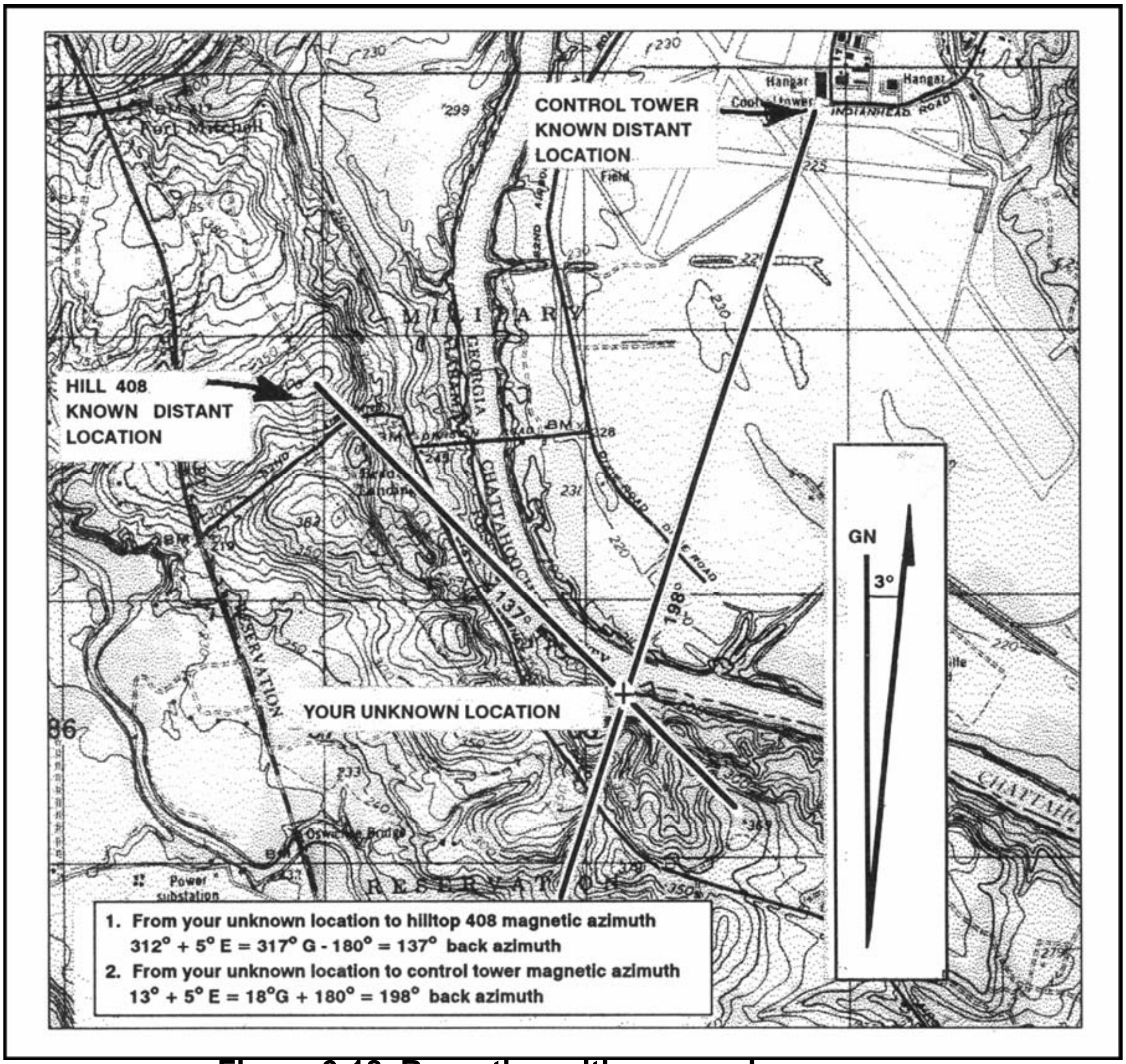
CONTROL TOWER
KNOWN DISTANT
LOCATION
Hangar
Control tower
Hangar
INDIANHEAD ROAD
HILL 408
KNOWN DISTANT
LOCATION
MILITARY
GEORGIA
ALABAMA
CHATTAHOOCHEE
137°
198°
YOUR UNKNOWN LOCATION
RESERVATION
Oswichee Bridge
Power substation
86
GN
3°

1. From your unknown location to hilltop 408 magnetic azimuth 312° + 5° E = 317° G - 180° = 137° back azimuth
2. From your unknown location to control tower magnetic azimuth 13° + 5° E = 18°G + 180° = 198° back azimuth

Figure 6-18. Resection with map and compass.

a. When using the straightedge method (Figure 6-19)—

(1) Orient the map on a flat surface by the terrain association method.

(2) Locate at least two known distant locations or prominent features on the ground and mark them on the map.

(3) Lay a straightedge on the map using a known position as a pivot point. Rotate the straightedge until the known position on the map is aligned with the known position on the ground.

(4) Draw a line along the straightedge away from the known position on the ground toward your position.

(5) Repeat 3 and 4 using a second known position.

(6) The intersection of the lines on the map is your location. Determine the grid coordinates to the desired accuracy.

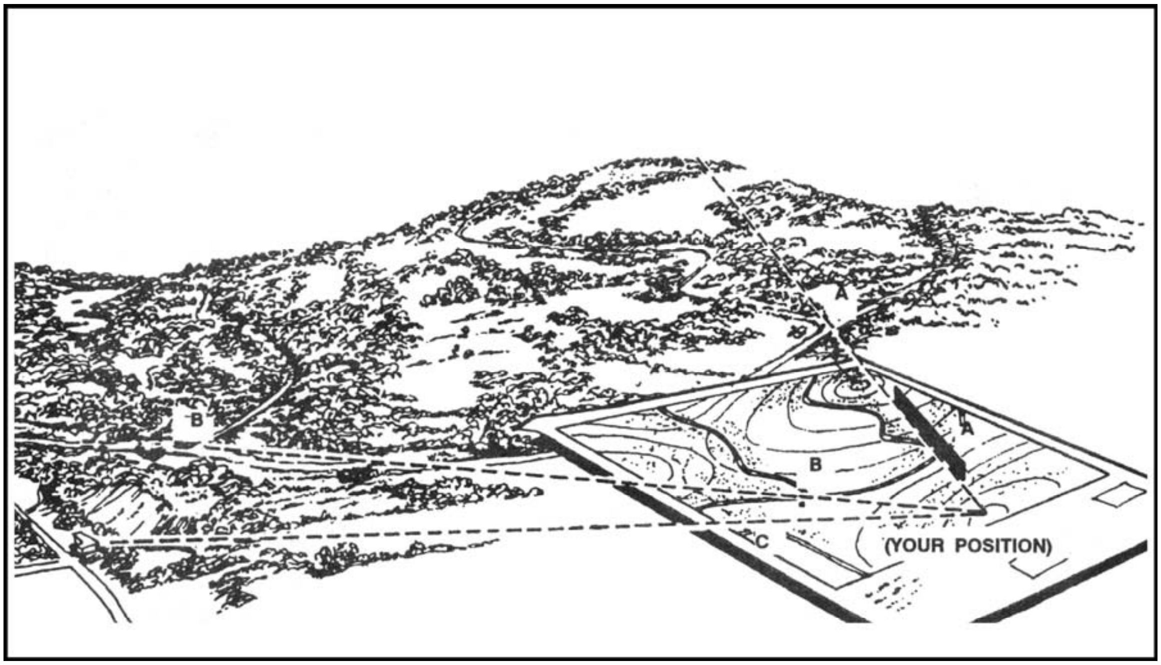

Figure 6-19. Resection with straightedge.

6-9. MODIFIED RESECTION

Modified resection is the method of locating one's position on the map when the person is located on a linear feature on the ground, such as a road, canal, or stream (Figure 6-20). Proceed as follows:

a. Orient the map using a compass or by terrain association.

b. Find a distant point that can be identified on the ground and on the map.

c. Determine the magnetic azimuth from your location to the distant known point.

d. Convert the magnetic azimuth to a grid azimuth.

e. Convert the grid azimuth to a back azimuth. Using a protractor, draw a line for the back azimuth on the map from the known position back toward your unknown position.

f. The location of the user is where the line crosses the linear feature. Determine the grid coordinates to the desired accuracy.

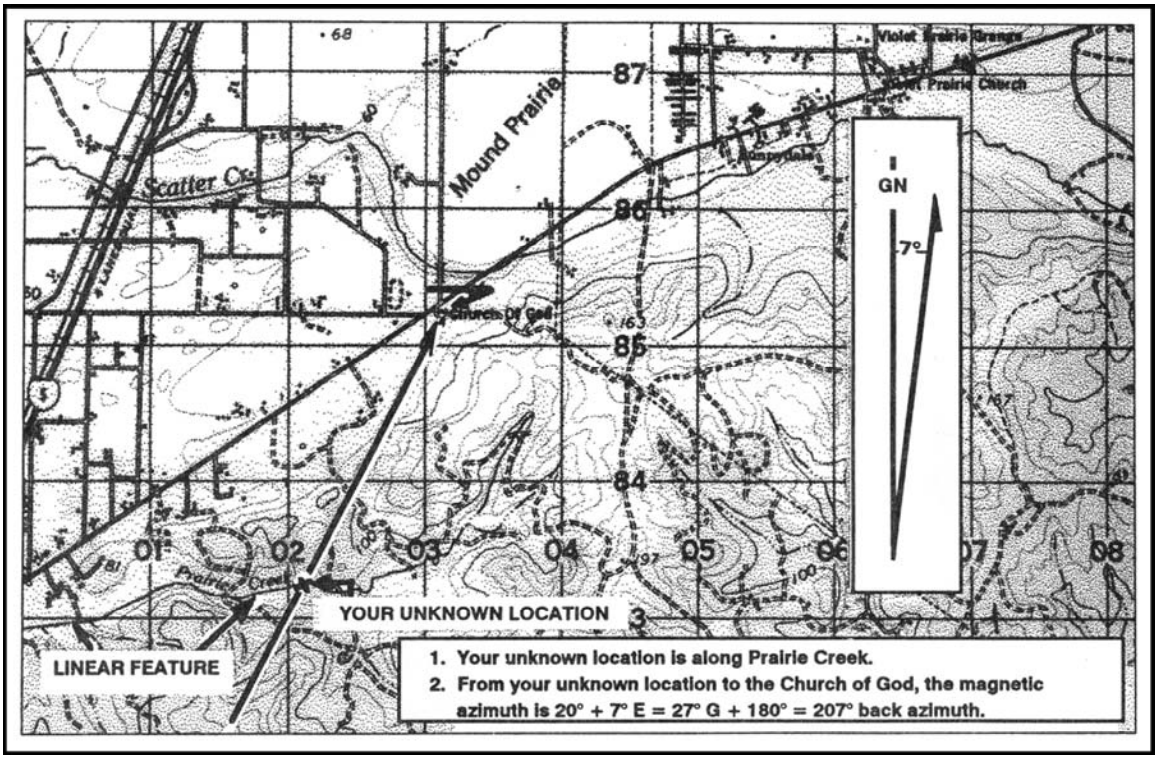
Violet Prairie Grange
Violet Prairie Church
Mound Prairie
Scatter Cr.
Church of God
Prairie Creek
87
86
85
84
01
02
03
04
05
06
07
08
GN
7°
YOUR UNKNOWN LOCATION
LINEAR FEATURE

1. Your unknown location is along Prairie Creek.
2. From your unknown location to the Church of God, the magnetic azimuth is 20° + 7° E = 27° G + 180° = 207° back azimuth.

Figure 6-20. Modified resection.

6-10. POLAR COORDINATES

A method of locating or plotting an unknown position from a known point by giving a direction and a distance along that direction line is called polar coordinates. The following elements must be present when using polar coordinates (Figure 6-21).

- Present known location on the map.
- Azimuth (grid or magnetic).
- Distance (in meters).

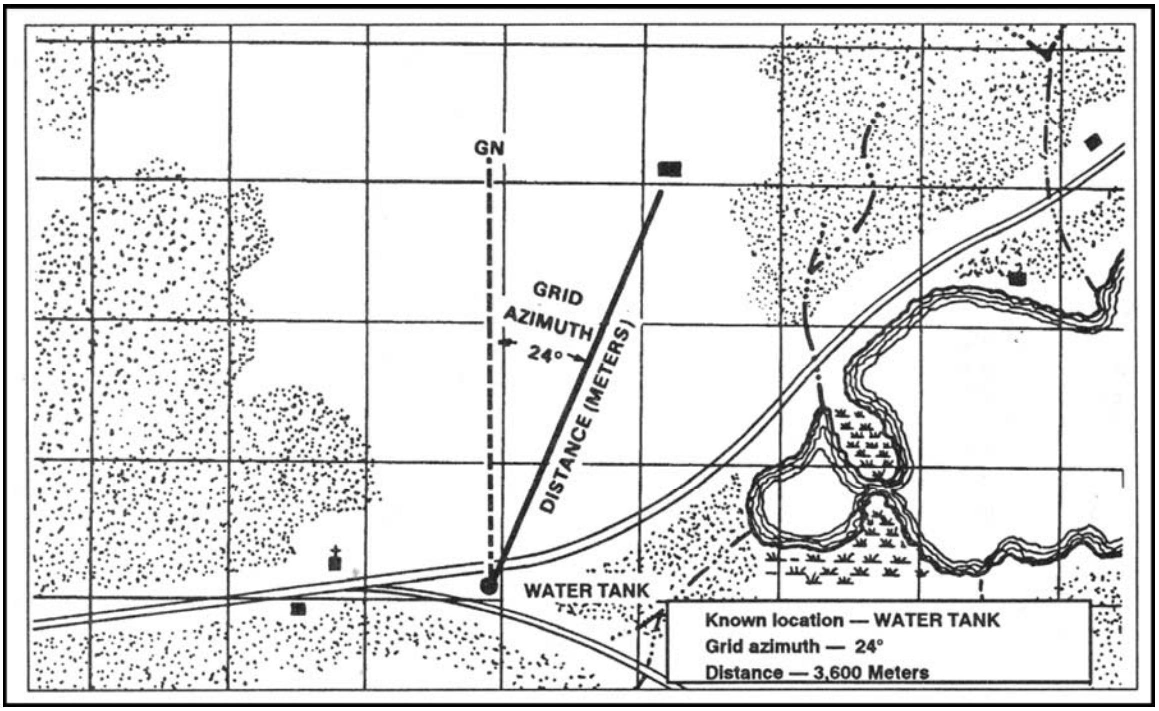
GN
GRID AZIMUTH
24°
DISTANCE (METERS)
WATER TANK
Known location — WATER TANK
Grid azimuth — 24°
Distance — 3,600 Meters

Figure 6-21. Polar plot.

Using the laser range finder to determine the range enhances your accuracy in determining the unknown position's location.

CHAPTER 7
OVERLAYS

An overlay is a clear sheet of plastic or semi-transparent paper. It is used to display supplemental map and tactical information related to military operations. It is often used as a supplement to orders given in the field. Information is plotted on the overlay at the same scale as on the map, aerial photograph, or other graphic being used. When the overlay is placed over the graphic, the details plotted on the overlay are shown in their true position.

7-1. PURPOSE

Overlays are used to display military operations with enemy and friendly troop dispositions, and as supplements to orders sent to the field. They show detail that will aid in understanding the orders, displays of communication networks, and so forth. They are also used as annexes to reports made in the field because they can clarify matters that are difficult to explain clearly in writing.

7-2. MAP OVERLAY

There are three steps in the making of a map overlay—orienting the overlay material, plotting and symbolizing the detail, and adding the required marginal information (Figure 7-1).

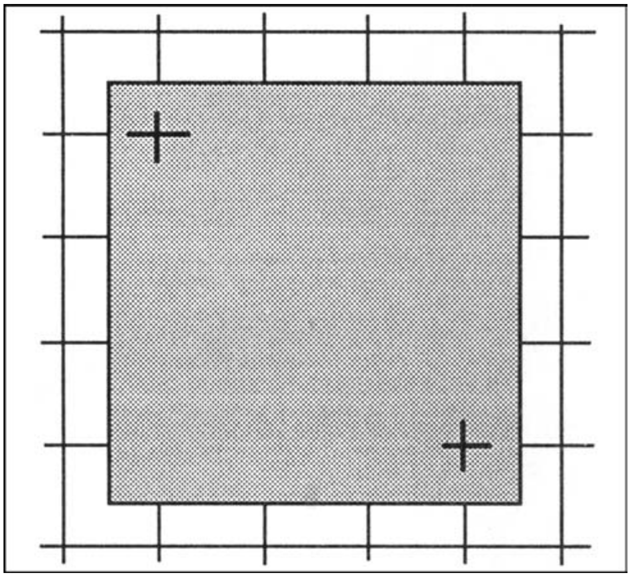

Figure 7-1. Registering the overlay.

a**. Orienting.** Orient the overlay over the place on the map to be annotated. Then, if possible, attach it to the edges of the map with tape. Trace the grid intersections nearest the two opposite corners of the overlay using a straightedge and label each with the proper grid coordinates. These register marks show the receiver of your overlay exactly where it fits on his map; without them, the overlay is difficult to orient. It is imperative that absolute accuracy be maintained in plotting the register marks, as the smallest mistake will throw off the overlay.

b. **Plotting of New Detail.** Use pencils or markers in standard colors that make a lasting mark without cutting the overlay to plot any detail (FM 101-5-1).

(1) Use standard topographic or military symbols where possible. Nonstandard symbols invented by the author must be identified in a legend on the overlay. Depending on the conditions under which the overlay is made, it may be advisable to plot the positions first on the map, then trace them onto the overlay. Since the overlay is to be used as a supplement to orders or reports and the recipient will have an identical map, show only that detail with which the report is directly concerned.

(2) If you have observed any topographic or cultural features that are not shown on the map, such as a new road or a destroyed bridge, plot their positions as accurately as possible on the overlay and mark with the standard topographic symbol.

(3) If difficulty in seeing through the overlay material is encountered while plotting or tracing detail, lift the overlay from time to time to check orientation of information being added in reference to the base.

c. **Recording Marginal Information.** When all required detail has been plotted or traced on the overlay, print information as close to the lower right-hand corner as detail permits (Figure 7-2). This information includes the following data:

(1) ***Title and Objective***. This tells the reader why the overlay was made and may also give the actual location. For example, "Road Reconnaissance" is not as specific as "Route 146 Road Reconnaissance."

(2) ***Time and Date***. Any overlay should contain the latest possible information. An overlay received in time is very valuable to the planning staff and may affect the entire situation; an overlay that has been delayed for any reason may be of little use. Therefore, the exact time the information was obtained aids the receivers in determining its reliability and usefulness.

(3) ***Map Reference***. The sheet name, sheet number, map series number, and scale must be included. If the reader does not have the map used for the overlay, this provides the information necessary to obtain it.

(4) ***Author***. The name, rank, and organization of the author, supplemented with a date and time of preparation of the overlay, tells the reader if there was a time difference between when the information was obtained and when it was reported.

(5) ***Legend***. If it is necessary to invent nonstandard symbols to show the required information, the legend must show what these symbols mean.

(6) ***Security Classification***. This must correspond to the highest classification of either the map or the information placed on the overlay. If the information and map are unclassified, this will be so stated. The locations of the classification notes are shown in Figure 7-2, and the notes will appear in both locations as shown.

(7) ***Additional Information***. Any other information that amplifies the overlay will also be included. Make it as brief as possible.

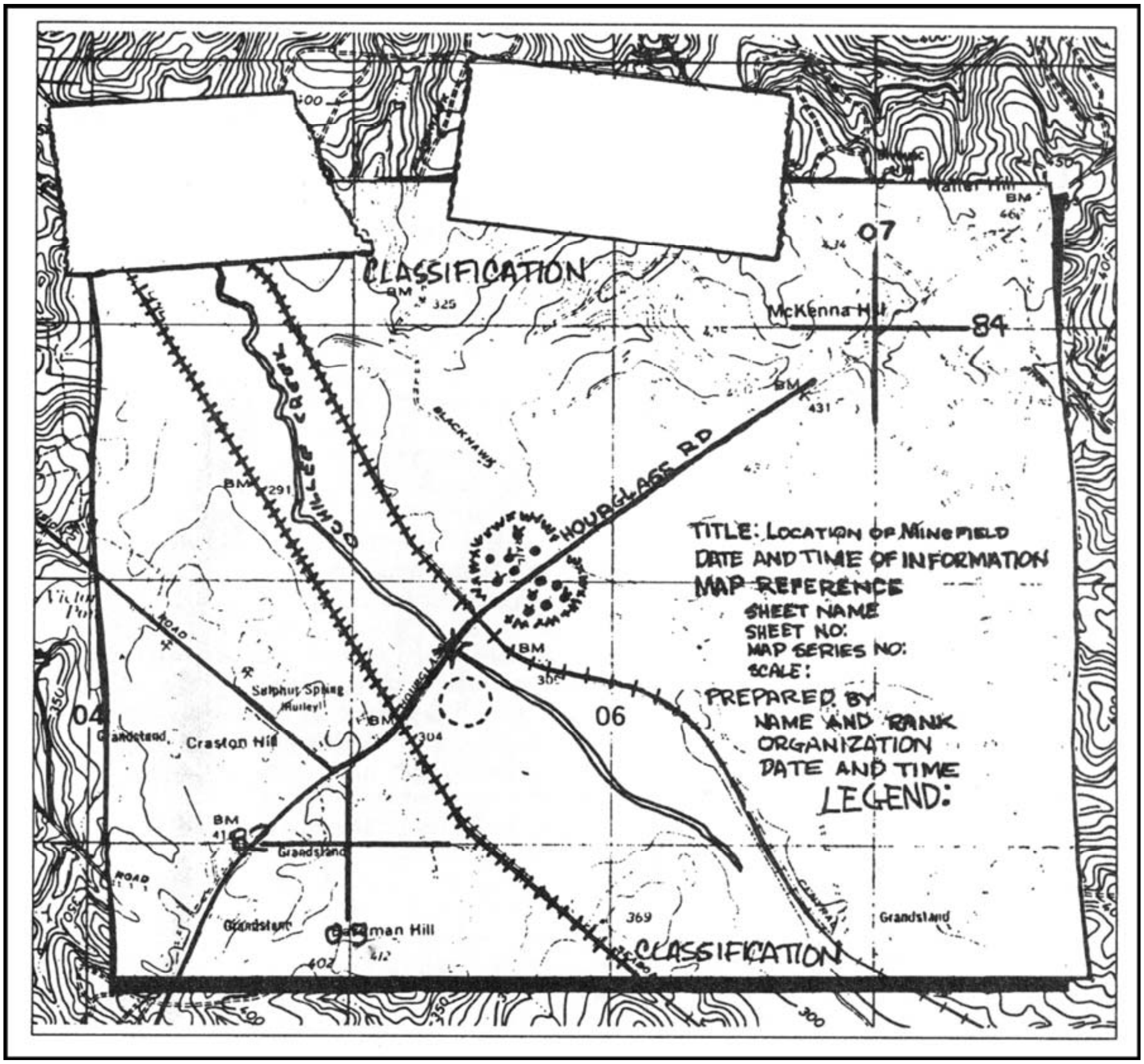
CLASSIFICATION
BM 325
07
McKenna Hill
84
BM 431
HOURGLASS RD
BM 291
TITLE: LOCATION OF MINEFIELD
DATE AND TIME OF INFORMATION
MAP REFERENCE
SHEET NAME
SHEET NO:
MAP SERIES NO:
SCALE:
PREPARED BY
NAME AND RANK
ORGANIZATION
DATE AND TIME
LEGEND:
BM
06
ROAD
Sulphur Spring
04
Craston Hill
BM 304
BM
Grandstand
ROAD
Grandstand
man Hill
402
369
CLASSIFICATION
Grandstand
300
350

Figure 7-2. Map overlay with marginal information.

7-3. AERIAL PHOTOGRAPH OVERLAY

Overlays of single aerial photographs are constructed and used in the same way as map overlays. The steps followed are essentially the same, with the following exceptions:

a. **Orienting of Overlay.** The photograph normally does not have grid lines to be used as register marks. The borders of the photograph limit the area of the overlay, so the reference marks or linear features are traced in place of grid register marks. Finally, to ensure proper location of the overlay with respect to the photograph, indicate on the overlay the position of the marginal data on the photograph as seen through the overlay.

b. **Marginal Information.** The marginal information shown on photographs varies somewhat from that shown on maps. Overlays of photographs (Figure 7-3, page 7-4) should show the following information:

(1) ***North Arrow.*** This may be obtained in two ways—by comparing with a map of the area or by orienting the photograph by inspection. In the latter case, a compass or expedient direction finder must be used to place the direction arrow on the overlay. Use the standard symbol to represent the actual north arrow used—grid, magnetic, or true north.

(2) ***Title and Objective***. This tells the reader why the photo overlay was made and may also give the actual location.

(3) ***Time and Date***. The exact time the information was obtained is shown on a photo overlay just as on a map overlay

(4) ***Photo Reference***. The photo number, mission number, date of flight, and scale appear here, or the information is traced in its actual location on the photograph.

(5) ***Scale***. The scale must be computed since it is not part of the marginal data.

(6) ***Map Reference***. Reference is made to the sheet name, sheet number, series number, and scale of a map of the area, if one is available.

(7) ***Author***. The name, rank, and organization of the author are shown, supplemented with a date and time of preparation of the overlay.

(8) ***Legend***. As with map overlays, this is only necessary when nonstandard symbols are used.

(9) ***Security Classification***. This must correspond to the highest classification of either the photograph or the information placed on the overlay. If the information and photograph are unclassified, this will be so stated. The locations of the classification notes are shown in Figure 7-3, and the notes will appear in both locations.

(10) ***Additional Information***. Any other information that amplifies the overlay will also be included. Make it as brief as possible.

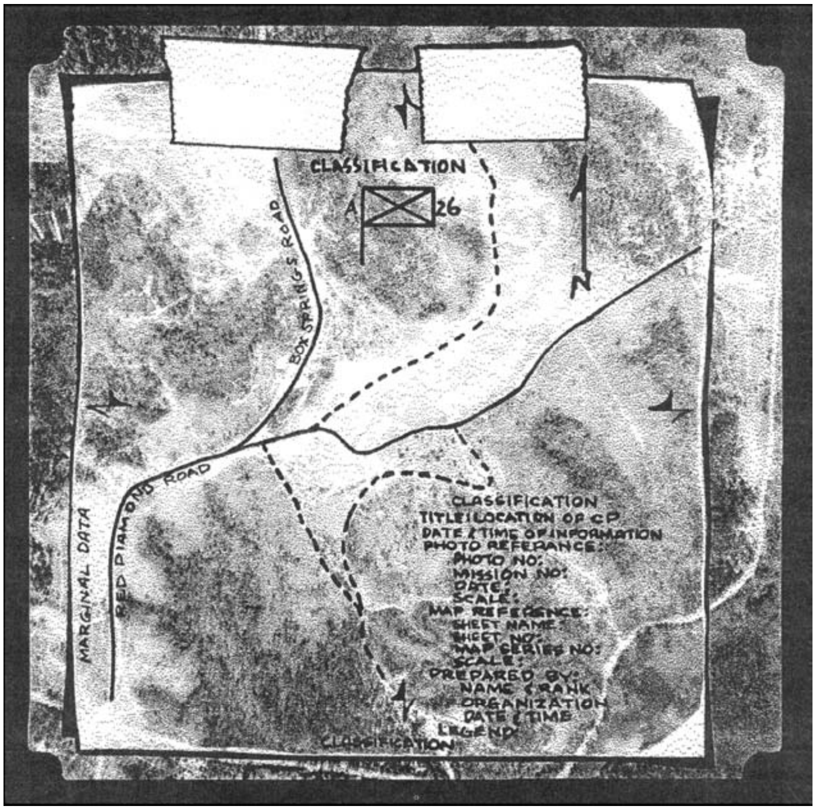
CLASSIFICATION
A
26
BOX SPRINGS ROAD
N
RED DIAMOND ROAD
MARGINAL DATA
CLASSIFICATION
TITLE: LOCATION OF CP
DATE & TIME OF INFORMATION
PHOTO REFERANCE:
PHOTO NO:
MISSION NO:
DATE:
SCALE:
MAP REFERENCE:
SHEET NAME:
SHEET NO:
MAP SERIES NO:
SCALE:
PREPARED BY:
NAME & RANK
ORGANIZATION
DATE & TIME
LEGEND
CLASSIFICATION

Figure 7-3. Photographic overlay with marginal information.

CHAPTER 8

AERIAL PHOTOGRAPHS

An aerial photograph is any photograph taken from an airborne vehicle (aircraft, drones, balloons, satellites, and so forth). The aerial photograph has many uses in military operations; however, for the purpose of this manual, it will be considered primarily as a map supplement or map substitute.

8-1. COMPARISON WITH MAPS

A topographic map may be obsolete because it was compiled many years ago. A recent aerial photograph shows any changes that have taken place since the map was made. For this reason, maps and aerial photographs complement each other. More information can be gained by using the two together than by using either alone.

a. **Advantages.** An aerial photograph has the following advantages over a map:

(1) It provides a current pictorial view of the ground that no map can equal.

(2) It is more readily obtained. The photograph may be in the hands of the user within a few hours after it is taken; a map may take months to prepare.

(3) It may be made for places that are inaccessible to ground soldiers.

(4) It shows military features that do not appear on maps.

(5) It can provide a day-to-day comparison of selected areas, permitting evaluations to be made of enemy activity.

(6) It provides a permanent and objective record of the day-to-day changes with the area.

b. **Disadvantages.** The aerial photograph has the following disadvantages as compared to a map:

(1) Ground features are difficult to identify or interpret without symbols and are often obscured by other ground detail as, for example, buildings in wooded areas.

(2) Position location and scale are only approximate.

(3) Detailed variations in the terrain features are not readily apparent without overlapping photography and a stereoscopic viewing instrument.

(4) Because of a lack of contrasting colors and tone, a photograph is difficult to use in poor light.

(5) It lacks marginal data.

(6) It requires more training to interpret than a map.

8-2. TYPES

Aerial photography most commonly used by military personnel may be divided into two major types, the vertical and the oblique. Each type depends upon the attitude of the camera with respect to the earth's surface when the photograph is taken.

a. **Vertical.** A vertical photograph is taken with the camera pointed as straight down as possible (Figures 8-1 and 8-2 on page 8-2). Allowable tolerance is usually + 3° from the perpendicular (plumb) line to the camera axis. The result is coincident with the camera axis. A vertical photograph has the following characteristics:

(1) The lens axis is perpendicular to the surface of the earth.

(2) It covers a relatively small area.

(3) The shape of the ground area covered on a single vertical photo closely approximates a square or rectangle.

(4) Being a view from above, it gives an unfamiliar view of the ground.

(5) Distance and directions may approach the accuracy of maps if taken over flat terrain.

(6) Relief is not readily apparent.

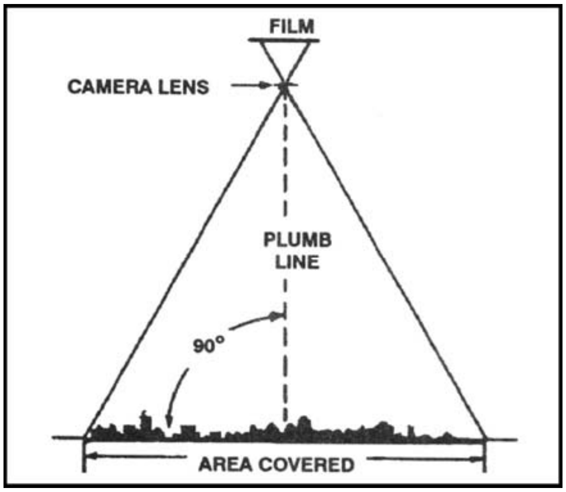

Figure 8-1. Relationship of the vertical aerial photograph with the ground.

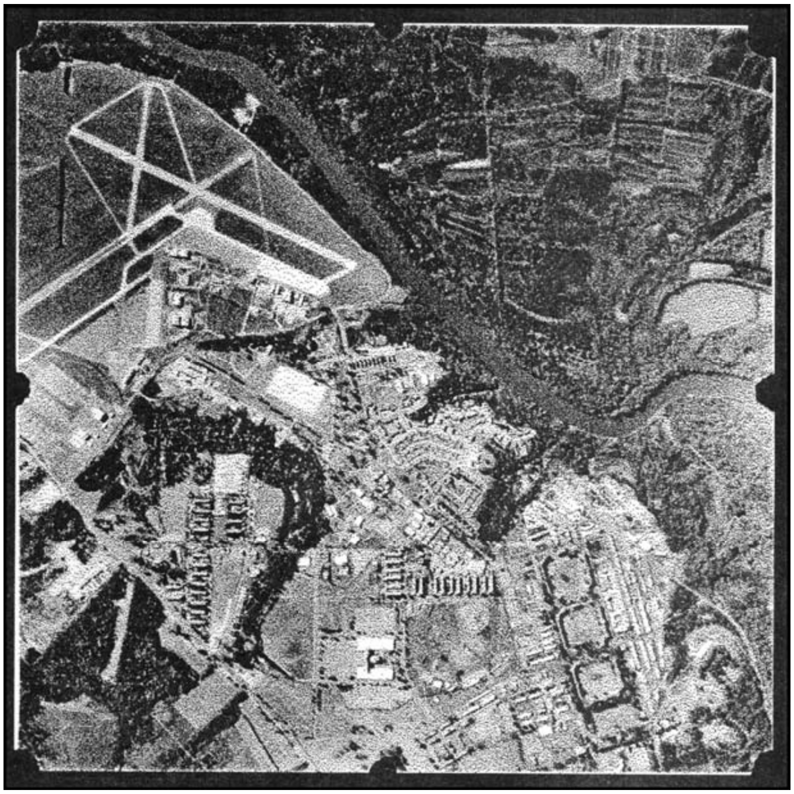

Figure 8-2. Vertical photograph.

a. **Low Oblique.** This is a photograph taken with the camera inclined about 30° from the vertical (Figure 8-3, and Figure 8-4 on page 8-4). It is used to study an area before an attack, to substitute for a reconnaissance, to substitute for a map, or to supplement a map. A low oblique has the following characteristics:

(1) It covers a relatively small area.

(2) The ground area covered is a trapezoid, although the photo is square or rectangular.

(3) The objects have a more familiar view, comparable to viewing from the top of a high hill or tall building.

(4) No scale is applicable to the entire photograph, and distance cannot be measured. Parallel lines on the ground are not parallel on this photograph; therefore, direction (azimuth) cannot be measured.

(5) Relief is discernible but distorted.

(6) It does not show the horizon.

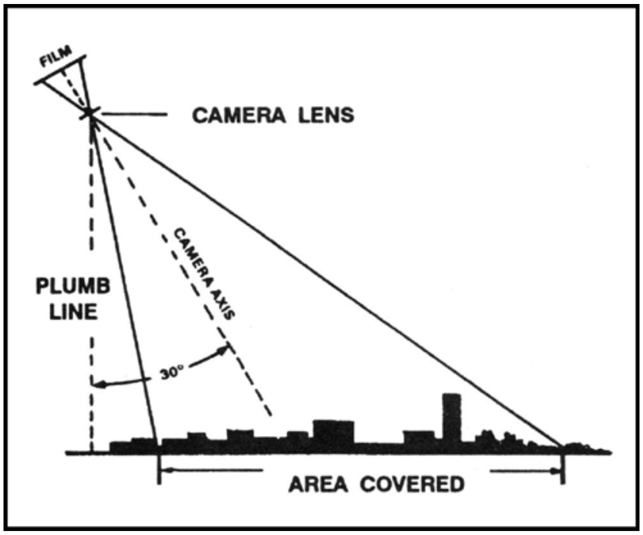

Figure 8-3. Relationship of low oblique photograph to the ground.

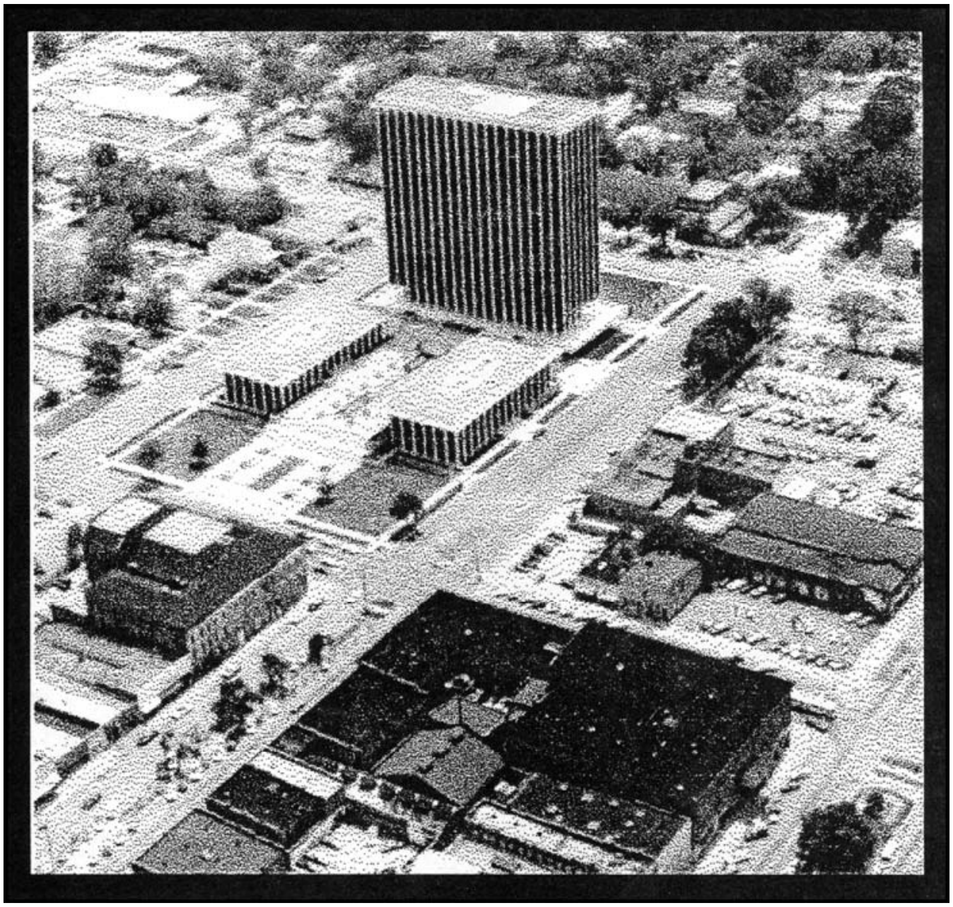

Figure 8-4. Low oblique photograph.

c. **High Oblique.** The high oblique is a photograph taken with the camera inclined about 60° from the vertical (Figures 8-5 and 8-6). It has a limited military application; it is used primarily in the making of aeronautical charts. However, it may be the only photography available. A high oblique has the following characteristics:

(1) It covers a very large area (not all usable).

(2) The ground area covered is a trapezoid, but the photograph is square or rectangular.

(3) The view varies from the very familiar to unfamiliar, depending on the height at which the photograph is taken.

(4) Distances and directions are not measured on this photograph for the same reasons that they are not measured on the low oblique.

(5) Relief may be quite discernible but distorted as in any oblique view. The relief is not apparent in a high altitude, high oblique.

(6) The horizon is always visible.

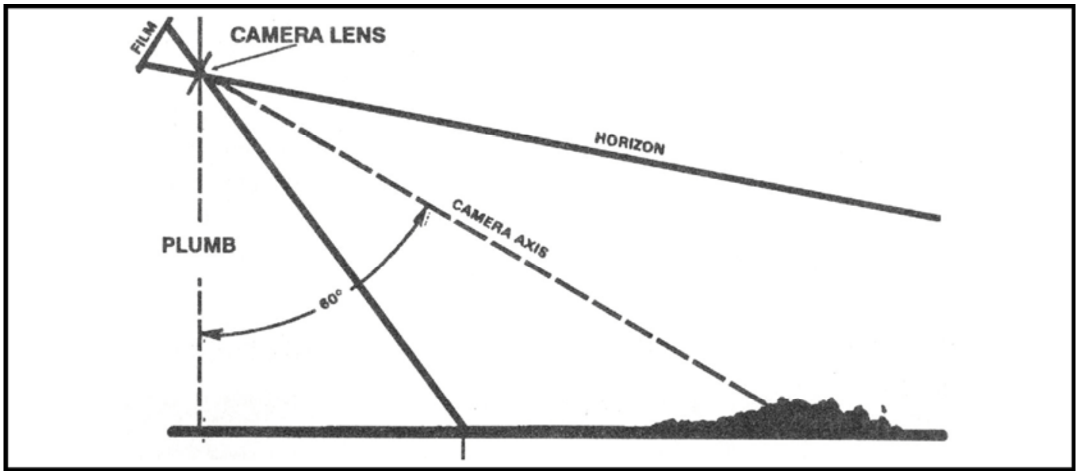
FILM
CAMERA LENS
HORIZON
CAMERA AXIS
PLUMB
60°

Figure 8-5. Relationship of high oblique photograph to the ground.

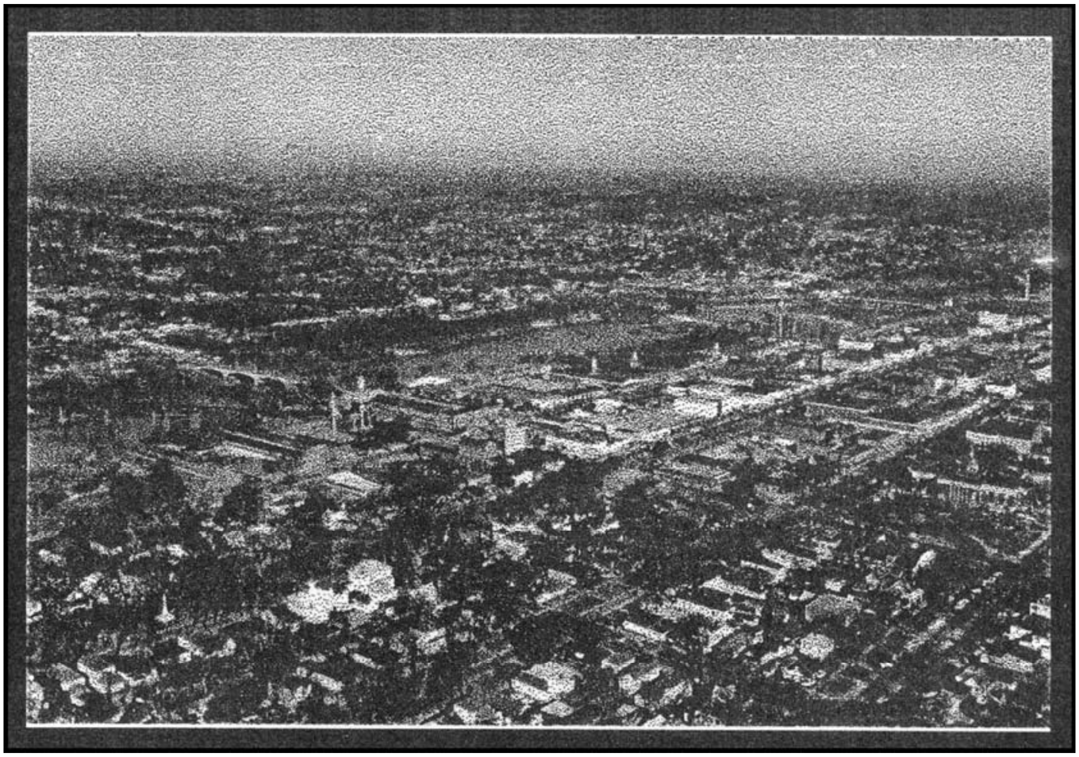

Figure 8-6. High oblique photograph.

d. **Trimetrogon.** This is an assemblage of three photographs taken at the same time, one vertical and two high obliques, in a direction at right angle to the line of flight. The obliques, taken at an angle of 60° from the vertical, sidelap the vertical photography, producing composites from horizon to horizon (Figure 8-7).

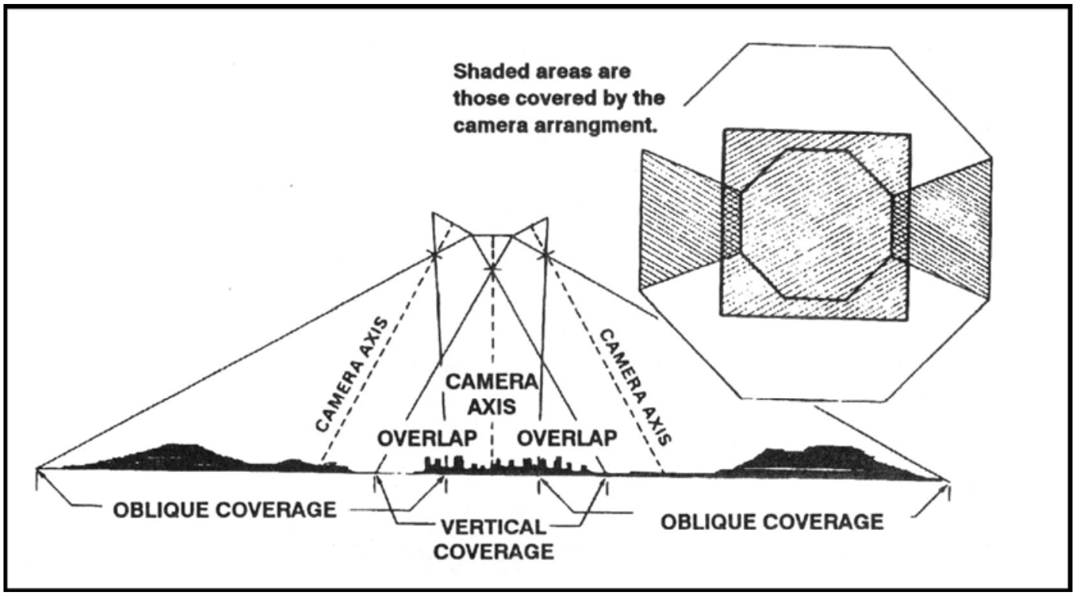

Figure 8-7. Relationship of cameras to ground for trimetrogon photography (three cameras).

e. **Multiple Lens Photography.** These are composite photographs taken with one camera having two or more lenses, or by two or more cameras. The photographs are combinations of two, four, or eight obliques around a vertical. The obliques are rectified to permit assembly as verticals on a common plane.

f. **Convergent Photography.** These are done with a single twin-lens, wide-angle camera, or with two single-lens, wide-angle cameras coupled rigidly in the same mount so that each camera axis converges when intentionally tilted a prescribed amount (usually 15 or 20°) from the vertical. Again, the cameras are exposed at the same time. For precision mapping, the optical axes of the cameras are parallel to the line of flight, and for reconnaissance photography, the camera axes are at high angles to the line of flight.

g. **Panoramic.** The development and increasing use of panoramic photography in aerial reconnaissance has resulted from the need to cover in greater detail more and more areas of the world.

(1) To cover the large areas involved, and to resolve the desired ground detail, present-day reconnaissance systems must operate at extremely high-resolution levels. Unfortunately, high-resolution levels and wide-angular coverage are basically contradicting requirements.

(2) A panoramic camera is a scanning type of camera that sweeps the terrain of interest from side to side across the direction of flight. This permits the panoramic camera to record a much wider area of ground than either frame or strip cameras. As in the case of the frame cameras, continuous cover is obtained by properly spaced exposures timed to give sufficient overlap between frames. Panoramic cameras are most advantageous for applications requiring the resolution of small ground detail from high altitudes.

8-3. TYPES OF FILM

Types of film generally used in aerial photography include panchromatic, infrared, and color. Camouflage detection film is also available.

a. **Panchromatic.** This is the same type of film that is used in the average hand-held small camera. It records the amount of light reflected from objects in tones of gray running from white to black. Most aerial photography is taken with panchromatic film.

b. **Infrared.** This is a black-and-white film that is sensitive to infrared waves. It can be used to detect artificial camouflage materials and to take photographs at night if there is a source of infrared radiation.

c. **Color.** This film is the same as that used in the average hand-held camera. It is limited in its use because of the time required to process it and its need for clear, sunny weather.

d. **Camouflage Detection.** This film is a special type that records natural vegetation in a reddish color. When artificial camouflage materials are photographed, they appear bluish or purplish. The name of this film indicates its primary use.

8-4. NUMBERING AND TITLING INFORMATION

Each aerial photograph contains in its margin important information for the photo user. The arrangement, type, and amount of this information is standardized; however, the rapid development of cameras, film, and aeronautical technology since World War II has caused numerous changes in the numbering and titling of aerial photographs. As a result, the photo user may find that the marginal information on older photographs varies somewhat from the standard current practice. With certain camera systems, some of the data are automatically recorded on each exposure, while other systems require that all titling data be added to the film after processing.

a. Standard titling data for aerial photography prepared for the use of the Department of Defense are as follows. For reconnaissance and charting photography, items 2 through 14 and item 19 are lettered on the beginning and end of each roll of film. Items 1 through 9 and item 19 are lettered on each exposure. For surveying and mapping photography, items 2 through 19 are lettered on the beginning and end of each roll of film, and items 1, 2, 3, 5, 6, 7, 8, 9, 13, and 19 are lettered on each exposure.

(1) Negative number.
(2) Camera position.
(3) Taking unit.
(4) Service.
(5) Sortie/mission number.
(6) Date (followed by a double hyphen [=]).
(7) Time group and zone letter (GMT).
(8) Focal length.
(9) Altitude.
(10) Kind of photography or imagery.
(11) Geographic coordinates.
(12) Descriptive title.
(13) Project number and or name.
(14) Camera type and serial number.

(15) Cone serial number (if any).
(16) Lens type and serial number.
(17) Magazine type and serial number.
(18) Type of photographic filter used.
(19) Security classification.

b. Automatically recorded data may differ somewhat in arrangement from the sequence listed above, but the same information is available to the photo user. A detailed explanation of the titling items and the codes used to indicate them is found in TM 5-243.

8-5. SCALE DETERMINATION

Before a photograph can be used as a map supplement or substitute, it is necessary to know its scale. On a map, the scale is printed as a representative fraction that expresses the ratio of map distance to ground distance, For example: $RF = \frac{MD}{GD}$

On a photograph, the scale is also expressed as a ratio, but is the ratio of the photo distance (***PD***) to ground distance**.** For example: $RF = \frac{PD}{GD}$

The approximate scale or average scale (***RF***) of a vertical aerial photograph is determined by either of two methods; the comparison method or the focal length-flight altitude method.

a. **Comparison Method.** The scale of a vertical aerial photograph is determined by comparing the measured distance between two points on the photograph with the measured ground distance between the same two points.

$$SCALE\ (RF = \frac{Photo\ Distance}{Ground\ Distance}$$

The ground distance is determined by actual measurement on the ground or by the use of the scale on a map of the same area. The points selected on the photograph must be identifiable on the ground or map of the same area and should be spaced in such a manner that a line connecting them will pass through or nearly through the center of the photograph (Figure 8-8).

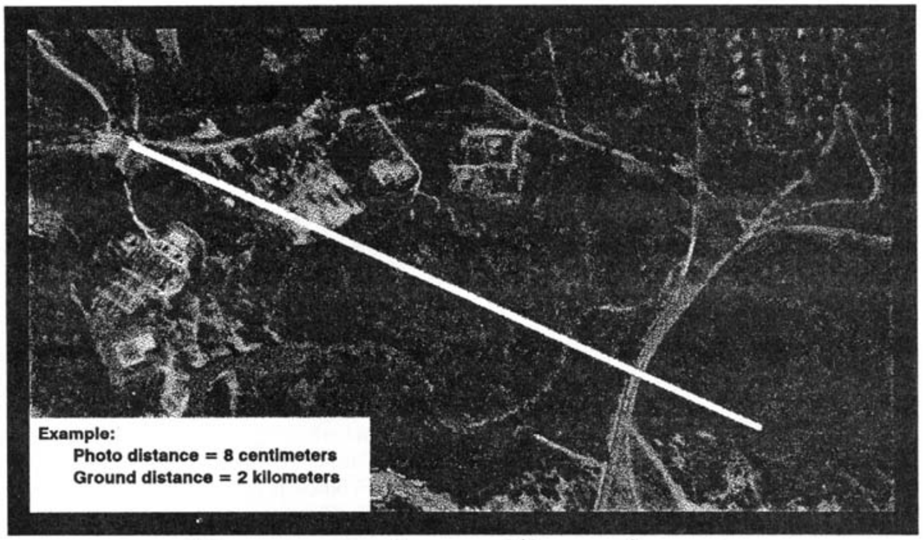

Example:
Photo distance = 8 centimeters
Ground distance = 2 kilometers

$$\frac{8cm}{2km \times 100{,}000\ (cm\ in\ 1km)} = \frac{8}{200{,}00}\ or\ \frac{8/8}{8/200{,}000} = \frac{1}{25{,}000}\ or\ RF = 1{:}25{,}000$$

Figure 8-8. Selection of points for scale determination.

b. **Focal Length-Flight Altitude Method.** When the marginal information of a photograph includes the focal length and the flight altitude, the scale of the photo is determined using the following formula (Figure 8-9).

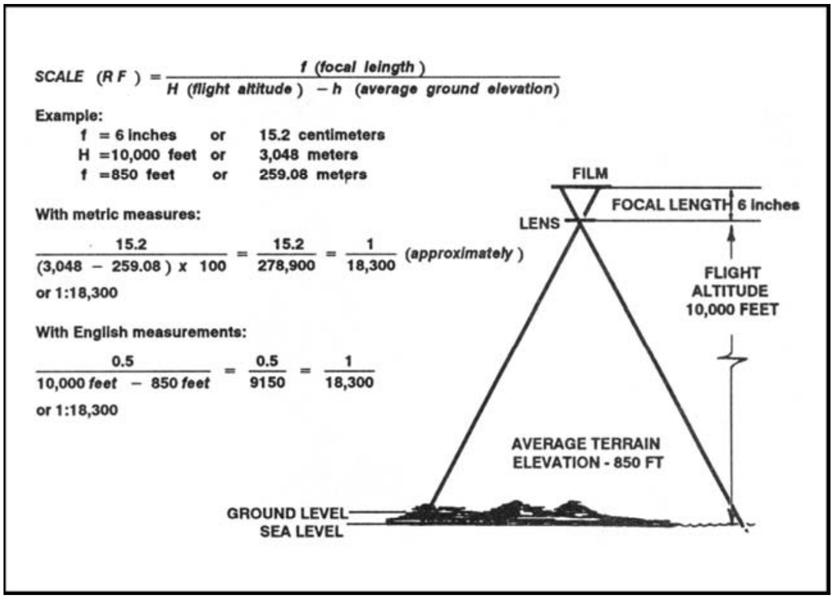

$$SCALE\ (RF) = \frac{f\ (focal\ leingth)}{H\ (flight\ altitude) - h\ (average\ ground\ elevation)}$$

Example:
f = 6 inches or 15.2 centimeters
H =10,000 feet or 3,048 meters
f =850 feet or 259.08 meters

With metric measures:

$$\frac{15.2}{(3{,}048 - 259.08) \times 100} = \frac{15.2}{278{,}900} = \frac{1}{18{,}300}\ (approximately)$$

or 1:18,300

With English measurements:

$$\frac{0.5}{10{,}000\ feet - 850\ feet} = \frac{0.5}{9150} = \frac{1}{18{,}300}$$

or 1:18,300

FILM
LENS
FOCAL LENGTH 6 inches
FLIGHT ALTITUDE 10,000 FEET
AVERAGE TERRAIN ELEVATION - 850 FT
GROUND LEVEL
SEA LEVEL

Figure 8-9. Computation of scale from terrain level.

When the ground elevation is at sea level, H becomes zero, and the formula is as shown in Figure 8-10.

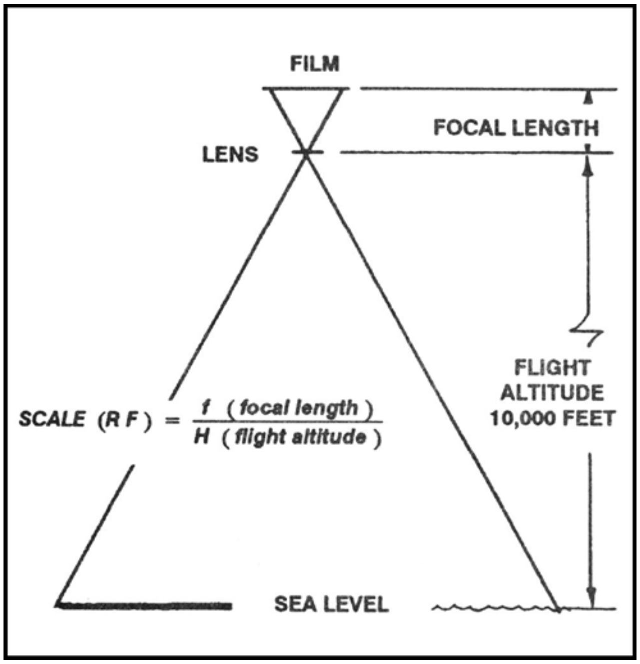
FILM
LENS
FOCAL LENGTH
FLIGHT ALTITUDE 10,000 FEET
SCALE (R F) = f (focal length) / H (flight altitude)
SEA LEVEL

Figure 8-10. Basic computation of scale from sea level.

8-6. INDEXING

When aerial photos are taken of an area, it is convenient to have a record of the extent of coverage of each photo. A map on which the area covered by each photo is outlined and numbered or indexed to correspond to the photo is called an index map. There are two methods of preparing index maps.

a. The four-corner method (Figures 8-11 and 8-12) requires location on the map of the exact point corresponding to each corner of the photo. If a recognizable object such as a house or road junction can be found exactly at one of the corners, this point may be used on the map as the corner of the photo. If recognizable objects cannot be found at the corners, then the edges of the photo should be outlined on the map by lining up two or more identifiable objects along each edge; the points where the edges intersect should be the exact corners of the photo. If the photo is not a perfect vertical, the area outlined on the map will not be a perfect square or rectangle. After the four sides are drawn on the map, the number of the photograph is written in the enclosed area for identification. This number should be placed in the same corner as it is on the photo.

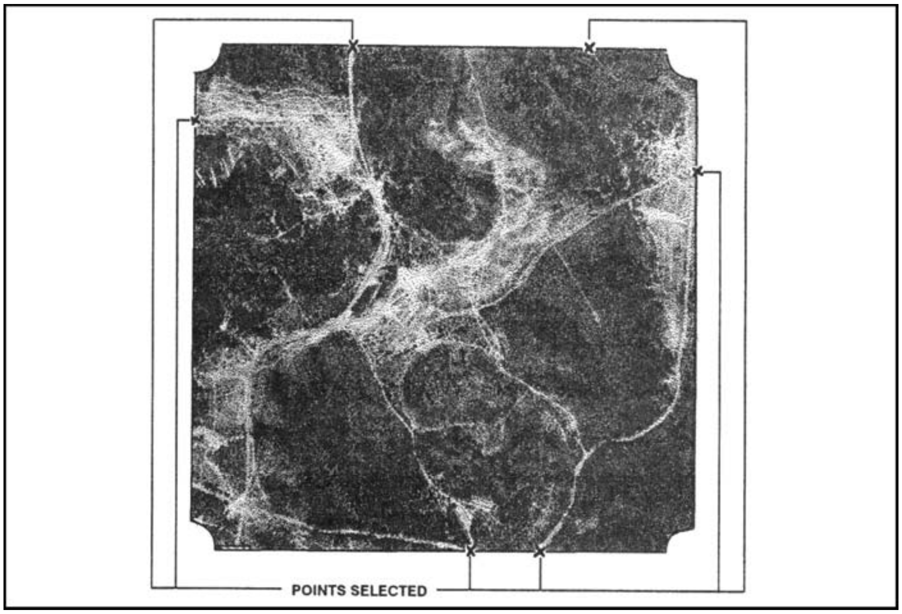
POINTS SELECTED

Figure 8-11. Four-corner method (selection of points).

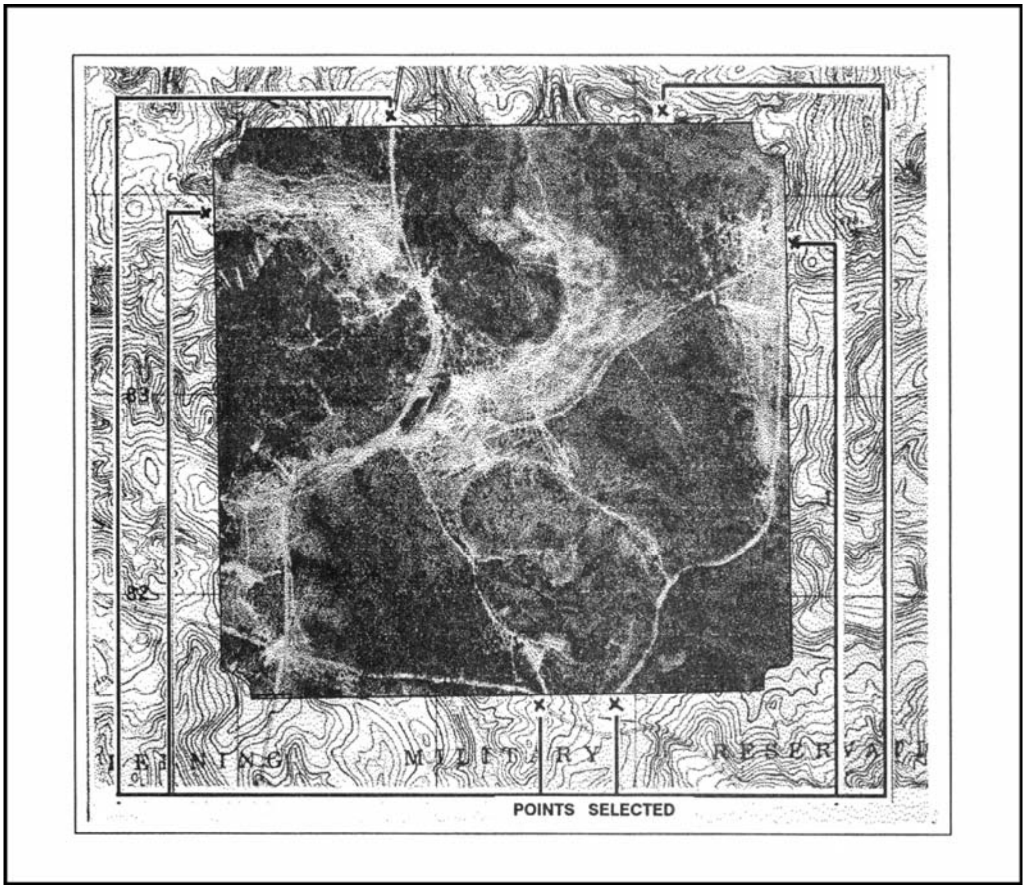
83
82
BENNING MILITARY RESERVATI
POINTS SELECTED

Figure 8-12. Plotting, using the four-corner method.

b. The template method is used when a large number of photos are to be indexed, and the exact area covered by each is not as important as approximate area and location. In this case, a template (cardboard pattern or guide) is cut to fit the average area the photos cover on the index map. It is used to outline the individual area covered by each photo. To construct a template, find the average map dimensions covered by the photos to be indexed as follows. Multiply the average length of the photos by the denominator of the average scale of the photos; multiply this by the scale of the map. Do the same for the width of the photos. This gives the average length and width of the area each photo covers on the map--or the size to which the template should be cut (Figure 8-13).

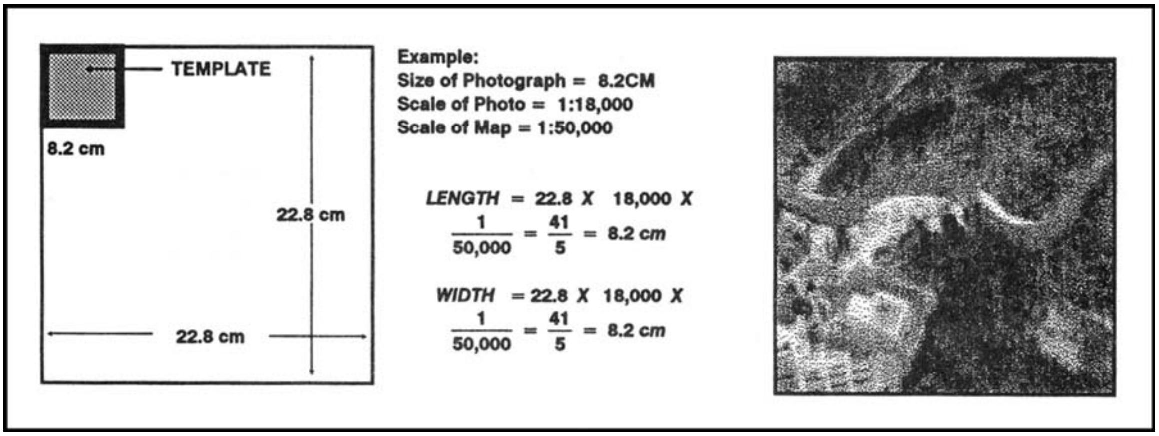

Example:
Size of Photograph = 8.2CM
Scale of Photo = 1:18,000
Scale of Map = 1:50,000

$$LENGTH = 22.8 \times 18{,}000 \times \frac{1}{50{,}000} = \frac{41}{5} = 8.2\ cm$$

$$WIDTH = 22.8 \times 18{,}000 \times \frac{1}{50{,}000} = \frac{41}{5} = 8.2\ cm$$

Figure 8-13. Constructing a template.

c. To index the map, select the general area covered by the first photo and orient the photo to the map. Place the template over the area on the map and adjust it until it covers the area as completely and accurately as possible. Draw lines around the edges of the template. Remove the rectangle and proceed to the next photo (Figure 8-14).

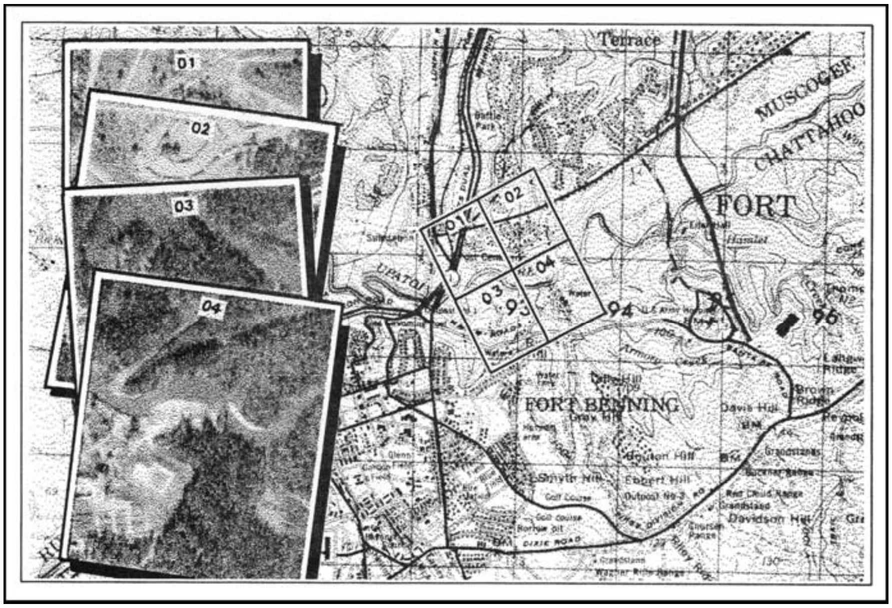

Figure 8-14. Indexing with a template.

d. After all photos have been plotted, write on the map sufficient information to identify the mission or sortie. If more than one sortie is plotted on one map or overlay, use a different color for each sortie.

e. In most cases, when a unit orders aerial photography, an index is included to give the basic information. Instead of being annotated on a map of the area, it appears on an overlay and is keyed to a map.

8-7. ORIENTING OF PHOTOGRAPH

Orienting the photograph is important because it is of very little value as a map supplement or substitute if its location and direction are not known by the user.

a. If a map of the same area as the photograph is available, the photograph is oriented to the map by comparing features common to both and then transferring a direction line from the map to the photograph.

b. If no map is available, the shadows on a photograph may be used to get an approximate true-north line. This method is not recommended in the torrid zone (Figure 8-15).

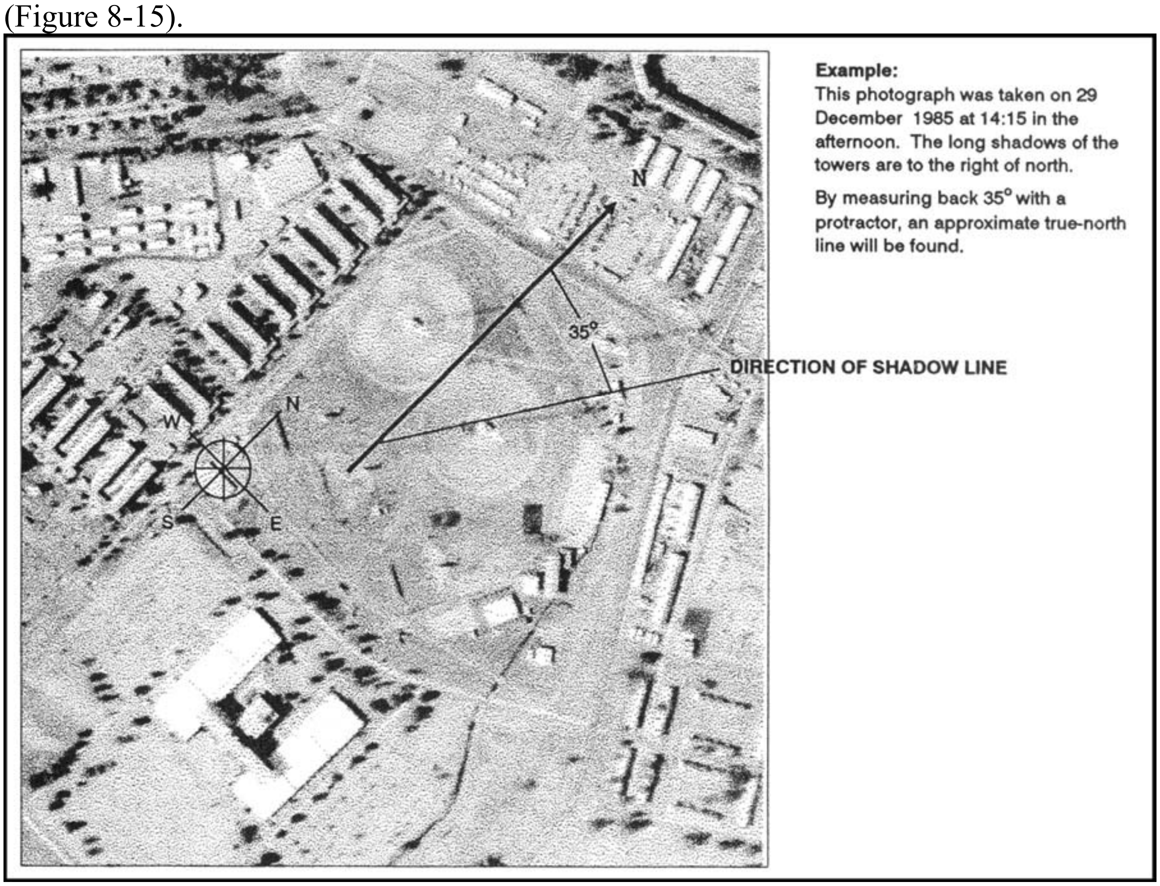

Example:
This photograph was taken on 29 December 1985 at 14:15 in the afternoon. The long shadows of the towers are to the right of north.

By measuring back 35° with a protractor, an approximate true-north line will be found.

Figure 8-15. Using shadows on a photograph to find north.

(1) ***North Temperate Zone***. The sun moves from the east in the morning through south at noon to west in the afternoon. Conversely, shadow fall varies from west through north to east. Before noon, therefore, north is to the right of the direction of shadow fall; at noon, north is the direction of shadow fall; and after noon, north is to the left of shadow fall. On an

average, the amount of variation in shadow fall per hour is 15 degrees. From marginal information, determine the number of hours from noon that the photo was taken and multiply that number by 15°. With a protractor, measure an angle of that amount in the proper direction (right to left) from a clear, distinct shadow, and north is obtained. For photographs taken within three hours of noon, a reasonable accurate north direction can be obtained. Beyond these limits, the 15° must be corrected, depending on time of year and latitude.

(2) ***South Temperate Zone***. The sun moves from east through north at noon to west. Shadows then vary from west through south to east. Before noon, south is to the left of shadow fall; at noon, south is shadow fall; and after noon, south is to the right of shadow fall. Proceed as in (1) above to determine the direction of south.

c. On a photograph that can be oriented to the surrounding ground features by inspection, a magnetic-north line can be established using a compass.

(1) Orient the photograph by inspection.

(2) Open the compass and place it on the photograph.

(3) Without moving the photograph, rotate the compass until the north arrow is under the stationary black line.

(4) Draw a line along the straight edge of the compass. This is a magnetic-north line.

8-8. POINT DESIGNATION GRID

Since aerial photographs are seldom exactly the same scale as a map of the same area, it is not feasible to print military grids on them. A special grid is used for the designation of points on photographs (Figure 8-16). This grid, known as the point designation grid, has no relation to the scale of the photo, to any direction, or to the grid used on any other photograph or map. It has only one purpose, to designate points on photographs.

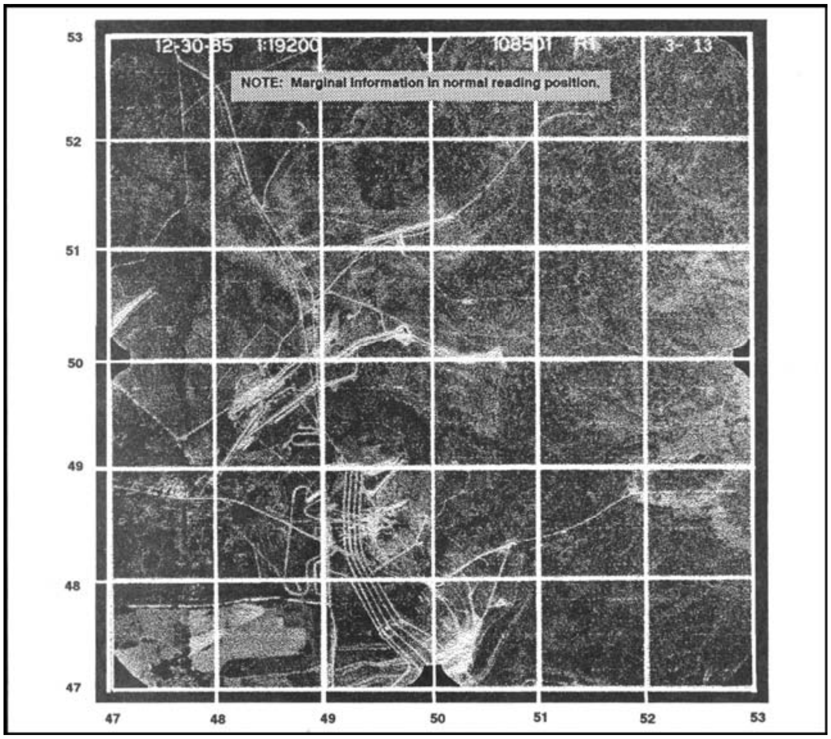

Figure 8-16. Point designation grid.

a. The point designation grid is rarely printed on photographs; therefore, it becomes the responsibility of each user to construct the grid on the photograph. All users must construct the grid in exactly the same way. Before the grid can be constructed or used, the photograph must be held so that the marginal information, regardless of where it is located, is in the normal reading position (Figure 8-17, step 1).

(1) Draw lines across the photograph joining opposite reference marks at the center of each photograph (fiducial marks). If there are no fiducial marks, the center of each side of the photograph is assumed to be the location of the marks (Figure 8-17, step 2).

(2) Space grid lines, starting with the center line, 4 centimeters (1.575 inches) apart (a distance equal to 1,000 meters at a scale of 1:25,000). The 1:25,000 map coordinate scale can be used for this dimension and to accurately designate points on the photograph, but this does not mean that distance can be scaled from the photograph. Extend the grid past the margins of the photograph so that a horizontal and vertical grid line fall outside the picture area (Figure 8-17, step 3).

(3) Number each center line "50" and give numerical values to the remaining horizontal and vertical lines so that they increase to the right and up (Figure 8-17, step 4).

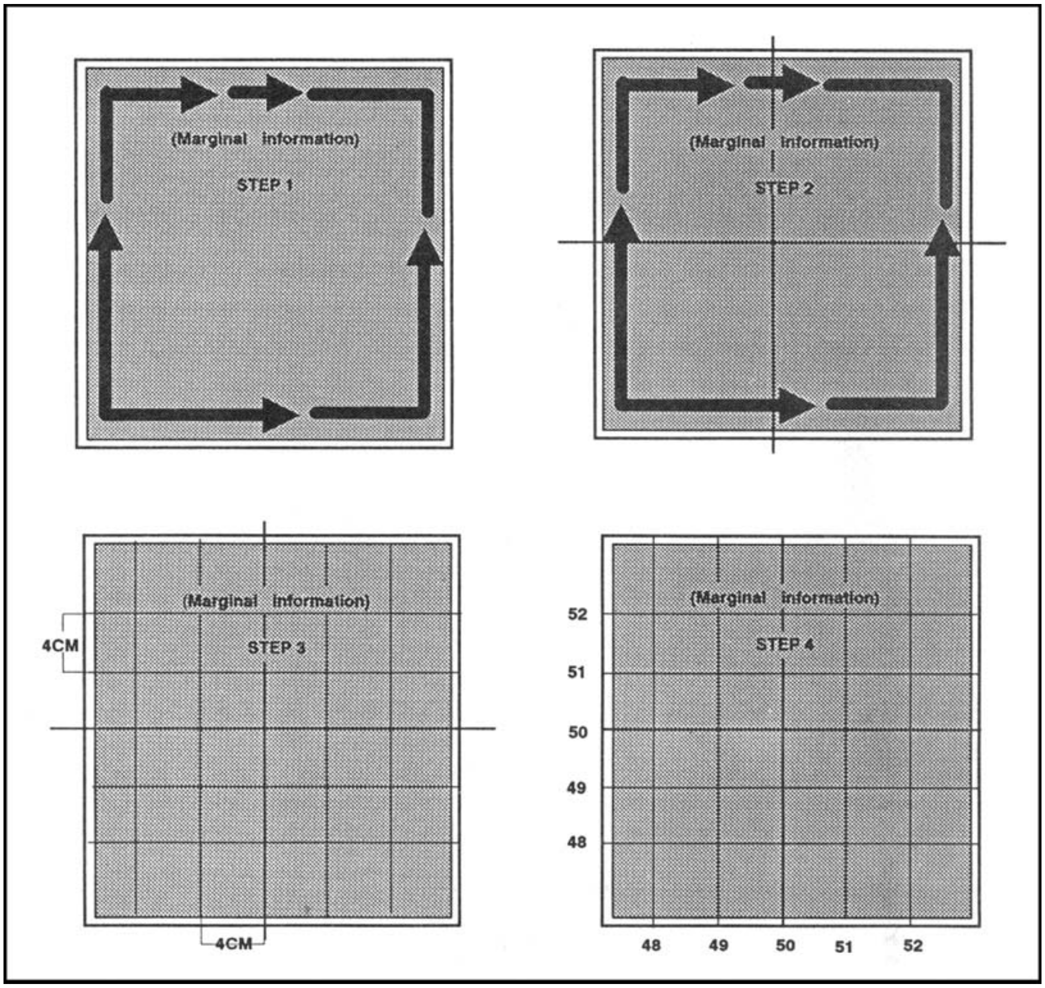

Figure 8-17. Constructing a point designation grid.

b. The point designation grid is used, once the photograph is oriented, in the same manner as the grid on a map (Figure 8-18), **read right and up**. The coordinate scale used with the UTM grid on maps at the scale of 1:25,000 may be used to subdivide the grid square in the same manner as on a map. However, because the same point designation grid is used on all photographs, the coordinates of a point on the photograph must be prefixed by the identifying marginal information of the photograph.

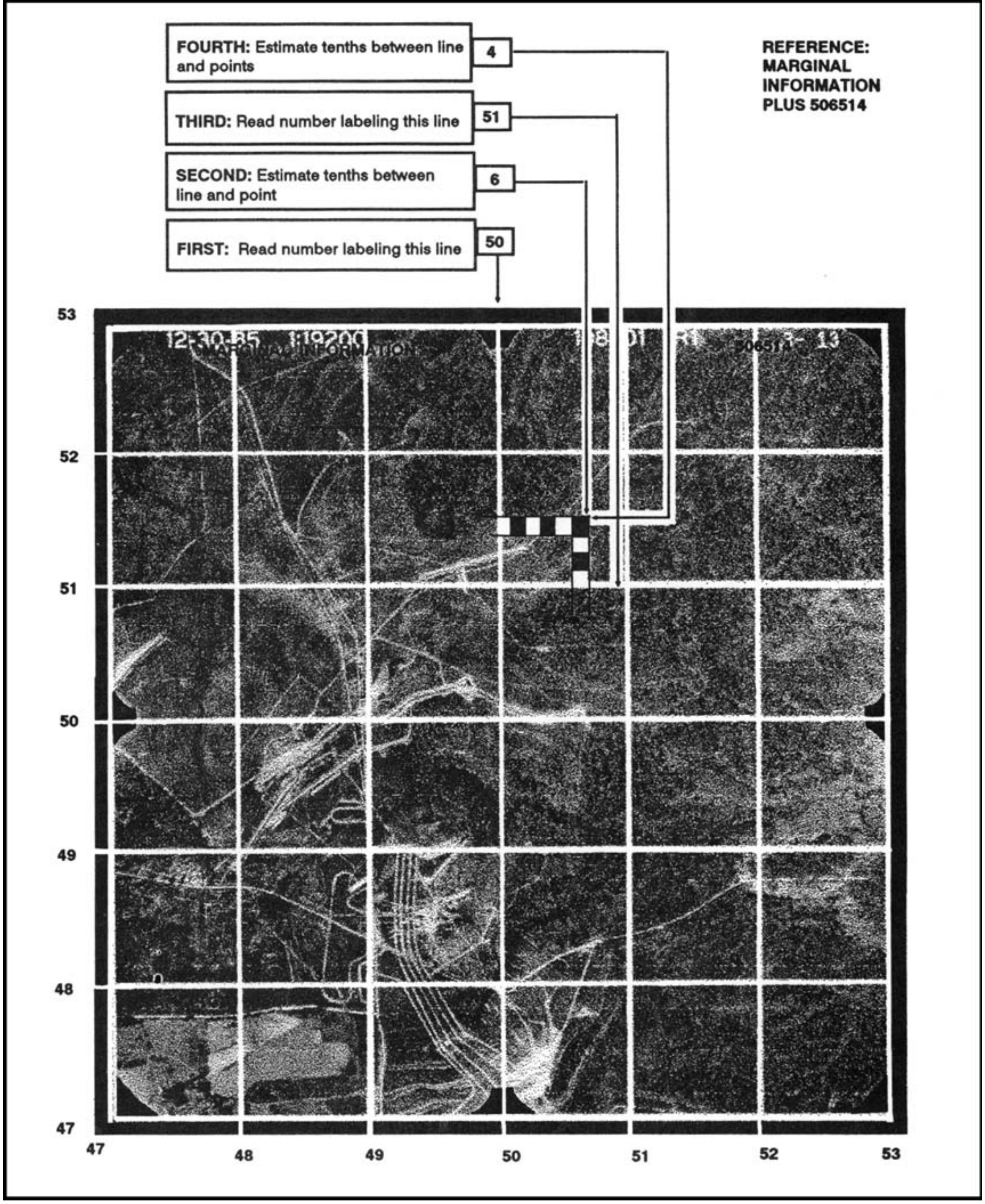
FOURTH: Estimate tenths between line and points
4
THIRD: Read number labeling this line
51
SECOND: Estimate tenths between line and point
6
FIRST: Read number labeling this line
50
REFERENCE: MARGINAL INFORMATION PLUS 506514
12-30-85 1:19200
506514
53
52
51
50
49
48
47
47
48
49
50
51
52
53

Figure 8-18. Reading point designation grid coordinates.

c. A grid coordinate using the point designation grid (Figure 8-19) consists of three parts:

(1) The letters "PDG" to indicate an aerial photograph rather than a map grid coordinate.

(2) The mission and photo negative number to identify which photograph is being used.

(3) The six numerical digits to locate the actual point on the photograph.

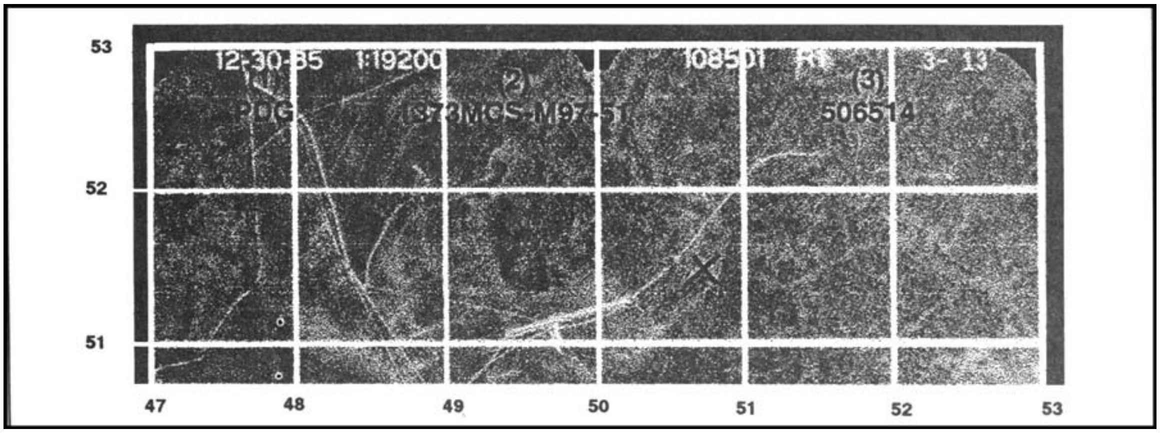

Figure 8-19. Locating the grid coordinate on a point designation grid.

8-9. IDENTIFICATION OF PHOTOGRAPH FEATURES

The identification of features on a photograph is not difficult if the following facts are remembered. The view that is presented by the aerial photograph is from above and, as a result, objects do not look familiar. Objects that are greatly reduced in size appear distorted. Most aerial photography is black and white, and all colors appear on the photograph in shades of gray. Generally speaking, the darker the natural color, the darker it will appear on the photograph.

a. The identification of features on aerial photographs depends upon a careful application of five factors of recognition. No one factor will give a positive identification; it requires the use of all five.

(1) ***Size***. The size of unknown objects on a photograph, as determined from the scale of the photograph or a comparison with known objects of known size, gives a clue to their identity. For example, in a built-up area the smaller buildings are usually dwellings, and the larger buildings are commercial or community buildings.

(2) ***Shape (Pattern)***. Many features possess characteristic shapes that readily identify the features. Man-made features appear as straight or smooth curved lines, while natural features usually appear to be irregular. Some of the most prominent man-made features are highways, railroads, bridges, canals, and buildings. Compare the regular shapes of these to the irregular shapes of such natural features as streams and timber lines.

(3*) Shadows*. Shadows are very helpful in identifying features since they show the familiar side view of the object. Some excellent examples are the shadows of water towers or smoke stacks. As viewed directly from above, only a round circle or dot is seen, whereas the shadow shows the profile and helps to identify the object. Relative lengths of shadows also usually give a good indication of relative heights of objects.

(4) ***Shade (Tone or Texture)***. Of the many different types of photographic film in use today, the film used for most aerial photography, except for special purposes, is

panchromatic film. Panchromatic film is sensitive to all the colors of the spectrum; it registers them as shades of gray, ranging from white to black. This lighter or darker shade of features on aerial photographs is known as the tone. The tone is also dependent on the texture of the features; a paved highway has a smooth texture and produces an even tone on the photograph, while a recently plowed field or a marsh has a rough, choppy texture and results in a rough or grainy tone. It is also important to remember that similar features may have different tones on different photographs, depending on the reflection of sunlight. For example, a river or body of water appears light if it is reflecting sunlight directly toward the camera, but appears dark otherwise. Its texture may be smooth or rough, depending on the surface of the water itself. As long as the variables are kept in mind, tone and texture may be used to great advantage.

(5) ***Surrounding Objects***. Quite often an object not easily recognized by itself may be identified by its relative position to surrounding objects. Large buildings located beside railroads or railroad sidings are usually factories or warehouses. Identify schools by the baseball or football fields. It would be hard to tell the difference between a water tower next to a railroad station and a silo next to a barn, unless the surrounding objects such as the railroad tracks or cultivated fields were considered.

b. Before a vertical photograph can be studied or used for identification of features, it must be oriented. This orienting is different from the orienting required for the construction or use of the point designation grid. Orienting for study consists of rotating the photograph so that the shadows on the photograph point toward yourself. You then face a source of light. This places the source of light, an object, and its shadow in a natural relationship. Failure to orient a photograph properly may cause the height or depth of an object to appear reversed. For example, a mine or quarry may appear to be a hill instead of a depression.

8-10. STEREOVISION

One of the limitations of the vertical aerial photograph is the lack of apparent relief. Stereoscopic vision (or as it is more commonly known, stereovision or depth perception) is the ability to see three-dimensionally or to see length, width, and depth (distance) at the same time. This requires two views of a single object from two slightly different positions. Most people have the ability to see three-dimensionally. Whenever an object is viewed, it is seen twice--once with the left eye and once with the right eye. The fusion or blending together of these two images in the brain permits the judgment of depth or distance.

a. In taking aerial photographs, it is rare for only a single picture to be taken. Generally, the aircraft flies over the area to be photographed taking a series of pictures, each of which overlaps the photograph preceding it and the photograph following it so that an unbroken coverage of the area is obtained (Figure 8-20). The amount of overlap is usually 56 percent, which means that 56 percent of the ground detail appearing on one photo also appears on the next photograph. When a single flight does not give the necessary coverage of an area, additional flights must be made. These additional flights are parallel to the first and must have an overlap between them. This overlap between flights is known as side lap and usually is between 15 and 20 percent (Figure 8-21, page 8-20).

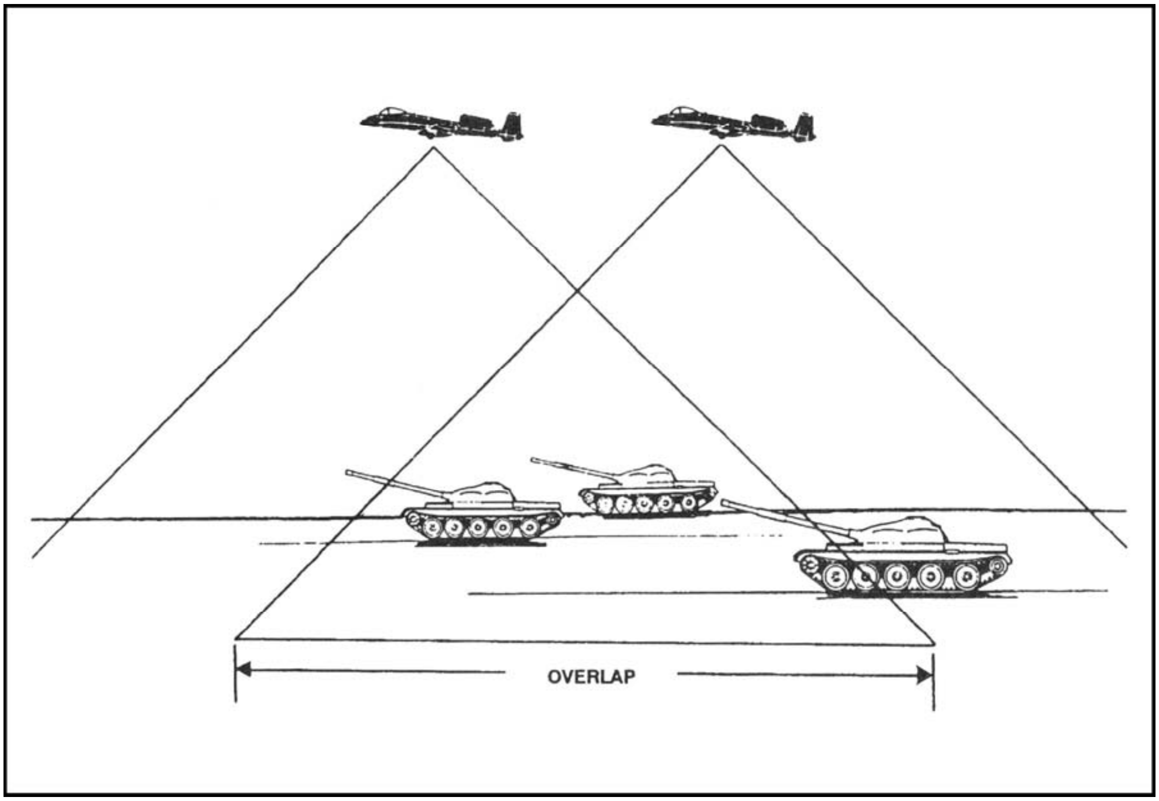

Figure 8-20. Photographic overlap.

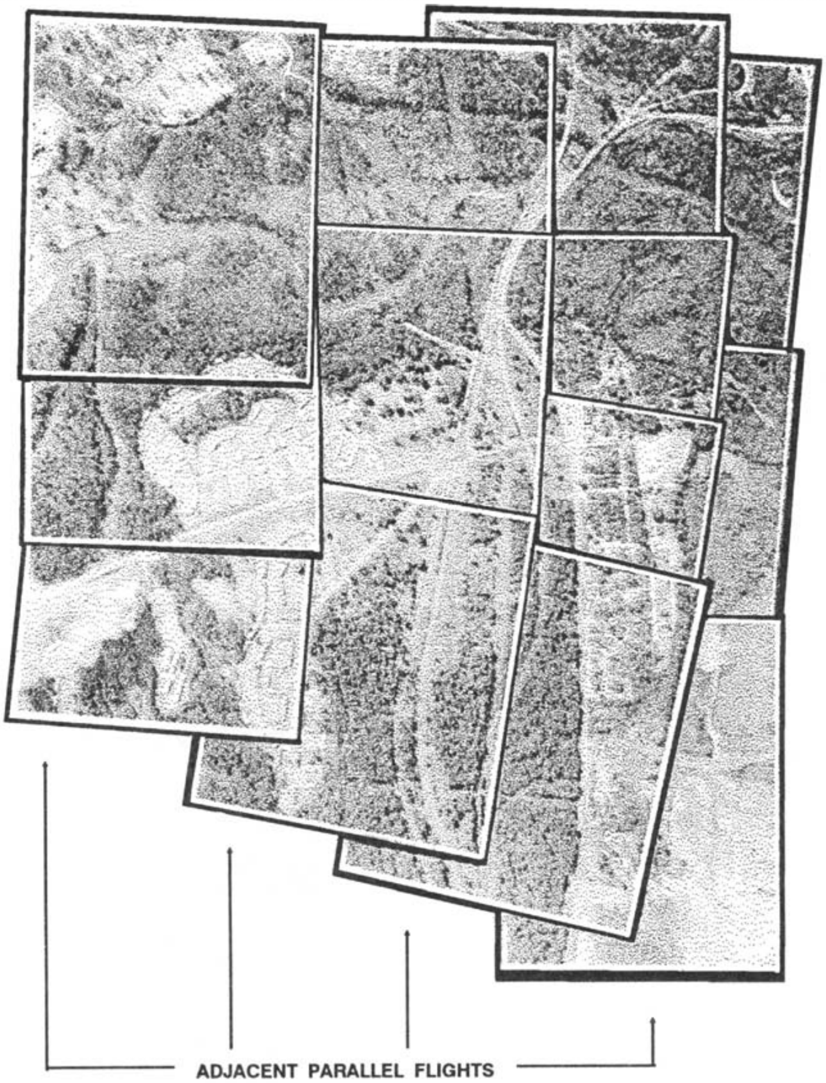

Figure 8-21. Side lap.

b. The requirement for stereovision can be satisfied by overlapping photographs if one eye sees the object on one photograph and the other eye sees the same object on another photograph. While this can be done after practice with the eyes alone, it is much easier if an optical aid is used. These optical aids are known as stereoscopes. There are many types of stereoscopes, but only the two most commonly used are discussed in this manual.

(1) ***Pocket Stereoscope***. The pocket stereoscope (Figure 8-22), sometimes known as a lens stereoscope, consists of two magnifying lenses mounted in a metal frame. Because of its simplicity and ease of carrying, it is the type used most frequently by military personnel.

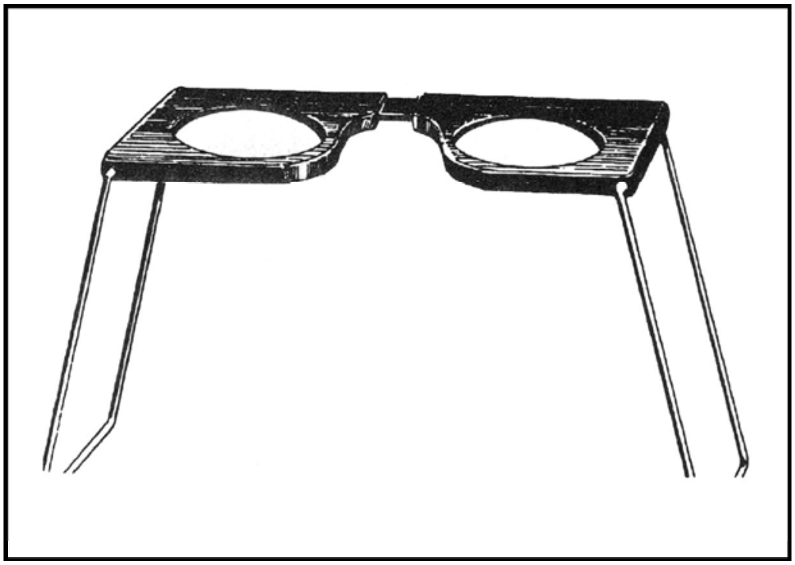

Figure 8-22. Pocket stereoscope.

(2) ***Mirror Stereoscope***. The mirror stereoscope (Figure 8-23) is larger, heavier, and more subject to damage than the pocket stereoscope. It consists of four mirrors mounted in a metal frame.

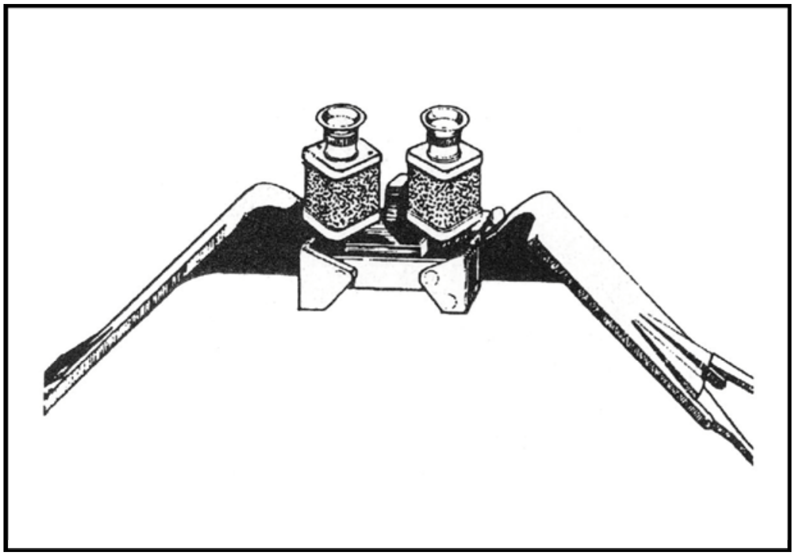

Figure 8-23. Mirror stereoscope.

c. A method to orient a pair of aerial photographs for best three-dimensional viewing is outlined below:

(1) Arrange the selected pair of photos in such a way that the shadows on them generally appear to fall toward the viewer. It is also desirable that the light source enters the side away from the observer during the study of the photographs (Figure 8-24, page 8-22).

(2) Place the pair of photographs on a flat surface so that the detail on one photograph is directly over the same detail on the other photograph (Figure 8-24, page 8-22).

(3) Place the stereoscope over the photographs so that the left lens is over the left photograph and the right lens is over the right photograph (Figure 8-24).

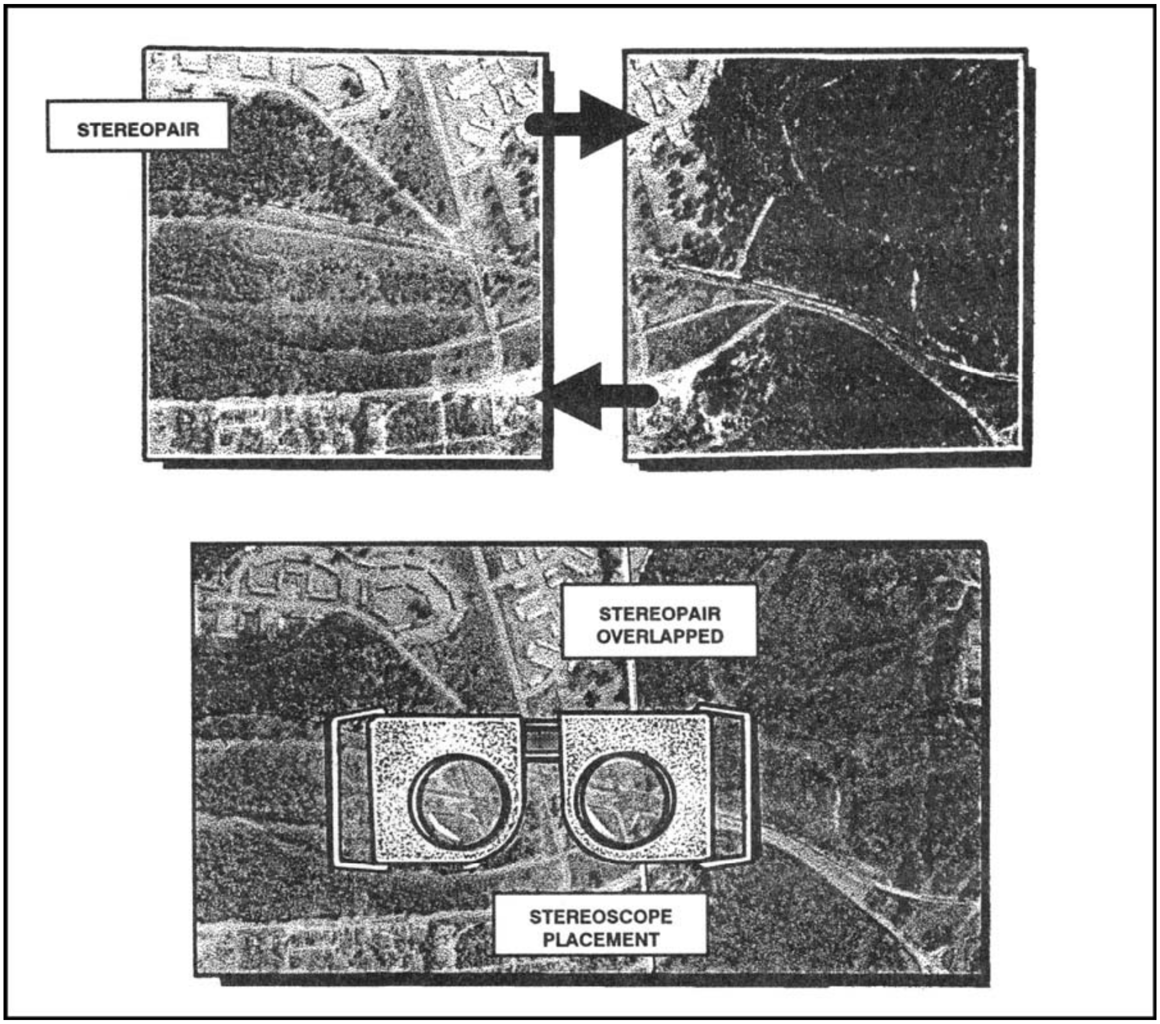

Figure 8-24. Placement of stereoscope over stereopair.

(4) Separate the photographs along the line of flight until a piece of detail appearing in the overlap area of the left photograph is directly under the left lens and the same piece of detail on the right photo is directly under the right lens.

(5) With the photograph and stereoscope in this position, a three-dimensional image should be seen. A few minor adjustments may be necessary, such as adjusting the aerial photographs of the stereoscope to obtain the correct position for your eyes. The hills appear to rise and the valleys sink so that there is the impression of being in an aircraft looking down at the ground.

(6) The identification of features on photographs is much easier and more accurate with this three-dimensional view. The same five factors of recognition (size, shape, shadow, tone, and surrounding objects) must still be applied; but now, with the addition of relief, a more natural view is seen.

PART TWO
LAND NAVIGATION

CHAPTER 9
NAVIGATION EQUIPMENT AND METHODS

Compasses are the primary navigation tools to use when moving in an outdoor world where there is no other way to find directions. Soldiers should be thoroughly familiar with the compass and its uses. Part One of this manual discussed the techniques of map reading. To complement these techniques, a mastery of field movement techniques is essential. This chapter describes the lensatic compass and its uses, and some of the field expedient methods used to find directions when compasses are not available.

9-1. TYPES OF COMPASSES

The **lensatic compass** is the most common and simplest instrument for measuring direction. It is discussed in detail in paragraph 9-2. The **artillery M2 compass** is a special-purpose instrument designed for accuracy; it will be discussed in Appendix G. The **wrist/pocket compass** is a small magnetic compass that can be attached to a wristwatch band. It contains a north-seeking arrow and a dial in degrees. A **protractor** can be used to determine azimuths when a compass is not available. However, it should be noted that when using the protractor on a map, only grid azimuths are obtained.

9-2. LENSATIC COMPASS

The lensatic compass (Figure 9-1) consists of three major parts: the cover, the base, and the lens.

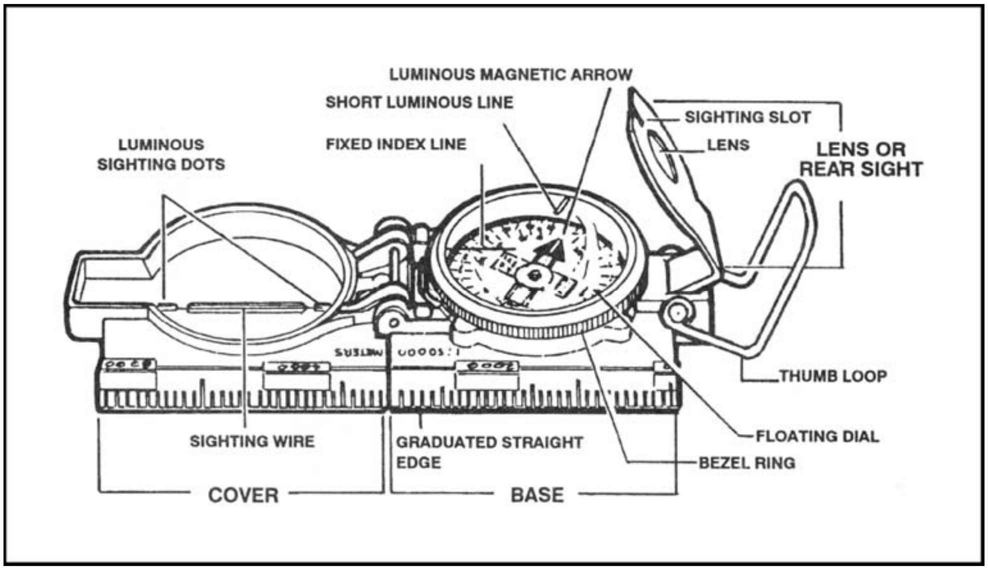
LUMINOUS MAGNETIC ARROW
SHORT LUMINOUS LINE
SIGHTING SLOT
LUMINOUS SIGHTING DOTS
FIXED INDEX LINE
LENS
LENS OR REAR SIGHT
THUMB LOOP
SIGHTING WIRE
GRADUATED STRAIGHT EDGE
FLOATING DIAL
BEZEL RING
COVER
BASE

Figure 9-1. Lensatic compass.

a. **Cover.** The compass cover protects the floating dial. It contains the sighting wire (front sight) and two luminous sighting slots or dots used for night navigation.

b. **Base.** The body of the compass contains the following movable parts:

(1) The floating dial is mounted on a pivot so it can rotate freely when the compass is held level. Printed on the dial in luminous figures are an arrow and the letters E and W. The arrow always points to magnetic north and the letters fall at east (E) 90° and west (W) 270° on the dial. There are two scales; the outer scale denotes mils and the inner scale (normally in red) denotes degrees.

(2) Encasing the floating dial is a glass containing a fixed black index line.

(3) The bezel ring is a ratchet device that clicks when turned. It contains 120 clicks when rotated fully; each click is equal to 3°. A short luminous line that is used in conjunction with the north-seeking arrow during navigation is contained in the glass face of the bezel ring.

(4) The thumb loop is attached to the base of the compass.

c. **Lens.** The lens is used to read the dial, and it contains the rear-sight slot used in conjunction with the front for sighting on objects. The rear sight also serves as a lock and clamps the dial when closed for its protection. The rear sight must be opened more than 45° to allow the dial to float freely.

NOTE: When opened, the straightedge on the left side of the compass has a coordinate scale; the scale is 1:50,000 in newer compasses.

WARNING

Some older compasses will have a 1:25,000 scale. This scale can be used with a 1:50,000-scale map, but the values read must be halved. Check the scale.

9-3. COMPASS HANDLING

Compasses are delicate instruments and should be cared for accordingly.

a. **Inspection.** A detailed inspection is required when first obtaining and using a compass. One of the most important parts to check is the floating dial, which contains the magnetic needle. The user must also make sure the sighting wire is straight, the glass and crystal parts are not broken, the numbers on the dial are readable, and most important, that the dial does not stick.

b. **Effects of Metal and Electricity.** Metal objects and electrical sources can affect the performance of a compass. However, nonmagnetic metals and alloys do not affect compass readings. The following separation distances are suggested to ensure proper functioning of a compass:

High-tension power lines	55 meters.
Field gun, truck, or tank	18 meters.
Telegraph or telephone wires and barbed wire	10 meters.
Machine gun	2 meters.
Steel helmet or rifle	1/2 meter.

c. **Accuracy.** A compass in good working condition is very accurate. However, a compass has to be checked periodically on a known line of direction, such as a surveyed azimuth using a declination station. Compasses with more than 3° + variation should not be used.

d. **Protection.** If traveling with the compass unfolded, make sure the rear sight is fully folded down onto the bezel ring. This will lock the floating dial and prevent vibration, as well as protect the crystal and rear sight from damage.

9-4. USING A COMPASS

Magnetic azimuths are determined with the use of magnetic instruments, such as lensatic and M2 compasses. The techniques employed when using the lensatic compass are as follows:

a. **Using the Centerhold Technique.** First, open the compass to its fullest so that the cover forms a straightedge with the base. Move the lens (rear sight) to the rearmost position, allowing the dial to float freely. Next, place your thumb through the thumb loop, form a steady base with your third and fourth fingers, and extend your index finger along the side of the compass. Place the thumb of the other hand between the lens (rear sight) and the bezel ring; extend the index finger along the remaining side of the compass, and the remaining fingers around the fingers of the other hand. Pull your elbows firmly into your sides; this will place the compass between your chin and your belt. To measure an azimuth, simply turn your entire body toward the object, pointing the compass cover directly at the object. Once you are pointing at the object, look down and read the azimuth from beneath the fixed black index line (Figure 9-2). This preferred method offers the following advantages over the sighting technique:

(1) It is faster and easier to use.

(2) It can be used under all conditions of visibility.

(3) It can be used when navigating over any type of terrain.

(4) It can be used without putting down the rifle; however, the rifle must be slung well back over either shoulder.

(5) It can be used without removing eyeglasses.

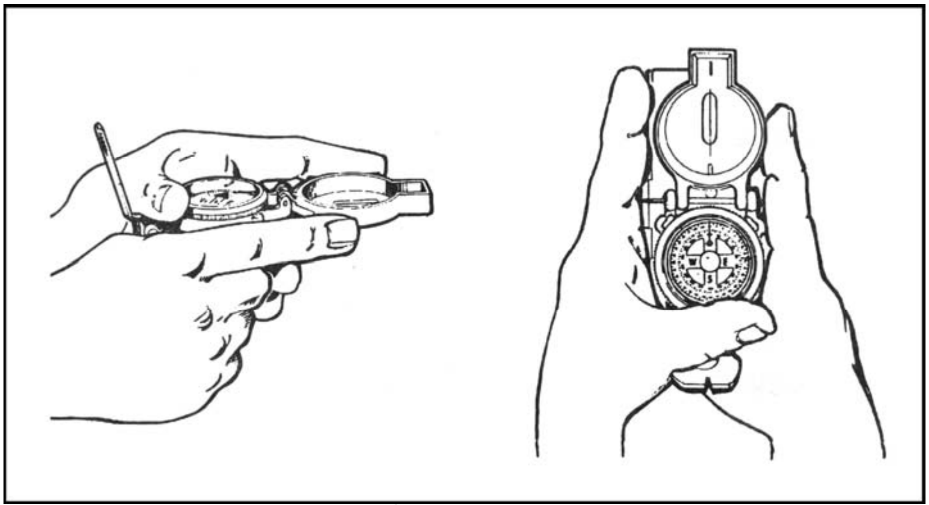

Figure 9-2. Centerhold technique.

b. **Using the Compass-to-Cheek Technique.** Fold the cover of the compass containing the sighting wire to a vertical position; then fold the rear sight slightly forward. Look through the rear-sight slot and align the front-sight hairline with the desired object in the distance. Then glance down at the dial through the eye lens to read the azimuth (Figure 9-3).

NOTE: The compass-to-cheek technique is used almost exclusively for sighting, and it is the best technique for this purpose.

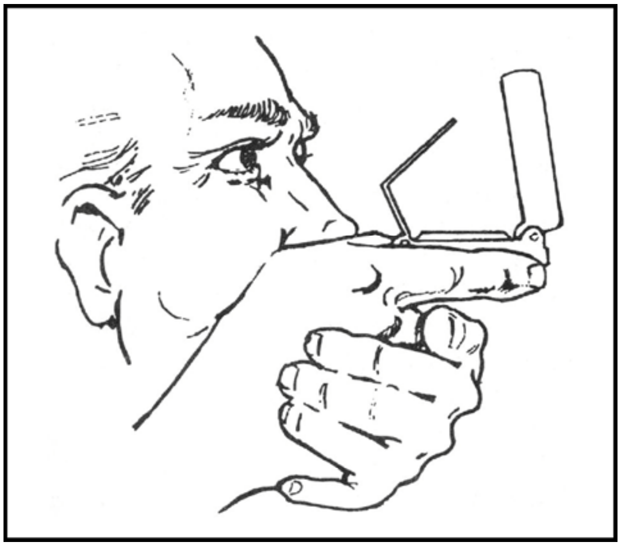

Figure 9-3. Compass-to-cheek technique.

c. **Presetting a Compass and Following an Azimuth.** Although different models of the lensatic compass vary somewhat in the details of their use, the principles are the same.

(1) During daylight hours or with a light source:

(a) Hold the compass level in the palm of the hand.

(b) Rotate it until the desired azimuth falls under the fixed black index line (for example, 320°), maintaining the azimuth as prescribed (Figure 9-4).

(c) Turn the bezel ring until the luminous line is aligned with the north-seeking arrow. Once the alignment is obtained, the compass is preset.

(d) To follow an azimuth, assume the centerhold technique and turn your body until the north-seeking arrow is aligned with the luminous line. Then proceed forward in the direction of the front cover's sighting wire, which is aligned with the fixed black index line that contains the desired azimuth.

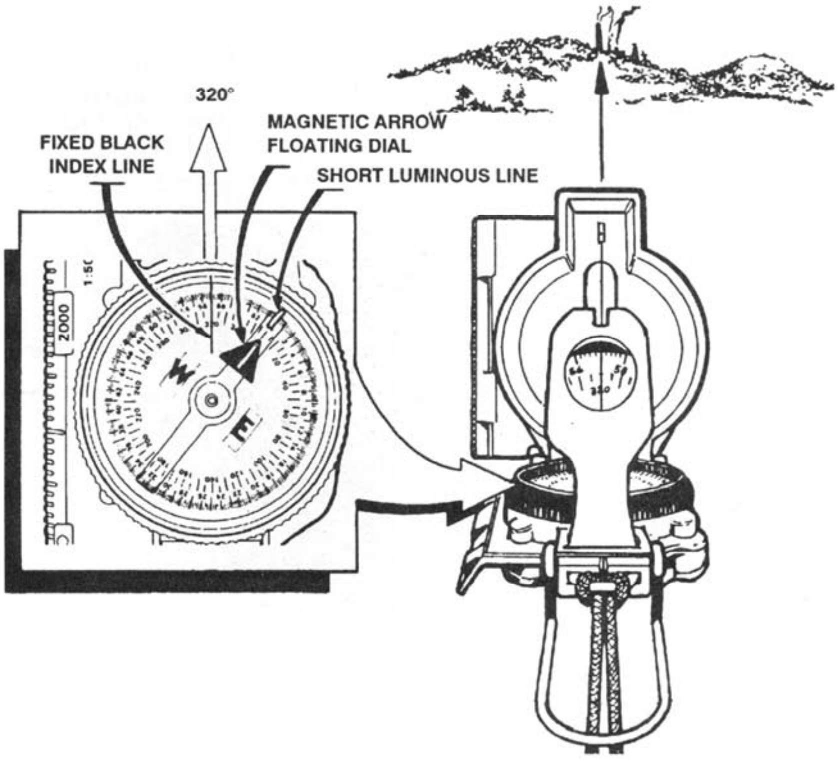

Figure 9-4. Compass preset at 320 degrees.

(2) During limited visibility, an azimuth may be set on the compass by the click method. Remember that the bezel ring contains 3° intervals (clicks).

(a) Rotate the bezel ring until the luminous line is over the fixed black index line.

(b) Find the desired azimuth and divide it by three. The result is the number of clicks that you have to rotate the bezel ring.

(c) Count the desired number of clicks. If the desired azimuth is smaller than 180°, the number of clicks on the bezel ring should be counted in a counterclockwise direction. For example, the desired azimuth is 51°. Desired azimuth is 51°÷ 3 = 17 clicks counterclockwise. If the desired azimuth is larger than 180°, subtract the number of degrees from 360° and divide by 3 to obtain the number of clicks. Count them in a clockwise direction. For example, the desired azimuth is 330°; 360°-330° = 30 ÷3 = 10 clicks clockwise.

(d) With the compass preset as described above, assume a centerhold technique and rotate your body until the north-seeking arrow is aligned with the luminous line on the bezel. Then proceed forward in the direction of the front cover's luminous dots, which are aligned with the fixed black index line containing the azimuth.

(e) When the compass is to be used in darkness, an initial azimuth should be set while light is still available, if possible. With the initial azimuth as a base, any other azimuth that is a multiple of three can be established through the use of the clicking feature of the bezel ring.

NOTE: Sometimes the desired azimuth is not exactly divisible by three, causing an option of rounding up or rounding down. If the azimuth is rounded up, this causes an increase in the value of the azimuth, and the object is to be found on the left. If the azimuth is rounded down, this causes a decrease in the value of the azimuth, and the object is to be found on the right.

d. **Bypassing an Obstacle**. To bypass enemy positions or obstacles and still stay oriented, detour around the obstacle by moving at right angles for specified distances.

(1) For example, while moving on an azimuth of 90° change your azimuth to 180° and travel for 100 meters. Change your azimuth to 90°and travel for 150 meters. Change your azimuth to 360°and travel for 100 meters. Then, change your azimuth to 90°and you are back on your original azimuth line (Figure 9-5).

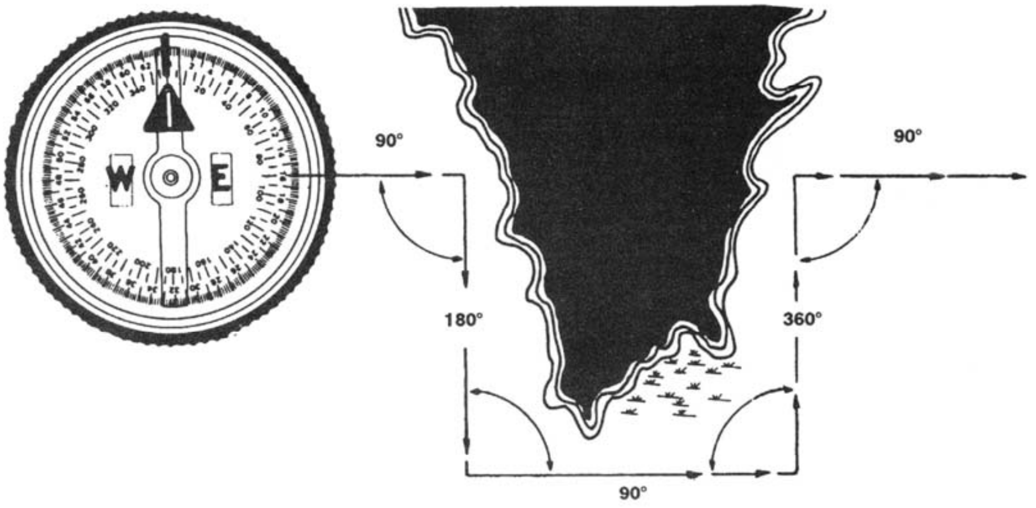

Figure 9-5. Bypassing an obstacle.

(2) Bypassing an unexpected obstacle at night is a fairly simple matter. To make a 90° turn to the right, hold the compass in the centerhold technique; turn until the center of the luminous letter E is under the luminous line (*do not* move the bezel ring). To make a 90° turn to the left, turn until the center of the luminous letter W is under the luminous line. This does not require changing the compass setting (bezel ring), and it ensures accurate 90° turns.

e. **Offset.** A deliberate offset is a planned magnetic deviation to the right or left of an azimuth to an objective. Use it when the objective is located along or in the vicinity of a linear feature such as a road or stream. Because of errors in the compass or in map reading, the linear feature may be reached without knowing whether the objective lies to the right or left. A deliberate offset by a known number of degrees in a known direction compensates for possible errors and ensures that upon reaching the linear feature, the user knows whether to go right or left to reach the objective. Ten degrees is an adequate offset for most tactical uses. Each degree offset moves the course about 18 meters to the right or left for each 1,000 meters traveled. For example, in Figure 9-6, the number of degrees offset is 10. If the distance traveled to "x" in 1,000 meters, then "x" is located about 180 meters to the right of the objective.

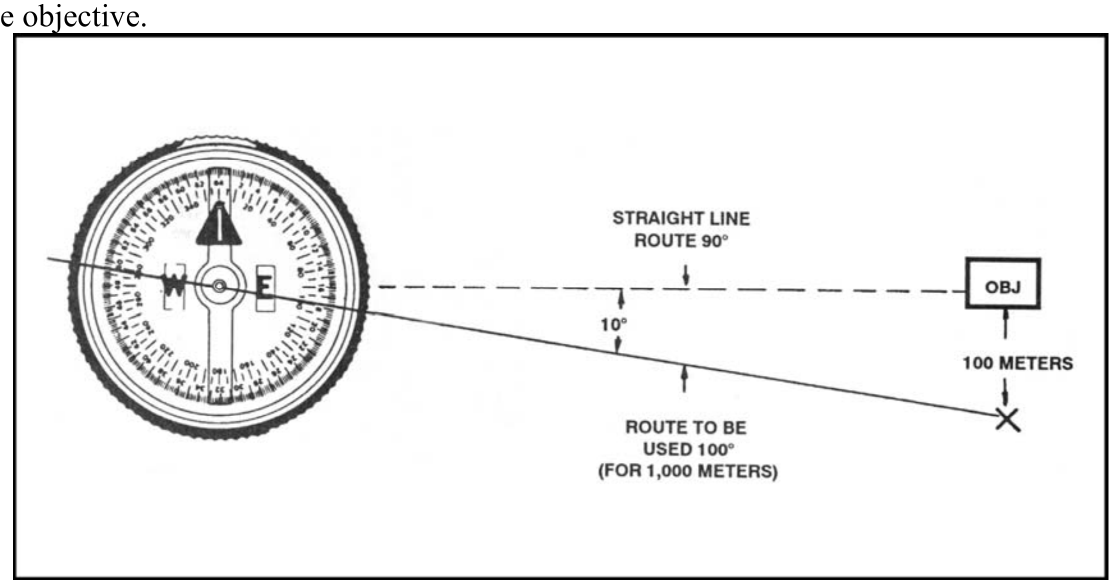
STRAIGHT LINE
ROUTE 90°
OBJ
10°
100 METERS
ROUTE TO BE
USED 100°
(FOR 1,000 METERS)

Figure 9-6. Deliberate offset to the objective.

9-5. FIELD-EXPEDIENT METHODS

When a compass is not available, different techniques should be used to determine the four cardinal directions.

a. **Shadow-Tip Method.**

(1) This simple and accurate method of finding direction by the sun consists of four basic steps (Figure 9-7).

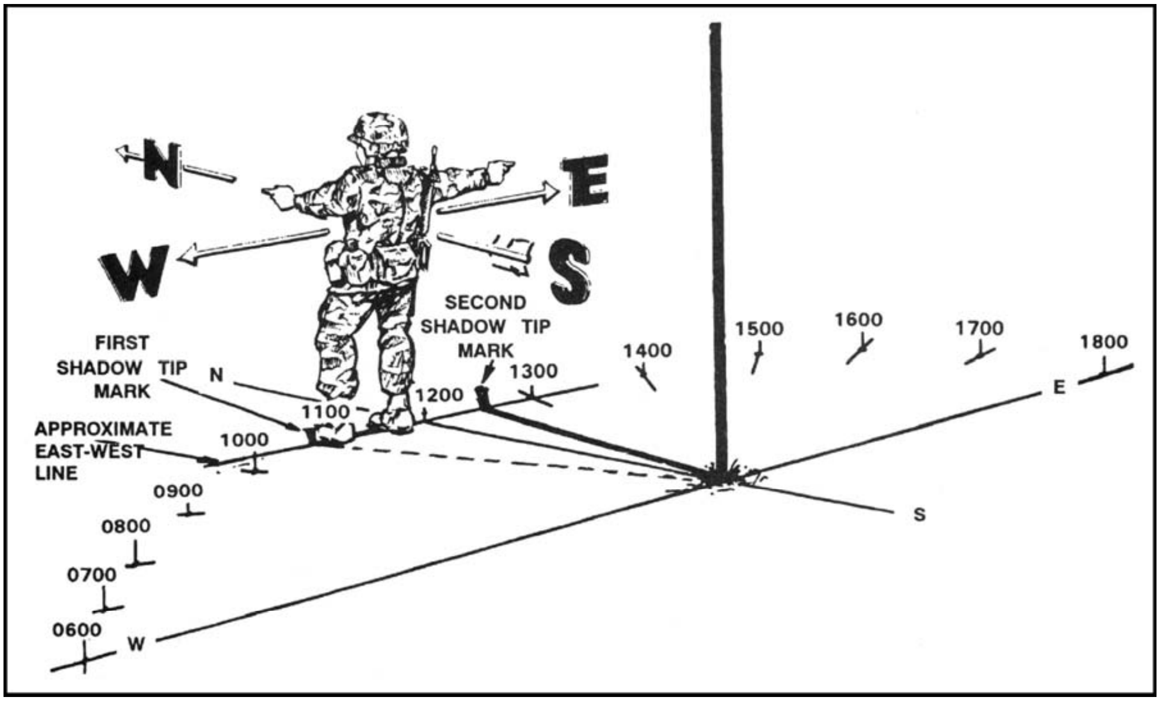
N
E
W
S
SECOND
SHADOW TIP
MARK
FIRST
SHADOW TIP
MARK
APPROXIMATE
EAST-WEST
LINE
N
1100
1200
1300
1000
0900
0800
0700
0600
W
1400
1500
1600
1700
1800
E
S

Figure 9-7. Determining directions and time by shadow.

Step 1. Place a stick or branch into the ground at a level spot where a distinctive shadow will be cast. Mark the shadow tip with a stone, twig, or other means. This first shadow mark is always the west direction.

Step 2. Wait 10 to 15 minutes until the shadow tip moves a few inches. Mark the new position of the shadow tip in the same way as the first.

Step 3. Draw a straight line through the two marks to obtain an approximate east-west line.

Step 4. Standing with the first mark (west) to your left, the other directions are simple; north is to the front, east is to the right, and south is behind you.

(2) A line drawn perpendicular to the east-west line at any point is the approximate north-south line. If you are uncertain which direction is east and which is west, observe this simple rule--the first shadow-tip mark is always in the west direction, everywhere on earth.

(3) The shadow-tip method can also be used as a shadow clock to find the approximate time of day (Figure 9-7 on page 9-7).

(a) To find the time of day, move the stick to the intersection of the east-west line and the north-south line, and set it vertically in the ground. The west part of the east-west line indicates 0600 hours, and the east part is 1800 hours, anywhere on earth, because the basic rule always applies.

(b) The north-south line now becomes the noon line. The shadow of the stick is an hour hand in the shadow clock, and with it you can estimate the time using the noon line and the 6 o'clock line as your guides. Depending on your location and the season, the shadow may move either clockwise or counterclockwise, but this does not alter your manner of reading the shadow clock.

(c) The shadow clock is not a timepiece in the ordinary sense. It makes every day 12 unequal hours long, and always reads 0600 hours at sunrise and 1800 hours at sunset. The shadow clock time is closest to conventional clock time at midday, but the spacing of the other hours compared to conventional time varies somewhat with the locality and the date. However, it does provide a satisfactory means of telling time in the absence of properly set watches.

(d) The shadow-tip system is not intended for use in polar regions, which the Department of Defense defines as being above 60° latitude in either hemisphere. Distressed persons in these areas are advised to stay in one place so that search/rescue teams may easily find them. The presence and location of all aircraft and ground parties in polar regions are reported to and checked regularly by governmental or other agencies, and any need for help becomes quickly known.

b. **Watch Method.**

(1) A watch can be used to determine the approximate true north and true south. In the north temperate zone only, the hour hand is pointed toward the sun. A south line can be found midway between the hour hand and 1200 hours, standard time. If on daylight saving time, the north-south line is found between the hour hand and 1300 hours. If there is any doubt as to which end of the line is north, remember that the sun is in the east before noon and in the west after noon.

(2) The watch may also be used to determine direction in the south temperate zone; however, the method is different. The 1200-hour dial is pointed toward the sun, and halfway

between 1200 hours and the hour hand will be a north line. If on daylight saving time, the north line lies midway between the hour hand and 1300 hours (Figure 9-8).

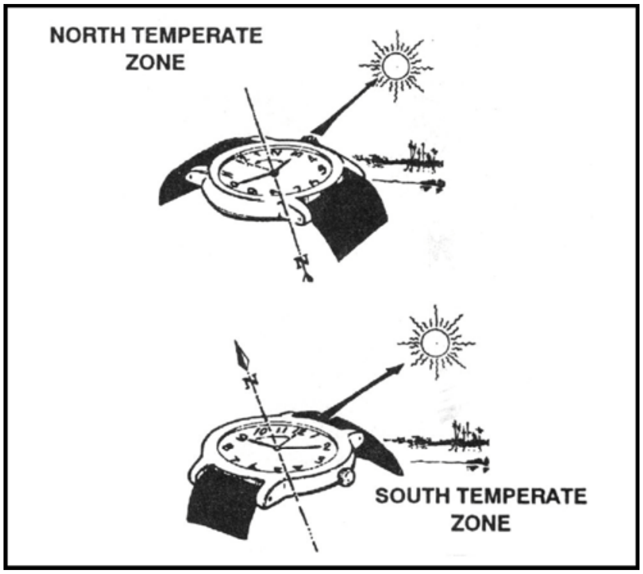

Figure 9-8. Determining direction by using a watch.

(3) The watch method can be in error, especially in the lower latitudes, and may cause *circling*. To avoid this, make a shadow clock and set your watch to the time indicated. After traveling for an hour, take another shadow-clock reading. Reset your watch if necessary.

c. **Star Method.**

(1) Less than 60 of approximately 5,000 stars visible to the eye are used by navigators. The stars seen as we look up at the sky at night are not evenly scattered across the whole sky. Instead they are in groups called constellations.

(2) The constellations that we see depends partly on where we are located on the earth, the time of the year, and the time of the night. The night changes with the seasons because of the journey of the earth around the sun, and it also changes from hour to hour because the turning of the earth makes some constellations seem to travel in a circle. But there is one star that is in almost exactly the same place in the sky all night long every night. It is the North Star, also known as the Polar Star or Polaris.

(3) The North Star is less than 1° off true north and does not move from its place because the axis of the earth is pointed toward it. The North Star is in the group of stars called the Little Dipper. It is the last star in the handle of the dipper. There are two stars in the Big Dipper, which are a big help when trying to find the North Star. They are called the Pointers, and an imaginary line drawn through them five times their distance points to the North Star. There are many stars brighter than the North Star, but none is more important because of its location. However, the North Star can only be seen in the northern hemisphere so it cannot serve as a guide south of the equator. The farther one goes north, the higher the North Star is in the sky, and above latitude 70°, it is too high in the sky to be useful (Figure 9-9).

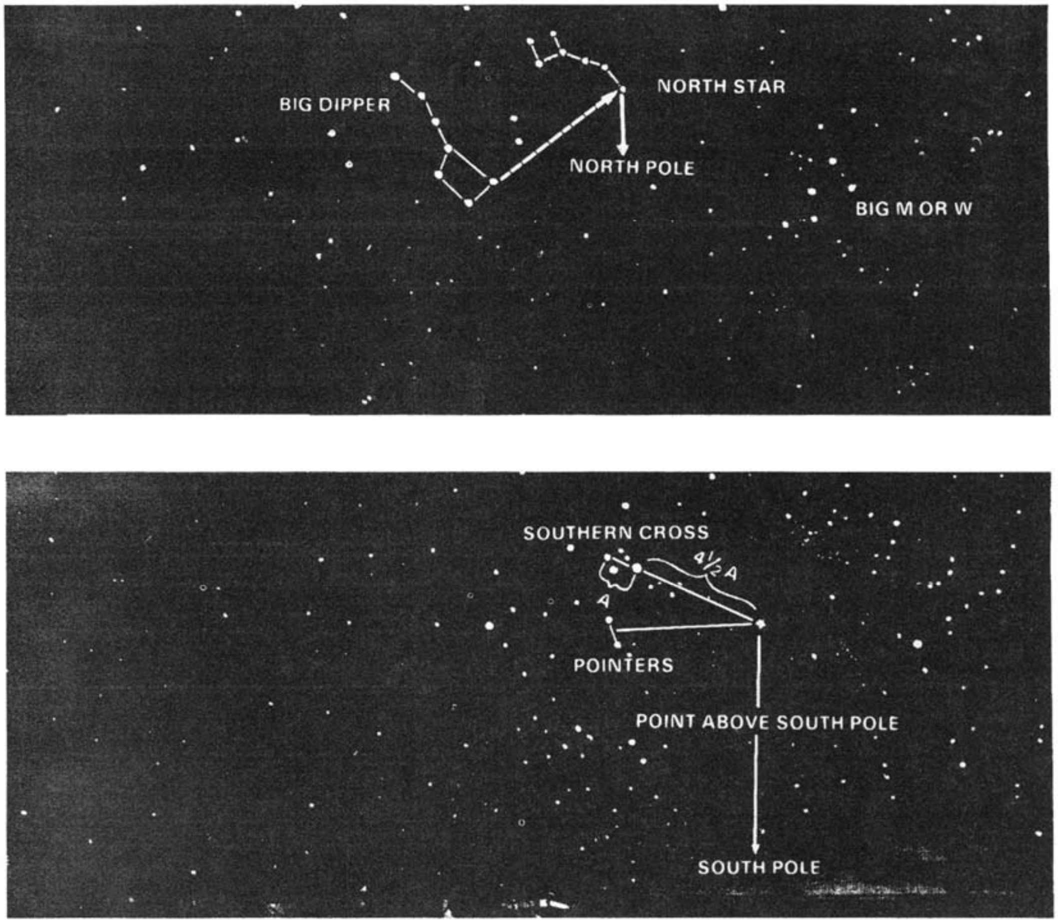
BIG DIPPER
NORTH STAR
NORTH POLE
BIG M OR W
SOUTHERN CROSS
4½ A
A
POINTERS
POINT ABOVE SOUTH POLE
SOUTH POLE

Figure 9-9. Determining direction by the North Star and Southern Cross.

(4) Depending on the star selected for navigation, azimuth checks are necessary. A star near the north horizon serves for about half an hour. When moving south, azimuth checks should be made every 15 minutes. When traveling east or west, the difficulty of staying on azimuth is caused more by the likelihood of the star climbing too high in the sky or losing itself behind the western horizon than it is by the star changing direction angle. When this happens, it is necessary to change to another guide star. The Southern Cross is the main constellation used as a guide south of the equator, and the above general directions for using north and south stars are reversed. When navigating using the stars as guides, the user must know the different constellation shapes and their locations throughout the world (Figure 9-10 and Figure 9-11 on page 9-12).

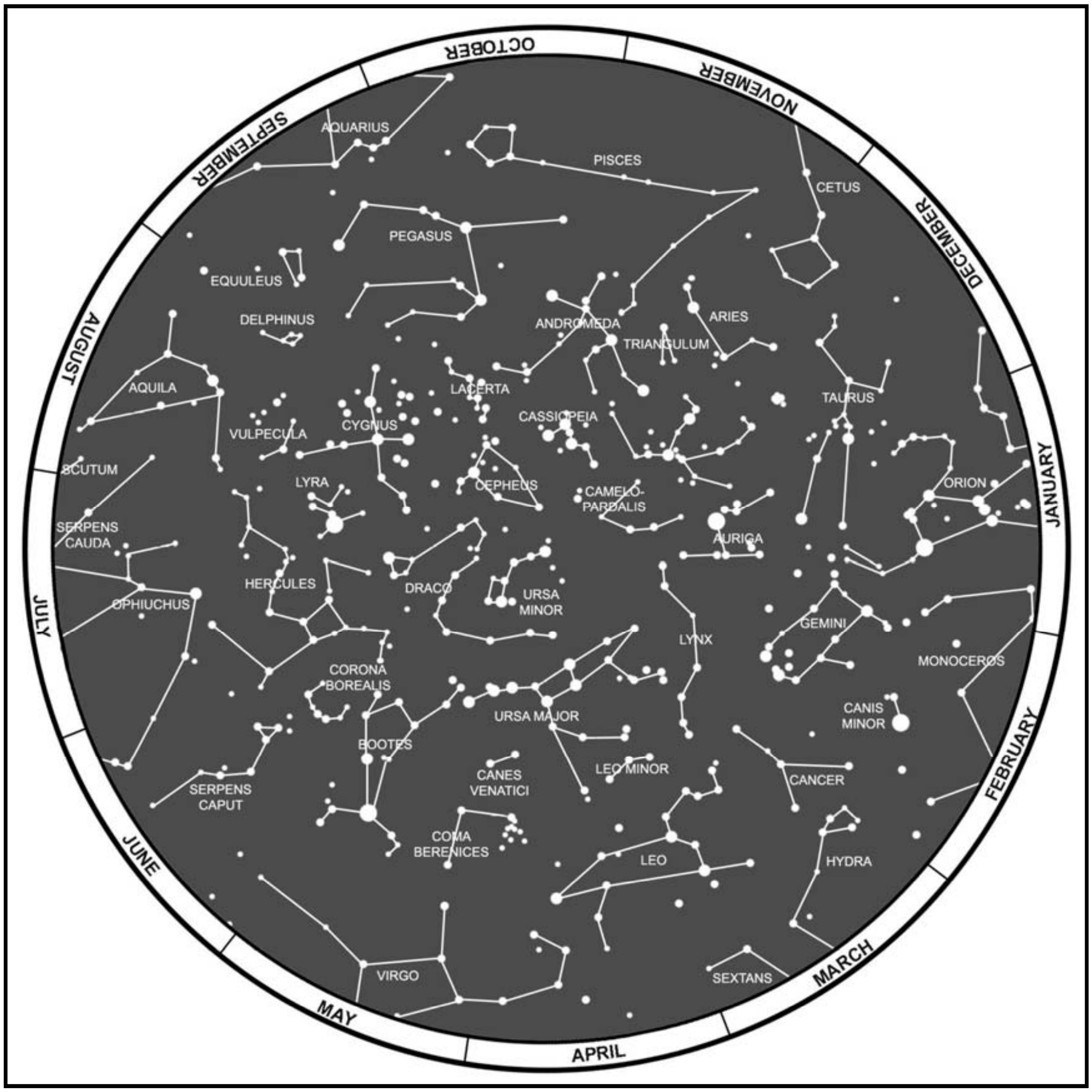
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
AQUARIUS
PISCES
CETUS
PEGASUS
EQUULEUS
DELPHINUS
ANDROMEDA
ARIES
TRIANGULUM
AQUILA
LACERTA
TAURUS
VULPECULA
CYGNUS
CASSIOPEIA
SCUTUM
LYRA
CEPHEUS
CAMELO-
PARDALIS
ORION
SERPENS
CAUDA
AURIGA
HERCULES
DRACO
URSA
MINOR
OPHIUCHUS
GEMINI
LYNX
MONOCEROS
CORONA
BOREALIS
URSA MAJOR
CANIS
MINOR
BOOTES
LEO MINOR
CANES
VENATICI
CANCER
SERPENS
CAPUT
COMA
BERENICES
LEO
HYDRA
VIRGO
SEXTANS

Figure 9-10. Constellations, northern hemisphere.

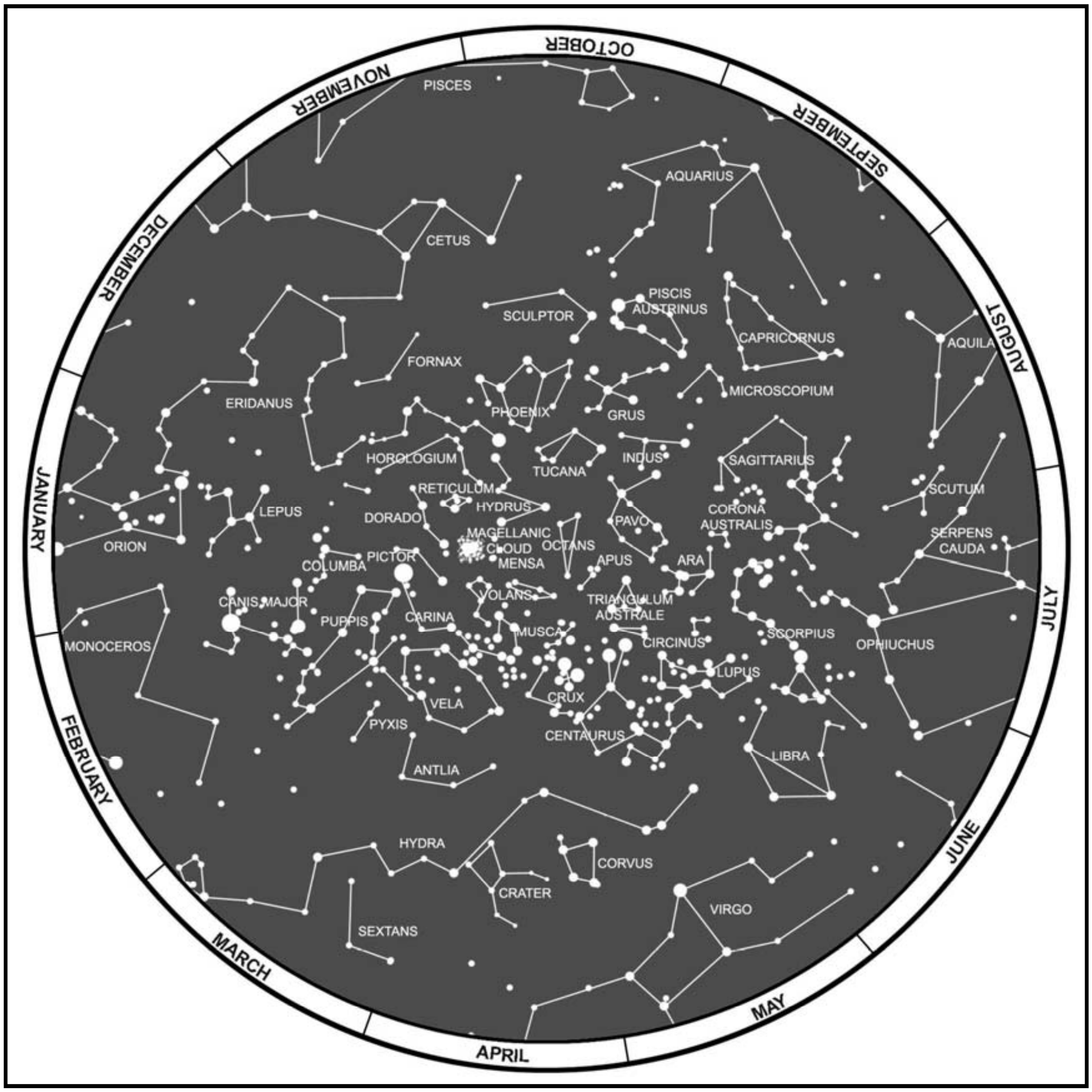
OCTOBER
NOVEMBER
SEPTEMBER
DECEMBER
AUGUST
JANUARY
JULY
FEBRUARY
JUNE
MARCH
MAY
APRIL
PISCES
AQUARIUS
CETUS
PISCIS AUSTRINUS
SCULPTOR
CAPRICORNUS
AQUILA
FORNAX
ERIDANUS
PHOENIX
GRUS
MICROSCOPIUM
HOROLOGIUM
TUCANA
INDUS
SAGITTARIUS
RETICULUM
HYDRUS
SCUTUM
LEPUS
DORADO
MAGELLANIC CLOUD
OCTANS
PAVO
CORONA AUSTRALIS
SERPENS CAUDA
ORION
COLUMBA
PICTOR
MENSA
APUS
ARA
CANIS MAJOR
VOLANS
TRIANGULUM AUSTRALE
PUPPIS
CARINA
MUSCA
SCORPIUS
OPHIUCHUS
MONOCEROS
CIRCINUS
LUPUS
VELA
CRUX
PYXIS
CENTAURUS
LIBRA
ANTLIA
HYDRA
CORVUS
CRATER
VIRGO
SEXTANS

Figure 9-11. Constellations, southern hemisphere.

9-6. GLOBAL POSITIONING SYSTEM

The GPS is a space-based, global, all-weather, continuously available, radio positioning navigation system. It is highly accurate in determining position location derived from signal triangulation from a satellite constellation system. It is capable of determining latitude, longitude, and altitude of the individual user. It is being fielded in hand-held, manpack, vehicular, aircraft, and watercraft configurations. The GPS receives and processes data from satellites on either a simultaneous or sequential basis. It measures the velocity and range with respect to each satellite, processes the data in terms of an earth-centered, earth-fixed coordinate system, and displays the information to the user in geographic or military grid coordinates.

a. The GPS can provide precise steering information, as well as position location. The receiver can accept many checkpoints entered in any coordinate system by the user and convert them to the desired coordinate system. The user then calls up the desired checkpoint and the receiver will display direction and distance to the checkpoint. The GPS does not have inherent drift, an improvement over the Inertial Navigation System, and the receiver will automatically update its position. The receiver can also compute time to the next checkpoint.

b. Specific uses for the GPS are position location; navigation; weapon location; target and sensor location; coordination of firepower; scout and screening operations; combat resupply; location of obstacles, barriers, and gaps; and communication support. The GPS also has the potential to allow units to train their soldiers and provide the following:

- Performance feedback.
- Knowledge of routes taken by the soldier.
- Knowledge of errors committed by the soldier.
- Comparison of planned versus executed routes.
- Safety and control of lost and injured soldiers.

(See Appendix J for more information of the GPS.)

CHAPTER 10

ELEVATION AND RELIEF

The elevation of points on the ground and the relief of an area affect the movement, positioning, and, in some cases, effectiveness of military units. Soldiers must know how to determine locations of points on a map, measure distances and azimuths, and identify symbols on a map. They must also be able to determine the elevation and relief of areas on standard military maps. To do this, they must first understand how the mapmaker indicated the elevation and relief on the map.

10-1. DEFINITIONS

The reference or start point for vertical measurement of elevation on a standard military map are the **datum plane** or **mean sea level**, the point halfway between high tide and low tide. **Elevation** of a point on the earth's surface is the vertical distance it is above or below mean sea level. **Relief** is the representation (as depicted by the mapmaker) of the shapes of hills, valleys, streams, or terrain features on the earth's surface.

10-2. METHODS OF DEPICTING RELIEF

Mapmakers use several methods to depict relief of the terrain.

a. **Layer Tinting.** Layer tinting is a method of showing relief by color. A different color is used for each band of elevation. Each shade of color, or band, represents a definite elevation range. A legend is printed on the map margin to indicate the elevation range represented by each color. However, this method does not allow the map user to determine the exact elevation of a specific point—only the range.

b. **Form Lines.** Form lines are not measured from any datum plane. Form lines have no standard elevation and give only a general idea of relief. Form lines are represented on a map as dashed lines and are never labeled with representative elevations.

c. **Shaded Relief.** Relief shading indicates relief by a shadow effect achieved by tone and color that results in the darkening of one side of terrain features, such as hills and ridges. The darker the shading, the steeper the slope. Shaded relief is sometimes used in conjunction with contour lines to emphasize these features.

d. **Hachures.** Hachures are short, broken lines used to show relief. Hachures are sometimes used with contour lines. They do not represent exact elevations, but are mainly used to show large, rocky outcrop areas. Hachures are used extensively on small-scale maps to show mountain ranges, plateaus, and mountain peaks.

e. **Contour Lines.** Contour lines are the most common method of showing relief and elevation on a standard topographic map. A contour line represents an imaginary line on the ground, above or below sea level. All points on the contour line are at the same elevation. The elevation represented by contour lines is the vertical distance above or below sea level. The three types of contour lines (Figure 10-1, page 10-2) used on a standard topographic map are as follows:

(1) ***Index.*** Starting at zero elevation or mean sea level, every fifth contour line is a heavier line. These are known as index contour lines. Normally, each index contour line is numbered at some point. This number is the elevation of that line.

(2) ***Intermediate.*** The contour lines falling between the index contour lines are called intermediate contour lines. These lines are finer and do not have their elevations given. There are normally four intermediate contour lines between index contour lines.

(3) ***Supplementary***. These contour lines resemble dashes. They show changes in elevation of at least one-half the contour interval. These lines are normally found where there is very little change in elevation, such as on fairly level terrain.

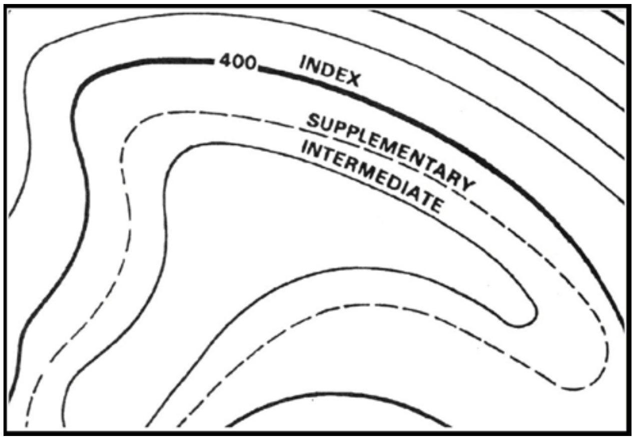

Figure 10-1. Contour lines.

10-3. CONTOUR INTERVALS

Before the elevation of any point on the map can be determined, the user must know the contour interval for the map he is using. The contour interval measurement given in the marginal information is the vertical distance between adjacent contour lines. To determine the elevation of a point on the map—

a. Determine the contour interval and the unit of measure used, for example, feet, meters, or yards (Figure 10-2).

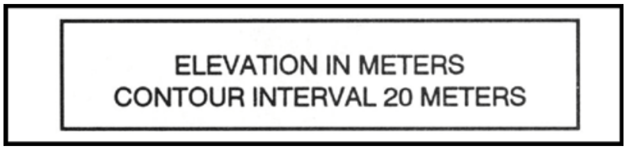

ELEVATION IN METERS
CONTOUR INTERVAL 20 METERS

Figure 10-2. Contour interval note.

b. Find the numbered index contour line nearest the point of which you are trying to determine the elevation (Figure 10-3).

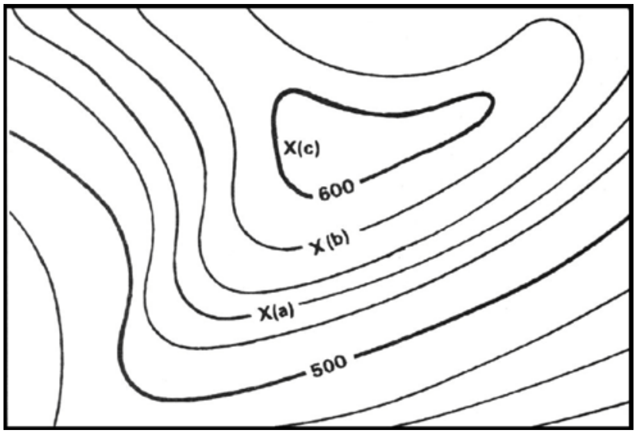

Figure 10-3. Points on contour lines.

c. Determine if you are going from lower elevation to higher, or vice versa. In Figure 10-3, point (a) is between the index contour lines. The lower index contour line is numbered 500, which means any point on that line is at an elevation of 500 meters above mean sea level. The upper index contour line is numbered 600, or 600 meters. Going from the lower to the upper index contour line shows an increase in elevation.

d. Determine the exact elevation of point (a), start at the index contour line numbered 500 and count the number of intermediate contour lines to point (a). Locate point (a) on the second intermediate contour line above the 500-meter index contour line. The contour interval is 20 meters (Figure 10-2), thus each one of the intermediate contour lines crossed to get to point (a) adds 20 meters to the 500-meter index contour line. The elevation of point (a) is 540 meters; the elevation has increased.

e. Determine the elevation of point (b). Go to the nearest index contour line. In this case, it is the upper index contour line numbered 600. Locate point (b) on the intermediate contour line immediately below the 600-meter index contour line. Below means downhill or a lower elevation. Therefore, point (b) is located at an elevation of 580 meters. Remember, if you are increasing elevation, add the contour interval to the nearest index contour line. If you are decreasing elevation, subtract the contour interval from the nearest index contour line.

f. Determine the elevation to a hilltop point (c). Add one-half the contour interval to the elevation of the last contour line. In this example, the last contour line before the hilltop is an index contour line numbered 600. Add one-half the contour interval, 10 meters, to the index contour line. The elevation of the hilltop would be 610 meters.

g. There may be times when you need to determine the elevation of points to a greater accuracy. To do this, you must determine how far between the two contour lines the point lies. However, most military needs are satisfied by estimating the elevation of points between contour lines (Figure 10-4).

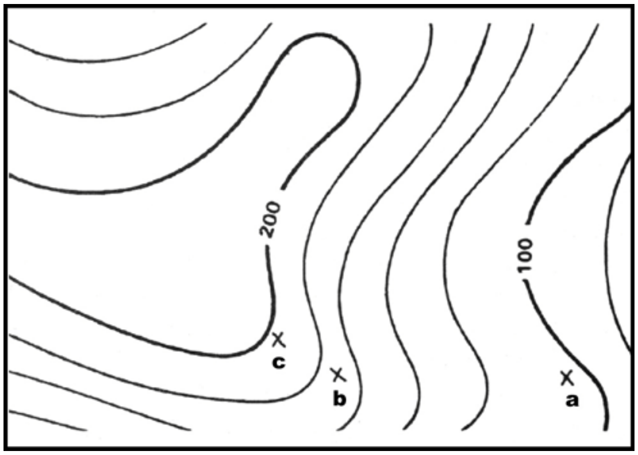

Figure 10-4. Points between contour lines.

(1) If the point is less than one-fourth the distance between contour lines, the elevation will be the same as the last contour line. In Figure 10-4, the elevation of *point a* will be 100 meters. To estimate the elevation of a point between one-fourth and three-fourths of the distance between contour lines, add one-half the contour interval to the last contour line.

(2) *Point b* is one-half the distance between contour lines. The contour line immediately below *point b* is at an elevation of 160 meters. The contour interval is 20 meters; thus one-half the contour interval is 10 meters. In this case, add 10 meters to the last contour line of 160 meters. The elevation of *point b* would be about 170 meters.

(3) A point located more than three-fourths of the distance between contour lines is considered to be at the same elevation as the next contour line. *Point c* is located three-fourths of the distance between contour lines. In Figure 10-4, *point c* would be considered to be at an elevation of 180 meters.

h. To estimate the elevation to the bottom of a depression, subtract one-half the contour interval from the value of the lowest contour line before the depression. In Figure 10-5, the lowest contour line before the depression is 240 meters in elevation. Thus, the elevation at the edge of the depression is 240 meters. To determine the elevation at the bottom of the depression, subtract one-half the contour interval. The contour interval for this example is 20 meters. Subtract 10 meters from the lowest contour line immediately before the depression. The result is that the elevation at the bottom of the depression is 230 meters. The tick marks on the contour line forming a depression always point to lower elevations.

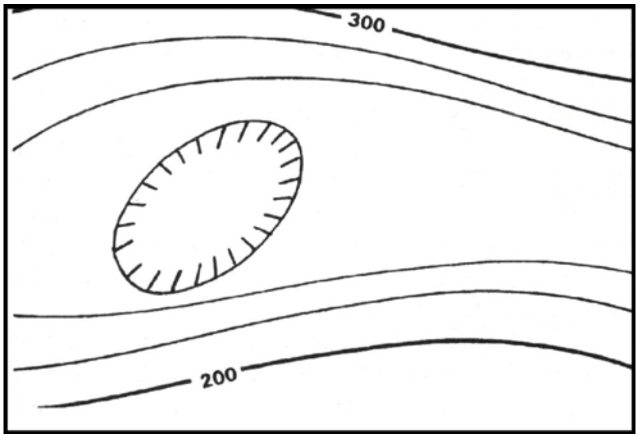

Figure 10-5. Depression.

i. In addition to the contour lines, bench marks and spot elevations are used to indicate points of known elevations on the map.

(1) Bench marks, the more accurate of the two, are symbolized by a black X, such as X BM 214. The 214 indicates that the center of the X is at an elevation of 214 units of measure (feet, meters, or yards) above mean sea level. To determine the units of measure, refer to the contour interval in the marginal information.

(2) Spot elevations are shown by a brown X and are usually located at road junctions and on hilltops and other prominent terrain features. If the elevation is shown in black numerals, it has been checked for accuracy; if it is in brown, it has not been checked.

NOTE: New maps are being printed using a dot instead of brown Xs.

10-4. TYPES OF SLOPES

Depending on the military mission, soldiers may need to determine not only the height of a hill, but the degree of the hill's slope as well. The rate of rise or fall of a terrain feature is known as its slope. The speed at which equipment or personnel can move is affected by the slope of the ground or terrain feature. This slope can be determined from the map by studying the contour lines—the closer the contour lines, the steeper the slope; the farther apart the contour lines, the gentler the slope. Four types of slopes that concern the military are as follows:

a. **Gentle.** Contour lines showing a uniform, gentle slope will be evenly spaced and wide apart (Figure 10-6, page 10-6). Considering relief only, a uniform, gentle slope allows the defender to use grazing fire. The attacking force has to climb a slight incline.

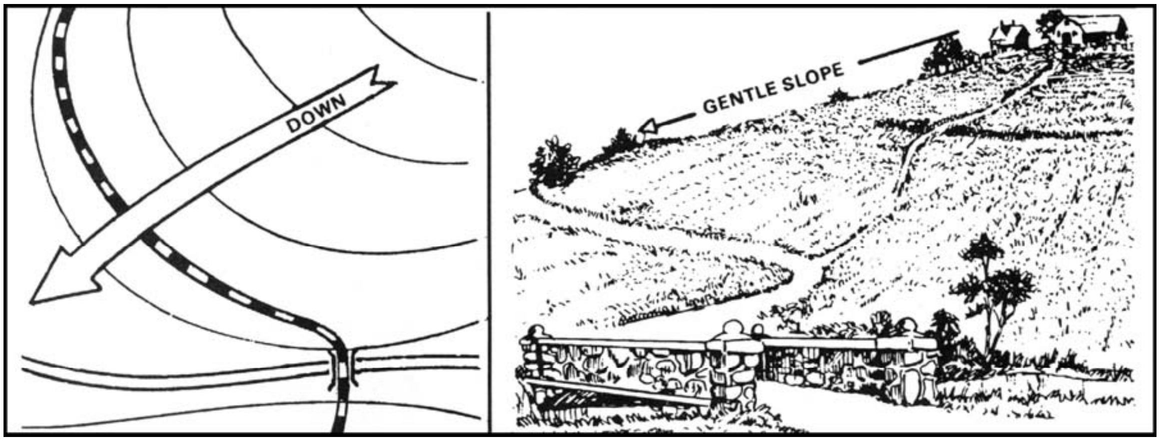

Figure 10-6. Uniform, gentle slope.

b. **Steep.** Contour lines showing a uniform, steep slope on a map will be evenly spaced, but close together. Remember, the closer the contour lines, the steeper the slope (Figure 10-7). Considering relief only, a uniform, steep slope allows the defender to use grazing fire, and the attacking force has to negotiate a steep incline.

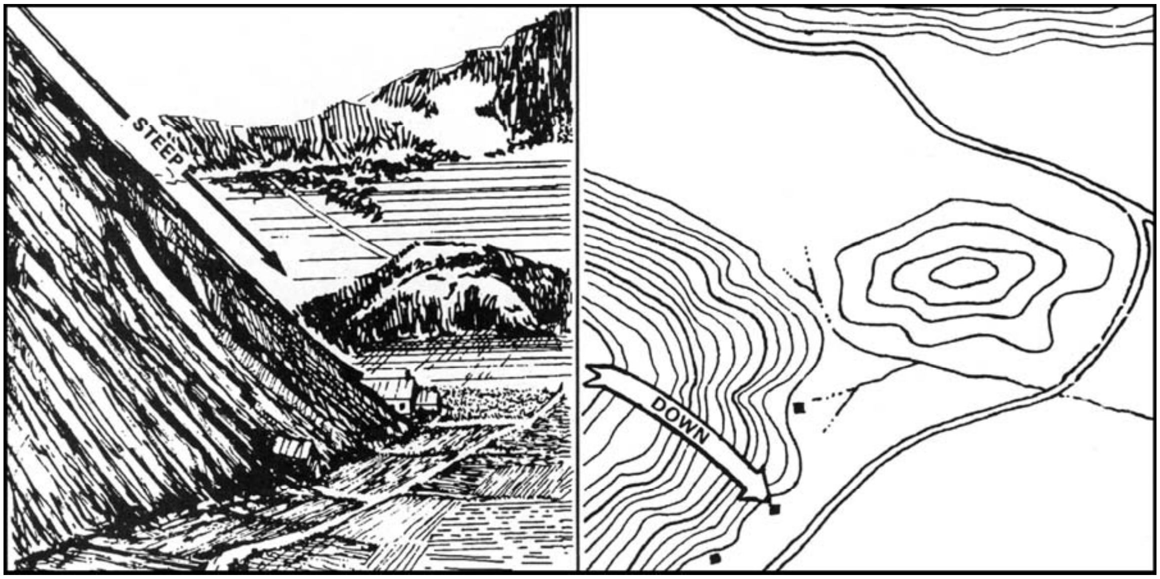

Figure 10-7. Uniform, steep slope.

c. **Concave.** Contour lines showing a concave slope on a map will be closely spaced at the top of the terrain feature and widely spaced at the bottom (Figure 10-8, page 10-7). Considering relief only, the defender at the top of the slope can observe the entire slope and the terrain at the bottom, but he cannot use grazing fire. The attacker would have no cover from the defender's observation of fire, and his climb would become more difficult as he got farther up the slope.

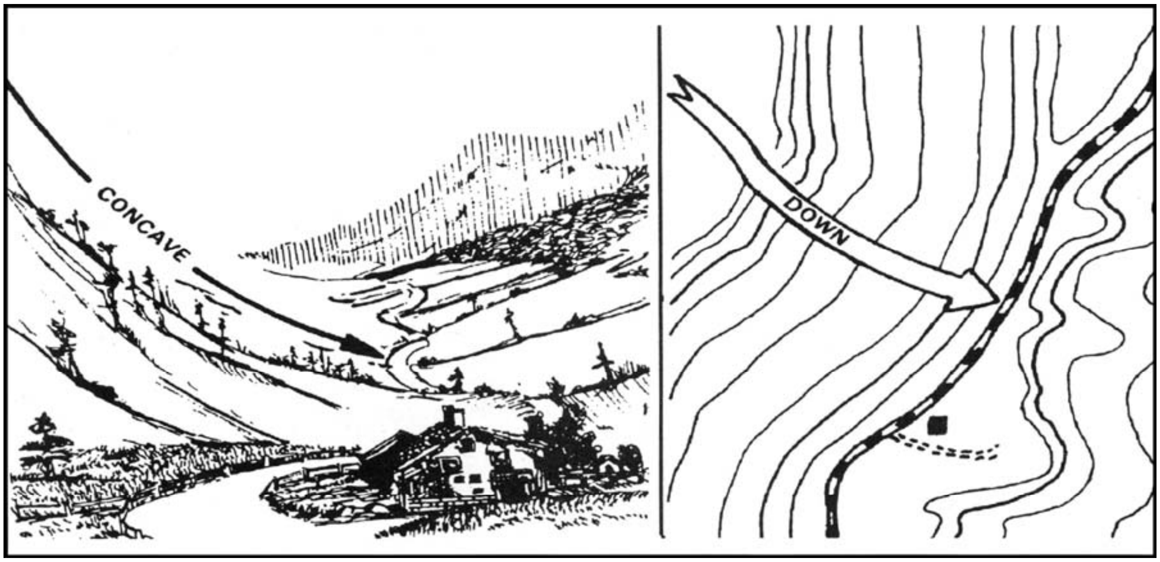

Figure 10-8. Concave slope.

d. **Convex.** Contour lines showing a convex slope on a map will be widely spaced at the top and closely spaced at the bottom (Figure 10-9). Considering relief only, the defender at the top of the convex slope can obtain a small distance of grazing fire, but he cannot observe most of the slope or the terrain at the bottom. The attacker will have concealment on most of the slope and an easier climb as he nears the top.

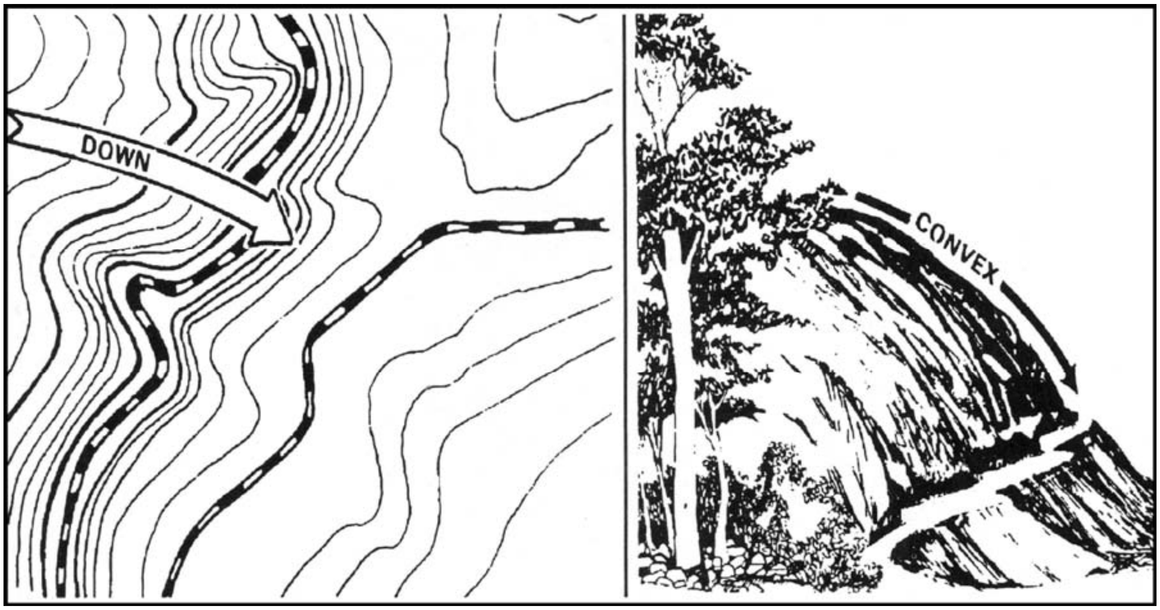

Figure 10-9. Convex slope.

10-5. PERCENTAGE OF SLOPE

The speed at which personnel and equipment can move up or down a hill is affected by the slope of the ground and the limitations of the equipment. Because of this, a more exact way of describing a slope is necessary.

a. Slope may be expressed in several ways, but all depend upon the comparison of vertical distance (VD) to horizontal distance (HD) (Figure 10-10). Before we can determine the percentage of a slope, we must know the VD of the slope. The VD is determined by subtracting the lowest point of the slope from the highest point. Use the contour lines to determine the highest and lowest point of the slope (Figure 10-11).

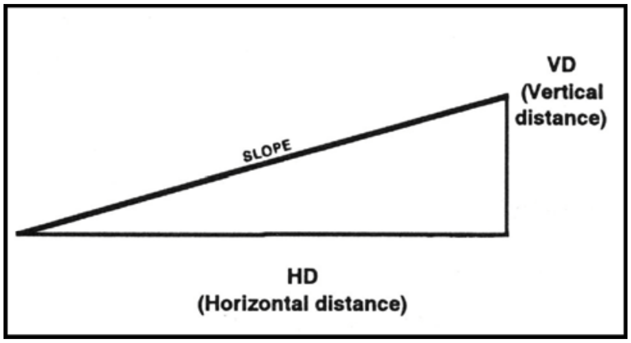

Figure 10-10. Slope diagram.

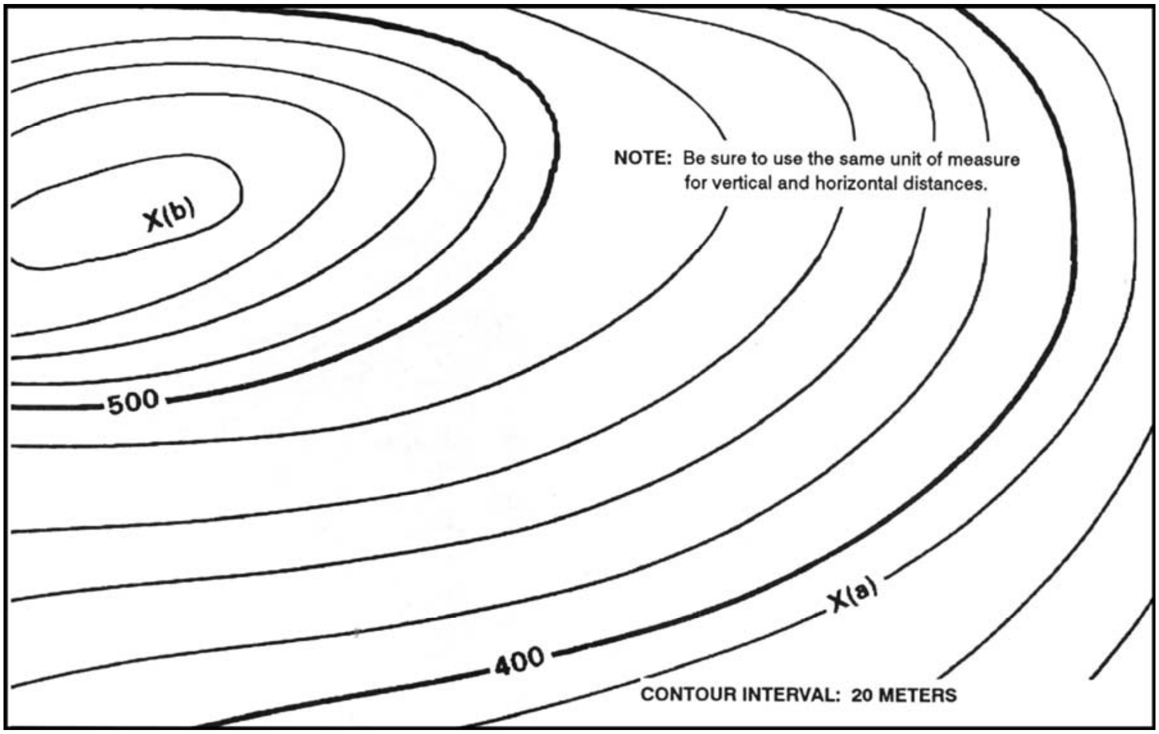

NOTE: Be sure to use the same unit of measure for vertical and horizontal distances.

CONTOUR INTERVAL: 20 METERS

Figure 10-11. Contour line around a slope.

b. To determine the percentage of the slope between points (a) and (b) in Figure 10-11, determine the elevation of point (b) (590 meters). Then determine the elevation of point (a) (380 meters). Determine the vertical distance between the two points by subtracting the elevation of point (a) from the elevation of point .The difference (210 meters) is the VD between points (a) and (b). Then measure the HD between the two points on the map in Figure 10-12. After the horizontal distance has been determined, compute the percentage of the slope by using the formula shown in Figure 10-13.

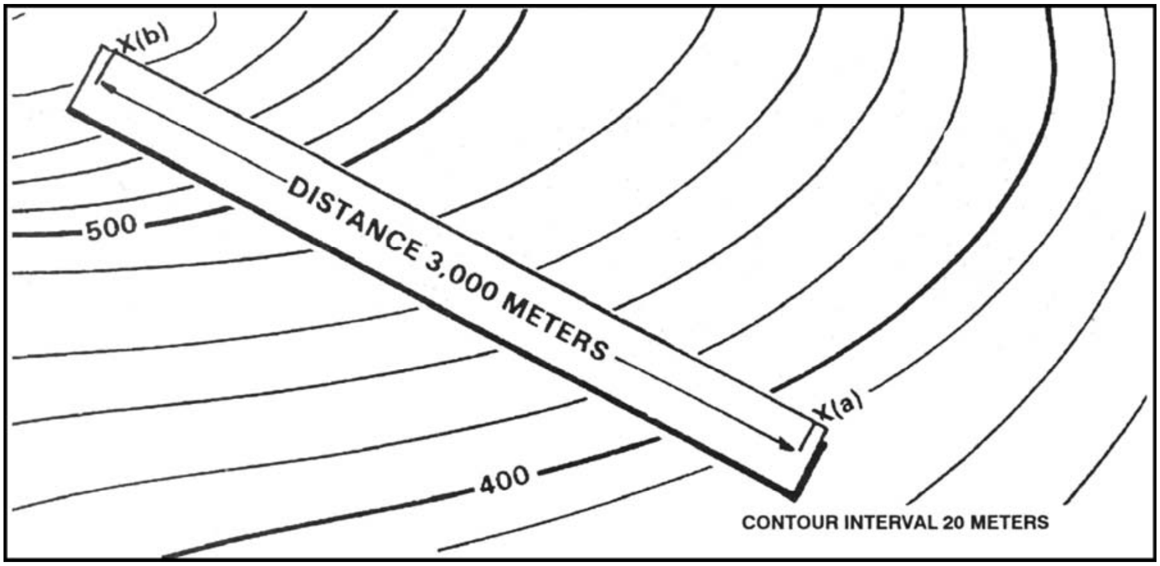

Figure 10-12. Measuring horizontal distance.

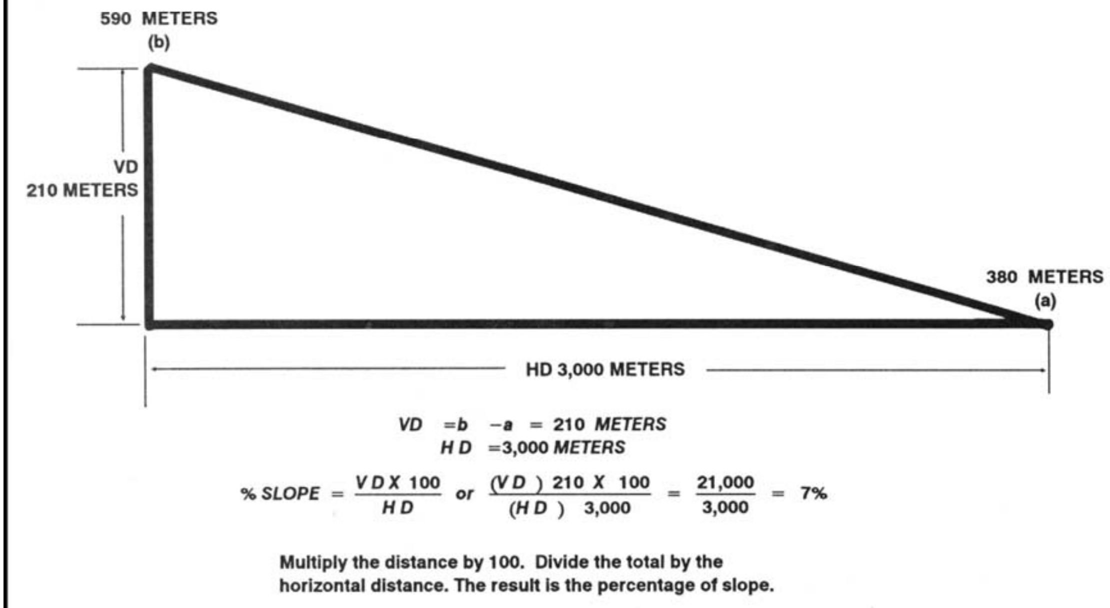
590 METERS
(b)
VD
210 METERS
380 METERS
(a)
HD 3,000 METERS
VD =b −a = 210 METERS
HD =3,000 METERS
% SLOPE = VD X 100 / HD or (VD) 210 X 100 / (HD) 3,000 = 21,000 / 3,000 = 7%
Multiply the distance by 100. Divide the total by the horizontal distance. The result is the percentage of slope.

Figure 10-13. Percentage of slope in meters.

c. The slope angle can also be expressed in degrees. To do this, determine the VD and HD of the slope. Multiply the VD by 57.3 and then divide the total by the HD (Figure 10-14). This method determines the approximate degree of slope and is reasonably accurate for slope angles less than 20º.

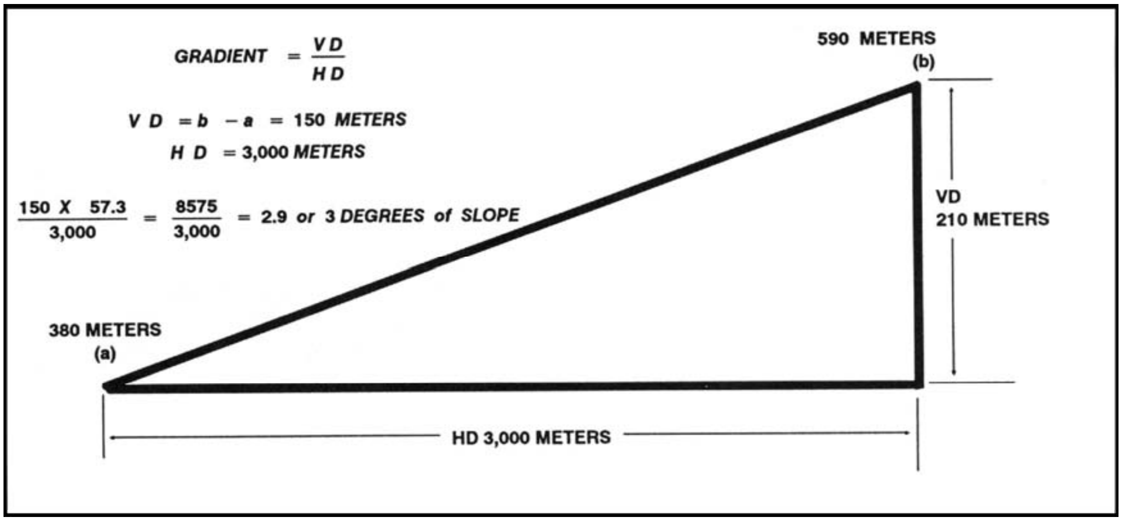
GRADIENT = VD / HD
VD =b −a = 150 METERS
HD = 3,000 METERS
150 X 57.3 / 3,000 = 8575 / 3,000 = 2.9 or 3 DEGREES of SLOPE
590 METERS
(b)
VD
210 METERS
380 METERS
(a)
HD 3,000 METERS

Figure 10-14. Degree of slope.

d. The slope angle can also be expressed as a gradient. The relationship of horizontal and vertical distance is expressed as a fraction with a numerator of one (Figure 10-15).

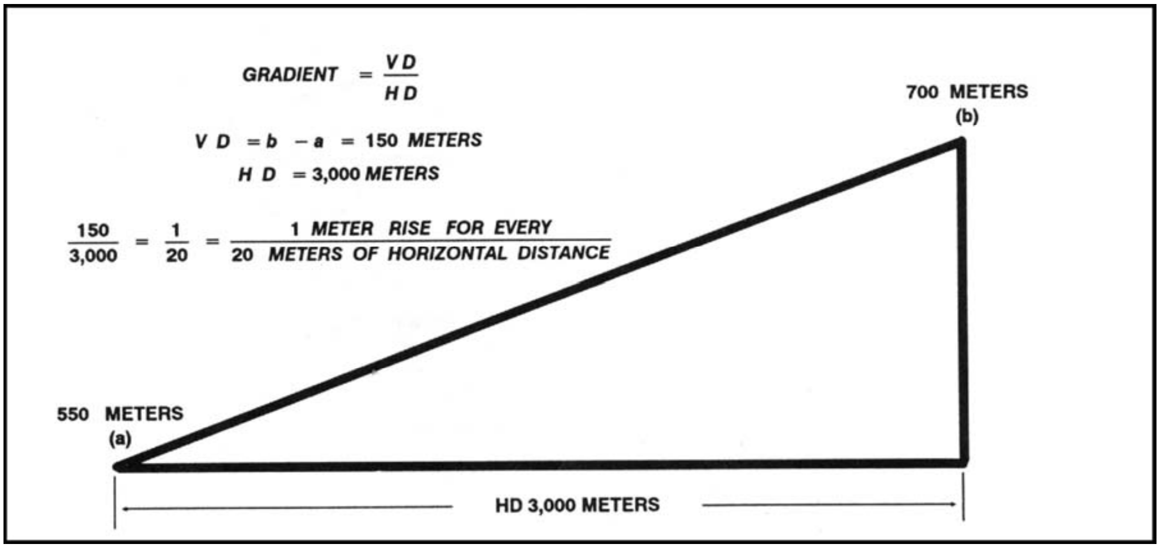
GRADIENT = VD / HD
V D = b − a = 150 METERS
H D = 3,000 METERS
150/3,000 = 1/20 = 1 METER RISE FOR EVERY / 20 METERS OF HORIZONTAL DISTANCE
700 METERS
(b)
550 METERS
(a)
HD 3,000 METERS

Figure 10-15. Gradient.

10-6. TERRAIN FEATURES

All terrain features are derived from a complex landmass known as a mountain or ridgeline (Figure 10-16). The term ridgeline is not interchangeable with the term ridge. A ridgeline is a line of high ground, usually with changes in elevation along its top and low ground on all sides from which a total of 10 natural or man-made terrain features are classified.

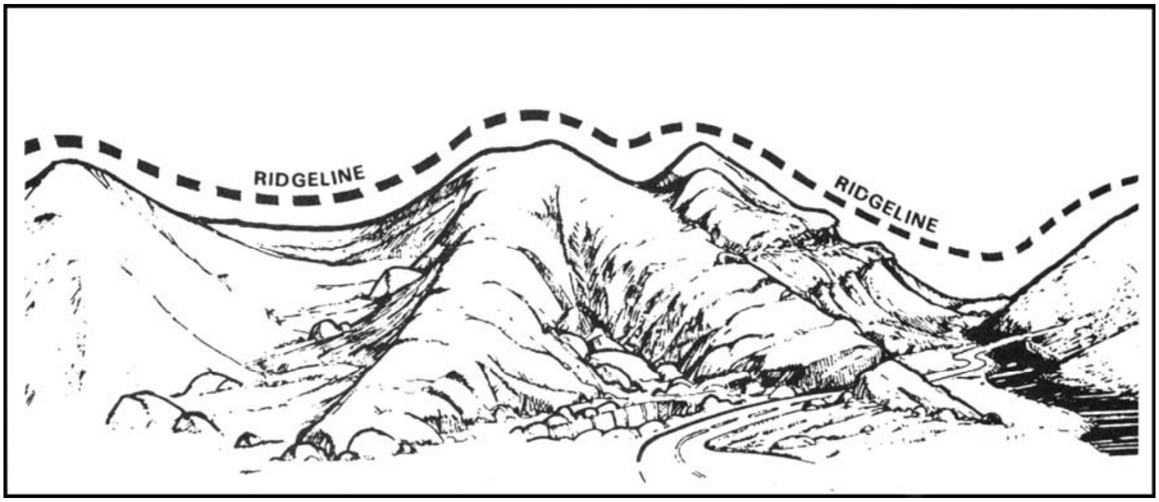
RIDGELINE
RIDGELINE

Figure 10-16. Ridgeline.

a. **Major Terrain Features.**

(1) ***Hill***. A hill is an area of high ground. From a hilltop, the ground slopes down in all directions. A hill is shown on a map by contour lines forming concentric circles. The inside of the smallest closed circle is the hilltop (Figure 10-17).

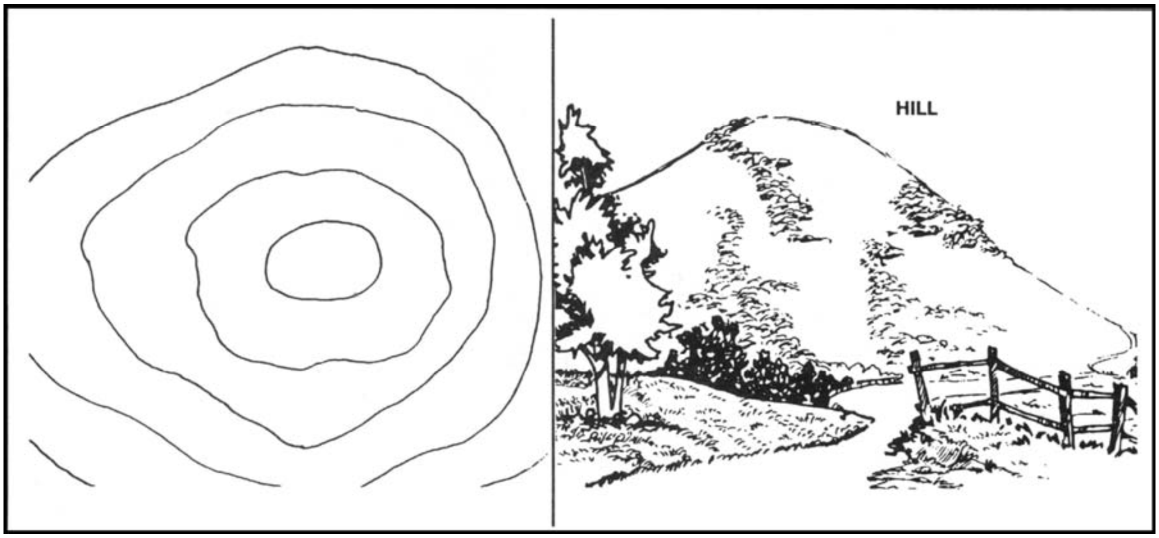

Figure 10-17. Hill.

(2) ***Saddle***. A saddle is a dip or low point between two areas of higher ground. A saddle is not necessarily the lower ground between two hilltops; it may be simply a dip or break along a level ridge crest. If you are in a saddle, there is high ground in two opposite directions and lower ground in the other two directions. A saddle is normally represented as an hourglass (Figure 10-18).

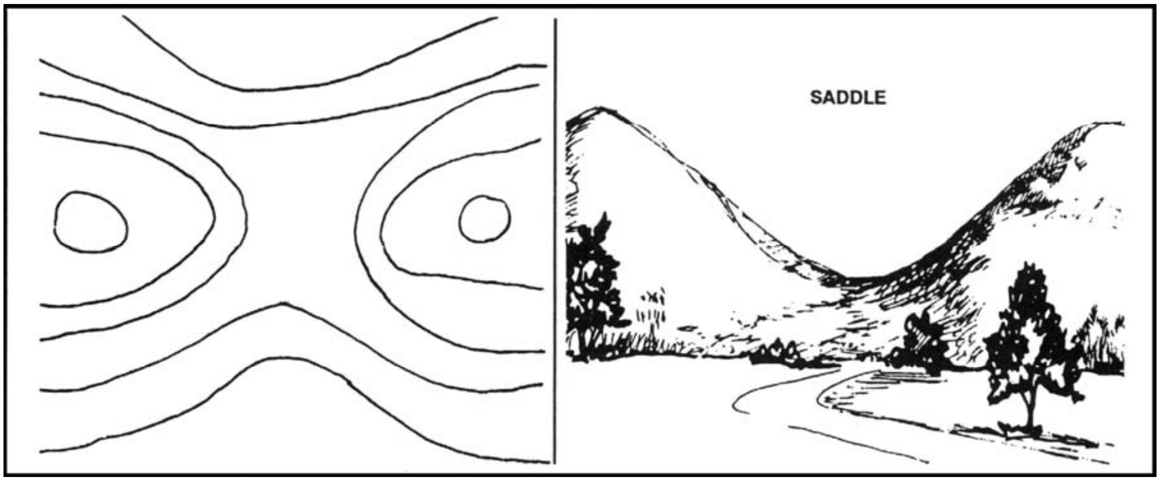

Figure 10-18. Saddle.

(3) ***Valley***. A valley is a stretched-out groove in the land, usually formed by streams or rivers. A valley begins with high ground on three sides, and usually has a course of running water through it. If standing in a valley, three directions offer high ground, while the fourth

direction offers low ground. Depending on its size and where a person is standing, it may not be obvious that there is high ground in the third direction, but water flows from higher to lower ground. Contour lines forming a valley are either U-shaped or V-shaped. To determine the direction water is flowing, look at the contour lines. The closed end of the contour line (U or V) always points upstream or toward high ground (Figure 10-19).

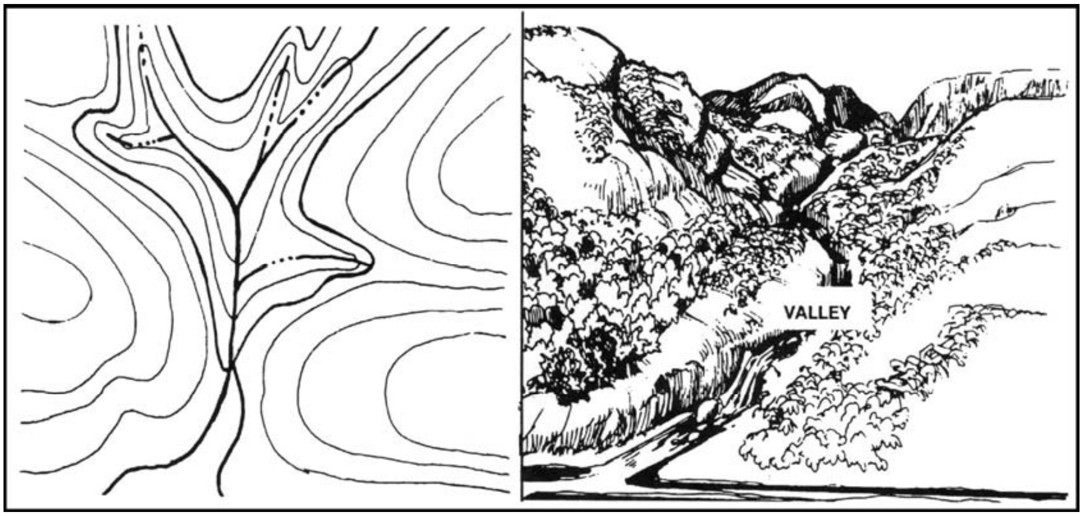

Figure 10-19. Valley.

(4) ***Ridge***. A ridge is a sloping line of high ground. If you are standing on the centerline of a ridge, you will normally have low ground in three directions and high ground in one direction with varying degrees of slope. If you cross a ridge at right angles, you will climb steeply to the crest and then descend steeply to the base. When you move along the path of the ridge, depending on the geographic location, there may be either an almost unnoticeable slope or a very obvious incline. Contour lines forming a ridge tend to be U-shaped or V-shaped. The closed end of the contour line points away from high ground (Figure 10-20).

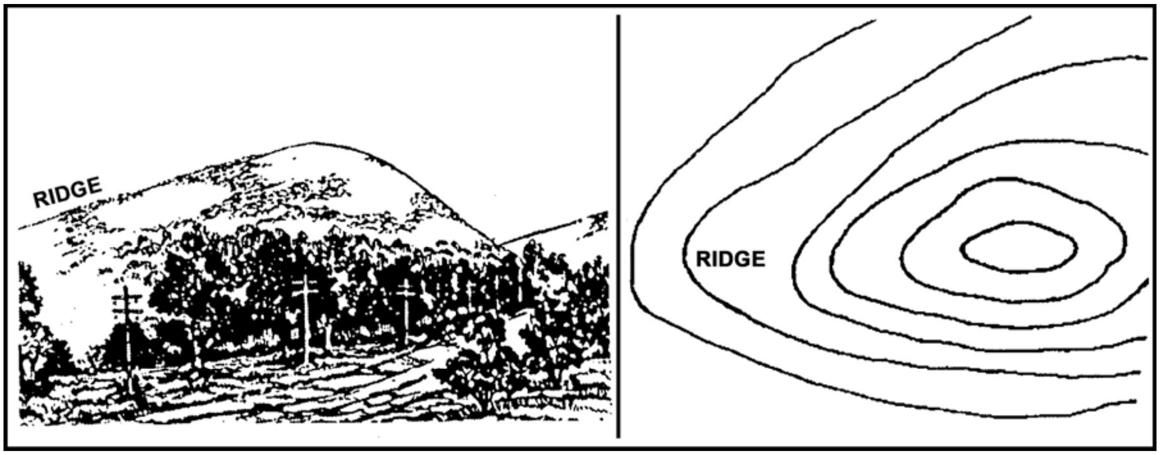

Figure 10-20. Ridge.

(5) ***Depression***. A depression is a low point in the ground or a sinkhole. It could be described as an area of low ground surrounded by higher ground in all directions, or simply a hole in the ground. Usually only depressions that are equal to or greater than the contour interval will be shown. On maps, depressions are represented by closed contour lines that have tick marks pointing toward low ground (Figure 10-21).

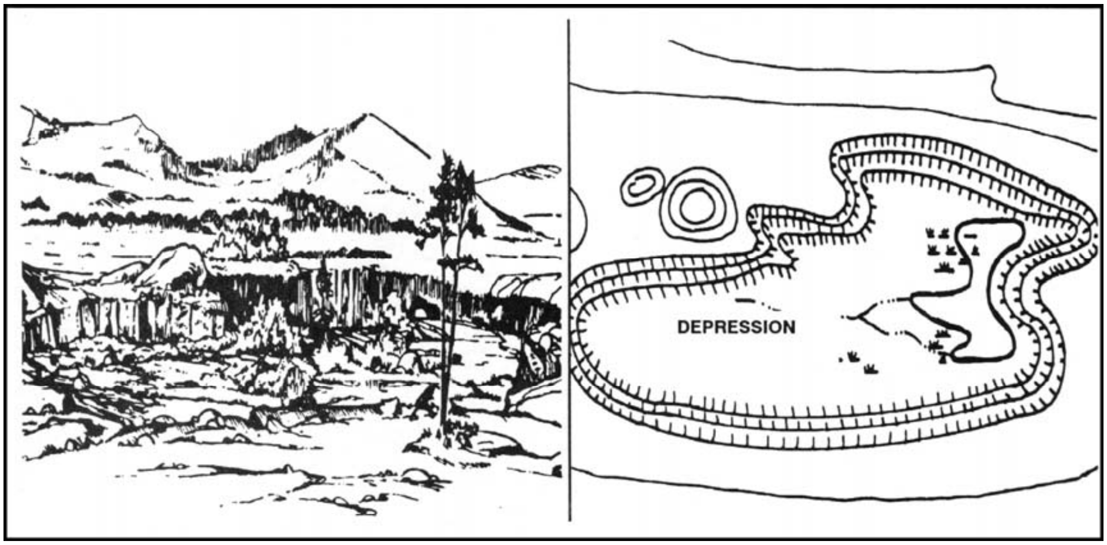

Figure 10-21. Depression.

b. **Minor Terrain Features.**

(1) ***Draw***. A draw is a less developed stream course than a valley. In a draw, there is essentially no level ground and, therefore, little or no maneuver room within its confines. If you are standing in a draw, the ground slopes upward in three directions and downward in the other direction. A draw could be considered as the initial formation of a valley. The contour lines depicting a draw are U-shaped or V-shaped, pointing toward high ground (Figure 10-22).

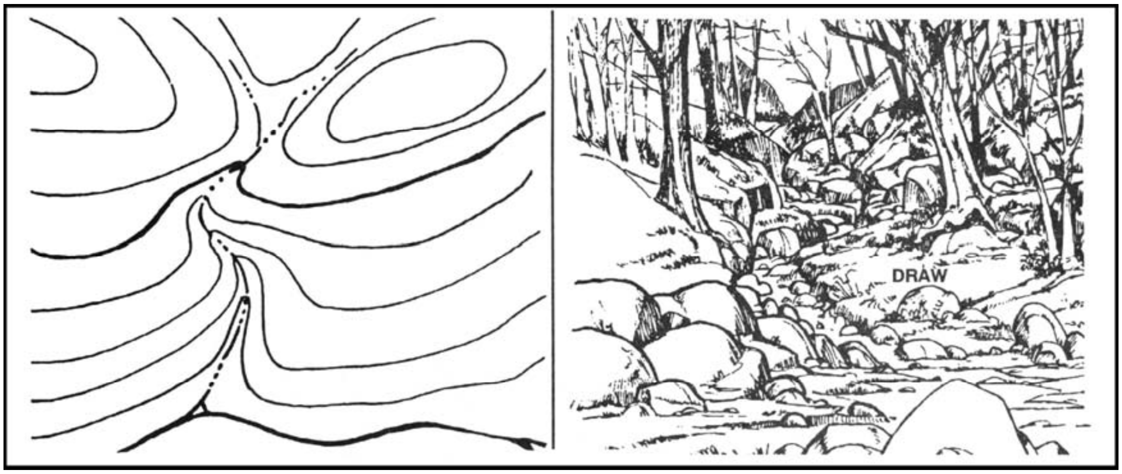

Figure 10-22. Draw.

(2) ***Spur***. A spur is a short, continuous sloping line of higher ground, normally jutting out from the side of a ridge. A spur is often formed by two rough parallel streams, which cut

draws down the side of a ridge. The ground sloped down in three directions and up in one direction. Contour lines on a map depict a spur with the U or V pointing away from high ground (Figure 10-23).

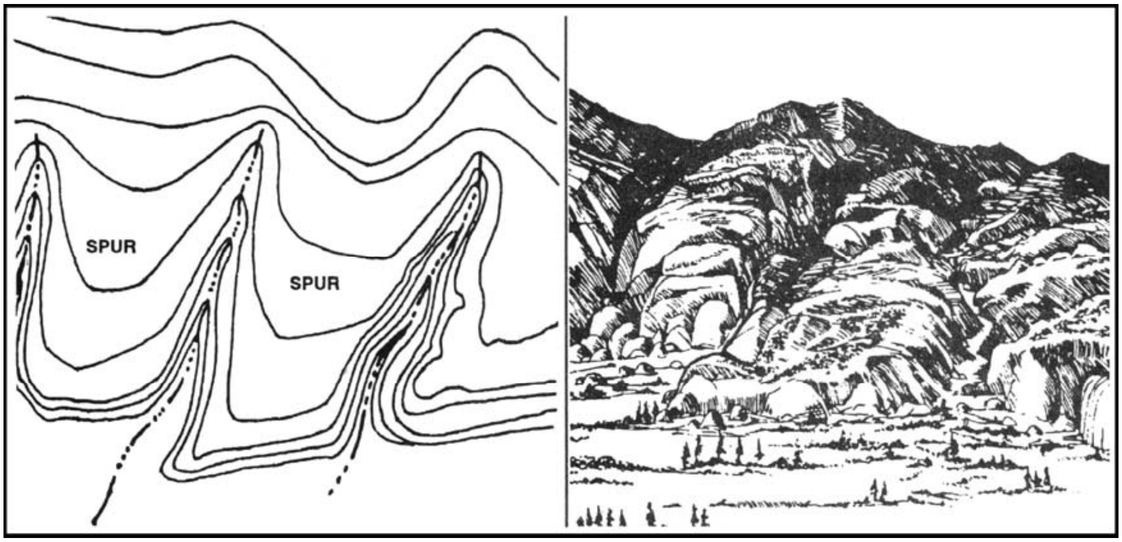

Figure 10-23. Spur.

(3) ***Cliff***. A cliff is a vertical or near vertical feature; it is an abrupt change of the land. When a slope is so steep that the contour lines converge into one "carrying" contour of contours, this last contour line has tick marks pointing toward low ground (Figure 10-24A). Cliffs are also shown by contour lines very close together and, in some instances, touching each other (Figure 10-24B, page 10-16).

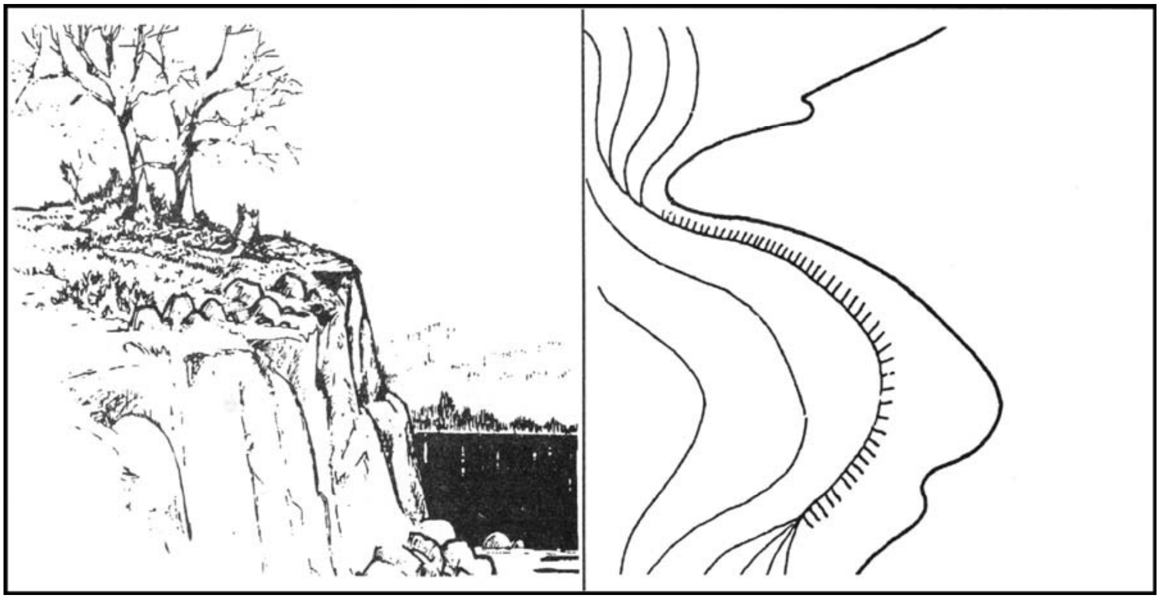

Figure 10-24A. Cliff.

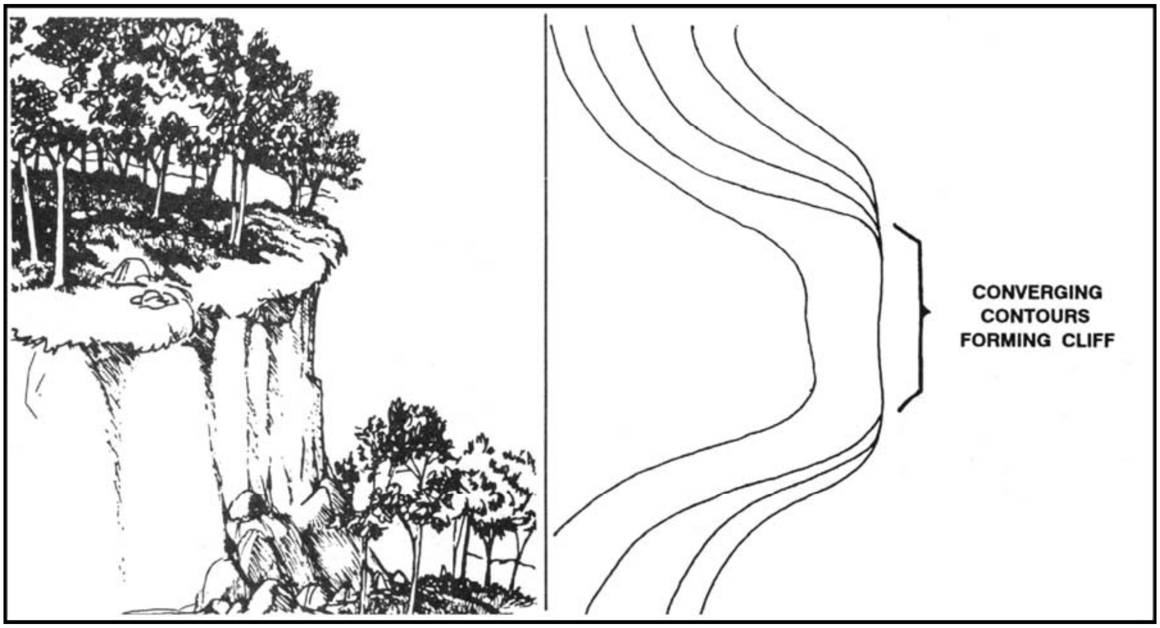

Figure 10-24B. Cliff.

c. **Supplementary Terrain Features.**

(1) ***Cut***. A cut is a man-made feature resulting from cutting through raised ground, usually to form a level bed for a road or railroad track. Cuts are shown on a map when they are at least 10 feet high, and they are drawn with a contour line along the cut line. This contour line extends the length of the cut and has tick marks that extend from the cut line to the roadbed, if the map scale permits this level of detail (Figure 10-25).

(2) ***Fill***. A fill is a man-made feature resulting from filling a low area, usually to form a level bed for a road or railroad track. Fills are shown on a map when they are at least 10 feet high, and they are drawn with a contour line along the fill line. This contour line extends the length of the filled area and has tick marks that point toward lower ground. If the map scale permits, the length of the fill tick marks are drawn to scale and extend from the base line of the fill symbol (Figure 10-25).

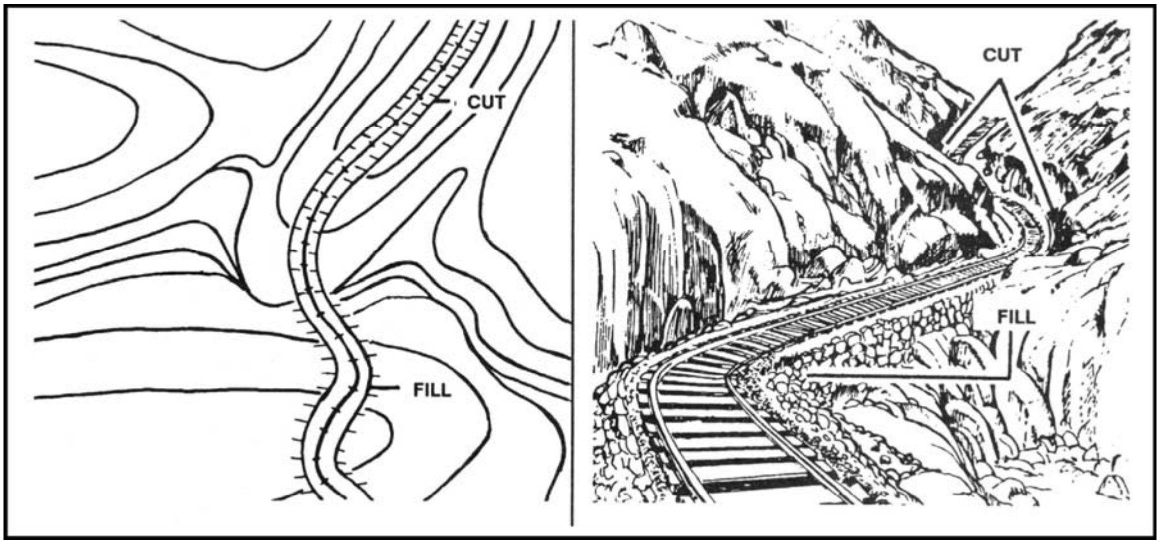
CUT
FILL
CUT
FILL

Figure 10-25. Cut and fill.

10-7. INTERPRETATION OF TERRAIN FEATURES

Terrain features do not normally stand a lone. To better understand these when they are depicted on a map, you need to interpret them. Terrain features (Figure 10-26) are interpreted by using contour lines, the SOSES approach, ridgelining, or streamlining.

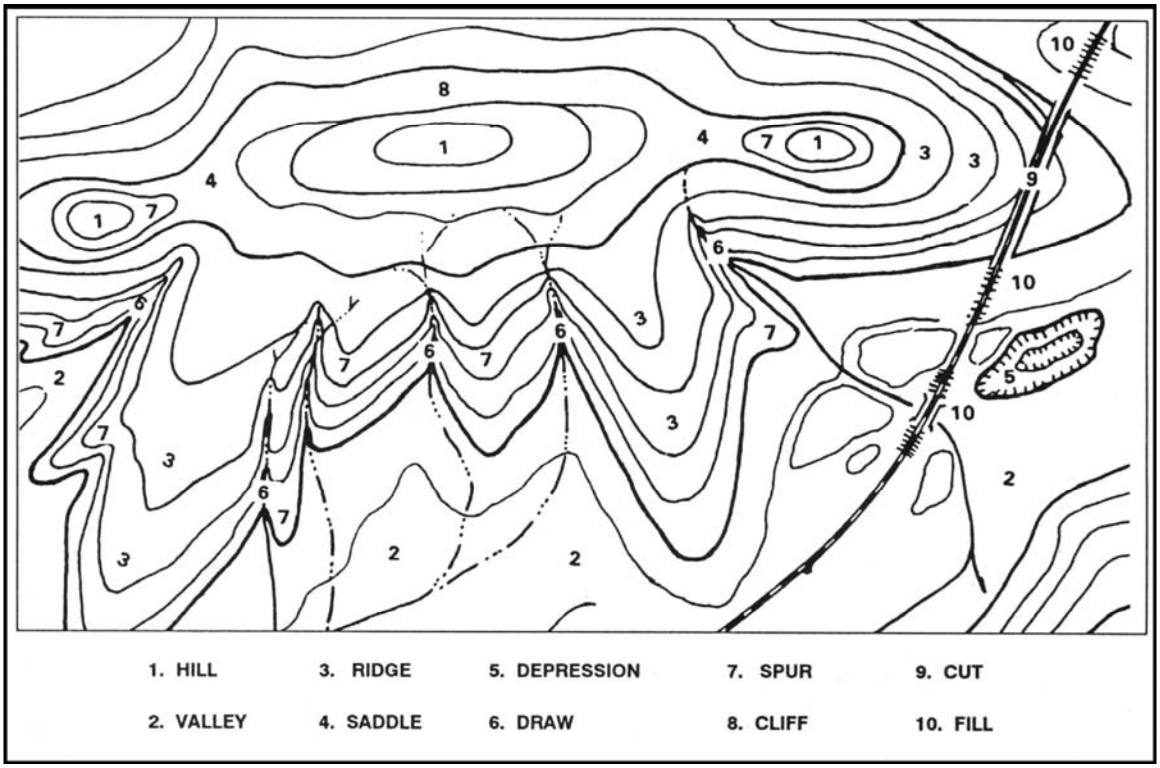
1. HILL
2. VALLEY
3. RIDGE
4. SADDLE
5. DEPRESSION
6. DRAW
7. SPUR
8. CLIFF
9. CUT
10. FILL

Figure 10-26. Terrain features.

a. **Contour Lines**. Emphasizing the main contour lines is a technique used to interpret the terrain of an area. By studying these contour lines, you able to obtain a better understanding of the layout of the terrain and to decide on the best route.

(1) The following description pertains to Figure 10-27 on page 10-20. Running east to west across the complex landmass is a ridgeline. A ridgeline is a line of high ground, usually with changes in elevation along its top and low ground on all sides. The changes in elevation are the three hilltops and two saddles along the ridgeline. From the top of each hill, there is lower ground in all directions. The saddles have lower ground in two directions and high ground in the opposite two directions. The contour lines of each saddle form half an hourglass shape. Because of the difference in size of the higher ground on the two opposite sides of a saddle, a full hourglass shape of a saddle may not be apparent.

(2) There are four prominent ridges. A ridge is on each end of the ridgeline and two ridges extend south from the ridgeline. All of the ridges have lower ground in three directions and higher ground in one direction. The closed ends of the U's formed by the contour lines point away from higher ground.

(3) To the south lies a valley; the valley slopes downward from east to west. Note that the U of the contour line points to the east, indicating higher ground in that direction and lower ground to the west. Another look at the valley shows high ground to the north and south of the valley.

(4) Just east of the valley is a depression. There is higher ground in all directions when looking from the bottom of the depression.

(5) There are several spurs extending generally south from the ridgeline. They, like ridges, have lower ground in three directions and higher ground in one direction. Their contour line U's point away from higher ground.

(6) Between the ridges and spurs are draws. They, like valleys, have higher ground in three directions and lower ground in one direction. Their contour line U's and V's point toward higher ground.

(7) Two contour lines on the north side of the center hill are touching or almost touching. They have ticks indicating a vertical or nearly vertical slope or a cliff.

(8) The road cutting through the eastern ridge depicts cuts and fills. The breaks in the contour lines indicate cuts, and the ticks pointing away from the roadbed on each side of the road indicate fills.

b**. SOSES.** A recommended technique for identifying specific terrain features and then locating them on the map is to make use of five of their characteristics known by the mnemonic SOSES. Terrain features can be examined, described, and compared with each other and with corresponding map contour patterns in terms of their shapes, orientations, sizes, elevations, and slopes.

(1) ***Shape***. The general form or outline of the feature at its base.

(2) ***Orientation***. The general trend or direction of a feature from your viewpoint. A feature can be in line, across, or at an angle to your viewpoint.

(3) ***Size***. The length or width of a feature horizontally across its base. For example, one terrain feature might be larger or smaller than another terrain feature.

(4) ***Elevation***. The height of a terrain feature. This can be described either in absolute or relative terms as compared to the other features in the area. One landform may be higher, lower, deeper, or shallower than another.

(5) ***Slope***. The type (uniform, convex, or concave) and the steepness or angle (steep or gentle) of the sides of a terrain feature.

Through practice, you can learn to identify several individual terrain features in the field and see how they vary in appearance.

NOTE: Further terrain analysis using SOSES can be learned by using the Map Interpretation and Terrain Association Course. It consists of three separate courses of instruction: basic, intermediate, and advanced. Using photographic slides of terrain and other features, basic instruction teaches how to identify basic terrain feature types on the ground and on the map. Intermediate instruction teaches elementary map interpretation and terrain association using real world scenes and map sections of the same terrain. Advanced instruction teaches advanced techniques for map interpretation and terrain association. The primary emphasis is on the concepts of map design guidelines and terrain association skills. Map design guidelines refer to the rules and practices used by cartographers in the compilation and symbolization of military topographic maps. Knowledge of the selection, classification, and symbolization of mapped features greatly enhances the user's ability to interpret map information.

c. **Ridgelining.** This technique helps you to visualize the overall lay of the ground within the area of interest on the map. Follow these steps:

(1) Identify on the map the crests of the ridgelines in your area of operation by identifying the close-out contours that lie along the hilltop.

(2) Trace over the crests so each ridgeline stands out clearly as one identifiable line.

(3) Go back over each of the major ridgelines and trace over the prominent ridges and spurs that come out of the ridgelines.

The usual colors used for this tracing are red or brown; however, you may use any color at hand. When you have completed the ridgelining process, you will find that the high ground on the map will stand out and that you will be able to see the relationship between the various ridgelines (Figure 10-27, page 10-20).

d**. Streamlining.** This procedure (Figure 10-27, page 10-20) is similar to that of ridgelining.

(1) Identify all the mapped streams in the area of operations.

(2) Trace over them to make them stand out more prominently.

(3) Then identify other low ground, such as smaller valleys or draws that feed into the major streams, and trace over them.

This brings out the drainage pattern and low ground in the area of operation on the map. The color used for this is usually blue; but again, if blue is not available, use any color at hand so long as the distinction between the ridgelines and the streamlines is clear.

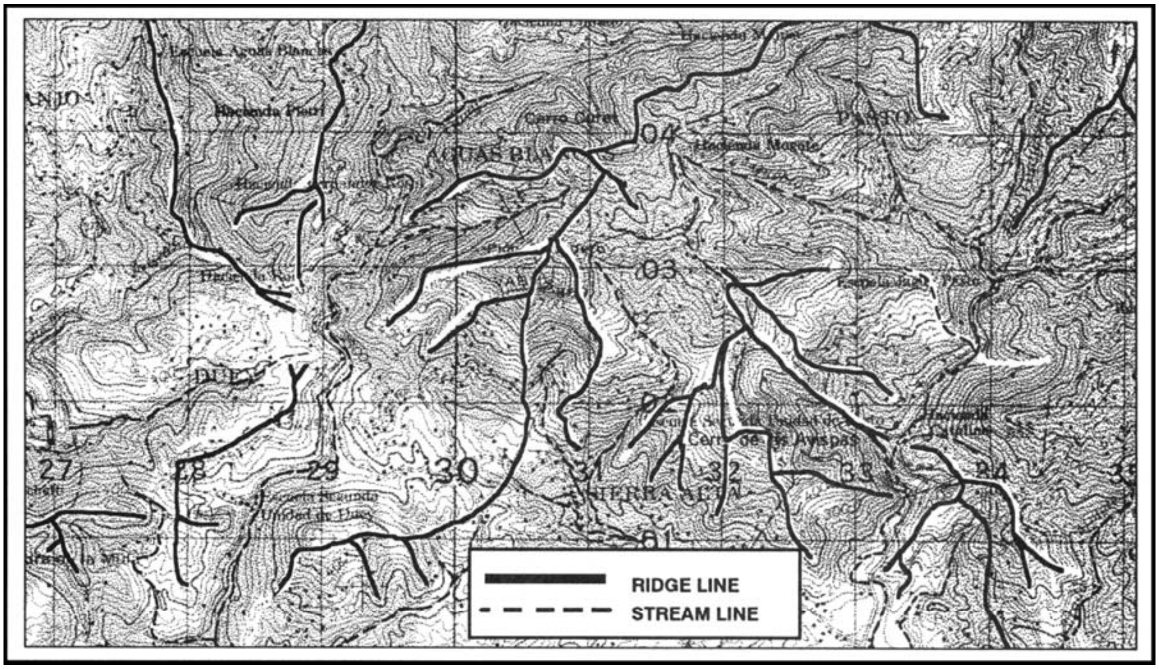

Figure 10-27. Ridgelining and streamlining.

10-8. PROFILES

The study of contour lines to determine high and low points of elevation is usually adequate for military operations. However, there may be a few times when we need a quick and precise reference to determine exact elevations of specific points. When exactness is demanded, a profile is required. A profile, within the scope and purpose of this manual, is an exaggerated side view of a portion of the earth's surface along a line between two or more points.

a. A profile can be used for many purposes. The primary purpose is to determine if line of sight is available. Line of sight is used—

(1) To determine defilade positions.

(2) To plot hidden areas or dead space.

(3) To determine potential direct fire weapon positions.

(4) To determine potential locations for defensive positions.

(5) To conduct preliminary planning in locating roads, pipelines, railroads, or other construction projects.

b. A profile can be constructed from any contoured map. Its construction requires the following steps:

(1) Draw a line on the map from where the profile is to begin to where it is to end (Figure 10-28).

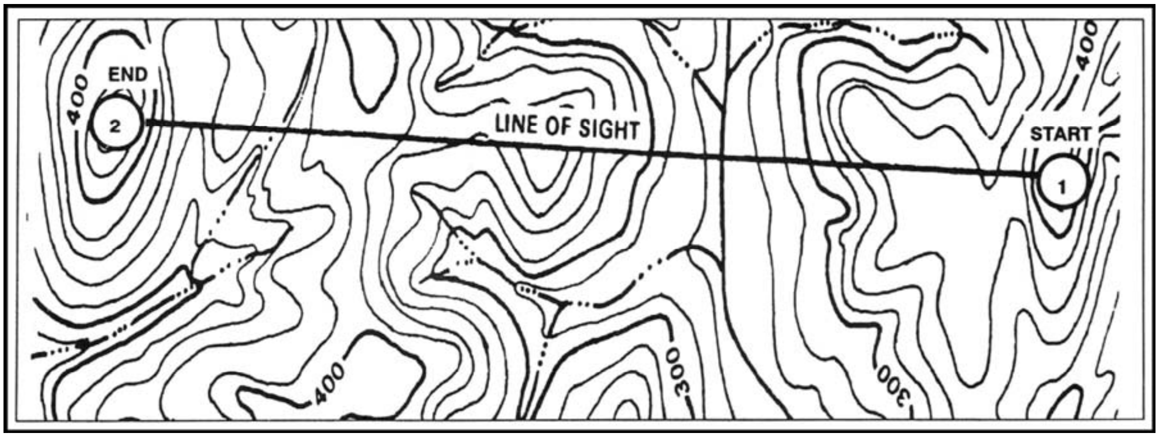

Figure 10-28. Connecting points.

(2) Find the value of the highest and lowest contour lines that cross or touch the profile line. Add one contour value above the highest and one below the lowest to take care of hills and valleys.

(3) Select a piece of lined notebook paper with as many lines as was determined in (2) above. The standard Army green pocket notebook or any other paper with 1/4-inch lines is ideal. Wider lines, up to 5/8-inch, may be used. If lined paper is not available, draw equally spaced horizontal lines on a blank sheet of paper.

(4) Number the top line with the highest value and the bottom line with the lowest value as determined in (2) above.

(5) Number the rest of the lines in sequence, starting with the second line from the top. The lines will be numbered in accordance with the contour interval (Figure 10-29).

(6) Place the paper on the map with the lines next to and parallel to the profile line (Figure 10-29).

(7) From every point on the profile line where a contour line, stream, intermittent stream, or other body of water crosses or touches, drop a perpendicular line to the line having the same value. Place a tick mark where the perpendicular line crosses the number line (Figure 10-29). Where trees are present, add the height of the trees to the contour line and place a tick mark there. Assume the height of the trees to be 50 feet or 15 meters where dark green tint is shown on the map. Vegetation height may be adjusted up or down when operations in the area have provided known tree heights.

(8) After all perpendicular lines have been drawn and tick marks placed where the lines cross, connect all tick marks with a smooth, natural curve to form a horizontal view or profile of the terrain along the profile line (Figure 10-29).

NOTE: The profile drawn may be exaggerated. The spacing between the lines drawn on the sheet of paper determines the amount of exaggeration and may be varied to suit any purpose.

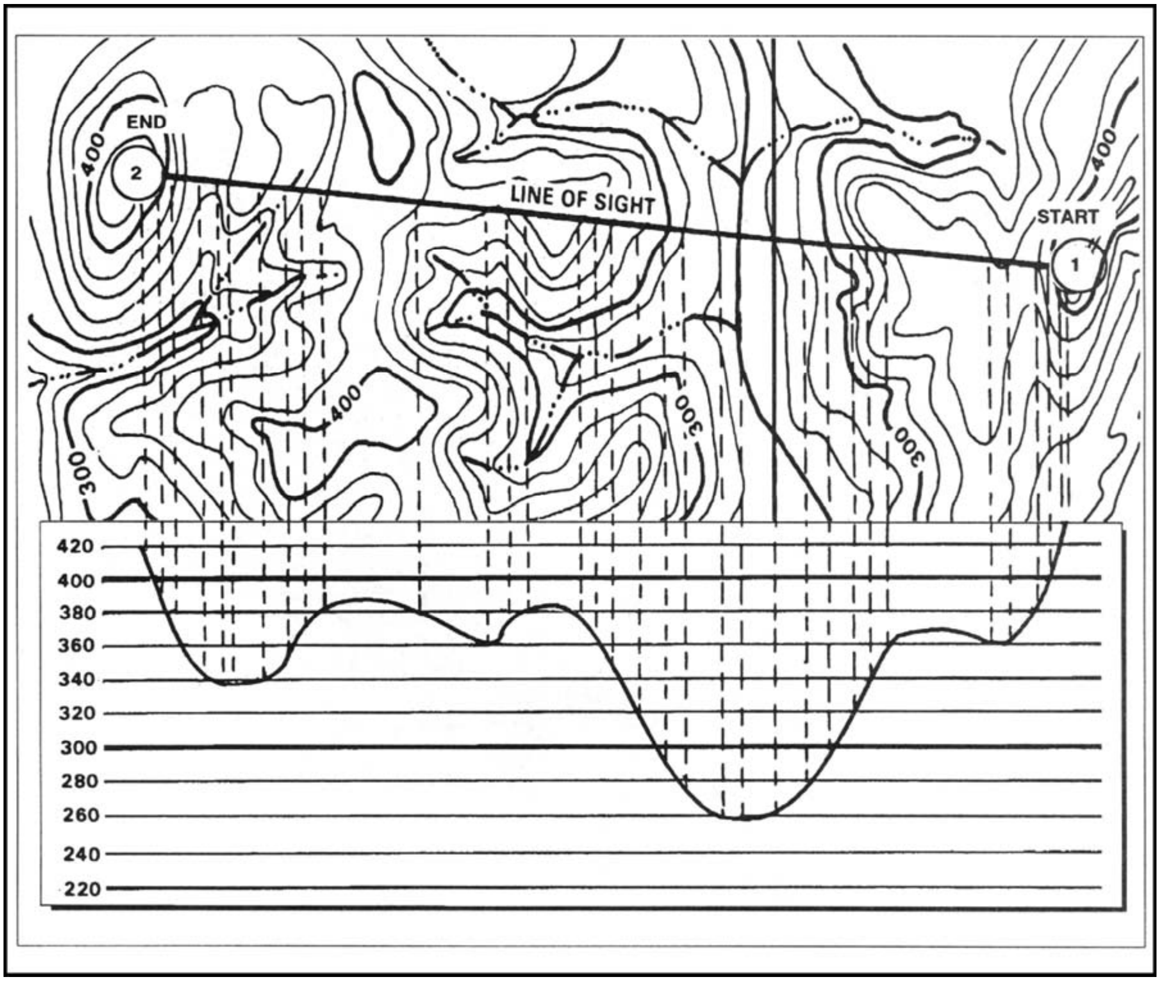
END
2
400
LINE OF SIGHT
START
1
400
400
300
300
300
420
400
380
360
340
320
300
280
260
240
220

Figure 10-29. Dropping perpendiculars.

(9) Draw a straight line from the start point to the end point on the profile. If the straight line intersects the curved profile, line of sight to the end point is not available (Figure 10-30).

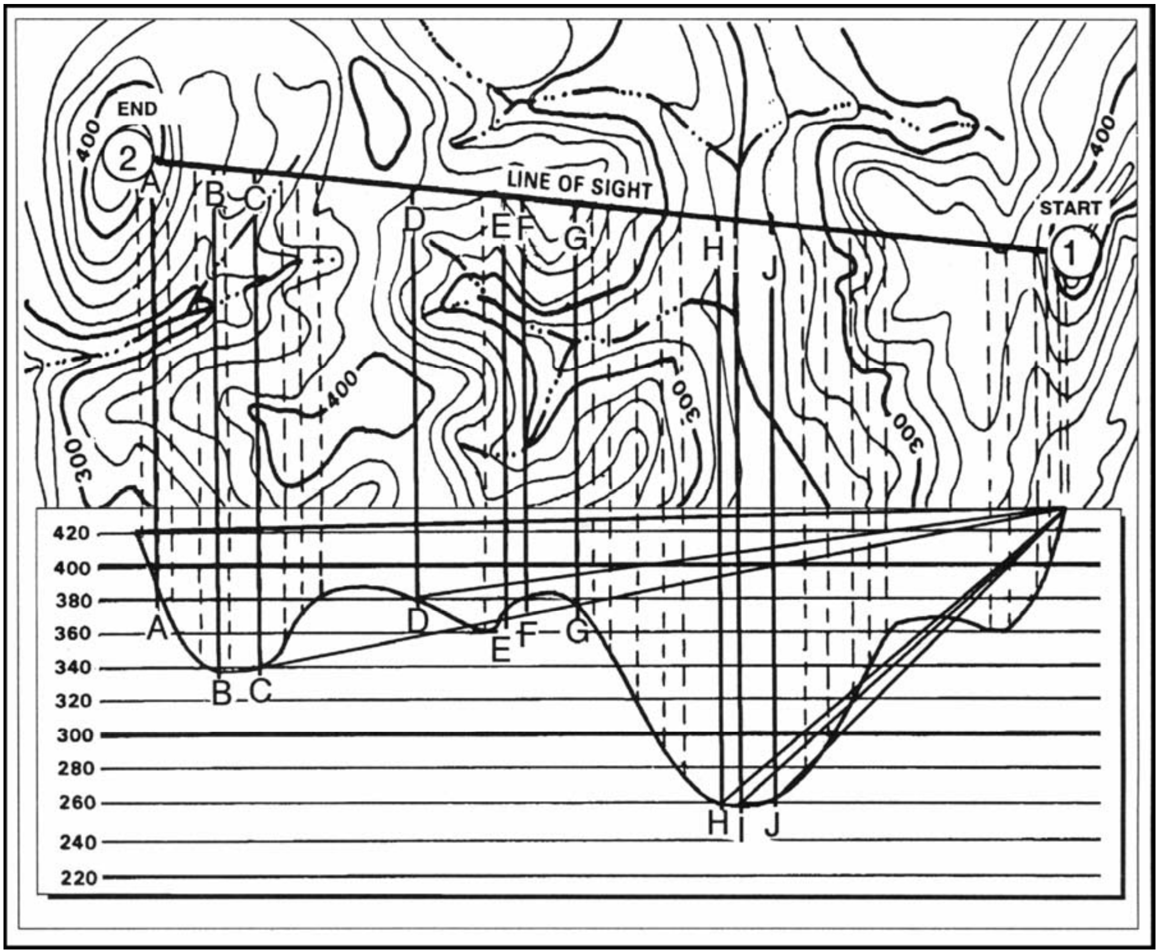
END
2
400
LINE OF SIGHT
START
1
400
300
300
300
400
A
B
C
D
E
F
G
H
J
420
400
380
360
340
320
300
280
260
240
220
A
B
C
D
E
F
G
H
I
J

Figure 10-30. Drawing lines to additional points.

(10) Determine the line of sight to other points along the profile line by drawing a line from the start point to additional points. In Figure 10-31 on page 10-24, line of sight is available to—

A—Yes
B—No
C—No
D—Yes
E—No
F—No
G—Yes
H—No
I—No

The vertical distance between navigable ground up to the line of sight line is the depth of defilade.

c. When time is short, or when a complete profile is not needed, one may be constructed showing only the hilltops, ridges, and if desired, the valleys. This is called a hasty profile. It is constructed in the same manner as a full profile (Figure 10-31).

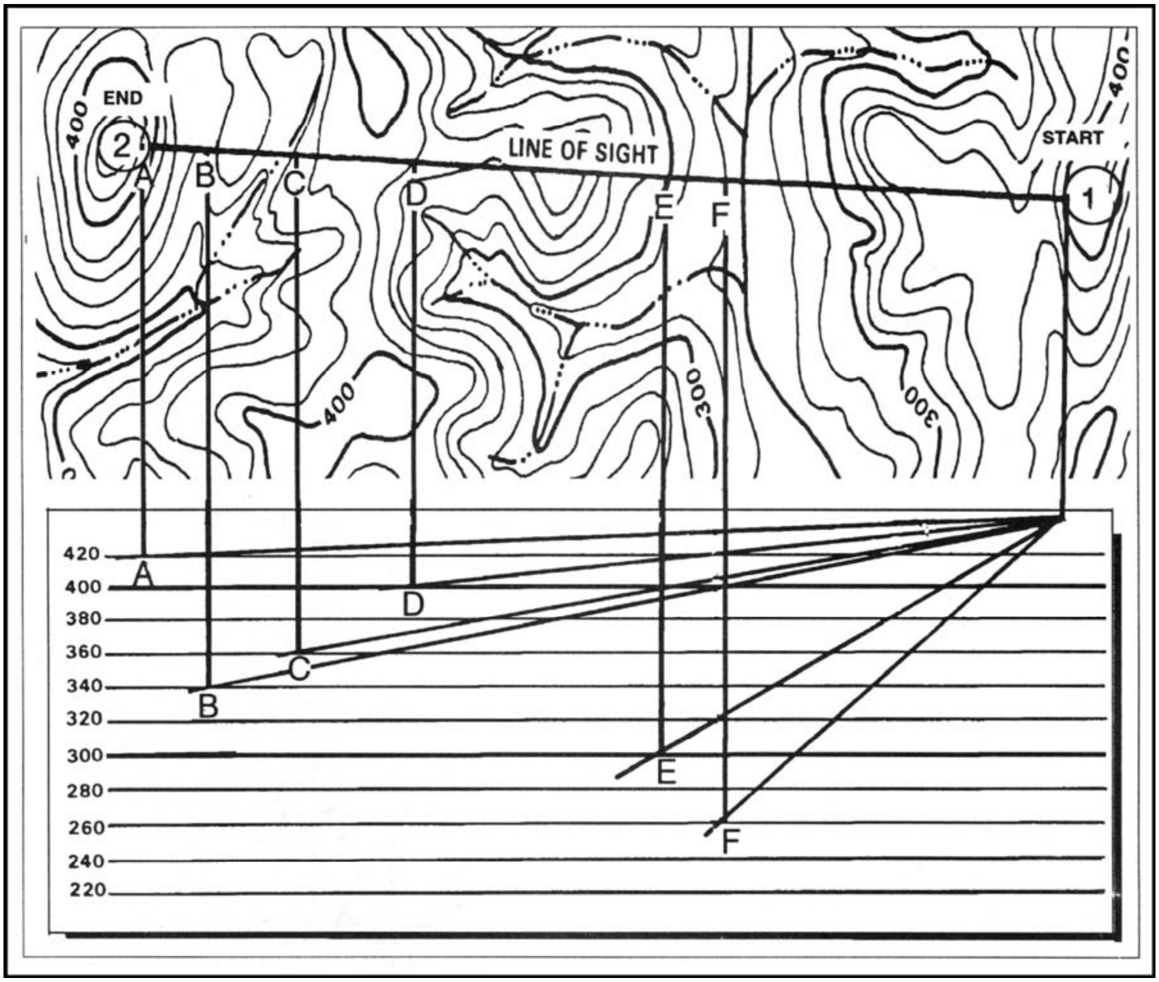
END
2
400
LINE OF SIGHT
START
1
400
A
B
C
D
E
F
400
300
300
420
400
380
360
340
320
300
280
260
240
220
A
D
C
B
E
F

Figure 10-31. Drawing a hasty profile.

CHAPTER 11

TERRAIN ASSOCIATION

Failure to make use of the vast amounts of information presented by the map and available to the eye on the ground reduces the chances for success in land navigation. The soldier who has repeatedly practiced the skills of identifying and discriminating among the many types of terrain and other features knows how these features are mapped. He can begin to visualize the shape of the land by studying the map, estimate distances, and perform quick resection from the many landmarks he sees is the one who will be at the right place to help defeat the enemy on the battlefield. This chapter tells how to orient a map with and without a compass, how to find locations on a map as well as on the ground, how to study the terrain, and how to move on the ground using terrain association and dead reckoning.

11-1. ORIENTING THE MAP

The first step for a navigator in the field is orienting the map. A map is oriented when it is in a horizontal position with its north and south corresponding to the north and south on the ground. Some orienting techniques follow:

a. **Using a Compass**. When orienting a map with a compass, remember that the compass measures magnetic azimuths. Since the magnetic arrow points to magnetic north, pay special attention to the declination diagram. There are two techniques used.

(1) ***First Technique***. Determine the direction of the declination and its value from the declination diagram.

(a) With the map in a horizontal position, take the straightedge on the left side of the compass and place it alongside the north-south grid line with the cover of the compass pointing toward the top of the map. This procedure places the fixed black index line of the compass parallel to north-south grid lines of the map.

(b) Keeping the compass aligned as directed above, rotate the map and compass together until the magnetic arrow is below the fixed black index line on the compass. At this time, the map is close to being oriented.

(c) Rotate the map and compass in the direction of the declination diagram.

(d) If the magnetic north arrow on the map is to the left of the grid north, check the compass reading to see if it equals the G-M angle given in the declination diagram. The map is then oriented (Figure 11-1, page 11-2).

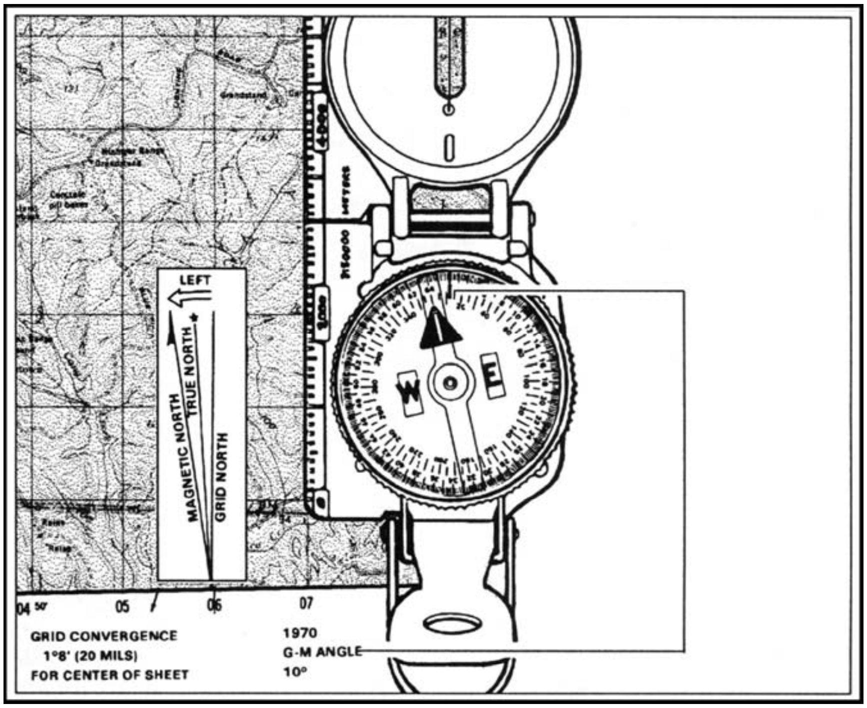
LEFT
MAGNETIC NORTH
TRUE NORTH
GRID NORTH
04 50'
05
06
07
GRID CONVERGENCE
1°8' (20 MILS)
FOR CENTER OF SHEET
1970
G-M ANGLE
10°

Figure 11-1. Map oriented with 11 degrees west declination.

(e) If the magnetic north is to the right of grid north, check the compass reading to see if it equals 360 degrees minus the G-M angle (Figure 11-2).

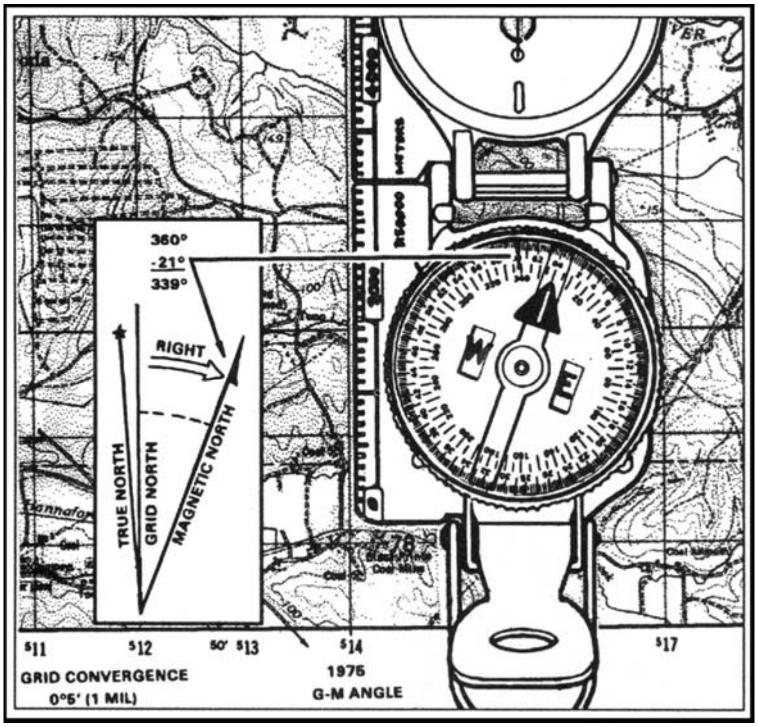
360°
-21°
339°
RIGHT
TRUE NORTH
GRID NORTH
MAGNETIC NORTH
511
512
50' 513
514
517
GRID CONVERGENCE
0°5' (1 MIL)
1975
G-M ANGLE

Figure 11-2. Map oriented with 21 degrees east declination.

(2) ***Second Technique***. Determine the direction of the declination and its value from the declination diagram.

(a) Using any north-south grid line on the map as a base, draw a magnetic azimuth equal to the G-M angle given in the declination diagram with the protractor.

(b) If the declination is easterly (right), the drawn line is equal to the value of the G-M angle. Then align the straightedge, which is on the left side of the compass, alongside the drawn line on the map. Rotate the map and compass until the magnetic arrow of the compass is below the fixed black index line. The map is now oriented (Figure 11-3).

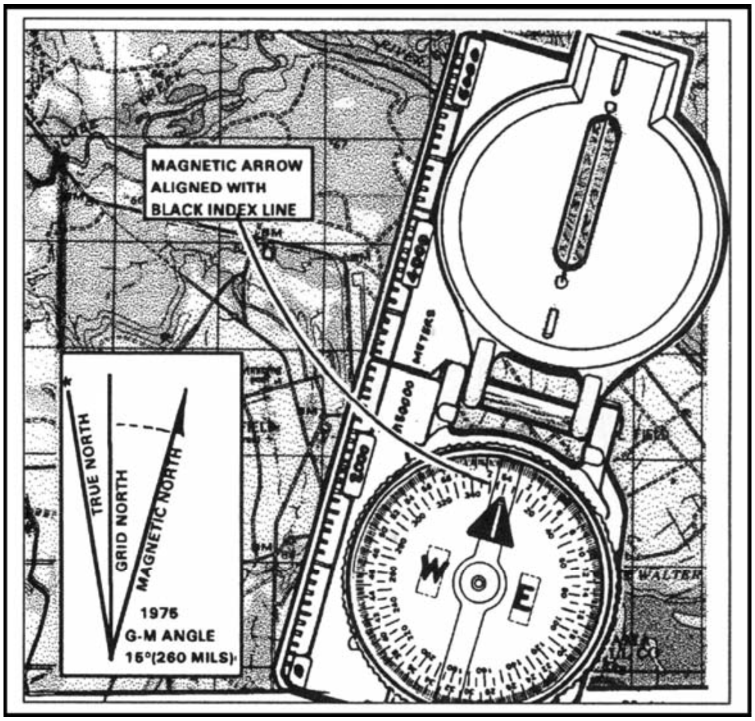

Figure 11-3. Map oriented with 15 degrees east declination.

(c) If the declination is westerly (left), the drawn line will equal 360 degrees minus the value of the G-M angle. Then align the straightedge, which is on the left side of the compass, alongside the drawn line on the map. Rotate the map and compass until the magnetic arrow of the compass is below the fixed black index line. The map is now oriented (Figure 11-4, page 11-4).

NOTES:

1. Once the map is oriented, magnetic azimuths are determined using the compass. Do not move the map from its oriented position since any change in its position moves it out of line with the magnetic north. [See paragraph 11-6b(1).]
2. Special care should be taken whenever orienting your map with a compass. A small mistake can cause you to navigate in the wrong direction.

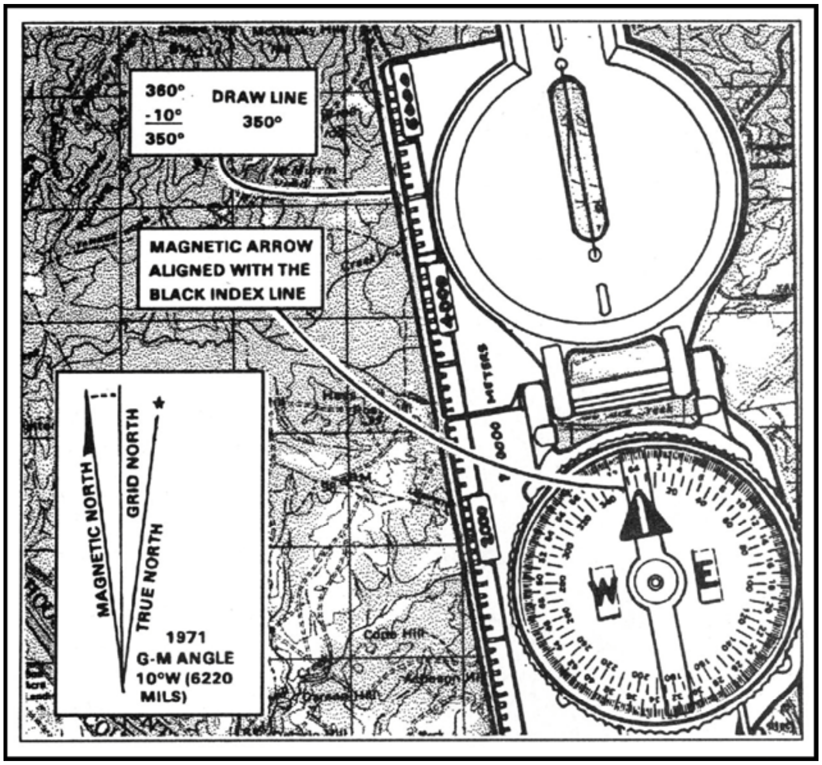
360°
-10°
350°
DRAW LINE
350°
MAGNETIC ARROW
ALIGNED WITH THE
BLACK INDEX LINE
MAGNETIC NORTH
GRID NORTH
TRUE NORTH
1971
G-M ANGLE
10°W (6220
MILS)
METERS
W
E

Figure 11-4. Map oriented with 10 degrees west declination.

b. **Using Terrain Association**. A map can be oriented by terrain association when a compass is not available or when the user has to make many quick references as he moves across country. Using this method requires careful examination of the map and the ground, and the user must know his approximate location (Figure 11-5). Orienting by this method is discussed in detail in paragraph 11-3.

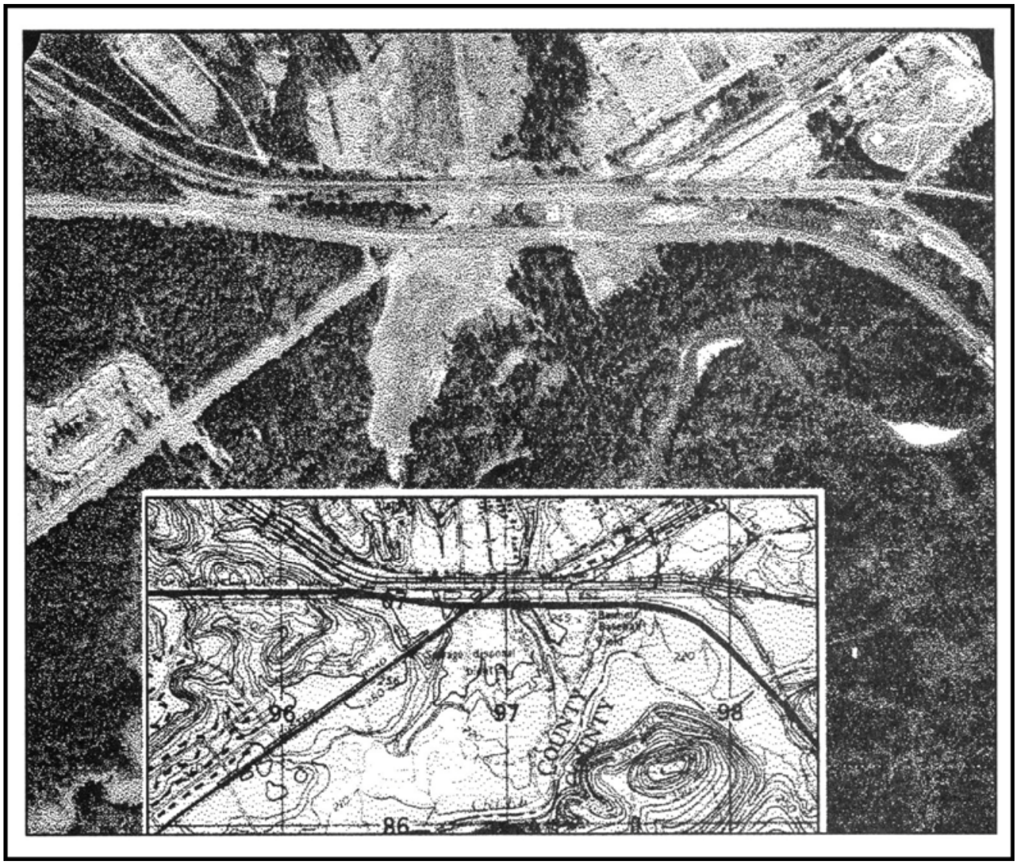

Figure 11-5. Terrain association.

c. **Using Field-Expedient Methods.** When a compass is not available and there are no recognizable terrain features, a map may be oriented by any of the field-expedient methods described in paragraph 9-5. Also see Figure 11-6.

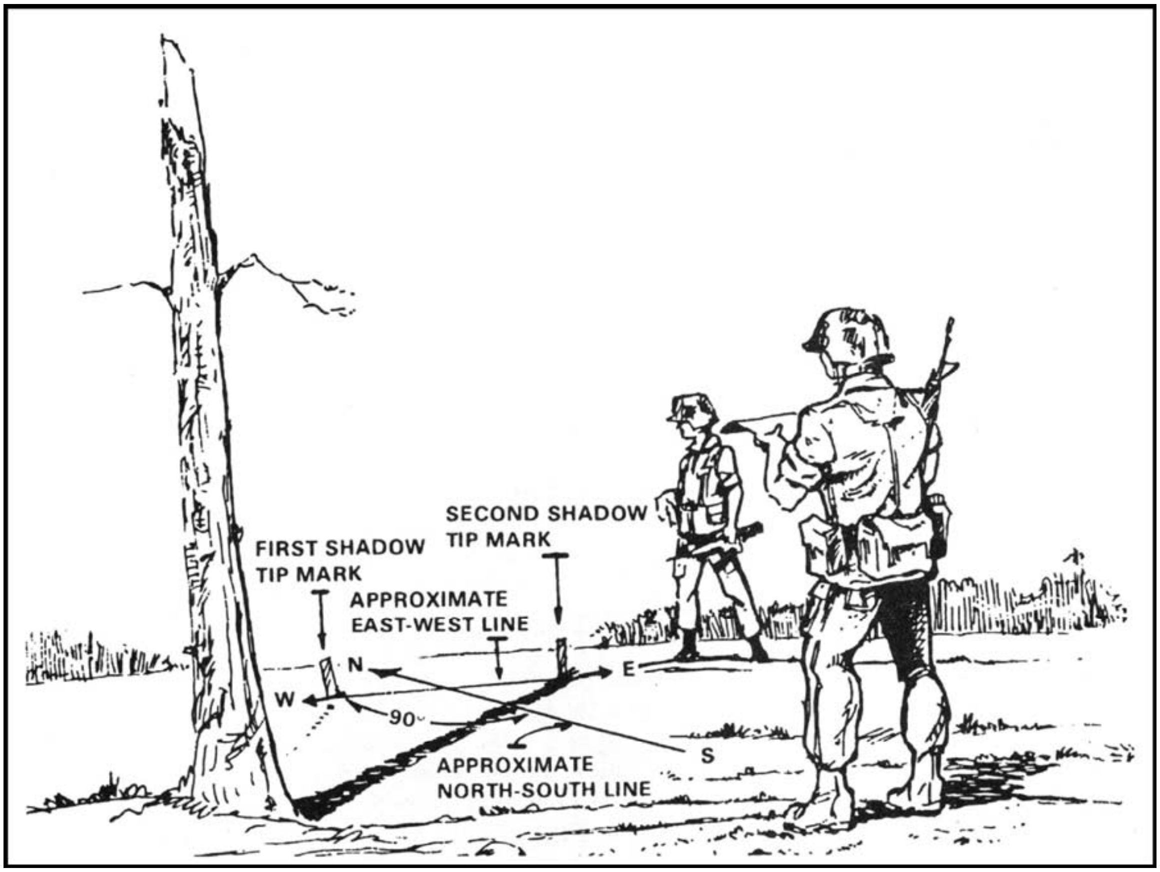

Figure 11-6. Field-expedient method.

11-2. LOCATIONS

The key to success in land navigation is to know your location at all times. With this basic knowledge, you can decide what direction and what distance to travel.

a. **Known Position**. Most important of all is the initial location of the user before starting any movement in the field. If movement takes place without establishing the initial location, everything that is done in the field from there on is a gamble. Determine the initial location by referring to the last known position, by grid coordinates and terrain association, or by locating and orienting your position on the map and ground.

b. **Known Point/Known Distance (Polar Plot)**. This location can be determined by knowing the starting point, the azimuth to the desired objective, and the distance to it.

c. **Resection**. See Chapter 6.

d. **Modified Resection**. See Chapter 6.

e. **Intersection**. See Chapter 6.

f. **Indirect Fire**. Finding a location by indirect fire is done with smoke. Use the point of impact of the round as a reference point from which distances and azimuth can be obtained.

11-3. TERRAIN ASSOCIATION USAGE

The technique of moving by terrain association is more forgiving of mistakes and far less time-consuming than dead reckoning. It best suits those situations that call for movement from one area to another. Errors made using terrain association are easily corrected because you are comparing what you expected to see from the map to what you do see on the ground. Errors are anticipated and will not go unchecked. You can easily make adjustments based upon what you encounter. Periodic position-fixing through either plotted or estimated resection will also make it possible to correct your movements, call for fire, or call in the locations of enemy targets or any other information of tactical or logistical importance.

a. **Matching the Terrain to the Map by Examining Terrain Features**. By observing the contour lines in detail, the five major terrain features (hilltop, valley, ridge, depression, and saddle) should be determined. This is a simple task in an area where the observer has ample view of the terrain in all directions. One-by-one, match the terrain features depicted on the map with the same features on the ground. In restricted terrain, this procedure becomes harder; however, constantly check the map as you move since it is the determining factor (Figure 11-5).

b. **Comparing the Vegetation Depicted on the Map**. When comparing the vegetation, a topographic map should be used to make a comparison of the clearings that appear on the map with the ones on the ground. The user must be familiar with the different symbols, such as vineyards, plantations, and orchards that appear on the legend. The age of the map is an important factor when comparing vegetation. Some important vegetation features were likely to be different when the map was made. Another important factor about vegetation is that it can change overnight by natural accidents or by man (forest fires, clearing of land for new developments, farming, and so forth).

c. **Masking by the Vegetation**. Camouflage the important landforms using vegetation. Use of camouflage makes it harder for the navigator to use terrain association.

d. **Using the Hydrography**. Inland bodies of water can help during terrain association. The shape and size of lakes in conjunction with the size and direction of flow of the rivers and streams are valuable help.

e. **Using Man-made Features**. Man-made features are an important factor during terrain association. The user must be familiar with the symbols shown in the legend representing those features. The direction of buildings, roads, bridges, high-tension lines, and so forth make the terrain inspection a lot easier; however, the age of the map must be considered because man-made features appear and disappear constantly.

f. **Examining the Same Piece of Terrain During the Different Seasons of the Year**. In those areas of the world where the seasons are distinctive, a detailed examination of the terrain should be made during each of the seasons. The same piece of land does not present the same characteristics during both spring and winter.

(1) During winter, the snow packs the vegetation, delineating the land, making the terrain features appear as clear as they are shown by the contour lines on the map. Ridges, valleys, and saddles are very distinctive.

(2) During spring, the vegetation begins to reappear and grow. New vegetation causes a gradual change of the land to the point that the foliage conceals the terrain features and makes the terrain hard to recognize.

(3) During summer months, the effects are similar to those in the spring.

(4) Fall makes the land appear different with its change of color and gradual loss of vegetation.

(5) During the rainy season, the vegetation is green and thick, and the streams and ponds look like small rivers and lakes. In scarcely vegetated areas, the erosion changes the shape of the land.

(6) During a period of drought, the vegetation dries out and becomes vulnerable to forest fires that change the terrain whenever they occur. Also during this season, the water levels of streams and lakes drop, adding new dimensions and shape to the existing mapped areas.

g. **Following an Example of Terrain Association**. Your location is hilltop 514 in the lower center of the map in Figure 11-7.

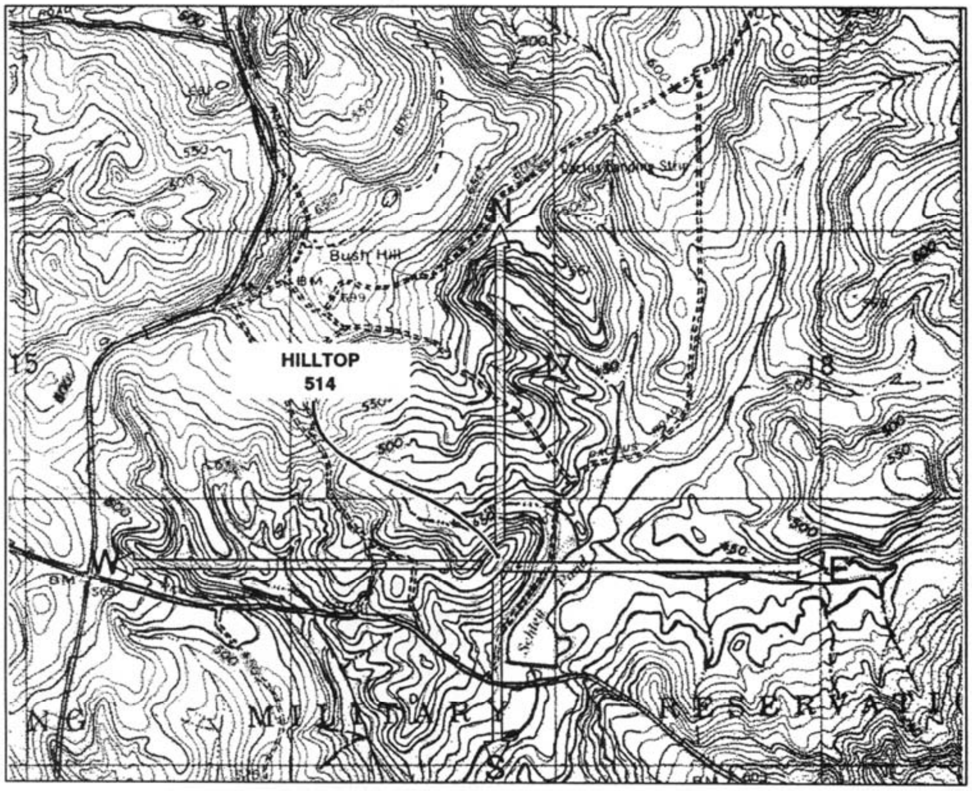

Figure 11-7. Example of terrain association.

(1) ***To The North***. The contour lines indicate that the hill slopes down for about 190 meters, and that it leads into a small valley containing an intermittent stream. On the other side of the stream as you continue with your northerly inspection, the terrain starts a gradual ascent, indicating a hilltop partially covered with vegetation, until an unimproved road is reached. This road runs along a gradual ridgeline with north-west direction. Then the contour line spacings become narrow, indicating a steeper grade that leads to a narrow valley containing a small intermittent stream. As you continue up, you find a small but prominent ridge with a clearing. The contour lines once again show a steeper grade leading to a moderate valley containing an intermittent stream running in a south-east direction.

(2) ***To The East***. There is a clearing of the terrain as it slopes down to Schley Pond. An ample valley is clearly seen on the right side of the pond, as indicated by the "U" and "V" shape of the contour lines. This valley contains some swamp areas and there is a long ridgeline on the north portion of the valley.

(3) ***To The South***. The terrain gently slopes downward until a clear area is reached. It continues in a downward direction to an intermittent stream running south-east in a small valley. There is also an improved road running in the same direction as the valley. At the intersection of the roads as you face south, there is a clearing of about 120 meters on the ridge. At the bottom of it, a stream runs from Schley Pond in a south-west direction through an ample valley fed by two intermittent streams. As you continue, a steep, vegetated hill is found with a clearing on its top, followed by a small saddle and another hilltop.

(4) ***To The West***. First, you see a small, clear valley. It is followed by a general ridgeline running north-west in which an unimproved road is located just before a hilltop. Continuing on a westerly direction, you will find a series of alternate valleys and ridges.

11-4. TACTICAL CONSIDERATIONS

Military cross-country navigation is intellectually demanding because it is imperative that the unit, crew, or vehicle survive and successfully complete the move in order to accomplish its mission. However, the unnecessary use of a difficult route makes navigation too complicated, creates more noise when proceeding over it, causes wear and tear on equipment and personnel, increases the need for and needlessly complicate recovery operations, and wastes scarce time. On receipt of a tactical mission, the leader begins his troop-leading procedures and makes a tentative plan. He bases the tentative plan on a good terrain analysis. He analyzes the considerations covered in the following mnemonics—OCOKA and METT-T.

a**. OCOKA**. The terrain should be analyzed for observation and fields of fire, cover and concealment, obstacles, key terrain, and avenues of approach.

(1) ***Observation and Fields of Fire***. The purpose of observation is to see the enemy (or various landmarks) but not be seen by him. Anything that can be seen can be hit. Therefore, a field of fire is an area that a weapon or a group of weapons can cover effectively with fire from a given position.

(2) ***Cover and Concealment***. Cover is shelter or protection (from enemy fire) either natural or artificial. Always try to use covered routes and seek cover for each halt, no matter how brief it is planned to be. Unfortunately, two factors interfere with obtaining constant cover. One is time and the other is terrain. Concealment is protection from observation or surveillance, including concealment from enemy air observation. Before, trees provided good concealment, but with modern thermal and infrared imaging equipment, trees are not always effective. When you are moving, concealment is generally secondary; therefore, select routes and positions that do not allow covered or concealed enemy near you.

(3) ***Obstacles***. Obstacles are any obstructions that stop, delay, or divert movement. Obstacles can be natural (rivers, swamps, cliffs, or mountains) or they may be artificial (barbed wire entanglements, pits, concrete or metal antimechanized traps). They can be ready-made or constructed in the field. Always consider any possible obstacles along your movement route and, if possible, try to keep obstacles between the enemy and yourself.

(4) ***Key Terrain***. Key terrain is any locality or area that the seizure or retention of affords a marked advantage to either combatant. Urban areas that are often seen by higher

headquarters as being key terrain because they are used to control routes. On the other hand, an urban area that is destroyed may be an obstacle instead. High ground can be key because it dominates an area with good observation and fields of fire. In an open area, a draw or wadi (dry streambed located in an arid area) may provide the only cover for many kilometers, thereby becoming key. You should always attempt to locate any area near you that could be even remotely considered as key terrain.

(5) ***Avenues of Approach***. These are access routes. They may be the routes you can use to get to the enemy or the routes they can use to get to you. Basically, an identifiable route that approaches a position or location is an avenue of approach to that location. They are often terrain corridors such as valleys or wide, open areas.

b**. METT-T.** Tactical factors other than the military aspects of terrain must also be considered in conjunction with terrain during movement planning and execution as well. These additional considerations are mission, enemy, terrain and weather, troops, and time available.

(1) ***Mission***. This refers to the specific task assigned to a unit or individual. It is the duty or task together with the purpose that clearly indicates the action to be taken and the reason for it—but not how to do it. Training exercises should stress the importance of a thorough map reconnaissance to evaluate the terrain. This allows the leader to confirm his tentative plan, basing his decision on the terrain's effect on his mission.

(a) Marches by foot or vehicle are used to move troops from one location to another. Soldiers must get to the right place, at the right time, and in good fighting condition. The normal rate for an 8-hour foot march is 4 kmph. However, the rate of march may vary, depending on the following factors:

- Distance.
- Time allowed.
- Likelihood of enemy contact.
- Terrain.
- Weather.
- Physical condition of soldiers.
- Equipment/weight to be carried.
- A motor march requires little or no walking by the soldiers, but the factors affecting the rate of march still apply.

(b) Patrol missions are used to conduct combat or reconnaissance operations. Without detailed planning and a thorough map reconnaissance, any patrol mission may not succeed. During the map reconnaissance, the mission leader determines a primary and alternate route to and from the objectives.

(c) Movement to contact is conducted whenever an element is moving toward the enemy but is not in contact with the enemy. The lead element must orient its movement on the objective by conducting a map reconnaissance, determining the location of the objective on both the map and the ground, and selecting the route to be taken.

(d) Delays and withdrawals are conducted to slow the enemy down without becoming decisively engaged, or to assume another mission. To be effective, the element leader must know where he is to move and the route to be taken.

(2) ***Enemy***. This refers to the strength, status of training, disposition (locations), doctrine, capabilities, equipment (including night vision devices), and probable courses of action that impact upon both the planning and execution of the mission, including a movement.

(3) ***Terrain and Weather***. Observation and fields of fire influence the placement of positions and crew-served weapons. The leader conducts a map reconnaissance to determine key terrain, obstacles, cover and concealment, and likely avenues of approach.

(a) Key terrain is any area whose control affords a marked advantage to the force holding it. Some types of key terrain are high ground, bridges, towns, and road junctions.

(b) Obstacles are natural or man-made terrain features that stop, slow down, or divert movement. Consideration of obstacles is influenced by the unit's mission. An obstacle may be an advantage or disadvantage, depending upon the direction of attack or defense. Obstacles can be found by conducting a thorough map reconnaissance and study of recent aerial photographs.

(c) Cover and concealment are determined for both friendly and enemy forces. Concealment is protection from observation; cover is protection from the effects of fire. Most terrain features that offer cover also provide concealment from ground observation. There are areas that provide no concealment from enemy observation. These danger areas may be large or small open fields, roads, or streams. During the leader's map reconnaissance, he determines any obvious danger areas and, if possible, adjusts his route.

(d) Avenues of approach are routes by which a unit may reach an objective or key terrain. To be considered an AA, a route must provide enough width for the deployment of the size force for which it is being considered. The AAs are also considered for the subordinate enemy force. For example, a company determines likely AAs for an enemy platoon; a platoon determines likely AAs for an enemy squad. Likely AAs may be either ridges, valleys, or by air. By examining the terrain, the leader determines the likely enemy AAs based on the tactical situation.

(e) Weather has little effect on dismounted land navigation. Rain and snow could possibly slow down the rate of march, that is all. But during mounted land navigation, the navigator must know the effect of weather on his vehicle. (See Chapter 12 for mounted land navigation.)

(4) ***Troops***. Consideration of your own troops is equally important. The size and type of the unit to be moved and its capabilities, physical condition, status of training, and types of equipment assigned all affect the selection of routes, positions, fire plans, and the various decisions to be made during movement. On ideal terrain such as relatively level ground with little or no woods, a platoon can defend a front of up to 400 meters. The leader must conduct a thorough map reconnaissance and terrain analysis of the area his unit is to defend. Heavily wooded areas or very hilly areas may reduce the front a platoon can defend. The size of the unit must also be taken into consideration when planning a movement to contact. During movement, the unit must retain its ability to maneuver. A small draw or stream may reduce the unit's maneuverability but provide excellent concealment. All of these factors must be considered.

(a) Types of equipment that may be needed by the unit can be determined by a map reconnaissance. For example, if the unit must cross a large stream during its movement to the objective, ropes may be needed for safety lines.

(b) Physical capabilities of the soldiers must be considered when selecting a route. Crossing a large swampy area may present no problem to a physically fit unit, but to a unit that has not been physically conditioned, the swampy area may slow or completely stop its movement.

(5) ***Time Available***. At times, the unit may have little time to reach an objective or to move from one point to another. The leader must conduct a map reconnaissance to determine the quickest route to the objective; this is not always a straight route. From point A to point B on the map may appear to be 1,000 meters, but if the route is across a large ridge, the distance will be greater. Another route from point A to B may be 1,500 meters—but on flat terrain. In this case, the quickest route would be across the flat terrain; however, concealment and cover may be lost.

11-5. MOVEMENT AND ROUTE SELECTION

One key to success in tactical missions is the ability to move undetected to the objective. There are four steps to land navigation. Being given an objective and the requirement to move there, you must know where you are, plan the route, stay on the route, and recognize the objective.

a**. Know Where You Are (Step 1).** You must know where you are on the map and on the ground at all times and in every possible way. This includes knowing where you are relative to—

- Your directional orientation.
- The direction and distances to your objective.
- Other landmarks and features.
- Any impassable terrain, the enemy, and danger areas.
- Both the advantages and disadvantages presented by the terrain between you and your objective.

This step is accomplished by knowing how to read a map, recognize and identify specific terrain and other features; determine and estimate direction; pace, measure, and estimate distances, and both plot and estimate a position by resection.

b**. Plan the Route (Step 2)**. Depending upon the size of the unit and the length and type of movement to be conducted, several factors should be considered in selecting a good route or routes to be followed. These include—

- Travel time.
- Travel distance.
- Maneuver room needed.
- Trafficability.
- Load-bearing capacities of the soil.
- Energy expenditure by troops.
- The factors of METT-T.
- Tactical aspects of terrain (OCOKA).
- Ease of logistical support.
- Potential for surprising the enemy.
- Availability of control and coordination features.
- Availability of good checkpoints and steering marks.

In other words, the route must be the result of careful map study and should address the requirements of the mission, tactical situation, and time available. It must also provide for ease of movement and navigation.

(1) Three route-selection criteria that are important for small-unit movements are cover, concealment, and the availability of reliable checkpoint features. The latter is weighted even

more heavily when selecting the route for a night operation. The degree of visibility and ease of recognition (visual effect) are the key to the proper selection of these features.

(2) The best checkpoints are linear features that cross the route. Examples include perennial streams, hard-top roads, ridges, valleys, railroads, and power transmission lines. Next, it is best to select features that represent elevation changes of at least two contour intervals such as hills, depressions, spurs, and draws. Primary reliance upon cultural features and vegetation is cautioned against because they are most likely to have changed since the map was last revised.

(3) Checkpoints located at places where changes in direction are made mark your **decision points**. Be especially alert to see and recognize these features during movement. During preparation and planning, it is especially important to review the route and anticipate where mistakes are most likely to be made so they can be avoided.

(4) Following a valley floor or proceeding near (not on) the crest of a ridgeline generally offers easy movement, good navigation checkpoints, and sufficient cover and concealment. It is best to follow terrain features whenever you can—not to fight them.

(5) A lost or a late arriving unit, or a tired unit that is tasked with an unnecessarily difficult move, does not contribute to the accomplishment of a mission. On the other hand, the unit that moves too quickly and carelessly into a destructive ambush or leaves itself open to air strikes also have little effect. Careful planning and study are required each time a movement route is to be selected.

c. **Stay on the Route (Step 3).** In order to know that you are still on the correct route, you must be able to compare the evidence you encounter as you move according to the plan you developed on the map when you selected your route. This may include watching your compass reading (dead reckoning) or recognizing various checkpoints or landmarks from the map in their anticipated positions and sequences as you pass them (terrain association). A better way is to use a combination of both.

d**. Recognize the Objective (Step 4).** The destination is rarely a highly recognizable feature such as a dominant hilltop or road junction. Such locations as this are seldom missed by the most inexperienced navigators and are often dangerous places for soldiers to occupy. The relatively small, obscure places are most likely to be the destinations.

(1) Just how does a soldier travel over unfamiliar terrain for moderate to great distances and know when he reaches the destination? One minor error, when many are possible, can cause the target to be missed.

(2) The answer is simple. Select a checkpoint (reasonably close to the destination) that is not so difficult to find or recognize. Then plan a short, fine-tuned last leg from the new *expanded objective* to the final destination. For example, you may be able to plan and execute the move as a series of sequenced movements from one checkpoint or landmark to another using both the terrain and a compass to keep you on the correct course. Finally, after arriving at the last checkpoint, you might follow a specific compass azimuth and pace off the relatively short, known distance to the final, pinpoint destination. This procedure is called *point navigation*. A short movement out from a unit position to an observation post or to a coordination point may also be accomplished in the same manner.

11-6. NAVIGATION METHODS

Staying on the route is accomplished through the use of one or two navigation techniques—dead reckoning and terrain association. These methods are discussed in detail below.

a. **Moving by Dead Reckoning.** Dead reckoning consists of two fundamental steps. The first is the use of a protractor and graphic scales to determine the direction and distance from one point to another on a map. The second step is the use of a compass and some means of measuring distance to apply this information on the ground. In other words, it begins with the determination of a polar coordinate on a map and ends with the act of finding it on the ground.

(1) Dead reckoning along a given route is the application of the same process used by a mapmaker as he establishes a measured line of reference upon which to construct the framework of his map. Therefore, triangulation exercises (either resection or intersection) can be easily undertaken by the navigator at any time to either determine or confirm precise locations along or near his route. Between these position-fixes, establish your location by measuring or estimating the distance traveled along the azimuth being followed from the previous known point. You might use pacing, a vehicle odometer, or the application of elapsed time for this purpose, depending upon the situation.

(2) Most dead reckoned movements do not consist of single straight-line distances because you cannot ignore the tactical and navigational aspects of the terrain, enemy situation, natural and man-made obstacles, time, and safety factors. Another reason most dead reckoning movements are not single straight-line distances is because compasses and pace-counts are imprecise measures. Error from them compounds over distance; therefore, you could soon be far afield from your intended route even if you performed the procedures correctly. The only way to counteract this phenomenon is to reconfirm your location by terrain association or resection. Routes planned for dead reckoning generally consist of a series of straight-line distances between several checkpoints with perhaps some travel running on or parallel to roads or trails.

(3) There are two advantages to dead reckoning. First, dead reckoning is easy to teach and to learn. Second, it can be a highly accurate way of moving from one point to another if done carefully over short distances, even where few external cues are present to guide the movements.

(4) During daylight, across open country, along a specified magnetic azimuth, never walk with the compass in the open position and in front of you. Because the compass will not stay steady or level, it does not give an accurate reading when held or used this way. Begin at the start point and face with the compass in the proper direction, then sight in on a landmark that is located on the correct azimuth to be followed. Close the compass and proceed to that landmark. Repeat the process as many times as necessary to complete the straight-line segment of the route.

(5) The landmarks selected for this purpose are called *steering marks*, and their selection is crucial to success in dead reckoning. Steering marks should never be determined from a map study. They are selected as the march progresses and are commonly on or near the highest points that you can see along the azimuth line that you are following when they are selected. They may be uniquely shaped trees, rocks, hilltops, posts, towers, and buildings—anything that can be easily identified. If you do not see a good steering mark to the front, you might use a back azimuth to some feature behind you until a good steering mark appears out in front. Characteristics of a good steering mark are:

(a) It must have some characteristics about it, such as color, shade of color, size, or shape (preferably all four), that will assure you that it will continue to be recognized as you approach it.

(b) If several easily distinguished objects appear along your line of march, the best steering mark is the most distant object. This procedure enables you to travel farther with fewer references to the compass. If you have many options, select the highest object. A higher mark is not as easily lost to sight as is a lower mark that blends into the background as you approach it. A steering mark should be continuously visible as you move toward it.

(c) Steering marks selected at night must have even more unique shapes than those selected during daylight. As darkness approaches, colors disappear and objects appear as black or gray silhouettes. Instead of seeing shapes, you begin to see only the general outlines that may appear to change as you move and see the objects from slightly different angles.

(6) Dead reckoning without natural steering marks is used when the area through which you are traveling is devoid of features, or when visibility is poor. At night, it may be necessary to send a member of the unit out in front of your position to create your own steering mark in order to proceed. His position should be as far out as possible to reduce the number of chances for error as you move. Arm-and-hand signals or a radio may be used in placing him on the correct azimuth. After he has been properly located, move forward to his position and repeat the process until some steering marks can be identified or until you reach your objective.

(7) When handling obstacles/detours on the route, follow these guidelines:

(a) When an obstacle forces you to leave your original line of march and take up a parallel one, always return to the original line as soon as the terrain or situation permits.

(b) To turn clockwise (right) 90 degrees, you must add 90 degrees to your original azimuth. To turn counterclockwise (left) 90 degrees from your current direction, you must subtract 90 degrees from your present azimuth.

(c) When making a detour, be certain that only paces taken toward the final destination are counted as part of your forward progress. They should not be confused with the local pacing that takes place perpendicular to the route in order to avoid the problem area and in returning to the original line of march after the obstacle has been passed.

(8) Sometimes a steering mark on your azimuth of travel can be seen across a swamp or some other obstacle to which you can simply walk out around. Dead reckoning can then begin at that point. If there is no obvious steering mark to be seen across the obstacle, perhaps one can be located to the rear. Compute a back azimuth to this point and later sight back to it once the obstacle has been passed in order to get back on track.

(9) You can use the deliberate offset technique. Highly accurate distance estimates and precision compass work may not be required if the destination or an intermediate checkpoint is located on or near a large linear feature that runs nearly perpendicular to your direction of travel. Examples include roads or highways, railroads, power transmission lines, ridges, or streams. In these cases, you should apply a deliberate error (offset) of about 10 degrees to the azimuth you planned to follow and then move, using the lensatic compass as a guide, in that direction until you encounter the linear feature. You will know exactly which way to turn (left or right) to find your destination or checkpoint, depending upon which way you planned your deliberate offset.

(10) Because no one can move along a given azimuth with absolute precision, it is better to plan a few extra steps than to begin an aimless search for the objective once you reach the linear feature. If you introduce your own mistake, you will certainly know how to correct it. This method will also cope with minor compass errors and the slight variations that always occur in the earth's magnetic field.

(11) There are disadvantages to dead reckoning. The farther you travel by dead reckoning without confirming your position in relation to the terrain and other features, the more errors you will accumulate in your movements. Therefore, you should confirm and correct your estimated position whenever you encounter a known feature on the ground that is also on the map. Periodically, you should accomplish a resection triangulation using two or more known points to pinpoint and correct your position on the map. Pace counts or any type of distance measurement should begin anew each time your position is confirmed on the map.

(a) It is dangerous to select a single steering mark, such as a distant mountaintop, and then move blindly toward it. What will you do if you must suddenly call for fire support or a medical evacuation? You must periodically use resection and terrain association techniques to pinpoint your location along the way.

(b) Steering marks can be farther apart in open country, thereby making navigation more accurate. In areas of dense vegetation, however, where there is little relief, during darkness, or in fog, your steering marks must be close together. This, of course, introduces more chance for error.

(c) Finally, dead reckoning is time-consuming and demands constant attention to the compass. Errors accumulate easily and quickly. Every fold in the ground and detours as small as a single tree or boulder also complicate the measurement of distance.

b. **Moving by Terrain Association**. The technique of moving by terrain association is more forgiving of mistakes and far less time-consuming than dead reckoning. It best suits those situations that call for movement from one area to another. Once an error has been made in dead reckoning, you are off the track. Errors made using terrain association are easily corrected, however, because you are comparing what you expected to see from the map to what you do see on the ground. Errors are anticipated and will not go unchecked. You can easily make adjustments based upon what you encounter. After all, you do not find the neighborhood grocery store by dead reckoning—you adjust your movements according to the familiar landmarks you encounter along the way (Figure 11-8). Periodic position-fixing through either plotted or estimated resection will also make it possible to correct your movements, call for fire, or call in the locations of enemy targets or any other information of tactical or logistical importance.

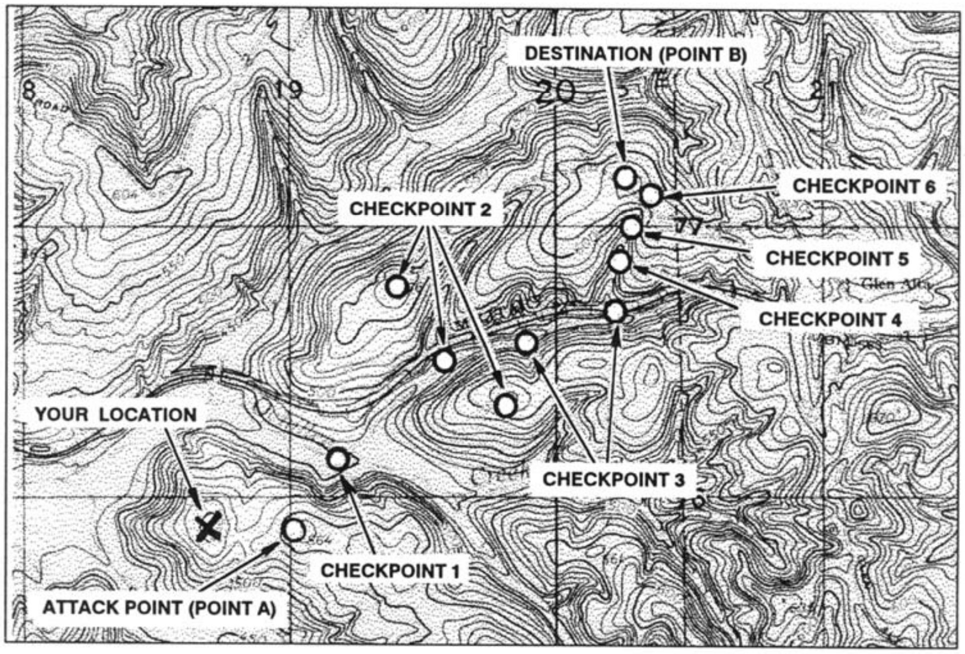

Figure 11-8. Terrain association navigation.

(1) ***Identifying and Locating Selected Features***. Being able to identify and locate the selected features, both on the map and on the ground, are essential to the success in moving by terrain association. The following rules may prove helpful.

(a) Be certain the map is properly oriented when moving along the route and use the terrain and other features as guides. The orientation of the map must match the terrain or it can cause confusion.

(b) To locate and identify features being used to guide the movement, look for the steepness and shape of the slopes, the relative elevations of the various features, and the directional orientations in relation to your position and to the position of the other features you can see.

(c) Make use of the additional cues provided by hydrography, culture, and vegetation. All the information you can gather will assist you in making the move. The ultimate test and the best practice for this movement technique is to go out in the field and use it. The use of terrain, other natural features, and any man-made objects that appear both on the map and on the ground must be practiced at every opportunity. There is no other way to learn or retain this skill.

(2) ***Using Handrails, Catching Features, and Navigational Attack Points***. First, because it is difficult to dead reckon without error over long distances with your compass, the alert navigator can often gain assistance from the terrain.

(a) **Handrails** are linear features like roads or highways, railroads, power transmission lines, ridgelines, or streams that run roughly parallel to your direction of travel. Instead of using precision compass work, you can rough compass without the use of steering marks for as long as the feature travels with you on your right or left. It acts as a handrail to guide the way.

(b) Second, when you reach the point where either your route or the handrail changes direction, you must be aware that it is time to go your separate ways. Some prominent feature located near this point is selected to provide this warning. This is called a *catching feature*; it can also be used to tell you when you have gone too far.

(c) Third, the catching feature may also be your *navigational attack point*; this point is the place where area navigation ends and point navigation begins. From this last easily identified checkpoint, the navigator moves cautiously and precisely along a given azimuth for a specified distance to locate the final objective. The selection of this navigational attack point is important. A distance of 500 meters or less is most desirable.

(3) ***Recognizing the Disadvantages of Terrain Association***. The major disadvantage to navigation by terrain association is that you must be able to interpret the map and analyze the world around you. Recognition of terrain and other features, the ability to determine and estimate direction and distance, and knowing how to do quick-in-the-head position fixing are skills that are more difficult to teach, learn, and retain than those required for dead reckoning.

c. **Combination of Techniques.** Actually, the most successful navigation is obtained by combining the techniques described above. Constant orientation of the map and continuous observation of the terrain in conjunction with compass-read azimuths, and distance traveled on the ground compared with map distance, used together make reaching a destination more certain. One should not depend entirely on compass navigation or map navigation; either or both could be lost or destroyed.

NOTE: See Appendix F for information on orienteering.

11-7. NIGHT NAVIGATION

Darkness presents its own characteristics for land navigation because of limited or no visibility. However, the techniques and principles are the same as that used for day navigation. The success in nighttime land navigation depends on rehearsals during the planning phase before the movement, such as detailed analysis of the map to determine the type of terrain in which the navigation is going to take place and the predetermination of azimuths and distances. Night vision devices (Appendix H) can greatly enhance night navigation.

a. The basic technique used for nighttime land navigation is dead reckoning with several compasses recommended. The point man is in front of the navigator but just a few steps away for easy control of the azimuth. Smaller steps are taken during night navigation, so remember, the pace count is different. It is recommended that a pace count obtained by using a predetermined 100-meter pace course be used at night.

b. Navigation using the stars is recommended in some areas; however, a thorough knowledge of constellations and location of stars is needed (paragraph 9-5c). The four cardinal directions can also be obtained at night by using the same technique described for the shadow-tip method. Just use the moon instead of the sun. In this case, the moon has to be bright enough to cast a shadow.

CHAPTER 12
MOUNTED LAND NAVIGATION

A vehicle commander should be able to navigate from one point on the ground to another with or without a compass. If separated from his unit and given an azimuth and distance from their position to his, he should be able to reach the unit and continue the mission. To move effectively while mounted, he must know the principles of mounted navigation.

12-1. PRINCIPLES

The principles of land navigation while mounted are basically the same as while dismounted. The major difference is the speed of travel. Walking between two points may take one hour, but riding the same distance may only take 15 minutes. To be effective at mounted land navigation, the travel speed must be considered.

12-2. NAVIGATOR'S DUTIES

The duties of a navigator are so important and exacting that he should not be given any other duties. The leader should never try to be the navigator, since his normal responsibilities are heavy, and one or the other job would suffer.

a. **Assembling Equipment.** The navigator must gather all the equipment that will help him perform his job (maps, pencils, and so forth). He must do this before the mission starts.

b. **Servicing Equipment.** It is the navigator's duty to make sure that all the equipment he may use or require is working.

c. **Recording Data for Precise Locations.** During movement, the navigator must make sure that the correct direction and distance are recorded and followed. Grid coordinates of locations must be recorded and plotted.

d. **Supplying Data to Subordinate Leaders**. During movement, any change in direction or distance must be given to the subordinate leaders in sufficient time to allow them to react.

e. **Maintaining Liaison with the Commander.** The commander normally selects the route that he desires to use. The navigator is responsible for following that route; however, there may be times when the route must be changed during a tactical operation. For this reason, the navigator must maintain constant communication with the commander. The navigator must inform the commander when checkpoints are reached, when a change in direction of movement is required, and how much distance is traveled.

12-3. MOVEMENT

When preparing to move, the effects of terrain on navigating mounted vehicles must be determined. You will cover great distances very quickly, and you must develop the ability to estimate the distance you have traveled. Remember that 0.1 mile is roughly 160 meters, and 1 mile is about 1,600 meters or 1.6 kms. Having a mobility advantage helps while navigating. Mobility makes it much easier if you get disoriented to move to a point where you can reorient yourself.

NOTE: To convert kmph to mph, multiply by .62. (9 kmph x .62 = 5.58 mph). To convert mph to kmph, divide mph by .62 (10 mph ÷ 0.62 = 16.12 kmph).

a. **Consider Vehicle Capabilities.** When determining a route to be used when mounted, consider the capabilities of the vehicles to be used. Most military vehicles are limited in the degree of slope they can climb and the type of terrain they can negotiate. Swamps, thickly wooded areas, or deep streams may present no problems to dismounted soldiers, but the same terrain may completely stop mounted soldiers. The navigator must consider this when selecting a route.

(1) Most vehicles will knock down a tree. The bigger the vehicle, the bigger the tree it can knock down. Vehicles cannot knock down several trees at once. It is best to find paths between trees that are wide enough for your vehicle. Military vehicles are designed to climb 60 percent slopes on a dry, firm surface (Figure 12-1).

(2) You can easily determine approximate slope; just look at the route you have selected. If there is a contour line in any 100 meters of map distance on that route, it is a 10 percent slope. If there are two contour lines, it is 20 percent, and so forth. If there are four contour lines in any 100 meters, look for another route.

(3) Side slope is even more important than the slope you can climb. Normally, a 30 percent slope is the maximum in good weather. If you traverse a side slope, do it slowly and without turns. Rocks, stumps, or sharp turns can cause you to throw the downhill track under the vehicle, which would mean a big recovery task.

(4) For tactical reasons, you will often want to move in draws or valleys because they give you cover. However, side slopes force you to move slowly.

NOTE: The above figures are true for a 10-meter or a 20-foot contour interval. If the map has a different contour interval, just adjust the arithmetic. For instance, with one contour line in 100 meters, a 20-meter interval would give a 20 percent slope.

b**. Know the Effects of Weather on Vehicle Movement.** Weather can halt mounted movement. Snow and ice are obvious dangers, but more significant is the effect of rain and snow on soil load-bearing ability. Cross-country vehicles may be restricted to road movement in heavy rain. If it has rained recently, adjust your route to avoid flooded or muddy areas. A mired vehicle only hinders combat capability.

c. **Prepare Before Movement.** Locate the start point and finish point on the map. Determine the map's grid azimuth from start point to finish point and convert it to a magnetic azimuth. Determine the distance between the start point and finish point or any intermediate points on the map and make a thorough map reconnaissance of that area.

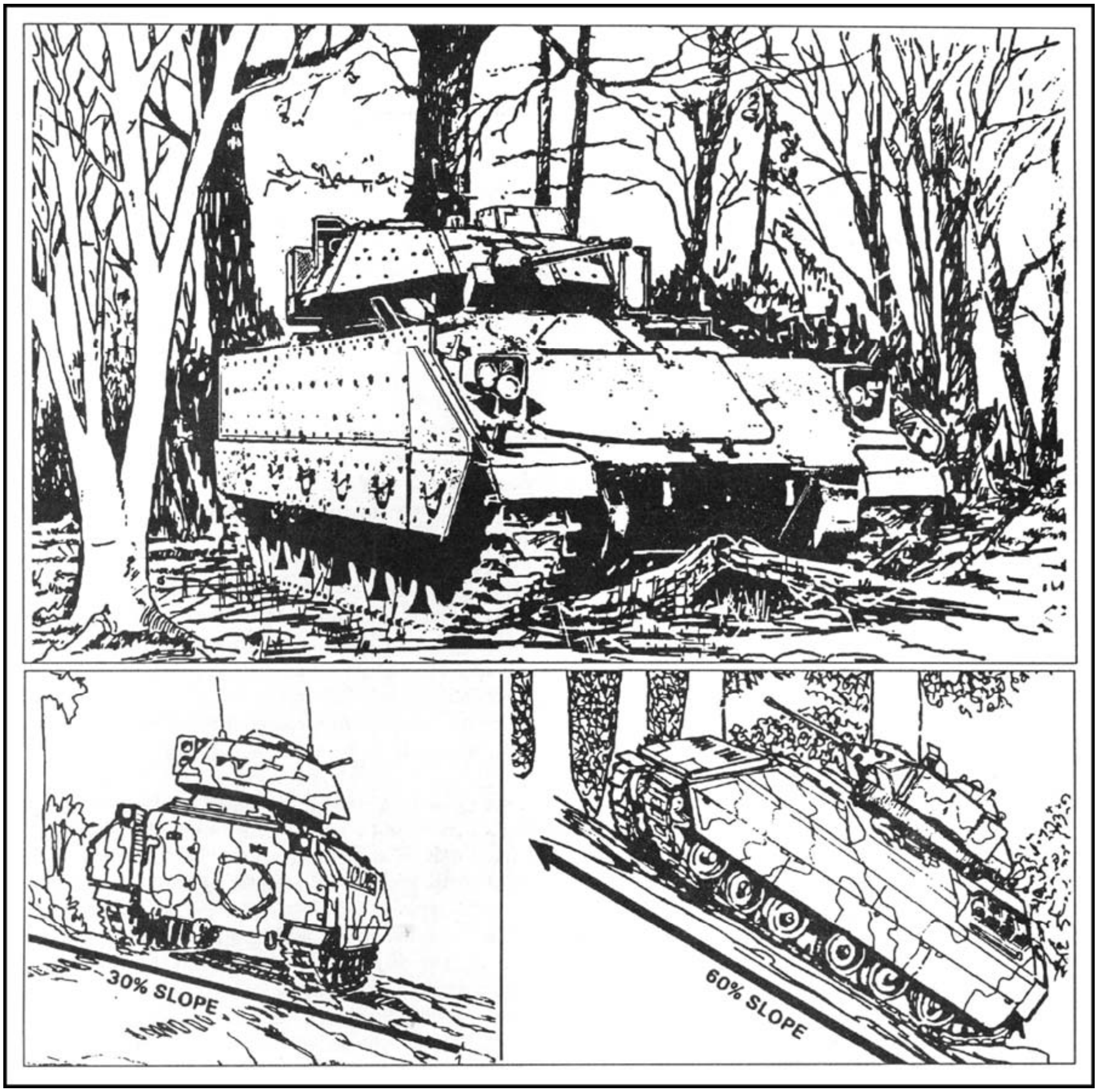

Figure 12-1. Tracked vehicle capabilities.

12-4. TERRAIN ASSOCIATION NAVIGATION

This is currently the most widely used method of navigation. The navigator plans his route so that he moves from terrain feature to terrain feature. An automobile driver in a city uses this technique as he moves along a street or series of streets, guiding on intersections or features such as stores and parks. Like the driver, the navigator selects routes or *streets* between key points or *intersections*. These routes must be capable of sustaining the travel of the vehicle or vehicles, should be relatively direct, and should be easy to follow. In a typical move, the navigator determines his location, determines the location of his objective, notes the position of both on his map, and then selects a route between the two. After examining the terrain, he adjusts the route by the following actions:

a**. Consider Tactical Aspects.** Avoid skylining, select key terrain for overwatch positions, and select concealed routes.

b. **Consider Ease of Movement.** Use the easiest possible route and bypass difficult terrain. Remember that a difficult route is harder to follow, is noisier, causes more wear and tear (and possible recovery problems), and takes more time. Tactical surprise is achieved by doing the unexpected. Try to select an axis or corridor instead of a specific route. Make sure you have enough maneuver room for the vehicles (Figure 12-2).

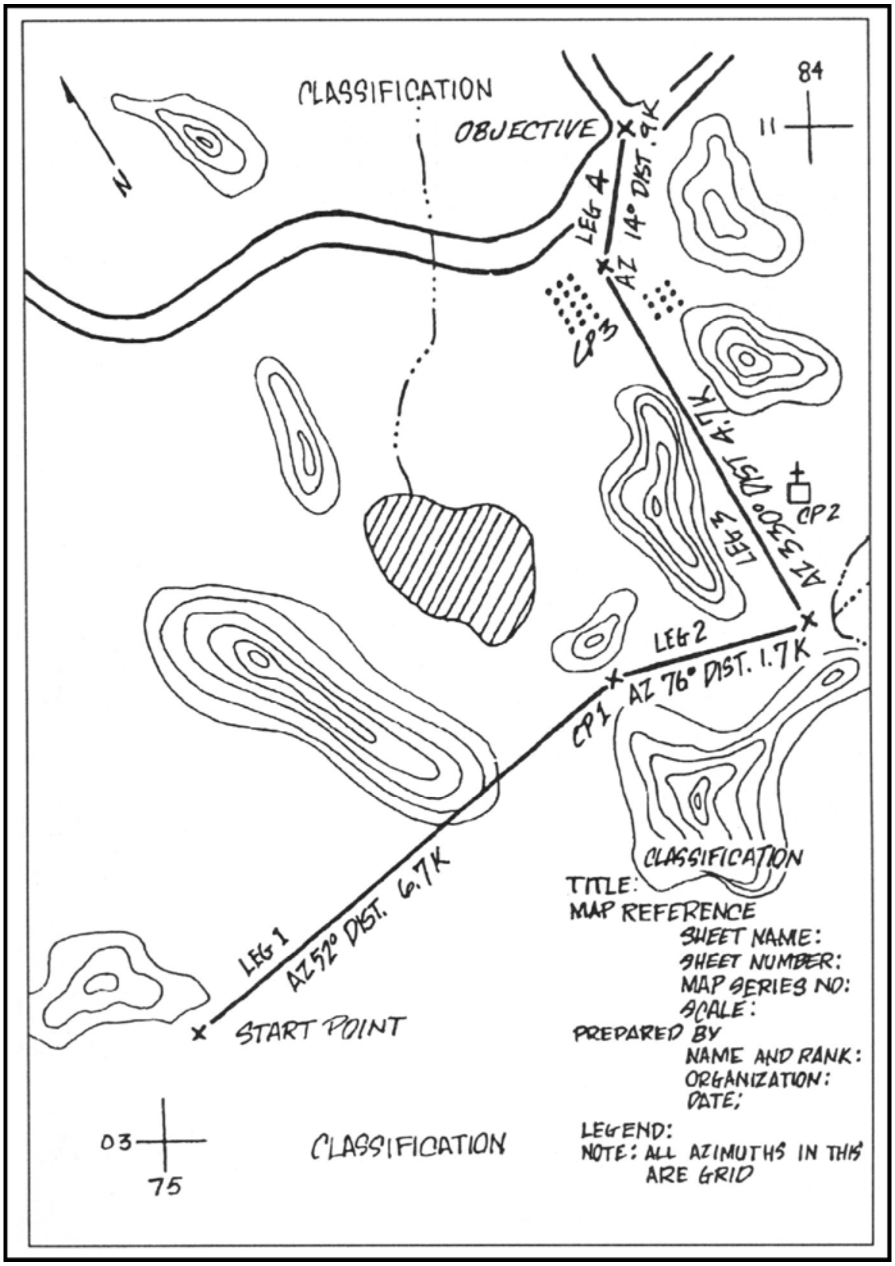
CLASSIFICATION
N
OBJECTIVE
84
11
LEG 4
AZ 14° DIST .9K
CP3
LEG 3
AZ 330° DIST 4.1K
CP2
LEG 2
AZ 76° DIST. 1.7K
CP1
LEG 1
AZ 52° DIST. 6.7K
START POINT
CLASSIFICATION
TITLE:
MAP REFERENCE
SHEET NAME:
SHEET NUMBER:
MAP SERIES NO:
SCALE:
PREPARED BY
NAME AND RANK:
ORGANIZATION:
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03
75
CLASSIFICATION
LEGEND:
NOTE: ALL AZIMUTHS IN THIS ARE GRID

Figure 12-2. Primary route.

c. **Use Terrain Features as Checkpoints.** These checkpoints must be easily recognizable in the light and weather conditions and at the speed at which you will move. You should be able to find a terrain feature from your location that can be recognized from almost anywhere and used as a guide. An example is checkpoint 2, the church, and checkpoint 3, the orchard, in Figure 12-2.

(1) The best checkpoints are linear features that cross your route. Use streams, rivers, hard-top roads, ridges, valleys, and railroads.

(2) The next best checkpoints are elevation changes, such as hills, depressions, spurs, and draws. Look for two contour lines of change. You will not be able to spot less than two lines of change while mounted.

(3) In wooded terrain, try to locate checkpoints at no more than 1,000-meter intervals. In open terrain, you may go to about 5,000 meters.

d. **Follow Terrain Features.** Movement and navigation along a valley floor or near (not necessarily on) the crest of a ridgeline is easiest.

e. **Determine Directions.** Break the route down into smaller segments and determine the rough directions that will be followed. You do not need to use the compass; just use the main points of direction (north, northeast, east, and so forth). Before moving, note the location of the sun and locate north. Locate changes of direction, if any, at the checkpoints picked.

f. **Determine Distance.** Get the total distance to be traveled and the approximate distance between checkpoints. Plan to use the vehicle odometer to keep track of distance traveled. Use the pace-count method and keep a record of the distance traveled. When using a pace count, convert from map distance to ground distance by adding the conversion factors of 20 percent for cross-country movement.

g. **Make Notes.** Mental notes are usually adequate. Try to imagine what the route is like and remember it.

h. **Plan to Avoid Errors**. Restudy the route selected. Try to determine where errors are most apt to occur and how to avoid any trouble.

i. **Use a Logbook.** When the routes have been selected and the navigator has divided the distance to be traveled into legs, prepare a logbook. The logbook is an informal record of the distance and azimuth of each leg, with notes to aid the navigator in following the correct route. The notes list easily identifiable terrain features at or near the point where the direction of movement changes (Figure 12-3, page 12-6).

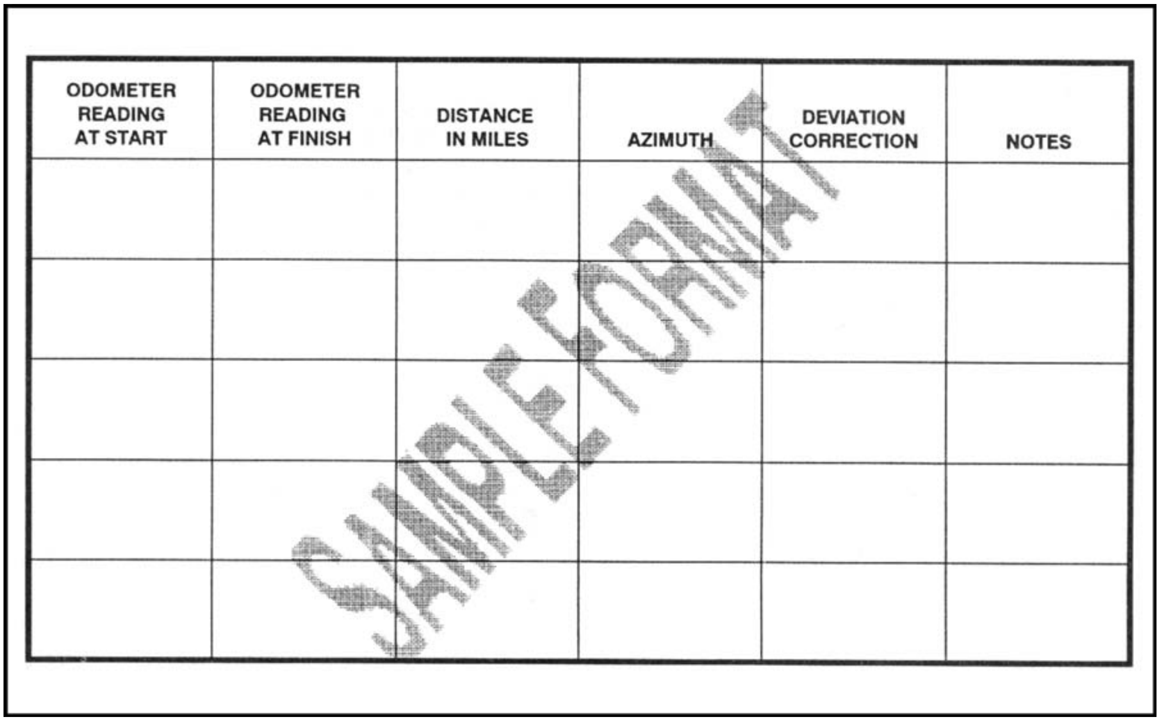
SAMPLE FORMAT

ODOMETER READING AT START	ODOMETER READING AT FINISH	DISTANCE IN MILES	AZIMUTH	DEVIATION CORRECTION	NOTES

Figure 12-3. Sample of a logbook format.

12-5. DEAD RECKONING NAVIGATION

Dead reckoning is moving a set distance along a set line. Generally, it involves moving so many meters along a set line, usually an azimuth in degrees. There is no accurate method of determining a direction in a moving vehicle. A magnetic vehicle-heading reference unit may be available in a few years; for now, use a compass.

a. **With Steering Marks.** This procedure is the same for vehicle travel as on foot.

(1) The navigator dismounts from the vehicle and moves away from the vehicle (at least 18 meters).

(2) He sets the azimuth on the compass and picks a steering mark (rock, tree, hilltop) in the direction on that azimuth (Figure 12-4).

(3) He remounts and has the driver identify the steering mark and proceeds to it in as straight a line as possible.

(4) On arrival at the steering mark or on any changes in direction, he repeats the first three steps above for the next leg of travel.

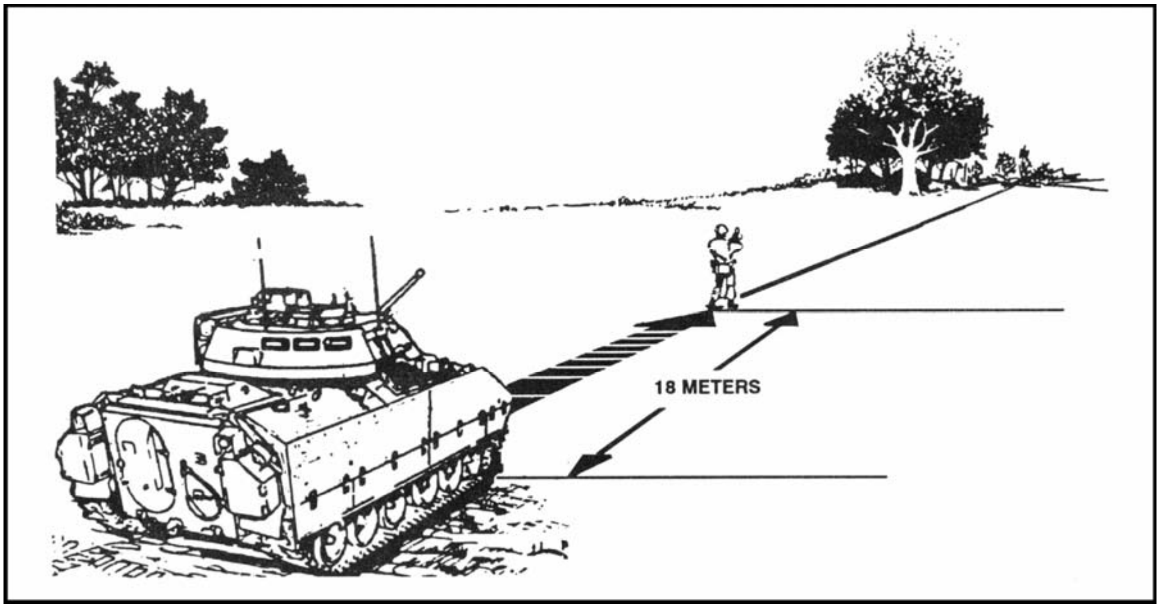

Figure 12-4. Determining an azimuth, dismounted.

b. **Without Steering Marks.** This procedure is used only on flat, featureless terrain.

(1) The navigator dismounts from the vehicle, which is oriented in the direction of travel, and moves at least 18 meters to the front of the vehicle.

(2) He faces the vehicle and reads the azimuth to the vehicle. By adding or subtracting 180º, he determines the forward azimuth (direction of travel).

(3) On order from the navigator, the driver drives on a straight line to the navigator.

(4) The navigator remounts the vehicle, holds the compass as it will be held while the vehicle is moving, and reads the azimuth in the direction of travel.

(5) The compass will swing off the azimuth determined and pick up a constant deviation. For instance, say the azimuth was 75º while you were away from the vehicle. When you remounted and your driver drove straight forward, your compass showed 67º. You have a deviation of -8º. All you need to do is maintain that 67º compass heading to travel on a 75º magnetic heading.

(6) At night, the same technique can be used. From the map, determine the azimuth you are to travel. Convert the grid azimuth to a magnetic azimuth. Line the vehicle up on that azimuth, then move well in front of it. Be sure it is aligned correctly. Then mount, have the driver move slowly forward, and note the deviation. If the vehicle has a turret, the above procedure works unless you traverse the turret; this changes the deviation.

(7) The distance factor in dead reckoning is easy. Just determine the map distance to travel and add 20 percent to convert to ground distance. Use your vehicle odometer to be sure you travel the proper distance.

12-6. STABILIZED TURRET ALIGNMENT NAVIGATION

Another method, if you have a vehicle with a stabilized turret, is to align the turret on the azimuth you wish to travel, then switch the turret stabilization system on. The gun tube remains pointed at your destination no matter which way you turn the vehicle. This technique has been proven; it works. It is not harmful to the stabilization system. It is subject to stabilization drift, so use it for no more than 5,000 meters before resetting.

NOTE: If you have to take the turret off-line to engage a target, you will have to start all over, re-do the entire process.

12-7. COMBINATION NAVIGATION

Some mounted situations may call for you to combine and use both methods. Just remember the characteristics of each.

a. Terrain association is fast, is error-tolerant, and is best under most circumstances. It can be used day or night if you are proficient in it.

b. Dead reckoning is very accurate if you do everything correctly. You must be very precise. It is also slow, but it works on very flat terrain.

c. You frequently will combine both. You may use dead reckoning to travel across a large, flat area to a ridge, then use terrain association for the rest of the move.

d. You must be able to use both methods. You should remember that your probable errors, in order of frequency, will be—

- Failure to determine distance(s) to be traveled.
- Failure to travel the proper distance.
- Failure to properly plot or locate the objective.
- Failure to select easily recognized checkpoints or landmarks.
- Failure to consider the ease of movement factor.

CHAPTER 13
NAVIGATION IN DIFFERENT TYPES OF TERRAIN

The information, concepts, and skills already presented will help you to navigate anywhere in the world; however, there are some special considerations and helpful hints that may assist you in various special environments. The following information is not doctrine.

13-1. DESERT TERRAIN

About 5 percent of the earth's land surface is covered by deserts (Figure 13-1). Deserts are large arid areas with little or no rainfall during the year. There are three types of deserts—mountain, rocky plateau, and sandy or dune deserts. All types of forces can be deployed in the desert. Armor and mechanized infantry forces are especially suitable to desert combat except in rough mountainous terrain where light infantry may be required. Airborne, air assault, and motorized forces can also be advantageously employed to exploit the vast distances characteristic of desert warfare.

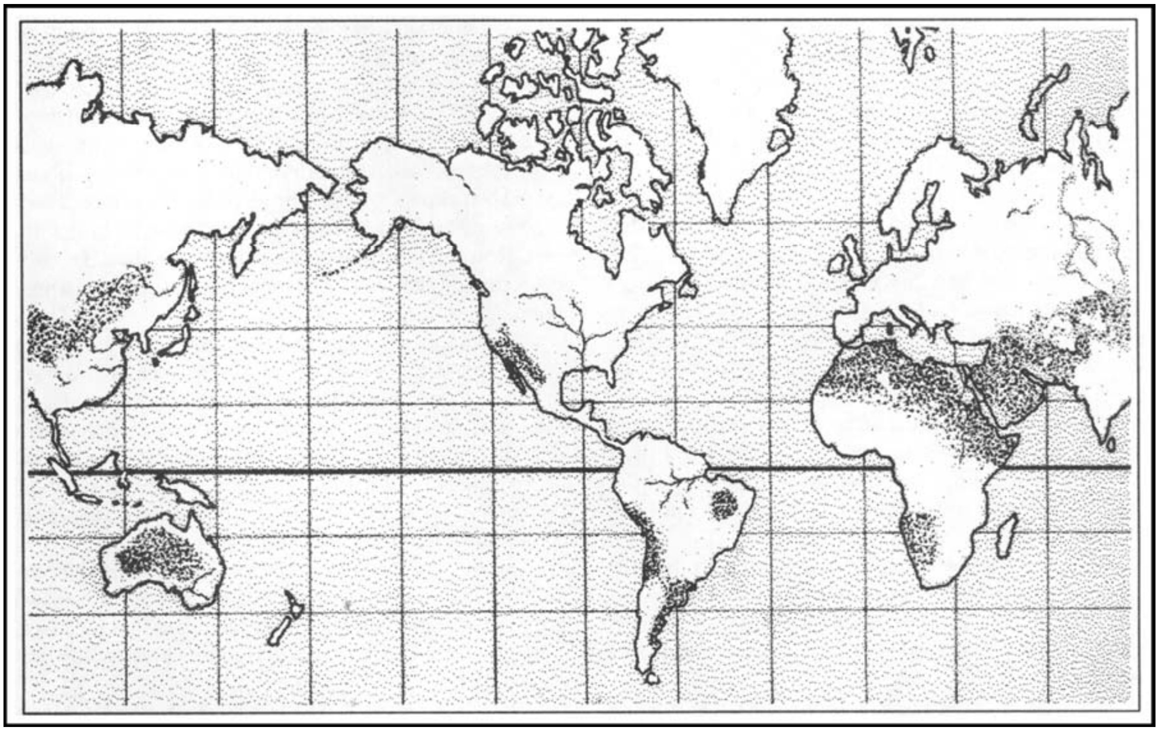

Figure 13-1. Deserts.

a. **Desert Regions.** In desert regions, terrain varies from nearly flat to lava beds and salt marshes. Mountain deserts contain scattered ranges or areas of barren hills or mountains. Table 13-1, on page 13-2, lists some of the world's major desert regions and their locations.

REGION	LOCATION
Sahara	North Africa
Kalahari	Southwest Africa
Arabian	Southwest Asia
Gobi	Mongolia and Northern China
Rub'al Khali	South Arabia
Great Basin, Colorado, Chihuahua, Yuma Sonoran, and Mohave	Northern Mexico and Western United States
Takla Makan	Northern China
Kyzyl Kum	Southwest USSR
Kara Kum	Southwest USSR
Syrian	Saudi Arabia, Jordan, and Iraq
Great Victoria	Western and South Australia
Great Sandy	Northwestern Australia
Patagonia	Southern Argentina and Chile
Atacama	Northern Chile

Table 13-1. Major desert regions.

(1) Finding the way in a desert presents some degree of difficulty for a person who has never been exposed to this environment. Desert navigators have learned their way through generations of experience.

(2) Normally, desert people are nomadic, constantly moving in caravans. Navigating becomes second nature to them. Temperature in the tropical deserts reaches an average of 110° to 115° during the day, so most navigation takes place at night using the stars. Most deserts have some prevailing winds during the seasons. Such winds arrange the sand dunes in a specific pattern that gives the navigator the opportunity to determine the four cardinal directions. He may also use the sun's shadow-tip method.

(3) A sense of direction can be obtained by watching desert animals on their way to and from water holes (oases). Water, navigation, and survival are closely related in desert areas. Most deserts have pigeons or doves, and their drinking habits are important to the navigator. As a rule, these birds never drink in the morning or during the day, making their evening flights the most important. When returning from the oases, their bodies are heavier from drinking and their flight is accompanied by a louder flapping of their wings.

(4) Visibility is also an important factor in the desert, especially in judging distance. The absence of trees or other features prevents comparison between the horizon and the skyline.

b. **Interpretation and Analysis.** Many desert maps are inaccurate, which makes up-to-date air, aerial photo, and ground reconnaissance necessary. In desert mountain areas contour intervals are generally large, so many of the intermediate relief features are not shown.

(1) The desert normally permits observation and fire to maximum ranges. The terrain is generally wide open and the exceptionally clear atmosphere offers excellent long-range

visibility. Combine this with a powerful sun and low cloud density and you have nearly unlimited light and visual clarity, which often contribute to gross underestimations of ranges. Errors of up to 200 or 300 percent are not uncommon. However, visibility conditions may be severely affected by sandstorms and mirages (heat shimmer caused by air rising from the extremely hot daytime desert surface), especially if the observer is looking into the sun through magnifying optical instruments.

(2) Cover can be provided only by terrain feature masking because of the lack of heavy vegetation and man-made objects. It only takes a few meters of relief to provide cover. Concealment in the desert is related to the following factors:

(a) *Shape*. In order not to be observed by the enemy, attempt to alter the standard shapes of vehicles so they and their shadows are not instantly recognized.

(b) *Shine*. Shine or glitter is often the first thing that attracts the observer's eye to movement many kilometers away. It must be eliminated.

(c) *Color and texture*. All equipment should either be pattern painted or mudded to blend in with the terrain.

(d) *Light and noise*. Light and noise discipline are essential because sound and light travel great distances in the desert.

(e) *Heat*. Modern heat image technology makes shielding heat sources an important consideration when trying to hide from the enemy. This technology is especially important during night stops.

(f) *Movement*. Movement itself creates a great deal of noise and dust, but a rapid execution using all the advantages the topography offers can help conceal it.

c. *Navigation*. When operating in the broad basins between mountain ranges or on rocky plateau deserts, there are frequently many terrain features to guide your movement by. But, observing these known features over great distances may provide a false sense of security in determining your precise location unless you frequently confirm your location by resection or referencing close-in terrain features. It is not uncommon to develop errors of several kilometers when casually estimating a position in this manner. Obviously, this can create many problems when attempting to locate a small checkpoint or objective, calling for CAS, reporting operational or intelligence information, or meeting CSS requirements.

(1) When operating in an area with few visual cues, such as in a sandy or dune desert, or restricted visibility by a sandstorm or darkness, you must proceed by dead reckoning. The four steps and two techniques for navigation presented earlier remain valid in the desert. However, understanding the special conditions found there are extremely helpful as you apply them.

(2) Tactical mobility and speed are key to successful desert operations. Obstacles and areas such as lava beds or salt marshes, which preclude surface movements, do exist. But most deserts permit two-dimensional movement by ground forces similar to that of a naval task force at sea. Speed of execution is essential. Everyone moves farther and faster on the desert. Special navigation aids sometimes used in the desert include:

(a) *Sun compass*. It can be used on moving vehicles and sextants. It requires accurate timekeeping. However, the deviation on a magnetic compass that is caused by the metal and electronics in the vehicle is usually less than +10°.

(b) *Gyro compass*. The gun azimuth stabilizer is in fact a gyro compass. If used on fairly flat ground, it is useful for maintaining direction over limited distances.

(c) *Fires*. Planned tracer fire or mortar and artillery concentrations (preferably smoke during the day and illumination at night) provide useful checks on estimated locations.

(d) *Prepositioned lights*. This method consists of placing two or more searchlights far apart, behind the line of contact, beyond enemy artillery range, and concealed from enemy ground observation. Units in the area can determine their own locations through resection, using the vertical beams of the lights. These lights must be moved on a time schedule known to all friendly units.

(3) One final note on desert navigation is that the sand, hard-baked ground, rocky surfaces, thorny vegetation, and heat generally found in the desert impose far greater demands for maintenance than you would plan for in temperate regions. It may also take longer to perform that maintenance.

13-2. MOUNTAIN TERRAIN

Mountains are generally understood to be larger than hills. Rarely do mountains occur individually; in most cases, they are found in elongated ranges or circular groups. When they are linked together, they constitute a mountain system (Figure 13-2). Light forces (infantry, airborne, and air assault forces) can operate effectively in mountainous regions because they are not terrain limited. Heavy forces must operate in passes and valleys that are negotiable by vehicle.

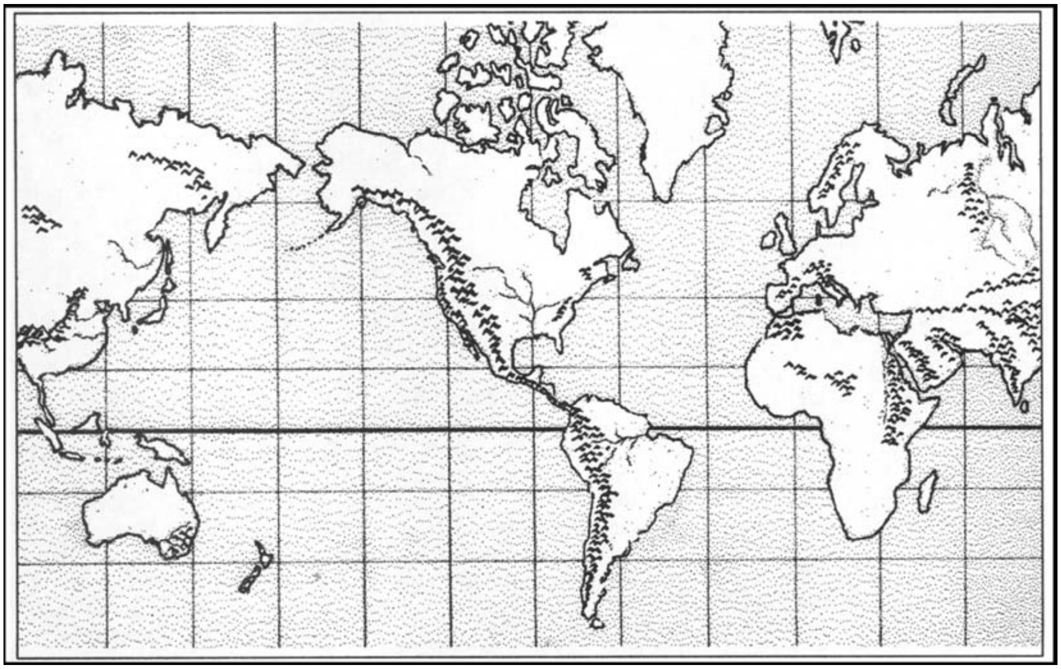

Figure 13-2. Mountain systems.

a. **Major Systems**. Major systems are listed in Table 13-2.

SYSTEM	LOCATION
The Andes	Central and South America
The Rockies	North America (USA-Canada)
The Appalachians	North America (USA-Canada)
The Alps	Central Europe
The Himalayas	Asia
The Caucasus	Western Asia and Europe (Russia)

Table 13-2. Major systems.

b. **Minor Systems.** Some other systems are in Antarctica, Hawaii, Japan, New Zealand, and Oceania. Mountain systems are characterized by high, inaccessible peaks and steep slopes. Depending on the altitude, they may be snow covered. Prominent ridges and large valleys are also found. Navigating in this type of terrain is not difficult providing you make a careful examination of the map and the terrain.

c. **Climate.** Because of the elevations, it is always colder (3° to 5° per 300-meter gain in altitude) and wetter than you might expect. Wind speeds can increase the effects of the cold even more. Sudden severe storms and fog are encountered regularly. Below the tree line, vegetation is heavy because of the extra rainfall and the fact that the land is rarely cleared for farming.

d. **Interpretation and Analysis.** The heights of mountainous terrain permit excellent long-range observation. However, rapidly fluctuating weather with frequent periods of high winds, rain, snow, or fog may limit visibility. Also, the rugged nature of the terrain frequently produces significant dead space at mid-ranges.

(1) Reduced mobility, compartmented terrain, and the effects of rapidly changing weather increase the importance of air, ground, aerial photo, and map reconnaissance. Since mountain maps often use large contour intevals, microrelief interpretation and detailed terrain analysis require special emphasis.

(2) At first glance, some mountainous terrain may not appear to offer adequate cover and concealment; however, you can improve the situation. When moving, use rock outcroppings, boulders, and heavy vegetation for cover and concealment; use terrain features to mask maneuvers. Use harsh weather, which often obscures observation, to enhance concealment.

(3) Since there are only a few routing options, all-round security must be of primary concern. Natural obstacles are everywhere, and the enemy can easily construct more.

e. **Navigation.** Existing roads and trails offer the best routes for movement. Off-road movement may enhance security provided there is detailed reconnaissance, photo intelligence, or information from local inhabitants to ensure the route is negotiable. Again, the four steps and two techniques for navigation presented earlier remain valid in the mountains. Nevertheless, understanding the special conditions and the terrain will help you navigate. Other techniques that are sometimes helpful in mountains are:

(1) ***Aspect of Slope***. To determine the aspect of slope, take a compass reading along an imaginary line that runs straight down the slope. It should cut through each of the contour lines at about a 90° angle. By checking the map and knowing the direction of slope where you are located, you will be able to keep track of your location, and it will help guide your cross-country movement even when visibility is poor.

(2) ***Use of an Altimeter***. Employment of an altimeter with calibrations on the scale down to 10 or 20 meters is helpful to land navigators moving in areas where radical changes in elevation exist. An altimeter is a type of barometer that gauges air pressure, except it measures on an adjustable scale marked in feet or meters of elevation rather than in inches or centimeters of mercury. Careful use of the altimeter helps to pinpoint your position on a map through a unique type of resection. Instead of finding your position by using two different directional values, you use one directional value and one elevation value.

13-3. JUNGLE TERRAIN

These large geographic regions are found within the tropics near the equator (Central America, along the Amazon River, South-Eastern Asia and adjacent islands, and vast areas in the middle of Africa and India) (Figure 13-3). Jungles are characterized as rainy, humid areas with heavy layers of tangled, impenetrable vegetation. Jungles contain many species of wildlife (tigers, monkeys, parrots, snakes, alligators, and so forth). The jungle is also a paradise for insects, which are the worst enemy of the navigator because some insects carry diseases (malaria, yellow fever, cholera, and so forth). While navigating in these areas, very little terrain association can be accomplished because of the heavy foliage. Dead reckoning is one of the methods used in these areas. A lost navigator in the jungle can eventually find his way back to civilization by following any body of water with a downstream flow. However, not every civilization found is of a friendly nature.

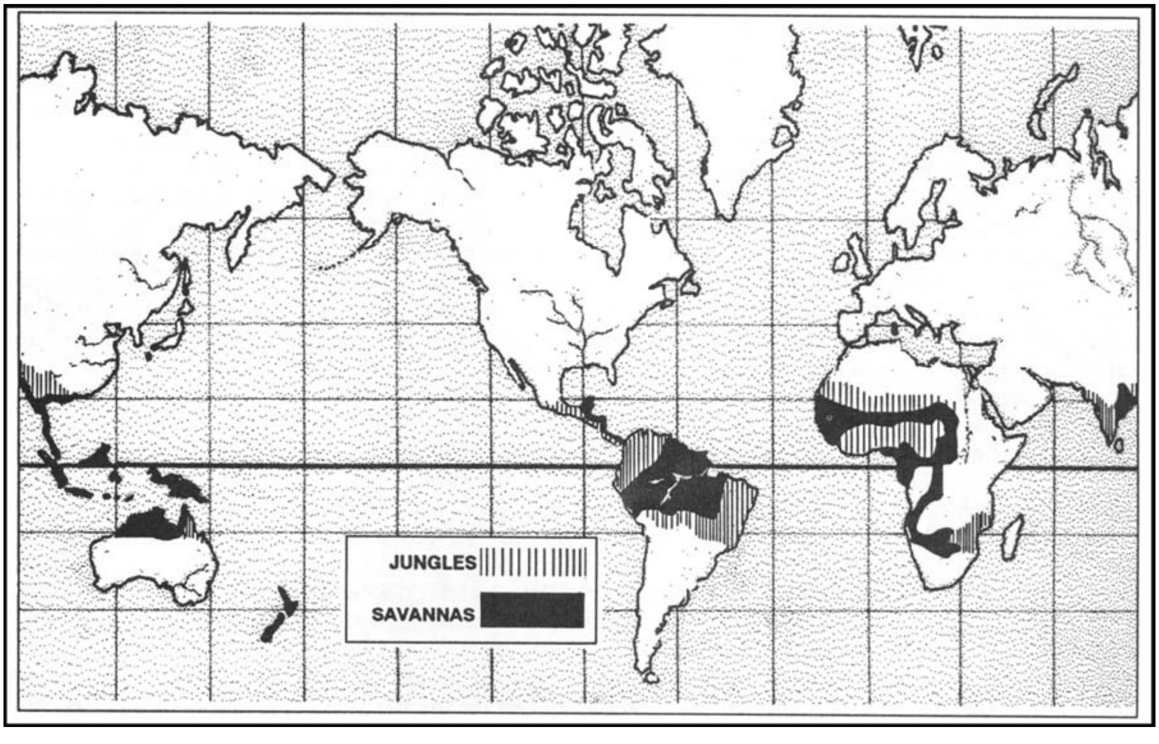

Figure 13-3. Jungles and savannas.

a. **Operations.** Operations in jungles tend to be isolated actions by small forces because of the difficulties encountered in moving and in maintaining contact between units. Divisions can move cross-country slowly; but, aggressive reconnaissance, meticulous intelligence collection, and detailed coordination are required to concentrate forces in this way. More commonly, large forces operate along roads or natural avenues of movement, as was the case in the mountains. Patrolling and other surveillance operations are especially important to ensure security of larger forces in the close terrain of jungles.

(1) Short fields of observation and fire, and thick vegetation make maintaining contact with the enemy difficult. The same factors reduce the effectiveness of indirect fire and make jungle combat primarily a fight between infantry forces. Support by air and mechanized forces can be decisive at times, but it will not always be available or effective.

(2) Jungles are characterized by high temperatures, heavy rains, high humidity, and an abundance of vegetation. The climate varies with location. Close to the equator, all seasons are nearly alike with heavy rains all year. Farther from the equator (India and Southeast Asia), there are distinct wet (monsoon) and dry seasons. Both zones have high temperatures (averaging 75 to 95+ degrees Fahrenheit), heavy rainfall (as much as 400+ inches annually, and high humidity (90 percent) all year.

(3) In temperate climates, it is the areas of vegetation that are most likely to be altered and incorrectly portrayed on a map. In jungle areas, the vegetation grows so rapidly that it is more likely to be cleared and make these areas be shown incorrectly.

b. **Interpretation and Analysis.** The jungle environment includes dense forests, grasslands, swamps, and cultivated areas. Forests are classified as primary and secondary based upon the terrain and vegetation. Primary forests include tropical rain forests and deciduous forests. Secondary forests are found at the edges of both rain forests and deciduous forests and in areas where jungles have been cleared and abandoned. These places are typically overgrown with weeds, grasses, thorns, ferns, canes, and shrubs. Movement is especially slow and difficult. The extremely thick vegetation reaches a height of 2 meters and severely limits observation to only a few meters.

(1) Tropical rain forests consist mostly of large trees whose branches spread and lock together to form canopies. These canopies, which can exist at two and three different levels, may form as low as 10 meters from the ground. They prevent direct sunlight from reaching the ground, causing a lack of undergrowth on the jungle floor. Extensive above-ground root systems and hanging vines are common and make vehicular travel difficult; foot movement is easier. Ground observation is limited to about 50 meters and air observation is nearly impossible.

(2) Deciduous forests are in semitropical zones that have both wet and dry seasons. In the wet season, trees are fully leaved; in the dry season, much of the folliage dies. Trees are usually less dense than in rain forests, which allows more sunlight to filter to the ground. This procedure produces thick undergrowth. During the wet season, air and ground observation is limited and movement is difficult. During the dry season, both improve.

(3) Swamps are common to all low, jungle areas where there is poor drainage. When navigating in a swampy area, a careful analysis of map and ground should be taken before any movement. The soldiers should travel in small numbers with only the equipment required for their mission, keeping in mind that they are going to be immersed in water part of the time. The usual technique used in swamp navigation is dead reckoning. There are two basic types of swamps—mangrove and palm. Mangrove swamps are found in coastal areas wherever tides influence water flow. Mangrove is a shrub-like tree that grows 1 to 5 meters high. These trees have a tangled root system, both above and below the waterline, which

restricts movement either by foot or small boat. Observation on the ground and from the air is poor, but concealment is excellent.

(4) Grassy plains or savannas are generally located away from the equator but within the tropics. These vast land areas are characterized by flatlands with a different type of vegetation than jungles. They consist mainly of grasses (ranging from 1 to more than 12 feet in height), shrubs, and isolated trees. The most difficult areas to navigate are the ones surrounded by tall grass (elephant grass); however, vehicles can negotiate here better than in some areas. There are few or no natural features to navigate by, making dead reckoning or navigation by stars the only technique for movement (Figure 13-3). Depending on the height of the grass, ground observation may vary from poor to good. Concealment from air observation is poor for both soldiers and vehicles.

(5) Bamboo stands are common throughout the tropics. They should be bypassed whenever possible. They are formidable obstacles for vehicles, and soldier movement through them is slow, exhausting, and noisy.

(6) Cultivated areas exist in jungles also. They range from large, well-planned, well-managed farms and plantations to small tracts, cultivated by farmers. The three general types of cultivated areas are rice paddies, plantations, and small farms.

c. **Navigation.** Areas such as jungles are generally not accurately mapped because heavy vegetation makes aerial surveys difficult. The ability to observe terrain features, near or far, is extremely limited. The navigator must rely heavily upon his compass and the dead reckoning technique when moving in the jungle. Navigation is further complicated by the inability to make straight-line movements. Terrain analysis, constant use of the compass, and an accurate pace count are essential to navigation in this environment.

(1) Rates of movement and pace counts are particularly important to jungle navigators. The most common error is to overestimate the distance traveled. The distances below can be used as a rough guide for the maximum distances that might be traveled in various types of terrain during one hour in daylight.

Type of Terrain	Maximum Distance (In Meters)
Tropical rain forest	up to 1,000
Deciduous forest	500
Secondary jungle	100 to 500
Tall grass	500
Swamps	100 to 300
Rice paddies (wet)	800
Rice paddies (dry)	2,000
Plantations	2,000
Trails	up to 3,000

Table 13-3. Guide for maximum distance.

(2) Special navigation strategies that are helpful in jungles include:

(a) Personal pace table. You should either make a mental or written personal pace table that includes your average pace count per 100 meters for each of the types of terrain through which you are likely to navigate.

(b) Resection using indirect fire. Call for mortar or artillery fire (airbursts of white phosphorous or illumination) on two widely separated grids that are not on terrain features like the one you are occupying and are a safe distance from your estimated location. Directions to the airbursts sometimes must be determined by sound.

(c) Modified area/point navigation. Even when making primary use of the compass for dead reckoning, you are frequently able to area navigate to an expanded objective, which is easily identified by terrain association. Then, simply develop a short, point-navigation leg to your final destination.

13-4. ARCTIC TERRAIN

Arctic terrain includes those areas that experience extended periods of below freezing temperatures. In these areas, the ground is generally covered with ice or snow during the winter season. Although frozen ground and ice can improve trafficability, a deep accumulation of snow can reduce it. Vehicles and personnel require special equipment and care under these adverse conditions.

a. **Operations.** Both the terrain and the type and size of unit operations vary greatly in arctic areas. In open terrain, armored and mechanized forces will be effective although they will have to plan and train for the special conditions. In broken terrain, forests, and mountains, light forces will predominate as usual. However, foot movement can take up to five times as long as it might under warmer conditions.

b. **Interpretation and Analysis.** Both the terrain and cultural features you may confront in winter may vary to any extreme, as can the weather. The common factor is an extended period of below-freezing temperatures. The terrain may be plains, plateaus, hills, or mountains. The climate will be cold, but the weather will vary greatly from place to place. Most arctic terrain experiences snow, but some claim impressive accumulations each season, such as the lake-effected snow belts off Lake Ontario near Fort Drum, New York. Other areas have many cold days with sunshine and clear nights, and little snow accumulation.

(1) In areas with distinct local relief and scattered trees or forests, the absence of foliage makes movement by terrain association easier; observation and fields of fire are greatly enhanced except during snowstorms. But in relatively flat, open areas covered with snow (especially in bright sunlight), the resulting lack of contrast may interfere with your being able to read the land. With foliage gone, concealment (both from the ground and from the air) is greatly reduced. As in desert areas, you must make better use of the terrain to conceal your movements.

(2) Frozen streams and swamps may no longer be obstacles, and thus identification of avenues of approach may be difficult in winter. However, the concept as to what is key terrain is not likely to be affected.

c. **Navigation.** Special skills may be required in arctic terrain, such as the proper use of winter clothing, skis, and snowshoes; but this does not affect your navigation strategies. There are no special techniques for navigating in arctic terrain. Just be aware of the advantages and disadvantages that may present themselves and make the most of your opportunities while applying the four steps and two techniques for land navigation.

(1) Remember, the highest caliber of leadership is required to ensure that all necessary tasks are performed, that security is maintained, and that soldiers and their equipment are protected from the physical effects of very low temperatures. There is a great temptation to do less than a thorough job at whatever the task may be when you are very cold.

(2) Night navigation may be particularly enhanced when operating in arctic terrain. Moonlight and starlight on a clear night reflect off the snow, thus enabling you to employ daytime terrain association techniques with little difficulty. Even cloudy winter nights are often brighter than clear moonlit summer nights when the ground is dark and covered with foliage. Movements with complete light discipline (no black-out drives) can often be executed. On the other hand, areas with severe winter climates experience lengthy periods of darkness each day, which may be accompanied by driving snow and limited visibility.

13-5. URBAN AREAS

The world continues to become more urbanized each year; therefore, it is unlikely that all fighting will be done in rural settings. Major urban areas represent the power and wealth of a particular country in the form of industrial bases, transportation complexes, economic institutions, and political and cultural centers. Therefore, it may be necessary to secure and neutralize them. When navigating in urban places, it is man-made features, such as roads, railroads, bridges, and buildings that become important, while terrain and vegetation become less useful.

a. **Interpretation and Analysis.** Military operations on urbanized terrain require detailed planning that provides for decentralized execution. As a result of the rapid growth and changes occurring in many urban areas, the military topographic map is likely to be outdated. Supplemental use of commercially produced city maps may be helpful, or an up-to-date sketch can be made.

(1) Urbanized terrain normally offers many AAs for mounted maneuver well forward of and leading to urban centers. In the proximity of these built-up areas, however, such approach routes generally become choked by urban sprawl and perhaps by the nature of adjacent natural terrain. Dismounted forces then make the most of available cover by moving through buildings and underground systems, along edges of streets, and over rooftops. Urban areas tend to separate and isolate units, requiring the small-unit leader to take the initiative and demonstrate his skill in order to prevail.

(2) The urban condition of an area creates many obstacles, and the destruction of many buildings and bridges as combat power is applied during a battle further limits your freedom of movement. Cover and concealment are plentiful, but observation and fields of fire are greatly restricted.

b. **Navigation.** Navigation in urban areas can be confusing, but there are often many cues that will present themselves as you proceed. They include streets and street signs; building styles and sizes; the urban geography of industrial, warehousing, residential housing, and market districts; man-made transportation features other than streets and roads (rail and trolley lines); and the terrain features and hydrographic features located within the built-up area. Strategies for staying on the route in an urban area include:

(1) ***Process Route Descriptions***. Write down or memorize the route through an urban area as a step-by-step process. For example, "Go three blocks north, turn left (west) on a wide divided boulevard until you go over a river bridge. Turn right (north) along the west bank of the river, and. . . "

(2) ***Conceptual Understandings of the Urban Area***. While studying the map and operating in a built-up area, work hard to develop an understanding (mental map) of the entire area. This advantage will allow you to navigate over multiple routes to any location.

It will also preclude your getting lost whenever you miss a turn or are forced off the planned route by obstacles or the tactical situation.

(3) ***Resection***. Whenever you have a vantage point to two or more known features portrayed on the map, do not hesitate to use either estimated or plotted resection to pinpoint your position. These opportunities are often plentiful in an urban setting.

CHAPTER 14

UNIT SUSTAINMENT

Land navigation is a skill that is highly perishable. The soldier must continually make use of the skills he has acquired to remain proficient in them. The institution is responsible for instruction in the basic techniques of land navigation. The institution tests these skills each time a soldier attends a leadership course. However, it is the unit's responsibility to develop a program to maintain proficiency in these skills between institution courses. The unit sustainment program provides training that builds on and reinforces the skills the soldier learned in the institution. It should use the building-block approach to training: basic map reading instruction or review, instruction on land navigation skills, dead reckoning training, dead reckoning practice, terrain association training, terrain association practice, land navigation testing, and building of leader skills. These leader skills should include following a route selected by the commander and planning and following a route selected by the leader. The unit trainer should be able to set up a sustainment program, a train-the-trainer program, and a land navigation course for his unit's use. It is recommended that units develop a program similar to the one outlined in this chapter. Complete lesson outlines and training plans are available by writing to Commander, 29th Infantry Regiment, ATTN: ATSH-INB-A, Fort Benning, GA 31905-5595.

14-1. SET UP A SUSTAINMENT PROGRAM

The purpose of setting up a sustainment program in the unit is to provide soldiers with training that reinforces and builds on the training that they have received in the institution. All soldiers should receive this training at least twice a year. The program also provides the unit with a means of identifying the areas in which the soldiers need additional training.

a. **Training Guidance**. The unit commander must first determine the levels of proficiency and problems that his unit has in land navigation. This determination can be done through after-action reports from the unit's rotations to NTC/JRTC, ARTEP final reports, feedback from his subordinates, personal observation, and annual training. Once the unit commander decides where his training time should be concentrated, he can issue his training guidance to his subordinate leaders. He also directs his staff to provide training sites, resources, and time for the units to train land navigation. It is recommended that land navigation be trained separately, not just included as a subtask in tactical training.

b. **Certification**. The unit commander must also provide his subordinate commanders with a means of certifying training. The unit staff must provide subject matter experts to ensure the training meets the standards decided upon by the unit commander. Instructors should be certified to instruct, and courses should be certified before the unit uses it.

c. **Program Development**. The sustainment program should meet the requirements of all of the unit's soldiers. It should address all skills from basic map reading to leaders' planning and executing a route. The program should cover the following:

- Diagnostic examination.
- Map reading instruction/review.

- Land navigation skills training.
- Dead reckoning training/practice.
- Terrain association training/practice.
- Land navigation written/field examination.
- Leaders' training and testing.

The sustainment program should be developed and then maintained in the unit's training files. The program should be developed in training modules so that it can be used as a whole program or used separately by individual modules. It should be designed so the commander can decide which training modules he will use, depending on the proficiency of the unit. The unit commander need only use those modules that fit his training plan.

14-2. SET UP A TRAIN-THE-TRAINER PROGRAM

The purpose of a train the trainer program in the unit is to develop trainers capable of providing soldiers with the confidence and skills necessary to accomplish all assigned land navigation tasks.

a. **Development of the Program**. The unit commander should appoint a cadre of officers and NCOs to act as primary and alternate instructors for land navigation training. Use the training modules the unit has developed and have these soldiers go through each module of training until they can demonstrate expertise. Determine which instructors conduct each module of training and have them practice until they are fully prepared to give the training. These instructors act as training cadre for the entire unit. They train their peers to instruct the subordinate units, and they certify each unit's training.

b. **Conduct of Training**. Conduct training at the lowest level possible. Leaders must be included in all training to keep unit integrity intact.

14-3. SET UP A LAND NAVIGATION COURSE

The unit commander provides specific guidance on what he requires in the development of a land navigation course. It depends upon the unit's mission, training plan, and tasks to be trained. There are basic guidelines to use when setting up a course.

a. **Determine the Standards**. The unit commander determines the standards for the course. Recommended standards are as follows:

(1) Distance between points: no less than 300 meters; no more than 1,200 meters.

(2) Total distance of lanes: no less than 2,700 meters; no more than 11,000 meters.

(3) Total number of position stakes: no less than seven for each lane; no more than nine for each lane.

(4) Time allowed: no less than three hours; no more than four hours.

b. **Decide on the Terrain.** The unit should use terrain that is similar to terrain they will be using in tactical exercises. Terrain should be different each time training is conducted; the training area for a dismounted course needs to be at least 25 square kilometers. Mounted courses require twice as much terrain so that vehicles are not too close to each other.

c. **Perform a Map and Ground Reconnaissance**. Check the terrain to determine position stake locations, look for hazards, and to develop training briefings.

(1) Plot the locations of your position stakes on a 1:50,000-scale map.

(2) Fabricate or order position stakes.

(3) Request support from the local engineer or field artillery unit to survey the position stakes in.
(4) Survey the position stakes in and emplace them.
(5) Certify the course by having your SMEs negotiate each lane of the course.
(6) Prepare course requirement sheets and print them.
(7) Complete a risk assessment of the training area.
(8) Begin teaching.

This sequence can be used to develop any type of land navigation course. The difference in each course depends on the commander's guidance.

APPENDIX A
FIELD SKETCHING

A sketch is a free-hand drawing of a map or picture of an area or route of travel. It shows enough detail and has enough accuracy to satisfy special tactical or administrative requirements.

A-1. PURPOSE

Sketches are useful when maps are not available or the existing maps are not adequate, or to illustrate a reconnaissance or patrol report. Sketches may vary from hasty to complete and detailed, depending upon their purpose and the degree of accuracy required. For example, a sketch of a large minefield will require more accuracy than a hasty sketch of a small unit's defensive position.

A-2. MILITARY SKETCHES

The scale of a sketch is determined by the object in view and the amount of detail required to be shown. The sketch of a defensive position for a platoon or company normally calls for a sketch of larger scale than a sketch for the same purpose for a division. Military sketches also include road and area sketches.

a. **Field Sketches**. A field sketch (Figure A-1) must show the north arrow, scale, legend, and the following features:

- Power lines.
- Rivers.
- Main roads.
- Towns and villages.
- Forests.
- Rail lines.
- Major terrain features.

b. **Road Sketches**. These sketches show the natural and military features on and in the immediate vicinity of the road. In general, the width of terrain sketches will not exceed 365 meters on each side of the road. Road sketches may be used to illustrate a road when the existing map does not show sufficient detail.

c. **Area Sketches**. These sketches include those of positions, OPs, or particular places.

(1) ***Position Sketch***. A position sketch is one of a military position, campsite, or other area of ground. To effectively complete a position sketch, the sketcher must have access to all parts of the area being sketched.

(2) ***Observation Post Sketch***. An OP sketch shows the military features of ground along a friendly OP line as far toward the enemy position as possible.

(3) ***Place Sketch***. A place sketch is one of an area made by a sketcher from a single point of observation. Such a sketch may cover ground in front of an OP line, or it may serve to extend a position or road sketch toward the enemy.

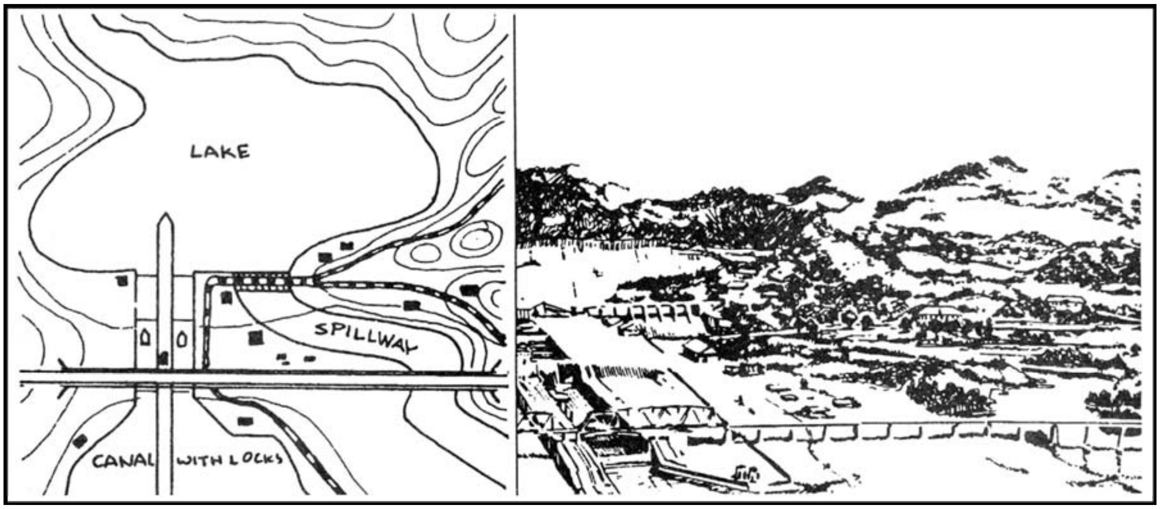
LAKE
SPILLWAY
CANAL WITH LOCKS

Figure A-1. Sketch map.

APPENDIX B
MAP FOLDING TECHNIQUES

One of the first considerations in the care of maps is its proper folding.

B-1. FOLDING METHODS

Figures B-1 and B-2 show ways of folding maps to make them small enough to be carried easily and still be available for use without having to unfold them entirely.

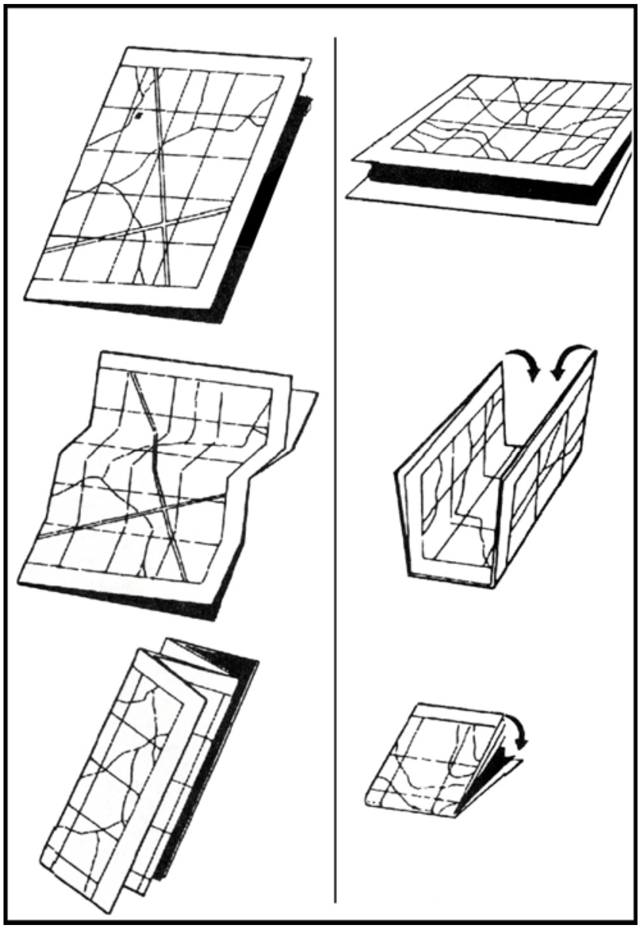

Figure B-1. Two methods of folding a map.

B-2. PROTECTION METHOD

After a map has been folded, it should be pasted in a folder for protection. Apply adhesive to the back of the segments corresponding to A, F, L, and Q (Figure B-2, page B-2).

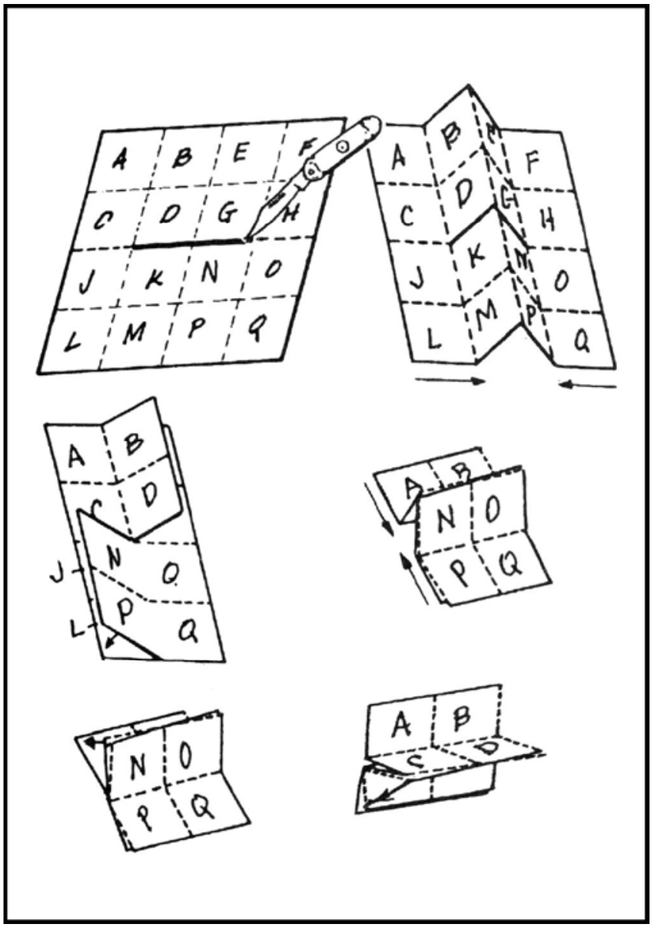
A B E F
C D G H
J K N O
L M P Q
A B F
C D G H
J K N O
L M P Q
A B
C D
J N O
L P Q
A B
N O
P Q
N O
P Q
A B
C D

Figure B-2. How to slit and fold a map for special use.

B-3. PRACTICE CUT

It is suggested that before attempting to cut and fold a map in the manner illustrated in Figure B-2, make a practice cut and fold with a piece of paper.

APPENDIX C
UNITS OF MEASURE AND CONVERSION FACTORS

This appendix provides conversion tables for units of measure and conversion factors that are used in military operations.

12 inches	=	1 foot
36 inches	=	1 yard
3 feet	=	1 yard
1,760 yards	=	1 mile statute
2,026.8 yards	=	1 mile nautical
5,280 feet	=	1 mile statute
6,080.4 feet	=	1 mile nautical
63,360 inches	=	1 mile statute
72,963 inches	=	1 mile nautical

Table C-1. English system of linear measure.

1 millimeter	=	0.1 centimeter	=	0.0393 inches
10 millimeters	=	1.0 centimeter	=	0.3937 inches
10 centimeters	=	1.0 decimeter	=	3.937 inches
10 decimeters	=	1.0 meter	=	39.37 inches
10 meters	=	1.0 decameter	=	32.81 feet
10 decameters	=	1.0 hectometer	=	328.1 feet
10 hectometers	=	1.0 kilometer	=	0.62 mile
10 kilometers	=	1.0 myriameter	=	6.21 miles

Table C-2. Metric system of linear measure.

1 mil	=	1/6400 circle	=	0.05625°	=	0.0625 grad
1 grad	=	1/400 circle	=	16.0 mils	=	0°54' = 0.9°
1 degree	=	1/360 circle	=	about 17.8 mils	=	about 1.1 grad

Table C-3. Equivalent units of angular measure.

ONE	INCHES	FEET	YARDS	STATUTE MILES	NAUTICLE MILES	mm
Inch	1	0.0833	0.0277	-	-	25.40
Foot	12	1	0.333	-	-	304.8
Yard	36	3	1	0.00056	-	914.4
Statute Mile	63,360	5,280	1,760	1	0.8684	-
Nautical Mile	72,963	6,080	2,026	1.1516	1	-
Millimeter	0.0394	0.0033	0.0011	-	-	1
Centimeter	0.3937	0.0328	0.0109	-	-	10
Decimeter	3.937	0.328	0.1093	-	-	100
Meter	39.37	3.2808	1.0936	0.0006	0.0005	1,000
Decameter	393.7	32.81	10.94	0.0062	0.0054	10,000
Hectometer	3,937	328.1	109.4	0.0621	0.0539	100,000
Kilometer	39,370	3,281	1,094	0.6214	0.5396	1,000,000
Myriameter	393,700	32,808	10,936	6.2137	5.3959	10,000,000

ONE	cm	dm	M	dkm	hm	km	mym
Inch	2.540	0.2540	0.0254	0.0025	0.0003	-	-
Foot	30.48	3.048	0.3048	0.0305	0.0030	0.0003	-
Yard	91.44	9.144	0.9144	0.0914	0.0091	0.0009	-
Statute Mile	160,930	16,093	1,609	160.9	16.09	1.6093	0.1609
Nautical Mile	185,325	18,532	1,853	185.3	18.53	1.8532	0.1853
Millimeter	0.1	0.01	0.001	0.0001	-	-	-
Centimeter	1	0.1	0.01	0.001	0.0001	-	-
Decimeter	10	1	0.1	0.01	0.001	0.0001	-
Meter	100	1	1	0.1	0.01	0.001	0.0001
Decameter	1,000	10	10	1	0.1	0.01	0.001
Hectometer	10,000	100	100	10	1	0.1	0.01
Kilometer	100,000	1,000	1,000	100	10	1	0.1
Myriameter	1,000,000	10,000	10,000	1000	100	10	1

Table C-4. Conversion factors.

Example I

Problem: Reduce 76 centimeters to (?) inches.
76 cm x 0.3937 = 29 inches

Answer: There are 29 inches in 76 centimeters.

Example II

Problem: How many feet are there in 2.74 meters?

$$\frac{2.74}{.3048} = 9 \text{ feet}$$

Answer: There are approximately 9 feet in 2.74 meters.

SCALE	1 INCH EQUALS	1 CENTIMETER EQUALS
1:5,000	416.67 feet 127.00 meters	164.00 feet 50.00 meters
1:10,000	833.33 feet 254.00 meters	328.10 feet 100.00 meters
1:12,500	1,041.66 feet 317.00 meters	410.10 feet 125.00 meters
1:20,000	1,666.70 feet 508.00 meters	656.20 feet 200.00 meters
1:25,000	2,083.30 feet 635.00 meters	820.20 feet 250.00 meters
1:50,000	4,166.70 feet 1,270.00 meters	1,640.40 feet 500.00 meters
1:63,360	5,280.00 feet 1,609.30 meters	2,078.70 feet 633.60 meters
1:100,000	8,333.30 feet 2,540.00 meters	3,280.80 feet 1,000.00 meters
1:250,000	20,833.00 feet 6,350.00 meters	8,202.00 feet 2,500.00 meters
1:500,000	41,667.00 feet 12,700.00 meters	16,404.00 feet 5,000.00 meters

Table C-5. Ground distance at map scale.

APPENDIX D
JOINT OPERATIONS GRAPHICS

Joint operations graphics (paragraph 2-6b[4]) are based on the format of the standard 1:250,000-scale military topographic maps. They contain additional information needed in present-day joint air-ground operations.

D-1. TYPES

Each JOG is prepared in two types; one is designed for air operations and the other for ground operations. Each version is identified in the lower margin as JOINT OPERATIONS GRAPHIC (AIR) or JOINT OPERATIONS GRAPHIC (GROUND).

D-2. BASIC CONTENTS

The basic topographic information is the same on both JOG versions.

a. Power transmission lines are symbolized as a series of purple pylons connected by a solid purple line.

b. Airports, landing facilities, and related air information are shown in purple. The purple symbols that may be unfamiliar to the user are shown in the legend in the margin.

c. The top of each obstruction to air navigation is identified by its elevation above sea level and its elevation above ground level.

d. Along the north and east edges of the graphic, detail is extended beyond the standard sheet lines to create an overlap with the graphics to the north and to the east.

e. Layer tinting (paragraph 10-2a) and relief shading (paragraph 10-2c) are added as an aid to interpreting the relief.

f. The incidence of the graphic in the world geographic reference system (paragraph 4-8b) is shown by a diagram in the margin.

D-3. JOINT OPERATIONS GRAPHIC (AIR)

The JOG (AIR) series, prepared for air use, contains detailed information on air facilities such as radio ranges, runway lengths, and landing surfaces. The highest terrain elevation in each 15-minute quadrangle is identified by the large open-faced figures shown in the legend. Elevations and contours on JOG (AIR) sheets are given in feet.

D-4. JOINT OPERATIONS GRAPHIC (GROUND)

The JOG (GROUND) series is prepared for use by ground units, and only stable or permanent air facilities are identified. Elevations and contours are located in the same positions as on the air version, but are given in meters.

APPENDIX E

EXPORTABLE TRAINING MATERIAL

This appendix provides information on the exportable training material available for unit training in basic land navigation skills. These materials are available from the Army Research Institute, Fort Benning Field Unit, Fort Benning, Georgia 3l905.

E-1. PLANNING TO NAVIGATE

This training material describes the planning process in detail. Planning may be the most important aspect of land navigation. Planning to navigate includes background information for map interpretation, a practical example in planning to navigate, and a description of how to train these skills.

E-2. HOW TO TRAIN BASIC LAND NAVIGATION SKILLS

This training material offers guidance for unit training in basic land navigation skills. It includes training modules for distance and location skills. Each module is self-contained, so training can be given in each skill separately from other skills.

E-3. DISMOUNTED LAND NAVIGATION TECHNIQUE

This training material describes the process of navigating with an emphasis on movement skills and the techniques and strategies that should be used while navigating. Critical training covers how to put skills together for movement and how to decide which technique to use in a certain situation.

E-4. MAP INTERPRETATION TERRAIN ASSOCIATION COURSE

The MITAC program is designed to teach terrain association through a "building block" approach starting with simple elements first, then adding more complex information as the soldier progresses from one level to another. The MITAC consists of three systematic courses of instruction: basic, intermediate, and advanced.

E-5. ROUTE PLANNING GUIDE

The route planning guide provides the small-unit leader with a comprehensive reference document, which he can use in learning to plan dismounted administrative or tactical moves. It offers him a planning procedure that he can use in the field without any notes to plan successful moves over unfamiliar terrain.

E-6. LAND NAVIGATION SUSTAINMENT PROGRAM

The land navigation sustainment program is designed to develop trainers that are capable of providing soldiers with the confidence and skills necessary to accomplish all assigned land navigation tasks and therefore to develop soldiers capable of accomplishing these tasks.

APPENDIX F
ORIENTEERING

What is orienteering? Orienteering is a competitive form of land navigation. It is for all ages and degrees of fitness and skill. It provides the suspense and excitement of a treasure hunt. The object of orienteering is to locate control points by using a map and compass to navigate through the woods. The courses may be as long as 10 km.

F-1. HISTORY

Orienteering began in Scandinavia in the nineteenth century. It was primarily a military event and was part of military training. It was not until 1919 that the modern version of orienteering was born in Sweden as a competitive sport. Ernst Killander, its creator, can be rightfully called the father of orienteering. In the early thirties, the sport received a technical boost with the invention of a new compass, more precise and faster to use. The Kjellstrom brothers, Bjorn and Alvan, and their friend, Brunnar Tillander, were responsible for this new compass. They were among the best Swedish orienteers of the thirties, with several individual championships among them. Orienteering was brought into the US in 1946 by Bjorn Kjellstrom.

F-2. DESCRIPTION

Each orienteer is given a 1:50,000 topographic map with the various control points circled. Each point has a flag marker and a distinctive punch that is used to mark the scorecard. Competitive orienteering involves running from checkpoint to checkpoint. It is more demanding than road running, not only because of the terrain, but because the orienteer must constantly concentrate, make decisions, and keep track of the distance covered. Orienteering challenges both the mind and the body; however, the competitor's ability to think under pressure and make wise decisions is more important than speed or endurance.

F-3. THE COURSE

The orienteering area should be on terrain that is heavily wooded, preferably uninhabited, and difficult enough to suit different levels of competition. The area must be accessible to competitors and its use must be coordinated with appropriate terrain and range control offices.

a. The ideal map for an orienteering course is a multi-colored, accurate, large-scale topographic map. A topographic map is a graphic representation of selected man made and natural features of a part of the earth's surface plotted to a definite scale. The distinguishing characteristic of a topographic map is the portrayal of the shape and elevation of the terrain by contour lines.

b. For orienteering within the United States, large-scale topographic (topo) maps are available from the Defense Mapping Agency Hydrographic Topographic Center. The scale suitable for orienteering is 1:50,000 (DMA).

F-4. SETTING UP THE COURSE

The challenge for the course setter is to keep the course interesting, but never beyond the individual's or group's ability. General guidance is to select locations that are easily identifiable on the map and terrain, and accessible from several routes.

a. Those who set up the initial event should study a map for likely locations of control points and verification of the locations. Better yet, they should coordinate with an experienced competitor in selecting the course.

b. There are several forms of orienteering events. Some of the most common are route, line, cross-country, and score orienteering.

(1) ***Route Orienteering***. This form can be used during the training phase and in advanced orienteering. In this type of event, a master or advanced competitor leads the group as they walk a route. The beginners trace the actual route walked on the ground on their maps. They circle the location of the different control points found along the walked route. When they finish, the maps are analyzed and compared. During training, time is not a factor. Another variation is when a course is laid out on the ground with markers for the competitor to follow. There is no master map, as the course is traced for the competitor by flags or markers. The winner of the event is the competitor who has successfully traced the route and accurately plotted the most control points on his map.

(2) ***Line Orienteering***. At least five control points are used during this form of orienteering training. The competitor traces on his map a preselected route from a master map. The object is to walk the route shown on the map, circling the control points on the map as they are located on the ground (Figure F-1).

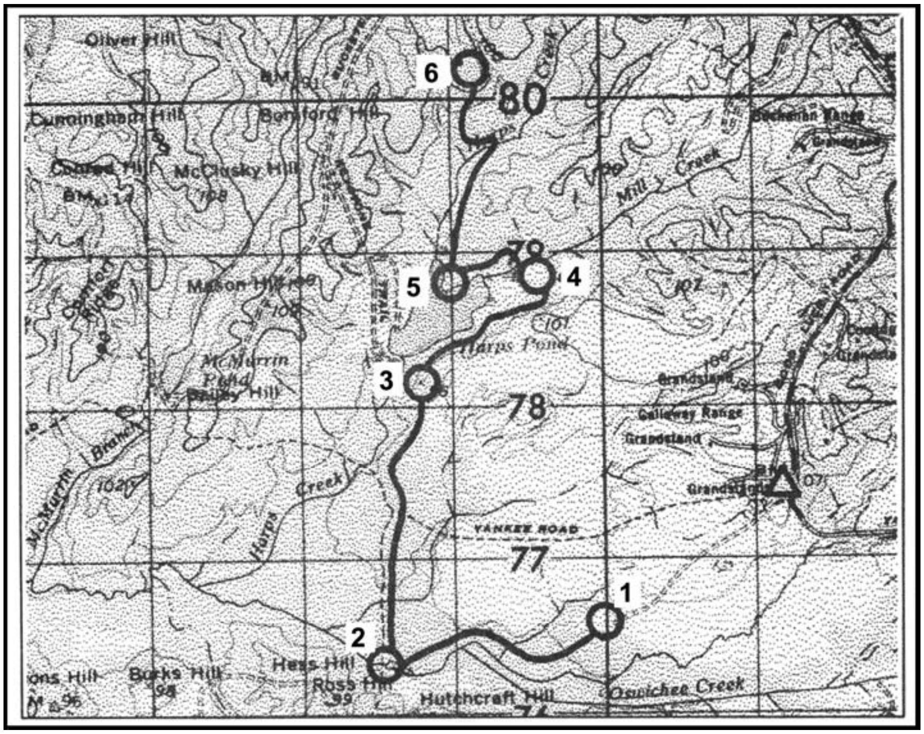
Oliver Hill
6
80
Cunningham Hill
Bonford Hill
McClusky Hill
Mill Creek
5
4
Mason Hill
McMurrin Pond
Bailey Hill
Harps Pond
3
78
Grandstand
Calloway Range
McMurrin Branch
Harps Creek
YANKEE ROAD
77
1
2
Burks Hill
Hess Hill
Ross Hill
Hutchcraft Hill
Ossuchee Creek

Figure F-1. Line orienteering.

(3) ***Cross-Country Orienteering***. This is the most common type of orienteering competitions. It is sometimes called free or point orienteering and is considered to be the most competitive and intriguing of all events (Figure F-2). In this event, all competitors must visit the same controls in the same order. With the normal one-minute starting interval, it becomes a contest of route choice and physical skill. The winner is the contestant with the fastest time around the course.

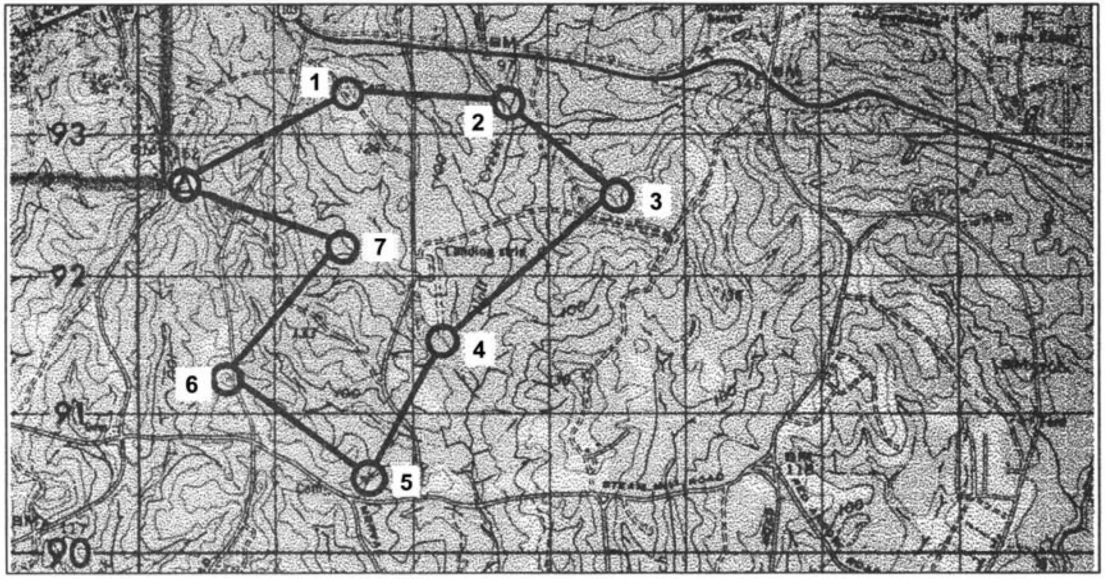

Control Number	Coordinates	Control Code	Description of Clues
1	GL01589334	WE	Cemetery, nothern part
2	GL02709323	WT	Creek junction-center
3	GL03509260	DA	Draw, center
4	GL02229155	WK	South end of runway
5	GL01709046	CM	East end of pond
6	GL00659125	RD	Hilltop 134-top
7	GL01509218	JD	Spur-150 southeast of hilltop

Figure F-2. A cross-country orienteering map.

(a) After selecting the control points for the course, determine the start and finish locations. The last control should be near the finish. In describing each control's location, an eight-digit grid coordinate and a combination of two letters identifying the point (control code) should be included in each descriptive clue list that is normally given to each competitor at least two minutes before his start time.

(b) There are usually 6 to 12 control markers on the course in varying degrees of difficulty and distances apart so that there are no easy, direct routes. Instead, each competitor is faced with many choices of direct but difficult routes, or of indirect but easier routes. Each control's location is circled, and the order in which each is to be visited is clearly marked on the master map. The course may be a closed transverse with start and finish collocated, or the start and finish may be at different locations. The length of the course and difficulty of control placement varies with the competitors' degree of expertise. Regardless of the class of event, all competitors must indicate on their event cards proof of visiting the control markers. Inked stamps, coded letters, or punches are usually used to do this procedure.

NOTE: The same orienteering range may serve in both cross-country and score events. However, a separate set of competitor maps, master maps, and event cards are necessary.

(4) *Score orienteering*. In this event, the area chosen for the competition is blanketed with many control points (Figure F-3). The controls near the start/finish point (usually identical in this event) have a low point value, while those more distant or more difficult to locate have a high point value. (See Figure F-6 for a sample card.) This event requires the competitor to locate as many control markers as he can within the specified time (usually 90 minutes). Points are awarded for each control visited and deducted for exceeding the specified time. The competitor with the highest point score is the winner.

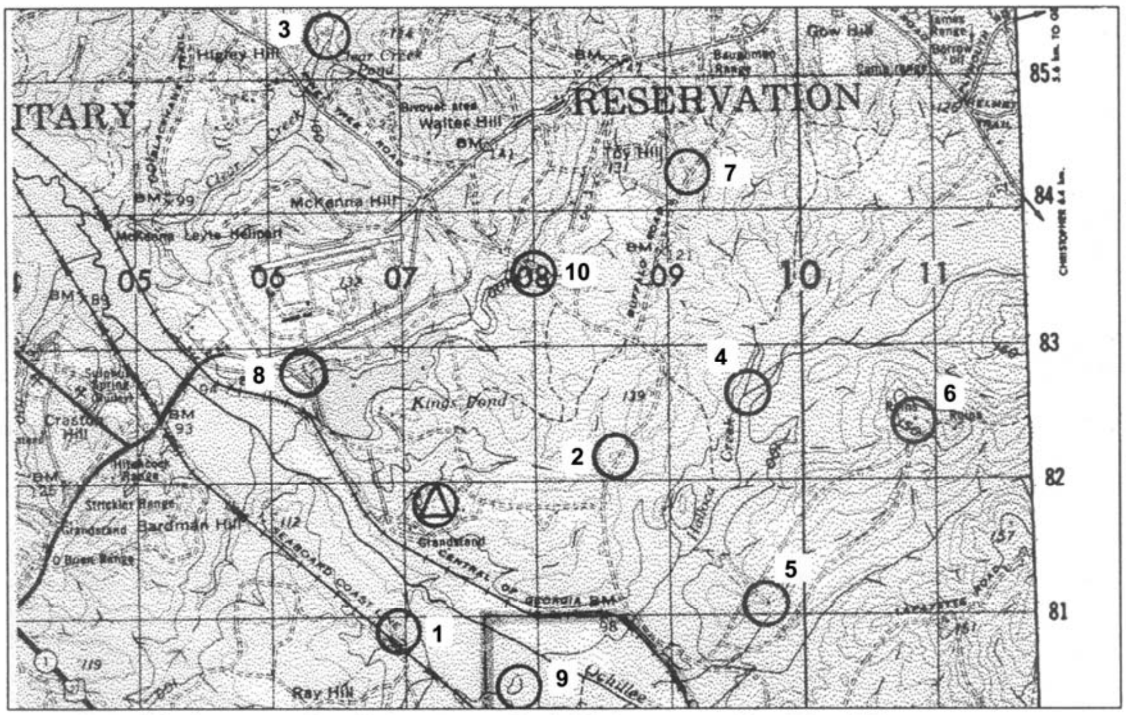

Control Number	Coordinates	Control Code	Description of Clues
1	GL06938085	TK	Railroad bridge-north
2	GL08608218	RZ	Top of hill
3	GL06508535	CD	North of pond-swamp
4	GL09608265	PR	Center-creek junction
5	GL09858109	AC	Building-dead end
6	GL10968245	SM	Ruins
7	GL09208430	WN	Road junction-north
8	GL06338275	YV	Building-west end of pond
9	GL07858050	NT	Top of hill
10	GL08158350	YM	East end of lake

Figure F-3. A score orienteering map.

(a) Conducting a score event at the start is basically the same as the cross-country event. The competitor is given a map and an event card. The event card lists all the controls with their different point values. When released to the master map, the competitor finds the circles and numbers indicating the location of all the controls listed on his event card. He copies all the red circles on his map. Then he chooses any route he wishes to take in amassing the highest possible point score in the time available. The course is designed to ensure that there are more control points than can possibly be visited in the allotted time. Again, each control marker visited must be indicated on the event card.

(b) It is important for the competitor to take time initially to plot the most productive route. A good competitor may spend up to 6 minutes in the master map area while plotting the ideal route.

(c) There is no reward for returning early with time still available to find more points, so the good competitor must be able to coordinate time and distance with his ability in land navigation in running the course.

F-5. OFFICIALS

The same officials can be used at the start and finish. More officials or assistants can be used; the following material lists the minimum that can be used for a competition. They include the following:

a. **At The Start.**

(1) ***Course Organizer*****—**Briefs the orienteers in the assembly area, issues event cards and maps, and calls orienteers forward to start individually.

(2) ***Recorder*****—**Records orienteer's name and start time on recorder's sheet, checks orienteer's name and start number on his event card, and issues any last-minute instructions.

(3) ***Timer*****—**Controls the master clock and releases the orienteers across the start line at their start time (usually at one-minute intervals) to the master map area.

b. **At The Finish.**

(1) ***Timer***—Records finish time of each orienteer on the orienteer's event card and passes card to recorder.

(2) ***Recorder*****—**Records finish time of each orienteer on the orienteer's event card and passes card to recorder.

(3) ***Course Organizer***—Verifies correctness of names, finish times, and final score; posts orienteers' positions on results board; and accounts for all orienteers at the end of event.

F-6. START/FINISH AREA

The layout of the start/finish areas for orienteering events is basically the same for all forms.

a. **Assembly Area.** This is where orienteers register and receive instructions, maps, event cards, and start numbers. They may also change into their orienteering clothes if facilities are available, study their maps, and fill out their event cards here. Sanitation facilities should be available in this area.

b. **Start.** At the start, the orienteer reports to the recorder and timer's table to be logged in by the recorder and released by the timer.

c. **Master Map Area.** There are three to five master maps 20 to 50 meters from the start. When the orienteer arrives at this area, he must mark his map with all the course's control points. Having done this, he must decide on the route that he is to follow. The good orienteer takes the time to orient his map and carefully plot his route before rushing off. It is a good idea to locate the master map area out of sight of the start point to preclude orienteers tracking one another.

d. **Equipment.** The following is a list of equipment needed by the host of an orienteering event:

- Master maps, three to five, mounted.
- Competitor maps, one each.
- Event cards, one each.
- Recorder's sheets, two.
- Descriptive clue cards, one each.
- Time clocks, two.
- Rope, 100 to 150 feet, with pegs for finish tunnel.
- Card tables, one or two.
- Folding chairs, two or three.
- Results board.
- Control markers, one per point.
- Extra compasses.
- Whistle, for starting.
- First aid kit.
- Colored tape or ribbon for marking route to master map and from last control point to finish.

e. **Control Markers.** These are orange-and-white markers designating each control point (Figure F-4). Ideally, they should have three vertical square faces, forming a triangle with the top and bottom edges. Each face should be 12 inches on a side and divided diagonally into red and white halves or cylinders (of similar size) with a large, white, diagonal stripe dividing the red cylinder. For economy or expediency, 1-gallon milk cartons, 5-gallon ice cream tubs, 1-gallon plastic bleach bottles, or foot-square plaques, painted in the diagonal or divided red and white colors of orienteering, may be used.

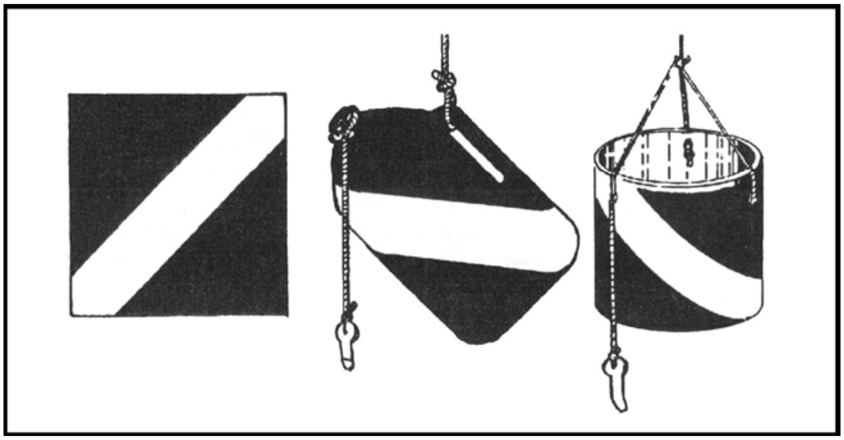

Figure F-4. Control markers.

(1) Each marker should have a marking or identification device for the orienteer to use to indicate his visit to the control. This marker may be the European-style punch pliers, a self-inking marker, different colored crayons at each point, different letter combinations, different number combinations, or different stamps or coupons. The marking device must be unique, simple, and readily transcribable to the orienteers' event cards.

(2) The control marker should normally be visible from at least 10 meters. It should not be hidden.

f. **Recorder's Sheets.** A suggested format for the recorder's sheet is depicted in Figure F-5.

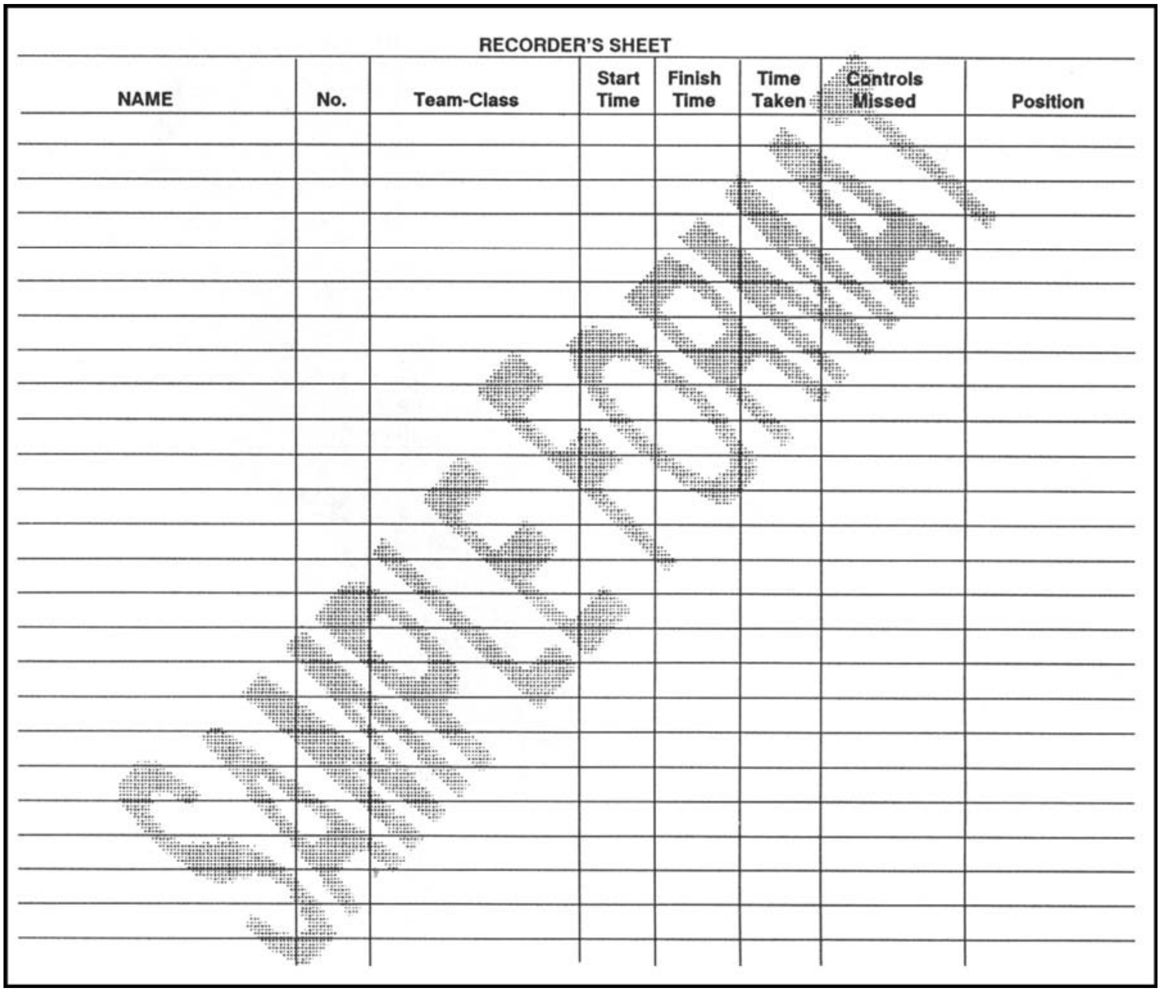

RECORDER'S SHEET

NAME	No.	Team-Class	Start Time	Finish Time	Time Taken	Controls Missed	Position

SAMPLE FORMAT

Figure F-5. Recorder's sheet.

g. **Event Card.** The event card can be made before the event and should be as small as possible, as it is carried by the competitor. It must contain the following items: name, start number, start time, finish time, total time, place, and enough blocks for marking the control points. As indicated earlier, it may also contain a listing of descriptive clues (Figure F-6).

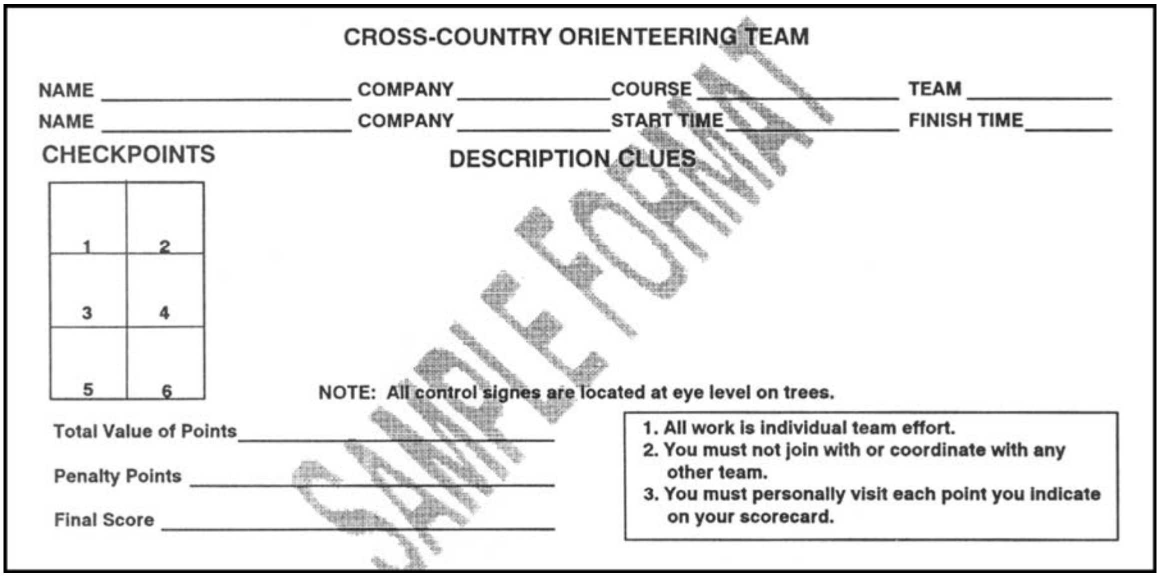

CROSS-COUNTRY ORIENTEERING TEAM

NAME ______________________ COMPANY _____________ COURSE __________________ TEAM _____________
NAME ______________________ COMPANY _____________ START TIME ________________ FINISH TIME ________

CHECKPOINTS

DESCRIPTION CLUES

1	2
3	4
5	6

NOTE: All control signes are located at eye level on trees.

Total Value of Points ______________________
Penalty Points ______________________
Final Score ______________________

1. All work is individual team effort.
2. You must not join with or coordinate with any other team.
3. You must personally visit each point you indicate on your scorecard.

SAMPLE FORMAT

Figure F-6. Cross-country orienteering event card.

h. **Results Board.** This board displays the orienteer's position in the event at the finish (Figure F-7). There are a variety of ways of displaying the results, from blackboard to ladder-like to a clothesline-type device where each orienteer's name, point score, and times are listed.

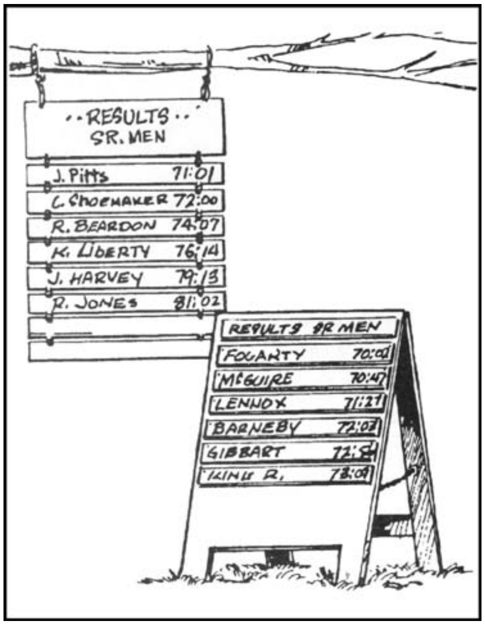
• • RESULTS • •
SR. MEN
J. Pitts 71:01
C. Shoemaker 72:00
R. BEARDON 74:07
K. LIBERTY 76:14
J. HARVEY 79:13
R. JONES 81:02
RESULTS SR MEN
FOGARTY 70:00
McGUIRE 70:47
LENNOX 71:21
BARNEBY 72:02
GIBBART 72:54
KLINK R. 73:04

Figure F-7. Results board.

i. **Clue Description Card.** These cards are prepared with the master maps after the course is set. They contain the descriptive clues for each control point, control code, grid coordinate references, returning time for competitors, removal times for each location, and panic azimuth (Figure F-8). The terminology on these must be identical to that listed in the definition section. These cards and the master maps must be kept confidential until the orienteers start the event.

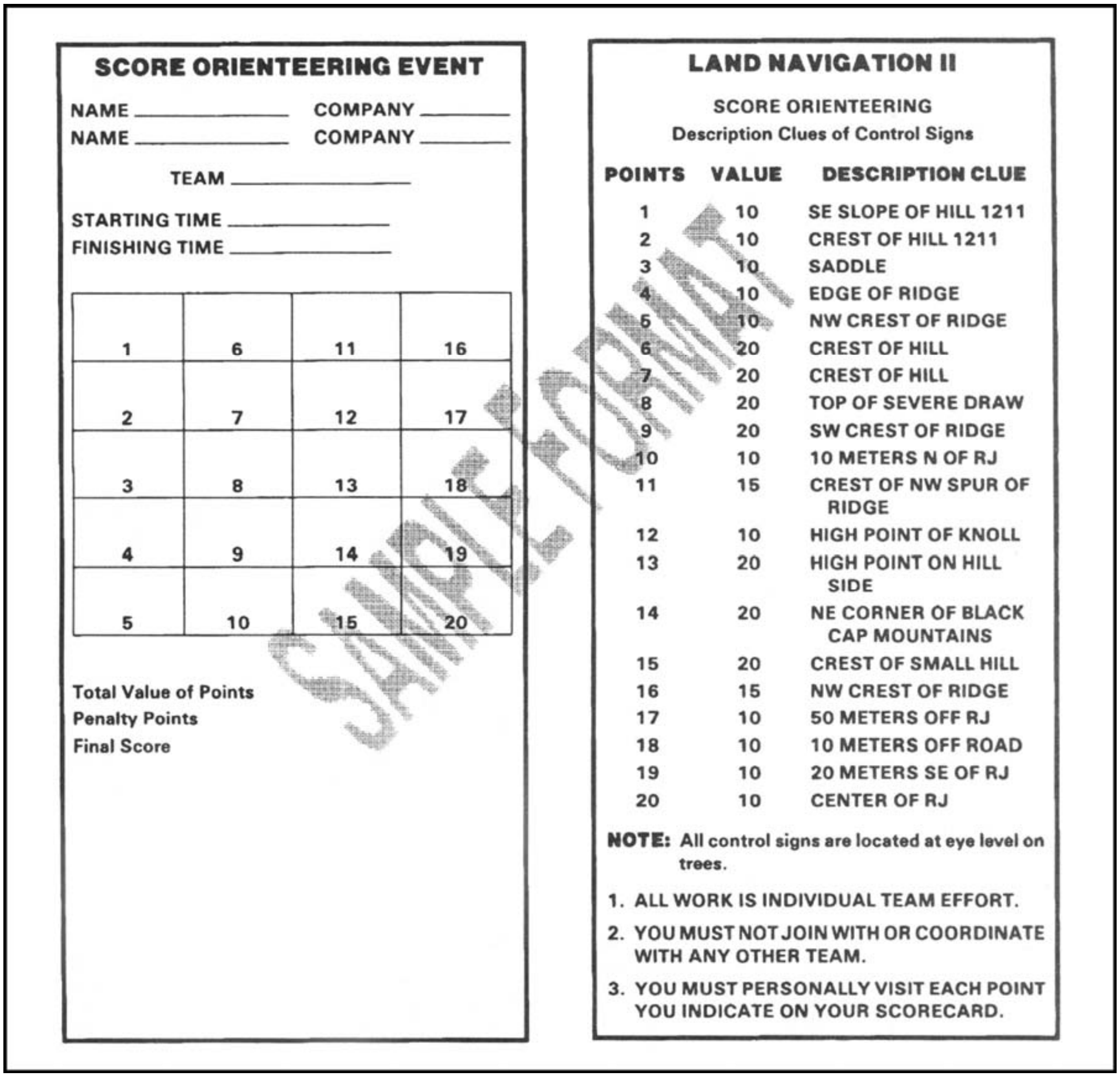

SCORE ORIENTEERING EVENT

NAME ______________ COMPANY ________

NAME ______________ COMPANY ________

TEAM ________________

STARTING TIME ______________

FINISHING TIME ______________

1	6	11	16
2	7	12	17
3	8	13	18
4	9	14	19
5	10	15	20

Total Value of Points

Penalty Points

Final Score

LAND NAVIGATION II

SCORE ORIENTEERING

Description Clues of Control Signs

POINTS	VALUE	DESCRIPTION CLUE
1	10	SE SLOPE OF HILL 1211
2	10	CREST OF HILL 1211
3	10	SADDLE
4	10	EDGE OF RIDGE
5	10	NW CREST OF RIDGE
6	20	CREST OF HILL
7	20	CREST OF HILL
8	20	TOP OF SEVERE DRAW
9	20	SW CREST OF RIDGE
10	10	10 METERS N OF RJ
11	15	CREST OF NW SPUR OF RIDGE
12	10	HIGH POINT OF KNOLL
13	20	HIGH POINT ON HILL SIDE
14	20	NE CORNER OF BLACK CAP MOUNTAINS
15	20	CREST OF SMALL HILL
16	15	NW CREST OF RIDGE
17	10	50 METERS OFF RJ
18	10	10 METERS OFF ROAD
19	10	20 METERS SE OF RJ
20	10	CENTER OF RJ

NOTE: All control signs are located at eye level on trees.

1. ALL WORK IS INDIVIDUAL TEAM EFFORT.
2. YOU MUST NOT JOIN WITH OR COORDINATE WITH ANY OTHER TEAM.
3. YOU MUST PERSONALLY VISIT EACH POINT YOU INDICATE ON YOUR SCORECARD.

SAMPLE FORMAT

Figure F-8. Clue description card.

j. **Scoring.** The cross-country or free event is scored by the orienteer's time alone. All control points must be visited; failure to visit one results in disqualification. In this event, the fastest time wins.

(1) A variation that can be introduced for novices is to have a not-later-than return time at the finish and add minutes to the orienteer's final time for minutes late and control points not located.

(2) The score event requires the amassing of as many points as possible within the time limit. Points are deducted for extra time spent on the course, usually one point for each 10 seconds extra.

k. **Prizes.** A monetary prize is not awarded. A suggested prize for beginners is an orienteering compass or some other practical outdoor-sports item.

F-7. SAFETY ON THE COURSE

A first aid kit must be available at the start and finish. One of the officials should be trained in first aid or have a medic at the event. Other safety measures include:

a. **Control Points.** Locate the controls where the safety of the competitor is not jeopardized by hazardous terrain or other circumstances.

b. **Safety Lane.** Have a location, usually linear, on the course where the competitor may go if injured, fatigued, or lost. A good course will usually have its boundary as a safety lane. Then a competitor can set a panic azimuth on the compass and follow it until he reaches the boundary.

c. **Finish Time.** All orienteering events must have a final return time. At this time, all competitors must report to the finish line even if they have not completed the course.

d. **Search-and-Rescue Procedures.** If all competitors have not returned by the end of the competition, the officials should drive along the boundaries of the course to pick up the missing orienteers.

F-8. CONTROL POINT GUIDELINES

When the control point is marked on the map as well as on the ground, the description of that point is prefaced by the definite article **the**; for example, **the pond**. When the control point is marked on the ground but is not shown on the map, then the description of the point is prefaced by the indefinite article **a**; for example, **a trail junction**. In this case, care must be taken to ensure that no similar control exists within at least 25 meters. If it does, then either the control must not be used or it must be specified by a directional note in parentheses; for example, a depression (northern). Other guidelines include:

a. Points of the compass are denoted by capital letters; for example, S, E, SE.

b. Control points within 100 meters of each other or different courses are not to be on the same features or on features of the same description or similar character.

c. For large (up to 75 meters across) features or features that are not possible to see across, the position of the control marker on the control point should be given in the instructions. For example, the east side of the pond; the north side of the building.

d. If a very large (100 to 200 meters) feature is used, the control marker should be visible from most directions from at least 25 meters.

e. If a control point is near but not on a conspicuous feature, this fact and the location of the marker should be clearly given; for example, 10 meters E of the junction. Avoid this kind of control point.

f. Use trees in control descriptions only if they are prominent and a totally different species from those surrounding. Never use bushes and fauna as control points.

g. Number control points in red on the master map.

h. For cross-country events, join all control points by a red line indicating the course's shape.

F-9. MAP SYMBOLS

The map symbols in Figure F-9 are typical topographic and cultural symbols that can be selected for orienteering control points. The map cutouts have been selected from DMA maps.

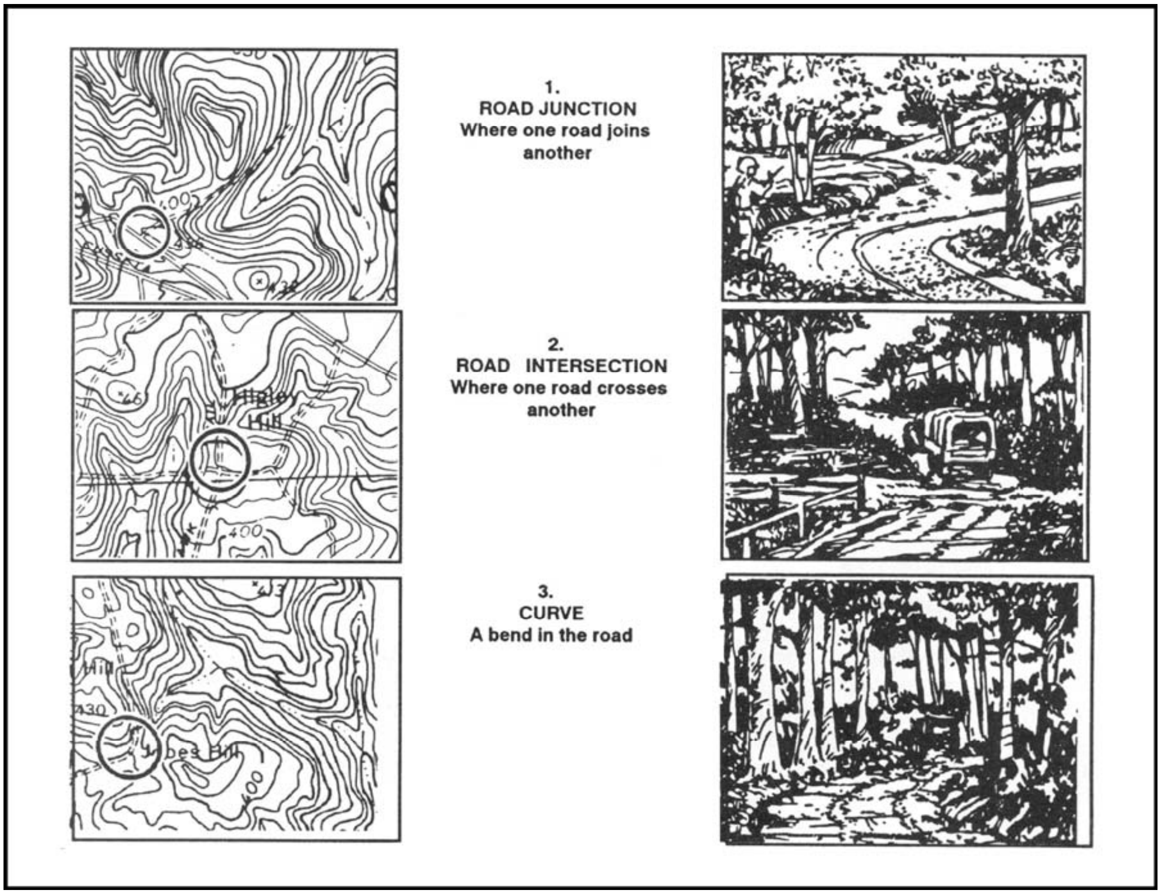
1.
ROAD JUNCTION
Where one road joins another
2.
ROAD INTERSECTION
Where one road crosses another
Higley Hill
400
3.
CURVE
A bend in the road
Hill
430

Figure F-9. Map symbols.

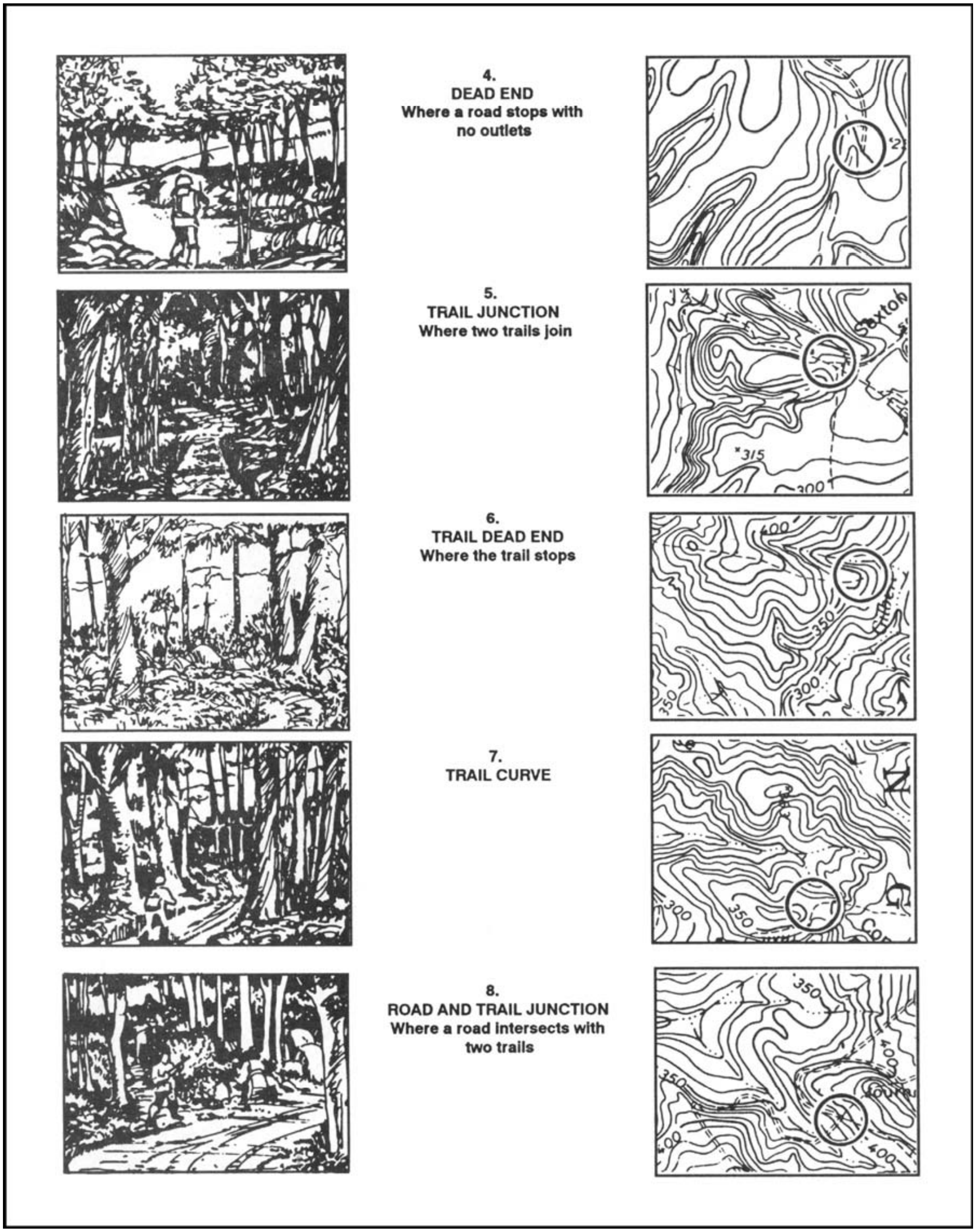
4.
DEAD END
Where a road stops with no outlets
5.
TRAIL JUNCTION
Where two trails join
Saxton
315
300
6.
TRAIL DEAD END
Where the trail stops
400
350
300
350
7.
TRAIL CURVE
300
350
8.
ROAD AND TRAIL JUNCTION
Where a road intersects with two trails
350
350
400
400
400

Figure F-9. Map symbols (continued).

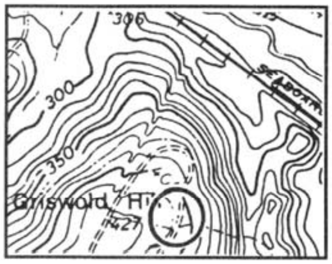
300
300
350
Griswold Hill
427

9.
ROAD AND TRAIL INTERSECTION
Where a road crosses a trail

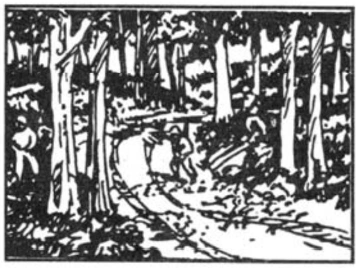

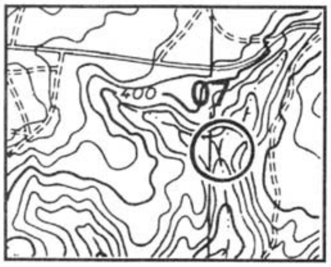

10.
INTERMITTENT STREAM JUNCTION

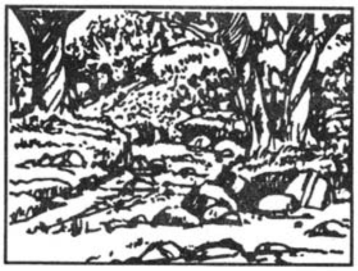

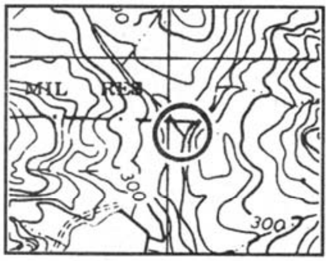
MIL RES
300
300

11.
STREAM JUNCTION

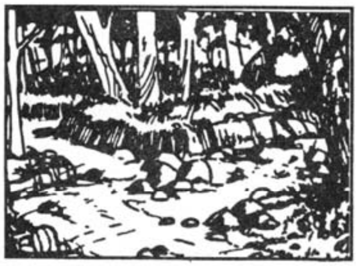

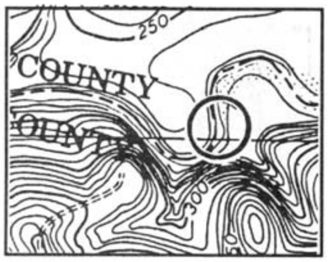
250
COUNTY
300

12.
BEND IN STREAM

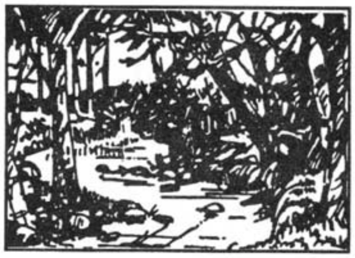

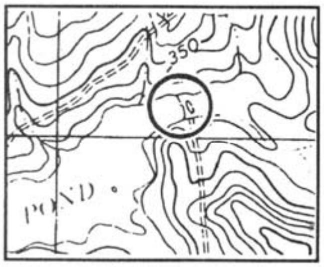

13.
POND'S EASTERNMOST POINT

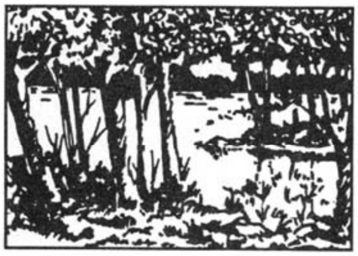

Figure F-9. Map symbols (continued).

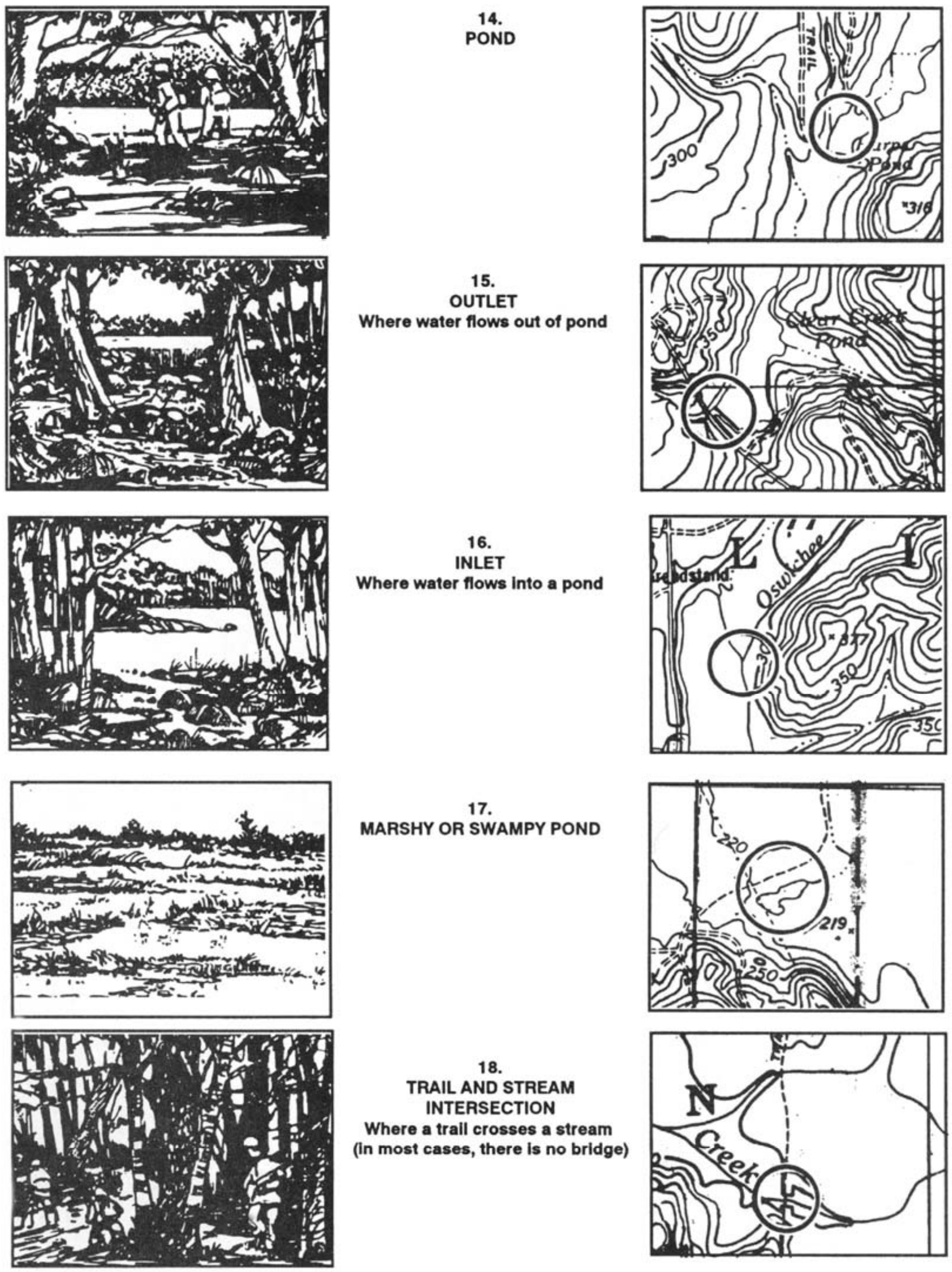

14.
POND

15.
OUTLET
Where water flows out of pond

16.
INLET
Where water flows into a pond

17.
MARSHY OR SWAMPY POND

18.
TRAIL AND STREAM INTERSECTION
Where a trail crosses a stream
(in most cases, there is no bridge)

TRAIL
300
Pond
316
350
Pond
Oswehee
377
350
350
220
219
250
N
Creek

Figure F-9. Map symbols (continued).

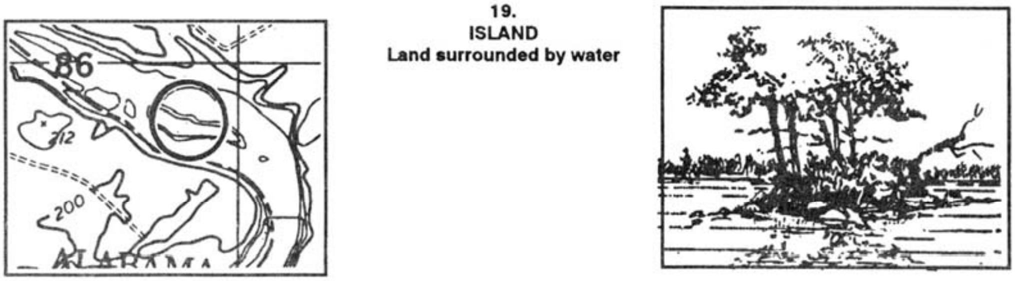

19.
ISLAND
Land surrounded by water

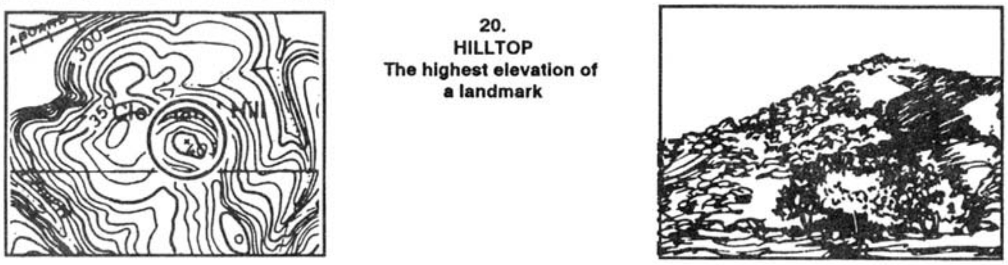

20.
HILLTOP
The highest elevation of
a landmark

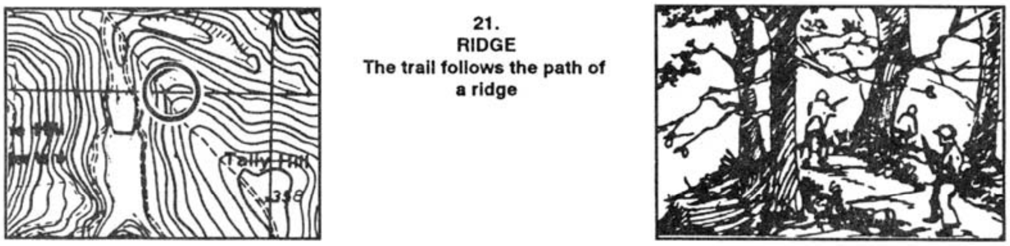
Tally Hill
356

21.
RIDGE
The trail follows the path of
a ridge

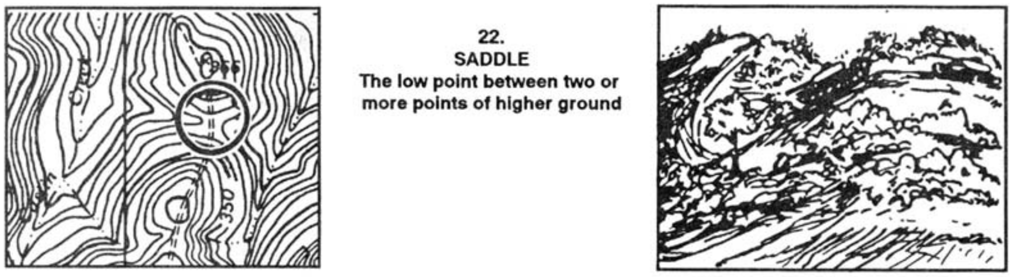

22.
SADDLE
The low point between two or
more points of higher ground

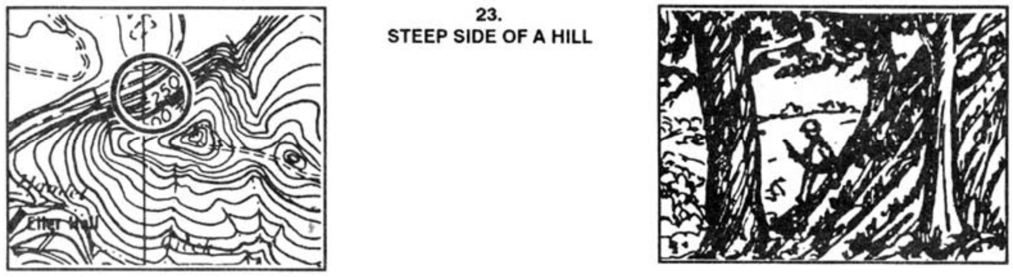
750
Etter Hall

23.
STEEP SIDE OF A HILL

Figure F-9. Map symbols (continued).

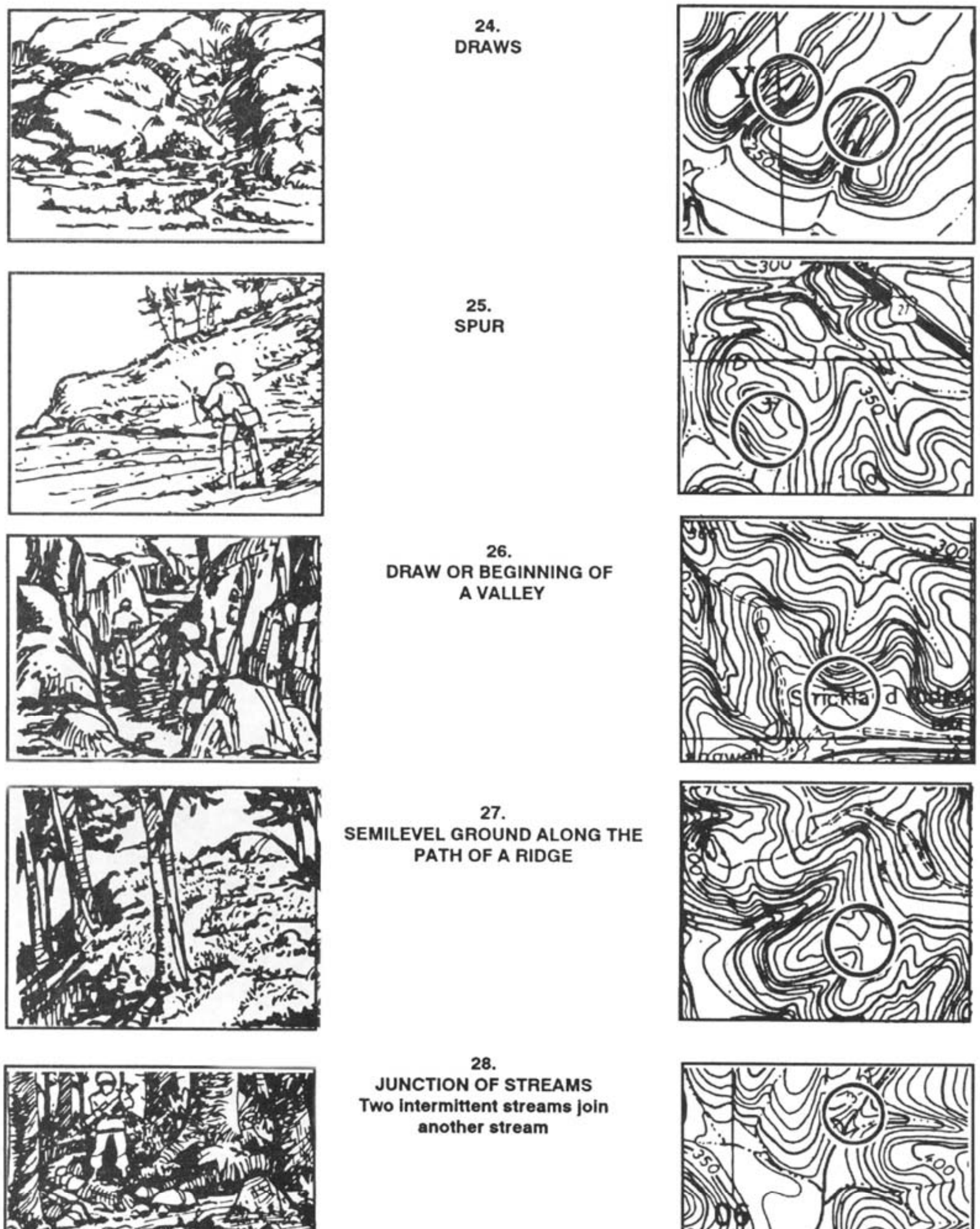

24.
DRAWS

25.
SPUR

26.
DRAW OR BEGINNING OF
A VALLEY

27.
SEMILEVEL GROUND ALONG THE
PATH OF A RIDGE

28.
JUNCTION OF STREAMS
Two intermittent streams join
another stream

Figure F-9. Map symbols (continued).

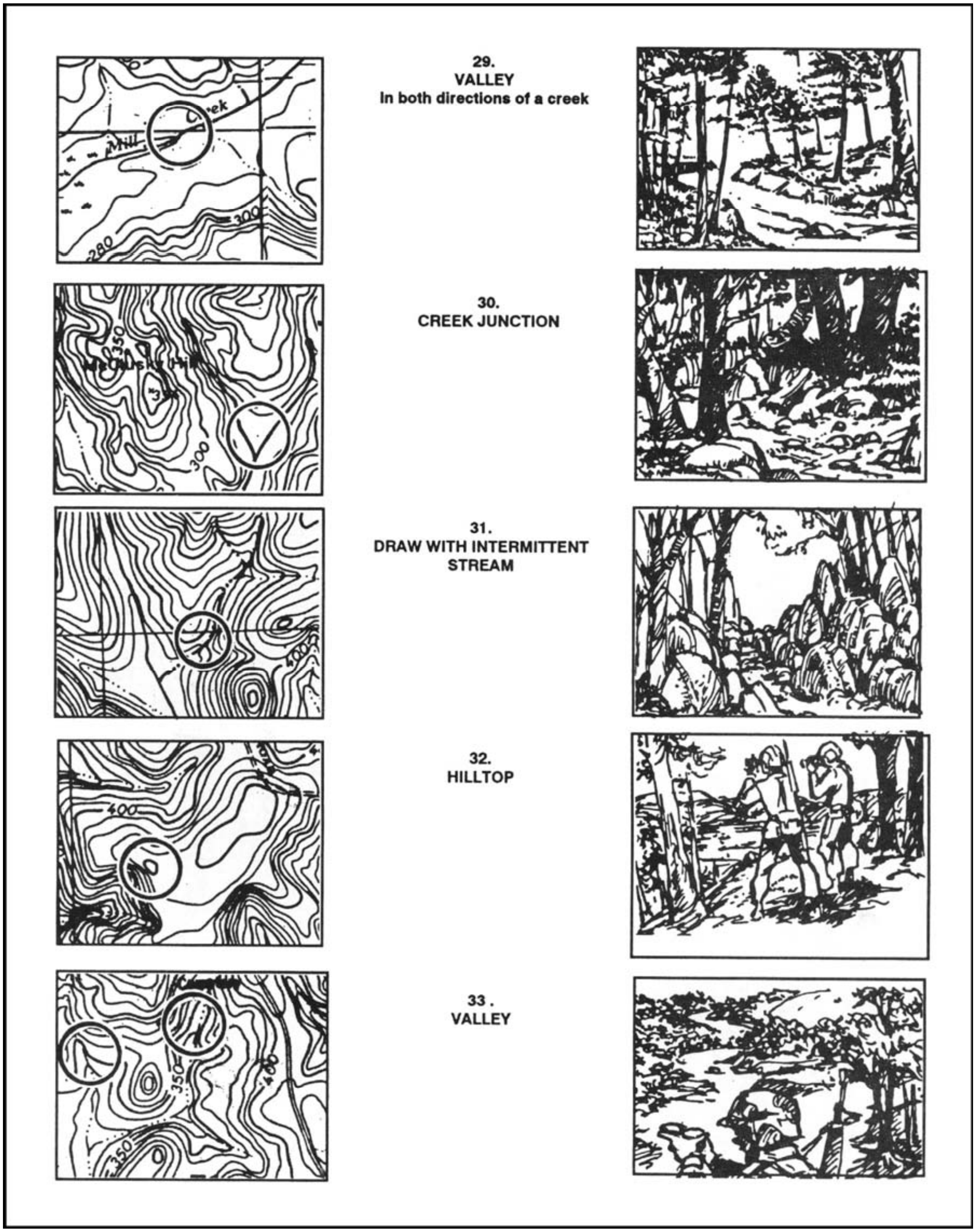
29.
VALLEY
In both directions of a creek
Mill Creek
300
280
30.
CREEK JUNCTION
350
300
31.
DRAW WITH INTERMITTENT
STREAM
400
32.
HILLTOP
400
33.
VALLEY
350
400
350

Figure F-9. Map symbols (continued).

34 .
SPOT ELEVATION

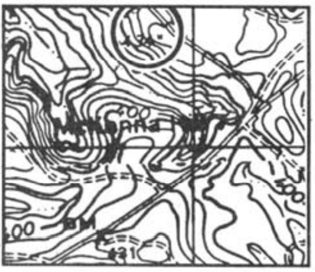
400
500
BM
431

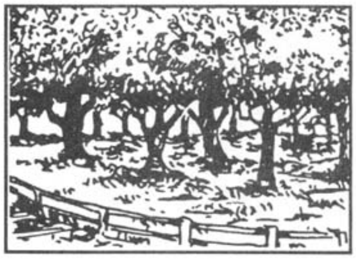

35.
ORCHARD

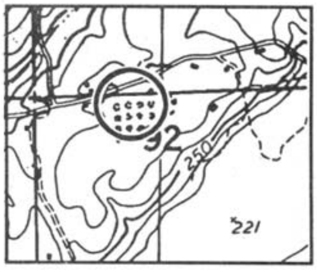

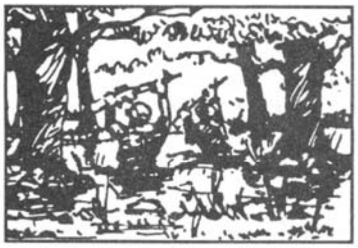

36.
MARSH OR SWAMP

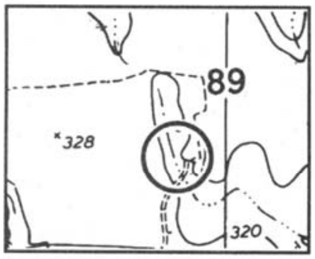

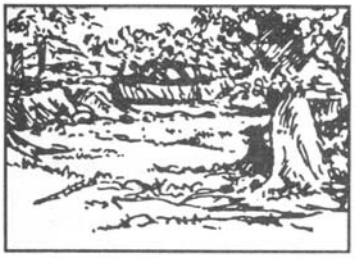

37.
DEPRESSION

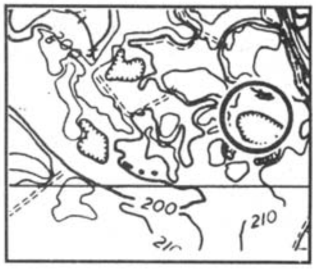

Figure F-9. Map symbols (continued).

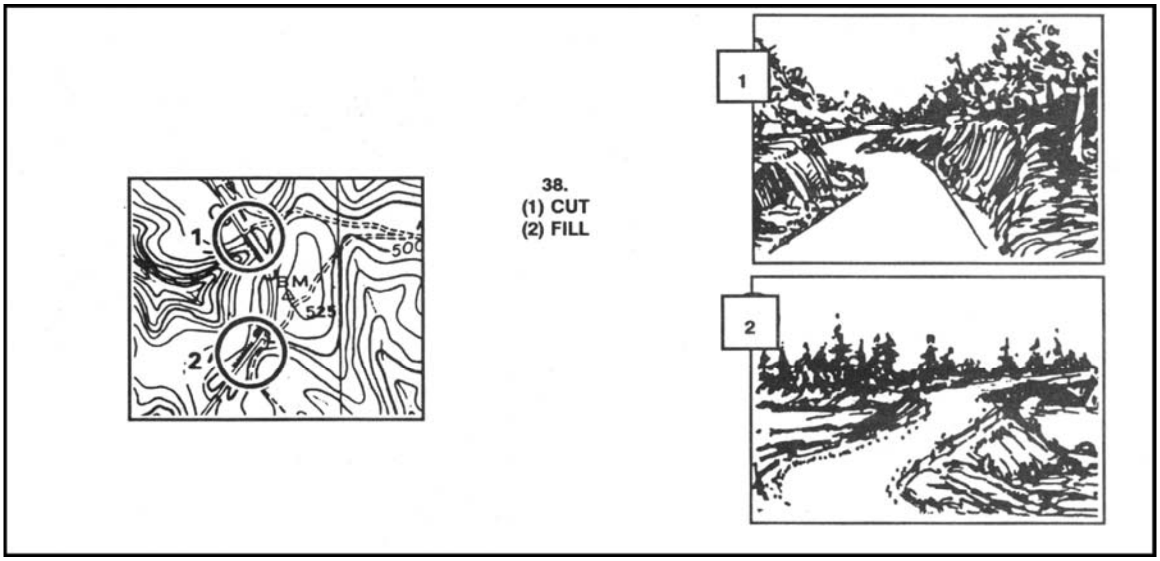

Figure F-9. Map symbols (continued).

F-10. ORIENTEERING TECHNIQUES

The orienteer should try not to use the compass to orient the map. The terrain association technique is recommended instead. The orienteer should learn the following techniques:

a. **Pacing.** One of the basic skills that the orienteer should develop early is how to keep track of distance traveled while walking and running. This is done on a 100-meter pace course.

b. **Thumbing.** This technique is very simple, but the map has to be folded small to use it. The orienteer finds his location on the map and places his thumb directly next to it. He moves from point to point on the ground without moving his thumb from his initial location. To find the new location, the only thing that he has to do is look at the map and use his thumb as a point of reference for his last location. This technique prevents the orienteer from looking all over the map for his location.

c. **Handrails.** This technique enables the orienteer to move rapidly on the ground by using existing linear features (such as trails, fences, roads, and streams) that are plotted along his route. They can also be used as limits or boundaries between control points (Figure F-10).

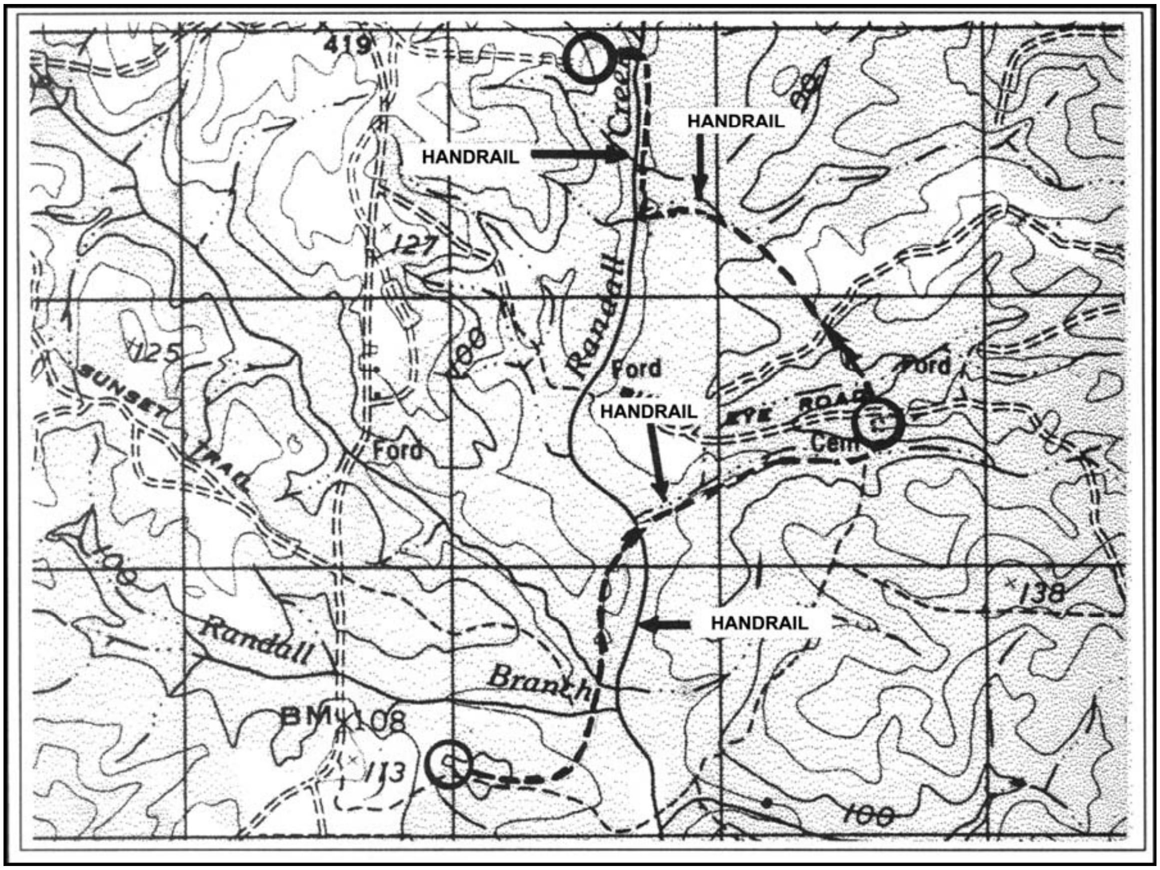

Figure F-10. Handrails.

d. **Attack Points.** These are permanent known landmarks that are easily identified on the ground. They can be used as points of reference to find control points located in the woods. Some examples of attack points are stream junctions, bridges, and road intersections.

F-11. CIVILIAN ORIENTEERING

Civilian orienteering is conducted under the guidelines of the United States Orienteering Federation with at least 70 clubs currently affiliated. Although civilian orienteering is a form of land navigation, the terms, symbols, and techniques are different from the military.

a. An expert military map reader/land navigator is by no means ready to compete in a civilian orienteering event. However, military experience in navigating on the ground and reading maps will help individuals to become good orienteers. Several orienteering practices and complete familiarization with the map symbols and terms before participating in a real orienteering event is recommended.

(1) ***Map***. The standard orienteering map is a very detailed, 1:15,000-scale, colored topographical map. All orienteering maps contain only north-south lines that are

magnetically drawn; this eliminates any declination conversions. Because of the absence of horizontal lines, grid coordinates cannot be plotted and therefore are not needed.

(2) ***Symbols (Legend)***. Despite standard orienteering symbols, the legend in orienteering maps has a tendency to change from map to map. A simple way to overcome this problem is to get familiar with the legend every time that a different map is used.

(3) ***Scale***. The scale of orienteering maps is 1:15,000. This requires an immediate adjustment for the military land navigator, especially while moving from point to point. It takes a while for a person that commonly uses a 1:50,000 scale to get used to the orienteering map.

(4) ***Contours***. The normal contour interval in an orienteering map is 5 meters. This interval, combined with the scale, makes the orienteering maps so meticulously detailed that a 1-meter boulder, a 3-meter shallow ditch, or a 1-meter depression will show on the map. This may initially shock a new orienteer.

(5) ***Terms and Description of Clues***. The names of landforms are different from those commonly known to the military. For example, a valley or a draw is known as a reentrant; an intermittent stream is known as a dry ditch. These terms, with a description of clues indicating the position and location of the control points, are used instead of grid coordinates.

b. The characteristics of the map, the absence of grid coordinates, the description of clues, and the methods used in finding the control points are what make civilian orienteering different from military land navigation.

APPENDIX G
M2 COMPASS

The M2 compass (Figure G-1) is a rustproof and dustproof magnetic instrument that provides slope, angle of site, and azimuth readings. One of the most important features of the M2 compass is that it is graduated in mils and does not require a conversion from degrees to mils as does the M1 compass. It can be calibrated to provide a grid azimuth or it can be used uncalibrated to determine a magnetic azimuth.

G-1. MAGNETIC NEEDLE

Except for the magnetic needle and its pivot, the compass is made of nonmagnetic materials. When the cover is closed, the magnetic needle is automatically lifted from its pivot and held firmly against the glass window. When the compass is open and leveled, the needle floats freely upon its pivot and points to magnetic north. Note that both ends of the needle are shaped like an arrow, and that one arrow is painted white and the other is black. It is the white end of the needle that points to magnetic north. Because the needle is magnetic, it will also be attracted to large iron or steel objects in the near vicinity, to electrical power lines, and to operating generators (see paragraph 9-3b). Magnetic compass readings measured near such objects are apt to be in error due to the magnetic attraction of these objects.

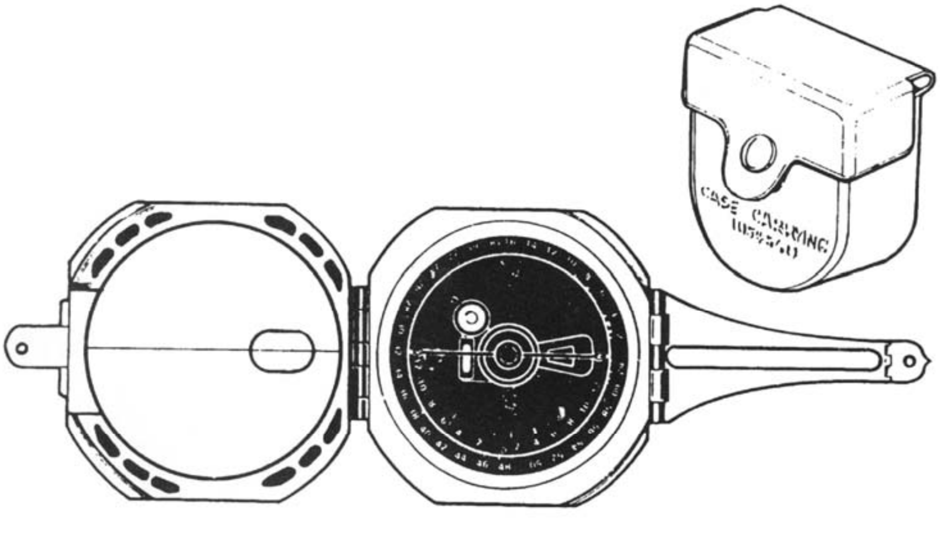

Figure G-1. M2 compass.

G-2. CIRCULAR LEVEL

The M2 compass has a circular level that is used to level the instrument when measuring azimuths. The circular level bubble must be centered before reading the azimuth. The compass is equipped with front and rear sights for aligning on the object to which the azimuth is desired.

G-3. COMPASS AZIMUTH SCALE

The compass azimuth scale is a circle divided into 6400 mils. Beginning with zero, the graduations are numbered every 200 mils. The long, unnumbered graduations appearing halfway between the numbered graduations are the odd-numbered hundreds (100, 300, 500, and so forth). Short graduation marks divide each 100-mil segment into equal portions of 20 mils.

a. **Reading the Azimuth Scale.** Azimuths are read from the azimuth scale from the black end of the compass needle.

b. **Setting Up the Compass.** To set up the M2 compass, open the cover and fold the rear sight holder out parallel with the face of the compass. Fold the rear sight up, perpendicular with its holder. Fold the front sight up, parallel with the mirror. Then fold the cover (mirror) toward the compass until it is at an angle of approximately 45 degrees to the face of the compass so that, with your eye behind the rear sight, the black end of the compass needle can be readily viewed in the mirror. The compass is now set up for measuring an azimuth.

c. **Measuring an Azimuth.** Once the compass is set up and all steel objects are at least 18 meters away from your position, you are ready to measure an azimuth. Hold the compass in both hands at eye level with your arms braced against your body and with the rear sight nearest your eyes. Sight through the rear sight and the window in the mirror and align the hairline at the reflection of the face of the compass. Center the circular level bubble. With the bubble centered and the hairline aligned on the object, look at the mirror reflection of the compass scale and read the azimuth to which the black end of the needle is pointing. Remember, magnetic attractions or movement by you may cause errors in your readings.

APPENDIX H
ADDITIONAL AIDS

This appendix provides information on the operation and function of already fielded, and soon to be fielded, devices that can be used as aids to navigation.

H-1. AN/PVS-5, NIGHT VISION GOGGLES

These goggles are passive night vision devices. An infrared light source and positive control switch permit close-in viewing under limited illumination. The AN/PVS-5 has a field of view of 40 degrees and a range of 150 meters.

a. The device has the capability for continuous passive operation over a 15-hour period without battery replacement. It weighs 1.5 pounds and is face-mounted. An eyepiece diopter is provided so the device can be worn without corrective lenses.

b. The device is designed to assist the following tasks: command and control, fire control, reconnaissance, close-in surveillance, terrain navigation, first aid, operation and maintenance of vehicles, selection of positions, traffic control, rear and critical area security, patrolling, combat engineer tasks, radar team employment, resupply activities, and flight-line functions.

c. It is a fielded system used by combat, CS, and CSS elements. The infantry, armor, air defense, field artillery, aviation, engineer, intelligence, military police, transportation, signal, quartermaster, chemical, maintenance, missile, and munitions units all use the device to help accomplish their missions.

d. The AN/PVS-5 can assist the land navigator under limited visibility conditions. Chemical lights may be placed at selected intervals along the unit's route of movement, and they can be observed through the AN/PVS-5. Another navigation technique is to have one person reading the map while another person reads the terrain, both using AN/PVS-5's. This allows the map reader and the terrain interpreter to exchange information on what terrain is observed, both on the map and on the ground. It allows each user to concentrate his AN/PVS-5 on one task. Land navigation, especially mounted, is a task better performed by more than one person. The above technique allows one soldier to perform map interpretation in the cargo portion of the vehicle while another soldier, possibly the driver, transmits to him information pertaining to the terrain observed on the ground.

H-2. AN/PVS-7, NIGHT VISION GOGGLES

The AN/PVS-7 is a lightweight (1.5 pounds), image intensification, passive night-vision device that uses ambient light conditions. It has the same applications as the AN/PVS-5. It is designed to be used in the same way as, and by the same units as, the AN/PVS-5. The AN/PVS-7 has a field of view of 40 meters and a range of 300 meters in moonlight and 150 meters in starlight.

H-3. ENHANCED PLRS USER UNIT

The enhanced position location reporting system (EPLRS)/joint tactical information distribution system (JTIDS), hybrid (PJH), is a computer-based system. It provides near real-time, secure data communications, identification, navigation, position location, and automatic reporting to support the need of commanders for information on the location, identification, and movement of friendly forces.

a. The EPLRS is based on synchronized radio transmissions in a network of users controlled by a master station. The major elements of a EPLRS community include the airborne, surface vehicular, and man-pack users; the EPLRS master station; and an alternate master station. The system can handle 370 user units in a division-size deployment per master station with a typical location accuracy at 15 meters. The man-pack unit weighs 23 pounds and includes the basic user unit, user readout, antenna, backpack, and two batteries.

b. The EPLRS are deployed at battalion and company level. Its use allows—

(1) Infantry or tank platoons to locate their positions, know the location of their friendly units, navigate to predetermined locations, and be informed when near or crossing boundaries.

(2) Artillery batteries to locate forward observers and friendly units, and position firing batteries.

(3) Aircraft to locate their exact positions; know the location of other friendly units; navigate to any friendly units, or a location entered by pilot; navigate in selected flight corridors; and be alerted when entering or leaving corridors or boundaries.

(4) Command and control elements at all echelons to locate and control friendly units/aircraft.

c. The network control station is located at brigade level to provide position location/navigation and identification services. It also provides interface between the battalion and company systems, and the JTIDS terminals.

d. It is fielded to infantry, armor, field artillery, military police, engineer, intelligence, aviation, signal, and air defense artillery units.

e. The EPLRS is a system that allows units to navigate from one point to another with the capability of locating itself and other friendly units equipped with the same system.

H-4. GLOBAL POSITIONING SYSTEM

The GPS is a space-based, radio-positioning navigation system that provides accurate passive position, speed, distance, and bearing of other locations to suitably equipped users.

a. The system assists the user in performing such missions as siting, surveying, tactical reconnaissance, sensor emplacement, artillery forward observing, close air support, general navigation, mechanized maneuver, engineer surveying, amphibious operations, signal intelligence operations, electronic warfare operations, and ground-based forward air control.

b. It can be operated in all weather, day or night, anywhere in the world; it may also be used during nuclear, biological, and chemical warfare.

c. It has been widely fielded in both active and reserve component units. (See Appendix J for more information on GPS.)

H-5. POSITION AND AZIMUTH DETERMINING SYSTEM

The PADS is a highly mobile, self-contained, passive, all-weather, survey-accurate position/navigation instrument used by field artillery and air defense artillery units for fire support missions. Its basis of issue is two sets per artillery battalion. The device is about the size of a 3-kilowatt generator and weighs 322.8 pounds in operational configuration.

a. The two-man PADS survey party uses the high-mobility, multipurpose, wheeled vehicle, the commercial utility cargo vehicle, the small-unit support vehicle, or the M151 1/4-ton utility truck. The system can be transferred while operating into the light observation helicopter (OH-58A) or driven into the CH-47 medium cargo helicopter.

b. The system provides real-time, three-dimensional coordinates in meters and a grid azimuth in mils. It also gives direction and altitude.

c. The PADS can be used by the land navigator to assist in giving accurate azimuth and distance between locations. A unit requiring accurate information as to its present location can also use PADS to get it. The PADS, if used properly, can assist many units in the performance of their mission.

WARNING

Laser devices are potentially dangerous. Their rays can and will burn someone's eyes if they look directly at them. Users should not direct the beams at friendly positions or where they could reflect off shiny surfaces into friendly positions. Other soldiers must know where lasers are being used and take care not to look directly at the laser beam.

H-6. GROUND-VEHICULAR LASER LOCATOR DESIGNATOR

The G/VLLD is the Army's long-range designator for precision-guided semi-active laser weapons. It is two-man portable for short distances and can be mounted on the M113A1 interim FIST vehicle when it has the vehicle adapter assembly. The G/VLLD provides accurate observer-to-target distance, vertical angle, and azimuth data to the operator. All three items of information are visible in the operator's eyepiece display.

a. The G/VLLD is equipped with an AN/TAS-4 night sight. This night sight increases the operator's ability to detect and engage targets during reduced visibility caused by darkness or battlefield obscuration.

b. The G/VLLD can give the navigator accurate line-of-sight distance to an object. The system can be used to determine its present location using resection and can assist the navigator in determining azimuth and distance to his objective.

H-7. QUICK RESPONSE MULTICOLOR PRINTER

The QRMP is a self-contained, laser, xerography printer capable of reproducing maps, photographs, annotated graphics, transparent originals, and digital terrain data in full color on transparent material or standard map paper. The QRMP system will consist of a QRMP housed in an 8' by 8' by 20' ISO shelter mounted on a 5-ton truck with a dedicated military-standard 30-kilowatt generator. Each system will carry at least a seven-day supply of all necessary materials.

a. The QRMP system has map size (24" by 30" paper size and 22.5" by 29" image size), color printing, scanning and electronics subsystems. It produces the first copy in less than five minutes in full color and sustains a copy rate of 50 to 100 copies per hour for full color products. The system uses a charged couple device array for scanning and sophisticated electronic signal processing to electrostatically discharge a selenium photoreceptor drum.

b. The QRMP has the capability to print terrain and other graphics directly from digital output from the digital topographic support system or another QRMP. The first unit is scheduled to be equipped with the QRMP in 1QFY97, and the initial operating capability is scheduled for 4QFY97. The QRMP system is used by the engineer topographers at division, corps, and echelons above corps.

APPENDIX I

FOREIGN MAPS

The use of foreign maps poses several problems to the land navigator. These products are often inferior in both content reliability and topographic accuracy to those produced by the DMA. Clues to these weaknesses are the apparent crudeness of the maps, unusually old compilation dates, or differences in mapped and actual terrain. The following characteristics should be examined closely.

I-1. HYDROGRAPHY

Of all the symbols on foreign maps, those for hydrography conform most closely to DMA usage. The use of blue lines and areas to depict streams, rivers, lakes, and seas seems to be universally accepted. The one caution to be observed is that foreign cartographers use different sets of rules to govern what is and what is not included on the map. Distinction between perennial and intermittent streams is usually not made.

I-2. VEGETATION

The classification and symbols for vegetation on most foreign maps are different to those used on DMA maps. The vegetation included on many foreign maps is often extensive, identifying not only vegetated areas--but also the specific types of vegetation present. Green is the predominant color used to represent vegetation; but, blue and black are sometimes used. The symbols that depict the various types of vegetation differ greatly from one foreign map to another.

I-3. CULTURAL AND LINEAR FEATURES

Perhaps the most striking difference between DMA and foreign maps is the set of symbols used to portray cultural features. Some symbols found on foreign maps are very unusual. Symbols for linear features on foreign maps are also likely to confuse the user who is accustomed to DMA symbols. DMA uses 10 basic road symbols to portray different classes of roads and trails; foreign mappers use many more.

I-4. TERRAIN RELIEF

Foreign maps generally use contour lines to portray terrain relief, but substantial variability exists in the contour intervals employed. They may range from 5 to 100 meters.

I-5. SCALE

Scales found on foreign maps include 1:25,000, 1:63,360, 1:63,600, 1:75,000, and 1:100,000. Most foreign large-scale topographic maps have been overprinted with 1,000-meter grid squares; so, it is unlikely that the variable scales will have much effect on your ability to use them. However, you must learn to estimate grid coordinates because your 1:25,000 and 1:50,000 grid coordinate scales may not work.

I-6. STEPS TO INTERPRETING FOREIGN MAPS

After discussing the many difficulties and limited advantages encountered when using foreign maps, it is only appropriate that some strategy be offered to help you with the task.

a. In the August 1942 issue of The Military Engineer, Robert B. Rigg, Lieutenant, Cavalry, suggested a five-step process for reading and interpreting foreign maps. It is as appropriate today as it was when he first proposed it.

Step 1. Look for the date of the map first. There are generally four dates: survey and compilation, publication, printing and reprinting, and revision. The date of the survey and compilation is most important. A conspicuous date of revision generally means that the entire map was not redrawn—only spot revisions were made.

Step 2. Note whether the publisher is military, government, or civilian. Maps published by the government or the military are generally most accurate.

Step 3. Look at the composition. To a great extent, this will reveal the map's accuracy. Was care taken in the cartography? Are symbols and labels properly placed? Is the draftsmanship precise? Is the coastline or river bank detailed?

Step 4. Observe the map's color. Does it enhance your understanding or does it obscure and confuse? The importance of one subject (coloring) must warrant canceling others. If it confuses, the map is probably not very accurate.

Step 5. Begin to decode the various map colors, symbols, and terms. Study these items by examining one feature classification at a time (culture, hydrography, topography, and vegetation). As an accomplished navigator, you should already have a good understanding of your area of operations, so translation of the map's symbols should not present an impossible task. Use your notebook to develop an English version of the legend or create a new legend of your own.

b. In dealing with the challenge of using a foreign map, be certain to use these five steps. In doing so, you are also encouraged to bring to bear all that you know about the geographic area and your skills in terrain analysis, map reading, map interpretation, and problem solving. After careful and confident analysis, you will find that what you do know about the foreign map is more than what you do not know about it. The secret often lies in the fact that the world portrayed on a map represents a kind of international language of its own, which allows you to easily determine the map's accuracy and to decode its colors, symbols, and labels.

APPENDIX J

GLOBAL POSITIONING SYSTEM

The ability to accurately determine position location has always been a major problem for soldiers. However, the global positioning system has solved that problem. Soldiers will now be able to determine their position accurately to within 10 meters.

J-1. DEFINITION

The GPS is a satellite-based, radio navigational system. It consists of a constellation with 24 active satellites that interfaces with a ground-, air-, or sea-based receiver. Each satellite transmits data that enables the GPS receiver to provide precise position and time to the user. The GPS receivers come in several configurations, hand-held, vehicular-mounted, aircraft-mounted, and watercraft-mounted.

J-2. OPERATION

The GPS is based on satellite ranging. It figures the users' position on earth by measuring the distance from a group of satellites in space to the users' location. For accurate three-dimensional data, the receiver must track four or more satellites. Most GPS receivers provide the user with the number of satellites that it is tracking, and whether or not the signals are good. Some receivers can be manually switched to track only three satellites if the user knows his altitude. This method provides the user with accurate data much faster than that provided by tracking four or more satellites. Each type receiver has a number of mode keys that have a variety of functions. To better understand how the GPS receiver operates, refer to the operators' manual.

J-3. CAPABILITIES

The GPS provides worldwide, 24-hour, all-weather, day or night coverage when the satellite constellation is complete. The GPS can locate the position of the user accurately to within 21 meters—95 percent of the time. However, the GPS has been known to accurately locate the position of the user within 8 to 10 meters. It can determine the distance and direction from the user to a programmed location or the distance between two programmed locations called way points. It provides exact date and time for the time zone in which the user is located. The data supplied by the GPS is helpful in performing several techniques, procedures, and missions that require soldiers to know their exact location. Some examples are:

- Sighting.
- Surveying.
- Sensor or minefield emplacement.
- Forward observing.
- Close air support.
- Route planning and execution.
- Amphibious operations.
- Artillery and mortar emplacement.

- Fire support planning.

J-4. LIMITATIONS

A constellation of 24 satellites broadcasts precise signals for use by navigational sets. The satellites are arranged in six rings that orbit the earth twice each day. The GPS navigational signals are similar to light rays, so anything that blocks the light will reduce or block the effectiveness of the signals. The more unobstructed the view of the sky, the better the system performs.

J-5. COMPATABILITY

All GPS receivers have primarily the same function, but the input and control keys vary between the different receivers. The GPS can reference and format position coordinates in any of the following systems:

- **Degrees, Minutes, Seconds (DMS):** Latitude/longitude-based system with position expressed in degrees, minutes, and seconds.
- **Degrees, Minutes (DM):** Latitude/longitude-based system with position expressed in degrees and minutes.
- **Universal Traverse Mercator (UTM):** Grid zone system with the northing and easting position expressed in meters.
- **Military Grid Reference System (MGRS):** Grid zone/grid square system with coordinates of position expressed in meters.

The following is a list of land navigation subjects from other sections of this manual in which GPS can be used to assist soldiers in navigating and map reading:

a. **Grid Coordinates (Chapter 4).** GPS makes determining a 4-, 6-, 8-, and 10-digit grid coordinate of a location easy. On most GPS receivers, the position mode will give the user a 10-digit grid coordinate to their present location.

b. **Distance (Chapter 5) and Direction (Chapter 6).** The mode for determining distance and direction depends on the GPS receiver being used. One thing the different types of receivers have in common is that to determine direction and distance, the user must enter at least one way point (WPT). When the receiver measures direction and distance from the present location or from way point to way point, the distance is measured in straight line only. Distance can be measured in miles, yards, feet, kilometers, meters, or nautical knots or feet. For determining direction, the user can select degrees, mils, or rads. Depending on the receiver, the user can select true north, magnetic north, or grid north.

c. **Navigational Equipment and Methods (Chapter 9).** Unlike the compass, the GPS receiver when set on navigation mode (NAV) will guide the user to a selected way point by actually telling the user how far left or right the user has drifted from the desired azimuth. With this option, the user can take the most expeditious route possible, moving around an obstacle or area without replotting and reorienting.

d. **Mounted Land Navigation (Chapter 12).** While in the NAV mode, the user can navigate to a way point using steering and distance, and the receiver will tell the user how far he has yet to travel, and at the current speed, how long it will take to get to the way point.

e. **Navigation in Different Types of Terrain (Chapter 13).** The GPS is capable of being used in any terrain, especially more open terrain like the desert.

f. **Unit Sustainment (Chapter 14).** The GPS can be used to read coordinates to quickly and accurately establish and verify land navigation courses.

APPENDIX K

PRECISION LIGHTWEIGHT GLOBAL POSITIONING SYSTEM RECEIVER

> *The precision lightweight global positioning system receiver (PLGR) is a highly accurate satellite signal navigation set (referred to in this appendix as AN/PSN-11).*

K-1. CONCEPT OF OPERATION

The AN/PSN-11 is designed for battlefield use anywhere in the world. It is sealed watertight for all weather day or night operation. The AN/PSN-11 is held in the left hand and operated with the thumb of the left hand. Capability is included for installation in ground facilities, and air, sea, and land vehicles. The AN/PSN-11 is operated stand-alone using prime battery power and integral antenna. It can be used with external power source and external antenna.

a. The AN/PSN-11 provides the user with position coordinates, time, and navigation information under all conditions, if—

- No obstructions block the line-of-sight satellite signal from reaching the antenna.
- Valid crypto keys are used to protect the AN/PSN-11 from intentionally degraded satellite signals.

b. Many data fields, such as elevation, display units of information. The format of the units can be changed to your most familiar format.

c. Map coordinates are entered as a way point. When a way point is selected as a destination, the AN/PSN-11 provides steering indications, azimuth, and range information to the destination. A desired course to a way point is entered. Offset distance from this course line is shown.

d. Up to 999 way points can be entered, stored, and selected as a destination. A route is defined for nav either start-to-end or end-to-start. The route consists of up to nine legs (10 way points) linked together.

K-2. CAPABILITIES

Data provided by the AN/PVS-11 helps complete missions such as:

- Siting.
- Surveying.
- Tactical reconnaissance.
- Sensor emplacement.
- Artillery forward observing.
- Close air support.
- General navigation.
- Mechanized maneuvers.
- Engineer surveying.
- Amphibious operations.
- Parachute operations.
- Signal intelligence.
- Electronic warfare.

- Ground-based forward air control.

This data is displayed on the AN/PSN-11display. It is also available from a serial data port.

K-3. CHARACTERISTICS

The AN/PSN-11 is less than 9.5 inches long, 4.1 inches wide, and 2.6 inches deep. It weighs 2.75 pounds with all batteries in place. The small size and lightweight make the set easy to carry and use. The durable plastic case is sealed for all-weather use. The AN/PSN-11 features make it easy to use. (These features are highlighted in the physical description in Figure K-1).

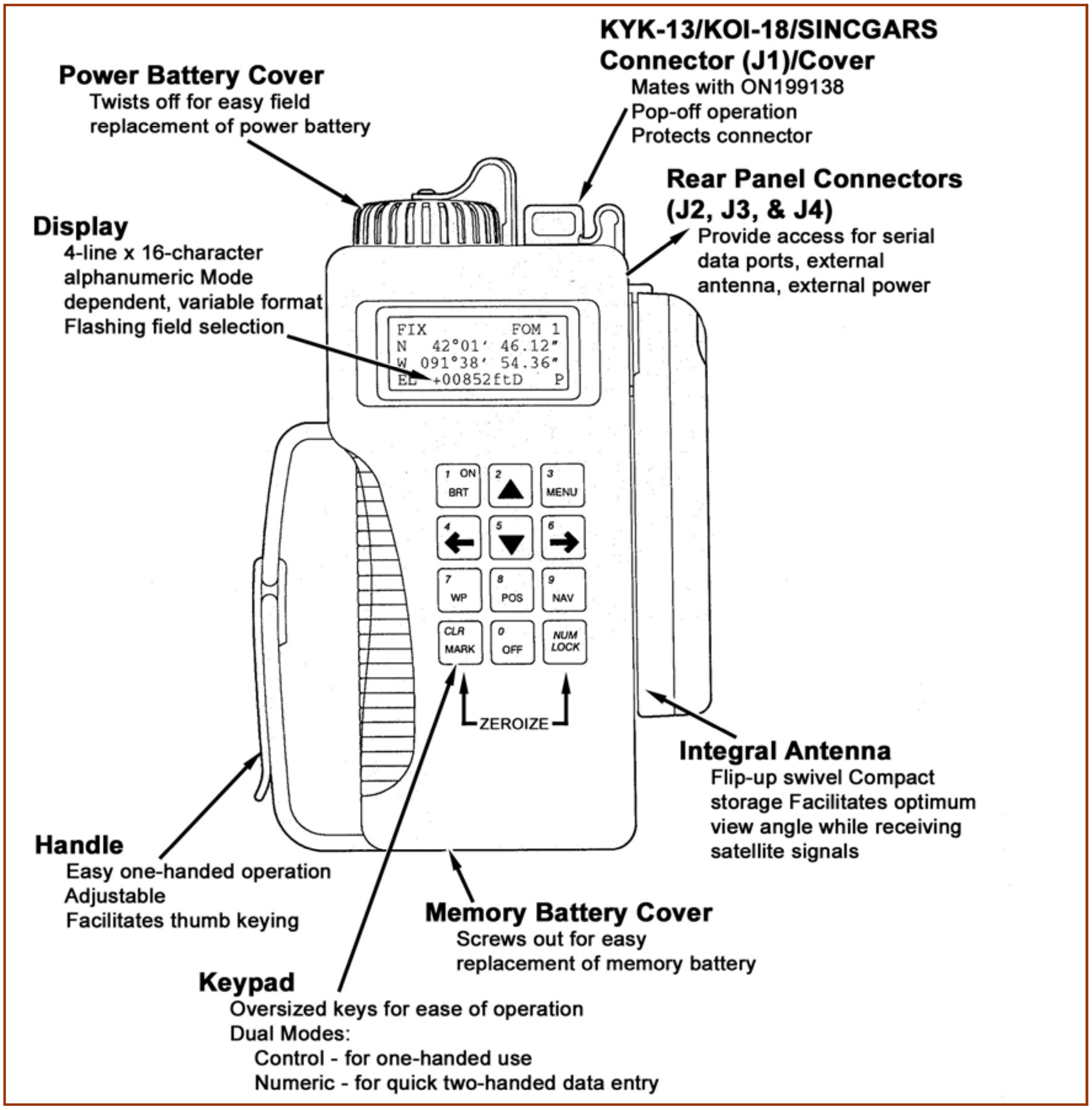
KYK-13/KOI-18/SINCGARS Connector (J1)/Cover
Mates with ON199138
Pop-off operation
Protects connector
Power Battery Cover
Twists off for easy field replacement of power battery
Rear Panel Connectors (J2, J3, & J4)
Provide access for serial data ports, external antenna, external power
Display
4-line x 16-character alphanumeric Mode dependent, variable format Flashing field selection
FIX FOM 1
N 42°01' 46.12"
W 091°38' 54.36"
EL +00852ftD P
1 ON BRT
2
3 MENU
4
5
6
7 WP
8 POS
9 NAV
CLR MARK
0 OFF
NUM LOCK
ZEROIZE
Integral Antenna
Flip-up swivel Compact storage Facilitates optimum view angle while receiving satellite signals
Handle
Easy one-handed operation
Adjustable
Facilitates thumb keying
Memory Battery Cover
Screws out for easy replacement of memory battery
Keypad
Oversized keys for ease of operation
Dual Modes:
Control - for one-handed use
Numeric - for quick two-handed data entry

Figure K-1. Physical features.

K-4. SETUP AND CONTROL

Setting up the operation parameters of the PLGR is critical. This section describes the display, procedures, and principles used in setting the AN/PSN-11displays to suit the needs of the user. This display consists of seven pages that allows the user to control the following parameters:

- Operating mode.
- Type of satellites to use.
- Coordinate system.
- Units.
- Magnetic variation.
- Display customization.
- Navigation Display mode.
- Elevation hold mode.
- Time and error formats.
- Datum.
- Automatic off timer.
- Datum port configuration.
- AutoMark mode.

To set the PLGR up for continuous operation:

a. Turn the PLGR **ON**. Once it has completed its built-in-test (BIT) press the **MENU** key and move the cursor to **SETUP** (Figure K-2). Activate the SETUP function.

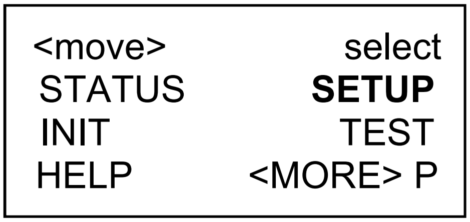

Figure K-2. SETUP.

b. The first screen (Figure K-3) allows the operator to set the operating mode and SV-Type. Scroll through the operating modes and select **CONT** and for the SV-Type **Mixed**.

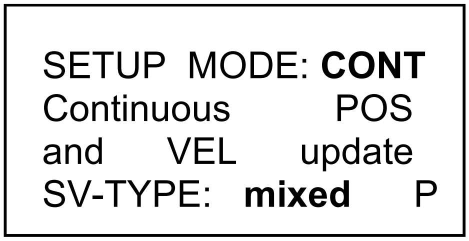
SETUP MODE: **CONT**
Continuous POS
and VEL update
SV-TYPE: **mixed** P

Figure K-3. Operating mode and SV-type.

c. The second screen (Figure K-4) allows the operator to setup the units. Scroll through the available coordinates and select **MGRS-New** and **Metric**. For the Elevation select **meter** and **MSL** and for the Angle select **Degrees** and **Magnetic**.

```
SETUP              UNITS
MGRS-New          Metric
Elev:  meter         MSL
ANGL:  Deg    Mag      P
```

Figure K-4. Setup the units.

d. The third screen (Figure K-5) should be set for the MAGVAR (Magnetic variation or GM Angle for your area). The operator can select Calculate the degree or manually enter degrees as an Easterly or Westerly GM Angle; for example, **E021.0** for the TENINO Map Sheet.

```
SETUP          MAGVAR
TYPE:  Calc       deg
         WWM     1995
                    P
```

Figure K-5. Magnetic variation or GM angle setup.

e. The fourth screen (Figure K-6) of setup allows the operator to set the Elevation Hold, Time, and Error. The operator should set the ELHOLD to **automatic**. As for time the operator needs to know, from their present location, how many hours they are ahead of or behind Greenwich Mean Time. For example, during Daylight savings time, Fort Benning, GA. is **Loc=Z-0400**. To set the ERR, the operator selects **-+m** to let him know in meters how accurate the PLGR is operating.

```
SETUP
ELHold :    automatic
TIME:      Loc=Z-0400
ERR: +-m            P
```

Figure K-6. Set elevation, time, hold, and error.

f. The fifth screen (Figure K-7) of setup allows the operator to set the PLGR Datum to their area of operation and to set the Automatic Off Timer. The PLGR has fifty-two map Datum sets available. The operator should set the PLGR Datum to their area of operation. For example, if your map Datum is WGS-84, the operator sets the PLGR to WGS-84. If the map is 1927 North America Datum, the operator sets the Datum to NAS-C. The automatic timer off is used to turn the PLGR off after a prescribed time once it has acquired a fixed position. The operator should set this mode to **OFF**.

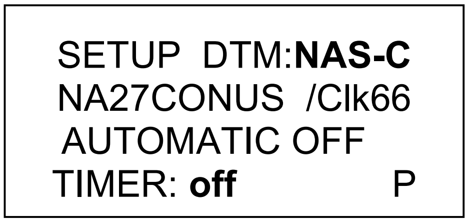

```
SETUP  DTM:NAS-C
NA27CONUS  /Clk66
 AUTOMATIC OFF
TIMER: off          P
```

Figure K-7. Set the PLGR Datum.

g. The sixth screen (Figure K-8) in setup is the In/Out Port screen. This page allows the operator to control serial communications, HAVEQUICK and 1PPS options. Select **Standard** unless otherwise directed and select **OFF** for Havequick and 1PPS.

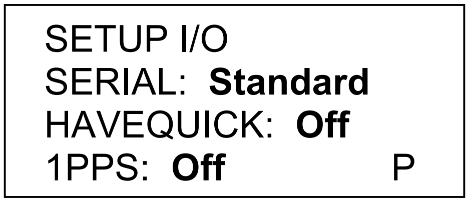

```
SETUP I/O
SERIAL:  Standard
HAVEQUICK:  Off
1PPS:  Off           P
```

Figure K-8. In/out port screen.

h. The seventh screen (Figure K-9) is setup AUTOMARK. This feature allows the operator to have the PLGR periodically wake-up, acquire a position fix, store the position as a way point, or return to the mode of operation it was previously in. The operator should set this mode to **OFF**. The remaining pages for SETUP are for advance GPS users.

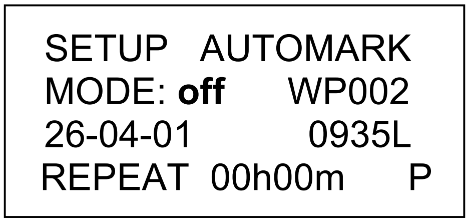

```
SETUP   AUTOMARK
MODE: off     WP002
26-04-01         0935L
REPEAT  00h00m     P
```

Figure K-9. AUTOMARK setup.

i. Once the PLGR is SETUP, the operator can now obtain a position. This procedure is accomplished by activating the Position (POS) key. The position displayed is *OLD* information until the receiver collects and calculates satellite data and displays the current position. The receiver must be tracking three satellites to obtain a two-dimensional fix position and four or more satellites for a three-dimensional fix position. The third dimension is elevation.

K-5. WAY POINT OPERATIONS

A way point is the location of a point on a desired course described by coordinates or a physical location. A normal mission consists of a series of way points. The way points available on the AN/PSN-11 are 999 (numbered 01 through 999).

a. This paragraph describes the AN/PSN-11 way point displays and way point operations. The way point display pages are used to perform the following operations:

- Enter, edit, or review way points.
- Copy way points.
- Determine the distance between way points.
- Calculate a new way point.
- Clear way points.
- Define a mission route.

b. To enter a way point, the operator needs to press the way point **(WP)** key (Figure K-10). When the way point menu appears, the ENTER function flashes. The operator presses the down arrow key to activate this field. Now the operator enters a way point name, grid zone designator, 100,000-meter grid square identifier, 10-digit grid coordinate, and elevation.

```
WP     <move>    sel
ENTER  EDIT   COPY
SR-CALC  RNG CALC
DIST  CLEAR  ROUTE
```

Figure K-10. Enter a way point.

c. To enter a way point name, the operator presses the right arrow key until the first letter of the word UNUSED(WP#) is flashing (Figure K-11). Scroll up or down through the alphabet changing the letter U to whatever is desired. For example, if the operator wanted to name their way point NORTH STAR, the operator scrolls down the alphabet until the letter U is changed to the letter N (Figure K-12). The operator repeats this process for the remaining letters.

```
WP002  UNUSED002
B           MGRS-New
AN   00000e   00000n
No  EL         CLR   P
```

Figure K-11. Unused.

```
WP002  NORTHSTAR
10T          MGRS-New
EG   13130e    95750n
No  EL          CLR  N
```

Figure K-12. Change a name.

d. Second line, the operator enters the grid zone designator for their area of operation. For example, the Fort Benning area falls in the 16S zone.

e. Third line, the operator must enter a 10-digit grid coordinate with its 100,000-meter grid square identifier. For example, if the way point location is Offutt Lake, Tenino map sheet, the 100,000-meter grid square identifier is EG. Then, the operator plots the grid coordinates on the map and enters it into the PLGR.

NOTE: Operator plots 8-digit grid coordinates, however a 10-digit coordinate is entered. Therefore, the 5th and 10th digit entered is a zero (0).

f. For the fourth line, if the elevation of the way point is known, the operator can enter it. If the elevation is not known the operator can just leave the data as zero or No EL. The operator moves the cursor until the Up and Down arrow symbol appears before the letter P or N in bottom right corner. When activating the down arrow key the operator stores the way point into the PLGR's memory. The PLGR notifies the operator that the way point has been stored.

NOTE: When entering numbers, the NUM LOCK can be activated. The letter N appears in the bottom right corner allowing the operator to use the numbers on the keypad rather then scrolling up/down (Figure K-12).

K-6. NAVIGATION

Navigation (nav) is using the AN/PSN-11 to find your present position, relative to other points. The AN/PSN-11 provides azimuth, range, and steering information in a variety of formats. There are four navigation display modes that may be accessed and selected. The navigation display mode selected determines the type of information shown on the navigation displays. These navigation displays give the user the most useful information for a certain mission profile: *SLOW, 2D FAST, 3D FAST OR CUSTOM.*

- In **SLOW** nav mode, the AN/PSN-11 performs two-dimensional (2D) nav. Slow nav mode is used for land or sea nav, when the user cannot maintain the minimum speed necessary (about 1.5 kmph).
- In **2D FAST** nav mode, the AN/PSN-11 performs two-dimensional (2D) nav. 2D FAST nav mode is used for land or sea nav, when the user can maintain the minimum speed necessary for GPS to compute navigation parameters based on velocity.
- In **3D FAST** nav mode, the AN/PSN-11 performs three-dimentional (3D) nav. 3D FAST nav mode has an APPROACH sub-mode. 3D FAST nav mode is used for air nav, when the user can travel in three dimensions and can maintain the minimum speed necessary for GPS to compute navigation parameters based on velocity.
- In **CUSTOM** nav mode, the AN/PSN-11 performs the users navigational display pages as so desired. It can be set-up to support the individual user's performances or mission requirements. The following custom display modes are available:
    - Direct.
    - Course To.
    - Course From.

- Route.
- Approach.

To navigate with the PLGR on land in a Dead-Reckoning method, the PLGR nav mode is accomplished as follows.

a. The operator presses the NAV key activating the nav function. The first screen that appears is the nav mode (Figure K-13). For example, SLOW, 2D FAST, 3D FAST, CUSTOM, DIRECT, CRS TO, and CRS FROM.

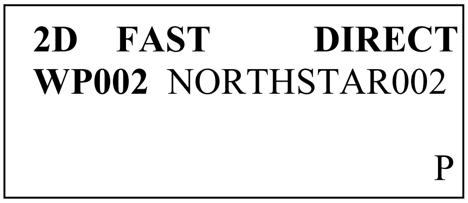

```
2D   FAST        DIRECT
WP002  NORTHSTAR002

                      P
```

Figure K-13. Navigation mode.

b. The operator selects the **2D FAST and DIRECT**. The second line is the way point desired to be navigated. (Scroll through the way points that are stored to choose the desired way point.)

c. To see the azimuth that the navigator should be traveling on, go to the next page by pressing the down arrow key (Figure K-14). This page tells the navigator what azimuth they are heading on (TRK=tracking), and the actual azimuth the navigator should be heading on (AZ). The fourth line tells the navigator Steering (STR). A direction (< >) and a number of degrees the navigator needs to move to travel on their actual azimuth.

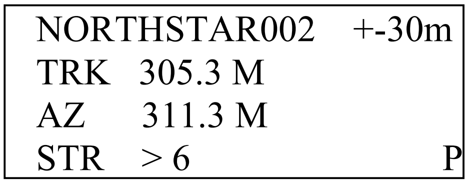

```
NORTHSTAR002   +-30m
TRK   305.3 M
AZ     311.3 M
STR   > 6            P
```

Figure K-14. Azimuth.

d. The third screen (Figure K-15) tells the navigator the range or distance to their way point and how much time (TTG2) it will take them to get to their way point. This page also lets the navigator know what is the elevation difference from their present location to the way point and by how much they will miss their way point by (MMD).

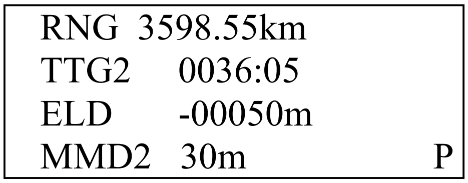

```
RNG  3598.55km
TTG2     0036:05
ELD      -00050m
MMD2   30m           P
```

Figure K-15. Range or distance.

GLOSSARY

AA	avenue of approach
ANCOC	advanced noncommissioned officer course
AR	Army regulation
BNCOC	basic noncomissioned officer course
BT	basic training
cm	centimeter
CONUS	continental United States
CS	combat support
CSS	combat service support
CUCV	commercial utility cargo vehicle
DD	Department of Defense
DMA	Defense Mapping Agency
E	east
EPLRS	enhanced position location reporting system
FIST	fire support team
FM	field manual
FORSCOM	United States Army Forces Command
GD	ground distance
GEOREF	geographic reference system
G-M	grid-magnetic
GPS	global positioning system
GSR	ground surveillance radar
GTA	graphic training aid
G/VLLD	ground/vehicular laser locator designator
HD	horizontal distance
HHC	headquarters and headquarters company
HMMWV	high-mobility multipurpose wheeled vehicle
JOG	joint operations graphics
JTIDS	joint tactical information distribution system
km	kilometer
LAT	latitude

MD	map distance
METT-T	mission, enemy, terrain, troops and time available
MITAC	map interpretation and terrain association course
N	north
NCO	noncommissioned officer
OAC	officer advanced course
OBC	officer basic course
OCS	officer candidate school
OSUT	one station unit training
PADS	position and azimuth determining system
PD	photo distance
PJH	hybrid (PLRS and JTIDS)
PLDC	primary leadership development course
PLGR	Precision Lightweight Global Positioning System Receiver
POI	program of instruction
PRE	precommission
QRMP	quick response multicolor printer
ROTC	Reserve Officers' Training Corps
S	south
SF	standard form
SOSES	shapes, orientations, sizes, elevations, and slopes
SUSV	small-unit support vehicle
tan	tangent
TM	technical manual
TOW	tube-launched, optically tracked, wire-guided missile
TRADOC	Training and Doctrine Command
topo	topographic
UPS	universal polar stereographic
US	United States
USGS	United States Geological Survey
UTM	universal transverse mercator
VD	vertical distance
VNAS	vehicular navigation aids system
W	west

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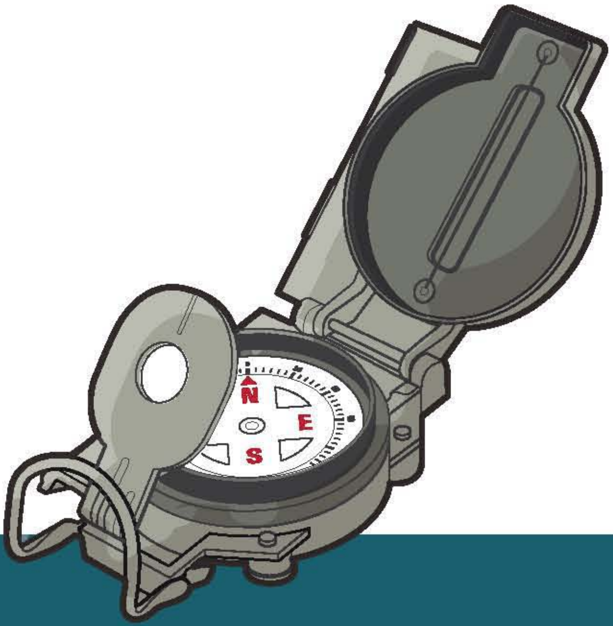

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INTRODUCTION

HAVING TAUGHT SURVIVAL SKILLS FOR MANY YEARS, I have learned that four elements must be in place for a survival situation to have the chance of a positive outcome: knowledge, ability, the will to survive, and luck. While knowledge and ability can be learned, the will to survive is hard-wired into our survival mechanism and we may not know we possess it until we're put to the test. For example, people who were fully trained and well-equipped have given up hope in survivable conditions, while others, who were less well-prepared and ill-equipped, have survived against all odds because they refused to give up.

> “Always apply the **principle** of the **least** amount of **energy expended** for the **maximum** amount of **gain**”

Anyone venturing into the wilderness—whether for an overnight camping trip or a lengthy expedition—should understand the basic principles of survival. Knowing how to survive in a particular situation will allow you to carry out the correct beforehand preparation, choose the right equipment (and learn how to use it), and practice the necessary skills. While you may be able to start a fire using a lighter, for example, what would you do if it stopped working? Equally, anyone can spend a comfortable night inside a one-man bivy shelter, but what would you do if you lost your pack? The knowledge gained through learning the skills of survival will enable you to assess your situation, prioritize your needs, and improvise any items of gear that you don’t have with you.

> Treat the **wilderness** with **respect**: carry in only what you can **carry out**; leave only **footprints**, take only **pictures**

Survival knowledge and skills must be learned—and practiced—under realistic conditions. Starting a fire with dry materials on a sunny day, for example, will teach you very little. The real survival skill is in understanding why a fire won't start and working out a solution. The more you practice, the more you learn (I am yet to teach a course where I didn't learn something new from one of my students). Finding solutions and overcoming problems continually adds to your knowledge and, in most cases, will help you deal with problems should they occur again.

There are differences between teaching survival courses to civilians and teaching them to military personnel. Civilians have enrolled on (and paid for) a course to increase their knowledge and skills, not because their life may depend on it (although, should they find themselves in a life-threatening situation, it may well do), but because they are interested in survival techniques in their own right. In contrast, the majority of military personnel who undergo survival training may very well need to put it into practice, but they invariably complete the training simply because they are required to do so. While no one in the military forces would underestimate the importance of survival training, it is a fact that, if you want to fly a Harrier, or become a US Marine Mountain Leader, survival training is just one of the many courses you must undertake.

In the military, we categorize the four basic principles of survival as protection, location, water, and food. Protection focuses on your ability to prevent further injury and defend yourself against nature and the elements. Location refers to the importance of helping others to rescue you by letting them know where you are. The principle of water focuses on making sure that, even in the short term, your body has the water it needs to enable you to accomplish the first two principles. Food, while not a priority in the short term, becomes more important the longer your situation lasts. We teach the principles in this order, but their priority can change depending on the environment, the condition of the survivor, and the situation in which the survivor finds him- or herself.

> “Understanding your **environment** will allow you to select the **best equipment**, adopt the **best techniques**, and learn the **correct skills**”

We also teach advanced survival techniques to selected personnel who may become isolated from their own forces, such as when operating behind enemy lines. The four principles of survival remain the same, but we substitute “location” with “evasion”. The military definition of evasion is recognized as: “being able to live off the land while remaining undetected by the enemy”. This involves learning how to build a shelter that cannot be seen, how to maintain a fire that doesn’t give away your position, and how to let your own forces know where you are but remain undetected by the enemy.

In military training, and with most expeditions, the equipment with which you train will be specific to a particular environment—marines operating in the jungles of Belize will not pack a set of cold-weather clothing, for example; and Sir Ranulph Fiennes won't practice putting up his jungle hammock before venturing into the Arctic! However, the standard practice of being equipped and trained for a specific environment can prove to be a major challenge for some expeditions. During my career as a survival instructor, for example, I have been fortunate enough to have worked on two of Sir Richard Branson's global circumnavigation balloon challenges with Per Lindstrand and the late Steve Fossett. For these expeditions, the responsibility for selecting the survival equipment and training the pilots was a unique, if daunting, task. The balloon would be flying at up to 30,000 ft (9,000 m) and would potentially cross every type of environment: temperate, desert, tropical rain forest, jungle, and open ocean. While it would have taken some very strong winds to blow the balloon into the polar regions, we did fly—after a brief and unplanned excursion into China—across the Himalayas.

> “The more you understand **how and why** something works, the more prepared you will be to **adapt and improvise** should it be **damaged or lost**”

We also had to train for the worst-case scenario, which would be a fire in the balloon capsule. A capsule fire would leave the three pilots no option but to bail out, potentially from a great height, breathing from an oxygen cylinder, at night, and anywhere in the world, whether over land or sea. The chances of them landing in the same vicinity as each other under such circumstances would be slim to non-existent, so each pilot would need not only the necessary equipment to address the priorities of survival in each environment, but also the knowledge to be able to use it confidently and alone. We addressed this challenge by providing each pilot with survival packs devised for specific environments, a single-man liferaft (which provides shelter that's just as good in a desert as it is at sea) and realistic training with the equipment contained in each pack. As the balloon moved from one environment to another, the packs were rotated accordingly, and the pilots re-briefed on their survival priorities for each environment.

> “There is a **thin line** between **being in awe** of an environment and **being at its mercy**”

As you read this book and plan to put the skills and techniques covered here into practice, you will typically be equipping yourself for just one particular type of environment—but it's important that you fully understand that one environment. Make sure you research not only what the environment has to offer you as a traveller—so that you can better appreciate it—but also what it offers you as a survivor: there is sometimes a very thin line between being in awe of the beauty of an environment and being at its mercy. The more you understand both the appeal and dangers of an environment, the better informed you will be to select the right equipment and understand how best to utilize it should the need arise.

Remember, no matter how good your survival equipment, or how extensive your knowledge and skills, never underestimate the power of nature. If things aren't going as planned, never hesitate to stop and re-assess your situation and priorities, and never be afraid to turn back and try again later—the challenge will always be there tomorrow. Finally, always remember that the most effective method of dealing with a survival situation is to avoid getting into it in the first place.

Colin Towell

> Twenty years from now you will be **more disappointed** by the things **you didn't do** than by the **ones you did do**
>
> MARK TWAIN

BEFORE YOU GO

PREPARE YOURSELF

Most survival situations arise in one of two ways: either you are thrust into a situation not of your making and beyond your control, or (as is more often the case) a situation develops because of a sequence of events that could have been avoided had you recognized the danger signs and acted on them at the earliest opportunity. Unfortunately, most survival situations occur as a result of ignorance, arrogance, an overconfident belief in one's own ability, or because the forces of nature have been underestimated.

In the military forces, troops prepare for survival situations by learning the basic principles and techniques and then practicing them until they become second nature. The more you practice a particular survival skill, the more you'll understand how and why it works, and the more you'll understand your own strengths and weaknesses. Many helicopter crew members who have been involved in a survival situation, for example, report that, having ditched their aircraft in the sea, they could not remember how they subsequently

In this section YOU WILL DISCOVER...

- how keeping **in shape** can keep you **out of trouble...**
- the importance of a **positive mental attitude...**
- that where there's a **will to survive** there's a **way to survive...**
- the difference between a **coping strategy** and an **aggravating factor...**
- how **"show-stoppers"** could **scupper your trip...**
- why an **emergency plan of action** could **save your life...**

escaped from their aircraft and successfully boarded their liferaft. Thanks to their intense training regime, their actions had become instinctive and therefore subconscious.

Whether you're preparing for an overnight camping trip or a year in Africa, the more prepared you are to meet the challenges posed by a particular environment, the more likely you are to be able to cope—both physically and mentally—should you then find yourself confronted with a survival situation.

It would be foolish to think that the amount of prior preparation required for an expedition is directly related to the length of the trip or its perceived danger.

ACCIDENTS CAN HAPPEN anywhere. One of the most important things you can do to improve your chances of survival is to let people know where you're going and when you'll be back. Leave an itinerary of your trip with family or friends, and arrange a time when you will call to let them know you are safe.

In many instances, simply making sure you have a cell phone with you can prevent an accident becoming a major survival incident. In 2007, a professional athlete, out running with her dog in Moab, Utah, slipped on ice, fell approximately 60 ft (18 m), and broke her pelvis. Having left her cell phone in her vehicle, she managed to survive for two nights in the freezing desert before rescuers were finally lead to her by her dog.

In a separate incident in 2008, a farm worker in the UK caught his arm in machinery. Unable to attract attention and not having his cell phone with him, he was faced with a stark choice when the machinery caught fire: bleed to death, burn to death, or cut off his own arm with a pocket knife—he chose the latter.

> “Never assume that the amount of **prior preparation** required is directly related to the length of a trip or its **perceived danger**”

GETTING INTO SHAPE

IN ANY SURVIVAL SITUATION you're likely to be at your best, both physically and mentally, in the moments before the situation occurs. From that point on, through lack of sleep, food, and water, your situation will deteriorate until your rescue. Being in good physical condition will help you overcome the challenges you'll face in a survival situation.

KNOWING YOUR LIMITS

Having an idea of how fit you are and knowing how much you are capable of achieving before entering the wilderness means you can set yourself realistic goals—which will help to keep you out of danger.

THE BENEFITS OF EXERCISE

Over time, exercise induces changes such as weight loss, as well as improved posture, physique, strength, agility, mental alertness, and stamina. These are all vital attributes should you find yourself in a survival situation.

HOW FIT ARE YOU?

A fit heart pumps blood more slowly and efficiently than an unfit one. The hearts of women, children, and older people beat faster than those of young adult males. Take your pulse first thing in the morning—this is known as the "base rate." As the table below shows, the faster your pulse returns to its base rate after a period of exercise, the fitter you are. Note that < denotes "less than" and > denotes "more than".

AGE	20-29	30-39	40-49	50+
RATING	**BASE RATE**			
MEN				
Good	<69	<71	<73	<75
Average	70-85	72-87	74-89	76-91
Poor	>85	>87	>89	>91
WOMEN				
Good	<77	<79	<81	<83
Average	78-94	80-96	82-98	84-100
Poor	>94	>96	>98	>100

AGE	20-29	30-39	40-49	50+
RATING	**BEATS AFTER EXERCISE**			
MEN				
Good	<85	<87	<89	<91
Average	86-101	88-102	90-105	92-107
Poor	>101	>102	>105	>107
WOMEN				
Good	<93	<95	<97	<99
Average	94-110	96-112	98-114	100-116
Poor	>110	>112	>114	>116

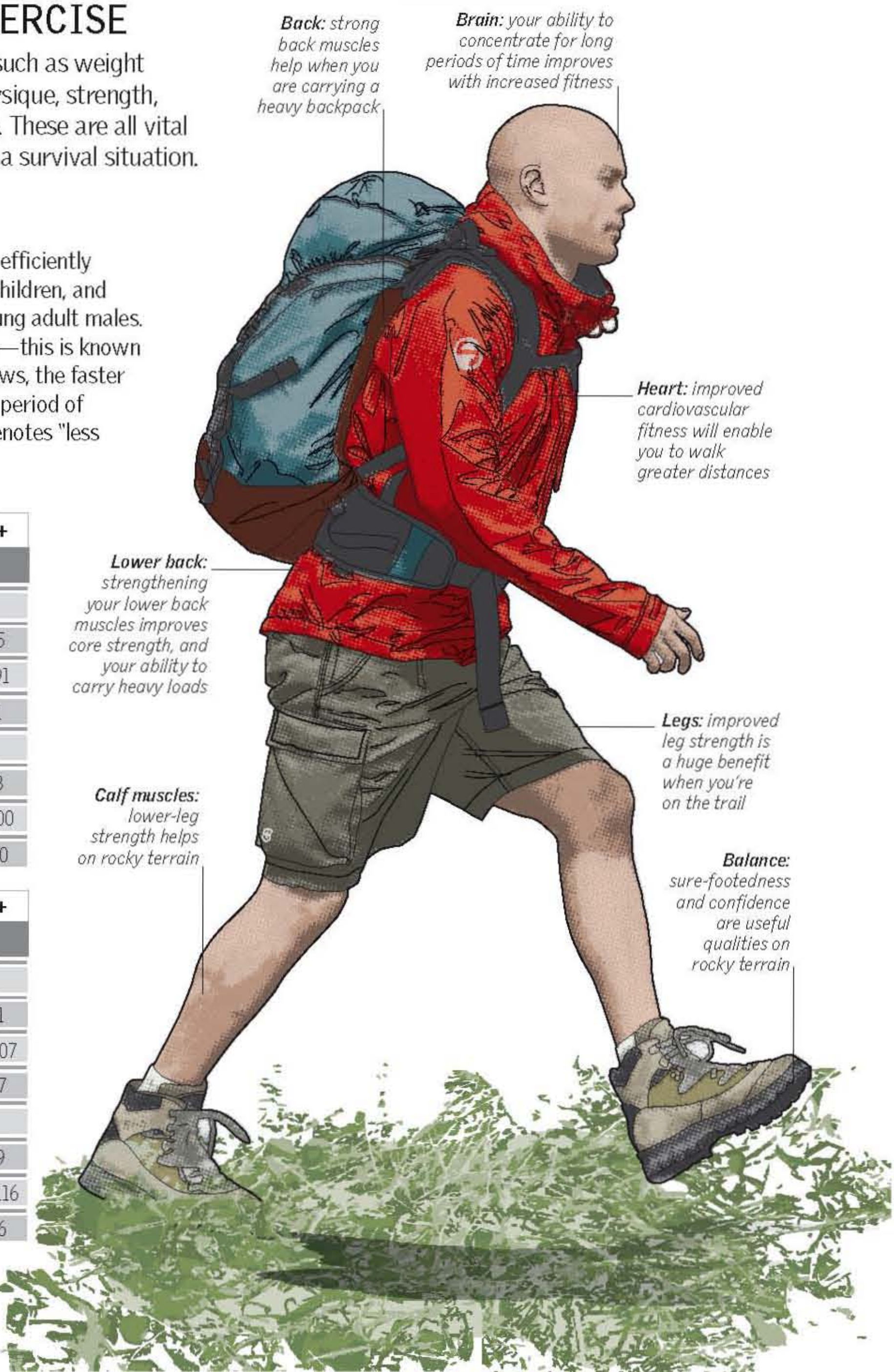
Back: *strong back muscles help when you are carrying a heavy backpack*
Brain: *your ability to concentrate for long periods of time improves with increased fitness*
Heart: *improved cardiovascular fitness will enable you to walk greater distances*
Lower back: *strengthening your lower back muscles improves core strength, and your ability to carry heavy loads*
Legs: *improved leg strength is a huge benefit when you're on the trail*
Calf muscles: *lower-leg strength helps on rocky terrain*
Balance: *sure-footedness and confidence are useful qualities on rocky terrain*

FIT FOR THE CHALLENGE

Survival fitness is not about trying to run the 100 meters in 10 seconds; it's about stamina and endurance, and about knowing your physical limitations and being able to work with them. It is also about understanding that you may have to push yourself beyond your limits and that having a positive mental attitude is paramount to survival—the mind will often give up long before the body has reached its limit. Bear in mind that every task in a survival situation will sap your energy.

EXERCISING REGULARLY

Any effective training schedule must include at least three 45-minute sessions per week, with exercises that raise the heartbeat to more than 120 beats per minute.

STARTING A FITNESS PROGRAM

To spend time in the wilderness with a pack on your back requires a combination of strength and aerobic fitness. Training in the gym before you set off will strengthen your heart, lungs, and leg muscles, and will increase your stamina levels when you are out on the trail.

- Seek expert instruction and guidance wherever possible.
- Start gradually and then build up your routine progressively.
- Never try to work through injuries—rest and seek medical advice.
- Devise a relevant fitness program; there are many websites and organizations that provide you with detailed fitness programs for various levels of specific activities, from training for a trek through the jungle to mountain-biking along the Appalachian Trail.
- Duplicating in training what you'd like to be able to achieve on the trail will allow you to build up reference points about how your body works, and how it copes in different situations. The more you know about how you perform, the better equipped you'll be on the trail.

WARMING UP AND COOLING DOWN

Time spent warming up and cooling down after exercise will help to improve your endurance levels and will also accelerate the recovery process. Get into the habit of starting and ending your session with a five-minute jog.

GO FOR A CHECK-UP

It's a sad fact that the majority of us don't have regular medical check-ups. Many people work on the principle that you only need to see a doctor or dentist if something is wrong. However, you should always make sure that you start any adventure or wilderness trek in top condition. Therefore, before you set out, pay a visit to your doctor and dentist and make sure that your body and teeth are in good condition.

VISIT THE DOCTOR

- Let the doctor know of any ailments that have been a concern to you during the course of the previous year.
- Tell the doctor where you are going and enquire about relevant inoculations or medication that you should be taking with you.

VISIT THE DENTIST

- Have any problems with your teeth dealt with before you go. Any minor dental problem will almost certainly turn into full-blown toothache when you least want it to.

USEFUL EXERCISES

If you already get regular exercise, you'll find yourself far more comfortable in a survival situation than your more sedentary counterparts. Any pre-expedition training regime should include plenty of stretching, aerobic exercise, and weight-training.

STRETCHING YOUR UPPER BODY AND BACK

Regularly stretching your arms, neck, chest, and shoulders will help your body to maintain a strong core. This will be of great use when it comes to activities such as rock climbing or using trekking poles. Undergoing a regular back-stretching routine will loosen the back muscles, making them more flexible and less susceptible to injury, and will increase both the back's range of motion and its endurance.

STRETCHING YOUR LEGS

Because your leg muscles bear the brunt of the work, leg stiffness is a common complaint at the end of a long day on the trail. Stretching your legs will improve your flexibility, increase blood circulation, and relax your muscles. Concentrate on your calves, quads, and hamstrings.

AEROBIC EXERCISES

Also called cardiovascular fitness, aerobic fitness refers to the ability of your heart, blood vessels, and lungs to supply oxygen and nutrients to the rest of your body during sustained physical activity. Regular aerobic exercise—such as swimming, jogging, or cycling—will reduce the risk of developing coronary heart disease or high blood pressure, will help you to manage your weight and increase your stamina levels, and will make your heart stronger and more efficient, thus improving blood flow around your body.

WEIGHT-TRAINING

Increased muscle strength will enhance your ability to perform everyday tasks such as lifting, carrying, and walking. A regular weight-training program will improve your posture, build muscle density around the joints and bones, improve your sense of balance, help your stress management abilities, aid sleep, and reduce the chances of you sustaining an injury. In addition, research has shown that a regular resistance-training program can improve your metabolic rate by up to 15 percent, which will help you shed any unwanted weight at a faster rate.

MENTAL PREPARATION

REGARDLESS OF WHETHER you're backpacking through a remote area, or on a day hike in familiar territory, a situation may arise that changes your circumstances for the worse. Very quickly you move into the unknown, which causes tremendous psychological and emotional stress, known as "psychogenic shock." Understanding this will help you to deal with it better and reduce its impact.

INDIVIDUAL REACTIONS TO DISASTER

People react to survival situations in different ways, although you can expect to find some common emotional reactions in victims who are experiencing, or have survived, a disaster situation. You may experience one or more of them during or after any survival experience or trauma.

YOUR RESPONSE TO DISASTER SITUATIONS

Your psychological response to a survival situation is crucial. Statistics show that 95 percent of people who die with psychological trauma die within the first three days. Losing the will to survive—or suffering psychological disorders that prevent you from coping with the physical conditions—is your main concern. If you break down psychologically, your chances of overcoming a situation will be compromised.

PSYCHOLOGICAL PROGRESSION

It's useful to examine how people are likely to react in a survival situation. Using this knowledge, it's possible to prepare mentally for such eventualities and, in so doing, lessen the impact if the worst should happen to you when out on the trail. Normal psychological reactions to disaster tend to occur in a set pattern of four stages: the pre-impact period, the impact period, the recoil period, and the post-trauma period (see right). Contrary to popular belief, people don't normally panic, although it can be contagious if someone does.

AGGRAVATING FACTORS	HUNGER	THIRST
Reactions to disaster can result from a direct blow to the psychological system, such as extreme shock, but they can also be brought on, or aggravated by, other factors. As with all psychological problems, knowing what these aggravating factors are, and attempting to avoid them—or at least recognizing what they might lead to—will maximize your chances of preventing or overcoming the problem. The most common aggravating factors are: hunger, thirst, fatigue, seasickness, and hypothermia.	Initially, hunger is not a problem, but a long-term lack of food will cause psychological changes to occur. Symptoms include: ▪ Apathy ▪ Irritability ▪ Depression ▪ Lack of concentration	Thirst is a serious problem, especially for survivors at sea or in the desert, and its effects are more acute than hunger. Agitation is commonplace; other symptoms include: ▪ Irrational behavior (see box, right) ▪ Delusions ▪ Visual hallucinations

COPING STRATEGIES	TRAINING	MOTIVATION
There are many things you can do to prepare yourself psychologically for a survival situation—such as learning about what you should expect if the worst were to happen—and to cope better if you find yourself in one. As with all survival skills, prior knowledge is power, and will help you to deal with a survival situation far more successfully. The main areas to think about are: training, motivation, attachment, hope, acceptance, and helping others. Developing coping strategies is an important technique for survival.	People who are properly prepared, who know their environment and how to use their equipment, and have an understanding of what to expect in a survival situation, will be far more effective if they find themselves in one. Adequate training and practice using your equipment will help you to function effectively at an automatic level. Prior knowledge is key to your survival.	Often known as "the will to survive," motivation involves a refusal to accept death, and to hang on to the belief that you were not meant to die under these conditions. It involves overcoming the emotional and physical discomforts of extreme conditions. Linked to motivation is the ability to establish goals, work out the steps to those goals, and to follow those steps through.

PANIC

Panic arises from the fear of what might happen rather than what has happened. It tends to occur when people are trapped, or if there is a time limit to their escape.

DEPRESSION

Depressed people will sit among chaos and debris vacantly gazing and not replying to questions. They're unaware of their situation and unable to help themselves, so risk further injury.

HYPERACTIVITY

Hyperactive victims are easily distracted, and are full of chatter, ideas, and often unhelpful suggestions. Sufferers can reach this stage after a state of depression.

ANGER

Aggression, anger, and hostility are common reactions to trauma. They're often irrational and may even be directed at the rescuers or medical staff trying to help them.

GUILT

Some sufferers feel guilty for surviving, and for not having done enough for others—and some irrationally blame themselves for bringing about the incident.

SUICIDE

Disaster victims have been known to commit suicide immediately after being rescued, in some cases when they're already safe in the hospital. Victims should be closely monitored.

Pre-impact period

The "pre-impact" period is divided into two stages:

- Threat: danger exists but, though obvious to those who recognize it, those who will not accept it respond with denial and under-activity.
- Warning: threat of danger is now apparent to all; response is now likely to be over-activity.

Impact Period

This is the life-threatening stage. Statistically, individuals behave in one of three ways:

- 10–20 percent of people are calm and retain full awareness.
- Up to 75 percent of people are stunned, bewildered, and unable to react rationally.
- 10–25 percent exhibit extreme behavior, such as screaming.

Recoil period

This follows on directly from the impact period; for example, victims may have escaped a sinking ship and are in the liferafts. It can last for up to three days, but generally lasts for around three hours. In most cases, it is characterized by a gradual return to normal reasoning abilities, awareness, and emotional expression.

Post-trauma period

If the recoil period is not fully successful, individuals may develop psychiatric disorders. The full impact of the incident becomes apparent and a range of emotions—guilt, depression, anxiety, aimlessness, and a feeling of bereavement—may develop. These are often referred to as Post-Traumatic Stress Disorders (PTSD).

FATIGUE

In many cases, physical exhaustion is present from the outset. At other times, it may result from sleep deprivation and the physical hardship endured over time. Most survivors agree that fatigue overwhelms them, but when they want to sleep they can't—they have an inability to relax. Fatigue causes a deterioration in mental and physical performance, followed by a psychological and physical debility.

SEASICKNESS

Seasickness often brings about an overwhelming desire to curl up and die, which in survival situations can easily become a reality. It's important not to give in to this urge. Fight seasickness with the following methods:

- Keep a fixed point such as the horizon in sight.
- Take small sips of water (not salt water) if you have sufficient supplies—but ration them if you're in a life or death situation.

HYPOTHERMIA

Hypothermia (see p. 273) produces both physical and psychological effects—the psychological consequences occur early in the condition, and cause:

- Loss of concentration
- Loss of memory
- Motor impairment
- Faulty decision-making
- Irrational behavior

IRRATIONAL BEHAVIOR

Irrational behavior can take many forms. Examples include the earthquake victims who were found collecting flowers instead of helping the injured, and famously, the band of the *Titanic*, who played while the ship sank rather than trying to save themselves.

ATTACHMENT

One of the strongest motivating forces for survival is the desire to be reunited with principal figures of attachment in your life. These may include:

- Husbands
- Wives
- Partners
- Children
- Grandchildren
- Close friends

HOPE

To hope means to entertain ideas that a distressing situation will improve and get better. In any survival situation it's important to cling onto hope, despite information or perceptions to the contrary. Thinking positively will help to ward off psychological trauma. It's often easier to be optimistic in a group situation than it is if you're on your own, as people can support each other.

ACCEPTANCE

An inability to accept one's situation or condition leads to frustration, anger, and irrational behavior, and it's important to avoid these feelings in a survival situation. The ability to accept the situation doesn't equate to giving in to it—far from it. Those who have this ability, and know when to be active and when to be passive often have a better chance of long-term survival.

HELPING OTHERS

First, monitor your own condition and check that you're really up to the task. Determine who is genuinely disturbed rather than showing "normal" reactions. Psychological first aid is only required for those who are failing to recover. Simple words of comfort and interest will make the majority who are numbed more responsive. Those who are disturbed should be monitored closely. Avoid giving sedatives.

PLANNING YOUR JOURNEY

WHETHER YOUR TRIP involves a day out with your backpack, or a full expedition over weeks, crossing continents in four-wheel-drive vehicles, you need to plan it very carefully. The plan for your day out won't be as detailed as it would be for the longer expedition, but it's equally important. It's a good idea to have a basic planning outline for your most regular trips, to which you can add supplementary information as your trips become more involved.

MINIMIZING THE "IF ONLY"

There's no way that you can plan for every eventuality—there are just too many variables—but what you can do is look at the type of trip you intend to take, and ensure that if a situation arises you're not left wishing you'd done something differently. The time to minimize the chances of an "if only" situation is during the planning stage. Look at the potential problems and risks, plan to avoid them, and equip yourself with the knowledge and/or equipment to deal with them if they arise.

WARNING!

The social customs of a country are not the same all over the world. Many cultural differences stem from ancient cultural or religious pasts, and are taken extremely seriously. While ignoring or breaking some customs may lead only to embarrassment, breaking others can result in a penalty, punishment, or even imprisonment. Cultural differences may require females in your group to dress so that they don't show bare arms or legs, or they may dictate which hand you use to greet someone politely. Always research a country's customs thoroughly when planning your trip.

THE SIX P'S

Remember the six p's: **P**rior **P**lanning and **P**reparation **P**revents **P**oor **P**erformance. Research has shown that the longer and more complicated the trip is, the less likely there is to be a major "survival" situation. This type of trip is likely to be well organized, and potential problems will have been considered. This means that they can either be avoided, or that there will be mechanisms in place to deal with them. In many ways, simply having a good understanding of how to deal with a situation, and being able to interpret the basic principles of survival, can prevent a minor problem from escalating into a disaster. In a survival situation, it may be your knowledge, combined with your ability to improvise, that determines whether you become a survivor or a statistic.

ORGANIZATIONAL PRIORITIES

When planning for a trip always start with the most important things—known as the "show-stoppers." These are generally the things that would actually stop the trip from happening in the first place if not organized in advance. If you then work backward from the show-stoppers to items that would simply make the trip more comfortable, most other things will fall into place. The chart on the right lists the things that you definitely cannot do without.

	SHOW-STOPPERS
MONEY	▪ You'll need enough to cover your needs plus extra for emergencies. ▪ It must be in the correct currency for the country you are visiting. ▪ Ensure your ATM card is set up for use in that particular country. ▪ Make sure you have a secure way of storing your money.
PASSPORT	▪ Your passport must be valid. If you need to renew it, do so well in advance. ▪ Some countries require your passport to be valid for a number of months after your visit. ▪ Keep your passport number in several places, such as inside your survival kit. ▪ Keep your passport safe, and in a waterproof container, such as a Ziploc bag.
VISA	▪ Research the regulations regarding visas relevant to the countries you're traveling to. ▪ Find out how to apply, how far in advance you should apply, whether or not you can apply in the country, and what other documents you need. ▪ As with your passport, always keep your visa safe, dry, and in good condition.
VACCINATION	▪ Check the regulations for the country—many have strict vaccination policies. ▪ Ensure you have the vaccinations, and any boosters, within the correct timeframe. ▪ Some inoculations last only for six months, so for extended trips you might have to have more while away. This can usually be arranged through local hospitals or clinics.
TICKETS	▪ Make sure you have the correct tickets for your journey. ▪ Read the tickets and make sure they have the correct names, dates, and locations. ▪ Should you need to prove your movements, always keep your tickets in a safe place and never throw them away—often the return journey is included on the same ticket.
INSURANCE	▪ It's advisable to get insurance against your trip being cancelled. ▪ Ensure that your insurance will cover your medical expenses should the worst happen. You don't have to be climbing Everest—even a twisted or broken ankle when hill-walking could prove to be very expensive if you don't have adequate insurance.

YOUR TEAM

If you're embarking on a trip with a group, remember that team dynamics will play an important part in the success, or otherwise, of your trip. Stressful situations—and particularly survival situations—can bring out the best, or the worst, in people. When planning a long trip, it's always a good idea to plan several shorter trips beforehand, to use as practice sessions. These will not only help you decide what equipment to take, and provide you with an opportunity to practice using it, but will also allow team members to assess how they work together as a group. This can help you to organize your team more effectively.

MIXED-GENDER GROUPS

If the team has both male and female members, it's important to factor this into the planning stage. You'll need to consider sleeping and washing arrangements, who carries what, who is responsible for what, and so on. All this should be planned in detail before you set off. It should also be noted that taking it for granted that the women will cook the meals while the men make the shelters is not the best way to start an expedition.

MIXED-AGE GROUPS

When planning your trip, remember that different age groups may have different levels of fitness, which will affect the pace of your group. However, what older members may lack in pace, they may make up for in expedition experience.

PREPARATION THROUGH TRAINING

Training yourself both mentally and physically—and practicing with the equipment you'll be using—may seem like the obvious thing to do, but in many cases the obvious can often get overlooked. You'll get the most out of your trip if you're mentally and physically prepared to a level that means you can operate within your own capabilities and comfort zone. This will allow you to enjoy and appreciate the experience, as opposed to just getting yourself through it.

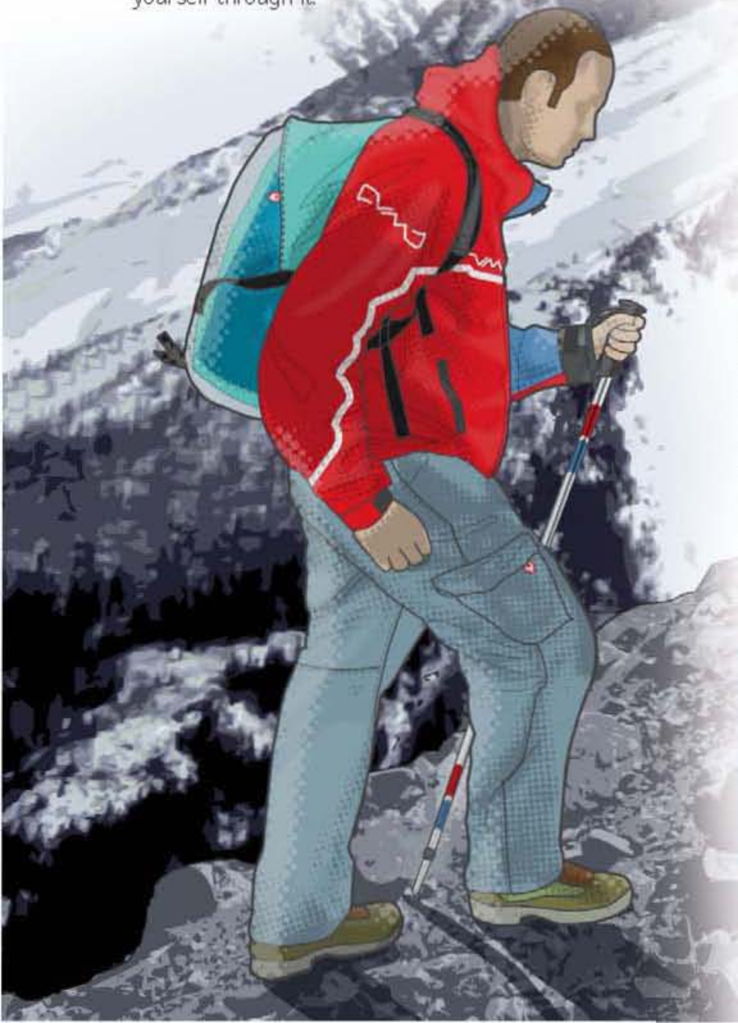

TRAINING YOURSELF

Duplicate in training what you intend to do on your trip. Build up your training gradually, over a period of weeks and months, and take into account the following:

- **The environment**: research the weather conditions you'll be facing, and look at the extremes as well as the average. For example, desert areas may be hot during the day, but can drop to below freezing at night.
- **Weight:** increase the amount of weight you carry until you're eventually carrying what you intend to take. This will not only condition you to the weight but also help you to decide just what's important to take and what's not.
- **Distance:** if your trip involves covering a certain distance a day, then train for that distance. This will give you an indication of whether it's achievable and sustainable.
- **Language**: if visiting a country in which your native language is not widely spoken, it will be beneficial if you can learn some useful phrases. Take a phrase book or an electronic translator.

TRAINING WITH EQUIPMENT

Use your equipment as much as you can, and find out the best way to operate it through practice under realistic conditions (see box, below). This will highlight its strengths and weaknesses, and allow you to determine both its capabilities and your own—the compass may be working perfectly, but practice may highlight the fact that you're not confident enough using it, in which case you'd need to do further training before you set off on your expedition. The wrong time to be trying to find the jack and spare wheel on your rented vehicle is at night, in the rain, with the mosquitoes looking at you as their next free meal. Before you set off, always think about the various skill demands required, and ensure that you're capable of addressing those demands.

OPERATING UNDER REALISTIC CONDITIONS

When training with new equipment, always practice using it under realistic conditions. For example, if you're going to be using your GPS in cold conditions, can you operate it using the gloves you have selected? If you're pitching a tent, have you got **all** the necessary components, and can you put it up in the dark and rain?

EMERGENCY PLAN OF ACTION

UNFORTUNATELY, EVEN THE MOST meticulously planned, thoroughly equipped, and best-executed trip can run into difficulties. Unforecasted strong winds could trap you and your kayak on an island overnight, or a sprained ankle could leave you unable to climb down the rocks you climbed up so easily. Each of these survival scenarios are difficult to predict, but could easily happen.

USING YOUR EPA

An EPA should contain up-to-date information about you as a person. This may change very little over the years, so you may only need to create a standard EPA and just update the details specific to each trip.

RUNNING INTO PROBLEMS

It's important to make sure that you have done all you can to help yourself, and help any rescue attempt that might take place if you do have any problems. Always remember that there are two sides to any survival or rescue situation: the part that you play and the part that the rescue services play. However, the effectiveness of the rescue services can be greatly increased when they have access to all relevant information—in many cases this arrives too late. It's vital to keep people informed of your intended whereabouts, so that they can raise the alarm if you deviate from your plans.

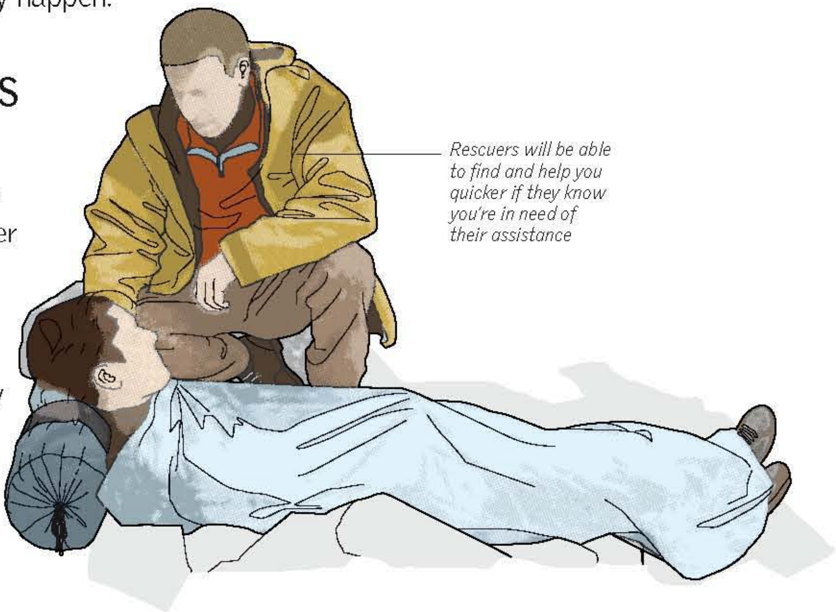
Rescuers will be able to find and help you quicker if they know you're in need of their assistance

WORST-CASE SCENARIO

In the military, every mission that's undertaken, particularly in a theater of conflict, has plans in place for the worst-case scenario. Each part of the mission is meticulously planned, and the team completes a form that states what their basic intention will be should anything happen during the various stages.

IF THE WORST HAPPENS

Having planned for the worst, should the team find themselves in difficulty, the rescue group will not have to try to second-guess what the team will do—they will have a clear indication of the team's intent and can plan effectively and decisively around this information. The team will be found quicker as a result. It's a good idea to apply this principle to your own trip.

KEEPING PEOPLE INFORMED

A good way of keeping your friends, family, and the relevant rescue services informed of your whereabouts is to write down the details of your trip, including pertinent itinerary places and dates, so that if you don't reach your destination when planned, the alarm can be raised. Similar to the "worst-case scenario" principle practised by the military (see left), an "emergency plan of action" (EPA) should be prepared by anyone venturing into the great outdoors (see right). Give a copy to your next of kin and group members, and keep a copy on your person. Where applicable, inform local services, such as park and ranger stations, of your intentions. Remember to inform these people when you arrive safely at your destination.

WRITING AN EMERGENCY PLAN OF ACTION (EPA)

The best way to determine what should be included in your plan is to look at the worst-case scenario you could find yourself in, and ask yourself what information your next of kin would need to know about you and your intentions if they felt they had to raise the alarm. In addition, if you did go missing—particularly in another country—there are many things that the relevant rescue services would need to aid their efforts, for example a recent photograph, your passport details, what equipment you have with you, what languages you can speak, and your skills. The clearer their understanding of you, your abilities, and your intentions, the easier their job will be. In addition, the more information your next of kin have, the more proactive they will feel in your rescue.

EMERGENCY PLAN OF ACTION FORM

Full name as appears on passport:
John William Smith

Date of birth:
(dd/mm/yy)
05/28/60

Height: *5' 10" (178cm)*
Weight: *168 pounds (76 kilos)*
Hair color: *Brown*

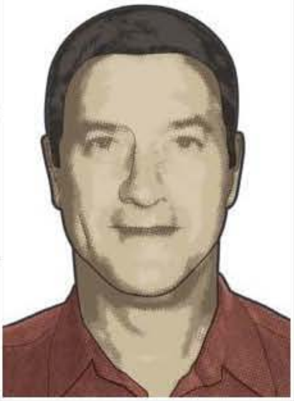

Passport number:
2008XXXXX63
Expires:
11/03/13

Driver's license number:
JHY280771smit
Expires:
12/28/22

Distinguishing marks (scars, tattoos):
Small scar—center of forehead
Large scar—right hand, middle finger
Chinese symbol tattoo—right arm

Languages spoken (fluent/basic):
English—native
French—basic
German—basic

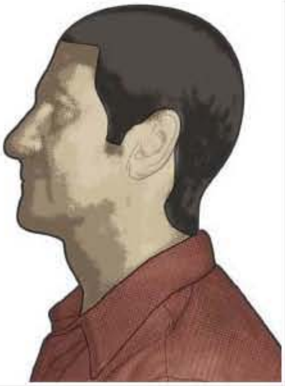

Medication:
Medication—anti-malaria tablets

Allergies:
Amoxicillin

Swimmer: *Strong swimmer*
Outdoor skills/experience:
Attended basic military survival training.
Attended basic bushcraft course
Experienced in living outdoors

Next of kin 1: *Father*
William Smith
1018 Furlong Avenue
Brunswick, Maine,
USA 04555

Next of kin 2: *Brother*
Andrew Smith
1023 Parkglen
Ashford, Kent,
TM24 5HZ
UK

Tel: *(001) 55 555 2356*

Tel : *(0044) (0)155 555 2357*

Email: *willsmith@internet.com*

Email: *andrewsmith@internet.com*

Trip details:
Campsite 1 = Grid ST456654
Campsite 2 = Grid ST654987
Vehicles: Landrover 1 = white, reg MH55 555
Landrover 2 = blue, reg MH56 555
Group = Ben Jones, Kim Smith, and myself
Day 1: Park Landrover 2 at Campsite 2, and drive in Landrover 1 to Campsite 1
Day 2: Follow well-defined path along the Derwent Line Trail, aiming to camp overnight at Grid 4561559
Day 3: Continue along the Derwent Line Trail, aiming to be at Campsite 2 by mid-afternoon. Camp overnight at Campsite 2
Day 4: Travel in Landrover 2 to campsite 1 and retrieve Landrover 1

Foreseeable problems/intentions:
Day 1: None
Day 2: None but will use Ranger Station 18, grid 555555 (Tel. 666 6666) as an emergency rendezvous point
Day 3: None but will use Ranger Station 19, grid 666666 (Tel. 555 5555) as an emergency rendezvous point
Day 4: None

Communications plan:
Will speak to Dad on the morning of Day 1 and try to phone during the trek but am unsure of cell reception once on the trail so don't worry if you hear nothing.
Will phone Dad again when we reach campsite 2 on day 3.

My mobile: *07979 555555*
My email: *jws@internet.com*
Alt. No: *Ben 05555 555555*
Alt. No: *Kim 05555 555555*
Alt. No: *Campsite 1 555 555 55555*
Alt. No: *Campsite 2 555 555 55555*

Date: *November 23, 2009*

KNOW YOUR ENVIRONMENT

The continued survival of the human race can be attributed to our ability to adapt to our environment. While we may have lost some of our ancient ancestors' survival skills, we have, in their place, learned new skills as and when they have become necessary. The issue we face today is that the gap between the skills we once had and the skills we now have grows ever wider as we rely more heavily on modern technology. Therefore, when you head off into the wilderness, it is important to fully prepare for the environment.

Before a trip, research how the native inhabitants dress, work, and eat. How they have adapted to their way of life will help you to understand the environment and allow you to select the best gear, adopt the best techniques, and learn the correct skills. This is crucial given that most survival situations arise as a result of a sequence of events that could have been avoided—while you may have no control over the aircraft crashing, for example, you can recognize a change in the weather and choose whether to continue or turn back.

In this section YOU WILL DISCOVER...

- the difference between **tundra** and **taiga...**
- why you should **step-up** the size of your **survival footprint...**
- the **way to go** when it comes to **snowy peaks** or **swampy creeks...**
- how to avoid **getting lost** in the **permafrost...**
- the best way to **stay at the top** of the **food chain...**
- how to **feel at home** where the tropical **butterflies roam...**
- how a high-visibility **survival suit** could really **get you noticed...**

The four basic principles of survival are:

protection, location, water, and food. In most survival situations, this is also the order in which you should prioritize them.

P **PROTECTION** You must stay in a condition that allows you to be proactive in your continued survival and rescue. Physically, you should protect yourself against injury, the elements, and wildlife. Mentally, you should protect yourself against emotions that could rob you of the will to live: fear, guilt, despondency, and depression, for example. The best way to achieve this level of protection is to light and maintain a fire. Not only does it offer physical protection against the elements and wildlife, but it also provides a sense of security and familiarity that can help normalize even the most dire situation.

L **LOCATION** Your second priority is to recognize the importance of your location to your chances of survival and rescue. You will usually have two options: stay or go. Your preferred option should be to remain where you are and use anything at your disposal to mark your location to aid rescuers in their efforts to find you. If you can't stay where you are (perhaps because you are in imminent danger) you may have no option but to move to another location that provides either a better chance of survival or rescue, or both. Select a location aid that offers you the best chance of attracting attention in the environment in which you're traveling.

W **WATER** Put simply, water is the essence of life. While you may be able to survive for a few days without it, your ability to function and carry out even simple mental and physical tasks will be dramatically reduced in less than 24 hours. However, if you are injured, if the weather conditions are very hot, and if your workload is particularly heavy, for example, your survival time without water could be reduced to just a few hours. You should learn how to procure water in the particular environment in which you're traveling, and understand the ways in which a lack of water affects you.

F **FOOD** The importance of food is directly related to the length of time you are in a survival situation: the longer the situation lasts, the more important food will become in helping you stay fit and healthy. Even with a moderate workload, going without food for five to seven days will not kill you. You will, of course, feel hungry, you will grow tired, your movements will slow, and your body will lose its ability to repair itself. However, unless you're malnourished before you enter a survival situation, you are unlikely to starve to death within a week. Your body needs water to digest food, so always remember to prioritize water over food.

> “We rely so heavily on **modern technology**: water at the **turn of a tap**; heat at the **flick of a switch**; food raised, harvested and **prepared by others**”

TEMPERATE ENVIRONMENTS

THE TEMPERATE ZONES are the two regions between the Tropic of Cancer and Arctic circle, and the Tropic of Capricorn and Antarctic circle. Typified by seasonal variations in climate, conditions can include baking hot summers, freezing cold winters, and rainfall all year round. Landscape features range from forests and snow-covered peaks to grasslands and deserts. Although most temperate regions are highly populated, don't be lulled into a false sense of security—a worst-case scenario can still arise just a few miles from help.

WARNING!
Brown bears inhabit extensive wilderness areas in the northern temperate zone, and are the most dangerous temperate animal. The Grizzly, found in North America, is the most likely to attack humans.

TEMPERATE FEATURES

Although they contain a wide range of environmental features, the temperate zone's typical feature is forest, ranging from deciduous trees that shed their leaves in fall to coniferous trees that retain their leaves all year round. Grassland predominates where forests have been cleared, while highland areas contain hills and mountains. The abundance of rain means that rivers and lakes are common, and swampy wetlands form in areas with poor drainage.

TEMPERATE ESSENTIALS

Climate and terrain can vary widely in temperate areas, so preparation for a range of eventualities is essential:

- Don't underestimate the temperate environment. Although the vast majority of the human race lives in temperate zones, the diversity of terrain and weather means that survival equipment and knowledge must be broad enough to cope with a wide range of situations and conditions.
- Temperate weather can change very quickly, so check the local forecast before you set off, and carry a small AM/FM radio so you can listen to local weather reports.
- Plan a realistic and achievable route, and prepare an EPA (see pp. 24–25). Be ready to re-assess your route during the trip.
- Take clothing for the full range of conditions you may encounter.
- Carry a survival kit (see pp. 60–61), knife, emergency equipment, cell phone, and first-aid kit (see pp. 260–61)—and know how to use them.
- Carry adequate water, and equipment to collect and purify more if necessary.
- Carry some form of basic shelter, even if only going out for the day.
- Always take a map and compass, and consider using a GPS as an aid.

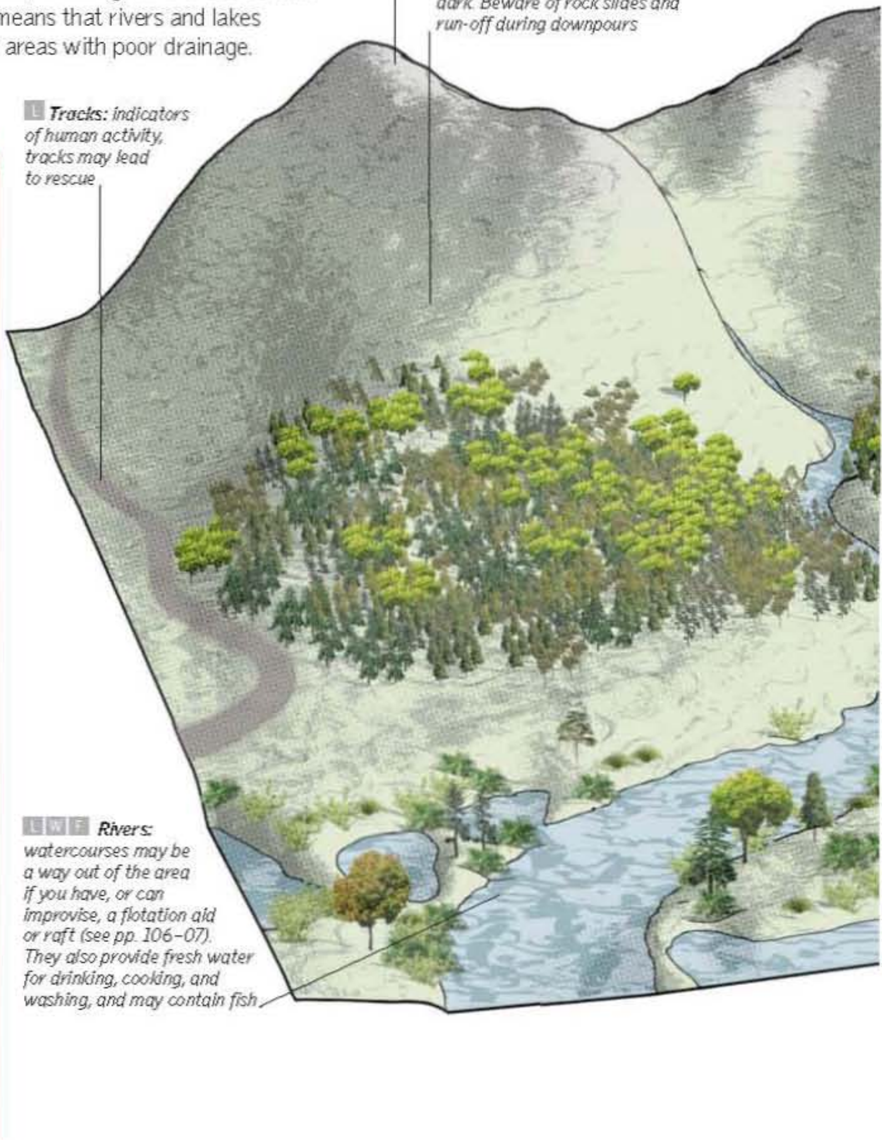

L ***High ground:*** *elevated areas afford a view of your surroundings and may indicate which area offers the best prospects for your survival, or where to go to find rescue*

P L ***High ground:*** *night-time temperatures are lowest at altitude, so descend to warmer levels before dark. Beware of rock slides and run-off during downpours*

L ***Tracks:*** *indicators of human activity, tracks may lead to rescue*

L W F ***Rivers:*** *watercourses may be a way out of the area if you have, or can improvise, a flotation aid or raft (see pp. 106–07). They also provide fresh water for drinking, cooking, and washing, and may contain fish*

WHERE TO FIND TEMPERATE AREAS

Deciduous forests are scattered throughout the temperate zones, but the largest occur in eastern North America, western Europe, and east Asia. Extensive coniferous forests are found in the higher latitudes of North America and Eurasia, while grassland is most common in continental interiors.

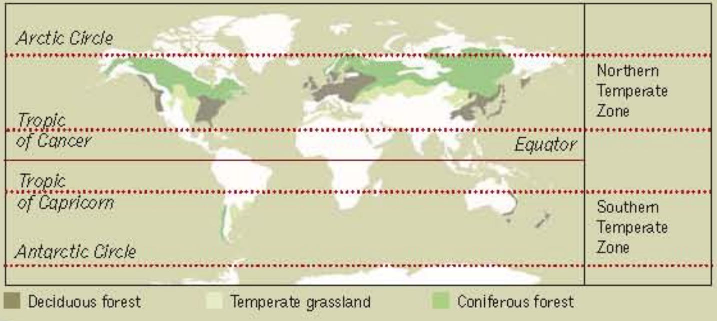

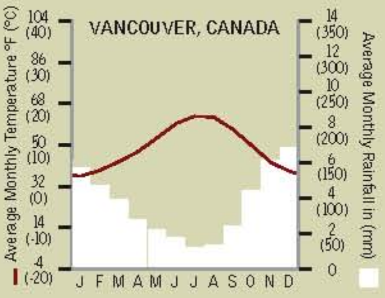

TYPICAL CLIMATE

Vancouver lies on the Pacific coast of Canada, and experiences a typical temperate climate of warm summers and cool, wet winters.

SURVIVING IN TEMPERATE AREAS

Most temperate environments have a relatively mild climate and good natural resources, making them favorable places for long-term survival. Water can be found in most areas, wood for building shelters and lighting fires is usually abundant, and different types of edible plants and animals can be found at different times of year if you know where to look. Potentially the greatest threat is hypothermia (see pp. 272–73), a particular problem in cold, wet and windy conditions, especially in winter and at night, when temperatures tend to fall even further.

WILDLIFE AND PLANT LIFE

Plant and animal life can be abundant in temperate areas and represents both a valuable food resource and a potential hazard. Shoots and stems, leaves, roots, nuts, or berries of some plants are edible, but only when positive identification—or at the least, the Universal Edibility Test (see p. 206)—is achieved. Small mammals, birds, insects, reptiles, and fish can also be found, but may be difficult to catch and kill, and must be prepared and cooked properly. Wildlife can also pose a threat—snakes, spiders, and scorpions may bite and, though rare, bears, wolves, and cougars may attack if cornered.

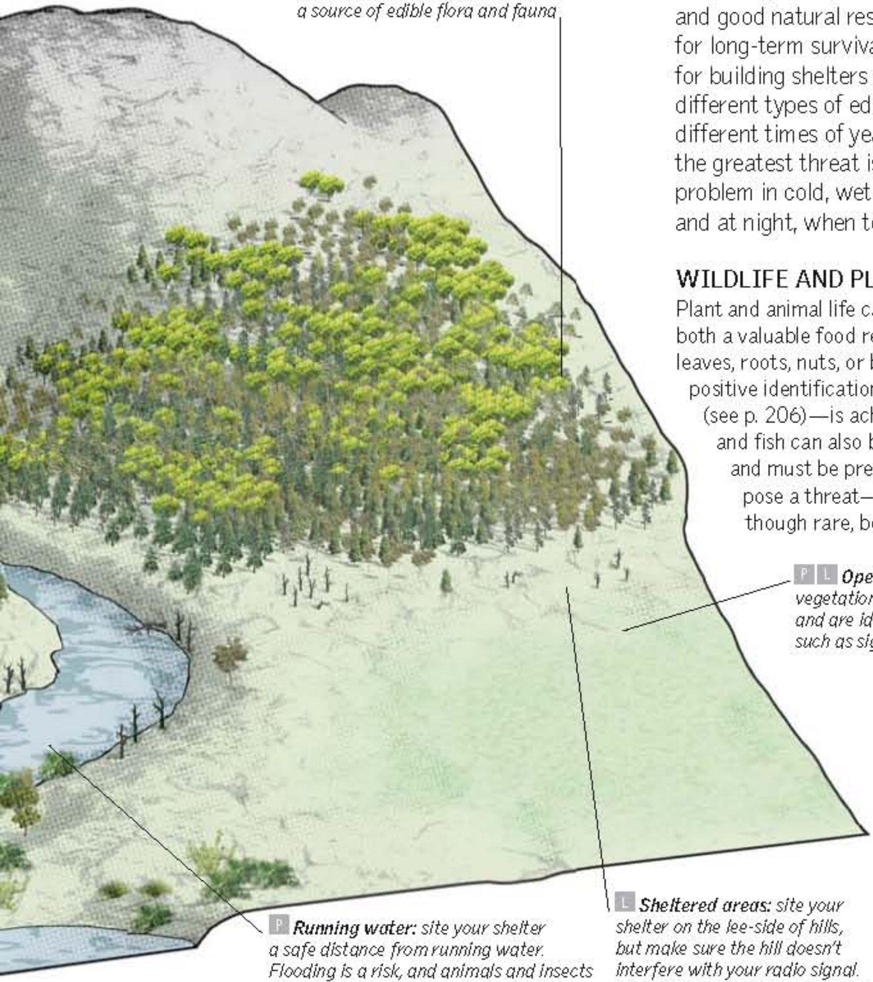

P L F ***Woodland:*** *tree cover affords protection from the elements, and wood for shelter, cooking, and signal fires. It is also a source of edible flora and fauna*

P L ***Open ground:*** *areas with no vegetation offer a clear view of dangers, and are ideal for deploying location aids, such as signal fires*

P ***Running water:*** *site your shelter a safe distance from running water. Flooding is a risk, and animals and insects are drawn to water. The noise may also hide the sound of animals or rescuers*

L ***Sheltered areas:*** *site your shelter on the lee-side of hills, but make sure the hill doesn't interfere with your radio signal. Choose a spot that faces the sun to maximize warmth and light*

FIND OUT MORE...

P **PROTECTION Shelters** pp. 156–65, 178–81 **Fire** pp. 118–33, 204–05 **Dangers** pp. 242–49, 300–05

L **LOCATION Navigation** pp. 66–77 **Movement** pp. 86–89 **Signaling** pp. 236–41

W **WATER Finding** pp. 188–91 **Purifying** pp. 200–01

F **FOOD Plants** pp. 206–07, 280–81 **Animals** pp. 208–13, 216–29, 290–99

TROPICAL ENVIRONMENTS

THE TROPICAL ZONE stretches from the Tropic of Cancer to the Tropic of Capricorn, and is centered over the Equator. A range of environmental features occurs in this area depending on the local climate, from lush, humid, biodiverse tropical rain forests to dry, more sparsely vegetated tropical scrub. With adequate preparation and caution you should be able to survive unsupported for extended periods—the jungle holds just as many resources as dangers.

WARNING!

Mosquitoes are responsible for more fatalities than any other creature in tropical areas. They carry a range of diseases including malaria and yellow fever, which kill millions of people every year.

TROPICAL ESSENTIALS

Rain forests contain everything you need to stay alive, so remember the following tips when venturing out:

- While the jungle teems with predatory wildlife (such as big cats, crocodiles, and anacondas) that sees you as part of the food chain, it is the small creatures that can make life miserable. Most animals in the jungle want to avoid you as much as you want to avoid them—making a noise will scare most away.
- High humidity encourages infections, so keep everything covered (sleeves down, gloves on), and wash at every opportunity.
- Always sleep off the ground.
- Boil or treat all water. Some water found in plants can be safe to drink, but if in doubt, and if the water is yellow, milky, or very cloudy, treat before drinking.
- Many plants have defense mechanisms and can emit toxic liquids that may sting or burn—if you can't identify it, leave it alone.
- Dry tinder can be hard to find, so if you come across any, collect it and keep it safe and dry—lighting a fire in a moist, humid environment can be challenging.
- The smoke of a signal fire must penetrate through all the layers of the jungle, so light your fire where the canopy is sparse, such as the bend of a river or a clear-cut area.
- Navigation can be difficult, as you may only be able to see a few yards in front of you. Use dead reckoning—walking a short distance to a recognizable feature on your bearing—or pace-counting (see pp. 72–73).
- Rivers in the jungle usually run downhill to civilization and, eventually, the coast.
- Don't fight the jungle—tune in to its rhythm and work with it rather than against it.

TROPICAL FEATURES

Tropical rain forest, which occurs within 10 degrees of the Equator, is the predominant environmental feature in the tropics. But there are several other environment types just a few degrees of latitude away.

VERDANT RAIN FOREST

Tropical rain forests occur in areas with steady year-round temperatures and rainfall. Annual rainfall can reach around $6\frac{1}{2}$–10 ft (2–3 m) and daytime temperatures may reach 90°F (30°C), dropping to 70°F (20°C) during the night. Monsoon (or "seasonal") rain forests occur in areas with a wet and dry season, while montane rain forests, also known as "cloud forests," occur in mountainous areas.

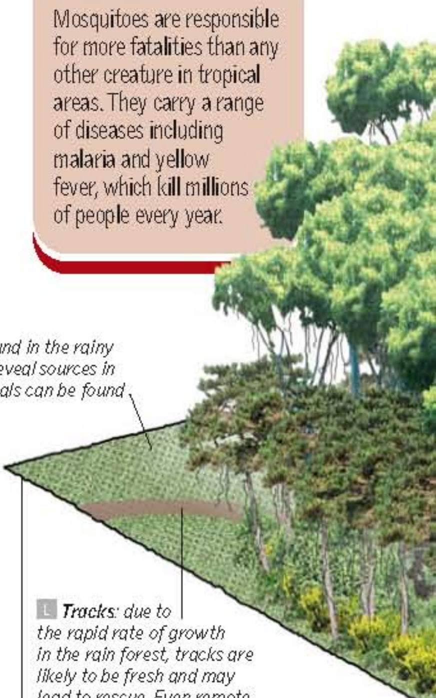

W F ***Tropical scrub:*** *water can be found in the rainy season, while animal movements may reveal sources in the dry season. Edible plants and animals can be found*

L ***Tracks:*** *due to the rapid rate of growth in the rain forest, tracks are likely to be fresh and may lead to rescue. Even remote areas may contain tracks left by loggers, prospectors, or local people*

P L ***Tropical scrub:*** *provides shade from the sun and materials for fire and shelter, but may be home to dangerous wild animals. Dense vegetation during the rainy season may impede visibility*

SCRUB AND SWAMPS

Also known as "thorn forest," tropical scrub consists of low, woody plants with thorns, which usually grow in clusters separated by patches of bare ground (grasses are uncommon). Leaves are shed in the dry season, forming a dense, herbaceous layer in the wet season. Swamps are another common tropical feature, and may consist of fresh or saltwater. Freshwater swamps are found in low-lying, inland areas, and consist of masses of undergrowth, reeds, grasses, occasional short palms, and islands. Saltwater swamps often contain mangroves, and occur in coastal areas that are prone to tidal flooding so are best navigated by boat. Visibility in both types of swamp is poor, and movement is difficult.

SURVIVING IN THE RAIN FOREST

While natural resources are abundant in the rain forest, the heat, humidity, number of animals, and voracious rate of vegetal growth can make it an uncomfortable place. Water, materials for shelter and fire, and edible plants may all be found, although identification of plants is crucial to avoid poisonous species. Animal life is everywhere, so sleeping platforms must be built off the ground to avoid biting insects, snakes, and spiders. The greatest danger is becoming lost—navigation is difficult due to dense undergrowth at ground level, and rescuers will struggle to find you beneath the thick jungle canopy.

FIND OUT MORE...

P PROTECTION Shelters pp. 158–61, 166–71 **Fire** pp. 118–33, 204–05 **Dangers** pp. 167, 242–49

L LOCATION Navigation pp. 66–77 **Movement** pp. 106–07 **Signaling** pp. 236–41

W WATER Finding pp. 192–93 **Purifying** pp. 200–01

F FOOD Plants pp. 206–07, 284–85 **Animals** pp. 208–13, 224–29, 292–99

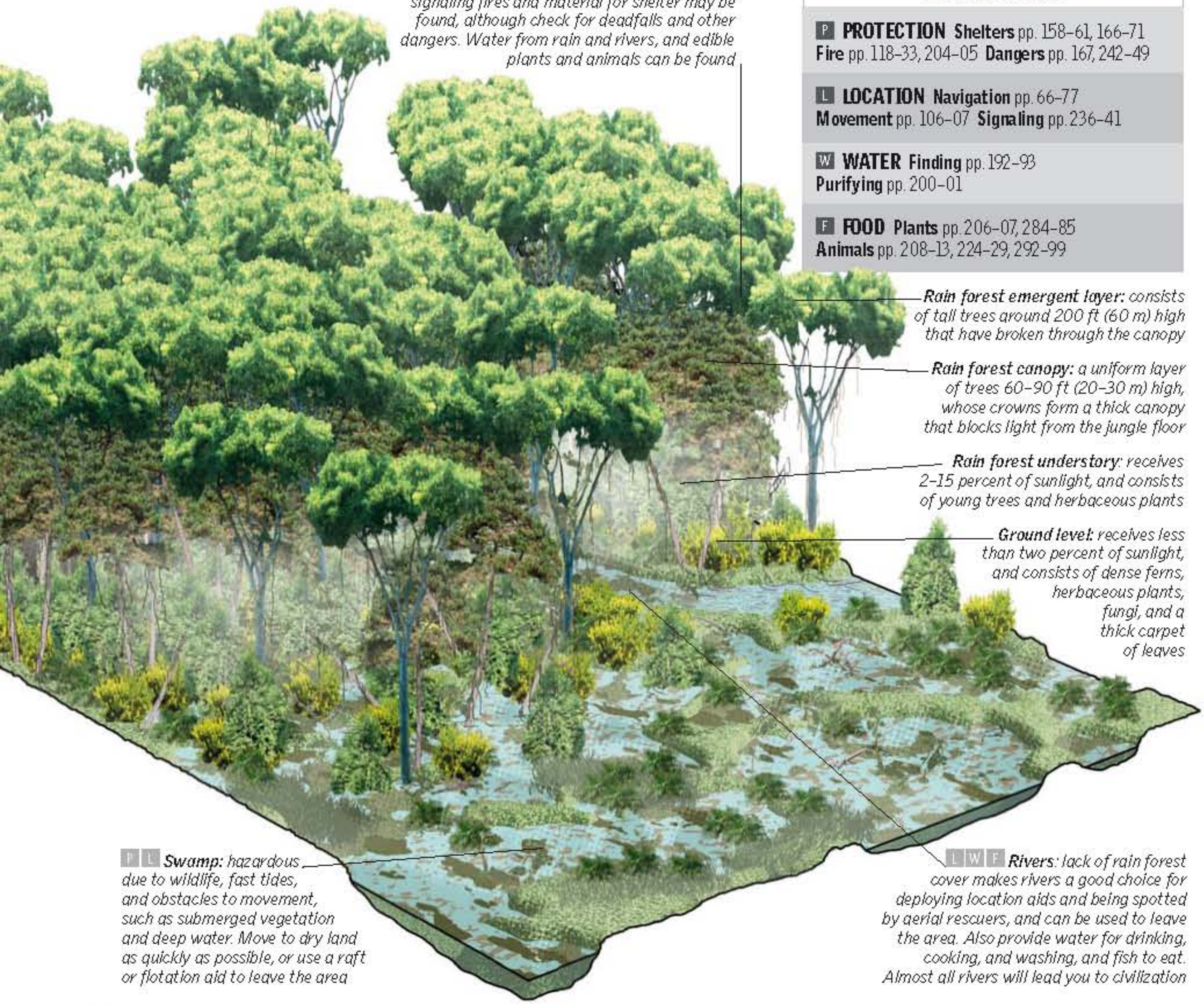

P L W F ***Rain forest:*** *fuel for cooking and signaling fires and material for shelter may be found, although check for deadfalls and other dangers. Water from rain and rivers, and edible plants and animals can be found*

Rain forest emergent layer: *consists of tall trees around 200 ft (60 m) high that have broken through the canopy*

Rain forest canopy: *a uniform layer of trees 60–90 ft (20–30 m) high, whose crowns form a thick canopy that blocks light from the jungle floor*

Rain forest understory: *receives 2–15 percent of sunlight, and consists of young trees and herbaceous plants*

Ground level: *receives less than two percent of sunlight, and consists of dense ferns, herbaceous plants, fungi, and a thick carpet of leaves*

P L ***Swamp:*** *hazardous due to wildlife, fast tides, and obstacles to movement, such as submerged vegetation and deep water. Move to dry land as quickly as possible, or use a raft or flotation aid to leave the area*

L W F ***Rivers:*** *lack of rain forest cover makes rivers a good choice for deploying location aids and being spotted by aerial rescuers, and can be used to leave the area. Also provide water for drinking, cooking, and washing, and fish to eat. Almost all rivers will lead you to civilization*

WHERE TO FIND TROPICAL AREAS

Tropical rain forests are clustered around the Equator. The largest rain forest areas are found in Central and South America, sub-Saharan Africa, southeast Asia, northern Australia, and several Pacific islands.

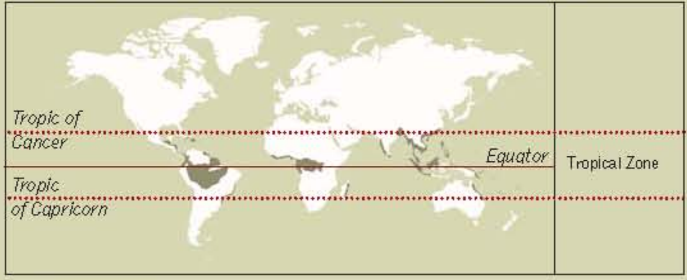

■ Rain forest areas

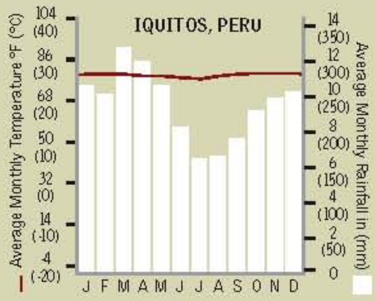

TYPICAL CLIMATE

Iquitos sits on the Amazon river in the heart of the Peruvian rain forest. It lies just south of the Equator and has a typical hot, wet tropical climate.

MOUNTAIN ENVIRONMENTS

THE MOUNTAIN ENVIRONMENT is one of the harshest places for humans to survive. Defined as landmasses with a summit above 2,000 ft (600 m), mountains can be very dangerous places due to their elevation and terrain. Lower temperatures and poor weather are more likely at higher altitudes, so there is a significant risk of hypothermia, frostbite, and altitude sickness, while snow, ice, and precipitous terrain present further hazards. Survival may depend on your ability to descend to areas with better prospects of survival and rescue.

MOUNTAIN FEATURES

Above the treeline, mountain terrain is typically barren, featuring bare rocks, gravel, boulders, and snow and ice, which are most extensive during the winter but may persist at high elevations during the summer. At lower levels, coniferous forest is the predominant feature, dissected by streams and rivers fed by snowmelt. Topographical features include scree slopes, cliffs, ravines, boulder fields, snowslopes, and glaciers.

ELEVATION CHANGE

Mountains of sufficient height may have vastly different ecosystems at different elevations, due to harsh conditions at high altitude. Plant and animal life varies at different elevations, so the natural resources available for survival will differ according to height. Mixed deciduous trees are common on low slopes and conifers grow at intermediate levels, but thin out to grass, isolated shrubs, moss, and lichen higher up. At the highest levels, high winds, frost, snow, and ice discourage any growth.

WARNING!

One of the most dangerous animals in mountain areas is the cougar, also known as the puma, panther, and mountain lion. Found in North and South America, more than 20 percent of attacks are fatal.

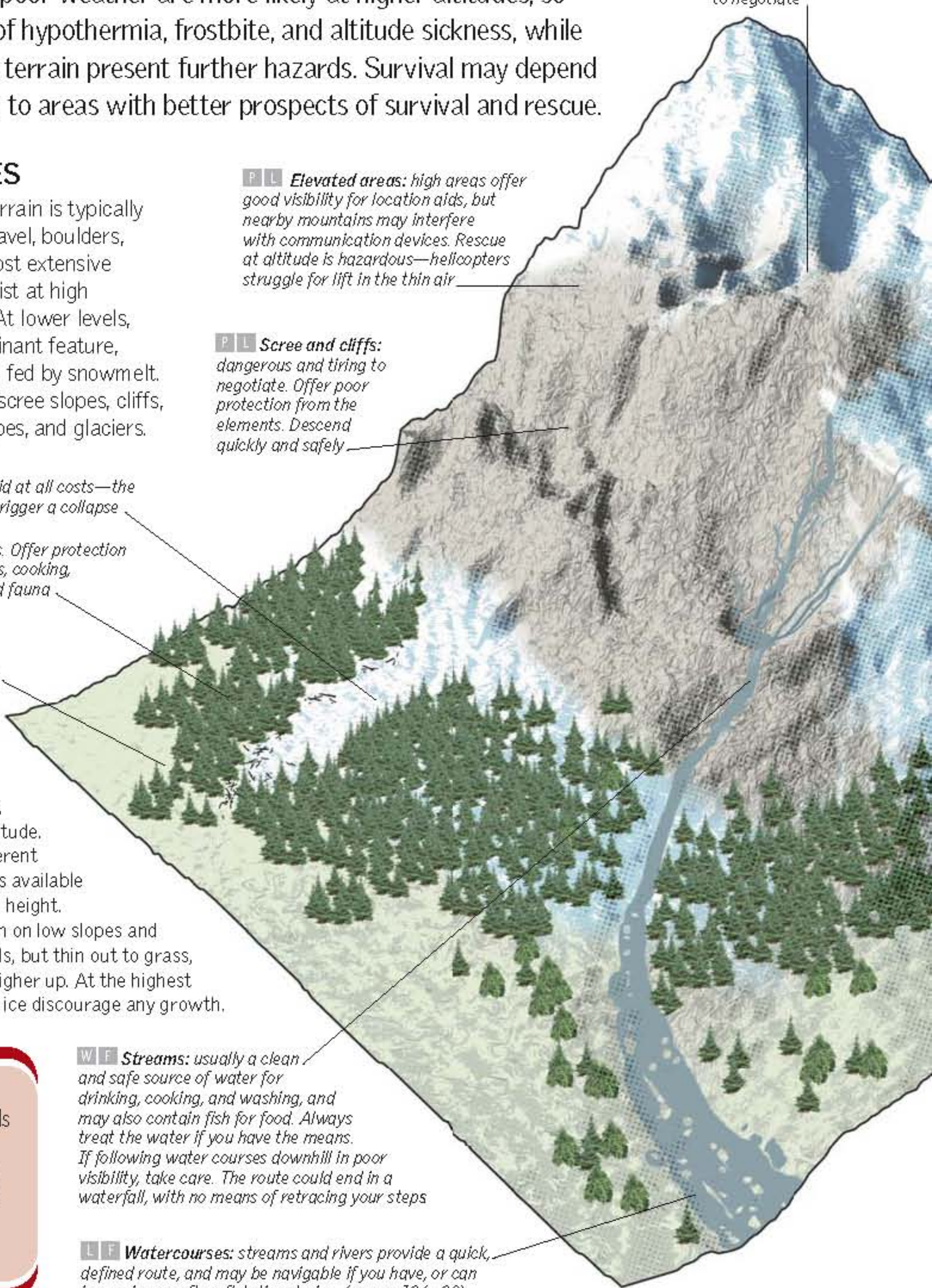

P L ***Mountains:*** *shelter is limited and dangers include unpredictable weather and rock falls. They may require special equipment and knowledge to negotiate*

P L ***Elevated areas:*** *high areas offer good visibility for location aids, but nearby mountains may interfere with communication devices. Rescue at altitude is hazardous—helicopters struggle for lift in the thin air*

P L ***Scree and cliffs:*** *dangerous and tiring to negotiate. Offer poor protection from the elements. Descend quickly and safely*

P ***Avalanche-prone slopes:*** *avoid at all costs—the smallest noise or movement can trigger a collapse*

P L F ***Forest areas:*** *rich in resources. Offer protection from the elements, material for shelters, cooking, fires, and signaling, and edible flora and fauna*

P ***Shelter:*** *always site your shelter away from areas of avalanche risk, especially if avalanche debris is present*

W F ***Streams:*** *usually a clean and safe source of water for drinking, cooking, and washing, and may also contain fish for food. Always treat the water if you have the means. If following water courses downhill in poor visibility, take care. The route could end in a waterfall, with no means of retracing your steps*

L F ***Watercourses:*** *streams and rivers provide a quick, defined route, and may be navigable if you have, or can improvise, a raft or flotation device (see pp. 106–09)*

SURVIVING IN THE MOUNTAINS

The prospects for survival are good at lower elevations, where trees provide material for shelter and fire, rivers provide water, and edible plants and animals are likely to be present. At higher elevations vegetation is scarce, so there are fewer options for shelter and food, although water from streams or snow is likely to be available. There may be a risk of avalanche on snow-covered slopes, and crevasses pose a hidden danger in glaciated areas. Cold-related injuries pose the greatest threat (see pp. 270–71).

HIGH-LEVEL HAZARDS

The primary threats to survival at high altitude are cold-related ailments, the most dangerous of which is hypothermia. This occurs when the body's core temperature falls below 95°F (35°C)—if allowed to drop as low as 86°F (30°C), it can be fatal. Frostbite may also occur in the extremities in freezing or cold and windy weather, and may lead to permanent tissue damage. Altitude sickness, which can cause pulmonary or cerebral edema—and in extreme cases, death—is also a risk above 8,000 ft (2,500 m).

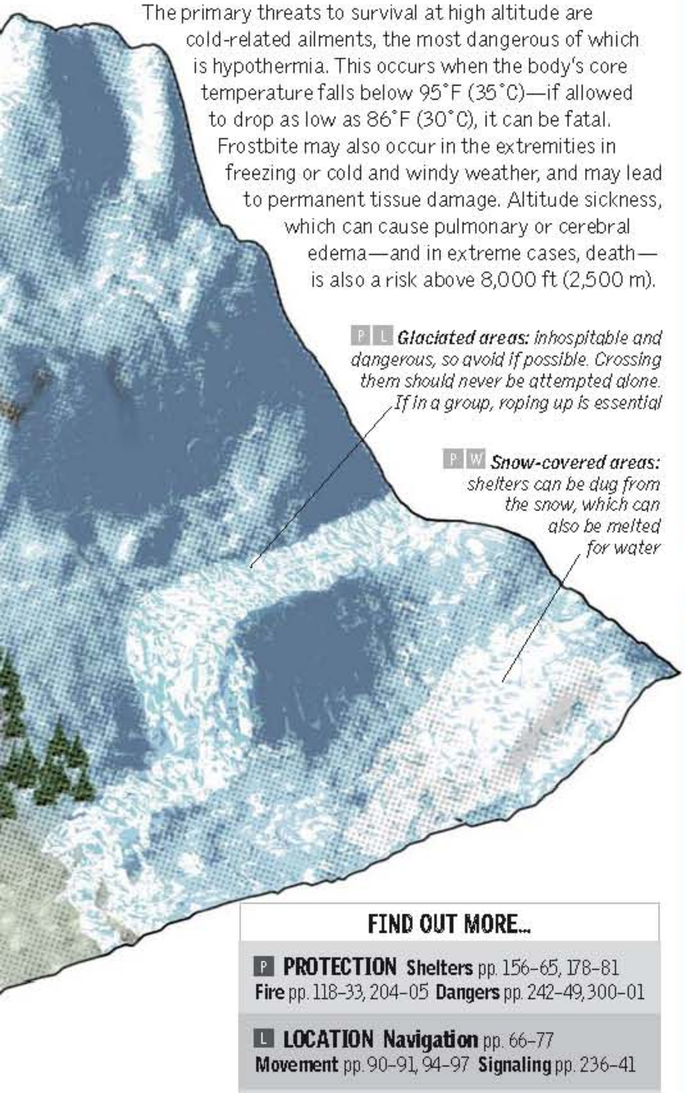

P L *Glaciated areas: inhospitable and dangerous, so avoid if possible. Crossing them should never be attempted alone. If in a group, roping up is essential*

P W *Snow-covered areas: shelters can be dug from the snow, which can also be melted for water*

FIND OUT MORE...

P **PROTECTION** **Shelters** pp. 156–65, 178–81 **Fire** pp. 118–33, 204–05 **Dangers** pp. 242–49, 300–01

L **LOCATION** **Navigation** pp. 66–77 **Movement** pp. 90–91, 94–97 **Signaling** pp. 236–41

W **WATER** **Finding** pp. 188–91, 194–95 **Purifying** pp. 200–01

F **FOOD** **Plants** pp. 206–07, 280–81, 286–87 **Animals** pp. 208–13, 216–23, 290–97

MOUNTAIN DISTRIBUTION

Mountains are found on every continent, but the major ranges are the Himalayas and Karakoram in Asia, the Andes in South America, the Rocky Mountains in North America, and the Alps and Pyrenees in Europe.

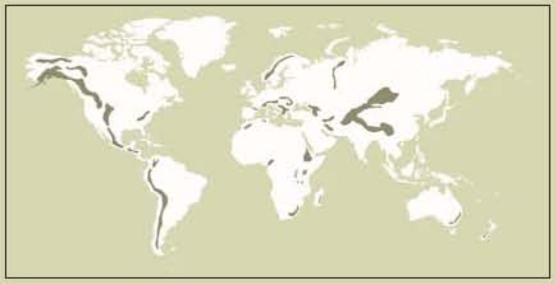

▨ Mountain ranges

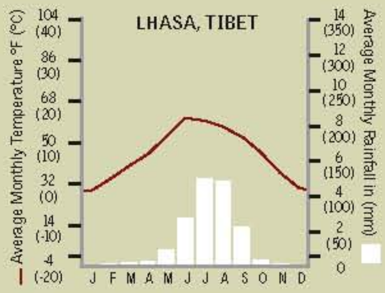

TYPICAL CLIMATE

Lhasa, the capital city of Tibet, lies at 11,972 ft (3,649 m) on the Tibetan Plateau, sometimes known as "the roof of the world." The high altitude means that winters are cool, and precipitation is relatively low because it mostly falls as snow, which has just 10 percent of the density of rain.

MOUNTAIN ESSENTIALS

High altitude and lower oxygen levels place higher-than-normal demands on even a fit body, so be prepared. Survival in the mountains is also tough on equipment.

- Respect nature and err on the side of caution—mountains are unforgiving, and rescue is unlikely to be quick or easy.
- Plan an achievable and safe route, and prepare an Emergency Plan of Action (see pp. 24–25).
- Dress in layers (see pp. 46–47). Start a walk lightly dressed (cold) and add or remove layers as necessary.
- Wear a hat (up to 70 percent of body heat is lost through the head) and gloves—cold fingers will hinder your functions.
- Tie loose items of clothing (hat, gloves, sunglasses) to your person—a lost glove could result in a lost hand, or life.
- Take a flashlight—weather changes and unforeseen problems may mean you are on the mountain in low light or darkness.
- Always carry basic equipment to give adequate protection if forced to camp overnight, such as a bivy sack and sleeping bag.
- Check avalanche warnings and carry an avalanche transceiver.
- Contact with snow makes clothing wet and less effective.
- If moving over snow, make a pair of improvised snow shoes (see pp. 94–95).

DESERT ENVIRONMENTS

THE DESERT ENVIRONMENT is a hostile place for human survival due to temperature extremes and the scarcity—or absence—of water. Most deserts are either hot and dry or cold and dry, and all typically receive less than 10 in (250 mm) of annual rainfall. They are areas of extremes, where heat exhaustion and hypothermia are threats, and flash floods may rapidly replace dry conditions. A harsh place to survive, the desert should only be entered by those who are prepared.

WARNING!
Desert areas are home to a range of venomous snakes, including the black mamba of eastern and southern Africa. It is particularly dangerous due to its aggressive nature and highly venomous bite.

DESERT FEATURES

The popular depiction of a desert is of a dry, sandy landscape with searing skies and temperatures among the highest in the world. Such areas do exist, but the desert environment has far greater diversity, from cold deserts in the polar regions to highlands, grassland, and broken, rocky terrain that contain "wadis" (seasonal stream beds).

HOT, DRY DESERTS

Temperate and tropical deserts are usually hot and dry due to high daytime temperatures, which leads to low precipitation and high evaporation. There may be months or even years between rainfall, which usually occurs in dramatic bursts but then quickly drains into seasonal stream beds (wadis), or evaporates either in the air or soon after touching the hot ground. Very little rain soaks into the ground, which results in sparse vegetation that has evolved to maximize water, usually via extensive root systems that collect moisture, waxy skin and leaves that prevent water loss, and stems or roots that hold water. At night, in winter, and at higher altitudes, freezing temperatures and frost may occur.

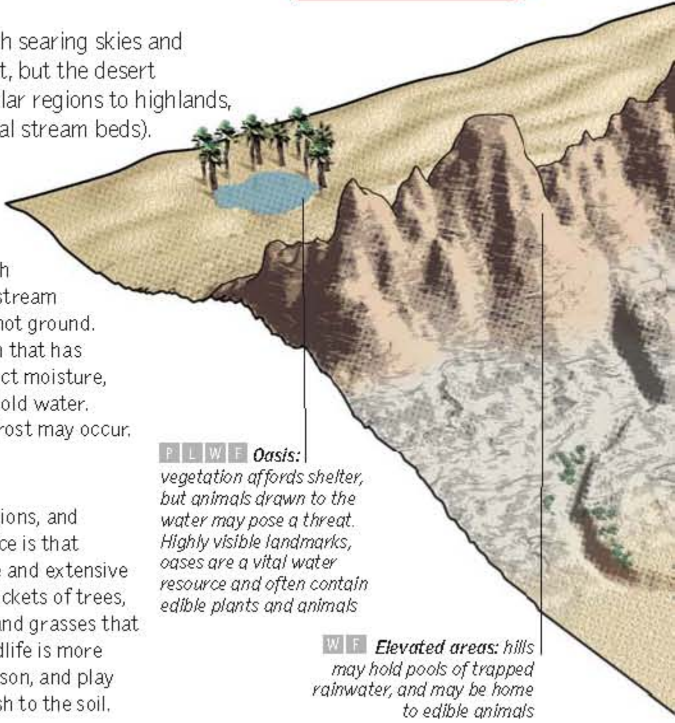

P L W F ***Oasis:*** *vegetation affords shelter, but animals drawn to the water may pose a threat. Highly visible landmarks, oases are a vital water resource and often contain edible plants and animals*

W F ***Elevated areas:*** *hills may hold pools of trapped rainwater, and may be home to edible animals*

GRASSLANDS

Known as savanna in tropical areas, grasslands often border desert regions, and experience a similarly dry climate for most of the year. The key difference is that they also experience a wet season, which accounts for the more diverse and extensive vegetation. Temperate grassland features grasses, shrubs, and small pockets of trees, while savanna is typically more varied, with denser tree cover, bushes, and grasses that grow tall during the wet season but die back in periods of drought. Wildlife is more prevalent, including predators. Wildfires may spread during the dry season, and play an important role by destroying dead plant matter and adding fertile ash to the soil.

WHERE TO FIND DESERT AREAS

Although deserts occur on every continent, the largest hot desert in the world is the Sahara in North Africa, which forms part of a desert band stretching through the Middle East and into south and central Asia.

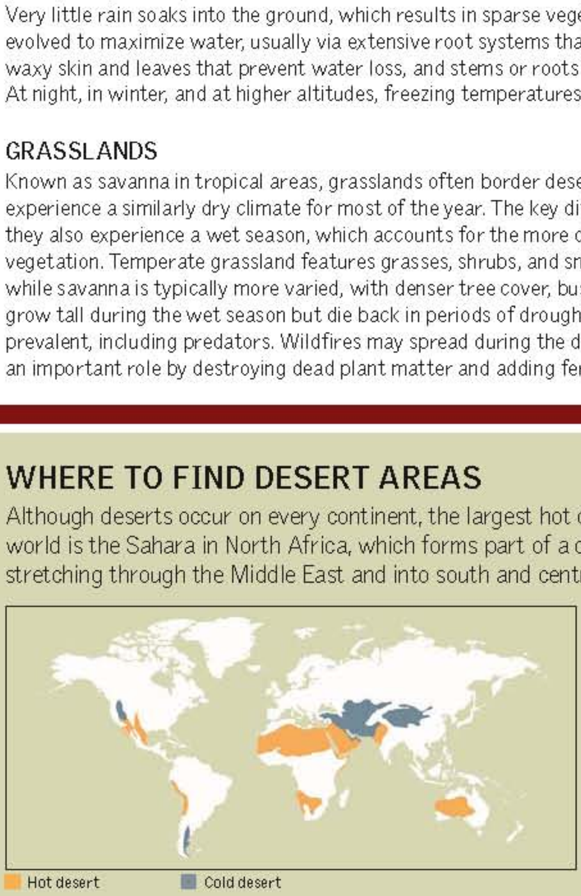

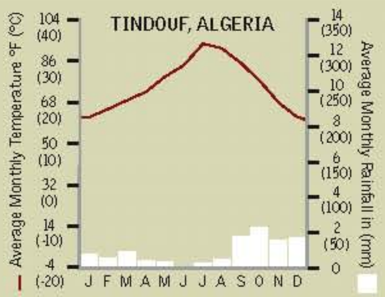

TYPICAL CLIMATE

Tindouf lies in the heart of the Sahara, and experiences a typical hot-desert climate. Precipitation is virtually zero all year round, while temperatures peak in the summer.

SURVIVING IN THE DESERT

Hostile temperatures and few natural resources limit chances of survival in the desert. Water and shelter are scarce, if not non-existent, edible vegetation is limited, and animals hide from the sun in the day. Wadis, grasslands, and higher ground all hold better prospects. The greatest dangers are dehydration and heat exhaustion (see pp. 272–73), although African savanna areas may be home to large, dangerous mammals. The main killers are big cats, hippos, rhinos, elephants, and crocodiles.

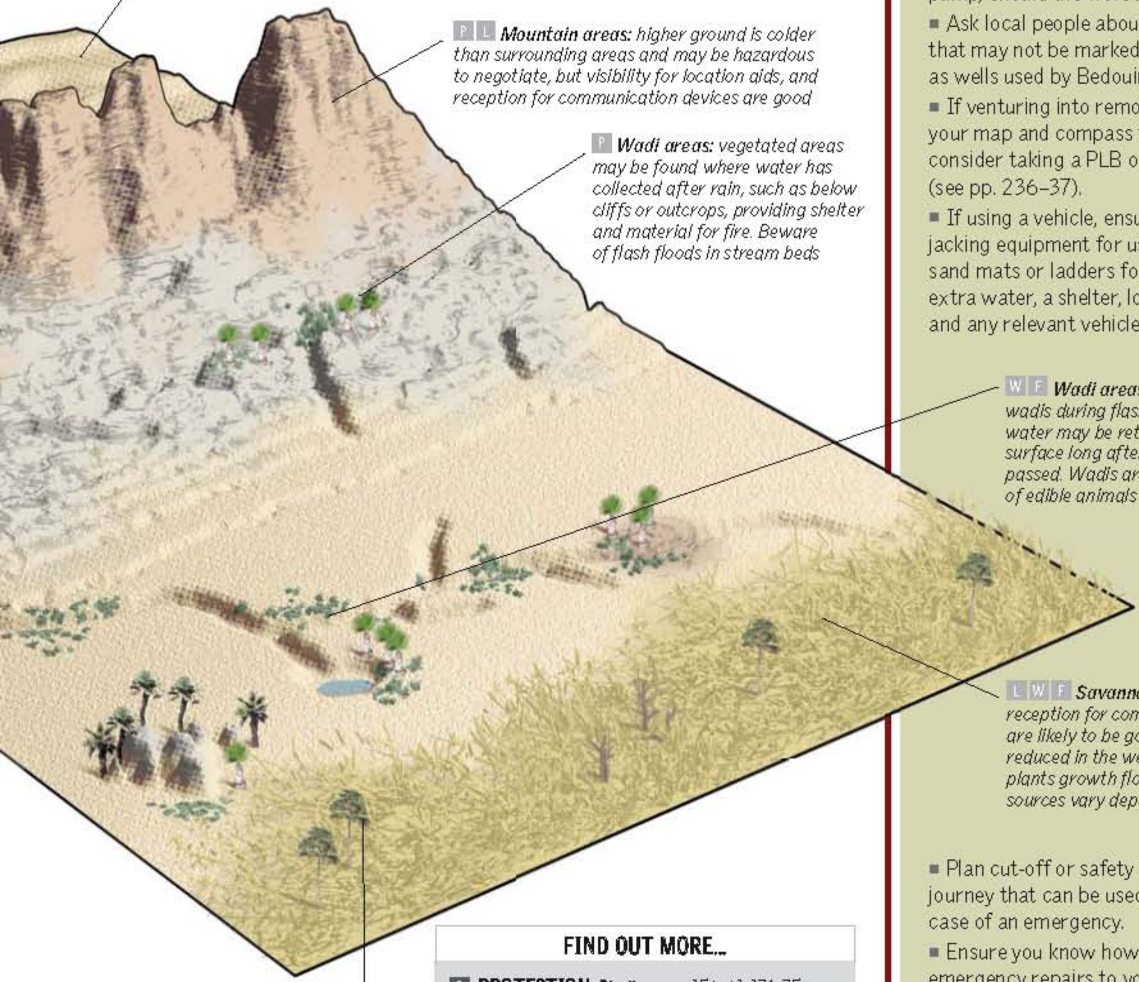

P L W ***Sand dunes:*** *shelter from the elements is poor, but visibility for location aids and for spotting rescuers is good. Observing converging animal and bird tracks or movements may indicate the direction to a water source.*

P L ***Mountain areas:*** *higher ground is colder than surrounding areas and may be hazardous to negotiate, but visibility for location aids, and reception for communication devices are good*

P ***Wadi areas:*** *vegetated areas may be found where water has collected after rain, such as below cliffs or outcrops, providing shelter and material for fire. Beware of flash floods in stream beds*

W F ***Wadi areas:*** *rivers flow in wadis during flash floods, and water may be retained below the surface long after the flood has passed. Wadis are also the habitat of edible animals*

L W F ***Savanna:*** *visibility and reception for communication devices are likely to be good but will be reduced in the wet season when plants growth flourishes. Water sources vary depending on the season*

P ***Savanna:*** *protection from the elements is limited, although material for building shelters may be found in the wet season. Sunstroke and dehydration are killers, so seek shade during the hottest parts of the day. Beware of snakes or scorpions in shaded areas, big cats and large mammals, and nocturnal animal activity*

FIND OUT MORE...

P PROTECTION Shelters pp. 156–61, 174–75 **Fire** pp. 118–33, 204–05 **Dangers** pp. 242–49, 300–05

L LOCATION Navigation pp. 66–77 **Movement** pp. 100–01 **Signaling** pp. 236–41

W WATER Finding pp. 192–93 **Purifying** pp. 200–01

F FOOD Plants pp. 206–07, 282–83 **Animals** pp. 216–21, 224–29, 292–95

DESERT ESSENTIALS

Survival in the extreme conditions of the desert is impossible without full preparation. Consider the following:

- Always prepare an EPA to notify someone of your plans before entering a desert area (see pp. 24–25).
- Water is life. Do not underestimate your needs, carry extra just in case, and carry equipment to maximize your chances of finding and procuring more (binoculars, surgical tubing, filtration/purification pump) should the worst happen.
- Ask local people about water sources that may not be marked on maps, such as wells used by Bedouin tribes.
- If venturing into remote areas, augment your map and compass with a GPS, and consider taking a PLB or satellite phone (see pp. 236–37).
- If using a vehicle, ensure you carry jacking equipment for use in soft ground, sand mats or ladders for self-recovery, extra water, a shelter, location aids, and any relevant vehicle spares.
- Plan cut-off or safety points into your journey that can be used to divert to in case of an emergency.
- Ensure you know how to accomplish emergency repairs to your vehicle.
- Ask local people about known dangers, such as impassable roads, misleading tracks, and soft-sand areas.
- When using a ladder for self-recovery, tie it to the back of the vehicle so that it's dragged behind once crossed, and can be retrieved when you reach solid ground.
- If your vehicle breaks down, leave it only if staying is no longer safe or feasible—rescuers will search for it first.

COLD ENVIRONMENTS

LOW TEMPERATURES are a potentially lethal hazard, but as long as you can conserve body heat, survival in the cold is quite possible. The ice-covered Arctic and Antarctic polar regions, sub-polar tundra and taiga, as well as parts of most temperate zones during the winter, can all be classed as cold environments. Wet, windy weather can drive moderately cold temperatures down further, increasing the risk of the most lethal cold-weather condition—hypothermia.

WARNING!
The largest predatory land mammal on Earth, the polar bear inhabits the Arctic. Attacks are most likely when the bears are hungry, and are usually fatal.

COLD ENVIRONMENT FEATURES

Outside temperate areas, the typical cold environments are the polar areas, which feature glacial ice sheets and sea ice; tundra, which contains permafrost (permanently frozen soil), small shrubs, mosses, and lichens; and taiga, with extensive conifer forests. Almost half of the northern hemisphere's landmass can be classified as a cold region, due to the influence of cold air masses (see pp. 78–83), while ocean currents and altitude can also have a cooling effect.

POLAR WASTES

The northern polar area is situated over the Arctic Ocean, so largely consists of sea ice, the extent and depth of which varies throughout the year. Because of the lack of land, melting ice is a serious danger. The southern polar area is located over the continent of Antarctica, and contains the largest glacial ice sheet on Earth. Both areas contain ice shelves—glaciers that have extended over the sea—parts of which break off to form icebergs.

TUNDRA AND TAIGA

Latitudes that neighbor the polar areas are home to tundra, an environment of permafrost and vegetation that is stunted due to low temperatures. Taiga is located further away from the poles, where temperatures are high enough to support coniferous forests.

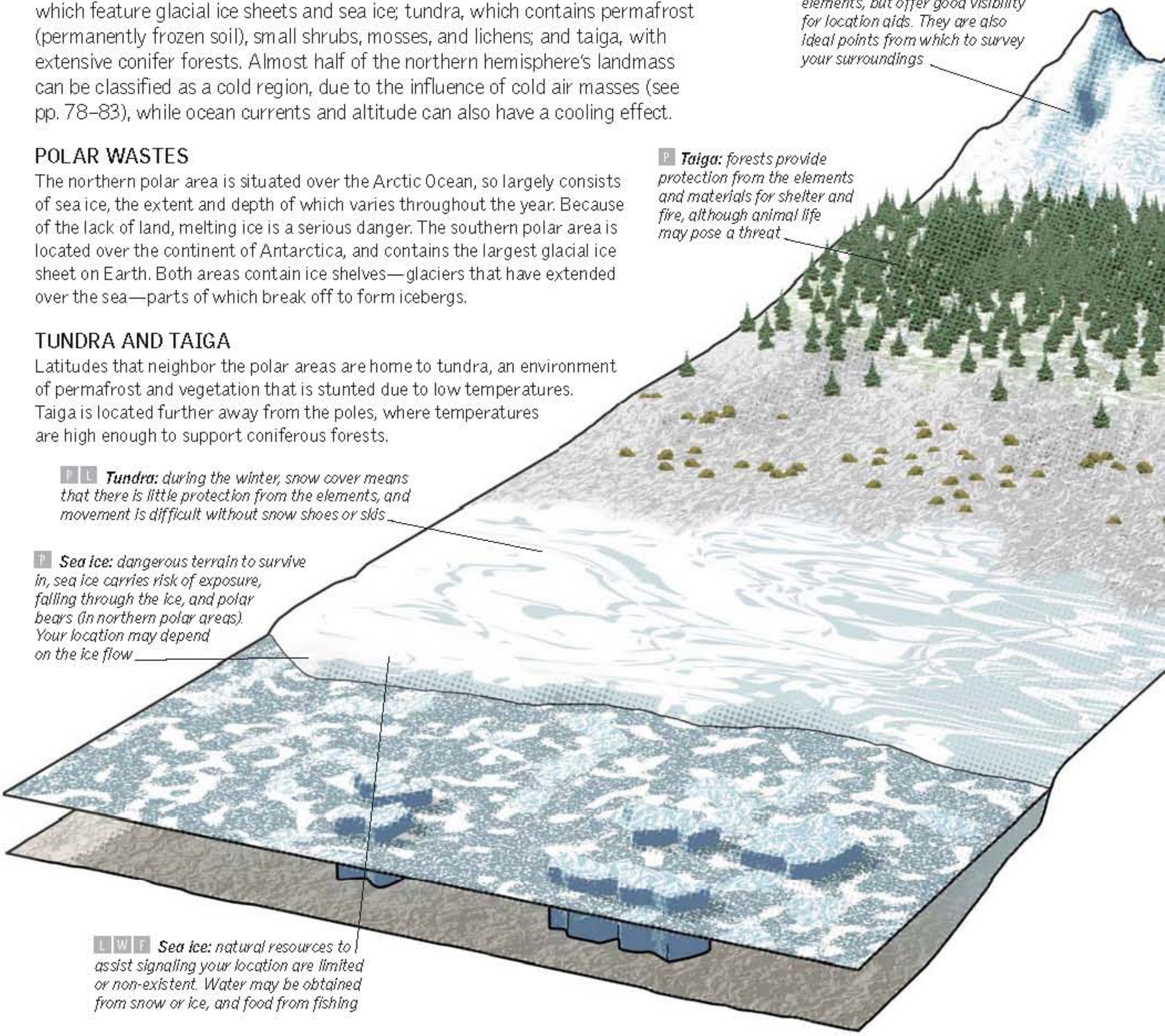

P L ***Mountains:*** *elevated areas give little protection from the elements, but offer good visibility for location aids. They are also ideal points from which to survey your surroundings*

P ***Taiga:*** *forests provide protection from the elements and materials for shelter and fire, although animal life may pose a threat*

P L ***Tundra:*** *during the winter, snow cover means that there is little protection from the elements, and movement is difficult without snow shoes or skis*

P ***Sea ice:*** *dangerous terrain to survive in, sea ice carries risk of exposure, falling through the ice, and polar bears (in northern polar areas). Your location may depend on the ice flow*

L W F ***Sea ice:*** *natural resources to assist signaling your location are limited or non-existent. Water may be obtained from snow or ice, and food from fishing*

SURVIVING IN THE COLD

Natural resources may be scarce in cold environments, so your survival is likely to depend on the equipment and supplies you have with you. Shelters can be dug from the snow to help you stay warm and avoid exposure to freezing temperatures, but material for making fire is limited in polar and tundra areas. Survival is more feasible in the taiga, where wood is available, and fresh water and edible flora and fauna can also be found. The greatest dangers are hypothermia (see pp. 272–73) and—in northern polar areas—polar bears.

LOW-TEMPERATURE DANGER

Heat loss occurs in several ways, and minimizing it is essential to survival in cold conditions. It's important to avoid over-exertion, since heat is lost through sweating, and to cover your head and wear layered clothing to trap radiated body heat. Heat is also lost through conduction—direct contact between the skin and a cooler surface—particularly when wet, since water conducts heat away from the body 25 times faster than air. For this reason, it's vital to wear insulated and waterproof clothing, and to stay dry. Respiration also involves heat loss—each inhaled breath contains cold air, which is warmed as it passes through the lungs, and laden with moisture when exhaled. Reduce heat loss by covering your nose and mouth with a ski-mask or scarf, or by breathing warmer air next to a fire or in a warm shelter.

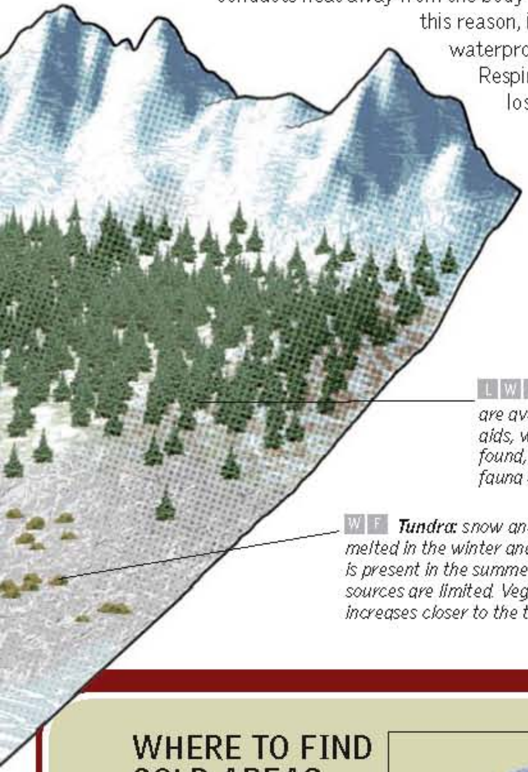

L W F *Taiga: natural resources are available for making location aids, water sources may be found, and edible flora and fauna are likely to be present*

W F *Tundra: snow and ice can be melted in the winter and ground water is present in the summer, although sources are limited. Vegetation increases closer to the treeline*

COLD ESSENTIALS

The main threats in cold environments are hypothermia and exposure, so ensure you are fully prepared:

- Dress in loose-fitting layers of clothing (see pp. 46–47), avoid overheating, and ensure your clothing stays dry and clean.
- If your hands are cold, don't warm them with your breath, which will make them wet—tuck them under your armpits.
- Regularly check your extremities (face, toes, hands, and ears) for frostnip, the first stage of frostbite (see p. 273).
- Wind-chill is dangerous, so take shelter from the wind at every opportunity, particularly if you are in a survival situation.
- Always ensure that your shelter is well ventilated—keep vent holes clear and check regularly, especially when snow falls.
- Get off the cold ground, snow, or ice—sit on your pack or make a sleeping platform using boughs to avoid losing body heat.
- If fire is your primary means of warmth, triple the amount of firewood you think you need—you will need enough to last the night.

FIND OUT MORE...

P **PROTECTION** **Shelters** pp. 156–65, 178–79 **Fire** pp. 118–33, 204–05 **Dangers** pp. 242–49

L **LOCATION** **Navigation** pp. 66–67 **Movement** pp. 94–97 **Signaling** pp. 236–41

W **WATER** **Finding** pp. 194–95 **Purifying** pp. 200–01

F **FOOD** **Plants** pp. 206–07, 286–87 **Animals** pp. 208–13, 216–23, 290–91, 296–97

WHERE TO FIND COLD AREAS

The Arctic and Antarctic polar areas are the coldest places on Earth, and are found at the furthest points from the Equator. Tundra exists next to polar regions, and is bordered by taiga, which is found in northern Eurasia and North America.

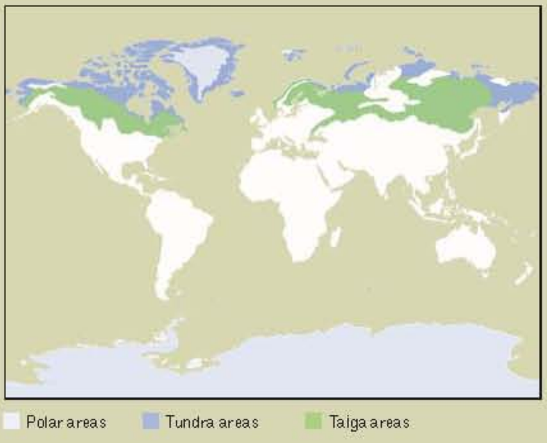

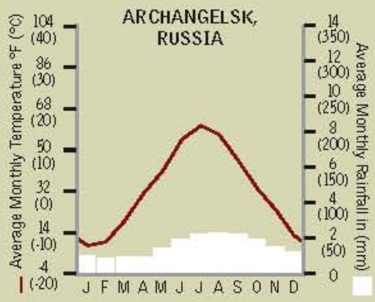

TYPICAL CLIMATE

Archangelsk is a Russian port on the Barents Sea. Located in the taiga zone, it experiences below-zero temperatures for half the year and low precipitation.

MARINE ENVIRONMENTS

POTENTIALLY THE MOST HARSH and challenging of all environments, the sea is unlike any other due to the lack of the most essential requirement for human life—fresh water. Around 70 percent of the Earth's surface is covered by saltwater, ranging from the freezing, wind-torn polar oceans to the warm tropical seas. Winds and currents govern your movement, protection is limited, and natural resources are virtually nil, so reaching land is your best hope for survival.

WARNING!
There are sharks in every ocean, but those in tropical waters are the most aggressive. Around 20 of the hundreds of species have attacked humans, and the most dangerous types are the great white, tiger, and bull sharks.

MARINE FEATURES

The marine environment ranges from the coastal margins, which are shallow enough— 650 ft (200 m) or less—to support a huge array of animal and plant life, to the open oceans, the deepest of which plunge to more than 33,000 ft (10,000 m).

SHELTERED COAST TO OPEN SEA

The coastal margins are home to the majority of ocean life, and include terrestrial areas—the shoreline and intertidal zone—and aquatic—the sea up to the edge of the continental shelf. A variety of environmental features are found, such as sand, rock, and pebble beaches, dunes, cliffs, estuaries, mud flats, mangroves, lagoons, kelp forests, and coral reefs. The open ocean is a more barren environment that supports less life, and is notable for its vast extent, comprising 92 percent of all saltwater. Survival depends on your equipment, supplies, and ingenuity.

OCEAN CONDITIONS

Your protection and location at sea depends largely on the weather—you may need to deal with anything from exposure to the hot sun, to cold, wet, windy conditions and high seas. Conditions are toughest in the South Atlantic Ocean, where winds (known as the "Roaring Forties") are strong all year round, and sea ice is extensive in the winter. Severe seasonal storms occur: hurricanes in the tropical areas of the western Atlantic, typhoons in the western Pacific. India and Southeast Asia also experience severe weather during the monsoon seasons.

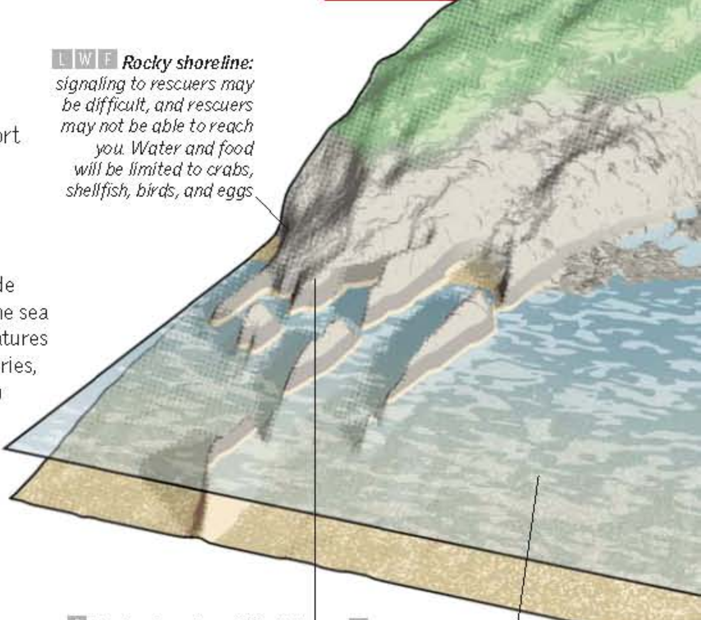

L W F ***Rocky shoreline:*** *signaling to rescuers may be difficult, and rescuers may not be able to reach you. Water and food will be limited to crabs, shellfish, birds, and eggs*

P ***Rocky shoreline:*** *difficult to make landfall and to survive on, and poses risk of injury when landing. Progress to safer areas may be difficult or impossible due to cliffs or slippery rocks. Protection from the elements and tides is limited*

F ***Coastal margins:*** *the majority of ocean life is found near the coasts, and most species live within 650 ft (200 m) of the surface*

WINDS AND CURRENTS

Winds and currents follow prevailing patterns, so if you know roughly where you are, you can figure out where they'll carry you. With a drift of just 1 knot, a liferaft can move 24 miles (38 km) from its last known position in 24 hours. It may also drift up to 35° either side of the wind, further widening the search area to more than 400 sq miles (1,000 sq km) in the first 24-hour period, and increasing exponentially over time. Conversely, favorable currents can also be used to help you drift to landfall faster.

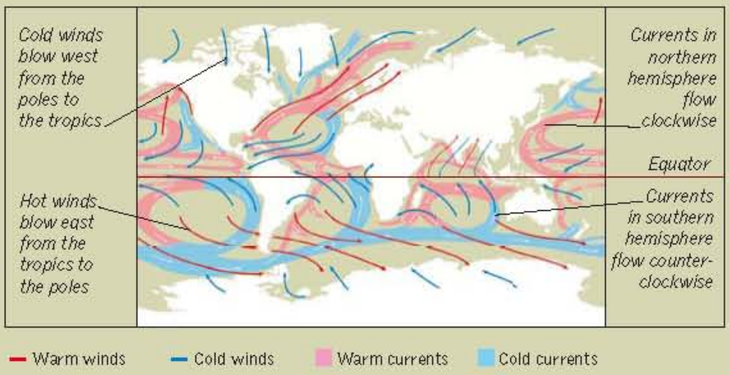

Cold winds blow west from the poles to the tropics

Hot winds blow east from the tropics to the poles

Currents in northern hemisphere flow clockwise

Currents in southern hemisphere flow counter-clockwise

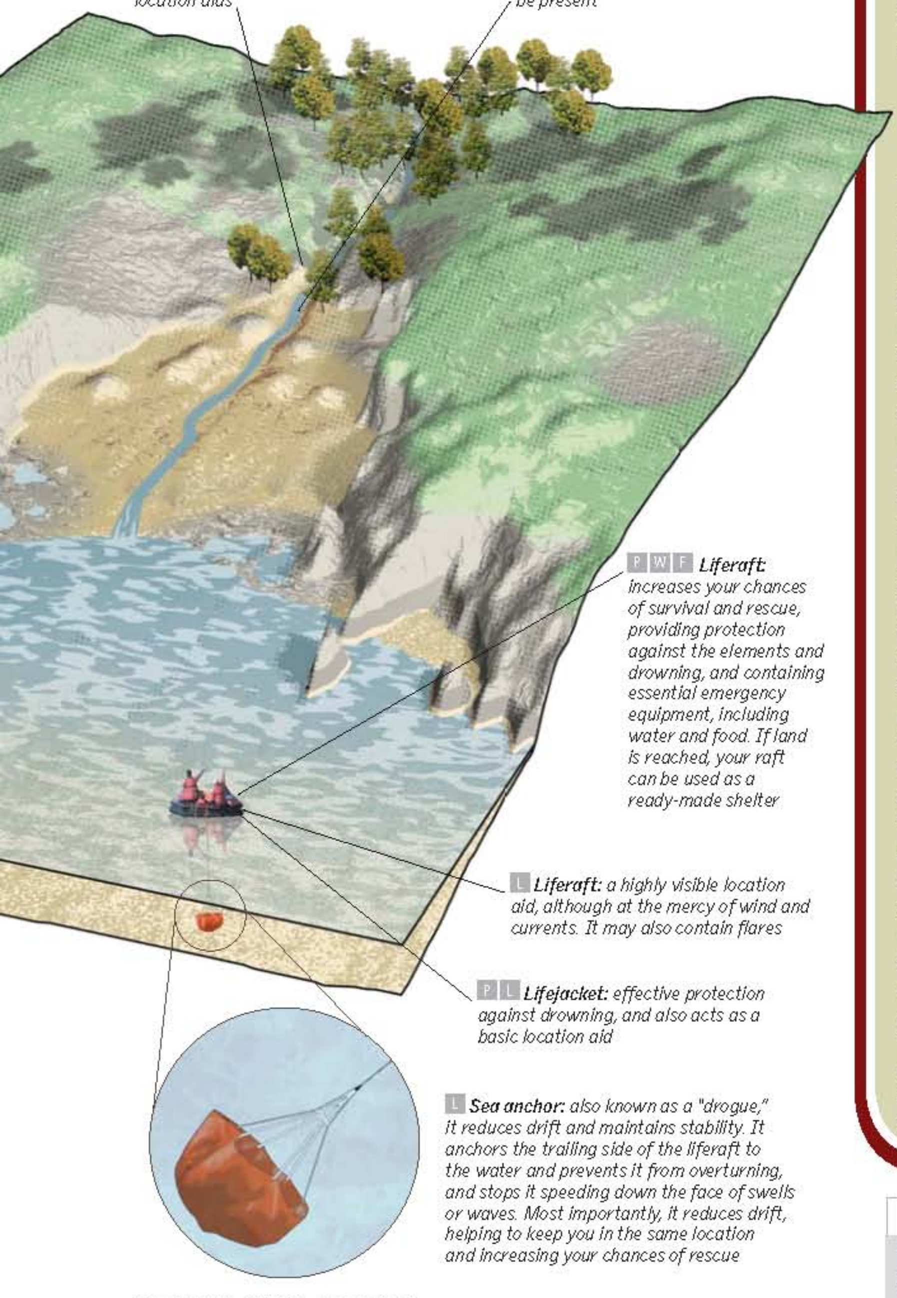

P L **Beach:** *above the high-tide mark, beaches may provide protection from wind and rain, and materials for building shelters, lighting fires, and improvising location aids*

W F **Beach stream:** *streams may drain on to beaches, providing water for drinking, cooking, and washing. Edible plants and animals may be present*

P W F **Liferaft:** *increases your chances of survival and rescue, providing protection against the elements and drowning, and containing essential emergency equipment, including water and food. If land is reached, your raft can be used as a ready-made shelter*

L **Liferaft:** *a highly visible location aid, although at the mercy of wind and currents. It may also contain flares*

P L **Lifejacket:** *effective protection against drowning, and also acts as a basic location aid*

L **Sea anchor:** *also known as a "drogue," it reduces drift and maintains stability. It anchors the trailing side of the liferaft to the water and prevents it from overturning, and stops it speeding down the face of swells or waves. Most importantly, it reduces drift, helping to keep you in the same location and increasing your chances of rescue*

SURVIVING AT SEA

Natural resources in the open ocean are virtually nil, so improvising shelter or location aids is limited to what you have with you. Seasickness, especially in a small liferaft, can seriously affect your ability to remain both hydrated and motivated. Unless you can reach land, your only drinking water will come from rain or mechanical desalination devices—consuming urine or saltwater will only increase your rate of dehydration. Reaching land or shipping lanes greatly increases your chances of rescue.

MARINE ESSENTIALS

Your chances of survival at sea will be greatly enhanced by good preparation, so consider the following:

- Pack sea-survival equipment as if your life depends on it—it might! Other environments allow you to improvise survival and location aids, but not the sea.
- Take emergency immersion-survival suits. They will protect you against the elements and aid flotation, and their color (high-visibility orange or red) is an aid to location.
- Always carry a Personal Locator Beacon (PLB), just in case.
- Take several means of obtaining water, such as a reverse-osmosis pump, which turns saltwater into drinking water, a saltwater desalination kit, a solar still, and rain catchers.
- Always keep a pre-packed emergency bag handy. It should contain; first aid kit, reverse-osmosis pump, emergency beacon, solar still, water, flares, fishing kit. (see pp. 250).
- If your vessel sinks, do not abandon it until absolutely necessary. Stay nearby unless it is unsafe to do so—anything that gives you a bigger "survival footprint" will increase your chances of being rescued, and you may be able to retrieve provisions from the vessel.
- If imminent rescue is unlikely, you will need to ration your water. Consider how much you have, how much can be procured, the chances of seasickness (which leads to dehydration), and the likelihood of being rescued later on.
- Protect yourself from the elements (sun, wind, cold, heat, and salt) as well as you can—prevention is better than cure.
- The sea, especially in rough conditions, can sap the will to live quicker than any other environment. Seasickness is literally draining, resulting in lost fluid, energy, and motivation. Take anti-seasickness tablets at the earliest opportunity—even before abandoning ship—so that you can keep them down, and keep taking them as recommended.

FIND OUT MORE...

P **PROTECTION** **Shelters** pp. 156–61, 176–77 **Fire** pp. 118–33, 204–05 **Dangers** pp. 250–55, 300–01

L **LOCATION** **Movement** pp. 106–07 **Signaling** pp. 236–41

W **WATER** **Finding** pp. 196–97 **Treating** pp. 200–01

F **FOOD** **Plants** pp. 206–07, 288–89 **Animals** pp. 208–13, 224–29, 292–99

GET THE RIGHT GEAR

Whether you're equipping yourself for a lengthy expedition or just a day trip, it's important to choose the correct equipment and clothing. The wrong time to realize that your gear isn't up to the job is when your life depends on it doing what it was designed to do.

When selecting gear, it's always a good idea to work backward from a worst-case-scenario survival situation. Think about what you would need to survive if the worst happened. This is your "first-line" equipment, which you should carry with you at all times. It should enable you to address the basic principles of survival relevant to the environment you are in, and consists of the clothing you would wear and your basic survival equipment—your survival tin and belt-order (see pp. 43, 61).

Once you have organized this basic equipment, you can then decide what pieces of essential gear would make your expedition enjoyable rather than just survivable. This will probably consist of a bivy or tent, a sleeping bag, cooking equipment and food, and something to carry it all in.

In this section YOU WILL DISCOVER...

- the **meaning** of the term "**bomb-burst gear**"...
- that it's always **good to share** when you're **in a group**...
- which **backpacks** are the **best backpacks** to pack...
- why you should **hike around the house** to **break in your boots**...
- a good reason to take a **three-season tent**...
- how to **sleep** like a **mummy**...
- what **gorp** is and **when** you should **eat it**...

It's at this stage that you should conduct a short trial to check that your chosen gear will fit in your pack and that you can comfortably carry it.

Finally, any spare capacity can be utilized for non-essential "luxury" items, such as an inflatable mattress and pillow, an MP3 player, or a book. Double-check that your gear works and that you know how to use it properly. The more you understand how and why a piece of equipment works, the better able you will be to improvise should it be damaged or lost.

With each venture into the wilderness, your confidence in your abilities and that of your equipment will increase. As it does, you may want to explore the world of ultralight camping.

ULTRALIGHT CAMPING refers to the careful selection of your three largest items of gear to dramatically reduce the load you have to carry. A standard tent, pack, and sleeping bag have a combined weight of approximately 20 lb (9kg). Ultralight camping has the potential to halve the weight of your "big three."

- Take a hooped bivy instead of a tent and choose a low season-rated sleeping bag (wear your day clothes inside the bag for extra warmth).
- You can then reduce the size of your pack because your tent and sleeping bag are smaller.

Trekking with less equipment but still staying safe allows you greater freedom to enjoy the wilderness—carrying less weight puts less strain on your body, enabling you to cover greater distances. Ultralight camping can become addictive and is safe if you use common sense—but never compromise on the quality of equipment. Try:

- Using a hexamine stove to cook food and boil water—you won't have to carry a stove and fuel.
- Taking one pot to cook food and boil water.
- Using natural materials as a mattress.

> “The **wrong time** to realize that **your equipment** isn't up to the **task in hand** is when **your life depends** on it doing what it was **designed to do**”

CHOOSING YOUR GEAR

FORWARD PLANNING IS ESSENTIAL when you're deciding on what equipment to take on your trip. You'll need to assess your own personal requirements, the likely demands of weather and terrain, and the amount of gear you'll actually be able to transport. With a little forethought, you'll be as well equipped as you can be for any situation.

PACKING FOR YOUR TRIP

You will first need to weigh up your particular kit requirements against the limitations of your chosen mode of transport (see below). It's then vital to organize and prioritize your gear (see opposite) to ensure that any items you may need in a survival scenario are always close at hand, should the worst happen.

KEY PACKING TIPS

- Pack your gear in reverse order: the things you want to get to first should be the last things you pack.
- Stash items you may need during the day in side or lid pockets, for easy access.
- Coil and tape long straps so that they aren't a snagging hazard.
- Use a dry bag inside your backpack.
- Ensure that all pockets are fully closed and zipped.
- Air out anything packed wet as soon as you stop for the day.

HOW MUCH TO PACK

The environment of the region you're traveling to will dictate the type of equipment you will need to take with you, but your proposed mode of transport is the main constraint on the quantity of kit you can take (see chart, right). The more gear you have to carry yourself, the fewer luxuries you can take: the added weight will make traveling uncomfortable, use up too much valuable energy, slow your progress, and also limit the distance you can travel each day. It's also worth considering whether you can reduce the weight and volume of the kit items you're taking (see box, below).

LIGHTENING THE LOAD

When you're going to be traveling on foot, it's important to get rid of all the excess weight and volume you can, even if it's only by a small amount. The larger and heavier your backpack, the harder you will find the journey. If you have already ruthlessly pared your gear down to the bare essentials, try to reduce the weight or volume of the kit itself. First concentrate on the big three items: tent, sleeping bag, and backpack. Consider using a hooped bivy or tarpaulin rather than a tent; look for a lighter sleeping bag—some can weigh as little as 2lb (0.9 kg); and consider buying a backpack with a lighter frame.

WEIGHT AND SPACE RESTRICTIONS	
ON FOOT	Backpacks (see pp. 44–45) are available in a wide range of volumes—from 30 liters (a day pack) to 80 liters (suitable for a trip of a week or more). Bear in mind that you'll have to carry whatever gear you take with you, and that the weight of the pack will determine what you're realistically able to achieve each day in terms of distance and activity. Pack only the bare minimum: there's no room for luxuries when traveling on foot.
MOUNTAIN/ TOURING BIKE	Pannier bags for bicycles are designed to fit on front, rear, or side pannier racks, and are available in a range of shapes, sizes, and capacities (from 5 to 50 liters). Larger bags will provide you with enough space to pack essentials, such as tent, sleeping bag, cooking equipment, and spare clothes, but you'll be restricted by the weight, and also by the need to carry cycle-maintenance gear, such as spare tires, inner tubes, cables, and tools.
MOTORCYCLE	Side panniers have a capacity of up to 80 liters and tank bags up to 25 liters, and weight is not a major issue. However, you'll need to take extra protective equipment, maintenance tools (including spare tires), and, in some cases, spare fuel, all of which will impact on available space.
PACK ANIMAL	Ideal for rough terrain, such as mountains or desert, pack animals can carry serious weight. A horse can transport up to 20 percent of its body weight; a camel can carry a weight of up to 990 lb (450 kg)—although 330 lb (150 kg) is more common—but you'll need to factor in the animal's food and water.
VEHICLE	The size of the vehicle will determine the amount and the weight of gear you can take with you, but you shouldn't have to compromise; extra equipment can be packed in peli boxes—waterproof storage containers with a hard, plastic exterior—that can be strapped to the outside of the vehicle. The main issue will be the weight-versus-fuel ratio: the heavier the vehicle, the more fuel it will use.
CANOE/ KAYAK/BOAT	Some kayaks and canoes are designed to bear loads of up to 660 lb (300 kg), including the craft's occupant(s), so you should be able to take all of your essential gear, plus a few luxuries. Given your proximity to the water, keeping your gear dry is the main priority. Weight and space restrictions don't apply for larger vessels.

PRIORITIZING YOUR KIT

However much gear you decide to take, you should group individual items into one of three categories—first-line, second-line, and third-line—according to their importance to your survival in a worst-case scenario. It's very unlikely that you'll be able to carry all of your equipment all of the time, and in an emergency situation, you may not have time to gather it all together. However, by prioritizing your gear beforehand, you'll have all your essential items on your person, or close enough to grab at a second's notice.

FIRST-LINE GEAR

Known as "bomb-burst gear" in the military, first-line gear (see right) is your basic survival equipment. If something goes wrong and you have to abandon the bulk of your gear to avoid injury, or death, what you're standing in is all you'll have to help you survive. First-line gear should therefore comprise crucial items of outdoor clothing, along with essential items for navigation and safety. Your bushcraft knife, firesteel, and belt pouch make up your belt order (see pp. 60–61). You'll need to risk-assess your particular situation and adapt your kit priorities accordingly, as conditions change, meaning that your first-line gear may alter as the day progresses. Bear in mind that if a removed layer of clothing goes into your backpack, it's no longer part of your first-line kit.

SECOND-LINE KIT

Second-line gear is everything you would need to stay safe on a daily basis under normal conditions. It can either be packed in a small day pack, or contained in pouches on a belt, the idea being that you carry it at all times. For example, a climber may decide to leave the bulk of his or her equipment (third-line gear) while attempting to reach the summit of a peak. By proceeding with first- and second-line gear, the climber is sacrificing equipment for weight and speed, but is still safe, as they have the essentials on them. Examples of second-line gear can include:

- A spare set of clothes, a bivy sack, and cordage
- Emergency rations and first-aid kit (see p. 260)
- Hexamine stove (see p. 58–59) and items to make a hot drink
- Matchless fireset (see p. 118), and a metal cup

THIRD-LINE GEAR

Also known as your "sustainment load," third-line gear is essentially the equipment you need to keep yourself alive and to function for longer periods of time. How much third-line gear you have will ultimately depend on your mode of transport and the amount of equipment you can carry. Examples of third-line gear include:

- A form of shelter—a tent or a tarpaulin
- Cooking utensils, such as a stove or cooking pot
- A backpack
- Food stores
- A sleeping bag and sleeping mat
- Any large water containers or hydration packs
- Wash kit and sanitary items

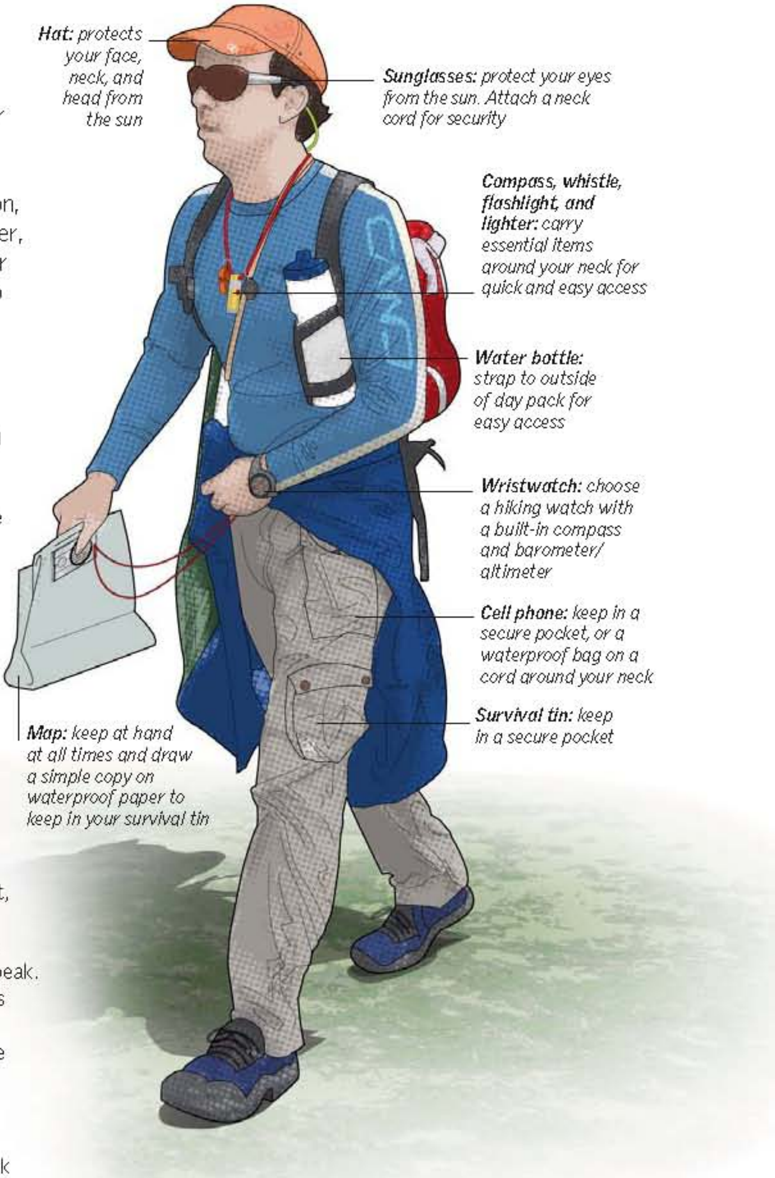

Hat: *protects your face, neck, and head from the sun*

Sunglasses: *protect your eyes from the sun. Attach a neck cord for security*

Compass, whistle, flashlight, and lighter: *carry essential items around your neck for quick and easy access*

Water bottle: *strap to outside of day pack for easy access*

Wristwatch: *choose a hiking watch with a built-in compass and barometer/altimeter*

Cell phone: *keep in a secure pocket, or a waterproof bag on a cord around your neck*

Survival tin: *keep in a secure pocket*

Map: *keep at hand at all times and draw a simple copy on waterproof paper to keep in your survival tin*

FLASHLIGHTS

A flashlight is a piece of first-line gear, even if you don't intend to be out in the dark, because situations can change unexpectedly. Modern flashlights use LEDs, and are small, lightweight, powerful, and very efficient. Opt for a "hands-free" headlamp and tape a spare set of batteries to your head-band. Also include two miniature Photon (LED) flashlights in your survival kit (see pp. 60–61).

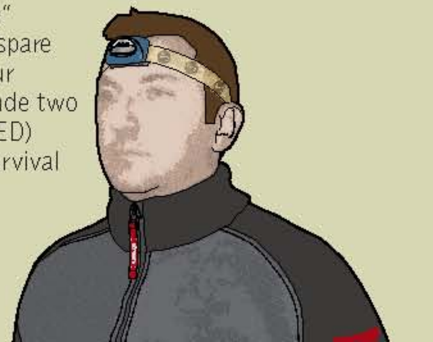

CHOOSING A BACKPACK

BACKPACKS ARE DESIGNED to enable hikers to carry large loads comfortably. They are made from a variety of materials, most of them waterproof. However, you should always use a separate waterproof bag inside your backpack to ensure your sleeping bag and spare clothes are kept dry; they are of little use in a survival situation if they get wet.

CARRY ONLY WHAT YOU NEED

Regardless of your pack size, you are the one who has to carry it. If in a group, many communal items can be shared. Try not to double up on basics (a party of four does not need four tubes of toothpaste, for example).

WHAT DO YOU NEED?

Your choice of backpack will depend on a number of factors. How long is your trip? How much do you intend to carry? What type of gear will you be taking with you? The answers to these questions will determine the size of pack—known as the "capacity"—that is right for you. Pack sizes range from 30 liters (a day pack) to 80 liters or more (suitable for trips lasting a week or more).

BACKPACK FRAMES

If you have chosen a medium- to large-sized pack, you will have to choose between an internal- or an external-frame pack.

DAY PACK

Day hikers can sometimes find themselves in trouble because they are not carrying the appropriate equipment to protect them from the elements. A day pack provides you with the means to carry essential items such as food, water, maps, compasses, and protection from cold and wet weather on a day trip.

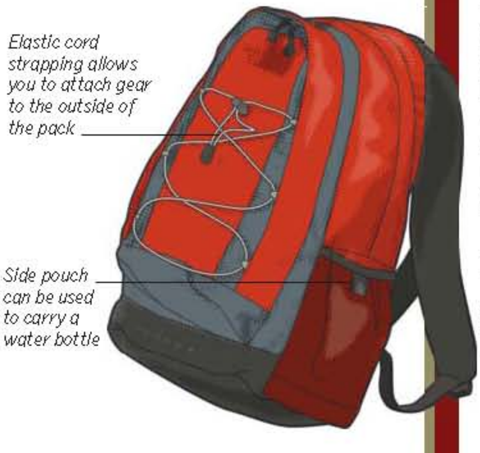

Elastic cord strapping allows you to attach gear to the outside of the pack

Side pouch can be used to carry a water bottle

INTERNAL-FRAME PACKS

Internal-frame packs are narrower in profile than their external-frame counterparts and tend to be longer, with either one or two internal compartments and very few pockets on the outside. The frame is integrated within the pack and usually consists of stays or flat bars, about 1 in (25 mm) wide and 1/10 in (3 mm) thick, made from plastic. Straps on the outside allow you to compress the pack, which prevents the items inside the pack from shifting and throwing you off-balance.

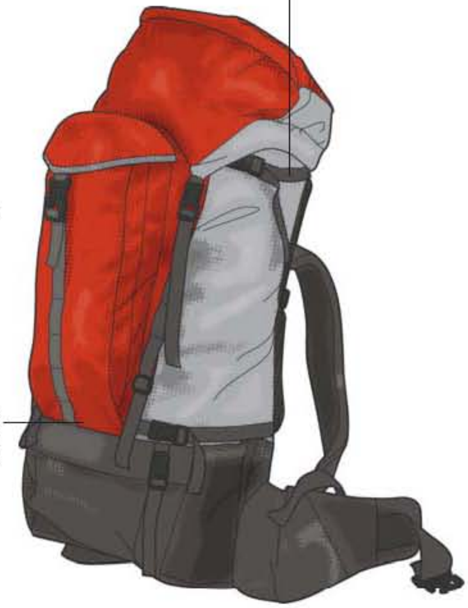

Compression straps reduce bulk and keep contents of pack in place

Additional compartment for quick access to essential items, such as wet-weather gear

EXTERNAL-FRAME PACKS

An external frame houses the pack on a lightweight tubing framework. They are great for heavy loads, as the pack sits more squarely on your hips. They are also cooler to carry than internal-frame packs, as the air can circulate between your back and the pack. External-frame packs usually have more pockets on the outside, which allows you to pack your items by category, rather than packing everything into one or two compartments. This makes locating items easier and allows you to unpack only the compartment you need, rather than the entire pack. Chest and waist straps ensure a comfortable fit.

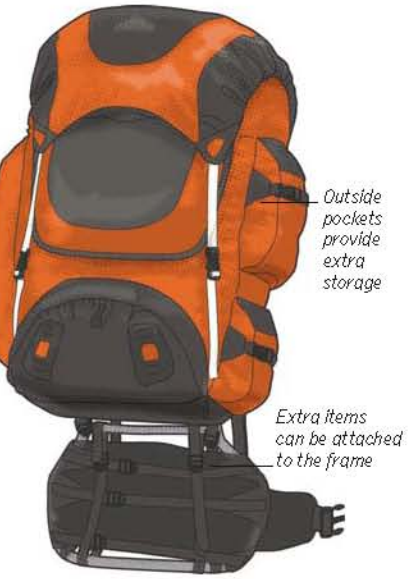

Outside pockets provide extra storage

Extra items can be attached to the frame

FITTING A BACKPACK

Once you have chosen a backpack of the right size, design, and features for your trip, you will have to make sure that it's a comfortable fit. You will need someone's help, but here are a few tips for ensuring your new pack sits comfortably on your back.

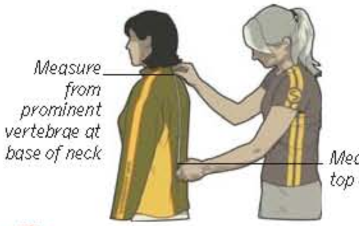
Measure from prominent vertebrae at base of neck
Measure to the top of hip bones

1 First measure your back. The pack you choose should be based on the length of your torso.

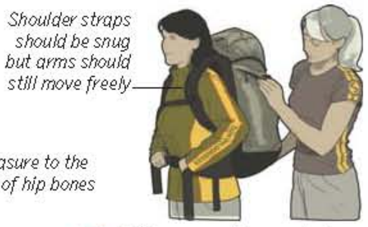
Shoulder straps should be snug but arms should still move freely

2 Make sure the pack is a comfortable fit, allowing for any extra layers of clothing.

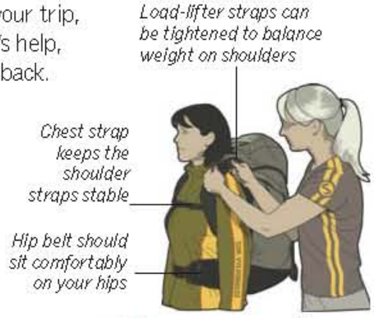
Load-lifter straps can be tightened to balance weight on shoulders
Chest strap keeps the shoulder straps stable
Hip belt should sit comfortably on your hips

3 You can now fine-tune the pack's fit by adjusting the shoulder and hip straps.

PACKING A BACKPACK

Always pack in reverse order: the items you need first should go in last. Heavy items should be placed close to your back to prevent the pack pulling away from your shoulders.

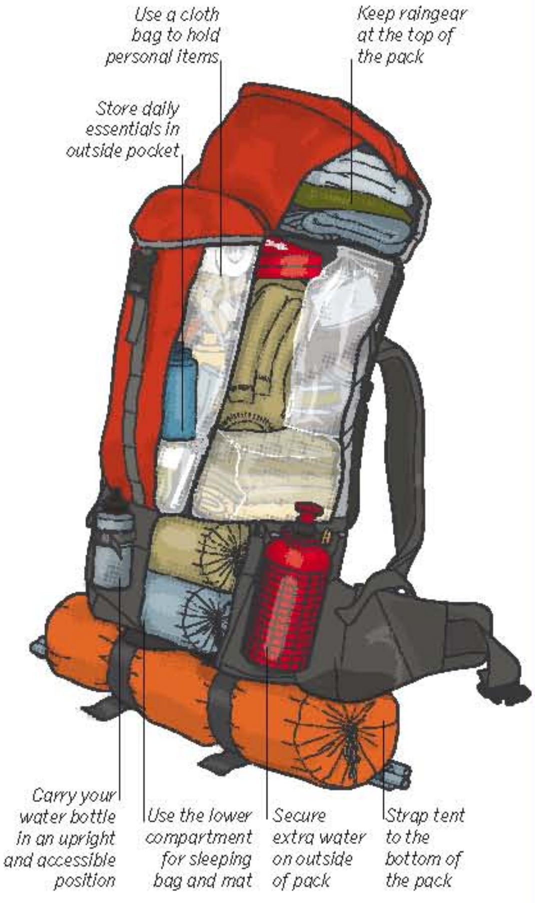
Use a cloth bag to hold personal items
Keep raingear at the top of the pack
Store daily essentials in outside pocket
Carry your water bottle in an upright and accessible position
Use the lower compartment for sleeping bag and mat
Secure extra water on outside of pack
Strap tent to the bottom of the pack

MAKING A SIMPLE PACK FRAME

In a survival situation, having something to carry your gear will be a huge advantage. All you need to make your own improvised backpack is a knife, some wood, some cord, and a waterproof sheet.

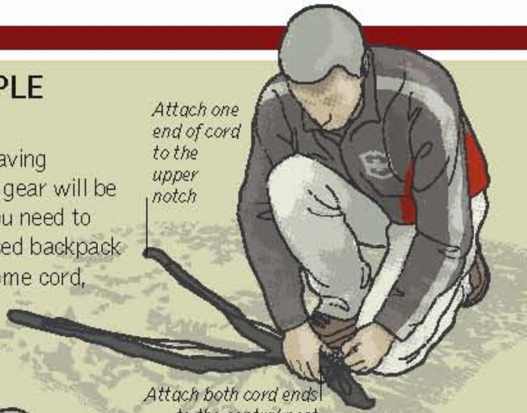
Attach one end of cord to the upper notch
Attach both cord ends to the central post

1 Cut a light bough about 1 ft (30 cm) below the point where it branches, leaving about 3 ft (1 m) above the fork.

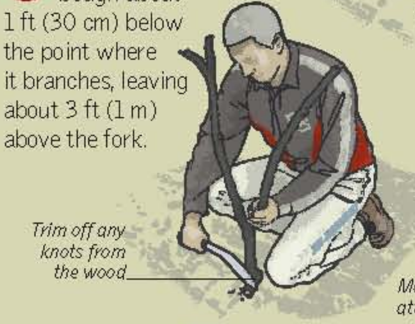
Trim off any knots from the wood

2 Cut notches on all three ends of the bough and tie lengths of cord around the notches to serve as straps to go over your shoulders.

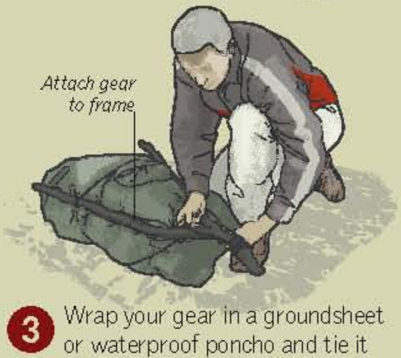
Attach gear to frame

3 Wrap your gear in a groundsheet or waterproof poncho and tie it as high as possible onto the frame on the side opposite the straps.

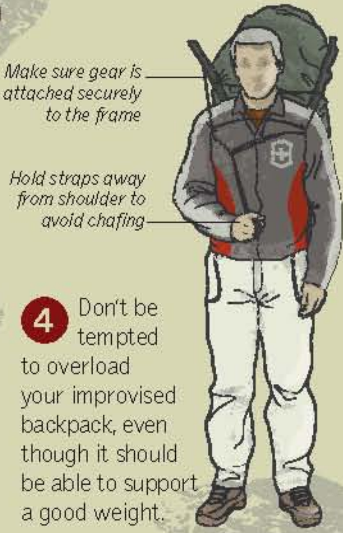
Make sure gear is attached securely to the frame
Hold straps away from shoulder to avoid chafing

4 Don't be tempted to overload your improvised backpack, even though it should be able to support a good weight.

DRESSING FOR THE OUTDOORS

MODERN OUTDOOR CLOTHING is technologically advanced and highly sophisticated. New materials and designs are extremely lightweight, durable, and versatile. To make the most of your gear, choose the fabrics and combinations of clothes most suited to the environment and conditions in which you are traveling.

REGULATING BODY HEAT

Don't be tempted to overdress. Sweat can soak you as much as rain, and a sudden change of temperature can leave you vulnerable to hypothermia. Wearing layers helps you to control your body temperature.

LAYERING CLOTHES

The rule of layering is simple: several light layers are better than one heavy layer. Wearing multiple layers gives you flexibility to fine-tune your temperature by taking off or putting on layers to regulate your body heat. Choose fabrics such as wool, fleece, microfleece, and down—all of which are good insulators.

HOW LAYERING WORKS

Layering is effective because it traps air between the layers of clothes and helps you stay warm in any environment. If you wear the correct layers in the right order, your clothing will move sweat away from your body, keep moisture out, and help to keep you insulated. Wear wicking fabrics, such as polypropylene, in hot and cold weather.

THE LAYERING SYSTEM

The top (outer) layer repels rain, while dampness is wicked away from the skin by the base layer closest to the skin. The mid-layers insulate the body and help retain warmth.

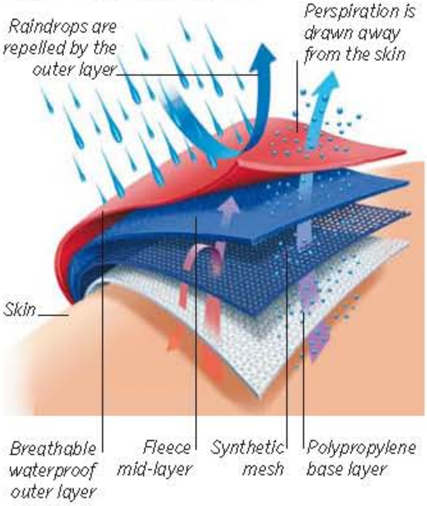
Raindrops are repelled by the outer layer
Perspiration is drawn away from the skin
Skin
Breathable waterproof outer layer
Fleece mid-layer
Synthetic mesh
Polypropylene base layer

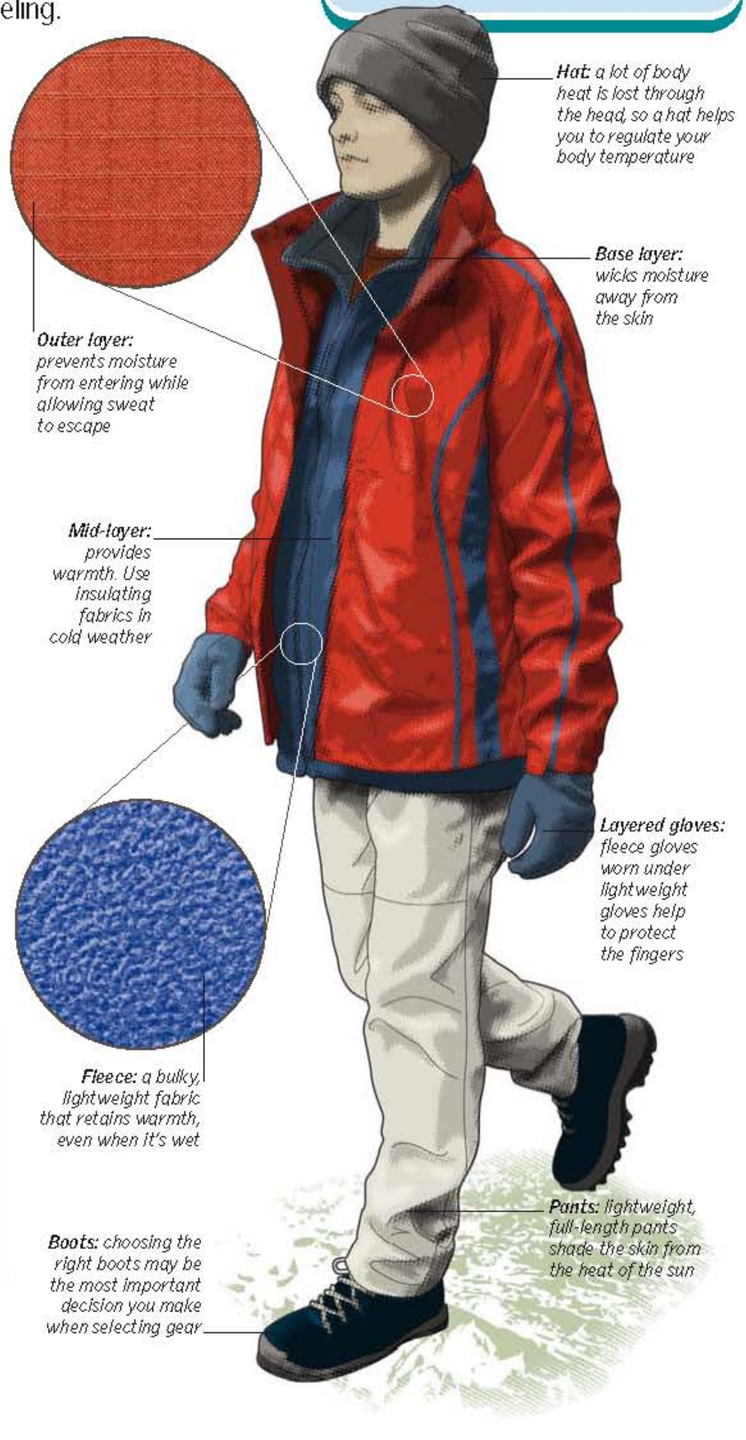
Hat: a lot of body heat is lost through the head, so a hat helps you to regulate your body temperature
Base layer: wicks moisture away from the skin
Outer layer: prevents moisture from entering while allowing sweat to escape
Mid-layer: provides warmth. Use insulating fabrics in cold weather
Layered gloves: fleece gloves worn under lightweight gloves help to protect the fingers
Fleece: a bulky, lightweight fabric that retains warmth, even when it's wet
Pants: lightweight, full-length pants shade the skin from the heat of the sun
Boots: choosing the right boots may be the most important decision you make when selecting gear

WARM-WEATHER CLOTHING

It's vital to stay as cool as possible in warm weather to avoid heat exhaustion or heat stroke (see p. 272). Too much exposure to direct sunlight can cause sunburn and dehydration, and heat rashes can be exacerbated if sweat is not able to evaporate properly. Choose breathable fabrics that will keep you cool and protect your skin from the sun. Stay hydrated and always wear a hat.

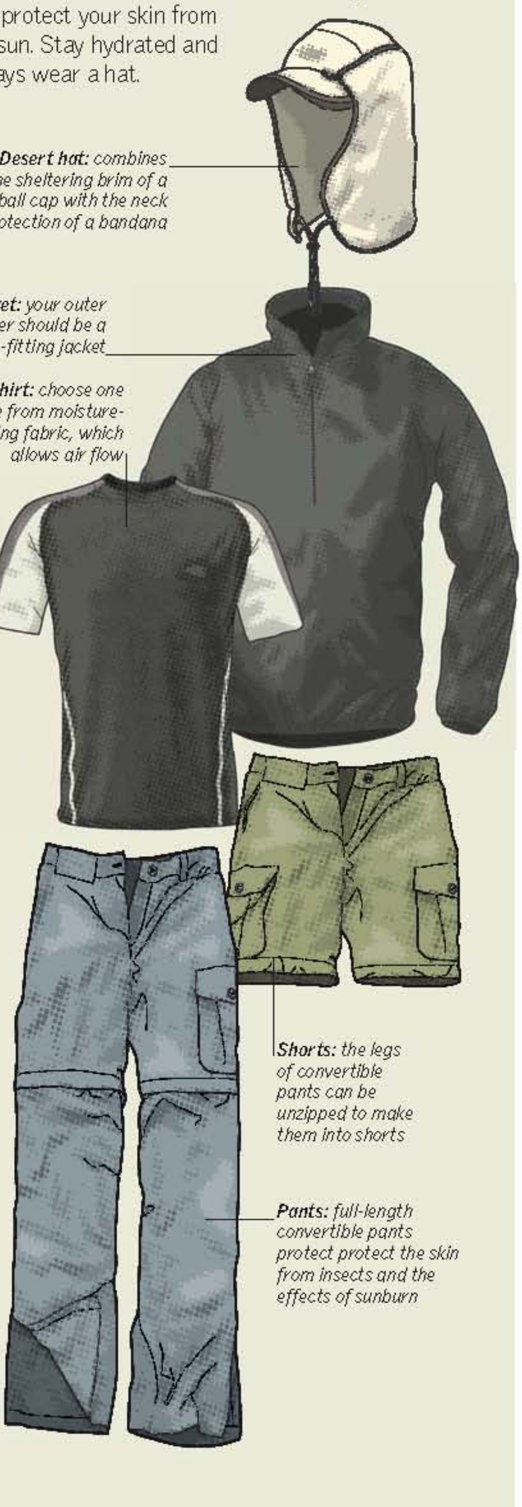

Desert hat: *combines the sheltering brim of a baseball cap with the neck protection of a bandana*

Jacket: *your outer layer should be a loose-fitting jacket*

T-shirt: *choose one made from moisture-wicking fabric, which allows air flow*

Shorts: *the legs of convertible pants can be unzipped to make them into shorts*

Pants: *full-length convertible pants protect protect the skin from insects and the effects of sunburn*

COLD-WEATHER CLOTHING

In cold weather, you need to pay particular attention to your clothing layers. Use a lightweight base layer, which will wick moisture from your skin, several layers of warm, insulating clothing, and an outer shell that's windproof and waterproof. The secret to staying comfortable is to adjust your layers as your body temperature changes. Remove layers as your body temperature rises to avoid sweating.

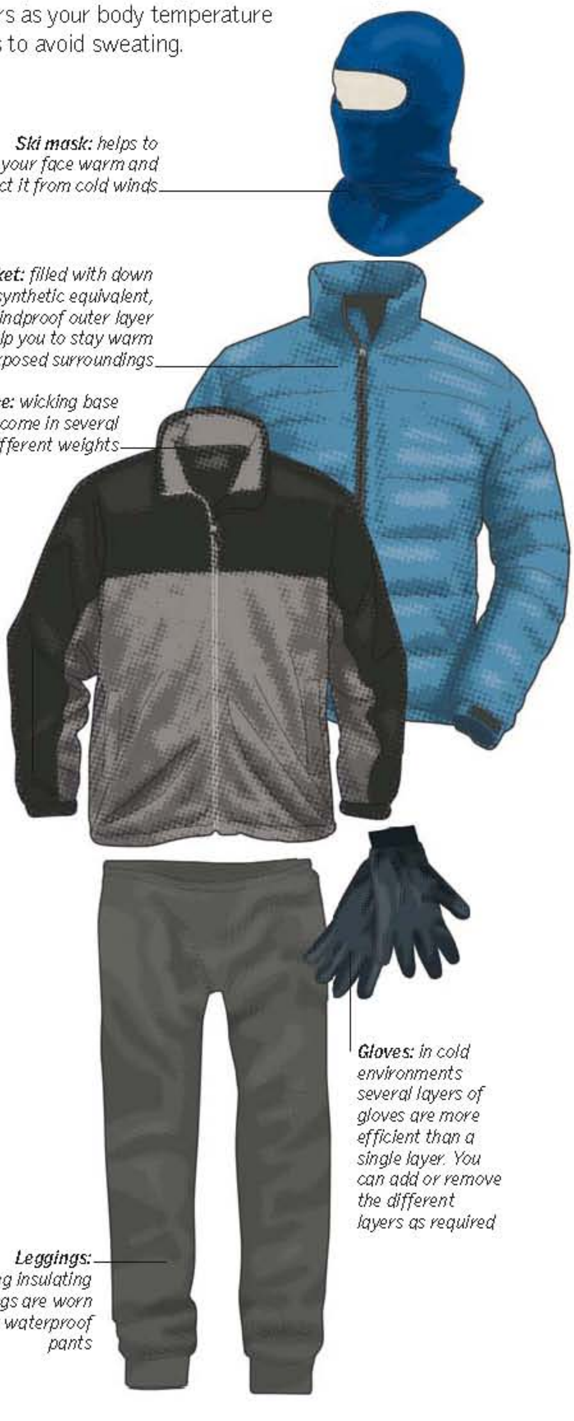

Ski mask: *helps to keep your face warm and protect it from cold winds*

Jacket: *filled with down or a synthetic equivalent, a windproof outer layer will help you to stay warm in exposed surroundings*

Fleece: *wicking base layers come in several different weights*

Gloves: *in cold environments several layers of gloves are more efficient than a single layer. You can add or remove the different layers as required*

Leggings: *wicking insulating leggings are worn under waterproof pants*

WET-WEATHER CLOTHING

Sudden downpours can occur almost anywhere and it is easy to be caught out by them. The best fabrics to wear in such conditions are those that are breathable, waterproof, and allow sweat to escape—the best known of these is Gore-Tex®. Always carry the gear necessary to stay warm and dry, and make sure you can access it quickly if you are caught out— it can be the difference between comfort and misery.

HOW BREATHABLE WATERPROOF FABRIC WORKS

Breathable waterproof fabric is a laminate of three layers: two layers of nylon on either side of a thin layer of microporous teflon, which contains tiny pores—50 times smaller than the width of a human hair—that keep rain droplets out but allow perspiration (water vapor) to escape.

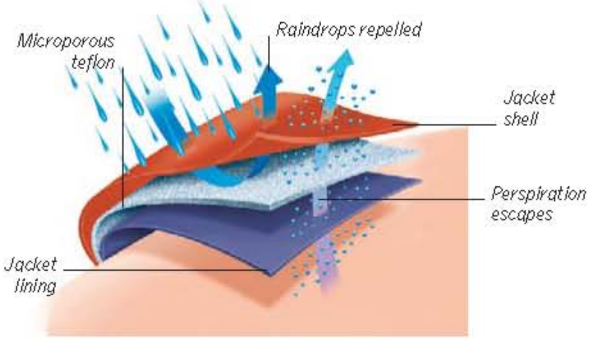

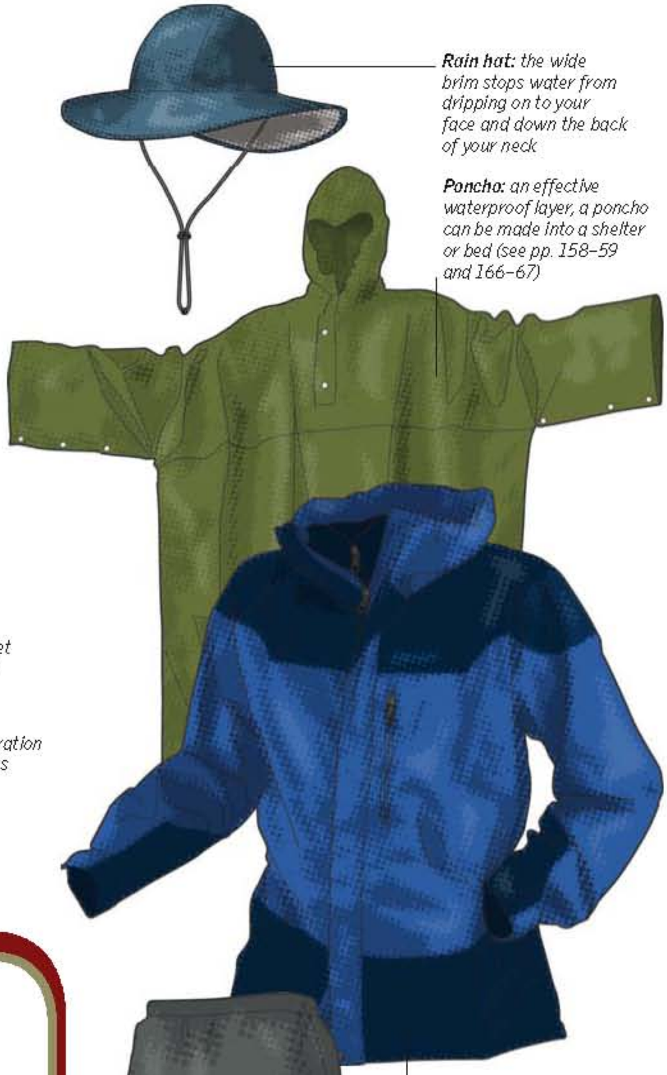

Rain hat: *the wide brim stops water from dripping on to your face and down the back of your neck*

Poncho: *an effective waterproof layer, a poncho can be made into a shelter or bed (see pp. 158–59 and 166–67)*

Waterproof jacket: *allows sweat to escape while keeping rain out*

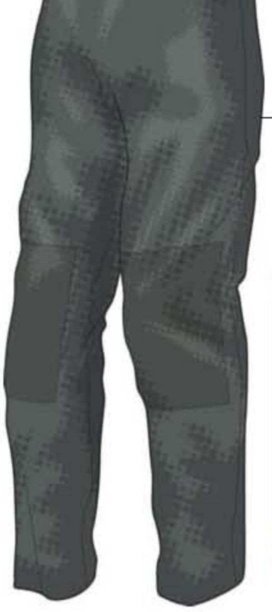

Waterproof pants: *keep your legs dry in wet conditions*

SOCKS

Socks are a vital part of your footwear system. Their function is two-fold. Firstly, they cushion the feet and prevent boots from rubbing and causing blisters. Secondly, they keep the feet warm and dry by wicking moisture away from the feet. Note that socks made from breathable waterproof fabric can be worn with regular boots but should not be combined with breathable waterproof boots.

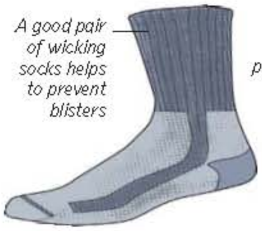

A good pair of wicking socks helps to prevent blisters

WICKING SOCK

A lightweight inner sock that helps wick moisture away from the skin and reduces friction.

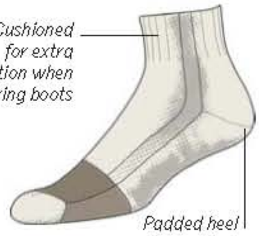

Cushioned for extra protection when wearing boots

Padded heel for comfort

WALKING SOCK

The thick fabric of the walking sock offers maximum cushioning, comfort, and protection.

GAITERS

Gaiters are useful, both in temperate areas for keeping the feet and lower pant legs dry, and in polar regions for keeping out snow.

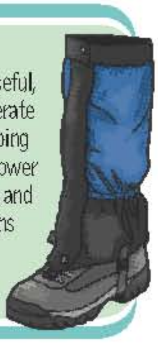

FOOTWEAR

A number of factors determine which type of footwear is right for you. The first concerns your personal requirements, which include the shape of your feet and the amount of support you need. You also need to consider how far you are traveling and the type of terrain you'll be covering. Then there is cost: footwear varies from the relatively cheap to the extremely costly. Bear in mind that if you intend to spend a lot of time in the wilderness, it pays to invest a little extra in comfortable, sturdy footwear.

BREAKING IN BOOTS

Your boots and feet should coexist in perfect harmony when you're on the trail. When you buy a pair of boots, wear them around the house and go on short hikes to make sure you have broken them in.

ANATOMY OF A SOLE

A boot sole has several layers to protect and support your feet. Look for a good tread on the outsole, and for cushioning beneath the heel and toe areas.

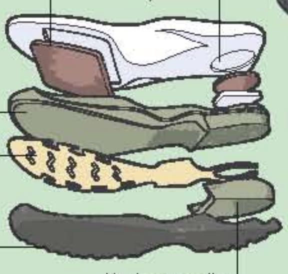

Cushioning pads absorb shock

Insole stabilizes foot and keeps it in position

Full-length shank plate for rigidity

Heel cup cradles the midsole

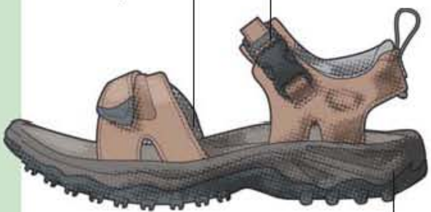

Arch straps hold the shoe in place in any terrain

An adjustable fastener ensures a snug fit

Modern sandal has solidly constructed soles

SANDALS

Modern sandal designs offer great support, and are extremely comfortable, while offering additional ventilation.

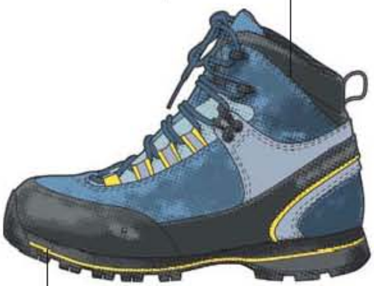

A flexible fabric upper dries quickly when wet and allows the foot to breathe

Shock-absorbing sole gives added comfort on hard terrain

LIGHTWEIGHT BOOT

Fabric and leather hybrids are increasingly popular because they combine the support and traction of a heavier shoe with the flexibility of a sports shoe, so there is less friction on the foot.

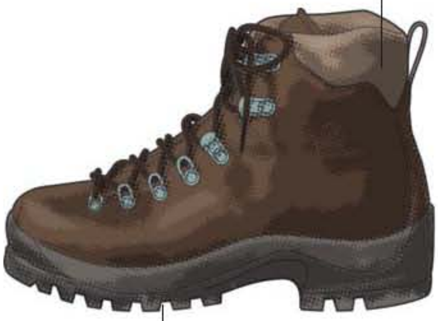

The padded ankle provides comfort and support

Sole provides grip on slippery ground

HIKING BOOTS

A compromise between weight, durability, and protection produces a good, all-round leather boot with a sole of hard-wearing rubber, such as Vibram®, water-resistant uppers, and valuable support for the ankles.

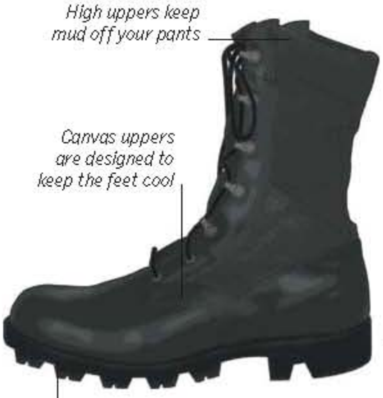

High uppers keep mud off your pants

Canvas uppers are designed to keep the feet cool

Sole contains wide, deep studs to provide grip on the wet ground

JUNGLE-TREKKING BOOT

This is a high boot made from rot-proof leather and canvas with a directly molded sole. Breather holes in the instep aid ventilation and help to drain moisture in hot or humid conditions.

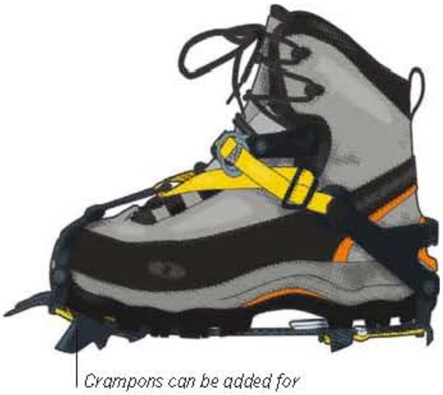

Crampons can be added for extra grip on ice and snow

CLIMBING/HIKING HYBRID BOOT

More flexible than traditional climbing boots, modern hybrid boots are designed to be worn with crampons and to keep the feet warm in very cold environments.

TRUE-LIFE ACCOUNT

EXTREME SURVIVAL—IN THE WILDERNESS

USEFUL EQUIPMENT

- Walking staff
- Pocket chainsaw
- Whistle, flashlight, signal mirror
- Animal deterrent spray
- Water purifiers
- Small AM/FM radio
- Map, compass, GPS
- Survival tin, bushcraft knife
- Cell/satellite phone
- Poncho/bivy sack

BLAKE STANFIELD, 38, AND HIS 65-YEAR-OLD FATHER, Neil, endured being trapped beneath river ice, encounters with bears, and four days and nights in the Alaskan wilderness without food. They survived thanks to good survival skills, knowledge of the local area, and an abundance of water and firewood.

Father and son were dropped by floatplane on Friday, June 6, 2003, at a remote point on the Koyukuk River, deep inside Alaska. They planned to spend seven days rafting approximately 90 miles (145 km) to the town of Bettles. The trip had hardly begun when disaster struck—the raft crashed at speed into a massive sheet of ice, throwing the pair into the freezing water. They were both caught by the strong current and pulled under the ice. Somehow Blake was washed ashore, and he used a branch to haul his father to the riverbank.

Blake quickly realized that Neil was close to hypothermia, so used his waterproof lighter to light a fire of sticks and pine needles. Far from rescue, with their supplies lost and no one expecting their return for six days, their prospects looked bleak. With night approaching they built a shelter.

"THE RAFT CRASHED AT SPEED INTO A MASSIVE SHEET OF ICE"

The next morning, Blake decided to hike the 65 miles (105 km) to Bettles to get help. On Sunday his progress was brought to a halt by the confluence of two large rivers—the Tinayguk and Koyukuk. However, Blake realized that he had reached a landmark on the flight path of supply planes that frequently flew into the interior, so he built a signal fire and waited. Two days later, a pilot spotted him and radioed his position to a US Army base 200 miles (320 km) away in Fairbanks, then dropped him a two-way radio and supplies. The pilot then continued up the river to find Neil, dropping him a sleeping bag, tent, and supplies, before radioing his position to the Army. Both men were picked up the next day—exhausted, malnourished, and close to hypothermia, but alive.

WHAT TO DO

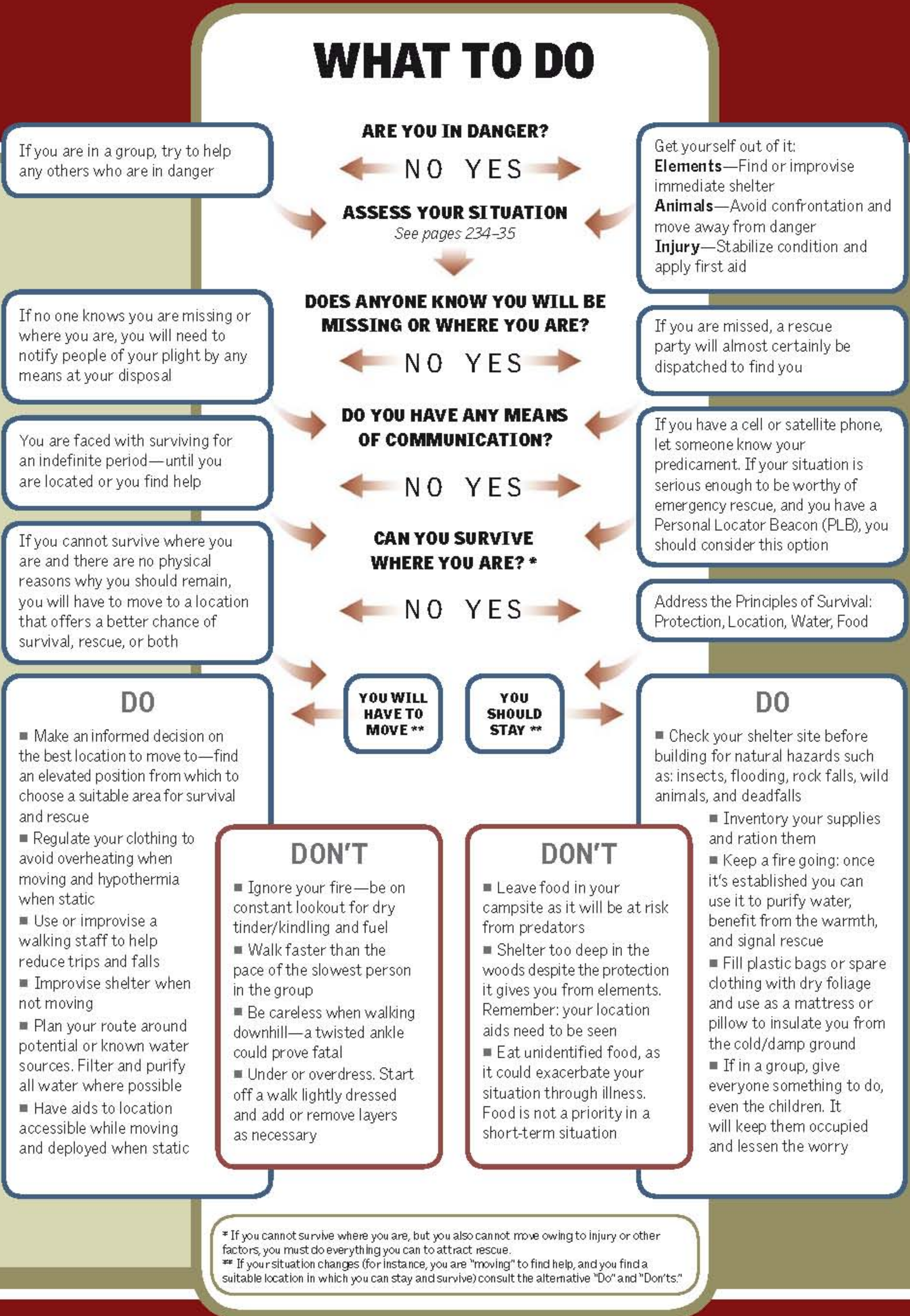

ARE YOU IN DANGER?

NO YES

If you are in a group, try to help any others who are in danger

Get yourself out of it:
Elements—Find or improvise immediate shelter
Animals—Avoid confrontation and move away from danger
Injury—Stabilize condition and apply first aid

ASSESS YOUR SITUATION
See pages 234–35

DOES ANYONE KNOW YOU WILL BE MISSING OR WHERE YOU ARE?

NO YES

If no one knows you are missing or where you are, you will need to notify people of your plight by any means at your disposal

If you are missed, a rescue party will almost certainly be dispatched to find you

DO YOU HAVE ANY MEANS OF COMMUNICATION?

NO YES

You are faced with surviving for an indefinite period—until you are located or you find help

If you have a cell or satellite phone, let someone know your predicament. If your situation is serious enough to be worthy of emergency rescue, and you have a Personal Locator Beacon (PLB), you should consider this option

CAN YOU SURVIVE WHERE YOU ARE? *

NO YES

If you cannot survive where you are and there are no physical reasons why you should remain, you will have to move to a location that offers a better chance of survival, rescue, or both

Address the Principles of Survival: Protection, Location, Water, Food

YOU WILL HAVE TO MOVE **

DO

- Make an informed decision on the best location to move to—find an elevated position from which to choose a suitable area for survival and rescue
- Regulate your clothing to avoid overheating when moving and hypothermia when static
- Use or improvise a walking staff to help reduce trips and falls
- Improvise shelter when not moving
- Plan your route around potential or known water sources. Filter and purify all water where possible
- Have aids to location accessible while moving and deployed when static

DON'T

- Ignore your fire—be on constant lookout for dry tinder/kindling and fuel
- Walk faster than the pace of the slowest person in the group
- Be careless when walking downhill—a twisted ankle could prove fatal
- Under or overdress. Start off a walk lightly dressed and add or remove layers as necessary

YOU SHOULD STAY **

DON'T

- Leave food in your campsite as it will be at risk from predators
- Shelter too deep in the woods despite the protection it gives you from elements. Remember: your location aids need to be seen
- Eat unidentified food, as it could exacerbate your situation through illness. Food is not a priority in a short-term situation

DO

- Check your shelter site before building for natural hazards such as: insects, flooding, rock falls, wild animals, and deadfalls
- Inventory your supplies and ration them
- Keep a fire going: once it's established you can use it to purify water, benefit from the warmth, and signal rescue
- Fill plastic bags or spare clothing with dry foliage and use as a mattress or pillow to insulate you from the cold/damp ground
- If in a group, give everyone something to do, even the children. It will keep them occupied and lessen the worry

* If you cannot survive where you are, but you also cannot move owing to injury or other factors, you must do everything you can to attract rescue.

** If your situation changes (for instance, you are "moving" to find help, and you find a suitable location in which you can stay and survive) consult the alternative "Do" and "Don'ts."

SLEEPING SYSTEMS

REST IS AS ESSENTIAL for survival as food. A good night's sleep can offset much of the worry and stress of a difficult situation. Making sure your shelter is suitable for the environment you're in, and choosing the right sleeping bag, can be vital factors in survival.

SLEEPING BAGS

Although there are many different shapes and styles of sleeping bag, the one you choose should have enough padding to keep you warm at night even without a tent. A sleeping bag must never be allowed to get wet, so always keep it inside a waterproof cover, such as the bag's stuff sack or a bivy sack. Always try a sleeping bag before you buy it. If it's too snug, it will be less effective.

TIPS ON BUYING A SLEEPING BAG

There are many types of bag available. Here are a few things you should consider to ensure you buy the right sleeping bag for you.

- Determine the lowest temperature you're likely to encounter on your trip and choose a bag that will perform at this temperature.
- Synthetic bags are cheaper and easier to clean than down bags, and continue to provide insulation even when wet.
- Down bags are more expensive than synthetic bags, but provide a better warmth-to-weight ratio and last longer.
- A mummy-shaped bag provides better insulation than a rectangular-shaped bag, but has less room to move around in.

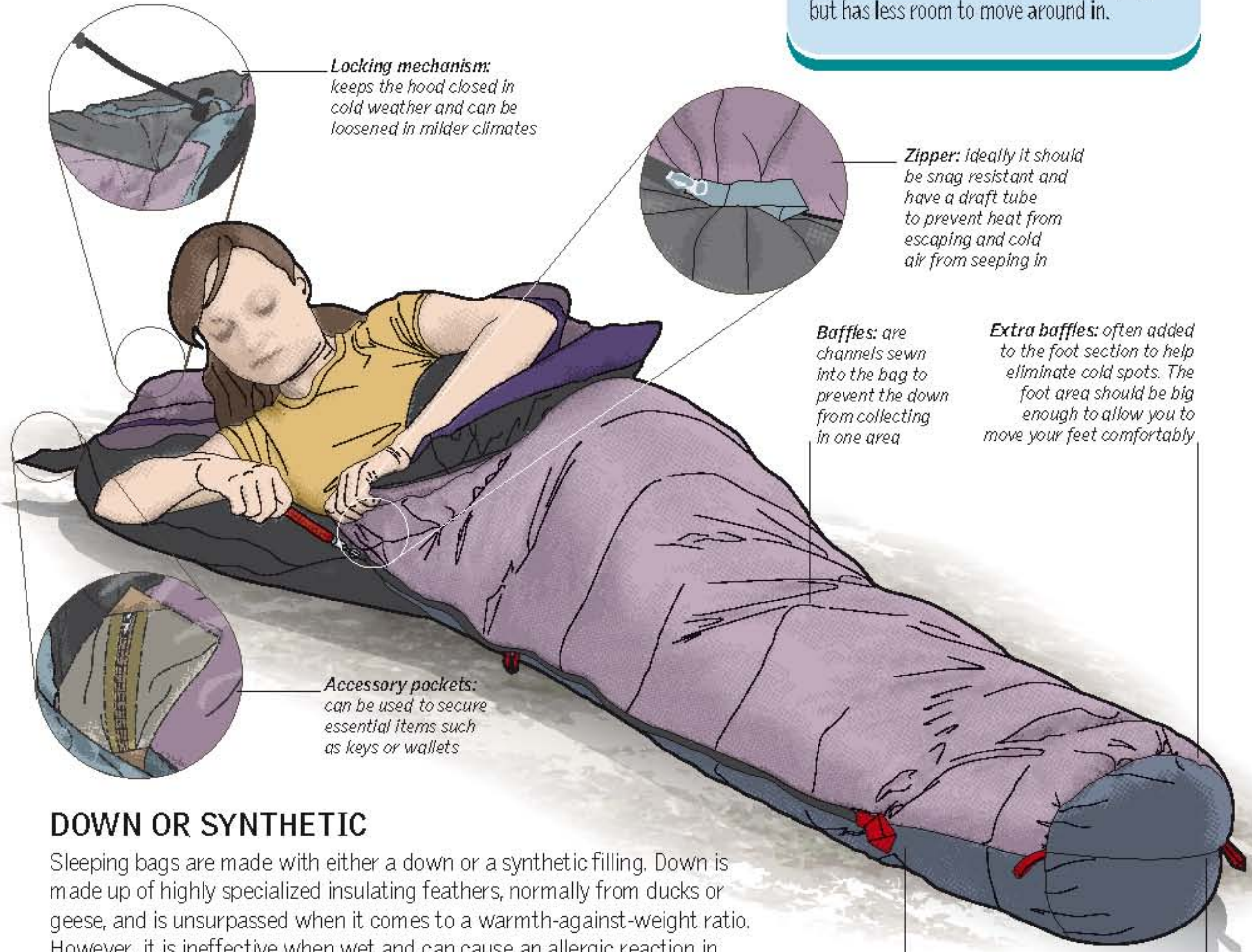

Locking mechanism: *keeps the hood closed in cold weather and can be loosened in milder climates*

Zipper: *ideally it should be snag resistant and have a draft tube to prevent heat from escaping and cold air from seeping in*

Baffles: *are channels sewn into the bag to prevent the down from collecting in one area*

Extra baffles: *often added to the foot section to help eliminate cold spots. The foot area should be big enough to allow you to move your feet comfortably*

Accessory pockets: *can be used to secure essential items such as keys or wallets*

Loops: *allow you to attach sleeping bag to the sleeping mat*

Box foot: *creates a mummy shape and is designed to conform to the position of your feet when you're sleeping on your side*

DOWN OR SYNTHETIC

Sleeping bags are made with either a down or a synthetic filling. Down is made up of highly specialized insulating feathers, normally from ducks or geese, and is unsurpassed when it comes to a warmth-against-weight ratio. However, it is ineffective when wet and can cause an allergic reaction in some people. Synthetic fillings range from simple hollow fibers all the way up to complex fibers designed to mimic the structure of down. They still retain some of their insulating capacity if they get wet.

TEMPERATURE RATINGS

Because manufacturers have no standardized way of registering how warm a sleeping bag is, temperature ratings for sleeping bags remain an inexact science. Some manufacturers give a bag both a comfort rating and a survival rating—known as a "season rating.' These give some indication as to how manufacturers expect a sleeping bag to perform.

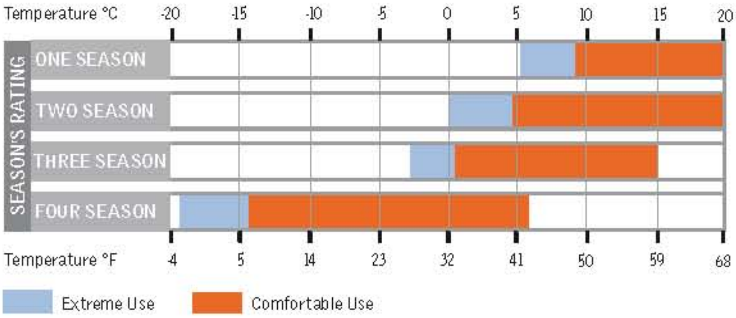

CONSTRUCTION

The principle of all sleeping bags is the same: to trap air and prevent its circulation so that the body heats the trapped air and keeps you warm while you sleep. This can be achieved in a number of ways.

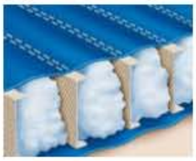

BOXWALL

Used in cold-weather down bags, the filling is contained within box-like sections to minimize bunching.

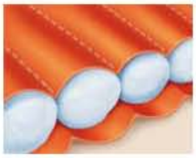

SEWN-THROUGH

Filling is in separate oval channels, although heat is still lost through the stitching.

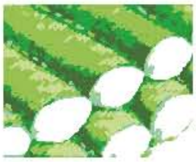

OFFSET CHANNELS

The filling is laid out in two layers to prevent bunching and heat loss through the stitching.

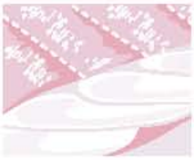

SHINGLE

Slanted layers of overlapping fibers that fill with warm air to aid insulation.

USING YOUR SLEEPING BAG

Before using your sleeping bag, always check inside for spiders and other dangers, and shake it to make sure the filling is distributed evenly. During use, if the bag is too warm, simply unzip it to cool down, or use the bag as a quilt. If it's too cold, either put on some clothing, or use a silk liner or waterproof bivi bag to increase its performance. Always air your sleeping bag well after using it.

SLEEPING ACCESSORIES

You'll need to get a sleeping mat as well as a sleeping bag to ensure a comfortable, dry night's sleep. Additional gear, such as bivy sacks, sleeping bag liners, and inflatable pillows, will also increase comfort.

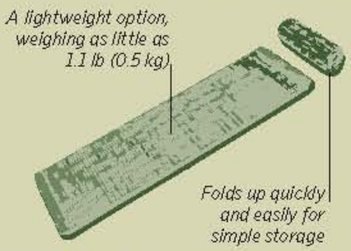

A lightweight option, weighing as little as 1.1 lb (0.5 kg)

Folds up quickly and easily for simple storage

FOAM MATS

The lightest and simplest type of mat, foam mats are best used on soft surfaces, such as sand or pine needles.

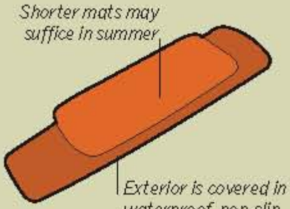

Shorter mats may suffice in summer

Exterior is covered in waterproof, non-slip polyester material

AIR MATS

They may be heavier and more expensive than foam mats, but air mats provide superior comfort and thermal insulation.

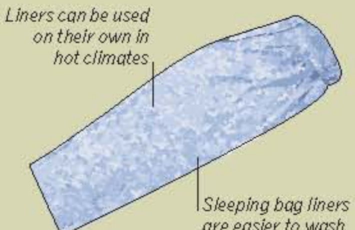

Liners can be used on their own in hot climates

Sleeping bag liners are easier to wash than sleeping bags

SLEEPING BAG LINER

Usually made of cotton or silk, sleeping bag liners trap air between your body and the sleeping bag.

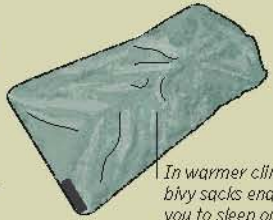

In warmer climates, bivy sacks enable you to sleep outside without a tent

BIVY SACKS

A simple waterproof bag that is used over a sleeping bag to keep it dry or used on its own as a shelter.

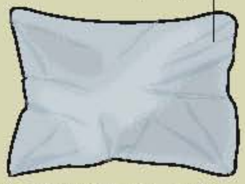

Outer layer of pillow is padded for extra comfort

INFLATABLE PILLOW

An inflatable pillow adds some luxury to expeditions. Alternatively, fill a stuff sack with spare clothing.

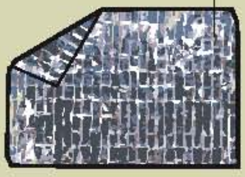

Foil prevents body heat from escaping and deflects it back to the body

SPACE BLANKET

A lightweight foil blanket for use in emergencies, space blankets can also be used as a temporary canopy.

PORTABLE SHELTERS

Shelter from the elements at night is essential for long-term survival. A variety of products are available to you, depending on the conditions you're about to enter and the amount you're prepared to carry. You can choose from lightweight options, such as hammocks and variations on bivy sacks, and the more traditional alternatives, tents, which are heavier but can accommodate up to eight people.

USING A HAMMOCK

If you have a hammock you can camp even if the ground is muddy, rocky, or on an incline. The advantage of a hammock is that it's lightweight and can be erected just about anywhere. Modern hammocks provide a shelter and bed solution in one portable package.

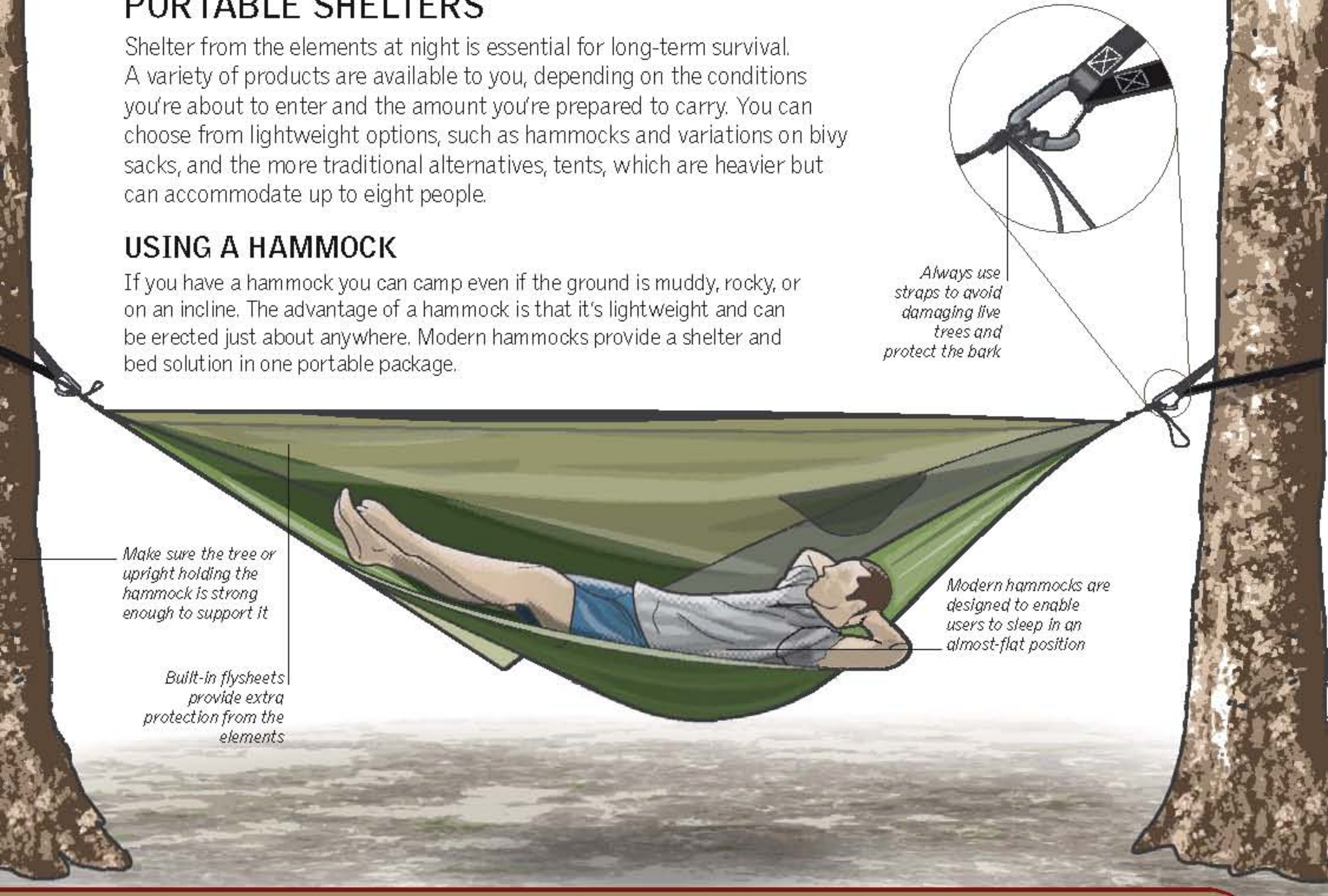

Always use straps to avoid damaging live trees and protect the bark

Make sure the tree or upright holding the hammock is strong enough to support it

Built-in flysheets provide extra protection from the elements

Modern hammocks are designed to enable users to sleep in an almost-flat position

USING A TARP TENT

A cross between a tarpaulin and a tent, a tarp tent is a highly versatile, extremely light form of shelter that's capable of withstanding even the most extreme conditions. Groundsheets should be laid out on the ground for added protection, and a suitable sleeping bag is essential. A one-person version can weigh as little as 18½ oz (0.52 kg).

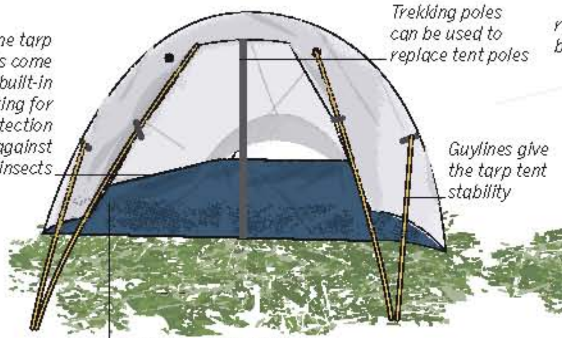

Some tarp tents come with built-in netting for protection against insects

Trekking poles can be used to replace tent poles

Guylines give the tarp tent stability

A groundsheet provides insulation from the cold, damp ground

USING A HOOPED BIVY

The hooped bivy is a waterproof and breathable bivy sack that has been designed to form a one-person shelter. It usually incorporates pegging points and a zippered and hooped entrance that form a small vestibule for your backpack. Many incorporate a heavy-duty groundsheet and can be set up and taken down in a matter of minutes.

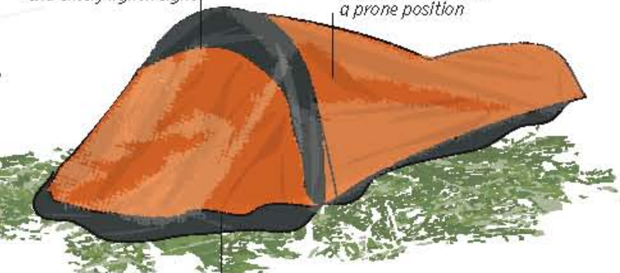

While they may have restricted space, hooped bivys pack small and are extremely lightweight

Limited height means you're restricted to a prone position

A small vestibule provides minimal storage for your gear

USING A TENT

Tents keep the rain and wind out while retaining warmth. The outer flysheet should be strong, impermeable, taut, and able to withstand high winds. The inner tent—which may be attached to a flysheet—is loose and made of permeable material to minimize condensation but retain heat. The inner and outer parts of the tent must not touch each other; if they do, heat may be lost and condensation may form on the underside of the flysheet, then seep into the tent.

WARNING!

In some climactic conditions, such as extreme high winds, severe storms, or heavy snow cover, stakes and guylines may not be enough to anchor the tent securely to the ground. This could result in the tent being blown away—and could have severe consequences for the tent's occupants. In such conditions, use extra means—such as rocks or logs—to anchor your tent securely.

THREE-SEASON TENT

Three-season tents are designed for use in a variety of climates. The inner layer is made of a lightweight material that offers both ventilation and protection against insects. The flysheet—which should extend about 4 in (10 cm) above the ground—and the groundsheet are made of waterproof fabric.

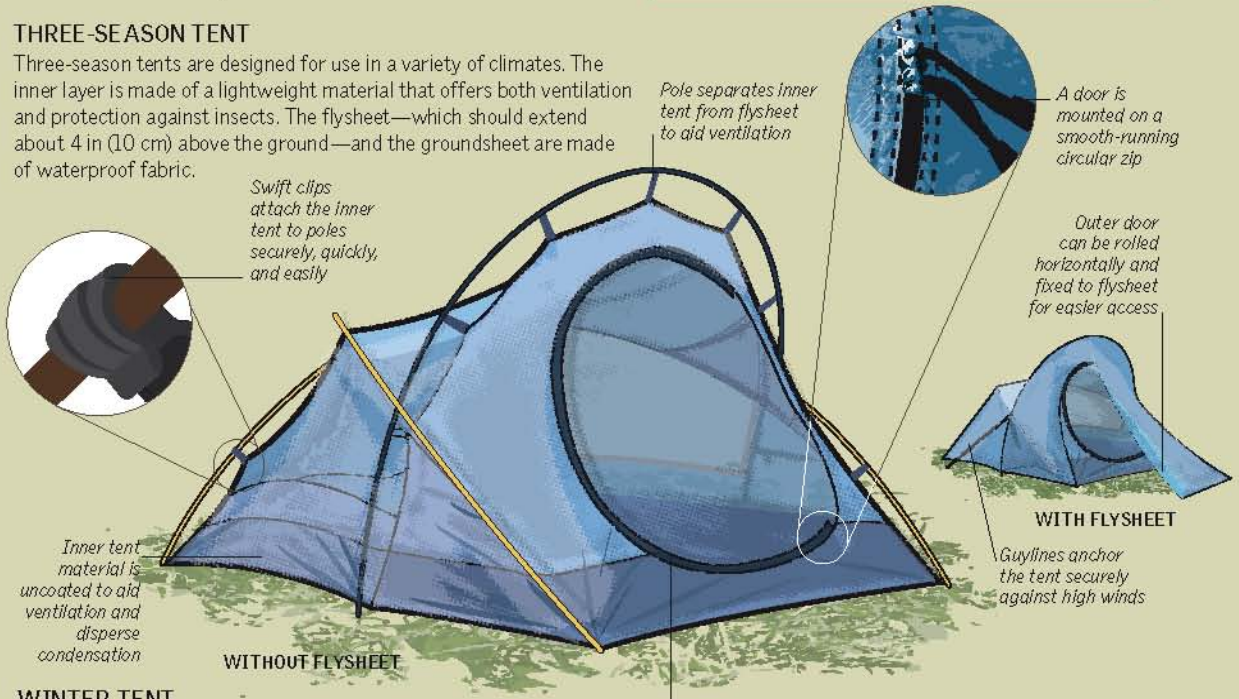
Pole separates inner tent from flysheet to aid ventilation
A door is mounted on a smooth-running circular zip
Swift clips attach the inner tent to poles securely, quickly, and easily
Outer door can be rolled horizontally and fixed to flysheet for easier access
WITH FLYSHEET
Guylines anchor the tent securely against high winds
Inner tent material is uncoated to aid ventilation and disperse condensation
WITHOUT FLYSHEET
Mesh door allows light to enter but keeps insects out

WINTER TENT

For cold-weather climates, look for a tent that offers extra-strong poles, storm windows, and ample pockets so that you can store your gear inside the tent. However, these extra features increase the tent's weight. The dome shape sheds snow well, and withstands high winds.

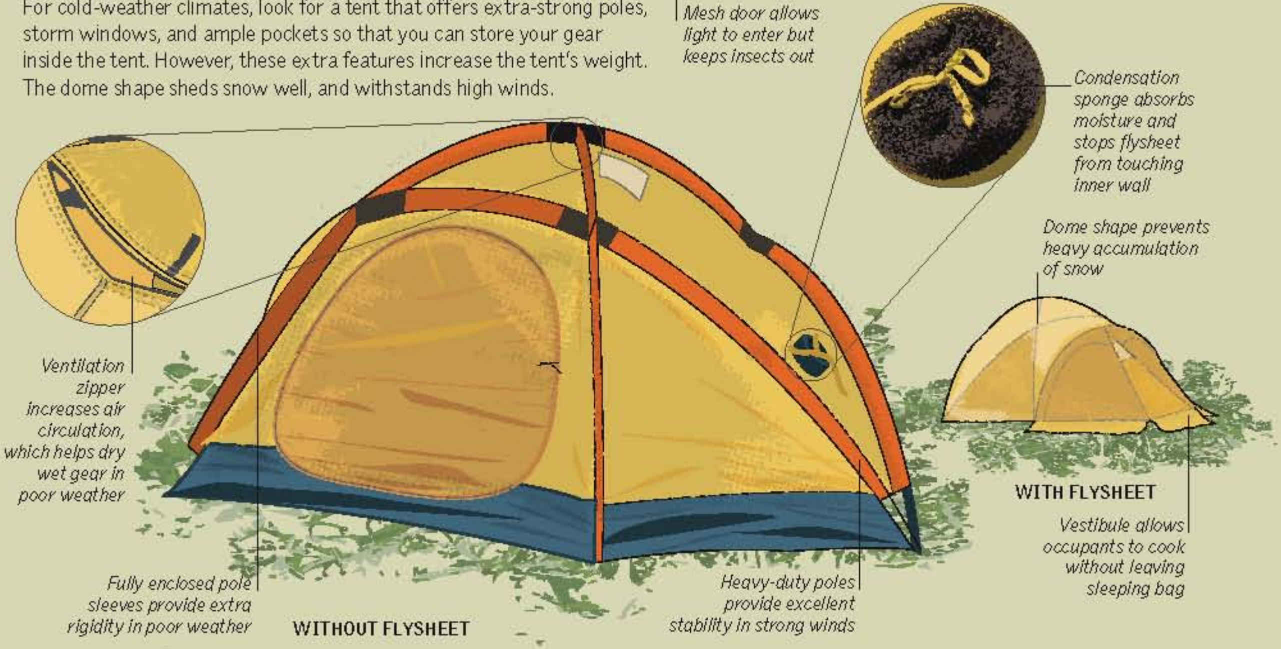
Condensation sponge absorbs moisture and stops flysheet from touching inner wall
Dome shape prevents heavy accumulation of snow
Ventilation zipper increases air circulation, which helps dry wet gear in poor weather
WITH FLYSHEET
Vestibule allows occupants to cook without leaving sleeping bag
Fully enclosed pole sleeves provide extra rigidity in poor weather
WITHOUT FLYSHEET
Heavy-duty poles provide excellent stability in strong winds

EATING ON THE TRAIL

THE FOOD YOU EAT determines how efficiently your body will function. This is never more important than when you're undertaking an expedition that will test your physical and mental endurance beyond normal levels.

BODY FAT AND SURVIVAL

Being physically fit and active keeps you strong and less prone to injury, but being slightly overweight can actually be an advantage in a survival situation: 1 lb (½ kilo) of body fat converts to roughly 3,500 calories—the amount of energy you would usually expend during an average day.

FOOD FOR LIFE

Your body requires energy to fuel the chemical and biological reactions that take place within it, and to power your muscles. This, and other nutrients, comes from the food you eat (see below).

TYPES OF NUTRITION	EXAMPLES	BENEFITS
CARBOHYDRATE	▪ Rice, pasta, bread, and cereals ▪ Fresh and dried fruit ▪ Root vegetables ▪ Chocolate and candy	▪ Major source of energy, as it converts most readily to glucose, which is your body's preferred source of fuel.
PROTEIN	▪ Meat and poultry ▪ Fish, such as tuna and salmon ▪ Eggs and dairy products ▪ Beans, legumes, and seeds	▪ Essential for growth and repair of muscle tissue. ▪ Increases your stamina and energy levels, and helps you fight fatigue. ▪ Makes you feel satisfied after eating.
FAT	▪ Nuts and seeds ▪ Dairy products, such as butter and cheese ▪ Meats, such as bacon and sausage ▪ Cooking oil	▪ Good source of energy. ▪ Makes you feel satisfied after eating.
FIBER	▪ Fresh and dried fruit, especially the skins ▪ Vegetables, beans, and seeds ▪ Whole-grain cereals ▪ Whole-meal bread, whole-meal pasta, and brown rice	▪ Provides bulk to help your digestion. ▪ Helps to make you feel full.
VITAMINS AND MINERALS	▪ Fresh and dried fruit ▪ Green vegetables ▪ Meat and fish ▪ Nuts and seeds	▪ Essential for growth and the repair of your body's tissues. ▪ Help you to maintain healthy teeth and eyes. ▪ Aids bloodflow and the production of energy.

BALANCING YOUR ENERGY LEVELS

You replace the energy that you expend on a daily basis through the food you eat. The energy obtained from food is measured in calories, and you require a certain number of calories each day to remain alive. If you consume too few calories, you will lose weight. However, eating too many calories will lead to weight gain, which can cause long-term health issues. The number of calories you require per day depends on many things, such as your age and level of activity (see right). When you don't replace the energy expended and continue to work, you start to use the energy store contained in your body's fat.

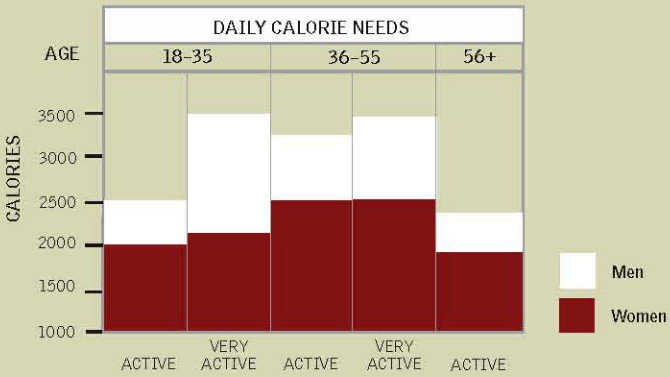

WILDERNESS DINING

Even if you're only going on a short hike, you should take food with you, such as fruit and chocolate, to replace the energy you're using. For longer expeditions, you'll need to take a number of different foodstuffs—for energy and for variety.

WARNING!
In a survival situation, don't eat for the first 24 hours unless to replace expended energy. Ration your food, as digestion uses up water.

TYPES OF FOOD	EXAMPLES	BENEFITS
BREAKFAST CEREALS AND DRIED FRUIT	▪ Trail mix—also known as "gorp" ▪ Muesli or granola ▪ Oatmeal ▪ Dried fruit	▪ Provide a vital source of carbohydrates, vitamins, and minerals to set you up at the start of the day. ▪ Contain dietary fiber to aid digestion.
TRAIL SNACKS	▪ Cookies and crackers ▪ Energy bars and cereal/granola bars ▪ Fruits, such as apples, pears, and oranges ▪ Nuts and seeds	▪ High in carbohydrates to help you maintain energy levels. ▪ Help to keep your hunger pangs at bay between main meals.
HIGH-CALORIE SNACKS	▪ Dehydrated ice cream ▪ Chocolate ▪ Hard candies ▪ Pudding mixes	▪ Provide a quick boost of energy, when required. ▪ Offer a comfort factor, although they are of limited nutritional value.
PRE-PREPARED MAIN MEALS	▪ Boil-in-the-bag meals—you can buy a wide variety of fully prepared meals, sealed in a foil bag. Cook for five to seven minutes. ▪ Freeze-dried and dehydrated meals—simply add boiling water, stir, and wait about five minutes. Extremely lightweight and take up little space. ▪ Canned meals—a great variety of them are available, but they are bulky and heavy.	▪ Provide a balanced range of food groups, vitamins, and minerals to help your body to recover and repair itself after the day's exertions. ▪ Quick and easy to prepare, and require few utensils. ▪ Many require minimal fuel to cook them, or water to rehydrate them. ▪ Can be bulked out with beans, legumes, and grains. ▪ Smaller cans may have a pull-top to open them.
MEAT, FISH, AND CHEESE	▪ Canned fish, such as sardines or tuna ▪ Cured meats, such as ham, salami, and beef jerky ▪ Hard cheese, such as cheddar and parmesan	▪ A great source of proteins and fats. ▪ Easy to store and long-lasting, although cans are heavier than other sources of food.
BEANS, LEGUMES, AND GRAINS	▪ Lentils and dried peas ▪ Dried beans and pearl barley ▪ Rice and pasta ▪ Couscous	▪ Can be used to bulk up main meals and help you to feel full. ▪ An important source of carbohydrates. ▪ Also provide fiber and protein.
MIXERS	▪ Flour ▪ Salt ▪ Suet ▪ Sugar	▪ Flour and salt can be used to make dough. ▪ Sugar and salt help to make wild food palatable. ▪ Suet is an invaluable source of fat that can be used to supplement meals.
FLAVORINGS	▪ Powdered soup ▪ Tomato puree ▪ Powdered sauces ▪ Gravy cubes	▪ Add flavor and variety to your meals. ▪ Especially useful if you're cooking with wild food.
BEVERAGES	▪ Tea ▪ Coffee ▪ Chocolate powder ▪ Dried milk	▪ Provide warmth and comfort, although they are of limited nutritional value. ▪ Chocolate powder is high in carbohydrates. ▪ Dried milk is an excellent source of calcium.

CAMPING STOVES

ALTHOUGH NOTHING CAN BEAT the satisfaction of building your own campfire, the convenience and reliability of purpose-made camping stoves make them an essential piece of cooking equipment, especially in areas where open fires are banned.

THE BENEFITS OF CAMPING STOVES

Modern camping stoves are very light and collapse down to an incredibly small, compact size. Gas-fueled stoves are by far the most common, but liquid-fueled stoves are also worth considering. Both have their own advantages and disadvantages (see below), but your choice will be dictated by space and weight constraints, the distance you're traveling, and environmental factors. A hexamine stove is a good item to have in a survival situation (see opposite).

CHOOSING A GAS- OR LIQUID-FUELED STOVE

Gas-fueled stoves are safer, cleaner, lighter, and easier to use than liquid-fueled stoves, but are less economical, and not suitable for low-temperature, high-altitude use. Liquid stoves offer greater stability, fuel versatility and economy, but you need to pump and prime (preheat) them before use, and they are less clean.

TRANSPORTING FUEL

There are many factors to consider when transporting fuel to make your expedition safer:

- When hiking, pack your fuel container upright in the middle of your backpack, and surround with clothing to protect it from knocks. Make sure you can access it easily when you reach camp. Use similar principles when traveling by other methods.
- Ensure that your fuel bottles look very different from your water bottles to prevent confusion.
- If you're going on a long expedition, check the availability of the fuel, and consider how you will dispose of cylinders safely.

	GAS-FUELED STOVES		
TYPE OF STOVE	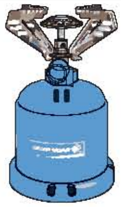 BUTANE OR ISOBUTENE	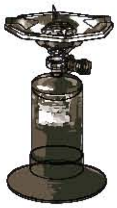 PROPANE	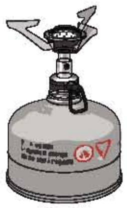 BLENDED FUEL
INFORMATION	■ Both fuels sold in disposable, pressurized canisters.	■ Fuel sold in disposable, pressurized canisters. ■ Used in most portable stoves and barbecue grills.	■ Fuel sold in disposable, pressurized canisters. ■ Is a mix of butane, propane, and/or isobutene.
PROS	■ Lightweight, sealed fuel container. ■ Butane very efficient and burns at a high temperature. ■ Isobutene more efficient than butane, and performs better in cold conditions.	■ Lightweight, sealed fuel container. ■ Fuel burns at a very hot, steady heat, and produces an almost sootless flame. ■ Performs very well in cold conditions.	■ Lightweight, sealed fuel container. ■ Fuel safer than pure propane, and performs better than either pure butane or isobutene in cold conditions. ■ Isobutene blends give a more efficient flame.
CONS	■ Higher cost and lower heat output than liquid fuels. ■ Fuel efficiency reduced at higher altitudes. ■ Butane less efficient than isobutene in temperatures below 50°F (10°C).	■ Higher cost and lower heat output than liquid fuels. ■ Fuel efficiency reduced at higher altitudes. ■ Highly combustible, so less safe than other fuels.	■ Higher cost and lower heat output than liquid fuels. ■ Fuel efficiency reduced at higher altitudes.

USING CAMPING STOVES SAFELY

Always take care when storing the fuel and using your stove. Use only the stove manufacturer's recommended fuel, and check all connections and fittings before each and every use. Also:

- Clear the cooking area of dry vegetation and leaves, in case you spill fuel or knock over your stove.
- Place your stove on a level and stable surface.
- Keep naked flames and sparks away from the fuel, especially when filling or refilling the stove. Before refilling, make sure the flame is out and the stove has cooled down.
- Use the cooker in a well-ventilated space. Liquid fuels, in particular, can give off poisonous fumes, such as carbon monoxide, and all cookers also burn vital oxygen.
- Don't use a stove inside your tent. In addition to the risk of poisonous fumes, fire is also a significant danger. A confined space with limited access, your tent can be reduced to ashes in minutes, along with everything inside, and you may not be able to escape in time to protect yourself. Losing your tent and your equipment is bad enough, without you receiving third-degree burns at the same time.
- Don't leave a burning stove unattended. If it topples over, it could easily start a fire. If the stove flame goes out, a spark or naked flame could also ignite the vapors and cause an explosion.

THE HEXAMINE STOVE

A very useful piece of emergency equipment, the hexamine stove (or hexi-stove) burns solid blocks of hexamethyl-enetetramine (also known as "methenamine"), and folds away compactly. The stove acts as a small windbreak and cooking platform, while the fuel blocks it uses provide a very reliable means of starting a fire in any conditions. The blocks produce a smokeless flame, don't liquefy while burning, and leave no ashes.

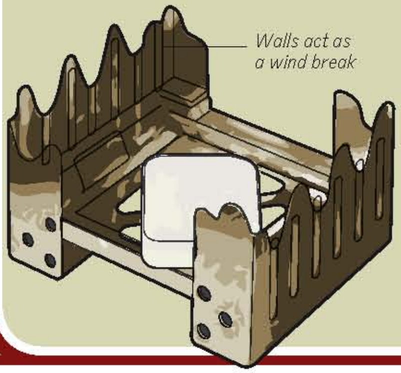
Walls act as a wind break

LIQUID-FUELED STOVES			
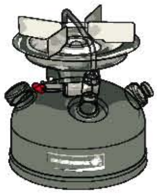 **WHITE (COLEMAN) FUEL**	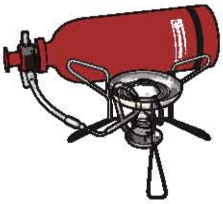 **MULTI-FUEL**	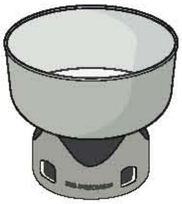 **DENATURED ALCOHOL**	**TYPE OF STOVE**
▪ Fuel sold in disposable canisters.	▪ Stove can use a variety of fuels, from unleaded gas, kerosene (paraffin), aviation fuel, and white fuel, to diesel—most of which are readily available.	▪ Fuel sold in disposable plastic containers. ▪ Stove basically consists of a vessel to burn the fuel in, and a windshield that also acts as a cooking platform.	**INFORMATION**
▪ Fuel can withstand low temperatures, high altitudes, and most weather conditions. ▪ Produces a clean flame.	▪ Stove uses a range of fuels. ▪ Fuel is non-pressurized, so can be stowed safely in almost any airtight container. ▪ Stove tends to perform reliably, efficiently, and quickly, producing a hot flame.	▪ Fuel is non-pressurized, so can be stowed safely in almost any airtight container. ▪ Economical and produces a clean flame. ▪ Stove is lightweight, stable, and safe. ▪ Usually supplied with pots and pans.	**PROS**
▪ Stove must be pumped to generate required pressure for use. ▪ Fuel needs to be primed.	▪ Potential for spillage of flammable fuel. ▪ Stove must be pumped to generate required pressure for use. ▪ Fuel needs to be primed. ▪ Some fuels produce soot and noxious fumes.	▪ Potential for spillage of flammable fuel. ▪ Stove slower to heat up than other liquid stoves, because it's not pumped. ▪ Flame vulnerable to wind and other environmental conditions.	**CONS**

YOUR SURVIVAL KIT

A BASIC SURVIVAL KIT is an essential item to take with you on any outdoor expedition. It should be compact enough to carry on your person at all times, and its contents should address the key principles of survival: protection, location, water, and food.

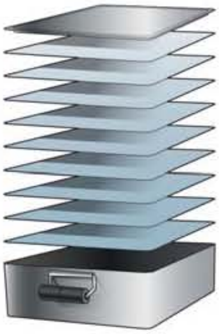

LAYERS OF A SURVIVAL TIN

EXAMPLE OF A SURVIVAL KIT

Choose a tin with a waterproof seal and locking clasps. While you can buy ready-made kits, you should always adapt the contents, both to your needs and to the environment you'll be in. Ideally, items in the survival kit should be high-quality and multi-purpose—for example, the tin itself could be used as a cup, a small cooking pot, or even a signal mirror. Your kit should contain the following:

LAYER 1

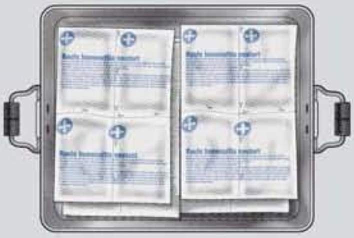

- **Blister medical pads and bandages:** useful for minor cuts and blisters. Include a range of bandages (both waterproof and fabric) in a selection of sizes. Waterproof bandages can also be used to mend holes in tents and tarpaulins.

LAYER 2

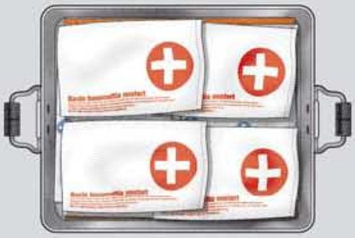

- **Antiseptic wipes:** for treating wounds and cleaning bites. Can also be iginited by a spark and used to get a fire going.

LAYER 3

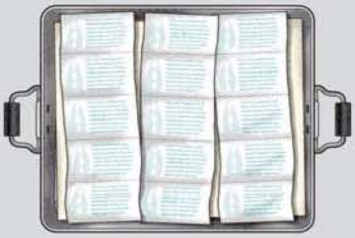

- **Water purification tablets:** choose from tablets or iodine (but don't use iodine if you're allergic to it, or to shellfish). Water will need to be filtered before being purified.

LAYER 6

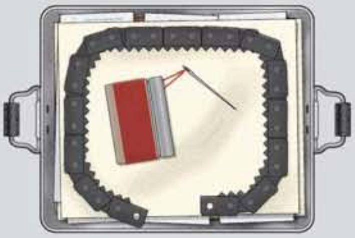

- **Survival saw, or pocket chainsaw:** can be wrapped around the inside of the tin or cut in half, if space is limited.
- **Single-edged razor:** multi-purpose—from skinning an animal to cutting cord. Store in its packaging.
- **Needle and cotton:** use strong, waxed cotton, pre-threaded through the needle.

LAYER 7

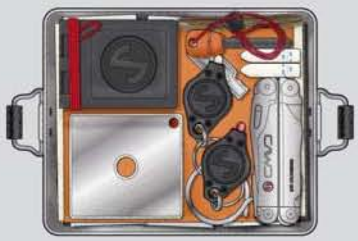

- **Flashlights:** two small Photon (LED) lights—one white and one red—taped in "off" position.
- **Mini multi-tool:** see panel, opposite.
- **Chainsaw handles:** use with pocket chainsaw.
- **High-viz card, signal mirror:** location aids.
- **Compass:** an emergency back-up.
- **Flint, fire steel, tampons:** for starting fires.
- **Snare wire:** for animal traps and lashing.

LAYER 8

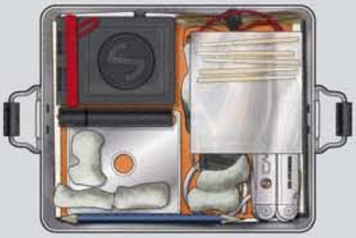

- **Waterproof matches and tinder balls:** for starting fires. Store the matches in a small, resealable plastic bag.
- **Pencil:** sharpened at both ends.
- **Potassium permanganate:** dissolve in water to sterilize water at low concentration, and to clean wounds at a high concentration. Can also be used with sugar to make fire. Store in a waterproof container.

CHOOSING A MULTI-TOOL

A useful item to carry with you on your trip, multi-tools are usually designed with a specific task or hobby in mind, and include useful features for survival, such as a small compass, pliers, saw, and various blades. Use one that has quality tools that most suit your needs, with a comfortable grip, and ensure that the blades are lockable to prevent injuries. Carry your multi-tool in a secure pocket, or in a pouch on your belt, and include a miniature version in your survival tin (see below). Bear in mind that your multi-tool should be an addition to, not a replacement for, your bushcraft knife (see p. 146).

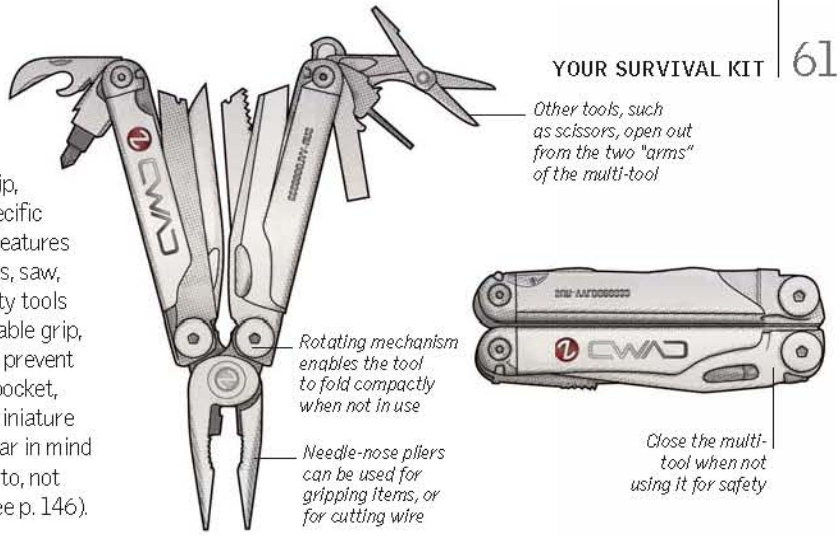

Other tools, such as scissors, open out from the two "arms" of the multi-tool

Rotating mechanism enables the tool to fold compactly when not in use

Needle-nose pliers can be used for gripping items, or for cutting wire

Close the multi-tool when not using it for safety

LAYER 4

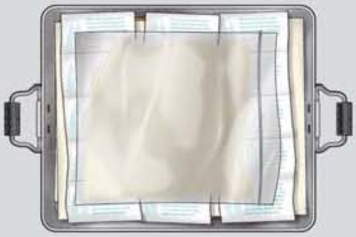

- **Petroleum jelly:** apply to chapped lips, rashes, and sores. Can also be smeared onto tampons to make them burn longer. Store in a small, resealable plastic bag.

LAYER 5

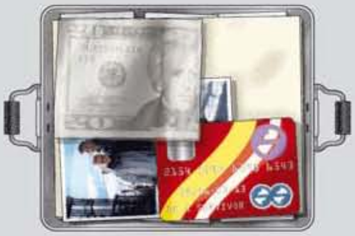

- **Waterproof notepaper:** for drawing maps or leaving messages.
- **Photograph of loved ones:** a psychological incentive in a survival scenario.
- **Credit card:** an effective means of extracting insect stings (see pp. 266–67).
- **Money:** wrapped in cellophane.

LAYER 9

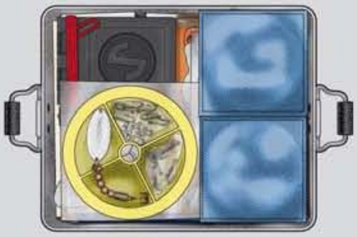

- **Non-lubricated condoms:** can be used to carry water, or as a waterproof cover for smaller items, such as your mobile phone.
- **Mini fishing kit:** if you are near water, fish can be easier to catch, prepare, and cook than mammals. Fishing line can be also used for other survival tasks. Should contain a selection of hooks, flies, swivels, and split-shots.

TIN LID SEALED WITH TAPE

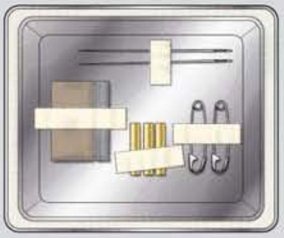

- **Sailmaker's needles:** multi-purpose—can be used as an arrow point, or for mending tents and tarpaulins. Wide eyes are best.
- **Safety pins:** for securing clothing, or mending your sleeping bag or tent.
- **Mini glowsticks (cyalumes):** useful for emergency lighting, and as a location aid.
- **Single-edged razor:** multi-purpose (see Layer 6). Store in its packaging.

ADDITIONAL USEFUL ITEMS TO INCLUDE

While your survival tin's size may be restrictive, you can always improve your kit with items that can fit on your belt, or in a belt pouch, known as a "belt order." This will form part of your first-line equipment (see p. 43).

- **Space blanket or aluminum foil:** can be used as a signaling device; for shelter; to carry, store, and heat water; or to cook in. Many are dual-sided: one silver, the other green for camouflage, or orange to stand out.
- **Plastic bags:** you can never have too many. Numerous uses—from a water carrier to a transpiration bag.
- **Medicines (such as painkillers and antibiotics):** should not replace your main first-aid kit, but ensures you have some basics if you're separated from your gear.
- **Small candle:** once lit, this will provide a reliable flame that you can build your fire around.
- **Nylon stockings:** can be used for warmth, or as an improvised water filter, mosquito net, or fishing net.
- **Small AM/FM radio:** battery- or solar-powered.
- **Surgical tubing:** enables you to reach water in otherwise inaccessible rock crevices.
- **Fire tin or matchless fire set:** self-contained methods of starting a fire, when no natural fuel is available.

2

ON THE TRAIL

FIND YOUR WAY

Before you set off on an expedition, you should have at least a basic understanding of how to read a map and use a compass. Your ability to correctly assess a map of the area you intend to visit will allow you to make informed decisions during your preparation. If you understand the area and terrain, your chances of getting lost will be reduced, and you will be able to continually evaluate your progress and therefore alter your plans as necessary. You will also be able to plan the safest and most appropriate route, and locate water, shelter, and areas that will allow you to use your location aids properly. If you're proficient with a map and compass, you'll have no cause to worry about getting lost or straying off-track and will be free to enjoy your outdoors experience.

In a survival situation, you will be faced with many tough decisions. You may have to decide whether to stay where you are and await rescue or move to an area that offers a better chance of survival and rescue. Your ability to navigate effectively—whether

In this section YOU WILL DISCOVER...

- how to **use your map** to tell the **lie of the land...**
- that the **path ahead** is as long as a **piece of string...**
- the difference between **eastings** and **northings** and an **ERV** and a **GPS...**
- how a **detour** could be the **most direct route...**
- how to **navigate** using your **hair...**
- why an **anvil of cumulonimbus** is no **fair-weather cloud...**

by using a map and compass or by using natural features—will play a major role in your decision-making process. Whilst a Global Positioning System (GPS) is an excellent aid, it relies on batteries and technology—both of which can fail.

An understanding of weather patterns will also allow you to evaluate conditions and make informed decisions as you travel. The ability to assess your situation and modify your plans means that you will be able to avoid many potential survival situations.

The ability to take a bearing (see pp. 68–71) and navigate using pace counting (see p. 72) could prove to be crucial skills in a survival situation.

TEST HOW ACCURATELY you can walk on a set bearing and pace out a set distance by following the exercise below. If you have stayed on your bearings and your pacing has been accurate, you should finish at your starting point. Pick a suitable area where you can walk at least 330 ft (100 m) in any direction. Don't cheat by heading for your marker! For this exercise to be useful, make sure you follow your bearings and count your paces to navigate.

1. Place a marker on the ground. Dial a bearing onto your compass (110° in our example).
2. Walk on this bearing, counting your paces until you think you have traveled 330ft (100m), then stop.
3. Add 120° to your original bearing. Dial this new bearing (230° in our example) onto your compass.
4. Pace out another 330 ft (100 m) on your new bearing, then stop.
5. Add another 120° to your latest bearing. Dial a last bearing (350° in our example) onto your compass.
6. Walk on your final bearing for a further 330 ft (100 m). You should be back at your starting point.

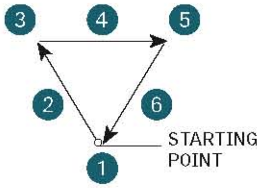

> Never underestimate the **combined power** of a map, a compass, a GPS unit, and the **skills and knowledge** to use them well—your life may **depend on it**

MAPS AND MAP-READING

A MAP IS A TWO-DIMENSIONAL representation of a three-dimensional area—from a map you can determine distance and height on the ground. If you are able to read a map, and can interpret the information it contains, you can visualize what an area looks like and use these features as landmarks to make navigation easier. Your map is very important, so keep it safe.

UNDERSTANDING MAPS

Although there are many types of map available—with varying levels of detail and scale—topographic maps are best for hiking. They show important features, such as rivers, roads, railroads, paths, buildings, and forested areas, and also depict the lie of the land through the use of contour lines (see opposite) to represent height.

These symbols represent the vegetation type

Contour lines join points of equal height

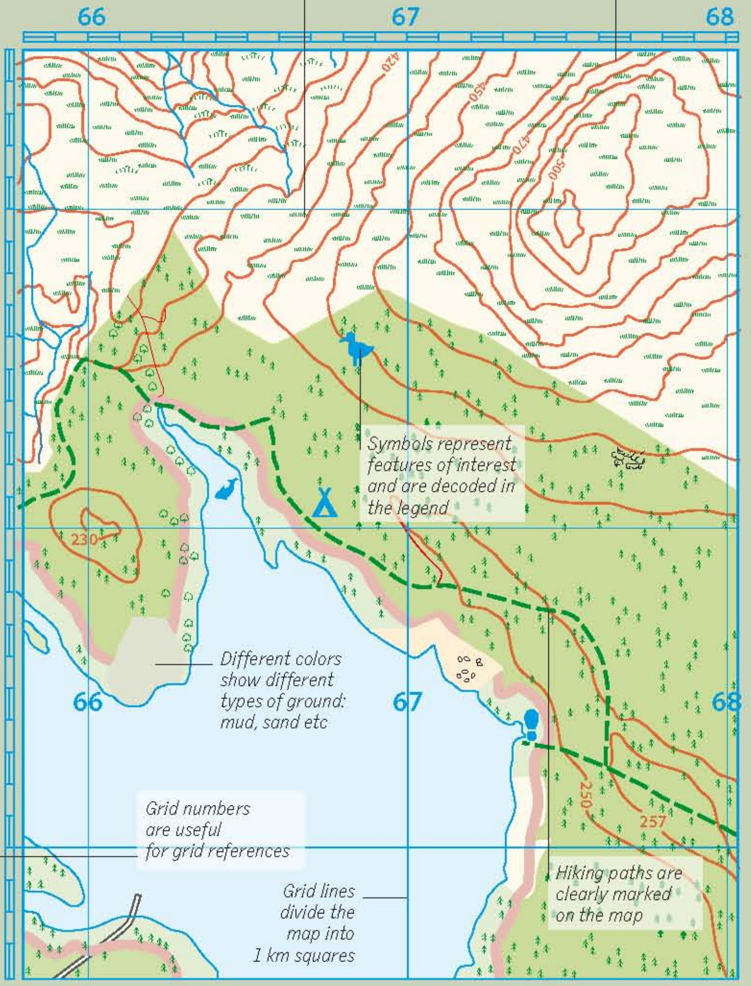
66
67
68
96
95
94
420
450
470
500
230
250
257

Symbols represent features of interest and are decoded in the legend

Different colors show different types of ground: mud, sand etc

Grid numbers are useful for grid references

Grid lines divide the map into 1 km squares

Hiking paths are clearly marked on the map

THE LEGEND

Topographic maps incorporate a legend, or key, which deciphers the information shown on the map. It's important to familiarize yourself with the symbols used, as this will help you visualize what's being represented on the map more effectively. Some examples are listed below:

HEIGHTS AND NATURAL FEATURES

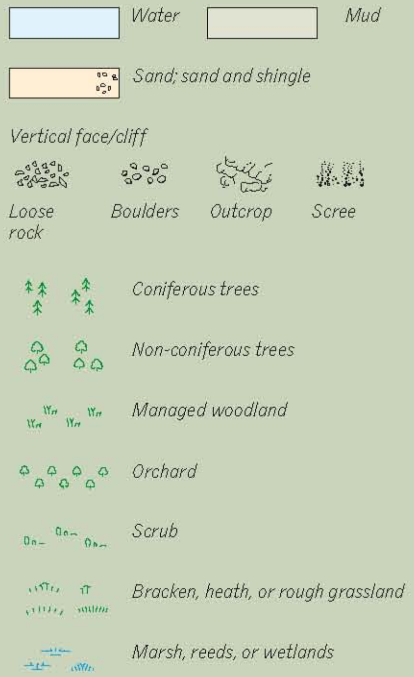
Water
Mud
Sand; sand and shingle
Vertical face/cliff
Loose rock
Boulders
Outcrop
Scree
Coniferous trees
Non-coniferous trees
Managed woodland
Orchard
Scrub
Bracken, heath, or rough grassland
Marsh, reeds, or wetlands

TOURIST AND RECREATIONAL INFORMATION

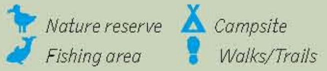
Nature reserve
Campsite
Fishing area
Walks/Trails

THE SCALE

Hiking maps are always drawn to a scale provided in the legend. This is a ratio of how much you would have to enlarge the map to reach actual size. 1:25,000—whereby 4 cm on the map equates to 1 km on the ground ($2^1/_2$ in to 1 mile)—is the most useful level of detail for hikers. A smaller-scale of 1:50,000, for example, will provide a more basic overview of the terrain.

MEASURING DISTANCE

Maps are drawn to scale so that you can use them to accurately estimate distances on the ground. Being able to measure distance is important because it means you can calculate the most direct—and energy-efficient—route to your destination. In a survival situation, every last bit of energy counts, so the shorter the distance, the better.

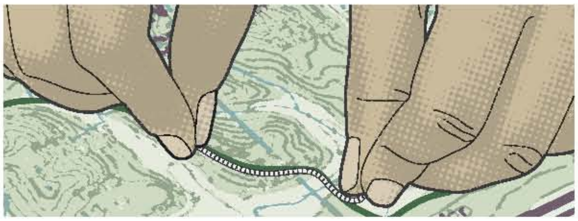

USING THE GRID LINES

The simplest method of measuring distance on a map is to use the grid lines—on a scale 1:25,000 map each grid square represents 1 km (traveling diagonally across a square, it's approximately 1.5 km). You can also lay a piece of paper between the two points, mark the start and end of your route, and place it underneath the scale line to read the distance.

USING STRING OR SOLDER

Invariably you will deviate from a straight line and will have to navigate around obstacles or bends. A far better way of measuring distance is therefore to take a piece of string, curve it around your intended route, and transfer it to the scale line. Solder wire (use wire that is lead-free) is even more accurate because it holds its shape on the map and remains flexible.

CONTOUR LINES

Topographic maps feature lines called contour lines. A contour joins points of equal height above sea level, and allows the topography of the ground to be depicted in detail. The contour interval is specified in the legend—for maps with a 1:25,000 scale you would usually expect to see a 5-meter vertical interval between each line, although for maps of mountainous regions this interval may be 10 meters. The ability to look at the contour lines, and imagine how they translate to the ground, is a skill that takes a little while to acquire, but once mastered will allow you to read a map more proficiently.

USING CONTOURS

Knowing how steep the ground is will greatly improve your navigational skills, as well as your route-planning (see p. 73). Walking up and down hills uses a lot of energy, so it is far better to follow the contour lines on your map to go around hills instead.

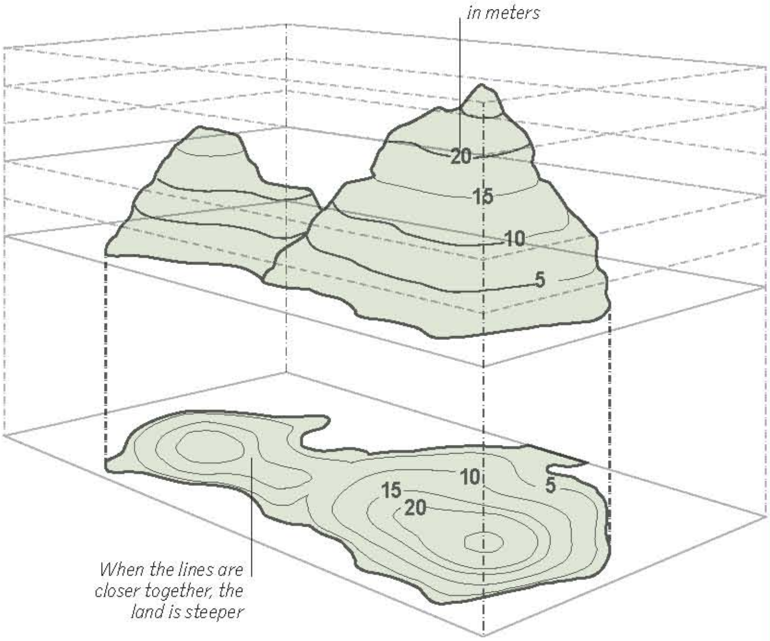

These numbers show the height above sea level in meters

When the lines are closer together, the land is steeper

GRID REFERENCES

Maps contain grid lines, which help you locate a specific point anywhere on a map, using a unique number known as a grid reference. The vertical grid lines are called "eastings," as they increase in value as they travel east on the map. The horizontal lines are called "northings," where these perpendicular lines cross creates the grid.

WORKING OUT GRID REFERENCES

Use the numbers on the grid lines and apply the easting number first. On a scale 1:25,000 map, where the grid lines are 1 km apart, the shaded area on the grid below would have a four-figure grid reference of 2046, and indicate a grid square that is 1 km by 1 km. To be more accurate, use a six-figure number—mentally divide the square into tenths. The cross would therefore have a grid reference of 185445.

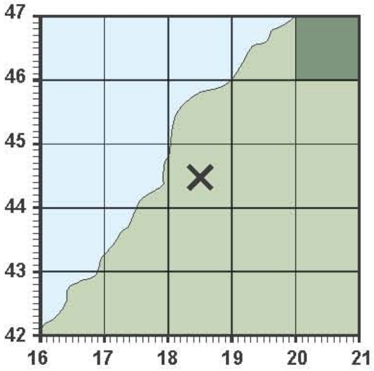

GET YOUR BEARINGS

IN ADDITION TO understanding and reading maps, it's important to know how to orientate your map to the land so you can use it to navigate. It's possible to do this by sight, although in most cases you'll need a more reliable method and for this you should use a compass. Use your compass to determine direction, orientate your map and yourself, take and plot bearings, and navigate.

CARDINAL POINTS

The four cardinal points of the compass are:

- North (N)—0°/360°
- East (E)—90°
- South (S)—180°
- West (W)—270°

HOW A COMPASS WORKS

A compass needle is a magnetized piece of metal that, when allowed to rotate freely, will orientate itself to the North and South magnetic poles. Always hold a compass level.

STANDARD COMPASS

This standard orienteering Silva compass is a good compass for hiking. It allows you to set your map and work out distances using the printed scale on the base.

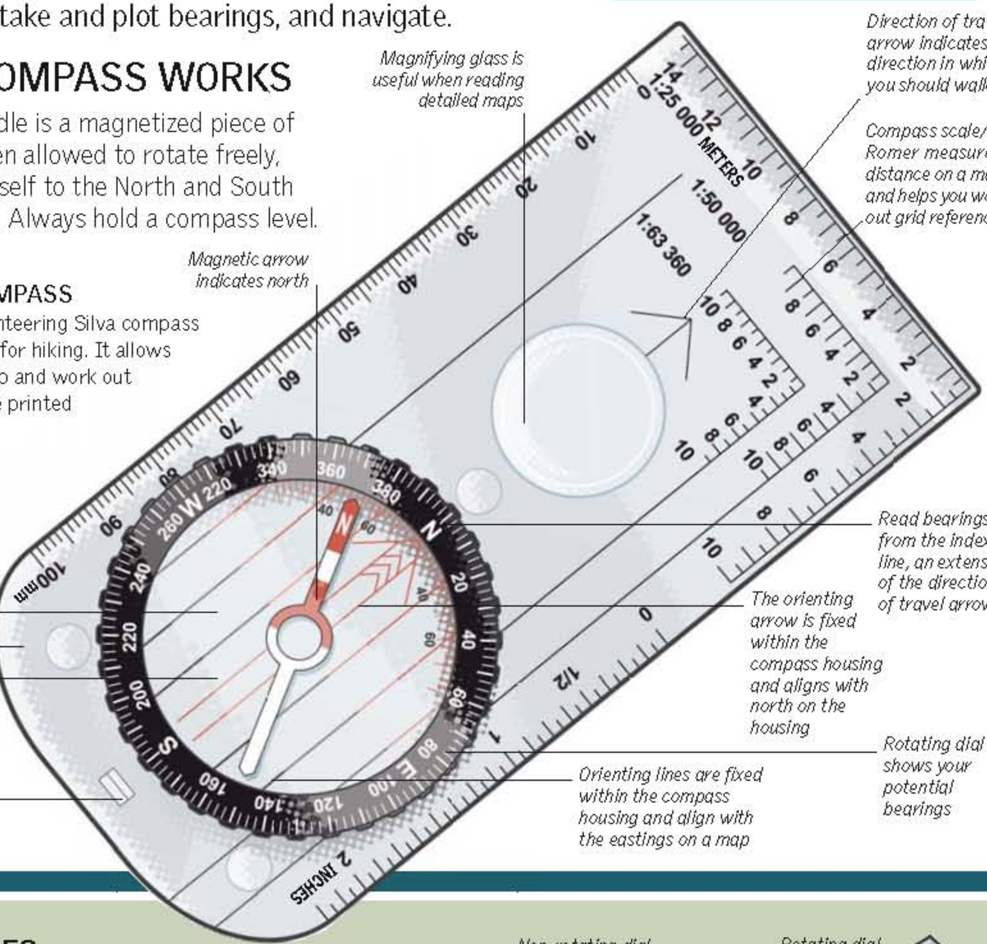

Magnifying glass is useful when reading detailed maps

Direction of travel arrow indicates the direction in which you should walk

Compass scale/ Romer measures distance on a map and helps you work out grid references

Magnetic arrow indicates north

Compass housing contains the needle and has the points of the compass marked on a circular, rotating bezel

Base plate

Liquid inside the housing dampens the needle to allow it to settle more quickly

Hole for attaching a lanyard

Read bearings from the index line, an extension of the direction of travel arrow

The orienting arrow is fixed within the compass housing and aligns with north on the housing

Rotating dial shows your potential bearings

Orienting lines are fixed within the compass housing and align with the eastings on a map

OTHER TYPES OF COMPASS

There are many different types of compass, ranging from simple button compasses to complex instruments that include features such as sighting mirrors. Use a quality compass that suits your needs, and carry a simpler backup for emergencies.

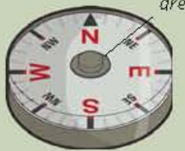

Only the points of the compass are shown

BUTTON

The simplest compass available—its small size and basic level of detail makes it ideal as a backup compass.

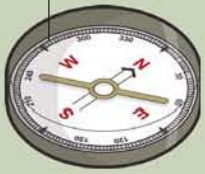

Non-rotating dial

FIXED DIAL

As well as the basic points of the compass, degrees and bearings are also shown on the immovable dial.

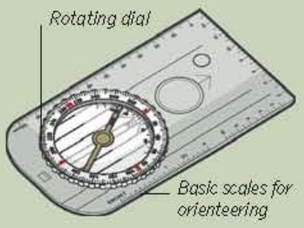

Rotating dial

Basic scales for orienteering

BASIC ORIENTEERING

With a rotating dial, this has simpler markings than the standard compass above, and is ideal for beginners.

SETTING YOUR MAP

Walking with your map set allows you to read the ground from the map as you pass over it, and to recognize and predict features as you progress, which means that you'll soon realize if you are heading off course. In some cases, when you have a good view of the terrain around you, and know the approximate area you're in, you can simply rotate your map until the features line up with the corresponding features on the ground. However, using your compass is a far more accurate method.

1 Rotate the dial so that "N" sits under the index line. Lay your map flat on the ground and ensure there is nothing nearby that could affect your compass (see box below).

- Lay the compass on the map so its edge runs parallel with a vertical grid line (easting).

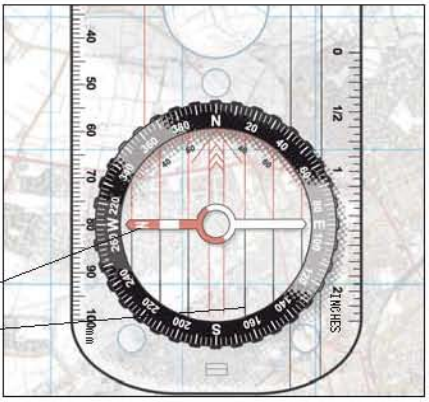
N
E
S
W
0
1/2
1
2 INCHES
40
50
60
70
80
90
100mm

Needle will not be aligned at present

Orienting lines run parallel to the vertical grid lines on your map

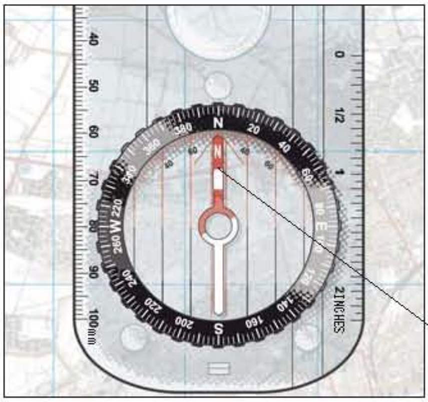
N
E
S
W
0
1/2
1
2 INCHES
40
50
60
70
80
90
100mm

2 Keeping orienting lines aligned with the grid lines on the map, rotate the entire map until the north magnetic needle on the compass sits inside the orienting arrow. The map is now set to magnetic north and should basically line up with the features that surround you.

- If magnetic variation in your area is high (+ 5°), compensate accordingly (see right).

Needle is now aligned

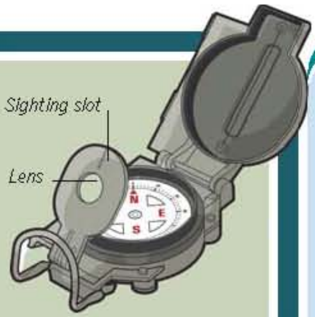
Sighting slot
Lens

LENSATIC

The lensatic compass is an excellent instrument for taking very precise navigational measurements.

TAKING AN ACCURATE READING

Always hold the compass level to allow the needle to rotate easily. A compass is simply a magnetized piece of metal and, as such, is susceptible to interference. To avoid this, never use your compass near:

- Metal or other magnetized objects
- Electric currents, such as overhead high-tension power cables
- Buildings and vehicles—these often contain metal and electricity that might affect the accuracy of your compass readings

MAGNETIC VARIATION

Map legends refer to north in three ways: "true north," "grid north," and "magnetic north." The angle between magnetic north and grid north is known as "magnetic variation," and is provided in the map legend. True north is the direction of a meridian of longitude that converges on the North Pole. Grid north runs parallel to the vertical grid lines on a map and differs from true north because a map is flat. Magnetic north is the direction indicated by a magnetic compass.

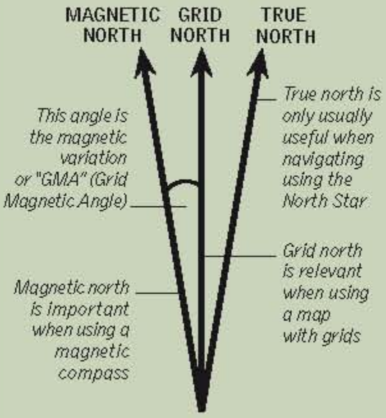
MAGNETIC NORTH
GRID NORTH
TRUE NORTH
This angle is the magnetic variation or "GMA" (Grid Magnetic Angle)
True north is only usually useful when navigating using the North Star
Grid north is relevant when using a map with grids
Magnetic north is important when using a magnetic compass

COMPENSATING FOR VARIATION

When converting a magnetic bearing to a grid bearing, or vice versa, you have to adjust for magnetic variation. When the variation is west, use the phrases "Mag to grid—get rid" or "Grid to mag—add." If the variation is east, the opposite applies.

1 Check the legend of your map to establish the magnetic variation. This depends on your location, and whether it is east or west of grid north.

2 If the variation is 0°, there's no magnetic variation affecting the compass, so make no adjustments.

3 If converting a magnetic bearing to a grid bearing with a 12° west variation, take off the 12°. With an east variation, add it on.

4 If converting a grid bearing to a magnetic bearing with a 12° west variation, add on the 12°. With an east variation, take it off.

TAKING BEARINGS

Always give any compass work your full attention. Rushing it, especially when working out bearings, can lead to navigational errors that could, at best, involve more walking and, at worst, get you lost.

USING A MAP

Using your map to work out the direction in which you need to walk is simple. Use your compass as a protractor to work out your bearing, and then to keep you on track.

BACK BEARING

A back bearing enables you to find your position by taking a bearing from a feature back to you. To do this, take a bearing to a point in the normal way and either add or subtract 180 degrees. You can also read the bearing exactly opposite to the index line. This is useful when working out the bearing from a feature back to you and transferring it to your map (see below).

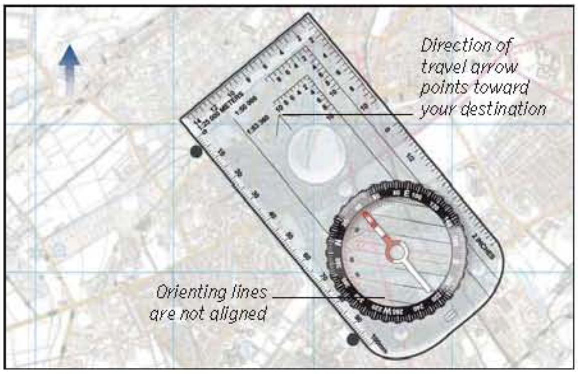
Direction of travel arrow points toward your destination
Orienting lines are not aligned

1 Lay your map on a flat surface, ensuring that there's nothing nearby to interfere with the compass reading (see box, p. 69).

- Lay the edge of your compass so that it runs between the point you want to navigate from and the point you want to navigate toward.
- Ensure that the direction of travel arrow on the compass is pointing in the direction you want to travel on the map.

USING FEATURES ON THE GROUND

Sometimes you may need to take a bearing to a specific point to navigate toward it. The point may be a feature that you can see at the time but may subsequently lose sight of during your journey because of the terrain. You can also plot that bearing and others on a map in order to work out your own position (see right, and panel, far right).

TAKING A BEARING ON A FEATURE

Pointing your compass at the feature, hold the base plate steady and rotate the compass housing until the orienting arrow sits directly under the north needle. Read the bearing—this is the magnetic bearing you would walk on to navigate to the feature.

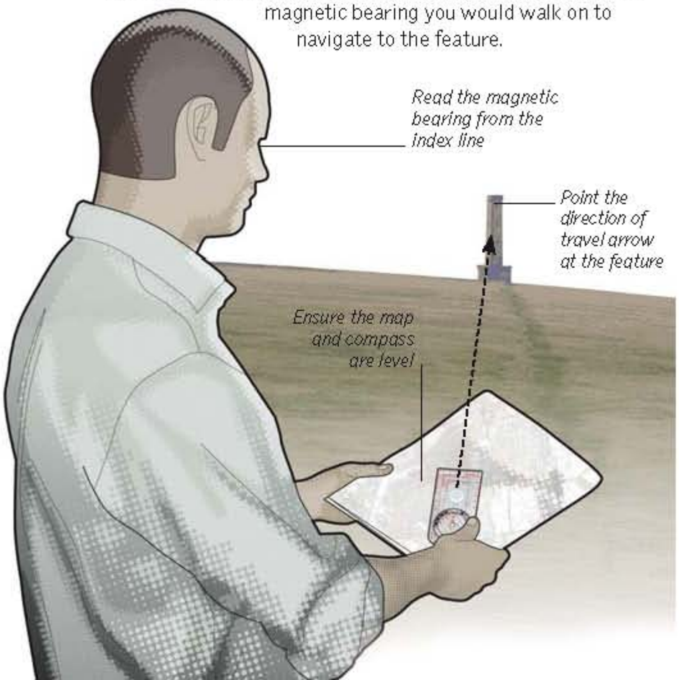
Read the magnetic bearing from the index line
Point the direction of travel arrow at the feature
Ensure the map and compass are level

TRANSFERRING A MAGNETIC BEARING TO A GRID BEARING

It is important that you know how to transfer a compass bearing from a feature (a magnetic bearing) onto a map (a grid bearing). For this example, imagine that the magnetic variation is 12° west.

- Take a bearing on your chosen feature (see left). In this example it is 45° magnetic.
- You want to plot this bearing on your map, which has a grid, so remember the phrase "mag to grid—get rid." You would therefore subtract the magnetic variation (12°) from the magnetic bearing (45°), which equals 33°.
- Dial this revised bearing into your compass.

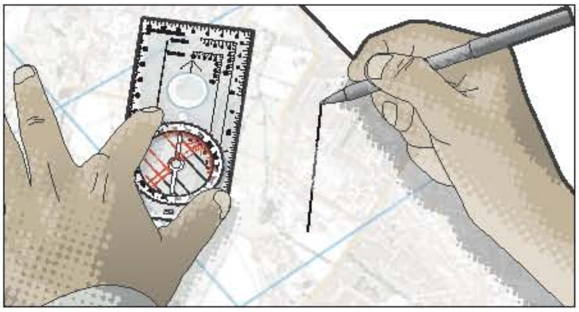

TRANSFERRING THE BEARING ONTO THE MAP

Place the top left corner of the compass base plate over the feature on your map. Keeping it there, rotate the entire compass until the orienting lines are parallel with the vertical grid lines. Draw a line from the feature down the left side of the base plate to map your bearing.

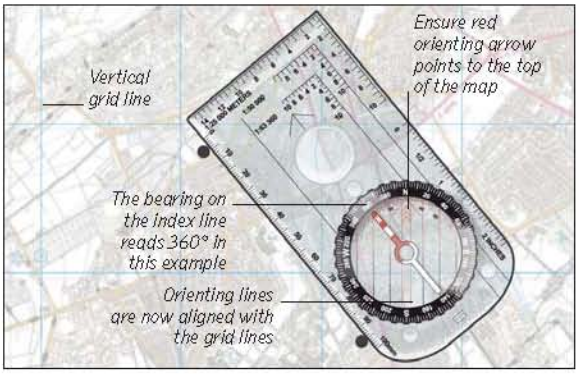
Vertical grid line
Ensure red orienting arrow points to the top of the map
The bearing on the index line reads 360° in this example
Orienting lines are now aligned with the grid lines

2 Turn the compass housing around until the orienting arrow and the orienting lines within the housing line up with the vertical grid lines on the map. Read the bearing between the two points from the index line on the compass.

- For this grid bearing to deliver you successfully to your destination, you'll need to convert it to a magnetic bearing by using the magnetic variation information on the map legend (see p. 69). Add or subtract your figure, and adjust your compass accordingly.

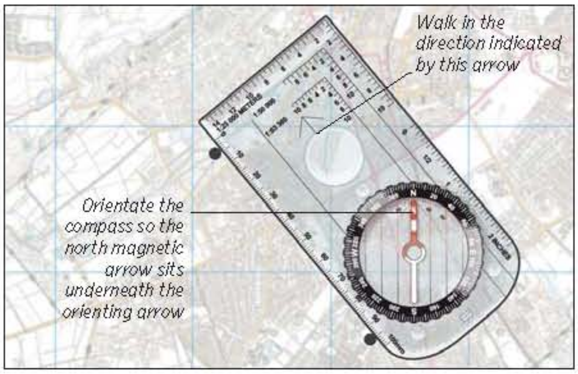
Walk in the direction indicated by this arrow
Orientate the compass so the north magnetic arrow sits underneath the orienting arrow

3 In order to walk on this bearing you must now orientate your compass.

- Hold the compass level and at a height that allows you to comfortably look squarely down on it (close to your chest is a good position).
- Turn your body until the north end of the compass needle sits inside the orienting arrow. The direction of travel arrow is now pointing exactly in the direction that you need to walk.

FINDING YOUR POSITION

If you are unsure of your position but can see features on the ground that you also recognize marked on your map, you can take bearings on these features with your compass and transfer them onto your map (see far left, and left) to accurately determine where you are. This process is called "triangulation" (also known as "resection" in military terminology). You'll need to transfer your compass bearings into grid bearings.

AT A KNOWN FEATURE

If you are at or on a known feature on a map—such as a river, road, or track—and you can see another recognizable feature, you can take a bearing on that feature and mark it on your map. Where that line crosses your known feature is your position. In the example below, you know you are somewhere along the banks of a river and can see a church that you can identify on your map.

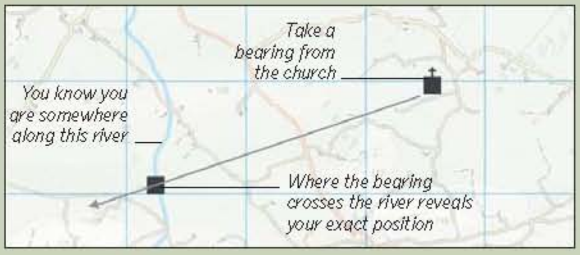
Take a bearing from the church
You know you are somewhere along this river
Where the bearing crosses the river reveals your exact position

NOT AT A KNOWN FEATURE

If you are not at a known feature, but can see other recognizable features on the ground that you can identify and locate on your map, you can take bearings on these features and transfer them to your map. In order to do this you need two features that are at least 1 km ($^{6}/_{10}$ mile) away and at least 40° apart. After you have transferred both bearings onto your map, the point at which the two lines cross will reveal your exact location. For greater accuracy, plot a third feature onto your map. The lines will cross and form a triangle—your position will be inside this triangle.

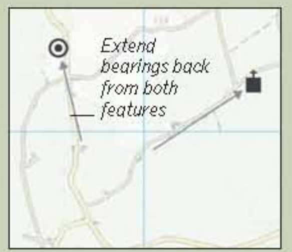
Extend bearings back from both features

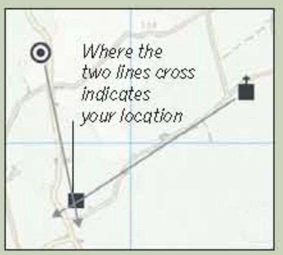
Where the two lines cross indicates your location

1 Using your compass, take bearings to the features on the ground.

- Transfer these bearings to back bearings (see box, above left), and draw them on the map from your chosen features.

2 Extend these lines further over the map until they cross each other.

- The point at which the lines cross shows your location.
- If you want to be more accurate, repeat the process with a third feature.

ROUTE FINDING

WHETHER YOU ARE PLANNING to walk a specific route, or are in a survival situation and need to move to a safer area or to one that offers better chances of rescue, being able to study your map and calculate what you can achieve in a certain time can mean the difference between reaching your destination or spending a night in the wilderness.

CALCULATING DISTANCE

There are several methods of calculating the distance you are walking, and a seasoned hiker will always use at least two of them at any one time.

PACE COUNTING

Pace counting involves knowing how many paces you take to cover a set distance and then counting them as you travel. It is reasonably accurate. Distances are usually calculated in meters and kilometers, and most people take approximately 60 paces (120 steps) every 100 m. Try any of these methods:

- Cut 10 notches in your walking staff. Move an elastic band down a notch every 100 m.
- Use pace counting beads (a piece of webbing with two sets of beads divided by a central knot). One side contains nine beads to count off every 100 m, and the other has four beads to count off kilometers.
- Place 10 small pebbles in your pocket. Every time you cover 100 m, transfer a pebble to the other pocket.

NAISMITH'S RULE

Naismaith's rule takes into account distance and topography, and is used for estimating the duration of hikes.

- Allow one hour for every 3 miles (5 km) you will travel
- Add 30 minutes for every 985 ft (300 m) you will climb
- Subtract 10 minutes for every 985 ft (300 m) you will descend. However, for very steep slopes you should add 10 minutes for every 985 ft (300 m) you will descend

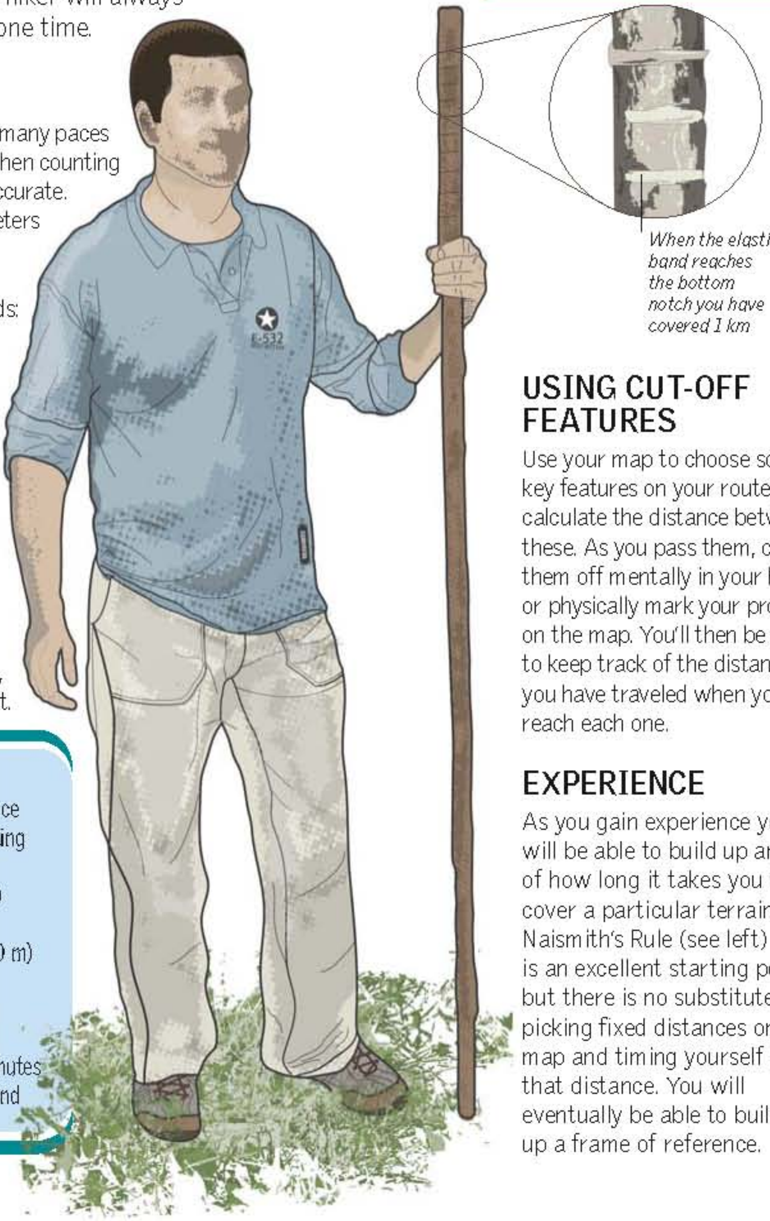

When the elastic band reaches the bottom notch you have covered 1 km

ROUTE PLANNING

Break your route down into small sections. This will focus your navigation and make the overall distance seem less daunting. If you're in a group, designate an emergency rendezvous (ERV) point within each section—if someone gets separated you should all head there. If you can, include water sources and a safety point, such as a campsite, on your route.

USING CUT-OFF FEATURES

Use your map to choose some key features on your route, and calculate the distance between these. As you pass them, check them off mentally in your head or physically mark your progress on the map. You'll then be able to keep track of the distance you have traveled when you reach each one.

EXPERIENCE

As you gain experience you will be able to build up an idea of how long it takes you to cover a particular terrain. Naismith's Rule (see left) is an excellent starting point, but there is no substitute for picking fixed distances on your map and timing yourself over that distance. You will eventually be able to build up a frame of reference.

NAVIGATION TECHNIQUES

When navigating across land, you're less likely to get lost if you take direct bearings from one feature to another. Unfortunately this may not always be possible; obstacles such as lakes and swamps may be directly in your path and it may be easier to walk around some features rather than walk over or through them.

PRINCIPLES OF NAVIGATION

You will never get lost if you know:

- Where you started from
- What bearing or course you have been traveling on
- How far you have traveled

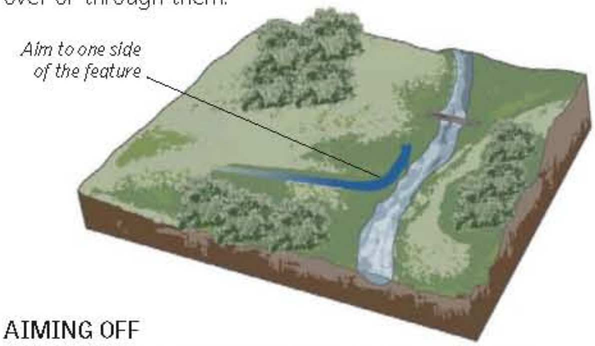
Aim to one side of the feature

AIMING OFF

It's easy to find yourself slightly off-course after a while. If you were aiming for a small footbridge over a stream and didn't arrive exactly at the bridge, you would need to guess whether to turn left or right to reach it. By deliberately aiming off to one side (also called "deliberate off-set") you can guarantee this direction.

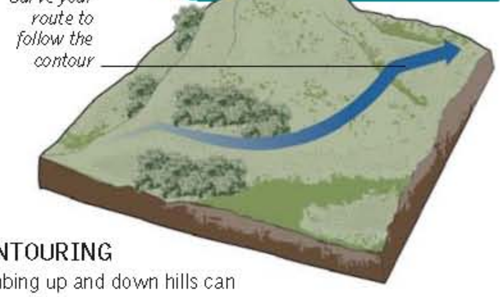
Curve your route to follow the contour

CONTOURING

Climbing up and down hills can expend a lot of energy and may not be the most effective method of navigating a particular terrain. Instead, use a technique called "contour navigation." This involves walking at the same height around a feature, which will conserve energy.

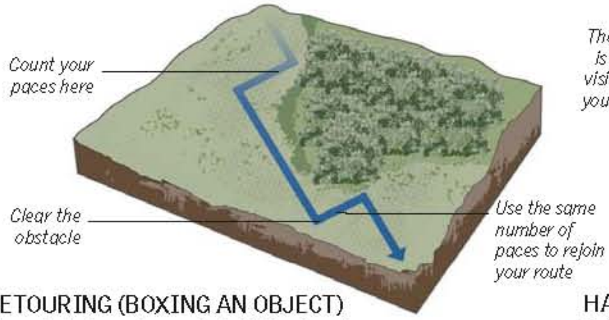
Count your paces here
Clear the obstacle
Use the same number of paces to rejoin your route

DETOURING (BOXING AN OBJECT)

If an obstacle makes a straight-line bearing impossible, use your compass to calculate four 90° turns, which you will then need to walk on to pass the obstacle. Count your paces on the first and third detours to return to your original, intended route as accurately as possible.

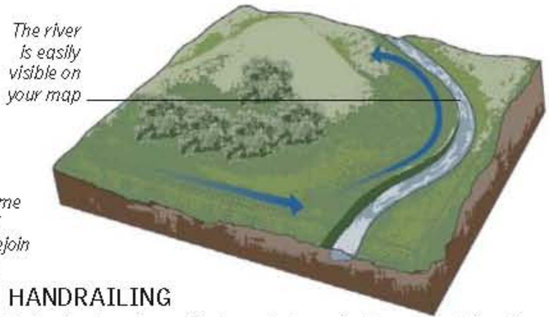
The river is easily visible on your map

HANDRAILING

Following long linear features that run in the general direction of your travel—such as rivers, roads, or paths—can be an effective way of navigating. Because you use the features rather than your compass, navigation becomes simpler, as the features are usually easy to follow. A slight detour toward one can be worthwhile.

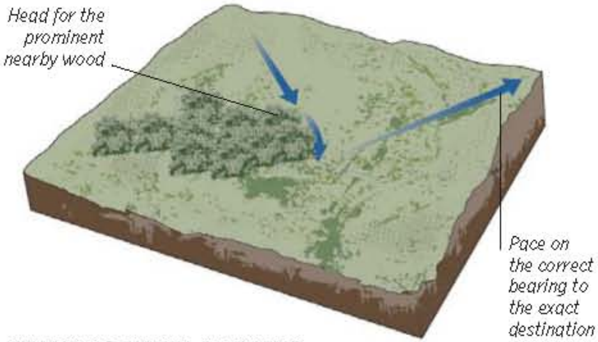
Head for the prominent nearby wood
Pace on the correct bearing to the exact destination

STAND OFF/ATTACK POINT

Useful when navigating to a specific point that may be difficult to locate, this technique involves aiming initially for a nearby prominent feature. Calculate a distance and bearing from it and use pacing to accurately locate the specific point. If you fail to find it, simply return to the prominent feature and start again.

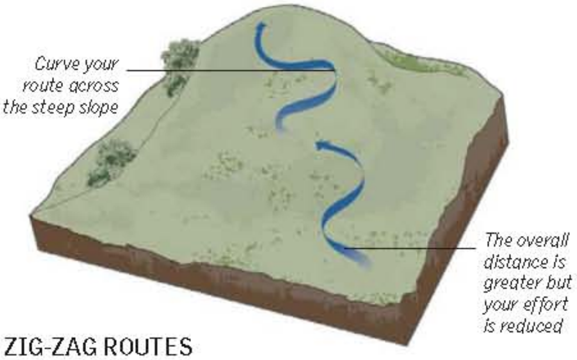
Curve your route across the steep slope
The overall distance is greater but your effort is reduced

ZIG-ZAG ROUTES

You may have no alternative but to climb a steep slope and this can be exhausting. However, if you choose a zig-zag route up the slope you can reduce the effort required to achieve the climb. This will dramatically reduce the strain on your legs, ankles, lungs, and heart. It is also effective when walking down steep slopes.

NAVIGATING WITHOUT A COMPASS

IF YOU DON'T HAVE A COMPASS you can use a few simple items from your survival kit to determine direction and enable you to navigate reasonably accurately. Advances in technology have also made satellite-navigation aids more readily available.

TOOLS AND MATERIALS

You will need an improvised needle or razor blade, plus one of the following:

- Knife
- Hair
- Silk
- Magnet
- Battery and wire; paper and tape

IMPROVISING A COMPASS

It's relatively simple to make an improvised compass using a piece of magnetized ferrous metal. How accurate your compass is depends on the materials you have available to you and your own ingenuity.

SOURCING AND MAGNETIZING THE NEEDLE

If you have a compass but it's damaged, you may still be able to use the needle from it, which will already be magnetized. If this is unusable, you'll need to find a piece of ferrous metal to magnetize. Suitable items you could use include:

- A needle from your survival tin or sewing kit
- A paperclip, opened up and straightened out
- A razor blade from your survival kit
- A small nail or straightened staple taken from a fence

Once you have your improvised needle, you will need to magnetize it. The smaller and thinner the needle is, the easier this will be. Use one of the methods shown here.

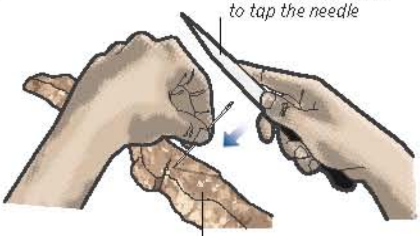

You can use the blade of your survival knife to tap the needle

Tap the needle into hard wood to heighten the effect, but make sure it doesn't become embedded

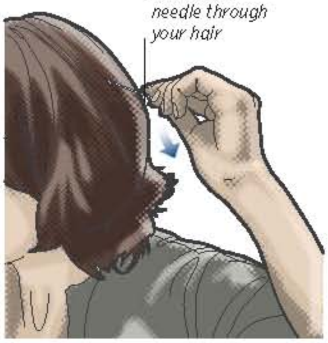

Stroke the needle through your hair

THE TAPPING METHOD

Align the needle as close to the north-south line as you can determine, hold the needle at an angle of 45 degrees, and gently tap the end of it with another piece of metal. Lightly tapping it into a hard piece of wood will increase the effect.

USING YOUR HAIR

Hold the sharp end of the needle perpendicular to your head and—taking care not to hurt yourself—stroke the needle in one direction through your hair, using careful and deliberate strokes. Repeat until the needle is magnetized.

ALLOWING THE NEEDLE TO FLOAT FREELY

Once you have made your improvised needle using one of the methods above, you need to find a way to allow it to turn freely so that it is able to indicate direction. Take care to protect your needle from elements such as the wind, which will affect its movement.

SUSPENSION METHOD

The advantage of the suspension method is that the equipment is portable and can be reused. It works best with a magnetized razor blade, which will balance well. Attach the magnetized blade to a cotton thread and suspend it inside a plastic bottle. If the bottle's neck is not wide enough to fit the blade through, remove the base of the bottle instead.

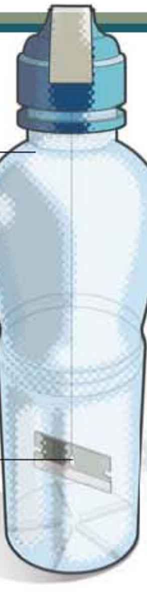

The bottle protects the compass from the elements

Use the hole in the blade to attach the cotton

FLOATING METHOD

In a sheltered place, float the needle on the surface of some water—a puddle or a small non-magnetic container filled with water, for example. Balance the needle on a small, dry leaf (or piece of paper, piece of bark, blade of grass, or inside a shortened straw).

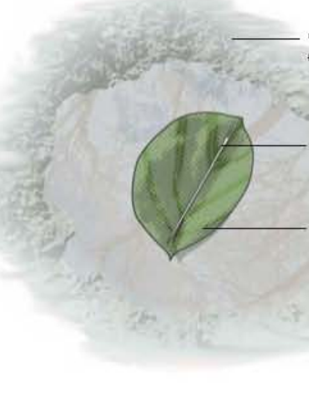

Use a puddle in a sheltered area

The needle will rotate, settle, and align itself

The leaf enables the needle to float on the surface of the water

PRINCIPLES OF MAGNETIZING

In general, the longer you work on the needle the stronger the magnetization will be and the longer it will last. To tell when it is magnetized sufficiently, hold the needle up against another metal object—if it is attracted to the metal and has enough strength to hold itself against it then it will be strong enough. Once the needle is magnetized you will need to allow it to float freely (see below), and then determine which end points north by using natural aids, such as the sun (see pp. 76–77). Mark the north end of the needle with a pen or a small scratch.

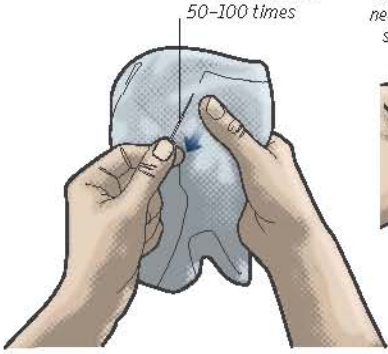
Stroke the needle 50–100 times

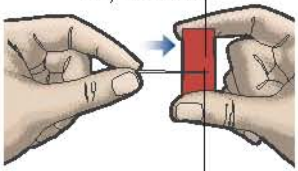
The end of the magnetized needle that attracts to the south pole of the magnet will point north
The more times you stroke, the more effective the magnetization

USING SILK

This works on a similar principle to the hair method but is more effective. If you have anything made from silk, such as a sleeping bag liner or thermal clothing, stroke the needle repeatedly in one direction against the silk.

USING A MAGNET

Stroke the magnet along the length of the needle repeatedly in one direction. It's a good idea to carry a magnet with you at all times, although you should never keep it near your compass as it will affect its accuracy.

USING ELECTRICITY

The most effective way to magnetize a needle is to pass a small electrical current around it. Use a battery and insulated wire; alternatively, use brass snare wire from your survival kit and insulate it using something non-conductive, such as paper.

1. Wrap the needle in a small piece of paper, which will insulate it from the electrical current.

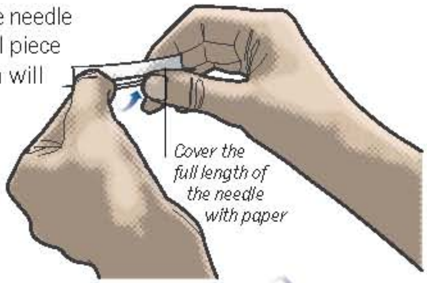
Cover the full length of the needle with paper

2. Wrap the wire tightly around the full length of the insulated needle.

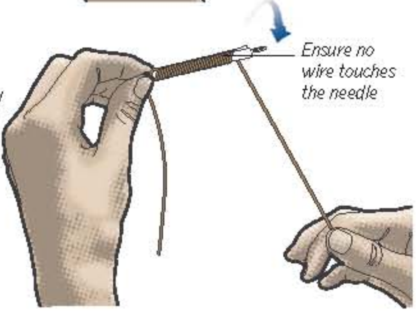
Ensure no wire touches the needle

3. Attach the wire to the battery until battery starts to get warm—this indicates the process is complete.

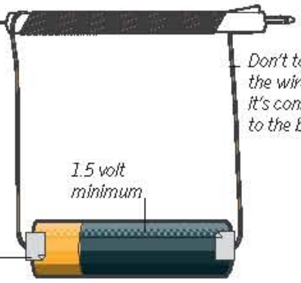
Don't touch the wire once it's connected to the battery
1.5 volt minimum
Attach the wire using some tape

USING GPS TECHNOLOGY

A Global Positioning System (GPS) is a hand-held unit that uses 24 orbiting satellites to triangulate your position on the Earth's surface to within meters. A GPS will allow you to work out straight-line distances and bearings to and from points, but unless it incorporates mapping it will not show you the best way to get there or take into account hazards on your route. Use it in conjunction with your map and compass.

TAKING EFFECTIVE GPS READINGS

A GPS needs to have a clear view of the sky. Anything that obstructs its signal, such as tall buildings or heavy tree canopy, will reduce its ability to lock onto satellites.

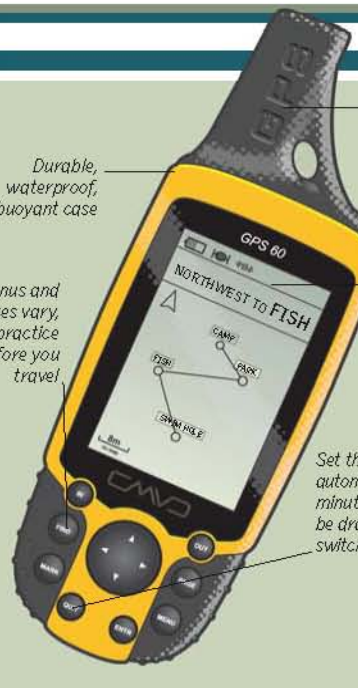
GPS
GPS 60
NORTHWEST TO FISH
CAMP
FISH
PARK
SWIM HOLE
Durable, waterproof, buoyant case
Menus and features vary, so practice before you travel
Receiver locks onto at least four satellites to obtain a three-dimensional fix (latitude, longitude, and height) displayed as a grid reference
The screen lights up for use in gloomy conditions, but avoid using this feature if you can as it will drain the batteries
Set the unit to switch off automatically after two minutes so the battery won't be drained if the GPS is switched on accidentally

NATURAL NAVIGATION

IF YOU HAVE LOST or damaged your compass and don't have the materials necessary to make an improvised version, use natural indicators to determine direction. The east-west rotation of the Earth means that you can orientate yourself according to the position of the sun, moon, and stars. All you need are some very basic materials and these simple techniques.

SHADOW STICK BASICS

Use a shadow stick to determine direction and time anywhere between the Arctic (66.5°N) and Antarctic Circles (66.5°S).

- In the northern hemisphere the shadow of the stick will be on the north side of the east-west line
- In the southern hemisphere the reverse is true: the shadow of the stick will be on the south side of the east-west line.
- When the shadow is at its shortest, it is midday.

USING THE SUN

When visible, the sun is the clearest natural signpost to the four cardinal points (north, south, east, and west). It rises approximately in the east and sets approximately in the west and, at midday, is due south in the northern hemisphere and due north in the southern hemisphere. Use the sun's course across the sky to determine direction and approximate the time.

ORIENTATION

Tracking the movement of the sun across the sky using a shadow stick will provide an indication of its direction of travel. The sun moves from east to west at 15° an hour.

1 Drive a stick into a piece of level ground, and ensure it's as upright as possible.

2 Place a stone at the tip of the stick's shadow.

3 Wait three hours and place a second stone at the new position of the shadow's tip.

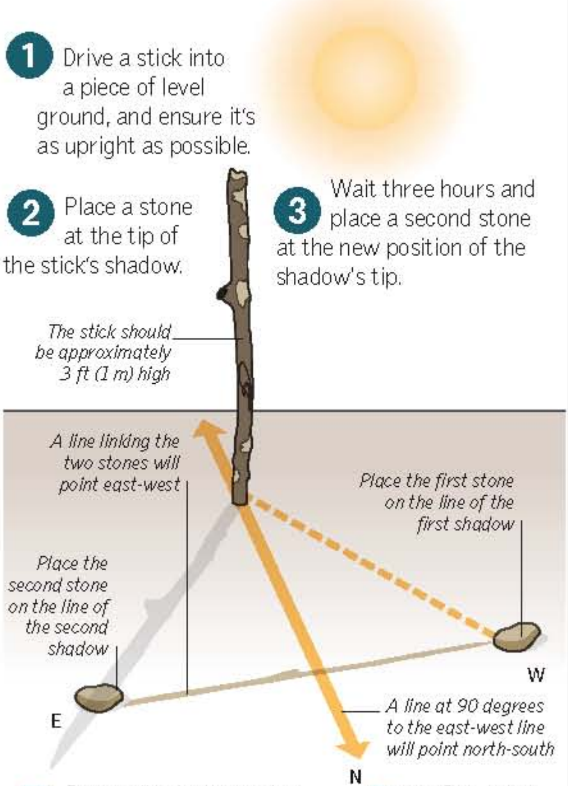

The stick should be approximately 3 ft (1 m) high

A line linking the two stones will point east-west

Place the first stone on the line of the first shadow

Place the second stone on the line of the second shadow

A line at 90 degrees to the east-west line will point north-south

4 Draw a line between the stones to find east-west; the first stone will be at due west and the second at due east.

5 To find north-south, mark a line at 90° to the east-west line.

TELLING THE TIME

Once you have established the east-west and north-south lines, you can turn the shadow-stick apparatus into a sundial, to give an approximate idea of the time.

1 Place the stick at the intersection of the north-south and east-west lines

2 Tie a piece of cord to the stick. Attach a smaller stick to the other end of the cord and use it to draw an 180-degree arc between the two marker stones.

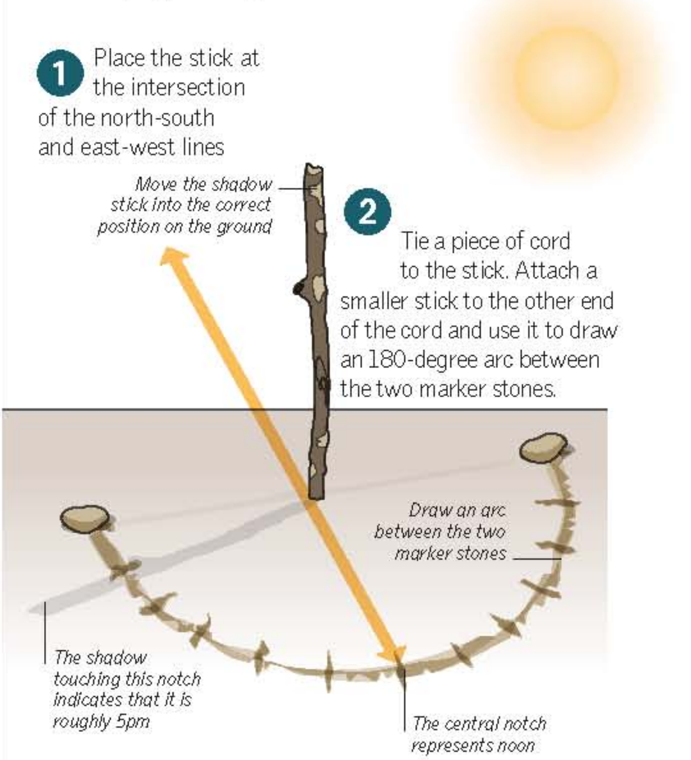

Move the shadow stick into the correct position on the ground

Draw an arc between the two marker stones

The shadow touching this notch indicates that it is roughly 5pm

The central notch represents noon

3 Divide the arc into 12 equal sections and mark each division with a notch. The notches represent one hour of time, from 6am to 6pm with noon at the middle notch.

USING THE STARS

It's possible to orientate yourself by spotting certain recognizable stars. In the northern hemisphere, Polaris is located above due north on the horizon, from which you can determine east, west, and south. Find it by locating the Plow (also known as the Big Dipper). In the southern hemisphere, you can work out the approximate position of south on the horizon by finding the Southern Cross.

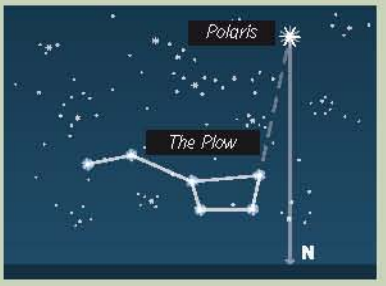

NORTHERN HEMISPHERE

Find the Plow and project a line from the top of the two stars that form its front. Follow this line until you find Polaris, which is located approximately four times the distance from the Plow as the distance between its two front stars.

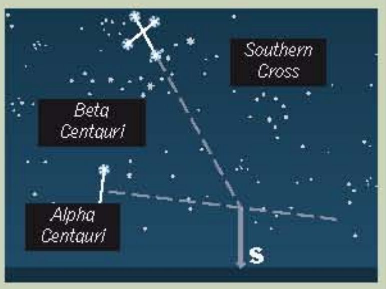

SOUTHERN HEMISPHERE

Project a line from the longer axis of the Southern Cross until you find a dark area of sky. Project a second line at 90° from the mid-point between two bright stars in the Centaurus constellation. Due south is below the point where these lines meet.

USING THE MOON

Reflecting the light of the sun, the moon rises in the east and sets in the west, so can be used for orientation. A shadow stick will work on a cloudless, full-moon night.

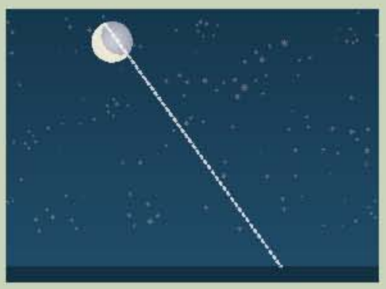

CRESCENT MOON

Although not an entirely accurate method, a line vectored between two horns of a crescent (quarter) moon will lead to a point that is approximately south on the horizon in the northern hemisphere, and roughly north in the southern hemisphere.

USING AN ANALOG WATCH

If you can see the sun, you can use an analog watch as a protractor to determine an approximate direction. Ensure it is set to the correct local time and that you have taken daylight savings (DST) into account. If you don't have a watch but know the time, simply draw a watch face on a piece of paper, marking 12 o'clock and the hour hand. This method is increasingly less effective as you near the Equator.

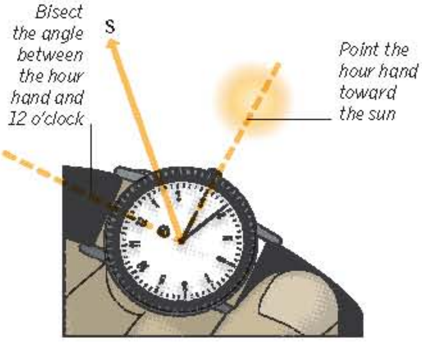
Bisect the angle between the hour hand and 12 o'clock
S
Point the hour hand toward the sun

NORTHERN HEMISPHERE

In the northern hemisphere, the cardinal point nearest to the sun is south. Point the hour hand of your watch at the sun and bisect the angle between the hour hand and 12 o'clock. This will be due south.

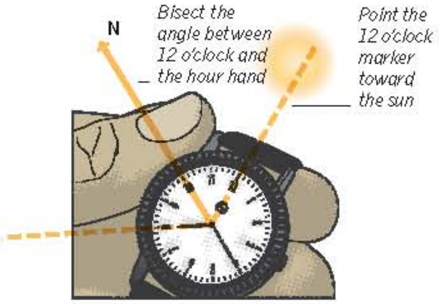
N
Bisect the angle between 12 o'clock and the hour hand
Point the 12 o'clock marker toward the sun

SOUTHERN HEMISPHERE

In the southern hemisphere, the cardinal point nearest to the sun is north. Point the 12 o'clock marker on your watch at the sun and bisect the angle between 12 o'clock and the hour hand on the watch. This will be due north.

NATURAL SIGNPOSTS

Nature responds to the elements in a range of ways, some of which can be studied for orientation tips. This is useful if you know the predominant wind direction of an area.

TREES AND PLANTS

- Windswept trees point away from the wind.
- Tree growth is most lush on the side that faces the sun (south in the northern hemisphere, north in the southern hemisphere).
- Some plants, such as the barrel cacti, twist toward the sun as they grow.
- Moss and lichen grow out of direct sunlight, on the shady side of rocks or trees.

ANIMALS AND INSECTS

- In very windy areas, small animals and birds tend to nest or burrow on the lee-side of hills.
- Spiders spin webs out of the wind, so an area with a lot of broken webs could indicate a recent change of wind direction, away from the dominant wind.

SNOW AND ICE

- In powder-snow conditions, snow "dunes" often form parallel to the prevailing wind.
- Frost erosion is most severe on slopes facing the sun (south in the northern hemisphere, north in the southern hemisphere).

HOW WEATHER WORKS

CHANGES IN THE WEATHER can have a significant effect on your expedition—or chances of survival if something goes wrong—so it's important to be as prepared as possible for all the conditions you might face. Check the weather report for the days ahead thoroughly, and pack and wear appropriate clothing. If the weather forecast is so bad that it could make traveling or navigation difficult, rethink your plans.

WHAT IS WEATHER?

The term "weather" relates to current conditions on the ground—such as the temperature, and whether or not it is windy or raining—while "climate" refers to a region's conditions over a longer period of time. Changes in the weather are caused by alterations in air pressure and temperature. Extreme weather, such as a hurricane, occurs when these changes are more marked than usual. Weather is monitored by meteorologists, and very accurate predictions can be made. However, weather can still cause surprises, so always prepare for all possible scenarios when packing or dressing for an expedition.

UNDERSTANDING THE WEATHER

Weather is created by the movement of air currents, the moisture content of the air, and the meeting of warm and cold fronts. Looking at weather maps before you leave for your trip will help you track these elements. You'll then need to use your understanding to forecast the effects of these movements on the ground.

READING WEATHER CHARTS

It can be helpful to compare weather charts with regular topographic land maps. Just as the gradient is steeper where contour lines appear closer together on land maps, the wind is stronger where isobar contours appear closer together on weather charts.

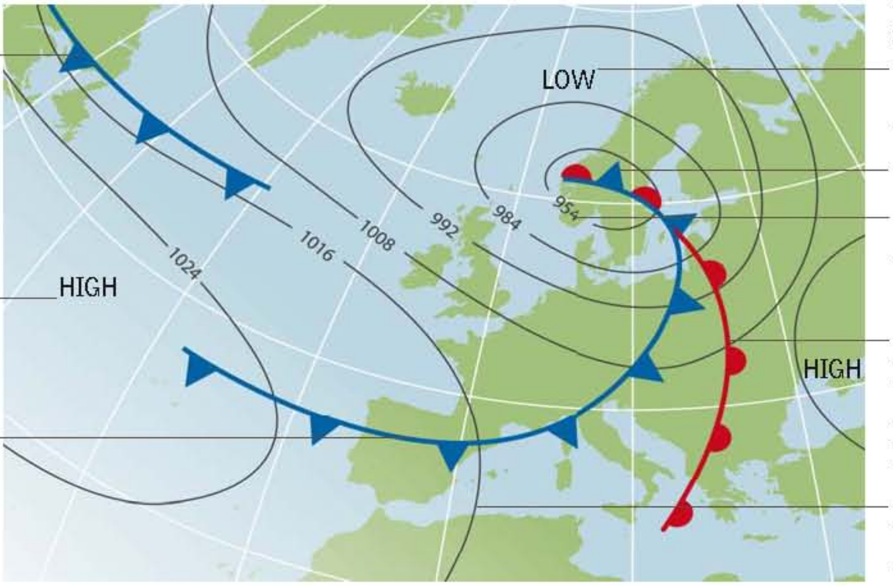

Fronts move in the direction that their symbols point toward

Areas of high pressure are generally associated with warm weather

A blue line with triangles represents a cold front, and marks the leading edge of cold air

Areas of low pressure are associated with cooler weather

Occluded fronts are fronts where two air masses merge

The lower the value of the central pressure, the more severe the wind and rain

A red line with semi-circles represents a warm front, and marks the leading edge of warm air

Isobars join areas where the air pressure is the same

HIGH
1024
1016

HIGH PRESSURE

Under conditions of high pressure, air descends in a spiral formation, and warms. The water vapor does not condense into clouds and we would expect to observe fairly clear skies.

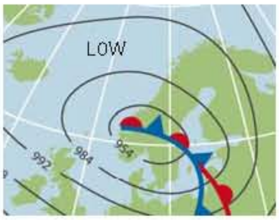

LOW PRESSURE

Under conditions of low pressure, air spirals upward—parallel to the center of the isobars—and cools. The air condenses to form clouds, and skies are usually overcast.

GLOBAL CIRCULATION

Warm air from the equator rises and moves toward the poles in each hemisphere. As it cools it descends and travels back toward the equator. Because of the Earth's rotation, three separate cells of circulating air in each hemisphere develop, which produce predictable wind and pressure patterns.

AIR MASSES

Large bodies of air with a particular temperature and humidity help weather forecasters predict the forthcoming weather and are known as air masses. They are largely defined by the area that they originated from. In general, northerly winds are colder than southerly winds, and air that has tracked over the sea ("maritime air mass") accumulates moisture and is more cloudy than air that has tracked over the land ("continental air mass"). The boundaries between tropical and polar air become warm and cold fronts.

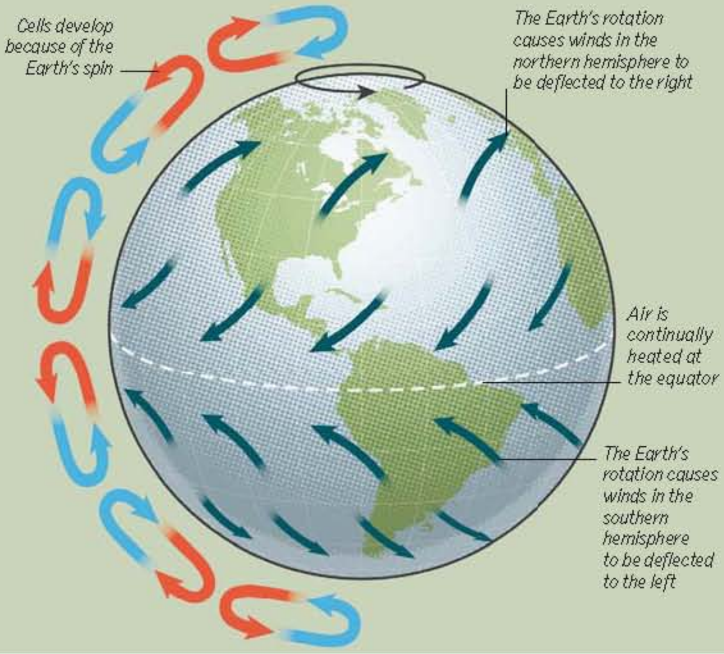
Cells develop because of the Earth's spin
The Earth's rotation causes winds in the northern hemisphere to be deflected to the right
Air is continually heated at the equator
The Earth's rotation causes winds in the southern hemisphere to be deflected to the left

ON THE GROUND

As a weather system travels over the ground, it changes in predictable ways. Knowing how the system will progress is an important part of interpreting your weather map or forecast.

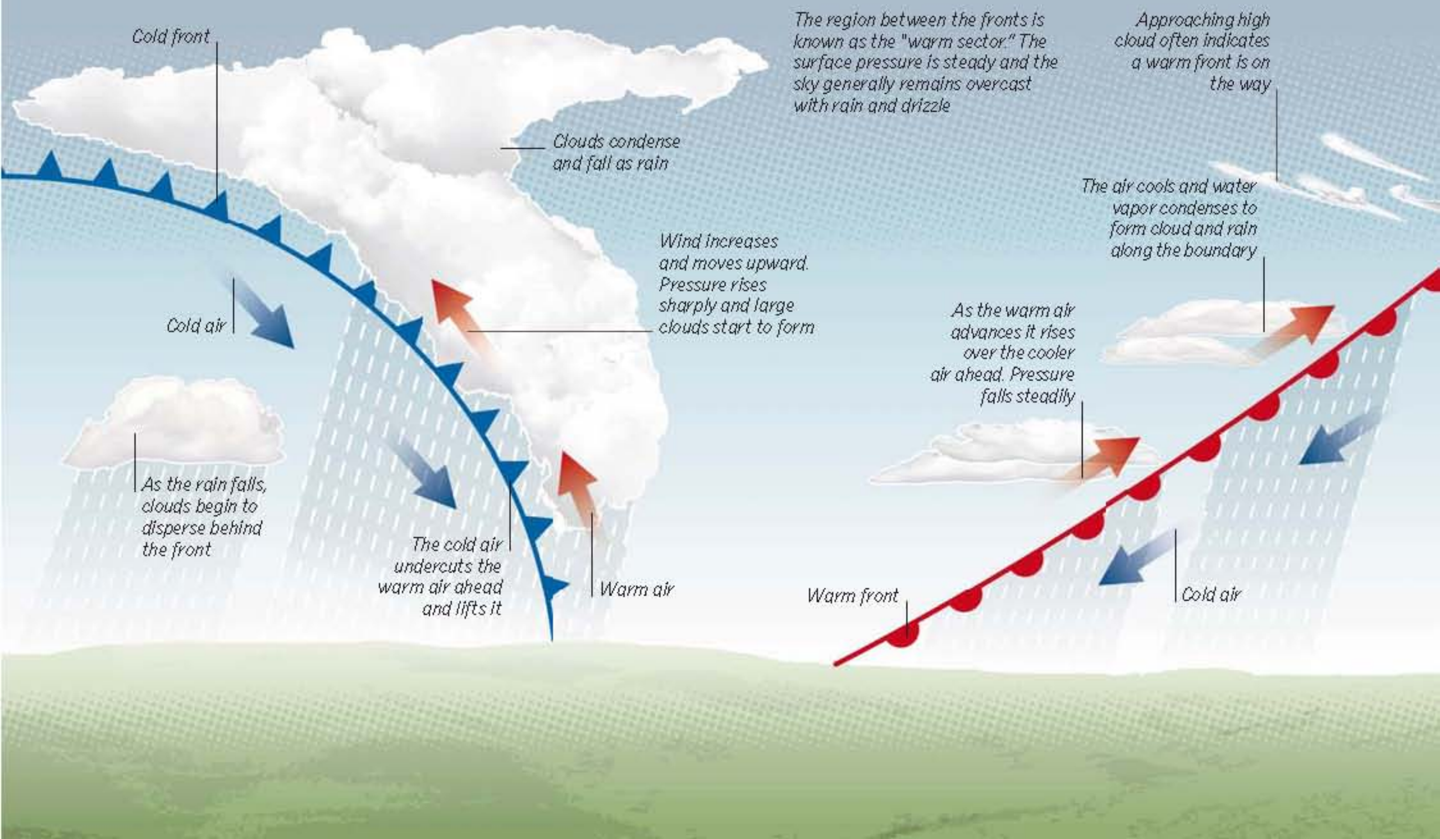
Cold front
Clouds condense and fall as rain
The region between the fronts is known as the "warm sector." The surface pressure is steady and the sky generally remains overcast with rain and drizzle
Approaching high cloud often indicates a warm front is on the way
The air cools and water vapor condenses to form cloud and rain along the boundary
Wind increases and moves upward. Pressure rises sharply and large clouds start to form
Cold air
As the warm air advances it rises over the cooler air ahead. Pressure falls steadily
As the rain falls, clouds begin to disperse behind the front
The cold air undercuts the warm air ahead and lifts it
Warm air
Warm front
Cold air

WEATHER PHENOMENA

LOOKING AT THE CLOUDS can help you to read approaching weather, which is invaluable when you're on the move with no access to weather forecasts or charts. Knowing how to recognize a storm cloud, for example, will ensure that you have enough warning to seek shelter or to change into appropriate clothing. If low cloud threatens to impair your visibility, use your compass to navigate and proceed with caution.

READING THE CLOUDS

Clouds are condensing masses of water vapor that provide precipitation and reflect solar radiation. They are categorized by height—into low, medium, and high clouds—and further defined by their shape. The shape of a cloud is determined by the way in which warm air rises, and is an indicator of the air stability.

HOW CLOUDS FORM

Clouds form by a cooling process. This process can be compared to breathing on cold glass, when condensation appears because invisible water vapor in your breath, cooled to a temperature known as the "dew point," condenses into its visible liquid state. Clouds form in a very similar way. Air temperature falls at an average rate of two degrees celcius per 1,000 ft (300 m). When air containing moisture—perhaps because it has travelled over sea—reaches the height at which it meets its dew point temperature, the water vapor condenses to form visible cloud.

HIGH CLOUDS

Fair-weather clouds are white and high in the sky. If there are no clouds, expect excellent conditions. Blankets of high cloud progressively invading the sky can signify the onset of bad weather. High clouds include:

- Anvil of cumulonimbus
- Cirrus
- Cirrustratus

MEDIUM CLOUDS

Thick layers of medium-layer cloud give heavy, persistent rain, especially if the clouds are dark and gray. The clouds you are most likely to see at this level are:

- Altocumulus
- Nimbostratus
- Altostratus

LOW CLOUDS

Low clouds have clearly defined edges and can indicate whether rain will fall in short downpours (cumulus) or persistently (stratus). Common clouds are:

- Cumulonimbus
- Stratus
- Stratocumulus
- Cumulus

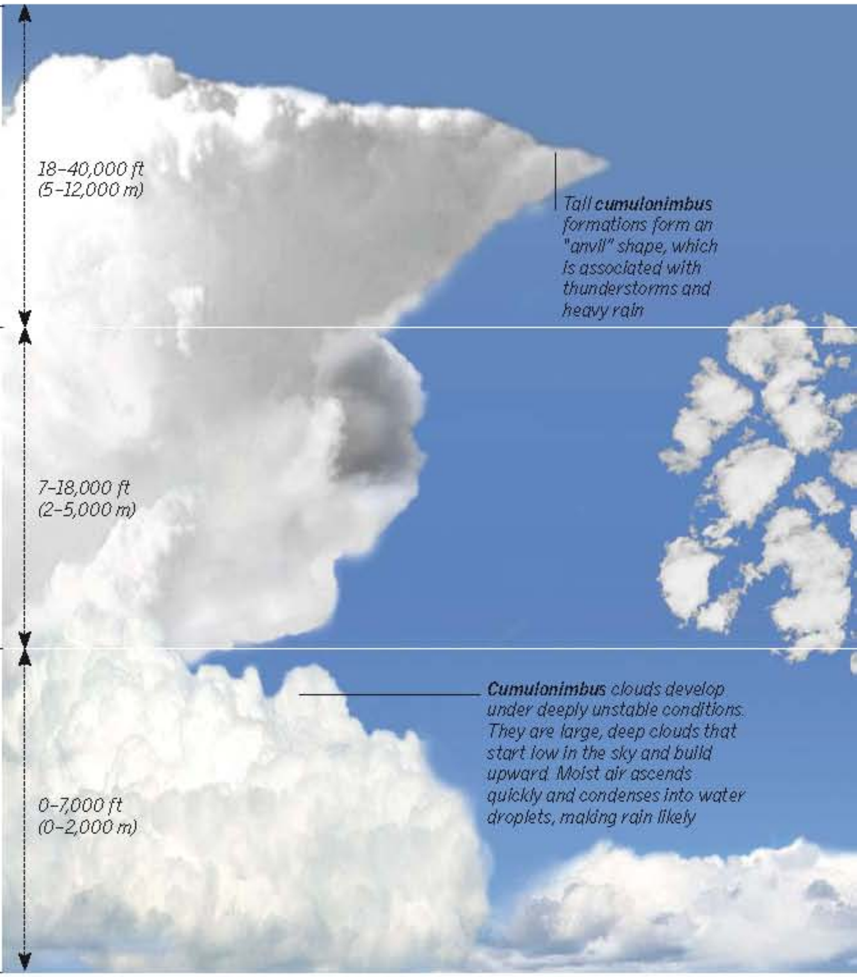

*Tall **cumulonimbus** formations form an "anvil" shape, which is associated with thunderstorms and heavy rain*

***Cumulonimbus** clouds develop under deeply unstable conditions. They are large, deep clouds that start low in the sky and build upward. Moist air ascends quickly and condenses into water droplets, making rain likely*

WEATHER RISKS

The weather can have a massive impact on your trip, bringing with it added dangers. It can affect your visibility levels, and the safety of the ground you're hiking over. In a survival situation, the temperature, and whether or not it's raining, can have a huge effect on your chances.

WARNING!
Never shelter under a solitary tree during a lightning storm—get in your vehicle if possible or find low ground.

HEAVY RAIN

If heavy rain falls quickly, the ground may become saturated, slippery, or flood. Seek shelter or proceed cautiously in waterproof clothing.

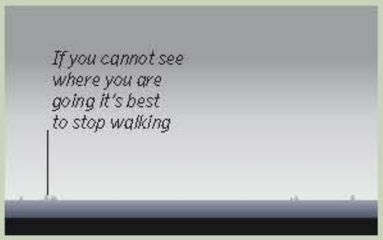

If you cannot see where you are going it's best to stop walking

FOG

Essentially a cloud in contact with the ground, fog reduces visibility, so beware of dangerous terrain, especially on mountains.

LIGHTNING

Lightning is an atmospheric discharge of electricity—it will strike the first object it encounters on its route to earth, so avoid high, exposed places.

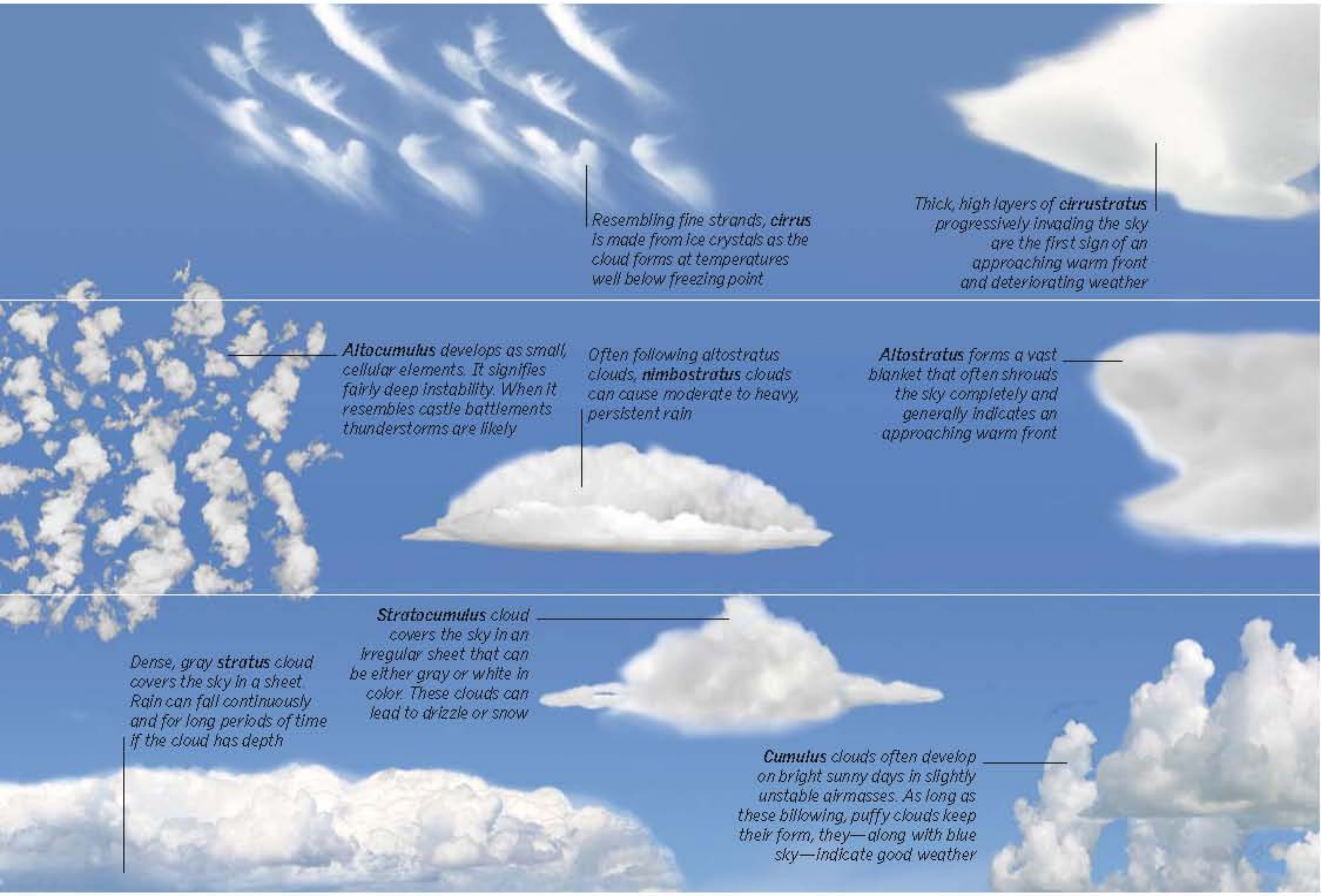

*Resembling fine strands, **cirrus** is made from ice crystals as the cloud forms at temperatures well below freezing point*

*Thick, high layers of **cirrustratus** progressively invading the sky are the first sign of an approaching warm front and deteriorating weather*

***Altocumulus** develops as small, cellular elements. It signifies fairly deep instability. When it resembles castle battlements thunderstorms are likely*

*Often following altostratus clouds, **nimbostratus** clouds can cause moderate to heavy, persistent rain*

***Altostratus** forms a vast blanket that often shrouds the sky completely and generally indicates an approaching warm front*

***Stratocumulus** cloud covers the sky in an irregular sheet that can be either gray or white in color. These clouds can lead to drizzle or snow*

*Dense, gray **stratus** cloud covers the sky in a sheet. Rain can fall continuously and for long periods of time if the cloud has depth*

***Cumulus** clouds often develop on bright sunny days in slightly unstable airmasses. As long as these billowing, puffy clouds keep their form, they—along with blue sky—indicate good weather*

UNDERSTANDING LOCAL WEATHER

WEATHER IS AFFECTED—and can be predicted—by the local geography surrounding you. High ground forces air to rise and cool, and the relative temperatures of land and sea produce predictable effects.

REGIONAL EFFECTS

It helps to understand how these predictable weather patterns occur in various geographic areas. They may influence your decisions when on the trail.

THE FOHN EFFECT

The leeward side of high ground is warmer and more sheltered than the windward side. Air rises as it travels over obstacles and, if the air contains moisture, the water vapor condenses to form cloud once cooled to a certain level. The air loses water at the summit, then descends and warms on the leeward side.

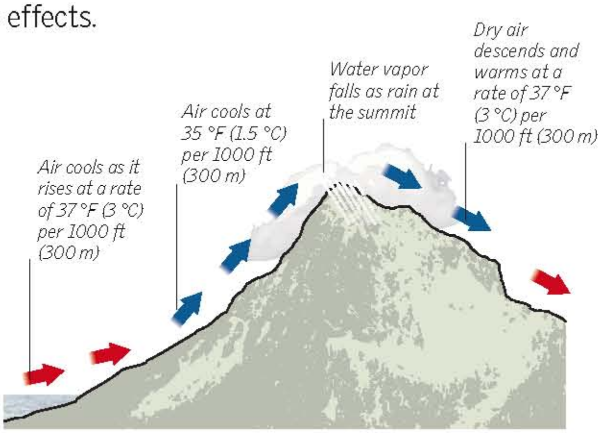
Air cools as it rises at a rate of 37 °F (3 °C) per 1000 ft (300 m)
Air cools at 35 °F (1.5 °C) per 1000 ft (300 m)
Water vapor falls as rain at the summit
Dry air descends and warms at a rate of 37 °F (3 °C) per 1000 ft (300 m)

ANABATIC AND KATABATIC WINDS

Winds that flow up and down slopes during certain atmospheric conditions are known as "anabatic" and "katabatic." They typically occur in mountainous regions.

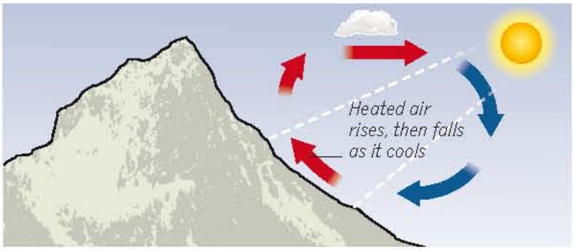
Heated air rises, then falls as it cools

ANABATIC WINDS

During the day, the surface of sloping terrain heats up. The air rises and creates a gentle upslope breeze. Anabatic winds are lighter than katabatic winds because they act against gravity.

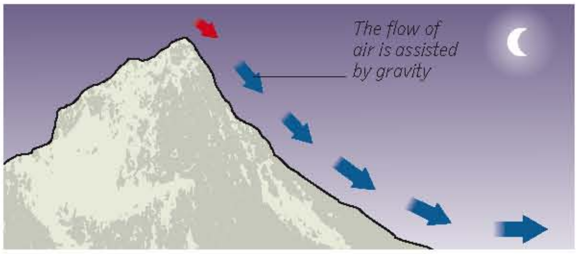
The flow of air is assisted by gravity

KATABATIC WINDS

Katabatic winds form on clear nights with a light breeze. Air in contact with the ground cools and its density increases, causing it to flow down the slopes of the hillside.

SEA AND LAND BREEZES

Sea breezes often develop along coastlines on clear sunny days, whereas land breezes tend to develop along coastlines on cloudless nights.

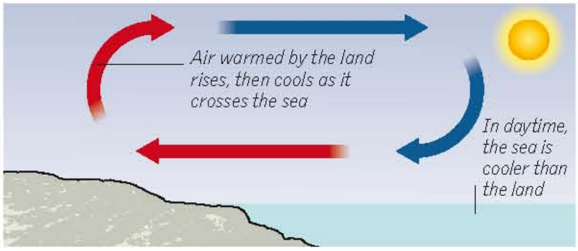
Air warmed by the land rises, then cools as it crosses the sea
In daytime, the sea is cooler than the land

SEA BREEZE

Warm air rises over land during the afternoon, drawing in cool air to replace it along the coast. The result of this coastal air circulation by day is a wind that blows from sea to land.

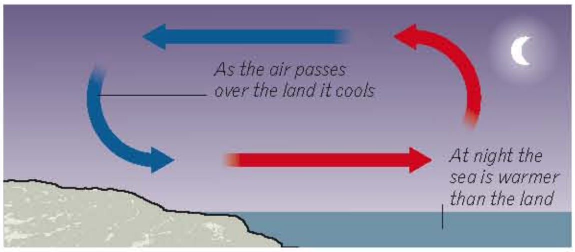
As the air passes over the land it cools
At night the sea is warmer than the land

LAND BREEZE

At night, the sea becomes comparatively warmer and air begins to rise. Air from the neighboring land is drawn toward the sea. The result is a wind that blows from land to sea.

NATURAL WEATHER FORECASTERS

These natural indicators are based on observation and can be useful if you have no alternative means of predicting the weather.

LOOKING AT THE SKY

- If the sky is red at dawn there is moisture in the air and a potential storm ahead. A red sky at night often indicates good weather to come.
- A rainbow usually indicates good weather is on the way, or a light shower.

PLANTS AND FLOWERS

- The scent of plants and flowers is often stronger before rain.
- Certain flowers, such as Scarlet Pimpernel and Morning Glory, are said to close up if bad weather is on the way.
- Pine cones are one of the best natural forecasters—their scales absorb moisture in the air and close up if wet weather is approaching, and unfurl in dry air.

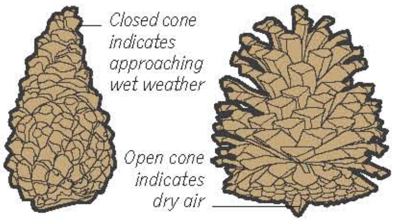
Closed cone indicates approaching wet weather

Open cone indicates dry air

WATCHING ANIMALS

- Animals migrating from high to low areas may indicate that a storm is on the way.
- Cows often lie down before it rains.
- Wool reacts to moisture in the air by swelling and straightening. It shrivels in dry weather conditions.
- Humans can also sense atmospheric change—some people suffer headaches before a thunderstorm.

CHANGING WEATHER

Watch out for alterations in the wind direction or strength as this may lead to a change in the weather. A dry, steady wind that changes direction or decreases in strength often indicates that rain is on its way.

THE BEAUFORT SCALE

Providing visual references for the effects of wind speed on land and at sea, the Beaufort Scale was designed by Sir Francis Beaufort in 1805. It provides a simple way of estimating wind speeds without the need for equipment, and is still in common usage today. The scale ranges from calm to hurricane, and is numbered from zero to 12.

BEAUFORT NUMBER	WIND DESCRIPTION	WIND SPEED MPH (KPH)	WIND EFFECT ON LAND AND AT SEA
0	Calm	0 (0)	Smoke rises vertically. Sea like a mirror.
1	Light air	1–2 (1–3)	Smoke drifts gently. Sea ripples like scales.
2	Light breeze	3–7 (4–11)	Leaves rustle. Wind felt on skin. Small wavelets.
3	Gentle breeze	8–12 (12–19)	Leaves and twigs move. Large wavelets with scattered whitecaps.
4	Moderate breeze	13–18 (20–29)	Small branches move. Small waves with frequent whitecaps.
5	Fresh wind	19–24 (30–39)	Small trees begin to sway. Moderate waves with some foam and spray.
6	Strong wind	25–31 (40–50)	Umbrella usage is difficult. Large waves of 10 ft (3 m) with some spray.
7	Near gale	32–38 (51–61)	Whole trees sway. Sea heaps up and foam begins to streak.
8	Gale	39–46 (62–74)	Walking is difficult. Moderately high waves of more than 18 ft (5 m).
9	Severe gale	47–54 (75–87)	Damage to roofs. High waves with toppling crests.
10	Storm	55–63 (88–101)	Trees uprooted or broken off. Very high waves and sea surface appears white.
11	Severe storm	64–74 (102–119)	Houses damaged. Exceptionally high waves of more than 38 ft (11 m).
12	Hurricane	More than 75 (More than 120)	Buildings destroyed. Huge waves of more than 46 ft (14 m).

MAKE A MOVE

While some survival situations are simply unavoidable, many are entered into because basic techniques relevant to a particular mode of transport have not been followed correctly. This could be due to a lack of knowledge, a loss of concentration, an individual's over-confident belief in his or her own equipment or skills, or as a result of sheer recklessness. Therefore, before you venture into an unfamiliar environment, make sure that you carefully research the type of terrain you will be encountering and investigate the best method of traveling safely and efficiently across it. Knowing the correct techniques for scrambling up a mountain or walking down a steep hillside, for example, could mean the difference between an enjoyable day out and a life-threatening survival situation arising from a fractured ankle in a remote location. Equally, being able to regain control of your vehicle after it has entered a skid could quite simply save your life. Thoroughly researching the terrain will also allow you to select the correct

In this section YOU WILL DISCOVER...

- how to make a **paddle** (so you're never **up a creek** without one)...
- the difference between your **finger shelf** and your **hand jam...**
- how to **pull** your own **pulk** and **scramble** over **scree...**
- when to **blaze a trail** or **ski without skis...**
- how to tell your **front-wheel skid** from your **skidoo...**
- when to let the **camel train** take the **strain...**
- how **chewing gum** can stop that **sinking feeling...**

equipment and most appropriate clothing, and enable you to familiarize yourself with the survival techniques relevant to a particular environment.

Whether you're planning to travel on foot, by boat, on horseback, in a 4WD vehicle, or by boat, you must consider not only your own capabilities and those of other members of your team, but also the capabilities of your equipment. Remember, pushing anything beyond its limits—whether that be a person, an animal, or a vehicle—will invariably lead to it failing.

A walking staff is one of the simplest yet most important survival aids you will ever need. It's the first piece of equipment to improvise should you find yourself in a survival situation.

THE "SURVIVOR'S THIRD LEG"—as a walking staff is also known—increases your ability to support yourself by allowing you to have two points of contact with the ground at any one time. This will reduce the chance of you slipping—a crucial factor given that your ability to walk is your main means of rescue; reduce your mobility and you seriously reduce your ability to survive.

A versatile tool, your survivor's third leg can be employed in many different survival situations. Among its many uses, it can be employed to:

- Support you as you walk
- Protect your face when you're walking through thickets or gorse
- Check for adequate support when crossing marshy ground
- Test the ground ahead for obstructions
- Check the depth of water when you're crossing streams and rivers
- Protect you against wild animals
- Form a ridgepole for your shelter
- Help you with your pace counting
- Spear fish or catch game
- Dig up roots or plants

> "Your ability to walk may be your **primary means of rescue**; reduce your mobility and you dramatically reduce your **chances of survival**"

TRAVELING ON FOOT

HIKING IS A GREAT WAY to explore wilderness terrain. It's important to have a decent level of fitness before you set out, and to wear and carry appropriate clothing and equipment. Hiking requires basic skills—using the correct techniques will help you move more efficiently, and ensure that your trip is safe.

BASIC WALKING SKILLS

Aim for a slow, even pace that can be maintained for the duration of the hike by all members of the group. A good way to maintain this pace is to develop a hiking rhythm. Take regular rest breaks and, if you're walking in a group, ensure everyone knows the route.

UPHILL TECHNIQUES

When traveling uphill, lean forward slightly, maintain your momentum but shorten your stride. When pushing upward, keep your feet flat on the ground.

- Carry a walking staff for support as you ascend.
- Move your legs forward from the hips.

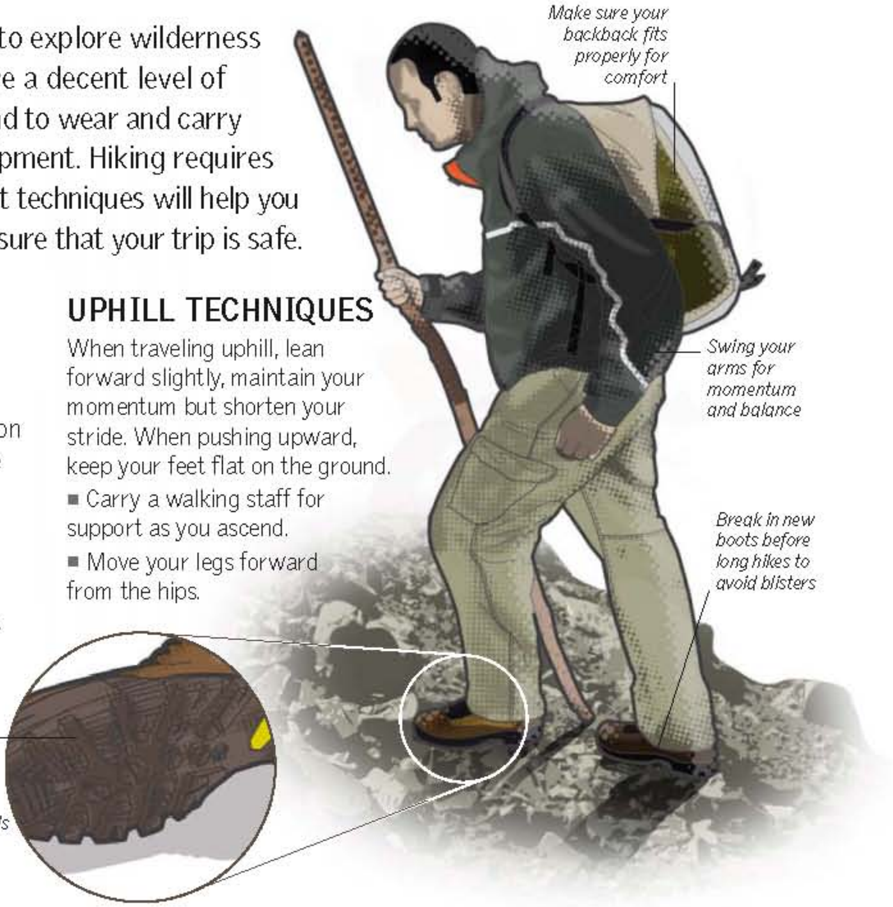

Make sure your backback fits properly for comfort

Swing your arms for momentum and balance

Break in new boots before long hikes to avoid blisters

Deep tread grips the ground and reduces slipping

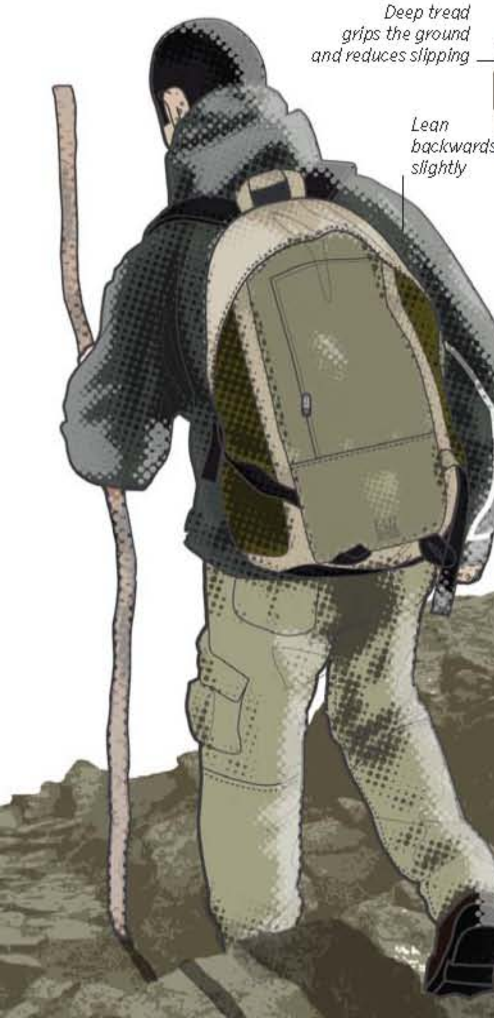

Lean backwards slightly

DOWNHILL TECHNIQUES

Walking downhill can place a lot of strain on your thighs, knees, and ankles, especially when you're carrying a heavy backpack. Be careful not to lose control or gather too much speed.

- Use your arms for balance.
- Maintain a steady rhythm.

WALKING AT NIGHT

Unless you're in the desert and it's cooler to move in darkness, avoid walking at night because of the added risks posed by navigational difficulties, and predators that hunt at night. If there's no alternative, try the following:

- Use your flashlight or improvise a torch by setting alight some birch bark or similar.
- If this isn't possible and you've time, close your eyes for 20 minutes to allow them to adjust to night vision.
- Use your walking stick or pole to feel in front of you for obstacles, tripping hazards, or sudden drops in the ground.
- Keep your pace slow and deliberate, and check your compass regularly.

NEGOTIATING DIFFICULT GROUND

One of the most challenging terrains to hike over is "scree," a mass of small rocks that slides underfoot making uphill and downhill travel difficult. The slippery nature of the surface can make progress slow, and care should be taken to avoid falling and injuring yourself. Hiking on scree is hard work, but using the correct techniques will help you to advance confidently, efficiently, and safely.

TRAVERSING SCREE

Choose a zig-zag route and look for a path that contains similar-sized rocks. Walk sideways across the slope, taking small steps and testing rocks for stability before placing your full weight on them.

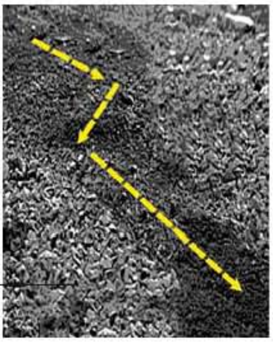
Rocks at the edge of the slope are likely to be larger and more stable

ASCENDING SCREE

Tread carefully, kicking your toes into the slope and testing the step before transferring your weight to that leg. Alternatively, walk with your feet splayed, placing your weight on the inside of each foot.

DESCENDING SCREE

"Screeing" downhill combines sliding with slow-motion jogging. When you have the technique it can be great fun, but avoid larger rocks to prevent ankle injuries.

TRAIL MARKERS

Your map and compass should be your primary method of navigation, but keep an eye out for trail markers, or "blazes," during your hike.

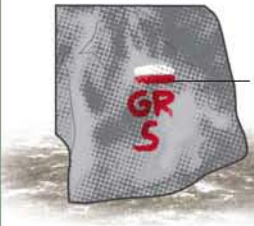

Trails are coded using colors or symbols

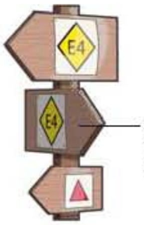

Arrows indicate direction

ROCKS

Trail blazes painted onto rocks and boulders are especially common in rocky terrain. They may be low on the ground so look carefully.

SIGNPOSTS

Made from wood, metal, or plastic, these signposts are particularly useful in areas where there are few rocks or trees on which to blaze.

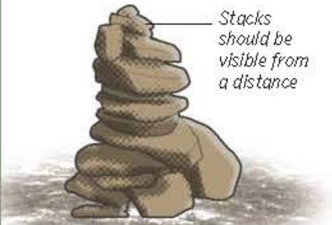
Stacks should be visible from a distance

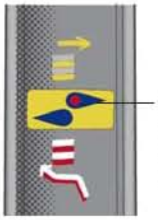
The same sign may indicate several trails

CAIRNS

Piles of rocks, known as "cairns," are designed to be visible in thick fog. Their size can vary from a few rocks to a large stack of boulders.

DIRECTIONAL SIGNS

When reading markers, look out for painted arrows or variations in the blazing, such as a bend. This indicates a change of direction in the trail.

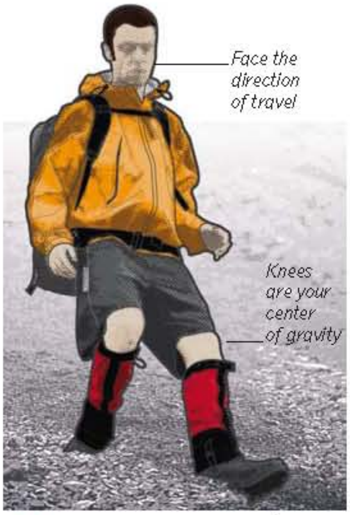
Face the direction of travel

Knees are your center of gravity

1 Ensuring the scree is fine and deep, use gentle hops to launch yourself down the slope. Keep balanced and let gravity do the hard work.

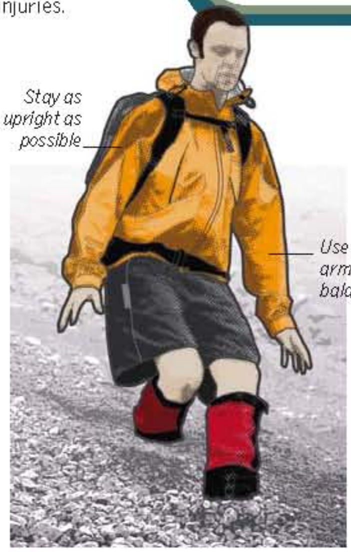
Stay as upright as possible

Use your arms for balance

2 As you build up momentum and rhythm, dig your heels into the slope and slide a short distance with each step, avoiding leaning forward.

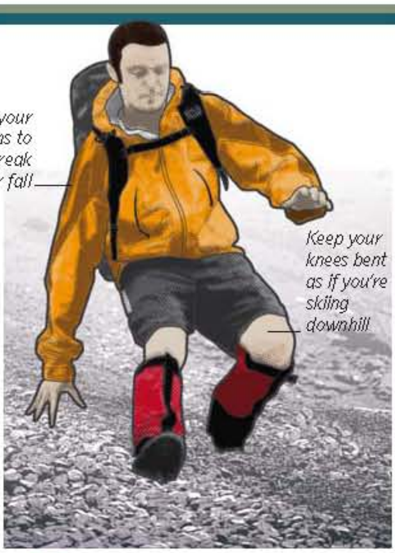
Use your arms to break your fall

Keep your knees bent as if you're skiing downhill

3 If you lose your balance temporarily, use your arms to steady yourself, relax your knees, and continue your descent.

CROSSING RIVERS

RIVER CROSSINGS ARE DANGEROUS and should be avoided unless absolutely necessary. In a survival situation, once you are cold and wet—which can lead to hypothermia—it is hard to get warm and dry. Always check your map for routes around the river, and choose the safest available crossing point.

CROSSING SAFELY

Before you get into the water, make sure you have a change of clothes or means of getting dry on the other side. In cold conditions, collect everything you need to get a fire going (tinder, kindling, and dry wood), and keep this dry as you cross.

CHOOSING YOUR CROSSING POINT

Walking upstream generally leads to shallower water, but be aware that even shallow water can have strong currents, as can water that looks calm on the surface. Always check for bridges further up- or downstream.

WADING BASICS
Wear footwear when wading to protect your feet from rocks and other dangers. Remove pants to keep them dry and decrease resistance in the water. Use a walking staff for added support.

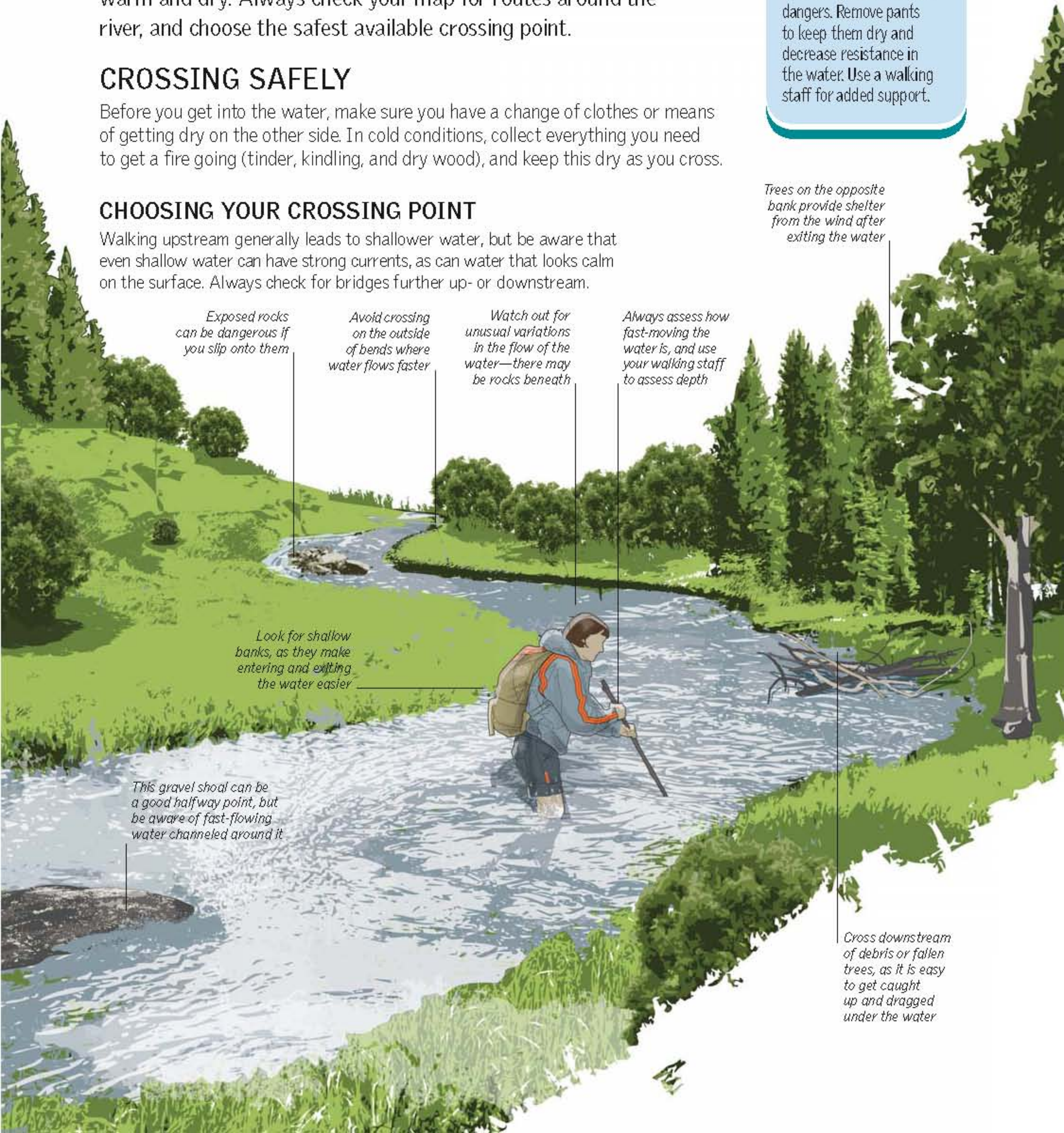

Trees on the opposite bank provide shelter from the wind after exiting the water

Exposed rocks can be dangerous if you slip onto them

Avoid crossing on the outside of bends where water flows faster

Watch out for unusual variations in the flow of the water—there may be rocks beneath

Always assess how fast-moving the water is, and use your walking staff to assess depth

Look for shallow banks, as they make entering and exiting the water easier

This gravel shoal can be a good halfway point, but be aware of fast-flowing water channeled around it

Cross downstream of debris or fallen trees, as it is easy to get caught up and dragged under the water

WADING WITH OTHERS

Crossing in a group is safer than crossing alone. Linking your arms together creates a stronger, more stable structure against the current and provides backup for anyone who falls. Loosen the straps of your backpack, and place only one arm through them, so you can release the pack quickly if you fall.

WARNING!

Never cross white water, or rivers that have flooded. In these situations it is safer not to cross at all than to risk injury.

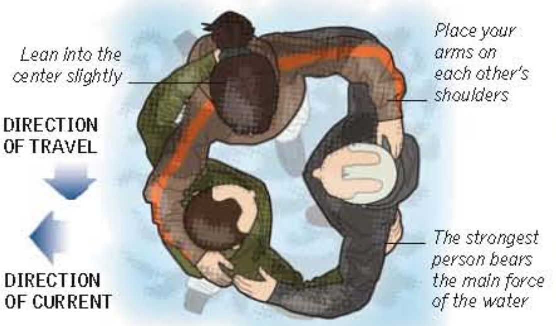
Lean into the center slightly
Place your arms on each other's shoulders
DIRECTION OF TRAVEL
DIRECTION OF CURRENT
The strongest person bears the main force of the water

CROSSING IN A HUDDLE

Positioning the strongest person upstream, with the others providing stability and support, link your arms tightly and take short, deliberate steps across the river.

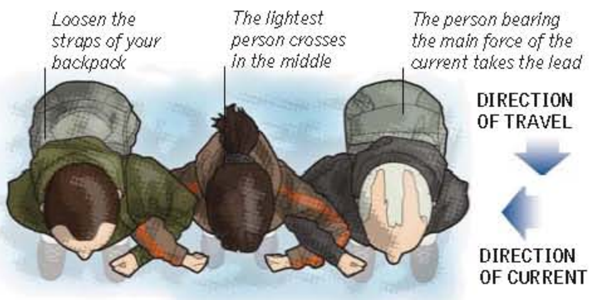
Loosen the straps of your backpack
The lightest person crosses in the middle
The person bearing the main force of the current takes the lead
DIRECTION OF TRAVEL
DIRECTION OF CURRENT

CROSSING IN A LINE

Keeping well balanced, cross the river perpendicular to the current. Move slowly and position each step carefully to avoid being swept away by the force of the water.

WADING ALONE

Wading across a river alone is not ideal, but if you have no option then your walking staff or "survivor's third leg" (see p. 72)—or simply any long stout stick—will provide additional support and balance. Use it as a probe to alert you to any sudden changes of depth in the river bed.

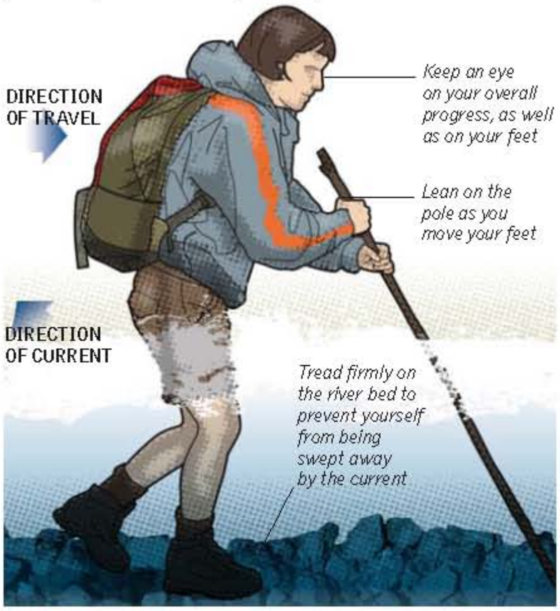
DIRECTION OF TRAVEL
Keep an eye on your overall progress, as well as on your feet
Lean on the pole as you move your feet
DIRECTION OF CURRENT
Tread firmly on the river bed to prevent yourself from being swept away by the current

USING A WALKING STAFF

Facing the current, walk diagonally across the river, placing each foot down firmly and deliberately, and leaning on your walking staff for support. Your feet and your staff are your three points of contact—keep at least two of them in contact with the river bed at all times.

CROSSING WITH ROPES

Using ropes is a good option for dangerous crossings, but they can get tangled, and drag you under the water. Always aim for the easiest and safest option—using ropes is complicated and should be your last resort.

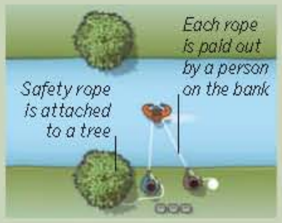
Each rope is paid out by a person on the bank
Safety rope is attached to a tree

1 A "safety" rope is tied to a tree and then carried across by the strongest person, who also takes a "crossing" rope with a carabina tied centrally.

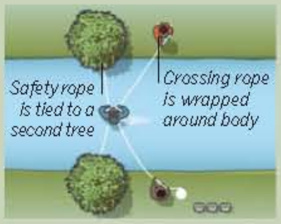
Safety rope is tied to a second tree
Crossing rope is wrapped around body

2 The safety rope is tied to a tree and the carabina clipped to the safety rope. The carabina is pulled back and fixed to the next person to cross.

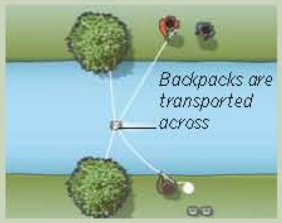
Backpacks are transported across

3 He or she crosses upstream of the safety rope, holding it for support. Backpacks can be clipped to the carabina and transported, too.

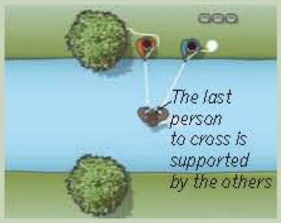
The last person to cross is supported by the others

4 The final person unties the safety rope from the tree, wraps it around his or her body, and wades across, supported by the others.

SCRAMBLING AND CLIMBING

CLIMBING WITHOUT ROPES is known as "scrambling." As with roped techniques, the idea is to maintain three points of contact with the rock at all times—either two feet and one hand or both hands and one foot. Your legs should power the climb, with your arms used predominantly for balance. Proceed carefully, making sure you are always balanced and confident of your next move.

WARNING!
Climbing is a dangerous activity that should only be considered as a last resort. Ideally, plan ahead using your map to find a way around the obstacle.

HAND AND FOOT HOLDS

When planning your route, choose your hand and foot holds carefully. Don't reach too far, and test each hold for stability before using it to support your weight.

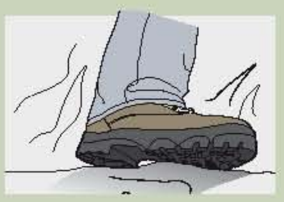

EDGES
For very small footholds, place the inside edge of your foot in the hold in the rock to take the pressure off your toes.

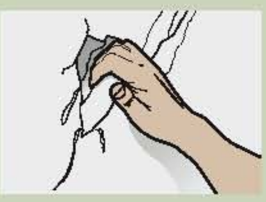

FINGER SHELVES
Curl your fingers over the rock for a secure fingerhold. The larger the fingerhold, the more secure it will be.

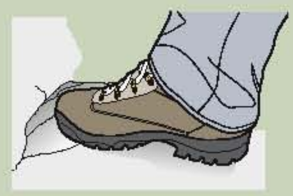

LARGE POCKETS
Placing your foot securely within the pocket, balance yourself so both your arms and legs take the strain.

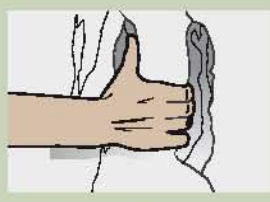

SIDE PULLS
Side pulls can be used to maintain balance or to pull yourself across the rock. Grip the rock tightly.

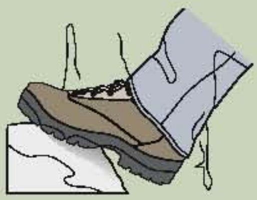

PROTRUSIONS
If possible, place the entire sole of your foot on the protrusion. If only the ball of your foot will fit, keep your heel low.

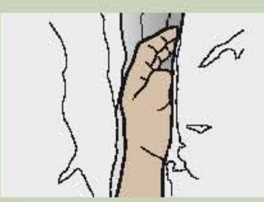

HAND JAMS
Insert your hand into the crack, push your thumb into your palm, arch your hand, and wedge it tightly inside.

BASIC CLIMBING TECHNIQUES

Always climb within your capabilities. It's important not to take any risks, as it's far safer to descend and start the climb again than to chance a fall. Before you start to climb, plan the easiest and safest route.

SCRAMBLING

When moving across the rock you will need to combine a variety of techniques to negotiate different obstacles. Always plan your moves several steps in advance, and keep three points of contact with the rock at all times.

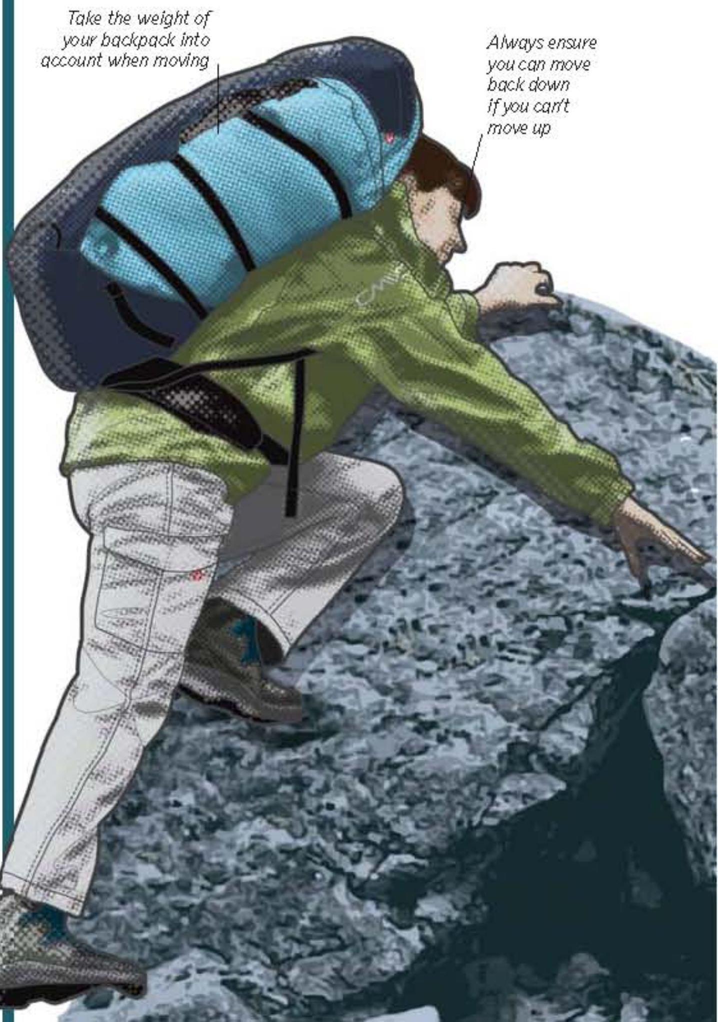

Take the weight of your backpack into account when moving

Always ensure you can move back down if you can't move up

MANTELLING

The mantelling technique is used to climb overhangs in the rock. Use your lead ankle and then your knee to lever your body up over the obstacle. It's a physically challenging technique, but useful.

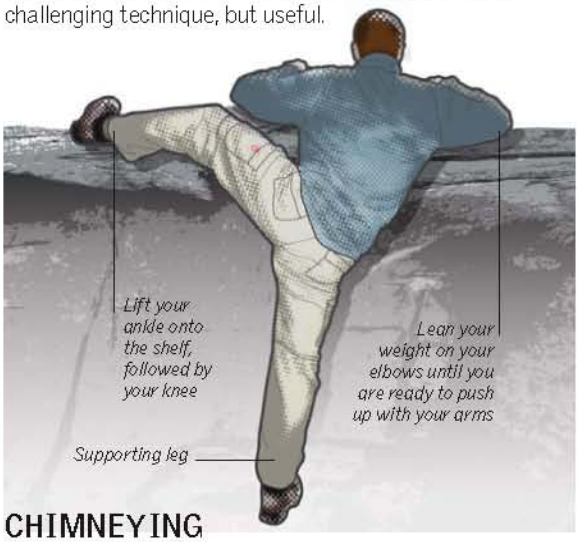
Lift your ankle onto the shelf, followed by your knee
Lean your weight on your elbows until you are ready to push up with your arms
Supporting leg

CHIMNEYING

To climb up the inside of large rock clefts, or "chimneys," use the chimneying technique. To ascend, move your back and hands up the wall, and push and follow with your legs. It's easy to get stuck at the top so plan your exit route carefully.

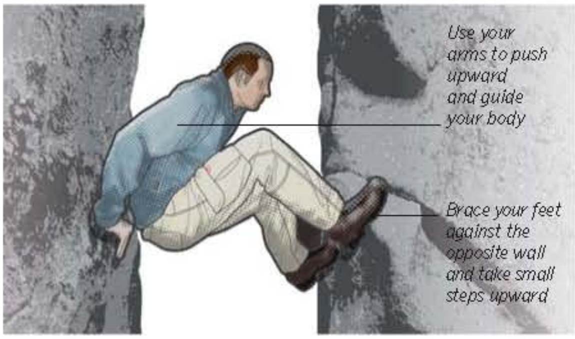
Use your arms to push upward and guide your body
Brace your feet against the opposite wall and take small steps upward

STRADDLING

If the chimney is relatively wide, you may need to alter your body position to straddle the gap. With a leg and arm on each wall, inch yourself up the rock using your legs to push your body upward.

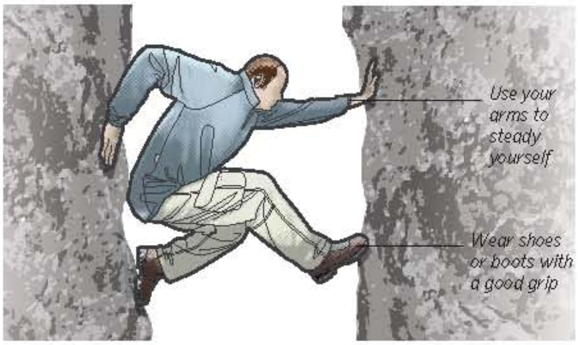
Use your arms to steady yourself
Wear shoes or boots with a good grip

CLIMBING WITH EQUIPMENT

The advantages of climbing with ropes cannot be underestimated as far as safety is concerned, although a lot of specialized equipment is required. As well as ropes, helmets, and harnesses, climbers can also use screws to secure themselves to the rock as they progress each stage.

BELAYING

Belaying is a technique used by climbing partners to safeguard each other during a climb. The belayer secures himself to the rock and stands on a suitable ledge while the lead climber ascends. Once at the top, the lead climber secures himself and acts as the belayer.

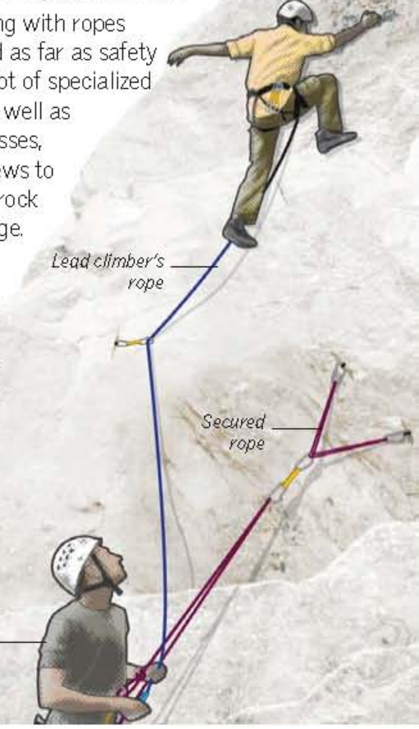
Lead climber's rope
Secured rope
The belayer must watch the climber at all times

ICE CLIMBING

Ice climbers utilize similar techniques to rock climbers, although they carry ice axes and wear crampons on their feet, to help them grip the ice.

MOVING UPWARD

As with rock climbing and scrambling, ice climbers ascend using power from their legs and arms. Crampons and ice axes are used to create holds in the rock.

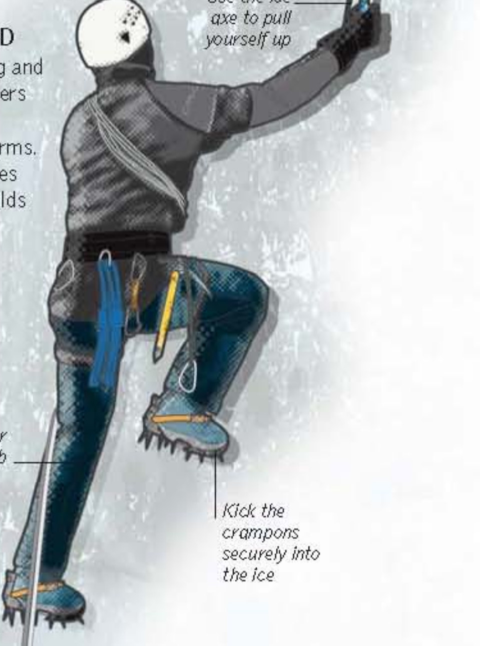
Use the ice axe to pull yourself up
Legs power the climb
Kick the crampons securely into the ice

TRUE-LIFE ACCOUNT

EXTREME SURVIVAL— IN THE MOUNTAINS

USEFUL EQUIPMENT

- Two-way radio
- Avalanche beacon and probe
- Waterproof clothing
- Spare clothing layers
- Collapsible shovel
- Climbing equipment, if needed
- Signal flares
- Map, compass, GPS
- Survival tin, bushcraft knife
- Cell/satellite phone
- Poncho/bivy sack

STEVEN GREEN, 32, AN EXPERIENCED HILL WALKER from Dumfries, Scotland, spent four nights lying on a remote mountainside after a life-threatening fall. Suffering from a broken jaw and fractured skull, he survived via a combination of good preparation, quick thinking, and improvisation.

On Thursday, October 7, 1999, Steven set out alone for a trek in the hills of Wester Ross in the northwest Highlands of Scotland. He was well equipped with, among other things, a cell phone, bivy sack, pita bread, and water—and had taken the wise precaution (or so he thought) of informing his girlfriend of his intended route.

Following an all-day trek and an overnight camp, he was descending the mountain on Friday when he slipped on wet grass and fell down a waterfall, coming to rest in the shallow, rocky riverbed. He knew he would not survive for long in the cold water so, despite being in intense pain, he crawled to the relative safety of the bank, then wisely got into his bivy sack for warmth and waited. He sustained himself by eating pita bread, which he softened in water because he couldn't chew. His phone was damaged in the fall so he was unable to call for help. When he failed to return home on time, the alarm was raised by Steven's girlfriend, but she had forgotten to write down his intended route so no one knew his exact location.

"HE SLIPPED ON WET GRASS AND FELL DOWN A WATERFALL"

Steven experienced a further four days and nights of exposure while local and RAF rescue teams and search-and-rescue dogs combed the mountains for him. As the days passed they feared the worst, but when they located Steven on Tuesday morning—after finding his car and, inside it, his route map—they found him in good spirits. At hospital Steven was diagnosed with a fractured skull, broken jaw, missing front teeth, cuts and bruises, and a leg injury—but he was alive.

WHAT TO DO

ARE YOU IN DANGER?

NO

If you are in a group, try to help any others who are in danger

YES

Get yourself out of it:
Elements—Find or improvise immediate shelter
Animals—Avoid confrontation and move away from danger
Injury—Stabilize condition and apply first aid

ASSESS YOUR SITUATION

See pages 234–35

DOES ANYONE KNOW YOU WILL BE MISSING OR WHERE YOU ARE?

NO

If no one knows you are missing or where you are, you will need to notify people of your plight by any means at your disposal

YES

If you are missed, a rescue party will almost certainly be dispatched to find you

DO YOU HAVE ANY MEANS OF COMMUNICATION?

NO

You are faced with surviving for an indefinite period—until you are located or you find help

YES

If you have a cell or satellite phone, let someone know your predicament. If your situation is serious enough to be worthy of emergency rescue, and you have a Personal Locator Beacon (PLB), you should consider this option

CAN YOU SURVIVE WHERE YOU ARE? *

NO

If you cannot survive where you are and there are no physical reasons why you should remain, you will have to move to a location that offers a better chance of survival, rescue, or both

YOU WILL HAVE TO MOVE **

YES

Address the Principles of Survival: Protection, Location, Water, Food

YOU SHOULD STAY **

DO

- Keep all clothing dry and clean
- Collect drinking water from fast-moving streams; filter and disinfect if you have the means
- Be on constant lookout for signs of cold-related injuries such as frostnip, frostbite, and hypothermia
- Regulate your clothing to avoid overheating when moving and hypothermia when static
- Use a walking staff to aid safe movement
- Watch the weather closely and be prepared to change your plans at short notice—mountain climates are highly unpredictable
- Improvise shelter when not on the move

DON'T

- Descend hills in a careless manner; zig-zagging across hills is less tiring and puts less strain on leg muscles
- Travel at too fast a pace—high altitude equals less air and this will place greater demands on even a fit person
- Sweat too much, as the moisture will chill you further
- Ignore any opportunities to collect dry tinder/kindling

DON'T

- Allow your extremities to get too cold as those areas are most susceptible to frostbite
- Overlook the dangers of carbon monoxide poisoning in cramped shelter. Don't let candles, stoves, or fires burn all night
- Breathe on your hands to warm them up: you are exhaling warm air that you will have to replace with cold

DO

- Select a shelter site that offers protection from the elements. Build it no bigger than it needs to be
- Fill plastic bags or spare clothing with dry foliage and use as a mattress or pillow to insulate you from the cold, damp ground
- Deploy all your aids to location and prepare for immediate use
- Check upstream for the quality of your water source
- Light a fire and (if in a group) take turns tending it to keep it going all night
- Continually re-assess your situation and adapt your actions as necessary.
- Be constantly alert for signs of rescue

* If you cannot survive where you are, but you also cannot move owing to injury or other factors, you must do everything you can to attract rescue.

** If your situation changes (for instance, you are "moving" to find help, and you find a suitable location in which you can stay and survive) consult the alternative "Do" and "Don'ts."

MOVING OVER SNOW

PREPARATION IS ESSENTIAL when hiking over frozen terrain. Not only must you be physically fit—the conditions make for slow, exhausting progress—but you must also have the right equipment and know how to use it. Wearing snowshoes or skis, and breathable and layered clothing to regulate your temperature, is essential. With the correct techniques you can hike safely and enjoy the surroundings.

WARNING!

Walking over deep snow without snowshoes is called "post-holing" and should be avoided unless absolutely necessary. Sinking into the snow will leave you exhausted and very wet, which in cold conditions can quickly lead to hypothermia. The exertion can also cause sweating and a dangerous reduction in your body temperature when you stop.

SNOW AND ICE

Knowing how to deal with different types of snow and ice is invaluable when hiking over frozen terrain.

DEEP SNOW

- If in a group, walk in single file and take turns at the front: the most strenuous position, as you're creating the path.
- Avoid rocks—in spring, they absorb heat and the snow above becomes unstable.

FROZEN CRUST

- Use a walking staff to test the snow ahead. An ice crust above deep snow may take your weight, but progress carefully.
- Later in the day you may come across melted depressions, called "sun cups." Cross on the rims to avoid sinking into the snow.

SLOPES

- Kick firmly into the slope and test your weight before ascending. When descending, you can use a technique called "boot skiing" (skiing without your skis).
- Choose your route based on the conditions: travel in straight lines if you are able to, or in zig-zags if the terrain is steep.

ICE

- Always progress carefully, using your walking staff to test the ice, especially over rivers and lakes. If in a group, rope yourselves together for safety.
- Wear crampons for extra grip. On very steep slopes, use your ice ax to cut steps.
- Use your ice ax to halt a fall by turning to face the slope and digging it into the ice.

GLACIERS

- Never attempt to cross glaciers without a guide—glaciers require specialized skills.

WAYS OF TRAVELING

When traveling over snow, your main aim is to get to your destination as safely as possible, without expending too much energy or losing too much body heat. Methods range from improvised snowshoes to motor vehicles.

USING SNOWSHOES AND SKIS

Snowshoes and skis are an effective way of traveling over snow. They work by spreading your body weight over a larger surface area, which enables you to walk on the surface of the snow rather than sink into it. Always set off cold, as you'll warm up quickly, and add or remove layers as required.

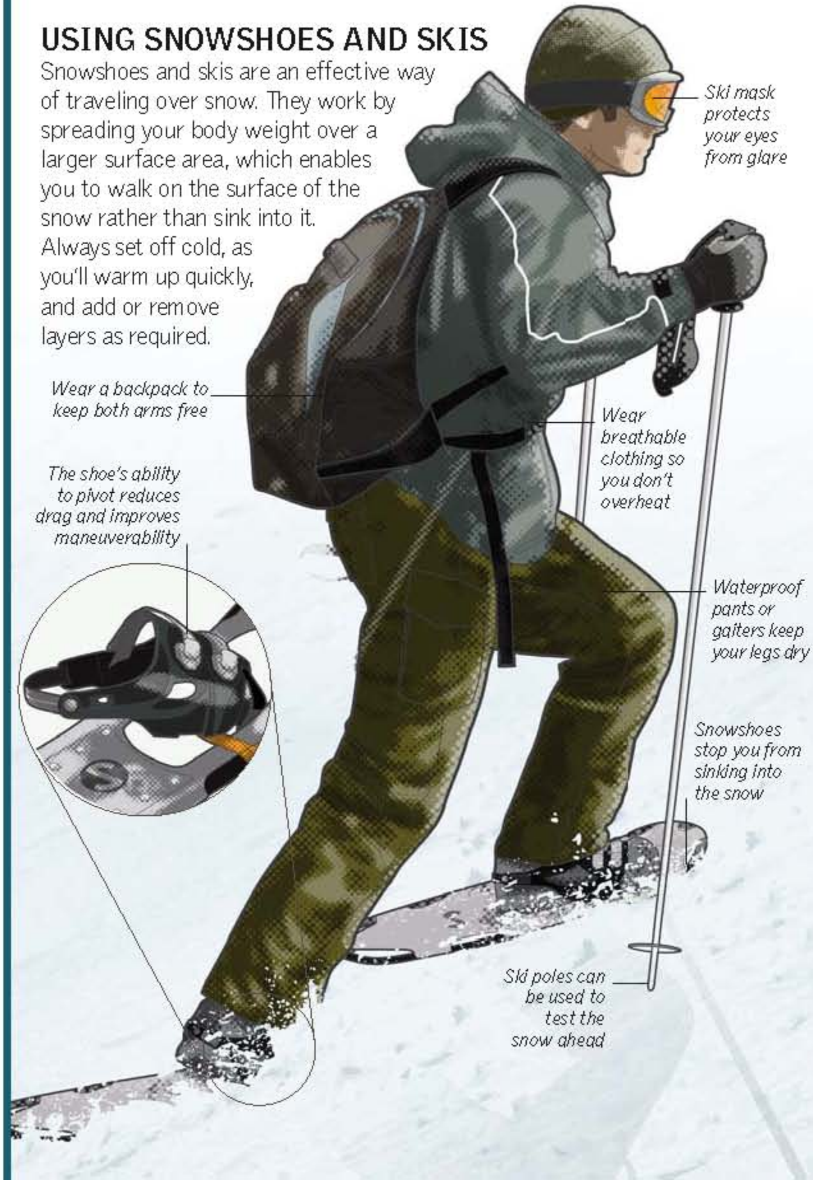
Ski mask protects your eyes from glare
Wear a backpack to keep both arms free
Wear breathable clothing so you don't overheat
The shoe's ability to pivot reduces drag and improves maneuverability
Waterproof pants or gaiters keep your legs dry
Snowshoes stop you from sinking into the snow
Ski poles can be used to test the snow ahead

MAKING IMPROVISED SNOWSHOES

If you don't have any pre-manufactured snowshoes—for example, in a survival situation—you can make some very simple shoes to help you negotiate the snow more effectively, using your knife, some green wood, and cordage. They may take time to build, but will save time and effort in the long run.

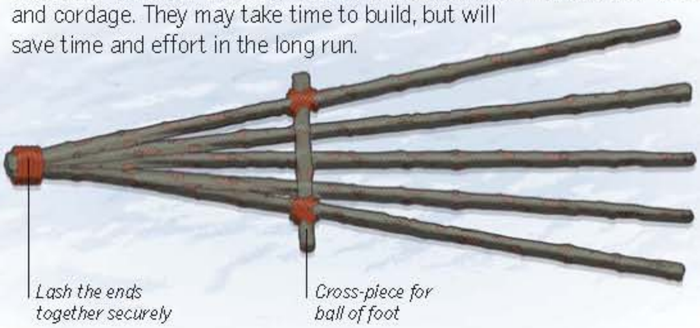
Lash the ends together securely
Cross-piece for ball of foot

1 Cut five lengths of green wood. They should be as thick as your thumb and the same length as the distance from your foot to your armpit. Cut three shorter lengths for the cross-pieces.

- Lash the ends of the five longer pieces together securely using cordage.
- Calculate where the ball of your foot will be positioned on the shoe and lash a cross-piece across the five lengths. Ensure the shoe will balance.

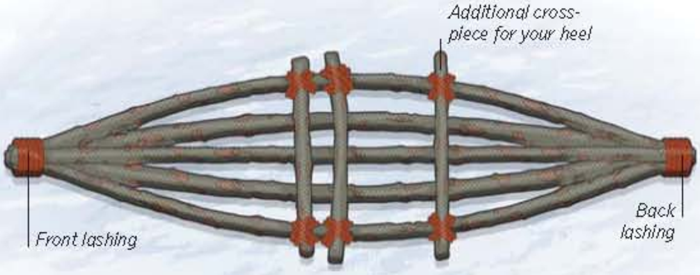
Additional cross-piece for your heel
Front lashing
Back lashing

2 Lash the five loose lengths of wood together at the back of the shoe. It's important to make this lashing as secure as possible.

- Fix the second cross-piece roughly 2 in (5 cm) behind the first.
- Lash the third cross-piece where your heel will rest.
- Repeat steps 1 and 2 to make a second shoe before progressing to step 3.

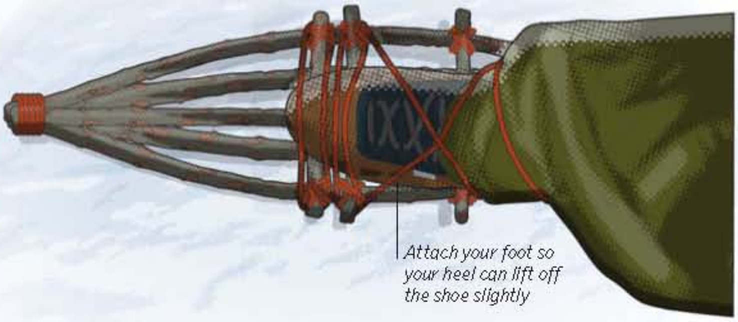
Attach your foot so your heel can lift off the shoe slightly

3 Place your foot on top of the snow shoe, ensuring that the ball of your foot sits directly over the front cross-piece and that your heel is positioned on the back cross-piece.

- Tie your boot to the snow shoe using whatever cordage you have, but ensure the heel is allowed to remain free to pivot. Repeat for the other foot.

ALTERNATIVE METHODS

These alternative methods will also spread your weight on the snow. If you have no gaiters, tie plastic bags around the bottom of your legs to keep them dry.

USING BRANCHES

Ideal for short distances, a simple way to get you out of deep snow and to a road or track is to attach branches to your feet using cordage. Select a tree, such as pine, that has strong, close branches.

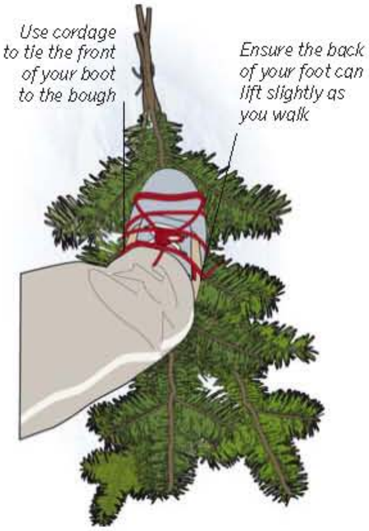
Use cordage to tie the front of your boot to the bough
Ensure the back of your foot can lift slightly as you walk

USING SAPLINGS

You will need branches that have some flexibility. Gently bend the longest branch into a teardrop shape and lash the two ends together. Heating the saplings over a fire will make them easier to bend.

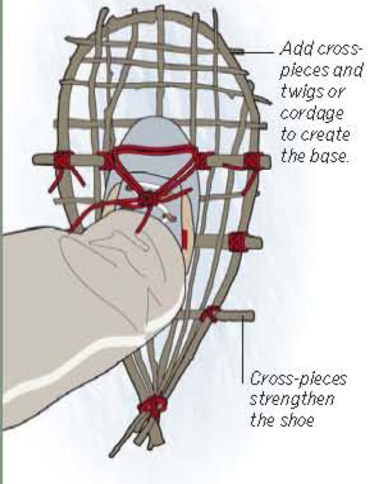
Add cross-pieces and twigs or cordage to create the base.
Cross-pieces strengthen the shoe

MAKING A SLED

If you find yourself in a survival situation with heavy equipment to carry over snow, making a simple sled or "pulk" (see panel, right) will help you transport it more efficiently. You could also build one to transport an injured person or small child. You can make your sled as large or as small as you need, providing you follow these basic principles.

TOOLS AND MATERIALS

- Survival saw or pocket chainsaw
- Knife
- Cordage
- Forked branch (for bulk of sled)
- Two branches (for bracing pieces)
- Sticks (for cross-pieces)

1 Using a short saw or penknife, cut a forked branch to form the base of the sled.

- Tie the two ends of the fork to the main branch with cord. This creates tension and forces the branches to curve and act as runners.

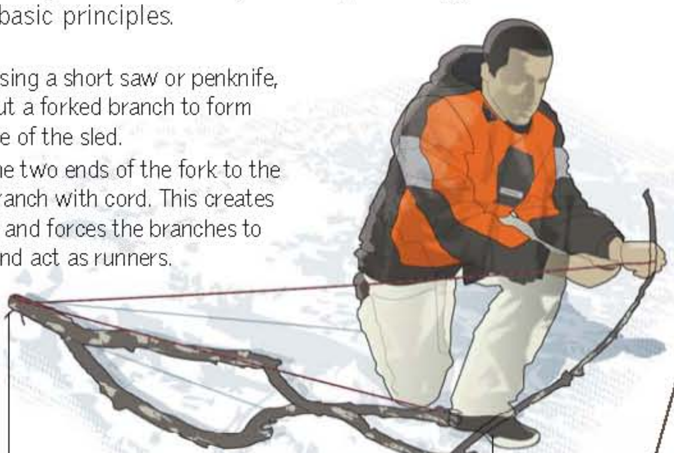

Attach the cord to the main branch using a slip knot (see p. 142)

Attach the cord to the end of the fork using a taut line hitch (see p. 145)

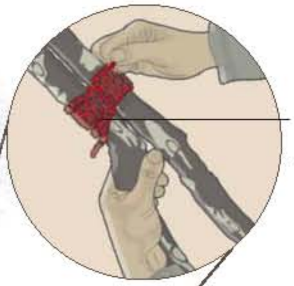

Lash the bracing piece to the main branch

2 Lash an additional branch to one of the runners to create a bracing piece.

- Repeat on the other side.
- The bracing pieces strengthen the branches and prevent any cord from touching the ground—if it does, it will wear out quickly and disintegrate once the sled is on the move.

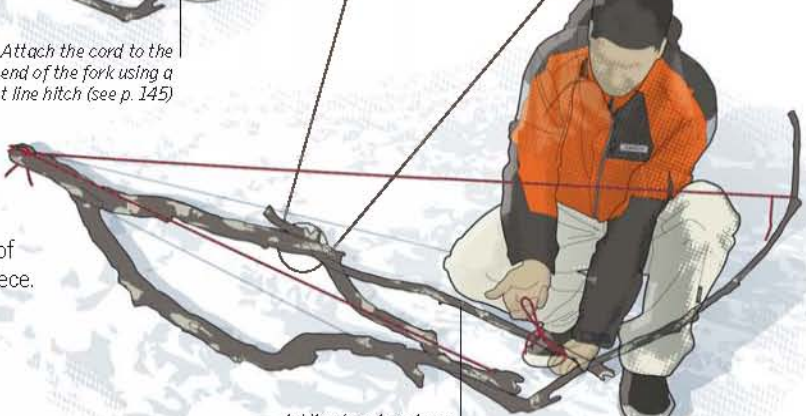

Adding bracing pieces creates a support for the carrying platform

ANIMAL POWER

Huskies, or sled dogs, are ideal for transporting people and equipment across winter terrain. Because of their thick coat they can endure very low temperatures, and their large, furred feet allow them to move quickly over snow. Huskies work well as a team and can pull heavy loads easily and efficiently.

TRAVELING WITH DOGS

Although huskies are easy to care for and relatively simple to handle, you should not undertake an expedition with dogs unless you are traveling with an expert or have first undergone extensive training. The same goes for all expeditions in snowy terrain.

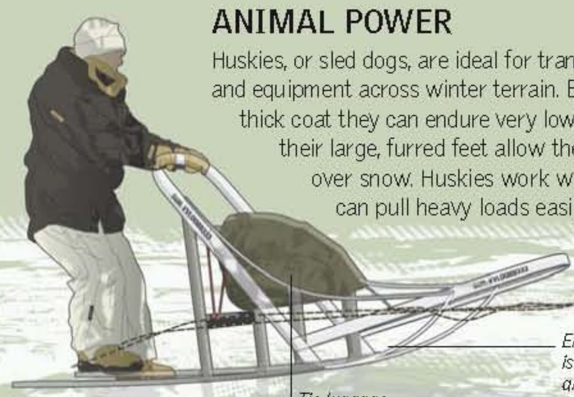

Ensure the sled is well balanced and not overloaded

Tie luggage securely to the frame

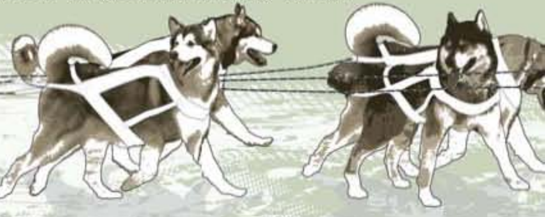

HUMAN POWER

Pulling your equipment behind you using a pulk is an extremely efficient way of moving over snow. Pulks are small, low-slung toboggans, typically made from lightweight plastic, and come in many different sizes.

TRAVELING WITH A PULK

Although pulks are the most efficient method of carrying heavy loads over snow using human power, they can be hard work, especially in softer snow. Wear breathable clothing to allow excess body heat to escape. Know how to release your harness quickly in an emergency. If you are in a group, one person can be harnessed to the rear of the pulk to act as a brakeman when going downhill.

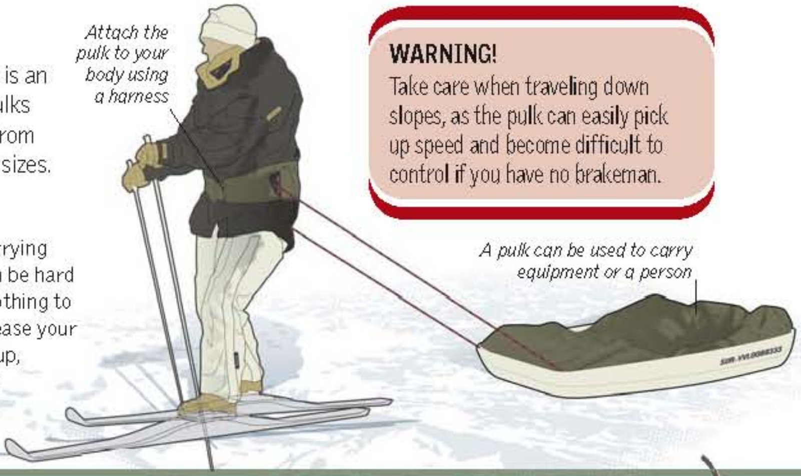
Attach the pulk to your body using a harness
A pulk can be used to carry equipment or a person

WARNING!
Take care when traveling down slopes, as the pulk can easily pick up speed and become difficult to control if you have no brakeman.

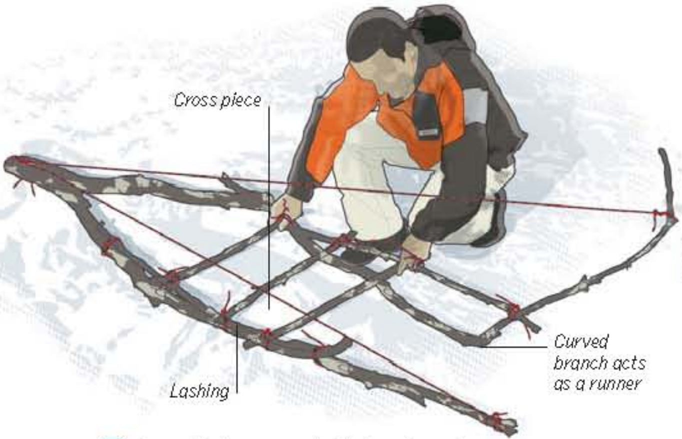
Cross piece
Lashing
Curved branch acts as a runner

3 Lay sticks across both bracing pieces and lash them together. These cross-pieces strengthen the structure.

- You can use as many sticks as you can find, but three or four should suffice.
- These cross-pieces will also form the main carrying platform of your sled.

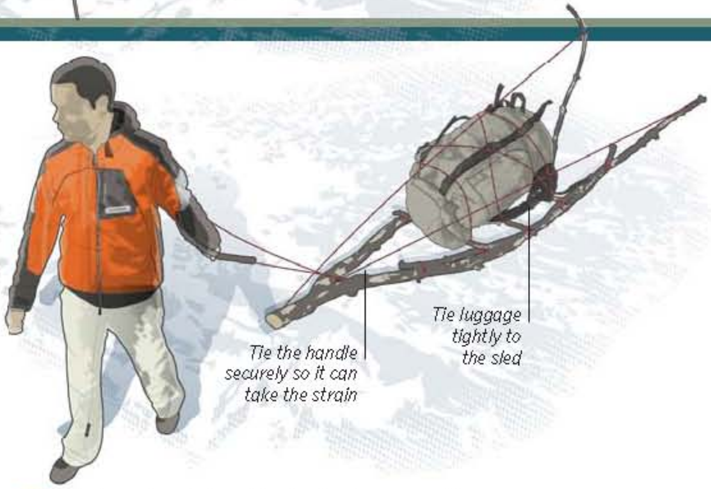
Tie the handle securely so it can take the strain
Tie luggage tightly to the sled

4 Make a handle for the sled using a small branch. The branch should be as smooth as possible to make pulling the sled more comfortable.

- Attach the handle to the front of the sled using a long piece of cord.

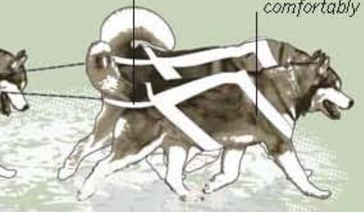
Linking the dogs together helps them to power forward in unison
Harnesses allow the dogs to pull comfortably

MOTOR POWER

Snowmobiles are practical and quick, and have revolutionized arctic travel. They are easier to handle than huskies, and can reach relatively high speeds. However, although you can cover great distances in short periods of time, if anything goes wrong you may be far from help. Always carry survival equipment when you travel.

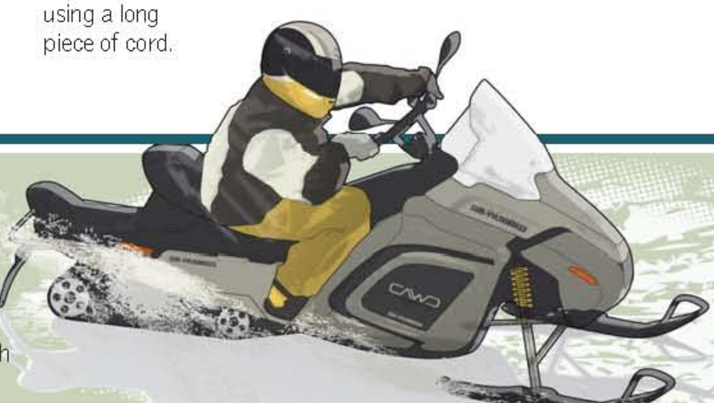

BEFORE YOU GO

Prior to a snowmobile trip, regardless of distance, it is vital to check your vehicle maintenance and ensure that you have sufficient fuel for the trip. Plan your route carefully and inform someone of your plans so that they can raise the alarm if you don't reach your destination when planned. Dress warmly, wear goggles or a ski mask to reduce glare, and drive safely.

USING PACK ANIMALS

PACK ANIMALS CAN BE USED to transport heavy loads when hiking over wilderness terrain. Ideally suited to carrying substantial loads, they can cover great distances in areas where vehicles would struggle. When you are organized, and know how to care for the animals, traveling with pack animals can be very rewarding.

PACKING TIPS

- Know the capabilities of your animal, and what weight they can safely carry over the necessary distance.
- Before loading the animal, groom it well and check for sores or ticks.
- Place heavier items at the bottom of your panniers and lighter items at the top.

LOADING THE ANIMAL

Stand on level ground, making sure that the animal has all four legs placed firmly on the ground. Before placing the loaded panniers onto the animal, lift them to ensure they are well balanced. Rearrange if one is lighter. You may need to hobble or blindfold the animal to keep it still while loading.

ANIMAL WELFARE

Remember to transport food, water, and supplies for the animal as well as for yourself. Their welfare is paramount, so treat them well.

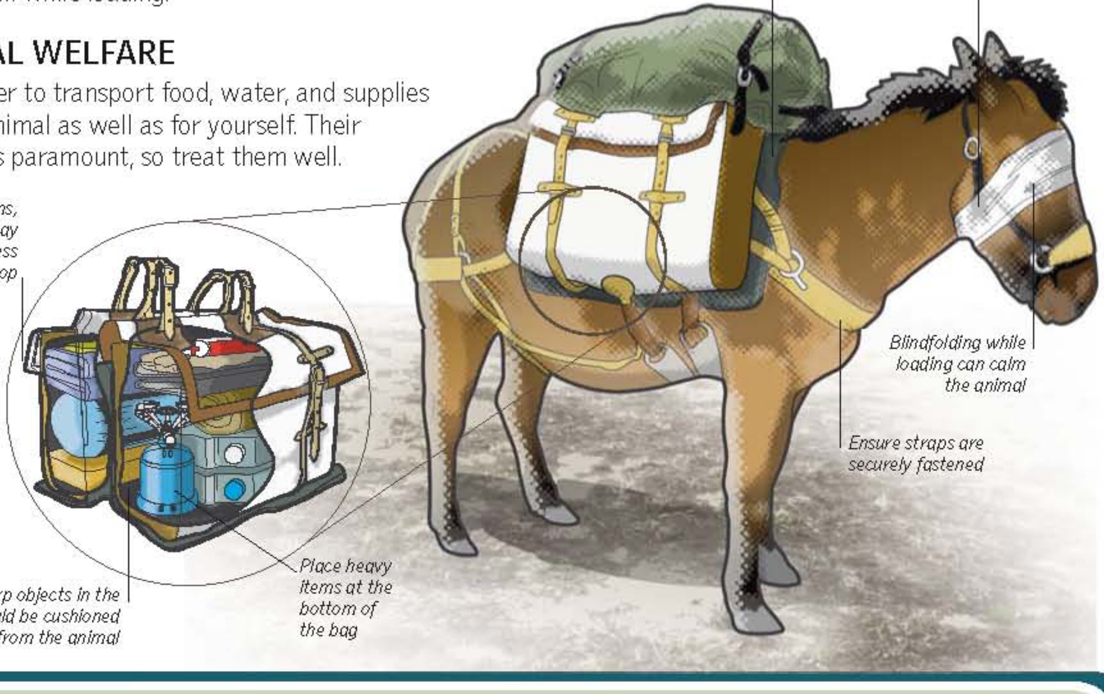

Fit a blanket for the animal's comfort

A headcollar gives you control over the animal

Place lighter items, and items you may need to access quickly, at the top

Blindfolding while loading can calm the animal

Ensure straps are securely fastened

Place heavy items at the bottom of the bag

Any sharp objects in the bag should be cushioned from the animal

PACK TRAINS

Roping animals together on the trail is standard practice when traveling with more than one animal. When tying them together, ensure the ropes are long enough to allow the animals to walk comfortably, and short enough to prevent tripping.

THE PEOPLE

Appoint a driver to lead the group and take control of navigation. You will need sufficient people to control and care for the animals.

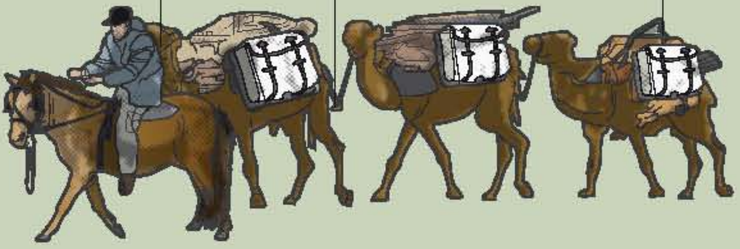

Driver leads the trail

Ropes need to be short enough to prevent tripping

Divide the loads equally

USING PACK ANIMALS TO SURVIVE

In an emergency situation, your priorities change significantly when using pack animals. Unpack the panniers and remove any heavy items not essential for survival. If necessary, you can climb on and ride to safety or, in a worst-case scenario, your animal can be used for food.

CARRYING INJURED PEOPLE

If a member of your group is injured, build a makeshift stretcher (see pp. 278–79) and use the animal to drag him or her to safety.

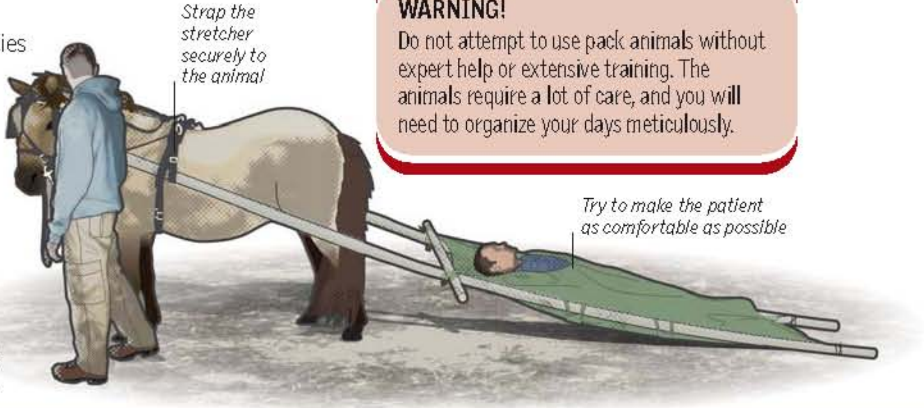

Strap the stretcher securely to the animal

Try to make the patient as comfortable as possible

WARNING!

Do not attempt to use pack animals without expert help or extensive training. The animals require a lot of care, and you will need to organize your days meticulously.

CHOOSING YOUR ANIMAL

The availability of pack animals depends on the region you are traveling in. Within any region, your choice of animal should take into account the load you are expecting them to carry, the distance you require them to travel, and the terrain you plan to cross. However, remember that individual animals' abilities can vary depending on their age and size.

ANIMAL	REGION	AVERAGE LOAD	ADVANTAGES	DISADVANTAGES
Horse	Worldwide	▪ 175–240 lb (80–110 kg) ▪ 20 percent of body weight	▪ Easy to train, with a good temperament ▪ Strong ▪ Can tolerate heat ▪ Can manage steep terrain	▪ Require grooming ▪ Can stray from camp if not securely tethered
Mule	Eurasia, Americas	▪ 120–180 lb (55–80 kg) ▪ 20 percent of body weight	▪ Will stick by a mare closely—this can be used to keep them moving and to keep them within the camp at night ▪ Very hardy and can manage steep terrain	▪ Young mules can be easily startled, so good training is essential ▪ Stubborn
Husky	Arctic	▪ 85lb (40kg) ▪ 7 dogs can pull 600lb (270 kg)	▪ Hardy—can cope well with snow and cold conditions ▪ Can travel fast	▪ Need a lot of fresh meat, which must be carried ▪ Prone to fight among themselves
Camel	Central Asia, North Africa, Australia	▪ 198–308 lb (90–140 kg) ▪ 30 percent of body weight	▪ Versatile on different terrains ▪ Can drink up to a quarter of its body weight and then go without water for several days	▪ Strong-willed and difficult to control ▪ Violent—can spit and bite
Llama	Andes	▪ 77–123 lb (35–55 kg) ▪ 25–30 percent of body weight	▪ Minimal environmental impact ▪ Travels well at high altitudes on difficult and steep terrain	▪ Makes horses and mules nervous ▪ Can be difficult to control if poorly trained
Elephant (Indian)	South Asia	▪ 1,650–2,750 lb (750–1,250 kg) ▪ 25 percent of body weight	▪ Can carry very heavy loads ▪ Can manage steep terrain	▪ Slow-moving ▪ Requires large amounts of food and water ▪ Takes time to train
Ox	Eurasia, Americas	▪ 300–450 lb (135–205 kg) ▪ 30 percent of body weight	▪ Hardworking ▪ Very strong ▪ Surefooted and can manage steep terrain	▪ Slow-moving ▪ Stubborn

FOUR-WHEEL DRIVING

A FOUR-WHEEL-DRIVE (4WD) vehicle can cover large areas of difficult terrain that would be inaccessible in a 2WD vehicle. With an experienced driver, most 4WD vehicles can tackle deep mud, water, snow, ice, and sand.

CHOOSING YOUR VEHICLE

When choosing your vehicle it's important to consider what you'll be using it for. Large vehicles have more internal space than smaller ones, but may find it harder to negotiate very rough ground without getting stuck. Similarly, very powerful vehicles can cross almost any terrain but use a lot of fuel, so may not be a viable option for long-term expeditions.

EXPEDITION CHECKLIST

- Check your map and inform others of your route and intended timeframe.
- Ensure the vehicle is fit for the journey, with all necessary spares. Check the fuel, oil, water, brakes, and hydraulic fluids, and check that there are no leaks.
- Inspect the tire treads, wheel nuts, lights, and steering arms.
- Always carry spare water, wheel(s), and fuel, as well as survival equipment, sand ladders, a 12v heavy-duty tire inflator, winching strap, and first aid kit.

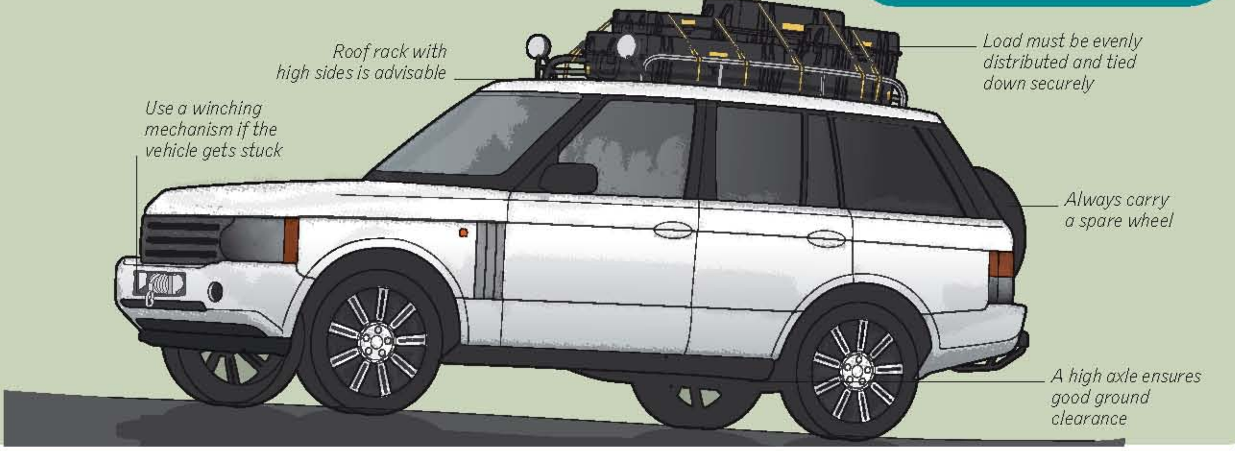
Roof rack with high sides is advisable
Load must be evenly distributed and tied down securely
Use a winching mechanism if the vehicle gets stuck
Always carry a spare wheel
A high axle ensures good ground clearance

GENERAL DRIVING TECHNIQUES

Four-wheel-drive vehicles enable you to manually switch between two-wheel-drive, for driving on roads, and four-wheel-drive, for low-traction conditions, such as on soft ground. The difference is the number of wheels powered by the engine at any one time.

CHOOSING A ROUTE

When unsure about the conditions immediately ahead, walk the route first, checking for potential problems and obstacles. Where necessary, mark the route you have walked and follow these markers when you drive. Ask yourself whether you really need to go that way and, if so, which route is best to avoid getting stuck. And, if you do get stuck, what are your options for self-recovery or escape?

WHEN TO ENGAGE 4WD

Engaging 4WD uses up a lot of fuel and should not be used on hard roads because of the risk of damaging tires and gears. Always choose the four-wheel-drive option on difficult terrain. It allows you to travel in a very low gear and gives the vehicle a far superior traction. Just before starting to cross the rough ground, stop the vehicle and engage the four-wheel-drive.

WARNING!
Don't hook your thumbs around the steering wheel when driving over rough terrain. Hitting a rut can jerk the wheel and break them.

DRIVING AS A TEAM

Driving off-road over rough terrain is both mentally and physically tiring. Take regular breaks and share the driving if in a group. You should always have at least two people in the vehicle:

- A driver—who takes responsibility for powering and steering the vehicle.
- A spotter—who takes responsibility for navigation and helps the driver pick a good route across the terrain. This may involve getting out of the vehicle and guiding the driver across a difficult section of ground.

DRIVING OVER DIFFICULT TERRAIN

A 4WD vehicle handles difficult terrain well because all four wheels can be powered by the engine at any one time (gas engines are generally more powerful, but diesel engines last longer and work well at low speeds). Using a few simple techniques, you will find that you are able to drive over terrain—and to places—that would otherwise be inaccessible. Always remember that the principle behind 4WD is to reduce the chances of you getting stuck—not to allow you to go further until you do get stuck.

MAXIMUM TRACTION

Your vehicle's traction on soft surfaces can be improved by lowering your tire pressure slightly. As a guide, place a brick ½in (1 cm) away from the side of a rear tire on flat ground, deflate the tire until it touches the brick, measure this pressure, and apply to all four tires. Make sure you can reinflate them.

DRIVING ON SAND

In soft sand the tires tend to move the sand from the front of the tire to the rear of the tire. If forward movement is halted for even a few seconds the wheel can dig itself into a hole. To prevent this, continually steer from side to side, so that the tire steers out of its own ruts. Avoid rapid changes in speed.

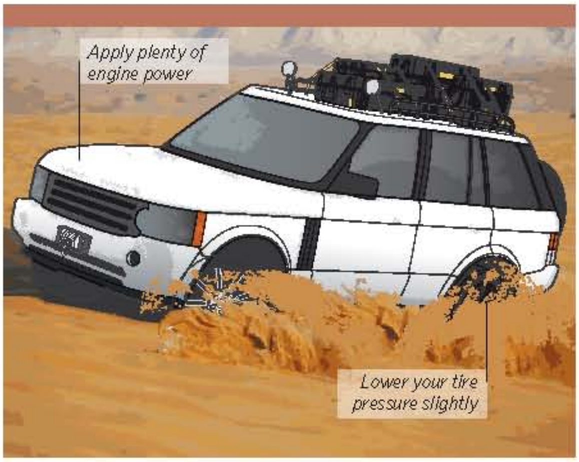

Apply plenty of engine power

Lower your tire pressure slightly

MUDDY TRACKS

Driving in mud requires concentration and the ability to adapt your driving to suit the conditions. In deep mud, use wide tires or lower the tire pressure slightly; however, if there is a hard surface below the mud this will make things worse. Steering outside existing track ruts is most likely to ensure the best traction.

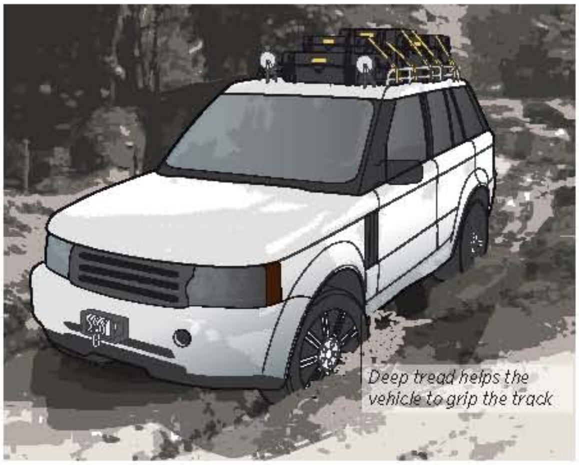

Deep tread helps the vehicle to grip the track

DRIVING ON SNOW AND ICE

Snow and ice require very smooth driving methods. Apply gradual pressure to the accelerator and brakes to avoid wheel spin, use low gears, especially when traveling downhill, and avoid changing gears unnecessarily. Using snow chains will increase traction, and you should practice fitting them before you need them.

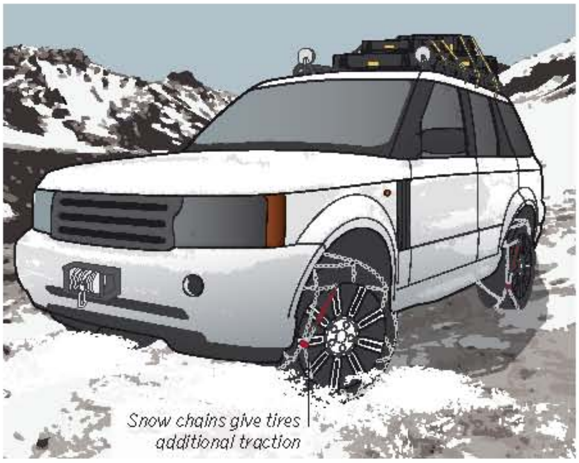

Snow chains give tires additional traction

CROSSING WATER

Always walk your route before driving across water. If the water seems too deep or the current too fast, don't attempt the crossing. It's important to drive at the correct speed—too fast will send water everywhere, but driving too slowly may flood the engine bay.

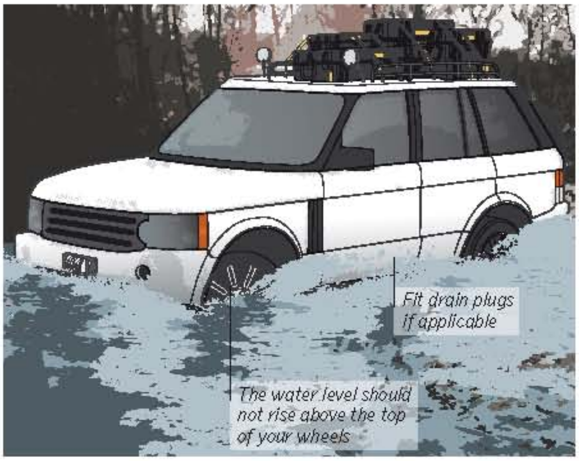

Fit drain plugs if applicable

The water level should not rise above the top of your wheels

RECOVERY FROM SOFT GROUND

Although using the correct techniques will certainly improve your chances of crossing soft ground successfully, it's important to know what to do if you do get stuck. Ideally you should never set out on a driving expedition with fewer than two vehicles. A second vehicle can be used for winching, dealing with breakdowns, or driving for help.

EQUIPMENT LIST

- Winching mechanism and strap
- Cable or tow rope
- Spare tire (inflated)
- Shovel and saw
- Sleeping bag or blanket
- Branches or stakes
- Sand ladders or mats

BASIC RECOVERY TECHNIQUES

When you get stuck, it's tempting to keep trying to aggressively free your vehicle. However, churning up what solid ground is left—and digging yourself into deeper ruts—will only make things more difficult in the long run. Stop, evaluate your options (reversing or pushing, digging, using branches, and winching), and calmly decide how best to achieve your aim. Don't act in haste—an ill-thought-out plan could leave you in more trouble than you were in originally.

REVERSING OR PUSHING

If you can't free the vehicle using four-wheel drive, try alternating between reversing and driving forward in first gear.

- If this has no effect, ask the passengers to get out and push while you drive forward.
- If you are making the situation worse, stop immediately and try an alternative solution.

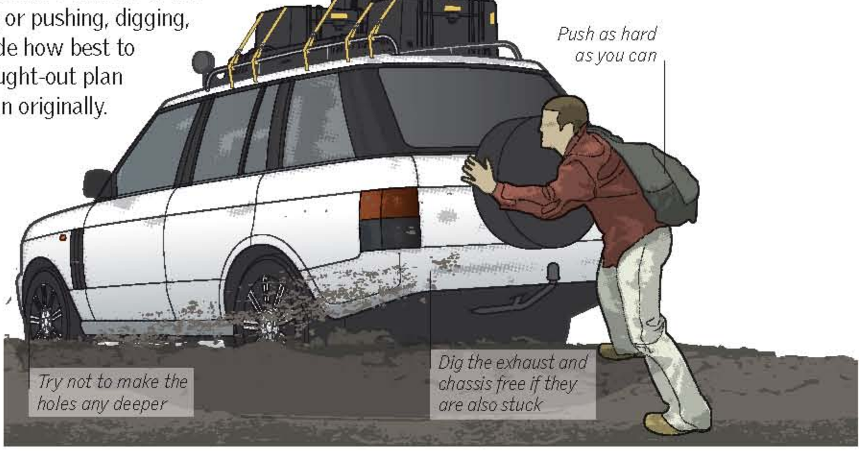
Push as hard as you can
Try not to make the holes any deeper
Dig the exhaust and chassis free if they are also stuck

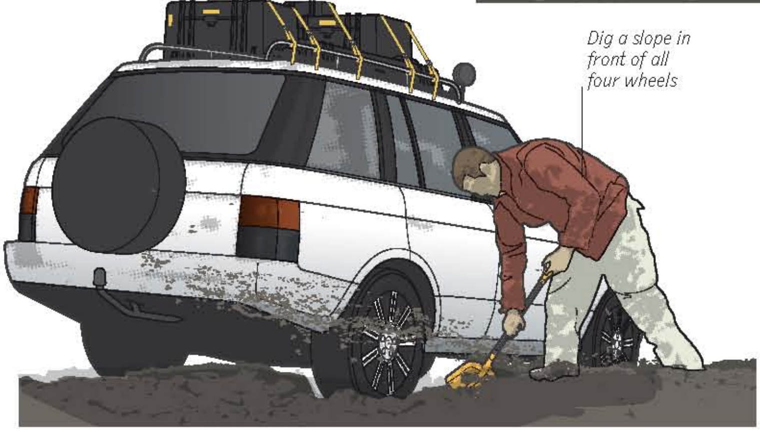
Dig a slope in front of all four wheels

DIGGING

If reversing and pushing don't work, the next step toward freeing your vehicle is to dig down in front of the wheels in an attempt to create a slope that you can then drive up.

- Dig out the sand in front of each tire to create an upward slope
- Drive very gently up the slope. Avoid revving the engine as this can cause the wheels to spin and lose their grip on the ground.

USING BRANCHES

If the vehicle still won't move, place branches, wooden planks, sand ladders, or blankets—in fact, anything that will increase your traction—in front of the wheels. The idea is to give the tires something to grip, and it should get you moving fairly quickly.

- Without revving the engine too much, gently ease the vehicle forward onto the branches or other material.
- Maintain a slow, steady speed and continue until you are back on firmer ground.
- Once clear, remember to stop and pick up your equipment, and remove any obstacles from the track.

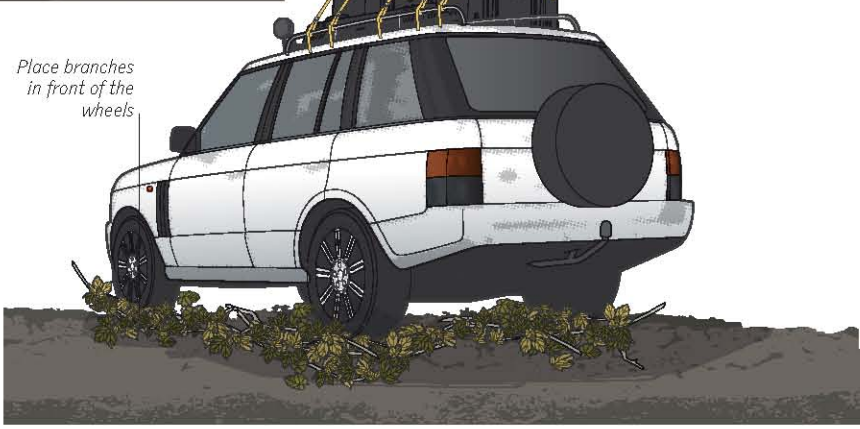
Place branches in front of the wheels

WINCHING

If none of the basic techniques work, and your vehicle is still stuck, it's time to consider winching. Use a cable attached to an electric-powered winching mechanism to pull the vehicle out of the hole via a strong anchor point. You can winch to another vehicle if you're traveling in convoy, although you do run the risk of both vehicles getting stuck. When winching, take time to assess your options—using a natural anchor point is the easiest method and should be your first approach.

NATURAL ANCHOR POINTS

Trees, rocks, roots, or deadfalls can all be used as anchor points. When using a tree, always place the strap or cable near the ground, and use a winch strap where possible to avoid damaging the tree. If the tree looks as if it may not be able to provide the required support, tie the tree to others in the vicinity. If you intend to use rocks, ensure they are large enough and firmly embedded in the ground.

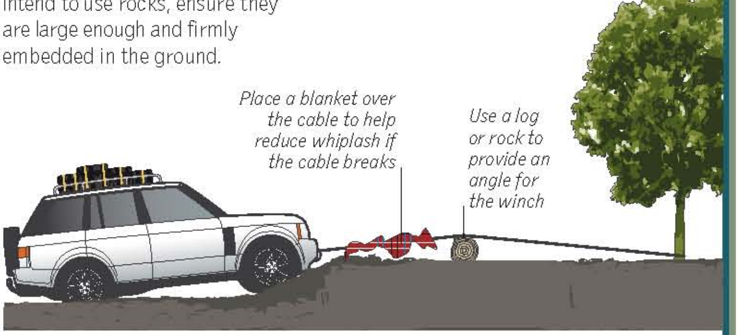
Place a blanket over the cable to help reduce whiplash if the cable breaks
Use a log or rock to provide an angle for the winch

BURIED ANCHOR POINTS

If there are no natural anchor points, you can construct an improvised anchor by burying objects such as logs or a spare wheel. Dig a hole in the ground that's at least 3 ft (1 m) deep, attach your winch cable to your improvised anchor, then bury the anchor in the hole. Refill the hole to secure it. If you're using a tire, use the tire lever behind your spare wheel as an attachment point for the cable.

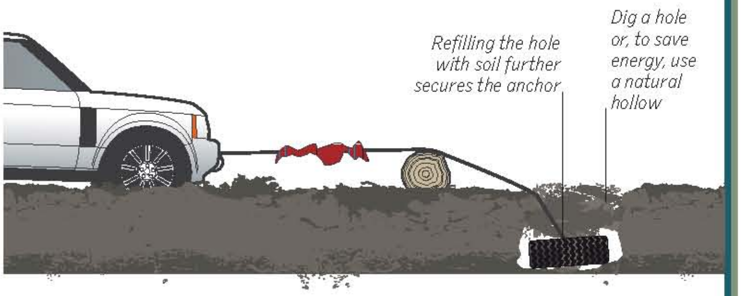
Refilling the hole with soil further secures the anchor
Dig a hole or, to save energy, use a natural hollow

WINCHING TO A STAKE

A series of long stakes in the ground can also provide an improvised anchor point. You will need a long, sturdy main stake—to which the winch cable is attached—and a series of supporting stakes, lashed together for additional strength. Push the stakes securely into the ground at a slight angle. Be careful not to stand near the stakes when winching, in case they come loose.

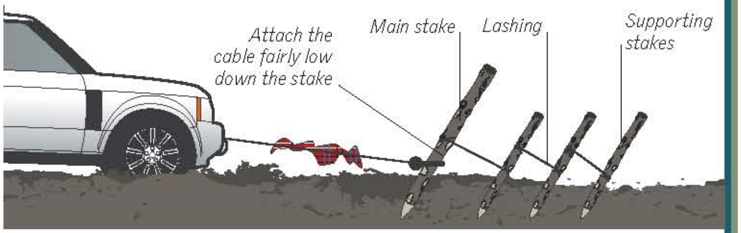
Attach the cable fairly low down the stake
Main stake
Lashing
Supporting stakes

WARNING!
When winching, don't stand within range of the cable in case it snaps under the strain. A breaking cable can cut a tree—or a person—in half. Place a blanket or sleeping bag over it to absorb some of the shock and reduce whiplash.

EMERGENCY ACTION

Knowing what to do in certain emergency situations will help you stay calm if the worst happens.

FRONT SKIDS

The term "skid" covers any kind of slide in which the wheels fail to grip the road. In a front skid—also called an "understeer"—the front wheels fail to turn when you steer so the vehicle continues to travel forward.

- Steer in the direction of the skid but be careful not to oversteer. If you're on ice and skidding straight, step on the clutch or shift to neutral.
- Once you have gained control, correct your course and continue driving. Consult your driver's manual if you have anti-lock brakes.

REAR SKIDS

In a rear skid, the back wheels lose control and the vehicle rotates more than usual and can spin.

- Steer in the direction of the skid but face toward where you want to travel.
- Once facing in the right direction, bring the steering wheel back to the center and continue to steer, regardless of what the rear is doing, until you have gained total control.

BRAKE FAILURE

Before setting out on a drive, always check to see whether there is brake fluid leaking from the vehicle. If so, don't travel. If the brakes fail when on the move, do the following:

- Without turning off the engine, shift down the gears to reduce speed while maintaining control.
- Once the vehicle reaches a speed of less than 25 mph (40 kph) apply the handbrake, keeping a firm grip on the steering wheel.

ACCELERATOR MALFUNCTION

If the accelerator sticks and your engine will not slow down, you can decelerate by putting the vehicle into neutral and applying the brakes.

- If it's safe to do so, switch off the engine, but you'll lose functions like power steering and lights.
- Steer safely to a stop. If possible, avoid using the handbrake as this may cause a skid—although it may be necessary if you need to avoid a collision.

KAYAKING AND CANOEING

TRAVELING IN A KAYAK OR CANOE is a good way of negotiating river systems and open water. With your equipment safely stowed in your boat, expeditions can range from short day trips to year-long adventures.

KAYAKING

Kayaks are an extremely efficient method of water transport, especially on open sea, rivers, and lakes. Their narrow design and light frame make them easy to maneuver.

CAPSIZING IN A KAYAK

Capsizing is an almost inevitable part of kayaking in rough water. The "wet exit"—slipping out of the kayak completely while still holding on to it—is sometimes the only option, but wherever possible use an eskimo roll instead.

ESKIMO ROLL

Mastering the eskimo roll enables you to avoid getting your legs wet and having to climb back in your kayak. With practice, it should become one fluid movement.

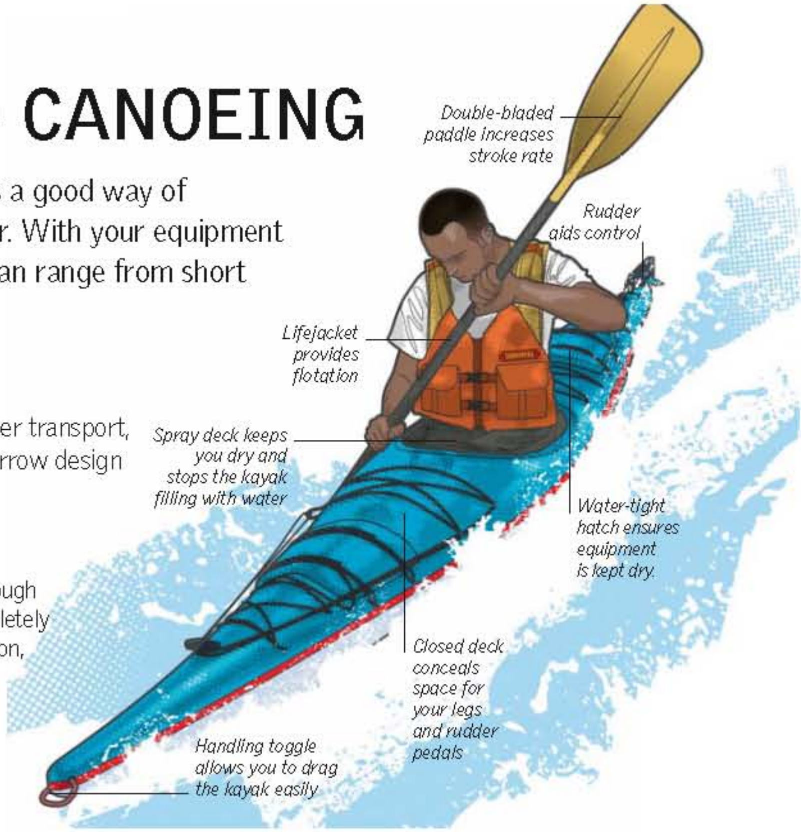

Double-bladed paddle increases stroke rate

Rudder aids control

Lifejacket provides flotation

Spray deck keeps you dry and stops the kayak filling with water

Water-tight hatch ensures equipment is kept dry.

Closed deck conceals space for your legs and rudder pedals

Handling toggle allows you to drag the kayak easily

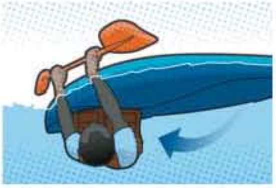

1 From the upside-down position, twist your body to the side of the kayak.

- Gripping your paddle, firmly push your arms out of the water, then rest them on the side of the kayak.

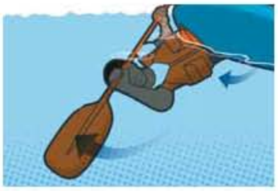

2 With your head near the surface, sweep your body and paddle away from the side of the kayak.

- At the same time, flick your hip away to start the rotation of the kayak.

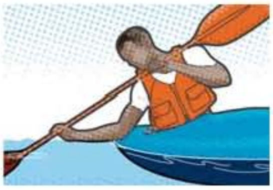

3 Continue the hip flick until the kayak returns to an upright position in the water.

- Straighten your back so you are sitting upright again, and continue to paddle your course.

WARNING!

- Always wear a lifejacket. Empty water bottles in your pockets can be used as makeshift flotation devices in an emergency.
- In a survival situation, never leave your kayak or canoe unless it is life-threatening not to do so. A kayak is highly visible, especially from the air, and is far more likely to be spotted first by rescuers.

BASIC PADDLING SKILLS

Kayak paddles have two blades that sweep alternately through the water, propelling the kayak forward. To steer, paddle on the opposite side to the direction in which you want to go. Some kayaks have a foot-operated rudder.

CATCH

Place your lead blade firmly in the water so that it enters near to your feet.

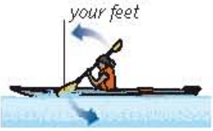

Lead blade enters the water near your feet

BRACE

Rotate your torso and lead blade in preparation for the propulsive stroke.

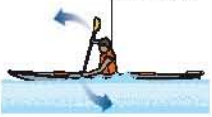

The power comes from your torso

STROKE

Sweep your lead blade firmly through the water to propel the kayak forward.

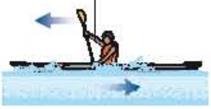

Keep your grip loose on the following arm

TRANSITION

As the blade exits the water, repeat the catch on the other side and continue paddling.

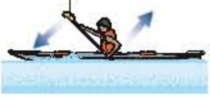

The transition should be as smooth as possible

CANOEING

As with kayaks, canoes can hold one or two people with equipment, and are powered by the body from a seated position. They are generally wider than kayaks, however, and their decks are open. Canoe paddles have one blade as opposed to two.

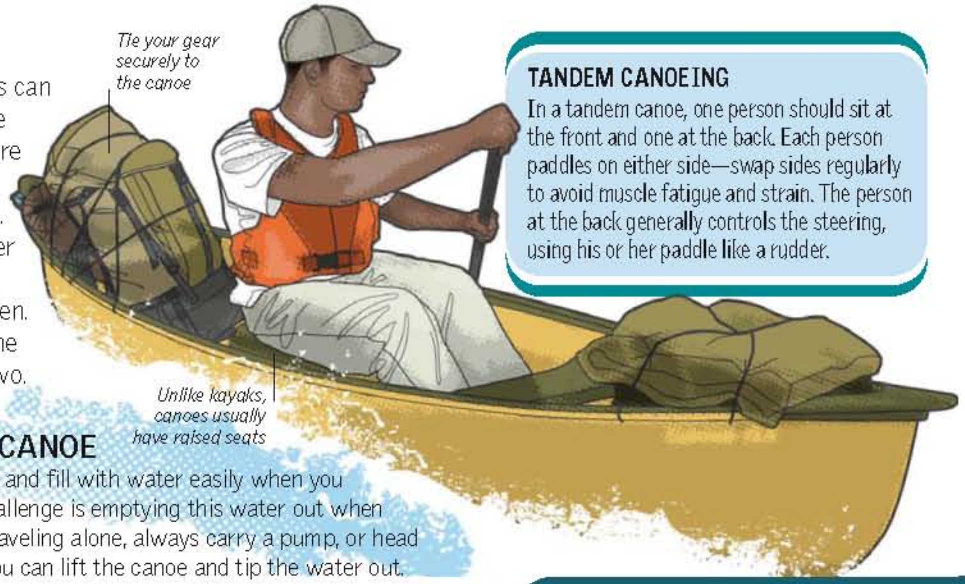
Tie your gear securely to the canoe
Unlike kayaks, canoes usually have raised seats

TANDEM CANOEING

In a tandem canoe, one person should sit at the front and one at the back. Each person paddles on either side—swap sides regularly to avoid muscle fatigue and strain. The person at the back generally controls the steering, using his or her paddle like a rudder.

CAPSIZING IN A CANOE

Because canoes are open and fill with water easily when you capsize, your greatest challenge is emptying this water out when the canoe is righted. If traveling alone, always carry a pump, or head for shallower water so you can lift the canoe and tip the water out.

CANOE-OVER-CANOE RESCUE

If you are traveling with another canoe and are far from shallow water, the best option is the canoe-over-canoe rescue. The capsized canoe is rotated upside-down and pushed onto the rescue vessel, which empties the water out. The people on the rescue craft then rotate the canoe back to an upright position and return it to the water.

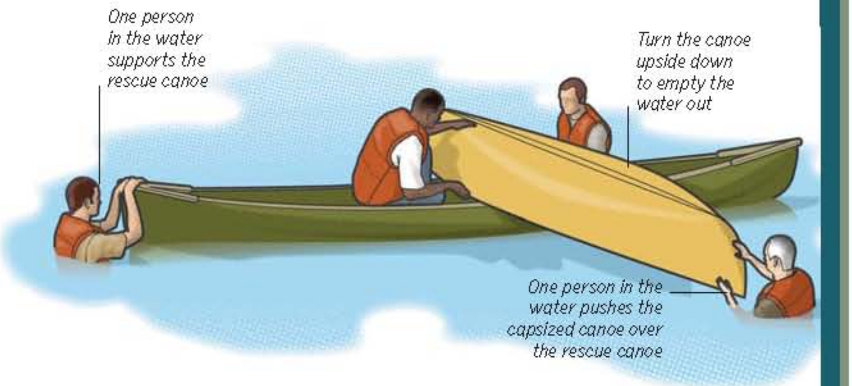
One person in the water supports the rescue canoe
Turn the canoe upside down to empty the water out
One person in the water pushes the capsized canoe over the rescue canoe

KAYAKING AND CANOEING TIPS

- Research your route and weather conditions thoroughly.
- Don't overload the boat, and ensure it's well balanced.
- Carry a high-volume pump so you can rescue yourself when alone.
- If watertight bulkheads are not fitted on your kayak, use airbags to add buoyancy and reduce the amount of water that can enter a compartment.
- Use waterproof dry bags to keep your kit dry.
- Clip valuables onto the boat or yourself. If they don't float, attach a float to them so they won't sink if they fall in the water.
- Carry waterproof material and bungee cord to repair blown hatches.
- Never enter a cave alone, or without head protection.
- Fit a leash to your paddle and attach it to the craft. If you then have to perform a rescue you can throw it in the water and keep both arms free.
- Chewing gum is great for the short-term repair of small holes in the craft, as is black masking tape and plumber's repair tape.

BASIC PADDLING SKILLS

When canoeing solo, use a "switch" style of paddling to ensure your canoe travels in a straight line—if the canoe starts to veer off course, switch sides.

CATCH

Sit in the middle of the canoe, ensuring that it's well balanced. Reach forward and thrust the blade into the water.

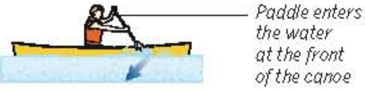
Paddle enters the water at the front of the canoe

DOWN STROKE

Drive the paddle swiftly and firmly down into the water so that it assumes a vertical position.

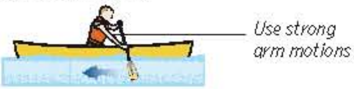
Use strong arm motions

PULL STROKE

Firmly pull the paddle blade backward through the water. This will propel the canoe forward.

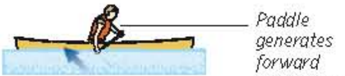
Paddle generates forward momentum

REPEAT STROKE

Lift the blade out of the water toward the rear of the canoe and return to the starting position to repeat the stroke.

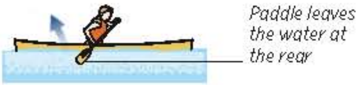
Paddle leaves the water at the rear

BUILDING A RAFT

IF VENTURING INTO the wilderness, it is useful to know how to build an improvised raft or flotation aid. You may find that a major water obstacle lies between you and rescue, or you may be in an area in which dense undergrowth makes cross-country travel difficult but river travel relatively easy. However, in a survival situation you are unlikely to have a lifejacket, so assess the risks carefully.

WARNING!
Apart from the brushwood raft (below), most improvised rafts will float half-submerged, so you'll be constantly sitting or kneeling in water. This could lead to hypothermia in certain conditions, so build an additional raised platform if necessary.

MAKING A BRUSHWOOD RAFT

If you have a poncho, shelter sheet, or tarpaulin, you can construct a brushwood raft. This is a one-man raft, but if built correctly will keep you completely out of the water. Build it as close to the water as possible so you don't have to carry it far.

TOOLS AND MATERIALS

- Knife or small saw
- Poncho, shelter sheet, or tarpaulin
- Long sticks, brushwood, and thatch
- Cordage

1 Construct your raft near a suitable launching place.

- Lay your poncho on the ground to determine the size of the finished raft. Make sure there's enough material to come up the sides and gather on top.

2 Peg out sticks to form an oval shape, the size and shape of your intended raft.

- Interlace brushwood and thatch tightly through the sticks to form the sides of the raft. The tighter you weave the brushwood, the stronger the body of the raft will be, and the better it will float. The height of the brushwood will also determine how high the raft sits in the water.

3 Form a sitting platform by pushing a selection of long poles or sticks through the sides of woven brushwood. Weave the sticks under and over each other as much as you can to create a stable structure.

- Using your knife or a small saw, trim the sticks to size so that they don't protrude from the sides.
- Remove the pegs from around the brushwood.

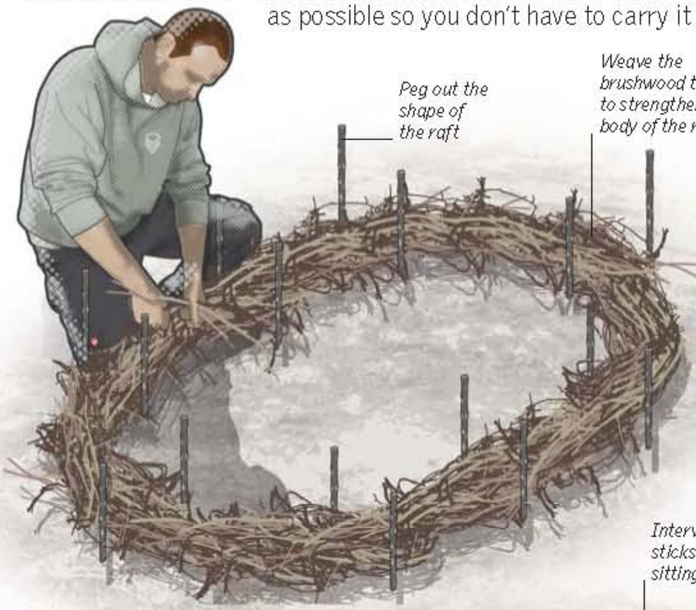

Peg out the shape of the raft

Weave the brushwood tightly to strengthen the body of the raft

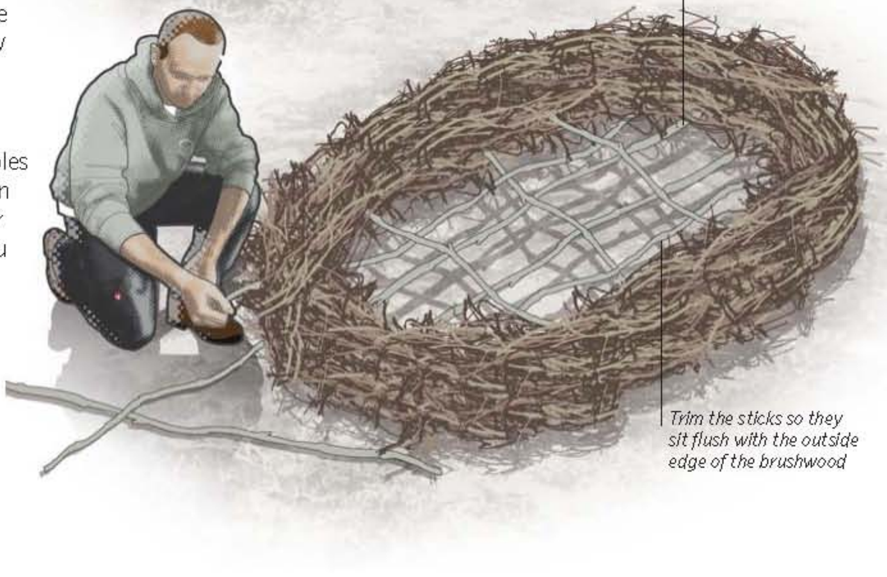

Interweave the sticks to create a sitting platform

Trim the sticks so they sit flush with the outside edge of the brushwood

MAKING A PADDLE

In most cases, you can use the current of the river for momentum rather than having to paddle, and your walking staff to maneuver the raft. However, where there is no current you will have to provide the propulsion yourself, and will need to improvise some form of paddle.

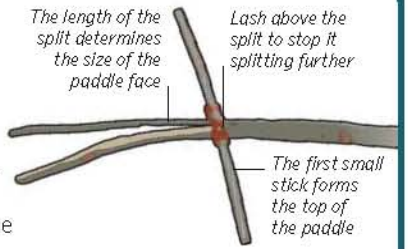
The length of the split determines the size of the paddle face
Lash above the split to stop it splitting further
The first small stick forms the top of the paddle

1 Find a suitable length of green wood to form the handle. This should be as wide as possible but still comfortable to grip.

- In the end of the wood, make a split long enough to form the paddle face.
- Collect smaller branches and insert one of them into the split. Lash into place.

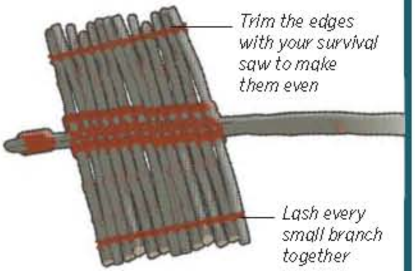
Trim the edges with your survival saw to make them even
Lash every small branch together

2 Continue to force smaller branches into the split, lashing each one as you progress until you have a sufficient paddle area.

- Securely lash the two open splits of the handle together.
- To make the paddle more rigid, lash the ends together.

4 Slide your poncho underneath the raft to form a waterproof seal.

- Push the poncho hood through to the inside and tie its neck securely to ensure it's completely water tight.
- Pull the poncho up the sides of the raft and lash securely across the top.

5 Fill the space underneath the sitting platform with natural materials, such as additional brushwood, grass, or moss. You could also use any item that would aid buoyancy—such as empty plastic bottles or waterproof bags filled with air and tied off.

- Drag or push the raft into the water, checking to see whether it floats in shallower water before loading your equipment and climbing aboard.

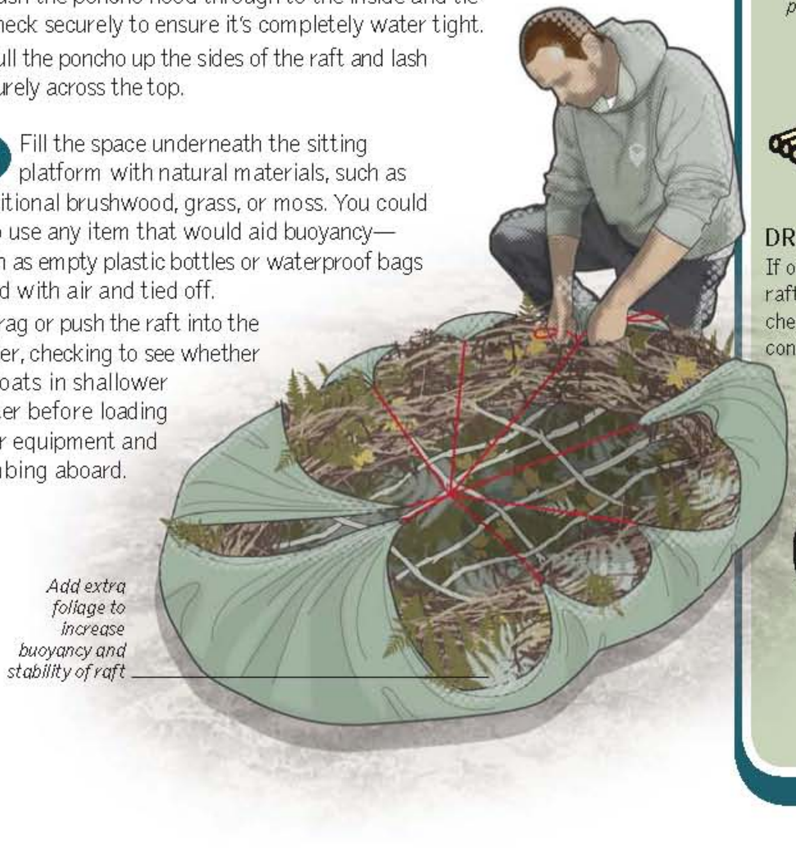
Add extra foliage to increase buoyancy and stability of raft

ALTERNATIVE RAFTS

Use whatever materials are available to you to make your raft. Look out for logs, bamboo, and discarded oil drums, as they are naturally buoyant materials that can be used to make an effective raft.

LOG RAFT

To make a log raft, use dry wood—ideally standing deadwood—as this will float higher in the water. Cut notches in the logs to allow the cross-pieces to sit snugly.

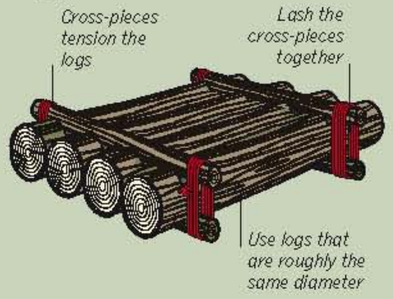
Cross-pieces tension the logs
Lash the cross-pieces together
Use logs that are roughly the same diameter

BAMBOO RAFT

Bamboo is made up of hollow compartmentalized sections, which means it is ideal for raft-making. Bamboo rafts are much lighter than log rafts.

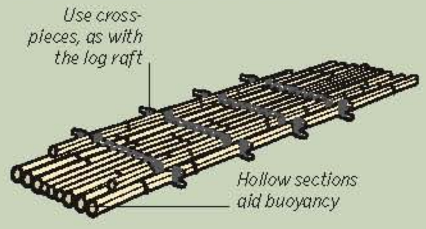
Use cross-pieces, as with the log raft
Hollow sections aid buoyancy

DRUM RAFT

If oil drums are available, they make ideal rafts. Always take care when handling chemical drums, as they may once have contained toxins.

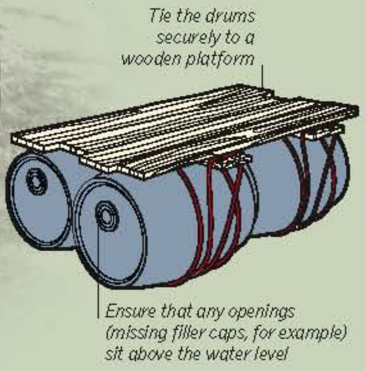
Tie the drums securely to a wooden platform
Ensure that any openings (missing filler caps, for example) sit above the water level

SWIMMING

WHEN THE WATER IS TOO DEEP to wade and you don't have the materials to build a raft, you may need to swim to negotiate a water obstacle. Before you get into the water, plan how you will get warm and dry when you get out. Making a float will help to keep clothing and equipment dry.

WARNING!
As with any survival activity involving water, try to avoid getting wet—find a way around the obstacle if possible, or find shallower water to wade across. The cold water increases your risk of hypothermia so ensure you have the necessary equipment for building a fire. Never enter water where there are likely to be dangers such as crocodiles or hippos.

SURVIVAL SWIMMING

Unless you need to cross rocky ground to enter the water, remove your boots and most of your clothing to reduce drag and keep them dry. Place them either in a waterproof survival bag or in an improvised poncho float (see opposite) and float them across.

SWIMMING ACROSS RIVERS

Choose a safe place to cross (see p. 88), and plan where you will exit the water.

- Take the current into account as you are likely to drift downstream slightly.
- Lower yourself in gently—never jump or dive into the water.
- If the water is cold, gently immerse yourself until your body has recovered from the initial shock.

THE CROSSING

Choosing a stroke you feel comfortable with (and that will expend the least energy), swim across your route with your float in one arm.

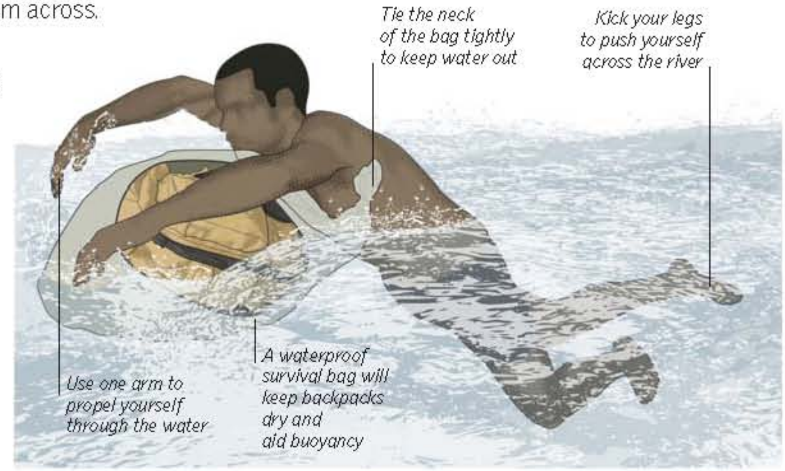
Tie the neck of the bag tightly to keep water out
Kick your legs to push yourself across the river
Use one arm to propel yourself through the water
A waterproof survival bag will keep backpacks dry and aid buoyancy

SWIMMING DOWN RIVERS

Avoid swimming up or down rivers—walking the route instead is far safer. However, if you accidentally fall in and find yourself traveling downstream in fast-moving water, there are ways of protecting yourself until you reach safety.

DEFENSIVE SWIMMING

The aim of defensive swimming is to adopt a position that keeps you as safe as possible and prevents your feet from becoming ensnared in rocks, which, in a strong current, could push you under the water. Assume the defensive swimming position until you reach shallower water, and can stand up and climb onto the bank.

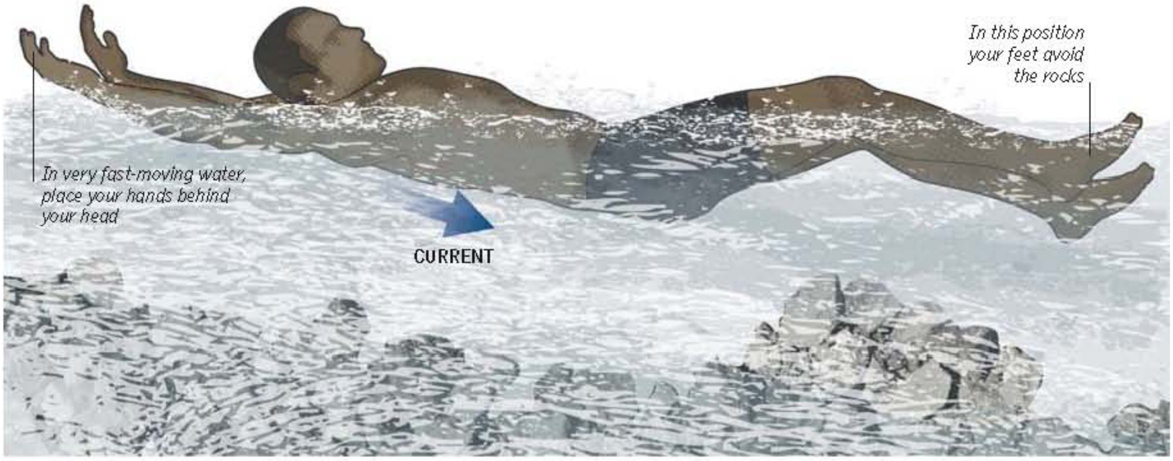
In this position your feet avoid the rocks
In very fast-moving water, place your hands behind your head
CURRENT

SWIMMING STROKES

It's important to know what the different swimming strokes are, although you're unlikely to stick to them strictly in a survival situation. If you're a confident swimmer, always choose the stroke that will use the least amount of energy, such as breaststroke. If you're less experienced you should avoid getting in the water unless in a life-or-death situation.

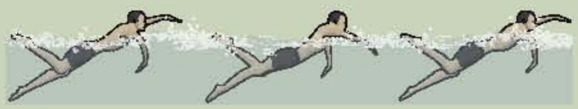

DOG PADDLE

An easy stroke suitable for less confident swimmers, this involves simply paddling forward with your arms and legs. When you paddle with your left arm, kick with your right leg and vice versa.

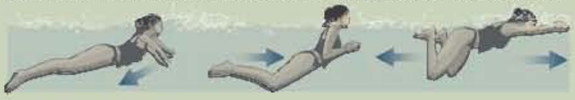

BREAST STROKE

This is perhaps the most common stroke for crossing rivers. Your arm and leg movements should be made simultaneously and smoothly. It is a good option if you're pulling a float.

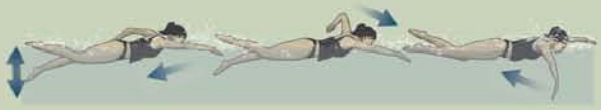

FRONT CRAWL

Also known as "freestyle," front crawl uses a lot of energy so is not the best stroke for a normal survival situation. However, you can build up a lot of speed, which may sometimes be required.

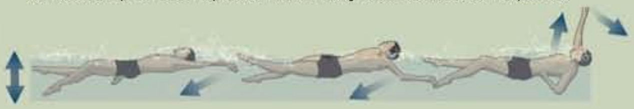

BACK STROKE

If you know the water is safe, this stroke can be a good choice, as it uses little energy. However, not being able to see where you're going can be a disadvantage, especially in rocky areas.

MAKING A PONCHO FLOAT

Constructing a poncho float will keep your belongings dry and provide limited flotation as you cross the river. If you don't have a poncho, use any large piece of waterproof material.

① Push your poncho hood to the inner side, and tightly secure its neck with the drawstrings or cordage.

- Lay the poncho on the ground with the inner side facing upward.
- Place your gear on top.

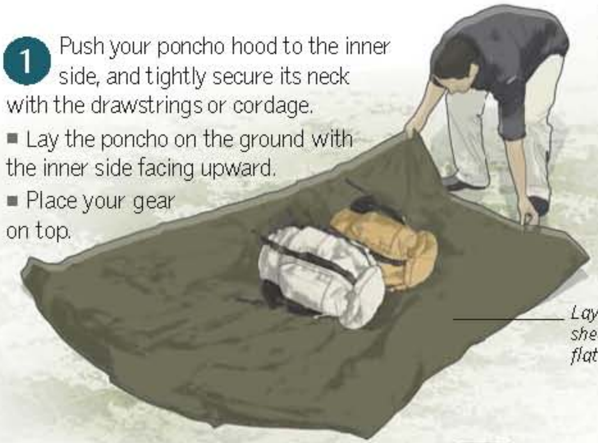

Lay the sheet on flat ground

③ Wrap carefully to make it watertight.

- At this point, if you have a second poncho, repeat from step one, placing the float face down on top of the second sheet and wrapping again.
- If available, place brushwood inside the float for added buoyancy.

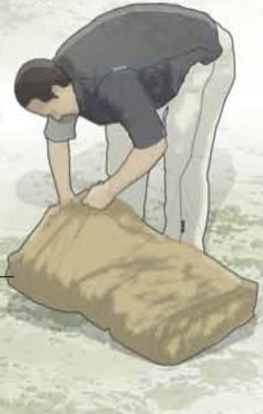

Tuck the corners in neatly

② Bring one side of the poncho up and over the equipment that is piled together in the middle.

- Repeat with the other three sides to create a rectangular parcel.
- Fold the corners, and ensure that they won't allow water to enter the float.

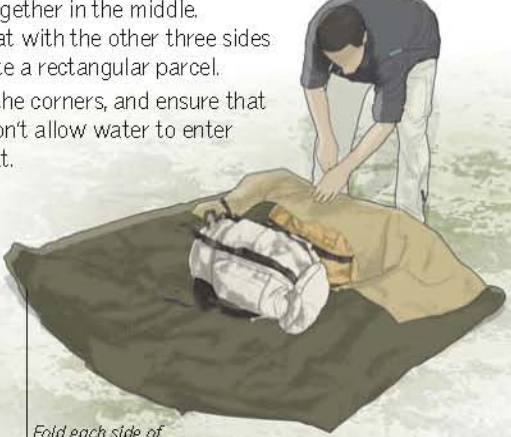

Fold each side of the poncho over your equipment

④ Tie ropes, bootlaces, vines, or improvised cordage around the float to secure it.

- As you enter the water, gently lower the float in with you. Pull it along as you cross the river.

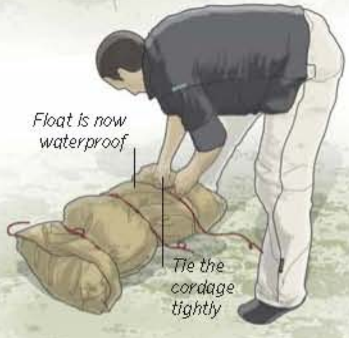

Float is now waterproof

Tie the cordage tightly

3

CAMP CRAFT

CAMP ESSENTIALS

Whether you intend to remain where you are and wait for rescue, move to a safer area and await rescue there, or walk out of the survival situation yourself, you're probably going to need to select a site on which to put up a shelter. This could be for just a single night or for a longer-term stay.

A sound understanding of what constitutes a good location will allow you to address the basic principles of survival. For example, a well-selected site will help keep you safe from danger while still allowing you to deploy your location aids effectively. It should also provide you with adequate materials for building a shelter and a fire, and offer an accessible supply of water, both for drinking and for hygiene.

A well-organized site will not only give you a sense of purpose and order, but will also provide a safe environment for yourself and your equipment. Designating an area for storing equipment and tools, for example, will help prevent vital items from being lost and will reduce the likelihood of you or members of your team being injured.

In this section YOU WILL DISCOVER...

- how to **make a shower** before you **take a shower...**
- why **keeping clean** is good for both **body and soul...**
- how to work up a **lather** with **wood ash...**
- when a **thatched screen** could **protect your modesty...**
- what turns a **hard candy** into a **firestarter...**
- the **difference** between **cattails** and **fire dogs...**

A fire is an integral part of any campsite. It can be used for warmth, for purifying water, for cooking, for signaling to potential rescuers, for protection against wild animals, and for providing light when darkness falls. It also provides a sense of security. The psychological effects of being able to start a fire in a survival situation should never be underestimated; neither should the psychological effects of *not* being able to start one. Even in a survival situation, a simple camp can give a sense of normality and "home."

You can produce a spark—and therefore light a fire—by using a device such as a firesteel or a ranger's flint and steel (see p. 127).

A FIRESTEEL COMPRISES two main parts: the material that will produce the spark (usually a rod made from ferrocerium or magnesium alloy) and a sharp striker device (usually a knife blade or short piece of hacksaw blade). When the striker is drawn over the rod, a spark is produced.

To control the spark created by these two moving parts, follow the method outlined below. It will allow you to direct the spark accurately, and reduce the chance of you knocking and scattering your tinder. This can be a problem if you hold the rod next to the tinder and strike down into it—especially if you are cold, wet, and tired and your hands are shaking.

1. Place the rod in the center of the tinder. Then position your striker onto the rod. Lock the hand holding the striker into position.
2. Pull the rod up and away from the tinder, drawing it against the striker. By drawing away from the tinder you avoid the danger of disrupting or scattering it.
3. To direct the sparks, alter the angle at which you pull the rod up and away.

> "The **psychological effects** of being able to **start a fire** should not be underestimated; neither should the effects of **not being able** to start one"

ORGANIZING YOUR SITE

WHERE YOU CHOOSE to set up your shelter depends on the environment, but always take into account the four principles of survival: protection, location, water, and food. First, make sure there are no obvious dangers, and that you're able to signal for rescue. If possible, select a location close to a water source.

SITE FEATURES

Once you're happy with your chosen site—and confident it doesn't hold any forseeable dangers—you can organize the area to accommodate your needs, and to make your time in camp easier and more efficient.

CAMP ADMINISTRATION

Whether you're in a group or on your own, it's important to organize your site, and quickly establish disciplines and routines to ensure camp safety and to reduce the risk of accidents. Designate specific areas—for storing equipment, firewood, cooking, and sleeping—and specific routines for when you do things (see panel, right).

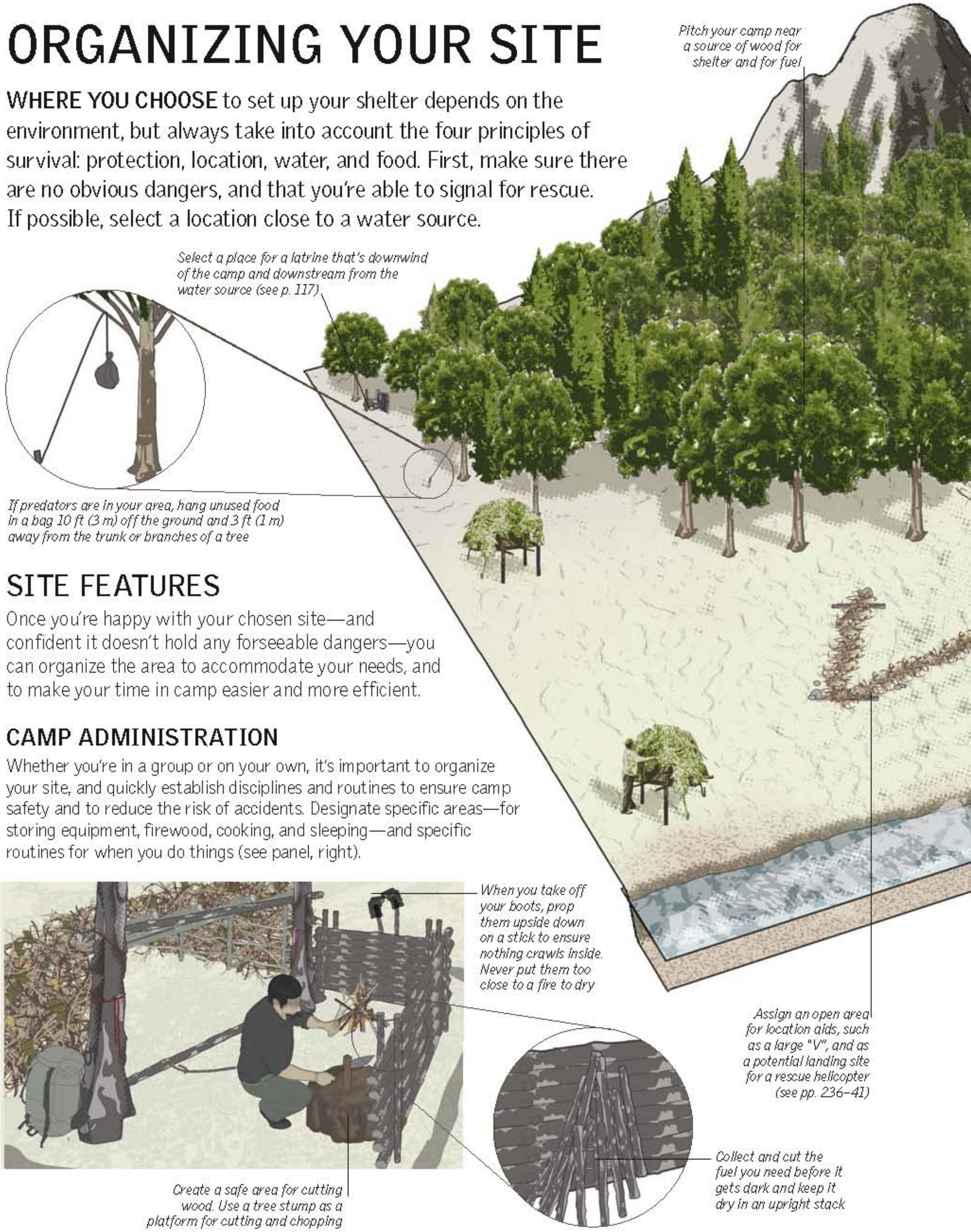

Pitch your camp near a source of wood for shelter and for fuel

Select a place for a latrine that's downwind of the camp and downstream from the water source (see p. 117)

If predators are in your area, hang unused food in a bag 10 ft (3 m) off the ground and 3 ft (1 m) away from the trunk or branches of a tree

Assign an open area for location aids, such as a large "V", and as a potential landing site for a rescue helicopter (see pp. 236–41)

When you take off your boots, prop them upside down on a stick to ensure nothing crawls inside. Never put them too close to a fire to dry

Create a safe area for cutting wood. Use a tree stump as a platform for cutting and chopping

Collect and cut the fuel you need before it gets dark and keep it dry in an upright stack

ASSESSING YOUR ENVIRONMENT

You need to protect yourself from injury, threats, and risks, so have a good look around your campsite and assess it for any potential dangers, such as animals, unstable rocks or trees, and the likelihood of flooding.

ANIMALS

Look out for signs of animals, especially near water. If possible, pitch your camp against a rock face so it can only be approached from one direction. Keep a fire going all night. If you're in a group, organize a watch system. Keep things to hand that you can make a noise with to scare off prowling predators. Don't camp close to standing water where insects, such as mosquitoes, swarm.

WIND AND FLASH FLOODS

Position the entrance to your shelter at an angle to the wind. Gullies run the risk of flash floods or avalanches; inside river bends are prone to erosion and floods; and a river might burst its banks on an outside bend during a heavy downpour.

STANDING DEADWOOD

These are dead trees that haven't yet fallen. Heavy wind, or the weight of rain or snow, can make them fall. This is the best type of wood for kindling and fire fuel (see p. 121).

DEADFALLS

These are dangerous branches that have broken off a tree, but haven't yet fallen to the ground. Some trees, such as beech, ash, and yew, drop their branches without warning.

ROCKFALLS AND ICE FALLS

If you camp next to rocks, check for cracks and fissures. Fires below them can cause rockfalls. When it's cold, ice sheets can suddenly fall from the rocks.

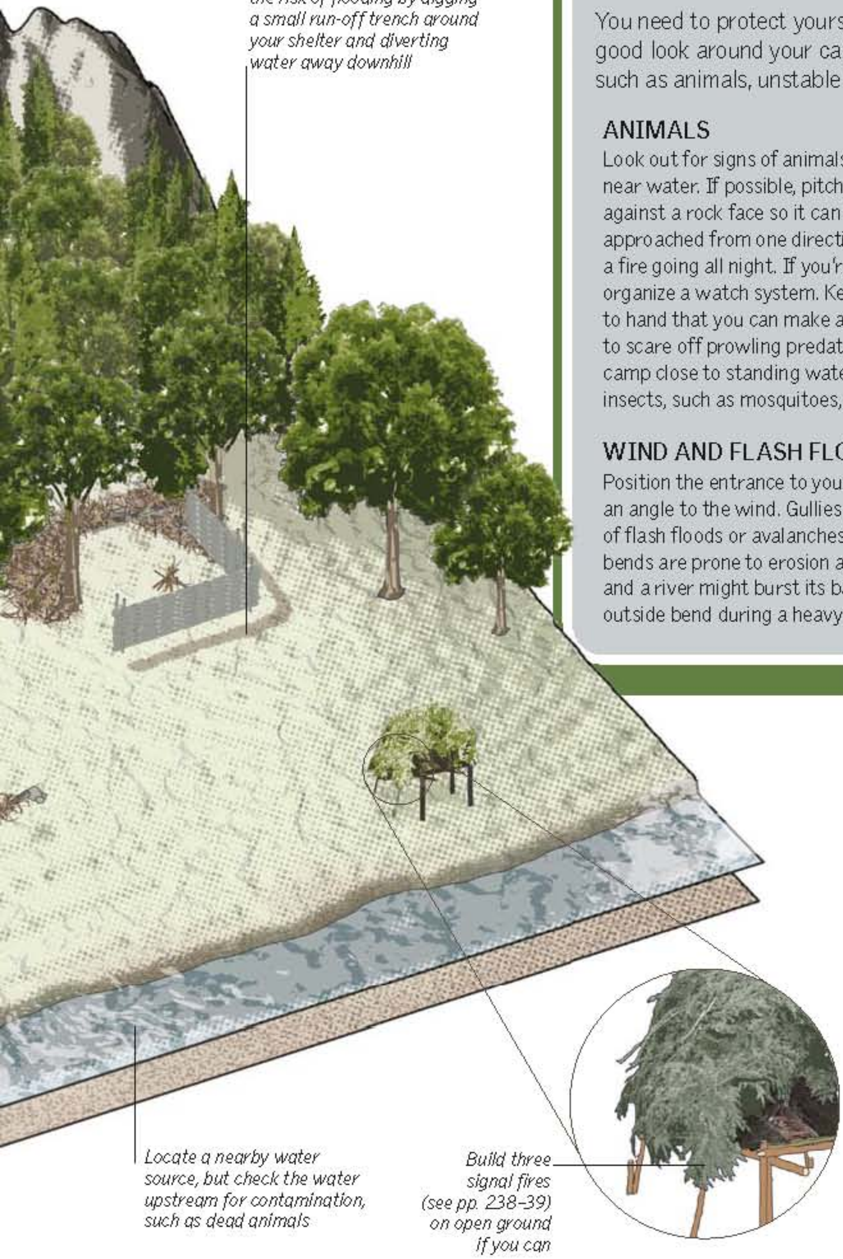

If heavy rain is likely, reduce the risk of flooding by digging a small run-off trench around your shelter and diverting water away downhill

Locate a nearby water source, but check the water upstream for contamination, such as dead animals

Build three signal fires (see pp. 238–39) on open ground if you can

WHERE NOT TO CAMP

- Don't set up your shelter on sloping, poorly drained ground.
- Don't pitch your camp too close to water because of the risk of flooding and the presence of insects and animals.
- Avoid camping near noisy water sources, such as waterfalls, because they mask any other sounds that could alert you to the presence of threats, such as wild animals, or even possible rescue, such as a helicopter or emergency whistles.

CAMP TIMETABLE

In most cases, when you arrive at an area in which you intend to remain for a while (known as "going static"), start planning your activities by working back from a cut-off time—usually when it gets dark.

THREE HOURS UNTIL DARK

You arrive in the area. Drink water, stow what is no longer needed (map, compass, and so on), and change from wet clothing, but keep one set of clothes dry at all times. Scout the area for the most suitable campsite.

THEN...

Start pitching your camp. Build your shelter, including bedding. Gather tinder, kindling, and fuel and make a safe firebase and reflector. Collect water and forage for food. Prepare all aids to location (for both night and day).

ONE HOUR UNTIL DARK

During twilight, finish organizing the site and see to your personal needs—wash, use the latrine, and check your equipment. If you're in a group, make sure everyone knows where the emergency equipment is and who has been designated each task (lighting the signal fire, shining the flashlight, blowing the whistle). Set up a watch system for the fire.

STAYING CLEAN

PERSONAL HYGIENE IN THE FIELD is an important element of protection. Keeping yourself clean and healthy helps to ensure that your body is working at its most efficient and reduces the risk of illness. How you feel physically also has a direct impact on how you feel psychologically. It's a state of mind: if you let your personal hygiene slip, it's just a matter of time before everything else starts to follow.

CLEAN CLOTHING

The condition of your clothing and equipment can affect your state of mind. If your clothing is dirty and unkempt, your attitude to survival will lack discipline. Try to keep your clothing clean and in good repair.

HYGIENE CHECKLIST

Personal hygiene is about keeping clean and healthy, so develop a daily routine that ensures you correctly use personal protection aids (tablets, insect repellents, sunblock), and safely handle food, water, and cooking and eating utensils. Keep your clothes clean, and attend to your bodily functions (see opposite).

HAIR

You don't need to shampoo your hair—let it make its own oils and minerals and establish a natural balance. Wash out incidental smells, such as fire smoke, with hot or cold water.

SCALP

Check your head for insects and bites every morning and night. Local knowledge will help—for example, look for ticks if you are in a wooded area populated by deer.

EYES

Wear sunglasses or a hat to protect your eyes from bright sunlight and snow glare. Rinse your eyes with water twice a day to protect against infections like conjunctivitis.

EARS

Carefully check your ears for foreign objects with a clean, wet finger, especially if you're sleeping rough on the ground.

TEETH AND GUMS

Use clean fingers to rub your teeth and gums, or make a toothpaste from baking soda, or a mouthwash from salt and water.

BODY

Every two days wash your armpits, crotch, hands, feet, and toes with running water to keep fungal infections at bay.

MAKING A SHOWER

Standing under a shower can work wonders for your spirit—it removes accumulated dirt and sweat and makes your body feel refreshed. An improvised shower is quick and easy to make from a metal or a plastic container.

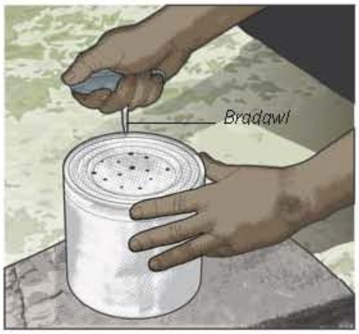

① Turn the container upside down on a flat surface.

- Punch holes in the bottom with the bradawl on your penknife or the point of your knife.

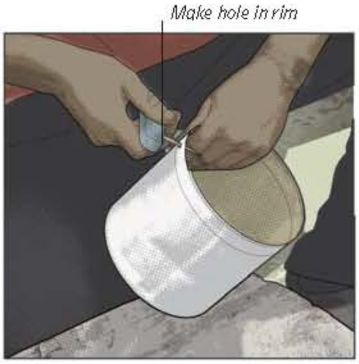

② Make a hole about 1 in (2.5 cm) down from the rim of the container.

- Make a matching hole on the opposite side of the container.

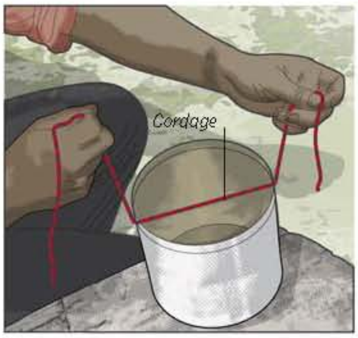

③ Smooth out any rough edges around the two holes.

- Thread a piece of cordage more than 2 ft (60 cm) long through the two holes.

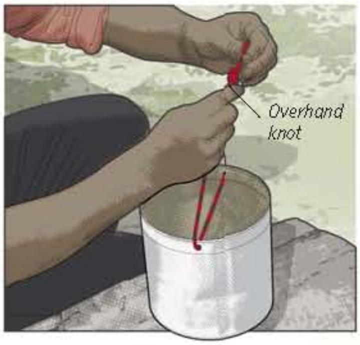

④ Pull the cord through until you have the same length—about 1 ft (30 cm)—on either side.

- Tie the two strands together with an overhand knot (see p. 143).

BODILY FUNCTIONS

In a genuine survival situation, you don't eat as much food as usual and your toilet functions—particularly with regards to solid waste—will reduce dramatically after a day or so. Nevertheless, it's important to maintain a routine, especially if you are in a group.

IN TRANSIT

If you're moving every day or so, it's not worth making a latrine, so just attend to your bodily functions as follows:

- **Urination:** choose a tree away from the water source and downwind of the camp.
- **Defecation:** dig a hole at the base of a tree, fill the hole afterward, and mark it with stones or two crossed sticks. Clean yourself (but don't use the hand you eat with) with toilet paper, leaves, or grass, then running water. Wash your hands and fingernails. Burn or bury used toilet paper.
- **Menstruation:** if you don't have tampons or sanitary napkins with you, use something cotton and washable, or even sphagnum moss. Burn or bury whatever you have used.

GOING STATIC

If you're going static by staying in one place for more than a few days, build a latrine downwind of your camp, and downhill and away from your water source. Dig a deep trench, either next to or between two trees, and make a seat from two poles. Cover the deposits with sand or soil to reduce the smell and keep flies away. When you leave, dismantle the latrine, fill the trench, and mark the area with stones or crossed sticks.

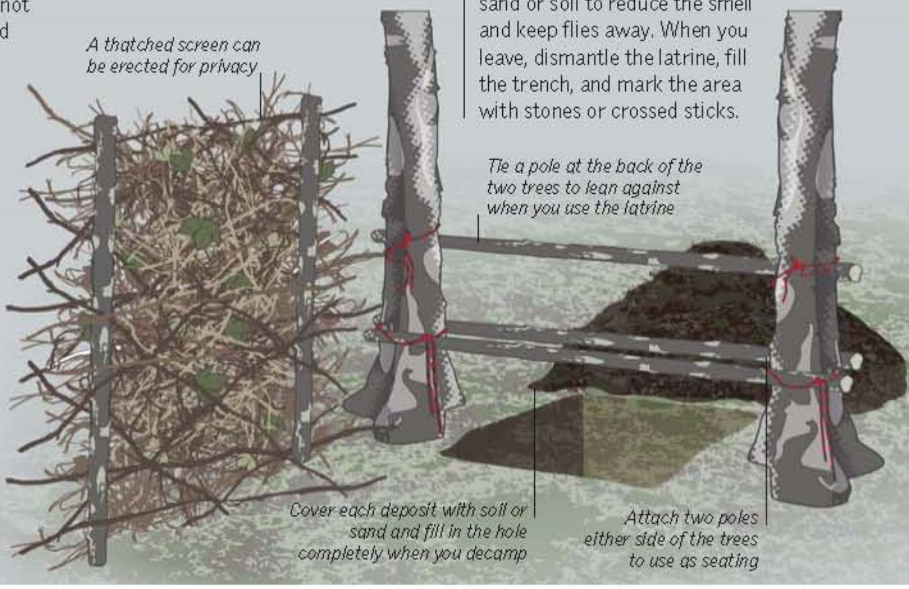

A thatched screen can be erected for privacy

Tie a pole at the back of the two trees to lean against when you use the latrine

Cover each deposit with soil or sand and fill in the hole completely when you decamp

Attach two poles either side of the trees to use as seating

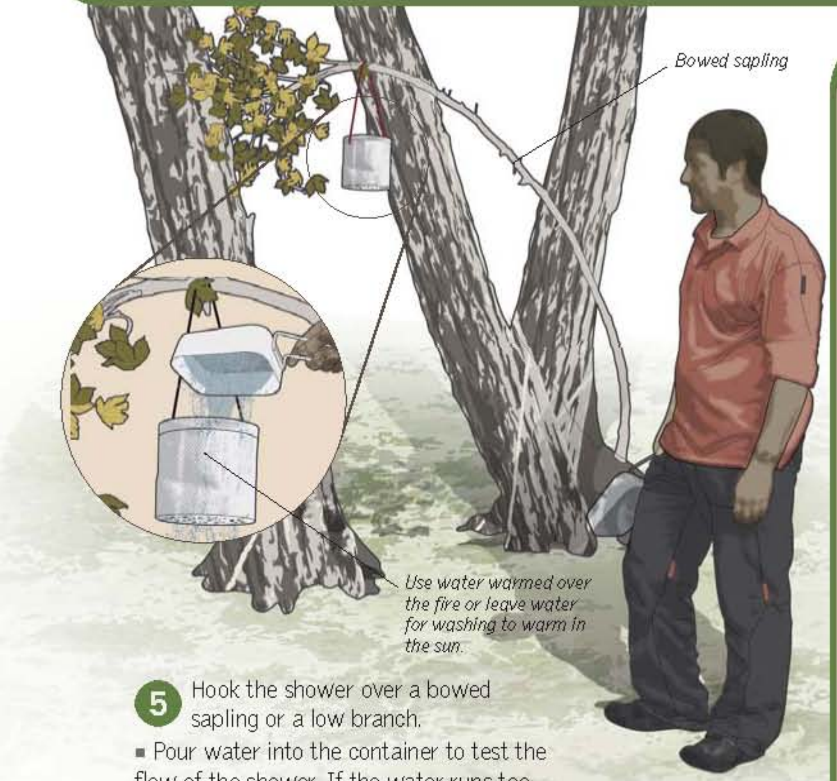

Bowed sapling

Use water warmed over the fire or leave water for washing to warm in the sun.

5 Hook the shower over a bowed sapling or a low branch.

- Pour water into the container to test the flow of the shower. If the water runs too quickly, put leaves in the bottom to slow it.

LATHERING UP

Camping soap is a concentrated antibacterial liquid soap that can be used without water. Decant a little into a small container, such as an old 35mm film container, and it will last for weeks. Alternatively, you can make soap from natural materials.

MAKING SOAP

You can make natural soap from various sources that contain a substance called saponin, which —when mixed with water—has a cleaning effect.

- **Birch leaves:** Select young leaves and place them in a container (even a plastic bag will do). Add some cold water, then add some hot or boiling water (whichever your container can handle without melting). Agitate the mixture—this allows the saponin in the leaves to dissolve into a natural soap.
- **Soapwort:** Agitate soapwort roots in water until they foam up. Let the light foam settle before using it to wash yourself and your clothes.
- **Horse chestnut:** Dip horse chestnut leaves in warm or hot water then remove. Squeeze the leaves in your hand to produce saponin.
- **Wood ash:** Mix wood ash with water. Don't use this method too often, as it can dry out your skin.

MAKING FIRE

THE ABILITY TO MAKE and maintain a fire can be a significant psychological factor between determining whether you do all you can to survive or just give up. Fire gives you a sense of "being," and, like a shelter, it can transform a clearing under a tree into a "home."

A PORTABLE KIT

It's important to gather all your materials before you start—not only your tinder, kindling, and fuel, but also your means of lighting a fire. This involves a fair amount of organization, so a portable kit that keeps it all in one place is much more convenient.

FIRE PRECAUTIONS

If you intend to have a fire in front of your shelter, bear in mind some basic rules:

- Don't build the fire too close to the shelter as it may get out of control or a spark may blow into the shelter and ignite it.
- Make sure you have fully extinguished your fire before you decamp and leave the site. Pour water (if you have enough) onto the fire and the immediate surrounding area, or use damp soil, sand, or earth.

COMPONENTS OF FIRE

Three crucial components—oxygen, heat, and fuel—need to be present in order for a fire to start and be sustained. Although you don't have any control over the resulting chemical reaction, known as combustion, you can develop the skill of lighting a fire. The key is to achieve the best balance between the components. If your fire isn't going well, get back to basics and ask yourself which one of the components is working against you.

OXYGEN

Although oxygen is vital for combustion to happen, it's all too easy to prevent it from getting to the flame by smothering the fire with too much wood. If your initial fire looks as though it's dying, try fanning it with your hand or a map to create a draft that feeds oxygen to the fire.

HEAT

Heat is essential for igniting the fuel. In most cases this heat can be generated either by a spark (such as flint and steel), by a chemical reaction and friction (such as matches or potassium permanganate), or by friction alone (such as a bow drill). (See pp. 126–27 and pp. 130–33.)

FUEL

Once the fire gets going, you need to have fuel to burn (see pp. 120–21). You should start with small, dry pieces of fuel that will catch the flame and generate enough heat to then burn increasingly large pieces of fuel.

MATCHLESS FIRESET TIN

Working on the principle of "Don't make things any harder than they need be," this matchless fireset, designed for the military, contains a one-stop solution to getting a fire going—regardless of the weather conditions.

INSIDE THE TIN

The small tin, which is waterproof when taped, contains everything you need to produce a fire: a sparking device, tinder, kindling, and fuel. Hexamine from the fuel blocks is scraped onto cotton wool, then a spark from the flint and steel ignites the cotton wool long enough for the fuel blocks to light.

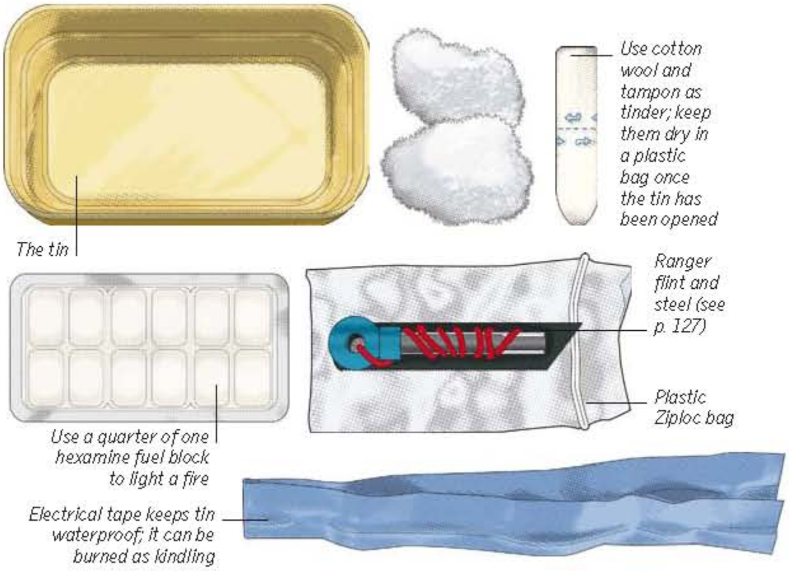

The tin

Use cotton wool and tampon as tinder; keep them dry in a plastic bag once the tin has been opened

Ranger flint and steel (see p. 127)

Plastic Ziploc bag

Use a quarter of one hexamine fuel block to light a fire

Electrical tape keeps tin waterproof; it can be burned as kindling

USING THE TIN

You can use the tin itself to boil water. Raise the tin 1 in (2.5 cm) off the ground with two sticks and light a quarter of a hexamine fuel block underneath. After a while, the water boils so you can have a potentially life-saving drink.

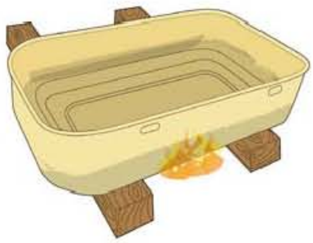

PREPARING BEFOREHAND

More than any other survival task, starting a fire needs good prior preparation. If you don't have the correct materials and in sufficient quantities, you will probably fail in your attempts to start a fire. Preparing the ground, your materials, and your equipment will usually make firelighting much easier and more likely to succeed.

KEY POINTS TO REMEMBER

- Carry some form of firelighter with you at all times.
- Practice your skills before you need them—in different conditions and using different materials. You'll soon learn what works and what doesn't.
- Collect tinder as soon as you enter the forest. If it's wet, dry it in your pockets against your warm body.
- Collect everything you need to get a fire going, then multiply it by ten. If you're in a dire situation, you may have only one or two chances of getting a fire going before you either run out of matches or tinder, or you suffer from exhaustion or hypothermia.

CHOOSING YOUR GROUND

You need to be careful when selecting the place in which you intend to start your fire. Clear the ground before building your fire. Never light a fire directly on the ground and watch that your fire doesn't spread or burn out of control.

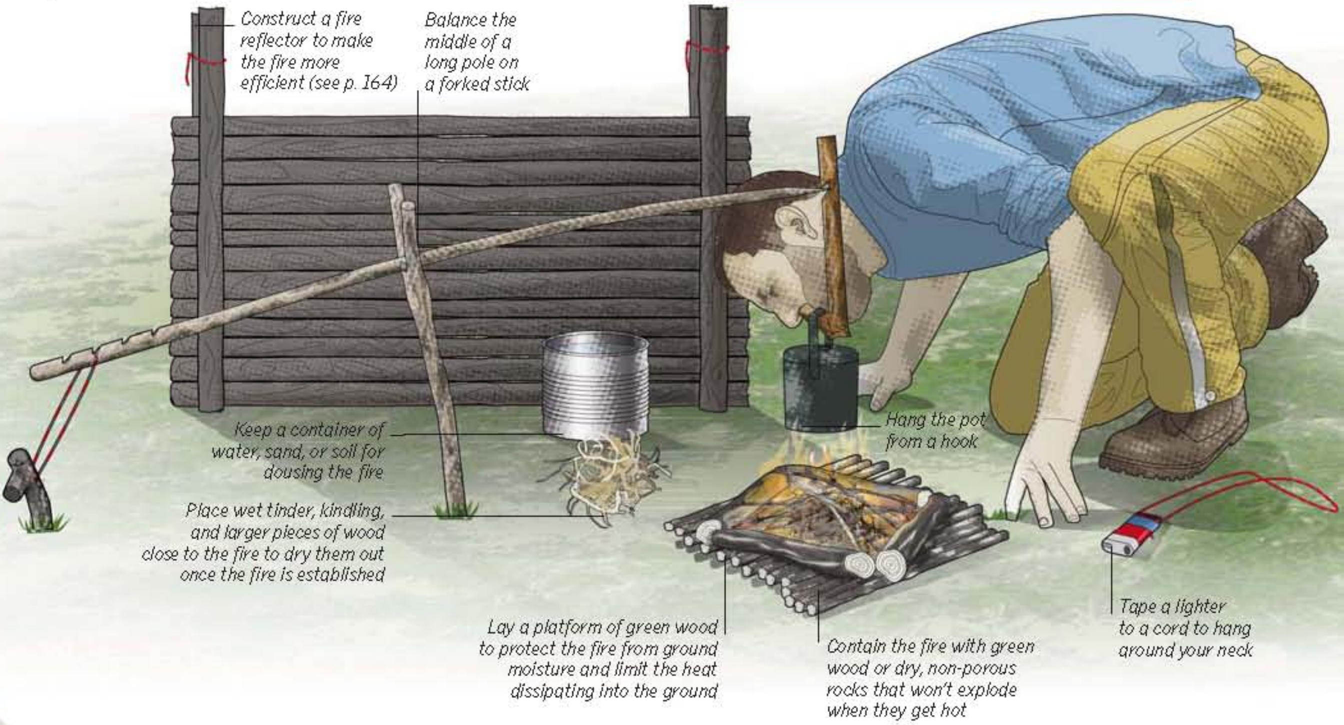
Construct a fire reflector to make the fire more efficient (see p. 164)

Balance the middle of a long pole on a forked stick

Keep a container of water, sand, or soil for dousing the fire

Place wet tinder, kindling, and larger pieces of wood close to the fire to dry them out once the fire is established

Hang the pot from a hook

Lay a platform of green wood to protect the fire from ground moisture and limit the heat dissipating into the ground

Contain the fire with green wood or dry, non-porous rocks that won't explode when they get hot

Tape a lighter to a cord to hang around your neck

CAMP FIRE DO'S

- Make sure you have enough wood close by to fuel your fire. Carrying wood to your fire uses energy, which may be at a premium in a survival situation.
- Rake the area around the spot where you intend to start the fire and brush away leaves or anything else that may ignite and start a forest fire.
- Check the ground for tree roots. Your fire could set an exposed root alight, or even one just under the surface. Once a root starts to burn underground, the heat works its way along the root and could start a forest fire.
- If you're trying to get rescued, choose a spot for the fire where passing vehicles and aircraft can see it.

CAMP FIRE DON'TS

- Don't use your hands as a rake to clear the ground, because you may get bitten by an insect or a snake. Use your feet or a branch instead.
- Don't build a fire next to old logs or fallen trees, as they may catch fire. They may not look alight but they can smolder for several days and a heavy breeze could subsequently fan the embers and start a blaze.
- Don't build your fire under an overhanging branch, or leaves, as the heat from the fire can soon dry them out and then set them alight.
- Don't position your fire so that the wind affects the way the fire burns, or blows smoke or flames into your shelter.

THE ELEMENTS OF FIRE

THE THREE MATERIAL ELEMENTS you need to build a fire are tinder, kindling, and fuel. They must be dry and collected in sufficient quantities. A well-made feather stick effectively provides tinder, kindling, and fuel on one piece of wood—and it needs only a spark to set it alight.

EMERGENCY TINDER

Carry tinder, such as a tampon or cotton wool balls, in a 35mm film canister or a Ziploc bag in your emergency kit. For each fire, use some cotton wool and a small piece of tampon. Cotton wool balls smeared with petroleum jelly make a flame last ten times longer.

MAKING A FEATHER STICK

Between four and six well-made feather sticks provide enough combustible material to get a fire going. Keep a few already made and packed away to use in an emergency. The best feather sticks are made from standing dead wood, but just about any type of dry wood will do. If you use small, dead branches that have snapped off a tree, remove the bark first.

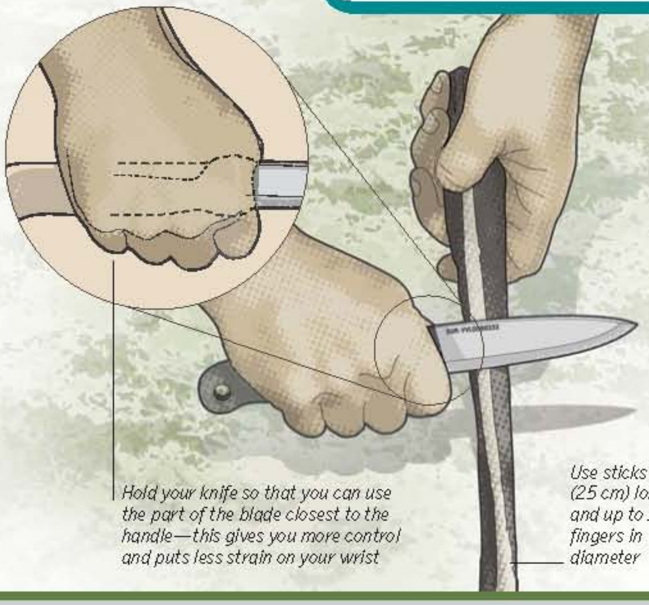

Hold your knife so that you can use the part of the blade closest to the handle—this gives you more control and puts less strain on your wrist

Use sticks 10 in (25 cm) long and up to 3 fingers in diameter

1 Choose the side of a stick with an even grain and no knots. Work on a hard, flat surface to stop the stick slipping.

- Lay the blade flat on the stick and run it all the way down without cutting into the wood—do this ten times. This gives you a feel for the wood and how your knife moves over it.

TINDER

The first element you use to make a fire is dry, combustible material called tinder. You may have tinder in your equipment (see pp. 122–23), or you may need to find natural or other man-made sources. The key to success is to experiment with what's around you before you actually need it. Make sure it's dry—leave it in the sun if it's damp. When you use some tinder, replace it at the earliest opportunity.

TYPES OF TINDER

Natural sources: Feather sticks (see above), shavings from the outside of a bamboo stem, bark shavings, fine wood dust, pine pitch, plant and animal down, powdered dung, and fire dog (a charred stick). Also, birch bark (silver birch bark can be lit even when it's wet), clematis, honeysuckle, cattail, dry grass, dead and dry moss, and some fungi. The best tinder for friction methods of firelighting (see pp. 130–33) is tree bark, dry grass, fungi, lichen, plant roots, fibers, and down.

Man-made sources: Cotton wool balls, tampons, char cloth, fire tin (see p. 123), lint, tissue paper, camera film, strips of rubber, and candle wick.

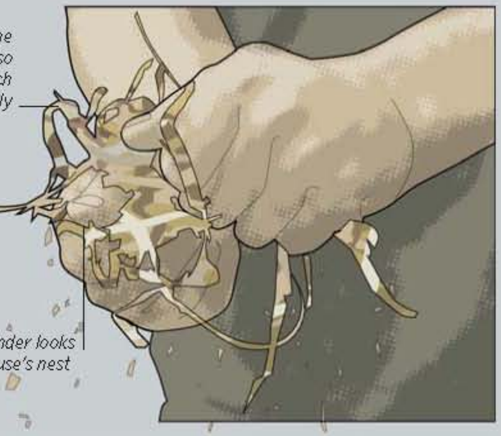

Loosen the fibers so they catch alight easily

Buffed tinder looks like a mouse's nest

TINDER BUNDLE

A good way to prepare your tinder to take a spark or a coal is to make it into a tinder bundle. Vigorously tease, rub, and pull the fibers with your fingers until it becomes a ball the size of a grapefruit. Push the finest, most combustible material into the interior of the ball. Try mixing up your tinder to make it more effective—for example, dry grass, birch bark, and cattail.

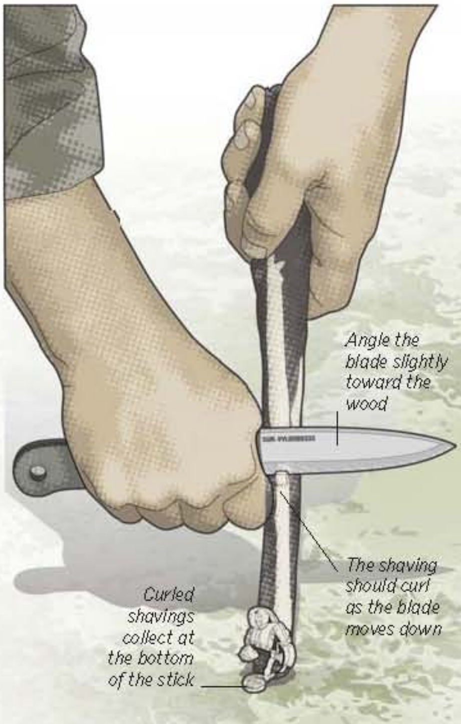
Angle the blade slightly toward the wood
The shaving should curl as the blade moves down
Curled shavings collect at the bottom of the stick

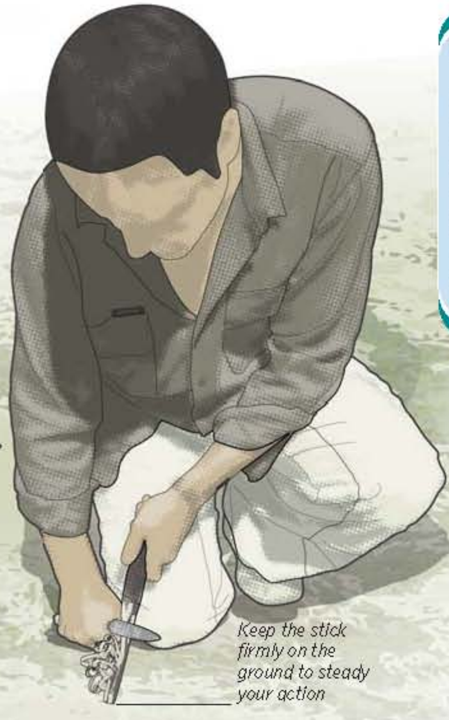
Keep the stick firmly on the ground to steady your action

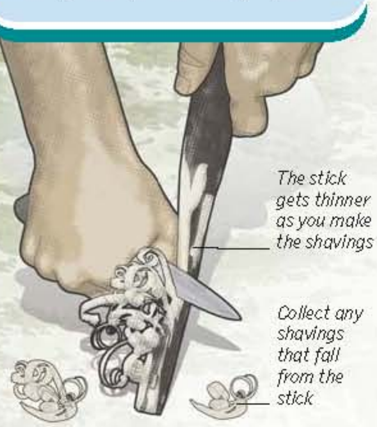
The stick gets thinner as you make the shavings
Collect any shavings that fall from the stick

2 Now tilt the angle of the blade slightly toward the wood.

- Keeping a part at the top of the wood to use as a handle, run the blade down the wood to cut a shaving.
- Stop just before the bottom so that the shaving stays attached to the stick.

3 Turn the stick slightly and run the knife down the edge created in step 2 to create a second shaving. Turn the stick again and repeat, working around the stick.

- Try to get a rhythm going, and put your body behind the cutting action.

4 Once you have mastered the technique, continue to feather the rest of the stick.

- When you've finished you will have a thin stick with curled shavings still attached, and ready for use as kindling.

STANDING DEADWOOD

A tree that's died but hasn't fallen over has no green foliage and the bark falls off without being replaced. This is the ultimate wood for firelighting, as it can provide kindling and fuel and, when split, makes excellent feather sticks. The bottom few inches may be wet where the tree wicks up moisture from the ground.

KINDLING

Kindling is the second material element of firelighting and, when dry, is added to burning tinder. Kindling can be as thin as a match or as thick as a finger. You should be able to snap it with your hands. If it doesn't break with a crack then it's probably not completely dry. If it's damp, remove the outer bark (this retains most of the moisture) and break the kindling down into small sticks 6 in (15 cm) long.

TYPES OF KINDLING

- Soft-wood twigs are very combustible, while wood with flammable resin, such as pine, burns hot and long.
- You can use some types of tinder as kindling—for example, bark, palm leaves, pine needles, grass, ground lichens, and ferns—but you will need larger quantities for kindling than you needed for tinder.

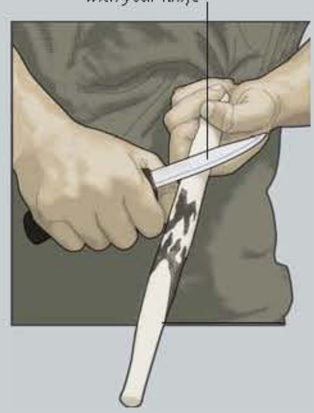
Strip off the bark with your knife

FUEL

Initially, your fire needs constant tending, but once it can sustain itself for five minutes it's established and you can add increasingly larger fuel to create a good heart—a bed of hot coals that sustains the fire with minimum effort on your part. The fuel should be about as thick as your wrist or forearm. At first, use dry fuel split into sticks that catch alight easily. Add green (live) wood and larger logs (whole or split) later, once when the fire is established. In wet conditions, build your fire under cover to keep off the rain.

TYPES OF FUEL

- Hard woods from mainly deciduous trees (such as oak, maple, ash, beech, and birch) burn hot and long, produce good coals, and are more efficient. But they are hard to get going.
- Soft woods from conifers (such as pine, fir, and spruce) are easier to light as they can contain resin, but burn faster and produce less heat than hard woods. They also make more smoke.
- Peat is found on well-drained moorland and can be cut with a knife. However, it needs a good air supply.
- Charcoal is lightweight, smokeless, and burns hot.
- Dried animal droppings provide a good smokeless fuel.

CHAR CLOTH AND FIRE CAN

BEFORE SETTING OFF ON A TRIP, add either some char cloth or a fire can to your backpack. These excellent forms of tinder are reliable and potentially life-saving. Alternatively, you can take some mayasticks. Char cloth is very easy to make, so keep some dry in your emergency fire kit or lining the bottom of your survival kit (see pp. 60–61).

TOOLS AND MATERIALS

- A can with a tight-fitting lid, such as a small shoe-polish can
- Nail
- 100 percent cotton cloth
- Knife or scissors
- Spark or flame

MAKING CHAR CLOTH

Char cloth is cotton cloth that's been combusted in the absence of oxygen (pyrolysis). It's lightweight, takes up almost no space, and produces an ember from even a weak spark extremely well. Char cloth works only when it's completely dry, so keep it in a watertight container.

1 Turn the lid of a can upside-down and hammer a nail into the center.

- Experiment with the size of the hole. Usually, the smaller the hole the better.

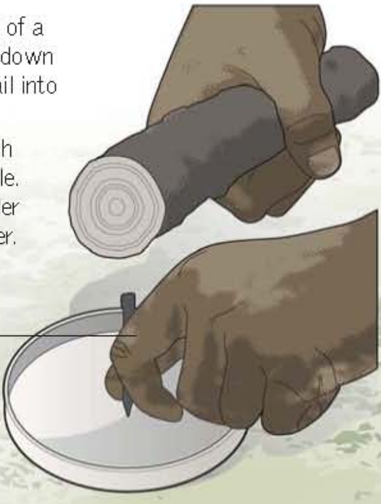

Punch a hole into the lid, if possible using a nail

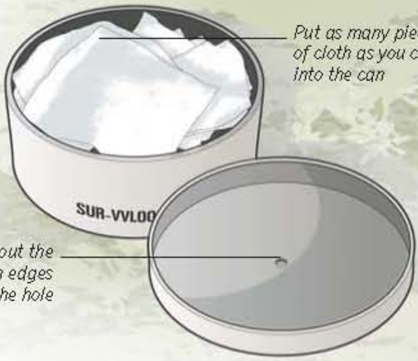

Put as many pieces of cloth as you can into the can

Smooth out the rough edges around the hole

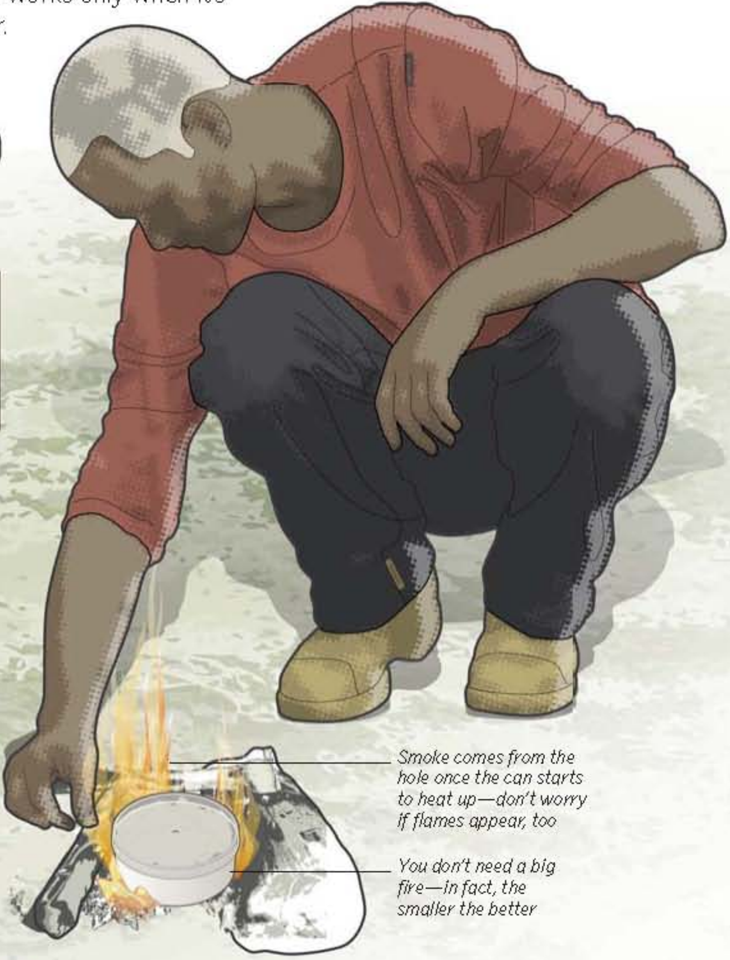

Smoke comes from the hole once the can starts to heat up—don't worry if flames appear, too

You don't need a big fire—in fact, the smaller the better

2 Cut 100 percent cotton cloth into pieces that fit into the can without folding.

- Vary the sizes of the pieces so they don't just stack flatly on top of each other, but at the same time don't squash them in.
- Securely place the lid on the can.

3 Place the can on a fire to burn off all the oxygen inside the can, or place it on top of some good coals scraped to the side of your camp fire.

- When the smoke stops the process is complete.
- Safely remove the can from the fire.
- Don't open the can until it's cool.

MAKING A FIRE CAN

You can use a fire can to start a stubborn fire when conditions are less than perfect, or to boil water, do some basic cooking, or warm your hands on a cold day. Once lit, a fire can burns for hours with a concentrated, controllable flame that produces no smoke. When it starts to fail, you can either replenish the existing cardboard with more wax or replace the cardboard and start again.

TOOLS AND MATERIALS

- A can with a tight-fitting lid, such as a small shoe-polish tin
- Cardboard (ribbed or plain)
- Candle and a match or lighter
- Knife or scissors

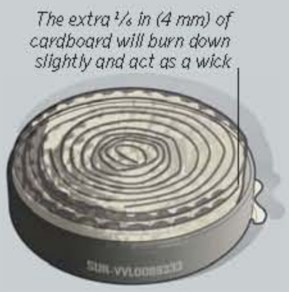
The extra ⅙ in (4 mm) of cardboard will burn down slightly and act as a wick

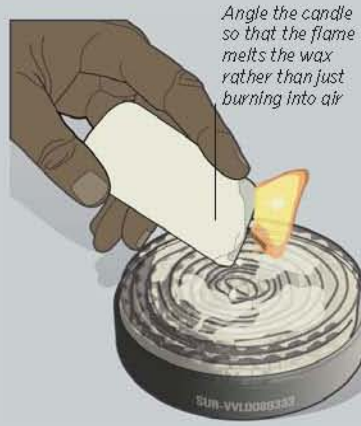
Angle the candle so that the flame melts the wax rather than just burning into air

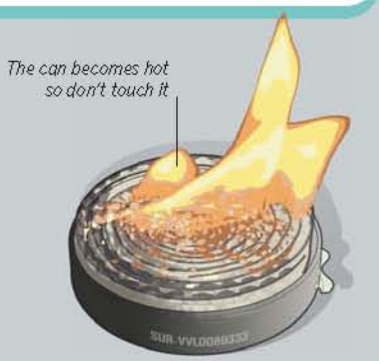
The can becomes hot so don't touch it

1 Cut out a long, thin piece of cardboard that's ⅙ in (4 mm) wider than the depth of your can.

- If it's ribbed, cut it across the grain.
- Roll it tightly along its length until the roll just fits inside the can.

2 Light your candle and let the melting wax drop into the can.

- Let the wax soak the cardboard and fill up the can—it's a slow process.
- Stop when the wax nears the top.
- Allow the wax to harden.

3 When the can has cooled down, hold it at an angle and light the top of the cardboard with the candle.

- The flame should be concentrated and spread across the top of the can.

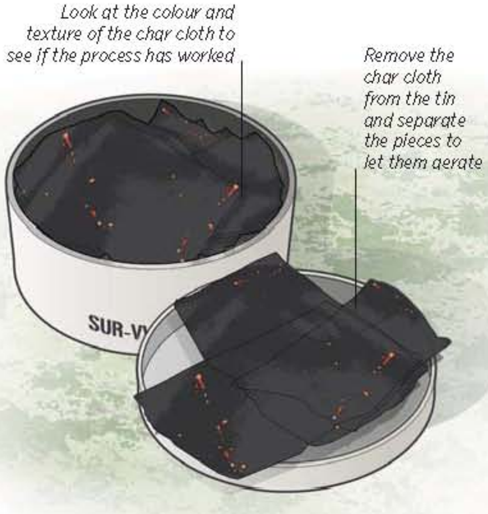
Look at the colour and texture of the char cloth to see if the process has worked
Remove the char cloth from the tin and separate the pieces to let them aerate

4 Once the tin has cooled down, remove the lid and examine the charred cloth.

- The cloth should be completely black and have a semi-rigid, but softish texture. If it's fawn or brown, put it back on the fire and leave for longer.
- Cloth that's brittle and crumbles is of no use.
- Check the cloth works by striking a spark on to a piece; the spark should create a small red ember.

FIRE WADS AND MAYASTICKS

Fire wads are rolled strips of newspaper soaked in a fuel. Once dry, they make handy waterproof tinder. Mayasticks are pieces of resinous fatwood from the highlands of Mexico and Guatemala. The pieces are easy to light, even when wet, and generate a hot flame.

MAKING FIRE WADS AND MAYASTICKS

- To make fire wads, tightly roll strips of newspaper into a tube 4 in (10 cm) long and tie them with cord. Soak them in melted wax and allow to dry. Light the center with a match.
- To light a mayastick, cut a little sliver of wood with your knife and lift it from the surface of the stick. When a little resin seeps out, set it alight with a flint and steel (see p. 127).

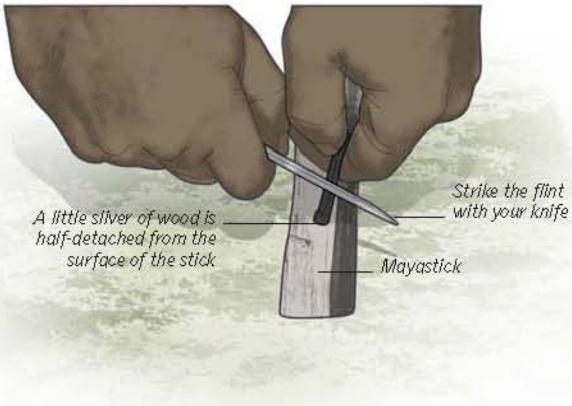
A little sliver of wood is half-detached from the surface of the stick
Strike the flint with your knife
Mayastick

TYPES OF FIRE

ONCE YOU HAVE COLLECTED your tinder, kindling, and fuel, and made sure it's dry and ready at hand, you can set about making your fire. There are many different types of fire to choose from, depending on what you need the fire for (see below). Before you start to build your fire, make sure you have prepared the ground so that everything is safe (see pp. 118–19).

CHOOSING A FIRE

If you have a choice of fuel, as well as time to invest in building a specific type of fire, look at the choices below and determine which one is likely to suit your immediate needs.

- Your primary consideration should be the function of the fire: warmth is probably your most urgent requirement, but other uses include cooking, signaling (see pp. 238–39), drying wet clothing, and disposing of waste. You may want a particular type of fire because it lasts all night.
- Consider the availability of the components you need to build the fire—for example, the right fuel and the best ground. A rule of thumb is to estimate how much you think you'll need, then double it.

FIRE ESSENTIALS

There's plenty of advice surrounding the pros and cons of making fires, but three general tips will help:

- Never make things any harder than they need to be. Choose a fire that requires the least effort for the maximum gain.
- It is more efficient to build a small fire and sit close to it, than to build a large fire and sit far away from it.
- If all your wood appears wet, remove the bark and split the wood—the center will usually be dry.
- Once the fire is established, place damp tinder, kindling, and larger pieces of wood close to the fire to dry out. Keep watch on them so that they don't dry out to the point where they catch fire!

TYPE OF FIRE	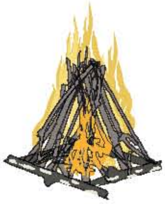 **TEEPEE**	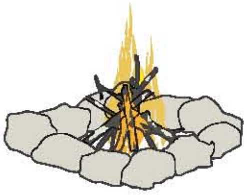 **STONE-LINED**	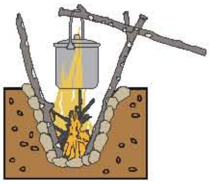 **AUTOMATIC**	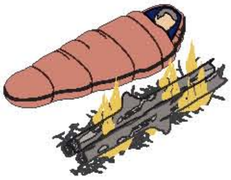 **LONG LOG**
HOW	▪ Surround the tinder ball with kindling in the shape of a teepee. Arrange small, medium, and large fuel logs in a square at the foot of the teepee.	▪ Arrange large non-porous stones in a circle, place a tinder ball in the middle, with kindling around it. Add fuel logs when the fire is established.	▪ Line a hole 3 ft (1 m) deep with non-porous stones. Put tinder and kindling inside and rest large logs against the sides so they drop down as they burn.	▪ Put tinder, kindling, and fuel logs in a depression 6 ft (2 m) long. Lay two long fuel logs on top of the burning fire.
WHERE	▪ Areas with abundant fuel, because the fire requires lots of firewood	▪ Windy locations ▪ Popular areas with existing fire rings and where low-impact camping is vital	▪ Rock-free earth or sand, because it's easy to dig	▪ Forested areas, because the fire requires long logs for fuel
WHY	▪ Quick to light ▪ Wet wood can be burned because it's dried by the heat of the inner fire	▪ Stones shelter fire from wind ▪ Using an existing fire ring reduces the fire's impact on the environment	▪ Self-feeding once lit, which means you don't need to keep adding fuel	▪ Long-lasting (the fire can stay alight all night) ▪ Emits a great deal of heat
USES	▪ Warmth ▪ Cooking ▪ Signaling (if green vegetation is burned)	▪ Warmth ▪ Cooking ▪ Signaling (if green vegetation is burned)	▪ Cooking ▪ Signaling (if green vegetation is burned)	▪ Warmth (in cold weather, build a fire either side of you). ▪ Cooking (once embers have formed)

LIGHT YOUR FIRE

There are numerous ways to build a fire and get one going, and everyone has their favorite. The following example is a tried-and-trusted method that's versatile and works well in a variety of conditions.

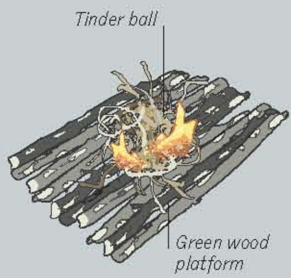
Tinder ball
Green wood platform

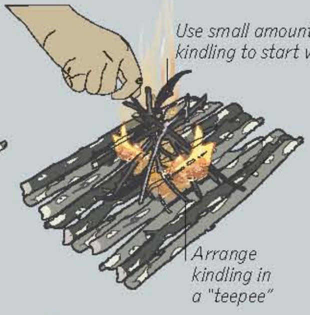
Use small amounts of kindling to start with
Arrange kindling in a "teepee"

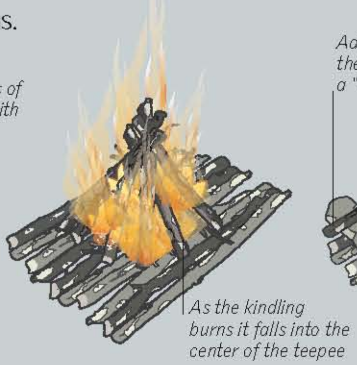
As the kindling burns it falls into the center of the teepee

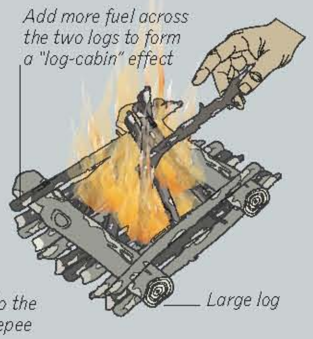
Add more fuel across the two logs to form a "log-cabin" effect
Large log

1 Place your tinder ball (see p. 120) on a platform composed of green wood.

- Light the tinder with your chosen method (see pp. 126–27) and let it catch.

2 Gently lay kindling by the tinder ball.

- Build a kindling "teepee", as this lets the fire breathe where the heat is strongest.
- Feather sticks also make ideal kindling (see p. 120).

3 As the kindling catches fire and the flames grow, add larger pieces of kindling.

- Continue to add kindling, gradually building up to split logs (see p. 148).

4 The fire is established when you can leave it alone for five minutes without it going out.

- Then lay a large log on the wind-facing side and one on the other side.

TYPE OF FIRE	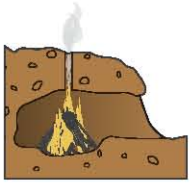 **SNAKE HOLE**	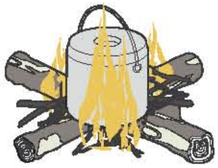 **STAR-SHAPED**	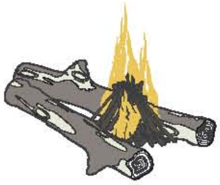 **HUNTER**	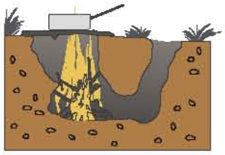 **DAKOTA HOLE**
HOW	▪ Create a hole in the side of a bank and a chimney up through the earth. Light a fire inside using any fuel.	▪ Build a fire from tinder, kindling, and fuel. ▪ Arrange four logs so they meet in the middle. ▪ Push logs in as they burn.	▪ Make a fire out of tinder, kindling, and any type of fuel. Place two long logs either side of the fire in a V-shape.	▪ Dig a large hole for the fire and a slightly smaller hole for the chimney, with a tunnel linking the two. Use small logs as fuel and cook at ground level.
WHERE	▪ Windy locations ▪ Rock-free earth or sand bank	▪ Forested areas, because of the logs the fire needs	▪ Cold or windy locations	▪ Anywhere you can dig a hole, because the fire requires very little fuel once established
WHY	▪ Chimney creates a draft, giving a high-temperature fire ▪ Sheltered from the elements	▪ Long-lasting ▪ Good embers for cooking	▪ Hardwood logs shelter the fire from the wind ▪ Produces a great deal of heat	▪ Concentrated heat ▪ Flames are below ground so fire is hidden
USES	▪ Warmth ▪ Cooking ▪ Waste disposal	▪ Cooking—balance a pot on the logs ▪ Heating water	▪ Warmth ▪ Cooking	▪ Cooking ▪ Keeping warm ▪ Drying wet clothing

MAKING SPARKS AND FLAMES

LIGHTING TINDER IS THE FIRST STAGE of making a fire. Matches and lighters do this instantly, but there are a number of ways to create a spark that you can then use to coax your tinder into a flame. This is relatively easy when everything is dry, but with patience and persistence it is also possible when conditions are bad.

IGNITION DEVICES

There are various ingenious methods of creating that all-important spark or flame to ignite your fire. If you don't have matches or a lighter, you'll need to use another device, such as a flint and steel. You can also improvise by using an external energy source, such as:

- Focusing the sun's heat with a magnifying glass or beverage can.
- Making sparks with a battery.
- Creating a chemical reaction using potassium permanganate.

STRIKING A MATCH

It may seem simple enough, but there's a way of striking a match—known as "commando style"—that reliably produces a flame in all kinds of conditions.

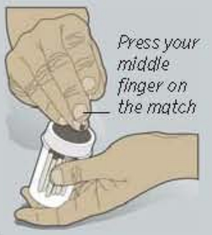
Press your middle finger on the match

1 Hold the box in one hand and a match between the thumb and first two fingers of the other.

- Strike the match firmly away from you.

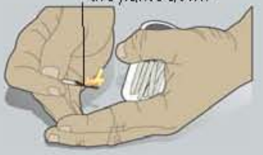
Point the head of the flame down

2 When the match lights, immediately cup your hands to protect the flame.

- Let the flame burn a little way along the stem before using it to light the tinder.

TYPE OF DEVICE	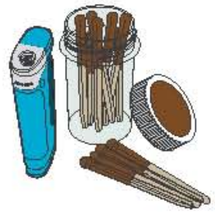 MATCHES/LIGHTERS	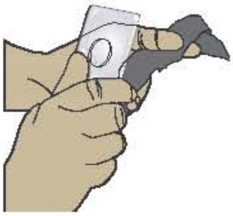 MAGNIFYING GLASS	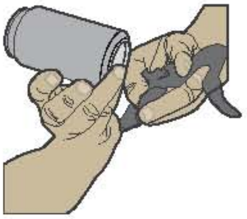 BEVERAGE CAN	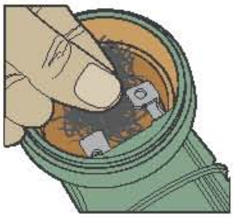 BATTERY
GEAR	▪ Waterproof box of matches. ▪ Cigarette lighter taped to a piece of cord around your neck. ▪ Dry tinder	▪ Magnifying glass ▪ Dry tinder	▪ Empty beverage can ▪ Dry tinder	▪ Flashlight and its battery ▪ Wire or wire wool ▪ Dry tinder
WHAT TO DO	▪ To light a match "commando style," strike it away from you on the box and then cup it in your hands (see above).	▪ With the magnifying glass, focus bright sunlight onto some dry tinder and create a hot spot. Hold the magnifying glass steady until the tinder catches alight.	▪ Polish the bottom of the can (see Signal mirror, p. 245). ▪ Catch bright sunlight on the shiny surface and reflect it onto tinder to create a hot spot. Hold the can steady until the tinder catches alight.	▪ Lay the wire across the battery terminals to create some sparks. ▪ Remove the bulb from the flashlight and place wire wool over the terminal. Switch on the flashlight to create sparks.
COMMENTS	▪ Waterproof matches are usually just standard matches that have been coated with wax and varnish. ▪ Always have a lighter around your neck on a piece of cord.	▪ When you choose a compass, make sure it has a magnifying glass incorporated into it (for reading the details on maps). ▪ You can also use the lens in reading spectacles.	▪ You'll need to practice this technique so that you can rely on it in a survival situation.	▪ The thinner the wire the better this will work, especially with lower voltage batteries (1.5v). ▪ Use this method for a short period only, otherwise you will drain the battery.

CREATING A CHEMICAL FLAME

Potassium permanganate is an extremely useful item to have in your survival kit, because you can use the chemical not only to sterilize water and wounds, but also to create a spark to light a fire. You will need some sugar to make it work, so use some from your survival rations or crush a hard candy.

WARNING!
Potassium permanganate is a strong oxidizer that can, when mixed with certain chemicals, create an explosive mixture. It can also stain your clothes and skin.

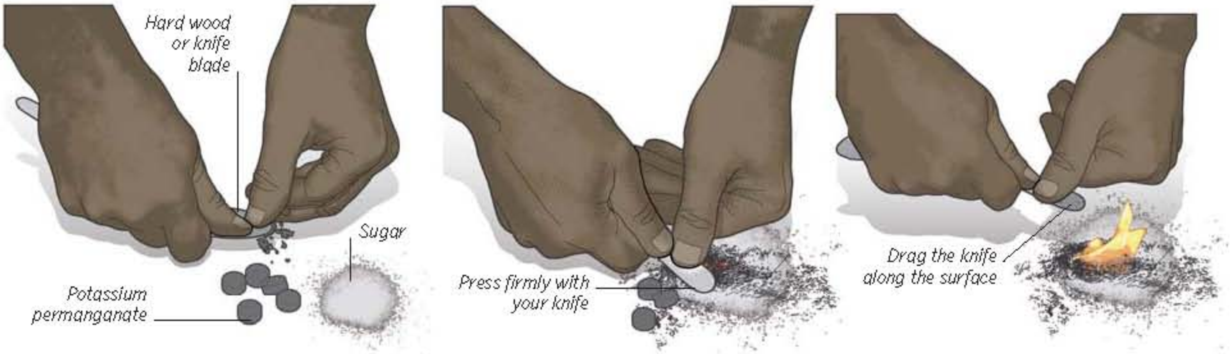
Hard wood or knife blade
Sugar
Potassium permanganate
Press firmly with your knife
Drag the knife along the surface

1. On a hard surface, such as a flat piece of wood or rock, crush some potassium permanganate. Have an equal amount of sugar ready.

2. Mix the ingredients. With the back of your knife, push down on the mixture and drag it along the hard surface to create friction.

3. Continue to push down and drag your blade until you get a spark.
   - The flame dies down quickly so have your tinder at the ready.

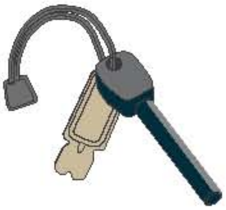 FIRESTEEL	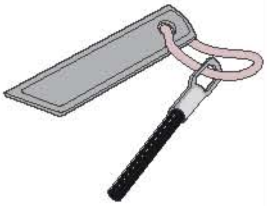 FLINT AND STEEL	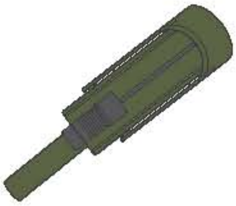 ONE-HANDED STRIKER	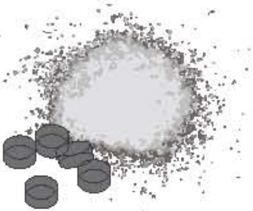 POTASSIUM PERMANGANATE	TYPE OF DEVICE
▪ Ferrocerium firesteel ▪ Metal striker ▪ Dry tinder	▪ Magnesium-alloy rod ▪ Steel striker (usually a short piece of hacksaw blade) ▪ Dry tinder	▪ A magnesium-alloy rod and steel device that can be operated using only one hand ▪ Dry tinder	▪ Potassium permanganate ▪ Sugar ▪ Knife ▪ Dry tinder	GEAR
▪ Hold striker next to the tinder. ▪ Place the firesteel under the striker, directly onto the tinder. ▪ Draw the firesteel back across the striker to direct the sparks onto the tinder. The firesteel moves, not the striker.	▪ Follow instructions for the firesteel (left).	▪ Place the flint rod in the tinder. ▪ Press the thumb button onto the rod and push the handle down the length of the rod. ▪ Pushing harder creates greater friction, which leads to a more intense spark.	▪ Mix potassium permanganate and sugar in equal amounts on a hard surface. ▪ Press down on the mixture with your knife and drag the blade along to create a spark (see above).	WHAT TO DO
▪ Lasts for about 12,000 strikes. ▪ Temperature reaches 3,000°C. ▪ Works in all weathers and at any altitude.	▪ There are many variations and kits; one has a magnesium block for the holder and the striker shaves slivers of magnesium into the tinder to help with ignition.	▪ Works in all weathers. ▪ Has a safety feature that prevents accidental use. ▪ Designed for fighter pilots, who may injure an arm or hand after ejecting.	▪ You can also mix a small amount of potassium permanganate with glycol or antifreeze. Quickly wrap in paper and put on the ground. Warning: stand well clear as the combustion can be sudden and dangerous.	COMMENTS

TRUE-LIFE ACCOUNT

EXTREME SURVIVAL—IN THE DESERT

USEFUL EQUIPMENT

- Personal Locator Beacon (PLB)
- Sunglasses and sunscreen
- Cotton scarf or hat
- Signal mirror and signal flares
- Map, compass, GPS
- Survival tin, bushcraft knife
- Cell/satellite phone
- Poncho/bivy sack

DESPITE A LACK OF SURVIVAL KNOWLEDGE, a party of five survived searing temperatures, dehydration, hunger, and the threat of animal attack for six days when their plane crashed in the Kalahari Desert in Botswana.

On Wednesday, March 1, 2000, Carl du Plessis and three associates—Mike and Lynette Nikolic, and Nebojea Graorac—set off on a business flight from the capital of Botswana, Gaborone, bound for Maun, a popular tourist town in the north of the country. However, the aircraft developed engine trouble during the flight and was forced to crash-land. Critically, radio contact was lost, so no distress call was emitted before the plane went down. The pilot and all four passengers on board suffered burns during the crash and subsequent fire, but two sustained even more serious injuries—Lynette Nikolic damaged her spine and left arm, and Graorac suffered a punctured lung.

"CRITICALLY, RADIO CONTACT WAS LOST, SO NO DISTRESS CALL WAS EMITTED BEFORE THE PLANE WENT DOWN"

The following morning, Du Plessis and pilot Costa Marcandonatos decided to walk the estimated four days to Maun to find help. Their plan was misguided from the start—Maun was actually around some 190 miles (300 km) to the west, and other settlements to the east were much closer. They attempted to navigate by the sun but, lacking a machete, couldn't penetrate the dense bush. They were forced to follow elephant tracks to find watering holes, meeting elephants on one occasion, and heard the roar of lions at night. By Saturday they had walked 56 miles (90 km), but their zig-zag route had taken them only 20 miles (30 km) from the crash site.

Despite their mistakes, they stumbled upon a manned hunting lodge the following day. After their initial efforts to radio the authorities had failed, a helicopter finally reached the crash site on Monday, March 6, airlifting the casualties to hospital for emergency treatment six days after the crash.

WHAT TO DO

ARE YOU IN DANGER?

NO YES

If you are in a group, try to help any others who are in danger

Get yourself out of it:
Sun/Heat—Find or improvise immediate shelter
Animals—Avoid confrontation and move away from danger
Injury—Stabilize condition and apply first aid

ASSESS YOUR SITUATION

See pages 234–35

DOES ANYONE KNOW YOU WILL BE MISSING OR WHERE YOU ARE?

NO YES

If no one knows you are missing or where you are, you will need to notify people of your plight by any means at your disposal

If you are missed, a rescue party will almost certainly be dispatched to find you

DO YOU HAVE ANY MEANS OF COMMUNICATION?

NO YES

You are faced with surviving for an indefinite period—until you are located or you find help

If you have a cell or satellite phone, let someone know your predicament. If your situation is serious enough to be worthy of emergency rescue, and you have a Personal Locator Beacon (PLB), you should consider this option

CAN YOU SURVIVE WHERE YOU ARE? *

NO YES

If you cannot survive where you are and there are no physical reasons why you should remain, you will have to move to a location that offers either a better chance of survival, rescue, or both

Address the Principles of Survival: Protection, Location, Water, Food

YOU WILL HAVE TO MOVE **

DO

- Make an informed decision on the best location to move to
- Leave clear indications of your intent (written messages or signs) if abandoning a vehicle
- Have aids to location accessible while moving and deployed when static
- Protect yourself against glare from the sun and windburn
- Seek or improvise shelter when not moving and seize all opportunities to collect fuel for a fire—deserts get cold at night
- Be on constant lookout for signs of water or civilization—such as green vegetation, converging animal/human tracks, or circling birds

DON'T

- Sit directly on the hot ground when you stop
- Travel during the hottest part of the day
- Take risks—a twisted ankle caused by running down a sand dune could be fatal
- Force the pace—travel at the speed of the slowest person in the group
- Shelter in dry river beds, because of the potential risk of flash floods

YOU SHOULD STAY **

DON'T

- Leave a broken down vehicle unless absolutely necessary—it's easier to see and is what rescuers will be looking for
- Waste energy unnecessarily—be idle unless there is something that requires doing
- Ignore your fire—use anything that burns (wood, vehicle tires) to generate heat and smoke

DO

- Seek or improvise shade and work during the coolest part of the day/night. A shelter dug even 6 in (15 cm) below ground level will provide a much cooler place to rest
- Ration sweat, not your water; you require around $1^{3}/_{4}$ pints (1 liter) per hour in temps above 100°F (38°C), half of this if it's cooler
- Continually re-assess your water situation and options for augmenting your supplies
- Leave everything out overnight that could collect dew so you can drink it
- Prepare all of your aids to location for immediate use. Be constantly alert for signs of rescue

---

* If you cannot survive where you are, but you also cannot move owing to injury or other factors, you must do everything you can to attract rescue.

** If your situation changes (for instance, you are "moving" to find help, and you find a suitable location in which you can stay and survive) consult the alternative "Do" and "Don'ts."

FIRE BY FRICTION

THIS METHOD USES PRIMITIVE EQUIPMENT, such as a bow drill, and requires knowledge, skill, practice, the correct wood, time, and effort. However, once learned it's possibly the most rewarding of all survival skills. Your first fire created from a coal produced by a fireset that you have made yourself will be a fire you will never forget. In a genuine survival situation, however, you would always start a fire with the quickest and easiest method available.

TOOLS AND MATERIALS

- Cordage such as para cord, fishing line, shoelaces, or bailing twine
- Wood
- Knife
- Bradawl (optional)

THE FOUR SKILLS

There are many ways to make fire by friction, including a hand drill, bamboo fire saw (see p. 133), and bow drill. Each has its own advantages, depending on the materials available and your practical skills. Regardless of the method, however, there are four main elements to producing fire by friction—each a skill on its own:

- Identifying and procuring the correct types of wood.
- Manufacturing the individual pieces that make the fireset.
- Using the fireset to produce a coal.
- Nurturing the coal into a flame.

MAKING A BOW DRILL

The bow drill set is one of the most efficient methods of making fire by friction. Try to find the right type of wood for each part, especially the drill and hearth board (see Testing Wood, opposite).

1. To make the bow, cut a stick to the same length as the distance between your armpit and your fingertip.

- Cut a notch (or make a hole with a bradawl) near each end.
- Tie cord with an arbor knot (see pp. 142–43) to one notch and with half hitches (see pp. 144–45) to the other. Leave only enough slack to wrap around your finger.

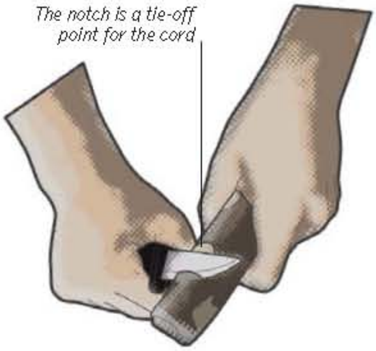
The notch is a tie-off point for the cord

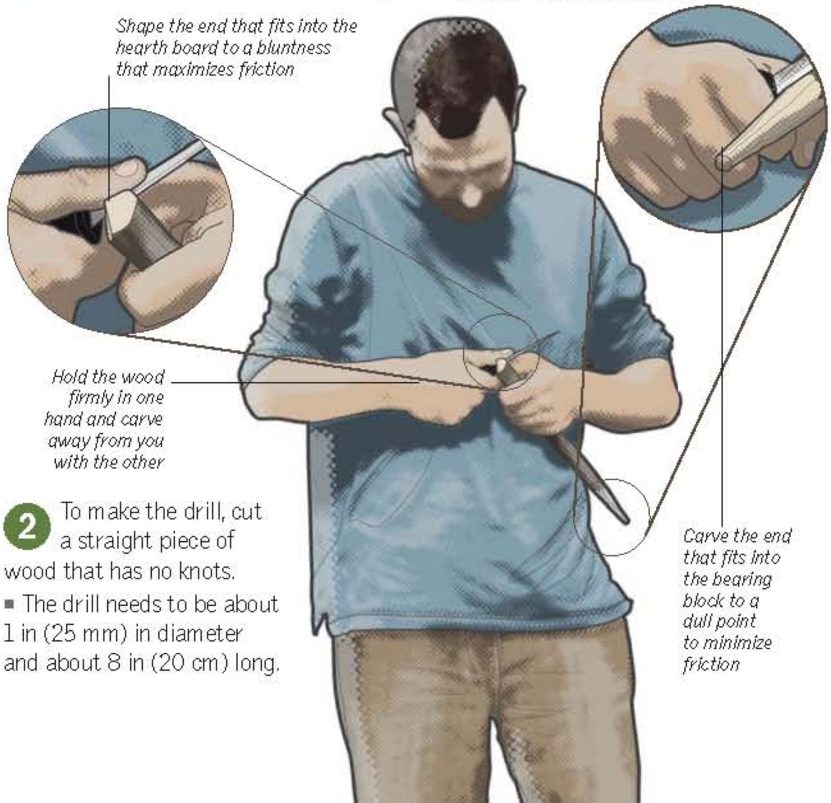
Shape the end that fits into the hearth board to a bluntness that maximizes friction

Hold the wood firmly in one hand and carve away from you with the other

Carve the end that fits into the bearing block to a dull point to minimize friction

2. To make the drill, cut a straight piece of wood that has no knots.

- The drill needs to be about 1 in (25 mm) in diameter and about 8 in (20 cm) long.

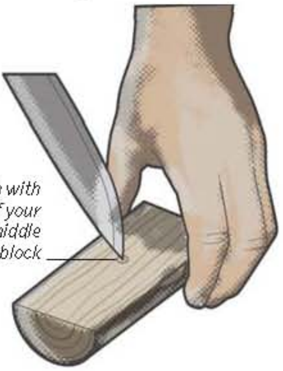
Make a notch with the point of your knife in the middle of the block

3. Make the bearing block from a piece of hard wood about 3–4 in (7.5–10 cm) across.

- Cut it to a length of 4–5 in (12–15 cm), split it in two, and make a notch in it.
- The drill's dull point fits into the notch, while you hold the block when you are bowing (see p. 132).

TESTING WOOD

Standing deadwood is ideal for the drill and hearth board as it's dry. Soft deadwood is easier to use than hard deadwood, but if you can't tell the difference, use these tests.

THUMBNAIL TEST

Cut through the bark of a branch, exposing a patch of wood beneath. If you dent this wood easily with your thumbnail, it's a soft wood. If you can only make a small impression, then it's a hard wood.

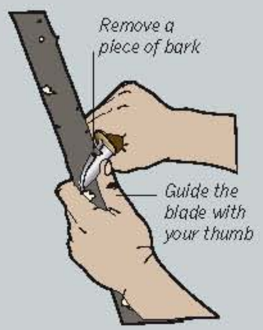
Remove a piece of bark
Guide the blade with your thumb

1 Hold your knife at a slight angle to the wood. Push it with a thumb on top of the blade.

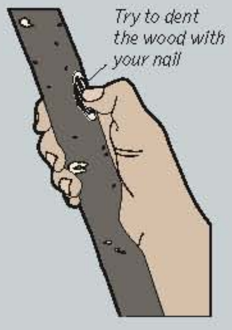
Try to dent the wood with your nail

2 Press your thumbnail at an angle of 90 degrees to the wood in the exposed patch.

CHAR TEST

Each type of wood produces a distinctive char and coal. Some, such as hazel and lime, make a coal easily but the fireset will wear out quickly. The char test helps you discover which woods make a good coal. Drill into a softwood hearth board until it smokes, continue for five seconds and then stop. Look at the char produced:

- If it's like a fine powder it will probably produce a coal.
- If it's coarse, or appears to disintegrate into nothing, it probably won't make a coal.

4 Make the hearth board from a flat piece of wood about 1 in (25 mm) thick. You may have to split some wood to get what you need.

- Hold your drill so that it sits about 2/5 in (10 mm) from the edge of the board.
- Mark this point with your knife and notch out a small hole to help the drill get started.

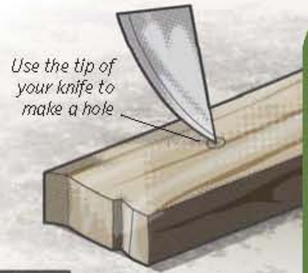
Use the tip of your knife to make a hole

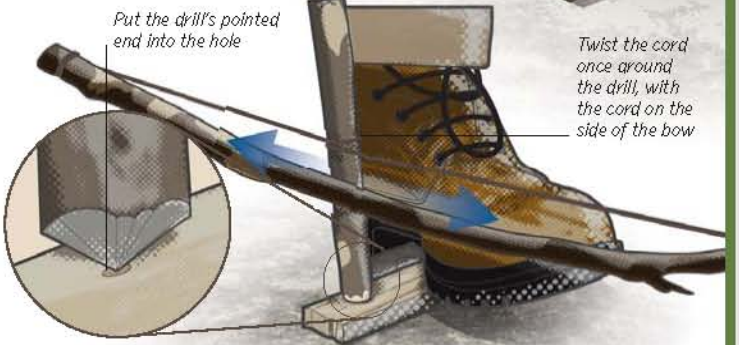
Put the drill's pointed end into the hole
Twist the cord once around the drill, with the cord on the side of the bow

5 Set up the bow, drill, and bearing block (see also p. 132) and bow the drill into the hole in the hearth board until the hole is as wide as the drill. Don't go all the way through.

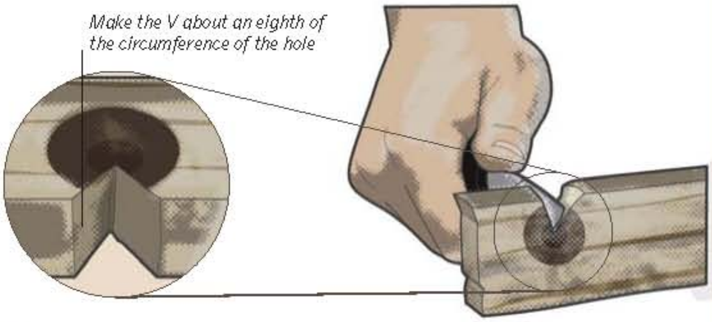
Make the V about an eighth of the circumference of the hole

6 Cut a V to the center of the hole through the hearth board. The bottom of this V is where the char collects and the ember forms in the ember pan (see p. 132).

THE FINISHED FIRESET

The bow drill set works best when the drill and hearth board are made from the same wood, because both parts then wear down evenly. This may not always be possible, so experiment with different woods.

- Good woods to start with are sycamore, hazel, ivy, lime, willow, and sotol (not found in Europe).
- Also useful are alder, birch, cedar, pine, spruce, maple, oak, and poplar.

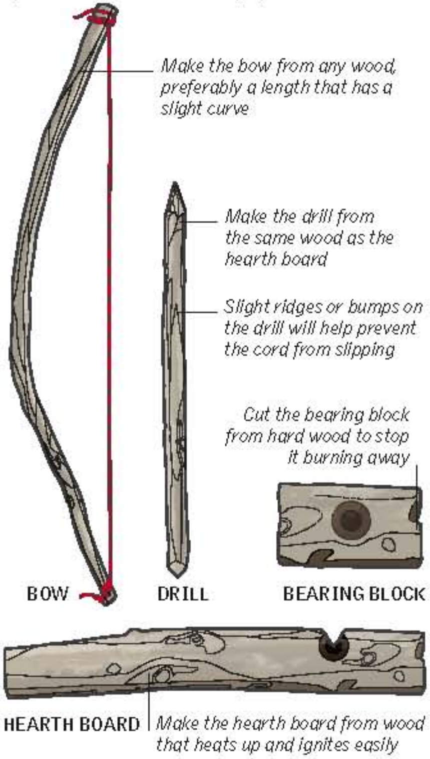
Make the bow from any wood, preferably a length that has a slight curve
Make the drill from the same wood as the hearth board
Slight ridges or bumps on the drill will help prevent the cord from slipping
Cut the bearing block from hard wood to stop it burning away
BOW
DRILL
BEARING BLOCK
HEARTH BOARD
Make the hearth board from wood that heats up and ignites easily

USING A BOW DRILL

Before you use a bow drill, have your dry tinder bundle, kindling, and fuel beside you. Until you become proficient at using a drill, you will use lots of energy, so beware of overheating and dehydration. Turning a coal into a fire is a skill in itself, so use every opportunity to practice making tinder bundles and lighting them with a small coal from your camp fire.

TOOLS AND MATERIALS

- Bow drill set (see pp. 130–31)
- Thin, dry piece of bark to use as an ember pan
- Buffed tinder, kindling, and fuel

GETTING INTO POSITION

Place the ember pan on a flat, dry surface and align it with the V on the hearth board. Rest one foot on the board. Loop the bow cord once around the drill, starting on the inside. Insert the drill into the hole on the hearth board, slot the block on top (with a green leaf in the notch for lubrication), and lock your wrist into your shin as support. Kneel on the other leg and bear down on the block.

1 Hold the bow horizontal to the ground and parallel to your body.

- Lean slightly forward to apply downward pressure to the drill and back to reduce it.
- Start bowing slowly, using the full length of the bow. Aim for an even, flowing rhythm.
- Breathing steadily as you bow, gradually increase speed and pressure until smoke appears. Vigorously bow with maximum effort ten more times—this usually produces a coal in the ember pan.

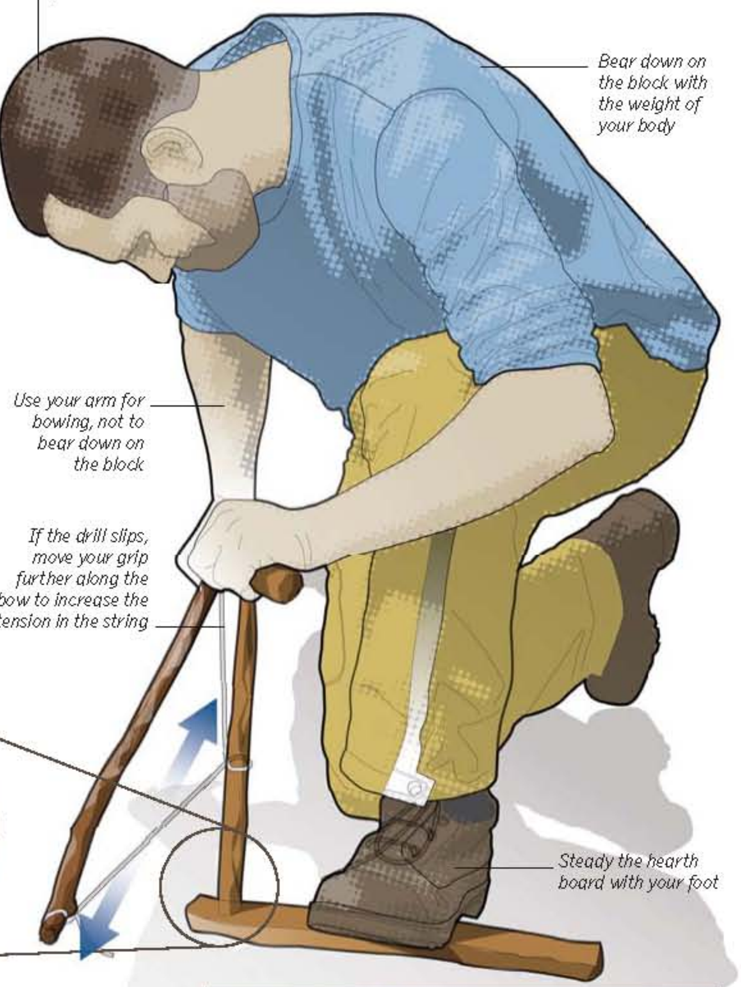
Keep your head as still as you can above the bow
Bear down on the block with the weight of your body
Use your arm for bowing, not to bear down on the block
If the drill slips, move your grip further along the bow to increase the tension in the string
Steady the hearth board with your foot

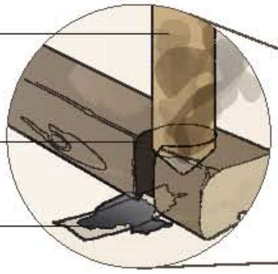
Keep the drill upright as you bow
As the drill turns, friction heats the wood
A pile of black ash will collect on the ember pan

2 Gently remove the drill and lift the hearth board up and away from the smoking coal in the ember pan.

- If the coal is sticking to the board, gently tap the board with your knife to loosen it.
- Carefully lift the ember pan off the ground and hold it in the air to see if the coal is glowing.
- If the coal in the ember is just smoking, and not glowing, then gently fan it with your hand until you see it glow.

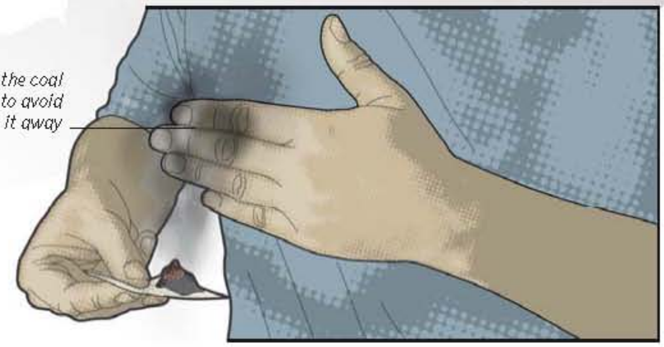
Fan the coal gently to avoid blowing it away

3 Gently transfer the glowing coal into your tinder bundle.

- The coal must touch the tinder to transfer its heat, so squeeze the tinder around the coal, but don't crush it or starve it of oxygen.

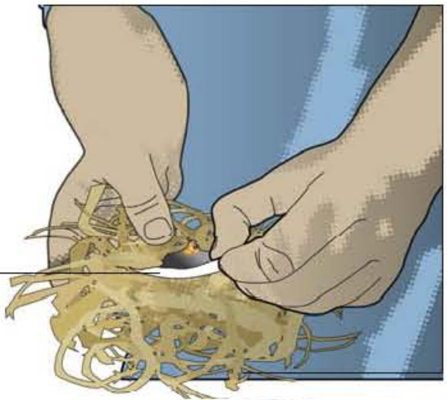
Tip the coal off the ember pan and into the center of the tinder bundle

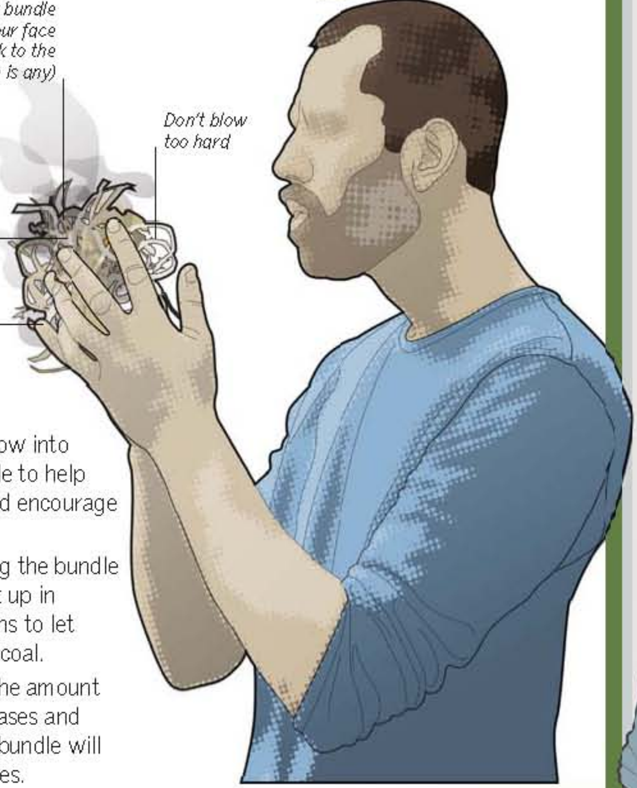
Hold the tinder bundle away from your face (turn your back to the wind if there is any)
Don't blow too hard
Air from your breath or the breeze helps with combustion
Hold the tinder bundle up, but not too close to your face

4 Gently blow into the bundle to help fan the coal and encourage it to catch.

- You can swing the bundle down and back up in between breaths to let dry air fan the coal.
- Continue as the amount of smoke increases and eventually the bundle will burst into flames.

5 Don't throw the burning bundle on the ground, just calmly place it where you intend to have your fire. Start building the fire around the bundle (see pp. 124–25).

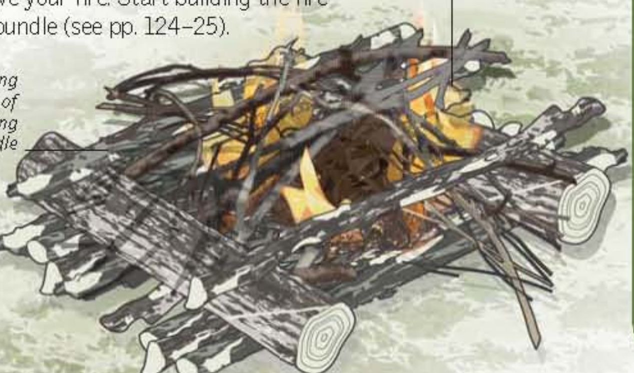
Once the kindling is set alight, you can add some fuel
Place kindling over the top of the burning tinder bundle

BAMBOO FIRE SAW

This friction method uses a saw technique to light tinder collected from scraping the outside of the bamboo with your knife.

MAKING THE FIRE SAW

You need a bamboo section 18 in (45 cm) long. Split it lengthways into two equal pieces.

1 Sharpen the edge of the first piece with your knife and then cut a V-shaped notch in the outside middle of the second piece.

2 Hold tinder over the notch in the second piece of bamboo with another bamboo strip that's snapped but not fully broken.

- Kneel down and brace the sharpened piece of bamboo vertically between the ground and your stomach (place a pad on your stomach for comfort).
- Place the notch and tinder over the sharp edge of the first piece, and rub the second piece up and down in a rhythmic movement.

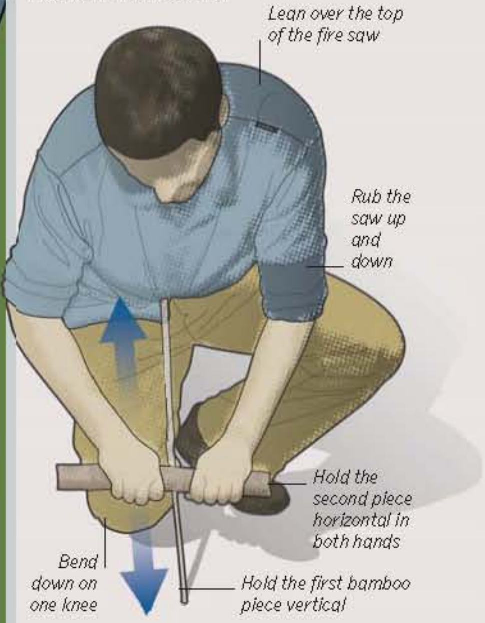
Lean over the top of the fire saw
Rub the saw up and down
Hold the second piece horizontal in both hands
Bend down on one knee
Hold the first bamboo piece vertical

3 When the friction produces lots of smoke, continue for 20 strokes more and you should have a coal.

MANUAL SKILLS

Learning skills that you can use in the wilderness is always a "work in progress." Having taught thousands of students over several years, I am yet to conduct a course in which I didn't learn a new skill. For example, this could be a more efficient way to erect a shelter, how to tie a new knot, or the best way to carry out a task more safely and efficiently.

In the military, we invariably teach students how to accomplish a particular task using only the most basic gear. By learning how to perform a task using the absolute basic equipment, they will be able to understand the important elements of the task and will have no choice but to get them right in order to succeed. This in turn helps students to appreciate how and why certain techniques do and don't work, and gives them an opportunity to use their improvisational skills to modify basic techniques in order to get the most out of them. Knowing the correct method of using a knife, for example, will not only improve safety on an expedition, but will also mean that only the minimum

In this section YOU WILL DISCOVER...

- the merits of a **hank** in **your pocket**...
- how to strip a **nettle stem** and not **get stung**...
- when **to twist** and when **to roll**...
- how to tell a **working end** from a **standing end**...
- the uses of a **sheet bend** or a **Siberian hitch**...
- the **difference** between a **parang** and a **kukri**...
- how to **fell a tree** with a **thumping stick**...

amount of valuable energy is being used to complete a task. Equally, knowing how to tie a few simple knots, which can be used in the majority of survival situations, will allow you to use whatever cordage you have in the most efficient way possible.

If you find yourself in a survival situation with more than the most basic gear, life will be much easier. However, the ability to improvise what you need when you don't have it could mean the difference between continued survival and despair.

If you give someone with little understanding of knots a length of cord and ask them to complete a task, they will invariably use the whole length of cord. If, however, you teach someone two simple knots and set them the same task, they will invariably use only the necessary amount of cord.

USING THE BEST KNOT, lashing, or hitch for a particular task means that you will use cord more efficiently and, therefore, ensure that your supply will go further. In a survival situation, where you may be moving every day, you need to be able to use the same pieces of cordage day after day.

- Use knots that don't require cutting and that can be untied quickly and easily (trying to undo a knot with cold, wet hands in the dark, and when you are tired and miserable, can be an emotional experience that usually ends in frustration and several pieces of cut cordage).
- Before you set off into the wilderness, learn a few basic knots, such as the Siberian hitch and the taut-line hitch, which are great for rigging a simple poncho shelter.
- Practice these knots until you can tie—and untie—them with your eyes closed.
- If you are trekking in a cold environment, practice tying them wearing gloves.

> “The **ability** to **improvise** what you **need** when you **don't have it** can mean the **difference** between **continued survival** and **despair**”

MAN-MADE CORDAGE

A VITAL PIECE OF SURVIVAL EQUIPMENT, man-made cordage is one of those small items that has many uses: building a shelter, repairing equipment and clothing, making traps and nets, and producing fire by friction using a bow drill. Always pack plenty.

PACKING CORDAGE

Before you set off on your travels, check how much cordage you will need. Make sure you pack it in two places—in your backpack and on your person, in case you get separated from your pack. Make sure, too, that the needle you pack in your survival kit has an eye big enough for the inner strands of the cordage.

PARACORD

Parachute cord, or "paracord," is a type of cordage originally developed for the rigging lines of parachutes and then adopted as the standard utility cordage by most of the world's military forces. It is a lightweight, nylon rope composed of 32 braided strands. Each strand contains a number of smaller threads that can also be used. In most situations, paracord is a very good option because it's readily available, strong, and packs down small.

SURVIVAL TIP

Green is the ideal color for military paracord as it remains camouflaged. In a survival situation, red is best because it stands out—it's easier to find if you drop it and can be used as an aid to location. Don't pack just one very long piece of paracord (150ft/30m, for example). It's much better to cut the paracord into 30 ft (10 m) lengths and tie each of them into a coil called a hank (see opposite and below).

TEN HANKS

A hank can fit in the palm of your hand. It takes up very little room so you can easily stuff up to 10 of them into your pack and pockets, and leave them there until you need them.

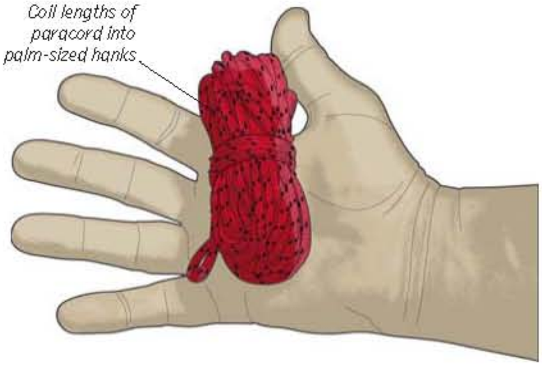
Coil lengths of paracord into palm-sized hanks

USING CORDAGE

It is vital that you use your limited supply of cordage as efficiently as possible.

- Use only the minimum cordage that is absolutely necessary to accomplish each task.
- Use simple, strong knots that, if possible, can be released without cutting. This leaves the cordage intact for the next task.

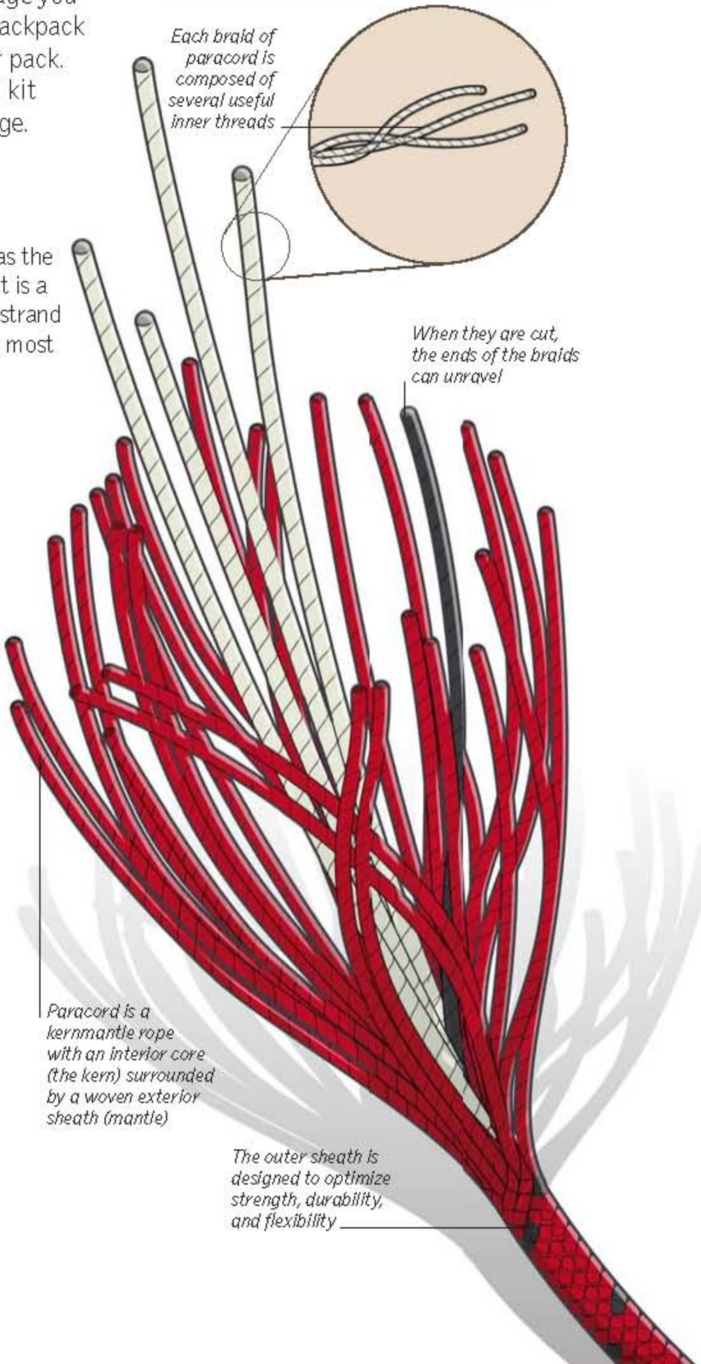
Each braid of paracord is composed of several useful inner threads
When they are cut, the ends of the braids can unravel
Paracord is a kernmantle rope with an interior core (the kern) surrounded by a woven exterior sheath (mantle)
The outer sheath is designed to optimize strength, durability, and flexibility

TYING A HANK

It's best to keep your cordage in a hank—you can untie it when you need a piece and retie it to store it again. Tying a hank is straightforward and soon becomes second nature, because you'll do it again and again.

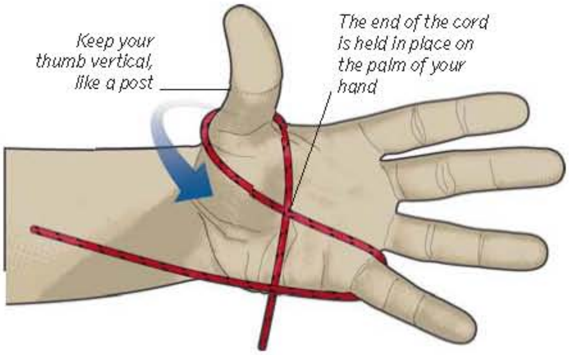
Keep your thumb vertical, like a post
The end of the cord is held in place on the palm of your hand

1 Hold out your hand (you can use either hand) with the thumb and the fingers spread.

- Lay the end of the cord on your palm, then loop the cord in a figure-eight around your thumb and little finger.

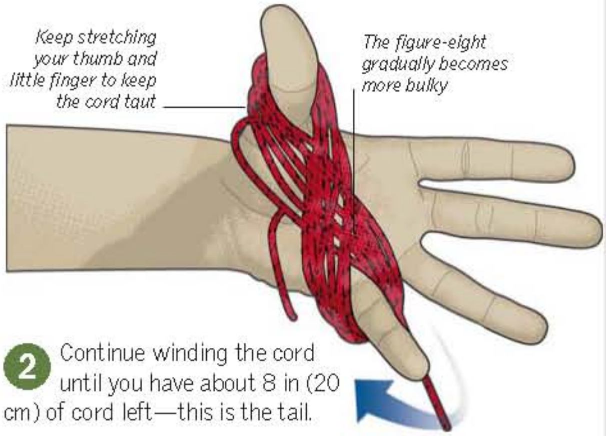
Keep stretching your thumb and little finger to keep the cord taut
The figure-eight gradually becomes more bulky

2 Continue winding the cord until you have about 8 in (20 cm) of cord left—this is the tail.

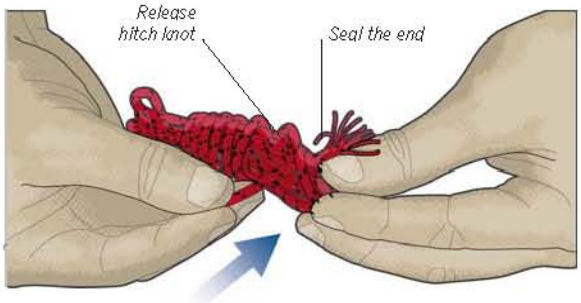

3 Take the hanked cordage off your thumb and little finger.

- Secure the hank by tying the tail around it with a release hitch knot (see p. 143).

OTHER TYPES OF CORDAGE

In a survival situation you may have to improvise and use other types of cordage, especially if you didn't bring any paracord with you or have run out. Before you start making it from natural materials (see pp. 138–41), see what else you might have that would be quicker and easier to adapt.

SHOELACES

The normal laces of shoes and boots are often strong enough to use as cord. However, the members of many military units, who are limited to the amount of equipment they can stow or carry, replace their bootlaces with paracord. They use twice as much as they need and wrap the extra length around the top of their boots before tying it. This gives them a ready supply of extra cordage that they can cut off as needed. You can easily do the same—but never sacrifice all the cordage you are using as shoelaces as you'll need to make sure you can still walk comfortably.

BELTS, CLOTHING, AND HATS

You can cut any type of belt, whatever it's made of (leather, canvas, and so on) into strips to use as cordage. You can cut clothing into strips, too. However, you don't have to destroy a shirt completely: start at the bottom hem and cut 1 in (2.5 cm) strips all the way round. You can even use your hat—a 1 in (2.5 cm) strip from the brim of a jungle hat is just over 3 ft (1 m) long. Better still, coil paracord around the crown of your hat and stitch it in place (just the front and the back).

RAIDING YOUR KIT

You may have other items in your equipment that you could use as cordage, such as guylines from tents or draw cords from clothing or sleeping bags. Dental floss, especially the waxed type, is extremely strong and can be used effectively for lashing or sewing. If you have a vehicle, you probably have a towrope; take a part of it and unravel the rope into smaller pieces of cordage.

BE A SCAVENGER

Few places are untouched by modern man. Even in remote areas you'll come across discarded items from the "civilized world"—from plastic bottles to bailing twine. In a situation where improvisation could be the difference between life and death, collect anything you could use to your advantage.

SEALING PARACORD

Paracord can be awkward to use because its ends, if left unprotected, eventually unravel. Try to seal the ends after you have cut them by holding a flame next to them until they melt. Be careful, as the melted nylon can drip and burn.

NATURAL CORDAGE

IF YOU DON'T HAVE any man-made cordage, you may be able to make a natural substitute. Use the roots and stems of plants to produce improvised rope for erecting shelters, and use sinew from the tendons of larger animals for strong whipping and sewing.

WARNING!
Take extreme care when you collect and work with plant fibers, especially removing plants such as green ferns from the ground. Bending a stem at its base and pulling it up can expose fibers that are razor-sharp. Cut the plant with a knife or wear gloves. The juice of some plants can irritate the skin, so wash your hands when you've finished.

PREPARING NETTLE FIBERS

Old stinging nettles or wood nettles with long stems have the most fibers. Wearing gloves (or with your hands covered), strip the leaves from the nettles by grasping the stem at the base and pulling your clenched fist up the full length of the stem.

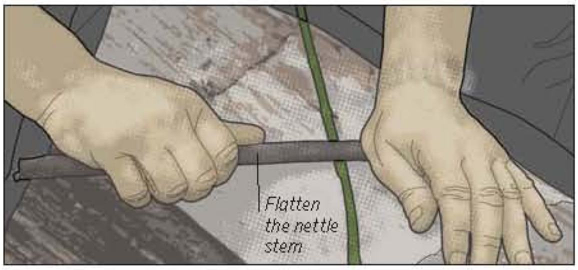

1 Sit astride a log and lay a nettle stem in front of you. Roll a smooth, rounded stick backward and forward on the stem, pressing down hard.

- Continue rolling until the whole stem is crushed.

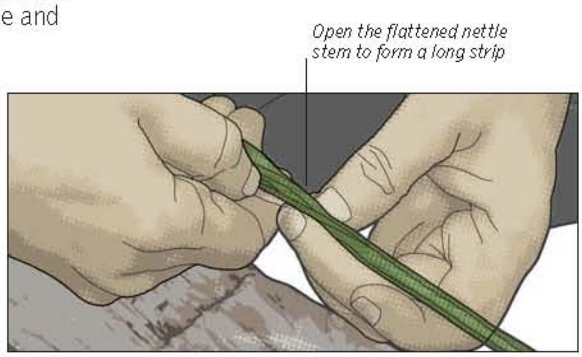
Open the flattened nettle stem to form a long strip

2 Tease open the crushed tissue along the whole length of the stem of the nettle with your thumbnail. This exposes the spongy pith within.

CHOOSING YOUR RAW MATERIALS

Many kinds of raw material can be used to make natural cordage, from bark and roots to stems and sinews. Search your immediate environment first to see what can be used—you may not have to look too far.

	BARK	ROOTS
FACTS	■ Tree trunks have layers between the bark and heartwood called the "cambium" layers, which are best for cordage.	■ Many tree roots make good cordage and lashings, but evergreen trees, such as pine, fir, spruce, and cedar, work best.
FINDING	■ The bark of trees such as willow and linden make good cordage. ■ Use other types of bark, such as clematis or honeysuckle, as they break from the tree or vine.	■ Look for new roots near the surface of the soil; these are flexible. Cut slightly thicker roots than you need, as you have to remove the bark. Remove only a few roots from each tree and repair any damage you do to the topsoil.
PREPARING	■ Strip the bark from a dead tree, then beat it to loosen the inner cambium fibers. ■ Pull off the cambium fibers in long strips. Use them as they are (clematis and honeysuckle), or braid them into stronger lengths.	■ Cut a slit along the root. Peel the bark and let the bare root dry and shrink before splitting in half or into quarters. ■ Keep the bark for tinder or kindling. You could also put it on a fire to produce smoke that keeps away flies.

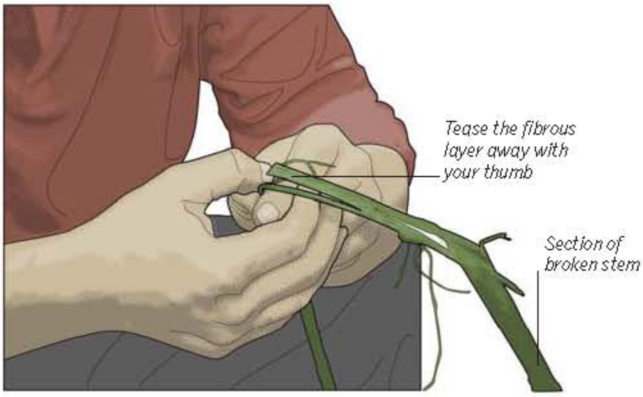

Tease the fibrous layer away with your thumb

Section of broken stem

3 Bend the stem in the middle of its length. When you bend it, the inner pith will break away from the outer skin, making it easy for you to separate them.

MAKING CORDAGE FROM PLANTS

To begin with, you must have access to enough quantities of the plant. Don't start making cordage with the only plant in the area. There should also be some basic characteristics present in order for plant material to work well as cordage.

- The fibers need to be long enough. If you have to splice them together to make workable lengths, you will weaken the line.
- If you're braiding pieces together to make a stronger line, use rougher fibers, as they will bite together better. Shiny or smooth fibers tend to unravel easily.
- The fibers need to be strong. Pull on them to see how much strain they take before breaking. They also need to be pliable enough so they don't break when you bend and tie them.

4 Carefully peel the outer skin from the inner pith.

- With the finger and thumb of one hand, gently pull the layer outward, while pushing down on it with the thumb of the other hand.
- You'll be left with long fibrous strips of outer skin, which you can make into short bindings or natural cordage (see p. 140).

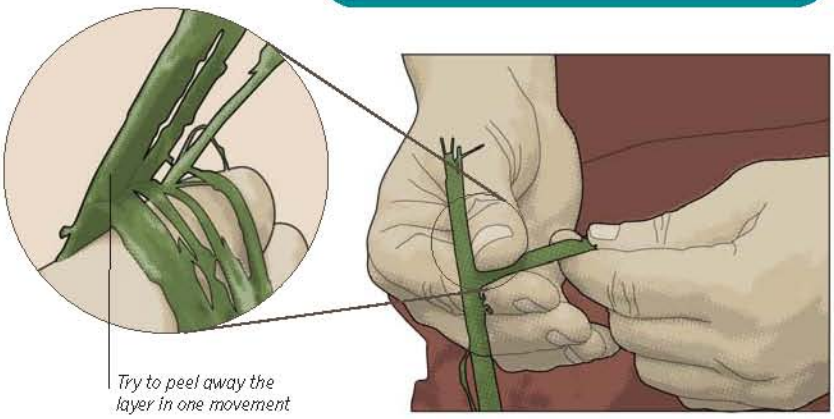

Try to peel away the layer in one movement

	WITHIES	LEAVES	SINEW
FACTS	■ The strong, flexible stems of willow, birch, ash, and hazel are called "withies" and are used for thatching and in gardening. ■ Withies make useful and robust lashing and are best used in spring or summer.	■ The leaves of many plants, such as the lily family, agave, and sisal hemp, contain useful fibers.	■ Animal sinew makes strong and versatile cordage—some sinews can support the weight of a man. ■ Sinew has been used to bind arrow heads to shafts and to sew together everyday clothing, such as leather and mulduks.
FINDING	■ Choose a young sapling or branch that's long and flexible. The fewer the stems or branches the better, as they will need to be removed.	■ To find out if the leaves of a plant contain useful fibers, simply tear a leaf apart to see if it breaks into stringy layers.	■ Sinews are the tendons connecting bone to muscle. The largest are on both sides of the spinal column, running parallel to it. ■ Shorter lengths can be taken from the calves of the hind legs.
PREPARING	■ Remove stems or branches. Grasp the wand at the base and twist until the fibers break, working your way to the tip. Bend the wand into an S-shape and crank the middle of the wand to loosen the fibers. Then cut the wand from the tree and use the withies.	■ Soak the leaves in water to make the inner layers swell and burst. Bacteria work on the cell tissue, separating it from the fibers. ■ Rinse the fibers in fresh water to stop further bacterial decay and then dry them.	■ Take a tendon from an animal's body, remove its outer sheath, then clean it and let it dry. Separate the dried fibers and use them as individual threads, or splice or braid them together to form stronger cords. You can soften dried sinew with water or saliva.

MAKING NATURAL CORDAGE

Once you have prepared a sufficient quantity of fibers, it's best to let them dry before using them—hang them up in the sun or near a fire. In a survival situation, you can use them before drying. Twisting or rolling the fibers are the two main methods of making natural cordage. As with most survival tasks, practice makes perfect.

TOOLS AND MATERIALS
Enough prepared natural fibers (see pp. 138–39) to give you the length of cordage that you require

TWISTED CORDAGE

Start your first length of cordage toward one end, not in the middle, to prevent all the subsequent splices from coinciding at the same point. This provides strength, as each splice is a potential weak point. If they are thin enough, the twisted cordage fibers can then be plaited to create a thicker cord that's even stronger.

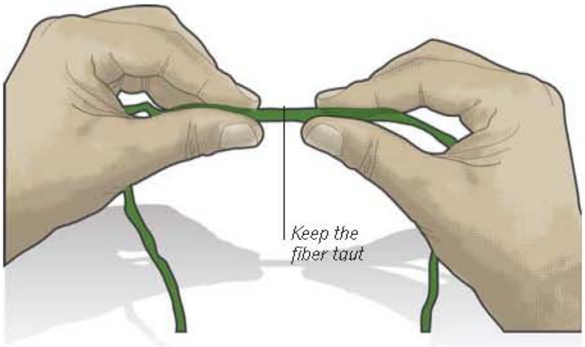

1 Grip the first length of fiber a third of the way along its length between your left thumb and forefinger.

- Grasp the fiber with the thumb and forefinger of your right hand 1 in (3 cm) from your left.

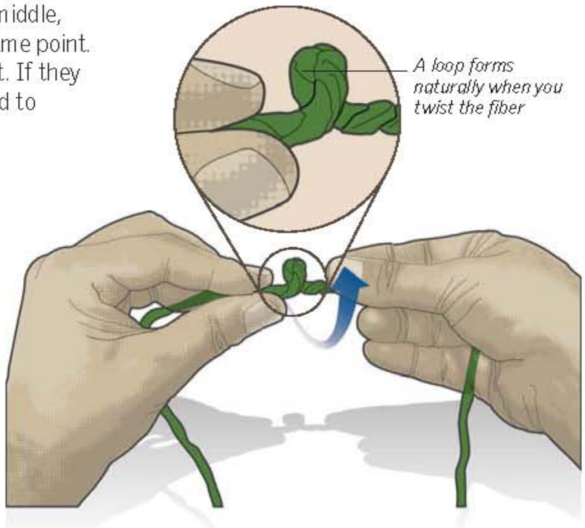
A loop forms naturally when you twist the fiber

2 Twist the fiber with your right hand until a tight loop is formed.

- Keeping the tension in the cord, inch your left thumb and forefinger forward and clamp down on the loop.

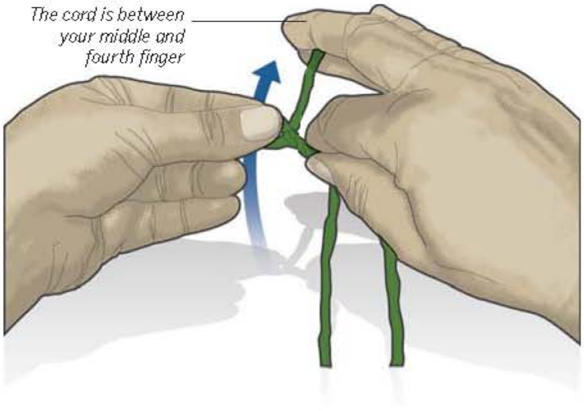
The cord is between your middle and fourth finger

4 Sweep the middle and fourth fingers of your right hand upward, pulling the left-hand cord under the captive piece.

- Inch your left thumb and forefinger forward, and clamp down on the new twist.

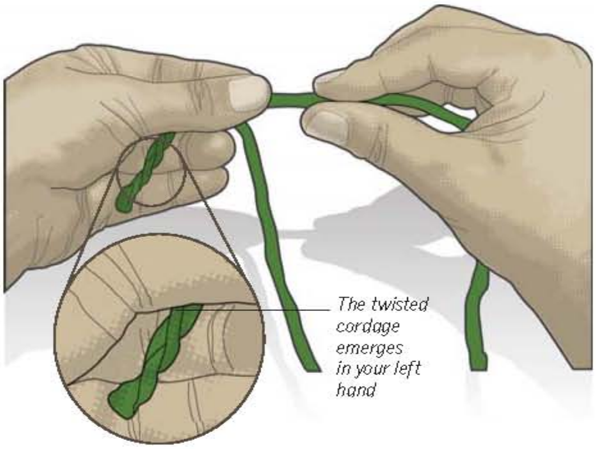
The twisted cordage emerges in your left hand

5 Now that the new twist is clamped by your left hand, you can release your right thumb and forefinger, letting the lower cord fall.

- Grip the upper cord 1 in (3 cm) from your left fingers with your right thumb and forefinger.

SIMPLE ALTERNATIVE TWIST

You need to start with two fibers of different lengths so that when you splice on additional lengths the splices are staggered. Start by tying one end of one fiber with one end of the other.

- Clamp tied ends in your left thumb and forefinger and the two tails in your right thumb and forefinger about 2 in (5 cm) down.
- Roll both fibers between your fingers away from you for one complete roll. Repeat this until you have about 3 in (7.5 cm) of rolled fibers, then clamp them in your right thumb and forefinger.
- Release your left thumb and forefinger and the rolled fibers will naturally twist together to form a strand of cordage.
- Repeat the process until you have enough for your needs.

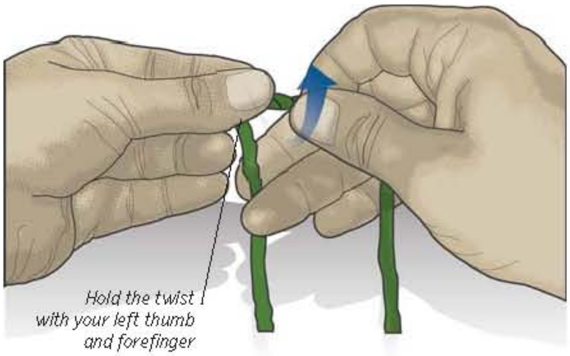
Hold the twist with your left thumb and forefinger

3 Move your right hand back so that 1 in (3 cm) of cord is visible and apply another twist.

- At the same time reach forward with the middle and fourth fingers of your right hand and grasp the cord hanging from your left fingers.

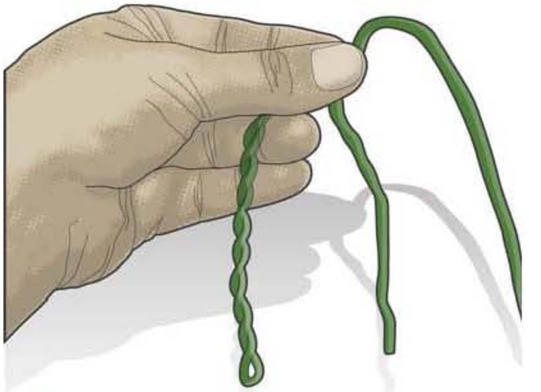

6 Repeat Steps 3, 4, and 5 as you work your way along the length of cord.

- To splice in an extra length, overlap the new piece 2 in (6 cm) along the existing fiber and twist the two together between your left thumb and forefinger. Then continue with the process as before.

ROLLED CORDAGE

This method of rolling cordage, which is also known as the "pygmy roll," is easier to do if you're sitting down. As with the simple alternative twist (see left), you need to start with two fibers of different lengths and tie one end of one fiber to one end of the other.

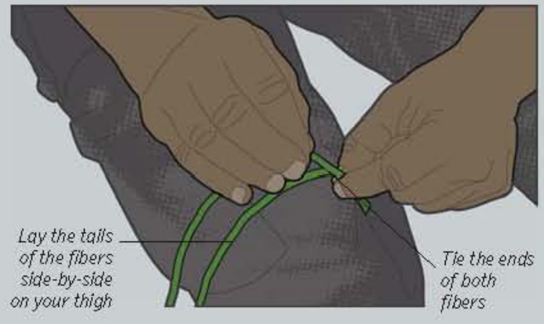
Lay the tails of the fibers side-by-side on your thigh
Tie the ends of both fibers

1 Hold the tied ends between the thumb and forefinger of your left hand.

- Lay the two tails of the fibers on your right thigh.

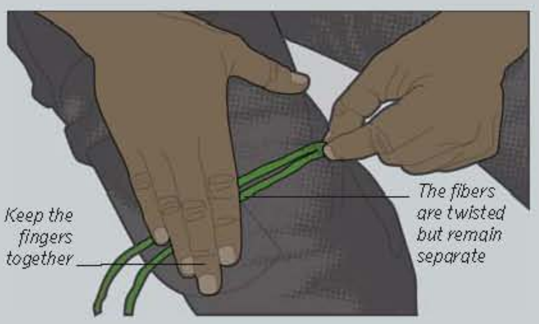
Keep the fingers together
The fibers are twisted but remain separate

2 Use the flat palm of your right hand to roll both fibers simultaneously away from you. You may find it easier to use the flat of your fingers.

- At the end of the roll, clamp the fibers down onto your thigh with the tips of your fingers.

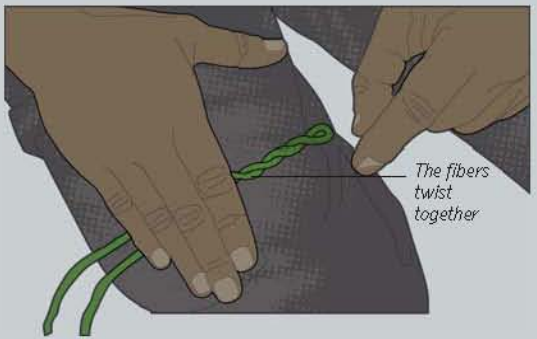
The fibers twist together

3 Release your left thumb and forefinger and the rolled fibers will naturally twist together to form a strand of cordage.

- Repeat the process, splicing in more cordage as required.

TYING KNOTS

THERE ARE HUNDREDS of different types of knot in existence, but by practicing the handful of straightforward knots shown here and overleaf, you should be able to accomplish most survival tasks. Start by tying each knot in the situation you expect to use it—for example, erecting a poncho shelter—and then practice it at least 20 times.

THE ENDS OF A LINE

The end of a rope or line that takes the most active part in knot tying is the working end. The other end is called the standing end—it's more passive, as the knot is tied around it.

SLIP KNOT

A slip knot is a good example of a simple knot that has many practical uses in survival situations.

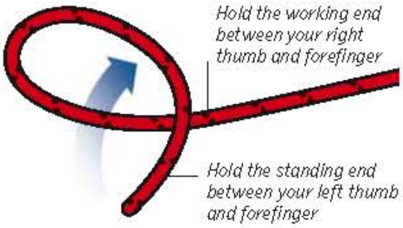
Hold the working end between your right thumb and forefinger
Hold the standing end between your left thumb and forefinger

1 Twist the standing line over the working line to form a loop.

- Hold the loop between your left thumb and forefinger.

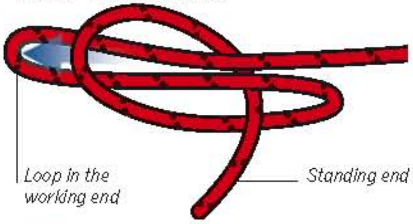
Loop in the working end
Standing end

2 Make a loop with the working end and pass it into the first loop.

- Collect the second loop with your left thumb and forefinger and pull it through.

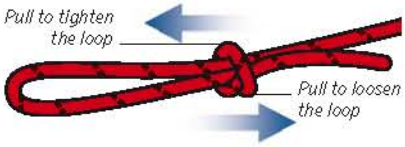
Pull to tighten the loop
Pull to loosen the loop

3 Gather both ends in your right thumb and forefinger and pull them away from the loop in your left hand.

- Put the loop over whatever you want to secure—for example, a button-tie on your bivy sack—and pull the knot tight.

ARBOR KNOT

This all-purpose knot has several survival uses. When erecting a poncho or a tarp (see Chapter Four), it can be used as a tie-off knot to secure one end of a line to a fixed point, such as a tree or peg, where no adjustment is required. It can also be used as a lashing to secure two poles together—for example, in an A-frame shelter (see p. 164)—with just one turn of cordage.

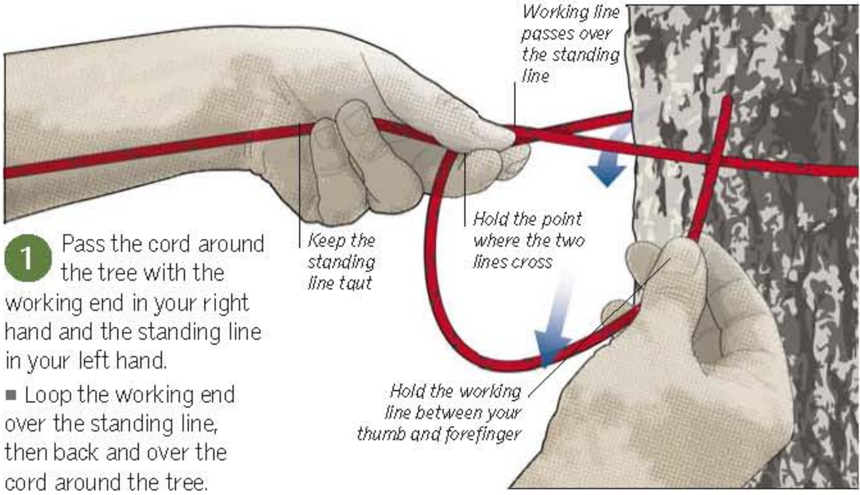
Working line passes over the standing line
Keep the standing line taut
Hold the point where the two lines cross
Hold the working line between your thumb and forefinger

1 Pass the cord around the tree with the working end in your right hand and the standing line in your left hand.

- Loop the working end over the standing line, then back and over the cord around the tree.

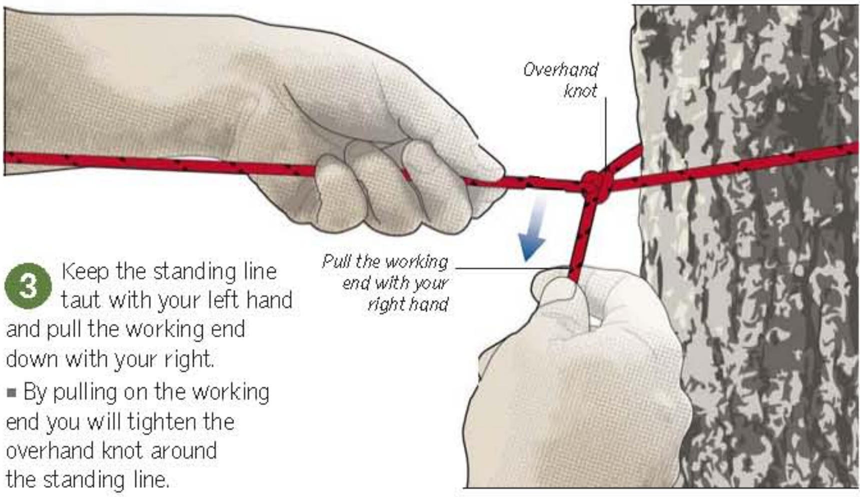
Overhand knot
Pull the working end with your right hand

3 Keep the standing line taut with your left hand and pull the working end down with your right.

- By pulling on the working end you will tighten the overhand knot around the standing line.

OVERHAND KNOTS

An overhand knot is the first part of the knot you use to tie the laces on your shoes. One overhand knot tied around another forms a stop knot or they can be tied as a double overhand knot around a fixture.

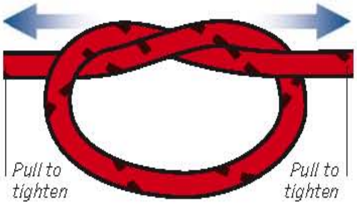
Pull to tighten
Pull to tighten

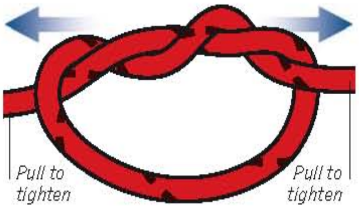
Pull to tighten
Pull to tighten

OVERHAND KNOT

Twist the left line over the right to form a loop. Hold it with your right thumb and forefinger.

- Pass the working end through the loop with your left forefinger and thumb and pull both ends to tighten.

DOUBLE OVERHAND KNOT

Follow the sequence for the overhand knot (left), but pass the working end through the loop twice before pulling the two ends.

- A stop knot used at the end of a line can stop the line from slipping.

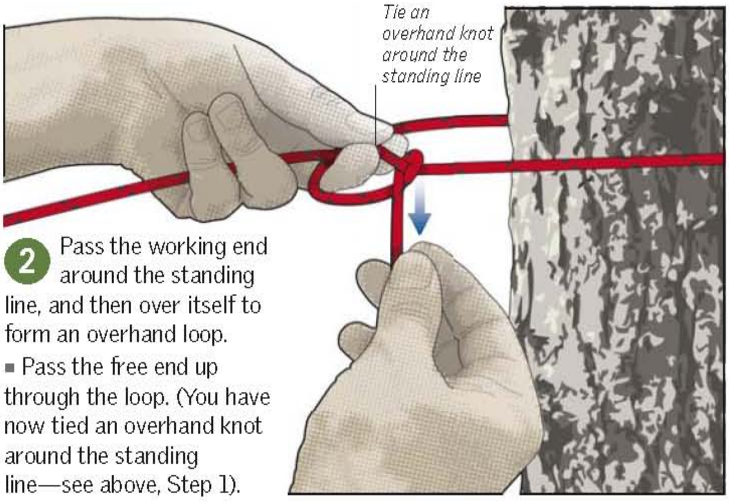
Tie an overhand knot around the standing line

2 Pass the working end around the standing line, and then over itself to form an overhand loop.

- Pass the free end up through the loop. (You have now tied an overhand knot around the standing line—see above, Step 1).

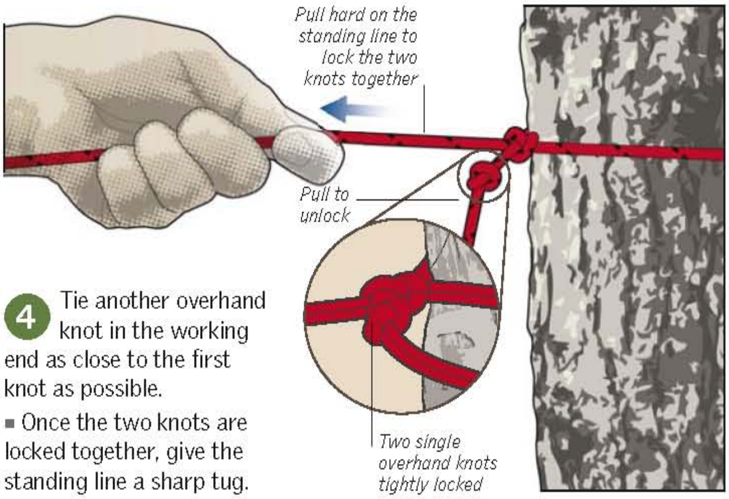
Pull hard on the standing line to lock the two knots together
Pull to unlock
Two single overhand knots tightly locked

4 Tie another overhand knot in the working end as close to the first knot as possible.

- Once the two knots are locked together, give the standing line a sharp tug.

DOUBLE CHAIN FASTENING KNOT

This knot securely attaches the free end of a line to a fixture, particularly when weight is involved and you don't want the knot to slip or come loose.

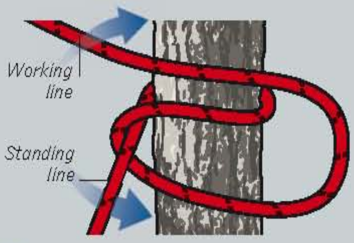
Working line
Standing line

1 Loop the working end around the fixture, such as a tree or pole.

- Pass the working end over and around the standing line.

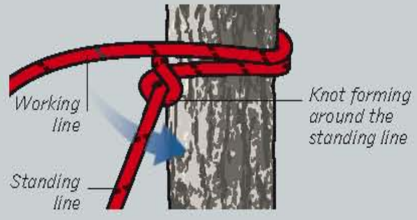
Working line
Knot forming around the standing line
Standing line

2 Pass the working end back around the fixture and then bring it back under the standing line.

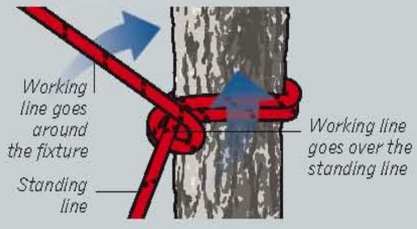
Working line goes around the fixture
Working line goes over the standing line
Standing line

3 Pass the working end over the top and around the standing line again, and once more around the fixture.

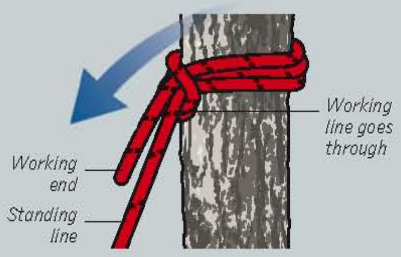
Working line goes through
Working end
Standing line

4 As you bring round the working line, thread it underneath itself to complete the knot.

- Lock the knot neatly into position.

DOUBLE SHEET BEND

The sheet bend, also known as the "weaver's hitch," is an extremely useful survival knot as it securely ties together two ropes. Double sheet bends are even more secure and are recommended for tying ropes of different thickness. In this instance you use the thinner of the two ropes to tie the knot.

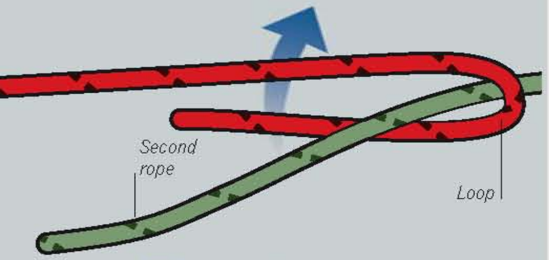

1 Start with two ropes and form a loop in the working end of one of them.

- Pass the end of the second rope through the loop.

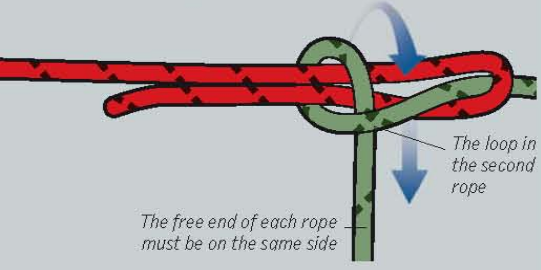
The loop in the second rope
The free end of each rope must be on the same side

2 Pass the free end of the second rope first under, then up and over the loop. Pass the end through the new loop you have created.

- To finish a single sheet bend, pull the standing end of each rope to tighten it.

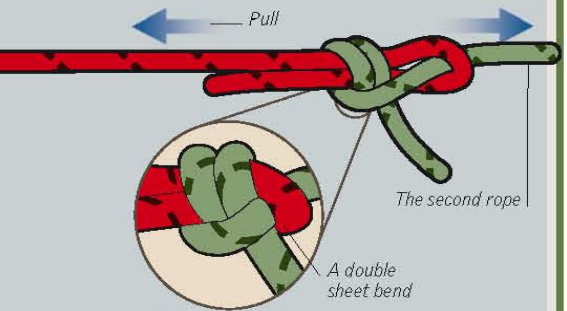

3 To tie a double sheet bend, pass the free end of the second rope through the loop (as in step 2) again.

- Tighten the knot as before by pulling the free end of each rope.

SIBERIAN HITCH

This knot, which is also known as the "Evenk knot," is good for attaching a rope to a fixture—for example, when securing a ridgeline to a tree for a poncho shelter (see p. 158).

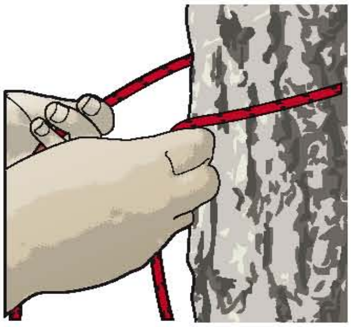

1 Pass the cord around the tree with the working line in your right hand and the standing line in your left hand.

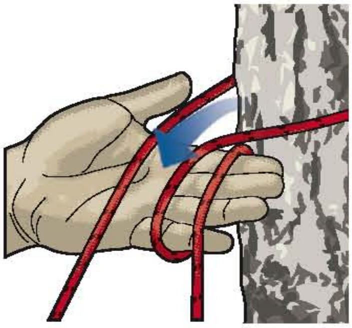

2 Lay the standing line on the palm of your left hand.

- Loop the working line one and a half times around your fingers.

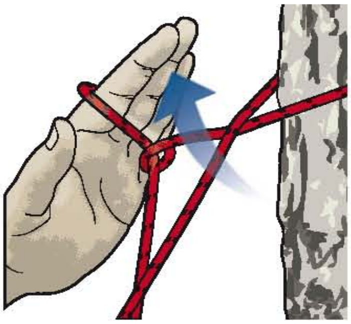

3 Bring your left hand under the standing line.

- Turn the palm of your hand so that one loop twists over another.

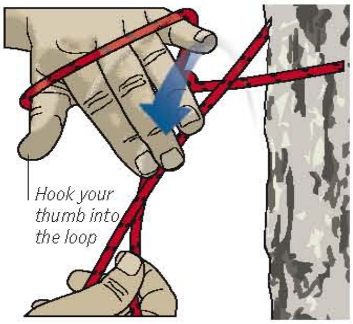
Hook your thumb into the loop

4 Hold the working end in your right thumb and forefinger.

- Bring the loop that is around your left fingers over the standing line.

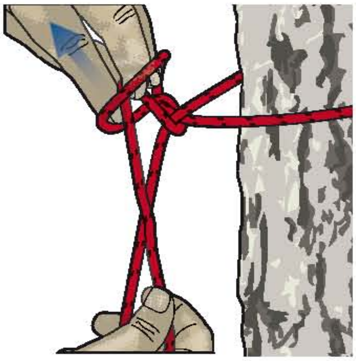

5 Pinch the working line with the fingers of your left hand.

- Pull it up through the loop to tighten the knot on itself.

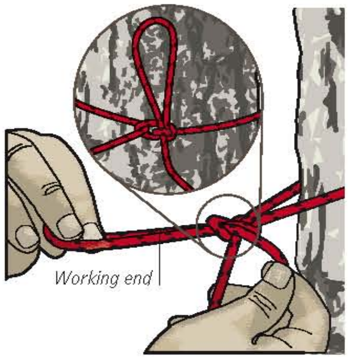

6 Pull the working end again, to tighten the knot around the tree.

- To free the knot, pull the end of the standing line.

TAUT LINE HITCH

This knot is widely used in survival and outdoor activities because it can be adjusted to increase or decrease the tension in a fixed line—for example, a guide rope on a tent or a mooring on a boat in tidal waters.

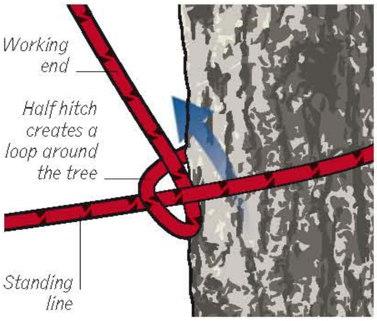
Working end
Half hitch creates a loop around the tree
Standing line

1 Attach the standing line to an anchor point, such as a tent, and pass the working line around a tree.

- Tie a half hitch (see below) with the working end around the standing line.

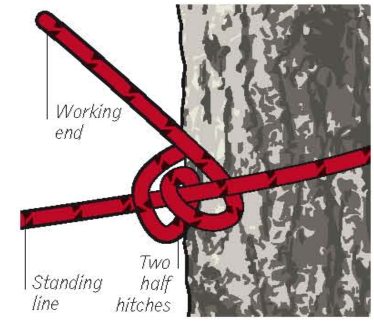
Working end
Standing line
Two half hitches

2 Tie another half hitch next to the first one, so that the two half hitches sit side by side around the standing line.

- Don't tighten the half hitches yet.

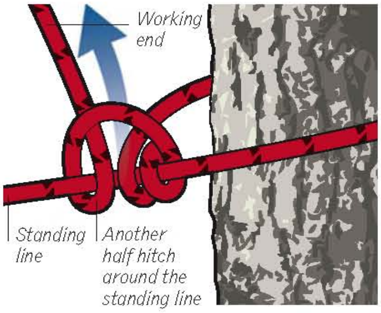
Working end
Standing line
Another half hitch around the standing line

3 Pass the working end under the standing line and back through the new loop it created (but outside of the loops in Steps 1 and 2).

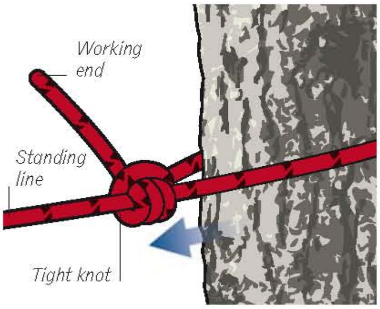
Working end
Standing line
Tight knot

4 Tighten the knot by pulling both the lines.

- Pull the knot further from the anchor point to increase the tension.

QUICK KNOT RELEASE

You can dismantle a tent or free a boat from its mooring more quickly by finishing off the taut line hitch (see left) with a quick-release knot.

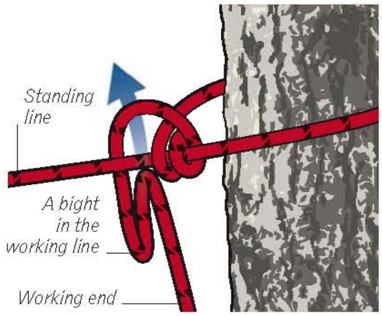
Standing line
A bight in the working line
Working end

1 Repeat Step 3 of the taut line hitch (see left), but this time make a loop, known as a "bight," in the working line and pass it—rather than just the end—through the loop.

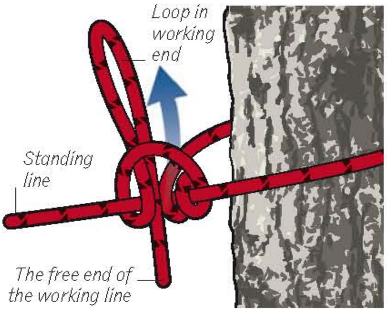
Loop in working end
Standing line
The free end of the working line

2 Tighten the knot as in Step 4 (see left).

- Leave the working end free so you can pull it quickly to release the knot.

HALF HITCH

The half hitch is a simple knot that forms the basis for other knots (see taut line hitch, above). It's not a secure knot and, when used alone, it tends to slip. You can double or treble the knot to remedy this. Two half hitches under tension can be difficult to undo without cutting the cord, especially after a few days, if the knot has dried out after being wet.

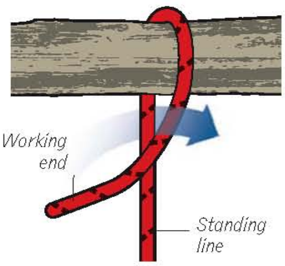
Working end
Standing line

1 Pass the cord around the fixture, such as a bar or tree.

- Pass the working end around the standing line and back through the loop.

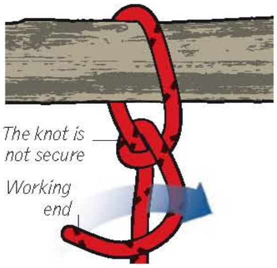
The knot is not secure
Working end

2 Hold the standing line and push the half hitch knot toward the fixture to tighten it.

- Repeat the sequence and tie another half hitch.

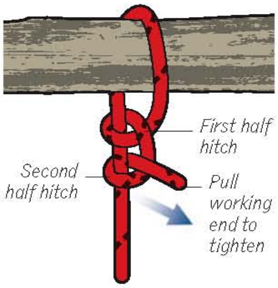
First half hitch
Second half hitch
Pull working end to tighten

3 Push the second knot tight to the first hitch knot for more security.

- If you need to, finish off the working end with an overhand knot (see p. 143).

USING CUTTING TOOLS

ANYONE VENTURING INTO THE WILDERNESS should carry some kind of knife, preferably a bushcraft knife. It's probably the most important survival tool after knowledge. Although a good knife will help you through many survival situations, look at the environment you are traveling to and choose your cutting tools according to their potential uses—for example, you may need a saw as well as a knife.

WARNING!
If you drop a bushcraft knife, never attempt to catch it because there's a very good chance you will lose your fingers!

BUSHCRAFT KNIFE

An experienced person can accomplish most survival skills, such as making feather sticks (see pp. 120–21), with a quality bushcraft knife. This type of cutting tool has a number of crucial features that will stand you in good stead in every situation.

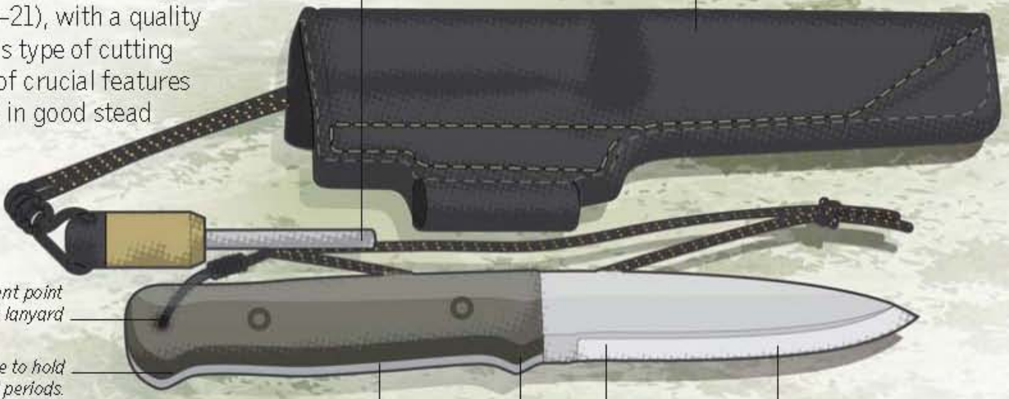
A firesteel that fits into your sheath means that, as long as you have your knife, you can also get a fire going
Fitted leather sheath holds the knife securely
Attachment point for a wrist lanyard
The handle is comfortable to hold and work for extended periods. Avoid ribbed, rubber handles
Blades that extend through to the end of the handle (full tang) have no weak points
Sharpened blade ends near the handle – working close to the handle puts less strain on your wrist
Blade is $^{3}/_{16}$ in (4 mm) thick and made of stainless or high-carbon steel
The guard is a ridge in the handle that reduces the chance of your hand slipping on to the blade

LARGE KNIVES

All over the world, people living primitive lives have two essential items: a cooking pot and a large working blade, either a parang or machete.

- Parangs and machetes are similar types of knife. The parang is associated with the Malay people and there are many varieties available. Machetes are more common—you can still see machetes being used in Africa today that were made 40 years ago from old Landrover suspension springs! The kukri is a similar knife used by the Ghurkas of Nepal.
- A parang or machete blade is about 18–20 in (45–50 cm) long and is used primarily for cutting and slashing but, like the ax, can be used for intricate work.
- Always wear a wrist lanyard when using a machete, parang, or kukri—and pay attention to what you are doing.

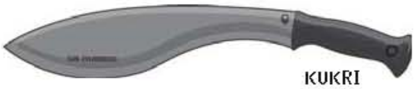

KUKRI

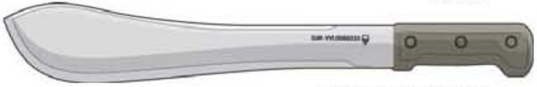

MACHETE/PARANG

KNIFE KNOW-HOW

- A bushcraft knife is used primarily for carving, cutting, and splitting small logs. If you need to chop large logs, use either a machete or a saw.
- A knife doesn't need to be longer than 8–9 in (20–22.5 cm).
- Don't use a knife with a serrated edge when working with wood, as the serrations make it hard to use the part of the blade closest to the handle (essential for making feather sticks, etc).
- Keep your knife safe when not in use. Clean and dry the blade and return it to its sheath.
- Wear your sheath on your belt or around your neck on a lanyard. Belt sheaths may be high (the handle is above the belt) or low (the handle is below the belt, which allows you to sit down without the handle poking you in the side).

SHARPENING A KNIFE

It's very important to keep the blade of your knife sharp. Blunt blades are dangerous because they are likely to bounce or slip off the wood you're working on. Also, blades that have completely lost their cutting edge are very difficult to sharpen.

SHARPENING STONES

Keep a good sharpening stone at home to ensure you always set out with a knife that is sharp.

- In the field, carry a smaller, lightweight device for quickly re-sharpening a blade that is beginning to lose its edge.
- There is a good range of small sharpening stones (medium one side, fine the other) that fit into a neat leather pouch.
- Small automatic sharpeners are available to buy that use two sets of ceramic stones to sharpen a knife pulled between them.

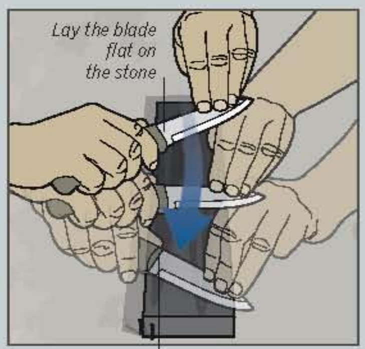
Lay the blade flat on the stone
Raise the back of the blade to lay the edge on the stone

1 Hold the knife in a forehand grip, with the blade pointing away from you. Support the tip of the blade with the thumb and fingers of your other hand.

- Push the knife so the full blade arcs over the stone in one sweep.
- Lift the blade and return to the start, repeating the action 6–8 times.

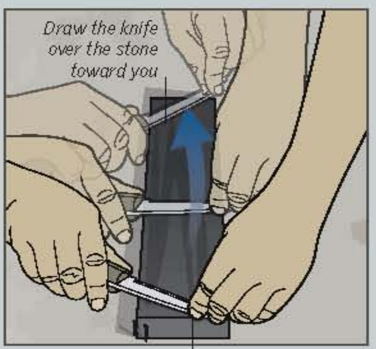
Draw the knife over the stone toward you
Start from the far end of the stone

2 Repeat the sequence for the other side of the blade, but reversing the crucial elements.

- Hold the knife with a backhand grip, with the blade pointing toward you at the far end of the stone.
- Pull the knife in an arc over the stone in one draw. Lift and return to the start, repeating the action 6–8 times.

WORKING WITH YOUR KNIFE

The way you hold your bushcraft knife can help you accomplish a variety of cutting tasks easily and safely. There are several essential grips, including the forehand, backhand, and chest lever. In most cases, you need to grip the handle firmly at the end nearest the blade so that you can cut with the part of the blade nearest the handle.

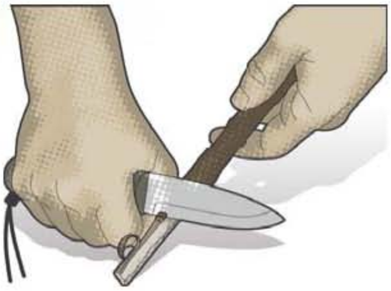

FOREHAND GRIP

This grip is the most natural and the one most often used. It allows your back and arm to provide the power and strength, while your wrist provides the control. Placing one or both thumbs on the back of the blade allows you additional control for finer, more detailed work. Make sure the blade is facing down. Otherwise you are likely to give yourself a serious cut.

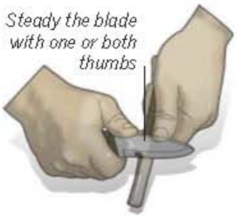
Steady the blade with one or both thumbs

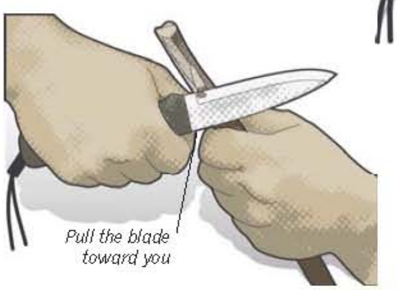
Pull the blade toward you

BACKHAND GRIP

This is the same as the forehand grip, except the blade faces up toward you. You can use it when you want to see and control exactly where the blade is going, or when you're cutting something and a follow-through would injure you—for example, when sharpening a stick.

CHEST LEVER

This is an extremely effective technique in which you hold the knife in a backhand grip and use the muscles of your arm and chest to provide power and strength. You can cut close to your body while your wrists control the cutting action.

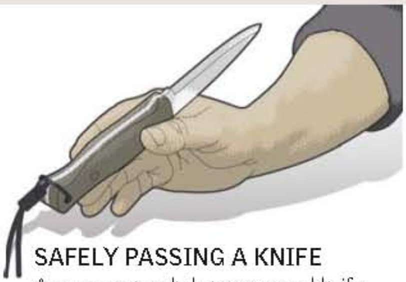

SAFELY PASSING A KNIFE

A group may only have one good knife for everybody to use, so you'll need to pass it to each other frequently. Pass the knife handle first, with the blade up. This simple and safe method is easily learned and can be adopted by everyone.

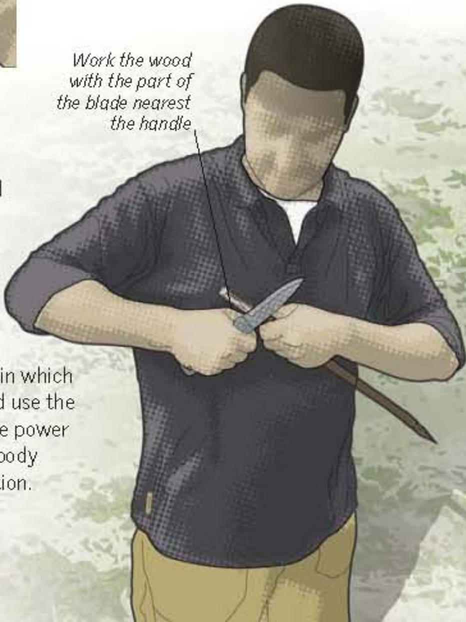
Work the wood with the part of the blade nearest the handle

TREE-FELLING WITH A BLADE

For shelters and fuel, the largest tree you are likely to cut down will be about 4 in (10 cm) in diameter. For anything larger you'd need an ax, but for smaller ones use a saw (see pp. 150–51). If you don't have a saw, use the blade of your bushcraft knife or a machete or parang. Whichever blade you use, keep its lanyard around your wrist.

1 Figure out the lean of the tree and start your first cut on the opposite side. This stops your blade jamming in the cut as the tree leans further.

- Hit the top of the blade with a thumping stick (club).
- Move the blade about ⅝ in (15 mm) to one side of the first cut, and then angle the blade at 45 degrees toward the first cut.
- Continue to alternate this action from side to side, cutting a V into the wood.

WARNING!
Ensure your blade is sharp. Keep what you're cutting between you and the blade, with the blade pointing away.

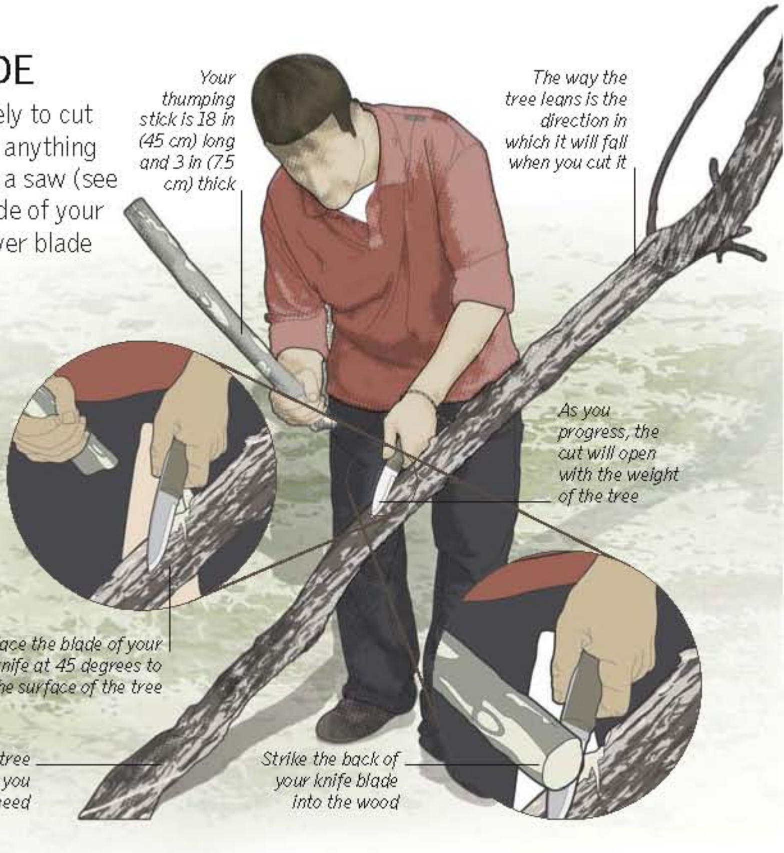
Your thumping stick is 18 in (45 cm) long and 3 in (7.5 cm) thick
The way the tree leans is the direction in which it will fall when you cut it
As you progress, the cut will open with the weight of the tree
Place the blade of your knife at 45 degrees to the surface of the tree
Choose the smallest tree that will provide you with the wood you need
Strike the back of your knife blade into the wood

SPLITTING FIREWOOD

When you split wood into fuel for a fire, use the largest blade you have, work on a solid surface, and avoid wood that has large knots as these prevent the blade from making a clean cut.

SAFE WORKING AREA
Chop wood in a safe area that other people won't wander into and where there are no snagging hazards or objects to impede your swing and knock your knife off-target.

LARGE LOGS

If you only have a bushcraft knife to work with, and you need to split large logs into smaller pieces, the following method works well.

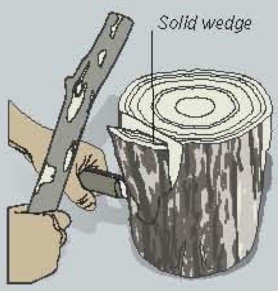
Solid wedge

1 Hit the back of your knife with a stick and cut a solid wedge from the side of the log.

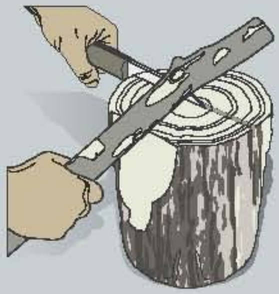

2 Use your knife and a thumping stick to start the initial cut across the top of the log.

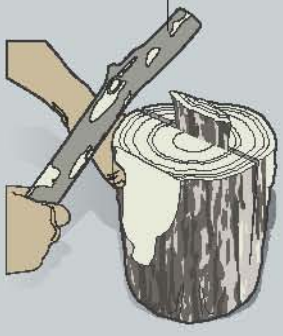
Hit the wedge hard with your stick until it sinks into the log

3 Hit the wedge into the initial cut. Keep doing this until the log splits. Use more wedges if you need to.

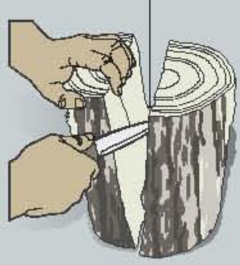
Even wet wood will be dry in the center

4 If the log does not split completely, force it open with your hands or pry it with your blade.

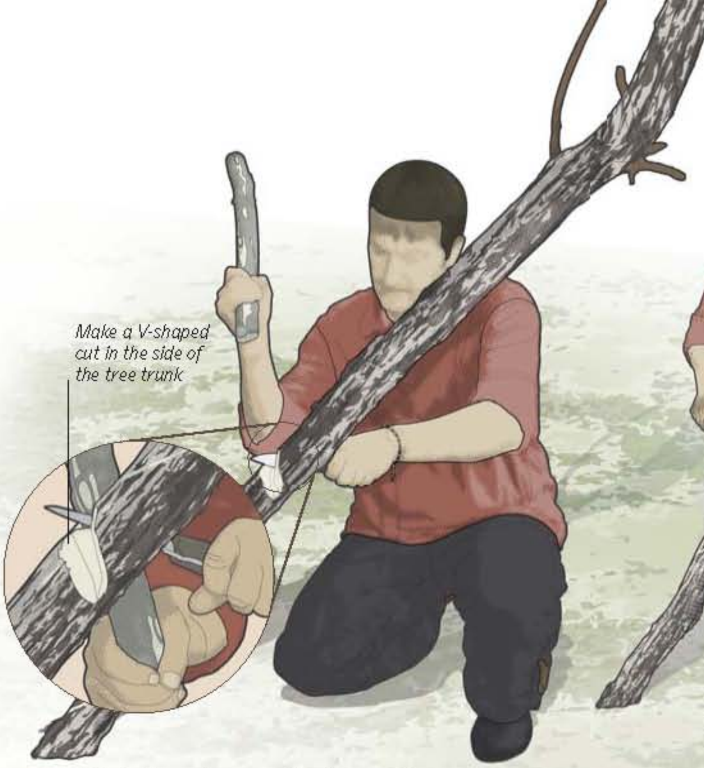
Make a V-shaped cut in the side of the tree trunk

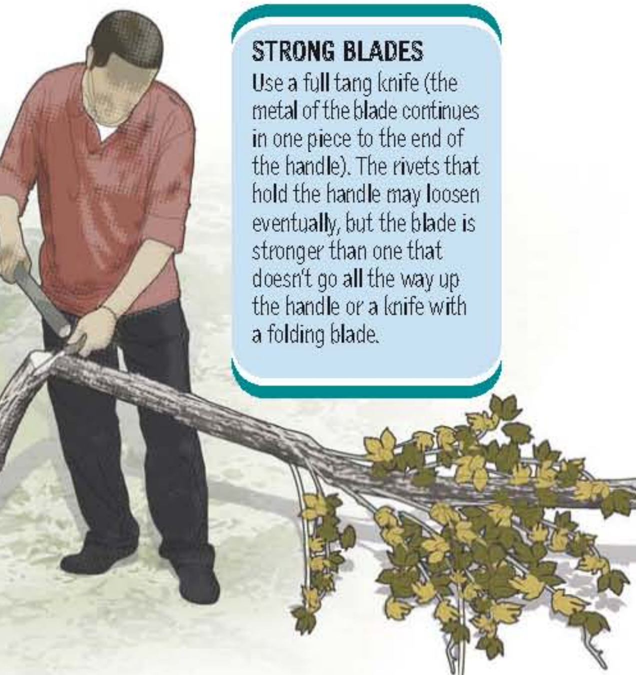

STRONG BLADES

Use a full tang knife (the metal of the blade continues in one piece to the end of the handle). The rivets that hold the handle may loosen eventually, but the blade is stronger than one that doesn't go **all** the way up the handle or a knife with a folding blade.

2 Work the cut around the tree until you've almost reached the middle from every direction except from below.

- If you try to cut completely through the wood from one side it will get increasingly difficult as the blade goes deeper.

3 Once the cuts are deep enough to weaken the wood, you will be able to snap the tree in two.

- Take care that the tree doesn't fall on your feet.

4 To trim the branches from the fallen tree, start at the bottom and work your way to the top. This allows you a clear, short swing for your thumping stick.

- Keep the tree between you and the blade, and trim each branch in the direction of its growth.
- If you're using a machete, you don't need a thumping stick, as the heavy blade has enough momentum of its own.

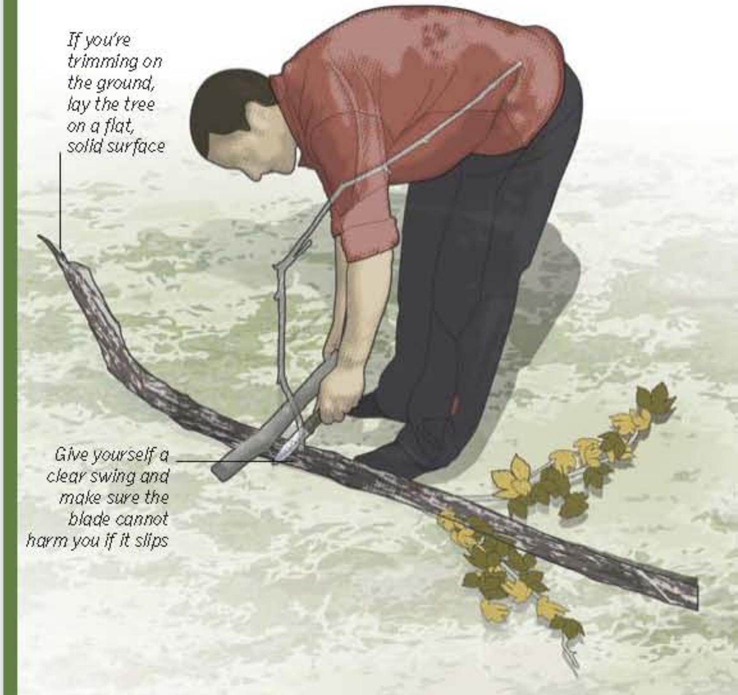
If you're trimming on the ground, lay the tree on a flat, solid surface
Give yourself a clear swing and make sure the blade cannot harm you if it slips

SMALL LOGS

Splitting a small log can be more tricky than splitting a large log, because it's difficult to balance it safely while you hit the blade with your thumping stick.

1 Place the log on a solid surface and put your knife in the middle of the end of the log you're about to chop.

- Hit the back of the blade firmly with your stick.

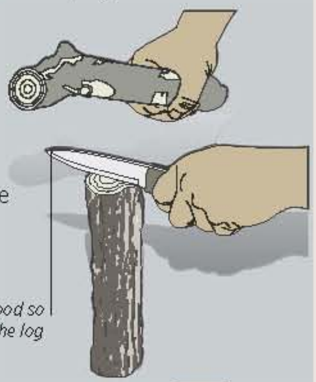
Put the blade in the wood so you can steady the log

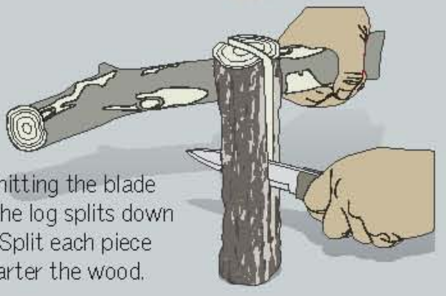

2 Keep hitting the blade until the log splits down the middle. Split each piece again to quarter the wood.

USING A SAW

A saw is much better than a bushcraft knife for larger jobs, such as preparing logs for a fire or cutting down the poles needed to build a shelter. There are several types of pocket saw available that are lightweight and take up very little room in your backpack or survival tin.

USING A POCKET CHAINSAW

Using a pocket chainsaw to cut down a small tree is safe and not especially hard work. You can use the same saw to trim the branches and then cut the wood into manageable sections.

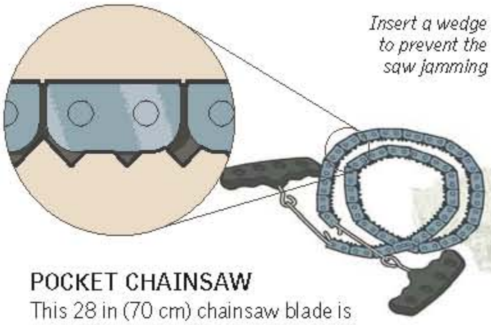

POCKET CHAINSAW
This 28 in (70 cm) chainsaw blade is compact and has attachment rings and handles. It can cut through a 3 in (7.5 cm) diameter tree in under 10 seconds.

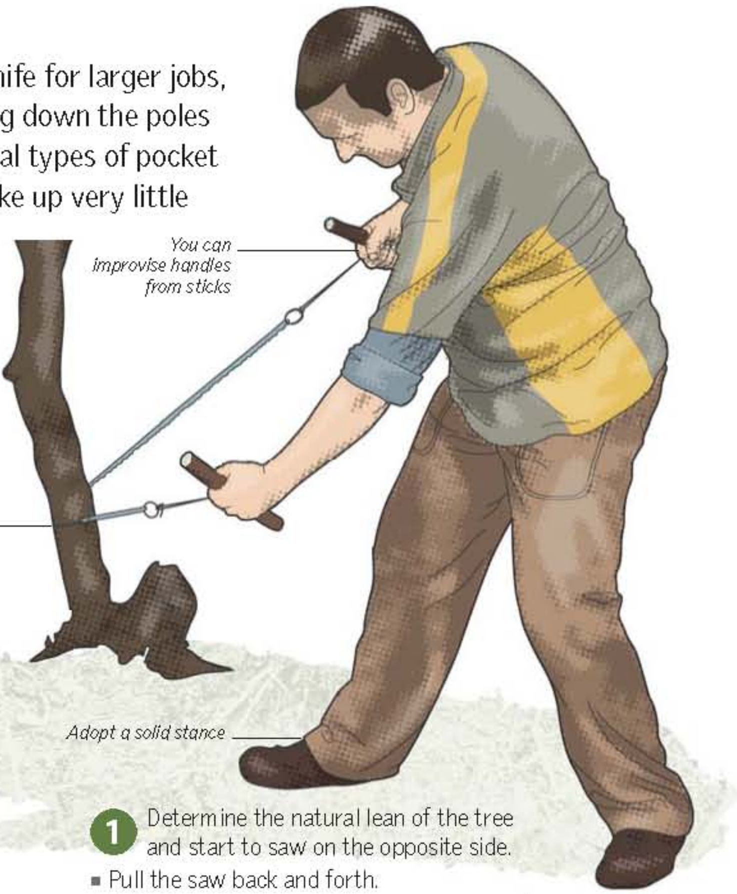

You can improvise handles from sticks

Insert a wedge to prevent the saw jamming

Adopt a solid stance

1 Determine the natural lean of the tree and start to saw on the opposite side.

- Pull the saw back and forth.
- Knock a wedge in behind the saw when halfway through to stop the tree from jamming the blade.

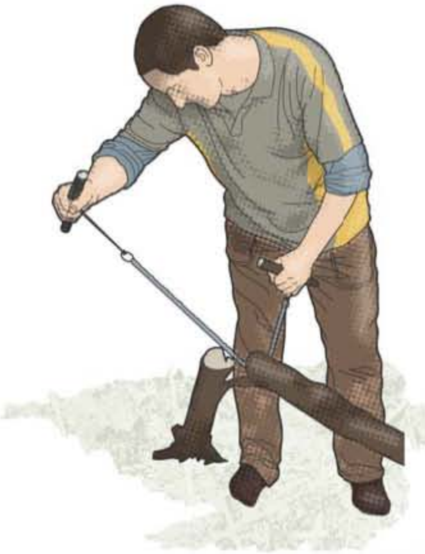

2 Slow down when the saw has nearly cut through the tree.

- Allow the weight of the tree to snap the cut and break it in two.

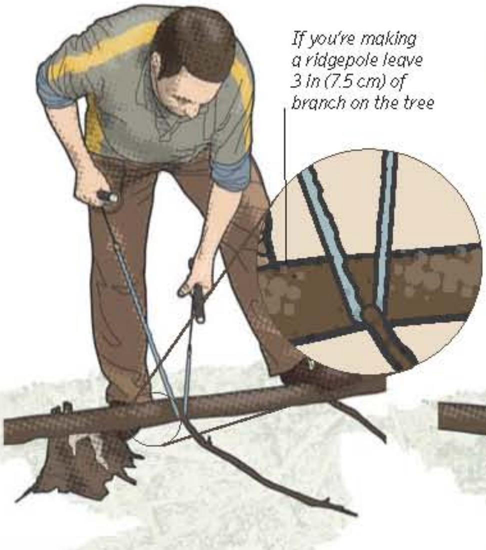

If you're making a ridgepole leave 3 in (7.5 cm) of branch on the tree

3 Use the same back-and-forth rhythm to trim the branches.

- Clear the branches away as you trim them from the tree.

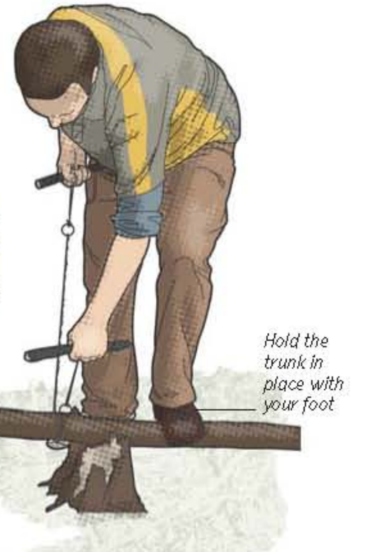

Hold the trunk in place with your foot

4 Saw the trimmed trunk into a measured section.

- When you're halfway through, prop up the trunk to make sawing easier.

FOLDING SAWS

Folding saws are strong, light, and convenient. Some, such as the Sandvik Laplander, have a serrated blade that folds into the handle (see right). Others, such as the backpacker's (see below), can be dismantled for stowing.

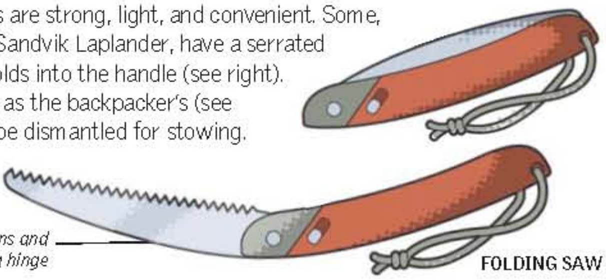
The blade opens and closes at a hinge

FOLDING SAW

BACKPACKER'S FOLDING SAW

These saws are generally lightweight and strong, but are not as effective as the pocket chainsaw. If space is tight, then you can pack only the blade and improvise a bow saw, using natural materials found in the woods.

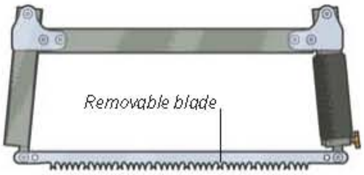
Removable blade

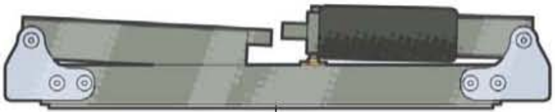
The tension frame and saw blade can usually be taken apart and stowed safely

BACKPACKER'S FOLDING SAW

COMMANDO SAW

This saw takes up very little space and consists of a serrated wire blade with a swivel ring at each end. It's a useful piece of survival equipment, although it tends to snag and snap easily unless you keep it completely straight. You can easily convert it into an improvised bow saw, and, with a little more effort, make it into a very effective tension saw.

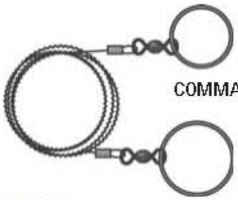

COMMANDO SAW

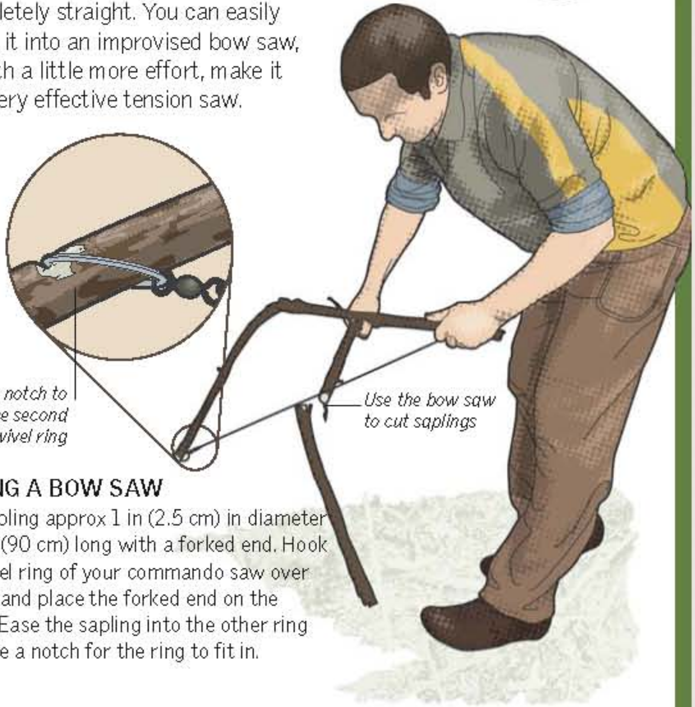
Make a notch to secure the second swivel ring
Use the bow saw to cut saplings

MAKING A BOW SAW

Cut a sapling approx 1 in (2.5 cm) in diameter and 3 ft (90 cm) long with a forked end. Hook the swivel ring of your commando saw over the fork and place the forked end on the ground. Ease the sapling into the other ring and make a notch for the ring to fit in.

IF YOU HAVE NO TOOLS

Even without any cutting tools, it's still possible to safely break wood down to size. The answer is snapping—or even burning—the wood. Don't be tempted to stand branches and sticks against a log or rock and then stamp on them in the middle. In a genuine survival situation your feet are your only means of transportation so don't do anything that risks injuring them.

SNAPPING THE WOOD

You need to limit the size of wood you're trying to break—don't try to snap branches that are too broad. Use wood that's dead, because green living wood just bends and refuses to break completely.

- Find two trees that are 1–2 ft (30–60 cm) apart—or a tree with two trunks close together—to use as a fulcrum for the wood. Place the wood in the fulcrum.
- Adopt a firm and steady stance and, with one foot in front of the other, pull the wood toward you until it breaks. Pulling toward you keeps your center of gravity over your spread feet, while pushing away from you causes you to stumble forward when the wood breaks.

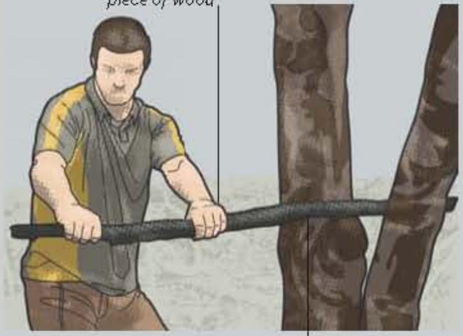
Hold firmly on to the piece of wood
Place the wood between two trees—one is a stop or buffer, the other is a leverage point

BURNING THE WOOD

If you have a fire going, place the wood on the fire where you want it to break. Leave it on the fire until it burns all the way through. Alternatively, when it has burned halfway through, use the snapping method described above—but don't work on the wood while it's still burning or hot.

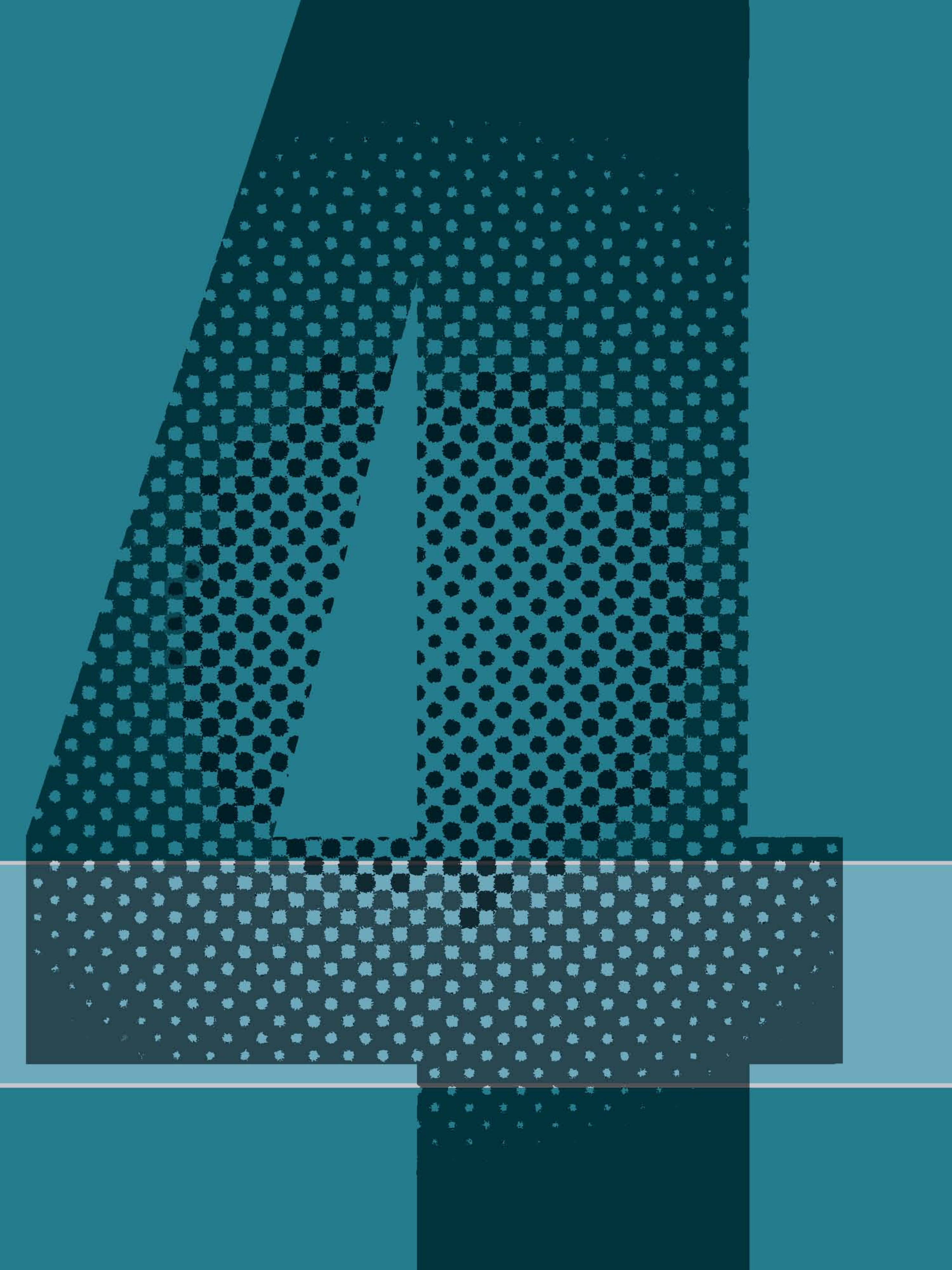

TAKING SHELTER

TAKING SHELTER

A shelter is your primary means of protection in a survival situation. It can be somewhere to simply keep dry during a sudden downpour or a place to spend several nights while out in the wilds. It's important, therefore, that you understand how to correctly construct your shelter. After all, its effectiveness could mean the difference between relative comfort and abject misery!

In a survival situation, it's important to play a proactive role in your own continued survival and rescue. You can only achieve this effectively if you're in a good condition—both physically and mentally. A day or night spent exposed to the elements will determine how well or how badly you perform the next day. A restless and uncomfortable night, for example, will lead to sleep deprivation, which can make you moody, irritable, and easily frustrated. This in turn can lead to a lack of concentration and irrational thinking—none of which are helpful in a survival situation.

Cold nights spent in the wilderness seem to last longer than they should, so time spent ensuring that you can

In this section YOU WILL DISCOVER...

- when to **lie low** in a hollow or **camp in a cave...**
- how to **modify** your **poncho** to put up a **shelter...**
- the difference between a **bothy** and a **bivy...**
- how to **bed down** with **duck down** or **wake up** in a **wickiup...**
- the **importance** of using your **noggins** to **secure** your shelter...
- how to **configure** your **fig leaves** to keep out the **rain...**

always enjoy as warm, dry, safe, and comfortable a night as possible is rarely wasted.

With shelter-building—as with other areas of survival—you should always apply the principle of expending the least amount of energy for the maximum amount of gain. This could mean simply exploiting the options nature has already provided, such as caves or hollows. Finally, plan for the worst conditions—it may be sunny when you build your shelter but pouring with rain at three in the morning!

On any expedition, you should aim to carry equipment—such as a basic bivy or a tarpaulin—that could be used to form a shelter should you need to protect yourself from the elements.

A SPACE BLANKET, however, is quite simply an essential piece of gear—if you pack nothing else, make sure you carry one and keep it with you at all times. Space blankets pack down very small and are available with one side silver (to reflect heat) and one side bright orange (to aid location). No matter what environment you're exploring, a space blanket can offer you immediate protection from the elements.

With a little ingenuity, a space blanket can also be converted into a basic shelter. You will find instructions on how to build a variety of shelters throughout this chapter, but always remember the following general tips, too:

- First look for natural sheltering places
- Look out for hazards such as signs of flooding
- Construct your shelter well before nightfall
- Clear the ground before you start to build
- Position the entrance at right angles to the wind
- Build for the worst possible weather conditions
- Make sure your shelter is sturdy and secure
- Don't over-exert yourself as you build
- Raise your sleeping area off the ground
- If on a slope, sleep with your head higher than your feet

> “The **effectiveness of a shelter** can mean the difference between relative comfort and **abject misery**”

HOLLOWS AND CAVES

IF YOU DON'T HAVE a shelter of your own, look for shelter opportunities that nature has already provided for you, such as a cave or a natural hollow in the ground. However, avoid natural hollows in low-lying areas that may flood and, if you're on a slope, keep well away from hollows exposed to run-off water.

TOOLS AND MATERIALS

- Sturdy digging stick
- Strong branches (or poles) and logs
- Saw, such as pocket chainsaw
- Tree bark, turf, leaves, forest mulch, moss, bracken, and pine boughs for the roof

NATURAL HOLLOWS

A hollow that may be too shallow to sit in can still provide shelter from the wind if you lie in it—and, with a basic roof, keep you dry too.

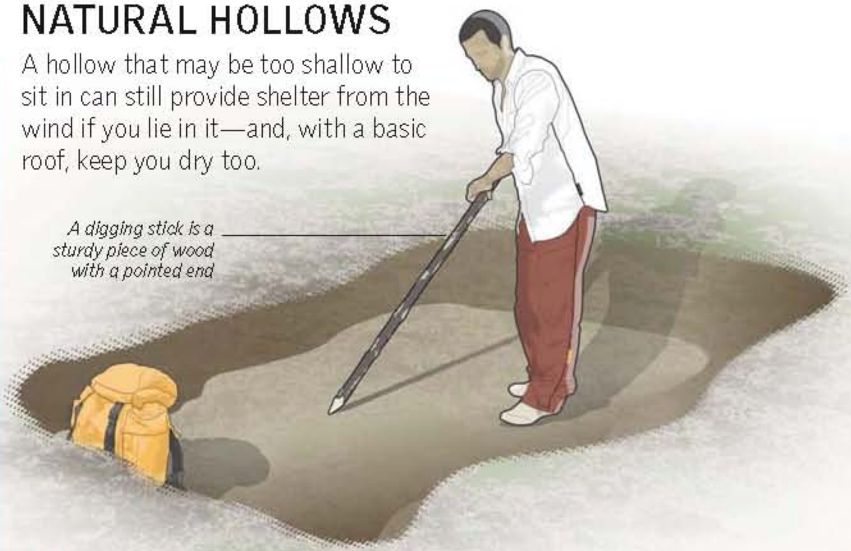
A digging stick is a sturdy piece of wood with a pointed end

1 If the hollow isn't deep enough to lie in, remove some soil with a digging stick.

- Beware wet soil, as it could be prone to flooding.
- If the ground is too hard to dig, build up the sides with logs for extra depth.
- Lay bedding material on the ground before continuing.

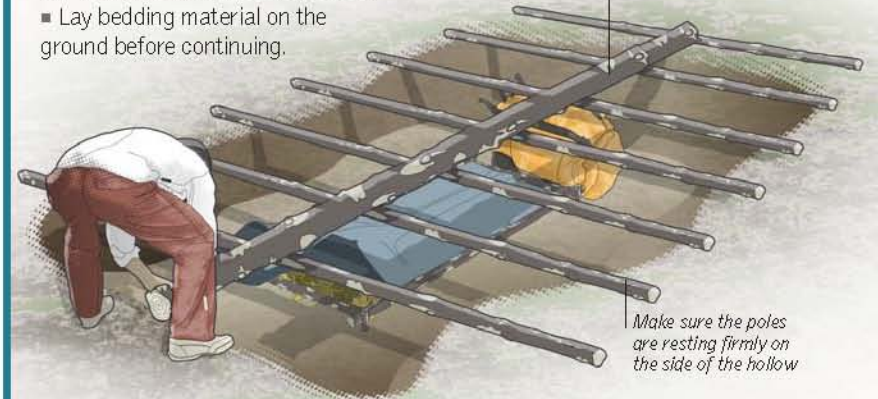
Lay a log on top of the cross poles and along the length of the hollow
Make sure the poles are resting firmly on the side of the hollow

2 With your saw, cut a number of sturdy poles or branches (see pp. 150–51) that are long enough to place across the hollow to create a supporting roof.

- Cut a thicker, longer log and place it across the poles. This will create height and slope for a pitched roof. Make sure the log isn't too heavy.

BEDDING

Cover the floor of a shelter with some form of bedding to prevent your body from losing heat to the cold ground through conduction. After all the energy you've used to build the shelter, why waste it on an uncomfortable night? Use the driest materials you can find (see list below).

MAKE YOURSELF COMFORTABLE

Here are some ideas to help you enjoy a good night's sleep in your shelter:

- Collect twice as much bedding as you think you need: 6 in (15 cm) of holly, for example, compresses to about 2 in (5 cm) after you've been lying on it for a while.
- Place logs around the bedded area to stop the bedding from shifting and spreading.
- If the ground slopes, sleep with your head higher than your feet.

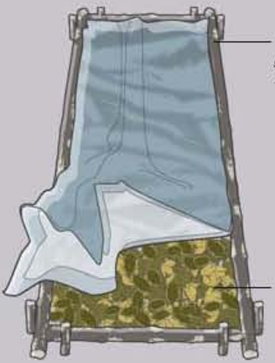
Use wooden pegs to keep the side logs in place
Bedding keeps you warm

BEDDING MATERIALS

- Feathers, such as duck and goose down, are the best bedding as they retain warmth but not moisture.
- You're unlikely to find enough feathers, so also try pine and spruce boughs, dry leaves, moss, bracken, grasses, and holly (cover it to prevent it from pricking you).

TAKING SHELTER IN CAVES

Caves are ready-made shelters that are usually dry and secure. There are some dangers, including animals, poor air quality, and water. Many caves are outlets for streams or are connected to pools. Don't go any further in than you can see, as there may be hidden drops, slippery surfaces, and crevasses. Avoid old and disused mines, as they may be prone to collapse.

ANIMAL DANGERS

Many animals, such as bears, bats, insects, spiders, and snakes, shelter in caves, so check the ground around the entrance and inside for signs of tracks and nests. Vampire bats can be dangerous as they are known to carry rabies. Bat droppings (guano) form a thick layer on the ground and, in large quantities, can be highly combustible.

LIGHTING FIRES

If you build a fire at the front of a cave the smoke can blow back inside and the fire can block your exit if it gets too big. Build a fire toward the rear of the cave, but make sure that there is a sufficient flow of air for the smoke to escape. You can erect a small fire reflector or make a pile of rocks at the entrance to reflect heat back into the cave.

POOR AIR QUALITY

If a cave makes you feel light-headed or nauseous, leave at once because the air may be foul due to excess carbon dioxide. Other warning signs are an increased pulse and breathing rate. If a flame starts to dim, or turn blue, leave the cave immediately—this may not be a sign of excess carbon dioxide but a lack of oxygen, which can be worse.

COASTAL CAVES

Coastal caves share the same dangers as any other cave, but they are also subject to the tides, which can rise very quickly—in some areas they can advance hundreds of yards in a matter of minutes.

THE DANGERS OF COASTAL CAVES

When you're assessing a coastal cave, look out for the following warning signs of flooding during high tide:

- A line of seaweed, driftwood, or flotsam and jetsam—either in the cave or further back on the beach either side of the entrance.
- A damp or wet smell. The cave may even look wet if the tide has recently gone out.
- Rock pools in the cave or in front of it.

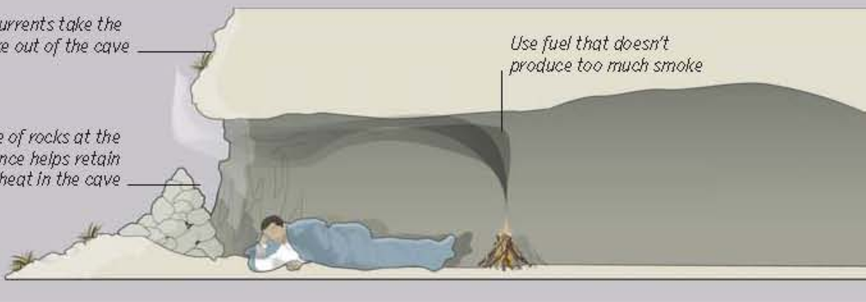
Air currents take the smoke out of the cave
Use fuel that doesn't produce too much smoke
A pile of rocks at the entrance helps retain heat in the cave

③ Place shorter branches, sticks, or poles over the top of the log and cross branches to create the pitched roof.

- Pack these materials tightly together and make sure they're firmly in position.

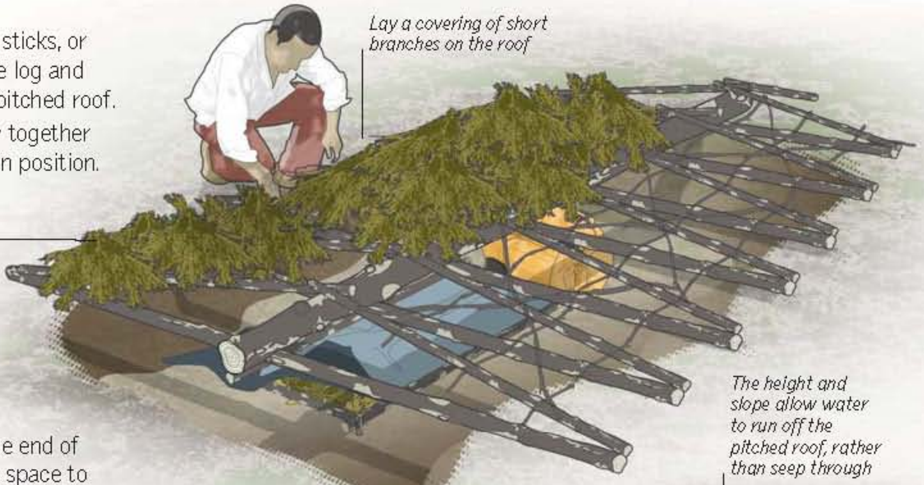
Lay a covering of short branches on the roof
The space between the support and pitched roof will help retain the heat generated inside the shelter

④ Leave an entrance at one end of the shelter with enough space to get in and out without disturbing the roof.

- Ensure the entrance doesn't face the wind—an angle of 90 degrees to the wind is best.
- Insulate the pitched roof with as much foliage as possible.
- Start the final insulation layer at the ground, working up to the top of the roof to create an overlap for rainwater to run off.
- In wet conditions secure your poncho or space blanket over the top.

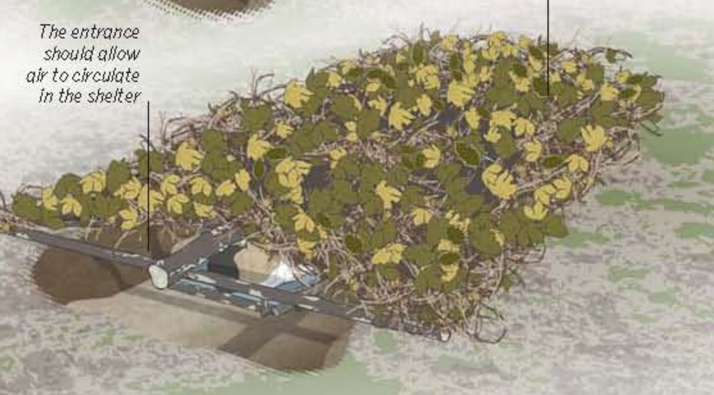
The height and slope allow water to run off the pitched roof, rather than seep through
The entrance should allow air to circulate in the shelter

USE-ANYWHERE SHELTERS

WITH A PONCHO OR BIVY SACK (see pp. 160–61), you can make a shelter for use in any environment and in any conditions. You can also adapt any type of material—a survival space blanket, ground sheet, or tarpaulin—in the same way.

TOOLS AND MATERIALS

- Poncho, bivy sack, groundsheet, space blanket, or tarpaulin
- Cordage or elastic bungees
- Pegs; stick or pole
- Rock or log for hammering
- Survival knife or penknife

ONE-POLE PONCHO

This shelter is very quick and easy to erect and take down—useful when energy levels are low or when you just want to get out of the rain. If you need to be rescued, put the most visible color on the outside to increase the chance of being spotted.

1 Cut three 2 ft (60 cm) lengths of cordage and one 6 ft (2 m) length.

- Tie the shorter lengths into loops using an overhand knot (see p. 143).
- Tie the long length to one corner with a Siberian hitch knot (see p. 144).
- Fasten the cordage loops to the corner grommets.

2 Tie the long cord to a tree with another Siberian hitch knot at a height of 3 ft (1 m) off the ground.

- If no tree is available, run the cordage over a stick (staked into the ground) and peg it down.

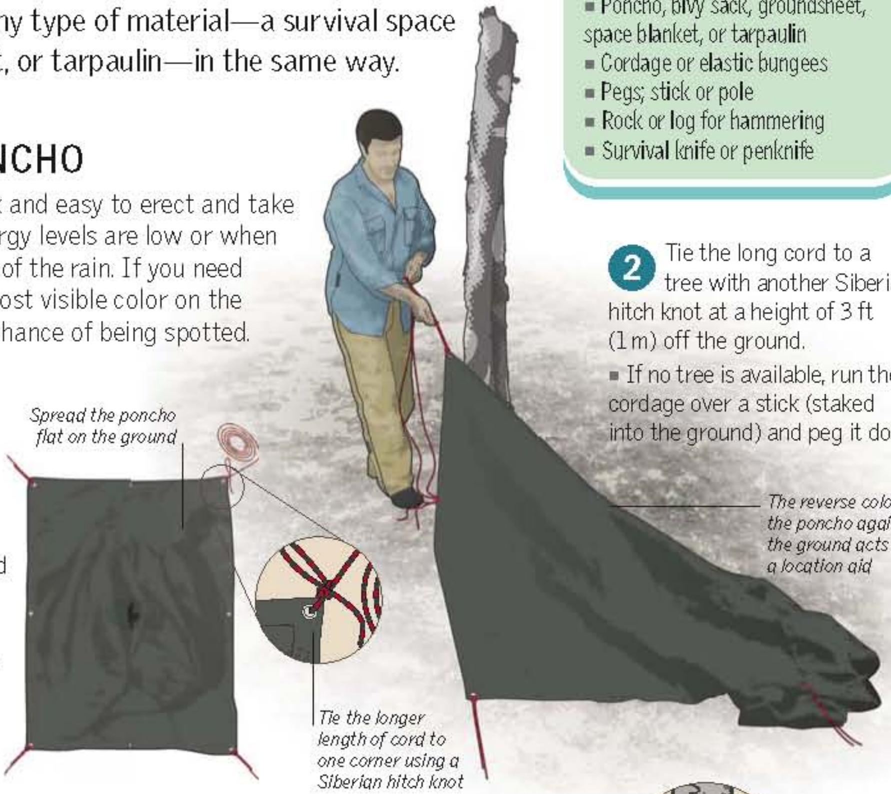

Spread the poncho flat on the ground

Tie the longer length of cord to one corner using a Siberian hitch knot

The reverse color of the poncho against the ground acts as a location aid

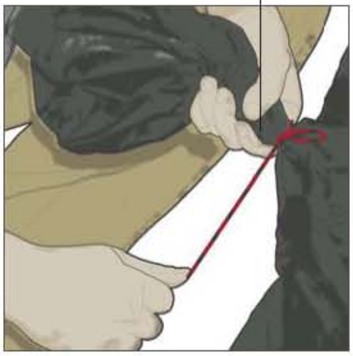

Make sure the top of the stick in the poncho is secure

3 Place one end of a 3-ft (1-m) long stick in the hood of the poncho.

- Seal the hood by tying a simple knot.
- Wind several turns of cordage around the knot and secure it with an arbor knot (see p. 142).

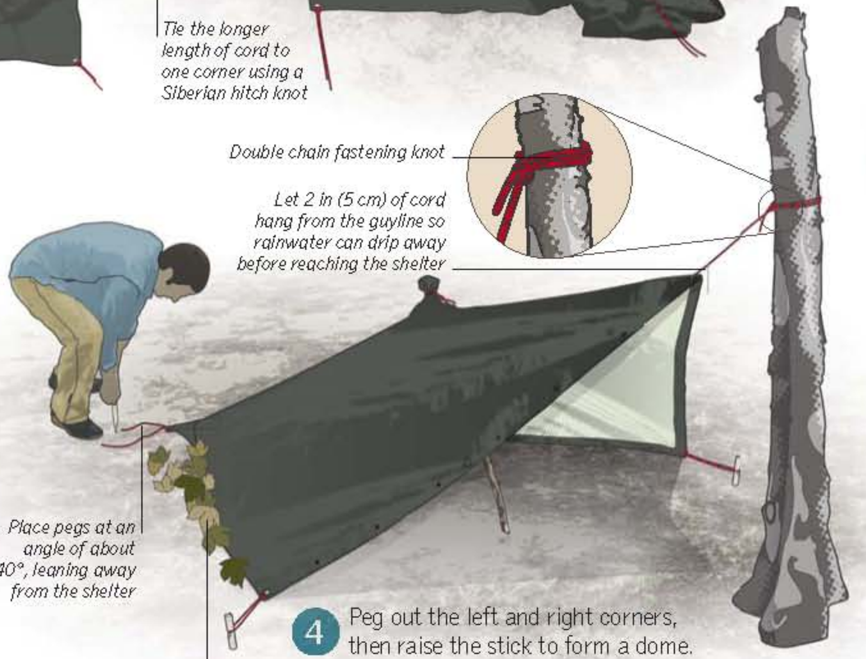

Double chain fastening knot

Let 2 in (5 cm) of cord hang from the guyline so rainwater can drip away before reaching the shelter

Place pegs at an angle of about 40°, leaning away from the shelter

Pile leaves around the edges of the shelter to keep out the wind

4 Peg out the left and right corners, then raise the stick to form a dome.

- Pull the rear corner taut and peg it out to add tension, making the structure rigid.
- To enter the shelter, curl your body around the center pole.

CORDED A-FRAME

This poncho A-frame creates a tentlike shelter between two trees. If you have enough cordage, a single ridgeline can be tied between the trees; if not, use two cordage loops, as shown below. Alternatively, you can use a ridgepole at the same height.

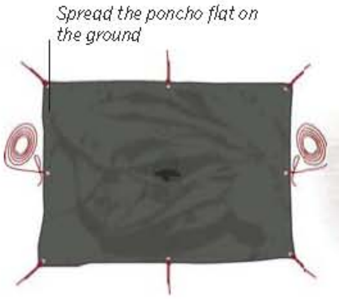
Spread the poncho flat on the ground

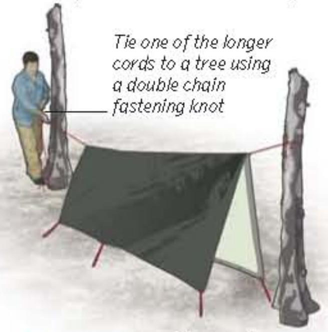
Tie one of the longer cords to a tree using a double chain fastening knot

1 Find two trees 2 ft (60 cm) further apart than the length of your poncho.

- Attach cordage loops 1 ft (30 cm) long to each grommet on the longer sides of your poncho and 3-ft (1-m) loops to the end ones.
- Tie a knot around the hood to seal it.

2 Tie the end of one of the longer cords to a tree with a double chain fastening knot (see p. 143) at a height of 3 ft (1 m).

- Tie the other long cord to the second tree with a taut line hitch knot (see p. 145) and adjust the hitch to pull it tight.

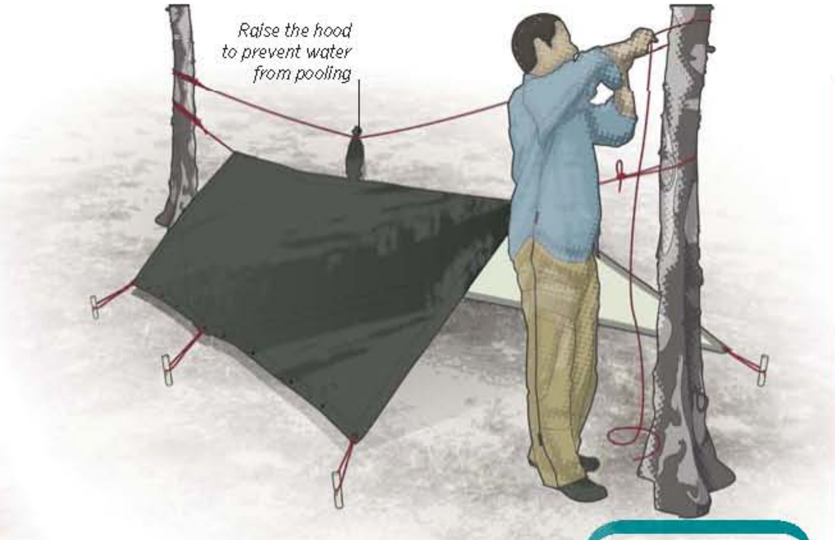
Raise the hood to prevent water from pooling

3 Peg the middle loop of each side to pull the poncho taut. Peg out the four remaining loops, pulling tight as you go.

- If you have enough cordage, raise the hood by tying it either to a second horizontal line or to a vertical line passed over a branch above.
- Place long boughs along each side of the shelter, with shorter boughs at each end to hold in bedding material.

NEED TO KNOW

- Block one end of the shelter with branches, boughs, and mulch to help retain heat.
- If your material has no grommets, use button ties instead (see p. 161).

TENT PEGS

You can make your own tent pegs and then either reuse them or replace them with new ones when necessary. Discard old pegs that naturally decompose over time.

MAKING TENT PEGS

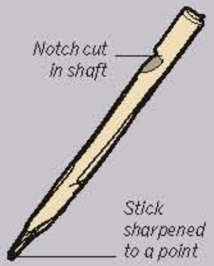
Notch cut in shaft
Stick sharpened to a point

- Pegs should be about 9in (22.5 cm) long and 1 in (2.5 cm) in diameter. Anything less will either snap under pressure or pull out in high winds.
- Cut wood for the pegs from green trees.
- Don't use wood from the ground as it will be in some stage of decay.
- Dry out new pegs slowly over the embers of a fire to harden them. Remove them when they're a light brown color. Wet wood sounds deep and dull when you tap it; as it dries the sound gets higher and crisper.
- Never drive a peg in with your foot. Use a stone or a heavy stick instead. If you misjudge it, the peg may stab you through the ankle or pierce your boot and even your foot.

ALTERNATIVE DESIGN

If you're in a group and you each have a poncho, you can clip two ponchos together and use one as a built-in floor.

USING TWO PONCHOS

First clip the poppers of both ponchos on their two long sides to form a tube. The top one is the A-frame, the bottom one the groundsheet.

- Pack all your bedding material under the bottom poncho and hold it in place by laying branches at either end.
- Assemble the shelter with the top poncho in the same way as the single poncho version.

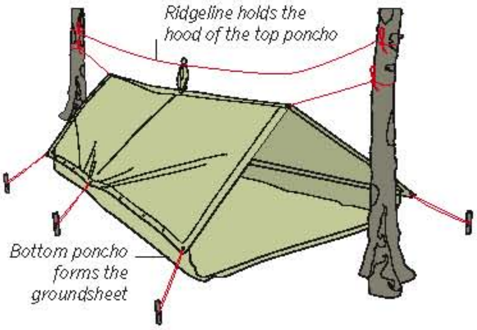
Ridgeline holds the hood of the top poncho
Bottom poncho forms the groundsheet

BIVY PUP TENT

A bivy sack is a lightweight, waterproof cover for a sleeping bag and is made out of a breathable material that cuts down condensation. It's an essential component of ultralight camping (see p. 52) and can very easily be turned into a single-person pup tent. The advantage of making a tent from the bivy sack is that, in wet conditions, the rain runs off the side and doesn't seep to the inside as quickly as it does when the bag is flat on the ground.

TOOLS AND MATERIALS

- Bivy sack
- Saplings
- Button ties
- Wooden pegs
- Cordage and knife
- Rock or log for hammering

1 Lay the bivy sack flat on the ground where you intend to set it up.

- If you have the flap of the hood on top it will form a door that hangs down. However, if the flap is on the bottom you can tie it up as a door.
- Attach a button tie (see panel, opposite) with a loop to each of the bottom corners of the bivy sack.
- Peg the button-tie loops into the ground.

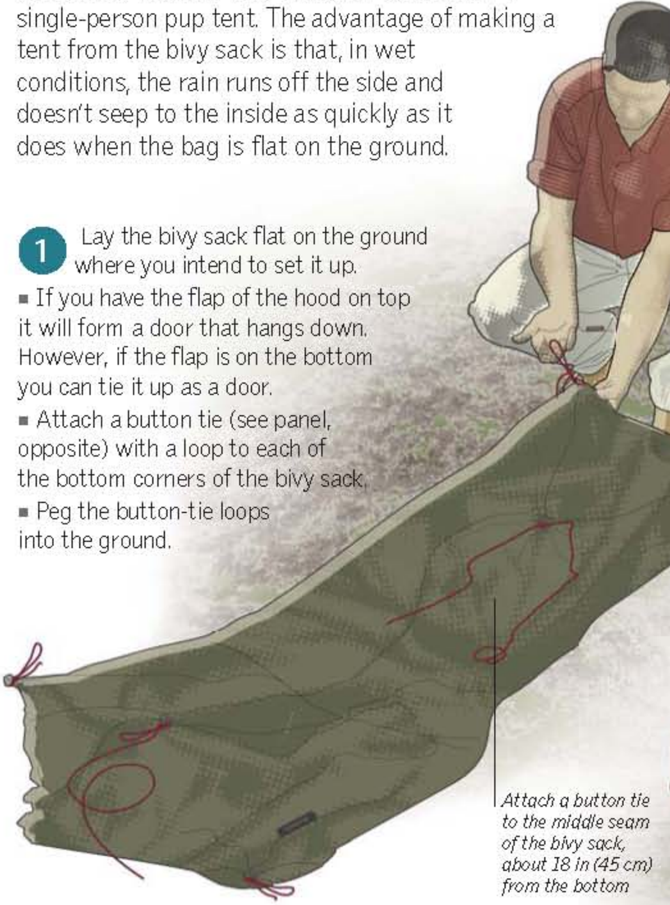

Attach a button tie to the middle seam of the bivy sack, about 18 in (45 cm) from the bottom

2 Attach a button tie with a long length of cordage to the center of the bivy sack's opening and hold it up.

- Pull down the right and left sides of the opening and place a button tie and loop where they meet the ground.
- Peg out the button-tie loops into the ground.

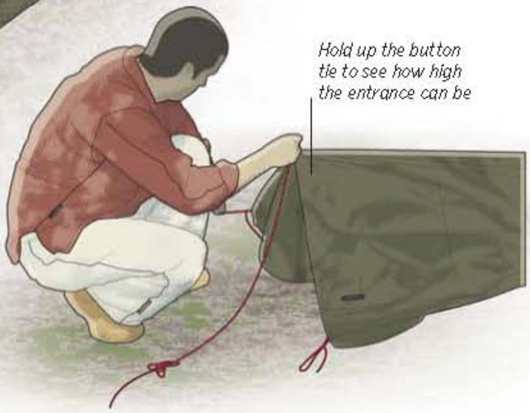

Hold up the button tie to see how high the entrance can be

4 Cut a pole the same height as the entrance (you could use a hooped sapling or crossed sticks instead).

- Stand the pole at the entrance, run the middle button-tie cord over the top, and peg out the cord tightly.
- Readjust all the pegs to ensure tight and even tension.

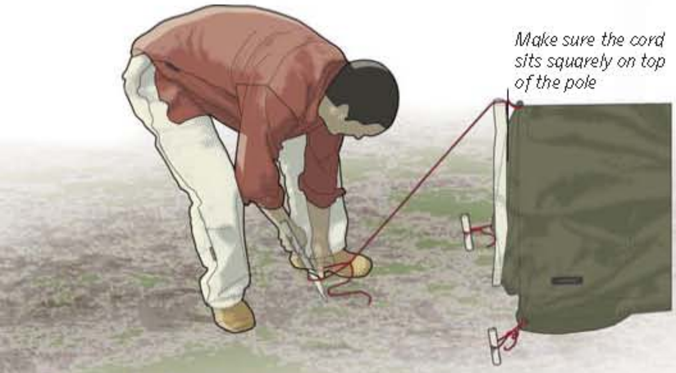

Make sure the cord sits squarely on top of the pole

5 When you want to get into the bivy pup tent, simply remove the opening pole and climb in feet first.

- Make sure you avoid the long cord as you wriggle in.

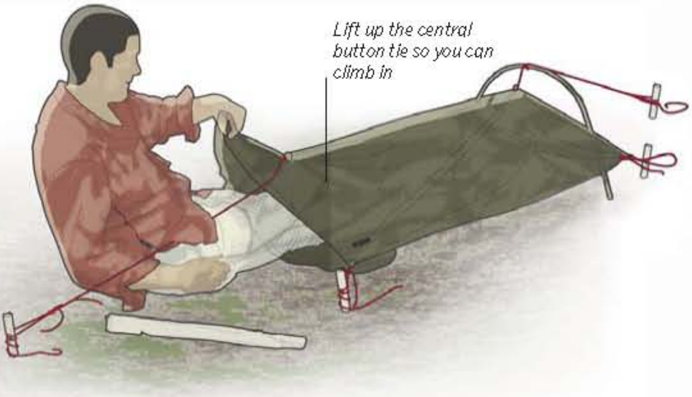

Lift up the central button tie so you can climb in

OTHER SHELTERS

There are other temporary shelters you can erect by adapting the techniques, tools, and materials outlined for both the use-anywhere shelter and the bivy pup tent. Which shelter you choose depends on whether you have a poncho, tarpaulin, or bothy bag.

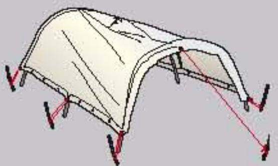

HOOPED SHELTER
If there are saplings or soft wood trees, you can form three hoops and peg out your poncho over them.

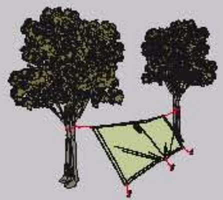

TARPAULIN
Attach one side of the tarp to a line between two trees and peg the other end down to the ground at an angle.

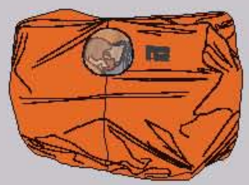

BOTHY BAG
A bothy bag, or storm shelter, is a large, light, nylon bag that protects one or two people from the elements.

3 Place a hooped sapling (or two crossed sticks) over the bottom of the bivy sack.

- Attach the button tie that's 18 in (45 cm) from the foot of the bivy sack to the hoop to raise it and provide more space for your feet.
- Tightly peg out the cord from the hoop.

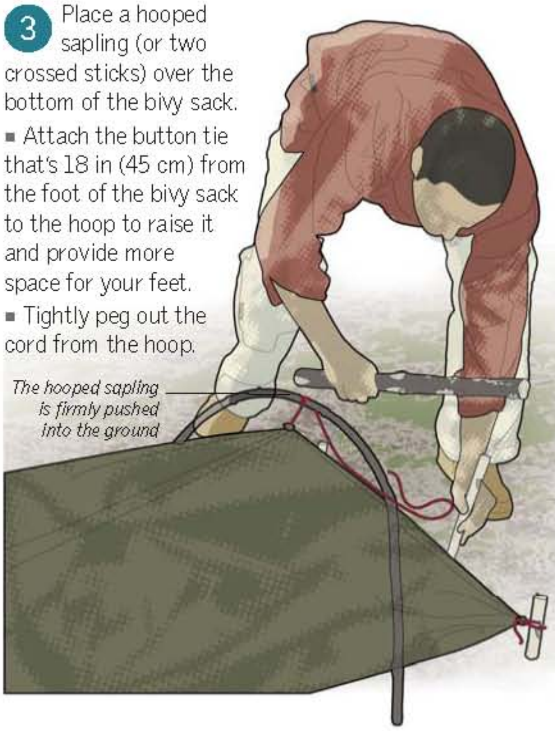

The hooped sapling is firmly pushed into the ground

6 After you have climbed in, replace the pole under the long cord.

- Use the hood of the bivy sack as a door and open and close as necessary.

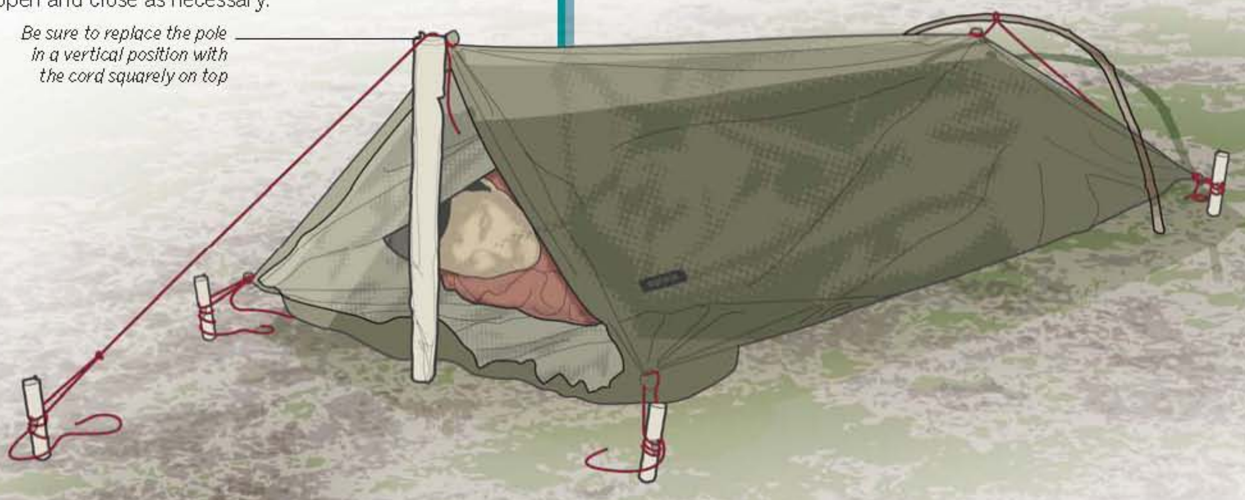

Be sure to replace the pole in a vertical position with the cord squarely on top

MAKING A BUTTON TIE

Button ties provide a simple, secure fastening for staking out ponchos and tarpaulins that have no loops or grommets to which you could attach a line. As you don't have to cut holes in the material, it remains waterproof and less prone to ripping.

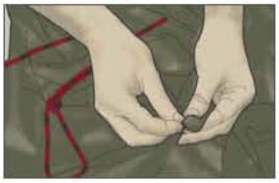

1 Encase a small, round, smooth stone (or similar) in material to form a "button". Prepare cord, with the open loop of a slip knot (see p. 142) at one end.

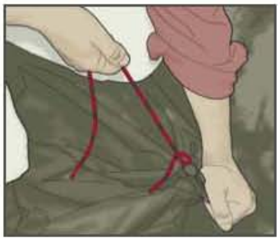

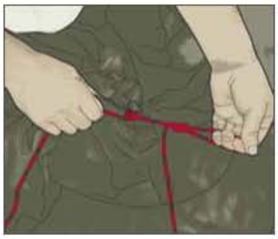

2 Place the open loop of the slip knot over the neck of the button and pull it tight.

3 At the other end of the cord make a simple loop to place over your shelter pegs.

FOREST SHELTERS

IF YOU FIND YOURSELF in a survival situation in a temperate forest without a poncho, bivy sack, or tarp, you can make a shelter from natural materials. For example, you can construct a lean-to or an A-frame, or simply adapt a fallen tree. A forest lean-to is easier for a group to build because you can share the workload and don't have to use up too much precious energy.

TOOLS AND MATERIALS

- Poles and stakes
- Saw and knife
- Cordage
- Saplings
- Foliage for the roof covering

BUILDING A FOREST LEAN-TO

A lean-to has a sloping roof that leans against a horizontal ridgepole. It works best on a flat area between two trees or vertical supports secured firmly into the ground. If you're building a lean-to for a group, ask everyone to lie down next to each other and add an additional 6 in (15 cm) per person—this will establish how wide the shelter needs to be.

BUILDING IN A FOREST

Temperate forests, whether they consist of deciduous or coniferous trees or both, provide many opportunities for finding or building a shelter. Expend the least amount of energy for the most amount of protection—first see what nature can provide before building a shelter yourself.

POINTS TO REMEMBER

If you do need to make a shelter in a forest, here are some tips:

- Select a place close to water but away from water hazards, such as flooding, animals, and insects.
- Before you start, check for hazards such as deadfalls (sudden branch falls), rockfalls, and flash floods.
- Select a place that gives you maximum protection from the elements and with all the materials you need nearby.
- Collect everything you need before you start building and before it gets dark.
- Make sure your aids to location can be seen or activated quickly (signal fires, heliograph, flares, radio signals).
- Think safety: if possible, wear gloves to clear leaves and debris from the ground to protect you from spiders and snakes.
- Layer down your clothing as you work to prevent overheating.
- Make your shelter as waterproof as you can and ensure your bedding raises you at least 4 in (10 cm) off the ground.

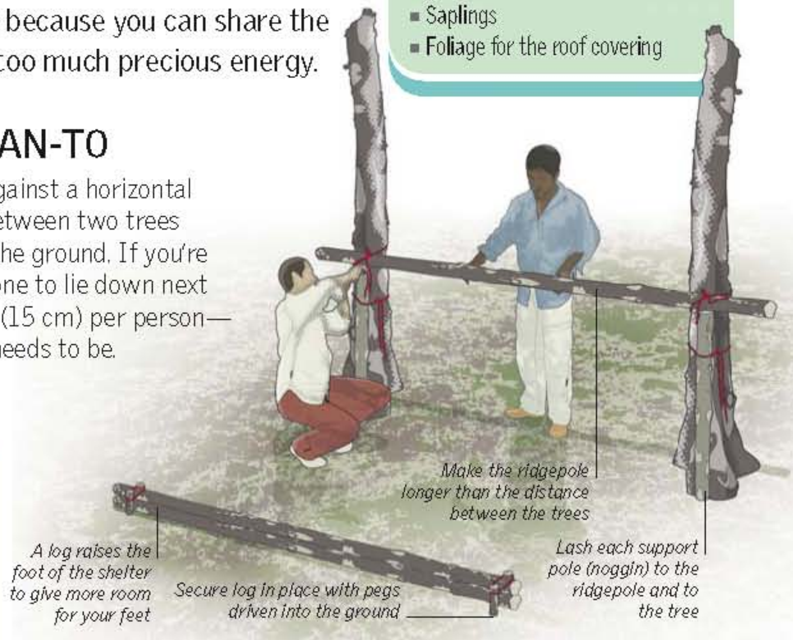
Make the ridgepole longer than the distance between the trees
A log raises the foot of the shelter to give more room for your feet
Secure log in place with pegs driven into the ground
Lash each support pole (noggin) to the ridgepole and to the tree

1. Place the ridgepole against the trees at the height you require and lash it with an arbor knot (see p. 142) to both trees.

- Place a support pole (noggin) under the ridgepole and lash to the trees.
- Firmly peg a log where you want the foot of the shelter to be.

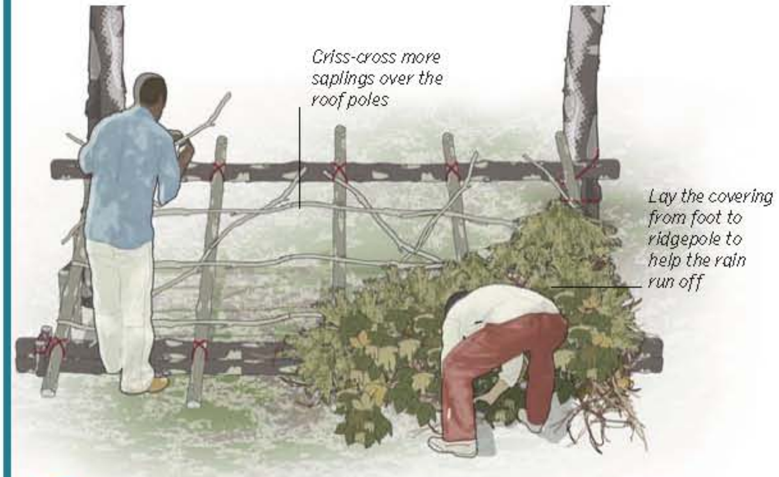
Criss-cross more saplings over the roof poles
Lay the covering from foot to ridgepole to help the rain run off

4. Apply the covering to the woven skeleton of the roof and walls. How much you apply depends on the weather you're experiencing.

- Lay large materials—for example, pine or fir boughs, large leaves, clumps of moss—as a base to stop smaller materials from falling through.

TREE SHELTERS

The branches, roots, or trunk of a fallen tree can make a basic shelter. Make sure the tree is safe before you use it, as a further fall could injure you. Dead trees are probably dry, so don't light a fire under them. Check the base of the tree for snakes, spiders, and nests of insects.

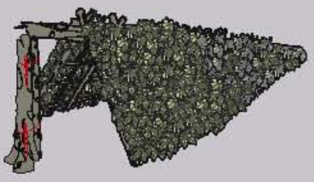

BROKEN BRANCHES

A branch that has snapped from a tree trunk but hasn't yet fallen makes a good ridgepole. Prop smaller branches and roofing material up against it.

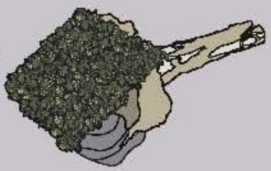

UPTURNED ROOTS

The base of an uprooted tree can give good protection from the elements. Make sure it's safe and won't flood if it rains, then add boughs and foliage.

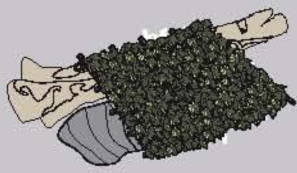

FALLEN TRUNK

Lay sticks or branches against a fallen trunk to form a pitched roof. Weave saplings across them and cover with bark, turf, moss, leaves, and mulch.

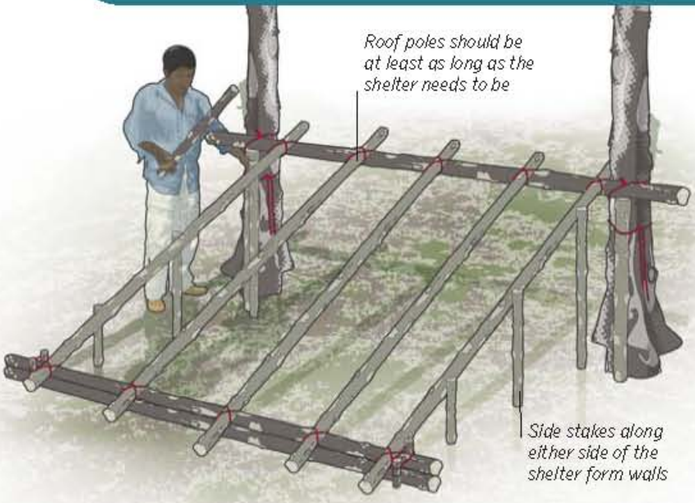

Roof poles should be at least as long as the shelter needs to be

Side stakes along either side of the shelter form walls

② Place five roof poles evenly along the ridgepole so that they slope back to the foot of the lean-to.

- Keep the outside poles between the trees to stop them moving outward.
- Lash each roof pole to the ridgepole.
- Hammer in side stakes alongside the outside poles.

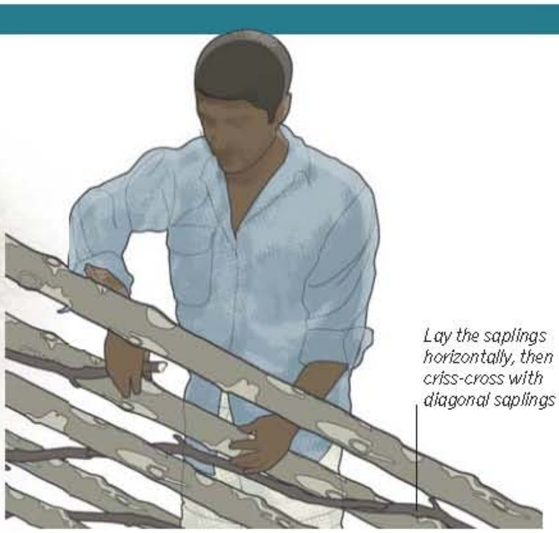

Lay the saplings horizontally, then criss-cross with diagonal saplings

③ Weave saplings in and out through the roof poles, working across and down from the ridgepole.

- Alternate the weave of each row of saplings, first horizontally and then diagonally.
- Weave smaller saplings through side stakes to form walls.

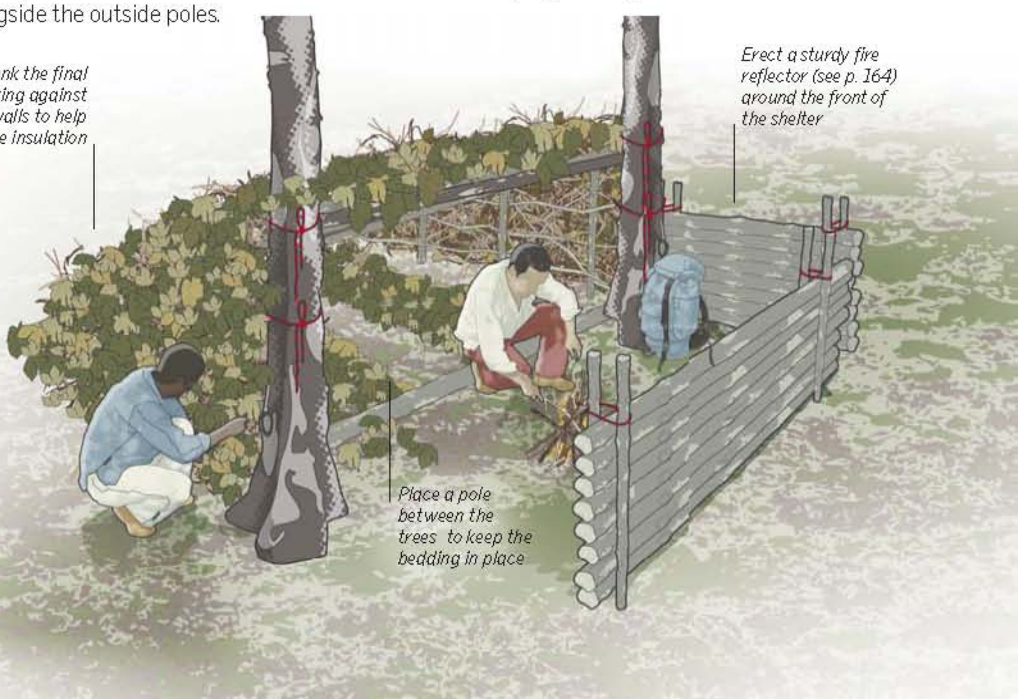

Bank the final covering against the walls to help the insulation

Erect a sturdy fire reflector (see p. 164) around the front of the shelter

Place a pole between the trees to keep the bedding in place

⑤ With everyone in the same lean-to shelter you need to light and tend only one fire.

- Layer the inside floor with dry material to form bedding.
- Establish a watch system during the night to ensure that the fire is maintained and controlled.

FOREST A-FRAME

A-frames can take several hours to build, but if you're staying in one place for a few days it may be worth expending the energy. One-person A-frames are relatively simple to construct and are easy to keep warm. They can be adapted into multi-person shelters to accommodate groups of people.

TOOLS AND MATERIALS

- Poles of various lengths
- Saplings
- Knife
- Saw (or ax)
- Cordage
- Covering for walls—such as pine boughs, leaves, and moss

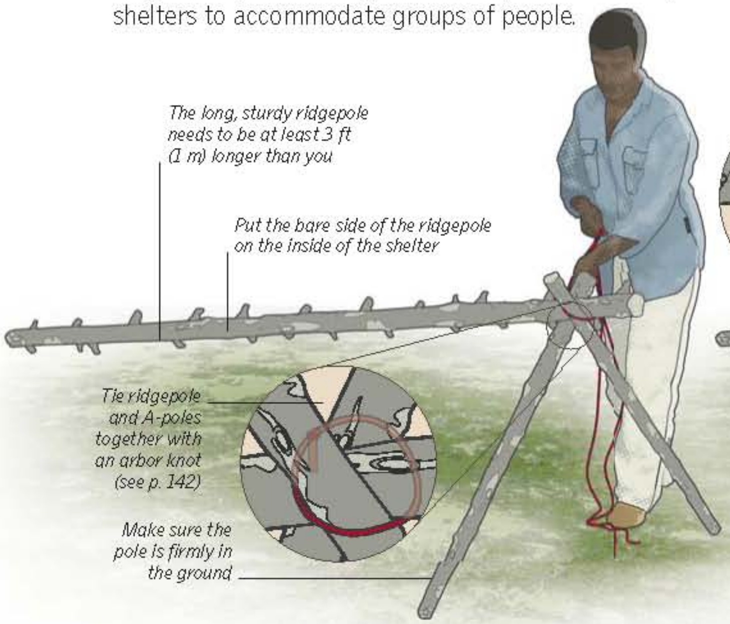
The long, sturdy ridgepole needs to be at least 3 ft (1 m) longer than you
Put the bare side of the ridgepole on the inside of the shelter
Tie ridgepole and A-poles together with an arbor knot (see p. 142)
Make sure the pole is firmly in the ground

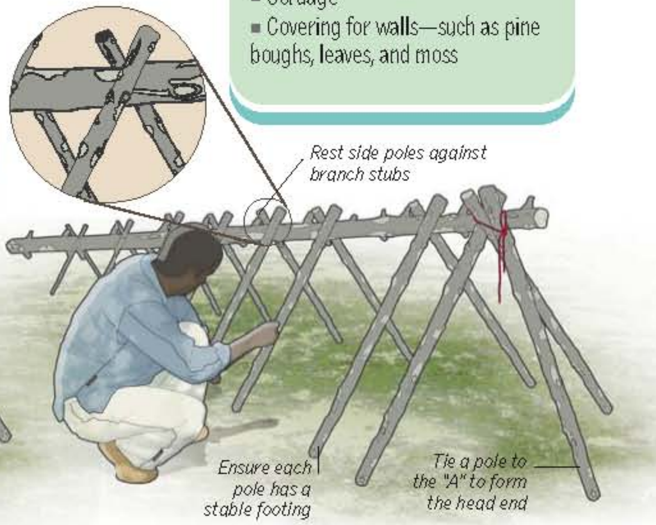
Rest side poles against branch stubs
Ensure each pole has a stable footing
Tie a pole to the "A" to form the head end

1 Smooth one side of the ridgepole with your knife, leaving one side bare and one with branch stubs.

- Hammer two poles into the ground to form an "A".
- Rest one end of the ridgepole on top of the "A" and the other end on the ground.

2 Lay a series of poles against the branch stubs on the ridgepole. These will be of decreasing height as you work your way from front (the "A") to back (the ground).

- At each junction, rest the side poles against the stubs or tie them to the ridgepole with an arbor knot (see p. 142).

FIRE REFLECTOR

A fire radiates heat in all directions—up, down, and 360 degrees around. A fire reflector makes a fire more efficient as it directs heat into your shelter.

Construct your reflector so that you can build a fire about 3 ft (1 m) from the entrance to your shelter. You can sit in the entrance and tend the fire at arms' length—any closer and you would be too hot and the shelter might catch fire; any further away and you lose too much heat. An L-shaped end to the reflector will retain more heat.

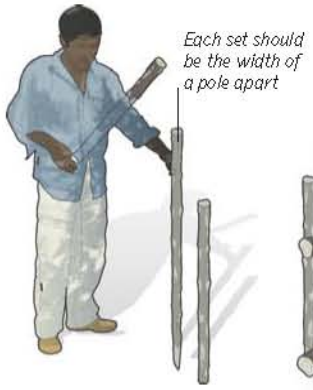
Each set should be the width of a pole apart

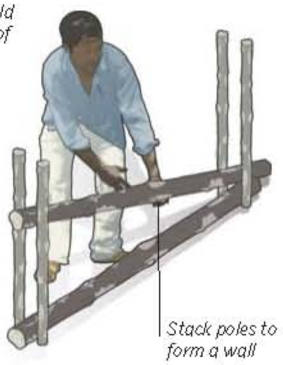
Stack poles to form a wall

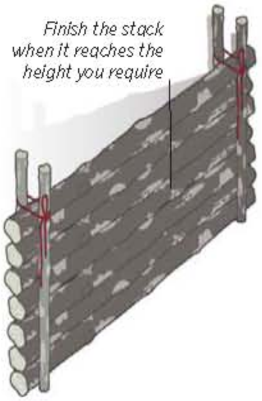
Finish the stack when it reaches the height you require

1 Check the air flow will be across the proposed reflector (to disperse smoke).

- Hammer two poles into the ground. Put a second set in at poles' length apart.

2 If the fire is going to be close to the reflector, use green wood to prevent the heat setting it on fire.

- Put poles between the sets to form a wall.

3 Tie the top of the upright poles together.

- Make sure the wall is as long as the shelter's entrance to retain heat and keep out wind and rain.

ALTERNATIVE SHELTERS

Two other options are a front-opening A-frame and a one-person lean-to. For the former, secure a ridgepole or line to a tree at the height you want the entrance to be, then adapt the forest A-frame (see opposite). For the latter, tie the ridgepole to two forked sticks hammered into the ground and apply a cover similar to the forest lean-to (see pp. 162–63).

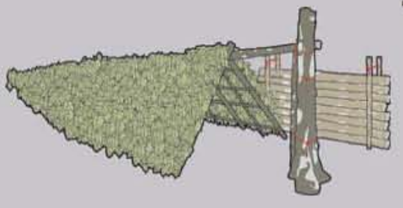

FRONT OPENING A-FRAME

Wedge a noggin under the ridgepole and lash it to the tree with an arbor knot to take some of the weight. Build a fire reflector to the side with the prevailing wind.

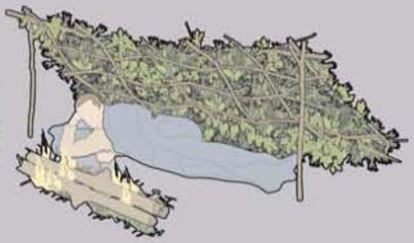

ONE-PERSON LEAN-TO

A small one-person lean-to, together with a long log fire built in front, provides you with a warm, dry, and comfortable shelter for an overnight stay.

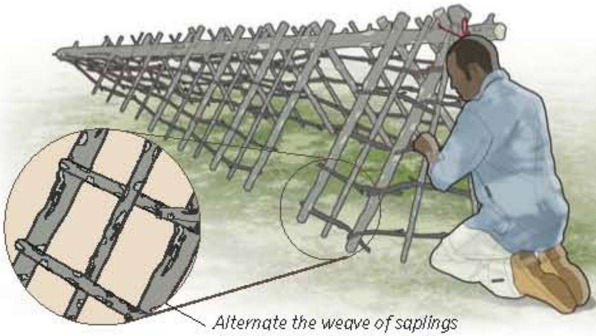

Alternate the weave of saplings between one row and the next

3 Weave four or five rows of saplings horizontally through the side poles to make the walls into a strong framework for the covering.

- Leave an entrance in the side near the front. Make sure it's large enough for you to sit inside comfortably.

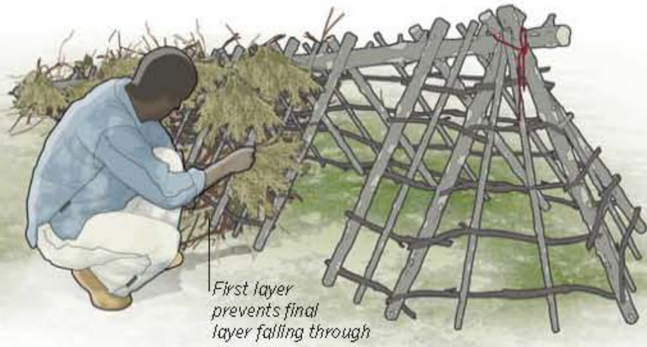

First layer prevents final layer falling through

4 Cover the framework with a thick layer of natural material, such as pine boughs, small branches, and sturdy twigs. Weave the materials into a "thatch".

- On each side, work your way gradually from the back of the shelter to the front, and from the bottom to the top.

NEED TO KNOW

Build your shelter so that the wind blows across the front of it at a slight angle, rather than into it. This maintains its effectiveness and prevents smoke entering from the fire. If the shelter backs on to the wind, there's a risk the wind will blow around it and curl into the entrance.

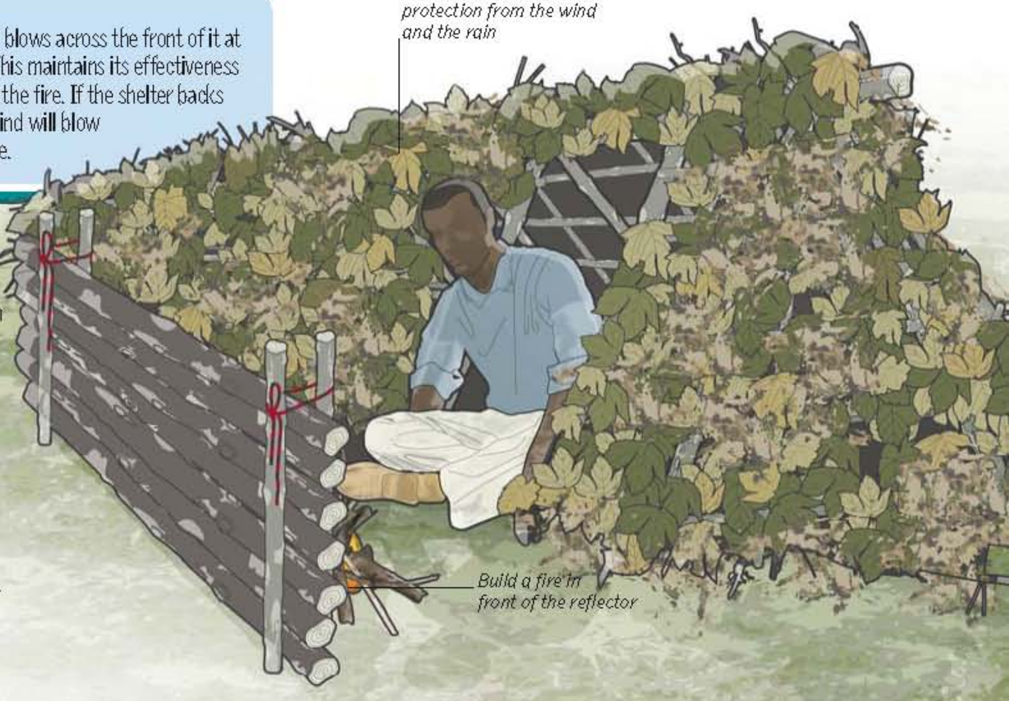

The covered walls provide protection from the wind and the rain

Build a fire in front of the reflector

5 Cover the first layer with leaves, moss, and mulch, starting from the ground and working up to the ridgepole.

- Build a fire reflector (see opposite) in front of the entrance to help direct heat towards you.
- Stow your equipment and pack in the front of the shelter.

TROPICAL SHELTERS

TROPICAL RAIN FORESTS CAN BE the easiest environments for building shelters because of the wealth of available materials. Once you've found a suitable location just decide what type of shelter you need. The most important thing is to raise the shelter off the ground. Make it as comfortable as you can, because quality sleep is important.

TOOLS AND MATERIALS

- Poncho fitted with press-studs
- Cordage
- Long, heavy poles or wide bamboo stalks
- Spacer bars
- Knife, saw, machete, or parang
- Needle
- Strong, waxed, cotton thread

MODIFIED PONCHO BED

Most ponchos have press-studs to allow you to clip up the edges or to clip two ponchos together. They also have grommet holes that you can use as lashing points. Here, a poncho is modified into a tropical bed.

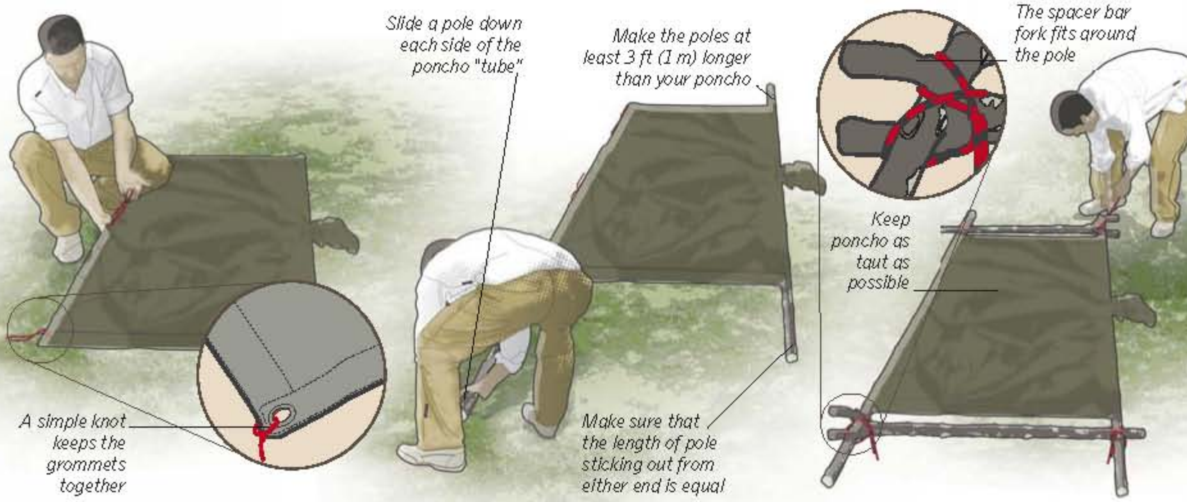

A simple knot keeps the grommets together

Slide a pole down each side of the poncho "tube"

Make the poles at least 3 ft (1 m) longer than your poncho

Make sure that the length of pole sticking out from either end is equal

The spacer bar fork fits around the pole

Keep poncho as taut as possible

1 Clip the press-studs of the two sides of your poncho together to form a kind of "tube"."

- Tie the grommets on the clipped side with pieces of cordage so that the press-studs don't come undone.

2 Cut two strong support poles that can take your weight.

- Insert the two support poles inside the "tube" of your poncho, one down each side.

3 Cut two "spacer bars" that will fit perpendicularly across the support poles or, if you can find them, cut poles with a natural fork in them.

- Tie the spacer bars into position using an arbor knot (see p. 142).

HAMMOCKS

Many types of hammock are designed for the kind of hot weather you get in the tropics, and are often fitted with mosquito nets. In fact, hammocks make the best overnight shelter, as long as you can find two trees the right distance apart. The Hennessy hammock is a good choice because it packs down small.

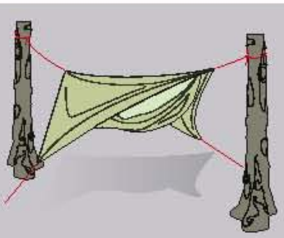

HENNESSY HAMMOCK

This ultralight, quick-drying hammock is both easy to set up and comfortable to sleep in (see p. 54). It's equipped with a self-closing door.

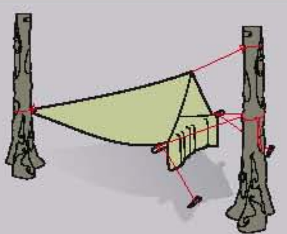

PARACHUTE SHELTER

Fold the panels of a parachute into a triangle. Lash a spacer bar to the opening and peg it out. Tie off the apex of the triangle further up the tree.

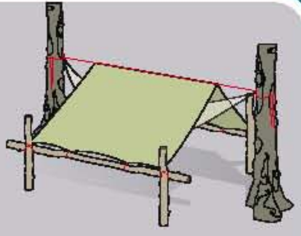

HAMMOCK AND TARP

Tie a ridgeline above the hammock. Drape the tarp over the line and anchor it on either side to a horizontal pole tied to two uprights.

ALTERNATIVE METHODS

You can easily modify other forms of sheeting, such as a tarpaulin, shelter sheet, and groundsheet. You will need a decent needle and plenty of strong, waxed, cotton thread (see Survival kits, pp. 60–61). There are two methods, which you can do either on the trail or as part of your prior preparation. Adding spacer bars keeps the poles apart and the sleeping platform tight. Both of these methods produce an excellent emergency stretcher.

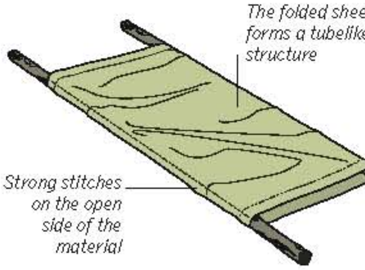

The folded sheeting forms a tubelike structure

Strong stitches on the open side of the material

METHOD ONE

Lay the material on the ground and fold it once to create a wide "tube." Stitch the length of the open sides and then insert a pole along each side of the tube.

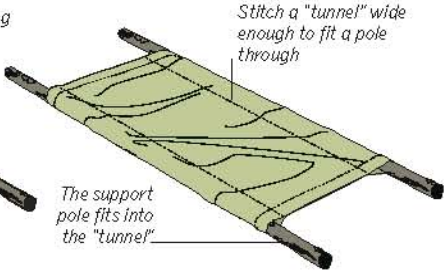

Stitch a "tunnel" wide enough to fit a pole through

The support pole fits into the "tunnel"

METHOD TWO

Fold the sheet and stitch a "tunnel" along both sides just wide enough to take a pole that will support your weight. Push the support poles through the tunnels.

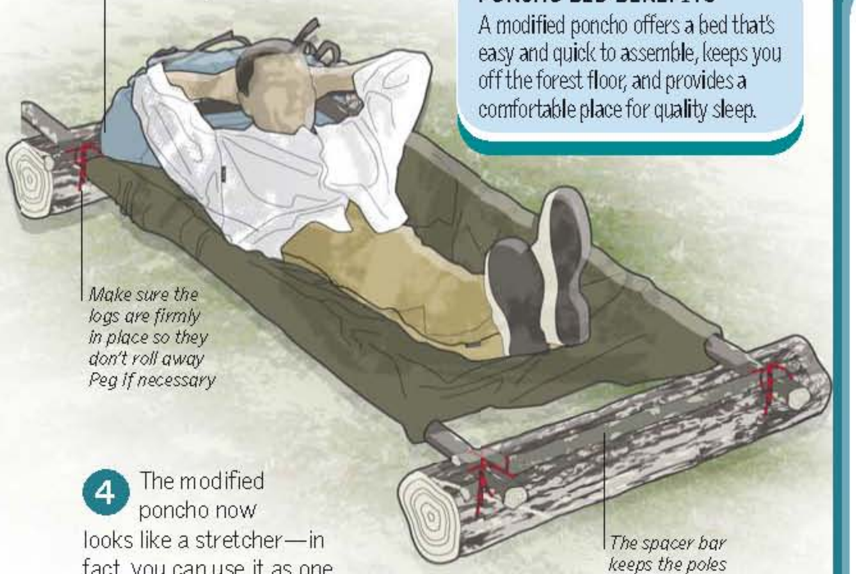

The modified poncho makes a comfortable bed

Make sure the logs are firmly in place so they don't roll away Peg if necessary

The spacer bar keeps the poles in place when you lie on the poncho

4 The modified poncho now looks like a stretcher—in fact, you can use it as one in an emergency.

- Raise the poncho off the ground by resting it either on thick logs or sturdy poles.

PONCHO BED BENEFITS

A modified poncho offers a bed that's easy and quick to assemble, keeps you off the forest floor, and provides a comfortable place for quality sleep.

ALTERNATIVE DESIGN

If you have a second poncho, shelter sheet, or tarp you can create a shelter to keep the rain off your modified poncho (see also Corded A-frame, p. 159).

- Tie a ridgeline between two trees and hang the poncho, sheet, or tarp over the top of it.
- If you're using a second poncho, tie its hood to another ridgeline.
- Peg out the four corners of the poncho, sheet, or tarpaulin.

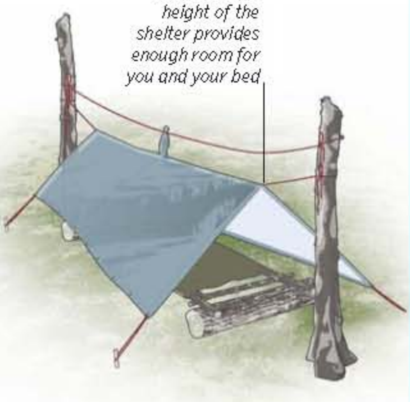

Make sure the height of the shelter provides enough room for you and your bed

BUILDING IN THE JUNGLE

Shelters in the rain forest need to be quick to erect, just big enough for your needs, and safe from animals.

CHECKLIST

If you're thinking about building a shelter in a tropical forest, the following tips may help you:

- Check for hazards such as deadfalls (sudden branch falls)—a major cause of injuries during military jungle training.
- You'll need a sharp cutting tool—ideally a parang or machete, but a decent bushcraft knife or small ax will suffice.
- Clear the ground around your shelter to deter animals. Use a makeshift brush, never your bare hands, to avoid being bitten by snakes or spiders.
- Build your shelter far enough off the ground to avoid being bothered by insects, snakes, or any other animals—particularly those that move around at night.
- Start building your shelter well before darkness sets in, which, in tropical zones, usually happens very quickly. Using a large knife in reduced light or by the light of a flashlight can be very dangerous.
- Work at a rate that you can manage. Humid conditions can very quickly lead to dehydration and heat-related injuries such as heat stress and heat stroke. Your body tries to keep itself cool by sweating, so don't work too fast, drink water frequently, and take regular breaks.
- Make your shelter secure—you don't want to make repairs at night.
- Inside your shelter use a full mosquito net and a mosquito head-net.
- A fire will deter insects and animals.

JUNGLE A-FRAME

An A-frame is relatively easy to make. If you have a poncho, tarpaulin, shelter sheet, groundsheet, or another type of sheet, you'll need to modify it first to make it into a bed (see pp. 166–67). If you do not have a poncho, lay branches across the poles to form a sleeping platform.

1 Cut seven long poles that will take your weight. Tie two poles together with an arbor knot (see p. 142) to form an "A" and tie the joint to a tree or branch of a tree (as shown).

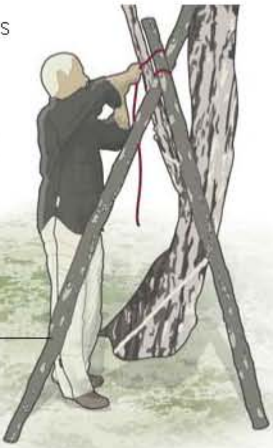
The angle formed by the "A" determines how far down the legs the platform will sit

2 Tie two more poles together to form an "A" for the other end.

- Position these in line with the first "A".
- The distance between the two "A"s needs to be at least 2 ft (60 cm) longer than your height.

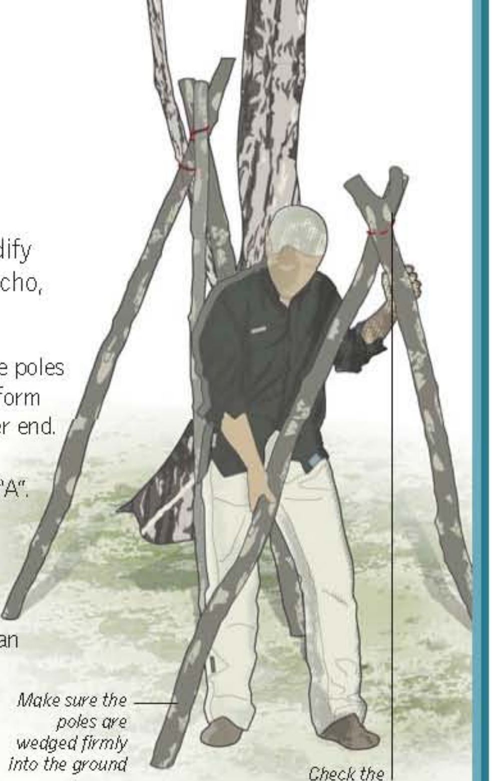
Make sure the poles are wedged firmly into the ground
Check the junctions are securely tied

3 Put a ridgepole on top of the two "A"s.

- Tie this to both junctions for extra stability.

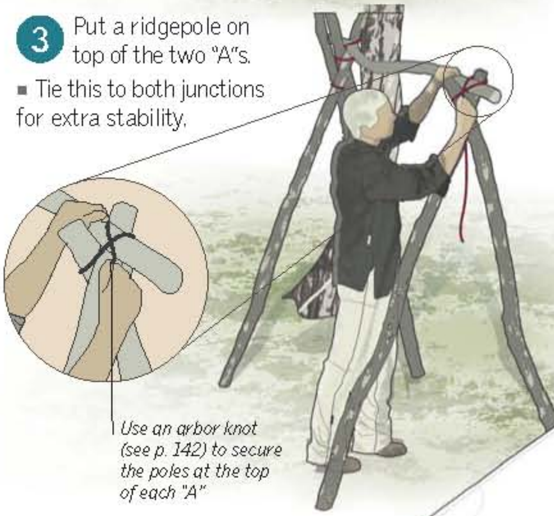
Use an arbor knot (see p. 142) to secure the poles at the top of each "A"

4 Position both poles of your poncho bed (see p. 166) on the outside of the A-frame.

- Move the poles down the outside of the frame legs until the sheet is taut.

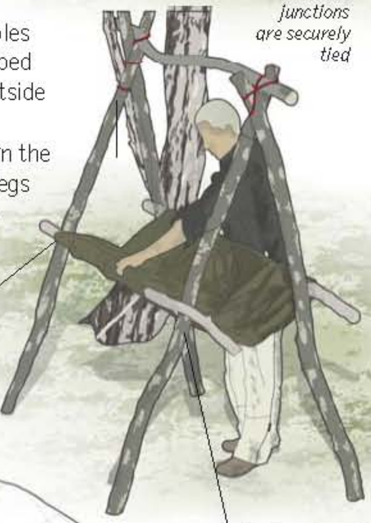
The poles of the modified poncho settle into position
Tie the poles of the modified poncho to the legs of the A-frame for extra stability

5 Place a tarpaulin or shelter sheet over the ridgepole.

- Securely tie a guyline to each corner with a Siberian hitch (see p. 144).
- Run each guyline to a peg or tree and secure it with a taut line hitch (see p. 145).

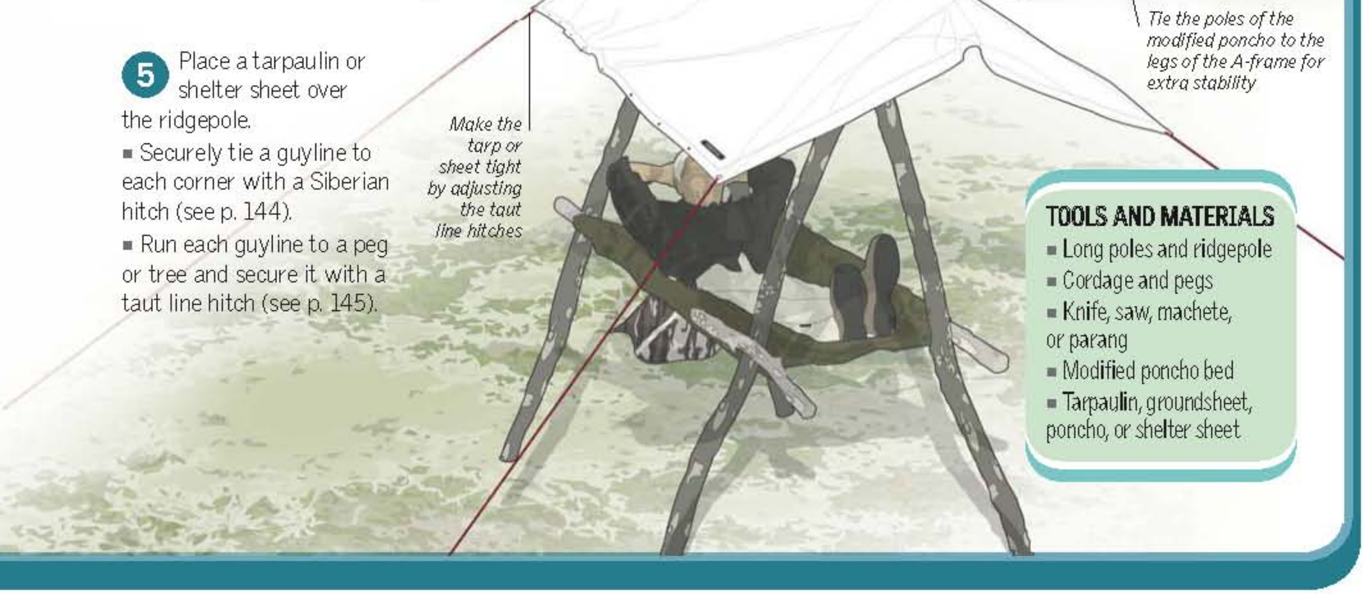
Make the tarp or sheet tight by adjusting the taut line hitches

TOOLS AND MATERIALS

- Long poles and ridgepole
- Cordage and pegs
- Knife, saw, machete, or parang
- Modified poncho bed
- Tarpaulin, groundsheet, poncho, or shelter sheet

BAMBOO LEAN-TO

If you can find enough bamboo you can make a type of lean-to shelter. Find a spot close to the bamboo supply to reduce the amount you have to carry. If you need a raised sleeping platform, adapt the method used for the jungle hut (see p. 174).

TOOLS AND MATERIALS

- Thick wooden poles and bamboo poles
- Knife, saw, machete, or parang
- Cordage and pegs
- Poncho and tarpaulin (if you have them)

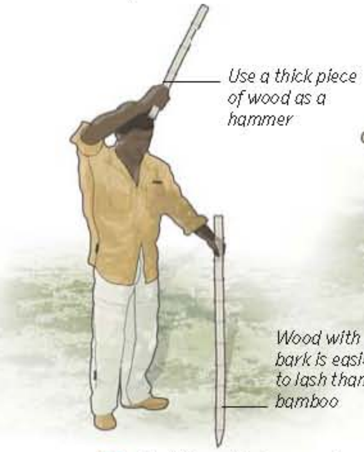
Use a thick piece of wood as a hammer
Wood with bark is easier to lash than bamboo

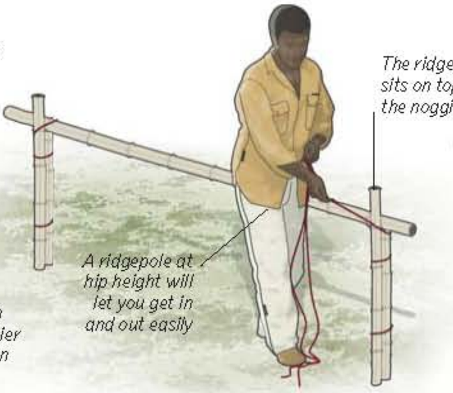
A ridgepole at hip height will let you get in and out easily
The ridgepole sits on top of the noggin

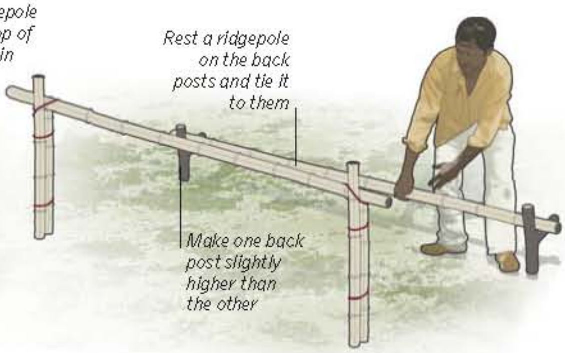
Rest a ridgepole on the back posts and tie it to them
Make one back post slightly higher than the other

1 Cut four thick, wooden support posts.

- Hammer two posts into the ground, wide enough to let you lie lengthways between them.

2 Tie a noggin to each post for support. Make sure they are level and at the height you need for an entrance.

- Place a wooden ridgepole on top of the noggins and tie it to the posts.

3 Make two short, forked back posts to give the shelter a sloped roof.

- Align them with the front posts and far enough back so the roof is wide enough to shelter you.
- Hammer them into the ground and tie a second ridgepole to them.

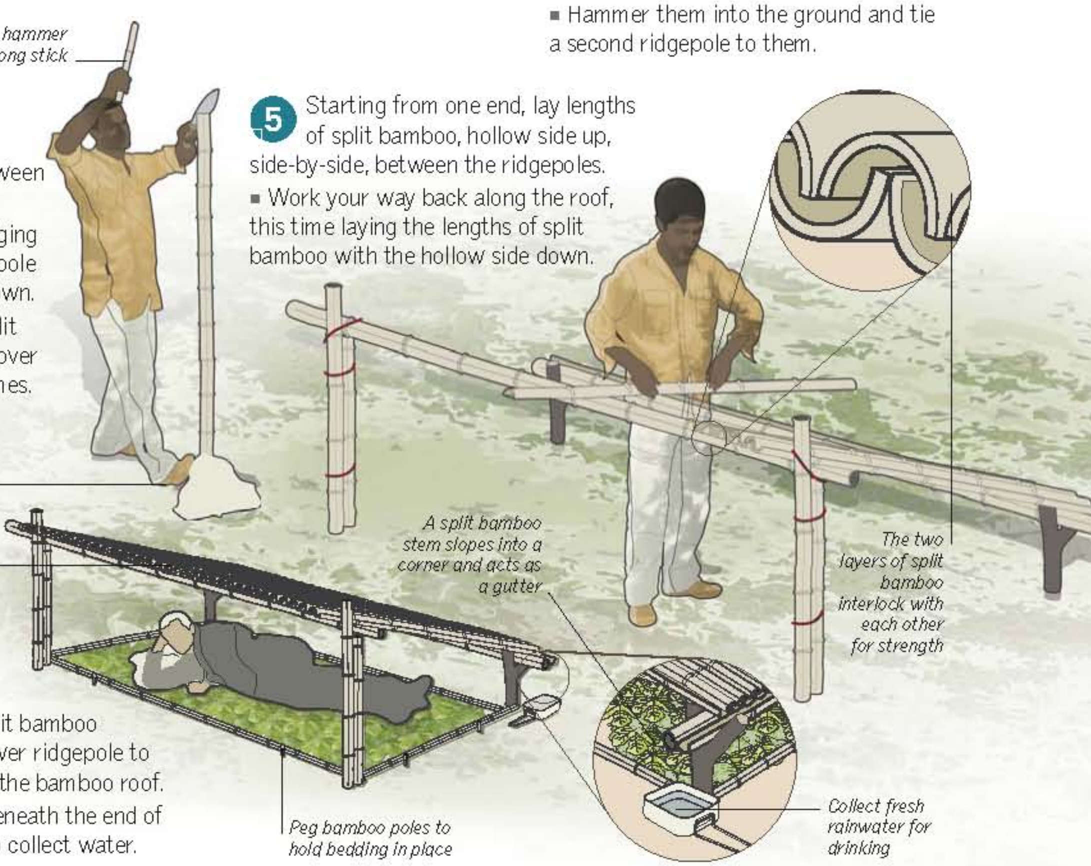
Wedge in knife then hammer it down with a strong stick
Steady the bamboo stem against a rock with your foot
The two layers of split bamboo interlock with each other for strength
The split bamboo layers of the roof direct water into the gutter
A split bamboo stem slopes into a corner and acts as a gutter
Peg bamboo poles to hold bedding in place
Collect fresh rainwater for drinking

4 Cut lengths of bamboo long enough to reach between the two ridgepoles.

- Split these by wedging your knife into each pole and hammering it down.
- Prepare enough split bamboo lengths to cover the roof area two times.

5 Starting from one end, lay lengths of split bamboo, hollow side up, side-by-side, between the ridgepoles.

- Work your way back along the roof, this time laying the lengths of split bamboo with the hollow side down.

6 Lash a long split bamboo stem to the lower ridgepole to form a gutter under the bamboo roof.

- Put a pan or pot beneath the end of this sloping gutter to collect water.

JUNGLE HUT

With a little extra effort you can make a more permanent and substantial shelter than a jungle A-frame. The raised apex roof of a jungle hut allows you to sit on the platform in relative comfort. This method uses a framework of four posts, but using two trees instead of two of the poles would make it more rigid.

TOOLS AND MATERIALS

- Strong posts and poles
- Branches for platform
- Knife, saw, machete, or parang
- Digging tool
- Broad leaves for thatching the roof

1 Dig four strong posts into the ground to form a rectangle at least 1 ft (30 cm) longer and wider than yourself.

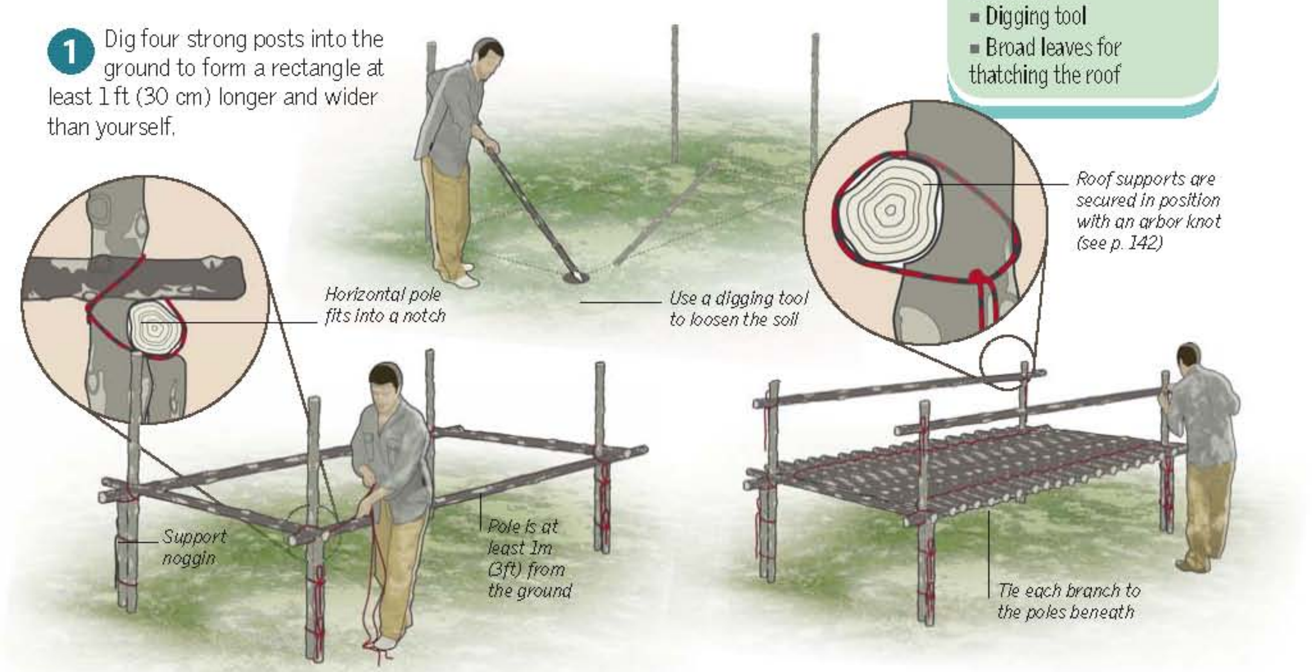
Horizontal pole fits into a notch
Use a digging tool to loosen the soil
Roof supports are secured in position with an arbor knot (see p. 142)
Support noggin
Pole is at least 1m (3ft) from the ground
Tie each branch to the poles beneath

2 With your knife or saw, cut a notch into each post deep enough to fit the curve of the horizontal pole.

- Wedge the four horizontal poles into their notches and secure the junction using an arbor knot (see p. 142).
- Lash a noggin to each post to support the poles.

3 Lay a row of stripped branches side-by-side across the horizontal poles to form a raised floor.

- To make the roof supports, cut a notch on the inside of each post about 3 ft (1 m) higher than the platform.
- Tie a pole into the notches on the posts.

THATCHING LEAVES

By taking advantage of the shapes of some tropical leaves, you can make a substantial, long-lasting roof or walls. The bigger and broader leaves involve less work. If you use rattan palm leaves you can create an alternating interweave that gives a tighter thatch than the overlapping method described above.

RATTAN LEAVES

The rattan palm has leaves that are composed of rows of smaller leaflets. You can split the leaves in two and hang the halves in layers on the framework of your roof. Alternatively, you can use them whole, by folding the leaflets from one side and individually weaving them with leaflets from the other side.

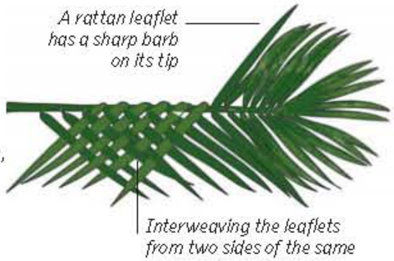
A rattan leaflet has a sharp barb on its tip
Interweaving the leaflets from two sides of the same leaf creates a tight mesh

LONG, BROAD LEAVES

Many tropical plants have long, broad leaves that are good for thatching. These include some banyan figs, rubber plants, and types of banana. Arrange these leaves side-by-side on the poles of your roof frame, tuck them over the pole, and sew them into position with strips of vine. The tips of the leaves in one row point down over the leaves of the row underneath.

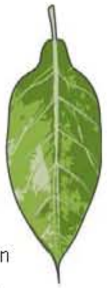

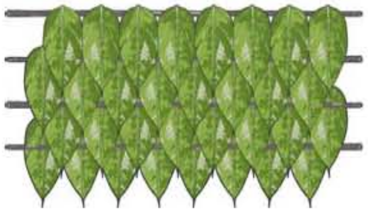

ALTERNATIVE SHELTERS

Wickiups are found in various forms around the world and are adapted as local needs and materials dictate. For example, Native Americans made them as temporary shelters in the plains, where they were also known as teepees. The pygmies of the rain forest used saplings to form a hemisphere that, once covered with natural material, created a warm, dry shelter.

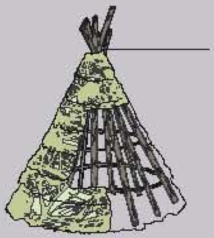

An opening at the top of the wickiup allows air to circulate

WICKIUP

The wickiup is a cluster of straight poles that are lashed together at the top, with an interwoven framework that's covered with animal hides or grass.

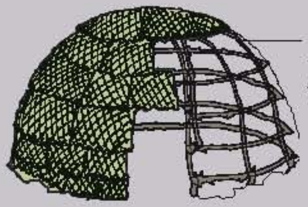

The domed shape gives plenty of room inside

PYGMY HUT

The domed pygmy hut is made from a circle of bent saplings or limber poles secured firmly in the ground, then lashed and thatched with natural materials.

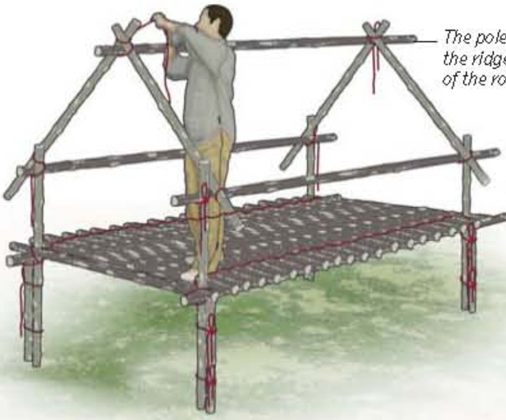

The pole forms the ridge of the roof

④ Tie poles together to form two A-frames. Tie these on top of the roof support poles at each end of the framework.

- Place a ridgepole across the apex of the two A-frames and tie it in place.

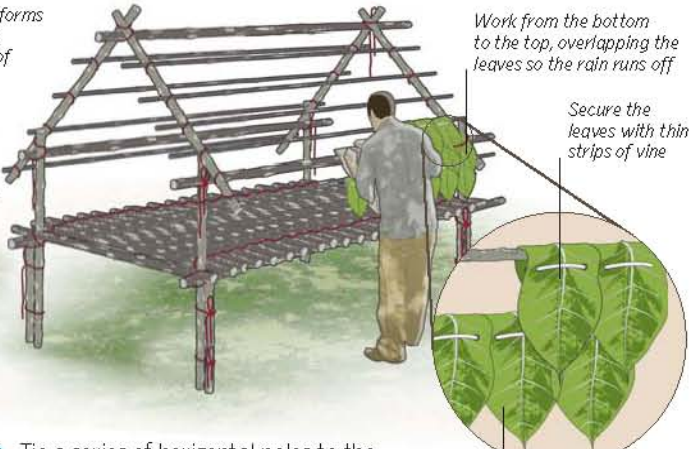

Work from the bottom to the top, overlapping the leaves so the rain runs off

Secure the leaves with thin strips of vine

Hang leaves with tips pointing down and shiny side up

⑤ Tie a series of horizontal poles to the legs of both A-frames to create a roof.

- Cover the roof with big, broad leaves (such as palm or banana) by folding them over the horizontal roof poles.

THREE-LOBED LEAVES

Leaves with three lobes, such as the familiar fig leaf, can simply be hooked over the poles of your roof with the stem pointing upward. On each row of leaves you need to hang the left and right lobes either behind the pole or in front of it in an alternating pattern. The middle lobe then hangs down over two leaves on the row underneath.

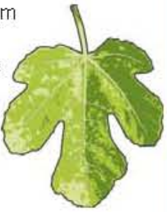

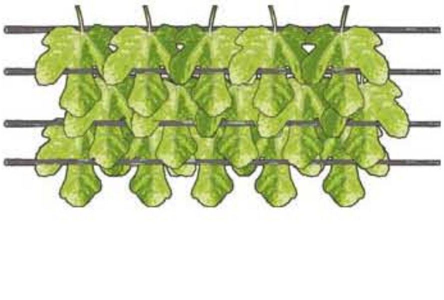

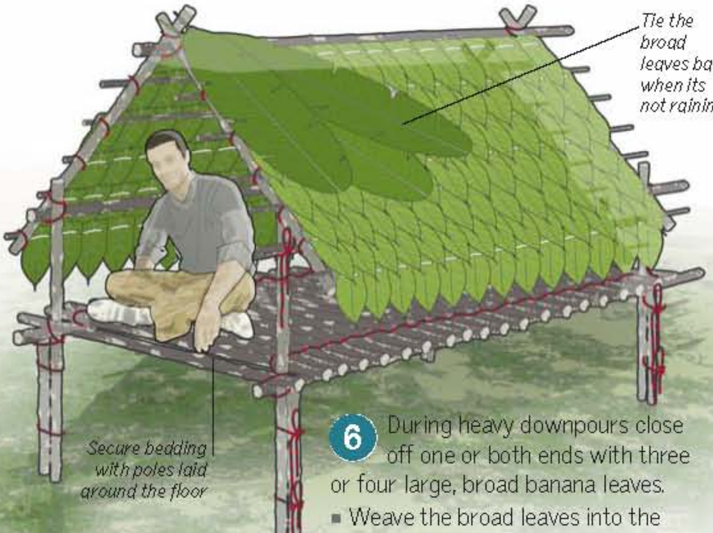

Tie the broad leaves back when its not raining

Secure bedding with poles laid around the floor

⑥ During heavy downpours close off one or both ends with three or four large, broad banana leaves.

- Weave the broad leaves into the A-frame at the entrance, and let them hang down.

TRUE-LIFE ACCOUNT

EXTREME SURVIVAL—IN THE JUNGLE

USEFUL EQUIPMENT

- Machete/parang
- Tarpaulin/shelter sheet
- Hammock and mosquito net
- Insect repellant
- Signal flares and whistle
- Flashlight and batteries
- First-aid kit
- Map, compass, GPS
- Survival tin, bushcraft knife
- Cell/satellite phone
- Poncho/bivy sack

FRENCHMEN GUILHEM NAYRAL AND LOÏC PILLOIS lost their way on a 78 mile (125 km) trek through virgin rain forest in French Guiana. They survived for 51 days in the jungle by drinking rainwater and eating palm seeds, snakes, and insects—although Nayral narrowly escaped death after eating a poisonous spider.

The pair set off from the Grand Kanori rapids on the Approuague River on Wednesday, February 14, 2007, bound for Saül, a former mining village at the center of the country. They planned to spend 12 days hiking, and carried sufficient food supplies, a compass and map, machete, a tarpaulin, and two hammocks. They soon found that the going was tough—some days it would take several hours of hacking through vines to hike just one mile. On the morning of February 26, when Nayral and Pillois had been due to reach Saül, the pair found themselves far from civilization and in unexpected terrain.

Knowing that a search operation would be launched, they set up camp and waited to be rescued. They built a shelter and divided the tasks—Nayral in charge of food and Pillois the fire, which was kept alight constantly to attract rescuers. They had abundant water from rainfall, but were reduced to scavenging for palm seeds, beetles, snakes, frogs, and spiders.

> **"THE PAIR FOUND THEMSELVES FAR FROM CIVILIZATION AND IN UNEXPECTED TERRAIN"**

Occasionally, helicopters passed overhead, but failed to spot them through the dense canopy of foliage. After waiting for three weeks, the pair decided to abandon camp and trek west toward Saül. After another week of trekking for just three hours a day, unknowingly just 3 miles (5 km) from Saül, Nayral was incapacitated after eating a still-poisonous half-cooked spider. With no choice but to leave his companion behind, Pillois pushed on and reached Saül, returning with a helicopter to rescue Nayral—dehydrated, with intestinal poisoning, and plagued by parasites—on April 5, 51 days after beginning his trek.

WHAT TO DO

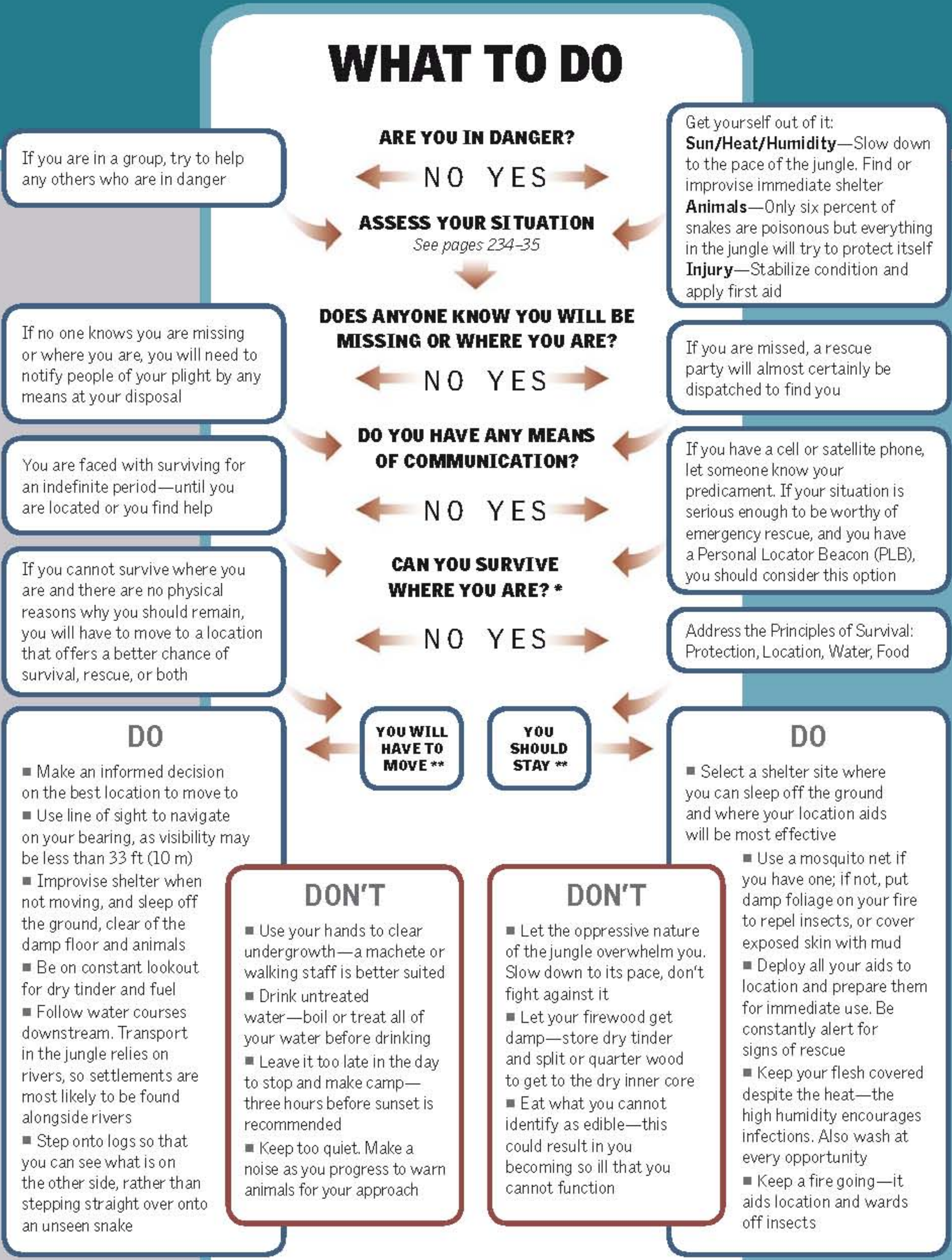

ARE YOU IN DANGER?

NO — If you are in a group, try to help any others who are in danger

YES — Get yourself out of it:
Sun/Heat/Humidity—Slow down to the pace of the jungle. Find or improvise immediate shelter
Animals—Only six percent of snakes are poisonous but everything in the jungle will try to protect itself
Injury—Stabilize condition and apply first aid

ASSESS YOUR SITUATION
See pages 234–35

DOES ANYONE KNOW YOU WILL BE MISSING OR WHERE YOU ARE?

NO — If no one knows you are missing or where you are, you will need to notify people of your plight by any means at your disposal

YES — If you are missed, a rescue party will almost certainly be dispatched to find you

DO YOU HAVE ANY MEANS OF COMMUNICATION?

NO — You are faced with surviving for an indefinite period—until you are located or you find help

YES — If you have a cell or satellite phone, let someone know your predicament. If your situation is serious enough to be worthy of emergency rescue, and you have a Personal Locator Beacon (PLB), you should consider this option

CAN YOU SURVIVE WHERE YOU ARE? *

NO — If you cannot survive where you are and there are no physical reasons why you should remain, you will have to move to a location that offers a better chance of survival, rescue, or both

YES — Address the Principles of Survival: Protection, Location, Water, Food

YOU WILL HAVE TO MOVE **

DO

- Make an informed decision on the best location to move to
- Use line of sight to navigate on your bearing, as visibility may be less than 33 ft (10 m)
- Improvise shelter when not moving, and sleep off the ground, clear of the damp floor and animals
- Be on constant lookout for dry tinder and fuel
- Follow water courses downstream. Transport in the jungle relies on rivers, so settlements are most likely to be found alongside rivers
- Step onto logs so that you can see what is on the other side, rather than stepping straight over onto an unseen snake

DON'T

- Use your hands to clear undergrowth—a machete or walking staff is better suited
- Drink untreated water—boil or treat all of your water before drinking
- Leave it too late in the day to stop and make camp—three hours before sunset is recommended
- Keep too quiet. Make a noise as you progress to warn animals for your approach

YOU SHOULD STAY **

DO

- Select a shelter site where you can sleep off the ground and where your location aids will be most effective
- Use a mosquito net if you have one; if not, put damp foliage on your fire to repel insects, or cover exposed skin with mud
- Deploy all your aids to location and prepare them for immediate use. Be constantly alert for signs of rescue
- Keep your flesh covered despite the heat—the high humidity encourages infections. Also wash at every opportunity
- Keep a fire going—it aids location and wards off insects

DON'T

- Let the oppressive nature of the jungle overwhelm you. Slow down to its pace, don't fight against it
- Let your firewood get damp—store dry tinder and split or quarter wood to get to the dry inner core
- Eat what you cannot identify as edible—this could result in you becoming so ill that you cannot function

* If you cannot survive where you are, but you also cannot move owing to injury or other factors, you must do everything you can to attract rescue.
** If your situation changes (for instance, you are "moving" to find help, and you find a suitable location in which you can stay and survive) consult the alternative "Do" and "Don'ts."

DESERT SHELTERS

IF YOU'RE PLANNING A TRIP into the desert, take something you can use to improvise an immediate shelter from the sun—for example, a shelter sheet, tarpaulin, poncho, space blanket, or even a couple of pieces of parachute material that will pack down into almost nothing. You can either build a shelter called a "scrape" in a natural hollow or erect a quick shelter above the ground using your poncho.

TOOLS AND MATERIALS

- Cordage and pegs
- Digging tool
- Knife
- Poncho, space blanket, tarp, or parachute material
- Rocks or ballast material
- Strong posts

BUILDING IN THE DESERT

Erecting a natural shelter in the desert is a challenge because of the heat and potential lack of materials, so try to find a site that's shaded by a tree or shrub.

POINTS TO REMEMBER

The following tips will help you deal with the extremes of temperature:

- Never try to build your shelter during the hottest part of the day.
- Ration your sweat and not your water. Avoid exerting yourself. If you start to sweat then stop what you're doing and take a break in the shade (30 minutes under an unfolded map or a space blanket and have a drink). If in a group, share the work.
- Don't leave it until the last minute to find a suitable location for your shelter. Make the decision early and plan accordingly.
- Never build a shelter in a low-lying area, dry river bed, or wadi as they are potentially at risk of flash floods.
- Avoid the top of large, isolated hills or mountains because of the danger from lightning and extreme winds.
- Try to set up your shelter on a small rise, where the temperature can be as much as 10 degrees warmer at night (cold air sinks).
- Ensure the opening faces north in the Northern Hemisphere and south in the Southern Hemisphere so the sun doesn't shine directly in during the day.
- Try to dig down to create a depression, as the ground is cooler below the surface.
- Build your shelter for the worst possible conditions and not the conditions at the time. Desert weather can change very quickly and dramatically, and the ferocious winds will rip apart any shelter that is not secure.
- If your shelter sheet has a shiny side, make sure it faces up to reflect heat and act as an aid to location from above.

DESERT SCRAPE

If you have cord, you can dig a scrape and use the cord to peg out the sheet above the scrape. If you don't have cord the sheet will have to be held in place by other means, such as soil, sand, or rocks. With all layered desert shelters try to maintain tautness and separation between the layers.

CORDLESS SCRAPE

If you don't have enough cord to peg out a sheet, you can make a scrape by either digging down or building up the sides with rocks or sand mounds placed at regular intervals. Anchor your sheet with rocks.

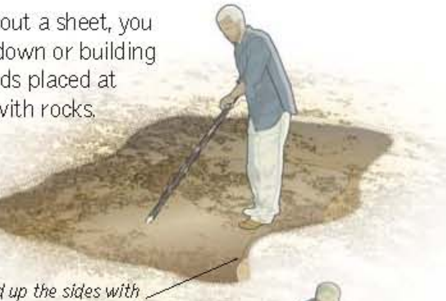
Build up the sides with rocks covered with soil

1 If the hollow isn't deep enough to lie in, make a digging tool and scrape out the soil from the bottom to build up the sides of the hollow.

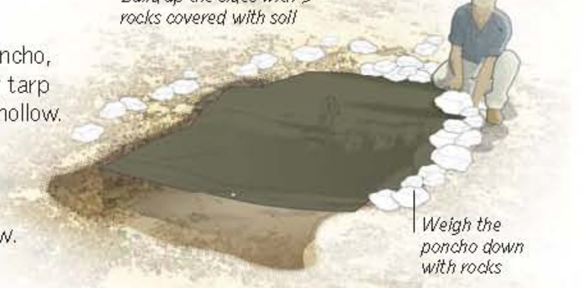
Weigh the poncho down with rocks

2 Spread your poncho, shelter sheet or tarp across the top of the hollow.

- Make sure the edges of the material overlap the sides of the hollow.

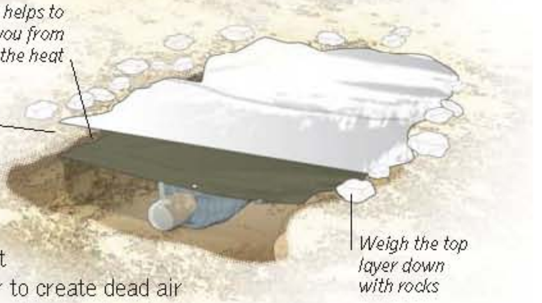
Air space helps to insulate you from the heat
Make a gap of at least 6 in (5 cm) between the layers
Weigh the top layer down with rocks

3 Use an additional sheet to make a second layer to create dead air space that helps to reduce the temperature below.

- If you only have one piece of material to use as cover, try to double it over to create the two layers.

QUICK SHELTER

If you can't find a hollow, erect a poncho shelter (see pp. 158–59) in a place that keeps you cool during the day—for example, under existing shade, such as trees or bushes, or at the top of a slight rise in order to benefit from any cool breeze.

1 Find a site beside a tree or secure a post next to where you want the shelter's opening to be.

- Rig a ridgeline to the tree or post, and peg your poncho over it to form a shelter.
- Repeat with a second poncho, shelter sheet, or space blanket to create a separate layer.

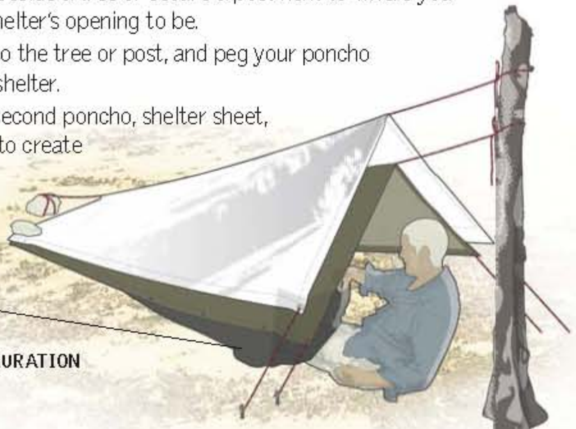
Leave sides and bottom open to air the shelter

DAY-TIME CONFIGURATION

2 At night, de-rig the outer shelter and use it as a sleeping cover for warmth.

- Prevent heat escaping by securing the sides and bottom with rocks, stones, shingle, or sand.
- Sleep on some bedding if possible.

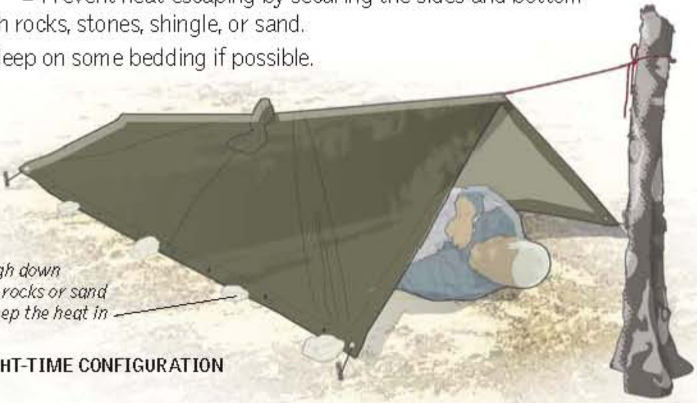
Weigh down with rocks or sand to keep the heat in

NIGHT-TIME CONFIGURATION

PARA SCRAPE

If you have cordage you can tie your sheet to four posts. If you haven't got enough cordage for four, use your backpack or a pile of stones instead.

- Prepare the depression or hollow as for a cordless scrape (see left).
- Use trees if available, or improvise posts from wood, piles of stones, or your backpack.
- Tie the sheet to the trees or the posts above the depression, leaving a gap for air to flow over.
- Create a second layer at least 6 in (15 cm) above the first.
- If foliage is available, place it between the layers to maintain separation.

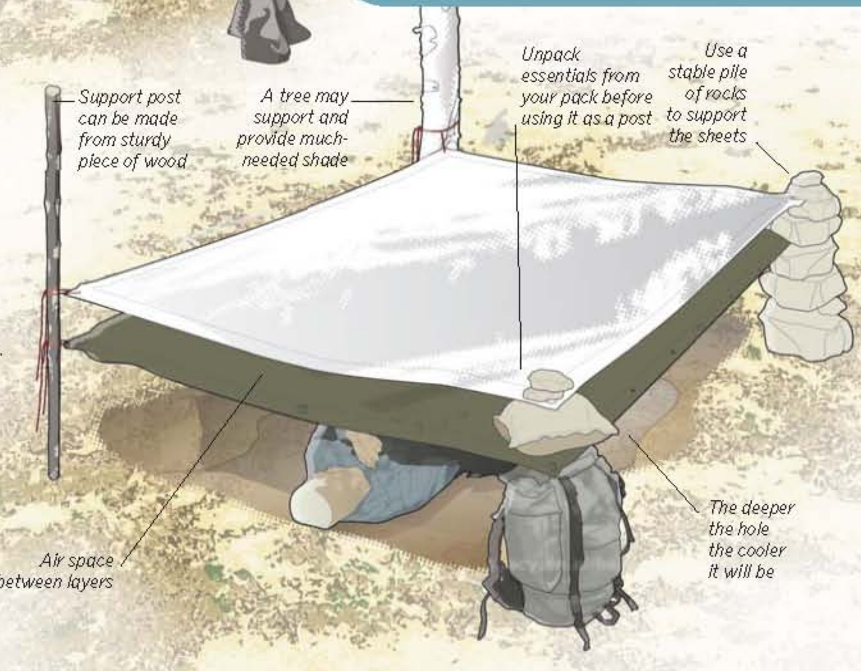
Support post can be made from sturdy piece of wood
A tree may support and provide much-needed shade
Unpack essentials from your pack before using it as a post
Use a stable pile of rocks to support the sheets
The deeper the hole the cooler it will be
Air space between layers

SUN PROTECTION

You should always carry immediate protection against the sun. You may be able to create shade using something you've brought, such as a trekking umbrella, tent, or space blanket.

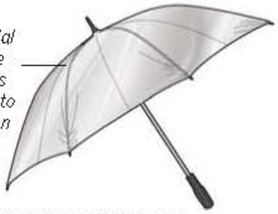
Material may be used as an aid to location

TREKKING UMBRELLA

A small, lightweight umbrella protects against sun, wind, and rain, creates cool shade, and doubles as a walking stick. Some have reflective material, or a flashlight in the handle.

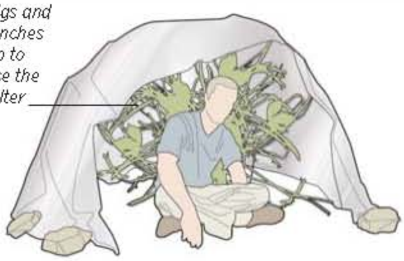
Twigs and branches help to raise the shelter

SPACE BLANKET

This should be part of your basic survival equipment and will afford immediate relief from the sun. Remember that it's almost impossible to pack a space blanket to its original size once it's unpacked.

SHORELINE SHELTERS

IF YOU FIND YOURSELF in a survival situation, and can make your way to a shoreline or beach, it may offer you particular benefits. Rescue is more likely here than further inland as your aids to location work better in open areas, people are more likely to live on the coasts, and useful flotsam washes up twice daily on even the remotest of beaches.

TOOLS AND MATERIALS

- Digging tool
- Driftwood and/or rocks
- Broad-leaved plants or grass, or poncho or tarp
- Knife
- Cordage and pegs

DRIFTWOOD SHELTER

If there's enough driftwood around on the shoreline, you can use it to make a variety of shelters covered in this chapter. A hole-in-the-ground driftwood shelter offers simple protection, but may need continued attention if the sand is very fine or gets wet.

BESIDE THE WATER

Shorelines vary with the environment—from tropical beaches, where sleeping out under the stars is not a problem, to rugged coasts in higher latitudes, where spending a night unprotected from the elements would be suicidal.

POINTS TO REMEMBER

If you intend to spend a night on a shoreline, exposed to the elements, the following tips may help you:

- Build the shelter above the highest high-tide mark on a seashore (see opposite) and above the highest watermark on a river or lake beach. If in doubt, move slightly further inland, where the protection may be better and materials more easily available.
- Try to establish what the weather's going to do by looking at the sky, watching the water, or detecting changes in the wind (see pp. 82–83).
- Plan for the worst, or at least have a back-up location should things not work out.
- Check the area for insects, such as midges, mosquitoes, gnats, and horseflies.
- Look for signs of wildlife, such as crabs and even turtles as sources of food.
- Finish your shelter and collect water and firewood before it gets dark.
- Beware the effects of sun and windburn, even on overcast days.
- Utilize driftwood and other building materials. Remember, any wood that's been in the sea is likely to be very heavy.

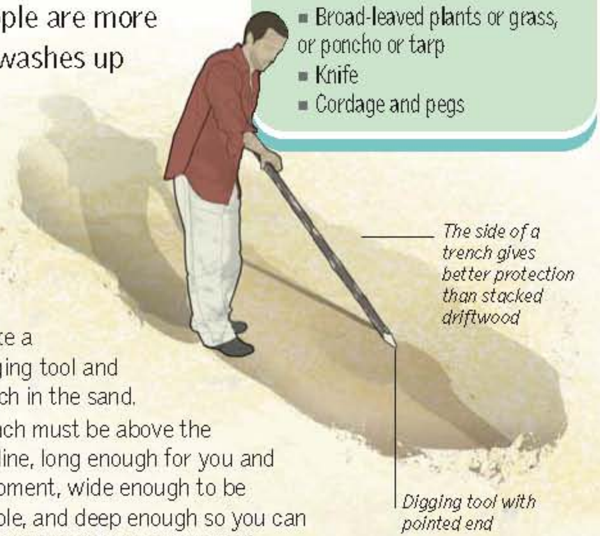
The side of a trench gives better protection than stacked driftwood
Digging tool with pointed end

① Make a digging tool and dig a trench in the sand.

- The trench must be above the high-tide line, long enough for you and your equipment, wide enough to be comfortable, and deep enough so you can roll over without disturbing the roof.

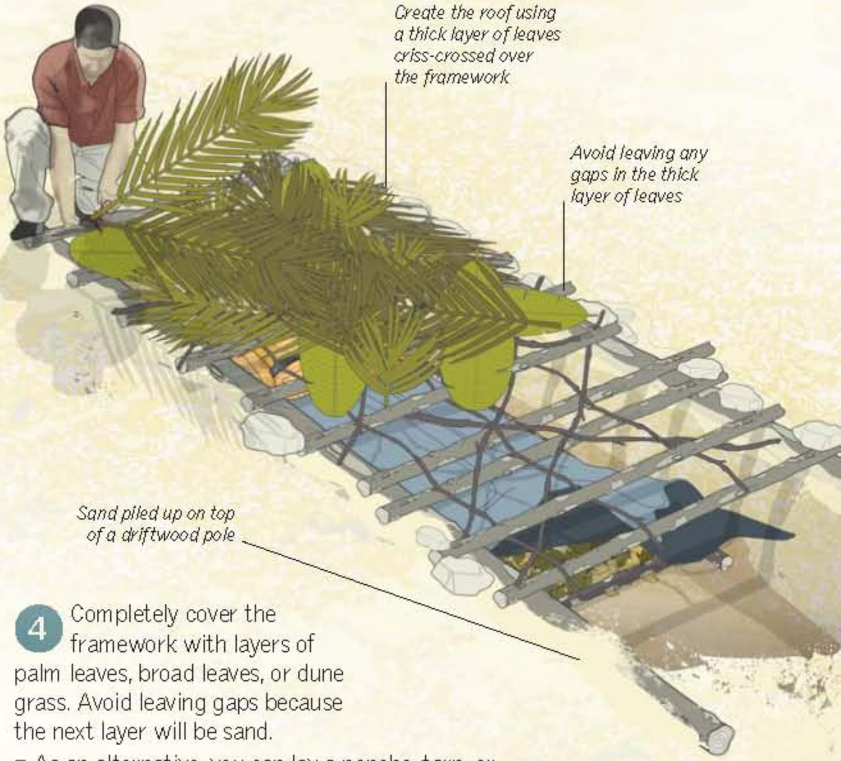
Create the roof using a thick layer of leaves criss-crossed over the framework
Avoid leaving any gaps in the thick layer of leaves
Sand piled up on top of a driftwood pole

④ Completely cover the framework with layers of palm leaves, broad leaves, or dune grass. Avoid leaving gaps because the next layer will be sand.

- As an alternative, you can lay a poncho, tarp, or shelter sheet over the framework. Weigh it down with sand or stones, or peg it out if you have cordage.

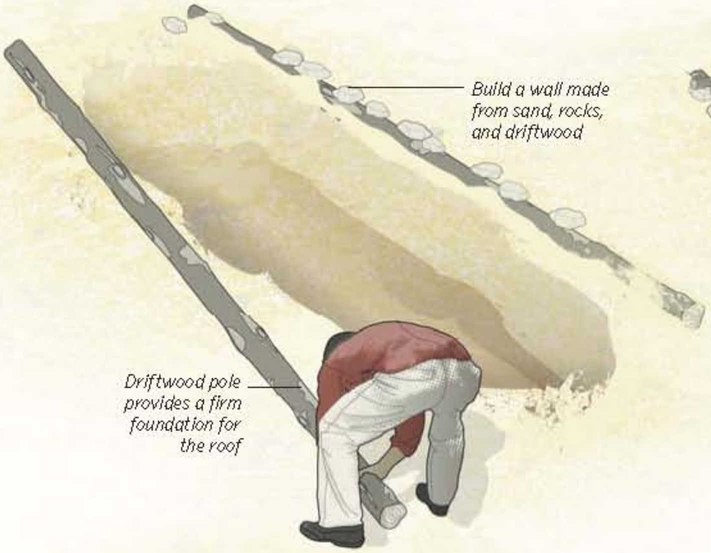

Build a wall made from sand, rocks, and driftwood

Driftwood pole provides a firm foundation for the roof

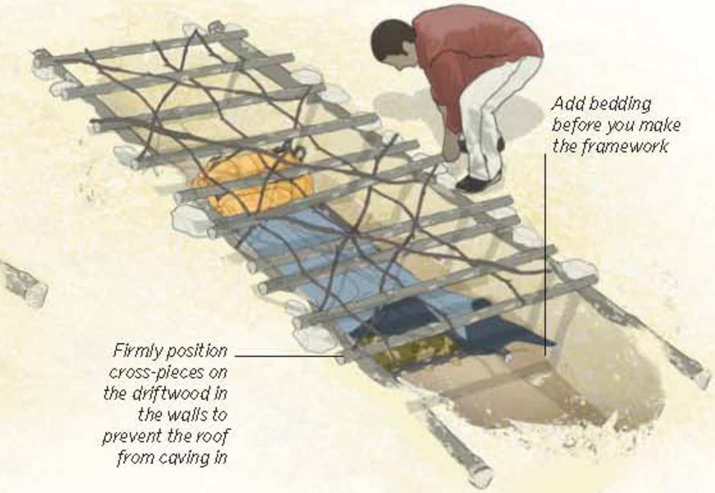

Add bedding before you make the framework

Firmly position cross-pieces on the driftwood in the walls to prevent the roof from caving in

2 Find two pieces of driftwood that are as long as your trench. Several shorter pieces in a line will work equally well if you can't find long pieces.

- Place the driftwood beside the trench and pile on sand and rocks to build up the height of the walls.

3 Place pieces of driftwood across the trench to form the framework of a basic roof.

- Weave smaller pieces of driftwood into the framework, making sure they sit firmly on the driftwood in the walls.

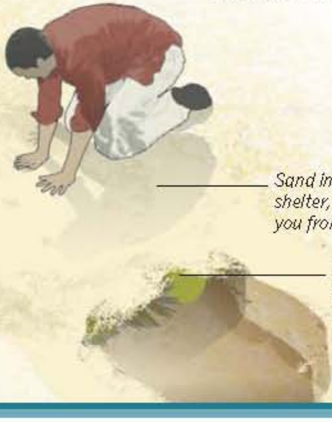

Sand insulates the shelter, and protects you from the elements

Bedding material is essential for keeping warm at night

5 Once you have covered the framework sufficiently, finish the shelter with a thick layer of sand or soil.

- The more cover you put on the roof, the more protected from the elements you will be. However, take care not to put so much weight on it that it collapses.

USING A LIFERAFT AS SHELTER

Remember, if you have abandoned ship in a liferaft, it can be used as a ready-made immediate shelter—even on land.

ON THE BEACH

The best place for a shelter is the landward side of the backshore: you can watch the sea, your daily fire can be seen from the sea, and you can see your shelter as you scavenge along the beach. In bad weather, however, the landward side of the dune crest is the best place.

PARTS OF A BEACH

A beach is shaped by the tides and the berm (a natural ridge) consists of deposits of the materials that make up the changing shoreline (sand, shingle, shale, and so on).

- At the top of the berm is a crest. A slope, or face, leads down from the crest to the water. At the very bottom of the face there may be a trough.
- The storm beach extends inland and this is where the wind and storms blow small particles of sand.
- Dunes form where the wind creates larger deposits of sand behind the beach.
- Longshore bars (sandbanks) may lie further out to sea and are formed where the waves first start to break.

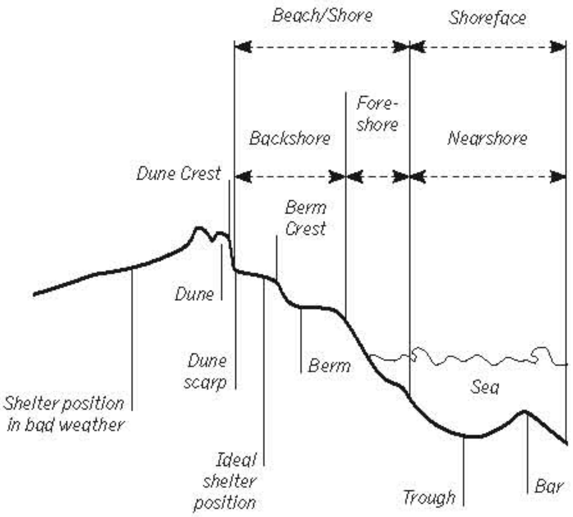

SNOW SHELTERS

THE TYPE OF SNOW SHELTER you can build depends on the kind of snow, the equipment you have, and the opportunities offered by the environment—for example, wooded areas are usually better than open areas because they provide protection and natural materials. You could build a snow trench, snow cave, tree pit, snow ledge, or a quinzhee.

TOOLS AND MATERIALS

- Boughs and branches
- Bedding
- Long pole
- Spade or pan for shovelling snow
- Long knife or saw
- Knife (or other long blade)
- Tarpaulin or shelter sheet

COMPACTED SNOW TRENCH

If the snow is compact enough, and if you have a long knife or snow saw, you can cut out blocks of snow to form a trench and then use the blocks to form an apex roof. This design requires a lot of effort and a bit of practice, but gives you a solid shelter with some additional height.

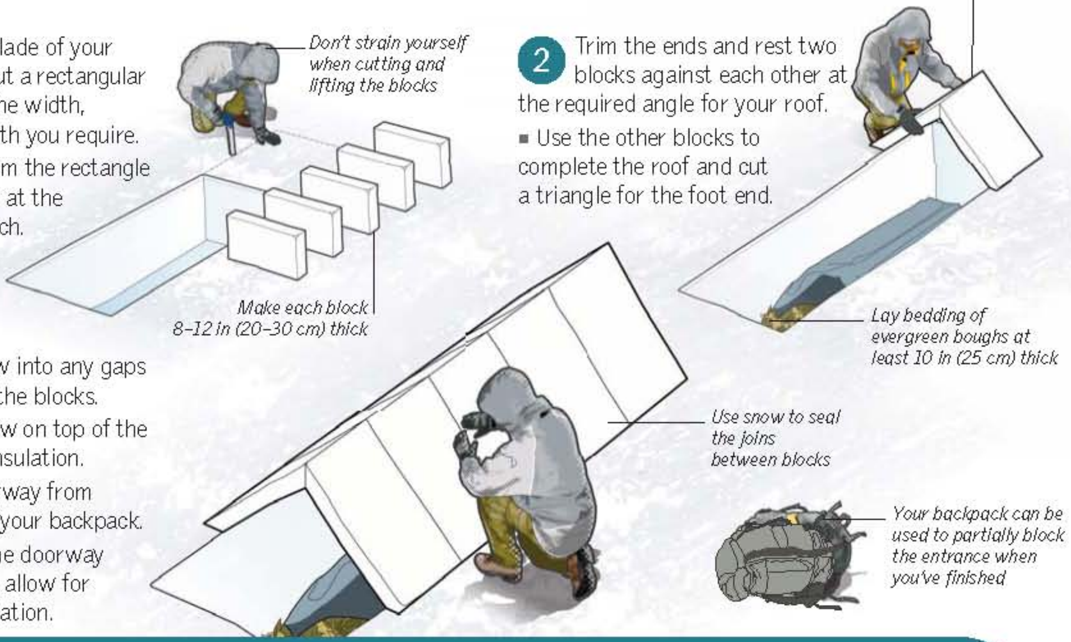

1 Use the blade of your knife to cut a rectangular trench that is the width, length, and depth you require.

- Cut blocks from the rectangle and place them at the side of the trench.

Don't strain yourself when cutting and lifting the blocks

Make each block 8–12 in (20–30 cm) thick

2 Trim the ends and rest two blocks against each other at the required angle for your roof.

- Use the other blocks to complete the roof and cut a triangle for the foot end.

Carefully balance and fit the trimmed blocks, starting at the foot end

Lay bedding of evergreen boughs at least 10 in (25 cm) thick

3 Pack snow into any gaps between the blocks.

- Pile extra snow on top of the blocks to add insulation.
- Create a doorway from snow blocks or your backpack.
- Don't block the doorway completely, but allow for adequate ventilation.

Use snow to seal the joins between blocks

Your backpack can be used to partially block the entrance when you've finished

BUILDING SNOW SHELTERS

Study the snow around you to determine whether it's compacted or uncompacted before you start.

POINTS TO REMEMBER

The following tips may help if you intend to build and stay in a snow shelter:

- Make a shelter that's just big enough for you and your equipment. Don't spend hours building a shelter for only one night: do the least amount of work for the maximum amount of protection.
- If you need to peg out guylines in the snow, tie a short stick 6–12 in (15–30 cm) long to a line or cordage and bury it in the snow. Compact the snow down on top and, when the snow sinters (hardens), your peg will be held secure.
- Snow is an excellent insulator. Fresh, uncompacted snow is typically 90–95 percent trapped air. Since the air barely moves, the snow can keep you warm and dry if used correctly.
- Check your site for hazards, such as snowdrifts, freezing winds, avalanche, cornice collapse, and big animals.
- Create ventilation holes—make one near the ground to let fresh air in and one at the top to let air escape. Check the holes are clear every 1–2 hours.
- Keep tools inside the shelter in case you have to dig your way out.
- If you leave the shelter, mark the entrance. Take basic survival equipment with you: it's better to have and not need than to need and not have.
- Brush snow off your equipment and clothing before entering the shelter.
- Tie all vital equipment to yourself so that you can't accidentally drop and lose it in deep snow.

FOUND SHELTERS

If you're lucky you may find a tree that has space under it so you don't have to dig a trench. For example, under a low bough or in a tree pit—an area where a heavy and deep snowfall has built up around a tree, leaving little or no snow under the lower branches. Use your walking stick to check the depth of the snow, and also to check for pockets of air.

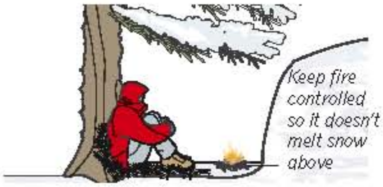
Keep fire controlled so it doesn't melt snow above

LOW BOUGH

Find an evergreen tree with a large branch lying on top of the snow. Dig down from the leeward side, excavate a pit, insulate the floor with boughs, and make sure you have adequate ventilation.

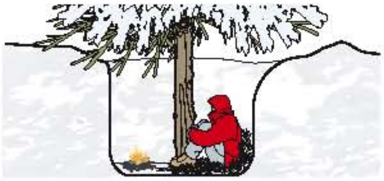

TREE PIT

Test the snow around a tree that has large, low, snowbound branches. Little or no resistance indicates a pit. Dig from the leeward side, place boughs on the floor, and ventilate the pit.

FIGHTER TRENCH

If the snow is soft, a fighter trench is quick and easy to build. In an emergency, you can even make a trench by kicking out the soft snow. First, find a location that protects you from the elements as much as possible, then test the depth of the snow with your walking stick or a pole.

WARMING AND COOLING TIPS

Whether you're building a shelter or resting inside it, the following tips may help you stay at the right temperature:

- Remove layers of clothing as you work, perhaps to your base layers with a waterproof layer on top. Keep clothing dry so that when you stop working you can put it on again.
- Keep shelters at a constant temperature. If snow melts and then re-freezes, it stops insulating.
- Avoid heating your shelter too much. Even a candle flame can raise the temperature inside by four degrees.

1 Using a spade or pan, or by simply kicking away the snow, clear a trench large enough for you and your equipment.

- Allow at least enough depth for you to be able to roll over in your sleep without disturbing the roof.

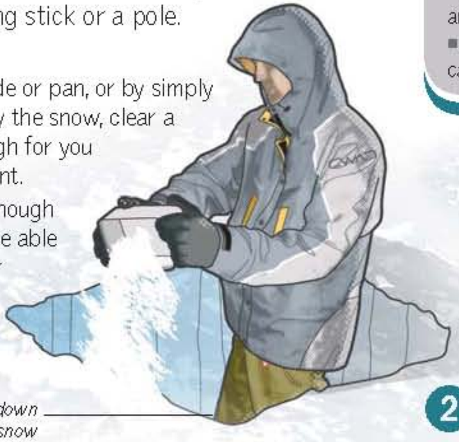
If you can, dig down through the soft snow to the ground

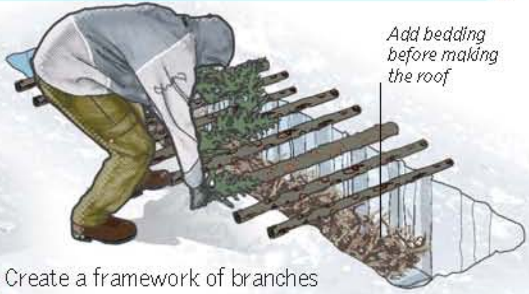
Add bedding before making the roof

2 Create a framework of branches and boughs across the trench.

- Make sure you have enough roofing material on top to stop the snow from penetrating through.

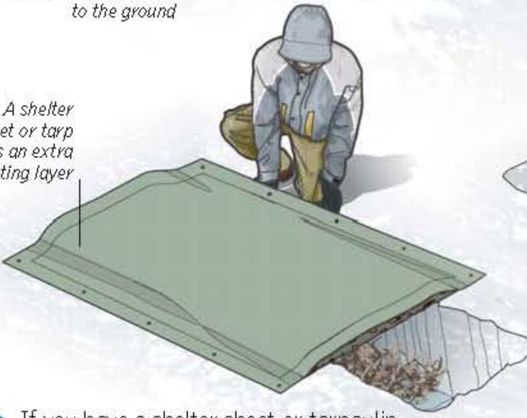
A shelter sheet or tarp makes an extra insulating layer

3 If you have a shelter sheet or tarpaulin, place it on top of the framework to form an extra insulating layer.

- Alternatively, you can use it to cover your bedding.

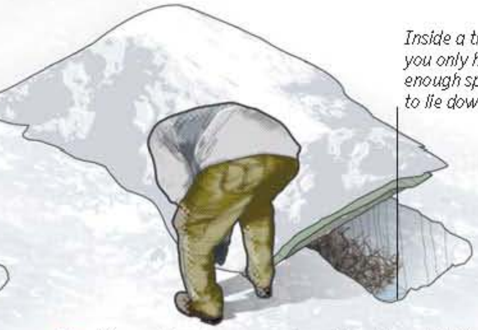
Inside a trench you only have enough space to lie down

4 Cover the framework with at least 12 in (30 cm) of snow to act as insulation.

- Dig a small pit at the entrance to allow easy access.
- At the entrance, you can make a small, controlled fire on a green log base.

QUINZHEE

A quinzhee is a dome-shaped shelter made by hollowing out a pile of settled snow. It's an overnight shelter that is easier to construct than the more permanent igloo ("igloo" means "home"), which is made from cut blocks of snow and requires skill and knowledge. You can't stand up in a quinzhee, but you can sit upright or just curl up.

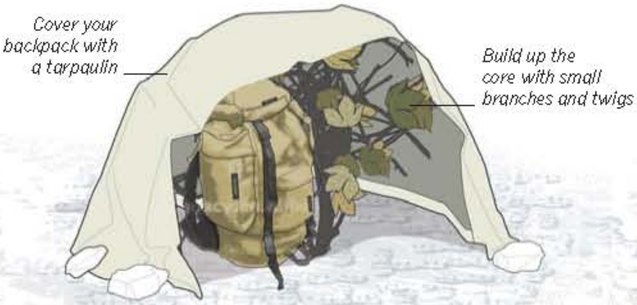
Cover your backpack with a tarpaulin
Build up the core with small branches and twigs

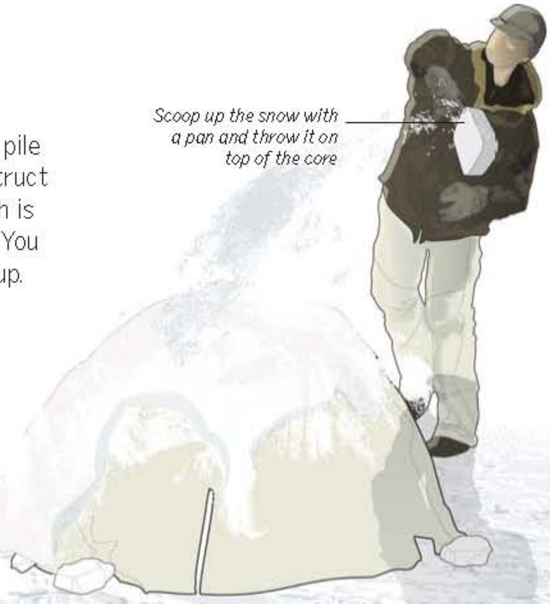
Scoop up the snow with a pan and throw it on top of the core

1 Find a relatively flat area that's covered with an abundance of snow.

- Mark a circle for your quinzhee, including walls that will be about 10 in (25 cm) thick, and stamp down the snow.
- Use your backpack and boughs or leaves covered with a tarpaulin to form the core of the shelter. Site the doorway at 90 degrees to the prevailing wind.

2 Use a container, pan, snowshoe, or other suitable item to gather as much soft snow as you can.

- Pile snow on the shelter's core to form a dome of the required height. Build up layers of snow until you have a covering of at least 10 in (25 cm), smoothing out each layer as you go.

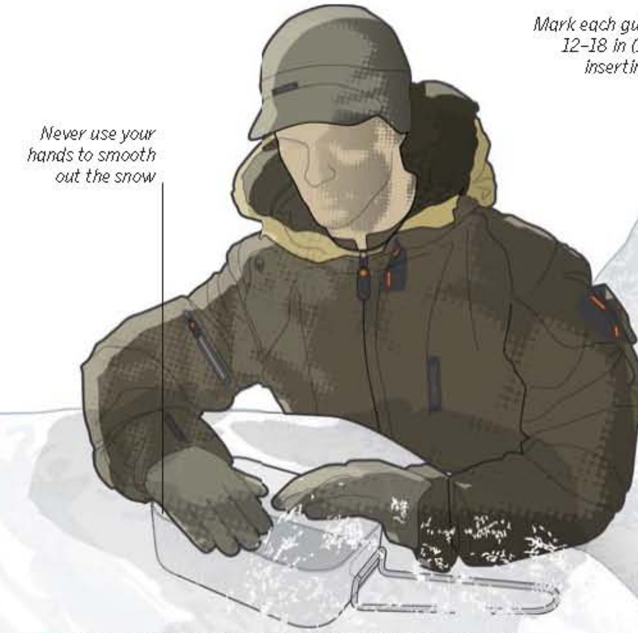
Never use your hands to smooth out the snow

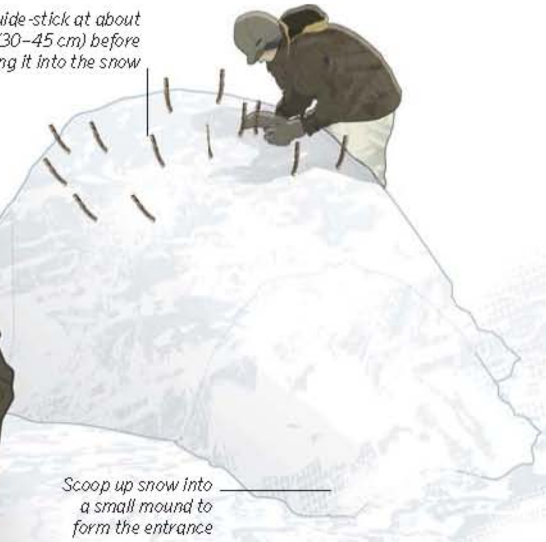
Mark each guide-stick at about 12–18 in (30–45 cm) before inserting it into the snow
Scoop up snow into a small mound to form the entrance

3 Smooth out the snow on the dome and leave it to sinter (harden) for 1–3 hours, depending on the type of snow and the ambient temperature.

- Keep active during this waiting period, particularly if it's windy: collect wood, build a fire (away from the quinzhee), and prepare yourself for the night.

4 To get an even thickness in the roof and walls, push guide-sticks of equal length through the snow toward the center of the dome.

- Build a small compact mound in front of the dome.

SNOW CAVE

A snow cave provides good protection but it takes a lot of work. Suitable locations might be compact snow on the lee side of a hill or an established snowdrift with a firm crust. Avoid snow that's newly fallen, powdery, loose, or shallow and uneven. The cave should be high enough to sit up in and deep enough for you and your equipment. Locate the entrance 45 degrees downwind to keep it free of drift.

BUILDING THE CAVE

- Dig a tunnel 3 ft (1 m) long into the snow bank, then excavate a cave on two levels. The lowest is the tunnel, while the other is a ledge at least 2 ft (70 cm) higher, and wide enough to sleep on.
- Create an arched ceiling to give the cave more support. Make it at least 18 in (45 cm) thick so it can take the weight of heavy snow.
- Mark the area with boughs to warn people where the shelter is.
- Insulate the sleeping ledge with plenty of natural material.
- Make at least one ventilation hole in the roof, but not facing into the wind.

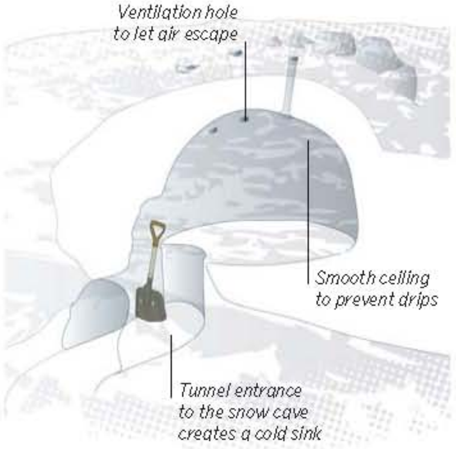
Ventilation hole to let air escape
Smooth ceiling to prevent drips
Tunnel entrance to the snow cave creates a cold sink

SNOW LEDGE

You can build a snow ledge from a well-packed drift of snow out of the wind, or at least perpendicular to it.

MAKING THE SNOW LEDGE

- Dig out blocks to form a doorway about 2 ft (70 cm) into the snow. Dig out blocks to form a horizontal rectangle above.
- Dig upward to create a sleeping platform and then form an arched ceiling.
- Place the cut blocks across the horizontal rectangle and seal any gaps with snow.
- Make a ventilation hole in the roof and one lower down to let fresh air circulate.

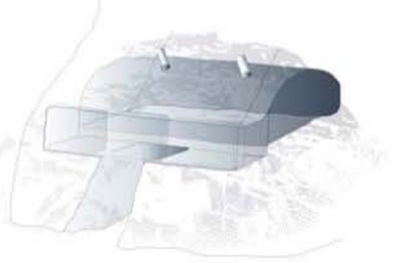

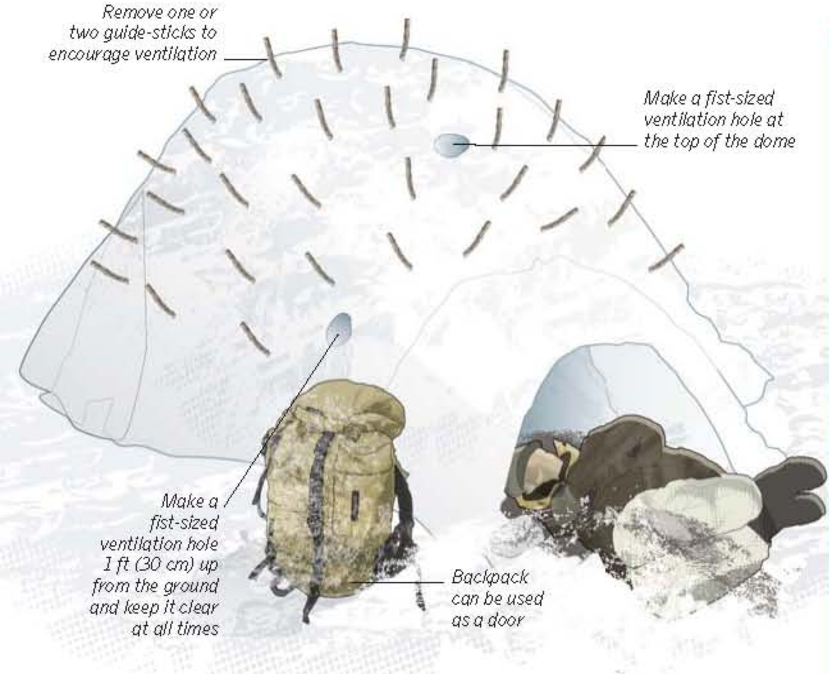
Remove one or two guide-sticks to encourage ventilation
Make a fist-sized ventilation hole at the top of the dome
Make a fist-sized ventilation hole 1 ft (30 cm) up from the ground and keep it clear at all times
Backpack can be used as a door

5 When the snow has hardened, burrow into the mound, remove your backpack and tarpaulin, and excavate snow from the core.

- Use the guide-sticks to keep the walls at least 10 in (25 cm) thick.
- Don't use your hands to dig as they will get cold and wet.
- Smooth out the snow on the inside to prevent drips from forming.
- Build a raised sleeping platform. This creates a cold sink (an area into which the coldest air falls), taking cold air away from your sleeping area.

CARBON MONOXIDE

Carbon monoxide is an odorless gas that's produced when there's not enough oxygen to create carbon dioxide from burning fuel. Carbon monoxide poisoning can be fatal in a well-insulated, non-ventilated environment.

PREVENTION IS BETTER THAN CURE

Create one or more holes, 3–4 in (7.5–10 cm) in diameter, at the base and top of your shelter. Make sure the air flows out unobstructed.

SIGNS OF POISONING

Carbon monoxide poisoning is cumulative and can build up over a few days. Mild effects are fatigue, faintness, and flu-like symptoms. As it progresses, the effects are severe headaches, nausea, and decreased mental coordination.

TAKE ACTION

Get into the fresh air at once. You need to breathe fresh air for at least four hours to reduce the amount of carbon monoxide in your system by half.

DETECTORS

Carbon monoxide detectors are widely available, but tend to be made for the home or RV. Some models are battery-operated, but they're too bulky for camping. You can wear a patch that changes color when carbon monoxide is in the air, giving an early visual warning.

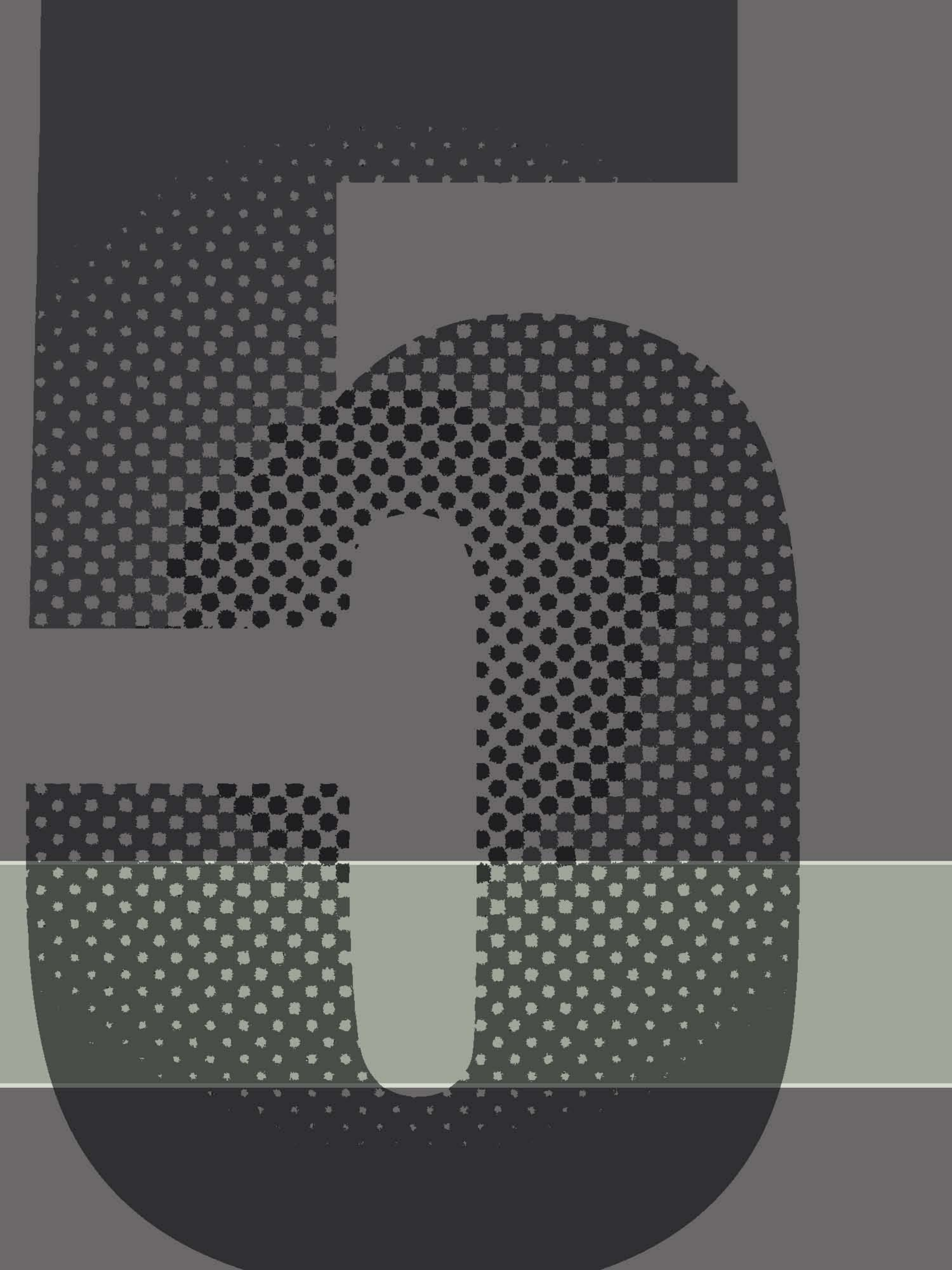

WATER AND FOOD

FIND AND TREAT WATER

The importance of water, even in a short-term survival situation, should never be underestimated. Water is essential to life, and a regular intake of 2–3 liters ($4^1/_5$–$6^1/_3$ pints) a day is needed just to maintain your water balance and prevent dehydration. The amount required can increase dramatically depending on factors such as the temperature of the environment, your age and physical condition, your workload, and whether you have been injured. It's not unusual for UK Royal Marines operating in desert or jungle environments to require 14 liters ($3^3/_4$ gallons) per day. We tend to take water for granted, not appreciating just how important it is until we don't have any—at which point it becomes the most important thing in the world.

You should always plan your treks around your need for water and your ability to replace it as required. There are many hydration systems available and many small and efficient methods of filtering and purifying water on the trail. In a survival situation, you should always strive to filter and purify any

In this section **YOU WILL DISCOVER...**

- that **birds** can **show you** the **way** to **water**...
- when to **suck** on a **small pebble**...
- how to **make** a **gypsy well** and a **solar still**...
- why a **Finnish marshmallow** could **save your life**...
- how to **absorb water** without **drinking it**...
- how to **improvise** a **basic bladder**...
- the **importance** of **surgical tubing**...

water before drinking it. Bringing water to the boil will kill all water-borne diseases. In the short-term, stomach bugs from contaminated water may not kill you but they can seriously affect your ability to carry out other survival tasks. However, if you have no choice, it's better to drink contaminated water than not to drink at all. That way, a doctor will at least be able to treat you, whereas dehydration will kill you—and death can't be treated! Never drink urine or salt water, as these will only dehydrate you more.

If a source of water is undrinkable, such as salt or stagnant water, or even urine, you can still produce drinking water if you have the means to start and maintain a fire.

THERE ARE MANY WAYS to purify water, but if you have a fire you will always be able to distill it—and therefore make it drinkable. Build your fire close to the water source (if the water can be poured into a container or a hole dug in the ground where it will not seep away quickly, this will make the process more efficient). When the fire is established, place rocks in it (don't use slate or other layered rocks as they might shatter). Once the rocks are heated, use a forked stick or similar to transfer them into the salt or foul water. Then, suspend a piece of absorbent material, such as a T-shirt or moss, over the hot rocks to collect the steam. The steam will condense on the material and the resulting water, which you can wring out, will be fit to drink. If you have a cooking pot or survival tin, you can simply fill it with water, boil it over a fire, and collect the steam in the same way.

If you have absolutely no means of treating or boiling water, you should try to:

- Find the clearest flowing water and collect it from the surface.
- Filter debris out, even if only through a sock.
- Remember, it's better to drink foul water than not to drink at all.

> “We tend to take **water for granted** until we don't have any—at which point it becomes the most **important thing in the world**”

THE IMPORTANCE OF WATER

YOU REQUIRE A STEADY supply of water to sustain yourself in a survival situation and without it you will dehydrate. Left unchecked, dehydration will end in death. To survive, a balance between water intake and loss must exist.

WHY YOU NEED WATER

Water is essential to life. It is needed, directly or indirectly, for every physical and chemical process that takes place in your body. Here are just a few of the functions that water performs:

- **Delivery service:** water carries oxygen, nutrients, and other essentials around the body.
- **Waste remover:** the kidneys use water to flush out toxins via urine.
- **Coolant:** water regulates the body's temperature.
- **Breathing aid:** the lungs use water to moisten inhaled air so that it doesn't irritate the sensitive pulmonary linings.
- **Sensory aid:** water helps conduct nervous impulses around the body.
- **Shock absorber:** water protects the vital organs and provides lubrication around the joints.

HOW MUCH WATER DO YOU NEED?

How much water you need to survive a particular situation is dictated by a number of factors, such as your physical state, the environment you are in, and your exertion levels. Even when resting in the shade, the average person will lose more than 1 liter (1¾ pints) of water each day just through breathing and urination, a figure that increases dramatically once loss of water through sweat is taken into account. A minimum of 3 liters (5¼ pints) per day is required to remain healthy in a survival situation, with this amount increasing for higher temperatures and heavier workloads.

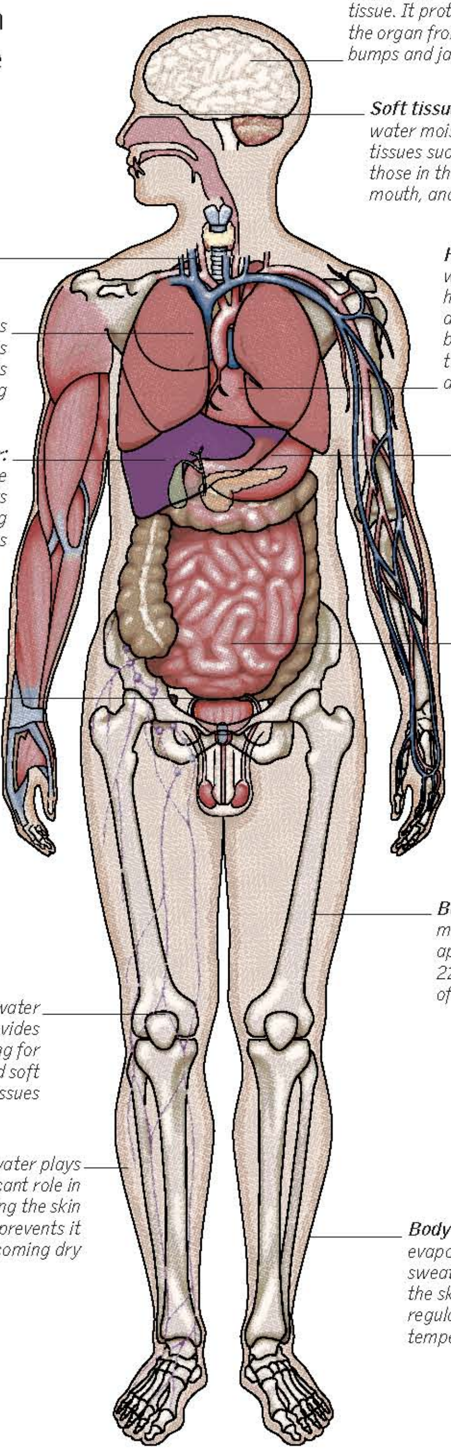

Brain: *water makes up approximately 80 percent of brain tissue. It protects the organ from bumps and jarring*

Soft tissue: *water moistens tissues such as those in the nose, mouth, and eyes*

Blood: *water plays a significant role in regulating blood pressure*

Heart: *higher water consumption helps remove fatty acids from the body and reduces the risk of a heart attack*

Lungs: *water helps moisten the lungs and assists breathing*

Kidneys and liver: *water lessens the burden on kidneys and liver by flushing out waste products*

Stomach: *water helps the body digest food in the stomach and turn it into energy*

Mineral absorption: *water helps dissolve minerals and other nutrients to make them accessible to the body*

Bladder: *water enables the body to flush out waste and toxins through the bladder*

Bones: *water makes up approximately 22 percent of bones*

Joints: *water provides cushioning for joints and soft tissues*

Skin: *water plays a significant role in hydrating the skin and prevents it from becoming dry*

Body temperature: *evaporation of sweat (water) from the skin helps regulate body temperature*

WHAT IS DEHYDRATION?

Dehydration occurs when you fail to replace the water your body loses. It's vital to recognize the symptoms early. Factors that can lead to dehydration include high and low temperatures, humidity, work-rate, clothing, body size, fitness levels, and injury.

THE EFFECTS OF WATER LOSS		
1–5% LOST	**6–10% LOST**	**11–12% LOST**
▪ Thirst	▪ Dizziness	▪ Stiffness of joints
▪ Discomfort	▪ Dry mouth	▪ Deafness
▪ Urine becomes darker	▪ Blueness of extremities	▪ Defective vision
▪ Loss of appetite	▪ Slurred speech	▪ Shriveled skin
▪ Impatience	▪ Swollen tongue	▪ Lack of feeling in skin
▪ Drowsiness	▪ Blurred vision	▪ Inability to swallow
▪ Lethargy	▪ Tingling in limbs	▪ Delirium
▪ Nausea	▪ Inability to walk	▪ Unconsciousness
▪ Headache	▪ Difficulty in breathing	▪ Death

WATER-BORNE DISEASES

Water-borne diseases are caused by ingesting water contaminated by the faeces or urine of humans or animals that contains protozoa, viruses, bacteria, or intestinal parasites. Globally, they cause 10 million deaths a year.

	DISEASE	SYMPTOMS
PROTOZOA	Cryptosporidium	Loss of appetite, nausea, and abdominal pain, usually followed by profuse, foul-smelling, watery diarrhea, and vomiting.
	Giardiasis	Loss of appetite, lethargy, fever, vomiting, diarrhea, blood in the urine, and abdominal cramps.
VIRUS	Infectious hepatitis (Hepatitis A)	Nausea, loss of appetite, mild fever, aching muscles, dark-colored urine, jaundice, and abdominal pain.
BACTERIUM	Amoebic dysentery	Feeling of fatigue and listlessness. Feces may be solid, but will smell foul and contain blood and mucus.
	Bacillary dysentery (Shigellosis)	Fever, abdominal pain, muscle cramps, high temperature, and blood, pus, and mucus in stools.
	Cholera	Vomiting, poor circulation, cold and clammy skin, muscle cramps, rapid dehydration, and increased heart-rate.
	E. coliform	Diarrhea and vomiting. Can cause death in vulnerable groups such as the very young or the elderly.
	Leptospirosis	Jaundiced appearance, lethargy, high temperature, aching muscles, and vomiting. Can be fatal if not diagnosed early.
	Salmonella	Nausea, diarrhea, headaches, stomach cramps, fever, possible blood in the feces, and vomiting.
PARASITES	Bilharzia	Irritation to the urinary tract and blood in urine, rash or itchy skin, abdominal pain, cough, diarrhea, fever, and fatigue.
	Hookworms	Anaemia and lethargy. Larvae travel to lungs and are coughed up and swallowed into the stomach, where they grow into worms.

TOO MUCH WATER?

Hyponatraemia is a condition caused when excess water accumulates in the body at a higher rate than it can be excreted. It results in a diminished sodium concentration in the body's plasma and the swelling of the body's cells. It can lead to a swollen brain and other neurological problems and, in extreme cases, coma and death. The way to prevent hyponatraemia is to control the amount of water that you drink, and to regulate your body's salt intake. If you don't have salt or sodium tablets in your survival tin, you can filter saltwater through fabric to sift out the salt content.

RATIONING YOUR WATER

If your water supplies are limited, you'll have to use what rations you have efficiently until you're rescued. If your water rations will not last that long, you'll have to procure water yourself. There is much debate about the advantages and disadvantages of drinking no water for the first 24 hours of a survival situation, but at this early stage it's best to make sure you're adequately hydrated. Your particular circumstances will dictate what's best to do, but always consider the following:

- The incident that put you in the survival situation may have been both dramatic and stressful; this will make you thirsty.
- In the first 24 hours of a survival situation, you'll be addressing the principles of survival: protection (shelter) and location (see p. 27). This is hard, thirsty work.
- Physical factors—such as seasickness, injury, or the environment you're in, such as a desert—may dictate that water-rationing is not a viable option.
- If you only have a limited water supply, but drink nothing for the first 24 hours, you may end up being so dehydrated that what little water you have in your possession will have no positive effect on your dehydrated state.

FINDING WATER: TEMPERATE CLIMATES

THE ABILITY TO LOCATE drinking water can challenge even the most experienced survivor and the challenges can vary dramatically according to the environment and the local conditions. It is, therefore, extremely important that you're aware of all the potential sources of water for the environment you're in.

WARNING!
In a survival situation, even if you think your chances of rescue are high and that help is imminent, you should start to look for water sources as soon as you have addressed the immediate problems of protection and shelter (see pp. 154–81). Remember that you can survive for up to three weeks without food; without water, you won't be able to survive for more than a few days.

COLLECTING WATER

You can find water in a range of sources, which vary in terms of quality and accessibility. Your priority is to locate the best and most accessible source of water in your immediate environment.

CATCHING RAINWATER

Collecting rain as it falls is the safest way to procure drinking water. It will need no treatment prior to drinking, as long as the catchment device itself has not been contaminated. Any number of non-porous materials—such as tarpaulins, ponchos, flysheets, survival blankets, or even large leaves—can be used as a rain-catchment device. Bear in mind that the larger the surface area of the material, the more rainwater you'll be able to catch.

1. Select a place as close to your camp as possible where your catchment device will be exposed to the most possible rain.

2. Firmly secure the tarpaulin to four stakes (sticks of equal length could be used) using string. Make sure that one end is higher than the other to provide a natural run-off for the water.

3. Place a heavy stone in the middle of the tarpaulin, roughly two-thirds of the way toward the lower end, to create a channel into which the rain will run down from the tarpaulin's sides.

4. Place a container, such as a pan or can, beneath the end of the channel to collect the water as it starts to flow off the tarpaulin.

MATERIALS AND TOOLS
- Tarpaulin
- Four sticks
- String
- Heavy stone
- Container

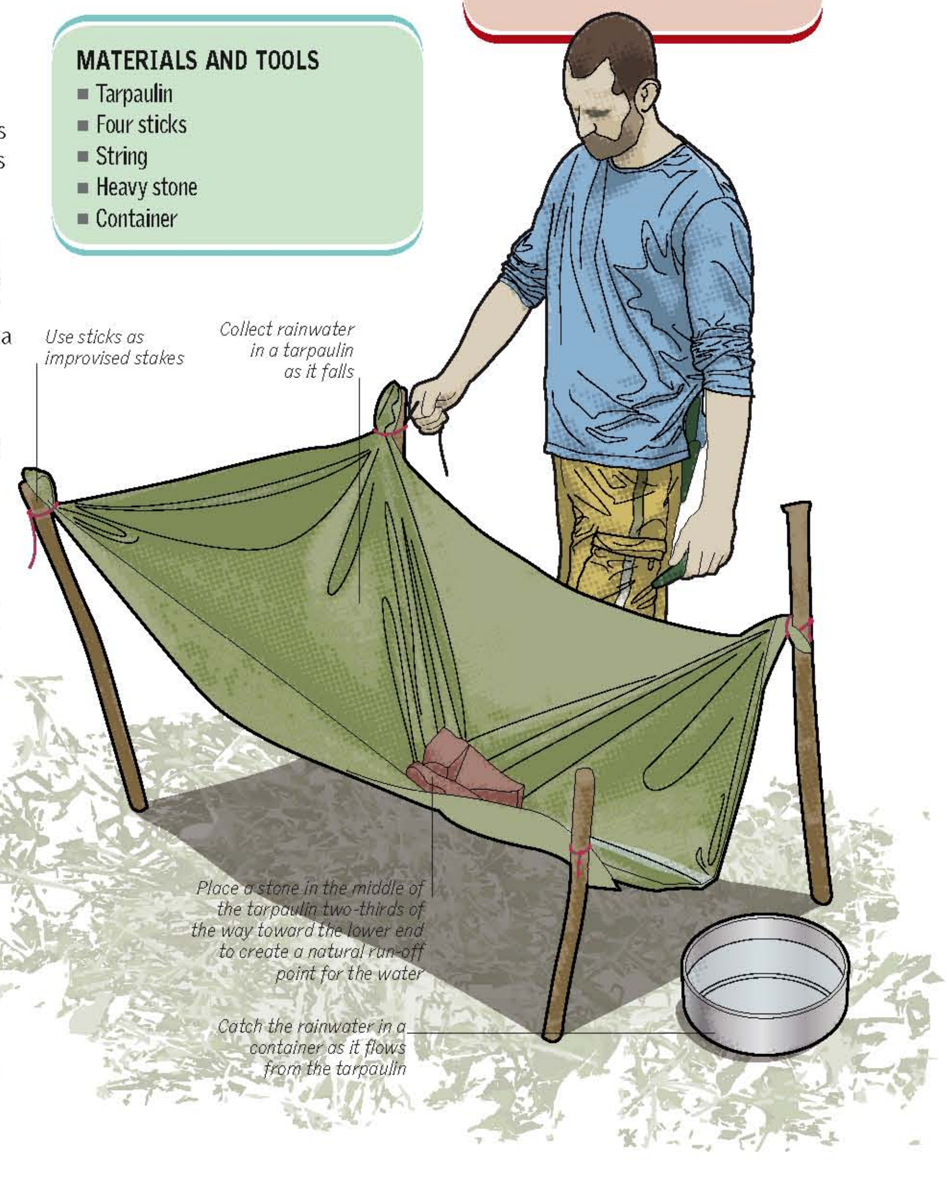
Use sticks as improvised stakes
Collect rainwater in a tarpaulin as it falls
Place a stone in the middle of the tarpaulin two-thirds of the way toward the lower end to create a natural run-off point for the water
Catch the rainwater in a container as it flows from the tarpaulin

LOCATING OTHER NATURAL WATER SOURCES

If rainwater is not available, there may be other natural sources of water, from easily visible streams and rivers, to bores and holes, which can be hidden. Whatever your source, you should always treat the water before drinking.

SOURCE	CHARACTERISTICS
SPRINGS	These occur when the water is forced to the surface as a result of subterranean pressures or from gravitational flow from higher sources. Found in low-lying areas, springs normally provide a permanent water source. Contrasting green vegetation is an indicator of their presence.
STREAMS AND RIVERS	Rivers and streams are an invaluable source of water, but there are still a few things you need to bear in mind when collecting water from them. The closer to the mountaintop the river or stream is, the clearer the fast-running water will be. The further downstream the water travels, the more likely it is to pick up minerals, debris, and pollutants that might be harmful to you. If possible, either check upstream for dead animals that may have contaminated the water, or follow the water downstream. Always try to collect the fast-flowing water near to the surface. In arid areas, rivers and streams tend only to flow during floods and will contain more pollutants and debris.
ROCK HOLES	Usually found in high ground, rock holes are natural collectors of rainwater. If the water appears to be trapped deep down, you can use your surgical tubing to retrieve it. Make sure you filter and purify the water before you drink it.
WELLS AND BORES	In some areas, you may find wells or old bore holes. Wells, which may be featured on local maps, can be deep and covered, making water procurement more difficult. In remote areas, wells are covered and marked in certain ways by the locals—find out what the markers are for your area.
LAKES AND PONDS	Rivers, streams, and water run-offs all flow into lakes or ponds. If you're collecting water from these sources, always try to collect it as it runs into the body of water, as lakes and ponds are more static than flowing water and can, therefore, become increasingly stagnant. Try to find the cleanest-looking area and avoid areas where debris has collected or where algae has formed. Note that the presence of fish indicates that the water is still oxygenated.
SEEPAGE	Usually located at the base of cliffs, high ground, or rocky outcrops, seepage is caused by slow-running channels that drain off these features.
SOAKS	Soaks are found close to rivers and creeks in low-lying areas, and are normally lower than the existing water table. The presence of soaks is often indicated by vegetation and they may be subject to pollution as a result of their use by animals. Make sure you filter and purify the water before you drink it.

AVOIDING POTENTIAL DANGERS

Most water sources are likely to be used by animals for drinking, bathing, urinating, and defecating, so always filter and purify any water collected before use (see pp. 200–01); the only exception to this rule is if you have collected rainwater. When collecting water, you should also be aware of the following dangers.

- It is possible that you'll encounter dangerous animals either using the water source, or on the way to or from the water source.
- Almost all major water sources will have a ranking system to determine which animals can use it. If all of the small gazelles suddenly disappear, ask yourself why.
- If you're collecting water from rivers, be aware of the potential dangers of river wildlife, such as crocodiles and snakes.
- If using dry riverbeds during the rainy season, be aware that flash floods can move quicker than you can run.

LOCATING HIDDEN WATER SOURCES

The presence of water is usually indicated by signs of life, such as green vegetation, animal tracks, or human habitation. Even if the terrain you're in appears lifeless, there may be plenty of indicators of a possible water source.

USE THE TERRAIN

- Observe the landscape for patches of green. Be aware that vegetation may not need obvious surface water for survival and may get its water from deep roots that tap into moisture below the surface.
- Water is subject to gravity and is more likely to be found downhill or in low-lying areas, such as valleys, dry riverbeds, narrow canyons, gullies, and at the base of cliffs or rock formations. Green vegetation forms next to a river and decreases as the ground rises away from the water source.
- Water will often seep inland on coastlines, leaving behind wetlands that contain water with tolerable levels of salt or that can be distilled in a solar still (see p. 189) to procure fresh water.

WATCH THE ANIMALS

- The Bedouin listen to the twittering of birds at dawn and dusk and follow their flight path to discover where they drink.
- Flocks of birds circling over one spot are usually flying over a water source. This does not apply to meat-eating birds, such as vultures, eagles, or hawks, who get their fluid requirements from the meat they eat.
- All finches and grain-eaters need a regular supply of water. Observe their flight patterns to locate a water source.
- Bees need water, so beehives are never far from a water source.
- Animal tracks, especially those of herd animals, will often lead to a water source. Look for converging sets of tracks.
- Flies stay close to water and the presence of mosquitoes almost certainly means that water is nearby.
- Look out for herd animals, such as buffalo, hippos, elephants, impala, and wildebeest, as they depend on water.

PROCURING WATER

Even if you find yourself in an environment without any obvious water sources, it doesn't necessarily mean that water will not be available to you. There are a number of water-procurement techniques that may mean the difference between you making it through a survival situation or not.

SOURCING WATER FROM DEW

Dew is water in the form of droplets that form on exposed surfaces in the early morning or late evening and can provide an invaluable supply of fresh water. It occurs when the temperature of a surface is low enough to allow the moisture in the warmer air above it to condense. Dew can easily be collected from any non-porous surface—such as a car roof or a tarpaulin—with a piece of cloth that can then be wrung out into a container. You can also harvest or trap dew.

HARVESTING DEW

You can harvest dew by walking through a field of long grass before sunrise or late in the evening with a piece of absorbent material—such as rags or a T-shirt—tied around your ankles.

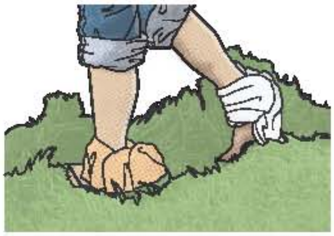

① Tie the material tightly around each ankle and walk through the dew-covered grass. It will absorb the dew as you move.

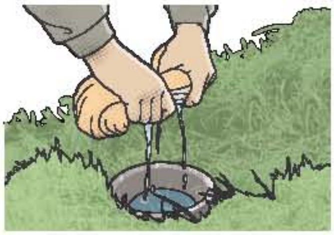

② Wring the rags to extract the water. Repeat the process until you have an ample supply of water or the dew has evaporated.

DELAYING DEHYDRATION

When water is scarce, the following points will help you delay the onset of dehydration:

- Conserve what water you have and use it as efficiently as possible.
- Work only in the coolest part of the day and avoid sweating.
- If the sun is shining, seek shade and keep covered.
- Suck a small, smooth button or pebble to help stimulate saliva and remove the sensation of thirst.
- Avoid eating protein-rich food as it requires more water to digest than those in other food groups.

MAKING A DEW TRAP

Dig a hole about 18 in (45 cm) deep, line with a plastic sheet, and fill with smooth, clean stones. Water will condense on the stones overnight. Harvest as early as possible the next morning to ensure it does not evaporate.

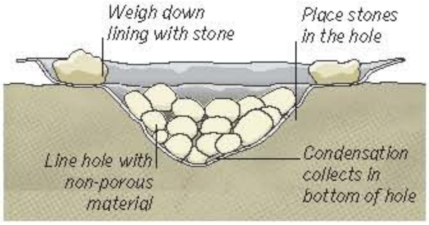
Weigh down lining with stone
Place stones in the hole
Line hole with non-porous material
Condensation collects in bottom of hole

SOURCING WATER FROM PLANTS

Transpiration is the evaporation of water from a plant, primarily from its leaves. You can collect this vapor to boost your fresh water supply. All you need is a clear plastic bag.

MAKING A TRANSPIRATION BAG

Place a smooth rock in the lower corner of the plastic bag, and place the bag over the leaves of a tree branch, tying the end. As water evaporates from the leaves, it will condense on the inside of the plastic bag and collect at its lowest point.

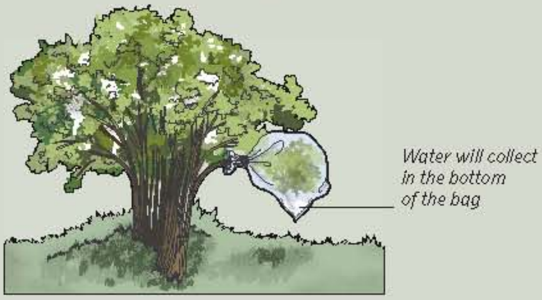
Water will collect in the bottom of the bag

MAKING A VEGETATION BAG

Cut green vegetation and place it in a plastic bag. Place a smooth rock in the lower corner of the bag and tie off the open end. Secure the bag in direct sunlight. The sun causes water in the leaves to evaporate, condensation forms on the plastic bag and drips to the lower corner of the bag.

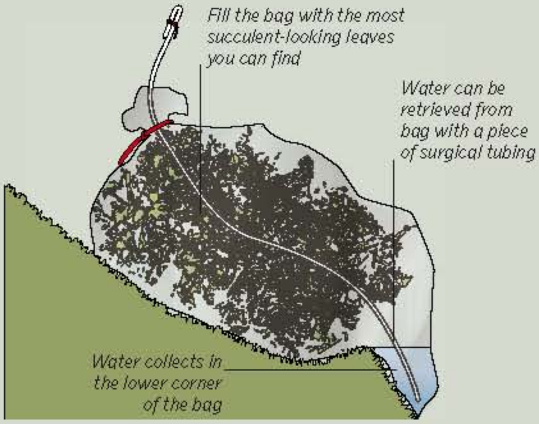
Fill the bag with the most succulent-looking leaves you can find
Water can be retrieved from bag with a piece of surgical tubing
Water collects in the lower corner of the bag

MAKING A SOLAR STILL

A solar still works using the same principle as a vegetation bag (see opposite). It collects potable water from the vapor that is produced by vegetation, water that is unfit to drink, or moisture from the ground.

1 Ideally find, or dig, a hole in the ground at least 2 ft (0.6 m) wide and 2 ft (0.6 m) deep. Place an empty container in the center of the hole. Fill the hole with vegetation, a receptacle containing undrinkable water, such as saltwater or urine, or fabric soaked in undrinkable water.

2 Cover the hole with a plastic sheet, and secure it in place with stones. Place a stone in the center of the sheet to create a run-off point for the water. The sun's heat will evaporate water from the vegetation, or distill the undrinkable water, producing pure water vapor. The water vapor, which is now free of contaminants, will condense on the underside of the plastic sheet, and drip into the container where it can be collected.

TOOLS AND MATERIALS

- Spade or shovel
- Two containers
- Vegetation and/or undrinkable water
- Piece of fabric or clothing
- Plastic sheet, tarpaulin, or space blanket
- Stones
- Surgical tubing

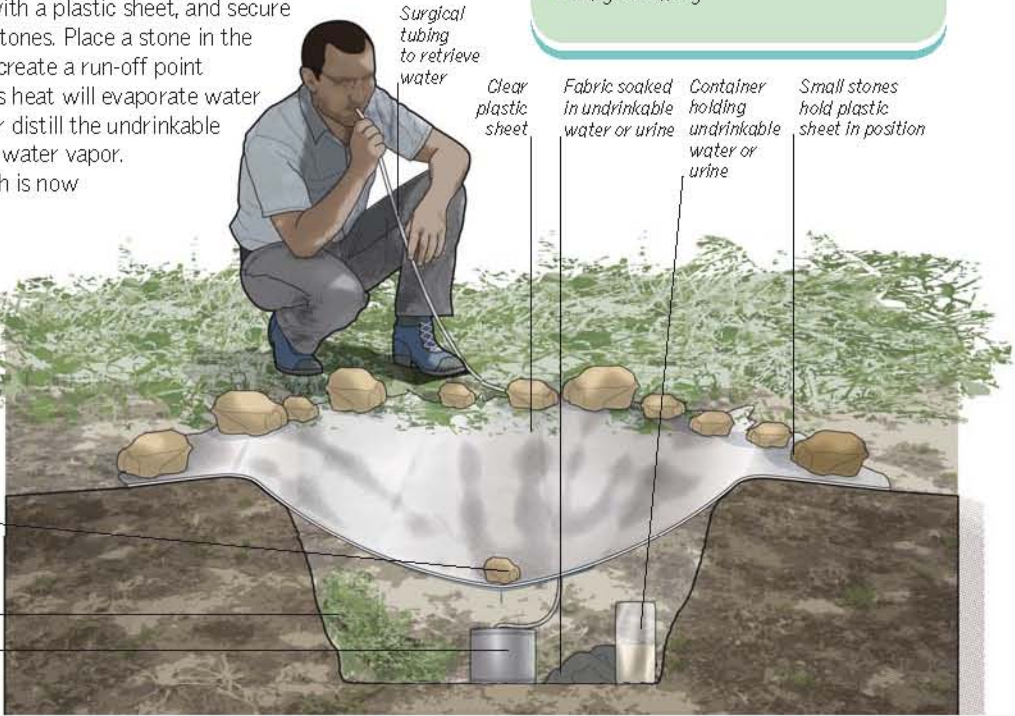
Surgical tubing to retrieve water
Clear plastic sheet
Fabric soaked in undrinkable water or urine
Container holding undrinkable water or urine
Small stones hold plastic sheet in position
Small stone forms a drip point on underside of plastic
Fresh, green vegetation
Container catches condensed water droplets

MAKING A GYPSY WELL

A good method of using the ground to create cleaner water from stagnant water sources, a gypsy well can also be used to collect water from saturated ground. The water collected through this method will still need to be treated before it is safe to drink (see p. 201).

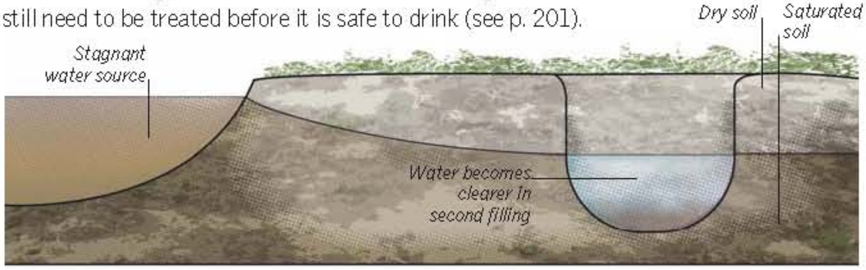
Dry soil
Saturated soil
Stagnant water source
Water becomes clearer in second filling

1 Dig a hole a few feet away from a stagnant water source. It should be wide enough for you to be able to dip into it with a container and at least 12 in (30 cm) below the first layer of saturated soil. The hole will quickly fill with water.

2 Bail out the muddy water and allow the hole to refill—you may have to repeat this process several times. Once the water is clear, it can be collected, treated, and used. Cover the well when not in use to prevent debris or small animals falling in.

SURGICAL TUBING

Always pack a length of surgical tubing in your survival kit. It doesn't take up much space and is an extremely versatile piece of equipment:

- It can be used as an improvised straw to reach water trapped in rocks, hollows, and trees.
- It allows you to access water procured from a solar still without taking the still apart.
- It can be built into transpiration and vegetation bags so that you can remove water without having to open the bag.

FINDING WATER: HOT CLIMATES

YOUR NEED FOR WATER increases in hot climates as your body starts to use more of its water supply to regulate its temperature through perspiration. If you fail to drink more than you perspire, you will start to dehydrate and even approaching the first stages of dehydration can affect your chances of survival. Hot climates can be divided into two groups: hot-humid and hot-dry.

HOT-HUMID CLIMATES

The hot-humid conditions found in jungles and rain forests mean that procuring water is rarely an issue. However, the body's need for water in these conditions should not be underestimated; it is not unusual to have to drink up to 3 ¾ gallons (14 liters) a day to avoid dehydration.

SOURCING WATER FROM VEGETATION

Many plants, such as pitcher plants, have hollow parts that collect rainfall or dew. Some trees store and catch rainwater in natural receptacles, such as cracks or hollows. In an emergency, life-saving liquid can be garnered from a tree's roots or sap. You can find water trapped in the sections of green bamboo by carefully cutting into the bamboo with your machete or knife; or collect small, unripe coconuts and quench your thirst with the fluid they contain; or make a spigot and tap into the water contained inside the water tree. Life-saving fluid is everywhere in the jungle, and you don't have to look far to find it.

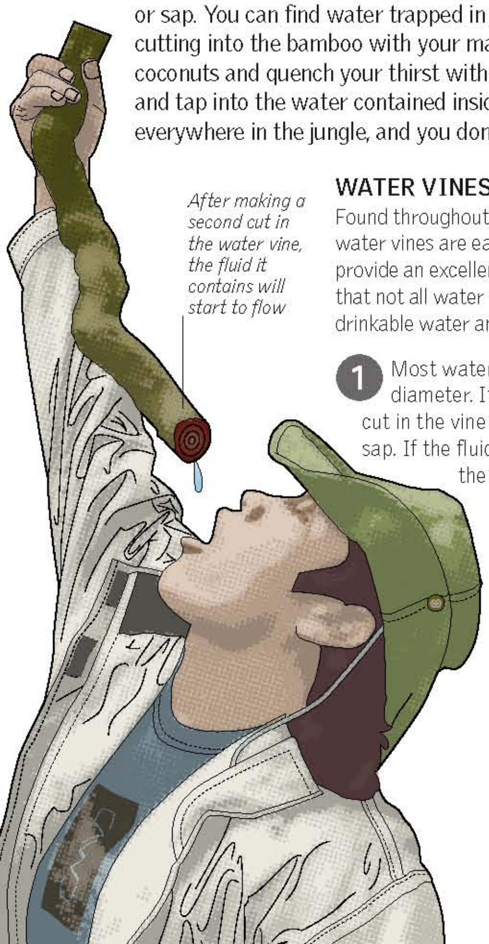

After making a second cut in the water vine, the fluid it contains will start to flow

WATER VINES

Found throughout the jungles and rain forests of tropical regions, water vines are easily identifiable by their size and shape and can provide an excellent sort of fresh water. However, bear in mind that not all water vines are water-bearing; not all contain drinkable water and some even contain poisonous sap.

1. Most water-bearing vines are about 2 in (5 cm) in diameter. If you think you have found one, make a small cut in the vine with a machete and check the color of the sap. If the fluid is milky, don't drink it; if it's clear, then the water in the vine will be safe to drink, so cut through the vine as high as you can with a knife or machete.

2. Cut off the vine at a point lower than the first cut. The liquid, which has a neutral, fruity taste, will start to flow. Don't let the vine touch your mouth as the bark may contain irritants.

3. The pores in the upper end of the vine may re-close, stopping the flow of water. To rectify this, simply cut the top of the vine again with your machete.

WARNING!

Water sources are plentiful in jungle and rain forest environments and, under normal circumstances, you should have no problem getting hold of enough water to satisfy your needs. However, rivers and streams may not be available during certain seasons, or if you have climbed too high, so knowledge of other water procurement methods could be crucial to your survival.

CATCHING RAINWATER

Catching rainwater is the best way to procure water: it is passive and requires no energy to collect once you place your containers. There are many forms of catchment device, but make sure you filter and purify the water (see pp. 200–01) before drinking it.

BAMBOO ROOF

Construct a sloped bamboo roof with a bamboo gutter. This could be the roof of your shelter (see p. 169), but if water procurement is a problem, you will have to construct additional bamboo roofs.

WIDE-LEAF ROOF

If you're in an area where there are wide-leafed plants, it's easy to construct a roof from them. Overlay the leaves as you would with roof tiles, working from the bottom to the top (see p. 170). Placed in this way, they will allow the water to run to the bottom. A length of bamboo cut in half lengthways can be placed as a collection gutter at the bottom.

BAMBOO DRAINPIPE

Observe rainwater's route down a tree trunk and tie a length of bamboo that has been cut in half lengthwise in its path. Place the other end of the bamboo into a suitable container.

DRIP RAGS

Wrapping any absorbent material around a leaning tree, such as a rag or a T-shirt, will result in the water running down the tree and soaking the material. Shape the rag to form a low point from which water will drip and place a suitable container underneath to catch the water.

HOT-DRY CLIMATES

Anyone venturing into this environment should have sufficient water for their needs, plus an emergency supply just in case, otherwise they have no right to enter the desert. Green vegetation usually signifies water or moisture in some form, and many techniques of procuring water in temperate climates (see pp. 188–91) may work in some desert conditions.

SOURCES OF EMERGENCY FLUID

If there is no surface water to be found, and you have no other means of procuring water, a water-yielding plant may be your only option. In some plants, the clear sap, fruit, or trapped rainwater, may quench your immediate thirst, but do not rely on these sources to keep you alive for long.

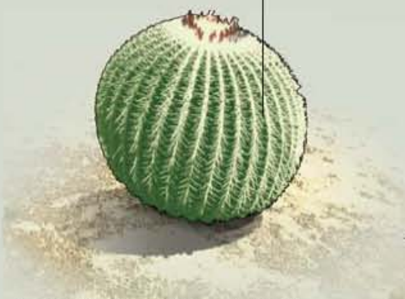
The barrel-shaped cactus is characterized by numerous ribs and hundreds of sharp spines

BARREL-SHAPED CACTUS

Barrel-shaped cacti contain a milky fluid that's safe to drink. Carefully remove the top of the cactus with a machete, mash up the flesh inside with a stick to make a pulp, and extract the juice from the pulp by sucking through a hollow grass stem. Alternatively, use a cloth to soak up as much of the fluid as possible and then wring the material to extract the fluid. The rewards from both techniques are minimal.

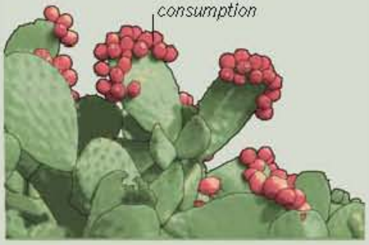
The prickly outer layer of the fruit has to be removed before consumption

PRICKLY PEARS

Found in low-spreading clumps measuring 3 ft (0.9 m) in height, and native to dry, sandy soils throughout the world, the prickly pear cactus has an edible fruit that can provide a life-saving amount of fluid.

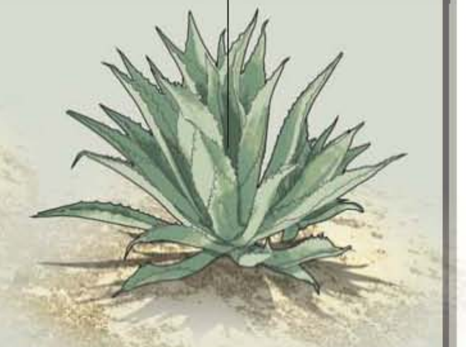
Agaves have large clusters of thick, fleshy leaves surrounding a large central stalk

AGAVES

Native to Mexico and the southern and western United States, agaves have a rosette of thick, fleshy leaves containing fluid that is safe to drink. Cut the huge flower stalk with a knife or machete and collect the juice.

FINDING UNDERGROUND WATER

Water is life in the desert; wherever there is life there'll be water. Unusual clusters of green plants may indicate a minor presence of water; an abundance of greenery may indicate a more substantial water source. Water is rarely found above a depth of 6 ft (1.8 m) below the surface, so you will have to dig for it. If you do, make sure you only do so during the coolest part of the day. Bear in mind that, despite what you may have seen in movies, or read in other books, your chances of procuring water from the inside bend of a dry wadi in a real survival situation are slim to non-existent. In fact, you're more likely to waste what water you do have looking for the dry wadi and die in the process!

THINK LATERALLY

The chances are that if you're having to procure water in the desert you'll already be in a desperate situation. Bear in mind that, in addition to the methods mentioned above, if you have knowledge of the techniques outlined in the temperate environment section (see pp.190–91)—such as solar stills, dew traps, and vegetation and transpiration bags—it could be enough to keep you alive in the desert.

CHECKLIST FOR HOT-DRY CLIMATES

Even the best-laid plans can hit unforeseen problems, but many problems encountered in a desert environment can be avoided with some prior preparation.

- Always start hydrated.
- Carry enough water for your needs plus emergency water; your emergency supply should be enough to get you out of danger.
- Monitor your progress against the water you use. If you're using more than you thought, re-evaluate what you want to accomplish. It's better to turn back and learn from the mistake than to push on and create a survival situation that need not exist.
- Cache water ahead if necessary.
- Check your map for probable water sources. Confirm the reliability of these sources with locals and ask if there are any sources, such as wells, that are not shown on the map.
- Mark your map, or waypoint your GPS, with any water sources you sight as you progress. It's better to go back to a known source than to move on with nothing more than hope.
- To keep the water cool, always keep the bottles in the shade or in a windy location.

FINDING WATER: COLD CLIMATES

ADOPT THE SAME METHODS of trying to find drinking water in cold climates as you would in temperate ones (see pp. 186–91), although the ability to procure water becomes a major problem in freezing temperatures. The cold-weather survivor faces a dilemma: he or she is surrounded by water, but could die of thirst because most of that water is frozen.

WARNING!
Never try to melt ice or snow in your mouth, as it can cause freezing injuries to your mouth and lips. What's more, your body will expend heat as it melts the ice, and this could cause you to cross that very fine survival line between being cold or being hypothermic.

CHECKLIST FOR COLD CLIMATES

You should prioritize water usage in cold-weather conditions in the same manner as you would in desert conditions (see p. 193).

- One of your first thoughts should be about procuring water. You will have to find a water source that's close to everything you need to build and maintain a fire.
- Always look for an alternative water source before trying to melt snow or ice. It's easier, less time-consuming, and more fuel-efficient to fill your water containers with natural meltwater than it is to melt snow or ice by the heat of a fire.
- Your ability to procure water in freezing conditions will be directly related to your ability to start and maintain a fire.
- Be aware that it takes time and patience to melt snow and ice. You'll also need enough fuel to maintain a fire for a considerable period of time.
- Regulate your body heat to minimize overheating and sweating.
- Keep drinking water close to your body to prevent it from freezing, but avoid having water containers directly next to your skin. Instead, keep them between layers of clothing and use the warmer air trapped between the layers to help raise the water's temperature.
- Do not use recently frozen sea water, as it contains high levels of salt.

MELTING ICE AND SNOW

If you have the choice between melting ice and snow, favor ice, as it melts more quickly than snow and is up to 17 times denser. However, if you can't find ice, use dense, compact snow. Always look for the whitest, purest-looking ice or snow.

MELTING ICE

If you have some water to begin with, pour some into a container and heat it over a fire. Break the ice into small pieces—rather than adding it in one lump—and keep adding pieces to the container to melt them. Keep the water hot, but not boiling, so that you avoid losing water through evaporation.

USING A HOT PLATFORM

If you don't already have water for the method above, you can melt ice slowly on a gently sloping platform fashioned from any flat piece of stone or wood positioned above a fire.

① Build a fire. Search for a large stone with a flat surface and two logs, or smaller stones, that are strong enough to support it. Place the small logs or stones on either side of the fire as a support for the flat-surfaced stone. Make sure that the platform is at an angle. This will create a natural run-off for the ice as it melts. Place a block of ice in the center of the platform.

② As the fire starts to heat up the platform, the ice will begin to melt. The meltwater will flow off the platform, where it can be collected in a container, such as a mess tin.

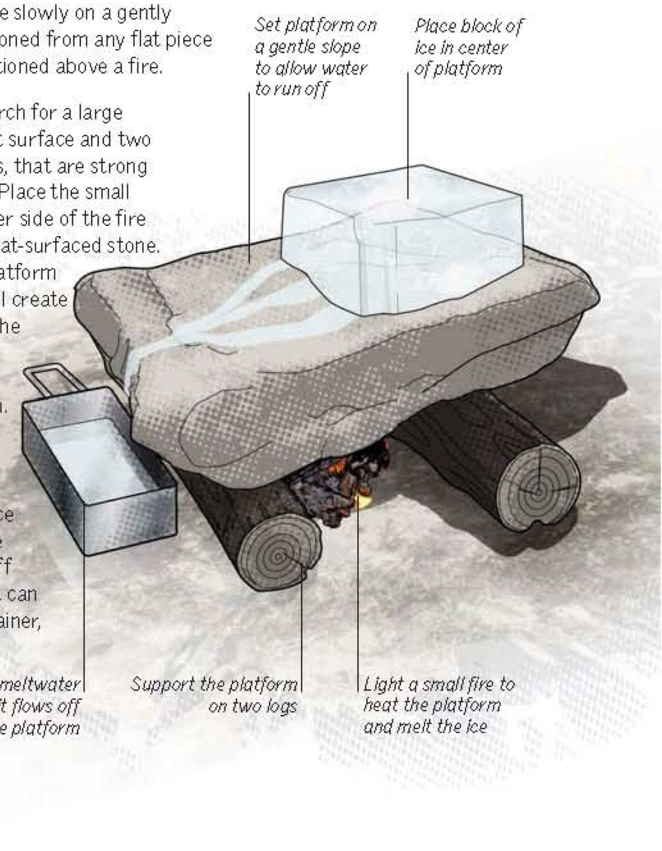
Set platform on a gentle slope to allow water to run off

Place block of ice in center of platform

Collect the meltwater in a pan as it flows off the platform

Support the platform on two logs

Light a small fire to heat the platform and melt the ice

MELTING SNOW

If you already have water, follow the techniques for melting ice (see opposite), heating a little water and adding the snow little by little. Don't pack the snow too tightly; if an air pocket forms, the heat from the fire will be absorbed by the metal container rather than by the snow and could result in the fire burning a hole through the metal container before it melts the snow.

MAKING A FINNISH MARSHMALLOW

Cut a solid piece of dense snow—often referred to as a "marshmallow" or a "snowman's head"—and skewer it with a stick. Secure the stick in the ground close enough to a fire that it receives heat, and position a suitable container underneath it to capture the water as it melts.

STORING WATER

Snow is a great insulator: even if the temperature dips to -40°F (-40°C), water in a bottle will remain largely unfrozen if placed under at least 1 ft (0.3 m) of snow. Make sure you store the bottles upside down. That way, if some of the water does freeze, it will freeze at the bottom of the bottle and not at the top.

USING A MELTING SACK

Using a similar principle to the Finnish marshmallow (see left), this technique involves using an improvised sack—made from any porous material, such as a T-shirt or a sock—suspended near to a fire. The heat from the fire will start to melt the snow, which can then be collected in a well-positioned container.

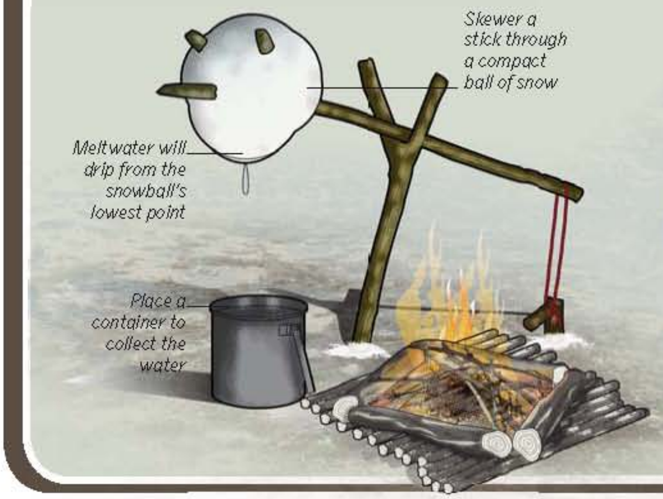
Skewer a stick through a compact ball of snow
Meltwater will drip from the snowball's lowest point
Place a container to collect the water

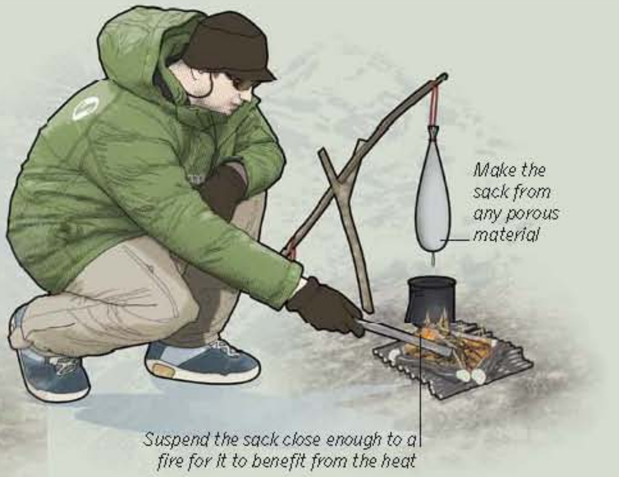
Make the sack from any porous material
Suspend the sack close enough to a fire for it to benefit from the heat

IN A WORST-CASE SCENARIO

If you're caught out on barren snow or ice, you're unlikely to have access to natural fuel to burn in order to melt snow or ice into water. As long as you have your second-line survival equipment (see p. 42), you'll have all you need to procure life-saving water.

USING YOUR FIRE TIN

Set up your fire tin on the ground and shelter it from any wind using either your body or your pack. Using your survival tin as a container, place small quantities of ice or snow into the tin. Light your fire tin and place your survival tin over the flame. Add more ice or snow as it starts to melt.

USING YOUR MATCHLESS FIRESET

Place the lid of the matchless fireset tin on the ground. Light a hexi fuel block using the cotton wool and flint/striker. Using the fireset container or your survival tin, melt small quantities of ice or snow over the flame. Once the ice or snow has melted, let the container cool so you don't burn yourself. The water is then safe to drink.

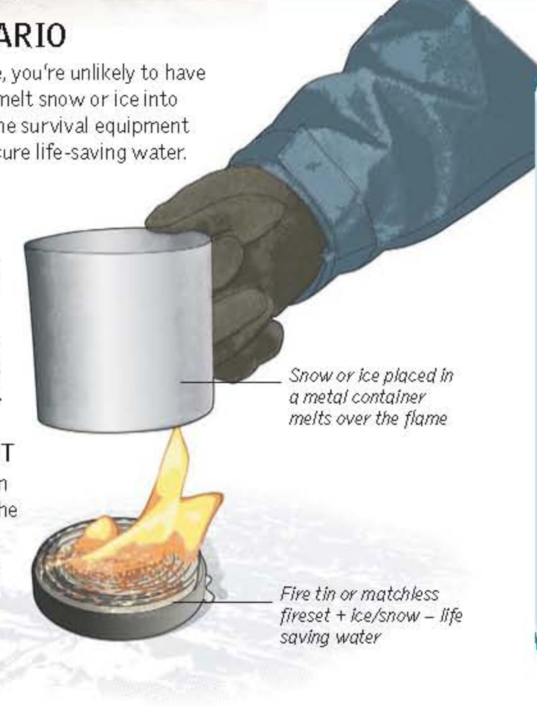
Snow or ice placed in a metal container melts over the flame
Fire tin or matchless fireset + ice/snow – life saving water

USING BODY HEAT

When Inuit hunters capture a caribou, they empty out the contents of its stomach, turn the stomach inside out, fill it with snow, and tie it shut with a length of intestine. They then put the stomach back in the cavity while they skin the caribou. By the time they have finished, the heat given off by the animal's body has melted the snow. The Inuit then open the bag carefully and suck out the water through a block of snow to filter it.

FINDING WATER: AT SEA

OF ALL ENVIRONMENTS, the sea is possibly the most difficult in a survival situation. It offers no natural resources for protection against the extremes of temperatures, wind, rain, and sea state, and provides little to aid location. Being surrounded by water that you can't drink only adds to the difficulty. Some devices are capable of making seawater safe do drink, but if you don't have one, you'll have to find a way of procuring enough fresh water to keep you alive.

WARNING!

Never drink salt water. Its salt concentration is three times higher than that of blood and ingesting it will dehydrate you. Continued use over a prolonged period will lead to kidney failure and, ultimately, death.

CONSERVING YOUR WATER RATIONS AT SEA

Rationing fresh water supplies when you're adrift at sea is a sensible precaution, as you have no idea how long it will be before you're rescued or before you reach land. Here are a few tips to help you conserve what water you have while you're at sea:

- Fix your daily water ration after taking stock of the amount of water you have, the output of solar stills and desalting kits, and the number and physical condition of your party.
- Prevent fresh water supplies from becoming contaminated by saltwater.
- Keep water supplies well shaded, both from the overhead sun and from the glare off the sea's surface.
- In hot conditions, dampening your clothes with saltwater can help to lower your body temperature—but don't overdo it. This is a trade-off between cooling yourself down and the saltwater boils and rashes that will result from continued exposure.
- Don't exert yourself. Relax and sleep whenever possible.
- Use every container you have—even a simple trash bag—to collect rainwater, and keep them well sealed and attached to the raft.
- If you don't have water, don't eat. Protein consumption will hasten the onset of dehydration.

COLLECTING FRESH WATER

If you find yourself adrift with no hope of immediate rescue, obtaining drinking water will be a major priority. If you don't have a solar still or a reverse-osmosis pump, you must find another means of procuring fresh water. Fortunately, there are several ways of doing so.

GATHERING RAINWATER

Most modern liferafts incorporate a built-in rainwater catchment system that channels rainwater and dew from the outer surface of the liferaft into collection pockets inside the liferaft. However, even if you're not in a liferaft, you can construct a similar system using a tarpaulin or any other waterproof material. Watch the clouds, be ready for the possibility of any showers (see pp. 80–81) and spread your tarpaulin in a bowl shape to catch the largest amount of rainwater possible. Always place a tarpaulin before nightfall, so that you don't miss out on any overnight rainfall.

HARVESTING DEW

At night, secure the tarpaulin like a sunshade and turn up its edges to capture dew. It's also possible to harvest any dew that may have collected on the sides of the raft using a sponge or cloth that you then wring out.

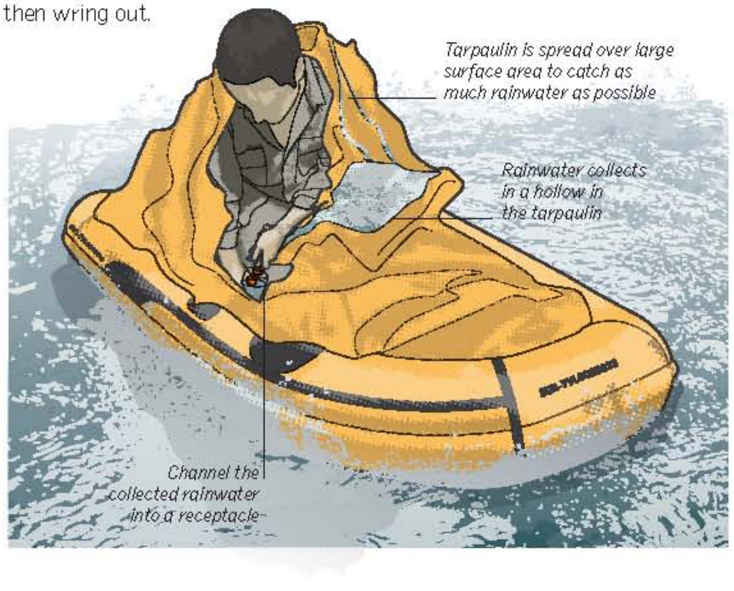
Tarpaulin is spread over large surface area to catch as much rainwater as possible

Rainwater collects in a hollow in the tarpaulin

Channel the collected rainwater into a receptacle

TREATING SALTWATER

If you have no means of collecting rainwater or dew, there are several products capable of turning undrinkable saltwater into fresh water. Although these products are standard issue on most liferafts, you should always try to have at least one of them with you if you are venturing into a marine environment.

SOLAR STILL

Solar stills are a simple way of distilling water using the power of the sun. Saltwater is placed at the bottom of the container, where it is evaporated by the sun through clear plastic. Pure water condenses on the top of the plastic and drips down to the side, where it can be collected, often via a tube. Most solar stills on modern liferafts are inflatable.

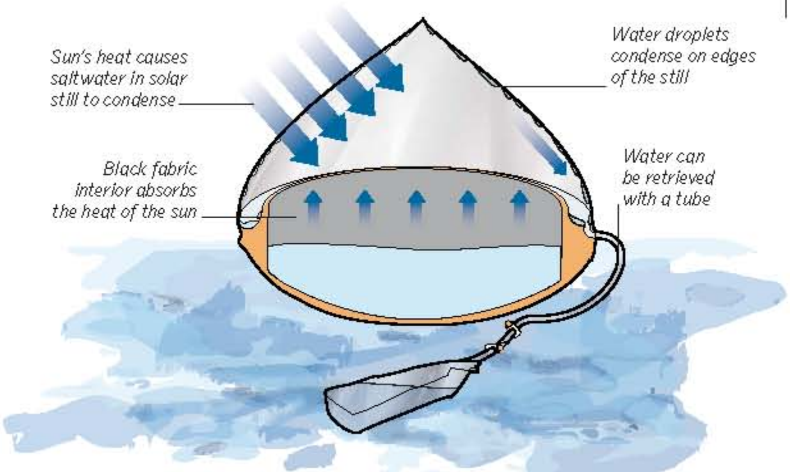
Sun's heat causes saltwater in solar still to condense
Water droplets condense on edges of the still
Black fabric interior absorbs the heat of the sun
Water can be retrieved with a tube

MAKE YOUR OWN SOLAR STILL

If you have a chance to gather together the right materials, it's easy to make a small solar still. All you need are two containers (one larger than the other), a sheet of plastic, some string, and a weight to form a natural run-off point for the water as it condenses under the heat of the sun. If you have some surgical tubing, you can use it to retrieve the fresh water without taking the still apart.

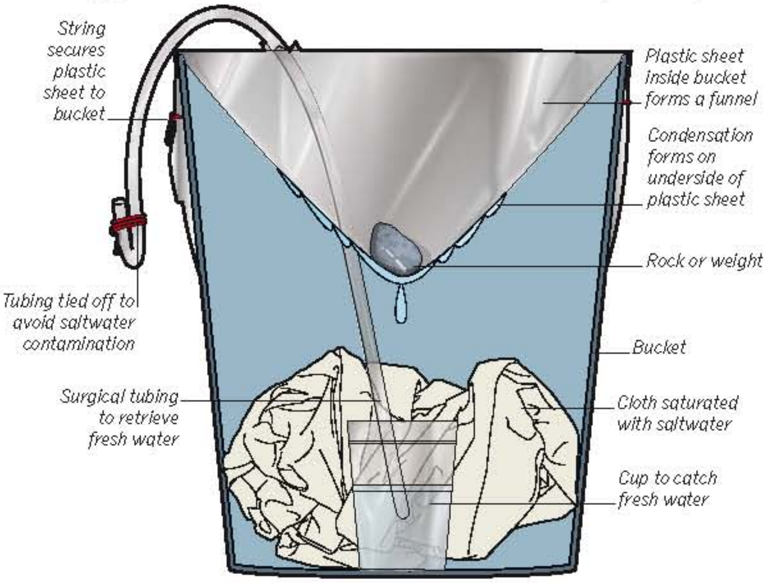
String secures plastic sheet to bucket
Plastic sheet inside bucket forms a funnel
Condensation forms on underside of plastic sheet
Rock or weight
Tubing tied off to avoid saltwater contamination
Bucket
Surgical tubing to retrieve fresh water
Cloth saturated with saltwater
Cup to catch fresh water

REVERSE-OSMOSIS PUMP

These hand-powered devices pump seawater at a very high pressure through a membrane that filters out the salt. Depending on the model, they can produce around 23 liters (49 pints) of fresh water per day.

DESALTING KIT

These kits turn seawater into freshwater through a process called "ion exchange." Because they only produce small amounts of fresh water over several hours, use desalting kits only during long periods of overcast weather when you can't use a solar still.

THE LAST RESORT

In absolute emergencies, potentially life-saving forms of liquid can be obtained from the ocean.

SEA ICE

In Arctic seas, you can obtain drinking water from old sea ice. This ice is bluish in color, has rounded corners, splinters easily and, more importantly, is nearly free of salt. New ice is gray, milky, hard, and salty. Water from icebergs is fresh, but icebergs are dangerous to approach, so you should only use them in an emergency.

FISH

Drink the aqueous fluid found along the spine and in the eyes of large fish. Carefully cut the fish in half to get to the fluid along the spine and suck the eye. If you are so short of water that you need to do this, do not drink any of the other fluids: they are rich in protein and fat and your body will use up more of its water digesting them than it obtains from them.

SEA TURTLE

Sea turtle blood has a salt concentration similar to that of humans. The blood can be collected by slitting the turtle's throat. Note that, although this may help prolong survival, sea turtles are an endangered species, so you should only kill one as a last resort.

REHYDRATION ENEMA

If you have some water that is not salty or poisonous, but is too foul to take orally, you can absorb as much as a pint a day—enough to keep you alive—through the large intestine using an improvised tubing device.

CARRYING AND STORING WATER

YOU WILL NEED TO make many decisions in any survival situation, some of which could mean the difference between life and death. One of these decisions will be whether to stay and wait for rescue or to attempt self-rescue. A major factor in this decision will be the availability of water and your ability to carry and store it.

WARNING!
Mark your containers clearly. Late at night in camp it's easy to confuse bottles that contain treated water with ones that contain untreated water or camping fuel.

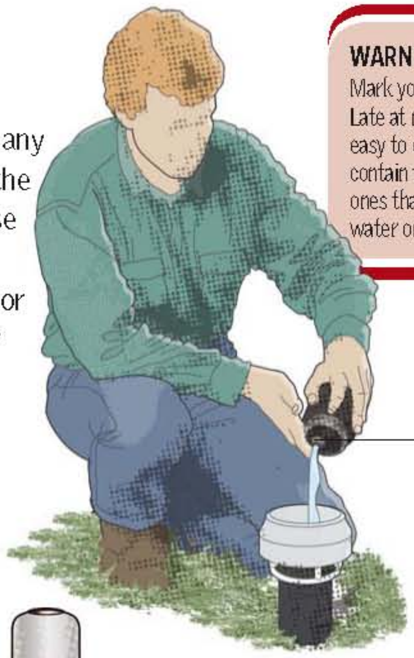

If your container has a lid, it can be used to scoop water from a stream before you pour it into a larger water bottle

WATER CONTAINERS

There are many different kinds of container for carrying both hot and cold liquids. They range from solid plastic or steel flasks or bottles, to collapsible waterproof bags that can be folded up when they're empty.

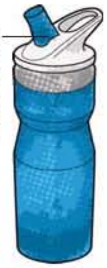

Fitted with a push-pull nozzle for ease of use while on the move

PLASTIC WATER BOTTLE

Strong and lightweight, with screw-off tops or push-pull nozzles.

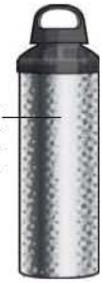

Metal container can be used to boil water

METAL WATER BOTTLE

Slightly heavier, but stronger, than plastic water bottles.

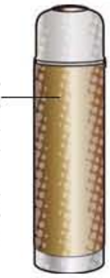

A metal exterior and a glass interior makes a thermos a heavy alternative

THERMOS FLASK

Although very heavy, thermos flasks allow you to store either hot or cold water.

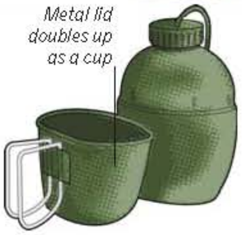

Metal lid doubles up as a cup

MILITARY WATER BOTTLE

A standard issue bottle used by most of the world's military forces.

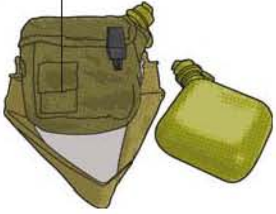

Store purification tablets in pouch

COLLAPSIBLE WATER CANTEEN

Heavy-duty plastic water canteen that can be hung round the neck.

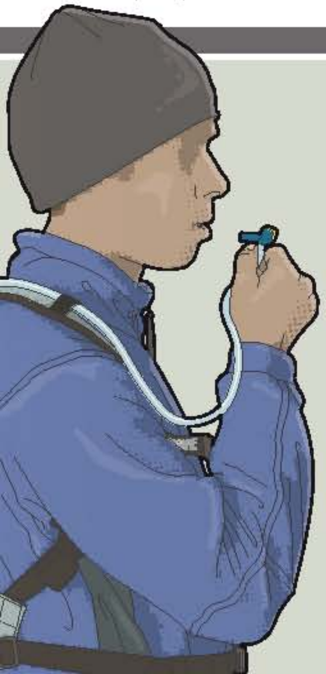

HYDRATION SYSTEMS

Hydration systems usually consist of a water-storage container (called a "reservoir"), an on-demand, one-way drinking tube, and a harness. However, a common problem with these systems is that, because you can't see the water, you can suddenly discover you have used all of it without realizing.

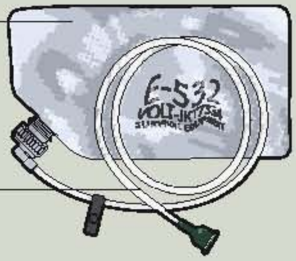

Water container is filled and then carried in a backpack

Water is accessed via a one-way drinking tube

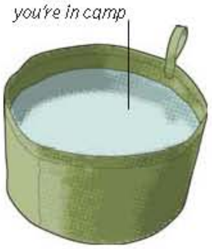

Use to store water once you're in camp

COLLAPSIBLE WATER BOWL

Easy to pack, light, and can also be used to seperate items in your backpack.

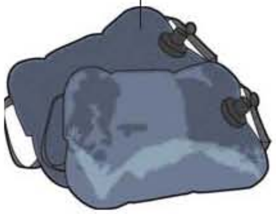

Stow water bags flat in your pack when not in use

WATER BAGS

Useful for carrying water from its source back to your camp. Can also be used to keep your equipment dry.

IMPROVISING WATER CONTAINERS

In an emergency, there's a strong chance that you won't have the luxury of having water bottles or storage systems at your disposal. However, with luck—and a little ingenuity—you should be able to find something that allows you to store and carry enough water to satisfy your needs.

SEA SURVIVAL SUIT

Because they are designed to keep water out, they can also be used to keep water in. Most survival suits are packed with a layer of chalk to prevent the material from sticking together, so wash it out before use.

WATERPROOF CLOTHING

Many types of waterproof clothing can be adapted to hold water. Jacket sleeves and trouser legs can be knotted to form a basic bladder; Gore-Tex® socks will hold water; and some waterproof backpacks can be used for water storage.

DISCARDED MATERIALS

Always be on the lookout for anything that can hold water, from empty plastic bags and bottles, to large industrial-type containers. Clean and sterilize found items before use.

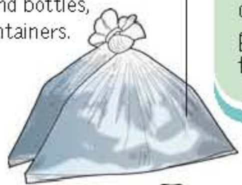

Heavy-duty plastic bags can be used to carry water

GOURDS

The shell of a hollowed-out and dried fruit—a gourd—can hold water. Gourds made from large fruits, such as squashes, pumpkins, and melons, can hold a considerable amount of water.

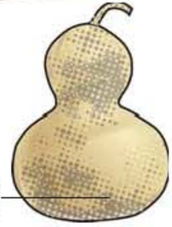

Look for a gourd with a shell thickness of ¼ in (60 mm)

EMERGENCY WATER

Sachets of emergency water can be bought and stored for emergency use. They usually come in a packet that contains five $1\frac{7}{10}$fl oz (50 ml) sachets of water, each being little more than a mouthful. These should always only be used as a last resort. Always try to procure water by other means before turning to your emergency water supply.

BAMBOO

A bamboo cane will provide a natural cup if you cut 1 in (2½cm) below one joint and then 1 in (2½cm) below the next. Take care to smooth the edges after cutting.

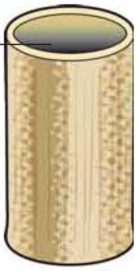

Bamboo can be cut into a ready-made cup

MAKING A MINI-RESERVOIR

Your ability to store sufficient water for your needs in a survival situation may be limited and it may be impractical—because of injury or distance—to travel back and forth for water every time you need it. If you have some basic materials, making a mini-reservoir to catch rainwater (see also p. 188) solves this problem.

1. To reduce the amount of effort required, choose a site that offers the least resistance (such as a natural hollow). Dig a shallow pit using whatever materials you have to hand, such as a stick.

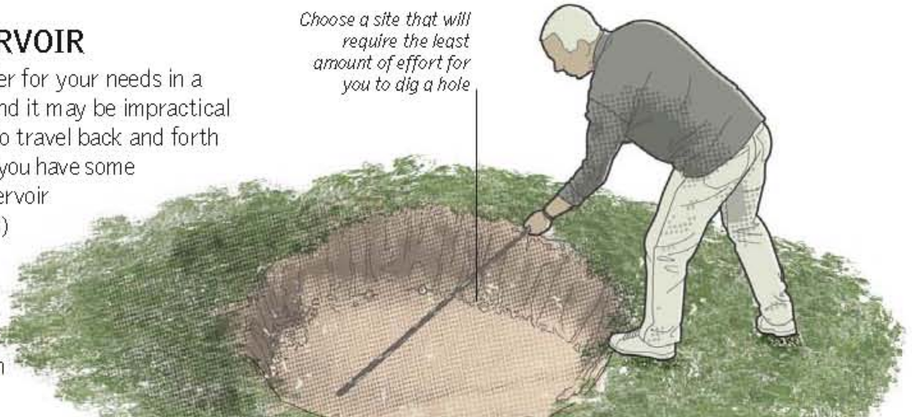

Choose a site that will require the least amount of effort for you to dig a hole

2. Smooth the edges of the pit and line it with waterproof material, such as a survival blanket. Weight the edges with rocks, soil, or logs, making sure that dirt can't run into the pond when it rains.

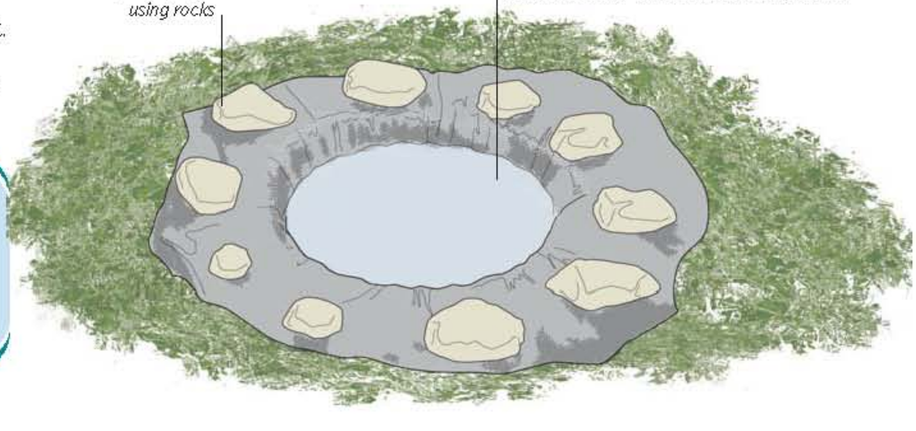

Secure the survival blanket in place using rocks

Leave the pond uncovered when it rains, but cover it at other times to reduce evaporation

WATER HYGIENE

Water stored in a mini-reservoir for any period of time will need to be filtered and purified before it's safe to drink (see pp. 200–01).

TREATING WATER

WITH THE EXCEPTION OF rainwater, all other water procured in a survival situation should be treated before it is safe to drink to remove or destroy harmful pathogens and microorganisms that could lead to gastrointestinal illness.

FILTERING WATER

If you don't have a device that filters and disinfects the water, you will have to accomplish the same task in two stages. Before purifying the water, you will have to filter it to remove any debris. You could use the popular Millbank bag (see opposite), but it may be necessary for you to construct your own improvised filter.

MILLBANK BAG

Used extensively by military forces around the world, the Millbank bag is an effective water filter that packs down small and can be used many times to produce large quantities of filtered water. Set up the bag as soon as you arrive in camp, because the process is quite slow: the Millbank bag will filter 1 liter (2.1 pints) of water in five minutes. Note that water filtered in this way will still need to be purified.

BUILDING A TRIPOD FILTER

If you're not carrying a filtration system with you such as a Millbank bag, you could make an improvised filter. All you need are three sticks to form a tripod, and some materials to create three separate layers.

1. Use three sticks or a bent sapling to form a tripod. Using any materials you have, form layers, starting at the top with the coarsest material and working your way down using finer materials—such as parachute silk or nylon—as you go.

2. Pour water into the top layer. It will become filtered as it passes through the increasingly fine materials.

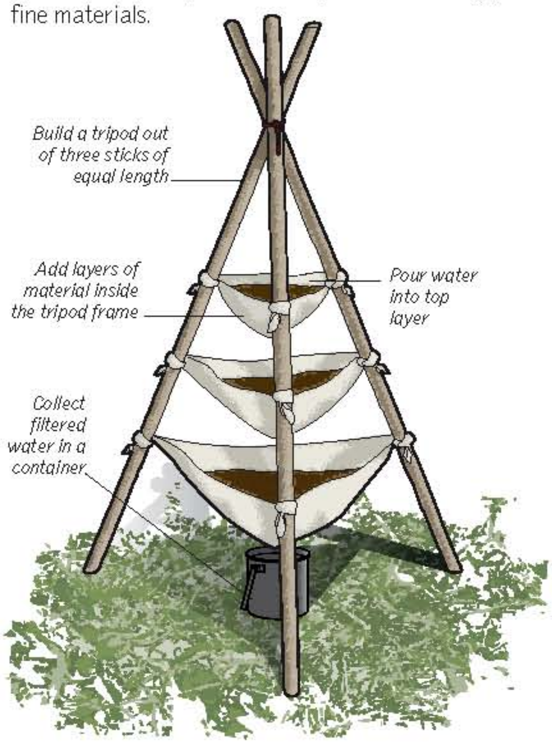
Build a tripod out of three sticks of equal length
Add layers of material inside the tripod frame
Pour water into top layer
Collect filtered water in a container

MAKING A BOTTLE FILTER

To make an improvised bottle filter, take a container, such as a plastic bottle, and cut off the bottom (or make a hole). Note that a sock used in the same manner is still effective.

1. Hang the bottle upside down from a branch. Fill the bottle with layers of different materials working from coarse to fine as you work your way down the container.

2. Pour the water into the top end of the bottle and allow it to work its way down through the layers.

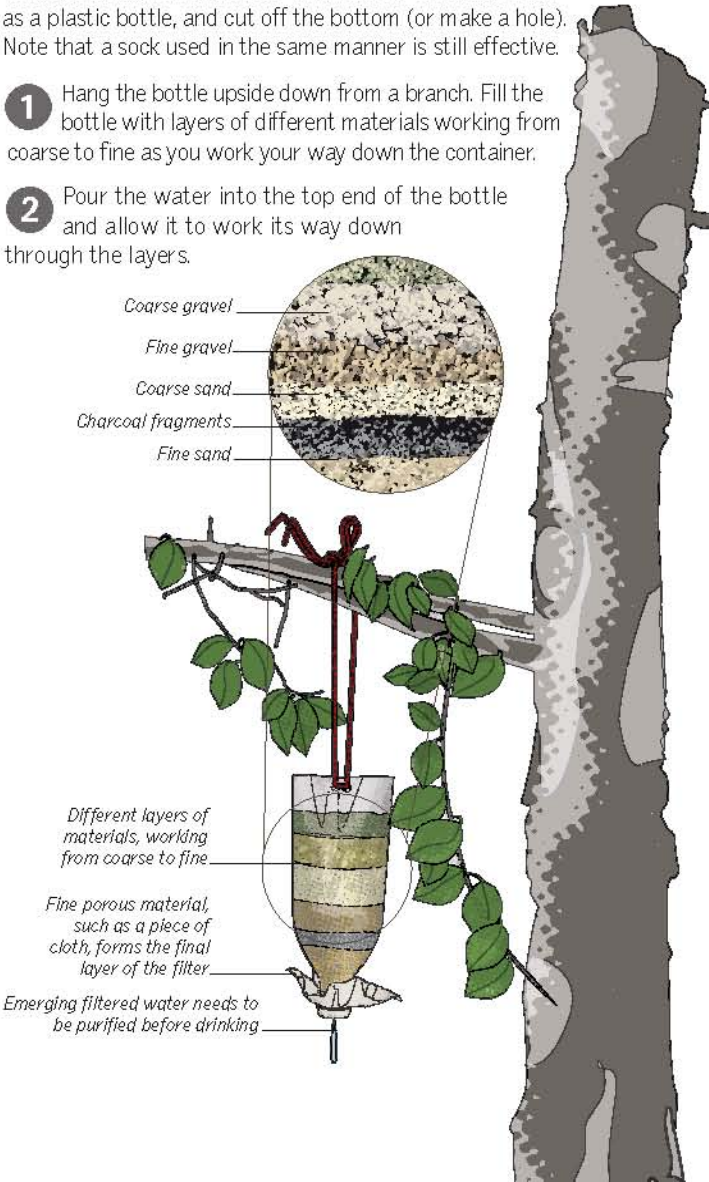
Coarse gravel
Fine gravel
Coarse sand
Charcoal fragments
Fine sand
Different layers of materials, working from coarse to fine
Fine porous material, such as a piece of cloth, forms the final layer of the filter
Emerging filtered water needs to be purified before drinking

DISINFECTING WATER

If you drink untreated water, you run the risk of becoming infected with a water-borne disease (see p. 187), so it's vital that you treat any water first. If you have the ability to start a fire, the most effective way of making water safe to drink is by boiling it. However, if you are unable to make a fire, there are several devices available that are capable of filtering and purifying water to make it safe for drinking.

MINI PORTABLE WATER PURIFIERS

These are specially designed units that filter the water and then purify it, by pumping the contaminated water through either microfilters, chemicals, or a combination of both. Sizes vary from small emergency pumps capable of purifying up to 13 gallons (50 liters) of water, to larger units that can filter huge quantities of water.

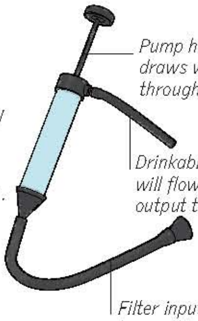

Pump handle draws water through the pump

Drinkable water will flow from the output tube

Filter input tube is lowered into water that requires treatment

GRAVITY/PRESSURE FILTERS

These devices are incorporated within drinking bottles. The water is either allowed to flow naturally through the system via gravity, or is squeezed through by the operator. All bottles of this type usually employ: a filter to remove sediment and organic contaminants; a micron filter to remove protozoa; and a chemical that kills water-borne bacteria and viruses.

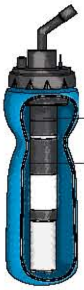

The filter system is housed inside a water bottle

Water passes through a filter which removes debris and water-borne diseases

SURVIVAL STRAWS

Compact emergency water purifiers, survival straws contain a filter system and employ either carbon or iodine resin systems to eliminate water-borne diseases and harmful chemicals. You need to get the water to a point where you can reach it with your straw. If you want to draw a supply of water to carry with you, you'll have to draw the water into your mouth and decant it into a container—a laborious process.

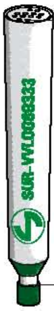

The filter end of the straw can be placed into any accessible non-saline water source

Water is sucked through the straw

OTHER METHODS

If you can't boil water, or if you don't have a water-purification device, you'll have to rely on non-mechanical techniques. The concentration and contact time required for some of these methods is dictated by the quality and temperature of the water being treated.

"BIG BUBBLES, NO TROUBLES"

Microorganisms and virtually all intestinal pathogens are killed at temperatures well below boiling point. The process of bringing water to the boil is sufficient to disinfect it—continuing to boil it just wastes fuel, time, and water.

METHOD	DESCRIPTION
Iodine (Liquid and Tablets)	Iodine—which destroys bacteria, viruses, and cysts—can be used to disinfect water effectively and conveniently. Its action is dependent on its concentration, the water temperature, and duration of contact—a concentration of 8 mgs per liter at 68°F (20°C) will destroy all pathogens if left for ten minutes.
Chlorine tablets	Chlorine-based tablets will destroy most bacteria, but are less effective for viruses and cysts. They are more effective when used in combination with phosphoric acid and will destroy both Giardiasis and Cryptosporidium.
Potassium Permanganate	Potassium permanganate can be bought at most pharmacies. Mix a few granules with your water until it turns light pink. Leave for at least 30 minutes before drinking.
Bleach	Adding unscented household bleach is the cheapest way of adding chlorine to water (it contains 5 percent sodium hypochlorite). Be careful to add just one drop of bleach per liter of water—two if the water is cloudy—and leave for at least 30 minutes before drinking. This method is not always effective against Giardiasis and Cryptosporidium.
Ultraviolet (UV) Light	When many harmful microorganisms are exposed to UV light, the process of light absorption disrupts the cell's DNA, rendering the organism harmless. The quality of the water will affect the amount of exposure to UV light required: the cloudier the water the harder it will be for UV to penetrate.
UV Passive	Fill plastic bottles with water, replace the lids, and place them in direct sunlight, preferably on a dark surface. The sun's rays will kill the bacteria that cause common water-borne diseases.
UV Active (Steripen)	A small UV purifier that is placed in pre-filtered water and activated for a short time. Some models can purify up to 1 liter (2.1 pints) of water in as little as 48 seconds.

FIND AND PREPARE FOOD

Your body converts food into fuel, which provides you with heat and energy, and helps you to recover from hard work, injury, or sickness. If you are healthy, your body can survive for weeks without food by using the reserves stored in its tissues—although you will use approximately 70 calories per hour just breathing and up to 5,500 calories a day if laboring hard.

In a short-term survival situation, food should not be your major priority. You would probably have eaten recently and, if you'd prepared properly, you should have some basic emergency food in your pack. While you may go through food withdrawal symptoms—when your stomach complains because the food it's expecting doesn't arrive—you're not going to die of starvation within a few days. However, the body will react to its fuel not being replaced: hunger, a lack of energy, and a deterioration in coordination can be expected after a few days. If the opportunity to procure food arises, it should always be taken. Eat little and often but always make sure you have sufficient water to digest it.

In this section YOU WILL DISCOVER...

- how to **cook** with **hot rocks**...
- how to **make** a **fishing reel** from a **beverage can**...
- why a **snare** must have a **perfect end**...
- how to **lasso a lizard** and **snare a squirrel**...
- that there's **more than one way** to **skin a rabbit**...
- which **grubs taste** like **scrambled eggs**...
- how to **catch** a **bird** in a **bush**...

In a long-term survival situation, your survival priorities will change and the need for food in order to simply survive will become more important. There is a thin line between food not being your priority and then subsequently finding that you're in no physical condition to do anything about it when it does become a priority—you should regularly reassess your situation and alter your plans accordingly. It takes effort, skill, and a certain amount of luck to obtain food in the wild, especially if you're not in your natural environment.

When gathering food in the wild, always ensure that the energy gained from the food is more than the energy you expended in procuring it, otherwise it's a wasteful exercise.

FOOD THAT'S EASY TO FIND and gather should always be your first priority:

- **Plants** are easy to collect and, as long as they're readily available in the environment you're in, should be your first choice for food. However, make sure that you are absolutely sure that they are edible—mistakenly eating the wrong leaf or berry could cause vomiting and diarrhea, making your situation worse.
- **Fishing** requires little effort once the lines or traps have been set, and they will work for you around the clock. Fish is high in protein and relatively simple to prepare and cook.
- **Insects, reptiles, and amphibians** may also be available, but be careful that you don't expend more energy in catching them than you gain in nutrients from eating them. Remember also that many insects, snakes, and amphibians are poisonous, but they can still be used as bait for fish and mammals.
- **Birds and mammals** have their own survival mechanisms and are wary of humans, especially in remote areas where contact with humans is limited. Even if caught, the bird or mammal will need to be killed, plucked or skinned, and cooked.

> “Always ensure that the **energy gained** from the **food** is **more than** the **energy you expended** in **procuring it**, otherwise it's a **wasteful exercise**”

WILD COOKING

IN A SURVIVAL SITUATION, you must cook every item of food that you're not sure about in order to kill any parasites or harmful bacteria. While cooking reduces the nutritional value of food, it does help to improve the taste of many wild foods and to make them more digestible than if eaten raw.

COOKING OVER AN OPEN FIRE

Use the fierce flames of a fire to boil water then, when the flames have died down, use the steady heat of the embers to cook on (see p. 121). The most basic method of cooking is roasting, using a spit made from green wood to suspend the food over a fire. Make sure the meat is thoroughly cooked.

BOILING OR STEWING

When you boil food, fat and natural juices are retained in the water. It is important to drink the water to obtain the maximum nutrition from the meal, unless you have been boiling toxic substances out of the food.

FOUND MEAT

If you find a dead animal, you can eat the meat if you cut it into small pieces and boil it for 30 minutes. Don't touch it if you have cuts on your hands—you don't know how it died.

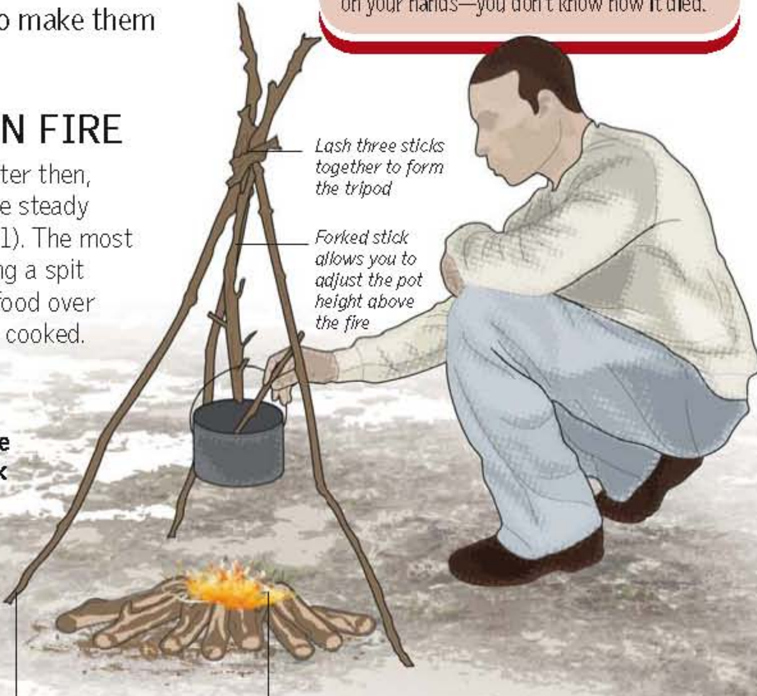
Lash three sticks together to form the tripod
Forked stick allows you to adjust the pot height above the fire
A tripod is a very stable and therefore safe way to suspend a cooking pot over a fire
Wait until flames die down a little before you begin cooking

DAMPER BREAD

This simple method for making yeast-free bread was developed by stockmen working out in the Australian bush.

1. Mix flour and water (and a pinch of salt, if you have it) into a pliable dough, then roll it into a long, thick sausage shape.

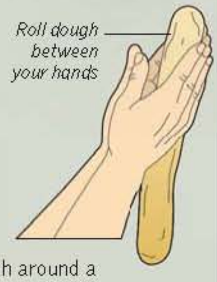
Roll dough between your hands

2. Wind the dough around a stick, then hold it over the embers of a fire, turning regularly until it browns. It will slide easily off the stick when cooked.

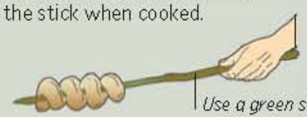
Use a green stick, which is less likely to burn

STEAMING FOOD

Steaming leaches fewer nutrients away than boiling and is a particularly good way of cooking fish and green vegetables—fresh leaves will be ready to eat in just a few minutes. To steam food, it must be suspended above boiling water in some way.

BAMBOO STEAMER

Bamboo stems are tough, hollow, and divided into sections. Use a sharp stick to make small holes in the walls dividing a three-section piece of cane, leaving the wall at the base intact. Pour water into the stem until it's just below the bottom section ring. Add food to the top section and cover with grass and a loose-fitting bamboo lid. Lean the stem over a fire, propping it against a forked stick.

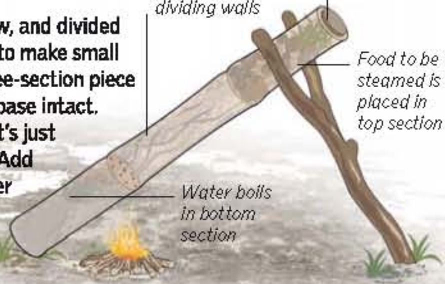
Place grass on top of food to retain heat and cover with a lid
Steam rises up stem through holes in dividing walls
Food to be steamed is placed in top section
Water boils in bottom section

CLAY BAKING

Baking food in clay requires no cooking utensils. Animals must be cleaned and gutted first, but can otherwise just be covered in soft clay. When the meat is cooked, skin, spines, or feathers will remain embedded in the clay. Cooking root vegetables or fish in this way removes their skins, losing valuable nutrients, so it's best to wrap them in leaves first.

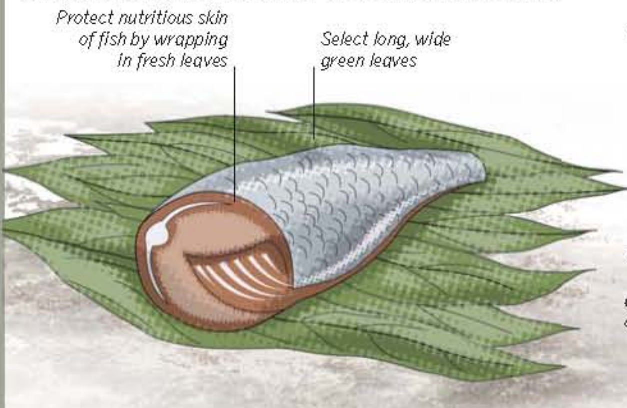
Protect nutritious skin of fish by wrapping in fresh leaves
Select long, wide green leaves

1 Wrap the food in a bundle of fresh green leaves and tie them in place with some long strands of grass to make a secure parcel. Use only leaves from plants that you have identified as non-toxic.

2 Cover the food parcel with an even layer of clay, making sure it's well sealed.

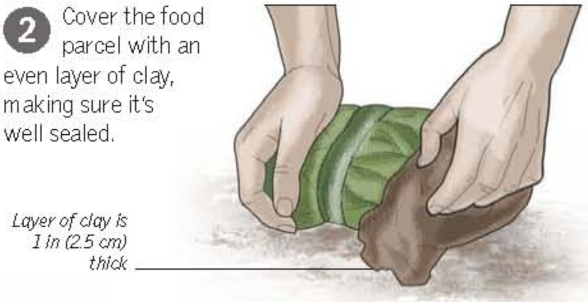
Layer of clay is 1 in (2.5 cm) thick

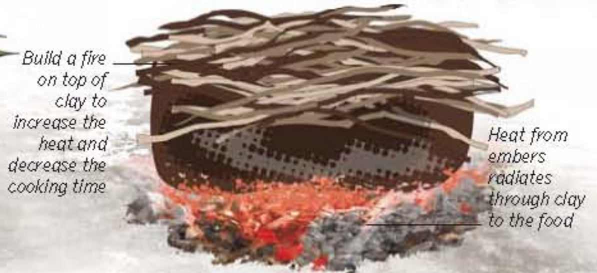
Build a fire on top of clay to increase the heat and decrease the cooking time
Heat from embers radiates through clay to the food

3 Place the parcel of clay in a bed of hot embers and build a fire up on top of it. Cooking time will be between 30 and 60 minutes, depending on the size of the food item. Break open the clay and remove the food.

COOKING WITH HOT ROCKS

Rocks take a while to heat up but they stay hot for a long time, allowing food to bake steadily on them. To reduce cooking time, cover the food with some birch bark or a flat piece of wood. When cooking on rocks, don't use slate or other layered rocks as they are likely to shatter when heated. Another method of cooking with hot rocks is to place them in a pit. The food is covered with leaves and placed on the rocks, then the pit is filled in to retain the heat. The food is left buried until it is ready to eat.

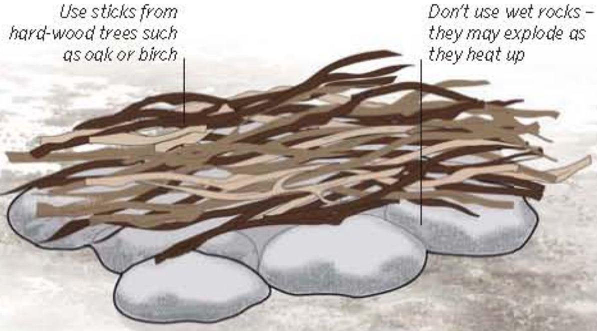
Use sticks from hard-wood trees such as oak or birch
Don't use wet rocks – they may explode as they heat up

1 Place some large, reasonably flat rocks close together. Light a fire on top of the rocks using some tinder and dry sticks, then leave the fire to burn down to hot ashes while you prepare your food.

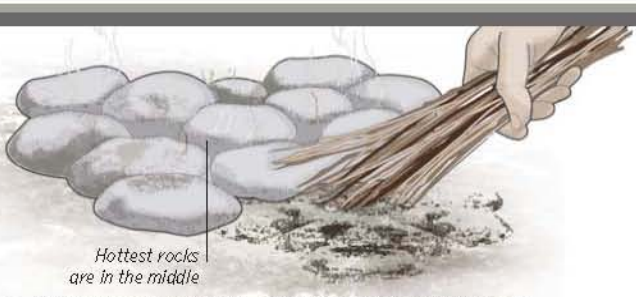
Hottest rocks are in the middle

2 Brush the embers and ash off the rocks, taking care not to touch the rocks with your hands as they will now be extremely hot.

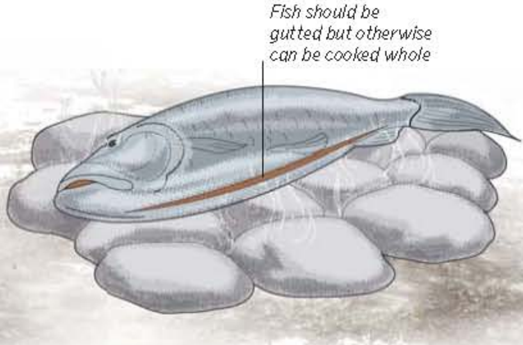
Fish should be gutted but otherwise can be cooked whole

3 Place food on top of the rocks to bake. The hottest rocks will be in the center, so items that must be cooked more slowly should be put near the edges. Keep adding more food to cook until the rocks have cooled.

EDIBLE PLANTS

IN A SHORT-TERM survival situation, food is not a priority—identifying edible plants uses energy, requires knowledge and skill, and the risks of getting it wrong far outweigh the benefits. In a long-term survival situation, however, your priorities would change, so being able to identify edible plants is advantageous.

GATHERING PLANTS

When foraging for plants, take a bag or can with you and be careful not to crush what you collect. Gather only a few species to lessen the chances of mixing in something inedible or poisonous. Don't assume that because birds or mammals have eaten a plant it's safe for you to eat too. Unless you are absolutely certain, you will need to carry out the following test to find out whether a plant is edible.

WARNING!

The Universal Edibility Test (see below) does not apply to mushrooms. For this reason alone, you should never eat any mushrooms that you have gathered (especially in a survival situation) unless you are 100 percent positive that you can identify each specific mushroom as being edible. In 2008, a British woman died after eating a poisonous mushroom that had been foraged by mistake with edible mushrooms.

DIGGING FOR ROOTS

Roots and tubers are a good source of carbohydrate and their skins contain vitamins. Take care when gathering in spring as some plants will only have small shoots and will be hard to identify.

1 Cut a stick from a hard-wood tree, such as oak, sharpen one end to a chisel-shape then harden it in a fire.

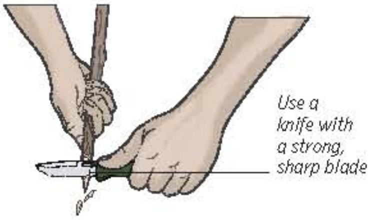
Use a knife with a strong, sharp blade

2 Choose a larger plant, then dig down at its side, loosening the earth around the root until it can be pulled out in one piece.

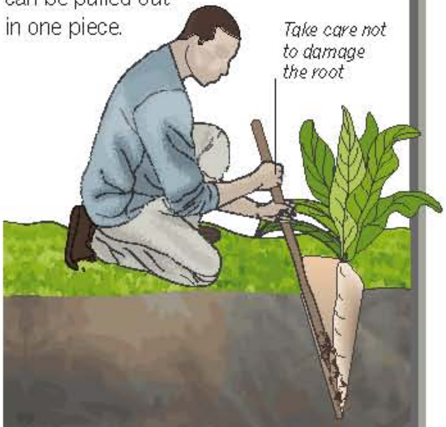
Take care not to damage the root

UNIVERSAL EDIBILITY TEST

This test enables you to check whether a plant is safe to eat. If you're in a group, only one of you should test the plant. Make sure that you have plenty of drinking water and firewood with you (see box, right), and eat nothing for eight hours beforehand. Test only one type of plant at a time, use only one part of that plant—roots, leaves, stalk, buds, fruit—at a time, and test it in the same state in which it will be eaten: either raw or cooked. Make sure that the plant you are testing is in plentiful supply (there's no point testing it otherwise) and avoid plants with milky or soapy sap, or bright colors—they are usually Nature's warning signal.

1 First, inspect the plant—it should look fresh and in good condition. Avoid anything slimy. Next, sniff the plant. Discard it if it smells bad. If it smells of peaches or bitter almonds, it may contain cyanide.

2 Take a small portion of the plant part you're testing and gently rub it on the sensitive skin inside your elbow or wrist. Wait for 15 minutes. If no irritation, stinging sensation, rash, or swelling develops, proceed to Step 3.

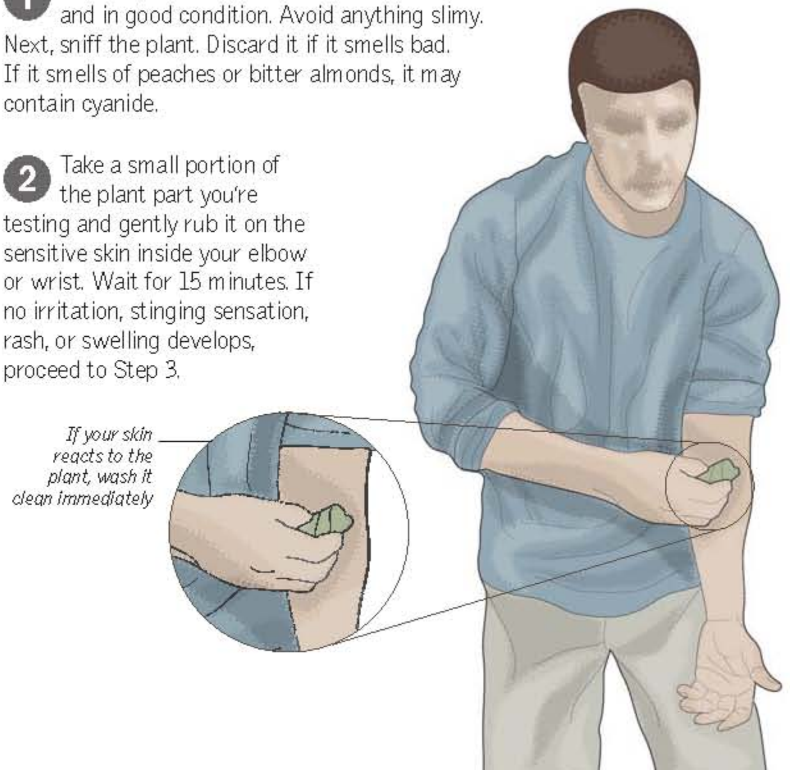
If your skin reacts to the plant, wash it clean immediately

NEEDLE TEA

The needles of evergreen trees such as pine and spruce are rich in vitamins A and C and can be used to make a refreshing—and potentially life-saving—tea.

1. For each cup of tea, collect two teaspoons of fresh green needles and bruise them with a stone.

2. Drop the needles into boiling water, then let them infuse for 10 minutes. Keep the pot warm and stir occasionally.

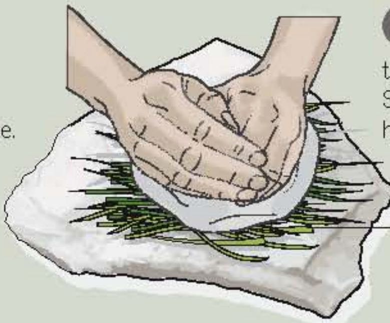

Rub needles with a large stone

3. Strain the tea through a cloth tied over a container. Sweeten with sugar or honey, if you have any.

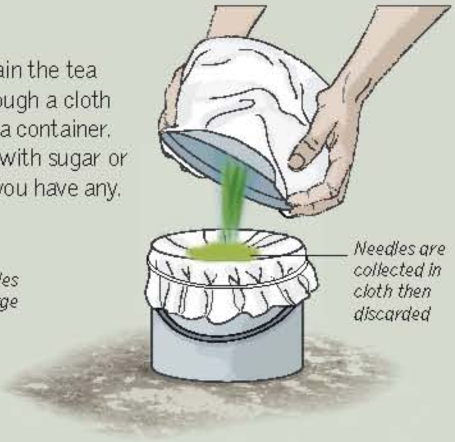

Needles are collected in cloth then discarded

3. Touch the corner of your mouth with the plant and wait 15 minutes. If no adverse reaction occurs, touch your lip and tongue with it. Wait another 15 minutes. If you suffer no ill effect, proceed to Step 4.

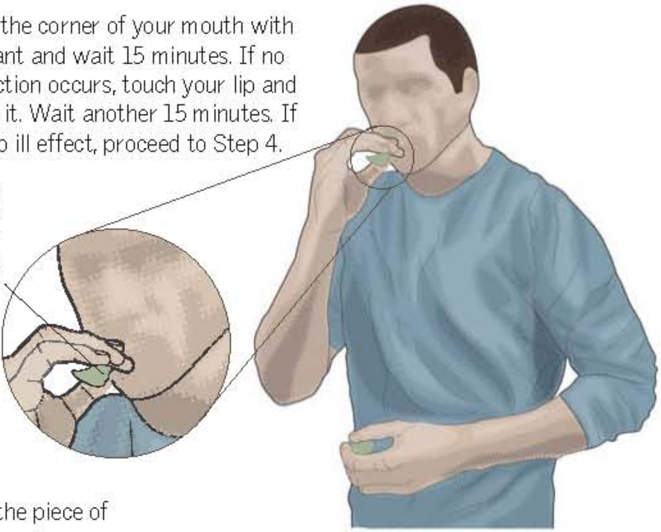

If your lips or tongue start to tingle or become numb, reject the plant

4. Place the piece of plant on your tongue, wait 15 minutes, then chew it and hold it in your mouth for 15 minutes more. If there are no ill effects, swallow the piece and wait eight hours. Eat nothing else but continue to drink water.

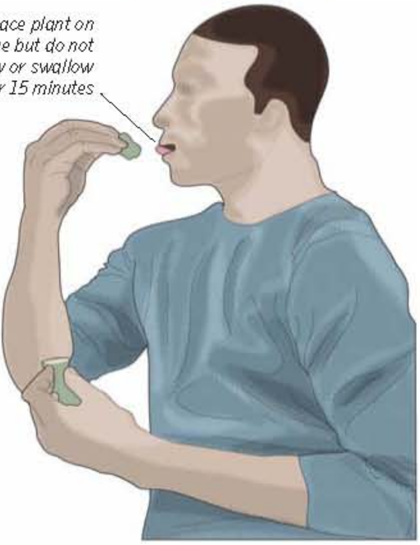

Place plant on tongue but do not chew or swallow it for 15 minutes

5. If no ill effect occurs, eat a quarter of a cup of the same part of the plant, prepared in the same way, then wait another eight hours. If there is no reaction, it is safe to eat. Eat little and often rather than gorging.

WHAT TO DO IF YOU HAVE AN ADVERSE REACTION

If at any stage you experience any type of adverse reaction to a plant during the edibility test, you should:

- Stop the test immediately.
- Avoid eating anything else until the symptoms cease.
- Wash the affected area thoroughly (if the reaction is external).
- Attempt to induce vomiting (if the reaction comes after eating the plant) by drinking salt water or by pushing a finger into the back of your throat.
- Drink lots of warm water (this is why you must ensure that you have a plentiful supply of purified water and firewood before you begin the test).
- Crush a teaspoonful of charcoal taken from a partially burned log and mix it into a paste with warm water, then swallow the mixture. It will either induce vomiting or, if you can keep it down, it may absorb the toxins.
- Try swallowing a paste made from white wood ash and water to reduce stomach pain.

If the tester is unconscious:

Do not induce vomiting if the tester is unconscious—get medical help and monitor the casualty.

CATCHING FISH

FISH CAN BE HOOKED, netted, trapped, speared, or even caught by hand if you're lucky. Observe their behavior—where and when they feed, and what they eat—to determine which method to try. It must be noted that some fishing techniques are illegal in some parts of the world and should only be used in a genuine survival situation.

FISHING TACKLE

Fishing equipment can be made from all kinds of material. Your survival kit should have some fishing line and a few hooks, but if you don't have a kit you can improvise. You can use a stick as a makeshift rod, for example.

IMPROVISED HOOKS

Fishhooks can be fashioned from any piece of metal, such as a nail, pin, safety pin, needle, or some wire. You can also make them from natural materials, such as thorns, hard wood, coconut shells, bone, spines, or seashells. If you don't have any fishing line you can use parachute cord (see p. 136) or make cordage from plant fibers (see p. 138).

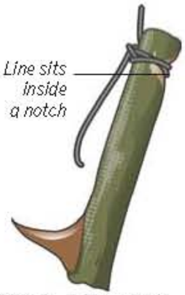
Line sits inside a notch

SINGLE THORN
Cut a 1 in (2.5 cm) length of bramble stem with a large, strong thorn. Tie a line to a notch at the other end.

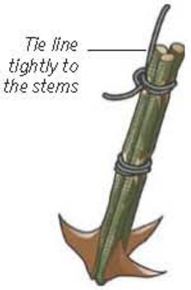
Tie line tightly to the stems

MANY THORNS
Tie three strong thorns together securely with some fishing line. Cut a notch in the stems and attach the line.

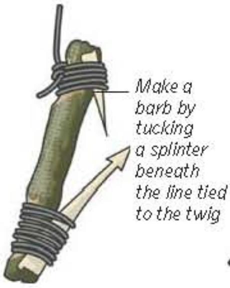
Make a barb by tucking a splinter beneath the line tied to the twig

WOOD OR BONE
Carve a splinter of bone into an arrow point or take a sliver of hard wood, like oak, and tie to a twig.

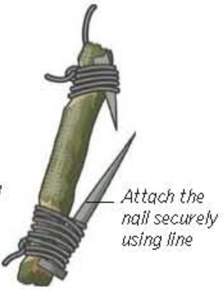
Attach the nail securely using line

NAIL
Cut a notch at one end of a small piece of hard wood. Place the head of a nail in the notch and tie it in place.

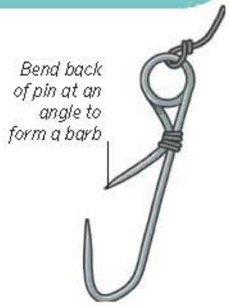
Bend back of pin at an angle to form a barb

SAFETY PIN
Remove the safety clasp. Bend the sharp point of the pin round to form a hook. Attach line to the wire loop.

BAIT AND LURES

Fish have a keen sense of smell to help them find their preferred food, so if one type of bait doesn't work, try another. Predatory fish are attracted to live bait by its movement—a worm wriggling on a hook, for example. You can make artificial bait out of shiny metal, cloth, or feathers. Try to imitate the fish's natural prey, such as an insect skimming across the water, to lure the fish into biting.

MAKING A FISHING REEL

You can make a reel with an empty beverage can. Tie one end of a line to the tab, then wrap it around the can until you have about 2 ft (60 cm) left. Attach a hook, float, and some sinkers. Hold the top of the can in one hand and the float in the other. Point the bottom of the can toward where you want the hook to land and throw the float. The rest of the line will unwind and follow. If a fish bites, give the line a jerk then wind it in around the can.

REMOVING A FISHHOOK

You should never try to remove a fishhook that is deeply embedded in flesh. Cut the fishing line as close to the hook as possible, then put a pad around the exposed part of the hook and secure with a bandage. Seek medical help as soon as possible and monitor for signs of infection. However, in a survival situation, you can try to remove the hook by doing the following:

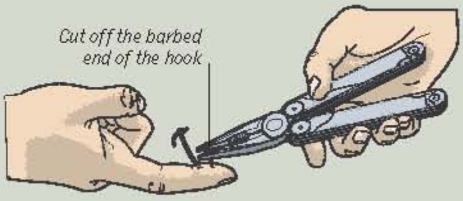
Cut off the barbed end of the hook

① If the barb is visible, cut it off with a pair of pliers. If you can't see the barb, firmly and quickly push the hook in further until the barb emerges.

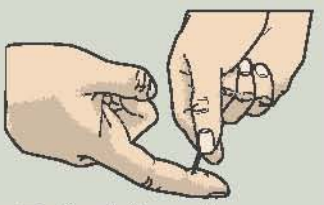

② Carefully ease the hook out by its eye. Clean the wound then cover it with a bandage.

TYPES OF BAIT

Live bait includes creatures such as:

- Worms and slugs
- Grasshoppers, crickets, and beetles
- Maggots and caterpillars
- Frogs (including large tadpoles)
- Small fish—to catch larger fish

Examples of inanimate bait include:

- Meat, guts, and reproductive organs recovered from animals
- Nuts and small fruits
- Bread, cheese, and pasta

FEATHER LURE

Make a hook, then attach it to a line. Tie a brightly colored feather just above the hook. Slowly move the lure across the water's surface to attract the fish.

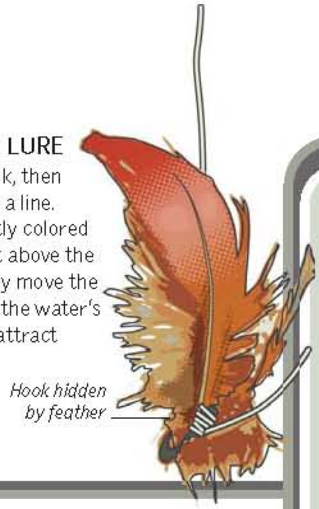

FLOATS AND SINKERS

A float keeps a baited hook at the best depth to attract the species of fish you're trying to catch. A sinker (weight) placed below the hook also helps to hold it in position. Your survival kit should include a few split-shot weights but, if it doesn't, you can tie small stones to the line instead. If the float bobs below the water's surface, you may have hooked a fish.

MAKING A FLOAT

You can use any natural material that floats, such as a piece of bark or a rose hip (see below). If you find a bird's flight feather, you can make a float by trimming the feather until you are left with just the hollow quill, then folding it in half and tying the two ends together.

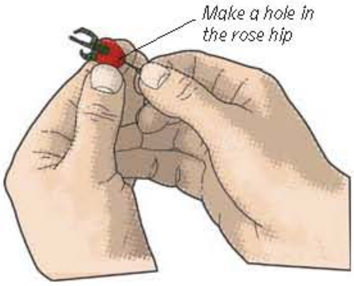
Make a hole in the rose hip

1 Using a sharp pin, a piece of wire, or a long thorn, pierce through the center of a rose hip.

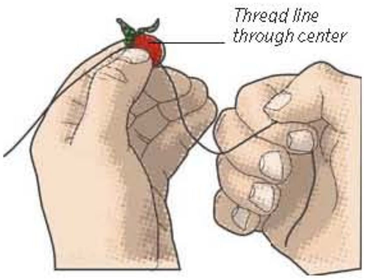

2 Thread fishing line through the hole. If you don't have line, use a length of fine cordage.

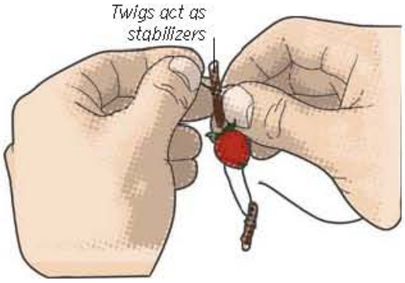

3 Tie small twigs above and below the rose hip. These will act as stabilizers and will also prevent the float from slipping up or down the line.

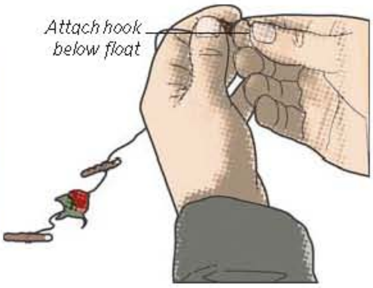

4 Attach the hook (in this example, a modified safety pin) to the line at the required depth below the float. If you have one, tie a sinker below the hook.

LINE FISHING

The more hooks you can get in the water, the greater your chances of catching a fish. All the methods shown below are passive—you simply set them and leave them to work for you.

SELF-STRIKING LINE

If a fish bites at the bait, the trigger will be jerked out of the catch and the bent rod will fly up. The line will be pulled tight, embedding the hook in the fish's mouth.

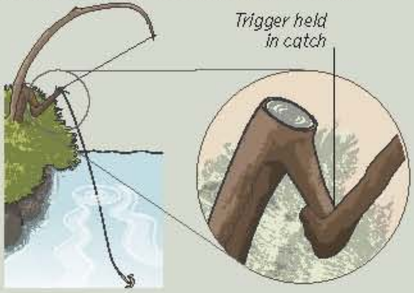

ICE FISHING

First check that the ice is at least 2 in (5 cm) thick and can bear your weight, then cut a hole about 1 ft (30 cm) in diameter over the deepest part of the lake.

1 Tie a hooked and baited line to a stick with a flag at the other end and a central crosspiece.

2 If a fish takes the bait, the crosspiece will be jerked over the hole and the flagpole pulled upright.

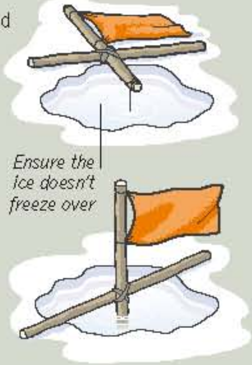
Ensure the ice doesn't freeze over

NIGHT LINES

To increase your chances of making a catch, you need to attract fish that live at all depths. Tie a rock to one end of a line and attach hooks with live bait at intervals along it. Tie the other end to a post at the edge of the bank and throw the line in the water, leaving it there overnight.

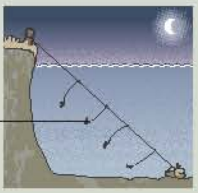
Keep hooklines short to avoid them getting tangled

NETS, TRAPS, AND HARPOONS

You can leave a hooked line in the water, but unless you regularly check it any fish you catch may be eaten by bigger fish. In a survival situation, nets and traps are more convenient methods of fishing because once set you can leave them and they work for you all the time.

WARNING!
Gill nets and traps are illegal fishing methods in many parts of the world, so use them only in an emergency.

MAKING A DIPPING NET

Fish that are too small to hook or harpoon may still be large enough to catch with a dipping net. Such fish are usually found at the edges of streams and lakes, and around rocks in pools. You can make a simple dipping net if you can split a branch or find a forked sapling and have a mosquito net—or a spare item of clothing, such as a sleeveless vest, T-shirt, or stockings.

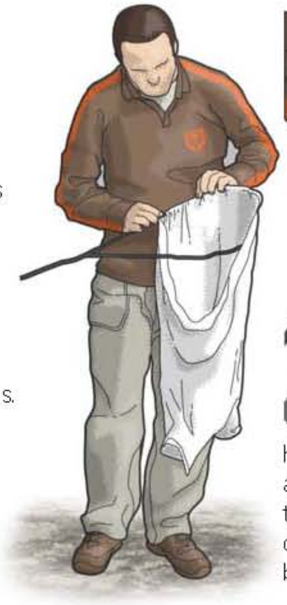

1 Make two small nicks in the hem of the mosquito net, vest, or stockings, then thread the forks of the sapling through them.

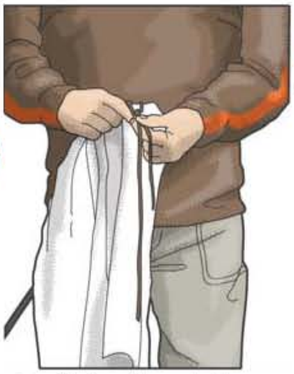

2 Cut another nick in the other side of the hem, where the forks meet, and pull them through. Tie the ends together with cordage, then push them back inside the hem.

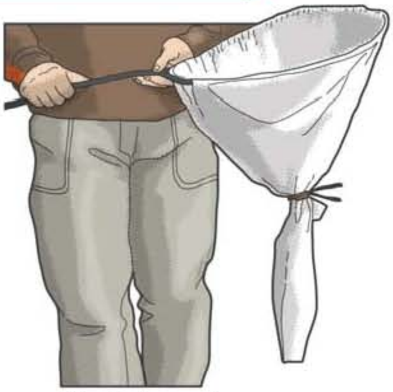

3 Tie off the net (or the vest above the armholes and neck), then either cut off the excess material or invert the net. This will prevent extra drag when you use the net.

MAKING A GILL NET

Once it has been set in a river, a gill net is a highly effective way of catching fish, whether they are swimming up- or downstream. However, a gill net should only be set for short periods of time as fish of all sizes can be entangled or injured. Make the lines out of paracord or natural cordage (see pp. 136–39).

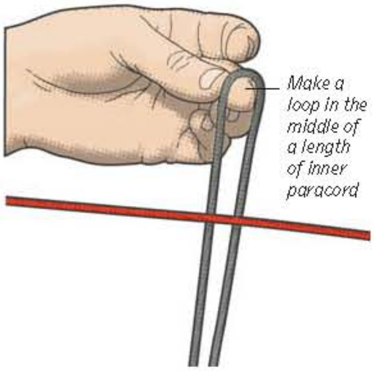

Make a loop in the middle of a length of inner paracord

1 Take a section of the outer sheath of some paracord and suspend it between two trees. Loop the inner paracord behind this line.

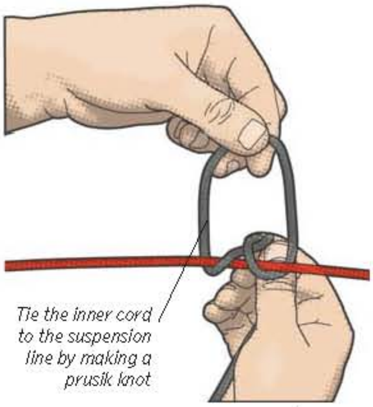

Tie the inner cord to the suspension line by making a prusik knot

2 Holding the two ends of the inner cord in your other hand, pass them around the suspended line and through the loop.

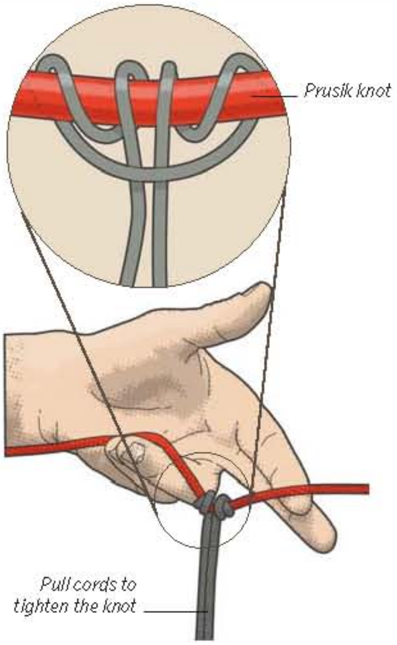

Prusik knot

Pull cords to tighten the knot

3 Pull the knot tight. Repeat the process every 1½ in (4 cm) along the suspended line for the required width of the net.

MAKING A HARPOON

Using a harpoon to spear fish takes time, patience, and a certain level of skill. Keep the point of your harpoon in the water to avoid splashing and scaring off the fish. Strike quickly when you see a potential catch, aiming just ahead of it. A spiked harpoon is the simplest to make.

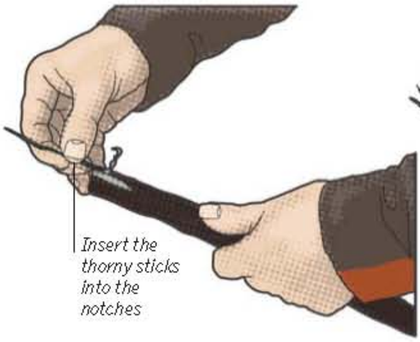
Insert the thorny sticks into the notches

1 Gather a few short, thorny sticks to form the barbs of the harpoon. Cut a long, thick, straight branch and make notches around one end.

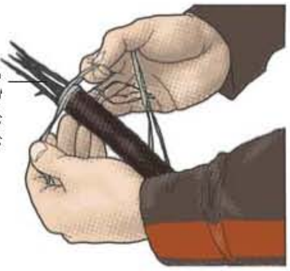
Wrap cordage around the sticks several times

2 Bind the thorny sticks tightly to the shaft with cordage. They will need to be able to support some of the weight of the fish so wrap them securely.

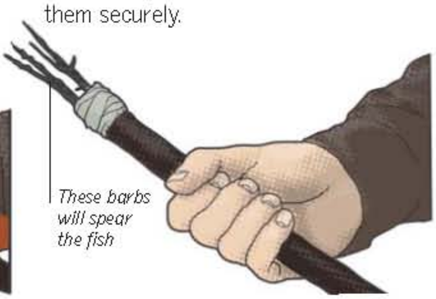
These barbs will spear the fish

3 When using the harpoon, take care not to damage the barbs by driving them against rocks or onto the riverbed. Use a dipping net, if you have one, to land the fish.

4 Make the mesh by tying a cord from one pair of cords to a cord from an adjacent pair, using a simple overhand knot (see p. 143).
■ Continue alternating along and down the line. Tie stones to the ends of the net to hold it down once it is in the water.

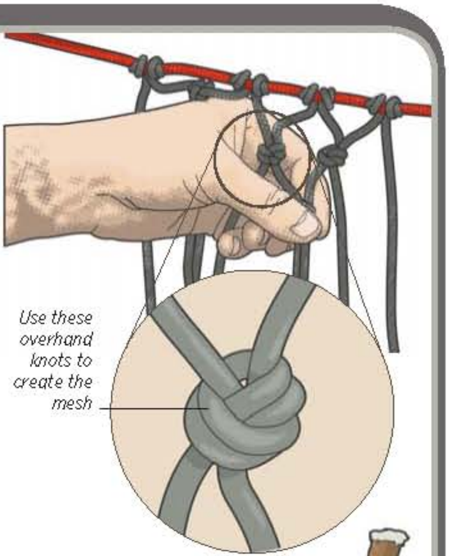
Use these overhand knots to create the mesh

5 To set the gill net, hang the suspension line between trees or poles on either side of the river, submerging the net in the water to a depth of about 6 in (15 cm).
■ The net can also be used to catch birds (see p. 226).

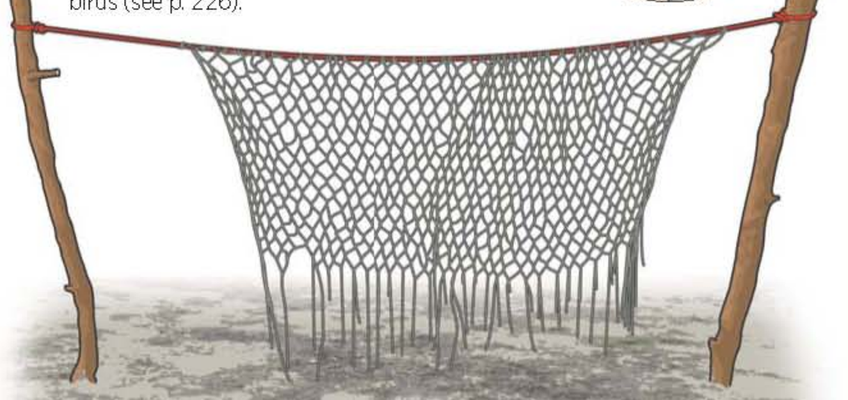

TRAPS

Fish traps can be made from a variety of materials. You can use rocks to build a wall or you can make a basket from sticks and cordage. You can even use man-made materials, such as bottles. If you only succeed in catching very small fish you can still use them as bait.

BOTTLE TRAP

Also known as a "minnow trap," this method uses a large plastic bottle to catch small fish. Cut the bottle in two just below the shoulder. Invert the neck and insert it into the cut end, then tie the two pieces together. Make holes in the plastic with a hot pin so the trap will sink. Bait the trap, then place it in a stream. Check it regularly to remove any fish caught and replace the bait.

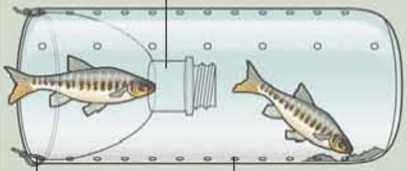
Fish smells bait and swims into bottle but can't find its way back out
Bottle neck tied to bottle base
Holes in bottle let water in

SINGLE-WALL TRAP

If your camp is near a tidal creek, you can build a curved wall of large rocks out from the bank. Pick the location at high tide and build a low wall at low tide. Fish may be trapped in the pool created between the wall and the bank as the tide recedes.

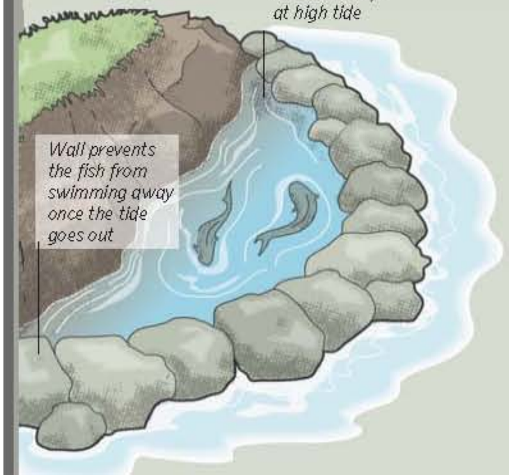
Water and fish enter the trap at high tide
Wall prevents the fish from swimming away once the tide goes out

PREPARING FISH

ALL FRESHWATER FISH are edible but they must be cooked before eating as they are often infested with parasites and harbor bacteria. Saltwater fish are safer to eat raw, if necessary, but will taste better cooked. Never eat a fish that has pale gills, sunken eyes, flabby skin or flesh, or that smells bad.

FISH HYGIENE

As soon as you have landed a fish, it should be killed and gutted, then cooked and eaten as quickly as possible, particularly in a warm climate. It doesn't take long for fish to go bad because their slimy skin provides a breeding site for flies and bacteria. In a cold climate, you can delay filleting for up to 12 hours, which will make the job easier.

FILLETING A FISH

Filleting removes the parts of a fish that might quickly go bad, while leaving as much flesh as possible. With some species, you may find it easier to remove the bones after the fish has been cooked. Boil the bones and the head to make a nutritious stock. This must be done immediately and the stock should be kept in a cool place and drunk within a few hours.

WARNING!
When handling fish be careful not to accidentally touch your eyes. The slime may contain bacteria that can cause a painful inflammation of the eye covering (conjunctivitis). Make sure you wash your hands clean of all slime. If you have any cuts on your hands, cover them before touching the fish.

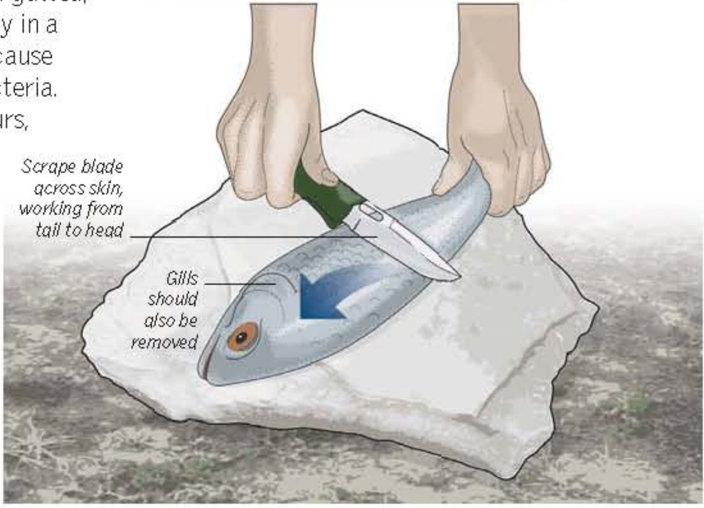
Scrape blade across skin, working from tail to head
Gills should also be removed

1 Once you have killed the fish, cut its throat to bleed it and cut out the gills. Wipe the slime off its skin to make it less slippery.

- Most fish don't need to be skinned—in fact, the skin is nutritious—but eels and catfish do (see panel, opposite).

2 Fish can be cooked with their scales on but, if you have time, it is best to remove them, particularly if they are large, as they can be a choking hazard.

- Hold the fish by the tail and scrape off the scales, holding the blade away from you and moving toward the head.

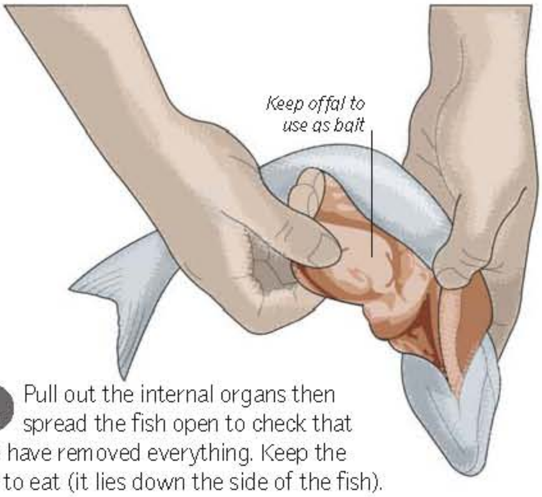
Keep offal to use as bait

4 Pull out the internal organs then spread the fish open to check that you have removed everything. Keep the roe to eat (it lies down the side of the fish).

- Wash the fish thoroughly, inside and out.

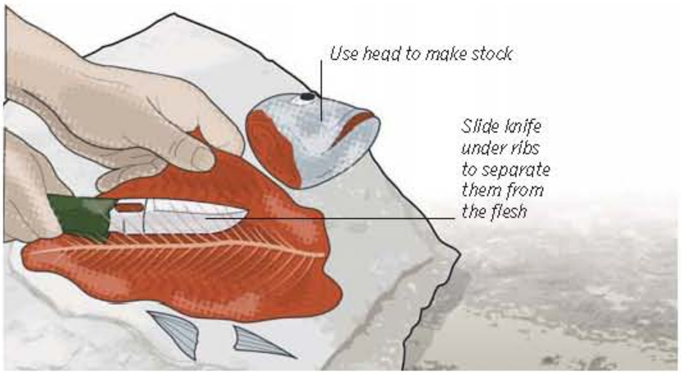
Use head to make stock
Slide knife under ribs to separate them from the flesh

5 Cut off the head, tail, and fins. Open out the body and slide the knife under the ribs to separate them from the body, working toward the head. Fish oils can make the knife slippery, so you can use your thumbs instead.

- Repeat for the ribs on the other side of the backbone.

SMALL FISH

Any fish that is less than 6 in (15 cm) long doesn't need to be filleted. After gutting, they can be fried, grilled, or roasted whole. Keeping the heads and tails on helps to prevent the fish from falling to pieces.

SKEWERING FISH

Small fish, such as perch, can be grilled over an ember fire on a skewer to make a simple, yet tasty and nutritious meal. Impale the fishes on a green stick and hold them close to the embers. They won't take long to cook.

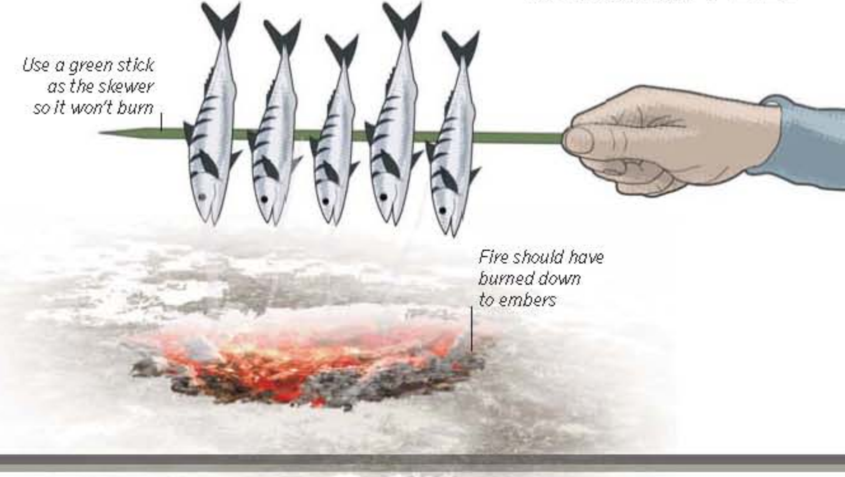
Use a green stick as the skewer so it won't burn
Fire should have burned down to embers

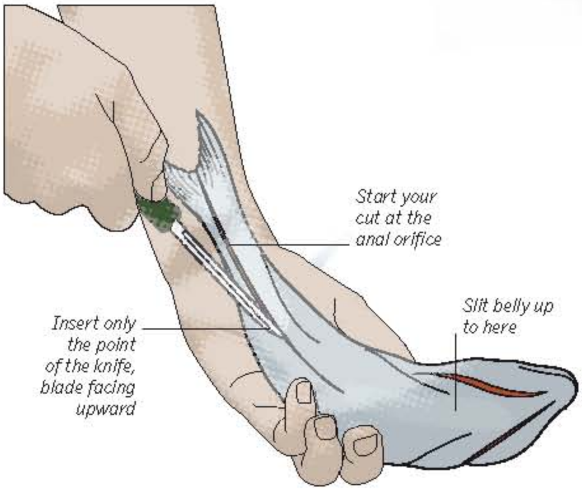
Start your cut at the anal orifice
Insert only the point of the knife, blade facing upward
Slit belly up to here

3 Holding the fish with its tail toward you, insert the point of a sharp knife, blade up, into the anal orifice and slit the fish open along its belly to its throat. This prevents you from puncturing the internal organs.

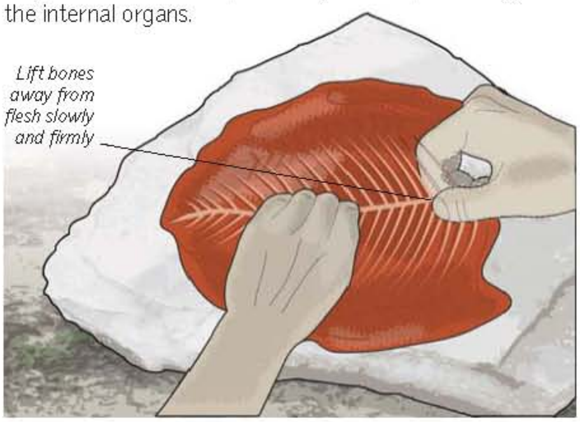
Lift bones away from flesh slowly and firmly

6 Separate the top and bottom of the backbone from the flesh with the tip of your knife. Carefully pull the backbone and ribs away from the flesh in one piece.

- If you have any tweezers or needle-nose pliers, use them to remove any small bones that remain.

SKINNING FISH

Eels and catfish are tasty but have to be skinned and gutted before cooking. To gut the fish, either use the filleting method shown opposite or Step 3 below. Catfish have a cartilage skeleton and can simply be cut crosswise into steaks.

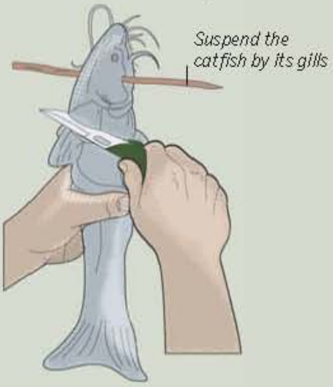
Suspend the catfish by its gills

1 Pass a stake through the gills of the fish and support on two strong uprights.

- Cut around the skin below the head with a sharp knife.
- Cut around the fins.

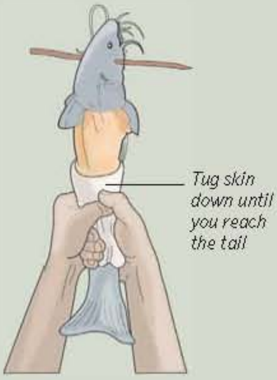
Tug skin down until you reach the tail

2 Separate the top of the skin from the flesh then peel the skin downward.

- You will need to use both hands to get a good grip, and a firm, steady action. If the fish is very large, you may need to slit the skin.

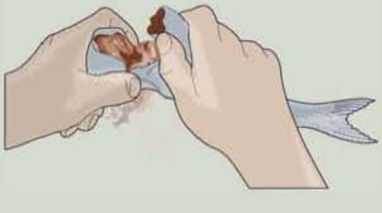

3 Remove the fish from the stake and break its backbone. When you pull the head off, the guts will come away with it.

- Remove tail and fins.

TRUE-LIFE ACCOUNT

EXTREME SURVIVAL—ADRIFT AT SEA

USEFUL EQUIPMENT

- Liferaft, lifejacket, survival suit
- Water catchment devices
- Solar still/reverse-osmosis pump
- Emergency Locator Beacon
- Marine VHF radio
- First-aid kit, sunscreen, sunglasses
- Flashlight and batteries
- Map, compass, GPS
- Survival tin, bushcraft knife
- Cell/satellite phone
- Poncho/bivy sack

IN 1972, A FAMILY OF FIVE SURVIVED for 38 days adrift in the Pacific Ocean. The Robertson family were 18 months into a round-the-world sailing trip when their 43 ft (13 m) wooden schooner *Lucette* sank. They survived thanks to a combination of good seamanship, improvisation, and good fortune.

The family set off from Falmouth, England, on January 27, 1971—father Dougal at the helm, wife Lynn, and children Anne (who disembarked in the Bahamas), Douglas, and twins Neil and Sandy as crew—and safely navigated the Atlantic and Caribbean. On June 15, 1972, however, about 200 miles (320 km) west of the Galapagos, disaster struck—a pod of killer whales charged the boat, splintering the hull and holing her irreparably.

With *Lucette* sinking rapidly and no time to radio a distress call, the crew launched their inflatable liferaft and roped it to the boat's 10 ft (3 m) solid-hull dinghy, the *Ednamair*, which they used as a towboat after improvising a sail. Their supplies amounted to 2 gallons (10 liters) of water, a bag of onions, oranges and lemons, vitamin-fortified bread, glucose, four fishing hooks, a fishing line, a first-aid kit, a kitchen knife, and eight signal flares. They sailed north toward the Doldrums to find rain, which they collected with the use of a tarpaulin, and caught fish, eating some of the meat raw and drying the rest in the sun to be stored as rations.

"A POD OF KILLER WHALES CHARGED THE BOAT...HOLING HER IRREPARABLY"

After 16 days, the liferaft had deteriorated to such an extent that the family was forced to transfer to the dinghy, using the remnants of the raft as a canopy to provide shelter and aid in the collection of rainwater. They used the wind and currents to sail northeast toward Central America, and built up sufficient rations over the next three weeks to provide energy for the extra exertion of rowing toward the coast. Luckily for them, there was no need—their ordeal came to an end on July 23, when a Japanese fishing boat spotted a signal flare and picked them up.

WHAT TO DO

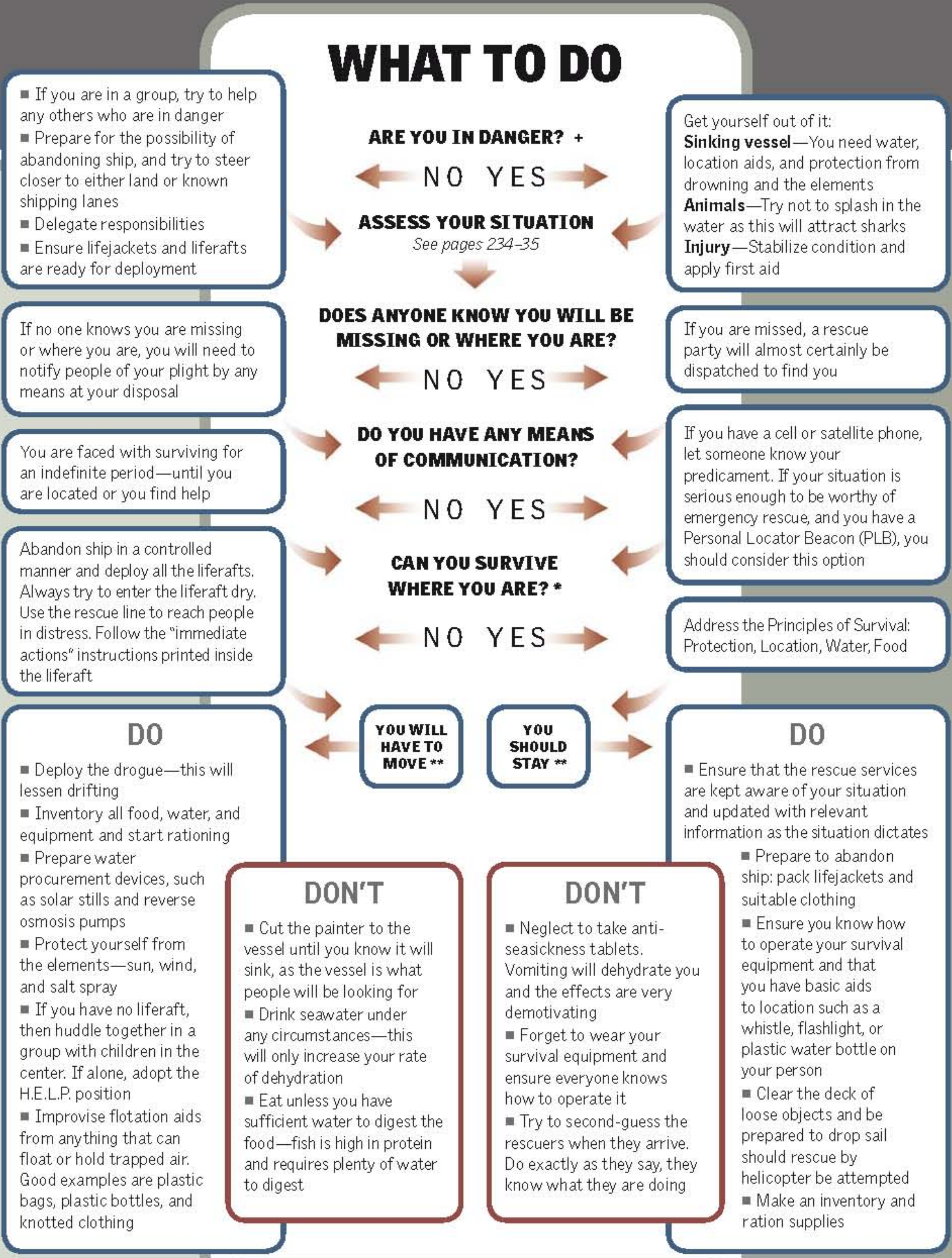

ARE YOU IN DANGER? +

NO YES

- If you are in a group, try to help any others who are in danger
- Prepare for the possibility of abandoning ship, and try to steer closer to either land or known shipping lanes
- Delegate responsibilities
- Ensure lifejackets and liferafts are ready for deployment

Get yourself out of it:
Sinking vessel—You need water, location aids, and protection from drowning and the elements
Animals—Try not to splash in the water as this will attract sharks
Injury—Stabilize condition and apply first aid

ASSESS YOUR SITUATION
See pages 234–35

DOES ANYONE KNOW YOU WILL BE MISSING OR WHERE YOU ARE?

NO YES

If no one knows you are missing or where you are, you will need to notify people of your plight by any means at your disposal

If you are missed, a rescue party will almost certainly be dispatched to find you

DO YOU HAVE ANY MEANS OF COMMUNICATION?

NO YES

You are faced with surviving for an indefinite period—until you are located or you find help

If you have a cell or satellite phone, let someone know your predicament. If your situation is serious enough to be worthy of emergency rescue, and you have a Personal Locator Beacon (PLB), you should consider this option

CAN YOU SURVIVE WHERE YOU ARE? *

NO YES

Abandon ship in a controlled manner and deploy all the liferafts. Always try to enter the liferaft dry. Use the rescue line to reach people in distress. Follow the "immediate actions" instructions printed inside the liferaft

Address the Principles of Survival: Protection, Location, Water, Food

YOU WILL HAVE TO MOVE **

DO

- Deploy the drogue—this will lessen drifting
- Inventory all food, water, and equipment and start rationing
- Prepare water procurement devices, such as solar stills and reverse osmosis pumps
- Protect yourself from the elements—sun, wind, and salt spray
- If you have no liferaft, then huddle together in a group with children in the center. If alone, adopt the H.E.L.P. position
- Improvise flotation aids from anything that can float or hold trapped air. Good examples are plastic bags, plastic bottles, and knotted clothing

DON'T

- Cut the painter to the vessel until you know it will sink, as the vessel is what people will be looking for
- Drink seawater under any circumstances—this will only increase your rate of dehydration
- Eat unless you have sufficient water to digest the food—fish is high in protein and requires plenty of water to digest

YOU SHOULD STAY **

DO

- Ensure that the rescue services are kept aware of your situation and updated with relevant information as the situation dictates
- Prepare to abandon ship: pack lifejackets and suitable clothing
- Ensure you know how to operate your survival equipment and that you have basic aids to location such as a whistle, flashlight, or plastic water bottle on your person
- Clear the deck of loose objects and be prepared to drop sail should rescue by helicopter be attempted
- Make an inventory and ration supplies

DON'T

- Neglect to take anti-seasickness tablets. Vomiting will dehydrate you and the effects are very demotivating
- Forget to wear your survival equipment and ensure everyone knows how to operate it
- Try to second-guess the rescuers when they arrive. Do exactly as they say, they know what they are doing

+ Never abandon a vessel unless you have to—searchers will be trying to locate it. Use the vessel's equipment while you can, and before you leave collect essential items to aid your survival.
* If you cannot survive where you are, but you also cannot move owing to injury or other factors, you must do everything you can to attract rescue.
** If your situation changes (for instance, you are "moving" to find help, and you find a suitable location in which you can stay and survive) consult the alternative "Do" and "Don'ts."

TRAPPING ANIMALS

ALTHOUGH YOU SHOULD be prepared to take down sitting prey if you get the opportunity, trapping small animals is easier than hunting them—it requires less skill and energy and leaves you free to carry on with other tasks. One of the simplest traps is a snare.

MAKING A SNARE

Stainless steel snares of various strengths can be bought ready-made, with a running loop, or eye, at one end and a securing loop at the other. However, most survival kits contain a length of single-strand brass wire that can be used to make a snare.

① Decide on the strength of snare you want (see panel, below) and double or quadruple the wire accordingly.

- Pass the strands around a stick, place it on the ground, then loop the loose ends around a second stick.
- Rotate the second stick until the strands have entwined, forming a single, thick wire. Remove the sticks.

STRENGTHS OF SNARE

The single-strand wire found in most survival kits isn't strong enough to hold most animals you would want to catch. You'll need to double or quadruple the strands by winding them together to increase their strength.

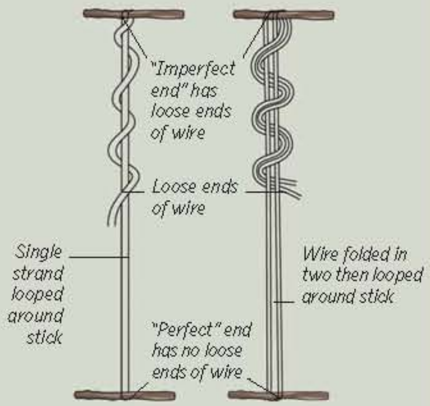
"Imperfect end" has loose ends of wire
Loose ends of wire
Single strand looped around stick
"Perfect" end has no loose ends of wire
Wire folded in two then looped around stick

TWO STRANDS
A two-strand snare will be sufficient to bear the weight of a squirrel-sized animal.

FOUR STRANDS
A four-strand snare will be strong enough to hold onto an animal the size of a rabbit.

ALTERNATIVE MATERIALS
Guitar strings make great snares as they already have a "perfect end." Natural cordage can also be used.

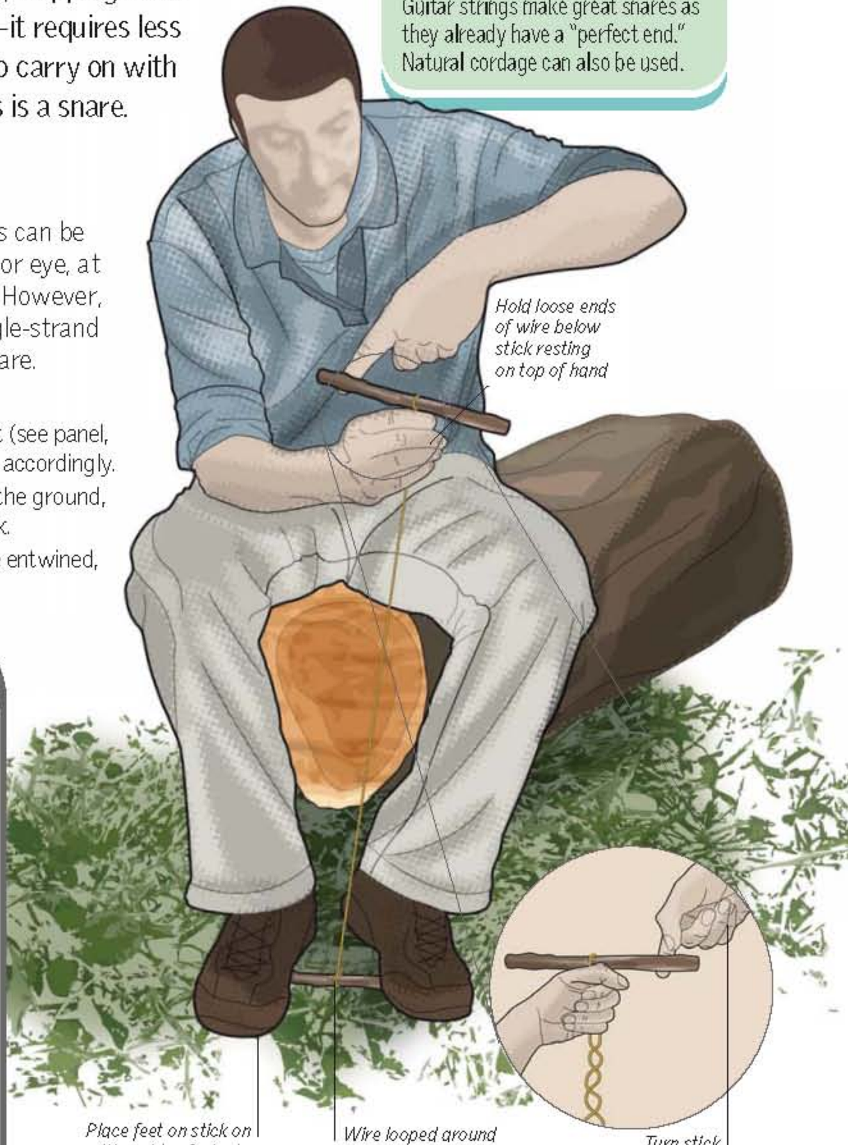
Hold loose ends of wire below stick resting on top of hand
Place feet on stick on either side of wire to hold it in place
Wire looped around stick on ground forms "perfect end"
Turn stick with other hand until the wire strands are intertwined

KILLING A RABBIT
Unless you're an expert, breaking a rabbit's neck by holding its head and pulling on its legs can be difficult and could result in you dislocating its hips, causing it more pain. The best method is to strike the rabbit on the back of the neck with a solid stick, thus avoiding having to pick it up and risk being bitten or scratched. The eyes will glass over immediately when the animal is dead.

LOOK AND LISTEN

To be successful at hunting and trapping, you need to decide which types of animal you are going to try to catch. To do that, you need to find out what animals are in the vicinity and where exactly they are to be found. Prey animals will use their keen senses to avoid being caught—so you will have to use your senses to find them. Look for any signs of animals, both on the ground and in the trees. And use your ears—you may be able to hear an animal even when you can't see it.

SIGNS TO LOOK OUT FOR:

- Runs, trails, and tracks
- Droppings
- Chewed or rubbed vegetation
- Feeding and watering areas
- Lairs, dens, and resting sites

SQUIRREL POLE

Make several two-strand snares with nooses 3 in (8 cm) in diameter and stake-out cords 8 in (30 cm) in length. Place them around a long pole, with the lowest 2 ft (60 cm) off the ground. If you snare a squirrel, leave it, as others will come to investigate.

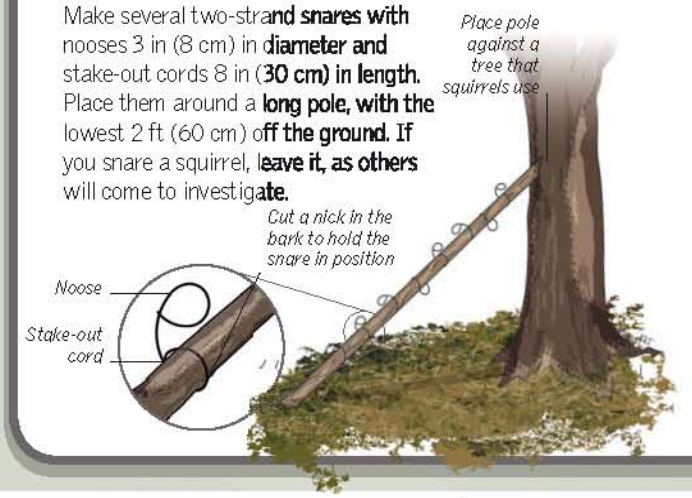
Place pole against a tree that squirrels use
Cut a nick in the bark to hold the snare in position
Noose
Stake-out cord

2 To make the noose, pass the imperfect end, or securing loop, through the perfect end, or running loop. The running loop has no loose ends of wire so it won't snag in an animal's fur and prevent the noose from tightening as it struggles.

- Use a single prusik knot (see p. 210) to tie a length of cord to the securing loop.

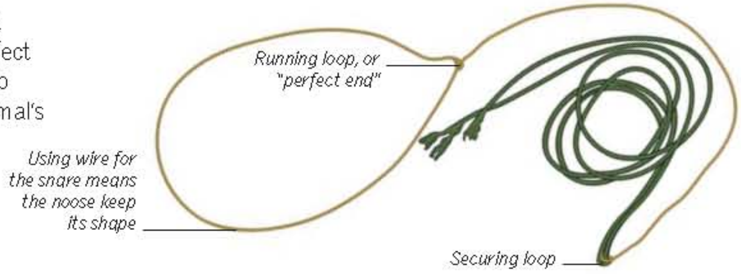
Running loop, or "perfect end"
Using wire for the snare means the noose keep its shape
Securing loop

3 Before setting the snare, either bury it in the ground for a few hours or pass it over a flame for a few seconds to remove any human scent and dull its surface.

- Don't waste snares; always set them on runs you know the animals are using and set as many as you can.
- Use sticks to make a support from which to suspend the snare, or bend saplings into an arch.

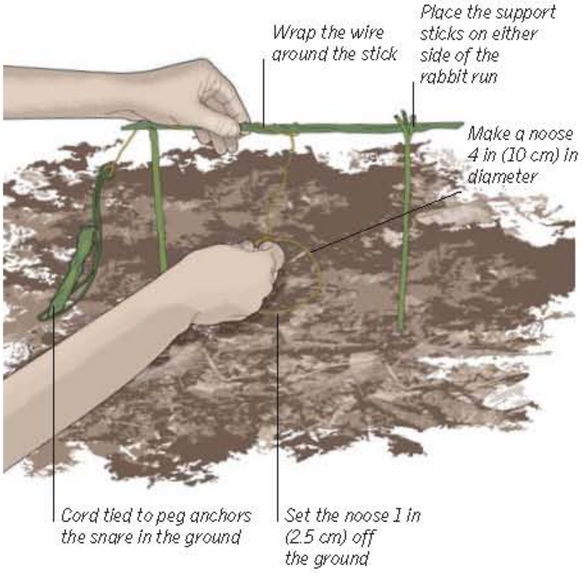
Wrap the wire around the stick
Place the support sticks on either side of the rabbit run
Make a noose 4 in (10 cm) in diameter
Cord tied to peg anchors the snare in the ground
Set the noose 1 in (2.5 cm) off the ground

4 Avoid disturbing or treading on the run, as the disturbance or your scent could alert the animal. Camouflage the frame with vegetation, which you can also use to funnel the animal toward the snare.

- Use natural vegetation, such as holly or other prickly shrubs, to form a funnel on either side of the snare.
- The funnel helps to ensure that the animal has no option but to pass through the snare.

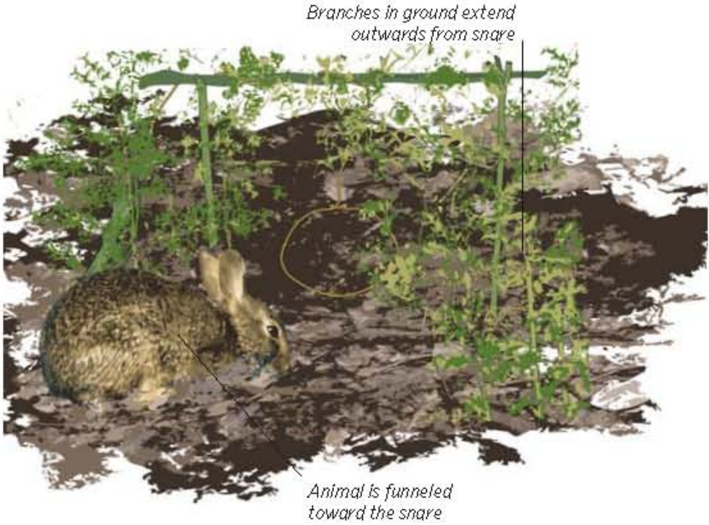
Branches in ground extend outwards from snare
Animal is funneled toward the snare

WEAPONS AND TECHNIQUES

A spear is the simplest weapon to make and use, but if you have the time and materials you can make more complicated weapons, although they require more skill to use. Learning other basic techniques, such as catching insects, is also invaluable when hunting.

THROWING STAR

With a throwing star you're four times more likely to hit prey than with a spear, and, if you don't succeed in wounding the animal with one of the sharp ends, the weight of the weapon will at least stun it. Keep it close at hand and ready to use, should the opportunity arise.

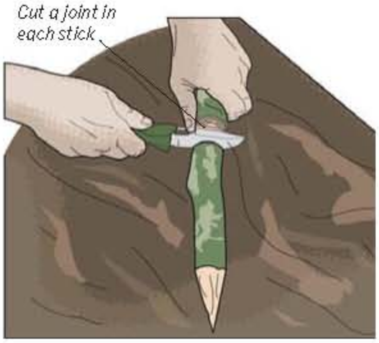
Cut a joint in each stick

1 Find two sticks 2 in (5 cm) thick and 18 in (45 cm) long. Make a square-cut joint in the center of each, then sharpen each end.

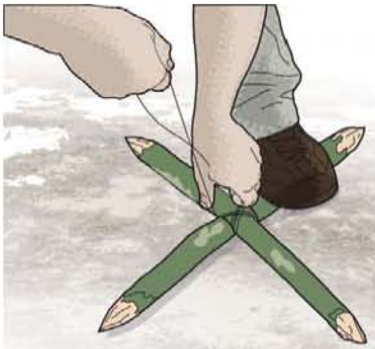

2 Join the sticks together by overlapping the two square-cut joints and lashing them to each other with paracord or natural cordage.

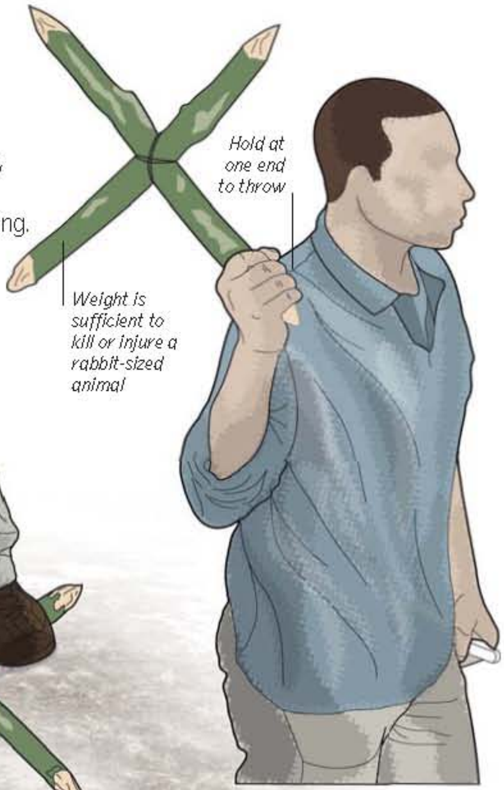
Hold at one end to throw
Weight is sufficient to kill or injure a rabbit-sized animal

3 You can exert more force if you're throwing from a standing position. Aim for the animal's legs.

RODENT SKEWER

A forked spear can be used to catch small mammals in their burrows. Thrust the pointed end into the hole. When you can feel the animal, twist the stick until you have snagged its fur, then carefully pull it out.

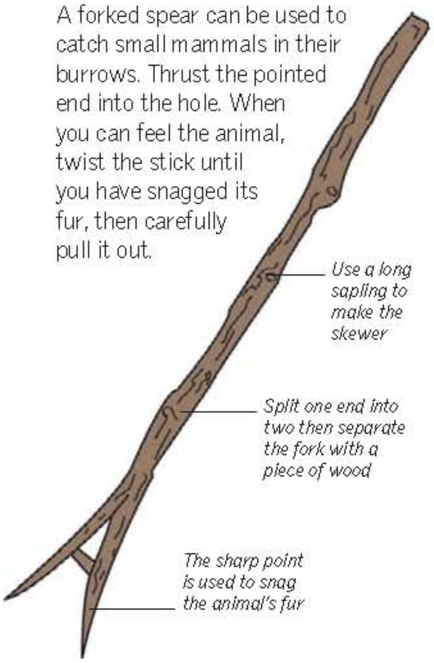
Use a long sapling to make the skewer
Split one end into two then separate the fork with a piece of wood
The sharp point is used to snag the animal's fur

SLINGSHOT

A slingshot can be used to kill small animals. Cut a strong forked branch and make a notch in each fork. Take the rubber tubing from your survival kit (see pp. 60–61) and thread it through a piece of leather or plastic. Tie the ends of the tubing to the notches. Place a pebble in the pouch, stretch back the sling, and take aim.

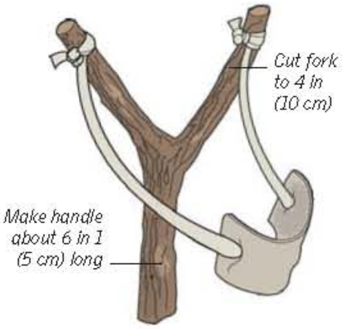
Cut fork to 4 in (10 cm)
Make handle about 6 in 1 (5 cm) long

NOOSE STICK

You can use a noose stick to lasso lizards, slow-moving mammals, or roosting birds, jerking the pole to tighten the noose around the animal's neck. Use a wire or cordage snare (see pp. 216–17). When stalking prey, move slowly and very quietly.

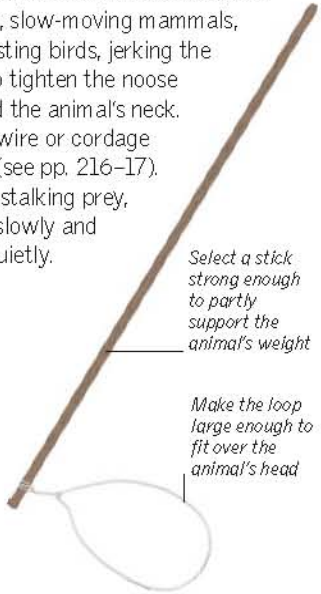
Select a stick strong enough to partly support the animal's weight
Make the loop large enough to fit over the animal's head

EASY PICKINGS

Ants are social insects, and most species are aggressive in defense of their nest. They have a stinging bite and some species will also squirt formic acid at their attacker. However, they make a nutritious meal if gathered with care. In summer months in northern temperate regions, you can eat the larvae of wood ants. And, if you use the technique shown below, you can get the ants to do all the work of collecting the larvae together for you. You'll have to vandalize the nest, but don't remove all of it.

ANT CUISINE

Ant larvae are best fried—they taste like shrimp. Adult ants also make a tasty snack—in Bogotá, Colombia, movie theaters sell roasted leaf-cutter ant abdomens instead of popcorn.

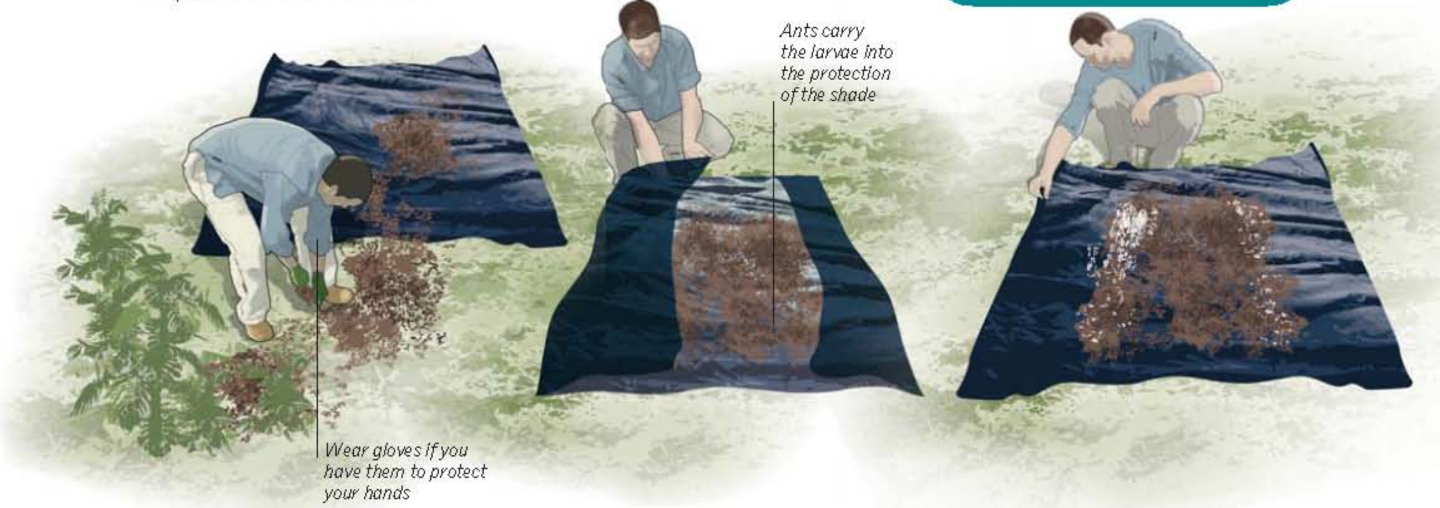

Wear gloves if you have them to protect your hands

Ants carry the larvae into the protection of the shade

① Place a tarpaulin in a sunny patch next to the nest. Scoop the nest material, ants, and larvae into the middle of the tarpaulin.

② Lay some sticks on the tarpaulin, close to the edge, then fold over the sides to create shade. The ants will carry the larvae into the shade.

③ After a while, throw back the folded sides of the tarpaulin and scoop up the larvae, which look like fat grains of white rice.

CATCHING INSECTS

Many flying insects can be eaten, but catching them takes a bit of ingenuity. Crawling insects, such as ants (see above) and termites, can provide a good meal if you can collect them in sufficient quantities.

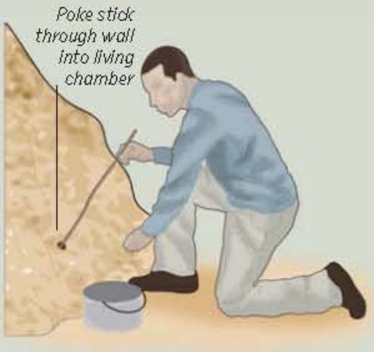

Poke stick through wall into living chamber

① Cut a long, thin, straight stick then peel it until smooth. Push it slowly into the termite hill.

TERMITE FISHING

Termites are found in the tropics and subtropics. Some species live in vast numbers inside mounds, which they build out of mud and saliva. If a foreign object breaches the walls, the termites will attack it with their powerful jaws.

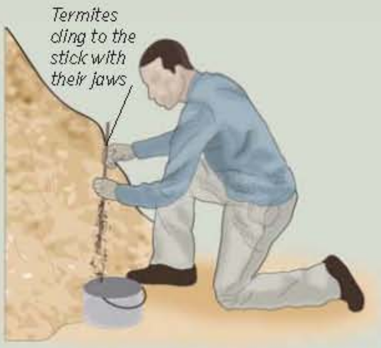

Termites cling to the stick with their jaws

② Remove the stick and scrape off the attached termites into a container ready for frying or roasting.

NIGHT FLIERS

Nocturnal flying insects, such as moths, are attracted to light. Stretch a white sheet between two branches and peg the bottom taut above a bowl of water. Hang a flashlight behind the sheet. Insects will fly into the sheet and fall into the water.

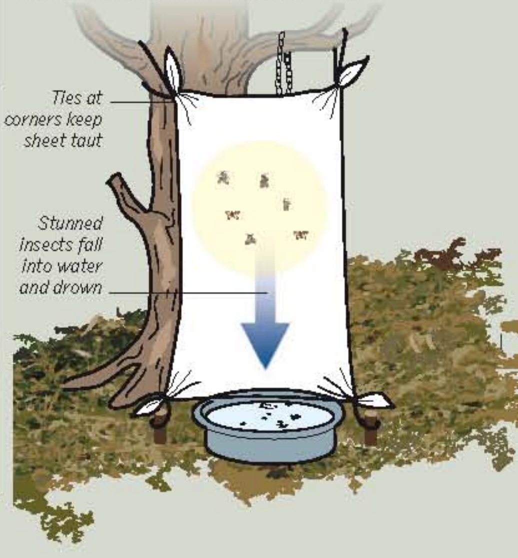

Ties at corners keep sheet taut

Stunned insects fall into water and drown

PREPARING SMALL MAMMALS

PARASITES SUCH AS FLEAS and lice will leave the body once a warm-blooded animal is dead so, if your circumstances permit, leave the carcass to cool before preparing it for cooking. In a hot climate, place the body in the shade. However, don't let it get too cold, as skin is more easily removed when a body is warm.

RABBIT-SIZED MAMMALS

The method shown here applies to all furred mammals approximately the same size as a rabbit. Before gutting the animal, remove any urine by holding the body by the forelegs and progressively squeezing down from the chest toward the bowels, making sure that you direct the spray away from your own body. You'll need to remove any scent glands, which are usually inside the forelegs or around the anus, in case the musk taints the meat (take particular care when handling a skunk).

WARNING!
Rabbits, hares, and rodents may be infected with a bacteria called tularemia, which can be fatal to humans. Do not touch these animals with your bare hands if you have a scratch on your skin. If you have no gloves, cover your hands in soap lather before handling the animal, and wash your hands when you have finished. The germ is destroyed by heat, so cook the meat well. Myxamatosis, a viral disease that affects rabbits' mucous glands, is not harmful to humans.

GUTTING

No part of a mammal carcass should be wasted. If your camp is near water, keep the guts for fish bait. The offal should be removed carefully and eaten if healthy—discard any organ that's pale or spotty. Liver is rich in essential vitamins and minerals and needs little cooking. It should be eaten as fresh as possible (removing the gall bladder from the middle first). Kidneys, which in most mammals are surrounded by fat, are also a valuable source of nutrition.

1. Place the animal on its back on clean ground, such as a bed of pine boughs, with its head pointing toward you. Cut a small hole in its belly with the point of your knife, taking care not to pierce the guts.

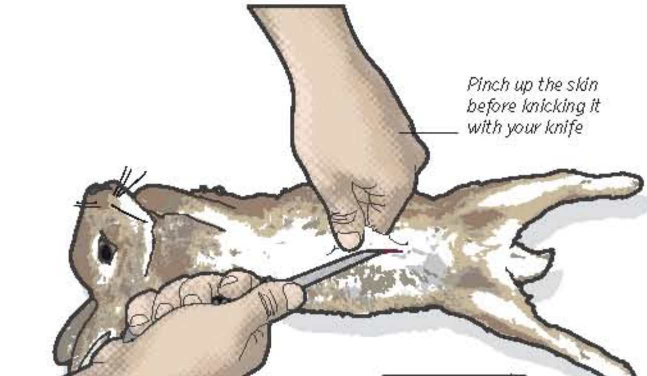

Pinch up the skin before knicking it with your knife

WARNING!
Rabbits make an easy meal, but their flesh lacks fat and vitamins so, if your diet consists entirely of rabbit, your body will use its own vitamins and minerals to digest the meat. These are then lost from your body in your feces and, if not replaced, you'll get diarrhea and so become hungry and weak. Eating more rabbit makes the condition worse and you will eventually die of starvation. You must supplement your diet with some vegetation and fatty food.

2. Pull the skin apart at the cut and insert a finger from each hand into the opening.

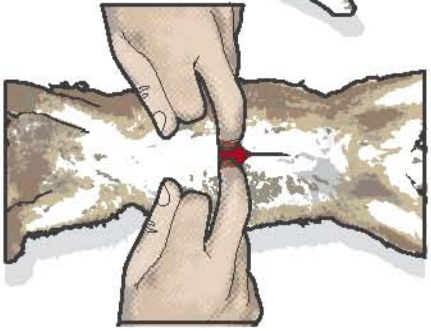

3. Prise open the belly to expose the guts; remove them along with the heart, liver, and kidneys. Wash your hands before moving on to skinning.

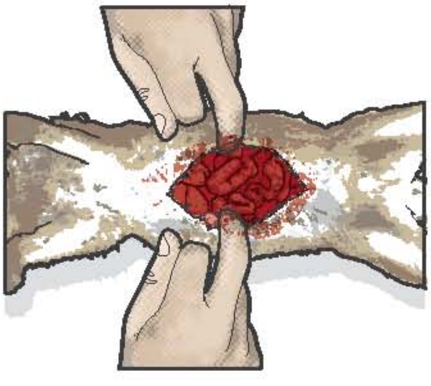

SKINNING

If you wish to keep the skin for use later (to make a pair of mittens, for example), you should remove it as carefully as possible. You'll also need to cure it; stretch the skin as tight as possible and leave it in the sun or hang it close to the heat of a fire to dry. Rubbing wood ash into the skin will help to speed up the process.

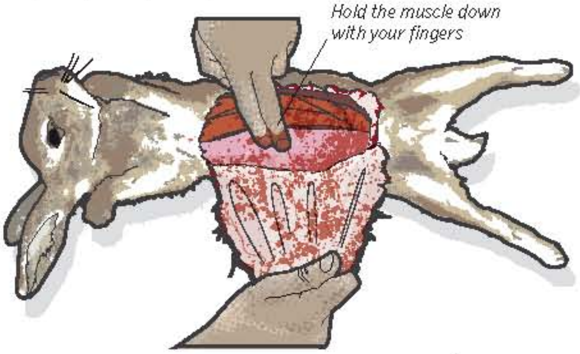
Hold the muscle down with your fingers

① Beginning at the belly, separate the skin from the muscle surrounding the gut cavity. You'll find that it pulls away quite easily. When you have reached the back on one side, repeat the process on the other.

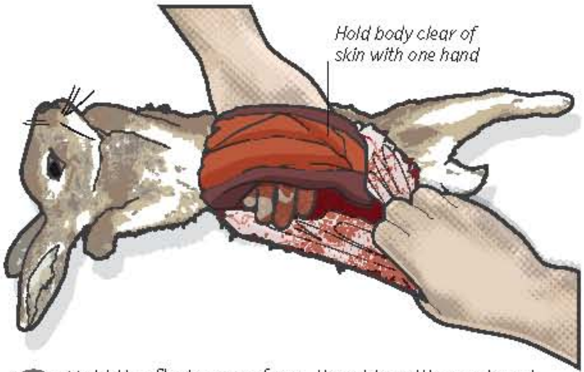
Hold body clear of skin with one hand

② Hold the flesh away from the skin with one hand and pull the skin over the rear legs, one by one. The hindquarters are now free of skin and fur, except for the tail, which should be cut off and the scent glands removed.

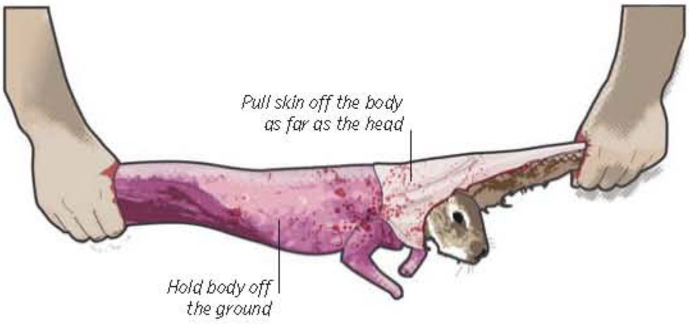
Pull skin off the body as far as the head
Hold body off the ground

③ Hold the animal by the rear legs and pull the skin forward, easing out both forelegs. Pull the skin over the neck and then cut off the head. Wash the body to remove any traces of fur.

GLOVE SKINNING

The preferred survival method of skinning and gutting a rabbit-sized mammal is to suspend it by its rear legs from a strong branch as this keeps the animal off the dirty ground.

- If you have no knife to hand, snap off the lower part of a foreleg and use the sharp edge of the broken bone to cut the skin.
- Gut the animal, then cut the skin around all four paws and between the rear legs.
- Tug the skin down toward the head.
- If you wish, pull the skin over the head. Otherwise just cut the head off.

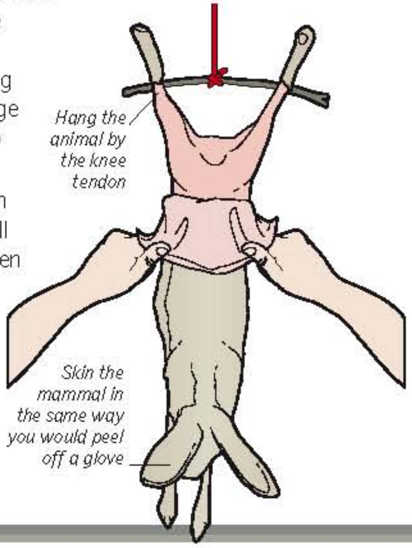
Hang the animal by the knee tendon
Skin the mammal in the same way you would peel off a glove

HOW TO SKIN A SQUIRREL

Squirrel flesh is tender and tasty. Once you have skinned the squirrel, you can simply skewer it on a spit and roast it whole over a fire. Alternatively, you can cut the meat into pieces and make a stew. A large squirrel will feed two people.

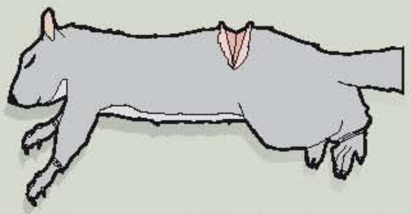

① Gut the squirrel following the method shown opposite. Cut the skin around the paws, then cut through the skin across the middle of its back.

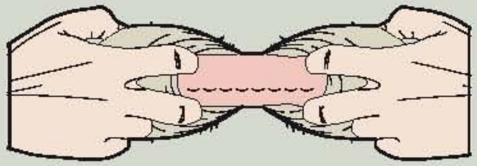

② Insert two fingers under the skin on either side of the cut and pull the two pieces apart and off the body. Wash off any traces of fur.

PREPARING LARGE MAMMALS

ALL LARGE MAMMALS are edible, but you must not eat the livers of polar bears or bearded seals as they contain toxic levels of vitamin A. Wild game is sometimes infected with roundworm larvae and, if you eat the meat raw or undercooked, it will infect you with parasites, so always cook all wild game thoroughly.

PREPARING THE KILL

Lifting large animals, such as deer, uses energy so, if you're alone, prepare the carcass on the ground. However, if you're in a group and circumstances permit, it's best to suspend the animal by its hocks (the tarsal joints of its hind legs) from a branch, as it will bleed better and will be easier to skin and gut. If you can't find a suitable tree from which to hang it, build a frame.

WARNING!
Approach all game with caution, as the animal may still be alive and most wounded animals are extremely dangerous. To check, touch its eye with the tip of a long stick (or the muzzle of a gun). Even if the animal is unconscious, it will blink if it's alive. Always skin, gut, and butcher game at the site of the kill. You don't want the smell of fresh blood to attract predators or scavengers to your camp.

BLEEDING

Bleeding is essential to preserve the meat and stops it from tasting too gamy. It also helps to cool the carcass. Slit the animal's throat from ear to ear and let the blood drain out. Blood is rich in vitamins and minerals, including salt, so, if you're able to, collect it in a container to use later in a stew. Cover the container to protect the blood from flies and to keep it cool.

SKINNING

If you wish to preserve the hide, it's better to take the skin off before gutting. Cut the belly skin from throat to tail, cutting around the genitals. Cut along each leg from above the foot to the belly. Pull the hide off the carcass, severing connective tissue as necessary. If you're skinning on the ground and you don't want to keep the hide, you can use it to protect the meat—remove it fully only after jointing is complete.

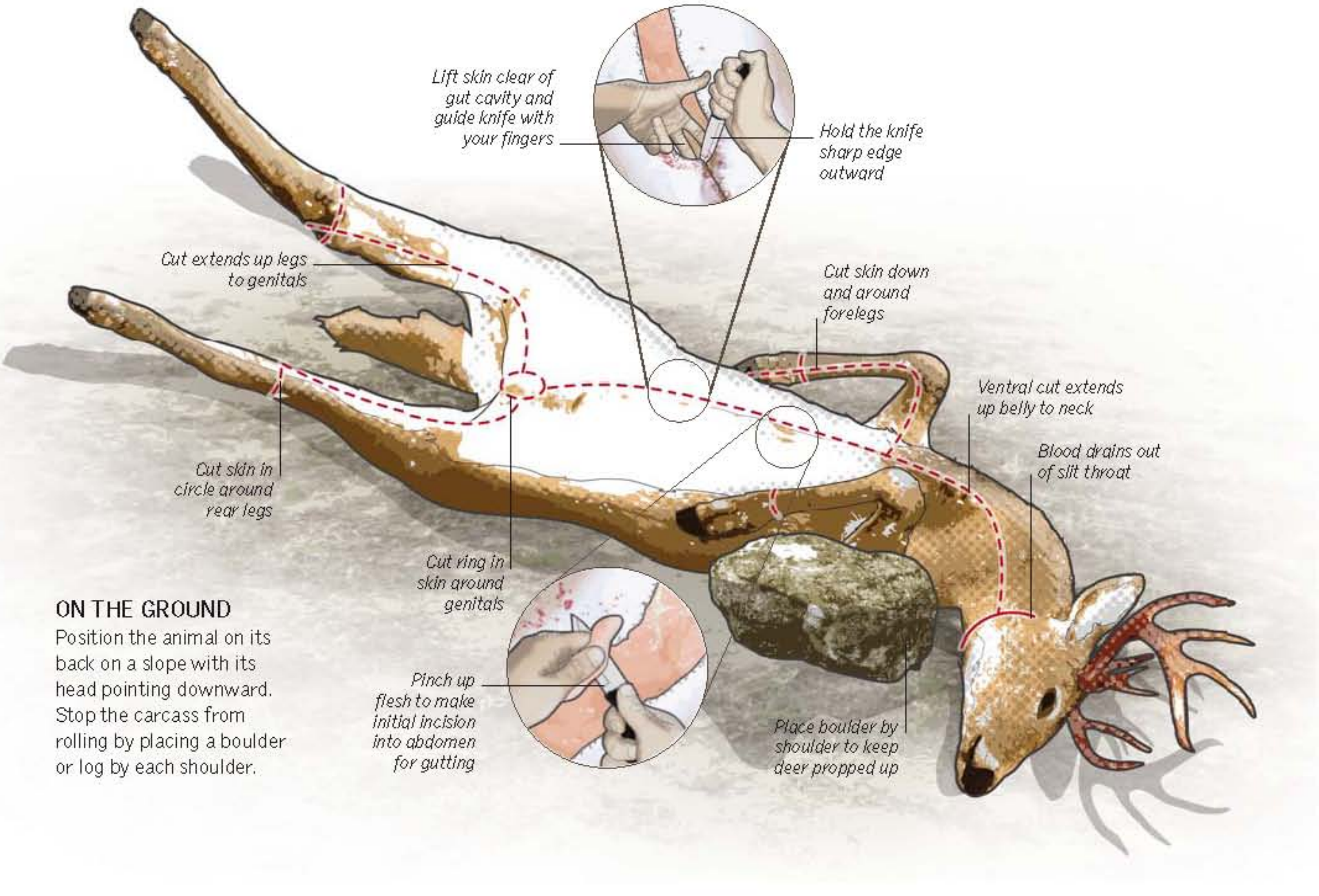
Lift skin clear of gut cavity and guide knife with your fingers
Hold the knife sharp edge outward
Cut extends up legs to genitals
Cut skin down and around forelegs
Ventral cut extends up belly to neck
Blood drains out of slit throat
Cut skin in circle around rear legs
Cut ring in skin around genitals
Pinch up flesh to make initial incision into abdomen for gutting
Place boulder by shoulder to keep deer propped up

ON THE GROUND

Position the animal on its back on a slope with its head pointing downward. Stop the carcass from rolling by placing a boulder or log by each shoulder.

GUTTING

The method shown here is for gutting a carcass on its back. When finished, inspect the heart, liver, and kidneys for signs of worms or other parasites and, if the organs are healthy, keep them to eat. If the liver is spotted, a sign of disease, discard all internal organs and boil the meat.

1 To avoid piercing the internal organs, pinch up the abdomen near the breastbone and make an incision big enough to insert two fingers.

- Use your fingers to guide the knife, cutting toward, then around, the anus with the sharp blade-edge upward.

2 Using a saw, if you have one, cut through the outer muscle and the breastbone to open up the chest cavity.

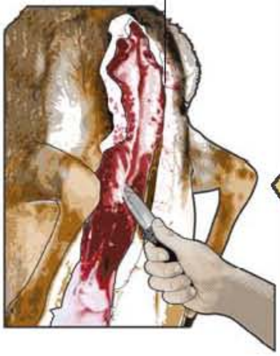
Slice through the muscle covering the breastbone

3 Using the knife, slice through the diaphragm muscle, which separates the chest cavity from the gut cavity, getting as close to the spine as you can.

- Remove the liver, taking care not to cut the gall bladder in the center.

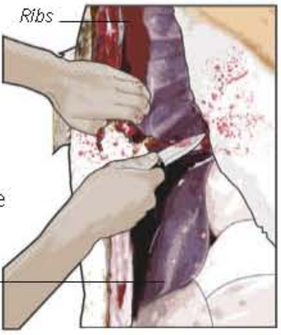
Ribs
Healthy liver is dark red-purple

4 Reach up through the chest cavity and cut the windpipe and esophagus. Hold them with one hand and pull out all the internal organs as one unit.

- Check that the anus is clear of feces, pushing a hand through if you can't see daylight.

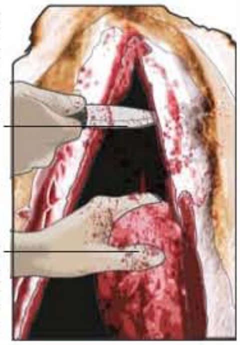
Use the knife to cut organs where they adhere to body wall
Hold the top end of lungs to remove innards

KEEP THE GUTS

If you're able to carry them, take the guts, reproductive organs, and glands back to your camp in a sealed container. You can use them as bait in traplines or for fishing. Keep the fat that surrounds the intestines for cooking.

JOINTING

Large game should be cut into manageable pieces that can be carried back to camp. Boning the meat helps to reduce the weight. Bag or wrap the meat as you remove it to keep it clean and free of flies, and keep it in the shade in hot climates. How a carcass is divided partly depends on the species, but the hindquarters contain the steaks and the best cuts.

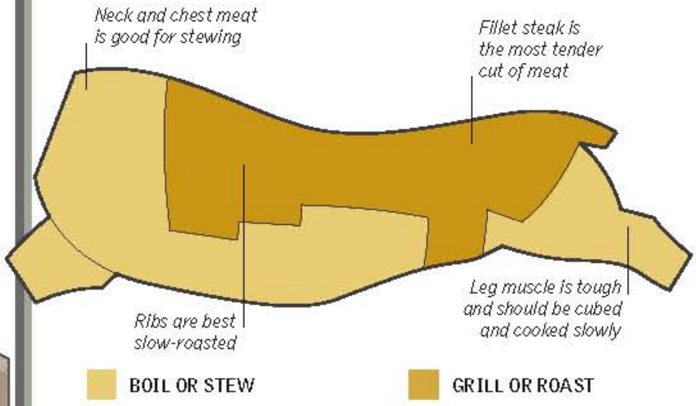
Neck and chest meat is good for stewing
Fillet steak is the most tender cut of meat
Ribs are best slow-roasted
Leg muscle is tough and should be cubed and cooked slowly
🟨 BOIL OR STEW
🟧 GRILL OR ROAST

USES FOR HIDES

Keep the skin if you can. When dried, it's light and can be used as a blanket, or it can be made into an item of clothing. Hide is one of the best materials for lashes. Sinew also makes good cordage (see p. 140).

TANNING THE HIDE

The best way to clean a skin is to stretch it on a frame and then carefully scrape off the fat and any remaining scraps of flesh, using a flint or a piece of bone. Every mammal, with the exception of buffalo, has enough brain matter for use in tanning its own hide. Mash the brains well in warm water, then apply the mixture to the hairless side of the skin and leave it to dry for 24 hours.

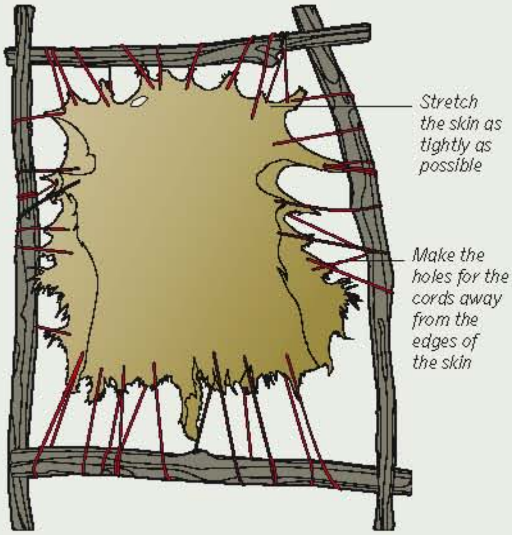
Stretch the skin as tightly as possible
Make the holes for the cords away from the edges of the skin

PREPARING OTHER ANIMALS

ALL TYPES OF ANIMAL should be considered when searching for your next meal. Invertebrates are far more plentiful and widespread than other animals, and take less energy to gather and prepare. Reptiles and amphibians can also provide a vital source of nutrition.

EATING FOR SURVIVAL

The thought of eating grubs or grasshoppers might not appeal, but experimentation is vital in a survival situation—don't forget that in some cultures such creatures are highly prized, if prepared properly. However, some animals are less palatable than others, in which case you should chop them finely and add to a stew.

SLUGS, SNAILS, AND WORMS

Slugs should be avoided as they often feed on poisonous fungi. To prepare snails, either starve them or feed them safe food such as wild garlic for 24 hours to purge their guts before cooking. Either boil them in water or bake them in their shells in hot embers until the juices bubble over. Avoid all marine snails and any terrestrial snail with a brightly colored shell as they may be toxic. All earthworms are edible. Place them in salty water until they are purged, then boil, though they can be eaten raw if necessary.

EDIBLE INSECTS

Insects are mostly protein and make good emergency food. Avoid any hairy or brightly colored insects or those that emit a foul smell (including larvae). As a general rule, avoid adults that sting or bite, but ants and honey bees can be eaten if collected carefully. Most insects, except those with a hard carapace, like beetles, can be eaten raw.

HOPPING INSECTS

Grasshoppers and crickets have large leg muscles, and most are quite tasty when cooked (avoid brightly colored ones). Remove the antennas, wings, and leg spurs, and roast to kill any parasites.

WITCHETTY GRUBS

Witchetty grubs are a highly nutritious Australian bush delicacy. They can be eaten raw but, if roasted quickly in hot ashes, they taste of scrambled eggs. Treat palm grubs in the same way.

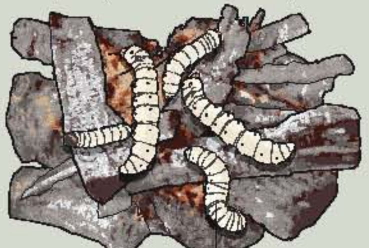

Large, white grubs high in protein and calcium

AMPHIBIANS AND REPTILES

All frogs in the *Rana* genus (see pp. 292–93) are edible. Skin and then boil or roast them. The best, most meaty part is the hind legs. Don't handle or eat toads or brightly colored tropical frogs as many have highly toxic skin secretions. Lizards and snakes are a good source of protein. They must be skinned and gutted, then either roasted on a stick if small, or cut into small pieces and boiled. All snake flesh is edible—and tastes like chicken—apart from the head, which must be removed.

1 Hold the dead snake firmly behind the head and cut it off about 6 in (15 cm) down the body.

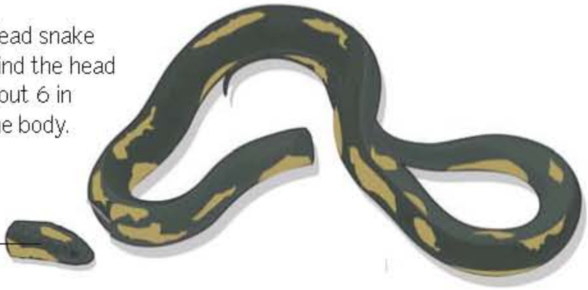

Bury the head if the snake is venomous

2 Slit the belly with a sharp knife and remove the entrails and other organs. Either throw them away or keep as bait.

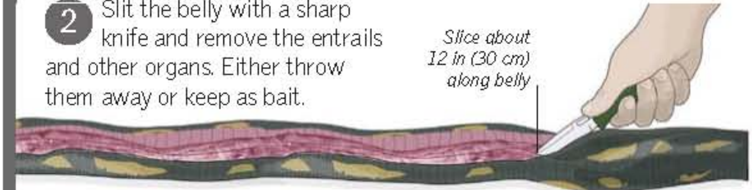

Slice about 12 in (30 cm) along belly

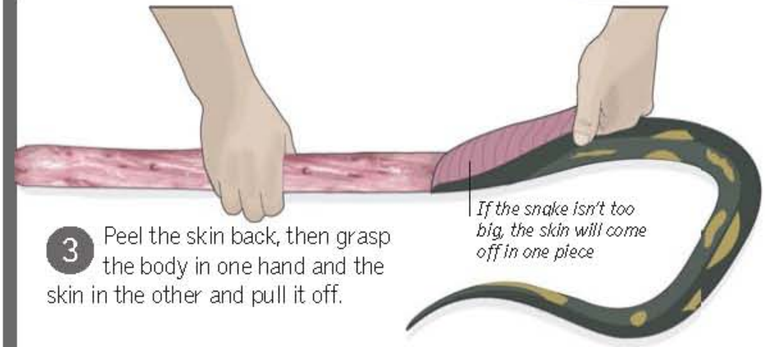

If the snake isn't too big, the skin will come off in one piece

3 Peel the skin back, then grasp the body in one hand and the skin in the other and pull it off.

PREPARING A CRAB

Avoid their strong claws (tie them up if you can). To kill a crab, plunge it in boiling water or stab it through the eye socket or the orifice under the shell flap on the body. Cook the crab for about 15 minutes.

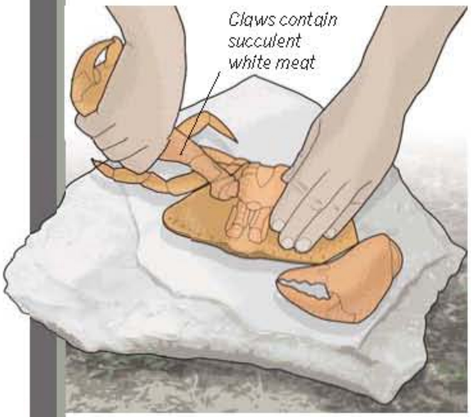
Claws contain
succulent
white meat

① Place the cooked crab on its back, then twist off its legs and the claws. They all contain edible meat, so crack them open with a rock.

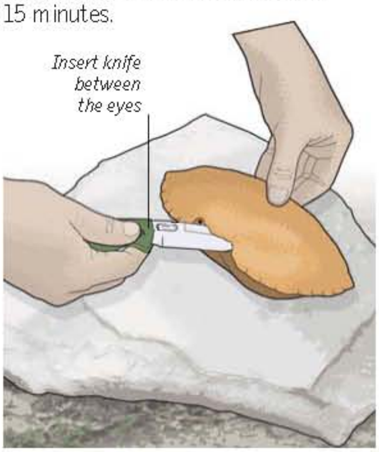
Insert knife
between
the eyes

② Open the shell by inserting the point of your knife between the two halves and twisting it. Lift back the lower shell.

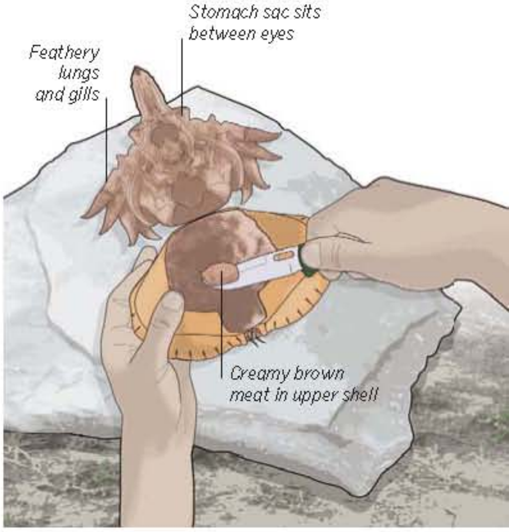
Stomach sac sits
between eyes
Feathery
lungs
and gills
Creamy brown
meat in upper shell

③ Remove and discard any green matter and the lungs, gills, and stomach as they're all poisonous. Scoop the meat out of the shell.

SHELLFISH

Shellfish can be found in streams and on lake and sea shores. Don't collect marine shellfish that are not covered at high tide or are near any source of pollution. Shellfish must be alive when you collect them—bivalves, such as mussels, will close their shell if you tap them, and univalves, such as limpets, will cling tightly to their rock—and you must cook and eat them immediately.

HOW TO SHUCK AN OYSTER

Oysters are rich in vitamins and minerals. To eat an oyster raw, first open its shell by inserting a blunt knife into the hinge at the thicker, more pointed end of the oyster and twisting. However, in a survival situation, play safe and boil oysters in their shells for five minutes after their shells open. Do not eat any whose shells do not open during cooking.

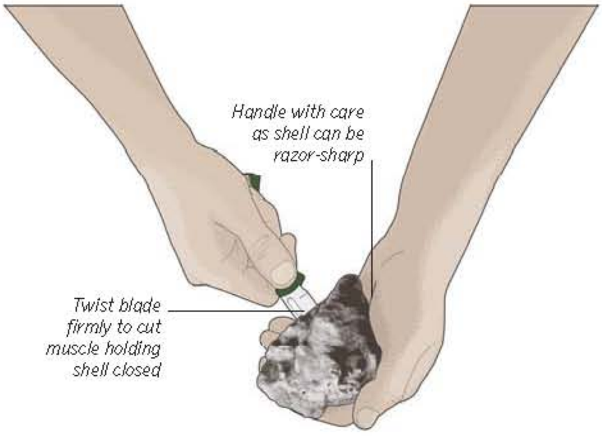
Handle with care
as shell can be
razor-sharp
Twist blade
firmly to cut
muscle holding
shell closed

WARNING!

Tropical species of mussel should be avoided in the summer as they may be poisonous. The black mussel, which is found on Arctic and sub-Arctic coasts, may be poisonous at any time of the year. The symptoms of mussel poisoning are acute nausea, vomiting, diarrhea, abdominal pain, and fever.

SHRIMPS, CRABS, AND LOBSTERS

Small crustaceans, such as shrimps and crawfish, should be cooked in boiling water for five minutes. Larger crustaceans, such as some crabs and lobsters, should be boiled for up to 20 minutes. A tasty alternative to boiling shrimps or prawns is to roast them on skewers made of green wood, placed in the embers of a fire.

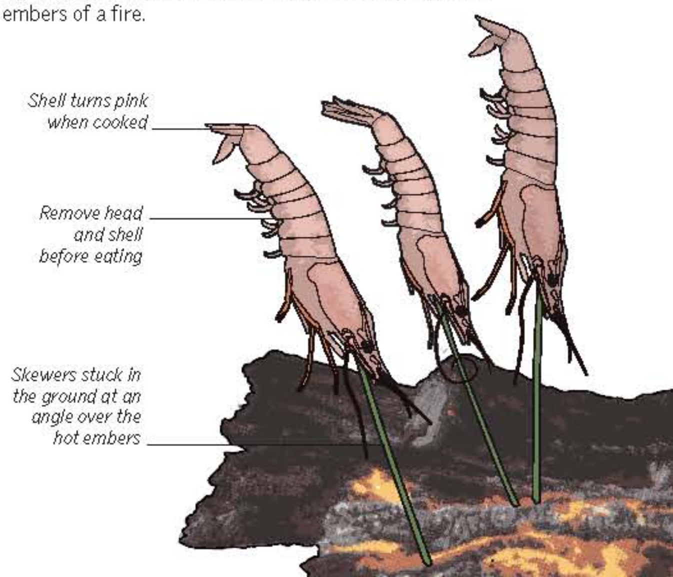
Shell turns pink
when cooked
Remove head
and shell
before eating
Skewers stuck in
the ground at an
angle over the
hot embers

CATCHING BIRDS

BIRDS CAN BE TRAPPED in a variety of ways—in snares, nets, tunnels, or cages—and they can be hunted with noose sticks or any projectile weapon. The trick is to observe their behavior and to match your technique—and bait—to the bird. You need to discover their regular roosts, feeding spots, and flight paths.

WARNING!
Eggs are easy to collect, particularly from ground-nesters, although gulls, for example, will attack you if you try. However, taking eggs from nests is illegal in many countries and should only be done if absolutely necessary.

FIGURE-4 CAGE TRAP

This trap enables you to catch ground-feeding birds (or rabbit-sized mammals) without killing or wounding them, so you can choose when you want to kill them and eat the meat fresh. The "Figure 4" is the trigger that's used to drop the cage over the animal.

MAKING THE TRIGGER

To construct the Figure 4 trigger you need to make three notched sticks (bait stick, upright stick, and release stick) and then link them together as shown below.

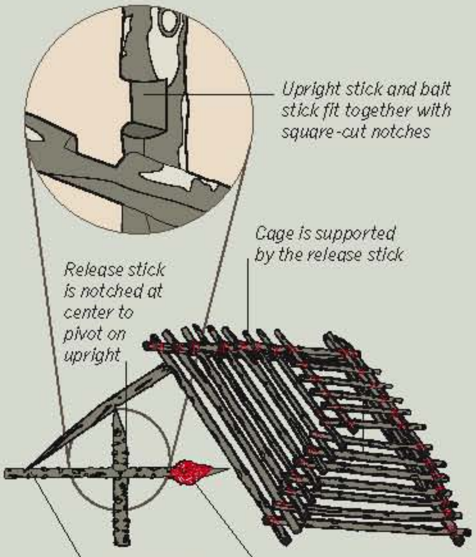
Upright stick and bait stick fit together with square-cut notches
Cage is supported by the release stick
Release stick is notched at center to pivot on upright
Notch at end of bait stick holds pointed end of release stick
Bird will peck at bait, setting off the trigger

MAKING THE CAGE

Create a pyramid of sticks by placing progressively shorter sticks across longer sticks and lashing them together at the ends. Balance the cage over the bait.

ON THE GROUND

Gamebirds, such as quail, and inquisitive scavengers, such as crows, can be lured into traps if you use the right bait. Migratory waterfowl, such as ducks and geese, molt in the late summer, which means they are easier to catch as they can't fly away.

WALK-IN TUNNEL TRAP

A tunnel trap can be used to catch gamebirds, which have stiff feathers that lie in one direction and bend only with difficulty. As a bird tries to retreat from the trap, its feathers will become wedged in the tunnel walls.

- Dig a near-horizontal, funnel-shaped tunnel close to the ground.
- Lay a trail of bait (seed or berries) leading to the rear of the tunnel.
- As it eats the bait, the bird will move deeper into the tunnel and will be unable to back out.

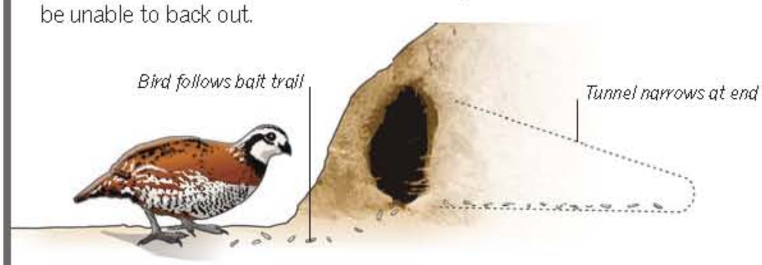
Bird follows bait trail
Tunnel narrows at end

ON THE WING

A fine net stretched between two trees across a flight path is an effective method of catching birds in flight. Throwing a bola requires more skill, and works by entangling the bird in the spinning ropes.

MAKING A BOLA

To make a bola, use an overhand knot (see p. 143) to tie three 3-ft (1-m) lengths of cord together about 3 in (8 cm) from one end. Find three rocks weighing about 7 oz (200 g), wrap each one in a piece of cloth, and tie it up with the free end of a cord.

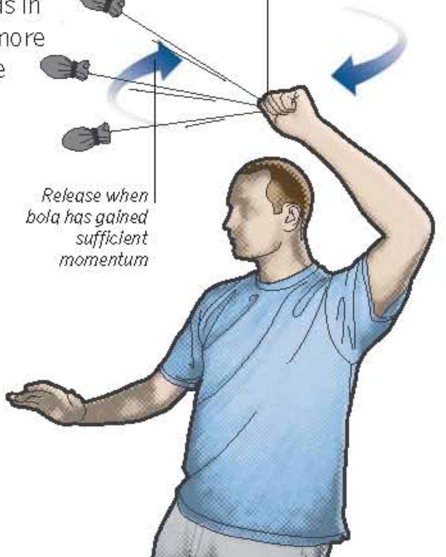
Hold bola by the knot and twirl it around your head, aiming at prey
Release when bola has gained sufficient momentum

ON THE NEST

Birds are creatures of habit and will usually roost in the same place every night, such as in the branches of a tree as protection against ground predators. They rarely move once it's dark. Many birds are more accessible when breeding as, once you've located the nest, you'll always know where to find them. However, you should only take nesting birds in a genuine survival situation.

MAKING A SNARE STICK

A snare stick is used to trap birds roosting in trees. Remove a bird once it has been snared, as its squawking and fluttering will alert other birds to the danger and scare them off.

- Make several single-strand snares (see pp. 216–27) with a loop diameter of about 1–2 in (2.5–5 cm), depending on the size of the bird.
- Place them close together along a stick, making notches in the stick to hold them in position with the loops uppermost.
- Tie the stick on top of a branch where you have seen birds roosting.

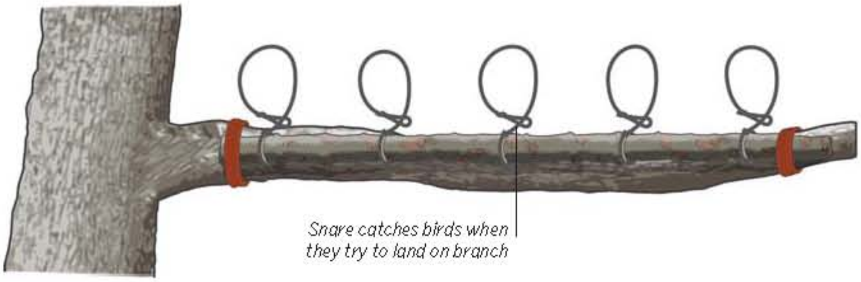
Snare catches birds when they try to land on branch

PHEASANT POLE

Pheasants roost in trees at night, usually returning to the same branch, and they won't leave once it's dark. To snare a sleeping pheasant, raise the pole up in front of it. The bird will wake and peck at the foil. As its head goes through the loop, pull the cordage and the snare will close around the bird's neck.

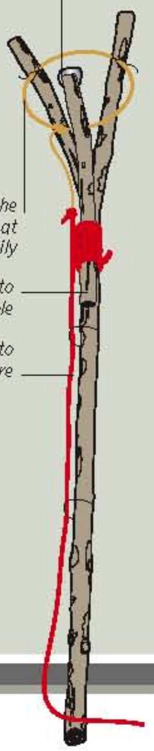
Silver foil or shiny paper
Lash the snare loop to the fork with something that will break easily
Lash foil stick to long forked pole
Attach cordage to snare wire

TO MAKE THE POLE

Cut a long forked pole. Tie a stick in the V of the fork and attach a piece of silver foil to it. Weakly lash the loop of a snare to the fork, then run a length of cordage down the pole from the snare wire.

BOUGH FENCE TRAP

This method is used to trap ducks, which often go ashore during the day to sun themselves, or at night to roost. They tend to favor small islands as protection against predators.

- Cut several saplings and make double-stranded snares (see p. 216).
- Place the boughs a few feet from the water's edge, and bend them into a series of overlapping hoops to form a fence around the island.
- **If you only have a few snares, place them over the ducks' inward and outward tracks. Placing logs between the snares will then force the birds to pass through the hoops in order to get onto the island.**
- **Suspend a snare from the center of each bough arch.**

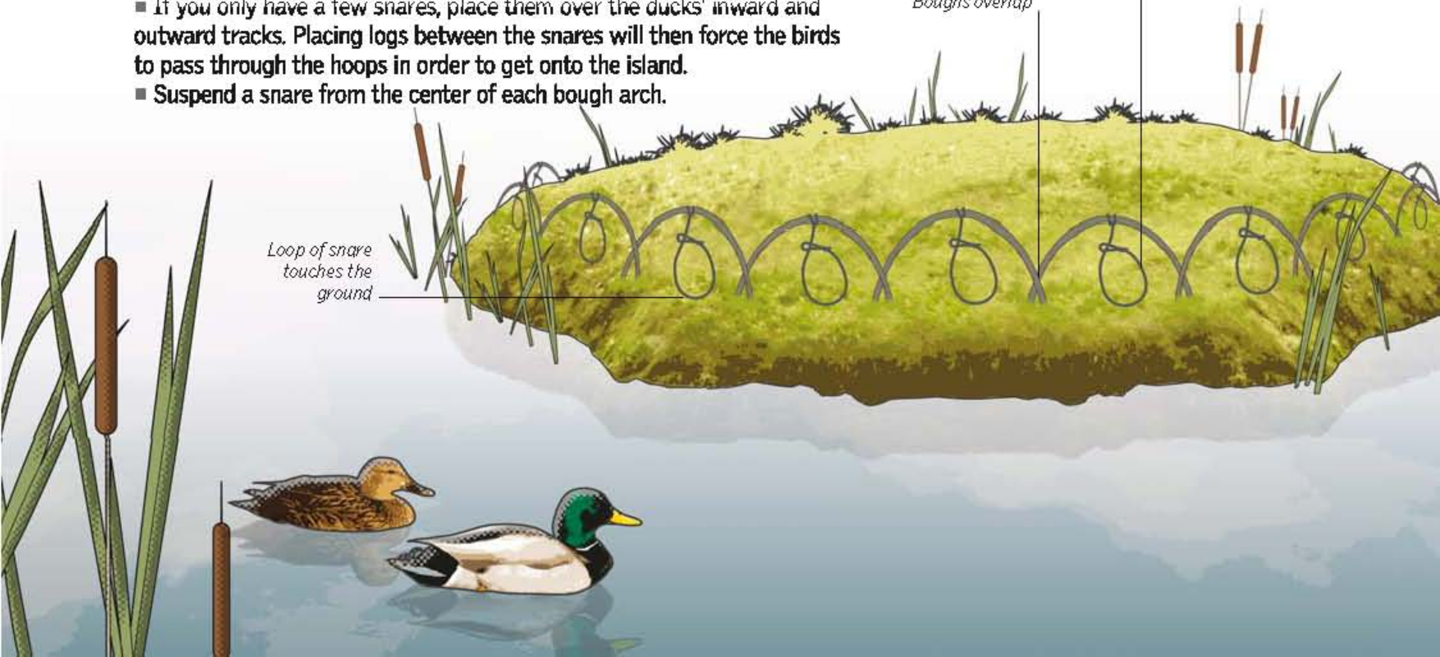
Loop diameter is approximately 2 in (5 cm)
Boughs overlap
Loop of snare touches the ground

PREPARING BIRDS

GAMEBIRDS AND WATERFOWL are the most commonly eaten wild birds, but all birds are edible if prepared correctly. Skinning a bird is the quickest way to get at the meat, but this removes the nutritional value of the skin, so always pluck a bird if you have the time to do so.

WARNING!
Handle scavengers and carrion eaters, such as crows, buzzards, and vultures, as little as possible, because they are more likely to be infested with lice and ticks, and are prone to infection.

- The meat of such birds must be boiled for at least 30 minutes to kill any infectious organisms. This will also tenderize the meat.
- Always wash your hands after handling any bird.

GETTING STARTED

If the bird hasn't already been killed by the method of capture you'll need to dispatch it—for example, by stretching its neck and cutting its throat (for the best way to kill gamebirds, see below). Whichever method you use to kill the bird, you must bleed it before plucking, but make sure you pluck it while the body is still warm.

KILLING GAMEBIRDS

To quickly and humanely dispatch a gamebird, such as a pheasant, fold its wings into the body and hold it under your arm. Cover its head with your jacket to calm it down (this also reduces the chances of you being injured by its claws or beak). Still holding the bird firmly, take a 2 ft (60 cm) long, thick stick and place it on the ground. Put the bird's head underneath the stick, place your feet on the stick either side of the head, and pull the bird up sharply by the legs—the bird's head will come off.

POACHER'S METHOD
The poacher's way to quickly get the meat from a dead pheasant that hasn't been decapitated is to place it face down on the ground with its head toward you, put a foot on each wing, take hold of the legs, and pull up sharply. This motion will tear the legs and breast meat away from the rest of the bird. Give it a sharp flick to detach the guts. In a survival situation, this is a good way to get meat off the bird if you don't have a knife or razor.

PLUCKING A BIRD

It's not essential, but scalding a bird in a bucket of hot (not boiling) water for a couple of minutes usually helps to loosen the feathers; the exceptions are waterfowl and seabirds—their feathers will tighten instead. Be careful not to overscald the bird or the skin will start to cook.

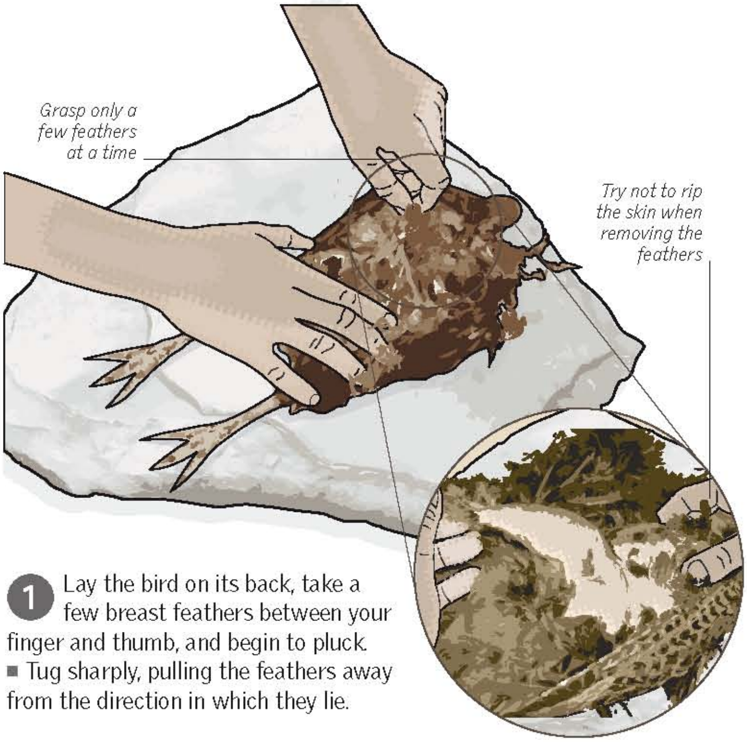
Grasp only a few feathers at a time
Try not to rip the skin when removing the feathers

1. Lay the bird on its back, take a few breast feathers between your finger and thumb, and begin to pluck.
   - Tug sharply, pulling the feathers away from the direction in which they lie.

2. Don't try to pluck too many feathers at once or you'll tear the skin. Work your way steadily around the front and back until you've plucked the whole body.
   - Keep the feathers (unless the bird is a scavenger, see box, above) to use for tinder, insulation, or fishing lures.

OPTIONAL EXTRAS

Keep the crop (esophagus) contents of a gamebird—you can use the seeds and berries as bait to catch other birds. If the bird is female and has eggs in the oviduct, keep them and eat them. You should also eat the heart and the liver if they are in good condition; discard them if they look old or spotty, or show signs of parasites.

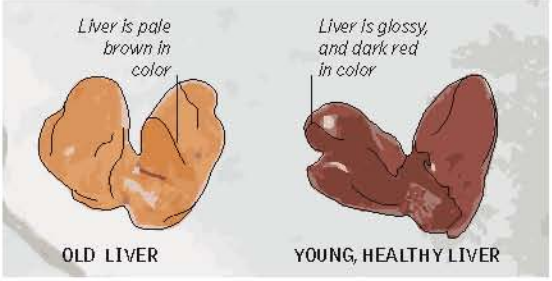
Liver is pale brown in color
Liver is glossy, and dark red in color
OLD LIVER
YOUNG, HEALTHY LIVER

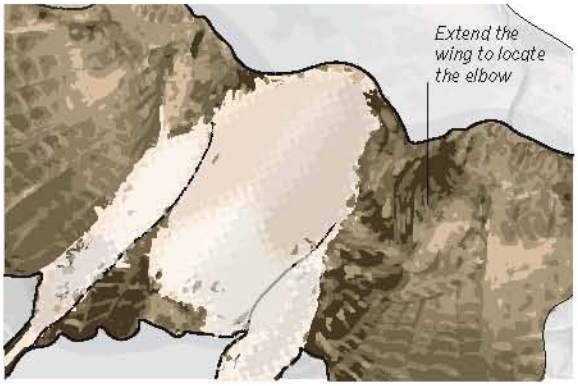
Extend the wing to locate the elbow

3 Pluck the legs in the same way, then turn to the wings. Locate the elbows and cut off the lower wings at this joint. Pluck the upper wings.

- If the bird's head is still attached, cut it off as close as possible to the body.

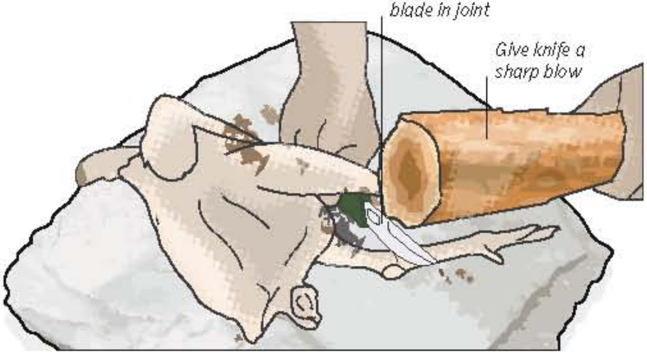
Place knife blade in joint

Give knife a sharp blow

4 To remove the feet, find the ankle, insert the blade of a sharp knife into the joint, and press down hard.

- If you're dealing with a large bird, such as a turkey, hit the back of the knife with a thick stick for extra force.

DRAWING METHODS

The usual way to remove the offal from a bird (known as "drawing") is to take the crop (esophagus) out of the neck end and the rest of the offal out of the rear end. The survival method is to make a cut from the throat to the tail with a sharp knife, reach in, and pull out all the offal (see below). Should you find yourself without a knife, you can still butcher a bird by pulling the skin apart with your fingers and working your way up the breast to the neck. The offal can be removed by ripping open the skin over the belly.

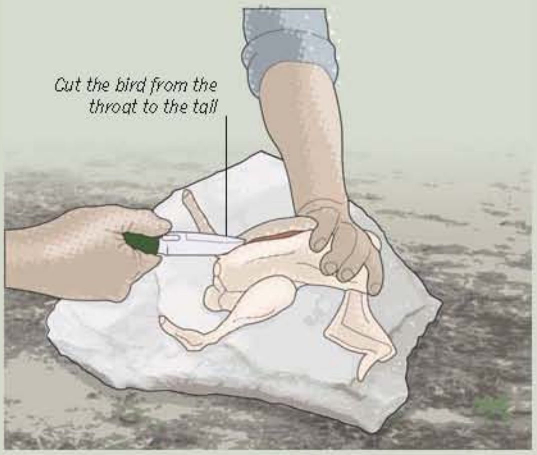
Cut the bird from the throat to the tail

1 Hold the bird in one hand, breast upward and with its rear end toward you. Insert the point of a sharp knife into the throat.

- Make a single incision down toward the tail, being careful to not pierce the guts.

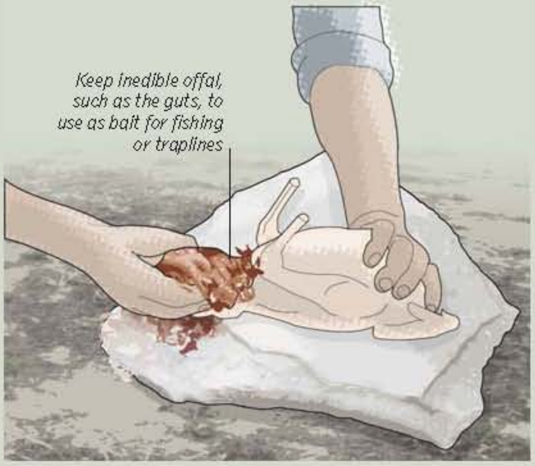
Keep inedible offal, such as the guts, to use as bait for fishing or traplines

2 Reach into the gut cavity and pull out the offal, taking care not to break any eggs. Keep the liver and heart if healthy (see above left).

- Wash the bird clean with cold water and wash your hands thoroughly before further handling.

6

IN AN EMERGENCY

IN AN EMERGENCY

You're only a survivor when you have been rescued. This means that you must be able to either get yourself out of the predicament you are in (self-rescue) or be rescued from that situation by others. Sometimes you will be able to choose whether to undertake self-rescue; at other times the decision will be out of your hands. There may be several reasons why you cannot achieve self-rescue: you could be utterly lost; local conditions such as flooding or bad weather could trap you; or injury to yourself or a group member could make movement impossible. In this situation, the onus is on you to attract attention. You must be able to make contact with rescuers, using location aids you have with you or those you can improvise. Never delay any form of rescue because of the embarrassment factor—the only important factor is the outcome, and I would always rather be embarrassed and alive than eventually found dead!

Preparation is key—informing people of your intentions and timeframes will at least have someone wondering why you are not back yet. Equally, taking the best

In this chapter YOU WILL DISCOVER...

- how to **recognize** the **enemies** of **survival**...
- why **LEOs** are so **important**...
- when to **set fire** to a **log cabin**...
- that **tinsel** isn't just for **Christmas**...
- what to **do** if a **hippo yawns**...
- that you **should go** with the **flow** in an **avalanche**...
- how to **inflate** your **pants**...

location aids for your environment and knowing how best to use them will increase the chances of you being found.

In many survival situations, a major decision will be whether you remain where you are or move to a location that offers a better chance of survival, rescue, or both. There are numerous factors that will dictate your best option but, in general, it's always best to stay where you are. It's all too easy to make a rash decision and attempt to walk out of a situation only to put yourself in even greater danger.

A location aid can make the difference between life and death. A comparatively recent invention is the multi-tasking Skystreme device.

SKYSTREME is a silver, inflatable foil kite, which weighs just 1½ oz (43 g) and packs down to a small and convenient size. It can perform four tasks in a survival situation:

Location aid The kite is orally inflated and its wedge shape means it can lift off from the ground unaided in 4 mph (6 kph) winds.

- The 165 ft (50 m) of line attached to the kite (this much cordage is invaluable in itself) allows it to rise above tree levels and reflect sunlight. It can be seen by the naked eye at a distance of 2 miles (3 km).
- At night, you can hang a small flashlight or lightstick underneath the kite to aid visibility.
- The metallic surface reflects radar and can be detected by aircraft at a distance of 10 miles (17 km). A UK Royal Marine on a polar crossing flew his Skystreme behind his sled so that support aircraft could find and track him.

Emergency first aid splint The kite can be inflated around a broken or sprained limb.

Thermal vest The kite can be inflated and put inside clothing to act as a body warmer.

Water storage Instead of being inflated with air, the kite can be used to carry and store water.

> "You are not a **survivor** until you have **been rescued**"

ASSESSING YOUR SITUATION

ONCE YOU'RE OUT of immediate danger, assess your situation and plan accordingly. At this initial stage, it's crucial to think clearly—the decisions you make now could mean the difference between life and death. In most cases, remaining where you are is the preferred option, but no two situations are ever the same: the circumstances, environment, conditions, and you—the individual—all have a major impact on what can and cannot be achieved.

THE STRATEGY FOR STAYING ALIVE

In an emergency situation, think of the four priorities of survival: protection, location, water, and food. Your situation will determine which is the most important. In most cases, as long as you're in no further danger from injury or the elements, you should focus your efforts on establishing a safe location and getting yourself rescued. The strategy for staying alive, known by the acronym SURVIVAL (see below), gives you a framework to use and helps you remember what you need to do to remain alive and get rescued.

THE RULE OF THREES

A common understanding among those concerned with survival is that various key time limits have a numerical value linked to the number three. Remembering the "rule of threes" can help you focus your decision-making, particularly if you are injured, at risk of further injury, or in immediate danger from the elements. In most cases:

- **Three seconds** is the psychological reaction time for making a decision.
- **Three minutes** is the length of time your brain can do without oxygen before it suffers irreparable damage.
- **Three hours** is the critical time you can survive unprotected in extreme climates.
- **Three days** is the approximate length of time you can live without water.
- **Three weeks** is the approximate length of time you can live without food.

SIZE UP YOUR SITUATION	USE ALL YOUR SENSES	REMEMBER WHERE YOU ARE	VANQUISH FEAR
▪ First, assess the particulars of your surroundings, physical condition, and equipment. ▪ If you're in a group, you can share tasks and responsibilities, but remember that everyone will be affected by the consequences of your decisions.	▪ Most people react to a true survival situation through either training (they automatically do what they've been trained to do in a particular situation) or by instinct (they automatically do what their mind and body tell them to do).	▪ In any survival situation, it always helps to know where you are so that you can make the best decisions about what to do and where to go next.	▪ Fear and panic can be formidable enemies, so it's imperative that you have the knowledge and training to counteract them and prevent them from making your situation worse.
▪ Your surroundings: every environment has its own idiosyncrasies—hot and dry, hot and wet, cold, exposed, or enclosed. Determine what you need to do in order to adapt to that environment. ▪ Your equipment: assess your equipment and consider how it can best be used in your particular situation. ▪ Your physical condition: remove yourself and others from danger. Check for injuries and administer first aid as necessary. Remember that the trauma and stress of a survival situation may cause you to overlook, or subconsciously ignore, injuries that you yourself may have received.	▪ Whatever has happened, approach your predicament in a calm and rational manner. The situation requires careful thought and planning. ▪ If you act in haste, you may overlook important factors, lose vital equipment, or simply make matters worse. The saying "Undue haste makes waste" is especially true in a survival situation. ▪ Listen to your subconscious survival senses and gut feelings, and learn to act on them when they send you warning signals.	▪ Knowing your precise location can clarify whether rescuers are likely to find you or if you'll have to rescue yourself. You'll get a good idea of the obstacles you may face, whether you should remain where you are, and where best to position your aids to location. ▪ If you have made an Emergency Plan of Action (see pp. 24–25), someone will know your approximate location, and when you're due back. ▪ Channel your efforts into making sure that when rescuers are looking for you, your aids to location are in place.	▪ If uncontrolled, fear and panic can destroy your ability to make intelligent and rational decisions. They can cause you to react to your feelings and imagination rather than to your actual situation and your abilities. Moreover, they can incapacitate you and drain your energy, thus triggering other negative emotions. ▪ If you're in a group, your responses can have a direct effect on others—positive responses are productive and can motivate, while negative responses can undermine confidence and morale.

THE ENEMIES OF SURVIVAL

In a survival situation, there are seven factors, known as "the enemies of survival," that can work against you. In many cases, you can deal with them by knowing what they are and understanding their effects. One way to memorize these is by using a mnemonic such as: "**B**e **P**repared **T**o **F**ace **T**hese **H**ostile **F**actors".

BOREDOM AND LONELINESS

When boredom sets in, you become inactive and lose the ability to deal with your situation effectively, so you need to keep busy. Loneliness makes you overwhelmed by what you need to achieve, leading to a feeling of helplessness.

PAIN

If you're injured, don't ignore the pain. Attend to a minor injury, as it could grow into a major problem that could impair your ability to survive. A positive mental attitude coupled with keeping busy helps to distract the mind from pain.

THIRST

Thirst is not a good indicator of the body's need for water. Your body can be dehydrated before you feel thirsty. Stay ahead of dehydration, rather than have to deal with it. Prioritize your need for water in a way that's relevant to your environment.

FATIGUE

Tiredness leads to mistakes that, at best, cause frustration and, at worst, may result in injury or death. In a survival situation, it's unlikely that you'll replace the energy you use effectively, so everything becomes harder to achieve. Never underestimate the importance of quality rest to your physical and mental wellbeing.

TEMPERATURE

Temperature is a major factor in any survival situation and it will be affected by wind, rain, and humidity. You should dress to suit the environment you're in and be aware of the signs and symptoms of temperature-related injuries, such as dehydration, hypothermia, heat stress, and heat stroke (see pp. 272–73).

HUNGER

In a short-term survival situation (one to five days), procuring food is not a high priority. You can offset your reduced energy and stamina levels by drinking water and pacing yourself so you work within your limits. However, take every opportunity to procure food without expending energy.

FEAR

Fear is one of our body's greatest survival tools, as it can stimulate you, so that you're ready to act—however, it can also debilitate. Fear is good as long as you have control over it, and the key to controlling fear in a survival situation is knowledge.

	IMPROVISE	VALUE LIVING AND LIFE	ACT LIKE THE LOCALS	LEARN BASIC SKILLS
	▪ The true skill of a survivor is to understand what's required and improvise solutions to particular problems. Do you have the skills and knowledge to keep yourself alive and in a condition to be proactive in your own rescue?	▪ Some people without training and equipment have survived the most horrendous situations. In many cases, this was simply because they had the will to live and refused to give up!	▪ Whatever environment you're trying to survive in, you can be sure that the local or indigenous people and the local wildlife have developed ways of adapting to it in order to survive.	▪ Learning basic skills increases your chances of survival. Without training your prospects of survival are down to luck, which is never the best place to start. There is a saying: "Luck favors those who are best prepared."
	▪ You may start out with all the right equipment, but it may get lost or broken, or simply wear out. Your ability to improvise may mean the difference between your continued struggle to survive in relative comfort, or absolute misery. ▪ Think laterally, like the climber who was stranded on the side of a mountain with no aids to location. He used the flash on his camera to signal his location to a rescue helicopter. Improvise and overcome!	▪ The stories of prisoners of war often reveal what kept them alive: religious beliefs, thoughts of family and friends, or a determination not to let the enemy win. While these alone may not always be enough, they're certainly a key factor in any survival situation. ▪ It helps to bear in mind that hardship means different things to different people and in different cultures. ▪ Survival is about dealing with hardships and having the will to live. If the will to live is not there, then just having the knowledge and equipment may not be enough.	▪ Look at how the local people dress and act: in hot countries they leave manual work until the coolest parts of the day and work in a slow and deliberate manner to reduce sweating and therefore conserve water. ▪ If you're in a desert, for example, watch where animals go to find shade: they're mostly nocturnal and spend the day underground. Learn their tricks to find water, like the darkling beetle in the Namib Desert that drinks water from the fog that condenses on its carapace. ▪ If you're in a jungle, pay attention when the animals go quiet or quickly leave an area—danger is usually around the corner.	▪ Prior preparation is the key to survival: discover what you need to know about the environment you're going to; familiarize yourself with all your equipment; and practice your basic skills until they become second nature. This thorough preparation will help you to combat the fear of the unknown and give you the self-confidence to meet the challenges of any survival situation you may be in.

ATTRACTING RESCUERS

TO BE A SURVIVOR you need to rescue yourself or be rescued by others. If you can't rescue yourself—perhaps you're injured, completely lost, or trapped by bad weather—you must attract attention with location aids that you've either brought with you or have improvised.

AIDS TO LOCATION

Location aids can save your life, so make sure you know how to use them effectively. A helicopter on a search pattern may make only one pass over an area before moving on, so you'll only have a few minutes to act decisively.

COMMUNICATING WITH SATELLITES

When activated, a Personal Locator Beacon (PLB) transmits a radio distress signal to two complementary satellite systems called LEOSAR and GEOSAR. Together, these form the "COSPAS-SARSAT" system. The signal is then relayed to a rescue coordination center closest to the beacon's location. PLBs mainly use 406Mhz; the military also use 243.5Mhz and 282.8Mhz.

ATTRACTING ATTENTION

When you're in a survival situation, you need to employ your location aids in the best way possible. There are three main principles for attracting attention:

- **Attract:** pick a place that maximizes your chances of attracting attention using your location aids, such as open or high ground. Place your aids carefully so they can be detected from as wide an area as possible. The more obvious the signal the better.
- **Hold:** you need to hold the attention of rescuers by maintaining the signal until they indicate they've seen you. Try to send some critical information (the type of assistance you require or the number of survivors and their condition, for example) via a May Day, or Help message (see pp. 237–41).
- **Direct:** regardless of which location aids you use, once rescuers have been alerted, do all you can to direct them to your present location. If you have voice communication, direct them to your position. If you leave notes before moving on from places, make sure they contain dates and precise details of your intentions.

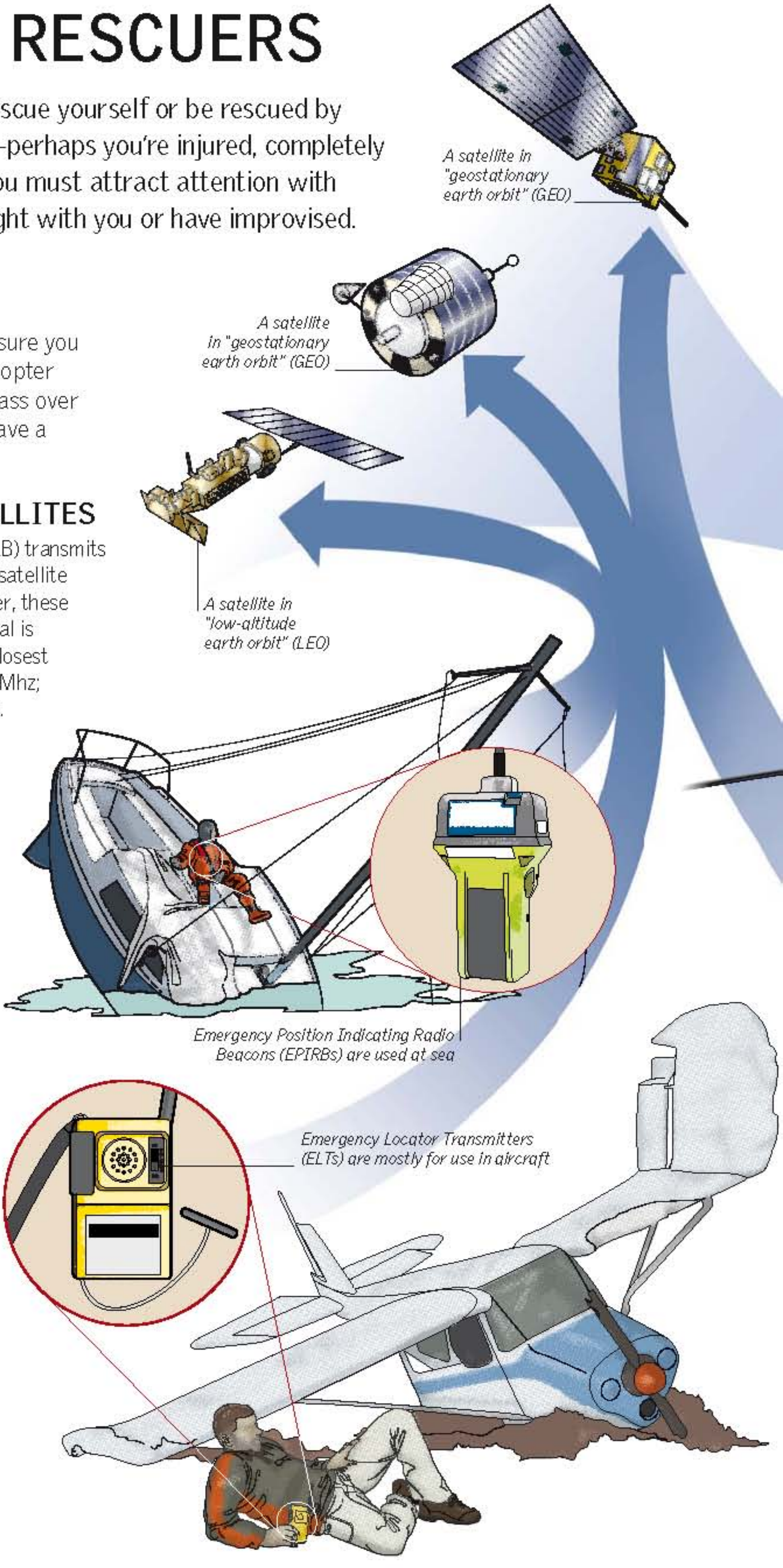
A satellite in "geostationary earth orbit" (GEO)
A satellite in "geostationary earth orbit" (GEO)
A satellite in "low-altitude earth orbit" (LEO)
Emergency Position Indicating Radio Beacons (EPIRBs) are used at sea
Emergency Locator Transmitters (ELTs) are mostly for use in aircraft

SHOULD I STAY OR SHOULD I GO?

You need to decide whether to stay where you are or to move to a location where you have a better chance of rescue or self-rescue. If you move on, remember the following:

- Keep your aids to location at hand. It's no good having your signal mirror at the bottom of your backpack when you may have only seconds to attract a passing vehicle or plane.
- Deploy your aids to location at the end of each day, even though it takes effort and you'll be moving in the morning.
- To show where you've been and where you're heading, leave markers, such as a note left in a visible position and visual clues on the ground or vegetation, to indicate your direction of travel.

MOBILE PHONES AND RADIOS

Always take a cell or satellite phone with you when traveling—they are essential in an emergency. On a sea trip, take a marine VHF radio to contact would-be rescuers.

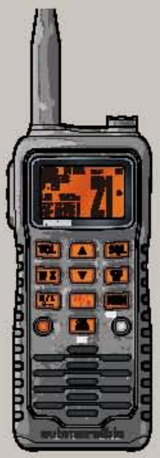

CELL AND SATELLITE PHONES

Wherever you are in the world, you can rent or buy a cell phone linked to local networks. Choose one with a GPS unit for fixing and racking your position and a camera so you can send pictures of your location and any injuries you've sustained. Alternatively, rent or buy a satellite phone that's connected to the Iridium Satellite Phone System, in which 66 low-earth orbiting (LEO) satellites provide complete coverage of Earth (including oceans, airways, and polar regions).

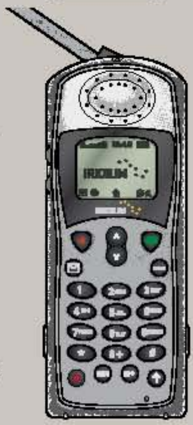

MARINE VHF RADIOS

All large ships and most motorized small craft are equipped with marine VHF radios. These hand-held units transmit and receive on frequencies between 156 to 174MHz—usually on Channel 16, the international calling and distress channel. Channel 9 can also be used in some places. Transmission power ranges between 1 and 25 watts, giving a maximum range of up to about 60 miles (110 km) between aerials mounted on tall ships and hills, and 5 miles (9 km) between aerials mounted on small boats at sea level. Your VHF radio should be waterproof, able to float, and kept on charge. Follow the instructions whenever transmitting and receiving on VHF.

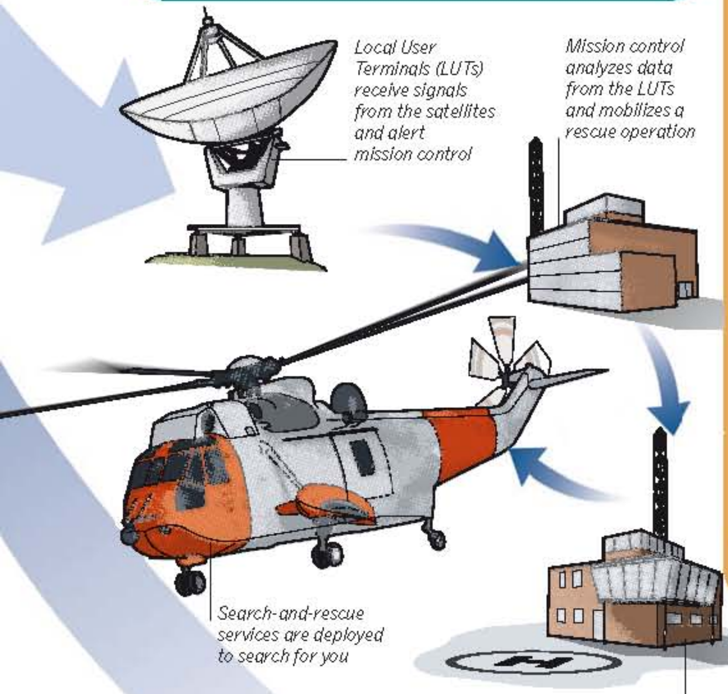
Local User Terminals (LUTs) receive signals from the satellites and alert mission control
Mission control analyzes data from the LUTs and mobilizes a rescue operation
Search-and-rescue services are deployed to search for you
A regional rescue coordination center alerts the search-and-rescue teams

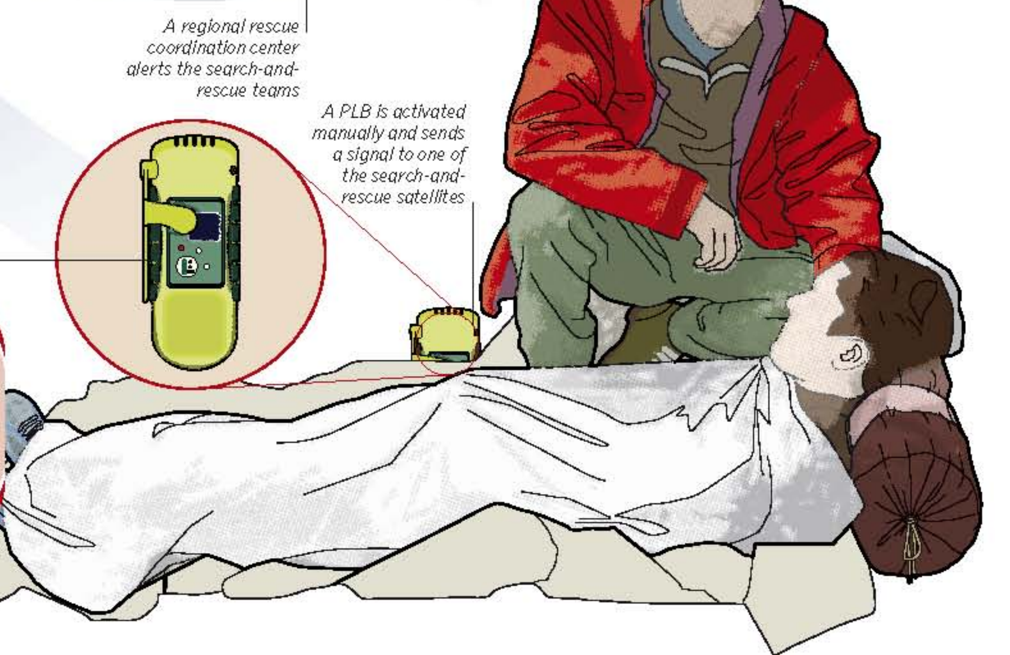
A PLB is activated manually and sends a signal to one of the search-and-rescue satellites
Personal Locator Beacons (PLBs) are for personal use and kept on the body

WARNING!

PLBs are for emergency use only and should always be used responsibly.

BUILDING SIGNAL FIRES

A signal fire is a very effective way of attracting the attention of rescuers, but you do need the right materials and building one requires some effort. A well-constructed signal fire located in a good position will generate a large amount of smoke that can be seen from a long way away. Two variations—the dome and the log cabin—are shown here.

TOOLS AND MATERIALS

- Knife and saw
- Poles and long saplings
- Green vegetation
- Tinder, kindling, and fuel
- Lighter or matches

MAKING A DOME SIGNAL FIRE

Prepare a large fire on a raised platform under a dome-shaped structure made from bent saplings. Fueled by air from below, the fire creates plumes of smoke from the green vegetation. If you have no saplings, use poles to a make a teepee shape.

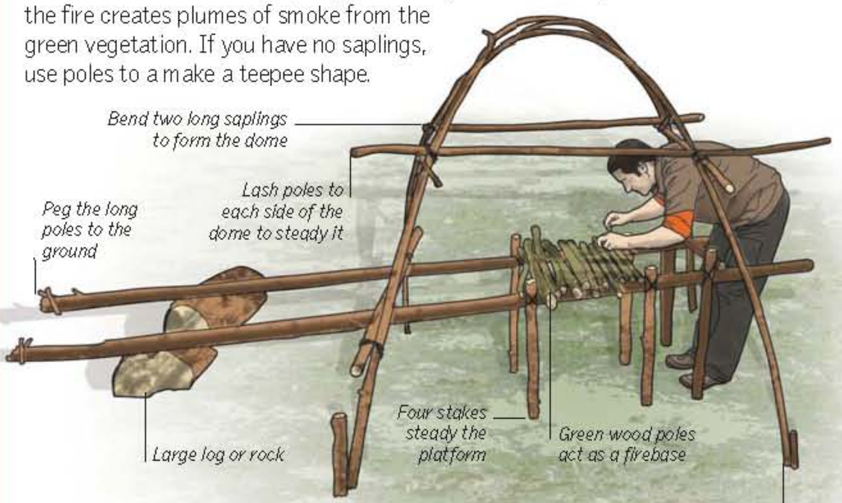

Bend two long saplings to form the dome

Lash poles to each side of the dome to steady it

Peg the long poles to the ground

Large log or rock

Four stakes steady the platform

Green wood poles act as a firebase

Stick the ends of the saplings firmly into the ground

1 Lay two long poles parallel to each other. Prop them up over a log or rock at one end, and tie them to four stakes at the other. Lay lengths of green wood side by side on the long poles under the dome, to act as a firebase.

- Bend two long saplings at 90 degrees to each other to form a dome.

4 Layer green vegetation on top of the dome to form a roof over the fire platform.

- Keep additional green vegetation nearby to add to the fire when it's alight.

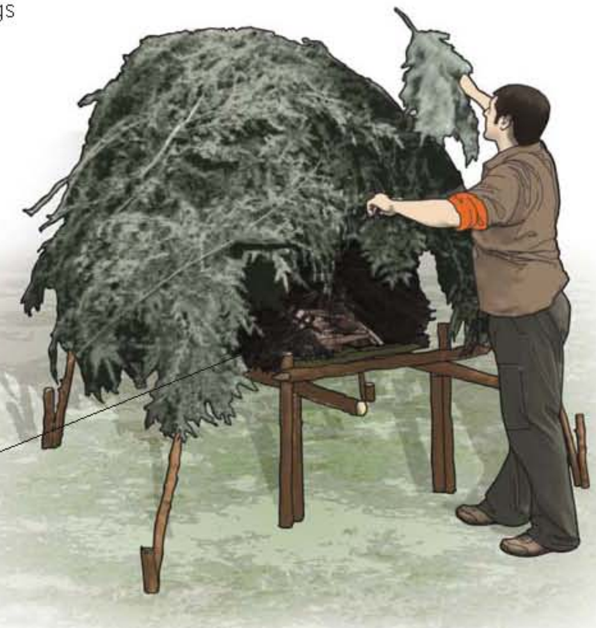

Leave an access point for lighting the fire, but keep it closed so the tinder, kindling, and fuel stays dry

SIGNAL FIRE ESSENTIALS

Whichever signal fire you make, there are several important principles to follow in order to make it as effective as possible.

FIRE FORMATION

If you can, prepare three signal fires in a recognized formation, such as a triangle or in a straight line. If the fires are random, they could be misread as a bush fire or a group of native fires. The distance between each fire should be at least 65 ft (20 m) but needs to be dictated by how quickly you can effectively light each one in turn.

FIRE COMPONENTS

Essentially, each signal fire is composed of a ready-to-light firebase made of dry tinder, kindling, and fuel. When you add the merest spark or flame to the tinder, the firebase immediately turns into a sustainable fire.

- Site the firebase off the ground to prevent damp from reaching it, and to allow enough airflow to help it ignite more effectively.
- Cover the top of the firebase with large amounts of green vegetation and anything else that produces smoke, such as tires. The covering keeps the firebase dry.
- Place a second stack of green vegetation near the firebase and add this as the original vegetation burns out.

AT THE READY

Once you have prepared the signal fire, you need to keep the following nearby, ready for use at a moment's notice:

- Dry tinder in a waterproof container underneath the firebase.
- Hexamine fuel tablets, stove fuel, gas, paper, or birch bark to guarantee the fire gets going again if it starts to dwindle.
- Something to create a spark or flame.
- A witch's broom, made of a cleft stick stuffed with kindling or bark, next to your camp fire, so you can quickly light the broom and transfer it to the signal fire.

MAKING A LOG CABIN SIGNAL FIRE

This signal fire is known as the "log cabin" because of the way the fuel wood is stacked.

- The framework for the fire is a stack of green wood, made up of pairs of poles arranged in alternating layers set at 90 degrees to each other.
- Place an additional supply of green vegetation nearby to be used as required, but not so close that it catches fire by accident.

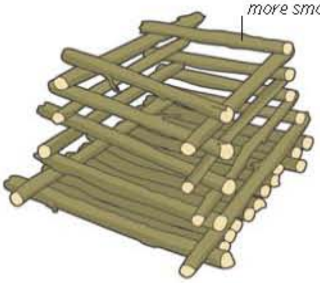

Green wood poles produce more smoke than dead wood

1 Lay a platform of green wood on the ground and build a firebase of dry tinder, kindling, and fuel on top.

- Build a "log cabin" over the firebase using green wood.

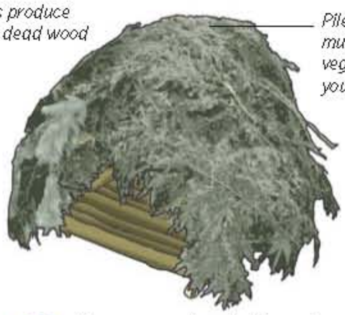

Pile on as much green vegetation as you can find

2 Heap green vegetation over the platform to generate thick plumes of smoke when the fire is lit.

- Leave an access point at the front to allow you to light the firebase.

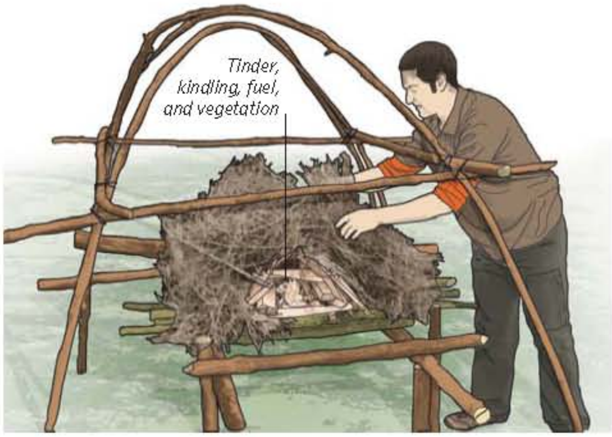

Tinder, kindling, fuel, and vegetation

2 Prepare a fire (see pp. 124–25) on the platform and load it with green vegetation.

- Lay the vegetation close enough to the fuel below to catch easily when the fire is lit—but don't smother it.

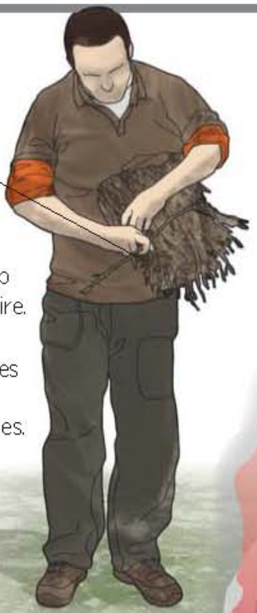

Stab a thin branch or vine into the bundle, wrap it around a few times and tuck it in under itself

3 Prepare some kindling bundles which will help turn the initial flame into a fire.

- Make the bundles by breaking small, dead branches (as thick as a small finger) from the lower trunks of trees.
- Fold them into a small bundle held together with a thin branch or vine.

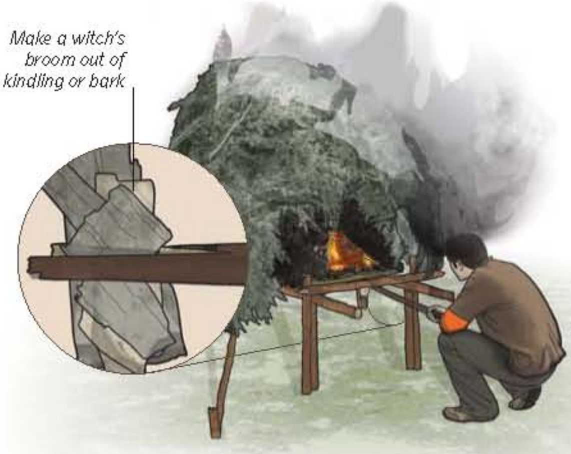

Make a witch's broom out of kindling or bark

5 Light a witch's broom (see panel, left) from your camp fire, take it to the dome, and light the fire.

- Use kindling bundles (see Step 3) to fuel the fire.

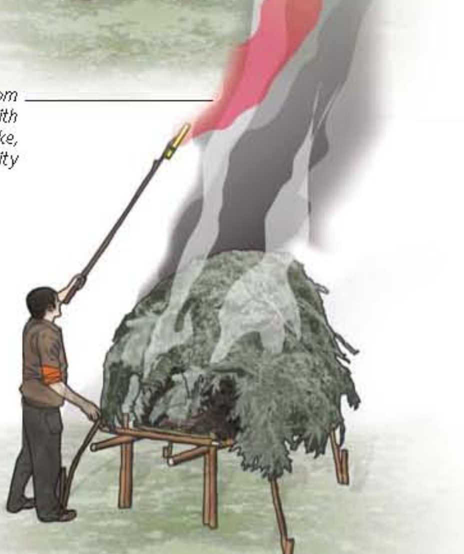

Orange smoke from the flare mingles with the fire smoke, increasing its visibility

6 When smoke billows upward, light a preprepared signal flare (see p. 241), if you have one, taped or tied to a long pole.

- Use the pole to position the flare as high into the smoke as you can.

OTHER RESCUE SIGNALS

As well as signal fires, there are other visual devices for attracting potential rescuers. Some are unusual and others, such as a whistle, quite obvious. Whatever device you use, you have to try to hold the rescuers' attention by persisting with your signal.

LIGHT WINDMILL

You can create a highly visible, illuminated "windmill" effect by whirling a chemical lightstick (cyalume) in front of you attached to the end of a cord 3 ft (1 m) long. Depending on local conditions it can be seen up to 2 miles (3 km) away—or further by an aircraft. Blow your whistle at the same time, using the International Distress Signal of six blasts over one minute, then one minute's silence. The reply is three short blasts.

CREATING A STROBE EFFECT

LED strobe lights are compact, robust, waterproof, and are sometimes incorporated within standard flashlights. They are very powerful and can be seen from a long way away. Many strobes can be set to produce a variety of sequenced flashes, including flashing SOS in Morse Code. Even if you don't have a dedicated strobe light, you can still switch your regular flashlight on and off repeatedly to attract attention.

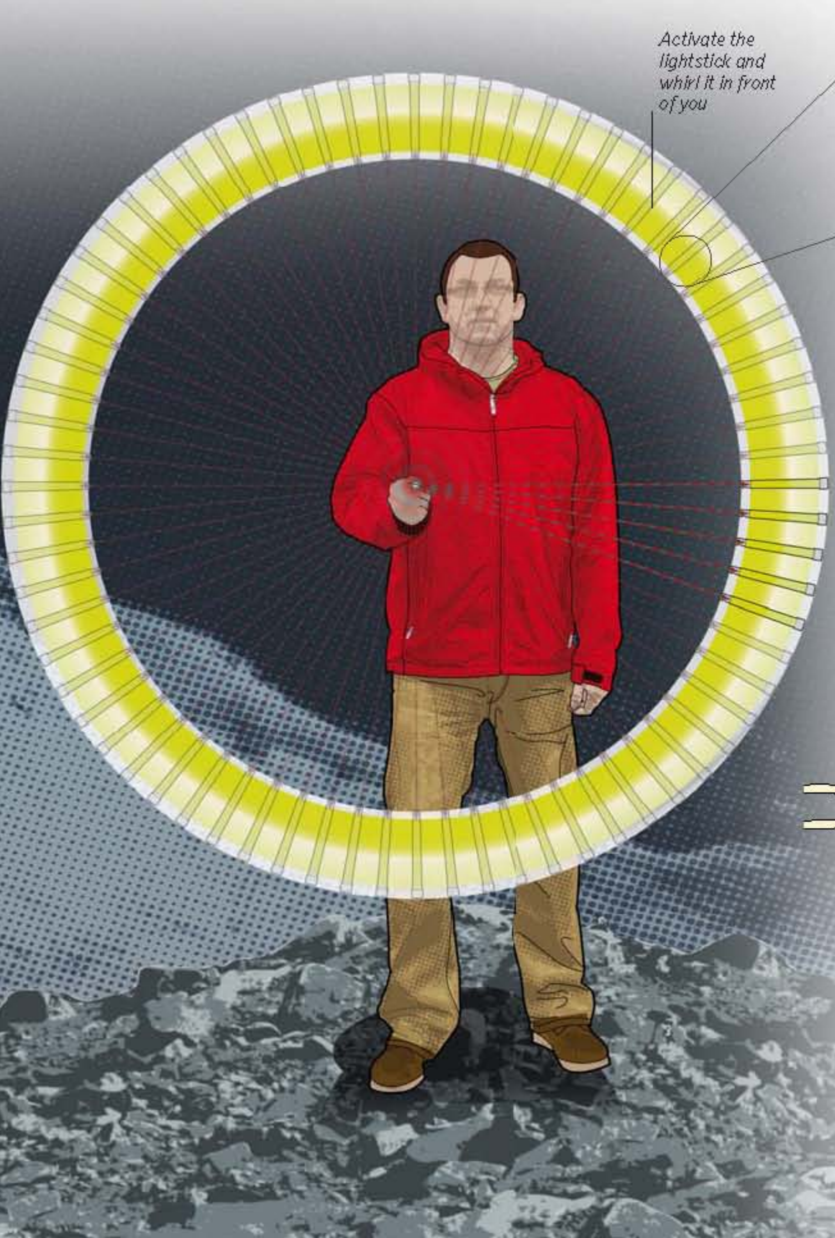

Activate the lightstick and whirl it in front of you

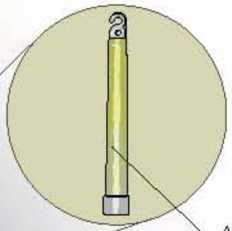

A lightstick is filled with a luminous substance known as cyalume

TINSEL TREE

The signaling device known as a "tinsel tree" is best used when you're remaining in one place for a while. It's effective only during daylight hours, so you'll need to find a suitable and easily visible tree or bush in a sunny position.

- Cut a silver survival blanket, a roll of aluminum foil, or any reflective material into strips.
- Attach the strips to the tree so that they move in the breeze, catching the sunlight and glinting like small mirrors.

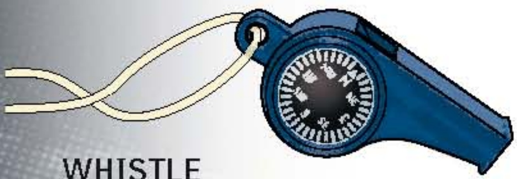

WHISTLE

Take a whistle with you when you venture out into the wilderness because sound, especially in remote areas where there's little or no noise pollution, travels incredible distances. A whistle is an item of first-line gear (see pp. 42–43), and should be kept on a cord around your neck.

SIGNALING DISTRESS

Two of the most recognized signs of distress are a little red star shooting up into the sky or a billowing cloud of orange smoke. There are many different types of signal flares and rockets, ranging from simple, handheld devices that fire flares into the sky to specialized kits designed to penetrate thick jungle canopy. Usually found in the emergency survival packs of aircraft and liferafts, flares are also available from specialized shops.

SIGNAL FLARES

One end of a signal flare has an orange-colored smoke signal for daytime use. The other end has a flare for night-time use (but it can be operated during the day, too). Remember the following:

- Follow the instructions on the outside of the device.
- Wear gloves to protect your hands.
- The heat from a flare can damage a liferaft, so keep your flare well clear when you light it.
- Don't discard flares unless you have used both ends.

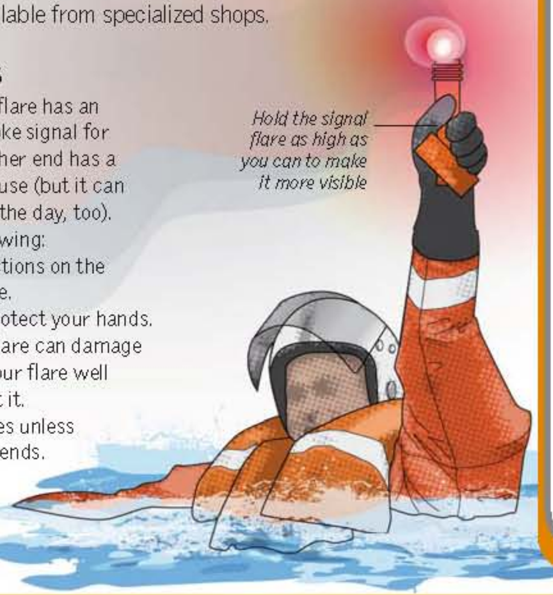

Hold the signal flare as high as you can to make it more visible

GROUND-TO-AIR MARKERS

You can improvise internationally recognized emergency signals on the ground that rescuers in the air can see.

GETTING NOTICED

To make a ground-to-air marker, use anything that contrasts with the ground, such as orange lifejackets, seaweed, clothing, rocks, branches of trees, or soil.

- Whatever you use, make sure the message is big and visible from all directions.
- Check on your markers regularly.
- When appropriate, use one of the emergency codes shown below. SOS or HELP written in big letters will attract attention too.

V	Require assistance
X	Require medical assistance
N	No/Negative
Y	Yes/Affirmative
↑	Proceed this way (arrow points)

SIGNAL MIRROR

A signal mirror, or "heliograph," has a shiny surface that reflects the sun and sends flashes over distances exceeding 30 miles (50 km), depending on the strength of the sun, the size of the mirror, and the clarity of the air. You can even use the light from the moon when it's full. By interrupting the flashes you can send messages in Morse Code.

IMPROVISING A SIGNAL MIRROR

If you don't have a heliograph or any other mirror, try using anything with a shiny, reflective surface, such as a foil food packet, a CD, or the bottom of a beverage can.

WARNING!

Don't dazzle your would-be rescuers by continuing to flash directly at them. Using your signal mirror intermittently is more effective for attracting attention.

1. Polish the base of a can to a shine with a slightly abrasive paste. You can use charcoal and water, toothpaste, or even chocolate.

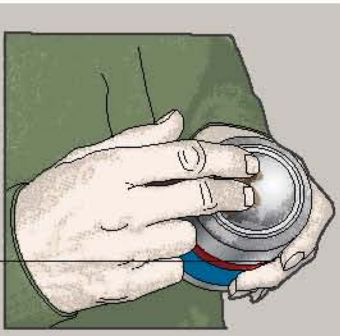

Polish the concave base—it will only take a couple of minutes

2. Hold the can in front of your face with the polished base facing the sun.
   - Direct the flash of reflected sunlight on to the palm of your other hand to practice controlling the light.
   - Aim the can toward a rescuer and send a signal, either by moving your palm up and down to interrupt the flash or by directing the flash between a "V" made with your thumb and fingers.

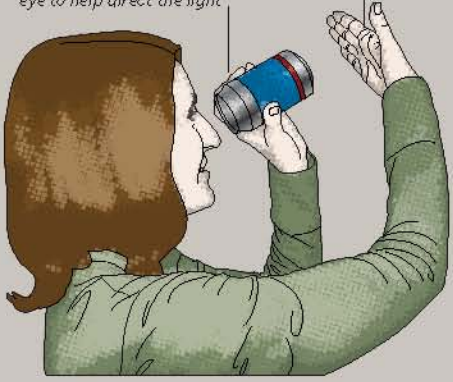

The V-shape helps you direct the light

Hold the can up to your eye to help direct the light

WILD ANIMALS

WALKING IN THE WILDS of Alaska and coming across a fresh deposit of bear feces is a sobering experience. It quickly dawns on you that you're potentially a part of the natural food chain. What do you have to do to protect yourself, and will it be effective or just provoke the animal? Fortunately, the survival instincts of wild animals are such that, with only a few exceptions, most animals, regardless of their size, will avoid confronting you. However, they will defend themselves by attacking you if provoked, cornered, or surprised, particularly when they have young.

FERAL ANIMALS

Wherever you go in the world there are animals that have escaped into the wild from zoos, wildlife parks, and domestic situations. These feral animals include pigs, cats, dogs, mink, and muntjacs. In many cases, they have become particularly aggressive and seem to have lost any fear of confrontation with humans. Try to find out which feral animals are common in the region you're traveling in and avoid them if at all possible.

	BEARS	BIG CATS	HIPPOS	ELEPHANTS	CROCODILIANS
ANIMAL FACTS	▪ Brown bears stand taller then black bears and weigh more. Polar bears are the largest land predator. All bears are powerful, with claws on their strong paws. Brown bears can run faster than humans. ▪ Bears are found in the Northern Hemisphere and parts of South America.	▪ Tigers are the largest cat, with lions a close second. All big cats have sharp teeth and claws. ▪ Other dangerous cats include cougars (also called pumas, mountain lions, and panthers), leopards, and jaguars. ▪ Big cats are found on all continents, except for Australasia.	▪ The hippopotamus is the third-largest animal in Africa after the elephant and white rhino. ▪ Hippos can weigh more than 3 tons. They have long, razor-sharp incisors and tusklike canines.	▪ African elephants have larger ears than Indian elephants and are more aggressive. ▪ Elephants stand up to 13 ft (4 m) tall and weigh up to 6 tons. ▪ They can reach speeds of 25–30 mph (40–48 kph).	▪ Crocodilians include alligators, gharials, and crocodiles. ▪ They can stay submerged for more than an hour at a time, can swim up to 20 mph (32 kph), and run as fast as 11 mph (17 kph) over short distances. ▪ Crocodilians live in many subtropical and tropical parts of the world.
PRECAUTIONS	▪ Look for signs of bears and check with locals about bear activity. ▪ Stow and cook food away from the campsite. Keep unused food and garbage out of reach. ▪ Avoid thickets and streams where bears rest and feed. ▪ Carry a stick, knife, or spray (see opposite).	▪ Avoid coming into contact with big cats. They are most unlikely to attack unless you provoke them or threaten their cubs. ▪ An exception is the cougar, which is responsible for an increasing number of unprovoked attacks in urban areas of North America.	▪ Avoid provoking a hippo. Many encounters are the result of hitting a partially submerged hippo with a canoe or boat. Almost all hippo attacks are fatal. ▪ Stay vigilant on or beside rivers that hippos are known to frequent. ▪ Don't get between a hippo and water.	▪ Keep away from places that elephants frequent, such as watering holes. ▪ If you do come across them, don't get too close, especially if there's a baby elephant nearby. ▪ Look for a safe place to retreat to, such as a vehicle, rocky outcrop, or a tree, before you need it.	▪ Stay away from waters and river banks where crocodilians live. Be vigilant at all times. ▪ If you need to go near the water, watch the area for at least 30 minutes first. ▪ Don't go to the same spot twice, as crocodiles may lie in wait the next time. ▪ Keep a defensive weapon, such as a knife, close by.
WHAT TO DO IF...	▪ Make a noise to let a bear know you're there. ▪ If you see a bear, stay calm. Make yourself look as big as possible by raising your arms. ▪ Walk slowly backward. Don't run. If the bear follows, stop and hold your ground. ▪ If the bear attacks, play dead, or fight back.	▪ If a big cat approaches, stare at its eyes, shout, and make a noise to confuse it. Use a spray if you need to (see opposite). ▪ Don't turn your back or run away. ▪ If a big cat sees you, do not crouch or bend down. An upright human makes less attractive prey than a four-legged animal.	▪ If you encounter a hippo, go back on your tracks and find another route. ▪ If a hippo yawns at you, he's not feeling sleepy—this is a threat. He's showing you his teeth, tusks, and jaws that can snap a canoe in half! Make every effort to escape.	▪ If an elephant squares up to you with flared ears, trumpeting, and kicking the dirt in front of it, then back away. ▪ If an elephant charges, run to your safe place (see above). ▪ As a last resort, play dead and hope the elephant loses interest.	▪ If you meet a crocodilian on land, run away. ▪ If a crocodilian does grab you, it may let go—if it does, run. ▪ If it drags you into the water, fight back. Stab under its throat with a knife, hit or poke its eyes, strike its nostrils hard, or bang the large valve at the back of its throat.

ARMING YOURSELF

If you're traveling in areas where encounters with wild animals are possible, be ready with a weapon such as a knife, large stick, or deterrent spray. Remember, avoidance is always better than confrontation.

PEPPER SPRAY

One type of deterrent spray contains the pepper ingredients capsaicin and capsaicinoids. It shoots a cloud or stream that irritates an animal's eyes. The animal usually withdraws, but take care until the danger has passed.

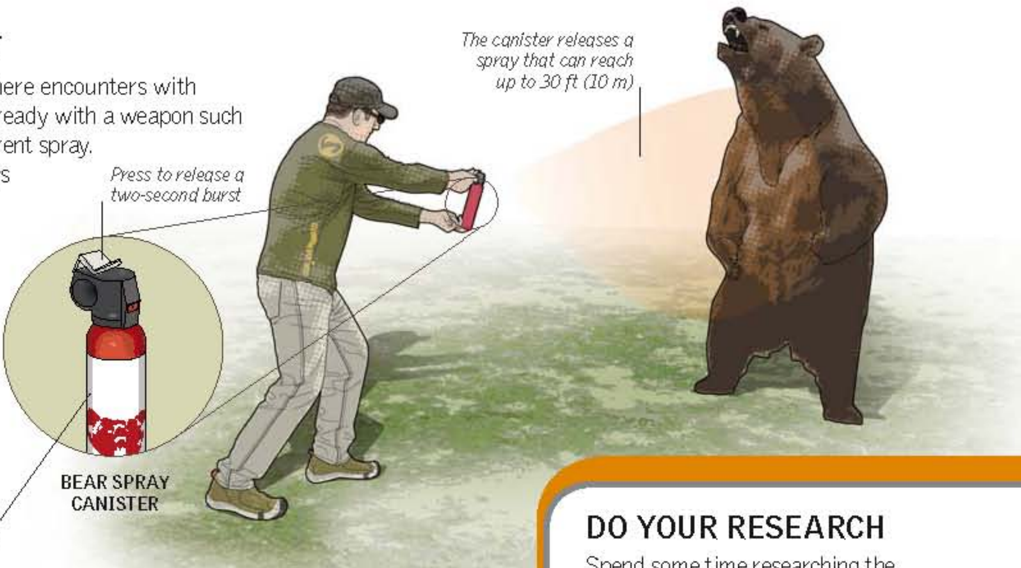

The canister releases a spray that can reach up to 30 ft (10 m)

Press to release a two-second burst

BEAR SPRAY CANISTER

The pepper spray is under pressure in a canister

	SHARKS	SNAKES	AMPHIBIANS
ANIMAL FACTS	▪ There are more than 450 species of shark, but only a few of them pose any danger to humans. These include great white, bull, and tiger sharks. ▪ Most attacks occur in coastal waters in the tropics and subtropics, especially where the water is murky or stirred up by the surf of breaking waves.	▪ Less than 15 percent of the 3000+ types of poisonous snake are regarded as being dangerous to humans. ▪ Depending on the snake, venom either affects the blood, the nervous system, or the heart. ▪ Snakes live in every part of the world except for very cold environments.	▪ Many frogs, toads, and salamanders secrete poison through their skin. The most poisonous frog known is the golden poison-dart frog from South America. ▪ Amphibians live where the climate is sufficiently warm and wet for them to breed.
PRECAUTIONS	▪ Avoid shark-infested waters or waters where sharks are known to feed or frequent. Ask the locals about recent sightings of shark activity. ▪ Carry something, such as a pole or spear, that you can use as a weapon.	▪ Wear long pants and boots, and cover your neck. ▪ As you walk, tap the ground in front of you with a stick to alert snakes to avoid you. ▪ Step onto logs rather than over them. ▪ At night, place your boots upside down on sticks. ▪ Don't put your hands into holes or cracks where snakes might be hiding.	▪ You can touch a poisonous frog or toad with no ill effect. The poison only takes effect if it enters your system via an open wound or your mouth or eyes. If this happens, get emergency help without delay.
WHAT TO DO IF...	▪ If you see a shark, stay calm and move to safety. ▪ If it makes a move toward you, swim away smoothly but keep watching it. ▪ If it rushes at you, hit it on the nose with whatever you have at hand. ▪ If it grabs you, aggressively strike its eyes or gills.	▪ If you come across a snake, try to remain completely still. Most snakes will instinctively move away and are more likely to attack a moving target. ▪ Don't panic. If you have a stick, slowly bring it to a position ready for use. ▪ If a snake attacks, hit it hard on the head.	▪ If contact with a poisonous amphibian is unavoidable, immediately wash the affected area. Keep the water you use away from open cuts or abrasions. ▪ Thoroughly wash your hands and don't put your fingers in your mouth or rub your eyes.

DO YOUR RESEARCH

Spend some time researching the area you'll be traveling in and find out which animals present the greatest dangers. Discover as much as you can about their habits and how best to avoid coming into contact with them.

SPOT THE SIGNS

Understand the habits of these dangerous creatures: when do they forage, sleep, and drink? What are their habits?

- Learn to recognize the natural signs that indicate their presence: tracks or prints; feces/droppings; territory markings, such as flattened vegetation where the animal rubs its scent on the ground; telltale signs, such as where bears have clawed the bark from trees.
- Be aware of other animals disappearing quickly from a watering hole, or a noisy jungle suddenly going quiet.
- Ask local people if there have been any reports of animals attacking people.
- Find out the best ways to ward off an attack or defend yourself should you have no option (see left). Adopting a certain stance or submissive posture, or avoiding or maintaining eye contact, could make the difference between safety or danger, life or death.

TRUE-LIFE ACCOUNT

EXTREME SURVIVAL—IN COLD CONDITIONS

USEFUL EQUIPMENT

- Waterproof, layered clothing
- Trekking pole or ice ax
- Collapsible snow shovel
- Light, whistle, avalanche beacon
- Tarpaulin
- Gore-Tex® gloves and gaitors
- Map, compass, GPS
- Survival tin, bushcraft knife
- Cell/satellite phone
- Poncho/bivy sack

34-YEAR-OLD ICE HOCKEY PLAYER ERIC LEMARQUE became lost in the snowy wilderness of the Sierra Nevada mountains in California after snowboarding at Mammoth Mountain ski resort. Despite being under-equipped and ill-prepared, his improvisation helped him to survive for seven days.

LeMarque was snowboarding alone late on Friday, February 6, 2004, setting off down an unmarked run of virgin powder snow just as the lifts were shutting for the day. Coming to a stop on a flat section, and with visibility reduced to just 10 ft (3 m), he realized he had lost the trail. Wearing uninsulated ski trousers and jacket, and with just an MP3 player, a cell phone with a dead battery, and wet matches, he was ill-prepared for survival, so he began to search for the trail.

LeMarque chose the wrong direction and walked away from the ski resort. Realizing he faced a night in the open, he used his snowboard to dig a crude trench, lining it with bark scraped from a pine tree for insulation from the snow. He tried to light a fire with pine needles and lint from his clothing, but his matches were too wet. He also ate pine needles and bark.

"WITH VISIBILITY REDUCED TO JUST 10 FT (3 M), HE REALIZED HE HAD LOST THE TRAIL"

Over the next five days, LeMarque walked further into the wilderness, leaving scraps of clothing for rescuers and attempting to signal to passing planes with the blue LCD screen of his MP3 player. Fortunately for LeMarque, rescuers spotted his snowboard tracks and followed it for 24 hours, finding him on February 13. He was barely conscious, dehydrated, hypothermic, and malnourished—having lost 35 lb (16 kg) in body weight—and was suffering from severely frostbitten feet, which later required both legs to be amputated below the knees. But he was alive.

WHAT TO DO

ARE YOU IN DANGER?

NO YES

If you are in a group, try to help any others who are in danger

Get yourself out of it:
Cold/wind/wet—These can quickly lead to hypothermia, so get yourself out of the elements quickly
Animals—Avoid confrontation and move away from danger
Injury—Stabilize condition and apply first aid

ASSESS YOUR SITUATION

See pages 234–35

DOES ANYONE KNOW YOU WILL BE MISSING OR WHERE YOU ARE?

NO YES

If no one knows you are missing or where you are, you will need to notify people of your plight by any means at your disposal

If you are missed, a rescue party will almost certainly be dispatched to find you

DO YOU HAVE ANY MEANS OF COMMUNICATION?

NO YES

You are faced with surviving for an indefinite period—until you are located or you find help

If you have a cell or satellite phone, let someone know your predicament. If your situation is serious enough to be worthy of emergency rescue, and you have a Personal Locator Beacon (PLB), you should consider this option

CAN YOU SURVIVE WHERE YOU ARE? *

NO YES

If you cannot survive where you are and there are no physical reasons why you should remain, you will have to move to a location that offers either a better chance of survival, rescue, or both

Address the Principles of Survival: Protection, Location, Water, Food

YOU WILL HAVE TO MOVE **

DO

- Make an informed decision on the best location to move to
- Keep hydrated by wrapping snow in a wet item of clothing and suck it as it melts—but only if you are walking or working and generating heat
- Improvise a walking staff that can be used to check depth and quality of snow, and unseen drop-offs
- Check regularly for signs of frostnip or frostbite and hypothermia
- Have aids to location accessible while moving and deployed while static
- Protect all extremities from the elements—tie gloves to cord threaded through your jacket so they don't get lost

DON'T

- Underestimate the need for water just because it is cold—you are just as likely to get dehydrated in a cold environment as in a hot one
- Post-hole through virgin snow—it is exhausting. Instead, improvise a pair of snow shoes
- Sleep directly on the ground. Ventilate your shelter and first check for natural dangers (avalanche)

YOU SHOULD STAY **

DO

- Select a suitable shelter site away from dangers. Build it big enough for you and your equipment. Incorporate a cold sink and a sleeping platform higher than the sink
- Keep cutting and digging tools in the shelter in case a very heavy snow fall or an avalanche requires you to dig your way out
- Mark the entrance to the shelter so you can find it easily
- Keep a fire going: once established, you can use it to melt snow and benefit from warmth
- Prepare all of your aids to location for immediate use

DON'T

- Use your body heat to melt snow as it lowers your body temperature and can induce hypothermia
- Breathe air onto cold hands—breath contains moisture which will then cool and conduct heat away from your hands
- Sit or lay directly on the cold ground. Use whatever is available to improvise a sitting or sleeping platform

---

* If you cannot survive where you are, but you also cannot move owing to injury or other factors, you must do everything you can to attract rescue.

** If your situation changes (for instance, you are "moving" to find help, and you find a suitable location in which you can stay and survive) consult the alternative "Do" and "Don'ts."

ENVIRONMENTAL HAZARDS

SOME PARTS OF THE WORLD have a reputation for sudden or extreme weather conditions, and unpredictable environmental hazards that cause havoc for everyone, not just travelers. Before you set off, make sure that you're aware of any such potential hazards in the areas you're visiting, and be ready for them, just in case.

BEING PREPARED

Many environmental hazards—from avalanches and volcanoes to forest fires, tornadoes, and hurricanes—can suddenly propel you into an emergency situation. While you can never be sure of escaping the worst excesses that Nature can throw at you, you can prepare yourself. A combination of the right equipment, local knowledge, and an awareness of evasive techniques will mean that you shouldn't have to find yourself in a survival situation thinking "if only".

COMMONSENSE ADVICE

No fail-safe guidelines will protect you from every environmental danger and hazard, but there is some commonsense advice that you will do well to heed before you venture into the wilderness:

- Check the prevailing weather conditions of your destination at the time of your journey. Log onto the internet or tune into local radio stations.
- Find out if you're heading into a particularly risky season of weather—for example, monsoons in India or hurricanes in the Caribbean.
- Take an emergency survival kit (see pp. 58–59).
- Learn the relevant survival techniques either before you go or as soon as you arrive at your destination—you may not get a second chance.
- Don't challenge Nature—it rarely loses.

EQUIPPING YOURSELF FOR AN AVALANCHE REGION

Before heading for the mountains, find out whether the prevailing conditions make avalanches more likely (see right).

- Take a collapsible shovel for moving snow and a probe for checking the depth of the snow.
- Keep some survival aids in your pockets in case you lose your backpack.
- Carry an avalanche transceiver—when activated, its signal can be detected by rescue services.

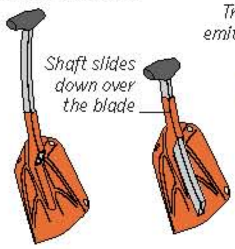
Shaft slides down over the blade

COLLAPSIBLE SHOVEL

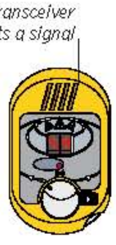

AVALANCHE TRANSCEIVER

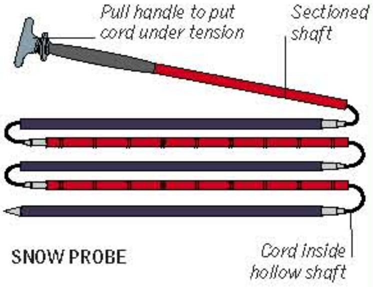

SNOW PROBE

SURVIVING AN AVALANCHE

There's always the danger of an avalanche on slopes that face away from the sun in the middle of winter, when a fresh layer of heavy snow sits on top of a weak layer of snow. An avalanche may be triggered when snow is disturbed by loud noises, an earth tremor, or the movement of skiers or snowboarders. Learn the warning signs, take the right equipment, and practice the emergency steps in case you get caught.

SPOTTING THE WARNING SIGNS

As you cross the snowbound mountains, hills, and valleys, look out for signs that warn of a possible avalanche:

- Convex slopes at an angle between 30 and 45 degrees.
- Slopes without trees or rocks.
- Loose, dry snow that doesn't settle.
- Soft, newly fallen snow that's more than 1 ft (30 cm) deep.
- Snow that sounds hollow.
- Snow that falls as crystals or pellets.
- Snow that falls at more than 1 in (2.5 cm) an hour.

TAKING EVASIVE ACTION

If you see or hear an avalanche, and you think it might be coming your way, take evasive action at once:

- Activate your avalanche transceiver in case you get caught in the snow.
- Try to take cover—for example, under a solid rock overhang if you can see one nearby (see below).
- If you can't find or reach suitable cover, try to sidestep the avalanche by skiing out of the way—at right angles to its potential path.

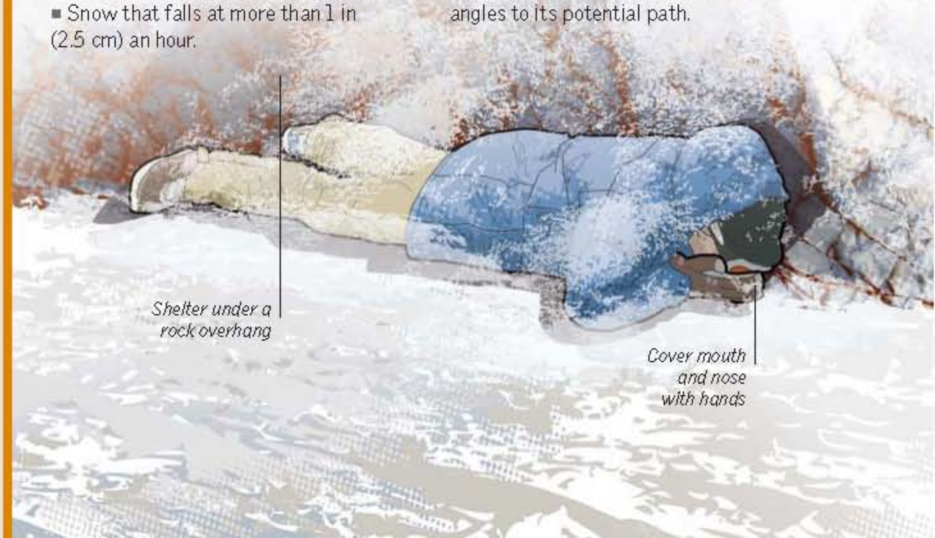
Shelter under a rock overhang
Cover mouth and nose with hands

HAZARDOUS GROUND

All kinds of local conditions can prove treacherous if you don't keep your wits about you. Walking through wetlands can be risky, as the ground can suddenly give way under foot and you can find yourself in a swamp or, worse still, a patch of quicksand.

SURVIVING A SWAMP

Freshwater swamps are found in low-lying inland areas and contain masses of thorny undergrowth, reeds, and grasses, and there may be dangerous animals, such as crocodilians and snakes. The water may be foul and mosquitoes, which can cause malaria, are often present. Moving through a swamp is difficult: you can be on solid ground one moment, and chest-deep in water the next. Where possible, try to build a raft or some kind of flotation aid to help you escape. Use the waterways to navigate your way to open water, where you have the best chance of either being seen by rescuers or finding your way back to civilization.

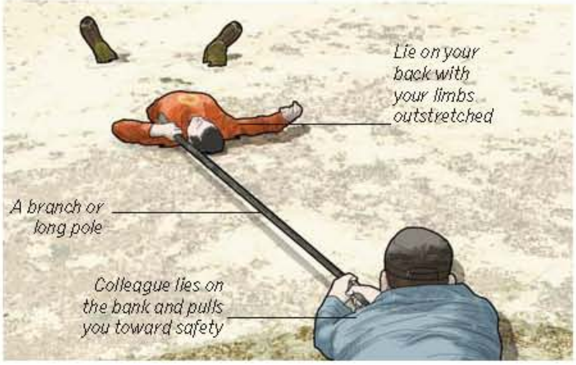
Lie on your back with your limbs outstretched
A branch or long pole
Colleague lies on the bank and pulls you toward safety

ESCAPING FROM QUICKSAND

If you step into quicksand, try to fall onto your back with your limbs outstretched to spread your weight. Try to get to the bank by paddling with your hands. Don't struggle as you will sink faster. If you're with someone, he or she needs to lie on firm ground and pull you to safety, reaching you with the help of a long pole, rope, or branch.

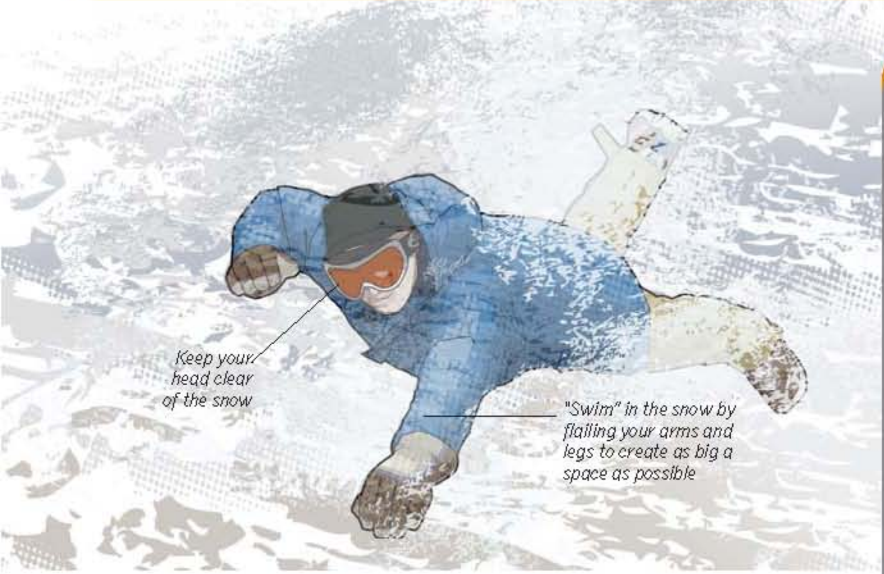
Keep your head clear of the snow
"Swim" in the snow by flailing your arms and legs to create as big a space as possible

ESCAPING FROM AN AVALANCHE

If you can't take evasive action and find yourself below an advancing avalanche with no prospect of escape, try to keep calm and remember the following advice:

- Remove the bindings from your skis and the loops from your ski poles. Put your rucksack on one shoulder, but ditch it rather than risk dislocating your shoulder.
- If you're overtaken by snow, "swim" with the flow (see above) to make a big space around you before the snow compacts and "sets". Use your hands or a collapsible shovel to clear the snow around your head and to create a space for you to breathe, as often people suffocate before they freeze.
- If you don't know which way is up, dribble saliva to find out which way is down—then dig in the opposite direction.
- Get out quickly, as time is of the essence, and shout when you hear potential rescuers to attract their attention.

ESCAPING A VOLCANIC ERUPTION

Find out if there's an active volcano in the region you're visiting. If there is, and its eruption is imminent, leave the area as soon as you can. It will pump enormous quantities of lava from the mantle below the crust and produce huge amounts of ash, toxic gases, debris, and mud. However, if you do get caught in an eruption:

- Be careful when driving to safety, as the ash and mud make roads slippery.
- Take cover to avoid the flying fiery debris, hot gases, and suffocating clouds of ash. Sulfur dioxide in the ash chokes your lungs and, when mixed with rain to form sulfuric acid, burns your skin.
- If you're caught in an ash cloud, cover your face with a wet cloth (or use a mask if you have one). Wash your skin afterward.

SURVIVING AN EARTHQUAKE

Find out if an earthquake is likely to happen in the region you're visiting. If you feel an earthquake coming:

- Get into the open, away from structures or trees that can fall on you. Then lie down.
- Stay in open ground until aftershocks and tremors have stopped altogether.
- If you're in a building, go to the lowest floor, and stay beside a wall or under a sturdy table. Turn off the gas if you have time.
- If you're in a vehicle, stop, but stay inside.

SURVIVING A FOREST FIRE

When vegetation on the ground is tinder dry, the slightest spark can start a fire that gets out of control and sweeps through a forest. A forest fire may be caused by lightning, a piece of glass focusing the sun's rays, a discarded cigarette, or a spark from a camp fire. Forest fires produce intense heat, thick smoke, and toxic gases—and they use up all the available oxygen in the air, making it impossible to breathe.

PREPARATION AND SPOTTING THE WARNING SIGNS

If you're going to a place where forest fires are a hazard, find out from local radio reports whether conditions are making them more likely. If you venture into a forest, make sure you carry a cell phone or some electronic means of signaling, and let others know your route and destination. The following warning signs may help you gain time before a fire is upon you:

- You'll probably smell a fire first, and you'll hear it crackling as it burns before you see it. If you smell a fire and you notice animals growing agitated, a forest fire may be close by.
- The smoke will help you establish how close the fire is. The direction of the smoke tells you which way the wind is blowing.

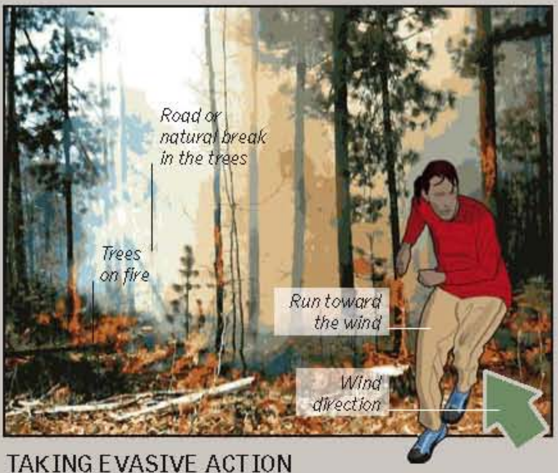

TAKING EVASIVE ACTION

If the wind is blowing toward the fire then move into it quickly. However, if the wind is behind the fire you could be in serious danger because the fire will be moving very fast.

- Try to find a river, lake, road, or natural break in the forest. Stay there until you're rescued or the fire has passed you by.
- Don't go up to high ground as fire is drawn faster uphill.
- Many forest fires spread on a wide front, so avoiding the fire by going around it may be impossible.
- If the fire is upon you, and the wall of flame is fragmented, the best course of action may be to run through the flames: take off man-made clothes (as they will melt onto you), cover as much of your skin as you can, and douse yourself in water if you have any. Take a deep breath, press a damp cloth to your mouth and nose, pick a spot where the wall of flames is thinnest, and run without stopping until you're through.
- If you're in a vehicle, stay inside. Park it as far away from the trees as possible, turn off the engine, close the windows, lie down on the floor, and cover yourself if you can.
- If escape is impossible, try to dig and bury yourself under soil. Dampen all clothing and get as low as possible.

EXTREME WEATHER

High winds and torrential rain are common seasonal occurrences across the world. From tornadoes and whirlwinds to tropical storms such as hurricanes and typhoons, these extreme weather patterns cause enormous damage and threaten many lives.

AVOIDING HURRICANES AND TORNADOES

Weather forecasts can predict approximate directions and paths of impending hurricanes and local emergency services will give advice on the predicted severity. If you're planning a trek in an area known for hurricanes and tornados, check long-range weather forecasts and be prepared to cancel or alter your plans if necessary—if you're caught in the open your chances of survival are extremely limited. If you're going to be in the wilderness during a "storm season" then take a battery- or solar-powered radio, check for weather updates, and be prepared to head back to civilization. If your home is in a tornado or hurricane area, follow the advice of local services, but most importantly be prepared with a plan that will ensure you don't get caught out.

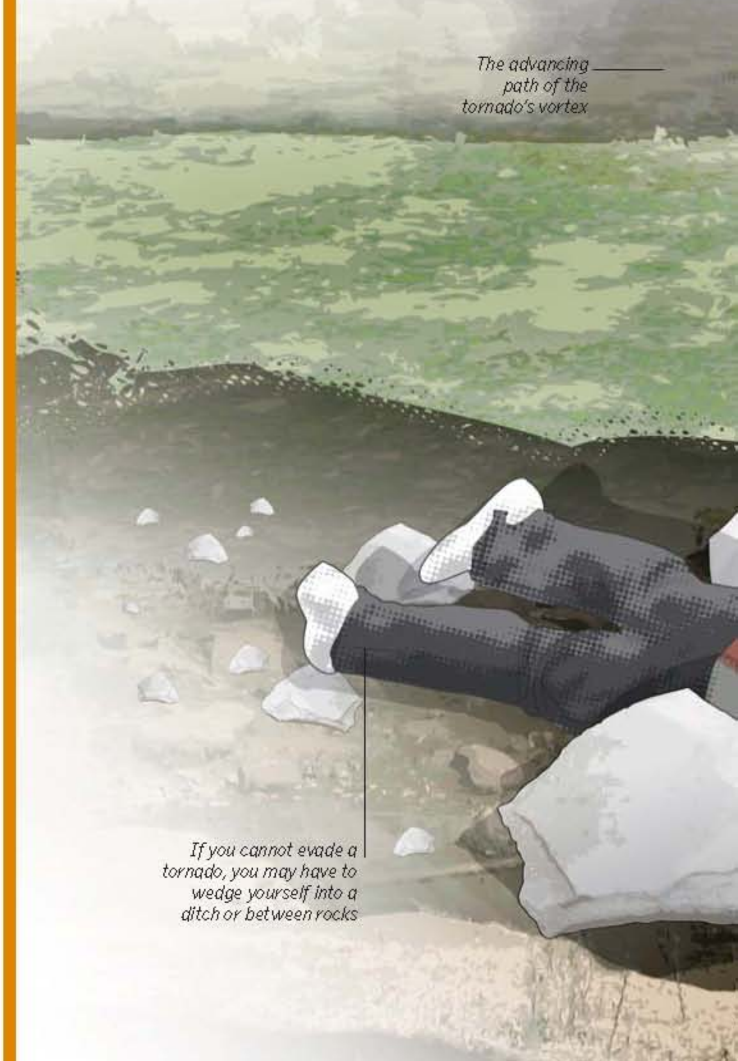
The advancing path of the tornado's vortex

If you cannot evade a tornado, you may have to wedge yourself into a ditch or between rocks

PREPARING TO EVACUATE

The arrival of a hurricane or tornado is a time when you can find yourself in a survival situation on your own home turf. The following advice can help you prepare to evacuate.

- Secure anything outside that could be picked up by winds and cause damage, such as rubbish bins and garden furniture.
- Prepare an evacuation plan (including pets if you have them). Find out where you will evacuate to and make several route plans to the location in case roads are unusable. Fuel your vehicle as soon as a hurricane warning is forecast.
- Put together a hurricane survival pack that contains what you need for a 72-hour period. Include drinking water, a change of clothing, non-perishable food, sleeping bags, radio, flashlights, and contact numbers for family and emergency services.
- Protect your house by securely boarding up all windows and doors. Turn off the water, gas, and electricity.

STAYING PUT

If you decide to stay put, you should still follow the guidelines above. As the storm approaches, move everyone and your supplies to an underground shelter or a room without windows.

- Monitor the radio reports and comply with the advice of the emergency services.
- Don't go outside until the "all-clear" has been given.

TAKING COVER OUTDOORS

If it appears that you are, or could be, in the path of a tornado or hurricane, do everything you can to move out of its way—choose a direction at a right angle to its path.

- If you're driving but can't get out of the way, try to park in an underpass. Leave the vehicle and wedge yourself into a secure position as high as you can under the underpass. If you're in the open, shelter upwind of your abandoned vehicle, so that it does not become a hazard to you.
- If you're out in the open, head for the lowest ground and find a ditch or depression (see below), in which you can shelter, or wedge yourself between rocks.

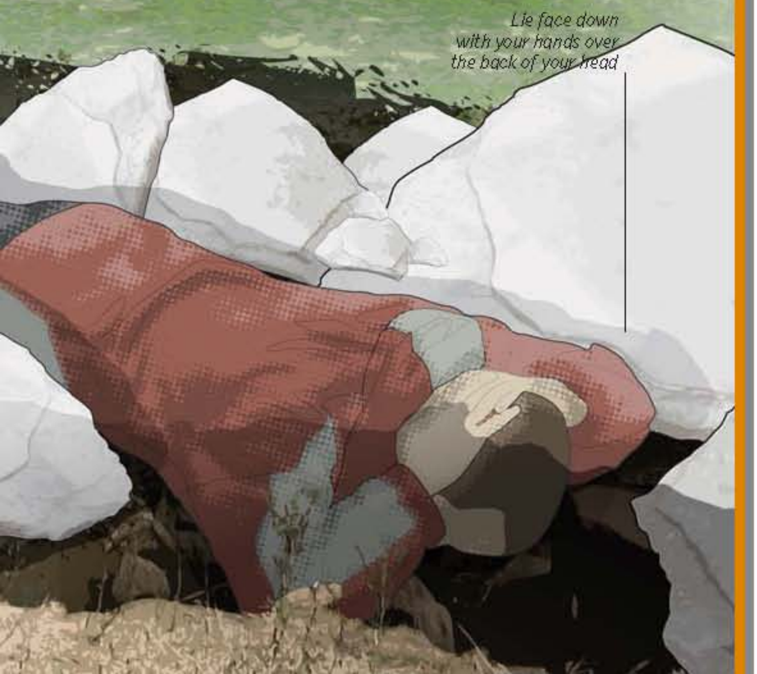

Lie face down with your hands over the back of your head

SURVIVING AN ELECTRICAL STORM

An electrical storm may develop when warm air rises and meets colder air. Electricity sparks between water droplets in the clouds, forming lightning that takes the shortest route to the ground. The following advice will help you avoid being struck by lightning, or minimize its effects if you are:

- Avoid getting caught in open ground—seek shelter but not under a lone tree: when lightning strikes a single tree a tremendous voltage fans out from its base.
- Remain in your vehicle if there is no other cover: it acts as a Faraday Cage (a metallic enclosure that prevents the entry or escape of an electromagnetic field).
- If caught in the open: make yourself as small as possible and limit the amount of area you cover. Do not lay down or stand up, crouch down low with feet together and hands off the ground.

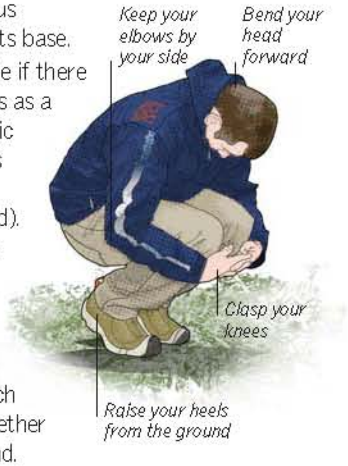

Keep your elbows by your side

Bend your head forward

Clasp your knees

Raise your heels from the ground

SURVIVING A FLASH FLOOD

A sudden deluge of rain doesn't always drain away quickly, instead flowing rampantly over the surface of the land in torrents, and causing flash floods. Soil, animals, vegetation, and even buildings can be quickly washed away. There may be landslides, too, and rivers may break their banks. The following advice can help in the event of a flash flood:

- If you're inside a building, move to the upper floors, taking with you essentials such as bedding, food, and matches. Unless the building is threatened, stay there until the waters have receded or you have been rescued.
- If you're outside, head for higher ground.
- Never walk or drive through a flood.
- Filter and boil water for drinking, as the sources of water around you may have been contaminated. Alternatively, collect rainwater to drink.

ESCAPING A SANDSTORM

If you can see a sandstorm coming, mark your direction of travel before it strikes and find somewhere safe to shelter—for example, behind some rocks. Face away from the direction of the wind and cover yourself as completely as you can, particularly your head, face, and neck.

SURVIVING AT SEA

THE SEA IS ARGUABLY THE HARSHEST environment of all and you could be thrown into a sea-survival situation for any number of reasons: bad weather, fire, mechanical failure, or collision. However, there's plenty of good advice to follow and equipment designed to protect you.

BE PREPARED
If you're venturing onto the open seas, you should plan for the worst and be prepared with knowledge, skills, and equipment.

KNOW YOUR VESSEL

Regardless of the size of your vessel, find out everything you can about what to do in the event of a major problem that requires you to abandon ship and take to the water. The points below are generic and may not apply to all situations or types of vessel.

LARGE PASSENGER VESSELS

If you're a passenger on a large vessel, such as a ferry, liner, or cruise ship, make sure you learn the safety procedures.

- Attend the "Abandon Ship" drills.
- Find out which emergency alarms indicate fire, collision, and abandon ship.
- Find out where the lifejackets are stowed, and how to put them on and operate them.
- Learn the escape routes.
- Locate the Emergency Lifeboat Stations and find out what your responsibilities are.
- If you have children or people with special needs with you, make sure you have a system for getting them on deck and providing them with suitable survival equipment.

SMALL VESSELS

These craft include yachts, small boats, canoes, and kayaks, so crew members need to agree on an emergency plan of action and delegate responsibilities relevant to the situation and the skills of each person.

- Know where the emergency equipment is stowed and how it's operated.
- If your vessel has an EPIRB (see p. 236), make sure everyone knows where it is and how it's operated. Those activated automatically are released hydrostatically from a bracket at a water depth of 3–10 ft (1–3 m). The buoyant EPIRB then floats to the surface and begins transmitting.
- Make sure your EPIRB has been registered so that, once the signal is detected, the rescue services know who it belongs to.
- Keep a grab bag to hand (see box, right).

SURVIVAL SUIT AND LIFEJACKET

A survival suit is designed to keep you warm and dry in extreme conditions and rough seas, and a lifejacket will keep you afloat with your head out of the water, even if you're unconscious.

PROTECTION

Survival suits and lifejackets are equipped with various protection features to help you survive in the sea.

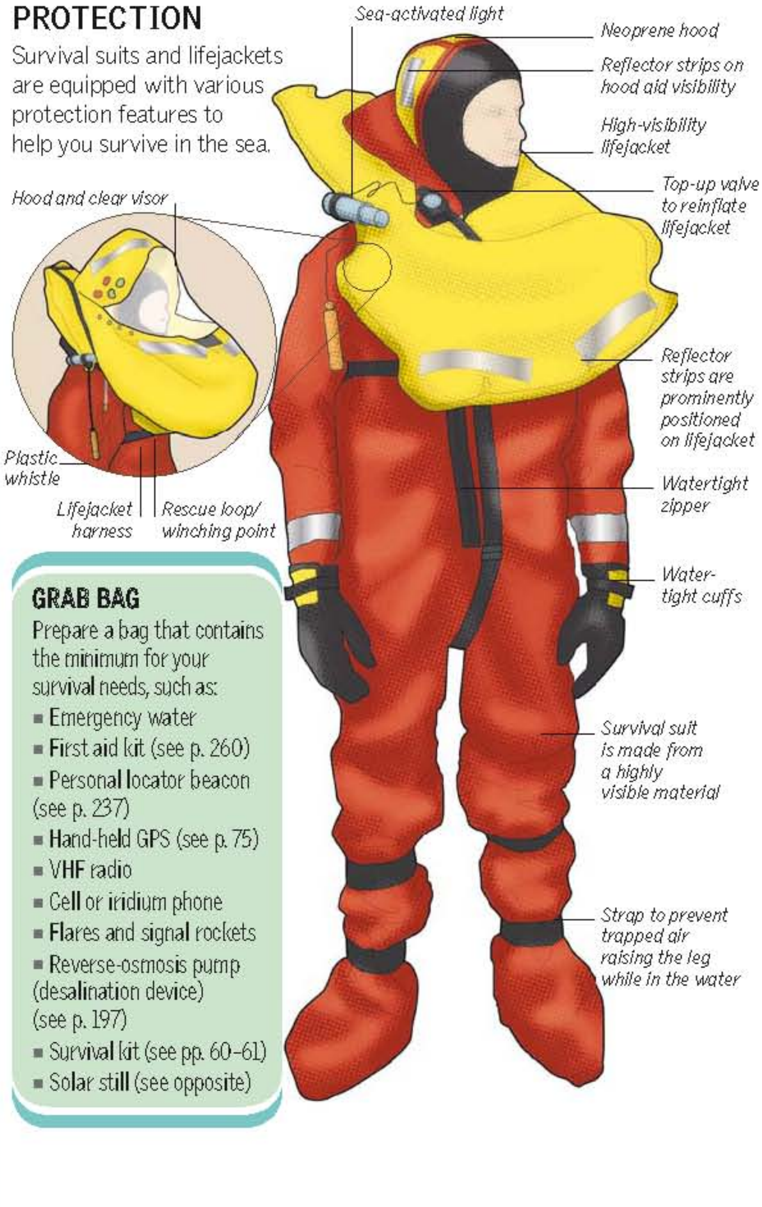

Sea-activated light
Neoprene hood
Reflector strips on hood aid visibility
High-visibility lifejacket
Top-up valve to reinflate lifejacket
Hood and clear visor
Reflector strips are prominently positioned on lifejacket
Plastic whistle
Lifejacket harness
Rescue loop/ winching point
Watertight zipper
Water-tight cuffs
Survival suit is made from a highly visible material
Strap to prevent trapped air raising the leg while in the water

GRAB BAG
Prepare a bag that contains the minimum for your survival needs, such as:

- Emergency water
- First aid kit (see p. 260)
- Personal locator beacon (see p. 237)
- Hand-held GPS (see p. 75)
- VHF radio
- Cell or iridium phone
- Flares and signal rockets
- Reverse-osmosis pump (desalination device) (see p. 197)
- Survival kit (see pp. 60–61)
- Solar still (see opposite)

TYPES OF LIFERAFT

Single-seater and multi-seater liferafts contain similar design features and survival aids. As well as being able to accommodate more people, multi-seaters carry larger quantities of fresh water and more anti-sea sickness tablets, for example.

SINGLE-SEAT LIFERAFT

Only one person can fit into a single-seat liferaft. You can inflate it with carbon dioxide, by pumping air in manually, or by oral inflation.

MULTI-SEATER LIFERAFT

Many vessels carry multi-seater liferafts in a valise or a hard container. Multi-seaters can accommodate between four and 25 people and may be open-topped or covered. Many larger multi-seaters may also include locator beacons (see p. 236), paddles, and a solar still (see below).

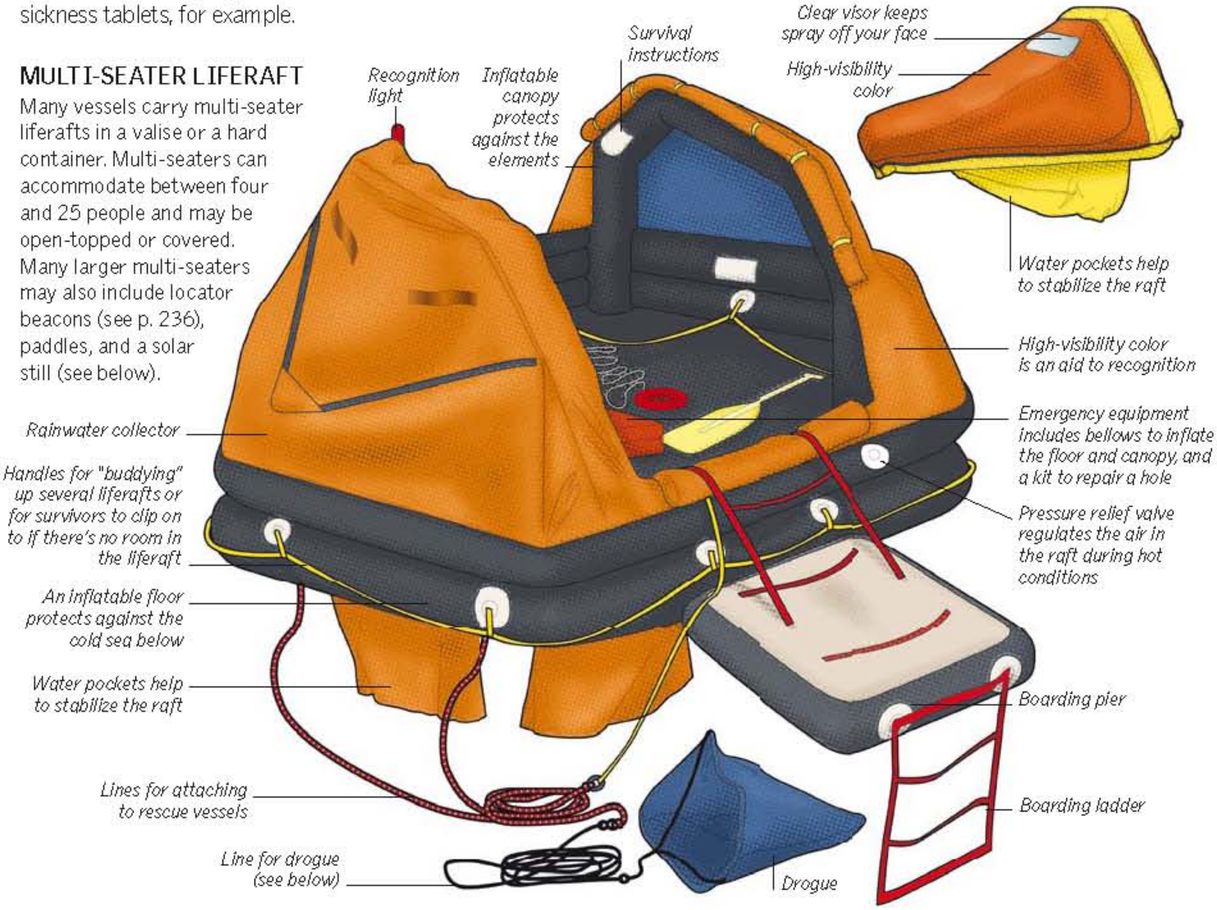
Clear visor keeps spray off your face
High-visibility color
Water pockets help to stabilize the raft
Recognition light
Inflatable canopy protects against the elements
Survival instructions
High-visibility color is an aid to recognition
Emergency equipment includes bellows to inflate the floor and canopy, and a kit to repair a hole
Pressure relief valve regulates the air in the raft during hot conditions
Rainwater collector
Handles for "buddying" up several liferafts or for survivors to clip on to if there's no room in the liferaft
An inflatable floor protects against the cold sea below
Water pockets help to stabilize the raft
Boarding pier
Lines for attaching to rescue vessels
Boarding ladder
Line for drogue (see below)
Drogue

SOLAR STILL

A solar still is a light, compact, and easy-to-use device for producing drinking water from sea water. Heat from the sun evaporates the salty water inside the still. Condensation on the walls collects in a channel around the rim and is directed to a store. Depending on the prevailing conditions and the availablilty of sunshine, a solar still can produce as much as 2 liters ($3\frac{1}{2}$ pints) of fresh drinking water a day.

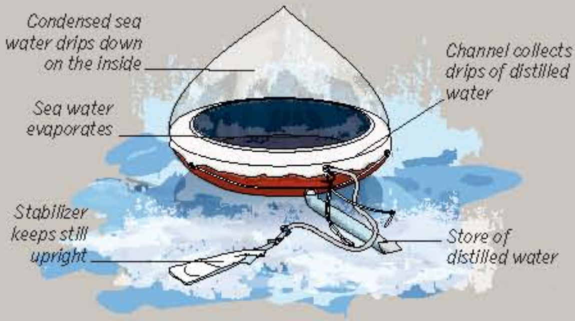
Condensed sea water drips down on the inside
Channel collects drips of distilled water
Sea water evaporates
Stabilizer keeps still upright
Store of distilled water

DROGUE

A sea anchor, known as a "drogue," is a critical piece of equipment because it helps to reduce drift and keeps the liferaft stable and seaworthy, particularly in heavy seas.

STEADYING A RAFT

A drogue stops a liferaft from overturning by creating drag that "anchors" the trailing side of the raft to the water.

- A drogue can position a liferaft either downwind or 90 degrees to the wind.
- It helps to keep the raft near the ditching location, thereby improving the chance of rescue. Even in a 2-knot current a liferaft can drift 50 miles (80 km) a day.

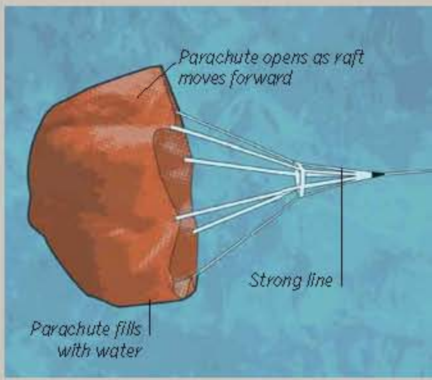
Parachute opens as raft moves forward
Strong line
Parachute fills with water

ABANDONING SHIP

Unless your vessel is an immediate danger to you, don't abandon it until you really need to. Even a badly damaged vessel can provide you with protection from the elements, equipment such as radios and flares, and provisions such as water and food. In addition, it is a big target for rescuers to spot. Make every effort to keep the vessel afloat.

BEFORE ABANDONING SHIP

Where time and circumstances permit, don't abandon your ship until absolutely necessary. Send a May Day signal with your name, position, group size, physical condition, and circumstances. Then carry out the following measures:

- Activate the 406 EPIRB (see p. 236).
- Ensure everyone on the vessel wears layers of clothing, and has a survival suit and lifejacket (see p. 250).
- Check the liferafts are ready for launch.
- Get the grab bag (see p. 250).
- Prepare to take the jerry-cans of water on board the liferafts.
- Fill spare containers with water.
- Gather up as much food as you can.

THE DANGERS THAT AWAIT

When you do decide to abandon ship, you will be faced with the following dangers. If you have prepared yourself properly before heading out to sea, you will—in many cases, at least—be able to deal with them.

- Hypothermia brought on by inadequate clothing and exposure to wet, windy, and rainy conditions.
- Drowning because you have no lifejacket.
- Dehydration caused by a lack of water or an injury.
- Malnutrition due to a lack of food.
- Cold shock (see p. 254) due to sudden immersion in cold water.

TAKING TO THE LIFERAFT

If you have to abandon ship, make every effort to launch all available liferafts. Even the craft that are not used will make it easier for search and rescue teams to detect the "footprint" of the survivors. They also contain additional supplies of water, flares, and other useful items.

- Many liferafts have a painter. This is a line that attaches the liferaft to the vessel to ensure it does not blow away when thrown overboard and inflated.
- Should the vessel sink, the painter has a weak link that breaks under pressure, or you can cut it.

PREVENTING HYPOTHERMIA

Getting wet greatly reduces your survival chances. At 41°F (5°C), a normally dressed person has only a 50 percent chance of surviving for one hour. You are six times more likely to survive in protective clothing.

- Climb into the liferaft carefully so that you don't get wet.
- Wear several layers of clothing to trap air. Even wet layers retain some heat around the body. Don't forget your head, hands, and feet.
- Wear a survival suit (see p. 250) to increase your survival time.

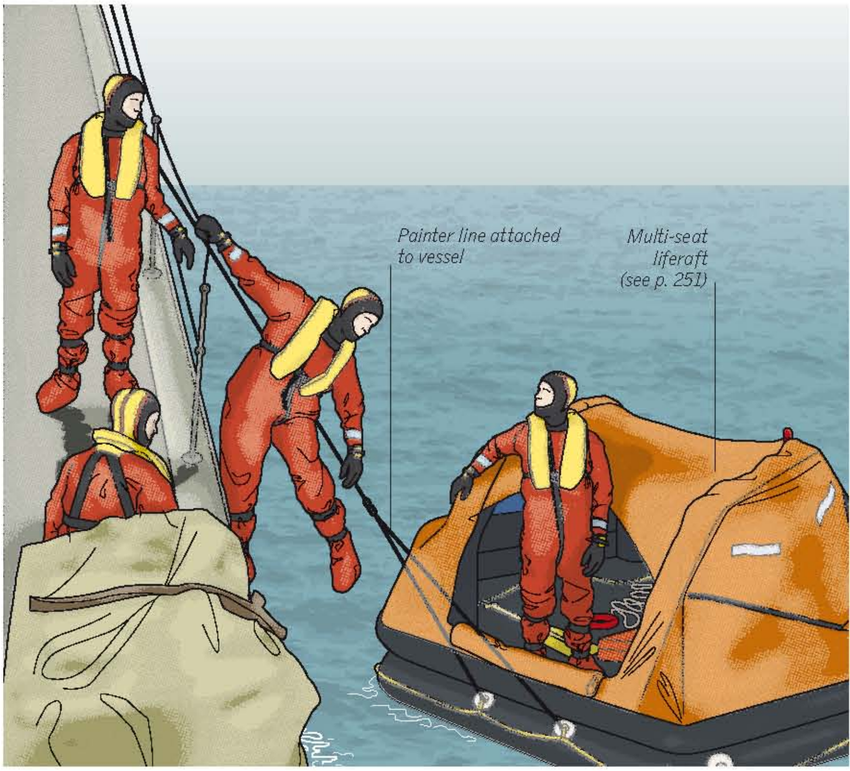
Painter line attached to vessel
Multi-seat liferaft (see p. 251)

① Move slowly and deliberately into the liferaft, keeping out of the water, and trying to stay as dry as possible. If you have to enter the water, climb down or lower yourself into it, rather than jumping.

- Look for the Day-Glo instruction patch inside the liferaft. Follow the recommended advice under "Immediate Actions" (see panel, opposite).

IN THE LIFERAFT

Once you have successfully negotiated the tricky procedure of abandoning ship and climbing into the liferaft, there are a number of actions you need to take. These are prioritized into immediate, secondary, and subsequent.

IMMEDIATE ACTIONS

- Inflate the floor of the liferaft with the bellows, while carrying out a roll call of your group to check for missing members.
- If the vessel is still afloat, keep the raft attached via the painter. Someone should be ready to cut the painter close to the vessel in case it starts to sink.
- Once clear of the vessel, set up the drogue (see p. 251).
- In difficult weather conditions, close the entrances of the raft in order to keep in heat, and keep out wind, rain, seawater, or spray.
- Bale out water, check for leaks, use the sponge to dry the liferaft, and use the leak stopper and clamps if necessary.

SECONDARY ACTIONS

- Treat the injured.
- Take anti-seasickness tablets.
- Post lookouts.
- Bring liferafts together.
- Warm up as best you can.

WARNING!

Never drink seawater, because the salt it contains will increase your rate of dehydration. If you're in hot conditions without any water, dehydration can set in within one hour.

SUBSEQUENT ACTIONS

- Delegate a leader based on experience.
- Find out who has useful skills, such as first aid and sea survival training.
- Ask everyone to look for sharp objects that could puncture the liferaft. At the same time, ask them if they have anything that could have a survival use.
- Find out what survival aids you have. Prepare aids to location (see p. 236) and show everyone how to operate them.
- Establish a routine and detail a watch system for inside and outside the liferaft.
- Delegate one member of the group to make repairs, another to keep the rations, and another to administer first aid.
- Establish how much water and food you have and start to ration in accordance with your particular situation.
- Procure water as soon as possible—don't wait until you need it. Deploy solar stills (see p. 251) and use the reverse-osmosis pump (see p. 197).

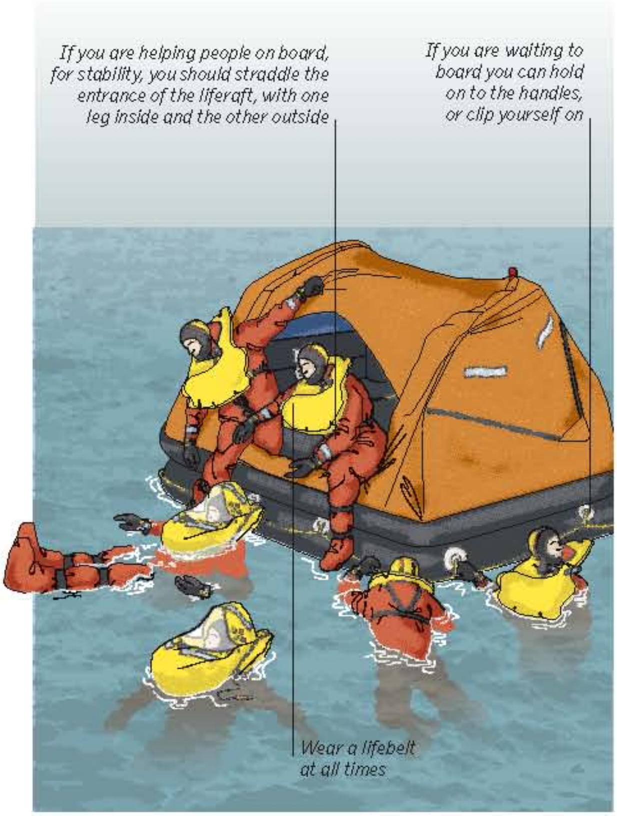
If you are helping people on board, for stability, you should straddle the entrance of the liferaft, with one leg inside and the other outside
If you are waiting to board you can hold on to the handles, or clip yourself on
Wear a lifebelt at all times

2 If your group does end up in the water, the first two people on board the liferaft should help others on, one at a time, lifting them under the arms.

- Don't overload the raft. Those least vulnerable can hang on to the raft's handles, or tie their lifejacket lifeline to one.

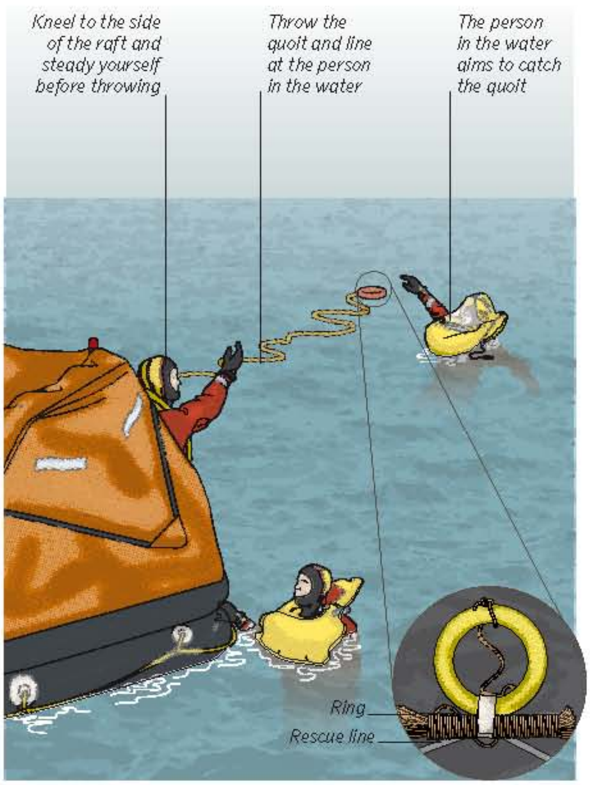
Kneel to the side of the raft and steady yourself before throwing
Throw the quoit and line at the person in the water
The person in the water aims to catch the quoit
Ring
Rescue line

3 Look for anyone who is struggling to make their way toward you. Use the rescue line and ring to pull them to safety in the liferaft.

- Avoid entering the sea unless you have to rescue an unconscious person from the water.

TAKING TO THE WATER

About two-thirds of people who drown in open water were within 10 ft (3 m) of a safe refuge and 60 percent of them were "good" swimmers. Here are some useful tips to prevent drowning.

JUMPING INTO THE WATER

Abandoning ship can be a dangerous procedure. If you have to enter the water, climb down using ropes or nets. If you have no option but to jump into the sea, these straightforward steps should improve your chances of survival. Jumping into the water is a last resort, as you will be prone to cold shock (see box, right) and at immediate risk of hypothermia and drowning. If you have to do it, first ensure your lifejacket is fitted correctly and check the surface of the water to find a safe entry point. Watch out for people, debris, and burning fuel. If you can't avoid the fuel, swim under it and, before coming up for air, poke your hand through the surface to ensure you're clear of it. As you come up, keep your face down to protect your nose, eyes, and mouth.

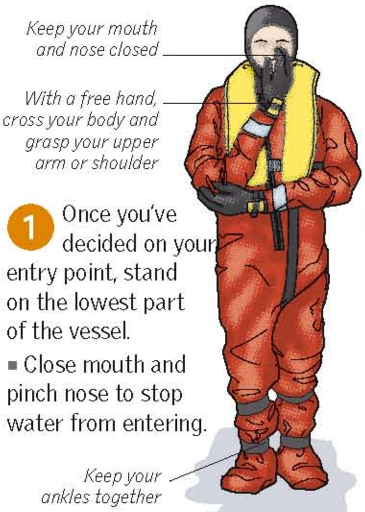
Keep your mouth and nose closed
With a free hand, cross your body and grasp your upper arm or shoulder
Keep your ankles together

1 Once you've decided on your entry point, stand on the lowest part of the vessel.

- Close mouth and pinch nose to stop water from entering.

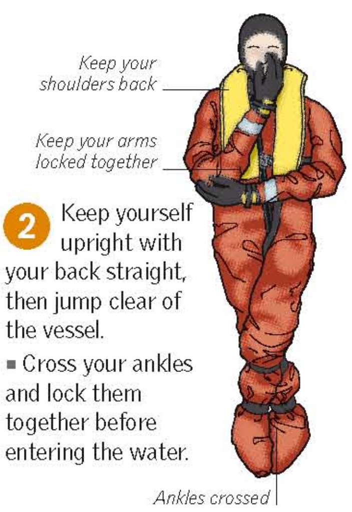
Keep your shoulders back
Keep your arms locked together
Ankles crossed

2 Keep yourself upright with your back straight, then jump clear of the vessel.

- Cross your ankles and lock them together before entering the water.

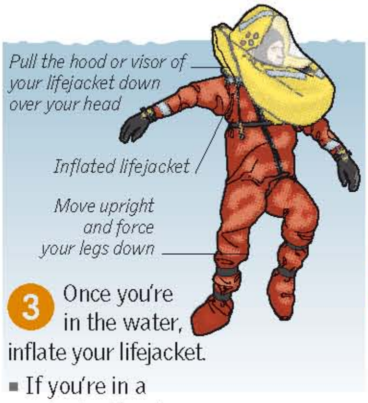
Pull the hood or visor of your lifejacket down over your head
Inflated lifejacket
Move upright and force your legs down

3 Once you're in the water, inflate your lifejacket.

- If you're in a survival suit, raise your arms and gently pull one seal away from your wrist to let the excess air escape.

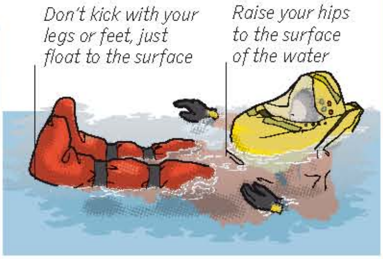
Don't kick with your legs or feet, just float to the surface
Raise your hips to the surface of the water

4 Lie on your back and swim as calmly as you can away from hazards, such as burning fuel.

- Push your head back onto the neck of the lifejacket to help raise your hips.
- Keep your feet and knees together, and use a backward butterfly stroke to swim toward the liferaft.

COLD SHOCK

Cold shock response is the body's reaction to immersion in very cold water—for example, if abandoning a ship in winter in the North Atlantic Ocean. It is a common cause of death in such circumstances. Symptoms include gasping for breath and hyperventilation, which can lead to the inhalation of water, disorientation, panic, and the possible onset of hypothermia. A sudden increase in blood pressure and heart rate can cause cardiac problems in some people. Prolonged immersion in water will make it hard to perform physical movements, making swimming, climbing aboard a liferaft, or firing a flare extremely difficult.

- Body type or mental conditioning can help some people survive swimming in icy water.
- Dressing in layers and/or wearing a survival suit improves your chances of survival.
- Avoid entering the water if you possibly can.

IF YOU HAVE NO LIFERAFT

Even without a liferaft, you stand a better chance of surviving at sea if you're in a group. More survivors create a larger target for rescuers to see, and being with others can be good for morale.

- Collect any floating debris before it disappears with the current, as this can increase your "footprint" so that rescuers can see you more easily.
- Determine what location aids and other equipment are available and prepare these for use.
- If there are children or injured among your group, place them in the center of the group and huddle close together.
- If you are alone, get into a position known as H.E.L.P. (see below), which stands for "Heat Escape Lessening Position." This will help to keep heat within the core of your body.

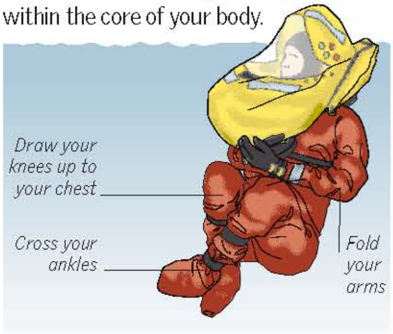
Draw your knees up to your chest
Cross your ankles
Fold your arms

FLOATING FACE DOWN

Don't panic if you have to enter the water without a lifejacket. Your body's natural buoyancy will keep at least the top of your head above water. To keep your face above water, too, make small windmill motions with your arms extended. However, if the water's rough, your only option may be to float face down.

STAY POSITIVE

It's very important to remain positive and to focus on your situation right now rather than on what might happen in a few hours or tomorrow.

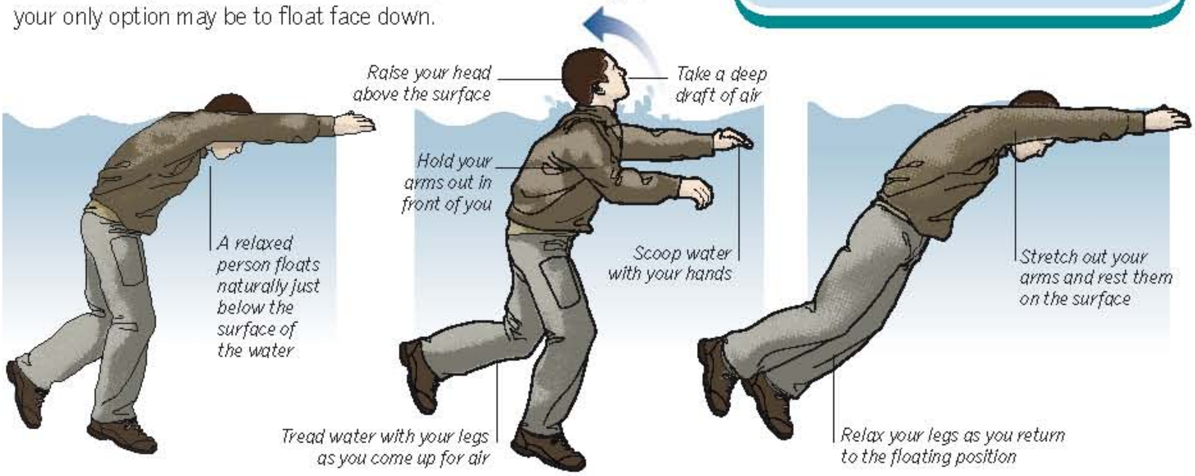
A relaxed person floats naturally just below the surface of the water
Raise your head above the surface
Take a deep draft of air
Hold your arms out in front of you
Scoop water with your hands
Tread water with your legs as you come up for air
Stretch out your arms and rest them on the surface
Relax your legs as you return to the floating position

1 It's important to relax, even though this seems hard when your life is in danger.

- Let your face lie in the water, and put your arms out in front of you.

2 Begin to exhale into the water as you raise your head up.

- Lift your head as it breaks through the surface and empty your lungs completely before inhaling more air.

3 With fresh air in your lungs, duck your face back into the water, keeping your mouth closed.

- Let your body float again, before you repeat the sequence.

IMPROVISING A BUOYANCY AID

If you're in the water and wearing pants, you can improvise a buoyancy aid that will help you to keep your head above water. Initially, it may be awkward to organize, but the benefit outweighs the effort involved.

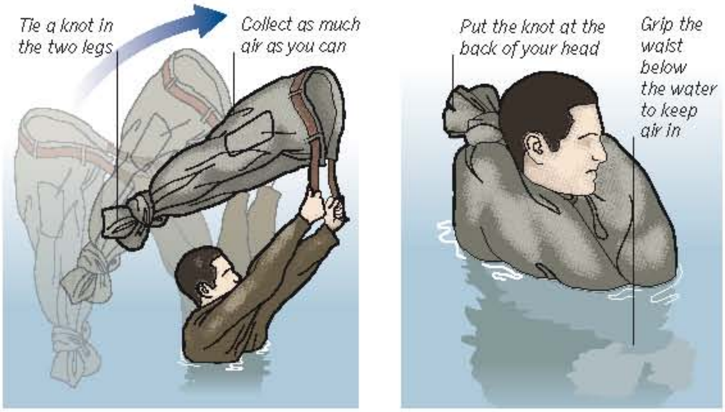
Tie a knot in the two legs
Collect as much air as you can
Put the knot at the back of your head
Grip the waist below the water to keep air in

1 Take off your pants and tie the legs together near the bottom. Tighten the knot as much as you can with your teeth.

- Flick the pants over your head from behind until they fill with air. Tread water as you do this.

2 Quickly catch the waist with your hands and grip it tight to hold air in.

- Put your head between the trouser legs and float.
- You will need to repeat the process regularly.

SECONDARY DROWNING

A person who nearly drowns inhales water that can cause potentially fatal chemical and biological changes in the lungs. This is known as "secondary drowning." It can be caused by inhaling fresh or salty water—even as little as 1fl oz (30 ml). Secondary drowning may occur 24–72 hours after immersion and, while uncommon, it's not rare. Take the following precautions to guard against secondary drowning:

- Monitor anyone who has nearly drowned or has spent some time in water.
- Ask the person to take a couple of deep breaths and check for any pain or discomfort that can't be accounted for.
- Look for symptoms such as coughing, breathing difficulties, chest pain, and saliva that looks like foam.
- Make sure the person is sitting in an upright position.
- If possible, provide oxygen—the blood levels of oxygen can fall quickly—and lots of rest and reassurance.

FIRST AID

FIRST AID

Regardless of the events that put you in a survival situation, a major factor that will dictate your options and actions will be whether anyone has been injured. Someone's survival may depend on the treatment they receive at the time of the incident, and during the ongoing survival ordeal, so it's essential that everyone should be proficient and confident in basic first aid techniques. In a true survival situation, the term "seek medical help" really means "deal with it yourself." While it would be impossible to be able to treat all injuries—a task even a paramedic would find daunting without the right equipment—the vast majority can be either dealt with or stabilized using a combination of basic first-aid techniques and common sense.

The "Protection" element of the survival principles (see p. 27) applies to your situation at all times—you should continually look at the consequences of every action in relation to protection against injury. Prevention is always a better option than cure. In hot climates, being able to recognize the first stages

In this chapter YOU WILL DISCOVER...

- that **maggots** have their **uses**...
- how to **improvise goggles** to prevent **snow blindness**...
- when to **stop**, **drop**, and **roll**...
- how to treat **snake bites** and **jellyfish stings**...
- when to **eat charcoal** or drink **bark tea**...
- how to prevent **frostnip** from becoming **frostbite**...
- when to **perform** a **firefighter's lift**...

of heat stress will allow you to take action with them before they develop into life-threatening dehydration and heatstroke. In cold climates, being able to recognize the first stages of frostnip will allow you to stop it from becoming frostbite. In many cases, further injury can be avoided by adopting the basic principles detailed throughout this book, such as being able to assess the best course of action in a given situation, plan a route and move safely over terrain, and protect yourself against the elements.

The will to survive is often the only factor that determines whether you live or die—regardless of your equipment, training, knowledge, and skills.

WHEN FACED WITH everything that man and nature can throw at you, when there appears to be no hope, you'll be faced with two choices: will you accept your situation and wait and see what hand fate deals you, or will you endure the pain and discomfort and fight for you own survival?

This determination was clearly shown by Aron Ralston during a hike in Blue John Canyon, Utah. After accidentally dislodging a 800 lb (363 kg) boulder, which pinned his right arm, he was faced with a bleak outlook. After five days, aware that no one knew he was missing and having run out of water, Ralston decided to amputate his own arm with his knife, applied a tourniquet, and hiked off to safety.

In another famous example, Simon Yates took the agonizing decision to cut the rope that held his injured climbing partner, Joe Simpson (who Yates thought had died), over a crevasse in the Peruvian Andes. Incredibly, Simpson survived the fall and chose to endure. He spent three days without food and only splashes of water from melting ice as he crawled and hopped the 5 miles (8 km) back over frozen mountainous terrain to reach their camp.

> “The **vast majority** of **injuries** can be either **dealt with** or **stabilized** using a **combination** of **basic first aid techniques** and **common sense**”

FIRST AID ESSENTIALS

SAFETY IS KEY on any expedition. Before you set off, make sure that you and everyone in your party has the necessary medical equipment—especially medications. If someone is injured, he or she should be treated immediately. If you can't contact the emergency services (and if there are enough of you), one person should stay with the casualty while two others go for help.

WARNING!
Protect yourself from danger at all times. You can't help anyone if you become a casualty as well. If the area is unsafe, don't approach the casualty—get emergency help and monitor the casualty's condition from a safe distance.

BASIC FIRST AID KIT

Keep your first aid kit (see panel, opposite) dry and readily accessible. Check the seals on sterile dressings; if they're not intact they're not sterile. Replace anything you use as soon as you can.

PRIORITIES AFTER AN INCIDENT

Assess a situation quickly and methodically. Find out what happened. Check casualties for life-threatening conditions such as unconsciousness or severe bleeding (see p. 264) and treat those first.

- **Response** Is the casualty conscious or unconscious? If the casualty is responding to you, he or she is conscious. Shake the shoulders gently if you're not sure.
- **Airway** Is it open and clear? If the casualty can talk, it is. If he or she is unconscious, open and clear it (see p. 276).
- **Breathing** Is it normal? Treat any difficulty such as asthma (see p. 275). If he or she is unconscious and not breathing, call for emergency help and begin CPR (see p. 277).
- **Circulation** Are there any signs of severe bleeding? If so, treat immediately. Once life-threatening conditions are under control, you can make a more detailed assessment. Examine the casualty methodically from head to toe. Ask how the incident occurred, as it can indicate likely injuries.

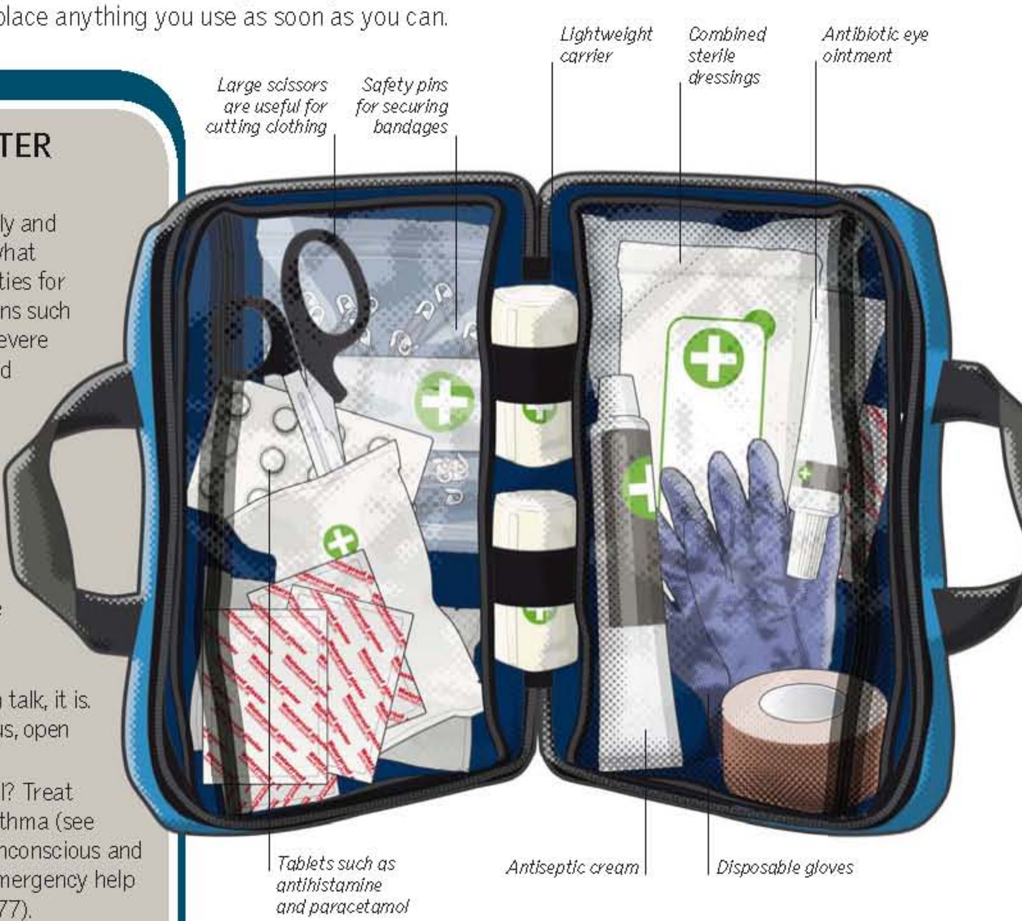
Large scissors are useful for cutting clothing
Safety pins for securing bandages
Lightweight carrier
Combined sterile dressings
Antibiotic eye ointment
Tablets such as antihistamine and paracetamol
Antiseptic cream
Disposable gloves

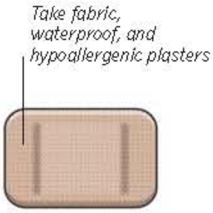
Take fabric, waterproof, and hypoallergenic plasters

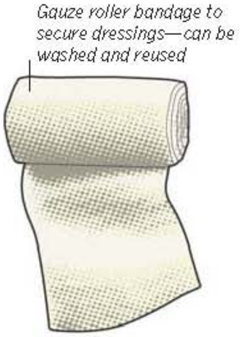
Gauze roller bandage to secure dressings—can be washed and reused

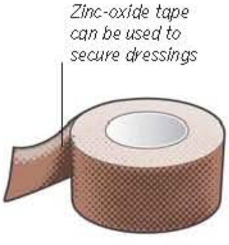
Zinc-oxide tape can be used to secure dressings

IMPROVISED SLINGS

Hand, arm, or shoulder injuries need to be immobilized and supported in a raised position. If you don't have a triangular bandage with you, use a piece of strong cloth about 3 ft (1 m) square, folded in half to form a triangle (see p. 270). You can also use your jacket or even rucksack straps. The jacket corner "sling" is the only one that provides enough support for a hand, wrist, or forearm injury. Ask the casualty to support the arm with his or her other hand while you secure the sling.

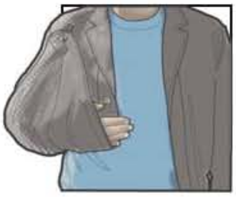

JACKET CORNER
To support an injured forearm or hand, fold the jacket up over the arm and pin it.

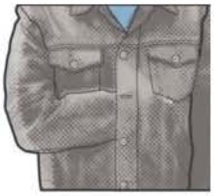

BUTTON-UP JACKET
Undo one of the buttons and slide the injured arm into the opening for support.

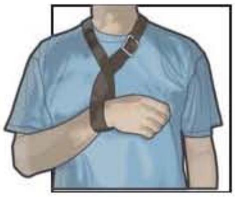

BELT SUPPORT
Support an upper arm injury in a raised position with a belt looped into a figure-eight.

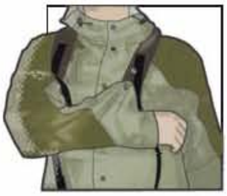

PINNED SLEEVE
Pin a sleeve to a jacket or the strap of a backpack for support.

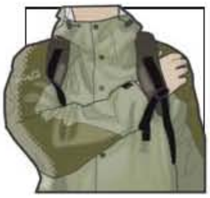

SHOULDER STRAP
Rest a sprain by tucking your hand in your backpack strap.

PROTECTING AGAINST INFECTION

Disposable gloves prevent cross-infection between you and the casualty; they must be latex-free, since contact with latex can cause an allergic reaction. Antiseptic wipes are also invaluable when cleaning wounds.

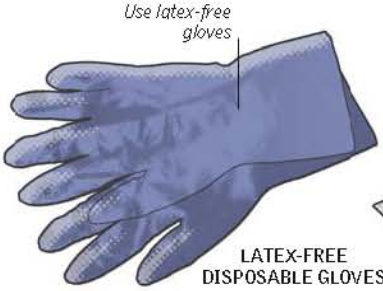

LATEX-FREE DISPOSABLE GLOVES

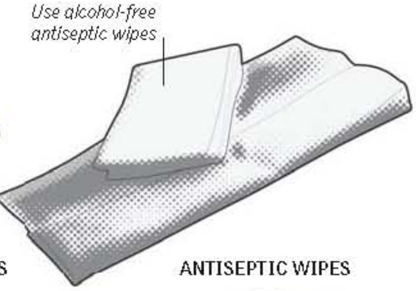

ANTISEPTIC WIPES

COMBINED STERILE DRESSING

This is a sealed dressing consisting of a pad attached to a bandage. It's easy to apply, and can be used as a sling. It should be taped on to your backpack strap for easy access in an emergency.

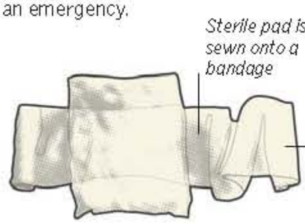
Sterile pad is sewn onto a bandage

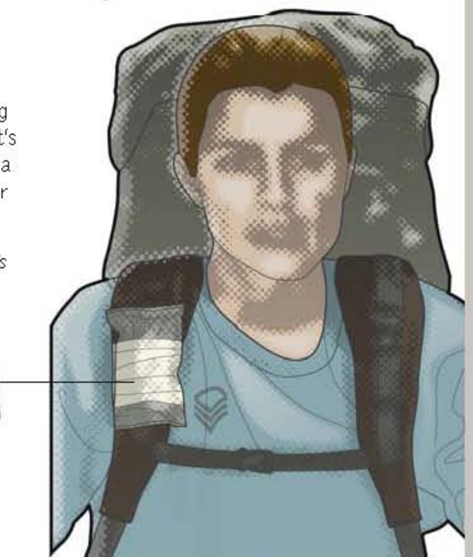

CHECK LIST

Make sure that your first aid kit and medicines are suited to the environment you will be visiting.

BASIC KIT

- Alcohol-free antiseptic wipes
- Latex-free disposable gloves
- Alcohol gel for handwashing
- Antiseptic cream
- Antibiotic eye ointment
- Adhesive dressings—fabric, waterproof, and hypoallergenic
- Gel blister bandages
- Combined sterile dressings, or sterile pads and bandages in assorted sizes
- Roller bandages—take self-adhesive for supporting joints and gauze for securing dressings
- Two triangular bandages
- Micropore or zinc oxide tape
- Scissors and tweezers
- Safety pins
- Disposable syringes

PERSONAL MEDICATION

- Painkillers
- Anti-inflammatories
- Medical alert bracelet/pendant
- Prescription medicines such as asthma inhaler and/or adrenaline (epinephrine) autoinjector
- Antihistamines
- Anti-diarrhea medicine
- Packets of oral rehydration salts
- Hydrocortisone cream

ENVIRONMENT-SPECIFIC EXTRAS

- Malaria tablets
- Mosquito repellent
- Anti-poison-ivy cream
- Sunblock
- Tick remover
- DEET powder for removing leeches

FLESH WOUNDS

ANY INJURY THAT BREAKS THE SKIN carries a risk of infection as germs can enter the body. These can come from the cause of injury, air, dirt, or clothing embedded in the wound. In the wilderness, keeping the injured area clean can be a real challenge, but it is essential. Tetanus is a potentially lethal infection caused by bacteria that live in soil. It can be prevented by immunization, so ensure that your vaccinations are up to date.

MAGGOT THERAPY

If a wound is seriously infected and you have no antibiotics, expose it to flies for one day, then cover. Maggots will develop and eat any dead tissue. Check daily, and flush the maggots out of the wound with sterile water before they start to eat healthy tissue.

BLISTERS AND BRUISING

A blister is a fluid-filled "bubble" of skin that occurs when skin is rubbed repeatedly against a surface (a friction burn). A bruise is bleeding into the skin and surrounding tissue from a blow that does not break the surface of the skin.

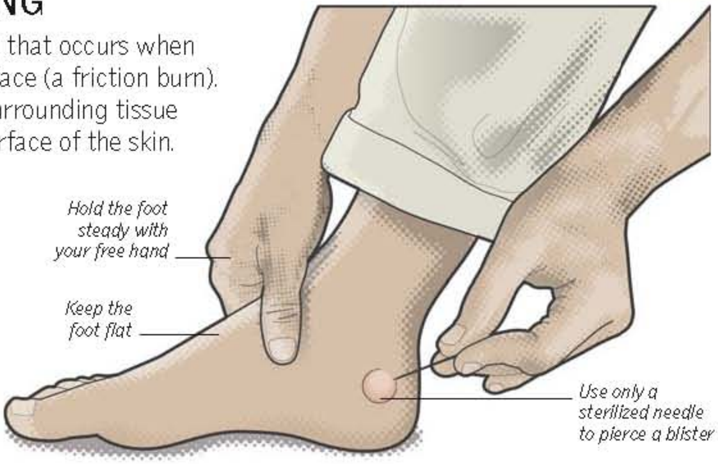
Hold the foot steady with your free hand
Keep the foot flat
Use only a sterilized needle to pierce a blister

HOW TO TREAT BLISTERS

The ideal treatment for a blister is to rest and wait until it has healed, but this may not be possible in a survival situation. Cover it with a gel blister dressing if you have one or, if the blister is large, you may have to pierce it to enable you to continue walking. However, never pierce a blister caused by a burn—you risk infection.

1 If you have to burst a blister, first sterilize a needle by holding it in a flame until it's red hot, then letting it cool.

- Clean the area with water or wipes, pat dry, then pierce the edge of the blister.

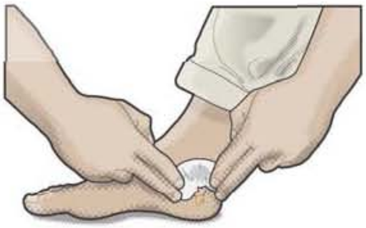

2 Carefully apply pressure to the side of the blister opposite the hole made by the needle. Continue to apply pressure until all of the fluid has been squeezed out.

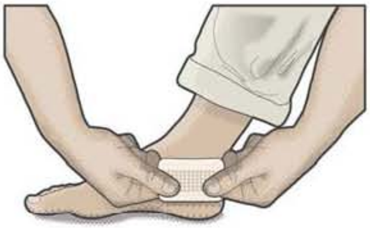

3 Gently clean and dry the blister, then protect the wound from infection by applying a dressing.

- Use a gel blister plaster or padded moleskin, if possible.
- Alternatively, use a pad held in place with zinc-oxide tape.

BLISTER PREVENTION

Following these simple rules when out hiking should prevent blisters from developing in the first place:

- Ensure boots or shoes fit properly and are well "broken in" before you set out.
- Always wear clean, dry, comfortable socks next to your skin. Avoid wearing two pairs as they may bunch up, increasing friction.
- Keep toenails cut short and straight.
- Remove boots and air your feet during rest periods.
- If you feel a "hot spot," treat it before it becomes a problem: stop immediately and apply moleskin, a gel pad, or zinc-oxide tape.

HOW TO TREAT BRUISING

To reduce the swelling and pain of a bruise, raise the injured area, and apply a cold compress. If you have access to cold running water, ice, or snow, soak a cloth and hold it against the bruised area for at least ten minutes. Severe bruising may indicate a more serious injury, such as a broken bone (see p. 271) or internal injury (see Shock, p. 274), which will require immediate treatment.

WOUNDS AND BLEEDING

Severe bleeding can be distressing for both you and the casualty, but it can usually be controlled by a combination of direct pressure and elevation of the injury. Remain calm and reassure the casualty while treating the wound. Treat for shock (see p. 274).

FOREIGN OBJECT IN A WOUND

Any loose foreign objects, such as pieces of dirt or gravel, should be removed from a wound, otherwise they may cause infection or delay healing. Either rinse them off with cold running water or carefully pick loose pieces off the wound with tweezers. However, if an object is embedded in a wound don't remove it, but treat as shown below.

MINOR CUTS OR GRAZES

Any break in the skin, however minor, needs to be cleaned and protected from infection. Rinse the wound with clean cold water and pat it dry. Then cover the injury; the dressing pad must be larger than the wound. For small grazes, use a plaster; for larger ones, use a sterile pad and a bandage.

NATURAL WOUND DRESSING

The birch polypore, or razorstrop fungus, which grows on the sides of old birch trees, can be used as a natural wound dressing. Cut a thin slice from the top of the fungus and secure it over the wound. If you are in any doubt about the identity of the fungus, do not use it.

1 Don't try to remove the object as it may be plugging bleeding. Control bleeding by pressing firmly on either side of the wound.

- Push the edges of the cut together but take care not to press directly on the object.
- Raise the wound above the level of the heart.

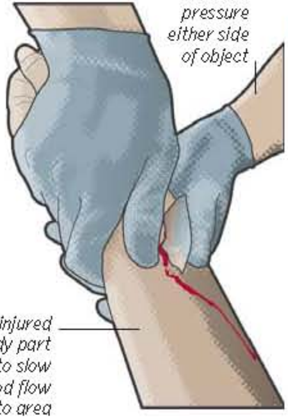

Maintain pressure either side of object

Keep injured body part raised to slow blood flow to area

2 Place a piece of gauze over the object to protect it, then build up padding on either side (rolled bandages are ideal). Bandage over the pads and the object.

- Check the circulation beyond the bandage every ten minutes (see p. 264).

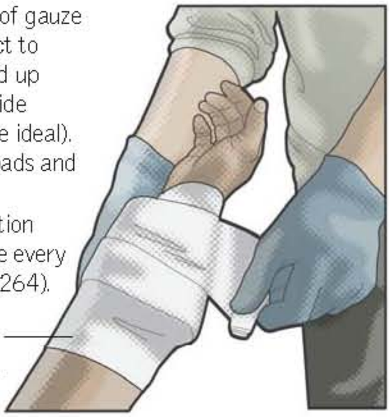

Bandage over the object to prevent further injury

TYPES OF WOUND

Different types of object and force produce different kinds of wound. It's useful to identify the type of wound you or the casualty has incurred so that the correct method of treatment can be applied.

BRUISE (CONTUSION)

A blunt blow will break blood vessels under the skin, causing blood to leak into the tissues. This results in a bruise: the skin is tender, swollen, and blue-black in color.

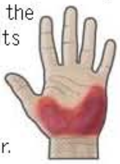

GRAZE (ABRASION)

A friction burn from a rope, or a sliding fall, will scrape off the top layers of skin, leaving a raw, tender area. Grazes often contain embedded foreign matter.

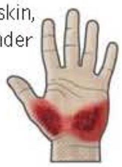

TEAR (LACERATION)

If the skin is torn open, the wound may not bleed as badly as an incised wound, but a larger area of tissue may be damaged and vulnerable to infection.

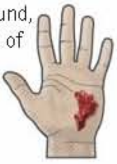

PUNCTURE WOUND

Sharp objects such as nails or sea urchin spines can puncture the skin. The entry hole will be small but the wound will be deep, with a high risk of infection.

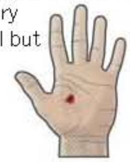

INCISED WOUND

If a sharp-edged object cuts across the skin, blood vessels will be sliced open and bleeding will be severe. Nerves or tendons may also be damaged.

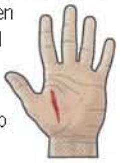

STAB WOUND

A penetrating wound from a long, bladed instrument is a very serious injury. A stab wound to the torso can damage vital organs and cause internal bleeding.

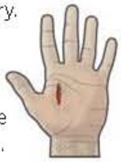

GUNSHOT WOUND

Check if the casualty has an exit wound. Treat entry and exit wounds separately.

ENTRY WOUND

Bullets drive deep into, or through, the body. They leave a small, neat entrance wound and cause serious internal damage and contamination.

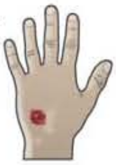

EXIT WOUND

If a bullet passes through the body, the exit wound will be large and ragged. Don't remove the bullet if there is no exit wound.

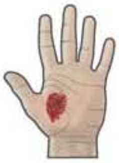

SEVERE EXTERNAL BLEEDING

Control the bleeding with direct pressure over a wound and, if possible, call for emergency help. Never use a tourniquet as this can cause severe tissue damage. Life-threatening shock is likely to develop if blood loss is severe (see p. 274).

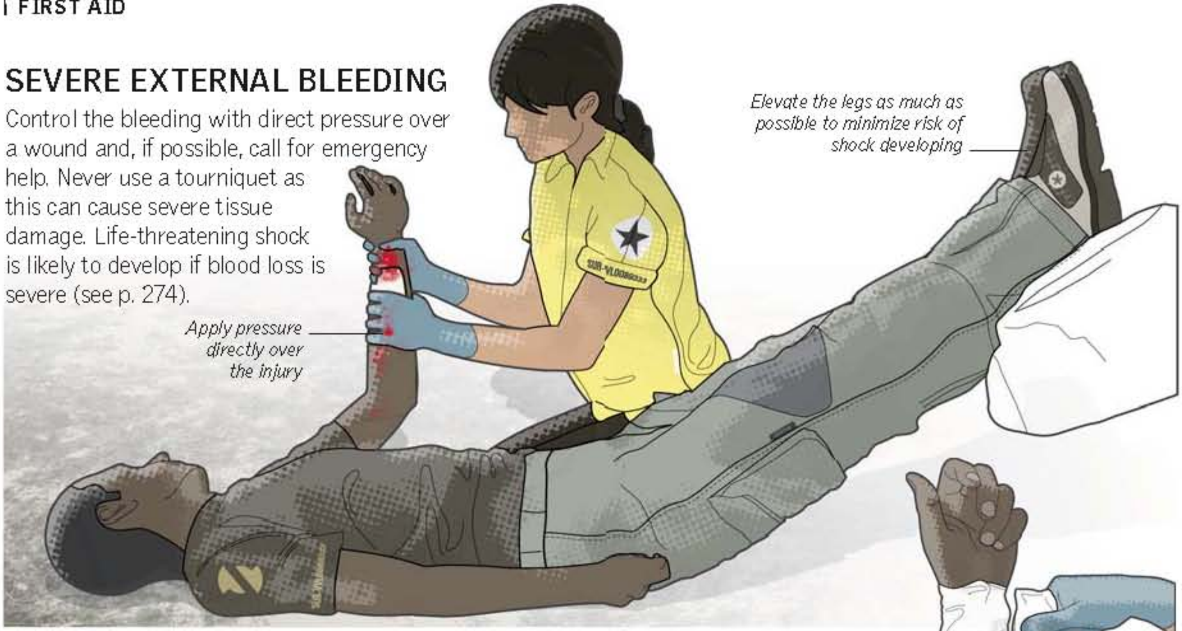
Apply pressure directly over the injury
Elevate the legs as much as possible to minimize risk of shock developing

1 Remove or cut away clothing to expose the wound. Apply direct pressure to the wound, over a sterile dressing or pad if you have one. Raise the injured limb above the level of the casualty's heart to reduce blood flow to the area. Help him to lie down and raise his legs.

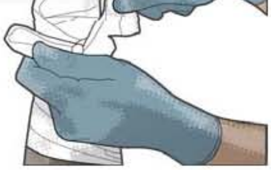

2 Secure the dressing with a bandage. If blood soaks through, apply a second dressing on top of the first.

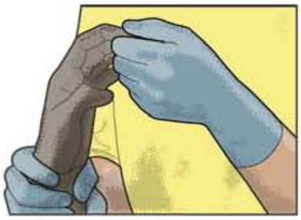

3 Every ten minutes, check the bandage is not too tight. Gently press a fingernail beyond the dressing. If the skin color does not return quickly, rebandage more loosely.

VARICOSE VEINS

When the one-way valves in veins fail, blood pools behind them, causing raised knobbly skin. The taut, thin-walled veins can easily be burst by a knock. Bleeding will be profuse.

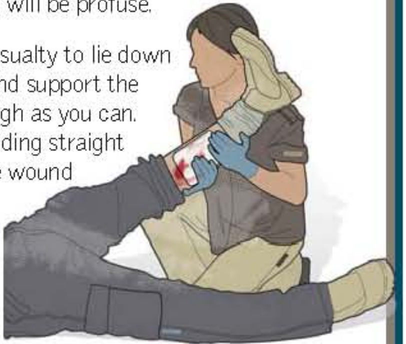

1 Help the casualty to lie down and raise and support the injured area as high as you can. This reduces bleeding straight away. Expose the wound and apply direct pressure over a sterile dressing or pad.

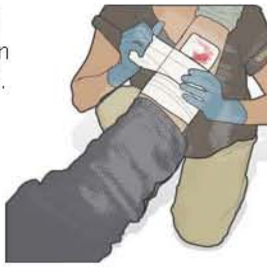

2 Bandage the pad firmly to maintain pressure on the wound. Keep the area raised. Check the bandage is not too tight (see step 3, above). If necessary, loosen it but maintain pressure.

SCALP WOUNDS

A scalp wound can bleed profusely, making it appear worse than it actually is. However, it may mask a more serious head injury. If a casualty becomes drowsy, has a headache, or double vision, get emergency help if possible.

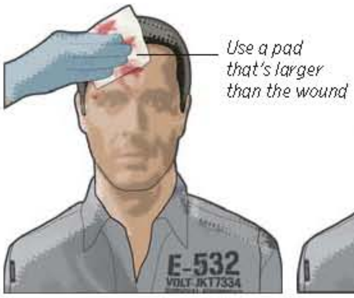
Use a pad that's larger than the wound
E-532
VOLT-JKT7334

1 Sit the casualty on the floor. Carefully replace loose flaps of skin, cover the wound with a sterile pad, and apply pressure.

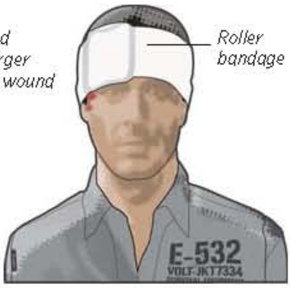
Roller bandage
E-532
VOLT-JKT7334

2 Secure the dressing with a roller bandage. If the casualty doesn't quickly recover or if he deteriorates, get help.

EYE INJURIES

The eye can be seriously injured by a blow or contact with sharp objects, such as a tree branch, risking scarring, infection, or even loss of vision. Always wear eye protection when hiking through dense vegetation.

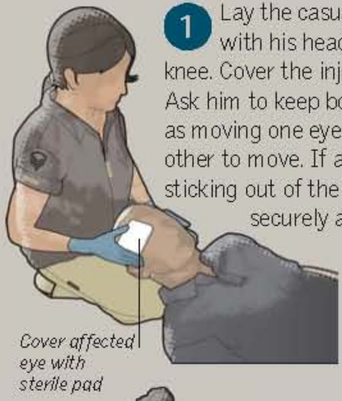
Cover affected eye with sterile pad

1 Lay the casualty down with his head on your knee. Cover the injured eye. Ask him to keep both eyes still, as moving one eye causes the other to move. If an object is sticking out of the eye, pad securely around it.

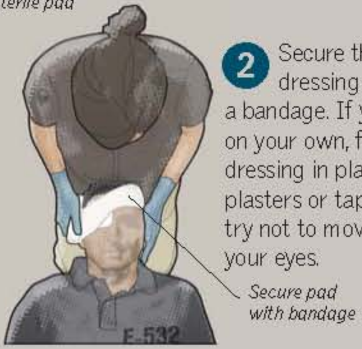

2 Secure the dressing with a bandage. If you're on your own, fix the dressing in place with plasters or tape and try not to move your eyes.

FOREIGN OBJECT IN THE EYE

If you can see an object on the surface of the eye, try lifting it off with the corner of a handkerchief, or wash it out with sterile water, washing away from the good eye. Don't remove anything that is sticking to the eye.

SNOW BLINDESS

Also known as "flash burn," this occurs if the surface of the eye is damaged through exposure to ultraviolet light, such as the glare from sun reflected off snow or water. Wearing sunglasses can prevent this. In an emergency, make your own goggles from cardboard or birch bark. If a person is affected by snow blindness, give him gauze pads to hold against his eyes. Bandage them in place if help is delayed.

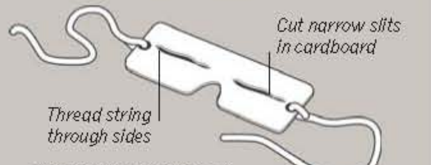
Cut narrow slits in cardboard
Thread string through sides

IMPROVISED GOGGLES

BURNS AND SCALDS

There is a serious risk of infection with all burns. Burns may affect only the outermost layer of skin, the upper layers, or the full thickness. Severe burns will affect all three layers. If the burn is larger than the casualty's hand it needs hospital treatment.

SMALL SUPERFICIAL BURNS

Cool the injury for ten minutes with cold running water or any cold, harmless liquid. Remove jewelry or watches from the affected area before it swells. Cover the burn to prevent infection.

LARGE OR DEEP BURNS

If a burn is extensive or deep, then fluid will be lost from the body and life-threatening shock is likely to develop (see p. 274). If the injury occured in a fire, the casualty could also have burns to his air passages so may have breathing difficulties. Don't burst any blisters as you will increase the risk of infection.

STOP, DROP, AND ROLL

If clothing is on fire:

- Stop moving
- Drop to the ground
- Roll over on the ground until flames are extinguished

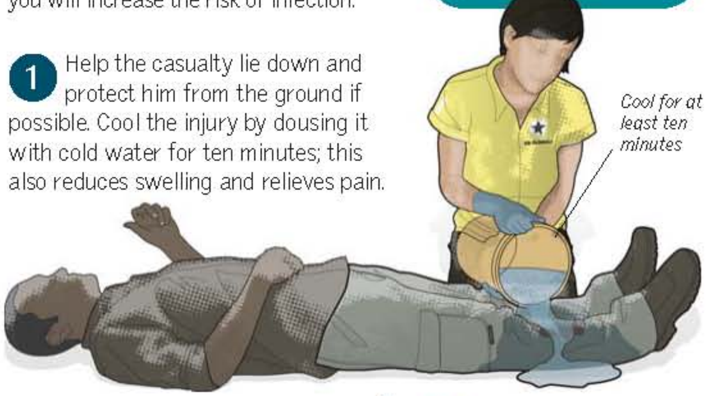
Cool for at least ten minutes

1 Help the casualty lie down and protect him from the ground if possible. Cool the injury by dousing it with cold water for ten minutes; this also reduces swelling and relieves pain.

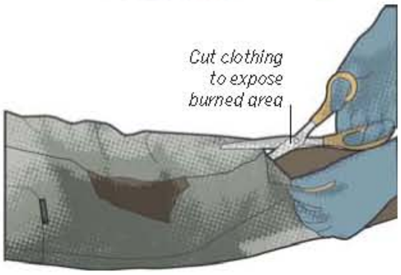
Cut clothing to expose burned area

2 While cooling the burn, remove or cut away clothing from around the burn. Don't touch or remove anything that's sticking to the burn.

3 Cover the entire area with plastic kitchen wrap, a clean plastic bag, or a clean, lint-free dressing. Get emergency help as soon as possible.

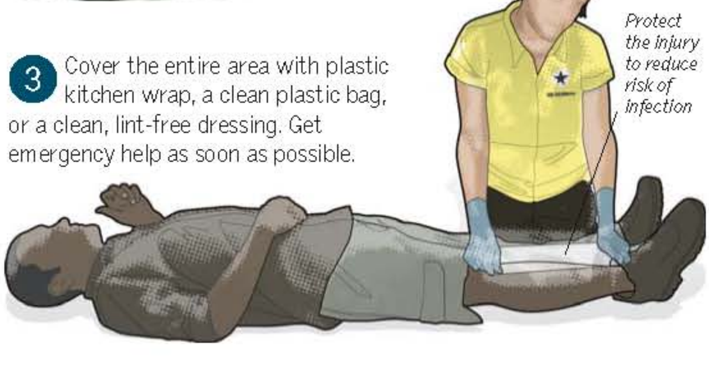
Protect the injury to reduce risk of infection

BITES AND STINGS

MANY BITES OR INSECT STINGS are painful, but most can be treated with simple first aid. However, there is a risk of an allergic reaction called anaphylactic shock. If a casualty develops a red blotchy rash, watery eyes or puffiness around the eyes, and/or breathing difficulties, get urgent medical help (see p. 274).

PORCUPINE QUILLS

If you are pierced by a porcupine's barbed quills, you must remove them or they will continue to work their way into the flesh and may pierce a vital organ.

- Cut off the ends of the quills, which are hollow, to allow them to deflate slightly.
- Pull the quills out, using pliers if you have them.
- Clean the puncture wounds and apply an antiseptic ointment.

TREATING BITES

An injury that breaks the skin carries a risk of infection. This is greatest with animal bites, since the mouth harbors so many germs. For a snake bite, you'll need to get emergency help, as the casualty needs to be transported on a stretcher in the treatment position to prevent the venom spreading through the body.

SNAKE BITES

Relatively few snakes are venomous, but it's generally safer to assume that all of them are. Most snakes cause a painful bite that leaves small puncture marks in the skin; however, the bite of a poisonous snake may in fact be painless. Symptoms also include nausea and vomiting, disturbed vision, and breathing difficulties.

1. Keep the casualty calm. Help her to lie down with her head, chest, and shoulders supported.
   - Advise her to keep still.
   - Make a note, if you can, of the time the bite occurred.
2. Apply a bandage around the site of the injury. Do not wash the area, remove any footwear or clothing, or attempt to suck the venom.
3. Tie another bandage around the affected limb that extends from the bite as far up the limb as possible.
   - Check the circulation (see p. 264).
   - Immobilize the affected limb.
   - Move the casualty only with the use of a stretcher.

MAMMAL BITES

Bites from mammals—animals or humans—carry a serious risk of infection because the sharp teeth cause puncture wounds that transport bacteria deep into the tissue (see p. 263). As always, wear gloves to protect yourself. The bite can also crush surrounding tissue, and bleeding may be severe (see p. 264).

CLEAN WOUND

Raise the injury. Wash the wound with clean gauze and water. Pat dry, and cover it with a wound dressing.

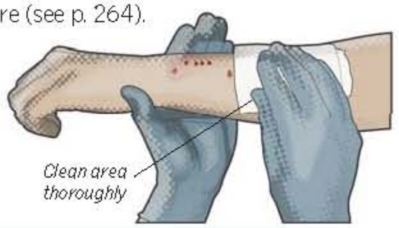

SNAKE IDENTIFICATION

Identify the snake if you can, since this will help medical teams find the correct antivenom. If you're not certain of the identity, make a note of its color or distinguishing features. If it's safe, put the snake in a secure container, but bear in mind that venom is active even if a snake is dead. Don't wash the venom off the bite; it can be used to identify the antivenom.

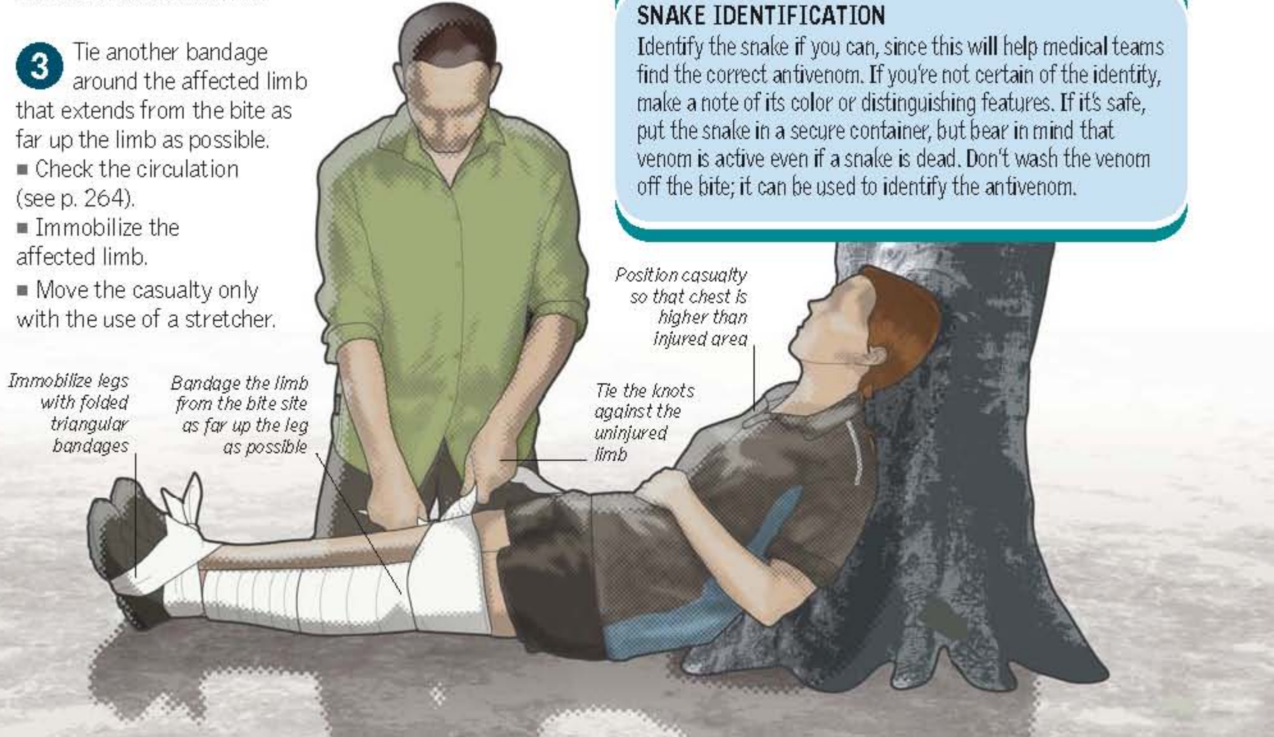
Immobilize legs with folded triangular bandages
Bandage the limb from the bite site as far up the leg as possible
Tie the knots against the uninjured limb
Position casualty so that chest is higher than injured area

TICK BITES

Ticks are tiny, spider-like parasites that live in grass or woodland. They feed on blood, attaching themselves to the skin with spiked mouthparts, and swell to the size of a pea. They carry Lyme Disease, so must be removed.

TRADITIONAL METHOD

Using tweezers, grasp the tick's head as close to the skin as you can. Pull the head upward using steady pressure (don't twist). Keep the tick in a container so it can be checked for Lyme Disease.

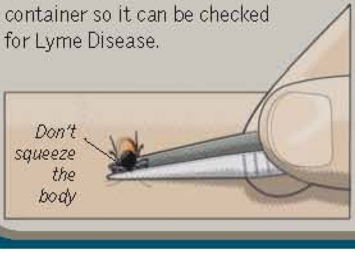

SPECIALIZED REMOVAL HOOK

Tick extractor tools that "unscrew" the mouthparts of the tick from the skin are available from pet shops. Slide the hook along the skin to grab the tick. Raise the hook very slightly and rotate it to lift the tick clear.

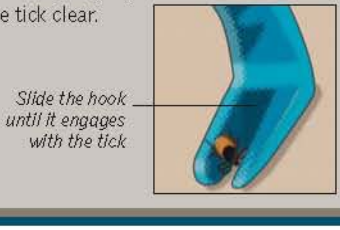
Slide the hook until it engages with the tick

HANDLING LEECHES

When in leech-infested territory, inspect your clothing and limbs every few minutes. Never pull a leech off if it's attached, as the jaws will remain in the skin and cause infection. To remove:

- Apply the juice of a raw lime, DEET, alcohol, or a dash of salt. If you're a smoker, put your cigarette butts in a piece of cloth, moisten the cloth, and squeeze nicotine onto the leech.
- Once the leech has dropped off, wash the area to remove the anticoagulant in and around the wound. Treat any bleeding (see p. 263) and cover the wound.

TREATING STINGS

Many stings are painful, but they are rarely life-threatening. Scorpion stings can be very painful and cause severe illness, and treatment should be as for snake bite (see opposite). Multiple insect stings of any type can produce a more serious reaction (see anaphylactic shock, p. 274).

WARNING!
A sting in the mouth or throat can cause swelling that blocks the airway. To minimize this, give the casualty cold water to sip.

INSECT STING

A bee, wasp, or hornet sting is often painful and followed by swelling and redness at the site. Some people have an allergy to stings, so monitor the casualty for signs of anaphylactic shock.

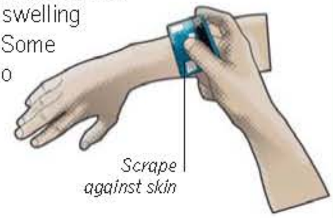

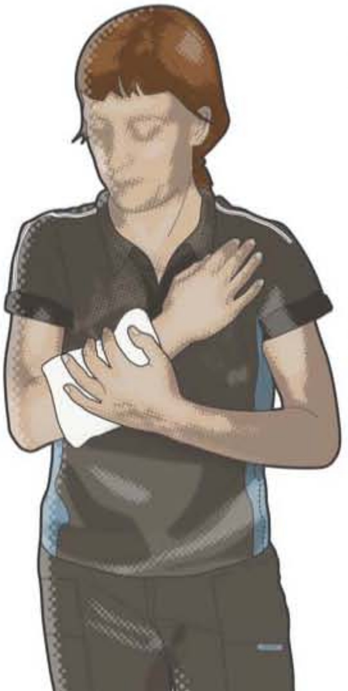

1. If the sting is visible, scrape it off sideways with the edge of a credit card, knife, or a fingernail.
   - Don't squeeze the sac as you may squeeze more venom into the area.
2. Raise the affected part and place a cold pad against it for at least ten minutes to minimize swelling.
   - Monitor the casualty for signs of allergy such as wheezing, or swelling around the face.

SEA CREATURES

When touched, sea anemones, corals, jellyfish, and Portuguese men-of-war release venomous cells that stick to the skin. Treat jellyfish stings as below; apply a cold compress to other stings to minimize swelling and relieve pain. Creatures such as weever fish have sharp spines that, if trodden on, become embedded, and may become infected.

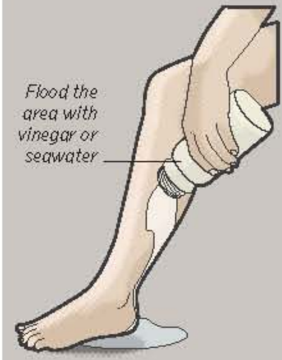
Flood the area with vinegar or seawater

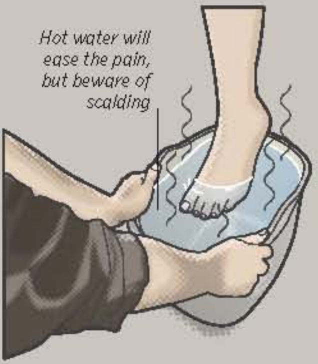
Hot water will ease the pain, but beware of scalding

JELLYFISH STING

Pour vinegar or seawater over the area to neutralize the sting. Help the casualty to sit down; treat as for snake bite (see opposite).

SEA URCHIN SPINES

Immerse the injured part in water as hot as the casualty can tolerate for about 30 minutes. Get medical help, as the spines must be removed.

POISONOUS PLANTS AND INTESTINAL PARASITES

IT'S ESSENTIAL TO MAINTAIN personal hygiene in camp, to purify all drinking water from natural sources (see pp. 198–201), and to observe the rules of food safety if you wish to remain healthy in the wilderness. You should also learn how to recognize and avoid the poisonous plants in the region you're traveling in.

CONTACT POISONING

Poisonous plants don't always have to be ingested to cause damage. If they come into contact with the skin, the result can be pain, swelling, redness, a rash, and itching. Get medical help fast and, in the meantime, rinse the skin with cold water for 20 minutes. If the water splashes an eye, rinse for ten minutes. Although plants are the most common cause of contact poisoning, chemicals such as camp fuel can also be harmful.

WARNING!

If you think you've handled a poisonous plant, don't touch especially sensitive parts of your body such as the eyes, mouth, or genitals until you have washed your hands thoroughly.

- If you develop blisters on your skin, don't scratch them—however much they itch. If you break the skin, you'll run the risk of getting an infection.
- As well as painful blistering, some people may have an extreme reaction to the toxin. They should be monitored and treated for shock (see p. 274). Get medical help as soon as possible.

POISONOUS PLANTS

Poison ivy, poison oak, and poison sumac are the most well known of the plants that contain urushiol, an irritant oil. If you damage the plant and get the oil on your skin, you must wash it off immediately with soap and cold water. You should also remove and wash any contaminated clothing to prevent the oil spreading. Apply an anti-poison-ivy cream as soon as possible. Many people will develop an itchy rash and often painful blistering within 4 to 24 hours of contact with the plant (see warning panel, above).

POISON SUMAC

Found in wet acid swamps in eastern North America, poison sumac can grow as tall as 18 ft (6 m).

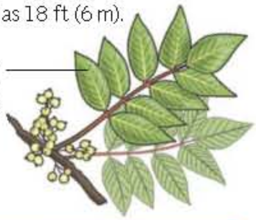

Oval leaflets grow in opposite pairs

STINGING NETTLES

Found in many countries, stinging nettles usually cause only a temporary stinging sensation where the plant's hairs touch the skin. Apply a soothing cold compress or rub the affected area with a dock leaf if you can find one. Watch for an itchy red rash that indicates an allergic reaction.

POISON IVY

Native to wooded areas of North America, poison ivy is now found worldwide.

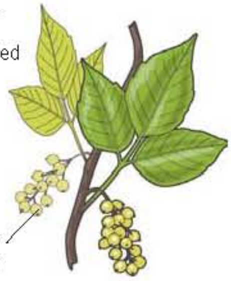

Berries are white when ripe

POISON OAK

Like poison ivy, the leaflets of poison oak grow in threes. This plant is found in wooded parts of North America.

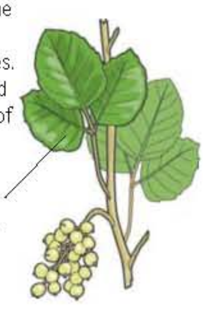

Leaflets are shaped like oak leaves

NATURAL REMEDIES

Where nature causes a problem, she sometimes provides the solution. The following counter the effects of urushiol:

- Jewelweed has a sticky juice that will dry out blisters in a few days. Cut a piece of stem, split it down the middle, and rub the pieces on the affected skin.

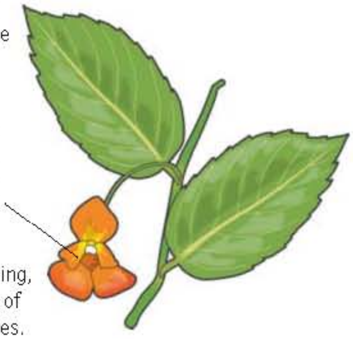

Jewelweed has distinctive pale yellow or orange, spotted flowers

- To soothe itching, make a poultice of witch hazel leaves. Mash up the leaves, adding water if too dry, then apply to the affected area.
- Try washing with a tannic acid solution. Tannic acid is found in tea, or you can make it from oak bark (see opposite).
- Tea tree oil, from the leaves of the melaleuca tree, is also said to counter the effects of urushiol. Apply directly to the affected area.

SWALLOWED POISON

Try to find out what the casualty ingested, how much, and when. If you suspect the casualty has swallowed a caustic chemical, such as camp fuel, do not induce vomiting as it will burn again on the way back up. Get medical help and monitor the casualty. If the lips are burnt, give frequent sips of cool milk or water. If you know the casualty has swallowed a poisonous plant or fungus and he or she is conscious, induce vomiting by tickling the back of the throat. Dilute the poison by getting him or her to drink large quantities of water or milk, or tea mixed with charcoal.

DIARRHEA AND VOMITING

In the wilderness, diarrhea and vomiting can kill, because they lead to dehydration (see p. 272) or even shock (see p. 274). The most likely causes are food poisoning or drinking contaminated water, although infectious diseases are a possibility, so get medical help if symptoms persist. You should rest, keep warm, and replace lost fluids. If you're hungry, you can eat small amounts of bland foods such as pasta for 24 hours.

NATURAL REMEDIES

In a survival situation, there are various natural remedies you can try to stop diarrhea or alleviate symptoms such as stomach pain, although some are more palatable than others:

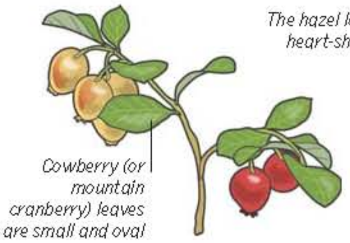

Cowberry (or mountain cranberry) leaves are small and oval

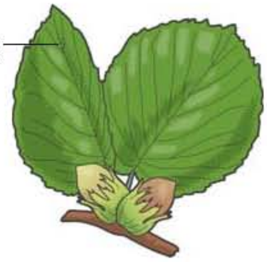

The hazel leaf is heart-shaped

- **Tea:** Drink tea made from hazel, cowberry, or cranberry leaves.
- **Bark:** Pull some bark off a tree (preferably oak), remove the inner bark and boil it for at least 12 hours, adding more water as necessary. The resulting black brew smells and tastes vile, but it contains tannic acid and will cure diarrhea. Drink one cup every two hours.
- **Charcoal**: Take a partially burned piece of wood, scrape off the char, then swallow about a handful with water.
- **Bones:** Burn to ashes then grind, or grind bones into a powder between two rocks. Make a paste with water, then swallow about a tablespoonful.
- **Chalk:** Grind into a powder, mix with water to a paste, then swallow about a tablespoonful.
- **Ash:** Make a paste of wood ash and water, then swallow. This will alleviate stomach pain.

REST AND REHYDRATE

Drink water to maintain your fluid levels. To help replace lost salts, dissolve a packet of rehydration salts in the water, or one teaspoon of salt in a liter of water, before drinking.

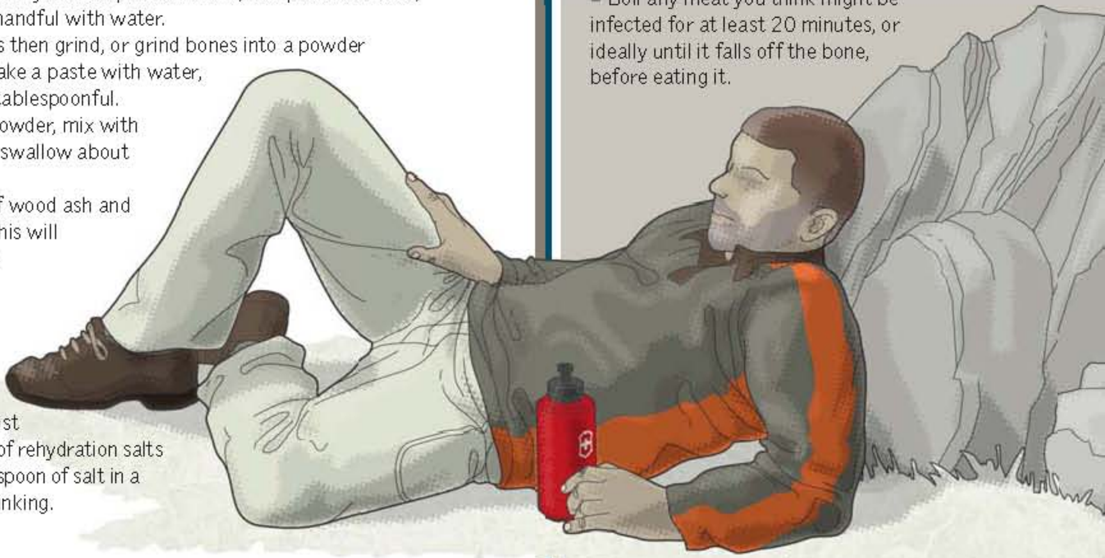

INTESTINAL PARASITES

There are two main types of intestinal parasite: helminths (tapeworms, pinworms, and roundworms) and protozoa (giardia, for example). The usual causes of infection are ingesting contaminated water or food, or poor personal hygiene. Symptoms include nausea or vomiting, diarrhea (see left), dysentry, bloating, stomach pain, weight loss, or a rash or itching around the rectum. Seek medical advice as soon as possible.

WILDERNESS CURE FOR WORMS

If you have passed a worm in your stool, swallow a couple of tablespoons of kerosene. While this method may make you sick, it will make the worms sicker. Gasoline will also work but is not as effective.

HOW TO AVOID BEING INFECTED

Prevention is far better than cure and to avoid being infected by parasites present in water or spread in feces you should always do the following in the wilderness:

- Boil all water, or use other reliable methods of purification (see pp. 198–201).
- Don't clean your teeth or rinse your mouth with water that isn't pure.
- Don't swim or stand in rivers or lakes in places where you could be at risk unless absolutely necessary.
- Cover any cuts or wounds on your skin.
- Maintain strict personal hygiene in camp (see pp. 116–17) and when handling food.
- Boil any meat you think might be infected for at least 20 minutes, or ideally until it falls off the bone, before eating it.

BONES, JOINTS, AND MUSCLES

IT CAN BE DIFFICULT TO TELL whether an injury is a sprain, a broken bone, or a dislocation. The ends of broken bones can move, damaging blood vessels or nerves nearby, so treat the casualty in the position found and immobilize the injured area before letting him or her move. Anyone with a spine injury or broken leg must be carried by stretcher.

SPRAINS AND STRAINS

A strain is a pulled muscle. A sprain occurs when ligaments that hold a joint together are damaged. The ideal treatment is to raise the injury, cool, and rest it. If you provide comfortable support, gentle movement can help the injury. If in any doubt, treat the injury as a broken bone (see opposite).

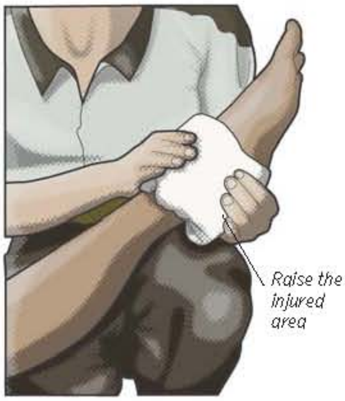
Raise the injured area

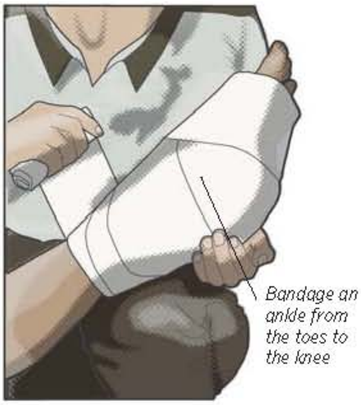
Bandage an ankle from the toes to the knee

1. Rest and support the injury. Wrap a cold compress around it for at least 10 minutes to reduce swelling and bruising.

2. Leave the compress in place, or wrap padding around the injury. Apply a crêpe bandage from below the injury to the next joint.

ARM INJURY

Falling onto an outstretched hand can cause a broken wrist, forearm, upper arm, or collar bone. Support the affected arm in a sling. If a casualty can't bend his arm, he may have injured his elbow, in which case don't use a sling. Instead wrap padding around the joint and secure the arm to the body with triangular bandages. To make sure that the bandage isn't too tight, check the wrist pulse.

USING A SLING

Slide a triangular bandage between the arm and the chest. Bring the front up over the arm and tie a reef knot on the uninjured side.

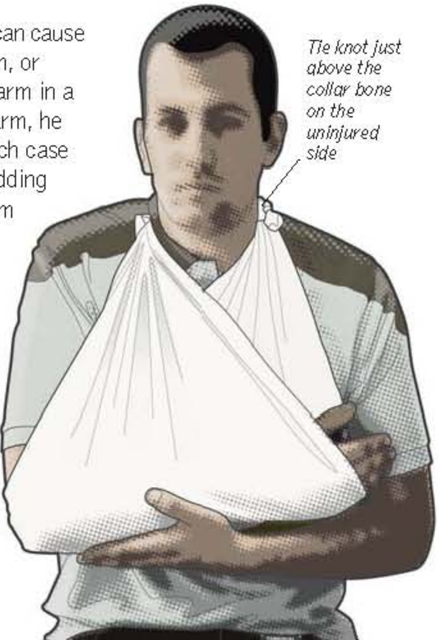
Tie knot just above the collar bone on the uninjured side

CRAMP

This painful muscle spasm can be caused by dehydration and a reduction of body salts through perspiration—so make sure you have enough to drink when exercising. Sit down, rest, and stretch the affected muscles.

FOOT

Help the person stand on his good foot and stretch the muscles to reverse the spasm. Once the cramp has eased, massage the affected area of the foot.

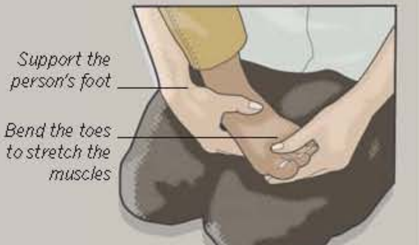
Support the person's foot
Bend the toes to stretch the muscles

CALF

Sit the person down and support the affected leg. Help him to straighten his leg, and flex his toes to reverse the spasm. Then massage the painful muscle.

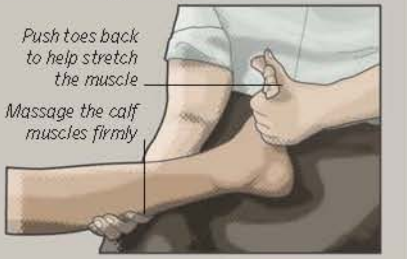
Push toes back to help stretch the muscle
Massage the calf muscles firmly

THIGH

If the cramp is in the back of the thigh, straighten the leg to stretch the muscle; if it's in the front of the thigh, bend the leg. Once the pain eases, massage the affected area.

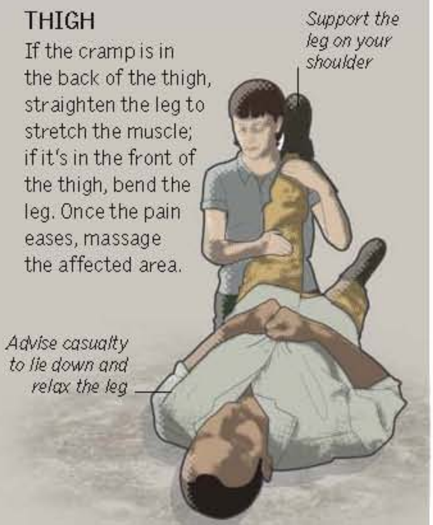
Support the leg on your shoulder
Advise casualty to lie down and relax the leg

LEG INJURY

Injuries to the legs can be serious, as any fracture is likely to be unstable, which means that the ends of the bones can move easily, and could pierce one of the large blood vessels in the leg, resulting in severe bleeding. Don't move the casualty unless you have to, and, even then, only when the legs have been immobilized. If you see any signs of shock (see p. 274) ensure the head is low, but do not raise the legs.

HAND INJURY

Injuries to hands are often complicated by bruising or bleeding. Raise the injured hand and treat bleeding with direct pressure (see p. 264). Remove jewelry before the area starts to swell. Wrap the hand in padding and support it in a raised position with a sling.

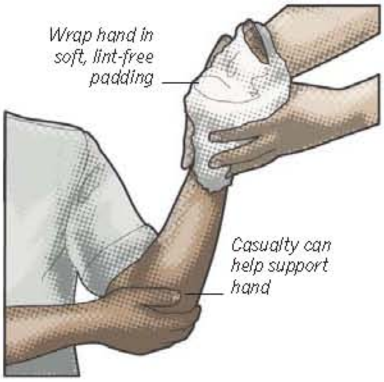

Wrap hand in soft, lint-free padding

Casualty can help support hand

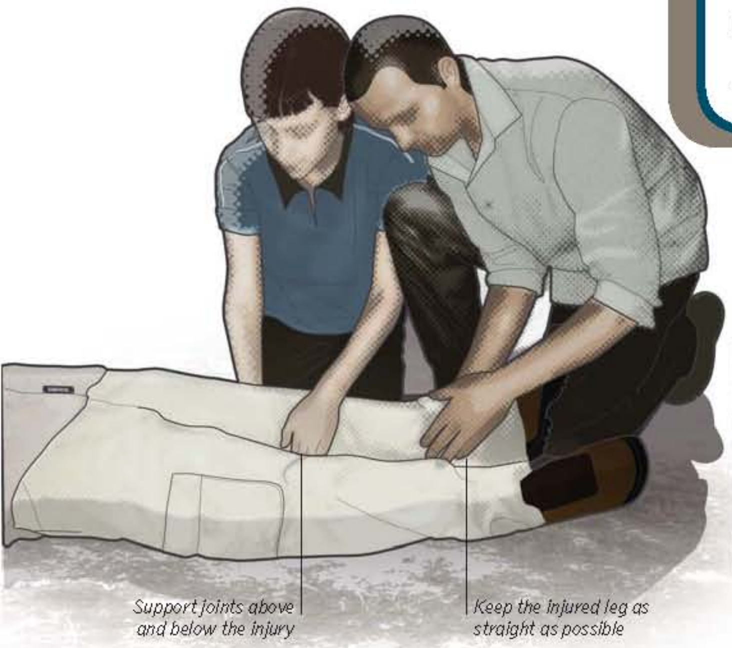

Support joints above and below the injury

Keep the injured leg as straight as possible

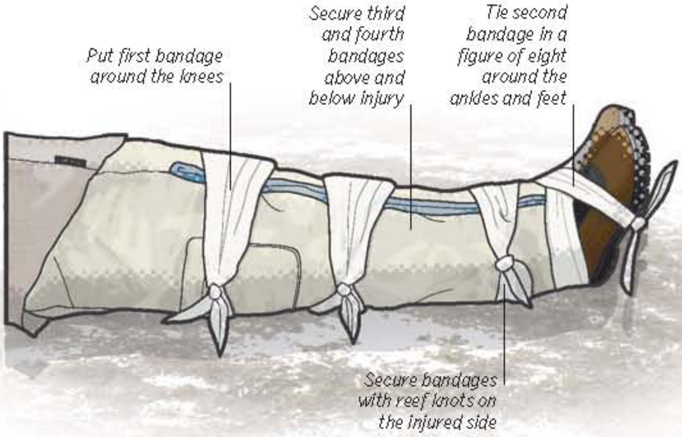

Put first bandage around the knees

Secure third and fourth bandages above and below injury

Tie second bandage in a figure of eight around the ankles and feet

Secure bandages with reef knots on the injured side

1. Lay the casualty down and support the injury to minimize further damage. Call for emergency help. If this is nearby just maintain this support. You can put rolled-up coats or blankets on either side for extra support.

2. If help is delayed or you need to transport the casualty, put bandages around the knees and ankles (and pelvis, if the thigh is injured), and above and below the injury. Place padding between the legs, then tie the bandages.

SPINAL INJURY

If a person falls and lands on his back, or falls from a height, it is best to assume that he has a spinal and, probably, a head injury. Don't move him—support his head and neck in line with the rest of his back. Moving him could damage the spinal cord, which may result in permanent loss of movement below the injured area. Call for emergency help, or send someone to get help while you stay with the casualty. If you have to move him because he is in danger, use the log-roll technique (see p. 279).

SUPPORT THE HEAD AND NECK

Kneel or lie behind the casualty's head. Keep your arms steady by resting your elbows on your thighs and place your hands on either side of his head to keep it in line with his body. Wait for help.

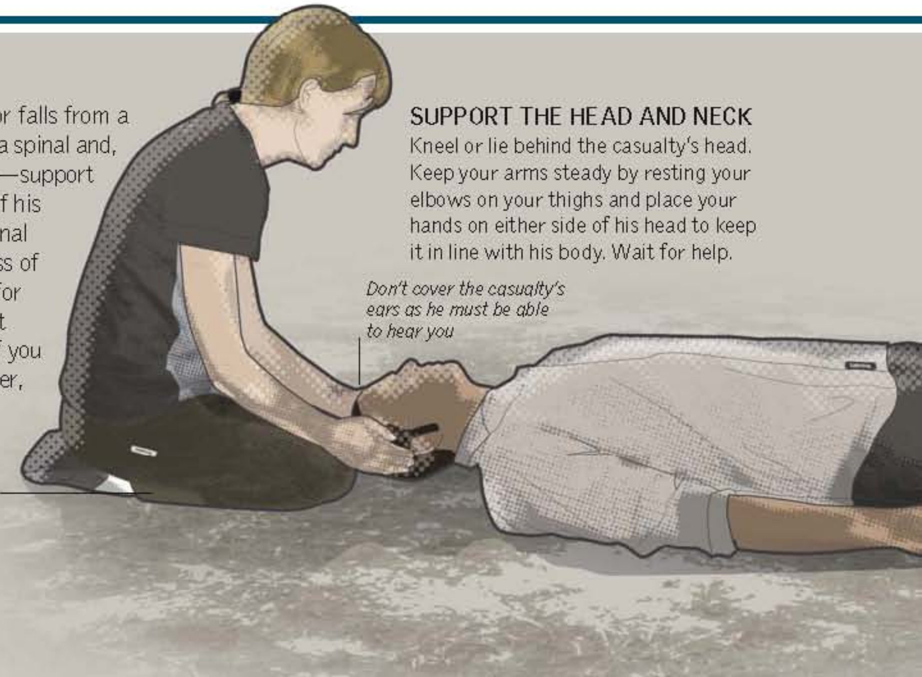

Don't cover the casualty's ears as he must be able to hear you

Make sure you are comfortable because you may have to wait for help to arrive

TREATING EXPOSURE

EXTREMES OF HEAT AND COLD can prevent the body's temperature-regulation mechanisms from functioning properly. Both extremes can cause life-threatening injures, so it's vital to act quickly. Don't leave a casualty—call for help or, if possible, send someone to seek help while you treat him or her.

WARNING!
If a casualty becomes unconscious, be prepared to give cardiopulmonary resuscitation (see p. 277).

HEAT INJURIES

In hot weather, wear a hat, reapply sunscreen frequently, and stay in the shade when you can to avoid heat injuries such as sunburn. You'll quickly become dehydrated if you don't drink enough water to replace fluids lost through sweating.

DEHYDRATION

Help the casualty to sit down and give him fluids to drink; water is usually sufficient, but rehydration salts mixed with water is best. If the casualty complains of cramp, help him stretch the affected muscles, then massage them firmly (see p. 270).

HEAT EXHAUSTION

If a casualty feels dizzy and starts to sweat profusely, but has cold, clammy skin, get him into the shade and give him fluids to drink. Help him to lie down then raise his legs—support his feet on a backpack—to help improve blood flow to the brain. Monitor him while he recovers.

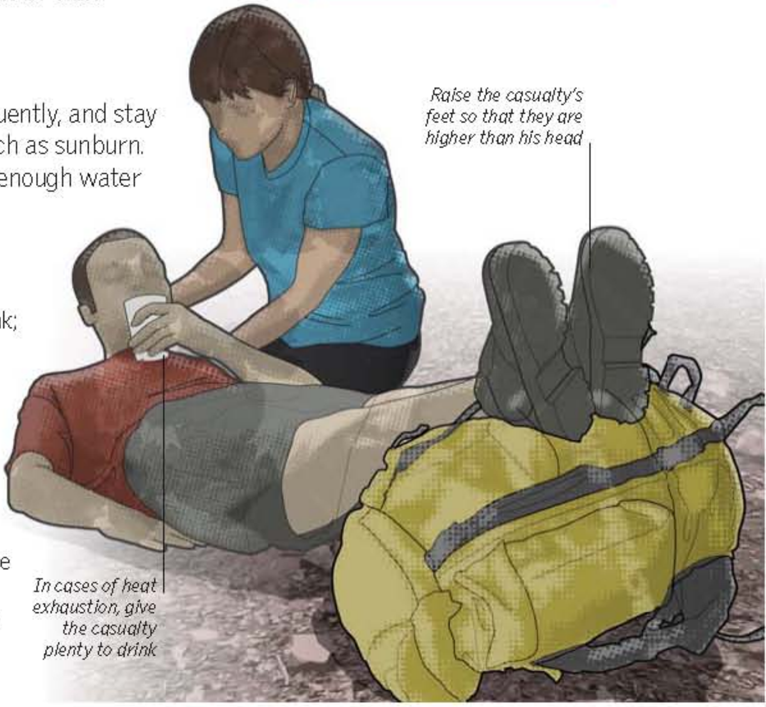

Raise the casualty's feet so that they are higher than his head

In cases of heat exhaustion, give the casualty plenty to drink

HEATSTROKE

This life-threatening condition may follow heat exhaustion or develop with no warning. Heatstroke causes the body's temperature-control mechanism to fail. If a person complains of headache, feels dizzy, has hot, dry skin, and begins losing consciousness, he or she may have heatstroke and will need urgent medical help.

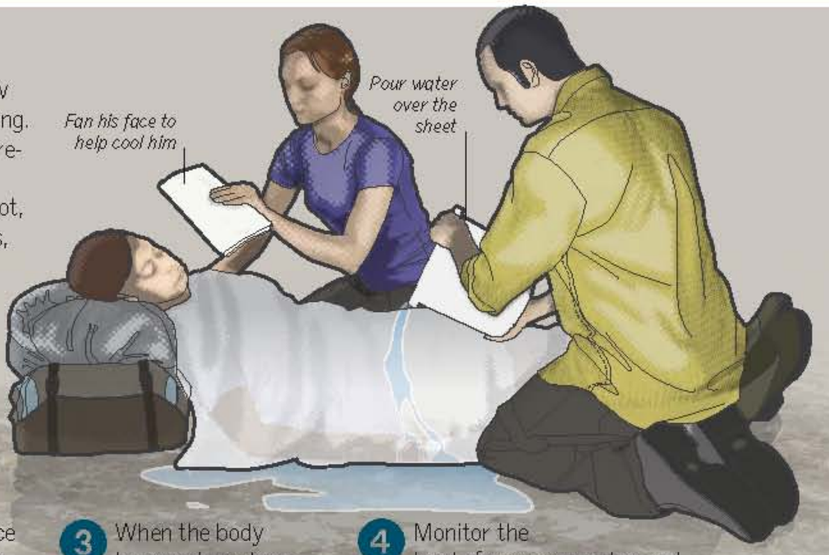

Fan his face to help cool him

Pour water over the sheet

1. Move the casualty to as cool a place as possible—out of the sun. Help him to sit or lie down with his head raised and remove all of his outer clothing.

2. Do anything possible to quickly reduce the body temperature. Ideally, wrap him in a cold, wet sheet. Keep the sheet cool by continually pouring water over it.

3. When the body temperature drops below 104°F (40°C), replace the wet sheet with a dry one.

4. Monitor the level of response, pulse, and breathing. If his temperature starts to rise again, repeat the treatment.

COLD INJURIES

Exposure to cold can result in parts of the body freezing (frostnip and frostbite) or the body's core temperature becoming dangerously low (hypothermia).

FROSTNIP AND FROSTBITE

Frostnip is the freezing of the top layer of skin, usually on the face and extremities. The skin turns numb, white, and hard. Untreated, it can lead to frostbite, which is much more serious—the deeper tissues, and even the bone, freeze. The skin turns white or blue and feels solidly frozen.

WARM GRADUALLY

Frostnip and frostbite can both be treated by warming the affected area, though frostbite requires more intensive treatment. Warm the affected area with body heat—place the casualty's hands in his own armpits, or place his feet in your armpits. Remove any rings and raise the injured part to reduce swelling. Ideally, place the affected area in warm water. Dress the injury in sterile dressings.

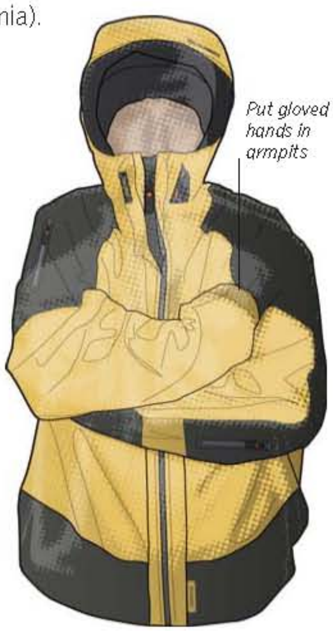

Put gloved hands in armpits

HYPOTHERMIA

This life-threatening condition develops if the body's core temperature falls below 95°F (35°C). Treatment aims to prevent further heat loss. It's vital that a casualty is warmed up gradually. If he or she is warmed up too quickly, blood is diverted away from vital organs, such as the heart and brain, to the skin, which can actually speed up cooling of the body. A casualty with hypothermia must be moved on a stretcher.

1. Help the casualty to a sheltered place where he should rest to prevent his body temperature falling further. Send someone else to get help.

2. If possible, and if there is no risk of further cold, remove any wet clothing and replace with warm, dry clothes—but don't give up your own clothes.

3. Put a thick layer of dry leaves underneath him to insulate him from the ground. Help him to lie down in a sleeping bag and, if you have one, cover him with a survival blanket.

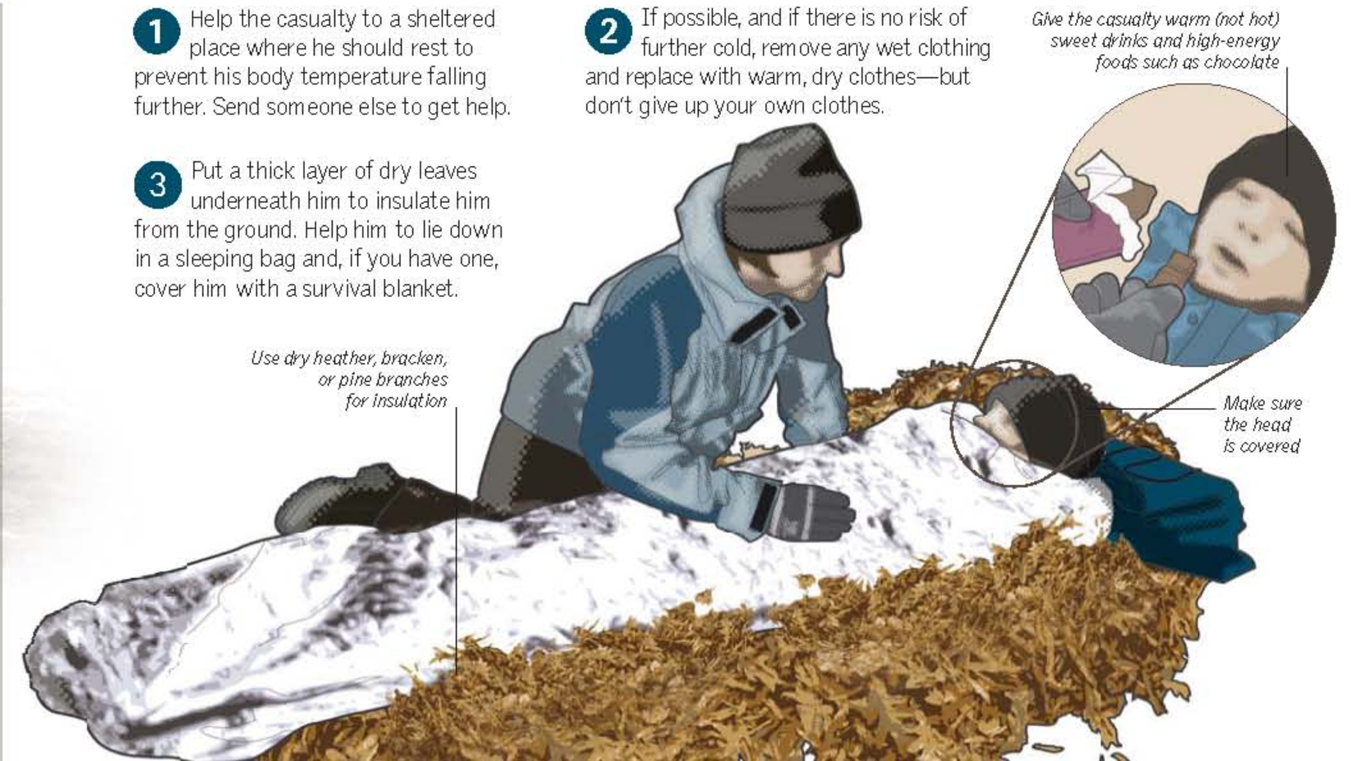

Give the casualty warm (not hot) sweet drinks and high-energy foods such as chocolate

Use dry heather, bracken, or pine branches for insulation

Make sure the head is covered

DROWNING

If a person has been immersed in cold water, there is a high risk of hypothermia. In addition, the cold can cause the heart to stop, or throat spasms can block the airway. Water can also enter the lungs and cause secondary drowning (see p. 255) hours after the person appeared to have recovered.

RESCUING A CASUALTY

If you have rescued a person from water, help him or her to lie down with the head low. Replace wet clothes with dry ones. Treat for hypothermia (see left). If the person is unconscious and not breathing, give five rescue breaths before beginning chest compressions (see p. 277).

ALTITUDE SICKNESS

Symptoms of altitude sickness include nausea, loss of appetite, shortness of breath, and a headache that's not relieved by medication. The casualty may also have difficulty sleeping and will feel unwell. The only solution is to start the descent immediately and remain at a lower altitude for a few days. Severe cases will need to be carried.

TREATING SHOCK

SHOCK IS A LIFE-THREATENING CONDITION that occurs if the circulatory system fails. The most common cause is severe bleeding, but it can also be a consequence of burns. Initially, there will be a rapid pulse and pale clammy skin. As the condition progresses, breathing becomes rapid and shallow, pulse weakens, and skin becomes pale gray-blue. If untreated, unconsciousness results.

ANAPHYLACTIC SHOCK

Anaphylactic shock is a rare but severe allergic reaction affecting the whole body. People who know they are susceptible to this carry a special adrenaline (epinephrine) autoinjector for use in an emergency. If the casualty has one, but is too weak to use it, take off the safety cap and, holding it in your fist, press it against the casualty's thigh (through clothing if necessary).

DEALING WITH SHOCK

Do not give the casualty anything to eat or drink as an anaesthetic may be needed; moisten his lips with water if he's thirsty. Call for help; the casualty must be transported in the treatment position.

1. Treat the cause of shock, for example bleeding or burns (see p. 265). Suspect shock, too, if you notice any symptoms, yet can't see any obvious injury—it could be caused by internal bleeding.

2. Help the casualty to lie down; insulate him from the ground with blankets or bracken. Raise and support his legs as high as you can above the level of his heart.

3. Loosen tight clothing, for example at the neck, chest, and waist. Keep his head low; this may prevent him from losing consciousness. Keep the casualty warm; cover him with a blanket or sleeping bag if you have one.

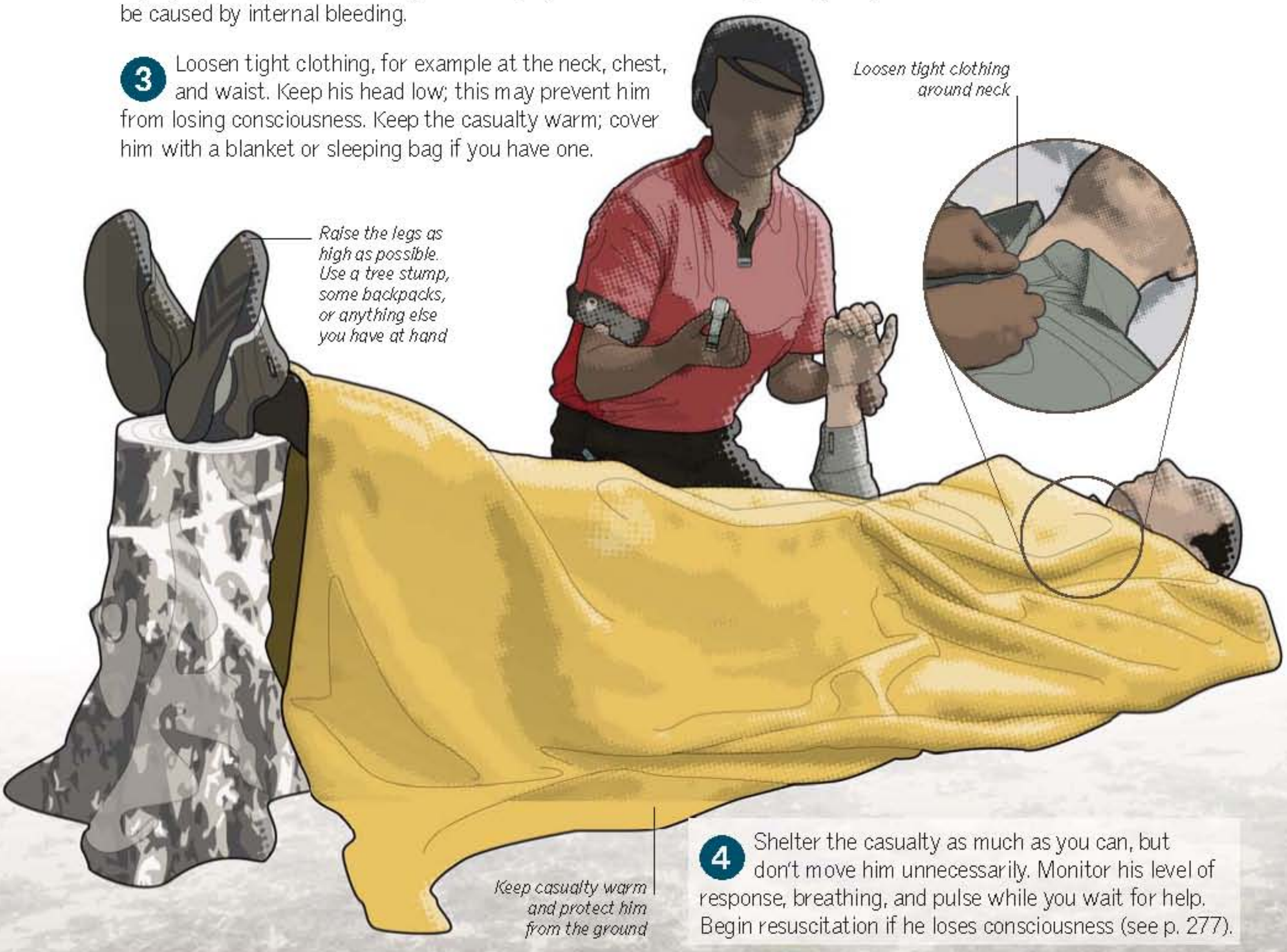
Loosen tight clothing around neck
Raise the legs as high as possible. Use a tree stump, some backpacks, or anything else you have at hand
Keep casualty warm and protect him from the ground

4. Shelter the casualty as much as you can, but don't move him unnecessarily. Monitor his level of response, breathing, and pulse while you wait for help. Begin resuscitation if he loses consciousness (see p. 277).

BREATHING DIFFICULTIES

RESPIRATORY PROBLEMS need prompt treatment because they can prevent sufficient oxygen reaching the body tissues. The cause may be temporary, for example choking, suffocation, or smoke inhalation, or it can be a long-term condition such as asthma that requires medication. You may need to get emergency help.

WARNING!
If at any stage the casualty loses consciousness, open the airway (see p. 276) and check breathing; the throat muscles may relax enough to allow breathing. If he or she is not breathing, begin resuscitation as this may dislodge the blockage (see p. 277).

CHOKING

When an object becomes stuck in the throat it can cause a muscular spasm that blocks the airway. Always ask the casualty if she is choking, to make sure. If she can speak, cough, or breathe, the obstruction is mild and she will probably be able to clear it herself.

1 If the casualty is breathing, tell her to continue coughing. If she can't speak or cough, help her to bend forward. Support her upper body and give up to five back blows in between her shoulder blades with the heel of your hand.

3 If the obstruction has still not cleared, repeat the five back slaps and five abdominal thrusts three times, then call for help if it's not already on the way. Continue until help arrives or the casualty becomes unconscious (see pp. 276–77).

2 If back blows fail, stand behind her. Put your arms around her abdomen, clench one fist and grasp it with the other hand. Pull sharply inwards and upward up to five times. Check the mouth and remove any obvious blockage.

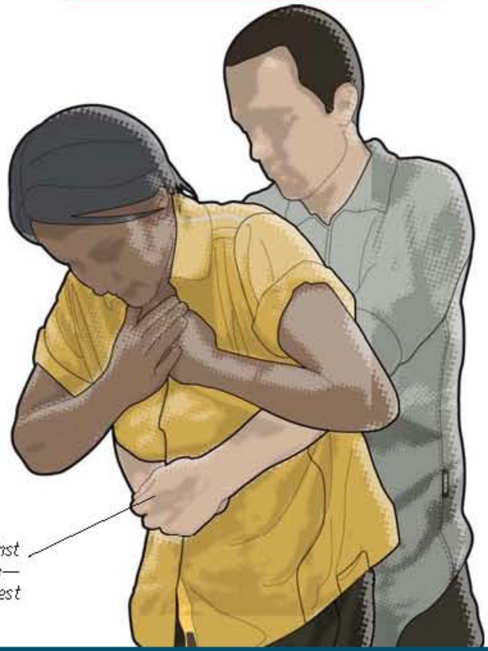
Pull against the abdomen—not the chest

ASTHMA

This is a condition in which breathing becomes difficult because the muscles in the air passages go into spasm. Most people who suffer from asthma carry inhalers with them. Many have two inhalers—a brown or white "preventer" inhaler and a blue "reliever" inhaler to use in an attack. If the person does not have any medication, sit him or her down and call for emergency help.

1 Sit the casualty down and advise her to take a puff from her reliever inhaler. Tell her to take slow, deep breaths and to sit as upright as she can. The attack should start to ease in a few minutes.

2 If the attack does not ease, tell her to take another dose from her inhaler and rest while she recovers. If the attack still does not ease, or is becoming worse, emergency help is needed as she could lose consciousness.

WHAT TO DO IN A SURVIVAL SITUATION

The best advice is prevention—know what triggers the asthma and avoid those things if at all possible. However, should someone have an asthma attack and not have an inhaler, try the following:

- Tell her to exhale as completely as she can. This expels the "stale" air, with little or no oxygen in it. It may be difficult—and will seem strange—to blow air out when the basic instinct is to gulp air in, but this does work.
- Then, tell her to inhale, slowly and steadily, and to close her eyes to help calm herself while doing so.

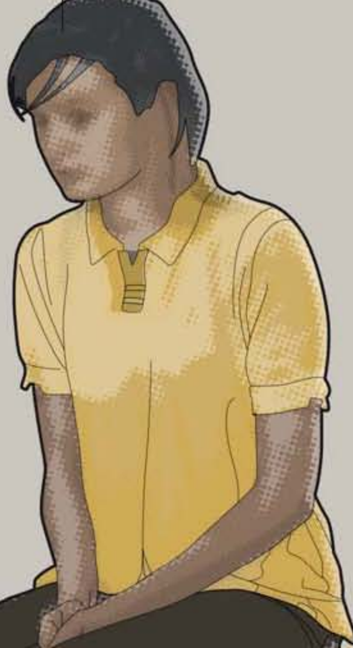
Take slow, deep breaths

UNCONSCIOUSNESS

IF SOMEONE FALLS UNCONSCIOUS, your priority is to make sure their airway is open so that they can breathe. Call for emergency help immediately (ideally ask someone to do this while you treat the casualty). Don't move the casualty and don't leave him or her alone unless you have to go and get help.

CHECK FOR RESPONSE

Gently shake the casualty's shoulders (if it's a child, tap the shoulders). Talk to him and watch for a response. If he's alert, he's conscious. If, for example, he reacts weakly, he may not be fully conscious—monitor him for any change (deterioration or improvement). If there's no response, he's unconscious.

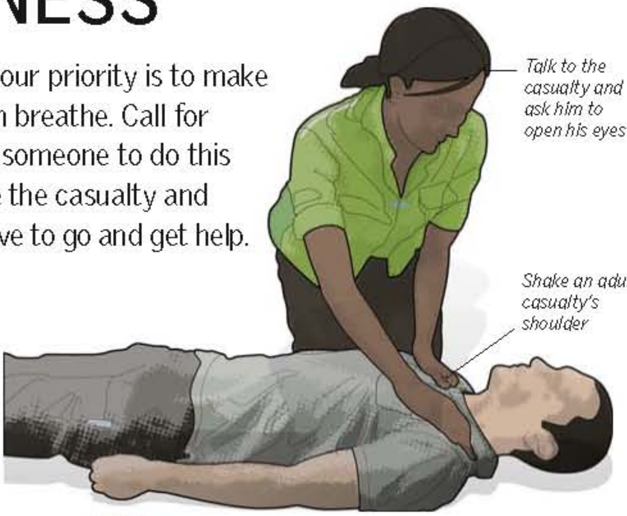
Talk to the casualty and ask him to open his eyes
Shake an adult casualty's shoulder

OPEN THE AIRWAY

If an unconscious casualty is on his back, he's at risk of swallowing his tongue—thereby blocking his air passages. Tilting the head and lifting the chin will "lift" the tongue, clearing the air passage.

CHECK THE BREATHING

Tilt a casualty's head back with one hand and lift the chin with two fingers of your other hand; don't press on the soft tissues under the chin. Keep the airway open, and look, listen, and feel for normal breathing. If the casualty is breathing normally, place him in the recovery position (see below). If he's not breathing, begin chest compressions right away (see opposite).

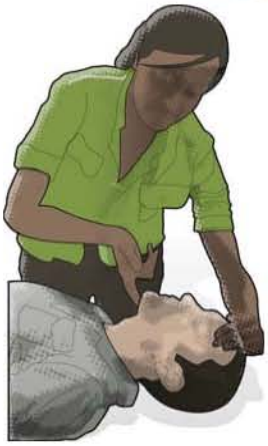

1 Place a hand on the forehead to tilt the head; lift the chin.

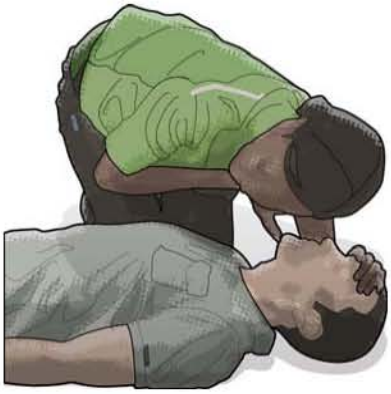

2 Look along the casualty's chest; listen, and feel, for breath against your cheek for no more than ten seconds.

RECOVERY POSITION

If an unconscious casualty is breathing, place him in the recovery position to keep his airway open and clear. Remove anything bulky from his pockets. Kneel beside him. Bend the arm nearest you at a right angle to his body then bring the other arm across his chest until his hand rests against his near cheek, and hold it there. Bend the far leg at the knee, and, still holding the knee, pull the casualty toward you until he is on his side.

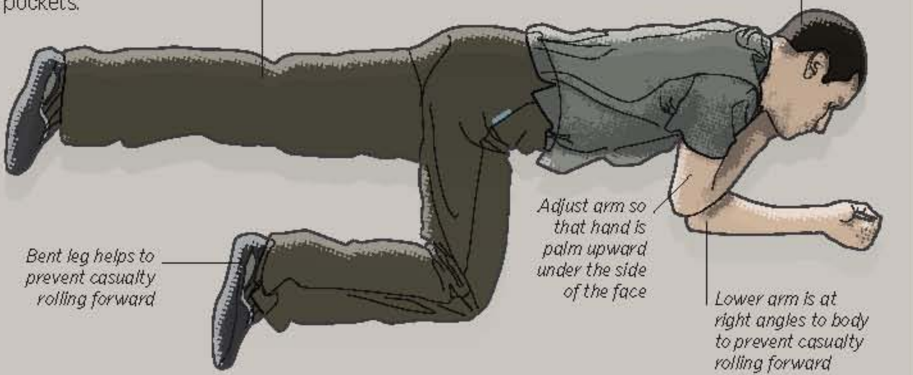
Keep lower leg straight, in line with the spine
Tilt the head back to keep airway open
Adjust arm so that hand is palm upward under the side of the face
Bent leg helps to prevent casualty rolling forward
Lower arm is at right angles to body to prevent casualty rolling forward

CARDIOPULMONARY RESUSCITATION (CPR)

If a casualty is not breathing, you must try to keep the body supplied with oxygen by using chest compressions and rescue breaths until emergency help arrives. This is known as cardiopulmonary resuscitation, or CPR. If an adult collapses, the cause is most likely to be a heart problem so treat as below. If you have rescued an unconscious casualty from water, start with rescue breaths as for a child (see right). If you are unable to achieve rescue breaths, you can give chest compressions alone.

CPR ON A CHILD

- Start by giving the child five rescue breaths.
- Give 30 compressions using the heel of one hand only and slightly less pressure than you would for an adult. Depress the chest by approximately one third of its depth.
- Continue with 30 compressions followed by two rescue breaths until the child recovers, help arrives, or you become exhausted.
- If you are on your own, give CPR for one minute before you try to call for help.

HOW TO GIVE CPR

Kneel beside the casualty, level with his chest so that you don't have to change position. If you have someone else with you, take it in turns to give CPR so you don't become too exhausted. Change over at the end of each two-minute cycle.

1. Put one hand on the center of the casualty's chest—make sure you don't press on the lower abdomen, the tip of the breastbone, or the ribs.
2. Place the heel of your other hand on top of the first and link your fingers together. Keep your fingers off the casualty's chest.
3. Begin chest compressions. Lean over and, keeping your arms straight, press straight down on the casualty's chest, depressing it by 1½–2 in (4–5 cm). Release the pressure and let the chest come back up, but don't move your hands. Repeat 30 times.
4. Tilt the casualty's head to open the airway and pinch his nose to close the nostrils. Let his mouth fall open slightly. Lift his chin with the fingers of your other hand.
5. To begin rescue breaths, take a normal breath and seal your lips over those of the casualty. Blow into his mouth until you see his chest rise, then lift your mouth away and watch his chest fall. If his chest doesn't rise, adjust his head and try again. Repeat to give a second breath, but don't make more than two attempts at giving rescue breaths before compressing again.
6. Continue the cycle of 30 compressions followed by two rescue breaths until the casualty recovers, help arrives, or you are too exhausted to keep going.

- If at any stage the casualty starts breathing normally, place him in the recovery position (see opposite) and monitor his condition until help arrives.

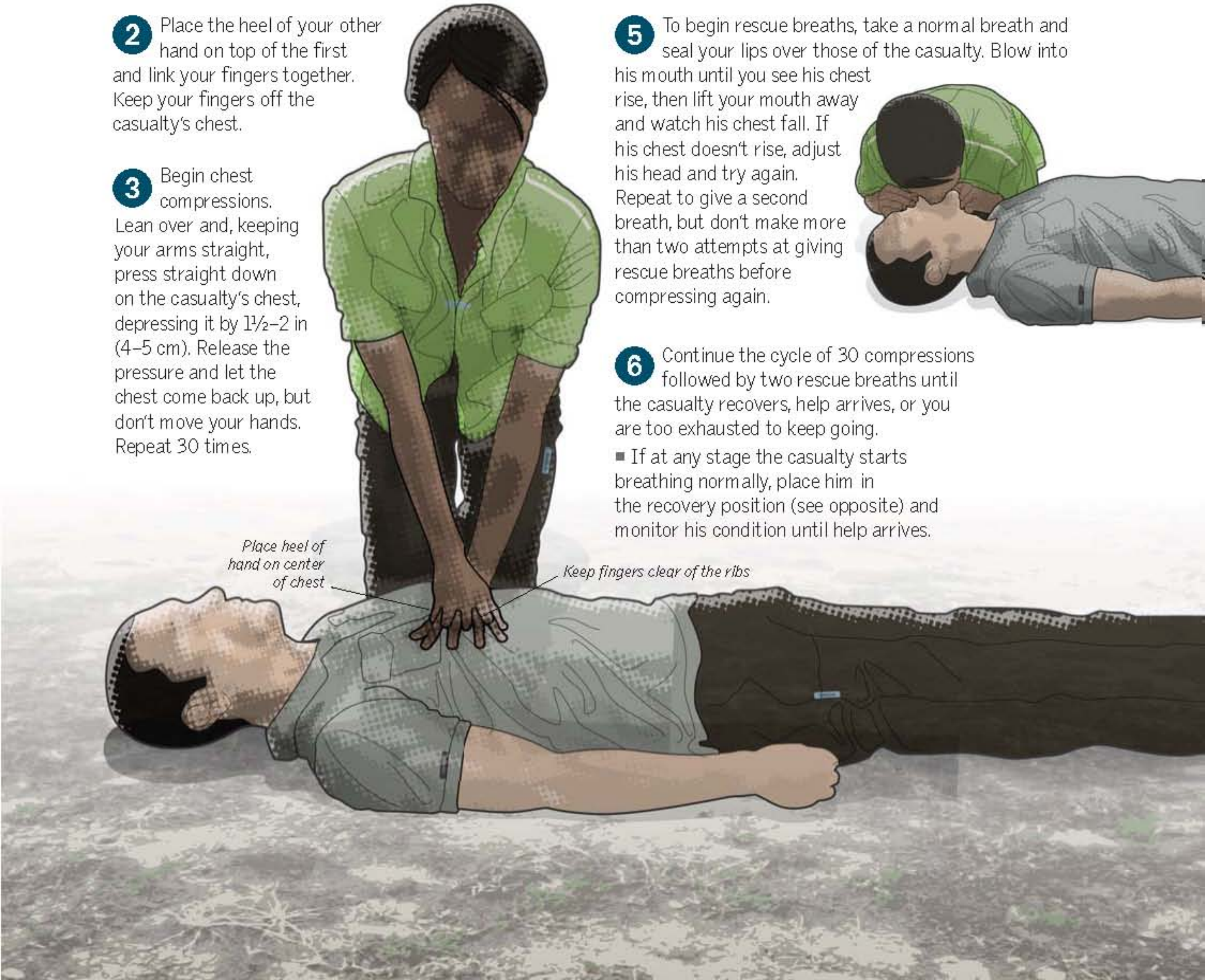

Place heel of hand on center of chest

Keep fingers clear of the ribs

MOVING A CASUALTY

IDEALLY, AN INJURED PERSON should be treated in the position in which he or she was found. Make the casualty as comfortable as possible and wait for help. In a survival situation, if you have to move someone, it's essential to immobilize an injury first to avoid aggravating it.

WARNING!
Move a casualty only if his life is in immediate danger if he is left where you found him. Even then, only move him if by doing so you will not injure yourself. Don't otherwise attempt to move a casualty, as it will make his injuries worse—stay with the casualty and send others for help.

PREPARING FOR A MOVE

Plan your move before you start. Choose a method appropriate to the injury. Don't attempt to move anyone by yourself if you have help. Encourage the casualty to do as much as possible himself.

FIREFIGHTER'S LIFT

This is a technique that can be used to move a conscious casualty if you're on your own and need to carry an injured person a short distance. It gets its name from the firefighters who originally used it. Don't use it if a casualty has head or facial injuries or a broken arm or leg. To prevent injuring your back, use your legs to power the move.

1 Support the casualty's injury with padding and bandages. Help him to stand up.

- Stand at right angles to the casualty, then squat down in front of him, staying as close to him as possible.
- Your shoulder should be level with the top of the casualty's legs.

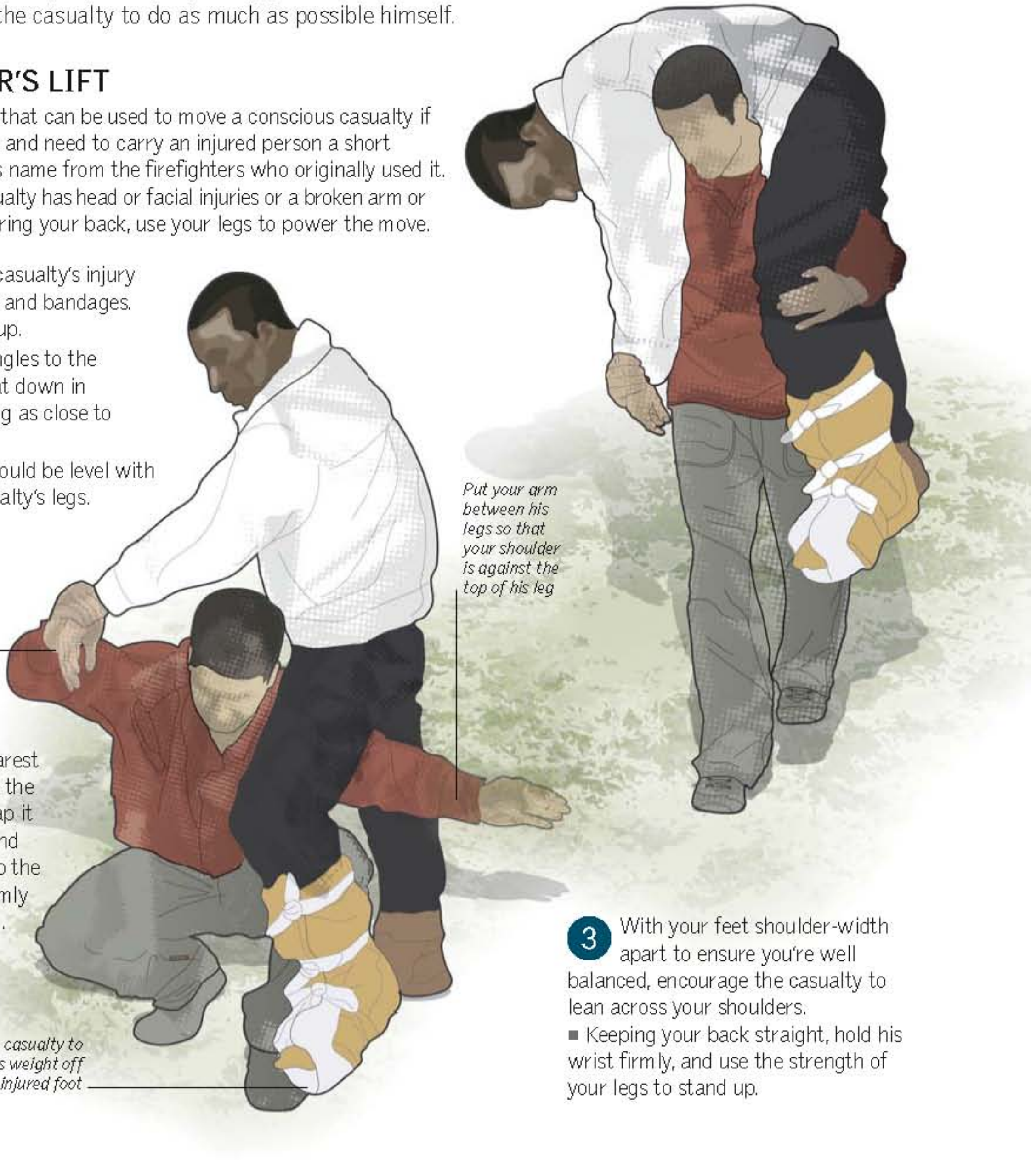

Hold his wrist to help support him

Put your arm between his legs so that your shoulder is against the top of his leg

Tell the casualty to keep his weight off the injured foot

2 Pass your nearest arm between the casualty's legs, wrap it around his thigh, and grasp his leg. Grasp the casualty's wrist firmly with the other arm.

3 With your feet shoulder-width apart to ensure you're well balanced, encourage the casualty to lean across your shoulders.

- Keeping your back straight, hold his wrist firmly, and use the strength of your legs to stand up.

IMPROVISING A STRETCHER

If you need to move a casualty who is unconscious, has a broken leg, or a spine injury, he must be carried by stretcher. Ideally, call the emergency services, and wait for them to arrive. If you can't contact them and you need to get the casualty to medical assistance, you may need to make a stretcher. Use a hurdle or gate, or make the stretcher from poles and coats.

WARNING!
Rescuers should not use their own clothing to make a stretcher if this might put them at risk of exposure.

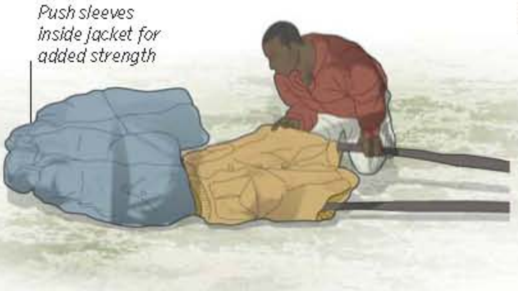
Push sleeves inside jacket for added strength

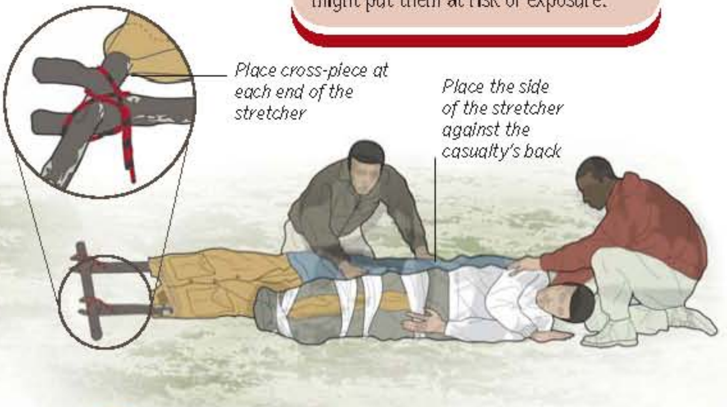
Place cross-piece at each end of the stretcher

Place the side of the stretcher against the casualty's back

1 Zip or button up two or three jackets. Cut two support poles, strong enough to bear the casualty's weight and 3 ft (1 m) longer than the casualty. Lash a short forked branch across each end (see pp. 166–67) to keep the support poles apart.

2 Immobilize any injury (see p. 271), and roll the casualty onto his uninjured side. One person should support his head while others help to keep his body straight, ideally one for the upper body and one for the legs. Slide the stretcher in place then roll him gently back on to it.

TWO-PERSON SEAT

If there are two of you, this method can be used to carry a conscious casualty who can't walk, but who can support himself with his arms. Nominate one person to be in charge of the move and give the instructions. Keep your backs straight at all times.

1 Stand facing each other behind the casualty. Grasp your left wrist with your right hand, then grasp each other's free wrist to make a seat.

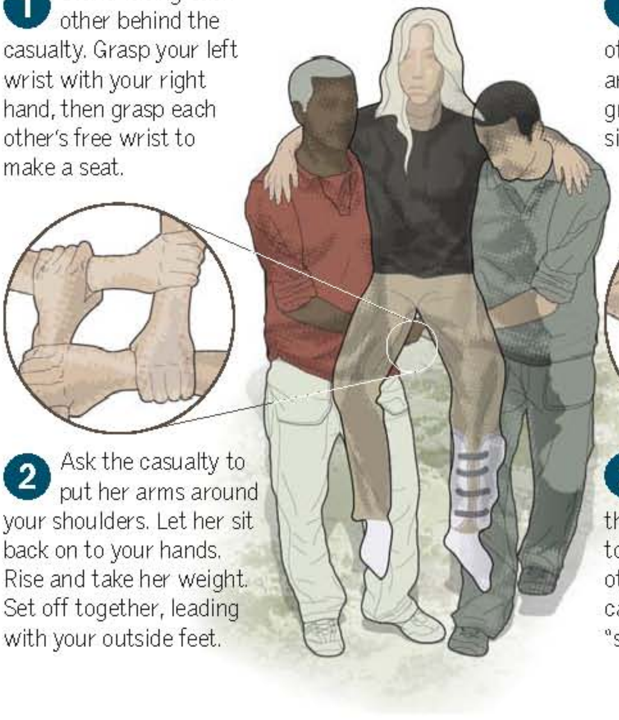

2 Ask the casualty to put her arms around your shoulders. Let her sit back on to your hands. Rise and take her weight. Set off together, leading with your outside feet.

SUPPORTING THE UPPER BODY

If a casualty has an injured arm, the seat carry (see left) can be adapted to support the upper body. As before, one of you should direct the move and always move together. Keep your backs straight as you walk, and stop if it causes you or the casualty any discomfort.

1 Stand facing each other, on either side of the casualty. Put your arms around her back and grasp her clothing on the side farthest from you.

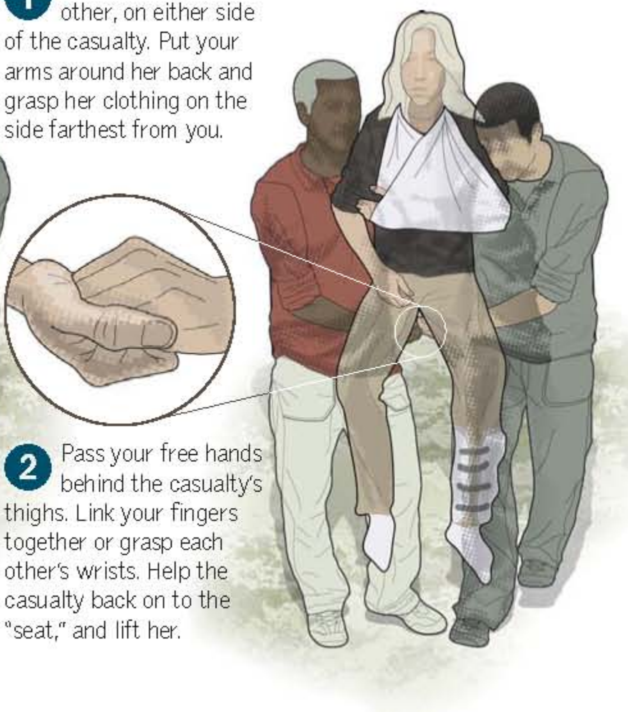

2 Pass your free hands behind the casualty's thighs. Link your fingers together or grasp each other's wrists. Help the casualty back on to the "seat," and lift her.

WILD FOOD

MANY POISONOUS PLANTS in temperate regions resemble edible ones, so you should only eat plants that you can positively identify. If you're in any doubt at all, carry out the Universal Edibility Test (UET) first (see pp. 206–07). Don't forget that some plants are edible only at certain stages of their growth. Never eat wild plants if you have any known

NAME	WHERE	IDENTIFICATION	EDIBLE PART
BISTORT/KNOTWEED *Polygonum* spp.	▪ Damp, grassy habitats, such as meadows, in North America and Eurasia.	▪ Perennial plant, 16–40 in (40–100 cm) tall. Green, triangular leaves. Small pink or white flowers form dense, cylindrical flowerheads at end of long, unbranched stem.	▪ Young shoots and leaves ▪ Roots
BRAMBLE/BLACKBERRY *Rubus fruticosus*	▪ In most temperate habitats worldwide, but particularly scrubland, hedges, and woodland.	▪ Scrambling deciduous shrub with thorny stems forming thickets. Green, toothed leaves. White or deep pink five-petaled flowers. Fruit ripens to blue-black in late summer.	▪ Fruit ▪ Young shoots ▪ Leaves
BUCKWHEAT *Fagopyrum esculentum*	▪ Open grassland worldwide.	▪ Red-stemmed plant up to 2 ft (60 cm) tall. Green, triangular leaves. Small pink, five-petaled flowers grow in clusters. Triangular seeds.	▪ Seeds
DANDELION *Taraxacum* spp.	▪ Widely distributed in temperate areas of Eurasia; introduced to the Americas, Australia, and New Zealand.	▪ Rosette of green, jagged-edged leaves grows close to the ground from a central taproot. Large, bright yellow flower head matures into a spherical "clock" of several seeds.	▪ Leaves ▪ Roots
DOG ROSE *Rosa canina*	▪ In hedgerows, woodland margins, and scrubland in Europe, northwest Africa, and western Asia; introduced to other regions.	▪ Scrambling deciduous shrub with spiny stems. Dark green, toothed leaves. Scentless, white, pink or deep pink five-petaled flowers. Fruit, or "hip," is orange-red and oval.	▪ Hips ▪ Buds and flowers ▪ Young leaves
STINGING/ COMMON NETTLE *Urtica dioica*	▪ By hedgerows and woodland margins in North America, Eurasia, and North Africa.	▪ Perennial herbaceous plant, 20–60 in (50–150 cm) tall. Green, oval, toothed leaves covered in stiff stinging hairs. Small green flowers sometimes have a red tinge.	▪ Young shoots and leaves
SUGAR MAPLE *Acer saccharum*	▪ Woods and forests in northeastern North America.	▪ Deciduous tree, usually 82–115 ft (25–35 m) tall. Gray-brown bark smooth on young trees, furrowed and flaky on old trees. Green, five-lobed leaves turn bright red in fall.	▪ Sap ▪ Inner bark
WALNUT *Juglans* spp.	▪ Temperate areas in Eurasia and North America. Common in the Himalayas.	▪ Large deciduous tree up to 82 ft (25 m) tall with distinctive gnarled bark. Green leaves have narrow leaflets. Nut has a thick, green husk, which rots away once it falls to the ground.	▪ Nuts
WATER CHESTNUT AND WATER CALTROP *Trapa natans* and *T. bicornis*	▪ In slow-moving water in warm temperate areas of Eurasia and Africa; introduced to North America and Australia.	▪ Green, triangular, saw-toothed leaves float on surface. White four-petaled flowers. Fruit is borne underwater and has four sharp spines and one hard gray seed.	▪ Seeds
WILD GRAPE *Vitis* spp.	▪ In most habitats in North America and Eurasia.	▪ Sprawling, high-climbing vine with large, lobed leaves. Fruit grows as hanging bunches of berries, which are amber or dark purple when ripe.	▪ Fruit ▪ Young leaves

TEMPERATE PLANTS

allergies, a pre-existing medical condition, or are pregnant. The UET doesn't apply to mushrooms, so never eat any mushrooms unless you can positively identify every single one as being edible. As part of your preparation for your trip, you should familiarize yourself with the edible plants in the region you're visiting, and their seasonal availability.

	PREPARATION	SIMILAR PLANTS	BEWARE OF	EXTRA INFORMATION
	▪ Young leaves and shoots can be eaten raw or boiled. ▪ Soak roots, then boil or roast.	▪ Alpine bistort (*P. viviparum*) is common on rocky soils in northern alpine regions and the Arctic.		▪ Roots are twice twisted and are said to resemble two snakes. They contain starch and can be used to make flour.
	▪ Fruit and peeled young shoots are edible raw. ▪ Infuse the leaves to make tea.	▪ Wild raspberry (*R. idaeus*) fruit ripens to a bright red. Tea made from the leaves can be used to treat diarrhea.	▪ Catching yourself on thorns.	▪ Blackberries and raspberries are high in vitamin C and sugars. Blackberry leaf tea can be used to treat colds and coughs.
	▪ Hull and grind the seeds to make buckwheat flour. ▪ Roast seeds and cook with water to make porridge.		▪ Buckwheat leaves are edible but can cause photosensitivity of the skin if eaten in large quantities.	
	▪ Young leaves can be eaten raw; boil old leaves to remove the bitter taste (change the water once). ▪ Boil the roots.			▪ Roots can be roasted and ground to make a substitute for coffee. The leaves are high in vitamins A and C, iron, and calcium.
	▪ Buds and flowers are edible raw. ▪ Chew the pulp of raw hips, or dry and eat later. ▪ Boil leaves in water to make tea.		▪ The hips of all wild roses (*Rosa* spp.) are edible, but do not eat the seeds if they are prickly as they will irritate the throat and stomach.	▪ Rose hips remain on the shrub all year. They are rich in vitamin C. Boil crushed hips in water then strain to make a nutritious syrup.
	▪ Boil the plants for 10 minutes to destroy the formic acid and histamine in the stinging hairs.	▪ Dead nettles (*Lamium* spp.) are also edible if cooked. They have heart-shaped leaves and white or purple flowers. No stinging hairs.	▪ Gather and handle the plants carefully, wearing gloves if you have them, to avoid being stung by the hairs.	▪ Fresh nettles are rich in protein and vitamin K. The fibers in mature stems can be woven into cordage (see pp. 138–41).
	▪ Boil sap into a high-energy syrup. ▪ Eat inner bark raw or boil into a gelatinous mass, then roast and grind into a flour.	▪ Red maple (*A. rubrum*) also produces sweet sap. ▪ White birch (*Betula* spp.) has edible inner bark.		▪ To collect the sap, cut a V-shape into the trunk, make a hole below the cut, and insert a leaf to guide the drips into a container below.
	▪ Crack the shell and eat the ripe nut raw.			▪ Rich in fat, protein, and vitamins. ▪ Crushed green husks of black walnut (*J. nigra*) are toxic to fish. Use to poison and catch them.
	▪ Seeds can be eaten raw or roasted.			▪ Water chestnuts are a source of carbohydrate.
	▪ Ripe fruit is best eaten raw. ▪ Boil young leaves.		▪ Moonseed vines (*Menispermum* spp.) have grapelike fruits, which are poisonous. Unlike edible grapes, they only have one seed.	▪ Ripe grapes are rich in vitamin C and sugar. Water can be obtained from the vine stem (see p. 192).

WILD FOOD

SOME OF THE PLANTS listed below are good sources of water/liquid. In a survival situation in the desert, don't eat food if you don't have any water, as your body will use up its own water to digest it. Only eat plants that you can positively identify and, if you are in any doubt at all, carry out the Universal Edibility Test (UET) first (see pp. 206–07).

NAME	WHERE	IDENTIFICATION
ACACIA/WATTLE *Acacia* spp.	▪ Africa, southern Asia, Australia, and the Americas.	▪ Thorny, medium-sized trees with gray-white bark. Green leaves divided into many small, oval leaflets. Small, ball-shaped yellow, white or pink flowers.
AGAVE *Agave* spp.	▪ Southern USA and Mexico, Central America, the Caribbean, and northeastern South America.	▪ Rosette of fleshy leaves with sharp tip and spiny margin. Central, tall flower stalk.
AMARANTH *Amaranthus* spp.	▪ The Americas, Africa, and Asia.	▪ Tall herb with alternating leaves and erect fleshy stems. Tiny brown/black seeds (one plant produces 40,000–60,000 seeds).
BAOBAB *Adansonia* spp.	▪ Africa and northern Australia.	▪ Large trees with swollen trunks, up to 30 ft (9 m) in diameter. Green leaves have 5–7 digit-like leaflets. Oblong fruit up to 8 in (20 cm) long.
CAROB TREE *Ceratonia siliqua*	▪ Mediterranean, northern Africa, Middle East, and India.	▪ Evergreen tree up to 50 ft (15 m) tall. Shiny green leaves up to 8 in (20 cm) long. Small red flowers. Flat leathery seed pods; dark-green/black when ripe. Hard brown seeds.
CARRION FLOWER *Hoodia* spp.	▪ Southwest Africa.	▪ Numerous thorny, succulent stems up to 6 ft (2 m) tall. Star-shaped or shallowly bell-shaped flowers give off the smell of rotting meat.
DATE PALM *Phoenix dactylifera*	▪ West and North Africa, Middle East, and India; introduced to Mexico and USA.	▪ Tall slender palms with a large crown of green leaves, divided into many narrow leaflets. Fruit reddish-brown when ripe.
PRICKLY PEAR CACTUS *Opuntia* spp.	▪ The Americas; introduced to the Caribbean, the Mediterranean, Africa, and Australia.	▪ Thick, jointed, flat, pad-like, green stems covered in spines. Red or yellow flowers. Fruit red when ripe.
WILD GOURDS *Cucurbitaceae*	▪ Kalahari Desert (Namibia), the Sahara, islands in the Mediterranean, the Middle East, and southeastern India.	▪ Ground-trailing green vine. Bright yellow flowers. Orange-sized green or yellow fruit.

DESERT PLANTS

Don't forget that some plants are edible only at certain stages of their growth. Don't eat wild plants if you have any known allergies, a preexisting medical condition, or are pregnant. When planning your trip, it's advisable to familiarize yourself with the edible plants in the region you are visiting and their seasonal availability.

EDIBLE PART	PREPARATION	BEWARE OF	EXTRA INFORMATION
▪ Seeds (from dark brown pods) ▪ Young leaves and shoots	▪ Roast seeds. ▪ Boil leaves and shoots.	▪ Catching yourself on thorns.	▪ Roots may be tapped for water.
▪ Stalk, before in flower ▪ Buds and flowers	▪ Roast the stalk. ▪ Boil buds and flowers.	▪ Juice from many species can cause acute contact dermatitis, with reddening and blistering lasting 1–2 weeks. Leaves have needle-like ends.	▪ Roasted stalk tastes sweet, like molasses.
▪ Young shoots and leaves ▪ Seeds	▪ Eat shoots and leaves raw or boiled or stir-fried. ▪ Remove chaff from seeds, then cook like popcorn or grind into flour to make bread.	▪ Amaranth leaves are high in oxalic acid, which can irritate the gut and cause kidney stones, so eat in moderation.	▪ Amaranth leaves are a common leaf vegetable in the tropics and warm temperate regions.
▪ Shoots and young leaves ▪ Fruit ▪ Seeds	▪ Eat the fruit pulp raw. ▪ Boil shoots and leaves. ▪ Roast seeds.		▪ Tap the trunk for water. Kalahari bushmen suck water through holes in the trunk using the hollow stems of grasses.
▪ Pods ▪ Seeds	▪ Eat the sweet, nutritious pulp of the pods raw. ▪ Grind the seeds into flour and make into porridge.		
▪ Stems	▪ Tap the stems for their water.		▪ The stems contain an appetite suppressant. Kalahari bushmen chew the stems of several *Hoodia* species before and during their long, arduous hunts.
▪ Fruit ▪ Growing tip of the palm (heart) ▪ Young leaves ▪ Sap	▪ Eat the fruit (dates) raw or sun-dried. ▪ Boil the leaves and heart. ▪ Boil the sap down to a syrup.		▪ Date palms always grow near water. The leaves can be used to thatch a shelter.
▪ Fruit ▪ Seeds ▪ Pads	▪ Peel fruit and eat raw. ▪ Roast and grind seeds to a flour. ▪ Boil or grill young pads, first removing thorns by peeling or scorching over a fire.	▪ Spines. Avoid any similar-looking plant that has milky sap as it may be poisonous.	▪ The non-milky sap from the pads is a good source of water.
▪ Fruit (Tsamma melon only) ▪ Flowers ▪ Seeds ▪ Young leaves and shoots	▪ Pound fruit to a pulp and eat raw. ▪ Eat the flowers raw. ▪ Roast or boil seeds. ▪ Chew leaves and shoots for water.	▪ The fruit of the wild desert gourd or colocynth (*Citrullus colocynthis*) is very bitter and is a strong laxative.	▪ The Tsamma melon (*C. lanatus*) is also known as the wild watermelon. The fruit pulp is a good source of water.

WILD FOOD

A GREAT NUMBER OF PLANTS flourish in the tropics, growing all year round in the warm and humid conditions—those listed below are just a few of the most common varieties. When you plan your trip, you should familiarize yourself with the edible plants in the region you are visiting. In tropical forests, most fruits are borne high in the canopy—out of reach,

NAME	WHERE	IDENTIFICATION	EDIBLE PART
BAMBOO *Bambuseae*	▪ Tropical and subtropical forests.	▪ Tree-like grasses with woody, segmented, hollow stems ranging from black to green to gold in color. Green blade-like leaves. Species range in height from 1⅔–11½ ft (0.5–3.5 m).	▪ Young shoots ▪ Seeds
BANANA AND PLANTAIN *Musa* spp.	▪ Native to Australia and Southeast Asia; introduced to other tropical regions.	▪ Tree-like herbaceous plants up to 33 ft (10 m) tall. Large, green, strap-like, split leaves. Flowers and fruit grow in dense hanging clusters.	▪ Fruit ▪ Buds and flowers ▪ Shoots and young stems ▪ Roots
BRAZIL NUT *Bertholletia excelsa*	▪ Along river banks in rain forests in South America.	▪ Large dry-season deciduous tree up to 150 ft (45 m) tall. Green, oblong, crinkly leaves. Yellow flowers. Fruit is the size of a coconut with a hard, woody shell and contains 8–24 seeds.	▪ Seeds or "nuts"
CEYLON/VINE SPINACH *Basella alba*	▪ Widespread in tropical forests.	▪ Trailing, vine-like plant reaching 100 ft (30 m) in length. Beet-red stems. Fleshy, oval or heart-shaped, green or red-purple leaves.	▪ Young leaves and stems
FIG *Ficus* spp.	▪ Variety of habitats in tropical and subtropical regions.	▪ Evergreen tree with long aerial roots growing from the trunk and branches. Leathery green leaves. Pear-shaped fruit grow directly from the trunk or branches.	▪ Ripe fruit
PAPAYA/PAWPAW *Carica papaya*	▪ Native to tropical rain forests in the Americas; introduced to other tropical and some temperate regions.	▪ Small tree up to 20 ft (6 m) high, with a soft hollow trunk. Large green leaves have seven lobes. Large melon-like fruit turn yellow or orange when ripe.	▪ Fruit ▪ Young flowers, leaves, and stems
PEANUT *Arachis hypogaea*	▪ Native to tropical rain forests in the Americas; introduced to other tropical and some temperate regions.	▪ Small, bushy plant up to 1⅔ft (50 cm) tall. Paired, oval green leaves grow four to a stem. Yellow flowers. Underground legume (pod) contains 1–4 nuts.	▪ Seeds or "nuts"
SAGO PALM *Metroxylon sagu*	▪ Damp lowlands of tropical rain forests in Southeast Asia; introduced elsewhere.	▪ Spiny-trunked palm up to 33 ft (10 m) tall. Crown of pinnate (feather-like) green leaves.	▪ Pith ▪ Young shoots ▪ Young nuts
WATER LILY *Nymphaea*	▪ Lakes, ponds, and rivers in tropical and subtropical regions worldwide. Also found in temperate regions.	▪ Flat, green, heart-shaped leaves float on surface of water. Large, white, yellow, pink, or blue fragrant flowers.	▪ Tubers ▪ Stems ▪ Seeds

TROPICAL PLANTS

unless you can climb the tree. Only eat plants that you can positively identify. If you are in any doubt at all, carry out the Universal Edibility Test (UET) first (see pp. 206–07). Don't forget that some plants are edible only at certain stages of their growth. Don't eat wild plants if you have a known allergy, a preexisting medical condition, or are pregnant.

PREPARATION	SIMILAR PLANTS	BEWARE OF	EXTRA INFORMATION
▪ Split the tough outer sheath of the shoots, and boil or steam. ▪ Boil the seeds or grind, mix with water, make into cakes, and bake.		▪ Shoots of the giant bamboo or volohosy (*Cathariostachys madagascariensis*) contain prussic acid (cyanide).	▪ Bamboo stems often hold water (see p. 190). The stems can be used for cooking (see p. 204) and building a shelter (see p. 169).
▪ Fruit and flowers are edible raw or cooked. ▪ Cook shoots, stems, and roots.			▪ Banana and plantain fruit is rich in potassium and vitamins A, B6, and C. Hard, unripe plantain fruit is only edible when cooked.
▪ Break fruit capsule open, crack the nut's shell, and eat raw.	▪ The sapucaia tree (*Lecythis* spp.) produces edible seeds in a similar fruit capsule. They are called paradise nuts.		▪ Ripe fruit capsules fall to the ground. Rodents and monkeys are attracted to the nuts, which are rich in fats and selenium.
▪ Steam, boil, stew, or stir-fry the leaves and stems.		▪ Don't eat too much, as the plant can have a mild laxative effect.	▪ Young leaves and stems are rich in vitamins.
▪ Eat the fruit raw or cooked.		▪ Don't eat any hard, woody fruit, or those covered in hairs.	▪ Edible figs are soft when ripe and green, red, or black in color.
▪ Flesh of ripe fruit is edible raw. Unripe fruit is edible cooked. ▪ Flowers, leaves, and stems must be boiled, and the water must be changed at least once.		▪ Don't get the milky juice of green, unripe fruit in your eyes as it will cause temporary blindness.	▪ Ripe fruit is rich in vitamin C. Unripe fruit will ripen quickly if placed in the sun.
▪ Remove the shell and eat the nuts raw.		▪ Don't handle or eat if you are allergic to peanuts.	▪ Peanuts are a good source of protein, B vitamins, and minerals.
▪ Crush the pith, knead it in water, strain into a pot, and let the fine sago settle. Squeeze and let it dry. Mix to a paste with boiling water.	▪ Many palms have edible parts. The sugar palm (*Arenga pinnata*) has an edible sap which can be boiled down to a thick syrup.	▪ Don't eat a palm's fruit unless you have positively identified it as an edible variety as the fruit of some species contain harmful crystals.	▪ A mature palm will yield 330–660 lb (150–300 kg) of sago starch—almost pure carbohydrate.
▪ Peel and slice the tubers, which can be eaten raw. ▪ Stems are best cooked. ▪ Dry and grind the seeds into flour.	▪ All parts of the lotus (*Nelumbo* spp.) are edible raw or cooked.		▪ The tubers are rich in starch. The seeds have a bitter taste but they are edible.

WILD FOOD

WHEN PREPARING FOR YOUR TRIP, you should familiarize yourself with the edible plants in the region you are visiting and their seasonal availability. Only eat plants that you can positively identify and, if you are in any doubt at all, carry out the Universal Edibility Test (UET) first (see pp. 206–07). Don't forget that some plants are edible only

	NAME	WHERE	IDENTIFICATION
LICHENS	**ICELAND MOSS** *Cetraria islandica*	▪ Mountainous areas in Arctic, sub-Arctic, and cold temperate regions in North America and Europe; lava slopes and plains of Iceland.	▪ Mat-forming lichen, up to 4 in (10 cm) high. Gray-green to pale chestnut branches, rolled into tubes terminating in flattened lobes with fringed edges.
	REINDEER MOSS *Cladonia rangiferina*	▪ Tundra, bogs, and open woodlands in Arctic, sub-Arctic, and northern temperate regions.	▪ Mat-forming lichen, 2–4 in (5–10 cm) high. Gray, rounded branches resemble antlers.
	ROCK TRIPE *Umbilicaria* spp.	▪ On rocks in Arctic, sub-Arctic, and northern temperate regions.	▪ Rounded lichens with curling edges, usually gray or brown.
PLANTS	**ARCTIC WILLOW** *Salix arctica*	▪ Tundra in North America, Europe, and Asia; mountainous areas in some northern temperate regions.	▪ Mat-forming shrub, 1–2 ft (30–60 cm) high. Rounded, shiny green leaves. Flowers grow as yellow catkins.
	BEARBERRY *Arctostaphylos uva-ursi*	▪ Mountainous areas in Arctic and sub-Arctic regions.	▪ Dwarf evergreen shrub. Thick, leathery, club-shaped green leaves. Pink or white flowers. Bright red berries grow in clusters.
	BOG LABRADOR TEA *Rhododendron groenlandicum*	▪ Bogs and alpine areas in Arctic, sub-Arctic, and temperate regions in North America and Europe.	▪ Evergreen shrub, 1–3 ft (30–90 cm) high. Narrow, leathery, green leaves are hairy underneath and fragrant. Small, fragrant, white flowers grow in clusters and are sticky.
	CLOUDBERRY *Rubus chamaemorus*	▪ Bogs, marshes, and wet meadows in alpine and sub-Arctic regions of North America, Europe, and Asia.	▪ Perennial shrub, 4–10 in (10–25 cm) high. Soft, green leaves have 5–7 lobes. White flowers have five petals. Rasberry-sized, amber berries grow at the top of the plant.
	CROWBERRY *Empetrum nigrum*	▪ Tundra, moorlands, bogs, and spruce forests in Arctic, sub-Arctic, and northern temperate regions. Also found in the Andes.	▪ Dwarf, evergreen, mat-forming shrub. Short, pale green, needle-like leaves. Small, purple-red flowers. Black berries.
	KERGUELEN CABBAGE *Pringlea antiscorbutica*	▪ Rocky areas of sub-Antarctic islands in the Indian and Southern Oceans.	▪ Cabbage-like plant.

PLANTS IN COLD CLIMATES

at certain stages of their growth. Don't eat wild plants if you have any known allergies, a preexisting medical condition, or are pregnant. There are no poisonous types of lichen (althought see rock tripe entry, below), but they must all be soaked in water overnight and boiled well before they can be eaten.

EDIBLE PART	PREPARATION	BEWARE OF	EXTRA INFORMATION
▪ All	▪ Soak for several hours then boil well.	▪ All lichens contain an acid that will cause stomach irritation unless soaked and boiled before eating.	▪ Lichens are low in protein but high in carbohydrates (lichen-starch).
▪ All	▪ Soak for several hours then boil well.	▪ All lichens contain an acid that will cause stomach irritation unless soaked and boiled before eating.	▪ High in vitamins A and B. Important source of food for reindeer (caribou). Partially digested lichens from the reindeer's stomach are considered a delicacy by herders.
▪ All	▪ Soak for several hours then boil well.	▪ There have been some reports of rock tripe poisoning so apply the Universal Edibility Test first.	
▪ Young shoots ▪ Leaves ▪ Young roots	▪ Peel off outer bark and eat inner shoots raw. ▪ Eat the leaves raw. ▪ Peel roots and eat raw.		▪ Arctic willow leaves have 7–10 times more vitamin C than an orange.
▪ Berries	▪ Cook before eating.	▪ Bears feeding on the berries.	▪ Forms mats in Arctic regions.
▪ Leaves	▪ Infuse to make tea.		▪ Pick individual leaves rather than whole branches and harvest from several shrubs. Northern Labrador tea (*R. tomentosum*) leaves also make a fragrant tea. The plant grows in peaty soils and on tundra.
▪ Berries	▪ Edible raw.	▪ Bears feeding on the berries.	▪ Berries initially pink, ripening to amber in fall. High in vitamin C.
▪ Berries	▪ Eat raw or cooked.	▪ Bears feeding on the berries.	▪ Previous year's berries will last on plant until spring if not picked. Fresh berries can be dried for storage. Low in vitamins.
▪ Leaves	▪ Boil well.		▪ Leaves have a bitter taste so must be well-boiled. High in potassium and vitamin C. Antarctic explorers and whalers used to eat Kerguelen cabbage to ward off scurvy, hence its scientific name.

WILD FOOD

THERE ARE NO POISONOUS SEAWEEDS, but some may cause gastrointestinal upset. The seaweeds listed below are common and safe to eat if gathered when still growing, but should only be eaten in small quantities at first. Don't eat seaweed if you are short of fresh water to drink. Only eat plants that you can positively identify and, if you are in

	NAME	WHERE	IDENTIFICATION
SEAWEEDS	**GUTWEED** *Enteromorpha* spp.	- Saltmarshes and rock pools in cold-temperate waters worldwide.	- Pale or bright green, tubular, unbranched stems, 8–16 in (20–40 cm) long.
	KELP *Alaria* spp., *Laminaria* spp., and *Macrocystis* spp.	- Rocky coasts of the Atlantic and Pacific oceans.	- Very long, strap-like, olive-green to brown fronds. Giant kelp (*M. pyrifera*) is the largest seaweed on Earth, reaching lengths of 150 ft (45 m).
	LAVER *Poryphyra* spp.	- Rocky coasts worldwide.	- Very thin, irregularly shaped membranous frond, up to 20 in (50 cm) long. Color varies from olive-green to purple-brown or blackish.
SEASHORE PLANTS	**COCONUT PALM** *Cocos nucifera*	- Sandy, rocky, and coral coasts in tropics and subtropics worldwide.	- Woody perennial tree, up to 72 ft (22 m) tall, with a crown of pinnate (feather-like) leaves. Gray trunk is ringed with growth scars.
	GLASSWORT/ MARSH SAMPHIRE *Salicornia* spp.	- Salt marshes and coastal mudflats of western and eastern North America, western Europe, and the Mediterranean.	- Bright green, jointed, fleshy stems, 4–12 in (10–30 cm) high. Scale-like leaves and tiny flowers are sunk into the stems.
	ORACHE/SALTBUSH *Atriplex* spp.	- Sandy and shingle beaches worldwide.	- Sprawling plant with spikes of small, greenish flowers. Pale- or silvery-green leaves are either triangular or spear-shaped, sometimes lobed.
	SCREW PINE *Pandanus* spp.	- Tropical coasts from Madagascar to southern Asia and islands in the southwestern Pacific.	- Tree up to 30 ft (9 m) tall, supported by stilt-like aerial roots. Strap-like, saw-toothed leaves are grouped in spirals. Large, globular knobbly fruit ripens from green to orange or red.
	SCURVY-GRASS *Cochlearia* spp.	- Salt marshes and rocky coasts of northern North America and northern Europe and Asia.	- Creeping plant, 4–16 in (10–40 cm) high, with thick, fleshy, dark green, heart-shaped leaves. Small, white, four-petaled flowers.
	SEA BEET *Beta vulgaris maritima*	- Salt marshes, shingle beaches, and cliffs in Europe.	- Sprawling plant up to 40 in (1 m) high, with glossy green, stems and leaves often tinged red. Tiny green flowers grow in clusters on the stems.
	SEAROCKET *Cakile* spp.	- Sandy shores in North America, Europe, Asia, and Australia.	- Up to 16 in (40 cm) high with deeply lobed, fleshy, green leaves. Pale lavender, four-petaled flowers.

COASTAL PLANTS

any doubt at all, carry out the Universal Edibility Test (UET) first (see pp. 206–07). Don't eat wild plants if you have any known allergies, a preexisting medical condition, or are pregnant. When planning your trip, it is advisable to familiarize yourself with the edible plants in the region you are visiting and their seasonal availability.

EDIBLE PART	PREPARATION	BEWARE OF	EXTRA INFORMATION
▪ All	▪ Eat raw or dry in the sun and grind to a powder, for ease of storage.		▪ Gutweed is a good indicator of where fresh water runs across a seashore as it is particularly abundant in such sites.
▪ Fronds	▪ Best boiled, though young fronds can be eaten raw.	▪ Large doses of iodine can be harmful.	▪ Sugarwrack (*L. saccharina*) tastes sweet, as its name implies, and can be eaten fried or boiled. Kelp is high in iodine, small amounts of which are needed for good health.
▪ All	▪ Boil, then mash.		▪ The Welsh make a cake of out of laver and oatmeal, called laverbread. The Japanese produce thousands of tons of paper-thin sheets of dried, processed laver, called nori.
▪ Seeds (coconuts)	▪ Drink the milk fresh. ▪ Eat the flesh raw or sun-dried.	▪ Mature coconut milk needs extra water to be digested. It's also a laxative, so don't drink too much.	▪ Green, unripe coconuts are a good source of water (see p. 190). Coconut milk is rich in sugar and vitamins and contains protein. The oily flesh is also nutritious.
▪ Stems	▪ Steam or boil.		▪ Also known as Poor Man's Asparagus. Rock samphire (*Crithmum maritimum*), which is found on cliffs and rocky shores, is unrelated but has edible succulent leaves.
▪ Leaves	▪ Young leaves can be eaten raw, older leaves should be boiled.		▪ *Atriplex* species are restricted to saline soils. As well as coasts, they are also found inland on the shores of alkaline lakes and in deserts. Gray saltbush (*A. cinerea*) is a type of bushfood in Australia.
▪ Fruit	▪ Inner flesh of ripe fruit can be eaten raw. Partly ripe fruit can be eaten if baked for two hours.	▪ The leaves have small, thorn-like spines at the edges, which can scrape and irritate the skin.	▪ Unripe, green fruit is inedible.
▪ Leaves	▪ Eat the leaves raw or pulp and drink.		▪ Scurvy-grass leaves are rich in vitamin C— sailors used to eat (or drink) them to prevent scurvy. They are very bitter, so are best leached in water, but you should eat them in a survival situation.
▪ Leaves	▪ Eat raw or boiled.		▪ Sea beet is the wild ancestor of beets, sugar beets, and Swiss chard.
▪ Leaves ▪ Young pods	▪ Leaves and young pods can be eaten raw.		▪ Searocket leaves have a peppery taste. One species of *Cakile* grows in the deserts of the Arabian Peninsula.

WILD FOOD

ALL MAMMALS ARE EDIBLE, but some species or groups of mammals are in danger of extinction and are protected by law; the mammal groups listed below contain many species that are common in their areas of distribution, and are not usually dangerous if approached and handled correctly. However, when preparing for your trip, you must

	NAME	WHERE	IDENTIFICATION
AERIAL	**BATS** *Chiroptera*	▪ Temperate and tropical regions worldwide.	▪ The only mammals with true wings and the ability to fly. Wingspans vary from 6 in (15 cm) to over 5 ft (1.5 m) in the large fruit bats, or flying foxes (*Megachiroptera*).
TREES / GROUND	**TREE SQUIRRELS** *Sciurus*	▪ North and South America, Europe, and temperate parts of Asia.	▪ Small or medium-sized rodents, with large, bushy tails.
	PORCUPINES *Hystricomorpha*	▪ North and South America, Africa, and tropical Asia.	▪ Large, rounded rodents, with a coat of sharp quills.
GROUND / BURROWS	**ANTELOPE AND DEER** *Bovidae* and *Cervidae*	▪ North and South America, Africa, and Eurasia.	▪ Hoofed mammals, with long legs and barrel-shaped bodies. Male antelope have permanent horns; male deer have antlers, which they shed and regrow each year.
	GUINEA PIGS *Cavia* spp.	▪ Northwestern, central, and southeastern South America.	▪ Small rodent, with dark, coarse fur, short legs, and no tail.
	HEDGEHOGS *Erinaceinae*	▪ Europe, Africa, and Asia; introduced to New Zealand.	▪ Small, short-legged insectivorous mammal, with spines on back and sides of body.
	KANGAROOS *Macropus* spp.	▪ Australia.	▪ The largest of the marsupials (pouched mammals), with long, strong tails, large back legs, and short forelegs.
	RABBITS AND HARES *Leporidae*	▪ Most habitats worldwide, from arctic tundra to semi-desert.	▪ Small or medium-sized herbivorous mammals, with large ears and small, round, furry tails. Fur is usually brown or dark gray; the Arctic hare (*Lepus arcticus*) has a winter coat: white with black ear tips.
GROUND / AQUATIC	**BEAVER** *Castor* spp.	▪ North America and northwestern Eurasia.	▪ Large semi-aquatic rodents, with coarse, brown fur, webbed feet, and a flat, scaly tail.
	CANE RATS *Thryonomys* spp.	▪ Sub-Saharan Africa.	▪ Large rodents, with coarse, brown fur and a long, naked tail. The greater cane rat (*T. swinderianus*) is semi-aquatic.

MAMMALS

familiarize yourself with those mammals that can be hunted in the region you are visiting and their seasonal movements. Some countries and/or states will require you to have a hunting license or permit. For trapping and preparation methods, see pp. 216–23, and for cooking suggestions, see pp. 204–05.

	HOW TO FIND	BEWARE OF	EXTRA INFORMATION
	▪ Active at night. Roost in colonies in caves and trees during the day. Temperate species hibernate in the winter.	▪ Sharp teeth. Some bats carry rabies or other diseases (see pp. 300–01), so cook the meat thoroughly. Bats are protected in Europe and some parts of North America.	▪ Large, plump, fruit-eating bats, such as the Indian flying-fox (*Pteropus giganteus*), are considered a delicacy in many tropical areas.
	▪ Mostly active by day, feeding in branches and on the ground on shoots, nuts, and birds' eggs. Nest in trees in a range of woodland habitats.	▪ Sharp teeth and claws.	▪ Flying squirrels (*Pteromyini*) are nocturnal, tree-living members of the squirrel (*Sciuridae*) family. They glide from tree to tree rather than fly.
	▪ Some New World porcupines climb trees to feed, but all Old World porcupines spend all their time on the ground across a range of habitats.	▪ Barbed quills (see p. 266 for how to remove).	▪ Slow-moving, so can easily be run down and speared. Unlike most small game, the meat is fatty rather than lean.
	▪ Antelope are mainly found in savanna, or marshland habitats, and deer mainly in woodland, forests, or tundra.	▪ Horns or antlers.	▪ Most active at dawn and dusk. Usually live in groups.
	▪ Feed mostly at dawn and dusk, in shrubby grassland in mountainous regions.	▪ Sharp teeth.	▪ Have communal feeding runways. Traps can be baited with leafy vegetables.
	▪ Habitats range from woodland, hedgerows, and grassland to desert. Feed at night on small animals, such as worms and insects.	▪ Sharp spines. Usually infested with parasites, so handle carefully and cook well.	▪ Traditionally prepared for eating by covering with clay and baking in embers of a fire (see p. 205).
	▪ Live in open savanna woodland, feeding mainly at night on vegetation. Gather at waterholes in times of drought.	▪ Sharp claws and a powerful kick.	▪ Kangaroos are protected in some Australian states, but can be hunted (if you have a permit) in others.
	▪ Rabbits live in burrows, often in large numbers, coming above ground to feed on vegetation, using well-worn runs. Hares live above ground.	▪ Rabbits and hares may be infected with germs, so handle them carefully and cook well. Their meat is very lean, and must be eaten with green vegetables (see p. 220).	▪ In most areas, these are the first animals to try to trap. The European rabbit (*Oryctolagus cuniculus*) is an invasive pest species in Australia.
	▪ Look for the distinctive mud-and-stick lodges in the middle of a pond or lake. Beavers leave the lodge at night to feed on water plants and trees along the riverbank.	▪ Strong, chisel-like teeth. The Eurasian beaver (*Castor fiber*) is protected in many of the countries in which it is found.	▪ Use regular runs along streams. The tail can be eaten as well as the flesh.
	▪ Feed at night on reeds and grasses in marshland and on riverbanks, or on grasses in moist savanna, and on rocky hillsides.	▪ Sharp teeth.	▪ Cane rats are a valuable source of bush meat in West and Central Africa. "True" rats (*Rattus* spp.) are edible but often carry diseases, so handle with care.

WILD FOOD

ALL BIRDS ARE EDIBLE, although a few taste horrible (birds-of-paradise, for example), and pitohuis have poisonous feathers and skin. Some species or groups of birds are in danger of extinction and are protected by law; the bird groups listed below contain many species that are common in their areas of distribution. When planning your trip,

NAMES	WHERE	IDENTIFICATION
GAMEBIRDS *Galliformes*	▪ Worldwide, except Antarctica.	▪ Typically have plump bodies, small heads, and short, rounded wings. Range in size from quail, which can weigh as little as 2 oz (50 g), to the wild turkey (*Meleagris galloparvo*), which can be as heavy as 22 lb (10 kg).
OSTRICH *Struthio camelus*	▪ From West to East Africa south of the Sahara, and southern Africa.	▪ The world's tallest and heaviest bird, reaching 220 lb (100 kg), the ostrich is flightless. Long neck and long, strong legs, with two-toed feet. Males have black and white plumage, females brown.
OWLS *Strigiformes*	▪ Every continent, except Antarctica.	▪ Upright posture and a flattened face with large, forward-facing eyes. Strong, hooked bill and sharp talons (claws).
PIGEONS AND DOVES *Columbiformes*	▪ Worldwide, except the polar regions.	▪ Plump, full-breasted bodies, with a small head and bill. Thick, soft plumage, which can be brown or gray, or brightly colored in some tropical species.
STORKS AND HERONS *Ciconiiformes*	▪ Worldwide, except the polar regions.	▪ All have large bodies, with long legs, long necks, and bills. Range height from 10 in (25 cm) for the smallest bitterns to 5 ft (1.5 m) for the largest storks.
VULTURES *Accipitridae* and *Cathartidae*	▪ All continents, except Antarctica and Australasia.	▪ Large carrion-eating birds, with large wings, powerful feet with sharp talons, and a strongly hooked bill. Head and neck is often bald or sparsely feathered.
WADERS AND GULLS *Charadriiformes*	▪ Worldwide.	▪ Vary greatly in size and shape, but most have subdued brown, gray, black, or white plumage. Waders (or shorebirds) usually have lightweight bodies and long legs. Gulls have compact bodies.
WATERFOWL *Anseriformes*	▪ Worldwide, except Antarctica.	▪ Typically have plump bodies, powerful wings, and short legs with webbed feet. Most species have a broad, flattened bill. Ducks usually have short necks, while geese and swans have long necks.

BIRDS

you must familiarize yourself with those birds that can be hunted in the region you are visiting and their seasonal availability. Some countries and/or states will require you to have a hunting license or permit. For trapping and preparation methods, see pp. 226–29; for cooking suggestions, see pp. 204–05.

HOW TO FIND	BEWARE OF	EXTRA INFORMATION
▪ Wide range of terrestrial habitats, from high mountains, to tropical forests, to Arctic tundra.	▪ Short but sharp beak and claws. In some species (including pheasants), the males have sharp spurs on their ankles.	▪ Nearly all gamebirds feed and nest on the ground. At night, many gamebirds roost in trees.
▪ Open semi-arid plains (from desert to savanna) and open woodland.	▪ Can run fast and deliver a powerful kick. Very protective of eggs in the nest and the young birds.	▪ The eggs are the largest of any bird, weighing 3 lb (1.4 kg). The nests are communal and contain up to 40 eggs.
▪ In most habitats, from tundra to dense forest.	▪ Sharp bill and talons.	▪ Most species hunt at night and roost in trees during the day. Usually nest in holes in trees, under rocky overhangs, or, sometimes, in burrows.
▪ Variety of forest habitats, from open woodland to dense, tropical rain forest, and grassland and semi-arid areas.		▪ Often feed in flocks on the ground or in trees, and usually roost communally in trees. Can be taken by hand from the roost if you approach slowly and quietly.
▪ Freshwater habitats, ranging from wetlands, rivers, lakes, marshes, swamps, mangroves, and lagoons to tidal mudflats.	▪ Sharp bill.	▪ Usually feed alone at the water's edge, but often nest communally in trees.
▪ Open areas, including mountains, plains, deserts, and savannas.	▪ Sharp bill and talons. Handle as little as possible, as prone to parasites and infection. Boil meat for at least 30 minutes.	▪ Carrion eaters and scavengers, such as crows (*Corvus* spp.) and gulls (see below), can be lured into traps baited with meat.
▪ Tundra and a variety of wetland and coastal habitats, including tidal mudflats, beaches, and cliffs.	▪ Sharp bill. Gulls and terns will aggressively defend their nest sites.	▪ Most birds in this group nest on the ground or on rock ledges, laying about four well-camouflaged eggs. Often nest in large colonies.
▪ Arctic tundra, wetlands, rivers, and lakes. Ducks and swans usually feed on the water, while geese graze on the land.	▪ Geese and swans can be very aggressive, particularly in the breeding season. Mute swans (*Cygnus olor*) can weigh up to 26 lb (12 kg).	▪ Many species migrate between their breeding grounds in the Arctic and their wintering grounds further south. They molt their feathers in the late summer, rendering them flightless for a couple of weeks and thus easier to catch.

WILD FOOD

SOME AMPHIBIAN AND REPTILE SPECIES are at risk of extinction and are protected by law; the animals listed below are common in their areas of distribution, and are non-venomous. As part of preparation for your trip, it is advisable to familiarize yourself with the reptiles and amphibians in the region you are visiting. Many countries and/or states

	NAME	WHERE	IDENTIFICATION
FROGS	**AFRICAN CLAWED FROG** *Xenopus* spp.	Sub-Saharan Africa; introduced to North America, South America, and Europe.	Flattened, brown body, 2¼–5 in (6–13 cm) long, with a line of white "stitch marks" along the sides. Clawed toes on the muscular legs.
	AMERICAN BULLFROG *Rana catesbeiana*	North America; introduced to Europe and Asia.	Body is green with brown markings above and white below, 3½–8 in (9–20 cm) long. Large legs and large eardrums.
	SOUTH AMERICAN BULLFROG *Leptodactylus pentadactylus*	Central and northern South America.	Smooth yellow or pale brown body with some dark markings, 3–9 in (8–22 cm) long.
TURTLES	**AFRICAN HELMETED TURTLE** *Pelomedusa subrufa*	Sub-Saharan Africa.	Flattened, brown shell, 8–12½ in (20–32 cm) long.
	ASIAN LEAF TURTLE *Cyclemus dentata*	Southeast Asia.	Oval, light to dark brown shell, 6–9½ in (15–24 cm) long, with serrated edge near tail. Reddish brown head and legs.
	PAINTED TURTLE *Chrysemys picta*	Southern Canada, USA, and northern Mexico.	Flattened, smooth shell, 6–10 in (15–25 cm) long; brown above and yellow below, sometimes patterned. Yellow or red stripes on the neck.
SNAKES	**CARPET PYTHON** *Morelia spilota*	Indonesia, New Guinea, and Australia.	Several subspecies, all of which have a bold pattern of irregular markings, which can be reddish brown, brown, black or gray. Average length is 6½ ft (2 m), but can reach 13 ft (4 m).
	COMMON BOA *Boa constrictor*	Central America, South America, and some Caribbean islands.	Several subspecies but all have characteristic dark saddle markings along the back and a dark stripe behind each eye. Narrow head and pointed snout.
	COMMON EGG-EATING SNAKE *Dasypeltis scabra*	Sub-saharan Africa	Reddish-brown or gray body with dark, angular markings. A slender snake, 28–39 in (70–100 cm) long. Rounded snout.
	COMMON RATSNAKE *Elaphe obsoleta*	Southern Canada, and central and eastern USA	Subspecies coloration varies from bright yellow-orange to pale gray with darker blotches. Length range is 4–6 ft (1.2–1.8 m). Long head with rounded snout.
LIZARDS	**COMMON/VIVIPAROUS LIZARD** *Zootoca vivipara*	Europe, extending to the Arctic Circle, and central to eastern Asia, including Japan.	Body is usually brown olive, sometimes black, with males having bright yellow or orange bellies and females creamy white ones. Length range is 4–7 in (10–18 cm).
	GREEN IGUANA *Iguana iguana*	Central America and northern South America.	Green or grayish body, 3¼–6½ ft (1–2 m) long, including the long striped tail. Long, stout legs for climbing trees. Adults have a fleshy dewlap beneath the throat, which is large in males.
	RAINBOW LIZARD *Agama agama*	West, Central, and East Africa.	Males turn brightly colored in the sun, with an orange-red head and a blue or turquoise body; females and juvenile males remain gray. Length range is 12–16 in (30–40 cm).
	WESTERN FENCE LIZARD *Sceloporus occidentalis*	Southwestern USA and northwestern Mexico.	Brown body with raised, pointed scales. Blue patches on belly are most pronounced in males. Length range is 6–9 in (15–23 cm).

AMPHIBIANS AND REPTILES

will require you to have a hunting license or permit. See p. 218 for some trapping methods and p. 224 for how to prepare the animal for cooking. Avoid brightly colored tropical frogs as they are often highly toxic. In addition, don't eat box turtles, as they sometimes eat poisonous fungi and their flesh may be toxic.

HOW TO FIND	SIMILAR SPECIES	EXTRA INFORMATION
▪ Wetlands and waterholes in savannas and tropical and subtropical forests.		▪ Also known as the African clawed toad.
▪ Wetlands.	▪ All frogs in the *Rana* genus are edible. The genus includes New World true frogs and the European common frog (*R. temporaria*).	▪ American bullfrog legs can be the size of chicken drumsticks. All temperate species of frog hibernate in the winter.
▪ Tropical forests and rain forests.		▪ Active at night. If picked up, the South American bullfrog emits a loud scream to startle the predator into dropping it.
▪ Watering holes and rain pools in open country.		▪ In the rainy season, this turtle wanders from pool to pool to forage. In the dry season, it buries itself in mud.
▪ Shallow streams in mountains or lowlands.		▪ Very active on land and in water.
▪ Lakes, ponds, and slow-moving streams and rivers.		▪ Active by day. You will often find several painted turtles piled up together on a log in the water, basking in the sun.
▪ Wide range of habitats.		▪ The carpet python is non-venomous, but it can inflict a nasty bite. It is one of Australia's most widespread snakes.
▪ Wide range of habitats, from tropical forest to dry savanna.	▪ There are several species in the boa family, which includes the world's largest snake, the green anaconda (*Eunectes murinus*).	▪ Kills its prey by coiling around it and suffocating it. Don't tackle large common boas—they can be up to 13 ft (4 m) long.
▪ Desert and open habitats.		▪ This nocturnal African snake feeds on eggs during the bird-breeding season then fasts for the rest of the year. It has no teeth.
▪ Rocky hillsides with open woodland.	▪ Ratsnakes (*Elaphe* spp.), which include the brightly colored corn snake (*E. guttata*), are found in both the New and Old Worlds.	▪ Like the common boa (see above), all ratsnakes kill their prey by constriction.
▪ Wide range of terrestrial habitats.		▪ There's no point trying to catch a common lizard by its tail as, like many lizards, it can shed the tail and regrow it.
▪ Tropical forest and rain forest.		▪ Defends itelf by lashing out with its tail and claws.
▪ Open habitats.		▪ Rainbow lizard can shed and regrow its tail.
▪ On rocks and other prominent places in temperate and coniferous woodlands.	▪ The eastern fence lizard (*S. undulatus*) is widely distributed across southeastern USA and northeastern Mexico.	▪ Fence lizard can shed and regrow its tail.

WILD FOOD

WHEN PLANNING YOUR TRIP, it is advisable to familiarize yourself with the species of fish in the region you are visiting, their seasonal availability, and the best method of catching them (see pp. 208–09 for how to make tackle and techniques to use in a survival situation). Many countries and/or states will require you to have a fishing

NAME	WHERE	IDENTIFICATION
BARRAMUNDI *Lates calcarifer*	▪ Western and eastern Indian Ocean, and northwestern and western Pacific Ocean.	▪ Up to 6½ft (2 m) long, with a rounded tail fin. Dark greenish-gray upper body fading to silver below.
COMMON/BRONZE BREAM *Abramis brama*	▪ Europe to Central Asia.	▪ Up to 2¾ft (82 cm) long, with a deep, narrow, bronze-colored body and a deeply forked tail.
COMMON/KING CARP *Cyprinus carpio*	▪ Europe and Asia; introduced in North America and Australasia.	▪ Up to 5 ft (1.5 m) long, with a dark gold upper body paling to silver below.
EUROPEAN TURBOT *Psetta maxima*	▪ Northeast Atlantic Ocean up to the Arctic Circle and the Mediterranean.	▪ Almost circular flatfish, up to 3¼ft (1 m) in diameter. Sandy brown with brown or black speckles on top.
NILE PERCH *Lates niloticus*	▪ Northern, central, and eastern Africa.	▪ Up to 6¼ft (1.9 m) long, with a rounded tail fin. Dark gray-blue upper body fading to silver below.
RUDD *Scardinius erythrophthalmus*	▪ Europe and Asia.	▪ Up to 17 in (45 cm) long, with a deeply forked tail. Dark greenish upper body paling to silver below. Red pelvic, pectoral, and anal fins.
ATLANTIC SALMON *Salmo salar*	▪ North Atlantic and Arctic oceans, and Baltic Sea and adjacent rivers; introduced to Argentina and Australasia.	▪ Up to 5 ft (1.5 m) long, with a powerful, streamlined, silver blue-green body.
TARPON *Megalops atlanticus*	▪ Eastern and western Atlantic Ocean, the Gulf of Mexico, and the Caribbean.	▪ Up to 8 ft (2.5 m) long, with a deeply forked tail. Bright silver body, with large, hard scales.
TENCH *Tinca tinca*	▪ Europe and Asia; introduced in North America.	▪ Olive green upper body, golden below, with a square tail fin. Small barbel at corners of mouth. Average length is 27 in (70 cm).
BROWN TROUT AND SEA TROUT *Salmo trutta*	▪ Temperate waters worldwide.	▪ Streamlined body with an average length of 3¼ft (1 m). The brown trout has a brownish body flecked with distinctive black and red spots. The sea-going form, the sea trout, is silver-blue with black spots.

FISH

license or permit, and some species of fish can only be caught at certain times of the year. Before fishing, you should also check with the locals that fish in the area are safe to eat—in some regions the waters may be contaminated. See pp. 212–13 for how to prepare a fish for cooking.

HOW TO FIND	SIMILAR FISH	EXTRA INFORMATION
▪ Tropical, slow-moving creeks and estuaries, hiding in mangrove roots and rocky outcrops.		▪ Beware of the sharp dorsal fin.
▪ Bottom of still and slow-moving waters, typically in lakes, rivers and ponds. Swim in large shoals.	▪ Silver bream (*Blicca bjoerkna*) and white-eye bream (*Abramis sapa*).	
▪ Still and slow-moving waters, often among vegetation near banks of lakes or ponds.	▪ Wild carp, mirrored carp, and leather carp are all varieties of the common carp.	
▪ Sandy, rocky, or mixed sea beds in shallow coastal and brackish water.	▪ Other flatfish (*Pleuronectiformes*) found in shallow water, such as sole, plaice, and flounder.	
▪ Lakes and large rivers.	▪ Other perch (*Perciformes*).	▪ Beware of the sharp dorsal fin and teeth (the Nile perch is a voracious predator). This species weighs up to 440 lb (200 kg).
▪ Still and slow-moving waters, often near banks of ponds and marshlands.	▪ Roach (*Rutilus rutilus*)	
▪ Cold, fast-flowing rivers and coastal waters.	▪ Pacific salmon (*Oncorhynchus* spp.)	▪ The salmon run (when the fish migrate from the sea to their birth rivers) is in the autumn, with spawning between November and January.
▪ Estuaries, lagoons, tidal flats and mangrove swamps. Feed in shoals.	▪ Indo-Pacific tarpon (*M. cyprinoides*), which is smaller and rarer.	▪ This species is hard to hook because of its bony mouth. It weighs up to 160kg (350lb).
▪ Still and slow-moving waters, in ponds, lakes and rivers. The best time of day to catch tench is at dawn, at the edges of dense vegetation.		
▪ Streams, rivers, lakes, and coastal waters.	▪ Rainbow trout and steelhead trout (*Oncorhynchus mykiss*) and the cutthroat trout (*O. clarki*).	▪ Sea-going forms migrate from the sea to rivers to spawn in the autumn. Beware of small bones when eating.

WILD FOOD

SOME SPECIES OF INVERTEBRATE are in danger of extinction and are protected by law; the animals listed below are common in their areas of distribution. When preparing for your trip, it is advisable to familiarize yourself with the edible invertebrates in the region you are visiting and the best way to catch them (see p. 219 for some techniques to use in a survival

	NAME	WHERE	IDENTIFICATION
MOLLUSCS	**COMMON/BLUE MUSSEL** *Mytilus edulis*	▪ Intertidal zones of estuaries and coasts of North and southeastern Atlantic and northeastern and southwestern Pacific.	▪ Dark-shelled bivalve, reaching 4–6 in (10–15 cm) in length.
	GIANT AFRICAN LAND SNAILS *Achatina* spp.	▪ Sub-tropical and tropical parts of Africa; introduced to the Asia-Pacific region.	▪ Large terrestrial snails, reaching up to 12 in (30 cm) in length when body is extended, and 4 in (10 cm) in diameter. Whorled, conical, brownish shell with darker bands.
ARTHROPODS	**GRASSHOPPERS** *Acrididae*	▪ Worldwide, on vegetation and the ground.	▪ Winged insects with powerful hindlegs, ⅖–3¼ in (1–8 cm) long, usually with camouflage coloring and patterning.
	HONEYPOT/HONEY ANTS *Myrmecocystus* spp.	▪ Semi-arid and arid regions of southwest USA, Mexico, Africa, and Australia.	▪ Segmented bodies with six legs and a pair of antennae, and a constricted waist. Range in colour and size, from ⅒–½in (2–12mm). Special members of the colony, called repletes, have abdomens that can swell to the size of a grape.
	WITCHETTY GRUB *Endoxyla leucomochla*	▪ Underground, in the roots of the witchetty bush (*Acacia kempeana*), central Australia.	▪ The larva of this species of cossid moth reaches about 2¾ in (7 cm) in length. It is white with a brown head.
CRUSTACEANS	**CRAYFISH/CRAWFISH/ YABBIES/KOURAS** *Astaclidea*	▪ Worldwide, in freshwater streams.	▪ Segmented bodies, which can be sandy yellow, green, dark brown, or blue-gray in color. Ten legs, the front two of which are large claws. Average length is 4 in (8 cm), but some species grow much larger.
	WOODLICE *Oniscidea* and *Armadillidiidae*	▪ Worldwide, in damp terrestrial microhabitats, such as in rotting wood and leaf litter.	▪ Flattened, segmented bodies up to ¾ in (2 cm) in length. Gray or light brown or black in color. Pill millipedes will roll up into a ball when threatened.
WORMS	**COMMON EARTHWORM** *Lumbricus terrestris*	▪ Temperate regions of Europe; introduced to most parts of the world.	▪ Reddish worm, reaching 14 in (35 cm) in length when extended.

INVERTEBRATES

situation). Many countries and/or states will require you to have a hunting license or permit, and some species of shellfish can only be caught at certain times of the year. Also check with the locals that the shellfish are safe to eat—in some regions the waters may be contaminated. See pp. 224–25 for some preparation and cooking methods.

SIMILAR INVERTEBRATES	BEWARE OF	EXTRA INFORMATION
▪ Most species of marine and freshwater bivalves and univalves are edible if alive and healthy when gathered.	▪ Don't collect marine shellfish that aren't covered at high tide. The black mussel (*Musculus niger*), found in Arctic waters, can be poisonous year-round. Mussels in tropical zones are poisonous during the summer.	▪ Healthy bivalves should close their shells when tapped and the shells should open when cooked. Healthy univalves, such as limpets, should be difficult to pry off the rocks on which they live.
▪ Many terrestrial and freshwater snails are edible. The winkle or common periwinkle (*Littorina littorea*) is an edible sea snail.	▪ Avoid any terrestrial snails with brightly colored shells and all sea snails unless you can positively identify them as an edible species, as they may be poisonous.	▪ Snails should be starved for 24 hours or fed a diet of edible green leaves to purge their guts before cooking. Boil for at least 10 minutes.
▪ Most species of cricket (*Gryllidae*) and katydid (*Tettigoniidae*) are edible.	▪ Avoid any brightly colored grasshoppers as they may be toxic.	▪ Remove the antennae, wings, and leg spurs, and roast to kill any parasites.
▪ Most species of ant are edible if gathered carefully. The larvae of wood ants (*Formica* spp.) in northern temperate regions make a nutritious meal in summer months. The abdomen of the green or weaver ant (*Oecophylla smaragdina*) found in southeast Asia and Australia tastes like citrus sherbert. Termites (*Isoptera*) are also edible. See p. 219 for catching methods.	▪ Most species of ant are aggressive in defense of their nest and have a stinging bite. Some will then squirt formic acid at the site of the bite.	▪ The swollen abdomens of the repletes contain a nutritious fluid. ▪ The repletes live deep underground in the ants' nest so you would have to dig them out.
▪ The term "witchetty grub" is also applied to the edible larvae of other cossid moths, ghost moths (*Hepialidae*), and longhorn beetles (*Cerambycidae*). Palm grubs are the edible larvae of the palm weevil (*Rhynchophorus* Spp.). They live in the trunks of sago palms (see pp. 284–285) in Southeast Asia.	▪ Do not eat any insect larvae that are already dead when you find them, or that look sick, smell bad, or that irritate the skin if handled.	▪ Should be eaten raw or roasted quickly in hot embers.
▪ Marine decapods such as crabs, lobsters, and prawns are also edible.	▪ May contain harmful parasites so cook well.	▪ Keep alive until ready to eat. See p. 225 for preparation and cooking methods.
		▪ Boil or fry gently. Will turn slightly pink, like shrimp, when cooked.
▪ All earthworms are edible.		▪ The common eathworm is unusual in that it feeds at the surface, making it easier to find and gather than other worms.

NATURAL DANGERS

FOR INFORMATION ON LARGER dangerous animals, such as bears, big cats, and sharks, and venomous animals, such as snakes, see pp. 242–43. When planning your trip, it is advisable to familiarize yourself with the potentially harmful wildlife in the region you are visiting, the nature of the threat, and how to avoid it if possible. In the case of suspected

	NAME	WHERE	IDENTIFICATION
MAMMALS	**VAMPIRE BATS** *Desmodontinae*	▪ In rain forests, deserts, and grasslands, from Mexico to northern and central South America.	▪ Small bats, with a body length of 2¾–3½ in (7–9 cm) and a wingspan of 14–16 in (35–40 cm). Dark brownish gray fur, paler on the belly. Razor-like upper incisors.
	RATS *Rattus* spp.	▪ Worldwide, except for the polar regions.	▪ Medium-sized rodents, with a minimum body length of 5 in (12 cm), and long, naked tails. Coarse brown, gray-brown, or black fur, paler on belly. Pink feet.
SNAKES	**SPITTING COBRAS AND RINKHALS** *Naja* spp. and *Hemachatus haemachatus*	▪ Warm temperate, subtropical, and tropical regions of Asia and Africa.	▪ Pale brown to black snakes up to 6 ft (2 m) long. When threatened, will rear up and spread their hoods, revealing striped patterns on their necks.
FISH	**ELECTRIC EEL** *Electrophorus electricus*	▪ Amazon and Orinoco river systems, South America, often in shallow water.	▪ Not a true eel, but an eel-like fish up to 8¼ ft (2.5 m) long and can be as thick as a human thigh. Continuous fin along lower body.
	STONEFISH *Synanceia verrucosa*	▪ In tropical coastal waters of northern Indian Ocean and southwestern Pacific Ocean.	▪ Up to 16 in (40 cm) long, this lumpy fish can match its color to the rock or sediment on which it lies while waiting for passing prey. Venomous spines in the dorsal fin.
OTHER ANIMALS	**BOX JELLYFISH/ SEA WASPS** *Cubomedusae*	▪ At the surface of tropical waters of southwest Pacific and eastern Indian Ocean.	▪ Box-shaped, transparent jellyfish, up to 10 in (25 cm) in diameter. Up to 15 long tentacles, which bear stinging cells, at each corner.
	CENTIPEDES *Chilopoda*	▪ In soil, leaf litter, cracks, and crevices in temperate, subtropical, and tropical regions worldwide.	▪ Elongated, flattened bodies divided into at least 16 segments, most of which have one pair of legs. Tropical species are typically brightly colored—yellow, red, orange, or green—with dark stripes. The world's largest centipede, *Scolpendra gigantea*, reaches 12 in (30 cm) in length.
	CONE SHELLS/ CONE SNAILS *Conidae*	▪ In inter-tidal zones and on coral reefs in warm temperate, subtropical, and tropical seas and oceans worldwide.	▪ Brightly colored and patterned, cone-shaped shells, up to 9 in (23 cm) long. These predatory snails have venomous, harpoon-like mouthparts.

WILD ANIMALS

poisoning, call the emergency services immediately. For further information regarding treatment for bites and stings, see pp. 266–67. If a casualty becomes unconscious, open the airway and check breathing (see p. 276). Be ready to begin CPR—chest compressions and rescue breaths (see p. 277), use a plastic face mask or face shield, if you have one.

	DANGER	TREATMENT	HOW TO AVOID
	▪ Many mammal species are infected with rabies, but because vampire bats feed by biting their victims, then lapping blood from the wound, the virus can be transmitted via their saliva. Symptoms include fever, headache, fear (especially of water), and seizures.	▪ If bitten by a vampire bat, or other potentially rabid mammal, clean the wound thoroughly and seek immediate medical help. Symptoms usually appear 2–8 weeks after infection, by which time the disease is almost always fatal.	▪ Vampire bats roost in hollow trees and caves, emerging at night to feed. Don't shelter in bat caves (bat dung can cause a respiratory disease). Keep covered at night, and sleep under a mosquito net. Get vaccinated before traveling to a high-risk area.
	▪ Can be infested with parasites and can also carry infectious diseases. Leptospirosis is a water-borne bacterial disease spread by infected rats' urine; the acute form in humans is called Weil's disease.	▪ If you've been in contact with potentially contaminated water and develop flu-like symptoms (fever, headache, muscle pain) you must get your blood tested as soon as possible. Antibiotics are effective in the early stages of the disease.	▪ If handling a rat, beware of its teeth and claws, and wash thoroughly afterward. Cook the meat thoroughly. In rat-infested areas avoid getting water into any cuts; if you do, wash with soap and boiled water.
	▪ Will eject a fine spray of venom from their fangs upward the eyes of an aggressor. Causes intense pain, tearing, and discharge from the eyes, spasm and swelling of the eyelids. Ulceration of the cornea can lead to infection resulting in blindness.	▪ Call the emergency services. Rinse the eyes with cool water for 10 minutes. Apply an antibiotic eye ointment.	▪ If you come across a spitting cobra, try to remain completely still and allow the snake to move away, if possible (see p. 243).
	▪ Can generate shocks of up to 600 volts, used to stun or kill prey when hunting, or in self-defense. Such a shock can be discharged up to 8 hours after its death, and is potentially lethal to humans.	▪ Call the emergency services. If the casualty becomes unconscious, open the airway and check breathing (see p. 276). Be ready to begin CPR (see p. 277).	▪ Keep your boots on if crossing a tributary and take care when washing. These waters are also home to piranhas (*Serrasalminae*), which have razor-sharp teeth.
	▪ The world's most venomous fish. If trodden on, the spines inject poison into the puncture wound. This is extremely painful and can be fatal. The injured body part will swell and muscular paralysis may set in.	▪ Call the emergency services—anti-venin is available. Immerse the injured part in water as hot as the casualty can stand for at least 30 minutes (see p. 267). Don't immobilize the injured limb. Be ready to begin CPR if the casualty loses consciousness (see pp. 276–77).	▪ Wear something on your feet when walking in shallow water. Weaverfish (*Trachinidae*) and scorpionfish (*Scorpaenidae*) also have venomous stings; the treatment is the same.
	▪ Sting is extremely painful—it will damage the skin and can cause permanent scarring. In severe cases, box jellyfish (*Chironex fleckeri*) stings can lead to cardiac arrest and death within minutes.	▪ Call the emergency services—anti-venin is available. Flood the stung area with vinegar or sea water for at least 30 seconds to neutralize the stinging cells (see p. 267). Be ready to begin CPR if the casualty loses consciousness (see pp. 276–77).	▪ Never touch jellyfish, even when dead. All jellyfish, sea anemones, corals, and the Portuguese man-of-war (*Physalia physalis*) release venomous cells when touched. Some are more toxic than others.
	▪ Have a pair of large, venomous claws on their heads, which in some species can be dangerous to humans. The sting is painful and leads to swelling. May result in anaphylactic shock.	▪ Call the emergency services. Apply a cold compress for at least 10 minutes to reduce pain and swelling. Monitor the casualty for anaphylactic shock (see p. 274) and be ready to begin CPR (see p. 277).	▪ As a general rule, avoid all multiple-legged arthropods. If you discover one on your body, gently brush it off in the direction in which it is walking.
	▪ Will fire its harpoon in self-defense if touched. Sting of most species is painful; that of the larger tropical species can be fatal. Symptoms include swelling and numbness, and may be followed by severe breathing difficulties.	▪ Call the emergency services and treat as for snake bite (see p. 266). Monitor the casualty for shock (see p. 274) and be ready to begin CPR (see p. 277).	▪ Don't pick up any cone shells in rock pools or when snorkeling or diving. (There is no anti-venin: treatment entails providing life support until the venom is metabolized by the casualty's body.)

NATURAL DANGERS

IN THE CASE OF SUSPECTED POISONING from a spider bite or a scorpion sting, you must call the emergency services immediately. For further information regarding treatment for bites and stings, see pp. 266–67. If a casualty becomes unsconscious, open the airway and check breathing (see p. 276). Be ready to begin CPR—chest compressions and rescue

	NAME	WHERE	IDENTIFICATION
INSECTS	**BEES, WASPS, AND HORNETS** *Hymenoptera*	▪ In a variety of terrestrial habitats worldwide.	▪ Narrow-waisted bodies, often striped black and yellow. Bees are hairy, while wasps and hornets have hairless bodies. Up to 1½ in (3.5 cm) long. Bees have barbed stingers, wasps and hornet stingers are smooth.
	MOSQUITOES *Culicidae*	▪ In a variety of terrestrial habitats near water worldwide, especially in warmer regions.	▪ Narrow bodies and long, slender legs. Up to ¾ in (2 cm) long. Females have syringe-like mouthparts for piercing skin.
ARACHNIDS	**BROWN RECLUSE/ FIDDLEBACK SPIDER** *Loxosceles reclusa*	▪ Southern midwestern states of USA, south to the Gulf of Mexico.	▪ Small brown spider, about ½in (1.25 cm) long) with a distinctive dark, violin-shaped mark on the back of its cephalothorax (head).
	FUNNEL-WEB SPIDERS *Atrax robustus* and *Hadronyche* spp.	▪ Moist, cool, sheltered habitats in eastern and southern Australia.	▪ Large spiders, up to 1½ in (4.5 cm) long, with glossy dark brown or black bodies and short legs.
	TARANTULAS *Theraphosidae*	▪ Deserts and forests in subtropical and tropical regions worldwide.	▪ Very large spiders with bodies up to 5 in (12 cm) long and a legspan of up to 11 in (28 cm). Bodies and legs are covered in bristly hairs. Pale brown to black in color, with pink, red, brown, or black markings.
	WIDOW SPIDERS *Latrodectus* spp.	▪ Warm temperate, subtropical, and tropical regions worldwide.	▪ Small spiders, with dark, glossy bodies and distinctive red, yellow, or white markings on the abdomen, which are shaped like an hourglass in some species.
	SCORPIONS *Scorpiones*	▪ Deserts, grasslands, woodland, and forests in warm temperate, subtropical, and tropical regions worldwide.	▪ Segmented bodies, with large, claw-like pedipalps and sting-bearing tails. Yellow, brown, or black bodies, 3–8 in (8–20 cm) long, depending on the species.
	TICKS *Ixodidae*	▪ Grassland and woodland habitats worldwide.	▪ Rounded bodies with no distinct divisions. Yellow to red- or black-brown in color. Up to ⅖ in (1 cm) long, but larger after feeding. They have spiked mouthparts, which they use to attach themselves to the skin of warm-blooded animals to feed on their blood.

INSECTS AND ARACHNIDS

breaths (see p. 277). If you need to give rescue breaths and there is poison in the casualty's mouth, or on his or her face, use a plastic face mask or face shield, if you have one. Before your trip, it is advisable to familiarize yourself with the harmful insects and arachnids (spiders, scorpions, and ticks) in the region you are visiting, and the nature of the threat.

DANGER	TREATMENT	HOW TO AVOID
▪ When a bee stings you, the stinger is ripped out of its body with the venom sac. Wasps and hornets can sting repeatedly. The stings are painful, followed by redness and swelling. A single sting may result in anaphylactic shock (see p. 274)	▪ Scrape the sting off sideways at the base of the sting if it is visible, using a fingernail or a credit card. Raise the affected part and place a cold compress against it for at least 10 minutes (see p. 267). Monitor for signs of allergic reaction.	▪ Watch out for flowers where bees may be feeding. Be careful when gathering fruit, or cleaning fish or game, as wasps or hornets will be attracted to the smell. Don't disturb their nests.
▪ Female mosquitoes feed on blood and their bites can irritate the skin. They are carriers of infectious diseases such as malaria, yellow fever, and dengue fever.	▪ Apply an antihistamine cream to the bites if they itch, and do not scratch them, as there is a risk of infection. If casualty develops a headache and fever, get medical help. Get casualty to rest, drink plenty of water, and take anti-malarials, if directed.	▪ Cover your arms and legs after sunset, use mosquito repellent, and sleep under a mosquito net. Take anti-malarial medication as directed. Get a yellow fever vaccination before traveling, where advised.
▪ Bite can cause fever, chills, vomiting, and, pain in the joints. In most cases the bite is minor, but in some cases the tissue around the wound will die, leaving a deep scar. Rarely fatal.	▪ Sit casualty down, treat as for snakebite (see p. 266), and call the emergency services. Apply a cold compress to the site of the sting. Monitor for signs of allergic reaction, such as wheezing, and anaphylactic shock (see p. 274).	▪ This spider likes to hide in dark places, so be careful where you put your hands and bare feet, and always check your bedding.
▪ Bite is very painful and cause profuse sweating, nausea, vomiting, tingling around the mouth and tongue, salivation, and weakness. Rarely fatal.	▪ Sit casualty down, treat as for snakebite (see p. 266), and call the emergency services—anti-venin is available. Monitor for signs of allergic reaction and anaphylactic shock (see p. 274).	▪ Take care when moving rocks and logs.
▪ Bite can be painful but is only mildly venomous. If provoked, tarantulas will flick irritating hairs from their abdomen which will cause itching and swelling of the skin and nasal passages, and watering of the eyes.	▪ Give pain relief and apply a cold compress to the site of the bite. Monitor for signs of allergic reaction, such as wheezing, and anaphylactic shock (see p. 274). Wash any hairs away with cool water.	▪ Tarantulas are nocturnal and hunt prey in trees and on the ground. Move away if you disturb one; don't touch it.
▪ Bite is painful and results in localized redness and swelling. More severe reactions include profuse sweating, abdominal and chest pains, nausea, and vomiting. Rarely fatal.	▪ Apply a cold compress (ice if available) and give pain relief. If symptoms worsen, call the emergency services – anti-venin is available. Monitor for signs of allergic reaction, such as wheezing, and anaphylactic shock (see p. 274).	▪ Widow spiders, which include Australia's redback spider (*L. hasselti*), build their webs in dry, sheltered spots, such as in shrubs or among rocks or logs, so take care when moving among them.
▪ Scorpion stings can be very painful and may cause severe illness. A few species have neurotoxins in their venom, resulting in temporary paralysis for 1–2 days. Rarely fatal and only in young children, the elderly, or the ill or infirm.	▪ If swelling occurs, sit casualty down, treat as for snake bite (see p. 266). Apply an ice pack or cold compress to the site of the sting. Call the emergency services, monitor for anaphylactic shock (see p. 274) and allergic reaction. Try to identify the scorpion.	▪ Scorpions are mostly nocturnal and take shelter during the day. Check your boots and clothing before putting them on and check your bedding at night. Take care when gathering firewood or turning over rocks.
▪ Ticks are carriers of infectious diseases such as Lyme disease and Rocky Mountain spotted fever. Sufferers of Lyme disease may develop a red, ringed "bull's-eye" skin lesion at the bite site.	▪ Carefully remove an attached tick with tweezers or a specialized tool (see p. 267). Clean and monitor the wound for symptoms. Get medical help if casualty develops a severe headache, stiff neck, or a fever.	▪ Wear light-shaded, tightly woven clothing and apply tick repellent. Check your skin and clothing for ticks at regular intervals.

NATURAL DANGERS

IN THE CASE OF SUSPECTED PLANT POISONING, you must call the emergency services immediately. If a casualty becomes unconscious, open the airway and check their breathing (see p. 276). Be ready to begin CPR—chest compressions and rescue breaths (see p. 277). If you need to give rescue breaths, use a plastic face mask or face shield, if you have one, to

	NAME	WHERE	IDENTIFICATION	POISONOUS PART
CONTACT POISONING	**COWHAGE/COWAGE/ COWITCH** *Mucana pruriens*	- Scrub and light woodland in the the tropics and USA.	- Vine-like plant with green, oval leaflets growing in threes. Spikes of hairy, dull purplish flowers. Hairy brown seedpods.	- Flowers - Pods
	POISON IVY *Toxicodendron radicans*	- Wooded areas in North America; widely introduced elsewhere.	- See p. 268 for illustration.	- All
	WHITE/GRAY MANGROVE *Avicennia marina*	- Mangrove swamps from tropical Africa to Indonesia and Australasia.	- Slender tree with pale bark and long aerial roots. Green, oblong, leathery leaves. Yellow flowers and fleshy, pale orange seed capsules.	- Sap
INGESTION POISONING	**BANEBERRY** *Actaea* spp.	- Temperate woodland in the northern hemisphere.	- Low shrub with, toothed green leaves. Small white flowers. White, black, or red berries grow in clusters.	- All, but the berries are the most poisonous.
	CASTOR OIL PLANT/ CASTOR BEAN *Ricinus communis*	- Throughout the tropics in scrub and wasteland; introduced to temperate regions.	- Tall shrub with glossy dark green or dark purple, star-like leaves. Spikes of yellow flowers. Spiky red pods.	- All, but the seeds contain particularly high levels of the poison ricin.
	DEATH CAMAS/ DEATH LILY *Zigadenus* spp.	- Grassy, wooded, and rocky areas in temperate regions of North America.	- Long grass-like leaves arise from a bulb. Flowers have six white petals with a green heart at base.	- All
	PANGI *Pangium edule*	- Tropical forests in Southeast Asia.	- Tall tree with green, heart-shaped leaves. Green flower spikes. Large brownish pear-shaped fruits grow in clusters.	- All, but especially the seeds, which contain prussic acid (cyanide).
	PHYSIC NUT *Jatropha curcas*	- Woodland throughout the tropics and southern USA.	- Large shrub with large, green, ivy-like leaves. Small greenish-yellow flowers. Apple-sized yellow fruit has large seeds.	- All, but particularly the seeds.
	POISON HEMLOCK *Conium maculatum*	- Wet or moist ground in temperate parts of Eurasia; introduced to North America and Australia.	- Tall herb with branching purple-spotted stem; toothed leaves; small clusters of white flowers grown in flat umbrellas.	- All, but the root has the highest level of toxins.
	STRYCHNINE TREE *Strychnos nux-vomica*	- Tropical and subtropical forests in India, Southeast Asia, and Australia.	- Evergreen tree with paired oval leaves. Small clusters of greenish flowers grow at end of branches. Large orange-red berries.	- All, but the seeds contain lethal levels of strychnine.

POISONOUS PLANTS

protect yourself from any poison on the casualty's mouth. When planning your trip, it is advisable to familiarize yourself with the poisonous plants in the region you are visiting. For further information regarding plant contact poisoning and ingestion poisoning, and their treatment in a survival situation, see pp. 268–69.

EFFECT	TREATMENT	ADDITIONAL INFO
▪ Skin irritation. Contact with the eyes can cause blindness.	▪ Call the emergency services. Rinse the skin with cold water for 20 minutes, the eye(s) for 10 minutes. Don't let the water collect under the casualty or you.	
▪ Reddening, itching, swelling, and blistering of skin within 4–24 hours of contact with the plant. Some people may suffer an allergic reaction called anaphylactic shock (see p. 274).	▪ Wash the affected area with soap and cold water. Apply anti-poison ivy cream. Monitor and treat for shock (see p. 274) if necessary. For natural remedies, see p. 268.	▪ Western poison oak (*T. diversilobum*), Atlantic poison oak (*T. pubescens*), and poison sumac (*T. vernix*) also cause contact poisoning (see p. 268).
▪ The sap blisters the skin and will cause temporary blindness if it gets in the eyes.	▪ Call the emergency services. Rinse the skin with cold water for 20 minutes, the eye(s) for 10 minutes. Monitor casualty and treat for shock (see p. 274).	▪ Blinding or milky mangrove (*Exoecaria agallocha*) also has poisonous sap.
▪ Can be fatal—ingestion of berries can lead to cardiac arrest and death. Other symptoms include dizziness, vomiting, and severe internal irritation.	▪ Call the emergency services. Induce vomiting if casualty is still conscious. Dilute the poison by getting him or her to drink large quantities of water or milk, or tea mixed with charcoal.	
▪ Can be fatal—ingestion of raw seeds causes severe diarrhea.	▪ Call the emergency services. Induce vomiting if casualty is still conscious. Dilute the poison by getting him or her to drink large quantities of water or milk, or tea mixed with charcoal.	▪ The seedpods explode when ripe, scattering the large, oval, glossy, brown-mottled seeds, which can be mistaken for beans.
▪ Deadly poisonous. Symptoms include profuse salivation, vomiting, diarrhea, confusion, slow, irregular heartbeat, low temperature, difficulty breathing, and unconsciousness, leading to death.	▪ Call the emergency services. Induce vomiting if casualty is still conscious. Dilute the poison by getting him or her to drink large quantities of water or milk, or tea mixed with charcoal.	▪ This plant looks similar to wild onions, which are edible, but the death camas does not have the onion smell.
▪ Deadly poisonous. Causes unconsciousness and severe breathing difficulties, which, if untreated, may lead to death.	▪ Call the emergency services (antidotes are available). Induce vomiting if casualty is still conscious. Dilute the poison (see Death Camas, above). Keep casualty warm and at rest.	▪ If the casualty is unconscious and stops breathing, give rescue breaths, using a face shield. Alternatively, use an oxygen bag and a mask, if possible.
▪ Severe diarrhea and vomiting.	▪ Call the emergency services. Induce vomiting if casualty is still conscious. Dilute the poison by getting him or her to drink large quantities of water or milk, or tea mixed with charcoal.	▪ The seeds look like betel nuts and taste sweet. Several species in the *Jatropha* genus are poisonous, for example, the aptly named bellyache bush (*J. gossypifolia*).
▪ Deadly poisonous. A small amount can result in death by respiratory failure from muscular paralysis. Early symptoms include nausea, vomiting, and rapid heartbeat.	▪ Call the emergency services. Induce vomiting if casualty is still conscious. Dilute the poison (see Physic Nut, above). If the casualty is unconscious and stops breathing, begin CPR, using a face shield.	▪ Water hemlock or spotted cowbane (*Cicuta* spp.), which looks similar, is also deadly poisonous. Don't mistake these plants for wild carrots or wild parsnips.
▪ Deadly poisonous. Muscle spasms occur 10–20 minutes after exposure, leading to seizures followed by death from severe breathing difficulties or exhaustion within 2–3 hours.	▪ Call the emergency services. Induce vomiting if casualty is still conscious. Dilute the poison by getting him or her to drink large quantities of water or milk, or tea mixed with charcoal.	▪ Warning: strychnine can also enter the system through contact with the eyes.

RESOURCES

SCOUTS AND SCOUTING

Boy Scouts of America

1325 West Walnut Hill Lane
P.O. Box 152079, Irving,
Texas 75015-2079
Phone: 972-580-2000
Fax: 972-580-2413
www.scouting.org

Boy Scouts of America prepares young people to make ethical and moral choices over their lifetimes by instilling in them the values of the Scout Oath and Law.

Girl Scouts of the USA

420 Fifth Avenue
New York, New York 10018-2798
Phone: 800-GSUSA-4-U [800-478-7248] or 212-852-8000
www.girlscouts.org

Girl Scouts is one of the largest organizations dedicated specifically to girls. It encourages them to develop skills and values such as leadership, social conscience, and self-worth that will stand them in good stead in the wider world.

National Scouting Museum

Boy Scouts of America, S505,
1329 West Walnut Hill Lane, Irving,
Texas 75038
Phone: 800-303-3047 and 972-580-2100
e-mail: nsmuseum@netbsa.org
www.bsamuseum.org

This museum is a tribute to the rich history of the Boy Scouts of America and features a Norman Rockwell art gallery, virtual reality adventures, hands-on learning experiences, and a collection that traces the Scouting movement from its beginnings.

WEATHER AND ENVIRONMENTAL HAZARDS

National Oceanic and Atmospheric Administration (NOAA)

1401 Constitution Avenue, NW,
Room 6217, Washington, DC 20230
Phone: 202-482-6090
Fax: 202-482-3154
www.noaawatch.gov

The NOAA has several departments, such as the National Severe Storms Laboratory (NSSL), the Storm Prediction Center (SPC), which is part of the National Weather Service (NWS), and the National Centers for Environmental Prediction (NCEP). The SPC provides regular, timely, and accurate storm forecasts, and watches out for severe thunderstorms, tornadoes, heavy rain, heavy snow, and fire weather events over the contiguous United States.

National Weather Service

1325 East West Highway, Silver Spring,
Maryland 20910
www.weather.gov/om/severeweather/index

Provides weather, hydrologic, and climate forecasts and observations for the whole country and the waters and oceans around it. The service offers a national information database for the use of public, private, and global communities.

NOAA Weather Radio All Hazards (NWR)

www.weather.gov/nwr

A nationwide network of radio stations broadcasts continuous weather information directly from the nearest National Weather Service office. NWR broadcasts official Weather Service warnings, watches, forecasts, and other hazard information 24 hours a day, seven days a week.

National Interagency Coordination Center (NICC)

www.nifc.gov/nicc/index.htm

The NICC serves as a focal point for coordinating the national mobilization of resources, such as heavy airtankers, helicopters, smokejumpers, area command teams, and Remote Automated Weather Stations (RAWS), for wildland fire and other incidents throughout the United States.

The Forest Fire Lookout Association (FFLA)

2590 W. Versailles Drive, Coeur d'Alene,
Idaho 83815
Phone: 208-765-1714 and 800-GRN-TREE
Email: weblookout@imbris.net
www.firelookout.org

The FFLA investigates former forest-fire lookout sites, ground cabins, and early forest fire detection methods to encourage public groups and others in restoring forest-fire lookouts.

U.S. Geological Service

Western Distribution Branch,
P.O. Box 25286, Denver, Colorado 80225
Phone: 303-236-7477
www.usgs.gov

This multi-disciplinary science organization focuses on biology, geography, geology, geospatial information, and water, and is dedicated to the timely, relevant, and impartial study of the US landscape, and natural resources and hazards.

DesertUSA

www.desertusa.com

This website is a comprehensive resource for North American deserts and Southwest destinations. It includes information about desert biomes, and the ways plants and animals adapt to them, and about national and state parks.

HEALTH AND MEDICAL

Centers for Disease Control and Prevention

1600 Clifton Rd, Atlanta, Georgia 30333
Phone: 800-232-4636 and 888-232-6348
Email: cdcinfo@cdc.gov
www.cdc.gov

Provides the expertise, information, advice, and tools that individuals and communities need to protect their health, including the promotion of healthy living and the prevention of disease, injury, and disability.

U.S. Department of Health and Human Services

200 Independence Avenue, S.W.,
Washington, D.C. 20201
Phone: 202-619-0257
Toll Free: 1-877-696-6775
www.hhs.gov/disasters/index.shtml

For information and advice on coping with disasters and related medical emergencies.

American Medical Association

515 N. State Street, Chicago, Illinois 60610
Phone: 800-621-8335
www.ama-assn.org/ama/pub/category/6206.html

The AMA's Center for Public Health Preparedness and Disaster Response is an important national educational resource for enhancing the disaster preparedness and response capabilities of both civilian and military providers.

American Red Cross

National Headquarters, 2025 E Street NW
Washington, DC 20006
Phone: 800-733-2767
www.redcross.org/services

The nation's premier response organization that provides relief for communities during natural and manmade emergencies. It belongs to a worldwide movement that offers neutral humanitarian care and assistance to victims of war and devastating natural disasters such as earthquakes.

National Capital Poison Center

3201 New Mexico Ave, Suite 310,
Washington D.C. 20016
Emergency Phone: 800 222 1222
www.poison.org

Affiliated with The George Washington University Medical Center, the Poison Center is committed to prevent poisonings, save lives, and limit injury from poisoning.

SEARCH AND RESCUE

National Association for Search & Rescue (NASAR)

PO Box 232020, Centerville,
Virginia 20120-2020
Phone: 703-222-6277
Toll Free: 877-893-0702
Email: info@nasar.org
www.nasar.org/nasar

A not-for-profit association dedicated to the advancement of professional, literary, and scientific knowledge in fields related to search and rescue throughout the United States and around the world.

National Institute for Urban Search & Rescue

PO Box 91648, Santa Barbara,
California 93190
Phone: 800-767-0093 and 805-569-5066
Cell: 805-798-0169
Email: niusr@cox.net
www.niusr.org

A non-profit organization dedicated to finding ways of saving lives by improving disaster readiness and response through public awareness, collaboration, research, and engineering.

Mountain Rescue Association

www.mra.org

Represents highly skilled and active mountain rescue teams throughout the country, who work for local government authorities and who are dedicated to saving lives through rescue and mountain safety education.

International Association of Dive Rescue Specialists

201 North Link Lane, Fort Collins,
Colorado 80524-2712
Phone (toll free): 800-IADRS-911
Phone (international): 1-970-482-1562
Fax (international): 970-482-0893
www.iadrs.org

An association of public safety divers and water rescue personnel who, over the years, have educated and assisted professionals in all 50 states and 15 foreign countries.

Association of Air Medical Services

526 King Street, Suite 415,
Alexandria, Virgina 22314
Phone: 703-836-8732
Fax: 703-836-8920
www.aams.org

An international not-for-profit organization that represents providers of air and surface medical transport systems, and aims to ensure that everyone has access to quality air medical and critical care support.

FEDERAL

Environmental Protection Agency (EPA)

EPA Headquarters, Ariel Rios Building
1200 Pennsylvania Avenue, N.W.,
Washington, DC 20460
EPA Hotlines: Various phone numbers and websites for assistance.
www.epa.gov/ebtpages/
emeremergencypreparedness.html

The EPA develops, implements, and coordinates preparations for chemical and other emergencies in order to be able to respond quickly and effectively to environmental crises and to keep the public informed about hazards in their community.

Federal Emergency Management Agency (FEMA)

500 C Street S.W., Washington, D.C. 20472
Phone: 800-621-FEMA-3362
TDD: TTY users can dial 1-800-462-7585 to use the Federal Relay Service.
www.fema.gov

FEMA aims to reduce the loss of life and property, and protect the country from all hazards, including natural disasters, acts of terrorism, and other manmade disasters.

U.S. Dept of the Interior National Parks Pass

1849 C Street, NW, Washington, DC 20240
Phone: 202-208-3100
Email: webteam@ios.doi.gov
www.doi.gov/parkpass.html

You can buy an annual pass for entry into national parks from the US Geological Survey store and through the government's federal lands recreation web portal at www.recreation.gov.

CANADA

National Search and Rescue Secretariat (NSS)

400-275 Slater Street, Ottawa,
Ontario K1A 0K2
Phone: (toll-free) 1-800-727-9414
Email: inquiry@nss.gc.ca
www.nss.gc.ca

An independent government agency that coordinates the search-and-rescue requirements of the military, coastguard, police, transport, parks, and meteorological services.

Search and Rescue Volunteer Association of Canada

8 Paradise Road, Paradise,
Newfoundland and Labrador A1L 3B4
Phone (toll free): 1-866-9SARVAC
(1-866-972-7822)
Phone (office): 709-368-5533
Fax: 709-368-1298
Email: info@sarvac.ca
www.sarvac.ca

A not-for-profit organization that provides a national search-and-rescue service, and is committed to fostering the exchange of information between other rescue services.

Meteorological Service of Canada

www.msc-smc.ec.gc.ca

Provides information and conducts research on water, climate, weather, atmospheric science, and other environmental issues.

Environment Canada

Inquiry Center, 351 St. Joseph Boulevard
Place Vincent Massey, 8th Floor
Gatineau, Quebec K1A 0H3
Phone: 1-800-668-6767
or 819-997-2800
Fax: 819-994-1412
TTY: 819-994-0736
Email: enviroinfo@ec.gc.ca
www.ec.gc.ca

Government department committed to preserving and enhancing the country's environment, and to providing weather forecasts.

GLOSSARY

A-frame A type of shelter design in which the roof is suspended by a single support running from the front to the back, resting on an "A"-shaped framework at either end.

Air mass A large body of air in a weather system that has its own temperature and humidity.

Altitude sickness An illness brought on by low air pressure at high altitudes.

Anabatic winds Daytime, upslope winds.

Anaphylactic shock A dangerous allergic reaction brought on by a bite or sting.

Attack point See *Stand-off*.

Avalanche transceiver A personal beacon that can be activated to alert rescuers by someone caught in an avalanche.

Base layer The bottom layer of clothing that sits directly against the skin and is designed to "wick" sweat away from the body.

Base rate The heart rate, as measured when the body is at rest.

Beaufort scale A way of describing wind speed on land and at sea, using a scale from 0 (calm) to 12 (hurricane).

Belaying A rope technique used by climbing partners to safeguard each other.

Bivi pup tent A basic one-man tent that uses a bivi bag as a covering.

Bivi bag A large waterproof sack suitable for use as a basic shelter; smaller and lighter than a tent.

Blazes A general term for markers on a trail.

Bola A hunting device made of a rope with weights attached, designed to be spun and thrown.

Boot skiing A technique for descending snow-covered slopes without skis.

Bothy bag A large waterproof bag that provides shelter from the wind, rain or sun.

Bow-and-drill set One of the oldest methods of creating a glowing ember (coal) for use in lighting a fire.

Boxing an object See *Detouring*.

Breathable clothing Clothing that allows sweat in the form of water vapour to be carried away from the body but is waterproof from the outside so keeps liquids (rain or snow) out.

Bungee A type of elasticated cord, often with hooks at either end.

Bushcraft knife A versatile survival knife used primarily for carving, cutting, and splitting small logs.

Button compass A small, simple compass, ideal as a back-up compass.

Button tie A method of attaching cordage to fabric that has no hoops or grommets; useful in that it avoids ripping a hole in the fabric, maintaining any waterproof qualities of the fabric, and allows both fabric and cordage to be reused subsequently for other purposes.

Cairn Trail marker consisting of a pile of rocks of varying sizes, designed to be visible in fog.

Canoe An open-deck paddle boat, for one or more people, and equipment.

Carabina A metal clip used for joining ropes or attachment.

Carbon monoxide A colourless, odourless, tasteless, but highly toxic gas.

Cardiopulmonary resuscitation (CPR) An emergency system of chest compressions and rescue breaths designed to restart a casualty's heart and lungs.

Cerebral oedema Accumulation of excess water in the brain that causes reduced brain function and potentially fatal swelling.

Char cloth Cotton cloth that has been combusted in the absence of oxygen. Used for lighting fires.

Chimneying A climbing technique used for climbing up the inside of large rock clefts.

Cirrus A wispy cloud that forms high in the sky and is made from ice crystals.

Cold shock An involuntary gasp reflex followed by hyperventilation, caused by sudden immersion in very cold water. In some circumstances cold shock response can lead to the inhalation of water, disorientation, panic, hypothermia, cardiac problems, and death.

Commando saw A small saw consisting of a serrated wire blade with a ring at each end.

Compacted snow trench A shelter dug into compacted snow; the excavated snow can be cut into blocks and used to form a roof.

Compass baseplate A plate to which some compasses are fixed, containing additional markings used for orientation and navigation.

Compass scale Scaled markings on a compass baseplate that measure distances on a map and help in working out grid references.

Compass An instrument used for orientation and navigation, using a freely rotating needle that indicates the direction of magnetic north.

Coniferous tree A needle-leaved, cone-bearing, mostly evergreen tree, such as pine, spruce, or fir.

Continental air mass Air that has tracked over land and carries comparatively less moisture than maritime air mass.

Contour lines Lines on a map that show points of equal height above sea level, thus detailing the changing height of natural features.

Contour navigation Walking at a constant height around a high natural obstacle.

Contouring See *Contour navigation*.

Contusion A bruise.

Cordage A type of light rope – an essential piece of survival equipment.

COSPAS–SARSAT system A satellite system, made up of low-altitude earth-orbiting (LEOSAR) and geostationary earth-orbiting (GEOSAR) satellites, that picks up signals from distress beacons.

Cramp Painful muscle spasm, often a result of dehydration.

Crampons Spiked metal plates that attach to boots to provide grip on icy surfaces.

Cumulonimbus A type of cloud that starts low in the sky and builds upwards, producing short, heavy downpours or thunderstorms.

Cumulus A billowing, puffy cloud that is generally small and develops on bright, sunny days, indicating fine weather.

Damper bread Yeast-free bread, suitable for making on a campfire.

Deadfall A trap in which a weight falls onto the prey. Also a mass of fallen dead timber.

Defensive swimming A type of swimming technique designed to keep the swimmer protected from obstacles in the water.

Degree A unit of latitude or longitude, equal to $^{1}/_{360}$ of a circle.

Dehydration A low level of water in the body. A very dangerous condition if not reversed.

Deliberate off-set (aiming off) Deliberately aiming left or right of a known feature.

Desalting kit An emergency desalination kit for turning saltwater into freshwater.

Detouring Walking around an obstacle as a method of clearing it, using a point in the distance as a reference.

Dew point The temperature at which water vapour held in the air cools to become liquid.

Dew trap A method of collecting dew to form usable water.

Digging stick A sturdy piece of wood with a pointed end.

Dipping net A fishing net used for scooping up fish that are too small to catch on a line.

Drill and flywheel A friction-based method of starting a fire.

Drip rag A method of collecting rainwater dripping down a tree using cloth.

Drogue A sea anchor used to stabilize a vessel.

Dysentery A water-borne disease that causes severe diarrhoea.

Eastings Vertical grid lines on a map; they increase in value the further east they are.

Emergency Locator Transmitter (ELT) A beacon that can send a distress signal to an orbiting satellite to initiate a rescue; mostly for use in aircraft.

Emergency plan of action (EPA) A document left with relevant authorities that contains vital details about you and your intended route, should you need to be rescued.

Emergency Position-Indicating Radio Beacon (EPIRB) A beacon that can send a distress signal to an orbiting satellite to initiate a rescue; mostly used at sea.

Emergency rendezvous (ERV) A pre-determined point at which all members of a group should meet in the event of separation.

Equator An imaginary circle running around the Earth's diameter that is equidistant from the North and South Poles at all points.

Eskimo roll A technique for righting a capsized kayak.

Faggot A bundle of kindling.

Feather stick A stick that has been feathered to use as kindling and fuel.

Fighter trench A type of snow trench dug into soft snow. Ideally uses a tarpaulin for the roof.

Finnish marshmallow A method of melting chunks of ice over a fire then collecting the water in a container.

Fire tin A tin filled with waxed cardboard, used for lighting a campfire in difficult conditions, or as a basic cooking device.

Firebase A stable, non-flammable base suitable for building a campfire on.

Firefighter's lift A method of moving a casualty by carrying them over your shoulder.

Fire set A set of components necessary to generate a glowing ember that can start a fire.

Firesteel A metal bar which, when hit with a striker, produces a spark for lighting campfires.

Flash burn See *Snow blindness.*

Föhn effect A dry downslope wind which occurs on the lee-side of a mountain or hill.

Four-wheel drive (4WD) A system on a vehicle in which drive is provided by all four wheels, rather than just two; results in superior traction.

Frostbite A serious condition caused by excessive exposure to extreme cold, in which body tissues actually freeze, sometimes to the bone. Often starts with the extremities.

Frostnip The freezing of the top layer of skin, usually on the face and extremities, caused by exposure to extreme cold. Can develop into frostbite if left untreated.

Gaiters Protective fabric that wraps around the lower leg and ankle, to keep out water and protect against sharp objects.

Gill net A fishing net in the form of a mesh stretched across a stream.

Global positioning system (GPS) A hand-held unit that uses orbiting satellites to determine the user's position accurately.

Gourd The shell of hollowed-out, dried fruit; often used to carry water.

Grab bag A pre-prepared bag of essential survival equipment suitable for quickly picking up in an emergency at sea.

Gravity filter An effective method of filtering and purifying water, incorporated into a bottle.

Grid bearing A horizontal direction expressed in degrees east or west of north or south.

Grid magnetic angle (GMA) The difference between magnetic north and grid north, expressed as an angle.

Grid north A northerly direction that runs parallel to vertical gridlines on a map. Different from true north because a map is flat.

Grid reference A method of pinpointing the location of a place or object anywhere on a map, using coordinates provided by a numbered grid system printed on the map.

Grommet A metal-ringed eyelet in clothing.

Groundsheet A waterproof sheet.

Gypsy well A method of using a hole in the ground to filter non-potable water.

Hand jam A crack in a rockface suitable for wedging your whole hand into when climbing.

Handrailing A method of navigating using long linear features on the landscape that run in the general direction of your travel, such as rivers, roads, or paths.

Hank A small coil of cordage.

Heat exhaustion (heat stress) Dehydration that results in dizziness and profuse sweating; often a precursor of heatstroke.

Heatstroke A life-threatening condition brought on by severe overheating.

HELP (Heat Escape Lessening Posture) A posture that reduces heat-loss from the body when floating in water.

Hexamine stove A stove that uses hexamine solid fuel instead of gas or liquid fuel.

Hot platform A method of melting ice over a fire and collecting the liquid in a container.

Hyperthermia An abnormally high body temperature; potentially fatal.

Hyponatraemia An accumulation of excess water in the body, leading to a dangerously low concentration of sodium.

Hypothermia A life-threatening condition caused by exposure to cold. Symptoms usually appear in the following order: uncontrollable shivering (which may stop as the body temperature lowers); irrational or out-of-character behaviour; confusion, mood swings, and withdrawal; pale, cold skin; and slurred speech and/or stumbling. Watching out for and counteracting the early symptoms may help prevent them developing into a full-blown potentially fatal condition.

Hypoxia Inadequate levels of oxygen in the blood or body tissues. Potentially fatal.

Igloo A shelter constructed from cut blocks of snow.

Iodine A chemical used to purify water.

Isobar contours Lines on a weather chart that connect points at which the barometric pressure is the same.

Katabatic winds Cool, light downslope winds that form on clear nights.

Kayak A closed-deck paddle boat for one or more people.

Kindling Small pieces of fuel for a fire, added to burning tinder.

Kukri A large-bladed knife from Nepal, used mainly for chopping.

Land breeze A night-time wind that blows from land to sea.

Lanyard A small cord or rope used for securing or suspending an item.

Latitude The angular distance north or south of the Equator, in degrees along a meridian.

Layering Wearing several light layers of clothes rather than just one or two thick ones. Layers can be added or taken off to maintain a consistent body temperature.

Lean-to A shelter with a sloping roof that leans against a horizontal ridgepole.

Lee-side The side that is sheltered from the wind.

Lensatic compass A type of compass used for precise navigational work.

Longitude The angular distance east or west across the Earth between one meridian and the prime meridian at Greenwich, England.

Machete A large-bladed knife used mainly for chopping, approximately 45–50cm (18–20in) long.

Magnetic north The direction indicated by a magnetic compass.

Magnetic variation The difference between magnetic north and grid north.

Mantelling A technique used for climbing overhanging rock.

Maritime air mass Air that has tracked over the sea, typically containing moisture.

Mayday The internationally recognized distress signal for a grave emergency.

Matchless fire set Small kit that includes everything you need to start a fire – tinder, fuel, and spark device.

Melting sack An improvised sack that can hold snow or ice and is positioned close to a fire to provide water.

Meridian An imaginary arc on the Earth's surface from the North to the South Pole, connecting all locations running along it.

Mid-layer An insulating layer of clothing that sits between the base layer and the outer layer.

Motor impairment A limitation or loss of muscle control or movement.

Naismith's Rule A method of calculating the time it will take to arrive at a destination, taking into account distance and topography.

Natural hollow A natural dip in the ground that can be used as an emergency shelter.

New World Non-Eurasian and non-African regions of the world – specifically the Americas and Australia.

Noggin A piece of wood used to help support a structure, reducing the amount of cordage required.

Non-potable water Water that is not suitable for drinking.

Northings The horizontal grid lines on a map; increase in value the further north they are.

Occluded front A point at which two air masses meet in a weather system.

Old World Europe, Asia, and Africa.

Outer layer Outer clothing; ideally it should keep out rain but let sweat (as water vapour) escape.

Pace counting A method of determining distance; involves knowing how many paces you take to cover a set distance.

Pack animal An animal such as a mule or horse used for carrying heavy loads.

Paracord A useful type of cordage originally developed as rigging lines for parachutes. Usually comprises an outer sheath over an inner section of yarn.

Parang A large-bladed knife from Malaysia, used mainly for chopping.

Pathogen A micro-organism, especially bacteria or fungi, that causes disease.

Permafrost Permanently frozen soil.

Personal Locator Beacon (PLB) A beacon that can transmit a distress signal to an orbiting satellite to initiate a rescue.

Poncho A multi-purpose waterproof outer garment made from one sheet of fabric; also useful for building a basic shelter or bed.

Post-holing A technique for walking in deep snow without snow shoes.

Potable water Water suitable for drinking.

Potassium permanganate A chemical used for a variety of tasks, from lighting fires to purifying water.

Precipitation Moisture in a cloud that may fall as rain, snow, or hail.

Prismatic compass See *Lensatic compass*.

Protractor A device for measuring angles.

Psychogenic shock A very high level of psychological and emotional stress brought on by a sudden disaster situation.

Pulk A simple plastic sled used for carrying equipment over snow.

Pulmonary oedema Swelling and fluid accumulation in the lungs that causes potentially fatal breathing problems.

Pygmy hut A domed hut made from a circle of bent saplings or limber poles and thatched with natural materials.

Pygmy roll A method of rolling fibres together to make cordage.

Quicksand A bed of loose, wet sand that yields easily to pressure and can engulf anything on its surface.

Quinzhee A basic dome-shaped, snow-covered overnight shelter.

Ranger flint and steel A rod of flint which, when hit with a striker, produces a spark for lighting campfires.

Recovery position The position an unconscious person should be placed in to minimize further injury and help recovery.

Reflector A device for directing heat from a campfire towards shelter.

Reverse-osmosis pump A survival pump system that turns saltwater into freshwater.

Ridgepole A long horizontal pole that forms the apex of a roof.

Romer measure See *Compass scale.*

Salting A salt marsh.

Scrambling Climbing without ropes.

Scrape A type of basic shelter built in a natural hollow or depression in the ground.

Sea breeze A daytime wind that blows from sea to land.

Secondary drowning Potentially fatal biological changes that can take place in the lungs after a person nearly drowns, caused by the body's response to inhaling water.

Shock A life-threatening condition that occurs if the circulatory system fails, often triggered by severe bleeding, burns, or sudden cold.

Show-stopper A failure in planning that could cause delays to, or stop a trip or expedition.

Sighting mirror An advanced component on a high-end compass used for helping in orientation and navigation.

Signal fire A fire specifically designed to produce lots of smoke to attract attention.

Signal flare A hand-held distress flare that gives off orange smoke in daylight and a bright light at night.

Signal mirror A simple signalling device that works by reflecting sunlight.

Silva compass A type of basic compass useful for hiking.

Sip well A method of extracting water trapped under rocks by sandy ground.

Skidoo A motorized vehicle used for travelling over snow and ice.

Slingshot A hunting weapon that fires small stones and is made from a Y-shaped stick with an elastic strip stretched between the prongs.

Snare A wire noose used for trapping animals.

Snow blindness Eye damage caused by ultraviolet light reflected off snow or water.

Snow cave An effective cave-like shelter dug into compacted snow on the lee-side of a hill.

Snowshoes Wide-soled strap-on shoes designed to stop you sinking into snow.

Soak A water source found close to rivers and creeks in areas that are usually lower-lying than the existing water table.

Solar still A method of extracting drinking water from any source of moisture by a process of evaporation and condensation.

Space blanket A plastic blanket covered in aluminum foil that can be used as a shelter or a reflective signalling device; to carry, store, and heat water; or to cook in.

Stand-off A technique for navigating to a point that may be hard to locate, by orientating from a nearby prominent feature.

Standing deadwood Wood from a tree that has died but is still standing. Hazardous, as branches or the whole tree may fall, but makes excellent firewood.

Straddling A climbing technique used for ascending wide chimneys.

Stratus Dense, grey cloud that forms a sheet. Rain can fall for long periods of time if the cloud has depth.

Strobe light An effective signalling device in the form of a rapidly flashing LED light.

Survival blanket See *Space blanket.*

Survival kit Essential items for survival carried on your person.

Survival straw A compact emergency water purifier.

Survival suit A waterproof, buoyant suit designed for survival in open water.

Survival tin An essential, compact container carried on the person that addresses basic survival needs: protection, location, water, and food.

Taiga A subpolar region characterized by coniferous forest.

Tarp Shortened form of "tarpaulin", a type of sturdy waterproof sheet.

Temperate climate A climate without extremes of temperature or rainfall.

Tetanus A potentially lethal infection caused by bacteria that live in soil.

Throwing star An improvised four-pointed hunting weapon used for throwing at prey.

Tinder A dry, light, combustible material that is the first fuel used when lighting a fire.

Topographic map A map that shows the main features on a landscape, and elevation via use of contour lines.

Transpiration bag A method of evaporating, condensing, and siphoning off water from foliage using a plastic bag and sunlight.

Triangulation A method of determining your location by taking bearings with a compass from recognizable landscape features.

True north The direction of a meridian of longitude that converges on the North Pole.

Tundra A polar region characterized by permafrost and stunted vegetation.

Universal Edibility Test (UET) A test that checks whether a plant is safe to eat via a methodical process of testing small amounts on the skin, in the mouth, and in the stomach.

UV active purification Purifying water via a battery-operated ultraviolet (UV) purifier.

UV passive purification Purifying water by leaving filled bottles in strong direct sunlight. The UV rays eventually kill most pathogens.

Vegetation bag See *Transpiration bag.*

VHF radio Very high frequency radio transmitter; usually used at sea.

Water balance The difference between water lost from the body through sweat and the water taken in through drinking.

Water purifier A device that filters and purifies water by pumping it through micro filters, chemicals, or a combination of both.

Weather chart A map of major weather systems and their predicted direction of travel.

Wicking material A material that moves moisture away from your body to evaporate.

Wickiup A small hut made from straight poles lashed together at the top, with an interwoven framework covered with animal hides or grass.

Witch's broom A cleft stick stuffed with thin, dry bark suitable for lighting a fire.

Withies The strong, flexible stems of plants, such as willow, birch, ash, and hazel.

Zig-zag route Method of climbing a steep slope using a zig-zag path to reduce the effort required to achieve the climb. Also effective when walking down steep slopes.

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After joining the Royal Navy in 1977, Colin Towell qualified as a Combat Survival Instructor with 22 Regiment SAS (the British army's elite Special Air Service), and has spent over 30 years teaching land, sea, desert, jungle, and cold-weather survival skills—as well as survival and conduct in captivity—to UK Army, Navy, Royal Marines, and Air Force personnel. He was the Royal Navy's Chief Survival Instructor and also served three years as Chief Instructor at the US Navy SERE (Survival, Evasion, Resistance, and Extraction) school. Colin saw service in the Falklands, Bosnia, Germany, USA, and Northern Ireland, and still serves as a Reserve Chief Instructor with the UK Defence SERE Training Organisation, training both instructors and students. He provided the survival training, equipment and rescue coordination for Sir Richard Branson's balloon global circumnavigation attempts, and also trials, evaluates, and instructs in the use of specialized survival equipment, both in the UK and abroad.

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FROM THE AUTHOR

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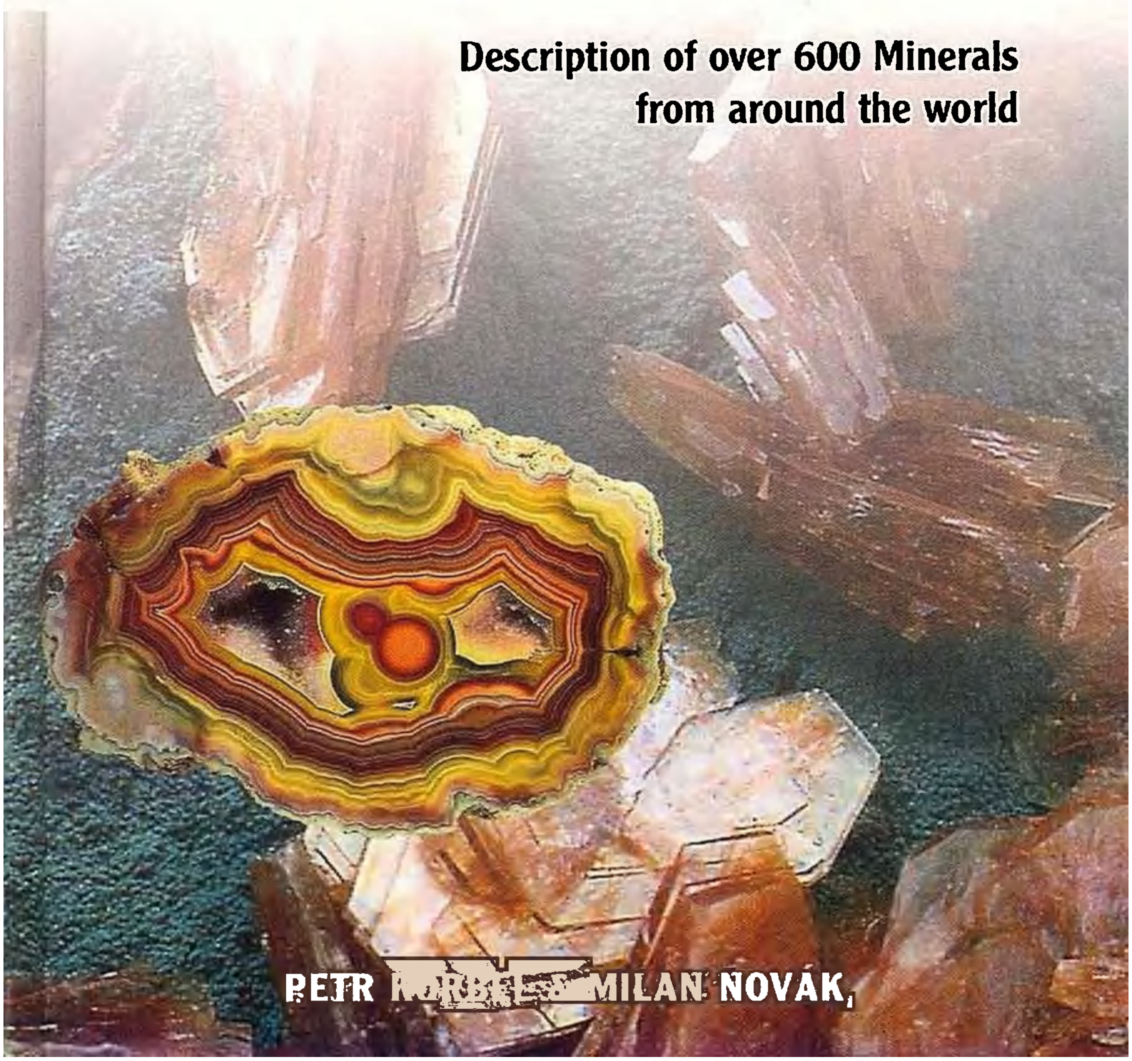

Description of over 600 Minerals
from around the world

PETR KORBEL & MILAN NOVÁK

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Explanation of the abbreviations used in the book

C – color
S – streak
L – luster
D – diaphaneity
DE – density
H – hardness
CL – cleavage
F – fracture
M – morphology
LU – luminescence
R – remark
X – crystal
XX – crystals

In the figure captions, the bigger dimension is always mentioned

Scale of the frequency of the occurrence

● - very rare
●● - rare
●●● - uncommon
●●●● - abundant
●●●●● - common

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Introduction

The ever increasing number of publications about minerals reflects a growing interest in nature. Most of those publications though only deal with a few dozen of the most common minerals or gemstones. This book fills the gap by also featuring less common and rare minerals. The authors describe over 600 mineral species and varieties, illustrated with about 750 color photographs. In choosing illustrations of particular minerals, aesthetic criteria such as size of crystal and color played a role in addition to their importance and distribution in nature. This book includes some rare minerals, known only from one locality, because they form very attractive crystals or aggregates. There are minerals known to humankind since prehistoric times such as quartz and gold, but also minerals first described quite recently like rossmanite. The photographs show well-formed and colorful crystals but many aggregates, which are more common in nature, are also included. The minerals in the book are listed according to the mineralogical system of Hugo Strunz, in his book *Mineralogische Tabellen* in 1978. The chemical formulae of individual minerals follow the form of Glossary of *Mineral Species* 1995 by M. Fleischer and J.A. Mandarino. The information is complemented in both cases with the latest knowledge from scientific literature, such as new nomenclature of amphiboles, micas and zeolites.

The mineral descriptions cover the basic physical and chemical data, including chemical formula and crystal system. The data provided correspond mainly to the end-members. The less common valence of the chemical elements is marked in the chemical formula (Fe^{3+}, Mn^{3+}, As^{3+}, Mn^{4+}, Pb^{4+}). Where an element features in both valences in the mineral, they are both marked (e.g. ilvaite, braunite).

The origin of individual minerals is described in detail. We chose for a relatively simplified scheme because the normal complexity cannot be described here in detail. Minerals can be distinguished as either primary (resulting directly from a solidifying of magma, crystallizing of an aqueous solution or metamorphism – re-crystallization in a solid state) and secondary (resulting from alteration of the original mineral, e.g. during its oxidation or reduction under low temperature and pressure close to the surface of the Earth). Primary minerals are divided into following groups: 1. magmatic, when a mineral crystallizes directly from a melt (it includes magmatic and effusive igneous rocks, including granitic and alkaline syenite pegmatites and meteorites); 2. sedimentary, when a mineral crystallizes during a process of diagenesis or from hydrous solutions under normal temperature (clastic, organic and chemical sedimentary rocks); 3. metamorphic, when a mineral crystallizes during metamorphic processes in a solid state at a wide range of temperature and pressure (it includes regionally and contact metamorphosed rocks and skarns); 4. hydrothermal, when minerals crystallize from aqueous solutions and fluids under high to low temperatures (it includes ore and the Alpine-type veins, cavities in volcanic rocks, minerals and rocks, hydrothermally altered under high temperature, e.g. greisens).

Secondary minerals are divided into following groups: 1. oxidation, when minerals result from the oxidation (weathering) of the primary minerals in the oxidation zone of ore deposits and other rocks (it includes the origin of malachite and azurite during the chalcopyrite oxidation, also the origin of secondary phosphates in granitic pegmatites during the oxidation of primary phosphates); 2. cementation, when minerals result from the reduction of the primary minerals (the origin of native copper and native silver under the reduction conditions in the cementation zone of ore deposits). This classification is very much simplified of course, because in many cases we cannot readily determine a specific origin of a particular mineral. This relates to minerals that crystallize under conditions which approximately represent a transition between separate phases of the origin, such as the magmatic or hydrothermal origins of elbaite in the pegmatite cavities; the metamorphic or hydrothermal origins of grossular in skarns; the magmatic or metamorphic origins of cordierite in migmatites; and the hydrothermal or secondary origins of some phosphates in granitic pegmatites etc.

With the localities for individual minerals we have tried to list the most important worldwide localities regardless of their recent production but we have also included recent discoveries since these may produce important mineral specimens. Where a mineral has an important use this is listed at the end of mineral description. We would like to acknowledge all who contributed in any way to the production of this book, particularly those private collectors and institutions which loaned minerals for photography. We hope those fascinated in the world of minerals and of nature will find this book a fascinating source of information.

This book is dedicated to the memory of Dr. Jaroslav Švenek, who was of extraordinary influence to several generations of Czech and Slovak mineralogists and mineral collectors with his enthusiasm for mineralogy and attitude to life.

Marcasite, 100 mm, Misburg, Germany

+
↓

1. Elements

Copper

Cu

CUBIC ● ● ● ● ●

Properties: C – light pink to copper-red, it darkens and covers green to black in air; S – red; L – metallic; D – opaque; DE – 8.9; H – 2.5 – 3; CL – none; F – hackly; M – cubic crystals and its combinations, dendritic aggregates, sheets, slabs, massive.
Origin and occurrence: Primary hydrothermal copper is mainly related to basic igneous rocks; it is also common as a product of supergene cementation. It is associated with cuprite, malachite, azurite, silver, chalkocite, bornite and other minerals. The largest accumulations of primary copper are in the Keweenaw Peninsular, Lake Superior, USA, the largest being 15 x 7 x 3m (approx. 50 x 23 x 10ft)and weighing 420 tons. Fine crystals up to 50 mm(approx. 2in) also occur there, as do calcite crystalwith copper inclusions. Superb supergene coppercrystals come from many localities like Tsumeb, Namibia and Chessy, France. Crystals up to 140mm (5½ in) long occurred in the Ray mine and in Bisbee, Arizona, USA. Very fine spinel-law twins up to 5 cm in size and dendritic aggregates come from Mednorudnyansk, Ural mountains, Russia; crystals up to 30 mm ($^{13}/_{16}$ in) were found in Dzhezkazgan, Kazakhstan. Fine specimens of copper, associated with cuprite, azurite and malachite occurred in Rudabanya, Hungary. *Application:* electronics, electrical engineering, ingredient in gold alloys.

Copper, 42 mm, Cornwall, UK

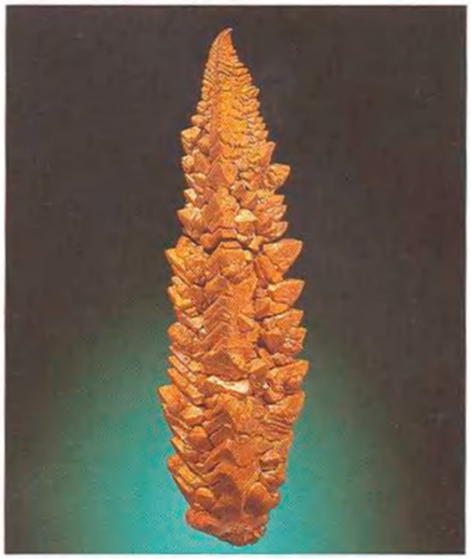

Silver, 52 mm, Freiberg, Germany
Copper, 120 mm, Keweenaw Peninsula, U.S.A.

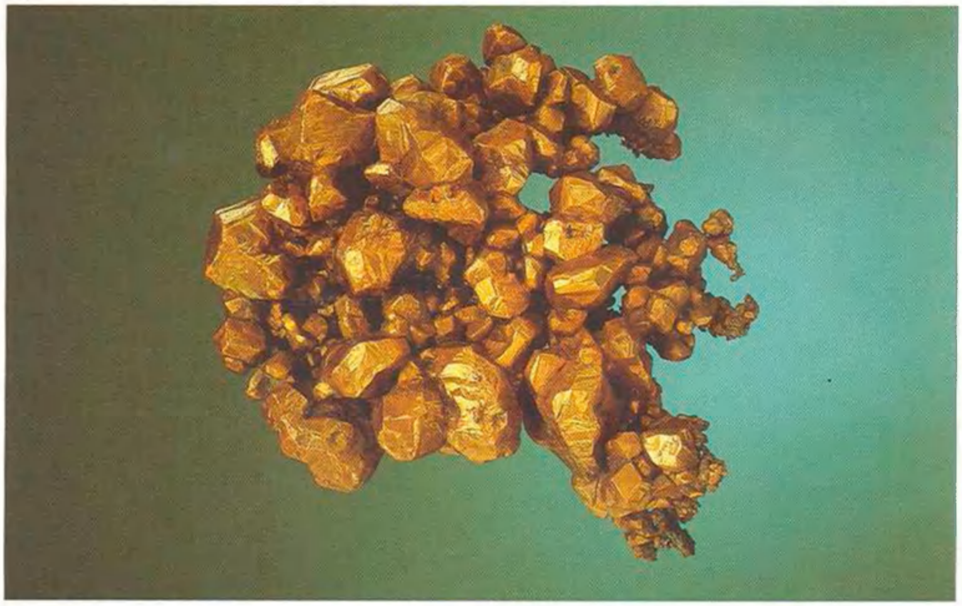

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Silver

Ag

CUBIC ● ● ●

Properties: C – silver-white, tarnishes gray to black; S – silver-white; L – metallic; D – opaque; DE – 10.5; H – 2.5 – 3; CL – none; F – hackly; M – cubic crystals, dendritic aggregates, wires, leaves, massive.
Origin and occurrence: Hydrothermal in ore veins and also of secondary cementation origin in association with acanthite, stephanite, proustite, pyrargyrite, copper and many other minerals. The best specimens of crystallized and wire silver come from Kongsberg, Norway, where wires up to 400mm (16 in) long and crystals up to 40 mm (1 9/16 in) in size have been found. Beautiful specimens of wire silver with wires over 100 mm (4 in) long are known from Freiberg, Schneeberg and St. Andreasberg, Germany. Wires several cm long were also found in Pribram and Jachymov, Czech Republic. Dendritic aggregates from Batopilas, Chihuahua, Mexico, reached up to 150 mm (6 in). Crystals and aggregates of silver, grown together with copper are genetically unique in the basalt cavities in the Keweenaw Peninsula near Lake Superior, Michigan, USA. Wires, up to 100 mm (4 in) long, come also from the San Genaro Mine in Huancavelica and Uchucchaqua, Peru. New finds of silver wires, up to 150 mm (6 in) long, have been made in Dzhezkazgan, Kazakhstan.
Application: photographic industry, jewelry, electronics.

Silver, 55 mm, Schwarzwald, Germany

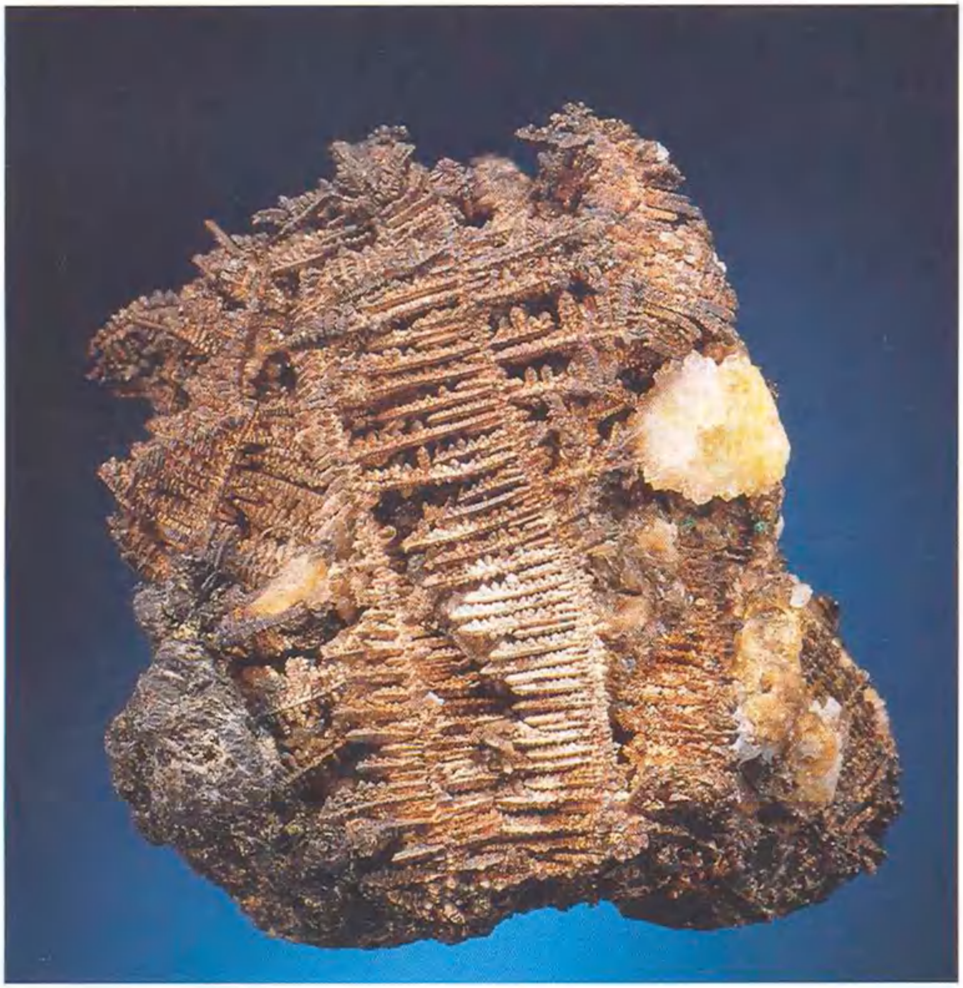

Gold, 48 mm, El Dorado, California, U.S.A.

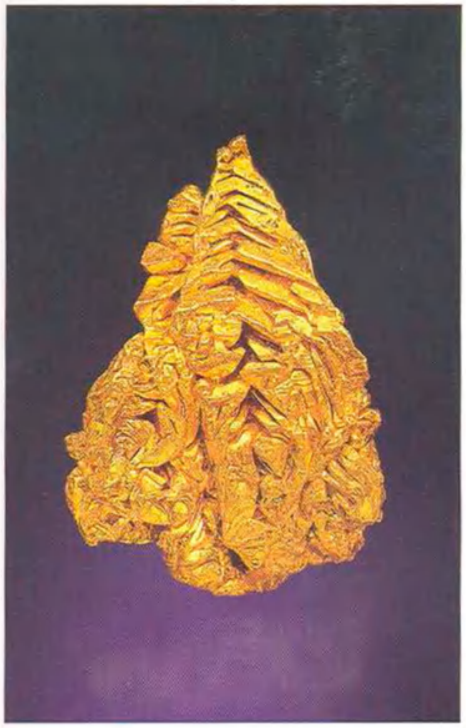

Gold, 68 mm, Eagle's Nest Mine, California, U.S.A.

Gold

Au

CUBIC ● ●

Properties: C – gold-yellow; S – yellow; L – metallic; D – opaque; DE – 19.3; H – 2.5-3; CL – none; F – hackly; M – octahedral and cubic crystals, skeletal and dendritic aggregates, leaves, nuggets.

Origin and occurrence: Primary hydrothermal in ore veins, also in contact metamorphic deposits and pegmatites. Placer deposits are secondary. It occurs with pyrite, arsenopyrite, quartz, sylvanite, calaverite, krennerite and other minerals. Beautiful leaves and crystals of gold found in many localities in California, USA (Colorado Quartz mine, Nigger Hill and others). Fine leaf gold comes from Rosia Montana, Romania. The best crystals, skeletal octahedra, up to 50 mm (2 in) have been found in alluvial sediments near Gran Sabana, Roraima Shield, Venezuela. Gold wires up to 110 mm ($4^{5}/_{16}$ in) long were very rare in Ground Hog mine, Gilman, Colorado, USA. The largest known sheets of crystallized gold occurred in the Jamestown mine, California, USA, where a cavity, which yielded 49 kg (108 lb) of golden leaves, was discovered on 26.12.1992. The largest measures about 300 mm ($11^{13}/_{16}$ in) and has about 25.79 kg (56 lb 13 oz) of gold on it. Typical aggregates of fine gold wires come from Farncomb Hill near Breckenridge, Colorado, USA. Fine crystals were also found in Berezovsk, Ural mountains and in the Lena River basin, Siberia, Russia. Fine scales and larger nuggets from placer deposits were found in Klondike, Alaska; Tuolumne County, California, USA and in Ballarat, Victoria, Australia. Fine dendritic aggregates occurred in the Hope's Nose, Devon, UK. A unique find of leaves up to 100 mm (4 in) was made in Krepice near Vodnany, Czech Republic.

Application: practically the only source of gold as a metal; used in jewelry, electronics and medicine.

Mercury

Hg

TRIGONAL ● ●

Properties: C – tin white; L – metallic to adamantine; D – opaque; DE – 13.6; M – liquid at temperatures above -39°C (-38.2°F); R – very poisonous fumes.

Origin and occurrence: Hydrothermal in low-temperature ore deposits, also connected with hot springs. It is associated with cinnabar, calomel and other Hg minerals. It occurred in Almaden, Spain;

Mercury, 30 mm, Socrates Mine, California, U.S.A.

Idria and Avala, Serbia; New Almaden and New Idria, California, Terlingua, Texas, USA; Dedova hora, Czech Republic and Rudnany, Slovakia as droplets and liquid cavity fillings.

Application: chemical industry, measuring instruments, metallurgy.

Moschellandsbergite

Ag_2Hg_3

CUBIC ● ●

Properties: C – silver-white; S – silver-white; L – metallic; D – opaque; DE – 13.5; H – 3.5; CL – good; F – conchoidal; M – dodecahedral crystals and their combinations, granular, massive.

Origin and occurrence: Hydrothermal in low-temperature deposits, associated with cinnabar, tetrahedrite, pyrite and other minerals. Crystals, several mm long, were found in Moschellandsberg, Germany. They are also known from Sala, Sweden; Les Chalanches, France and Brezina, Czech Republic.

Moschellandsbergite, 6 mm grain, Moschellandsberg

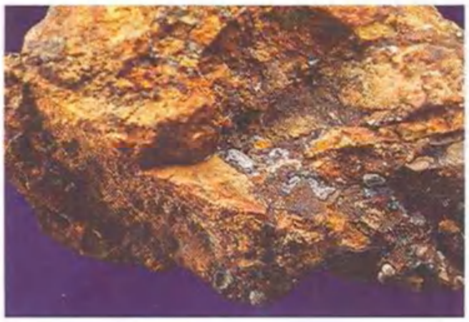

Lead

Pb

CUBIC ● ●

Properties: C – gray-white, tarnishes to lead-gray and gets dull; S – lead-gray; L – metallic; D – opaque; DE – 11.3; H – 1.5; CL – none; M – octahedral and cubic crystals, massive.

Origin and occurrence: Hydrothermal, also sedimentary (authigenic), associated with willemite and other minerals. The best specimens with crystals up to 40 mm ($1\frac{9}{16}$ in) in size, come from LDngban, crystallized also from Pajsberg, Sweden. Octahedra, up to 10 mm ($\frac{3}{8}$in), are described from El Dorado, Gran Sabana, Venezuela. It also occurs in Franklin, New Jersey, USA and Jalpa, Zacatecas, Mexico.

Iron

Fe

CUBIC ● ●

Properties: C – steel-gray to black; S – gray; L – metallic; D – opaque; DE – 7.9; H – 4; CL – perfect; F – hackly; M – crystals, granular, massive.

Origin and occurrence: Terrestric iron occurs mainly in basic rocks, but it is also known from carbonate sediments and the petrified wood. The most famous locality is Blaafjeld near Uivfaq on Disko Island, Greenland, where masses up to 20 tons were found.

Lead, 53 mm, Langban, Sweden

Chunks, weighing over 10 kg (22 lb) come from Bühl near Kassel, Germany. Impregnations of iron in dolerite occur in the Khuntukun massif and masses up to 80 kg (176 lb) are known from Ozernaya Mt., Siberia, Russia.

Platinum

Pt

CUBIC ● ●

Properties: C – steel-gray to dark gray; S – steel-gray to silver-white; L – metallic; D – opaque; DE – 21.5; H – 4-4.5; CL – none; F – hackly; M – cubic crystals, nuggets, grains and scales.

Iron, 80 mm, Bühl, Germany

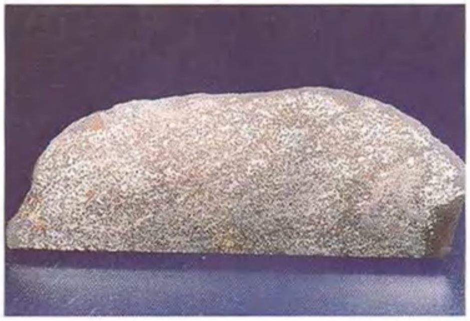

Origin and occurrence: Platinum occurs in magmatic segregations, together with chromite, olivine and magnetite in ultrabasic rocks; secondary in placers. The best crystals up to 15 mm ($^{19}/_{32}$ in) come from Konder in Khabarovsk Region, small crystals, but mainly nuggets, weighing up to 11.5 kg (25 lb 5 oz) found in the Tura River basin near Turiinsk, Ural Mountains. Primary platinum is known from deposits in the vicinity of Nizhniy Tagil, Ural Mountains, Russia; from the Onverwacht mine, Bushveld, South Africa and Sudbury, Ontario, Canada. Fine smaller nuggets, weighing up to 75 g (165 lb) were found in the Trinity River sediments in California, USA and the Choco River sediments in Columbia.
Application: chemical industry, catalytic convertors, rocket industry.

Platinum, 8 mm, Konder, Russia

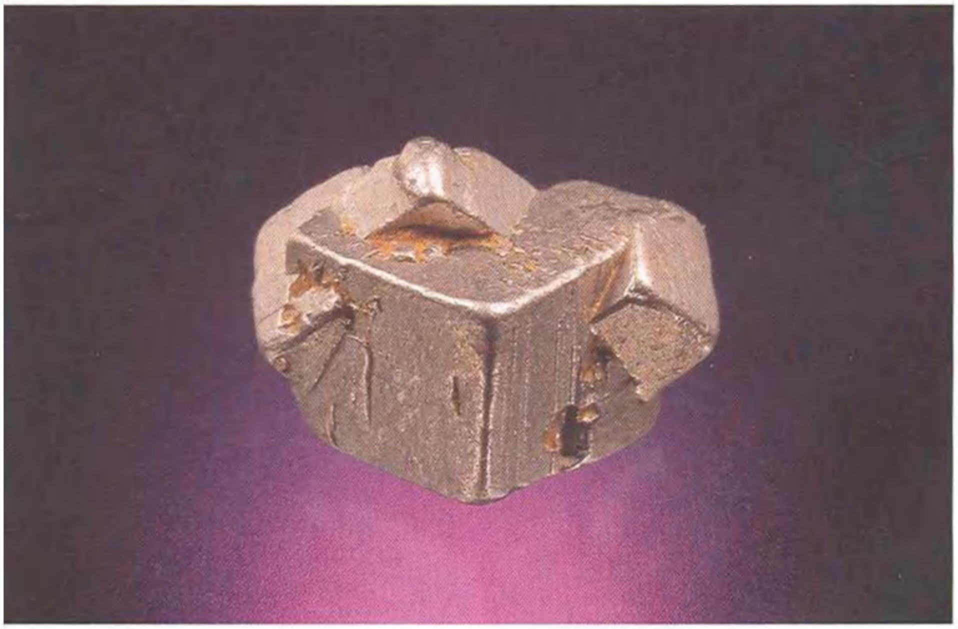

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Arsenic, 45 mm, Alden Island, Canada

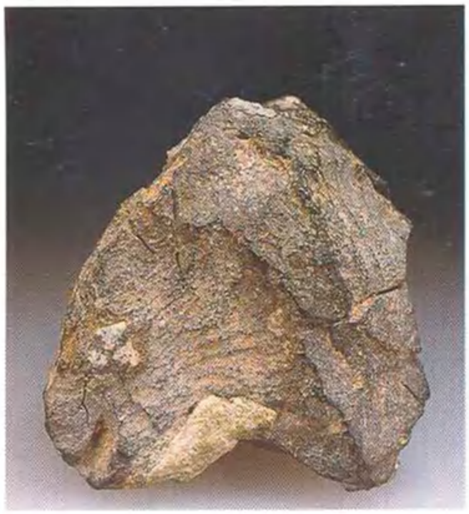

Arsenic

As

TRIGONAL ● ● ●

Properties: C – tin-white, tarnishes quickly to black; SB tin-white; L – metallic; D – opaque; DE – 5.8; H – 3.5; CL – perfect; F – uneven; M – rhombohedral crystals, botryoidal aggregates, granular, massive.
Origin and occurrence: Mainly hydrothermal, together with other As minerals. It forms massive veins, up to 200 mm (7⅞ in) thick, with botryoidal surface in Jachymov, Czech Republic and in Freiberg, Germany. In Akatani, Japan, spherical aggregates consisting of small crystals were found. It is also known from Sacarimb, Romania. Botryoidal aggregates of arsenic with leaf gold were found in the Royal Oak mine, Coromandel, New Zealand. Crystals of metamorphic origin come from Sterling Hill, New Jersey, USA.

Stibarsen, 58 mm, Atlin, Canada

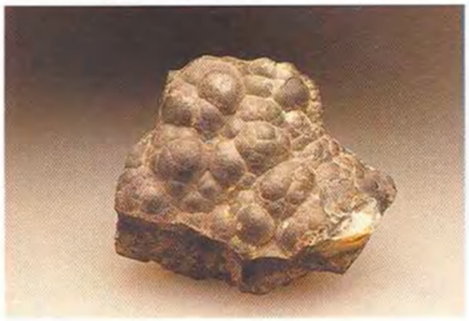

Antimony, 37 mm, New Brunswick, Canada

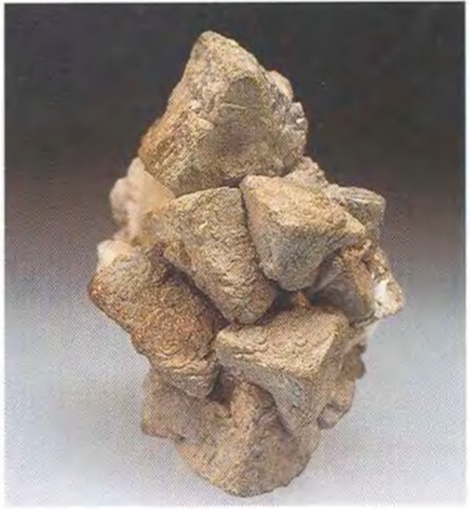

Stibarsen

SbAs

TRIGONAL ● ● ●

Properties: C – tin-white to gray, tarnishes black; S – gray; L – metallic, sometimes dull; D – opaque; DE – 6.3; H – 3-4; CL – perfect; M – indistinct crystals, botryoidal aggregates.
Origin and occurrence: In pegmatites with antimony, stibiotantalite and microlite; hydrothermal in ore veins withpyrargyrite, proustite, pyrostilpnite and dyscrasite. Beautiful botryoidal aggregates of stibarsen (previously labeled as allemontite), up to 100 mm (approx. 4 in) in size, come from Pribram and Trebsko, Czech Republic. Botryoidal aggregates up to 80 mm (3⅛ in) and imperfect crystals were found in quartz veins in Atlin, British Columbia, Canada. Fine specimens occurred in a Li-bearing pegmatite near Varutrask, Sweden.

Antimony

Sb

TRIGONAL ● ● ●

Properties: C – tin-white; S – gray; L – metallic; D – opaque; DE – 6.7; H – 3-3.5; CL – perfect; F – uneven; M – rhombohedral crystals, botryoidal aggregates, massive.
Origin and occurrence: Hydrothermal in ore veins with silver, stibnite, stibarsen, sphalerite and other minerals; also in pegmatites. As veinlets in a pegmatite in Varutrask, Sweden. Cleavable plates, up to 50 mm (2 in) known from Tornäva, Finland.

Massive aggregates up to 200 mm ($7\frac{7}{8}$ in) come from Pribram, Czech Republic. Rhombohedral crystals up to 10 mm ($\frac{3}{8}$ in) across and accumulations up to 300 mm ($11\frac{13}{16}$ in) in size described from Lake George, New Brunswick, Canada.

Bismuth
Bi

TRIGONAL ● ● ●

Properties: C – silver-white, tarnishes pink; S – silver-white; L – metallic; D – opaque; DE – 9.8; H – 2-2.5; CL – perfect; M – rhombohedral crystals, granular, massive.
Origin and occurrence: It is found in pegmatites, greisens and hydrothermal in ore veins together with chalkopyrite, arsenopyrite, lollingite, nickeline, breithauptite and many other minerals. Common in pegmatites in Anjanabonoina, Madagascar. Very fine crystals, up to 20 mm ($\frac{25}{32}$ in) known from Schlema and Hartenstein, Germany. Skeletal aggregates, overgrown with other arsenides, occurred in Jachymov, Czech Republic. Masses weighing several kg found in Bolivia (Tasna, Velaque) and Australia (Kingsgate, New South Wales). Cleavable masses up to 12 cm ($4\frac{11}{16}$in) described from Cobalt and Gowganda, Ontario, Canada.
Application: Bi ore.

Arsenolamprite
As

ORTHORHOMBIC ●

Properties: C – gray-white, it covers with a black coating; S – black, L – metallic to adamantine; D – opaque; DE – 5.6; H – 2; CL – perfect; M – acicular crystals, tabular and fan-shaped aggregates, massive.
Origin and occurrence: Hydrothermal in ore veins associated with arsenic, bismuth, silver and other minerals. Its crystals and veinlets were found with Cu arsenides in Cerny dul, Czech Republic. Occurs also in Jachymoc, Czech Republic and Marienberg Germany. Found recently in Cavnic, Romania.

Bismuth, 20 mm, Cinovec, Czech Republic

Arsenolamprite, 70 mm, Jachymov, Czech Republic

Graphite
C

HEXAGONAL ● ● ● ● ●

Properties: C – black to steel-gray; S – black to steel-gray; L – metallic, dull, earthy; D – opaque; DE – 2.3; H – 1-2; CL – perfect; M – hexagonal tabular crystals, massive.
Origin and occurrence: Metamorphic, from metamorphism of a sedimentarymaterial with C contents: also primary magmatic.Associated with many materials, stabile underconditions of the graphite origin. Crystals several cm in size known from Nordre Stromfjord. Greenland. Crystals were also found in Sterling Hill, New Jersey and Crestmore, California, USA Foliated aggregates are found in Sri Lanka (Radegara, Galle region). Accumulations in Buckingham and Grenville, Quebec, Canada are industrially important. Also common in Shunga deposit in Karelia, Russia; in Cesky Krumlov, Netolice and Blizna, Czech Republic.
Application: metallurgy, nuclear industry, production of lubricants.

Graphite, 130 mm, Krichim, Bulgaria

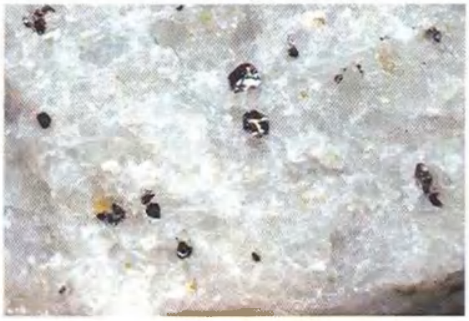

Diamond

C

CUBIC ● ●

Varieties: bort (opaque technical diamonds), balas (dark colored, spherical radial aggregates), carbonado (brown-black to black massive aggregates, up to egg sized)
Properties: C – colorless, yellow, brown, white, pink, black, red, blue, green; S – white; L – adamantine; D – transparent to translucent; DE – 3.5; H – 10; CL – perfect; F – conchoidal; M – octahedral and cubic crystals; LU – sometimes fluorescent, sometimes phosphorescent.
Origin and occurrence: Primary magmatic occurrences are limited to kimberlite pipes, secondary occurrences to placers. Large primary deposits are known from South Africa (Premier mine, Kimberley) and Yakutia, Russia (pipes in the vicinity of Mirnyi). Primary and secondary occurrences of diamonds are located in lamproites and placers near Argyle, Western Australia, Australia. Most historical diamonds from India (Golconda). Brazil (Diamantina, Minas Gerais), Congo, Angola and Namibia were found in placer deposits. Diamonds of industrial grade always prevail over the gem quality stones. The largest gem-grade diamond ever found, the Cullinan, weighing 3106 carats, comes from the Premier mine in Kimberley, South Africa. It yielded gem rough for 104 faceted stones, the heaviest of which weighs 531 carats. The largest faceted diamond known, called Golden Jubilee, was found in the same place in 1986. It weighed 755 carats before cutting and as a finished stone it weighs 545.65 carats. The dark blue Hope (44 carats) and the green Dresden (76 carats) probably came from India. Absolutely unique red diamond, weighing 5 carats, which is at the Smithsonian Institution, Washington, DC, USA, is of unknown origin.
Application: the most popular gemstone, bort and carbonado varieties are used as abrasives.

Sulfur

S

ORTHORHOMBIC ● ● ● ●

Properties: C – sulfur-yellow, yellow-brown, greenish, reddish to yellowish-gray; S – white; L – resinous to greasy; D – transparent to translucent; DE – 2.1; H – 1.5-2.5; CL – imperfect; F – conchoidal to uneven; M – dipyramidal, disphenoidic and thick tabular crystals, botryoidal and stalactitic aggregates.
Origin and occurrence: Hydrothermal product of fumaroles, product of an activity of microorganisms, disintegration of sulfides and acidic chemical reactions; associated with gypsum, anhydrite, aragonite, calcite,

Diamond, 15 mm x, Mirnyi, Russia

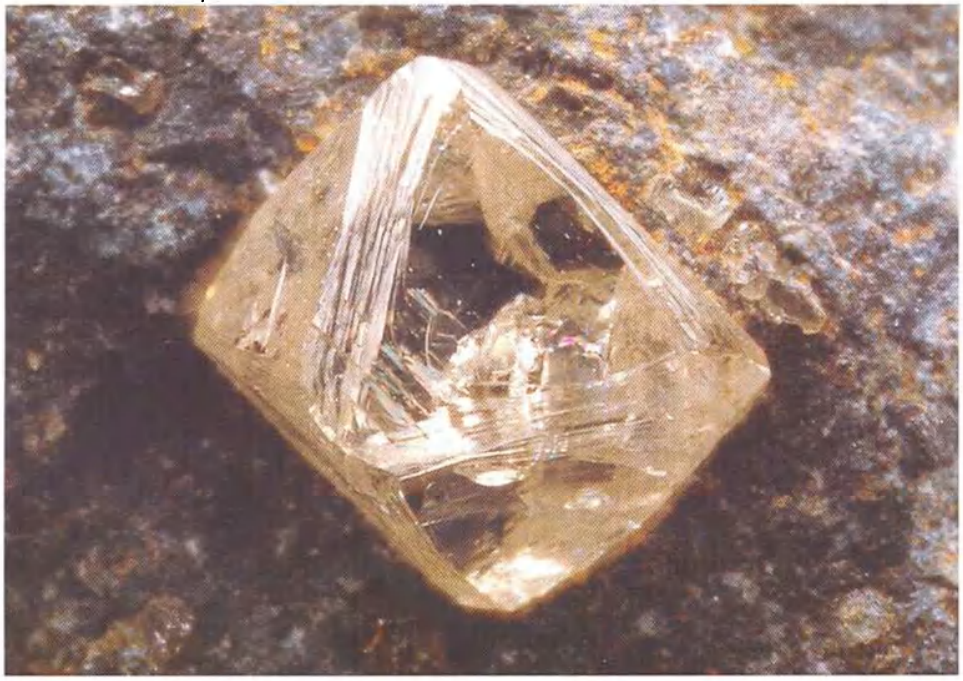

Sulphur, 66 mm, Sicily, Italy

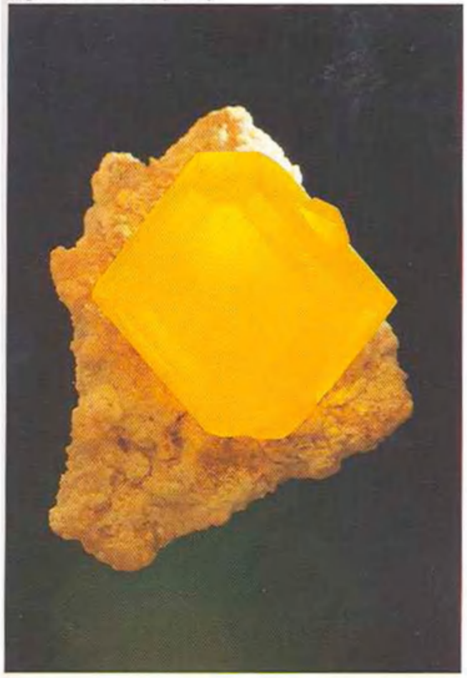

celestite and halite. The world's best crystals come from many localities near Girgenti, Sicily, Italy (Caltanisseta, Cianciana) where they reached up to 12 cm ($4\frac{11}{16}$ in) in size. Fine crystals are also known from Tarnobrzeg, Poland and Yavokskoye near Lvov, Ukraine. As a product of solfataras it occurs in many volcanically active places, like Solfatara near Pozzuoli, Italy or in sulfur lava near Shiretoku, Japan. Sulfur layers, up to 30 m (100 ft) thick, associated with salt diapirs, are located near Charles Lake, Louisiana, USA. It originates during intensive oxidation/reduction reactions of pyrite in Rio Tinto, Spain and in Kostajnik, Serbia.
Application: chemical, paper-making, rubber and leather-making industries, agriculture.

Selenium, 110 mm, Kladno, Czech Republic

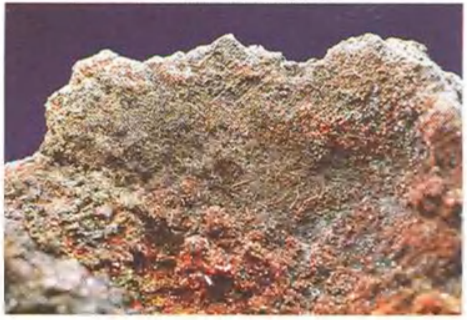

Selenium

Se

TRIGONAL ● ●

Properties: C – gray to red-gray; S – red; L – metallic, D – opaque to translucent; DE – 4.8; H – 2; CL – good; M – acicular crystals, droplets of vitreous surface, felt-like aggregates.
Origin and occurrence: Secondary, resulting from alteration, fumaroles and from burning coal dumps, with sulfur, sal ammoniac and other sulfates. Also from oxidation of organic compounds in U- and V-bearing deposits of the Colorado Plateau type, associated with pyrite, zippeite and other minerals. Red needles up to 20 mm ($\frac{25}{32}$ in) long come from the United Verde mine, Jerome, Arizona, USA. Black selenium needles found in burning coal dumps in Kladno and Radvanice, Czech Republic. Occurs with ores of U and V along sandstone fissures in the Peanut Mine, Bull Canyon, Colorado, USA. Occurred through volcanic activity in Vulcano, Lipari Islands, Italy.

Tellurium

Te

TRIGONAL ● ●

Properties: C – tin-white; S – gray; L – metallic; D – opaque; DE – 6.2; H – 2-2.5; CL – perfect; M – prismatic and acicular crystals, granular, massive.
Origin and occurrence: Primary hydrothermal in low-temperature ore deposits; it originates also as secondary through the oxidation/reduction reactions of tellurides. It is associated with gold, sylvanite, altaite, pyrite and other minerals. Crystals up to 30 mm ($1\frac{3}{16}$ in) long are known from Balya, Turkey. Crystals up to 20 mm ($\frac{25}{32}$ in) long occurred in the Au deposits Cripple Creek and Colorado City, USA. Crystals up to 10 mm ($\frac{3}{8}$ in) across come from Kawazu and Suzuki, Japan. Rich cleavage masses and crystals up to 70 mm (2¾ in) long were found in Uzbekistan. Crystallized tellurium is also known from Fata Baii and Baia de Aries, Romania.

Tellurium, 1 mm xx, Zlatna, Romania

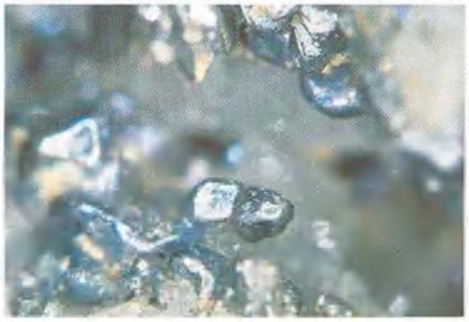

2. Sulfides

Algodonit

Cu_6As

HEXAGONAL ● ●

Properties: C – steel-gray to silver-white, it quickly covers with a brown coating on air; S – gray; L – metallic; D – opaque; DE – 8,7; H – 4; CL – none; F – conchoidal; M – crystals, granular, massive.
Origin and occurrence: Hydrothermal, mainly intimately inter-grown with other Cu arsenides. Its largest accumulations are known from Cu deposits in melaphyres in the Keweenaw Peninsula, Lake Superior, Michigan, USA. It is also known from Chile (Algodones mine near Coquimbo, Atacama). Other localities are Talmessi, Iran and Långban, Sweden.

Domeykite

Cu_3As

CUBIC ● ● ●

Properties: C – tin-white to steel-gray, it tarnishes yellow and covers with a brown coating; S – gray; L – metallic; D – opaque; DE – 7,9; H – 3-3,5; CL – none; F – uneven; M – botryoidal aggregates, massive.
Origin and occurrence: Hydrothermal with copper, cuprite, algodonite and silver. Common in masses, weighing several kg, together with algodonite in the Keweenaw Peninsula, Michigan, USA. The largest accumulations are known from Talmessi and Anarak, Iran. It occurs near Copiap and Chanarcillo, Chile. Massive aggregates in cuprite up to 50 mm (2 in) come from Biloves, Czech Republic.

Sphalerite, 56 mm, Picos de Europa, Spain
Algodonite, 60 mm, Keweenaw Peninsula, U.S.A.

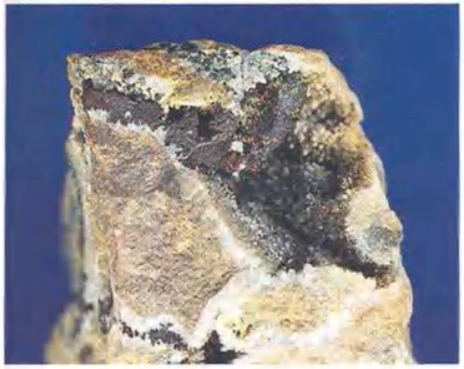

Domeykite, 3 mm x, Rudabanya, Hungary

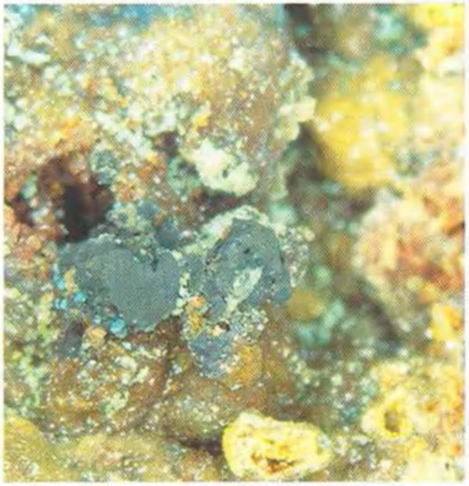

Allargentum

$Ag_{1-x}Sb_x$

HEXAGONAL ●

Properties: C – silver-white; S – gray; L – metallic; D – opaque; DE – 10,1; H – not determined; CL – none; M – small crystals, granular.
Origin and occurrence: Hydrothermal in the silver-bearing ore veins, associated with silver, breithauptite and dyscrasite. Crystals up to 1 mm (1/32 in) known from Hartenstein, Germany. Its intergrowths with silver ores were found in Cobalt, Ontario, Canada. It is also known from Broken Hill, New South Wales, Australia and microscopic in Rejska vein in Kutna Hora, Czech Republic.

Allargentum, 50 mm, Schlema, Germany

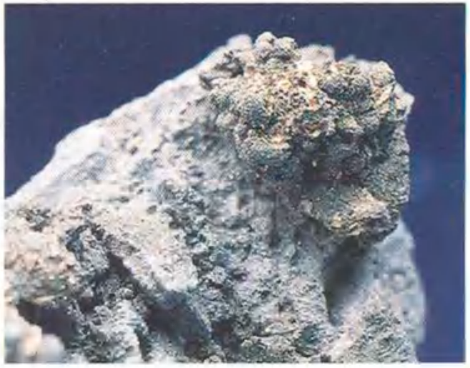

Dyscrasite

Ag_3Sb

ORTHORHOMBIC ● ●

Properties: C – silver-white, it tarnishes yellow to black; S – silver-white; L – metallic; D – opaque; DE – 9,7; H – 3,5-4; CL – good; F – uneven; M – pyramidal and prismatic crystals, granular, massive.
Origin and occurrence: Hydrothermal in the ore veins, associated with silver, stibarsen, pyrargyrite, calcite and other minerals. The best specimens come from the silver-bearing veins, cross-cutting the U deposit Hajc near Pøíbram, Czech Republic, where prismatic crystals up to 50 mm (approx. 2 in) long and striated tabular twins were found. They are mostly embedded in stibarsen; all the specimens, appearing in the mineral shows, are etched out of matrix. Deformed crystals of completely different habit are known from St. Andreasberg, Germany. Crystals occurred also in the Consols mine in Broken Hill, New South Wales, Australia.

Chalcocite

Cu_2S

MONOCLINIC ● ● ● ●

Properties: C – lead-gray to black; S – lead-gray to black; L – metallic; D – opaque; DE – 5,8; H – 2,5-3; CL – imperfect; F – conchoidal; M – prismatic to tabular crystals, granular, massive.
Origin and occurrence: Hydrothermal, also sedimentary and metamorphic, mostly secondary, in the oxidation and cementation zones of ore deposits. It occurs together with pyrite, chalcopyrite, covellite, bornite and other minerals. Crystals up to 25 cm ($9^7/_8$ in) found in the M'Sesa mine, Zaire. Beautiful crystals several cm across come from Redruth and St Just, Cornwall, UK. Crystals over 20 mm ($^{25}/_{32}$ in) across occurred in Bristol, Connecticut and in Butte, Montana. Crystals up to 50 mm (2 in) in size known from the Flambeau mine near Ladysmith, Wisconsin, USA. Shiny cyclic twins of crystals up to 20 mm ($^{25}/_{32}$ in) found in Dzhezkazgan, Kazakhstan. Massive aggregates are important Cu ore in Rio Tinto, Spain; Bor, Serbia; Bisbee, Arizona, USA and Tsumeb, Namibia.
Application: important Cu ore.

Djurleite

$Cu_{31}S_{16}$

MONOCLINIC ● ● ●

Properties: C – lead-gray to black; S – lead-gray; L – metallic; D – opaque; DE – 5,8; H – 2,5-3; CL – none; F – conchoidal; M – short prismatic to tabular crystals, granular, massive.
Origin and occurrence: Secondary as a product of the cementation zone in ore deposits. Crystals up to 10 mm ($^3/_8$ in) across known from the Botallack mine

Dyscrasite, 75 mm, P?ibram, Czech Republic

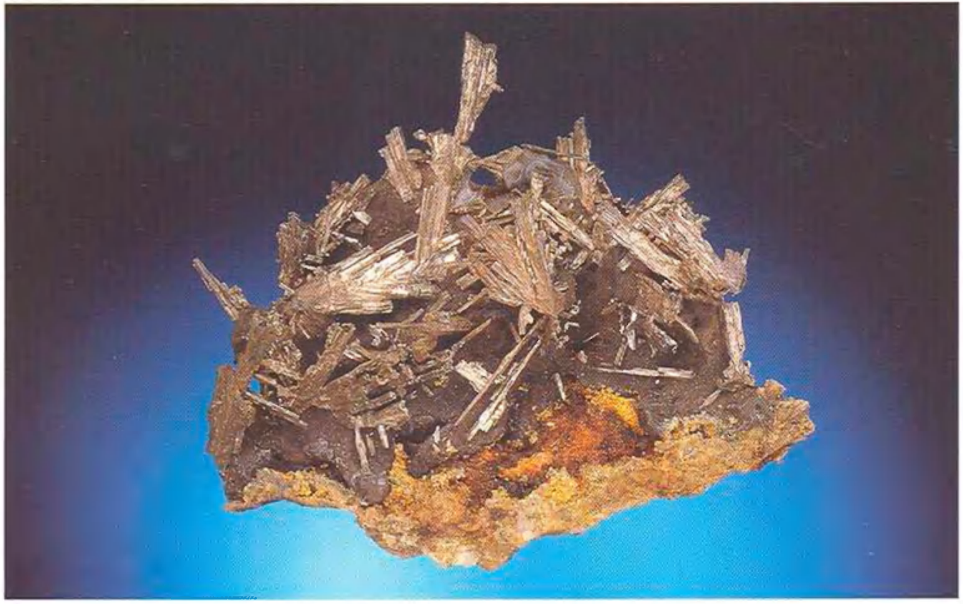

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Chalcocite, 17 mm x, Cornwall, UK

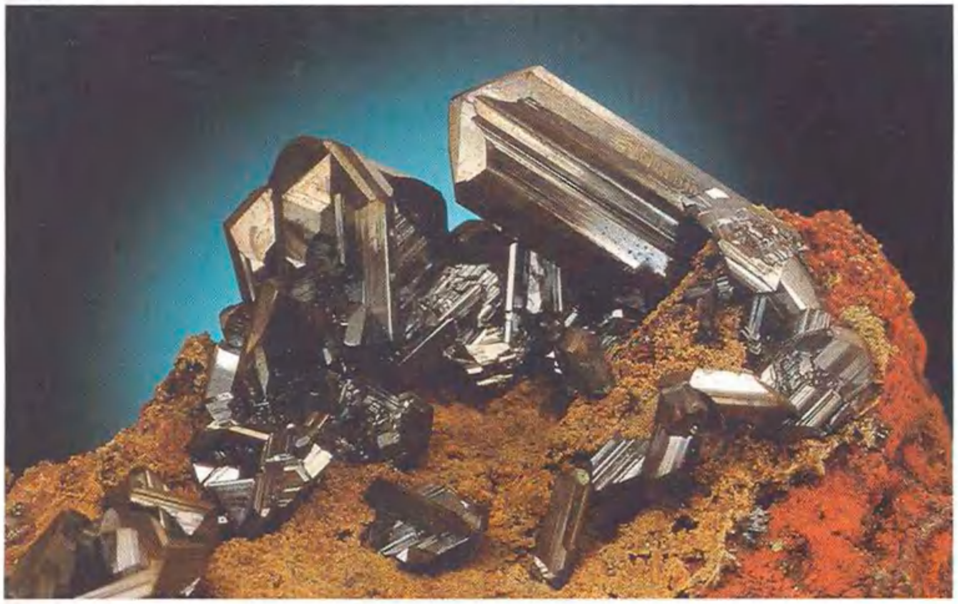

near St. Just, Cornwall, UK. Aggregates of thick acicular crystals up to 30 mm (1 3/16 in) long found in Dzhezkazgan, Kazakhstan.

It occurs in massive form in many porphyry copper deposits (Butte, Montana; Bisbee, Arizona, USA), also in Tsumeb, Namibia, together with chalcopyrite, pyrite and other minerals.

Djurleite, 3 mm xx, Dzhezkazgan, Kazakhstan

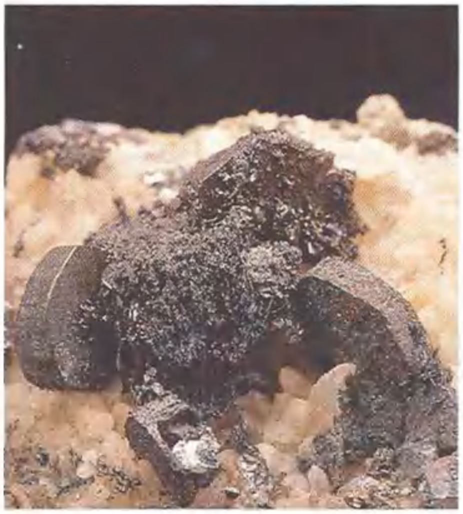

Berzelianite

Cu_2Se

CUBIC ● ● ●

Properties: C – silver-white, tarnishes black; S – silver shiny; L – metallic; D – opaque; DE – 7,3; H – 2,5; CL – none; F – uneven; M – granular, massive.
Origin and occurrence: Hydrothermal, together with other selenides in U, Fe and Au deposits. It is the main mineral in the selenide mineralization in Tilkerode, Germany. Grains, up to several tens of cm across, greenish tarnished, occurred together with other selenides in Bukov, Habøi, Petrovice and Pr edborice , Czech Republic. Similar occurrence is known from near Pinky Fault near Athabasca Lake, Saskatchewan, Canada.

Berzelianite, 60 mm, Bukov, Czech Republic

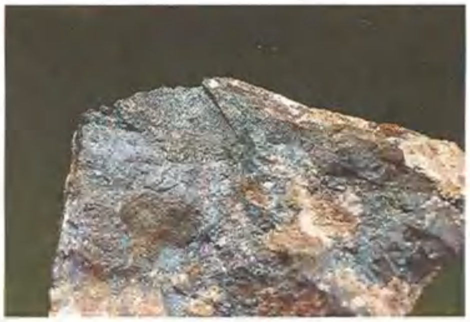

Bornite, 15 mm xx, Dzhezkazgan, Kazakhstan

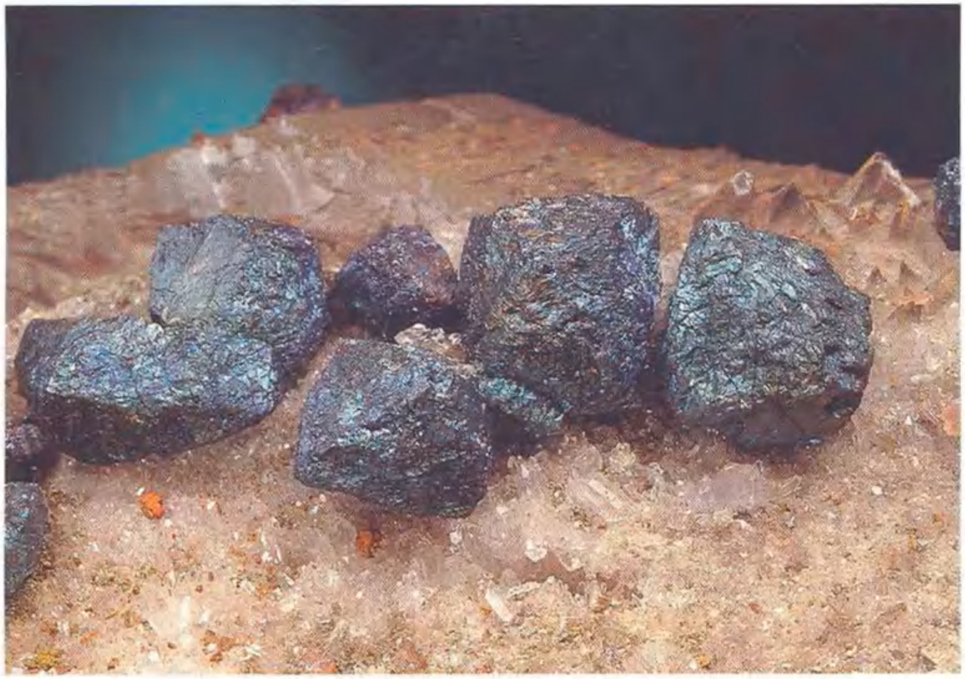

Bornite

Cu_5FeS_4

ORTHORHOMBIC ● ● ● ●

Properties: C – copper-red, tarnishes iridescent; S – gray-black; L – metallic; D – opaque; DE – 5,1; H – 3-3,5; CL – imperfect; F – uneven to conchoidal; M – pseudo-cubic octahedral crystals, massive.
Origin and occurrence: Magmatic, hydrothermal, sedimentary, in skarns and pegmatites together with chalcocite, chalcopyrite, pyrite, quartz and other minerals. Fine crystals up to 10 mm ($^{3}/_{8}$ in) across are known from Carn Brea, Cornwall, England, UK. Crystals up to 30 mm ($^{13}/_{16}$ in) come from Likasi, Shaba, Zaire. Beautiful crystals up to 40 mm (1$^{9}/_{16}$ in) across were found recently together with chalcocite in Dzhezkazgan, Kazakhstan. Massive aggregates are common and used as Cu ore in Kipushi, Shaba, Zaire. Fine-grained, sedimentary bornite occurs in Cu-bearing shales in Mansfeld, Germany, where it forms the main ore layer. Crystals, up to 20 mm ($^{25}/_{32}$ in) in size, occurred in the Cole shaft and masses, weighing several thousands of tons, were mined in the Campbell shaft, Bisbee, Arizona, USA. *Application:* Cu ore.

Bornite, 3 mm xx, Dzhezkazgan, Kazakhstan

Umangite

Cu_3Se_2

TETRAGONAL ● ● ●

Properties: C – blue-black with reddish tint, tarnishes purple; S – black; L – metallic; D – opaque; DE – 6,6; H – 3; CL – imperfect; F – uneven to conchoidal; M – granular, massive.
Origin and occurrence: Hydrothermal in ore veins together with other selenides (clausthalite, berzelianite). It is common, associated with berzelianite in Tilkerode, Germany; Sierra de Umango, Argentina and Slavkovice, Czech Republic. Larger accumulations occur in the Martin Lake mine near Athabasca Lake, Canada.

Acanthite

Ag_2S

MONOCLINIC ● ● ●

Properties: C – black; S – black; L – metallic; D – opaque; DE – 7,2; H – 2-2,5; CL – none; F – uneven; M – pseudo-cubic crystals, massive. It mainly occurs as paramorphs after argentite (high-temperature phase of the same composition).

Origin and occurrence: Hydrothermal in ore veins. Beautiful crystals over 50 mm (2 in) long occurred in the Himmelsfürst mine in Freiberg, in Annaberg and Schneeberg, Germany. Acicular crystals are known from Jachymov, Czech Republic. It is common in association with silver, proustite, pyrargyrite, polybasite, stephanite, galena and other minerals in Mexico. Probably the best paramorphs after argentite up to 70 mm (2¾ in) across come from the Rayas mine, Guanajuato. Fine crystals occur in the Las Chispas mine, Arizpe, Sonora and many localities in Zacatecas, Chihuahua.

Application: important Ag ore.

Acanthite, 23 mm, Arizpe, Mexico

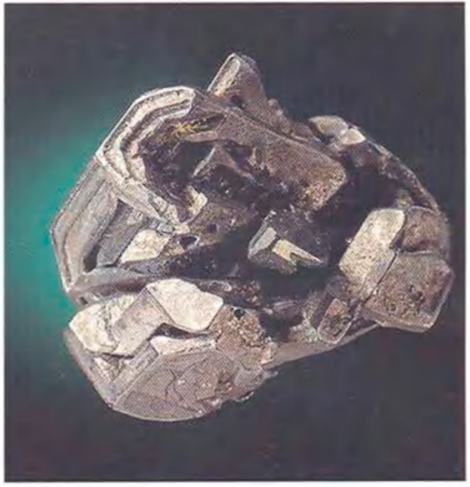

Argentite

Ag_2S

CUBIC ● ● ●

Properties: C – black-gray, tarnishes black; S – black; L – metallic; D – opaque; DE – 7,1; H – 2-2,5; CL – imperfect; F – uneven to conchoidal; M – octahedral and cubic crystals, dendritic aggregates, massive. Stabile at temperatures over 179EC (354.2°F), below this temperature there are paramorphs of acanthite after argentite.

Origin and occurrence: Hydrothermal in low-temperature ore deposits, associated with silver, galena and Ag sufosalts. Occurs between the oxidation and cementation zone with stromeyerite, silver, jalpaite, iodargyrite and other minerals. Fine crystals up to 40 mm ($1\frac{9}{16}$ in) across, are known from Freiberg and Schneeberg, Germany. Similar crystals found in Jachymov and Midinec, Czech Republic. Crystals up to 30 mm ($1\frac{3}{16}$ in) occur in Sarrabus, Sardinia, Italy. Maybe the best argentite crystals occurred in Mexico (Arizpe, Sonora; Zacatecas; Guanajuato), where crystals reached up to 40 mm ($1\frac{9}{16}$ in). Fine crystals up to 20 mm ($\frac{25}{32}$ in) across reported from Chañarcillo in Chile.

Application: important Ag ore.

Argentite, 29 mm, Zacatecas, Mexico

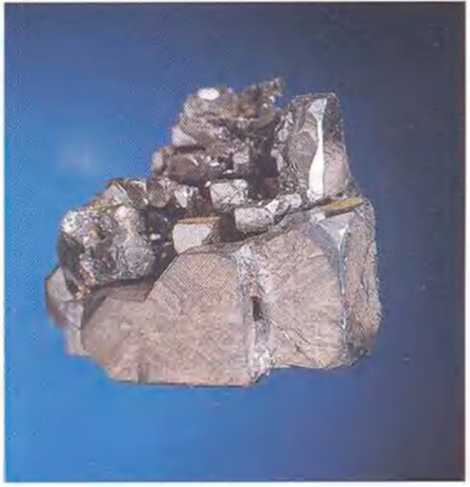

Umangite, 40 mm, Beaverlodge Lake, Canada

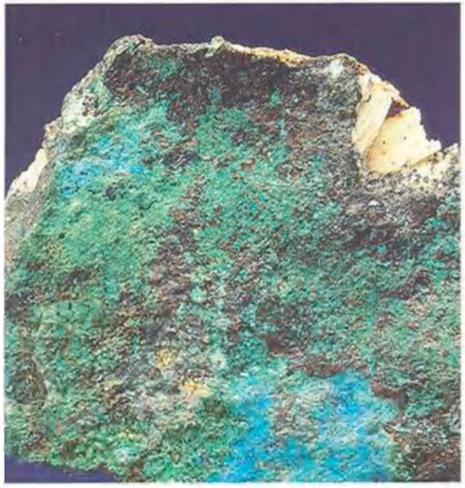

Aguilarite, 4 mm xx, Guanajuato, Mexico

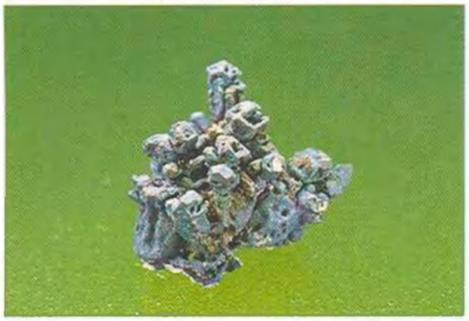

Hessite

Ag_2Te

MONOCLINIC ● ● ●

Properties: C – lead to steel-gray, tarnishes black; S – light gray; L – metallic; D – opaque; DE – 8,4; H – 2-3; CL – imperfect; F – even; M – pseudo-cubic crystal combinations, granular, massive.
Origin and occurrence: Hydrothermal in medium- and low-temperature ore veins together with calaverite, sylvanite, altaite, gold, tellurium and other sulfides. The best specimens with crystals up to 20 mm ($^{25}/_{32}$ in) across ($^{25}/_{32}$ in) and aggregates up to 100 mm (4 in) come from the Bote mine, Romania. Small crystals occur in the Jamestown mine, California, USA. Massive aggregates were found in Gold Hill, Colorado, USA and Moctezuma, Mexico. Aggregates, up to tens of cm^2 (several sq in) in size, were known in the Zavodinskii mine, Altai, Kazakhstan.

Aguilarite

Ag_4SeS

ORTHORHOMBIC ●

Properties: C – lead-gray, tarnishes black; S – gray-black; L – metallic; D – opaque; DE – 7,7; H – 2,5; CL – none; F – hackly; M – skeletal crystals, massive.
Origin and occurrence: Hydrothermal in ore veins, together with silver, stephanite, proustite, pearceite, calcite and quartz. The best crystallized specimens with crystals up to 30 mm (1$^{3}/_{16}$ in) across come from the San Carlos mine, Guanajuato and Chontalpan, Taxco, Guerrero, Mexico. It is also known in inter-

Hessite, 31 mm, Botes, Romania

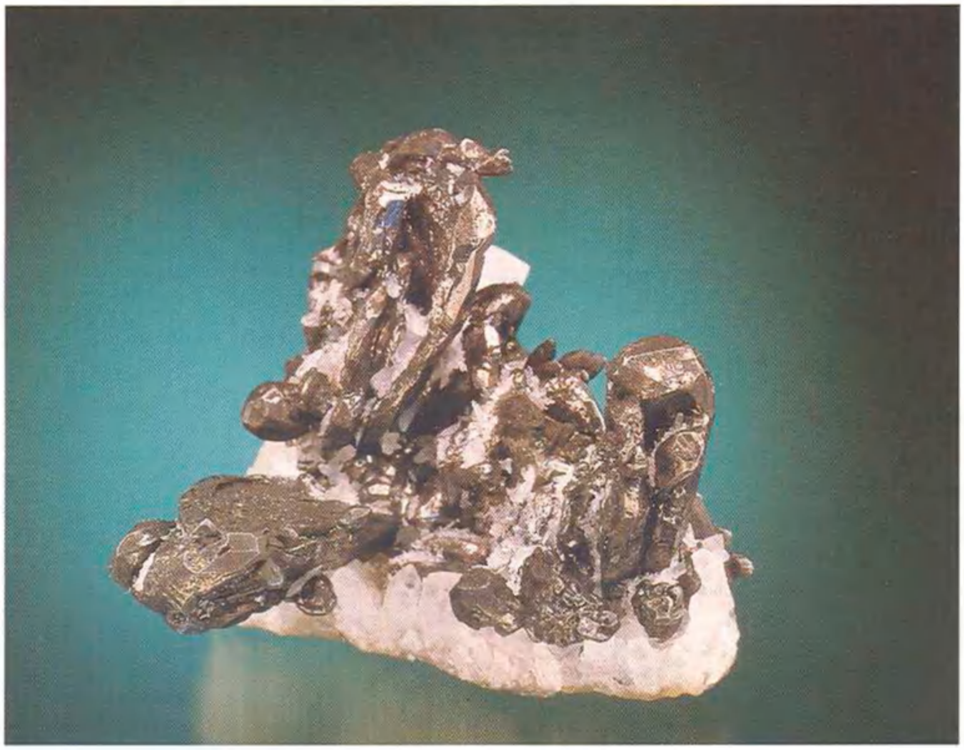

growths with acanthite and naumannite from the Comstock Lode, Virginia City, Nevada, USA.

Argyrodite

Ag_8GeS_6

ORTHORHOMBIC ●

Properties: C – steel-gray, tarnishes black; S – gray-black; L – metallic; D – opaque; DE – 6,3; H – 2,5-3; CL – none; F – uneven to conchoidal; M – combinations of cubic crystals, botryoidal aggregates, massive.
Origin and occurrence: Hydrothermal in low-temperature base metal deposits, associated with Ag sulfosalts. It occurred in crystals in the Himmelsfhrst mine, Freiberg, Germany. Crystals were also found in several localities in Bolivia (Atoche, Colquechaca, Potosí). Crystal measuring 60 mm (24 in) across is reported from Porco, Bolivia.

Stromeyerite

AgCuS

ORTHORHOMBIC ● ● ●

Properties: C – dark steel gray, tarnishes blue; S – steel-gray; L – metallic; D – opaque; DE – 6,3; H – 2,5-3; CL – none; F – conchoidal; M – pseudo-hexagonal tabular crystals, massive.
Origin and occurrence: Mostly secondary in the cementation zone of ore veins, associated with freibergite, bornite, chalcocite, galena and other minerals. Fine tabular crystals up to 10 mm ($^3/_8$ in) across found in Dzhezkazgan, Kazakhstan, where pseudo-morphs of stromeyerite after silver wires also occur. Skeletal prismatic pseudo-morphs after chalcocite crystals come from Vraneice, Czech Republic. Massive aggregates are common in many deposits in Colorado, USA (Aspen; Red Mountain), Chile (Copiapo), Bolivia (Potosi) and Canada (Cobalt, Ontario).

Stromeyerite, 6 mm xx, Dzhezkazgan, Kazakhstan

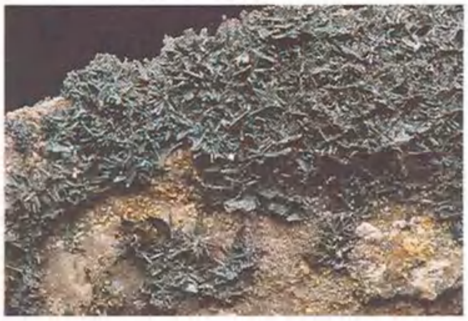

Argyrodite, 34 mm, Mexico

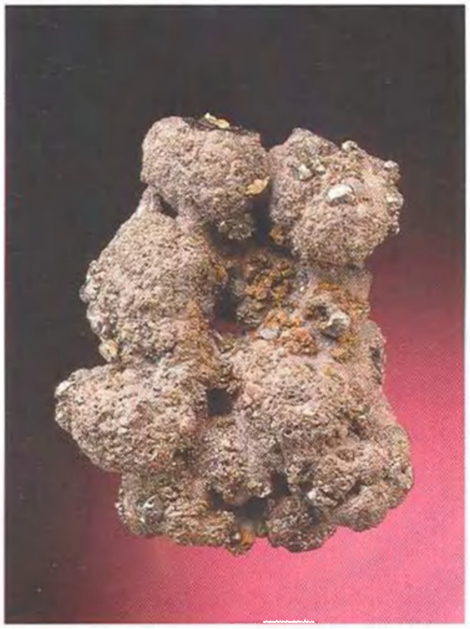

Jalpaite

Ag_3CuS_2

TETRAGONAL ● ●

Properties: C – light gray, tarnishes dark gray to iridescent; S – black; L – metallic; D – opaque; DE – 6,8; H – 2-2,5; CL – good; F – conchoidal; M – crystals, granular.
Origin and occurrence: Hydrothermal in low-temperature ore veins. Crystals up to 25 mm (1 in) across known from Jalpa, Queretaro, Mexico. Crystals up to 30 mm ($^{13}/_{16}$ in) across come from the Caribou mine, Colorado, USA. Massive aggregates, associated with galena, sphalerite, pyrite, stromeyerite, polybasite and other minerals, occurred in Pøibram, Czech Republic.

Jalpaite, 30 mm veinlet, P?íbram, Czech Republic

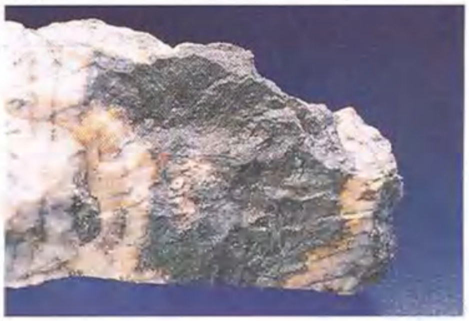

Pentlandite, 90 mm, Sudbury, Canada

Pentlandite

(Fe,Ni)$_9$S$_8$

CUBIC ● ● ● ●

Properties: C – light bronze to red-brown; S – light bronze; L – metallic; D – opaque; DE – 5,0; H – 3,5-4; CL – none; F – conchoidal; M – crystals, massive.
Origin and occurrence: Typical magmatic liquid mineral, associated with pyrrhotite and chalcopyrite. It is common in Sudbury, Ontario, Canada, as mostly microscopic inclusions in chalcopyrite, but also as imperfect crystals. Large accumulations are known from Talnakh near Norilsk, Siberia, Russia, where it occurs together with Cu, Pt and Pd sulfides. It is also important ore in the deposit near Rustenburg, South Africa.
Application: the most important Ni ore.

Sphalerite, 70 mm, Olkusz, Poland

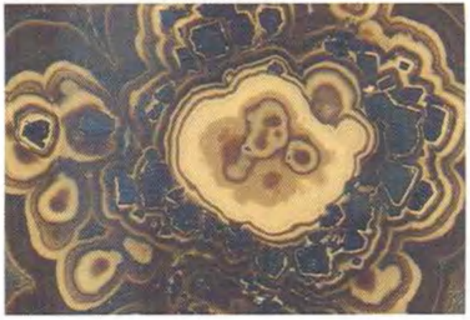

Sphalerite

ZnS

CUBIC ● ● ● ●

Varieties: cleiophane (green, yellow, orange), marmatite (black)

Properties: C – colorless, yellow, orange, green, brown, black; S – brownish, light yellow, white; L – resinous to adamantine; D – transparent, translucent, opaque; DE – 4,1; H – 3,5-4; CL – perfect; F – conchoidal; M – tetrahedral and dodecahedral crystals, botryoidal, fibrous and stalactitic aggregates, massive; LU – sometimes orange.
Origin and occurrence: Magmatic (liquid, in pegmatites); hydrothermal in low- to high-temperature deposits, skarns, hydrothermal sedimentary deposits;

Sphalerite, 31 mm, Elmwood, U.S.A.

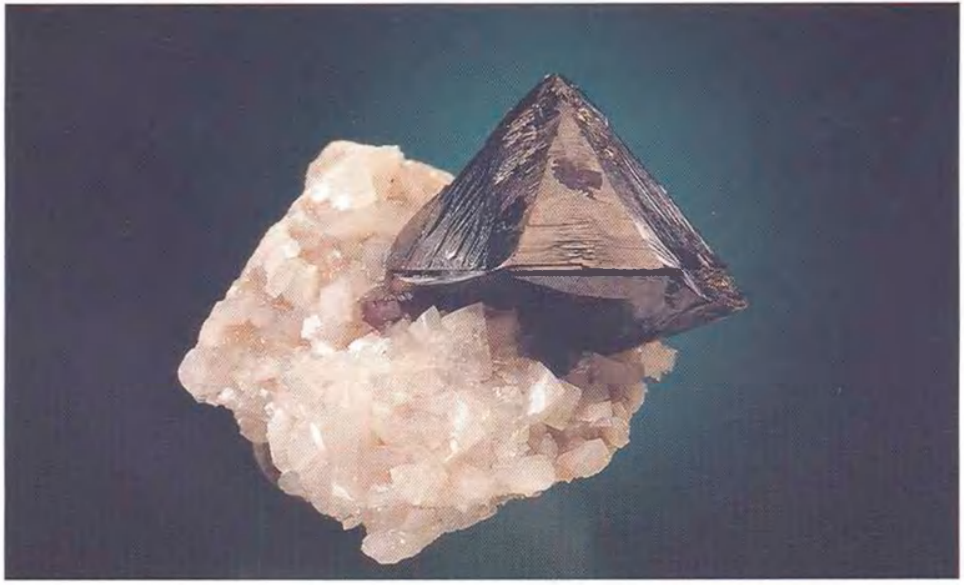

rare sedimentary and metamorphic. It occurs together with galena, pyrite, chalcopyrite, marcasite, fluorite, barite, quartz and other minerals. Beautiful crystals up to 100 mm (4 in) across come from Trepea, Serbia. Green and red crystals up to 100 mm (4 in) known from Cananea, Sonora, Mexico. Fine yellow crystals up to 30 mm ($1^{3}/_{16}$ in) were common in Banska "tiavnica, Slovakia; similar crystals occur in Madan, Bulgaria. The most beautiful yellow, orange and red crystals up to 150 mm (6 in) across found in Picos de Europa, Santander, Spain. They are sometimes faceted. Brown crystals up to 50 mm (2 in) come from Joplin, Missouri; stalactitic aggregates up to 150 mm (6 in) long come from Galena, Illinois, USA. Perfect black, shiny crystals and twins up to 50 mm (2 in) are famous from Dalnegorsk, Russia; yellow crystals, up to 30 mm ($1^{3}/_{16}$ in), occurred in Dzhezkazgan, Kazakhstan. Transparent crystals up to 30 mm ($1^{3}/_{16}$ in) also found in Franklin, New Jersey, USA. Green crystals up to 100 mm (approx. 4 in) across occurred in the Big Four mine, Colorado, USA. Crystals up to 50 mm (2 in) known from the Oppu mine, Aomori, Japan.
Application: principal Zn ore.

Coloradoite
HgTe

CUBIC ● ●

Properties: C – black-gray; S – black-gray; L – metallic; D – opaque; DE – 8,1; H – 2,5; CL – none; F – uneven to conchoidal; M – granular, massive.
Origin and occurrence: Hydrothermal, associated with altaite, calaverite, krennerite, gold, pyrite and other minerals in Au-bearing veins. It was common in Cripple Creek and in the Smuggler mine, Colorado; in the Norwegian mine, California, USA. Grains, reaching up to several mm, come from Jilove, Czech Republic.

Coloradoite, 70 mm, Kalgoorlie, Australia

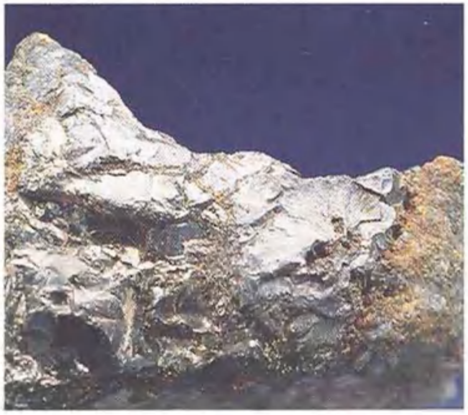

Chalcopyrite, 10 mm xx, Cavnic, Romania

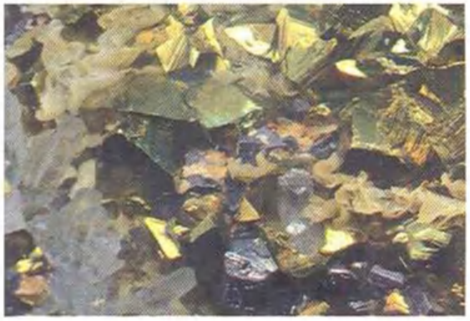

Chalcopyrite
$CuFeS_2$

TETRAGONAL ● ● ● ● ●

Properties: C – brass-yellow, tarnishes iridescent; S – green-black; L – metallic; D – opaque; DE – 4,3; H – 3,5-4; CL – imperfect; F – uneven; M – tetrahedral crystals, botryoidal aggregates, massive.
Origin and occurrence: Magmatic, hydrothermal and sedimentary, in association with sphalerite, galena, tetrahedrite, pyrite and many other sulfides. Fine crystals up to 30 mm ($1^{3}/_{16}$ in) across are known from Banska "tiavnica, Slovakia and from Cavnic, Romania.
Crystals up to 120 mm ($4^{11}/_{16}$in) across, associated with other sulfides, come from the Nikolai mine in Dalnegorsk, Russia. Beautiful crystals up to 120 mm ($4^{11}/_{16}$in) found in Japan (Arawaka, Osarizawa). Fine crystals reaching up to several cm occur in Peru (Huanzala, Huaron). Massive aggregates are important Cu ore in Sudbury, Ontario, Canada; Bingham, Utah; Bisbee, Arizona, USA and Rio Tinto, Spain.
Application: important Cu ore.

Chalcopyrite, 15 mm x, Ground Hog Mine, U.S.A.

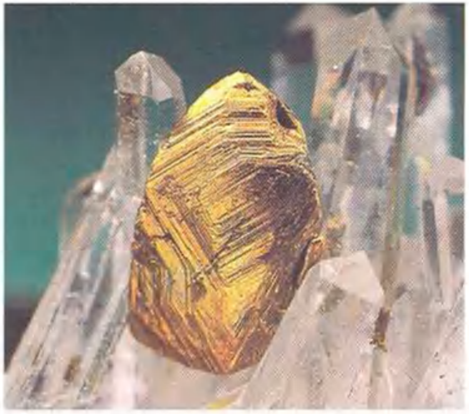

Luzonite, 60 mm, Recsk, Hungary

Luzonite

Cu_3AsS_4

TETRAGONAL ● ●

Properties: C – dark pink-brown; S – black; L – metallic; D – opaque; DE – 4,5; H – 3,5; CL – good; F – uneven to conchoidal; M – crystals, granular, massive.
Origin and occurrence: Hydrothermal in low- to medium-temperature veins, associated with enargite, tetrahedrite, sphalerite, bismuthinite, Ag sulfosalts and other minerals. Crystals up to 40 mm ($1^{9}/_{16}$ in) across come from Quiruvilca; it is common in Cerro de Pasco, Peru. It is also common in the Teine mine, Hokkaido, Japan; crystals also occur in Kinkwaseli, Taiwan. It is known from Bor, Serbia and Recsk, Hungary.

Stannite

Cu_2FeSnS_4

TETRAGONAL ● ● ●

Properties: : C – steel-gray to black, tarnishes blue; S – black; L – metallic; D – opaque; DE – 4,5; H – 4; CL – imperfect; F – uneven; M – pseudo-octahedral crystals, granular, massive.
Origin and occurrence: Hydrothermal in high-temperature Sn deposits. The best specimens come from Bolivia; crystals up to 50 mm (2 in) across known from Llallagua; crystals up to 30 mm ($1^{3}/_{16}$ in) from Chocaya and cross-like inter-growths from the San Jose and Itos mines near Oruro. It occurs as massive vein fillings in Carn Brea, Cornwall, UK and Cínovec, Czech Republic. It was also found in amblygonite pegmatites in Caceres, Spain and in quartz-amblygonite veins near Verneøov, Czech Republic.
Application: Sn ore.

Stannite, 10 mm xx, Potosí, Bolivia

Germanite, 40 mm, Tsumeb, Namibia

Germanite

$Cu_{26}Fe_4Ge_4S_{32}$

CUBIC ● ●

Properties: C– pink to purple-grey, S – black, L - metallic, D - opaque, DE – 4,5, H - 4, CL – none, F – uneven, M – tetrahedral crystals, granular, massive.
Origin and occurrence: Hydrothermal, often inter-grown with tennantite, bornite and other minerals. It was important only in one particular place in Tsumeb, Namibia, where larger accumulations were found. Smaller occurrences are known from the Shikanai mine, Japan; small cubic crystals come from the Humboldt mine, Colorado, USA.

Tennantite

$Cu_{12}As_4S_{13}$

CUBIC ● ● ● ●

Properties: C – steel-gray; S – black, brown to dark

red; L – metallic; D – opaque; DE – 4.6; H – 3-4,5; CL – none; F – conchoidal to uneven; M – tetrahedral crystals, granular, massive.
Origin and occurrence: Hydrothermal in ore veins and greisens with pyrite, calcite, dolomite, quartz and other sulfides and Cu-Pb-Zn-Ag sulfosalts. Fine crystals are known from Cornwall, UK (Wheal Jewel, Gwennap; Carn Brea). Crystals up to 150 mm (6 in) across, come from Tsumeb, Namibia. Crystals of binnite in Lengenbach, Binntal, Switzerland, up to 30 mm ($1\frac{3}{16}$ in). Crystals up to 20 mm ($\frac{25}{32}$ in) across were found recently in Dzhezkazgan, Kazakhstan. Large masses occurred in Kipushi, Zaire. Crystals up to 25 mm (1 in) known from El Cobre, Zacatecas, Mexico. *Application:* Cu ore.

Tennantite, 26 mm, El Cobre, Mexico

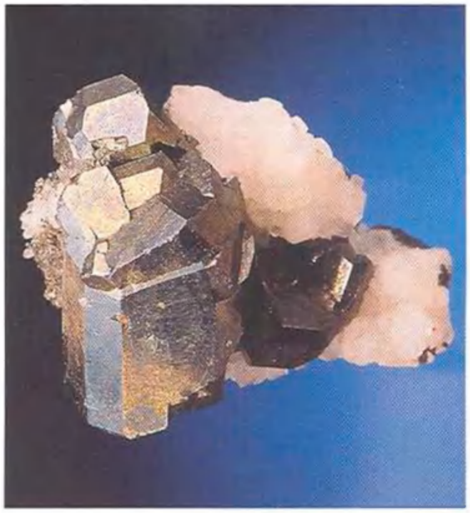

Tetrahedrite

$Cu_{12}Sb_4S_{13}$

CUBIC ● ● ● ●

Properties: C – steel-gray to black; S – black, brown; L – metallic; D – opaque; DE – 5.0; H – 3-4,5; CL – none; F – conchoidal; M – tetrahedral crystals, granular, massive.
Origin and occurrence: Hydrothermal in low- to medium temperature veins; in contact metamorphic deposits together with chalcopyrite, galena, sphalerite, pyrite, bornite, calcite, quartz and other minerals. The largest known crystals up to 25 cm ($9\frac{7}{8}$ in) across come from Anzen and Irazein in Pyrennees, France. Common crystals several cm in size occur in Cavnic, Romania. Fine specimens with crystals up to 70 mm ($2\frac{3}{4}$ in) across found in the Mercedes mine in Huallanca, Peru. Other Peruvian localities like Casapalca and Morococha yielded fine crystallized specimens. Fine crystals up to 20 mm ($\frac{25}{32}$ in) in size known from Pøibram, Czech Republic.
Application: ruda Cu.

Tetrahedrite, 10 mm xx, Peru

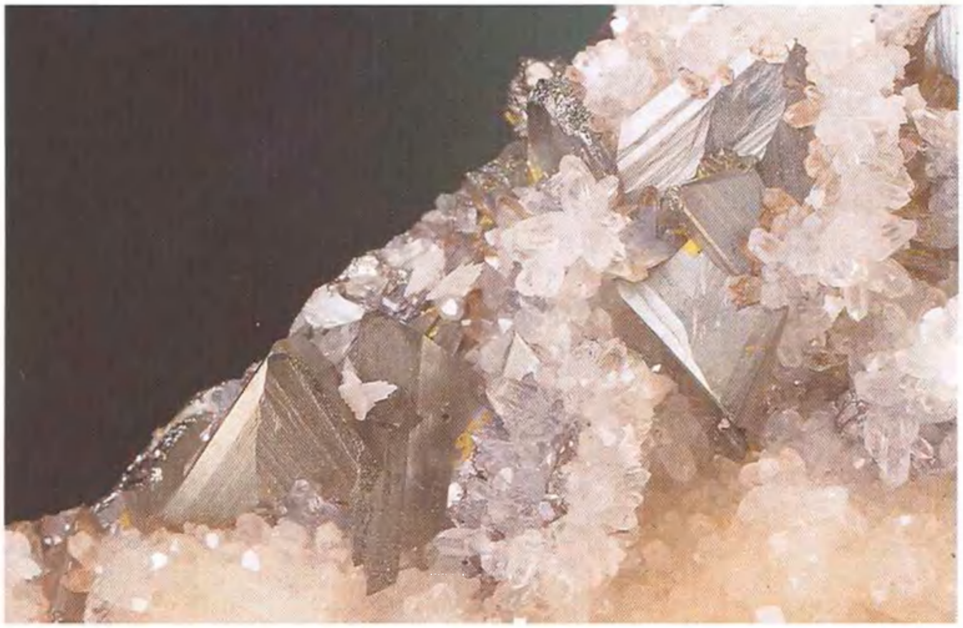

Freibergite, 15 mm xx, Obecnice, Czech Republic

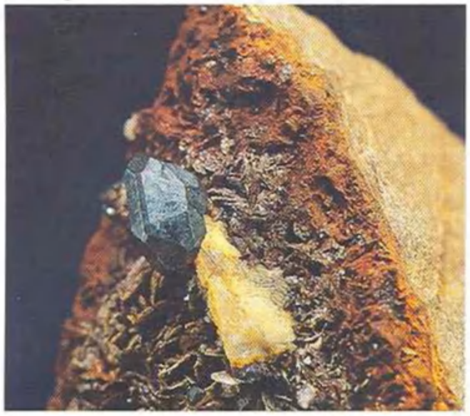

Freibergite

$(Ag,Cu,Fe)_{12}(Sb,As)_4S_{13}$

CUBIC ● ● ●

Properties: C – gray to black; S – black, brown to dark red; L – metallic; D – opaque; DE – 5,4; H – 3-4,5; CL – none; F – uneven to conchoidal; M – tetrahedral crystals, massive.
Origin and occurrence: Hydrothermal in ore deposits, associated with many sulfides and sulfosalts. It is mainly massive in the Himmelsfurst mine in Freiberg, Germany; Cobalt, Ontario, Canada and in Mount Isa, Queensland, Australia. It was a principal Ag ore in Kutná Hora, Czech Republic.
Application: Ag ore.

Wurtzite

ZnS

HEXAGONAL ● ● ●

Properties: C – dark red-brown, dark brown to brown-black; S – brown; L – resinous to submetallic; D – translucent to opaque; DE – 4,1; H – 3,5-4; CL – good; M – pyramidal, prismatic to thick tabular, striated crystals, concentric banded and radial aggregates.
Origin and occurrence: Hydrothermal in ore veins with sphalerite, marcasite, pyrite and other minerals. Also of low-temperature origin along the cracks of clay concretions. The best wurtzite crystals come from Bolivia; crystals up to 40 mm ($1^{9}/_{16}$ in) across from Animas and crystals up to 20 mm ($^{25}/_{32}$ in) across from Llallagua and Potosi. Fine crystals up to 30 mm ($1^{3}/_{16}$ in) across found in Talnakh near Norilsk, Siberia, Russia. Interesting radial aggregates, up to several cm in diameter, occurred in Pøibram, Czech Republic.

Wurtzite, 30 mm xx, Animas, Bolivia

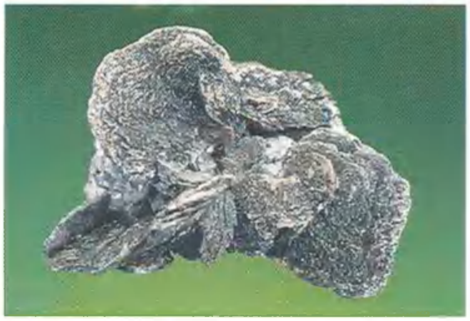

Greenockite

CdS

HEXAGONAL ● ● ●

Properties: C – yellow to orange, dark red; S – orange-yellow to brick-red; L – adamantine to resinous; D – opaque to translucent, DE – 4,8; H – 3-3,5; CL – good; F – conchoidal; M – trillings, pulverulent coatings.
Origin and occurrence: Mainly secondary as pulverulent coatings on sphalerites. It also occurs in cavities of volcanic rocks together with prehnite, zeolites and calcite. Crystals are known from ore veins in Llallagua, Bolivia. Pulverulent coatings are described from Pøibram, Czech Republic; Bleiberg, Austria and from the deposits in the Tri State region, Missouri, USA. Crystals up to 10 mm ($^{3}/_{8}$ in) occurred in the cavities of volcanic rocks near Renfrew, Scotland, UK.

Enargite

Cu_3AsS_4

ORTHORHOMBIC ● ● ● ●

Properties: C – gray-black to black; S – gray-black;

Grenockite, 20 mm, Ocna de Fier, Romania

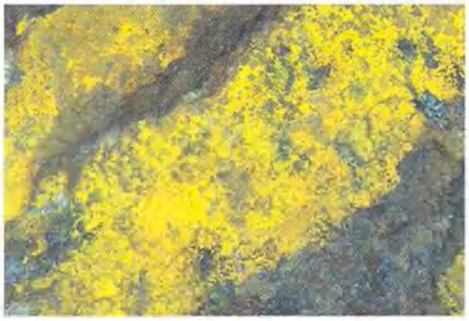

Enargite, 41 mm, Butte, U.S.A.

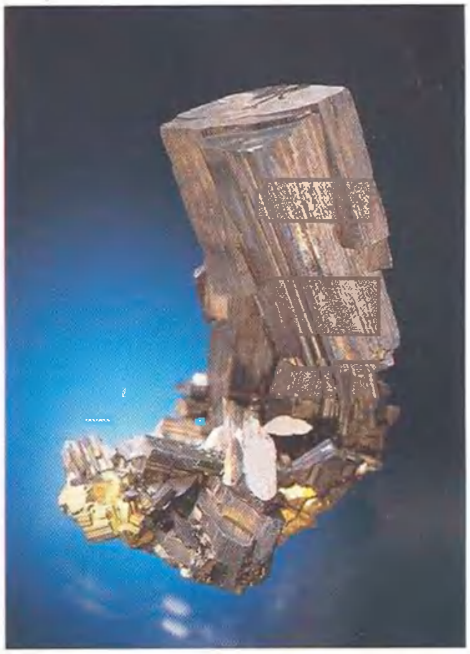

L – metallic; D – opaque; DE – 4,4; H – 3; CL – perfect; F – uneven; M – tabular and prismatic, striated crystals, massive.
Origin and occurrence: Hydrothermal in medium-temperature, sometimes in low-temperature deposits, associated with quartz, pyrite, sphalerite, galena, bornite and other minerals. Beautiful crystals, up to 100 mm (4 in) across, come from the Luz Angelica mine in Quiruvilca; crystals up to 150 mm (6 in) across from Morococha and Cerro de Pasco, Peru. Fine crystals were found in Butte, Montana, USA and in Mancayano, Luzon, Philippines. It occurs as a principal Cu ore in several deposits (Bor, Serbia; Huaron, Peru).
Application: Cu ore.

Cubanite

Cu_2FeS_3

ORTHORHOMBIC ● ● ●

Properties: C – brass-yellow to bronze; S – black; L – metallic; D – opaque; DE – 4,1; H – 3,5; CL – none; F – conchoidal; M – tabular crystals, massive.
Origin and occurrence: Magmatic in liquid deposits as inclusions in chalcopyrite, as hydrothermal in high-temperature deposits, associated with chalcopyrite, pyrite, pyrrhotite and sphalerite. The best crystals, twins, up to 40 mm ($1^{9}/_{16}$ in) across, come from the Henderson No.2 mine, Chibougamau, Quebec, Canada. It was also described in crystals from Sudbury, Ontario, Canada and Morro Velho, Brazil. Its large accumulations are important Cu ore in Sudbury, Ontario, Canada; in Mooihoek, South Africa and in Prince William Sound, Alaska, USA.
Application: important Cu ore.

Cubanite, 33 mm x, Chibougamau, Canada

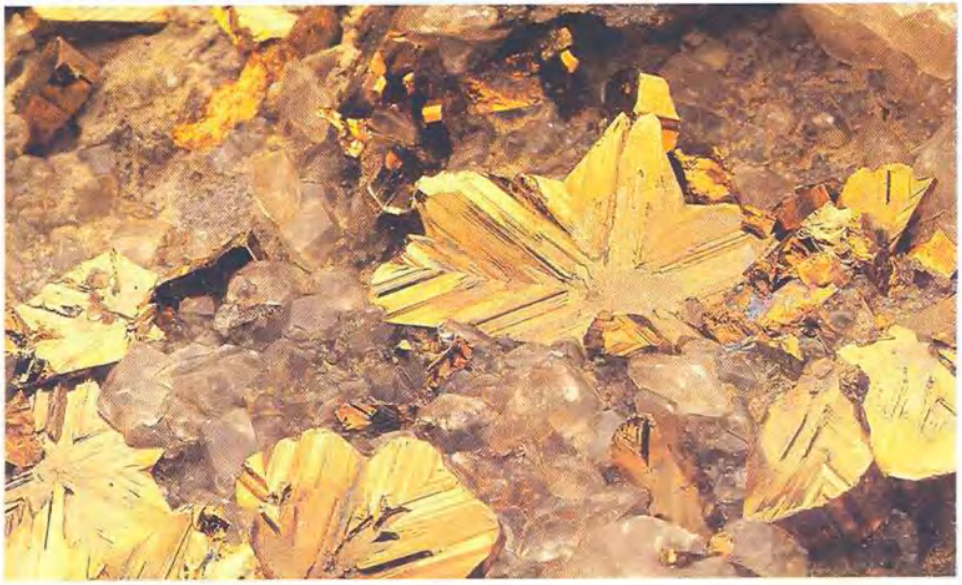

Sternbergite, 20 mm, St.Andreasberg, Germany

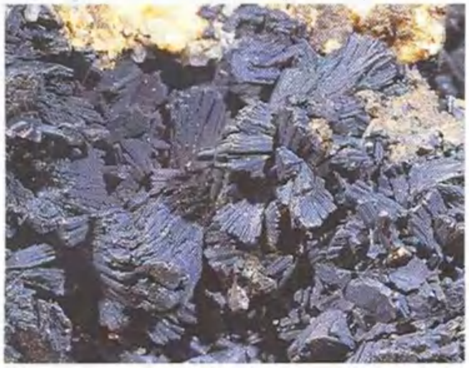

Sternbergite

Ag_2FeS_3

ORTHORHOMBIC ● ●

Properties: C – golden-brown; S – black; L – metallic to adamantine; D – opaque; DE – 4,3; H – 1-1,5; CL – perfect; M – thin tabular pseudo-hexagonal crystals, often in rosettes and fan-shaped aggregates. *Origin and occurrence:* Hydrothermal in Ag-bearing veins, associated with stephanite, acanthite, proustite, argentopyrite and other minerals. Tabular crystals up to several mm across known from Jachymov and Midinec, Czech Republic; from St. Andreasberg, Johanngeorgenstadt, Schneeberg and Freiberg, Germany.

Argentopyrite, 60 mm, M?d?nec, Czech Republic

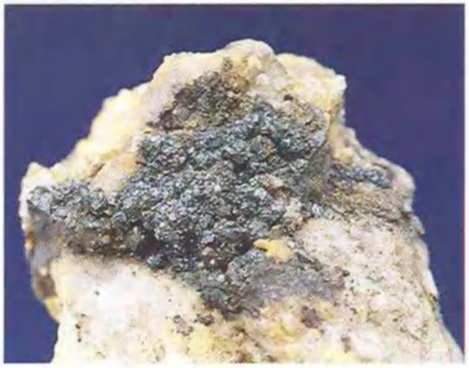

Argentopyrite

Ag_2FeS_3

ORTHORHOMBIC ● ●

Properties: C – gray-white, tarnishes iridescent; S – gray; L – metallic; D – opaque; DE – 4,3; H – 3,5 – 4; CL – none; F – uneven; M – thick tabular pseudo-hexagonal crystals, granular.
Origin and occurrence: Hydrothermal in ore veins, associated with proustite, pyrargyrite, stephanite, sternbergite, dolomite, quartz and other minerals. Crystals up to 5 mm ($^3/_{16}$ in) across come from Jachymov and Midinec, Czech Republic; it is also known from Schlema, Freiberg and Schneeberg, Germany and from Colquechaca, Bolivia.

Pyrrhotite, 68 mm, Dalnegorsk, Russia

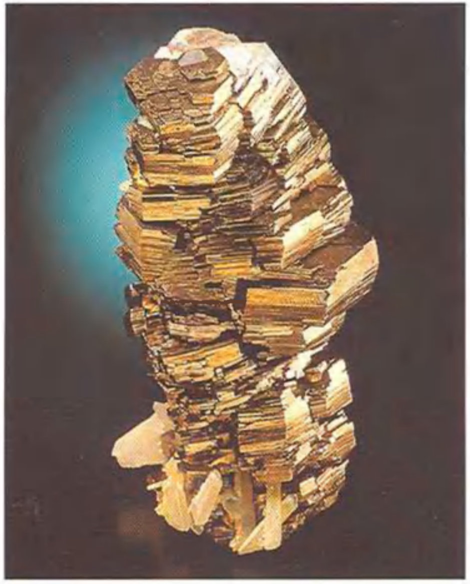

Pyrrhotite

$Fe_{1-x}S$ (x = 0-0,17)

MONOCLINIC ● ● ● ●

Properties: C – bronze-yellow to brown, tarnishes quickly; S – dark gray-black; L – metallic; D – opaque; DE – 4,7; H – 3,5-4,5; CL – none; F – uneven to conchoidal; M – tabular, pyramidal and prismatic crystals, massive.
Origin and occurrence: Magmatic liquid in basic rocks, together with pyrite and pentlandite; in pegmatites; hydrothermal in high-temperature and metasomatic deposits; sedimentary and metamorphic. Tabular crystals up to 300 mm (11$^{13}/_{16}$ in) across come from Trepca, Serbia and Dalnegorsk, Russia; prismatic crystals up to 150 mm (6 in) long found in Santa Eulalia, Chihuahua, Mexico and Chiuzbaia, Romania. Tabular crystals up to 110 mm (4$^5/_{16}$ in) occurred in Cavnic, Romania. Large imperfect crystals, coated with wavellite, are known from Llallagua, Bolivia. Huge masses of industrial importance occur in Sudbury, Ontario, Canada; Talnakh near Norilsk, Siberia, Russia and elsewhere. *Application:* sometimes as Fe ore.

Nickeline, 138 mm, Pohla, Germany

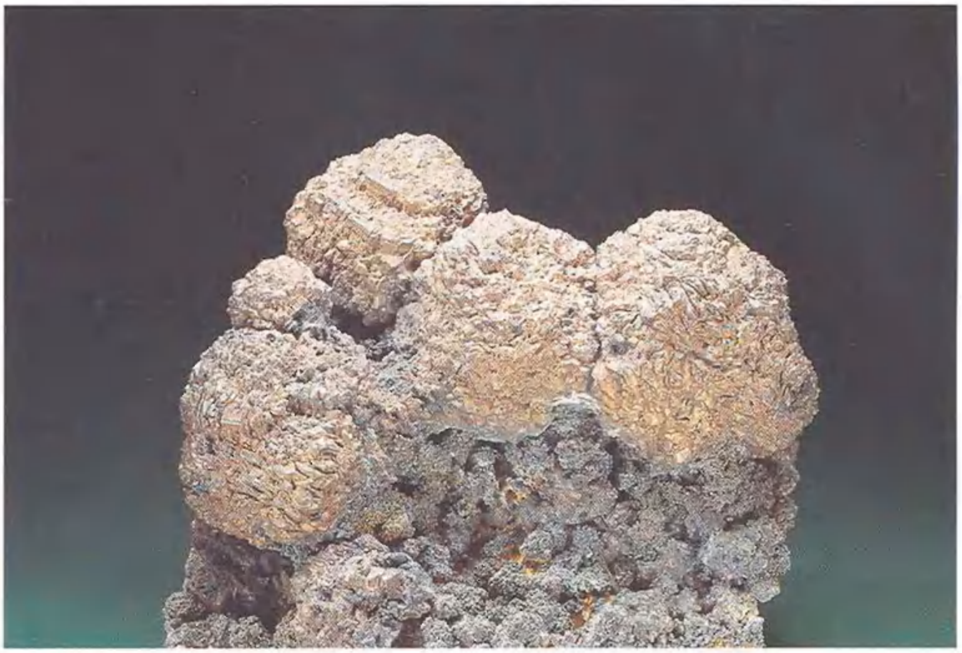

Nickeline

NiAs

HEXAGONAL ● ● ● ●

Properties: C – light copper-red, tarnishes gray to black; S – light brown-black; L – metallic; D – opaque; DE – 7,8; H – 5-5,5; CL – none; F – conchoidal; M – striated crystals, botryoidal and dendritic aggregates, granular, massive.
Origin and occurrence: Hydrothermal in high-temperature ore veins with skutterudite, nickel-skutterudite, safflorite, rammelsbergite and other minerals. Also magmatic in norites and peridotites. Crystals up to 15 mm ($^{19}/_{32}$ in) across come from Pohla; small crystals were found in Richelsdorf, Germany. Fine massive aggregates and small crystals occurred in Bou Azzer, Morocco. Huge accumulations are known in Cobalt and Gowganda, Ontario, Canada.
Application: Ni ore.

Breithauptite

NiSb

HEXAGONAL ● ●

Properties: C – light copper-red, purplish; S – red-brown; L – metallic; D – opaque; DE – 8,6; H – 5,5; CL – none; F – conchoidal to uneven; M – thin tabular crystals, dendritic aggregates, massive.
Origin and occurrence: Magmatic, hydrothermal and metamorphic, associated with silver, nickeline, cobaltite and other sulfides. It occurs inter-grown with pyrrhotite and pentlandite in magmatic liquid deposit Vlakfontein, South Africa. It is common in hydrothermal veins in Cobalt, Ontario, Canada; also known from Sarrabus, Sardinia, Italy and St. Andreasberg, Germany.

Breithauptite, 80 mm, Cobalt, Canada

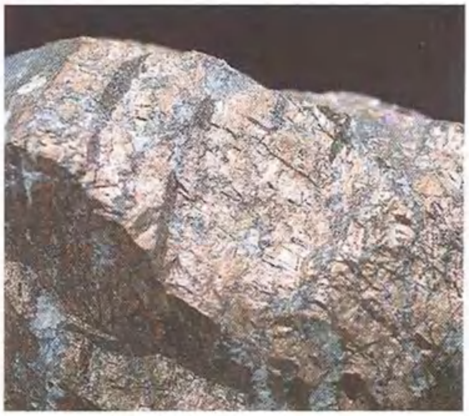

Millerite, 26 mm, Antwerp, U.S.A.

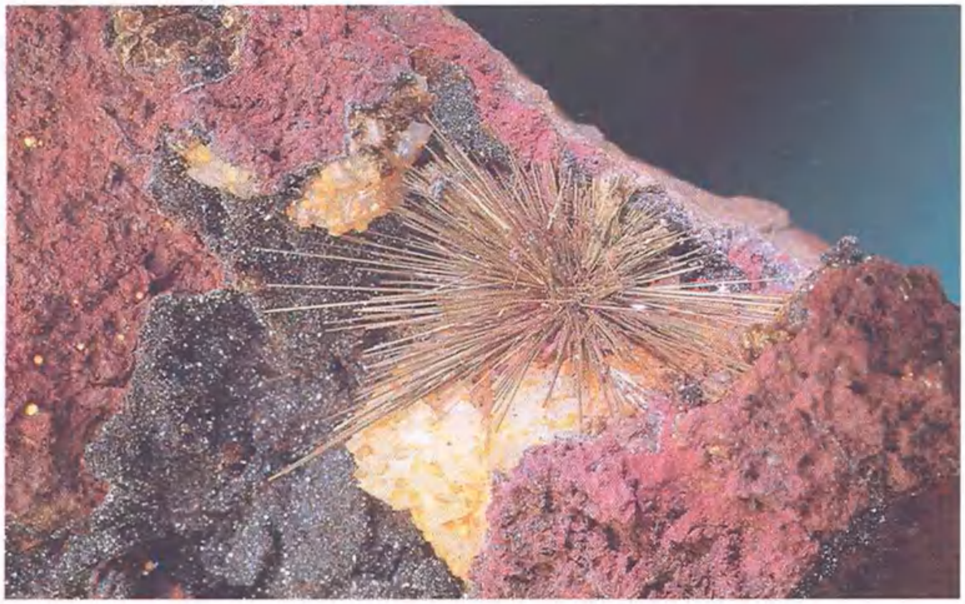

Millerite

NiS

TRIGONAL ● ● ●

Properties: C – light brass-yellow to bronze, tarnishes iridescent; S – greenish-black; L – metallic; D – opaque; DE – 5,4; H – 3-3,5; CL – perfect; F – uneven; M – acicular crystals, cleavable masses, aggregates of parallel inter-grown crystals with velvety surface.
Origin and occurrence: Hydrothermal in low-temperature ore deposits, also as a product of decomposition of Ni sulfides. It is associated with pyrrhotite, ankerite, whewellite, barite and other minerals. Cleavable masses occurred near Temagami near Sudbury, Ontario, Canada and in Kambalda, Western Australia, Australia. Acicular crystals come from ore veins in Jachymov and Príbram, Czech Republic; needles in cavities of siderite concretions in the vicinity of Kladno, Czech Republic, reached up to 70 mm ($2\frac{3}{4}$ in). Acicular crystals up to 80 mm ($3\frac{1}{8}$ in) long known from the limestone cavities near Dortmund, Germany. Beautiful specimens with crystals up to 50 mm (2 in) long in the cavities in hematite occurred in the Sterling mine, Antwerp, New York, USA. Velvety fibrous aggregates were found in the Thompson mine, Manitoba, Canada. *Application:* Ni ore.

Alabandite, 40 mm, Sacarimb, Romania

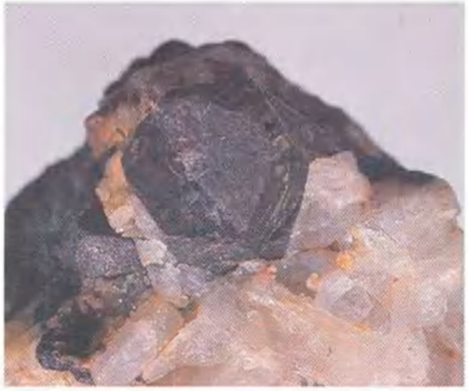

Alabandine

MnS

CUBIC ● ●

Properties: C – black; S – green; L – submetallic; D – opaque; DE – 4,1; H – 3.5-4; CL – perfect; F – uneven; M – cubic and octahedral crystals, granular, massive.
Origin and occurrence: Hydrothermal in ore veins, associated with rhodochrosite, calcite, galena, sphalerite, pyrite and other minerals. Crystals up to 20 mm ($\frac{25}{32}$ in) across together with granular aggregates are relatively common in Romania (Sacarîmb, Baia de Arieş , Roşia Montana). Crystals are also known from the Queen of the West mine, Colorado and from the Lucky Cuss mine, Tombstone, Arizona, USA.

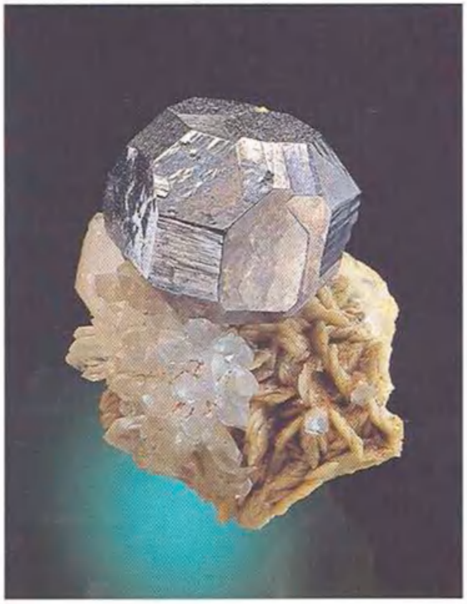
Galena, 56 mm, Neudorf, Germany

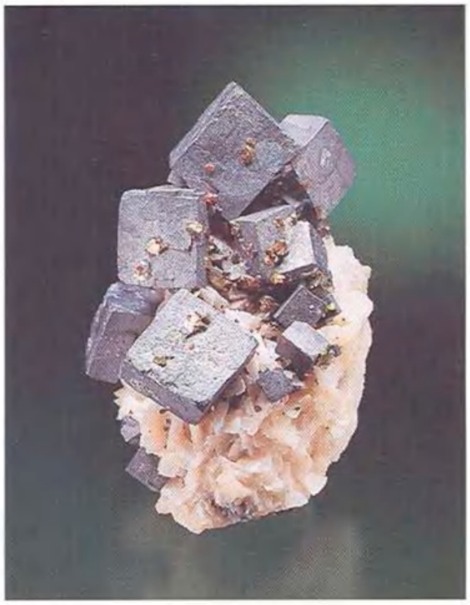
Galena, 66 mm, Picher, U.S.A.

Galena

PbS

CUBIC ● ● ● ● ●

Varieties: steinmannite

Properties: C – lead-gray; S – lead-gray; L – metallic; D – opaque; DE – 7,6; H – 2.5; CL – perfect; F – conchoidal; M – cubic crystals and their complex combinations, tabular crystals, skeletal aggregates, massive.
Origin and occurrence: Magmatic, hydrothermal, metamorphic, very rare sedimentary, associated with sphalerite, chalcopyrite, pyrite, quartz and other minerals. Large crystals up to several tens of cm in size come from many localities in the USA. (Joplin, Missouri; Galena, Kansas; Picher, Oklahoma; Sweetwater mine, Missouri). Beautiful, often skeletal crystals or spinel-law twins up to 200 mm (7⅞ in) across known from the Nikolai mine in Dalnegorsk, Russia. Fine crystals occur also in Naica, Chihuahua, Mexico. Famous complicated combinations of crystals were found in Neudorf, Germany. Octahedral crystals up to 10 mm (⅜ in) (steinmannite variety) were common in Pribram, Czech Republic. Beautiful specimens with cubes up to several cm across come from Madan, Bulgaria; spinel-law twins occurred in Herja, Romania.
Application: the most important Pb ore.

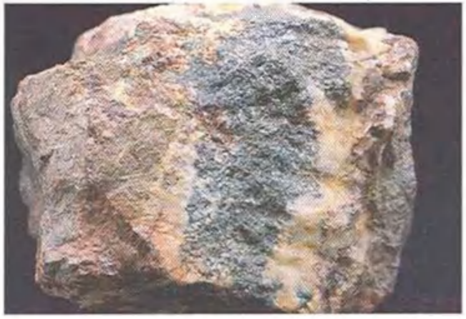
Clausthalite, 20 mm veinlet, Tilkerode, Germany

Clausthalite

PbSe

CUBIC ● ● ●

Properties: C – lead-gray, bluish; S – gray-black; L – metallic; D – opaque; DE – 8,3; H – 2,5 – 3; CL – good; F – granular; M – granular, massive..
Origin and occurrence: Hydrothermal in ore veins with a low S content, together with berzelianite, umangite, uraninite and other minerals. It occurs as massive aggregates in calcite veins with other selenides in Clausthal and Tilkerode, Germany. It is similar in Skrikerum, Sweden; common in the U deposits in Predborice, Bukov and Zlatkov, Czech Republic.

Altaite, 65 mm, Stania, Romania

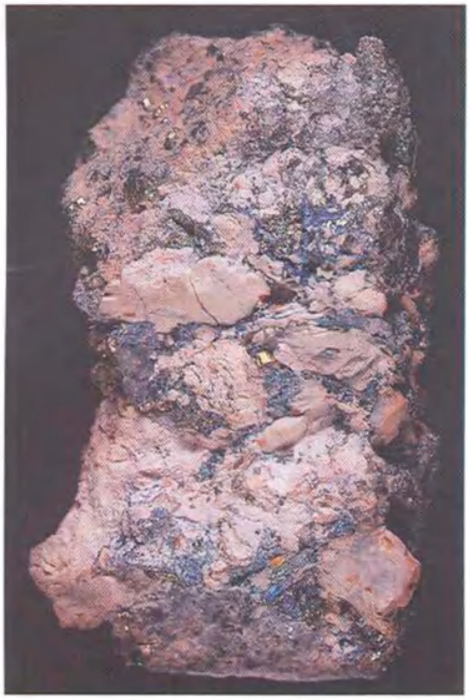

Altaite

PbTe

CUBIC ● ● ●

Properties: C – tin-white to yellowish, tarnishing to bronze; S – black; L – metallic; D – opaque; DE – 8,3; H – 3; CL – perfect; F – conchoidal; M – cubic and octahedral crystals, massive.

Origin and occurrence: Hydrothermal in vein Au deposits, associated with other tellurides, galena and other minerals. Crystals up to 20 mm ($^{25}/_{32}$ in) across are known from the Revenge mine, Colorado, USA. It is massive with aguilarite in Kalgoorlie, Western Australia, Australia. It is relatively common with other tellurides in Sacarîmb , Romania; in the Zavodinskii mine, Altai, Russia and in Zod near Sevan Lake, Armenia.

Miargyrite

$AgSbS_2$

MONOCLINIC ● ● ●

Properties: : C – black to steel-gray; S – cherry-red; L – metallic, adamantine; D – opaque; DE – 5,3; H – 2,5; CL – imperfect; F – conchoidal; M – thick tabular, striated crystals, massive.
Origin and occurrence: Hydrothermal in low-temperature ore veins, together with proustite, pyrargyrite, polybasite, silver, quartz and other minerals. Fine crystals, up to 10 mm ($^{3}/_{8}$ in) across, occurred in Príbram and Kutna Hora, Czech Republic; in Braunsdorf and Freiberg, Germany. It is also known from many localities in Bolivia (Tatasi, Oruro – 10 mm ($^{3}/_{8}$ in) crystals, Potosí) and Mexico (Sombrerete, Catorce). It was also found in Hiendelaencina, Guadalajara, Spain.
Application: Ag ore.

Franckeite

$(Pb,Sn)_6FeSn_2Sb_2S_{14}$

TRICLINIC ● ●

Properties: C – gray-black; S – gray-black; L – metallic; D – opaque; DE – 5,9; H – 2,5-3; CL –

Miargyrite, 20 mm, Kutna Hora, Czech Republic

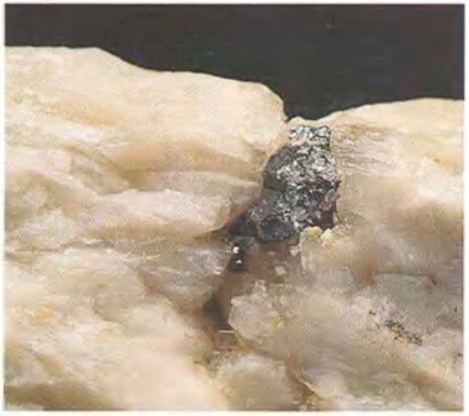

Franckeite, 30 mm, Oruro, Bolivia

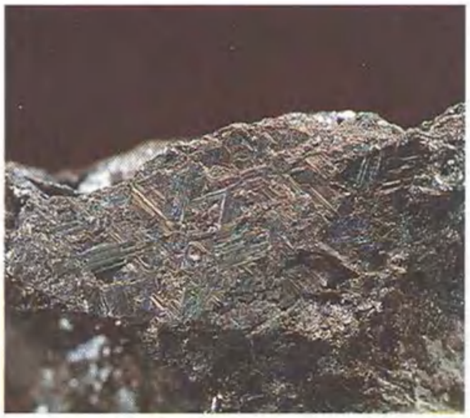

Cylindrite, 50 mm, Poopo, Bolivia

perfect; M – thin tabular, curved crystals, often rosette-like aggregates of crystals.
Origin and occurrence: Hydrothermal in Ag-Sn deposits, associated with cylindrite, zinkenite, cassiterite, wurtzite and other minerals; in contact metamorphic limestones. The best crystals up to 60 mm (24 in) across come from various localities in Bolivia (Mollecagua near Poopo; Huanuni; Chocoya near Potosi; Colquechaca and Oruro). It is known in contact metamorphic limestone from the Kalkar quarry, California, USA.
Application: Sn ore.

Cylindrite
$Pb_3Sn_4FeSb_2S_{14}$

TRICLINIC ● ●

Properties: C – lead-gray to black; S – black; L – metallic; D – opaque; DE – 5,4; H – 2,5; CL – perfect; M – cylindrical, conical and spherical crystal aggregates, massive.
Origin and occurrence: Hydrothermal in Sn-bearing veins with franckeite, stannite, cassiterite, galena and other minerals. World famous specimens with crystals up to 50 mm (2 in) long come from the Trinacria and Santa Cruz mines near Poopo, Bolivia. It was also reported from the Smirnovsk deposit, Transbaikalia, Russia.

Cinnabar
HgS

TRIGONAL ● ● ● ●

Properties: C – red to brownish-red; S – crimson; L – adamantine to metallic, also dull; D – opaque; DE – 8,2; H – 2-2,5; CL – perfect; F – conchoidal to uneven; M – rhombohedral, thick tabular and prismatic crystals, massive.
Origin and occurrence: Low-temperature hydrothermal mineral, associated with realgar, mercury, pyrite, marcasite and other minerals. The world's best specimens with crystals up to 70 mm (2¾ in) across are known from many localities in China (Hunan and Guizhou provinces). Fine shiny crystals up to 10 mm ($^3/_8$ in) across come from Nikitovka, Ukraine and in Khaidarkan, Kyrgyzstan. Crystals up to 30 mm ($1^3/_{16}$ in) also found in Monte Amiata and Rippa near Seravezza, Italy. Its massive aggregates are an important Hg ore in Allchar, Macedonia; Almaden, Spain and elsewhere.
Application: the most important Hg ore.

T ↓

Cinnabar, 30 mm x, Hunan, China

Covellite, 65 mm. Butte, U.S.A.

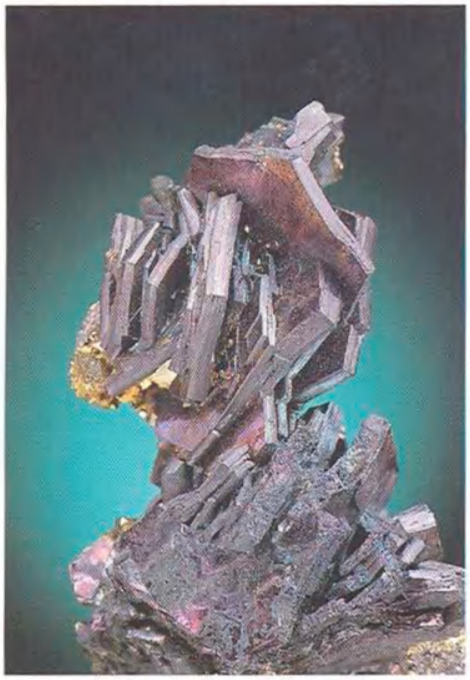

Covellite
CuS

HEXAGONAL ● ● ●

Properties: C – indigo-blue, tarnishing iridescent; S – lead-gray; L – submetallic to resinous; D – opaque; DE – 4,6; H – 1,5-2; CL – perfect; F – uneven; M – hexagonal tabular crystals, massive.
Origin and occurrence: Rare hydrothermal; mainly secondary in the oxidation zone of ore deposits, associated with chalcopyrite, chalcocite, djurleite, bornite and other minerals. Tabular crystals up to 30 mm ($1\frac{1}{16}$ in) across are known from Butte, Montana and Summitville, Colorado, USA; also from Sarrabus, Sardinia, Italy. Massive aggregates are common in Bor, Serbia; Bisbee, Arizona, USA and elsewhere.
Application: Cu ore.

Linneite
$Co^{2+}Co^{3+}{}_2S_4$

CUBIC ● ● ●

Properties: C – light gray to steel-gray; S – black-gray; L – metallic; D – opaque; DE – 4,9; H – 4,5-5,5; CL – imperfect; F – uneven to conchoidal; M – octahedral crystals, granular, massive.
Origin and occurrence: Hydrothermal in ore veins and metamorphic deposits, together with chalcopyrite, pyrrhotite, millerite, bismuthinite and sphalerite. The best crystals up to 30 mm ($1\frac{1}{16}$ in) across come from the Kilembe mine, Uganda. Crystals are also known from Musonoi, Shaba, Zaire; Mhsen, Germany; siderite concretions in Kladno, Czech Republic and from the Bastnas mine near Riddarhyttan, Sweden.

Carrolite
$Cu(Co,Ni)_2S_4$

CUBIC ● ● ●

Properties: C – light to steel-gray, tarnishing red-purple; S – gray; L – metallic; D – opaque; DE – 4,8; H – 4,5-5,5; CL – imperfect; F – conchoidal to uneven; M – octahedral crystals, granular, massive.
Origin and occurrence: Hydrothermal in ore veins, associated with linneite, chalcopyrite and other minerals. It is a principal Co ore in deposits in Zaire. Beautiful crystals up to 20 mm ($\frac{25}{32}$ in) across are known from the M'Sesa mine near Kambove, Kolwezi and from Kamoto, Shaba.
Application: Co ore.

Linneite, 60 mm, Ruwenzori, Uganda

Carrollite, 8 mm x, Kambove, Zair

Stibnite

Sb_2S_3

ORTHORHOMBIC ● ● ● ●

Properties: C – steel-gray, tarnishing iridescent or black; S – lead-gray; L – metallic; D – opaque; DE – 4,6; H – 2; CL – perfect; F – conchoidal to uneven; M – thick to thin prismatic crystals, thin needles, massive.
Origin and occurrence: Hydrothermal in medium- and low-temperature ore veins with quartz and gold, the other associated minerals are rare (arsenopyrite, berthierite, gudmundite, antimony). The largest known stibnite crystals occurred in the in the Ichinokawa mine, Shikoku, Japan, where they were up to 60 cm (24 in) long. Similar sized crystals were found recently in several localities in China (the Xikuangshan mine, Hunan). Crystals up to 200 mm (7⅞ in) across come from Manhattan, Nevada, USA. Beautiful crystals are known from Romania; long prismatic ones with barite crystals are prevalent in Baia Sprie, clusters of thin needles come from Herja and thick prismatic crystals from Baiuţ. Perfect druses of crystals up to 150 mm (6 in) long, associated with purple fluorite crystals, barite and calcite, occurred in Kadamdzhai, Kyrgyzstan. Beautiful druses of stibnite crystals with quartz come also from Kremnica, Slovakia. Also Kostajnik, Serbia and La Lucette, France yielded fine crystals in the past.
Application: Sb ore.

Stibnite, 187 mm, Ichinokawa, Japan

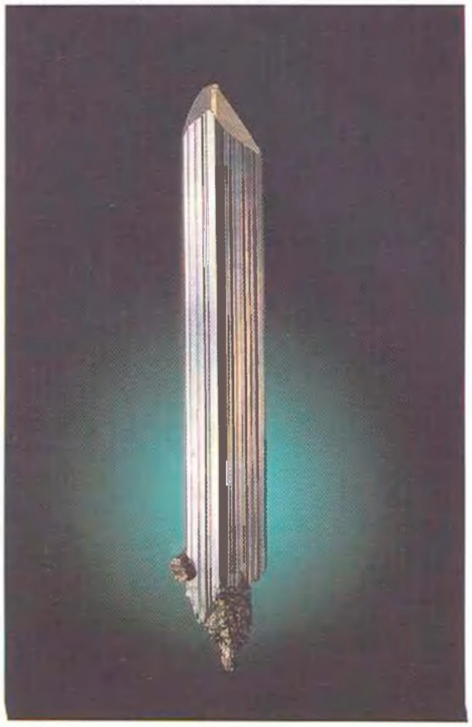

Stibnite, 120 mm, Baia Sprie, Romania

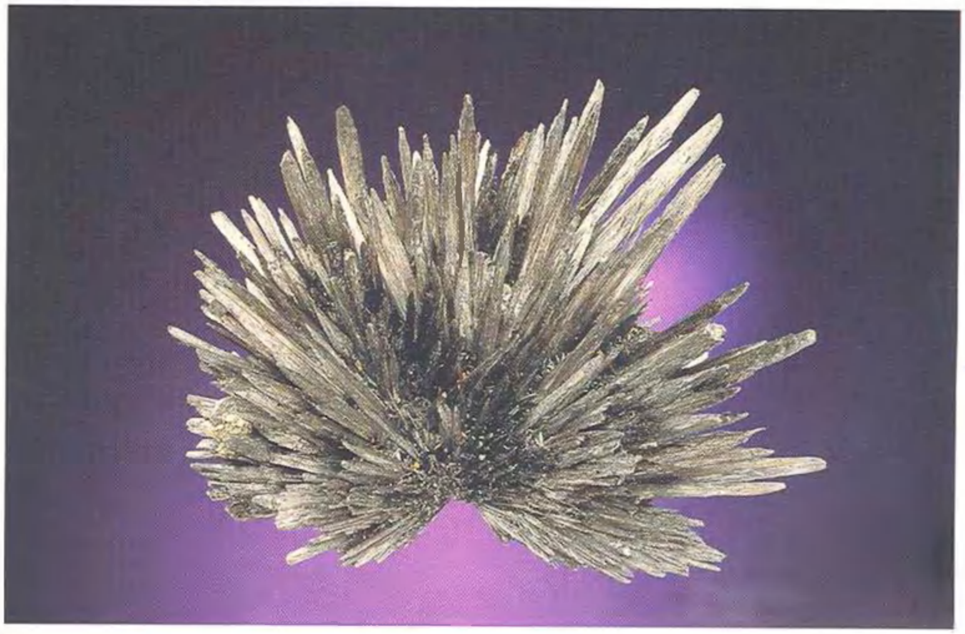

Bismuthinite, 160 mm, Tasna, Bolivia

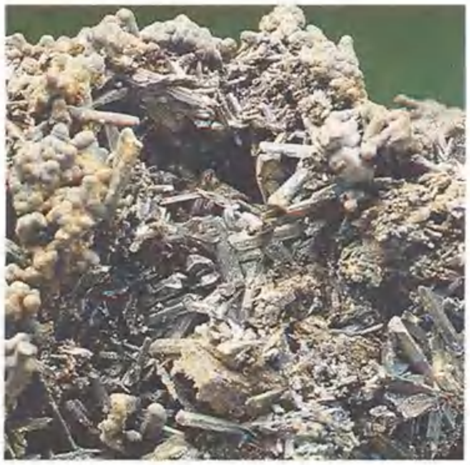

Bismuthinite

Bi_2S_3

ORTHORHOMBIC ● ● ● ●

Properties: C – lead-gray to tin-white, tarnishing yellow and iridescent; S – lead-gray; L – metallic; D – opaque; DE – 6,8; H – 2-2,5; CL – perfect; F – uneven; M – thick prismatic to acicular, striated crystals, fibrous aggregates, massive.

Kermesite, 20 mm xx, Freiberg, Germany

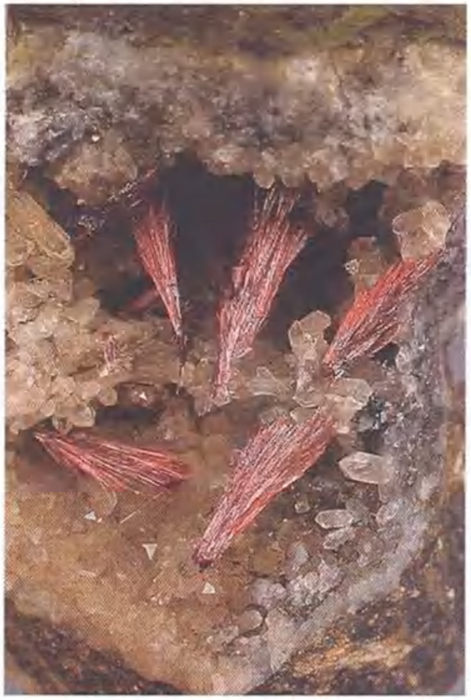

Tetradymite, 80 mm, Ciclova, Romania

Origin and occurrence: Hydrothermal in ore deposits; also in recent volcanic exhalation deposits, associated with bismuth, arsenopyrite, stannite, galena and other minerals. The world's best crystals over 50 mm (2 in) long, come from Bolivia (Tasna; Huanuni; Llallagua). Fine crystals were also found in Redruth, Cornwall, UK. Rich finds were made in Biggenden, Queensland, Australia. Interesting crystals are known from Spind, Norway.

Application: Bi ore.

Kermesite

Sb_2S_2O

TRICLINIC ● ● ●

Properties: C – cherry-red; S – brown-red; L – adamantine to submetallic; D – translucent to opaque; DE – 4,7; H – 1-1,5; CL – perfect; M – acicular crystals, radial aggregates.

Origin and occurrence: Secondary, as a result of a stibnite oxidation in Sb deposits, associated with stibnite, antimony, senarmontite, valentinite and stibiconite. Famous specimens with needles up to 100 mm (4 in) long, in radial aggregates, come from Pezinok and Pernek, Slovakia. Crystals up to 50 mm (2 in) long found in the Globe and Phoenix mines, Zimbabwe. It is also known from Bolivia (San Francisco mine, Poopo; Oruro) and Braunsdorf, Germany.

Nagyagite, 100 mm, Sacarimb, Romania

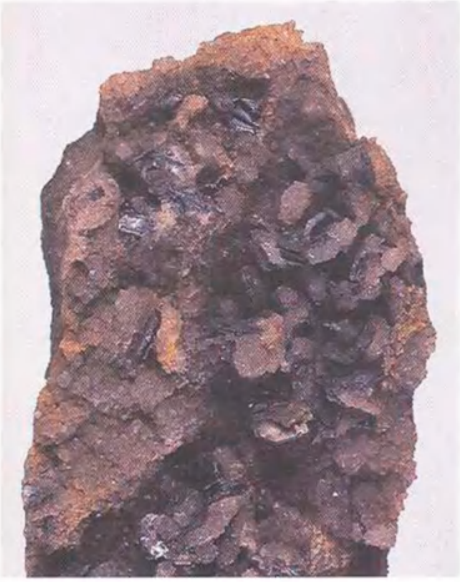

Tetradymite

Bi_2Te_2S

TRIGONAL ● ● ●

Properties: C – light steel-gray, tarnishing dark to iridescent; S – light steel-gray; L – metallic; D – opaque; DE – 7,3; H – 1,5-2; CL – perfect; M – pyramidal crystals, curved bladed aggregates, massive.
Origin and occurrence: Hydrothermal in medium- and high-temperature Au deposits; also in contact metamorphosed deposits, together with gold, hessite, calaverite, pyrite and other minerals. Crystals up to 10 mm (3/8 in) across are known from Župkov, Slovakia. It is common in Colorado (Red Cloud) and in California (Carson Hill), USA. It occurs with gold in skarns in Baiţa Bihorului, Romania.

Nagyagite

$Pb_5Au(Te,Sb)_4S_{5-8}$

TETRAGONAL ● ●

Properties: C – black-gray; S – black-gray; L – metallic; D – opaque; DE – 7,5; H – 1,5; CL – perfect; F – uneven; M – thin tabular to foliated crystals, granular, massive.
Origin and occurrence: Hydrothermal in low-temperature veins, associated with altaite, arsenic, gold, rodochrosite and other minerals. Foliated crystals up to 40 mm (1 9/16 in) across come from Sacarîmb and Baia de Arieş, Romania. Fine specimens were also found in Tavua, Viti Levu, Fiji and in the Sylvia mine, Tararu Creek, New Zealand. It also occurred in Gold Hill and Cripple Creek, Colorado, USA and in Kalgoorlie, Western Australia, Australia.

Sylvanite

$(Au,Ag)_2Te_4$

MONOCLINIC ● ● ●

Properties: C – steel-gray to silver-white, tarnishing to yellow; S – steel-gray to silver- white; L – metallic; D – opaque; DE – 8,2; H – 1,5-2; CL – perfect; F – uneven; M – short prismatic to thick tabular crystals, skeletal aggregates, granular.
Origin and occurrence: Hydrothermal in low-temperature ore veins, also in medium- and high-temperature deposits as one of the latest minerals, associated with gold, calaverite, hessite, krennerite and other minerals. The best specimens come from Sacarîmb and Baia de Arieş, Romania, where it occurs as skeletal crystals and aggregates. Crystals were also found in Cripple Creek, Colorado, USA; crystals up to 10 mm (3/8 in) across come from the Emperor mine, Viti Levu, Fiji.

Sylvanite, 20 mm, Cripple Creek, U.S.A.

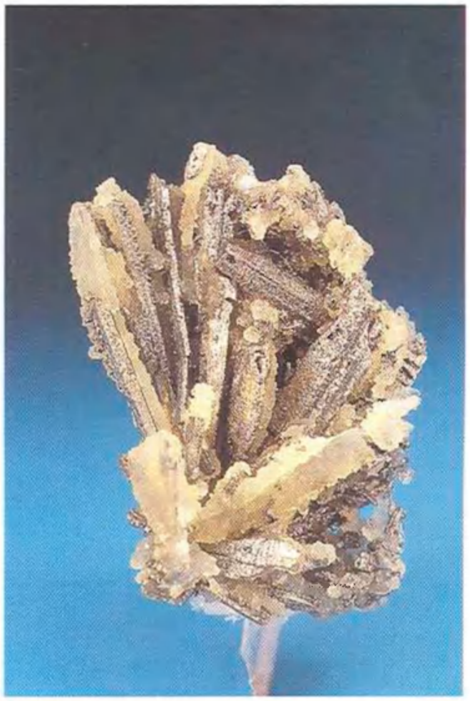

Krennerite, 3 mm xx, Sacarimb, Romania

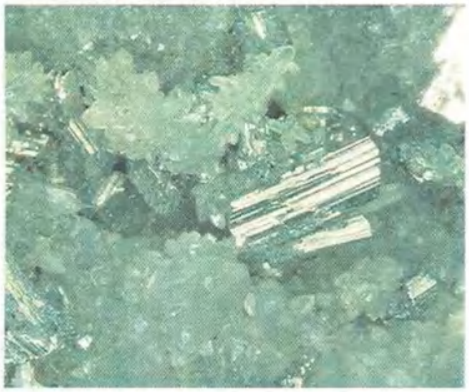

Krennerite

$AuTe_2$

ORTHORHOMBIC ● ●

Properties: C – silver-white to brass-yellow; S – silver-white; L – metallic; D – opaque; DE – 8,9; H – 2-3; CL – perfect; F – conchoidal to uneven; M – short prismatic, striated crystals, massive.
Origin and occurrence: Hydrothermal in gold-bearing veins, associated with gold, tellurium, pyrite, quartz and other tellurides. Crystals up to 20 mm ($^{25}/_{32}$ in) across found in Tavua, Viti Levu, Fiji. Small crystals occurred in Sacarîmb and Baia de Arieş , Romania and in Cripple Creek, Colorado, USA.
Application: Au ore.

Calaverite

$AuTe_2$

MONOCLINIC ● ● ●

Properties: C – brass-yellow to silver-white; S – greenish; L – metallic; D – opaque; DE – 9,3; H – 2,5-3; CL – none; F – uneven to conchoidal; M – bladed and short prismatic, striated crystals, granular, massive.
Origin and occurrence: Hydrothermal in low-temperature Au-bearing veins, sometimes in medium- and high-temperature deposits, associated with coloradoite, altaite, krennerite and other tellurides. It is common in the Mother Lode in California (Carson Hill). It is important, together with hessite in Cripple Creek, crystals up to 10 mm ($^{3}/_{8}$ in) across come from the Cresson mine, Colorado, USA.. It is also known from several mines near Kirkland Lake, Ontario, Canada.
Application: Au ore.

Pyrite

FeS_2

CUBIC ● ● ● ● ●

Properties: C – light brass-yellow, tarnishing iridescent and darkens; S – green-black to brown-black; L – metallic; D – opaque; DE – 5,0; H – 6-6,5; CL – imperfect; F – conchoidal to uneven; M – combinations of cubic crystals, striated, stalactitic and spherical aggregates, massive.
Origin and occurrence: Magmatic segregations in basic rocks with pyrrhotite and pentlandite, in pegmatites and skarns; hydrothermal in porphyry and vein deposits together with other sulfides; hydrothermal sedimentary, sedimentary and metamorphic. Magmatic segregations are known from Sudbury, Ontario, Canada and Merensky Reef, Transvaal, South Africa. Large crystals up to 200 mm ($7^{7}/_{8}$ in) across are known from Rio Marina, Elba, Italy. Fine octahedra come from Llallagua, Bolivia. Crystals, up to 120 mm ($4^{11}/_{16}$in) across, were found in Bingham and Park City, Utah, USA. Crystals up to 150 mm (6 in) are known from Huanzala and Quiruvilca, Peru. The largest pyrite deposit is Rio Tinto, Spain, where fine-grained pyrite formed accumulations about 1 billion tons. Beautiful cubes up to 80 mm ($3^{1}/_{8}$ in) come from Navajun, Spain. Large deformed crystals

Calaverite, 21 mm, Nagyag, Romania

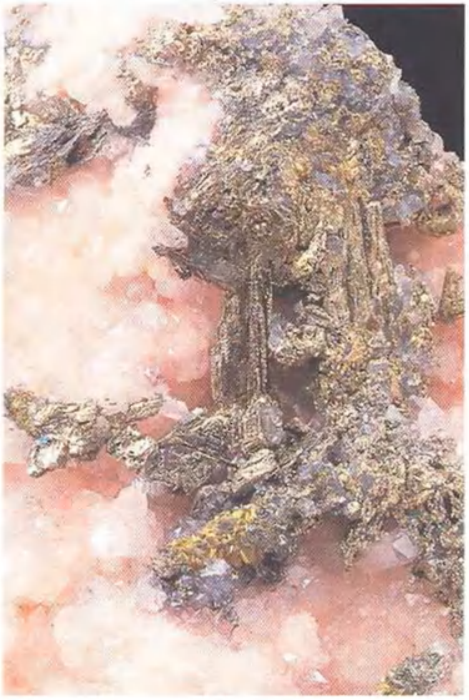

Pyrite, 74 mm, Navajun, Spain

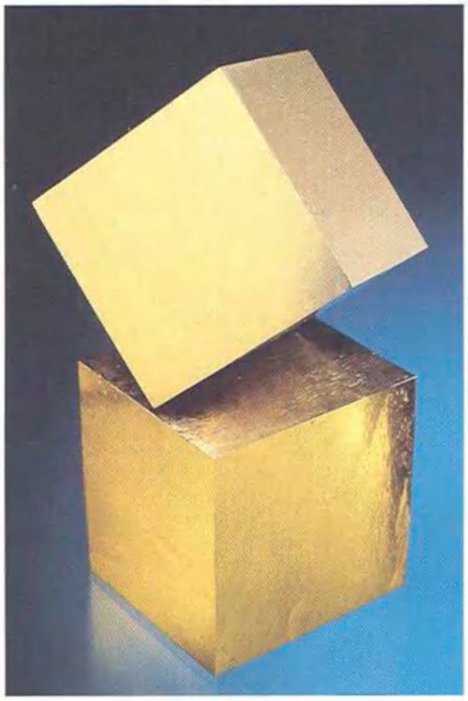

Pyrite, 135 mm, Washington, U.S.A.

up to 200 mm ($7\frac{7}{8}$ in) across occurred in the Samo mine near Hnust'a , Slovakia. Interesting, complex combinations of crystals found in Nanisivik, on an edge from Climax, Colorado, USA.
Application: production of sulfuric acid.

Hauerite

MnS_2

CUBIC ● ● ●

Properties: C – red-brown to brown-black; S – brown-red; L – metallic to adamantine; D – opaque; DE – 3,44; H – 4; CL – perfect; F – uneven to conchoidal; M – octahedral crystals and their combinations, spherical aggregates..
Origin and occurrence: Low-temperature sedimentary mineral, limited to clays with high S contents. The best crystals up to 50 mm (2 in) across come from the Destricella mine near Raddusa, Sicily, Italy. Crystals up to 25 mm (1 in) and their aggregates are known from Víglasška Huta (former Kalinka) near Zvolen, Slovakia. Crystals up to 15 mm ($\frac{19}{32}$ in) across occur in Tarnobrzeg, Poland. Also found with sulfur, gypsum, realgar and calcite in the salt domes near High Island, Texas, USA.

Hauerite, 39 mm, Raddusa, Italy

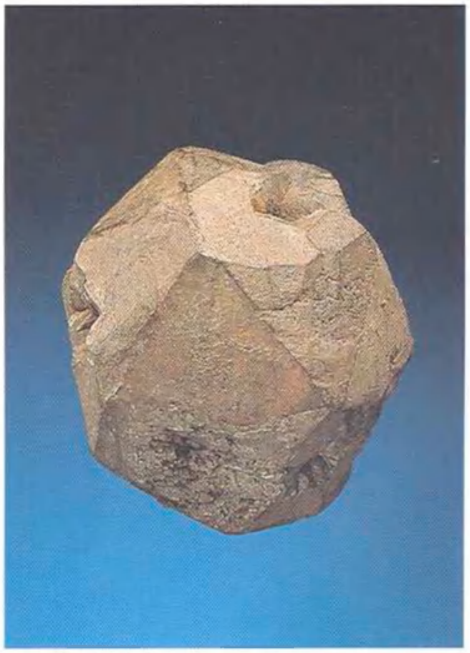

Sperrylite, 55 mm, Talnakh, Russia

Sperrylite

$PtAs_2$

CUBIC ● ●

Properties: C – tin-white; S – black; L – metallic; D – opaque; DE – 10,8; H – 6-7; CL – imperfect; F – conchoidal; M – complex combinations of cubic crystals, massive.
Origin and occurrence: It is mainly of magmatic liquid origin, associated with pyrrhotite, pentlandite, cubanite and other minerals. The best crystals come from Talnakh near Norilsk, Siberia, Russia, where inter-grown crystals reached up to 50 mm (2 in). Crystals up to 40 mm (1$^{9}/_{16}$ in) across known from Tweefontein, Potgietersrust, Bushveld, South Africa. It also occurred as disseminated aggregates in Sudbury, Ontario, Canada.

Aurostibite

$AuSb_2$

CUBIC ● ●

Properties: C – gray, tarnishing iridescent; S – gray; L – metallic; D – opaque; DE – 9,9; H – 3; CL Bnone; M – granular.
Origin and occurrence: Hydrothermal in quartz veins, associated with gold and other Sb minerals. Grains up to 5 mm ($^{3}/_{16}$ in) across come from Krasna Hora, Czech Republic. It also occurs in the Giant Yellowknife mine, Northwest Territories and Hemlo, Thunder Bay, Ontario, Canada and is also reported from Bestyube, Kazakhstan.

Krut'aite

$CuSe_2$

CUBIC ●

Properties: C – gray; S – gray; L – metallic; D – opaque; DE – 6,5; H – 4; M – microscopic crystals, massive.
Origin and occurrence: Hydrothermal, associated with clausthalite, uraninite and other minerals. The richest accumulations of massive aggregates were found in the El Dragon mine, Potosí, Bolivia, where crystals up to 1 mm ($^{1}/_{32}$ in) occurred as well. It was originally described as microscopic from Petrovice, Czech Republic.

Cobaltite

CoAsS

ORTHORHOMBIC ● ● ●

Properties: C – silver-white; S – gray-black; L – metallic, adamantine to dull; D – opaque; DE – 6,3; H – 5,5; CL – perfect; F – uneven; M – pseudo-cubic crystals, granular, massive.
Origin and occurrence: Hydrothermal in high-temperature ore deposits and metamorphic, together

Aurostibite, 4 mm grain, Krasna Hora, Czech Republic

Krut'aite, 40 mm, El Dragon, Bolivia

Cobaltite, 5 mm x, Hakansboda, Sweden

with magnetite, sphalerite, chalcopyrite, other sulfides and arsenides of Co and Ni. The best dodecahedra, several cm across, come from metamorphic sulfide deposits in Tunaberg, Sweden. Other Swedish localities, like Håkansboda and Ramsberg, yielded crystals up to 60 mm (24 in) across. Fine crystals about 10 mm (3/8 in) occurred in the magnesite deposit Mutnik near Hnust'a , Slovakia. Cubic crystals up to 30 mm (1 3/16 in) across found in Espanola, Ontario, Canada. Beautiful crystals are known from the skarn in Bimbowrie, South Australia, Australia.
Application: Co ore.

Gersdorfite

NiAsS

CUBIC ● ● ●

Properties: C – silver-white to steel-gray, tarnishing gray-black; S – gray-black; L – metallic; D – opaque; DE – 6,0; H – 5,5; CL – perfect; F – uneven; M – octahedral striated crystals and their combinations, massive. *Origin and occurrence:* Hydrothermal in medium-temperature ore deposits in association with nickeline, nickel-skutterudite, ullmanite, siderite and other minerals. Crystals up to 100 mm (4 in) across come from the Snowbird mine, Montana, USA. It is important in several mines near Sudbury and Cobalt, Ontario, Canada. Large cleavable masses are known from Dobsina, Rudnany and Nizna Slana, Slovakia. Crystals from the Aït Ahmane mine near Bou Azzer, Morocco, reached up to 40 mm (1 9/16 in) . *Application:* Ni ore.

Gersdorffite, 10 mm xx, Bou Azzer, Morocco

Ullmanite, 60 mm, Bou Cricha, Morocco

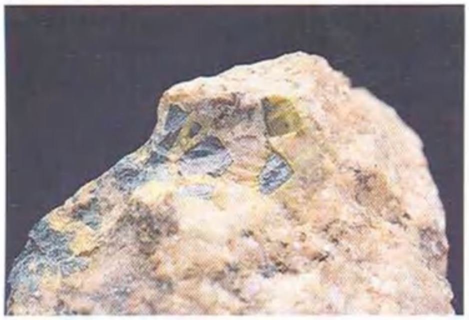

Ullmanite

NiSbS

CUBIC ● ●

Properties: C – steel-gray to silver-white; S – gray-black; L – metallic; D – opaque; DE – 6,8; H – 5-5,5; CL – perfect; F – uneven; M – combinations of cubic crystals, massive.
Origin and occurrence: Hydrothermal in ore veins together with other Ni minerals. Fine crystals, up to 20 mm ($^{25}/_{32}$ in) across, come from Monte Narba near Sarrabus, Sardinia, Italy. Twins are known from Lolling, Austria. Crystals up to 10 mm ($^{3}/_{8}$ in) were found in Ksice near Støibro, Czech Republic. It is common in Broken Hill, New South Wales, Australia and in Cochabamba, Bolivia.
Application: Ni ore.

Marcasite, 42 mm, Vintirov, Czech Republic

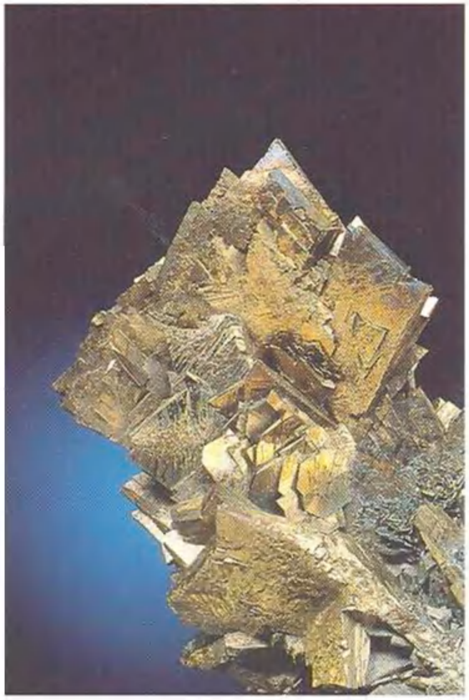

Marcasite

FeS_2

ORTHORHOMBIC ● ● ● ●

Properties: C – tin-white, bronze-yellow, tarnishing iridescent; S – grayish to brownish- black; L – metallic; D – opaque; DE – 4,9; H – 6-6,5; CL – good; F – uneven; M – tabular, pyramidal and prismatic crystals, often twinned into the form of cockscomb-like aggregates, stalactitic, botryoidal and massive.
Origin and occurrence: It originates at low temperatures in very acidic environment, either in sedimentary, or in hydrothermal deposits, associated with pyrite, pyrrhotite, galena, sphalerite, fluorite, dolomite and calcite. Hydrothermal crystals and pseudo-morphs after pyrrhotite are known from Freiberg, Germany; Llallagua, Bolivia and Chiuzbaia, Romania. Crystals from Wiesloch, Germany and Reocin, Santander, Spain are of similar origin. Large crystals occurred in Joplin, Missouri and in Galena, Illinois, USA. The best crystals of sedimentary marcasite come from coal basins. Fine crystals from black coal are known from Essen, Germany. Cockscomb-like aggregates up to 150 mm (6 in) across, come from the brown coal basin in Vintiøov, Czech Republic. Spherical, radial concretions with pyrite are known from Sparta, Illinois, USA and from Champagne, France.
Application: production of sulfuric acid.

Marcasite, 70 mm, Sparta, U.S.A.

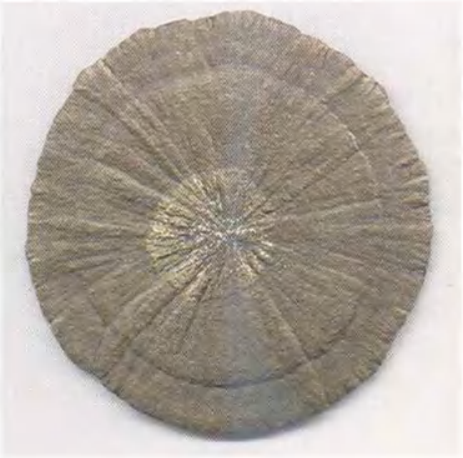

Lollingite, 7 mm xx, Cobalt, Canada

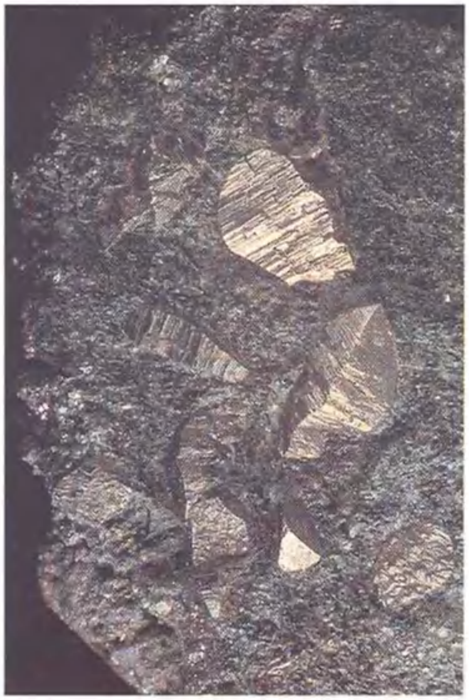

Löllingite

$FeAs_2$

ORTHORHOMBIC ● ● ●

Properties: C – steel-gray to silver-white; S – gray-black; L – metallic; D – opaque; DE – 7,5; H – 5-5,5; CL – sometimes good; F – uneven; M – prismatic crystals, massive.
Origin and occurrence: Magmatic in pegmatites; hydrothermal in greisens and Sn-W veins, rare in the other types of ore veins, together with skutterudite, bismuth, nickeline, siderite, calcite and other minerals. Fine crystals are known from syenite in Langensundsfjord, Norway. Crystals up to 50 cm (20 in) across come from a pegmatite in Kaatiala, Finland. Masses occur in the Kobokobo pegmatite, Kivu, Zaire. Massive aggregates with schorl were found in Dolni Bory, aggregates with cassiterite in Pøebuz, Czech Republic.

Safflorite, 70 mm, Bou Azzer, Morocco

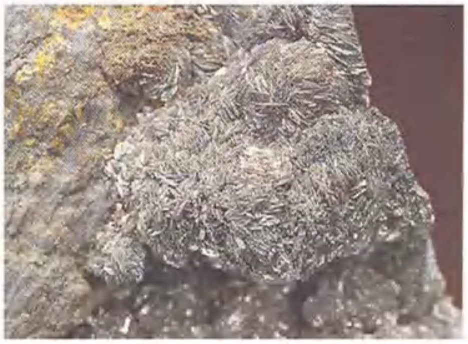

Safflorite

$(Co,Fe)As_2$

ORTHORHOMBIC ● ● ●

Properties: C – tin-white, tarnishing to dark gray; S – gray-black; L – metallic; D – opaque; DE – 7,5; H – 4,5-5; CL – good; F – uneven to conchoidal; M – prismatic crystals, radial aggregates, massive.
Origin and occurrence: Hydrothermal in medium-temperature with skutterudite, rammelsbergite, nickeline, silver, bismuth and lollingite. It is common in Schneeberg, Germany; Cobalt, Ontario, Canada; Batopilas, Chihuahua, Mexico and in Bou Azzer, Morocco.

Rammelsbergite

$NiAs_2$

ORTHORHOMBIC ● ● ●

Properties: C – tin-white, pinkish; S – gray-black; L – metallic; D – opaque; DE – 7,1; H – 5,5-6; CL – good; F – uneven; M – prismatic crystals, radial and fibrous aggregates, massive.
Origin and occurrence: Hydrothermal in medium-temperature veins associated with other Ni and Co minerals. Botryoidal aggregates come from Schneeberg, Germany. It is common in Sarrabus, Sardinia, Italy; in the Eldorado mine near Great Bear Lake; in Cobalt, Ontario, Canada and Bou Azzer, Morocco.

Rammelsbergite, 60 mm, Schneeberg, Germany

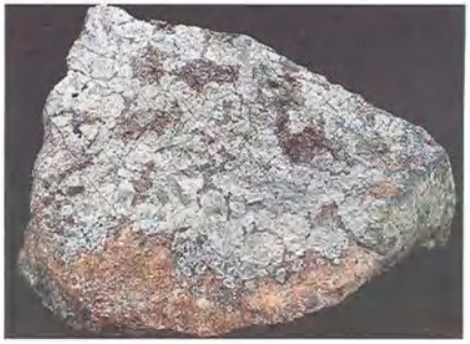

Arsenopyrite, 26 mm x, Portal, Mexico

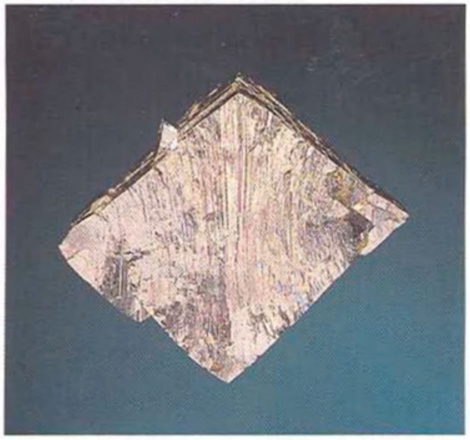

Arsenopyrite

$FeAsS$

MONOCLINIC ● ● ● ●

Properties: C – silver-white to steel-gray; S – black; L – metallic; D – opaque; DE – 6,2; H – 5,5 – 6; CL – good; F – uneven; M – thick tabular to prismatic striated crystals, granular, massive.
Origin and occurrence: It occurs in pegmatites; hydrothermal in high-temperature vein deposits and greisens; metamorphic in contact metamorphic skarns, gneisses and mica schists. Long prismatic crystals up to 30 cm (12 in) long are known from the Obira mine, Japan. It is very common in greisen Sn and W deposits, fine crystals are known from Horni Slavkov, Czech Republic and Ehrenfriedersdorf, Germany. Beautiful crystals up to 50 mm (2 in) across come from Panasqueira, Portugal, where they occurred associated with fluorapatite, wolframite and siderite. Historically important were large crystals from Tavistock, Devon , UK. Crystals up to 40 mm (1$^{9}/_{16}$ in) found in Llallagua, Bolivia. Crystals up to 50 mm (2 in) across were found recently in the Nikolai mine in Dalnegorsk, Russia.

Gudmundite, 10 mm xx, Polar Urals, Russia

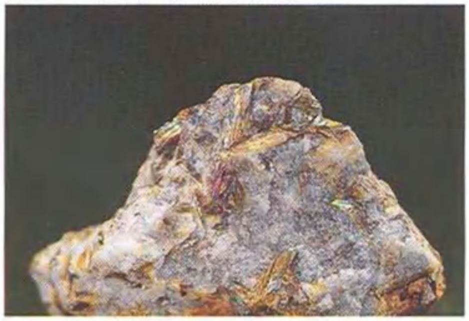

Shiny crystals up to 30 mm (1$^{3}/_{16}$ in) across, come from Hunan province, China. *Application:* As ore.

Gudmundite

$FeSbS$

MONOCLINIC ● ● ●

Properties: C – silver-white to steel-gray; S – black; L – metallic; D – opaque; DE – 7,0; H – 5-6; CL – none; F – uneven; M – prismatic twinned crystals, massive.
Origin and occurrence: Late hydrothermal mineral of ore deposits, also in metamorphic deposits and skarns. It is common in metamorphic sulfide deposits in Sweden (Boliden, Gudmundstorp). Massive aggregates are known from Kutna Hora and Vlastijovice, Czech Republic. It was common in Broken Hill, New South Wales, Australia.

Molybdenite

MoS_2

HEXAGONAL ● ● ● ●

Properties: C – lead-gray; S – blue-gray; L – metallic; D – opaque; DE – 4,0; H – 1-1,5; CL – perfect; M – tabular and prismatic crystals, scaly aggregates.
Origin and occurrence: Magmatic in pegmatites, granites and aplites, hydrothermal in high-temperature veins, also in porphyry ore deposits and in contact metamorphic deposits; associated with chalcopyrite, quartz and other minerals. Large crystals come from pegmatites in Blue Hill Bay, Maine, USA and in Mutue-Fides-Stavoren, Transvaal, South Africa, where they reach several tens of cm in size. Crystals up to 150 x70 mm (6 x 2¾ in) across come from the transitional type between pegmatites and quartz veins near Arendal and Moss, Norway; large crystals also occur in the Temiskaming district, Quebec, Canada; tabular crystals up to 120 mm ($^{23}/_{32}$ in) across found in quartz-molybdenite breccia pipes in veins in Australia (Queensland, New South Wales). Fine crystals are also known from Kladnica near Vito_a, Bulgaria; Horni Slavkov, Czech Republic and Ehrenfriedersdorf, Germany. As a fine grained disseminated ore was mined in Bingham, Utah and Climax, Colorado, USA.
Application: Mo ore.

Skutterudite

$CoAs_{2-3}$

CUBIC ● ● ●

Properties: C – tin-white to silver-gray, tarnishing to

gray and iridescent; S – black; L – metallic; D – opaque; DE – 6,8; H – 5,5 – 6; CL – good; F – conchoidal to uneven; M – combinations of cubic crystals, skeletal aggregates, granular, massive.
Origin and occurrence: Hydrothermal in medium- to high-temperature ore veins, associated with other Ni and Co minerals. Crystals up to 50 mm (2 in) across come from Bou Azzer, Morocco. Crystals up to several cm in size were found in Schneeberg and Annaberg, Germany. Large massive accumulations occur in Cobalt and Gowganda, Ontario, Canada. *Application:* Co ore.

Skutterudite, 25 mm, Schneeberg, Germany

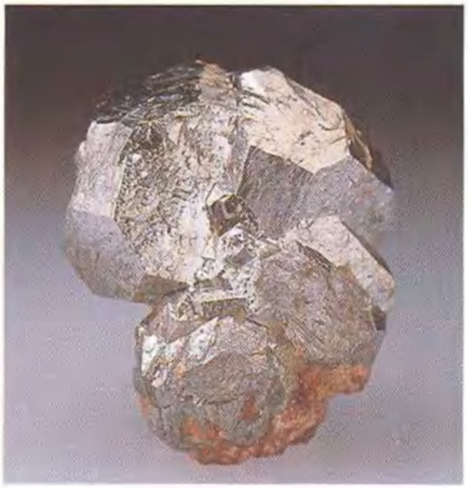

Nickel-skutterudite

$NiAs_3$

CUBIC ● ● ● ●

Properties: C – tin-white to silver, tarnishing to gray and iridescent; S – black; L – metallic; D – opaque; DE – 6,5; H – 5,5 – 6; CL – good; F – conchoidal to uneven; M – combinations of cubic crystals, skeletal aggregates, granular.
Origin and occurrence: Hydrothermal in medium-temperature veins with arsenopyrite, arsenic, bismuth, calcite and siderite. Known in crystals from Chatham, Connecticut and Chester, Massachusetts, USA; also Val d'Anniviers, Wallis, Switzerland. Massive aggregates come from Dobsina, Slovakia; Les Chalanches, France; Mohawk mine, Michigan, USA; Schneeberg, Germany. *Application:* ruda Co a Ni.

Nickel-skutterudite, 36 mm, Saxony, Germany

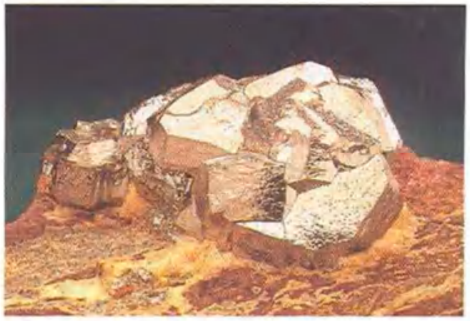

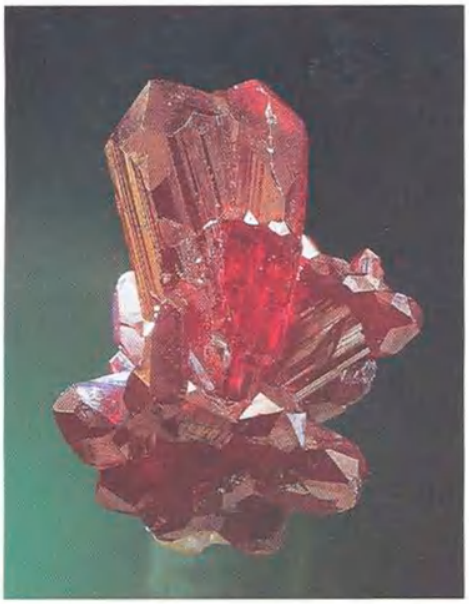

Proustite, 25 mm, Chanarcillo, Chile

Proustite

Ag_3AsS_3

TRIGONAL ● ●

Properties: C – crimson, darkens upon exposure to light; S – crimson; L – adamantine; D – translucent to opaque; DE – 5,6; H – 2-2,5; CL – good; F – conchoidal to uneven; M – prismatic, rhombohedral and scalenohedral crystals, massive.
Origin and occurrence: Low-temperature hydrothermal mineral, also in the oxidation and cementation zone together with stephanite, silver, xanthoconite, acanthite and other minerals. The best specimens with crystals up to 100 mm (4 in) long come from the Dolores mine, Chañarcillo, Chile. Crystals up to 80 mm ($3^{1}/_{8}$ in) long found in the Himmelsfürst mine in Freiberg, Niederschlema and Schneeberg, Germany. Large druses with crystals up to 40 x 20 mm ($1^{9}/_{16}$ x $^{25}/_{32}$ in) across occurred in Jachymov; crystals up to 20 mm ($^{25}/_{32}$ in) across known from Pøibram and Stara Vozice, Czech Republic. Fine crystals come from Batopilas, Chihuahua and Sombrerete, Zacatecas, Mexico. Crystalline masses of proustite, weighing over 250 kg (550 lb), were found in 1865 in the Poorman mine, Silver City, Idaho, USA. *Application:* Ag ore.

Pyrargyrite, 61 mm, Zacatecas, Mexico

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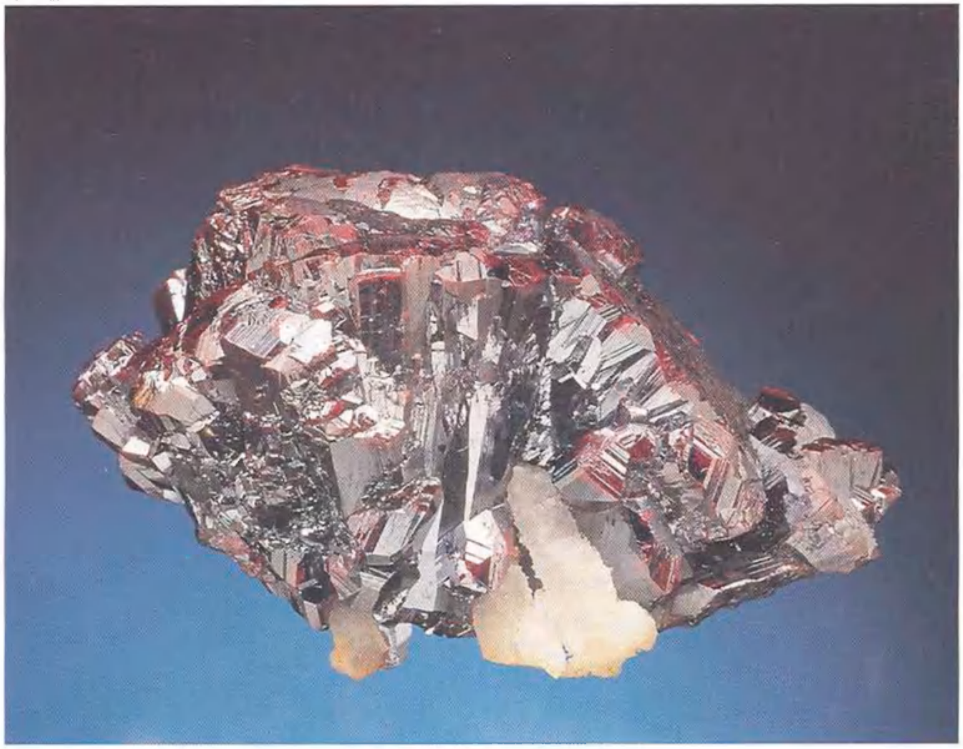

Pyrargyrite

Ag_3SbS_3

TRIGONAL ● ●

Properties: C – dark red, darkens upon exposure to light; S – crimson; L – adamantine; D – translucent to opaque; DE – 5,9; H – 2,5; CL – good; F – conchoidal to uneven; M – prismatic, rhombohedral and scalenohedral crystals, granular, massive.
Origin and occurrence: Low-temperature hydrothermal mineral, also secondary in the oxidation and cementation zone, together with silver, acanthite, other Ag sulfosalts, calcite and quartz. Crystals in Colquechaca, Bolivia and Chañarcillo, Chile reached several cm in size. Crystals up to 70 mm (2¾ in) long occurred in the Santo Nino vein in Fresnillo, Zacatecas, Mexico. San Genaro mine in Huancavelica, Peru yielded crystals up to 50 mm (2 in) across. Crystals up to 40 mm (1 9/16 in) across found in Freiberg; smaller crystals only are known from St. Andreasberg, Germany. Crystals up to 20 mm (25/32 in) across come from Pribram and Stara Vozice, Czech Republic. Crystals up to 50 mm (2 in) across found in the San Carlos mine, Hiendelaencina, Spain.
Application: Ag ore.

Xanthoconite

Ag_3AsS_3

MONOCLINIC ● ●

Properties: C – dark crimson, orange-yellow to yellow-brown; S – orange-yellow; L – adamantine; D – translucent; DE – 5,5; H – 2-3; CL – good; F – conchoidal; M – tabular and lath-like crystals, botryoidal and radial aggregates.

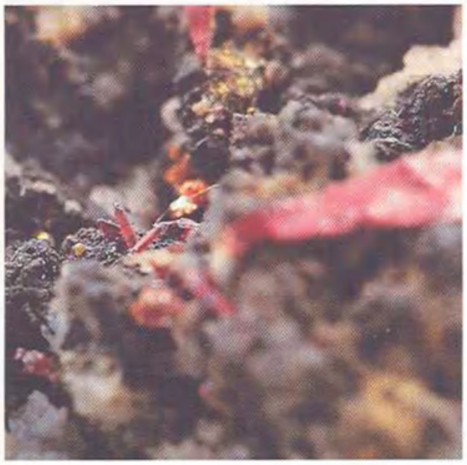

Xanthoconite, 2 mm xx, Marienberg, Germany

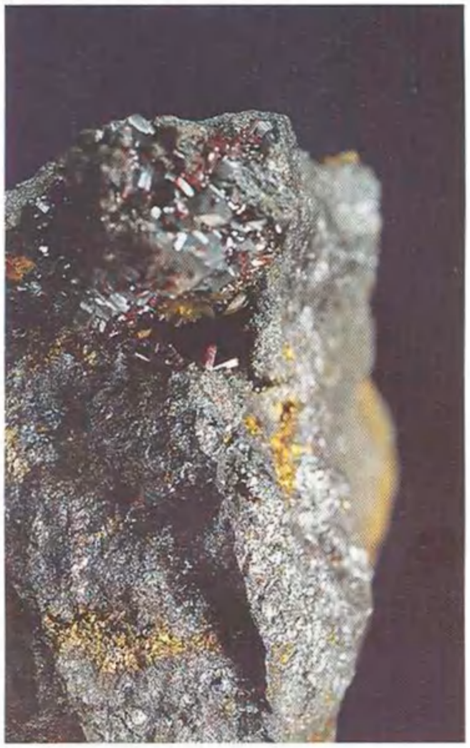

Pyrostilpnite, 60 mm, Potosí, Bolivia

Origin and occurrence: Hydrothermal in ore veins together with proustite, pyrargyrite, acanthite, arsenic and calcite. Botryoidal masses with yellow crystals up to 7mm (9/32 in) long come from Freiberg; other important localities are St Andreasberg, Germany; Ste-Marie-aux- Mines, France; Cobalt, Ontario, Canada; Příbram, Trebsko and Jachymov, Czech Republic.

Pyrostilpnite

Ag_3SbS_3

MONOCLINIC ● ●

Properties: C – hyacinth- to orange-red; S – orange-yellow; L – adamantine; D – translucent; DE – 6,0; H – 2; CLB perfect; F – conchoidal; M – tabular to lath-like crystals, radial aggregates.
Origin and occurrence: Hydrothermal in low-temperature veins, associated with pyrargyrite, stephanite, acanthite and other Ag minerals. The best crystals come from St. Andreasberg, Germany. Crystals up to 10 mm (3/8 in) long were found in Pribram, Trebsko and Jachymov, Czech Republic. It is also described from Colquechaca, Bolivia and Chañarcillo, Chile.

Samsonite

$Ag_4MnSb_2S_6$

MONOCLINIC ●

Properties: C – steel-gray; S – dark red; L – metallic; D – opaque; DE – 5,5; H – 2,5; CL – none; F – conchoidal; M – prismatic striated crystals.
Origin and occurrence: The only locality, where it occurred in relatively larger amount, was the Samson mine in St. Andreasberg, Germany, where crystals up to 10 mm ($^3/_8$ in) across were found.

Samsonite, 12 mm x, St.Andreasberg, Germany

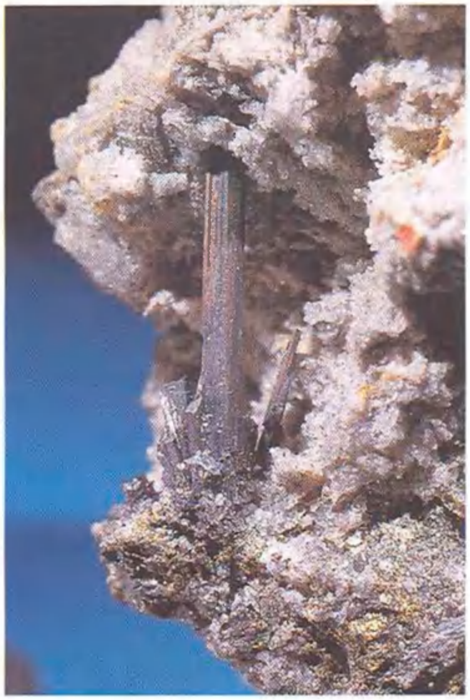

Chalcostibite

$CuSbS_2$

ORTHORHOMBIC ● ●

Properties: C – lead-gray, tarnishing to blue and green; S – lead-gray; L – metallic; D – opaque; DE – 5,0; H – 3-4; CL – perfect; F – conchoidal; M – long prismatic, striated crystals, granular, massive.
Origin and occurrence: Hydrothermal in ore veins, associated with jamesonite, chalcopyrite, tetrahedrite, stibnite, andorite and other minerals. Partly altered crystals up to 100 mm (4 in) long are known from Rar-el-Auz near Casablanca, Morocco. It is often in deposits in Bolivia (Huanchaca, Oruro, Colquechaca), where its crystals reach 10 mm ($^3/_8$ in)

Chalcostibite, 29 mm, Saint Pons, France

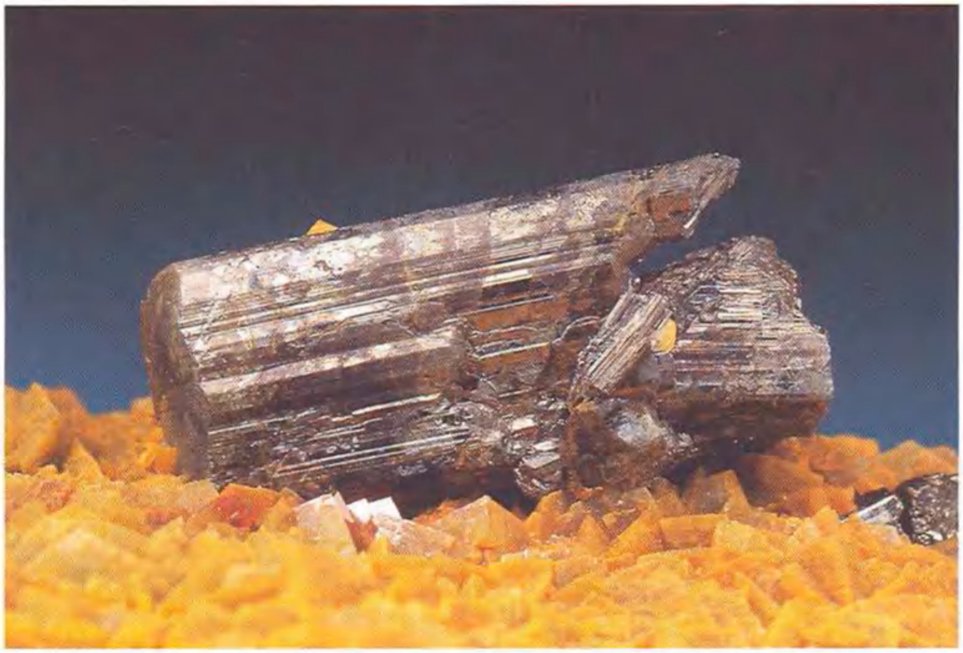

Emplectite, 60 mm, Schwarzenberg, Germany

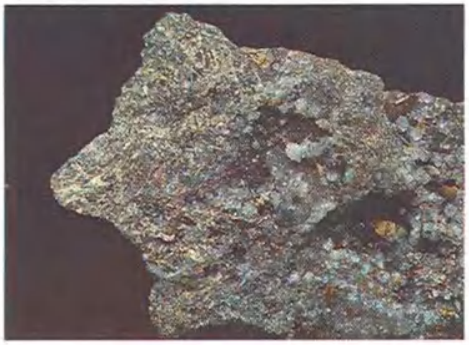

in size. The world's best crystals up to 16 cm ($6^{5}/_{16}$ in) long were discovered recently near St Pons, France.

Emplectite

$CuBiS_2$

ORTHORHOMBIC ● ● ●

Properties: C – gray to tin-white; S – gray; L – metallic; D – opaque; DE – 6,4; H – 2; CL – perfect; F – conchoidal to uneven; M – thin prismatic to acicular striated crystals.
Origin and occurrence: Hydrothermal in high-temperature veins associated with chalcopyrite, molybdenite, quartz, tetrahedrite and other minerals. Fine acicular crystals up to 30 mm ($1^{3}/_{16}$ in) long come from Krupka, Czech Republic. Crystallized specimens were also found in Wittichen and Johanngeorgenstadt, Germany; Colquijirca, Peru and in the Akenobe mine, Japan.

Berthierite, 98 mm, Herja, Romania

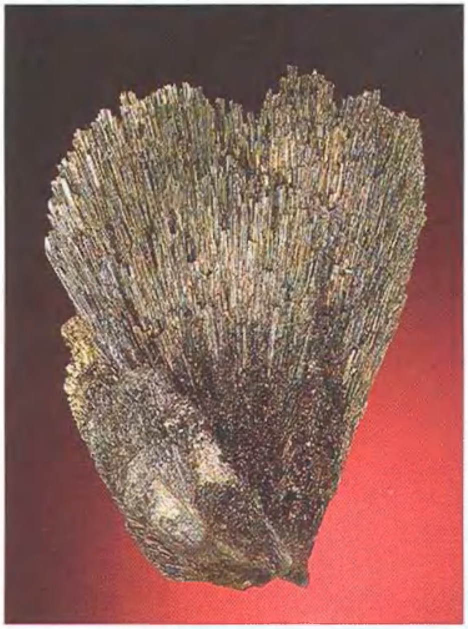

Wittichenite, 50 mm, Wittichen, Germany

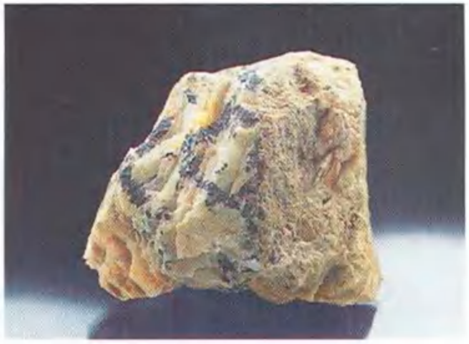

Wittichenite

Cu_3BiS_3

ORTHORHOMBIC ● ●

Properties: C – steel-gray to tin-white, tarnishing yellow to steel-gray; S – black; L – metallic; D – opaque; DE – 6,2; H – 2-3; CL – none; F – conchoidal; M – prismatic crystals, massive.
Origin and occurrence: Hydrothermal in ore veins, associated with other Bi minerals, Cu-Fe sulfides, selenides and secondary U minerals. It occurs in Wittichen, Germany; Baiţa Bihorului, Romania; Tsumeb, Namibia and Cerro de Pasco, Peru.

Berthierite

$FeSb_2S_4$

ORTHORHOMBIC ● ● ●

Properties: C – dark steel-gray, tarnishing iridescent to brown; S – dark brown-gray; L – metallic; D – opaque; DE – 4,7; H – 2-3; CL – imperfect; M – long prismatic, striated crystals, fibrous, felt-like and radial aggregates.
Origin and occurrence: Hydrothermal in low-temperature Sb deposits. Acicular crystals up to 10 mm ($^{3}/_{8}$ in) long are known from the St. Antoni de Padua gallery in Kutna Hora, Czech Republic; thick prismatic crystals come from Poproc, Slovakia. Iridescent columnar aggregates up to 200 mm ($7^{7}/_{8}$ in) long occur in Herja, Romania. Fine specimens are known also from Oruro, Bolivia.

Stephanite, 8 mm xx, Zacatecas, Mexico

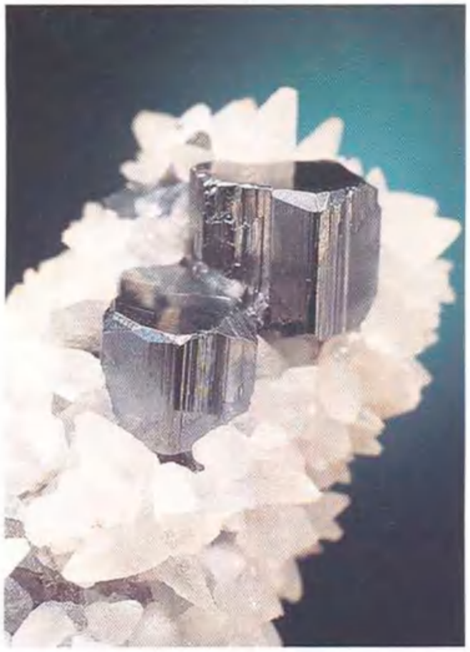

Stephanite

Ag_5SbS_4

ORTHORHOMBIC ● ●

Properties: C – black; S – black; L – metallic; D – opaque; DE – 6,3; H – 2-2,5; CL – imperfect; F – conchoidal; M – short prismatic to tabular striated crystals, massive.
Origin and occurrence: Late hydrothermal mineral in Ag deposits, associated with proustite, acanthite, silver, tetrahedrite, galena, sphalerite and pyrite. Crystals up to 40 mm (1$^{9}/_{16}$ in) long come from Pribram and Jachymov, Czech Republic and from St. Andreasberg, Germany. Crystals up to 50 mm (2 in) across found in the Las Chispas mine, Arizpe, Sonora, Mexico and Hiendelaencina, Spain. Smaller crystals occurred in Freiberg, Schneeberg and Annaberg, Germany. *Application:* Ag ore.

Pearceite

$Ag_{16}As_2S_{11}$

MONOCLINIC ● ●

Properties: C – black; S – black; L – metallic; D – opaque; DE – 6,1; H – 3; CL – none; F – conchoidal to irregular; M – short prismatic to tabular crystals and rosette-like aggregates, massive.
Origin and occurrence: Hydrothermal in low- to medium-temperature deposits with acanthite, silver, proustite, quartz, barite and calcite. Crystals several mm across are known from Jachymov, Moldava and Midinec, Czech Republic; from Arqueros, Chile and from the Veta Rica mine, Coahuila, Mexico. Crystals up to 12 mm ($^{15}/_{32}$ in) across were found in the Caribou mine, Colorado, USA; also in Dzhezkazgan, Kazakhstan.
Huge accumulations of almost pure pearceite occurred in the Mollie Gibson mine near Aspen, Colorado, USA.
Application: Ag ore.

Polybasite

$(Ag,Cu)_{16}Sb_2S_{11}$

MONOCLINIC ● ●

Properties: C – black; S – black; L – metallic; D Bopaque; DE – 6,4; H – 2-3; CL – imperfect; F – uneven; M – pseudo-hexagonal tabular crystals, massive.
Origin and occurrence: Hydrothermal in low- to medium-temperature ore veins, associated with

Pearceite, 15 mm xx, Guanajuato, Mexico

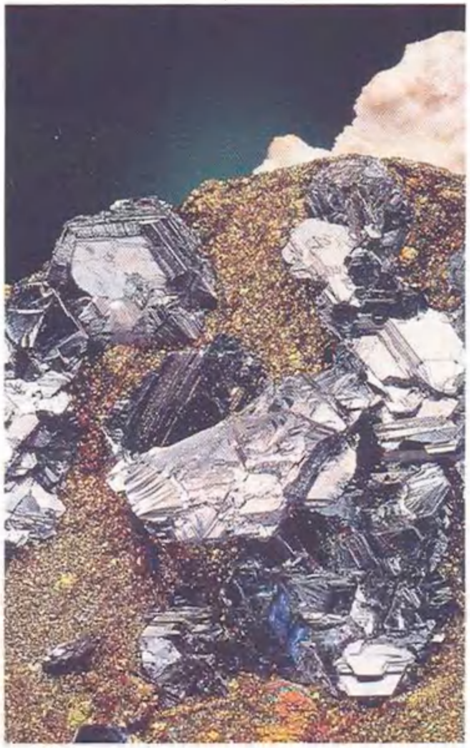

Polybasite, 39 mm, Zacatecas, Mexico

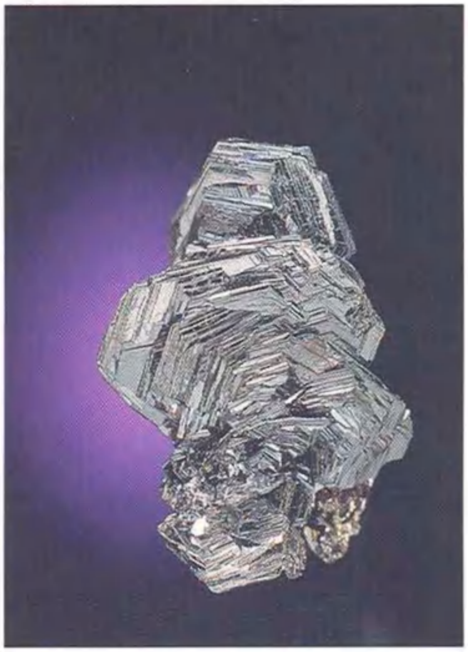

pyrargyrite, tetrahedrite, stephanite, acanthite, quartz and other minerals. Crystals, several cm across, are known from Wolfach, St. Andreasberg, Freiberg and Schneeberg, Germany; also from Guanajuato, Mexico. The best specimens with tabular crystals up to 90 mm ($3\frac{9}{16}$ in) across come from the Las Chispas mine, Arizpe, Sonora, Mexico.
Application: Ag ore.

Lorandite, 10 mm x, Allchar, Macedonia

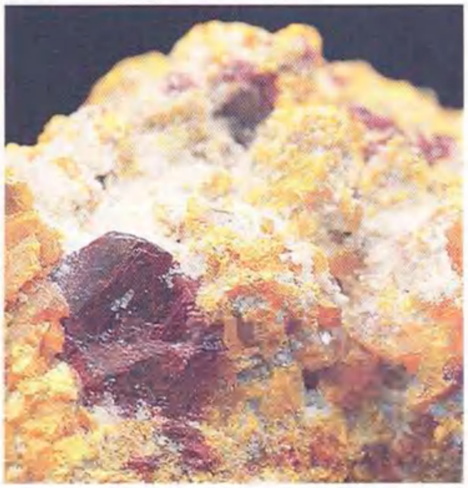

Lorandite

$TlAsS_2$

MONOCLINIC ● ●

Properties: C – crimson, lead-gray, it covers with a yellow coating; S – cherry-red; L – metallic to adamantine; D – translucent to transparent; DE – 5,5; H – 2-2,5; CL – perfect; M – short prismatic to tabular crystals, granular, massive.
Origin and occurrence: Hydrothermal, associated with stibnite, realgar, orpiment, pyrite and other minerals. Crystals up to 50 mm (2 in) across were found in Allchar, Macedonia. It is also known from Djijikrut, Tajikistan and from the cavities in dolomite from Lengenbach, Binntal, Switzerland.

Livingstonite

$HgSb_4S_8$

MONOCLINIC ● ●

Properties: C – black-gray; S – red; L – metallic to adamantine; D – opaque; DE – 5,0; H – 2; CL – perfect; M – acicular crystals, columnar and fibrous aggregates, massive.
Origin and occurrence: Hydrothermal in low-temperature veins, associated with cinnabar, stibnite, getchellite and other minerals. The best specimens with prismatic crystals up to 50 mm (2 in) long are known from Khaidarkan, smaller crystals only found from Kadamdzhai, Kyrgyzstan. It is also described from the La Cruz mine, Huitzuco, Guerrero, Mexico and from the Matsuo mine, Japan.

Livingstonite, 40 mm, Khaidarkan, Kyrgystan

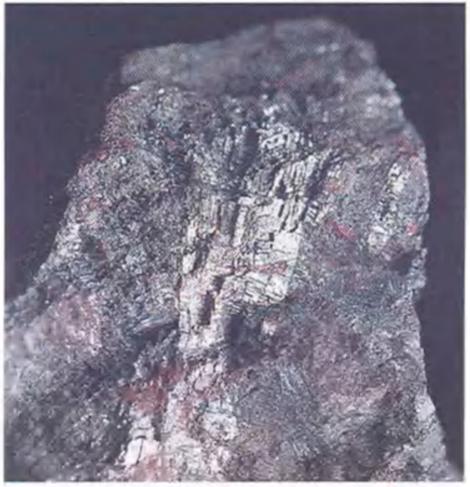

Bournonite, 62 mm, Cornwall, UK

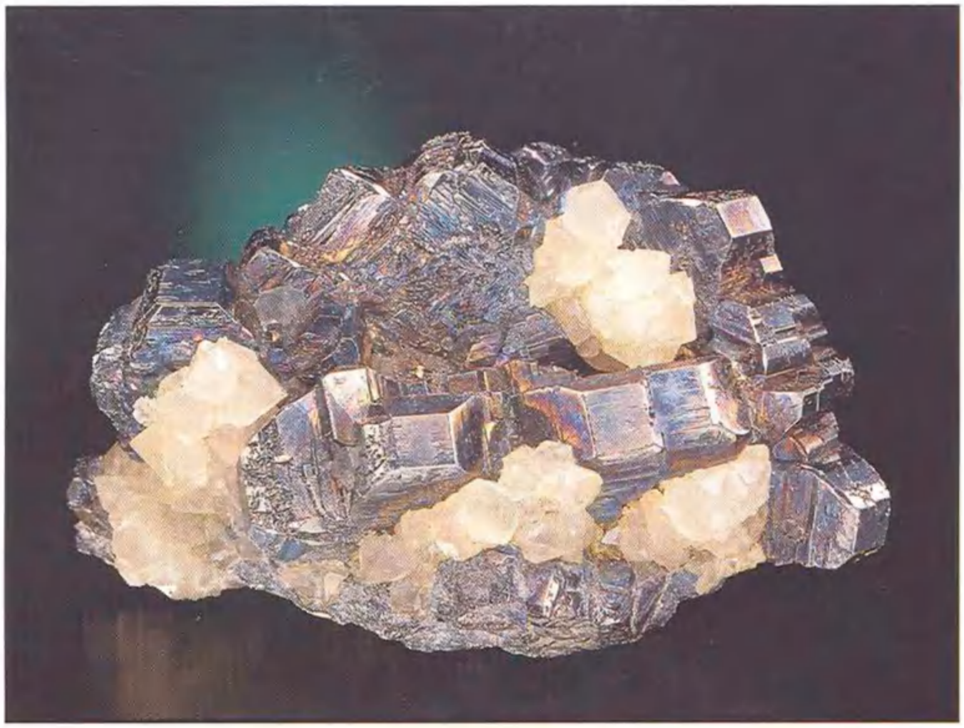

Bournonite

$PbCuSbS_3$

ORTHORHOMBIC ● ● ● ●

Properties: C – steel-gray to black; S – steel-gray to black; L – adamantine to dull; D – opaque; DE – 5,8; H – 2,5-3; CL – imperfect; F – conchoidal to uneven; M – short prismatic to tabular crystals, often striated, granular, massive.

Origin and occurrence: Hydrothermal in medium-temperature ore deposits, together with galena, tetrahedrite, pyrite, siderite and other minerals. The finest crystals, complex twins called cogswheel ore, over 50 mm (2 in) across come from the Herodsfoot mine near Liskeard, Cornwall, UK. Tabular crystals up to 40 mm (1 9/16 in) across found in siderite cavities in Příbram, Czech Republic; large prismatic and tabular crystals known from Neudorf, Germany. Smaller crystals common in Cavnic and Baia Sprie, Romania. Crystals, up to 100 mm (4 in) across, occurred in Machacamarca, Bolivia. Crystals up to 40 mm (1 9/16 in) come from Huancavelica, Peru. Crystals up to 100 mm (4 in) across reported from the Les Malines mine, France. Crystals up to 20 mm (25/32 in) across found at Chenzhou, Hunan province, China. *Application:* Pb, Cu and Sb ore.

Aikinite

$PbCuBiS_3$

ORTHORHOMBIC ● ●

Properties: C – black-gray, tarnishing brown; S – gray-black; L – metallic; D – opaque; DE – 7,3; H –

Aikinite, 2 mm xx, Rudňany, Slovakia

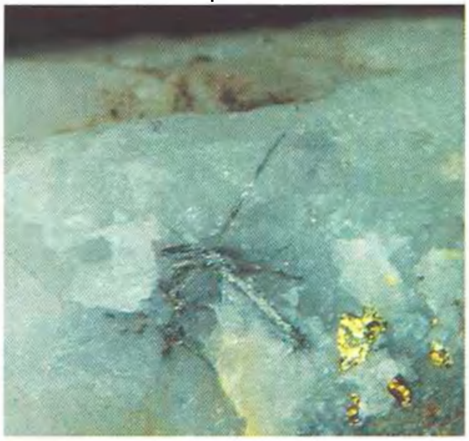

Betekhtinite, 10 mm xx, Dzhezkazgan, Kazakhstan

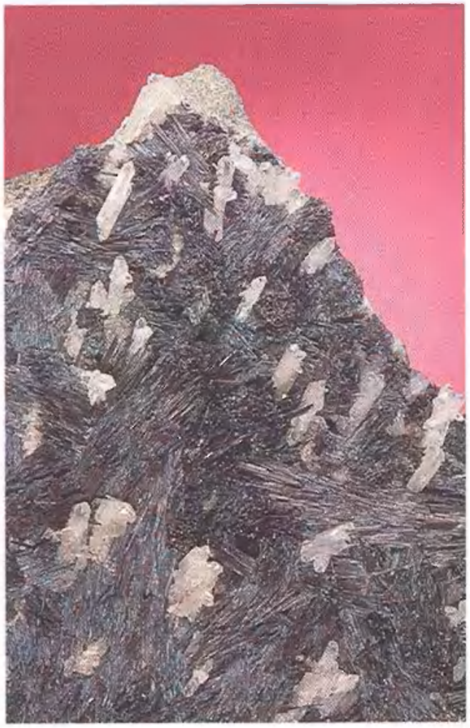

2-2,5; CL – imperfect; F – uneven; M – prismatic to acicular, striated crystals, massive.
Origin and occurrence: Hydrothermal in ore veins, associated with gold, pyrite, galena, tennantite and other minerals. It is common in quartz veins with gold in Berezovsk, Ural Mountains, Russia, where crystals up to 30 mm ($1\frac{3}{16}$ in) long were found; fine crystals come also from La Gardette, Bourg d'Oisans, France. Grains up to 50 mm (2 in) across occurred in the Outlaw mine, Nevada, USA. It is also known in metamorphic veins in Val d'Anniviers, Switzerland.

Betekhtinite

$Cu_{10}(Fe,Pb)S_6$

ORTHORHOMBIC ● ●

Properties: C – black; S – black; L – metallic; D – opaque; DE – 6,1; H – 3-3,5; CL – good; M – acicular crystals, granular.
Origin and occurrence: Hydrothermal in ore deposits. The best specimens come from Dzhezkazgan as clusters of acicular crystals up to 70 mm (2¾ in) long, associated with bornite, chalcocite, djurleite and other minerals. Rich specimens found in Kipushi Kipushi, Shaba, Zaire. Granular aggregates fairly common in calcite veinlets, cross-cutting Cu-bearing shales near Eisleben, Mansfeld, Germany.

Andorite

$PbAgSb_3S_6$

ORTHORHOMBIC ● ●

Properties: C – dark steel-gray, tarnishing to yellow and iridescent; S – black; L – metallic; D – opaque; DE – 5,4; H – 3-3,5; CL – none; F – conchoidal; M – prismatic and tabular striated crystals, massive.
Origin and occurrence: Hydrothermal in ore deposits, together with cassiterite, jamesonite, stannite and other minerals. The world's best specimens come from the Itos and San Jose mines in Oruro and the Tatasi mine in Potosí, Bolivia, where it forms crystals up to 30 mm ($1\frac{3}{16}$ in) across. Thin tabular crystals are known from Baia Spric, Romania and from the Keyser mine, Nevada, USA. Needles up to 10 mm ($\frac{3}{8}$ in) long occurred in Trebsko, Czech Republic.
Application: ruda Ag.

Andorite, 45 mm, Oruro, Bolivia

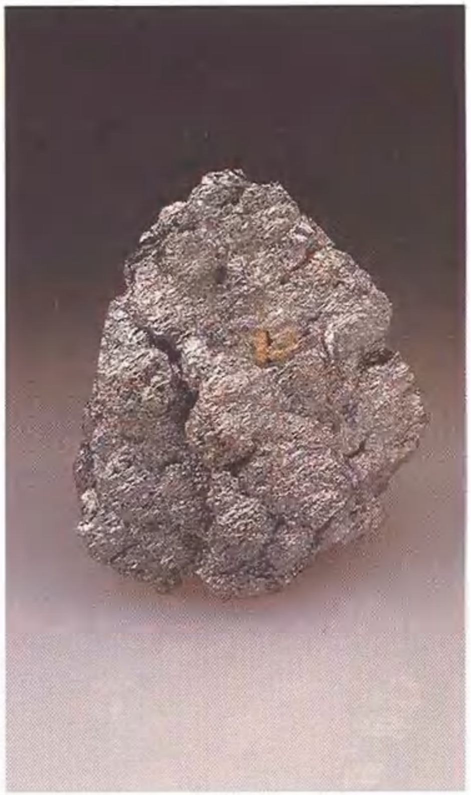

Freieslebenite, 2 mm xx, Baia Sprie, Romania

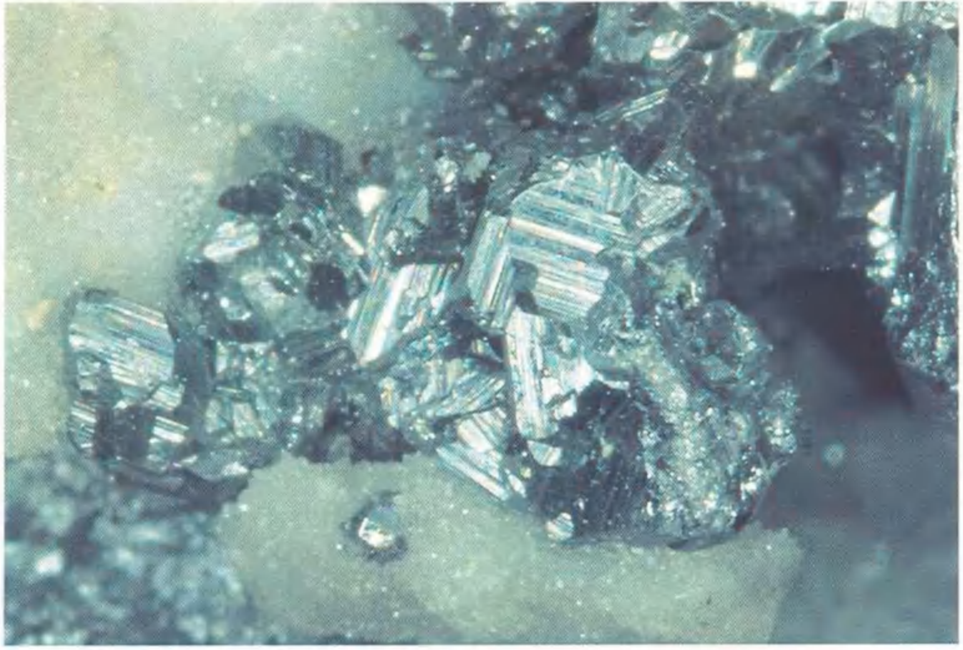

Freieslebenite

$AgPbSbS_3$

MONOCLINIC ● ●

Properties: C – light steel-gray, lead-gray to silver-white; S – light steel-gray, lead-gray to silver-white; L – metallic; D – opaque; DE – 6,2; H – 2-2,5; CL – imperfect; F – conchoidal to uneven; M – prismatic, striated crystals.

Origin and occurrence: Hydrothermal in ore deposits, associated with acanthite, pyrargyrite, silver, galena, siderite and andorite.

Crystals up to 20 mm ($^{25}/_{32}$ in) across come from the Santa Cecilia, Guadalajara, Spain; Freiberg, Germany; Oruro, Bolivia and from the Treasury Lode, Colorado, USA.

Diaphorite

$Pb_2Ag_3Sb_3S_3$

MONOCLINIC ● ●

Properties: C – steel-gray; S – steel-gray; L – metallic; D – opaque; DE – 6,0; H – 2,5-3; CL – none; F – conchoidal to uneven; M – prismatic striated crystals.

Origin and occurrence: Hydrothermal in medium-temperature ore veins, associated with galena,

Diaphorite, 5 mm xx, Pribram, Czech Republic

Sartorite, 4 mm x, Binntal, Switzerland

sphalerite, pyrargyrite, pyrite and other minerals. Beautiful striated crystals up to 10 mm ($^{3}/_{8}$ in) come from the cavities of quartz veins in Pøíbram; rare small crystals, several mm across found in the cavities of quartz veins in the St. Antoni de Padua gallery in Kutna Hora, Czech Republic. Complicated combinations of crystals were described from Bräunsdorf, Germany. Crystals up to 80 mm (3$^{1}/_{8}$ in) long occurred in Hiendelaencina, Guadalajara, Spain. It is also reported from Catorce, San Luis Potosí, Mexico.

Sartorite

$PbAs_2S_4$

MONOCLINIC ● ●

Properties: C – dark lead-gray; S – chocolate-brown; L – metallic; D – opaque; DE – 5,1; H – 3; CL – good; F – conchoidal; M – prismatic striated crystals.
Origin and occurrence: Hydrothermal in dolomite, associated with tennantite, dufrenoysite, pyrite and realgar. The best crystals up to 100 mm (4 in) long come from Lengenbach, Binntal, Switzerland. It was also found in the Zuni mine, Colorado, USA.

Baumhauerite

$Pb_3As_4S_9$

TRICLINIC ●

Properties: C – lead- to steel-gray, tarnishing iridescent; S – chocolate-brown; L – metallic; D – opaque; DE – 5,4; H – 3; CL – perfect; F – conchoidal; M – tabular to short prismatic striated crystals, granular.
Origin and occurrence: Hydrothermal, associated with realgar and other sulfosalts. The best crystals up to 25 mm (1 in) across come from Lengenbach, Binntal, Switzerland. Massive aggregates were found in Hemlo, Thunder Bay, Ontario, Canada and Sterling Hill, New Jersey, USA.

Baumhauerite, 50 mm, Binntal, Switzerland

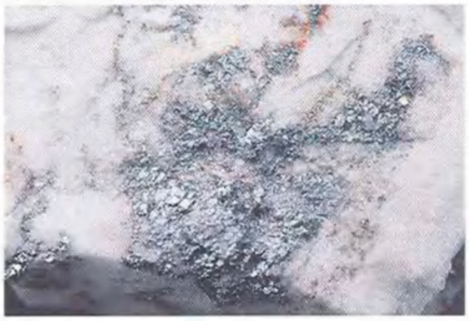

Rathite, 60 mm, Binntal, Switzerland

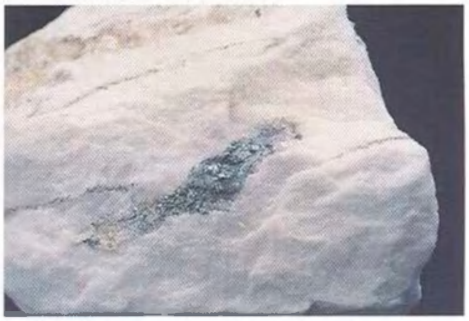

Rathite

$(Pb,Tl)_3As_5S_{10}$

MONOCLINIC ●

Properties: C – lead-gray, tarnishing iridescent; S – chocolate-brown; L – metallic; D – opaque; DE – 5,3; H – 3; CL – perfect; F – conchoidal; M – prismatic striated crystals.
Origin and occurrence: Hydrothermal, associated with other Pb-Tl-As-S minerals. Crystals up to 10 mm ($^{3}/_{8}$ in) across come from dolomite in Lengenbach, Binntal, Switzerland.

Dufrenoysite

$Pb_2As_2S_5$

MONOCLINIC ● ●

Properties: : C – lead- to steel-gray; S – red-brown to chocolate-brown; L – metallic; D – opaque; DE – 5,6; H – 3; CL – perfect; F – conchoidal; M – elongated striated tabular crystals.
Origin and occurrence: Hydrothermal low-temperature mineral, associated with rathite, sartorite, baumhauerite and realgar. Crystals up to 25 mm (1 in) across come from dolomite in Lengenbach, Binntal, Switzerland. Also found in Batopilas, Chihuahua, Mexico.

Dufrenoysite, 10 mm x, Binntal, Switzerland

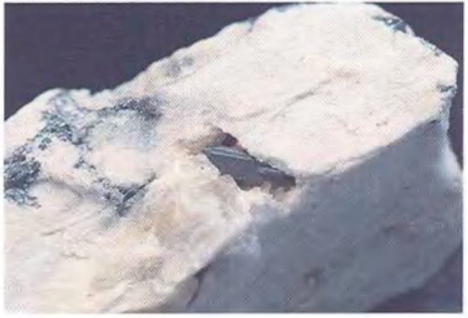

Jordanite, 12 mm x, Binntal, Switzerland

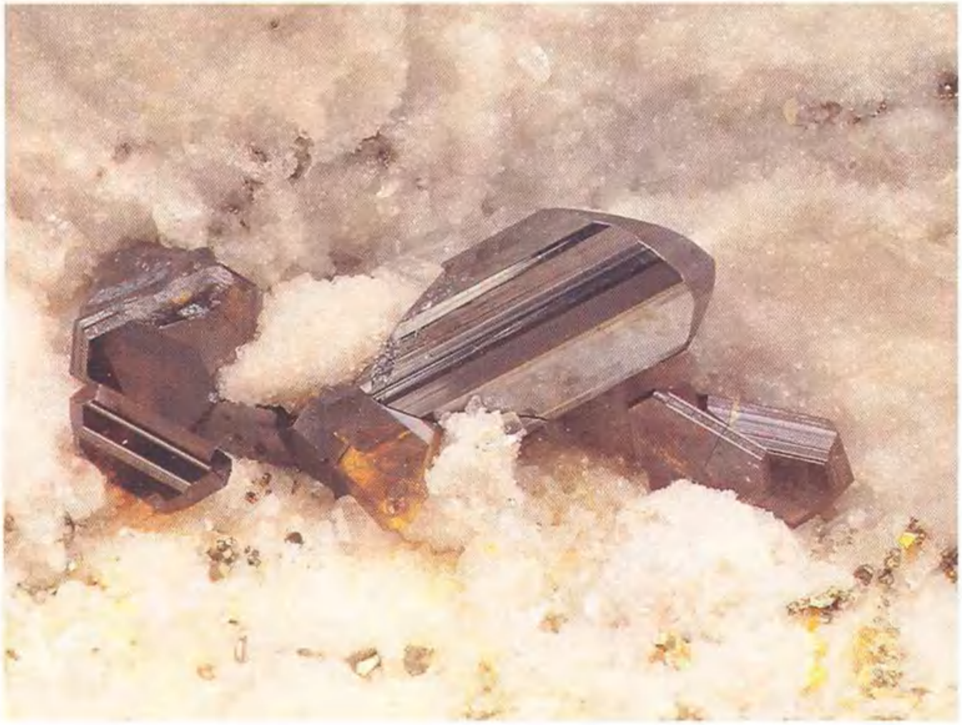

Jordanite

$Pb_{14}(As,Sb)_6S_{23}$

MONOCLINIC ● ●

Properties: C – lead-gray, tarnishing iridescent; S – black; L – metallic; D – opaque; DE – 6,4; H – 3; CL – perfect; F – conchoidal; M – tabular crystals, botryoidal aggregates.

Geocronite, 70 mm, Pribram, Czech Republic

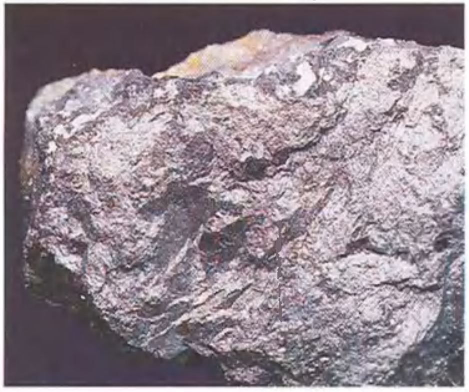

Origin and occurrence: Hydrothermal in low-temperature ore veins, also in metamorphic dolomites, together with tennantite, sphalerite, galena, dolomite and other minerals. The most famous crystals up to 50 mm (2 in) across come from cavities in dolomite in Lengenbach, Binntal, Switzerland. Tabular crystals occurred also in Sacarîmb , Romania. Botryoidal aggregates, growing on barite crystals, were described from the Yunosawa mine, Japan.

Geocronite

$Pb_{14}(Sb,As)_6S_{23}$

MONOCLINIC ● ●

Properties: C – light lead-gray; S – light lead-gray to gray-blue; L – metallic; D – opaque; DE – 6,4; H – 2,5; CL – good; F – uneven; M – tabular crystals, massive. *Origin and occurrence:* Hydrothermal in ore veins, associated with galena, pyrite, tetrahedrite, barite, fluorite and quartz. Crystals, up to 80 mm ($3\frac{1}{8}$ in) across, come from Pietrasanta, Italy. Crystals up to 90 mm ($3\frac{9}{16}$ in) found in Virgem da Lapa, Brazil. Tabular crystals up to 40 mm ($1\frac{9}{16}$ in) across occurred in the Kilbricken mine, Ireland. Massive aggregates are known from Příbram, Czech Republic.

Zinkenite

$Pb_9Sb_{22}S_{42}$

HEXAGONAL ● ● ●

Properties: C – steel-gray, tarnishing iridescent; S – steel-gray; L – metallic; D – opaque; DE – 5,3; H – 3-3,5; CL – imperfect; F – uneven; M – thin prismatic striated crystals, radial to felt-like aggregates, massive.
Origin and occurrence: Hydrothermal in ore veins, associated with stibnite, jamesonite, boulangerite, bournonite, stannite and other minerals. Crystals up to 50 mm (2 in) across are known from the Itos and San Jose mines in Oruro, Bolivia. It was also found in Wolfsberg, Germany; St. Pons, France; Sacarîmb and Baia Sprie, Romania.

Jamesonite

$Pb_4FeSb_6S_{14}$

MONOCLINIC ● ● ● ●

Properties: C – gray-black, tarnishing iridescent; S – gray-black; L – metallic; D – opaque; DE – 5,8; H – 2,5; CL – good; F – uneven; M – acicular crystals, fibrous and felt-like aggregates, massive.

Zinkenite, 39 mm, Oruro, Bolivia

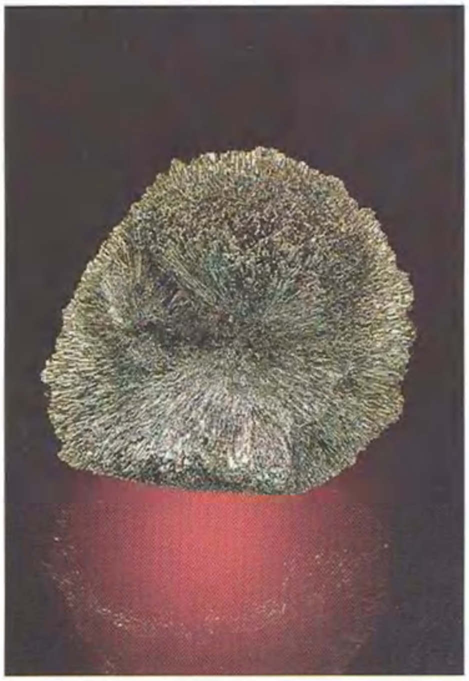

Jamesonite, 30 mm xx, Sombrerete, Mexico

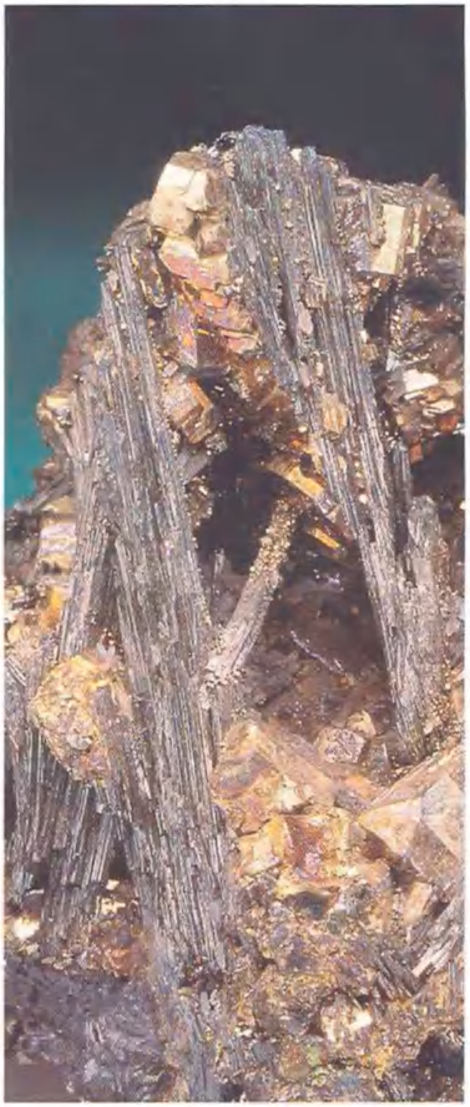

Origin and occurrence: Hydrothermal in medium- and low-temperature base metal ore veins, associated with other Pb-sulfosalts, pyrite, sphalerite, galena, tetrahedrite, quartz and other minerals. Needles up to 80 mm (3⅛ in) long occur in many localities in Bolivia (Tasna; Bolivia mine, Poopo; San Jose and Itos mines, Oruro). It also comes from Wolfsberg and Freiberg, Germany; Nižna Slaná . Slovakia and Sombrerete, Zacatecas, Mexico.
Application: Pb and Sb ore.

Semseyite

$Pb_9Sb_8S_{21}$

MONOCLINIC ● ●

Properties: C – gray to black; S – black; L – metallic; D – opaque; DE – 6,1; H – 2,5; CL – perfect; M – tabular and prismatic crystals and their rosette-like aggregates.

Origin and occurrence: Hydrothermal in medium-temperature veins, associated with jamesonite, bournonite, zinkenite, sphalerite and other minerals. Fine rosette-like aggregates of crystals over 10 mm (3/8 in) across come from Baia Sprie, Herja and Rodna, Romania. It was also found in the San Jose mine, Oruro, Bolivia; Wolfsberg, Germany and Huancavelica, Peru.

Boulangerite

$Pb_5Sb_4S_{11}$

MONOCLINIC ● ● ● ●

Properties: C – lead-gray; S – brownish; L – metallic to silky; D – opaque; DE – 6,2; H – 2,5-3; CL – good; M – acicular striated crystals, fibrous and felt-like aggregates.

Origin and occurrence: Hydrothermal in low- and medium-temperature ore veins, together with other Pb sulfosalts, galena, sphalerite and other minerals. Fine needles over 100 mm (4 in) long come from cavities in quartz in Příbram, Czech Republic. It is common in the Coeur d'Alene district, Idaho, USA. Acicular crystals up to 30 cm (12 in) long were found in Trepca, Serbia and Leadville, Colorado, USA. It is also known from Wolfsberg, Germany and Bolivia (Colquechaca, Huanuni, Isca-Isca).

Cosalite

$Pb_2Bi_2S_5$

ORTHORHOMBIC ● ● ●

Properties: C – lead- to steel-gray, silver-white; S – black; L – metallic; D – opaque; DE – 7,1; H – 2,5-3; CL – none; F – uneven; M – prismatic to acicular crystals, radial and fibrous aggregates.

Origin and occurrence: Magmatic in pegmatites, hydrothermal in medium-temperature deposits; also metamorphic, associated with sphalerite, chalco-

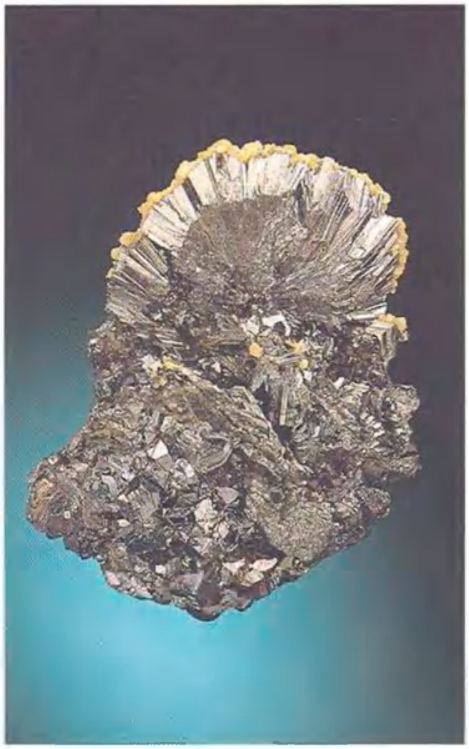

Semseyite, 40 mm, Cavnic, Romania

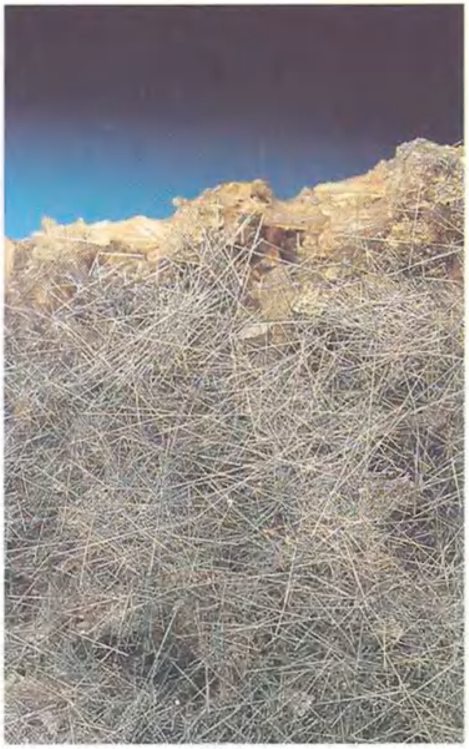

Boulangerite, 40 mm, Zacatecas, Mexico

Cosalite, 3 mm xx, Ocna de Fier, Romania

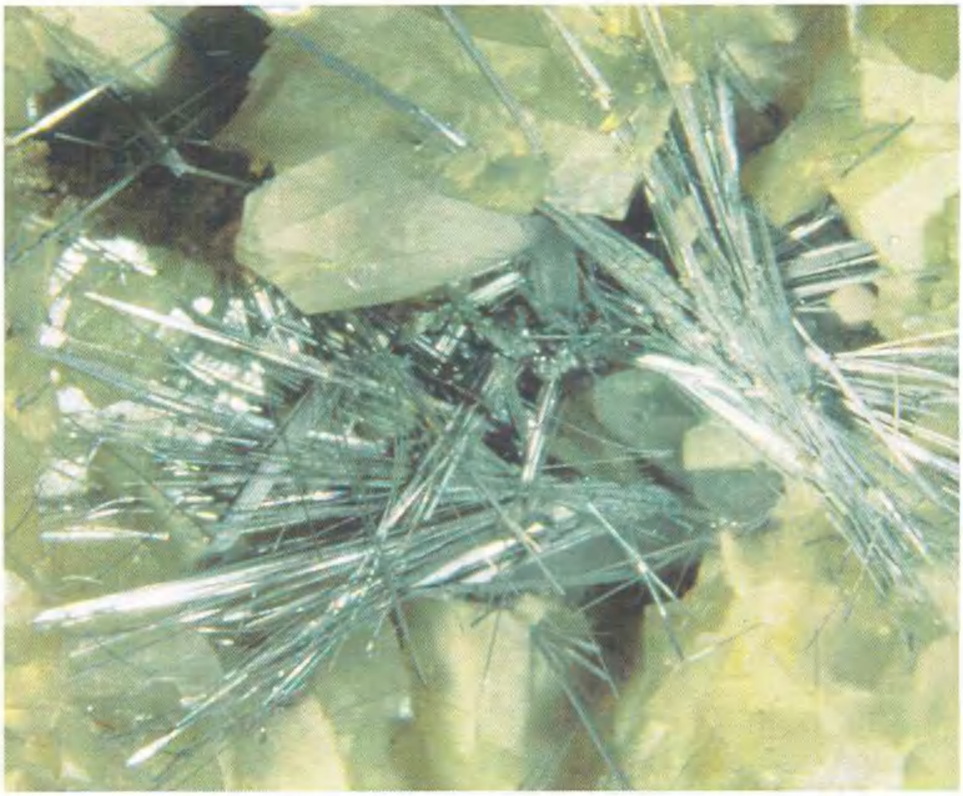

pyrite, pyrite, cobaltite and other minerals. Elongated crystals are known from Crodo, Italy. Fine needles up to 40 mm (1$^{9}/_{16}$ in) long, included in quartz crystals, were found in Kara-Oba, Kazakhstan. It occurs also in Au deposits (Homestake mine, South Dakota, USA) or in skarns (Baiţa Bihorului, Romania).

Kobellite

$Pb_{22}Cu_4(Bi,Sb)_{30}S_{69}$

ORTHORHOMBIC ● ● ●

Properties: C – black-gray to steel-gray; S – black; L – metallic; D – opaque; DE - 6,5; H - 2,5-3; CL – good; M – fibrous aggregates, granular, massive.

Origin and occurrence: Hydrothermal in high-temperature veins and pegmatites, together with cobaltite, arsenopyrite, chalcopyrite and other minerals. It is known from a sulfide rich pegmatite in the Superior Stone quarry, North Carolina, USA. Massive aggregates are common in Jedl'ovec , Slovakia. It was originally described from the Hvena mine near Åskersund, Sweden.

Kobellite, 20 mm xx, Rozňava, Slovakia

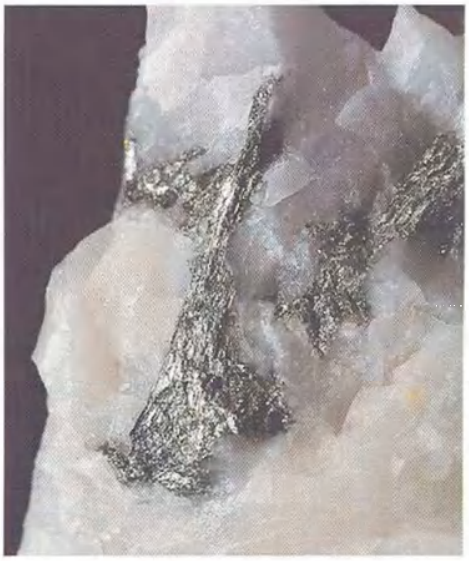

Realgar, 64 mm, Shimen, China

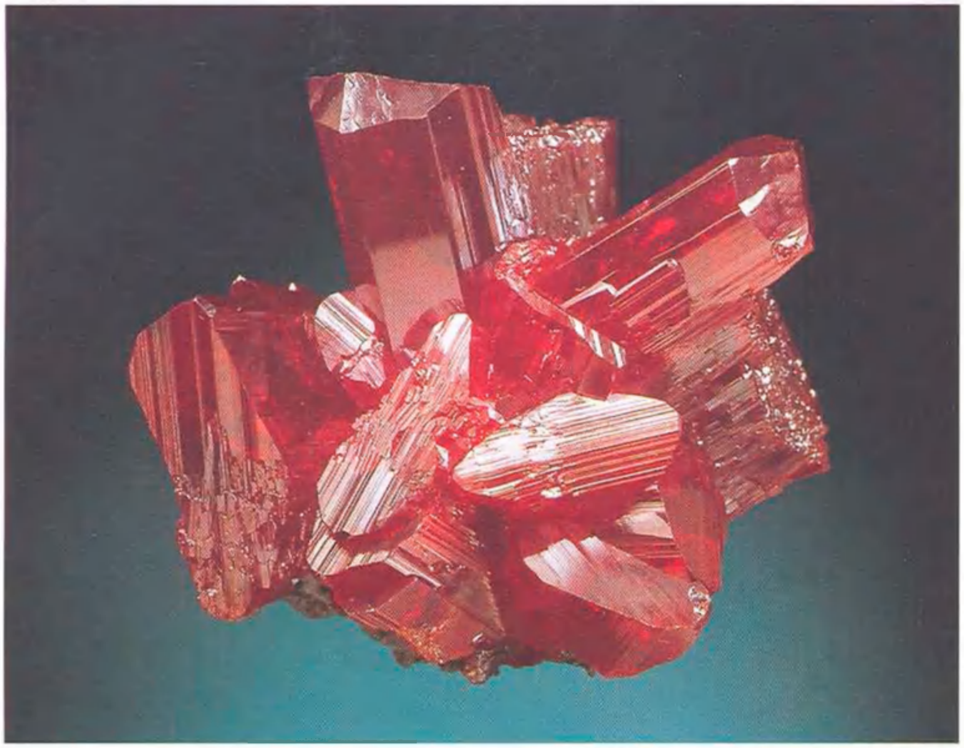

Realgar

AsS

MONOCLINIC ● ● ● ●

Properties: C – red to orange-yellow; S – orange-red to red; L – resinous to greasy; D – transparent to translucent; DE – 3,6; H – 1.5-2; CL – good; F – conchoidal; M – prismatic striated crystals, granular, massive.

Origin and occurrence: Hydrothermal in low-temperature veins, associated with other As-Sb minerals; also as a sublimation product of volcanic gasses, in hot springs and sediments. The most beautiful crystals over 100 mm (4 in) long come from Shimen, Hunan, China. Crystals up to 70 mm (2¼ in) long occurred in the Getchell mine, Nevada, USA. Crystals up to 80 mm (3⅛ in) long were found in Lengenbach, Binntal, Switzerland. Crystals are also known from Baia Sprie, Romania. Massive aggregates are common in Allchar, Macedonia.

Orpiment, 40 mm, Baia Sprie, Romania

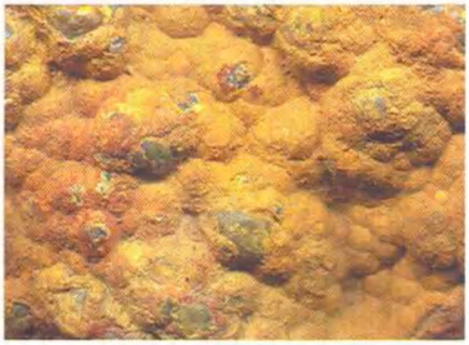

Orpiment

As_2S_3

MONOCLINIC ● ● ● ●

Properties: C – lemon-yellow to bronze-yellow; S – light lemon-yellow; L – resinous to pearly; D – transparent to translucent; DE – 3,5; H – 1,5-2; CL – perfect; M – prismatic crystals, foliated and fibrous aggregates. *Origin and occurrence:* Hydrothermal in low-temperature veins, together with realgar, stibnite, calcite etc., also from hot springs and fumaroles. It is also a common product of realgar oxidation. The best crystals up to 100 mm (4 in) long come from Shimen, Hunan, China. Fine cleavable lamellae occur in Lukhumi, Georgia and Men-Kyule, Yakutia, Russia. Crystals up to 50 mm (2 in) across found in the La Libertad mine, Quiruvilca and Huayllapon. Ancash, Peru. Crystals up to 80 mm ($3\frac{1}{8}$ in) long described from the Getchell mine, Nevada, USA.. Fine specimens are also known from Allchar. Macedonia and Khaidarkan. Kyrgyzstan. *Application:* As ore, pigment.

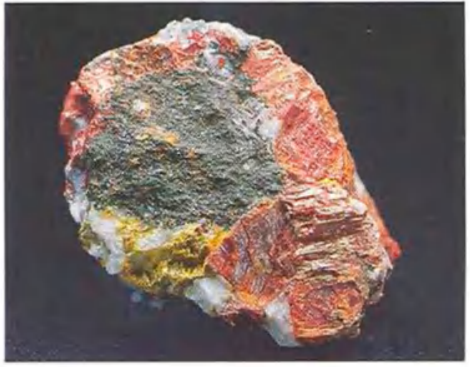

Getchellite, 60 mm, Khaidarkan, Kyrgystan

Getchellite

$AsSbS_3$

MONOCLINIC ● ●

Properties: C – dark red, tarnishing green and iridescent; S – orange-red; L – pearly to glassy, resinous; D – transparent; DE – 4,0; H – 1,5-2; CL – perfect; F – splintery; M – imperfect curved crystals, massive. *Origin and occurrence:* Hydrothermal in low-temperature ore deposits, associated with orpiment, realgar, stibnite, cinnabar and other minerals. It was described from the Getchell mine, Nevada, USA. Beautiful specimens with grains up to several cm across come from Khaidarkan, Kyrgyzstan. It is also known from Zarehshuran. Kurdistan, Iran.

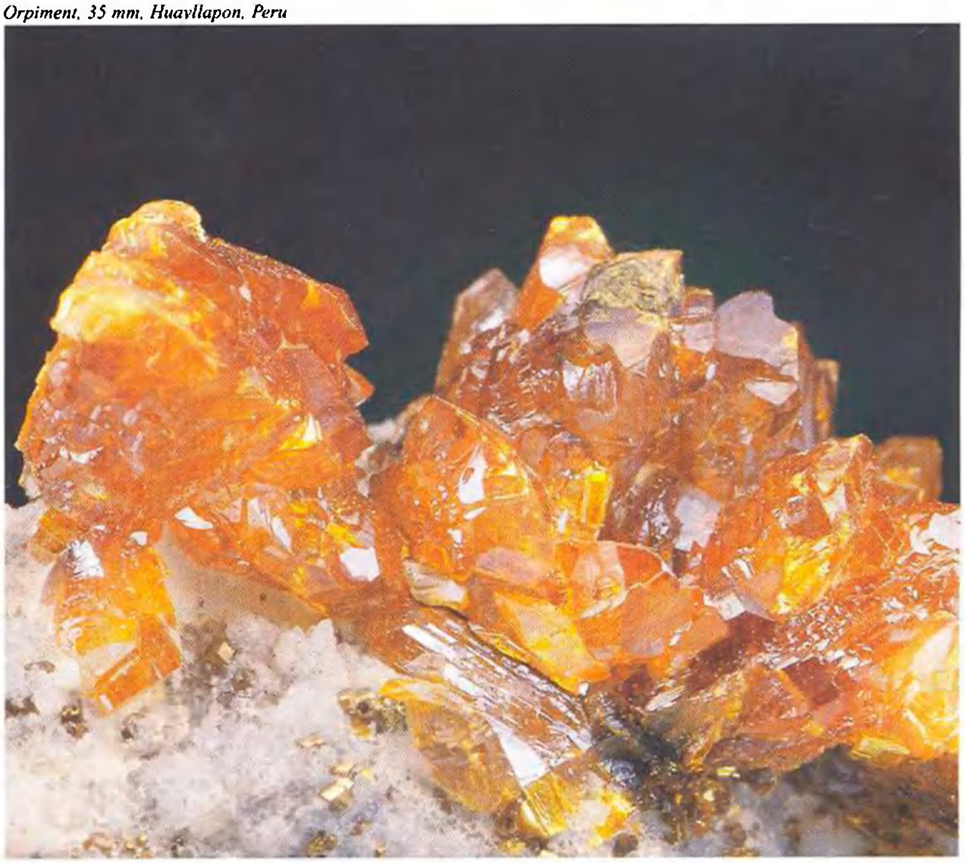

Orpiment, 35 mm, Huayllapon, Peru

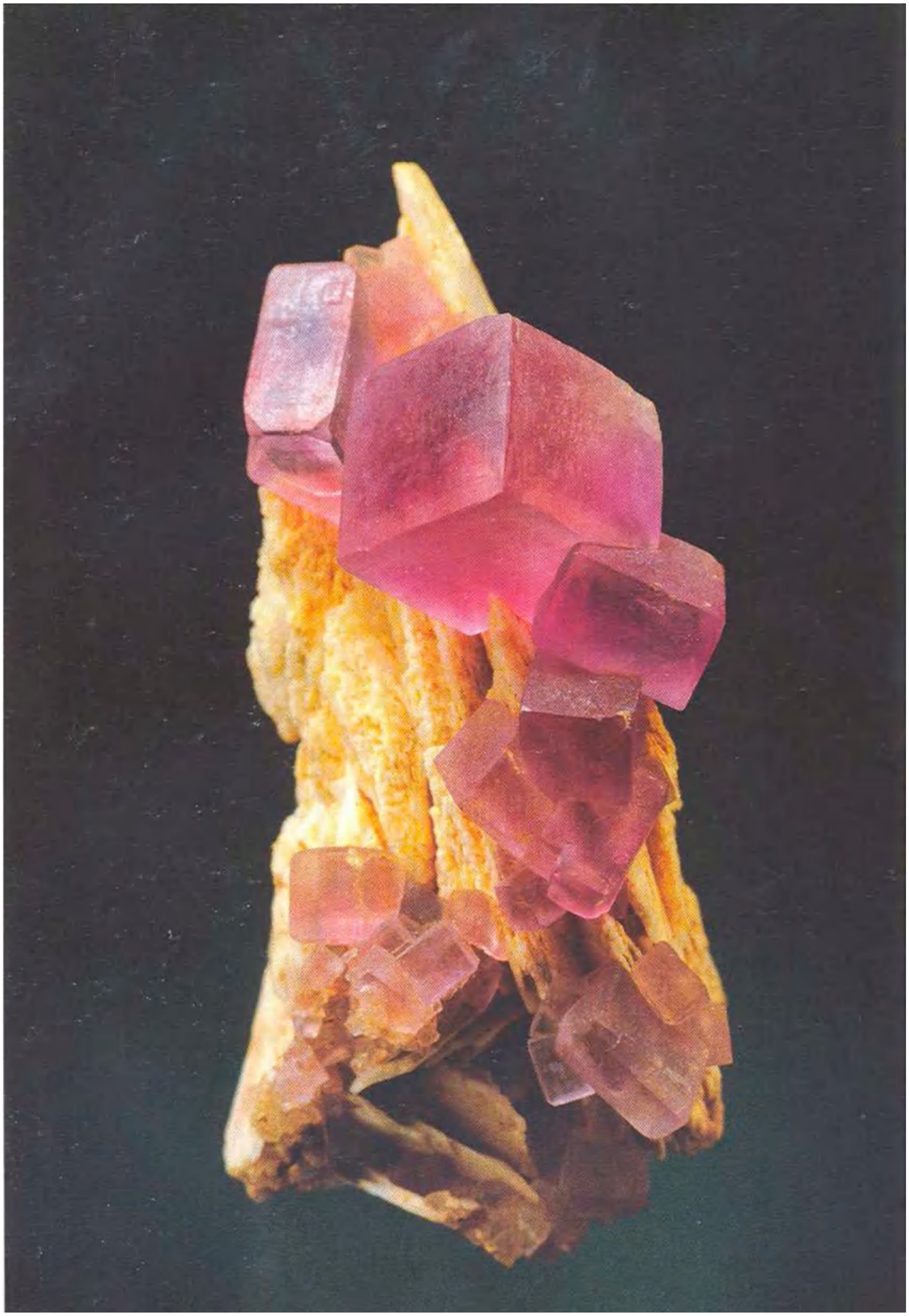

3. Halides

Fluellite

$Al_2(PO_4)F_2(OH) . 7 H_2O$

ORTHORHOMBIC ● ●

Properties: C – colorless, white, yellow; S – white; L – vitreous; D – transparent; DE – 2.2; H – 3; CL – imperfect; M – dipyramidal crystals.
Origin and occurrence: Hydrothermal in greisens, also secondary as a result of triplite alteration. Crystal druses over 10 mm (3/8 in) in size come from Horní Slavkov, Czech Republic. Very similar specimens were found in Stenna Gwyn near St. Austell, Cornwall, UK. Also found in pegmatites in Kynzvart, Czech Republic and in Hagendorf, Germany as a product of triplite alteration.

Cryolite

Na_3AlF_6

MONOCLINIC ● ● ●

Properties: C – colorless, white, purple, brownish; S – white; L – greasy to pearly; D – transparent to translucent; DE – 3; H – 2.5; CL – none; F – uneven; M – pseudo-cubic crystals, massive.

Fluellite, 10 mm x, Horni Slavkov, Czech Republic

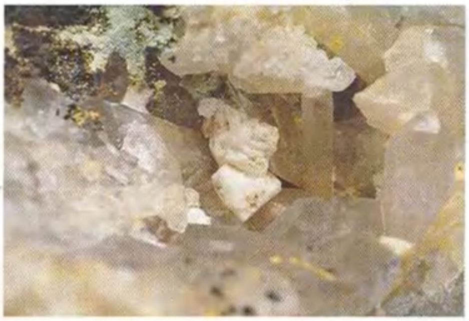

Origin and occurrence: Characteristic mineral of the cryolite pegmatites. Crystals up to 30 mm (1 3/16 in) in size were found in Ivigtut, Greenland, where it was mined as the Al ore for more than 100 years. It was associated with other aluminofluorides, sphalerite, cassiterite, ferrocolumbite and other minerals. It is also known from the Francon quarry in Montreal, Quebec, Canada in crystals up to 10 mm (3/8 in) across. Massive cryolite occurs in Miass, Ural Mountains, Russia and in St. Peter's Dome, Pikes Peak batholith, Colorado, USA.
Application: it was an important Al ore.

Fluorite, 67 mm, Berbes, Spain
Cryolite, 35 mm, Ivigtut, Greenland

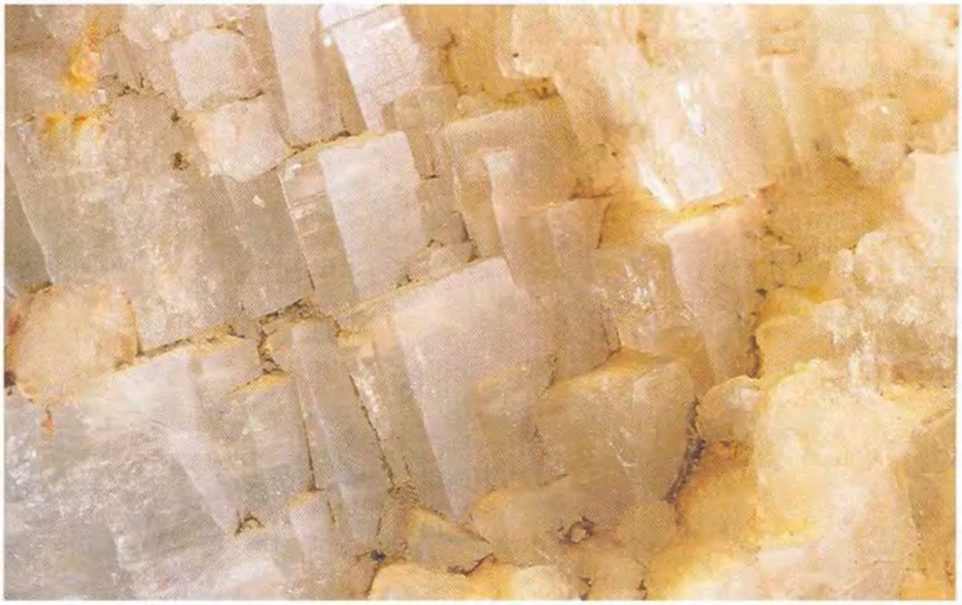

Creedite, 70 mm, Santa Eulalia, Mexico

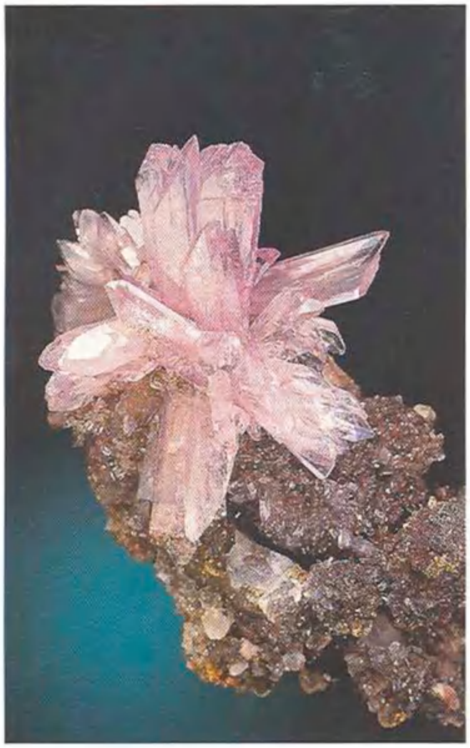

Creedite

$Ca_3Al_2(SO_4)(F,OH)_{10} \cdot 6\ H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white, purple; S – white; L – vitreous; D – transparent; DE – 2.7; H – 4; CL – perfect; F – conchoidal; M – short prismatic to acicular crystals, granular, massive.

Origin and occurrence: Hydrothermal, associated with fluorite and barite. Purple crystals, several cm long, come from Wagon Wheel Gap near Creede, Colorado, USA. Nice druses were found in Santa Eulalia, Chihuahua, Mexico. The best creedite specimens with purple crystals up to 30 mm (1$^{3}/_{16}$ in) long were recently found in Akcha-tau, Kazakhstan.

Carnallite

$KMgCl_3 \cdot 6\ H_2O$

ORTHORHOMBIC ● ● ● ●

Properties: C – colorless, white, yellowish, red, blue; S – white; L – vitreous to greasy; DE – 1.6; H – 1-2; CL – none; F – conchoidal; M – pseudo-hexagonal pyramidal and tabular crystals, granular; LU – strong; R – decomposes under wet conditions.

Origin and occurrence: Sedimentary, one of the last products of evaporation of salty solutions; also supergene as a product of a reaction of older salts with solutions, rich in potassium, associated with halite, sylvite and other minerals. Crystals up to 40 mm (1$^{9}/_{16}$ in) across are known from the vicinity of Carlsbad, New Mexico, USA. Nice crystals come also from Stassfurt and Alexanderhall, Germany. Massive aggregates are common in many salt deposits, like in Saskatchewan, Canada; in Kalush, Ukraine and elsewhere.

Application: : the most important potassium salt, used as fertilizer and for production of metal Mg.

Atacamite

$Cu_2Cl(OH)_3$

ORTHORHOMBIC ● ● ●

Properties: C – emerald-green, black-green; S – green; L – vitreous; D – translucent; DE – 3.8; H – 3-3.5; CL – perfect; F – conchoidal; M – prismatic crystals, columnar, radial and lamellar aggregates, granular, massive.

Origin and occurrence: Secondary in the oxidation zone of Cu deposits in the arid climate, associated with other Cu minerals. Crystals up to 10 mm ($^{3}/_{8}$ in) long were described from Burra district, Southern Australia, Australia. Crystals up to 10 mm ($^{3}/_{8}$ in) across come from Tsumeb, Namibia; also from Bisbee, Arizona, USA. Rich aggregates of acicular crystals occur in many localities in Atacama province, Chile (Copiapo, Remolinos).

Carnallite, 80 mm, Merkers, Germany

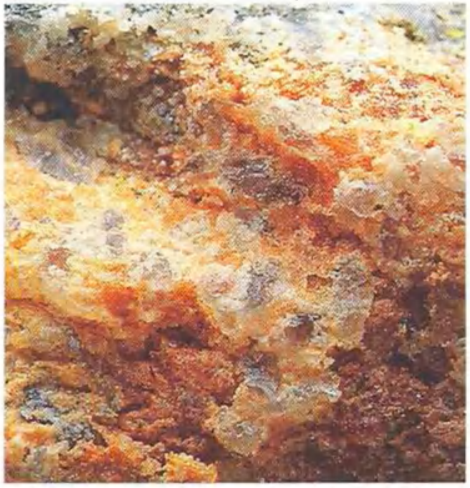

Atacamite, 78 mm, Atacama, Chile

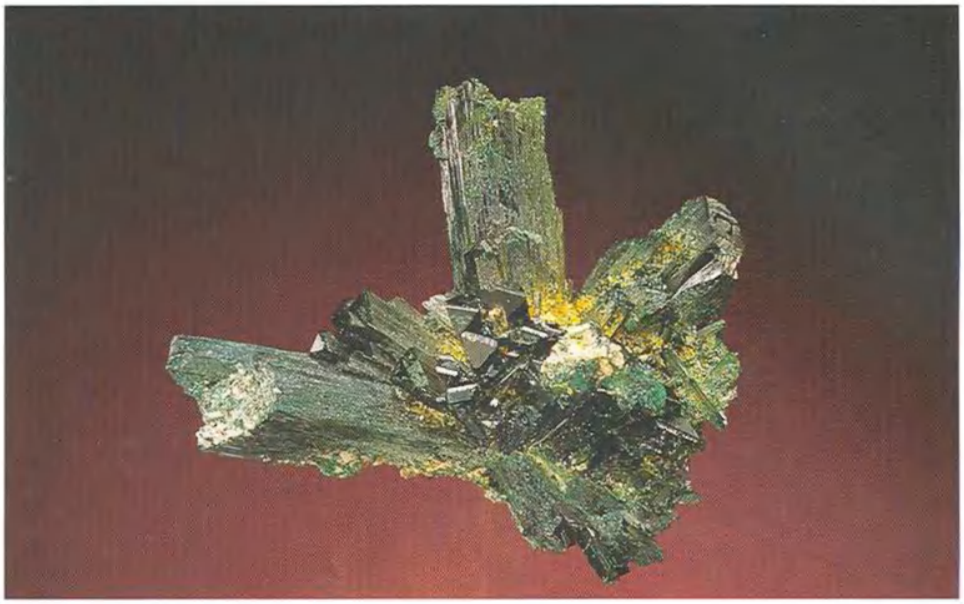

Boleite

$Pb_{26}Ag_9Cu_{24}Cl_{62}(OH)_{48}$

CUBIC ●

Properties: C – blue; S – blue; L – pearly; D – translucent; DE – 5.1; H – 3-3.5; CL – perfect; M – cubic crystals; R – soluble in water.

Origin and occurrence: Secondary, originated in the oxidation zone of Cu deposits in the arid climate. By far the best specimens were found in Boleo, Baja California, Mexico, where cubes up to 25 mm (1 in) in size were found. It is also known from Phillipsburg, Montana, USA and Challacollo, Chile.

Boleite, 65 mm, Santa Rosalia, Mexico

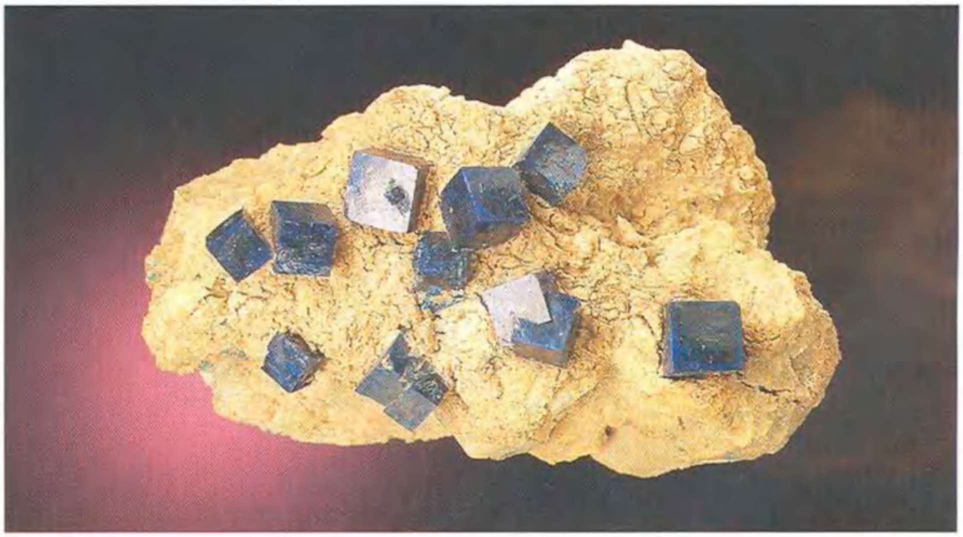

Cumengite, 21 mm, Boleo, Mexico

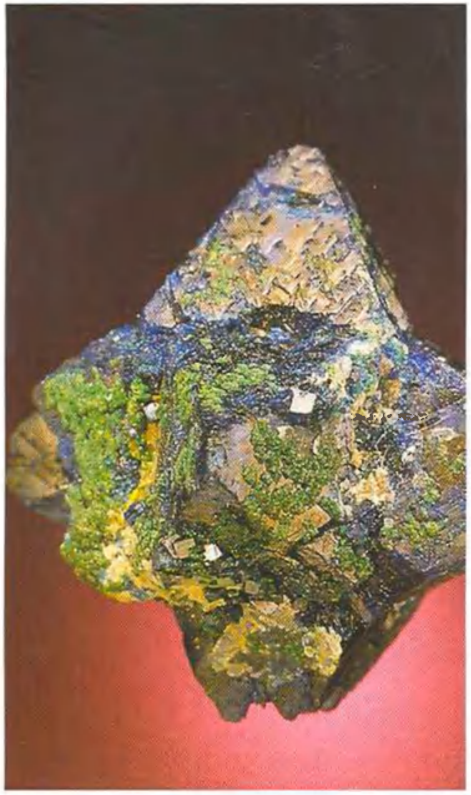

Cumengite

$Pb_{21}Cu_{20}Cl_{42}(OH)_{40}$

TETRAGONAL ●

Properties: C – indigo-blue; S – blue; L – vitreous; D – translucent; DE – 4.7; H – 2.5; CL – good; M – tetragonal pyramidal crystals, also epitaxially overgrown on boleite cubes. *Origin and occurrence:* Secondary in the oxidation zone of Cu deposits in the arid climate, associated with boleite. The largest crystals up to 35 mm ($1\frac{3}{8}$ in) are known from Boleo, Baja California, Mexico. It is also reported from Newport Beach near Falmouth, Cornwall, UK.

Iodargyrite

β-AgI

HEXAGONAL ● ● ●

Properties: C – colorless, tarnishes to yellow; S – yellow; L – adamantine; D – transparent to translucent; DE – 5.7; H – 1-1.5; CL – perfect; F – conchoidal; M – prismatic to tabular crystals, granular, massive.
Origin and occurrence: Secondary, product by oxidation of Ag ores, with other Ag minerals. Common greenish crystals over 10 mm ($\frac{3}{8}$ in) in size occur in Broken Hill, New South Wales, Australia. Also found in Vrancice, Czech Republic; Tonopah, Nevada, USA; Chanarcillo and Copiapo, Chile.

Villiaumite

NaF

CUBIC ● ● ●

Properties: C – dark red; S – white; L – vitreous; D – transparent to translucent; DE – 2.8; H – 2-2.5; CL – perfect; M – small crystals, granular, massive; R – soluble in water.
Origin and occurrence: Late mineral in cavities in alkaline igneous rocks (nepheline syenites). Crystals, several cm long, are known from the Rasvumchorr Mountain, Khibiny massif, Kola Peninsula, Russia; only slightly smaller crystals come from Mont St.-Hilaire, Quebec, Canada and Illimaussaq, Greenland.

Iodargyrite, 2 mm xx, Rudabánya, Hungary

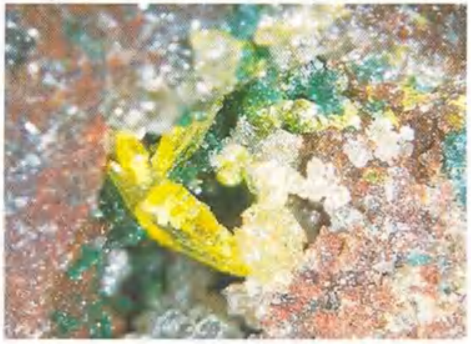

Villiaumite, 10 mm xx, Khibiny Massif, Kola, Russia

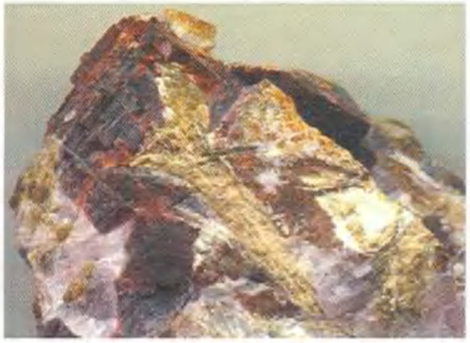

Halite, 55 mm, Trona, U.S.A.

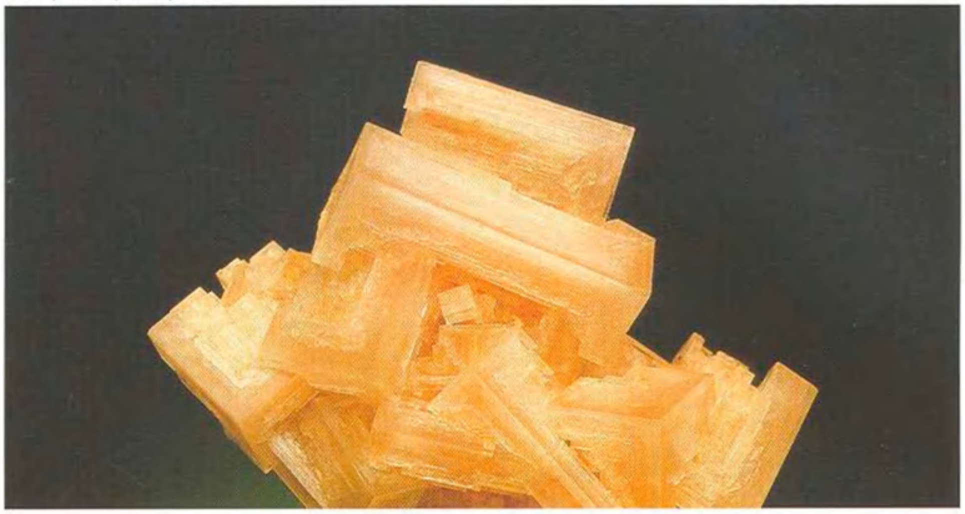

Halite

NaCl

CUBIC ● ● ● ●

Properties: C – colorless, gray, white, red, blue; S – white; L – vitreous; DE – 2.2; H – 2; CL – perfect; F – conchoidal; M – cubic crystals, granular, massive; R – soluble in water.

Origin and occurrence: Product of high-temperature fumaroles (Etna, Mt. Vesuvius; Italy); mainly sedimentary, as a result of evaporation of sea water, associated with sylvite, carnallite and other minerals. Very fine cubes over 10 mm (3/8 in) are known from Weliczka and Bochnia, Poland. Blue cleavable aggregates are found in Bernburg, Germany. Salt deposits in Austria (Hallstatt, Hallein) are also important. Huge halite deposits, associated with potassium salts are mined in the vicinity of Stassfurt, Germany. Fine skeletal crystals are known from many localities in California, USA.

Application: food and chemical industries.

Halite, 18 mm xx, Sonora, Mexico

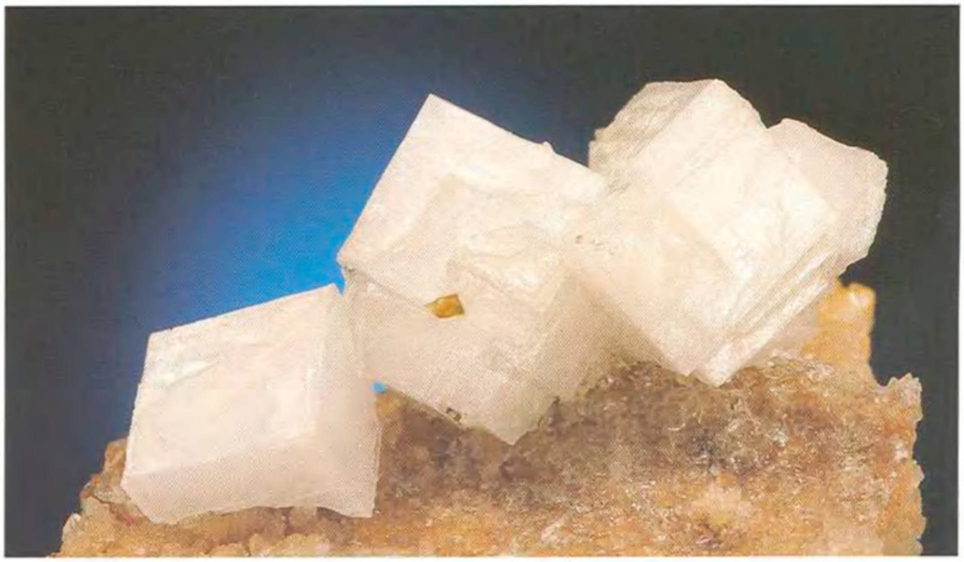

Sylvite, 77 mm, California, U.S.A.

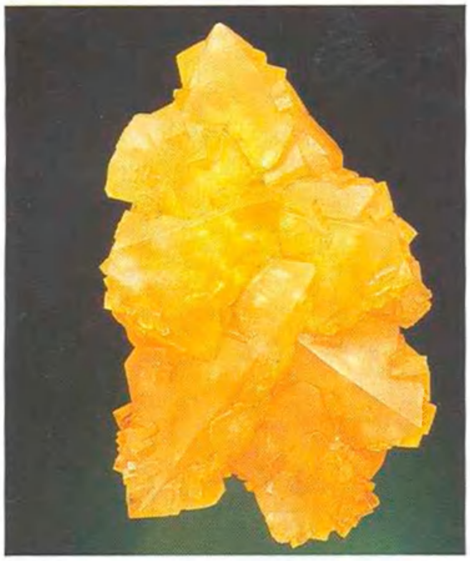

Sylvite

KCl

CUBIC ● ● ●

Properties: C – white, gray, blue, red; S – white; L – vitreous; D – transparent; DE – 2; H – 2; CL – perfect; F – uneven; M – cubic crystals and their combinations; granular, massive; R – soluble in water.
Origin and occurrence: Sedimentary as a result of evaporation of sea water, together with halite, carnallite and other minerals. Nice cubes up to 50 mm (2 in) come from Stassfurt; it forms stalactites in Wathlingen, Germany. Crystals are also known from Kalush, Ukraine and from Salton Sea, California, USA, where it occurs as octahedra on halite crystals.
Application: chemical industry.

Sal ammoniac, 10 mm x, Batonyterenye, Hungary

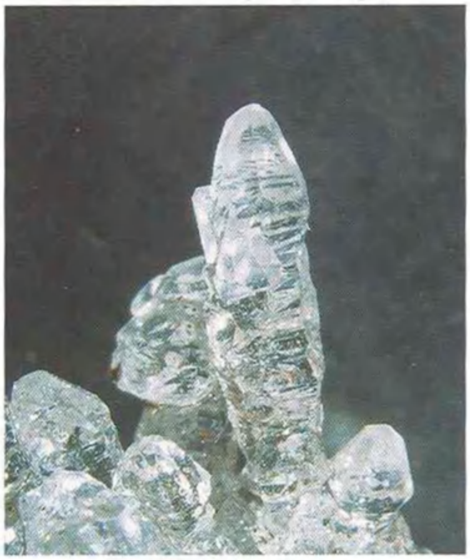

Sal ammoniac

NH_4Cl

CUBIC ● ● ●

Properties: C – colorless, white, gray, yellow, brown; S – white; L – vitreous; D – transparent; DE – 1.5; H – 1-2; CL – imperfect; F – conchoidal; M – combinations of cubic crystals, dendritic and skeletal aggregates; earthy.
Origin and occurrence: Typical mineral for fumaroles and burning coal dumps, associated with sulfur and other minerals. Complicated crystals are known from Mt. Vesuvius, Etna and Vulcano, Italy. Crystals over 10 mm ($^3/_8$ in) in size occurred on burning coal dumps near Kladno, Czech Republic; similar from localities in Eastern Pennsylvania, USA and near Ste-Etienne, France.

Calomel, 30 mm, Terlingua, U.S.A.

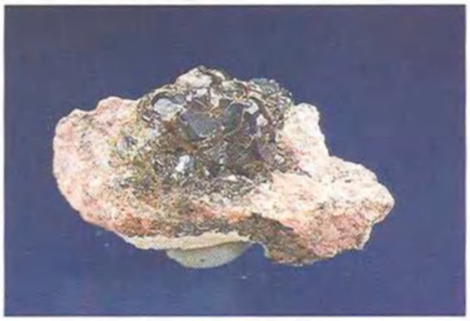

Calomel

HgCl

TETRAGONAL ● ●

Properties: C – colorless, white, gray, brown, it darkens on air; S – white; L – adamantine; D – transparent to translucent; DE – 7.2; H – 1.5; CL – good; F – conchoidal; M – tabular to pyramidal crystals, coatings, earthy; LU – dark red.
Origin and occurrence: Secondary as a result of alteration of Hg minerals, associated with cinnabar, mercury and other minerals. Crystals were found in Moschellandsberg, Germany; Avala, Serbia;

Khaidarkan, Kyrgyzstan and Terlingua, New Mexico, USA.

Fluorite

CaF_2

CUBIC ● ● ● ● ●

Properties: C – colorless, white, yellow, red, green, blue, purple, brown, black; S – colorless; L – vitreous; D – transparent to translucent, opaque; DE – 3.2; H – 4; CL – perfect; F – conchoidal to splintery; M – combinations of cubic crystals, granular, massive; LU – blue, blue-green, also phosphorescent.
Origin and occurrence: Rare magmatic, mainly hydrothermal and metasomatic. Associations are very diverse, depending on a type of the deposit, in which it occurs. Beautiful crystals are known from many localities all over the world. Pink octahedra, several cm in size, are known from pegmatites in Nagar, Pakistan. Nice crystals were also found in greisens in Cornwall, UK (Wheal Mary mine) and from Horni Slavkov, Czech Republic. Beautiful green cubes up to 20 cm across and colorless cubes up to 10 mm ($^{3}/_{8}$ in) across from Dalnegorsk, Russia are of hydrothermal origin. Famous green and purple crystals come from Alston Moor and Weardale, England, UK. Nice pink octahedra up to 30 mm ($1^{3}/_{16}$ in) occurred in Huanzala, Peru. Beautiful yellow cubes up to 50 mm (2 in) associated with barite, are known from Halsbrücke and Annaberg, Germany. Purple complex combinations of crystals come from La Collada, Spain. Mainly purple cubes up to 10 mm ($^{3}/_{8}$ in) occurred in Rosiclare, Illinois; in association with honey-yellow calcite crystals are known from the Elmwood mine, Tennessee; similar occurrences are also in several localities in Kentucky, USA. The most valuable fluorite specimens are pink octahedra up to 150 mm (6 in) from Göschenen, Switzerland; Mont Blanc massif, France and other Alpine localities.
Application: metallurgy, chemical industry, special optics.optika.

Fluorite, 50 mm, Argentina

Fluorite, 23 mm x, Chamonix, France

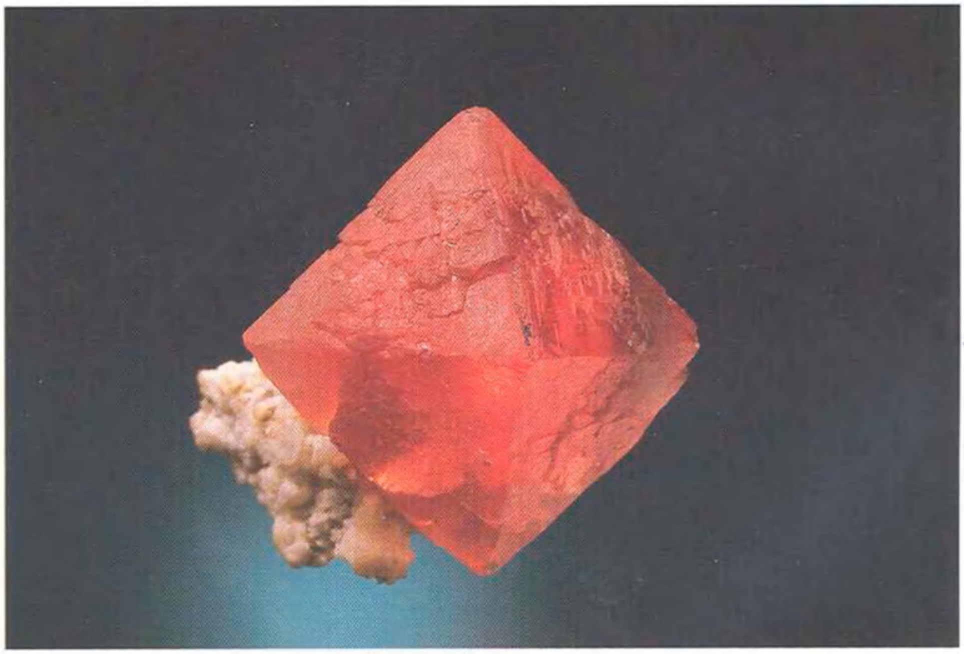

4. Oxides

Cuprite

Cu_2O

CUBIC ● ● ●

Varieties: chalcotrichite (acicular to hair-like crystals)
Properties: C – red; S – red; L – adamantine to submetallic; D – transparent to translucent; DE – 5.8-6.2; H – 3.5-4; CL – imperfect; F – conchoidal to uneven; M – combinations of cubic crystals, hair-like aggregates, granular, massive.
Origin and occurrence: Secondary, as a result of the oxidation of Cu sulfides. Crystals up to 150 mm (6 in) in size, covered with malachite, occur in Onganja, Namibia. Shiny octahedra, up to 40 mm ($1^{9}/_{16}$ in) in size, come from the Mashamba West mine, Zaire. Acicular and fibrous crystals of the chalcotrichite variety were found in Bisbee, Arizona, USA. Combinations of cubic crystals, covered with malachite, are known from Chessy near Lyon, France. Crystals up to 30 mm ($1^{3}/_{16}$ in) across are reported from Tsumeb, Namibia.
Application: important Cu ore.

Zincite

ZnO

HEXAGONAL ● ●

Properties: C – yellow, orange, red; S – orange-yellow; L – adamantine; D – transparent to translucent; DE – 5.7; H – 4.5-5; CL – perfect; F – conchoidal; M – pyramidal crystals, granular, massive.
Origin and occurrence: Metamorphic, associated with willemite and franklinite. It forms very rare crystals up to 40 mm ($1^{9}/_{16}$ in) in size in the metamorphosed Zn deposits in Franklin and Sterling Hill, New Jersey, USA, it is mostly granular and massive. Zincite crystals and aggregates of vitreous luster from Poland, which are offered at the mineral shows, are not of a natural origin, there are smelter products.

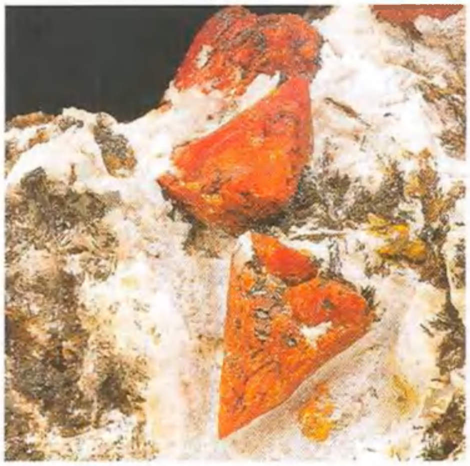

Zincite. 11 mm x. Franklin, U.S.A.

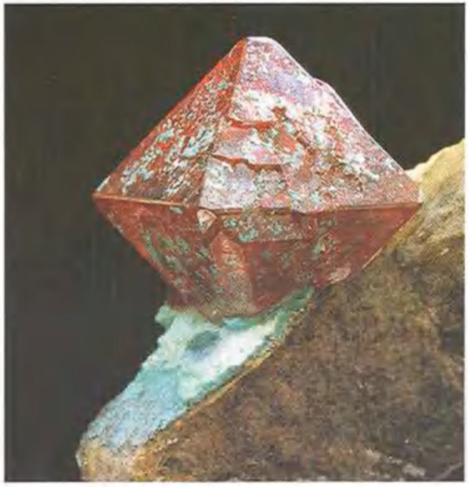

Amethyst. 122 mm, Guerrero, Mexico
Cuprite. 18 mm x. Mashamba West, Zair

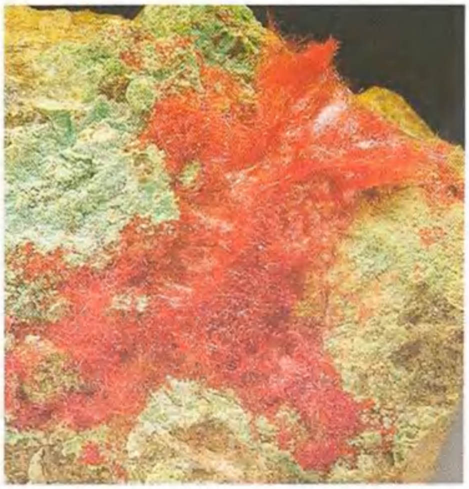

Chalcotrichite. 50 mm. Bisbee, U.S.A.

Tenorite
CuO

MONOCLINIC ● ● ●

Properties: C – steel-gray to black; S – gray; L – metallic; D – opaque; DE – 6.5; H – 3.5; CL – imperfect; F – uneven to conchoidal; M – thin tabular to scaly crystals, earthy, massive.
Origin and occurrence: Secondary, in the oxidation zone of Cu deposits, together with other Cu supergene minerals. It was common in Cu deposits in the Keweenaw Peninsula, Michigan, USA. It was mined as Cu ore in Bisbee, Globe and Morenci, Arizona, USA. Thin tabular crystals are known from Tsumeb, Namibia.

Tenorite, 3 mm xx, Bisbee, U.S.A

Spinel
$MgAl_2O_4$

CUBIC ● ● ●

Varieties: pleonast (black)
Properties: C – pink, red, green, blue, brown, black; S – white; L – vitreous to dull; D – transparent to opaque; DE – 3.6; H – 7.5-8; CL – imperfect; F – conchoidal to uneven; M – octahedral crystals, granular, massive.
Origin and occurrence: Magmatic, metamorphic, also in placers, associated with corundum, sillimanite and other minerals. Large pleonast crystals reaching up to 150 mm (6 in) were found in the Aldan massif, Yakutia, Russia. Fine crystals weighing up to 14 kg (30 lb 12 oz) come from Amity, New York. Crystals up to 120 mm ($4^{7}/_{16}$ in) across are known from Sterling Hill, New Jersey. Blue crystals of spinel come from Bolton, Massachusetts, USA and South Burgess, Ontario, Canada. Gemmy pink and red crystals up to 20 mm ($^{25}/_{32}$ in) reported near Ratnapura, Sri Lanka and in Mogok, Burma. Fine pink crystals up to 50 mm (2 in) in size occur in Kukh-i-lal, Tajikistan.
Application: gemstone.

Gahnite
$ZnAl_2O_4$

CUBIC ● ● ●

Properties: C – black-green, black; S – gray; L – vitreous to greasy; D – translucent to opaque; DE –

Spinel, 10 mm x, Mogok, Burma

Pleonast, 15 mm xx, Vietnam

Gahnite, 90 mm, Broken Hill, Australia

4.4-4.6; H – 7.5-8; CL – imperfect; F – conchoidal to uneven; M – octahedral crystals, granular.

Origin and occurrence: Magmatic and metamorphic, associated with wolframite, chalcopyrite and other minerals. Crystals up to 120 mm (4 7/16 in) in size come from Franklin and Sterling Hill, New Jersey, USA. Crystals from Broken Hill, New South Wales, Australia reached up to 30 mm (1 3/16 in). Blue-green crystals were found in Rowe, Massachusetts, USA. Cuttable blue crystals occur near Gidan Wayo, Nigeria.

Magnetite

$Fe^{2+}Fe^{3+}_2O_4$

CUBIC ● ● ●

Properties: C – black; S – black; L – metallic; D – opaque; DE – 5.2; H – 5.5-6.5; CL – none; F – uneven to conchoidal; M – octahedral crystals, granular, massive.

Origin and occurrence: Magmatic, hydrothermal and metamorphic, rare sedimentary. Parageneses differ according to the origin. Fine crystals up to 170 mm (6 11/16 in) in size, come from Traversella, Italy. A crystal 25 cm (9 13/16 in) in size was found in Vastanfors, Sweden. Fine crystals up to 40 mm (1 9/16 in) occur in Dashkesan, Azerbaijan, where it is associated with andradite, epidote and apatite. Beautiful shiny octahedra up to 40 mm (1 9/16 in) are known from Alpa Lercheltini, Binntal, Switzerland. Rare cubes up to 20 mm (25/32 in) on edge come from the ZCA No.4 mine, Balmat, New York, USA.. Magnetite crystals reaching up to 10 cm were found in pegmatites in Jaguaraçu, Minas Gerais, Brazil. Crystals up to 20 cm (7 7/8 in) in size reported from the Gardiner complex, Greenland. Crystals up to 50 mm (2 in) were lately found in Kovdor, Kola Peninsula, Russia.

Application: Fe ore.

Magnetite, 20 mm x, Chester, U.S.A.

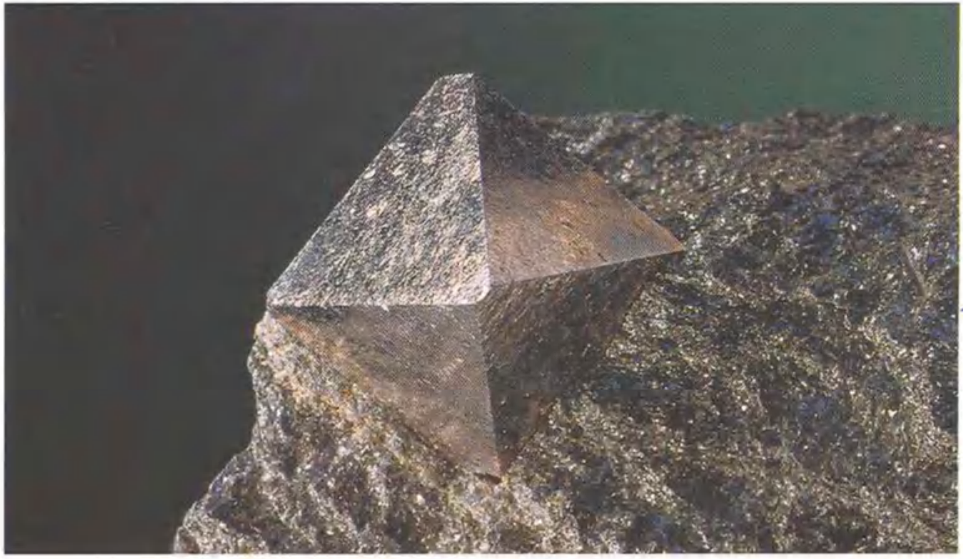

Franklinite, 30 mm, Sterling Hill, U.S.A.

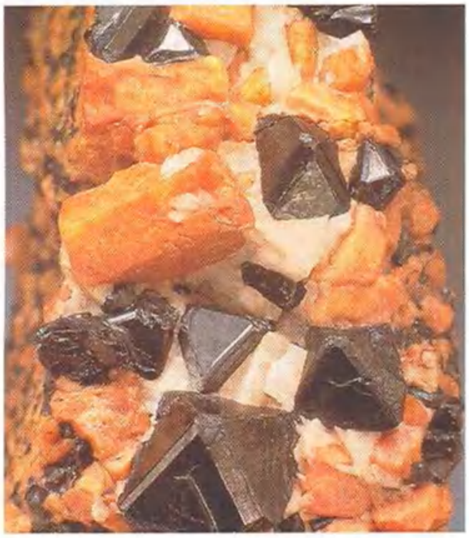

Franklinite

$(Zn,Mn^{2+},Fe^{2+})(Fe^{3+},Mn^{2+})_2O_4$

CUBIC ● ●

Properties: C – black; S – dark brown; L – metallic; D – opaque; DE – 5.1-5.5; H – 6; CL – none; F – uneven to conchoidal; M – octahedral crystals, granular, massive.
Origin and occurrence: Metamorphic, associated with willemite, zincite and other minerals. The only localities, where it is common and occurs in very large accumulations, are Franklin and Sterling Hill, New Jersey, USA. Crystals up to 170 mm (6 11/16 in) across are known from there. It is rare in Langban, Sweden and Ocna de Fier, Romania.
Application: Zn ore.

Chromite, 87 mm, Finnland

+ ↳

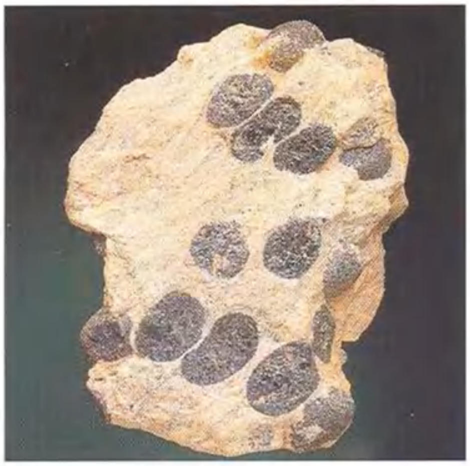

Chromite

$FeCr_2O_4$

CUBIC ● ● ●

Properties: C – black; S – brown; L – metallic; D – opaque; DE – 4.5-4.8; H – 5; CL – none; F – uneven; M – octahedral crystals, granular, massive.
Origin and occurrence: Magmatic, together with magnetite, uvarovite and other minerals. Rare crystals reaching up to 10 mm (3/8 in) are known from Uzun Damar, Turkey. It occurs mostly massive, like in deposits in Bushveld, South Africa; in Sarany, Ural Mountains, Russia and in Guleman, Turkey.
Application: Cr ore.

Hausmannite

$Mn^{2+}Mn^{3+}{}_2O_4$

TETRAGONAL ● ● ●

Properties: C – black; S – brown; L – submetallic; D – opaque; DE – 4.8; H – 5.5; CL – perfect; F – uneven; M – pseudo-octahedral crystals, granular, massive.
Origin and occurrence: Hydrothermal in high-temperature Mn deposits, also as a product of the contact metamorphism. The best specimens with crystals up to 30 mm (1 3/16 in) in size come from the N'Chwaning mine, Kuruman, South Africa. Smaller crystals were found in Ilfeld and Ilmenau, Germany. It also occurred as fine crystals in Langban and Jakobsberg, Sweden.

Minium, 60 mm, Broken Hill, Australia

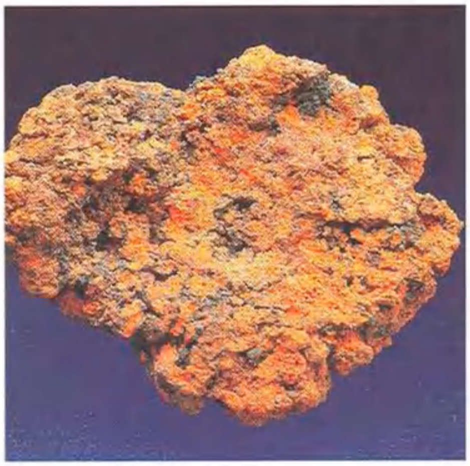

Minium

$Pb^{2+}_2Pb^{4+}O_4$

TETRAGONAL ● ● ●

Properties: C – red, S – orange-yellow; L – dull to greasy; D – opaque; DE – 8.9; H – 2.5; CL – perfect; M – earthy and pulverulent aggregates, massive.

Origin and occurrence: Secondary mineral, as a result of the galena oxidation. It occurs in Langban, Sweden; in Anarak, Iran; in Leadhills, Scotland, and in Broken Hill, New South Wales, Australia.

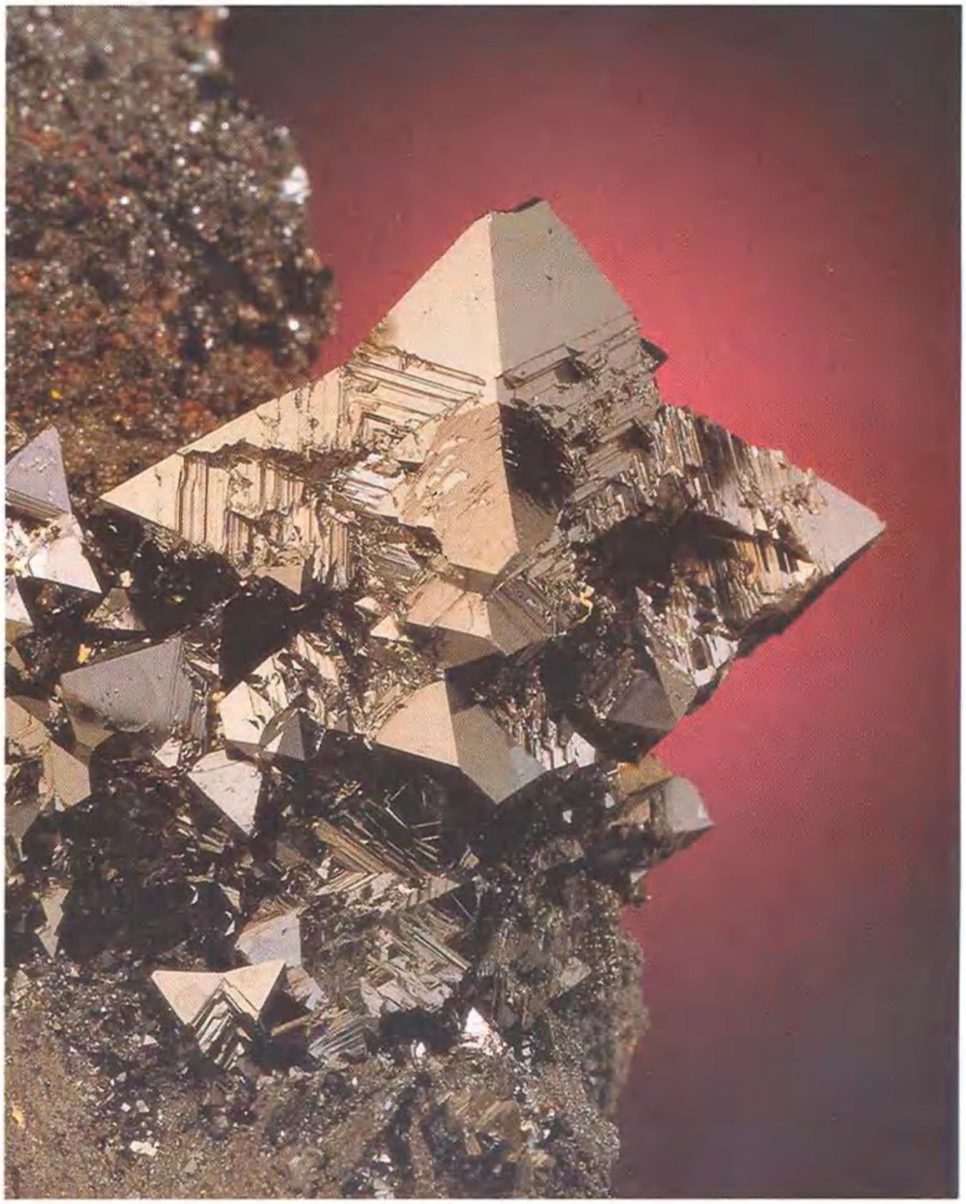

Hausmannite, 42 mm, Kuruman, South Africa

Chrysoberyl, 35 mm, Espírito Santo, Brazil

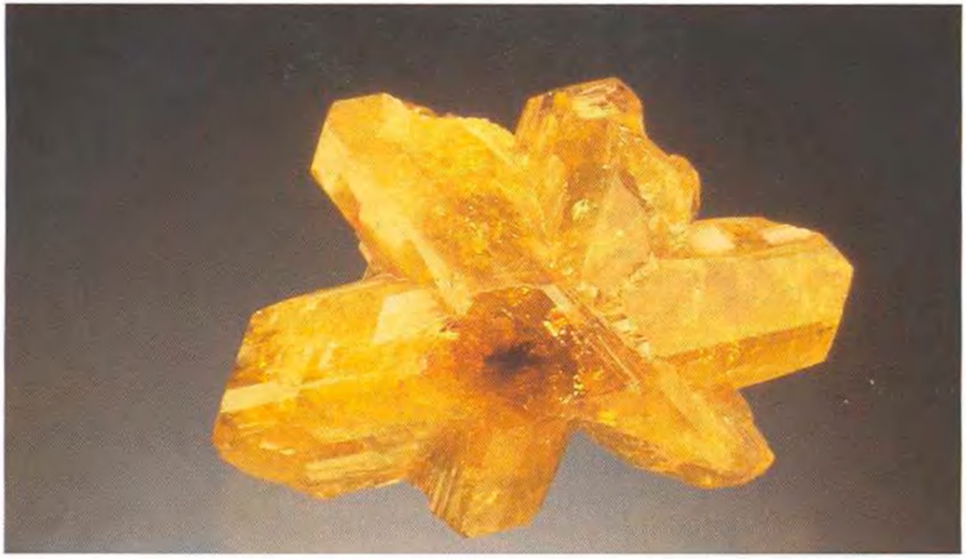

Chryzoberyl

$BeAl_2O_4$

ORTHORHOMBIC ● ● ●

Varieties: alexandrite

Properties: C – yellow-green, yellow, blue-green, alexandrite is green in daylight, purple in artificial light; S – white; L – vitreous; D – transparent to translucent; DE – 3.8; H – 8.5; CL – good; F – conchoidal to uneven; M – thin to thick tabular crystals common cyclic twins.

Origin and occurrence: Magmatic in pegmatites, prevailing as metamorphic, in association with schorl, phenakite and other minerals. Twins up to 22 cm (8¹¹/₁₆ in) occurred near Pancas, Espirito Santo, Brazil. Complicated twins up to 100 mm (4 in) in

Alexandrite, 75 mm, Malyshevo, Russia

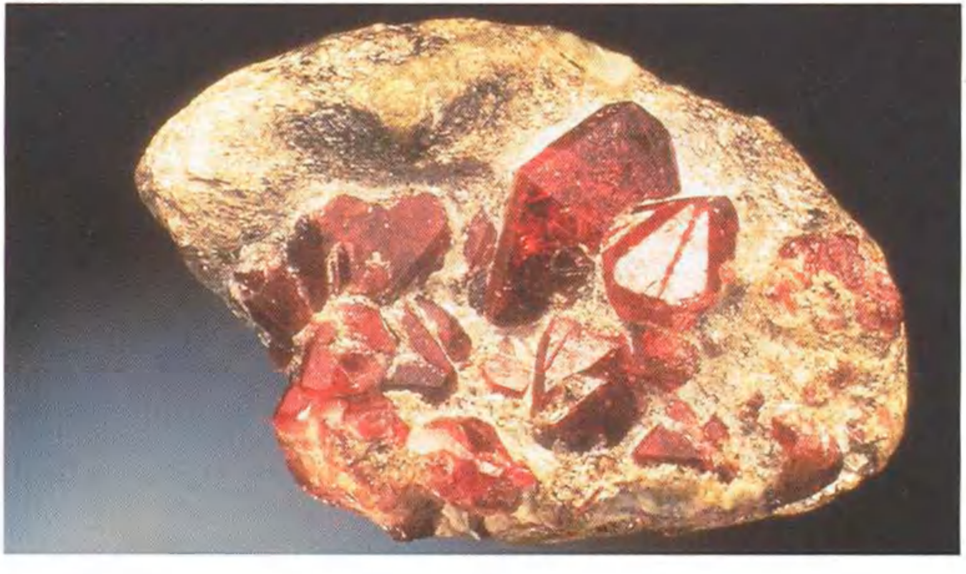

size come from Ambatondrazaka and other localities in Madagascar. Tabular crystals several cm in size, embedded in the sillimanitic rock, were found in Mar_ikov, Czech Republic. Fine alexandrite crystals up to 80 mm ($3^{1}/_{8}$ in) are known from Malyshevo, Ural mountains, Russia, together with emerald and phenakite. Alexandrite crystals reach up to 30 mm ($1^{3}/_{16}$ in) in Nyanda, Zimbabwe. Gemmy chrysoberyls, commonly with a cat's eye effect, come from the vicinity of Ratnapura, Sri Lanka.
Application: gemstone.

Valentinite

Sb_2O_3

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white, brownish; S – white; L – adamantine; D – transparent to translucent; DE – 5.7-5.8; H – 2.5-3; CL – perfect; M – prismatic to tabular crystals, radial aggregates, massive.
Origin and occurrence: Secondary mineral, originated in the oxidation of stibnite. The best specimens with crystals up to 30 mm ($1^{3}/_{16}$ in) were found in Pribram, Czech Republic. Fine crystals come also from Braunsdorf, Germany. Crystals up to 20 mm ($^{25}/_{32}$ in) long occur in Oruro, Bolivia. Beautiful radial aggregates up to 40 mm ($1^{9}/_{16}$ in) in diameter, associated with kermesite, are known from Pezinok and Pernek, Slovakia. Pseudo-morphs after stibnite crystals up to 35 cm ($13^{6}/_{8}$ in)long, are reported from the Xikuangshan Mine, Lengshuijiang, China.

Valentinite, 40 mm, Nicolet, Canada

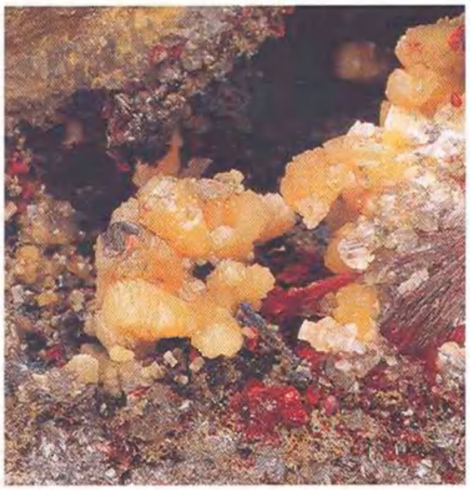

Arsenolite

As_2O_3

CUBIC ● ●

Properties: : C – white; S – white; L – vitreous; D – transparent to translucent; DE – 3.9; H – 1.5; CL – good; F – conchoidal; M – octahedral crystals, crusts, coatings; R – soluble in water.

Arsenolite, 3 mm xx, Recsk, Hungary

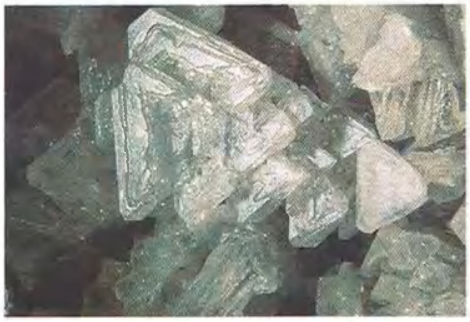

Origin and occurrence: Secondary mineral, resulting from the oxidation of As ores. Poorly developed crystals several mm long, occur in Jachymov, Czech Republic; in Johanngeorgenstadt and St. Andreasberg, Germany. Crystals up to 20 mm ($^{25}/_{32}$ in) long originated during a mine fire in the White Caps mine, Nevada, USA.

Senarmontite

Sb_2O_3

CUBIC ● ● ●

Properties: C – white, light gray; S – white; L – greasy, vitreous to adamantine; D – transparent to opaque; DE – 5.2-5.8; H – 2-2.5; CL – imperfect; F – uneven; M – octahedral crystals, granular, massive.
Origin and occurrence: Secondary, produced by stibnite oxidation, with valentinite and cerussite. The finest crystals up to 30 mm ($1^{3}/_{16}$ in) in size come from Djebel Hammimate, Algeria. Also occurred in Cetine, Italy and in Dubrava, Slovakia.

Senarmontite, 3 mm xx, Pernek, Slovakia

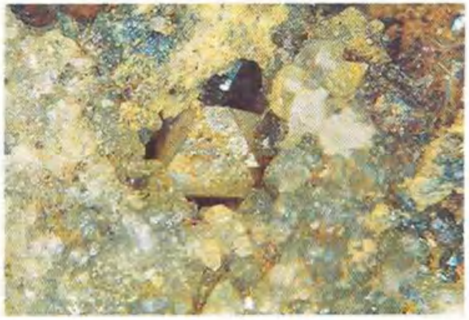

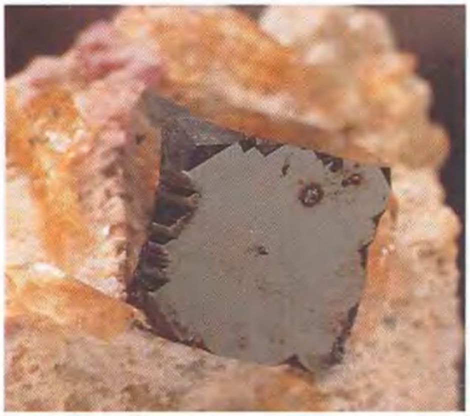
Bixbyite, 11 mm x, Thomas Range, U.S.A.

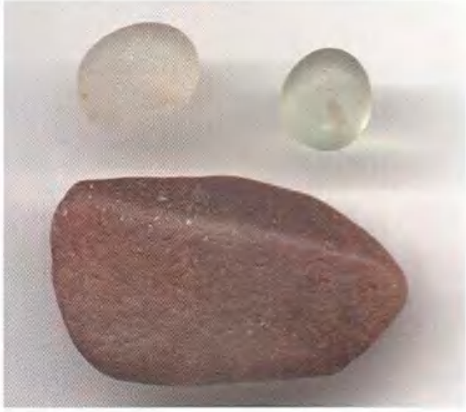
Leucosapphire, 30 mm, Sri Lanka

Bixbyite
$(Mn^{3+},Fe^{3+})_2O_3$

CUBIC ● ●

Properties: C – black; S – black; L – metallic to submetallic; D – opaque; DE – 5; H – 6-6.5; CLB imperfect; F – conchoidal to uneven; M – cubic crystals, also twins.
Origin and occurrence: Hydrothermal in rhyolite cavities and metamorphic. Cubes up to 12 mm (15/32 in) are found together with topaz in Thomas Range, Utah, USA. Crystals up to 25 mm (1 in) occurred in the Postmasburg mine, South Africa. Crystals up to 80 mm (3 1/8 in) come from Ultevis, Sweden.

Corundum
Al_2O_3

TRIGONAL ● ● ● ●

Varieties: ruby, sapphire, leucosapphire, emery

Properties: C – colorless (leucosapphire), yellow, pink, red (ruby), blue (sapphire), purple, green,

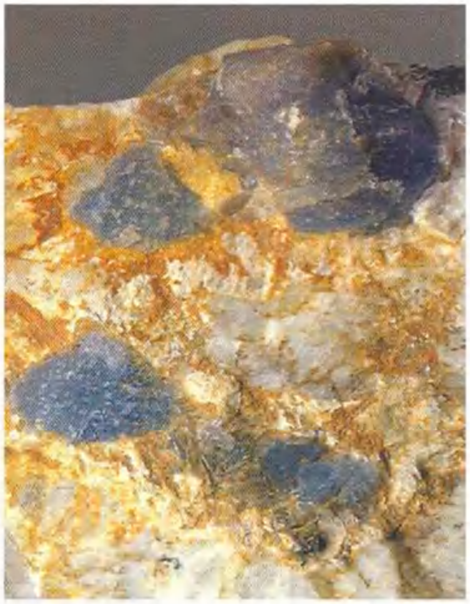
Corundum, 10 mm xx, Miass, Russia

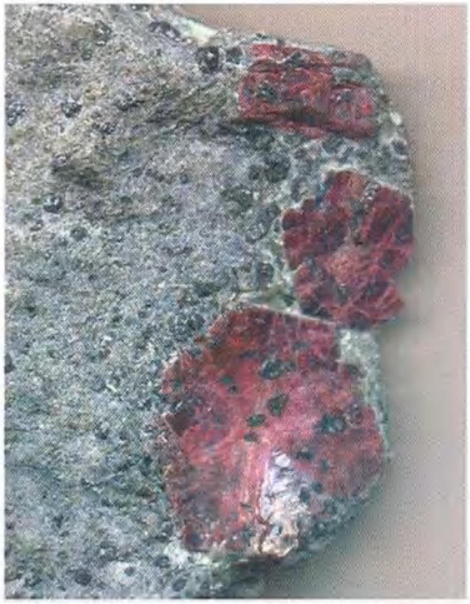
Ruby, 15 mm xx, Kola, Russia

Corundum, 4 mm, Montana, U.S.A.

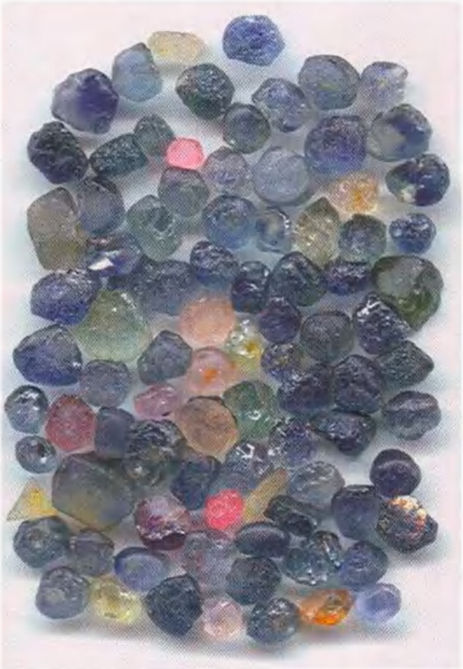

gray; S – white; L – vitreous to adamantine; D – transparent to opaque; DE – 4.0-4.1; H – 9; CL – none; F – conchoidal to uneven; M – long prismatic to barrel-like crystals, pebbles; LU – rare dark red.

Origin and occurrence: Magmatic in andesites, pegmatites and basalts, metamorphic and in placers, in association with andalusite, topaz, spinel and other minerals. Crystals of common corundum weighed up to 30 kg (66 lb) near Bancroft, Ontario, Canada. A crystal, weighing 151 kg (333 lb 3 oz) was also found in the Letaba district, South Africa. Sapphire crystals weighing up to 20 kg (44 lb), come from the vicinity of Ratnapura and Rakwana, Sri Lanka. Fine sapphire crystals are also known from Kashmir, India. Rough gem sapphire is mined from the Yogo Gulch sediments in Montana, USA and from Anikia, Queensland, Australia. Fine blue crystals up to 50 mm (2 in) long, occur near Miass, Ural mountains, Russia. Ruby is even much rarer variety of corundum. Its beautiful crystals up to 50 mm (2 in) long come from Jegdalek, Afghanistan; Mogok, Burma and from Luc Yen, Vietnam. Prismatic crystals of opaque ruby, up to 40 mm (1$^{9}/_{16}$ in) in size were found in the Khit Island near Kola Peninsula, Russia. Ruby crystals up to 30 cm (12 in) in size embedded in green zoisite from the vicinity of Arusha, Tanzania are very decorative.

Application: emery as abrasive material, sapphire and ruby as gemstones.

Ruby, 16 mm x, Jegdalek, Afghanistan

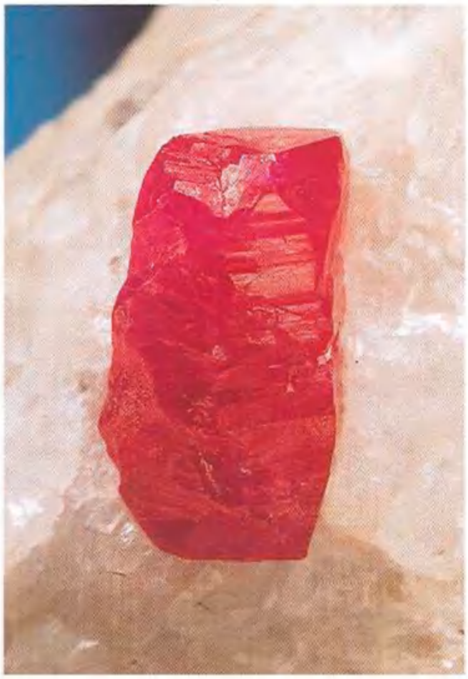

Sapphire, 41 mm, Kashmir, India

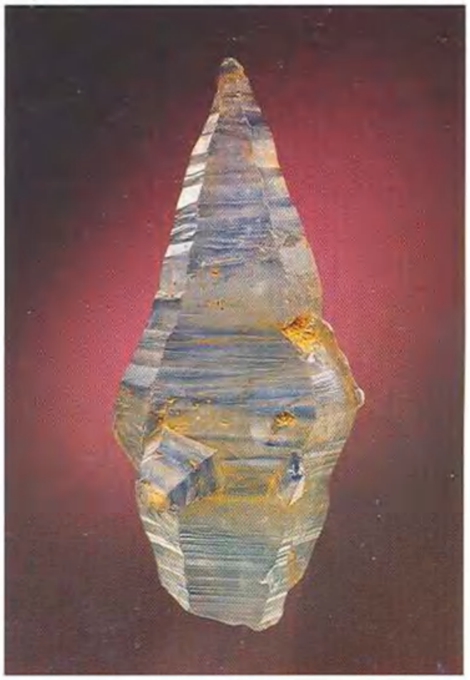

Hematite, 50 mm, La Fibbia, Switzerland

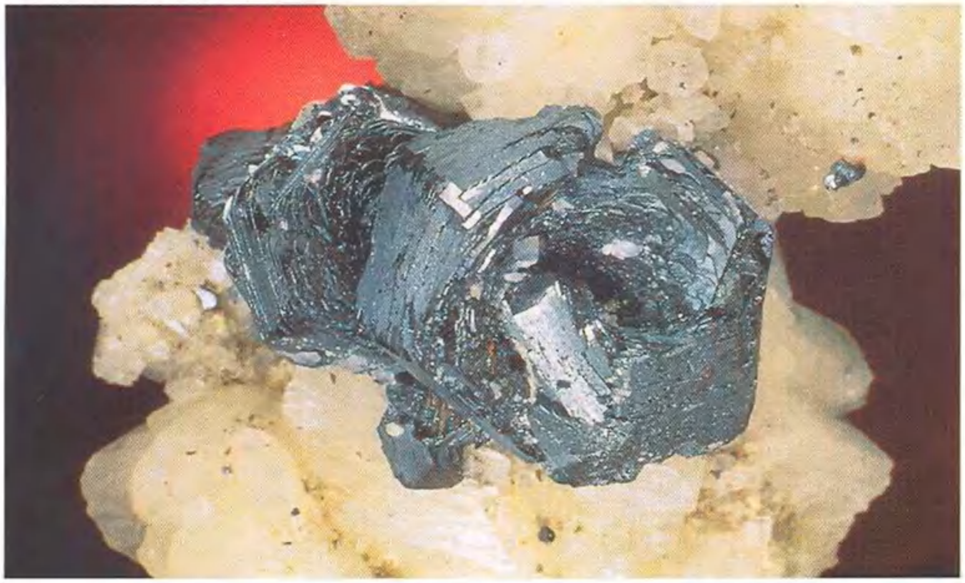

Hematite

Fe_2O_3

TRIGONAL ● ● ● ● ●

Properties: C – red, gray, black; S – red; L – metallic, dull; D – opaque; DE – 5.3; H – 6-6.5, earthy to 1; CL – none; F – uneven to conchoidal; M – thick to thin tabular crystals, massive, earthy.
Origin and occurrence: Magmatic, hydrothermal, sedimentary, also metamorphic, parageneses vary according to the origin. Beautiful crystals up to 100 mm (4 in) in size come from Brumado, BahRa. Brazil. Crystals up to 30 cm (12 in), were found in the Wessels mine, Kuruman, South Africa. So called iron roses reached up to 100 mm (4 in) near St. Gotthard, Switzerland. Fine crystals several cm in size, occurred in Rio Marina, Elba, Italy. Very fine tabular crystals reached up to 70 mm (2¾ in) in Nador, Morocco. New finds of fine crystals up to 40 mm ($1\frac{9}{16}$ in) in size were made in the Korshunovskoye deposit, Russia. Fine botryoidal aggregates come from Hradiste and Horni Blatna, Czech Republic and from Botallack, Cornwall, UK. Sedimentary banded iron ores form huge deposits near Krivoy Rog, Ukraine or in the vicinity of Lake Superior (Mesabi Range, Minnesota; Marquette, Michigan, USA).
Application: important Fe ore.

Loparite-(Ce), 10 mm xx, Khibiny Massif, Kola, Russia

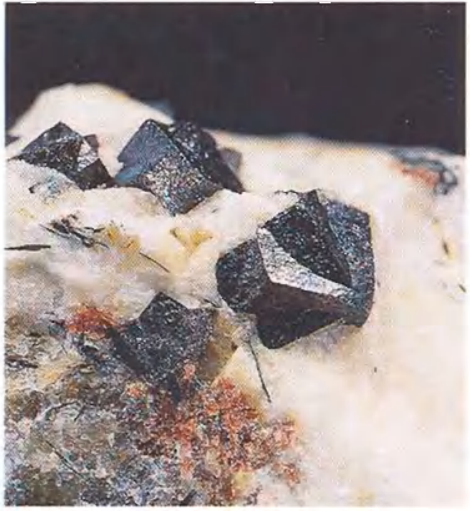

Ilmenite

$FeTiO_3$

TRIGONAL ● ● ● ●

Properties: C – black; S – black; L – metallic to dull; D – opaque; DE – 4.5-5; H – 5-6; CL – none; F – conchoidal to uneven; M – thick tabular crystals, granular, massive.
Origin and occurrence: Magmatic, metamorphic and in placers, associated with pyrrhotite, rutile, magnetite and other minerals. Crystals weighing up

Ilmenite, 11 mm x, Binntal, Switzerland

to 30 kg (66 lb) were described from the Faraday mine near Bancroft, Ontario, Canada. Crystals up to 150 mm (6 in) in size occurred near Girardville, Quebec, Canada. Crystals also reached up to 100 mm (4 in) near Miass, Ural mountains, Russia. Crystals up to 120 mm 120 mm ($4^{7}/_{16}$ in), were found in Arendal and Kragero, Norway. Crystal rosettes up to 10 mm ($^{3}/_{8}$ in) in size come from Maderanertal, Switzerland. It is also common in placers (Kamituga, Kivu, Zaire; Sri Lanka; Travancore, India; Madagascar etc.).

Perovskite

$CaTiO_3$

ORTHORHOMBIC ● ● ●

Properties: C – dark brown to black; S – colorless to gray; L – metallic to adamantine; D – opaque; DE – 4.0-4.3; H – 5.5-6; CL – imperfect; F – conchoidal to uneven; M – pseudo-cubic crystals, granular.
Origin and occurrence: Magmatic in basic and ultrabasic rocks, metamorphic, together with magnetite, zircon and other minerals. Fine pseudo-cubic crystals up to 40 mm ($1^{9}/_{16}$ in) in size come from Zlatoust and Akhmatovsk, Ural mountains, Russia. It occurs as crystals up to 80 mm ($3^{1}/_{8}$ in), associated with magnetite crystals in the Gardiner complex, Greenland. Crystals up to 40 mm ($1^{9}/_{16}$ in) were found in Jacupiranga, Sao Paulo, Brazil. Crystals from Val Malenco, Italy, reached up to 20 mm ($^{25}/_{32}$ in). Crystals up to 20 mm ($^{25}/_{32}$ in) were lately found in Afrikanda, Kola Peninsula, Russia.

Loparite-(Ce)

$(Ce,Na,Ca)TiO_3$

ORTHORHOMBIC ●

Properties: C – black, S – dark red-brown, L – metallic; D – opaque; DE – 4.6-4.9; H – 5.5-6; M – pseudo-cubic crystals, granular; R – metamict.
Origin and occurrence: Magmatic in alkaline rocks, with lorenzenite, eudialyte and aegirine. Fine interpenetration twins up to 20 mm ($^{25}/_{32}$ in) in size come from Mount Nyorkpakhk, Kola Peninsula, Russia.

Perovskite, 60 mm, Zlatoust, Russia

Stibiconite, 230 mm, Catorce, Mexico

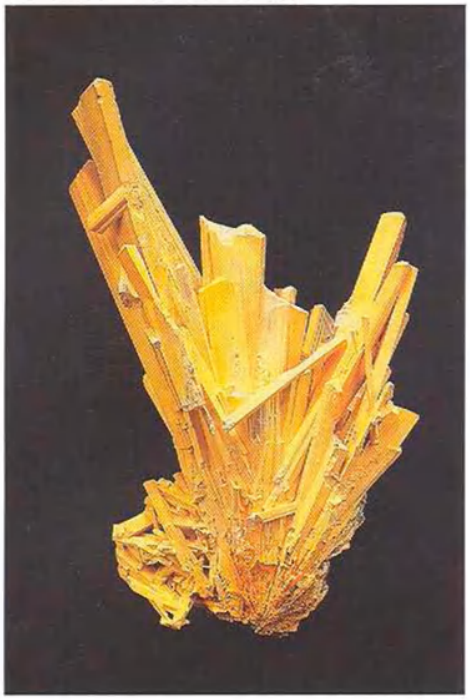

Stibiconite

$Sb^{3+}Sb^{5+}{}_2O_6(OH)$

CUBIC ● ● ●

Properties: C – white, creamy, light yellow, brown; S – white; L – vitreous, greasy to dull; D – opaque; DE – 4.1-5.8; H – 3-6; M – pseudo-morphs after stibnite crystals, earthy, massive.
Origin and occurrence: Secondary, as a result of the stibnite oxidation, associated with valentinite and other minerals. Fine pseudo-morphs after stibnite crystals up to 30 cm (12 in) long come from Catorce, San Luis Potosí, Mexico. Similar pseudo-morphs were also found in Kostainik, Serbia; in the Ichinokawa mine, Japan and in Pereta, Italy. Pseudo-morphs after stibnite up to 20 cm ($7^{7}/_{8}$ in) long occur also in Çukuroren, Turkey.

Bindheimite

$Pb_2Sb_2O_6(O,OH)$

CUBIC ● ● ●

Properties: C – yellow, brown, gray; S – yellow, L – resinous, dull to earthy; D – translucent to opaque; DE – 4.6-5.6; H – 4-4.5; F – conchoidal to earthy; M – botryoidal, nodular and earthy crusts.
Origin and occurrence: Secondary in the oxidation zone of Pb-Sb deposits. Needles up to 10 mm ($^{3}/_{8}$ in) long come from Rudník, Czech Republic. It is common in Broken Hill, New South Wales, Australia; in Bisbee, Arizona, USA and in Sidi-Amor-ben-Salem, Tunisia. Lamellar pseudo-morphs up to several cm in size are known from Tsumeb, Namibia.

Pyrochlore

$(Na,Ca)_2Nb_2O_6(OH,F)$

CUBIC ● ● ●

Properties: C – yellow-brown, brown, black; S – brown; L – vitreous to greasy; D – translucent to opaque. DE – 4.5; H – 5-5.5; CL – locally good; F – conchoidal to uneven; M – octahedral crystals, granular; R – radioactive (admixtures of U, Th).
Origin and occurrence: Magmatic in alkaline rocks, together with zircon, astrophyllite and other minerals. Fine brown shiny crystals up to 20 mm ($^{25}/_{32}$ in) in size come from the vicinity of Vishnevogorsk, Ural mountains, Russia. Crystals reaching 10 mm ($^{3}/_{8}$ in) occur in the Panda Hill deposit, Tanzania. Crystals are also known from Oka, Quebec, Canada. Single octahedra measuring 5 mm ($^{3}/_{16}$ in) were found in Luesha, Kivu, Zaire. *Application:* Nb,U and Th ore.

Bindheimite, 4 mm, Rudabánya, Hungary

Microlite, 7 mm x, Gillette Quarry, U.S.A.

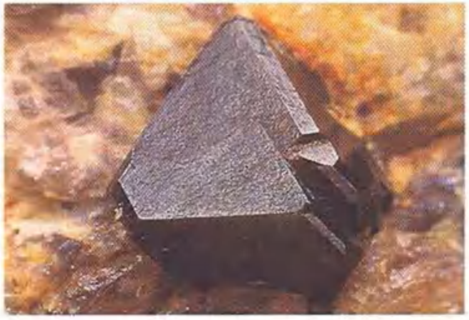

Pyrochlore, 58 mm, Vishnevogorsk, Ural Mts., Russia

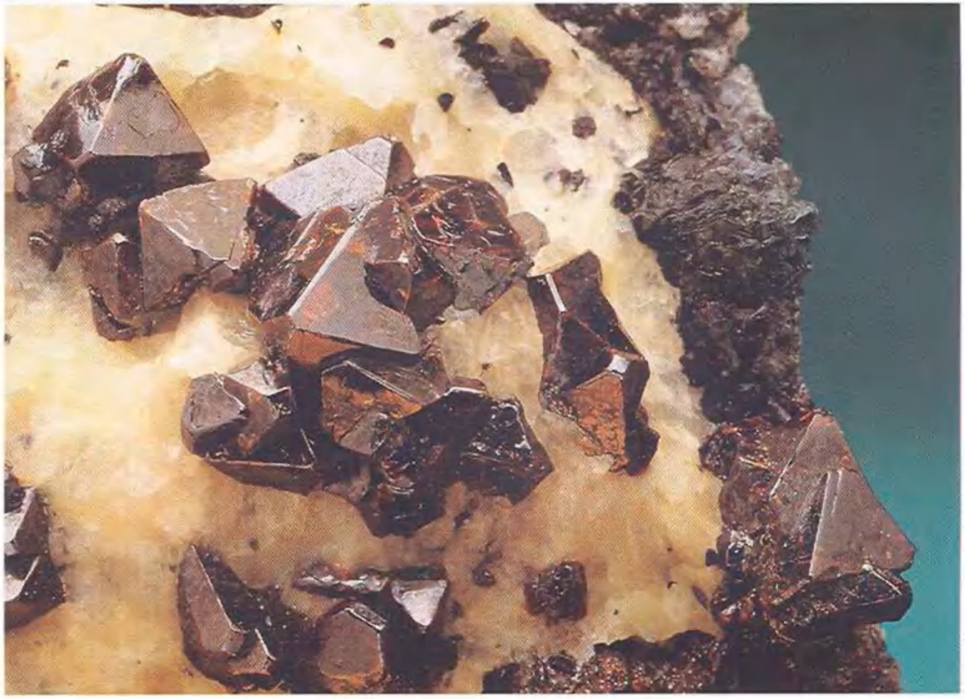

Betafite

$(Ca,Na,U)_2(Ti,Nb,Ta)_2O_6(OH)$

CUBIC ● ●

Properties: C – black, brown, yellow-brown; SB red-brown; L – resinous to greasy; D – translucent to opaque; DE – 4.2; H – 3-5.5; CL – none; F – conchoidal to uneven; M – octahedral crystals; R – radioactive, metamict.

Origin and occurrence: Magmatic in granitic pegmatites, rich in U, Th and rare earth elements, associated with beryl, euxenite-(Y) and other minerals. The world's best specimens come from many localities in Madagascar (Betafo, Ambatofotsikely etc.), where crystals up to 6 kg (13 lb 3 oz) were found. Beautiful specimens with crystals up to 100 mm (4 in) in size occur in the Silver Crater mine near Bancroft, Ontario, Canada. It is also known from Evje, Norway.

Betafite, 20 mm, Silver Crater, Canada

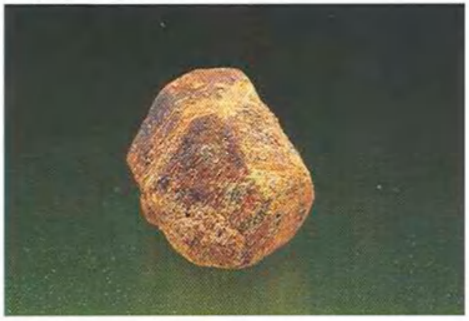

Mikrolite

$(Na,Ca)_2Ta_2O_6(O,OH,F)$

CUBIC ● ● ●

Properties: C – brown, yellow, green, reddish; S – white; L – vitreous to greasy, locally adamantine; D – translucent to opaque; DE – 5-6.4; H – 6-6.5; CL – locally good; F – conchoidal to uneven; M – octahedral crystals, granular, massive.

Origin and occurrence: Magmatic, typical for granitic pegmatites, together with manganocolumbite, manganotantalite and other minerals. Octahedra up to 65 mm ($2\frac{9}{16}$ in) in size occur in Ankola, Uganda. Crystals up to 30 mm ($1\frac{3}{16}$ in) in size come from Virgem da Lapa, Minas Gerais, Brazil. Crystals up to 75 mm (3 in) are reported from the Harding pegmatite, New Mexico, USA. It occurs in important accumulations near Wodgina, Western Australia.

Quartz, 60 mm, Herkimer, U.S.A.

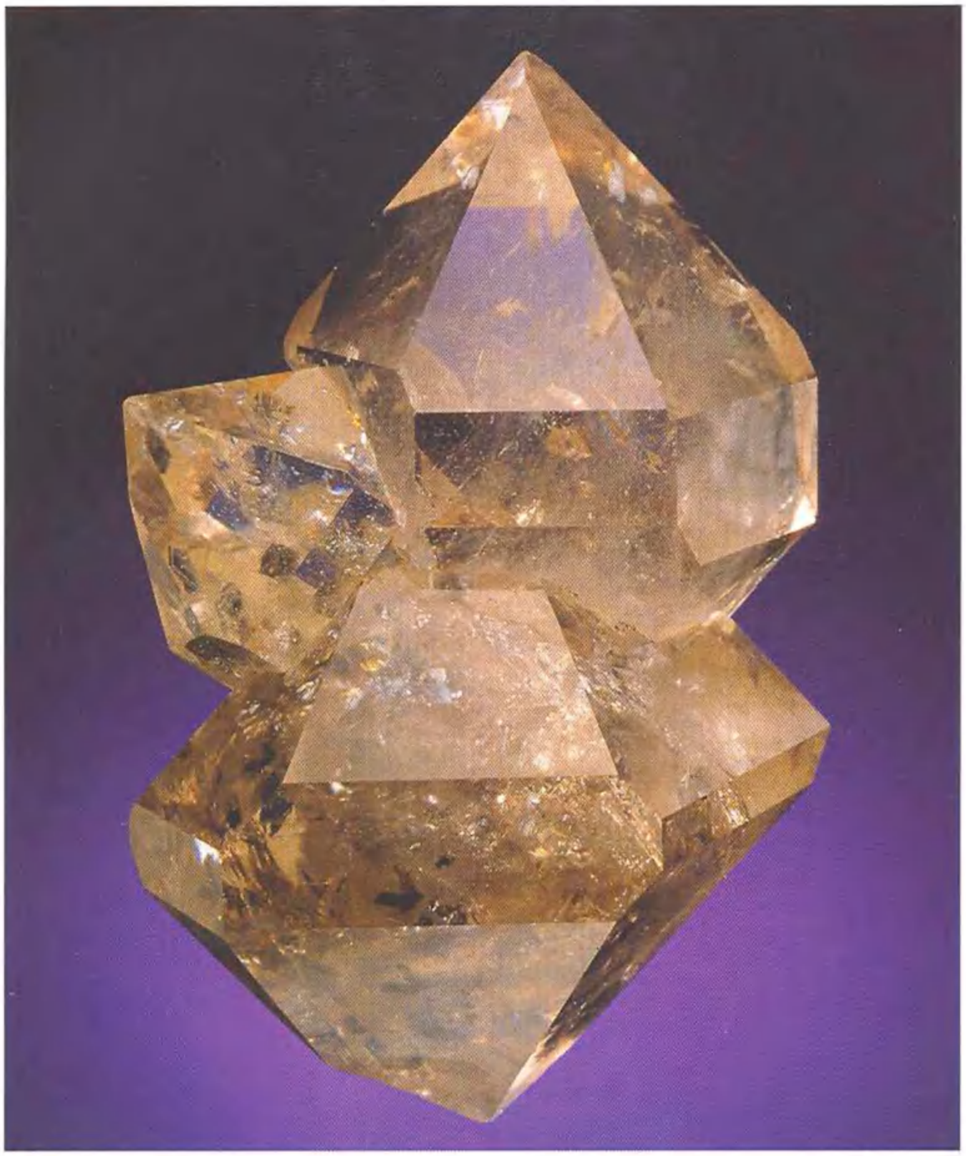

Quartz

SiO_2

TRIGONAL ● ● ● ● ●

Varieties: rock crystal, citrine, smoky citrine, morion, amethyst, rose quartz, chrysoprase, jasper, chalcedony, agate, onyx, sardonyx, aventurine, heliotrope, tiger's eye, falcon s eye.

Properties: C – colorless (rock crystal), white, yellow (citrine), brown (smoky citrine), black (morion), purple (amethyst), pink (rose quartz), green (chrysoprase); D – these varieties are mostly transparent, often translucent; C – other varieties are mainly multicolored, separate colors have different hues and the color is commonly caused by microscopic admixtures of other minerals; varieties: red, green, brown, yellow (jasper), banded with different colors (agate); white

Rock crystal, 95 mm, La Gardette, France

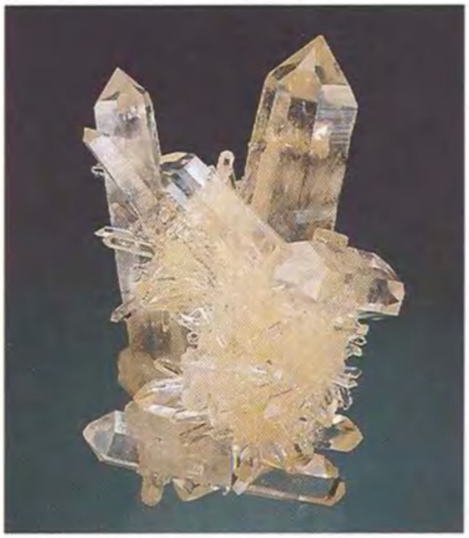

Citrine, 32 mm, Charcas, Mexico

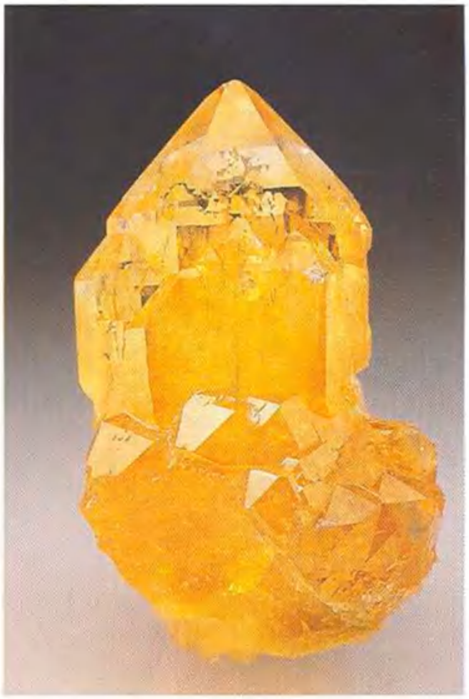

and black bands (onyx), white and red-brown bands (sardonyx), green to red-brown with mica or hematite inclusions (aventurine), dark green with red spots (heliotrope), yellow-brown to black-brown, fibrous with silky luster (tiger's eye), blue-gray to yellow-brown, fibrous with silky luster (falcon's eye); S – white; L – vitreous, silky, dull; D – transparent to translucent, opaque; DE – 2.6; H – 7; CL – none; F –

Smoky quartz, 70 mm, Middle Moat Mt., U.S.A.

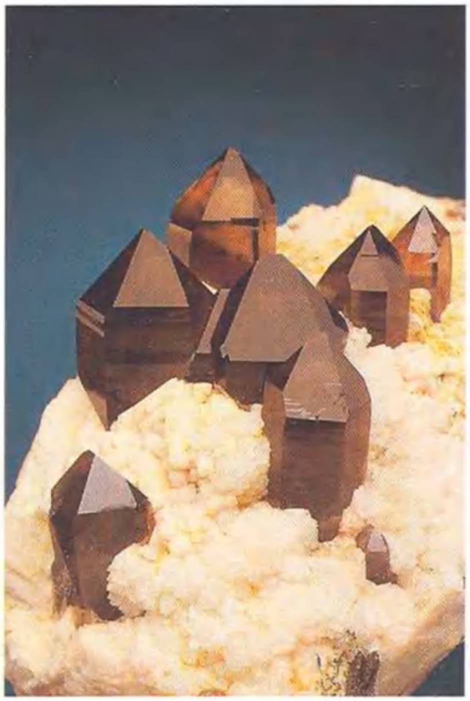

Smoky quartz, 81 mm, Switzerland

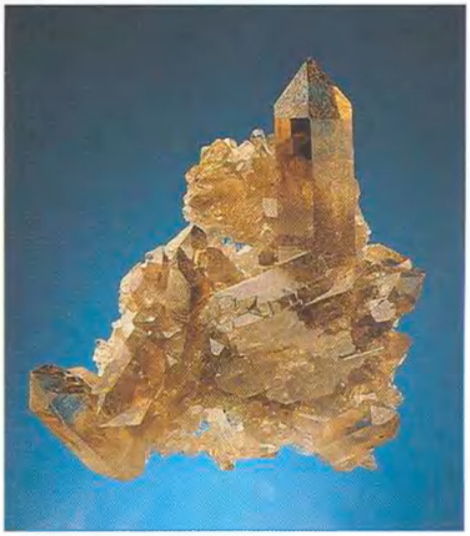

Morion, 100 mm, Agadir, Kazakhstan

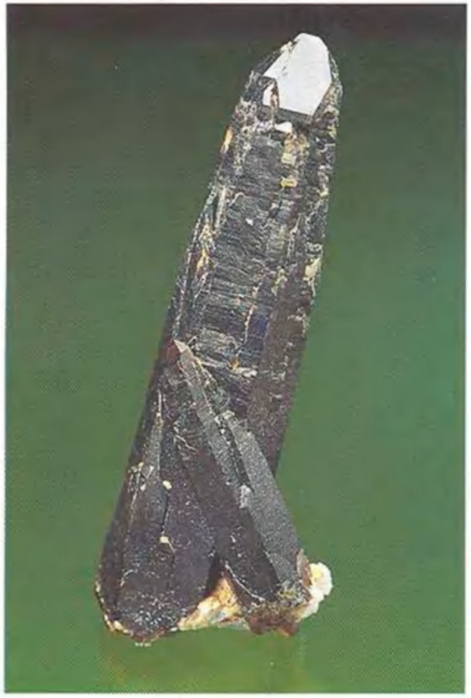

Amethyst, 100 mm, Bochovice, Czech Republic

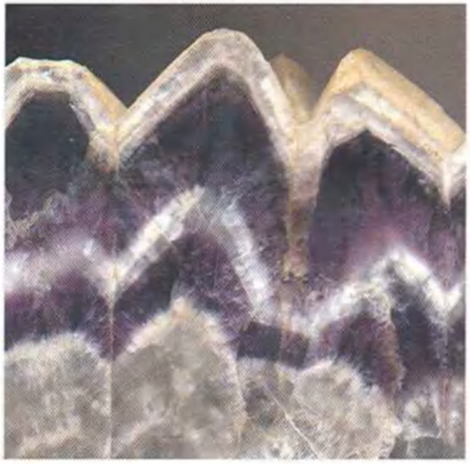

conchoidal; M – long to short prismatic, acicular, dipyramidal to tabular crystals, fibrous, botryoidal and stalactitic aggregates and coatings, concretions, geodes, granular, massive.
Origin and occurrence: Magmatic in different types of rocks, mainly in granites, granitic pegmatites and volcanic rocks; metamorphic in different types of rocks, mainly in quartzites and mica schists; hydrothermal in different types of ore and Alpine-

Rose quartz, 145 mm, Minas Gerais, Brazil

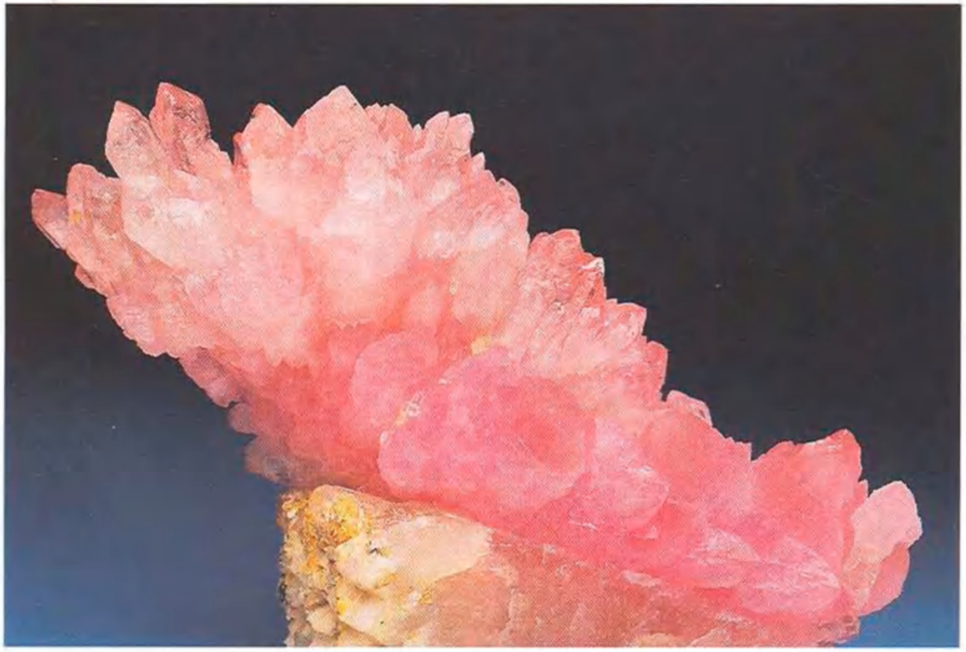

Amethyst, 200 mm, Guerrero, Mexico

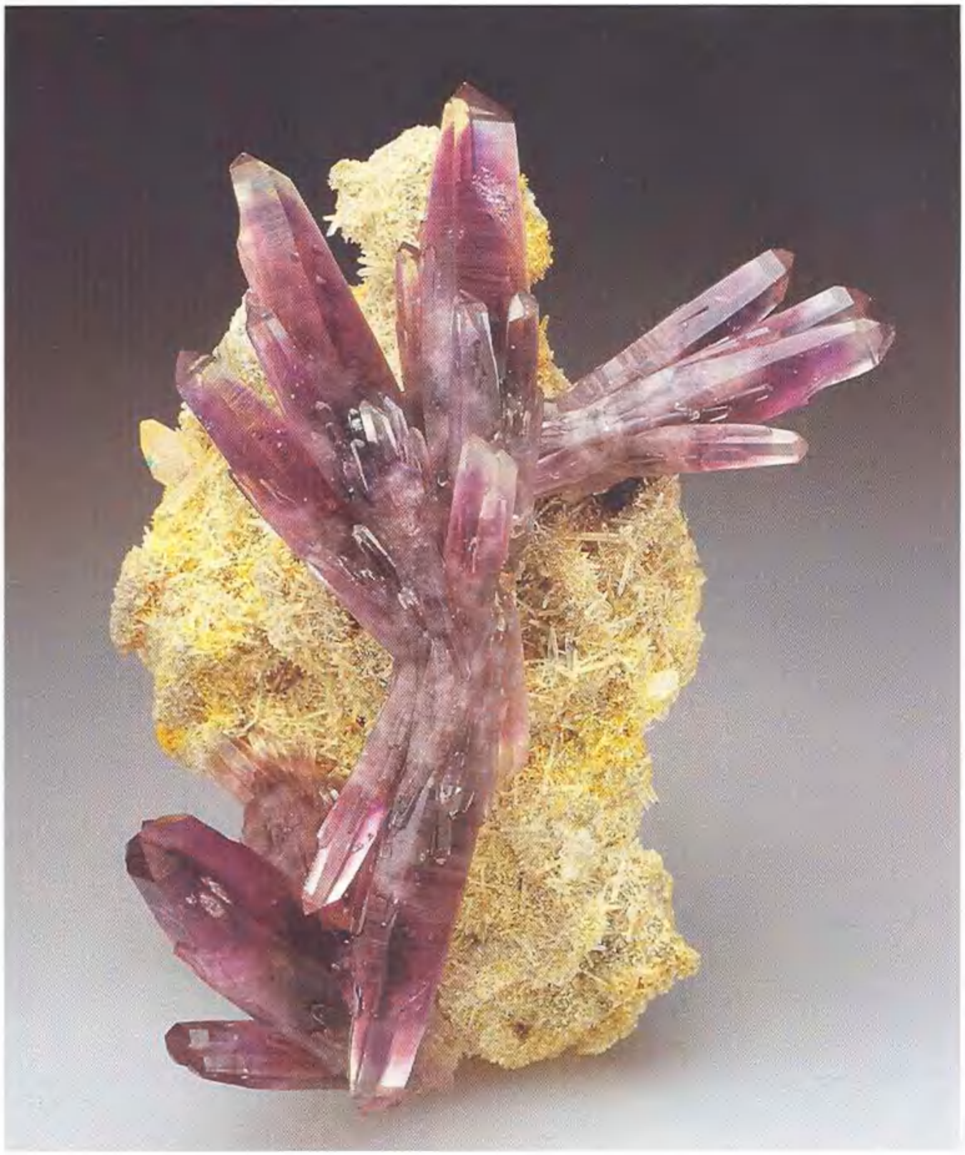

type veins; secondary in the oxidation zone of ore deposits; also in different types of sedimentary rocks and in organic remains, also in placers. Probably the most common mineral in the Earth's crust and the most important rock-forming mineral, as well.

Large crystals of rock quartz up to 7 m (23 ft) long come from pegmatites in the Betafo region in Madagascar and from the Alpine-type veins, like Uri, Grimsel and Furka, Switzerland; perfect crystals are known from the cracks in marbles near Carrara, Italy; it also occurs in the quartz veins in Herkimer, New York and Hot Springs, Arkansas, USA. Citrine occurs mainly in granitic pegmatites and large crystals come from Goias, Brazil; from Suky and Netín, Czech Republic; from Murzinka, Ural mountains, Russia. Smoky quartz originates mostly in granitic pegmatites, it also occurs in the

Chalcedony, 68 mm, High Atlas, Morocco

Carnelian, 40 mm, Nova Paka, Czech Republic

Chrysoprase, 60 mm, Szklary, Poland

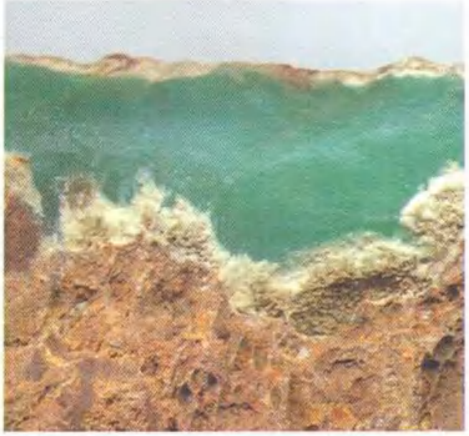

Alpine-type quartz veins and in cavities of volcanic rocks. Perfect crystals up to several meters long, come from many places, the largest crystal, weighing 77 tons, was found in Kazakhstan; perfect crystals occur in pegmatites in many places in Brazil; also in Korostenskiy massif, Ukraine; in the Pikes Peak batholith, Colorado, USA; in the Alpine-type veins in Maderanertal and in Grimsel, Switzerland. Morion crystals, commonly associated with smoky citrine, were found in quartz veins and in pegmatites.

Its crystals are known from St. Gotthard, Switzerland. Amethyst comes from quartz and ore veins, cavities in volcanic rocks, rare in the Alpine-type veins. Famous localities in volcanic rocks are in the states of Rio Grande do Sul and Minas Gerais, Brazil, doubly terminated crystal, weighing 5.5 tons, come from Diamantina. In Serra do Mar, Rio Grande do Sul, a cavity covered with amethyst

Jasper, 50 mm, Ural Mts., Russia

Jasper, 60 mm, Oregon, U.S.A.

Petrified wood, 70 mm, Podkrkonosi, Czech Republic

crystals measuring 10 x 2 x 1 m (33 x 6 x 3 ft 3in) was found; rich druses occur also in the ore veins in Porcura, Romania and Julimes, Mexico. Rose quartz, forming masses up to several meters in granitic pegmatites in the Rose Quartz pit, Quadeville, Ontario, Canada; in Ambositra, Madagascar; crystals up to 10 mm (3/8 in) long growing on quartz crystals, come from Sapucaia, Minas Gerais, Brazil. Dark green chrysoprase veins up to 50 mm (2 in) thick are known from serpentinites in Szklary,

Iron stained quartz, 95 mm, Horovice, Czech Republic

Agate, 50 mm, Železnice, Czech Republic

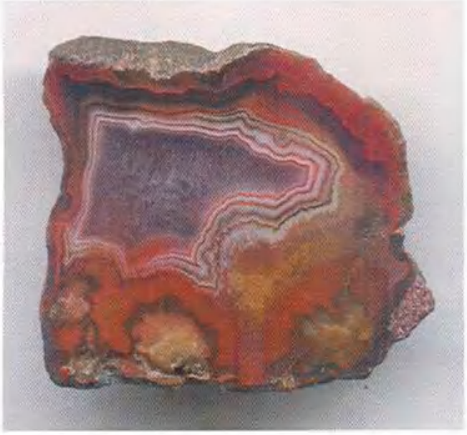

Onyx, 65 mm, Brazil

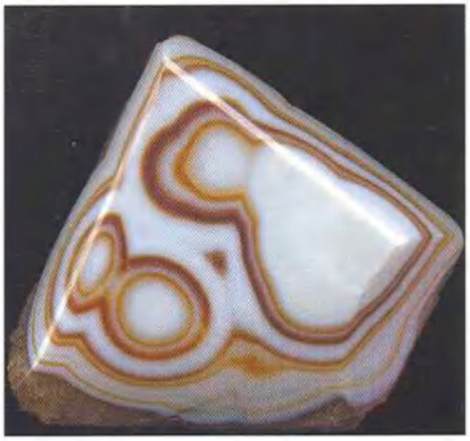

Poland. Jasper is known from volcanic rocks and their contacts with sediments, locally as a result of petrification of organic matter, mainly plants, it is also known from quartz veins. Rich aggregates occur in Idar-Oberstein, Germany; in Podkrkonoši region and in Krušne hory mountains, Czech Republic; in the Petrified Forest National Park, Holbrook, Arizona, USA; in Ural mountains, Russia; in Kabamby, Madagascar. Chalcedony is mostly found in quartz veins and geodes in volcanic rocks, also in sediments.
Rich aggregates come from Idar-Oberstein, Germany; Julimes, Mexico; many localities in Uruguay and Brazil; in Huttenberg, Austria. Agates are known from cavities in volcanic rocks, rare in hydrothermal veins and in sediments. The most important localities are located in the southern part of Brazil in the state of Rio Grande do Sul; in Uruguay; also in Yemen; India; Mongolia; in several

Moss agate, 40 mm, Krdjali, Bulgaria

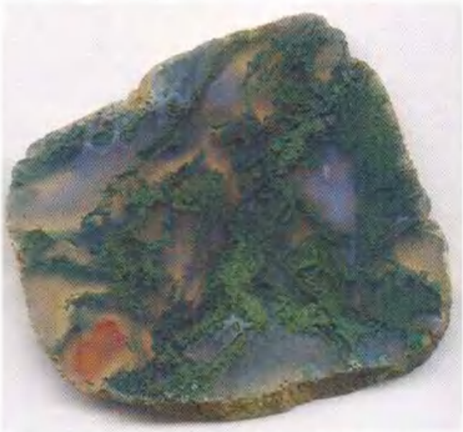

Agate, 140 mm, Horní Halze, Czech Republic

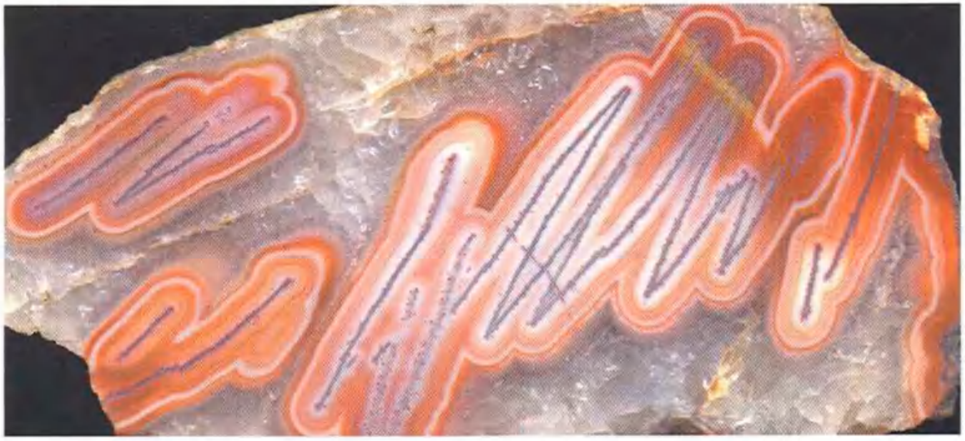

Agate, 60 mm, Brazil

localities in the USA; in Idar-Oberstein, Germany; in Podkrkonosi, Czech Republic. The most famous localities of onyx and sardonyx are in Brazil and Uruguay.

Rich aggregates of aventurine come from Miass, Ural mountains, Russia; Mariazell, Austria; Belany, India. Heliotrope occurs in Idar-Oberstein, Germany; Kozakov, Czech Republic and in Brazil.

Application: important raw material in glass industry, many colored varieties, like amethyst, smoky citrine, citrine, onyx, sardonyx, and heliotrope are cut as gemstones.

Aventurine, 50 mm, India

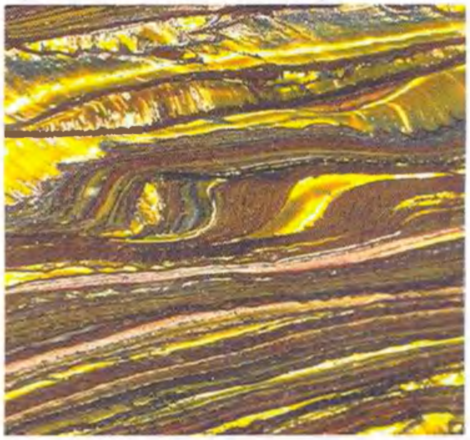
Tiger's eye, 50 mm, Griqualand, South Africa

Tridymite, 9 mm, Big Luc Mt., U.S.A.

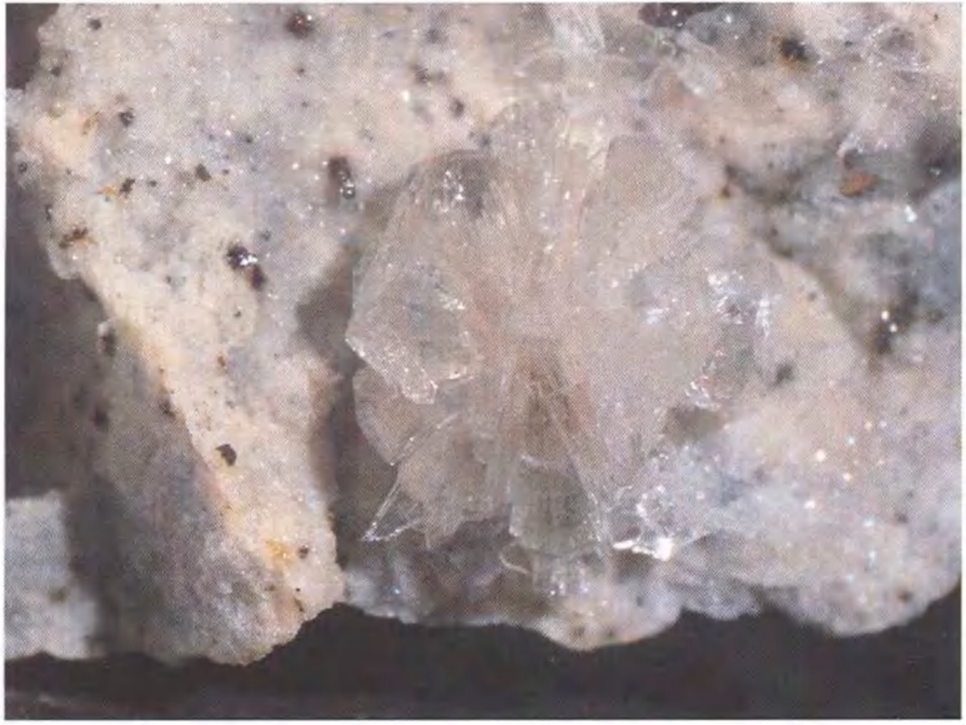

Tridymite

SiO_2

ORTHORHOMBIC ● ● ●

Properties: C – colorless to white; S – white; L – vitreous; D – transparent; DE – 2.3; H – 6.5-7; CL – none; F – conchoidal; M – pseudo-hexagonal tabular crystals.

Origin and occurrence: Magmatic in cavities of young felsic volcanic rocks in association with cristobalite, chalcedony and other minerals. Pseudo-hexagonal tabular crystals up to 10 mm (3/8 in) in size, come from Vechec, Slovakia. Similar crystals found in Ichigayama, Japan. Crystals up to 10 mm (3/8 in) occur with topaz and other minerals in the Thomas Range, Utah, USA.

Cristobalite, 110 mm, Vechec, Slovakia

Cristobalite

SiO_2

TETRAGONAL ● ● ●

Varieties: lussatite (fibrous)

Properties: C – colorless to white; S – white; L – vitreous; D – translucent; DE – 2.3; H – 6.5; CL – none; M – pseudo-octahedral crystals, spherical and botryoidal aggregates.

Origin and occurrence: Magmatic in cavities of young felsic volcanic rocks, associated with tridymite. Crystals up to 4 mm (5/32 in) are known from Cerro San Cristobal, Hidalgo, Mexico. Crystals up to 2 mm (1/16 in) long occur in Vechec, Slovakia. Gray spherical aggregates come from Coso Hot Springs, California, USA.

Common opal, 60 mm, Křemže, Czech Republic

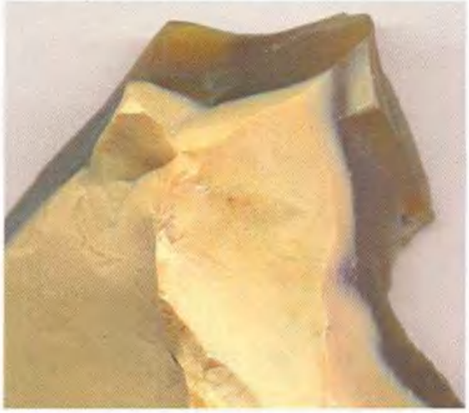

Opal, 50 mm, Herlany, Slovakia

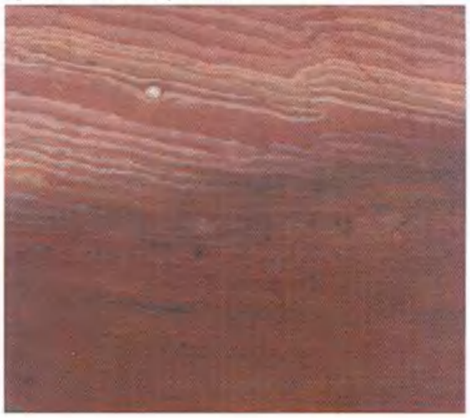

Opal

$SiO_2 . n H_2O$

AMORPHOUS ●●●●●

Varieties: hyalite, milky opal, fire opal, precious opal, wooden opal, geysirite.

Properties: C – colorless (hyalite), white (milky opal), red (fire opal), iridescence (precious opal), brown, red-brown, yellow, green, gray, blue; S – white; L – vitreous, dull, earthy, waxy; D – transparent to translucent, opaque; DE – 2.1; H – 5.5-6.5; CL – none; F – conchoidal; M – botryoidal and stalactitic aggregates, coatings, concretions, geodes, massive; LU – white, yellow-green, green.

Origin and occurrence: Hydrothermal in volcanic rocks and tuffs, also in various types of volcanic rocks and tuffites, in different types of sedimentary rocks, in organic remnants and hot springs, rare in

Hyalite, 45 mm, Valec, Czech Republic

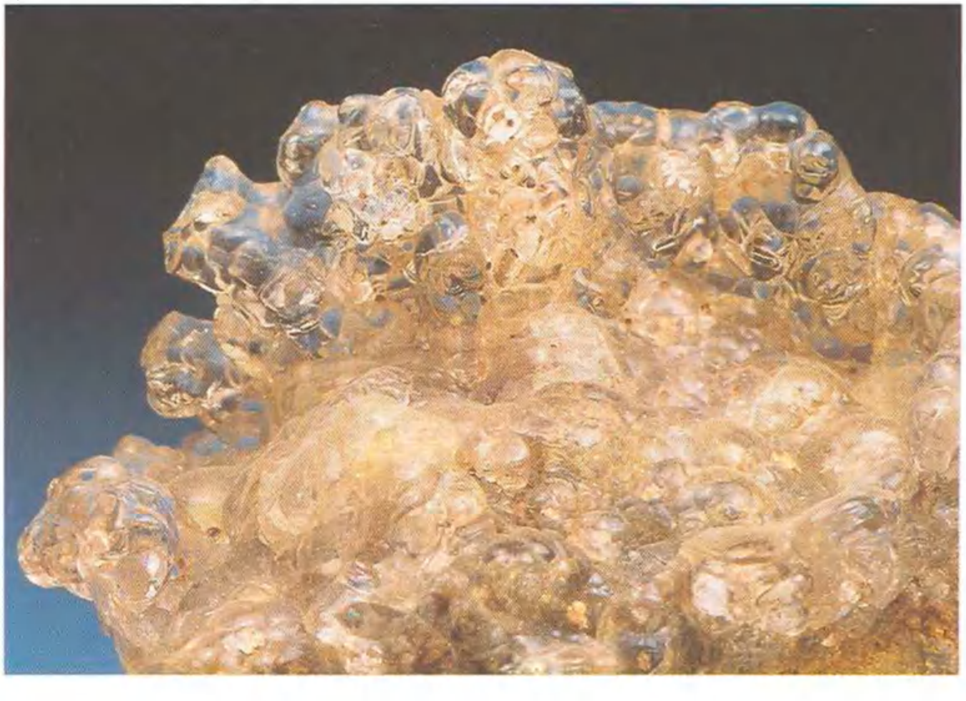

Opal, 47 mm, Opal Butte, U.S.A.

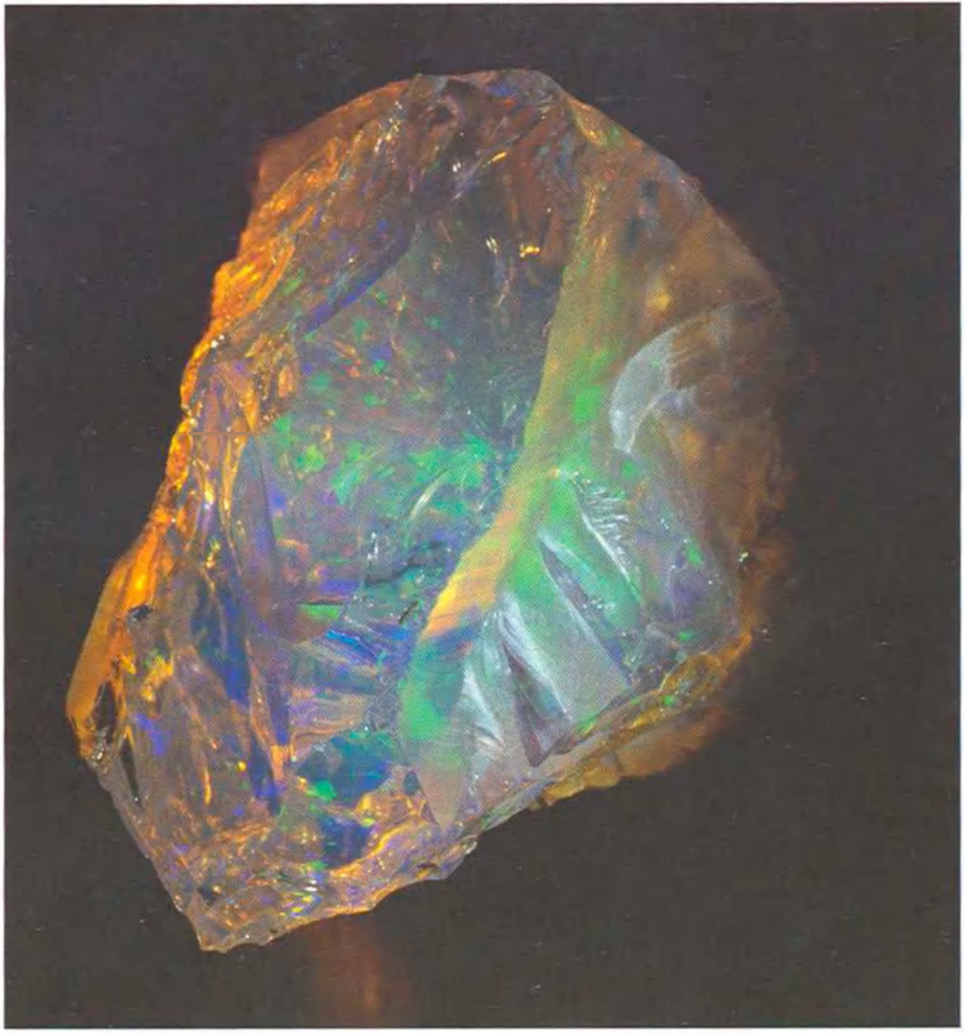

Wooden opal, 40 mm, Lubietová, Slovakia

hydrothermal veins; secondary in the weathering zone of different types of rocks. It is often associated with chalcedony. Coatings and stalactitic aggregates of hyalite up to 50 mm (2 in) thick known from Cerritos, Mexico; Valec, Czech Republic; Klamath Falls, Oregon, USA. Milky opal occurs in Dubník, Slovakia; Smrcek, Czech Republic and many other localities. The most famous locality of fire opal is Zimapan, Hidalgo, Mexico. Precious opal comes from many localities in Australia, e.g. Baracoo River, Queensland; Coober Pedy, Southern Australia and White Cliffs, New South Wales, where it forms rich aggregates and veinlets in sandstones; classic locality is Dubnik, Slovakia, where it occurs in

Dendritic opal, 56 mm, Křemže, Czech Republic

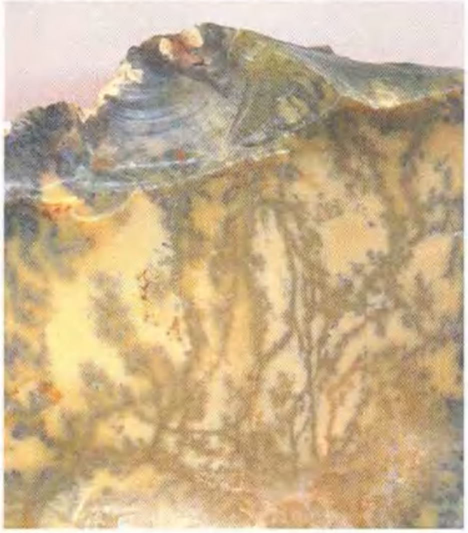

Fire opal, 20 mm, Mexico

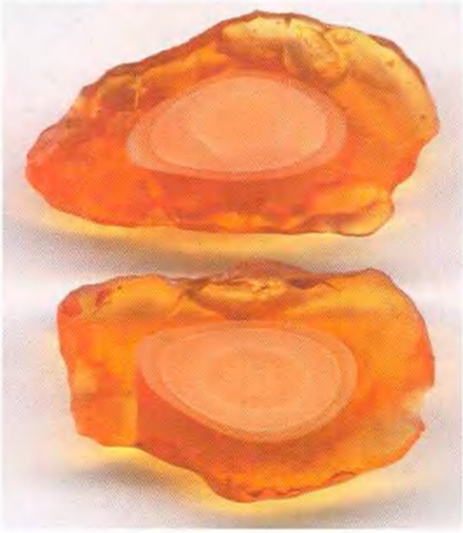

andesites and was probably mined already by ancient Romans. Beautiful precious opals come also from the Virgin Valley, Nevada, USA. Petrified trees, known as wooden opal, reach lengths of several meters in the Petrified Forest National Park, Holbrook, Arizona, USA; in L'ubietova and Povraznik, Slovakia. White geysirite is known mainly from the hot springs in Iceland; Yellowstone National Park, Wyoming, USA; New Zealand.

Application: colored opal varieties, primarily precious opal and fire opal are cut as gemstones, diatomite in chemical industry.

Precious opal, 55 mm, Opal Butte, U.S.A.

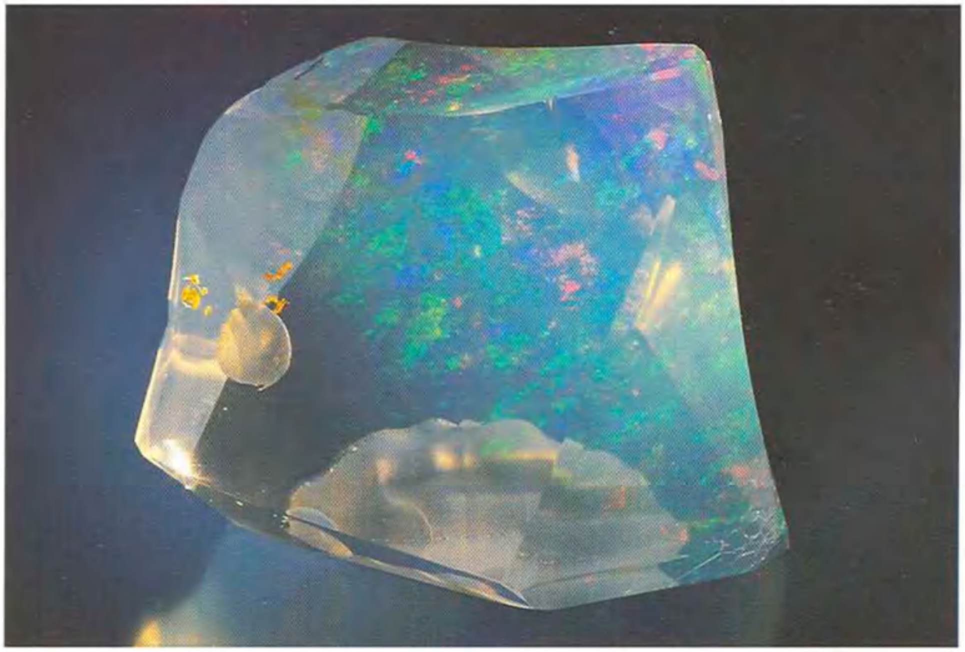

Melanophlogite, 80 mm, Fortullino, Italy

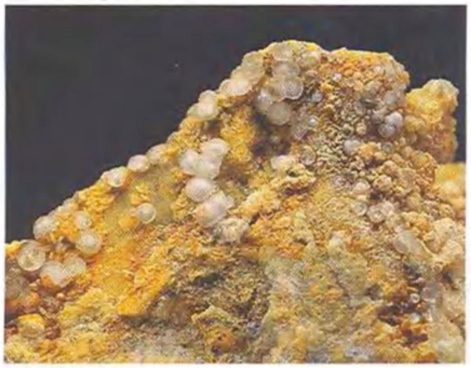

Melanophlogite

SiO_2

CUBIC ●

Properties: C – colorless, white; S – colorless; L – vitreous; D – transparent; DE – 2; H – 6.5; CL – none; M – pseudo-cubic crystals, spherical aggregates.
Origin and occurrence: Hydrothermal, associated with sulfur and other minerals. It was originally described from the sulfur deposit in Racalmuto, Sicily, Italy as crystals up to 4 mm (5/32 in) in size. It is also known from Chvaletice, Czech Republic, where it forms crystals up to 2 mm (1/16 in) in size, in Alpine-type veins.

Rutile

TiO_2

TETRAGONAL ● ● ● ●

Properties: C – red-brown, red, brown, yellowish, black; S – light brown; L – metallic to adamantine; D – transparent to translucent; DE – 4.2; H – 6-6.5; CL – good; F – conchoidal to uneven; M – short prismatic, striated crystals, common twins, acicular crystals, granular, massive.
Origin and occurrence: Magmatic and metamorphic, also in placers, together with monazite-(Ce), topaz, beryl, quartz and other minerals. The largest crystals up to 150 mm (6 in) in size come from the Mount Graves, Georgia, USA. Beautiful epitaxial intergrowths with hematite occur in Cavradischlucht, St. Gotthard, Switzerland and in Ibitiara, Bahía, Brazil. It is common as inclusions in smoky citrine (quartz) crystals from Ibitiara, Bahia and Itabira, Minas Gerais, Brazil. Knee-like crystal twins up to 70 (2¾ in) cm in size were found in the vicinity of Golcuv Jenikov and Sobeslav, Czech Republic.
Application: Ti ore.

Rutile, 21 mm, Ibitiara, Brazil

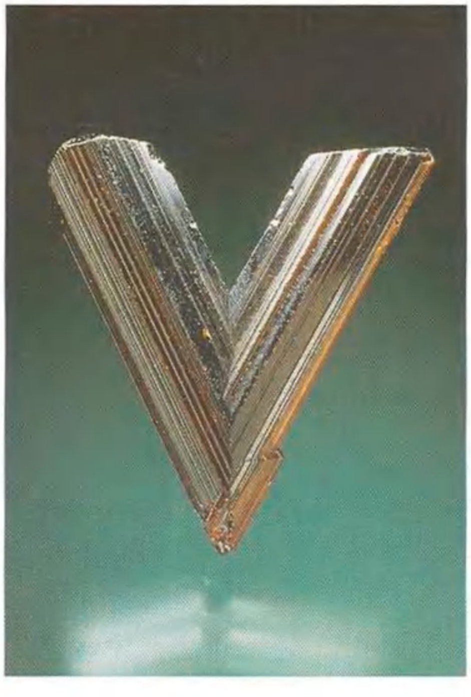

Rutile, 48 mm, Bahía, Brazil

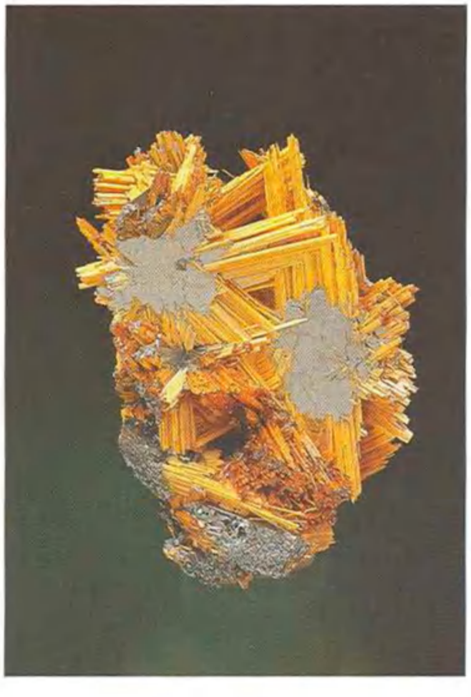

Cassiterite, 110 mm, Yunnan, China

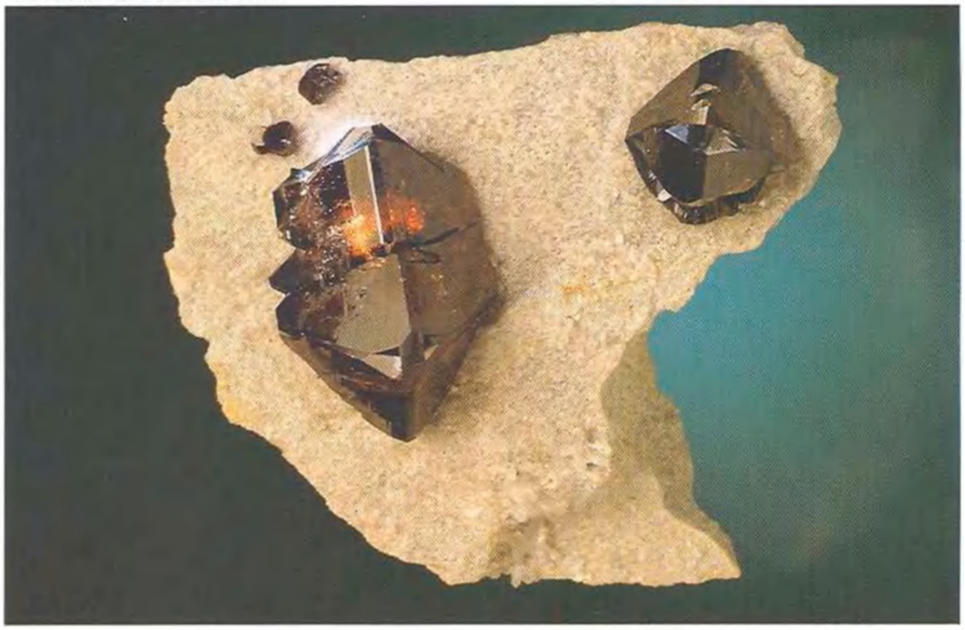

Cassiterite

SnO_2

TETRAGONAL ● ● ● ●

Properties: C – colorless, brown, black; S – white, grayish, brown; L – metallic to adamantine, dull; D – transparent to opaque; DE – 6.3-7.2; H – 6-7; CL – imperfect; F – conchoidal to uneven; M – dipyramidal and short prismatic crystals, multiple twins, granular, massive.
Origin and occurrence: Magmatic in pegmatites, hydrothermal in high-temperature deposits, metamorphic and in placers, together with wolframite, topaz and other minerals. Crystal twins up to 150 mm (6 in) in size come from Horni Slavkov, Czech Republic. Crystals of similar size were also found in Panasqueira, Portugal. Fine twins up to 80 mm ($3\frac{1}{8}$ in) were found in Rossarden, Tasmania, Australia. Crystals up to 70 mm (2¾ in) in size were found in Llallagua, colorless and transparent crystals up to 50 mm (2 in) in size in Viloco, Bolivia. Crystals up to 110 mm ($4\frac{5}{16}$ in) occurred lately in Tenkergin, Chukotka, Russia. Crystals up to 130 mm ($5\frac{2}{16}$ in) in size are known from pegmatites in Minas Gerais, Brazil (Fazenda do Funil). New finds of shiny crystals up to 100 mm (4 in) long were made in Hunan and Yunnan provinces, China.
Application: Sn ore.

Plattnerite

PbO_2

TETRAGONAL ● ●

Properties: C – black; S – brown; L – metallic to adamantine; D – opaque; DE – 9.6; H – 5.5; CL – none; M – acicular crystals, botryoidal aggregates, massive.
Origin and occurrence: Secondary, as a result of the oxidation of other Pb minerals, together with pyromorphite, hemimorphite and other minerals. Fine crystals come from Mina Ojuela, Mapimi, Durango, Mexico and from the Blanchard mine, New Mexico, USA. Botryoidal aggregates, weighing up to 100 kg (220 lb), were found in the Morning mine, Mullan, Idaho, USA.

Plattnerite, 150 mm, Mapimi, Mexico

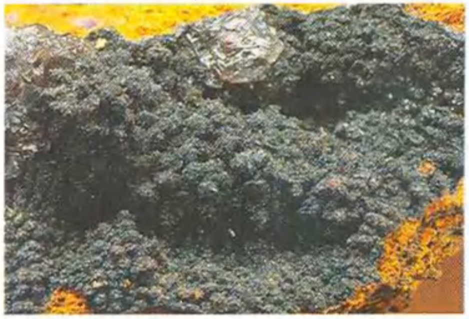

Pyrolusite, 88 mm, Baraga, U.S.A.

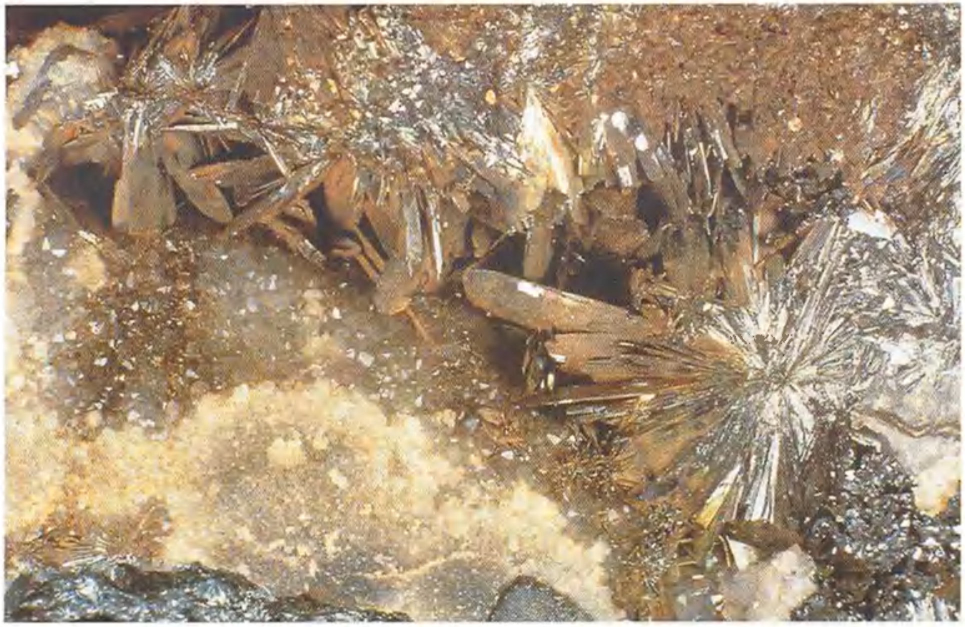

Pyrolusite

MnO_2

TETRAGONAL ● ● ● ●

Properties: C – black, steel-gray; S – black; L – metallic to dull; D – opaque; DE – 5.1; H – 6-6.5; CL – perfect; F – uneven; M – prismatic to acicular striated crystals, stalactitic and botryoidal aggregates, granular, massive.

Origin and occurrence: Secondary, as a result of alteration of manganite and other primary Mn minerals, also hydrothermal. Crystals up to 20 mm ($^{25}/_{32}$ in) long come from Horní Blatna, Czech Republic. Radial shiny aggregates were found in Ohrenstock, Germany. It occurred in Ilfeld, Germany, too. Large sedimentary Mn deposits, where pyrolusite is the main constituent, are known near Chiaturi, Georgia or near Nikopol, Ukraine. Crystals are reported also from Tsumeb, Namibia and Hotazel, South Africa.

Application: important Mn ore.

Hollandite

$Ba(Mn^{4+},Mn^{2+})_8O_{16}$

MONOCLINIC ● ● ●

Properties: C – gray-black; S – black; L – submetallic; D – opaque; DE – 5; H – 6; CL – good; M – short prismatic crystals, racemous and columnar aggregates.

Origin and occurrence: Metamorphic in Mn deposits with braunite, scheelite and other minerals, also secondary. Crystals up to 5 mm ($^{3}/_{16}$ in) long come from the Bradshaw mountains, Arizona, USA. It is common in the metamorphosed Mn deposits in Ultevis, Sweden; in Nagpur and Balaghat, India.

Coronadite

$Pb(Mn^{4+},Mn^{2+})_8O_{16}$

TETRAGONAL ● ● ●

Properties: C – black, black-gray; S – brown-black; L – submetallic to dull; D – opaque; DE – 5.4; H – 4.5-5.5; M – botryoidal crusts with fibrous structure, massive.

Origin and occurrence: Secondary in the oxidation zone of Mn deposits. Spherical aggregates up to 100 mm (4 in) in diameter come from the Bou Tazoult mine, Imini, Morocco. Small crystals were found in the Beltana mine, Southern Australia, Australia and in the Silver Bill mine, Arizona, USA.

Todorokite

$(Mn^{2+},Ca,Mg)Mn^{4+}{}_3O_7 . H_2O$

MONOCLINIC ● ● ●

Properties: C – gray, brown-black, black; S – brown;

L – metallic to dull; D – opaque; DE – 3.5-3.8; H – 1; CL – perfect; M – platy crystals, stalactitic and nodular aggregates.
Origin and occurrence: Secondary mineral, as a result of the oxidation of Mn minerals. Crystals are reported from several mines in the Kalahari region, South Africa (Hotazel, Smart). It was originally described from the Todoroki mine, Hokkaido, Japan. It is an important constituent of oceanic Mn concretions.

Ferrotapiolite

$FeTa_2O_6$

TETRAGONAL ● ● ●

Properties: C – black, brown; V – red-brown; L – submetallic, adamantine, resinous; D – opaque; DE – 7-7.8; H – 6-6.5; CL – none; F – uneven to conchoidal; M – dipyramidal and short prismatic crystals, massive.
Origin and occurrence: Magmatic in pegmatites, together with manganotantalite, microlite, cassiterite and other minerals. Crystals up to 40 mm ($1^{9}/_{16}$ in) in size are known from the vicinity of Governador Valadares, Minas Gerais, Brazil. A crystal 120 mm ($4^{7}/_{16}$ in) long has been described from Angarf, Morocco. Short prismatic crystals come from pegmatites near Topsham and Paris, Maine, USA.

Ilmenorutile

$(Ti,Nb,Fe)O_2$

TETRAGONAL ● ● ●

Properties: C – black; S – brown; L – submetallic; D – opaque; DE – 4.2; H – 6-6.5; CL – good; F – conchoidal to uneven; M – prismatic crystals, granular.
Origin and occurrence: Magmatic in pegmatites, together with schorl, zircon, fluorapatite and other minerals. Prisms several cm long come from Udraz near Pisek, Czech Republic. It is also known from the vicinity of Miass, Ural mountains, Russia and Evje, Norway.

Todorokite, 60 mm, Kamogun, Japan

Ferrotapiolite, 60 mm, Maršikov, Czech Republic

Ilmenorutile, 10mm x, Pisek, Czech Republic

Anatase

TiO_2

TETRAGONAL ● ● ●

Properties: C – black-gray, brown, red-brown, blue, rare colorless; S – white; L – submetallic to adamantine; D – transparent to opaque; DE – 3.8-4; H – 5.5-6; CL – perfect; F – conchoidal; M – dipyramidal and tabular crystals.
Origin and occurrence: Hydrothermal in the Alpine-type veins, associated with brookite and quartz, also sedimentary and metamorphic. Beautiful crystals up to 50 mm (2 in) long were found in Alpa Lercheltini, Binntal, Switzerland. Famous black-blue crystals reaching up to 30 mm ($1^3/_{16}$ in) come from Matskorhae, Hardangervidda, Norway. Crystals up to 15 mm ($1^9/_{32}$ in) were recently found in Dodo, Polar Ural, Russia. Crystals up to 30 mm ($1^3/_{16}$ in) in size occurred in the Old Lot and Vulcan mines, Colorado, USA.

Tellurite

TeO_2

ORTHORHOMBIC ● ●

Properties: C – yellow, yellow-orange; S – yellowish; L – adamantine; D – transparent; DE – 5.8; H – 2; CL – perfect; M – acicular and thin tabular crystals, radial aggregates, pulverulent.
Origin and occurrence: Secondary, resulting from the oxidation of AuBTe ores. Crystals up to 10 mm ($^3/_8$ in) long occurred in the Kawazu and Susaki mines, Japan. Beautiful specimens were found in Moctezuma, Sonora, Mexico; it also comes from Cripple Creek, Colorado, USA.

Brookite

TiO_2

ORTHORHOMBIC ● ● ●

Properties: C – light to dark brown, yellow-brown, black; S – white to gray; L – submetallic to adamantine; D – transparent to translucent, opaque; DE – 4.1; H – 5.5-6; CL – imperfect; F – conchoidal to uneven; M – tabular, dipyramidal, long and short prismatic crystals.
Origin and occurrence: Hydrothermal along the fissures of the Alpine-type veins and in granitic and alkaline pegmatites; it occurs as pseudo-morphs after titanite and ilmenite; also in sedimentary rocks. Perfect tabular crystals up to 50 mm (2 in) in size found in Rieder Tobel, Switzerland; Magnet Cove, Arkansas, USA; Passo di Viza, Italy. New finds of crystals up to 50 mm in size made in Dodo, Polar Ural, Russia.

Anatase, 16 mm, Hardangervidda, Norway

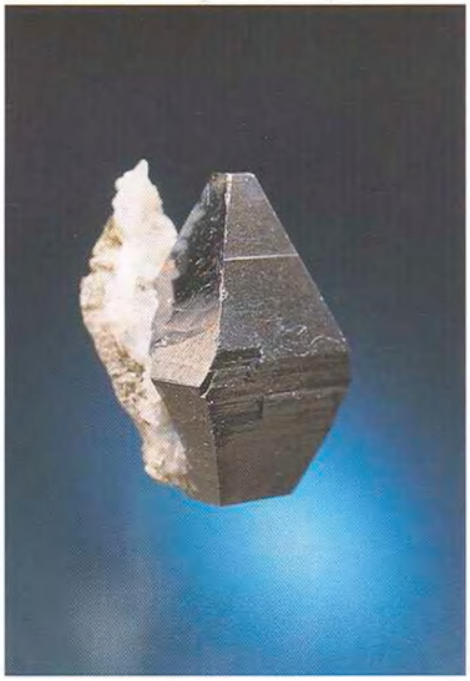

Brookite, 50 mm, Puiva, Polar Urals, Russia

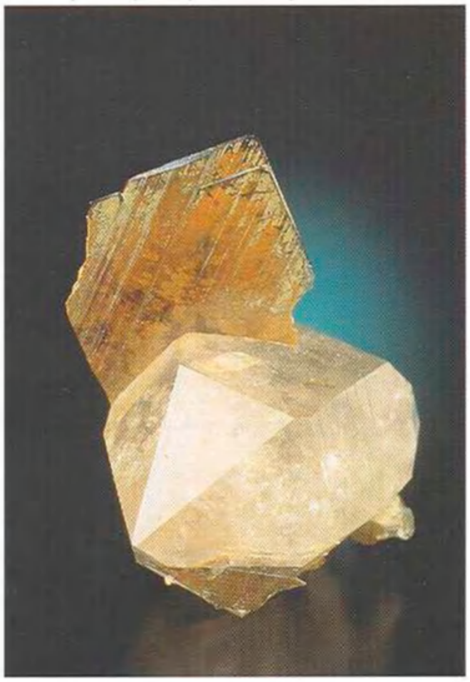

Tellurite, 1 mm x, Fata Baii, Romania

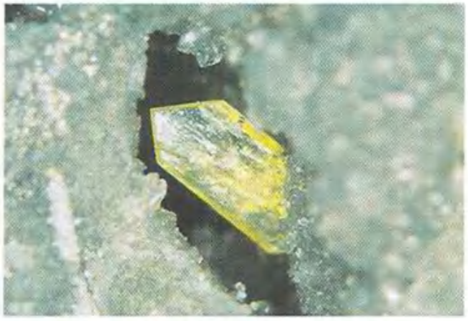

Ferberite

$FeWO_4$

MONOCLINIC ● ● ●

Properties: C – black; S – brown-black to black; L – submetallic; D – opaque; DE – 7.5; H – 4-4.5; CL – perfect; F – uneven; M – short prismatic to tabular crystals, granular, massive.
Origin and occurrence: Hydrothermal in high- to medium-temperature ore veins, in greisens and skarns; rare magmatic in granitic pegmatites and granites; it also occurs in placers. It is usually associated with cassiterite, scheelite, sulfides and quartz. Perfect tabular crystals up to 120 mm ($4\,^{7}/_{16}$ in) in size found in the Quartz Creek mine, Colorado, USA; also in Cínovec, Czech Republic; Panasqueira, Portugal; Ehrenfriedersdorf, Germany and Potosí, Bolivia.
Application: W ore.

Hübnerite

$MnWO_4$

MONOCLINIC ● ● ●

Properties: C – yellow-brown, red-brown, black; S – yellow-brown to black-gray; L – submetallic; D – translucent to opaque; DE – 7.2; H – 4-4.5; CL – perfect; F – uneven; M – short prismatic to tabular crystals, granular, massive.
Origin and occurrence: Hydrothermal in high- to medium-temperature ore veins, in greisens; rarely magmatic in granitic pegmatites; also in placers. Perfect tabular to short prismatic crystals up to 25 cm ($9\,^{13}/_{16}$ in) in size, come from the Huayllapon mine, Pasto Bueno, Peru; also from Baia Sprie, Romania; Kara-Oba, Kazakhstan; the Sweet Home mine, Alma and Silverton, Colorado, USA.
Application: W ore.

Ferberite, 68 mm, Mundo Nuovo, Peru

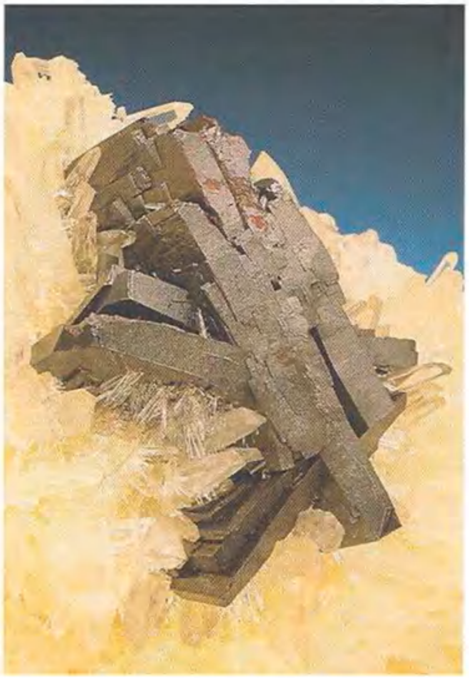

Hubnerite, 39 mm, Silverton, U.S.A.

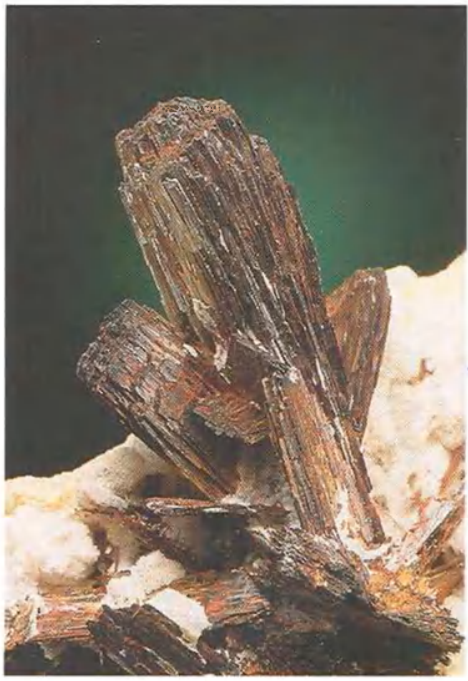

Titanowodginite, 20 mm, Tanco, Canada

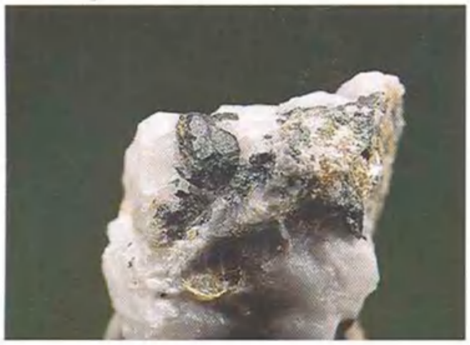

Titanowodginite

$MnTiTa_2O_8$

ORTHORHOMBIC ●

Properties: C – dark brown, black; S – dark brown; L – submetallic; D – translucent to opaque; DE – 6.9; H – 5.5; CL – imperfect; F – uneven; M – dipyramidal crystals, granular.

Origin and occurrence: Magmatic in granitic pegmatites. Dipyramidal crystals up to 10 mm ($\frac{3}{8}$ in) long occur in the Tanco mine, Bernic Lake, Manitoba, Canada.

Application: Ta ore.

Ferrocolumbite, 90 mm, Middletown, U.S.A.

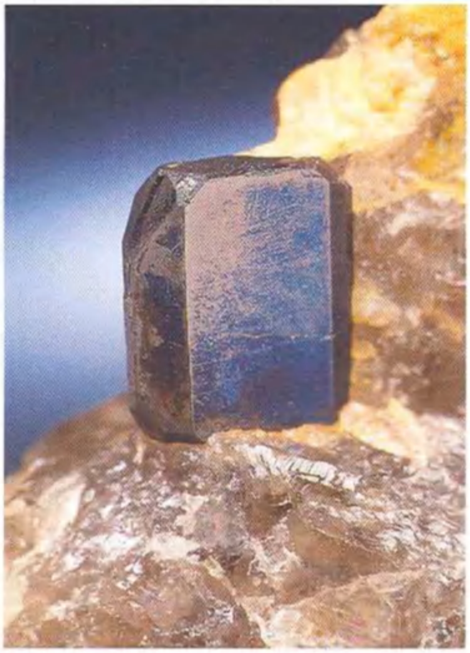

Ferrocolumbite

$FeNb_2O_6$

ORTHORHOMBIC ● ● ●

Properties: C – black, red-brown; S – red-brown to black; L – submetallic; D – translucent to opaque; DE – 5.2; H – 6; CL – good; F – uneven to conchoidal; M – long to short prismatic and tabular crystals, granular, massive.

Origin and occurrence: Magmatic in granitic pegmatites and granites; rare hydrothermal in high-temperature ore veins and in greisens; also in placers. Tabular crystals up to 1 m ($39\frac{3}{8}$ in) in size occur in granitic pegmatites near Custer and Keystone, South Dakota, USA; in Malakialina, Madagascar; Ichikawa, Japan; masses, weighing up to 270 kg (594 lb) come from the Meyers quarry, Colorado, USA.

Application: Nb ore.

Manganotantalite

$MnTa_2O_6$

ORTHORHOMBIC ● ● ●

Properties: C – red, red-brown, black-brown, black; S – dark red to black; L – submetallic; D – translucent to opaque; DE – 8.0; H – 6-6.5; CL – good; F – uneven

Manganotantalite, 19 mm, Nuristan, Afghanistan

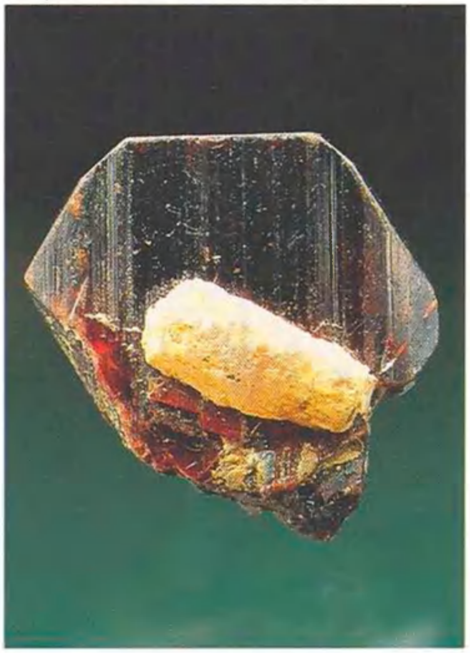

Euxenite-(Y), 40 mm, Ambatofotsy, Madagascar

to conchoidal; M – prismatic to tabular crystals, granular, massive.
Origin and occurrence: Magmatic in granitic pegmatites and granites; also in placers. Crystals up to 100 mm (4 in) in size come from Li-bearing pegmatites in the Tanco Mine, Bernic Lake, Manitoba, Canada; also from Sao Jose da Safira, Minas Gerais, Brazil.
Application: Ta ore.

Euxenite-(Y)

$(Y,Ce,U,Th)(Nb,Ta,Ti)_2O_6$

ORTHORHOMBIC ● ●

Properties: C – black with brownish and green hues; S – gray, yellowish, brownish; L – submetallic, resinous; D – translucent to opaque; DE – 4.6; H – 6; CL – none; F – conchoidal; M – tabular crystals, granular, massive; R – locally weakly radioactive, commonly metamict.
Origin and occurrence: Magmatic in granitic and alkaline pegmatites; also in placers. Typically associated with monazite-(Ce), zircon, ilmenite and other oxides of rare earth elements. Crystals up to 150 mm (6 in) in size are known from Kragero and Hitterö, Norway; from Ankazobe, Madagascar.

Aeschynite-(Ce)

$(Ce,Ca)(Ti,Nb)_2O_6$

ORTHORHOMBIC ● ●

Properties: C – black, red-brown, yellow; S – red-yellow; L – vitreous, resinous, adamantine; D – translucent to opaque; DE – 5.0; H – 5.5; CL – none; F – conchoidal; M – prismatic and tabular crystals, granular, massive; R – locally weakly radioactive, commonly metamict.
Origin and occurrence: Magmatic in alkaline and granitic pegmatites and carbonatites. It is associated with zircon and oxides of rare earth elements. Crystals up to 190 mm ($7^{3}/_{16}$ in) long occur in Quadeville, Ontario, Canada; other localities are Kragero, Norway; Trout Creek Pass, Colorado, USA.

Aeschynite-(Ce), 45 mm, Hittero, Norway

Stibiotantalite

$SbTaO_4$

ORTHORHOMBIC ● ●

Properties: C – yellow, yellow-brown, red-brown, yellow-green; S – yellow-brown; L – submetallic, vitreous, resinous; D – transparent to translucent; DE – 7.5; H – 5-5.5; CL – good; F – uneven to conchoidal; M – prismatic, tabular and dipyramidal crystals, granular, massive.
Origin and occurrence: Magmatic in granitic pegmatites; also in placers. Crystals up to 120 mm ($4^{7}/_{16}$ in) in size occur in Muiane, Alto Ligonha, Mozambique; also found in the Little Three mine, Ramona, and the Himalaya mine, Mesa Grande, California, USA. Also known from Greenbushes, Western Australia, Australia.
Application: Ta ore.

Stibiotantalite, 10 mm grain, Dobrá Voda, Czech Republic

Uraninite

UO_2

CUBIC ● ● ● ●

Properties: C – black, black-brown, black-gray; S – black, black-brown to greenish; L – submetallic, greasy, earthy; D – opaque; DE – 7.5-10,6; H – 5-6. earthy aggregates 3; CL – imperfect; F – uneven to conchoidal; M – cubic crystals, botryoidal aggregates, granular. massive; R – strong radioactive.
Origin and occurrence: Mainly hydrothermal in ore veins, skarns; magmatic in granitic pegmatites; in sedimentary rocks; also in placers. Usually associated with other U minerals, e.g. coffinite and secondary alteration products, mainly U micas. Perfect crystals up to 100 mm (4 in) in size and weighing up to 2.5 kg (5 lb 8 oz) come from the Fissure mine, Wilberforce, Ontario, Canada, where they occur in simple pegmatites, cross-cutting marbles.
Crystals are also known from Dieresis, Spain and Shinkolobwe, Zair. Rich botryoidal aggregates were found in Jachymov and Slavkovice, Czech Republic; in Bois-Noirs and Margnac, France.
Application: U ore.

Uraninite, 8 mm x, Portland, U.S.A.

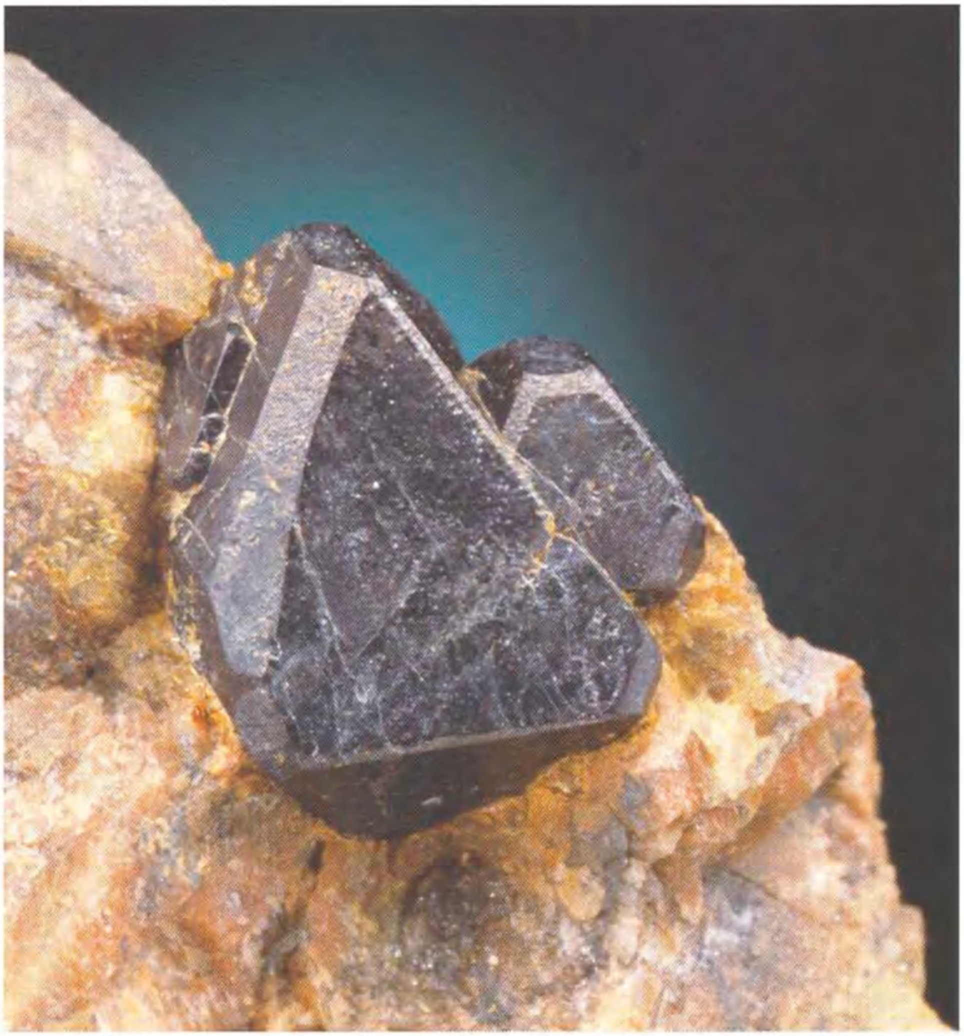

Gibbsite, 80 mm, Gamba, Brazil

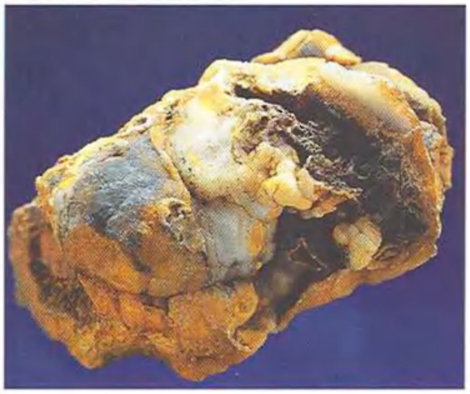

Gibbsite

$Al(OH)_3$

MONOCLINIC ● ● ●

Properties: C – colorless, gray, white, greenish; S – white; L – vitreous, pearly; D – transparent to translucent; DE – 2.4; H – 2.5-3.5; CL – perfect; F – uneven; M – tabular crystals, lamellar and earthy aggregates, coatings and stalactitic films, granular, massive.

Origin and occurrence: Hydrothermal as a product of alteration Al-rich rocks; secondary in the oxidation associated with goethite; metamorphic in weakly metamorphosed Al-rich rocks, typically with diaspore; a constituent of bauxites. Tabular crystals up to 100 mm (4 in) in size were found in Zlatoust, Ural mountains, Russia; also in Villa Rica, Minas Gerais, Brazil.

Brucite

$Mg(OH)_2$

TRIGONAL ● ● ●

Properties: C – colorless, gray, white, bluish, blue, yellow, brown; S – white; L – vitreous, pearly; D – transparent to translucent; DE – 2.4; H – 2.5; CL – perfect; F – uneven; M – tabular crystals, foliated, acicular and earthy aggregates, granular, massive.

Origin and occurrence: Hydrothermal in veins in serpentinites or dolomitic marbles, a product of periclase alteration; rare metamorphic in skarns and marbles. Perfect crystals up to 18 cm in size, come from the Low's mine, Pennsylvania and the Tiliy Foster mine, New York, USA; also known from Asbestos, Quebec, Canada; Predazzo, the Alps, Italy; blue crystals up to 50 mm (2 in) in size were found in the Bazhenovskoye deposit, Azbest, Ural mountains, Russia.

Brucite, 30 mm, Azbest, Russia

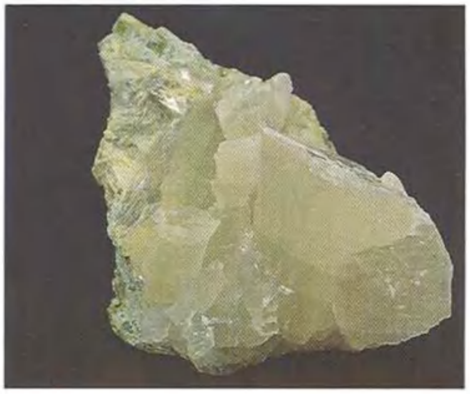

Diaspore

$AlO(OH)$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, gray, white, greenish, yellowish, pink, purplish; S – white; L – vitreous, pearly; D – transparent to translucent; DE – 3.4; H – 6.5-7; CL – perfect; F – conchoidal; M – tabular crystals, foliated aggregates, stalactitic films, granular, massive.

Origin and occurrence: Hydrothermal as a product of alteration Al-rich minerals, e.g. andalusite, typically with pyrophyllite and corundum; metamorphic in Al-rich rocks; a constituent of bauxites. Tabular crystals up to 120 mm ($4\frac{7}{16}$ in) in size come from Menderess, Turkey; also from Naxos, Greece; Chester, Massachusetts, USA.

Diaspore, 35 mm, Milas, Turkey

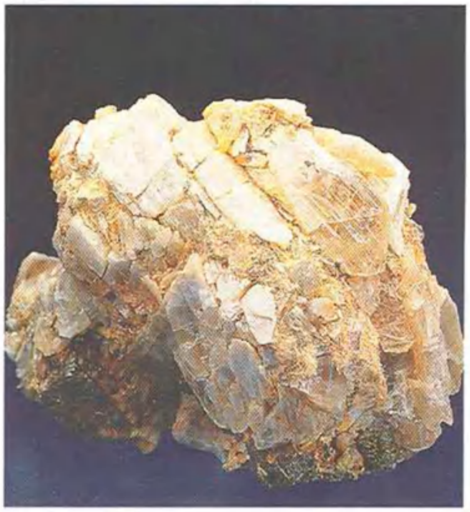

Goethite, 77 mm, Santa Eulalia, Mexico

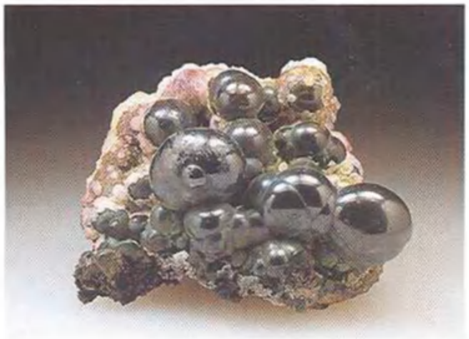

Goethite, 60 mm, Pribram, Czech Republic

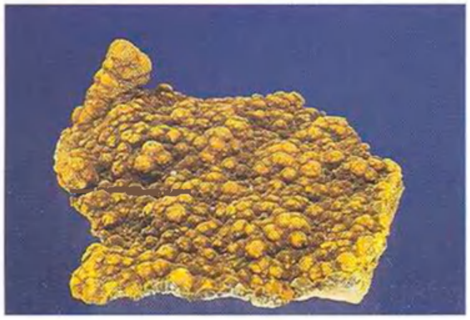

Goethite

$Fe^{3+}O(OH)$

ORTHORHOMBIC ● ● ● ● ●

Varieties: velvet ore

Properties: C – black-brown, yellow-brown, brown; S – yellow-brown; L – submetallic, metallic, silky, earthy; D – translucent to opaque; DE – 4.3; H – 5-5.5; CL – perfect; F – uneven to conchoidal; M – acicular to prismatic crystals, botryoidal aggregates, commonly with radial structure, coatings and stalactitic films, earthy, granular, massive.
Origin and occurrence: Secondary as one of the most common minerals of the oxidation zone of ore deposits, it forms a significant part of limonite; hydrothermal in ore veins, in cavities in pegmatites and volcanic rocks. It forms pseudo-morphs after pyrite and other Fe sulfides. Rich botryoidal aggregates of velvet ore with a velvety surface come from Príbram, Czech Republic; acicular crystals up to 50 mm (2 in) long are known from Bottalack and Redruth, Cornwall, UK; it also occurs in Siegen and Horhausen, Germany; in Florissant, Colorado, USA.
Application: Fe ore.

Lepidocrocite, 30 mm, Rudabanya, Hungary

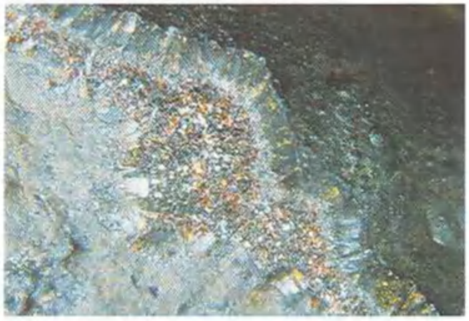

Manganite

$Mn^{3+}O(OH)$

MONOCLINIC ● ● ● ●

Properties: C – black to black-gray; S – red-brown to black; L – submetallic to dull; D – opaque; DE – 4.3; H – 4; CL – perfect; F – uneven to conchoidal; M – long to short prismatic crystals, acicular and earthy aggregates, concretions, granular, massive.
Origin and occurrence: Hydrothermal in low-temperature ore veins, together with quartz; secondary in the oxidation zone of ore deposits; sedimentary and rare metamorphic in Mn-rich rocks. Druses of black crystals up to 40 mm ($1\frac{9}{16}$ in) long come from the classic locality Ilfeld, Germany; it also occurs in Ohrenstock and Ilmenau, Germany; in Nikopol, Ukraine; in Sterling Hill, New Jersey, USA; in the N'Chwaning No. 2 mine, Kuruman, South Africa.
Application: Mn ore.

Lepidocrocite

$Fe^{3+}O(OH)$

ORTHORHOMBIC ● ● ●

Properties: C – dark red to red-brown; S – orange to brick-red; L – submetallic, adamantine to silky; D – transparent to opaque; DE – 4.0; H – 5; CL – perfect; F – uneven to conchoidal; M – tabular to short prismatic crystals, acicular, bladed and earthy aggregates, concretions, granular, massive.
Origin and occurrence: Secondary in the oxidation zone of ore deposits, overgrown on botryoidal goethite. It occurs together with goethite as a constituent of limonite, its tabular crystals and their aggregates are known from Herdorf, Germany and Rancie, France.

Manganite, 85 mm, Ilfeld, Germany

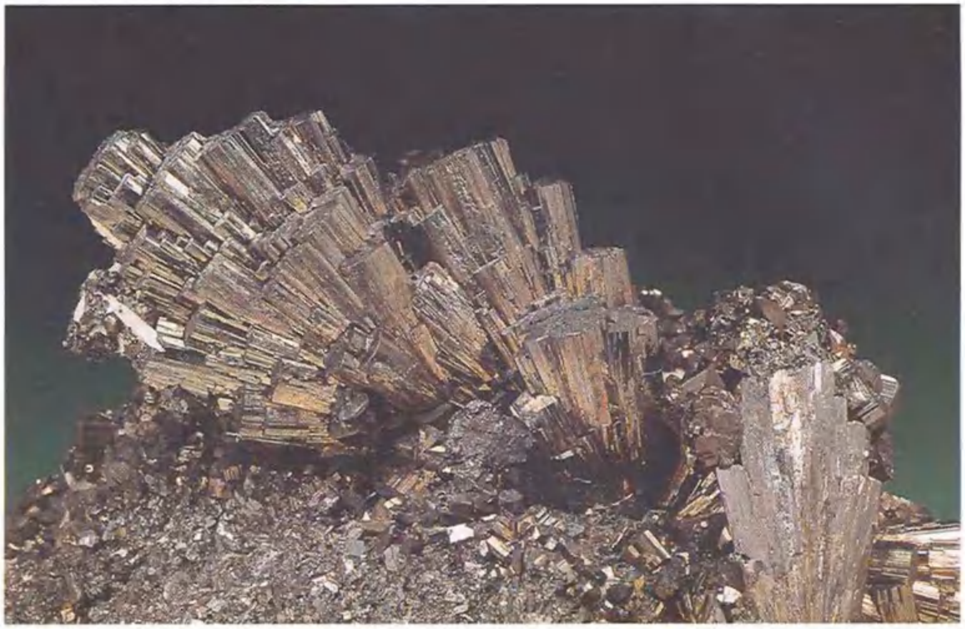

Lithiophorite

$(Al,Li)Mn^{4+}O_2(OH)_2$

MONOCLINIC ● ● ●

Properties: C – black, commonly with bluish tint; S – black-gray to black; L – metallic to dull; D – opaque; DE – 3.3; H – 3; CL – perfect; F – uneven; M – scaly crystals, botryoidal and earthy aggregates, coatings, granular, massive.
Origin and occurrence: Secondary in the oxidation zone of ore deposits and along the cracks in sedimentary rocks. Botryoidal aggregates occur in Schneeberg, Germany; Jivina and Zajecov, Czech Republic; Miyazaki, Japan.

Lithiphorite, 60 mm, Rangersdorf, Germany

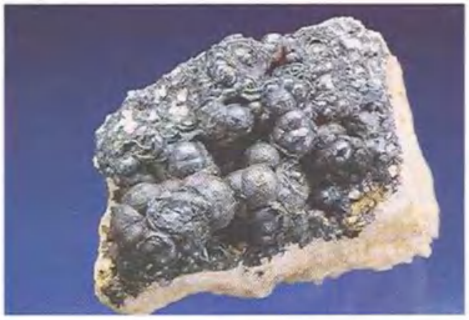

Curite

$Pb_2U_5O_{17} . 4 H_2O$

ORTHORHOMBIC ● ●

Properties: C – dark orange to red-orange; S – light orange; L – adamantine to earthy; D – transparent to translucent; DE – 7.4; H – 4-5; CL – good; F – uneven; M – acicular crystals, earthy aggregates, coatings, massive; R – strong radioactive.
Origin and occurrence: Secondary in the oxidation zone of U deposits, associated with other secondary U minerals, e.g. torbernite, kasolite and uranophane. Rich aggregates were found in Shinkolobwe, Zaire; also known from La Crouzille, France; South Alligator, Northern Territory, Australia.

Curite, 30 mm, Shinkolobwe, Zair

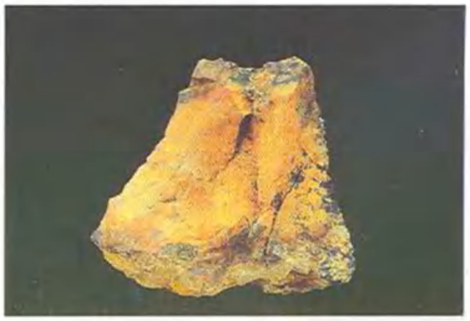

5. Carbonates

Magnesite

$MgCO_3$

TRIGONAL ●●●●

Properties: C – colorless, white, yellowish, brownish, black; S – white; L – vitreous to dull; D – transparent; DE – 3.1; H – 4; CL – perfect; F – conchoidal; M – rhombohedral and prismatic crystals, massive cleavable aggregates, earthy; LU – occasionally blue or green.
Origin and occurrence: Rarely magmatic, mainly hydrothermal metasomatic and metamorphic. The largest crystals are known from Brumado, Bahía, Brazil, reaching up to 1 m ($39\frac{3}{8}$ in) in size, embedded in metamorphosed dolomites. Crystals in cavities in the same locality are up to 50 mm (2 in) in size. Also crystals up to 50 mm (2 in) found in the Eugui quarries, Spain. Crystals up to 10 mm ($\frac{3}{8}$ in) across come also from Val Malenco, Italy. It prevails as massive aggregates, forming huge deposits, like Veitsch, Austria; Liao-Tung, China. Many deposits are located in Slovakia (Jelsavska Dubrava, Hnusta).
Application: heat-resistant material.

Calcite, 40 mm, Houghton Co., U.S.A.
Magnesite, 148 mm, Brumado, Brazil

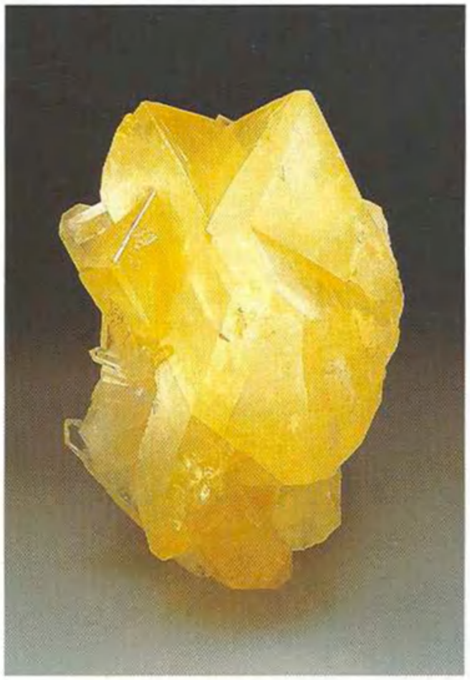

Smithsonite, 32 mm, Tsumeb, Namibia

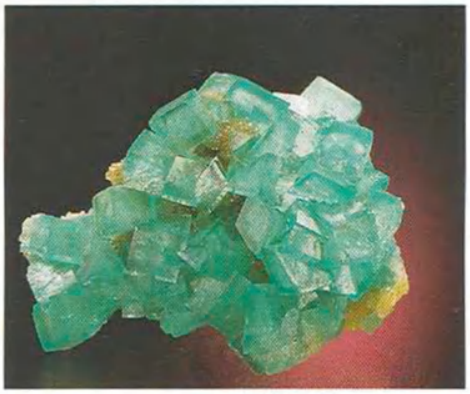

Smithsonite

$ZnCO_3$

TRIGONAL ●●●

Properties: C – white, gray, green, pink, blue; S – white; L – vitreous to pearly; D – transparent to translucent; DE – 4.4; H – 4-5; CL – perfect; F – conchoidal to uneven; M – rhombohedral crystals, botryoidal and stalactitic aggregates, massive; LU – sometimes green or blue.
Origin and occurrence: Supergene, as a result of oxidation of the primary Zn ores, associated with other supergene Pb minerals. The largest yellow scalenohedra crystals up to 40 mm ($1\frac{9}{16}$ in) in size come from Broken Hill, New South Wales, Australia. Pink crystals, up to 30 mm ($1\frac{3}{16}$ in) long occurred in Tsumeb, Namibia. World famous blue-green botryoidal crusts up to 100 mm (4 in) thick found in the Kelly Mine, Magdalena, New Mexico, USA. Nice aggregates and banded stalactites described from Monte Poni, Sardinia, Italy.

Smithsonite, 40 mm, New Mexico, U.S.A.

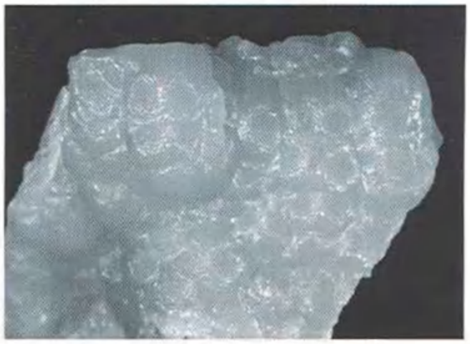

Siderite, 26 mm, Governador Valadares, Brazil

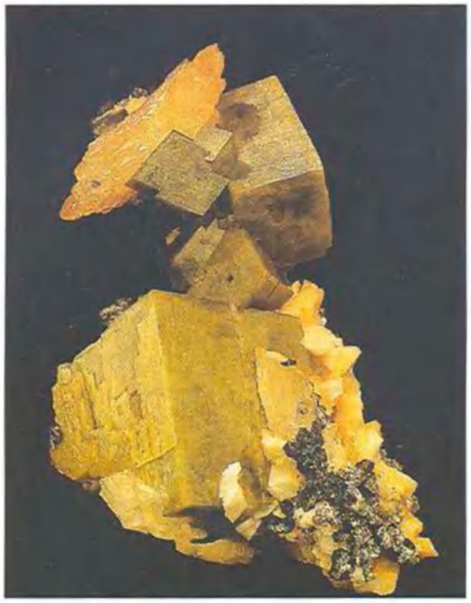

Siderite

$FeCO_3$

TRIGONAL ● ● ● ●

Properties: C – yellow, brown, black; S – yellowish-white; L – vitreous; D – translucent; DE – 4; H-4; CL – perfect; F – uneven to conchoidal; M – rhombohedral crystals, granular, massive.
Origin and occurrence: Hydrothermal in medium- and low-temperature deposits, sedimentary. Crystals up to 40 cm long found in Mont St.-Hilaire, Quebec, Canada. Crystals up to 100 mm (4 in) in size come from Panasqueira, Portugal. Crystals up to 30 mm ($1\frac{3}{16}$ in) in size occurred in Neudorf, Germany. Rhombs up to 20 mm ($\frac{25}{32}$ in) also found in Pribram, Czech Republic. Pseudo-morphs of goethite after siderite up to 70 mm (2¾ in) across described from Pikes Peak, Colorado, USA. Deposits of massive siderite in Erzberg and Huttenberg, Austria yielded crystals up to 50 mm (2 in) long. Fine crystals reported from Tavistock, Devon and Redruth, Cornwall, UK.
Application: important Fe ore.

Sfaerocobaltite

$CoCO_3$

TRIGONAL ● ● ●

Properties: C – pink, gray, brown; S – red; L – vitreous; D – transparent to translucent; DE – 4.1; H – 4; CL – perfect; M – scalenohedral and rhombohedral crystals, radial aggregates, massive.
Origin and occurrence: Secondary, as a product of the oxidation of primary Co minerals. The best specimens, with crystals up to 30 mm ($1\frac{3}{16}$ in) long, come from Zaire (Musonoi; Kakanda). Crystals up to 10 mm (4 in) long known from Bou Azzer, Morocco.

Sphaerocobaltite, 16 mm, Bou Azzer, Morocco

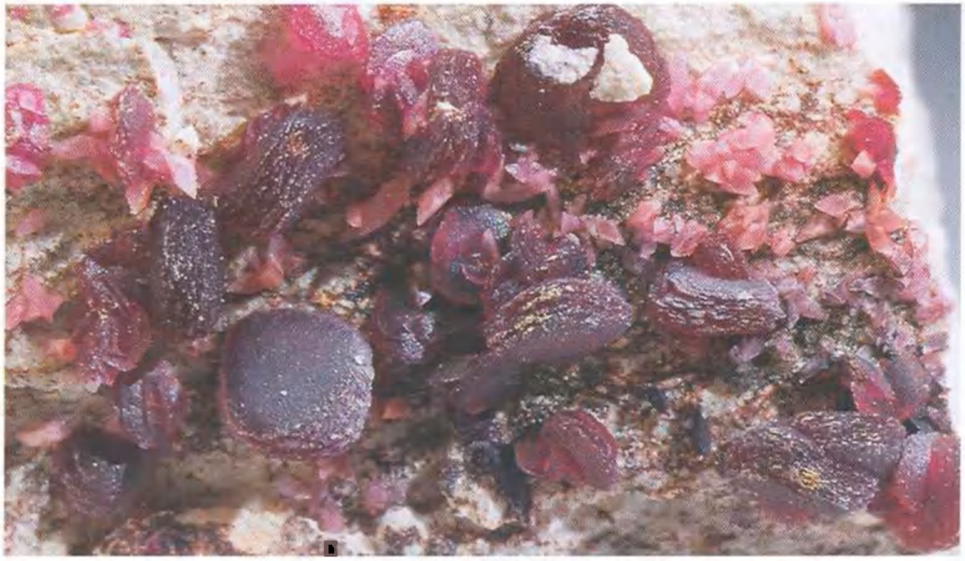

Rhodochrosite, 117 mm, Sweet Home Mine, U.S.A.

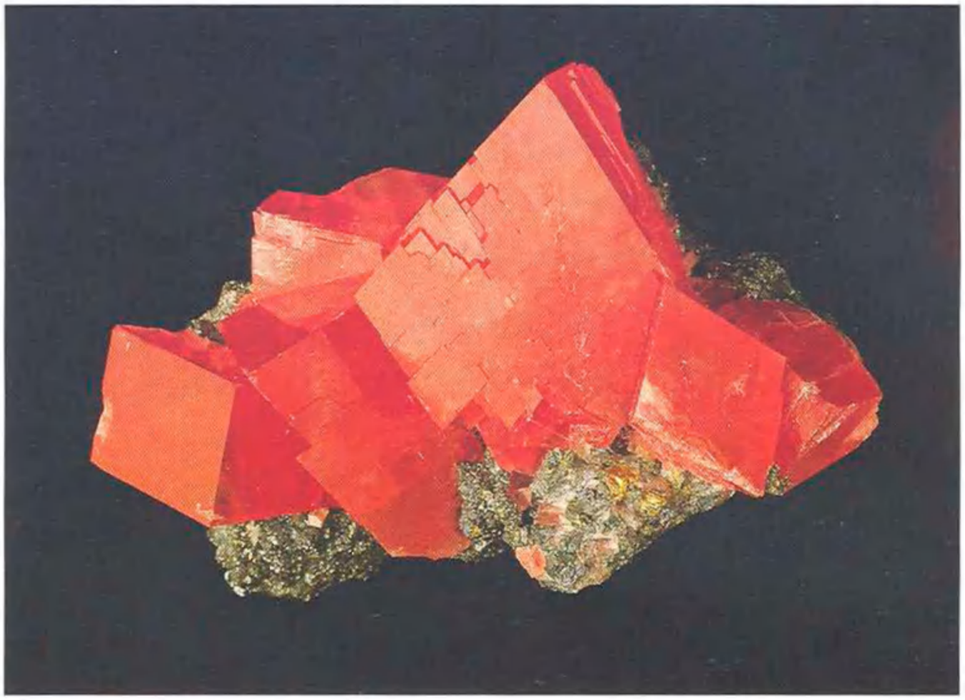

Rhodochrosite
$MnCO_3$

TRIGONAL ● ● ● ●

Properties: C – white, pink, red, brown, locally black coatings on crystals; S – white; L – vitreous; D – transparent to translucent; DE – 3.6; H – 3.5-4; CL – perfect; F – conchoidal to uneven; M – rhombohedral and scalenohedral crystals, hemispherical and botryoidal aggregates, granular, massive.

Origin and occurrence: Only rare in pegmatites, hydrothermal in medium- and low-temperature veins, sedimentary and metamorphic. The most beautiful crystals come from the Sweet Home mine, Alma, Colorado, USA, where rhombs up to 150 mm (6 in) in size occur, associated with purple fluorite, hubnerite, tetrahedrite and other minerals. Beautiful dark red scalehohedra, up to 100 mm (4 in) found in the N'Chwaning No.1 and 2 mines, Kuruman, South Africa. Pink rhombs up to 80 mm ($3^{1}/_{8}$ in) come from Silverton, Colorado, USA. Nice pink hemispheres and botryoidal aggregates are known from Cavnic and Baia Sprie, Romania. Similar specimens occurred in Huaron, Peru. Pink banded crusts and stalactites were found in the Mina Capillitas, Catamarca, Argentina. Pink rhombs, associated with bertrandite, were lately found in Kounrad, Kazakhstan.

Rhodochrosite, 70 mm, Mina Capillitas, Argentina

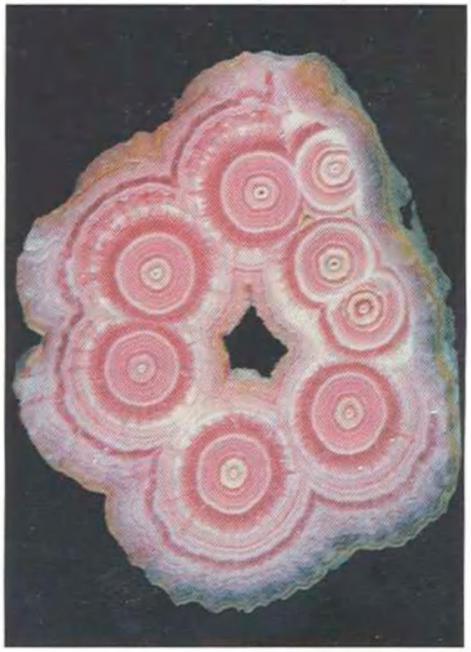

Calcite, 150 mm, Elmwood Mine, U.S.A.

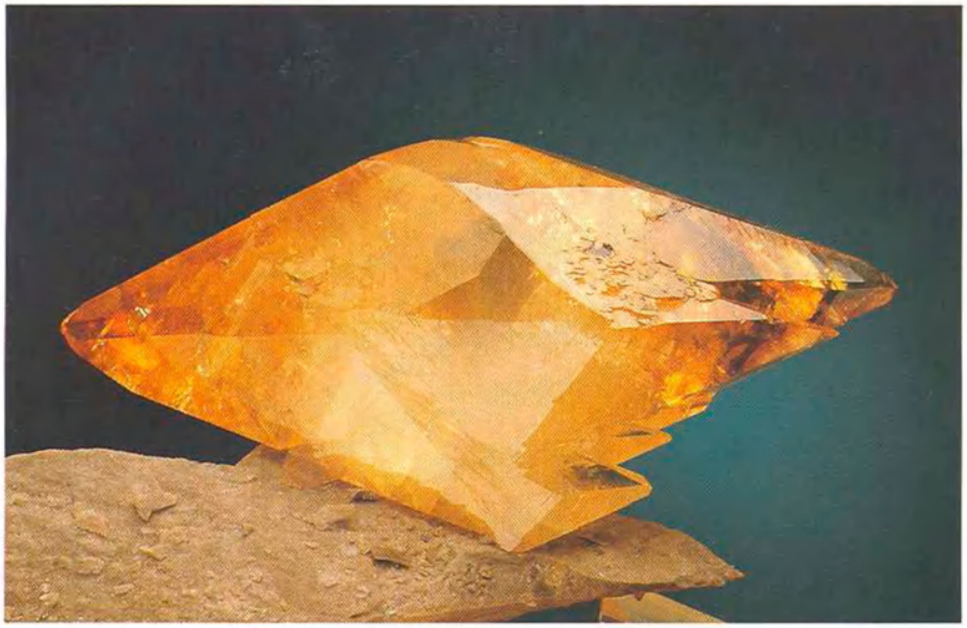

Calcite

$CaCO_3$

TRIGONAL ● ● ● ● ●

Properties: C – colorless, white, gray, yellow, brown, pink, red, blue, green, black; S – white; L – vitreous to pearly; D – transparent to opaque; DE – 2.7; H – 3; CL – perfect; F – conchoidal; M – crystals of various habit, concretions, stalactites, oolitic aggregates, granular, massive; LU – sometimes red to orange.

Calcite, 30 mm, Tunguzka, Russia

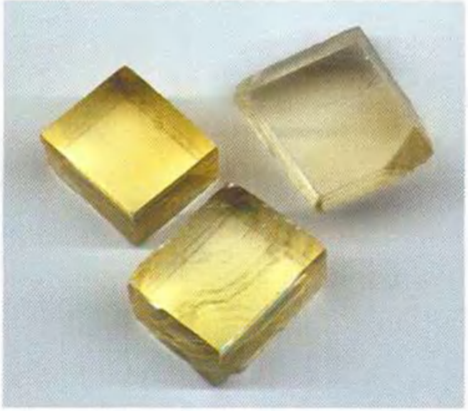

Origin and occurrence: One of the most common minerals, resulting from a wide range of conditions, it is magmatic, hydrothermal, sedimentary, metamorphic and secondary, it occurs in various parageneses. Large crystals found in many localities throughout the world. Pinkish and yellow crystals over 500 mm (20 in) long come from Joplin, Missouri and from the Elmwood mine, Tennessee, USA. Beautiful calcite crystals, crystallographically of very complex habits, found in Dalnegorsk, Russia. Nice calcite specimens occurred also in Mexico (Naica, Chihuahua; Charcas, San Luis Potosí). European localities, like Príbram, Czech Republic; St. Andreasberg, Germany; Kongsberg, Norway are famous by their calcites, too. Wine yellow, complicated crystals are known from the Sarbayskoye deposit in Rudnyi, Kazakhstan. Clear cleavable aggregates of the birefringent calcite (so called Iceland spar) were found in basalt cavities in Helgustadir, Iceland. The largest of them reached up to 6 x 2 m (20 x 6 ft 6 in) in size. Very nice scalenohedra up to 80 mm (3⅛ in) long with copper inclusions occur in Keweenaw Peninsula, Michigan, USA. Perfect scalenohedra and their twins up to 100 mm (4 in) long are known from Egremont and Frizington, UK. Beautiful butterfly twins up to 80 mm (3⅛ in) recently reported from Guiyang, Hunan, China. Crystals of calcite with sand inclusions up to 100 mm (4 in) in size come from the vicinity of Fontainebleau, France.

Application: building industry, optical industry.

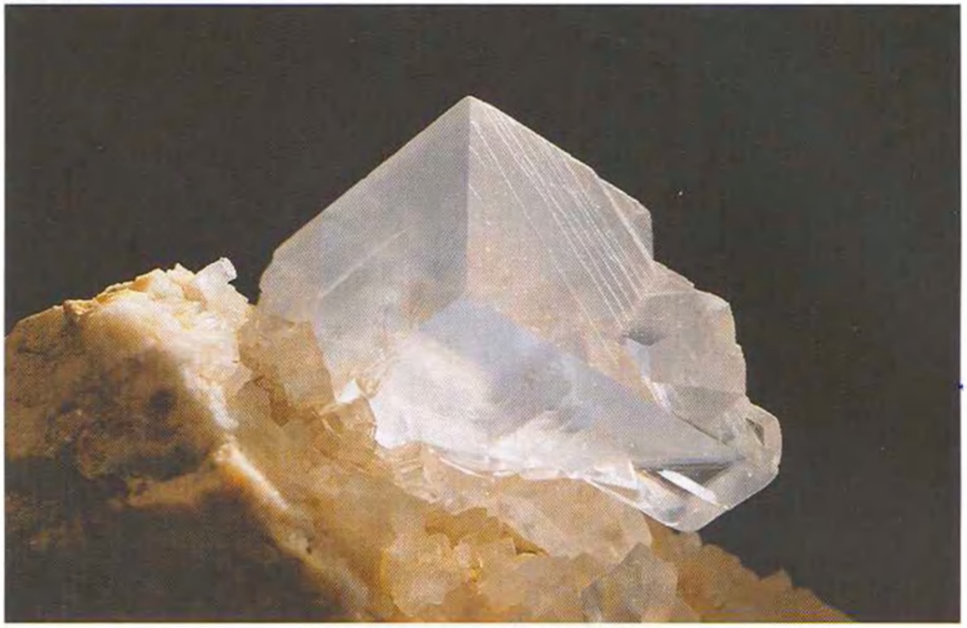
Dolomite, 33 mm x, Navarro, Spain

Dolomite

$CaMg(CO_3)_2$

TRIGONAL ● ● ● ● ●

Properties: C – gray-white, pink, red, green, brown, black; S – white; L – vitreous to pearly; D – transparent to translucent, DE – 2.9; H – 3.5; CL – perfect; F – conchoidal; M – rhombohedral crystals, massive.

Origin and occurrence: Magmatic in pegmatites, hydrothermal, metasomatic, sedimentary and metamorphic, together with siderite, magnesite, calcite and other minerals. Crystals up to 100 mm (4 in) long found in Brumado, Bahia, Brazil. Fine crystals also occurred in Banska Stiavnica, Slovakia and in Cavnic, Romania. Crystals up to 200 mm ($7\frac{7}{8}$ in) in size come from Eugui, Spain. Crystals up to 150 mm (6 in) long found in cavities in dolomitic rocks in Lengenbach, Binntal, Switzerland. Crystals several cm long known from Jachymov, Czech Republic. Large accumulations of massive dolomite are common in magnesite deposits.

Application: metallurgy, heat-resistant material.

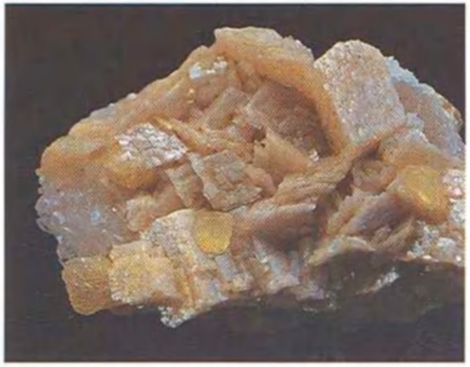
Ankerite, 20 mm xx, Roudny, Czech Republic

Ankerite

$CaFe(CO_3)_2$

TRIGONAL ● ● ● ●

Properties: C – white, yellowish, brown-yellow; S – white; L – vitreous to pearly; D – translucent; DE – 3; H – 3.5-4; CL – perfect; F – conchoidal; M – rhombohedral crystals, granular.

Origin and occurrence: Hydrothermal in medium- and low-temperature veins, also sedimentary and metamorphic, together with siderite and other minerals. Crystals up to 50 mm (2 in) occurred in the Tui mine, New Zealand. Brown rhombs up to 40 mm ($1\frac{9}{16}$ in) in size known from Gilman, Colorado, USA. Yellowish crystals up to 10 mm ($\frac{3}{8}$ in) come from concretions near Kladno, Czech Republic. Massive aggregates are common in metasomatic deposits of siderite (e.g. Nizna Slana, Slovakia).

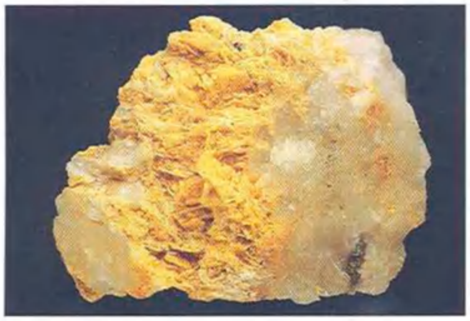

Kutnohorite, 60 mm, Kutna Hora, Czech Republic

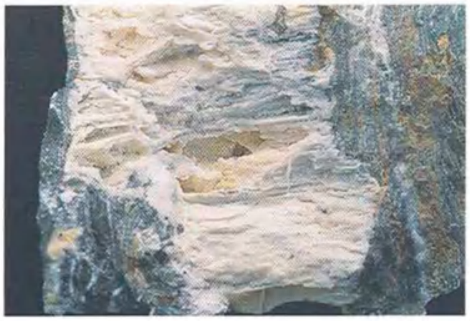

Huntite, 110 mm, Koksin, Czech Republic

Kutnohorite

$CaMn(CO_3)_2$

TRIGONAL ● ● ●

Properties: C – white, gray, pink, yellowish; S – white; L – vitreous; D – translucent; DE – 3.1; H – 3.5-4; CL – perfect; F – conchoidal; M – poorly developed crystals, granular, massive.
Origin and occurrence: Hydrothermal and metamorphic, associated with ankerite, quartz and other minerals. Poorly developed crystals are known from Kutna Hora, Czech Republic. Small crystals several mm in size are described from Mont St.-Hilaire, Quebec, Canada. Large crystals occurred in Moncure, North Carolina, USA. Small gray-white crystals were found in Broken Hill, New South Wales, Australia.

Huntite

$CaMg(CO_3)_2$

TRIGONAL ● ●

Properties: C – white; S – white; L – earthy; D – opaque; DE – 2.7; H – 1.5; CL – none; F – conchoidal; M – fibrous aggregates, earthy.
Origin and occurrence: Secondary mineral resulting from the oxidation of dolomite, associated with magnesite and dolomite. Fine fibrous aggregates come

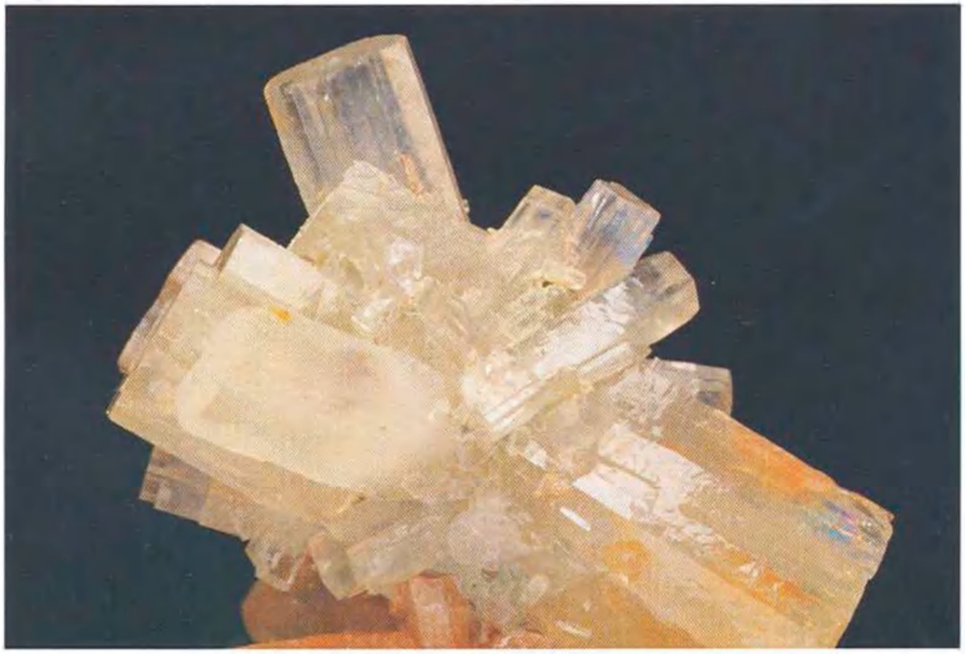

Aragonite, 49 mm, Tazouta, Morocco

Flos ferri, 110 mm, Erzberg, Austria

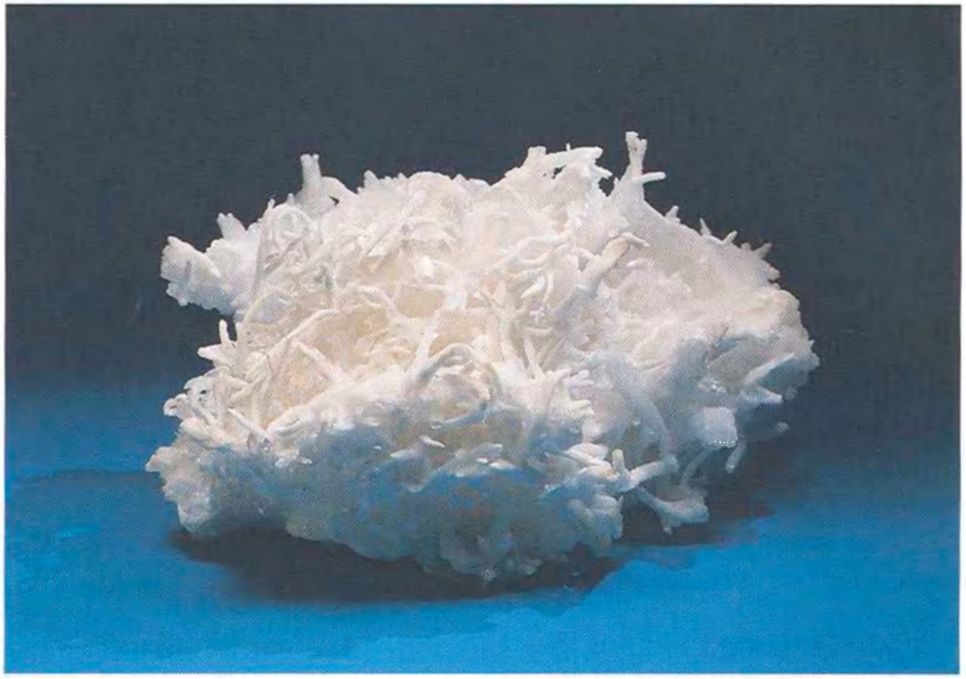

from Koksin, Czech Republic. It also occurs in the Ala-Mar deposit, Nevada, USA. Massive aggregates are known from the Boquira mine, Bahia, Brazil.

Aragonite
$CaCO_3$

ORTHORHOMBIC ● ● ● ●

Varieties: flos ferri, hot-spring tufa, peastone, tarnowitzite.
Properties: C – colorless, white, yellow, reddish, greenish, purplish, bluish, gray; S – white; L – vitreous; D – transparent to opaque; DE – 3; H – 3.5-4.5; CL – imperfect; F – conchoidal; M – prismatic crystals, oolitic, banded, columnar and dendritic aggregates, massive; LU – locally weak cream yellow.
Origin and occurrence: Primary as a late hydrothermal mineral of high-temperature deposits more commonly secondary as a product of the oxidation of siderite and pyrite. It also results from precipitation of thermal springs, it is sedimentary and metamorphic. Fine white prismatic crystals up to 70 mm ($2\frac{1}{4}$ in) long found together with blue celestite crystals in _pania Dolina, Slovakia. Similar crystals come from sulfur deposits in Cianciano, Italy and Tarnobrzeg, Poland. Maybe the best aragonite crystals in the world are known from the gossan of the magnesite deposit in Podrecany, Slovakia, where druses of crystals up to 200 mm ($7\frac{7}{8}$ in) long were found. Wine yellow crystals up to 100 mm ($\frac{3}{8}$ in) long occurred in cavities of volcanic rocks in Horenec near Bilina, Czech Republic. Those crystals were the only gem rough, suitable for facetting, in the world. Very interesting copper pseudo-morphs after aragonite come from Corocoro, Bolivia. Banded and oolitic aggregates found in Karlovy Vary, Czech Republic. Dendritic aggregates from Erzberg, Austria and elsewhere are known as flos ferri.
Application: decorative stone.

Peastone, 35 mm, Karlovy Vary, Czech Republic

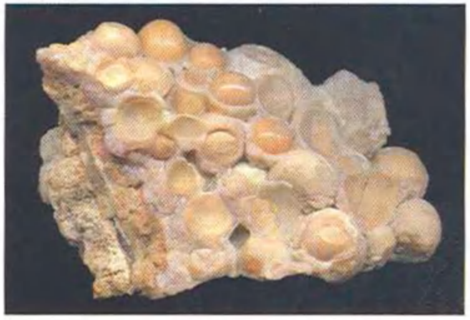

Strontianite, 34 mm, Hardin Co., U.S.A.

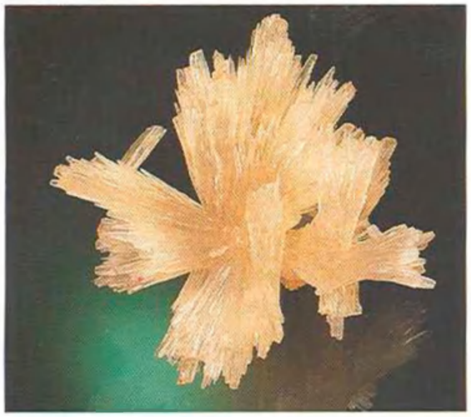

Strontianite

$SrCO_3$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, gray, yellowish, greenish, reddish, brown; S – white; L – vitreous to resinous; D – transparent to translucent; DE – 3.8; H – 3.5; CL – perfect; F – conchoidal to uneven; M – prismatic and acicular crystals, columnar and fibrous aggregates, massive, earthy.
Origin and occurrence: Hydrothermal in low-temperature veins, in cavities of volcanic rocks, mainly sedimentary, together with calcite and zeolites. Crystals up to 80 mm (3 1/8 in) long occur near Bleiberg, Austria. Smaller crystals known from Strontian, Scotland. Crystals up to 50 mm long found in marls in Ahlen near Münster, Germany.

Witherite

$BaCO_3$

ORTHORHOMBIC ● ●

Properties: C – white, gray, yellowish; S – white; L – vitreous to greasy. D – translucent; DE – 4.3; H – 3.5; CL – good; F – uneven; M – pseudo-hexagonal dipyramidal crystals, fibrous and botryoidal aggregates, massive.
Origin and occurrence: Hydrothermal in low-temperature deposits with fluorite, barite, calcite and other minerals. Beautiful yellowish crystals up to 120 mm (4 11/16in) long come from the Minerva No. 1 mine, Cave-in-Rock, Illinois, USA. Crystals, up to 70 mm (2¾ in) in size occurred in Hexham and Alston Moor, England, UK. Its pseudo-hexagonal crystals or botryoidal aggregates were very rare in Pribram, Czech Republic.

Cerussite

$PbCO_3$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, whitish, yellow, black; S – white; L – greasy to adamantine; D – translucent; DE – 6.6; H – 3-3.5; CL – good; F – conchoidal; M –

Witherite, 20 mm x, Alston Moor, UK

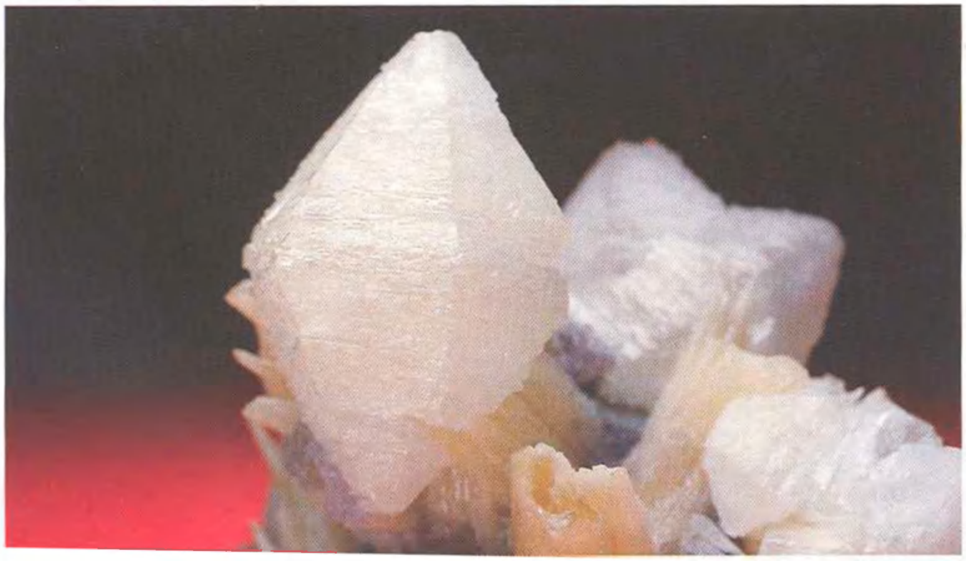

Cerussite, 92 mm, Tsumeb, Namibia

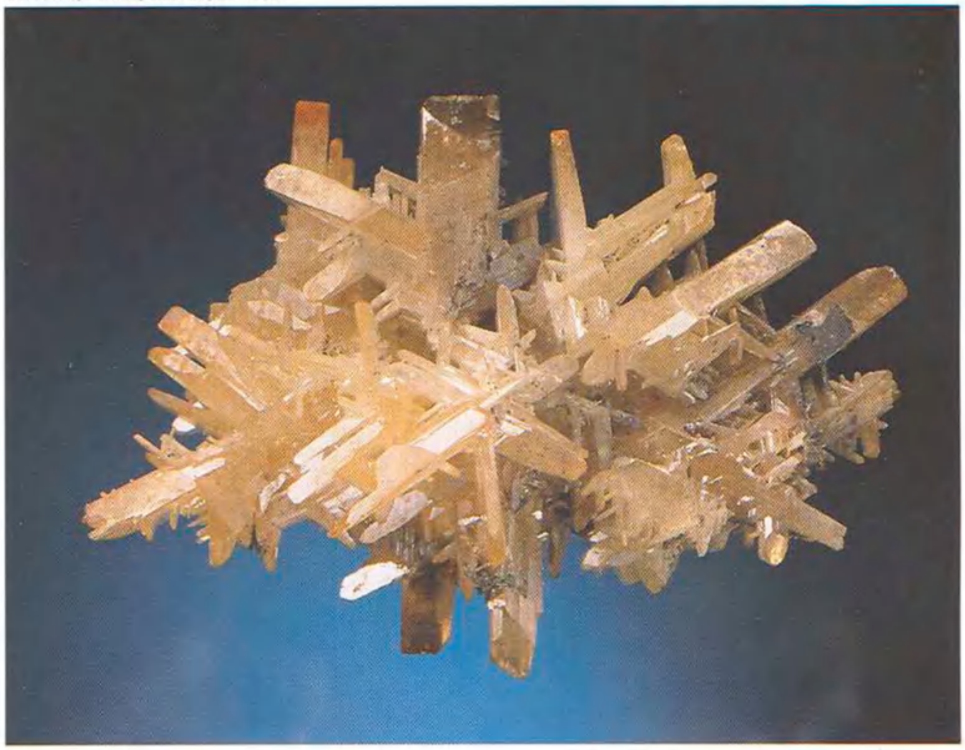

prismatic and pyramidal crystals, common trillings and twins, granular, massive; LU – sometimes yellowish.
Origin and occurrence: Secondary mineral, resulting from the oxidation of galena and other Pb minerals, together with pyromorphite, vanadinite, barite and other minerals. The best specimens come from Tsumeb, Namibia, where trillings up to 200 mm ($7^{7}/_{8}$ in) in diameter occurred. Large twins also known from Broken Hill, New South Wales, Australia. Beautiful crystals up to 50 mm (2 in) in size reported from Mibladen, Morocco. Fine crystals up to 50 mm (2 in) long found in Stribro, Czech Republic. Typical white acicular crystals, up to 60 mm ($2^{3}/_{8}$ in) long come from the Flux mine, Arizona, USA.

Barytocalcite

$BaCa(CO_3)_2$

MONOCLINIC ● ●

Properties: C – colorless, white, gray, yellowish; S – colorless; L – vitreous to resinous; D – transparent to translucent; DE – 3.7; H – 4; CL – perfect; F – conchoidal to uneven; M – prismatic, often striated crystals, massive; LU – light yellow.
Origin and occurrence: Hydrothermal in low-temperature veins, together with calcite, barite and other minerals. Crystals several cm in size and cleavable masses are known from Alston Moor, Cumbria, UK. Imperfect crystals about 10 mm ($^{3}/_{8}$ in) in size occurred in Stříbro, Czech Republic. It is also described from Freiberg, Germany and from Langban, Sweden.

Barytocalcite, 52 mm, Alston Moor, UK

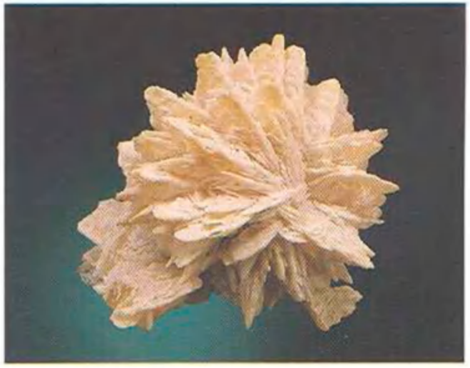

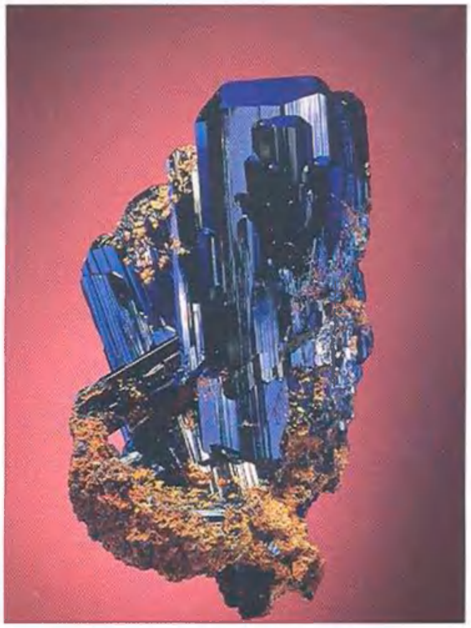

Azurite, 48 mm, Touissit, Morocco

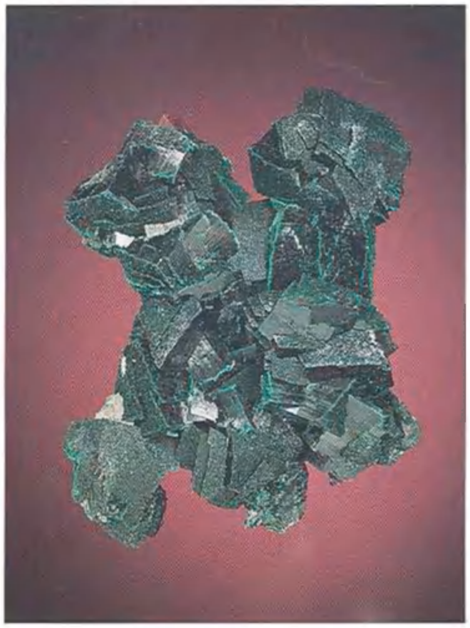

Malachite, 63 mm, Mashamba West, Zair

Azurite

$Cu_3(CO_3)_2(OH)_2$

MONOCLINIC ● ● ● ●

Properties: C – blue; S – blue; L – vitreous; D – transparent to opaque; DE – 3.8; H – 3.5; CL – perfect; F – conchoidal; M – tabular and prismatic crystals, pulverulent.
Origin and occurrence: Secondary, resulting from the oxidation of Cu sulfides, mainly associated with malachite. Crystals up to 200 mm ($7^{7}/_{8}$ in) long come from Tsumeb, Namibia. Crystals from Touissit, Morocco reach up to 70 mm (2¾ in). Tabular crystals up to 50 mm (2 in) in size found in Chessy near Lyon, France. Famous crystals up to 50 mm (2 in) across occurred in the Copper Queen mine in Bisbee, Arizona, USA. Fine azurite concretions with crystals on the surface come from La Sal, Utah, USA. Crystal rosettes, reaching up to 130 mm ($5^{1}/_{16}$ in) in size were found in the Yang Chweng Mine, Guang Dong, China.
Application: Cu ore.

Malachite

$Cu_2(CO_3)(OH)_2$

MONOCLINIC ● ● ● ●

Properties: C – green; S – light green; L – vitreous, dull, earthy; D – opaque; DE – 4.1; H – 3.5-4; CL – perfect; F – conchoidal to uneven; M – acicular and prismatic crystals, botryoidal aggregates, stalactites, massive.
Origin and occurrence: The most common supergene mineral of Cu, associated with azurite, cuprite and other minerals. Crystals up to 30 mm ($1^{3}/_{16}$ in) in size occur in Kambove, Zaire. Crystals up to 20 mm ($^{25}/_{32}$ in) also found in Rudab<nya, Hungary. Pseudomorphs after azurite crystals up to 100 mm (4 in) in size known from Tsumeb; pseudo-morphs after cuprite crystals up to 50 mm in size come from Onganja, Namibia. The blocks of banded malachite weighing up to 250 tons . occurred in Mednorudnjansk, Ural mountains, Russia. Similar material in huge quantities come from many deposits in Shaba

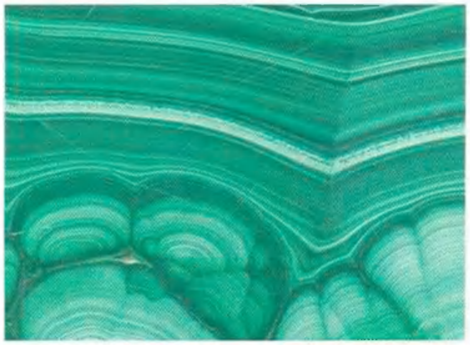

Malachite, 70 mm, Shaba, Zair

Rosasite, 270 mm, Gleeson, U.S.A.

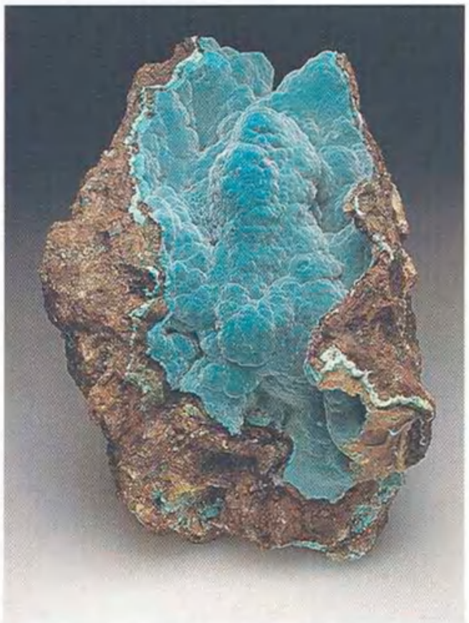

province, Zaire, where stalactites up to 500 mm (20 in) long were also found.
Application: Cu ore, production of decorative objects and jewelry.

Rosasite

$(Cu,Zn)_2(CO_3)(OH)_2$

MONOCLINIC ● ●

Properties: C – green, blue; S – greenish; D – opaque; DE – 4.0-4.2; H – 4.5; CL – good; M – small acicular crystals, fibrous and botryoidal crusts.
Origin and occurrence: Secondary, forming in the oxidation zone of Cu and Zn deposits, together with other secondary minerals of Cu. Spherical aggregates of acicular crystals up to 10 mm (3/8 in) found in Mina Ojuela, Mapimi, Durango, Mexico. Similar finds were made in Bisbee, Arizona, USA.

Hydrozincite, 65 mm, Tiger, U.S.A.

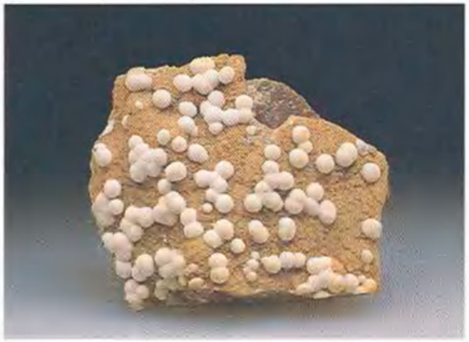

Hydrozincite

$Zn_5(CO_3)_2(OH)_6$

MONOCLINIC ● ● ●

Properties: C – white, yellowish; S – white; L – pearly to dull; D – opaque; DE – 4; H – 2-2.5; CL – perfect; F – conchoidal; M – tabular crystals, massive, earthy; LU – locally blue.
Origin and occurrence: Secondary, resulting from the oxidation of sphalerite, together with cerussite, smithsonite and hemimorphite. Small crystals are known from Mapimi, Durango, Mexico. Spherical aggregates, several mm in diameter, were found in Sterling Hill, New Jersey, USA. Stalactites and thick crusts occurred in Long-Kieng, Burma. Crusts and stalactites were also described from Bleiberg, Austria; from Mezica, Slovenia and from Raibl, Italy.

Aurichalcite

$(Zn,Cu)_5(CO_3)_2(OH)_6$

ORTHORHOMBIC ● ● ●

Properties: C – light green, blue-green, blue; S – blue-green; L – silky to pearly; D – translucent; DE – 4; H – 1-2; CL – perfect; M – acicular crystals, crusts.
Origin and occurrence: Secondary in the oxidation zone of Cu and Zn deposits in the arid climate, associated with linarite and other minerals. Large prismatic crystals come from Mina Ojuela, Mapimi, Durango, Mexico. Nice rosettes of acicular crystals are known from Bisbee and from the 79 mine, Banner district, Arizona, USA. It also occurred in Monteponi, Sardinia, Italy.

Aurichalcite, 80 mm, Arizona, U.S.A.

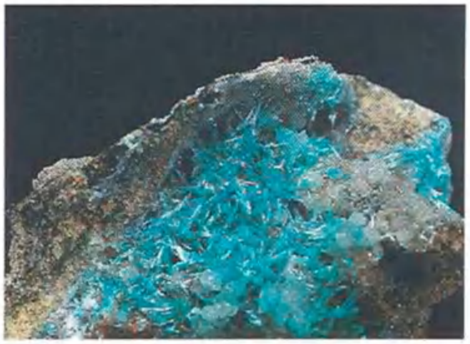

Dawsonite, 2 mm aggregate. Recsk, Hungary

Dawsonite

$NaAl(CO_3)(OH)_2$

ORTHORHOMBIC ● ● ●

Properties: C – colorless to white; S – white; L – vitreous; D – transparent; DE – 2.4; H – 3; CL – perfect; M – acicular to blade-like crystals, radial aggregates.
Origin and occurrence: Hydrothermal in low-temperature deposits, associated with calcite, dolomite and other minerals. Fine acicular crystals up to 35 mm ($1^{3}/_{8}$ in) long come from Mont St.-Hilaire, Quebec, Canada. Radial aggregates along the rock cracks were found in Dubník and Zlata Bana, Slovakia.

Bastnäsite-(Ce)

$(Ce,La)(CO_3)F$

HEXAGONAL ● ● ●

Properties: C – yellow to brown; S – yellow-brown; L – vitreous to greasy; D – translucent; DE – 4.8-5.2;

Parisite-(Ce), 71 mm. Boyaca, Colombia

Bastnasite-(Ce), 6 mm x, Ariege, France

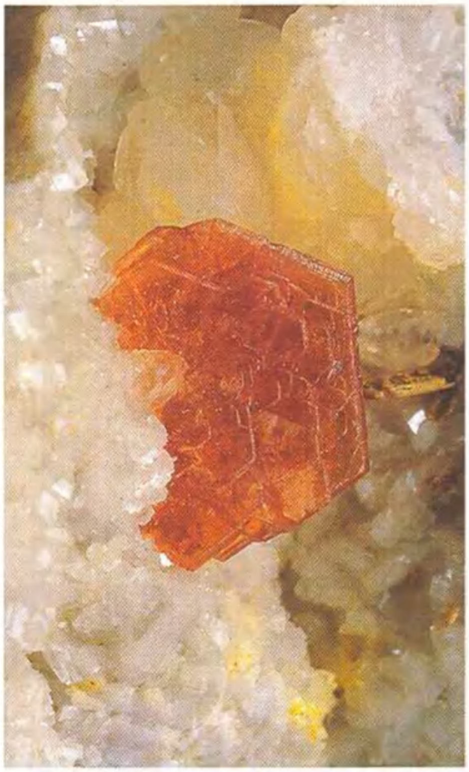

H – 4-4.5; CL – good; F – uneven; M – tabular crystals, granular, massive.
Origin and occurrence: Magmatic in pegmatites, also metamorphic, together with allanite-(Ce) and other rare earth elements minerals. Crystals up to 200 x 150 mm ($7\frac{7}{8}$ x 6 in) in size occur in Andekatany, Madagascar. Crystals up to 100 mm (4 in) long are known from Karonge, Burundi. Transparent crystals up to 25 mm (1 in) long were found recently in the Trimouns quarry, France. It forms important local deposits, as those of Mountain Pass, California, USA.*Application:* ore of rare earth elements.

Parisite-(Ce)

$CaCe_2(CO_3)_3F_2$

TRIGONAL ● ● ●

Properties: C – brown, yellow-brown, gray-yellow; S – brownish; L – vitreous to resinous; D – transparent to translucent; DE – 4.4; H – 4.5; CL – perfect; F – conchoidal to splintery; M – dipyramidal striated crystals.
Origin and occurrence: Magmatic in pegmatites, also hydrothermal and rarely metamorphic, together with bastnasite-(Ce) and other minerals of rare earth elements. Crystals several cm long come from Quincy, Massachusetts, USA. Crystals up to 80 mm ($3\frac{1}{8}$ in) long occurred in pegmatites near Hundholmen, Norway. Crystals up to 23 cm ($9\frac{1}{16}$ in) long found in the Snowbird mine, Montana, USA. Transparent crystals up to 15 mm ($1\frac{9}{32}$ in) were lately reported in the Trimouns quarry, France. Very unusual association have been described from Muzo, Columbia, where crystals up to 50 mm occur together with emeralds.

Phosgenite

$Pb_2(CO_3)Cl_2$

TETRAGONAL ● ●

Properties: C – colorless, white, yellow-white, gray, brown; S – white; L – adamantine; D – transparent to translucent; DE – 6.1; H – 2-3; CL – good; F – conchoidal; M – short to long prismatic and tabular crystals, granular, massive; LU – sometimes yellow.
Origin and occurrence: Secondary, resulting from the oxidation of galena, associated with cerussite and other secondary Pb minerals. Crystals up to 150 x 100 mm (6 x 4 in) across known from Monteponi, Sardinia, Italy. Crystals from Tsumeb, Namibia reached up to 100 mm. Crystals up to 30 mm ($1\frac{3}{16}$ in) in size found in Matlock, Derby, UK. Crystals up to 35 mm ($1\frac{3}{8}$ in) long occurred in the Mammoth mine, Tiger, Arizona, USA.

Phosgenite, 28 mm, Monteponi, Italy

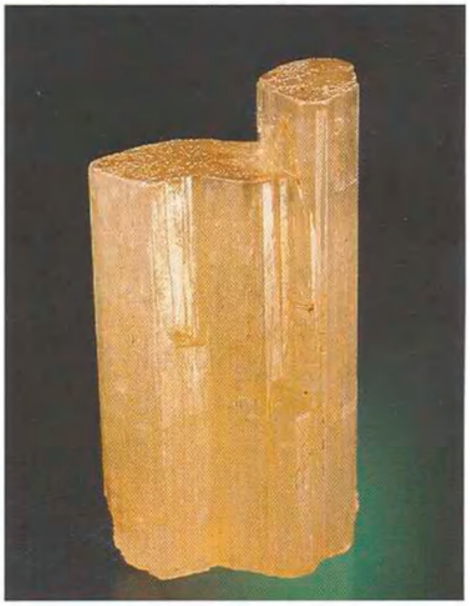

Bismutite, 3 mm xx, Brdarka, Slovakia

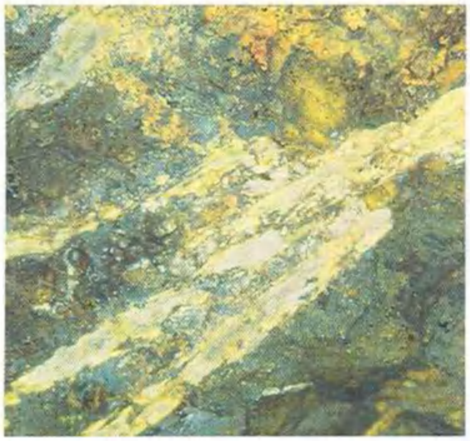

Gaylussite, 30 mm, Natron Lake, Tanzania

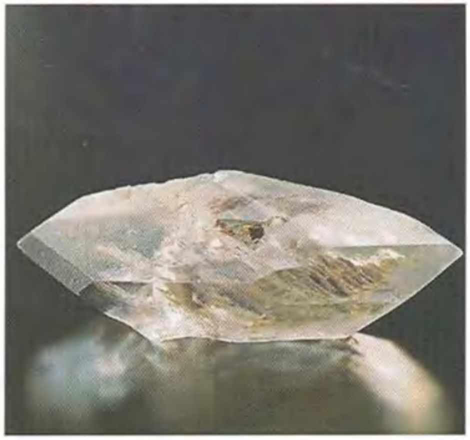

Bismutite

$Bi_2O_2(CO_3)$

TETRAGONAL ● ● ●

Properties: C – yellow, brown, gray, blue, black; S – white; L – vitreous, pearly to dull; D – translucent to opaque; DE – 6.1-7.7; H – 3.5; CL – good; M – spherical, radial aggregates, massive, pulverulent.
Origin and occurrence: Secondary, originated from the oxidation of Bi minerals, associated with bismuthinite and other minerals. It is common from pegmatites in Madagascar (Ampangabe) and in Mozambique. Large pebbles found in Kivu province, Zaire. It also occurred in Tasna, Bolivia.

Weloganite, 30 mm xx, Francon Quarry, Canada

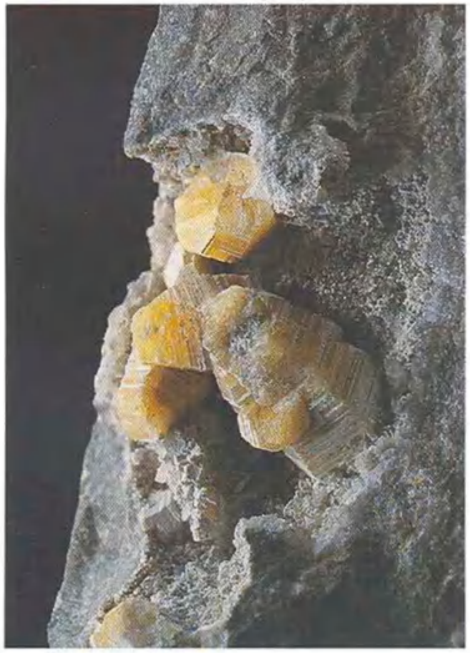

Gaylussite

$Na_2Ca(CO_3)_2 . 5 H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white, gray, yellowish; S – colorless; L – vitreous; D – transparent to translucent; DE – 2; H – 2.5-3; CL – perfect; F – conchoidal; M – lenticular to prismatic crystals.
Origin and occurrence: Sedimentary, typical a constituent of salt sediments. Crystals up to 80 mm (3$^{1}/_{8}$ in) long come from Searles Lake, California, USA. It also occurs in Borax Lake and Mono Lake, California, USA. Large crystals are known from Amboseli Lake, Kenya.

Weloganite

$Na_2Sr_3Zr(CO_3)_6 . 3 H_2O$

TRICLINIC ●

Properties: C – white, yellow; S – white; L – vitreous; D – transparent to opaque; DE – 3.2; H – 3.5; CL – perfect; F – conchoidal; M – pseudohexagonal striated crystals.
Origin and occurrence: Hydrothermal in the alkaline rocks, together with zircon, dresserite and other minerals. Crystals up to 50 mm (2 in) come from cavities in the Francon quarry, Montreal; crystals up to 30 mm (1$^{3}/_{16}$ in) are known from St. Michel, Quebec, Canada.

Artinite, 10 mm, Fethiya, Turkey

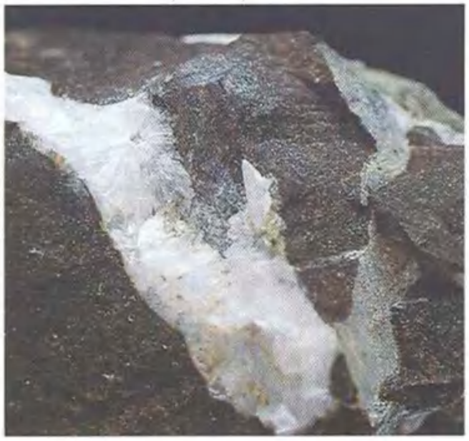

Artinite

$Mg_2(CO_3)(OH)_2 \cdot 3 H_2O$

MONOCLINIC ● ● ●

Properties: C – white; S – white; L – silky; D – transparent; DE – 2; H – 2.5; CL – perfect; M – spherical, radial aggregates, veinlets, crusts.
Origin and occurrence: Hydrothermal, originating at low temperatures in serpentinites, associated with magnesite, aragonite and other minerals. Radial aggregates up to 20 mm ($^{25}/_{32}$ in) in size occur in the Gem mine, San Benito County, California, USA. Needles up to 20 mm ($^{25}/_{32}$ in) long come from Val Malenco, Italy. Clusters of acicular crystals were found on Staten Island, New York, USA.

Zaratite, 70 mm, Lancaster Co., U.S.A.

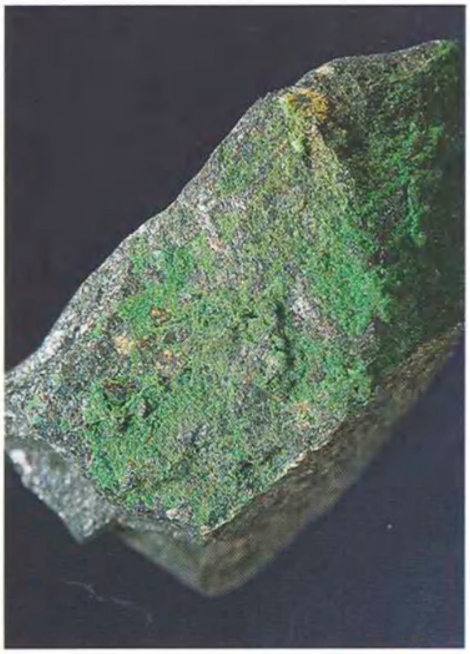

Hydrotalcite, 1 mm xx, Dunabogdány, Hungary

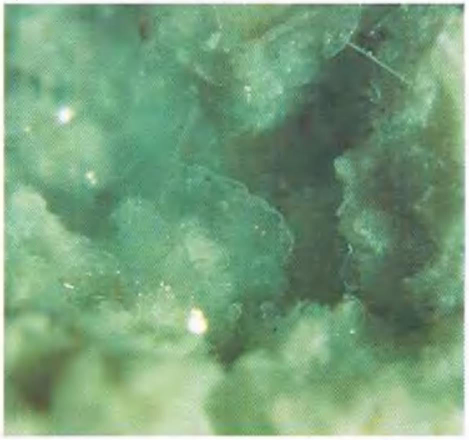

Zaratite

$Ni_3(CO_3)(OH)_4 \cdot 4 H_2O$

CUBIC ● ● ●

Properties: C – emerald-green; S – light green; L – vitreous to greasy; D – transparent to translucent; DE – 2.6-2.7; H – 3.5; CL – none; F – conchoidal; M – crystalline crusts, stalactites, coatings.
Origin and occurrence: Secondary, originating from the oxidation of Ni minerals, associated with millerite, brucite and other minerals. It occurs as a product of the oxidation of Ni minerals in ultrabasic rocks in Kraubat and Stubachtal, Austria. Large green coatings found in Heazlewood, Tasmania, Australia. It covers millerite needles in the vicinity of Kladno, Czech Republic.

Hydrotalcite

$Mg_6Al_2(CO_3)(OH)_{16} \cdot 4 H_2O$

TRIGONAL ● ●

Properties: C – white; S – white; L – pearly to waxy; D – transparent; DE – 2.1; H – 2; CL – perfect; M – fibrous and layered aggregates, massive.
Origin and occurrence: : Hydrothermal in ultrabasic and metamorphic rocks. It occurred with serpentine in Nordmark, Norway and also found at Franklin and Sterling Hill, New Jersey, USA.

Stichtite, 35 mm, Rouchovany, Czech Republic

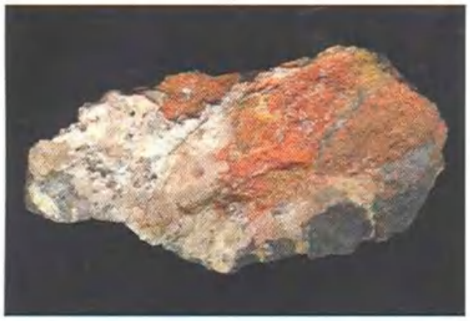

Stichtite

$Mg_6Cr_2(CO_3)(OH)_{16} \cdot 4\,H_2O$

TRIGONAL ● ●

Properties: C – pink to purple; S – white to light purple; L – pearly, waxy to greasy; D – translucent; DE – 2.2; H – 1.5-2; CL – perfect; M – lamellar and fibrous aggregates, massive.
Origin and occurrence: It occurs in serpentinites as scaly aggregates and veinlets in Bou Azzer, Morocco; in Dundas, Tasmania, Australia and in Barberton, South Africa.

Alumohydrocalcite

$CaAl_2(CO_3)_2(OH)_4 \cdot 3\,H_2O$

TRICLINIC ● ●

Properties: C – white, gray; S – white; L – earthy; D – opaque; DE – 2.2; H – 2.5; CL – perfect; M – chalky aggregates, consisting of acicular crystals.
Origin and occurrence: Secondary, associated with alophane and other minerals. It was described from the Khakasy deposit, Siberia, Russia, where it originates from the oxidation of alophane. Nice white radial aggregates occurred along the cracks in shales in L'adomírovo, Slovakia.

Ancylite-(Ce)

$Sr_3(Ce,La)_4(CO_3)_7(OH)_4 \cdot 3\,H_2O$

ORTHORHOMBIC ● ●

Properties: C – colorless, yellow, yellow- brown, light purple, brown; S – white; L – vitreous to greasy; D – transparent to opaque; DE – 4; H – 4-4.5; CL – none; F – splintery; M – short to long prismatic and pseudo-octahedral crystals.
Origin and occurrence: Hydrothermal in alkaline rocks, associated with nepheline and other minerals. Crystals up to 6 mm (¼ in) long are known from

Alumohydrocalcite, 70 mm, Ladomirovo, Slovakia

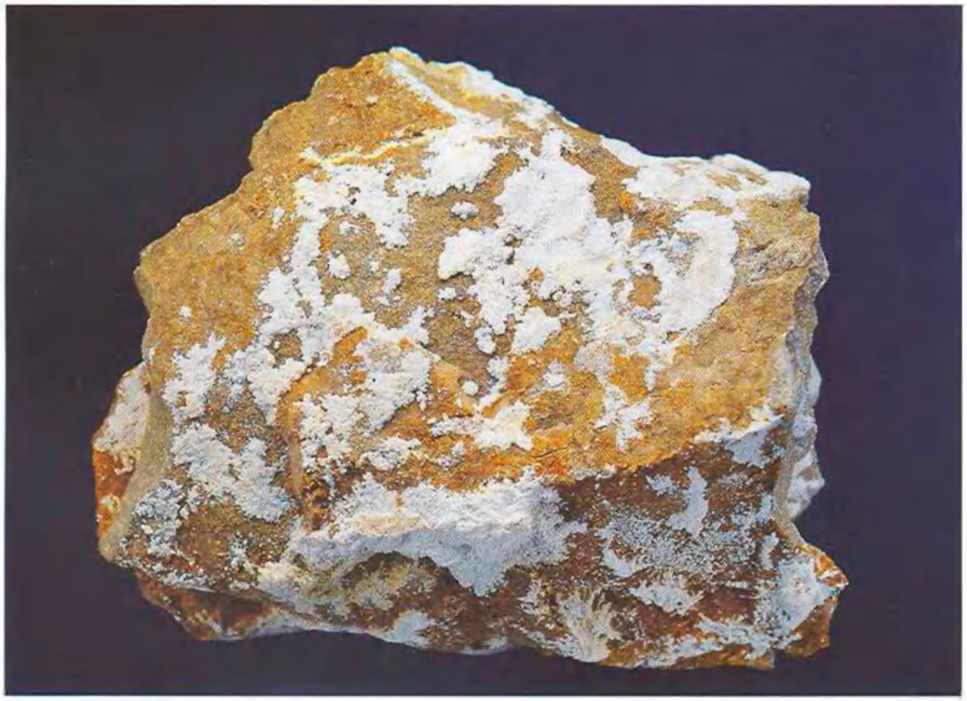

6. Borates

Ludwigite

$Mg_2Fe^{3+}BO_5$

ORTHORHOMBIC ● ● ●

Properties: C – dark green, black-green, black; S – blue-green; L B silky to dull; D – opaque; DE – 3.9; H – 5; CL – perfect; F B uneven; M – prismatic crystals, fibrous aggregates, granular, massive.
Origin and occurrence: Metamorphic in skarns and dolomitic marbles, locally associated with magnetite and other borates. Rich aggregates are known from Ocna de Fier, Romania; Kamineichi, Japan and the Hol Kol mine, Suan, North Korea.
Application: chemical industry, B ore.

Gaudefroyite

$Ca_4Mn^{3+}_3(BO_3)_3CO_3(O,OH)_3$

HEXAGONAL ●

Properties: C – black; S – black; L – adamantine to dull; D – opaque; DE – 3.4; H – 6; CL – good; F – uneven; M – prismatic crystals, fibrous and acicular aggregates.
Origin and occurrence: Hydrothermal in calcite veins. Prismatic crystals up to 50 mm (2 in) long were found on the mine dumps near Tachgagalt, Morocco and in the N'Chwaning No. 2 mine and the Wessels mine, Kuruman, South Africa.

Gaudefroyite, 40 mm, Kuruman, South Africa
Ludwigite, 120 mm, Ocna de Fier, Romania

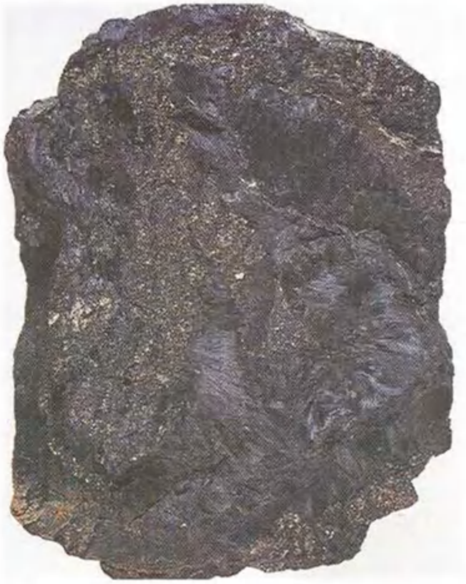

Inderite, 230 mm, Boron, U.S.A.

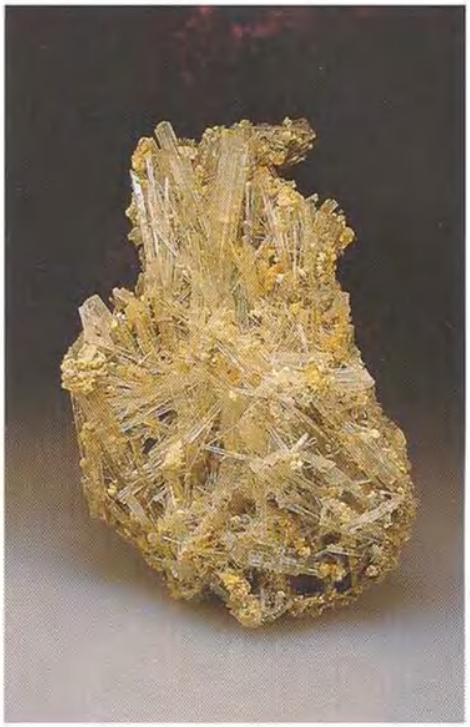

Inderite

$MgB_3O_3(OH)_5 \cdot 5\,H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white to pink in aggregates; S – white; L – vitreous; D – transparent to translucent; DE – 1.8; H – 2.5; CL – good; F – conchoidal to uneven; M – prismatic crystals, acicular and fibrous aggregates, nodules, massive.
Origin and occurrence: Sedimentary in boron deposits, commonly associated with colemanite and other borates. Prismatic crystals up to 100 mm (4 in) long occur in Boron, California, USA. It is also known from Inder, Kazakhstan.
Application: chemical industry, B ore.

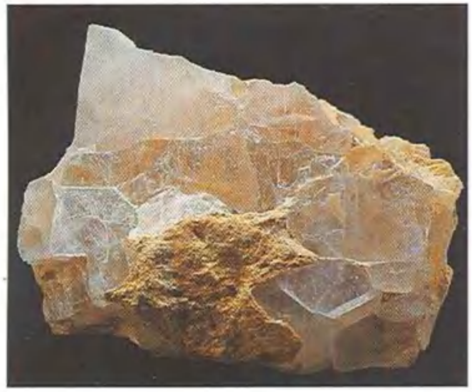

Inyoite, 90 mm, Turkey

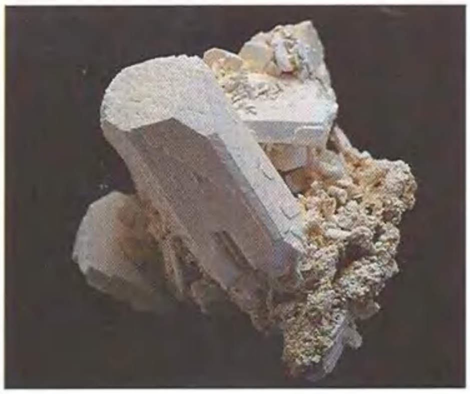

Borax, 60 mm x, Searles Lake, U.S.A.

Inyoite

$CaB_3O_3(OH)_5 . 4 H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white; S – white; L – vitreous; D – transparent to translucent; DE B 1.9; H – 2; CL – good; F – uneven; M – short prismatic to tabular crystals, columnar aggregates, massive.
Origin and occurrence: Sedimentary in boron deposits, commonly associated with colemanite and other borates. Clear tabular crystals up to 100 mm (4 in) long found in Kirka and Emet, Turkey. It also comes from Inder, Kazakhstan and the Corkscrew mine, California, USA.
Application: chemical industry, B ore.

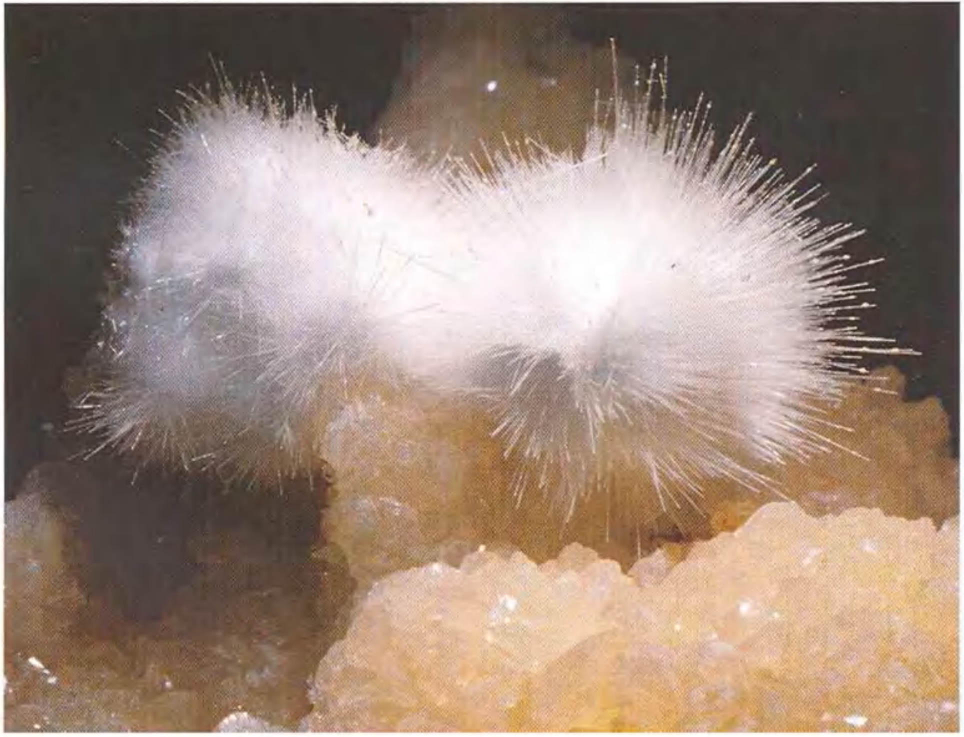

Ulexite, 20 mm aggregate, Death Valley, California, U.S.A.

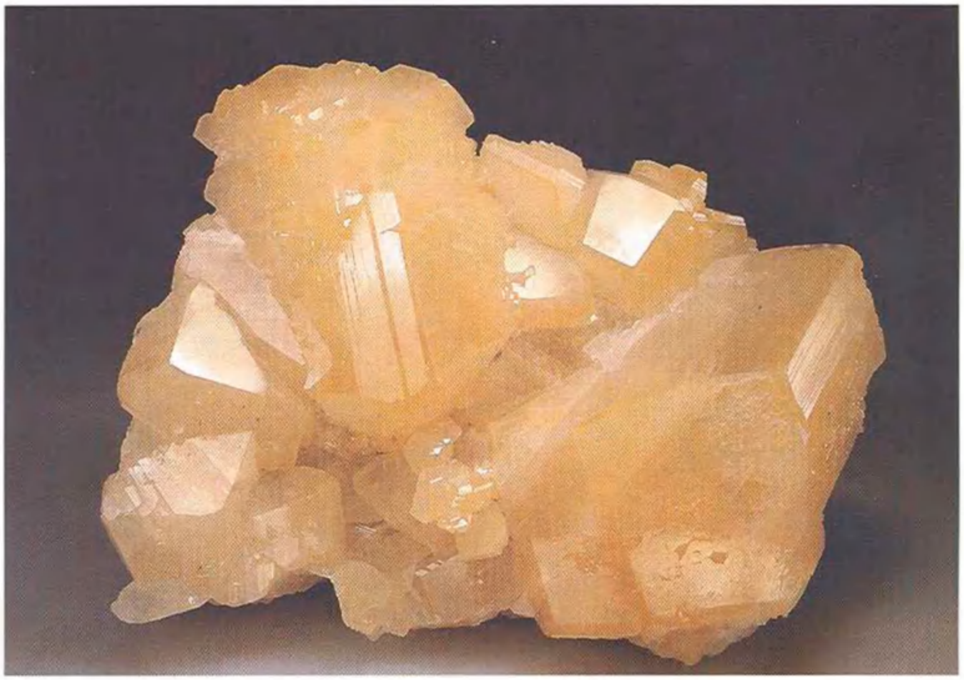

Borax

$Na_2B_4O_5(OH)_4 . 8 H_2O$

MONOCLINIC ● ● ●

Properties: C – white, colorless, yellowish, gray, greenish; S – white; L B vitreous to dull; D – transparent, translucent to opaque; DE – 1.7; H – 2-2.5; CL – perfect; F – conchoidal; M – short prismatic to tabular crystals, columnar to earthy aggregates, crusts, coatings, granular, massive; R – soluble in water.
Origin and occurrence: Sedimentary in boron deposits, associated with other borates and halite. Prismatic crystals up to 150 mm long are known from Borax Lake, also Searles Lake and Boron, California, USA. It also occurs in Kirka, Turkey.
Application: chemical industry, B ore.

Ulexite

$NaCaB_5O_6(OH)_6 . 5 H_2O$

TRICLINIC ● ● ●

Properties: C – white, colorless, light gray; S – white; L B vitreous to silky; D – transparent to translucent; DE – 2.0; H – 2.5; CL – perfect; F B uneven; M – elongated prismatic to acicular crystals, fibrous aggregates, crusts, nodules, granular, massive.
Origin and occurrence: Sedimentary in boron deposits, associated with other borates. Slabs up to 100 mm (4 in) thick consisting of fibrous aggregates occur in Boron, California; also found in Esmeralda, Nevada, USA; Emet, Turkey and Inder, Kazakhstan.
Application: chemical industry, B ore.

Colemanite

$Ca_2B_6O_{11} . 5 H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white, yellowish, light gray; S – white; L – vitreous; D – transparent to translucent; DE – 2.4; H – 4.5; CL – perfect; F B uneven; M – short prismatic and isometric crystals, granular, massive.
Origin and occurrence: Sedimentary in boron deposits, associated with other borates. Perfect crystals up to 200 mm (7⅞ in), come from Emet and Kirka, Turkey. Crystals up to 70 mm (2¾ in) long occur in Gower Gulch, Inyo, California; also known from Esmeralda, Nevada, USA and Inder, Kazakhstan.
Application: chemical industry, B ore.

Kernite, 100 mm, Boron, U.S.A.

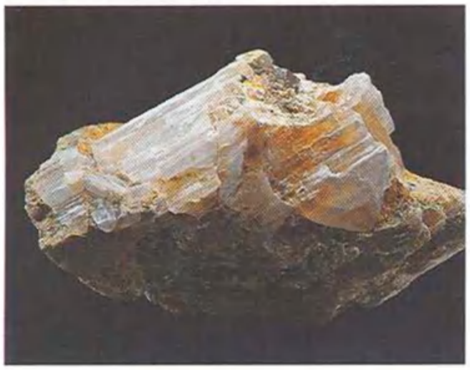

Kernite

$Na_2B_4O_6(OH)_2 . 3\ H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white, light gray; S – white; L – vitreous to dull, silky; D – transparent, translucent to opaque; DE – 1.9; H – 2.5-3; CL – perfect; F – uneven; M – isometric crystals, fibrous aggregates, granular, massive; R – soluble in water.

Rhodizite, 23 mm, Antsirabe, Madagascar

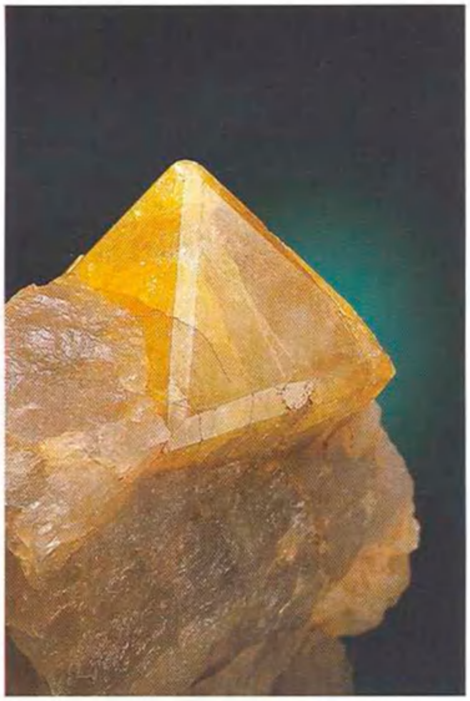

Hambergite, 64 mm, Pamir, Tadzhikistan

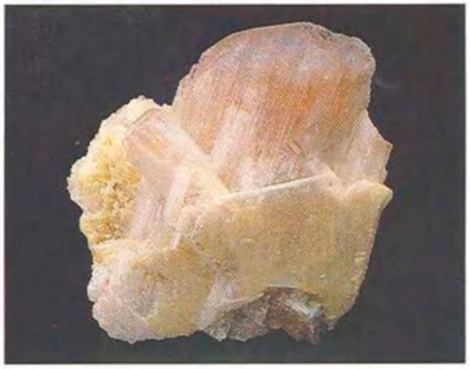

Origin and occurrence: Sedimentary in boron deposits, associated with borax and other borates. Platy aggregates and crystals up to 2.5 x 1 m (8 ft x 39⅜ in) found in Boron, California, USA; also known from the Tincalayu mine, Salta province, Argentina.

Hambergite

$Be_2BO_3(OH,F)$

ORTHORHOMBIC ● ●

Properties: C – colorless, white, light gray; S – white; L – vitreous; D – transparent to translucent; DE – 2.4; H – 7.5; CL B perfect; F B uneven; M – tabular to prismatic crystals, granular.
Origin and occurrence: Magmatic in granitic and rarely also in alkaline pegmatites; hydrothermal in cavities within the pegmatites, associated with tourmaline, danburite and beryl. Tabular crystals up to 200 mm (7⅞ in) from the Little Three mine, Ramona, California, USA. Crystals up to 110 mm (4 5/16 in) also known from several localities in Madagascar, e.g. Imalo and Anjanabonoina; also found in Hyakule, Nepal and Ctidruzice, Czech Republic .

Rhodizite

$(K,Cs)Al_4Be_4(B,Be)_{12}O_{28}$

CUBIC ● ●

Properties: C – colorless, white, yellow, light gray; S – white; L – vitreous to adamantine; D – transparent to translucent; DE – 3.5; H – 8.5; CL – imperfect; F – conchoidal to uneven; M – isometric crystals, granular.
Origin and occurrence: Magmatic in granitic pegmatites, associated with tourmaline, danburite and beryl. Cubic to tetrahedral crystals, reaching up to 30 mm (1 3/16 in) occur in several localities in

Madagascar, e.g. Sahatany and Antandrokomby; also known from the Animikie Red Ace pegmatite, Florence, Wisconsin, USA.

Boracite

$Mg_3B_7O_{13}Cl$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white, yellowish, light gray, light to dark green; S – white; L – vitreous; D – transparent to translucent; DE – 3.0; H – 7-7.5; CL – none; F – conchoidal to uneven; M – isometric crystals, fibrous aggregates, granular, massive.

Origin and occurrence: Sedimentary in evaporitic deposits, together with halite, gypsum and anhydrite; metamorphic in metamorphosed evaporates. Crystals up to 15 mm ($^{19}/_{32}$ in) come from Alto Chapare, Cochabamba, Bolivia; crystals about 5 mm ($^{3}/_{16}$ in) in size, occur in Stassfurt, Hanover and Kahlberg, Germany. Crystals are also known from Choctaw, Louisiana, USA and the Boulby mine, North Yorkshire, England, UK.

Boracite, 12 mm x, Alto Chapare, Bolivia

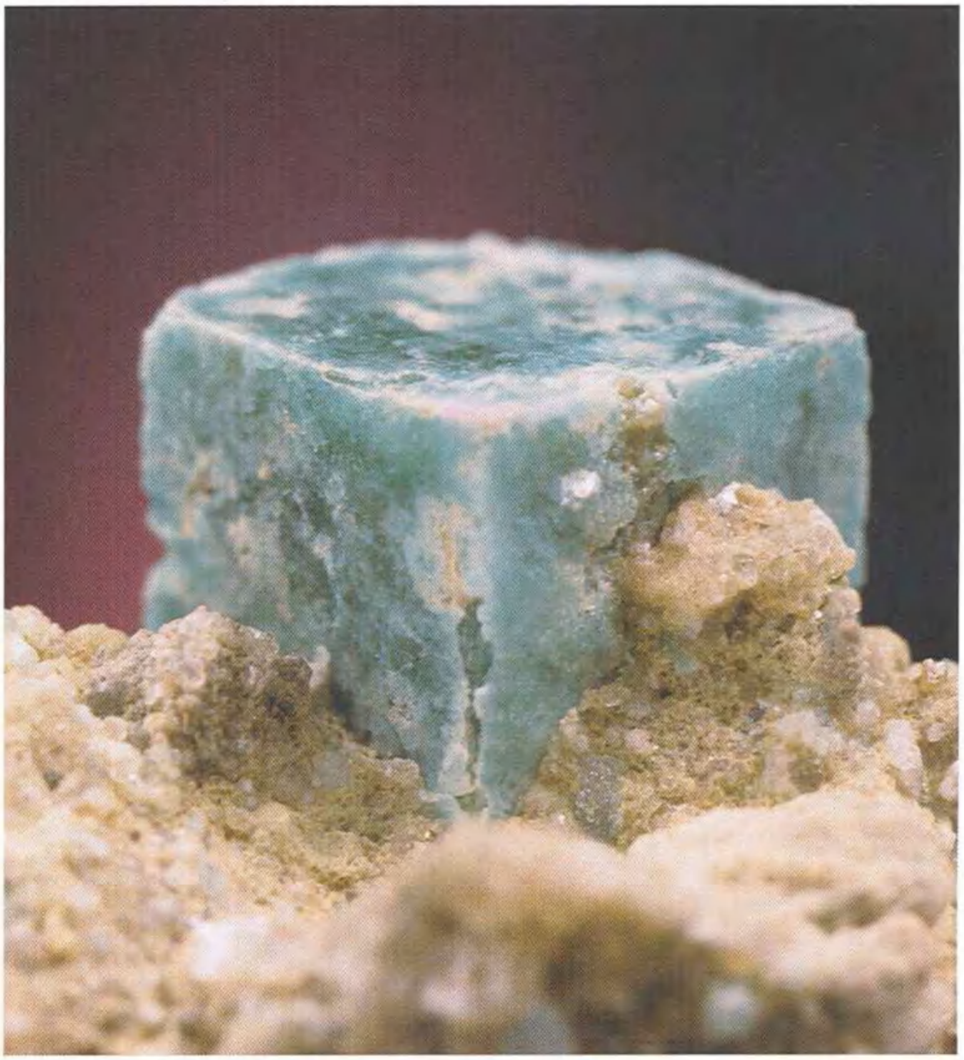

7. Sulfates

Anglesite

$PbSO_4$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white, yellowish, gray, greenish; S – white; L – adamantine to greasy; D – transparent to translucent; DE – 6.4; H – 2.5 – 3; CL – dobra; F – conchoidal; M – thick tabular crystals, massive, LU – sometimes yellowish.

Origin and occurrence: Secondary, as a result of the galena oxidation, together with cerussite and other minerals. Beautiful yellowish crystals up to 100 mm (4 in) in size come from Touissit, Morocco. Crystals from Tsumeb, Namibia, reached up to 40 mm (1$^{9}/_{16}$ in). Large crystals are also reported from Phoenixville, Pennsylvania, USA. Crystals up to 20 mm ($^{25}/_{32}$ in) occur in cavities in weathered galena in Sardinia, Italy. Crystals, reaching up to 40 mm (1$^{9}/_{16}$ in) also found in Mezica . Slovenia. Prismatic crystals up to 75 mm (3 in) long known from the Bunker Hill mine, Idaho, USA.

Barite, 17 mm xx, Pöhla, Germany

Anhydrite, 55 mm, Simplon Tunnel, Switzerland

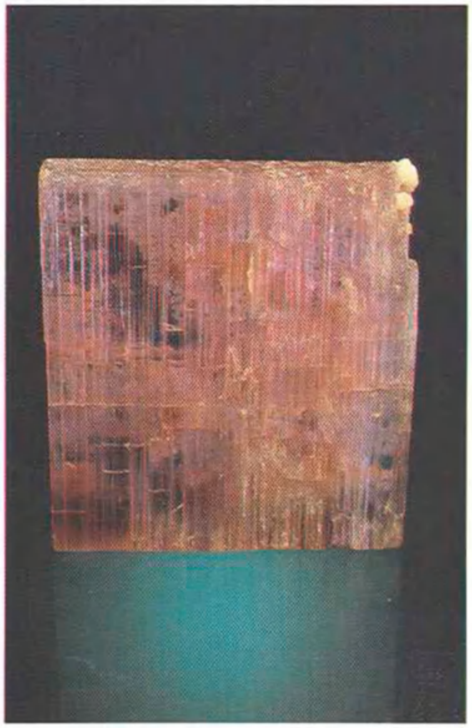

Anglesite, 81 mm, Touissit, Morocco

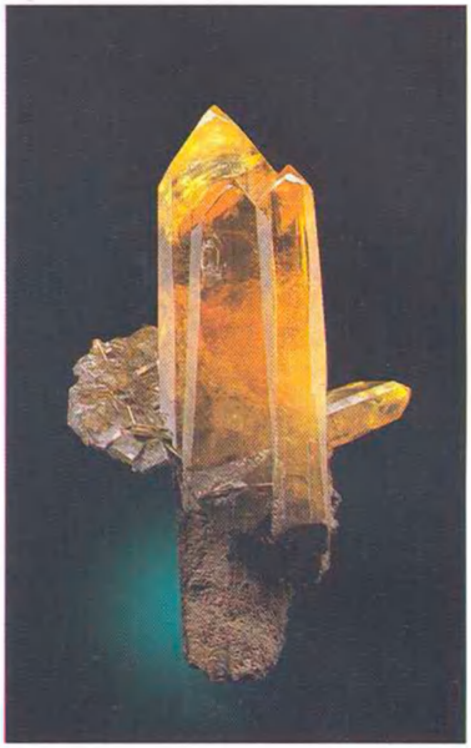

Anhydrite

$CaSO_4$

ORTHORHOMBIC ● ● ● ●

Properties: C – colorless, white, bluish, purplish, red, brown; S – white; L – pearly to vitreous; PS – transparent to translucent; DE – 2.8-3; H – 3-3.5; CL – good; F – splintery to uneven; M – isometric and prismatic crystals, granular, massive.

Origin and occurrence: Mostly sedimentary, as a result of the evaporation of sea water, associated with gypsum, calcite and other minerals; rare in pegmatites and hydrothermal. It is very common in form of massive aggregates in salt deposits in Stassfurt and Wathlingen, Germany, where small crystals also occur. Folded layers in clays known from Wieliczka, Poland. Purplish crystals up to 20 mm ($^{25}/_{32}$ in) found in cracks in metamorphic rocks near Simplon and St. Gotthard, Switzerland. Fine druses of bluish crystals up to 200 mm (7$^{7}/_{8}$ in) long found in Naica, Chihuahua, Mexico.

√+

Celestine, 270 mm, Madagascar

Celestite

$SrSO_4$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white, yellowish, blue; S – white; L – vitreous; D – transparent to translucent; DE – 4; H – 3-3.5; CL – perfect; F – uneven; M – prismatic and tabular crystals, columnar aggregates, concretions.
Origin and occurrence: Rare hydrothermal, mainly sedimentary, together with halite, anhydrite and gypsum. Beautiful blue crystals several cm long occur in cavities of concretions in the Sakoany mine, Madagascar. Prismatic crystals up to 100 mm (4 in) long in sulfur deposits in Poland (Tarnobrzeg) and Italy (Caltanissetta). Fine blue tabular crystals associated with aragonite crystals found in _pania Dolina, Slovakia. Fine crystals are known from marls in Tunisia and Libya.

Barite

$BaSO_4$

ORTHORHOMBIC ● ● ● ●

Properties: C – white, yellow, blue, red, brown, black; S – white; L – vitreous; D – transparent to translucent; DE – 4.3-4.7; H – 3.5; CL – perfect; F – conchoidal to splintery; M – tabular to prismatic crystals, massive; LU – sometimes blue.
Origin and occurrence: Hydrothermal, it originates under medium and low temperatures, also sedimentary, together with fluorite, calcite, cinnabar and other minerals. Beautiful barite crystals up to 50 mm (2 in) found in hydrothermal veins in Pribram, Czech Republic. Blue tabular crystals up to 100 mm (4 in) from Dedova hora, Czech Republic. Beautiful tabular crystals up to 100 mm (4 in) known from Banska Stiavnica, Slovakia; Cavnic and Baia Spric, Romania. Very fine crystals of up to 200 mm (7⅞ in) occurred in Alston Moor, Frizington and Mowbray, Cumbria, UK. Beautiful druses of honey-brown crystals up to 70 mm (2¾ in) long found in Pohla, Germany. Fine druses of prismatic crystals known from Elk Creek, South Dakota, USA; so called

Antlerite, 60 mm, Chuquicamata, Chile

Barite, 100 mm xx, Stoneham Co., U.S.A.

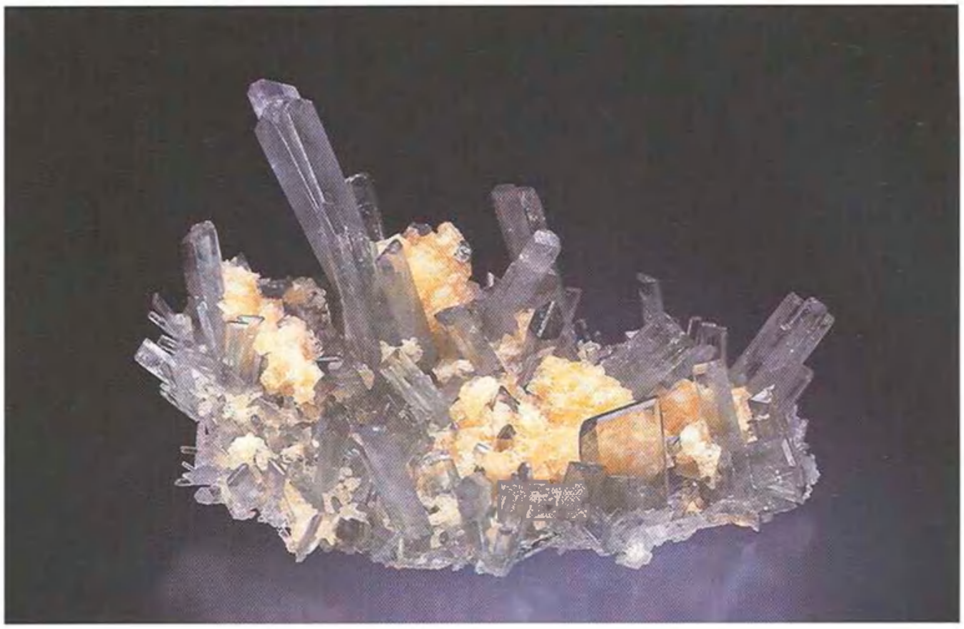

desert roses (crystals with inclusion of sand grains) originating in desert climate occur in the vicinity of Norman, Oklahoma, USA. Shiny crystals come from Freiberg and Halsbrucke, Germany.
Application: an ingredient of drilling fluids, chemical, glass, paper and rubber industries.

Antlerite

$Cu_5(SO_4)_2(OH)_6 \cdot 3\ H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – green; S – light green; L – vitreous; D – translucent; DE – 3.9; H – 3.5; CL – perfect; F – conchoidal to uneven; M – short prismatic and acicular crystals, crusts and earthy aggregates.
Origin and occurrence: Secondary, resulting from weathering of Cu ores, associated with other secondary Cu minerals. It is a principal mineral of the oxidation zone in Chuquicamata, Chile, where it forms crystals up to 5 mm ($^{3}/_{16}$ in). Acicular crystals, up to 20 mm ($^{25}/_{32}$ in) long, occurred in Bisbee, Arizona, USA. Crystalline crusts are known from Spania Dolina and Piesky, Slovakia.

Brochantite, 14 mm aggregate, Bingham, U.S.A.

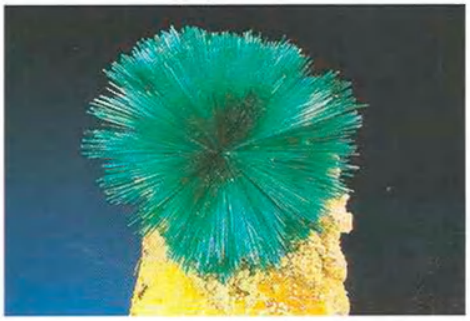

Brochantite

$Cu_4(SO_4)(OH)_6$

MONOCLINIC ● ● ●

Properties: C – green; S – light green; L – vitreous, in cleavage planes pearly; D – translucent to transparent; DE – 4; H – 3.5-4; CL – good; F – conchoidal to uneven; M – long prismatic to acicular crystals, granular.
Origin and occurrence: Secondary, as a result of the oxidation of Cu ores usually in the arid climate, together with other secondary Cu minerals. Crystals up to 70 mm (2¾ in) long found in Bisbee, together with pseudo-morphs of malachite after brochantite. Crystals are also known from Tsumeb, Namibia. Prismatic crystals up to 50 mm (2 in) long from Cerro Verde, Peru. Emerald-green crusts occur in L'ubietova, Slovakia.

Linarite, 23 mm xx, Graham Co., U.S.A.

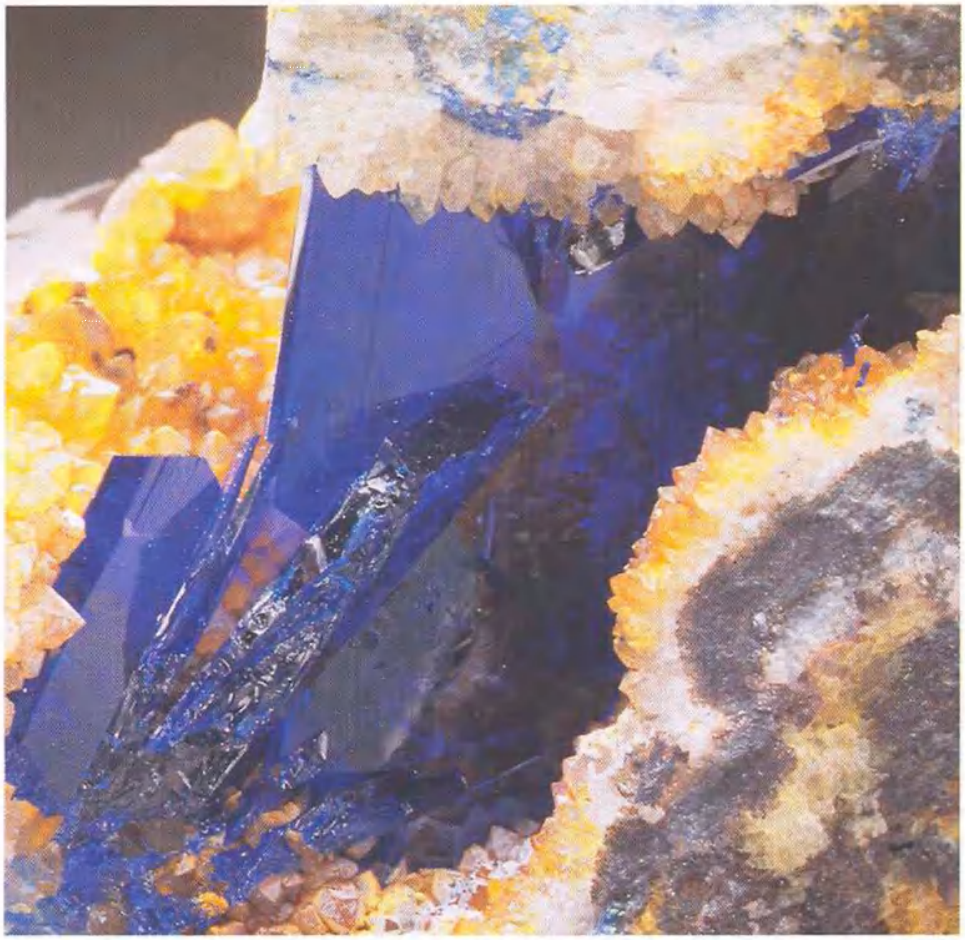

Linarite

PbCu(SO_4)($OH)_2$

MONOCLINIC ● ●

Properties: C – azure-blue; S – light blue; L – vitreous to adamantine; D – translucent; DE – 5.3-5.5; H – 2.5; CL – good; F – conchoidal; M – tabular and prismatic crystals, coatings.

Origin and occurrence: Secondary, as a result of the oxidation of Cu and Pb sulfides at low pH. The largest crystals, reaching up to 80 mm ($3\frac{1}{8}$ in), come from the Mammoth mine, Tiger, Arizona, USA. Crystals from the Grand Reef mine in Arizona up to 50 mm (2 in) long. Very fine crystals, up to 30 mm ($1\frac{3}{16}$ in) were found in Keswick, Cumbria, England, UK. Large crystals were also described from Tsumeb, Namibia and from Broken Hill, New South Wales, Australia.

Alunite

$KAl_3(SO_4)_2(OH)_6$

TRIGONAL ● ● ●

Properties: C – white, yellowish, gray; S – white; L – vitreous to pearly; D – transparent to opaque; DE – 2.8; H – 3.5-4; CL – perfect; F – conchoidal; M – rhombohedral crystals, porous aggregates, granular.

Origin and occurrence: Secondary, as a result of reactions of sulfuric acid with Al-rich rocks, associated with gypsum. Small crystals are known in Berehovo, Ukraine. Massive aggregates occur together with turquoise in Cu deposits in Arizona, USA. (New Cornelia mine and others). Huge alunite deposits, like Zaglik, Azerbaijan, are mined for Al.

Application: Al ore.

Alunite, 1 mm xx, Nagyegyhaza, Hungary

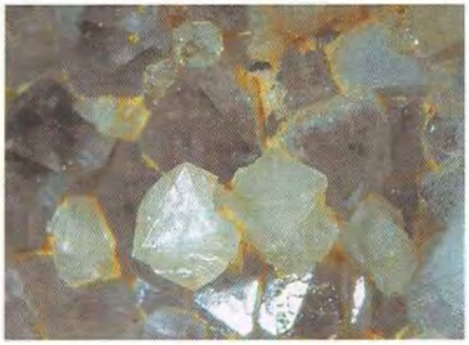

Natrojarosite

$NaFe^{3+}_3(SO_4)_2(OH)_6$

TRIGONAL ● ●

Properties: C – yellow, brown; S – light yellow; L – vitreous; D – transparent to translucent; DE – 3.2; H – 3; CL – good; F – conchoidal; M – tabular to rhombohedral crystals, earthy aggregates..
Origin and occurrence: Secondary, as a result of weathering Fe sulfides, associated with fibroferrite, alunite and other minerals. It occurs in Modum, Norway; Soda Springs Valley, Nevada, USA; Chuquicamata, Chile and elsewhere.

Jarosite

$KFe^{3+}_3(SO_4)_2(OH)_6$

TRIGONAL ● ● ●

Properties: C – yellow; S – light yellow; L – adamantine to dull; D – translucent; DE – 2.9-3.3; H – 2.5-3.5; CL – good; F – conchoidal to uneven; M – rhombohedral to tabular crystals, granular, massive.
Origin and occurrence: : Secondary, as a result of weathering Fe sulfides, usually associated with natrojarosite and other sulfates. The world's best specimens come from Pena Blanca Uranium mine, near Aldama, Chihuahua, Mexico, where crystals, up to 20 mm ($^{25}/_{32}$ in) were found. Crystals, up to 10 mm ($^{3}/_{8}$ in), were found in Tombstone, Arizona, USA. Crystals, together with pseudo-morphs of jarosite after alunite, occurred in Chuquicamata, Chile. Tabular crystals also were described from Horni Slavkov, Czech Republic.

Jarosite, 2 mm xx, Gyongyösoroszi, Hungary

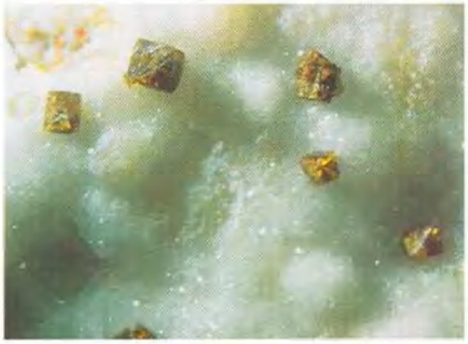

Natrojarosite, 50 mm, Laurion, Greece

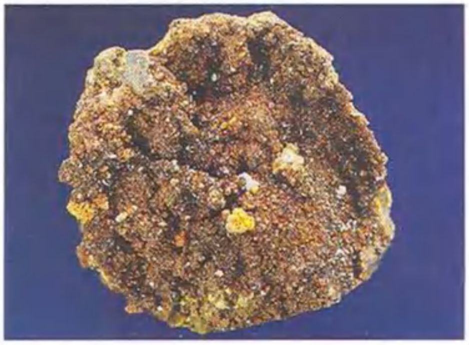

Beudantite

$PbFe^{3+}_3(AsO_4)(SO_4)(OH)_6$

TRIGONAL ● ●

Properties: C – dark green, brown, red-brown; S – greenish, gray-yellow; L – vitreous to resinous; D – transparent to translucent; DE – 4; H – 3.5-4.5; CL – good; M – rhombohedral crystals, crusts.
Origin and occurrence: Secondary, occurring in the oxidation zone of Pb deposits, together with scorodite and other minerals. Crystals, several mm in size, found in Tsumeb, Namibia, are the best in the world. Small crystals are known from Bisbee, Arizona, USA; Ashburton Downs, Western Australia, Australia and Kamarcza near Laurion, Greece.

Beudantite, 70 mm, Moldava, Czech Republic

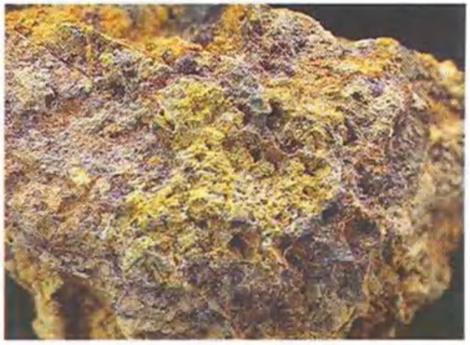

Hanksite

$Na_{22}K(SO_4)_9(CO_3)_2Cl$

HEXAGONAL ● ●

Properties: : C – colorless, yellowish; S – colorless; L – vitreous to dull; D – transparent to translucent; DE – 2.6; H – 3.5; CL – good; F – uneven; M – tabular to short prismatic crystals.
Origin and occurrence: Sedimentary in salt lake sediments, together with halite, borax and other minerals. Crystals up to 200 mm ($7^{7}/_{8}$ in) found in Searles Lake, California, USA. It is also known from borax deposits in the Death Valley, California, USA.

Caledonite

$Cu_2Pb_5(SO_4)_3(CO_3)(OH)_6$

ORTHORHOMBIC ● ●

Properties: C – green to blue-green; S – light green; L – resinous; D – transparent to translucent; DE – 5.6; H – 2.5-3; CL – perfect; F – uneven; M – prismatic crystals, radial aggregates.

Origin and occurrence: Secondary, occurring in the oxidation zone of Cu and Pb deposits, associated with linarite and other minerals. Crystals up to 20 mm ($^{25}/_{32}$ in) come from Leadhills, Scotland, UK. Crystals, up to 15 mm ($^{19}/_{32}$ in), were found in the Mammoth mine, Tiger, Arizona, USA. Rich druses are known from Anarak, Iran. Crystals reaching up to 20 mm ($^{25}/_{32}$ in) occurred in the Blue Bell mine, California, USA.

Leadhillite

$Pb_4(SO_4)(CO_3)_2(OH)_2$

MONOCLINIC ● ●

Properties: C – colorless, yellowish, gray; S – colorless; L – resinous to adamantine; D – transparent to translucent; DE – 6.5; H – 2.5-3; CL – perfect; F – conchoidal; M – pseudo-hexagonal tabular crystals.
Origin and occurrence: Secondary mineral from the oxidation zone of Pb deposits, associated with cerussite, anglesite, linarite and other minerals. The largest crystals, measuring up to 15 cm, come from Tsumeb, Namibia. Crystals up to 25 mm (1 in) found in the Mammoth mine, Tiger, Arizona, USA. Crystals in Leadhills, Scotland, UK were of similar size.

Chalcantite

$CuSO_4 . 5\,H_2O$

TRICLINIC ● ● ●

Properties: C – deep blue; S – white; L – vitreous to resinous; D – transparent to translucent; DE – 2.3; H – 2.5; CL – imperfect; F – conchoidal; M – short prismatic to tabular crystals, stalactites, films; R – soluble in water.

Hanksite. 50 mm. Searles Lake, U.S.A.

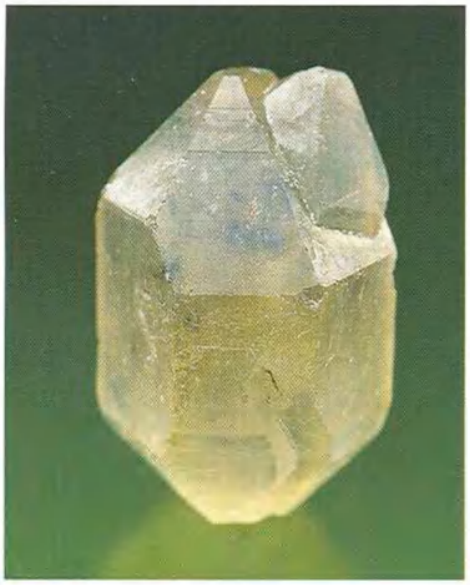

Caledonite. 5 mm x. Graham Co., U.S.A.

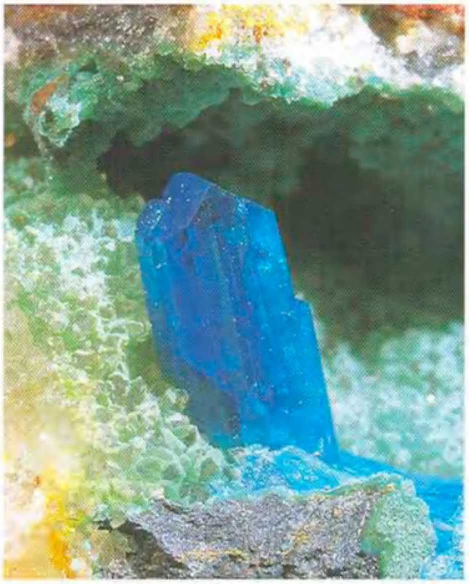

Leadhillite, 55 mm, Leadhill, UK

Chalcanthite, 30 mm, Pima Co., U.S.A.

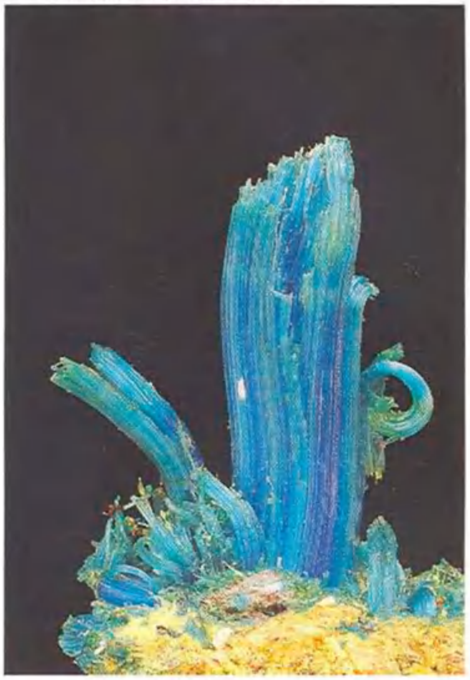

Origin and occurrence: Secondary, as a product of the oxidation of Cu sulfides, stable only in arid climate. Crystals up to 40 mm ($1^9/_{16}$ in) in size, and stalactites, up to 1 m ($39^3/_8$ in) long are known from Bisbee, Arizona, USA. Crystals were also found in the oxidation zone in Chuquicamata, Chile. Beautiful stalactites come from Rio Tinto, Spain.
Application: rarely mined as Cu ore.

Melanterite, 80 mm, Harz Mts., Germany

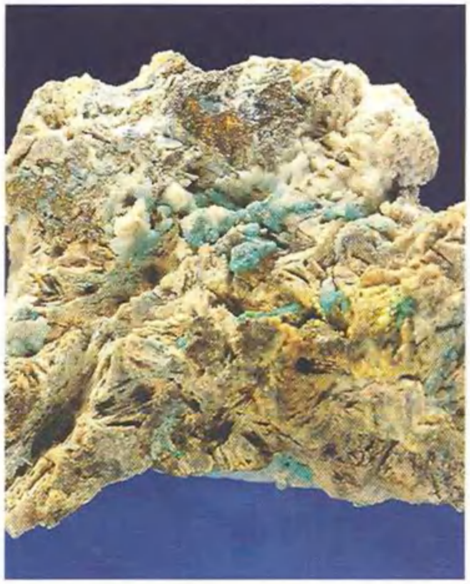

Melanterite

$FeSO_4 . 7 H_2O$

MONOCLINIC ● ● ● ●

Varieties: pisanite (with Cu contents), kirovite (with Mg contents)

Properties: C – light green; S – colorless; L – vitreous; D – translucent; DE – 1.9; H – 2; CL – perfect; F – conchoidal; M – granular crusts, botryoidal and stalactitic aggregates, films; R – soluble in water.
Origin and occurrence: Secondary, as a result of the oxidation of Fe sulfides, together with other sulfates. It is unstable under atmospheric conditions. Crystals up to 20 mm ($^{25}/_{32}$ in) long are known from Bisbee, Arizona and from the Boyd mine, Tennessee, USA. Stalactites, up to 50 cm (20 in) long, occurred in Chvaletice, Czech Republic. It is also common in Rio Tinto, Spain and Banska Stiavnica, Slovakia.

Epsomite
$MgSO_4 \cdot 7H_2O$

ORTHORHOMBIC ● ● ● ●

Properties: C – colorless to white; S – colorless; L – vitreous to silky; D – transparent to translucent; DE – 1.7; H – 2; CL – perfect; F – conchoidal; M – small crystals, granular, stalactitic aggregates; R – soluble in water, decomposing under atmospheric conditions.
Origin and occurrence: Secondary, as a result of the oxidation of Fe sulfides, also from crystallization of the salt lake water, associated with halite and other minerals. Crystals up to 1 m (39⅜ in) long were found on Mount Kruger, Washington; prismatic crystals up to 50 mm (2 in) long also occur in Bisbee, Arizona and needles of a similar size come from the White Caps mine, Nevada, USA. It is also known as a product of the activity of fumaroles in Mount Vesuvius, Italy.

Morenosite
$NiSO_4 \cdot 7H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – green, green-white; S – greenish; L – vitreous; D – transparent to translucent; DE – 2; H – 2-2.5; CL – good; F – conchoidal; M – stalactitic crusts and efflorescences; R – soluble in water.
Origin and occurrence: Secondary, as a product of the oxidation of Ni minerals, stable mainly in the arid regions. It is very common in Sudbury, Ontario, Canada; also in Richelsdorf, Germany and Potucky, Czech Republic.

Coquimbite
$Fe^{3+}_2(SO_4)_3 \cdot 9H_2O$

TRIGONAL ● ● ●

Properties: C – purple, yellow, green, colorless; S – colorless; L – vitreous; D – transparent; DE – 2.1; H – 2; CL – imperfect; F – conchoidal to uneven; M – prismatic to tabular crystals, granular, massive; R – soluble in water.
Origin and occurrence: Secondary, associated with other sulfates. Crystals, several cm long, were found in the Dexter No.7 mine, Calf Mesa, Utah, USA. Small prismatic crystals are known from Zelezník , tabular crystals occurred in Banská Stiavnica, Slovakia. It is very common in Chilean deposits, like Chuquicamata and Tierra Amarilla.

Alunogen
$Al_2(SO_4)_3 \cdot 17H_2O$

TRICLINIC ● ● ●

Properties: C – colorless, white, gray-yellow; S – colorless; L – silky; PS – transparent; DE – 1.8; H – 1.5; CL – perfect; M – pseudo-hexagonal crystals, granular; R – soluble in water.
Origin and occurrence: Secondary, as a result of the pyrite oxidation, also a product of sublimation on volcanoes and burning dumps, associated with other sulfates. Large crystals are known from the Dexter No.7 mine, Calf Mesa, Utah, crusts, over 1 m (39⅜ in) thick were found on Mount Alum, New Mexico,

Epsomite, 10 mm xx, Stassfurt, Germany

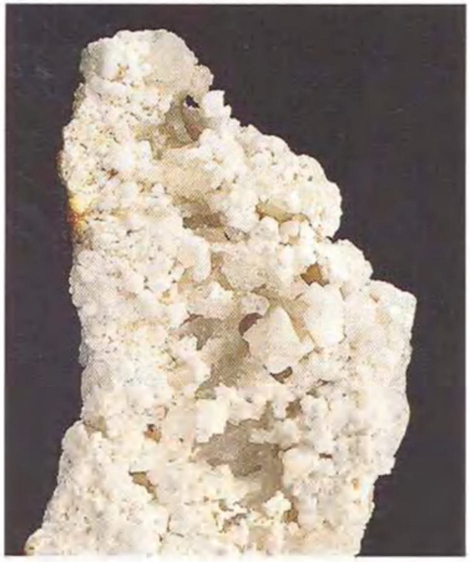

Morenosite, 60 mm, Potucky, Czech Republic

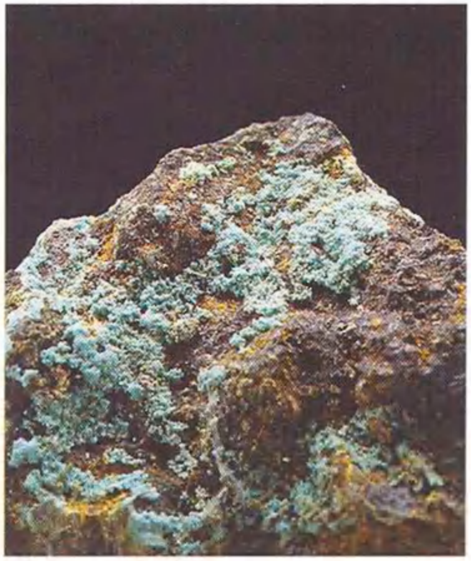

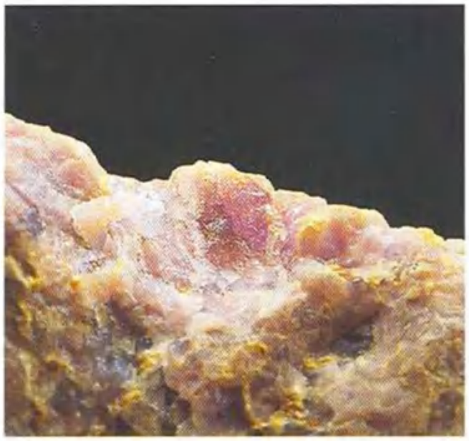

Coquimbite, 110 mm, Cerritos Bajos, Chile

USA. Fine aggregates occur on the walls of underground workings in the old opal mines in Dubník, Slovakia.

Halotrichite

$FeAl_2(SO_4)_4 \cdot 22\ H_2O$

MONOCLINIC ● ● ●

Properties: C – white, greenish; S – colorless; L – vitreous; PS – transparent to translucent; DE – 1.9-2.1; H – 1.5-2; CL – imperfect; F – conchoidal; M – acicular crystals, fibrous aggregates, efflorescences; R – soluble in water.
Origin and occurrence: Secondary, as a result of the pyrite oxidation, also a product of the activity of hot springs ans solfataras, associated with other sulfates. Common fibrous crusts occur in Dubnik, Slovakia. It looks similar in Rio Marina, Elba, Italy and in Chuquicamata, Chile. It is known from solfataras in Pozzuoli, Italy. It is a product of hot springs activity in the Lassen Peak National Park, California, USA.

Apjohnite

$MnAl_2(SO_4)_4 \cdot 22\ H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white, pink, greenish, yellow; S – colorless; L – silky; D – transparent; DE – 1.9; H – 1.5; M – fibrous aggregates, coatings, massive; R – soluble in water.
Origin and occurrence: Secondary, occurring together with other sulfates. Large accumulations are known from Little Pigeon Creek, Alum Cave, Tennessee, USA. It also occurs in Delagona Bay, Mozambique.

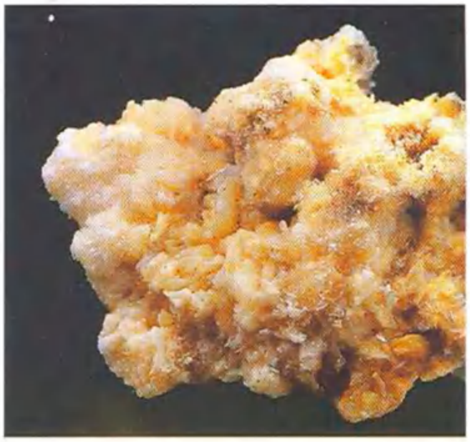

Alunogen, 80 mm, Dubnik, Slovakia

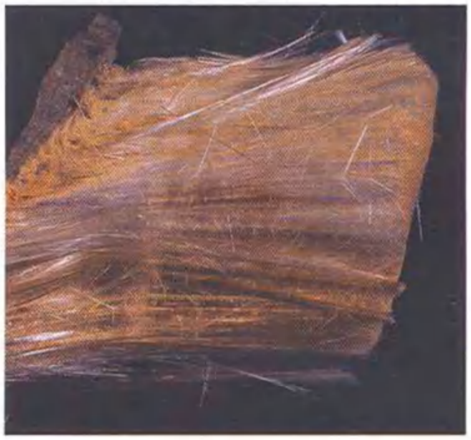

Halotrichite, 90 mm, Recsk, Hungary

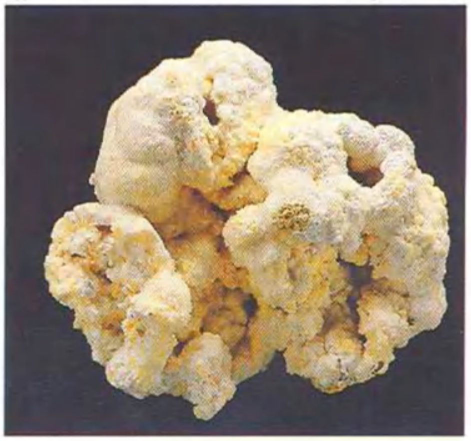

Apjohnite, 60 mm, Smolnik, Slovakia

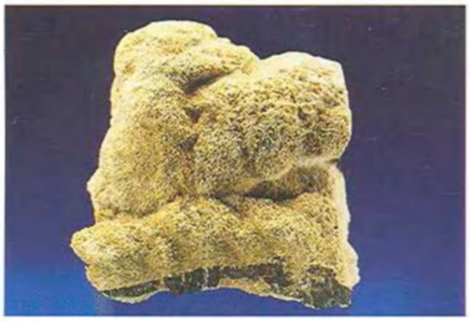

Bilinite, 60 mm, Bilina, Czech Republic

Bilinite

$Fe^{2+}Fe^{3+}_2(SO_4)_4 . 22 H_2O$

MONOCLINIC ● ●

Properties: C – white to wellowish; S – white; L – silky; D – opaque; DE – 1.9; H – 2; M – fibrous aggregates; R – soluble in water.

Origin and occurrence: Secondary, as a result of the pyrite oxidation, associated with other sulfates. Fibrous aggregates are known from Svitec near Bilina, Czech Republic. Also described from Bisbee, Arizona, USA.

Tschermigite

$(NH_4)Al(SO_4)_2 . 12 H_2O$

CUBIC ● ● ●

Properties: : C – colorless; S – colorless; L – vitreous; D – transparent; DE – 1.6; H – 1.5; F – conchoidal; M – octahedral crystals, fibrous and columnar aggregates; R – soluble in water.

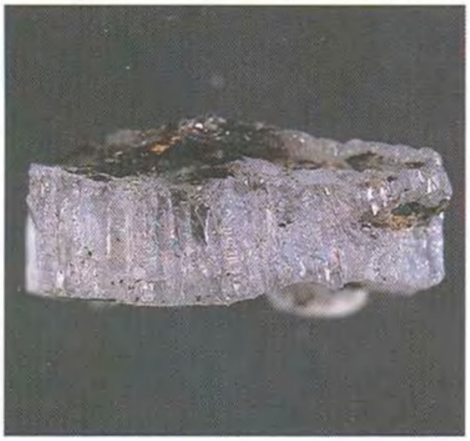

Tschermigite, 50 mm, Mogyororosbanya, Hungary

Origin and occurrence: Secondary in the brown coal, also on burning dumps and as a product of solfataras. Skeletal crystals up to 10 mm (3/8 in) in size are known from the brown coal basin near Most and Bilina, Czech Republic. Original locality Ecrmniky, Czech Republic yielded fibrous crusts, up to 50 mm (2 in) thick. Fine octahedra, up to 10 mm (3/8 in) come from burning dumps near Zastavka near Brno, Czech Republic. Octahedra occur also in Geysers, California, USA. Small crystals on Etna, Sicily, Italy are of volcanic origin.

Polyhalite

$KCa_2Mg(SO_4)_4 . 2 H_2O$

TRICLINIC ● ● ●

Properties: C – colorless, brown, red-brown; S – colorless; L – vitreous; D – transparent to translucent; DE – 2.8; H – 3-3.5; CL – perfect; M – acicular to prismatic crystals, columnar, scaly and fibrous aggregates.

Origin and occurrence: Sedimentary, as a constituent of salt deposits, also as a product of volcanic activity. Tabular and prismatic crystals are found rarely together with massive polyhalite aggregates in Stassfurt, Germany. Fibrous aggregates come from Halstatt, Austria. Large deposits of polyhalite are located near Carlsbad, New Mexico, USA. Coatings occur on Mount Vesuvius, Italy.

Görgeyite

$K_2Ca_5(SO_4)_6 . H_2O$

MONOCLINIC ● ●

Properties: C – colorless, yellowish; S – colorless; L – vitreous; D – translucent; DE – 3; H – 3.5;

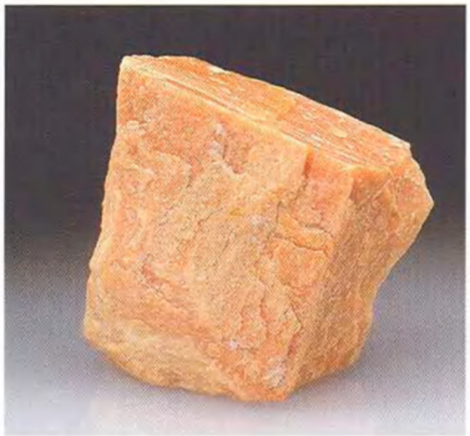

Polyhalite, 54 mm, Carlsbad, U.S.A.

Gypsum, 62 mm, Carneville, Utah, U.S.A.

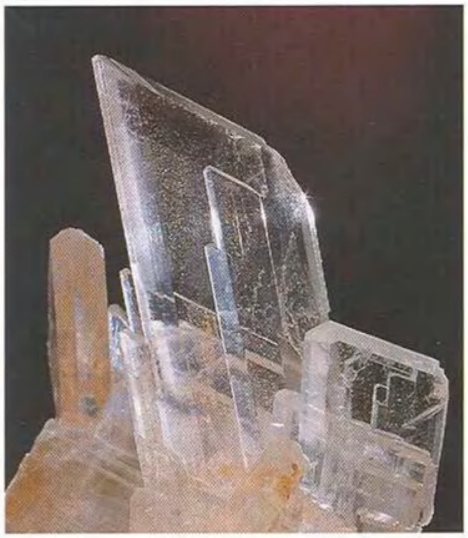

CL – good; F – conchoidal; M – tabular crystals. *Origin and occurrence:* Sedimentary in salt deposits, associated with halite and other minerals. Fine crystals up to 80 mm ($3^{1}/_{8}$ in) long found near Inder Lake, Kazakhstan; also known from Bad Ischl, Austria.

Gypsum

$CaSO_4 . 2 H_2O$

MONOCLINIC ● ● ● ● ●

Varieties: Maria-glass, alabaster, satin spar, selenite. *Properties:* C – colorless, white, gray, yellowish; S – colorless; L – vitreous to pearly; D – transparent to translucent; DE – 2.3; H – 1.5-2; CL – perfect; F – conchoidal; M – typical monoclinic crystals, often twins, fibrous and platy aggregates, granular, massive; LU – crystals with inclusions sometimes bluish to yellowish.

Gorgeyite, 80 mm, Inder Lake, Kazakhstan

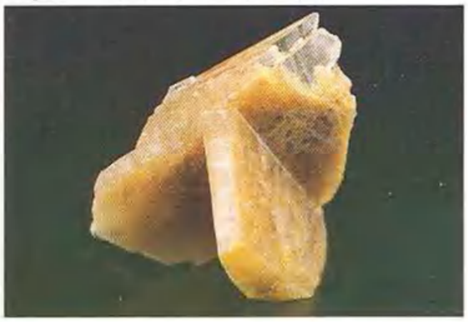

Origin and occurrence: Rare primary hydrothermal, mostly sedimentary and as a weathering product, associated with anhydrite, halite and other minerals. Crystals up to 50 mm from Cavnic, Romania are probably hydrothermal. Huge crystals up to 1.5 m (5 ft) long found in karst cavities (Cave of Swords) in gossan in the PbBZn deposit Naica, Chihuahua, Mexico. Crystals up to 9 m (29 ft 6 in) long from Santa Eulalia, Chihuahua, Mexico, where they were found combined with interesting aggregates, called 'ram's horns' from their shape. Crystals up to 4 m (13 ft) long occurred in Tarnobrzeg, Poland. Common crystals are also known from Gorguel, Spain. The 'desert roses' or crystal druses, from Sahara desert in Tunisia and Algeria, with sand grain inclusions are mineralogically interesting. Large slabs of the transparent variety, called Maria-glass, found in Friedrichsrode, Germany. Fine-grained variety alabaster occurs e.g. in Italy. Fibrous variety selenite (sometimes also called satin spar) comes from the Sylva river basin, Perm, Russia.
Application: building, chemical and medical industries.

Langite

$Cu_4(SO_4)(OH)_6 . 2 H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – blue, blue-green; S – light blue; L – vitreous to silky; D – translucent; DE – 3.3; H – 2.5-3; CL – perfect; M – small isometric crystals, fine-grained crusts, earthy aggregates..
Origin and occurrence: Secondary, as a product of the oxidation of Cu ores, associated with gypsum and other minerals. Crystals known from St. Just, Cornwall, UK. Crystals occurred in Tsumeb, Namibia. Fine specimens come from Spania Dolina and L'ubietova, Slovakia and from Borovec, Czech Republic. It is also common in Ely, Nevada, USA and in El Cobre, Chile.

Langite, 49 mm, Allihies, Cork, Ireland

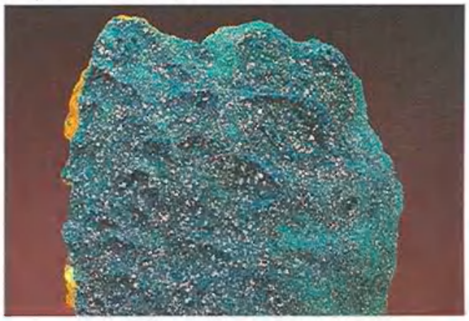

Fibroferrite, 70 mm, Dubnik, Slovakia

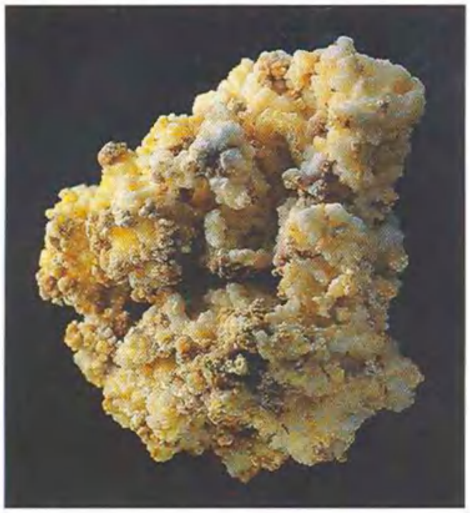

Fibroferrite

$Fe^{3+}(SO_4)(OH) \cdot 5\,H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – yellowish, greenish, gray; S – white; L – silky; D – opaque; DE – 1.9; H – 2.5; CL – perfect; M – small crystals, fibrous and botryoidal crusts; R – soluble in water.
Origin and occurrence: Secondary as a product of the pyrite oxidation, together with other sulfates. Crystals in cavities in melanterite found in the Dexter No.7 mine, Calf Mesa, Utah, USA. Vein fillings up to 3 m (10 ft) thick come from the Santa Elena mine, La Alcaparrosa, Argentina. Fine fibrous aggregates occur in Dubnik, Slovakia. It is common in many localities in Chile (Tierra Amarilla, Chuquicamata).

Aluminite

$Al_2(SO_4)(OH)_4 \cdot 7\,H_2O$

MONOCLINIC ● ● ●

Properties: C – white; S – white; L – dull; D – opaque; DE – 1.7-1.8; H – 1-2; CL – none; M – earthy nodules, consisting of microscopic needles.
Origin and occurrence: Secondary, resulting from the reaction of sulfuric acid with Al in Al-rich rocks. Large nodule, 30 cm (12 in) in diameter, known from Newhaven, Sussex, UK. Fine white nodules described from Mala Chuchle, Prague, Czech Republic. It also occurs near Halle, Germany and covers limestone in the vicinity of Joplin, Missouri, USA.

Aluminite, 60 mm, Bicske-Csordakut, Hungary

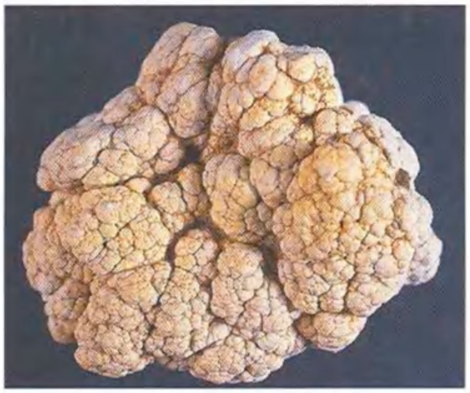

Botryogen

$MgFe^{3+}(SO_4)_2(OH) \cdot 7\,H_2O$

MONOCLINIC ● ● ●

Properties: C – orange-red; S – yellow; L – vitreous; D – transparent to translucent; DE – 2.1; H – 2-2.5; CL – perfect; F – conchoidal; M – prismatic striated crystals, racemose and spherical aggregates with radial structure.
Origin and occurrence: Secondary, as a result of the pyrite oxidation in arid regions, together with other sulfates. Crystals up to 35 mm ($1\frac{5}{16}$ in) long from the Libiola mine near Genoa, Italy. It is common in Chuquicamata and Quetena in Chile; also known from Rammelsberg, Germany.

Botryogen, 3 mm xx, Knoxville, U.S.A.

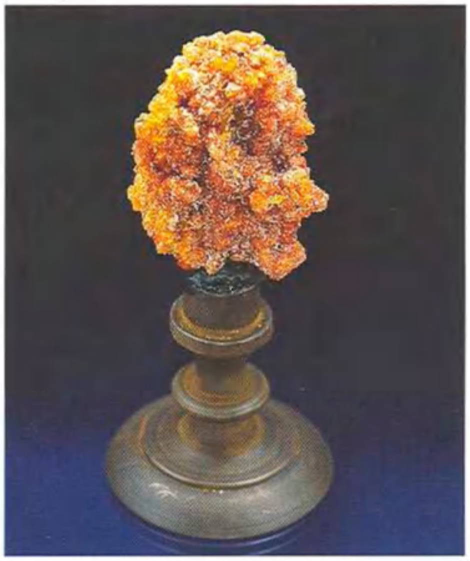

Devilline, 10 mm xx, Spania Dolina, Slovakia

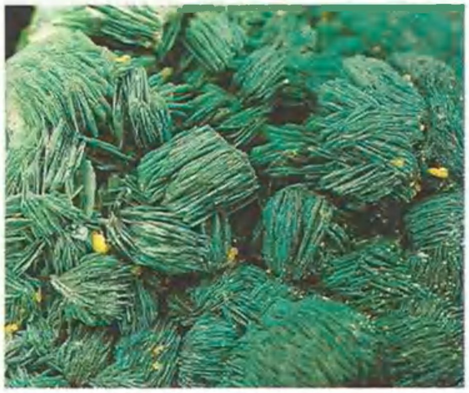

Copiapite

$(Fe^{2+},Mg)Fe^{3+}_4(SO_4)_6(OH)_2 \cdot 20\ H_2O$

TRICLINIC ● ● ●

Properties: C – yellow, green-yellow, orange; S – yellow; L – pearly; D – transparent to translucent; DE – 2.1-2.2; H – 2.5; CL – perfect; M – thin tabular crystals, scaly and pulverulent aggregates, earthy.
Origin and occurrence: Secondary, originated from the pyrite oxidation, together with other sulfates.
Tabular crystals come from the Dexter No.7 mine, Calf Mesa, Utah, USA and also from Zeleznik , Slovakia. Fine crystals were found in many localities in Chile (Tierra Amarilla, Chuquicamata). It also occurs in Rammelsberg, Germany.

Copiapite, 96 mm, Copiapó, Chile

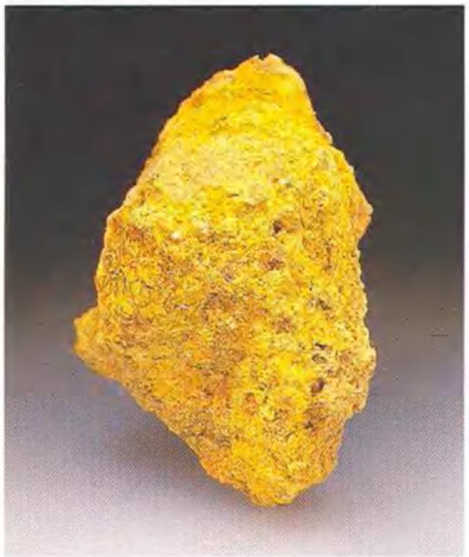

Serpierite, 80 mm, Příbram, Czech Republic

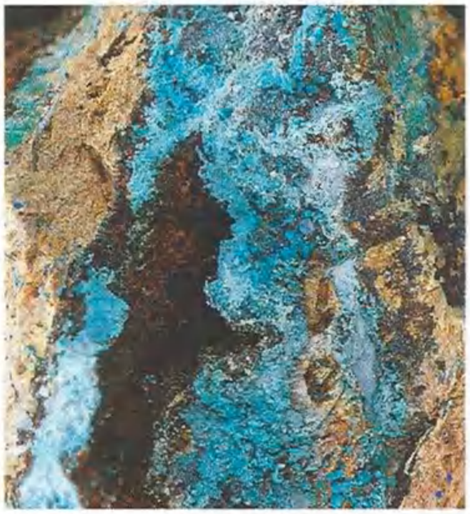

Devilline

$CaCu_4(SO_4)_2(OH)_6 \cdot 3\ H_2O$

MONOCLINIC ● ●

Properties: C – emerald-green; S – white to light green; L – vitreous to pearly; D – transparent to translucent; DE – 3.1; H – 2.5; CL – perfect; M – thin tabular pseudo-hexagonal crystals and coatings.
Origin and occurrence: Secondary, as a result of the oxidation of Cu sulfides, associated with other secondary Cu minerals. The world's best specimens come from Spania Dolina, Slovakia, where crystal rosettes up to 10 mm (⅜ in) in diameter were found in the past century; also known from Botallack, Cornwall, UK and Tsumeb, Namibia.

Serpierite

$Ca(Cu,Zn)_4(SO_4)_2(OH)_6 \cdot 3\ H_2O$

MONOCLINIC ● ●

Properties: C – blue; S – white; L – vitreous; D – transparent to translucent; DE – 3.1; H – 2.5; CL – perfect; M – tabular crystals, coatings.
Origin and occurrence: Secondary, originated in the oxidation zone of Cu-Zn deposits, together with smithsonite and other minerals. Its small crystals and aggregates occurred in Laurion, Greece. Recently confirmed at Příbram, Czech Republic.

Ettringite, 45 mm, Kuruman, South Africa

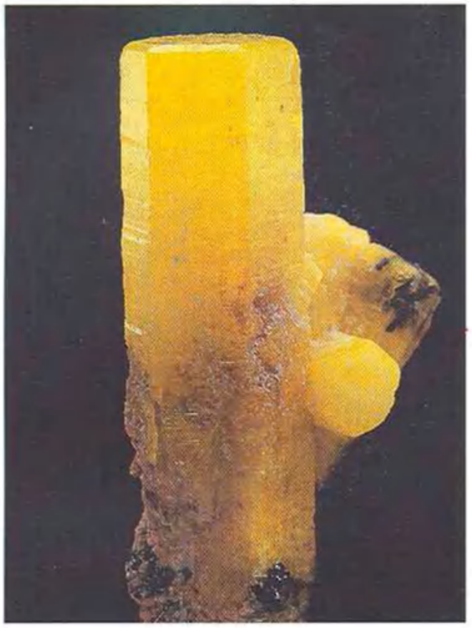

Ettringite

$Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\ H_2O$

HEXAGONAL ● ●

Properties: C – colorless, yellow; S – white; L – vitreous to silky; D – transparent; DE – 1.8; H – 2.5; CL – perfect; M – prismatic crystals, fibrous aggregates.
Origin and occurrence: Metamorphic, associated with sturmanite. The world's best crystals reaching up to 100 mm (4 in) come from the N'Chwaning mine, Kuruman, South Africa. Crystals up to 4 mm (5/32 in) occurred in Franklin, New Jersey, USA. Also known from the contact metamorphic conditions in Crestmore, California, USA.

Sturmanite

$Ca_6Fe^{3+}{}_2(SO_4)_2[B(OH)_4].(OH)_{12} \cdot 25\ H_2O$

TRIGONAL ●

Properties: C – yellow, yellow-green; S – white; L – vitreous; D – transparent to translucent; DE – 1.9; H – 2.5; CL – perfect; M – flat dipyramidal crystals.
Origin and occurrence: : Probably metamorphic, associated with barite, hematite and ettringite. Crystals up to 140 mm (5½ in) long come from the N'Chwaning mine, Kuruman, South Africa.

Sturmanite, 35 mm xx, Kuruman, South Africa

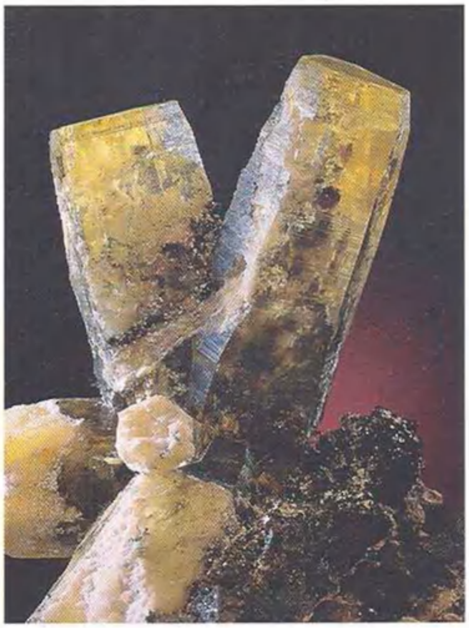

Johannite

$Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 8\ H_2O$

TRICLINIC ● ●

Properties: C – green; S – light green; L – vitreous; D – transparent to translucent; DE – 3.3; H – 2-2.5; CL – good; M – prismatic to thick tabular crystals, scaly aggregates, coatings; R – radioactive.
Origin and occurrence: Secondary, as a result of the uraninite oxidation, together with other secondary U minerals. Crystals are known from Jachymov, Czech Republic and Johanngeorgenstadt, Germany. It was common with zippeite in Central City, Colorado, USA and also reported from Mounana, Gabon.

Zippeite

$K_4(UO_2)_6(SO_4)_3(OH)_{10} \cdot 4\ H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – orange-yellow; S – yellow; L – dull to earthy; D – opaque; DE – 3.7; H – not determined; CL – perfect; M – acicular and tabular crystals, pulverulent and acicular aggregates, coatings; LU – green; R – radioactive.
Origin and occurrence: Secondary, forming during the uraninite oxidation, associated with other secondary U minerals. Small tabular crystals come from Drmoul, Czech Republic. Coatings and

Johannite, 70 mm, Jachymov, Czech Republic

Zippeite, 40 mm, Lodeve, France

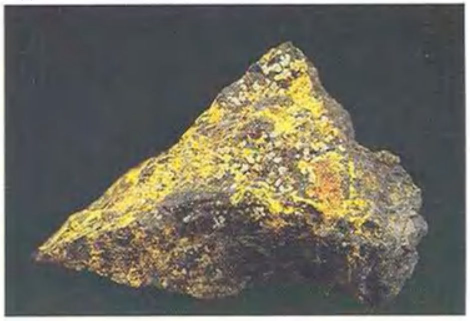

acicular aggregates are known from Jachymov, Czech Republic and Central City, Colorado, USA; also occurs in Shinkolobwe, Zaire.

Scheelite

$CaWO_4$

TETRAGONAL ● ● ● ●

Properties: C – colorless, gray-white, yellow-brown, orange, red, greenish; S – white; L – greasy to adamantine; D – translucent; DE – 6.1; H – 4.5-5; CL – good; F – conchoidal to uneven; M – pseudo-octahedral crystals, granular, massive; LU – blue-white.
Origin and occurrence: Magmatic in pegmatites, hydrothermal in greisens and metamorphic; parageneses vary significantly according to the origin. Beautiful brownish crystals up to 100 mm (4 in) in size come from Taewha and Tongwha in Korea. Similar crystals were recently found in China. Orange crystals up to 40 mm ($1^{9}/_{16}$ in) in size are associated with cassiterite crystals on quartz crystals from Iultin and Tenkergin, Russia. Clear crystals, weighing up to 50 kg (110 lb), occurred in pegmatites near Natas, Namibia. Crystals up to 70 mm (2¾ in) reported from several mines near Traversella, Italy. Beautiful red crystals up to 20 mm ($^{25}/_{32}$ in) were very rare in Pøibram, Czech Republic. Yellow crystals up to 40 mm ($1^{9}/_{16}$ in) are known from quartz veins with pumpellyite in Obøi Dsl, Czech Republic.
Application: W ore.

Scheelite, 77 mm, Sichuan, China

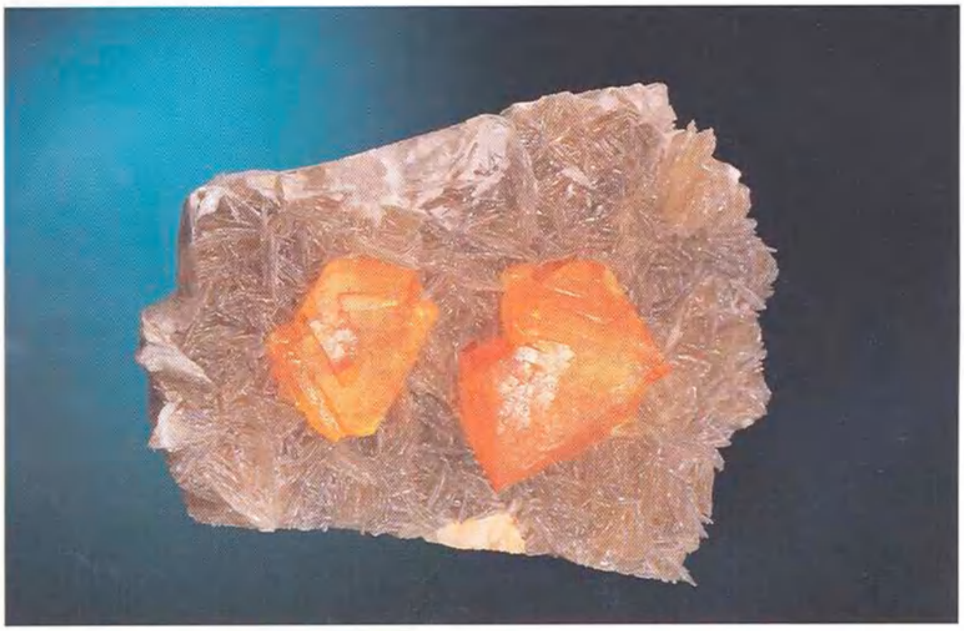

Stolzite, 20 mm, Arizona, U.S.A.

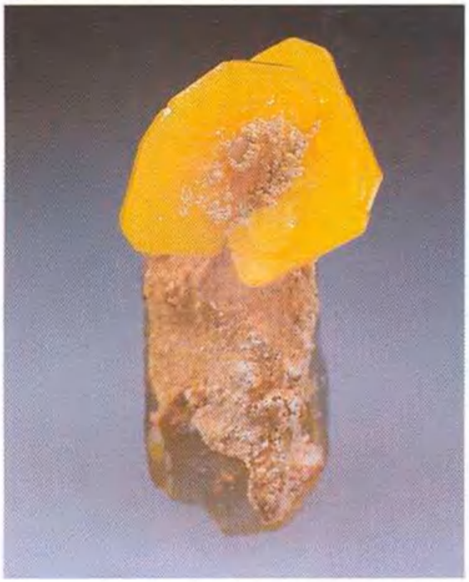

Stolzite

$PbWO_4$

TETRAGONAL ● ●

Properties: C – gray-brown, orange-yellow, red, green; S – colorless; L – adamantine to resinous; D – transparent to translucent; DE – 7.9-8.3; H – 2.5-3; CL – imperfect; F – conchoidal to uneven; M – dipyramidal and thick tabular, striated crystals.
Origin and occurrence: Secondary, as a product of the oxidation of primary W minerals. Crystals up to 60 mm (2$^{3}/_{8}$ in) from St Leger-de-Peyre, France. Prisms and needles up to 25 mm (1 in) long found in Broken Hill, New South Wales, Australia. Crystals up to 25 mm (1 in) also known from Tsumeb, Namibia. Crystals up to 20 mm ($^{25}/_{32}$ in) reported from Cínovec, Czech Republic and from the Black Pine mine, Montana, USA.

Ferrimolybdite, 60 mm, Hurky, Czech Republic

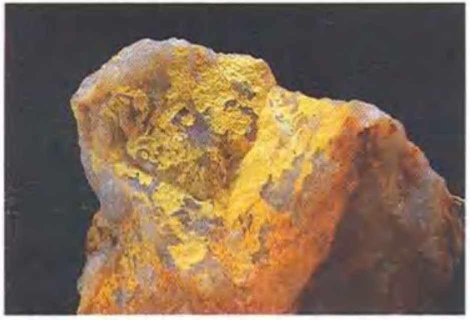

Crocoite, 44 mm, Dundas, Australia

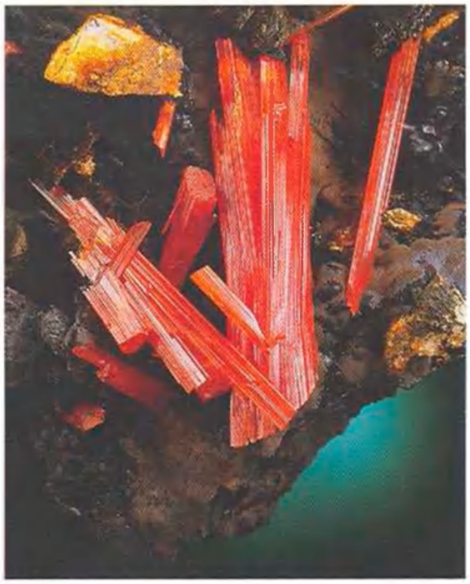

Crocoite

$PbCrO_4$

MONOCLINIC ● ●

Properties: C – orange, red; S – orange-yellow; L – adamantine to greasy; D – translucent; DE – 6; H – 3; CL – good; F – conchoidal to uneven; M – long prismatic to acicular crystals, crusts..
Origin and occurrence: Secondary, as a result of the galena oxidation in basic rocks. The world' best specimens come from the Dundas district, Tasmania, Australia where crystals up to 100 mm (4 in) long were found in several mines. Fine crystals up to 40 mm (1$^{9}/_{16}$ in) long are known from Berezovsk, Ural mountains, Russia. Crystals up to 20 mm ($^{25}/_{32}$ in) were recently found in Callenberg, Germany.

Betpakdalite, 70 mm, Bayan Tsogdo, Mongolia

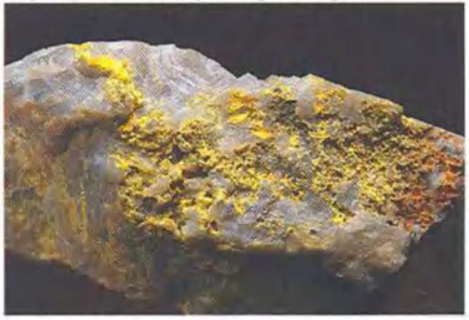

Ferrimolybdite

$Fe_2(MoO_4)_3 \cdot 8\,H_2O$

ORTHORHOMBIC ● ●

Properties: C – yellow, whitish; S – light yellow; L – adamantine, silky, earthy; D – opaque; DE – 4.4; H – 1-2; M – small acicular crystals, fibrous and radial aggregates, earthy.

Origin and occurrence: Secondary, as a product of the molybdenite oxidation. Microscopic crystals were found in Glen Innes, New South Wales, Australia. It occurred as yellow coatings in Climax and Telluride, Colorado, in the Getchell mine, Nevada, USA; also in Hsrky near Eista, Czech Republic.

Betpakdalite

$CaFe^{3+}H_8(MoO_4)_5(AsO_4)_2 \cdot 8\,H_2O$

MONOCLINIC ●

Properties: C – lemon-yellow; S – yellow; L – vitreous, waxy, dull; D – opaque; DE – 3; H – 3; CL – good; M – short prismatic microscopic crystals, pulverulent.

Origin and occurrence: Secondary mineral. Originally described from Kara-Oba, Kazakhstan. It also occurred in Tsumeb, Namibia and in Krupka, Czech Republic.

Wulfenite

$PbMoO_4$

TETRAGONAL ● ● ●

Properties: C – yellow, orange, brownish, red, greenish; S – white; L – greasy to adamantine; D – transparent to translucent; DE – 6.3-7; H – 3; CL – good; F – uneven to conchoidal; M – thin tabular and dipyramidal crystals, granular, massive.

Origin and occurrence: Secondary, as a result of the galena oxidation, together with cerussite, vanadinite and other minerals. The best specimens are known from the Red Cloud mine near Yuma, Arizona, where red tabular crystals found up to 50 mm (2 in) diameter. Yellow-brown crystals up to 100 mm (4 in) come from the Glove mine, Arizona, USA. Thick tabular orange crystals up to 20 mm (25/32 in) in diameter found in the Erupcion mine, Villa Ahumada, Los Lamentos, Chihuahua. Beautiful yellow plates up to 60 mm (2 3/8 in) with orange mimetite spheres occurred in the San Francisco mine, Magdalena, Sonora, Mexico. Rare tabular crystals up to 70 mm (2¾ in) across come from Tsumeb, Namibia. Fine orange-yellow tabular crystals up to 20 mm (25/32 in) across, and pyramidal crystals are known from Bleiberg, Austria and Mežica , Slovenia. Crystals up to 100 mm (4 in) were found recently in Touissit, Morocco.

Wulfenite, 38 mm, Los Lamentos, Mexico

8. Phosphates

Lithiophosphate

Li_3PO_4

ORTHORHOMBIC ●

Properties: C – colorless, white, pinkish; S – white; L – vitreous; D – transparent to translucent; DE – 2.5; H – 4; CL – perfect; F – uneven; M – prismatic crystals, granular.
Origin and occurrence: Hydrothermal in granitic pegmatites, where it forms by replacement of spodumene and montebrasite. Cleavable aggregates up to 100 mm (4in) across occur in the Tanco Mine, Bernic Lake, Manitoba, Canada; crystals up to 25 mm (1 in) across in the Foote mine, Kings Mountain, North Carolina, USA.

Beryllonit

$NaBePO_4$

MONOCLINIC ● ●

Properties: C – colorless, white, yellowish; S – white; L – vitreous; D – transparent to translucent; DE – 2.8; H – 5.5-6; CL – perfect; F – uneven; M – short prismatic to tabular crystals, granular.
Origin and occurrence: Hydrothermal in cavities in granitic pegmatites where it is associated with herderite, albite and tourmaline. Crystals and their twins, up to 150 mm (6 in) across come from Stoneham and Newry, Maine, USA; also from Viitaniemi, Finland and Paprok, Afghanistan.

Adamite, 52 mm, Mapimi, Mexico
Lithiophosphate, 30 mm, Tanco, Canada

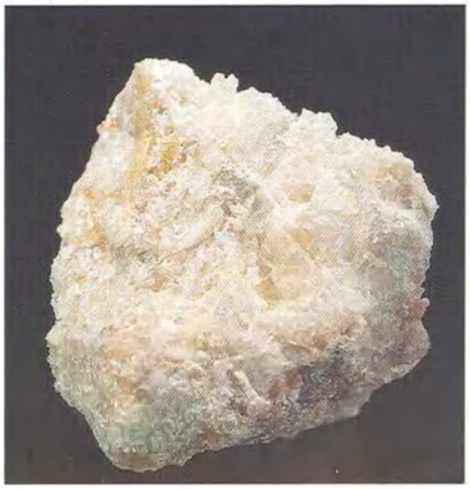

Beryllonite, 31 mm, Paprok, Afghanistan

Triphyllite

$LiFePO_4$

ORTHORHOMBIC ● ● ●

Properties: C – gray-green, gray-blue, gray, brown; S – gray-white; L – greasy to vitreous; D – transparent to translucent; DE – 3.4; H – 4-5; CL – good; F – uneven; M B short prismatic crystals, granular, massive.
Origin and occurrence: Magmatic in granitic pegmatites, associated with graftonite, sarcopside and many secondary phosphates. Large triphyllite crystals up to 1.5 m (5 ft) across are known from Hagendorf, Germany; from the Tip Top mine, Custer, South Dakota and Palermo No. 1 mine, North Groton, New Hampshire, USA; also from Hühnerkobel, Germany.

Triphylite, 70 mm, Hagendorf, Germany

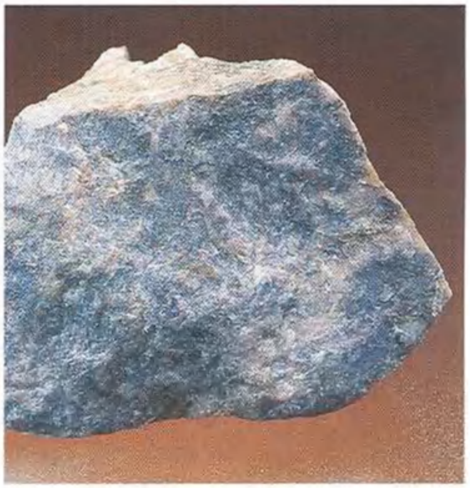

Lithiophilite, 120 mm, Viitaniemi, Finnland

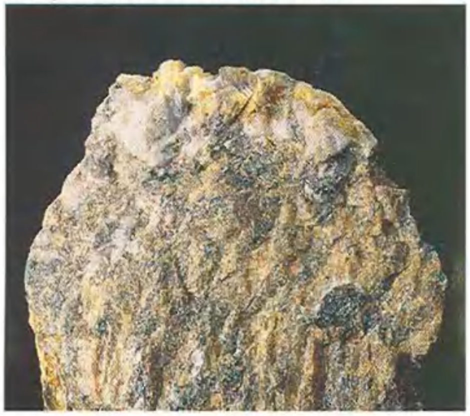

Lithiofilit

LiMnPO$_4$

ORTHORHOMBIC ● ●

Properties: C – pink, red-brown, brown; S – white; L – vitreous; D – transparent to translucent; DE – 3.3; H – 4-5; CL – good; F – uneven; M – short prismatic crystals, granular, massive.
Origin and occurrence: Magmatic in granitic pegmatites. It is sometimes associated with triplite and triphyllite, typically replaced by many secondary phosphates. Large masses of lithiophillite, reaching up to 1 m ($39^{3}/_{8}$ in), occur in Karibib, Namibia; Kitumbe, Rwanda. Other localities are Mangualde, Portugal; Tanco mine, Bernic Lake, Manitoba, Canada; Stewart Lithia Mine, Pala, California, USA.

Purpurite, 40 mm, Usakos, Namibia

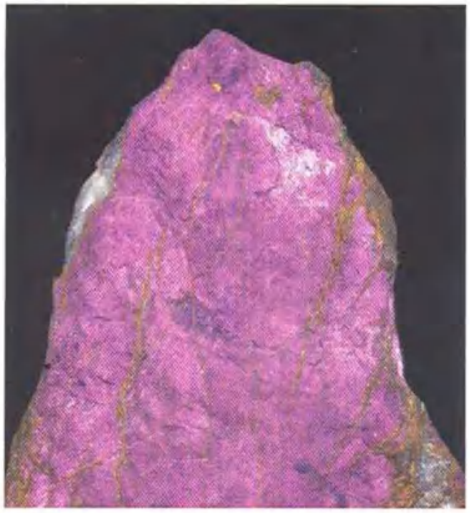

Berzeliite, 120 mm, Langban, Sweden

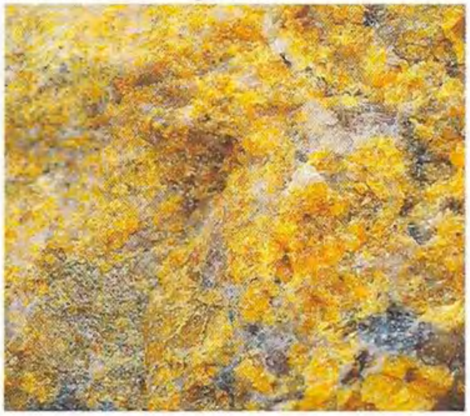

Purpurite

Mn^{3+}PO$_4$

ORTHORHOMBIC ● ●

Properties: C – pink, purple, dark brown; S B red-purple; L – dull to velvet; D – translucent to opaque; DE – 3.7; H – 4-4.5; CL – good; F – uneven; M B granular, massive.
Origin and occurrence: Hydrothermal, as a product of lithiophillite replacement in granitic pegmatites. It is usually associated with many secondary phosphates. It is known from Kitumbe, Rwanda; Usakos and Sandamab, Namibia; the Tip Top and Bull Moose mines, Custer, South Dakota and Branchville, Connecticut, USA.

Berzeliite

(Ca,Na)$_3$ (Mg,Mn)$_2$ (AsO$_4$)$_3$

CUBIC ● ●

Properties: C – yellow, orange; S – red-purple; L – resinous; D – transparent to translucent; DE – 4.1; H – 4-4.5; CL – none; F – conchoidal to uneven; M – isometric crystals, granular, massive.
Origin and occurrence: Metamorphic, together with haussmanite, rhodonite and tephroite. It occurs as massive in Langban and Nordmark, Sweden.

Whitlockite

Ca$_9$(Mg,Fe)H(PO$_4$)$_7$

TRIGONAL ● ●

Properties: C – colorless, white, yellowish, pinkish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.1; H – 5; CL – none; F – conchoidal to uneven; M – rhombohedral crystals, granular, massive.

Origin and occurrence: Hydrothermal, as a product of replacement of primary phosphates in granitic pegmatites, rare in sedimentary rocks – phosphorites; very rare magmatic in meteorites. Mainly associated with apatite and carbonates. Imperfect crystals around 10 mm ($^{3}/_{8}$ in) across, occur in the Palermo No. 1 mine, North Groton, New Hampshire; also in the Tip Top mine, Custer, South Dakota, USA.

Whitlockite, 10 mm xx, New Hampshire, U.S.A.

Xenotime-(Y)

YPO_4

TETRAGONAL ● ● ●

Properties: C – brown, yellow, gray, greenish; S – white; L – vitreous to resinous; D – transparent, translucent to opaque; DE – 4.5; H – 4.5; CL – good; F – conchoidal to uneven; M – long prismatic to tabular crystals, granular; R – sometimes weakly radioactive and metamict.

Origin and occurrence: Magmatic in granitic and alkaline pegmatites, granites and syenites; hydrothermal in the Alpine-type veins; metamorphic in gneisses; common in placers. It is associated with monazite-(Ce) and zircon. Perfect prismatic crystals up to 100 mm (4in) across occur mainly in pegmatites in Kragero and Hitterö, Norway; Ytterby, Sweden; in several places in Madagascar; in Ichikawa, Japan. Crystals about 20 mm ($^{25}/_{32}$ in) are known from the Alpine-type veins in Binntal, Switzerland.

Application: ore of rare earth elements.

Xenotime-(Y), 14 mm x, Washington Co., U.S.A.

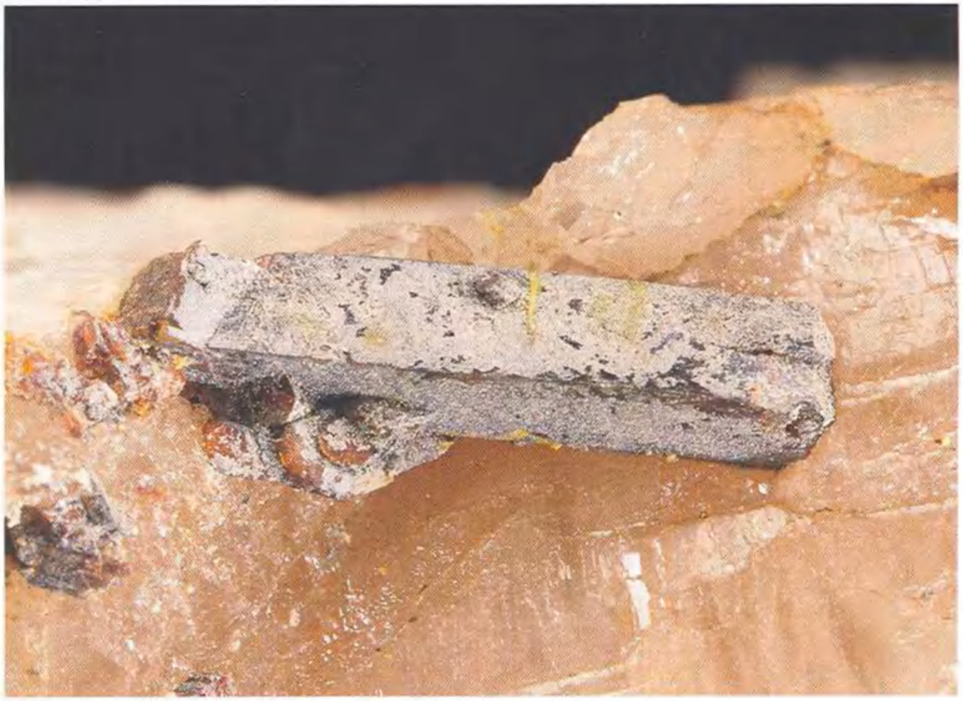

Monazite-(Ce)

$\mathrm{CePO_4}$

MONOCLINIC ● ● ●

Properties: C – yellow, brown, red-brown, orange, gray-green; S – white; L – vitreous to resinous; D – transparent, translucent to opaque; DE – 4.6; H – 5-5.5; CL – good; F – conchoidal to uneven; M – long prismatic to tabular crystals, granular; R – sometimes weakly radioactive and metamict.
Origin and occurrence: Magmatic in granitic and alkaline pegmatites, granites, syenites, carbonatites; hydrothermal in the Alpine-type veins and greisens; metamorphic in gneisses; common in placers.
It is associated with apatite, xenotime-(Y) and zircon. Perfect prismatic crystals up to 200 mm ($7\frac{7}{8}$ in) come from Mars Hill, North Carolina, Trout Creek Pass, Colorado, USA; also from Arendal, Norway; Ambatofotsikely and Ampangabe, Madagascar, where masses weighing several kg are common; crystals, up to 200 mm ($7\frac{7}{8}$ in) across found in Minas Gerais, Jaguaraçu, Brazil.
Application: ore of rare earth elements.

Monazite-(Ce), 31 mm, Felicio, Brazil

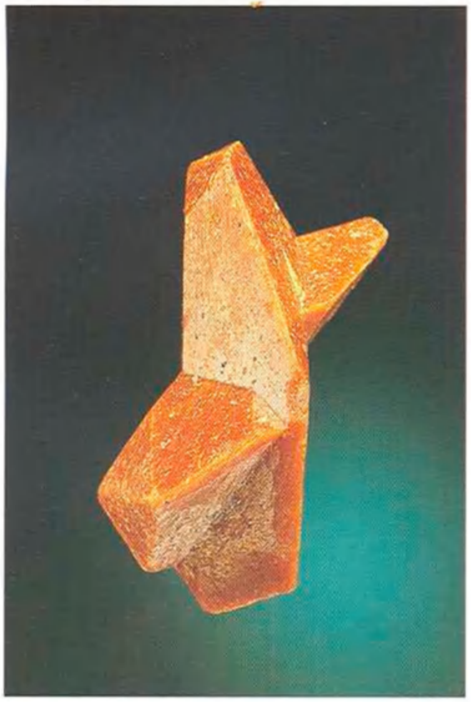

Hydroxylherderite

$\mathrm{CaBe(PO_4)(OH,F)}$

MONOCLINIC ● ●

Properties: C – colorless, white, yellowish, greenish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.0; H – 5-5.5; CL – good; F – conchoidal to uneven; M – prismatic to tabular crystals, radial aggregates, granular.
Origin and occurrence: Hydrothermal in cavities in granitic pegmatites and in greisens. Perfect crystals, up to 120 mm ($4\frac{11}{16}$ in) long come from Marilaca and together with colored tourmalines from Virgem da Lapa, Minas Gerais, Brazil; also known from Topsham and Stoneham, Maine, USA.

Amblygonite

$\mathrm{LiAl(PO_4)(F,OH)}$

TRICLINIC ● ● ●

Properties: C – colorless, white, yellowish, bluish, gray; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.1; H – 5.5-6; CL – good; F – conchoidal to uneven; M – short prismatic crystals, granular, massive.

Hydroxylherderite, 22 mm, Anza, California, U.S.A.

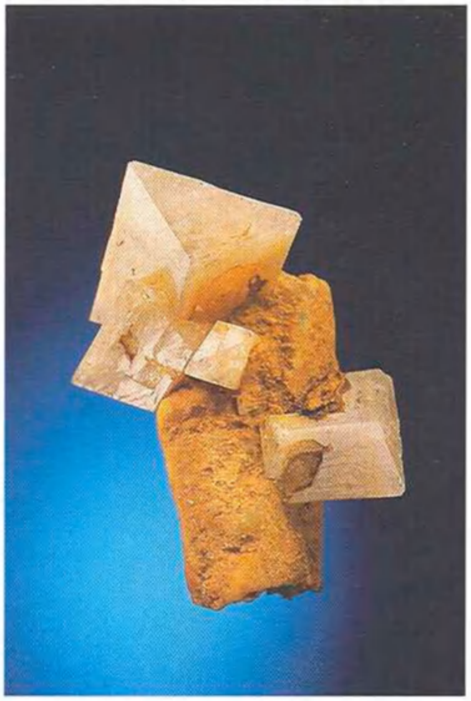

Montebrasite, 80 mm, White Picacho, Arizona, U.S.A.

Origin and occurrence: Magmatic in granitic pegmatites and some granites; rare hydrothermal in greisens and in ore veins. Large amblygonite masses, several meters across, come from pegmatites, like the Beecher, Custer and Hugo mines, Keystone, South Dakota, USA, where its blocks weighed up to 200 tons; also known from Viitaniemi, Finland; Uto, Sweden. Typical representative of the quartz-amblygonite veins is Vernerov, Czech Republic.
Application: Li ore and raw material for ceramics.

Montebrasite

$LiAl(PO_4)(OH,F)$

TRICLINIC ● ● ●

Properties: C – colorless, white, yellowish, yellow, bluish, gray; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.0; H – 5.5-6; CL – good; F – conchoidal to uneven; M – short prismatic to tabular crystals, granular, massive.
Origin and occurrence: Magmatic in granitic pegmatites and granites; hydrothermal in granitic pegmatites. It occurs very frequently with amblygonite, which it replaces. Large masses are known from Montebras, France; also from the Tin Mountain mine, Custer, South Dakota, USA.. Perfect tabular crystals up to 150 mm (6 in) across found in Taquaral, Minas Gerais, Brazil.

Wagnerite

$Mg_2(PO_4)(F,OH)$

MONOCLINIC ● ● ●

Properties: C – light yellow, yellow-green, yellow-brown, green; S – white; L – vitreous to greasy; D – transparent, translucent to opaque; DE – 3.2; H – 5-5.5; CL – imperfect; F – conchoidal to uneven; M – short prismatic crystals, granular, massive.

Wagnerite, 18 mm x, Werfen, Austria

Origin and occurrence: Magmatic in granitic pegmatites; metamorphic in gneisses and eclogites; hydrothermal in quartz veins and in salt deposits. The most famous finds come from the quartz veins in Hollgraben and Radelgraben, the Alps, Austria, where wagnerite occur together with lazulite and forms crystals up to 30 mm ($1^{3}/_{16}$ in) across; also known from Mangualde, Portugal and Bodenmais, Germany.

Amblygonite, 55 mm, Minas Gerais, Brazil

Zwieselite, 30 mm grain, Dolni Bory, Czech Republic

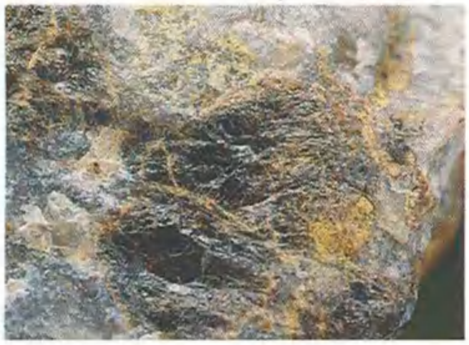

Zwieselite

$Fe_2(PO_4)(F,OH)$

MONOCLINIC ● ● ●

Properties: C – dark brown to black-brown; S – light brown; L – vitreous to greasy; D – translucent to opaque; DE – 4.0; H – 5-5.5; CL – imperfect; F – conchoidal to uneven; M – short prismatic crystals, granular, massive.
Origin and occurrence: Magmatic in granitic pegmatites; rare hydrothermal in greisens. It is associated with apatite, triplite and secondary phosphates. Imperfect crystals and granular aggregates are known from pegmatites near Zwiesel, Germany; Dolni Bory, Czech Republic.

Libethenite, 80 mm, L'ubietova, Slovakia

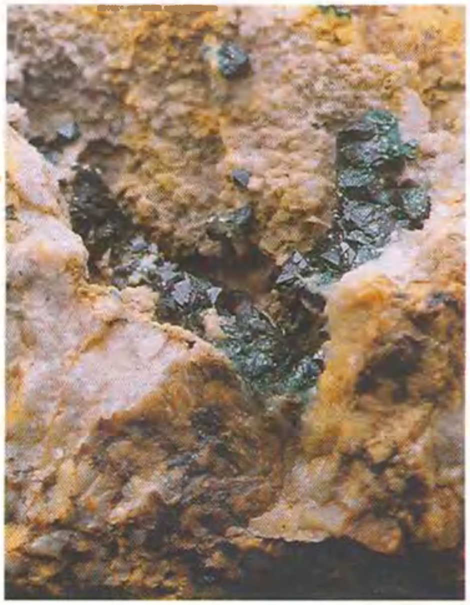

Triplite, 70 mm, Viitaniemi, Finnland

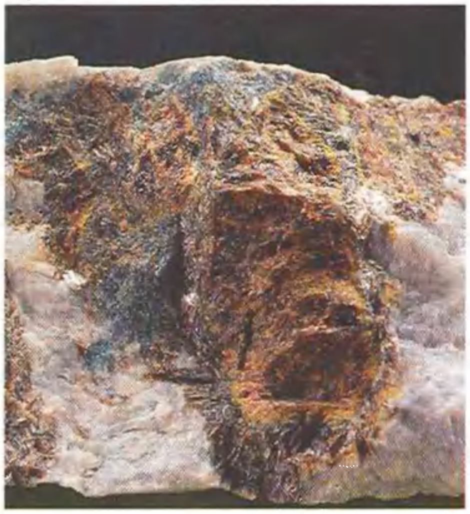

Triplite

$Mn_2(PO_4)(F,OH)$

MONOCLINIC ● ● ●

Properties: C – pink, light brown; S – light brown; L – vitreous to greasy; D – translucent to opaque; DE – 3.8; H – 5-5.5; CL – imperfect; F – conchoidal to uneven; M – short prismatic crystals, granular, massive.
Origin and occurrence: Magmatic in granitic pegmatites and granites; hydrothermal in greisens and in quartz veins. It is usually hydrothermally altered and replaced by secondary phosphates. Huge masses several meters in size come from pegmatites in Karibib, Namibia; it also occurs in Mangualde, Portugal and in Sukula, Finland.

Libethenit

$Cu_2(PO_4)(OH)$

ORTHORHOMBIC ● ● ●

Properties: C – black-green to light green; S – olive-green; L – greasy; D – translucent; DE – 3.9; H – 4; CL – imperfect; F – conchoidal to uneven; M – short prismatic and dipyramidal crystals, botryoidal aggregates, granular, massive.
Origin and occurrence: Secondary in Cu deposits, where it occurs together with malachite, pseudomalachite and brochantite. Perfect crystals, up to 30 mm ($1\frac{3}{16}$ in) across, come from the Rokana mine, Zambia; crystals, up to 10 mm ($\frac{3}{8}$ in), are known from Kambove, Zaire; L'ubietova . Slovakia; Nizhniy Tagil, Ural Mts., Russia.

Olivenite, 80 mm, Tsumeb, Namibia

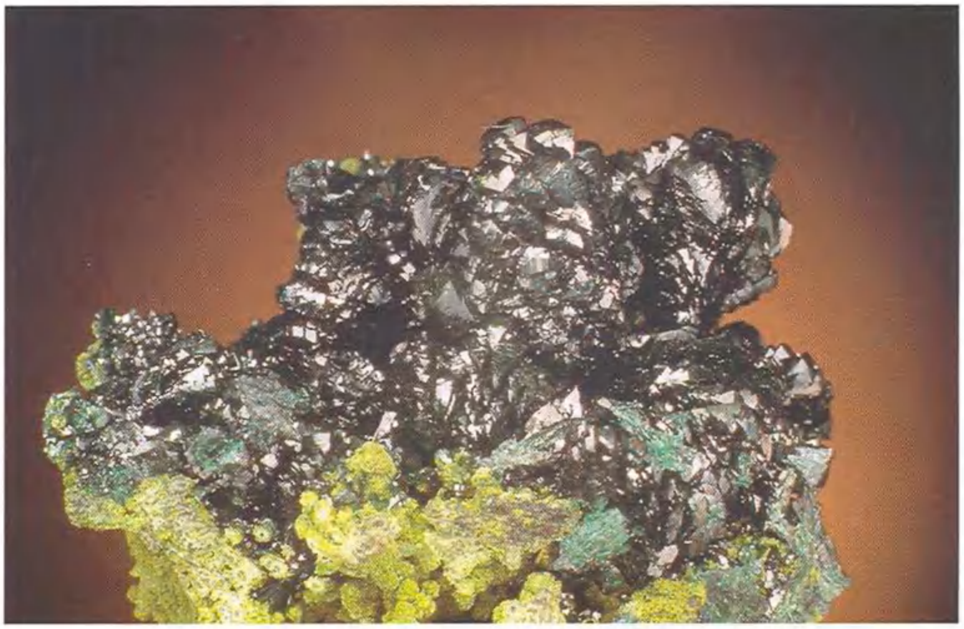

Olivenite

$Cu_2(AsO_4)(OH)$

ORTHORHOMBIC ● ● ●

Properties: C – olive-green, green-brown, gray-green to gray; S – light green; L – greasy; D – translucent to opaque; DE – 4.4; H – 3; CL – imperfect; F – conchoidal to uneven; M – long to short prismatic and dipyramidal crystals, acicular and radial aggregates, massive.
Origin and occurrence: Secondary in Cu deposits. It is associated with other secondary Cu minerals, malachite, azurite and scorodite. Perfect crystals up to 10 mm (3/8 in) across occurred in Wheal Gorland, Cornwall, and Tavistock, Devon UK; also in Tsumeb, Namibia and Ashburton Downs, Western Australia, Australia.

Adamine

$Zn_2(AsO_4)(OH)$

ORTHORHOMBIC ● ● ●

Properties: C – yellow-green, yellow, green, colorless, purple; S – white; L – vitreous; D – transparent to translucent; DE – 4.4; H – 3.5; CL – imperfect; F – conchoidal to uneven; M – long to short prismatic and dipyramidal crystals, acicular and radial aggregates, massive; LU – yellow-green.

Origin and occurrence: Secondary in Zn deposits, associated with hemimorphite, goethitee and smithsonite. Rich druses of green and rare purple crystals up to 70 mm (2¾ in) across come from Mina Ojuela, Mapimi, Durango, Mexico; also known from Tsumeb, Namibia; Laurion, Greece and Cap Garonne, France.

Adamite, 34 mm, Mapimi, Mexico

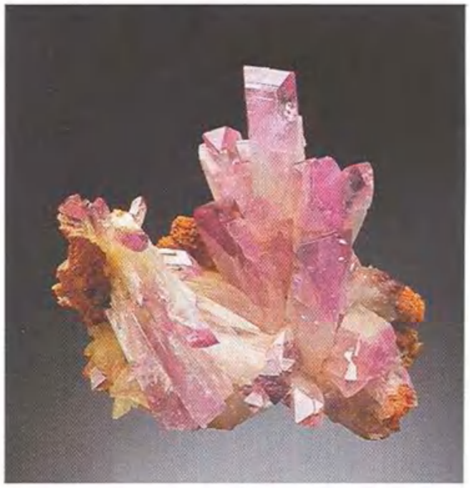

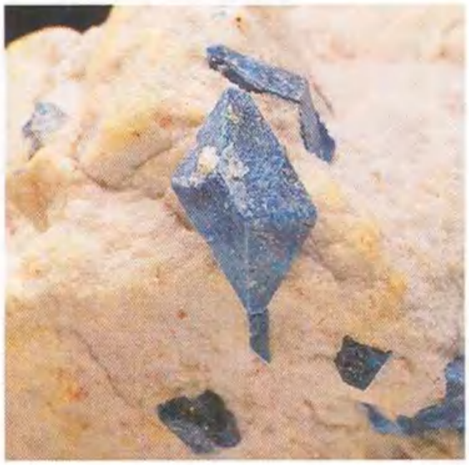
Lazulite, 11 mm x, Lincoln Co., U.S.A.

Lazulite
$MgAl_2(PO_4)_2(OH)_2$

MONOCLINIC ● ● ●

Properties: C – dark to light blue, blue-green; S – white; L – vitreous; D – transparent to translucent; DE – 3.1; H – 5.5-6; CL – imperfect; F – conchoidal to uneven; M – short prismatic and dipyramidal crystals, granular, massive.
Origin and occurrence: Hydrothermal in quartz veins and granitic pegmatites, where it is formed by decomposition of primary phosphates; metamorphic in quartzites.
Imperfect crystals up to 100 mm (4 in) across come from Horrsjoberg, Sweden; perfect crystals about 50 mm found in Ashudi, Pakistan; also known from Big Fish River, Yukon, Canada and near Werfen, Austria.

Scorzalite
$FeAl_2(PO_4)_2(OH)_2$

MONOCLINIC ● ● ●

Properties: C – dark blue, blue-green; S – white; L – vitreous; D – transparent to translucent; DE – 3.3; H – 6; CL – imperfect; F – conchoidal to uneven; M – prismatic crystals, granular, massive.
Origin and occurrence: Hydrothermal in granitic pegmatites, as a replacement product of primary phosphates, rare in quartz veins. Dark blue, granular aggregates up to 100 mm (4in) across occur in the Palermo No. 1 and No. 2 mines, North Groton, New Hampshire and the Victory mine, Custer, South Dakota, USA.

Rockbridgeite
$Fe^{2+}Fe^{3+}{}_4(PO_4)_3(OH)_5$

ORTHORHOMBIC ● ● ●

Properties: C – dark and light green, black-green; S – green; L – dull; D – translucent to opaque; DE – 3.4; H – 4.5; CL – good; F – uneven; M – acicular crystals, radial aggregates and crusts, granular, massive.
Origin and occurrence: Secondary in granitic pegmatites and in Fe deposits. It mostly originates from the hydrothermal alteration of primary phosphates, mainly triphyllite, and it is associated with other secondary phosphates. Rich radial aggregates up to 50 mm (2 in) across come from Hagendorf, Germany; the Tip Top mine, Custer, South Dakota and the Fletcher mine, Groton, New Hampshire, USA.

Scorzalite, 80 mm, Palermo No.2 Mine, U.S.A.

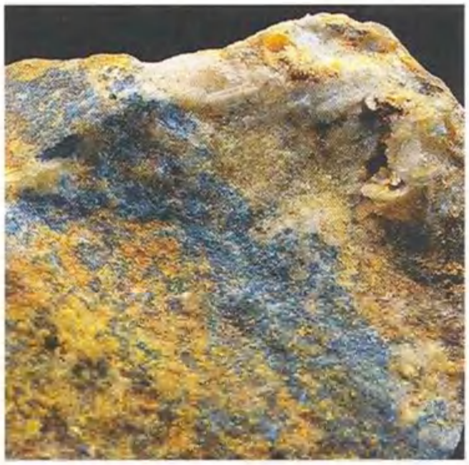

Rockbridgeite, 70 mm, Hagendorf, Germany

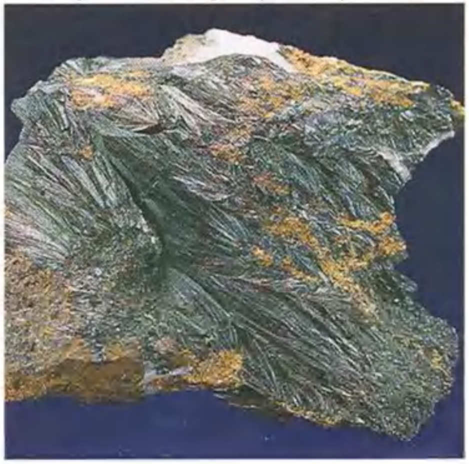

Frondelite, 15 mm xx, Custer, U.S.A.

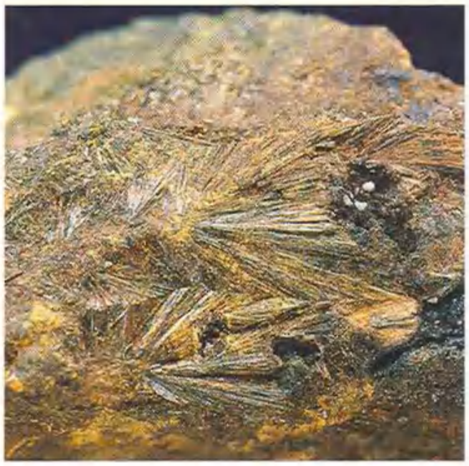

Frondelite

$MnFe^{3+}_4(PO_4)_3(OH)_5$

ORTHORHOMBIC ● ● ●

Properties: C – light olive-green, brown, black-green; S – green; L – dull; D – translucent to opaque; DE – 3.5; H – 4.5; CL – good; F – uneven; M – acicular crystals, radial aggregates and crusts, granular, massive.
Origin and occurrence: Secondary in granitic pegmatites, where it forms as a result of the hydrothermal alteration of primary phosphates, mainly lithiophillite. Radial aggregates occur in the Fletcher mine, Groton, New Hampshire, USA; also in Sapucaia, Minas Gerais, Brazil.

Dufrenite

$Fe^{2+}Fe^{3+}_4(PO_4)_3(OH)_5 \cdot 2\,H_2O$

MONOCLINIC ● ● ●

Properties: C – dark green, black-green, black; S – green; L – vitreous to dull; D – translucent to opaque; DE – 3.4; H – 3.5-4.5; CL – good; F – uneven; M – radial aggregates and crusts, granular, massive.
Origin and occurrence: Secondary in granitic pegmatites and in the oxidation zone of Fe deposits: it forms in pegmatites as a result of the hydrothermal alteration of primary phosphates. Radial aggregates occur in pegmatites in Hagendorf and Hühnerkobel, Germany; also in gossan in the Wheal Phoenix mine, Cornwall, UK.

Dufrenite, 9 mm, Lancaster, U.S.A.

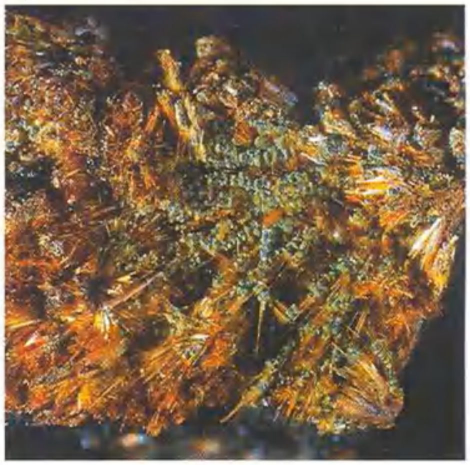

Pseudomalachite

$Cu_5(PO_4)_2(OH)_4$

MONOCLINIC ● ● ●

Properties: C – green, black-green; S – green; L – vitreous to dull; D – translucent to opaque; DE – 4.3; H – 4.5-5; CL – good; F – uneven; M – short prismatic crystals, botryoidal aggregates with radial structure, massive.
Origin and occurrence: Secondary in Cu deposits, associated with malachite, chrysocolla, libethenite and goethite. Beautiful botryoidal aggregates and large masses come from Nizhniy Tagil, Ural mountains, Russia; also from Ehl and Virneberg, Germany; from L'ubietova , Slovakia; and also from many localities in Shaba province, Zaire.

Pseudomalachite, 80 mm, L'ubietova, Slovakia

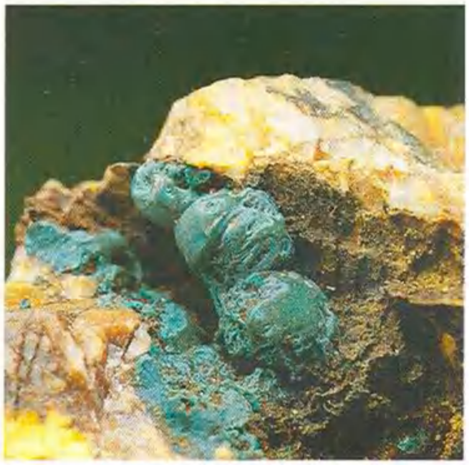

Cornubite, 30 mm, Farbiste, Slovakia

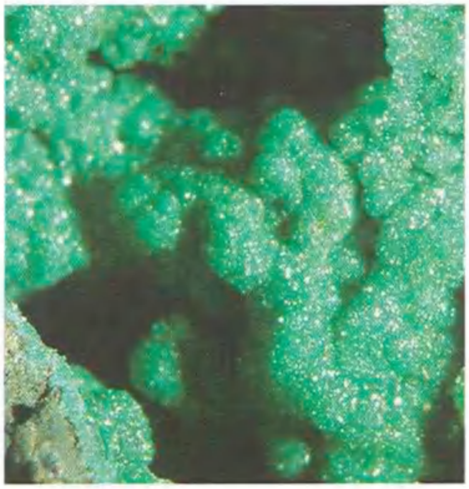

Cornubite

$Cu_5(AsO_4)_2(OH)_4$

TRICLINIC ●

Properties: C – light to dark green; S – light green; L – vitreous to dull; D – translucent; DE – 4.8; H – not determined; CL – not determined; F – uneven; M – botryoidal aggregates, massive.
Origin and occurrence: Secondary in Cu deposits. It was found together with olivenite and clinoclase in the Bedford United quarry, Cornwall, UK; also in Ashburton Downs, Western Australia, Australia and Farbiste, Slovakia.

Cornetite, 10 mm aggregate, Lumumbashi, Zair

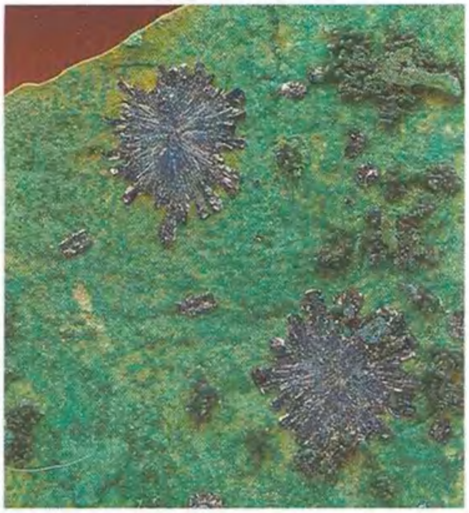

Augelite, 34 mm, Yukon Territory, Canada

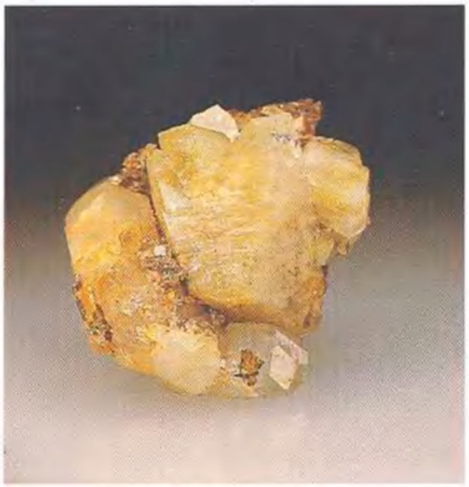

Augelite

$Al_2(PO_4)(OH)_3$

MONOCLINIC ● ● ●

Properties: C – colorless, white, yellowish, pinkish; S- white; L – vitreous to dull; D – transparent to translucent; DE – 2.7; H- 4.5-5; CL – good; F – uneven; M – thick tabular to prismatic crystals, granular, massive.
Origin and occurrence: Hydrothermal in granitic pegmatites as a product of primary phosphates replacement; rare metamorphic in quartzites. Massive aggregates several decimeters across occur in pegmatites in Burango, Rwanda; also in the Hugo mine, Custer, South Dakota and Mount White, California, USA. Crystals up to 20 mm (${}^{25}/_{32}$ in) across come from Rapid Creek, Yukon, Canada and from the Champion mine, California; rare small crystals found in the Palermo No. 1 mine, North Groton, New Hampshire, USA.

Cornetite

$Cu_3(PO_4)(OH)_3$

ORTHORHOMBIC ●

Properties: C – dark blue to blue-green; S – light blue; L – vitreous; D – transparent to translucent; DE – 4.1; H – 4.5; CL – none; F – conchoidal to uneven; M – short prismatic crystals, coatings.
Origin and occurrence: Secondary in Cu deposits. It is rare in the Etoile mine near Lumumbashi and in Kalagi, Shaba province, Zaire; also occurs in Yerington, Nevada and in Saginaw Hill, Arizona, USA.

Clinoclase, 40 mm, Cornwall, UK

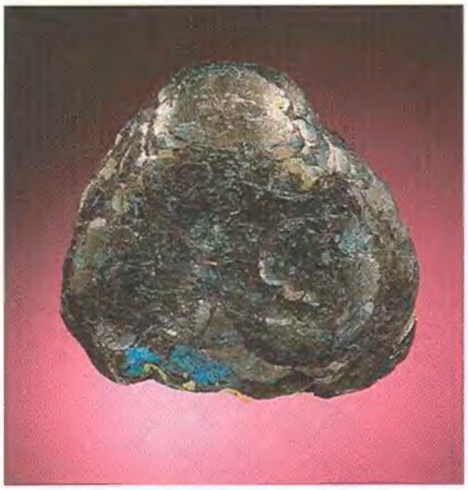

Clinoclase

$Cu_3(AsO_4)(OH)_3$

MONOCLINIC ● ●

Properties: C – dark green-blue to black-green; S – blue-green; L – vitreous; D – transparent to translucent; DE – 4.4; H – 2.5-3; CL – perfect; F – uneven; M – prismatic and tabular crystals, botryoidal aggregates.
Origin and occurrence: Secondary in Cu deposits, often associated with malachite, azurite and other secondary Cu minerals. Spherical aggregates up to 10 mm (⅜ in) known from the Majuba Hill mine, Nevada, USA; occurs rarely near Tavistock, Devon, UK; also in Novoveska Huta, Slovakia.

Conichalcite

$CuCa(AsO_4)(OH)$

ORTHORHOMBIC ● ● ●

Properties: C – yellow-green to emerald-green; S – light green; L – vitreous to greasy; D – transparent to translucent; DE – 4.3; H – 4.5; CL – none; F – uneven; M – short prismatic crystals, botryoidal aggregates with radial structure, massive.
Origin and occurrence: Secondary in Cu deposits. It occurs as rich botryoidal aggregates in Otavi, Namibia; Tintic, Utah, in the Higgins mine, Bisbee, Arizona and Yerington, Nevada, USA.

Conichalcite, 70 mm, Tintic, U.S.A.

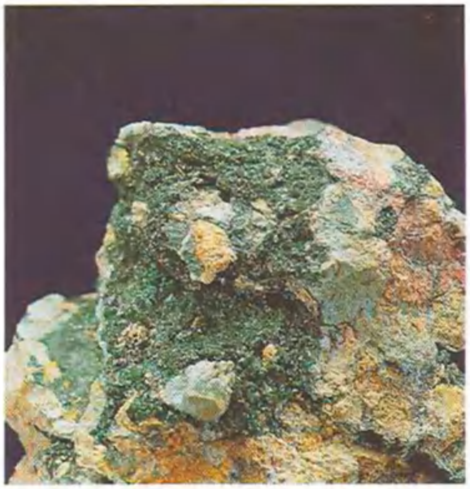

Duftite

$PbCu(AsO_4)(OH)$

ORTHORHOMBIC ● ●

Properties: C – yellow-green, olive-green to gray-green; S – light green; L – vitreous to greasy; D – translucent; DE – 6.5; H – 3; CL – not determined; F – uneven; M – small crystals, botryoidal aggregates and coatings.
Origin and occurrence: Secondary in base metals deposits. It is associated with malachite and azurite in Tsumeb, Namibia; in Mina Ojuela, Mapimi, Durango, Mexico; in Moldava, Czech Republic.

Duftite, 90 mm, Tsumeb, Namibia

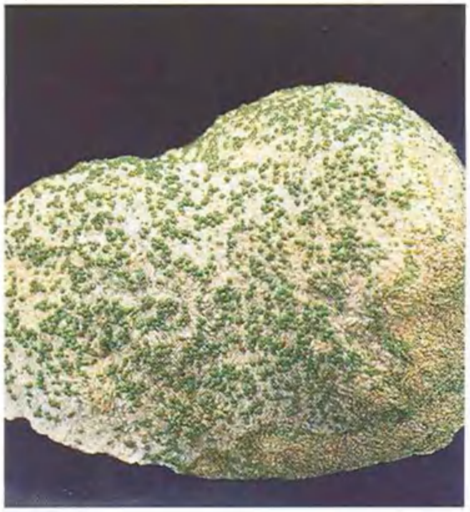

Descloizite, 38 mm, Grootfontein, Namibia

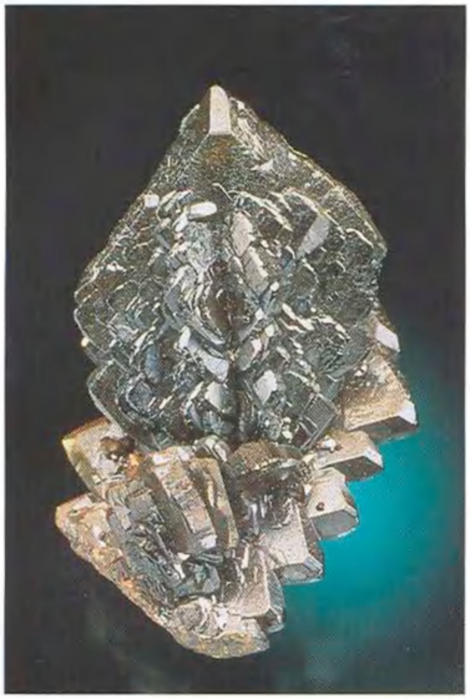

Descloizite

$PbZn(VO_4)(OH)$

ORTHORHOMBIC ● ● ●

Properties: C – red-orange, red-brown to brown-black, gray-green; S – light yellow-brown; L – greasy; D – transparent, translucent to opaque; DE – 6.1; H – 3-3.5; CL – none; F – conchoidal to uneven; M – crystals of different habits, mostly pyramidal or prismatic, botryoidal and skeletal aggregates, massive.
Origin and occurrence: Secondary in base metals deposits. It is mainly associated with pyromorphite, mimetite, vanadinite and other secondary Pb minerals. Occurs as crystals up to 30 mm ($1\frac{3}{16}$ in) long in Tsumeb and Berg Aukas, Namibia; also Broken Hill, Zambia; and the Mammoth mine, Tiger, Arizona, USA.

Arsendescloizite

$PbZn(AsO_4)(OH)$

ORTHORHOMBIC ●

Properties: C – light yellow; S – white; L – adamantine to greasy; D – transparent to translucent; DE – 6.1; H – 4; CL – none; F – conchoidal to uneven; M – tabular crystals, rosette-like aggregates.

Arsendescloizite, 95 mm, Mapimi, Mexico

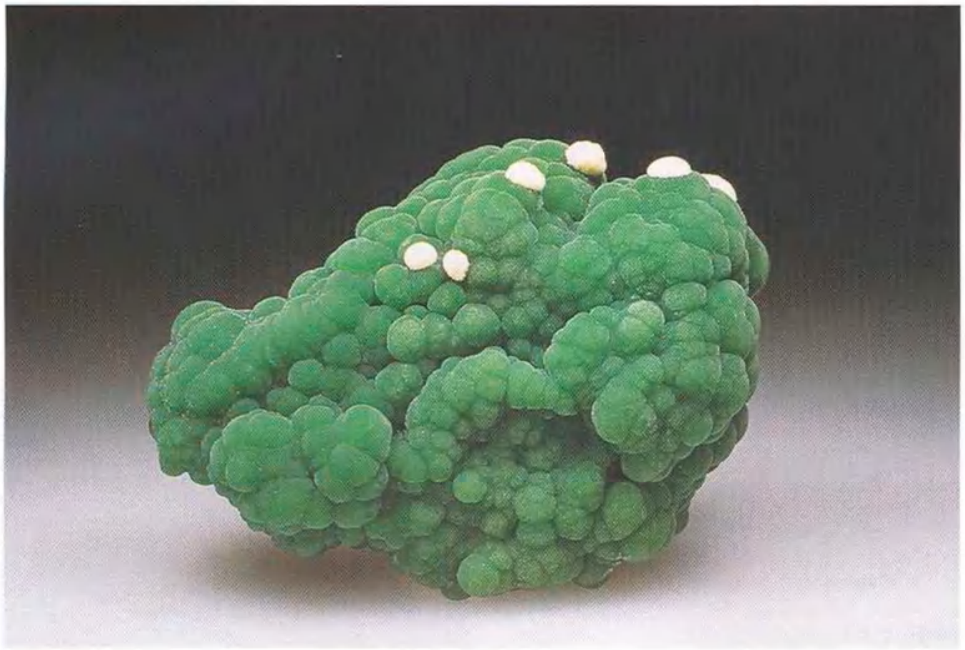

Origin and occurrence: Secondary in base metals deposits, associated with mimetite and goethite. Found rarely as crystals of 1 mm (1/32 in) in size in Tsumeb, Namibia; also Mina Ojuela, Mapimi, Durango, Mexico.

Mottramite
$PbCu(AsO_4)(OH)$

ORTHORHOMBIC ● ●

Properties: C – grass-green to black-green; S – light green; L – vitreous to dull; D – transparent to opaque; DE – 5.9; H – 3-3.5; CL – none; F – conchoidal to uneven; M – crystals of different habits, botryoidal and dendritic aggregates, crusts and coatings, massive.
Origin and occurrence: Secondary in base metals deposits, associated with mimetite, descloizite and vanadinite. It occurs in Mottram, Cheshire, UK; in Tsumeb, Namibia; Mammoth mine, Tiger, Arizona, USA.

Brazilianite
$NaAl_3(PO_4)_2(OH)_4$

MONOCLINIC ● ● ●

Properties: C – colorless, white, yellowish, yellow-green; S – white; L – vitreous; D – transparent to translucent; DE – 3.0; H – 5.5; CL – good; F – uneven; M – short prismatic to isometric crystals, radial aggregates, granular.
Origin and occurrence: Hydrothermal in cavities in granitic pegmatites, where it is associated with fluorapatite, albite and tourmaline. It occasionally originates as a product of amblygonite replacement. Perfect yellow-green crystals up to 150 mm (6 in) across found in cavities in pegmatites in Conselheira Pena and Corrego Frio, Linopolis, Minas Gerais and from Pietras Lavradas, Paraiba, Brazil.

Mottramite, 60 mm, Tiger, Arizona, U.S.A.

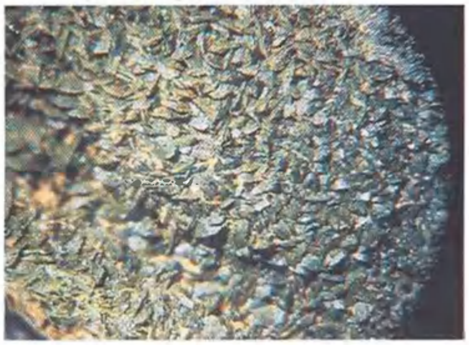

Cafarsite, 9 mm x, Binntal, Switzerland

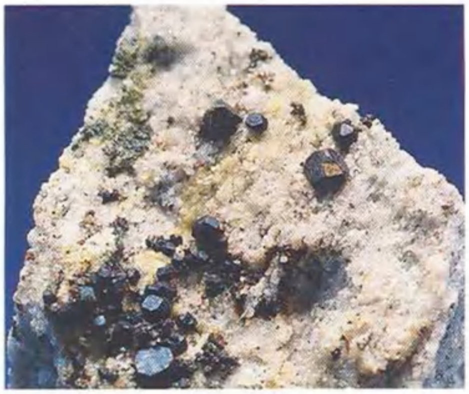

Cafarsite
$Ca_8(Ti,Fe^{2+},Fe^{3+},Mn)(As^{3+}O_3)_{12} \cdot 4\ H_2O$

CUBIC ●

Properties: C – dark brown; S – yellow-brown; L – submetallic; D – translucent; DE – 3.9; H – 5.5-6; CL – none; F – conchoidal; M – isometric crystals.
Origin and occurrence: Hydrothermal along cracks in Alpine-type veins. Cubic crystals up to 30 mm (1 3/16 in) across come from Binntal, Switzerland and Pizzo Cervandone, Italy.

Brazilianite, 47 mm, Conselheira Pena, Brazil

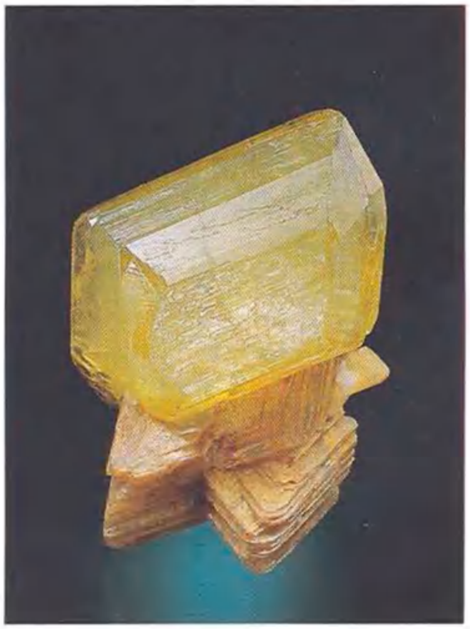

Carminite

$PbFe^{3+}_2(AsO_4)_2(OH)_2$

ORTHORHOMBIC ● ●

Properties: C – crimson-red, red-brown; S – red-yellow; L – adamantine to pearly; D – translucent; DE – 5.5; H – 3.5; CL – good; F – conchoidal to uneven; M – prismatic crystals, acicular, radial, felt-like to porous aggregates, coatings and crusts.
Origin and occurrence: Secondary in base metals deposits, associated with mimetite and scorodite. Crystals up to 10 mm (3/8 in) across occur in Tsumeb, Namibia; in Mina Ojuela, Mapimi, Durango, Mexico; in Calstock, Cornwall, UK.

Carminite, 2 mm xx, Nadap, Hungary

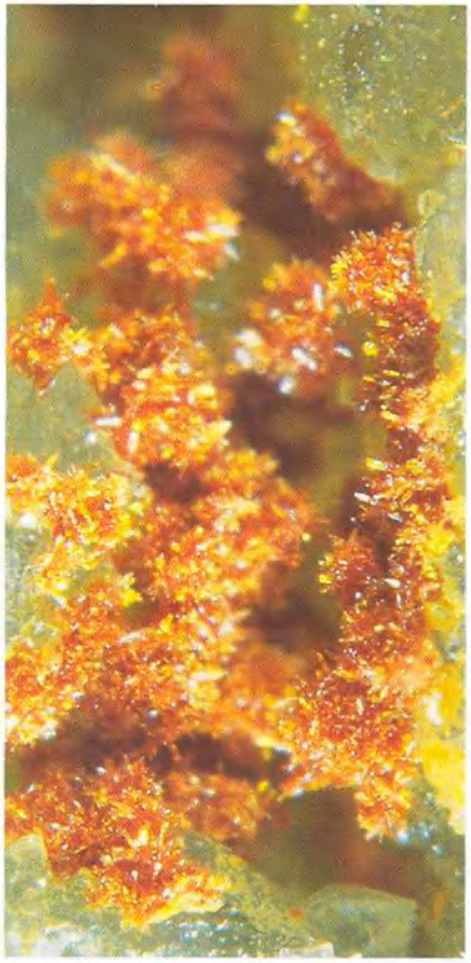

Bayldonite, 34 mm, Tsumeb, Namibia

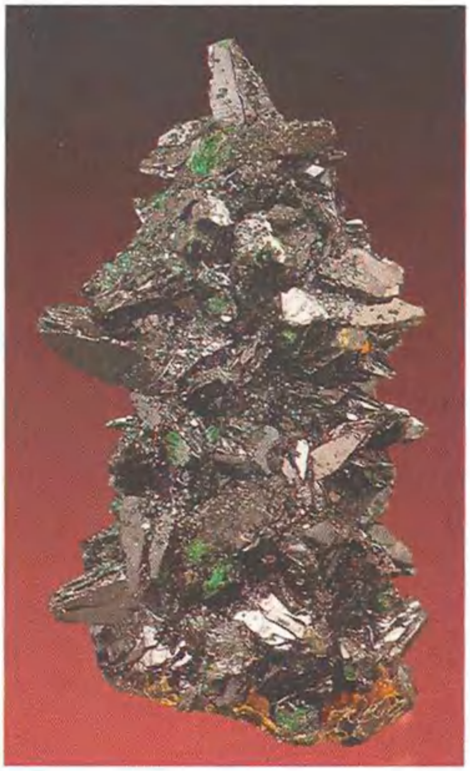

Bayldonite

$PbCu_3(AsO_4)_2(OH)_2 \cdot H_2O$

MONOCLINIC ● ●

Properties: C – yellow-green, olive-green; S – light green; L – resinous; D – translucent; DE – 5.5; H – 4.5; CL – not determined; F – uneven; M – earthy aggregates, coatings, massive.
Origin and occurrence: Secondary in the oxidation zone in hydrothermal Cu deposits and in greisens. It occurs as common yellow-green coatings and crystals up to 10 mm (3/8 in) across, associated with large azurite and mimetite crystals in Tsumeb, Namibia; also as coatings in St. Day, Cornwall, UK; in Moldava, Czech Republic.

Vesignieite

$BaCu_3(VO_4)_2(OH)_2$

MONOCLINIC ● ●

Properties: C – yellow-green, olive-green; S – light yellow-green; L – vitreous to dull; D – translucent;

Vesigneite, 80 mm, Vrancice, Czech Republic

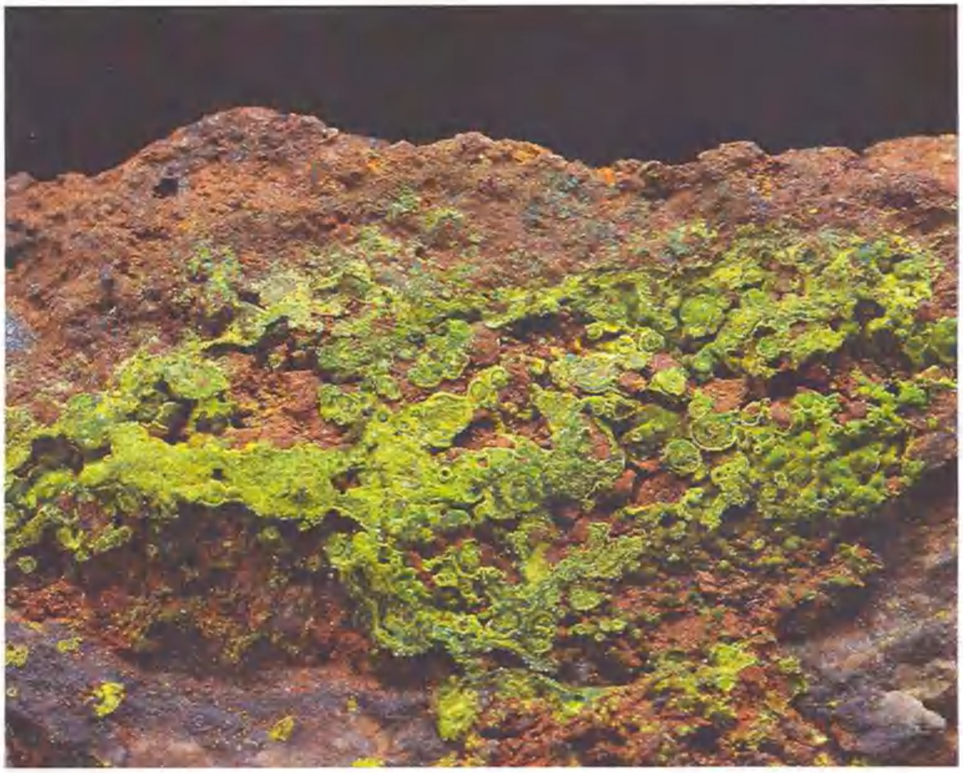

DE – 4.1; H – 3-4; CL – good; F – uneven; M – earthy and pulverulent aggregates and coatings, massive.

Origin and occurrence: Secondary in base metals deposits and in sediments, containing Cu sulfides. It occurs as yellow-green coatings in sediments in Horni Kalna, Czech Republic; also in the Mashamba West mine, Zaire; together with barite and psilomelane in Friedrichsroda, Germany.

Arsentsumebite

$Pb_2Cu(AsO_4)(SO_4)(OH)$

MONOCLINIC ●

Properties: C – bluish-green to light green; S – light green; L – dull; D – translucent; DE – 6.5; H – 3; CL – good; F – uneven; M – earthy aggregates, coatings, massive.

Origin and occurrence: Secondary in the oxidation zone, where it forms as a result of mimetite replacement. Found rarely in Moldava, Czech Republic; in Tsumeb, Namibia, where it forms pseudo-morphs after azurite crystals.

Arsentsumebite, 40 mm, Moldava, Czech Republic

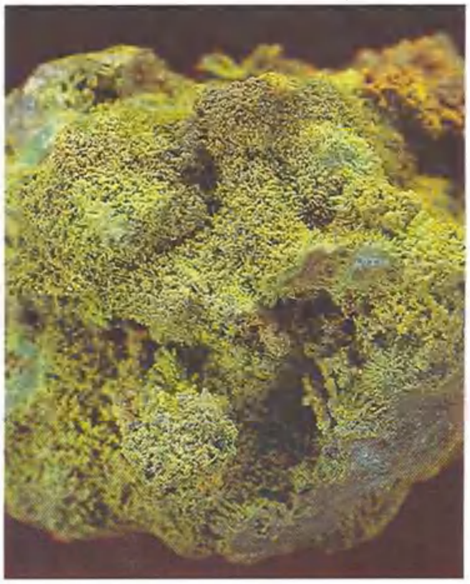

Fluorapatite, 50 mm, Dusso, Pakistan

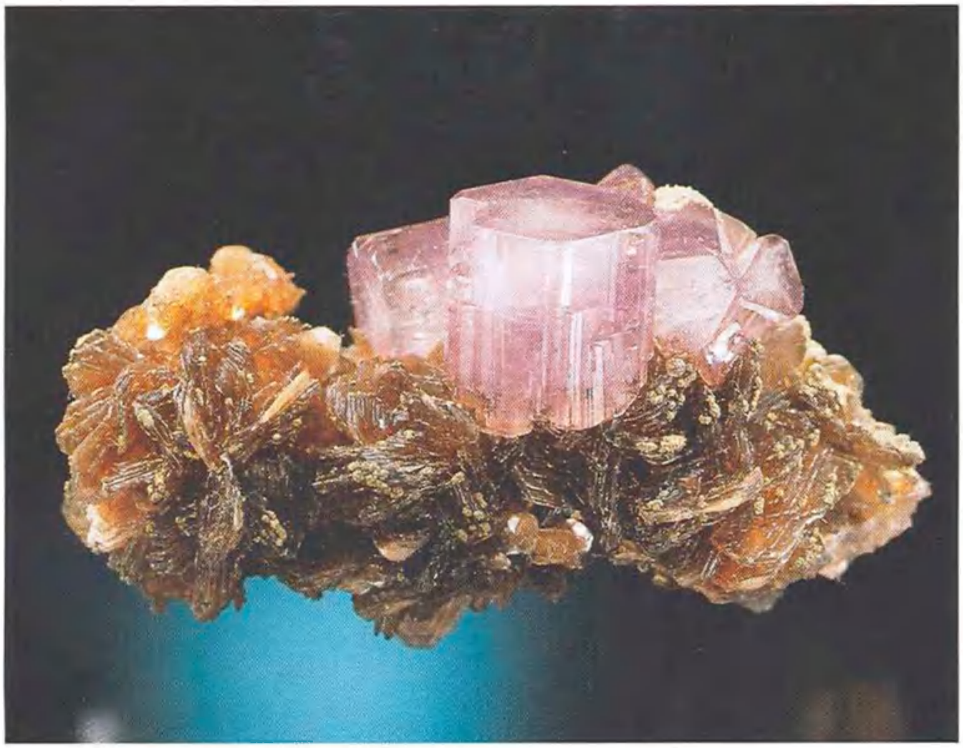

Fluorapatite

$Ca_5(PO_4)_3F$

HEXAGONAL ● ● ● ● ●

Properties: C – colorless, white, yellowish, pinkish, blue, purple, green, brown with various hues; S – white; L – vitreous to dull; D – transparent to translucent, sometimes opaque; DE – 3.2; H – 5; CL – imperfect; F – conchoidal to uneven; M – long prismatic to tabular crystals, botryoidal, earthy and fibrous aggregates, massive; LU – yellow.

Origin and occurrence: Magmatic in granites, syenites, diorites, gabbros and various types of pegmatites, also in volcanic rocks; hydrothermal in quartz veins, ore veins, greisens and Alpine-type veins; metamorphic in different types of gneisses, migmatites, mica schists, skarns and amphibolites; in different types of sedimentary rocks. Perfect, short prismatic, purple transparent crystals up to 40 x 40 mm ($1\frac{9}{16}$ x $1\frac{9}{16}$ in) are renowned from pegmatite in the Pulsifer quarry, Mount Apatite, Auburn, Maine, USA; pink crystals from Dusso, Pakistan. Perfect crystals about 100 mm (4in) across also from Alpine-type veins, e.g. in Fiesch, Switzerland; also known from the quartz veins in greisens, associated with wolframite, in Panasqueira, Portugal; in Horni Slavkov, Czech Republic; Ehrenfriedersdorf, Germany. Also found in skarns at Cerro de Mercado, Durango, Mexico. Large deposits of mas-

Chlorapatite, 20 mm x, Bob's Lake, Ontario, Canada

sive apatite located in Kola Peninsula, Russia; crystals weighing up to 300 kg (660 lb) from the vicinity of Clear Lake, Ontario, Canada.
Application: main source of P, chemical industry, fertilizer.

Chlorapatite

$Ca_5(PO_4)_3Cl$

HEXAGONAL ● ● ●

Properties: C – white, various hues of yellow; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.2; H – 5; CL – imperfect; F – conchoidal to uneven; M – long prismatic to tabular crystals, granular.
Origin and occurrence: Magmatic in nepheline syenites and their pegmatites, some gabbros and volcanic rocks, also in meteorites; metamorphic in skarns. It is usually associated with scapolite, amphibole, titanite and magnetite. Perfect prismatic crystals up to 35 cm ($13^{13}/_{16}$ in) long, come from pegmatites in Bamle, Norway; also from Kurokura, Japan.

Hydroxylapatite

$Ca_5(PO_4)_3(OH)$

HEXAGONAL ● ● ●

Properties: C – white, yellow, various hues of gray; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.2; H – 5; CL – imperfect; F – conchoidal to uneven; M – short prismatic to tabular crystals, acicular aggregates, granular.
Origin and occurrence: Metamorphic in talc schists and serpentinites; hydrothermal in granitic pegmatites; sedimentary in organic remnants. Crystals up to 30 mm ($1^{3}/_{16}$ in) across known from Snarum, Norway; Hospental, Switzerland; Eagle, Colorado, USA.

Carbonate-fluorapatite

$Ca_5(PO_4, CO_3)_3F$

HEXAGONAL ● ● ●

Properties: C – white, gray; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.2; H – 5; CL – imperfect; F – conchoidal to uneven; M B spherical and botryoidal aggregates, massive.
Origin and occurrence: Hydrothermal in ore veins and along the cracks in volcanic rocks. Rich botryoidal aggregates are known together with hyalite opal from Valec, Czech Republic; the Wheal Franco mine, Tavistock, Devon, UK.

Hydroxylapatite, 2 mm xx, Tornaszentandrás, Hungary

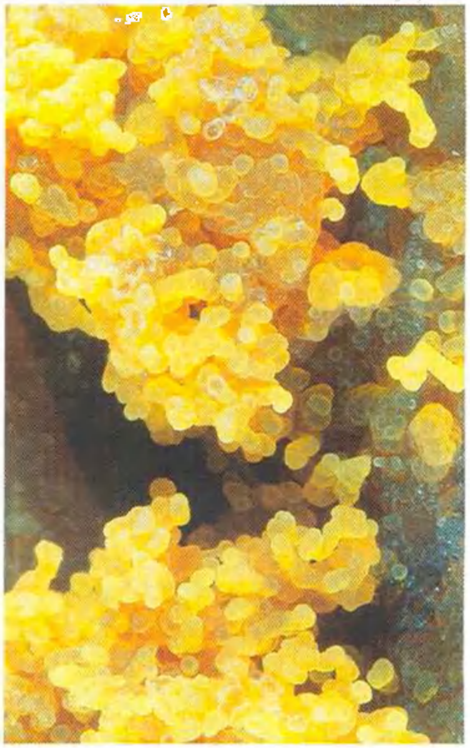

Carbonate-fluorapatite, 80 mm, Staffel, Germany

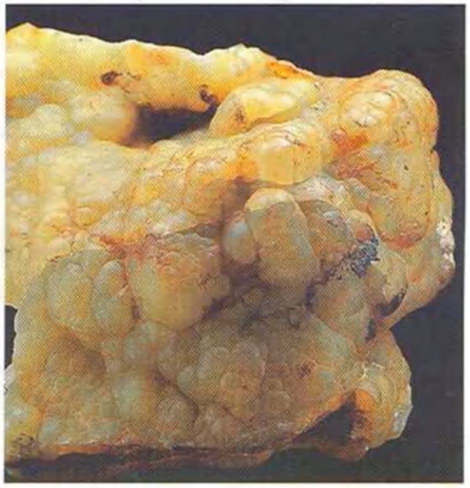

Pyromorphite, 41 mm, Les Farges, France

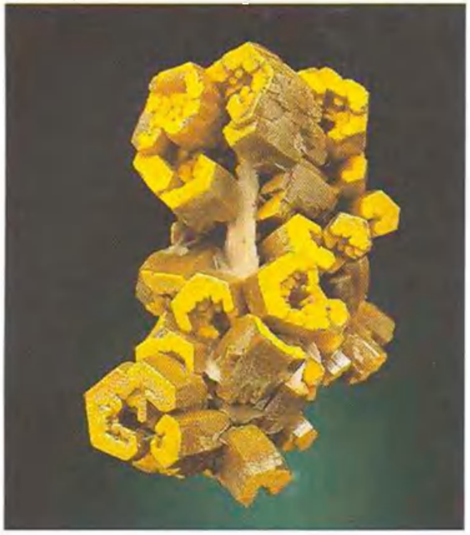

Pyromorfite

$Pb_5(PO_4)_3Cl$

HEXAGONAL ● ● ● ●

Properties: C – green, brown, yellow, orange, white, gray: S -white; L – adamantine to greasy; D – transparent to translucent; DE – 7.1; H – 3.5-4; CL – imperfect; F – conchoidal to uneven; M – long prismatic to tabular and pyramidal crystals, botryoidal aggregates with radial structure, acicular and earthy aggregates, massive.

Origin and occurrence: Secondary in the oxidation zone of Pb deposit, associated with cerussite, goethitee and other secondary minerals. Perfect crystals up to 40 mm (1 9/16 in) long come from many localities, e.g. green and brown ones from Bad Ems and Zschopau, Germany; yellow-brown ones from Les Farges, France; green, brown and yellow ones from Mina Ojuela, Mapimi, Durango, Mexico. Green, orange and brown crystals, up to 60 mm (2 3/8 in) long, are known from the Bunker Hill mine, Idaho, USA.

Pyromorphite, 62 mm, Les Farges, France

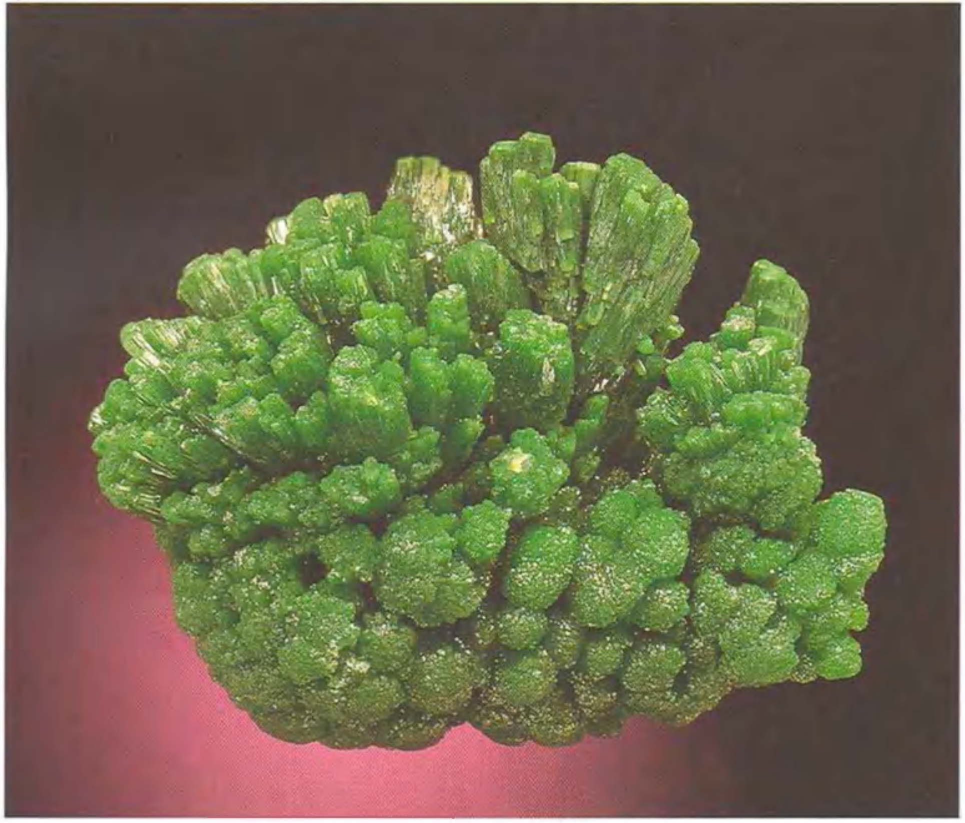

Mimetite, 14 mm x, Johanngeorgenstadt, Germany

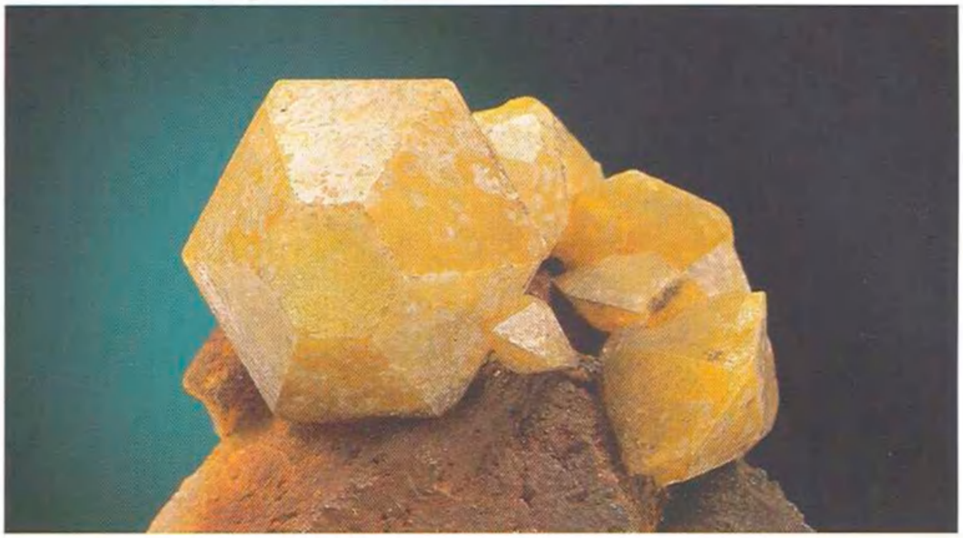

Mimetite

$Pb_5(AsO_4)_3Cl$

HEXAGONAL ● ● ●

Varieties: campylite

Properties: C – yellow, orange, brown, yellow-brown, white, gray; S – white; L – adamantine to greasy; D – transparent to translucent; DE – 7.3; H – 3.5-4; CL – imperfect; F – conchoidal to uneven; M – long to short prismatic and pyramidal crystals, botryoidal aggregates with radial structure, acicular and earthy aggregates, granular.
Origin and occurrence: Secondary in Pb deposits, associated with pyromorphite and goethite. Perfect crystals up to 20 mm ($^{25}/_{32}$ in) long come from Johanngeorgenstadt, Germany; campylite occurs in Drygill, UK; crystals up to 50 mm (2 in) across found in Tsumeb, Namibia; Santa Eulalia and San Pedro, Chihuahua, Mexico. Beautiful yellow crystals up to 30 mm (1$^{3}/_{16}$ in) found recently in Hat Yai province, Thailand.

Vanadinite

$Pb_5(VO_4)_3Cl$

HEXAGONAL ● ● ●

Properties: C – yellow, orange, red, brown, yellow-brown; S – white; L – adamantine to greasy; D – transparent to translucent; DE – 6.9; H – 2.5-3; CL – none; F – conchoidal to uneven; M – long to short prismatic and pyramidal crystals, botryoidal aggregates with radial structure, acicular and earthy aggregates, granular.
Origin and occurrence: Secondary in Pb deposits, associate with pyromorphite, wulfenite and goethite. Perfect crystals up to 130 mm (5$^{3}/_{16}$ in) long come from Djebel Mahseur and Mibladen, Morocco. Prismatic crystals were also found in Tsumeb, Namibia; in the Old Yuma, Red Cloud, Apache and Mammoth mines, Arizona, USA.

Vanadinite, 64 mm, Mibladen, Morocco

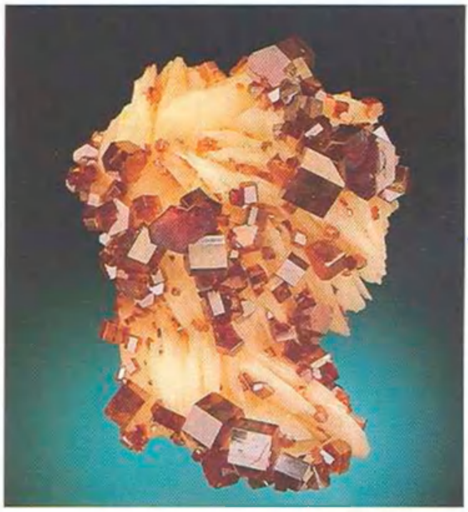

Atelestite, 70 mm, Schneeberg, Germany

Atelestite

$Bi_2(AsO_4)O(OH)$

MONOCLINIC ●

Properties: C – yellow, yellow-green; S – white; L – adamantine to greasy; D – transparent to translucent; DE – 7.0; H – 4.5-5; CL – imperfect; F – conchoidal to uneven; M – small tabular crystals, spherical aggregates.

Origin and occurrence: Secondary in the oxidation zone of Bi deposits. It was found in Schneeberg, Germany.

Hureaulite

$Mn_5(PO_4)_2[PO_3(OH)]_2 \cdot 4\,H_2O$

MONOCLINIC ● ● ●

Properties: C – orange-red, pink, purplish, white, gray; S – white; L – vitreous; D – transparent to translucent; DE – 3.2; H – 3.5; CL – good; F – uneven; M – prismatic to tabular crystals, coatings, granular, massive.

Hureaulite, 53 mm, Shingus, Pakistan

Variscite, 30 mm, Fairfield, U.S.A.

Origin and occurrence: Secondary in granitic pegmatites, as a result of alteration of the primary phosphates, mostly lithiophillite, triphylite and graftonite. Purplish crystals up to 50 mm (2 in) across come from Shingus, Pakistan. Similar crystals found in Hagendorf, Germany. Also known from Mangualde, Portugal; Sao Jose da Safira, Minas Gerais, Brazil; from the Tip Top mine, Custer, South Dakota, USA.

Variscite

$Al(PO_4) \cdot 2\,H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, greenish, blue-green; S – white; L – vitreous; D – transparent to translucent; DE – 2.6; H – 3.5-4.5; CL – good; F – uneven; M – isometric crystals, botryoidal aggregates, nodules, coatings, massive.

Origin and occurrence: : Hydrothermal in cracks in sedimentary rocks, rich in Al and P, also in phosphates deposits. It is associated with apatite, wavellite and other phosphates. Renowned greenish nodules up to 30 cm (12 in) in diameter come from Clay Canyon, Fairfield, Utah, USA; also known from Ronneburg, Germany and Jivina near Beroun, Czech Republic.

Strengite

$Fe^{3+}(PO_4) \cdot 2\,H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, pinkish, red-purple; S – white; L – vitreous; D – transparent to translucent; DE – 2.8; H – 3.5-4.5; CL – good; F – conchoidal; M – isometric, tabular to short prismatic crystals, botryoidal aggregates with radial structure, coatings.

Origin and occurrence: Secondary in granitic

Strengite, 34 mm, Svappavaara, Sweden

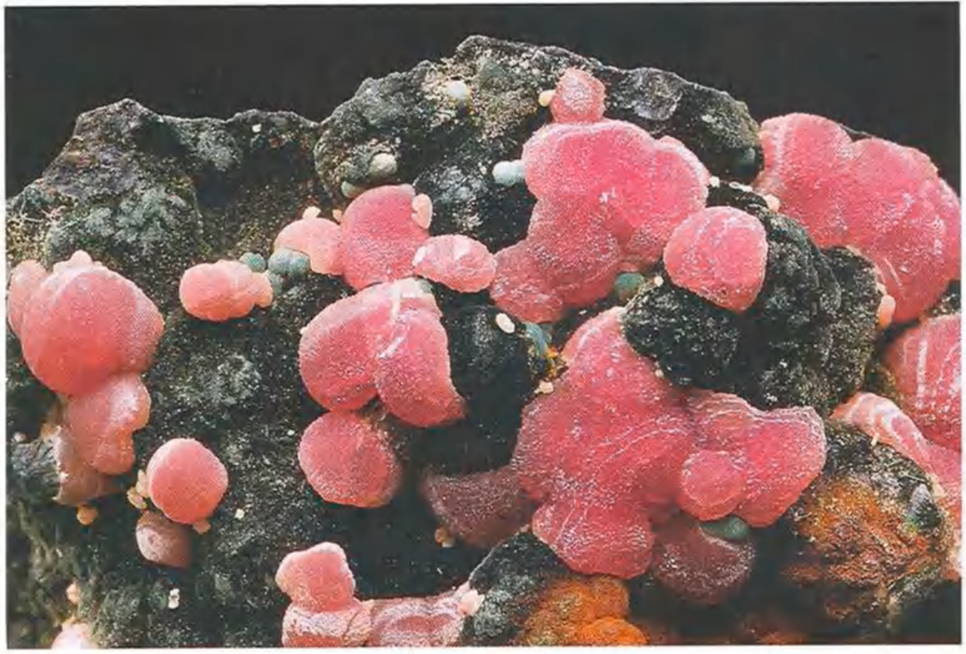

pegmatites where it forms as a result of hydrothermal replacement of primary phosphates; in the oxidation zone of Fe deposit together with goethite. Purple crystals up to 5 mm ($^3/_{16}$ in) across, come from the Bull Moose mine, Custer, South Dakota, USA; also known from Pleystein, Germany and from Teskov, Czech Republic.

Scorodite, 10 mm x, Zacatecas, Mexico

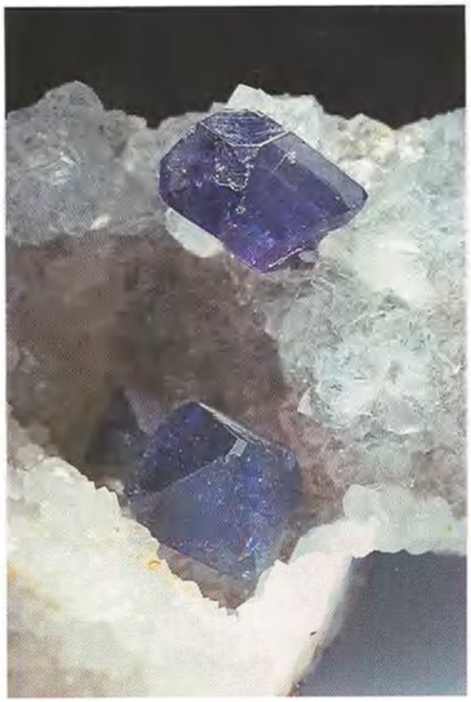

Scorodite

$Fe^{3+}(AsO_4) \cdot 2\ H_2O$

ORTHORHOMBIC ● ● ●

Properties: B – light green, gray-green, olive-green, colorless, blue, yellow-brown; S – light green; L – vitreous to resinous; D – transparent to translucent; DE – 3.3; H – 3.5-4; CL – imperfect; F – conchoidal; M – dipyramidal to short prismatic crystals, botryoidal and earthy aggregates, coatings, granular, massive.

Origin and occurrence: Secondary in the oxidation zone of ore deposits, associated with arsenopyrite, lollingite and other arsenides; in granitic pegmatites; hydrothermal in the hot springs.

Perfect crystals up to 50 mm (2 in) across come from Tsumeb, Namibia; the Kiura mine, Oita, Japan; Mina Ojuela, Mapimi, Durango, Mexico; green crusts, several cm thick, were found in Djebel Debar, Algeria.

Phosphophyllite, 18 mm x, Potosí, Bolivia

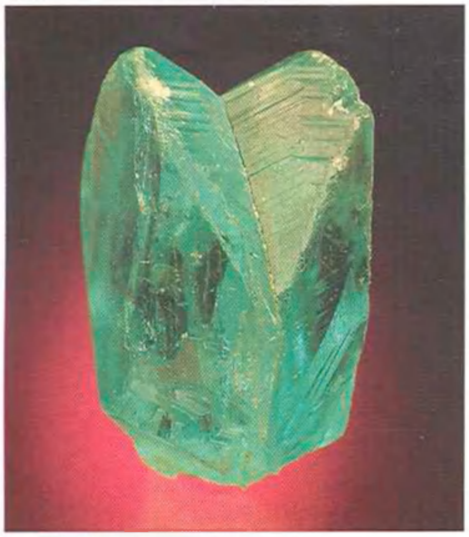

Phosphophyllite

$Zn_2Fe(PO_4)_2 . 4 H_2O$

MONOCLINIC ● ●

Properties: C – colorless, blue-green, blue; S – white; L – vitreous; D – transparent to translucent; DE – 3.1; H – 3-3.5; CL – good; F – uneven; M – long to short prismatic and thick tabular crystals, granular.

Origin and occurrence: Secondary in the oxidation zone of ore deposits; in granitic pegmatites, where it replaces primary phosphates. Perfect crystals, up to 140 mm (5½ in) across come from sulfide cavities in the Unificada mine, Potosí, Bolivia. Also occurs at Hagendorf, Germany.

Ludlamite

$Fe_3(PO_4)_2 . 4 H_2O$

MONOCLINIC ● ●

Properties: C – light green, green; S – white; L – vitreous; D – transparent to translucent; DE – 3.2; H – 3.5; CL – perfect; F – uneven; M – thin to thick tabular crystals, granular, massive.

Origin and occurrence: Secondary in the oxidation zone of ore deposits; in granitic pegmatites, where it replaces primary phosphates. Perfect crystals up to 90 mm (3$^{9}/_{16}$ in) across known from the San Antonio mine, Santa Eulalia, Chihuahua, Mexico; also from Morococala, Bolivia and the Blackbird district, Idaho, USA.

Ludlamite, 36 mm, Morococala, Bolivia

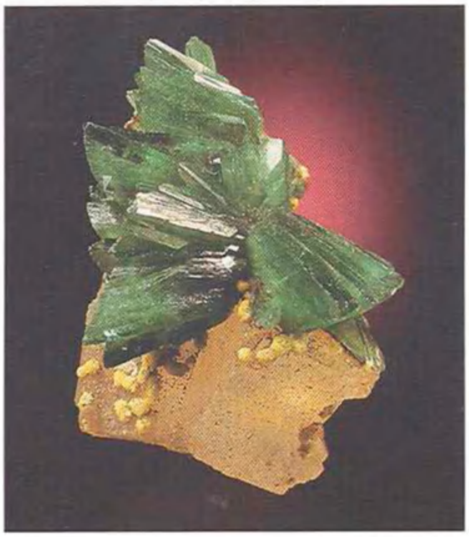

Anapaite

$Ca_2Fe(PO_4)_2 . 4 H_2O$

TRICLINIC ● ●

Properties: C – light to dark green, colorless; S – white; L – vitreous; D – transparent to translucent; DE – 2.8; H – 3.5; CL – perfect; F – uneven; M – thin to thick tabular crystals, rosette-like aggregates, granular.

Origin and occurrence: Secondary in the oxidation zone of Fe deposits and in sedimentary rocks, rich in P. Tabular crystals several mm across and spherical aggregates, up to 30 mm (1$^{3}/_{16}$ in) across, come from the cracks within oolitic ores near Anapa and Kerch, Crimea, Ukraine; also known from Bellaver de Cerdena, Spain.

Vivianite

$Fe_3(PO_4)_2 . 8 H_2O$

MONOCLINIC ● ● ● ●

Properties: C – colorless when fresh, quickly oxidizes to blue, green, purple, black-blue; S – white to bluish; L – vitreous; D – transparent, translucent to opaque; DE – 2.7; H – 1.5-2; CL – perfect; F – uneven; M – long prismatic to acicular crystals, fibrous, earthy to pulverulent aggregates, coatings, granular, massive.

Origin and occurrence: Secondary in the oxidation zone of Fe deposits; in granitic pegmatites, where it forms by the replacement of primary phosphates and in sedimentary rocks in proximity of organic

Anapaite, 18 mm aggregates, Anapa, Ukraine

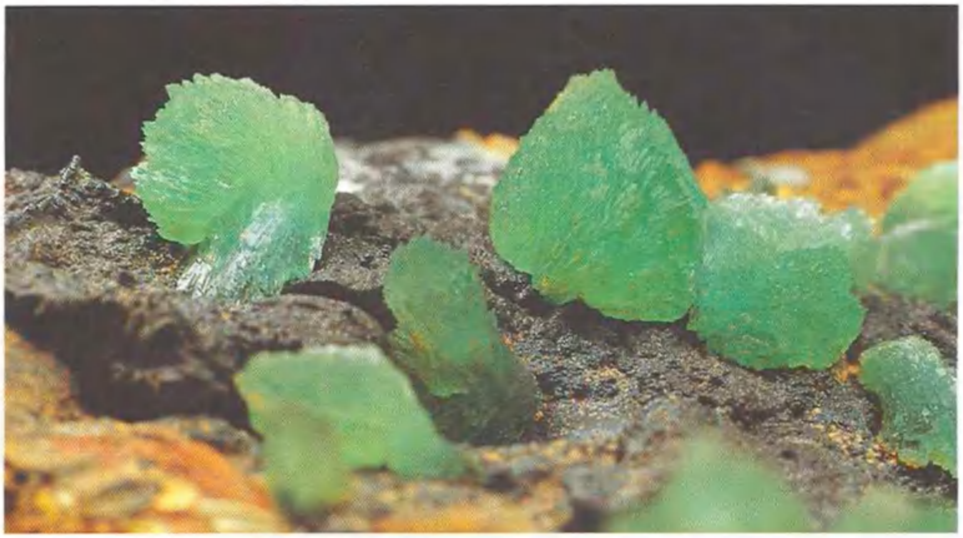

material; hydrothermal in the ore deposits. Crystals up to 1.5 m (5 ft) long found in clay sediments in Anloua, Cameroon; crystals up to 200 mm (7⅞ in) across known from Morococala, Bolivia. Smaller crystals come from Trepca, Serbia; Leadville, Colorado, Bingham Canyon, Utah, USA; also from Kerch and Anapa, Crimea, Ukraine.

Erythrine

$Co_3(AsO_4)_2 . 8 H_2O$

MONOCLINIC ● ● ●

Properties: C – dark purple, pink, colorless; S – light pink to white; L – vitreous; D – transparent to translucent; DE – 3.2; H – 1.5-2.5; CL – perfect; F – uneven; M – long prismatic, acicular to tabular crystals, earthy aggregates, coatings, granular, massive.

Origin and occurrence: Secondary in the oxidation zone of Co, Ni and U deposits. Tabular crystals up to 60 mm (2⅜ in) long come from Bou Azzer, Morocco. Other important localities are Schneeberg, Germany; Talmessi, Iran; Cobalt, Ontario, Canada; Mount Cobalt, Queensland, Australia.

Erythrite, 29 mm, Mexico

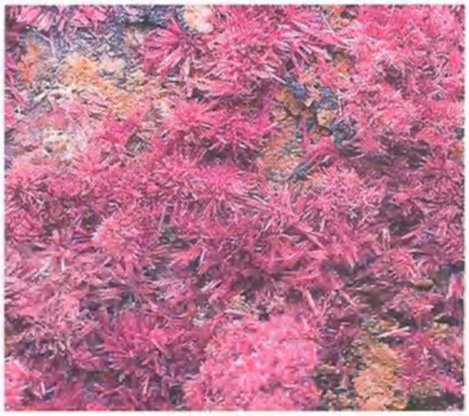

Vivianite, 48 mm, Morococala, Bolivia

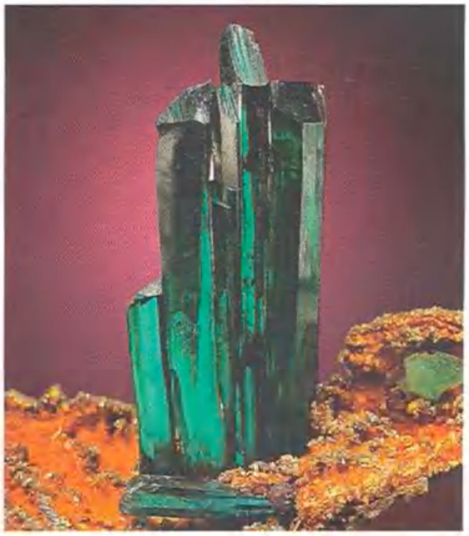

Phosphophyllite, 18 mm x, Potosi, Bolivia

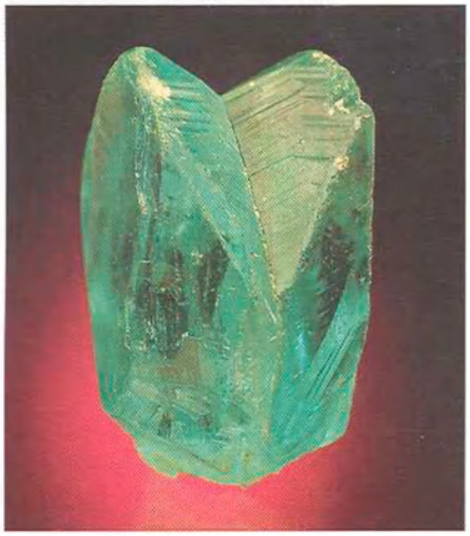

Ludlamite, 36 mm, Morococala, Bolivia

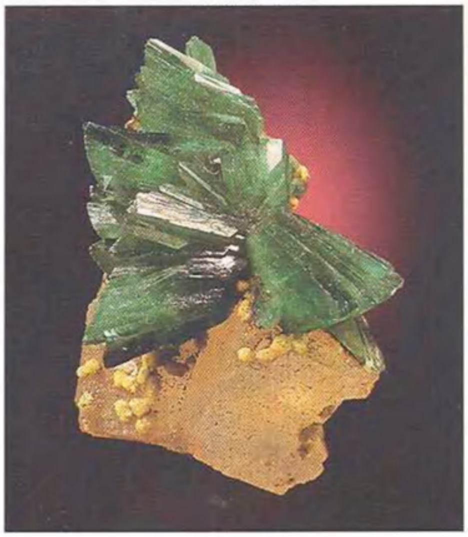

Phosphophyllite

$Zn_2Fe(PO_4)_2 \cdot 4\ H_2O$

MONOCLINIC ● ●

Properties: C – colorless, blue-green, blue; S – white; L – vitreous; D – transparent to translucent; DE – 3.1; H – 3-3.5; CL – good; F – uneven; M – long to short prismatic and thick tabular crystals, granular.
Origin and occurrence: Secondary in the oxidation zone of ore deposits; in granitic pegmatites, where it replaces primary phosphates. Perfect crystals, up to 140 mm (5½ in) across come from sulfide cavities in the Unificada mine, Potosi, Bolivia. Also occurs at Hagendorf, Germany.

Ludlamite

$Fe_3(PO_4)_2 \cdot 4\ H_2O$

MONOCLINIC ● ●

Properties: C – light green, green; S – white; L – vitreous; D – transparent to translucent; DE – 3.2; H – 3.5; CL – perfect; F – uneven; M – thin to thick tabular crystals, granular, massive.
Origin and occurrence: Secondary in the oxidation zone of ore deposits; in granitic pegmatites, where it replaces primary phosphates. Perfect crystals up to 90 mm ($3\frac{9}{16}$ in) across known from the San Antonio mine, Santa Eulalia, Chihuahua, Mexico; also from Morococala, Bolivia and the Blackbird district, Idaho, USA.

Anapaite

$Ca_2Fe(PO_4)_2 \cdot 4\ H_2O$

TRICLINIC ● ●

Properties: C – light to dark green, colorless; S – white; L – vitreous; D – transparent to translucent; DE – 2.8; H – 3.5; CL – perfect; F – uneven; M – thin to thick tabular crystals, rosette-like aggregates, granular.
Origin and occurrence: Secondary in the oxidation zone of Fe deposits and in sedimentary rocks, rich in P. Tabular crystals several mm across and spherical aggregates, up to 30 mm ($1\frac{3}{16}$ in) across, come from the cracks within oolitic ores near Anapa and Kerch, Crimea, Ukraine; also known from Bellaver de Cerdena, Spain.

Vivianite

$Fe_3(PO_4)_2 \cdot 8\ H_2O$

MONOCLINIC ● ● ● ●

Properties: C – colorless when fresh, quickly oxidizes to blue, green, purple, black-blue; S – white to bluish; L – vitreous; D – transparent, translucent to opaque; DE – 2.7; H – 1.5-2; CL – perfect; F – uneven; M – long prismatic to acicular crystals, fibrous, earthy to pulverulent aggregates, coatings, granular, massive.
Origin and occurrence: Secondary in the oxidation zone of Fe deposits; in granitic pegmatites, where it forms by the replacement of primary phosphates and in sedimentary rocks in proximity of organic

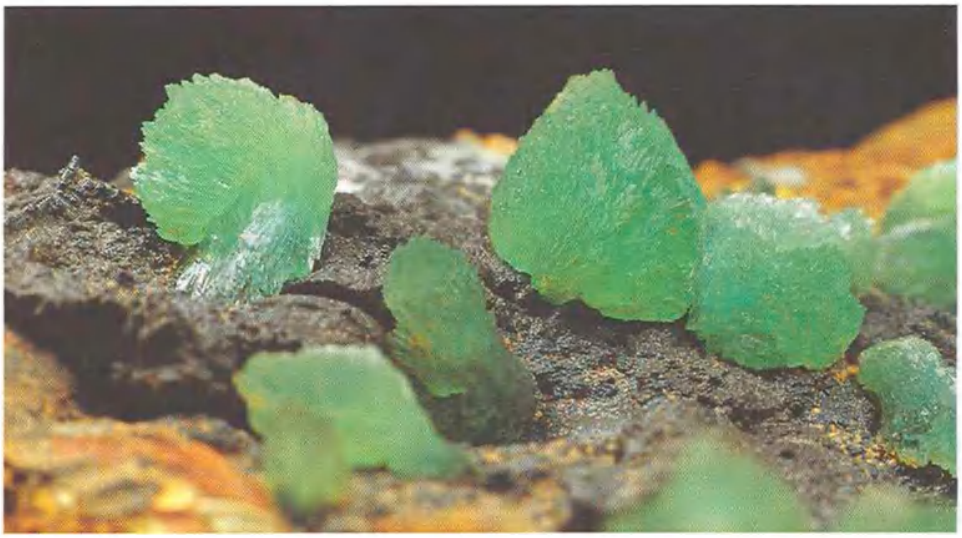
Anapaite, 18 mm aggregates, Anapa, Ukraine

material; hydrothermal in the ore deposits. Crystals up to 1.5 m (5 ft) long found in clay sediments in Anloua, Cameroon; crystals up to 200 mm (7⅞ in) across known from Morococala, Bolivia. Smaller crystals come from Trepca, Serbia; Leadville, Colorado, Bingham Canyon, Utah, USA; also from Kerch and Anapa, Crimea, Ukraine.

Erythrine

$Co_3(AsO_4)_2 . 8 H_2O$

MONOCLINIC ● ● ●

Properties: C – dark purple, pink, colorless; S – light pink to white; L – vitreous; D – transparent to translucent; DE – 3.2; H – 1.5-2.5; CL – perfect; F – uneven; M – long prismatic, acicular to tabular crystals, earthy aggregates, coatings, granular, massive.

Origin and occurrence: Secondary in the oxidation zone of Co, Ni and U deposits. Tabular crystals up to 60 mm (2⅜ in) long come from Bou Azzer, Morocco. Other important localities are Schneeberg, Germany; Talmessi, Iran; Cobalt, Ontario, Canada; Mount Cobalt, Queensland, Australia.

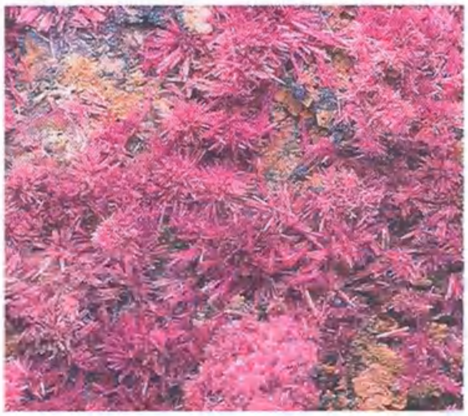
Erythrite, 29 mm, Mexico

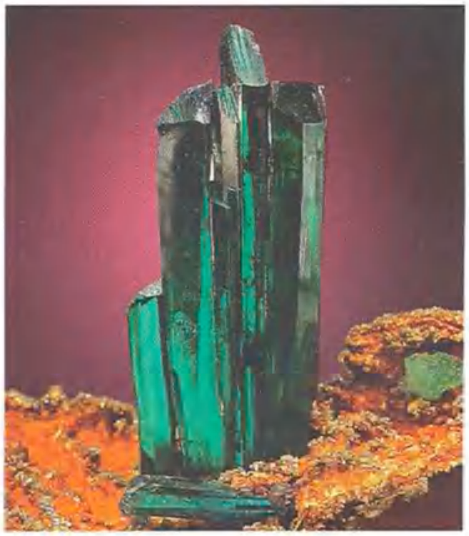
Vivianite, 48 mm, Morococala, Bolivia

Annabergite, 55 mm, Laurion, Greece

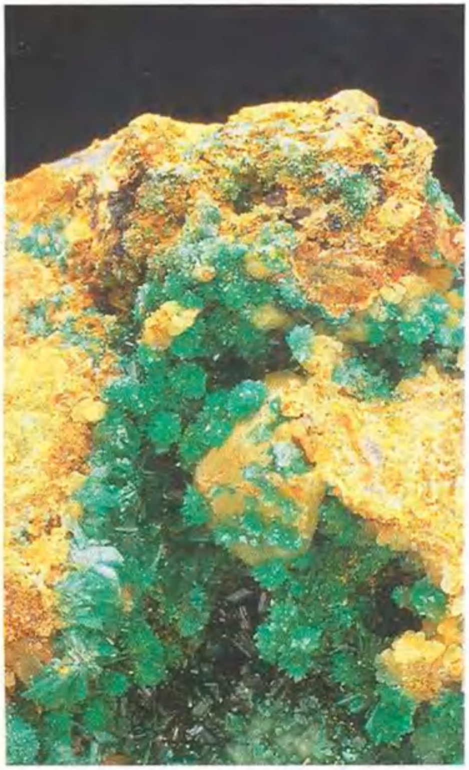

Annabergite

$Ni_3(AsO_4)_2 \cdot 8\ H_2O$

MONOCLINIC ● ● ●

Varieties: cabrerite (Mg contents)

Properties: C – light to dark green, white; S – white; L – vitreous; D – transparent to translucent; DE – 3.2; H – 1.5-2.5; CL – perfect; F – uneven; M – long prismatic to acicular and tabular crystals, acicular and earthy aggregates, coatings, granular, massive.
Origin and occurrence: Secondary in the oxidation zone of Ni deposits, associated with erythrite. Crystals up to 5 mm (3/16 in) across occur in Gukuroren, Turkey; Sierra Cabrera, Spain; Laurion, Greece. Nodules up to 20 mm (25/32 in) come from the Snowbird mine, Montana, USA.

Symplesite

$Fe_3(AsO_4)_2 \cdot 8\ H_2O$

TRICLINIC ● ●

Properties: C – bluish, dark blue, light green, black-green; S – white; L – vitreous; D – transparent to translucent; DE – 3.0 H – 2.5; CL – perfect; F – uneven; M – acicular to tabular crystals, spherical aggregates with radial structure, earthy aggregates and coatings, granular, massive.
Origin and occurrence: Secondary in the oxidation zone of ore deposits and in granitic pegmatites with

Symplesite, 12 mm xx, Baia Sprie, Romania

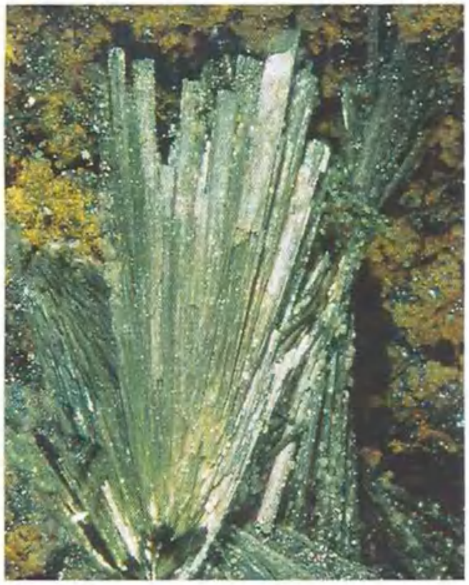

Picropharmacolite, 128 mm, France

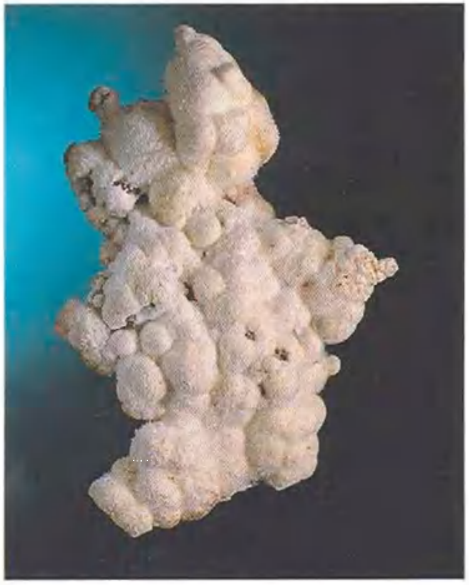

As minerals, mainly arsenopyrite and lollingite. It occurs in Schneeberg, Germany; Baia Sprie, Romania and Trebsko, Czech Republic.

Picropharmacolite

$Ca_4MgH_2(AsO_4)_4 . 12 H_2O$

TRICLINIC ● ●

Properties: C – colorless, white; S – white; L – vitreous; D – transparent to translucent; DE – 2.6; H – 2.5; CL – perfect; F – uneven; M – acicular crystals, spherical aggregates with radial structure, coatings.

Origin and occurrence: Secondary in the oxidation zone of ore deposits with As minerals, mostly arsenopyrite and lollingite. It is also known from Ste-Marie-aux-Mines and Salsigne, France; Freiberg, Germany and Jachymov, Czech Republic.

Brushite

$CaH(PO_4) . 2 H_2O$

MONOCLINIC ● ●

Properties: C – colorless, white; S – white; L – vitreous, pearly on cleavage planes; D – transparent to translucent; DE – 2.3; H – 2.5; CL – perfect; F – uneven; M – prismatic, acicular to tabular crystals, earthy aggregates and coatings, massive.

Origin and occurrence: Secondary on bat and bird excrements and bones, it impregnates bones, along the cracks of phosphorites. Tabular crystals up to 20 mm ($^{25}/_{32}$ in) across come from Quercy, France also occurs near Oran, Algeria and Pig Hole, Virginia, USA.

Brushite, 4 mm xx, Domica, Slovakia

Legrandite, 25 mm xx, Mapimi, Mexico

Legrandite

$Zn_2(AsO_4)(OH) . H_2O$

MONOCLINIC ● ●

Properties: C – colorless, yellow, purple; S – white; L – vitreous; D – transparent to translucent; DE – 4.0 H – 4.5; CL – imperfect; F – uneven; M – long prismatic crystals and their inter-growths, radial aggregates.

Origin and occurrence: Secondary in the oxidation zone of Zn deposits and in pegmatites. Prismatic crystals up to 250 mm (9$^{13}/_{16}$ in) long found in Mina Ojuela, Mapimi, Durango, Mexico. It is also known from Galileia, Minas Gerais, Brazil and Tsumeb, Namibia.

Euchroite, 10 mm xx, L'ubietova, Slovakia

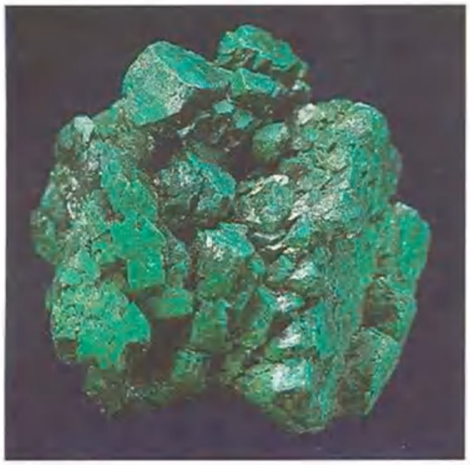

Euchroite

$Cu_2(AsO_4)(OH) . 3 H_2O$

ORTHORHOMBIC ● ●

Properties: C – emerald-green; S – white; L – vitreous; D – transparent to translucent; DE – 3.5; H – 3.5-4; CL – imperfect; F – conchoidal to uneven; M – short prismatic to thick tabular crystals, massive.
Origin and occurrence: Secondary in the oxidation zone of Cu deposits, associated with olivenite and malachite. Thick tabular crystals up to 30 mm ($1^{3}/_{16}$ in) come from L'ubietova, Slovakia. It also occurs in Zapacica, Bulgaria and Chessy, France.

Vauxite, 20 mm xx, Llallagua, Bolivia

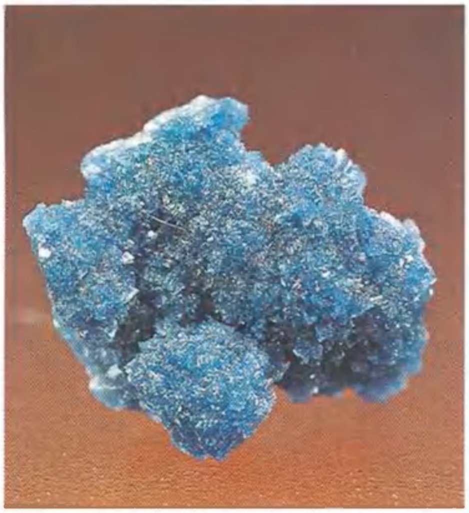

Strunzite, 10 mm xx, Hagendorf, Germany

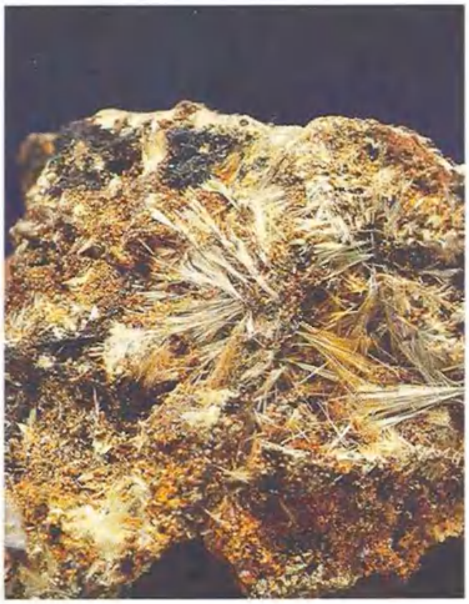

Vauxite

$FeAl_2(PO_4)_2(OH)_2 . 6 H_2O$

TRICLINIC ● ●

Properties: C – light to dark blue; S – white; L – vitreous; D – transparent to translucent; DE – 2.4; H – 3.5; CL – none; F – uneven; M – tabular crystals, radial aggregates, massive.
Origin and occurrence: Secondary in the oxidation zone of Sn deposits, associated with wavellite. Crystals occur in the Siglo XX Mine, Llallagua, Bolivia.

Strunzite

$MnFe^{3+}{}_2(PO_4)_2(OH)_2 . 6 H_2O$

MONOCLINIC ● ● ●

Properties: C – light yellow, yellow-brown; S – yellowish; L – vitreous; D – transparent to translucent; DE – 2.5; H – not determined; CL – not determined; F – uneven; M – acicular crystals, acicular and fibrous aggregates.
Origin and occurrence: Secondary in granitic pegmatites, as a result of weathering of primary phosphates, mostly triphyllite; rarely hydrothermal in the cracks of Fe-rich sedimentary rocks. Acicular crystals up to 20 mm ($^{25}/_{32}$ in) across known from Hagendorf, Germany; the Palermo No. 1 and No. 2 mines, North Groton and the Fletcher mine, Groton, New Hampshire, USA.

Cacoxenite, 1 mm xx, Hellertown, Pennsylvania, U.S.A.

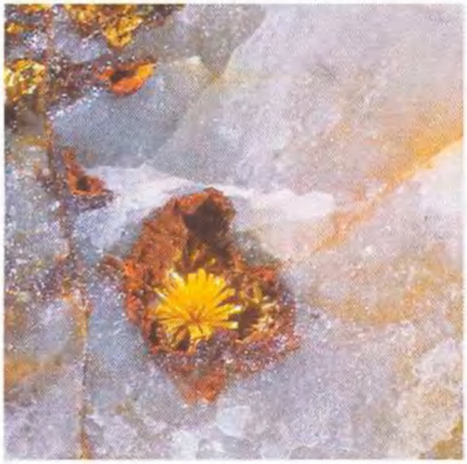

Cacoxenite

$(Fe^{3+},Al)_{25}(PO_4)_{17}O_6(OH)_{12}\cdot 75\,H_2O$

HEXAGONAL ● ● ●

Properties: C – light yellow, yellow-brown, orange; S – yellow; L – silky; D – transparent to translucent; DE – 2.3; H – 3-4; CL – not determined; F – uneven; M – acicular and fibrous aggregates, often with radial structure, botryoidal crusts and coatings.
Origin and occurrence: Hydrothermal on the cracks of sedimentary Fe ores, associated with wavellite; rare as secondary in granitic pegmatites, as a product of weathering of primary phosphates. Crystals up to 10 mm (3/8 in) across come from the Horcajo mine, Ciudad Real, Spain; golden-yellow acicular aggregates occur in Hrbek near Svata Dobrotiva and Trenice, Czech Republic and in Amberg, Germany.

Beraunite

$Fe^{2+}Fe^{3+}_5(PO_4)_4(OH)_5\cdot 4\,H_2O$

MONOCLINIC ● ●

Properties: C – red-brown, red, gray-green; S – yellow to green-brown; L – vitreous to dull; D – translucent; DE – 3.0; H – 3.5-4; CL – good; F – uneven; M – acicular aggregates, often with radial structure, botryoidal crusts and coatings.
Origin and occurrence: Hydrothermal on the cracks of sedimentary Fe ores, typically together with wavellite; secondary in granitic pegmatites, as a product of weathering of primary phosphates. Acicular aggregates up to 10 mm (3/8 in) across occur in Mount Indian, Alabama, USA; also known from Hrbek near Svata Dobrotiva, Czech Republic and Amberg, Germany.

Beraunite, 3 mm aggregates, Nekeszeny, Hungary

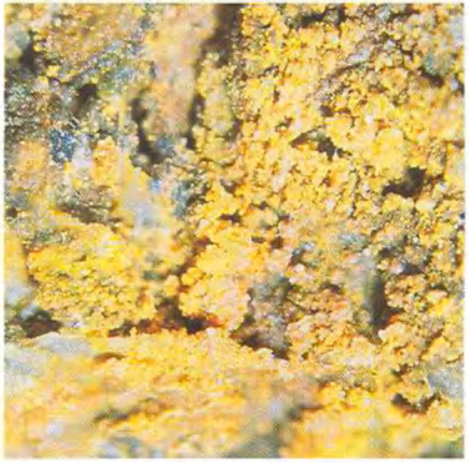

Diadochite

$Fe^{3+}_2(PO_4)(SO_4)(OH)\cdot 5\,H_2O$

TRICLINIC ● ● ●

Properties: C – yellow-brown, brown, red-brown, yellow-green, gray-green; S – yellow to light brown; L – dull, waxy; D – translucent to opaque; DE – 2.0-2.4; H – 3; CL – not determined; F – uneven, conchoidal, earthy; M – nodules, coatings and crusts, massive.
Origin and occurrence: Secondary in the oxidation zone of Fe deposits. Diadochite caves in abandoned mines are known from Saalfeld, Germany; nodules found in New Idria, California and Eureka, Nevada, USA.

Diadochite, 40 mm, Recsk, Hungary

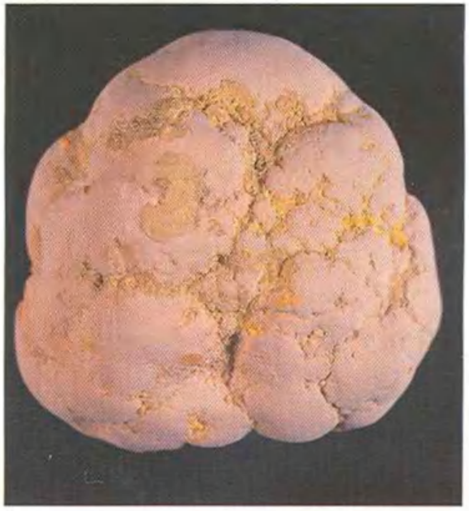

Wavellite, 40 mm, Trenice, Czech Republic

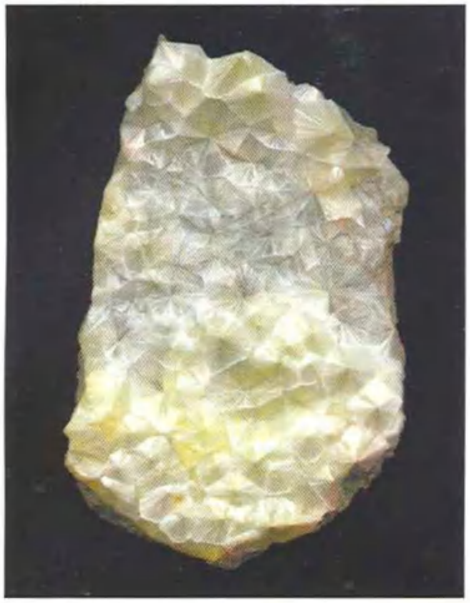

Eosphorite, 4 mm xx, Lavra da Ilha, Brazil

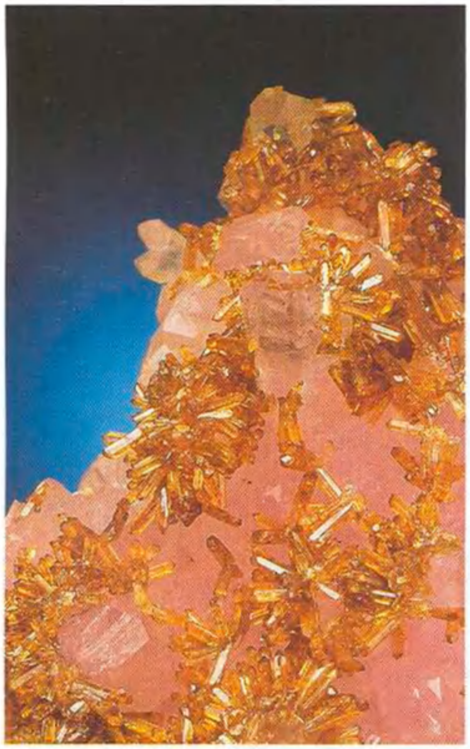

Wavellite

$Al_3(PO_4)_2(OH,F)_3 . 5\ H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white, greenish, light blue-green, green, yellowish; S – white; L – vitreous to pearly; D – transparent to translucent; DE – 2.4; H – 3.5-4; CL – perfect; F – uneven; M – isometric crystals, hemispherical aggregates with radial structure, botryoidal aggregates, nodules, coatings, massive.
Origin and occurrence: Hydrothermal in the cracks of Al and P-rich sediments, also in phosphate deposits, ore veins and pegmatites. Beautiful hemispherical aggregates up to 40 mm ($1\frac{9}{16}$ in) in diameter occur in Pencil, Garland and Magnet Cove, Arkansas, USA; also known from Trenice and Milina, Czech Republic and Ronneburg, Germany.

Eosphorite

$MnAl(PO_4)(OH)_2 . H_2O$

ORTHORHOMBIC ● ●

Properties: C – pinkish, colorless, white, brownish, red-brown; S – white; L – vitreous to pearly; D – transparent to translucent; DE – 3.1; H – 5; CL – imperfect; F – uneven to conchoidal; M – long to short prismatic crystals, radial aggregates, granular.
Origin and occurrence: Secondary in granitic pegmatites, as a product of hydrothermal replacement of primary phosphates. Crystals up to 100 mm (4in) long found in the Joao Modesto dos Santos mine, Minas Gerais, Brazil. It occurs in Rapid Creek, Yukon, Canada, too.

Turquoise

$CuAl_6(PO_4)_4(OH)_8 . 4\ H_2O$

TRICLINIC ● ● ●

Properties: C – blue, blue-green, green; S – white; L – waxy; D – transparent, translucent to opaque; DE – 2.9; H – 5-6; CL – good; F – conchoidal to uneven; M – short prismatic crystals, botryoidal aggregates, coatings, massive.
Origin and occurrence: Secondary in the surface parts of rocks with elevated contents of P and Cu, e.g. in the oxidation zone of some Cu deposits. Small crystals occurred near Lynch Station, Virginia, USA. Massive blue and blue-green concretions come from Mount Ali Mirsai near Maden, Iran. Other localities are Cortez, Nevada, Los Cerillos and Eureka, New Mexico and Bisbee, Arizona, USA.
Application: popular gemstone.

Turquoise, 3 mm aggregates, Humboldt Co., U.S.A.

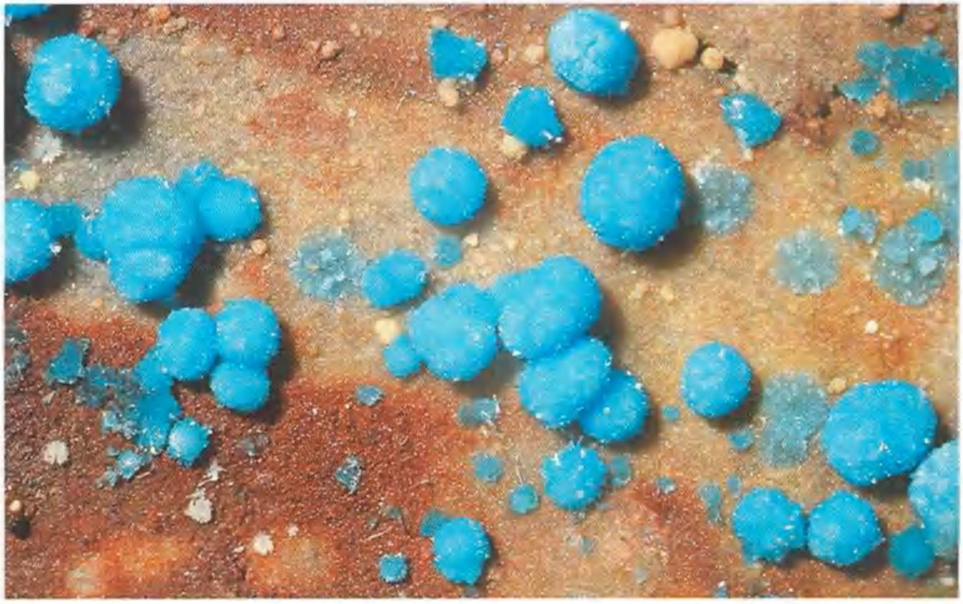

Chalcosiderite

$CuFe^{3+}_6(PO_4)_4(OH)_8 \cdot 4 H_2O$

TRICLINIC ● ●

Properties: C – dark green; S – white; L – vitreous; D – transparent to translucent; DE – 3.3; H – 4.5; CL – good; F – conchoidal to uneven; M – short prismatic crystals, coatings.

Origin and occurrence: Secondary in the oxidation zone of some Cu deposits, together with goethite, dufrenite and pharmacosiderite. It occurs in Bisbee, Arizona, USA; in the Wheal Phoenix mine, Cornwall, UK; Schneckenstein, Germany; Horni Slavkov, Czech Republic.

Turquoise, 50 mm, Kazakhstan

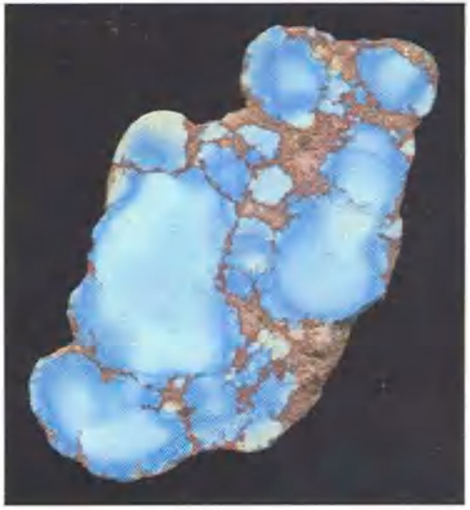

Chalcosiderite, 90 mm, Cornwall, UK

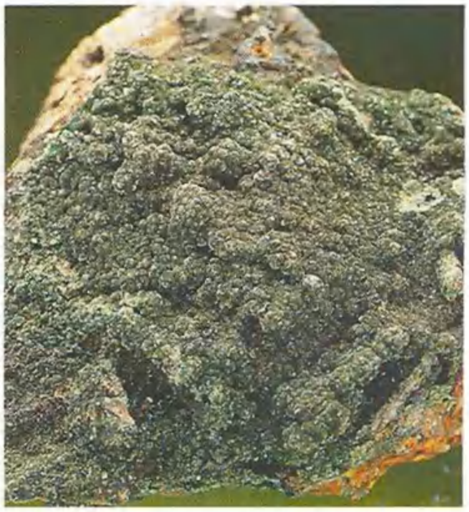

Chenevixite, 100 mm, Chuquicamata, Chile

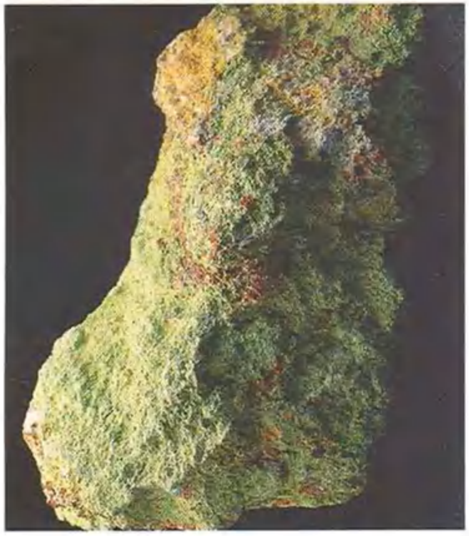

Chenevixite

$Cu_2Fe^{3+}_2(AsO_4)_2(OH)_4 \cdot H_2O$

MONOCLINIC ●

Properties: C – dark green, olive-green to yellow-green; S – yellow-green; L – greasy; D – translucent; DE – 3.9; H – 3.5-4.5; CL – not determined; F – conchoidal to uneven; M – earthy aggregates, coatings, massive.
Origin and occurrence: Secondary in the oxidation zone of Cu deposits, associated with malachite, tyrolite, azurite and other minerals. Massive aggregates occur in the Mammoth mine, Tintic, Utah, USA; also in Klein Spitzkopje, Namibia.

Tyrolite

$CaCu_5(AsO_4)_2(CO_3)(OH)_4 \cdot 6\ H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – apple-green, green-blue to blue; S – light green to blue-green; L – vitreous to pearly; D – transparent to translucent; DE – 3.3; H – 2; CL – perfect; F – uneven; M B scaly and fan-shaped aggregates, coatings and crusts.
Origin and occurrence: Secondary in the oxidation zone of Cu deposits, frequently associated with chalcophyllite. Rich aggregates occur in the Majuba Hill mine, Nevada, also in Tintic, Utah, USA. It is also known from Brixlegg, Austria; Saalfeld and Schneeberg, Germany; Novoveska Huta, Slovakia.

Tyrolite, 90 mm, Novoveska Huta, Slovakia

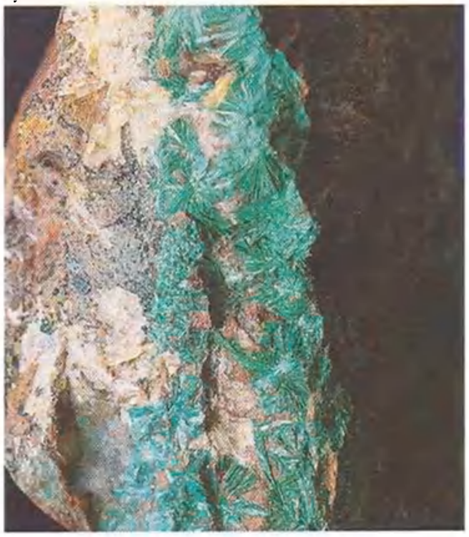

Delvauxite

$CaFe^{3+}_4(PO_4,SO_4)(OH)_8 \cdot 4\text{-}6\ H_2O$

AMORPHOUS ● ● ●

Properties: C – yellow-brown, brown, red-brown, black-brown; S – yellow; L – greasy, waxy; D – translucent to opaque; DE – 1.8-2.0; H – 2.5; CL – not determined; F – conchoidal, earthy; M – nodules, stalactites, coatings and crusts, massive.
Origin and occurrence: Secondary in oxidation zone of Fe deposits. Nodules of 50 cm (20 in) across in Czech Republic. Also known in Berneau and Richelle, Belgium; Zelezník, Slovakia; Kerch, Crimea, Ukraine.

Delvauxite, 80 mm, Nucice, Czech Republic

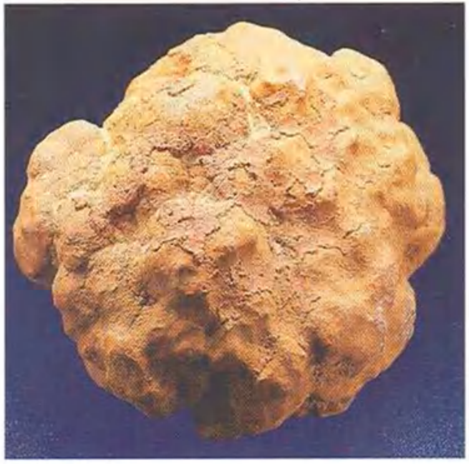

Bukovskyite, 40 mm, Kaňk, Czech Republic

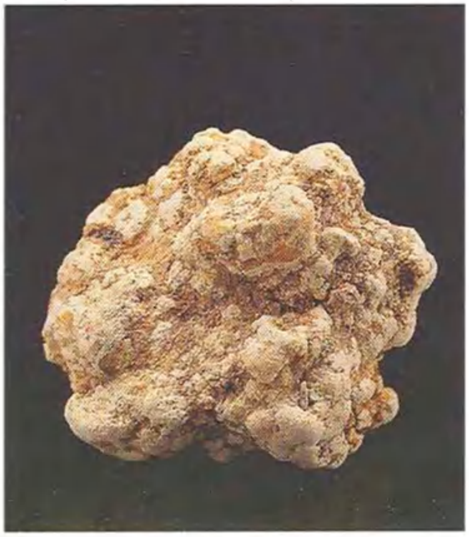

Bukovskyite

$Fe^{3+}{}_2(AsO_4)(SO_4)(OH) \cdot 7 H_2O$

TRICLINIC ●

Properties: C – yellow-green, gray-green; S – yellowish white; L – dull to earthy; D – translucent to opaque; DE – 2.3; H – not determined; CL – not determined; F – earthy; M B botryoidal aggregates and nodules.
Origin and occurrence: Secondary on the old mine dumps where it forms as a product of arsenopyrite weathering. Nodules up to 60 cm (24 in), occur on medieval dumps in Kank near Kutna Hora, Czech Republic.

Chalcophyllite, 36 mm, Chile

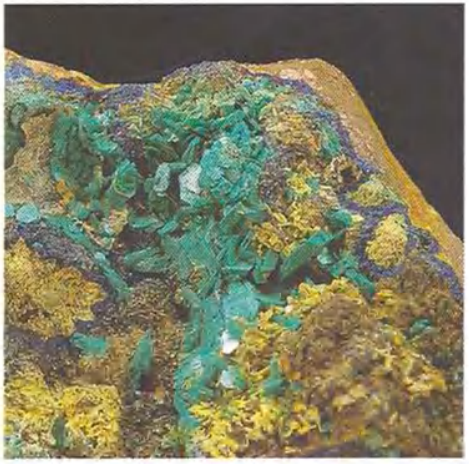

Veszelyite

$(Cu,Zn)_3(PO_4)(OH)_3 \cdot 2 H_2O$

MONOCLINIC ● ●

Properties: C – green, blue-green, dark blue; S – green; L – vitreous; D – translucent; DE – 3.4; H – 3.5-4; CL – good; F – uneven; M – short prismatic to tabular crystals, granular.
Origin and occurrence: Secondary in the oxidation zone of Cu-Zn deposits. Crystals up to 50 mm (2 in) across found in the Black Pine mine, Philipsburg, Montana, USA; also from Moravita, Romania; Arakawa, Japan; Wanlockhead, Scotland, UK.

Chalcophylite

$Cu_{18}Al_2(AsO_4)_3(SO_4)_3(OH)_{27} \cdot 36 H_2O$

TRIGONAL ● ● ●

Properties: C – emerald-green, blue-green; S – light green; L – vitreous, pearly; D – transparent to translucent; DE – 2.6; H – 2; CL – perfect; F – uneven; M – tabular crystals, scaly, fan-shaped aggregates, coatings, massive.
Origin and occurrence: Secondary in the oxidation zone of Cu deposits, usually associated with tyrolite. Rich aggregates occur in the Majuba Hill, Nevada and in the Tintic district, Utah, USA. Nice specimens also come from Novoveská Huta and Piesky, Slovakia; Nizhniy Tagil, Ural mountains, Russia; Cap Garrone, France.

Veszelyite, 13 mm, Philipsburg, U.S.A.

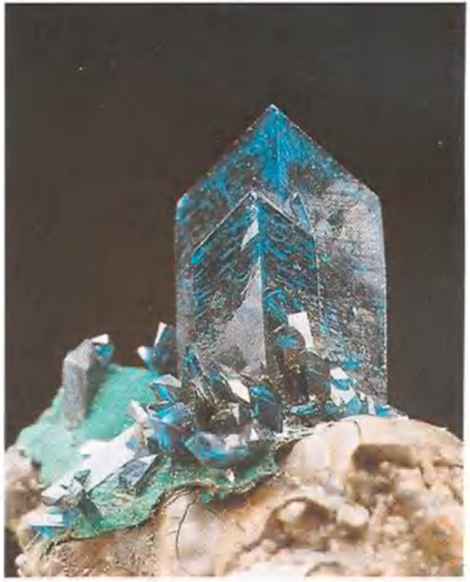

Liroconite, 86 mm, Cornwall, UK

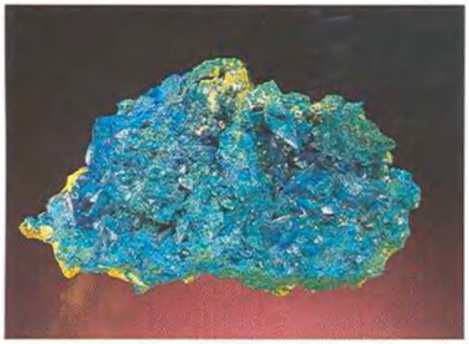

Lirokonit

$Cu_2Al(AsO_4)(OH)_4 . 4\ H_2O$

MONOCLINIC ● ●

Properties: C – blue, green; S – light blue; L – vitreous to resinous; D – transparent to translucent; DE – 3.0; H – 2-2.5; CL – imperfect; F – conchoidal to uneven; M – lenticular, dipyramidal crystals, massive.
Origin and occurrence: Secondary in the oxidation zone of Cu deposits, together with olivenite, malachite and azurite. Perfect crystals up to 30 mm ($1^{3}/_{16}$ in) across come from Redruth and St. Day, Cornwall, UK. It is also known from Cerro Gordo, California, USA.

Evansite, 5 mm aggregates, Sirk – Zeleznik, Slovakia

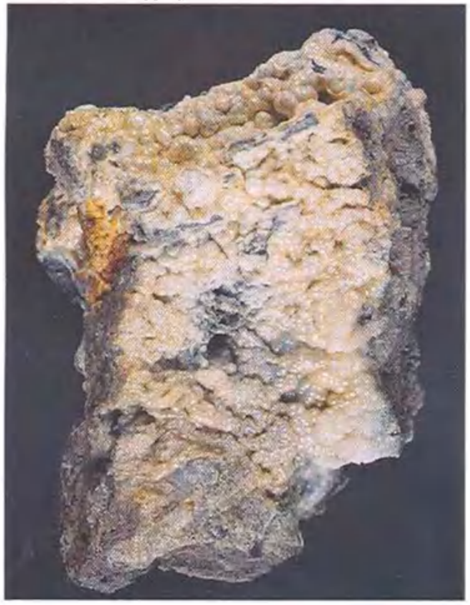

Evansite

$Al_3(PO_4)(OH)_6 . 6\ H_2O$

AMORPHOUS 3

Properties: C – colorless, white, greenish, light blue-green, yellowish; S – white; L – vitreous, resinous, waxy; D – transparent to translucent; DE – 1.8-2.2; H – 3-4; CL – none; F – conchoidal; M – botryoidal, stalactitic and hemispherical aggregates and coatings.
Origin and occurrence: Secondary in the oxidation zone of Fe deposits, rich in P, associated with alophane and goethite. Rich stalactitic aggregates come from Zelezník, Slovakia and from Epernay, France.

Whiteite-(CaFeMg)

$CaFeMg_2Al_2(PO_4)_4(OH)_2 . 8\ H_2O$

MONOCLINIC ● ●

Properties: C – brown; S – white; L – vitreous; D – transparent to translucent; DE – 2.6; H – 4; CL – good; F – uneven; M – short prismatic crystals.
Origin and occurrence: Hydrothermal in the cracks of P-rich sediments. Perfect crystals up to 20 mm ($^{25}/_{32}$ in) across come from Big Fish River, Yukon, Canada. Crystals up to 5 mm ($^{3}/_{16}$ in), are known from Lavra da Ilha de Taquaral, Minas Gerais, Brazil.

Whiteite-(CaFeMg), 65 mm, Yukon Territory, Canada

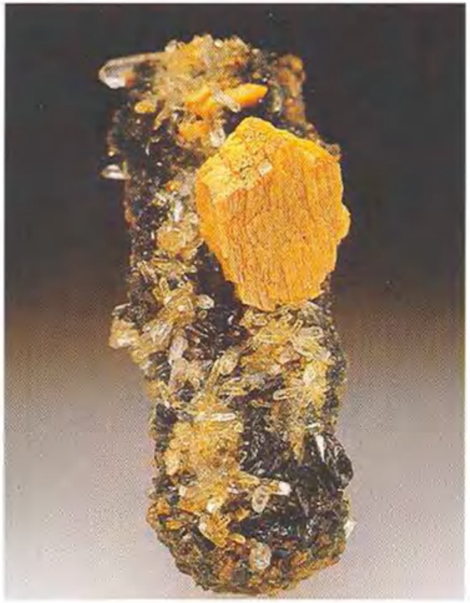

Jahnsite-(CaMnMg), 60 mm, Custer, U.S.A.

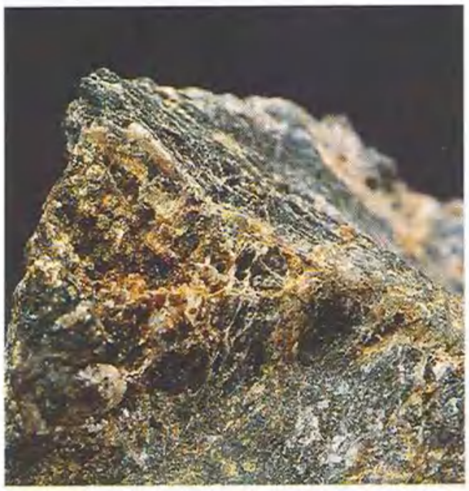

Jahnsite-(CaMnMg)

$CaMnMg_2Fe^{3+}_2(PO_4)_4(OH)_4 \cdot 8\,H_2O$

MONOCLINIC ● ●

Properties: C – yellow, light to dark brown; S – light yellow; L – vitreous; D – transparent to translucent; DE – 2.6; H – not determined; CL – good; F – uneven; M – short to long prismatic crystals, granular.
Origin and occurrence: Secondary in granitic pegmatites, where it forms as a result of replacement of primary phosphates. Perfect crystals up to 10 mm (⅜ in) across occur in the Tip Top mine, Custer, South Dakota, USA. It is also known from Hagendorf, Germany.

Wardite

$NaAl_3(PO_4)_2(OH)_4 \cdot 2\,H_2O$

TETRAGONAL ● ● ●

Properties: C – colorless, white, greenish, light blue-green; S -white; L – vitreous; D – transparent to translucent; DE – 2.8; H – 5; CL – perfect; F – uneven; M – dipyramidal crystals, radial and hemispherical aggregates, coatings, crusts, granular.
Origin and occurrence: Secondary in granitic pegmatites, where it forms as a product of primary phosphate replacement; hydrothermal in the cracks in P-rich sediments. Perfect crystals up to 30 mm (1 3/16 in) across come from Rapid Creek, Yukon, Canada. It is also known from Piedras Lavradas, Paraiba, Brazil.

Wardite, 48 mm, Yukon Territory, Canada

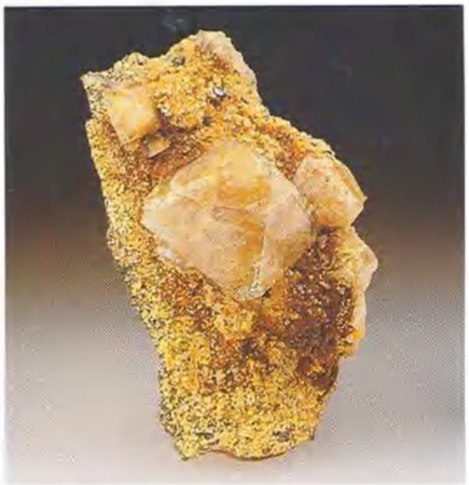

Cyrilovite

$NaFe^{3+}_3(PO_4)_2(OH)_4 \cdot 2\,H_2O$

TETRAGONAL ● ●

Properties: C – yellow, orange, brown-yellow; S – yellow; L – vitreous; D – transparent to translucent; DE – 3.1; H – 4; CL – good; F – conchoidal; M – tabular and dipyramidal crystals, coatings and crusts.
Origin and occurrence: Secondary in granitic pegmatites, where it forms as a result of replacement of primary phosphates. Small crystals occur in Cyrilov, Czech Republic; Hagendorf, Germany and Sapucaia, Minas Gerais, Brazil.

Cyrilovite, 60 mm, Iron Monarch, Australia

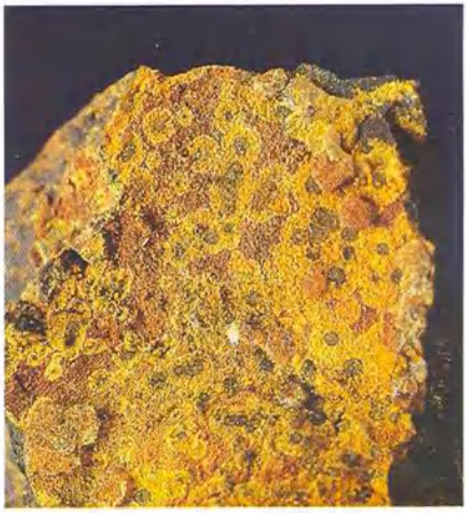

Liroconite, 86 mm, Cornwall, UK

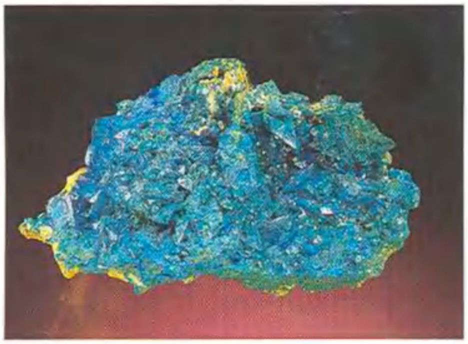

Lirokonit

$Cu_2Al(AsO_4)(OH)_4 . 4 H_2O$

MONOCLINIC ● ●

Properties: C – blue, green; S – light blue; L – vitreous to resinous; D – transparent to translucent; DE – 3.0, H - 2-2.5; CL – imperfect; F – conchoidal to uneven; M – lenticular, dipyramidal crystals, massive.
Origin and occurrence: Secondary in the oxidation zone of Cu deposits, together with olivenite, malachite and azurite. Perfect crystals up to 30 mm ($1^{3}/_{16}$ in) across come from Redruth and St. Day, Cornwall, UK. It is also known from Cerro Gordo, California, USA.

Evansite, 5 mm aggregates, Sirk – Zeleznik, Slovakia

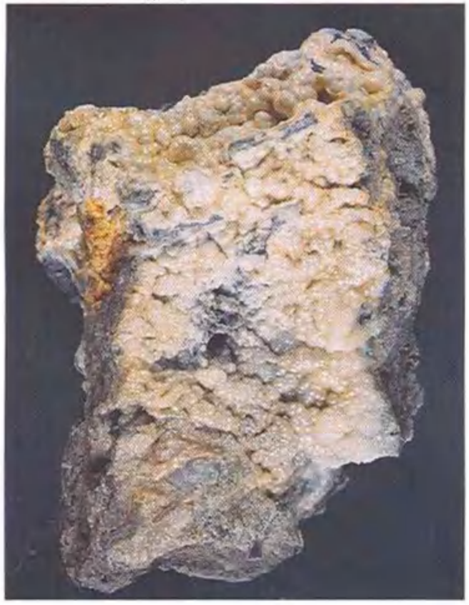

Evansite

$Al_3(PO_4)(OH)_6 . 6 H_2O$

AMORPHOUS 3

Properties: C – colorless, white, greenish, light blue-green, yellowish; S – white; L – vitreous, resinous, waxy; D – transparent to translucent; DE – 1.8-2.2; H – 3-4; CL – none; F – conchoidal; M – botryoidal, stalactitic and hemispherical aggregates and coatings.
Origin and occurrence: Secondary in the oxidation zone of Fe deposits, rich in P, associated with alophane and goethite. Rich stalactitic aggregates come from Zeleznik, Slovakia and from Epernay, France.

Whiteite-(CaFeMg)

$CaFeMg_2Al_2(PO_4)_4(OH)_2 . 8 H_2O$

MONOCLINIC ● ●

Properties: C – brown; S – white; L – vitreous; D – transparent to translucent; DE - 2.6; H – 4; CL – good; F – uneven; M – short prismatic crystals.
Origin and occurrence: Hydrothermal in the cracks of P-rich sediments. Perfect crystals up to 20 mm ($^{25}/_{32}$ in) across come from Big Fish River, Yukon, Canada. Crystals up to 5 mm ($^{3}/_{16}$ in), are known from Lavra da Ilha de Taquaral, Minas Gerais, Brazil.

Whiteite-(CaFeMg), 65 mm, Yukon Territory, Canada

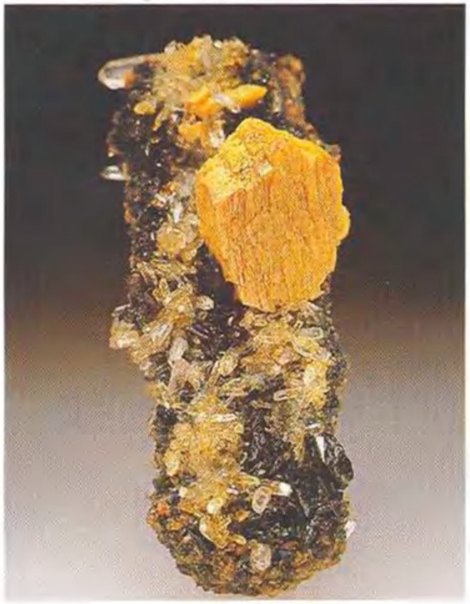

Jahnsite-(CaMnMg), 60 mm, Custer, U.S.A.

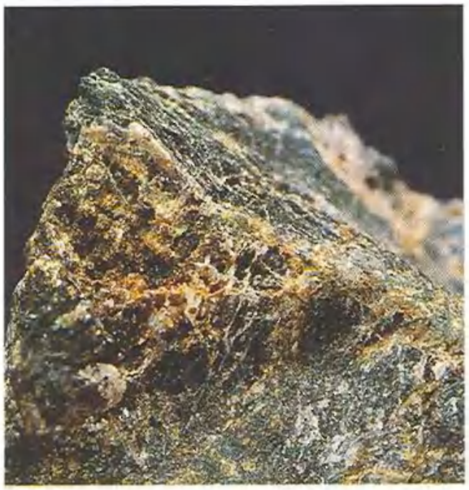

Jahnsite-(CaMnMg)

$CaMnMg_2Fe^{3+}{}_2(PO_4)_4(OH)_4 \cdot 8\,H_2O$

MONOCLINIC ● ●

Properties: C – yellow, light to dark brown; S – light yellow; L – vitreous; D – transparent to translucent; DE – 2.6; H – not determined; CL – good; F – uneven; M – short to long prismatic crystals, granular.
Origin and occurrence: Secondary in granitic pegmatites, where it forms as a result of replacement of primary phosphates. Perfect crystals up to 10 mm (3/8 in) across occur in the Tip Top mine, Custer, South Dakota, USA. It is also known from Hagendorf, Germany.

Wardite

$NaAl_3(PO_4)_2(OH)_4 \cdot 2\,H_2O$

TETRAGONAL ● ● ●

Properties: C – colorless, white, greenish, light blue-green; S -white; L – vitreous; D – transparent to translucent; DE – 2.8; H – 5; CL – perfect; F – uneven; M – dipyramidal crystals, radial and hemispherical aggregates, coatings, crusts, granular.
Origin and occurrence: Secondary in granitic pegmatites, where it forms as a product of primary phosphate replacement; hydrothermal in the cracks in P-rich sediments. Perfect crystals up to 30 mm (1 3/16 in) across come from Rapid Creek, Yukon, Canada. It is also known from Piedras Lavradas, Paraiba, Brazil.

Wardite, 48 mm, Yukon Territory, Canada

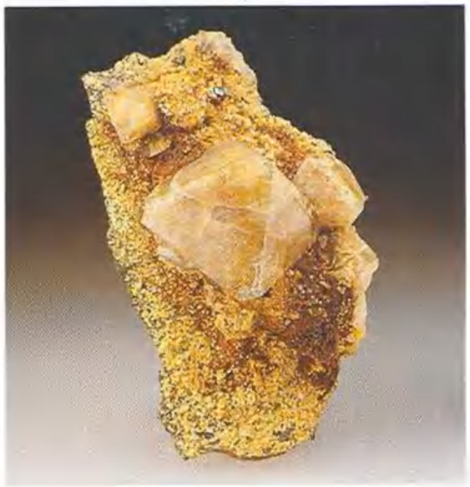

Cyrilovite

$NaFe^{3+}{}_3(PO_4)_2(OH)_4 \cdot 2\,H_2O$

TETRAGONAL ● ●

Properties: C – yellow, orange, brown-yellow; S – yellow; L – vitreous; D – transparent to translucent; DE – 3.1; H – 4; CL – good; F – conchoidal; M – tabular and dipyramidal crystals, coatings and crusts.
Origin and occurrence: Secondary in granitic pegmatites, where it forms as a result of replacement of primary phosphates. Small crystals occur in Cyrilov, Czech Republic; Hagendorf, Germany and Sapucaia, Minas Gerais, Brazil.

Cyrilovite, 60 mm, Iron Monarch, Australia

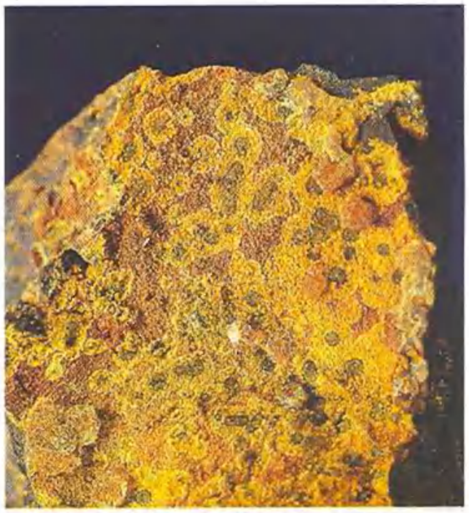

Pharmacosiderite, 35 mm, Cornwall, UK

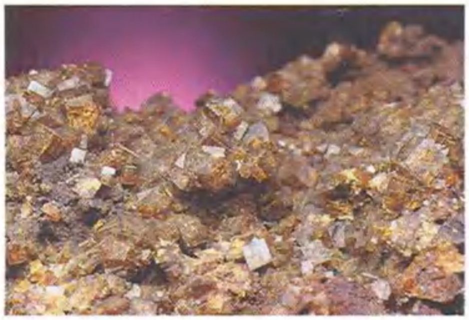

Arseniosiderite, 3 mm, Nagyborzsony, Hungary

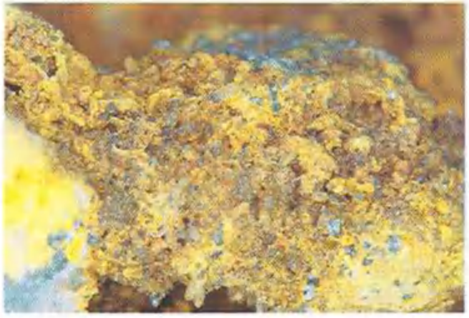

Lavendulan, 36 mm, San Juan, Chile

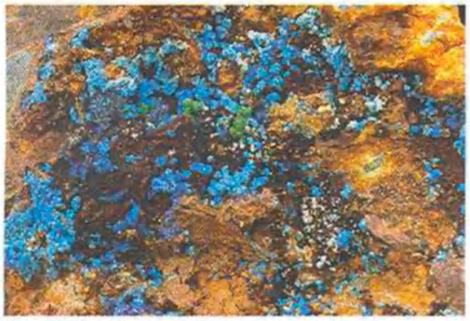

Mixite, 70 mm, Cinovec, Czech Republic

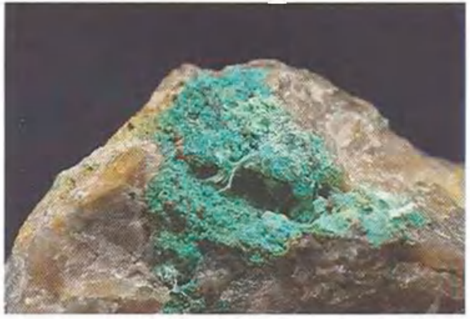

Pharmacosiderite

$KFe^{3+}_4(AsO_4)_3(OH)_4 \cdot 6\ H_2O$

CUBIC ● ● ●

Properties: C – green, yellow-brown, brown; S – white; L – adamantine to greasy; D – transparent to translucent; DE – 2.8; H – 2.5; CL – imperfect; F – uneven; M – cubic crystals, coatings, crusts, granular, massive.
Origin and occurrence: Secondary in granitic pegmatites and in the oxidation zone of ore deposits, where it forms as a product of arsenopyrite and lollingite replacement. Cubic crystals up to 10 mm (3/8 in) across occur in St. Day, Liskeard and Redruth, Cornwall, UK. It also comes from the Majuba Hill mine, Nevada, USA; Horhausen, Germany and Cap Garrone, France.

Arseniosiderite

$CaFe^{3+}_3(AsO_4)_3O_2 \cdot 3\ H_2O$

MONOCLINIC ● ●

Properties: C – yellow, light to dark brown; S – yellow; L – submetallic to silky; D – opaque; DE – 3.6; H – 1.5; CL – good; F – uneven; M – fibrous and earthy aggregates, coatings, crusts, massive.
Origin and occurrence: Secondary in the oxidation zone of ore deposits and in granitic pegmatites, where it forms as a product of arsenopyrite and lollingite replacement. Rich aggregates occur in Romanche, France; also from the Eureka mine, Tintic, Utah, USA and Wittichen, Germany.

Lavendulane

$NaCaCu_5(AsO_4)_4Cl \cdot 5\ H_2O$

ORTHORHOMBIC ● ●

Properties: C – light blue-purple, blue; S – white; L – vitreous to waxy; D – translucent; DE – 3.5; H – 2.5; CL – good; F – uneven; M – acicular crystals, acicular and earthy aggregates, coatings.
Origin and occurrence: Secondary in the oxidation zone of Co, Cu and Ni deposits, as a result of arsenide weathering, associated with erythrite. Rich acicular aggregates come from Talmessi and Anarak, Iran. Small crystals found in the Blanca mine, San Juan, Chile and in Annaberg, Germany. Crystals up to 4 mm (5/32 in) across occur in the Gold Hill mine, Utah, USA.

Kovdorskite, 15 mm x, Kovdor, Kola, Russia

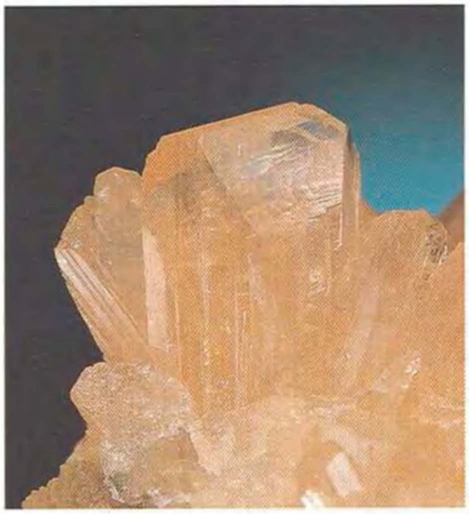

Mixite

$BiCu_6(AsO_4)_3(OH)_6 \cdot 3\ H_2O$

HEXAGONAL ● ●

Properties: C – emerald-green, blue-green, light blue, light green, whitish; S – light green, light blue; L – adamantine to dull; D – translucent; DE – 3.8; H – 3-4; CL – not determined; F – uneven; M – acicular crystals, acicular and earthy aggregates, coatings, massive.
Origin and occurrence: Secondary in the oxidation zone of Bi and Cu deposits, together with bismuthinite. It occurred in Jachymov, Czech Republic; in Tintic, Utah, USA; Schneeberg and Wittichen, Germany.

Kovdorskite

$Mg_5(PO_4)_2(CO_3)(OH)_2 \cdot 4{,}5\ H_2O$

MONOCLINIC ●

Properties: C – light pink-brown, white, blue; S – white; L – vitreous; D – transparent to translucent; DE – 2.6; H – 4; CL – none; F – conchoidal to uneven; M – tabular crystals, massive.
Origin and occurrence: Hydrothermal, associated with magnesite, magnetite and other minerals. Blue and pink-brown crystals up to 25 mm (1 in) across come from the Zheleznyi mine, Kovdor, Kola Peninsula, Russia.

Torbernite

$Cu(UO_2)_2(PO_4)_2 \cdot 8\text{-}12\ H_2O$

TETRAGONAL ● ● ●

Properties: C – emerald-green to grass-green; S – light green; L – vitreous to dull, pearly on the cleavage planes; D – transparent to translucent; DE – 3.3; H – 2-2.5; CL – perfect; F – uneven; M – tabular to pyramidal crystals, earthy aggregates, coatings, granular, massive; R – strongly radioactive.
Origin and occurrence: Secondary in the oxidation zone of U deposits, also in pegmatites and sedimentary rocks, resulting from the hydrothermal alteration of uraninite and other U minerals. Emerald-green tabular crystals, several cm across, come from Sabugal, Portugal; Jachymov, Czech Republic; Shinkolobwe, Zaire; Bois-Noirs, France; Moctezuma, Mexico and many localities in the Colorado Plateau, Utah, USA. Beautiful druses of crystals up to 20 mm ($^{25}/_{32}$ in) across, found in the Margabal mine, Aveyron, France.
Application: U ore.

Torbernite, 120 mm, Katanga, Zair

+
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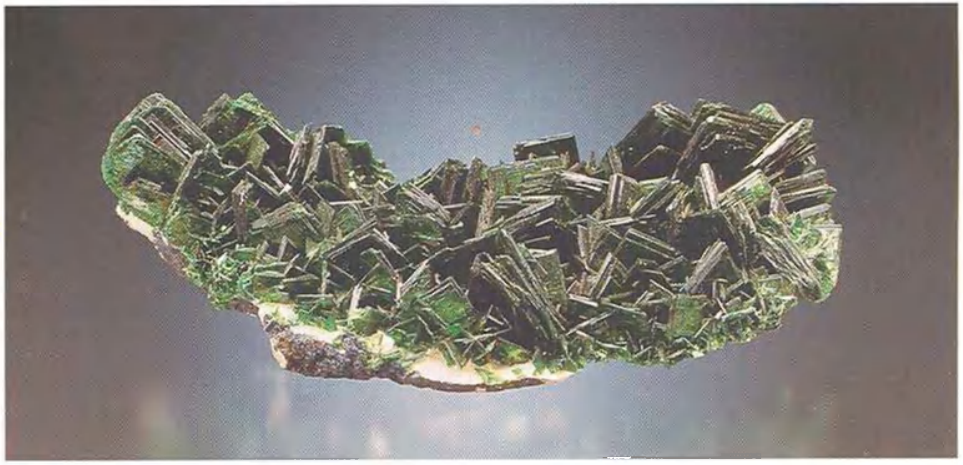

Autunite, 15 mm xx, Troncasa, Portugal

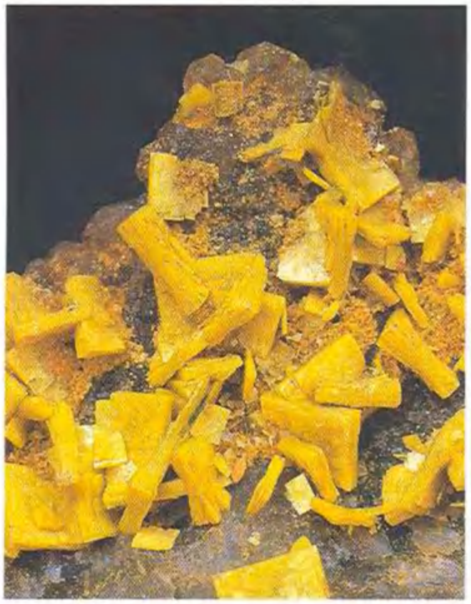

Novacekite, 70 mm, Brumado, Brazil

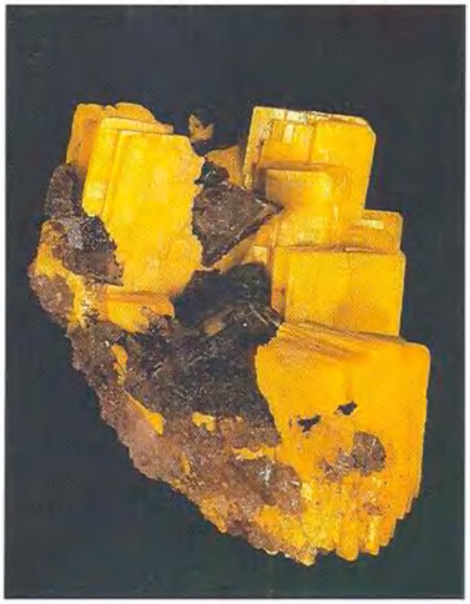

Autunite

$Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12\ H_2O$

TETRAGONAL ● ● ●

Properties: C – light to dark yellow, yellow-green to green; S – light yellow; L – vitreous to dull; D – transparent to translucent; DE – 3.1; H – 2-2.5; CL – perfect; F – uneven; M – tabular crystals, foliated, scaly, earthy and pulverulent aggregates, coatings, massive; LU – yellow-green; R – strongly radioactive.
Origin and occurrence: Secondary in the oxidation zone of U deposits, in pegmatites and in some U-rich sedimentary rocks, as a result of hydrothermal alteration of uraninite and other U minerals. It is frequently associated with torbernite and other U secondary minerals. Tabular crystals up to 30 mm ($1^{3}/_{16}$ in) across come from Schneeberg and Johanngeorgenstadt, Germany and Autun, France. It is also known from Rum Jungle, Northern Territory, Australia; St. Austel, Cornwall, UK; Mount Spokane, Washington, USA and Jachymov, Czech Republic.
Application: U ore.

Uranocircite

$Ba(UO_2)_2(PO_4)_2 \cdot 10\ H_2O$

TETRAGONAL ● ●

Properties: C – light to dark yellow, light yellow-green; S – light yellow; L – vitreous to dull, pearly on the cleavage planes; D – transparent to translu-

Uranocircite, 78 mm, Minas Gerais, Brazil

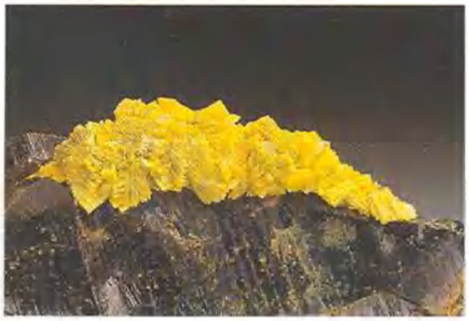

Zeunerite, 5 mm xx, Cinovec, Czech Republic

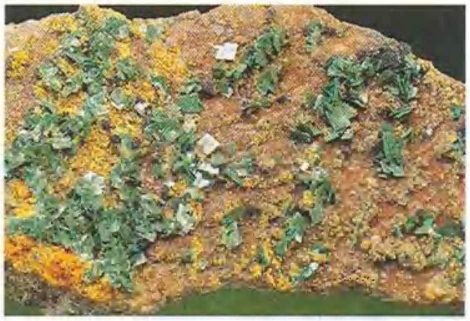

cent; DE – 3.5; H – 2-2.5; CL – perfect; F – uneven; M – tabular crystals, foliated and earthy aggregates, pulverulent coatings, massive; LU – green; R – strongly radioactive.
Origin and occurrence: Secondary in the oxidation zone of U deposits. Yellow tabular crystals up to 10 mm ($^{3}/_{8}$ in) across occurred in Dametice, Czech Republic; Bergen and Wolsendorf, Germany and in the Sao Pedro mine, Suaçui, Minas Gerais, Brazil.

Novácekite

$Mg(UO_2)_2(AsO_4)_2 \cdot 10\ H_2O$

TETRAGONAL ● ●

Properties: C – straw-yellow, light yellow; S – light yellow; L – vitreous to dull; D – transparent to translucent; DE – 3.7; H – 2.5; CL – perfect; F – uneven; M – tabular crystals, lamellar, earthy and pulverulent aggregates, massive; LU – dark green; R – strongly radioactive.
Origin and occurrence: Secondary in the oxidation zone of U deposits. Tabular crystals up to 50 mm (2 in) across come from the Pedra Preta Mine, Brumado, Bahia, Brazil. Lamellar aggregates are known from Zálesí, Czech Republic; Aldama, Chihuahua, Mexico; Wittichen, Germany.

Zeunerite

$Cu(UO_2)_2(AsO_4)_2 \cdot 10\text{-}16\ H_2O$

TETRAGONAL ● ●

Properties: C – emerald-green, yellow-green; S – light green; L – vitreous to dull; D – transparent to translucent; DE – 3.4; H – 2.5; CL – perfect; F – uneven; M – tabular crystals, foliated aggregates, massive; R – strongly radioactive.
Origin and occurrence: Secondary in the oxidation zone of U deposits. Tabular crystals up to 30 mm (1$^{3}/_{16}$ in) across, come from the Pedra Preta Mine, Brumado, BahRa, Brazil. It is also known from Zalesí, Czech Republic and Schneeberg, Germany.

Carnotite

$K_2(UO_2)_2(VO_4)_2 \cdot 3\ H_2O$

MONOCLINIC ● ● ●

Properties: C – light to dark yellow, yellow-green; S – light yellow; L – dull; D – transparent to translucent, opaque; DE – 4.9; H – not determined; CL – perfect; F – uneven; M – earthy aggregates, massive; R – strongly radioactive.
Origin and occurrence: Secondary in the oxidation zone of sedimentary U deposits, typically associated with tyuyamunite. Platy crystals, up to 2 mm ($^{1}/_{16}$ in) across found in the Mashamba West mine, Zaire. Earthy and pulverulent aggregates occur in many localities in the Colorado Plateau, e.g. Paradox Valley, Colorado and La Sal, Utah, USA. Also known from Tyuya Muyun, Uzbekistan and Radium Hill, Southern Australia, Australia.
Application: U and V ore..

Carnotite, 55 mm, Utah, U.S.A.

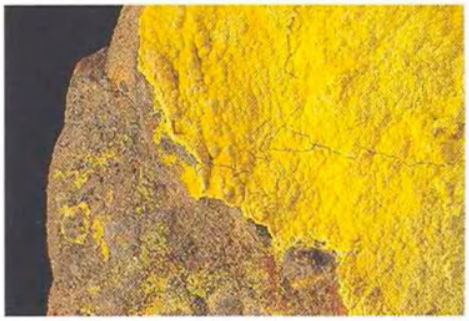

Tyuyamunite

$Ca(UO_2)_2(VO_4)_2 \cdot 5\text{-}8\ H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – yellow-green, canary yellow; S – light yellow; L – silky to adamantine; D – translucent to opaque; DE – 3.6; H – 2; CL – perfect; F – uneven; M – earthy aggregates, massive; LU – weak yellow-green; R – strongly radioactive.
Origin and occurrence: Secondary in the oxidation zone of sedimentary U deposits, together with carnotite. Common earthy and pulverulent aggregates occur in many localities in the Colorado Plateau, e.g. Paradox Valley, Colorado and Red Creek, Utah, USA. It was described from Tyuya Muyun, Uzbekistan.
Application: U and V ore.

Tyuyamunite, 80 mm, Fergana, Uzbekistan

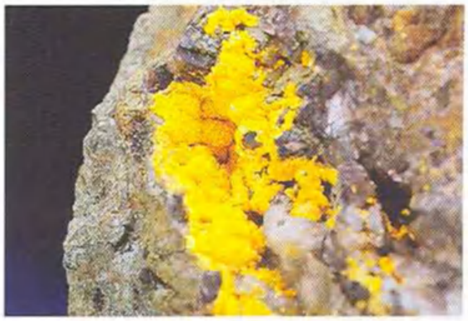

9. Silicates

Phenakite

Be_2SiO_4

TRIGONAL ● ● ●

Properties: C – colorless, white, yellowish; S – white; L – strong vitreous; D – transparent to translucent; DE – 3.0; H – 8; CL – imperfect; F – conchoidal; M – long prismatic to tabular crystals, radial aggregates, granular.
Origin and occurrence: Magmatic in granitic pegmatites; hydrothermal in greisens; metamorphic in mica schists, associated with beryl, chrysoberyl, apatite and quartz. Prismatic crystals up to 250 mm ($9^{13}/_{16}$ in) long occurred in Kragero, Norway. It is also known from Sao Miguel de Piracicaba, Minas Gerais, Brazil in crystals, up to 100 mm (4 in) long. The other localities are Habachtal, Austria; Malyshevo, Russia; Anjanabonoina, Madagascar.
Application: sporadically cut as a gemstone.

Phenakite. 200 mm. Kragero. Norway

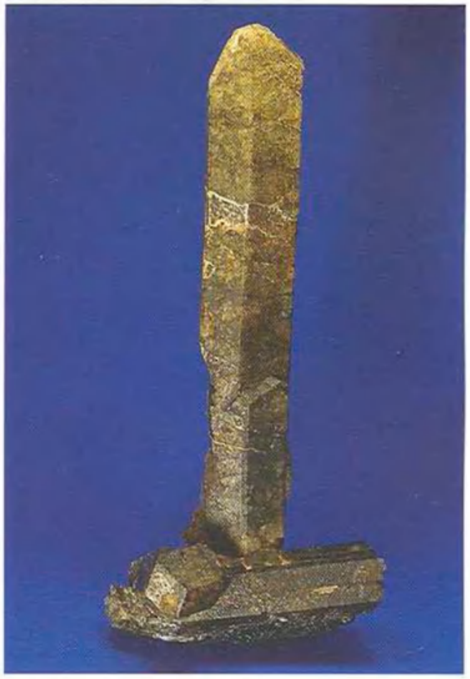

Willemite

Zn_2SiO_4

TRIGONAL ● ● ●

Properties: C – white, yellowish, gray, green; S – white; L – vitreous; D – translucent; DE – 4.0; H – 5.5; CL – good; F B conchoidal to uneven; M – prismatic to tabular crystals, radial aggregates, granular; LU – distinct light green.
Origin and occurrence: Metamorphic in marbles; secondary in the oxidation zone of ore deposits, associated with zincite, franklinite, hemimorphite and smithsonite. Crystals up to 100 mm (4 in) across come from Franklin, New Jersey, USA, Mont St.-Hilaire, Quebec, Canada.
Application: as Zn ore.

Topaz, 60 mm, Thomas Range, U.S.A.
Willemite, 76 mm, Tsumeb, Namibia

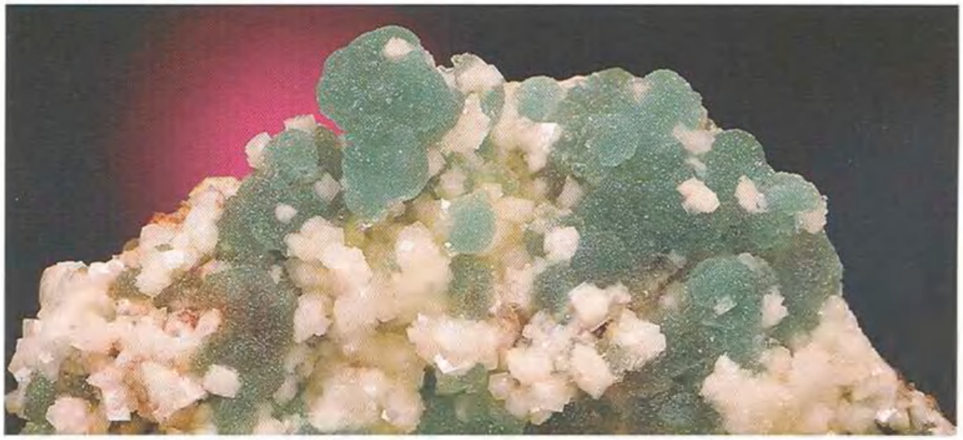

Forsterite, 40 mm, Suppat, Pakistan

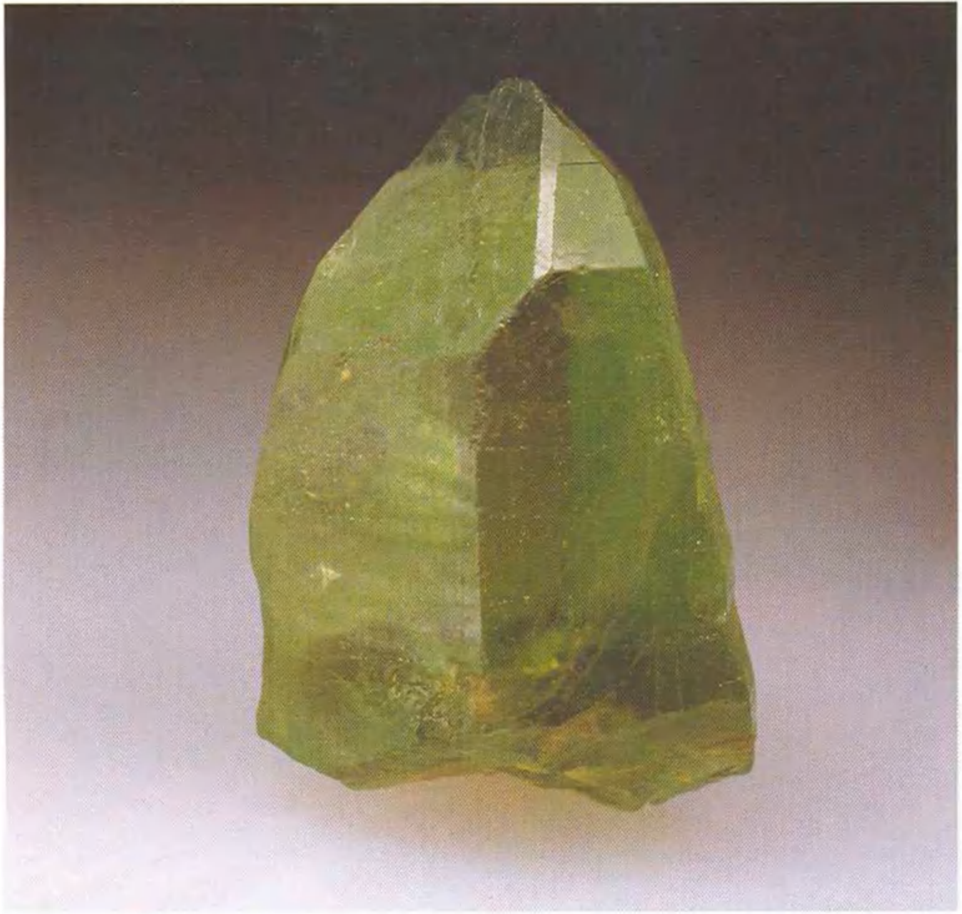

Forsterite

OLIVINE GROUP

Mg_2SiO_4

ORTHORHOMBIC ● ● ● ●

Properties: C – yellowish, greenish, colorless; S – white; L – vitreous; D – transparent to opaque; DE – 3.3; H – 6.5-7; CL – good; F – conchoidal to uneven; M – tabular to prismatic crystals, granular.
Origin and occurrence: Metamorphic in regionally and contact metamorphosed dolomites. Typical rock-forming mineral, associated with enstatite, spinel, phlogopite and chlorite. Green gemmy crystals up to 80 mm (3⅛ in) long come from Suppat, Pakistan. It also occurred in Crestmore, California, USA, Mount Timobly, British Columbia, Canada and Monte Somma, Italy.

Olivine

OLIVINE GROUP

$(Mg,Fe)_2SiO_4$

ORTHORHOMBIC ● ● ● ● ●

Varieties: chrysolite

Properties: C – green, yellow-green (chrysolite), brown-green to black-green; S – white; L – vitreous; D – translucent to opaque; DE – 3.3-3.6; H – 6.5-7; CL - good; F B conchoidal to uneven; M – imperfect crystals, granular.
Origin and occurrence: Magmatic in some ultrabasic rocks, e.g. dunites, lherzolites, peridotites, gabbros and in meteorites. Typical rock-forming mineral, usually associated with diopside, magnetite and pyrope. Classic locality of chrysolite is Zebirget Island in the Red Sea, Egypt, where tabular crystals

Olivine, 60 mm, Smrci, Czech Republic

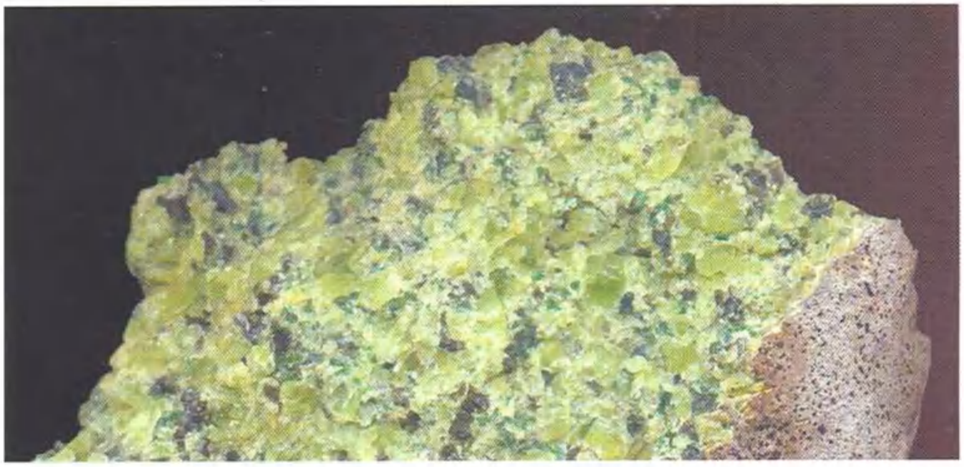

up to 100 mm (4 in) across occurred. It is also known from the San Carlos Indian Reservation, Arizona, USA. Olivine was found in many basaltic rocks in Laacher See, Germany; Rockport, Massachusetts, USA and elsewhere.
Application: chrysolite is cut as a gemstone.

Fayalite

OLIVINE GROUP

Fe_2SiO_4

ORTHORHOMBIC ● ● ●

Properties: C – black-green to black; S – gray; L – dull to vitreous; D – opaque; DE – 4.2; H – 6.5-7; CL – good; F B conchoidal to uneven; M – imperfect prismatic crystals, granular.
Origin and occurrence: Magmatic in granitic pegmatites, granites and syenites, associated with orthoclase, gadolinite-(Y) and epidote; rare metamorphic. Poorly developed crystals up to 150 mm (6 in) long found in pegmatites near Baveno, the Alps, Italy. It is also known from Strzegom, Poland and the Sawtooth Batholith, Idaho, USA.

Fayalite, 80 mm, Rockport, U.S.A.

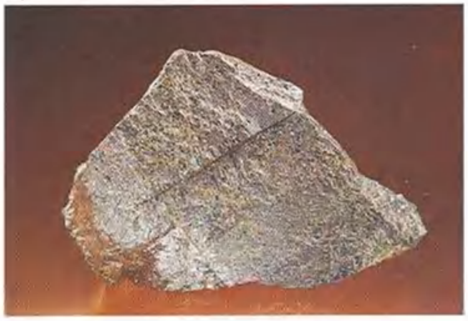

Tephroite

OLIVINE GROUP

Mn_2SiO_4

ORTHORHOMBIC ● ●

Properties: C – gray, olive-green, red-brown; S – white; L – dull to vitreous; D – translucent to transparent; DE – 4.2; H – 6; CL – good; F B conchoidal to uneven; M – prismatic crystals, granular.
Origin and occurrence: Metamorphic in skarns and Mn-rich metamorphosed sediments, together with rhodonite, franklinite and spessartine. Granular aggregates and perfect crystals up to 50 mm (2 in) across known from Franklin, New Jersey, USA; Langban, Sweden. It comes also from Tarnobrzeg, Poland, in crystals, up to 80 mm ($3\frac{1}{8}$ in) across.

Tephroite, 60 mm, Harstigen, Sweden

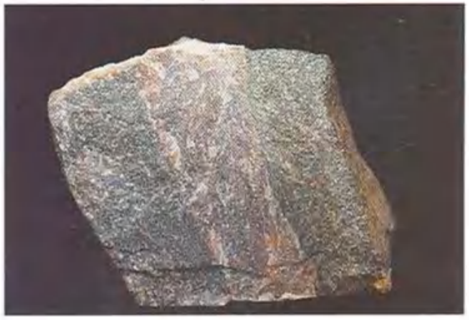

Pyrope, 3 mm grains, Trebivlice, Czech Republic

Pyrope

GARNET GROUP

$Mg_3Al_2Si_3O_{12}$

CUBIC ● ● ● ●

Properties: C – red to purple-red, light purple, black-brown; S – white; L – vitreous; D – transparent to translucent; DE – 3.5; H – 7-7.5; CL – none; F B conchoidal to uneven; M – isometric crystals, granular.

Origin and occurrence: Magmatic in some ultrabasic rocks, e.g. lherzolites, peridotites, kimberlites, eclogites and serpentinites; metamorphic in quartzites; also known from placers. It is associated with diopside, magnetite and diamond. It comes from many localities in ultrabasic rocks, like Trebenice and Mirunice, Czech Republic; Zoblitz, Germany; Madras, India; Kimberley, South Africa. Crystals up to 250 mm ($9^{13}/_{16}$ in) across were found in Dora Maria, the Alps, Italy.

Application: cut as a gemstone.

Almandine

GARNET GROUP

$Fe_3Al_2Si_3O_{12}$

CUBIC ● ● ● ●

Properties: C – red to purple-red, black-brown; S – white; L – vitreous; D – transparent to translucent; DE – 4.3; H – 7; CL – none; F B conchoidal to uneven; M B well-formed crystals, granular.

Origin and occurrence: Metamorphic in regionally metamorphosed rocks, as chlorite schists, gneisses,

Almandine, 38 mm x, Ötztal, Austria

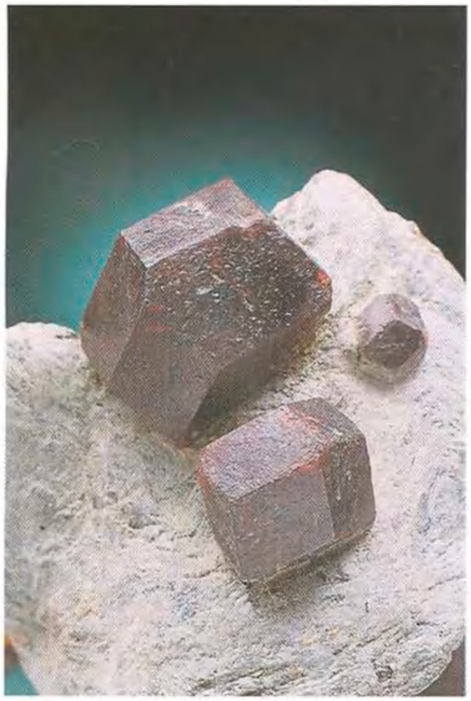

Spessartine, 96 mm, Gilgit, Pakistan

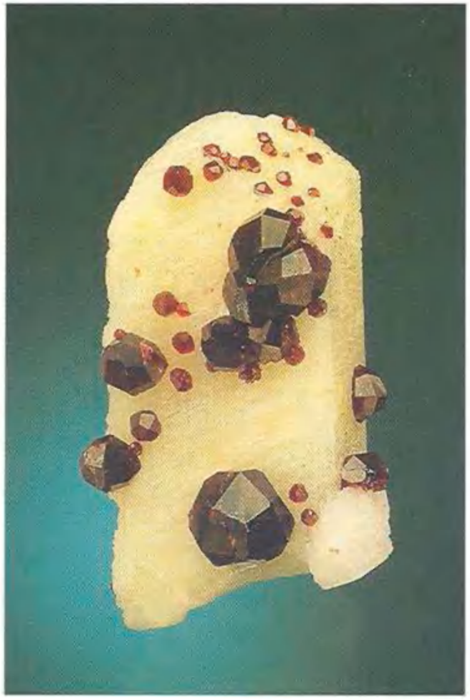

Grossular, 17 mm x, Asbestos, Canada

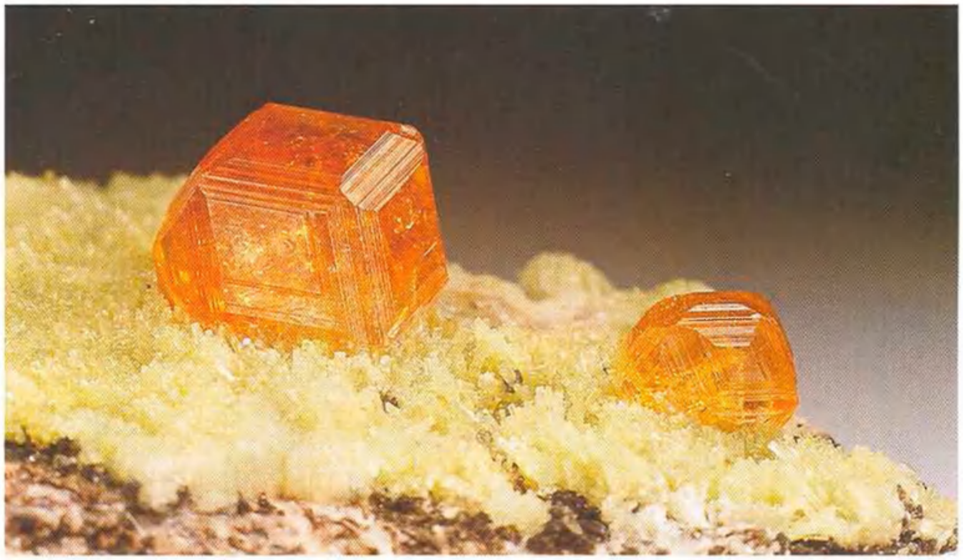

mica schists and migmatites; magmatic in some granites and pegmatites; also in placers. Well-developed crystals up to 150 mm (6 in) across are known from Ishikawa pegmatites, Japan and Shingus, Pakistan. It comes from many mica schists and gneisses as crystals, up to about 50 mm (2 in), like Fort Wrangel, Alaska, USA; Ötztal, Austria; Bodo, Norway. It occurs in placers near Ratnapura, Sri Lanka.
Application: cut as a gemstone, abrasive material.

Spessartine

GARNET GROUP

$Mn_3Al_2Si_3O_{12}$

CUBIC ● ● ● ●

Properties: C – red, orange, light brown to yellowish; S – white; L – vitreous; D – transparent to translucent; DE – 4.3; H – 7-7.5; CL – none; F B conchoidal to uneven; M – perfect crystals, granular.
Origin and occurrence: Magmatic in granitic pegmatites and some granites; hydrothermal in cavities in rhyolites; metamorphic in some skarns and Mn-rich metamorphic rocks. Perfect crystals up to 30 mm ($1^{3}/_{16}$ in) across were found in granitic pegmatites in the Hercules mine, Ramona, California, USA; near Marienfluss river, Namibia and in rhyolite cavities in Nathrop, Colorado, USA.
Gemmy crystal fragments up to 50 mm (2 in) across were recently found in an undisclosed locality in Minas Gerais, Brazil.
Application: cut as a gemstone.

Grossular

GARNET GROUP

$Ca_3Al_2Si_3O_{12}$

CUBIC ● ● ● ●

Varieties: hessonite, tsavorite

Properties: C – red, green (tsavorite), orange, red-brown (hessonite) to colorless; S – white; L – vitreous; D – transparent to tranlucent; DE – 3.4; H – 6.5-7; CL – none; F B conchoidal to uneven; M – perfect crystals, granular.
Origin and occurrence: Metamorphic in Ca-rich, contact metamorphic rocks, skarns, rodingites; hydrothermal along the cracks in these rocks, associated with diopside, vesuvianite, wollastonite, scapolite and epidote. Perfect crystals about 30 mm ($1^{3}/_{16}$ in) across occur in the Jeffrey quarry, Asbestos, Quebec, Canada and Sierra de las Cruces, Coahuila, Mexico.
Tsavorite crystals up to 50 mm (2 in) across come from the Tsavo National Park, Kenya and Merelani Hills, Arusha, Tanzania. The other well-known localities are Ala, Italy and Ciclova, Romania. Grossular crystals up to 100 mm (4 in) in size in Vapenna, Czech Republic; Xalostoc, Mexico and Sandare, Mali.
Application: cut as a gemstone.

Andradite, 30 mm xx, Graham Co., U.S.A.

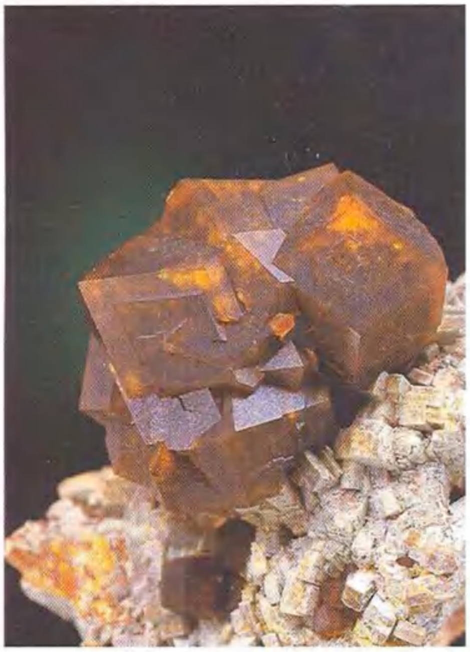

Andradite

GARNET GROUP

$Ca_3Fe^{3+}{}_2Si_3O_{12}$

CUBIC ● ● ● ●

Varieties: demantoid, melanite

Properties: C – dark red, black-brown, brown, green to yellow-green (demantoid), black-brown to black (melanite); S – white; L – vitreous; D – transparent to translucent; DE – 3.9; H – 6.5-7; CL – none; F B conchoidal to uneven; M B well-developed crystals, granular.
Origin and occurrence: Metamorphic in Ca and Fe rich contact metamorphosed rocks, skarns, rodingites; hydrothermal along the cracks of these rocks; magmatic in some alkaline igneous rocks, usually in the same localities as grossular. Crystals up to 40 mm (1$\frac{9}{16}$ in) across come from Sinerechenskoye, Russia. Fine crystals were also found in the Namgar mine, Usakos, Namibia and Ciclova, Romania. Fine melanite crystals occur in Magnet Cove, Arkansas, USA. Demantoid crystals up to 30 mm (1$\frac{3}{16}$ in) across known from Val Malenco, Italy and in the Bobrovka river basin, Ural mountains, Russia.
Application: demantoid is cut as a gemstone.

Demantoid, 3 mm xx, Bobrovka, Russia

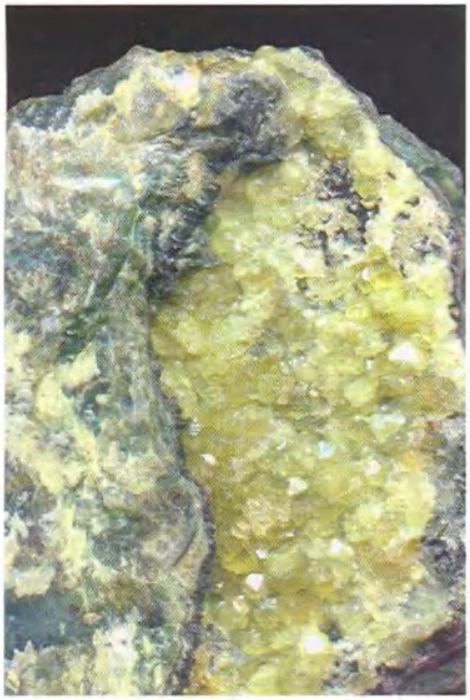

Melanite, 5 mm xx, Rudnyi, Kazakhstan

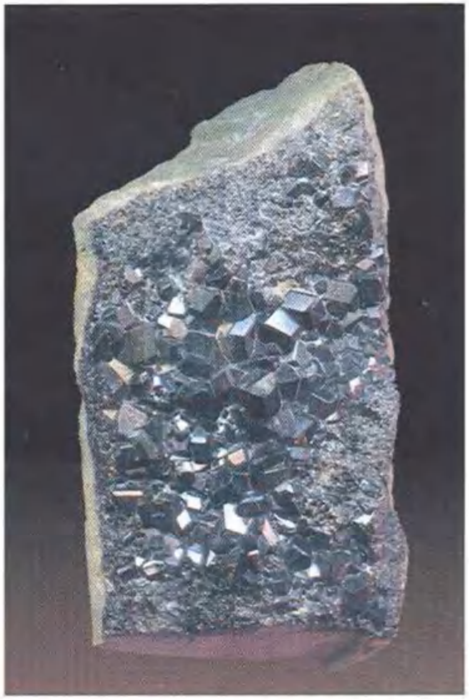

Uvarovite, 2 mm xx, Sarany, Russia

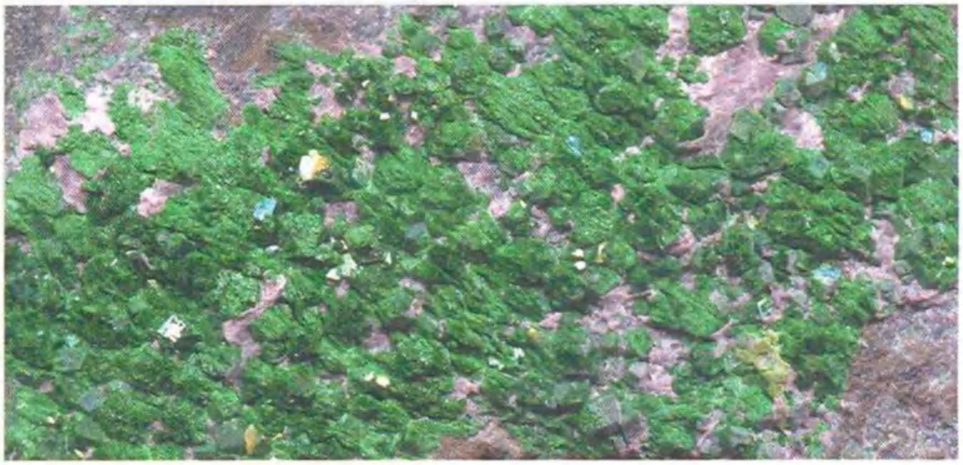

Uvarovite

GARNET GROUP

$Ca_3Cr_2Si_3O_{12}$

CUBIC ● ●

Properties: C – dark emerald-green; S – white; L – vitreous; D – transparent to translucent; DE – 3.9; H – 6.5-7; CL – none; F B conchoidal to uneven; M – perfect crystals, granular.

Origin and occurrence: Metamorphic and also hydrothermal are almost only limited to rocks with increased Cr content, ultrabasic rocks with chromite, serpentinites and skarns. It occurs as crystals up to 8 mm (5/16 in) across along cracks in chromite in Sarany, Ural mountains, Russia. Crystals up to 20 mm (25/32 in) across, come from Outokumpu, Finland. It is also known from Orford, Quebec, Canada.

Zircon

$ZrSiO_4$

TETRAGONAL ● ● ●

Varieties: jargon, hyacinth.

Properties: C – yellow (jargon), brown, yellow-brown, red-orange (hyacinth), red to colorless; S – white; L – vitreous, greasy to adamantine; D – transparent to translucent; DE – 4.7; H – 7.5; CL – imperfect; F B conchoidal to uneven; M – perfect long and short prismatic crystals, granular; LU – yellow; R B sometimes radioactive and usually metamict.

Origin and occurrence: Magmatic and metamorphic as an accessory mineral in different rock types; rarely hydrothermal in the Alpine-type and quartz veins; also in sediments and placers. Prismatic crystals up to 30 cm (12 in) across, occur in syenite pegmatites in Renfrew and Bancroft, Ontario, Canada. It is also known from Miass, Ural mountains and from Mount Vavnbed, Lovozero massif, Kola Peninsula, Russia. Classic occurrences in granitic pegmatites are Alto Ligonha, Mozambique; Arendal, Norway; Ytterby, Sweden and Jaguaraçu, Minas Gerais, Brazil. Gemmy zircons of different colors up to 80 mm (3 1/8 in) in size come from placers near Ratnapura, Sri Lanka and elsewhere.

Application: hyacinth and jargon are cut as gemstones, Zr ore.

Zircon, 20 mm x, Vishnevogorsk, Ural Mts., Russia

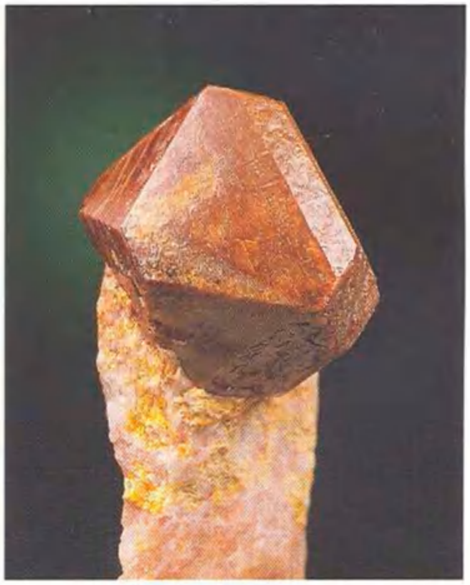

Eulytite, 2 mm xx, Schneeberg, Germany

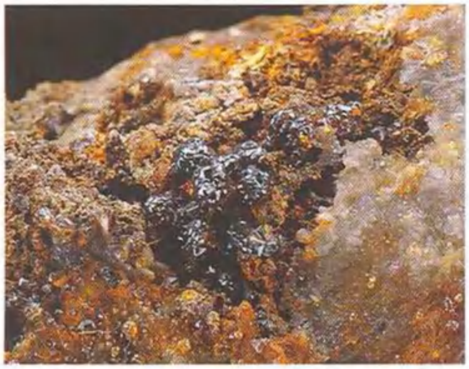

Sillimanite, 10 mm grains, Havlíčkův Brod, Czech Republic

Eulytine

$Bi_4Si_3O_{12}$

CUBIC ● ●

Properties: C – brown, yellow, gray, colorless; S – white; L – greasy; D – translucent; DE – 6.6; H – 4.5; CL – good; F B conchoidal to uneven; M – small dipyramidal crystals, radial aggregates, granular.
Origin and occurrence: Secondary in Bi deposits, typically associated with bismuth.
Its small crystals come from Horní Slavkov, Czech Republic; Schneeberg and Johanngeorgenstadt, Germany.

Euclase

$BeAlSiO_4(OH)$

MONOCLINIC ● ●

Properties: C – colorless, white, greenish, blue; S – white; L – vitreous; D – transparent to translucent; DE – 3.1; H – 7.5; CL – good; F B conchoidal to

Euclase, 42 mm, Minas Novas, Brazil

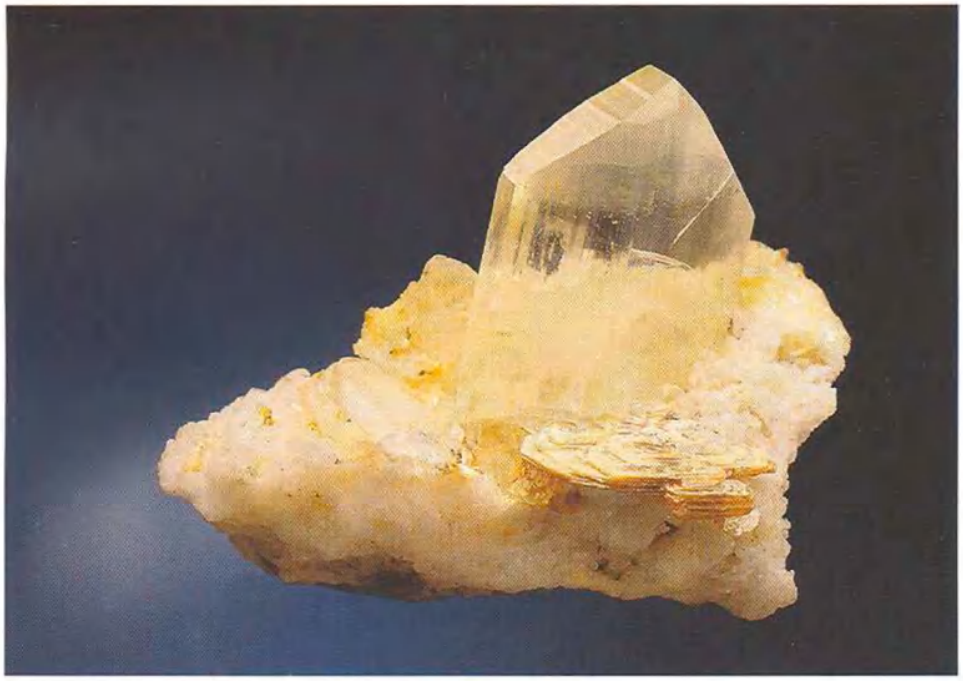

uneven; M – long prismatic crystals, radial aggregates, granular.
Origin and occurrence: Hydrothermal occurs in pegmatites, greisens and in quartz and Alpine-type veins; rare in placers. Well-formed crystals up to 80 mm (3$^{1}/_{8}$ in) in size known from Santa do Encoberto, Minas Gerais, Brazil. Blue crystals up to 50 mm (2 in) across occurred in the Last Hope Mine, Karoi, Zimbabwe. It also come from the sediments of Sanarka River, Ural mountains, Russia. Dark blue crystals up to 150 mm (6 in) across were found recently in the Chivor Mine, Colombia.
Application: locally cut as a gemstone.

Sillimanite

Al_2SiO_5

ORTHORHOMBIC ● ● ● ● ●

Properties: C – white, gray, greenish, yellowish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.3; H – 6.5-7.5; CL – good; F – uneven; M – long prismatic crystals, fibrous aggregates, granular.
Origin and occurrence: Almost exclusively metamorphic in gneisses and migmatites; only rare magmatic in pegmatites and granites; also in placers. Typical rock-forming mineral, very commonly associated with andalusite. Typical localities are Bodenmais, Germany and Mar_íkov, Czech Republic. Gemmy crystals up to 20 mm ($^{25}/_{32}$ in) long are known from Rakwana-Deniyaya, Sri Lanka.

Andalusite

Al_2SiO_5

ORTHORHOMBIC ● ● ● ●

Varieties: chiastolite, viridine

Properties: C – pink, red-brown, red, gray, whitish, green (viridine); S- white; L – vitreous to dull; D – translucent to transparent; DE – 3.2; H – 6.5-7.5; CL – good; F – uneven; M – prismatic crystals, fibrous aggregates, granular, massive.
Origin and occurrence: Metamorphic in regionally and contact metamorphosed rocks; magmatic in pegmatites and granites, hydrothermal in quartzites. Typical rock-forming mineral, commonly associated with sillimanite, corundum and cordierite. Renowned localities are Lisens, the Alps, Austria; Bimbowrie, South Australia, Australia. Green gemmy crystals come from Morro do Chapeu, Bahia, Brazil. Viridine is known from Darmstadt, Germany.

Andalusite, 28 mm x, Aracuay, Minas Gerais, Brazil

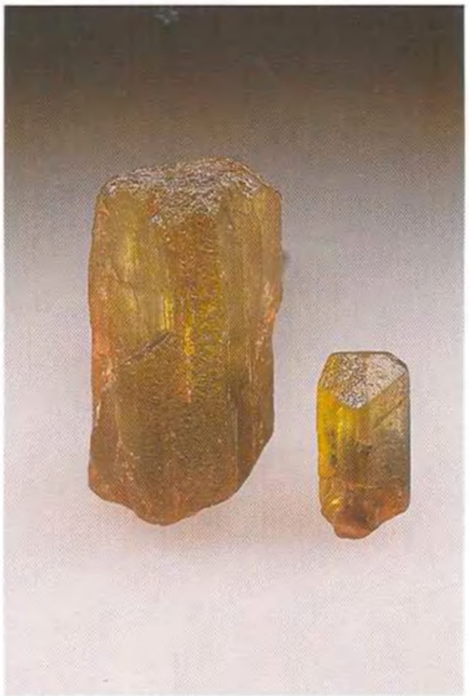

Chiastolith, 20 mm, Bimbowrie, Australia

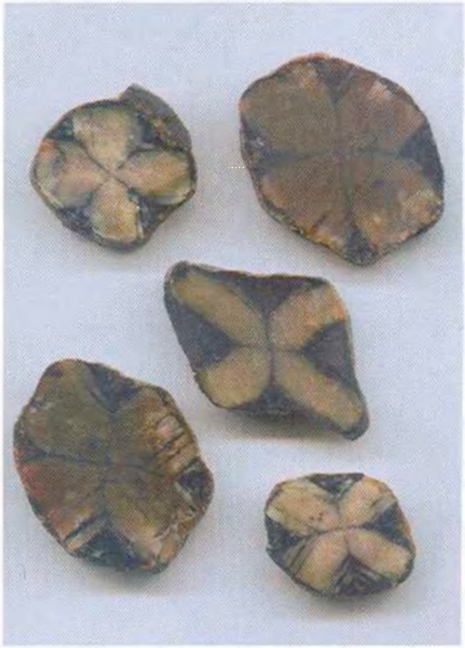

Kyanite

Al_2SiO_5

TRICLINIC ● ● ● ●

Properties: C – blue, gray, white, green, dark gray, colorless; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.6; H – 4.5-7.5; CL – good; F – uneven; M – prismatic to tabular crystals, fibrous aggregates, granular, massive.

Origin and occurrence: Almost only metamorphic in regionally metamorphosed rocks, mica schists, gneisses, granulites and eclogites; less frequently magmatic in pegmatites and granites; rarely hydrothermal in quartz veins. Typical rock-forming mineral, associated with andalusite and sillimanite. Blue columnar aggregates and crystals up to 150 mm (6 in) long occur in Barra do Salinas, Minas Gerais, Brazil. Other renowned localities are Pizzo Forno, Switzerland; Prilep, Macedonia; Keivy, Kola Peninsula, Russia.

Kyanite, 87 mm, Minas Gerais, Brazil

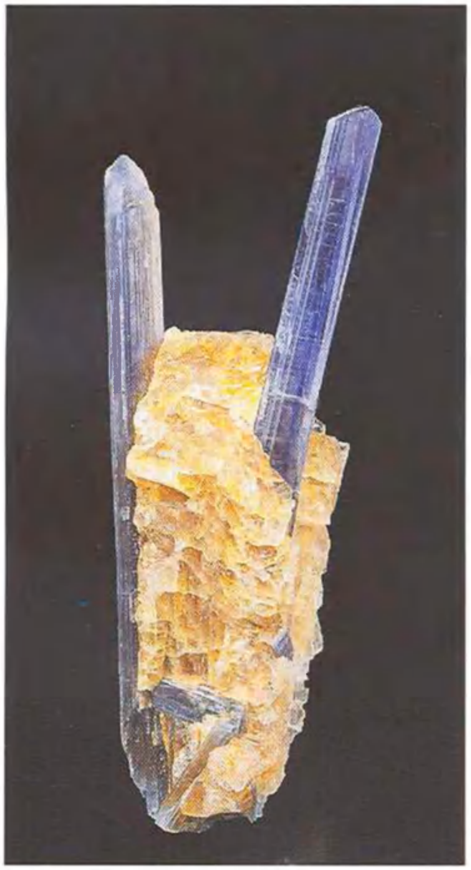

Topaz, 18 mm xx, Ghundao Hill, Pakistan

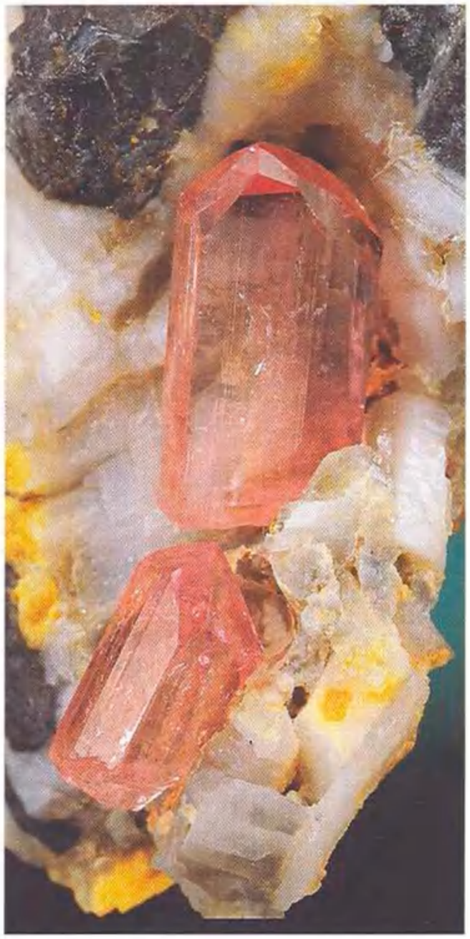

Topaz

$Al_2SiO_4(F,OH)$

ORTHORHOMBIC ● ● ●

Varieties: pycnite

Properties: C – colorless, blue, yellow, gray, white, greenish, pinkish, red; S – white; L – vitreous; D – transparent to translucent; DE – 3.6; H- 8; CL – good; F – uneven; M – perfect prismatic to tabular crystals, radial and columnar aggregates, granular.

Origin and occurrence: Magmatic in pegmatites and granites; hydrothermal in greisens, in rhyolite cavities, in quartz veins, also in placers. Topaz crystals in pegmatites are occasionally very large, like the crystal measuring 80 x 60 x 60 cm (31½ x 24 x 24 in) across from Fazenda do Funil; crystals

Topaz, 49 mm, Ramona, U.S.A.

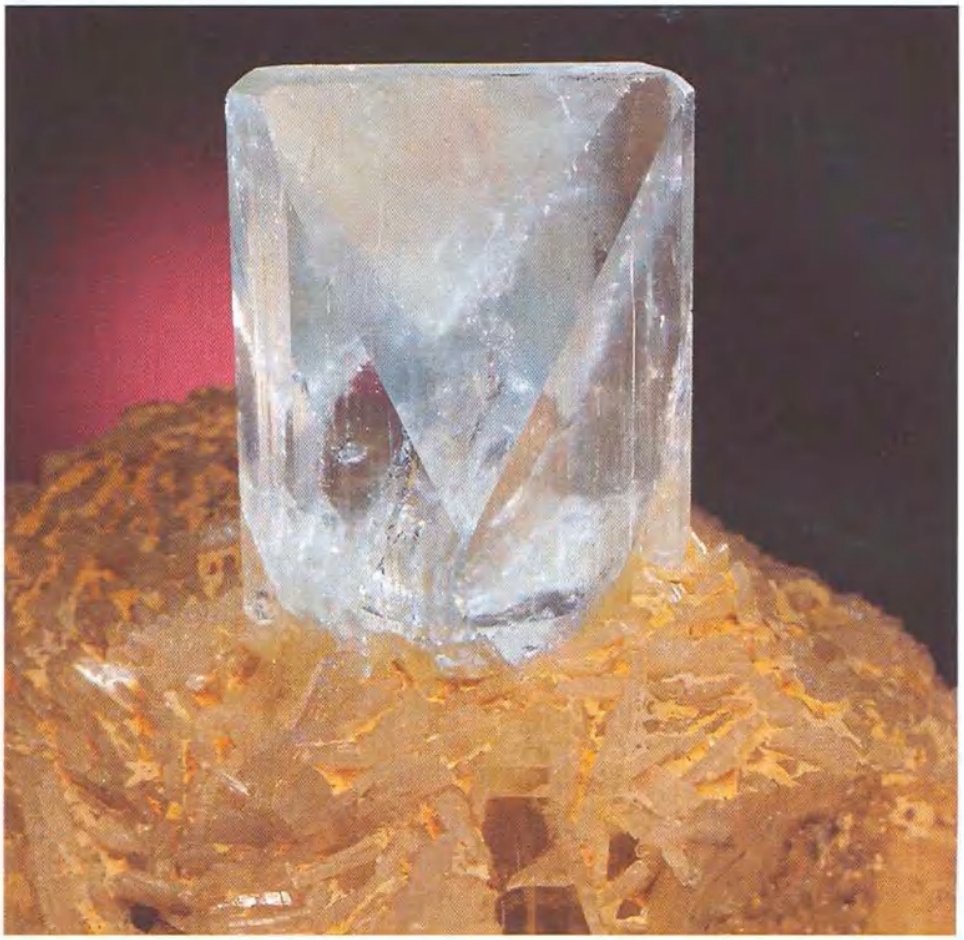

up to 30 cm (12 in) from Virgem da Lapa, both Minas Gerais, Brazil. Blue, brownish and bicolored crystals up to 40 cm (15¾ in) long come from Volodarsk Volynskii, Ukraine. Other topaz localities are Iveland, Norway; Murzinka, Ural mountains, Russia; Little Three mine, Ramona, California; Pikes Peak, Colorado, USA; Gilgit, Pakistan; Spitzkopje, Namibia. Orange to red topaz (imperial topaz) comes from quartz veins near Ouro Preto, Minas Gerais, Brazil. Pink topaz crystals up to 70 mm (2¾ in) found at Mount Ghundao, Mardan, Pakistan. Important topaz specimens were also found in Schneckenstein, Germany; Thomas Range, Utah, USA; Nerchinsk, Siberia, Russia. Columnar aggregates of pycnite come from Cínovec, Czech Republic and Altenberg, Germany. *Application:* cut as a gemstone.

Pycnite, 60 mm, Cínovec, Czech Republic

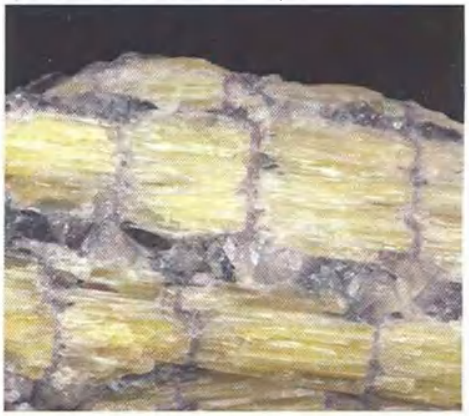

Staurolite, 80 mm, Keivy, Kola, Russia

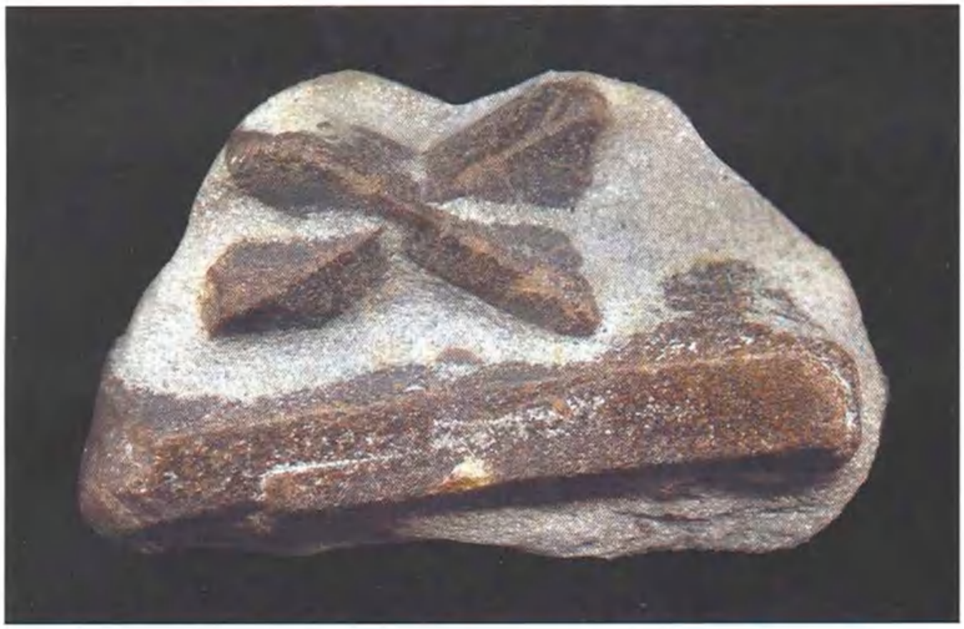

Staurolite

$Fe_2Al_9Si_4O_{22}(OH)_2$

ORTHORHOMBIC ● ● ● ●

Properties: C – dark to light brown, yellow; S – white; L – dull to vitreous; D – transparent to almost opaque; DE – 3.7; H – 7-7.5; CL – good; F – uneven; M – prismatic to tabular crystals and their combinations, granular.
Origin and occurrence: Metamorphic in regionally metamorphosed rocks, gneisses and mica schists; rare magmatic in granites; also in placers, commonly associated with almandine, andalusite and kyanite. Crystals up to 50 mm (2 in) across come from Pizzo Forno, Switzerland. It is also known from Rio Arriba, New Mexico, USA. Its cross-like twins, up to 200 mm ($7^7/_8$ in) across, occur in Keivy, Kola Peninsula, Russia and Morbihan, France.

Sapphirine, 26 mm, Vohimena, Madagascar

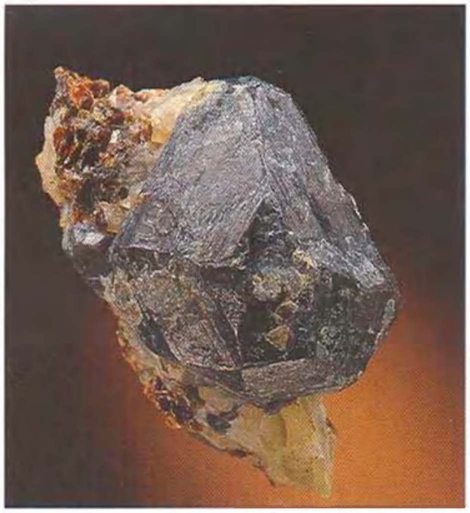

Sapphirine

$Mg_2Al_4SiO_{10}$

MONOCLINIC ● ●

Properties: C – dark to light blue, green; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.5; H – 7.5; CL – imperfect; F – uneven; M – tabular crystals, granular.
Origin and occurrence: Metamorphic in regionally metamorphosed rocks, rich in Al and Mg and poor in Si, associated with spinel and corundum. Crystals up to 40 mm ($1^9/_{16}$ in) across come from Fiskenaesset, Greenland; Betroka and Androy, Madagascar. Other localities include Val Codera, Italy and Enderby Land, Antarctica.

Chondrodite, 15 mm x, Brewster, U.S.A.

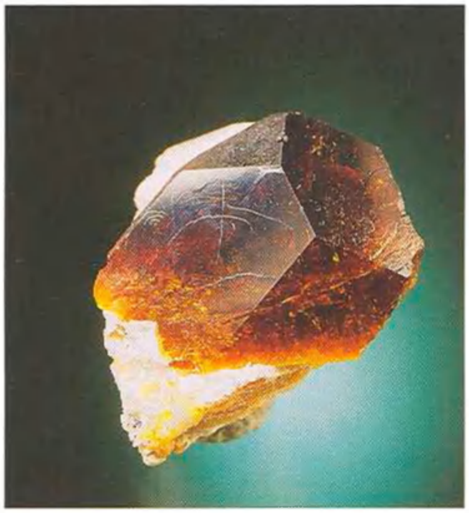

Chondrodite

$Mg_5Si_2O_8(OH,F)_2$

MONOCLINIC ● ● ●

Properties: C – yellow, greenish, brown; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.2; H – 6-6.5; CL – imperfect; F – uneven; M – crystals of different habits, granular.
Origin and occurrence: Metamorphic in contact and regionally metamorphosed carbonate rocks; rare magmatic in carbonatites, typically associated with spinel, chlorite and phlogopite. Perfect crystals up to 50 mm (2 in) long come from the Tilly Foster mine, Brewster, New York, USA. Other localities are Pargas, Finland; Monte Somma, Italy; Riverside, California, USA.

Clinohumite

$Mg_9Si_4O_{16}(OH,F)_2$

MONOCLINIC ● ● ●

Properties: C – yellow, red, brown, white; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.3; H – 6; CL – imperfect; F – uneven; M – crystals of different habits, granular.
Origin and occurrence: Metamorphic in contact and regionally metamorphosed carbonate rocks, serpentinites and talc schists, associated with spinel, chlorite, forsterite, serpentine and phlogopite. Gemmy yellow crystals up to 30 mm ($1^3/_{16}$ in) across come from Kukh-i-Lal, Pamir, Tajikistan. Other localities are Pargas, Finland; Monte Somma, Italy; Jensen quarry, California, USA.

Clinohumite, 19 mm, Kukh-i-lal, Tadzhikistan

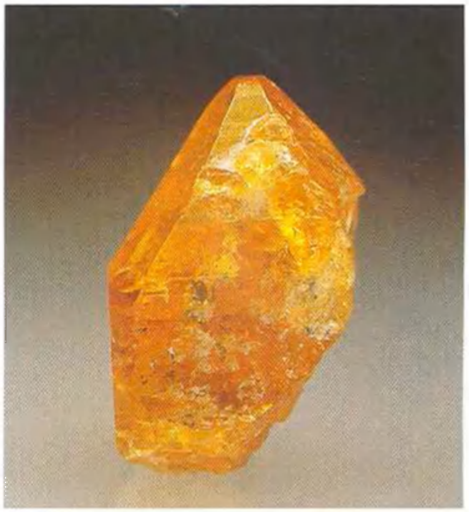

Chapmanite

$SbFe^{3+}{}_2Si_2O_8(OH)$

MONOCLINIC ● ●

Properties: C – olive-green to dark yellow; S – yellowish to yellow; L -dull; D – translucent; DE – 3.7; H – 2.5; CL – imperfect; F – uneven; M – elongated crystals, massive.
Origin and occurrence: Hydrothermal and secondary in the cracks of rocks, sometimes with stibnite. Its massive aggregates occur in Smilkov near Votice, Czech Republic; in the Keely mine, Cobalt, Ontario, Canada.

Chapmanite, 4 mm, Pernek, Slovakia

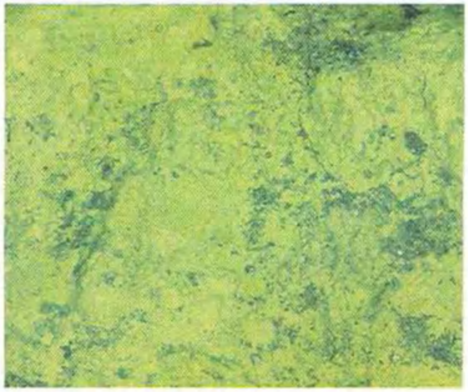

Braunite, 60 mm, Langban, Sweden

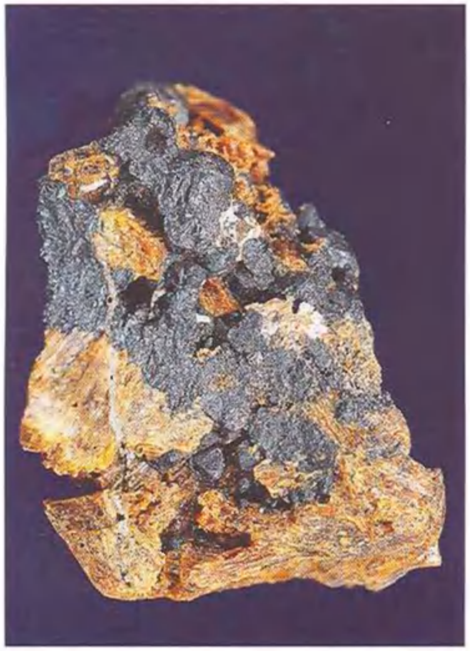

Braunite

$Mn^{2+}Mn^{3+}_6SiO_{12}$

TETRAGONAL ● ● ●

Properties: C – black, black-gray, black-brown; S – gray; L – submetallic to metallic; D – opaque; DE – 4.7; H – 6-6.5; CL – perfect; F – uneven to conchoidal; M – dipyramidal crystals, granular.
Origin and occurrence: Metamorphic in regionally and contact metamorphosed rocks; hydrothermal in sedimentary rocks rich in Mn and in hydrothermal veins, associated with hausmanite, pyrolusite and other Mn minerals. Its perfect crystals up to 70 mm (2¾ in) long, come from Kacharhavee and Tirodi, India. It is also known from Langban, Sweden; Ilfeld and Ilmenau, Germany; St. Marcel, Italy; Tizi Bashkun, Morocco.
Application: Mn ore.

Thaumasite

$Ca_6Si_2(CO_3)_2(SO_4)_2(OH)_{12} \cdot 24\ H_2O$

HEXAGONAL ● ●

Properties: C – white to colorless; S – white; L – vitreous to dull; D – transparent to translucent; DE – 1.9; H – 3.5; CL – imperfect; F – uneven; M B acicular aggregates, granular, massive; LU – white.
Origin and occurrence: Hydrothermal or metamorphic in contact metamorphosed carbonate rocks, usually associated with other Ca silicates and carbonates, like ettringite and prehnite. Typical localities are Crestmore, California; West Paterson, New Jersey, USA; Langban, Sweden; N'Chwaning mine No. 2, Kuruman, South Africa.

Titanite

$CaTiOSiO_4$

MONOCLINIC ● ● ● ●

Properties: C – colorless, yellow, brown, green, gray to black; S – white; L – vitreous to dull; D – transparent, translucent to opaque; DE – 3.5; H – 5-5.5; CL – good; F – uneven to conchoidal; M – tabular crystals and their combinations, granular, massive.
Origin and occurrence: Metamorphic and magmatic as a common accessory mineral in many igneous and

Thaumasite, 3 mm aggregate, Maglovec, Slovakia

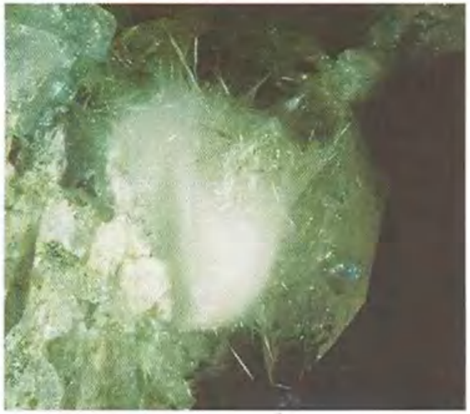

Fersmanite, 10 mm x, Khibiny Massif, Kola, Russia

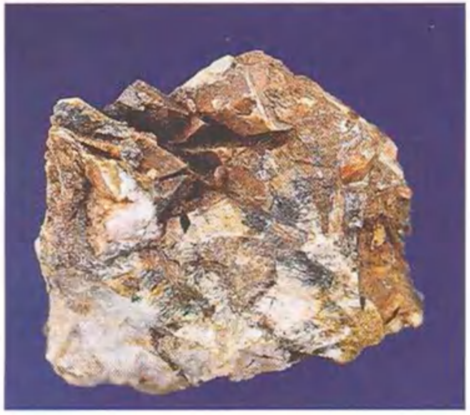

Titanite, 20 mm xx, Stubachtal, Austria

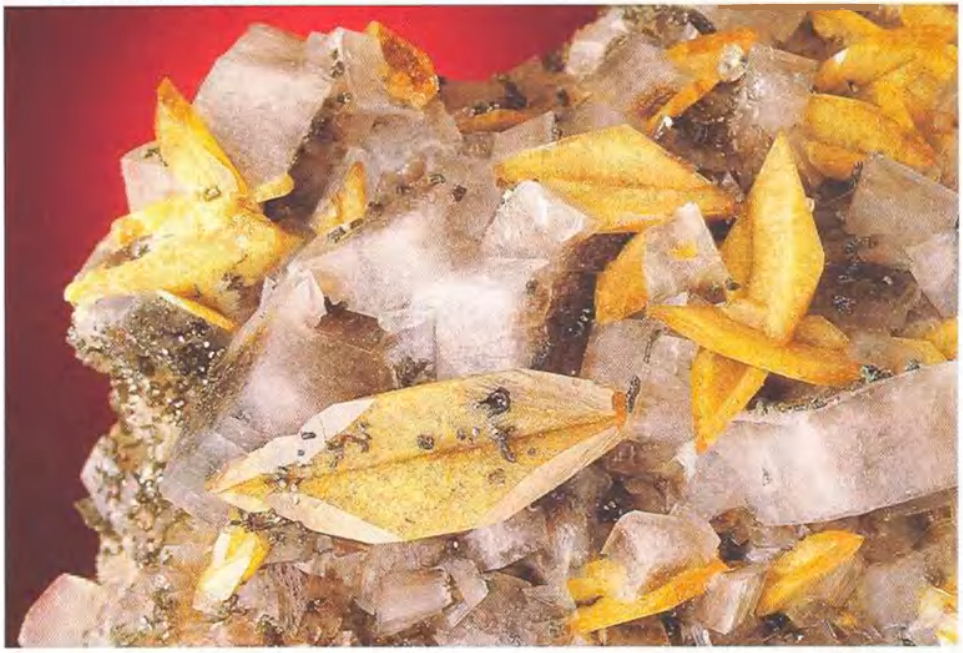

metamorphic rocks and pegmatites; hydrothermal in the Alpine-type veins; also in placers.
The most beautiful crystals up to 180 mm ($7^{1}/_{16}$ in) long occur in Alpine-type veins in Tavetsch and Binntal, Switzerland; Zillertal and Felbertal, Austria; Dodo, Polar Ural, Russia. Large, poorly developed crystals weighing up to 40 kg (88 lb), come from Eganville, Ontario, Canada and Rossie, New York, USA.

Chloritoid, 30 mm, Ile de Croix, France

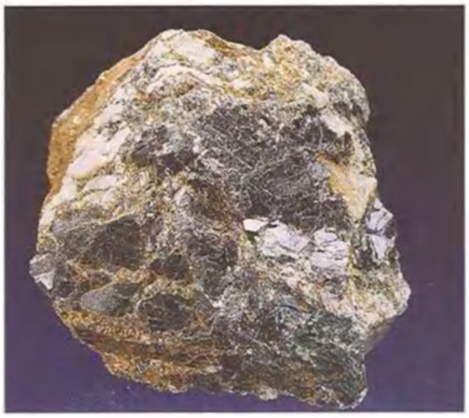

Fersmanite

$(Na,Ca)_4(Ti,Nb)_2Si_2O_{11}(OH,F)_2$

TRICLINIC ● ●

Properties: C – light to dark brown; S -white; L – vitreous to dull; D – translucent; DE – 3.5; H – 5-5.5; CL – none; F – uneven to conchoidal; M – tabular crystals.
Origin and occurrence: Magmatic to hydrothermal in alkaline pegmatites together with pectolite, apatite and sulfides. Crystals up to 30 mm ($1^{3}/_{16}$ in) across known from Mount Eveslogchorr, Khibiny massif, Kola Peninsula, Russia.

Chloritoid

$Fe_2Al_4Si_2O_{10}(OH)_2$

MONOCLINIC, TRICLINIC ● ● ●

Properties: C – dark gray, gray-green to black-green; S – gray; L – vitreous to dull; D – translucent; DE – 3.6; H – 6.5; CL – perfect; F – uneven to conchoidal; M – tabular crystals, foliated and scaly aggregates, granular.
Origin and occurrence: Metamorphic in some mica schists and phyllites; hydrothermal alteration product in lavas. Typical localities are Zermatt, Switzerland; Ottrez, Belgium; Pregraten, Austria.

Datolite, 30 mm xx, Dalnegorsk, Russia

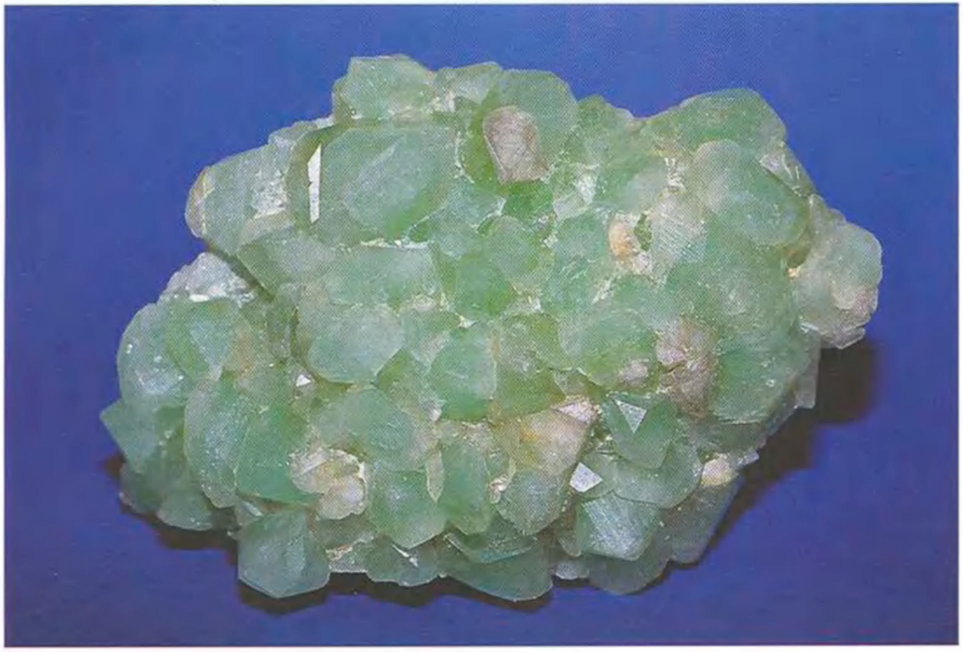

Datolite

$CaBSiO_4(OH)$

MONOCLINIC ● ● ●

Properties: C – white to colorless, yellowish, greenish, gray; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.1; H – 5-5.5; CL – none; F – uneven to conchoidal; M – prismatic to tabular crystals, nodules, granular.
Origin and occurrence: Metamorphic and hydrothermal in contact metamorphosed rocks, in cavities in volcanic rocks, in ore veins and pegmatites. It is commonly associated with zeolites, prehnite, calcite and also with tourmaline. Prismatic and tabular crystals up to 100 mm (4 in) long occur in Dalnegorsk, Russia. Other typical localities are West Paterson, New Jersey; Keweenaw Peninsula, Michigan, USA; Haslach, Germany; Charcas, San Luis Potosi, Mexico.

Gadolinite-(Y)

$Y_2FeBe_2Si_2O_{10}$

MONOCLINIC ● ●

Properties: C – black, dark red, brown, greenish; S – gray-green; L – vitreous to greasy, D – transparent to translucent; DE – 4.4; H – 6.5-7; CL – none; F –

Gadolinite-(Y), 60 mm, Hitterö, Norway

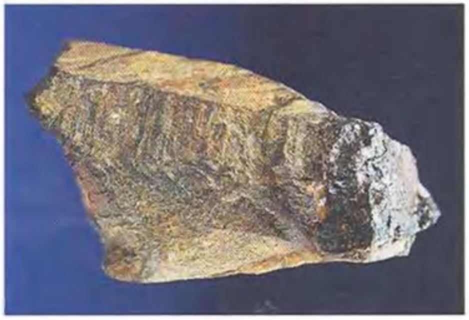

Howlite, 30 mm, California, U.S.A.

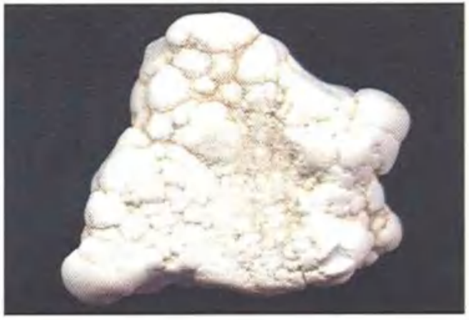

Dumortierite, 60 mm, Dehesa, U.S.A.

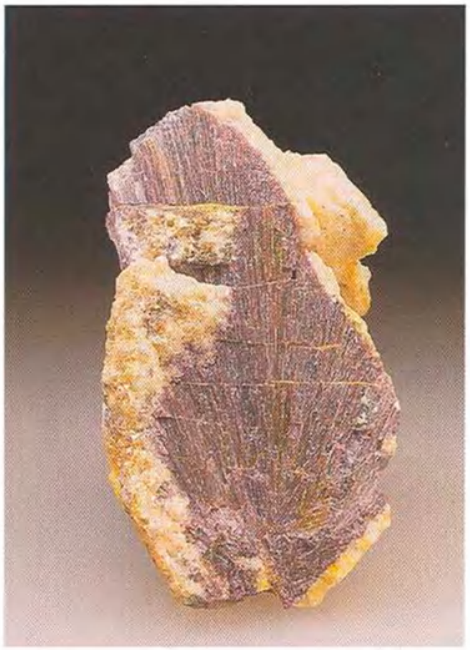

conchoidal; M – prismatic crystals, granular; R – locally metamict.
Origin and occurrence: Magmatic in granites and pegmatites, locally associated with fluorite and allanite; rare hydrothermal in the Alpine-type veins. Aggregates, up to 40 cm (15¾ in) across come from Hittero, Norway. Barringer Hill and Clear Creek, Texas, USA yielded aggregates, weighing up to 90 kg (198 lb). Other famous localities are Blatchford Lake, Northwest Territories, Canada; Baveno, the Alps, Italy; Iveland, Evje, Norway.

Kornerupine

$Mg_4Al_6(Si,Al,B)_5O_{21}(OH)$

ORTHORHOMBIC ● ●

Properties: C – colorless, white, greenish, gray, brown; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.3; H – 6.5-7; CL – none; F – conchoidal; M – prismatic crystals, radial aggregates, granular.
Origin and occurrence: Metamorphic in strongly metamorphosed rocks, as granulites. Crystals up to 230 mm ($9^{1}/_{16}$ in) across known from Fiskenaesset, Greensland. It also occurs in Lac Ste-Marie, Quebec, Canada; Waldheim, Germany; Itrongay, Madagascar.

Dumortierite

$(Al,Ti,Mg)Al_6BSi_3O_{16}(O,OH)_2$

ORTHORHOMBIC ● ● ●

Properties: C – purple, pink, blue, brown; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.4; H – 8.5; CL – good; F – uneven; M – prismatic crystals, radial and acicular aggregates, massive.
Origin and occurrence: Metamorphic in some Al-rich metamorphic rocks, e.g. in migmatites and gneisses; magmatic in granites and pegmatites; hydrothermal in altered rocks. It comes from Dehesa, California; Rochester, Nevada, USA; Beaunan, France; crystals are known from the vicinity of Kutna Hora, Czech Republic; Soavina, Madagascar.

Howlite

$Ca_2B_5SiO_9(OH)_5$

MONOCLINIC ● ●

Properties: C – white; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.5; H – 3.5; CL – good; F – uneven; M – tabular crystals, nodules, massive.
Origin and occurrence: Hydrothermal in borate deposits, associated with ulexite and colemanite. Crystals, several cm across, come from the vicinity of Bras d'Or Lake, Nova Scotia, Canada. It occurs also in Lang and Daggett, California, USA.

Kornerupine, 90 mm, Lac Ste.-Marie, Canada

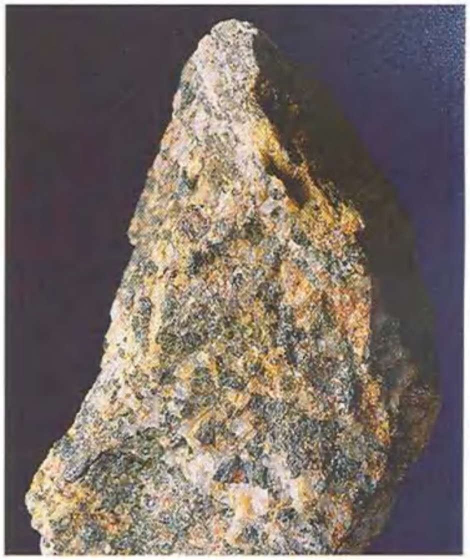

Cuprosklodowskite, 82 mm, Musonoi, Zair

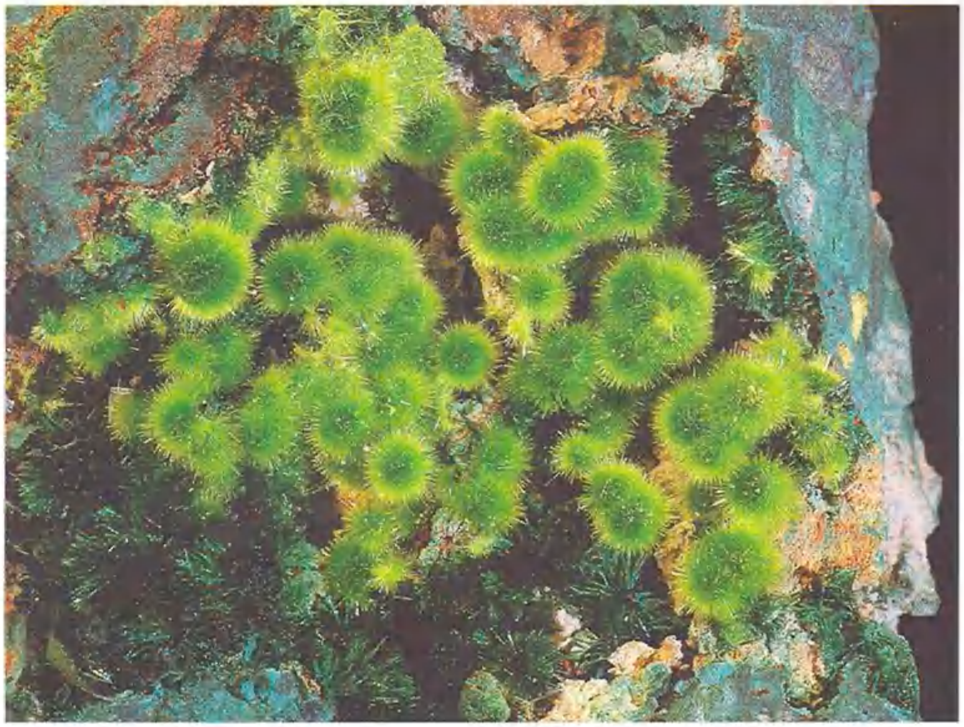

Cuprosklodowskite

$Cu(UO_2)_2Si_2O_7 \cdot 6 H_2O$

MONOCLINIC ● ●

Properties: C – various hues of green; S – greenish; L – vitreous to dull; D – transparent to translucent; DE – 3.8; H – 4; CL – good; F – uneven; M – radial, acicular aggregates, thin coatings, granular, massive; R – strong radioactive.

Origin and occurrence: Secondary in the oxidation zone of U deposits, associated with autunite, torbernite, uranophane and other U secondary minerals. Crystals, up to several cm long, come from

Uranophane, 125 mm, Brewster, Texas, U.S.A.

Kasolite, 30 mm, Musonoi, Zair

the Mashamba West mine, Musonoi, Zaire. It also occurred in Jachymov, Czech Republic.

Uranophane

$Ca(UO_2)_2Si_2O_7 . 6 H_2O$

MONOCLINIC ● ● ●

Properties: C – various hues of yellow to brown; S – yellowish; L – vitreous to dull; D – transparent to translucent; DE – 3.9; H – 2.5; CL – good; F – uneven; M – radial, acicular aggregates, thin coatings, granular, massive; LU – yellow-green; R – strong radioactive.
Origin and occurrence: Secondary in the oxidation zone of U deposits as a product of uraninite alteration, associated with autunite, torbernite and other secondary U minerals. Needles up to 10 mm (3/8 in) long, come from Musonoi, Shinkolobwe, Zaire.
It is also known from the Faraday mine, Bancroft, Ontario, Canada. It occurs in Wolsendorf, Germany, as well as in Jachymov, Czech Republic.

Kasolite

$Pb(UO_2)SiO_4 . H_2O$

MONOCLINIC ● ●

Properties: C – various hues of yellow, green to brown; S – yellowish; L – vitreous to dull; D – translucent to opaque; DE – 6.2; H – 4.5; CL – good; F – uneven; M – prismatic crystals, radial and acicular aggregates, thin coatings, granular, massive; R – strong radioactive.
Origin and occurrence: Secondary mineral in the oxidation zone of U deposits. It is a product of uraninite alteration and is associated with uranophane, torbernite and U hydroxides. Crystals up to 10 mm (3/8 in) long occur in Shinkolobwe, Kasolo, Zaire and Mounana, Gabon.

Akermanite

$Ca_2MgSi_2O_7$

TETRAGONAL ● ● ●

Properties: C – white, gray, green, brown; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.9; H – 5.5; CL – good; F – uneven to conchoidal; M – short prismatic crystals, granular.
Origin and occurrence: Magmatic in volcanic basic rocks; metamorphic in contact metamorphosed marbles. A typical representative of localities in marbles is Crestmore, California, USA. It occurs also in Ca-rich volcanic rocks in Velardena, Mexico.

Akermanite, 5 mm xx, Mt. Vesuvius, Italy

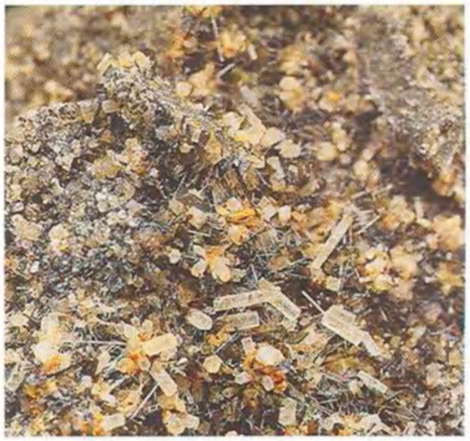

Gehlenite

$Ca_2Al_2SiO_7$

TETRAGONAL ● ● ●

Properties: C – white, gray, yellowish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.0; H – 5-6; CL – good; F – uneven to conchoidal; M – short prismatic crystals, granular.
Origin and occurrence: Magmatic in volcanic basic rocks; metamorphic in contact metamorphic marbles.
It occurs in Crestmore, California, USA; Monzoni, Italy; Oraviza, Romania and elsewhere.

Gehlenite, 80 mm, Vata de Sus, Romania

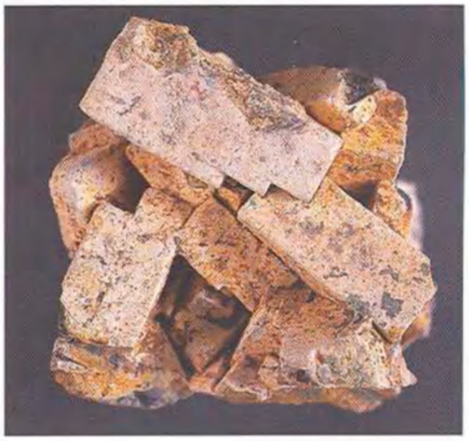

Ilvaite, 20 mm xx, Dalnegorsk, Russia

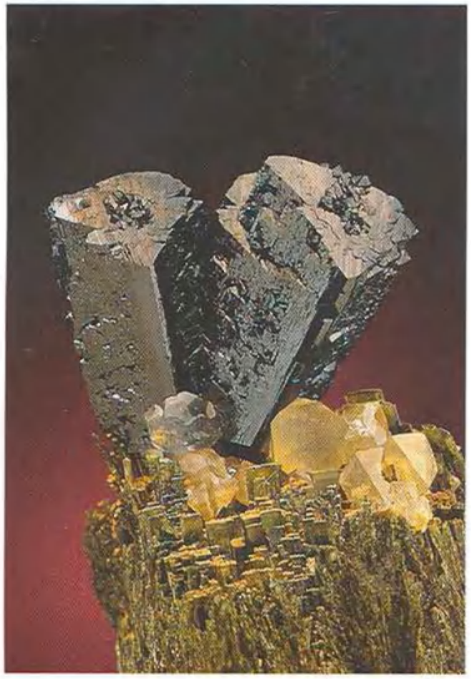

Bertrandite, 36 mm, Mt.Antero, U.S.A.

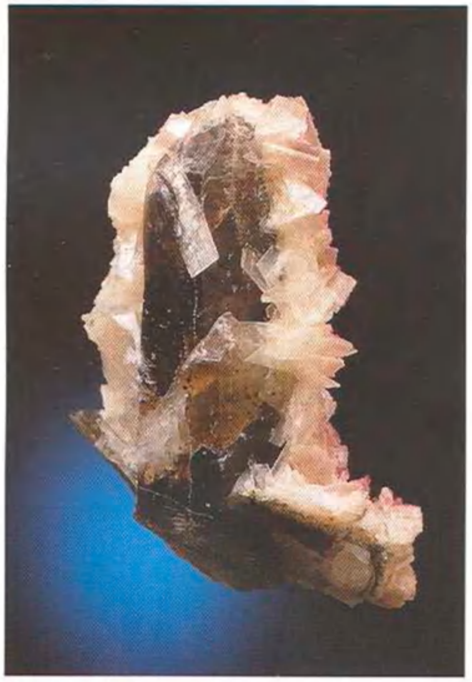

Ilvaite

$CaFe^{2+}{}_2Fe^{3+}Si_2O_8(OH)$

ORTHORHOMBIC ● ● ●

Properties: C – black to black-gray; S – black; L – submetallic to dull; D – opaque; DE – 4.1; H – 5.5-6; CL – good; F – uneven; M – prismatic crystals, granular.
Origin and occurrence: Metamorphic and hydrothermal in contact metamorphosed Fe, Zn and Cu deposits. Prismatic crystals up to 100 mm (4 in) long come from Rio Marina, Elba, Italy. Crystals up to 30 cm (12 in) long are known from Serifos Island, Greece. Crystals, several cm long occur also in Dalnegorsk, Russia and in the Laxey mine, Idaho, USA.

Bertrandite

$Be_4Si_2O_7(OH)_2$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white, yellowish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.6; H – 6-7; CL – perfect; F – uneven; M – tabular crystals and their combinations, radial aggregates, granular, massive.
Origin and occurrence: Hydrothermal in granitic pegmatites, greisens and in hydrothermal veins, together with beryl, also as pseudo-morphs after beryl. Tabular crystals up to 50 mm (2 in) across occur in Conselheira Pena, Minas Gerais, Brazil. It is known from Kounrad and Kara-Oba, Kazakhstan in crystals up to 30 mm ($1^{3}/_{16}$ in) across. It also comes from Stoneham, Maine, USA; Písek, Czech Republic and Iveland, Norway.
Application: the most important Be ore.

Hemimorphite

$Zn_4Si_2O_7(OH)_2 \cdot H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white, yellowish, greenish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.4; H – 4.5-5; CL – perfect; F – uneven; M – tabular crystals and their combinations, botryoidal and radial aggregates, granular, massive.
Origin and occurrence: Secondary in the oxidation zone of Zn deposits, associated with sphalerite, smithsonite and cerussite. Crystals up to 100 mm (4 in) long come from Bisbee, Arizona, USA.. It is also from the El Potosi Mine, Santa Eulalia, Chihuahua, Mexico; Bleiberg, Austria; Cho-Dien, Vietnam.
Application: Zn ore.

Hemimorphite, 30 mm xx, Mapimi, Mexico

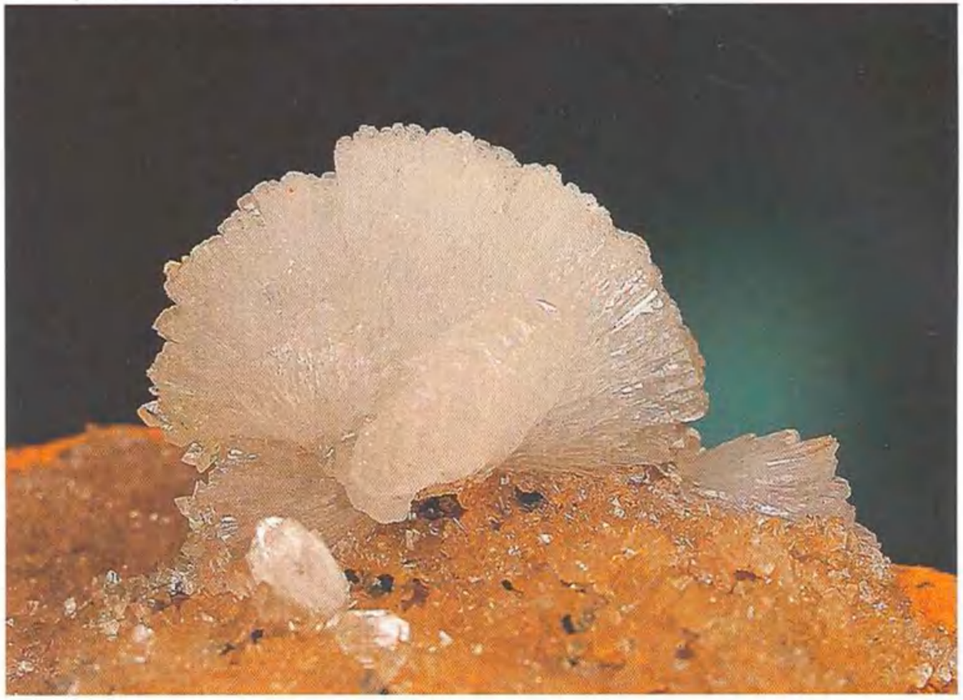

Lamprophylite

$Na_2Sr_2Ti_3Si_4O_{16}(OH,F)_2$

MONOCLINIC ● ●

Properties: C – brown to dark brown; S - white; L – vitreous to submetallic; D – translucent; DE – 3.5; H – 2-3; CL – perfect; F – uneven; M – tabular crystals, radial aggregates.

Origin and occurrence: Magmatic in alkaline syenites and their pegmatites, associated with nepheline, aegirine and eudialyte. The best crystals up to 150 mm (6 in) long come from Mount Flora, Lovozero massif, Kola Peninsula, Russia. It is also known from Langesundsfjord, Norway and Mont St.-Hilaire, Quebec, Canada.

Hemimorphite, 26 mm, Arizona, U.S.A.

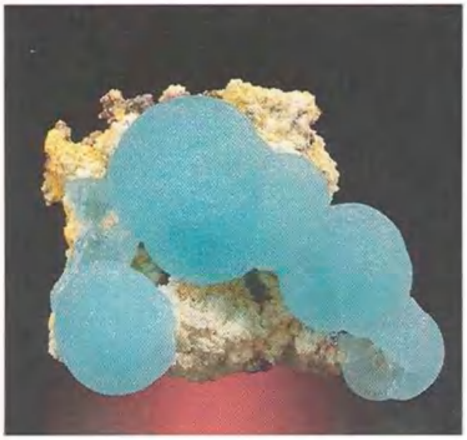

Lamprophyllite, 50 mm xx, Lovozero Massif, Kola, Russia

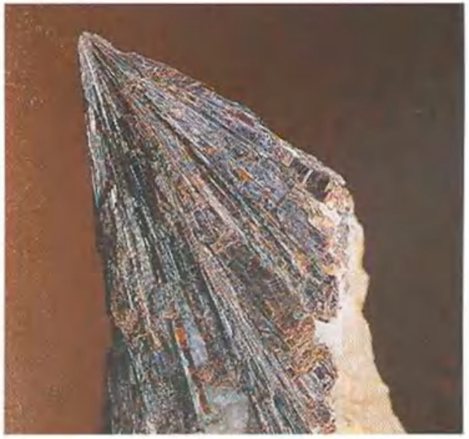

Clinozoisite, 36 mm, Eden Mills, U.S.A.

Clinozoisite

$Ca_2Al_3Si_3O_{12}(OH)$

MONOCLINIC ● ● ● ●

Properties: C – colorless, yellowish, green, pink; S – white; L – vitreous to dull; PS – transparent to translucent; DE – 3.4; H – 6.5; CL – good; F – uneven; M – prismatic crystals, columnar, radial aggregates, granular, massive.
Origin and occurrence: Metamorphic and hydrothermal in contacts of marbles and in the Alpine-type veins. Prismatic crystals up to 60 mm ($2^{3}/_{8}$ in) long come from Radoy Island, Norway. It comes also from Eden Mills, Vermont; Allens Park, Colorado, USA; Pinos Altos, Baja California, Mexico.

Epidote

$Ca_2(Al,Fe^{3+})_3Si_3O_{12}(OH)$

MONOCLINIC ● ● ● ● ●

Properties: C – green, brown, greenish, yellow-green; S – white; L – vitreous to dull; D – transparent to translucent, locally opaque; DE – 3.4; H – 6-7; CL – good; F – uneven; M – prismatic crystals, columnar and radial aggregates, granular, massive.
Origin and occurrence: Metamorphic in marble/granite contacts; hydrothermal in the Alpine-type veins and in hydrothermally altered rocks, typically associated with albite, prehnite and amphibole. Its green crystals up to 140 mm (5½ in) long, were found in Sobotín, Czech Republic. Perfect crystals up to 100 mm (4 in) across come from Knappenwand, Austria. Thick tabular crystals occur in Prince of Wales Island, Alaska, USA. Fine crystals, resembling Austrian crystals, were found recently in Alchuri, Shigar, Pakistan. Fine columnar aggregates of crystals are known from Pampa Blanca, Peru and also reported from Arendal, Norway.

Piemontite

$Ca_2(Al,Mn^{3+})_3Si_3O_{12}(OH)$

MONOCLINIC ● ●

Properties: C – red-brown to black, crimson, red-yellow; S – white; L – vitreous to dull; D – translucent, locally opaque; DE – 3.5; H – 6; CL – good; F – uneven; M – prismatic crystals, radial aggregates, granular.
Origin and occurrence: Metamorphic in shales and Mn-rich metamorphic rocks; rare magmatic in rhyolites and pegmatites. Needles up to 30 mm ($1^{3}/_{16}$

Epidote, Dashkesan, Azerbaidzhan

Epidote, 50 mm, Knappenwand, Austria

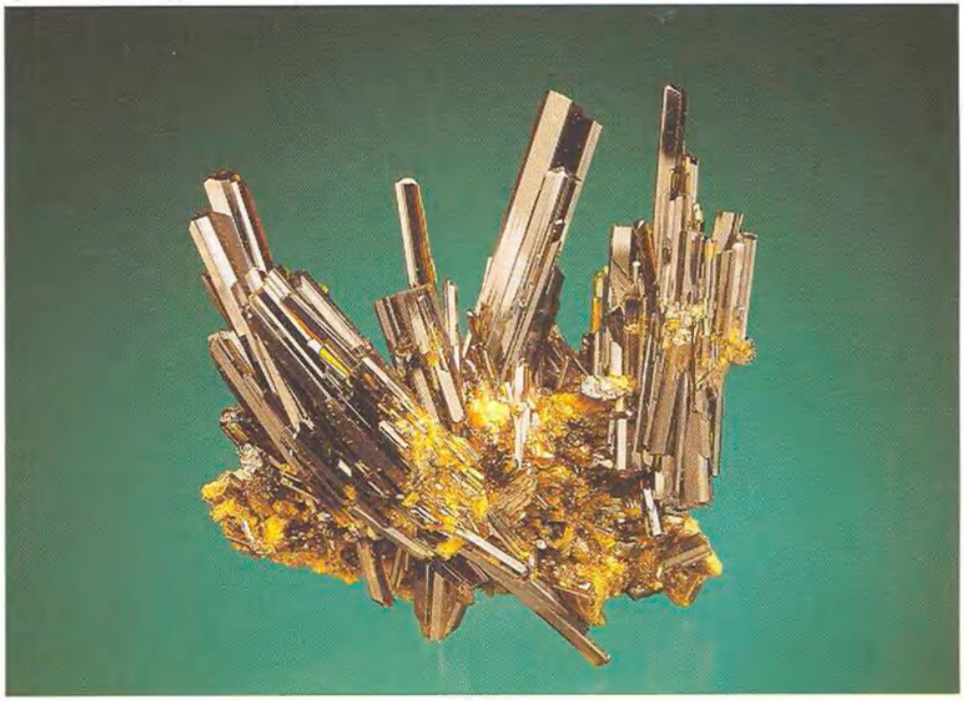

in) long come from St. Marcel, Piedmont, Italy and Otakiyama, Japan.

Allanit-(Ce)

$(Ca,Ce,Y)_2(Al,Fe^{3+})_3Si_3O_{12}(OH)$

MONOCLINIC ● ● ●

Properties: C – black to dark brown; S – light gray; L – greasy to submetallic; D – translucent to opaque; DE – 3.9; H – 5.5-6; CL – none; F – conchoidal to uneven; M – tabular crystals, granular; R – usually metamict.

Origin and occurrence: Magmatic in pegmatites and granites; metamorphic in various types of metamorphic rocks, e.g. migmatites, amphibolites and gneisses. Grains, up to 70 cm ($27\frac{9}{16}$ in) across found in pegmatites near Bancroft, Ontario, Canada. Also occurs in Barringer Hill, Colorado; Amelia district, Virginia, USA; Arendal and Hittero, Norway; Ytterby and Riddarhyttan, Sweden; Yates mine, Quebec, Canada.

Piemontite, 45 mm, Todyryact, Morocco

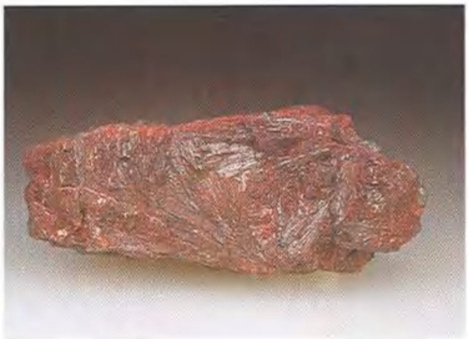

Allanite-(Ce), 40 mm, Vizcaya, Spain

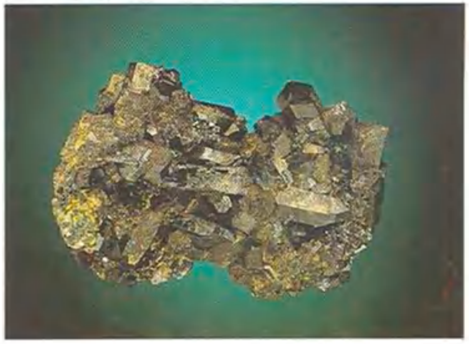

Tanzanite, 37 mm, Arusha, Tanzania

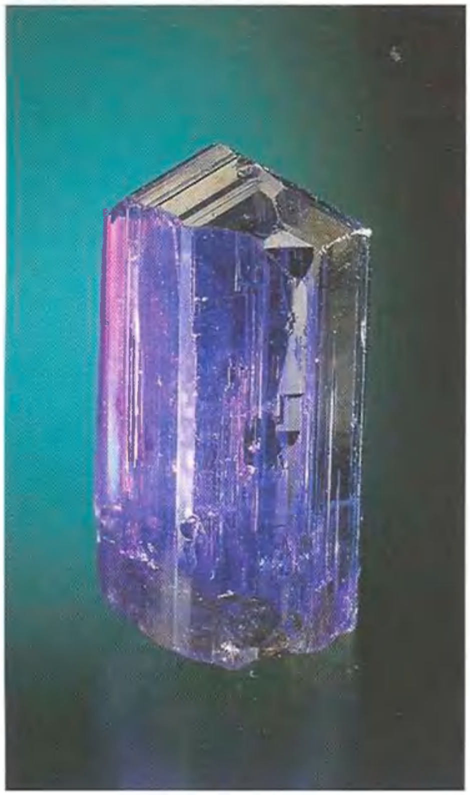

Zoisite, 60 mm, Weisenstein, Germany

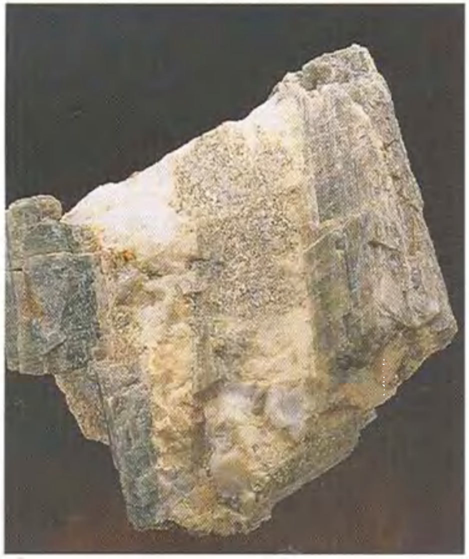

Zoisite

$Ca_2Al_3Si_3O_{12}(OH)$

ORTHORHOMBIC ● ● ●

Varieties: thulite, tanzanite

Properties: C – colorless, yellowish, green, pink, red (thulite), blue (tanzanite); S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.4; H – 6.5; CL – good; F – uneven; M – prismatic crystals, radial aggregates, granular.

Origin and occurrence: Metamorphic in regionally metamorphosed Ca-rich rocks, mainly in pyroxenic gneisses, amphibolites and in marble contacts. It is known from many localities like Saualpe, Austria; Zermatt, Switzerland; Lexviken, Norway (thulite); Traversella, Italy; Alchuri, Pakistan; Merelani Hills, Arusha, Tanzania (tanzanite), where crystals up to 70 mm (2¾ in) long were found.

Application: tanzanite and thulite are cut as gemstones.

Thulite, 40 mm, Lexviken, Norway

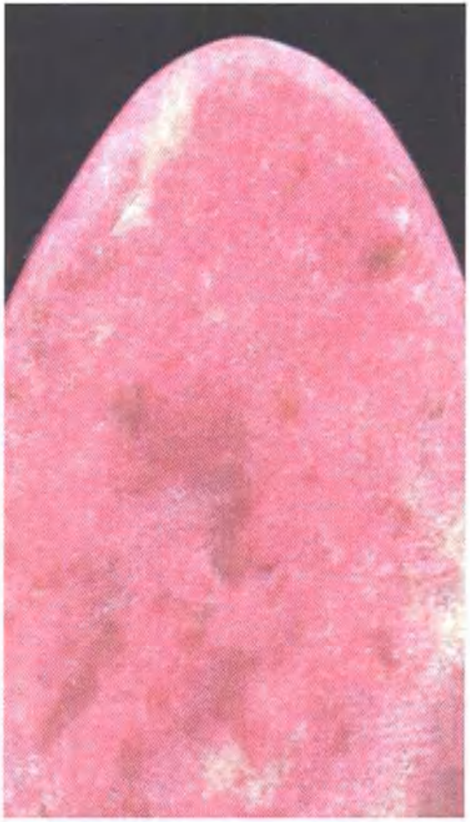

Vesuvianite

$Ca_{19}(Al,Mg,Fe)_{13}Si_{18}O_{68}(OH,F,O)_{10}$

TETRAGONAL ● ● ●

Properties: C – brown, yellowish, green, blue, purple, colorless; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.3; H – 6-7; CL – imperfect; F – uneven to conchoidal; M – prismatic to tabular crystals, columnar aggregates with radial structure, granular, massive.

Origin and occurrence: Metamorphic and hydrothermal in contact metamorphosed Ca-rich rocks, mainly in skarns, in marble contacts, also in rodingites; rarely magmatic in alkaline rocks. It is usually associated with grossular, wollastonite and diopside. Perfect green crystals up to 180 mm ($7\frac{1}{16}$ in) long and purple crystals up to 70 mm (2¾ in) long come from the Jeffrey quarry, Asbestos, Quebec, Canada. It is also known from Hazlov, Czech Republic; Crestmore, California, Franklin, New Jersey, USA; Monzoni, Italy.

Vesuvianite, 110 mm, Asbestos, Canada

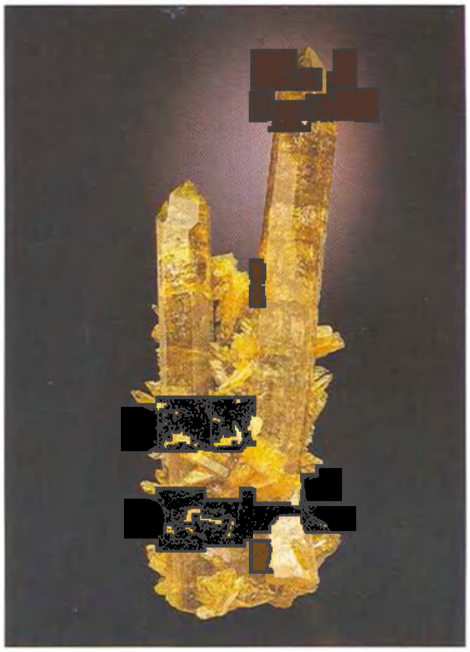

Viluite

$Ca_{19}(Al,Mg)_{13}B_5Si_{18}O_{68}(O,OH)_{10}$

TETRAGONAL ●

Properties: C – dark green, gray-brown; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.4; H – 6; CL – imperfect; F – uneven to conchoidal; M – prismatic crystals.

Origin and occurrence: Metamorphic in serpentinized skarn, associated with grossular. Its perfect prismatic crystals up to 50 mm (2 in) long are only known from the Vilui River basin, Yakutia, Russia.

Viluite, 30 mm xx, Vilui River, Russia

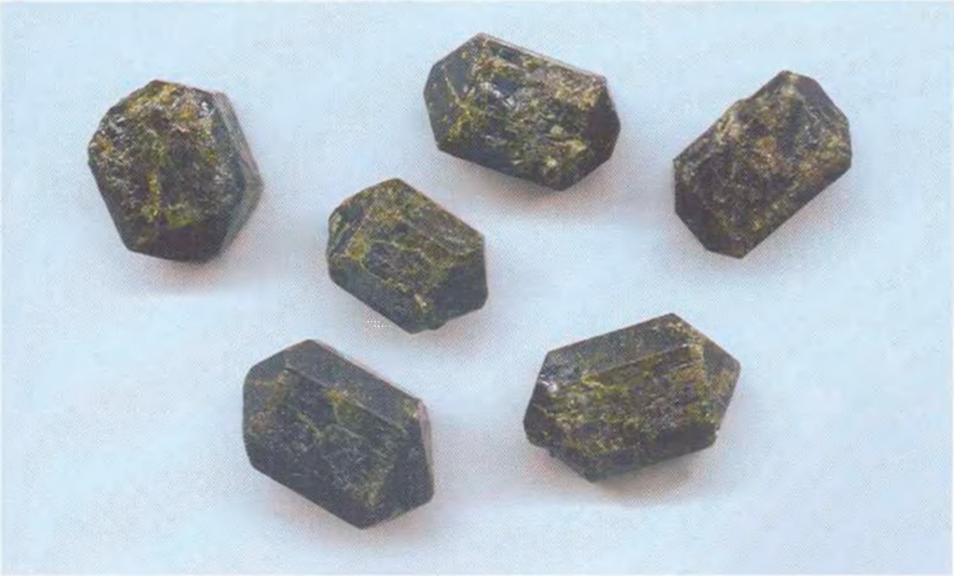

Benitoite

$BaTiSi_3O_9$

TRIGONAL ● ●

Properties: C – blue, pink, white, colorless; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.6; H – 6-6.5; CL – imperfect; F – uneven to conchoidal; M – prismatic to tabular crystals, mainly with trigonal cross-section; LU – bluish.
Origin and occurrence: Hydrothermal in veins, cross-cutting serpentinites, always associated with neptunite and natrolite. Its classic locality is the Benitoite Gem mine, San Benito Co., California, USA, where it forms tabular crystals up to 40 mm (1$^{9}/_{16}$ in) across.

Catapleiite

$Na_2ZrSi_3O_9 . 2 H_2O$

HEXAGONAL ● ●

Properties: C – light yellow, yellow-brown, pink, brown, blue; S – white; L – vitreous to dull; D – transparent to opaque; DE – 2.8; H – 5-6; CL – good; F – uneven; M – thin tabular crystals, lamellar aggregates.
Origin and occurrence: Magmatic in nepheline syenites and their pegmatites, together with aegirine, titanite, nepheline and microcline. It occurs in Mont St.-Hilaire, Quebec, Canada, as tabular crystals up to 150 mm (6 in) across. Crystals up to 30 mm (1$^{3}/_{16}$ in) across come from Mount Yukspor, Khibiny massif, Kola Peninsula, Russia. It is also known from Langesundsfjord, Norway; Magnet Cove, Arkansas, USA.

Eudialyte

$Na_4(Ca,Fe,Ce,Mn)_2ZrSi_6O_{18}(OH,Cl)$

TRIGONAL ● ●

Properties: C – red, pink to brown; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.8; H – 5-5.5; CL – imperfect; F – uneven; M – prismatic and tabular crystals, granular.
Origin and occurrence: Magmatic in nepheline syenites and their pegmatites, associated with aegirine, nepheline and microcline. Crystals up to 80 mm (3$^{1}/_{8}$ in) across come from Mount Kukisvumchorr, Khibiny massif, Kola Peninsula, Russia. Crystals up to 50 mm (2 in) across are also known from Mont St.-Hilaire, Quebec, Canada. It also occurs in Langesundsfjord, Norway and in Los Island, Guinea.

Ferroaxinite

$Ca_2FeAl_2BSi_4O_{15}(OH)$

TRICLINIC ● ● ●

Properties: C – brown to purple- brown, light purple; S – white; L – vitreous to dull; D – trans-

Benitoite, 28 mm x, San Benito Co., U.S.A.

Catapleiite, 37 mm, Mont St.-Hilaire, Canada

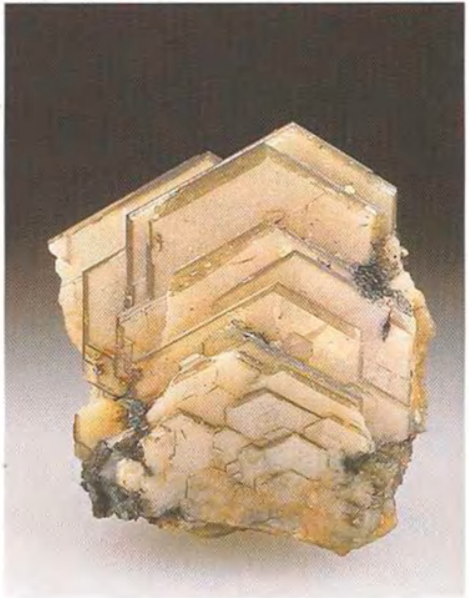

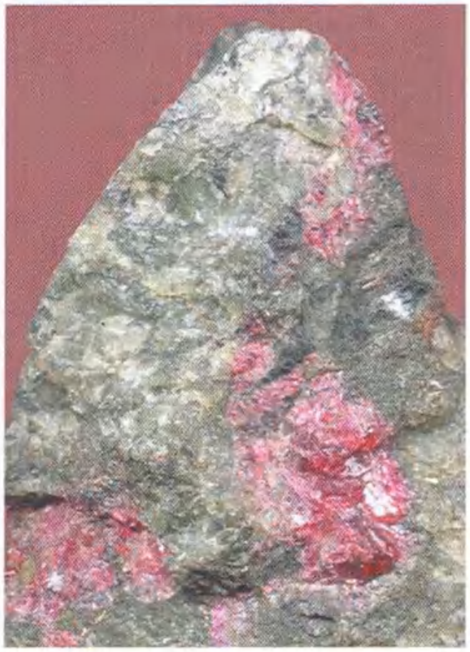
Eudialyte, 20 mm grain, Khibiny Massif, Kola, Russia

parent to translucent; DE – 3.3; H – 6. 5-7; CL – good; F – uneven to conchoidal; M – tabular crystals, platy aggregates, granular, massive.

Origin and occurrence: Metamorphic and hydrothermal in contacts of marbles and granites, associated with clinozoisite, prehnite, calcite and actinolite, also in the Alpine-type veins and pegmatites. Perfect tabular crystals up to 150 mm (6 in) across come from Puiva, Polar Ural, Russia. Other renowned localities are Obira, Japan; Bourg d'Oisans, France; Monte Scopi, Switzerland.

Tinzenite

$Ca(Mn,Fe)_2Al_2BSi_4O_{15}(OH)$

TRICLINIC ● ●

Properties: C – yellow, orange to red; S – white; L – vitrous to dull; D – transparent to translucent; DE – 3.3; H – 6.5-7; CL – good; F – uneven to conchoidal; M – tabular crystals, platy and fibrous aggregates, granular, massive.

Origin and occurrence: Hydrothermal in the Alpine-type veins, cross-cutting a rock, rich in braunite. It comes from Tinzen, Val d'Err, Switzerland and in the Cassagna mine, Genova, Italy.

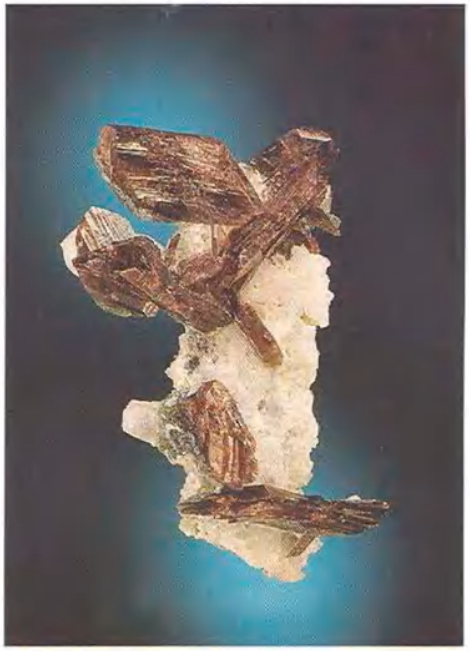
Ferroaxinite, 62 mm, Khapalu, Pakistan

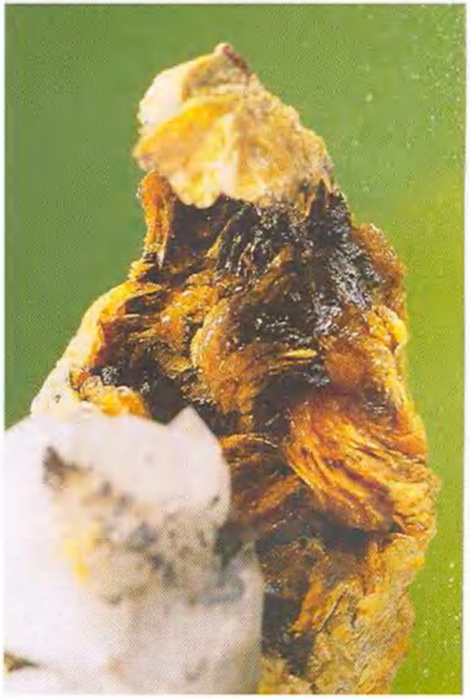
Tinzenite, 10 mm xx, Val Graveglia, Italy

Beryl

$Be_3Al_2Si_6O_{18}$

HEXAGONAL ● ● ● ●

Varieties: emerald, aquamarine, heliodor, morganite, goshenite, red beryl (bixbite).

Properties: C – variable in different varieties; common beryl – mostly yellow, yellow-green, light green to white, rare blue; varieties: emerald – dark emerald-green; aquamarine – light to dark blue-green; morganite – pink; heliodor – light yellow to yellow-green; goshenite – white to colorless; red beryl B red; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.6; H – 7.5-8; CL – imperfect; F – uneven to conchoidal; M – long prismatic to tabular crystals, columnar and radial aggregates, granular, massive.

Origin and occurrence: Magmatic in pegmatites and granites; hydrothermal in greisens, in cavities in rhyolite, in quartz veins; metamorphic in mica schists. Perfect prismatic crystals of common beryl up to 9 m (29 ft 6 in) long found in the Etta mine, Keystone, South Dakota, USA. Crystals weighing up to 177 tons, come from Namivo, Alto Ligonha, Mozambique. Other localities are Pici, Brazil; Iveland, Norway; Antsirabe, Madagascar. Emerald crystals occur in mica-schists, marbles and ultrabasic rocks, associated with other Be minerals, phenakite and

Emerald, 30 mm x, Boyaca, Colombia

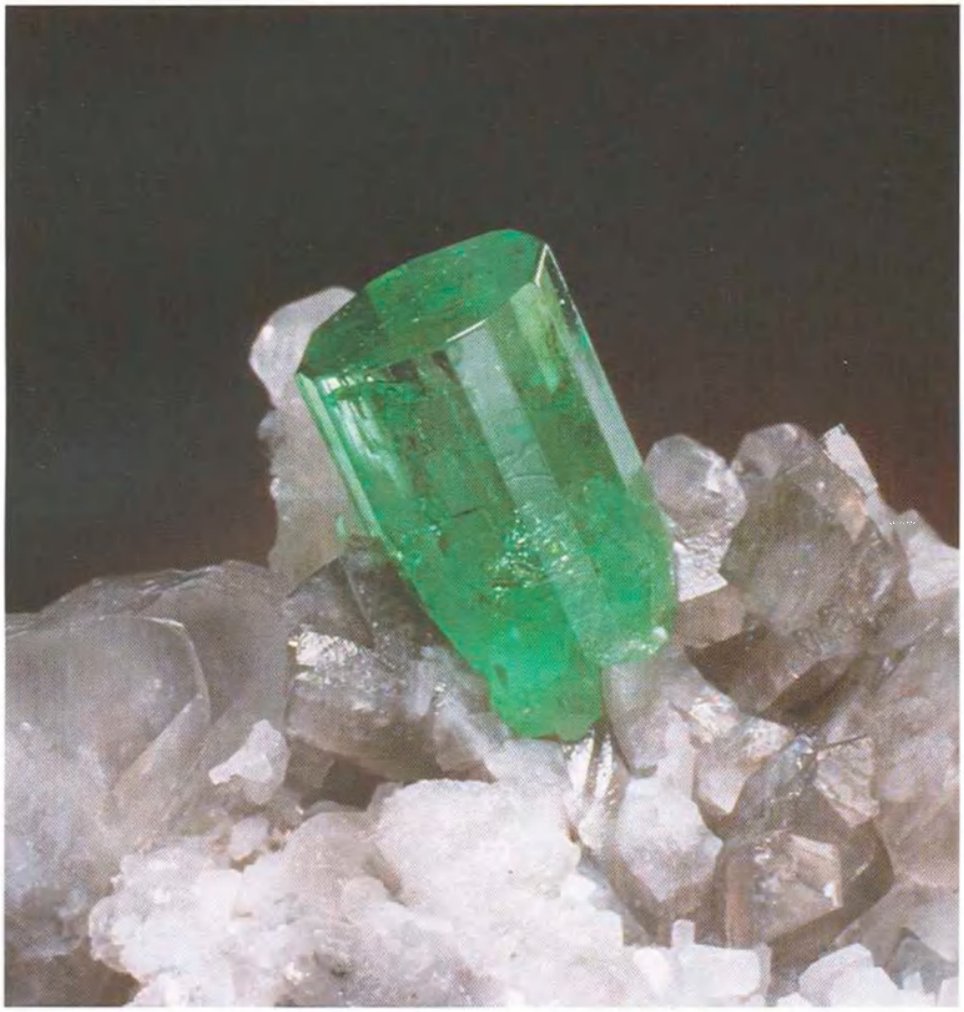

Emerald, 30 mm, Ural Mts., Russia

chrysoberyl. Beautiful dark green transparent crystals are known from Malyshevo, Ural Mts., Russia; Muzo and Coscuez, Colombia; Habachtal, Austria, where the largest crystals reach up to 120 mm ($4^{11}/_{16}$ in) in size. Aquamarine is mainly known from pegmatites and hydrothermal veins, commonly

Emerald, 90 mm, Muzo, Colombia

Aquamarine, 97 mm, Koronel Hurta, Brazil

Aquamarine, 158 mm, Shingus, Pakistan

Heliodor, 87 mm, Volodarsk Volynskii, Ukraine

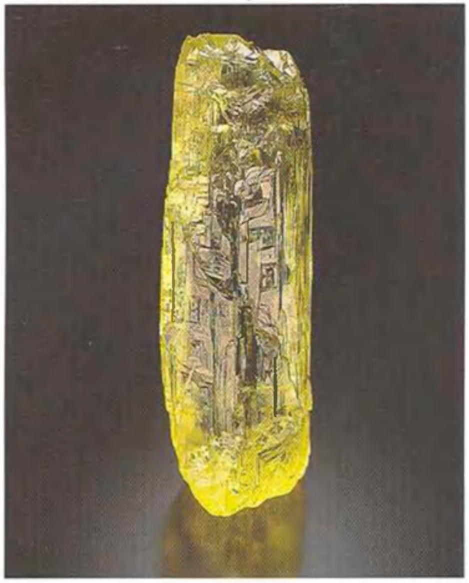

associated with tourmaline, quartz and albite. Intense blue crystals are known from many pegmatites in Minas Gerais, Brazil, where in the Marambaia mine, crystals, up to 70 cm ($27^{9}/_{16}$ in) long and weighing up to 110 kg (242 lb) found. Very beautiful gemmy crystals over 30 cm (12 in) long recently occurred in the Medina Mine. It also come from Murzinka, Ural mountains and Adun Chilon, Siberia, Russia. It also comes from Spitzkopje, Namibia; Gilgit, Pakistan and elsewhere. Morganite is a typical mineral of granitic pegmatites, where it occurs in mainly in cavities, usually associated with color varieties of tourmaline, quartz and albite. Its tabular crystals up to 100 mm (4 in) across found in the White Queen mine, Pala, California, USA. Smaller crystals come from San Piero in Campo, Elba, Italy. Crystals up to 50 cm (20 in) across reported from several localities in Minas Gerais, Brazil. Heliodor also occurs in pegmatite cavities, hydrothermal veins and in gneisses, commonly associated with quartz and albite. Prismatic crystals up to 200 mm ($7^{7}/_{8}$ in) long, come from Volodarsk Volynskii, Ukraine. It is also known from Nerchinsk, Siberia, Russia and several mines in Minas Gerais, Brazil. Goshenite occurs only in pegmatites. Its prismatic crystals come from Goshen, Massachusetts,

Heliodor, 26 mm x, Pamir, Tadzhikistan

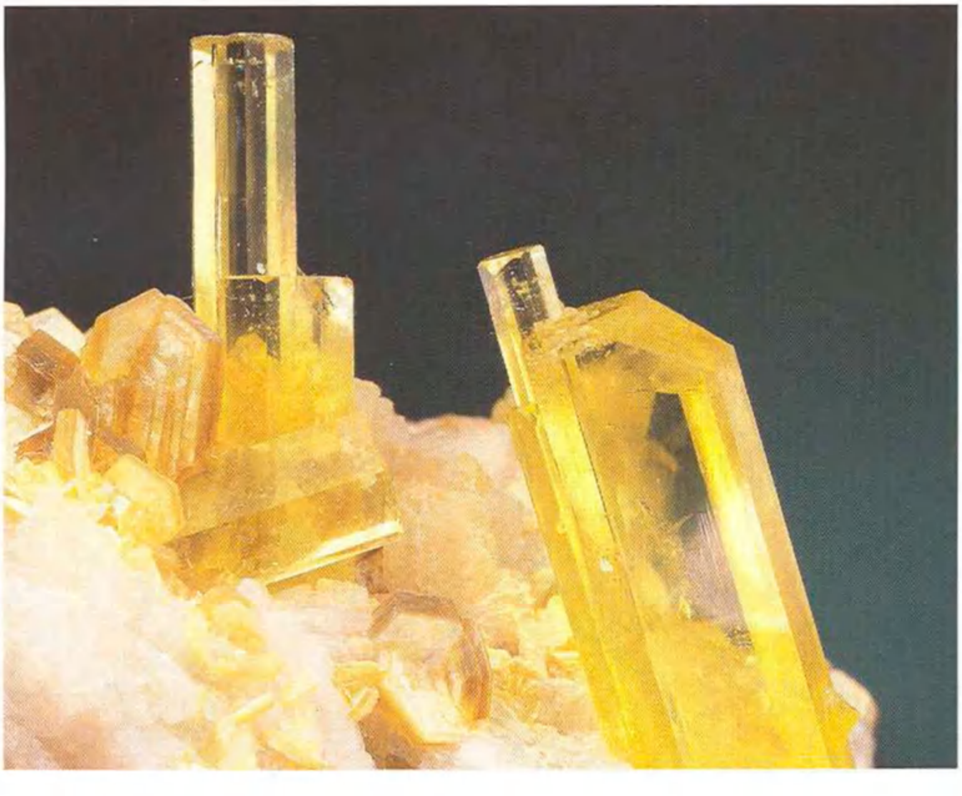

Goshenite, 39 mm, Apalygun, Pakistan

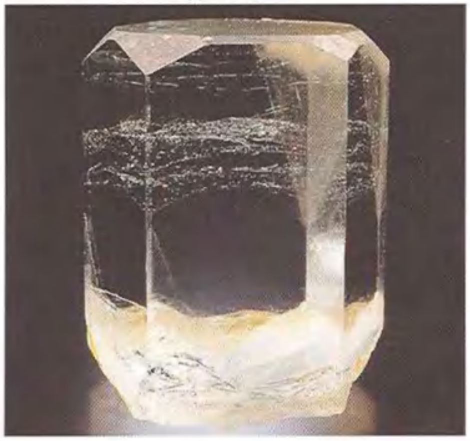

Red beryl, 17 mm x, Wah Wah Mts., U.S.A.

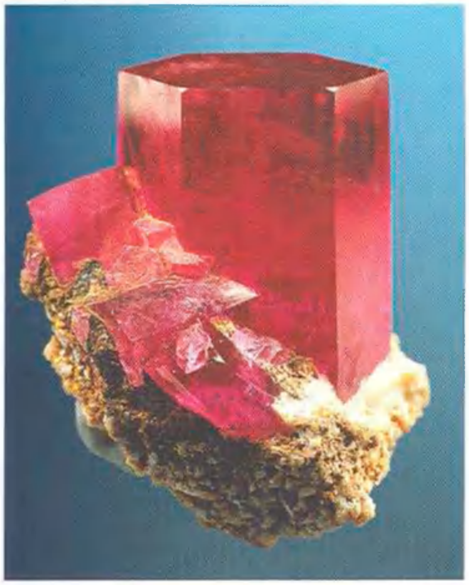

USA; San Piero in Campo, Elba, Italy. Red beryl occurs in Violet Claims, Wah Wah mountains, Utah, USA, where crystals up to 50 mm (2 in) were found. *Application:* Be ore, color varieties are cut as gemstones.

Morganite, 43 mm x, San Diego Co., U.S.A.

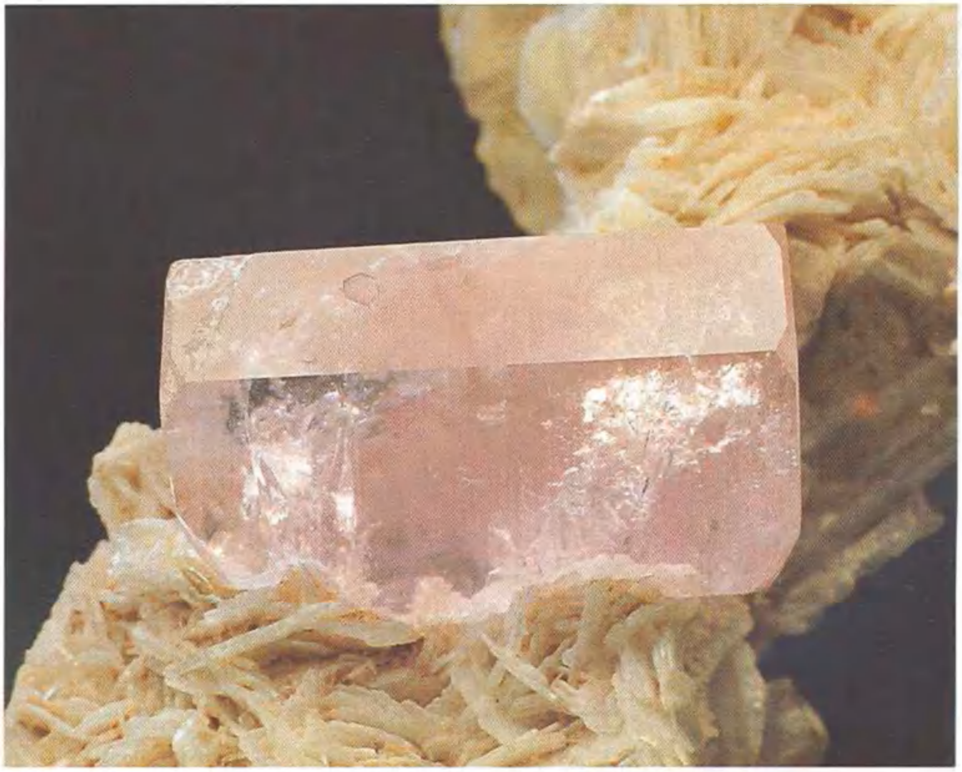

Bazzite, 70 mm, Tordal, Norway

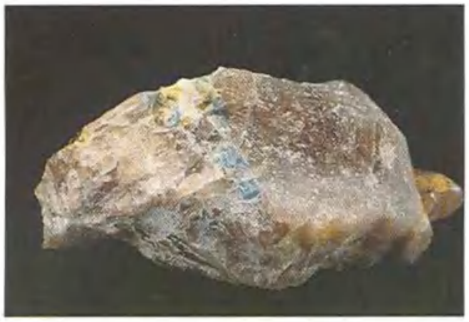

Bazzite

$Be_3(Sc,Al)_2Si_6O_{18}$

HEXAGONAL ●

Properties: C – light to intense blue; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.8; H – 6.5; CL – imperfect; F – uneven to conchoidal; M – long prismatic crystals, columnar and radial aggregates.
Origin and occurrence: Hydrothermal in the Alpine-type veins and pegmatites. Crystals up to 20 mm (25/32 in) long come from Tørdal, Norway. It is also known from Lago Maggiore, Italy and St. Gotthard, Switzerland.

Cordierite

$Mg_2Al_4Si_5O_{18}$

ORTHORHOMBIC ● ● ● ●

Varieties: iolite (gemmy blue)

Sekaninaite, 40 mm x, Dolni Bory, Czech Republic

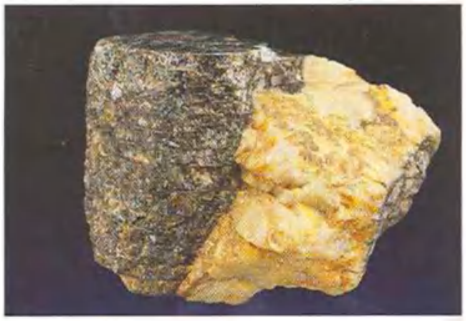

Properties: C – blue, purple, gray, gray-green, gray-brown, trichroic; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.5; H – 7-7.5; CL – imperfect; F – uneven to conchoidal; M – short prismatic crystals, granular.
Origin and occurrence: Metamorphic in migmatites and gneisses and in contact cherts; magmatic in granites and granitic pegmatites, usually associated with andalusite and sillimanite, also known from placers. It is a typical rock-forming mineral. Its prismatic crystals are very rare. Poorly developed transparent crystals up to 200 mm (7⅞ in) long come from Naverberg, Sweden. It also occurs in Orijarvi, Finland; Kragero, Norway; Bodenmais, Germany. Gemmy pebbles are known from the vicinity of Ratnapura, Sri Lanka.

Sekaninaite

$Fe_2Al_4Si_5O_{18}$

ORTHORHOMBIC ● ● ●

Properties: C – blue, purple, strongly pleochroic; S

Cordierite, 50 mm, Fishtail Lake, Canada

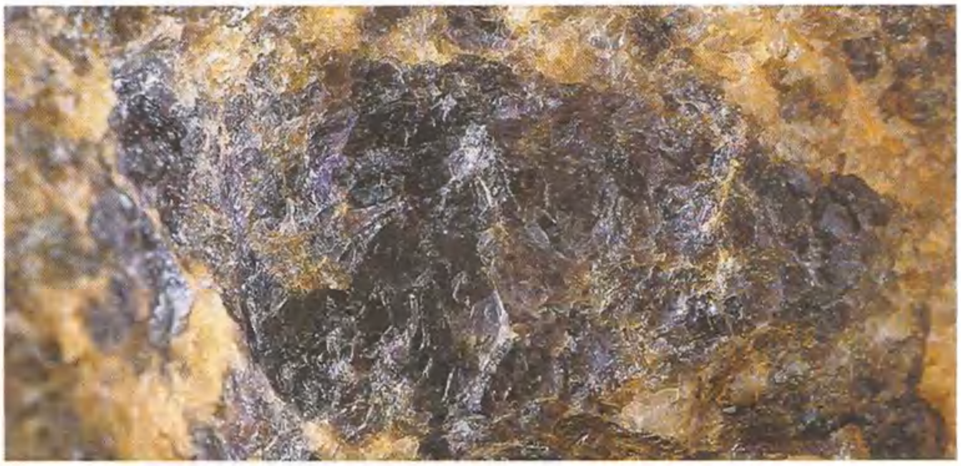

Dravite, 27 mm, Gujarkkot, Nepal

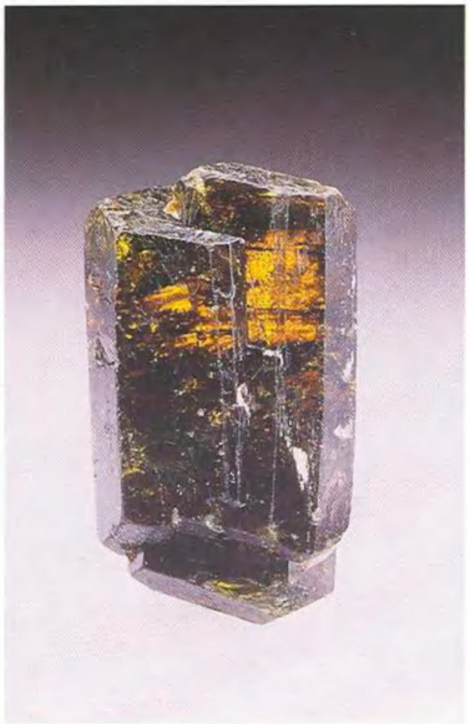

– white; L – vitreous to dull; D – transparent to translucent; DE – 2.8; H – 7-7.5; CL – imperfect; F – uneven to conchoidal; M – short prismatic crystals, granular.
Origin and occurrence: Magmatic in granitic pegmatites and some granites, associated with andalusite and tourmaline; metamorphic in gneisses and migmatites. Conical, imperfect crystals, up to 70 cm ($27^{9}/_{16}$ in) long typically come from Dolni Bory, Czech Republic; also known from San Piero in Campo, Elba, Italy.

Dravite

TOURMALINE GROUP
$NaMg_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

TRIGONAL ● ● ● ●

Properties: C – light to dark black-brown, blue, colorless, commonly pleochroic; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.0; H – 7-7.5; CL – none; F – uneven to conchoidal; M – long to short prismatic crystals, columnar to acicular aggregates, granular.
Origin and occurrence: Metamorphic in migmatites, gneisses, mica schists, marbles and in contact metasomatic rocks; magmatic in some granitic pegmatites; hydrothermal in quartz veins and ore veins, also known from placers. Brown to dark brown perfect crystals up to 200 mm ($7^{7}/_{8}$ in) long come from mica schists near Dravograd, Slovenia. It is also known from marbles in Gouverneur, New York, USA. Crystals up to 150 mm (6 in) across found in Yinnietharra, Western Australia, Australia. Crystals up to 50 mm (2 in) long were recently found in Gujarkot, Nepal.
Application: transparent crystals are cut as gemstones.

Buergerite, 12 mm x, San Luis Potosí, Mexico

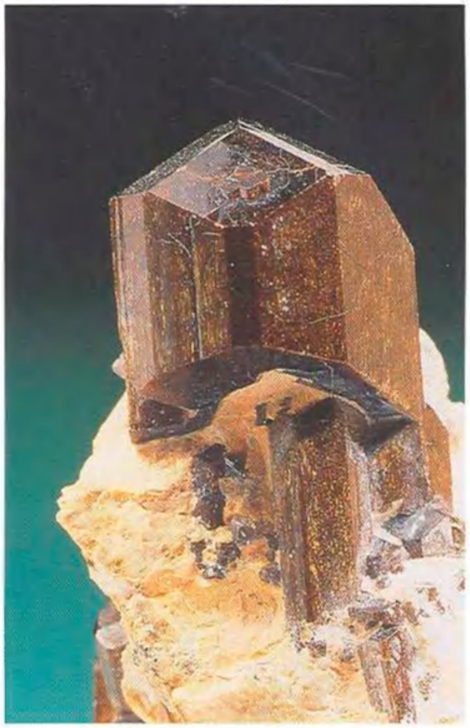

Buergerite

TOURMALINE GROUP
$NaFe^{3+}{}_3Al_6(BO_3)_3Si_6O_{21}F$

TRIGONAL ●

Properties: C – black, strongly pleochroic; S – yellow-brown; L – vitreous to dull; D – translucent to opaque; DE – 3.3; H – 7; CL – none; F – uneven to conchoidal; M B prismatic crystals, granular.
Origin and occurrence: Hydrothermal in rhyolites. Its black crystals, up to 40 mm (19/16 in) long, are known from Mexquitic, San Luis Potosi, Mexico.

Schorl, 40 mm, Gilgit, Pakistan

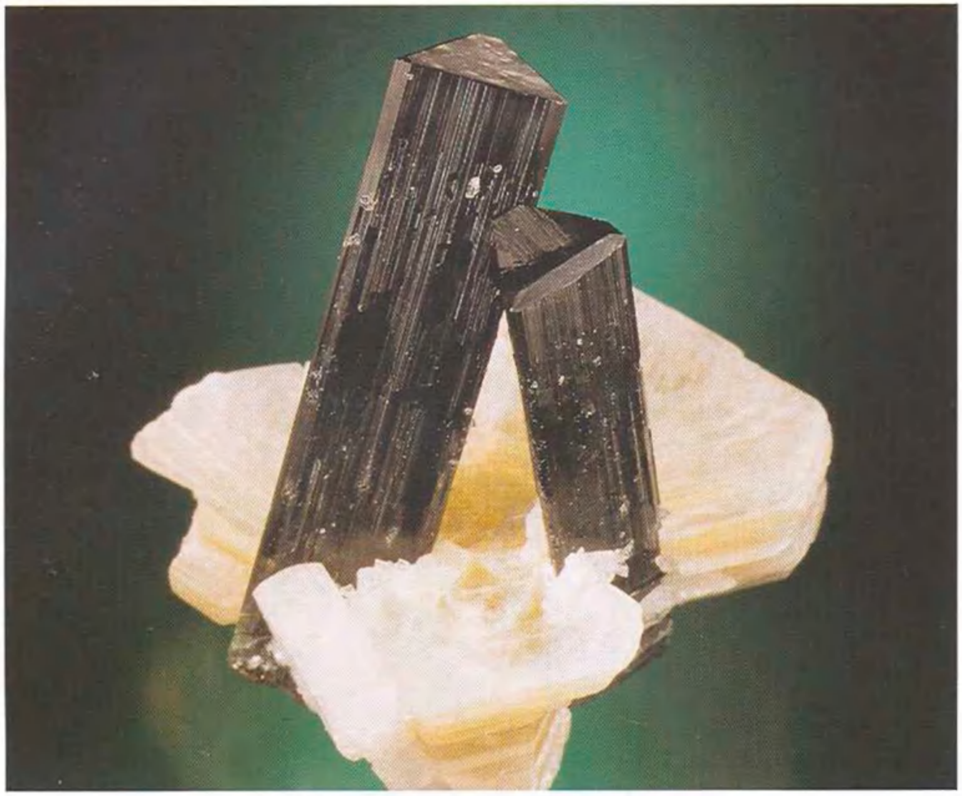

Schorl

TOURMALINE GROUP

$NaFe_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

TRIGONAL ● ● ● ●

Properties: C – black, black-brown, blue-black, strongly pleochroic; S – white; L – vitreous to dull; D – translucent to opaque; DE – 3.3; H – 7-7.5; CL – none; F – uneven to conchoidal; M – long to short prismatic crystals, columnar to acicular aggregates, granular, massive.

Origin and occurrence: Magmatic in granites and granitic pegmatites; hydrothermal in greisens, in quartz and ore veins; metamorphic in migmatites, gneisses, mica schists and tourmalinites; also known from placers. It is usually associated with muscovite, quartz and albite. Perfect black crystals come from many pegmatite localities.

Its long prismatic crystals, up to 5 m long, come from Arendal, Norway. Very good crystals are also known from Kaatiala, Finland; Dolni Bory, Czech Republic; Conselheira Pena and Galileia, Minas Gerais, Brazil.

Povondraite

TOURMALINE GROUP

$NaFe^{3+}{}_3Mg_2Fe^{3+}{}_4(BO_3)_3Si_6O_{18}(OH)_4$

TRIGONAL ●

Properties: C – black; S – gray; L – vitreous to dull; D – translucent to opaque; DE – 3.3; H – 7; CL –

Povondraite, 60 mm, Alto Chapare, Bolivia

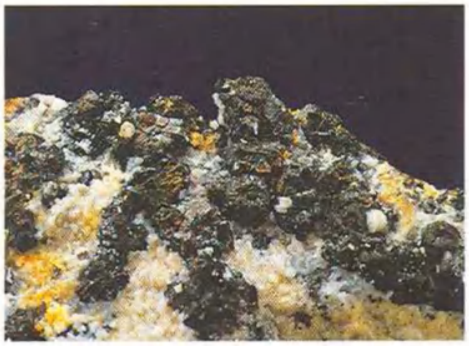

Elbaite, 115 mm, Tourmaline Queen Mine, U.S.A.

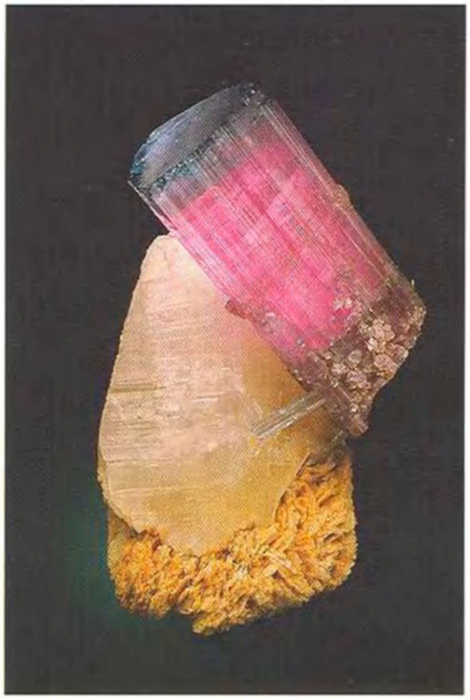

Elbaite, 153 mm, Afghanistan

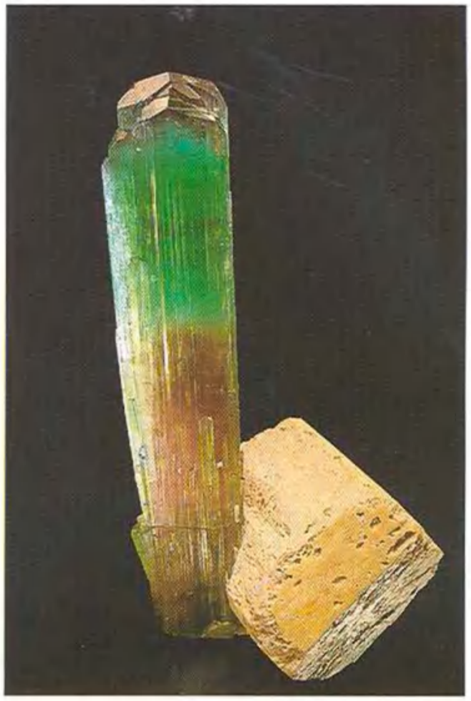

none; F – uneven to conchoidal; M – short prismatic crystals, granular.
Origin and occurrence: Hydrothermal along the cracks in metamorphosed evaporites. Its black crystals up to 10 mm ($^{3}/_{8}$ in) long typically come from Alto Chapare, Cochabamba, Bolivia.

Elbaite

TOURMALINE GROUP
$Na(Li_{1,5}Al_{1,5})Al_6(BO_3)_3Si_6O_{18}(OH)_3F$

TRIGONAL ● ● ●

Varieties: rubellite, verdelite, indicolite, achroite

Properties: C – varies in different varieties, rubellite – pink to red; verdelite – various hues of green; indicolite – blue; achroite – colorless, other colors include yellow, brown and black; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.0; H – 7; CL – none; F – uneven to conchoidal; M – prismatic crystals, columnar aggregates, granular, massive.
Origin and occurrence: Almost only magmatic and hydrothermal in granitic pegmatites, typically associated with lepidolite and albite; also in placers. Its crystals are mostly known from pegmatite cavi-

Rubellite, 23 mm, Pala, U.S.A.

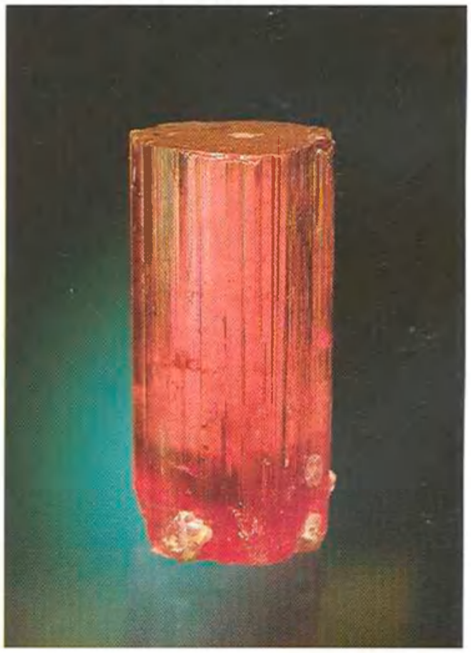

ties in many localities. Rubellite crystal called 'The Rocket' (109 cm/43 5/16 in long) was found in the Jonas mine, Minas Gerais, Brazil. Rubellite crystals up to 40 cm (15¾ in) long come from Alto Ligonha district, Mozambique. Rubellite crystals up to 250 mm (9 13/16 in) long occurred in the Stewart Lithia, Tourmaline King and Tourmaline Queen mines, Pala, California, USA. Verdelite crystal 270 mm (10 5/8 in) long, is known from the Dunton mine, Newry, Maine, USA. Other important localities include San Piero in Campo, Elba, Italy; Malkhan, Transbaikalia, Russia; Rozna , Czech Republic; Uto, Sweden; Gilgit, Pakistan; Paprok, Afghanistan.
Application: commonly used as a gemstone.

Uvite

TOURMALINE GROUP

$CaMg_4Al_5(BO_3)_3Si_6O_{18}(OH,F)_4$

TRIGONAL ● ● ●

Properties: C – gray, black, brown, green, red, pleochroic; S – white; L – vitreous to dull; D – translucent to opaque; DE – 3.3; H – 7-7.5; CL – none; F – uneven to conchoidal; M – long to short prismatic crystals, columnar aggregates, granular.
Origin and occurrence: Metamorphic in Ca-rich rocks, marbles, skarns; magmatic in some pegmatites; hydrothermal in ore veins.
Perfect green and red crystals, up to 30 mm (1 3/16 in) across, occur in Brumado, Bahía, Brazil. It is also known from Gouverneur and Pierrepont, New York, USA.

Uvite, 41 mm, Brumado, Brazil

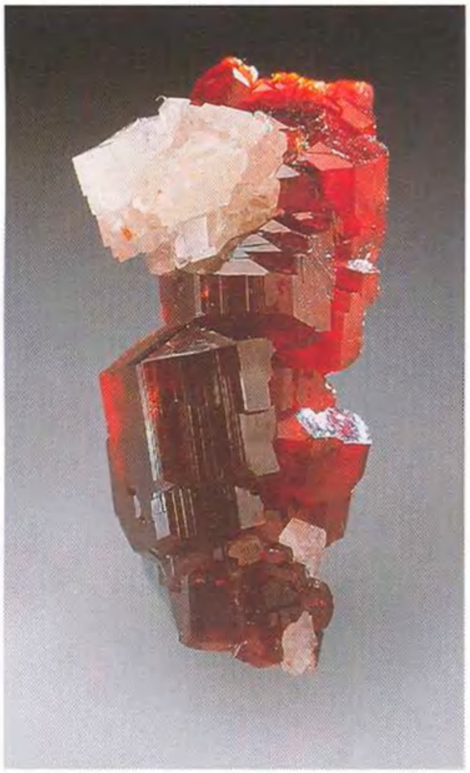

Liddicoatite

TOURMALINE GROUP

$Ca(Li_2Al)Al_6(BO_3)_3Si_6O_{18}(OH)_3F$

TRIGONAL ● ● ●

Varieties: rubellite, verdelite

Properties: C – varies in different varieties, mainly pink, green, green-brown to yellow-brown; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.1; H – 7; CL – none; F – uneven to conchoidal; M – prismatic crystals, columnar aggregates, granular.
Origin and occurrence: Magmatic in granitic peg-

Liddicoatite, 60 mm, Anjanobonoina, Madagascar

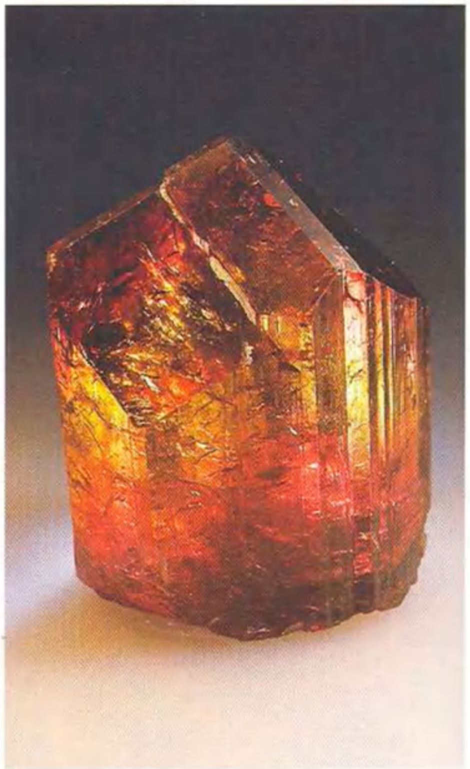

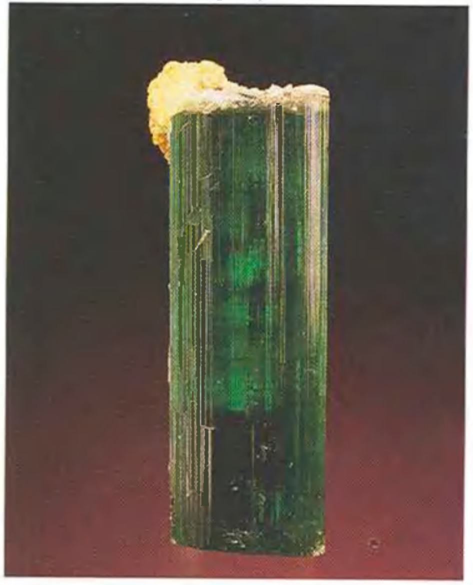
Verdelite, 24 mm, Gillette Quarry, U.S.A.

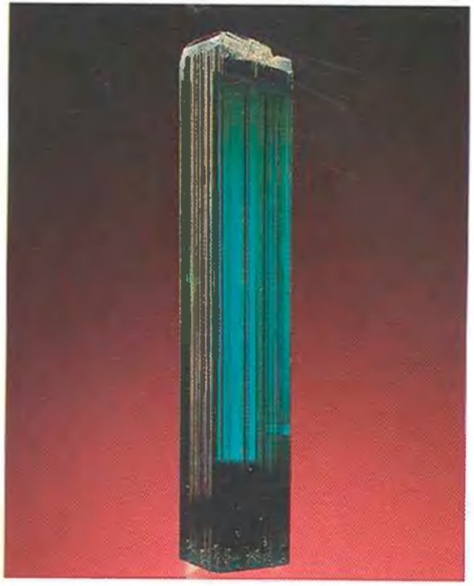
Indigolite, 32 mm, Esmeralda Mine, Mesa Grande, U.S.A.

matites in association with lepidolite, spodumene and albite. Its perfect red and green crystals up to 250 mm ($9^{13}/_{16}$ in) long come from pegmatite cavities in many localities in Madagascar, e.g. Sahatany and Anjanabonoina. It is also known from Blizná, Czech Republic.

Application: cut as a gemstone.

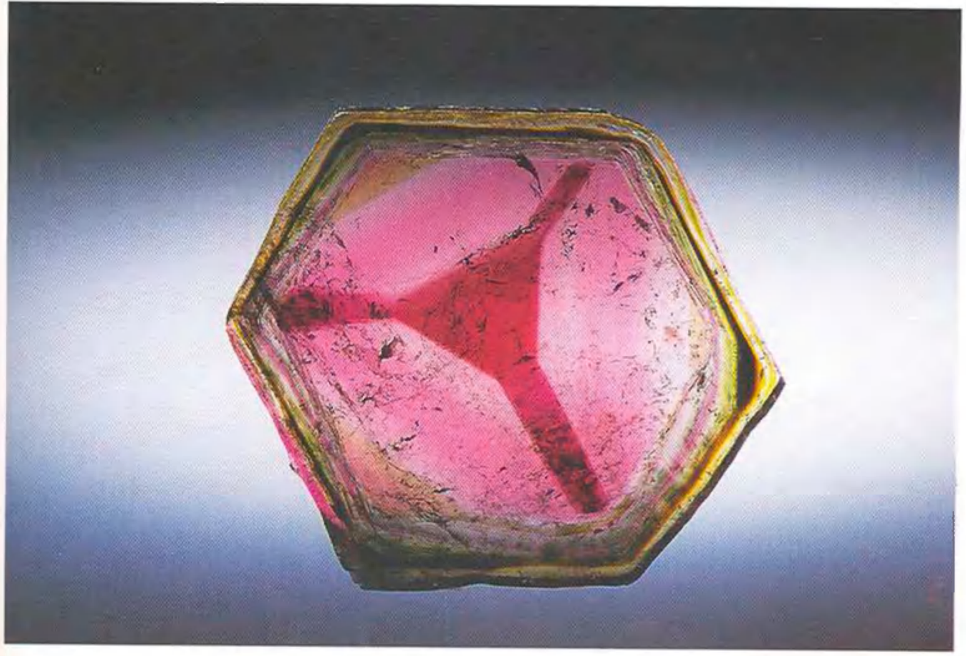
Liddicoatite, 41 mm, Madagascar

Foitite

TOURMALINE GROUP

☐ $Fe_2Al(Al_6(BO_3)_3Si_6O_{18}(OH)_4$

TRIGONAL ● ● ●

Properties: C – black to black-purple; S – white; L – vitreous to dull; D – translucent to opaque; DE – 3.3; H – 7; CL – none; F – uneven to conchoidal; M – prismatic crystals, acicular aggregates.
Origin and occurrence: Magmatic in granitic pegmatites and granites; hydrothermal in pegmatite cavities. Foitite typically forms black tips of elbaite crystals (moors heads) in Dobra Voda, Czech Republic; San Piero in Campo, Elba, Italy; White Queen mine, Pala, California, USA. It occurs together with schorl in some granitic pegmatites, like Rozna, Czech Republic.

Rossmanite

TOURMALINE GROUP

☐ $LiAl_2Al_6(BO_3)_3Si_6O_{18}(OH)_4$

TRIGONAL ●

Properties: C – pink; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.1; H – 7; CL – none; F – uneven to conchoidal; M – prismatic crystals, columnar aggregates.
Origin and occurrence: Magmatic in granitic pegmatites. Prismatic crystals, up to 20 mm (25/32 in) long, were found in massive lepidolite in Rozna, also in Lastovicky, Czech Republic.

Dioptase

$Cu_6Si_6O_{18} \cdot 6\,H_2O$

TRIGONAL ● ●

Properties: C – emerald-green to blue-green; S – light blue-green; L – vitreous to dull; D – transparent to translucent; DE – 3.3; H – 5; CL – good; F – uneven to conchoidal; M – long to short prismatic crystals, granular.
Origin and occurrence: Secondary in the oxidation zone of Cu deposits, associated with other secondary Cu minerals. Beautiful crystals up to 50 mm (2 in) across occur in Tsumeb, Namibia; Altyn Tyube, Kazakhstan; Renneville, Congo. It also comes from the Mammoth mine, Tiger, Arizona, USA.

Milarite

$KCa_2AlBe_2Si_{12}O_{30} \cdot H_2O$

HEXAGONAL ● ●

Properties: C – colorless, white, gray, light green; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.5; H – 5-6; CL – none; F – uneven to conchoidal; M – long prismatic to acicular crystals, granular.
Origin and occurrence: Hydrothermal in the Alpine-type veins, in pegmatites and hydrothermal veins, associated with adularia. Crystals up to 40 mm (1 9/16 in) long come from Jaguaraçu, Minas Gerais, Brazil. It was also found in St. Gotthard, Switzerland; Klein Spitzkopje, Namibia; Valencia mine, Guanajuato, Mexico.

Foitite, 20 mm x, Dobra Voda, Czech Republic

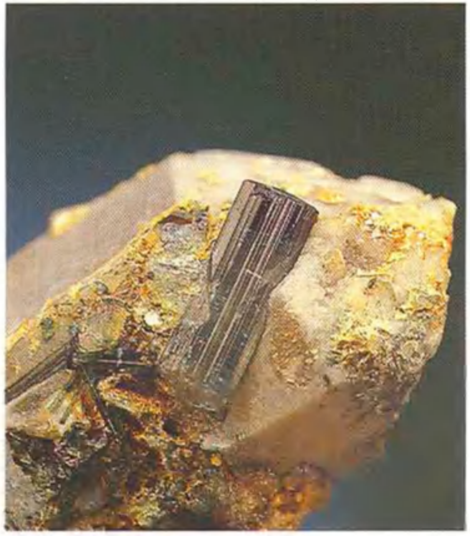

Rossmanite, 10 mm xx, Lastovicky, Czech Republic

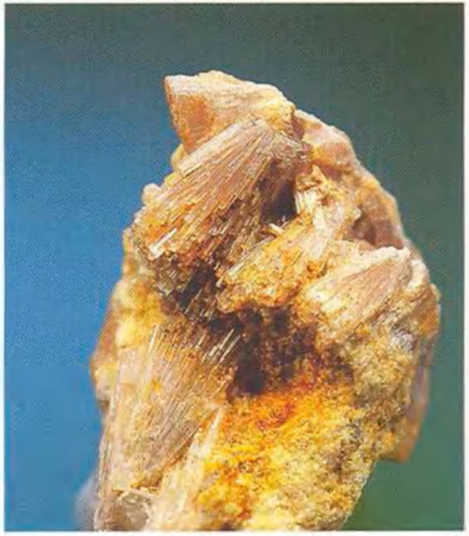

Dioptase, 40 mm, Mindouli, Zair

Sugilite

$KNa_2(Fe,Mn,Al)_2Li_3Si_{12}O_{30}$

HEXAGONAL ●

Properties: C – purple; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.7; H – 6-6.5; CL – none; F – uneven to conchoidal; M – long prismatic to acicular crystals, granular.

Origin and occurrence: Hydrothermal in alkaline syenites, associated with pectolite, albite and aegirine. It occurs in Iwagi Island, Japan and Hotazel, South Africa. *Application:* cut and polished as a gemstone and decorative stone.

Milarite, 22 mm, Jaguaracu, Brazil

Sugilite, 40 mm, Hotazel, South Africa

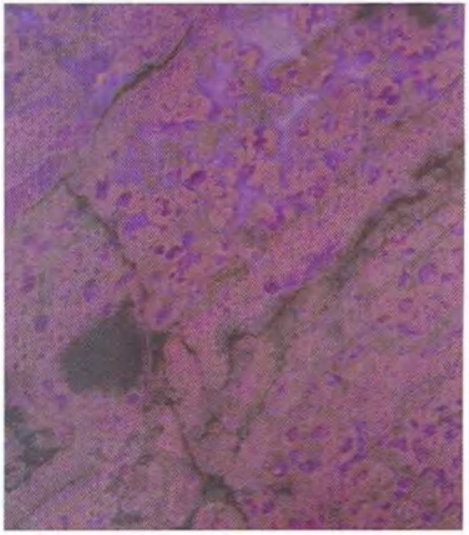

Bronzite, 15 mm, Minas Gerais, Brazil

Enstatite

PYROXENE GROUP

$Mg_2Si_2O_6$

ORTHORHOMBIC ● ● ● ●

Varieties: bronzite

Properties: C – colorless, gray, yellowish, greenish, brown (bronzite); S – white; L – vitreous to dull; D – transparent to opaque; DE – 3.2; H – 5-6; CL – good; F – uneven to conchoidal; M – prismatic crystals, granular.
Origin and occurrence: Magmatic in ultrabasic rocks, gabbros, peridotites and in meteorites; metamorphic in marbles, associated mainly with olivine and pyrope. Known from Bamle, Norway in crystals up to 50 cm (20 in) long. It was originally described from Ruda nad Moravou, Czech Republic. Gemmy crystals up to 20 mm ($^{25}/_{32}$ in) long occur in Brumado, Bahia, Brazil.

Diopside

PYROXENE GROUP

$CaMgSi_2O_6$

MONOCLINIC ● ● ● ● ●

Varieties: chrome diopside, fassaite, jeffersonite

Properties: C – light green, dark green (chrome diopside), colorless, white, gray, brown, rare blue; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.3; H – 5.5-6.5; CL – good; F – uneven to conchoidal; M – long to short prismatic crystals, granular.

Chrome diopside, 5 mm grains, Inagli, Russia

Origin and occurrence: Metamorphic in Ca-rich rocks, skarns, pyroxene gneisses, marbles; magmatic in basic igneous rocks, pegmatites and meteorites; hydrothermal in the Alpine-type veins. Fassaite occurs in skarns, chrome diopside in metamorphic deposits of Cu and Cr; jeffersonite in metamorphic deposits of Mn and Zn. Diopside is a typical rock-forming mineral.

Diopside, 22 mm x, Ala, Italy

associated with plagioclase, grossular and epidote. Well formed crystals are relatively rare. Jeffersonite forms prismatic crystals up to 250 mm (9$^{13}/_{16}$ in) long in Franklin, New Jersey, USA. Crystals in Corrego Setuba, Minas Gerais, Brazil reach up to 30 cm (12 in). Other typical localities are Zillertal, Austria; Nordmarken, Sweden; Orford mine, Quebec, Canada. Fassaite is known from Val di Fassa, Italy. Chrome diopside crystals reach up to 100 mm (4 in) in Outokumpu, Finland and gem rough recently found in Inagli, Yakutia, Russia.

Hedenbergite

PYROXENE GROUP

$CaFeSi_2O_6$

MONOCLINIC ● ● ● ●

Properties: C – dark green, brown-green, brown to black; S – white to gray; L – vitreous to dull; D – transparent to translucent; DE – 3.6; H – 6; CL – good; F – uneven to conchoidal; M – long to short prismatic crystals, granular.

Origin and occurrence: Metamorphic in Ca-rich rocks, like Fe-skarns and pyroxene gneisses; magmatic in some granites and syenites, associated with magnetite, grossular and epidote. Crystals are relatively rare, reaching up to 50 mm (2 in) from Dalnegorsk, Russia and Franklin, New Jersey, USA. Also occurs in Nordmarken, Sweden. Large lamellar aggregates come from skarns in Rio Marina, Elba, Italy.

Hedenbergite, 40 mm, Dalnegorsk, Russia

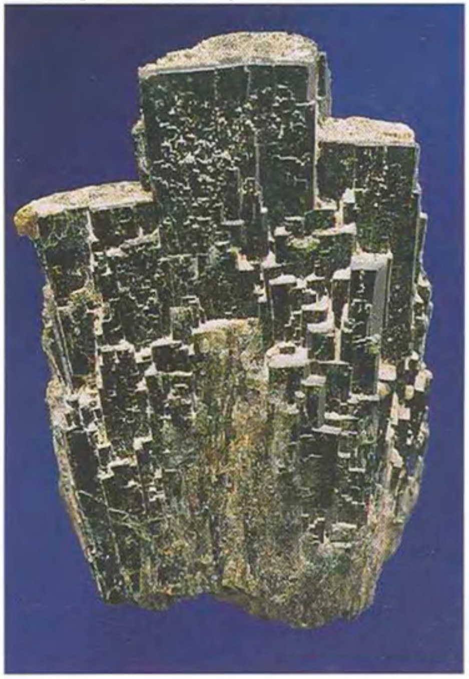

Augite, 17 mm, Firmerich, Germany

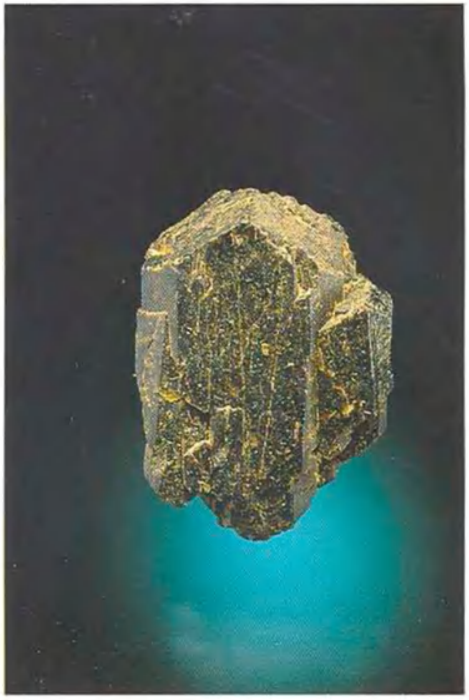

Augite

PYROXENE GROUP

$(Ca,Mg,Fe,Al)(Si,Al)_2O_6$

MONOCLINIC ● ● ● ● ●

Properties: C – dark brown to black; S – gray-green; L – vitreous to dull; D – translucent to opaque; DE – 3.6; H – 6; CL – good; F – uneven to conchoidal; M – short prismatic crystals, granular.

Origin and occurrence: Magmatic in basic rocks (basalts, gabbros, diabases and their tuffs); rare metamorphic in skarns. It is a typical rock-forming mineral, known from many localities. Well formed crystals up to 150 mm (6 in) across occur mainly in volcanic rocks, such as near Lake Clear, Ontario, Canada. Also known from Laacher See, Germany; Lukov and Pa_kapole, Czech Republic, in crystals, up to 50 mm (2 in) in size.

Omphacite, 90 mm, St.Leonhard, Austria

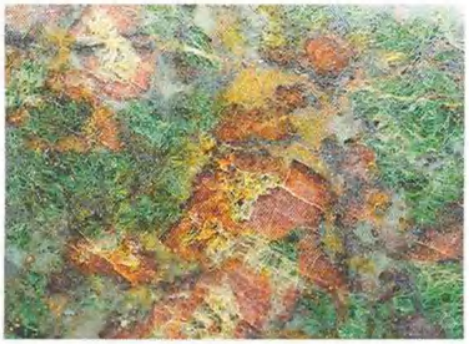

Omphacite

PYROXENE GROUP

$(Ca,Na)(Mg,Fe^{2+},Fe^{3+},Al)(Si,Al)_2O_6$

MONOCLINIC ● ● ● ●

Properties: C – green to dark green; S – gray-white; L – vitreous to dull; D – translucent to opaque; DE – 3.3; H – 5-6; CL – good; F – uneven to conchoidal; M – short prismatic crystals, acicular aggregates, granular. *Origin and occurrence:* Metamorphic in ultrabasic and basic rocks, originated under high-temperature, usually associated with pyrope, diopside and kyanite. It occurs in eclogites and granulites in Rubinberg, Germany; Headsburg, California, USA and elsewhere.

Jadeite, 85 mm, Guerro Negro, Baja California, Mexico

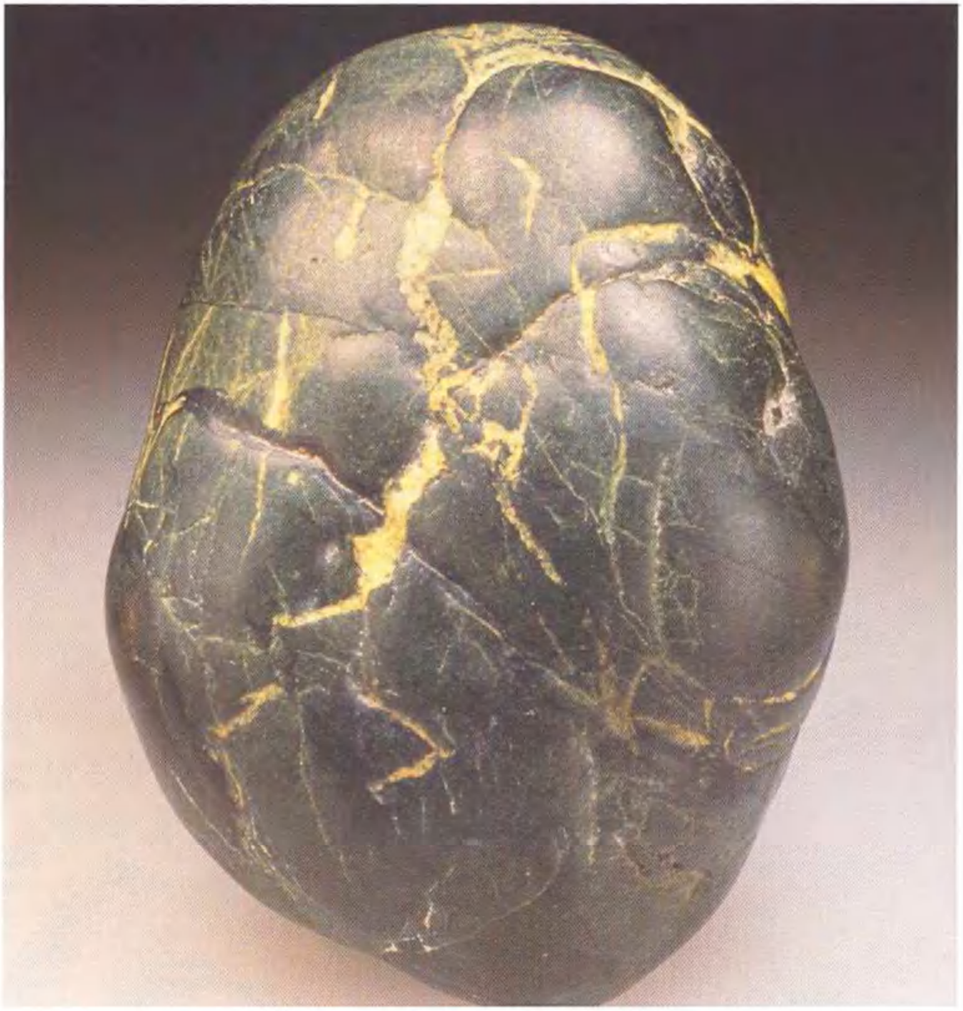

Nephrite, 60 mm, Jordanow, Poland

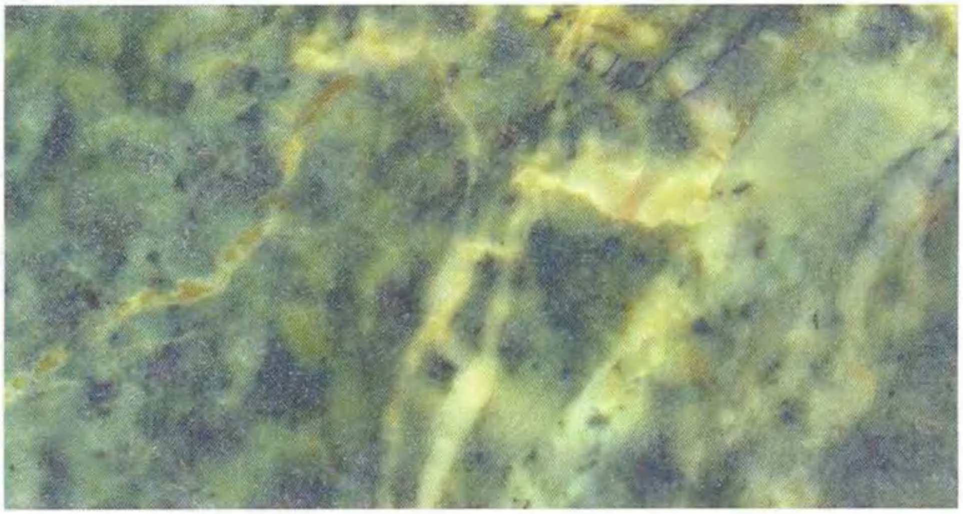

Jadeite

PYROXENE GROUP
$NaAlSi_2O_6$

MONOCLINIC ● ●

Varieties: nephrite

Properties: C – white, lavender to gray, in aggregates also light green (nephrite); S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.2; H – 6; CL – good; F – uneven to conchoidal; M – prismatic crystals, acicular aggregates, granular.
Origin and occurrence: Exclusively metamorphic in strongly metamorphosed rocks; also in placers. Blocks, weighing several tons, are known from Ben Sur, California, USA. It also come from Tawmaw, Burma; New Zealand; Tibet and elsewhere.
Application: as a material for carvings and decorative purposes.

Aegirine

PYROXENE GROUP
$NaFe^{3+}Si_2O_6$

MONOCLINIC ● ● ●

Properties: C – dark green to black-green; S – light yellow-gray; L – vitreous to dull; D – translucent to opaque; DE – 3.6; H – 6; CL – good; F – uneven to conchoidal; M – long prismatic to acicular crystals, acicular aggregates.
Origin and occurrence: Magmatic, mainly in alkaline magmatic rocks (syenites, carbonatites, alkaline granites and their pegmatites); rare hydrothermal in sediments. Well formed prismatic crystals up to 150 mm (6 in) long come from Mount Malosa, Malawi. Crystals up to 30 cm (12 in) occur in Langensundsfjord, Norway. Other localities are Mount Karnasurt, Lovozero massif, Kola Peninsula, Russia and Mont St.-Hilaire, Quebec, Canada.

Aegirine, 77 mm, Mt.Malosa, Malawi

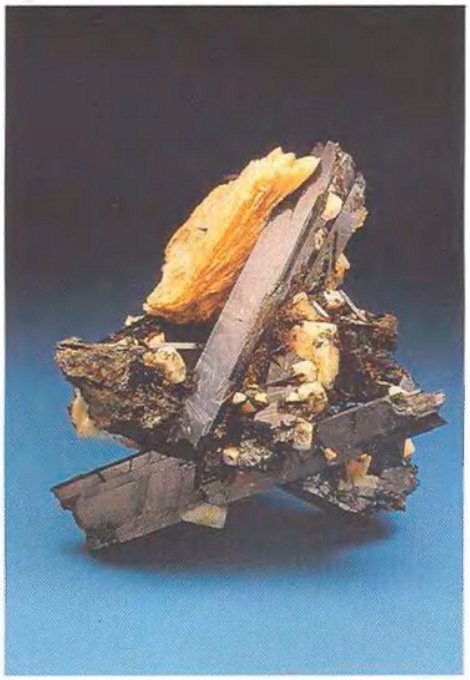

Spodumene, 52 mm x, Kunar, Afghanistan

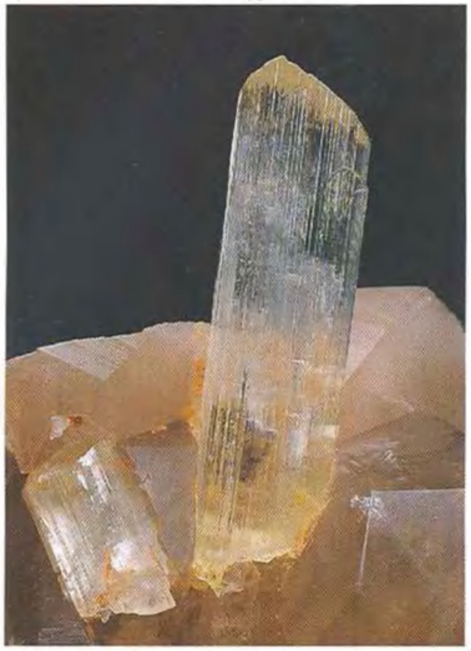

Hiddenite, 35 mm, Adams Property, U.S.A.

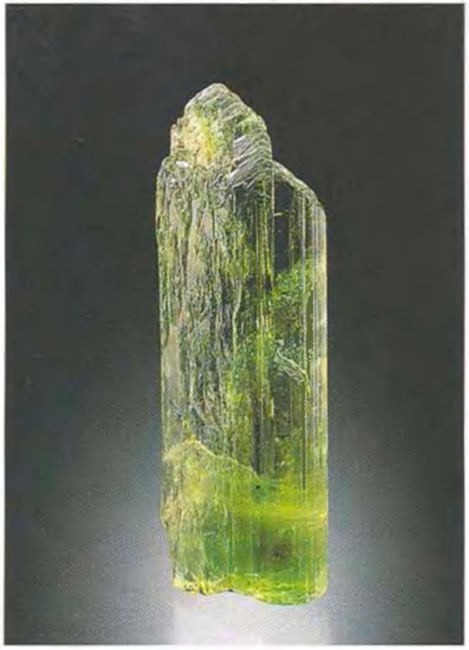

Kunzite, 118 mm, Nuristan, Afghanistan

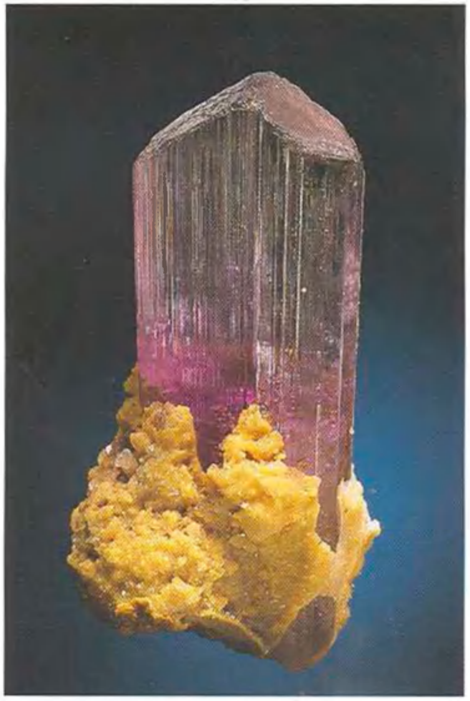

Spodumene

PYROXENE GROUP

$LiAlSi_2O_6$

MONOCLINIC ● ● ●

Varieties: kunzite, hiddenite, triphane

Properties: C – white, gray, yellowish (triphane), green (hiddenite), pink to purple (kunzite); S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.2; H – 6.5-7.5; CL – good; F – uneven to conchoidal; M – long to short prismatic crystals, cleavable aggregates, granular; LU – orange.
Origin and occurrence: Magmatic in granitic pegmatites; hydrothermal in pegmatite cavities. It is known from many localities. Its poorly developed crystals up to 6 m (20 ft) long occur in the Etta mine, Keystone, South Dakota and in Kings Mountain, North Carolina, USA. Transparent kunzite crystals up to 40 cm (15¾ in) long come from Mawi, Laghman, Afghanistan. Kunzite crystals up to 280 mm (11 in) long found in the Pala Chief mine, Pala, California, USA. Cracked kunzite crystals, up to 1 m ($39^{3}/_{8}$ in) long known from Araçuai, Minas Gerais, Brazil. Hiddenite occurs in crystals up to 250 mm ($9^{13}/_{16}$ in) long in Resplendor, Minas Gerais, Brazil. It also comes from the Adams property, North Carolina, USA.
Application: raw material for ceramics, kunzite and hiddenite are cut as gemstones.

Carpholite, 70 mm, Horni Slavkov, Czech Republic

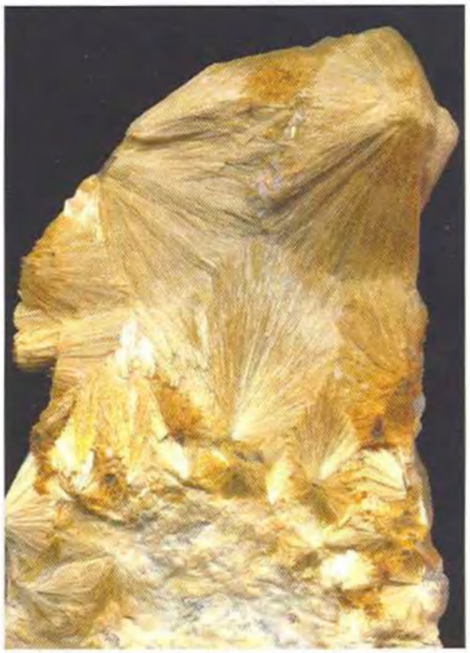

Carpholite

$MnAl_2Si_2O_6(OH)_4$

ORTHORHOMBIC ● ●

Properties: C – various hues of yellow; S – white; L – vitreous to dull; D – translucent; DE – 3.0; H – 5-5.5; CL – good; F – uneven to conchoidal; M – acicular crystals and their aggregates.
Origin and occurrence: Hydrothermal in veins, cross-cutting greisens, associated with fluorite, quartz and cassiterite; also in metamorphic rocks. It was described from Horni Slavkov, Czech Republic, where it forms acicular crystals up to 10 mm (⅜ in) long and radial aggregates. It is also known from Meuville, Belgium and Wippra, Germany.

Lorenzenite, 20 mm xx, Flora Mt., Kola, Russia

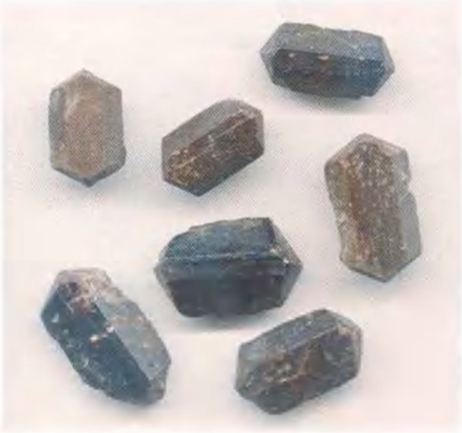

Lorenzenite

$Na_2Ti_2Si_2O_9$

ORTHORHOMBIC ● ●

Properties: C – brown to black; S – yellowish; L – vitreous to dull; D – translucent to opaque; DE – 3.4; H – 6; CL – good; F – uneven to conchoidal; M – prismatic crystals, columnar aggregates, granular.
Origin and occurrence: Magmatic in alkaline syenites and their pegmatites, associated with astrophyllite, nepheline and aegirine. Crystals up to 80 mm (3⅛ in) long come from Mount Flora, Lovozero massif, Kola Peninsula, Russia. Other localities are Narssarssuk, Greenland and Mont St.-Hilaire, Quebec, Canada.

Ajoite

$(K,Na)Cu_7AlSi_9O_{24}(OH)_6 \cdot 3\,H_2O$

TRICLINIC ●

Properties: C – blue-green; S – light green; L – vitreous to dull; D – translucent to opaque; DE – 3.0; H – not determined; CL – not determined; F – uneven to conchoidal; M – prismatic crystals, massive.
Origin and occurrence: Secondary in Cu deposits, associated with shattuckite. It occurs rarely as small crystals in the New Cornelia mine, Ajo, Arizona, USA. It is also known as inclusions in quartz crystals in the Messina mine, Transvaal, South Africa.

Ajoite, 60 mm, Ajo, U.S.A.

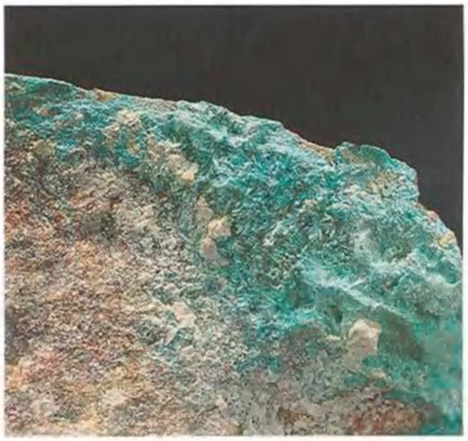

Holmquistite, 60 mm, Lac Malartic, Canada

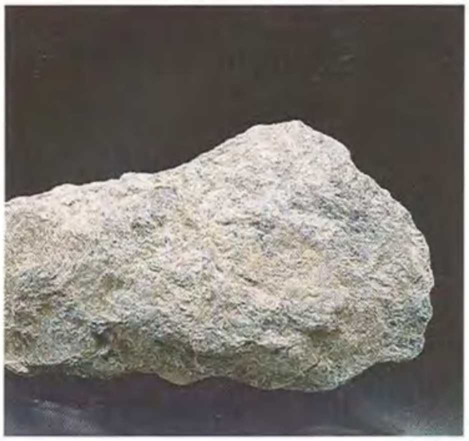

Antophyllite

AMPHIBOLE GROUP

$Mg_7Si_8O_{22}(OH,F)_2$

ORTHORHOMBIC ● ● ● ●

Properties: C – white, light brown, yellow, light green; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.4; H – 5.5-6; CL – good; F – uneven to conchoidal; M – long prismatic crystals, columnar and radial aggregates, granular.
Origin and occurrence: Metamorphic in gneisses, serpentinites and at the contact of serpentinites and pegmatites, usually with actinolite or tremolite and cordierite. Crystals up to 150 mm (6 in) long come from the Marbridge No.1 mine, Quebec, Canada. It is also known from Bodenmais, Germany; Snarum, Sweden and Hermanov, Czech Republic.

Anthophyllite, 60 mm, North Carolina, U.S.A.

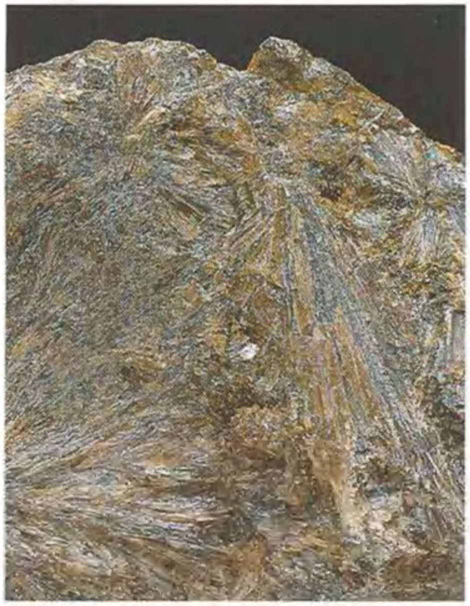

Holmquistite

AMPHIBOLE GROUP

$Li_2Mg_3Al_2Si_8O_{22}(OH,F)_2$

ORTHORHOMBIC ● ● ●

Properties: C – blue, purple, gray, black; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.0; H – 5.5-6; CL – good; F – uneven to conchoidal; M – acicular and prismatic crystals, fibrous aggregates, granular.
Origin and occurrence: Hydrothermal at the contacts between complex Li-bearing pegmatites and amphibolites, sometimes associated with biotite. It occurs in Greenbushes, Western Australia, Australia where its fibers reach up to 180 mm ($7\frac{1}{16}$ in) in length. It is also known from Uto, Sweden; Manono, Zaire and Brandbrucken, Austria.

Manganogedrite

AMPHIBOLE GROUP

$Mn_2Fe_5Si_8O_{20}(OH)_2$

MONOCLINIC ● ●

Properties: C – gray, dark green, brown, greenish; S – white; L – vitreous to dull; D – translucent to opaque; DE – 3.5; H – 5-6; CL- good; F – uneven to conchoidal; M – columnar, acicular and radial aggregates, granular.
Origin and occurrence: Metamorphic in contact and regionally metamorphosed Mn rich rocks, associated with chlorite and magnetite. It comes from Dannemora, Sweden and elsewhere.

Manganogedrite, 70 mm, Franz Joseph Iceberg, New Zealand

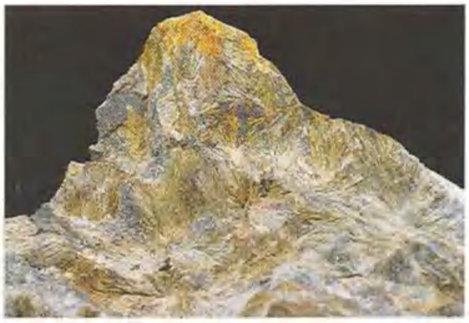

Tremolite, 37 mm, Maricopa Co., Arizona, U.S.A.

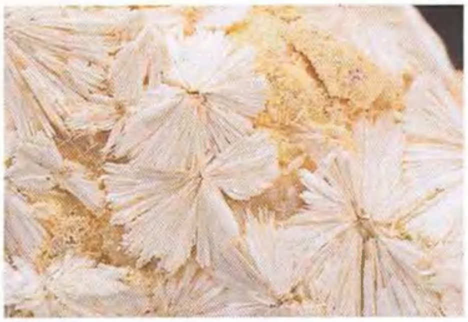

Tremolite

AMPHIBOLE GROUP

$Ca_2Mg_5Si_8O_{20}(OH)_2$

MONOCLINIC ● ● ● ● ●

Properties: C – white, gray, greenish, green, brown, pink; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.9; H – 5-6; CL – good; F – uneven to conchoidal; M – columnar, acicular and radial aggregates, granular.

Origin and occurrence: Metamorphic in contact and regionally metamorphosed rocks, dolomites and ultrabasic rocks; hydrothermal in the Alpine-type veins, typically associated with diopside, talc, dolomite and calcite. It is a typical rock-forming mineral, known from many localities. Prismatic crystals up to 40 cm (15¾ in) long come from Brumado, Bahia, Brazil. It occurs also in Campolungo, Switzerland; Zillertal, Austria; Gouverneur, New York, USA and elsewhere.

Actinolite

AMPHIBOLE GROUP

$Ca_2(Mg,Fe)_5Si_8O_{20}(OH)_2$

MONOCLINIC ● ● ● ● ●

Properties: C – light green to almost black; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.2; H – 5-6; CL – good; F – uneven to conchoidal; M – columnar, acicular and radial aggregates, granular.

Origin and occurrence: Metamorphic in contact and regionally metamorphosed rocks, also in dolomites and some basic rocks (amphibolites, shales). It is a typical rock-forming mineral, associated with anthophylite, chlorite, talc, dolomite and calcite. It is known from many localities where it forms columnar aggregates up to 250 mm ($9\frac{13}{16}$ in) long, as in Knappenwand and Zillertal, Austria; Val Malenco, Italy; Brumado, BahRa, Brazil and Sobotin, Czech Republic.

Actinolite, 30 mm xx, Austria

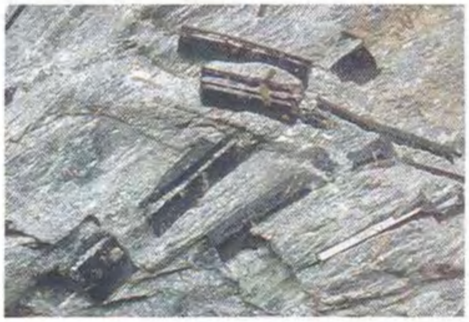

Edenite

AMPHIBOLE GROUP

$NaCa_2(Mg,Fe)_5Si_7AlO_{22}(OH)_2$

MONOCLINIC ● ● ● ●

Properties: C – white, gray to dark green; S – white; L – vitreous to dull; D – transparent, translucent to opaque; DE – 3.1; H – 5-6; CL – good; F – uneven to conchoidal; M – prismatic crystals, granular.

Origin and occurrence: Metamorphic in regionally metamorphosed basic rocks and marbles; magmatic in diorites and gabbros. Typical rock-forming mineral, its crystals up to 40 mm ($1\frac{9}{16}$ in) long come from Edenville, New York, USA and Bancroft, Ontario, Canada.

Edenite, 48 mm, Wilberforce, Canada

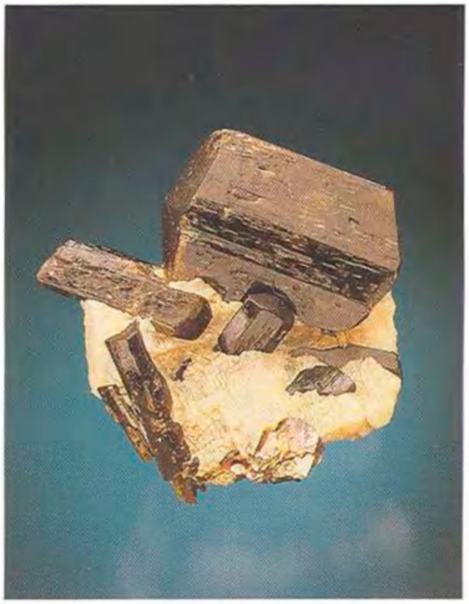

Pargasite

AMPHIBOLE GROUP

$NaCa_2(Mg,Fe)_4AlSi_6Al_2O_{22}(OH)_2$

MONOCLINIC ● ● ● ●

Properties: C – light brown, green-blue, brown to black-brown; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.1; H – 5-6; CL – good; F – uneven to conchoidal; M – prismatic crystals, granular, massive.
Origin and occurrence: Metamorphic in regionally metamorphosed basic rocks, marbles and skarns; magmatic in diorites and gabbros; typical rock-forming mineral. Crystals up to 80 mm ($3^{1}/_{8}$ in) across come from the Jensen quarry, Riverside, California, USA; Pargas, Finland; Hunza, Pakistan.

Common Amphibole

AMPHIBOLE GROUP

$(Ca,Na)_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$

MONOCLINIC ● ● ● ● ●

Properties: C – dark green, brown to black; S – gray; L – vitreous to dull; D – translucent to opaque; DE – 3.4; H – 5-6; CL – good; F – uneven to conchoidal; M – short prismatic crystals, columnar aggregates, granular.
Origin and occurrence: Metamorphic in basic rocks, as amphibolites and shales; magmatic in some igneous rocks, as syenites, diorites, andesites and basalts. Typical rock-forming mineral, known from many localities. Large crystals up to 1 m ($39^{3}/_{8}$ in) long come from Silver Crater, Ontario, Canada. It is also known from Zillertal, Austria; Lukov, Czech Republic and elsewhere.

Common Amphibole, 50 mm x, Lukov, Czech Republic

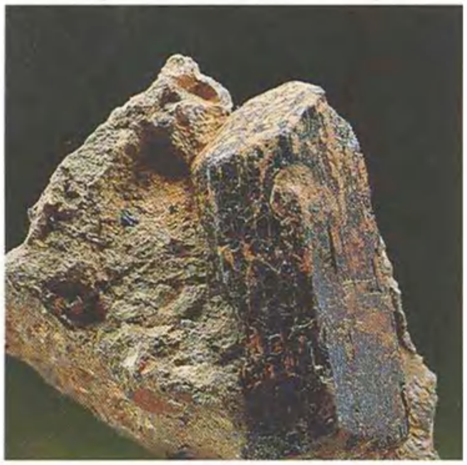

Richterite

AMPHIBOLE GROUP

$Na_2Ca(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$

MONOCLINIC ● ● ●

Properties: C – brown, yellow, dark red, dark green; S – gray; L – vitreous to dull; D – transparent to translucent; DE – 3.1; H – 5-6; CL – good; F – uneven to conchoidal; M – long prismatic crystals, columnar aggregates, granular.
Origin and occurrence: Magmatic in alkaline rocks, as trachytes and alkaline granites; rare metamorphic in some metamorphosed rocks, as skarns and marbles. Crystals up to 100 mm (4 in) long come from Wilberforce, Ontario, Canada and Langban, Sweden.

Pargasite, 70 mm, Limberg, Parainen, Finnland

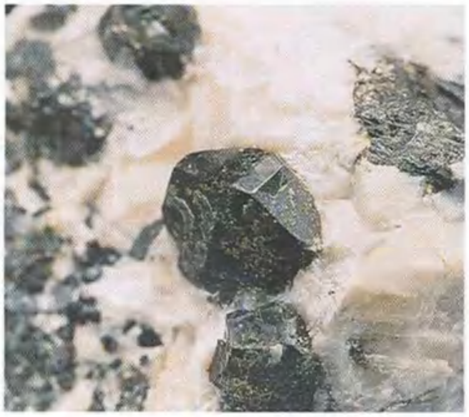

Richterite, 40 mm, Wilberforce, Canada

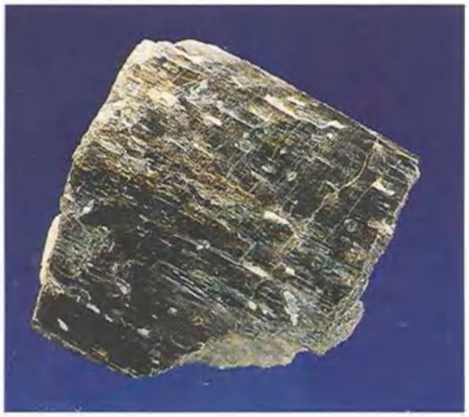

Riebeckite, 45 mm, Griqualand, South Africa

Riebeckite

AMPHIBOLE GROUP

$Na(Fe^{2+},Mg)_3Fe^{3+}{}_2Si_8O_{22}(OH)_2$

MONOCLINIC ● ● ● ●

Varieties: crocidolite (tiger's eye)

Properties: C – dark blue to black, crocydolite – gray-blue; S – white; L – vitreous to dull; D – translucent to opaque; DE – 3.4; H – 5; CL – perfect; F – uneven to conchoidal; M – long prismatic crystals, acicular to fibrous aggregates.
Origin and occurrence: Magmatic in alkaline rocks, as granites, syenites and rhyolites; metamorphic in regionally metamorphosed Fe rich shales. Large crystals up to 150 mm (6 in) long come from Khangay, Mongolia. Crocidolite is famous from Griqualand, South Africa.

Wollastonite, 44 mm, Crestmore, U.S.A.

Aenigmatite, 40 mm xx, Eveslogchorr, Kola, Russia

Aenigmatite

$Na_2Fe_5TiSi_6O_{20}$

TRICLINIC ● ●

Properties: C – black; S – red-brown; L – submetallic to dull; D -almost opaque; DE – 3.8; H – 5.5; CL – perfect; F – uneven to conchoidal; M – long prismatic crystals, columnar aggregates, granular.
Origin and occurrence: Magmatic in alkaline syenites and volcanic rocks, associated with aegirine and arfvedsonite. It occurs in Julianehab, Greenland; Lipari Island, Italy and elsewhere.

Wollastonite

$Ca_3Si_3O_9$

TRICLINIC ● ● ● ●

Properties: C - white, gray, light greenish, pink; S – white; L – vitrous to dull; D – transparent to translucent; DE – 3.0; H – 4.5-5; CL – good; F – uneven to conchoidal; M – tabular to short prismatic crystals, columnar and radial aggregates, granular; LU - orange.
Origin and occurrence: Metamorphic mainly in contact metamorphosed rocks, as marbles, skarns, less common in pyroxene gneisses and quartzites, associated with grossular, diopside and vesuvianite. Columnar and acicular aggregates up to 180 mm ($7^1/_{16}$ in) long occur in the Strickland quarry, Connecticut, USA. It also come from Crestmore, California, USA; Ciclova, Romania and Zulova , Czech Republic. Short prismatic crystals up to 30 cm (12 in) across are known from the Santa Fe mine, Chiapas, Mexico.

Bustamite, 20 mm xx, Broken Hill, Australia

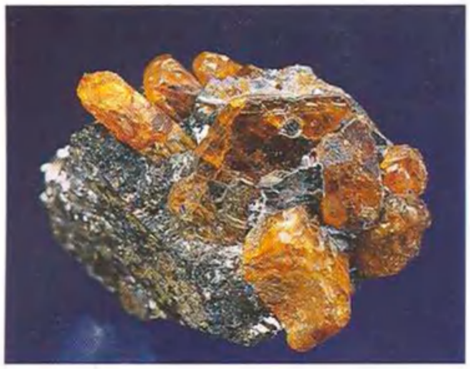

Bustamite

(Mn,Ca)$_3$Si$_3$O$_9$

TRICLINIC ● ● ●

Properties: C – pink to red-brown; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.4; H – 5.5-6.5; CL – good; F – uneven to conchoidal; M – tabular crystals, acicular aggregates, massive.
Origin and occurrence: Metamorphic or hydrothermal in Mn rich metamorphic rocks or skarns. It is associated with rhodonite and other Mn silicates in Franklin, New Jersey, USA; Langban, Sweden; Broken Hill, New South Wales, Australia.

Pectolite, 70 mm, Zelechovske udolí, Czech Republic

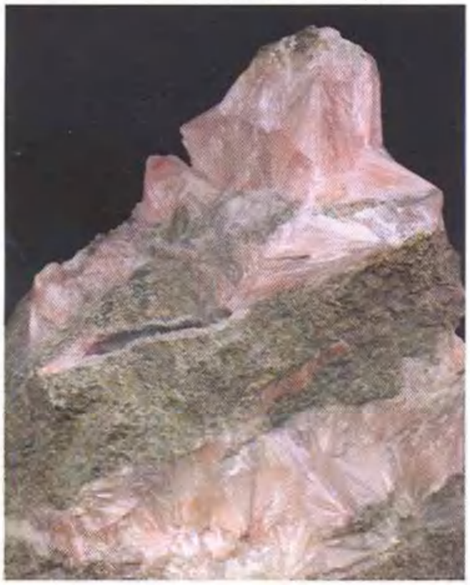

Pectolite

Ca$_2$NaSi$_3$O$_8$(OH)

TRICLINIC ● ● ●

Properties: C – white, pinkish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.9; H – 4.5-5; CL – good; F – uneven to conchoidal; M B acicular and radial aggregates; LU – locally yellow to orange.
Origin and occurrence: Hydrothermal in basalt cavities, less frequently along the cracks in marbles, associated with zeolites. Classic localities are West Paterson, New Jersey, USA, where it forms acicular spherical aggregates up to 180 mm (7$^1/_{16}$ in) across; also Monte Baldo, Italy; Zelechovske udolí, Czech Republic. Prismatic crystals up to 50 mm (2 in) long come from Mont St.-Hilaire, Quebec, Canada.

Serandite

Mn$_2$NaSi$_3$O$_8$(OH)

TRICLINIC ●

Properties: C – pink, red; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.9; H – 4.5-5; CL – good; F – uneven to conchoidal; M – tabular and prismatic crystals, granular.
Origin and occurrence: Hydrothermal in cavities of igneous rocks (alkaline syenite, carbonatite) together with aegirine and analcime. Perfect pink crystals up to 200 mm (7$^7/_8$ in) long come from Mont St.-

Serandite, 25 mm, Mont St.-Hilaire, Canada

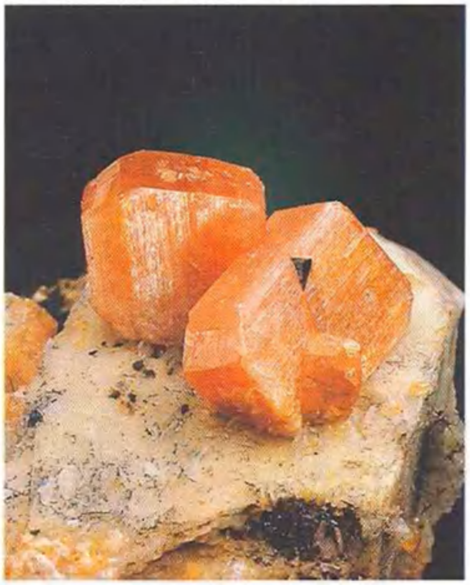

Hilaire, Quebec, Canada; crystals up to 60 mm (2 1/8 in) long found in the Yubileinaya dike, Mount Karnasurt, Lovozero massif, Kola Peninsula, Russia.

Charoite

$(K,Sr,Ba)(Ca,Na)_2(Si,Al)_4O_{10}(OH,F)$

TRICLINIC ● ●

Properties: C – purple; S – white; L – vitreous to dull; D – translucent to opaque; DE – 2.6; H – 5-6; CL – good; F – uneven; M – fibrous aggregates, massive.
Origin and occurrence: Hydrothermal in alkaline igneous rocks, associated with aegirine and nepheline. Rich aggregates occur in Sirenevyi Kamen, Chara river basin, Murun massif, Yakutia, Russia.
Application: cut and polished as decorative stone.

Agrellite

$NaCa_2Si_4O_{10}F$

TRICLINIC ●

Properties: C – gray-white to greenish; S – white; L – vitreous, dull to pearly; D – transparent to translucent; DE – 2.9; H – 5.5; CL – good; F – uneven; M – long prismatic crystals, granular.
Origin and occurrence: Metamorphic in alkaline gneisses. It occurs as prismatic crystals up to 100 mm (4 in) long in the Kipawa river basin, Quebec, Canada.

Okenite

$CaSi_2O_4(OH)_2 \cdot H_2O$

TRICLINIC ● ●

Properties: C – white, yellowish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.3; H – 4.5-5; CL – good; F – uneven to conchoidal; M B blade-shaped crystals, acicular crystals and their spherical aggregates.

Agrellite, 120 mm, Kipawa, Canada

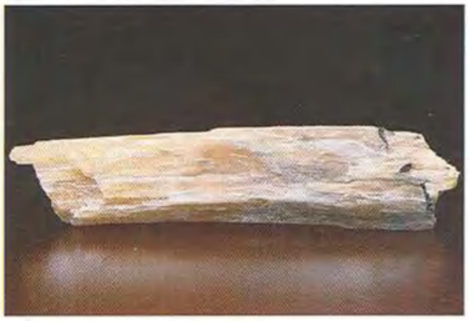

Charoite, 50 mm, Sirenevyi Kamen, Russia

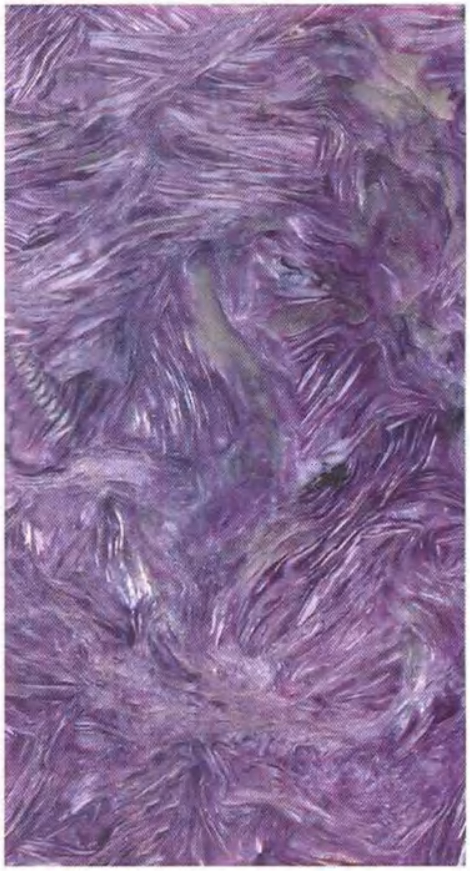

Origin and occurrence: Hydrothermal in basalt cavities together with zeolites. Rich acicular spherical aggregates up to 80 mm (3 1/8 in) in diameter come from basalt cavities in the vicinity of Poona, India; also known from Faeroe Islands.

Okenite, 125 mm, Mumbai, India

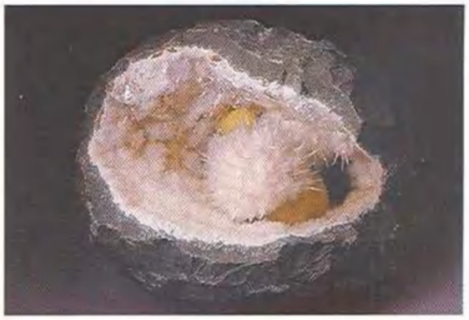

Xonotlite, 20 mm vein, Stare Ransko, Czech Republic

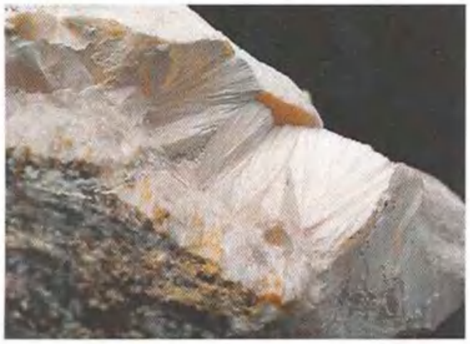

Xonotlite

$Ca_6Si_6O_{17}(OH)_2$

MONOCLINIC ● ●

Properties: C – white, pinkish, gray; S – white; L – vitreous, dull to pearly; D – transparent to translucent; DE – 2.7; H – 6.5; CL – good; F – uneven to conchoidal; M – acicular to fibrous aggregates, massive.
Origin and occurrence: Hydrothermal in cavities of basic and ultrabasic rocks and in the Alpine-type veins, associated with calcite and zeolites; rare metamorphic in skarns and in contact metamorphosed marbles. It comes from Tetela de Xonotla, Puebla, Mexico; Crestmore, California, USA; Mihara mine, Japan. It is was also found in Stare Ransko, Czech Republic.

Elpidite

$Na_2ZrSi_6O_{15} \cdot 3\ H_2O$

ORTHORHOMBIC ● ●

Properties: B – colorless, yellowish, red; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.6; H – 5.5-6.5; CL – good; F – uneven to conchoidal; M – long prismatic crystals, fibrous aggregates.
Origin and occurrence: Hydrothermal in albitized parts of alkaline pegmatites, associated with albite and aegirine. Perfect crystals up to 30 cm (12 in) long come from Tarbagatay, Kazakhstan. Crystals up to 200 mm (7^7/$_8$ in) long found at Mont St.-Hilaire, Quebec, Canada. Also known from Khan Bogdo, Gobi desert, Mongolia; Umbozero mine on Mount Alluaiv, Lovozero massif, Kola Peninsula, Russia.

Elpidite, 128 mm, Mont St.-Hilaire, Canada

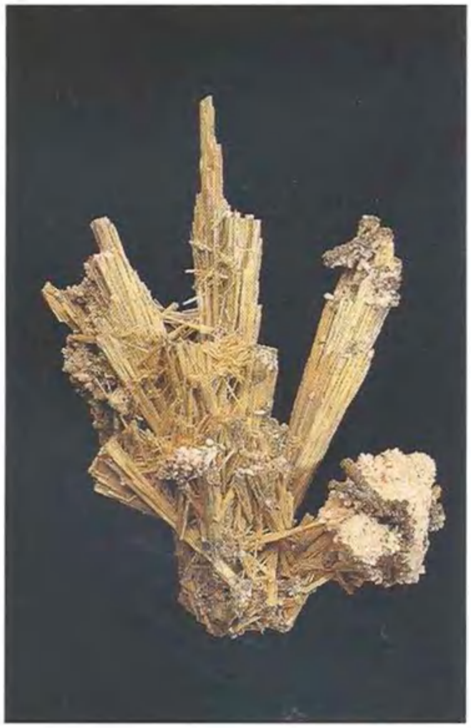

Rhodonite, 35 mm x, Broken Hill, Australia

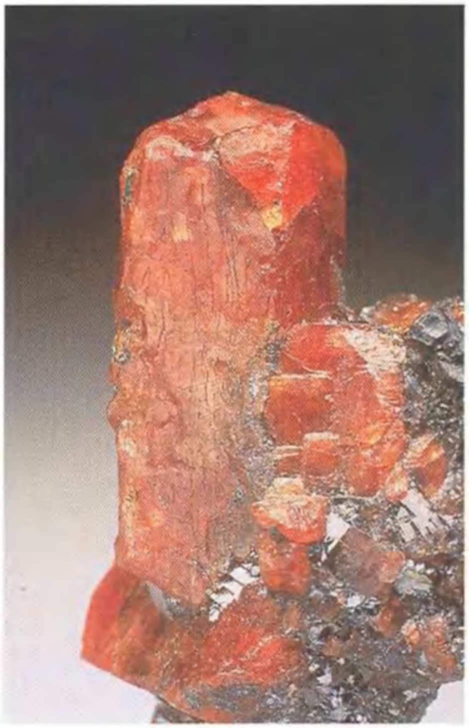

Rhodonite, 70 mm, Maloye Sedelnikovo, Ural Mts., Russia

Rodonite

$CaMn_4Si_3O_9$

TRICLINIC ● ● ●

Properties: C – pink, red, red-brown, gray; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.7; H – 5.5-6.5; CL – good; F – uneven to conchoidal; M – tabular crystals, granular, massive.
Origin and occurrence: Metamorphic in Mn-rich rocks, hydrothermal in ore veins, associated with spessartine and Mn oxides. Perfect crystals up to 200 mm (7⅞ in) long come from Franklin, New Jersey, USA; also from Broken Hill, New South Wales, Australia.

Granular and massive aggregates occur in Langban, Sweden and in Maloye Sidelnikovo, Ural mountains, Russia.

Application: cut and polished as a decorative stone.

Babingtonite

$Ca_2Fe^{2+}Fe^{3+}Si_5O_{14}(OH)$

TRICLINIC ● ●

Properties: C – green-black to black-brown; S – green-gray; L – vitreous to dull; D – translucent to opaque; DE – 3.3; H – 5. 5-6; CL – good; F – uneven to conchoidal; M – short prismatic crystals, granular.
Origin and occurrence: Hydrothermal along the cracks in rocks, associated with prehnite, adularia and epidote.

Well-formed crystals about 20 mm (25/32 in) across are known from Arendal, Norway. Other localities are Westfield, Massachusetts, USA; Baveno, Italy.

Babingtonite, 5 mm x, Mumbai, India

Kinoite

$Ca_2Cu_2Si_3O_8(OH)_4$

MONOCLINIC ●

Properties: C – blue; S – light blue; L – vitreous to dull; D – transparent to translucent; DE – 3.2; H – 5; CL B perfect; F – uneven to conchoidal; M – prismatic crystals, granular.
Origin and occurrence: Hydrothermal along cracks in rocks, associated with apophyllite and copper. Small crystals were found in the Christmas mine, Santa Rita mountains, Arizona, also in the Kearsarge vein, Keweenaw Peninsula, Michigan, USA.

Inesite

$Ca_2Mn_7Si_{10}O_{28}(OH)_2 . 5 H_2O$

TRICLINIC ● ●

Properties: C – pink, brown; S – white; L – vitreous to dull; D – translucent; DE – 3.0; H – 5.5; CL – good; F – uneven to conchoidal; M – short prismatic and tabular crystals, columnar and radial aggregates, granular.
Origin and occurrence: Hydrothermal in ore veins, associated with rhodochrosite, rhodonite and calcite. Rich aggregates and well-formed crystals about 10 mm ($^{3}/_{8}$ in) across found in Langban, Sweden; also in Hale Creek, California, USA; Broken Hill, New South Wales, Australia. Its spherical aggregates up to 30 mm ($1^{3}/_{16}$ in) in diameter are known from the Wessels mine, Kuruman, South Africa.

Neptunite

$KNa_2LiFe_2Ti_2Si_9O_{22}$

MONOCLINIC ● ●

Properties: C – dark brown to black; S – red-brown; L – vitreous to submetallic; D – translucent to opaque; DE – 3. 2; H – 5-6; CL – good; F – uneven to conchoidal; M – long prismatic crystals, granular.
Origin and occurrence: Hydrothermal in veins, associated with natrolite, benitoite and eudialyte. Well-formed prismatic crystals up to 80 mm ($3^{1}/_{8}$ in) long come from the Benitoite Gem mine, San Benito Co., California, USA. It is also known from Mont St.-Hilaire, Quebec, Canada and Narssarssuk, Greenland.

Epididymite

$NaBe_2Si_3O_7(OH)$

ORTHORHOMBIC ● ●

Properties: C – white, gray, yellowish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.6; H – 6-7; CL – good; F – uneven to conchoidal;

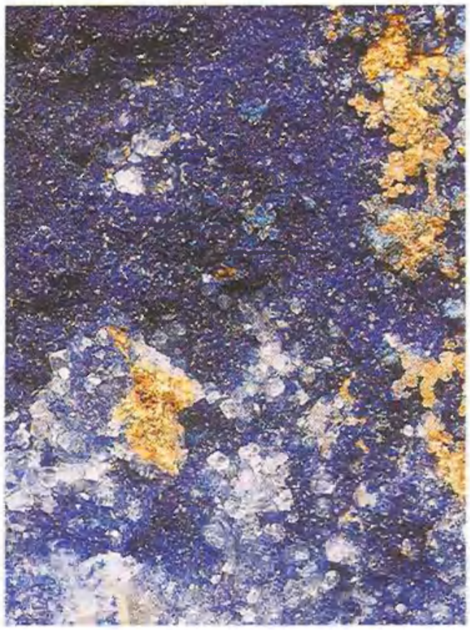

Kinoite, 36 mm, Christmas Mine, U.S.A.

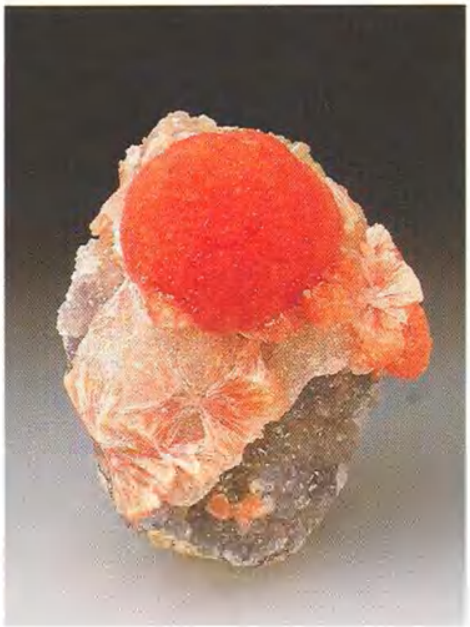

Inesite, 50 mm, Kuruman, South Africa

Neptunite, 28 mm, San Benito Co., U.S.A.

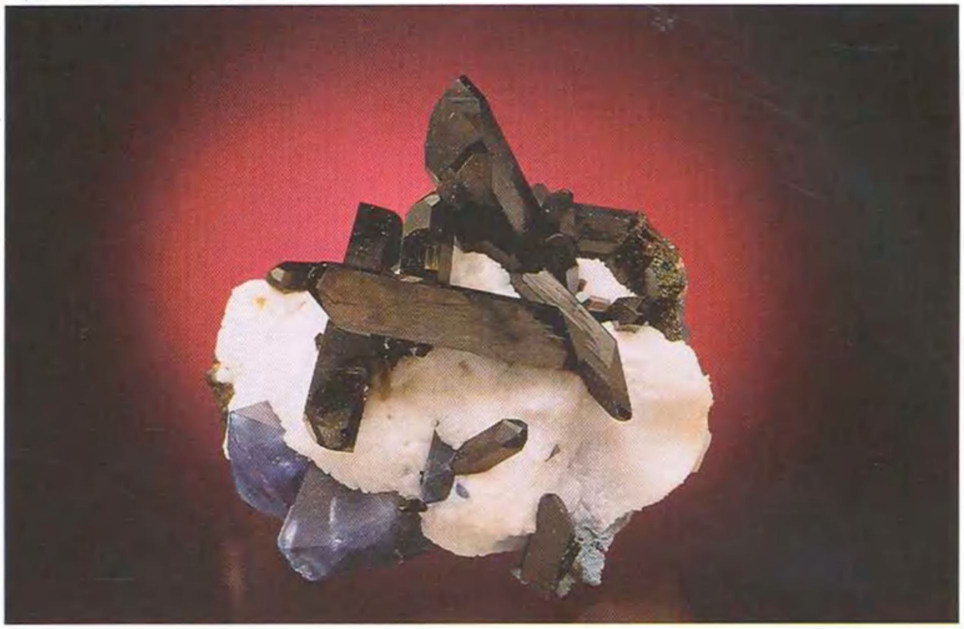

M – tabular crystals, lamellar aggregates, granular. *Origin and occurrence:* Hydrothermal in cavities of alkaline pegmatites, associated with zeolites. Tabular crystals up to 60 mm (2$^{3}/_{8}$ in) across come from Mount Malosa, Malawi. It is also known from Langesundsfjord, Norway; Mont St.-Hilaire, Quebec, Canada; Narssarssuk, Greenland.

Bavenite, 40 mm, Yermolayevskoye, Russia

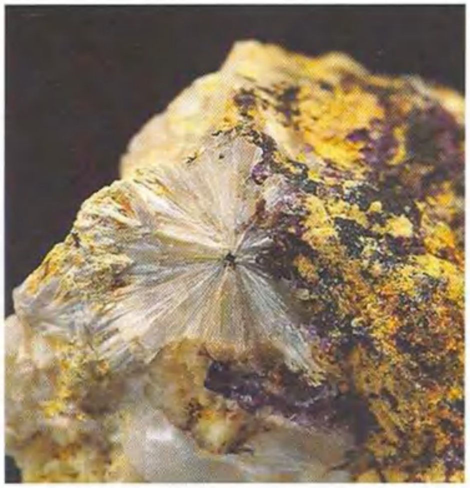

Bavenite

$Ca_4Al_2Be_2Si_9O_{26}(OH)_2$

ORTHORHOMBIC ● ● ●

Properties: C – white, yellowish, pinkish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.8; H – 5.5; CL – good; F – uneven to conchoidal; M – prismatic to tabular crystals, radial and lamellar aggregates. *Origin and occurrence:* Hydrothermal in pegmatic cavities with albite: typically produced by beryl replacement in pegmatites or helvite replacement in skarns. Found in Baveno, Italy with crystals up to 20 mm ($^{25}/_{32}$ in) across. Also known from Strzegom, Poland. Crystals up to 4 mm ($^{5}/_{32}$ in) across found in the Hewitt quarry, USA.

Epididymite, 70 mm, Apatity, Kola, Russia

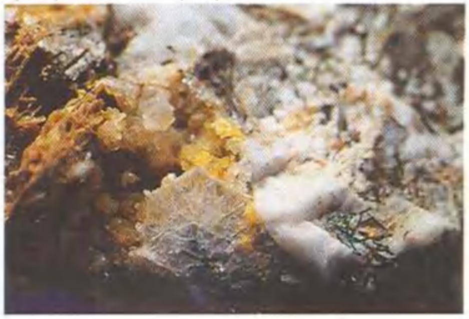

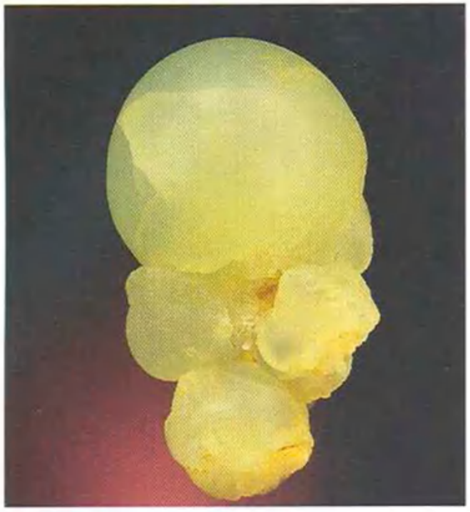

Prehnite, 28 mm, Brandberg, Namibia

Prehnite

$Ca_2Al_2Si_3O_{10}(OH)_2$

ORTHORHOMBIC ● ● ● ●

Properties: C – white, greenish to green, yellow, gray; S – white; L – vitreous; PS – transparent to translucent; DE – 2.9; H – 6-6.5; CL – good; F – uneven to conchoidal; M – tabular to prismatic crystals, usually forming botryoidal or spherical aggregates, granular.
Origin and occurrence: Hydrothermal in basalt cavities and in the Alpine-type veins, commonly associated with calcite, albite, epidote and zeolites. Rich aggregates are known from West Paterson, New Jersey, USA; Val di Fassa, Italy; Poona, India.

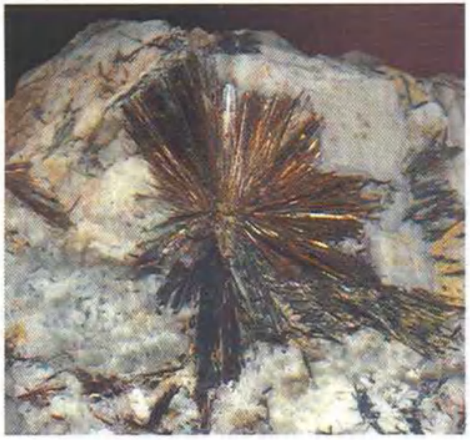

Astrophyllite, 30 mm xx, Khibiny Massif, Kola, Russia

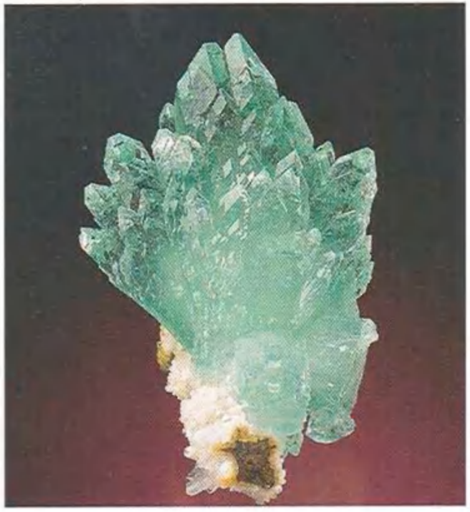

Fluorapophyllite, 47 mm, Poona, India

Crystals up to 45 mm (1¾ in) across found in Copper Valley, Brandberg, Namibia, Asbestos, Quebec, Canada and Talnakh, Siberia, Russia.

Astrophyllite

$(K,Na)_3(Fe,Mn)_7Ti_2Si_8O_{24}(O,OH)_7$

TRICLINIC ● ●

Properties: C – various hues of yellow; S – white; L – vitreous to dull; D – transparent to translucent; DE – 3.3; H – 3; CL – good; F – uneven to conchoidal; M – long prismatic crystals, bladed aggregates.
Origin and occurrence: Magmatic in alkaline pegmatites. Crystals and their radial aggregates reaching up to 100 mm (4 in) come from Mount Eveslogchorr, Khibiny massif, Kola Peninsula., Russia. It is also known from Mont St.-Hilaire, Quebec, Canada.

Fluorapophyllite

$KCa_4Si_8O_{20}(F,OH) . 8\ H_2O$

TETRAGONAL ● ● ●

Properties: C – white, greenish yellowish, pinkish; S – white; L – greasy to pearly; D – transparent to translucent; DE – 2.4; H – 4.5-5; CL – perfect; F – uneven; M – prismatic and tabular crystals, lamellar aggregates, massive.
Origin and occurrence: Hydrothermal in cavities in volcanic rocks, along the cracks in the Alpine-type veins, in ore veins and pegmatites. Well-formed crystals up to 100 mm (4 in) long are known from Jalgaon and Poona, India; Centreville and Fairfax,

Pyrophyllite, 37 mm, California, U.S.A.

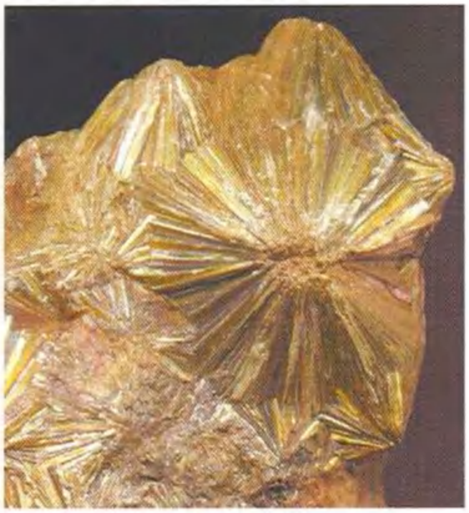

Virginia, USA. Other localities are St. Andreasberg, Germany; Bento Gonçalves, Rio Grande do Sul, Brazil.

Pyrophyllite

$Al_2Si_4O_{10}(OH)_2$

MONOCLINIC ● ● ● ●

Varieties: agalmatolite

Properties: C – white, greenish, yellow, gray; S – white; L – greasy to pearly; D – translucent to transparent; DE – 2.8; H – 1-2; CL – perfect; F – uneven; M B foliated and lamellar aggregates, massive (agalmatolite), radial to acicular aggregates.
Origin and occurrence: Metamorphic in Al-rich rocks, together with andalusite and kyanite; hydrothermal in veins with quartz and micas. Rich foliated and radial aggregates and poorly-formed crystals up to 10 mm ($^3/_8$ in) across are known from Zermatt, Switzerland; Berezovsk, Ural mountains, Russia and the Champion mine, California, USA.
Application: heat-resistant material, agalmatolite as decorative stone.

Talc

$Mg_3Si_4O_{10}(OH)_2$

MONOCLINIC ● ● ● ● ●

Properties: C – white, greenish, yellow, pinkish, gray; S – white; L – greasy to pearly; D – transparent to translucent; DE – 2.8; H – 1; CL – perfect; F – uneven; M – tabular crystals, foliated aggregates, massive.
Origin and occurrence: Metamorphic in metamorphosed basic rocks and dolomites, together with actinolite, dolomite and chlorite; hydrothermal in veins. Tabular crystals up to 20 mm ($^{25}/_{32}$ in) across come from Brumado, Bahia, Brazil and Chester, Massachusetts, USA. Rich foliated aggregates are known from Zillertal, Austria. Pseudo-morphs after quartz crystals come from St. Gotthard, Switzerland. Large deposits of massive talc are mined in China.
Application: as a filling material in textile, paper and chemical industries, heat-resistant material.

Agalmatolite, 70 mm, India

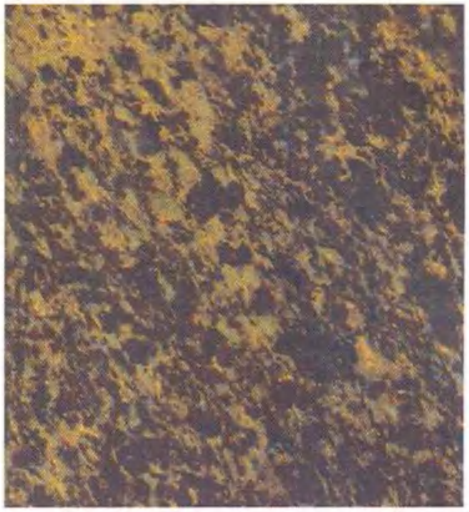

Talc, 61 mm, Rochester, U.S.A.

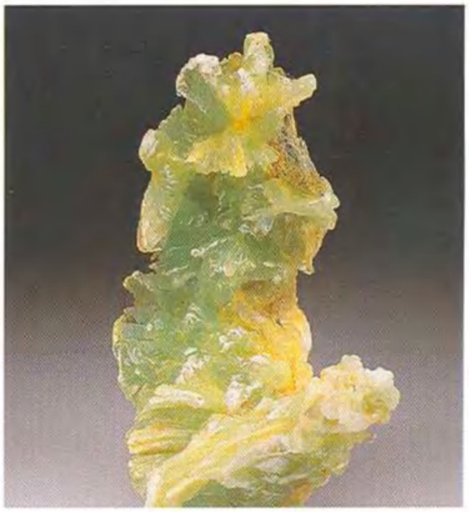

Muscovite

MICA GROUP

$KAl_3Si_3O_{10}(OH,F)_2$

MONOCLINIC ● ● ● ● ●

Varieties: fuchsite
Properties: C – white, greenish, yellowish, pinkish, green (fuchsite), gray; S – white; L – vitreous to pearly; D – transparent to translucent; DE – 2.8; H – 2.5-3; CL – perfect; F – uneven; M – tabular crystals, lamellar and scaly aggregates, massive.
Origin and occurrence: Metamorphic in various rock types, as mica schists, gneisses; magmatic in granites and pegmatites; hydrothermal in veins or next to ore veins (fuchsite). Important rock-forming mineral, usually associated with quartz, K-feldspar, albite and biotite. Its sheets, reached up to 5 x 3 m in size and weighed up to 85 tons in the Inikurti mine, Nellore, India. Large sheets are also known from Custer, South Dakota, USA. Well-formed crystals up to 100 mm (4 in) across come from Alabashka near Murzinka, Ural mountains, Russia. Other famous localities include Mamsk, Ural mountains, Russia and Cruzeiro mine, Minas Gerais, Brazil, where gemmy crystals were found.
Application: insulation material in electrical applications and construction.

Muscovite, 35 mm, Plumos, California, U.S.A.

Celadonite

MICA GROUP

$KFe^{3+}(Mg,Fe^{2+},Al)Si_4O_{10}(OH)_2$

MONOCLINIC ● ● ● ●

Properties: C – light green to blue-green; S – white; L – dull; D – translucent to almost opaque; DE – 3.0; H – 2; CL – perfect; F – uneven; M – earthy, sometime small scaly aggregates, massive.
Origin and occurrence: Hydrothermal as a product of mafic mineral replacement in volcanic rocks, associated with zeolites, prehnite and calcite. Famous localities are Val di Fassa and Monte Balda, Italy; also known from Bisbee, Arizona, USA.

Boromuscovite

MICA GROUP

$KAl_2BSi_3O_{10}(OH)_2$

MONOCLINIC ●

Properties: C – yellowish; S – white; L – dull; D – transparent to translucent; DE – 2.8; H – 2.5; CL – perfect; F – uneven; M – small scaly aggregates, massive.
Origin and occurrence: Hydrothermal in cavities in

Fuchsite, 4 mm xx, Pamir, Tadzhikistan

Celadonite, 60 mm, Unhošt'any, Czech Republic

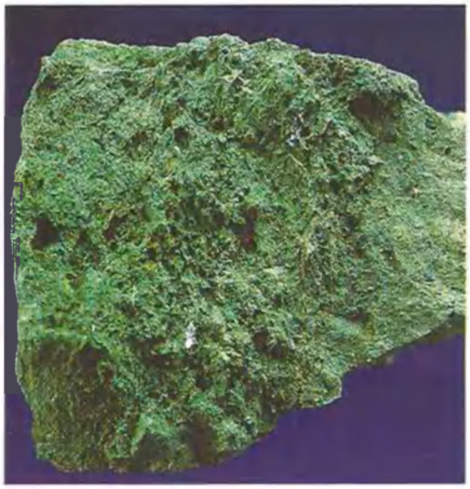

complex pegmatites, associated with albite, elbaite and lepidolite. Fine-grained scaly aggregates were described from the Little Three mine, Ramona, California, USA; also in Řecice, Czech Republic.

Paragonite

MICA GROUP

$NaAl_3Si_3O_{10}(OH,F)_2$

MONOCLINIC ● ● ●

Properties: C – white, greenish, yellowish, pinkish; S – white; L – vitreous to pearly; D – transparent to translucent; DE – 2.8; H – 2.5; CL B perfect; F – uneven; M – tabular crystals, scaly aggregates, massive.

Origin and occurrence: Metamorphic in various rock types, as mica schists and gneisses. Fine-grained scaly aggregates are known from Pizzo Forno, Switzerland and elsewhere.

Boromuscovite, 40 mm, Ramona, U.S.A.

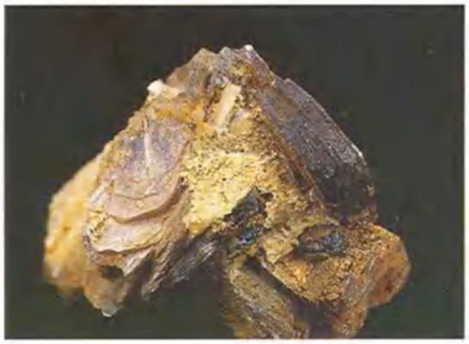

Paragonite, 80 mm, St.Gotthard, Switzerland

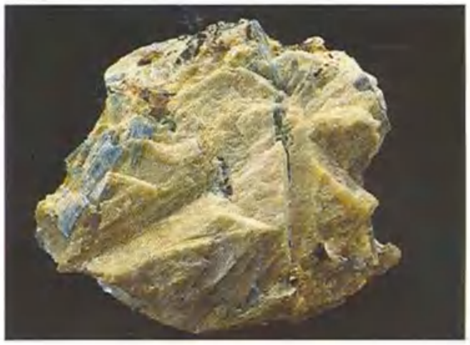

Glauconite

MICA GROUP

$K_{0.8}(Al,Fe^{2+},Fe^{3+},Mg)(Si,Al)_4O_{10}(OH)_2$

MONOCLINIC ● ● ● ● ●

Properties: C – light green, yellow-green to blue-green; S – light green; L – dull; PS – translucent to opaque; DE – 2.9; H – 2; CL B perfect; F – uneven; M B earthy and platy aggregates, massive.

Origin and occurrence: Hydrothermal in sedimentary and volcanic sedimentary rocks, also as a product of replacement of mafic minerals in volcanic rocks. Common in sandstones and limestones, locally associated also with phosphorites. It occurs in many localities in the Karpathians, Poland; in Polabi region, Czech Republic. Massive aggregates are known from the N'Chwaning No. 2 mine, Kuruman, South Africa.

Glauconite, 80 mm, Malomerice, Czech Republic

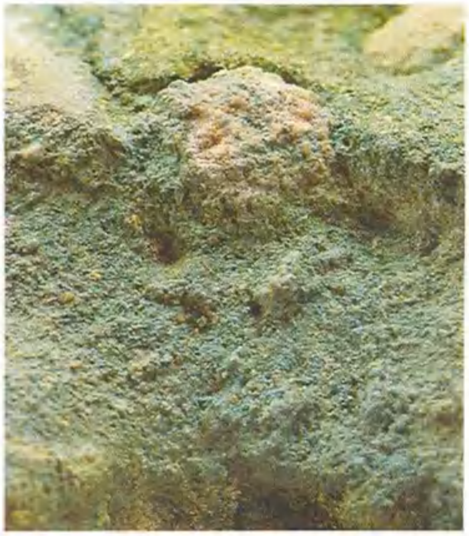

Annite, 120 mm, Budec, Czech Republic

Annite

MICA GROUP

$KFe_3AlSi_3O_{10}(OH,F)_2$

MONOCLINIC ● ● ●

Properties: C – black, locally with reddish or greenish tint; S – colorless; L – vitreous to pearly; D – transparent to translucent, locally opaque; DE – 2.8; H – 2.5-3; CL – perfect; F – uneven; M – tabular crystals, lamellar aggregates, massive.

Origin and occurrence: Metamorphic in skarns; magmatic in some pegmatites and granites. Its lamellar aggregates are known from Langban, Sweden and Cape Ann, Massachusetts, USA. Crystals up to 150 mm (6 in) across come from Mont St.-Hilaire, Quebec, Canada.

Phlogopite

MICA GROUP

$KMg_3AlSi_3O_{10}(OH,F)_2$

MONOCLINIC ● ● ● ● ●

Properties: C – light brown, greenish, yellowish, colorless, gray; S – white; L – vitreous to pearly; D – transparent to translucent; DE – 2.8; H – 2.5-3; CL – perfect; F – uneven; M – tabular crystals, platy and scaly aggregates, massive.

Origin and occurrence: Metamorphic in various rock types, as marbles and some ultrabasic rocks, at the contacts of pegmatites and serpentinites, magmatic in some ultrabasic rocks and pegmatites, associated with dolomite, diopside, anthophyllite. Rich scaly aggregates come from many localities, as Pargas, Finland and elsewhere. Crystals up to 5 m (16 ft) across found in Sludyanka, Siberia, Russia. Crystals up to 50 cm (20 in) across occurred in the Gardiner complex, Greenland. The largest crystals, 10 x 5 m (33 x 16 ft) across, weighing up to 90 tons, come from the Lacy mine, Ontario, Canada.

Application: as insulation material in electrical applications.

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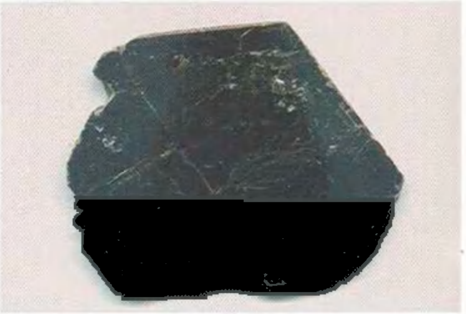

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Biotite

MICA GROUP

$K(Fe,Mg)_3AlSi_3O_{10}(OH,F)_2$

MONOCLINIC ● ● ● ● ●

Properties: C – brown to black, commonly with red or green tint; S – colorless; L – vitreous to pearly; D – transparent to translucent, locally opaque; DE – 2.8; H – 2.5-3; CL – perfect; F – uneven; M – tabular crystals, scaly aggregates, massive.

Origin and occurrence: Metamorphic in various rock types, as mica schists, gneisses, migmatites and different types of metamorphosed shales; magmatic in pegmatites, granites, syenites and diorites, rare in basalts and ultrabasic rocks. Typical rock-forming mineral, usually associated with quartz, feldspars and muscovite. Rich scaly aggregates are known from a pegmatite in Evje, Norway, where its crystals reach up to several meters across. Other famous localities are Bessnes, France; Uluguru mountains, Tanzania; Silver Crater mine, Ontario, Canada and Laacher See, Germany.

Polylithionite

MICA GROUP

$KLi_2AlSi_4O_{10}(F,OH)_2$

MONOCLINIC ● ● ●

Properties: C – gray, colorless, yellowish, purple; S – colorless; L – vitreous to pearly; D – transparent to translucent; DE – 2.8; H – 2.5-3; CL – perfect; F – uneven; M B tabular crystals, scaly aggregates, massive.

Origin and occurrence: Magmatic and locally also hydrothermal in alkaline pegmatites, granites and carbonatites, rare in Li-bearing granitic pegmatites. Well-formed crystals up to 40 mm ($1\frac{9}{16}$ in) across are known from cavities in alkaline pegmatites from Mont St.-Hilaire, Quebec, Canada. It comes also from Illimaussaq, Greenland and from cavities in granitic pegmatites in Recice, Czech Republic and

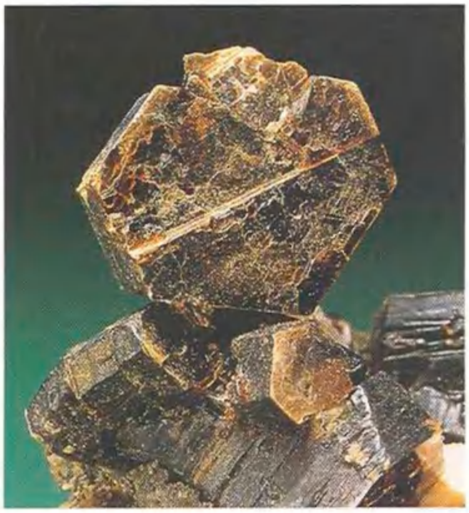

Biotite, 30 mm x, Ontario, Canada

elsewhere. Large industrial deposits known in Blatchford Lake, Northwest Territories, Canada.
Application: Li and Cs ore.

Trilithionite

MICA GROUP

$KLi_{1,5}Al_{2,5}Si_3O_{10}(F,OH)_2$

MONOCLINIC ● ● ● ●

Properties: C – purple, pink, blue, colorless, green; S – colorless; L – vitreous to pearly; D – transparent to translucent; DE – 2.8; H – 2.5-3; CL – perfect; F – uneven; M – tabular crystals, scaly aggregates, massive.
Origin and occurrence: Magmatic in Li-bearing pegmatites and granites, commonly associated with elbaite, spodumene, petalite, quartz and albite; sometimes hydrothermal in quartz veins and pegmatites. Well-formed crystals from pegmatite cavities are known from Virgem da Lapa, Minas Gerais, Brazil. Massive aggregates come from the Stewart Lithia mine, Pala, California and the Brown Derby No. 1 mine, Colorado, USA; Varutrask, Sweden; Rožna , Czech Republic; Meldon Quarry, Devon, UK.
Application: Li and Cs ore.

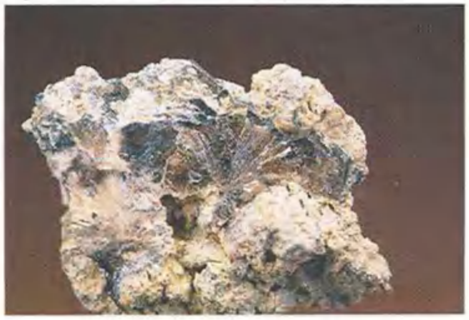

Polylithionite, 30 mm, Lovozero Massif, Kola, Russia

Zinnwaldite

MICA GROUP

$KLiFeAl_2Si_3O_{10}(F,OH)_2$

MONOCLINIC ● ● ●

Properties: C – gray, colorless, brown; S – colorless; L – vitreous to pearly; D – transparent to translucent; DE – 3.7; H – 2.5-3; CL – perfect; F – uneven; M – tabular crystals, scaly aggregates, massive.
Origin and occurrence: Hydrothermal in quartz veins and greisens; magmatic in pegmatites and granites, associated with fluorite, cassiterite and wolframite. Rich aggregates with scales up to 100 mm (4 in) across are known from quartz veins in Cínovec, Czech Republic. Crystals up to 150 mm (6 in) across come from pegmatite cavities in Virgem da Lapa, Minas Gerais, Brazil. It also occurs in the Pikes Peak batholith, Colorado, USA; Baveno, Italy.
Application: Li ore.

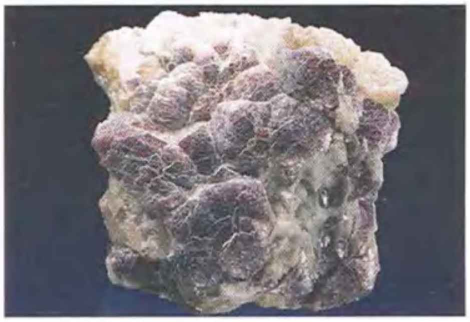

Trilithionite, 70 mm, Tanco, Canada

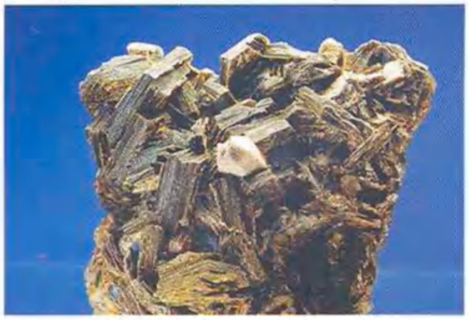

Zinnwaldite, 10 mm xx, Cinovec, Czech Republic

Margarite, 73 mm, Chester, U.S.A.

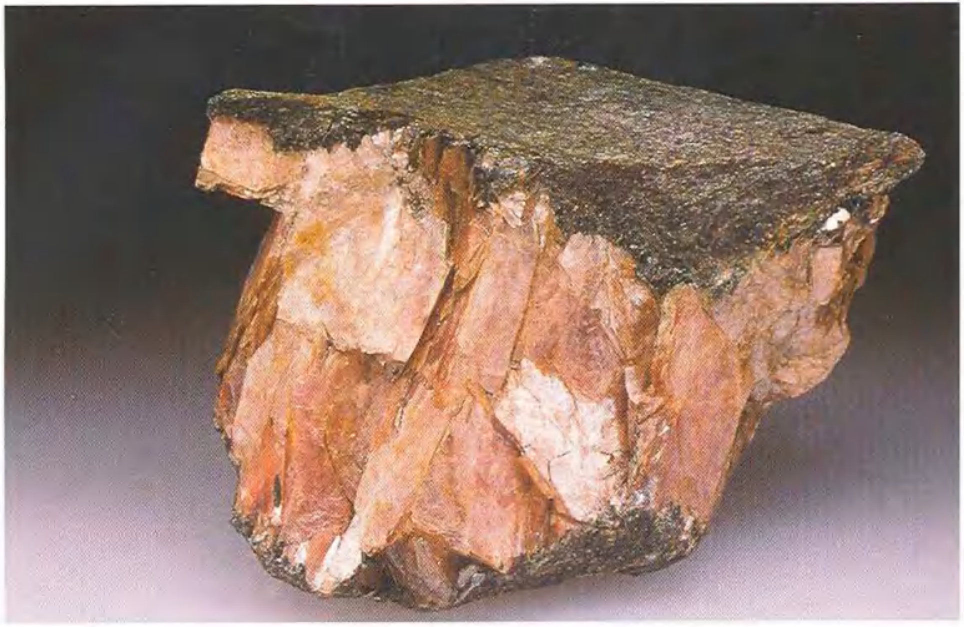

Margarite

$CaAl_4Si_2O_{10}(OH)_2$

MONOCLINIC ● ● ●

Properties: C – pinkish, colorless, yellowish; S – colorless; L – vitreous to pearly; D – transparent to translucent; DE – 3.1; H – 3.5-4.5; CL B perfect; F – uneven; M – tabular crystals, platy and scaly aggregates, massive.
Origin and occurrence: Metamorphic, associated with corundum, diaspore, tourmaline and staurolite in various types of metamorphosed shales. Coarse platy aggregates come from Chester, Massachusetts and Sterling Hill, New Jersey, USA.

Clintonite, 3 mm xx, Pomaz, Hungary

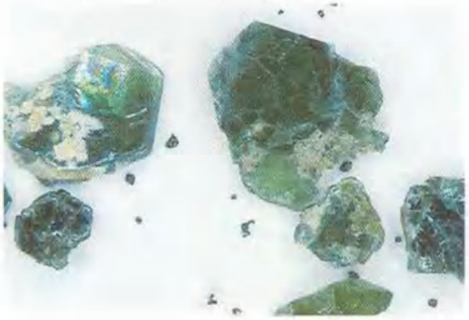

Clintonite

$Ca(Mg,Al)_3(Al_3Si)O_{10}(OH)_2$

MONOCLINIC ● ●

Properties: C – colorless, yellowish, pinkish, greenish; S – colorless; L – vitreous to pearly; D – transparent to translucent; DE – 3.1; H – 3.5; CL – perfect; F – uneven; M – tabular crystals, lamellar aggregates, massive.
Origin and occurrence: Metamorphic in contact metamorphosed marbles, associated with vesuvianite, grossular, diopside and spinel. Rich aggregates with lamellae up to 20 mm ($^{25}/_{32}$ in) across occur in Green Monster mountain, Alaska and Crestmore, California, USA and Monzoni, Italy.

Stilpnomelane, 100 mm, Horni Udoli, Czech Republic

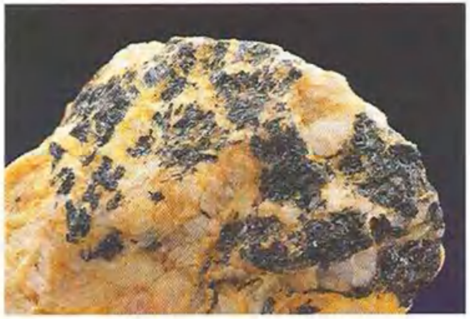

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Stilpnomelane

$K(Fe^{2+},Mg,Fe^{3+})_8(Si,Al)_{12}(O,OH)_{27}$

MONOCLINIC ● ● ● ●

Properties: C – black, black-brown, black-green, yellow-brown; S – colorless; L – vitreous to dull; D – translucent to opaque; DE – 2.8; H – 3; CL – perfect; F – uneven; M – tabular crystals, foliated, lath-like and acicular aggregates..
Origin and occurrence: Metamorphic in Fe-rich shales, usually associated with chlorite, magnetite and albite. Crystals up to 20 mm ($^{25}/_{32}$ in) across come from Jim Pond township, Maine, USA. Foliated aggregates are known from Horni Udoli near Zlate Hory, Czech Republic; Mesabi Range, Minnesota, USA.

Montmorillonite

$(Ca,Na)_{0.33}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot n\ H_2O$

MONOCLINIC ● ● ● ●

Properties: C – white, yellowish, greenish, bluish; S – white; L – greasy; D – translucent to opaque; DE – 2.3; H – 1-2; CL – perfect, wet massive aggregates are plastic; F – uneven; M – earthy aggregates, massive.
Origin and occurrence: Hydrothermal as a product of replacement of other minerals in volcanic rocks, granitic pegmatites and sediments. It is abundant in many localities. Montmorillonite deposits are known from Antrim, Northern Ireland, UK; in Hungary; Slovakia and many places in the USA.
Application: ceramics and chemical industry.

Saponite

$(Ca,Na)_{0.3}(Fe,Mg)_3(Si,Al)_4O_{10}(OH)_2 \cdot 4\ H_2O$

MONOCLINIC ● ● ●

Properties: C – white, yellowish, gray-green, bluish; S – white; L – greasy; D – translucent to opaque; DE – 2.1; H – 1-2; CL – perfect, massive aggregates are plastic under wet conditions; F – uneven; M – earthy, nodular, massive.
Origin and occurrence: Hydrothermal as a product of replacement of other minerals in volcanic rocks and serpentinites. It occurs together with copper in many places in Keweenaw Peninsula, Michigan, USA. Scales up to 10 mm ($^{3}/_{8}$ in) across described from Mont St.-Hilaire, Quebec, Canada.

Saponite, 2 mm crust, Erdobenye, Hungary

Montmorillonite, Kisthaas, Syria

Vermiculite

$(Fe,Mg,Al)_3(Si,Al)_4O_{10}(OH)_2 \cdot 4\ H_2O$

MONOCLINIC ● ● ●

Properties: C – yellow-brown, gray-green, green-brown; S – white; L – greasy; D – translucent to opaque; DE – 2.5; H – 1.5; CL B perfect; F – uneven; M – scaly aggregates, massive; R – it expands when heated.
Origin and occurrence: Hydrothermal as a product of replacement of phlogopite and other mafic micas in various rock types. It occurs in Palbora, South Africa; Milbury, Massachusetts, USA; Kovdor massif, Kola Peninsula, Russia.
Application: electrical applications and paper industry.

Vermiculite, 50 mm, Drahonin, Czech Republic

Cookeite, 60 mm, Dobra Voda, Czech Republic

Cookeite

CHLORITE GROUP

$LiAl_4Si_3O_{10}(OH)_8$

MONOCLINIC ● ●

Properties: C – white, yellowish, pinkish, brown; S – colorless; L – vitreous to pearly; D – transparent to translucent; DE – 2.6; H – 2.5-3.5; CL – perfect; F – uneven; M B scaly, locally radial aggregates, massive.

Origin and occurrence: Hydrothermal in cavities in Li-bearing pegmatites, associated with elbaite, lepidolite, fluorapatite and albite, it also replaces spodumene; metamorphic in Al-rich shales, together with diaspore and pyrophyllite. Massive aggregates, replacing spodumene, occur in the Tanco mine, Bernic Lake, Manitoba, Canada. It also comes from cavities in pegmatites in the Little Three mine, Ramona and the Himalaya mine, Mesa Grande, California. It is also known from the Pulsifer quarry, Maine, USA and Muiane, Mozambique.

Clinochlore, 5 mm xx, Sarany, Russia

Clinochlore

CHLORITE GROUP

$(Mg,Fe)_5Al_2Si_3O_{10}(OH)_8$

MONOCLINIC ● ● ● ● ●

Varieties: kammererite

Properties: C – greenish, gray, white, yellowish, brown, red-purple (kammererite); S – colorless; L – vitreous to pearly; D – transparent to translucent; DE – 2.7; H – 2-2.5; CL – perfect; F – uneven; M B poorly-developed tabular crystals, foliated and radial aggregates, massive.

Kammererite, 11 mm xx, Kop Daglari, Turkey

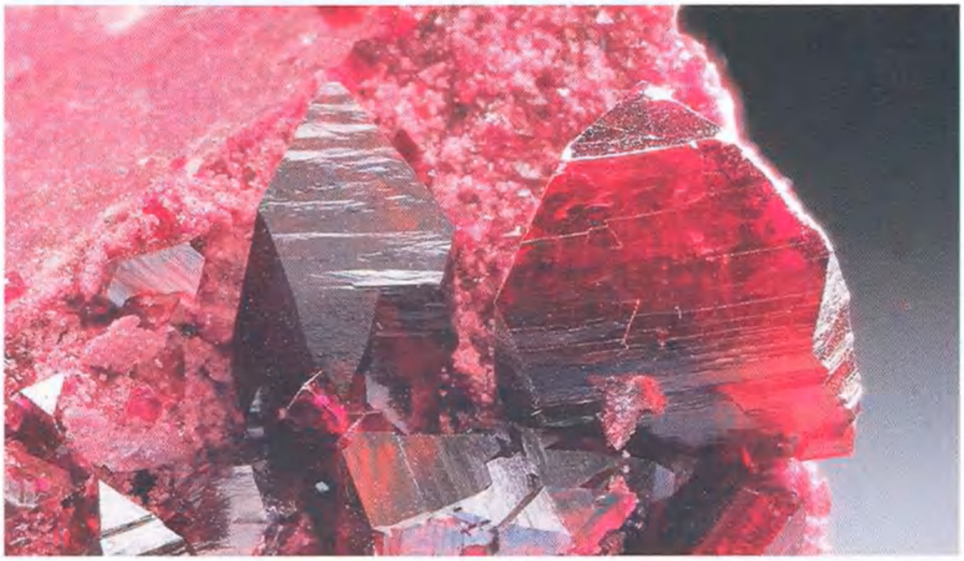

Chamosite, 70 mm, Hajan, Hungary

Origin and occurrence: Metamorphic in various types of shales and marbles; hydrothermal in quartz veins and Alpine-type veins, occasionally replaces certain minerals as biotite. Crystals up to 50 mm (2 in) across, associated with chondrodite and magnetite, are known from the Tilly Foster mine, Brewster, New York and Chester, Pennsylvania, USA. It also occurs in Val d'Ala, Italy and Zillertal, Austria. Scales up to 40 cm (15¾ in) across come from Beramy, Madagascar. Kammererite crystals up to 20 mm (25/32 in) across found in Kop Daolari, Erzerum, Turkey.

Chamosite

CHLORITE GROUP

$(Fe,Mg)_5Al_2Si_3O_{10}(OH)_8$

MONOCLINIC ● ● ● ●

Properties: C – gray, gray-green, brown; S – gray-green; L – vitreous to dull; D – translucent to opaque; DE – 3.2; H – 2-2.5; CL – perfect; F – uneven; M B scaly and oolitic aggregates, massive.
Origin and occurrence: Metamorphic to hydrothermal in various types Fe-rich sediments, typically associated with siderite and magnetite.
It is common in Chamoson, Switzerland; Nučice, Czech Republic. Spherical aggregates up to 15 mm (19/32 in) in diameter found in Mont St.-Hilaire, Quebec, Canada.

Kaolinite

$Al_2Si_2O_5(OH)_4$

TRICLINIC ● ● ● ● ●

Properties: C – white, yellowish, greenish, gray; C – colorless; L – earthy; D – translucent to opaque; DE – 2.6; H – 1; CL – perfect; F – uneven; M – earthy and exceptionally scaly aggregates, massive.
Origin and occurrence: Hydrothermal, as a result of feldspar replacement in various rock types, as granites and arcoses. It forms large deposits in China, France, UK and Czech Republic.
Application: raw material for ceramics.

Dickite, 100 mm, Nowa Ruda, Poland

Dickite

$Al_2Si_2O_5(OH)_4$

MONOCLINIC ● ● ●

Properties: C – white, yellowish; S – colorless; L – earthy to pearly; D – translucent to opaque; DE – 2.6; H – 1; CL – perfect; F – uneven; M – earthy and platy aggregates, massive.
Origin and occurrence: Hydrothermal in cavities in hydrothermal veins, together with quartz, carbonates and sulfides. It occurs in Essen, Germany; Anglesey, Wales , UK; Kladno, Czech Republic. Microscopic crystals come from Mas d'Alary, France.

Kaolinite, 50 mm, St.Austell, UK

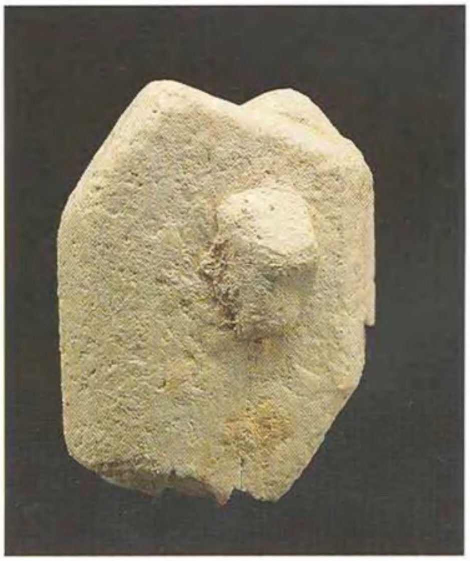

Nakrite, 70 mm, Rochlitz, Germany

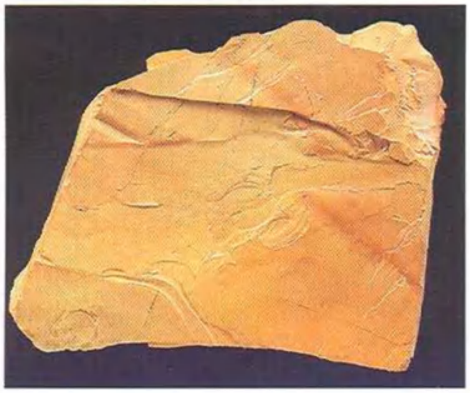

Nacrite

$Al_2Si_2O_5(OH)_4$

MONOCLINIC ● ● ●

Properties: C – white, yellowish, gray-white; S – colorless; L – earthy to pearly; D – translucent to opaque; DE – 2.6; H – 1; CL – perfect; F – uneven; M – earthy and scaly aggregates, massive.
Origin and occurrence: Hydrothermal in cavities of hydrothermal veins, associated with quartz, fluorite and topaz. It occurs in Horni Slavkov, Czech Republic; Freiberg, Germany. Pseudo-morphs after topaz come from Ouro Preto, Minas Gerais, Brazil.

Antigorite

$Mg_3Si_2O_5(OH)_4$

MONOCLINIC ● ● ● ● ●

Properties: C – white, yellowish, greenish, gray; S – colorless to gray; L – vitreous, pearly, silky, earthy; D – translucent to opaque; DE – 2.6; H – 2.5-3.5; CL – perfect; F – uneven; M B foliated, lamellar and fibrous aggregates, massive.
Origin and occurrence: Metamorphic in serpentinites, marbles and other Mg-rich rocks; hydrothermal in veins cross-secting these rocks. It is important rock-forming mineral. It occurs in Kraubat, Austria; Hrubsice, Czech Republic; Antigorio, Italy and elsewhere.

Antigorite, 110 mm, Felsocsatar, Hungary

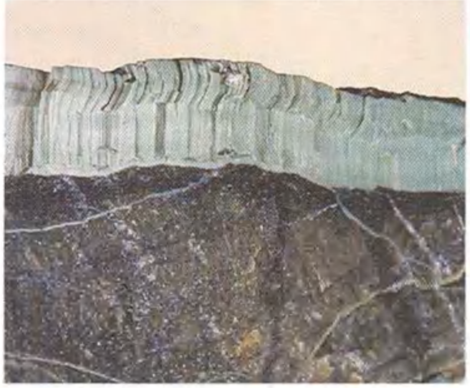

Amesite

$Mg_2Al(SiAl)O_5(OH)_4$

TRICLINIC ● ●

Properties: C – greenish, gray; S – colorless; L – vitreous to pearly; D – translucent; DE – 2.8; H – 2.5-3; CL – perfect; F – uneven; M B foliated to radial aggregates, massive.
Origin and occurrence: Hydrothermal in Mg-rich rocks, associated with diaspore, magnetite and chromite. It comes from Chester, Massachusetts, USA. Crystals up to 40 mm (1$^{9}/_{16}$ in) across found in Sarany, Ural mountains, Russia.

Cronstedtite

$Fe^{2+}{}_2Fe^{3+}{}_2SiO_5(OH)_4$

MONOCLINIC ● ●

Properties: C – black, black-brown, black-green; S – dark olive-green; L – vitreous to submetallic; D – translucent to opaque; DE – 3.6; H – 3.5; CL – perfect; F – uneven; M – prismatic crystals, columnar aggregates.
Origin and occurrence: Hydrothermal in ore veins. Fan-shaped aggregates of crystals come from Pribram and Kutna Hora, Czech Republic; Ouro Preto, Minas Gerais, Brazil; Salsigue mine, Auge, France.

Amesite, 40 mm, Sarany, Ural Mts., Russia

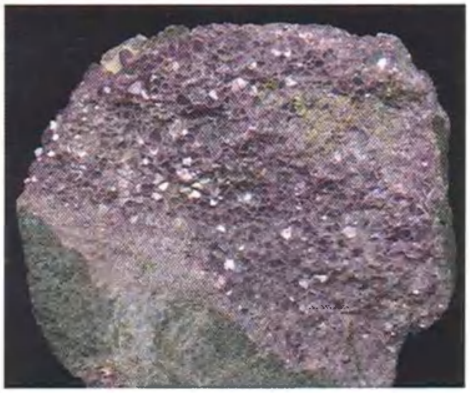

Cronstedtite, 42 mm, Hunan, Bolivia

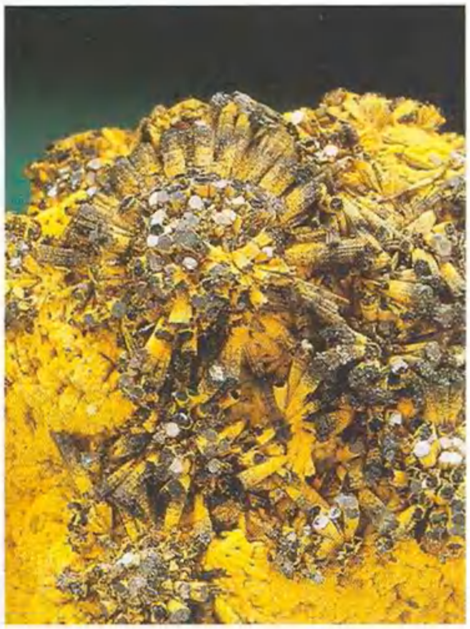

Chrysocolla, 50 mm, Arizona, U.S.A.

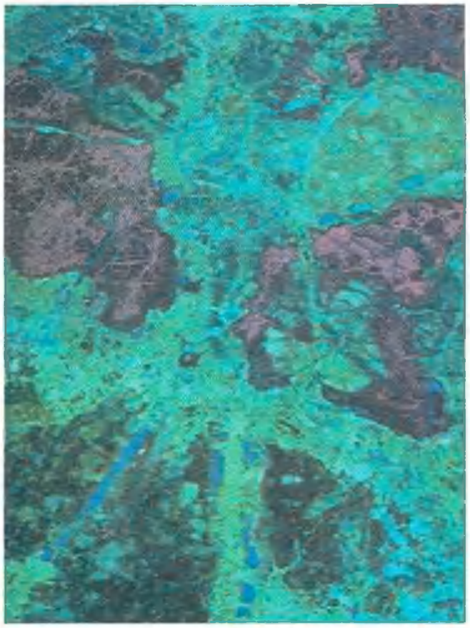

Chrysocolla

$(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot n\ H_2O$

MONOCLINIC ● ● ● ●

Properties: C – different hues of blue-green; S – white; L – vitreous, greasy to earthy; D – translucent to almost opaque; DE – 2.0-2.4; H – 2-4; CL – none; F – conchoidal to uneven; M – microscopic acicular crystals, botryoidal, stalactitic and earthy aggregates.
Origin and occurrence: Secondary in Cu deposits, associated with malachite and other secondary Cu minerals.
Rich aggregates come from many places in Arizona, USA, like Bisbee and Morenci. It is also known from Mednorudnyansk, Ural mountains, Russia and Broken Hill, New South Wales, Australia.

Allophane

approximately $Al_2SiO_5 \cdot n\ H_2O$

AMORPHOUS ● ● ●

Properties: C – white, gray, bluish, greenish, brown; S -white; L – vitreous, greasy and earthy; D – transparent, translucent to opaque; DE – 1.9; H – 2-3; CL – none; F – conchoidal to uneven; M – botryoidal, stalactitic and earthy aggregates.
Origin and occurrence: Hydrothermal product of alteration along the cracks of sedimentary rocks in coal deposits and in the oxidation zone of ore deposits, associated with other secondary minerals. Rich botryoidal aggregates occur in Dehr, Germany; Moldova Nuova, Romania; New Cornelia mine, Arizona, USA; El Dragon mine, Potosi, Bolivia.

Allophane, 90 mm, Zlate Hory, Czech Republic

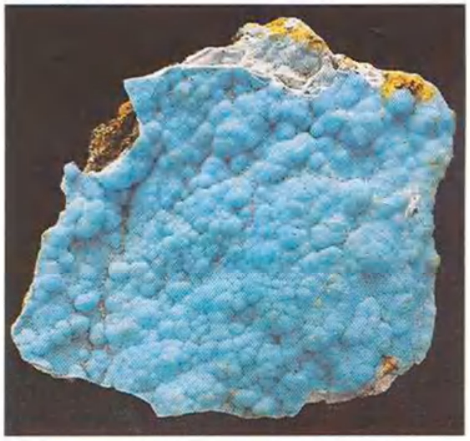

Palygorskite, 120 mm, Burda, Hungary

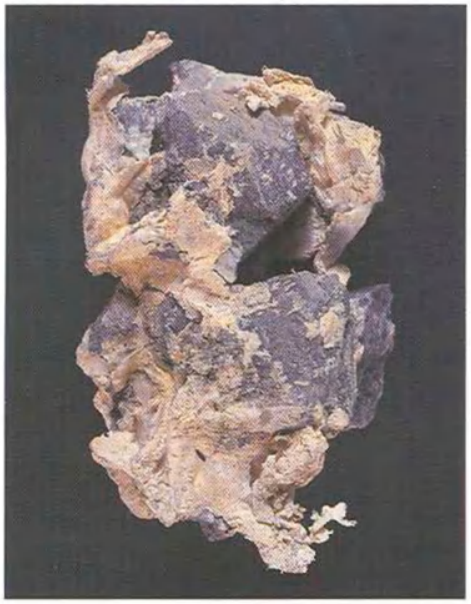

Palygorskite

$(Mg,Al)_2Si_4O_{10}(OH) \cdot 4\ H_2O$

MONOCLINIC ● ● ● ●

Properties: C – white, gray; S – white; L – dull; D - translucent to almost opaque; DE – 2.2; H – 1; CL – good; F – uneven, aggregates plastic under wet conditions; M – acicular crystals, fibrous aggregates, massive.
Origin and occurrence: Hydrothermal as a product of alteration of different rock types, such as serpentinites, granites, marbles and graywackes, also in ore veins and the Alpine-type veins. Rich aggregates resembling leather occur along the cracks in marbles in Hejná near Horazd'ovice, Czech Republic; in the Mammoth mine, Tiger, Arizona, USA and in Palygorskava, Russia.

Sepiolite, 70 mm, Eskisehir, Turkey

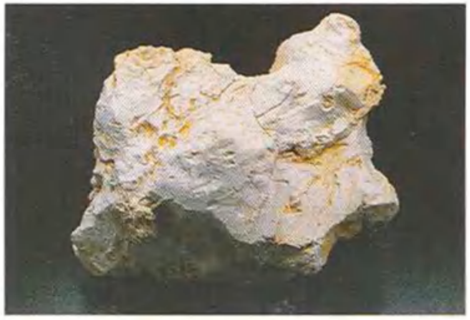

Sepiolite

$Mg_4Si_6O_{15}(OH)_2 \cdot 6\ H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – white, yellowish, gray; S – white; L – dull; D – opaque; DE – 2.0; H – 2-2.5; CL – not determined; F – uneven; M – earthy aggregates, massive.
Origin and occurrence: Hydrothermal as a product of serpentinite alteration, typically associated with magnesite. Classic locality is Eskişehir, Turkey; also known from Biskoupky, Czech Republic.

Zeophylite

$Ca_4Si_3O_8(OH,F)_4 \cdot 2\ H_2O$

TRICLINIC ● ●

Properties: C – white; S – white; L – pearly; D – transparent to translucent; DE – 2.6; H – 3; CL – perfect; F – uneven; M – platy crystals, commonly with radial structure.
Origin and occurrence: Hydrothermal in cavities of volcanic rocks, associated with zeolites. Its most important locality is Radejeín, Czech Republic, where it forms spherical aggregates up to 10 mm (3/8 in) in diameter. Also known from Schellkopf, Germany and Monte Somma, Italy.

Cavansite

$CaVOSi_4O_{10} \cdot 4\ H_2O$

ORTHORHOMBIC ● ●

Properties: C – green-blue, blue; S – light blue; L – vitreous; D – transparent; DE – 2.2; H – 3-4; CL – good; F – uneven; M – long prismatic to acicular crystals, radial aggregates.
Origin and occurrence: Hydrothermal in cavities of volcanic rocks, associated with calcite, apophyllite and zeolites. Rich radial aggregates up to 30 mm

Zeophyllite, 60 mm, Radejcin, Czech Republic

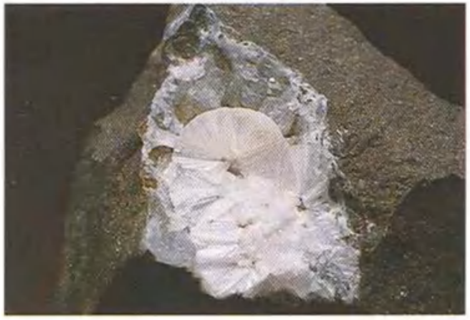

Cavansite, 120 mm, Poona, India

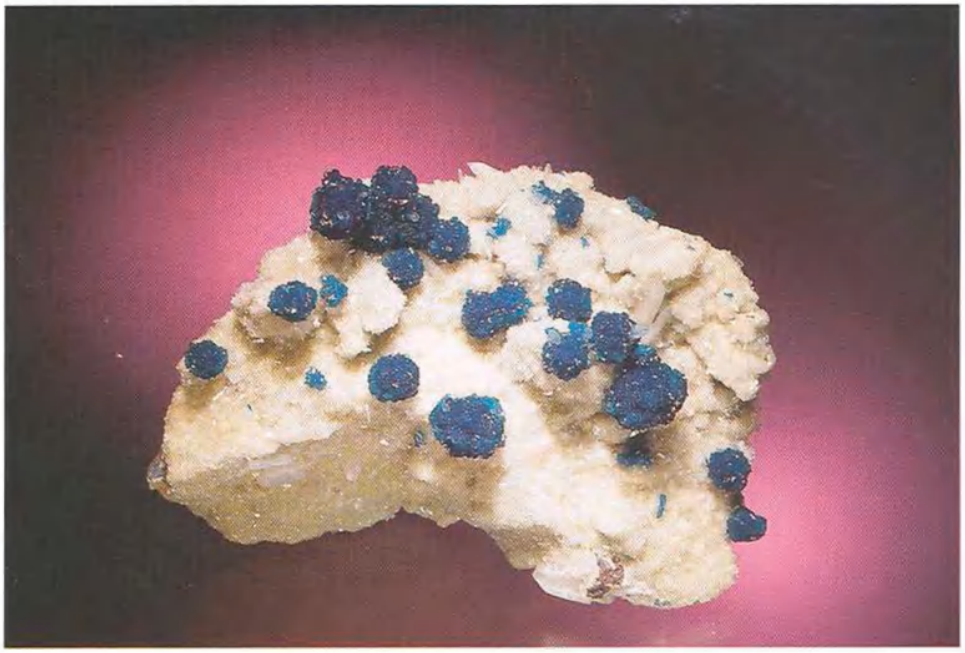

($1^{3}/_{16}$ in) in diameter come from the Wagholi Quarry, Poona, India.

Nepheline

$(K,Na)AlSiO_4$

HEXAGONAL ● ● ● ●

Properties: C – colorless, white, greenish, yellowish, gray, green, brown; S – white; L – vitreous to greasy; D – transparent to translucent; DE – 2.7; H – 5.5-6; CL – none; F – uneven to conchoidal; M – prismatic crystals, granular, massive.

Origin and occurrence: Magmatic in many alkaline rocks, as alkaline syenites and their pegmatites, also in some basalts; rare metamorphic in gneisses. It is a typical rock-forming mineral, associated with leucite, augite and apatite. Well-formed crystals found in Mount Vesuvius, Italy. Rich aggregates are known from many localities in Khibiny massif, Kola Peninsula, Russia. Crystals up to 70 cm ($27^{9}/_{16}$ in) long occur in Davis Hill, Bancroft, Ontario. Perfect crystals up to 35 mm ($1^{3}/_{8}$ in) long, come from Mont St.-Hilaire, Quebec, Canada.

Application: locally as Al ore and in ceramic industry.

Nepheline, 43 mm, Aouli, Morocco

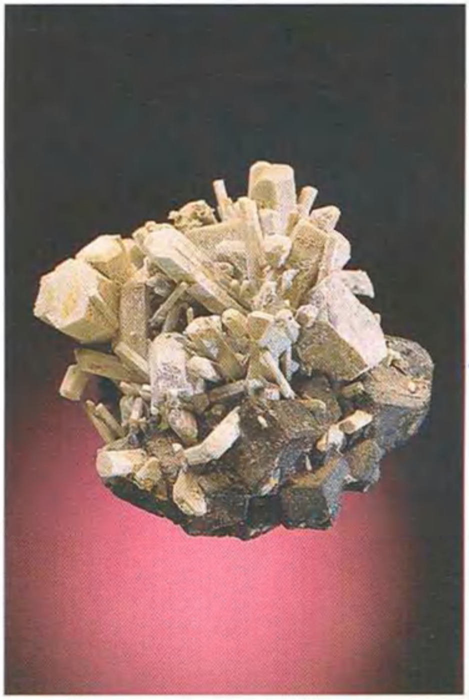

Petalite, 23 mm, Paprok, Afghanistan

Petalite

$LiAlSi_4O_{10}$

MONOCLINIC ● ● ●

Properties: C – colorless, white, greenish, yellowish; S – white; L – vitreous; D – transparent to translucent; DE – 2.5; H – 6-6.5; CL – good; F – uneven to conchoidal; M – prismatic crystals, granular.
Origin and occurrence: Magmatic in Li-bearing pegmatites, associated with lepidolite, elbaite, amblygonite and locally replaced by a mixture of quartz and spodumene. Gigantic crystals several meters long, come from Bikita, Zimbabwe; and Varutrask, Sweden. Clear gemmy crystals up to 230 mm ($9^{1}/_{16}$ in) across found in pegmatite cavities in Paprok, Afghanistanand also in San Piero in Campo, Elba, Italy. Crystals up to 100 mm (4 in) across occur in Araçuai, Minas Gerais, Brazil.
Application: ceramic industry.

Chkalovite, 70 mm, Umbozero, Kola, Russia

Chkalovite

$Na_2BeSi_2O_6$

ORTHORHOMBIC ● ●

Properties: C – colorless, white; S – white; L – vitreous; D – transparent to translucent; DE – 2.7; H – 6; CL – imperfect; F – conchoidal; M – prismatic crystals, granular, massive.
Origin and occurrence: Hydrothermal in alkaline pegmatites, usually associated with natrolite, sodalite and eudialyte. Crystals up to 200 mm ($7^{7}/_{8}$ in) across come from the Umbozero mine, Mount Alluaiv, Lovozero massif, Kola Peninsula, Russia; also at Julianhab, Greenland and Mont St.-Hilaire, Quebec, Canada.

Sanidine, 30 mm x, Drachenfels, Germany

Sanidine

FELDSPAR GROUP

$KAlSi_3O_8$

MONOCLINIC ● ● ● ●

Properties: C – colorless, white, yellowish, pinkish, gray; S – white; L – vitreous; D – transparent to translucent; DE – 2.6; H – 6-6.5; CL – good; F – uneven to conchoidal; M – prismatic crystals, granular, massive.
Origin and occurrence: Magmatic in acid volcanic rocks, as rhyolites and trachytes, a typical rock-forming mineral. Well-formed crystals and their combinations up to 100 mm (4 in) in size occur in rhyolites and trachytes in Drachenfels and Laacher See, Germany. It also comes from Roc de Courlande, France; Beaverdell, British Columbia, Canada; Kyustendil, Bulgaria.

Orthoclase

FELDSPAR GROUP

$KAlSi_3O_8$

MONOCLINIC ● ● ● ● ●

Varieties: adularia, moonstone (gemmy variety with chatoyancy)

Properties: C – colorless, white, yellowish, pinkish, gray, brown, yellow; S – white; L – vitreous to pearly (adularia); D – transparent to translucent; DE – 2.5; H – 6-6.5; CL – good; F – uneven to conchoidal; M – prismatic and tabular crystals and their combinations, granular, massive.
Origin and occurrence: Magmatic in rhyolites, trachytes, granites, syenites and pegmatites; metamorphic in various rock types, as orthogneisses and migmatites; hydrothermal in the Alpine-type veins, ore veins and some sediments, also in placers, a typical rock-forming mineral. Well-formed crystals and twins up to 200 mm (7⅞ in) across come from granites in Twentynine Palms, California, USA; Marina di Campo, Elba, Italy; Loket and Karlovy Vary, Czech Republic; in pegmatite cavities in Strzegom, Poland; San Piero in Campo, Elba, Italy. Yellow gemmy crystals up to 70 mm (2¾ in) across found in Itrongay, Madagascar. Gigantic feldspar crystals up to tens of meters long known from several pegmatite localities in Black Hills, South Dakota, USA; also Hagendorf, Germany. Adularia is known from Alpine-type veins in St. Gotthard, Switzerland; pebbles of moonstone occur in gem-bearing gravels in Ratnapura, Sri Lanka.
Application: ceramic and glass industry, moonstone as a gemstone.

Orthoclase, 32 mm x, Oro Grande, U.S.A.

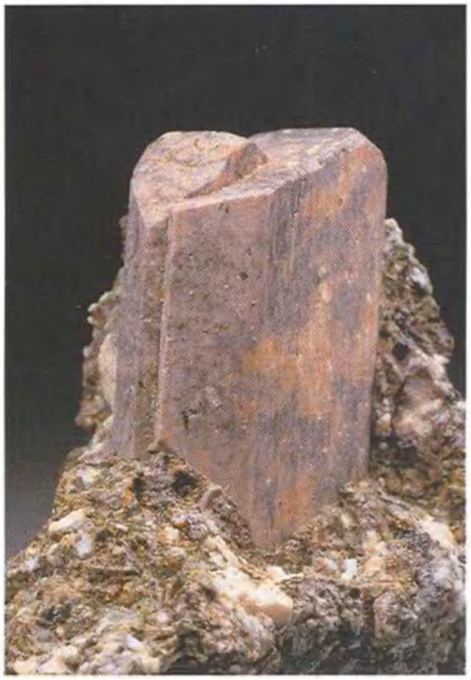

Adularia, 60 mm, Alps, Switzerland

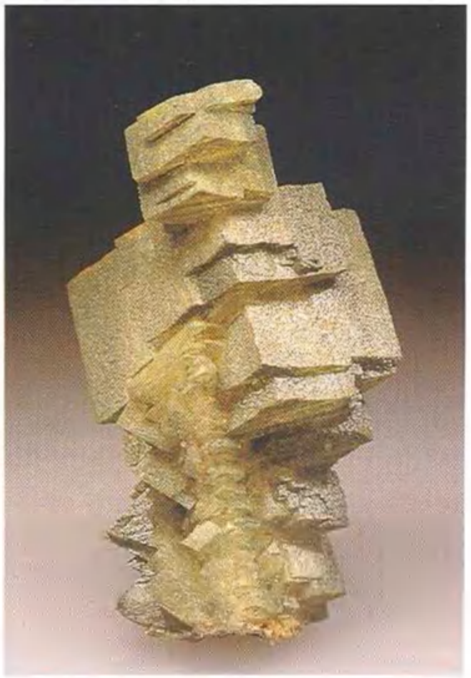

Microcline, 110 mm, Lake George, Teller Co., U.S.A.

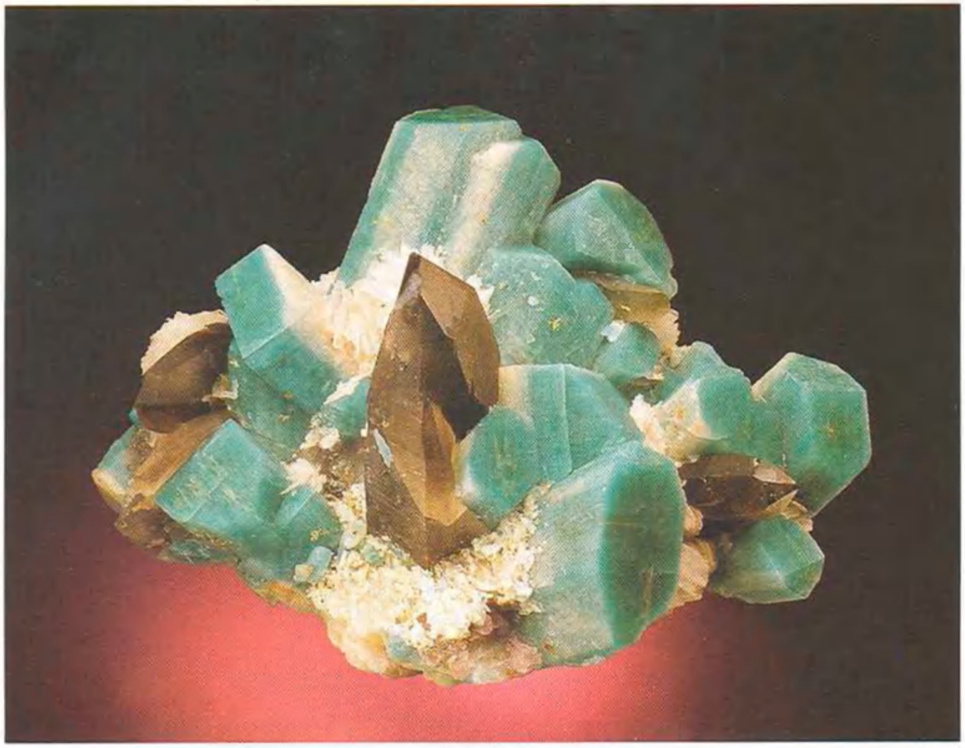

Microcline

FELDSPAR GROUP

$KAlSi_3O_8$

TRICLINIC ● ● ● ● ●

Varieties: amazonite

Properties: C – colorless, white, yellowish, pinkish, gray, light to dark green (amazonite); S – white; L – vitreous; D – transparent to translucent; DE – 2.6; H – 6-6.5; CL – good; F – uneven to conchoidal; M – prismatic crystals, granular, massive.

Origin and occurrence: Magmatic in granites, syenites and pegmatites; metamorphic in various rock types, as orthogneisses and migmatites; hydrothermal in the Alpine-type veins and ore veins; a typical rock-forming mineral. Well-formed amazonite crystals up to 40 cm (15¾ in) across occur in pegmatite cavities in Crystal Peak, Colorado, USA; Keivy, Kola Peninsula, Russia; Morefield mine, Virginia, USA. Gigantic microcline crystals up to 12 m (39 ft) across come from pegmatites in Black Hills, South Dakota, USA; Kaatiala, Finland.

Application: ceramic industry, amazonite as a decorative stone.

Hyalophane

FELDSPAR GROUP

$(K,Ba)Al(Si,Al)_3O_8$

MONOCLINIC ● ● ●

Properties: C – colorless, white, yellowish; S – white; L – vitreous; D – transparent to translucent; DE – 2.9; H – 6-6.5; CL – good; F – uneven to conchoidal; M – prismatic crystals, granular, massive.

Amazonite, 60 mm, Keivy, Kola, Russia

Hyalophane, 50 mm, Busovaca, Bosnia

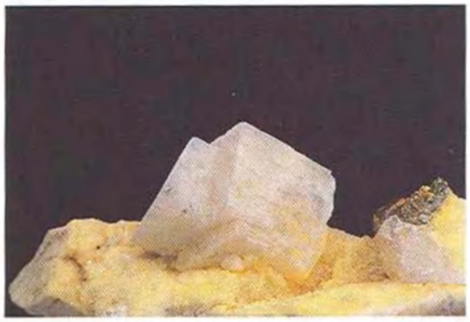

Origin and occurrence: Magmatic in phonolites; metamorphic in various rock types, as marbles, gneisses and Mn-rich rocks; hydrothermal in the Alpine-type and ore veins. Crystals up to 100 mm (4 in) across found in Alpine-type veins near Busovaca, Bosnia-Hercegovina.

Albite

FELDSPAR GROUP

$NaAlSi_3O_8$

TRICLINIC ● ● ● ● ●

Varieties: pericline, cleavelandite

Properties: C – colorless, white, yellowish, pinkish, gray, greenish, bluish; S – white; L – vitreous; D – transparent to translucent; DE – 2.6; H – 6-6.5; CL – good; F – uneven to conchoidal; M – tabular crystals and their twins, platy aggregates, granular, massive.

Albite, 85 mm, Governador Valadares, Brazil

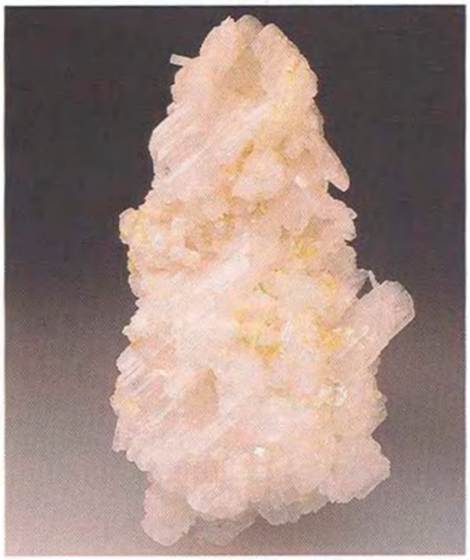

Oligoclase, 40 mm, Ural Mts., Russia

Origin and occurrence: Magmatic in granites, syenites and their pegmatites; metamorphic in various rock types, as orthogneisses, migmatites, phyllites and metamorphosed shales; hydrothermal in the Alpine-type veins and ore veins, a typical rock-forming mineral. Well-formed tabular to platy cleavelandite crystals up to 150 mm (6 in) across occur in pegmatite cavities in the Amelia district, Virginia and the Pala district, California, USA. Albite crystals also come from Strzegom, Poland; San Piero in Campo, Elba, Italy; Murzinka, Ural mountains, Russia; many localities in Minas Gerais, Brazil. Pericline crystals are known from the cracks along Alpine-type veins in Grossgreiner, Austria; St. Gotthard, Switzerland; also from ore veins in Rožnava, Slovakia.

Oligoclase

FELDSPAR GROUP

$(Na_{0,9-0,7}Ca_{0,1-0,3}Al_{1,1-1,3}Si_{2,9-2,7}O_8$

TRICLINIC ● ● ● ● ●

Varieties: peristerite, sunstone

Properties: C – white, yellowish, pinkish, greenish, iridescent (peristerite); S – white; L – vitreous; D – transparent to translucent; DE – 2.6; H – 6-6.5; CL – good; F – uneven to conchoidal; M – tabular crystals, platy aggregates, granular, massive.

Origin and occurrence: Magmatic in granites, syenites, andesites and pegmatites; metamorphic in gneisses and migmatites; hydrothermal in the Alpine-type veins; typical rock-forming mineral. Large crystals, several dm long, are known mainly from pegmatites. Peristerite comes from Arendal, Norway; Miass, Ural mountains, Russia; Quadeville, Ontario, Canada; Tvedestrand, Norway. It also occurs in Vezna , Czech Republic. Sunstone is mined in the Ponderosa mine near Lakeview, Oregon, USA.

Application: peristerite and sunstone are used as gemstones.

Andesine, 50 mm, Bodenmais, Germany

Andesine

FELDSPAR GROUP

$(Na_{0,7-0,5}Ca_{0,3-0,5}Al_{1,3-1,5}Si_{2,7-2,5}O_8$

TRICLINIC ● ● ● ●

Properties: C – yellowish, pinkish, gray, light green; S – white; L – vitreous; D – transparent to translucent; DE – 2.7; H – 6-6.5; CL – good; F – uneven to conchoidal; M – platy aggregates, granular, massive.

Labradorite, 50 mm, Labrador, Canada

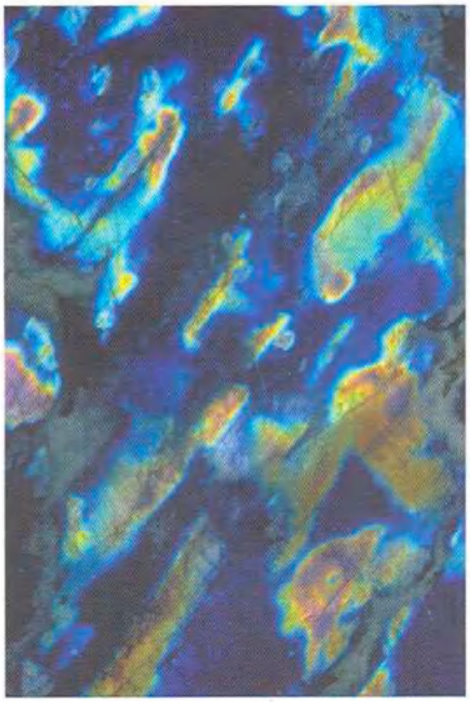

Anorthite, 10 mm xx, Pasmaada, Finnland

Origin and occurrence: C – white to dark gray, greenish; S – white; L – vitreous, pearly; D – transparent to translucent; DE – 2.7; H – 6-6.5; CL – good; F – uneven to conchoidal; M B cleavable aggregates, granular, massive.

Labradorite

FELDSPAR GROUP

$Ca_{0,7-0,5}Na_{0,3-0,5}Al_{1,5-1,7}Si_{2,5-2,3}O_8$

TRICLINIC ● ● ● ●

Properties: Magmatic in andesites, diorites; metamorphic in gneisses and migmatites; typical rock-forming mineral. Large grains are known from migmatites in Bodenmais, Germany and Adamello, Italy.
Origin and occurrence: Magmatic in gabbros, basalts, anorthosites; metamorphic in amphibolites. Large iridescent aggregates up to 1 m (39⅜ in) across, come from Nain, Labrador, Quebec, Canada and also occur in Korostenskiy massif. Ukraine and Ylamaa, Finland.
Application: as a decorative stone.

Anortite

FELDSPAR GROUP

$CaAl_2Si_2O_8$

TRICLINIC ● ● ●

Properties: C – gray, greenish, pinkish; S – white; L – vitreous, dull; D – transparent to translucent; DE – 2.8; H – 6-6.5; CL – good; F – uneven to conchoidal; M B granular, massive.
Origin and occurrence: Magmatic in gabbros, basalts, anorthosites; metamorphic in contact metamorphosed rocks. Pinkish grains and poorly-developed crystals come from Val di Fassa, Italy. Crystals up to 50 mm (2 in) across are known from Miyake-Jima Island, Japan. It was also found in Mount Erebus, Antarctica and Monte Somma, Italy.

Danburite

$CaB_2Si_2O_8$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white, gray, greenish, pinkish, yellow, brown, red-brown; S – white; L – vitreous, dull; D – transparent to translucent; DE – 3.0; H – 7; CL – imperfect; F – uneven to conchoidal; M – prismatic crystals, columnar aggregates, granular, massive.

Origin and occurrence: Hydrothermal in pegmatite cavities, ore veins and the Alpine-type veins; metamorphic in skarns and contact metamorphosed rocks.

Well-formed prismatic crystals up to 250 mm ($9^{13}/_{16}$ in) long come from Russell, New York, USA; Toroku, Japan; Dalnegorsk, Russia; and Charcas, San Luis Potosi, Mexico.

Cancrinite

$Na_6CaAl_6Si_6O_{24}(CO_3) . 2 H_2O$

HEXAGONAL ● ● ●

Properties: C – colorless, white, yellow, orange, bluish; S – white; L – vitreous; D – transparent to translucent; DE – 2.4; H – 5-6; CL – good; F – uneven to conchoidal; M – prismatic crystals, granular, massive.

Origin and occurrence: Magmatic in alkaline syenites; hydrothermal as a product of replacement of volcanic rocks, associated with nepheline and sodalite.

Crystals up to 20 mm ($^{25}/_{32}$ in) across come from Mont St.-Hilaire, Quebec, Canada. It was also found in Litchfield, Maine, USA; Cancrinite Hill, Bancroft, Ontario, Canada and elsewhere.

Cancrinite, 70 mm, Ditrau, Romania

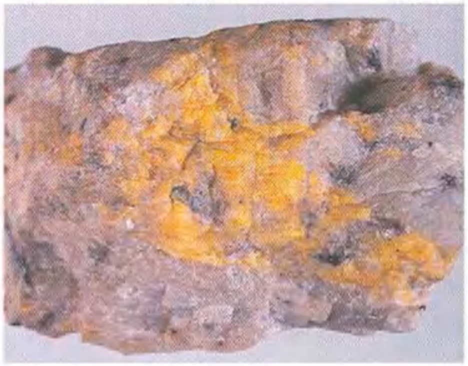

Danburite, 109 mm, Charcas, Mexico

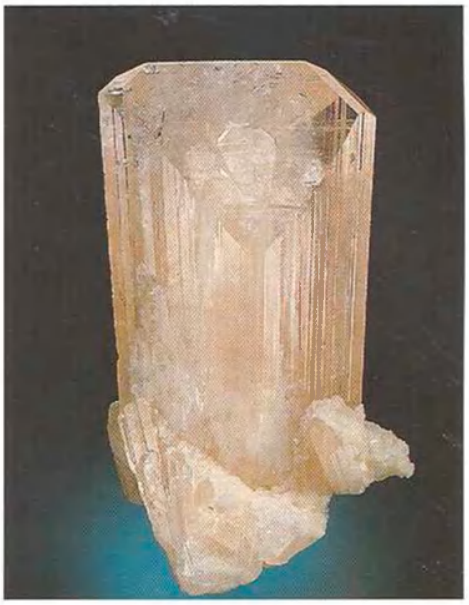

Leifite

$Na_2(Si,Al,Be)_7 (O,OH,F)_{14}$

TRIGONAL ●

Properties: C – colorless; S – white; L – vitreous; D – translucent; DE – 2.5; H – 6; CL – good; F – uneven; M – acicular crystals.

Origin and occurrence: Hydrothermal in cavities of alkaline pegmatites, associated with microcline and zinnwaldite. Crystals up to 20 mm ($^{25}/_{32}$ in) across occur in Narssarssuk, Greenland. Fine crystals are also known from Mont St.-Hilaire, Quebec, Canada, associated with serandite.

Leifite, 100 mm, Mont St.-Hilaire, Canada

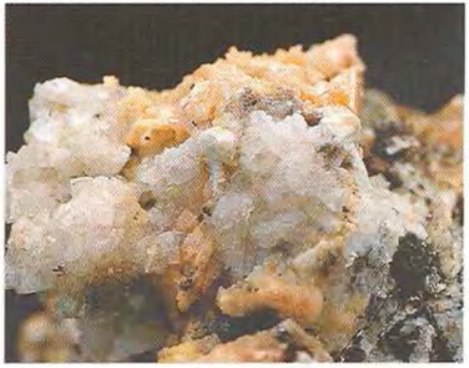

Sodalite, 50 mm, Bancroft, Canada

Sodalite

$Na_8Al_6Si_6O_{24}Cl_2$

CUBIC ● ● ●

Varieties: hackmanite

Properties: C – colorless, white, blue, yellow, pink (hackmanite); S – white; L – vitreous; D – transparent to translucent; DE – 2.3; H – 5.5-6; CL – imperfect; F – uneven to conchoidal; M – isometric crystals, granular, massive; LU – orange-red.
Origin and occurrence: Magmatic in alkaline syenites and phonolites, associated with nepheline, zircon and titanite; hydrothermal in marbles. Granular aggregates are known from the Princess Sodalite mine, Bancroft, Ontario, Canada and Ditrau, Romania. Crystals up to 100 mm (4 in) across come from Kangerdluarssuk, Greenland.
Application: cut as a gemstone.

Noseane

$Na_8Al_6Si_6O_{24}(SO_4)$

CUBIC ● ●

Properties: C – colorless, white, blue, gray, black; S – white; L – vitreous; D – transparent to translucent; DE – 2.3; H – 5-6; CL – good; F – uneven to conchoidal; M – isometric crystals, granular, massive.
Origin and occurrence: Magmatic in alkaline basalts and similar effusive rocks, associated with nepheline and haüyne. Granular aggregates are known from Laacher See, Germany and Monte Somma, Italy.

Lazurite

$(Na,Ca)_8Al_6Si_6O_{24}(S,SO_4)$

CUBIC ● ● ●

Properties: C – dark blue; S -light blue; L – vitreous; D – transparent to translucent; DE – 2.4; H – 5-5.5; CL – imperfect; F – uneven to conchoidal; M – isometric crystals, granular, massive.
Origin and occurrence: Metamorphic in contact metamorphosed marbles, associated with pyrite. Crystals up to 50 mm (2 in) across come from Sar-e-Sang, Badakhshan province, Afghanistan. Granular aggregates are known from many localities, such as Malobystrinskoye deposit near Lake Baikal, Russia or Monte Somma, Italy.
Application: decorative stone and gemstone.

Nosean, 6 mm grains, Laacher See, Germany

Lazurite, 60 mm, Afghanistan

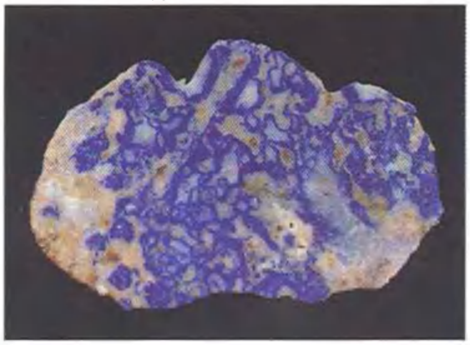

Lazurite, 21 mm x, Nuristan, Afghanistan

Lazurite, 60 mm, Chile

Tugtupite

$Na_8Be_2Al_2Si_8O_{24}Cl_2$

TETRAGONAL ● ●

Properties: C – white, pink, red, bluish; S – white; L – vitreous; D – transparent to translucent; DE – 2.3; H – 5; CL – good; F – uneven to conchoidal; M – small crystals, granular, massive.
Origin and occurrence: Hydrothermal in alkaline syenites and their pegmatites, also as a product of chkalovite alteration. Aggregates up to 60 mm (2$^{3}/_{8}$ in) across come from the Umbozero mine, Mount Alluaiv, Lovozero massif, Kola Peninsula, Russia and IIRmaussaq, Greenland. Small crystals occur in the Poudrette quarry, Quebec, Canada.

Tugtupite, 90 mm, Illimaussaq, Greenland

Danalite

$Fe_4Be_3Si_3O_{12}S$

CUBIC ● ●

Properties: C – gray,yellow,pink, red, brown; S – white; L – vitreous; D – transparent to translucent; DE – 3.4; H – 5.5-6; CL – imperfect; F – uneven to conchoidal; M – isometric crystals, granular, massive.
Origin and occurrence: Magmatic in granitic pegmatites; hydrothermal in greisens, skarns and ore veins. It occurs in Cape Ann, Massachusetts, USA; Hortekollen, Norway and Coolgardie, Western Australia, Australia.

Danalite, 70 mm, Yxjoberg, Sweden

Helvite, 2 mm xx, Cavnic, Romania

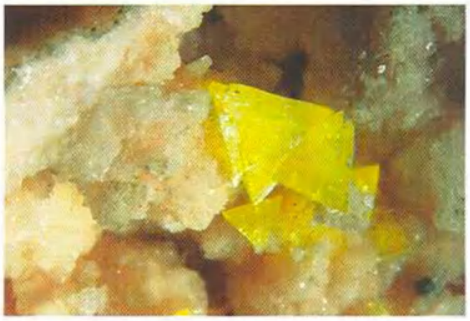

Helvite

$Mn_4Be_3Si_3O_{12}S$

CUBIC ● ● ●

Properties: C – brown, gray, yellow, yellow-green; S – white; L – vitreous; D – transparent to translucent; DE – 3.4; H – 6; CL – good; F – uneven to conchoidal; M – isometric crystals, granular, massive.
Origin and occurrence: Magmatic in granitic pegmatites and alkaline syenites; hydrothermal in greisens, skarns and ore deposits. Cubic crystals up to 25 mm (1 in) across known from the Sawtooth Batholith, Idaho, USA. Crystals also come from Schwarzenberg, Germany; Cavnic, Romania; and Oslofjord, Norway.
Application: Be ore.

Scapolite, 44 mm x, Leslie Lake, Quebec, Canada

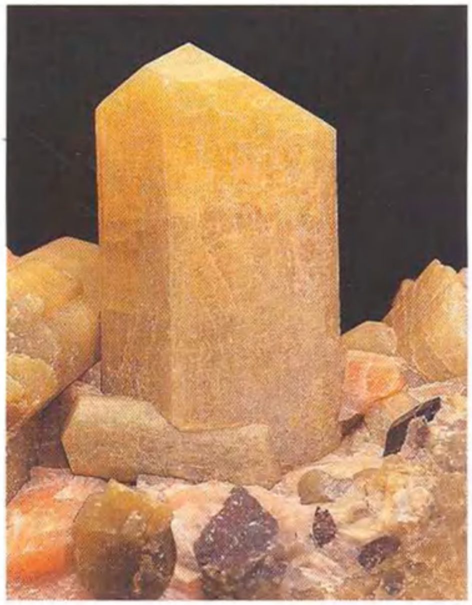

Marialite

SCAPOLITE GROUP

$Na_8(AlSi_3O_8)_6\ (Cl_2,SO_4)$

TETRAGONAL ● ● ●

Properties: : C – colorless, white, gray, purplish, yellow; S – white; L – vitreous, locally pearly; D – transparent to translucent; DE – 2.5; H – 5-6; CL – good; F – uneven to conchoidal; M – prismatic crystals, columnar aggregates, granular, massive; LU – yellow to orange.
Origin and occurrence: Hydrothermal in veins, cross-cutting alkaline metamorphic rocks and in pegmatites, cross-cutting ultrabasic rocks; metamorphic in marbles and metaevaporites. It comes from Ankazobe, Madagascar; Umba, Tanzania and Crestmore, California, USA.

Meionite

SCAPOLITE GROUP

$Ca_8(Al_2Si_2O_8)_6\ (CO_3,SO_4)$

TETRAGONAL ● ● ● ●

Properties: C – colorless, white, gray, purplish, green, blue; S – white; L – vitreous; D – transparent to translucent; DE – 2.8; H – 5-6; CL – good; F – uneven to conchoidal; M – long prismatic crystals, columnar aggregates, granular, massive; LU – yellow to orange.

Leucite, 30 mm, Mt.Vesuvius, Italy

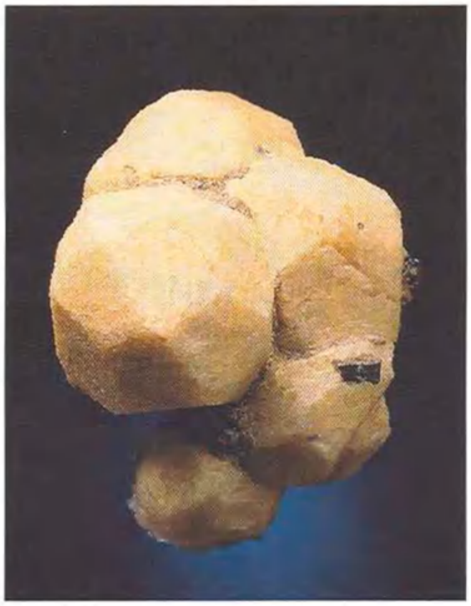

Analcime, 45 mm, Tunguzka, Russia

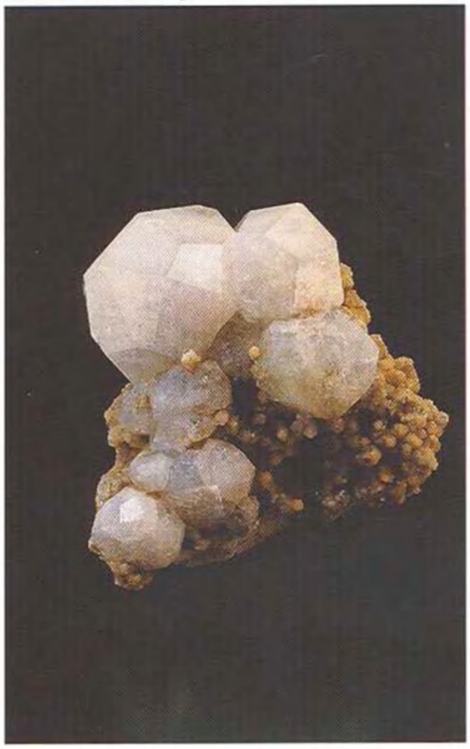

Origin and occurrence: Metamorphic in skarns, marbles, granulites and in contacts of volcanic rocks; hydrothermal in veins, cross-cutting Ca-rich rocks. Well formed crystals up to 40 cm (15¾ in) across come from Lake Clear and Eganville, Ontario, Canada. Crystals are also known from Monte Somma, Italy; Sludyanka, Siberia, Russia and Pargas, Finland.

Leucite

ZEOLITE GROUP

$KAlSi_2O_6$

TETRAGONAL ● ● ● ●

Properties: C – colorless, white, gray; S – white; L – vitreous; D – transparent to translucent; DE – 2.5; H – 5.5-6; CL- imperfect; F – uneven to conchoidal; M – isometric crystals, granular, massive.
Origin and occurrence: Magmatic in effusive K-rich basalts, associated with nepheline and sanidine. Well-formed crystals, several cm in size, come from Mount Vesuvius, Italy and Laacher See, Germany.
Application: ceramic industry.

Analcime

ZEOLITE GROUP

$NaAlSi_2O_6 . H_2O$

CUBIC ● ● ● ●

Properties: C – colorless, white, pinkish, yellowish; S – white; L – vitreous; D – transparent to translucent; DE – 2.3; H – 5-5.5; CL – imperfect; F – uneven to conchoidal; M – isometric crystals, granular, massive.
Origin and occurrence: Mainly hydrothermal as a product of nepheline or sodalite replacement; rare magmatic in effusive rocks; also in sediments, associated with calcite and zeolites. Well-formed crystals up to 30 cm (12 in) across come from Nidym, Siberia, Russia; Lago Maggiore, Italy; Mont St.-Hilaire, Quebec, Canada; West Paterson, New Jersey, USA and elsewhere.

Pollucite

ZEOLITE GROUP

$(Cs,Na)AlSi_2O_6 . H_2O$

CUBIC ● ● ●

Properties: C – colorless, white, gray; S – white; L – vitreous; D – transparent to translucent; DE – 2.9; H – 6.5-7; CL – none; F – uneven to conchoidal; M – isometric crystals, granular, massive.
Origin and occurrence: Magmatic and rarely also hydrothermal in Li-bearing pegmatites, associated with lepidolite, albite, quartz and petalite. Almost monomineral layer of pollucite several meters thick occurs in the Tanco mine, Bernic Lake, Manitoba, Canada. White and colorless crystals from pegmatite cavities up to 60 cm (24 in) across come from Paprok, Afghanistan. Also known from San Piero in Campo, Elba, Italy and Gilgit, Pakistan.
Application: ceramic industry, Cs ore.

Pollucite, 22 mm x, Gilgit, Pakistan

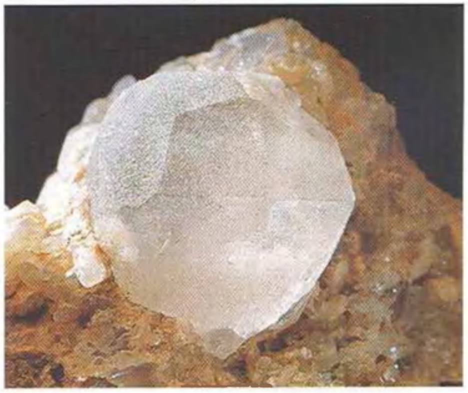

Natrolite, 47 mm, Maricopa Co., Arizona, U.S.A.

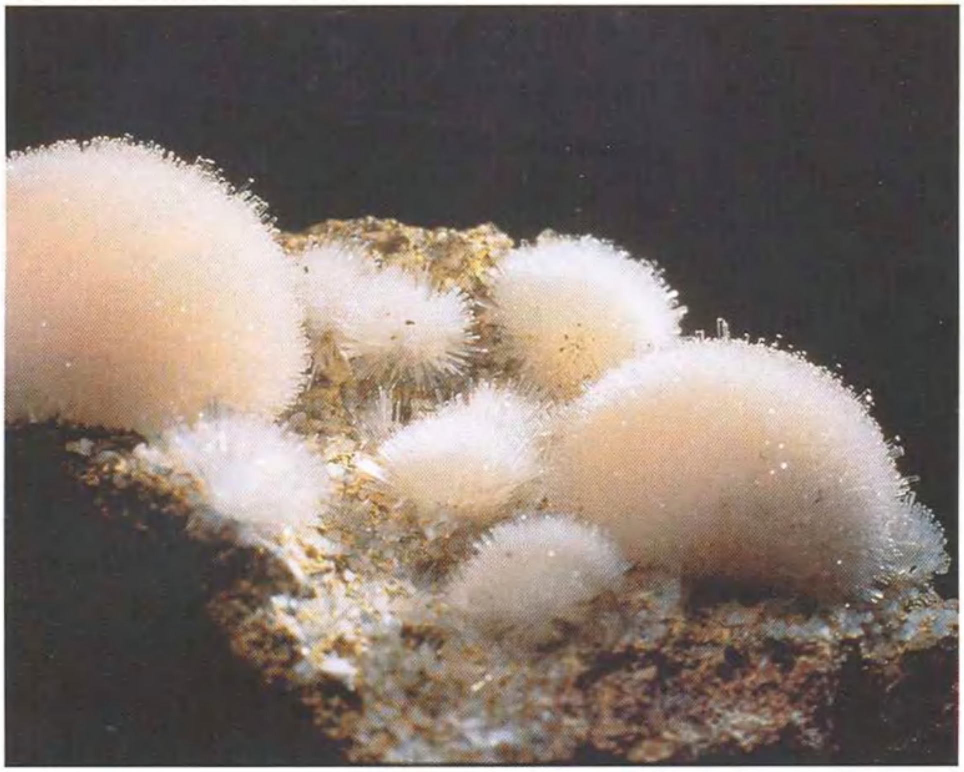

Scolecite, 165 mm, Nasik, India

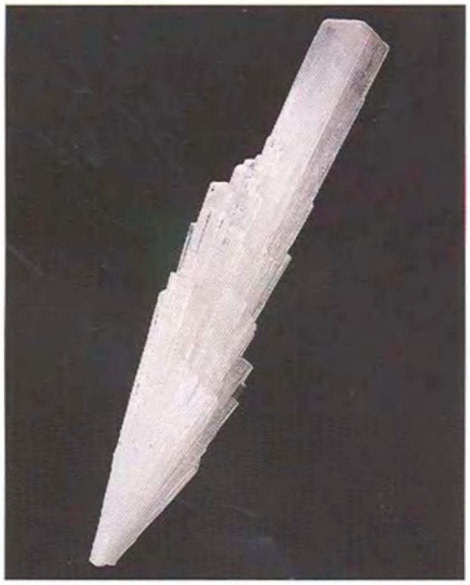

Natrolite

ZEOLITE GROUP

$Na_2Al_2Si_3O_{10} \cdot 2\,H_2O$

ORTHORHOMBIC ● ● ● ●

Properties: C – colorless, white, yellowish, pinkish; S – white; L – vitreous to silky; D – transparent to translucent; DE – 2.2; H – 5-5.5; CL – perfect; F – uneven to conchoidal; M – long prismatic to acicular crystals, fibrous and radial aggregates, granular, massive.

Origin and occurrence: Hydrothermal in cavities in volcanic rocks, alkaline pegmatites, along the Alpine-type fissures, also as a product of plagioclase replacement, commonly associated with calcite and zeolites. Colorless and white acicular crystals up to 30 cm (12 in) long come from cavities of alkaline pegmatites in Mount Putelichorr, Khibiny massif, Kola Peninsula, Russia. Crystals were also found in Narssarssuk, Greensland and Mont St.-Hilaire, Quebec, Canada. Crystals also occur in cavities of basaltic rocks in Teigarhorn, Iceland; Zalezly and Soutisky, Czech Republic and in Faeroe Islands.

Skolecite

ZEOLITE GROUP

$CaAl_2Si_3O_{10} \cdot 3\ H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white; S – white; L – vitreous to silky; D – transparent to translucent; DE – 2.3; H – 5; CL – good; F – uneven; M – long prismatic to acicular crystals, fibrous and radial aggregates.

Origin and occurrence: Hydrothermal in cavities in volcanic rocks and along the Alpine-type fissures, associated with calcite and zeolites. Clear prismatic crystals up to 200 mm ($7\frac{7}{8}$ in) long come from basalt cavities near Nasik, India. Crystals come also from Teigarhorn, Iceland and Suderoy, Faeroe Islands.

Mesolite

ZEOLITE GROUP

$Na_{16}Ca_{16}Al_{48}Si_{72}O_{240} \cdot 64\ H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white; S – white; L – vitreous to silky; D – transparent to translucent; DE – 2.3; H – 5; CL – good; F – uneven; M - acicular crystals, fibrous and radial aggregates, granular, massive.

Origin and occurrence: Hydrothermal in cavities in volcanic rocks, associated with other zeolites. Colorless needles up to 150 mm (6 in) long come from the basalt cavities in Berufjord and Teigarhorn, Iceland. Radial aggregates up to 200 mm ($7\frac{7}{8}$ in) in diameter known from the vicinity of Poona, India. Prismatic crystals up to 100 mm (4 in) long found in Skookumchuck Dam, Washington, USA.

Mesolite, 150 mm, Mahrashitra, India

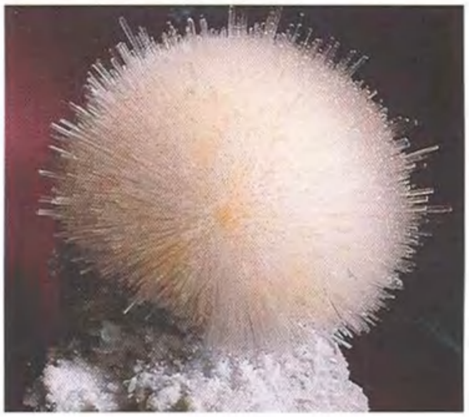

Thomsonite

ZEOLITE GROUP

$Ca_2NaAl_4(Al,Si)_2Si_4O_{20} \cdot 6\ H_2O$

ORTHORHOMBIC ● ● ●

Properties: C – colorless, white, yellowish, brown-red; S – white; L – vitreous to pearly; D – transparent to translucent; DE – 2.3; H – 5-5.5; CL – good; F – uneven to conchoidal; M – prismatic crystals in clusters with radial structure, botryoidal aggregates, massive.

Origin and occurrence: Hydrothermal in cavities in volcanic rocks, also as a product of hydrothermal feldspar replacement. Colorless and white acicular crystals, forming radial aggregates up to 50 mm (2 in) in diameter come from Old Kilpatrick, Scotland, UK and West Paterson, New Jersey, USA. Hemispherical aggregates up to 30 mm ($1\frac{3}{16}$ in) across known from Vinaicka hora near Kladno, Czech Republic.

Thomsonite, 50 mm, Bazsi, Hungary

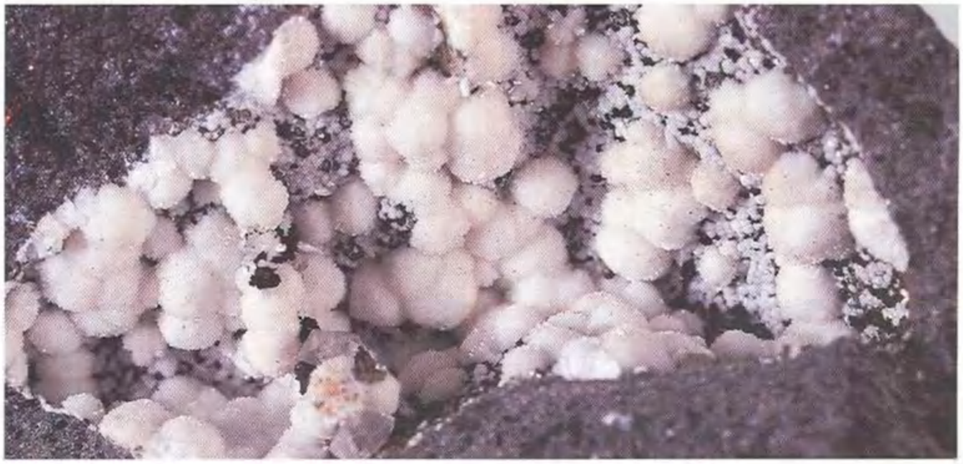

Gonnardite, 10 mm xx, Zalahalap, Hungary

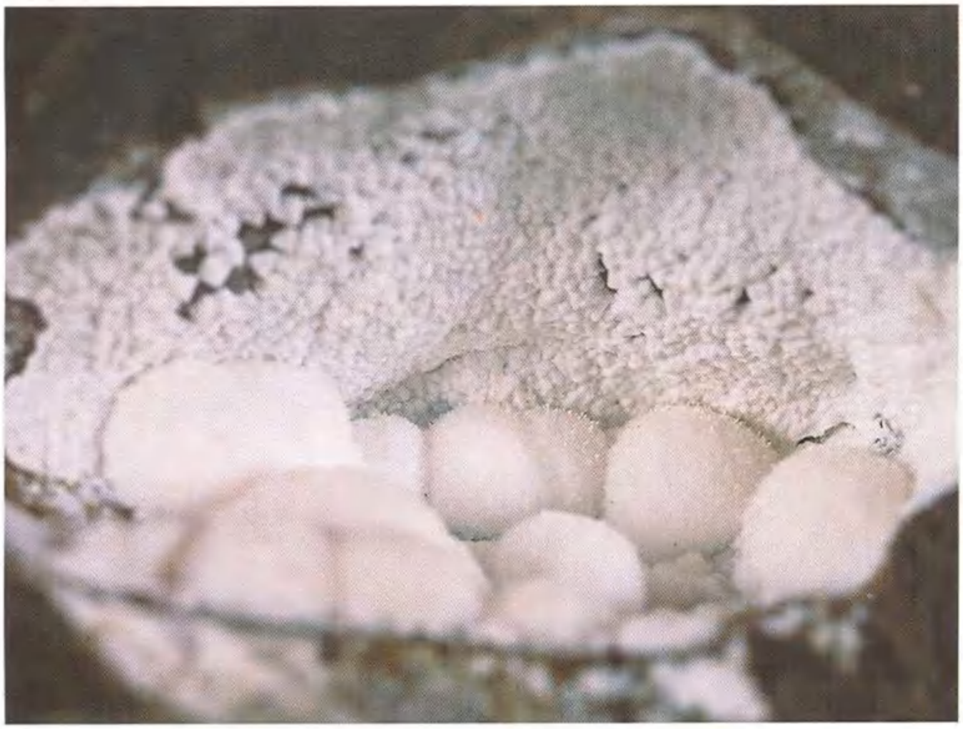

Gonnardite

ZEOLITE GROUP

$(Na,Ca)_{6-8}(Al,Si)_{20}O_{40} \cdot 12\ H_2O$

TETRAGONAL ● ● ●

Properties: C – colorless, white, yellowish; S – white; L – vitreous to pearly; D – transparent to translucent; DE – 2.3; H – 4.5-5; CL – good; F – uneven to conchoidal; M – prismatic crystals, fibrous and radial aggregates.

Origin and occurrence: Hydrothermal in cavities in volcanic rocks, associated with zeolites, also in the contact zone of marbles, associated with wollastonite. Acicular crystals and fibrous aggregates occur in Aci Castello, Sicily, Italy; Weilberg, Germany; Bundoora, Victoria, Australia.

Edingtonite

ZEOLITE GROUP

$BaAl_2Si_3O_{10} \cdot 3\ H_2O$

TETRAGONAL ● ● ●

Properties: C – white, gray, pinkish; S – white; L – vitreous; D – transparent to translucent; DE – 2.8; H – 4; CL – good; F – uneven to conchoidal; M – prismatic crystals, granular, massive.

Origin and occurrence: Hydrothermal in cavities and along the cracks in volcanic rocks, associated with calcite and harmotome. Colorless and white prismatic crystals up to 40 mm ($1\frac{9}{16}$ in) across come from Old Kilpatrick, Scotland, UK; Stare Ransko,

Edingtonite, 100 mm, Stare Ransko, Czech Republic

Czech Republic and Mont St.-Hilaire, Quebec, Canada.

Dachiardite-Ca

ZEOLITE GROUP

$(Ca_{0.5},Na,K)_5Al_5Si_{19}O_{48} \cdot 13\ H_2O$

MONOCLINIC ● ●

Properties: C – colorless, white, yellowish; S – white; L – vitreous to pearly; D – transparent to translucent; DE – 2.1; H – 4-4.5; CL – good; F – uneven to conchoidal; M – prismatic crystals and complex interpenetration twins.

Origin and occurrence: Hydrothermal in cavities in granitic pegmatites, associated with albite, petalite and elbaite, also as pseudo-morphs after petalite. It occurs in San Piero in Campo, Elba, Italy and in the Opal Hill quarry, Riverside, California, USA.

Ferrierite-Ca

ZEOLITE GROUP

$(Ca,Na,K,Mg)_6Al_6Si_{30}O_{72} \cdot 18\ H_2O$

ORTHORHOMBIC ● ●

Properties: C – colorless, white, greenish, pink, brownish; S – white; L – vitreous; D – transparent to translucent; DE – 2.1; H – 3-3.5; CL – good; F – uneven to conchoidal; M – tabular crystals, platy and columnar aggregates, massive.

Origin and occurrence: Hydrothermal in cavities in volcanic rocks, along the cracks of the Alpine-type veins and in volcanic tuffs, associated with calcite and zeolites. Platy aggregates occur in Svojanov, Czech Republic; Albero Bosso and Monastir, Sardinia, Italy; Kamploops Lake, British Columbia, Canada.

Ferrierite-Ca, 2 mm aggregates, Regec, Hungary

Dachiardite-Ca, 2 mm xx, Regec, Hungary

Laumontite

ZEOLITE GROUP

$Ca_4Al_8Si_{16}O_{48} \cdot 18\ H_2O$

MONOCLINIC ● ● ● ●

Properties: C – colorless, white, yellowish, pinkish; S – white; L – vitreous; D – transparent to translucent, weathered almost opaque; DE – 2.4; H – 3-4; CL – good; F – uneven to conchoidal; M – prismatic crystals, fibrous and radial aggregates.

Origin and occurrence: Hydrothermal in cavities in volcanic rocks, along the cracks in the Alpine-type veins, in ore veins and sediments, associated with calcite and other zeolites. Colorless and white acicular crystals up to 38 cm ($14\frac{15}{16}$ in) long come from the Pandulena Hill Quarries, India. Crystals up to 150 mm (6 in) long known from Pine Creek, Bishop, California, USA. It was also found in Dillenburg, Germany.

Laumontite, 120 mm, Markovice, Czech Republic

Heulandite-Ca, 8 mm xx, Parana, Brazil

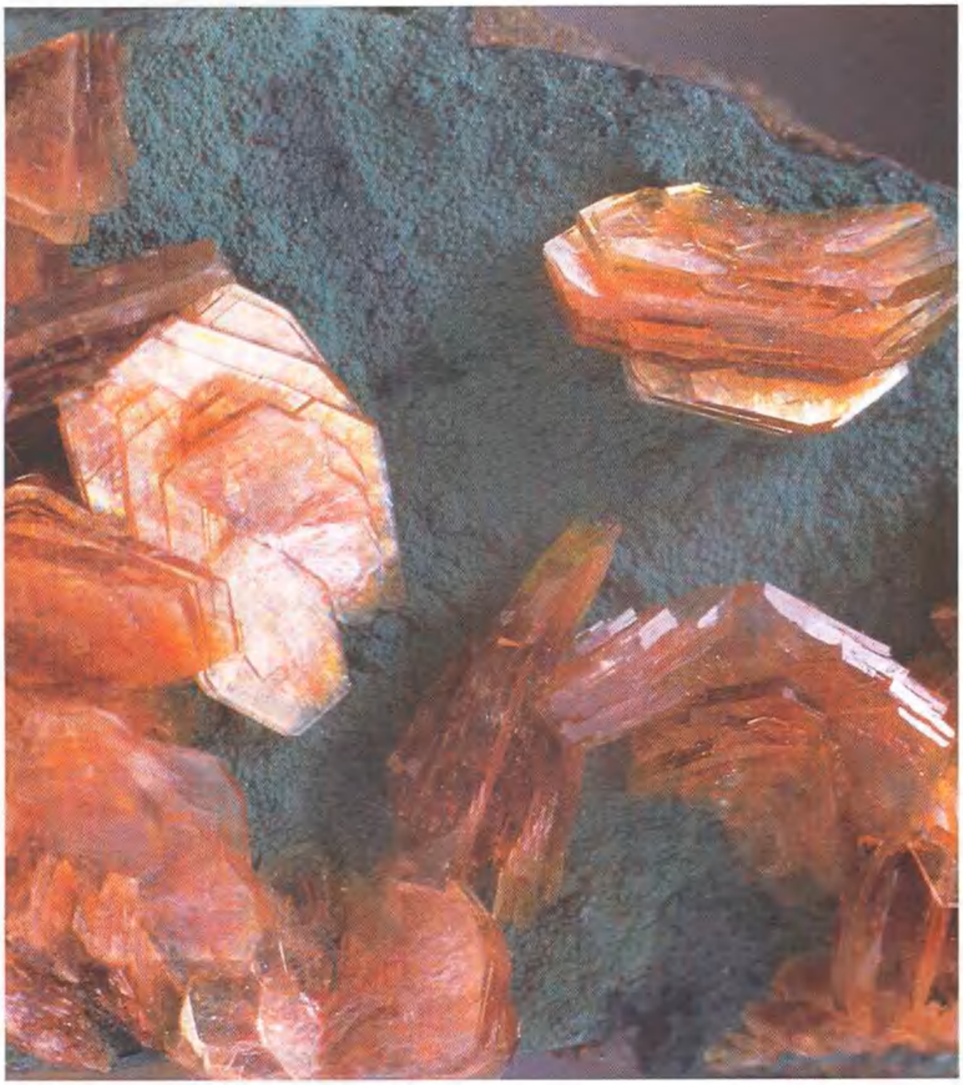

Heulandite-Ca

ZEOLITE GROUP

$(Ca_{0.5},Sr_{0.5},Na,K)_{4.5}Al_9Si_{27}O_{72} \cdot 24\ H_2O$

MONOCLINIC ● ● ● ●

Properties: C – colorless, white, yellowish, pinkish, red, brown; S – white; L B vitreous to pearly; D – transparent to translucent; DE – 2.1; H – 3.5-4; CL – perfect; F – uneven to conchoidal; M – prismatic to tabular crystals, granular, massive.

Origin and occurrence: Hydrothermal in cavities in volcanic rocks, in the Alpine-type fissures, ore veins and sedimentary rocks, usually associated with calcite and other zeolites. Colorless and white tabular crystals up to 100 mm (4 in) across come from Nasik, India; West Paterson, New Jersey, USA; Teigarhorn, Iceland. Red heulandite found in Val di Fassa, Italy.

Clinoptilolite-Ca, 2 mm xx, Hon?ova Hurka, Czech Republic

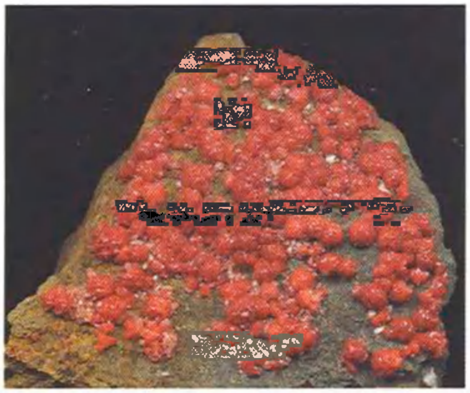

Clinoptilolite-Ca

ZEOLITE GROUP

$(Ca_{0.5},Na,K)_{4.5}Al_9Si_{27}O_{72} \cdot 24\ H_2O$

MONOCLINIC ● ● ● ●

Properties: C – colorless, white, yellowish, pinkish, red, greenish; S – white; L – vitreous; D – transparent to translucent; DE – 2.2; H – 3.5-4; CL – perfect; F – uneven to conchoidal; M – platy crystals, massive.
Origin and occurrence: Hydrothermal in volcanic-sedimentary rocks. Large industrial deposits occur in New Zealand, Japan and Australia. Crystals come from Agate Beach, Oregon, USA.
Application: construction, chemical industry and agriculture.

Stilbite-Ca

ZEOLITE GROUP

$(Ca_{0.5},Na,K)_9Al_9Si_{27}O_{72} \cdot 28\ H_2O$

MONOCLINIC ● ● ● ●

Properties: C – colorless, white, yellowish, pinkish, brown; S – white; L – vitreous, locally pearly; D – transparent to translucent; DE – 2.2; H – 3.5-4; CL – good; F – uneven to conchoidal; M – prismatic and tabular crystals, commonly complicated interpenetration twins and sheaf-like aggregates, granular, massive.
Origin and occurrence: Hydrothermal in cavities of volcanic rocks, along Alpine-type fissures, in ore veins, also in sedimentary rocks and hot springs, typically associated with calcite and other zeolites. Colorless and white tabular crystals and their combinations up to 200 mm ($7^{7}/_{8}$ in) across come from the Pandulena Hill Quarries, India. Crystals are also known from Teigarhorn, Iceland; Faeroe Islands; West Paterson, New Jersey, USA and elsewhere.

Epistilbite, 15 mm x, Nasik, India

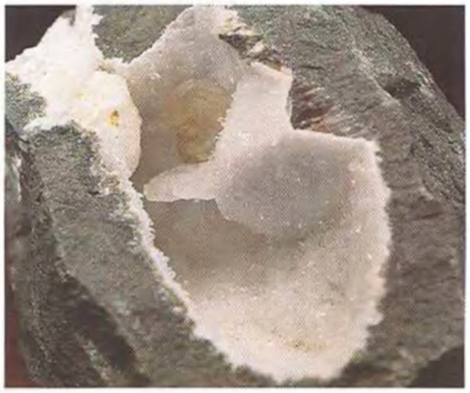

Epistilbite

ZEOLITE GROUP

$(Ca,Na_2)Al_2Si_4O_{12} \cdot 4\ H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white, yellowish, pinkish, light brown; S – white; L – vitreous; D – transparent to translucent; DE – 2.2; H – 4; CL – good; F – uneven to conchoidal; M – prismatic crystals, radial aggregates.
Origin and occurrence: Hydrothermal in cavities in volcanic rocks; associated with other zeolites. Clear and white tabular crystals and their twins up to 30 mm ($1^{3}/_{16}$ in) across come from Jalgaon, India; also in Teigarhorn, Iceland and Faeroe Islands.

Stilbite-Ca, 83 mm, Nasik, India

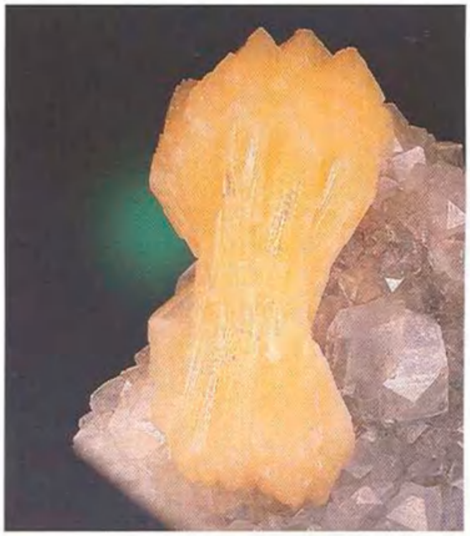

Gismondine, 2 mm xx, Tapolca-Diszel, Hungary

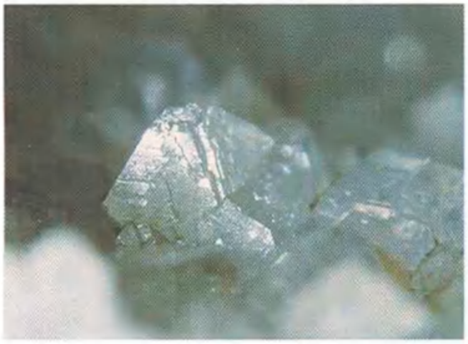

Gismondine

ZEOLITE GROUP

$CaAl_2Si_2O_8 \cdot 4{,}5\ H_2O$

MONOCLINIC ● ●

Properties: C – colorless, white, bluish, pinkish; S – white; L – vitreous; D – transparent to translucent; DE – 2.3; H – 4.5; CL – good; F – uneven; M – complex twins of crystals, platy aggregates.
Origin and occurrence: Hydrothermal in cavities in volcanic rocks, in hydrothermally altered rocks. It comes from Capo di Bove, Italy; Schiffenberg, Germany and Dobrna, Czech Republic.

Harmotome, 79 mm, Strontian, UK

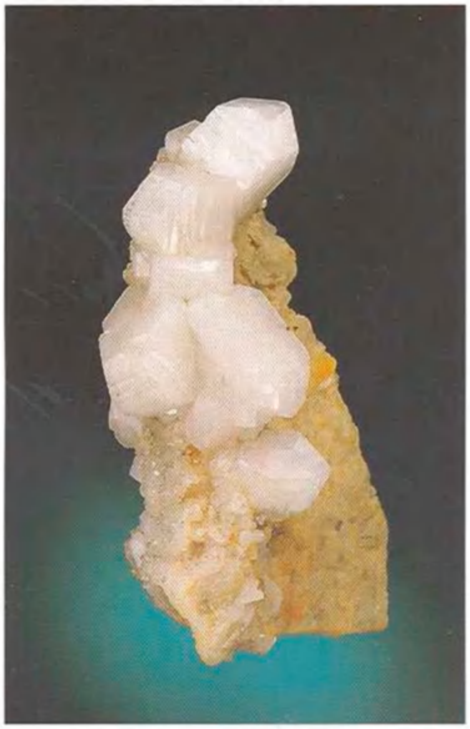

Phillipsite-K, 3 mm xx, Limberg, Germany

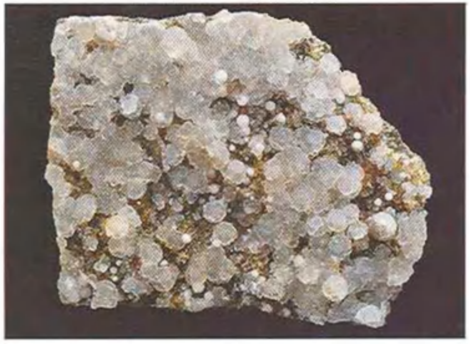

Phillipsite-K

ZEOLITE GROUP

$(K,Na,Ca_{0.5})Al_5Si_{11}O_{32} \cdot 12\ H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white, reddish; S – white; L – vitreous; D – transparent to translucent; DE – 2.2; H – 4-4.5; CL – good; F – uneven; M – prismatic crystals and complex interpenetration twins, granular, massive.
Origin and occurrence: Hydrothermal in cavities in volcanic rocks, sedimentary rocks and hot springs; associated with calcite and other zeolites. Colorless and white interpenetration twins up to 20 mm ($^{25}/_{32}$ in) across come from Capo di Bove, Italy; Doughboys, Tasmania, Australia; Sovince near Litomiøce, Czech Republic and elsewhere.

Harmotome

ZEOLITE GROUP

$(Ba_{0.5},Ca_{0.5},K,Na)_5Al_5Si_{11}O_{32} \cdot 12\ H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white, gray, reddish, yellow, brown; S – white; L – vitreous; D – transparent to translucent; DE – 2.4; H – 4.5; CL – good; F – uneven; M – prismatic crystals, commonly complex interpenetration twins, granular massive.
Origin and occurrence: Hydrothermal in cavities in volcanic rocks, in the Alpine-type veins, ore veins and in pegmatites. Prismatic crystals and their twins up to 20 mm ($^{25}/_{32}$ in) across are known from Strontian, Scotland, UK. Crystals also come from St. Andreasberg and Oberstein, Germany; Kozakov, Czech Republic and Kongsberg, Norway.

Goosecreekite

ZEOLITE GROUP

$CaAl_2Si_3O_{10} \cdot 5 H_2O$

MONOCLINIC ●

Properties: C – white, colorless; S – white; L – vitreous; D – transparent to translucent; DE – 2.2; H – 4.5; CL B perfect; F – uneven to conchoidal; M – prismatic crystals, granular.
Origin and occurrence: Hydrothermal in cavities in volcanic rocks. It is known from Goose Creek, Virginia, USA. Crystals up to 30 mm ($1\frac{3}{16}$ in) across found in the Pandulena Hill quarries, India.

Goosecreekite, 25 mm xx, Maharashtra, India

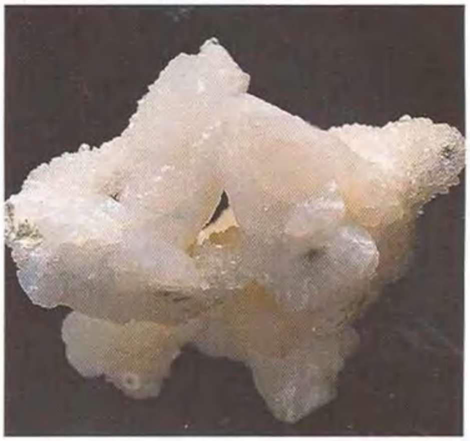

Chabasite-Ca

ZEOLITE GROUP

$(Ca_{0.5},Na,K)Al_4Si_8O_{24} \cdot 12 H_2O$

TRIGONAL ● ● ●

Properties: C – colorless, white, yellowish, pinkish, greenish; S – white; L – vitreous to dull; D – transparent to translucent; DE – 2.2; H – 4-4.5; CL – imperfect; F – uneven to conchoidal; M – rhombohedral crystals and their twins, granular, massive.
Origin and occurrence: Hydrothermal in cavities in volcanic rocks and pegmatites, along Alpine-type fissures and in hot springs, usually associated with calcite and other zeolites. Colorless and white interpenetration twins up to 60 mm (24 in) across, come from Faeroe Islands. Crystals are also known from Repcice, Czech Republic; Berufjord, Iceland; Panvil, India; Maglovec, Slovakia and elsewhere.

Chabazite-Ca, Passboro, Nova Scotia, Canada

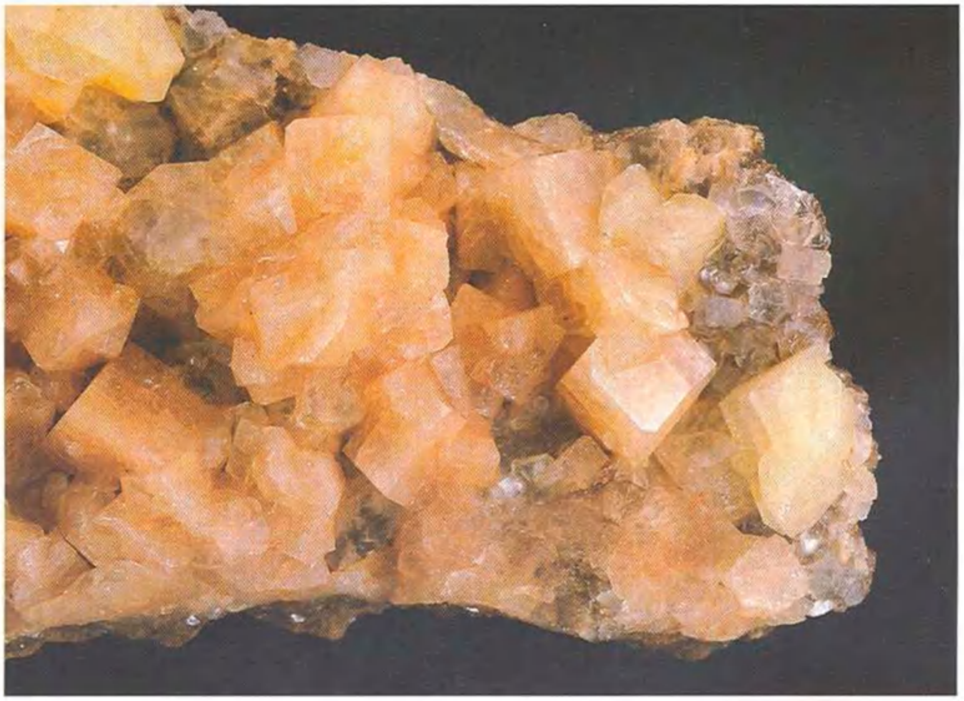

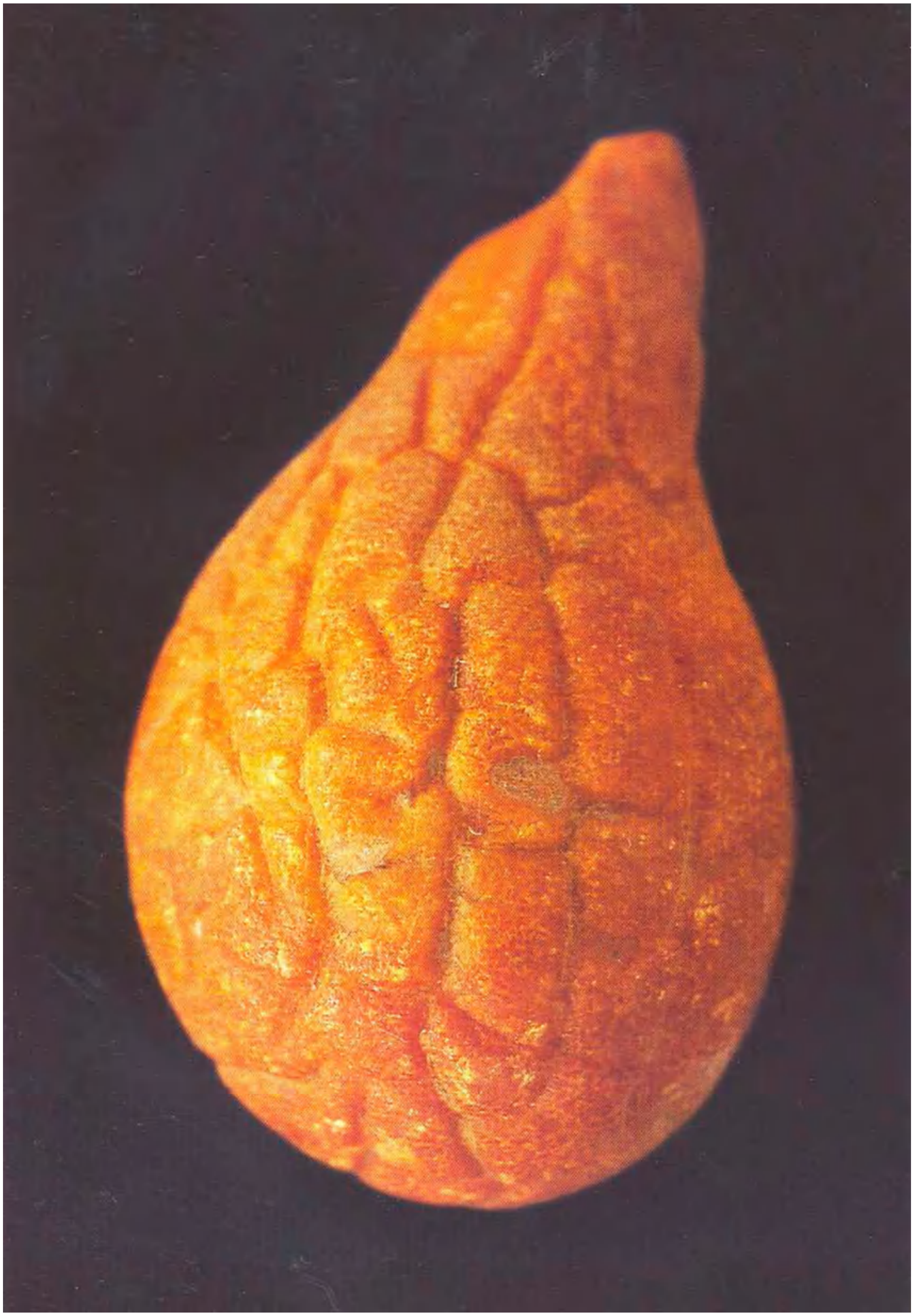

10. Organic compounds

Whewellite

$CaC_2O_4 . H_2O$

MONOCLINIC ● ● ●

Properties: C – colorless, white, grayish; S – colorless; L – vitreous; D – transparent to translucent; DE – 2,2; H – 2,5; CL – good; F – conchoidal; M – prismatic crystals, commonly twinned.
Origin and occurrence: Rare hydrothermal, mainly sedimentary in coal basins, associated with barite, ankerite and other minerals. Hydrothermal crystals up to 70 mm (2¾ in) long, come from U-bearing veins in PrRbram, Czech Republic. Similar crystals, up to 70 mm (2¾ in) long, occurred in Cavnic, Romania. Heart-shaped and butterfly twins, up to 100 mm (4 in) found in concretions near Kladno, Czech Republic. Similar specimens are known from Burgk near Dresden, Germany. Interesting flat radial aggregates found along cracks in clays in the vicinity of Most, Czech Republic.

Amber, 40 mm, Baltic Sea, Latvia
Whewellite, 27 mm x, Burgk, Germany

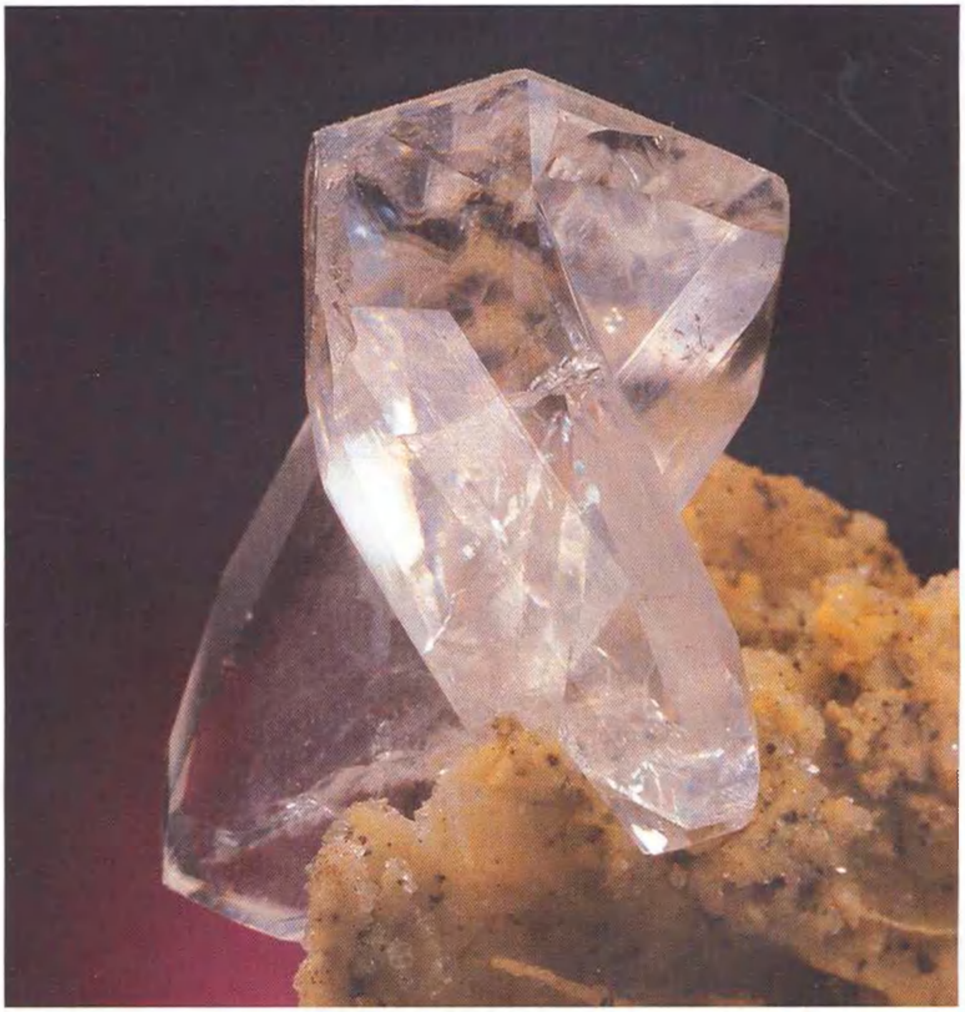

Mellite, 170 mm, Bicske-Csordakút, Hungary

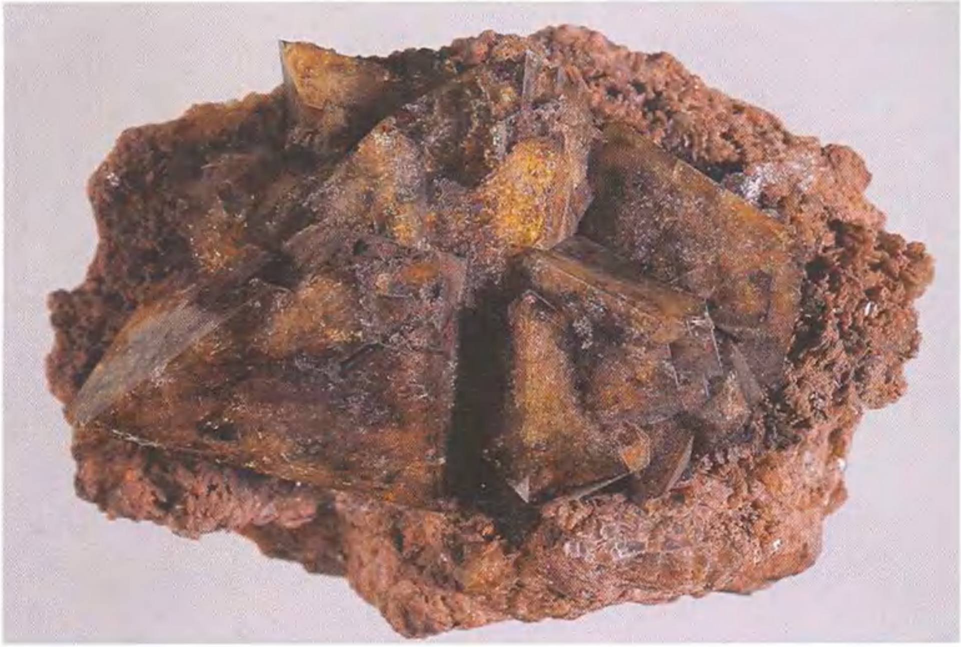

Mellite

$Al_2[C_6(COO)_6] . 18\ H_2O$

TETRAGONAL ● ●

Properties: C – honey-yellow; S – white; L – resinous to vitreous; D – transparent to translucent; DE – 1,7; H – 2; CL – imperfect; F – conchoidal; M – dipyramidal crystals, granular; LU – blue.
Origin and occurrence: Secondary in the cracks in brown coal and lignite. The best specimens with crystals up to 40 mm ($1\frac{9}{16}$ in) in size, come from Csordakut near Tatabanya, Hungary. Crystals, up to 10 mm ($\frac{3}{8}$ in) across, were found in Artern, Germany. Granular aggregates are known from Valchov, Czech Republic.

Evenkite

$C_{24}H_{50}$

MONOCLINIC ●

Properties: C – colorless to light yellow; S – colorless; L – waxy; D – translucent; DE – 0,9; H – 1; CL – good; M – pseudo-hexagonal tabular crystals; R – melts at 50EC (122°F).
Origin and occurrence: Probably secondary. It occurs within geodes near Evenki, Siberia, Russia. Also known from the cracks in altered andesite in Dubnik, Slovakia.

Fichtelite

$C_{19}H_{34}$

MONOCLINIC ● ● ●

Properties: C – colorless to yellowish; S – colorless; L – vitreous; PS – transparent to translucent; DE – 1; H – 1; M – thin tabular crystals, scales, crystalline crusts.

Evenkite, 50 mm, Dubnik, Slovakia

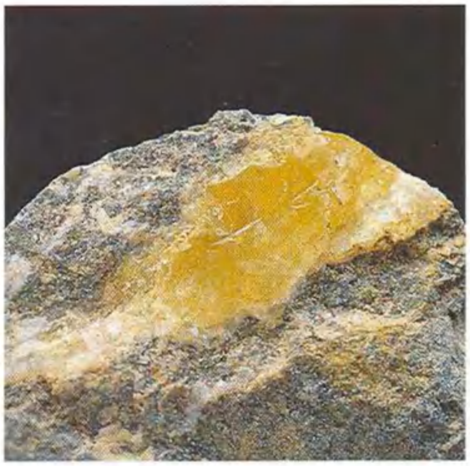

Origin and occurrence: Secondary, typical mineral of peat-bogs. Its crystals are known from Borkovice near Sobeslav, Czech Republic; also known from Marktredwitz, Germany.

Amber

a mixture of hydrocarbons

AMORPHOUS ● ● ●

Properties: C – honey-yellow, yellow-brown, brown, red-brown, blue, green, black; S – white; L – resinous, dull; D – transparent to translucent, rare opaque; DE – 1,0-1,1; H – 2-2,5; CL – none; F – conchoidal; M – massive irregular or drop-shaped aggregates, nodules and fragments; LU – light blue, yellow.
Origin and occurrence: Amber is a petrified resin from Tertiary and Mesozoic conifers, occurring rarely in sediments. Plant or insect remnants are sometimes found trapped in amber. The most famous localities are located along the southern coast of the Baltic Sea in Poland, Germany, Lithuania, Estonia, Latvia and Russia. The largest masses found weighed up to 10 kg (22 lb). Blue amber is known from the Dominican Republic. Other amber localities are found in Syria, Lebanon, Thailand, Vietnam, Canada and the USA.
Application: as a gemstone.

Fichtelite, 80 mm, Mazice, Czech Republic

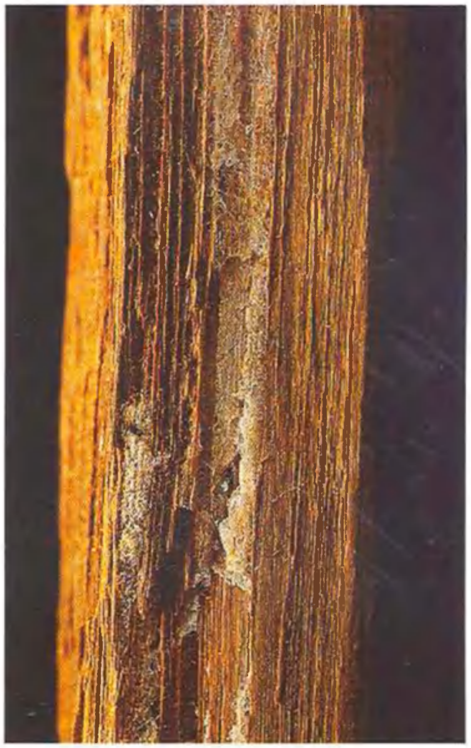

Amber, 95 mm, Madagascar

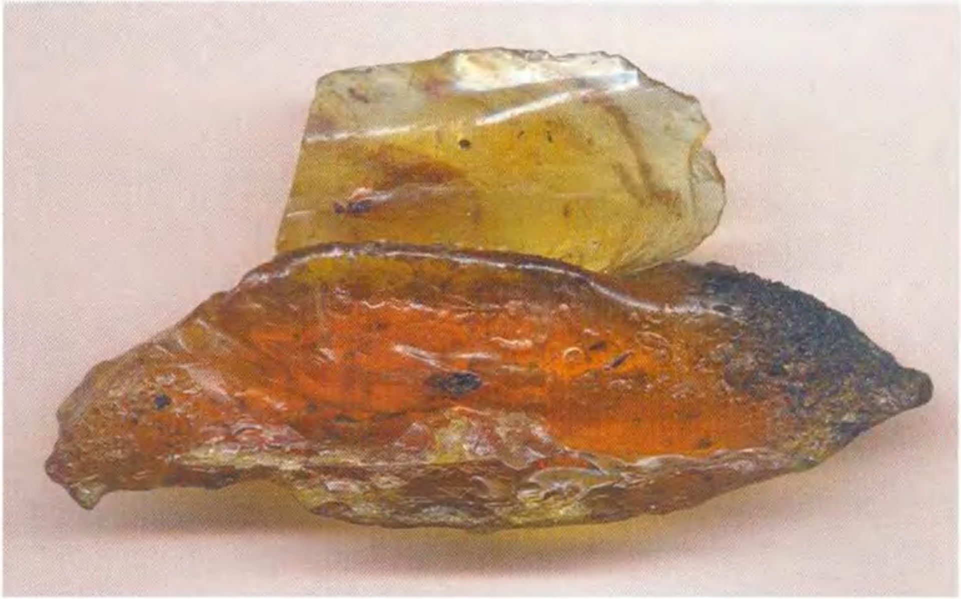

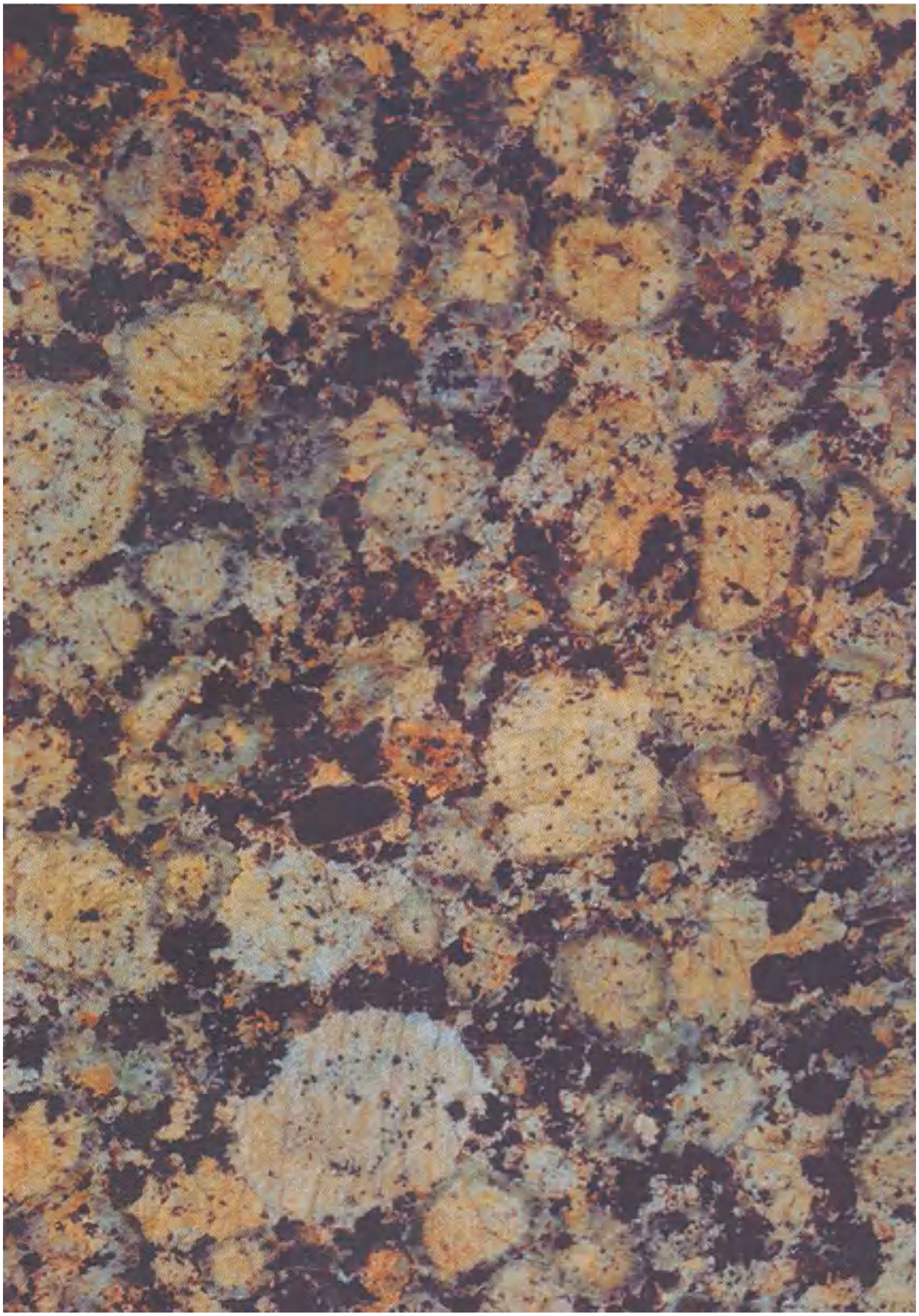

11. Rocks, meteorites and tektites

Rocks consist of minerals and often of fragments of other rocks and organic matter. Since rocks are mixtures, we cannot determine certain physical / chemical data (chemical formula, crystal system, hardness, etc.). Unlike minerals, some rocks form huge bodies which may cover several thousand km^2 so no single localities are shown in this book. Rocks are mainly used for building, in agriculture, and as raw materials for chemicals, ceramics and metals.
Rocks are generally divided into three principal groups according to their origin:

1. **igneous rocks**
2. **sedimentary rocks**
3. **metamorphic rocks**.

Granite, 65 mm, Norway

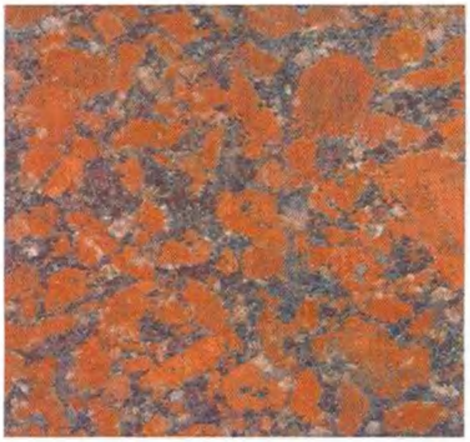

1. Igneous rocks

Properties: C – light gray, gray, white, brown, black, gray-green, pinkish, red-brown; D – opaque, rare transparent to translucent; L – dull, rare vitreous; DE – varies from 2.6 up to about 3.8; F – uneven, rare conchoidal; M – coarse to fine grained, commonly massive aggregates, consisting of microscopic or larger grains or crystals of various minerals, up to several decameters across, glass is also present rarely. Minerals in rocks usually have characteristic texture features, like graphic granite and others.

Origin and classification: Igneous rocks form at high temperature and commonly at high pressure in solidification of mainly silicate magma of variable composition. The mineral composition reflects a chemical composition of magma. Typical rock-forming minerals are quartz, orthoclase, microcline, plagioclase, biotite, muscovite, amphiboles, pyroxenes, olivine and nepheline. Rocks may solidify at various depths, according to which they are either intrusive, dyke or effusive. They can be grouped according to chemical composition (SiO2 content):
felsic – granite, syenite, pegmatite, rhyolite, obsidian
intermediate – diorite, andesit **basic** – gabbro, basalt
utrabasic – peridotite, varies from 1.0 up to about 2.8; F – uneven, sometimes conchoidal; M – coarse to fine grained and massive aggregates, consisting of grains or crystals, from microscopic to several dm in size, also of rock fragments and organic matter, banded textures are typical and some rocks are fossiliferous.

Orbicular granite, 150 mm, Sweden
Pegmatite, 65 mm, Dolni Bory, Czech Republic

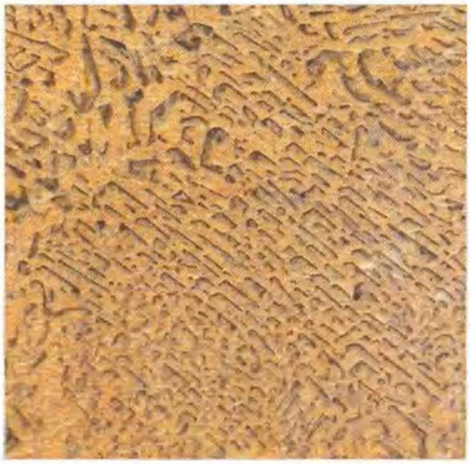

Diabase, 65 mm, Rožany, Czech Republic

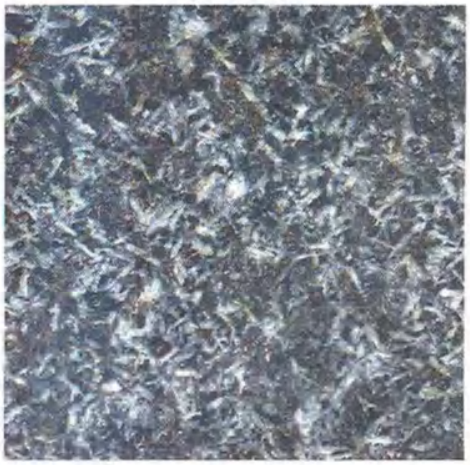

Sandstone, 65 mm, Buffalo Gap, South Dakota, U.S.A.

Conglomerate, 65 mm, St.Alban, UK

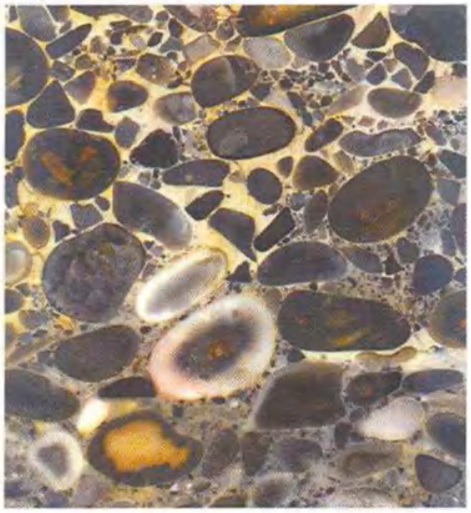

2. Sedimentary rocks

Properties: C – grey, brown, red-brown, black, green-grey, pinkish, white, yellow, often variable even within one rock, banding is typical; D – opaque, rare translucent; L – dull, sometimes vitreous, greasy or earthy; DE -varies from 1.0 up to about 2.8; F - uneven, sometimes conchoidal; M – coarse to fine grained and massive aggregates, consisting of grains or crystals, ranging from microscopic to several dm in size, also of rock fragments and organic matter, banded textures are typical and some rocks are fossiliferous.

Origin and classification: Sedimentary rocks originate under surface temperatures and pressures, as a result of sedimentation of mineral and rock fragments and organic matter of different size through the water and wind activity, or by precipitation from water solutions. Typical rock-forming minerals are quartz, calcite, dolomite, halite, clay minerals and others. According to their origins we can distinguish several groups of sedimentary rocks:

clastic (consisting of rock fragments) – sandstone, conglomerate, quartzite, siltstone.

organic (consisting mainly of organic matter) – limestone, coal.

chemical (originating by precipitation from water solutions) – evaporites, travertine.

Limestone, 65 mm, Italy

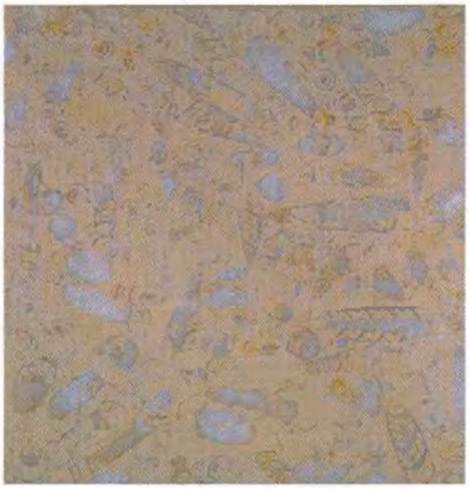

Evaporite, 40 mm, Walkenried, Germany

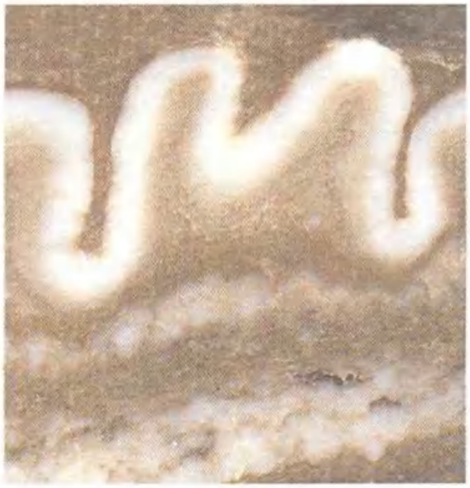

Serpentinite, 65 mm, Hrubšice, Czech Republic

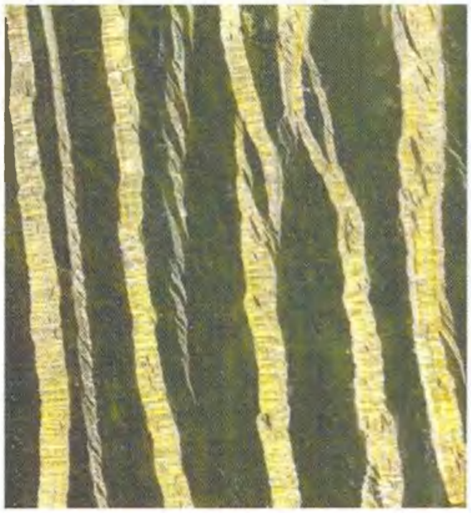

Gneiss, 65 mm, Doubravcany, Czech Republic

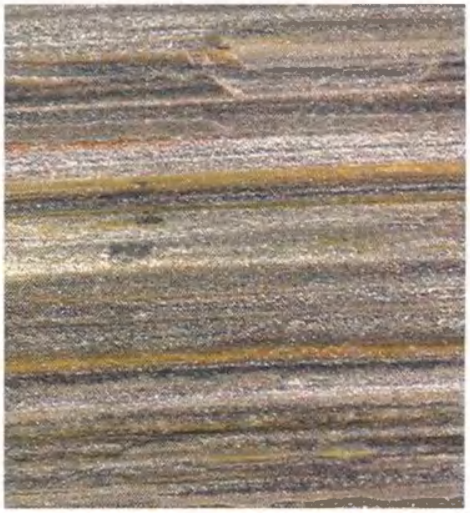

3. Metamorphic rocks

Properties: C – light gray, gray, brown, green, red-brown, black, green-gray, pinkish, white, sometimes variable within one rock, banding is relatively common; D – opaque; L – dull, rare vitreous; DE – varies from 2.5 to 4.8; F – uneven, rare conchoidal; M – coarse to fine-grained, platy, acicular and sometimes massive aggregates, consisting of grains and crystals, ranging from microscopic to several decimeters across. Typical are planar textures and foliation of some minerals.

Origin and classification: Metamorphic rocks originate under higher temperature and pressure during metamorphism of originally igneous or sedimentary rocks. The source of a thermal energy could be magma, then this type is called contact metamorphism, or the thermal source lies in the depth of the earth's crust and effects large areas, then this type is called regional metamorphism. During a process of metamorphism new minerals originate. Typical rock-forming metamorphic minerals are quartz, orthoclase, plagioclases, biotite, muscovite, amphiboles, pyroxenes, calcite, dolomite, sillimanite, kyanite, almandine, staurolite and serpentine.

Regionally metamorphosed rocks: serpentinite, mica schist, gneiss, marble.

Contact metamorphosed rocks: contact chert (porcelanite), skarn.

Marble, 100 mm, Greece

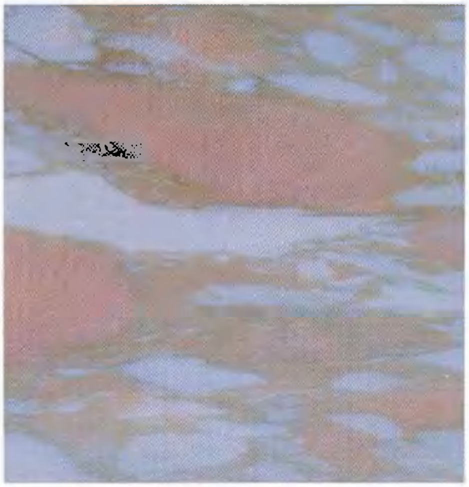

Skarn, 65 mm, Lisna, Czech Republic

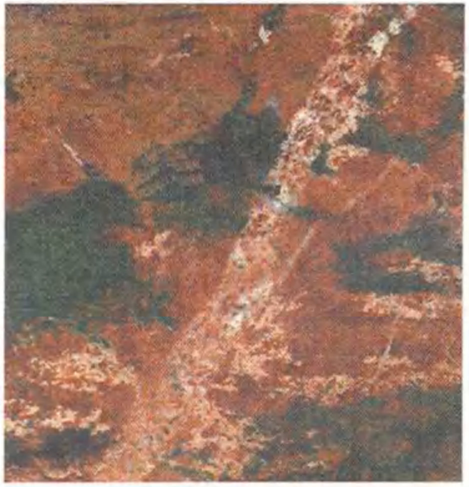

Iron meteorite, 50 mm, Sikhote-Alin, Russia

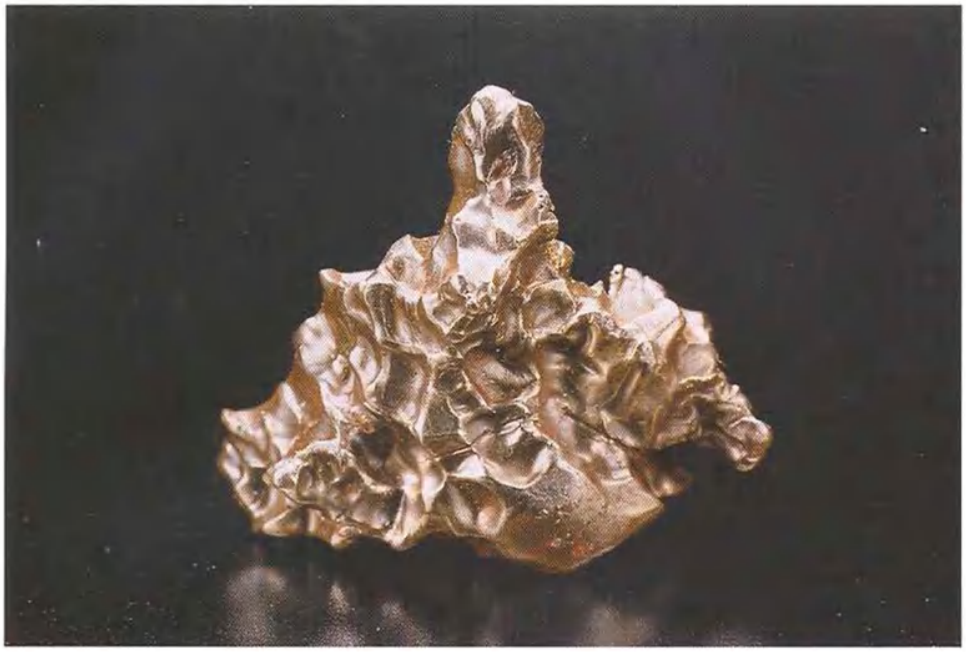

Iron meteorite, 40 mm detail, Gibeon, Namibia

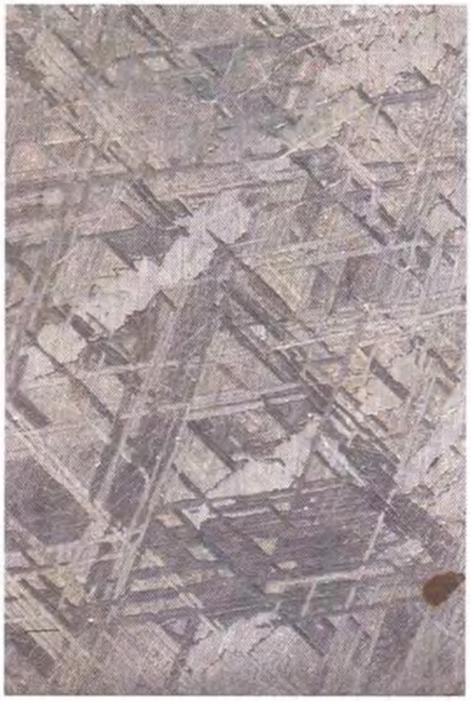

Meteorites

Properties: C - light gray, gray, gray-green, black; D – opaque; L – dull, metallic, rare vitreous; DE – varies from 3.0 to 7.3; F – uneven; M – coarse to fine-grained, sometimes massive aggregates, consisting of irregular grains of different minerals, ranging from microscopic to several cm across.
Origin and classification: Meteorites are igneousrocks formed in space. Most originate in the asteroidbelt between Mars and Jupiter. They consist of various minerals and their chemical composition differs greatly. Typical rock-forming minerals in meteorites are olivine, pyroxenes, plagioclases, Fe and Ni alloys and sulfides, rarely also organic matter. Meteorites fall into four main groups, accordingto metallic iron and silicate component:
iron meteorite;
siderolite;
chondrite;
achondrite;
Occurrence: Meteorite falls are known throughout the world. The largest known iron meteorite, weighing approximately 60 tons , is located near the Hoba farm, Namibia. The largest known chondrite, weighing about 1 ton , fell in 1948 in Norton County, Nebraska, USA. Most meteorites that have been found recently come from large glaciers such as those of Antarctica and from desert in Namibia.

Moldavite, 35 mm, Southern Bohemia, Czech Republic

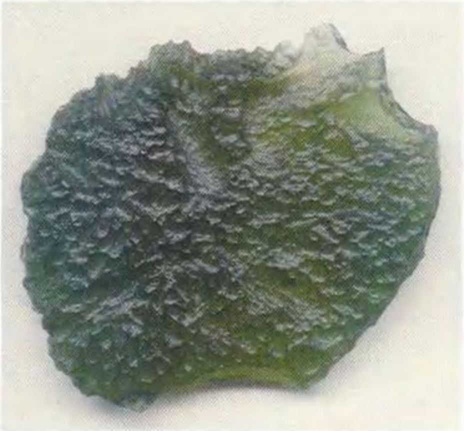

Tectite, 55 mm, Dalat, Vietnam

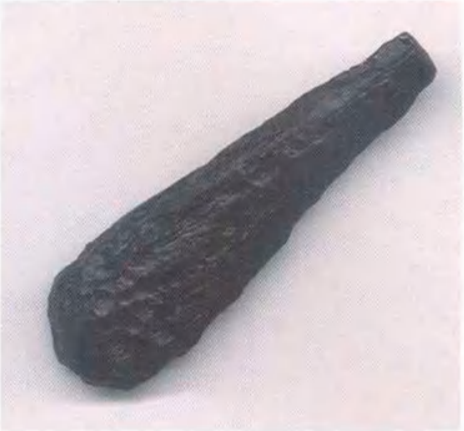

Tektites

Properties: C – light to dark green, yellow-green, brown-green, brown, green-gray, black; D – transparent, translucent to opaque; L – vitreous; DE – varies from 2.3 to 2.6; H – 6-7; F – conchoidal to uneven; M – massive irregular, drop-shaped or disc-shaped aggregates, irregular fragments, sometimes with typical sculptured surface.
Origin, classification and occurrence: Natural glasses, rich in SiO2, which formed as a result of rapid melting of surface rocks during impacts of large meteorites or comets.
They are classified according to their age and occurrence (following sequence from the oldest to the youngest):
Bediasites and georgianites – the USA, Mexico, Barbados, Cuba;
Urengoites – Novyi Urengoi, Russia;
Moldavites – southern Bohemia and western Moravia, Czech Republic;
Ivorites – Ivory Coast;
Irghisites – Zhamanshin, Russia;
Indochinites, phillipinites, javanites, bilitonites – southeastern Asia;
Australites – Australia.
Application: some tektites, mainly moldavites, as gemstones.

Moldavites, 40 mm, Southern Bohemia, Czech Republic

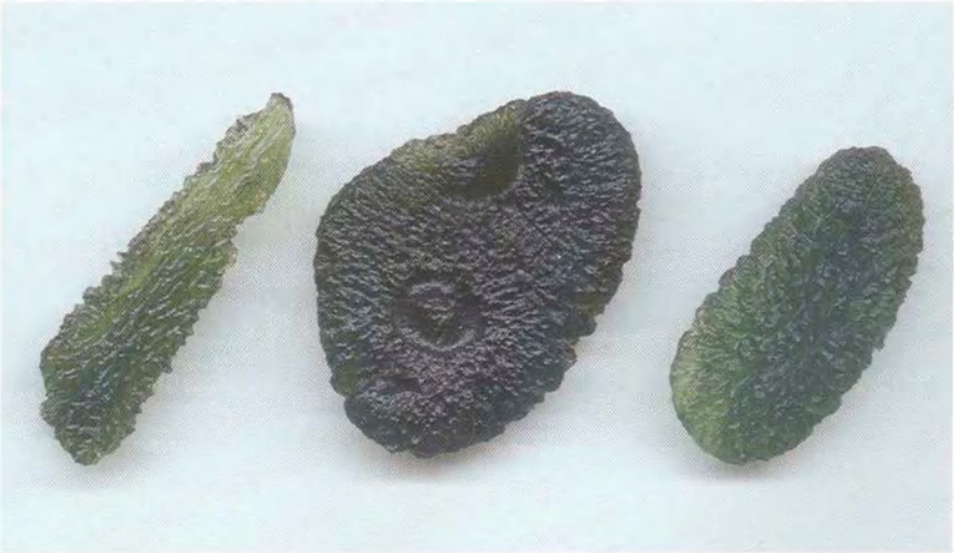

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Porcelanite, 85 mm, Komňa, Czech Republic
Agate, 50 mm, Zeleznice, Czech Republic

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THE COMPLETE ENCYCLOPEDIA OF

MINERALS

THE COMPLETE ENCYCLOPEDIA OF MINERALS

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- Carbonates • Borates • Sulphates • Phosphates
- Silicates • Organic compounds
- Rocks, meteorites and tektites

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Helium-filled balloon

Zirconium gemstone

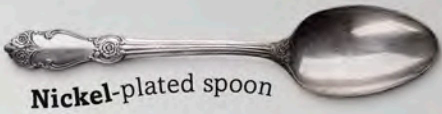
Nickel-plated spoon

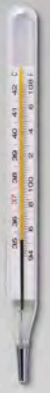
Mercury thermometer

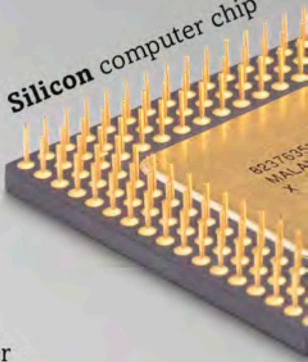
Silicon computer chip

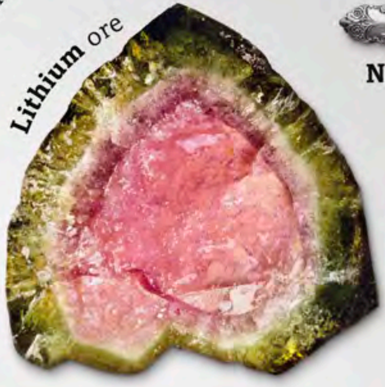
Lithium ore

THE PERIODIC TABLE BOOK

A VISUAL ENCYCLOPEDIA OF THE ELEMENTS

Indium LED

Vanadium ore

Sulfur ore

Aluminium foil

Hydrogen-rich atmosphere of Jupiter

Copper wire

THE PERIODIC TABLE BOOK

A VISUAL ENCYCLOPEDIA
OF THE ELEMENTS

THE PERIODIC TABLE BOOK

A VISUAL ENCYCLOPEDIA OF THE ELEMENTS

WRITTEN BY **TOM JACKSON**
CONSULTANT **JACK CHALLONER**

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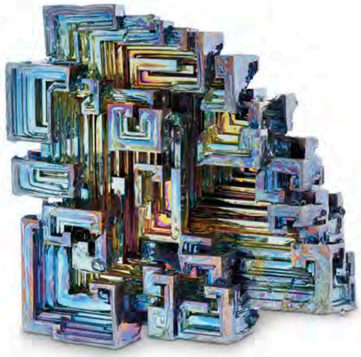

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Chunk of yttrium

Chunk of silver

Zirconium crystal bar

Foreword

Everything in nature, from the mountains and the oceans to the air we breathe and food we eat are made up of simple substances called elements. You may have already heard of several of them, including gold, iron, oxygen, and helium, but these are just four out of a total of 118. Many have unique – and sometimes surprising – chemical and physical properties. Gallium, for example, is a solid but melts in your hand. A compound of sulfur gives off a nasty smell of rotten eggs. Fluorine is a gas that can burn a hole straight through concrete!

The elements are rarely found in their pure form. Mostly, they are combined with each other to make compounds, which make up substances around us. For example, hydrogen and oxygen make water, sodium and chlorine form salt, and carbon is found in millions of compounds, many of which – including proteins and sugars – make our bodies work.

To find out more about the elements, we need to take a good look at the periodic table. This is used by scientists around the world to list and detail the elements. It shows the key information

Nickel balls

Cube of melting gallium

Iodine in a glass sphere

Barium
crystals

Chunk of grey
selenium

Magnesium
crystals

Osmium
pellet

for each element, grouping them into similar types. With this information, we can use the elements to make many things we need: a fluorine compound in toothpastes toughens our teeth and silicon crystals engineered into microchips operate our gadgets and phones.

Every element has its own story of where it comes from, what it can do, and how we use it. Let's begin a tour of every element one by one. It's going to be a fascinating journey.

Tom Jackson

Throughout this book you will find boxes with the following symbols. This is what each of them mean.

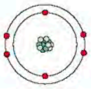

	This shows the structure of an atom of an element, with the nucleus (made of protons and neutrons) at the centre and electrons surrounding it in their shells.
⊖	Electron
⊕	Proton
○	Neutron
State	The state of the element at a temperature of 20°C (28°F). It can be a liquid, solid, or gas.
Discovery	This details the year in which the element was discovered.

Chunk of
uranium

Gold
crystals

Thulium
crystals

Calcium
crystals

Elemental building blocks

Elements are everywhere: some you can see, like gold, others are almost invisible, like oxygen gas. An element is a substance that cannot be broken up into simpler ingredients. Each one is made up of tiny building blocks called atoms, which are unique for every element. Most elements are joined with other elements to make compounds, which are made by combining two or more elements. This includes water, which is a compound of hydrogen and oxygen.

Elements in our world

There are 118 elements in the periodic table; 92 of them are found in nature, while the others are made by humans. Every element is unique. Most of the elements are solids, like the metals. At room temperature, 11 elements are gases, while bromine and mercury are the only two liquids.

Bromine liquid with bromine gas

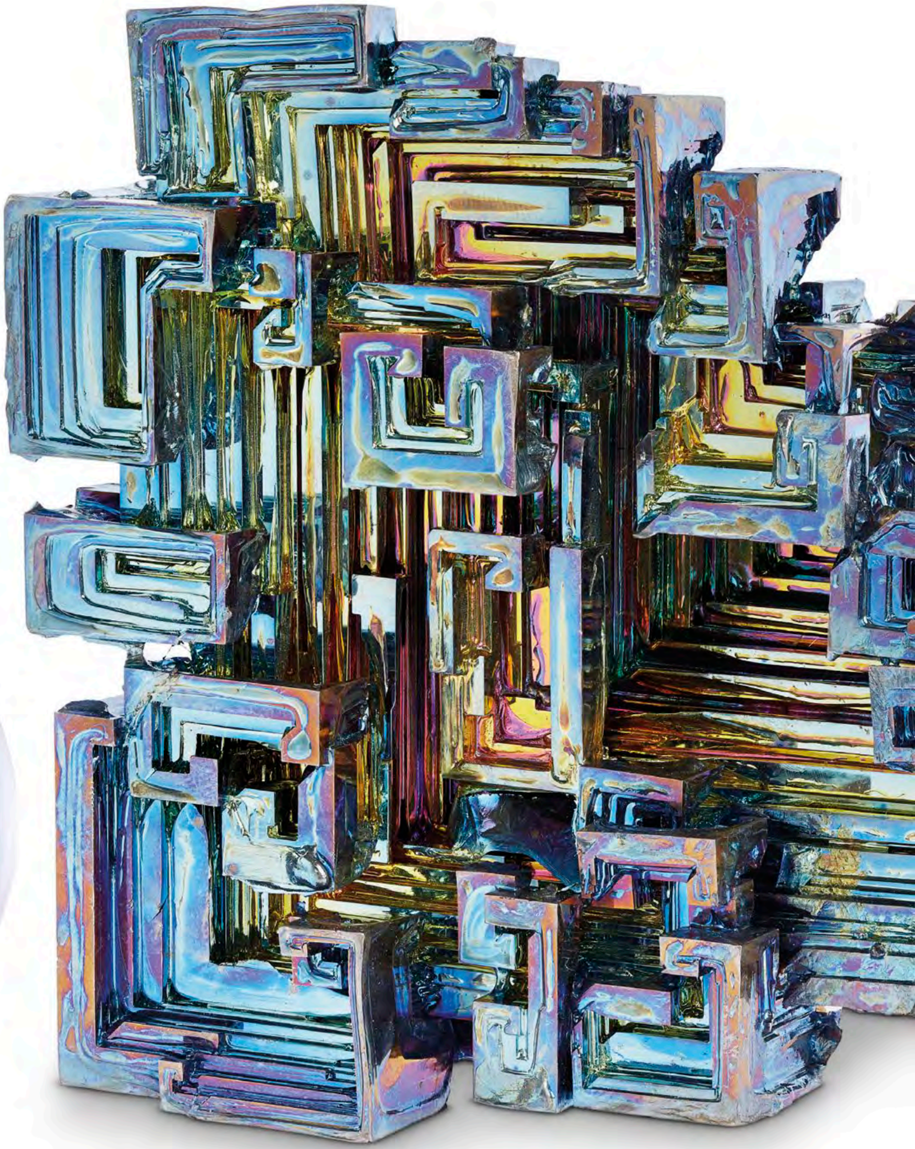

Bismuth crystals

Earth

Water

Air

Fire

Elements in and around us

About 99 per cent of the human body is made from just six elements, though they are combined together to form thousands of different compounds. On the other hand, Earth's atmosphere is a mixture of gases, most of which are pure elements. About 99 per cent of the air is made from nitrogen and oxygen.

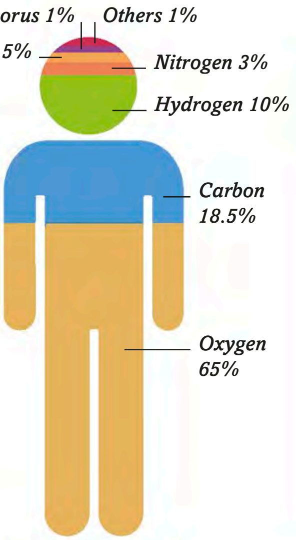

Human body

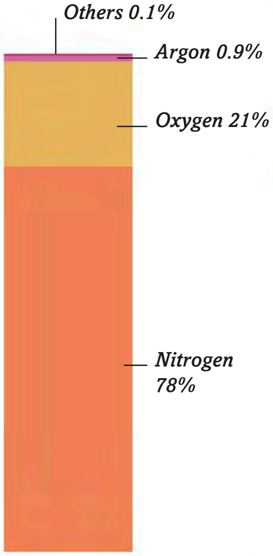

Earth's atmosphere

Gold crystals

Ancient ideas

The idea of elements is very old, dating back about 2,600 years to ancient Greece. However, Greek thinkers believed that the world was made of just four elements: earth, water, fire, and air. Empedocles, an influential scholar, was the first to propose that these elements made up all structures. Only much later did scientists learn that none of these are actually elements. For thousands of years, everybody from ancient Egyptian priests to medieval European alchemists, speculated about the definiton and classification of an element.

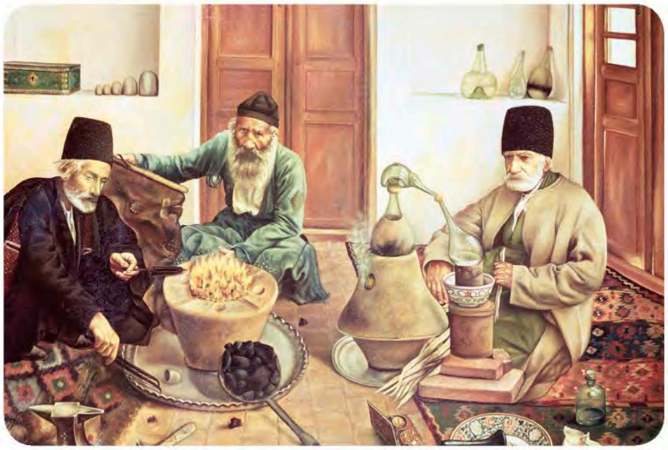

Iranian alchemists in their workshop

Alchemy and mysticism

Chemists are scientists who study elements and compounds. However, before they existed, the alchemists were medieval researchers. Believing in a mixture of science and magic, alchemists tried to change ordinary metals (such as lead) into gold. They failed because elements cannot be changed from one type to another. But, in the process, they discovered many new elements and developed several processes that chemists still use today.

ROBERT BOYLE

The first person to use science to understand the elements was the Irish scientist and inventor Robert Boyle. He pursued science through reason, and in the 1660s he performed the first chemistry experiments to show that much of what the alchemists believed was wrong.

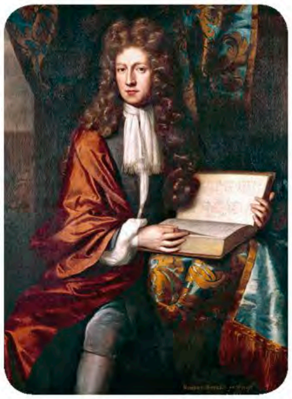

Chemical discoveries

Humphry Davy
In the early 19th century, the English scientist Humphry Davy discovered several new metals. He used a revolutionary process called electrolysis, in which electric currents split chemical compounds into their elements. Davy discovered a total of nine new elements, including magnesium, potassium, and calcium.

The ancient concept of four elements – earth, water, fire, and air – expanded to a belief that every substance on Earth was made from a mixture of these elements. However, many substances including mercury, sulfur, and gold did not fit this idea. Over the last 300 years, chemists have followed a long series of clues to reveal the true nature of elements, their atoms, and what happens to them during chemical reactions.

Pioneering chemists

Many of the first breakthroughs in chemistry came in the 1700s, from investigations into the composition of air. Chemists such as Joseph Black, Henry Cavendish, and Joseph Priestly discovered several different "airs", which we now call gases. They also found that the gases could react with solid substances, which they called "earths". These discoveries began a journey that revealed that there were dozens of elements, not just four. Today, scientists have identified 118 elements, but more may be discovered in time.

Antoine Lavoisier
In 1777, the French scientist Antoine Lavoisier proved that sulfur was an element. This yellow substance was familiar for thousands of years, but Lavoisier performed experiments to show that it was a simple substance that could not be divided up any further. In the same year, he also found out that water was not an element, but a compound of hydrogen and oxygen.

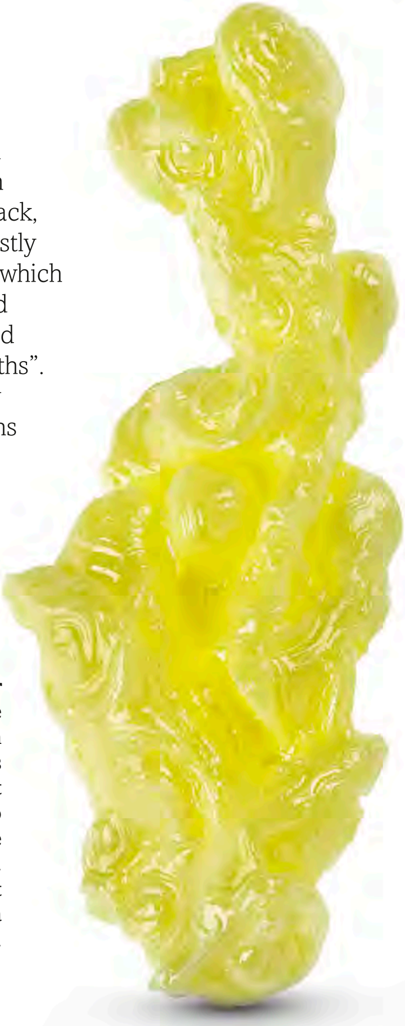

Granule of pure sulfur

Magnesium crystals

JOHN DALTON

Like many scientists of his day, the English scientist John Dalton already believed that matter must be made of tiny particles. In 1803, he began to think about how these particles might join together. He came to realize that there are different particles for every element, and that the particles of one element all have the same mass. He also realized that the particles of different elements combine in simple proportions to make compounds. So, for example, the particles of the elements carbon and oxygen can combine to make carbon monoxide. He suggested that during a chemical reaction, the particles rearrange to make compounds. He formulated the first modern theory of atoms.

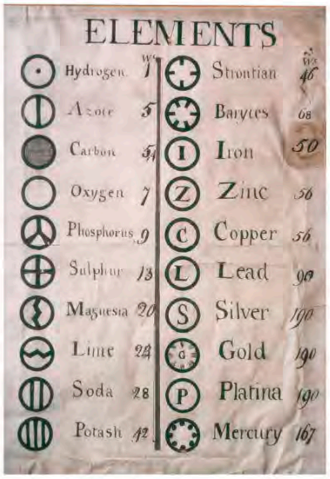

ELEMENTS

	Wt		Wt
Hydrogen	1	Strontian	46
Azote	5	Barytes	68
Carbon	5,4	Iron	50
Oxygen	7	Zinc	56
Phosphorus	9	Copper	56
Sulphur	13	Lead	90
Magnesia	20	Silver	190
Lime	24	Gold	190
Soda	28	Platina	190
Potash	42	Mercury	167

Dalton's table of elements

Jacob Berzelius
In the early 1800s, the Swedish doctor Jacob Berzelius investigated chemicals in rocks and minerals. He found two minerals that contained new elements. He named these elements cerium (after Ceres, the dwarf planet) and thorium (after Thor, the Viking god of thunder). Berzelius also invented a system of using symbols and numbers that chemists still use to identify elements and compounds today.

Chunk of pure cerium

Pure caesium inside a sealed container

States of matter

Elements can exist in three states of matter: solid, liquid, and gas. At room temperature, most elements are solids, 11 are gases, and only two are liquids. However, elements can change from one state into another. These changes don't alter the atoms of these elements, but arrange them in different ways.

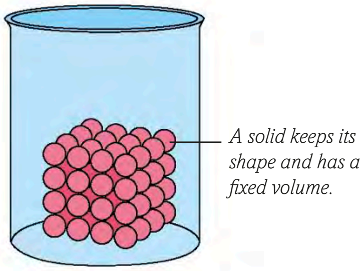

A solid keeps its shape and has a fixed volume.

In a solid, all the atoms are attracted to each other and locked in position.

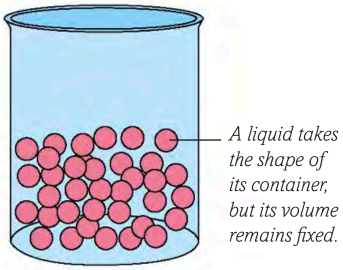

A liquid takes the shape of its container, but its volume remains fixed.

In a liquid, the atoms begin to move around as the attraction between them weakens.

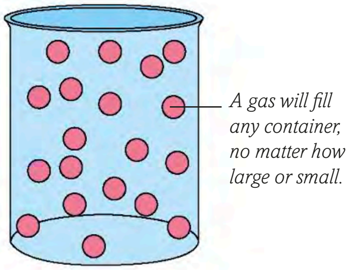

A gas will fill any container, no matter how large or small.

In a gas, the atoms are weakly attracted to each other, so they all move in different directions.

Robert Bunsen
The German chemist Robert Bunsen is best known for inventing a gas burner that is often used in laboratories. In the 1850s, Bunsen used such a burner – which produced a hot, clean flame – to study the unique flame colours produced by different elements. When an unknown substance made bright blue flames, he named it caesium, meaning "sky blue".

Inside an atom

An atom is the smallest unit of an element. Atoms are too small to see (even with the most powerful microscopes) but they are everywhere. They consist of smaller particles called protons, neutrons, and electrons. Every element has a unique number of protons.

What's the atomic number?

The number of protons in an atom of an element is called the atomic number. The atomic number of an atom identifies the element it belongs to. Every atom also has an equal number of electrons. For elements found naturally on Earth, hydrogen has the smallest atomic number (1), while uranium atoms have the highest atomic number (92).

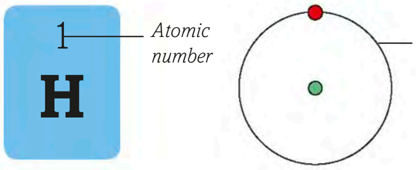

This shell is the space in the hydrogen atom where one electron circles the proton at the centre of the atom.

Hydrogen atom

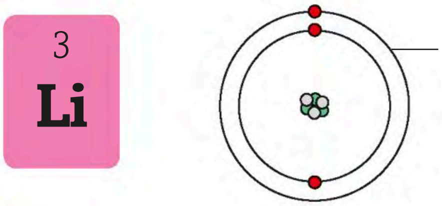

In a lithium atom, two shells house three electrons, which circle the protons and neutrons at the centre.

Lithium atom

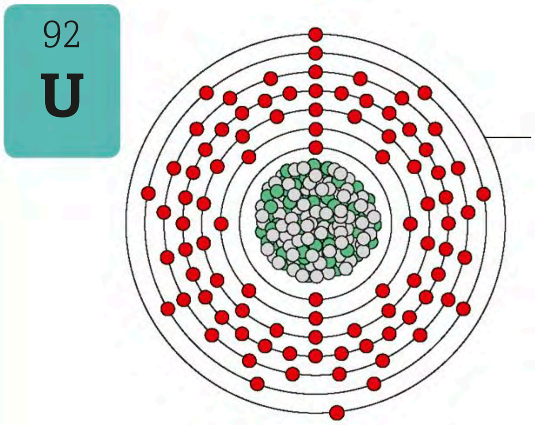

Seven shells house the 92 electrons in a uranium atom.

Uranium atom

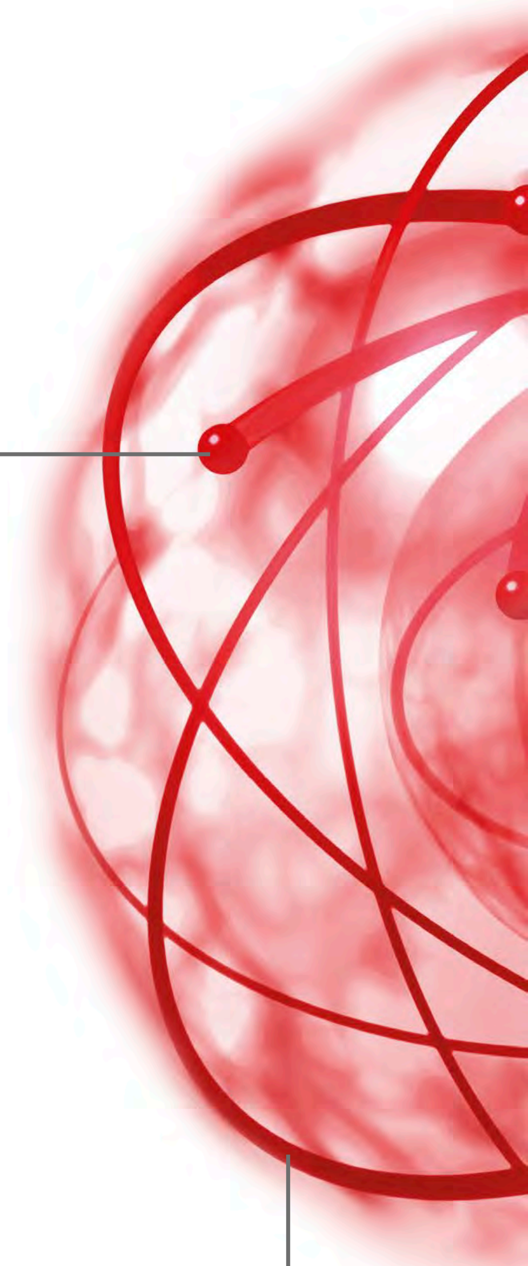

Electron ❯ The tiny, negatively charged particles in an atom are called electrons. They are involved in the way the atoms of an element react and form bonds with the atoms of other elements.

Shell ❯ The electrons in an atom move around the nucleus. They are arranged in layers called shells. When reacting with each other, atoms tend to fill up their outer shells to become more stable.

Neutron ❯ As its name suggests, neutrons are neutral particles, which means they do not have an electric charge. A neutron weighs the same as a proton, and much more than a electron.

Proton ❯ Protons have a positive electric charge. This charge attracts the negatively charged electrons, holding them in place around the nucleus. Because each proton's charge is cancelled out by the equal charge of an electron, the atom has no overall charge, and is therefore neutral.

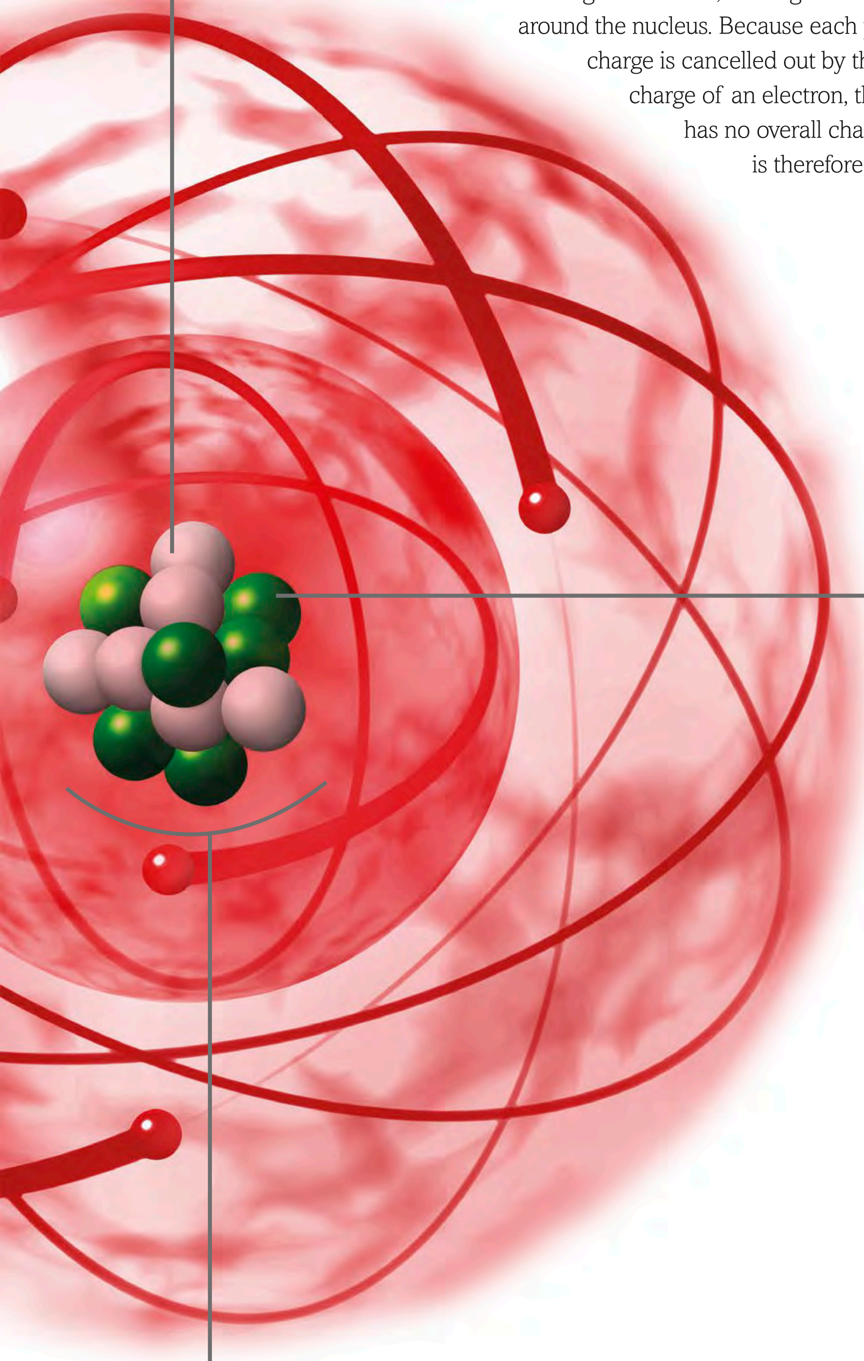

Nucleus ❯ The central core, or nucleus, of an atom is made up of protons and neutrons. Nearly all the mass of the atom is packed into the nucleus, and this gives every element a unique atomic mass.

Atomic facts

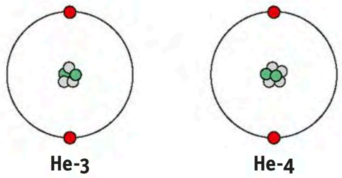

Isotopes

While every element has a unique number of electrons and protons in its atoms, the number of neutrons can vary. These different forms are called isotopes. For example, helium has two isotopes: one contains three neutrons (He-3), the other has four (He-4).

Electromagnet attracts metal pieces

Electromagnetism

Atoms work like tiny magnets. A force called electromagnetism holds them together. It makes particles with opposite charges, such as protons and electrons, attract each other. Those with similar charges repel each other. A magnet is an object in which the magnetic forces of the atoms attract and repel other objects. An electromagnet develops magnetism when an electric current runs through it.

ATOMIC PIONEERS

During his atomic research in the early 20th century, Sir Ernest Rutherford, a New Zealand scientist, expanded our understanding of the structure of atoms. He discovered protons and proved that they were located in an atom's nucleus.

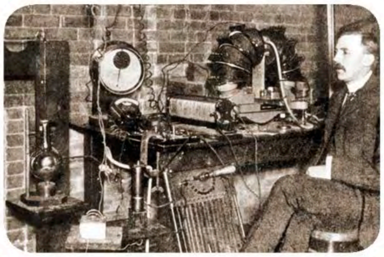

Sir Ernest Rutherford

Periodic table of elements

The periodic table is a useful way of organizing the elements. It arranges the elements in order of their atomic number, which is the number of protons in the nucleus of an atom, and is unique to every element. The table also divides the elements into rows, called “periods”, and columns, called “groups”. Dmitri Mendeleev, the chemist who devised the table, arranged the elements based on the similarity of certain physical and chemical properties.

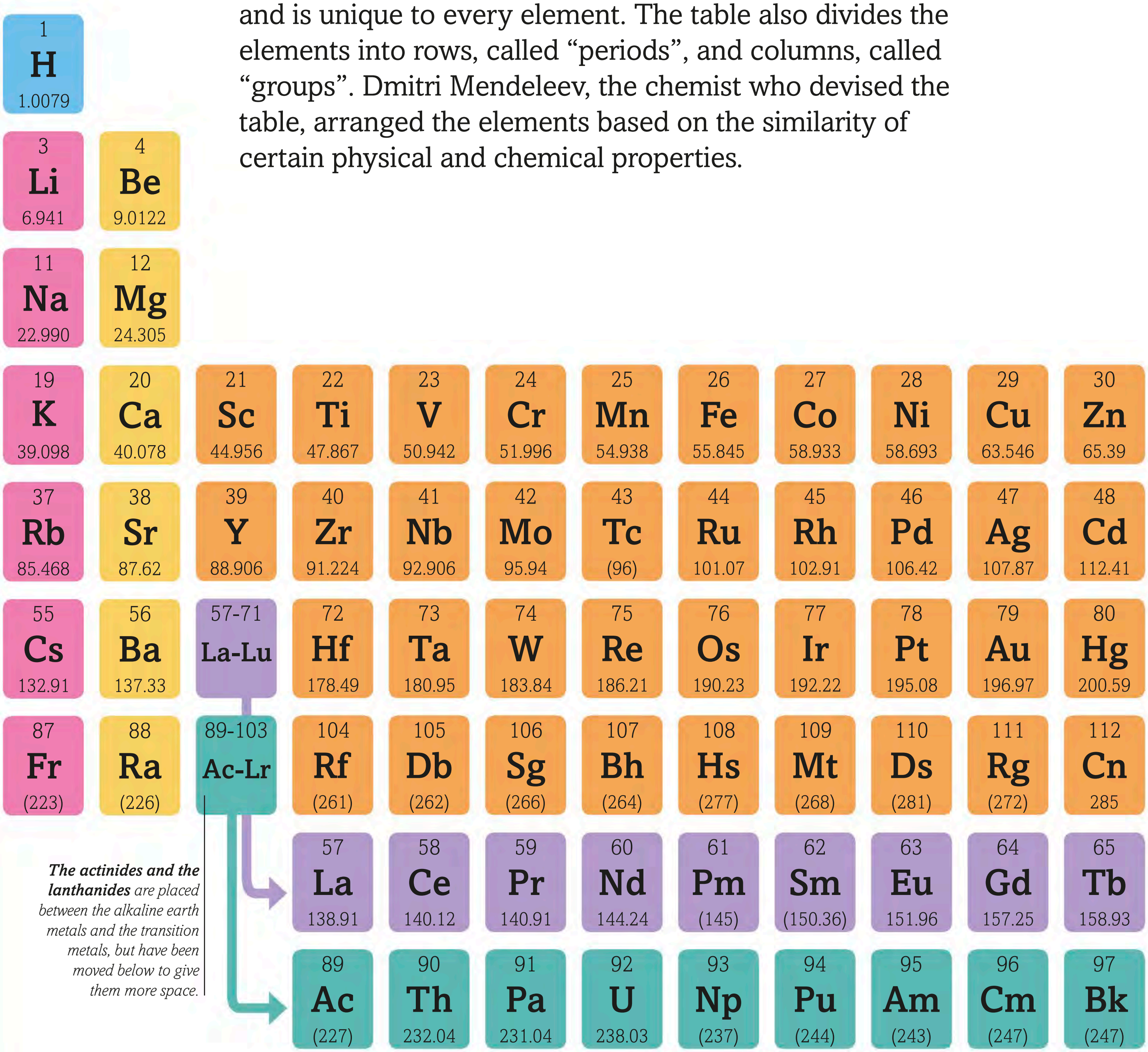

1 **H** 1.0079											
3 **Li** 6.941	4 **Be** 9.0122										
11 **Na** 22.990	12 **Mg** 24.305										
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.39
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (96)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41
55 **Cs** 132.91	56 **Ba** 137.33	57-71 **La-Lu**	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59
87 **Fr** (223)	88 **Ra** (226)	89-103 **Ac-Lr**	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** 285
			57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** (150.36)	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93
			89 **Ac** (227)	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)

The actinides and the lanthanides *are placed between the alkaline earth metals and the transition metals, but have been moved below to give them more space.*

KEY

- ■ Hydrogen
- ■ Alkali Metals
- ■ Alkaline Earth Metals
- ■ Transition Metals
- ■ Lanthanides
- ■ Actinides
- ■ The Boron Group
- ■ The Carbon Group
- ■ The Nitrogen Group
- ■ The Oxygen Group
- ■ The Halogen Group
- ■ Noble Gases

Elements of this group *are semi-metals (elements with the properties of metals and non-metals): they are shiny like metals but crumble easily like non-metals.*

This group *contains the noble gases, which never form bonds with other elements, and are unreactive.*

					2 He 4.0026
5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948
31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
81 Tl 204.38	82 Pb 207.2	83 Bi 208.96	84 Po (209)	85 At (210)	86 Rn (222)
113 Nh 284	114 Fl 289	115 Mc 288	116 Lv 293	117 Ts 294	118 Og 294
66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Reading the table

Element symbol

Every element has a unique symbol of one or two letters. These symbols ensure that scientists who speak different languages do not get confused while describing the same element.

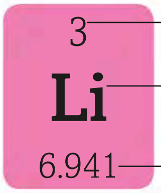

The atomic number is the number of protons in the nucleus of this element's atoms.

The first letter of a symbol is always a capital, but the second is lower case.

The atomic mass number is the average of all the atoms of the element. It is not a whole number because there are different isotopes (forms) of each element, each with a different number of neutrons.

Periods

Elements in the same period, or row, have the same number of electron shells in their atoms. So elements in period one have one electron shell, while those in period six have six electron shells.

Periods run from left to right.

Groups run from top to bottom.

Groups

Members of a group, or column, all have the same number of electrons in their outermost shell. For example, group one elements have one outer electron, while group eight elements have eight outer electrons.

DMITRI MENDELEEV

The periodic table was developed by the Russian chemist Dmitri Mendeleev in 1869. Others had tried before, but his table was periodic, or repeating, because the characteristics of elements follow a pattern. The table was incomplete as some elements had not yet been discovered. However, Mendeleev predicted the positions of the missing elements, and was proved right when they were finally isolated many years later.

Reactions and uses

The elements can combine in different ways to make 10 million compounds, possibly more. As well as learning about the physical and chemical properties of elements, chemists also want to find out how and why certain elements react with each other to form compounds. Chemical reactions are happening all the time. During a reaction, substances change into new substances. The bonds that hold them are broken and then remade in a different combination.

Explosive reaction

In this chemical reaction, pure lithium reacts with air to make the compound lithium oxide. It takes energy to break the links between the lithium atoms and then make bonds with oxygen in the air. Reactions need energy to begin, but they often produce energy as heat and light.

1. This piece of pure lithium is placed on a surface and is exposed to the air.

2. A gas torch is used to heat the lithium, and in just a few seconds it turns red, which is a typical colour for this metal when it becomes hot.

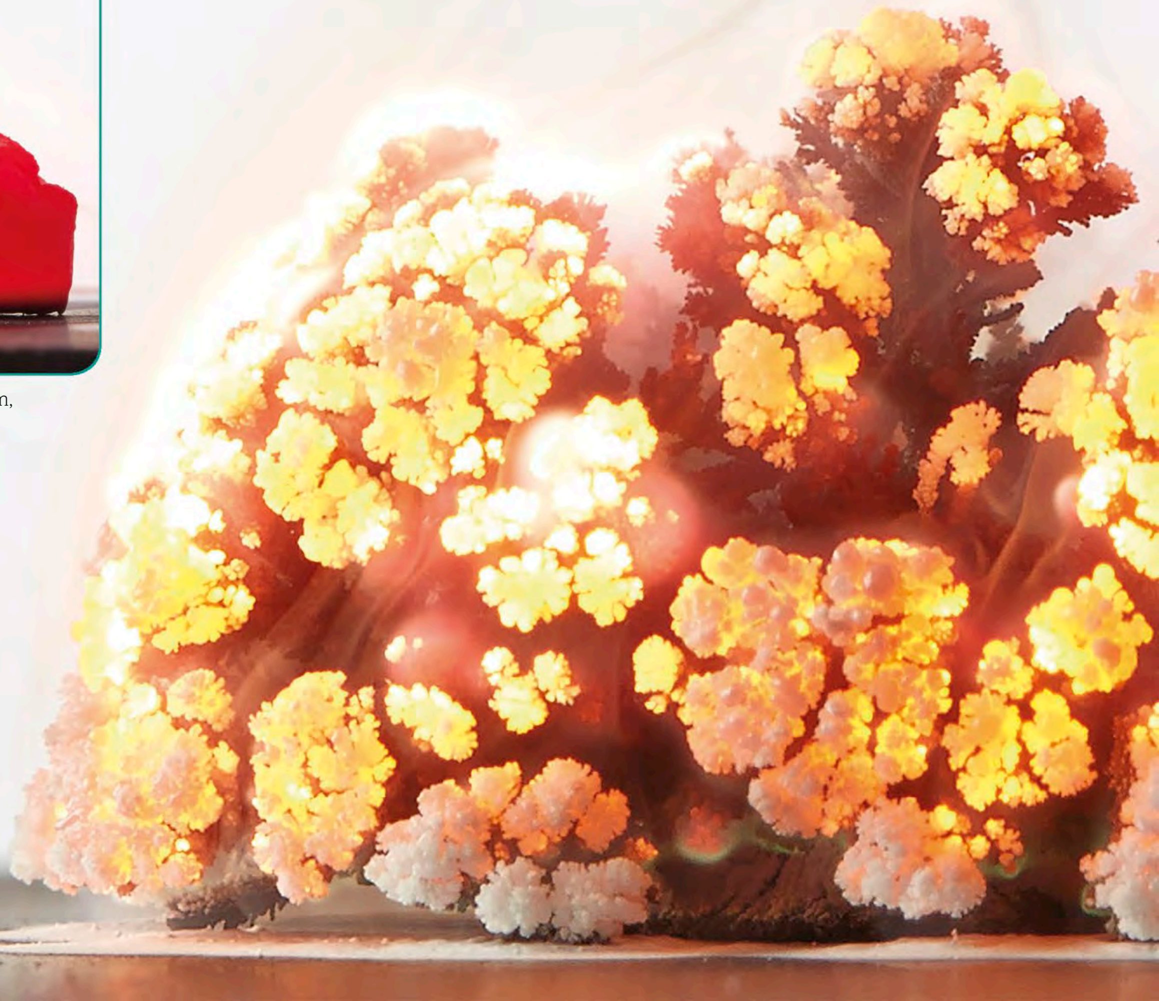

3. Very quickly, the lithium catches fire. The white areas forming here are the compound lithium oxide, which is a combintion of lithium and oxygen.

Mixtures

A mixture is a combination of substances that can be separated by physical means, such as filtering. It is not the same as a compound, where the ingredients are connected by bonds and can only be separated using a chemical reaction. Mixtures can be classified as solutions, colloids, and suspensions.

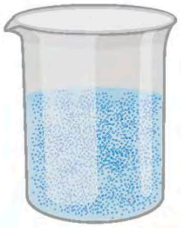

Solution
In this mixture, a substance is completely and evenly mixed, or dissolved, into another substance. Seawater is a solution.

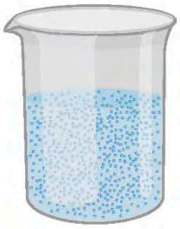

Colloid
This mixture contains unevenly spread particles and clusters that are too small to see. Milk is a colloid.

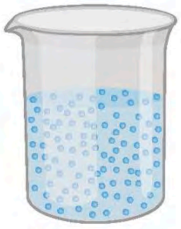

Suspension
This type of mixture consists of large particles of one substance floating in another substance. Muddy water is a suspension.

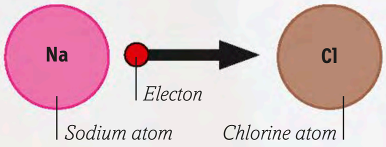

1. A sodium atom donates one electron to a chlorine atom. This gives both atoms full outer electron shells.

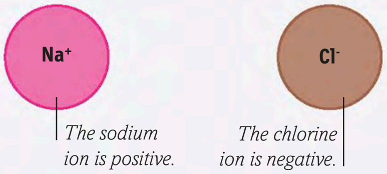

2. These are now charged atoms known as ions. The sodium ion has a positive charge and the chlorine ion has a negative charge.

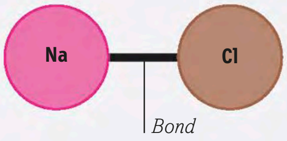

3. Sodium is attracted to – and forms a bond with – chlorine, forming a molecule of the compound sodium chloride.

Forming compounds

There are two kinds of bonds formed between elements during a chemical reaction. In an ionic bond, such as in sodium chloride (above), one atom gives away its electron(s) and another accepts them. This results in each having full outer electron shells. The other type is called covalent bonding. In this, atoms sit together and share their electrons so they both have full outer shells.

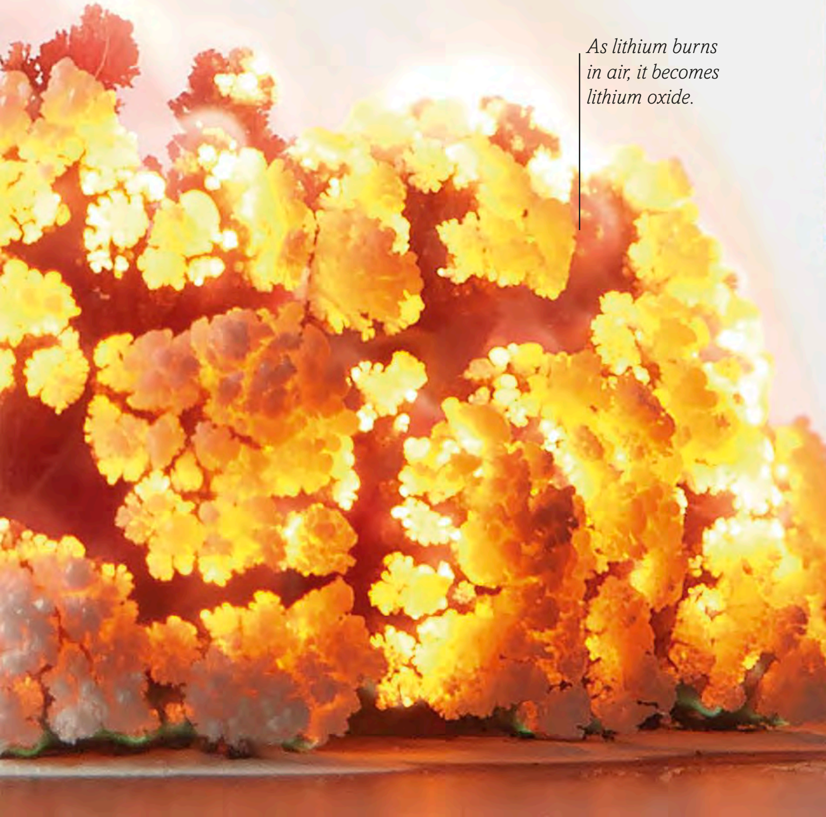

As lithium burns in air, it becomes lithium oxide.

Reactions in the real world

Chemical reactions happen all around us. There are reactions when we cook, take medication, or breathe. The image above shows a rusty iron ship. Over time, the element iron develops this red, flaky layer when it reacts with oxygen present in water or air to form the compound iron oxide – more commonly known as rust.

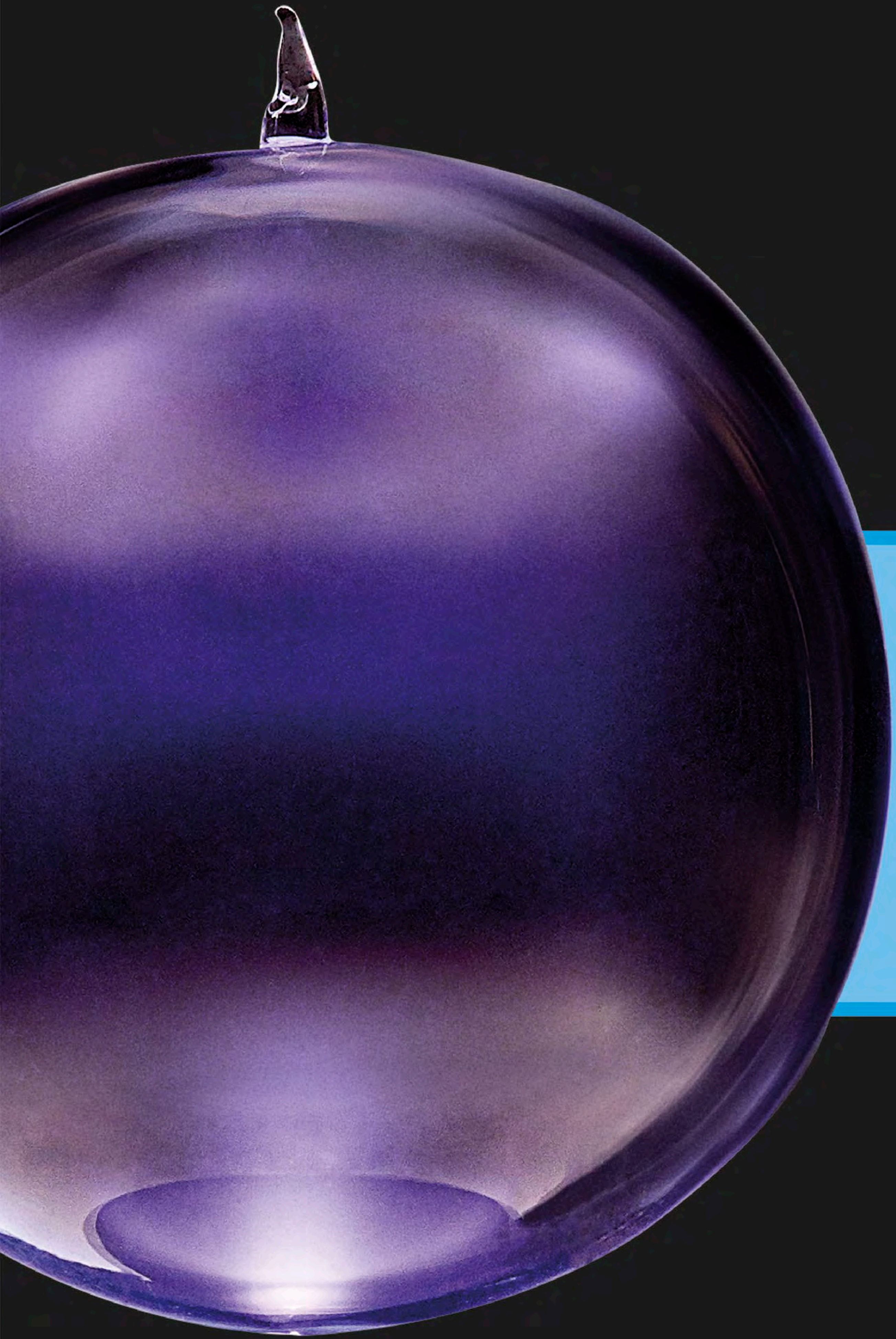

Pure hydrogen (H) fills this glass sphere, and produces a purple glow when electrified.

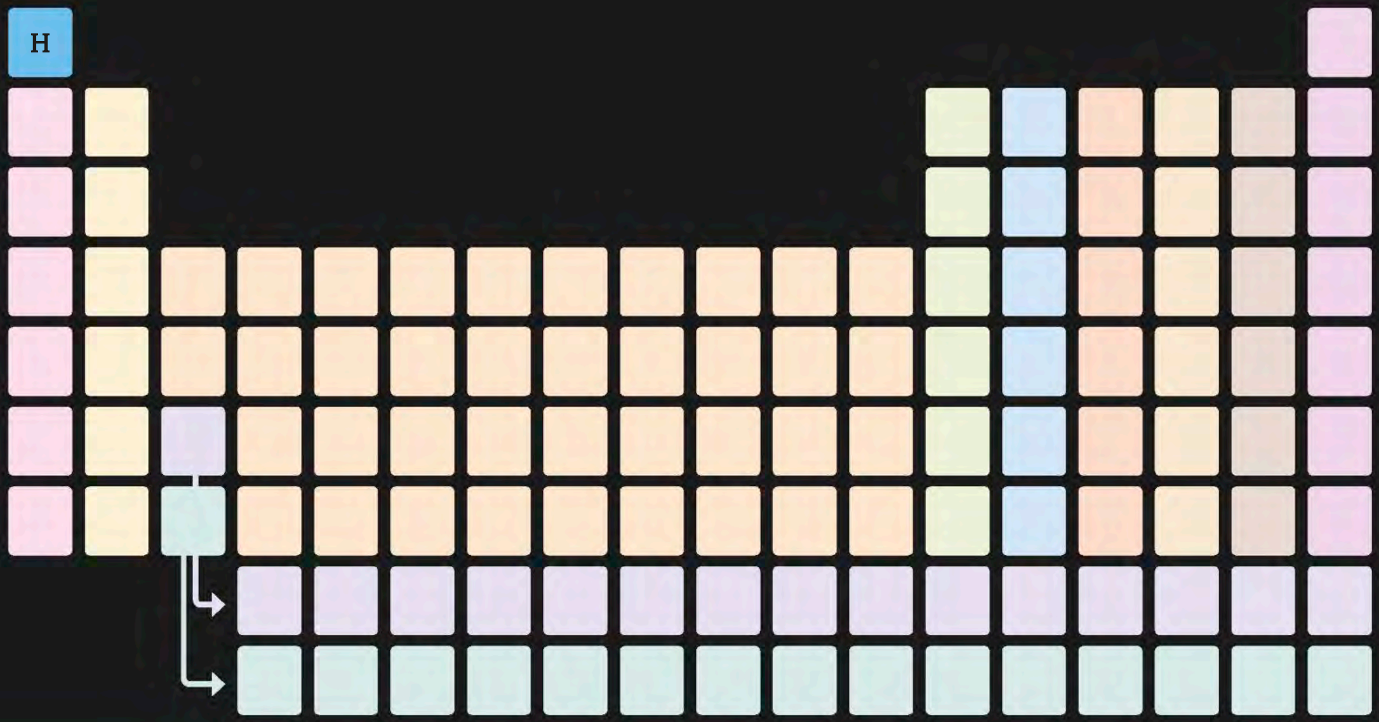

Hydrogen

The first element, hydrogen (H), is located above the alkali metals in the first column of the periodic table. However, because it is so different to the elements below it, hydrogen is not included in their group. This gas has the simplest atoms of any element with one electron and one proton. It is highly reactive and forms compounds with all kinds of other elements.

Atomic structure
A hydrogen (H) atom has one electron moving around a nucleus consisting of a single proton.

Physical properties
Hydrogen gas is the lightest material in the Universe. Pure hydrogen is rare on Earth, as it escapes quickly from the atmosphere into space.

Chemical properties
Hydrogen is highly flammable. It forms compounds with both metals and non-metals.

Compounds
The most common hydrogen compound is water. Acids are compounds that contain hydrogen.

1 H Hydrogen

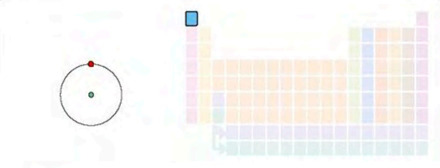

⊖ 1 ⊕ 1 ○ 0

State: Gas
Discovery: 1766

Forms

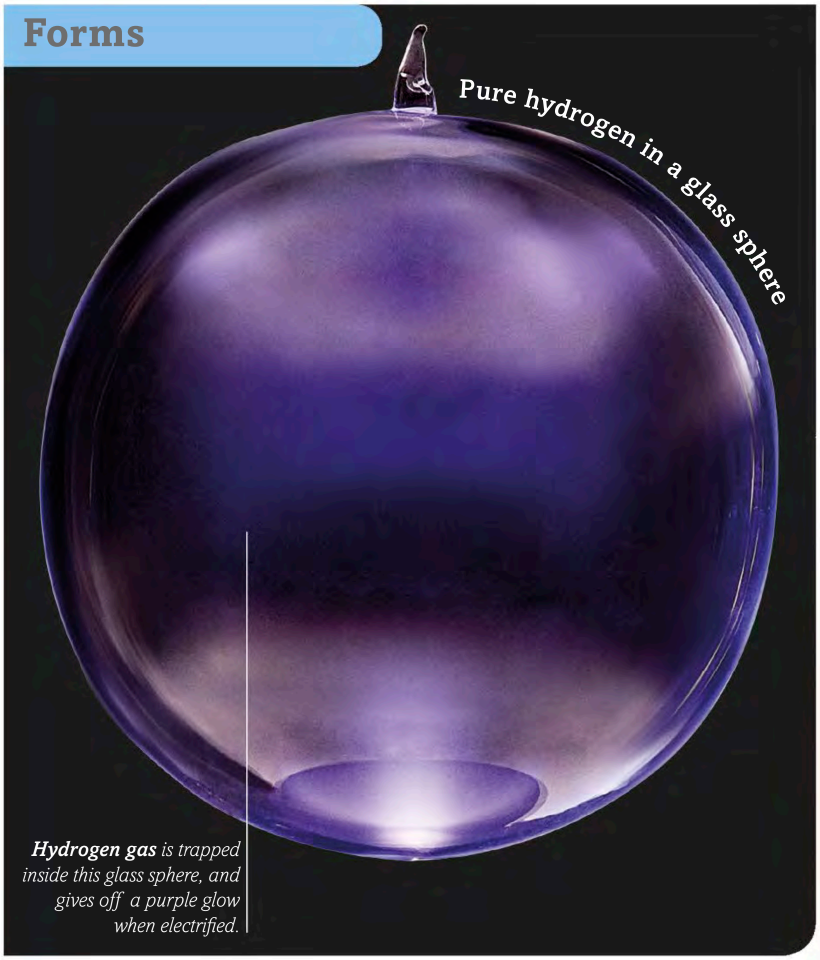

Hydrogen gas *is trapped inside this glass sphere, and gives off a purple glow when electrified.*

The Orion Nebula

This gaseous stellar nursery *is giving birth to thousands of stars.*

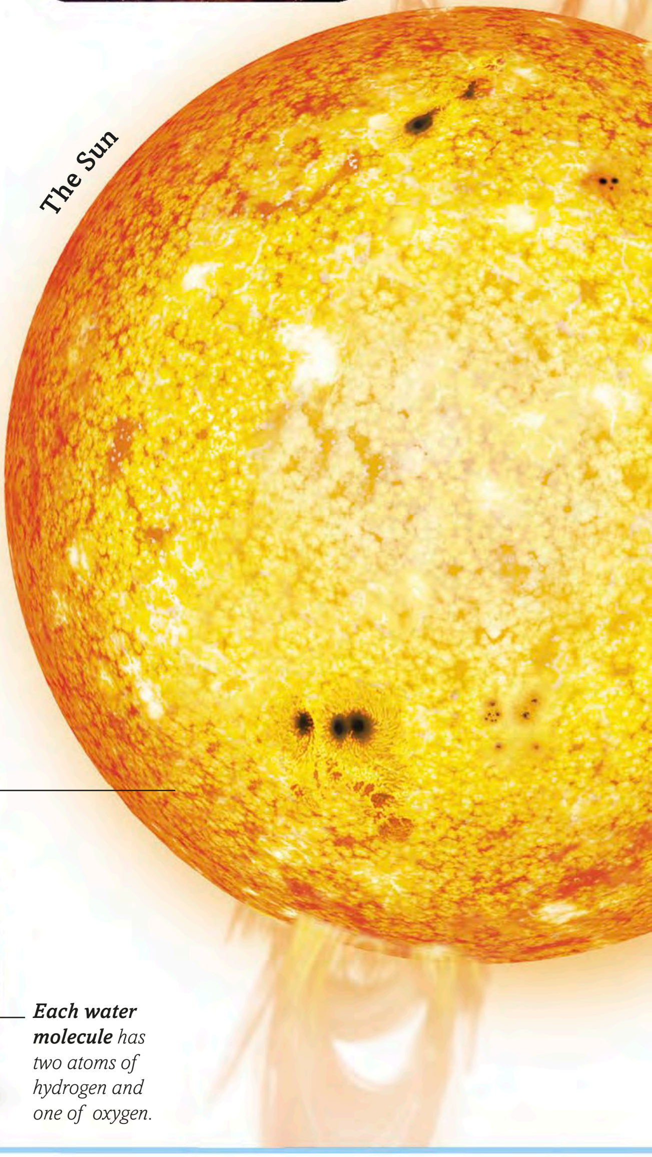

The Sun *is four-fifths hydrogen.*

Three quarters of this planet *is made up of layers of gaseous and liquid hydrogen.*

Each water molecule *has two atoms of hydrogen and one of oxygen.*

Hydrogen is the first member of the periodic table because it has the simplest atoms of all elements: they contain just one proton and one electron. **Pure hydrogen** is a transparent gas. The biggest planets, such as **Jupiter**, are vast balls of hydrogen mixed with other gases, such as helium and methane. On Earth, hydrogen is commonly found in **water**. Although it is rare in Earth's atmosphere, hydrogen is the most common element in the Universe. Stars, such as the **Sun**, contain large amounts of hydrogen. At the centre of a star, atoms of

Uses

Hydrogen-filled balloon

***This balloon** can rise high into the atmosphere where sensors gather information about atmospheric pressure, temperature, and wind speed.*

HOW ROCKET FUEL WORKS

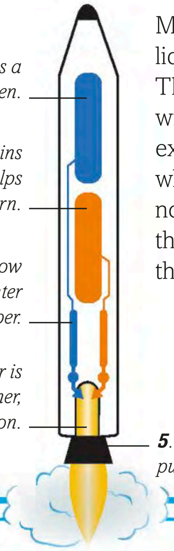

__1__. This chamber contains a fuel called liquid hydrogen.

__2__. This chamber contains liquid oxygen, which helps the hydrogen burn.

__3__. Pumps control the flow of the liquids as they enter the combustion chamber.

__4__. The combustion chamber is where the liquids mix together, creating an explosion.

__5__. The nozzle emits hot vapour, pushing the rocket upwards.

Many space rockets use liquid hydrogen as a fuel. The hydrogen reacts with oxygen to form extremely hot steam, which blasts out of the nozzle. This creates thrust, which pushes the rocket upwards.

Delta IV rocket

***This powerful rocket** uses 45,460 litres (12,000 gal) of liquid hydrogen as fuel.*

Margarine

***Margarine** is made of vegetable oils thickened by adding hydrogen.*

Hydrogen peroxide

***This liquid** is used as a cleaner.*

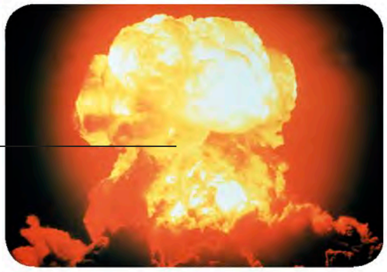

Hydrogen bomb explosion

***This powerful explosion was** created by fusing hydrogen atoms.*

The only **waste product** of hydrogen fuel is **steam**.

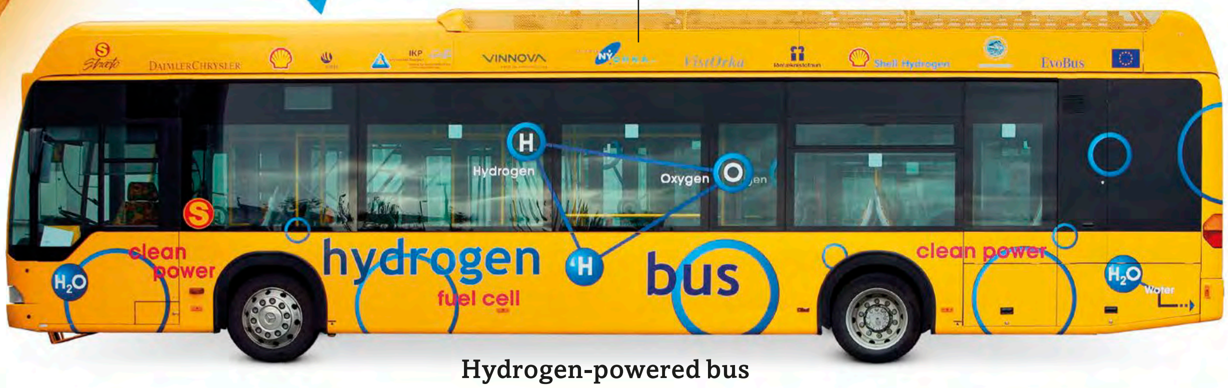

Hydrogen-powered bus

***This energy-efficient bus** runs on a fuel cell fed by hydrogen.*

this element are fused together, releasing heat and light. New stars form inside **nebulae** – such as the **Orion Nebula**. They are clouds of hydrogen gas that slowly collapse in on themselves. Hydrogen gas is the lightest element of all, and much lighter than air. This is why **hydrogen-filled balloons** can fly higher than air-filled ones. Supercold liquid hydrogen is used as **rocket** fuel. Atoms of hydrogen fuse together to produce a lot of energy in **hydrogen bomb** explosions. Pure hydrogen is also a clean energy source used to power some **buses** and cars.

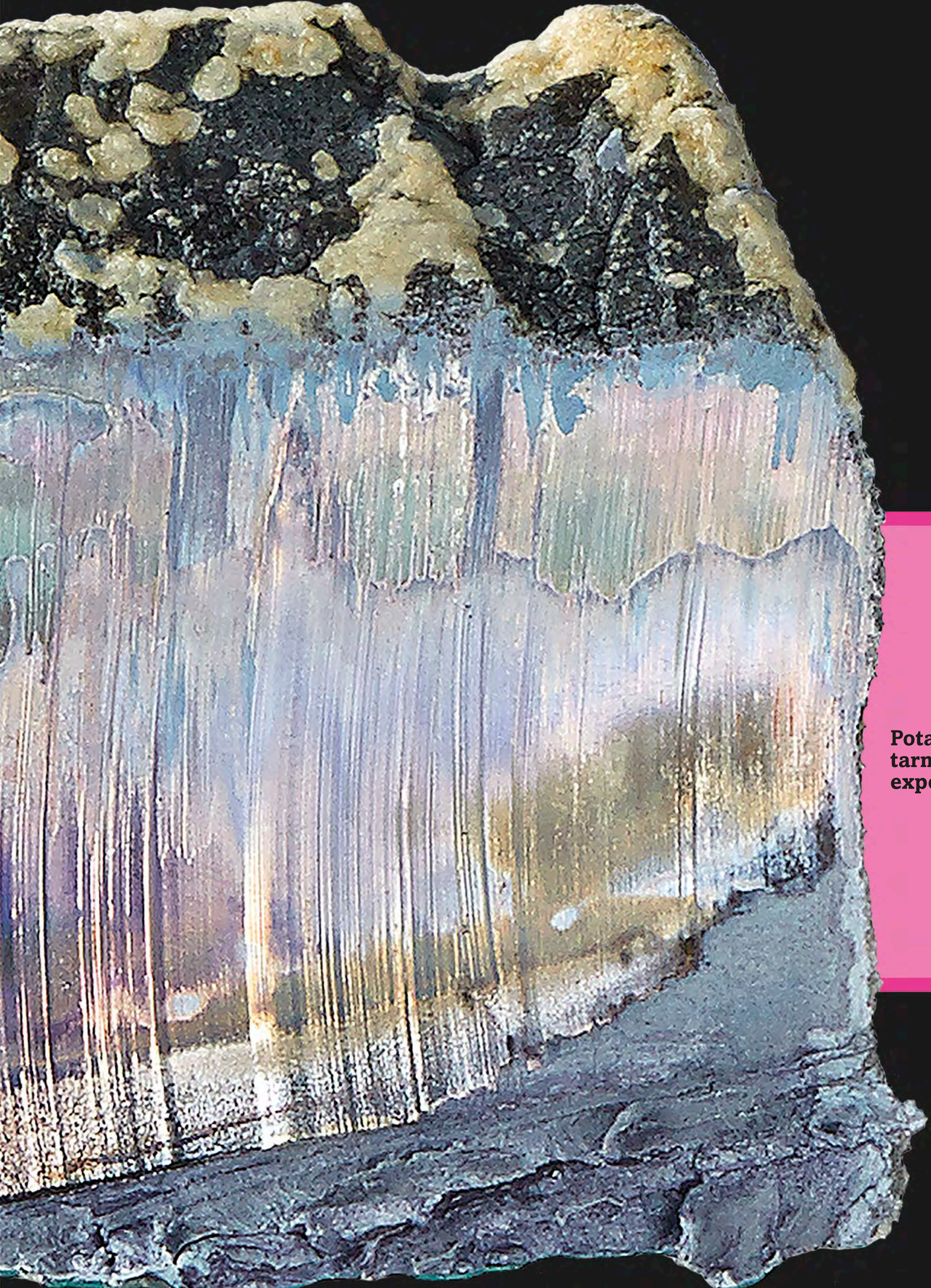

Potassium (K) tarnishes when exposed to air.

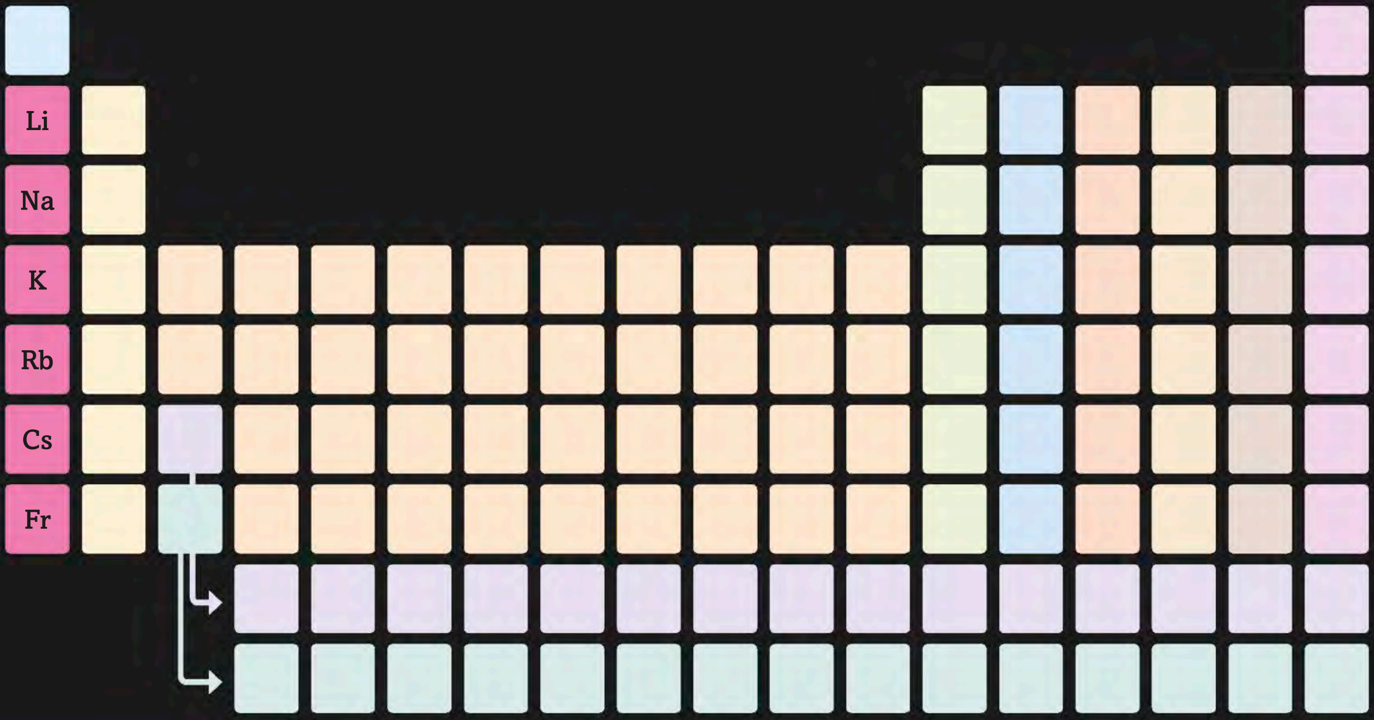

Alkali Metals

After hydrogen (H) – which is in a group of its own – the first column of the periodic table contains the alkali metals. This group gets its name from the way the elements react with water. These vigorous reactions always produce acid-attacking compounds called alkalis. None of the alkali metals are ever found in a pure form in nature. The first three metals are common in many minerals, while the last three are rarer.

Atomic structure
The atoms of all alkali metals have just one electron in their outer shell. Alkali metal atoms are among the biggest of all atoms.

Physical properties
These metals are soft enough to be cut with a knife. They are all silvery and very shiny when clean.

Chemical properties
Alkali metals are highly reactive. They form bonds with other elements, giving away their single outer electron.

Compounds
These metals react with water to form compounds called hydroxides. They react easily with halogens to form salts, such as sodium chloride.

3 Li Lithium

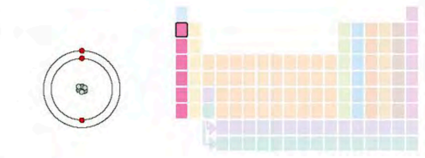

⊖ 3 ⊕ 3 ○ 4

State: Solid
Discovery: 1817

Forms

Drinking water

This water *contains tiny amounts of dissolved lithium minerals.*

Oyster mushrooms

These mushrooms *absorb lithium from the soil.*

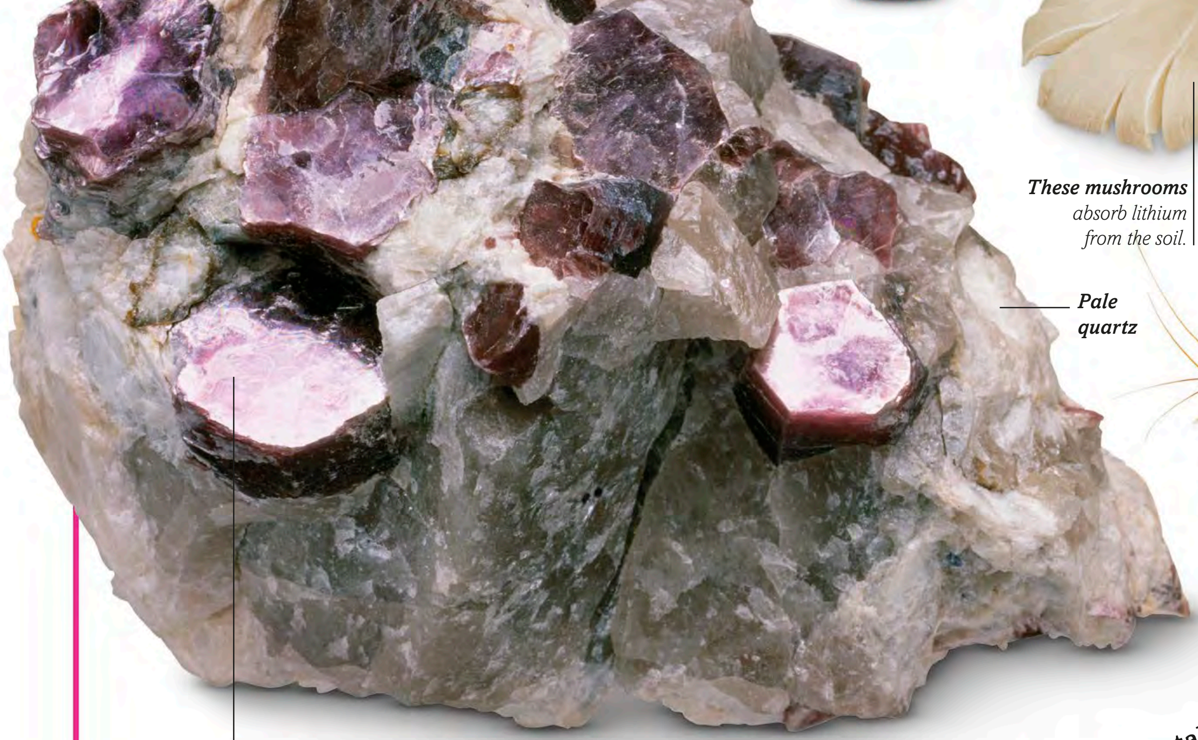

Lepidolite

Pale quartz

Purple crystals *containing lithium*

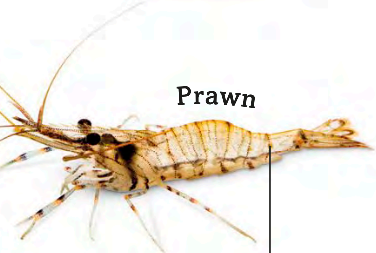

Prawn

Prawns *and other shellfish absorb lithium from seawater.*

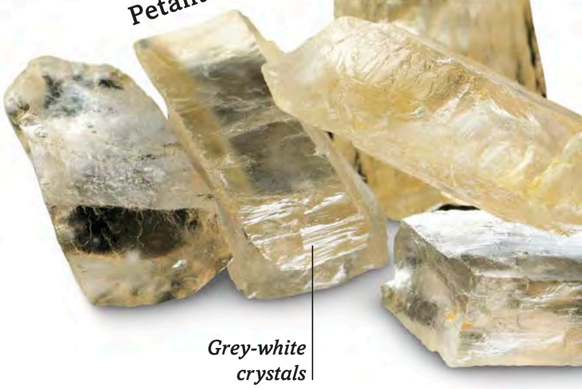

Petalite

Grey-white crystals

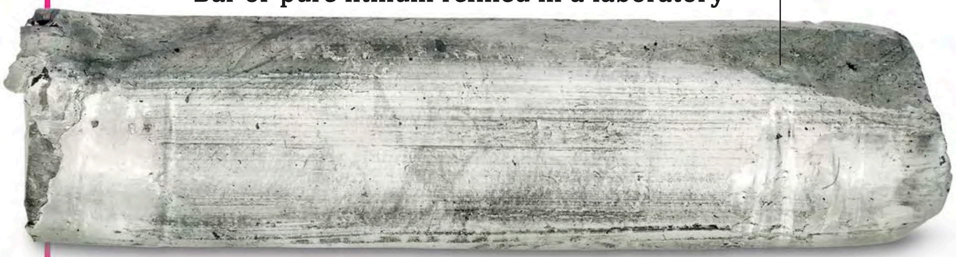

Bar of pure lithium refined in a laboratory

Shiny pure lithium *becomes dull when it is exposed to air.*

Lithium is the the lightest of all metals: in fact, it can easily float on water. **Pure lithium** is very reactive and exists in nature only in minerals, such as **lepidolite** and **petalite**. Many lithium minerals dissolve well in **water**, and the world's seawater contains millions of tonnes of dissolved lithium. Lithium is found in many foods, such as **mushrooms**, **prawns**, nuts, and seeds. It also has many everyday applications. Glass composed of lithium is resistant to heat and is used in scientific equipment, such as **mirrors inside**

Uses

Smartphones run on rechargeable batteries that use lithium to store electricity.

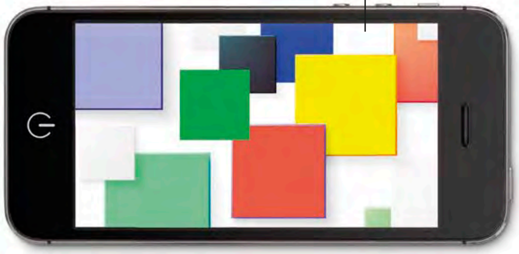

Smartphone

Hale telescope mirror

Lithium added to the glass in this mirror stops the disc warping at extreme temperatures.

LITHIUM-ION BATTERY

Lithium-ion batteries are widely used in digital devices. They store electrical energy to power gadgets and are rechargeable. This diagram shows a device's battery in use; when it is charging, this process is reversed.

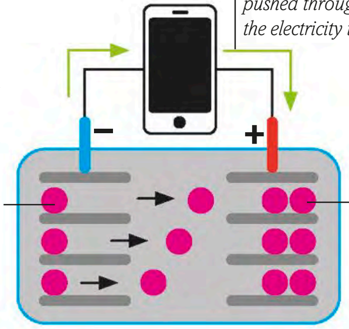

1. Inside the battery, positively charged lithium ions move from the negative electrode (-) to the positive electrode (+).

2. The positive electrode receives lithium ions as the battery loses charge.

3. As ions move inside the battery, negatively charged electrons are pushed through the phone, providing the electricity to make it work.

Syringe

Lithium coating on the inside of some syringes delays the clotting of the blood sample.

Lithium-rich grease is used to keep mechanical parts of engines running smoothly, even when hot.

TF2
LUBRICANT
Lithium Grease
40gms e

Grease

Some artificial teeth contain lithium disilicate, which makes them strong.

Artificial teeth

This car runs for at least **64 km** (40 miles) on one charge of its lithium-ion battery.

This charging point can recharge an electric car in one hour.

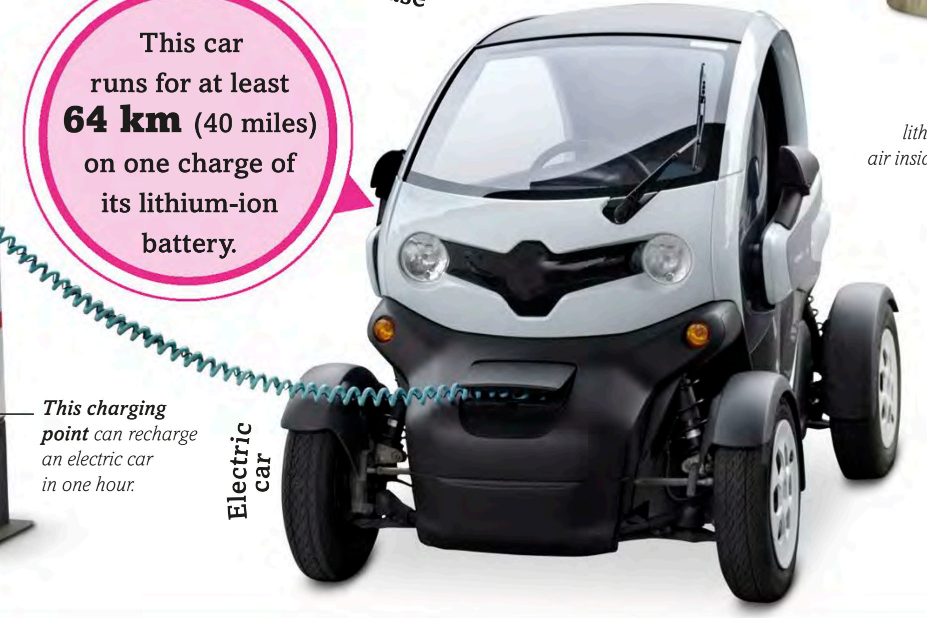

Electric car

This air scrubber used lithium hydroxide to purify the air inside the Apollo 13 spacecraft.

Air scrubber

telescopes. The main use for lithium is in rechargeable batteries. Lithium-ion batteries are small but powerful, so they are ideal for **smartphones** and tablet computers. Larger lithium batteries can power **electric cars**, which are less polluting than petrol-powered ones. A soapy compound called lithium stearate is used to make **grease**, which helps automobile engines run smoothly. This element also forms hard ceramics that are used to produce strong **artificial teeth**. Lithium compounds are used in some medicines as well.

11 Na Sodium

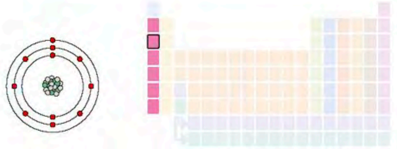

⊖ 11 ⊕ 11 ○ 12

State: Solid
Discovery: 1807

Forms

Clinoptilolite

***This sodium-rich mineral** is an example of a zeolite, a mineral with tiny holes that can trap gases.*

Pure halite crystals

***Cube-shaped** transparent crystals*

Laboratory sample of pure sodium in an airless vial

Soft, shiny metal

***This glass case** holding pure sodium has no air in it, to prevent the metal from reacting with oxygen in air.*

Sodalite cabochon

***Polished gemstone** made of the mineral sodalite*

***The thick, white crust** covering this salt flat contains sodium chloride and other salts.*

Salar de Uyuni, Bolivia

Everyday salt contains lots of sodium. Although abundant on Earth, sodium is never found in its pure form naturally: it forms compounds with other elements. Sodium chloride, which also contains chlorine, is the most common sodium compound. It is also known as the mineral **halite**, and it is what makes seawater salty. Other sodium minerals include **sodalite**, a soft blue stone that can be shaped and polished. **Pure sodium** is soft enough to be cut with a knife. It reacts with oxygen in the air, forming a compound called sodium oxide, and bursts

Uses

Common salt

Edible salt *is made by refining the mineral halite.*

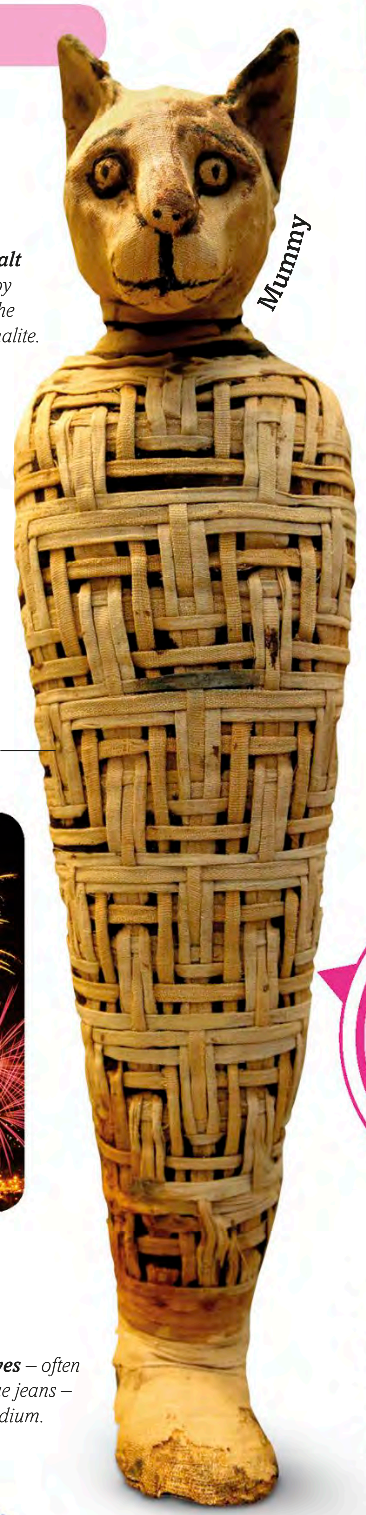

Mummy

This mummified body*, or mummy, was preserved using sodium compounds.*

MUMMIFICATION

Ancient Egyptians believed in life after death and so preserved the bodies of their dead. A dead body was washed and the organs removed, then crystals of sodium compounds were used to dry it out. Finally, the body was wrapped, which completed the process of mummification.

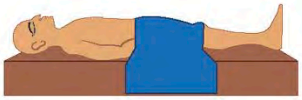

__1__. Organs, such as the stomach and lungs, were removed from the dead body.

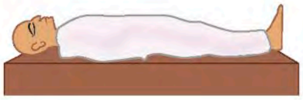

__2__. Sodium compounds were spread over the body to dry it.

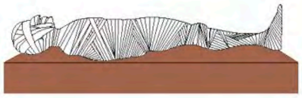

__3__. The body was wrapped in cloth to mummify it.

Sodium fireworks

Bright yellow lights in fireworks *get their colour from burning sodium compounds.*

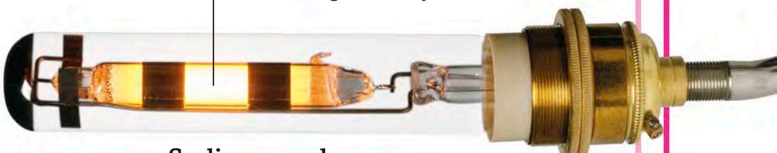

This tube *glows bright yellow-orange when sodium gas is electrified.*

Sodium gas lamp

Cats were sacred in ancient Egypt, so their bodies were mummified.

Bar of soap

Some soaps *contain sodium hydroxide.*

Baking soda

Odourless white powder

Indigo dyes *– often used in blue jeans – contain sodium.*

Indigo dye powder

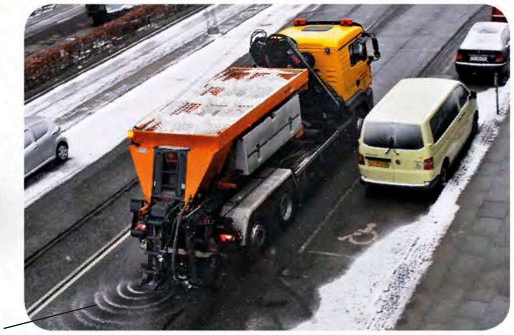

De-icing

Spraying salt *keeps roads free from ice and frost.*

into flames when in contact with water. Sodium compounds in **fireworks** burn with a yellow-orange colour. In ancient Egypt, crystals of sodium compounds were used to preserve dead bodies as **mummies**. Another useful compound is sodium bicarbonate, or **baking soda**, which makes dough rise by releasing bubbles of carbon dioxide. When refined, sodium chloride, or **common salt**, has several uses. It makes ice melt so it is used in salty grit added to slippery, frozen roads. This helps **de-ice** them to make them safer. It is also an important seasoning for meals.

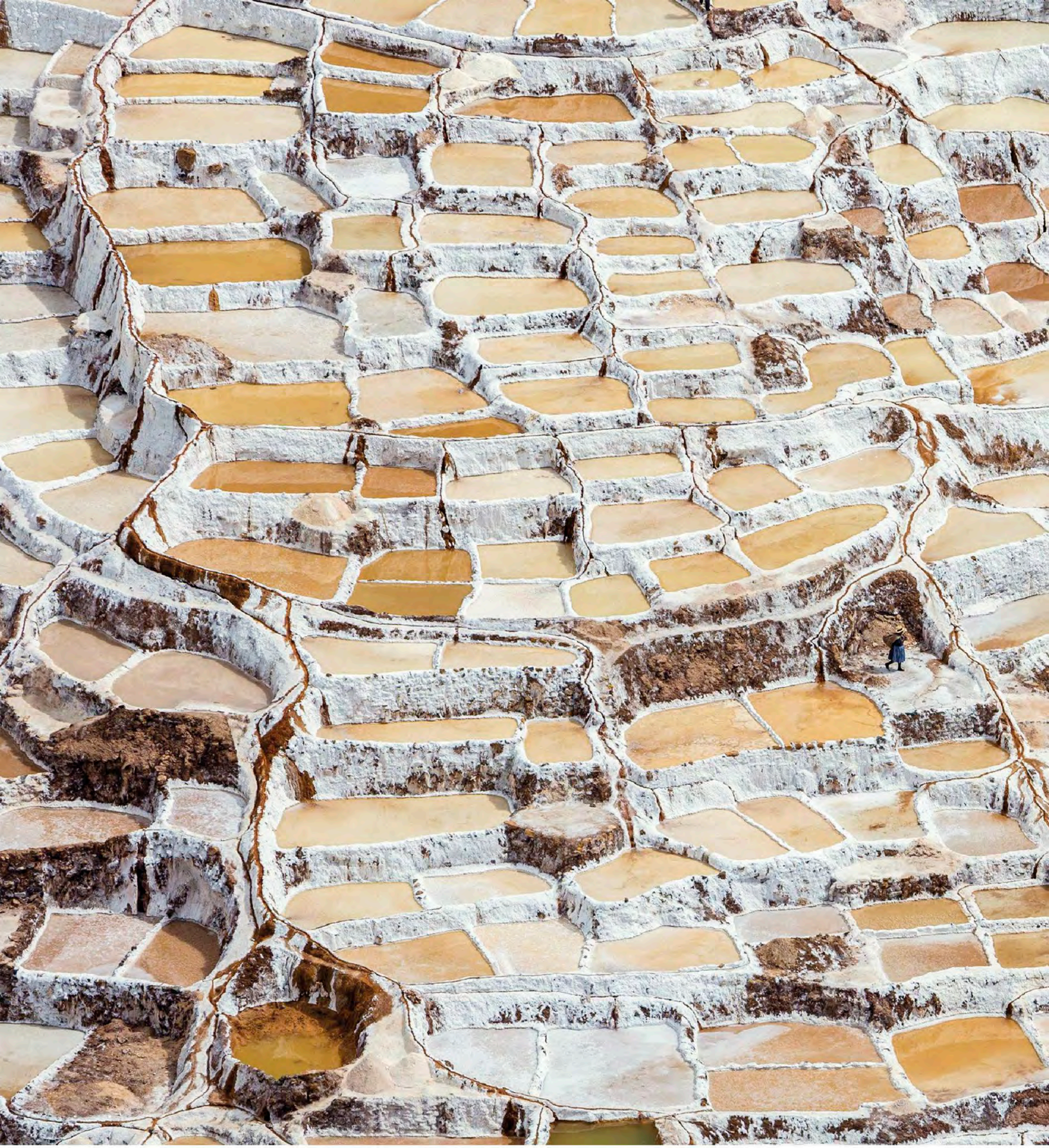

SALT FLATS Hundreds of artificial ponds dot the hillside near the small town of Maras, high in the Andes of Peru. The ponds fill with water from a stream that runs down from the nearby mountains. In the sunshine, the water evaporates, leaving behind a thick salt crust that can be collected. The people of Maras have been gathering salt in this way for at least 500 years.

The salt forms part of rocks deep underground before it is dissolved by the stream and flows into the pools. Evaporation can also be used to collect salt from seawater or other salty water sources (known as brines). Today, however, most of the world's salt comes from underground mines containing thick layers of salt that are a result of ancient seas drying out. Over millions of years, that dry salt has become buried under dense layers of rocks. This so-called "rock salt" is sometimes unearthed using excavators. At other mines, it is washed out by piping in warm water, which dissolves the salt. The brine is then pumped up to the surface for evaporation.

19
K

Potassium

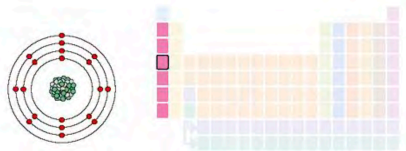

⊖ 19 ⊕ 19 ○ 20

State: Solid
Discovery: 1807

Forms

This mineral *is rich in potassium chloride.*

Potash

This glass case holding pure ***potassium*** *has no air in it, preventing the metal from reacting with oxygen in air.*

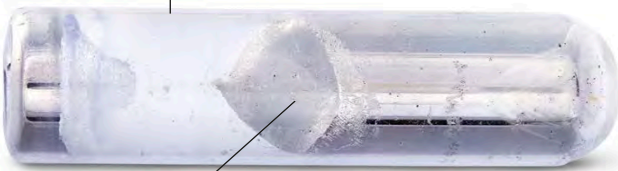

Soft and shiny solid

Laboratory sample of pure potassium in an airless vial

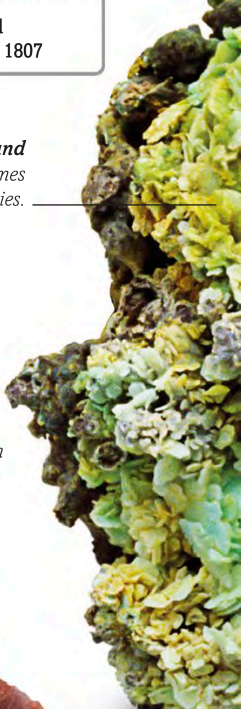

The yellow and green colour *comes from impurities.*

Sylvite

This mineral *contains potassium chloride, which gives it a salty taste.*

Potassium was first found in the dust of burnt plants. It was discovered by Sir Humphry Davy when he experimented with **potash** – a mixture of substances made from the ash of burnt plants soaked in water. The name potassium comes from potash but the element's chemical symbol, K, is taken from *kalium*, a Latin word for "ash". Potassium is never found pure in nature, but is present in minerals such as **aphthitalite** and **sylvite**. Potassium is vital for the human body, helping muscles and nerves work properly. For this, we rely on

Aphthitalite

Uses

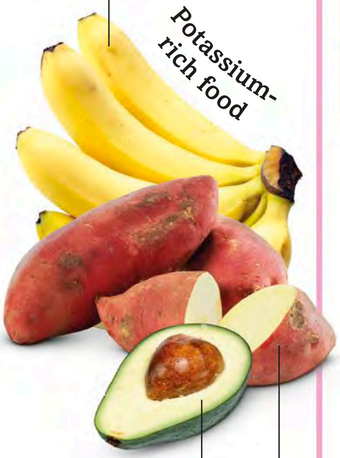
Potassium-rich food
Banana
Avocado
Sweet potato

Soda water *contains potassium compounds for added flavour.*

Potassium salt

This salt *contains potassium chloride, which helps lower blood pressure.*

REBREATHER

A rebreather is a machine used by expert divers so they can stay underwater for long periods.

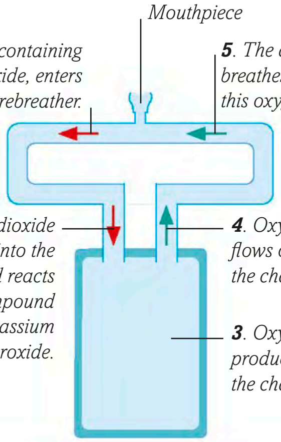
Mouthpiece

1*. Exhaled air, containing carbon dioxide, enters the rebreather.*

2*. Carbon dioxide flows into the chamber and reacts with a compound called potassium superoxide.*

3*. Oxygen is produced in the chamber.*

4*. Oxygen flows out of the chamber.*

5*. The diver breathes in this oxygen.*

Rebreather

This cylinder *contains a compound called potassium superoxide.*

Saline drip

Potassium solutions *are used to hydrate patients.*

Fertilizer

Potassium-rich fertilizer *is easily absorbed by the soil and boosts plant growth.*

This explosive mixture *contains powdered potassium nitrate.*

Liquid soap

This soap *contains potassium hydroxide, which is a cleaning agent.*

Toughened glass screen

This strengthened glass sheet *contains potassium nitrate.*

potassium-rich food, such as bananas, root vegetables, and avocados, which contain potassium chloride. In tiny amounts, this compound can enhance flavours, as it does in **soda water**. It is also a healthy alternative to sodium chloride, or common salt, and an important ingredient in **saline drips** for rehydrating patients who are seriously ill. Potassium nitrate is a compound of potassium, oxygen, and nitrogen, and is found in **gunpowder** and **toughened glass screens** for mobile phones.

37 Rb Rubidium

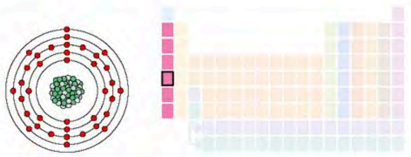

⊖ 37 ⊕ 37 ○ 48

State: Solid
Discovery: 1861

Forms

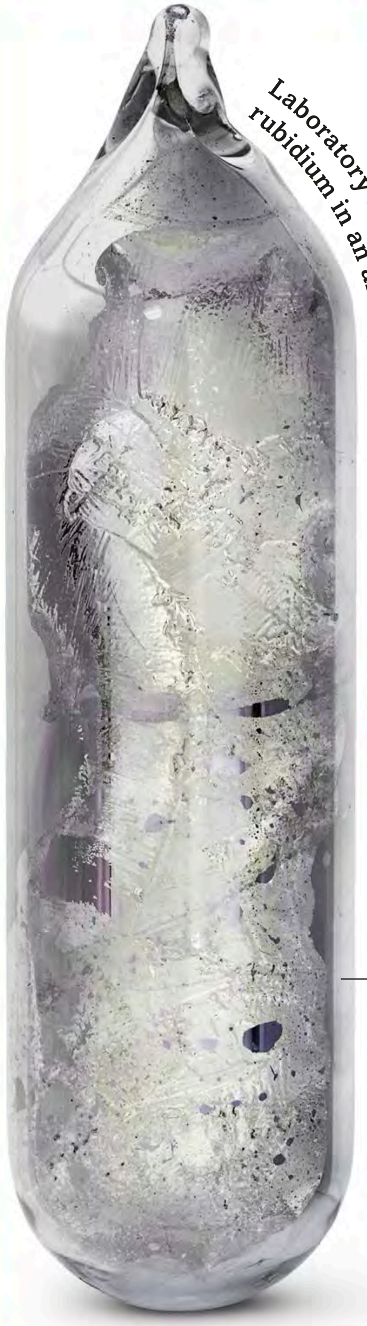

Laboratory sample of pure rubidium in an airless vial

This glass case contains pure rubidium, *preventing it from coming into contact with air and catching fire.*

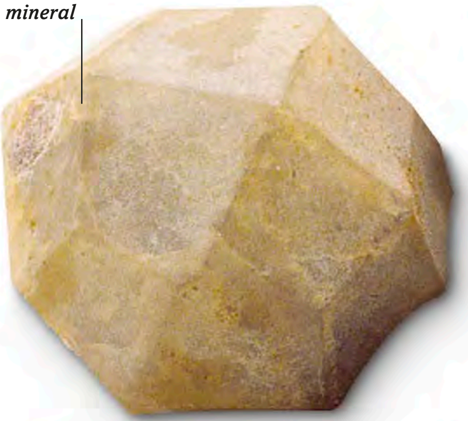

Leucite

Pale, waxy mineral

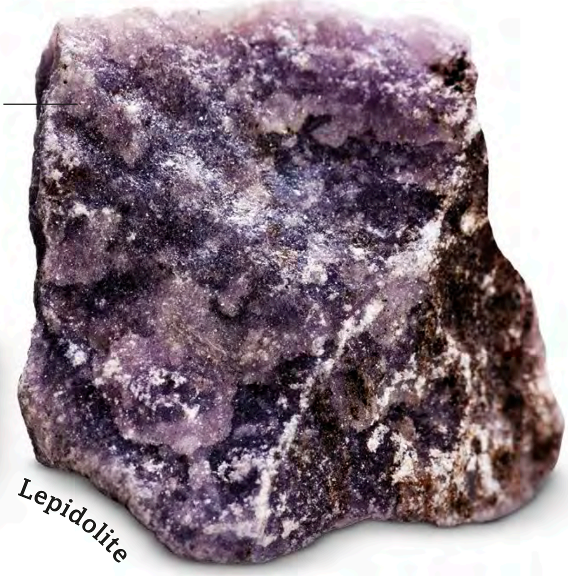

Lepidolite

This soft mineral *contains up to 3.5% rubidium.*

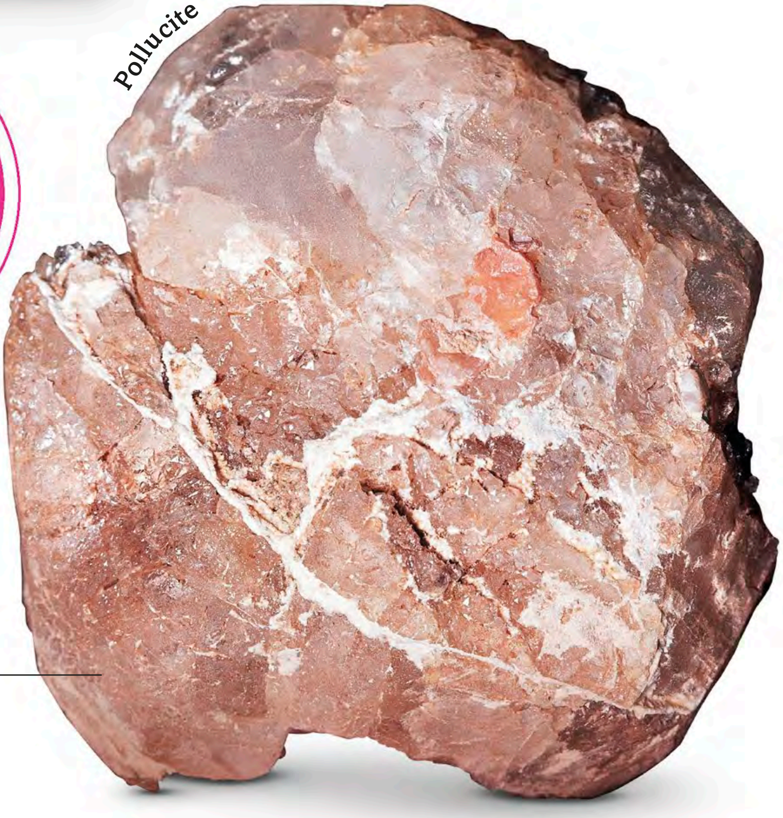

Pollucite

This ore *contains caesium and rubidium.*

Rubidium makes up only about **1 per cent** of this mineral.

Rubidium was named after the Latin word *rubidius*, meaning "deepest red". This refers to the red-coloured flame it produces when burned. This highly reactive element ignites on contact with air. On contact with water, it reacts vigorously, producing hydrogen gas and a lot of heat. Rubidium is not often concentrated in particular minerals, but instead is spread in small amounts through a wide range of minerals, such as **leucite** and **pollucite**. The pure metal is sourced mainly from the mineral **lepidolite**. Another mineral called rubicline has even more

Uses

These lenses *contain rubidium, which aids night vision.*

Night-vision goggles

RUBIDIUM-STRONTIUM DATING

About a quarter of all rubidium atoms are radioactive. Slowly over time, they break down into strontium atoms. Comparing the amounts of these elements in a rock shows when that mineral was formed. Older rocks have less rubidium and more strontium in them.

Rubidium-87 atoms (red) decay at a predictable rate.

Only small amounts of strontium-87 (blue) in the rock.

The amount of strontium-87 has increased over time.

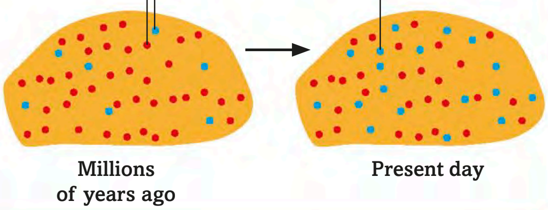

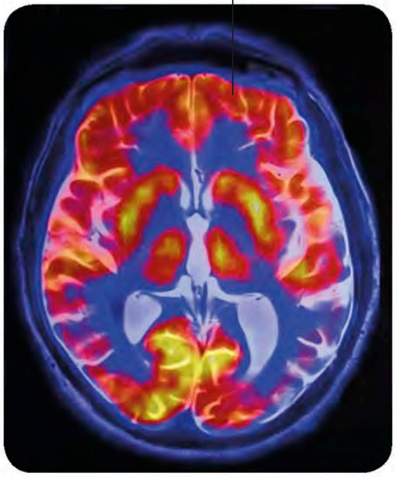
PET scan

The structure of the brain *can be seen clearly because of the use of radioactive rubidium.*

Photomultiplier

This sensitive device *detects light by using a rubidium compound.*

931B10
Serial No.
931B
has been selected for special electrical characteristics, at your request, from the RCA product line.
12404

Fireworks

This purple colour *comes from burning a nitrogen rubidium compound.*

Ceramic insulator

Electricity cables *are hung from these rubidium-rich insulators.*

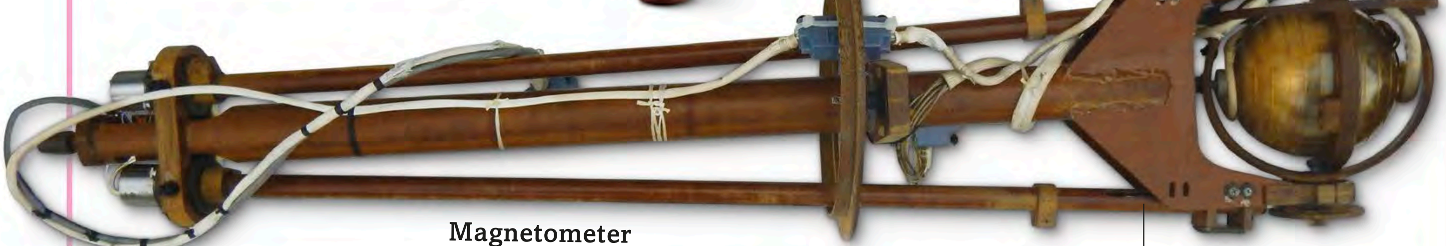
Magnetometer

This device *from the early 20th century used rubidium to measure the strength of magnetic fields.*

rubidium in it but is very rare. Rubidium atoms are sensitive to light and can be used in photoelectric cells (devices that convert light energy into electricity) and **night-vision equipment**. This element has radioactive forms, which can be used to measure the age of rocks. When injected into a patient's body, rubidium targets tumours, which show up clearly on **PET (positron emission tomography) scans**. Rubidium is also used by light-sensitive electronics called **photomultipliers**, and in making **insulators** for high-voltage cables and some special types of glass.

55
Cs

Caesium

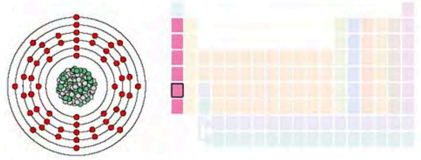

⊖ 55 ⊕ 55 ○ 78

State: Solid
Discovery: 1860

Forms

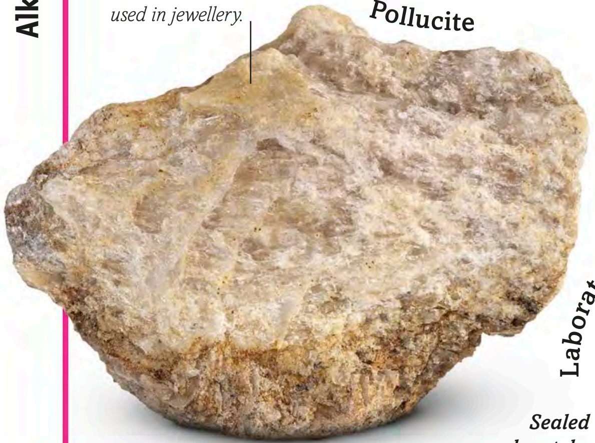

The crystals of this mineral are used in jewellery.

Pollucite

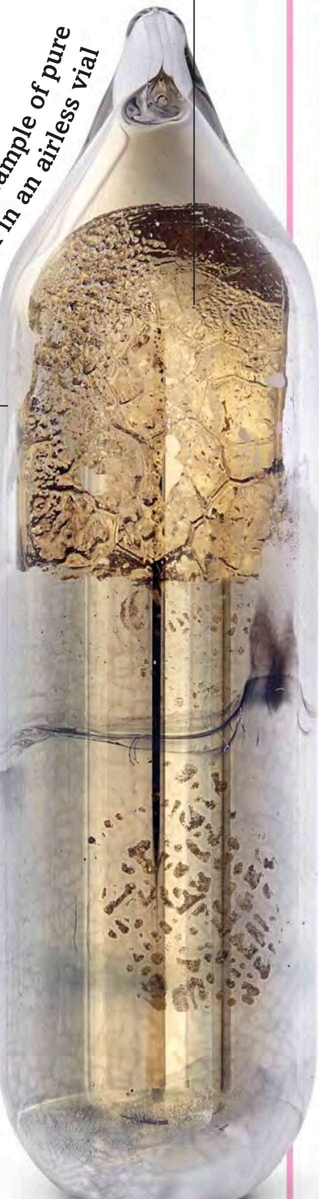

Shiny, silver-gold metal

Laboratory sample of pure caesium in an airless vial

Sealed glass tube

KIRCHHOFF AND BUNSEN

Caesium was discovered in 1860 by German scientists Robert Bunsen and Gustav Kirchhoff. They burned a sample of mineral water on a burner, which split the flame's light into individual colours. One of them was a distinctive light blue, which came from caesium.

Gustav Kirchhoff (left) and Robert Bunsen (right)

Uses

This highly accurate clock is also called a caesium clock.

Atomic clock

Drilling fluid

***High-density caesium compounds** in this fluid stop toxic gases rising to the surface.*

As the most reactive metal on Earth, caesium explodes into flames if in contact with air or water. Therefore, **pure caesium**, is stored in a sealed glass tube from which all the air has been sucked out. This element is rare, and most of it is extracted from the mineral **pollucite**. Its name means "sky blue" and refers to the colour of caesium's flame when burning. Caesium is used in **atomic clocks**, which measure time down to a billionth of a second. These clocks are so accurate that they would gain or lose no more than one second every 300 years.

87 **Fr** Francium

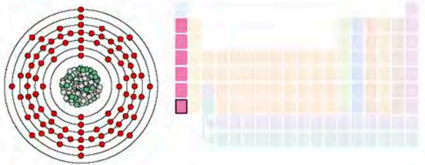

87 87 136

State: Solid
Discovery: 1939

MARGUERITE PEREY

The French chemist Marguerite Perey discovered francium in 1939 while studying the way a pure sample of another radioactive metal – actinium – decayed. She found that actinium broke down to form thorium and a previously unknown element. She named this element francium after her home country.

Thorite
Uraninite

This mineral *was discovered in 1828 in Norway.*

The dark crust *is a uranium mineral that holds tiny amounts of francium.*

Earth's rocks have **one** francium **atom** for every million trillion uranium atoms.

Francium is the rarest natural element on Earth. Scientists think there may be just 30 g (1.1 oz) of francium in Earth's rocks. Francium atoms are created when radioactive elements break down. Francium can be extracted from radioactive ores such as **thorite** and **uraninite**, both of which contain tiny amounts of this element. Even so, to date the largest sample of the metal made contained only 300,000 atoms, and lasted only a few days. Francium has no known uses outside of research.

Barium (Ba) crystals turn black in air.

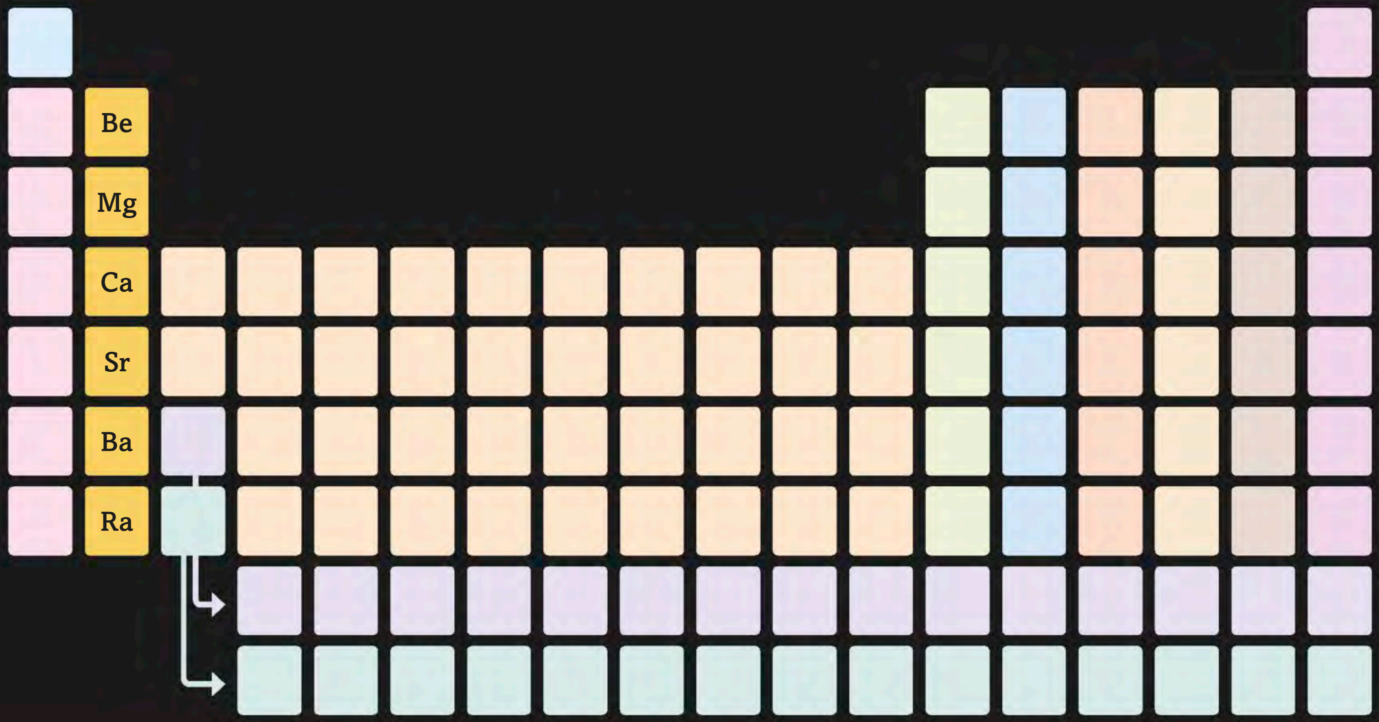

Alkaline Earth Metals

This group is a collection of reactive metals that were discovered as compounds inside common minerals in Earth's crust. Most of these minerals – known in the past as "earths" – are alkaline (alkali-producing), and this is how the group got its name. All alkaline earth metals were first purified in the 19th century.

Atomic structure
The alkaline earth metals have two electrons in their outermost electron shell. Radium (Ra) is the most radioactive member.

Physical properties
All members of this group are soft and shiny when pure. They are solid at room temperature.

Chemical properties
These metals are similar to the alkali metals, but not as reactive. Except for beryllium (Be), all alkaline earth metals react with hot water or steam.

Compounds
These elements form compounds with non-metals by losing their outermost electrons. Several compounds are found in teeth and bones.

4
Be

Beryllium

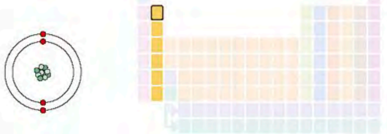

⊖ 4 ⊕ 4 ○ 5

State: Solid
Discovery: 1797

Forms

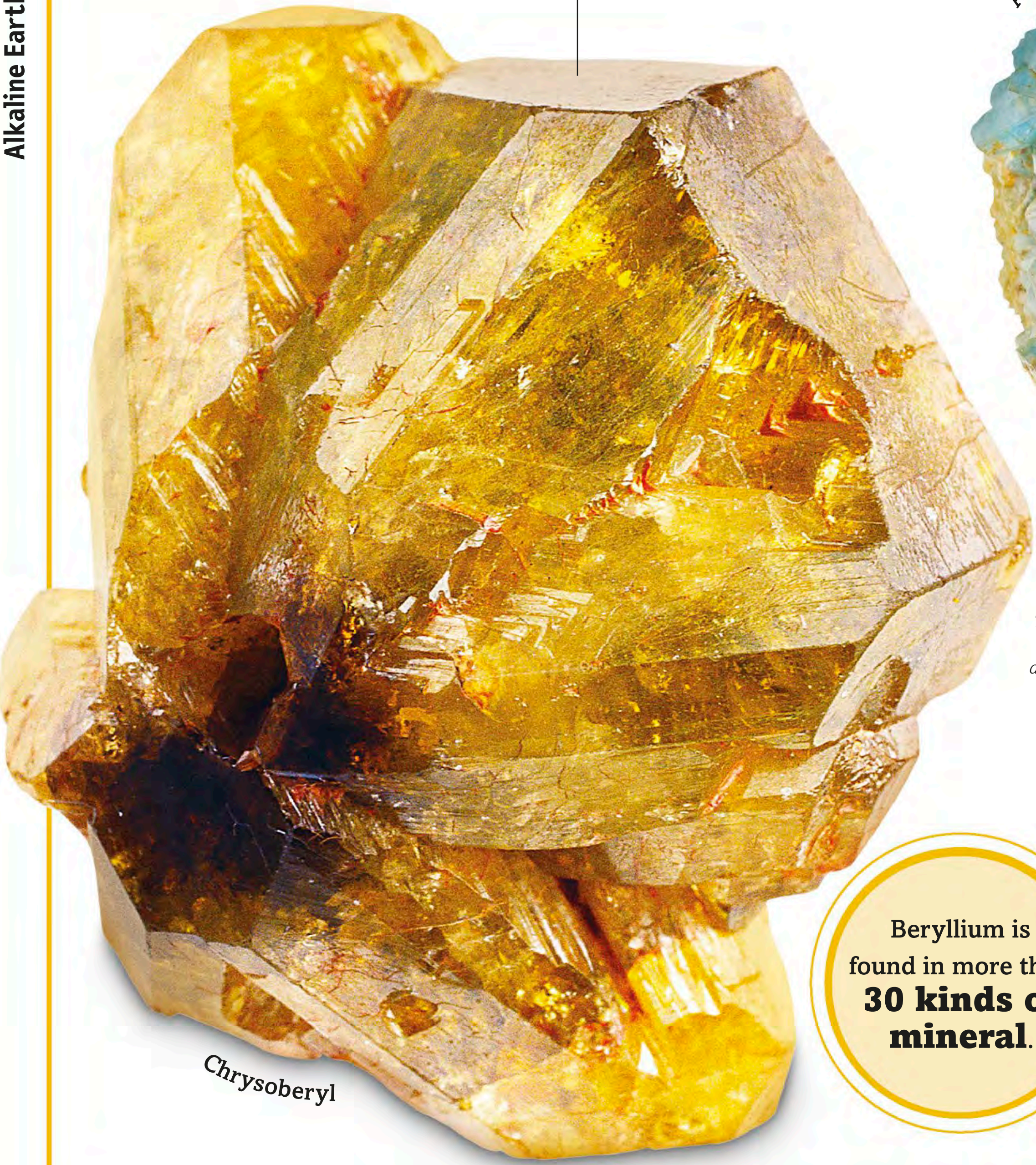

***This mineral** can also be brown, green, or orange.*

Chrysoberyl

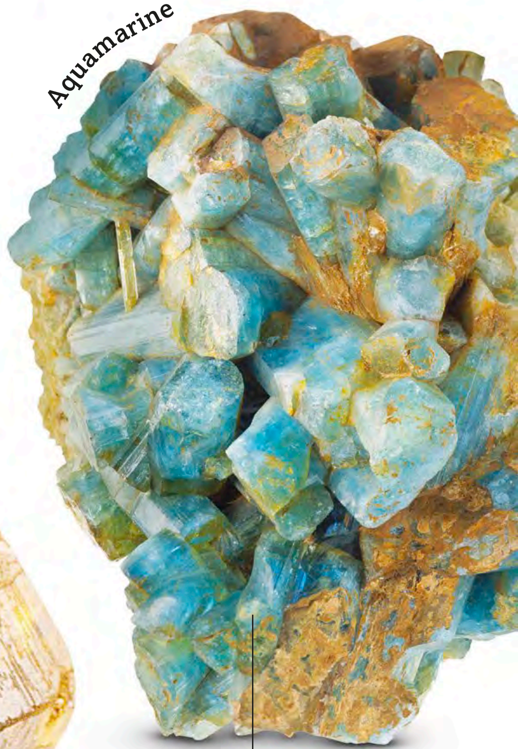

Aquamarine

***These crystals** have this pale blue colour due to iron impurities.*

Laboratory sample of pure beryllium

***Lightweight** metal*

Beryllium is found in more than **30 kinds of mineral**.

This widely used element gets its name from the Greek word *beryllos*, after which the mineral beryl is also named. Beryllium is the lightest of the alkaline earth metals, but it does not share many of the group's properties. For example, it does not react with water and is much harder than the other metals in its group. Two common beryllium minerals are **chrysoberyl** and beryl. Beryl has different forms, such as **aquamarine** and emerald. Beryllium is useful in many ways. For example, some military **helicopters** use windows made

Uses

Apache attack helicopter

Beryllium alloy window

LOUIS NICOLAS VAUQUELIN

Beryllium was discovered in 1798 by the French chemist Louis Nicolas Vauquelin. He extracted the pure metal from emerald, which is a valuable green form of the mineral beryl. He had already discovered the element chromium, which is also found in emerald and gives it its green colour.

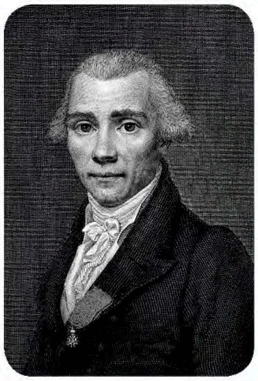

Fire sprinkler

This seal *made of a beryllium-nickel alloy is strong enough to stop high-pressure water supply leaking through.*

These beryllium mirror segments *will not contract in the cold of space.*

James Webb Space Telescope

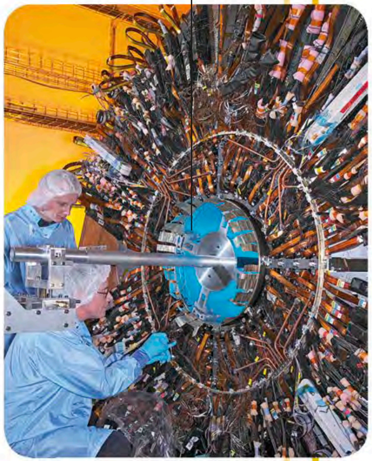

This beryllium pipe *delivers beams of protons into this device.*

ATLAS, a device at the Large Hadron Collider, CERN, Switzerland

This airbag *is triggered by a sensor that contains beryllium.*

Airbag

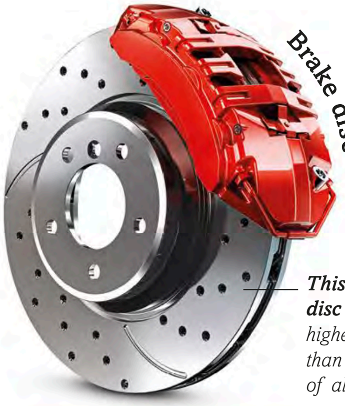

Brake disc

This beryllium disc *can withstand higher temperatures than a disc made of aluminium.*

of beryllium-rich glass to shield optical sensors to aid pilots flying at night or through fog. Objects made of this metal keep their shape well and hardly expand or contract if the temperature changes. This makes beryllium useful in valves for **fire sprinklers** and car sensors that trigger **airbags**. NASA's **James Webb Space Telescope** will use a large beryllium mirror that is light and strong. Beryllium is also used to make **brake discs** for racing cars. Alloys of beryllium and copper are used in springs as well.

12 Mg Magnesium

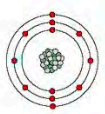

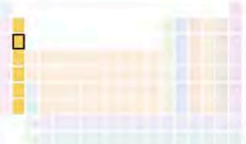

🔴 12 🟢 12 ⚪ 12

State: Solid
Discovery: 1755

Forms

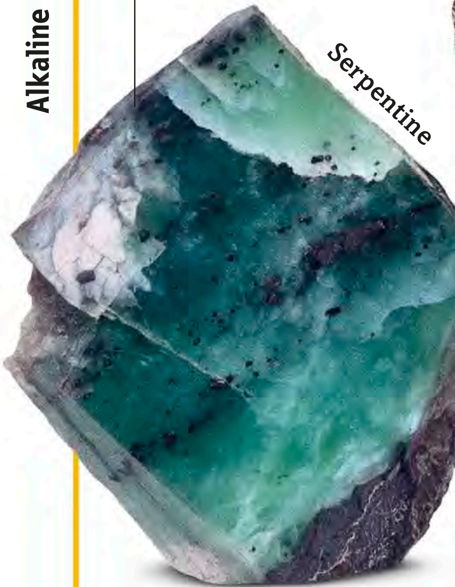

*This green, magnesium-rich **mineral** forms deep underground.*

Serpentine

Feather-like appearance

Tremolite

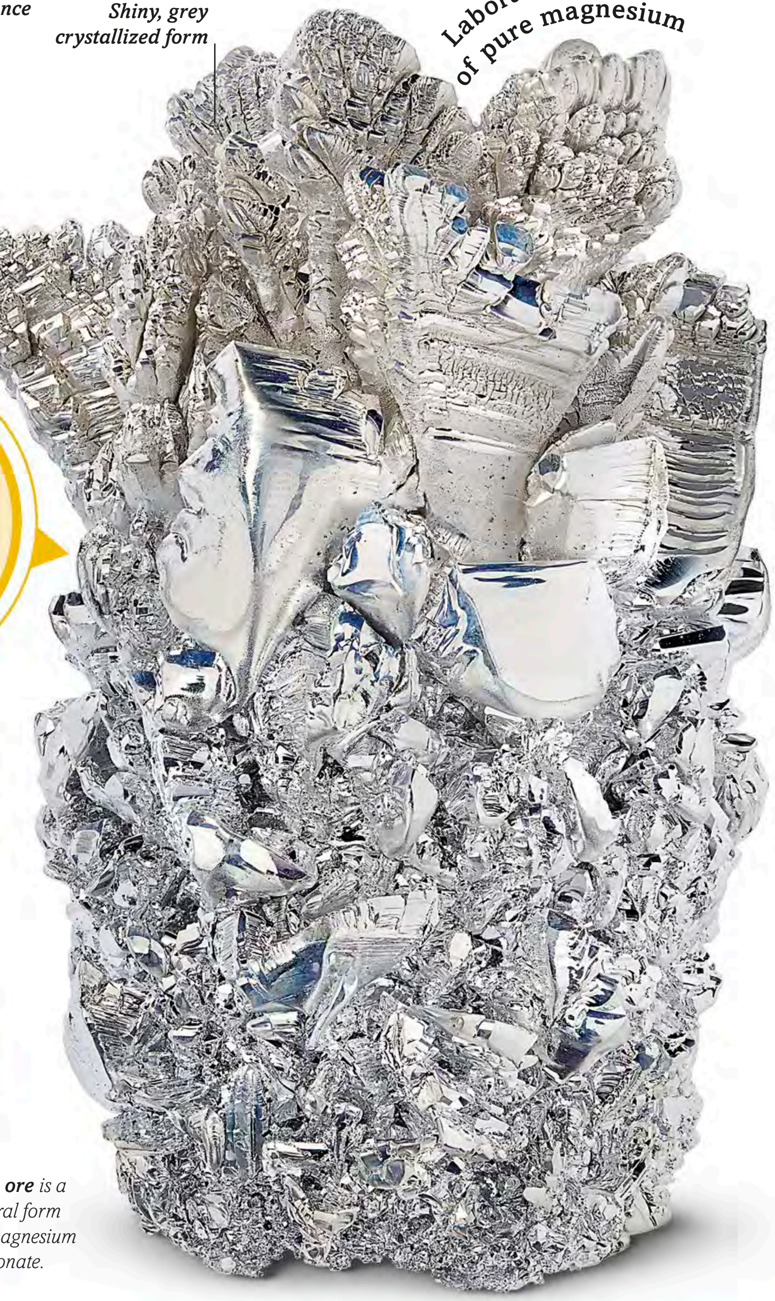

Shiny, grey crystallized form

Laboratory sample of pure magnesium

Magnesium has **22 known isotopes**.

Dolomite

***This ore** is a natural form of magnesium carbonate.*

Magnesium was named after Magnesia in Greece. This element largely exists deep inside Earth's mantle, but it can also be found in seawater and many minerals in our planet's crust, including **serpentine**. Another mineral, **dolomite**, is also a source of **pure magnesium**.

Magnesium has many important applications. Alloys of magnesium are not only strong, but also lightweight, so are used in a range of objects, from **car wheels** to **cameras**. For centuries, many naturally occurring magnesium minerals have been used in traditional medicines.

Uses

Alloy wheel

Magnesium alloy *makes this wheel strong and shiny.*

Digital camera

The magnesium alloy body *of this camera is lightweight and will not rust.*

Epsom salts

Crystals containing magnesium sulfate *are added to warm water for a soothing bath.*

Talcum powder

This powder *makes skin smooth and soft.*

Magnesium fireworks

White lights *from burning magnesium compounds*

Milk of magnesia

This indigestion medicine *is a mixture of water and magnesium carbonate.*

Portland cement

This widely used cement *contains powdered magnesium oxide.*

Laptop

The magnesium alloy case *of this laptop is strong but lightweight.*

MAGNESIUM IN CHLOROPHYLL

Chlorophyll is an important molecule in plants and is what makes them green. At its centre sits a magnesium atom, which helps plants convert sunlight into energy in a process called photosynthesis.

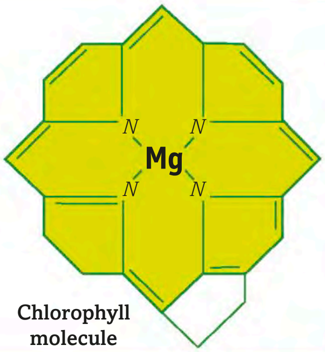

Chlorophyll molecule

Magnesium carbonate, or **magnesia**, reacts with acid in the stomach to settle indigestion. Heating magnesia produces magnesium oxide, which is one of the ingredients in **cement**. Magnesium compounds are also used in **fireworks**, and they burn hot with a white flame. Salts composed of magnesium, called **Epsom salts**, named after the place in England where they were first mined, work as a muscle relaxant. Magnesium silicate, known as **talc**, is a soft mineral used in body powders.

20 Ca Calcium

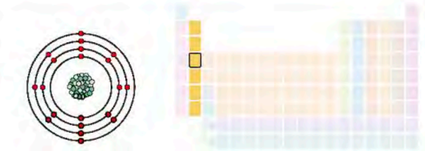

⊖ 20 ⊕ 20 ○ 20

State: Solid
Discovery: 1808

Forms

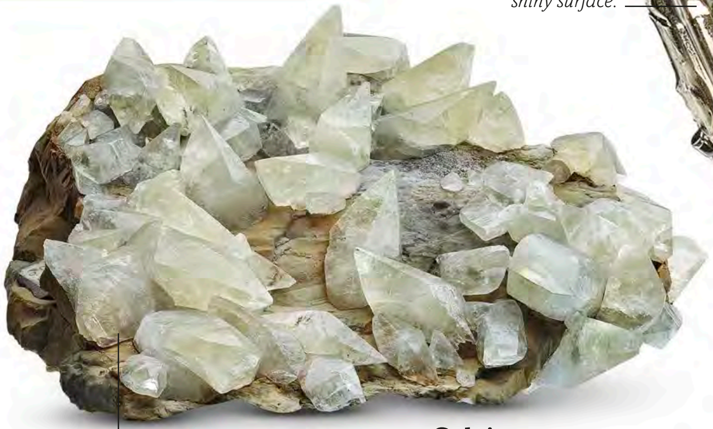

Calcite

Large, fang-like crystals

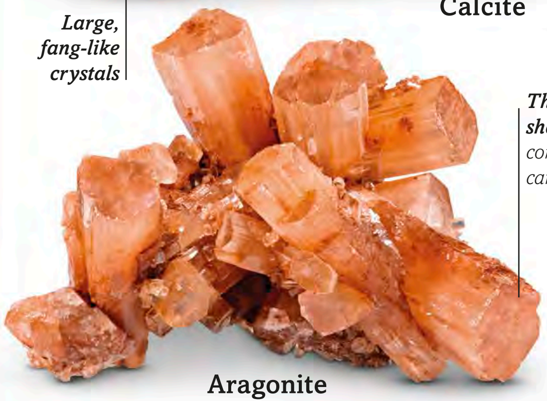

Aragonite

These column-shaped crystals *contain calcium carbonate.*

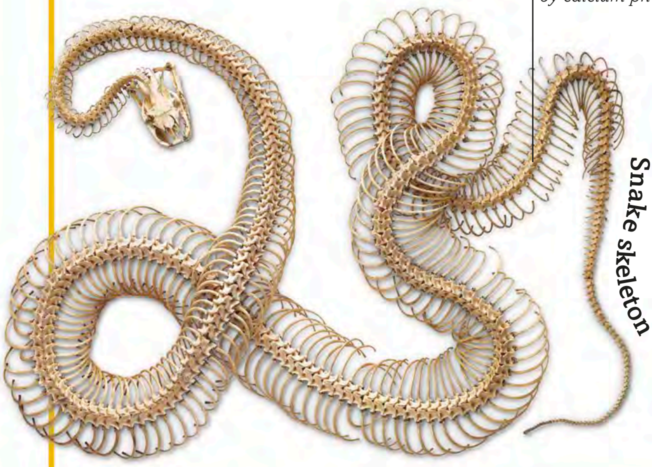

Snake skeleton

Bones *are hardened by calcium phosphate.*

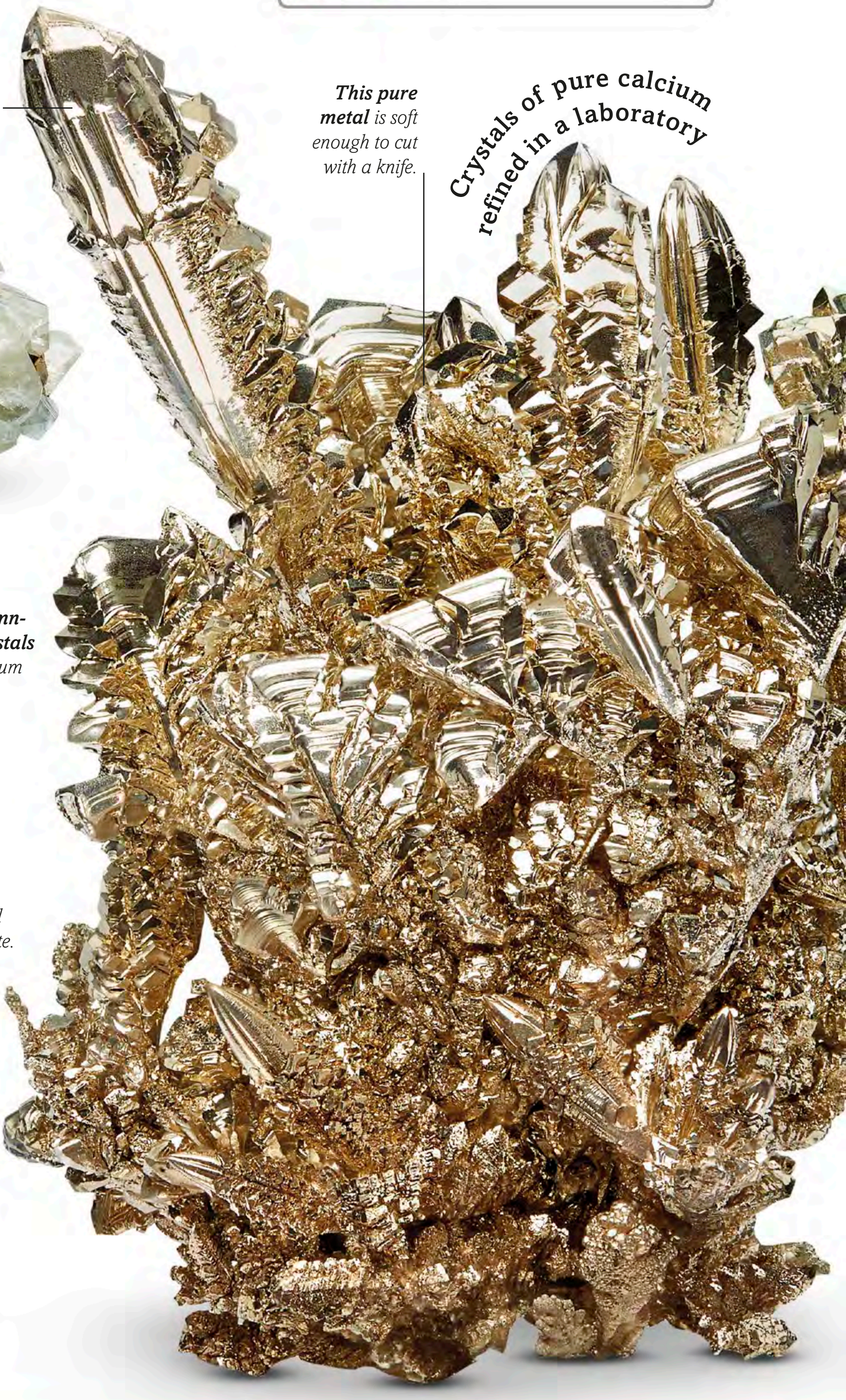

Crystals of pure calcium refined in a laboratory

This crystal *has a shiny surface.*

This pure metal *is soft enough to cut with a knife.*

The most abundant metal in the human body, calcium is also the fifth most common element on Earth. It appears in many minerals: **calcite** and **aragonite** are made of a compound of calcium and carbon called calcium carbonate. Bones in animal **skeletons** contain the compound calcium phosphate. The hard, outer layers of many other animals, such as the **shells** of sea snails, are made of calcium carbonate. Calcium is very important in our diet. We get calcium by eating **calcium-rich food**, including dairy products, green

Uses

Antacid tablets

***This tablet** contains calcium carbonate, which is an alkali – a substance that balances out acids.*

***Shells of sea snails** are hardened by calcium carbonate absorbed from sea water.*

CALCIUM CAVES

As running water flows into caves, it deposits calcium carbonate. These deposits build up to form structures called stalactites and stalagmites.

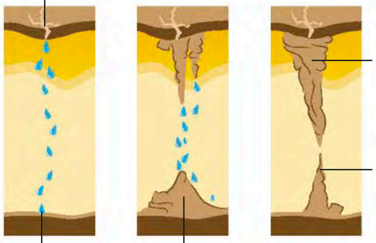

Water with dissolved calcium carbonate flows through a crack and into the cave.

Water drips onto the ground.

Over time, calcium carbonate starts to build up on the ground and ceiling.

Stalactite hangs from the ceiling.

Stalagmite grows up from the ground.

An adult **human** contains about **1 kg (2 lb) of calcium** in the body.

Plaster cast

***This plaster of Paris cast** hardens when dry, supporting broken bones.*

Writing chalk

***These chalks** contain calcium sulfate.*

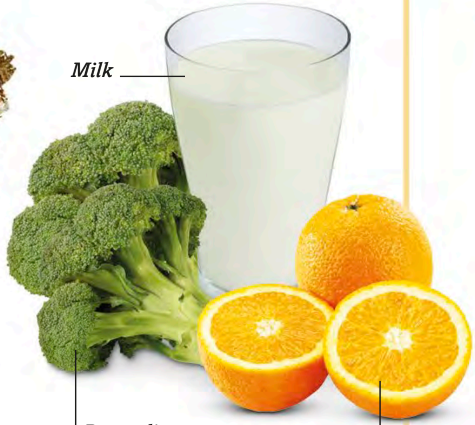

Milk

Broccoli

Orange

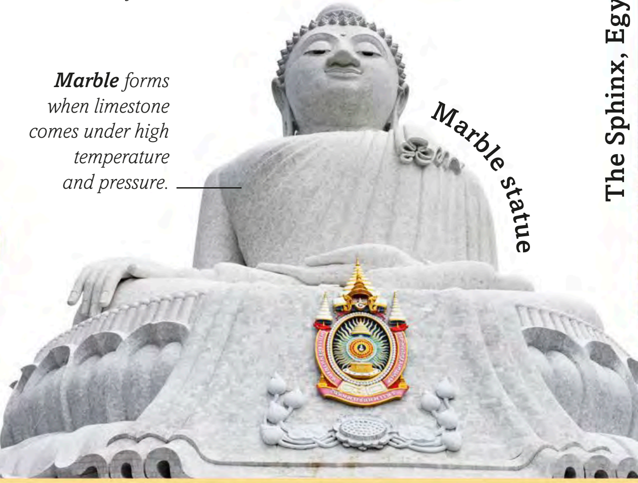

***Marble** forms when limestone comes under high temperature and pressure.*

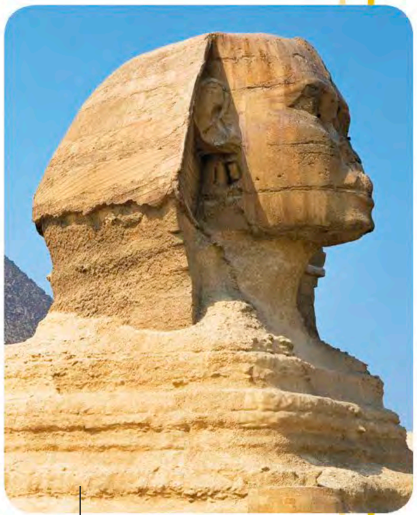

***This statue** is made of limestone, a natural rock containing calcium carbonate.*

Oranges are also a good source of calcium, and most orange juices have extra calcium added to them. **Antacid tablets**, used to settle indigestion, contain calcium carbonate. This compound reacts with acid in the stomach. Calcium compounds are also common in construction materials. Plasterboard, which is used to make walls smooth, **writing chalk**, and **Plaster of Paris** are all made from the mineral gypsum. Calcium oxide is an important ingredient in cement and helps turn it into hard concrete.

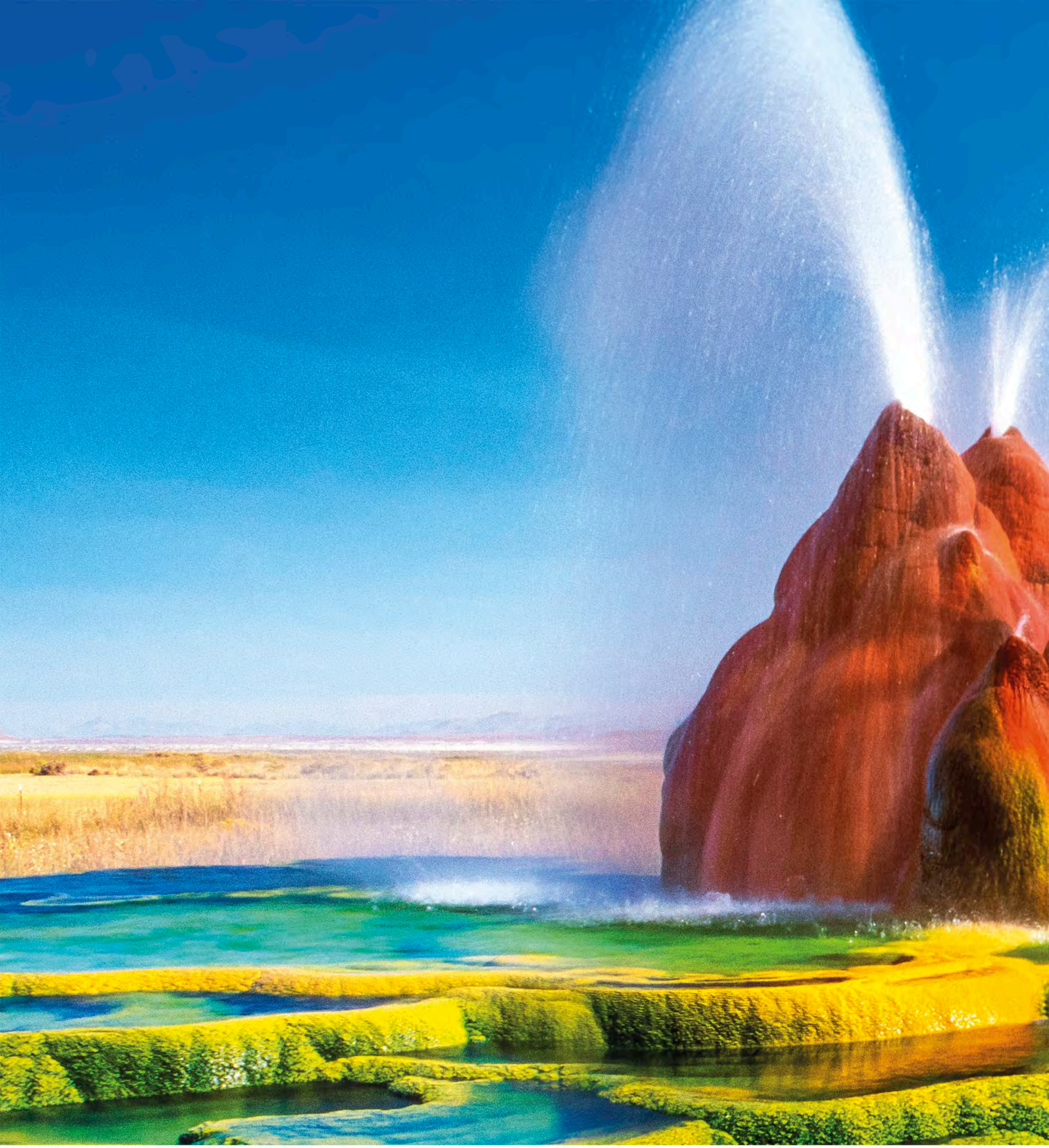

FLY GEYSER The multicoloured Fly Geyser in the Black Rock Desert of Nevada, USA, is made from a mound of calcium carbonate rock. Such mounds and pools are made naturally in many other places where springs gush out warm, calcium-rich waters. The amazing colours of the rocks are caused by algae and bacteria that live in this water.

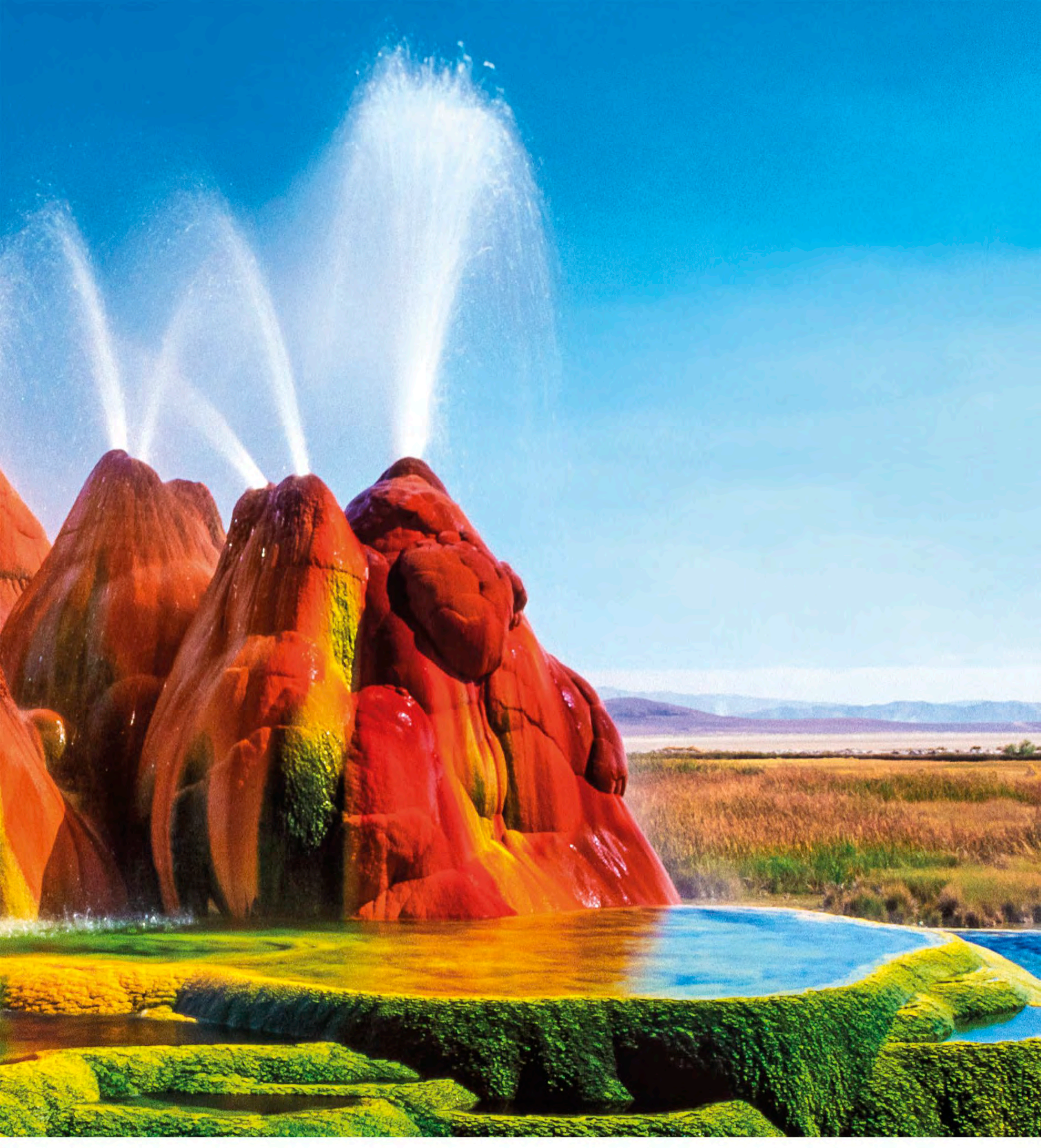

Fly Geyser is not a natural wonder. It was made by accident in 1964 when engineers were drilling a well to find a source of hot water. They did find a small reservoir of water that is heated by volcanic activity deep beneath the surface, but they chose to cap the well and look elsewhere. Eventually, the hot water broke through, creating a natural fountain, or geyser. Over the decades, the calcium deposits have slowly built up. The central mound is now 1.5 m (5 ft) tall and nearly 4 m (13 ft) wide. The scalding water that gushes out can reach a height of 1.5 m (5ft).

38 **Sr** Strontium

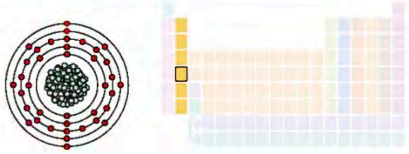

⊖ 38 ⊕ 38 ○ 50

State: Solid
Discovery: 1790

Forms

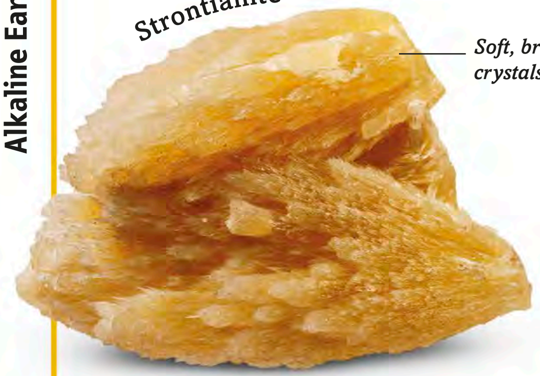

Strontianite

Soft, brittle crystals

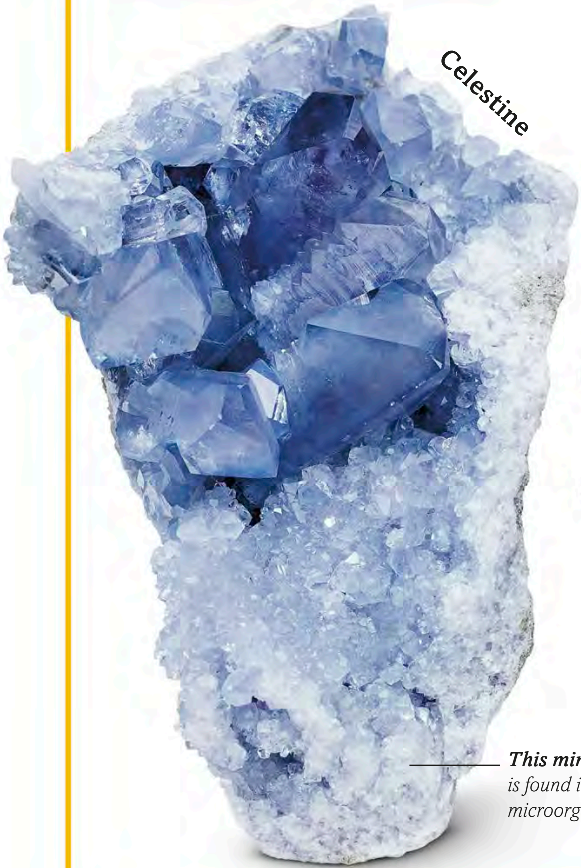

Celestine

***This mineral** is found in some microorganisms.*

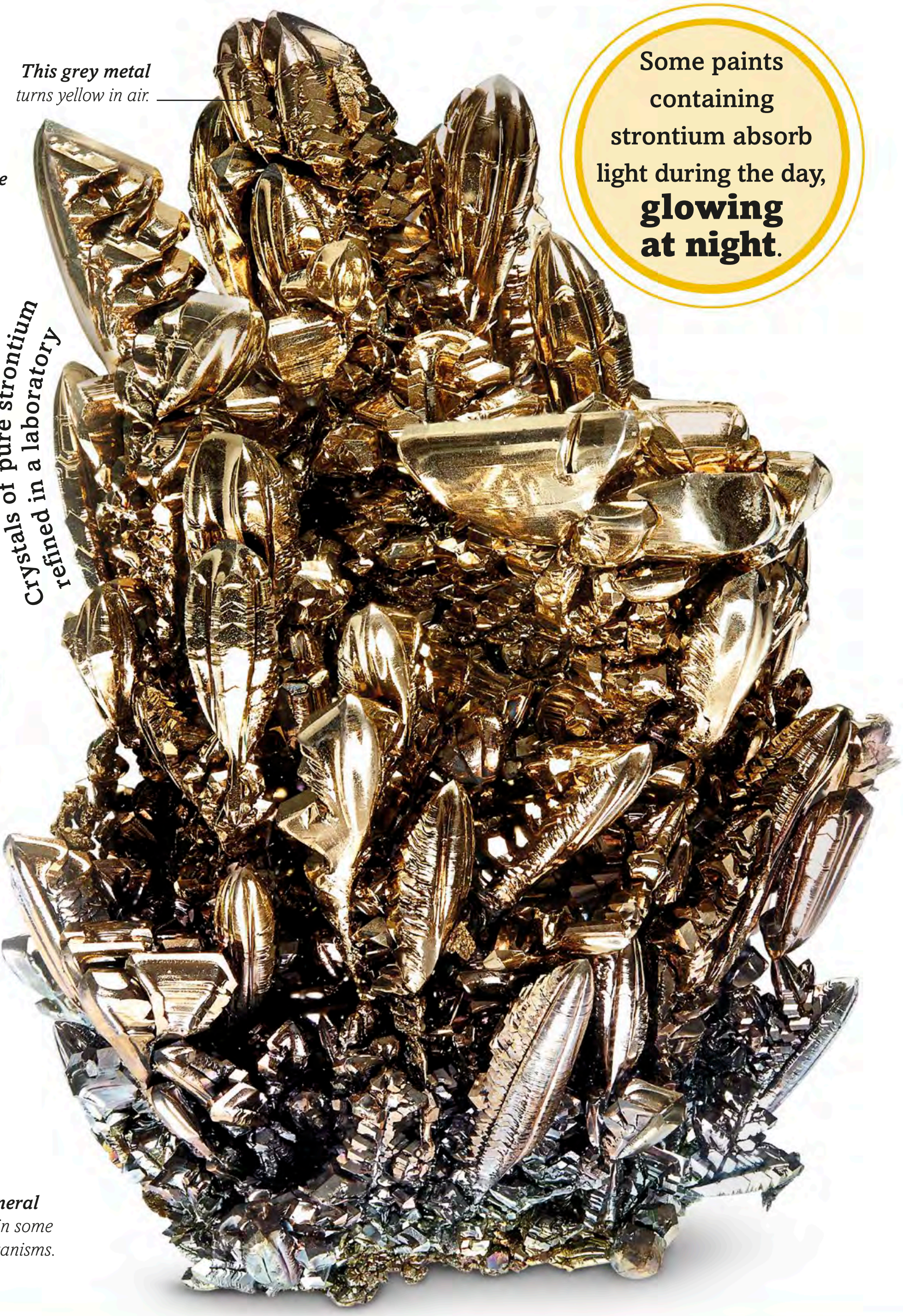

Crystals of pure strontium refined in a laboratory

***This grey metal** turns yellow in air.*

> Some paints containing strontium absorb light during the day, **glowing at night**.

Strontium was discovered in 1791 in a mineral found near the Scottish village of Strontian. The mineral burned with a bright crimson flame, and Scottish chemist Thomas Charles Hope studied it and found that it contained a new element. This mineral was called **strontianite**, and it is the main ore of strontium. **Pure strontium** was first extracted by British chemist Humphry Davy in 1808, who conducted an experiment using electricity to obtain the element from the mineral. Strontium was once used in television screens, but today

Uses

Glazed ceramic

The bowl's smooth finish *is due to strontium oxide.*

Lights in unmanned buoys *can be powered by radioactive strontium.*

Navigation buoy

Strontium burns *in air with a bright red colour.*

Flare

Loudspeaker

Magnets inside this loudspeaker *contain strontium.*

Strontium compounds in some toothpastes *provide relief from pain.*

Toothpaste for sensitive teeth

GENERATING ELECTRICITY

A radioactive form of strontium, called an isotope, can be used to produce electricity. A radioisotopic thermoelectrical generator (RTG) converts heat from the element into electricity for use in spacecraft.

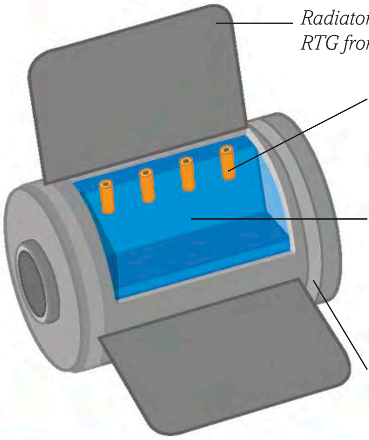

Radiator fin prevents the RTG from overheating.

A thermocouple is a device that converts heat from the radioactive metal into electricity.

Inside the capsule, atoms of radioactive strontium break down into those of lighter elements and produce heat.

RTG is insulated to stop radioactivity from leaking out.

Unmanned radar stations *run on electricity produced using a form of strontium called strontium-90.*

Weather radar station

there are fewer uses for it. Strontium oxide in pottery and **ceramic** glazes creates distinctive colours, while strontium carbonate produces a red colour in **flares** and fireworks. Magnets that contain iron oxide can be made stronger by adding strontium to them. These strong magnets are used in **loudspeakers** and microwave ovens. Strontium chloride is added to some kinds of **toothpaste**, while radioactive strontium is a source of electricity for **radar stations** in remote places where there are no power lines or fuel supplies.

56 Ba Barium

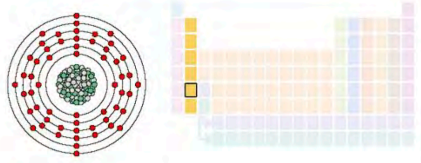

⊖ 56 ⊕ 56 ○ 81

State: Solid
Discovery: 1808

Forms

Farmers used witherite as **rat poison** until the 18th century.

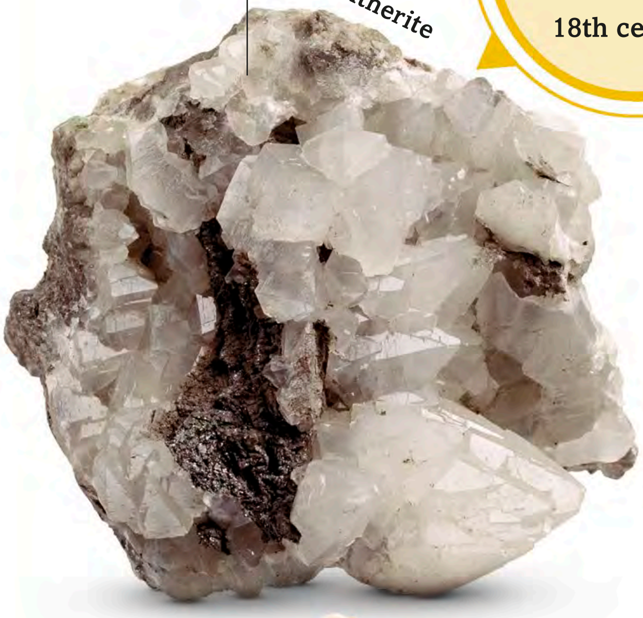

This mineral *is used to make ceramic glazes.*

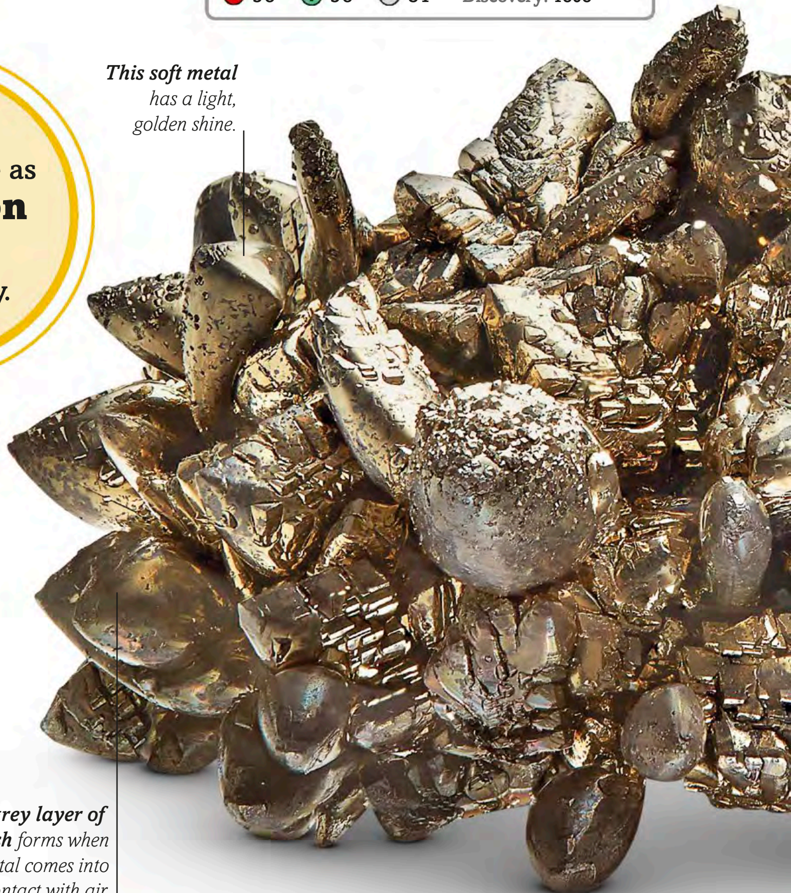

This soft metal *has a light, golden shine.*

A grey layer of tarnish *forms when the metal comes into contact with air.*

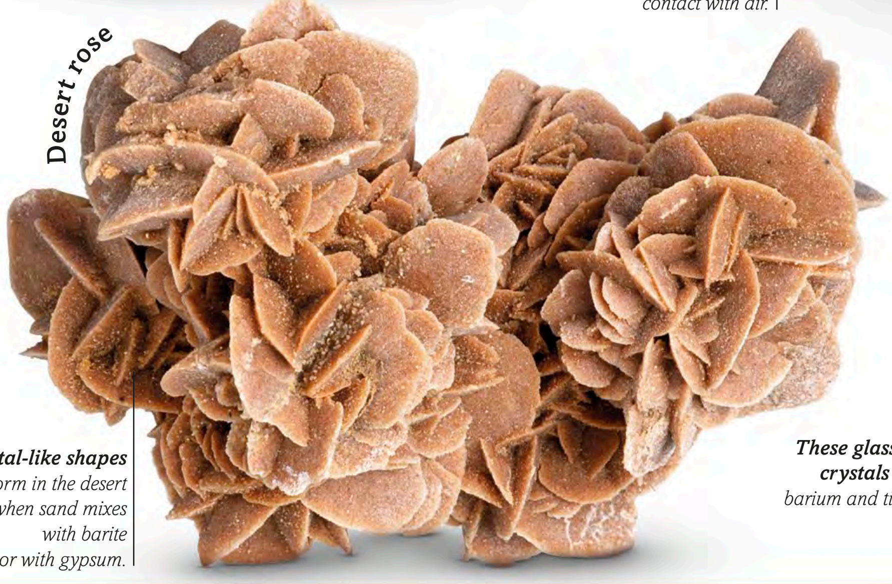

Petal-like shapes *form in the desert when sand mixes with barite or with gypsum.*

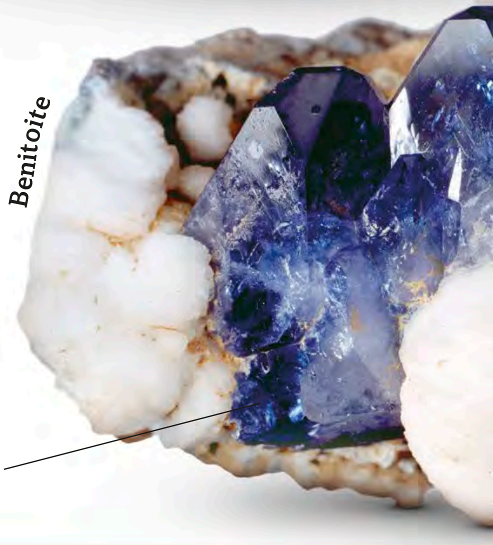

These glassy, blue crystals *contain barium and titanium.*

Barium is named after the Greek word *barys*, which means "heavy", because barium and its minerals are dense. The **pure form** of this element was first discovered in 1808 by the English chemist Humphry Davy, who extracted it from an oxide of barium. This does not exist in nature. Davy obtained it by heating the mineral **witherite**. Today, the main source of barium is barite, a mineral of sulfur that forms in deserts and in rock deposits that come into contact with hot water. A rarer mineral called **benitoite** also contains barium. The

Laboratory sample of pure barium crystals

Uses

Spark plug

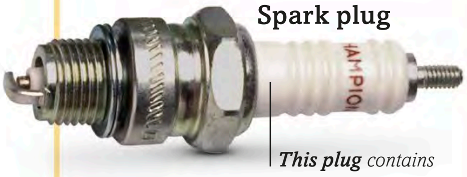

__This plug__ contains an alloy of barium and nickel.

Glass-making

__This glass__ can be made shinier by adding barium oxide and barium carbonate.

__This pot__ is made from clay that is rich in barium.

Jasperware pot

BARIUM SOLUTION

Barium is used in a medical test for checking a patient's digestive tract for problems. In this test, a patient swallows a barium liquid solution, which fills the organs in the digestive tract.

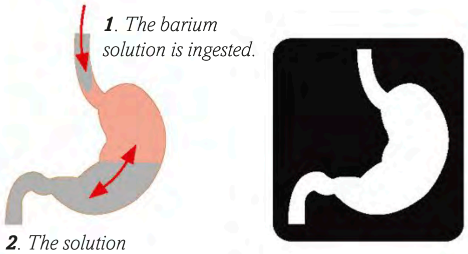

__1__. The barium solution is ingested.

__2__. The solution enters the stomach and begins to fill it.

__3__. Under an X-ray scan, the barium-filled stomach shows up clearly.

__The barium in the metallic strip__ absorbs gases in the tube, maintaining a vacuum.

Vacuum tube

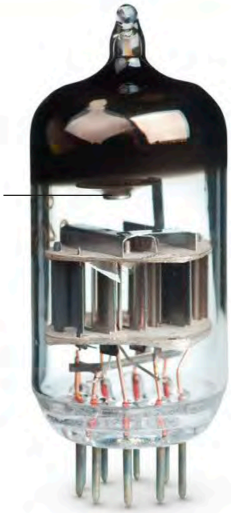

__The intestine__ is filled with a barium solution.

X-ray scan

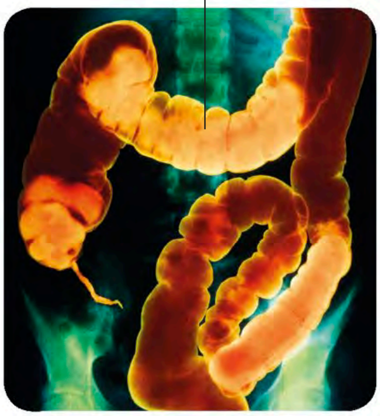

element is used in **spark plugs** to make them produce more powerful sparks and is added to **glass** to increase its shine. Barium compounds are added to some types of clay used for making **pots** and vases. In oil wells, barium compounds are added to drilling fluids to increase their density. Doctors make use of barium's density by giving patients a solution of barium compound to swallow, before taking **X-rays** of their digestive system. The barium makes the soft digestive organs denser, allowing them to be seen clearly with an X-ray machine.

88
Ra

Radium

⊖ 88 ⊕ 88 ○ 138

State: **Solid**
Discovery: **1898**

Forms

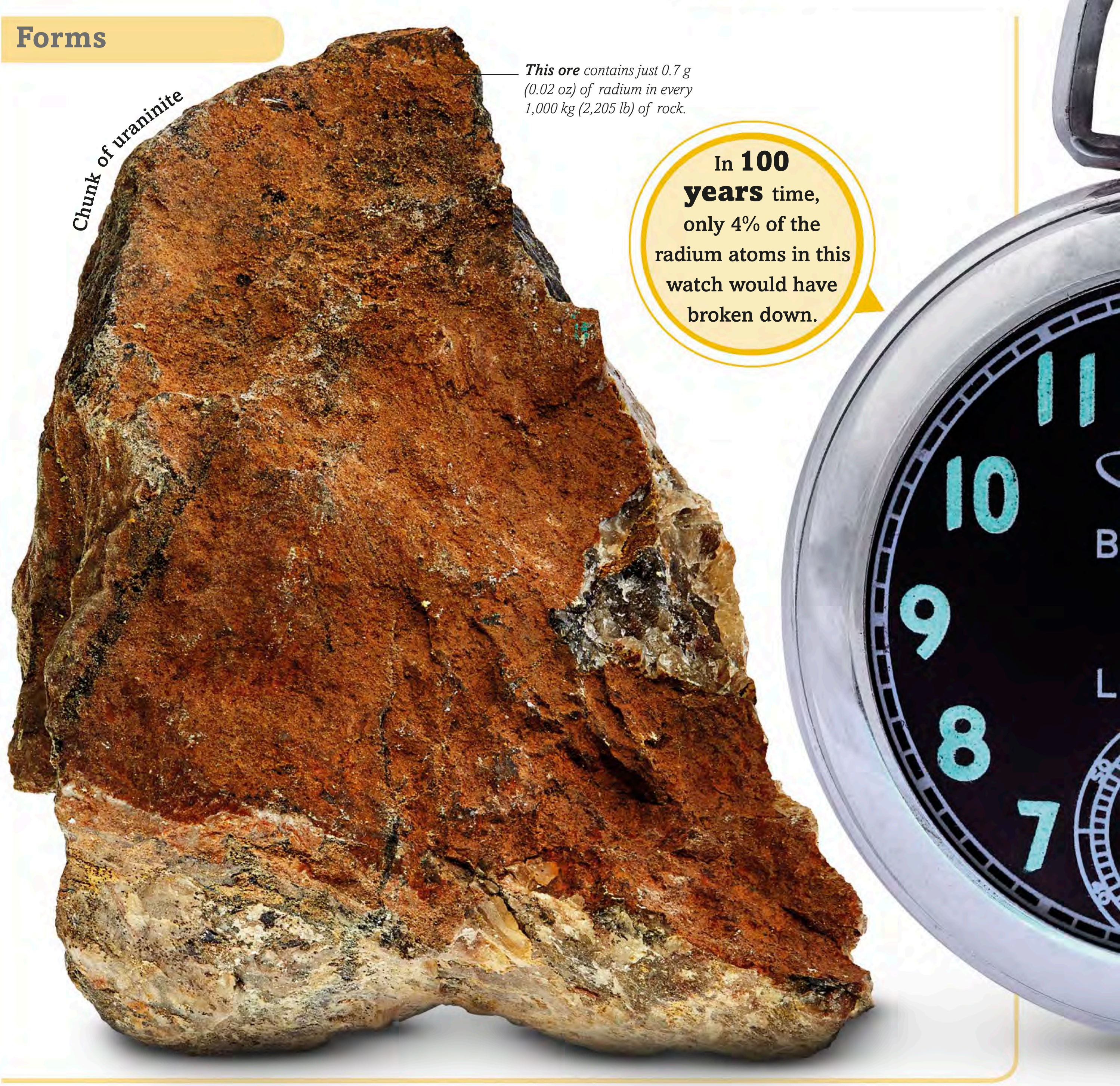

This ore *contains just 0.7 g (0.02 oz) of radium in every 1,000 kg (2,205 lb) of rock.*

In **100 years** time, only 4% of the radium atoms in this watch would have broken down.

Radium is the only radioactive member of the alkaline earth metals. It is also the rarest element in this group, and forms in small amounts when the atoms of more common metals – such as uranium and thorium – break down. Radium atoms do not survive for long, with most of them quickly decaying into radon, a radioactive noble gas. This element is highly dangerous and is rarely used today. However, in the early 20th century, radium compounds were in common use. Luminous paints, like those used to make **watch dials**

Uses

PIERRE AND MARIE CURIE

Radium was discovered in 1898 by Marie and Pierre Curie. They found that uranium ores produced more radioactivity than expected from samples of uranium. They realized another radioactive metal was present and named it radium.

Pocket watch with a luminous dial

The radium paint *in this clock makes the numbers glow green-blue in the dark.*

Vials for radium treatment

This vial *contains a liquid called radium chloride.*

RADIUM-EMANATOR
GUARANTEED
10000 MILLIMICROCURIE
OF RADIUM-EMANATION PER DAY
RADIUM VITA LTD.
LONDON S.W.
Vita

Radium emanator

This machine *from the early 20th century mixed radium into water, which was thought to make it healthier to drink.*

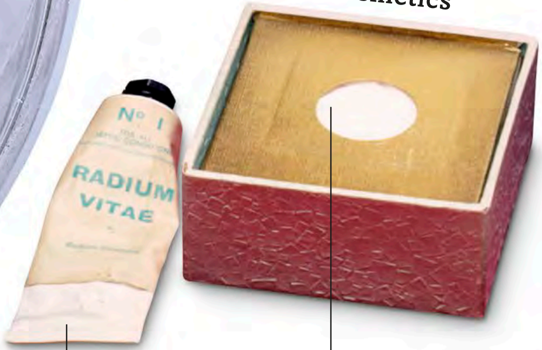

Cosmetics

Skin lotions *containing radium were common in the 1920s.*

Radium face powder *was once thought to be good for the skin.*

glow in the dark, were created using radium. People working with this paint often became ill, especially with cancer, because the radiation produced by radium damages DNA. Nevertheless, until the 1940s, many people thought radium's radioactivity made them stronger, not weaker. They injected themselves with **vials containing a radium compound**, believing it gave them an energy boost. They also thought that creams and **cosmetics** with radium in them made the skin healthier, even though they did exactly the opposite.

Oddly shaped piece of pure cobalt (Co).

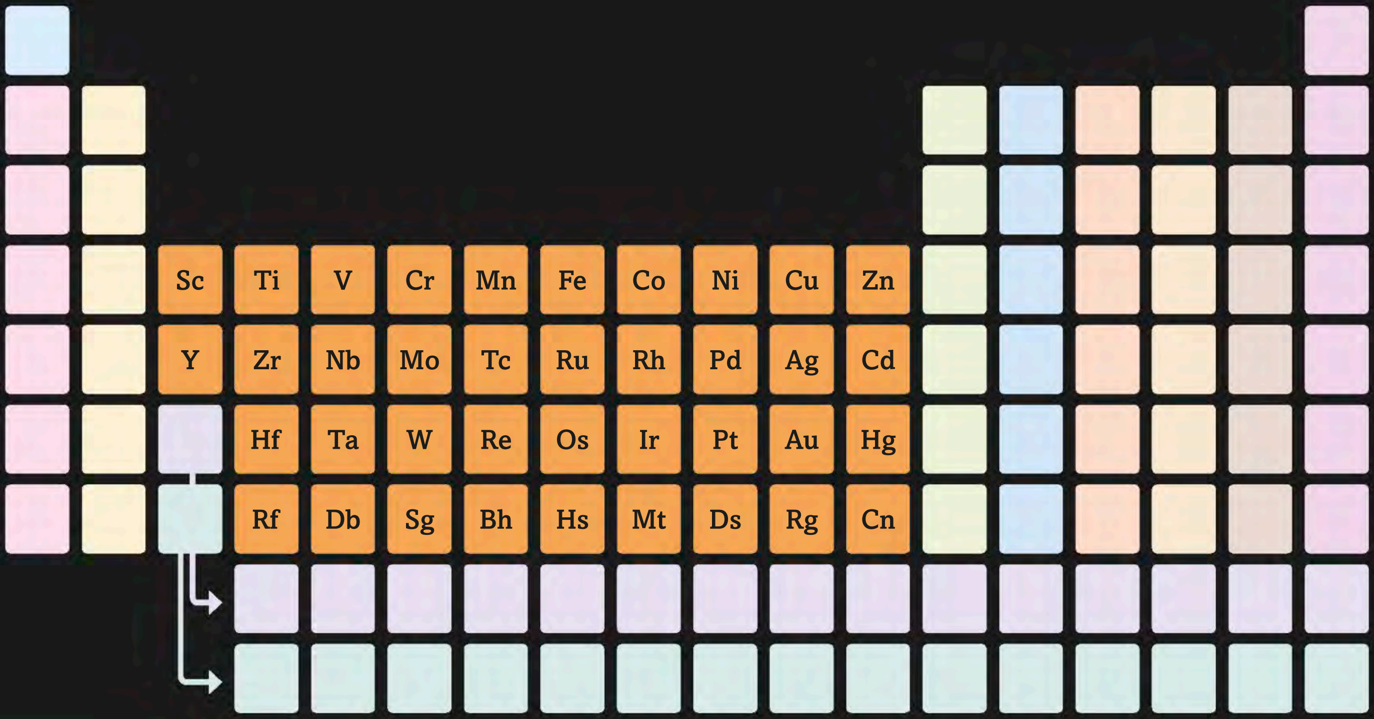
Sc Ti V Cr Mn Fe Co Ni Cu Zn
Y Zr Nb Mo Tc Ru Rh Pd Ag Cd
Hf Ta W Re Os Ir Pt Au Hg
Rf Db Sg Bh Hs Mt Ds Rg Cn

Transition Metals

This is the largest set of elements in the periodic table. This block of metals contains useful elements, such as gold (Au), iron (Fe), and copper (Cu). Many of these metals are easy to shape. The fourth period of the block – from rutherfordium (Rf) to copernicium (Cn) – are artificial and do not occur in nature. They were created by scientists in laboratories.

Atomic structure
Most transition metals have two outer electrons, but a few, such as copper (Cu), have just one.

Physical properties
These elements are generally hard and dense metals. Mercury (Hg), the only element that is liquid at room temperature, also belongs to this group.

Chemical properties
Transition metals are not as reactive as alkali and alkaline earth metals. However, they form many varied and colourful compounds.

Compounds
Many compounds of transition metals are brightly coloured. These metals are often used in alloys, such as brass and steel.

21 Sc Scandium

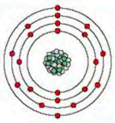

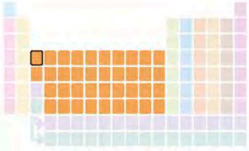

⊖ 21 ⊕ 21 ○ 24

State: Solid
Discovery: 1879

Forms

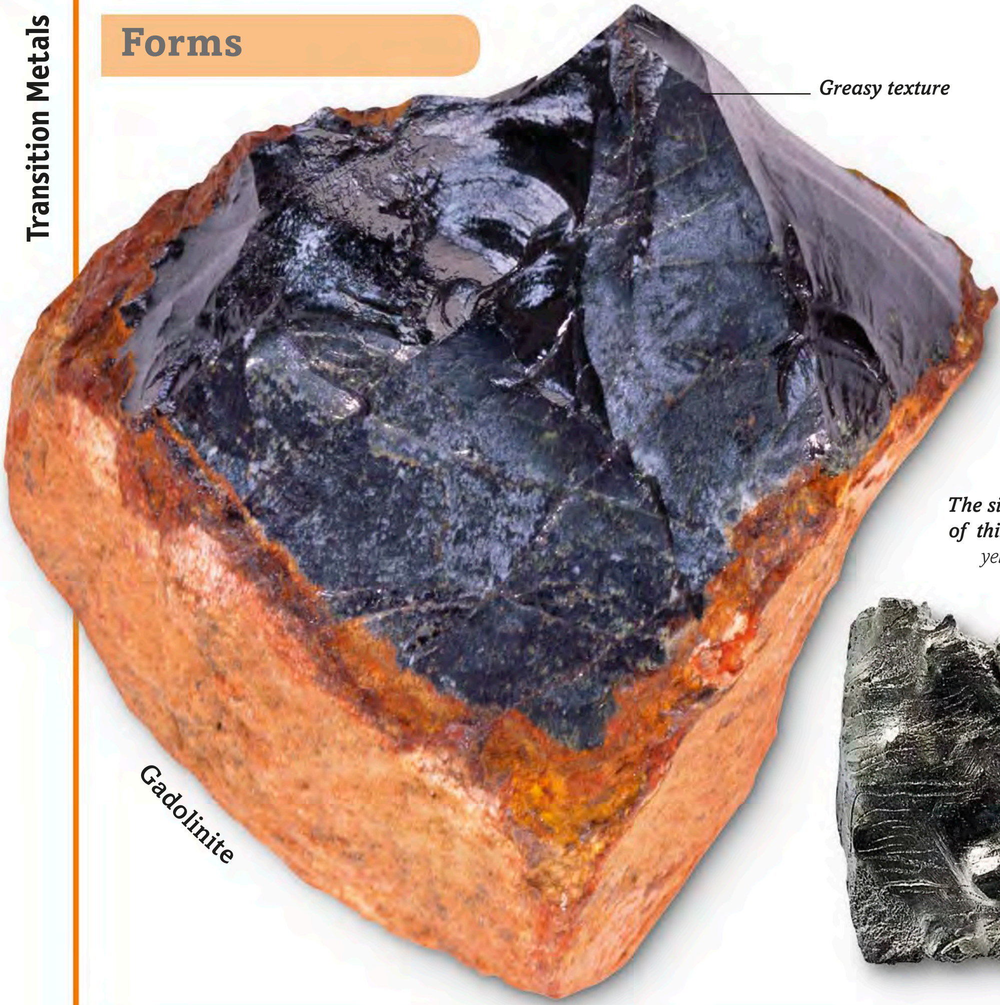

Greasy texture

Gadolinite

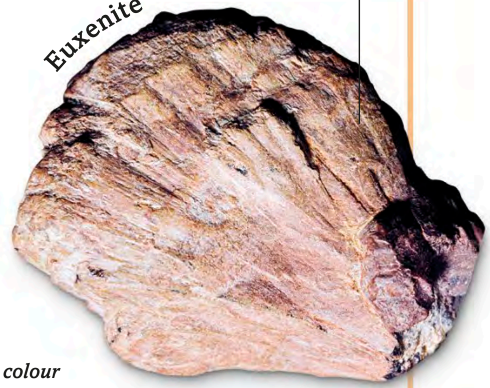

Euxenite

These crystals *contain only tiny amounts of scandium.*

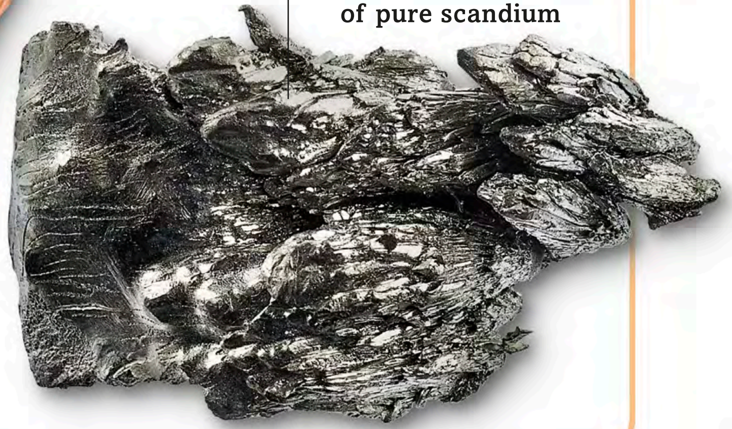

The silvery colour of this metal *turns yellow in the air.*

Laboratory sample of pure scandium

Uses

This lightweight alloy handle *does not bend.*

Lacrosse stick

The scandium iodide gas *inside the tube glows with a bright bluish light.*

Metal halide lamp

MiG-29 aircraft

Some high-speed jets *have a fuselage made of scandium alloys.*

A soft and lightweight metal, scandium is similar to aluminium. It is spread so thinly in Earth's rocks that it is very difficult to collect a large amount of this element. Scandium is only used for specialist applications. Its main ores are the minerals **gadolinite** and **euxenite**, which also contain small amounts of many other rare metals, such as cerium and yttrium. Scandium mixed with aluminium makes a strong alloy, which is used in lightweight equipment for sports, such as **lacrosse**, and to make high-speed jets, such as the **MiG-29**.

22
Ti

Titanium

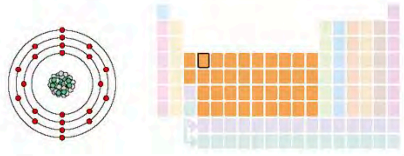

⊖ 22 ⊕ 22 ○ 26

State: Solid
Discovery: 1791

Forms

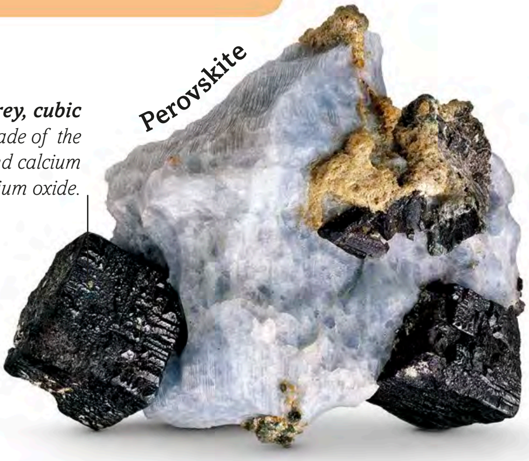

Perovskite

This grey, cubic crystal *is made of the compound calcium titanium oxide.*

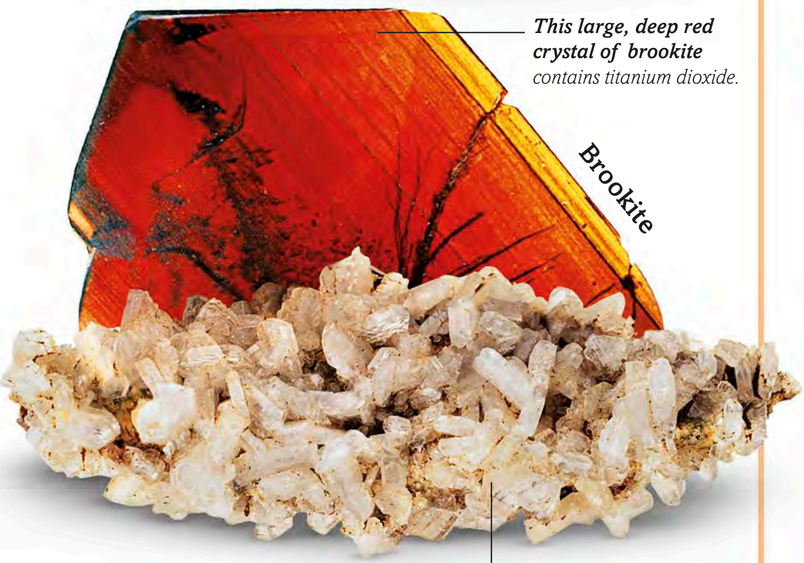

Brookite

This large, deep red crystal of brookite *contains titanium dioxide.*

These are crystals *of the mineral albite.*

This metal's shine fades to grey *when exposed to air.*

Laboratory sample of pure titanium

Uses

Body armour

The titanium plate *placed inside acts as as shield.*

Sunscreen

The titanium dioxide *in this sunscreen blocks damaging ultraviolet (UV) radiation in sunlight.*

Artificial hip joint

This titanium joint *can replace damaged bone in body.*

Drill bit

This drill bit *is hardened with a coating of titanium nitride.*

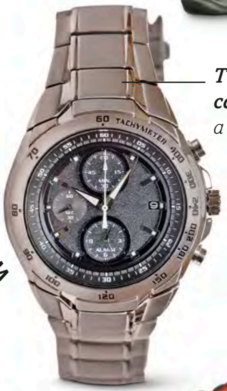

Wristwatch

This watch casing *is made of a titanium alloy.*

SALOMON
titalium

Roller blades

This titanium frame *is lightweight but strong.*

Named after the Titans, a race of mythic Greek gods, titanium is a silvery metal. It is as strong as steel but much lighter, and it is not corroded by water or chemicals. This strong metal also makes excellent protective shields in **body armour**. Titanium is commonly used to prepare titanium dioxide, a compound of titanium and oxygen that is used in paints and **sunscreen**. Titanium is not toxic so it can be used to make medical implants, such as artificial **hip joints**. **Wristwatches** made with titanium alloys are light and strong.

23
V

Vanadium

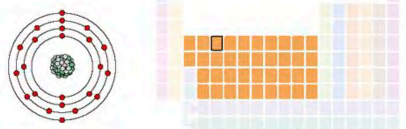

23 23 28

State: Solid
Discovery: 1801

Forms

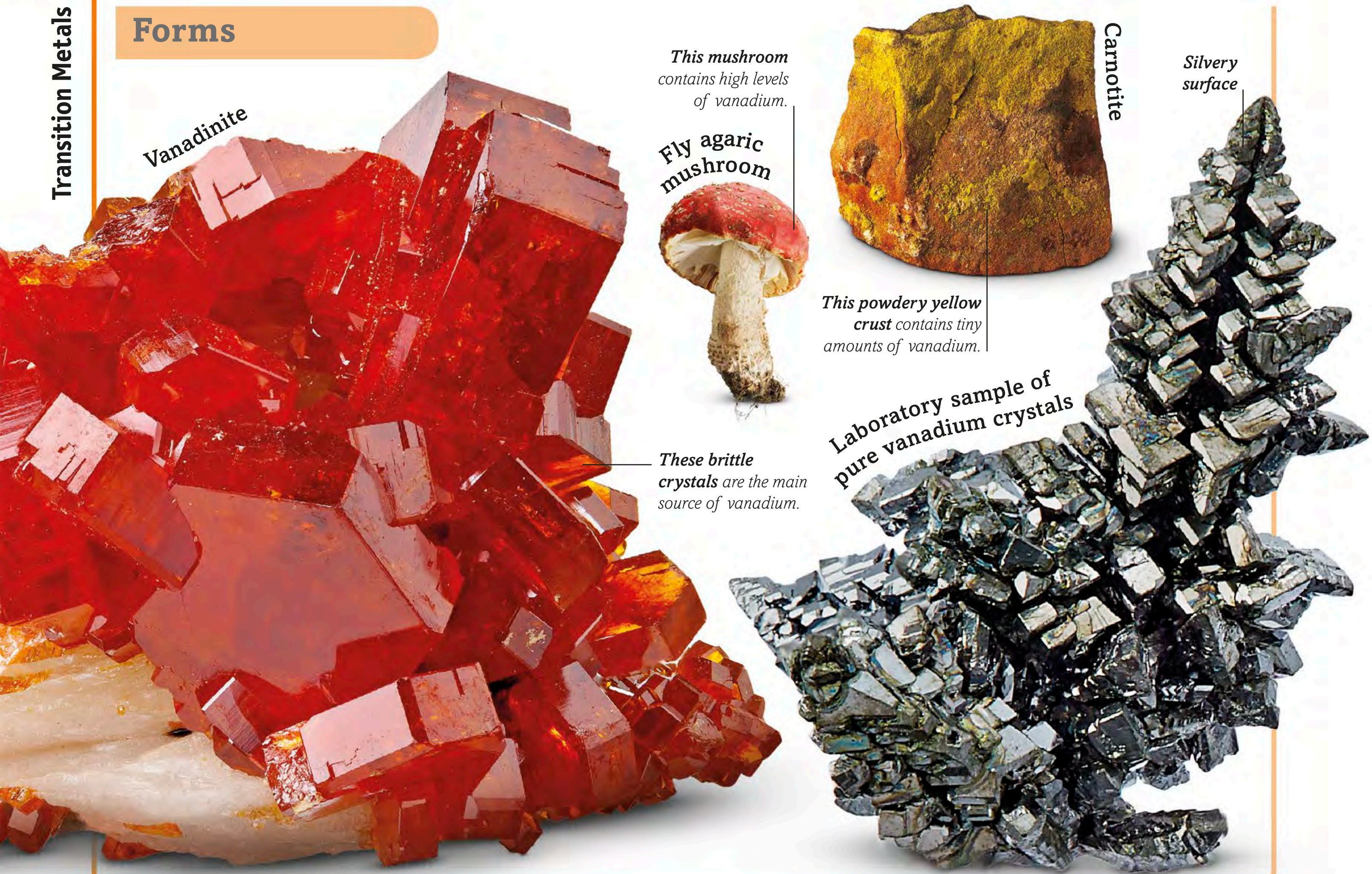

Vanadinite

These brittle crystals are the main source of vanadium.

Fly agaric mushroom

This mushroom contains high levels of vanadium.

Carnotite

This powdery yellow crust contains tiny amounts of vanadium.

Laboratory sample of pure vanadium crystals

Silvery surface

Uses

Spanners

Tools made with alloys of vanadium and steel are durable.

About **85% of all vanadium** is used to toughen steel.

This knife has been strengthened by the addition of vanadium.

Damascus Steel knife

Vanadium can be hammered and stretched without breaking. This hard, strong metal is easy to shape. **Vanadium** was first **purified** in 1869 by the British chemist Henry Roscoe. Today, it is commonly extracted from its ore **vanadinite**. Ancient metalworkers used tiny amounts of vanadium compounds to make a very tough substance called **Damascus Steel**. This was named after the capital city of Syria, where ironworkers made the world's sharpest swords. Vanadium is still used to toughen tools, such as **spanners** and knives.

24
Cr

Chromium

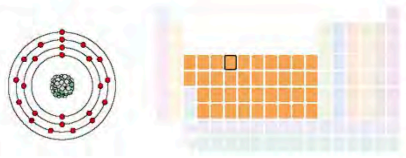

⊖ 24 ⊕ 24 ○ 28

State: Solid
Discovery: 1798

Forms

Chromite

Chromite *is dark grey to brown in colour.*

Crocoite

These large red crystals *contain chromium and lead.*

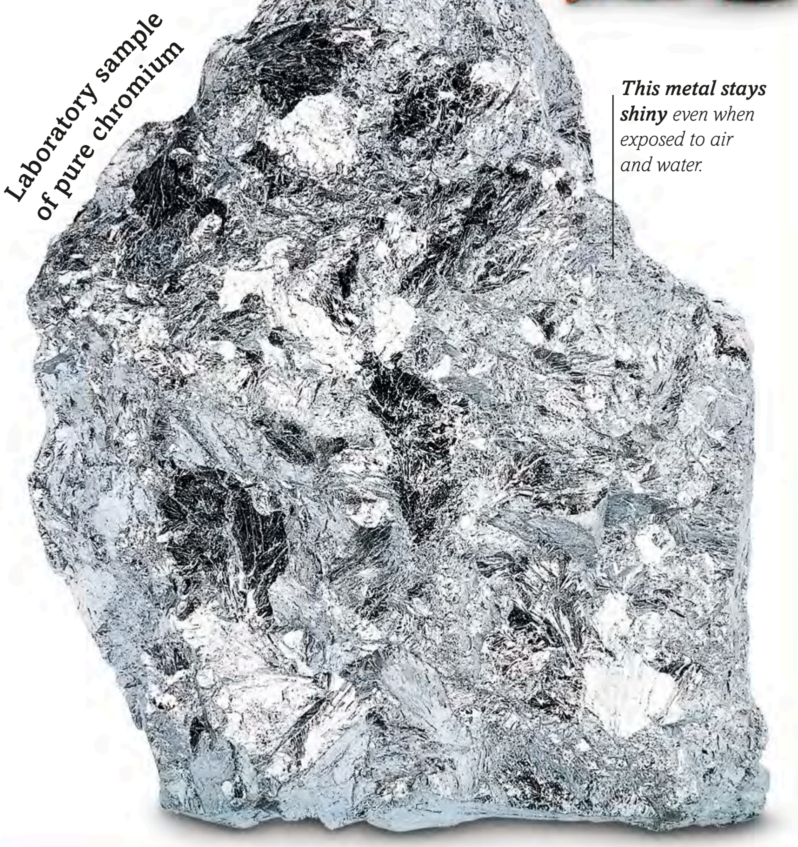

Laboratory sample of pure chromium

This metal stays shiny *even when exposed to air and water.*

Uses

Stainless steel kitchenware

This grater *can resist corrosion because it contains chromium.*

Ruby

This red colour *is due to the presence of tiny amounts of chromium oxide in the crystal.*

Motorcycle

The chromium plating *protects this motorbike from rusting.*

Chromium is named after *chroma*, the Greek word for "colour". Many minerals of chromium, including **chromite** and **crocoite**, are brightly coloured. An artificial form of crocoite, known as "chrome yellow", was once used in paints, but it was banned when scientists discovered it to be poisonous. **Pure chromium** doesn't corrode easily, so it is combined with iron and carbon to produce **stainless steel**. Chromium also gives gemstones, such as **rubies**, their deep-red colour. Some **motorcycles** have chromium-plated bodywork, giving them a shiny finish.

25 Mn Manganese

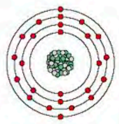

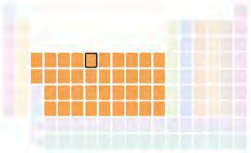

⊖ 25 ⊕ 25 ○ 30

State: Solid
Discovery: 1774

Forms

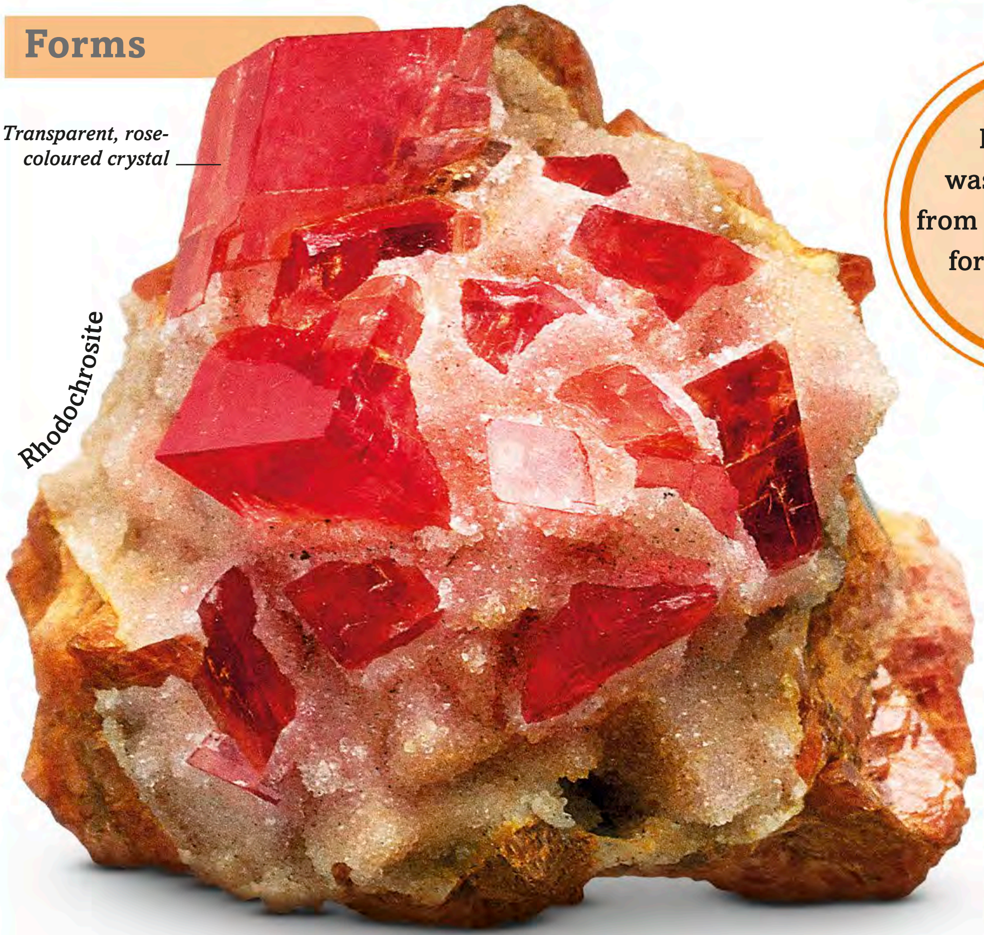

Transparent, rose-coloured crystal

Rhodochrosite

Manganese was **purified** from **pyrolusite** for the first time in 1774.

Shiny, silvery metal

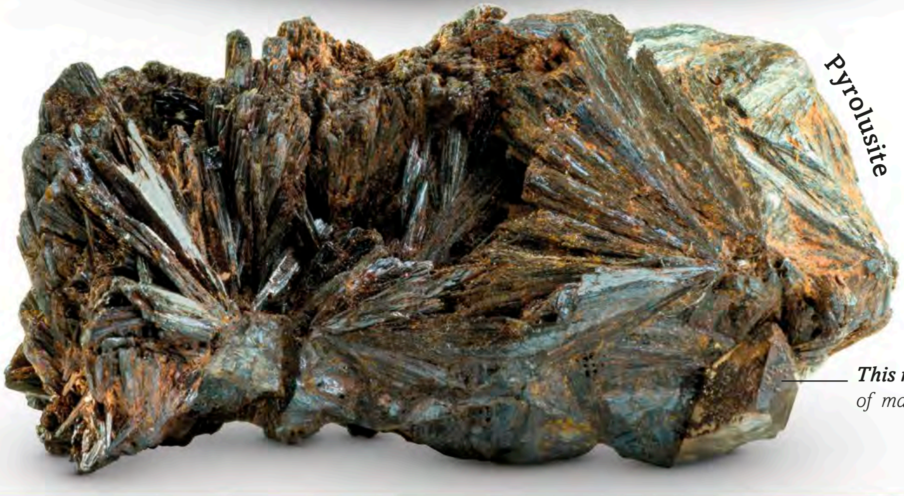

Pyrolusite

This mineral *is made of manganese dioxide.*

Like magnesium, this element gets its name from the Greek region of Magnesia. There are many manganese minerals, including the colourful mineral **rhodochrosite**. The pure form of the metal is obtained mainly from the ore **pyrolusite**. **Pure manganese** is dense, hard, and brittle. This element is present in seawater as the compounds manganese hydroxide and manganese oxide, which have built up in layers over millions of years to form masses on the sea bed. The human body needs a tiny amount of manganese, which we can get

Pineapple
Oats
Mussel
Hazelnut

Manganese-rich food

Laboratory sample of pure manganese

Uses

IN GOD WE TRUST
LIBERTY
1943

Jefferson nickel

This US coin *from World War II was made using manganese and silver because nickel was in short supply.*

JOHAN GOTTLIEB GAHN

In 1774, Swedish chemist Johan Gottlieb Gahn discovered manganese by reacting manganese dioxide with charcoal – which contains carbon – under a lot of heat. The carbon took the oxygen away from the compound, leaving behind pure manganese.

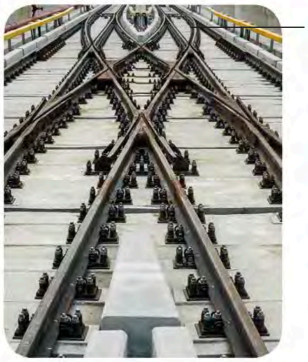

These steel tracks *have manganese added to them to make them stronger.*

Railway tracks

Dry cell battery

This battery *contains manganese dioxide.*

Unleaded petrol

This petrol *contains a manganese compound, which is less toxic than lead.*

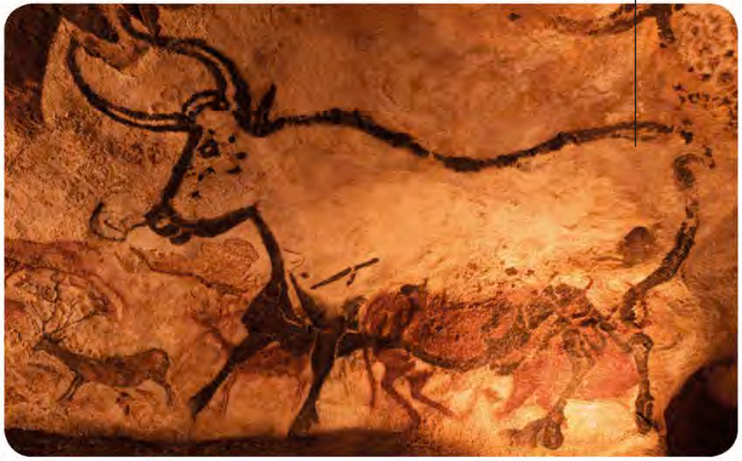

The black colour *comes from manganese dioxide.*

Lascaux cave paintings, France

Purple glass bottle

This glass is coloured *by adding a manganese compound called permanganate.*

from mussels, nuts, oats, and pineapples. The applications of manganese include its use in strengthening steel, which is used in making **railway tracks** and tank armour. Certain **dry cell batteries** carry a mixture containing manganese oxide. Manganese compounds are also added to **petrol** and used to clean impurities from **glass** to make it clear or to give it a purple colour. In prehistoric times, the compound manganese dioxide was crushed to make the dark colours used in **cave paintings**.

26 **Fe** Iron

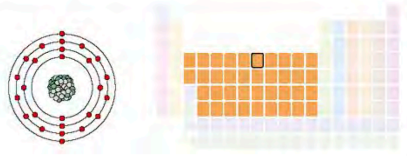

⊖ 26 ⊕ 26 ○ 30

State: Solid
Discovery: c. 3500 BCE

Forms

Pyrite

Cube-shaped crystal

***This mineral** is a compound of iron and sulfur.*

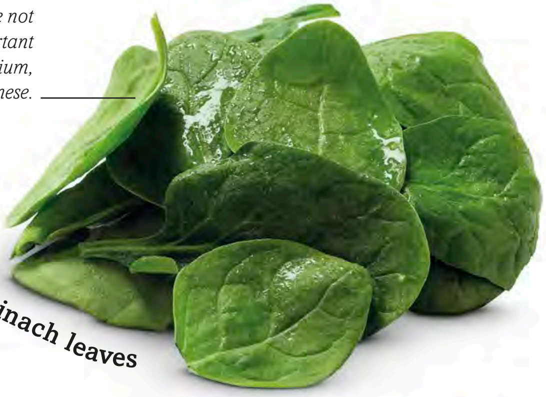

Spinach leaves

***Spinach leaves** provide not only iron but other important elements, such as potassium, calcium, and manganese.*

Iron is the **most common metal** on our planet.

Iron meteorite

Solid lump of pure iron

Chunk of pure iron refined in a laboratory

***Pure iron** is a brittle metal that can shatter easily.*

Blood sample

***Blood** contains almost 70% of the iron in the human body.*

Most of the iron on our planet is locked away in Earth's hot, molten core. This element is widely found in rocks worldwide, and almost 2.5 billion tonnes of iron is purified every year. Mineral ores rich in iron include **pyrite**. Other ores, including haematite, are used to extract **pure iron** in a process called smelting. **Iron-rich meteorites** – chunks of rock from outer space that crash to Earth – are one of very few sources of naturally pure iron. The human body uses iron to make haemoglobin, a substance in blood that carries oxygen around our body (oxygen helps

Uses

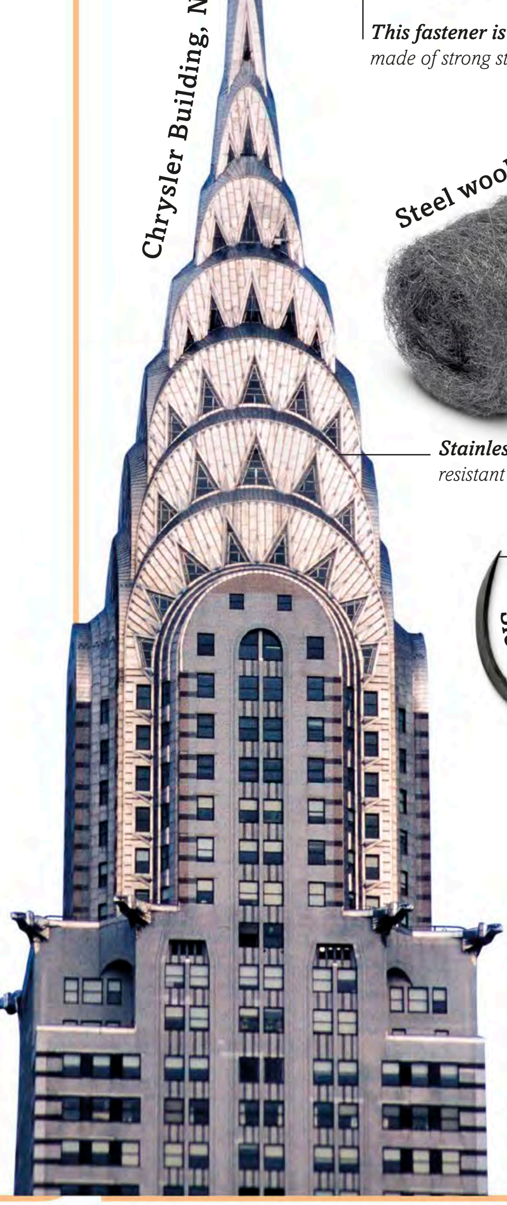

Chrysler Building, New York City, USA

Stainless steel is quite resistant to rain and wind.

Nuts and bolts

This fastener is made of strong steel.

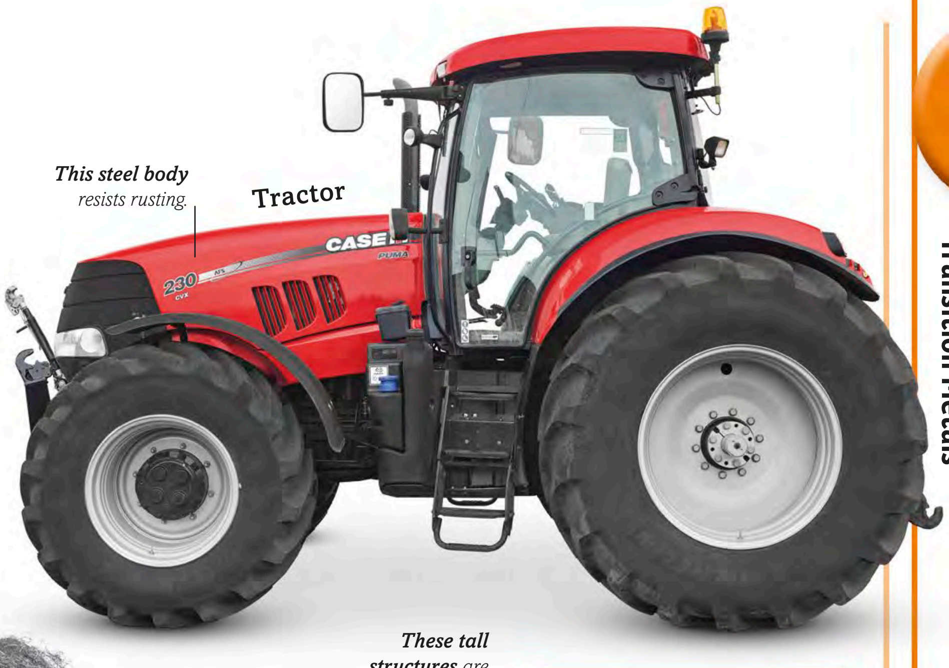

Tractor

This steel body resists rusting.

Steel wool

Thin wires of steel are used to clean hard surfaces.

Cast iron pot

This iron pot retains heat well while cooking.

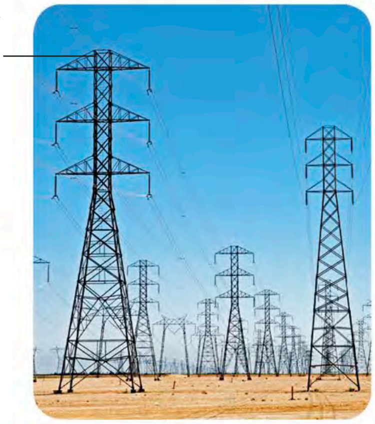

These tall structures are made from stiff steel girders.

Transmission towers

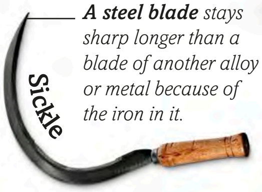

Sickle

A steel blade stays sharp longer than a blade of another alloy or metal because of the iron in it.

Iron filings and magnet

These small grains of pure iron are magnetic and are attracted to the end of a magnet.

SMELTING

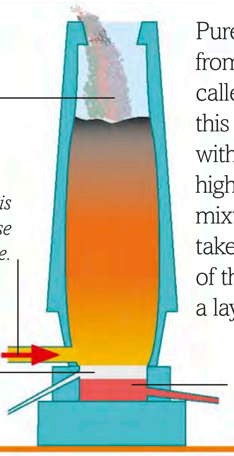

1. Iron ore and coal are added to the furnace.

2. Hot air is added here to raise the temperature.

3. Impurities float on the pure metal, then released.

4. Pure iron sinks to the bottom, then removed.

Pure iron is separated from its ores in a process called smelting. During this process, iron reacts with carbon in coal at a high temperature. As the mixture burns, the carbon takes the impurities out of the ore, leaving behind a layer of pure iron.

our cells produce energy for the body to work). Foods containing iron include meats and green vegetables, such as **spinach**. When pure iron comes into contact with air and water, it develops a flaky, reddish-brown coating called rust, which weakens the metal. In order to make iron tougher, tiny amounts of carbon and other metals, such as nickel and titanium, are added to it. This forms an alloy called steel, which is used to make **bolts** and strong **tractor** bodies, among other applications. Adding the element chromium to steel creates a stronger alloy called stainless steel.

STEELMAKING A stream of red-hot, liquid metal pours from a furnace at a steelmaking workshop. This is the end of a long process in which iron ore is transformed into steel, a tough alloy that is strong enough to make girders for supporting skyscrapers and bridges. The steel may even be moulded into car bodies, woven into superstrong cables for elevators, or turned into powerful magnets that can levitate maglev trains.

Steel is an alloy of iron that contains about two per cent carbon and some other elements. The carbon locks all the atoms together and prevents the metal from cracking. This makes steel harder than iron: it bends before it breaks and doesn't shatter easily. To make steel, iron ore is smelted in a blast furnace to remove its impurities, such as nitrogen, sulfur, or phosphorus. Other elements can be added to create different varieties of steel. For example, chromium in steel stops it from rusting, while manganese makes it harder. Adding silicon to steel can make the alloy more magnetic, while nickel makes it less brittle at extremely low temperatures.

27 Co Cobalt

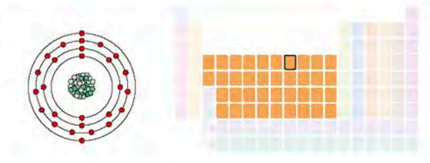

● 27 ⊕ 27 ○ 32

State: Solid
Discovery: 1739

Forms

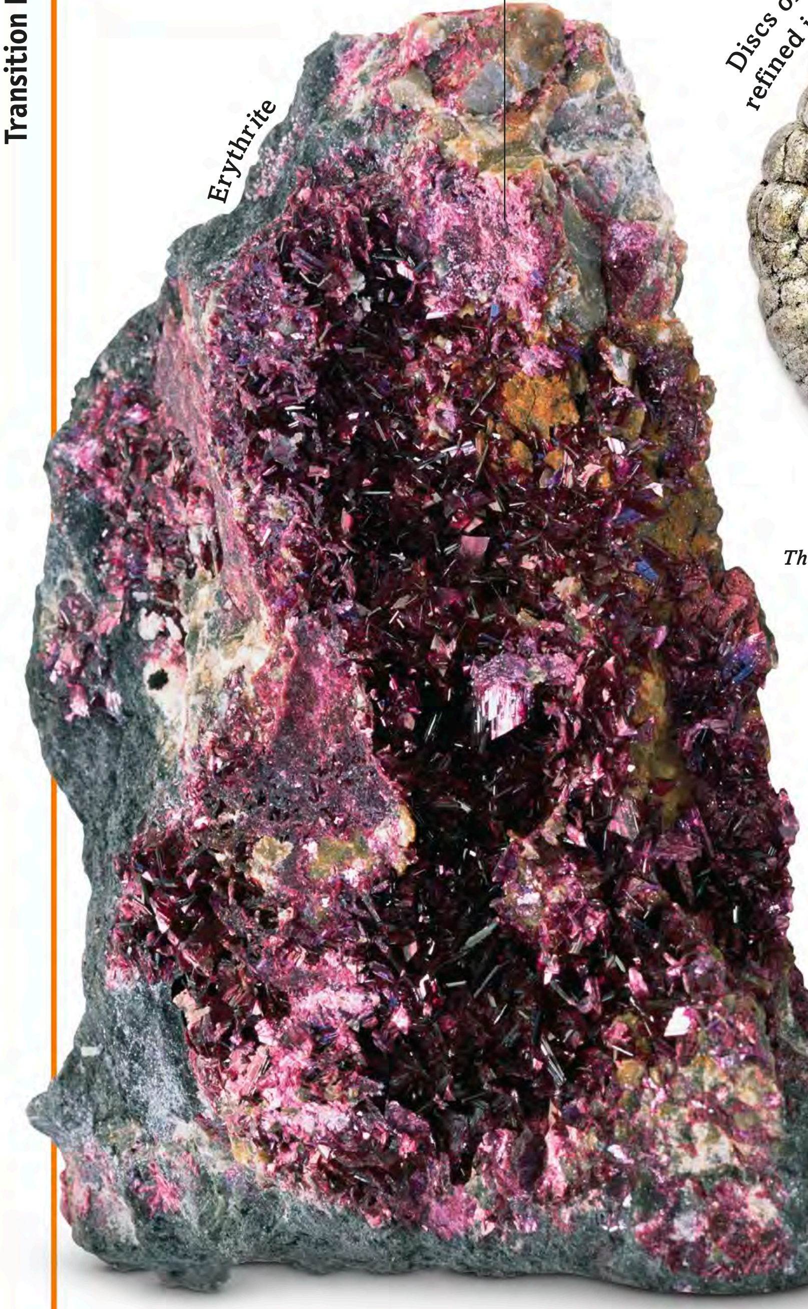

***The distinctive purplish colour** gives it the nickname "red cobalt".*

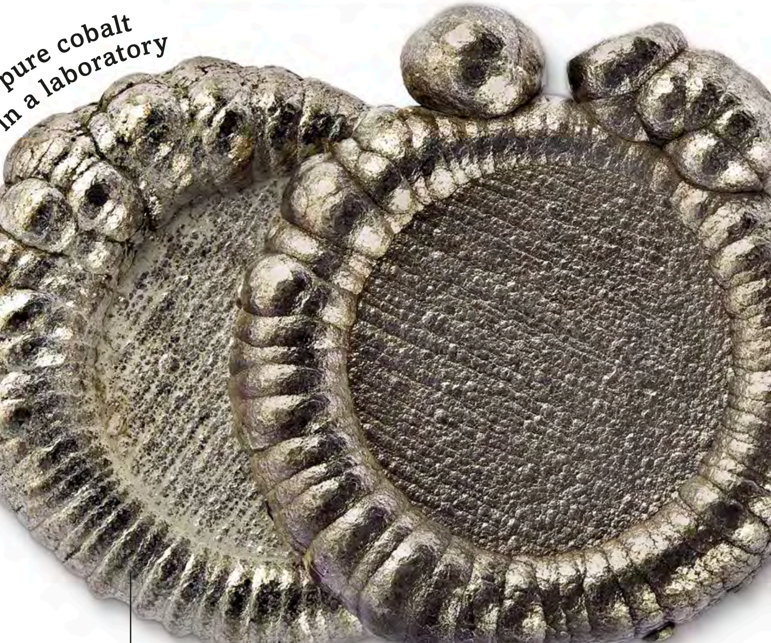

***This shiny metal** is fairly hard.*

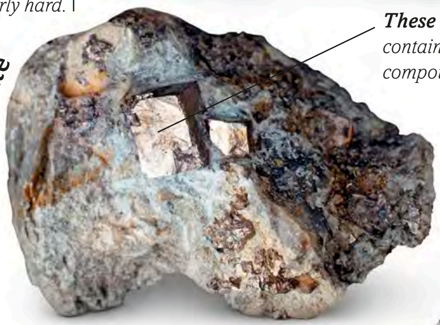

***These cubic crystals** contain a sulfur compound of cobalt.*

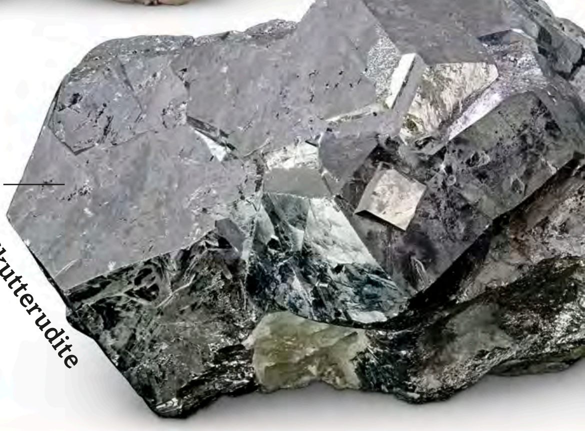

***This silvery mineral** smells like garlic when crushed due to the presence of arsenic.*

Medieval German miners often mistook ores of cobalt for precious metals. When they tried to purify these, the arsenic gas released made them sick. This unwanted side-effect led to the name *kobold*, which is German for "goblin", a mischievous spirit.

Pure cobalt is hard and shiny, and is added to steel and other alloys to make them stronger. Alloys containing cobalt are used in the blades of **jet engines** and in **artificial joints**, such as hip and knee joints. Cobalt is one of the few elements

Uses

Artificial hip joint

Tough and lightweight artificial joints *can be made from an alloy of cobalt and chromium.*

This part of the joint *is screwed into the hip bone.*

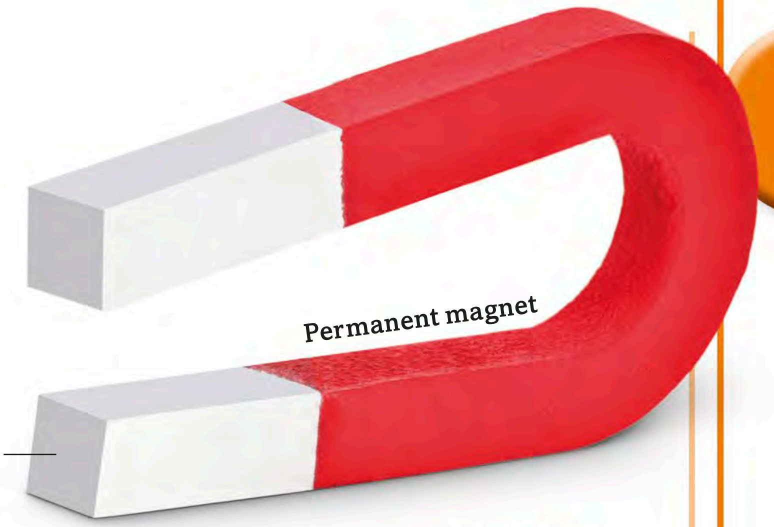

Permanent magnet

This magnet *can work at temperatures as high as 800°C (1,400°F).*

These blades *made of a cobalt alloy stay hard even when very hot.*

Jet engine turbine

Tiffany lamp

This blue glass *is manufactured using cobalt compounds.*

Cobalt blue paints have been in use **since 3000 BCE**.

Cobalt blue paint

This intense colour *does not fade easily over time or upon exposure to light.*

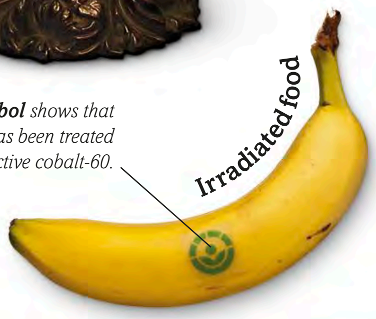

Irradiated food

This symbol *shows that this fruit has been treated with radioactive cobalt-60.*

FORMING AN ISOTOPE

Cobalt-60 is an isotope, or form, of this element. It is created artificially in nuclear reactors. Because of its radioactivity, it is useful in some cancer treatments.

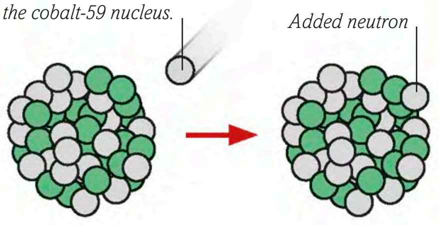

A neutron is fired at the cobalt-59 nucleus.

Added neutron

Cobalt-59 is a stable atom with 59 neutrons.

Cobalt-60 is a radioactive atom with 60 neutrons.

that can be used to make a permanent magnet. Large **permanent magnets** are made from a tough alloy of cobalt, nickel, and aluminium, called alnico. A radioactive form of cobalt, called cobalt-60, is produced in nuclear reactors. This form is widely employed to **irradiate food**, a process by which food is exposed to a tiny dose of radiation to kill harmful germs. Cobalt can also produce a deep shade of blue: **cobalt blue paints** and dyes are formed by reacting aluminium with cobalt oxide.

28

Ni Nickel

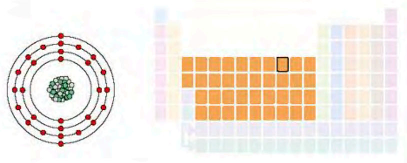

State: Solid
Discovery: 1751

Forms

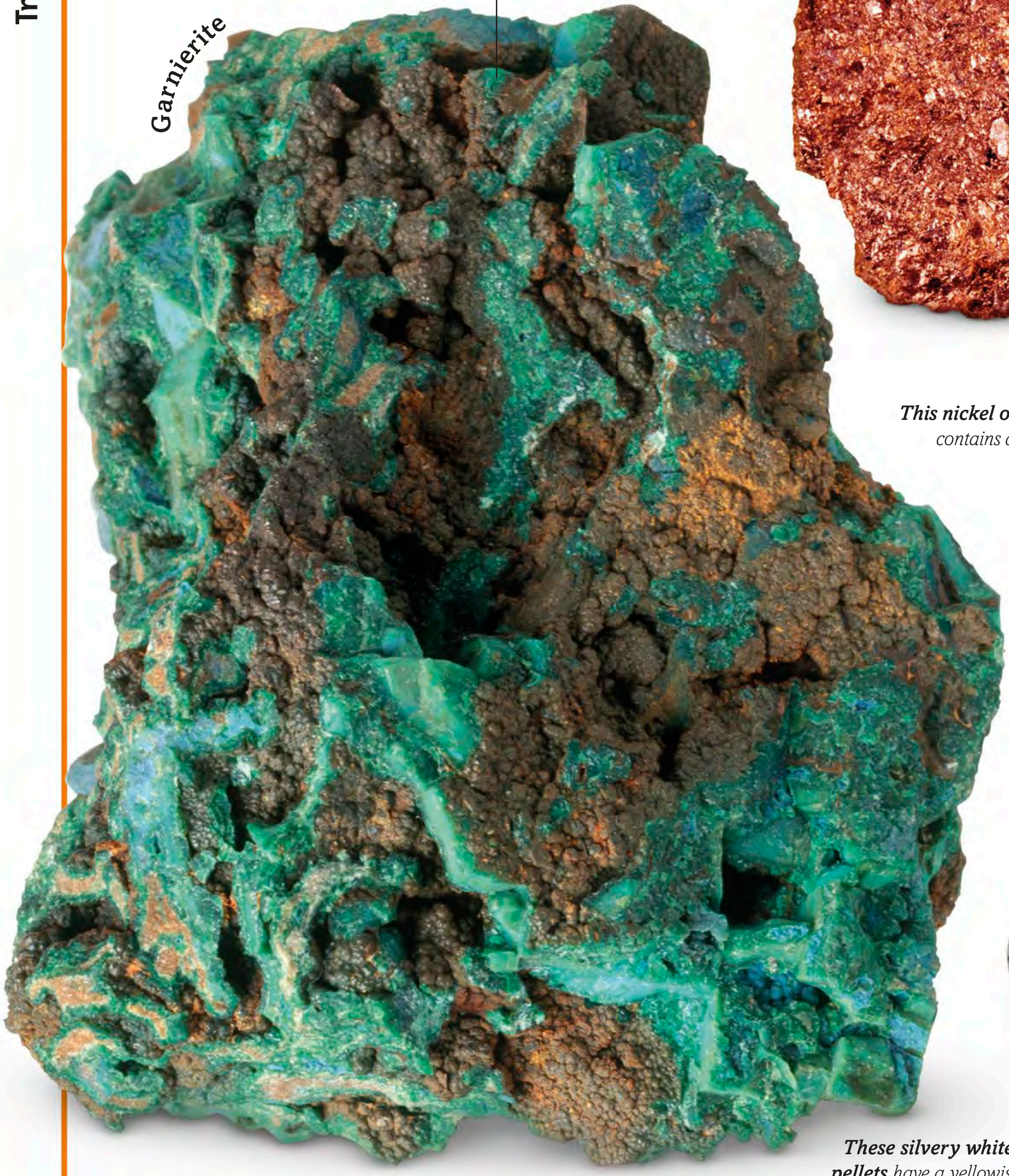

This green colour *comes from the presence of nickel.*

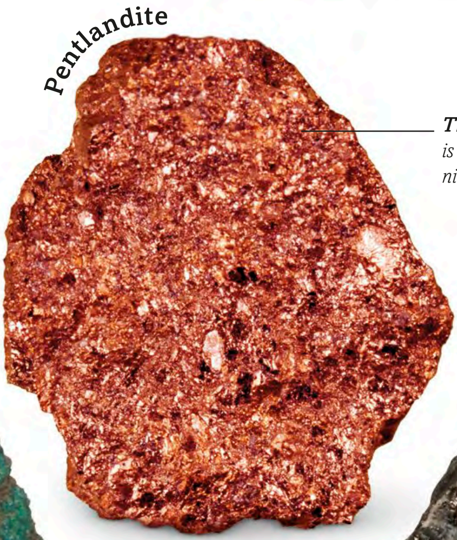

This reddish mineral *is made of iron and nickel sulfide.*

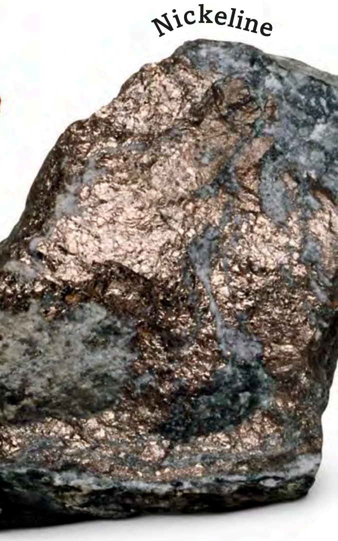

This nickel ore *also contains arsenic.*

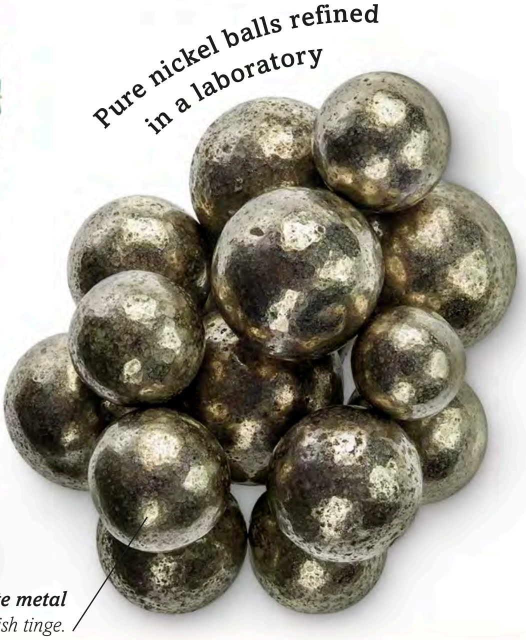

These silvery white metal pellets *have a yellowish tinge.*

Nickel is named after Old Nick, a demonic spirit from Christian lore that was believed to live underground. In the 18th century, German miners mistook a poisonous nickel mineral, now known as **nickeline**, for a copper ore. When this mineral failed to yield copper, they named it *Kupfernickel*, meaning "Old Nick's copper". Nickel is also found in other ores, such as **garnierite** and **pentlandite**. This element is one of the most useful metals, with a number of applications. Because **pure nickel** does not rust, it is used to coat objects to make

Uses

Nickel goblet drum

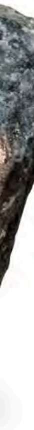

This nickel-plated *instrument has a shiny finish.*

Rust-resistant handle

Nickel-plated dagger

Nickel-based coin

The US five cent coin *is made of an alloy of 75% copper and 25% nickel.*

Nickel-copper alloy plating *makes propellers strong and durable.*

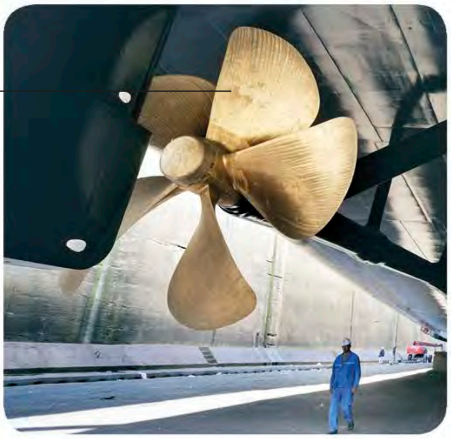

Ship propeller

Electric guitar

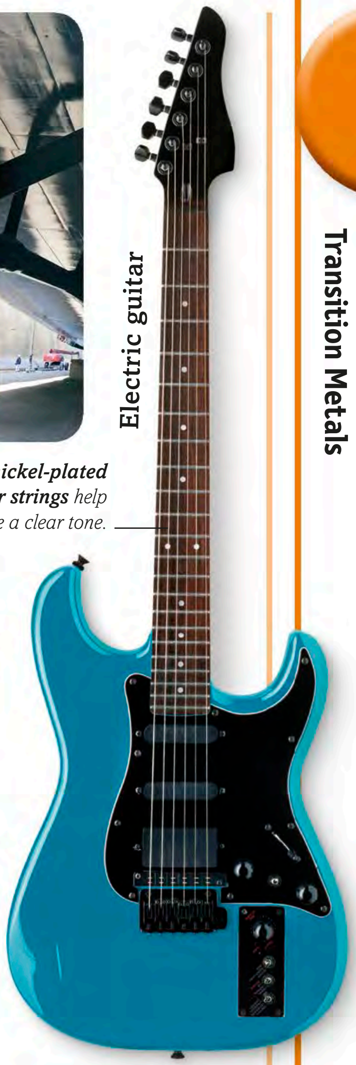

These nickel-plated guitar strings *help create a clear tone.*

This **coin** from the **USA**, made of a nickel-copper alloy, is called a **nickel**.

This silver-coated fork *is made of an alloy of nickel, copper, and zinc.*

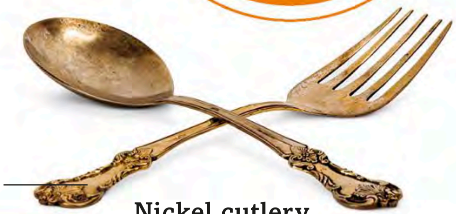

Nickel cutlery

Toaster

Nickel alloy wires *heat up to make toast.*

PERMANENT MAGNETS

A temporary magnet works when it is put in a magnetic field, but a permanent magnet retains its charge even when it is taken out of that field. Nickel is one of only a few elements that can be used to make permanent magnets.

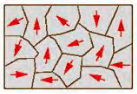

***1**. Atoms in a piece of nickel metal are arranged randomly.*

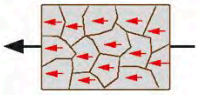

***2**. When a magnetic field is applied, the atoms align in one direction.*

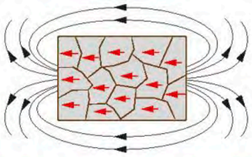

***3**. The atoms then stay aligned and produce a magnetic field of their own, even after the external field is removed.*

them look like silver – a trick still used to make inexpensive ornamental objects. Nickel is also mixed with copper to make an alloy called cupronickel. This is used as plating on **propellers** and other metallic parts of ships, as the alloy does not corrode in seawater. The same alloy is used in most of the world's silver-coloured **coins**. Nickel is used in the strings of **electric guitars**. This element is added to chromium to make an alloy called nichrome. Wires made of this alloy conduct heat very well, so are used in **toasters**.

29
Cu

Copper

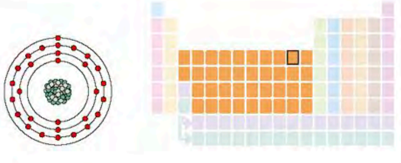

29 29 35

State: Solid
Discovery: Prehistoric

Forms

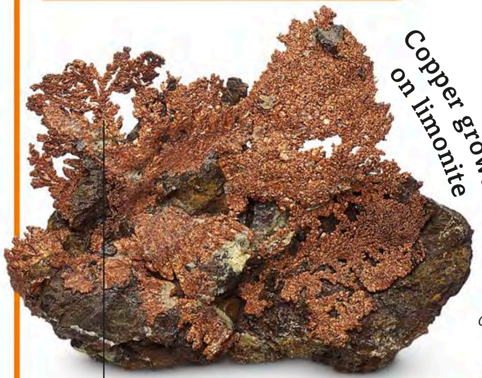

Copper growth on limonite

***Branchlike crystals** of copper*

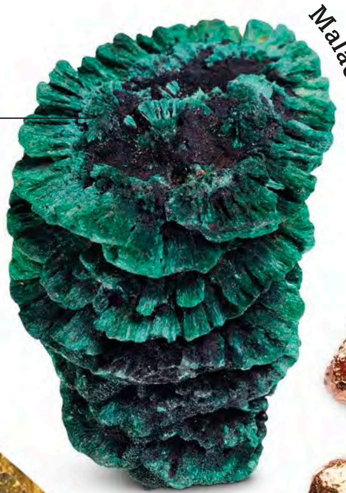

Malachite

***In caves, feather-like crystals** are often formed.*

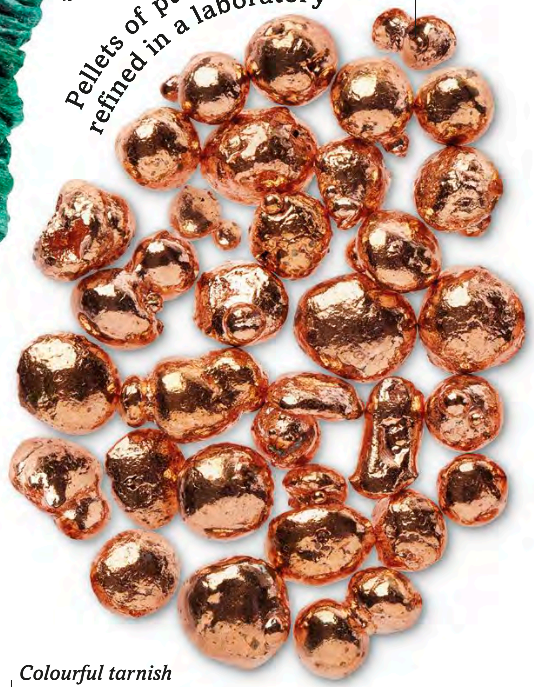

Pellets of pure copper refined in a laboratory

Unique reddish orange colour

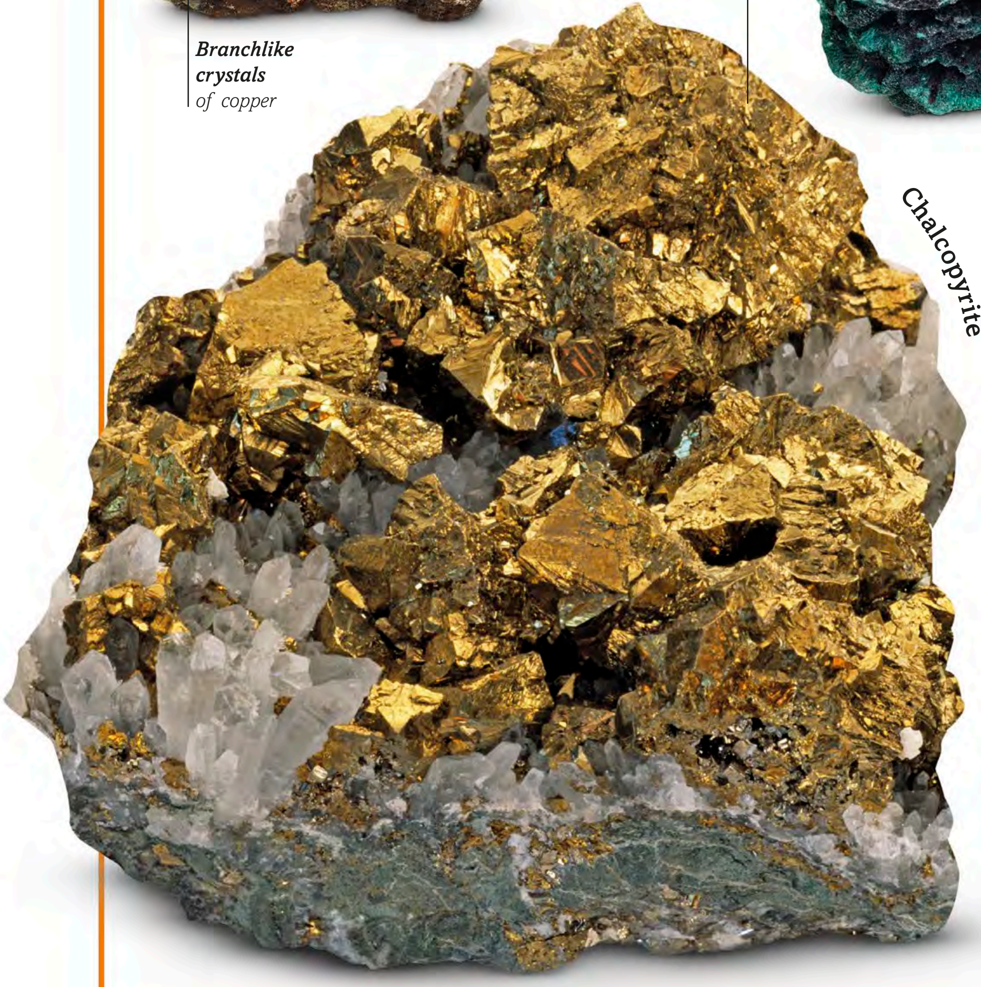

Chalcopyrite

***These golden yellow crystals** contain copper sulfide.*

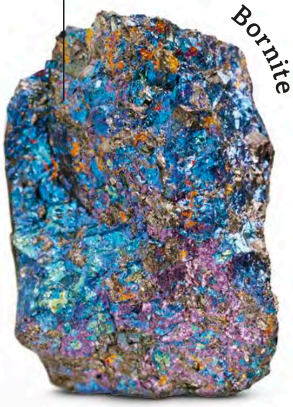

Bornite

***Colourful tarnish** develops when the mineral reacts with air.*

Crustacean blood

***Crustacean blood is blue** because it contains copper.*

Copper is a soft, bendy metal that is an excellent conductor of electricity and heat. Although it is one of the few elements found pure in nature, most of it exists in ores such as **chalcopyrite**. Other copper minerals, such as **malachite** and azurite, are brightly coloured.

Copper is the only metal that has a reddish colour in its pure form. **Pure copper** is mainly used as **wires** in electrical equipment. Copper wire wrapped around an iron core and then electrified helps create an **electromagnet**. Because they can be switched on or off, electromagnets can

Uses

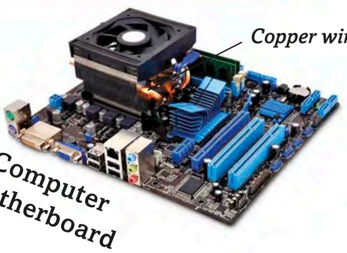

Copper wire

Computer motherboard

Giant electromagnet

Massive crane-mounted electromagnets *contain huge coils of copper wire.*

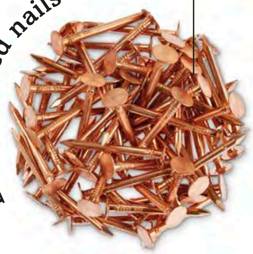

Electroplated nails

Copper coating on steel *slows down corrosion.*

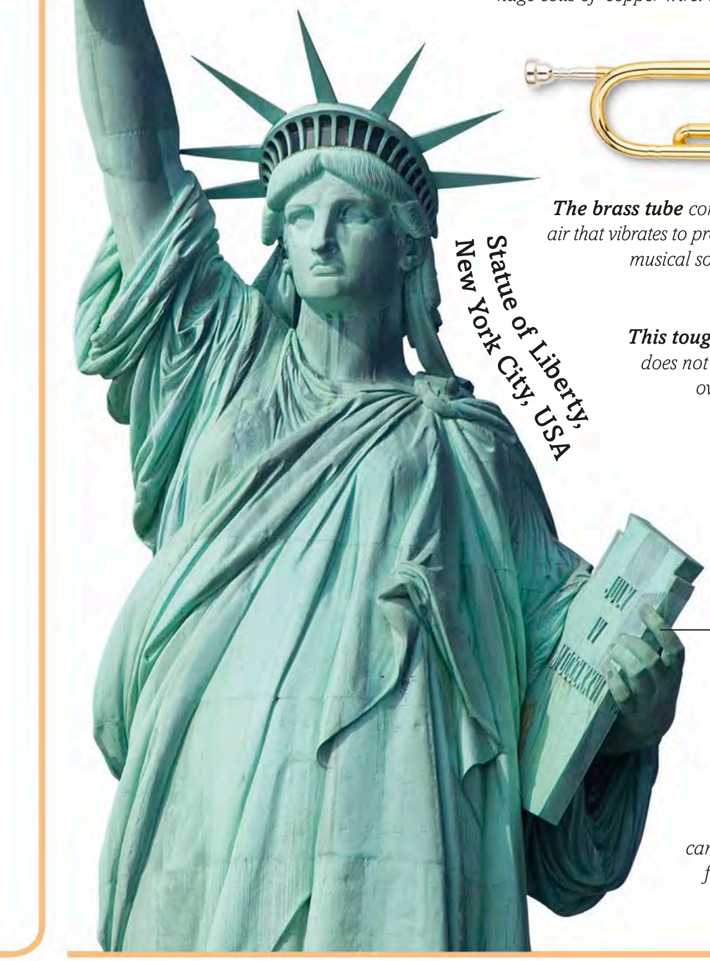

Statue of Liberty, New York City, USA

A verdigris layer *protects pure copper from additional weathering.*

ELECTROPLATING

A thin layer of copper can be added to metal, usually iron, to stop it from corroding easily. This process is called electroplating.

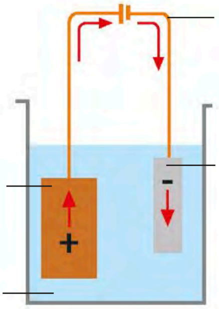

Electrons flow from the positive to the negative electrode.

This positive electrode is made of copper and slowly dissolves in the liquid.

This electrode is made of iron. Copper ions form a protective coating over the metal.

This solution contains dissolved copper ions.

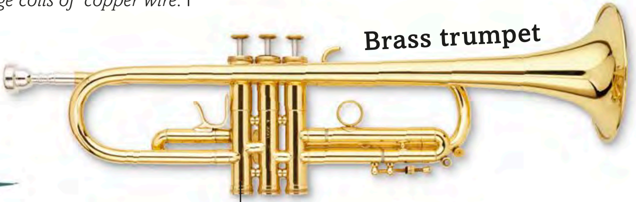

Brass trumpet

The brass tube *contains air that vibrates to produce musical sounds.*

Copper-glazed vase

A copper glaze *on the vase gives it a metallic shine.*

Bronze helmet

This tough alloy *does not weaken over time.*

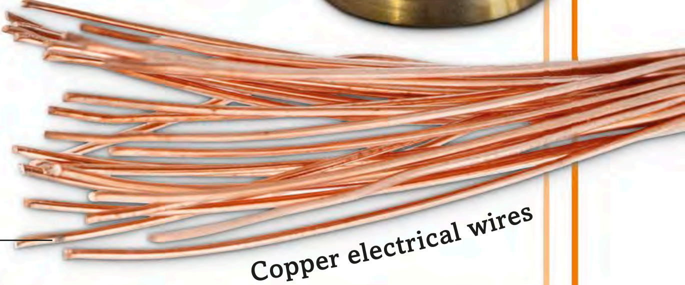

Copper electrical wires

Pure copper *can be stretched to form long wires.*

be magnetic as and when they are needed. They can be much more powerful than normal magnets and can lift heavy objects. Pure copper does not rust, but it reacts with air over time to form a layer of grey-green copper carbonate called verdigris. This can be seen on copper statues, such as the **Statue of Liberty**. Copper is often mixed with other metals to produce tougher alloys. Bronze, a copper-tin alloy, is more durable than pure copper and has been used since ancient times. Brass, a copper-zinc alloy, is used in musical instruments, such as **trumpets**.

COPPER WIRES Not much thicker than a human hair, these copper wires are twisted together and woven into a tight bundle. One of the main uses for these wires is to shield a thicker copper wire that transmits a signal to a television. As the signal carries pictures and sounds in the form of electrical currents, the wires wrapped around it prevent interference from other electrical sources nearby.

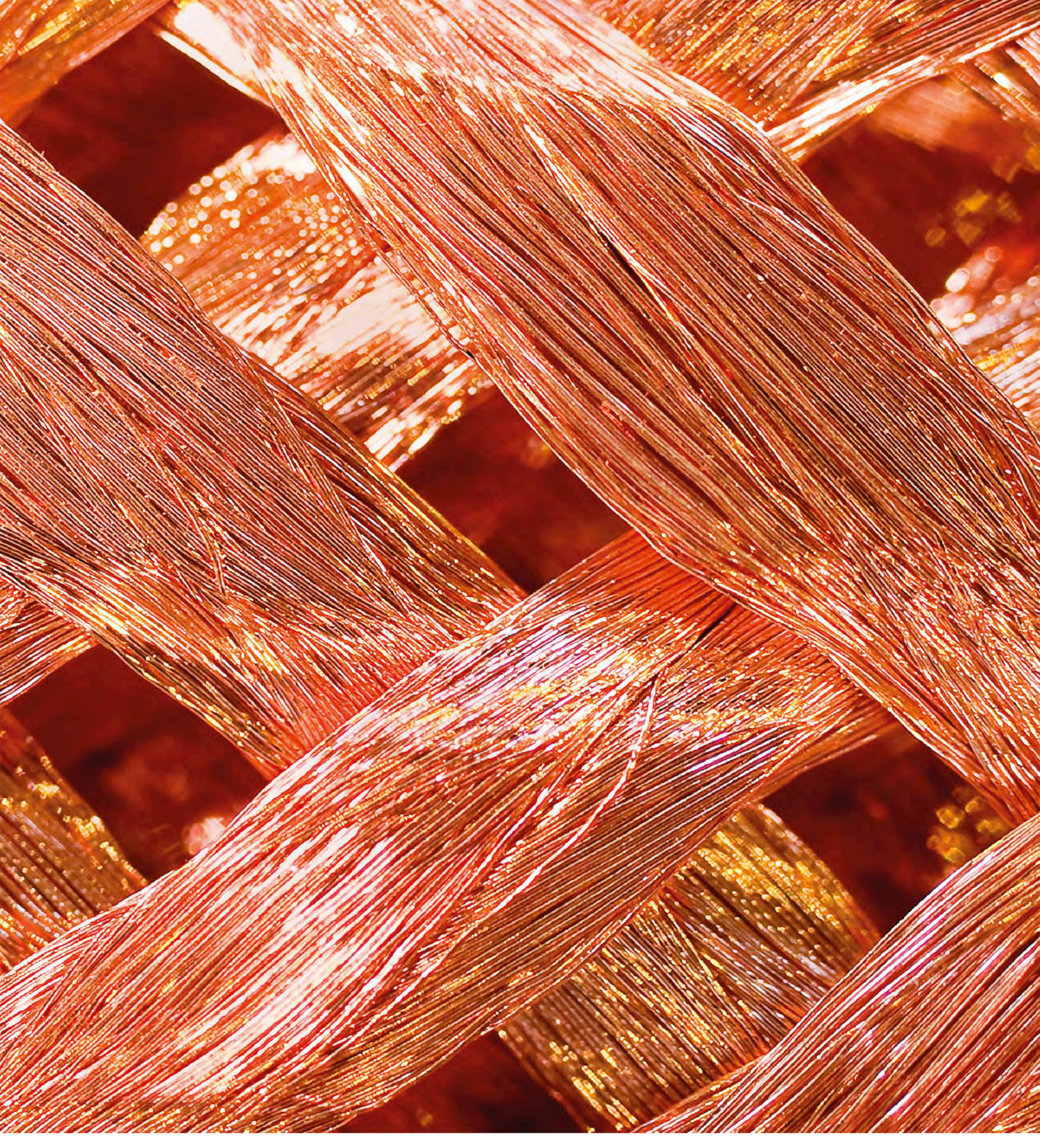

Copper is a very good conductor of electricity, but not the best; silver is better. However, copper is more widely used because it is much cheaper to find and purify. Each year, about 15 million tonnes of pure copper is produced, and more than half of it is used to make electrical components, such as this mesh. Today, more than a billion kilometres of copper wiring is running unseen in power supplies, buildings, and electronics. Copper is now the most common electrical metal, but it has a long history. It was the first element to be refined from ores in large amounts about 7,000 years ago in the region that is now Iraq. Today, Bingham Canyon in Utah, USA, is the world's largest copper mine.

30 Zn Zinc

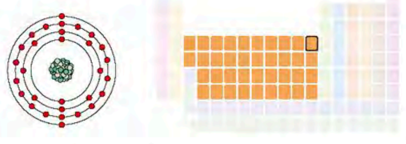

● 30 ⊕ 30 ○ 35

State: Solid
Discovery: 1746

Forms

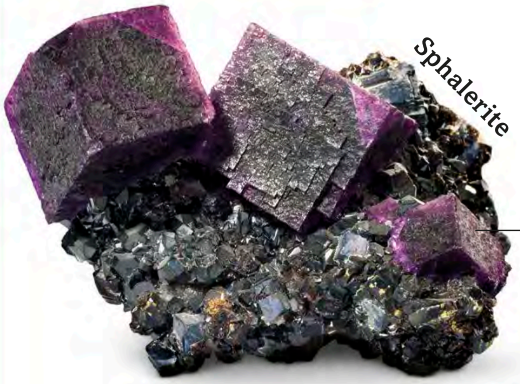

Sphalerite

This ore *is the main source of zinc.*

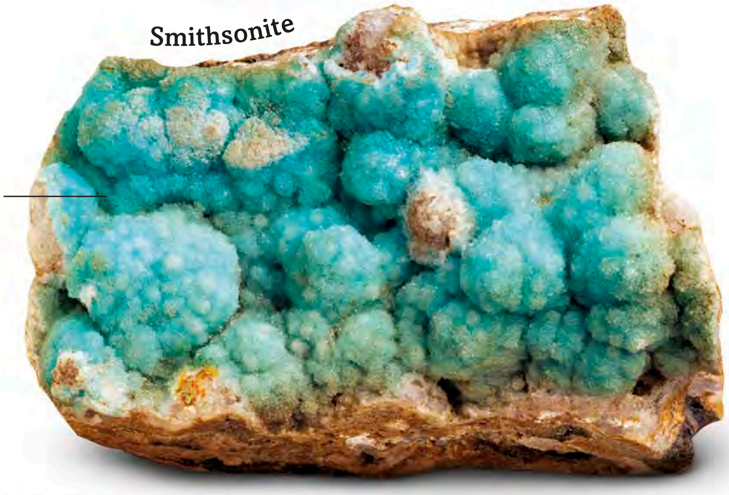

Smithsonite

This zinc mineral *forms rough nodules inside cracks.*

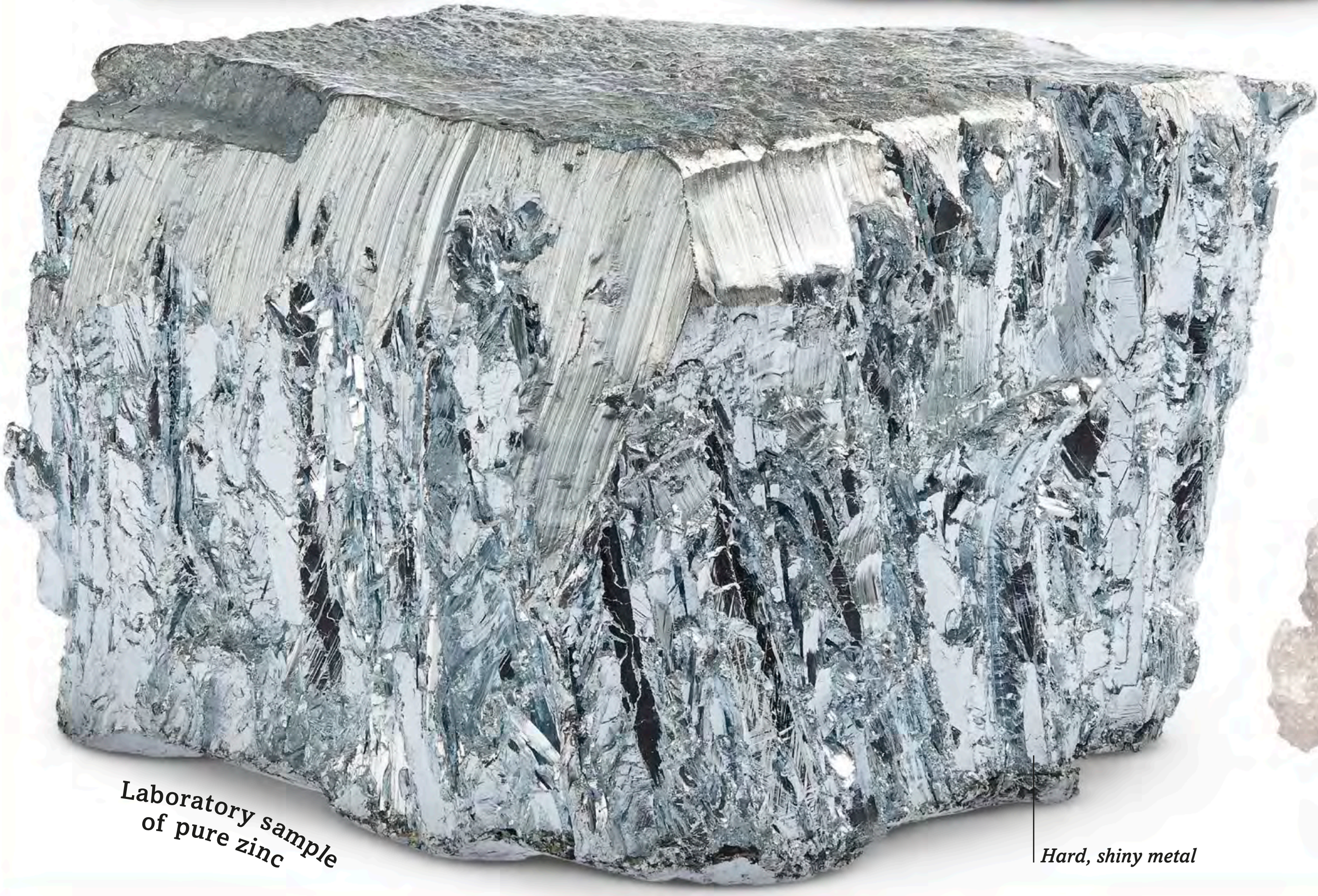

Laboratory sample of pure zinc

Hard, shiny metal

Zinc was used in India and China hundreds of years before the German chemist Andreas Marggraf identified it as a new element in the 18th century. This element is a rare transition metal that is never pure in nature, but is found in many minerals.

The mineral **sphalerite**, containing zinc sulfide, is the major source of **pure zinc**. Another principal mineral, **hemimorphite**, contains zinc and silicon. Zinc is essential in our diet. We consume it from food such as cheese and sunflower seeds. Zinc compounds have a wide

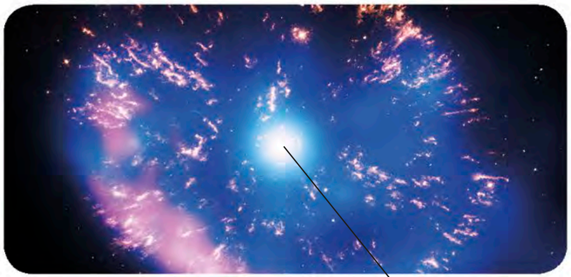

Supernova

Along with many other elements, zinc atoms *are formed inside supernovae (exploding giant stars).*

Hemimorphite

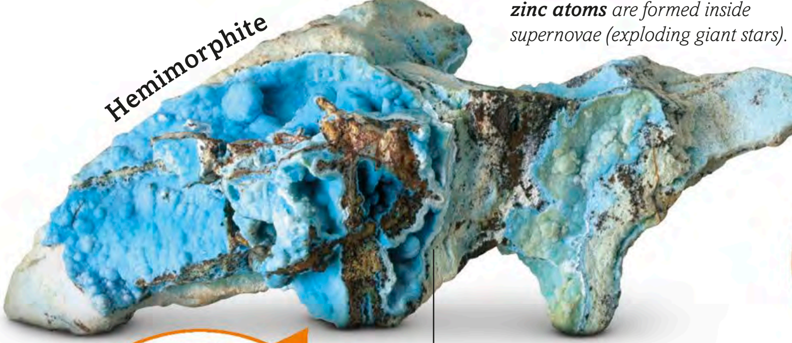

This mineral *contains zinc carbonate.*

Hemimorphite was discovered by James Smithson, the founder of the **Smithsonian** Institution.

Zinc oxide crystals *are generally colourless.*

Zincite

Uses

First-aid tape

Medical tapes *that contain zinc oxide stop wounds from getting infected with microbes.*

The zinc coating *on this steel bridge protects it from rust.*

Akashi Kaikyo Bridge, Kobe, Japan

American penny

This zinc coin *is coated with copper.*

Rubber boots

This flexible rubber *is made stronger by adding zinc oxide.*

Calamine lotion

This soothing skin lotion *contains a mixture of zinc compounds.*

GALVANIZED STEEL

Steel is protected from corrosion by coating it with zinc. Alloys of iron and zinc form in layers between the steel and pure zinc. This process is called galvanization.

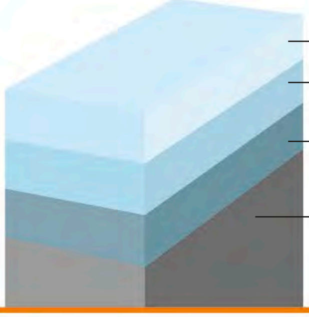

Pure zinc

94% zinc and 6% iron

90% zinc and 10% iron

Steel is an alloy of iron and carbon.

range of applications. For example, a compound of zinc and oxygen called zinc oxide is used in **medical tape** and sunscreen. Zinc oxide can also be used to toughen the rubber used in **boots** and tyres. A compound of zinc and sulfur called zinc sulfide is used to make some paints that glow in the dark. When pure zinc is exposed to air, the metal reacts with oxygen to form a protective layer of an oxide. This coating can prevent objects covered in zinc, such as **bridges**, from corroding easily.

39
Y

Yttrium

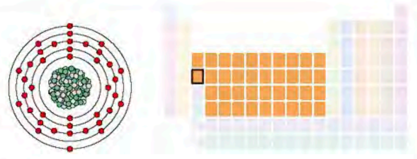

⊖ 39 ⊕ 39 ○ 50

State: Solid
Discovery: 1794

Forms

Xenotime

This mineral *contains trace amounts of uranium, which is radioactive.*

Yttrium is **400 times more common** in Earth's crust than silver.

Moon rock

This rock sample *was brought to Earth by NASA's Apollo 16 mission.*

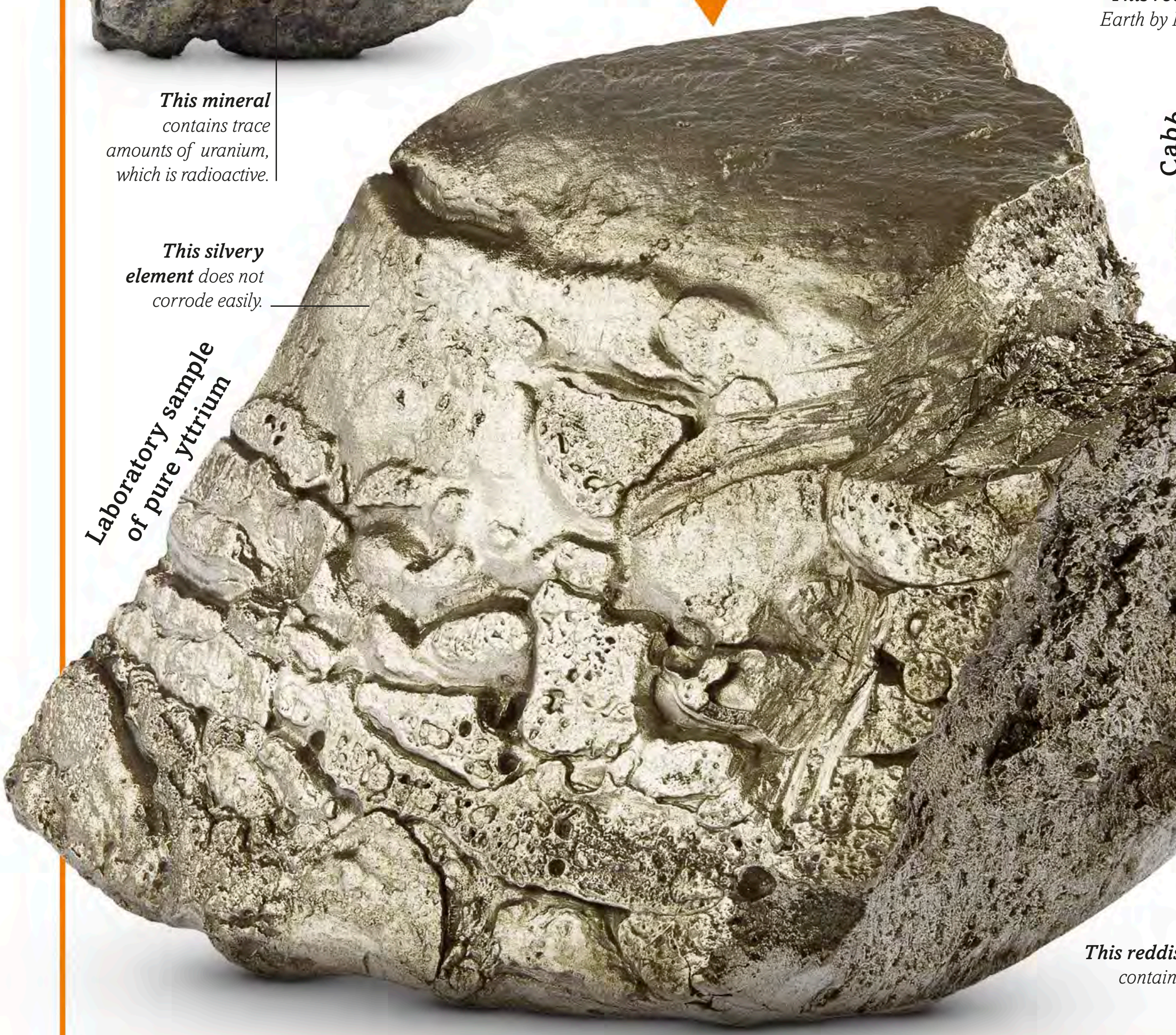

Laboratory sample of pure yttrium

This silvery element *does not corrode easily.*

Cabbage

This vegetable *contains yttrium.*

Monazite

This reddish-brown mineral *contains about 2% yttrium.*

The samples of rock brought back from the Moon by astronauts in NASA's Apollo missions contained higher levels of yttrium than rocks on Earth. This element is never found in pure form in nature, but small traces of it are present in many minerals, including **xenotime** and **monazite**. Yttrium was discovered in a compound in 1794 by the Finnish chemist Johan Gadolin, but it wasn't isolated until 1828. Other yttrium compounds have since been found in vegetables, including **cabbage**, and in seeds of woody plants. In

Uses

LED lamp

This bulb *contains yttrium compounds that enable it to produce a warmer, more yellow glow.*

Laser

This laser *is powered using crystals composed of yttrium and silicon, and can cut through metal.*

Yttrium-90

This radioactive form of yttrium *is used to treat cancers in the body.*

Yttrium gas mantle

This fabric mantle *holds the hot flame inside.*

Digital camera lens

Shock-proof lenses *are made from yttrium-infused glass to make them tough.*

NASA spacecraft use yttrium lasers to map the **surface of asteroids** in space.

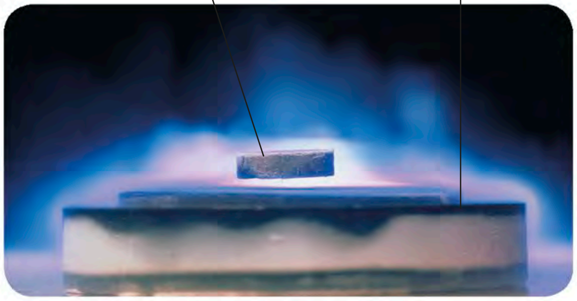

A small magnet *floats over the superconductor.*

This superconductor *produces a magnetic field that repels the magnet above it.*

Yttrium superconductor

FRIEDRICH WÖHLER

In 1828, the German chemist Friedrich Wöhler became the first person to purify yttrium. He did so by extracting it from the compound yttrium chloride. He was also the first person to extract the metals beryllium and titanium from their ores.

LED lamps, yttrium converts blue light to other colours. Many **lasers** use an artificial mixture of yttrium and aluminium inside a silicon-rich crystal called garnet. Powerful yttrium lasers are used for treating some skin infections, as well as by dentists during tooth surgery. A radioactive form of this element has medical applications. Yttrium is added to the glass in a **camera lens** to make it tough. Yttrium compounds are also used in **superconductors** – materials that conduct electricity easily when cooled to very low temperatures.

40
Zr

Zirconium

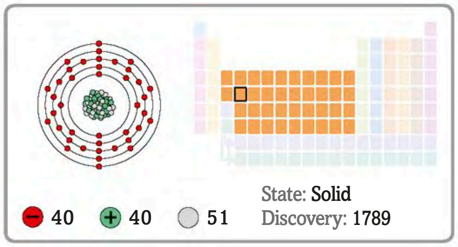

State: Solid
Discovery: 1789

Forms

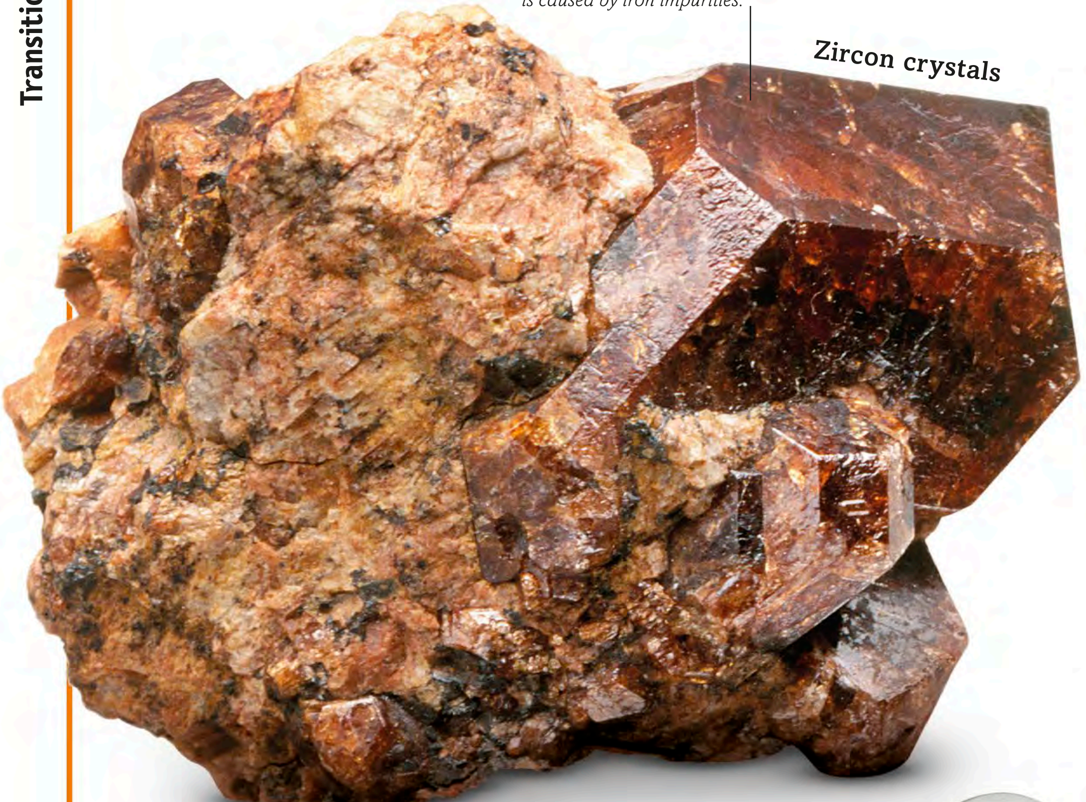

Zircon crystals

This dark brown colour *is caused by iron impurities.*

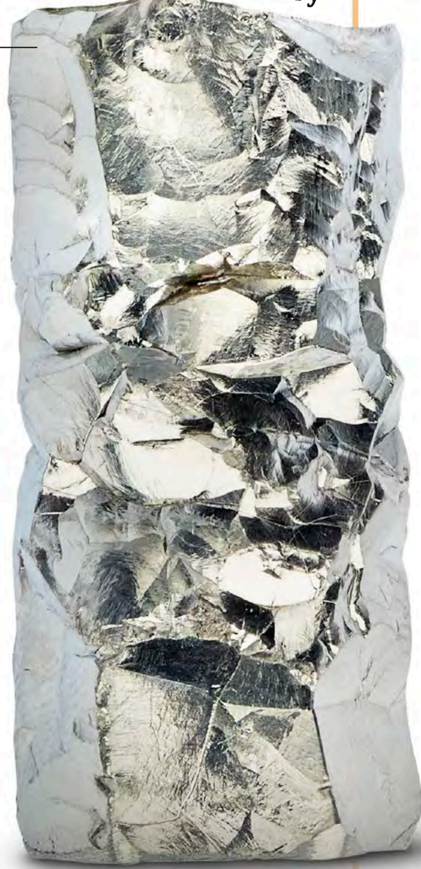

Bar of pure zirconium refined in a laboratory

This greyish-white pure element *is easy to shape.*

Uses

Dental crowns

These tough ***dental crowns*** *are made of a zirconium-rich ceramic.*

Ceramic knife

This hard, non-metallic blade *does not require frequent sharpening.*

Camera flash from the 1960s

This zirconium-filled bulb *produces a bright light.*

Zirconia crystal ring

This ring *contains cubic zirconia crystals.*

This element is named after the mineral zircon, which means "golden" in Persian, a reference to the golden-brown colour of its crystals. The Swedish chemist Jacob Berzelius was the first person to isolate **pure zirconium**, in 1824. Today, however, the element is mostly used in the form of the compound zirconium dioxide, or zirconia. Powdered zirconia is heated to produce a hard glass-like ceramic, which is used to create **dental crowns** and sharp **ceramic knives**. Powdered zirconia also forms sparkling **zirconia crystals** that look like diamonds.

41 Nb Niobium

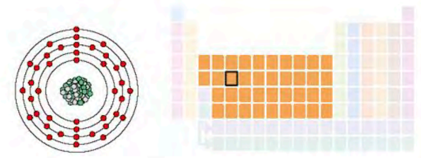

⊖ 41 ⊕ 41 ○ 52

State: Solid
Discovery: 1801

Forms

Columbite

This dark, dense ore *has a light metallic shine.*

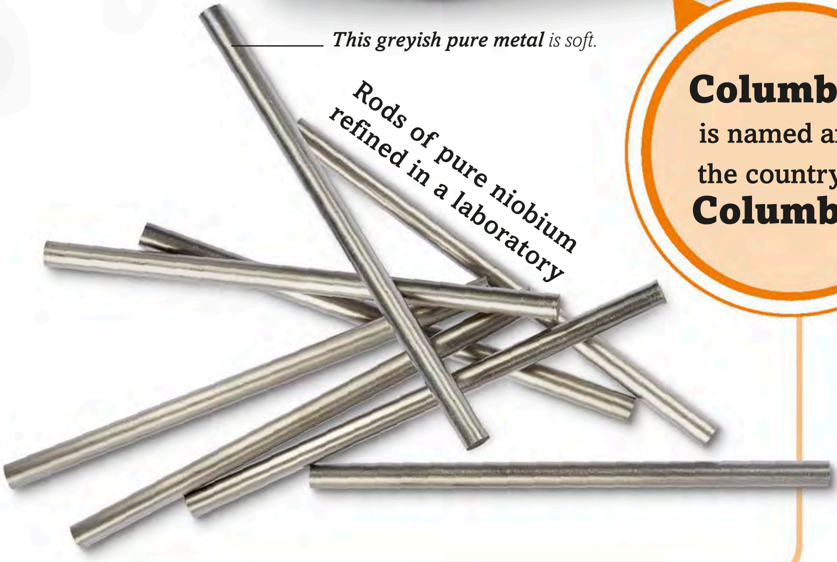

Rods of pure niobium refined in a laboratory

This greyish pure metal *is soft.*

Uses

Pacemaker

The niobium case *houses a battery that regulates the beating of a human heart.*

Command Module from the Apollo 15 mission

This nozzle *made of a niobium alloy kept its shape even when very hot.*

Spectacle lenses

This pair of spectacles *has thin, powerful lenses made of a niobium compound.*

Columbite is named after the country of **Columbia**.

Niobium is so similar to the metal tantalum that the two were wrongly thought to be the same element for almost 40 years. The mineral **columbite** is the main source of this shiny metal. Niobium is not found naturally in its **pure form**. When extracted, it has many uses. As the element does not react adversely in the human body, it is used in implants, such as **pacemakers**. Niobium also does not expand when hot, so it is used to make parts of rockets, such as the one on the **Command Module** from NASA's Apollo 15 spacecraft that went to the Moon in 1971.

42
Mo

Molybdenum

Forms

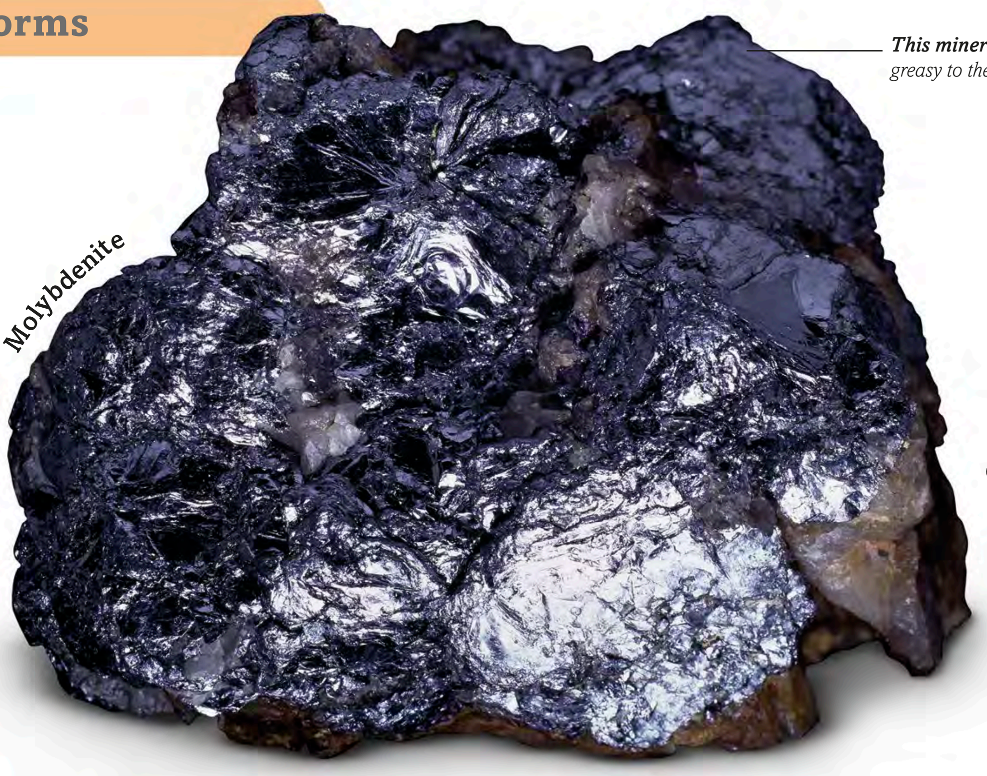
Molybdenite

This mineral feels greasy to the touch.

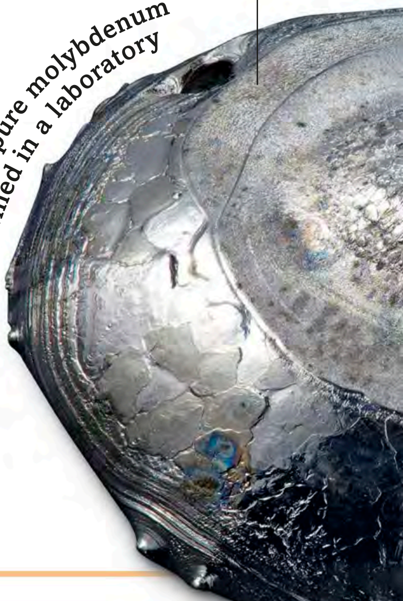
Chunk of pure molybdenum refined in a laboratory

This metal's pure form *is silver-grey and has a very high melting point: 2,623°C (4,753°F).*

Uses

Lubricant

This slippery lubricant*, which contains finely powdered molybdenite mixed with oil, protects fast-moving mechanical parts in engines.*

Chrome-Moly steel bike

This lightweight but stiff frame *is made from a steel containing molybdenum and chromium.*

Ratchet set

These closely fitting parts *are hard so they do not get damaged easily.*

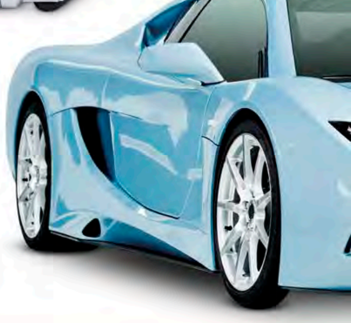

Molybdenum gets its unusual name from the Greek word *molybdos*, which means "lead". Miners once mistook **molybdenite**, a dark mineral containing this metal, for an ore of lead. This element is much harder than lead, so it is easy to distinguish between these two elements when they are pure. Molybdenite is soft and slippery, and it is the main molybdenum ore. **Pure molybdenum** is mainly used to make alloys that are resistant to corrosion. These are lightweight so are ideal for constructing **bike frames**, but

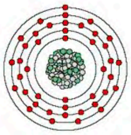

⊖ 42 ⊕ 42 ○ 54

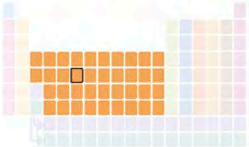

State: Solid
Discovery: 1781

This experimental sports car is built with a rust-resistant alloy that contains molybdenum.

Vencer Sarthe
vencer

are hard enough for making sturdy tools, too. Molybdenum alloys are used in the latest designs of supercars, such as the **Vencer Sarthe**.

43 Tc Technetium

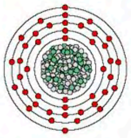

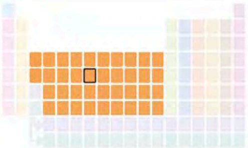

⊖ 43 ⊕ 43 ○ 55

State: Solid
Discovery: 1937

This pure form of the metal is produced inside nuclear reactors.

Foil of pure technetium produced in a reactor

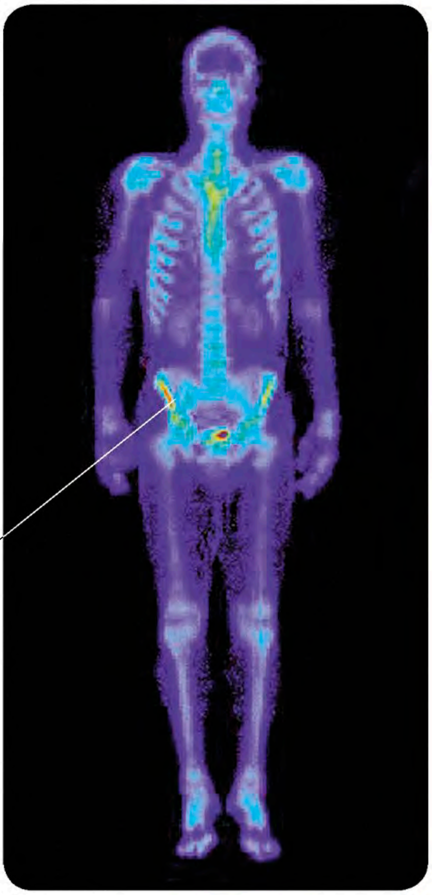

This body scan was created using the radioactive effects of technetium.

Technetium-based imaging

This box contains radioactive molybdenum, which breaks down into technetium.

Generating technetium

Technetium was the first element to be produced artificially by researchers. It is named after the Greek word for artificial, *tekhnetos*. Technetium does not exist in nature: any of its atoms that once existed on Earth broke down millions of years ago. Tiny amounts of this element were discovered in the waste produced by early nuclear reactors. Technetium is the lightest radioactive element. It is used extensively in **medical imaging**. It is injected into a patient's body, where it emits radiation for a short while. Some machines use this radiation to show bones clearly.

44

Ru

Ruthenium

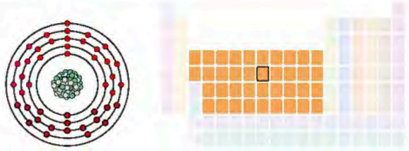

⊖ 44 ⊕ 44 ○ 57

State: Solid
Discovery: 1844

Forms

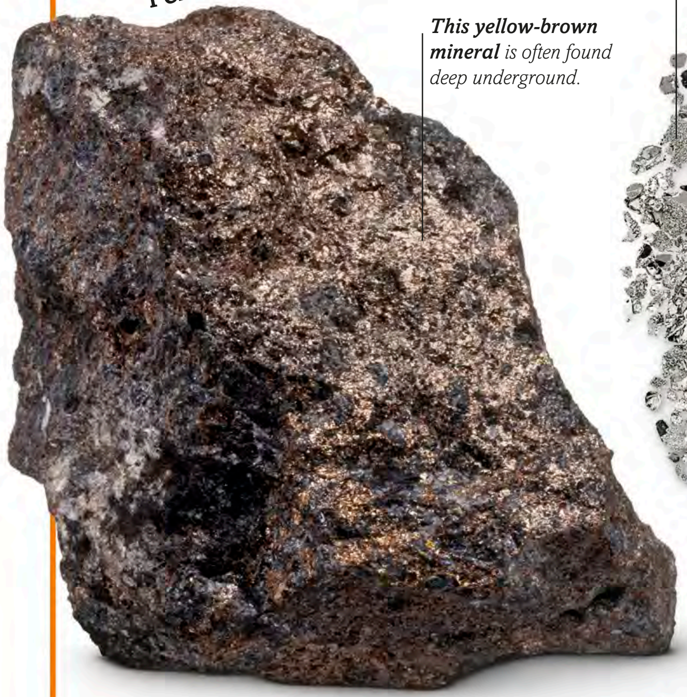

Pentlandite

This yellow-brown mineral is often found deep underground.

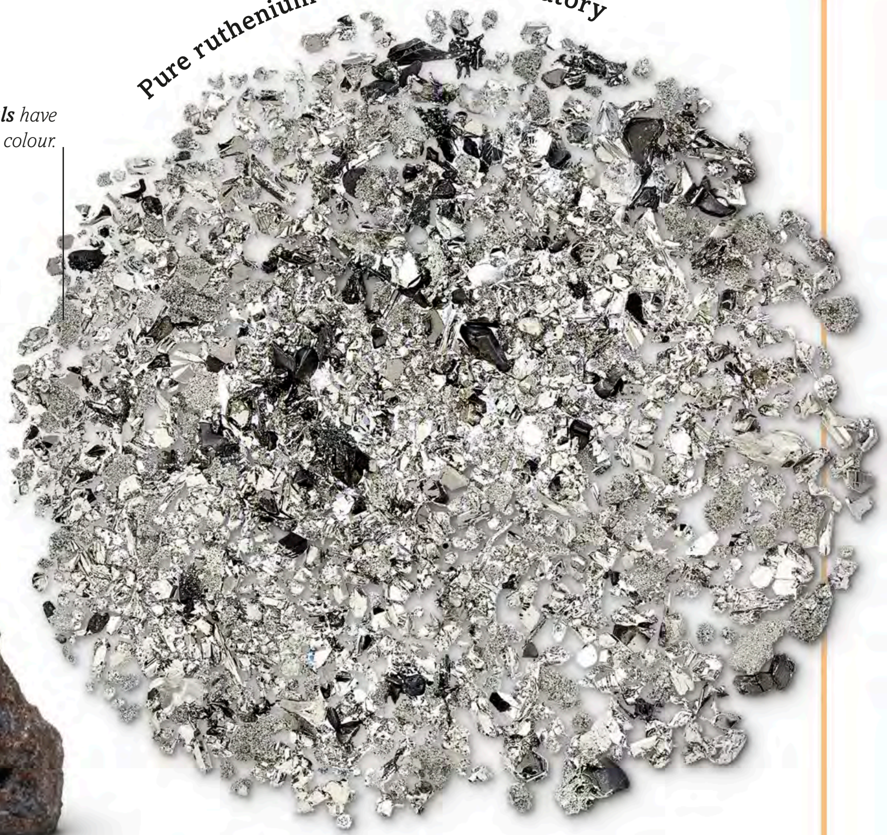

Pure ruthenium refined in a laboratory

These crystals have a bright, silver colour.

Uses

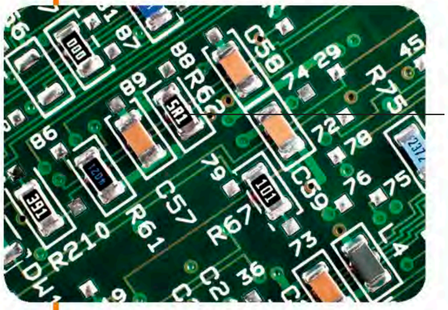

Electronic circuit board

This component contains ruthenium dioxide.

Toggle switch

The metal alloy in the switch is toughened by adding ruthenium.

SwissTech Convention Centre, Switzerland

These low-cost solar panels are made using ruthenium.

Ruthenium is named after *Ruthenia*, an old Latin name for Russia. This rare metal is found in the mineral **pentlandite**, and its **pure form** is commonly extracted from this ore. A compound called ruthenium dioxide is used in several components in **electronic circuits**, including resistors and microchips for computers and other digital devices. Adding a small amount of ruthenium makes softer metals, such as platinum and palladium, much tougher. Moving parts in devices such as **switches** benefit from this property.

45
Rh

Rhodium

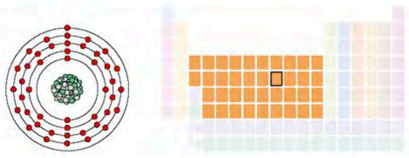

⊖ 45 ⊕ 45 ○ 58

State: Solid
Discovery: 1803

Forms

Pure rhodium pellet refined in a laboratory

***This metal** is shiny and silvery when pure.*

Millerite

***This golden mineral** is defined by its needle-shaped crystals.*

Uses

Rhodium-plated jewellery

***The rhodium plating** prevents jewellery from losing its shine.*

Headlight reflector

***This rhodium-alloy reflector** provides a bright light.*

Rhodium-plated microscope

***Parts of this microscope** are coated with rhodium and can resist corrosion.*

Fibreglass production

***These fibreglass strands** are made by passing molten glass through rhodium-enriched trays.*

The rosy red colour of one of its compounds inspired the name rhodium. The Greek word *rhodon* means "rose-coloured". Rhodium is unreactive and does not form compounds easily. It is a rare metal. Most of the **pure form** is extracted when platinum is mined. Pure rhodium is hard and is used to toughen precious **jewellery**, mirrors, and optical devices, such as **microscopes**. It is mainly used in the production of catalytic convertors for cars. **Fibreglass**, which is often found in protective gear – like helmets – also contains rhodium.

46
Pd

Palladium

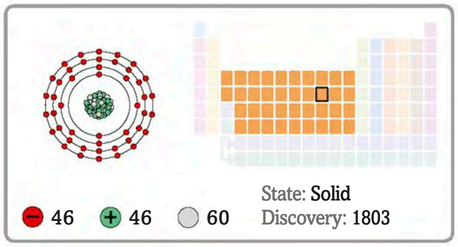

State: Solid
Discovery: 1803

Forms

The mines *in this area have a high concentration of palladium.*

Blue Ridge mines, South Africa

Palladium absorbs **hydrogen**, like a sponge soaking up water.

Pure form *can be produced by separating it from the ores of other metals, such as copper and nickel.*

Pure palladium pellet refined in a laboratory

Uses

The converter *gets hotter as more pollutants enter the exhaust.*

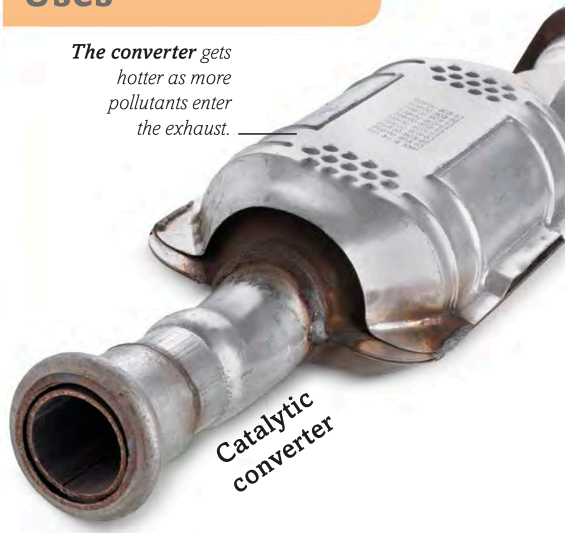

Catalytic converter

This device *uses palladium compounds that change colour when poisonous carbon monoxide is detected, which triggers an alarm.*

CARBON MONOXIDE ALARM
TEST/RESET
Power
Alarm

Carbon monoxide detector

This commemorative coin *is made from the palladium produced by the Stillwater Mining company in Montana, USA.*

STILLWATER PALLADIUM
LEWIS & CLARK CORPS OF DISCOVERY
2004

Palladium coin

Palladium is a rare, precious metal: it is 10 times rarer than silver and twice as rare as gold. Like these metals, palladium has a shiny surface and does not corrode easily. Palladium is found **pure** in nature, but it also has a few rare minerals, such as braggite. Of its many applications, the element's main use is in **catalytic converters**, which are devices used in vehicles to convert poisonous exhaust gases into less harmful ones. A compound called palladium chloride is used in **carbon monoxide detectors**. Because the element is

CATALYTIC CONVERTER

Many cars contain engines that are attached to catalytic convertors. These important devices convert toxic exhaust gases into less harmful pollutants. Palladium plays a key role in the process.

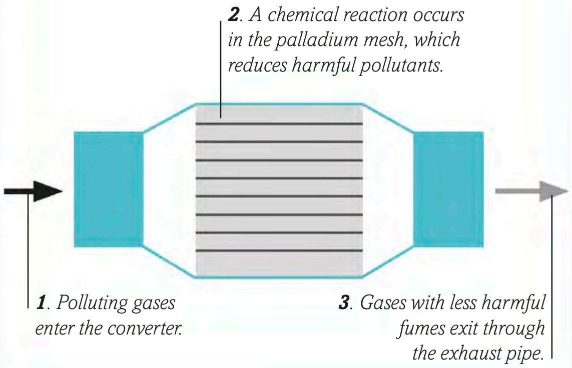
2. *A chemical reaction occurs in the palladium mesh, which reduces harmful pollutants.*
1. *Polluting gases enter the converter.*
3. *Gases with less harmful fumes exit through the exhaust pipe.*

White gold ring

Palladium is added to gold *to remove its colour.*

Fountain pen nib

This palladium nib *is decorated.*

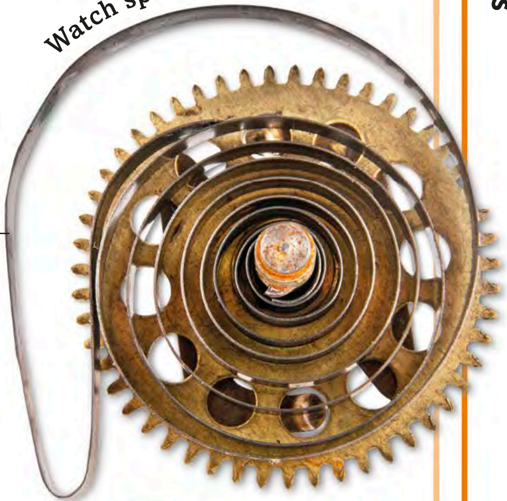

Watch spring

This tiny spring, *which keeps time in a watch, is made of palladium alloys.*

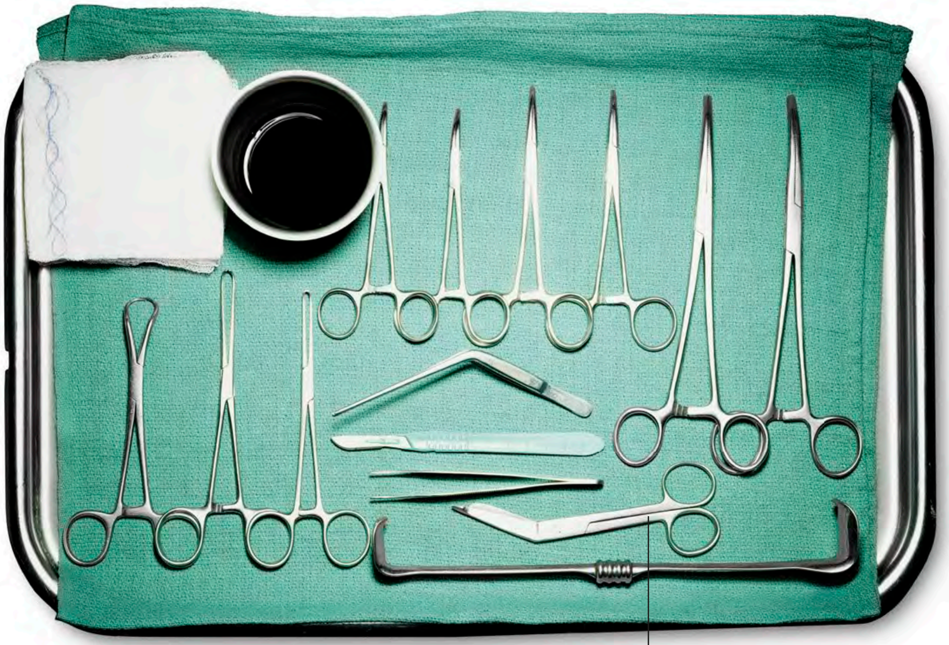

Surgical tools

These tools *are made of palladium alloys, which keep them sharp for a long time.*

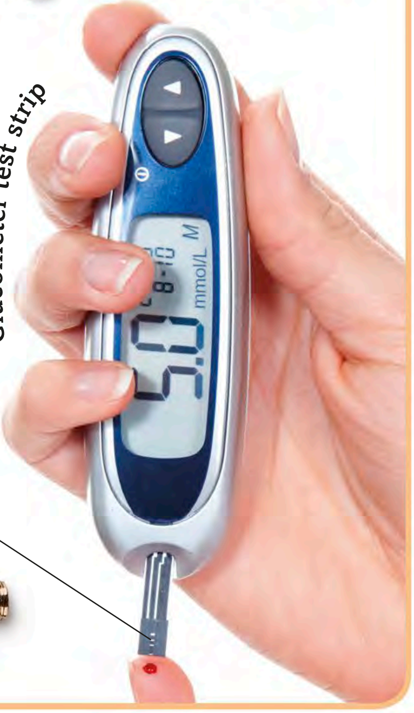

Glucometer test strip

This test strip *contains palladium, which contributes to a reaction that measures glucose in a drop of blood.*

This flute *contains palladium that enables it to resist corrosion.*

Orchestral flute

precious, it is used to make **commemorative coins** in some countries. Palladium is alloyed with steel to make it more resistant to corrosion. These alloys are used to make **surgical tools** and expensive musical instruments, such as some **flutes**. Palladium is often mixed with gold to form an alloy called white gold, which is used in jewellery. Some fountain pens have **nibs** decorated with palladium. The element is also used in **glucometer test strips** so that patients can check the level of glucose in their blood.

47 Ag Silver

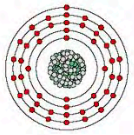

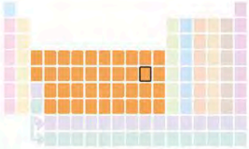

⊖ 47 ⊕ 47 ○ 61

State: Solid
Discovery: c. 3000 BCE

Forms

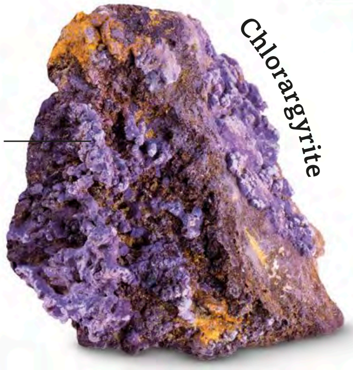

Chlorargyrite

This mineral's colour *changes to purple when it is exposed to bright light.*

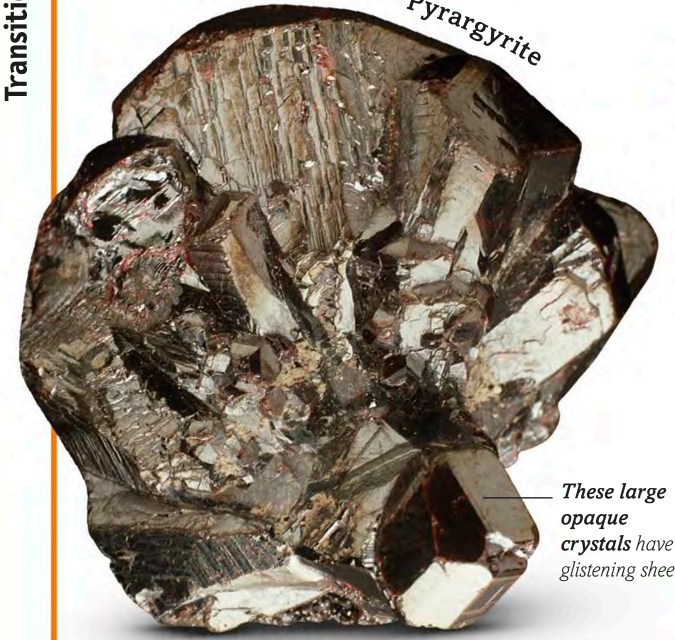

Pyrargyrite

These large opaque crystals *have a glistening sheen.*

1 g (0.03 oz) of silver can be drawn into a **2-km- (1.2-mile-) long** wire.

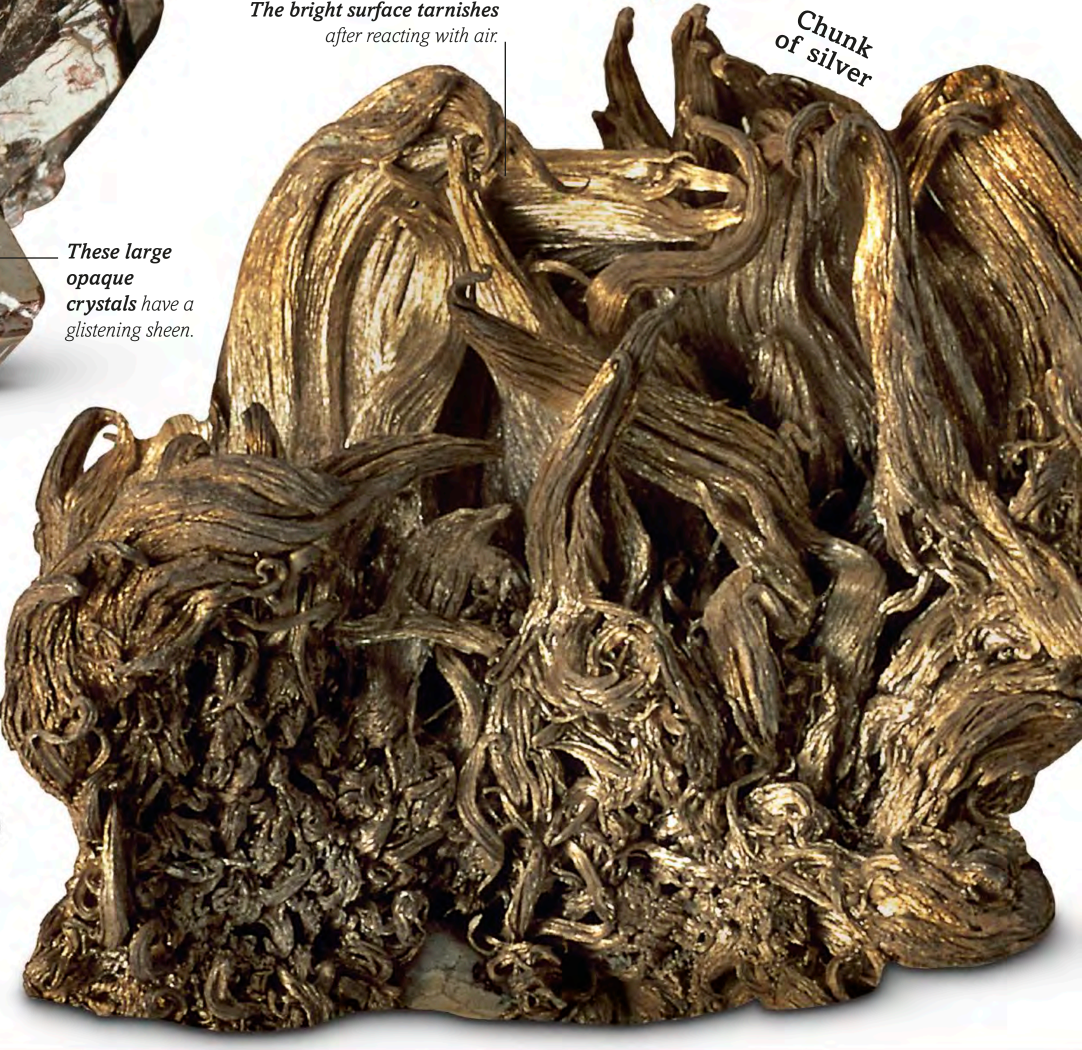

Chunk of silver

The bright surface tarnishes *after reacting with air.*

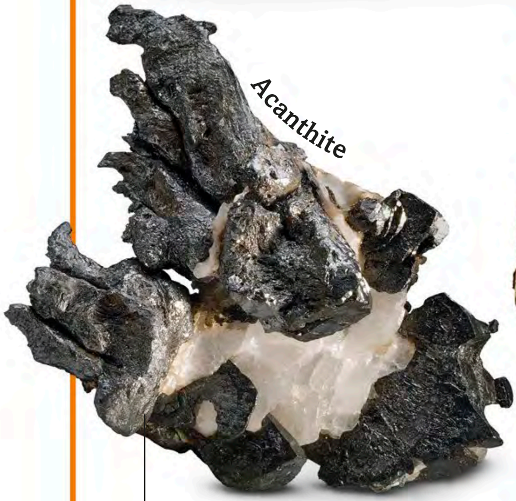

Acanthite

Black silver sulfide *forms twisted crystals.*

Silver gets its symbol "Ag" from its Latin name *argentum*, which means "shiny white". It is considered a precious metal because its pure form has a grey shine that does not corrode quickly, and it stays untarnished if cleaned regularly. Silver can be found pure in nature, but mostly it is mined from ores, such as **pyrargyrite** and **acanthite**. Because this element is valuable and can be moulded easily, pure silver was used historically to make **coins**. This metal is also ideal for making **bracelets** and settings for gems. Some people even use

Uses

MAKING CLOUDS

Rain is crucial to our Earth, especially for growing healthy crops. Where there are no clouds, scientists can form tiny water droplets that cling to silver iodide powder, forming artificial rain clouds.

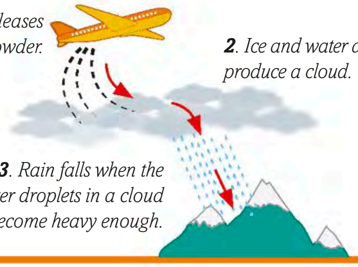

1. *Aircraft releases silver iodide powder.*

2. *Ice and water droplets produce a cloud.*

3. *Rain falls when the water droplets in a cloud become heavy enough.*

Silver coin

***Soft silver** is easily pressed into coins.*

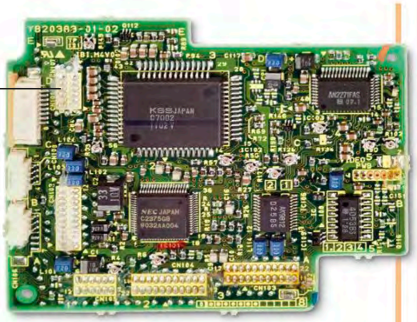

Circuit board

***Silver coating** is used on some circuit board parts.*

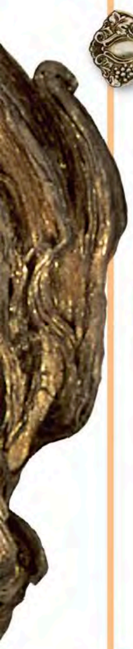

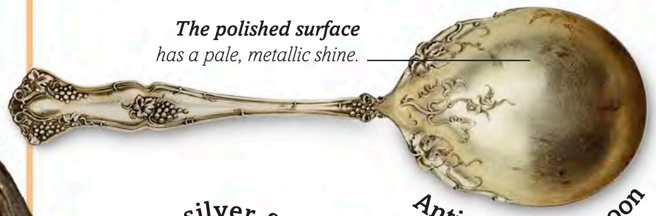

Antique silver spoon

***The polished surface** has a pale, metallic shine.*

Silver bracelet

***Pure silver** moulded and cut into varying shapes*

Edible silver foil

***These thin sheets of silver** called "vark" are edible.*

SILVER
NITRATE (V)
$AgNO_3$

Silver nitrate

***Silver nitrate** is mixed with water to clean cuts and scrapes.*

Photochromatic glasses

***Glass infused with silver chloride** turns brownish when exposed to sunlight.*

Photography plate

***An image forms** when silver bromide darkens quickly on exposure to light.*

flattened **silver foil** to decorate food. **Silver spoons** and forks were the only pieces of cutlery that did not create a nasty metallic flavour in the mouth in the days before the invention of stainless steel. Silver conducts electricity better than copper, and is used in some **circuit boards**. **Silver nitrate** (a compound of silver, nitrogen, and oxygen) is a mild disinfectant used in some anti-bacterial soaps. Silver forms light-sensitive compounds with chlorine (used in **sunglasses**) and bromine (used in old **photography plates**).

48
Cd

Cadmium

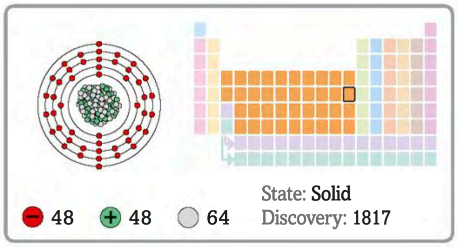

Forms

This mineral contains a rare form of cadmium sulfide, a compound of cadmium and sulfur.

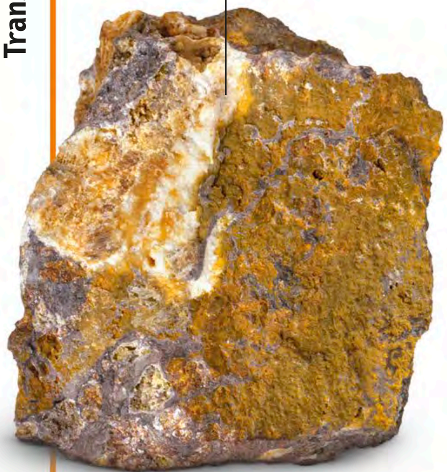

Greenockite

This soft metal has a bluish tinge.

Pellet of pure cadmium refined in a laboratory

The yellow colour of this zinc mineral is due to cadmium impurities.

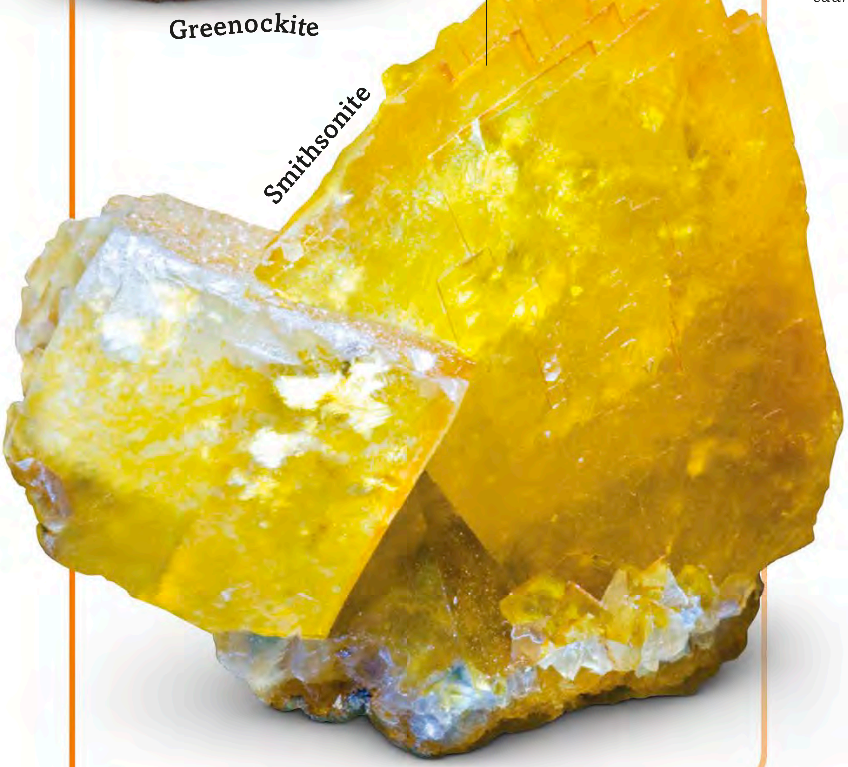

Smithsonite

Uses

Nickel-cadmium battery

Cadmium and nickel layers create electricity in this rechargeable battery.

This deep red pigment contains powdered cadmium oxide.

Red paint containing cadmium

This electronic component used in circuits contains a compound of cadmium and sulfur.

Light-sensitive resistor

Cadmium-covered screws do not rust.

Cadmium-plated screws

This research sample is being viewed under ultraviolet (UV) light produced by a cadmium laser.

Fluorescent microscope

Cadmium is a highly toxic metal, and is known to cause cancer. This rare element is found in the ore **greenockite**, but it is mostly obtained as a by-product of zinc extraction. **Cadmium** was discovered in 1817 from a mineral called calamine. Today, this metal is mainly used in conjunction with nickel in **rechargeable batteries**. The compound cadmium oxide was once used in preparing **red paints**, but not anymore because of its toxicity. Cadmium is also used to create lasers for use in powerful **microscopes**.

72

Hf

Hafnium

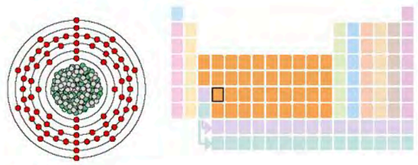

− 72 + 72 ○ 106

State: Solid
Discovery: 1923

Forms

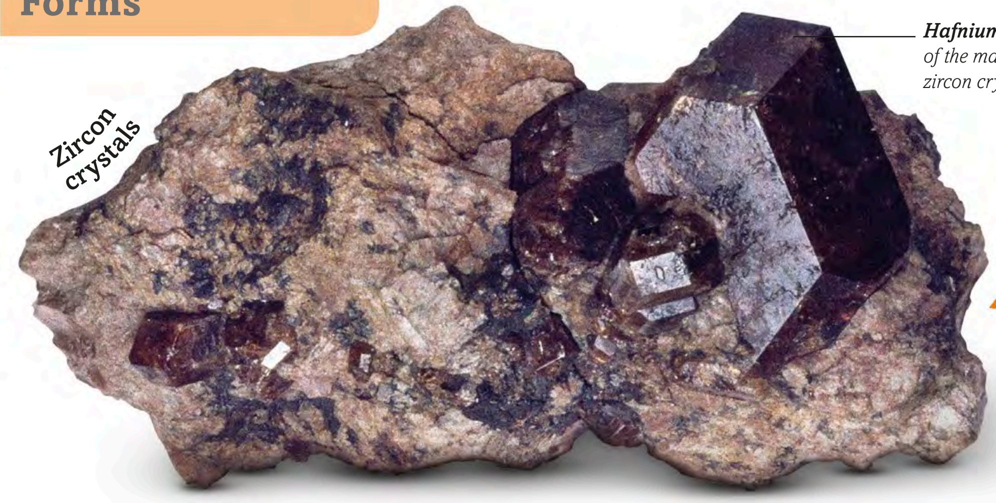

Hafnium *uses up 4% of the mass of this zircon crystal.*

A zircon crystal can be up to **4 billion years** old.

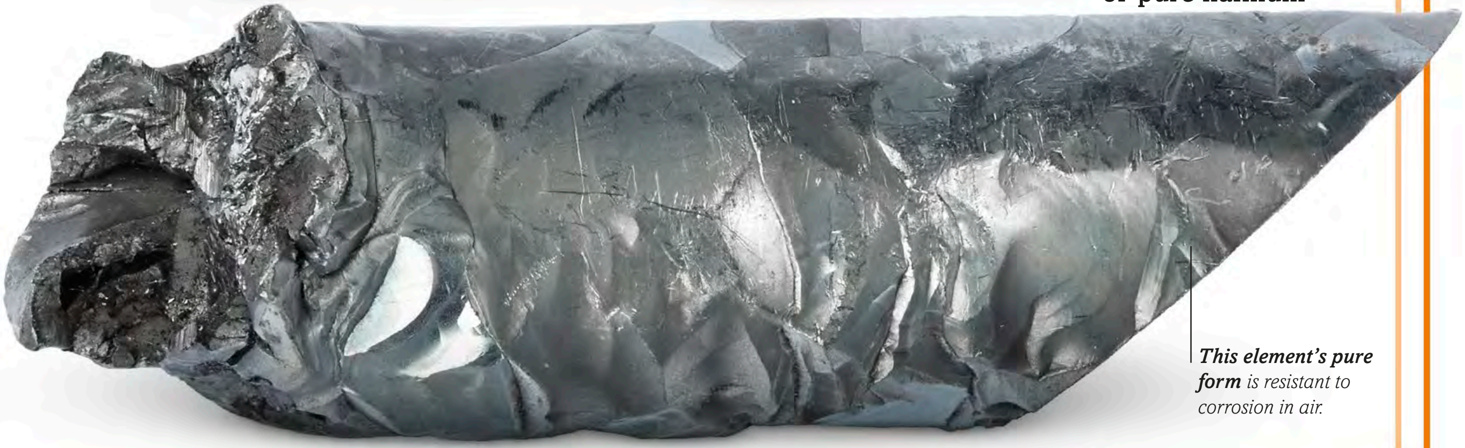

Laboratory sample of pure hafnium

This element's pure form *is resistant to corrosion in air.*

Uses

Sections of this cutter *are made of hafnium.*

Metal cutter

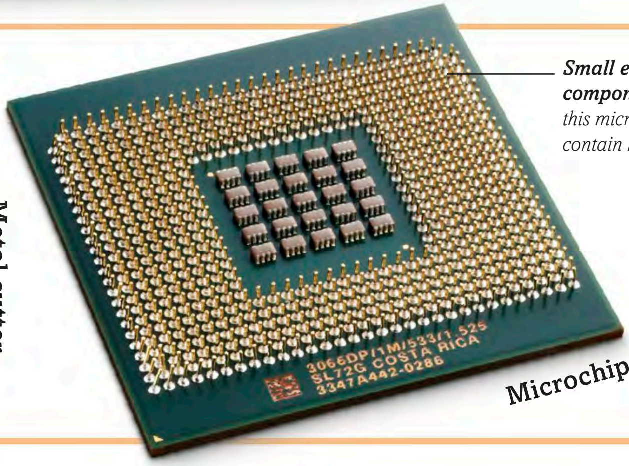

Small electronic components *in this microchip contain hafnium.*

Microchip

Hafnium is named after *Hafnia*, the Latin word for the city of Copenhagen in Denmark. It took a long time to distinguish hafnium from zirconium because the two elements are present together in crystals of the mineral **zircon** and their atoms are similar sizes. Hafnium is used in powerful **cutters** that pierce metallic objects with a hot stream of sparks. It is also used to make ultra-small electronics – only a few millionths of a millimetre wide – in **microchips**.

73

Ta

Tantalum

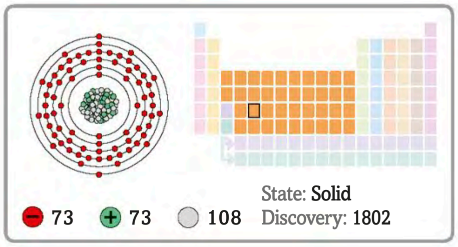

73 73 108

State: Solid

Discovery: 1802

Forms

Tantalite

The mineral has a dark, waxy surface.

These yellow crystals contain the mineral stibiotantalite.

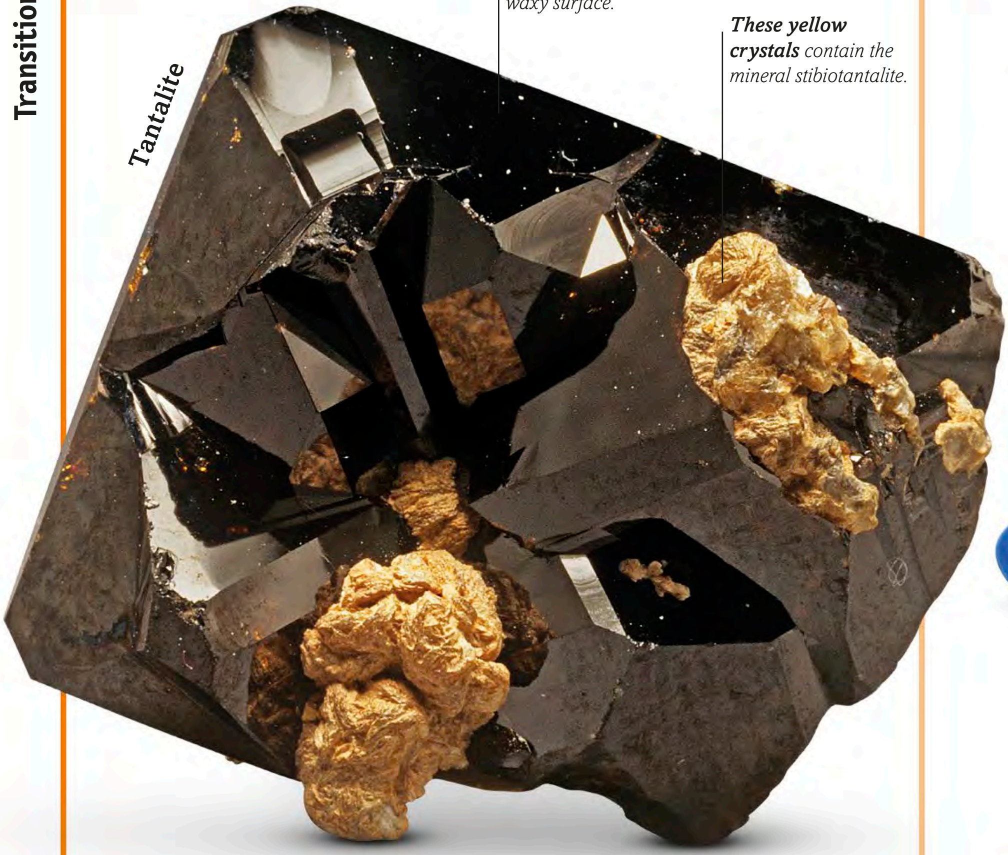

The pure metal barely reacts with air, so stays shiny.

Rods of pure tantalum refined in a laboratory

Uses

Artificial joint

The tantalum shell of this hip implant is lightweight and flexible.

Tantalum capacitors are used to store a lot of electric charge in small circuits, such as the ones inside mobile phones.

Electronic capacitor

Metallic watch

The case and strap of this watch are made of an alloy of tantalum, gold, and copper.

Tantalum is a hard metal named after Tantalus, a man from Greek mythology who was punished by the gods. It is extracted from a rare mineral called **tantalite**. This tough metal is not harmful to the human body, so it is used to make **artificial joints** and other body implants. Tantalum powder is used in **capacitors** – devices used in electronic circuits to store electricity. This strong metal toughens **watches** made of softer, precious metals. Tantalum is also used to create strong turbine blades that do not corrode.

74
W

Tungsten

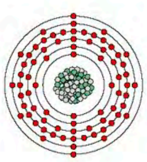

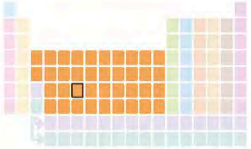

⊖ 74 ⊕ 74 ○ 110

State: Solid
Discovery: 1783

Forms

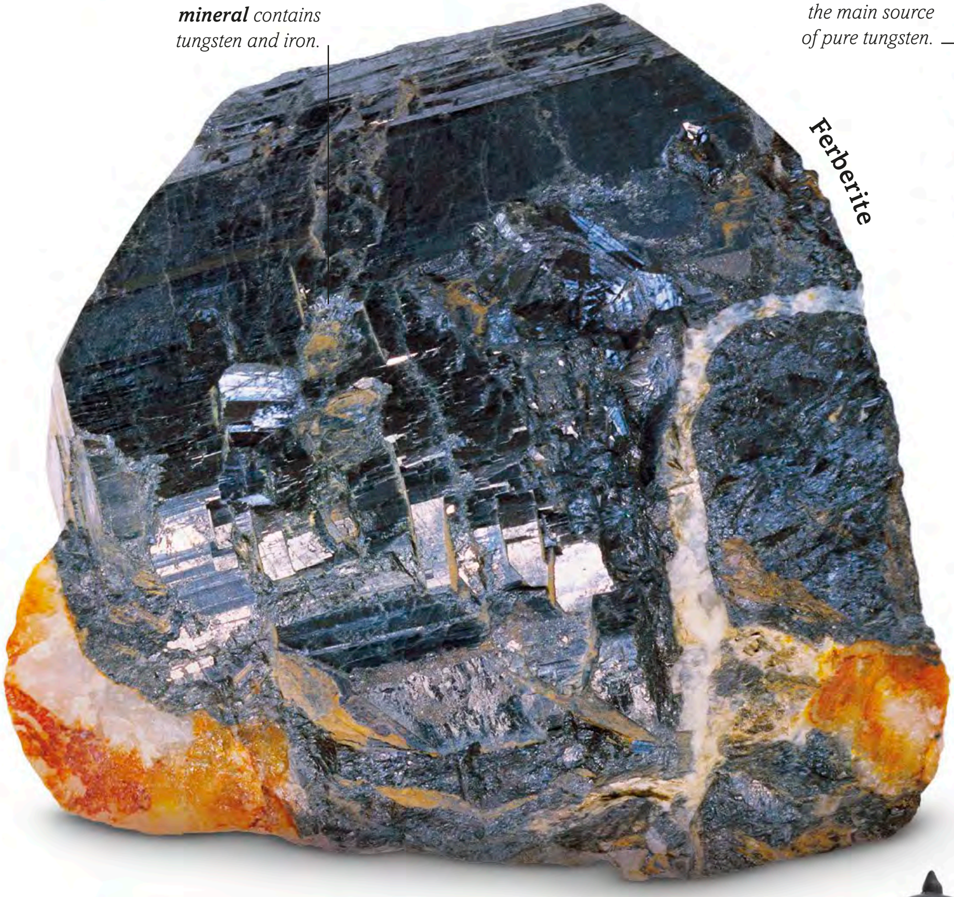

Ferberite

This dark, metallic mineral *contains tungsten and iron.*

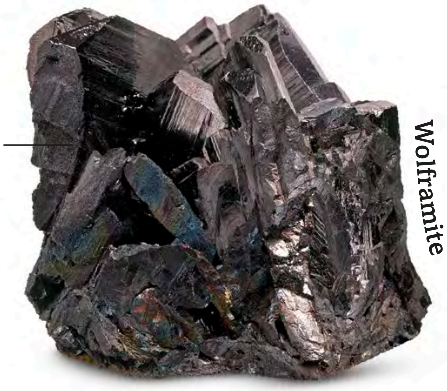

Wolframite

This mineral *is the main source of pure tungsten.*

Cylinder of pure tungsten refined in a laboratory

Pure tungsten *is a hard, grey metal.*

Uses

Drill bit

This drill bit *has a coating of tungsten carbide, which protects it from damage.*

Tungsten pigments were in use in Chinese porcelain 350 years ago.

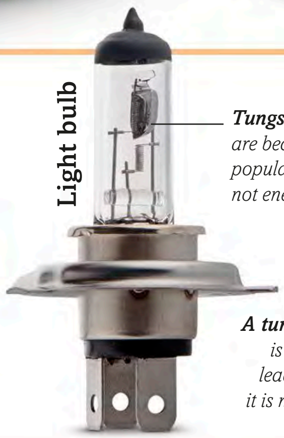

Light bulb

Tungsten filaments *are becoming less popular as they are not energy-efficient.*

Fishing sinker

A tungsten sinker *is preferred to a lead one because it is not poisonous.*

Tungsten has the highest melting point of any metal: it turns to liquid at a searing 3,414°C (6,177.2°F). It is a very dense metal, and its name comes from the Swedish phrase for "heavy stone". This metal is usually obtained from the mineral **wolframite**. A compound called tungsten carbide is used to harden objects such as **drill bits**. Tungsten's high melting point allows it to be used in the filaments of **light bulbs**. This element is also useful in producing weights, such as **sinkers** used with fishing lures.

75
Re

Rhenium

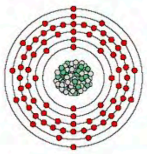

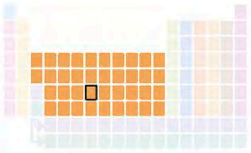

⊖ 75 ⊕ 75 ○ 111

State: **Solid**
Discovery: **1925**

Forms

Molybdenite

This ore *contains molybdenum and small amounts of rhenium.*

Pure rhenium pellet

Pure rhenium *is denser than gold.*

Uses

X-ray tube

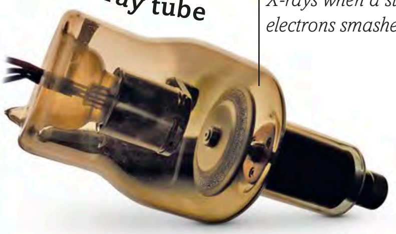

These tubes *contain a rhenium alloy that produces X-rays when a stream of electrons smashes into it.*

Rhenium has the **highest boiling point** of any element.

F-22 Raptor fighter plane

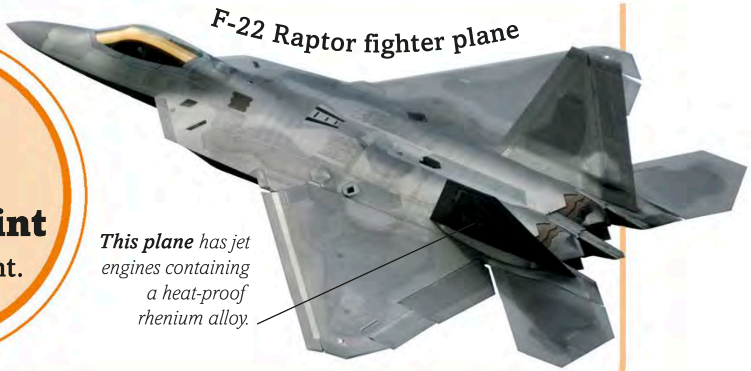

This plane *has jet engines containing a heat-proof rhenium alloy.*

Rhenium is very rare in nature: only one atom out of every billion in Earth's crust is a rhenium atom. Discovered in Germany in 1925, and named after the Rhine river – it was the last stable, non-radioactive element to be found. Rhenium has a very high melting point, and can stay solid at extreme temperatures. This allows alloys made of this element to be used in very hot conditions, such as those inside the tubes of **X-ray machines**, as well those in the exhaust nozzles of rockets and the jet engines of **fighter planes**.

76 Os Osmium

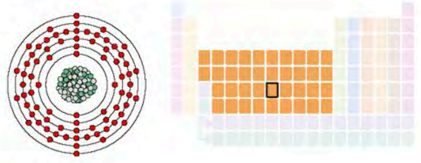

● 76 ⊕ 76 ○ 114

State: Solid
Discovery: 1803

Forms

Osmiridium sand

This is a natural alloy *of osmium and iridium.*

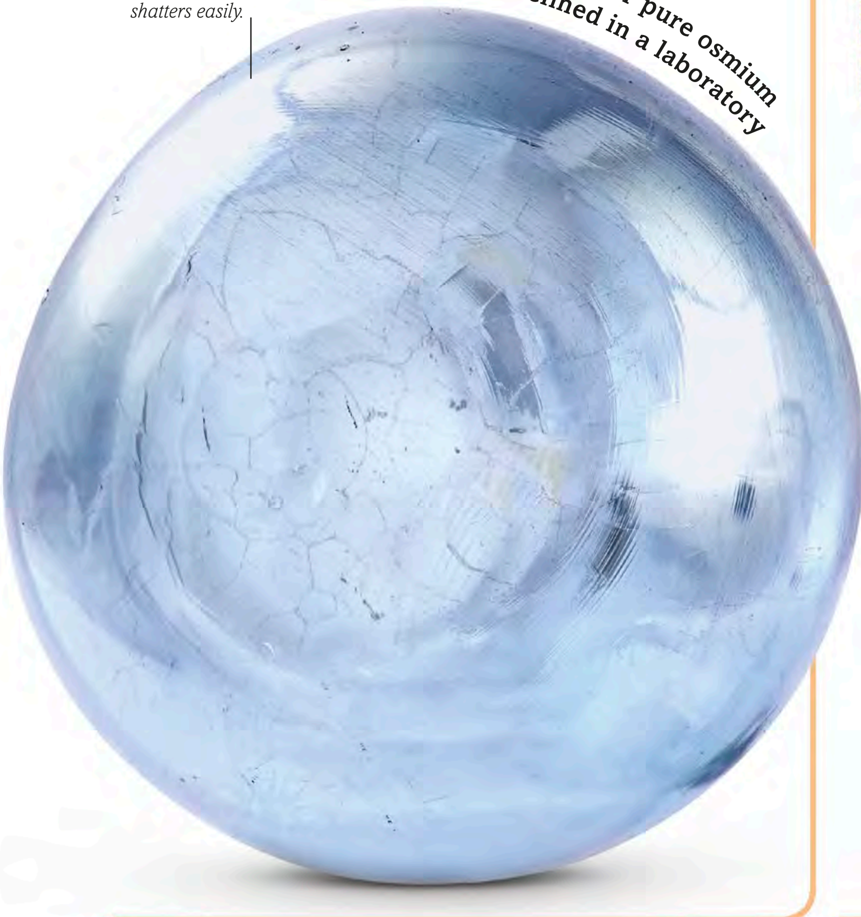

Pellet of pure osmium refined in a laboratory

The pure form *is hard but shatters easily.*

Uses

Transmission electron microscope (TEM) image

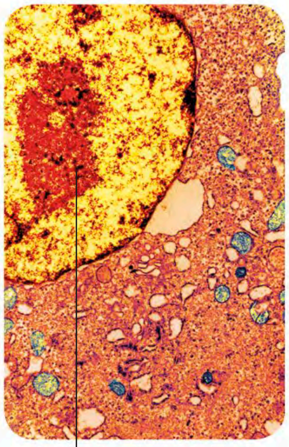

Osmium oxide *is used to highlight objects inside a cell.*

Fingerprint powder in use

Black osmium oxide powder *clings to oily fingerprints.*

Record player

The needle *of this old record player is made of osmium.*

Fountain pen

The nib of this pen *moves smoothly because of its hardy osmium alloy.*

Osmium is the densest of all naturally occurring elements: 250 ml (8.5 fl oz) of this metal (in its liquid form) weighs 5.5 kg (12 lb). This rare element is found in the ore **osmiridium**. **Pure osmium** reacts with oxygen in the air to form a poisonous oxide, so the metal is used safely by combining it with other elements or alloys. A red osmium oxide stains cells so they can be seen clearly under a powerful **microscope**, while a black oxide powder allows **fingerprints** to be revealed in crime investigations. A hard osmium alloy is used in **fountain pen** nibs.

77
Ir

Iridium

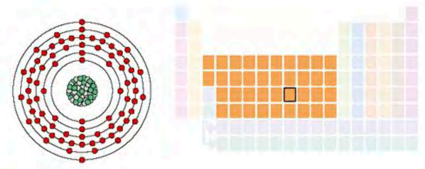

− 77 + 77 ○ 115

State: Solid
Discovery: 1803

Forms

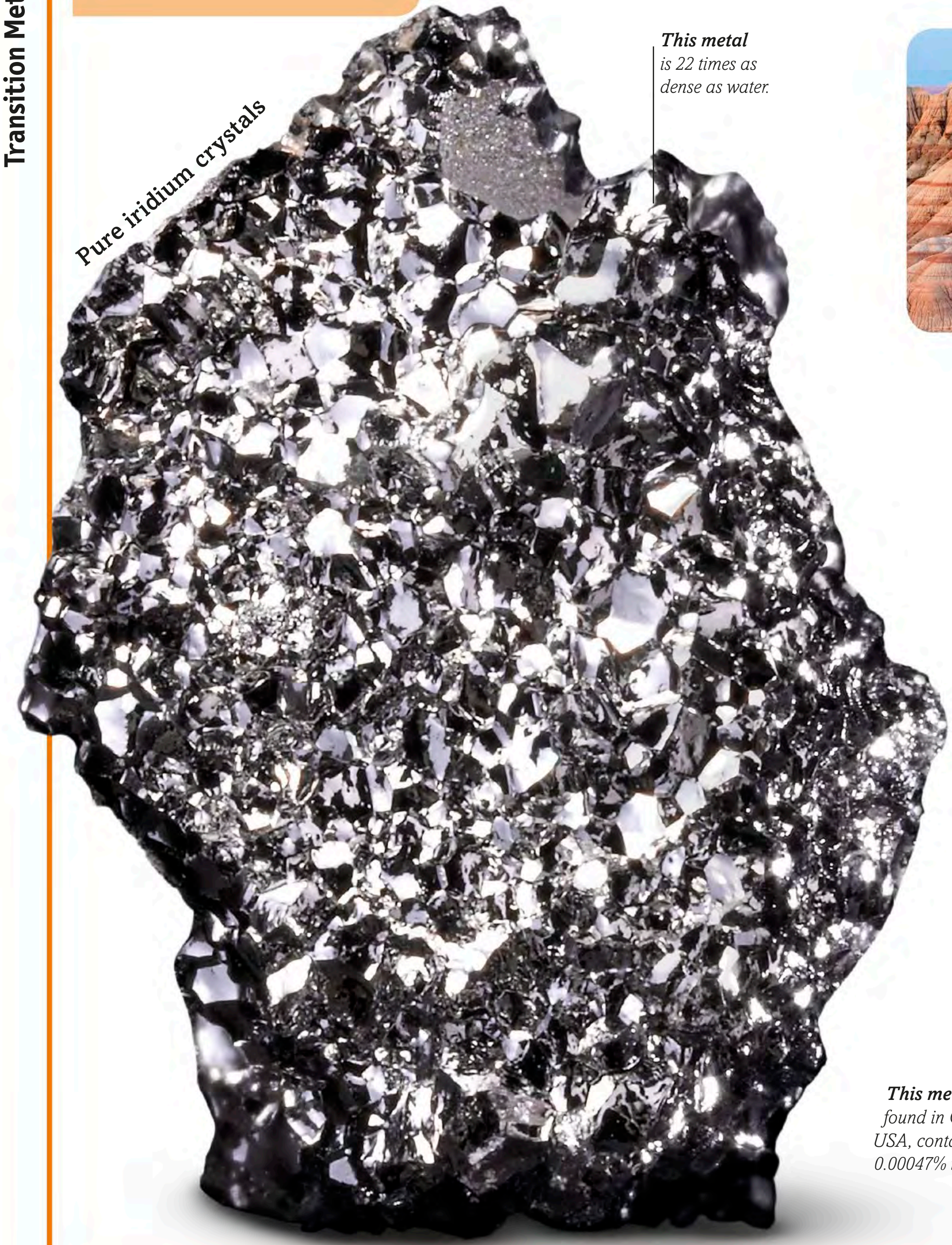

This metal *is 22 times as dense as water.*

These rocks *contain a layer of iridium-rich clay.*

Badlands National Parks, South Dakota, USA

Willamette meteorite

This meteorite*, found in Oregon, USA, contains just 0.00047% iridium.*

Iridium is the rarest natural element on Earth: there is one iridium atom out of every billion atoms in Earth's rocks. This dense metal can be found in its **pure** form in nature as well as in other common ores that contain nickel and copper. Iridium is present in **meteorites** and other space rocks. A layer of iridium-rich clay is found in Earth's crust all over the world, especially in the **Badlands of South Dakota, USA**. Scientists believe this small quantity of iridium in our planet's crust was deposited by the dust from an

Uses

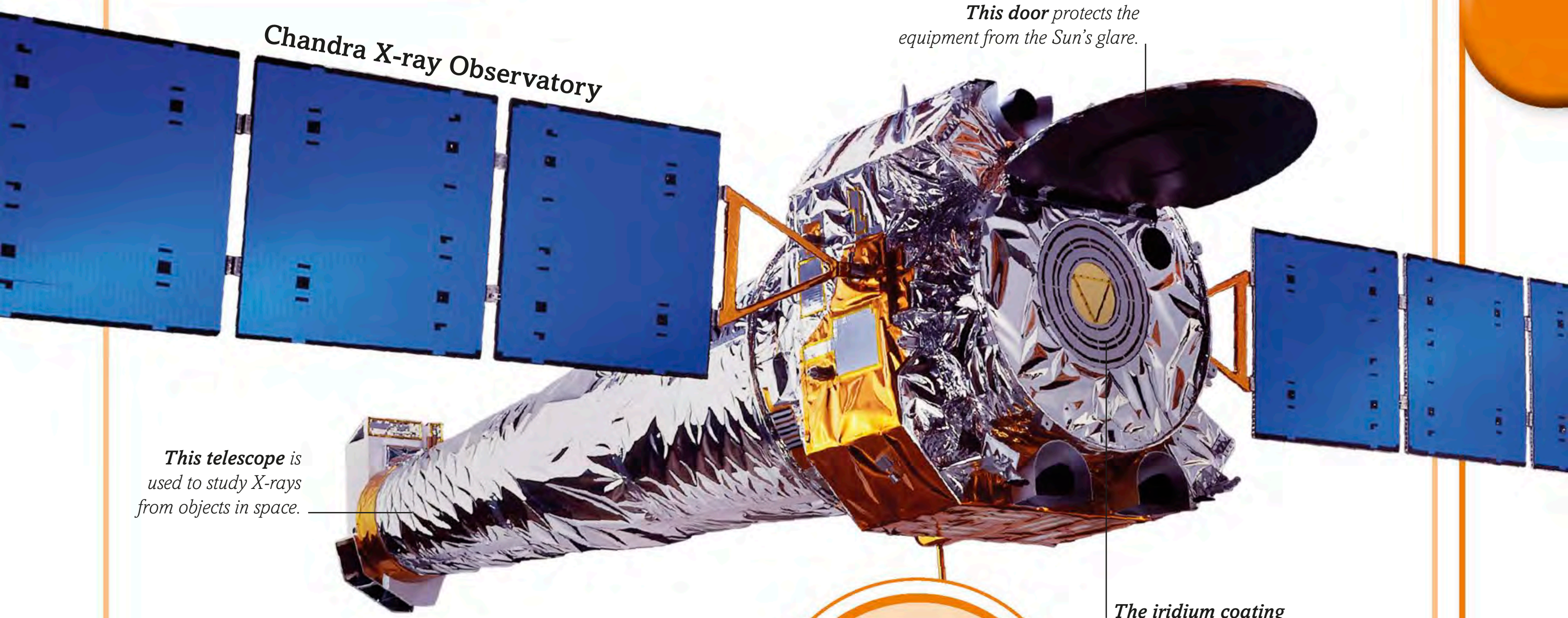

This door *protects the equipment from the Sun's glare.*

This telescope *is used to study X-rays from objects in space.*

The iridium coating *on the mirror is only a few atoms thick.*

This spark plug *contains a tiny amount of iridium, and can resist the high temperatures created during sparking in vehicles.*

Iridium is the **second densest metal**, after osmium.

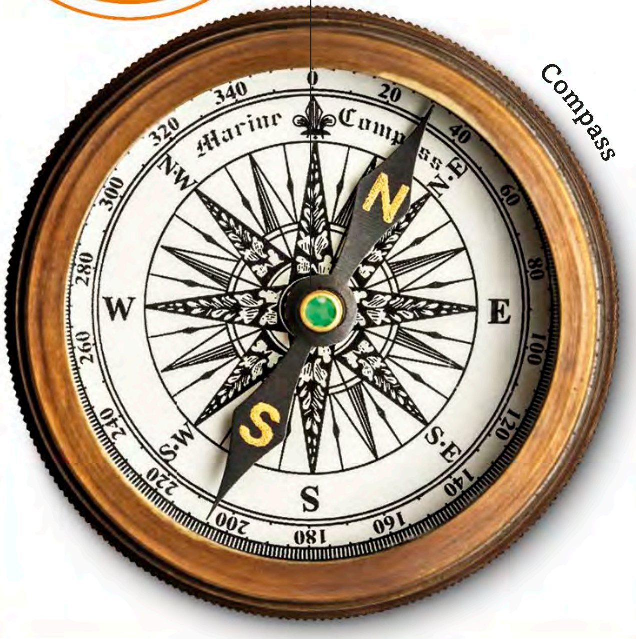

The moving parts of *some compasses are made of the alloy osmiridium.*

LUIS WALTER ALVAREZ

In 1980, the American physicist Luis Walter Alvarez and his son Walter discovered a layer of iridium-rich clay in rocks all over the world. They suggested that this was the result of a meteorite impact about 66 million years ago, which led to the extinction of the dinosaurs.

explosion 66 million years ago when a large meteorite hit our planet. The applications of this element include coating the mirror of NASA's **Chandra X-ray Observatory**, an Earth-orbiting telescope that studies X-rays from distant stars. Iridium is more durable than platinum and copper, and is therefore preferred over these metals for use in spark plugs. Iridium is also mixed with osmium to make an alloy called osmiridium, which is used in **compasses** and put in nibs for some fountain pens to make them hardy.

78
Pt

Platinum

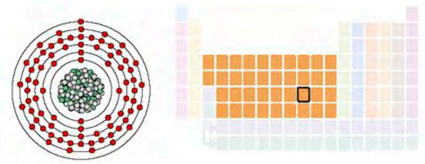

⊖ 78 ⊕ 78 ○ 117

State: Solid
Discovery: Unknown

Forms

Platinum melts at the high temperature of **1,768°C** (3,214°F).

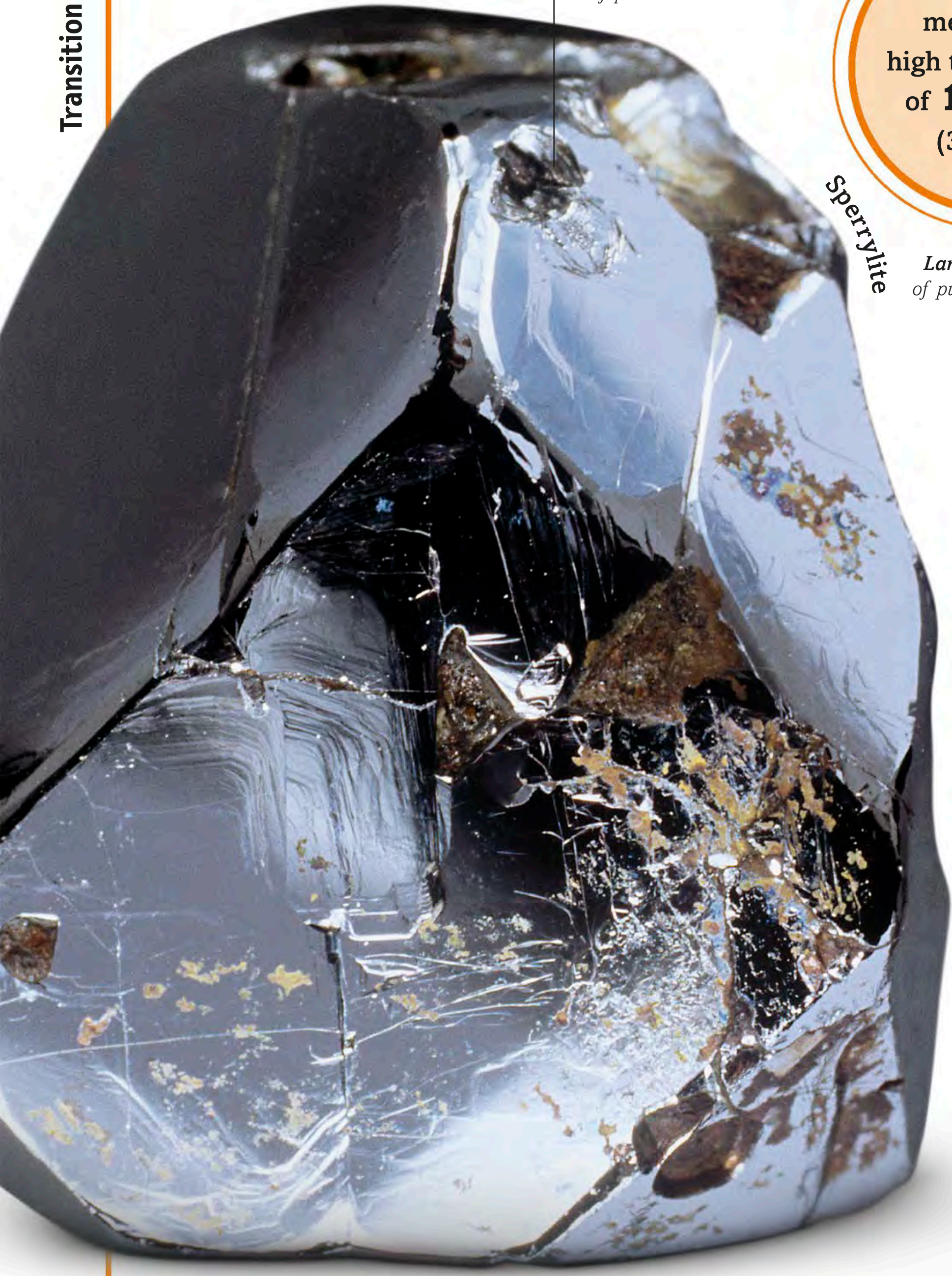

Sperrylite

This dense, shiny mineral *consisting of platinum and arsenic is the most common ore of platinum.*

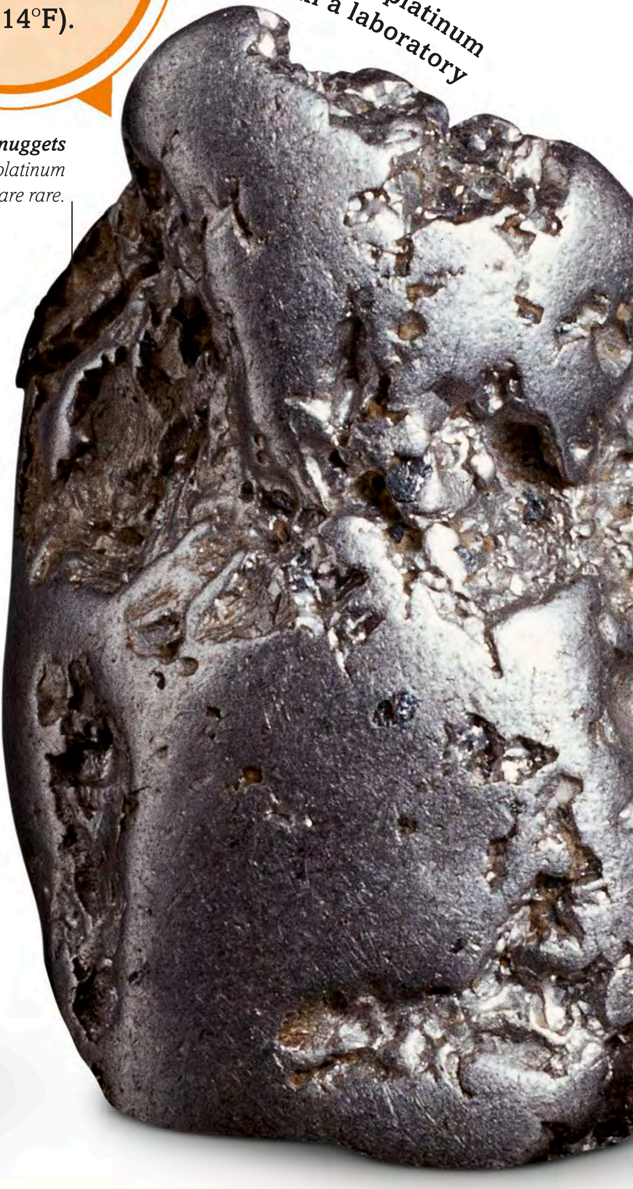

Nugget of pure platinum refined in a laboratory

Large nuggets *of pure platinum are rare.*

Spanish explorers first found platinum in the mines of South America in the 1700s. They obtained a whitish substance that the locals living near there called *platina*, meaning "little silver". This precious metal has a silvery white shine. Platinum rarely reacts with other elements, even at high temperatures. This makes it difficult to extract from its ores, such as **sperrylite**. **Pure platinum** does not corrode or tarnish. It is, however, not easy to shape or mould, so use of platinum was limited to the making of simple jewellery and **watches**. By the 20th century,

Uses

Platinum resistance thermometer

This thermometer *records temperature by measuring the electric current flowing through a fine platinum wire.*

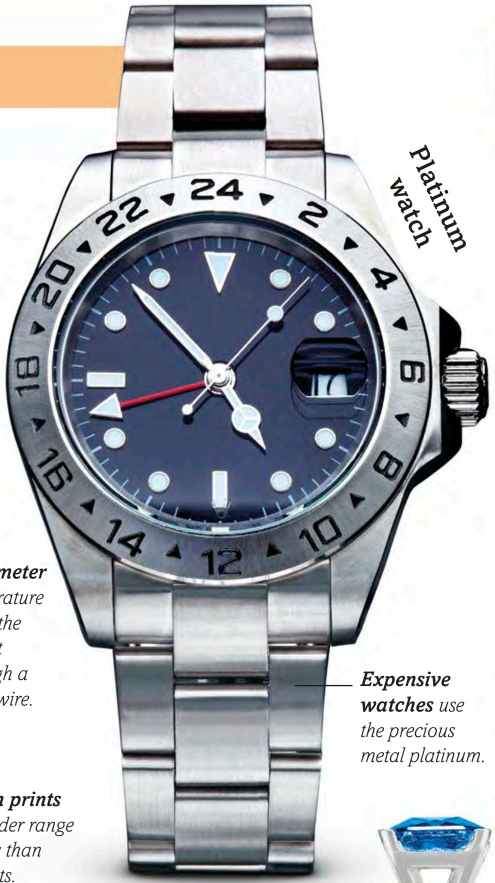

Platinum watch

Expensive watches *use the precious metal platinum.*

Platinum prints *have a wider range of shades than silver prints.*

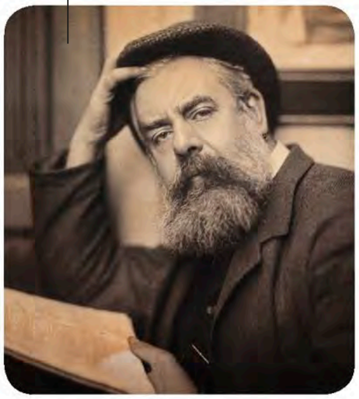

Black and white photographic print

Jewellery *made of platinum does not lose its shine.*

Platinum ring

Dental fillings *once contained platinum and mercury.*

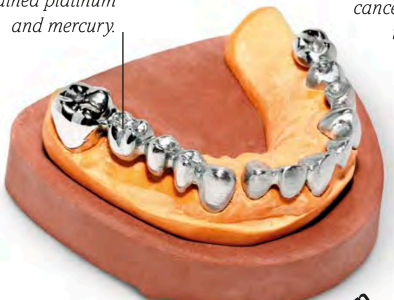

Dental crown

This drug *contains platinum and kills cancer cells in the body.*

Cisplatin
1 mg/ml concentrate for solution for infusion
50 mg
50 ml
Intravenous
1 mg/ml (50 ml = 50 mg)
For single use only
TEVA

Cancer drug

ANTONIO DE ULLOA

Although platinum had been in use in jewellery on the west coast of South America for more than 2,000 years, it was Spanish naval officer Antonio de Ulloa who made the first major study of it. In 1735, while on a South American expedition, he found grains of the metal in river sands. He brought them back to Spain to examine them.

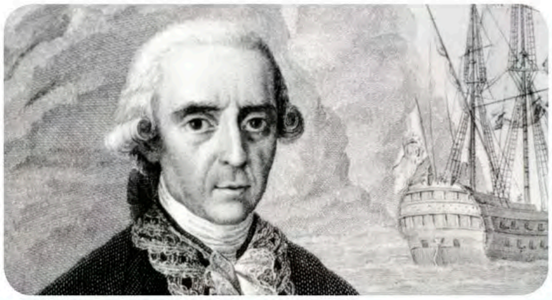

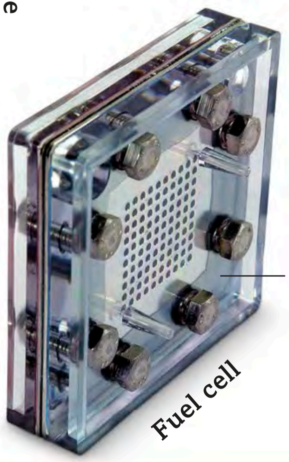

Fuel cell

This fuel cell *contains platinum, which speeds up the reaction between hydrogen and oxygen.*

This stent made of platinum *is not harmful to the body and anchors a damaged blood vessel as it heals.*

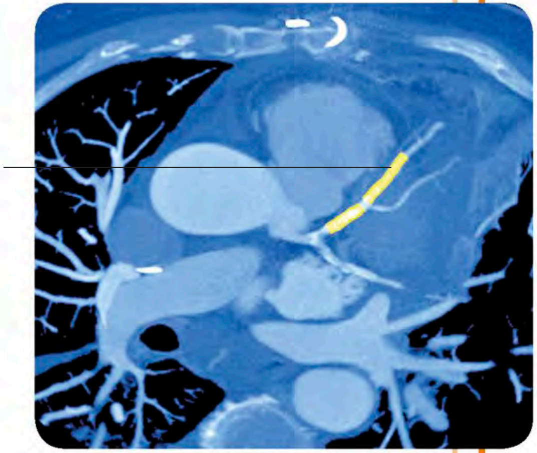

Medical stent

Platinum was found in an Egyptian casket from the **7th century BCE**.

more applications were discovered. Platinum can be used in place of silver to generate **photographic prints**, and in place of gold for making **dental fillings**. Today, platinum plays an important role in various technologies. For example, it is used in **fuel cells** – devices that generate electricity by combining hydrogen and oxygen. These cells do not need to be recharged like other batteries. Powerful **drugs for treating cancer** contain this element, while **stents** made of pure platinum help heal damaged blood vessels.

79

Au Gold

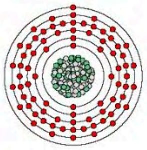

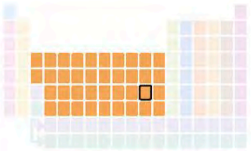

● 79 ⊕ 79 ○ 118

State: Solid

Discovery: c. 3000 BCE

Forms

Gold's chemical symbol **Au**, comes from its **latin name**, *aurum*.

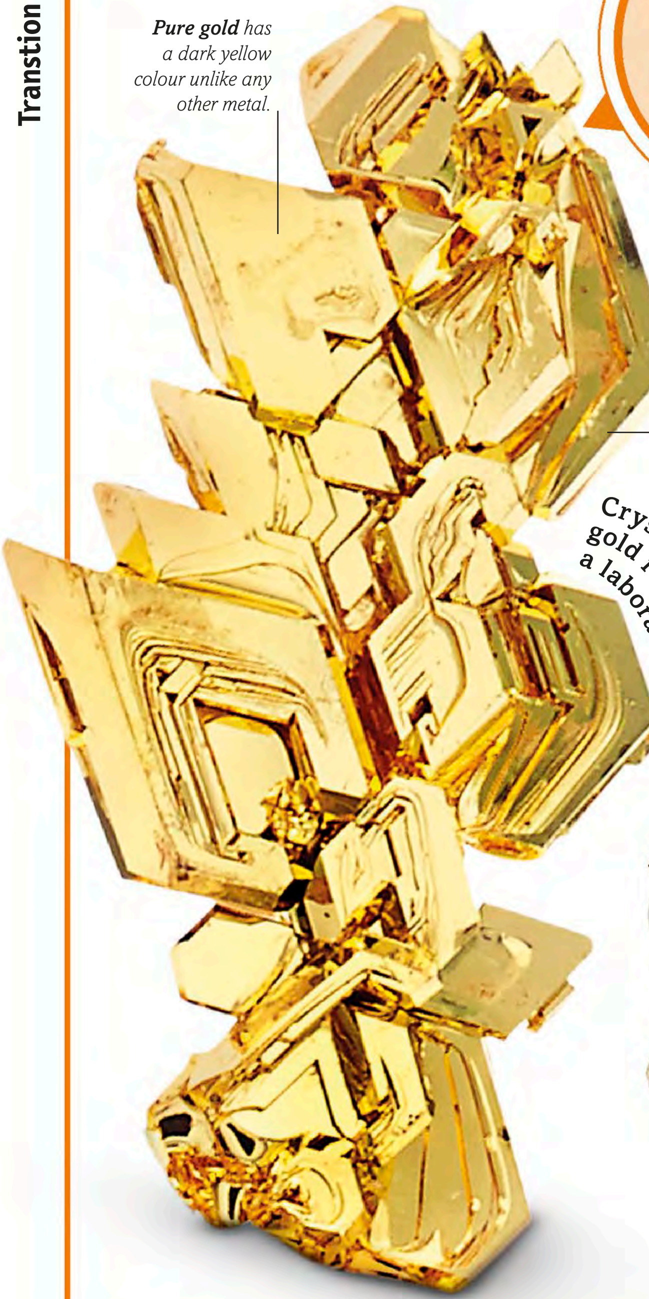

Crystals of pure gold refined in a laboratory

Pure gold *has a dark yellow colour unlike any other metal.*

These crystals *may be elongated, rectangular, or cubic.*

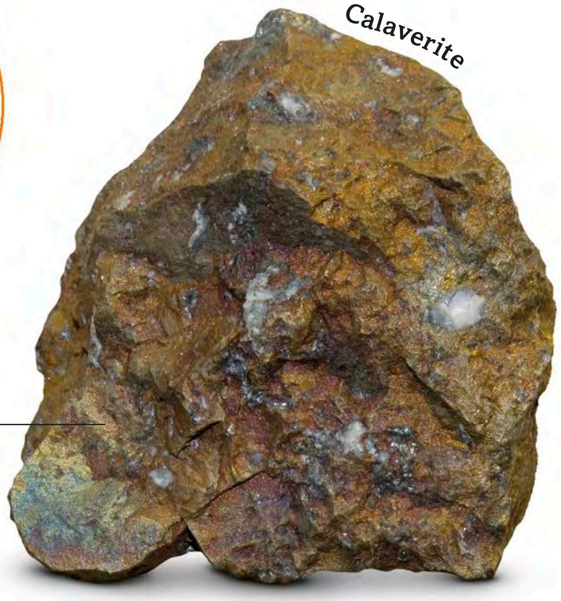

Calaverite

This mineral ore *contains gold and tellurium.*

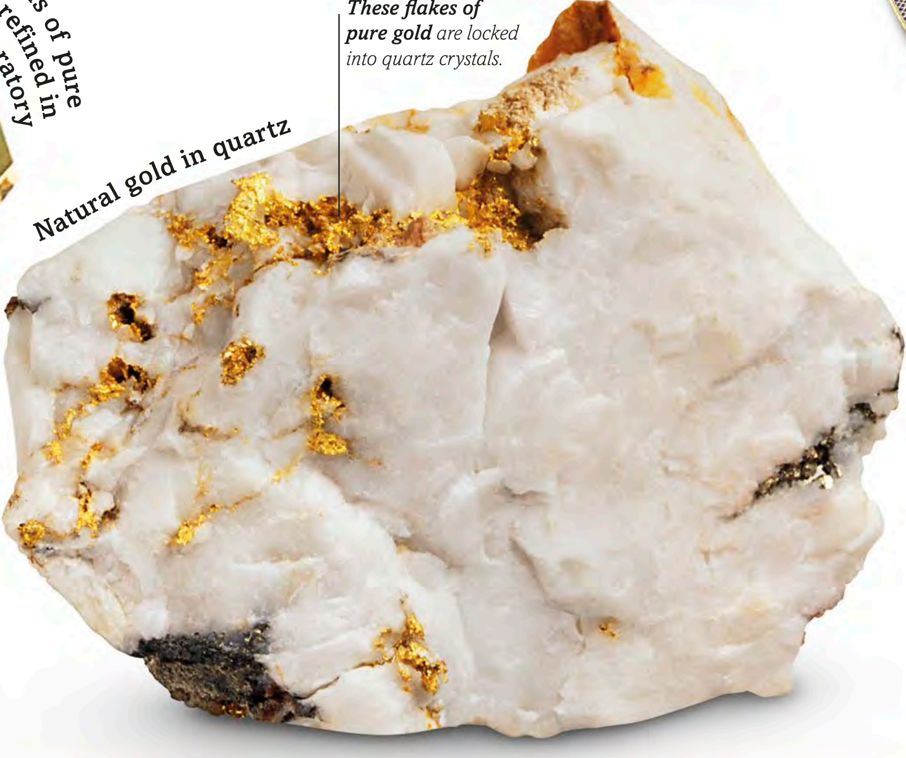

Natural gold in quartz

These flakes of pure gold *are locked into quartz crystals.*

People were making gold ornaments more than 6,000 years ago. This was many centuries before they learned how to purify copper, iron, and other metals. Gold is believed by many to be the first metal element to be identified. It is a dense, unreactive metal with a distinctive deep yellow colour. Gold is naturally **pure** and seldom makes compounds in nature; the compound in the mineral ore **calaverite** is an exception. **Pure gold** found in nature may form nuggets but mostly is found as tiny specks embedded in rocks. Gold miners crush up these rocks and wash out the

Uses

This very thin layer of ***gold*** *protects the astronaut from the Sun's heat.*

Astronaut's visor

This mask was placed over the pharaoh's mummified face.

Tutankhamun's death mask

THE HOLTERMANN NUGGET

The largest piece of natural gold was found on 19 October, 1872, near the small town of Hill End in Australia. Named after its discoverer, Bernhardt Holtermann, the piece contained moe than 90 kg (198 lb) of pure gold.

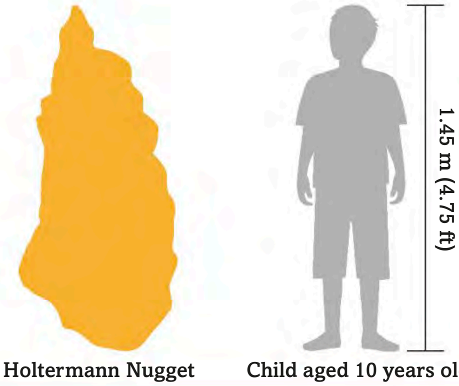

Royal Crown Derby plate

This glass plate *contains specks of gold.*

Gold bars

Gold bars *stored in banks are a sign of wealth.*

Edible gold flakes

The flakes *decorating this expensive chocolate are edible.*

Gold teeth

These replacement teeth *are made of gold and mercury.*

Wat Phrathat Doi Suthep temple, Thailand

A thin layer of gold *covers this entire temple.*

Gold foil *keeps this car engine at a stable temperature.*

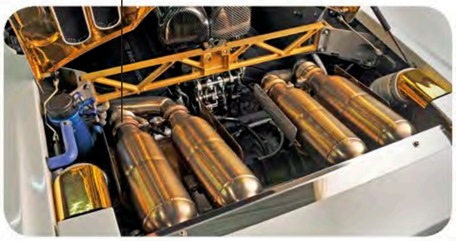

McLaren F1 car engine

Ancient gold jewellery

This neck ornament *is made from cast gold.*

gold dust with water or strong acids. The applications for gold include heat shields in **astronaut's visors**. This metal has always been seen as valuable and many ancient artefacts, such as the **3,300-year-old death mask** of Egyptian pharaoh Tutankhamun, were forged from it. Some of the earliest coins, found in Turkey, were made of it. Gold is used to cover important buildings, such as Thailand's **Wat Phrathat Doi Suthep** temple. This precious metal is most commonly used today in **jewellery** or decorations.

GOLDEN BUDDHA A precious statue of Buddha with one thousand eyes and one thousand hands stands in Long Son Pagoda, a temple in Nha Trang, Vietnam. The Buddha is depicted as holding a range of sacred objects, including scrolls and white lotus flowers. This statue is completely covered in a layer of pure gold, and it draws in hundreds of devotees from across the world.

Although humans have discovered many strong metals and useful elements, gold has remained one of the most valuable. Before people knew what it was, they saw glittering gold dust in river beds or dug large gold nuggets out from rocks. They found that gold has many valuable qualities: it is soft enough to hammer into any shape and can be melted down for moulding into ornaments. Best of all, its gleaming golden colour never fades away. Ancient cultures prized items made of gold: in ancient Egypt, gold was used to make coins as well as to cap the tops of pyramids. Gold is, however, so rare that if all the world's mined gold were forged into a cube, it would fit inside the penalty area of a soccer pitch.

80

Hg

Mercury

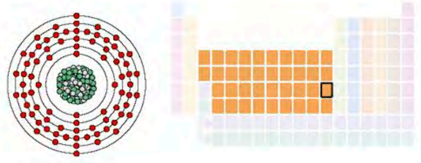

80 80 121

State: **Liquid**

Discovery: **c. 1500 BCE**

Forms

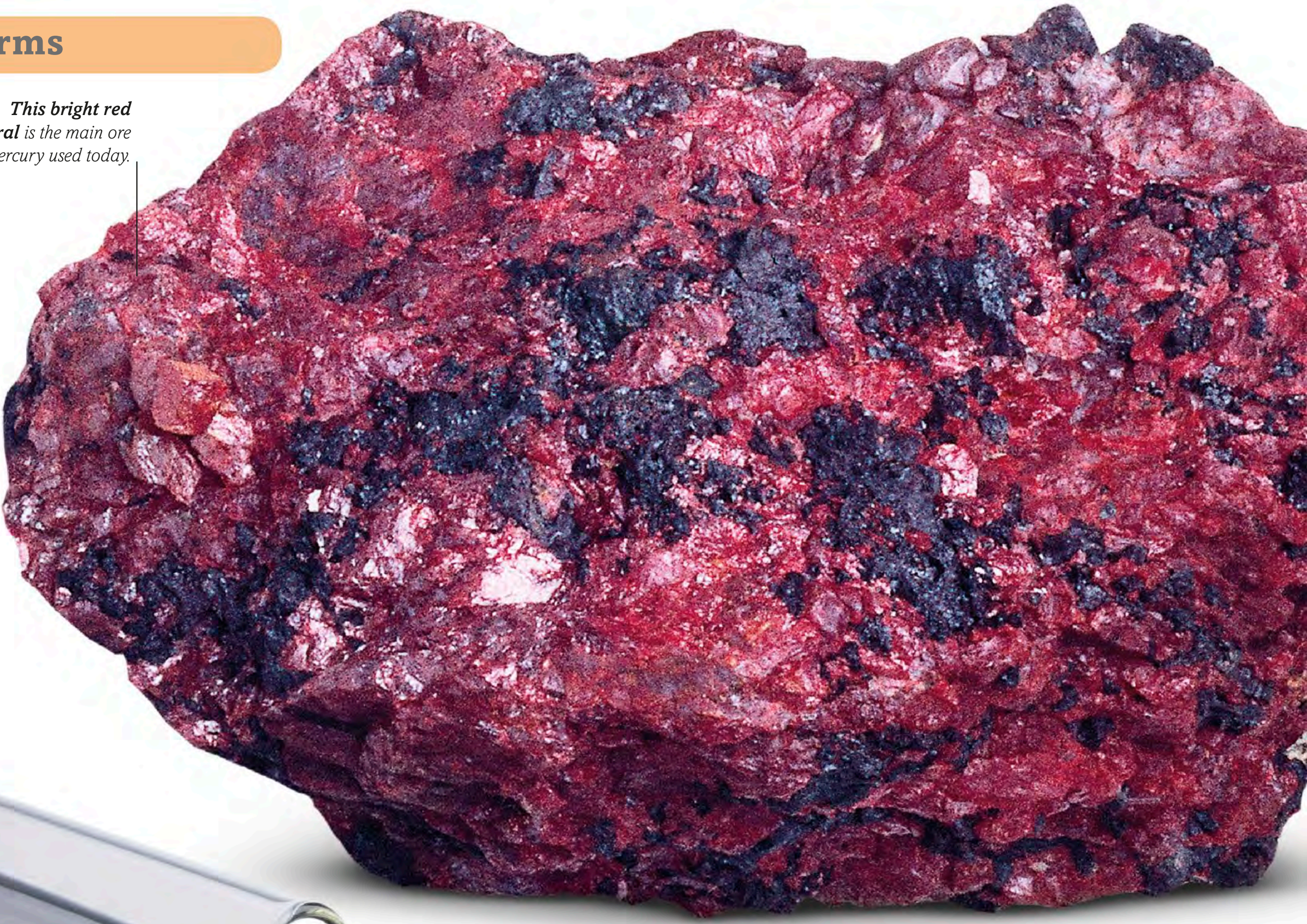

This bright red ***mineral*** *is the main ore of mercury used today.*

Cinnabar

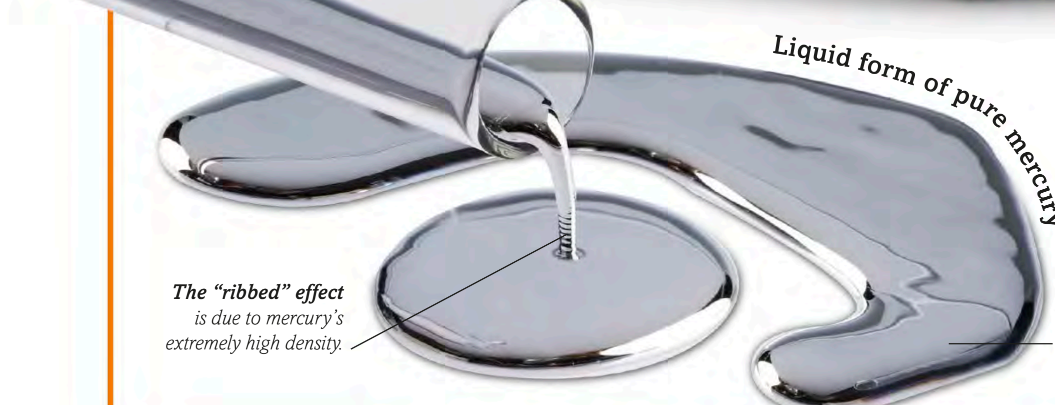

Liquid form of pure mercury

The "ribbed" effect *is due to mercury's extremely high density.*

This metal *melts at −39°C (−38°F).*

Solid mercury is soft enough to be **cut with a knife**.

Mercury is the only metal that is liquid at room temperature. Along with water, it is one of the few liquids found naturally on Earth's surface. **Pure mercury** forms around volcanoes where the heat separates it from its minerals, such as **cinnabar**. This red mineral has been used for many centuries: ancient Romans roasted cinnabar to release a liquid they called *hydrargyrum*, meaning "silver water". This was the element mercury. It was later known as quicksilver because of how fast it flowed as a stream of liquid. This metal is very poisonous:

Uses

This thermometer *contains mercury, which expands as it gets warmer and contracts as it cools.*

Mercury thermometer

Pills containing mercury *were commonly used to treat constipation and toothache.*

Mercury pills

This bulb *glows when the mercury vapour inside it is electrified.*

CFL bulb

Mercury has been in use for more than **4,000 years**.

HOW DOES A BAROMETER WORK?

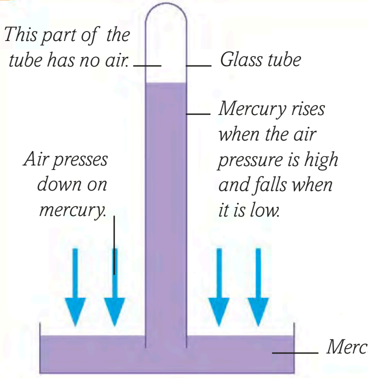
This part of the tube has no air.
Glass tube
Mercury rises when the air pressure is high and falls when it is low.
Air presses down on mercury.
Mercury in a container

A barometer is an instrument used to measure air pressure to forecast the weather. The simplest – and earliest – designs used a column of mercury inside a glass tube.

This bright red paint *is made with powdered cinnabar.*

Red paint

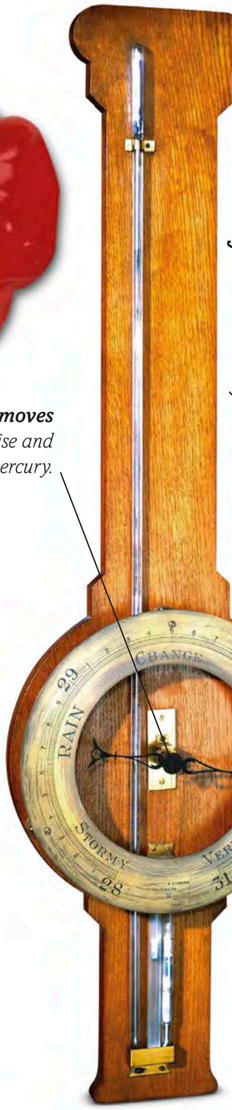
CHANGE
RAIN
FAIR
STORMY
VERY DRY
29
30
28
31

The needle moves *with the rise and fall of mercury.*

Mercury barometer, c. 1660

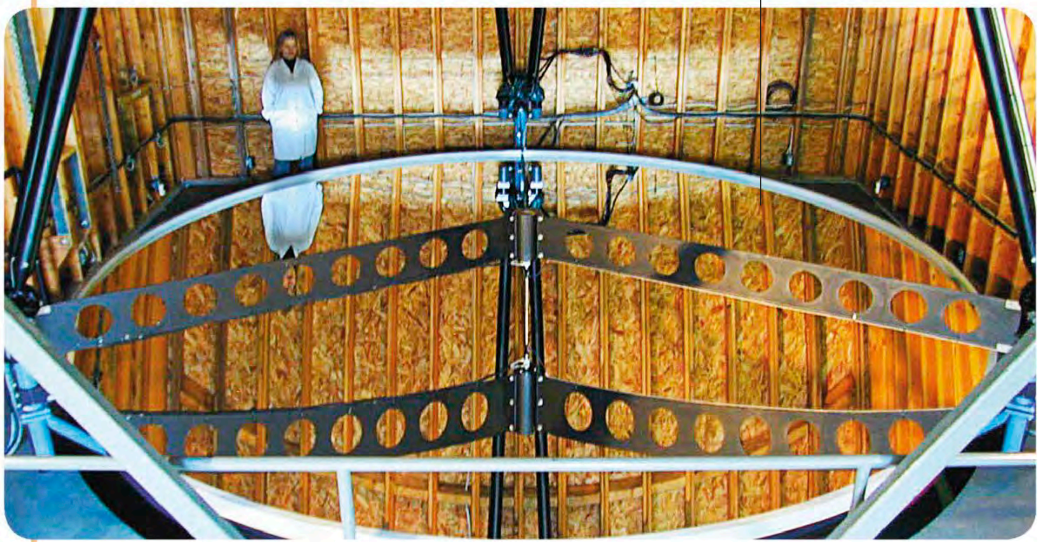

This large, low-cost mirror *made of a pool of pure mercury is used in an astronomical telescope.*

Liquid mirror inside telescope

it can damage organs and nerves if inhaled or swallowed. As a result, the use of this metal is carefully monitored today. Mercury is used in some batteries, some **thermometers**, and in low-energy, **compact fluorescent light (CFL) bulbs**. Its compounds are used to prepare strong, **red paints**. Until the early 18th century, mercury was used in **pills** for treating some common ailments. It gradually fell out of use when it was found to be toxic. The first accurate **barometers** also contained this liquid, but such devices are rarely seen today.

104
Rf

Rutherfordium

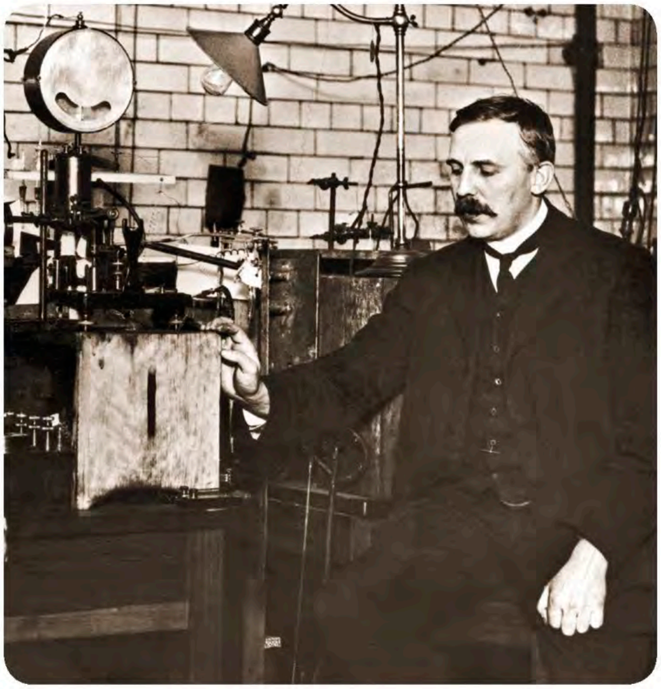

Ernest Rutherford

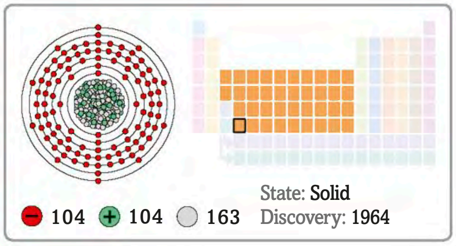

State: Solid
Discovery: 1964

Rutherfordium was the first superheavy element to be discovered. In this type of element, each atom has 104 or more protons in its nucleus. It is named after the New Zealand scientist **Ernest Rutherford**, who, in 1913, suggested that every atom has a nucleus, or core. Pure rutherfordium is synthesized by researchers in a laboratory.

105
Db

Dubnium

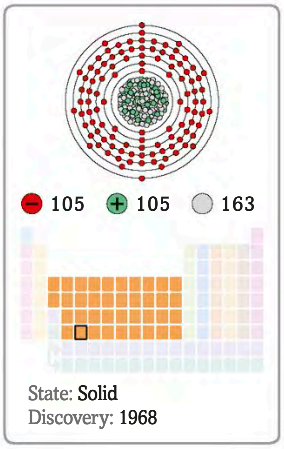

State: Solid
Discovery: 1968

Albert Ghiorso

The US scientist Albert Ghiorso discovered **12 elements** in the 20th century.

It took scientists nearly 30 years to agree on a name for this element. Dubnium was finally named after the Russian city of Dubna, where the first atoms of this artificial, radioactive element were created, in 1968. However, a team of American scientists led by **Albert Ghiorso** also produced samples of the element at the same time. This radioactive element has 12 isotopes, or forms, with different numbers of neutrons.

106 Sg Seaborgium

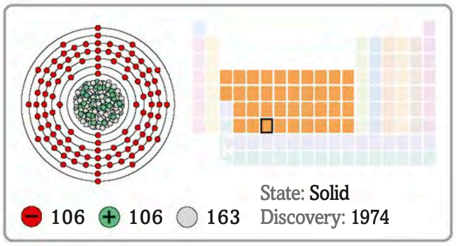

Atoms of seaborgium break apart in about three minutes, so little is known about it. Scientists think it may be a metal. The element was isolated in 1974 in a machine called the **Super Heavy Ion Linear Accelerator** at the Lawrence Berkeley National Laboratory. It was named after the US scientist Glenn T Seaborg.

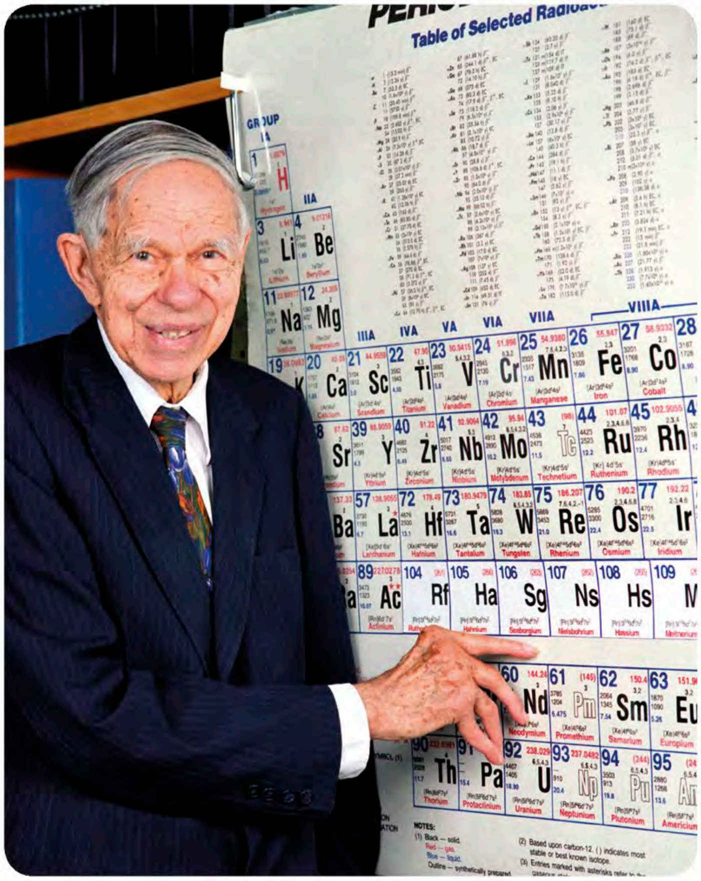

Glenn T Seaborg

This huge machine was used to discover **five new elements**.

***This giant tube** forms part of the Super Heavy Ion Linear Accelerator, which is a type of particle accelerator – a machine in which atoms are smashed together.*

Super Heavy Ion Linear Accelerator, Lawrence Berkeley National Laboratory, California, USA

NOBEL PRIZE IN CHEMISTRY

Glenn T Seaborg and his fellow US researcher Edwin McMillan were awarded the Nobel Prize for Chemistry in 1951 for their work in creating neptunium. This was the first element to be isolated that was heavier than uranium – the heaviest natural element.

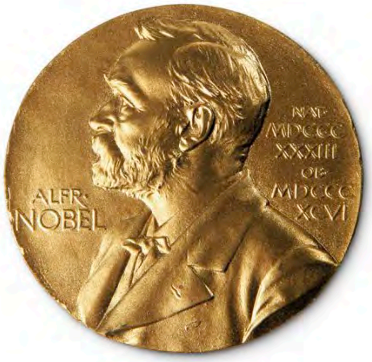

Nobel Prize medal

107
Bh

Bohrium

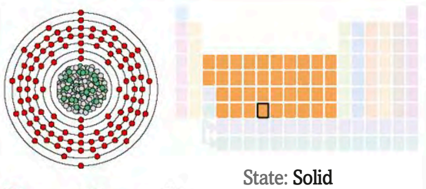

⊖ 107 ⊕ 107 ○ 163 State: Solid
Discovery: 1981

Niels Bohr

Bohrium is an artificial element named after the Danish scientist Niels Bohr. This was to honour his model of the structure of atoms' electron shells. Bohrium was first produced by firing chromium atoms at bismuth atoms in a particle accelerator (a machine in which atoms are smashed together). Atoms of this metal are unstable: half of any sample of bohrium atoms breaks apart in 61 seconds. As a result, it is not very well understood.

108
Hs

Hassium

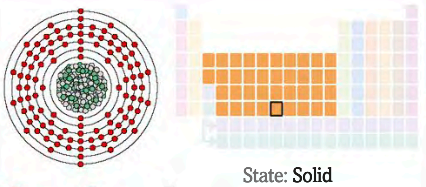

⊖ 108 ⊕ 108 ○ 169 State: Solid
Discovery: 1984

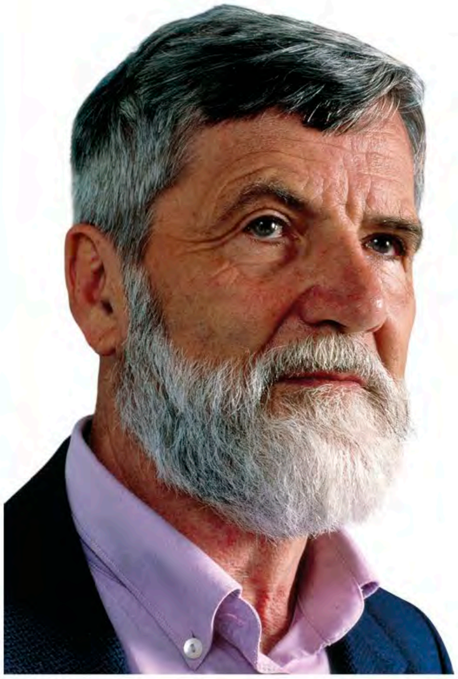

Peter Armbruster

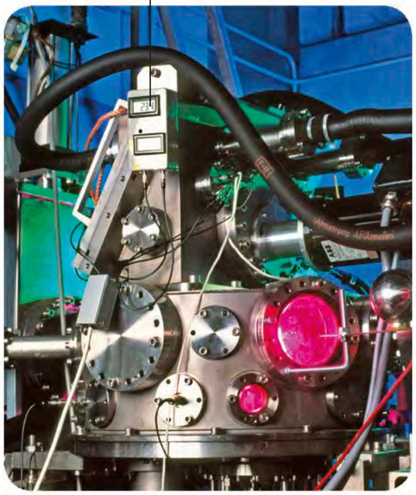

Hassium was produced inside this chamber.

A chamber at Centre for Heavy Ion Research, Darmstadt, Germany

Scientists think hassium is a metal, but they have not been able to produce enough of its atoms to study it in any detail. Hassium is very radioactive, and most of its atoms break apart within a few seconds. This element is named after the German state of Hesse, the location of the **Centre for Heavy Ion Research**, where hassium was first created artificially by a team led by the German physicist **Peter Armbruster**.

109 Mt Meitnerium

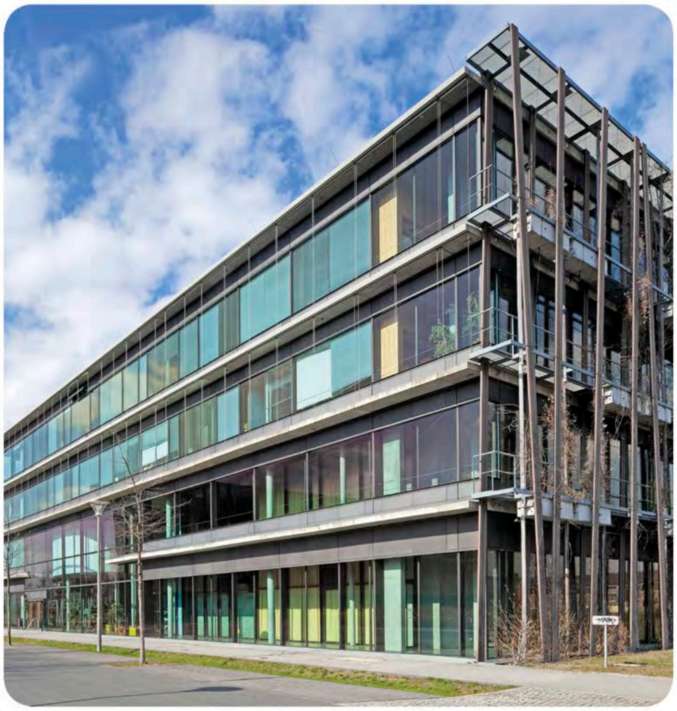

Meitner Haus building,
Humboldt University, Germany

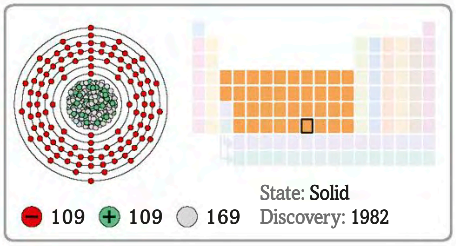

⊖ 109 ⊕ 109 ○ 169

State: Solid
Discovery: 1982

Researchers think meitnerium might be the densest of all elements. It is very unstable, and even the atoms of its most stable isotope, or form, break apart in a matter of seconds. Meitnerium is named after the Austrian physicist **Lise Meitner**, to honour her achievements in physics. Several universities, such as **Humboldt University** in Berlin, Germany, also have buildings in her name.

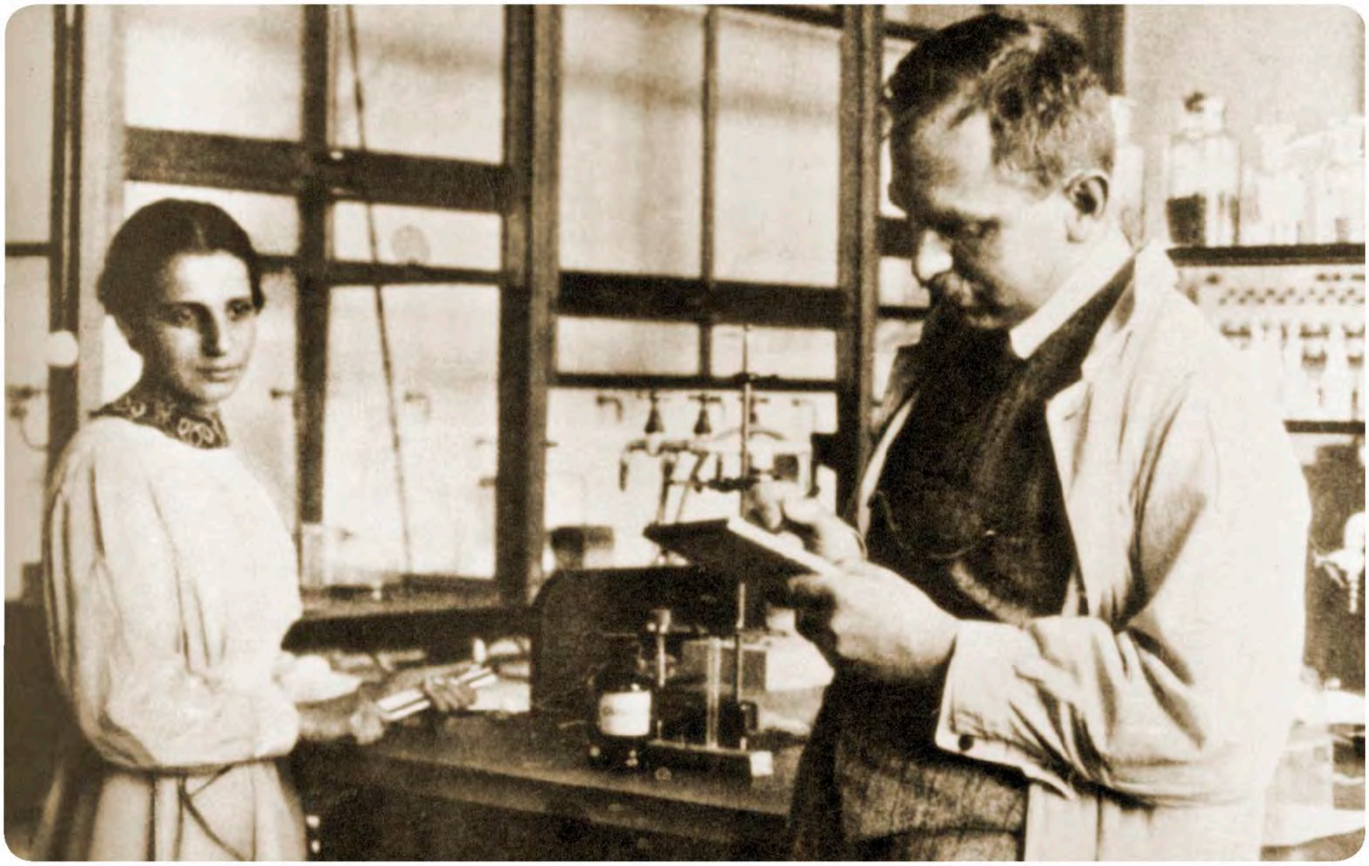

Lise Meitner (left) works with the German chemist Otto Hahn

110

Ds

Darmstadtium

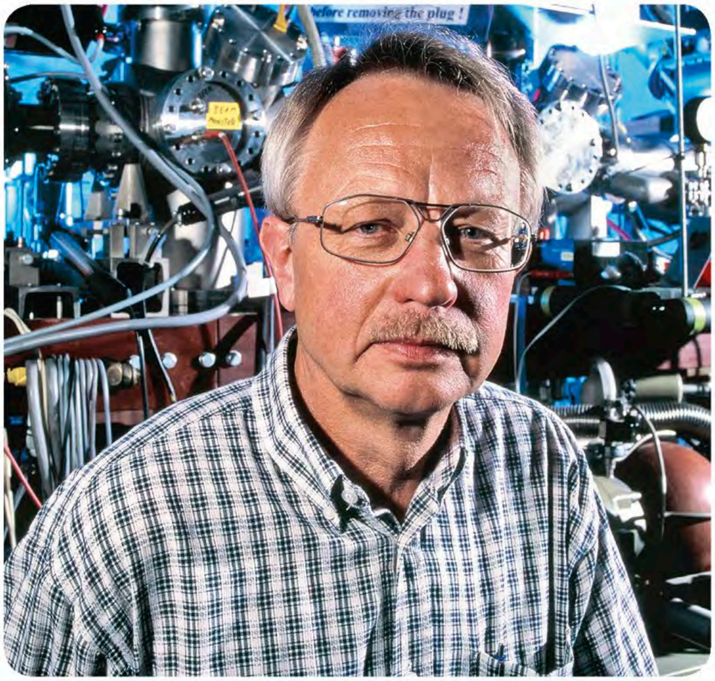

Sigurd Hofmann

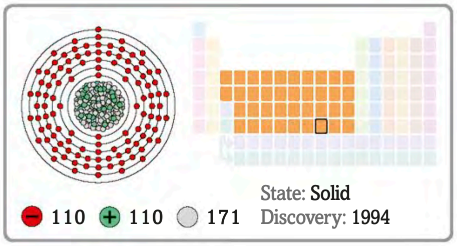

This artificial element is named after the German city of Darmstadt – the home of the Institute for Heavy Ion Research where this element was first produced. A team led by the German physicist **Sigurd Hofmann** created darmstadtium by smashing nickel atoms into lead atoms in a particle accelerator (a machine in which atoms are smashed together).

111

Rg

Roentgenium

Wilhem Röntgen

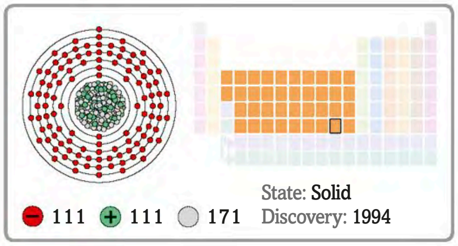

Scientists believe that this metal shares many characteristics with precious metals, such as gold and silver. However, its atoms break apart within seconds, so this has not yet been confirmed. Roentgenium was created in Darmstadt, Germany. It was named after **Wilhelm Röntgen**, the German scientist who discovered X-rays in 1895.

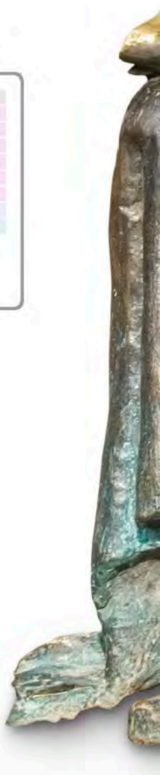

112
Cn

Copernicium

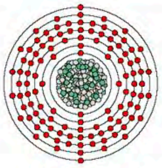

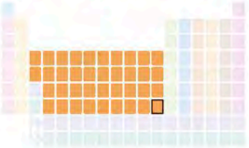

State: Solid
Discovery: 1996

Some scientists think copernicium could be the **only gaseous metal**.

Statue of Nicolaus Copernicus

This statue *stands in front of the Polish castle in which Copernicus lived.*

This German research institute *is where copernicium was discovered.*

Heavy Ion Research Centre, Germany

The atoms of this radioactive element survive only for a few minutes, before breaking down. Copernicium is created in particle accelerators by smashing together atoms of lead and zinc. Only a few atoms of this artificial element have ever been produced. Copernicium is named after **Nicolaus Copernicus**, the Polish astronomer who theorized that our planet orbits the Sun.

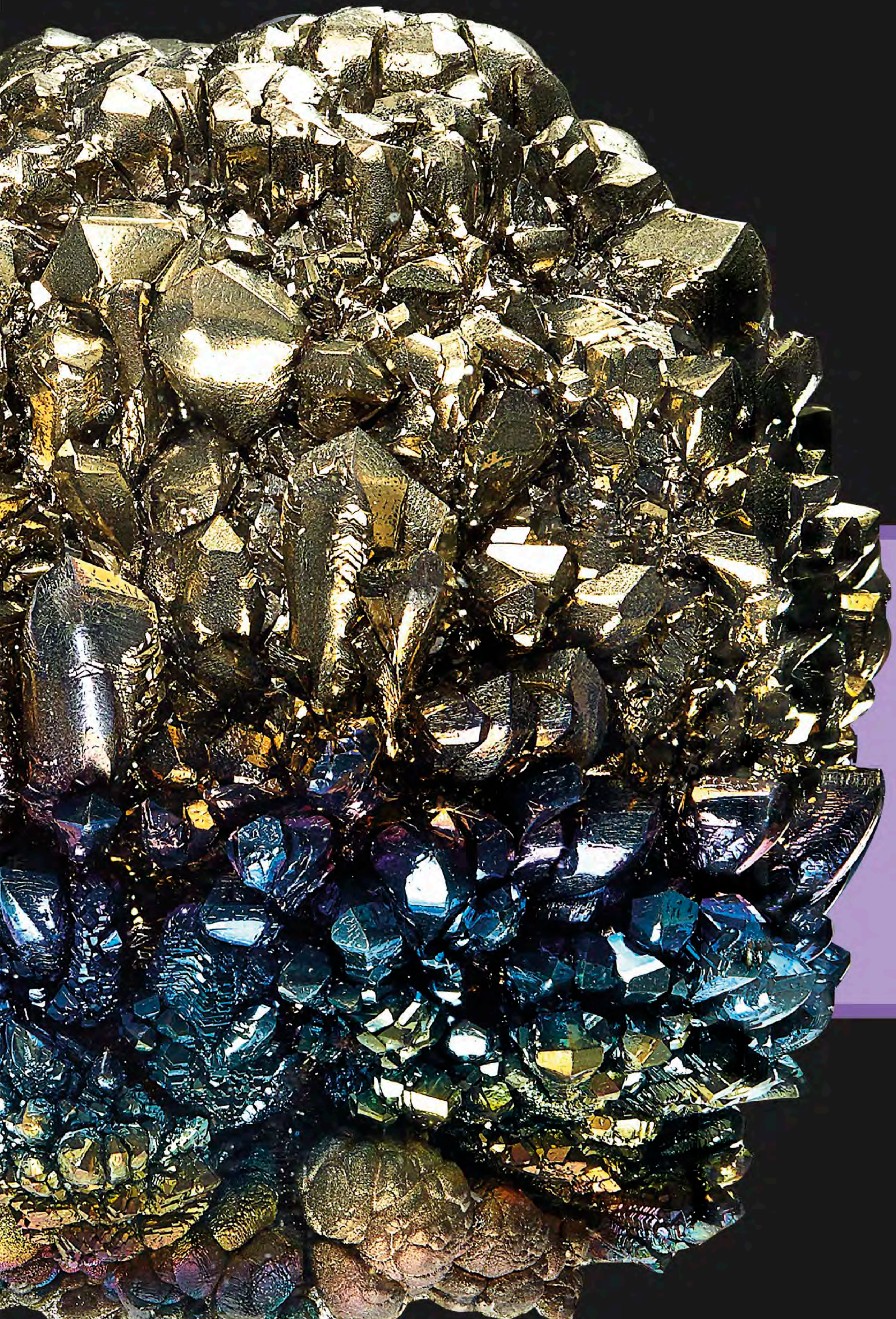

Europium's (Eu) colour changes when left in the air.

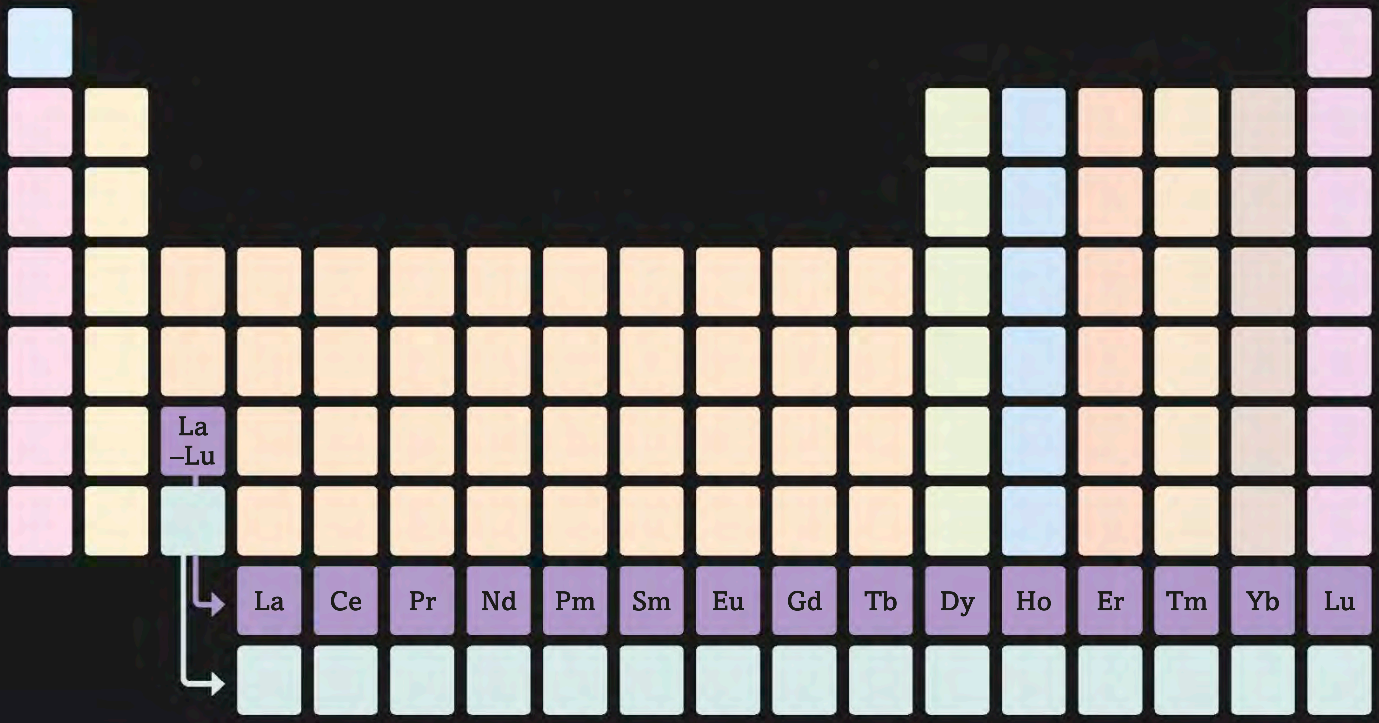

Lanthanides

This set is named after lanthanum, the first element in this series. The name “rare earth metals” is also given to these elements because they were discovered mixed together in complex minerals in Earth’s crust, and were thought to be uncommon. However, they are actually not rare but abundant. These metals – between barium (Ba) and hafnium (Hf) – should fit between the alkaline earth metals and the transition metals, but they are normally shown underneath the main table to save on space.

Atomic structure
Atoms of every element in this group have two outer electrons. The lanthanides have large atoms, all with six electron shells.

Physical properties
The lanthanides are dense, shiny metals, which tarnish easily when exposed to air. They do not conduct electricity very well.

Chemical properties
These elements react slowly with oxygen (O) at room temperature, but the reactions speed up when heated.

Compounds
Many lanthanides form compounds with oxygen called oxides. These are often used in lasers and magnets.

57 La Lanthanum

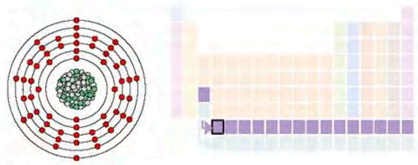

⊖ 57 ⊕ 57 ○ 82

State: Solid
Discovery: 1839

Forms

Bastnasite

This reddish-brown mineral *is also found in other colours, including white, tan, and grey.*

Lanthanum carbonate is used to treat patients with **kidney disease**.

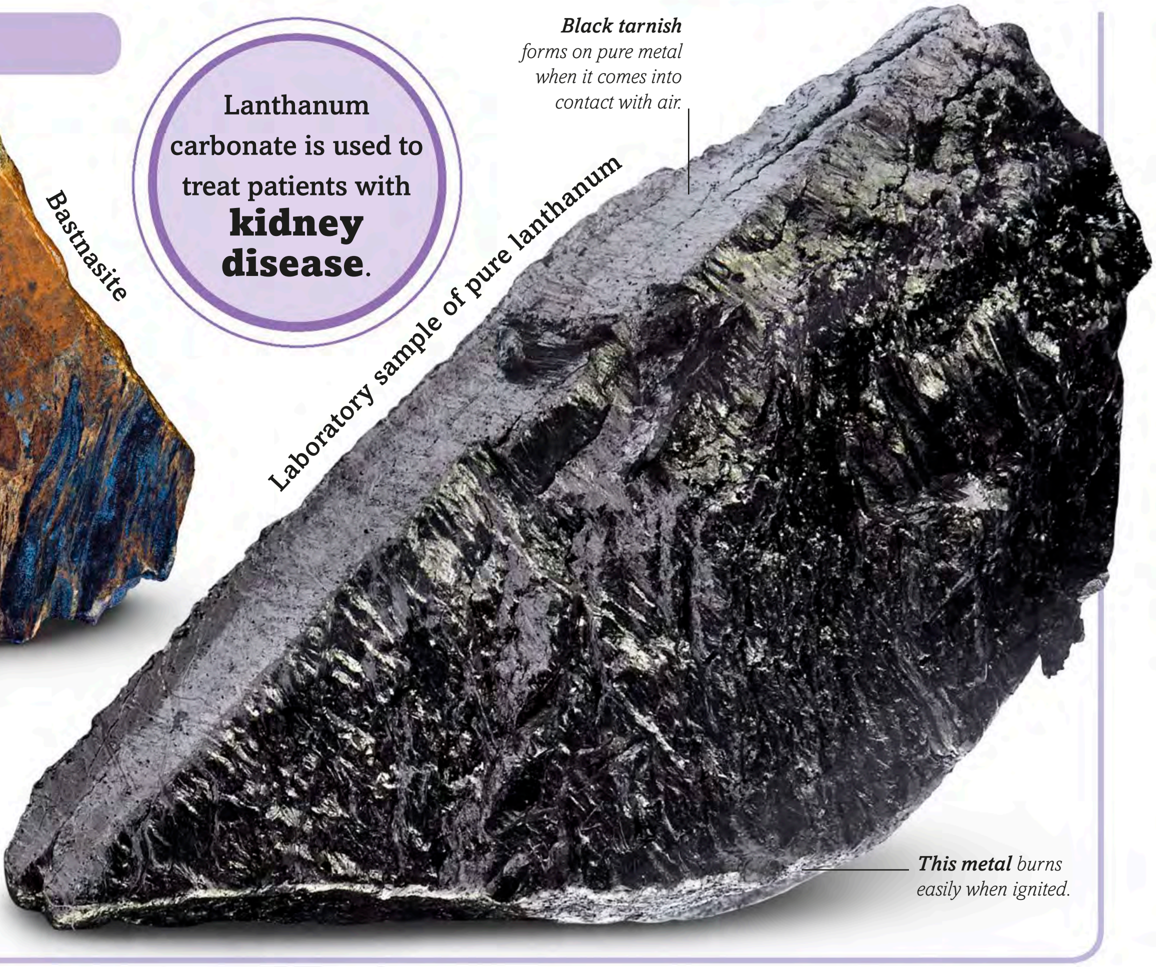

Laboratory sample of pure lanthanum

Black tarnish *forms on pure metal when it comes into contact with air.*

This metal *burns easily when ignited.*

Uses

Fluorescent lamp

This lamp *uses lanthanum to reduce the yellow colour in its light.*

Molten lanthanum

In its molten state*, lanthanum is used to smooth rough diamonds.*

Camera lens

This lens *can better focus light on an object due to the presence of lanthanum oxide in the glass.*

Although the word "lanthanum" means "to lie hidden", it is more abundant than most metals. For example, it is three times more common than lead. This element was discovered in the mineral cerite in 1839. However, it took chemists almost another 100 years to find a way to purify the metal. Today, the mineral **bastnasite** is a source of **pure lanthanum**. The element's applications range from its use in film studio lights and **lens-making** to refining petroleum.

58
Ce
Cerium

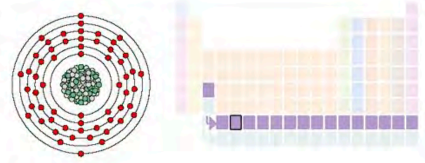

⊖ 58 ⊕ 58 ○ 82

State: Solid
Discovery: 1803

Cerium was the first of the lanthanides to be discovered. It is named after the dwarf planet Ceres, which was discovered two years before the element was isolated. Cerium is highly toxic when **pure**, but safer cerium compounds have some uses. The main use of cerium is in making phosphors, which are chemicals that produce lights of different colours. Phosphors are present in **flatscreen TVs** and bulbs.

Television

***The inside of this screen** is coated with cerium-containing phosphors, which emit red, green, and blue light.*

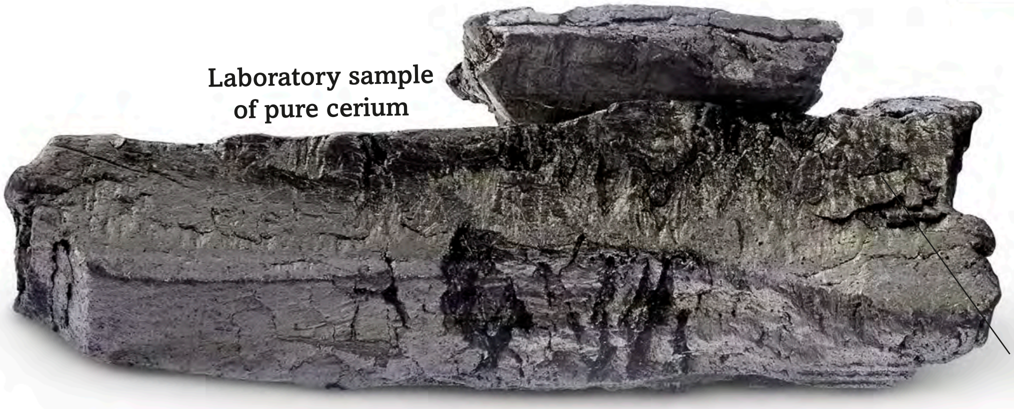

Laboratory sample of pure cerium

***The pure form** of the metal tarnishes on contact with air.*

Kitchen spatula

***This red colour** comes from a compound called cerium sulfide.*

59
Pr
Praseodymium

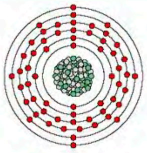

⊖ 59 ⊕ 59 ○ 82

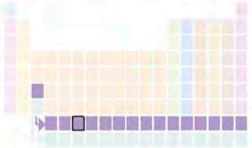

State: Solid
Discovery: 1885

Part of this element's name comes from *prasinos*, the Greek word for "green". Normally a grey colour when pure, the element reacts slowly on contact with air to form a green coating. Praseodymium compounds give a yellow colour to glass and heat-resistant **ceramics**, and provide a green colour to some **artificial jewels**. This element also boosts the strength of magnets that contain it.

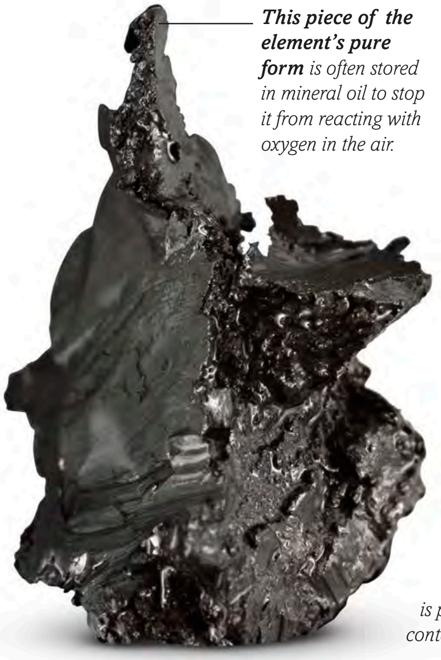

***This piece of the element's pure form** is often stored in mineral oil to stop it from reacting with oxygen in the air.*

Laboratory sample of pure praseodymium

Yellow ceramic pot

***This yellow colour** is produced by a solution containing praseodymium.*

Green cubic zirconia

***This artificial gem** gets its green colour from tiny amounts of a compound of praseodymium and oxygen.*

60 Nd Neodymium

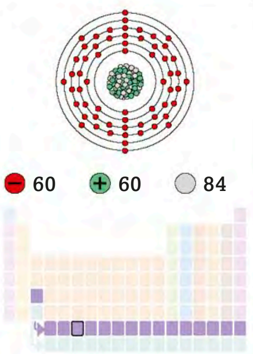

State: Solid
Discovery: 1885

***This glass** gets its colour from very tiny amounts of neodymium.*

Strong magnets made of neodymium can be used to lift thousands of times their own mass. This element was discovered in 1885 by the Austrian chemist Carl Auer von Welsbach, and it was originally used to colour glass. Small amounts of neodymium turn **glass** pinkish purple. Today, this element is also employed in lasers used in eye surgery.

Laboratory sample of pure neodymium

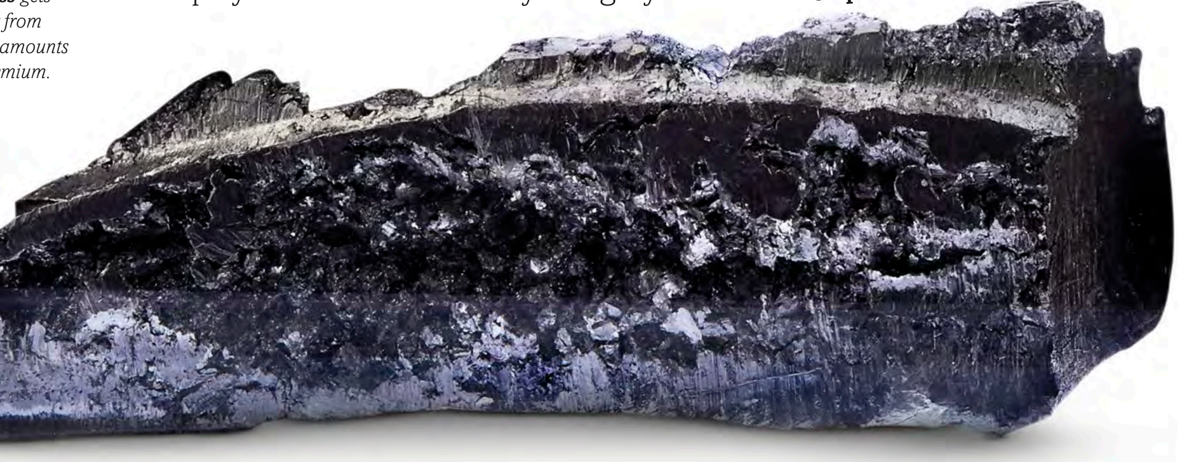

***The pure element** turns black when it reacts with air.*

---

61 Pm Promethium

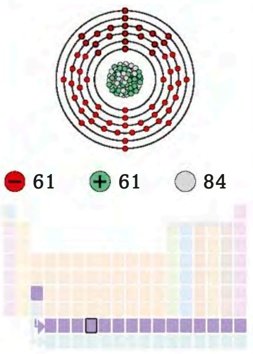

State: Solid
Discovery: 1945

***This paint** glows as a result of radioactive promethium.*

Promethium-rich paint in a tin seen from above

***This missile** uses radioactive promethium for electrical power.*

Missile

Promethium is the rarest lanthanide element. Any promethium that was in Earth's rocks decayed billions of years ago. Promethium is therefore produced artificially in nuclear reactors. Being very radioactive, it is used in some **missiles**, because it converts this radioactivity into electrical power. The addition of promethium also makes some **paints** glow in the dark.

62 Sm Samarium

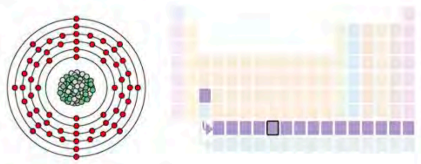

⊖ 62 ⊕ 62 ○ 88

State: Solid
Discovery: 1879

This element is named after the mineral samarskite from which it was first purified. However, another lanthanide-rich mineral called monazite is the main source of this element today. Samarium is mixed with cobalt to make permanent magnets that are often used in **electric guitars**.

Guitar pickups

These pickups *(components that sense vibrations produced by guitar strings) are made of samarium-cobalt magnets.*

Laboratory sample of pure samarium

This silvery white metal *darkens on contact with air.*

63 Eu Europium

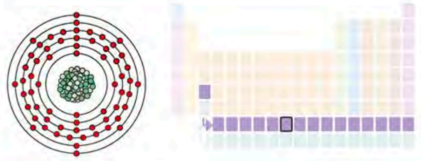

⊖ 63 ⊕ 63 ○ 89

State: Solid
Discovery: 1901

Europium was named after the continent of Europe. However, most of the world's supply of the element comes from the USA and China, where the mineral bastnasite is mined for the extraction of **pure europium**. A compound called europium oxide is used in euro and British bank notes. When placed under ultraviolet (UV) light, the compound gives off a red glow.

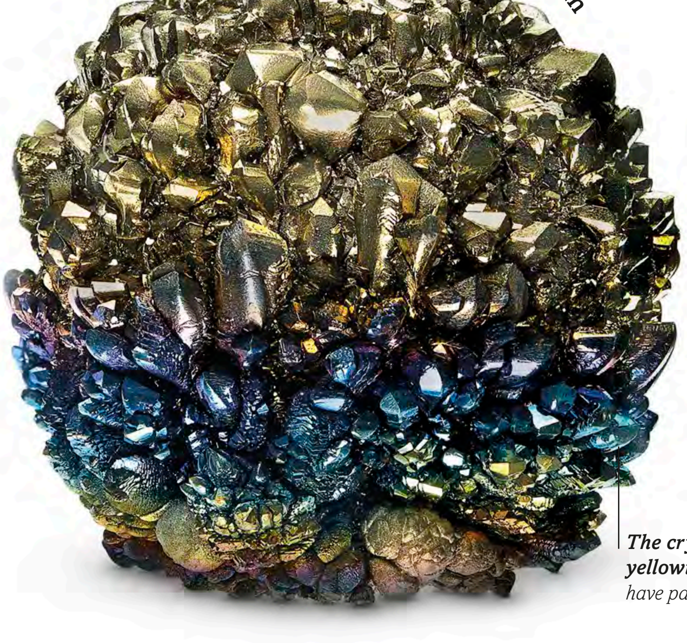

Laboratory sample of pure europium

The crystals of this yellowish metal *often have patches of dark oxides.*

Bank of England
I PROMISE TO PAY THE BEARER ON DEMAND THE SUM OF FIFTY POUNDS
50
E II R
Fifty

This red glow *proves this note is real.*

Section of British note under UV light

64 **Gd** Gadolinium

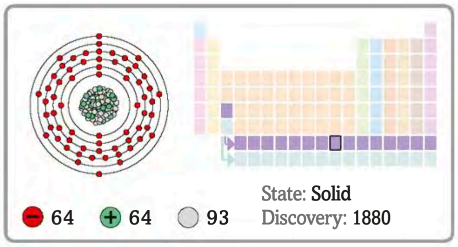

State: Solid
Discovery: 1880

Gadolinium, and its mineral ore gadolinite, are named after the Finnish chemist Johan Gadolin, who discovered the element. Gadolinium compounds are used to obtain clear **MRI scans**. It is also used in electronics, and to make rust-resistant steel.

***This soft, silvery metal** darkens when exposed to air.*

Laboratory sample of pure gadolinium

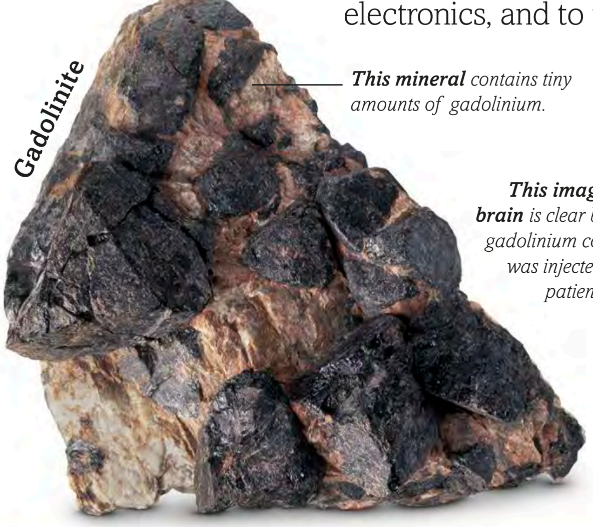

Gadolinite

***This mineral** contains tiny amounts of gadolinium.*

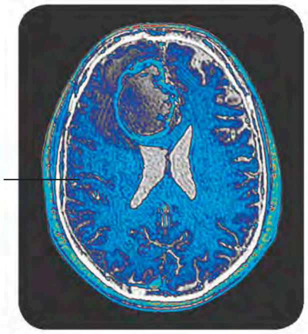

***This image of the brain** is clear because a gadolinium compound was injected into the patient's blood.*

MRI scan of the human brain

65 **Tb** Terbium

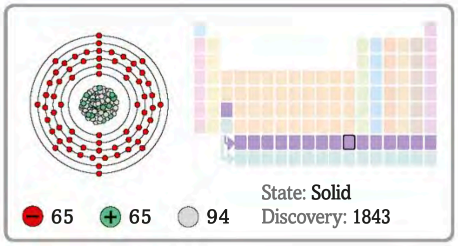

State: Solid
Discovery: 1843

Terbium is named after the village of Ytterby in Sweden. It is a silvery metal that can be obtained from the ore monazite. This element has only a few uses. **Pure terbium** is added to other metals to make powerful magnets used in sound-producing devices, such as the **SoundBug™**. Its compounds are used to line **mercury lamps**.

soundbug
OLYMPIA

SoundBug™ device

***This device** uses magnets to turn any flat surface, like a window, into a loudspeaker.*

***The mercury vapour in this lamp** produces ultraviolet light when electrified, and this is turned into a bright yellow glow by terbium.*

Mercury lamp

***The pure metal** is soft enough to be cut with a knife.*

Laboratory sample of pure terbium

66
Dy
Dysprosium

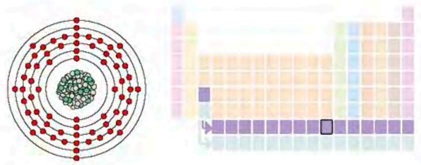

⊖ 66 ⊕ 66 ○ 97
State: Solid
Discovery: 1886

Dysprosium reacts more easily with air and water than most other lanthanide metals. Although it was discovered in 1886, it took until the 1950s to purify it. This metal is often used with neodymium to produce magnets that are used in **car batteries**, wind turbines, and generators.

Fergusonite

This mineral *contains tiny amounts of dysprosium.*

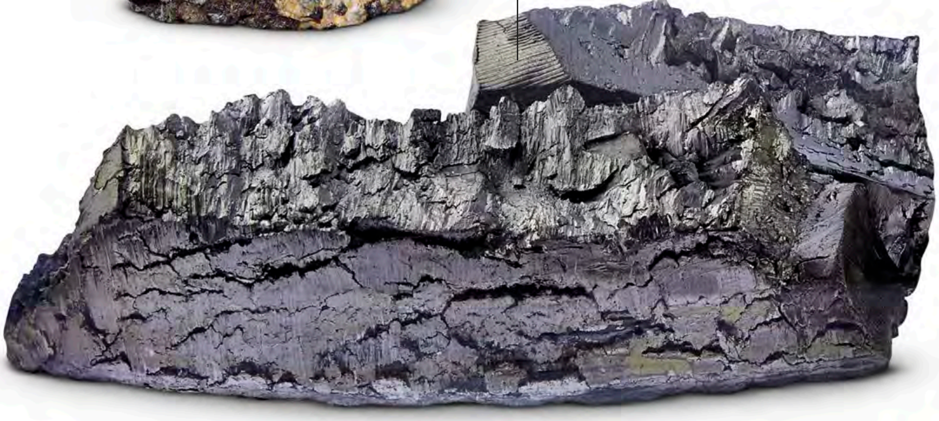

This pure metal *remains shiny at room temperature.*

Laboratory sample of pure dysprosium

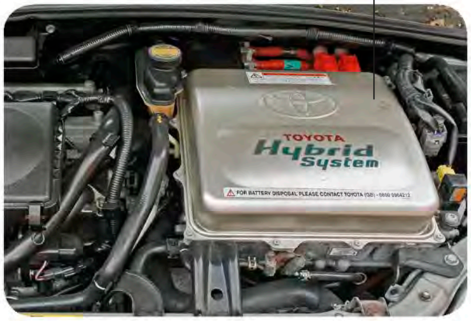

Some hybrid car batteries *contain dysprosium.*

Hybrid car battery

67
Ho
Holmium

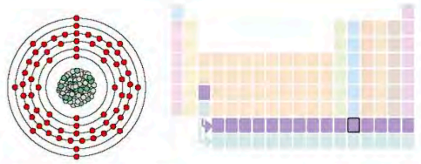

⊖ 67 ⊕ 67 ○ 98
State: Solid
Discovery: 1878

The Swedish chemist Per Teodor Cleve named holmium after the Swedish city of Stockholm. Pure holmium can produce a strong magnetic field and is therefore used in magnets. Its compounds are used to make lasers, and to colour glass and artificial jewels, such as **cubic zirconia**.

This artificial gemstone *is coloured red by small amounts of holmium.*

Red zirconia gemstone

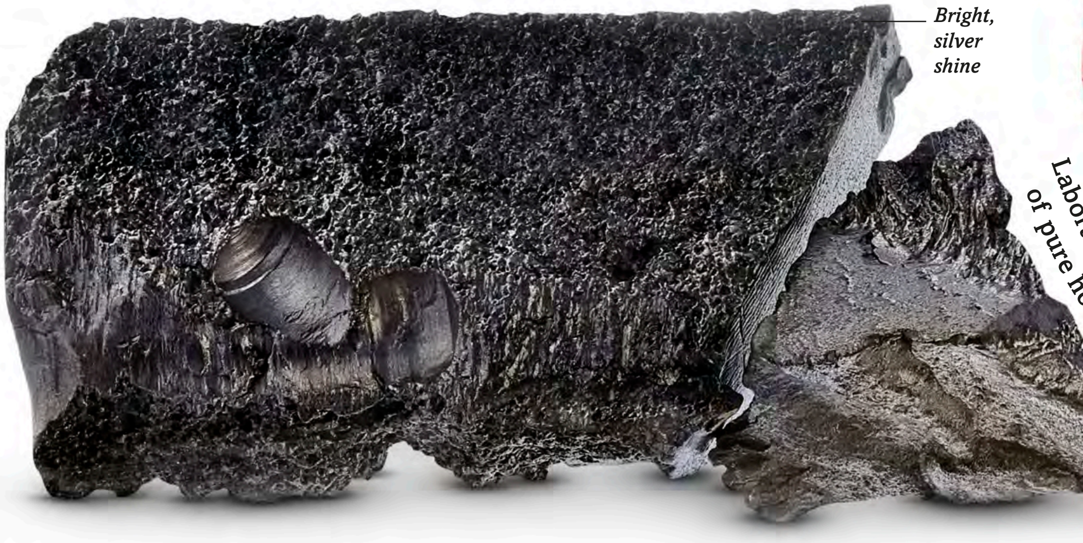

Bright, silver shine

Laboratory sample of pure holmium

68

Er

Erbium

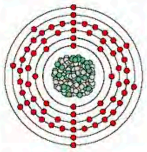

⊖ 68 ⊕ 68 ○ 99

State: Solid
Discovery: 1843

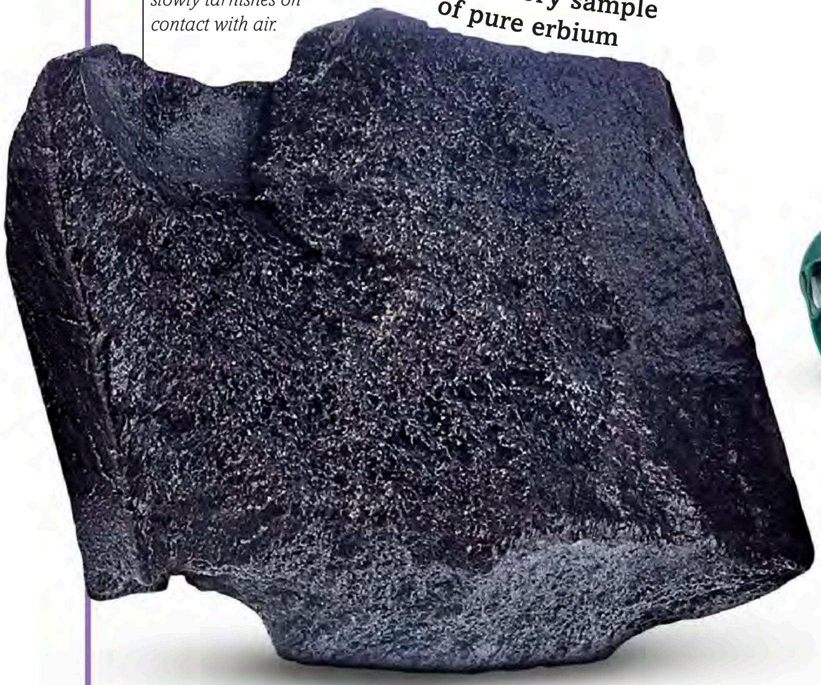

***This silvery element** slowly tarnishes on contact with air.*

Laboratory sample of pure erbium

***This glass** contains erbium, which protects a welder's eyes from heat and bright light.*

Welding goggles

***The rose pink finish** of this vase is from an erbium chloride glaze.*

Pink pottery

Like terbium and ytterbium, erbium is also named after the Swedish village of Ytterby, near which it was discovered. This element does not occur in its **pure form** in nature, but it can be obtained from the mineral monazite. Many erbium compounds are pink in colour and are used to colour **pottery** and glass.

69

Tm

Thulium

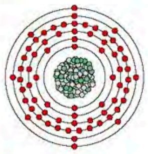

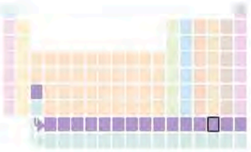

⊖ 69 ⊕ 69 ○ 100

State: Solid
Discovery: 1879

Laboratory sample of pure thulium

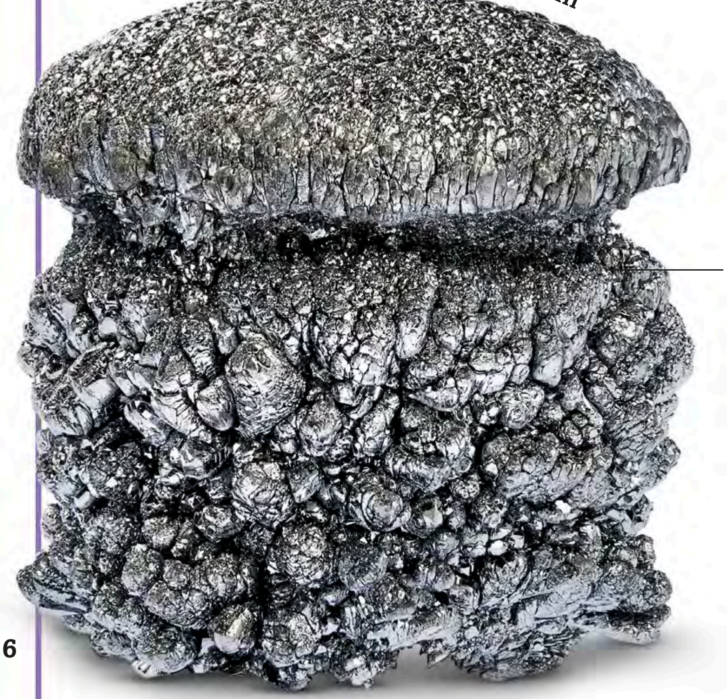

***This soft metal** glows blue under ultraviolet (UV) light.*

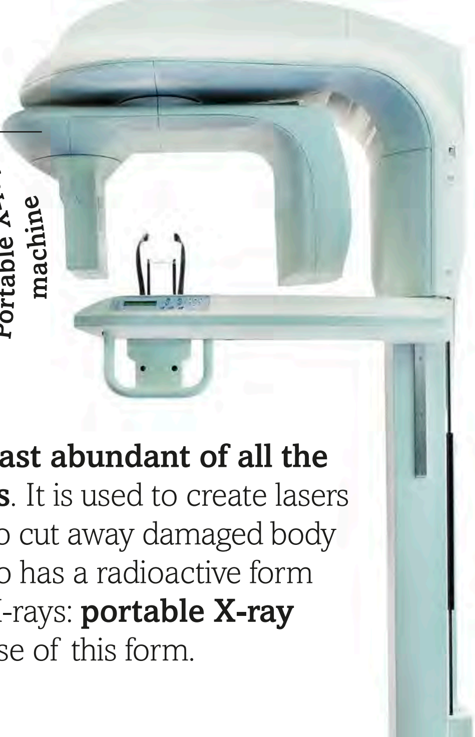

***This machine** emits X-rays using a very small amount of thulium.*

Portable X-ray machine

Thulium is the least abundant of all the lanthanide metals. It is used to create lasers that surgeons use to cut away damaged body tissue. Thulium also has a radioactive form that can produce X-rays: **portable X-ray machines** make use of this form.

70 Yb Ytterbium

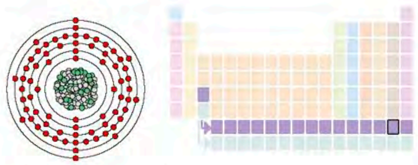

⊖ 70 ⊕ 70 ○ 103 State: Solid Discovery: 1878

Ytterbium tends to be more reactive than other lanthanide metals. It is stored in sealed containers to stop the metal from reacting with oxygen. The **pure metal** has only a few uses. A small amount of ytterbium is used in making steel, while its compounds are used in some **lasers**.

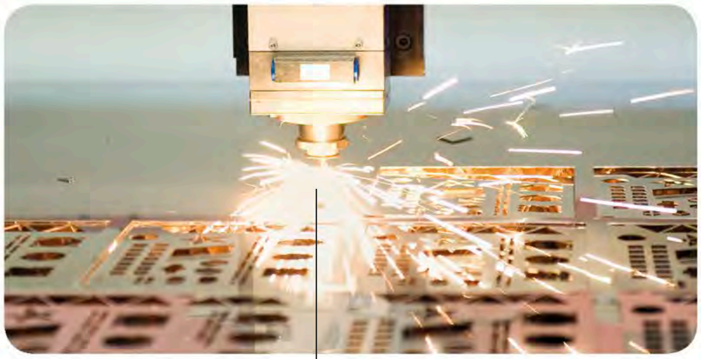

Laser cutting

An ytterbium laser *can cut through metals and plastics.*

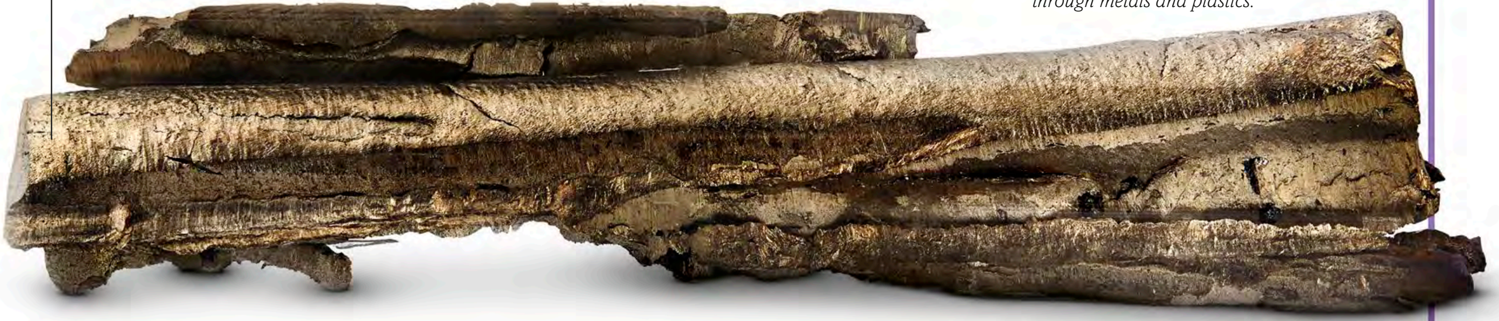

Laboratory sample of pure ytterbium

This bright, shiny metal *can be hammered into thin sheets.*

71 Lu Lutetium

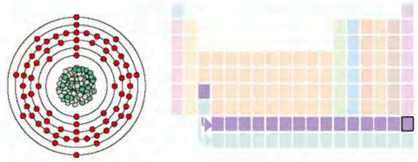

⊖ 71 ⊕ 71 ○ 104 State: Solid Discovery: 1907

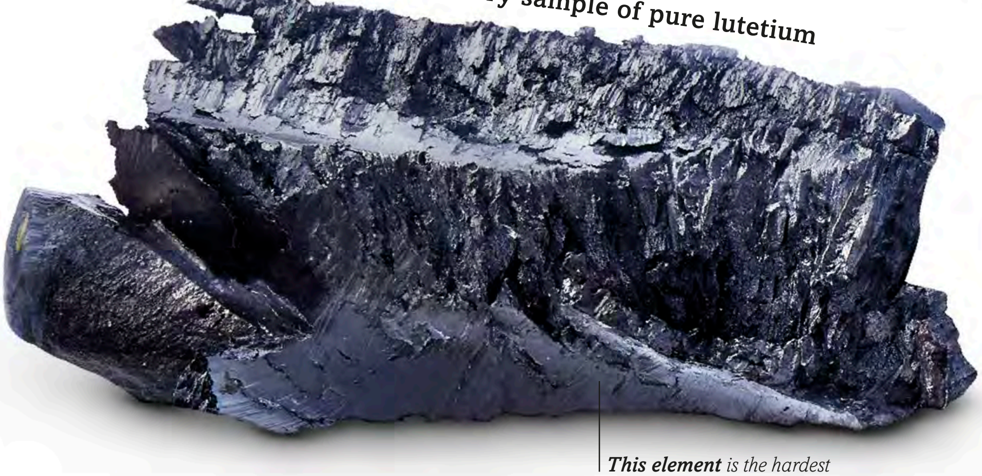

Laboratory sample of pure lutetium

This element *is the hardest and densest lanthanide metal.*

Lutetium was the last of the rare earth metals to be discovered. It is also the final member of the lanthanides. In its **pure form**, lutetium is very reactive and catches fire easily. It is rare and has few uses, mainly as a substance mixed with crude **oil**.

Oil refinery

Some oil refineries *use lutetium to break down crude oil to make fuels, such as petrol and diesel.*

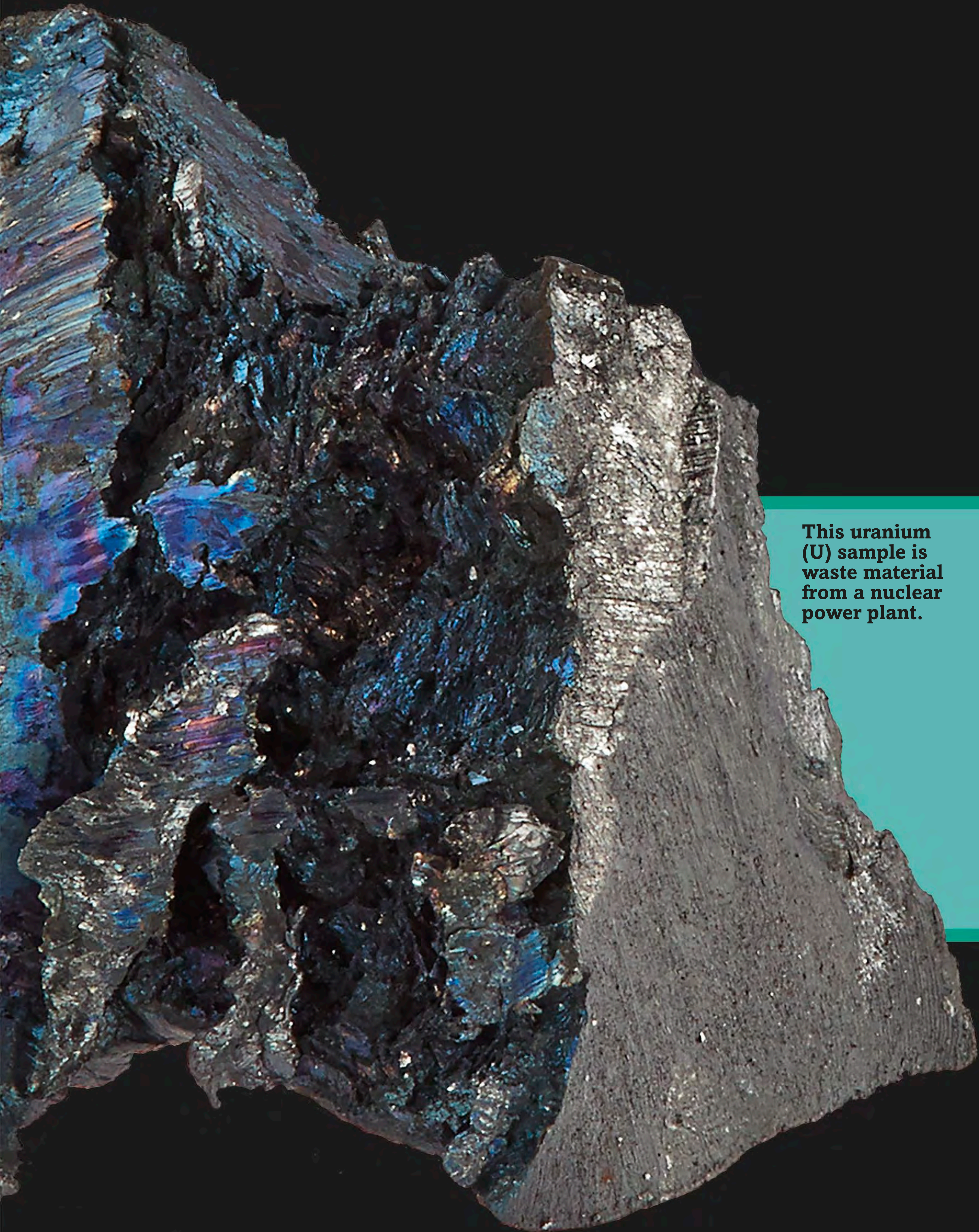

This uranium (U) sample is waste material from a nuclear power plant.

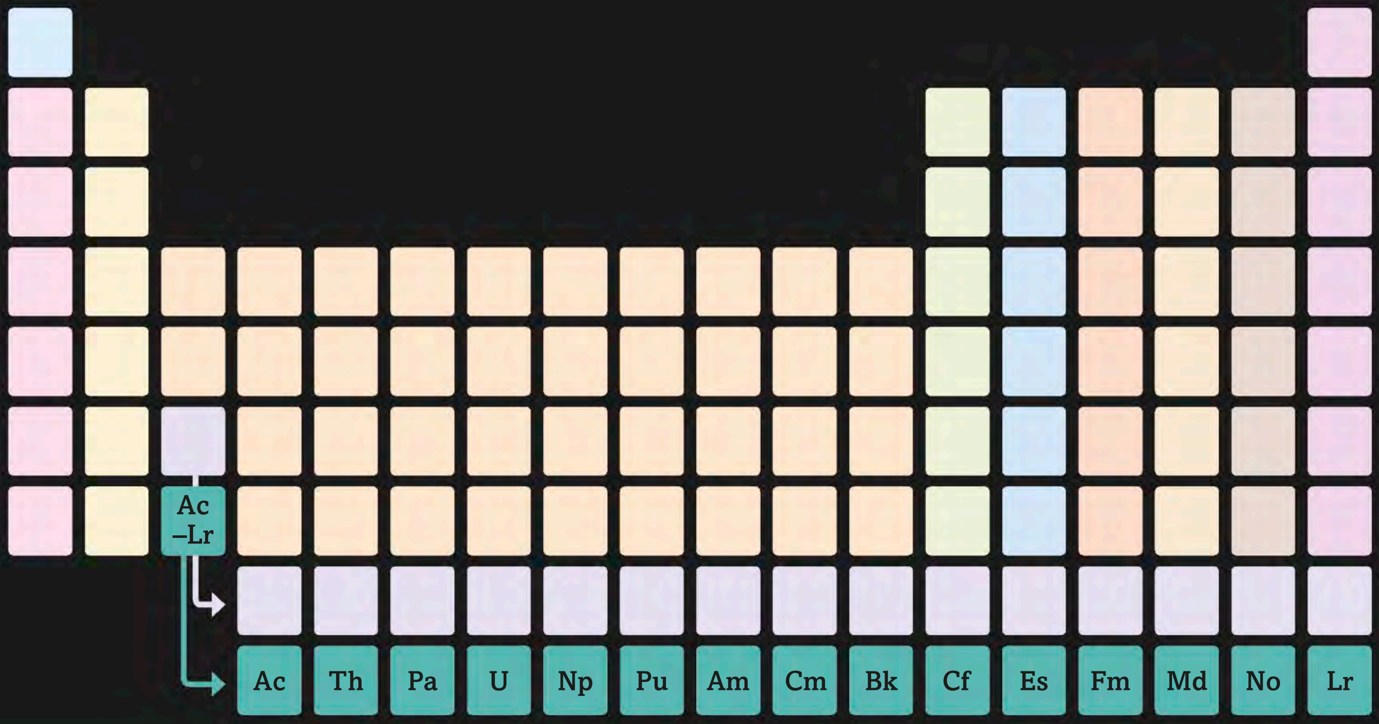

Actinides

These metals are named after actinium (Ac), the first member of the group. Although this group is often shown as the bottom row in the periodic table, to save space, they actually sit between radium (Ra), an alkali earth metal, and Rutherfodium (Rf), a transition metal. All the elements in this group are radioactive, and the final nine members are artificially produced in laboratories.

Atomic structure
All the elements in this group have two electrons in their outer shell. Their atoms all have seven electron shells.

Physical properties
Natural actinides are dense metals with high melting points. The physical properties of most of the artificial ones are unknown.

Chemical properties
The actinides are reactive metals and are never found in pure form in nature. They react easily with air, the halogens, and sulfur (S).

Compounds
Actinides form colourful compounds with halogens. Most actinide ores also contain compounds of oxygen (0) called oxides.

89 Ac Actinium

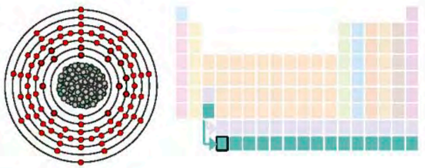

⊖ 89 ⊕ 89 ○ 138

State: Solid
Discovery: 1899

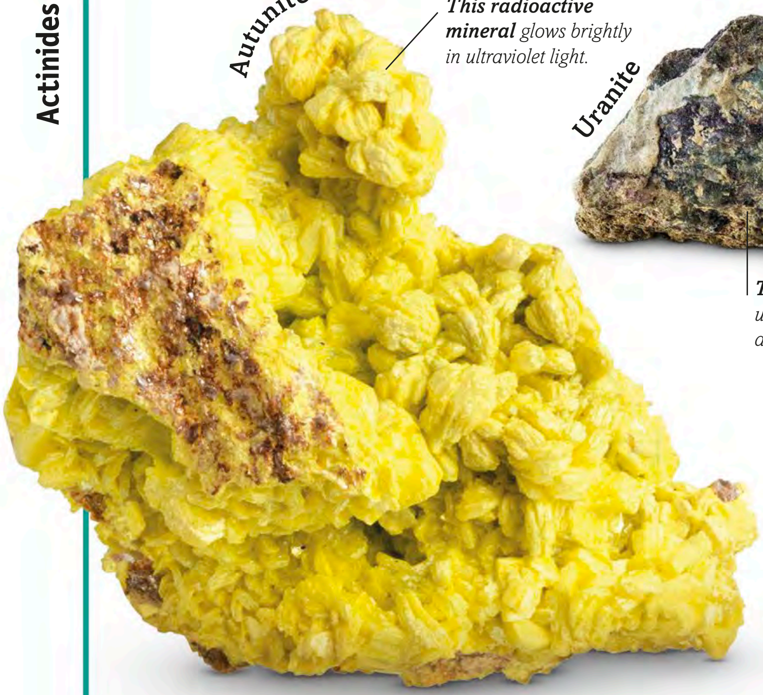

Autunite

This radioactive mineral *glows brightly in ultraviolet light.*

Uranite

This ore *contains uranium, which breaks down into actinium.*

This device *uses radioactive actinium to measure the amount of water.*

Neutron probe

Rare in nature, actinium is a metal formed by the decay of other radioactive elements. Its atoms are unstable and break down to make the elements francium and radon. Actinium is found in tiny amounts in uranium ores, such as **uranite**, and has limited applications. Its isotopes are used in radiation therapy to treat cancer.

90 Th Thorium

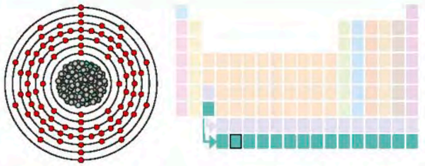

⊖ 90 ⊕ 90 ○ 142

State: Solid
Discovery: 1829

Monazite

This durable rock *made of solidified lava contains 12% thorium.*

The most common natural radioactive metal, thorium is used inside vacuum tubes to allow an electric current to flow. It can also undergo nuclear fission, a process in which atoms split in two and release energy. Scientists are exploring ways of making thorium-powered nuclear reactors that produce electricity.

Thorianite

This ore *contains small crystals of thorium compounds.*

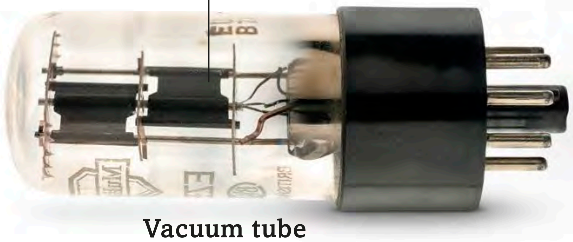

This thorium coating *creates an electric current by releasing electrons.*

Vacuum tube

91 Pa Protactinium

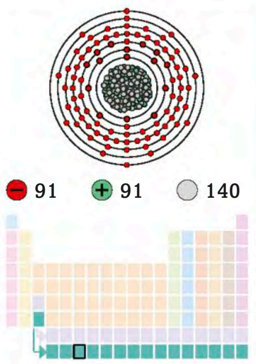

State: Solid
Discovery: 1913

This vibrant green radioactive mineral *contains tiny amounts of protactinium.*

This brittle, shiny ore *feels waxy.*

Torbernite

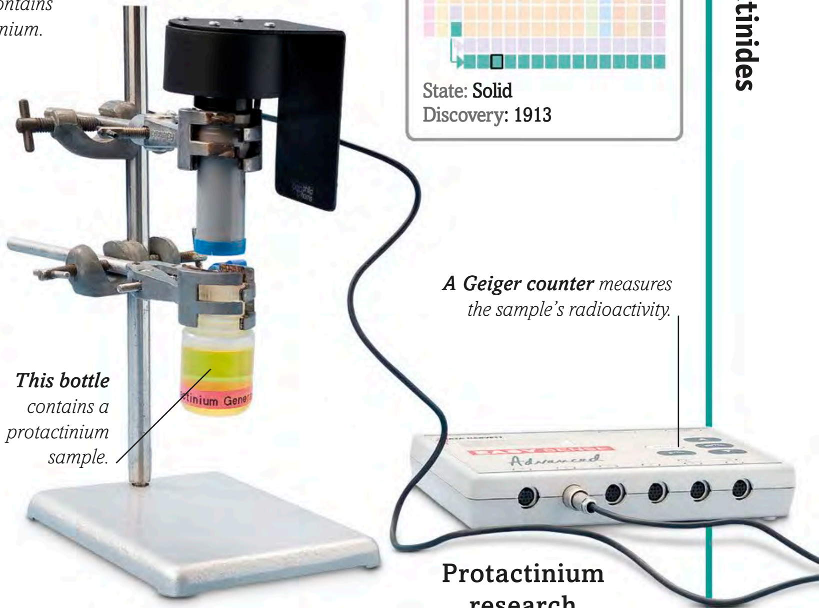

This bottle *contains a protactinium sample.*

A Geiger counter *measures the sample's radioactivity.*

Protactinium research

The name protactinium means "before actinium". This is because a uranium atom decays to form a protactinium atom, which then quickly breaks down into an actinium atom. Small quantities of protactinium are found in ancient sands and mud. Geologists use Geiger counters to carry out **research** to calculate how old the sands are.

These used nuclear fuel rods *contain protactinium.*

Nuclear waste

92 U Uranium

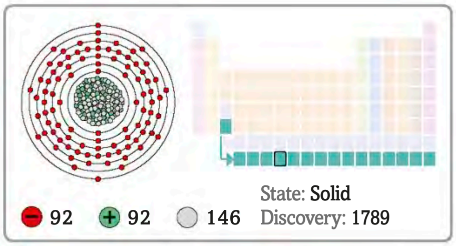

Named after the planet Uranus, uranium was the first known radioactive element. In the early 20th century, some manufacturers used uranium in **glass bowl** glazes, only to realize later that it was a harmful metal. An unstable form, called uranium-235, is used as fuel in nuclear reactors and in atomic bombs.

Chunk of pure uranium

*This sample of **pure uranium** is waste from a nuclear plant.*

These black sections contain uranium dioxide, which is the main source of uranium.

Uraninite

*Uranium mixed into **glass** makes this bowl glow bright green under ultraviolet (UV) lamps.*

Glass bowl

93 Np Neptunium

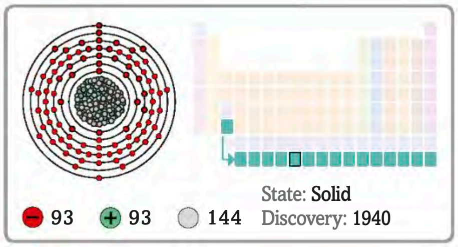

*The **radioactive elements** in this mineral decay to form neptunium.*

Uraninite

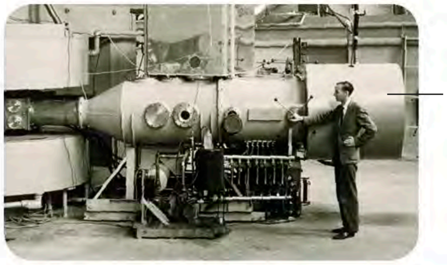

Cyclotron at the University of California, Berkeley, USA

*This **cyclotron**, built in 1938, was used to discover neptunium.*

Sitting next to uranium in the periodic table, neptunium was named after the planet Neptune. It exists in small amounts in radioactive ores, such as aeschynite. It forms during nuclear explosions and was first identified inside a machine called a **cyclotron**. There are no known uses for neptunium.

94

Pu

Plutonium

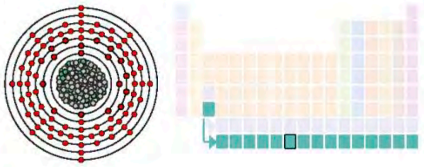

⊖ 94 ⊕ 94 ○ 239

State: Solid
Discovery: 1940

Hardly any plutonium exists in nature: most of it has decayed into other elements over time. It was discovered during the development of nuclear bombs in World War II. Today, plutonium is used mostly as a nuclear fuel.

This ore *contains trace amounts of plutonium.*

This plutonium battery *was used in early pacemakers.*

CAUTION
RADIOACTIVE - PLUTONIUM -238
LESS THAN 3 CURIES 1973
DO NOT DISCARD. CONTACT
NUCLEAR BATTERY CORP
COLUMBIA, MARYLAND
DATE OF MANUFACTURE 1973

1970's pacemaker battery

This Martian rover *uses the heat given off by a supply of plutonium to generate electrical power.*

Curiosity Rover

95

Am

Americium

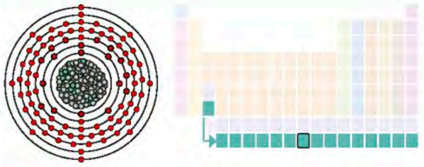

⊖ 95 ⊕ 95 ○ 148

State: Solid
Discovery: 1944

This metallic element is not found in nature. Instead, it is produced inside nuclear reactors when uranium or plutonium atoms are bombarded with neutrons. Remarkably, americium is the most common radioactive element used in the home. Radioactivity emitted by americium atoms causes the air inside **smoke detectors** to conduct electricity. When smoke disrupts the electric current, an alarm goes off.

Smoke detector component

This smoke detector *contains tiny, harmless quantities of americium.*

96 Cm Curium

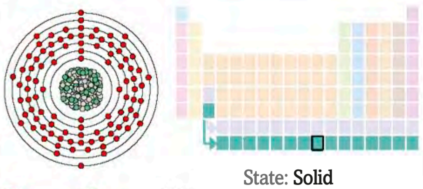

⊖ 96 ⊕ 96 ○ 151

State: Solid
Discovery: 1944

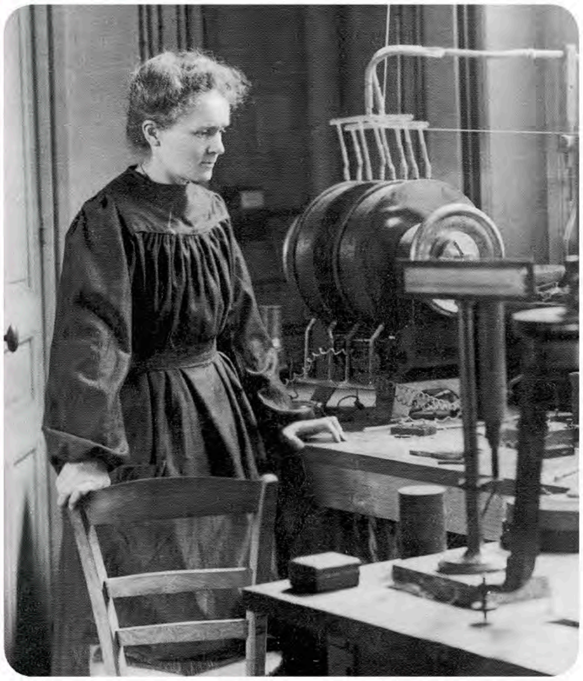

Marie Curie working in her laboratory

This lander studied the surface composition of the comet 67P.

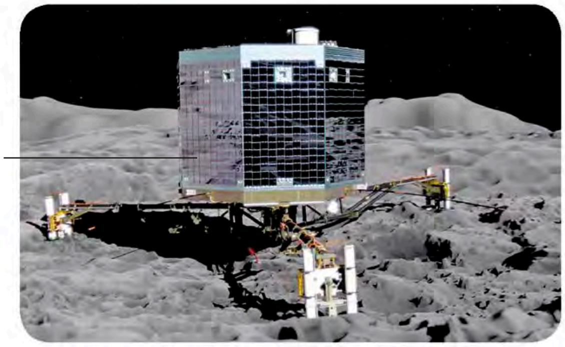

Philae lander

Curium is a silvery, radioactive metal that glows reddish purple in the dark. This element was discovered by the US scientist Glenn T Seaborg at the University of California. It was named after **Marie Curie**, the scientist who discovered the element polonium. Several space probes, such as the **Philae comet lander**, use X-ray devices containing curium to study their environment.

97 Bk Berkelium

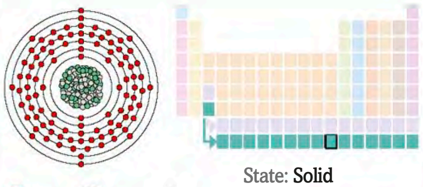

⊖ 97 ⊕ 97 ○ 150

State: Solid
Discovery: 1949

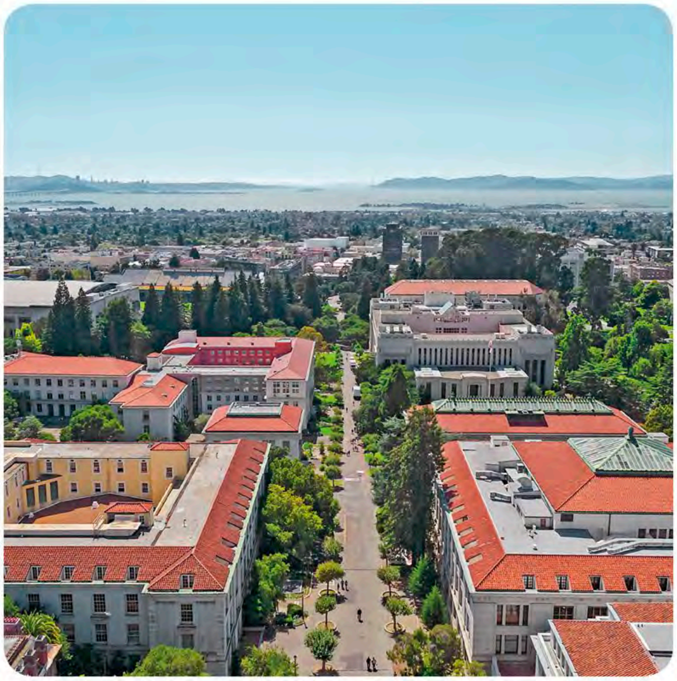

University of California, Berkeley campus, USA

This element was named after the city of Berkeley – home to the University of California – where this artificial element was discovered. It was first synthesized by **Glenn T Seaborg**. Berkelium has no uses other than the creation of heavier elements, such as tennessine.

Seaborg helped develop the atom bomb, but **opposed using it** in World War II.

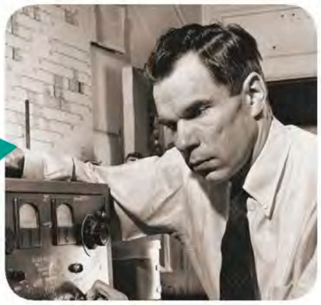

Glenn T Seaborg

98 Cf Californium

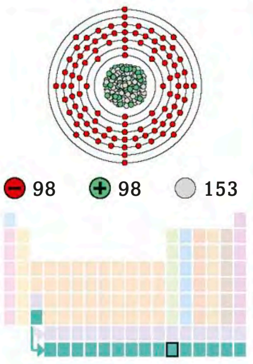

State: Solid
Discovery: 1950

Water detector

This machine uses californium to find water underground.

Pellets of radioactive californium

This isotope, or form, of californium produces a lot of neutrons.

Californium is named after the US state of California. This soft, silvery metal does not exist in nature and is made by smashing berkelium atoms with neutrons in a particle accelerator (a machine in which atoms are smashed together). This **radioactive element** is used in the treatment of cancer.

99 Es Einsteinium

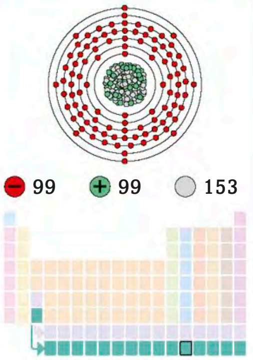

State: Solid
Discovery: 1952

Albert Einstein in his study

Only a **few milligrams** of einsteinium are made **every year**.

Einsteinium was discovered in the chemicals left over after the first hydrogen bomb test in 1952. The huge explosion fused smaller atoms together to make larger ones, including einsteinium. This element was named after the great German-born scientist **Albert Einstein**, and was found to be a silvery, radioactive metal that glows blue in the dark. It is only used for making heavier elements, such as mendelevium.

100 Fm Fermium

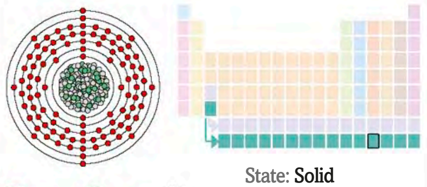

⊖ 100 ⊕ 100 ○ 157

State: Solid
Discovery: 1953

This artificial element was named after the Italian scientist Enrico Fermi. He built the first nuclear reactor in 1942, starting the American effort to build nuclear weapons during World War II. Fermium was first identified in the debris of an atom bomb test in 1953. This unstable element has no known uses beyond research.

Some scientists call Enrico Fermi the "father of the **atomic age**".

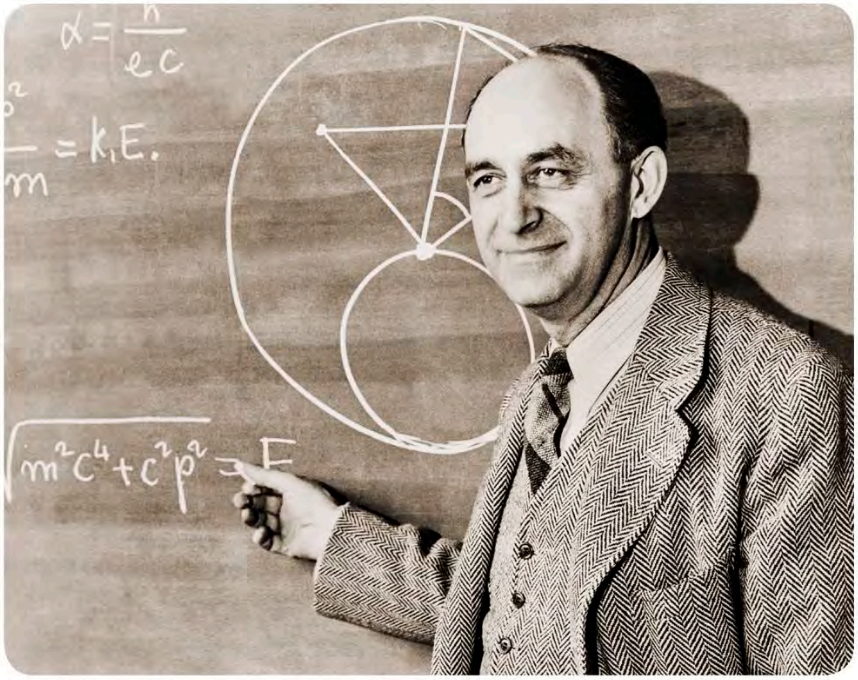

Enrico Fermi

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101 Md Mendelevium

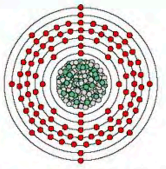

⊖ 101 ⊕ 101 ○ 157

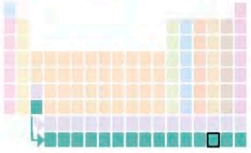

State: Solid
Discovery: 1955

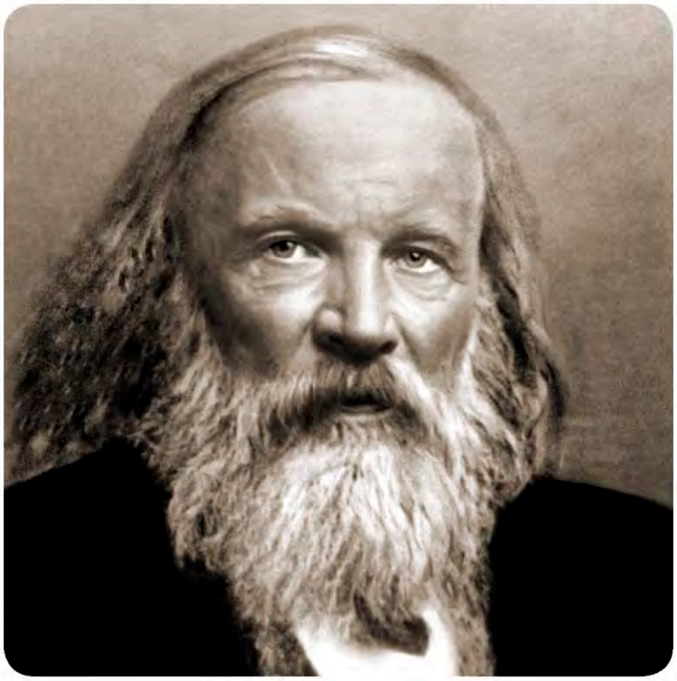

Dmitri Mendeleev

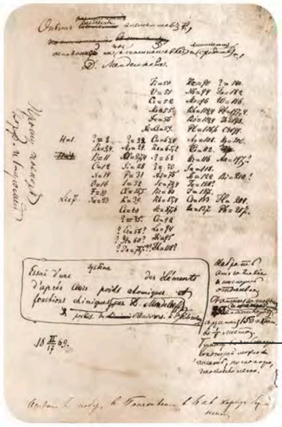

Mendeleev's periodic table

***Mendeleev's notes** from 1869 show his method of arranging elements in columns and rows.*

Mendelevium is named after the Russian chemist Dmitri Mendeleev, who invented the periodic table. Mendelevium is produced in very small amounts by firing parts of helium atoms at einsteinium atoms in a particle accelerator (a machine in which atoms are smashed together).

102 No Nobelium

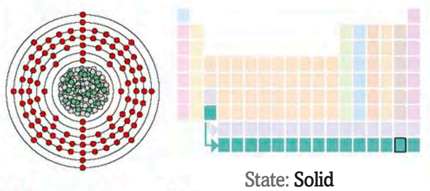

⊖ 102 ⊕ 102 ○ 157

State: Solid
Discovery: 1963

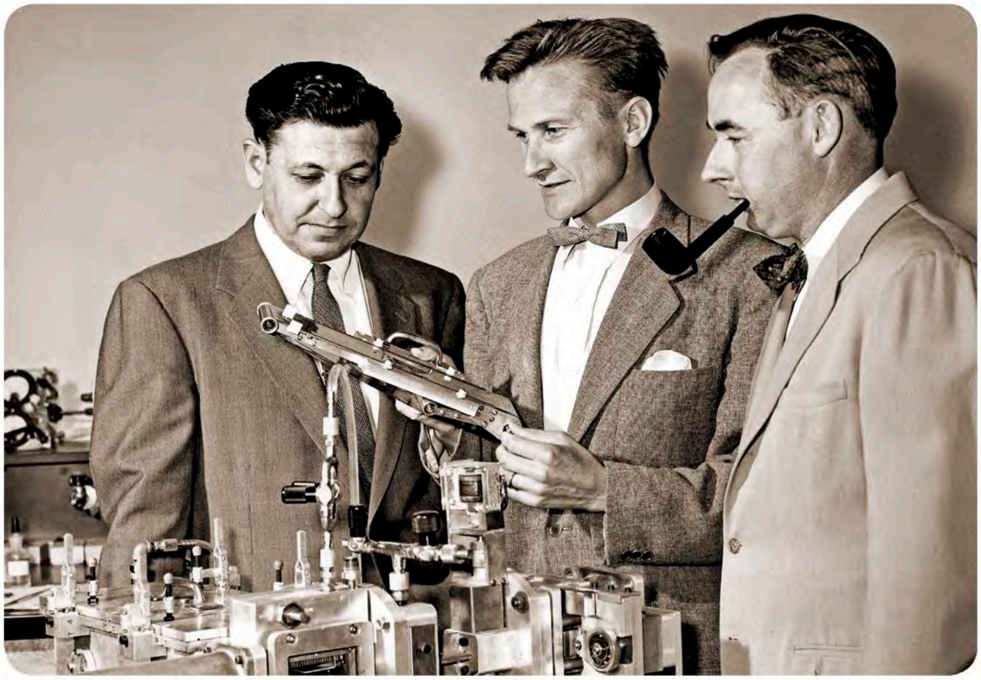

Albert Ghiorso, Torbjørn Sikkeland, and John R Walton

This artificial metal is named after the Swedish chemist Alfred Nobel, who started the Nobel Prize. It was discovered in 1963 by a team of scientists working in California, USA. This team included **Albert Ghiorso**, **Torbjørn Sikkeland**, and **John R Walton**. They used a particle accelerator to fire carbon atoms at curium atoms, creating nobelium atoms, which broke apart within minutes.

---

103 Lr Lawrencium

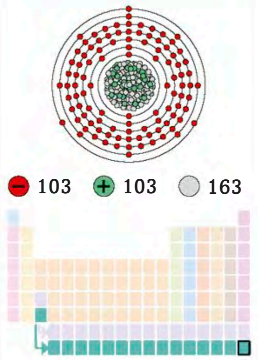

⊖ 103 ⊕ 103 ○ 163

State: Solid
Discovery: 1965

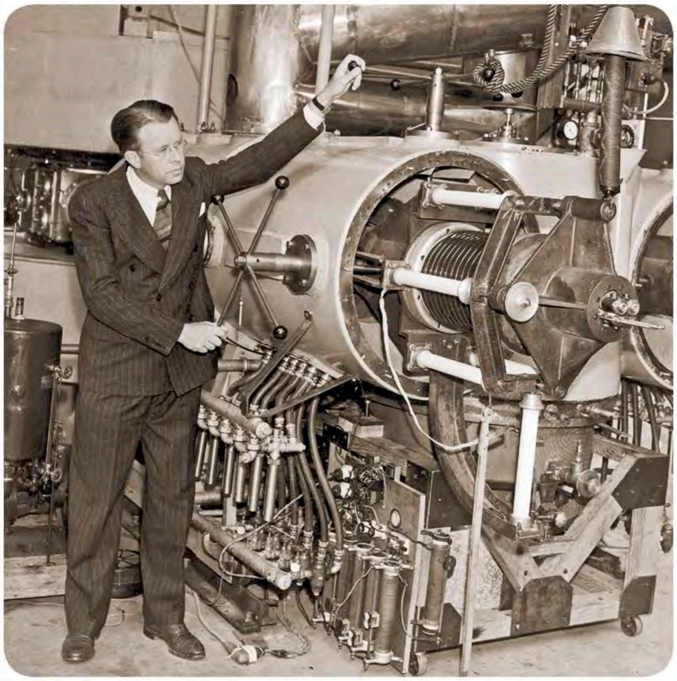

An early cyclotron

Lawrencium was produced at the **Berkeley lab** set up by Ernest Lawrence.

Lawrencium is named after the US scientist Ernest Lawrence, who developed the first cyclotron particle accelerator. This is a machine in which parts of atoms are smashed together by making them spin round in circles. Lawrencium atoms were produced in a similar machine by firing boron atoms at californium atoms.

Pure gallium (Ga) becomes liquid at 29°C (84.2°F).

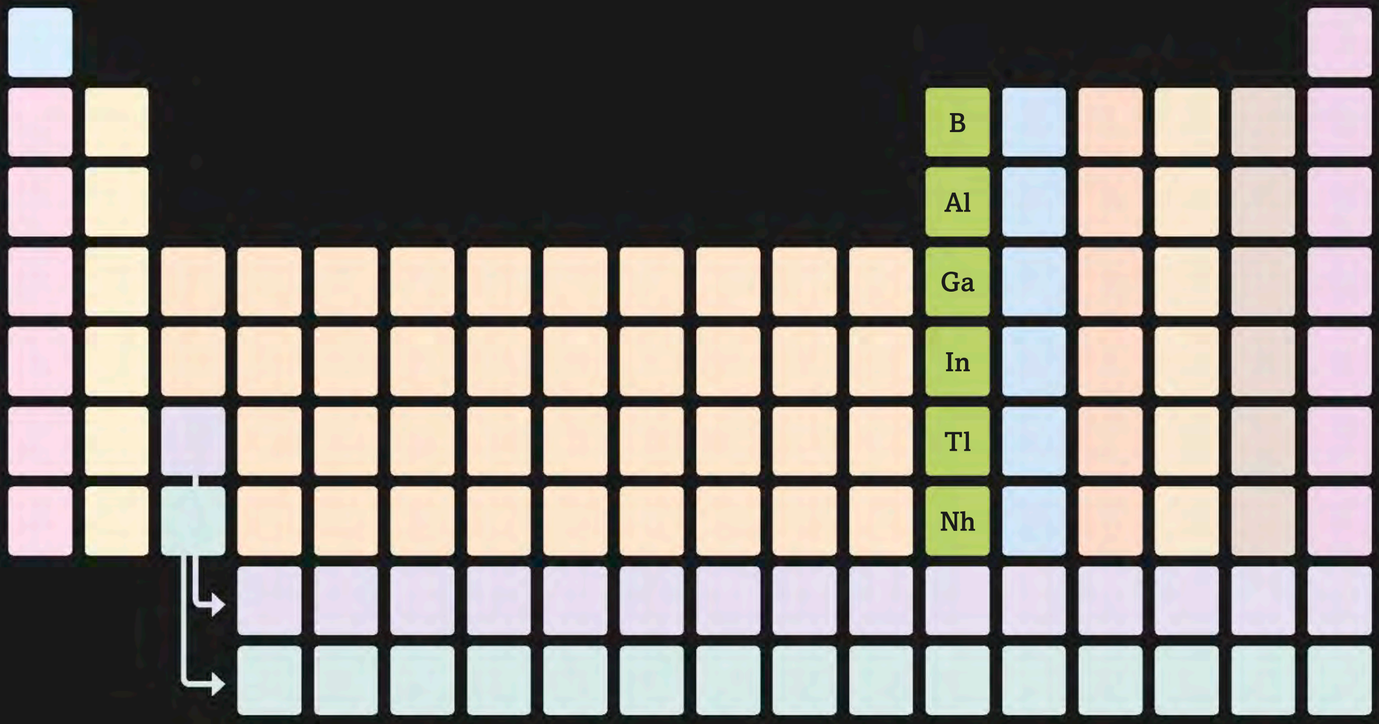

The Boron Group

This group contains five natural elements and one artificial element called nihonium (Nh). Although these elements are not very reactive, none of them are found in a pure form in nature. Boron (B), the first member, is a semi-metal (an element that has properties of both metals and non-metals), while the rest are metals. The second member, aluminium (Al), is the most common metal in Earth's rocks.

Atomic structure
Members of this group have three electrons in the outer shell of every atom. Some elements have unstable isotopes.

Physical properties
All elements, except boron, are shiny solids. Every member of this group is soft, except for boron (B), which is one of the hardest elements.

Chemical properties
Most of the elements don't react with water. Aluminium (Al) forms an oxide layer in water, and can react with it when this layer is corroded.

Compounds
They form compounds by losing electrons to other elements. All of them react with oxygen (O) by bonding to three oxygen atoms.

5 B Boron

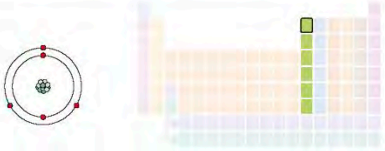

⊖ 5 ⊕ 5 ○ 6

State: Solid
Discovery: 1808

Forms

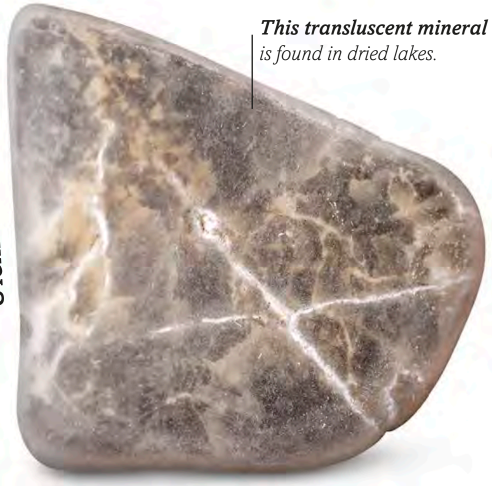

Ulexite

This translucent mineral *is found in dried lakes.*

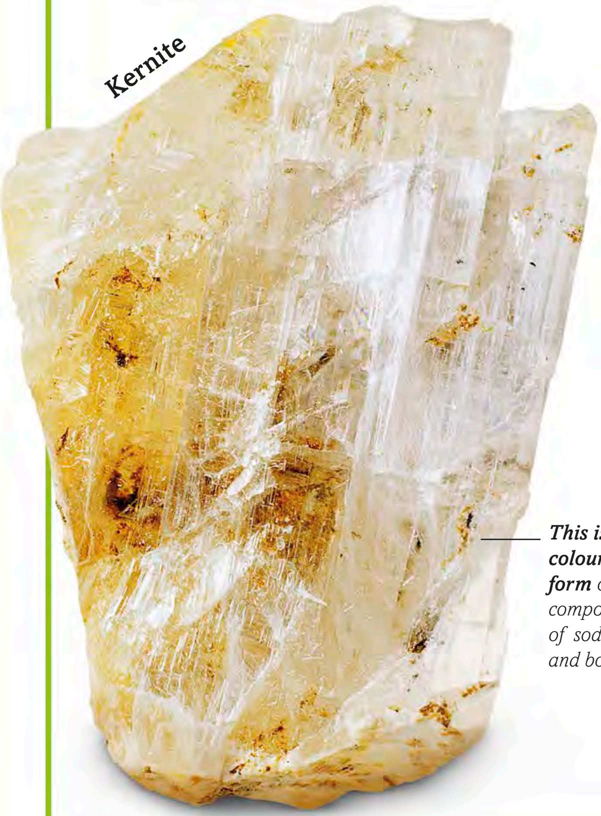

Kernite

This is a colourless form *of a compound of sodium and boron.*

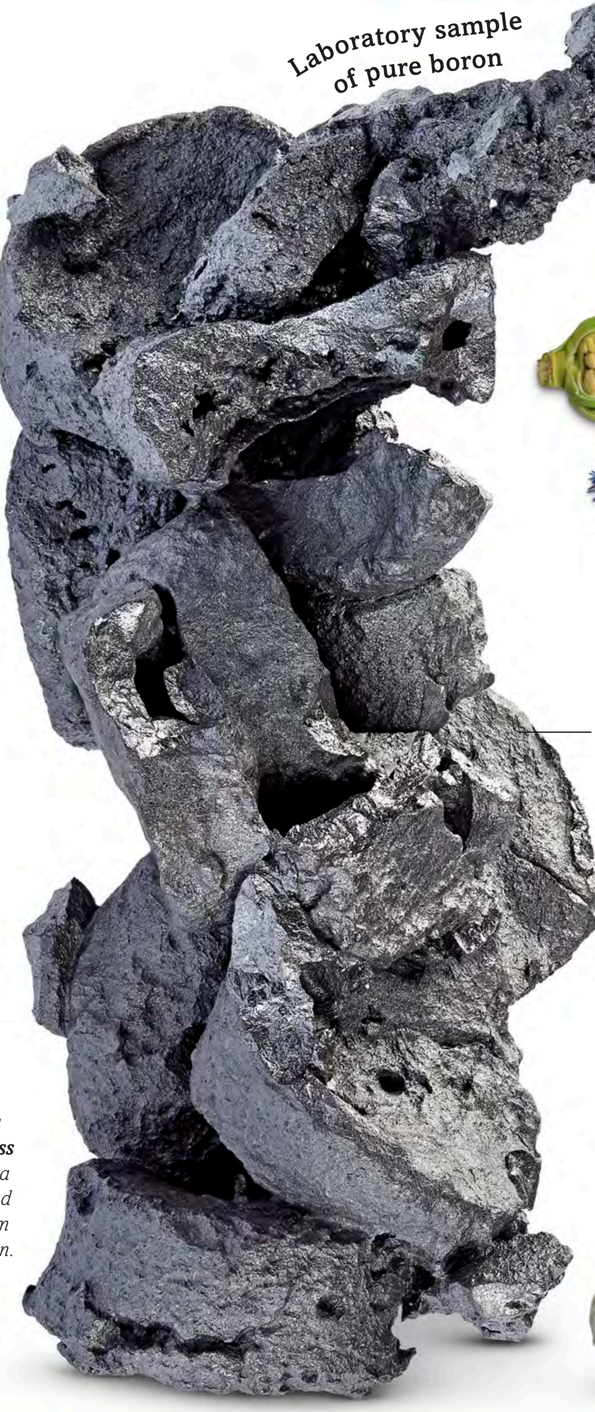

Laboratory sample of pure boron

This metal *is dark and slightly shiny.*

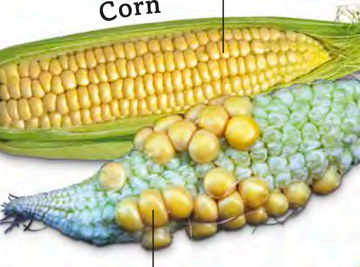

Corn

Boron-rich corn

Boron-deficient corn *does not grow properly.*

Colemanite

Some boron compounds are among the toughest artificial substances on Earth, with only diamond being harder. This element is a very hard material and becomes even harder when made to react with carbon or nitrogen. **Pure boron** can be extracted from various minerals, including **ulexite** and **kernite**. The demand for this element was once so high that people moved to live in the extreme heat of **Death Valley, USA**, to work in boron mines there. Compounds of boron in soil are essential for plants to grow healthily. We use boron in our homes every day.

This searing desert *is one of the main places on Earth where boron is found.*

Death Valley, USA

Needle- and leaf-shaped crystals

Uses

2 CUPS
1 PINT LIQUID
16 OZ.
1½
12
CUP
8
½
4

Measuring cup

This tough glass *contains boron oxide.*

Boric acid

These white crystals *are obtained from sodium borate.*

LCD screen

This screen *is composed of boron-rich glass, which makes it scratch-resistant.*

This clay *is bouncy but also firm because it contains boron.*

Modelling clay

Boron carbide is one of the **hardest** materials in use today.

The protective body of this tank *contains boron carbide, a compound of boron and carbon.*

Military tank

IIB
CHURCHILL
IIB

THÉNARD AND GAY-LUSSAC

The salt sodium borate, also called borax, was already in use 1,000 years ago. In 1808, the Frenchmen Joseph Louis Gay-Lussac and Louis Jacques Thénard isolated pure boron by heating borax with potassium.

Louis Jacques Thénard
Born into a poor family, Thénard excelled as a scientist. He also discovered a compound called hydrogen peroxide.

Joseph Louis Gay-Lussac
This French chemist is also remembered for discovering that the pressure of a gas goes up with its temperature.

Tough, heat-resistant glassware, such as **measuring cups**, are strengthened with boron. **Boric acid** is a natural antiseptic and can be used to treat minor cuts and scrapes. A flexible layer of boron-based glass fibres is used to toughen thin **LCD screens** for televisions and laptops. Even some kinds of **modelling clay** and bouncy silly putty contain boron compounds. Boron is named after a crumbly white salt called borax, which is used in detergents. The element is also present in a diverse range of objects, from insecticides to armour for **military tanks**.

13

Al

Aluminium

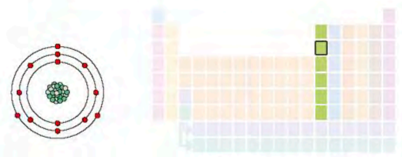

⊖ 13 ⊕ 13 ○ 14

State: **Solid**
Discovery: **1825**

Forms

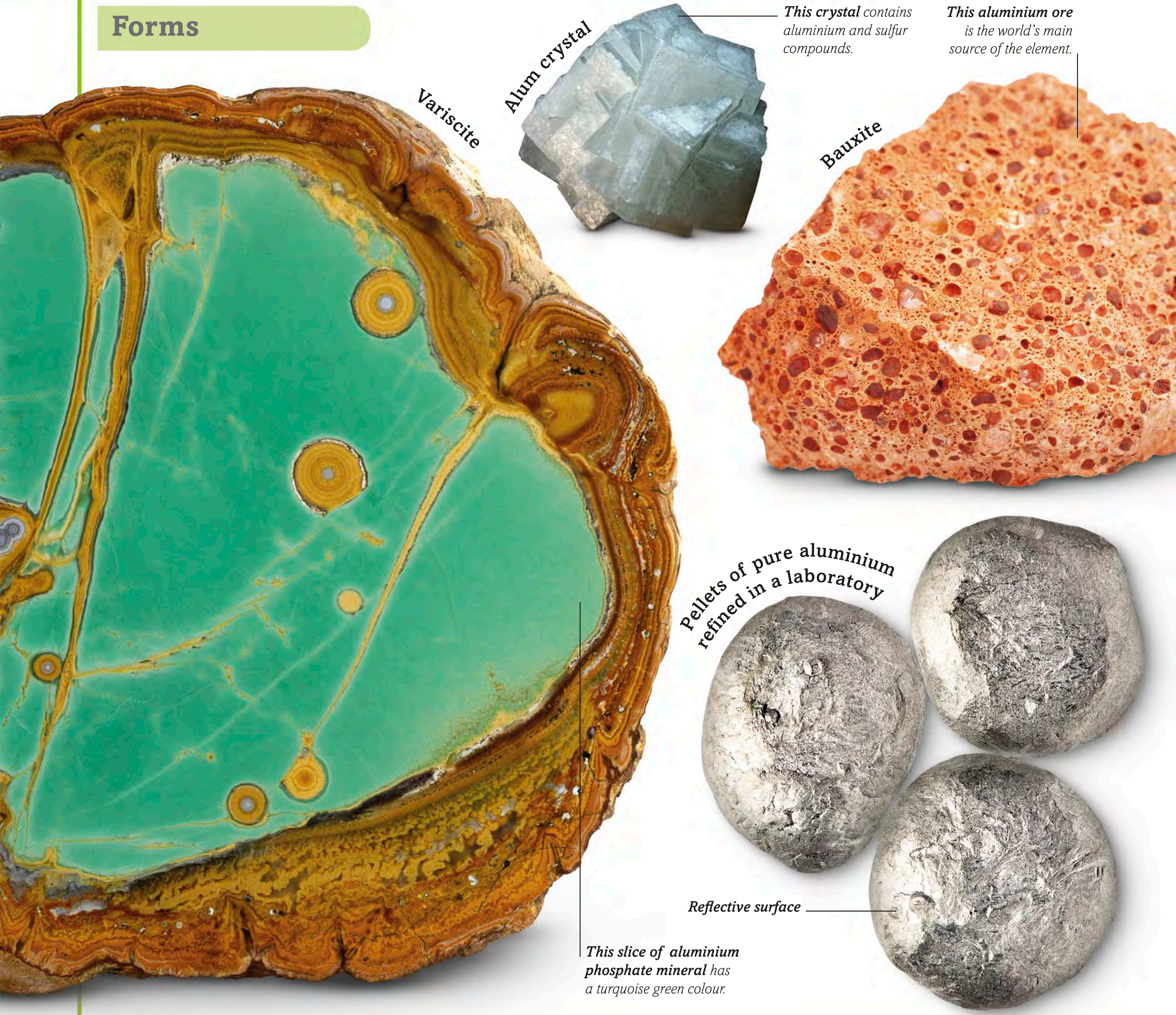

This crystal *contains aluminium and sulfur compounds.*

This aluminium ore *is the world's main source of the element.*

Reflective surface

This slice of aluminium phosphate mineral *has a turquoise green colour.*

Although aluminium is the most common metal in Earth's rocks, scientists did not discover it until the early 1800s. Even then, it took a further 80 years for scientists to work out how to use the ore **bauxite** to extract large amounts of **pure aluminium**. It can also be found in other minerals, including **variscite**. Today, aluminium is often recycled because producing it anew requires 15 times more energy. The metal makes a strong, shiny **foil** when rolled flat, and is useful for storing foods. A **fire protection suit** made from

Uses

Tennis racket

This aluminium frame *makes the racket light.*

Aluminium foil

This foil *does not break even as it is bent and twisted.*

Fire protection suit

This suit *protects against temperatures up to 1,000°C (1,800°F).*

Aluminium can

This can *is produced from recycled aluminium.*

RECYCLING ALUMINIUM

Aluminium is expensive to purify, so it is often recycled instead. Drinks cans are almost 100 per cent pure aluminium and can be shredded, melted down, and made into new cans.

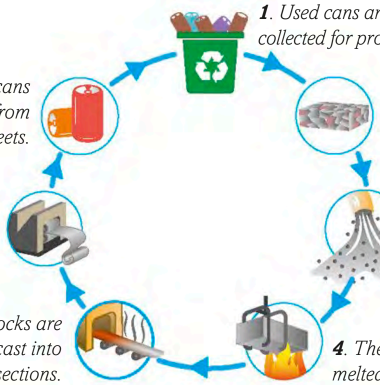

1. Used cans are collected for processing.

2. They are crushed into small bricks.

3. The blocks are shredded into tiny pieces.

4. The pieces are then melted into large blocks.

5. The blocks are then cast into smaller sections.

6. These are pressed into metal sheets.

7. New cans are made from these sheets.

Recycling one aluminium can saves enough energy to run a TV for three hours.

Smartwatch

The aluminium casing *protects the touchscreen.*

Parts of this dome *are made of aluminium.*

Esplanade Theatre, Singapore

Overhead cables

Aluminium cables *are lightweight.*

KLM
Royal Dutch Airlines
PH-BXY
KLM

Boeing 737

This plane's fuselage *is built from sheets of aluminium stretched around a frame.*

this foil reflects away heat. Aluminium is the most widely used metal after iron. It is very lightweight compared to iron's alloy steel and almost as strong. A dome made from aluminium, such as the one in the **Esplanade Theatre** in Singapore, can be much larger than a steel-based one, which would collapse under its own weight. Aluminium is also a good electrical conductor and so is used in **overhead cables**. Tough aluminium alloys are used to produce parts of some aircraft, including the **Boeing 737**.

JET TURBINE The curved blades of this jet engine are shaped very precisely to catch the air, and they are also strong enough to stay stiff when working at high temperatures. There are several tough metals that fit these requirements, but most are very dense, making them too heavy for an engine powering an aeroplane into the air. That leaves only one metal for the job: aluminium.

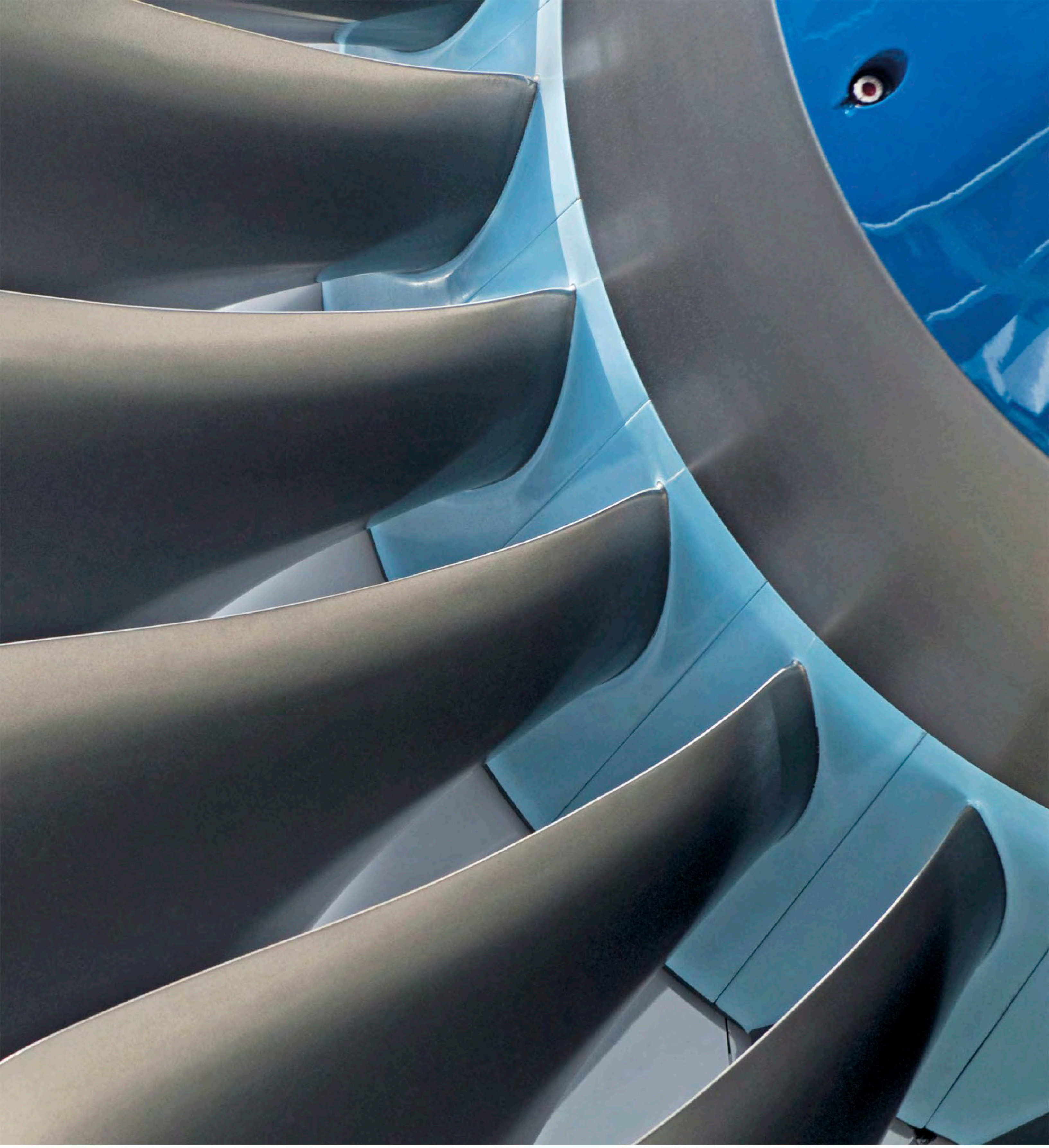

Aluminium is what makes high-speed, long-range air travel possible. Easily moulded, it is one-quarter the weight of steel, and it never rusts. Steel is stronger, but a plane made from it would be too heavy to fly. Instead aluminium is mixed with titanium and steel to produce tough yet lightweight alloys, which are used in the engines and bodies of jet aircraft. There is almost twice as much aluminium in Earth's rock as there is iron. However, purifying aluminium takes a lot of energy. Once pure, though, it can be recycled over and over again. So, one day these engine blades might transform into a fizzy drink can.

31

Ga

Gallium

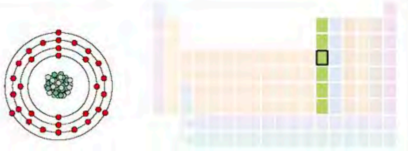

⊖ 31 ⊕ 31 ○ 39

State: Solid
Discovery: 1875

Forms

Diaspore

The needle-like crystals *form on the surface.*

Cube of melting gallium

Pure gallium *has a very low melting point.*

Uses

Thermometer

This medical thermometer *uses a gallium alloy instead of mercury.*

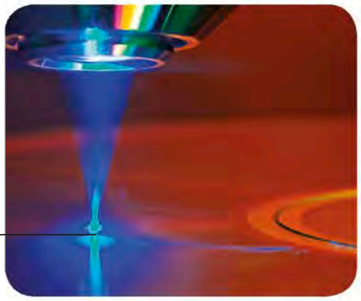

Blu-ray disc

A gallium laser *is used to read Blu-ray discs.*

Red LED lights

The red LED *gets its colour from gallium compounds.*

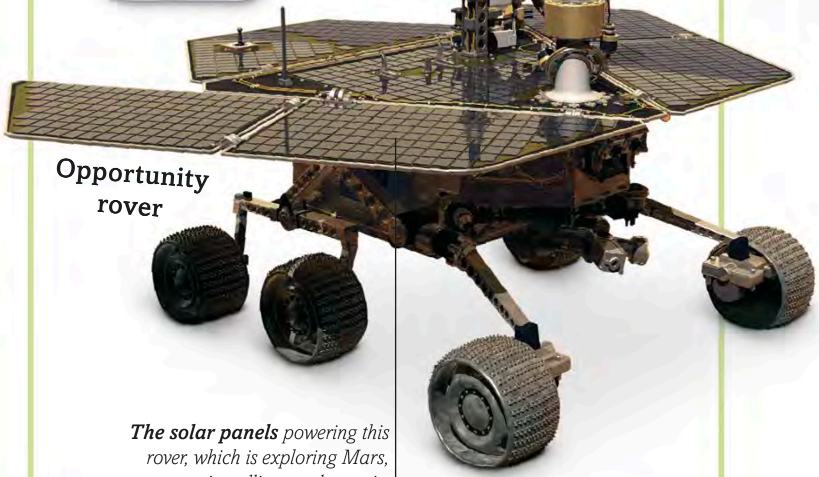

Opportunity rover

The solar panels *powering this rover, which is exploring Mars, contain gallium and arsenic.*

Gallium melts at just 29°C (84.2°F), which means it soon becomes liquid when held in the hand. This element is found in small amounts in ores of zinc and aluminium, such as **diaspore**. **Pure gallium** is isolated when the other elements from this ore are extracted.

Gallium has a number of uses. It is mixed with indium and tin to form a liquid alloy called galinstan, which can be used in **thermometers**. Gallium is also found in **Blu-ray lasers**, **LEDs**, and some solar panels, such as those on NASA's Mars **rovers**.

49
In

Indium

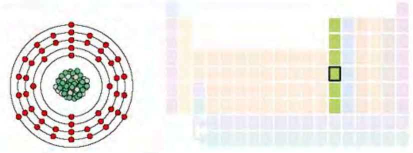

− 49 + 49 ○ 66

State: Solid
Discovery: 1863

Forms

When bent, indium produces a **“tin cry”** – a sound similar to a **scream**.

Sphalerite

This zinc mineral *is the main source of indium.*

Pure indium mould cast in a laboratory

Pure indium *is soft enough to draw lines on paper.*

Uses

This touchscreen *has a grid of very thin, transparent wires made of indium tin oxide.*

Touchscreen tablet

Welder’s goggles

Protective goggles *coated with indium stop the heat damaging the welder’s eyes.*

Transistor

The tiny electronic switches *inside this transistor contain indium.*

This glass coated with indium oxide *is shiny but still lets light through.*

Windows in a building

Indium is named after indigo, which is the colour of the light its atoms release when electrified. Its minerals are rare, and most of the metal is obtained from lead and zinc ores, such as **sphalerite**. **Pure indium** is very soft, and the element is mostly used in compound form. For example, a compound called indium tin oxide used on a **touchscreen** allows the computer to detect when a finger makes contact with the screen. Indium is also required in microchips, and to produce **welder’s goggles** and **windows** that are heat- and glare-proof.

81

Tl

Thallium

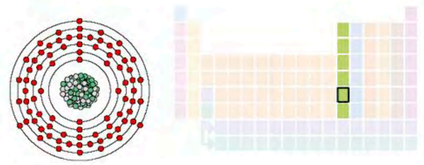

● 81 ⊕ 81 ○ 123

State: Solid

Discovery: 1861

Forms

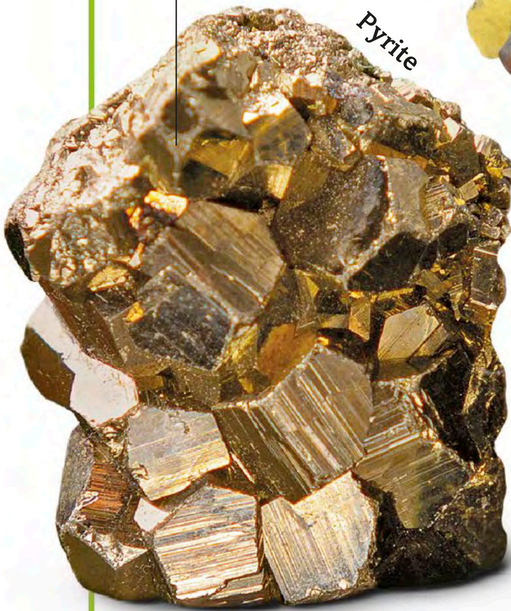

Pyrite

This mineral *contains iron, sulfur, and tiny amounts of thallium.*

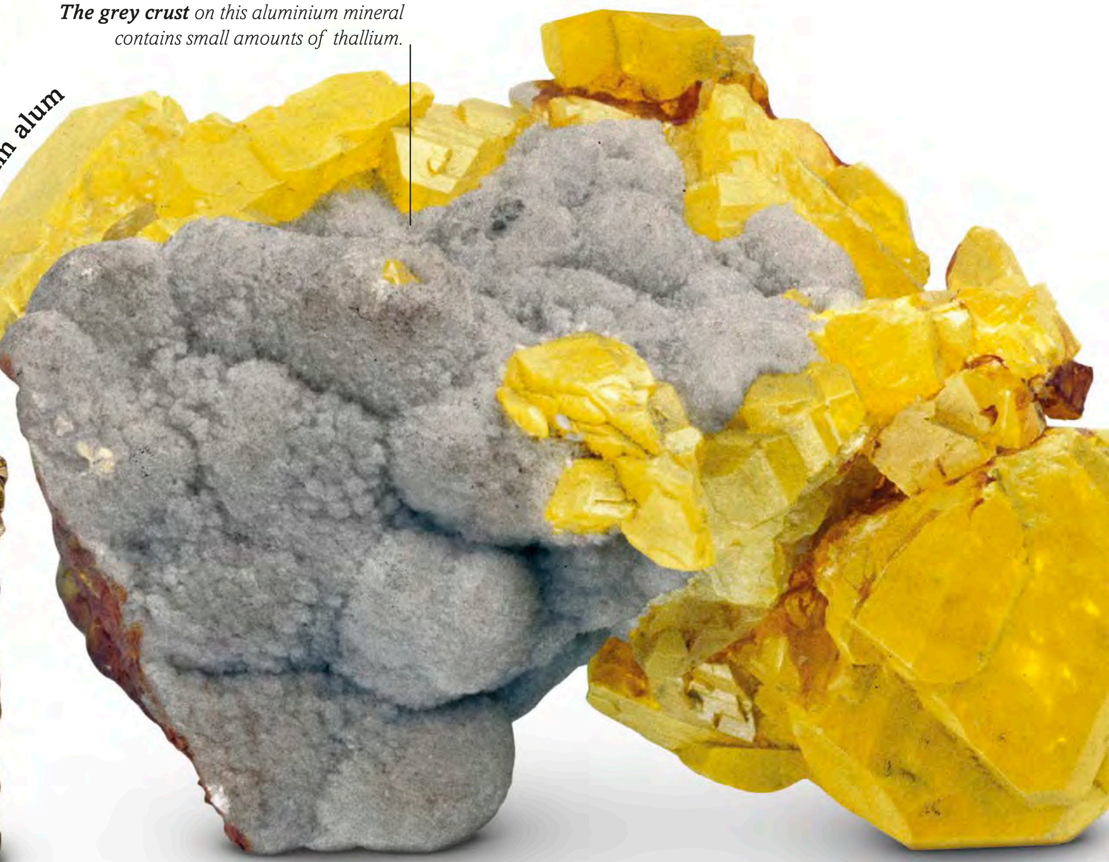

Thallium alum

The grey crust *on this aluminium mineral contains small amounts of thallium.*

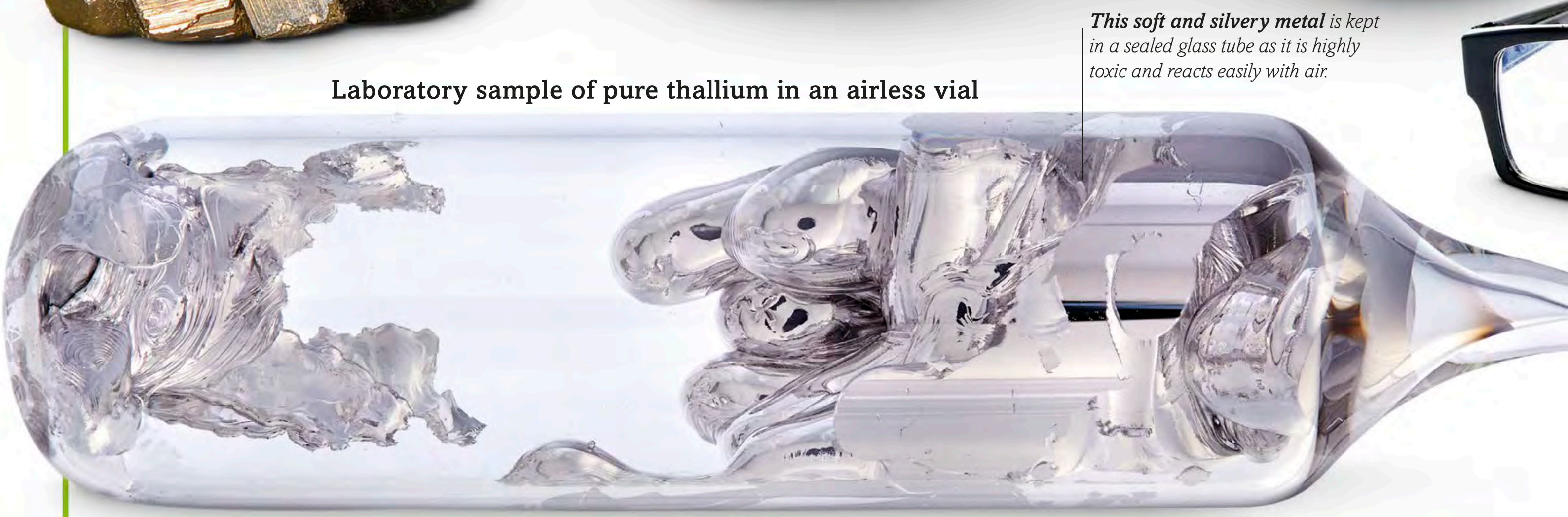

Laboratory sample of pure thallium in an airless vial

This soft and silvery metal *is kept in a sealed glass tube as it is highly toxic and reacts easily with air.*

Thallium was named after the Greek word *thallos*, which means "green shoot": it was first identified from the colours in its flame, which includes a bright green light. Thallium was discovered in 1861 by William Crookes and Claude-Auguste Lamy. Although both chemists worked separately, they found the element in the same way – as a residue while making strong acids using the mineral **pyrite**. Thallium was later found to exist in larger amounts in other minerals, including **thallium alum**. **Pure thallium** is toxic and has to be handled

Uses

Heart function scan

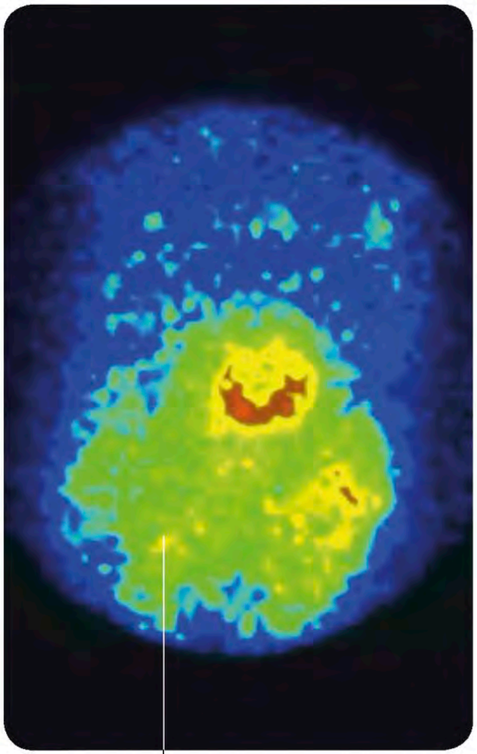

***Blood injected with a thallium compound** shows up on a patient's heart scan.*

Spectacles

***These thin lenses** contain strong, thallium-infused glass.*

Until the 1970s, thallium salts were commonly used as **ant poison**.

toxic and has to be handled with care when used. A chlorine compound of thallium is used in **scans** to study a patient's blood circulation. Thallium oxide also helps make glass stronger for use in **spectacles** and cameras.

113 Nh Nihonium

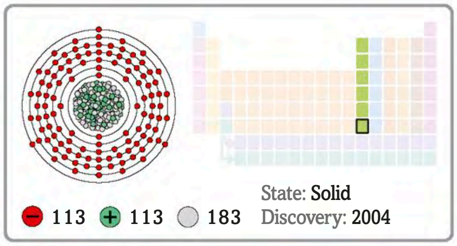

⊖ 113 ⊕ 113 ○ 183

State: Solid
Discovery: 2004

Kozuka Morita (left), with a visiting official at the RIKEN Nuclear Research Centre, Wako, Japan

Nihonium was named after the Japanese word *nihon*, which means Japan. A metallic element, nihonium was first detected in 2003 by teams studying the artificial element moscovium, which has the atomic number of 115. They noticed that atoms of moscovium broke apart after only a few seconds into atoms of an element with an atomic number of 113. In 2004, Kozuka Morita and a team of scientists at the **RIKEN Nuclear Research Centre** in Japan isolated this element in a different way: they fused bismuth and zinc atoms together.

Glassy carbon (C) has a high resistance to rust.

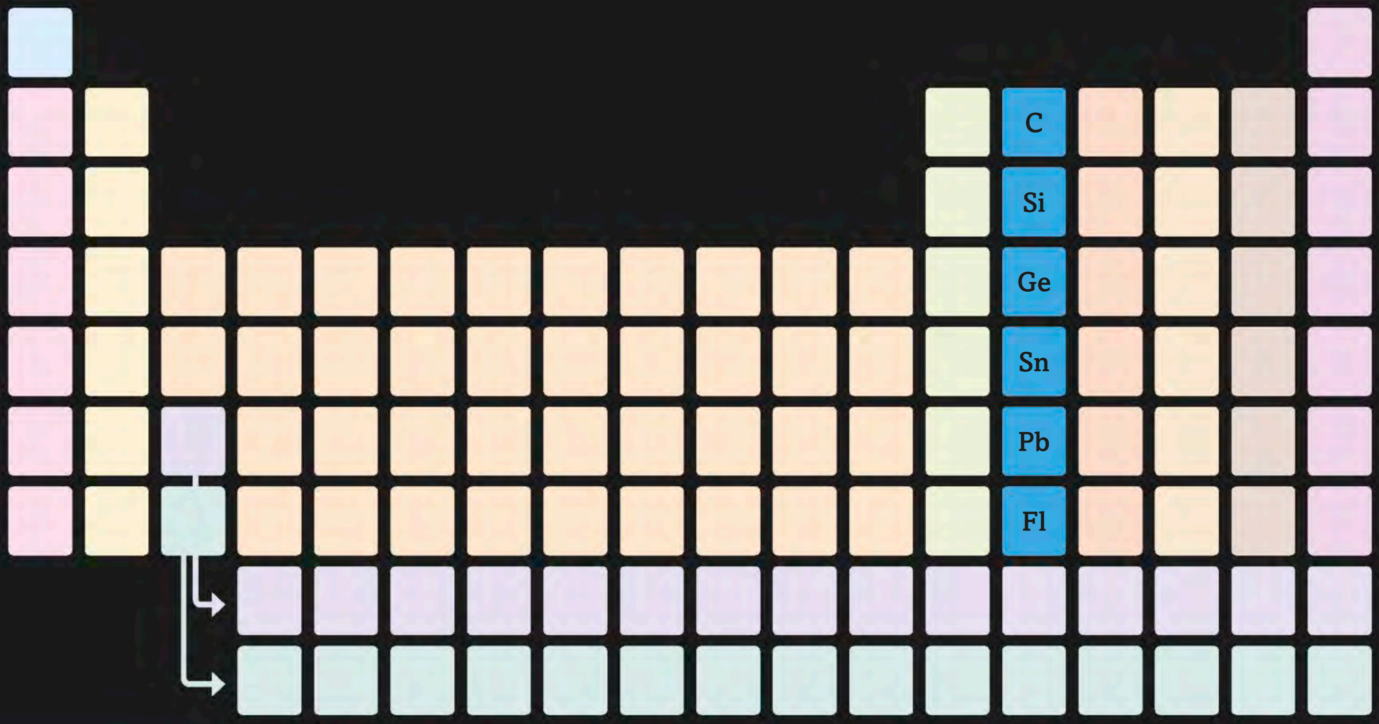

The Carbon Group

This group contains one non-metal, two semi-metals, and three metals. The non-metal carbon (C) is the main element in all living things. The semi-metals – silicon (Si) and germanium (Ge) – are elements that have the properties of both metals and non-metals, and they are essential in electronics. Two of the metals – tin (Sn) and lead (Pb) – have been used by humans for centuries. Flerovium (Fl), an artificial element, has no known uses.

Atomic structure
Members of this group have four electrons in the outer shell of each atom. These atoms can bond with up to four other atoms.

Physical properties
At room temperature, all natural elements in this set are solid. Flerovium (Fl) is an artificial element, and scientists think it may be a solid.

Chemical properties
All natural elements in this group can react with hydrogen (H). Carbon (C) and silicon (Si) can react with both metals and non-metals.

Compounds
These elements react with hydrogen to form compounds called hydrides. Each element can lose up to four electrons when forming compounds.

6 C Carbon

State: Solid
Discovery: Prehistoric

Forms

Coal

This compressed form* of *sooty carbon *is formed underground.*

Glassy carbon

Glossy surface

Crude oil

Mixture *of liquid, carbon-rich compounds*

Raw diamond

This colourless crystal *forms in magma deep underground.*

Laboratory sample of graphite

The shiny, metallic surface *feels soft and slippery.*

Cut diamond

This diamond's brightness *depends on its cut, which determines how many times light entering the gem will reflect inside.*

Carbon has the largest number of compounds of any element – with more than nine million known. Carbon is the fourth most common element in the Universe. Each carbon atom can bond to four others, allowing them to form chains and rings. Pure carbon exists in three forms on Earth – **graphite**, **diamond**, and buckminsterfullerene (a structure based on 60 interlinked carbon atoms). Diamond is the hardest substance in nature. It is often used in jewellery. The blades of some **saws** are coated with diamonds, and

Uses

Diamond blade saw

This sharp blade *is coated with tiny diamonds.*

Water purifier filter

This carbon filter *absorbs harmful chemicals in water.*

Battery

This battery *has a graphite core that carries electric current.*

LOTUS Sport
MAVIC
3G
Carbon-fibre bicycle

Sturdy and lightweight frame

This **strong** but **light** frame is made by fusing together carbon fibres.

This wheel *is composed of carbon fibre and some other materials, which make it rigid.*

Pencil "lead" containing graphite, not lead

Soft graphite *leaves a mark when pressed against paper.*

Kerosene lamp

This flame *is fuelled by carbon-rich oil.*

Polythene bag

This flexible plastic material *is composed of chains of carbon and hydrogen atoms.*

HARD AND SOFT CARBON

Diamond and graphite have different properties because of the arrangement of their atoms – tetrahedrons in diamond, and sheets of hexagons in graphite.

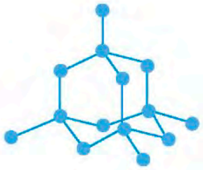
Hard as diamond
The tetrahedron, or pyramid structure, of atoms creates a rigid shape that is equally strong in all directions.

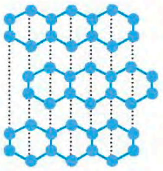
Soft as graphite
Graphite contains layers of carbon atoms that slide over each other easily, as there are only weak forces between them.

can cut into anything. Only a diamond can cut another diamond. Graphite is much softer, which is why it is used in **pencil "lead"**. It is also used in some batteries. Coal is currently the largest source of fuel for the generation of electricity, but its fumes are also known to have harmful environmental and health effects. Crude oil, natural gas, and **coal** are hydrocarbons (compounds containing only hydrogen and carbon) that occur in nature. They can be used as fuels and as plastics for objects such as **polythene bags**.

PINK DIAMOND With a mass of only just over 3 g (0.1 oz), this jewel – known as The Sweet Josephine – is one of the largest pink diamonds ever sold. Diamonds are normally colourless forms of pure carbon, and if there is any colour, it comes from tiny amounts of another substance. For example, boron makes the gem appear blue. Strangely, pink diamonds have no impurities, and no-one knows why they are pink.

The Sweet Josephine was cut from raw diamond that is more than 1.5 billion years old. This formed 150 km (93 miles) beneath Earth's surface and was then pushed up by a volcanic eruption, before eventually being dug out at a mine in Australia. Diamonds form when carbon is squeezed and heated to more than 1,000°C (1,832°F). This process rearranges the carbon atoms into a rigid crystal that makes diamond the world's hardest substance. The process also gives diamond the ability to bend light, a property that gives these jewels their glorious sparkle. With the right cut and polish, a diamond can be made into a beautiful gem that is prized throughout the world.

14 Si Silicon

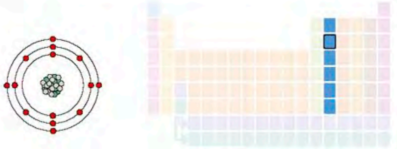

⊖ 14 ⊕ 14 ○ 14

State: Solid
Discovery: 1824

Forms

This purple form of quartz *gets its colour from iron impurities.*

This glassy mineral tube *is formed when quartz-rich sand is struck by lightning.*

Laboratory sample of pure silicon

The pure element *can shatter easily.*

Tiny hairs on these leaves *have silica tips that break off when you touch them, releasing chemicals that sting.*

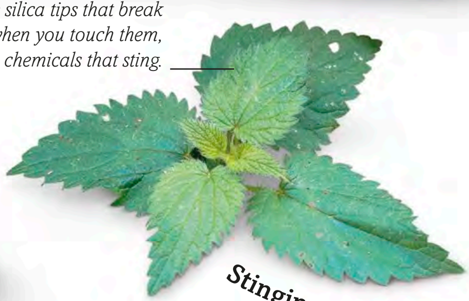

Sand *is mostly tiny grains of quartz that have broken away from rocks.*

About 90 per cent of the minerals that make up Earth's rocks contain silicon, a common element in our planet's crust. Nearly all silicon minerals are compounds of silicon and oxygen, known as silicates. The most common silicate is quartz, the mineral form of silicon dioxide, or silica. It is also the most common substance in **sand**. **Amethyst** is a type of quartz. Quartz deposits are widely found in rocks such as granite and sandstone. A valuable type of silica is **opal**, which is used as a gemstone. The clays used to make pottery and **ceramics** are also silicates.

Uses

Opal ring

Opal is a jewel *containing both silicon oxide and water molecules.*

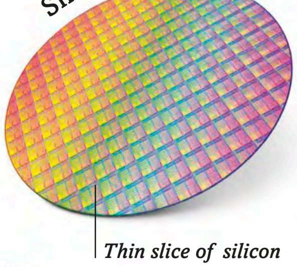

Silicon wafer

Thin slice of silicon

SILICON IN SPACE

Earth and Mars contain similar amounts of silicon. This element forms on the outer layer, or crust, of both planets. In contrast, the Moon is almost half silicon. Astronomers think this tells us that the Moon was formed from Earth's surface after an asteroid smashed into our planet about 4.4 billion years ago.

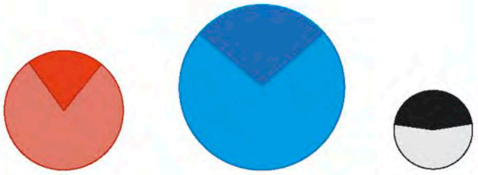

Mars 21% silicon

Earth 27.7% silicon

Moon 45.5% silicon

Screens of silicon-based smoke *can be used in battles.*

Smokescreen

SOLARIMPULSE

Sunlight-powered plane

Solar panels

The engines *run on electricity produced using sunlight.*

Silicone baking mould

This silicone tray *is soft, but it does not melt in the oven.*

Ceramic vase

Ceramic *is made of a silicon-based clay that has been shaped and permanently hardened by heat.*

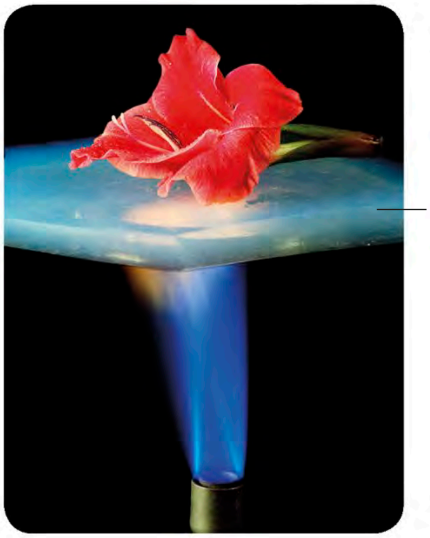

Aerogel *conducts the heat from the flame poorly, preventing it from passing to the flower.*

Silicate aerogel in an experiment

Silicone watch

This silicone band *is flexible and strong.*

One of the most important uses of silicon is in electronics. Thin slices called **silicon wafers** drive electronic circuits. This versatile element is also used to turn sunlight into electricity in solar panels. Artificial silica is used to create **aerogel**, a lightweight but tough substance that does not conduct heat well. It is used in fire-fighting suits, and prevents flames reaching a firefighter. Another silicon compound is silicone, which can be moulded into any shape, and is used in a wide range of products from **baking moulds** to **watches**.

32

Ge

Germanium

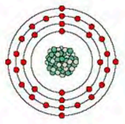

⊖ 32 ⊕ 32 ○ 41

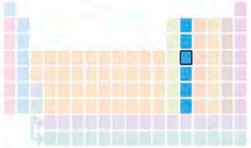

State: Solid
Discovery: 1886

Forms

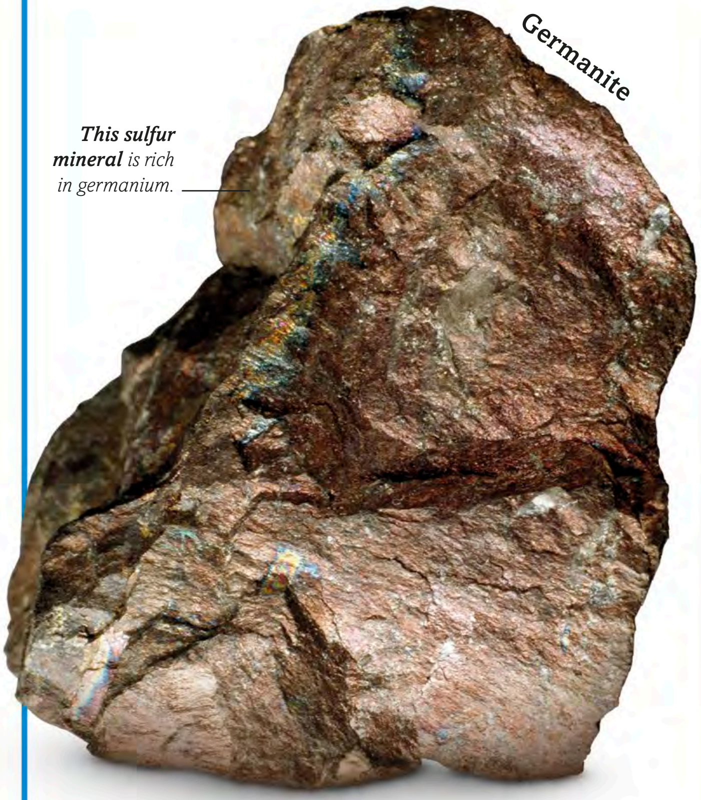

This sulfur ***mineral*** *is rich in germanium.*

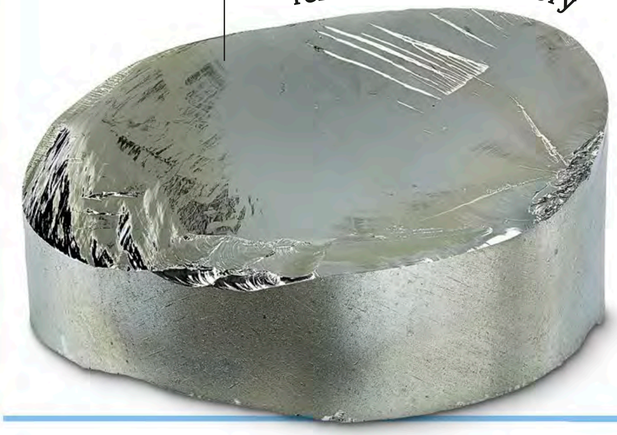
Disc of pure germanium refined in a laboratory

The pure form *is shiny like a metal, but brittle.*

Uses

Camera lens

The germanium oxide in the glass of this lens *bends surrounding light from a large area into the camera.*

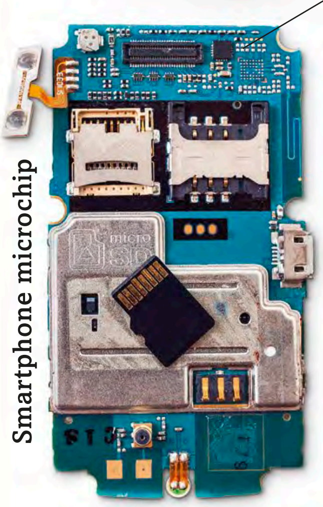
Smartphone microchip

This microchip *is made of silicon and germanium.*

Germanium is found in the **atmosphere** of **Jupiter**.

Car with germanium sensor

This car contains a germanium-based sensor *that measures its distance from obstacles.*

This semi-metal is named after the country Germany. It was discovered there in 1886 by chemist Clemens A Winkler, nearly 20 years after Russian chemist Dmitri Mendeleev predicted its existence and properties. **Germanite** is a mineral rich in germanium, but this element is mainly extracted from the ores of silver, copper, and lead. One of its compounds, germanium oxide, is used in wide-angle **camera lenses**. It is also used in some **microchips** and in a number of **car sensors** that aid in navigation.

50
Sn

Tin

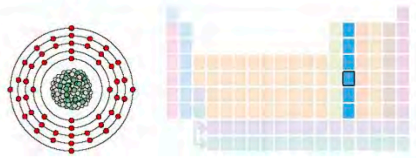

⊖ 50 ⊕ 50 ○ 69

State: **Solid**
Discovery: **c. 2100 BCE**

Forms

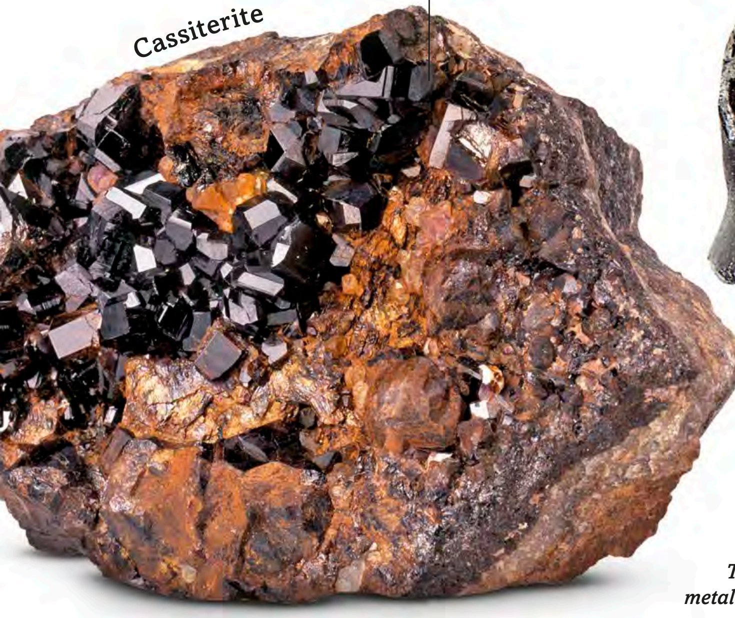

Cassiterite

***The black colour** of the crystals is due to iron impurities.*

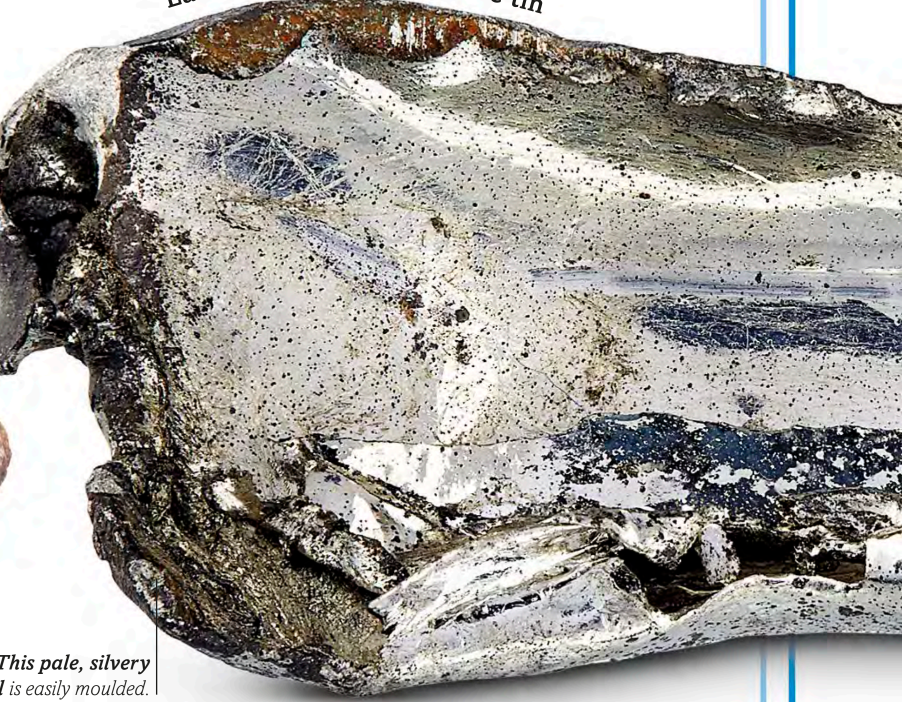

Laboratory sample of pure tin

***This pale, silvery metal** is easily moulded.*

Uses

Watering can

***Tin plating** over steel makes the can more resistant to corrosion.*

Pewter figurine

***This shiny alloy** contains around 90% tin.*

Pipe organ

***The large pipes** of this organ are made of tin and lead.*

Tin whistle

***The tin plating** on this steel whistle prevents rusting.*

Tin was one of the first metals used by humans. As long as 5,000 years ago, tin was mixed with copper to make bronze, an alloy that was stronger than either pure metal. The ore **cassiterite** is the main source of **pure tin**. Uses for tin are many, including plating steel objects, such as **cans**, to stop them corroding. A compound called tin chloride is used for dyeing silks. This metal continues to be used in a variety of tough alloys, including **pewter**, soft solder, and bronze.

82

Pb

Lead

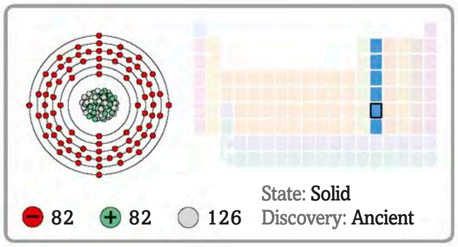

82 82 126

State: Solid

Discovery: Ancient

Forms

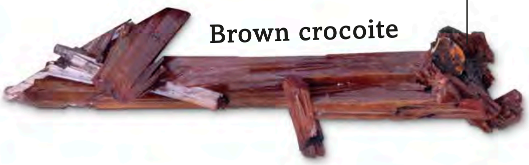

Brown crocoite

This soft, crumbly mineral *is made of lead chromate.*

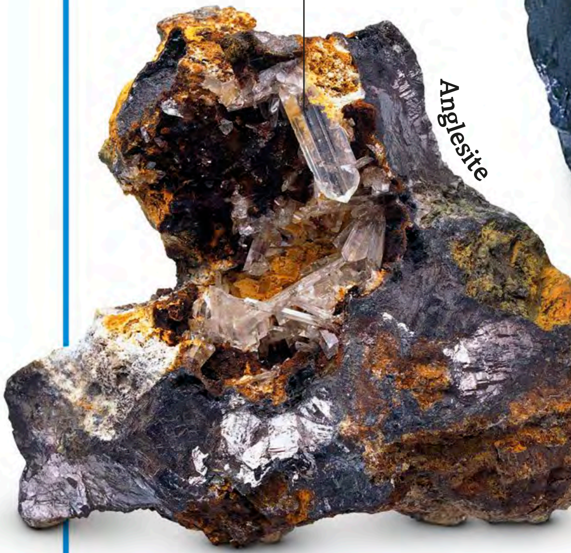

Anglesite

The prism-like crystals *of this mineral contain a lead-sulfur compound.*

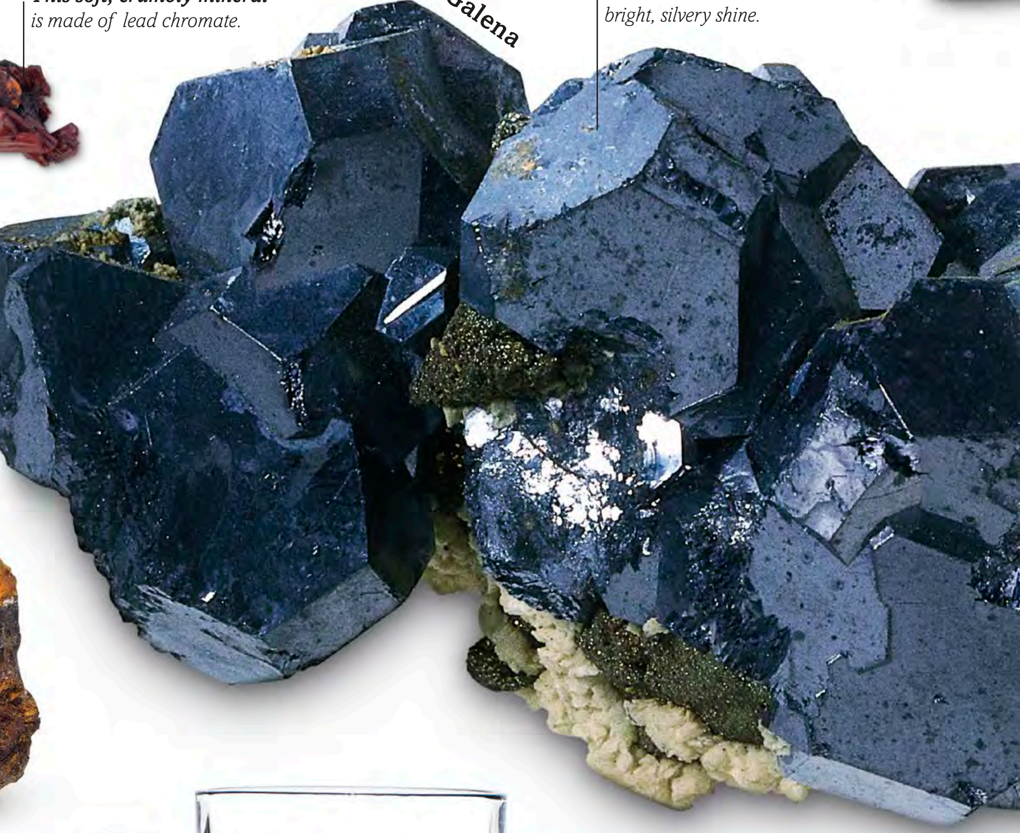

Galena

This mineral *has a bright, silvery shine.*

Uses

Lead crystal glass mug

This crystal glass *sparkles more than regular glass because it contains lead oxide.*

Lead pipe

Rust-resistant pipe

For many years, lead and tin were thought to be different forms of **the same metal**.

The chemical symbol for lead, Pb, comes from the Latin word *plumbum*. This is where the word "plumber" comes from: in ancient Roman times, water pipes used in plumbing were made from this soft metal. Lead compounds are found in the minerals **crocoite**, **anglesite**, and **galena** – the main source of **pure lead**. Lead was used far more commonly in the past as an important ingredient in paints, hair-dyes, and insecticides. A common historical use was in **glassware**. It has limited applications today. Lead can

Pure strip of lead refined in a laboratory

This pure form of the metal has a dull grey colour.
These pale crystals on the galena are a calcium mineral.

Flashings, or "lead sheets", cover exposed corners on roofs to make them waterproof.

Flashings

because it absorbs radiation. It is also used in weights for diving, car batteries, and bendy **"flashings"** for sealing roofs. Lead fell out of favour because it turned out to be poisonous.

114
Fl

Flerovium

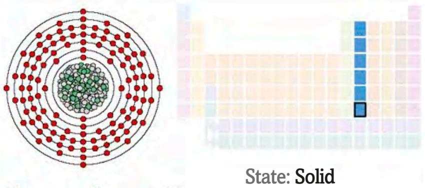

⊖ 114 ⊕ 114 ○ 175

State: Solid
Discovery: 1999

This machine produces flerovium by **smashing together** atoms of calcium and plutonium.

Particle accelerator at Joint Institute for Nuclear Research, Dubna, Russia

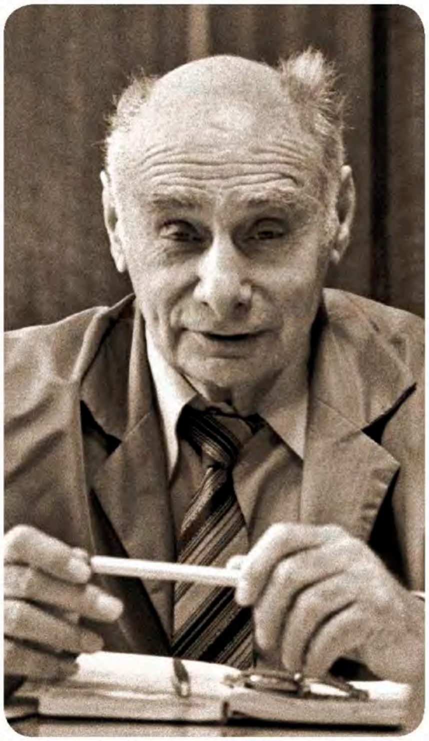

Georgy Flerov

Flerovium takes its name from the Russian scientist Georgy Flerov. He founded the **Joint Institute for Nuclear Research** in Dubna, Russia, where this element was first produced in a particle accelerator (a machine in which atoms are smashed together). Flerovium is highly radioactive and its atoms last for only a few seconds before breaking apart.

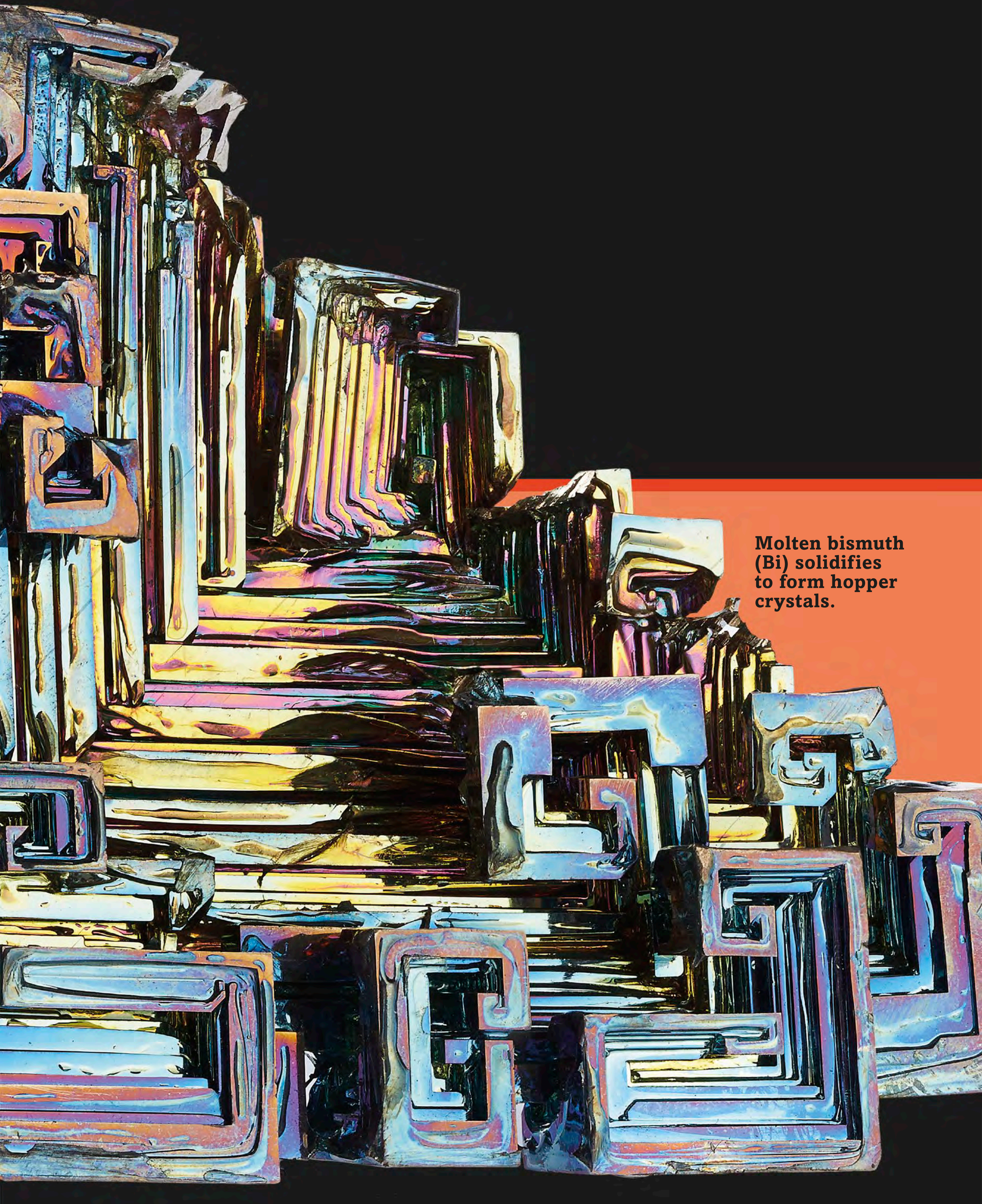

Molten bismuth (Bi) solidifies to form hopper crystals.

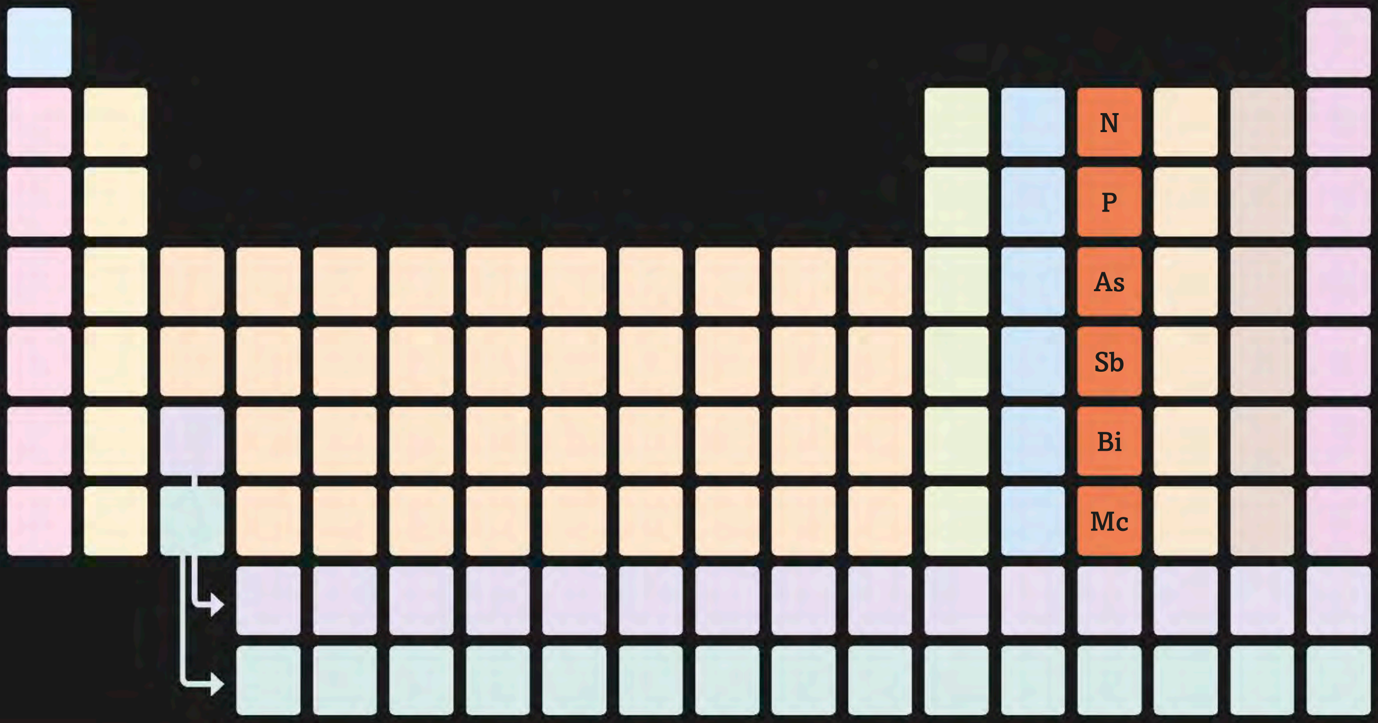

The Nitrogen Group

This group includes different types of natural element – non-metals, semi-metals, and dense metals – as well as moscovium (Mc), an artificial element. The group is also known as “pnictogens”. This derives from the Greek word *pnígein*, which means “to choke” and refers to the potential toxicity of nitrogen (N) in certain forms.

Atomic structure
Members of this group have atoms with five electrons in the outer shell. These atoms can form up to three bonds at the same time.

Physical properties
All the members are solids, except nitrogen (N). The density of elements increases down the group: bismuth (Bi) is 8,000 times denser than nitrogen.

Chemical properties
Phosphorus (P), which exists in two main forms, is reactive, but the others in this group are fairly stable.

Compounds
When reacting with three hydrogen (H) atoms, all members of the group form reactive gaseous compounds called hydrides.

7 N Nitrogen

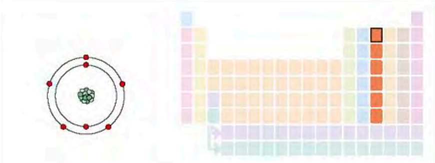
⊖ 7 ⊕ 7 ○ 7

State: Gas
Discovery: 1772

Forms

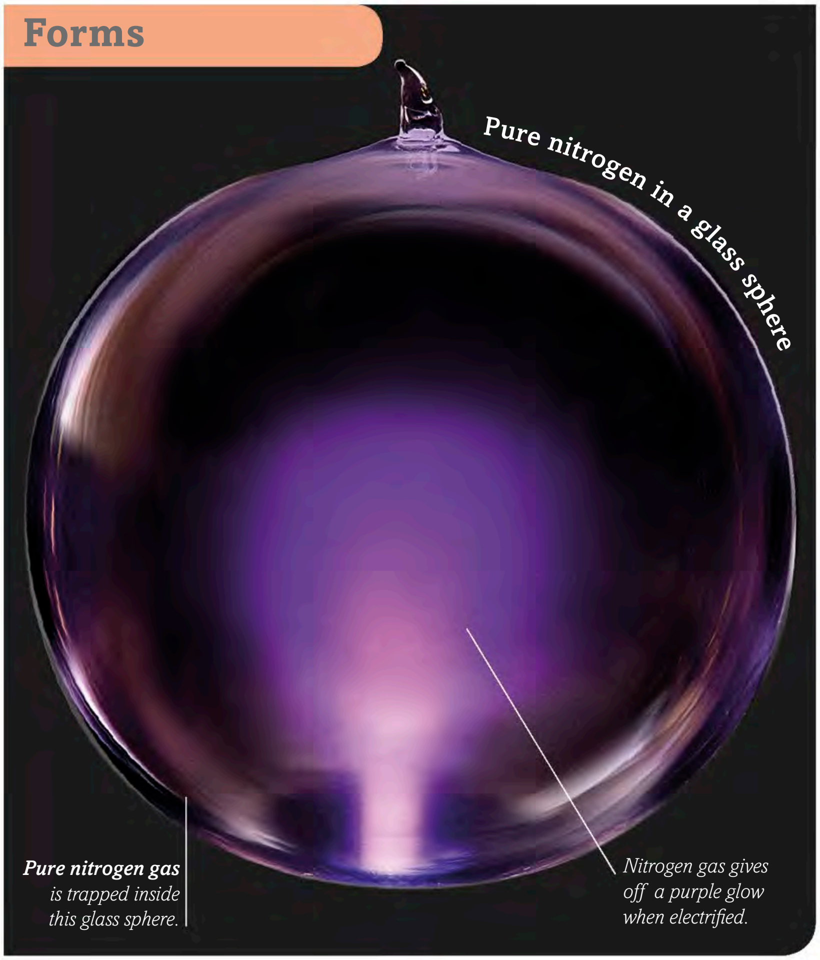

***Pure nitrogen gas** is trapped inside this glass sphere.*

Nitrogen gas gives off a purple glow when electrified.

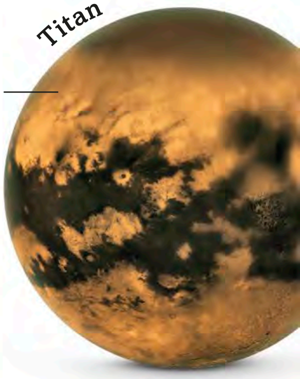

***Saturn's largest moon** has an atmosphere containing 48% nitrogen.*

Liquid nitrogen

***This clear and colourless liquid** forms when nitrogen is cooled to below –195°C (–319°F).*

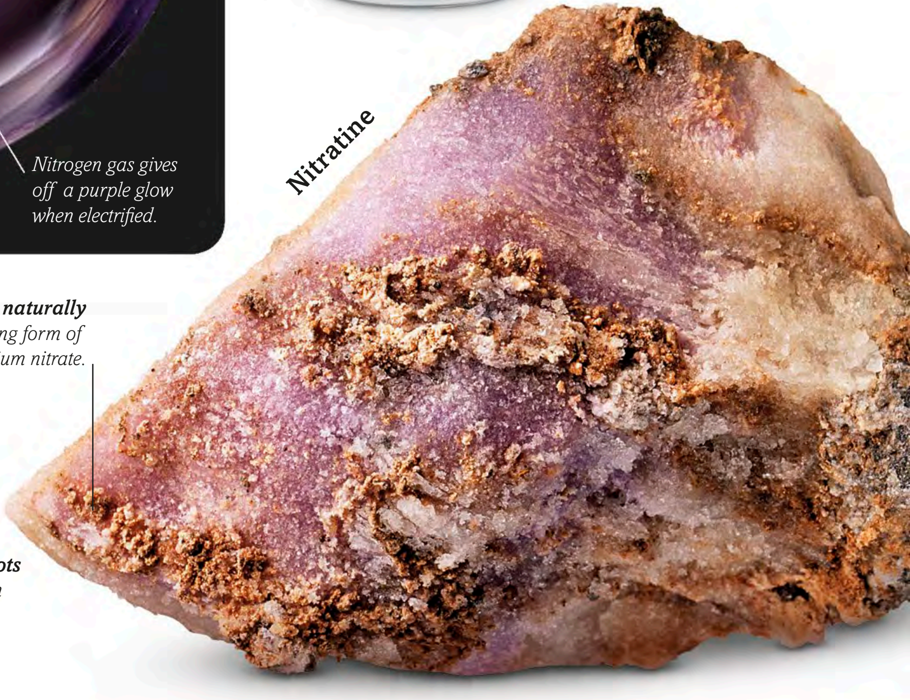

***This is a naturally** occurring form of sodium nitrate.*

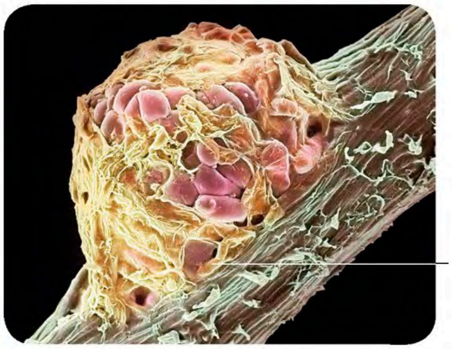

***Bacteria living inside plant roots** can take nitrogen from the air for use by the plant.*

Microscopic image of root nodule

Nitrogen surrounds us all the time because it is the transparent gas that makes up nearly three-quarters of Earth's atmosphere. Since **pure nitrogen** does not react easily, its **liquid form** can be used to freeze and preserve items such as blood and tissue samples.

Nitratine is one of the few minerals rich in nitrogen. Some useful nitrogen compounds can be made by industrial processes. A group of nitrogen compounds is used in explosives, including **TNT** and **nitroglycerine**. When ignited, they explode because the bonds

Uses

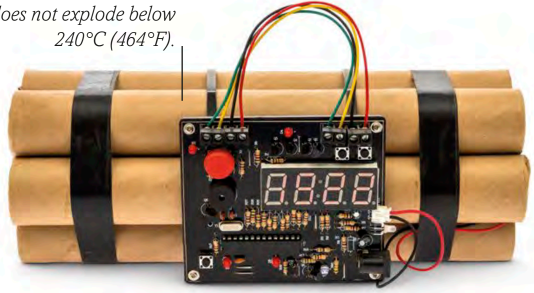

TNT

Trinitrotoluene (TNT) *does not explode below 240°C (464°F).*

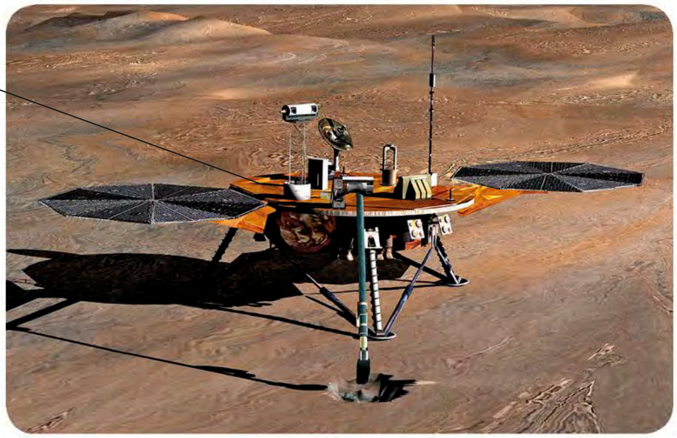

Phoenix Mars Lander

This lander *used 12 hydrazine-powered thrusters to land on Mars.*

Nitroglycerine spray

Nitroglycerine *can be used to treat heart conditions.*

Drag bike

Motorcycles *use nitromethane to fuel their powerful engines.*

Textile dye

These nitrogen-based azo dyes *are often used to colour textiles.*

Super glue

Superstrong glues *contain small nitrogen compounds that link together.*

Nitrogen fertilizer

These fertilizers *contain compounds called ammonium nitrates that promote growth in plants.*

NITROGEN CYCLE

Nitrogen is essential for life. The nitrogen cycle is a process that constantly recycles nitrogen between Earth's atmopshere and all living things.

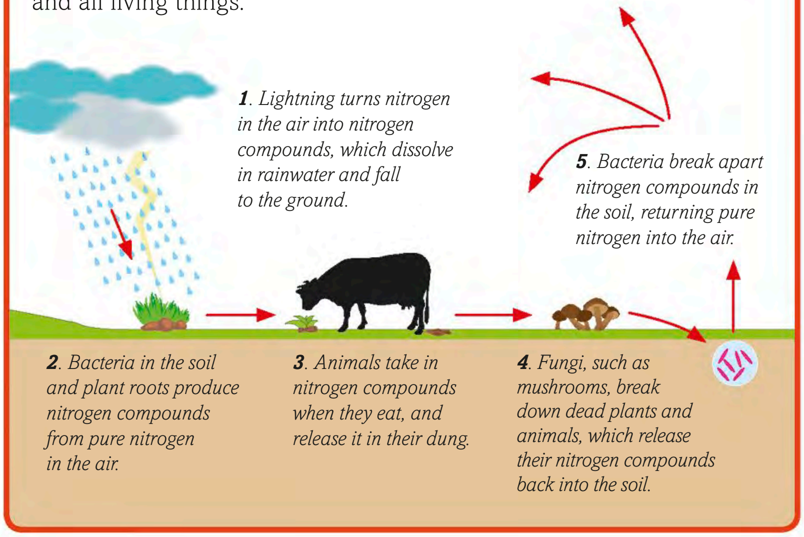

1. *Lightning turns nitrogen in the air into nitrogen compounds, which dissolve in rainwater and fall to the ground.*

2. *Bacteria in the soil and plant roots produce nitrogen compounds from pure nitrogen in the air.*

3. *Animals take in nitrogen compounds when they eat, and release it in their dung.*

4. *Fungi, such as mushrooms, break down dead plants and animals, which release their nitrogen compounds back into the soil.*

5. *Bacteria break apart nitrogen compounds in the soil, returning pure nitrogen into the air.*

between nitrogen atoms detach very quickly. Nitrogen fuels, such as nitromethane, are used in **drag bikes**, providing a lot more power than carbon-and-hydrogen only fuels, such as petrol. The compound hydrazine is used in thrusters on spacecraft, such as the **Phoenix Mars Lander**.

Some nitrogen compounds are put in **dyes** and **glues**. An industrial technique called the Haber process turns nitrogen and hydrogen gas into ammonia, a liquid commonly used to make **nitrogen fertilizers**. When mixed with soil, these fertilizers boost plant growth.

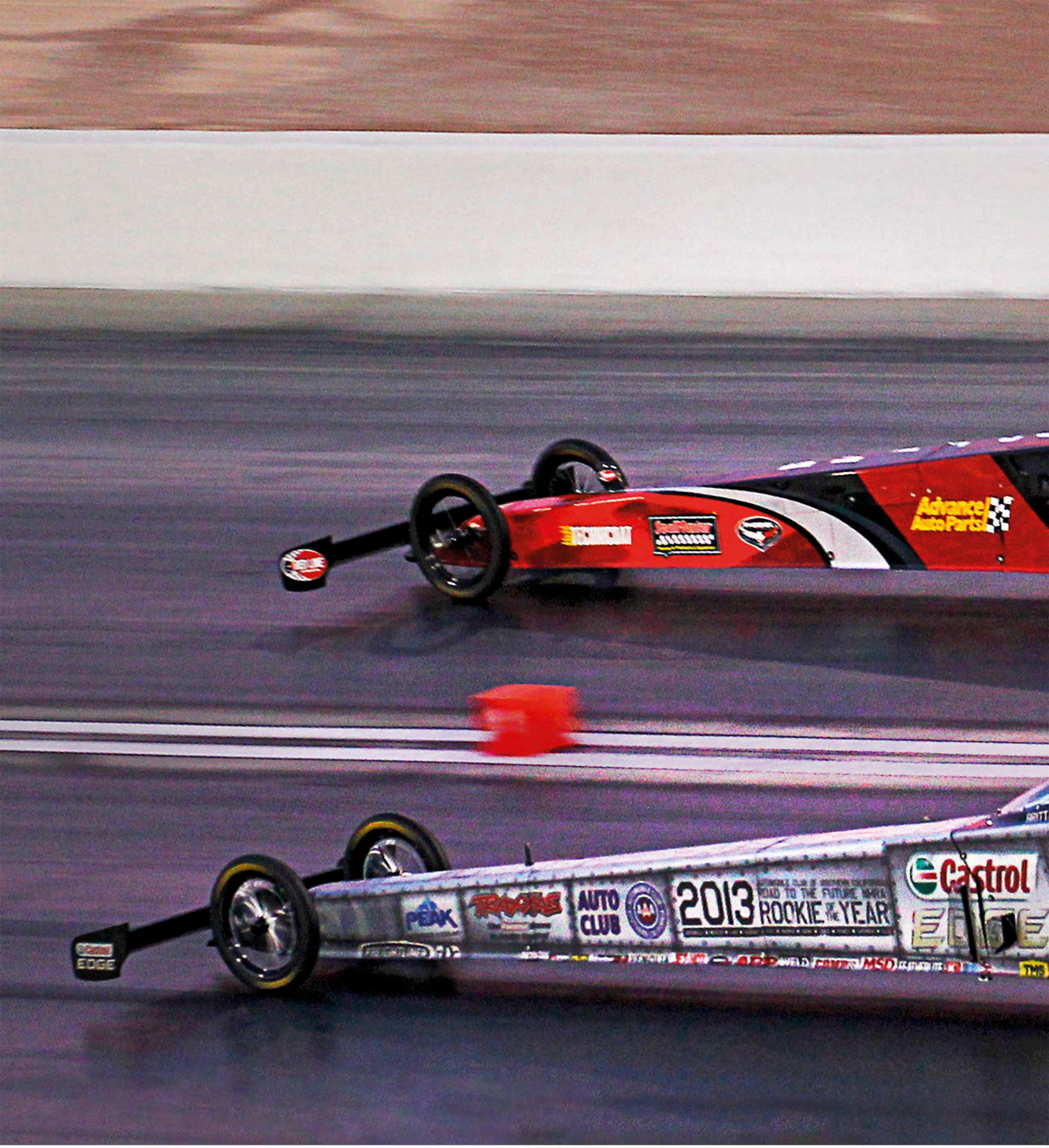
Advance Auto Parts
TECHNICRAFT
PEAK
AUTO CLUB
2013 ROOKIE OF THE YEAR
Castrol
EDGE
EDGE

DRAG RACING Zooming along a dead straight track, these all-powerful dragsters accelerate all the way to the finish line. They contain massive engines filled with an extra-powerful fuel called nitromethane, which is often shortened to "nitro". Burning eight times faster than regular petrol used in most cars, this super fuel can push dragsters to speeds in excess of 480 km/h (300 mph).

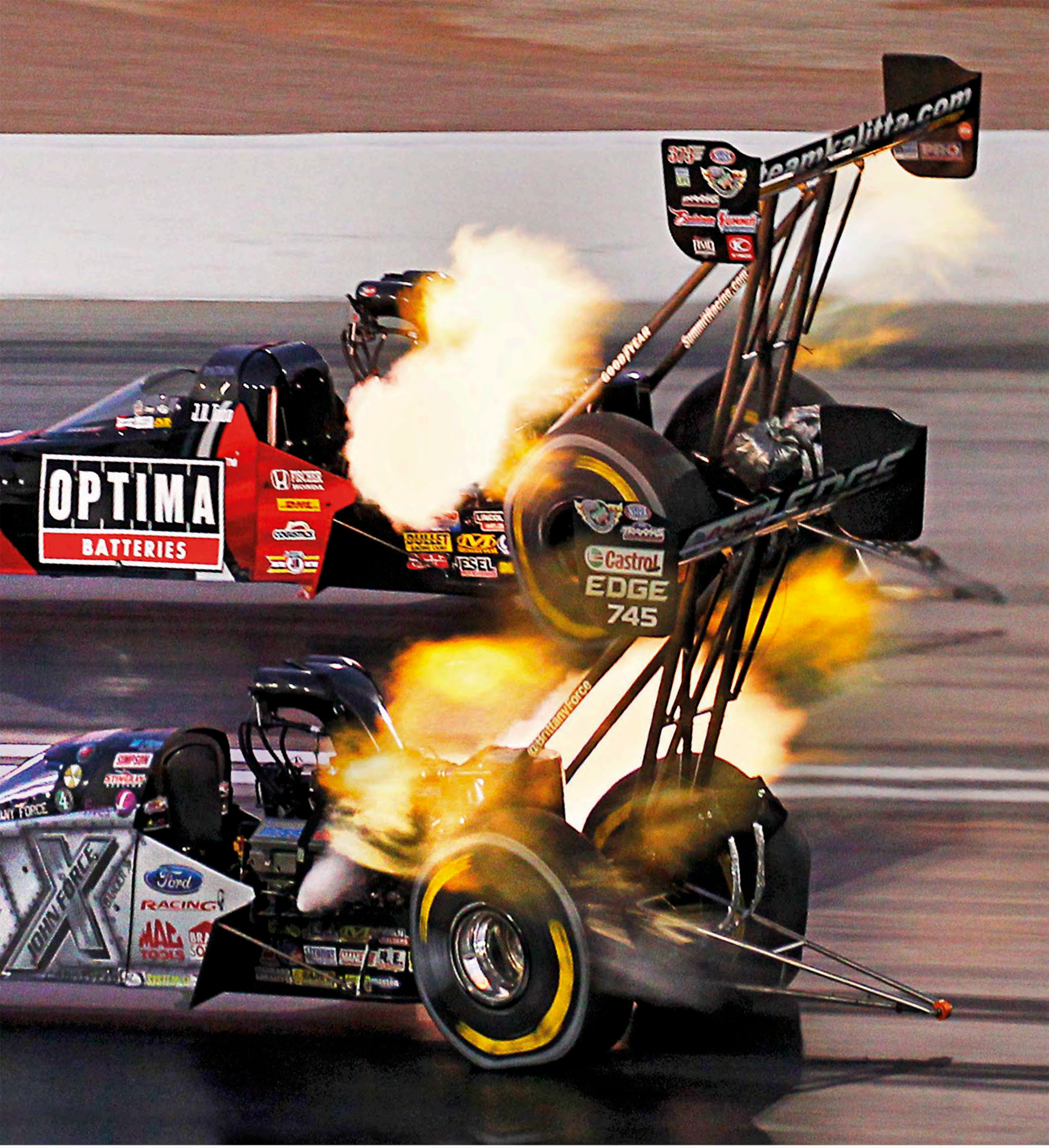
teamkalitta.com
OPTIMA
BATTERIES
GOODYEAR
Castrol
EDGE
745
JOHN FORCE
Ford
RACING

Nitromethane contains carbon, hydrogen, and nitrogen, but it is the latter element that really gives this fuel its immense power. During the process of combustion – when oxygen is mixed with the fuel in the race car's mighty engine – nitromethane burns so violently that nitrogen escapes from the fuel and returns to its pure form. This chain of events leads to a release of energy, which propels the dragsters to breakneck speeds. Although these races are an incredible spectacle to behold, driving using nitromethane can be dangerous due to the explosive nature of nitrogen when used in this way: drag racers are taking a risk to win.

15

P

Phosphorus

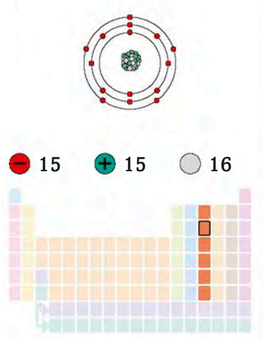

State: Solid
Discovery: 1669

Forms

Deep phosphate mines *make up 80% of this tiny Pacific island.*

Phosphate mining in Nauru

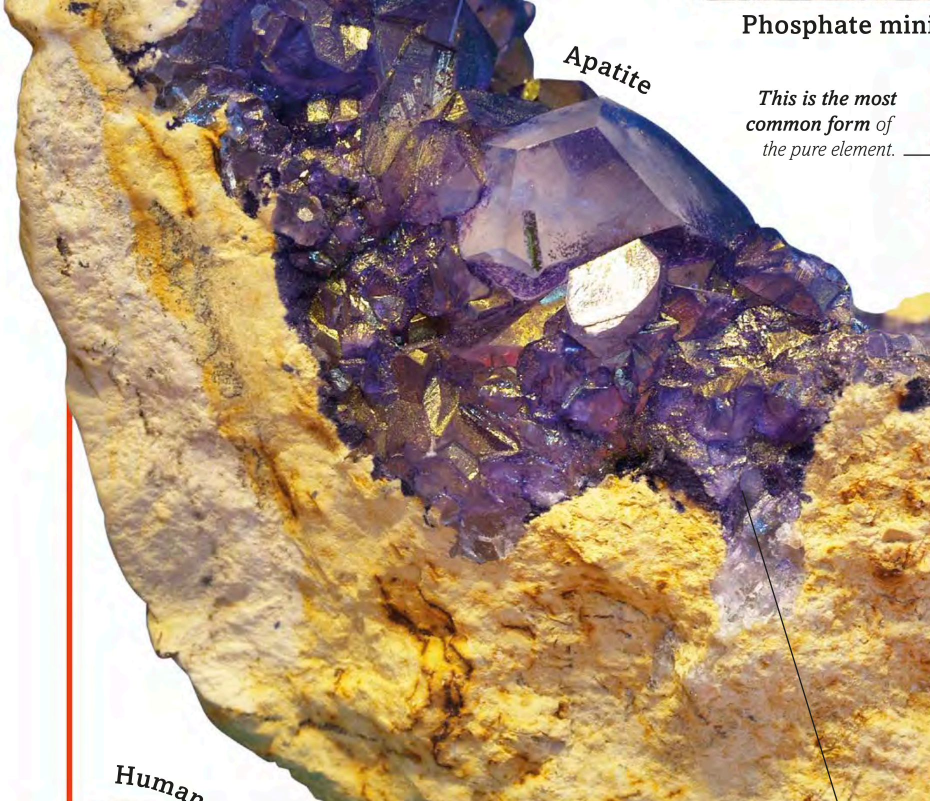
Apatite

This purple colour of the crystals is due to metal impurities.

Red phosphorus

This is the most common form *of the pure element.*

White phosphorus

This element *remains stable in water, but catches fire on contact with air.*

Chunk of violet phosphorus

This form of phosphorus *is made in a laboratory by heating red phosphorus.*

Human skull

All bones, including those in the skull*, are hardened by calcium phosphate.*

Tuna

This fish *is rich in phosphorus.*

Phosphorus was accidently discovered by German alchemist Hennig Brand. In 1669, in his quest for the mythical Philosopher's Stone (a material some believed could turn any metal into gold), he boiled a large pot full of urine for days. This produced a mysterious glowing substance, which he called phosphorus, meaning "giver of light". Phosphorus is the first element to have a discoverer with a recorded name. It is never pure in nature, and occurs in different minerals. Phosphorus has several flammable,

Uses

This light, strong china *contains calcium phosphate.*

China tea set

LIFE'S BUILDING BLOCKS

DNA – short for deoxyribonucleic acid – is like a mini database packed with instructions telling your body how to work properly. It consists of a chain of molecules and looks like a twisted ladder called a double helix. The edges are sugar molecules linked together by units containing phosphorus.

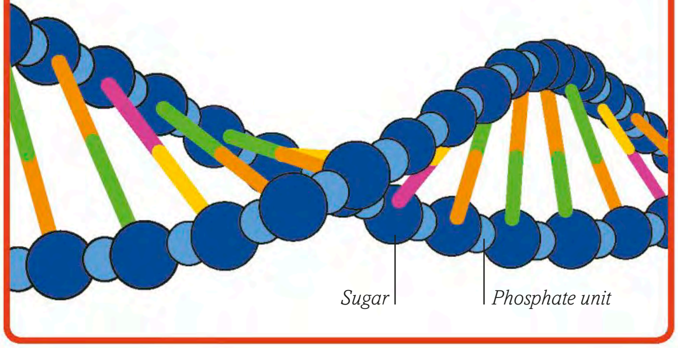

Fibre optics

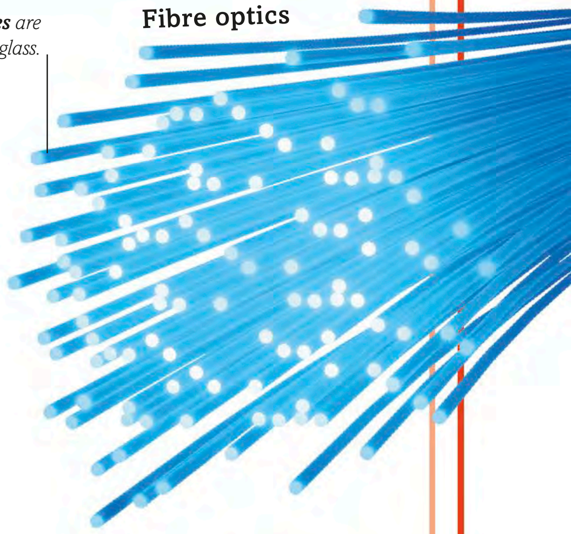

These flexible fibres *are composed of phosphate-rich glass.*

Safety match box

The striking surface on the sides of the box *contains phosphorus, which ignites the match upon contact.*

Spraying ammonium phosphate *over burning material cuts off its supply of oxygen. This extinguishes the fire.*

Fire extinguisher

Spraying crops with phosphates *kills pests, such as insects.*

Pesticides

Fertilizer

This fertilizer *contains ammonium phosphate to boost plant growth.*

solid forms, including **red**, **white**, black, and **violet**. The glow seen by Brand was caused by white phosphorus reacting with oxygen. Phosphorus is mainly found in **phosphate** minerals (in which phosphorus links to oxygen), such as **apatite**, its main ore.

Phosphates are present in **fine china**, and are an important ingredient in **fertilizers**. The strips on the sides of **safety match boxes** contain pure phosphorus. More complex phosphorus compounds used in **pesticides** are poisonous.

33

As Arsenic

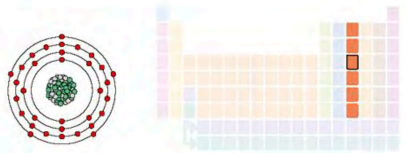

⊖ 33 ⊕ 33 ○ 42

State: Solid
Discovery: c. 1250

Forms

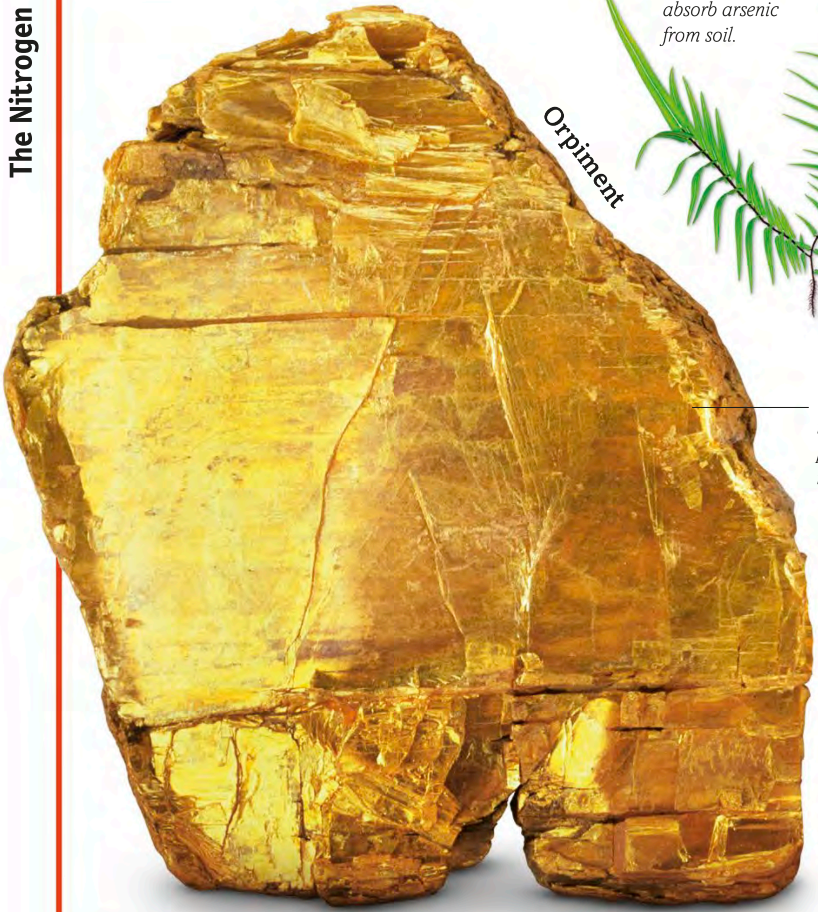

Orpiment

Until the 1800s, *this mineral was powdered for use in paints.*

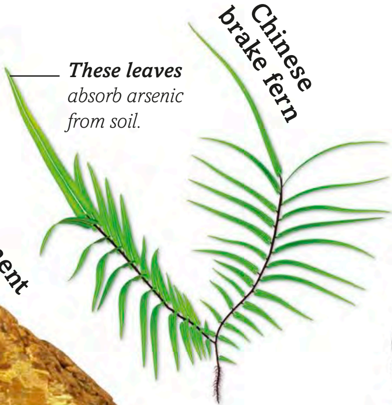

Chinese brake fern

These leaves *absorb arsenic from soil.*

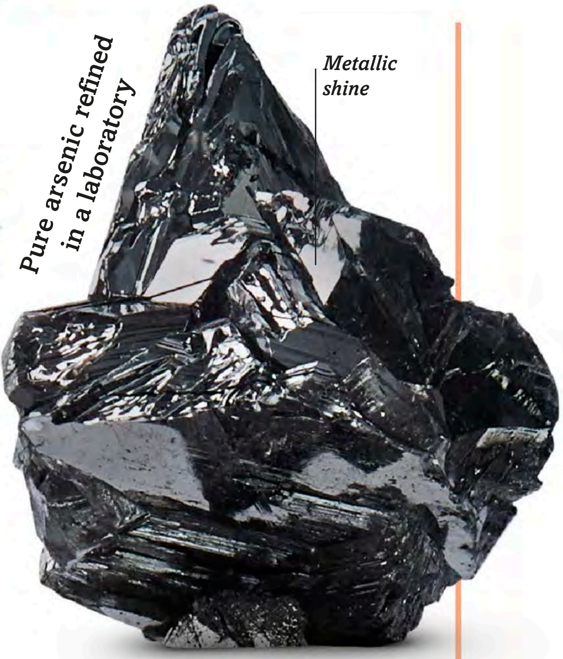

Pure arsenic refined in a laboratory

Metallic shine

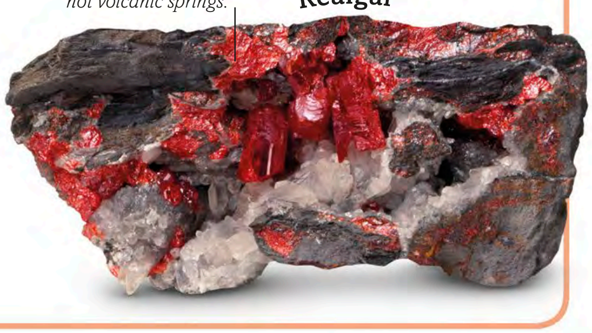

Realgar

This ore *is found in hot volcanic springs.*

Uses

Bullets

This tip *is an alloy of arsenic and lead.*

Rat poison

This poisonous arsenic compound *kills rats.*

When heated, arsenic **doesn't melt**, instead it **turns into a gas**.

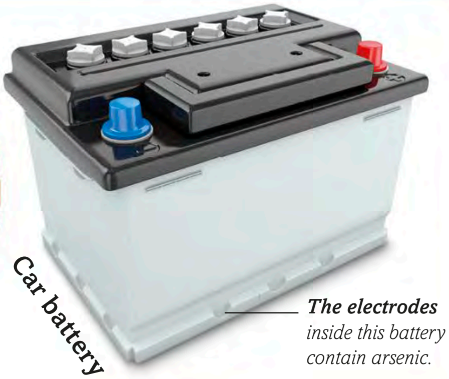

Car battery

The electrodes *inside this battery contain arsenic.*

Arsenic is often called the "king of poisons". Every form of arsenic – either pure or in a compound – is poisonous to animals. In fact, arsenic poisons have been used for centuries. This semi-metal is found in several minerals with striking colours, including **orpiment**. Naturally occurring **pure arsenic** has a shiny, grey colour. Arsenic compounds are used in making some **rat poisons**. The leading use of arsenic today is for strengthening lead. This is done by mixing arsenic with lead to create a tough alloy that is often used in **car batteries**.

51
Sb

Antimony

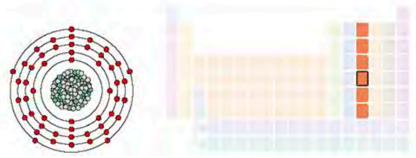

⊖ 51 ⊕ 51 ○ 71 State: Solid
Discovery: c. 1600 BCE

Forms

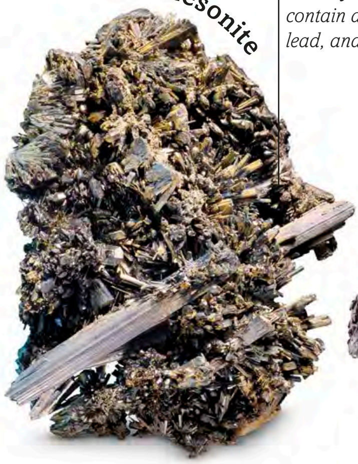

Jamesonite

These needle-like crystals *contain antimony, lead, and iron.*

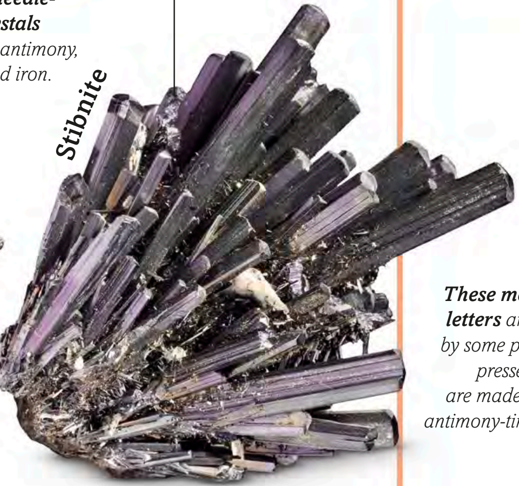

Stibnite

This mineral *tarnishes on contact with air.*

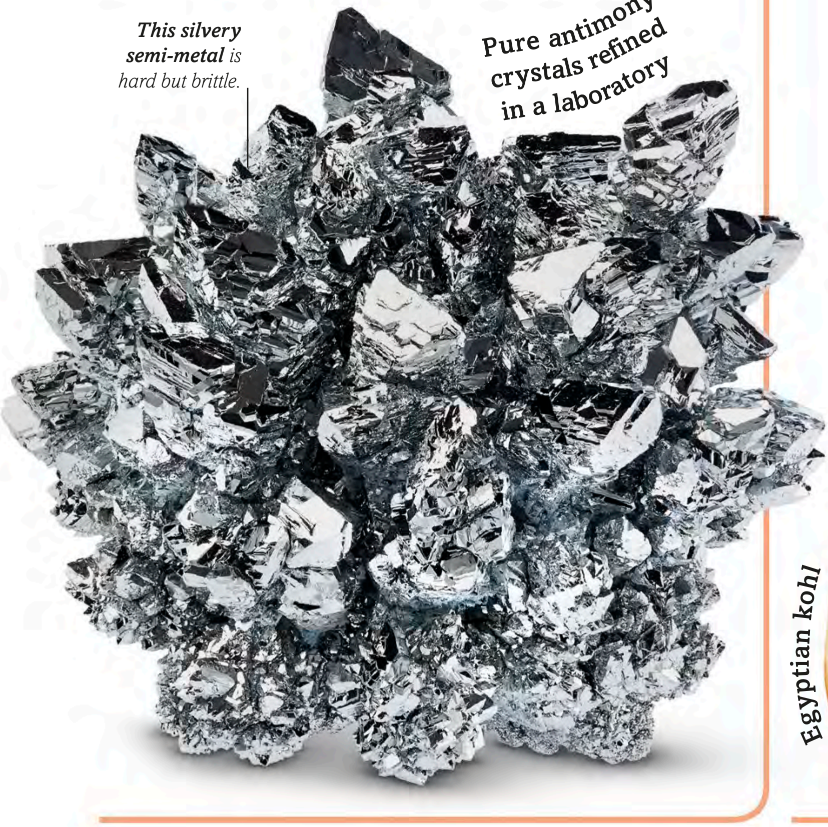

Pure antimony crystals refined in a laboratory

This silvery semi-metal *is hard but brittle.*

Uses

Printing press metal type

These metallic letters *are used by some printing presses, and are made of an antimony-tin alloy.*

Safety matches

These matches *with antimony in the tip burn brighter than the ones without it.*

Egyptian kohl

Kohl *is a dark eyeshadow.*

Kohl makes it **easier to see** in strong sunlight.

Antimony gets its name from the Greek word *anti-monos*, meaning "not alone". This may refer to the fact that the element is never found pure in nature, but is always found combined with heavier metals, such as lead. The element's symbol, Sb, comes from *stibium*, the Latin word for kohl, a form of eye make-up. The mineral ore **stibnite** is the largest source of **pure antimony**. Its pure form is mostly used to make hard alloys, such as that in the **metal type** used by some printers. Ancient **Egyptian kohl** was made from powdered stibnite.

83
Bi
Bismuth

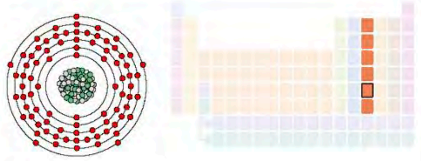

State: Solid
⊖ 83 ⊕ 83 ○ 126 Discovery: c. 1500

Forms

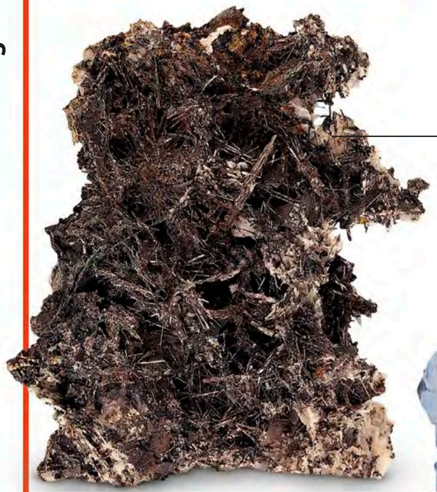

***This mineral** is the main source of pure bismuth.*

Bismuthinite

In Earth's crust, bismuth is about **twice as abundant as gold**.

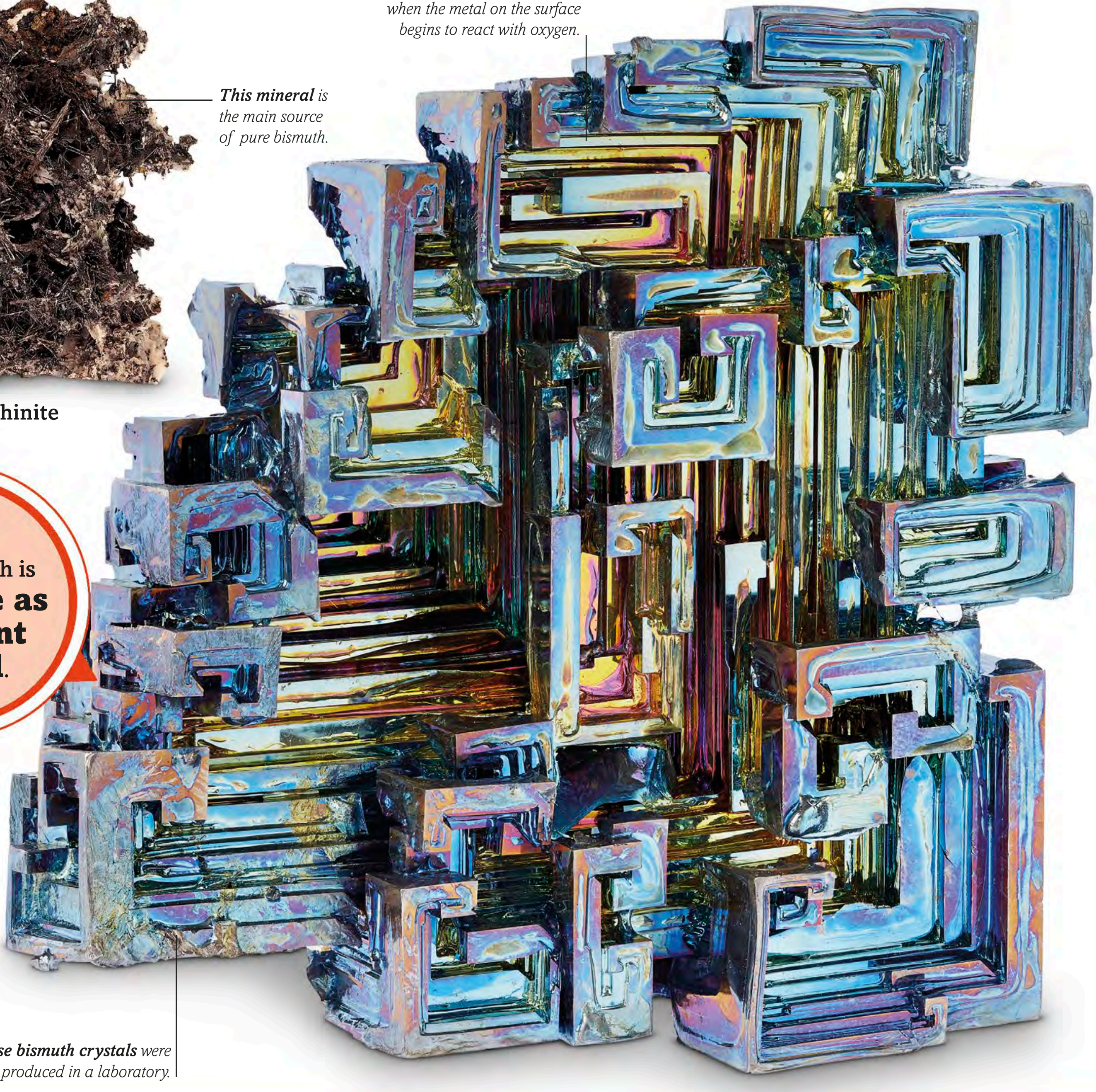

Hopper crystals refined in a laboratory

***These rainbow colours** form when the metal on the surface begins to react with oxygen.*

***These bismuth crystals** were produced in a laboratory.*

Bismuth is a radioactive element but its atoms are relatively stable and last for millions of years. People have known about bismuth for centuries. The Incas of South America added it to weapons made of the alloy bronze to harden them, while ancient Egyptians used a bismuth mineral to make their cosmetics glittery. Pure bismuth forms an oxide in air that is seen as colourful crystals called **hopper crystals**. This element is very brittle and has few uses when not in a compound form. Yellow bismuth

Uses

This cold box *uses a compound called bismuth telluride, which becomes cold when electrified, and keeps items cool.*

Portable refrigerator

This nail polish *gives a pearly effect because of bismuth compounds.*

Yellow cosmetics

This medicine *contains a bismuth compound that helps settle an upset stomach.*

Digestive medicine

Unlike most elements, bismuth's liquid state is **heavier** than its solid.

pigments are used in paints and **cosmetics**, while several bismuth compounds are also in **medicines**. An alloy of bismuth and tin is an ingredient in fire sprinklers.

115

Mc

Moscovium

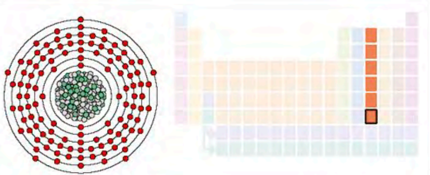

⊖ 115 ⊕ 115 ○ 174

State: Solid (predicted)
Discovery: 2004

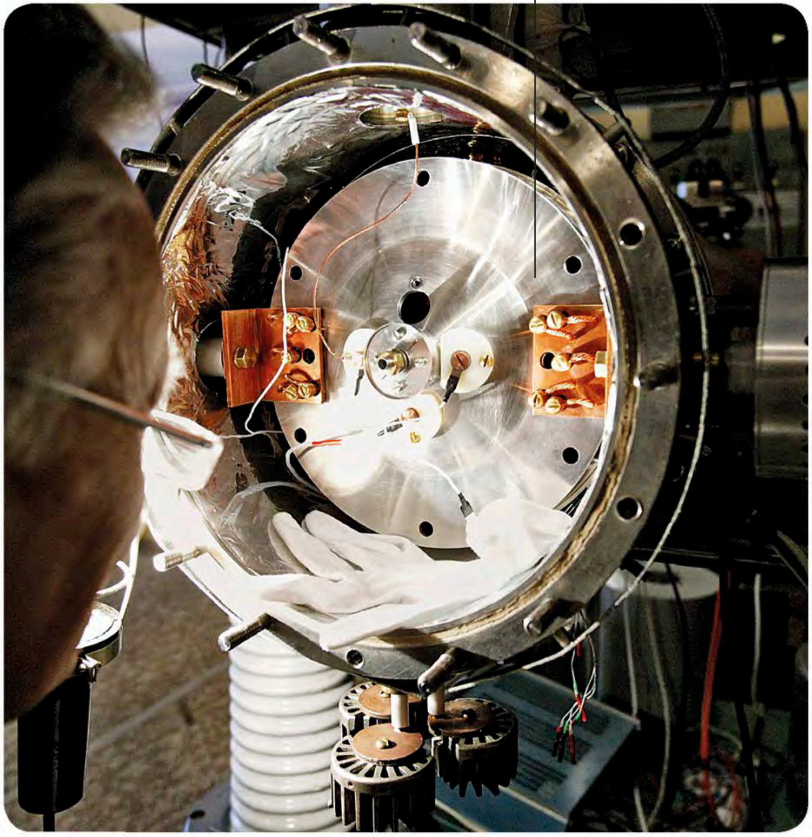

This is one of the machines *in this research centre.*

Joint Institute for Nuclear Research, Dubna, Russia

Only about a hundred or so atoms of this heavy, artificial element have been made. Moscovium was first created at the **Joint Institute for Nuclear Research** in Dubna, Russia. A team of Russian scientists, led by Yuri Oganessian, created this element by smashing americium atoms with parts of calcium atoms. It is named after the Russian capital city of Moscow. This element is extremely radioactive, and its atoms break up within a fraction of a second. Scientists think that moscovium would be a dense, metallic solid but with such small samples, they can only measure how big the atoms are before they break up.

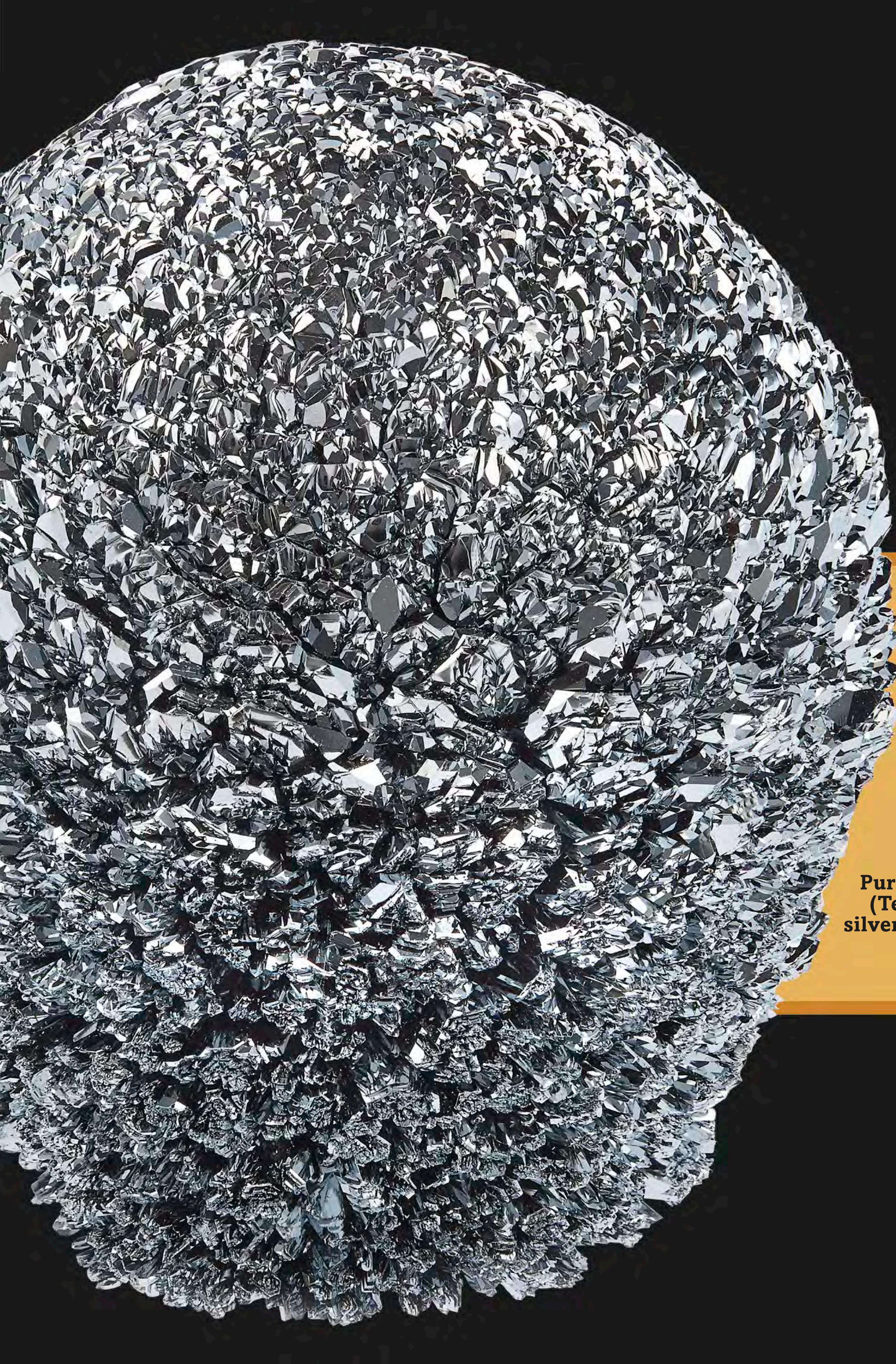

Pure tellurium (Te) can form silvery crystals.

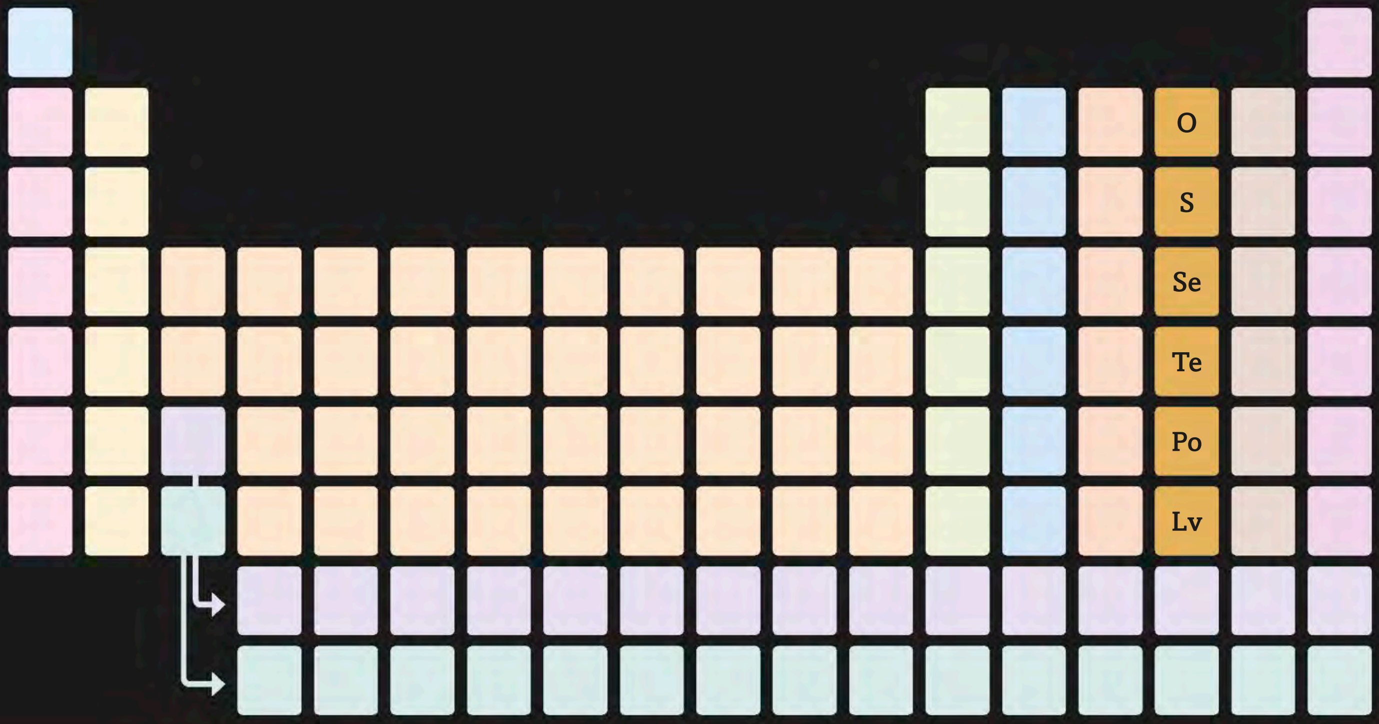

The Oxygen Group

This group does not include any natural metals. The first two members, oxygen (O) and sulfur (S), are non-metals widespread in nature. The remaining three natural elements are semi-metals. Only the artificial member, livermorium (Lv), is thought to be a metal, but chemists don't really know for sure.

Atomic structure
All members have six electrons in the outer shell of each atom. This electron structure makes these elements highly reactive.

Physical properties
The members of this group are solids, except oxygen (O), which is a gas at room temperature. The density of the elements increases down the group.

Chemical properties
The reactivity of these elements decreases down the group. Oxygen is always involved in the process of combustion.

Compounds
These elements can form compounds with each other. They all react with carbon (C) to form compounds, some with strong smells.

8

O

Oxygen

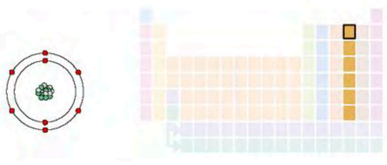

8 8 8

State: Gas
Discovery: 1774

Forms

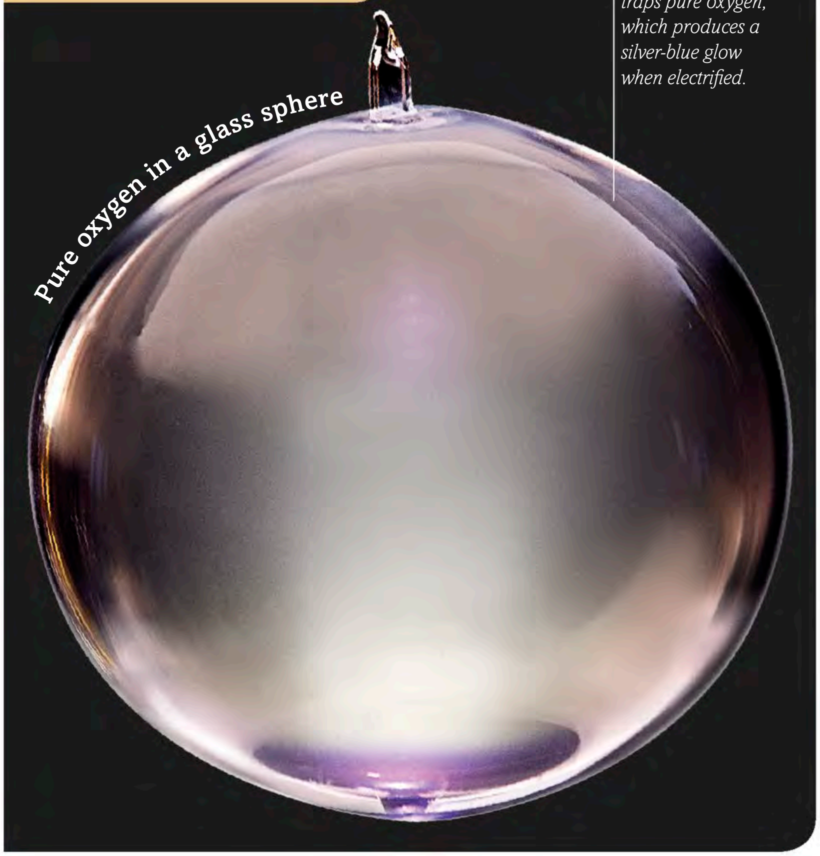

This glass sphere *traps pure oxygen, which produces a silver-blue glow when electrified.*

Streaks of light *adorn the sky as atoms of oxygen in the air are hit by a stream of particles blasting from the Sun.*

Northern lights

Plants *release oxygen in sunlight.*

Flames *are produced when oxygen reacts with fuel, such as wood.*

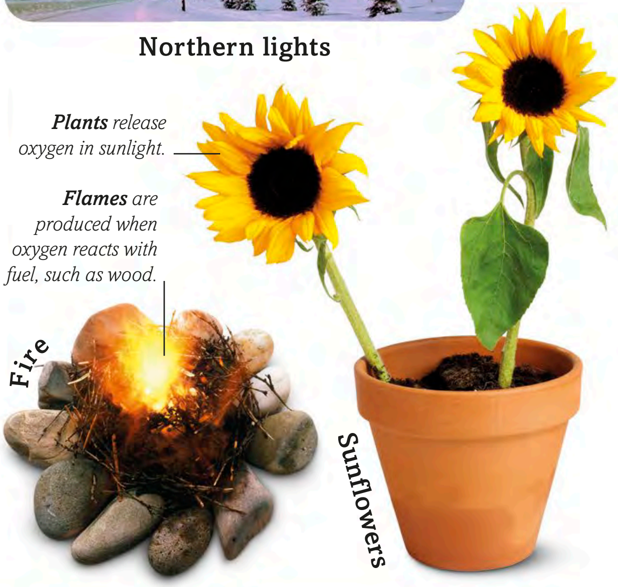

Each water *molecule has two atoms of hydrogen and one of oxygen.*

WHAT IS COMBUSTION?

Combustion is a chemical reaction that produces heat and light. Oxygen is essential for combustion to take place.

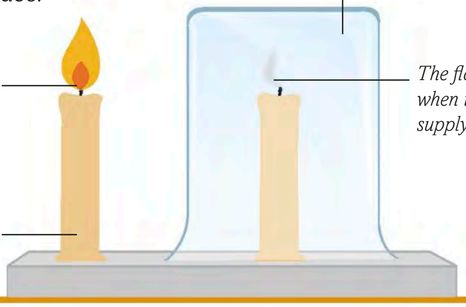

A beaker is placed over a candle, starving the flame of oxygen.

The flame is steady in the presence of oxygen.

The flame goes out when the oxygen supply is cut off.

Candle wax is made of a flammable carbon compound, which acts as a fuel.

Oxygen is the most common element in Earth's crust. Oxygen and its compounds make up half of all rocks and minerals on our planet. In the atmosphere, **pure oxygen** makes up around one-fifth of the air. This element is a transparent gas. Life on Earth depends on oxygen for survival. Animals breathe in air to collect the oxygen in it. Our bodies' cells then use that oxygen to break apart sugars to release energy, which powers our bodies. Another process that involves oxygen is the burning reaction called combustion, in which oxygen

Uses

This cylinder *takes in oxygen along with the fuel.*

The piston *then squeezes the mixture of oxygen and fuel.*

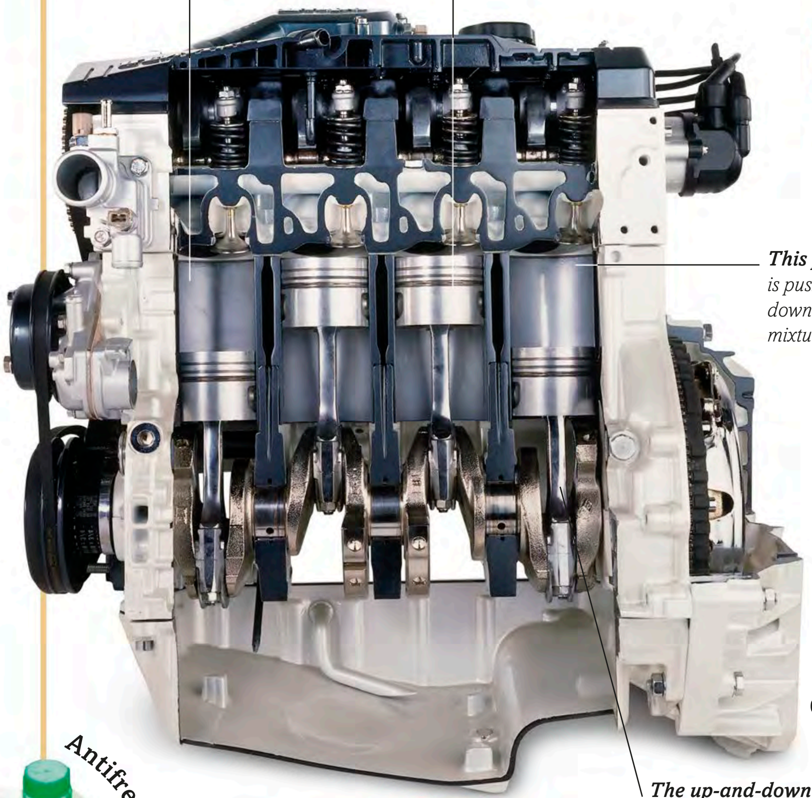

This piston *is pushed down when the mixture explodes.*

The up-and-down motion of the pistons *makes the wheels of a car spin.*

Internal combustion engine

Hot steel *may have impurities that are burned away using pure oxygen.*

Steelmaking

The oxygen in this cylinder *can last for up to 30 minutes.*

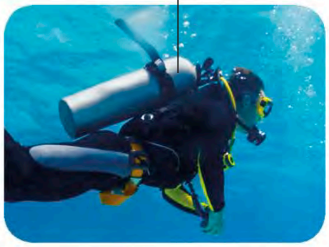

Scuba diver

This rocket *carries liquid oxygen that mixes with the fuel to produce hot gases, which help the rocket lift off.*

Atlas V rocket

Antifreeze

This liquid *contains an oxygen compound that prevents water from freezing in an engine.*

Oxygen is **colourless** as a gas, but looks **pale blue** as a liquid.

Mountaineers *have to adjust slowly to changing levels of oxygen as they climb higher.*

Mountaineer with oxygen supply

Medical oxygen cylinder

The oxygen in this cylinder *is given to patients in controlled amounts.*

Welding torch

This flammable gas-oxygen mixture *burns hot enough to melt metal.*

reacts with a fuel and produces **fire**. Oxygen is also used up when it reacts with other elements to form compounds called oxides. However, it is replenished by **plants** through a process called photosynthesis, which releases fresh oxygen. Car **engines** are powered by the combustion of petrol or other fuels. Oxygen is also useful in the **making of steel**. Tanks of oxygen let **mountaineers** breathe easily in environments that have low levels of this gas. Rockets, such as the **Atlas V**, carry liquid oxygen to burn fuel in the absence of air in space.

16 S Sulfur

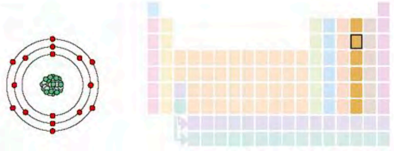

⊖ 16 ⊕ 16 ○ 16

State: Solid
Discovery: Prehistoric

Forms

Natural sulfur

These yellow sulfur crystals *often attach to volcanic mud.*

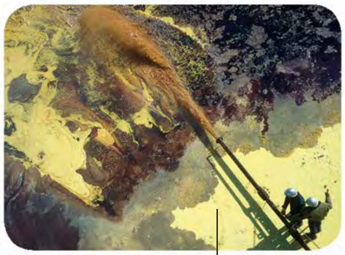

Liquid sulfur

Hot liquid sulfur *is pumped up from an underground mine.*

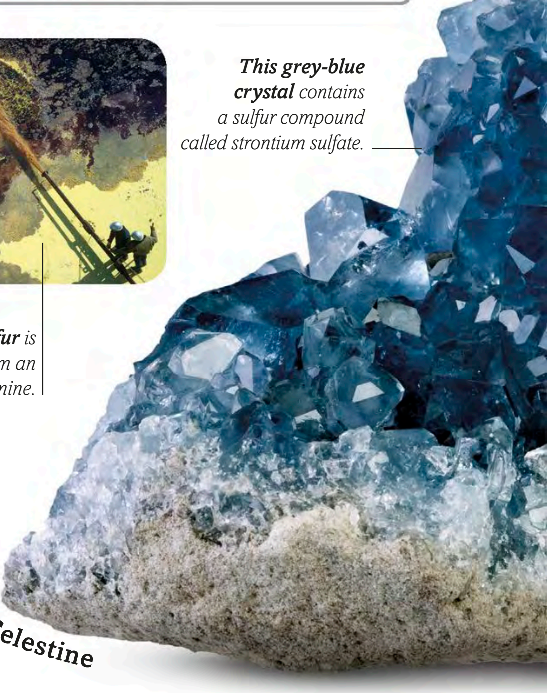

Celestine

This grey-blue crystal *contains a sulfur compound called strontium sulfate.*

Laboratory sample of pure sulfur

Soft, brittle granules

Skunk

Skunks *release a foul spray that contains three kinds of sulfur compounds.*

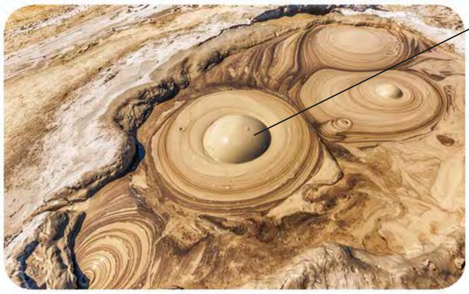

Mud volcano

Hydrogen sulfide bubbles *form in volcanic mud.*

Onions

Cut onions *release sulfur compounds that make our eyes water.*

Known since ancient times, sulfur is one of the few non-metals that can be found pure in nature. This yellow, crystalline element is found in large amounts near volcanic craters. Another name for sulfur is "brimstone", which refers to the way its crystals burn, melting into a blood-red liquid. In some religions, brimstone is thought to be the fuel that burns in the underworld. **Pure sulfur** is extracted from underground deposits using hot water. The hot **liquid sulfur** is then pumped to the surface. This element is a common ingredient in many

Uses

Vulcanized rubber *– made by heating sulfur with natural rubber – is weatherproof.*

Vulcanized tyre

Preserved dried fruits

Some dried fruits *are preserved using powder containing a sulfur compound.*

When burned, sulfur in this candle *drives away pests.*

Sulfur candle

ACID RAIN

Sulfur dioxide gas produced by burning fuel dissolves in rain water, making a sulfur acid. This falls to the ground as acid rain.

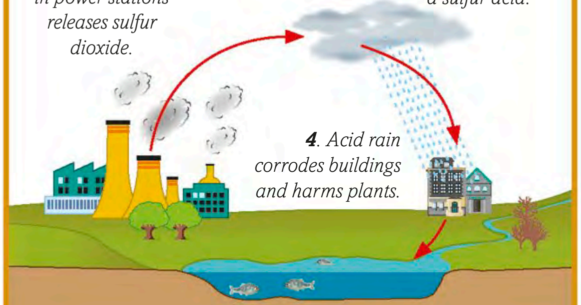

1*. Burning coal in power stations releases sulfur dioxide.*

2*. The wind carries pollutants.*

3*. Sulfur dioxide mixes with water in clouds and forms a sulfur acid.*

4*. Acid rain corrodes buildings and harms plants.*

5*. Acid rain changes soil chemistry.*

6*. It also makes rivers and lakes acidic.*

This plant *emits a rotting smell to attract meat-eating insects.*

Titan arum

Creams that contain sulfur compounds *can disinfect skin.*

Skin cream

Lead acid battery

This battery *contains strong sulfuric acid.*

Penicillin pills

Some antibiotics *contain sulfur compounds that kill harmful bacteria.*

Acid rain **destroys forests** by removing nutrients in the soil and in the leaves.

Sulfur acid rain damage

This limestone sculpture *has been weathered by acid rain.*

minerals, such as **celestine**. Many sulfur compounds smell bad. For example, the rotten-egg smell of volcanic pools is due to hydrogen sulfide gas. Other examples include **skunk** spray, the gaseous substance emitted by chopped **onions**, and the odour of the **titan arum** flower. There are many uses for this non-metal. Its compounds can harden natural rubber for use in **tyres**, preserve **dried fruits**, and make strong **battery** acids. The element has anti-bacterial properties and is used in antibiotic medicine, such as **penicillin**.

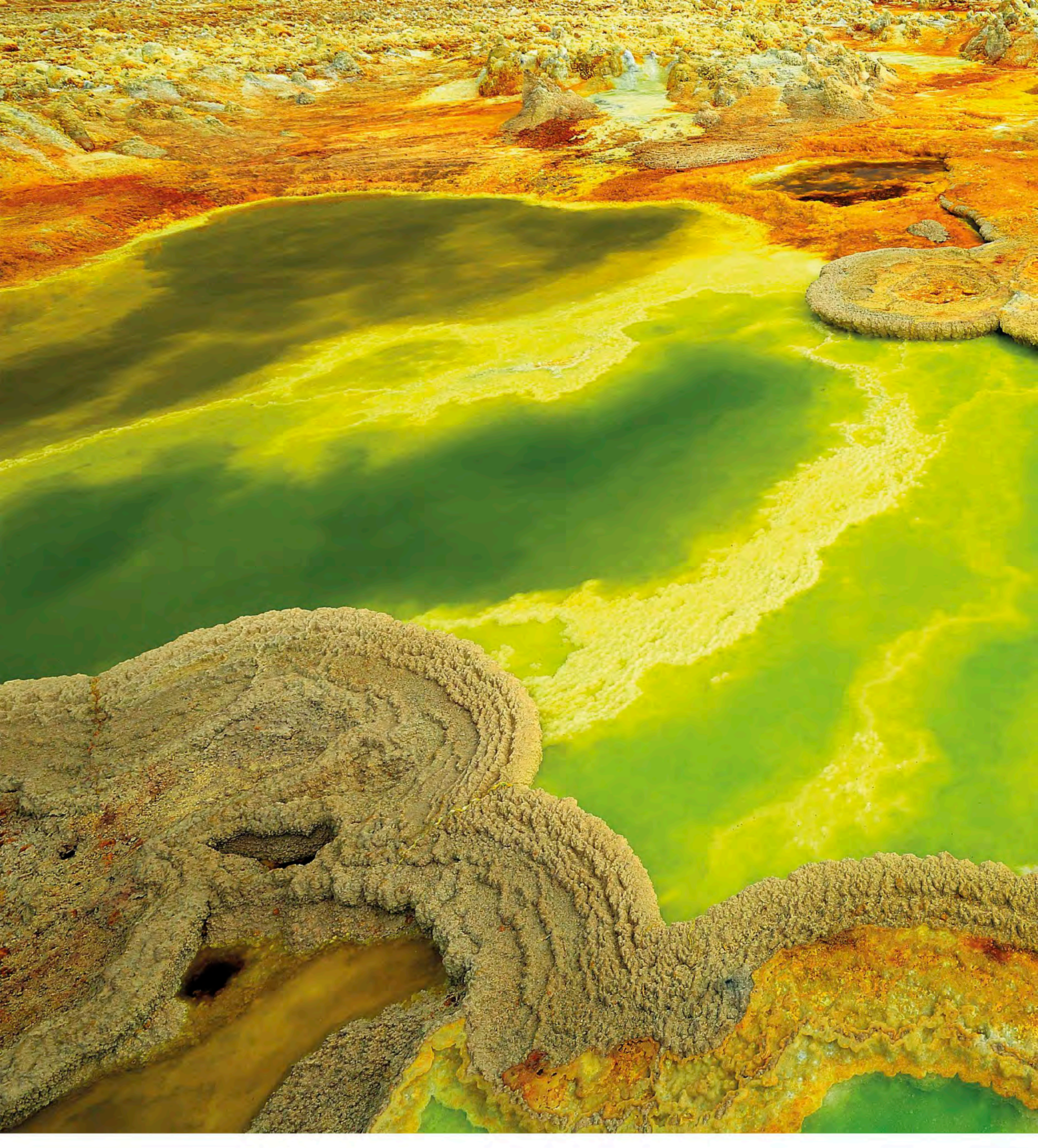

DANAKIL DEPRESSION This hot spring in Africa's Danakil Depression is surrounded by a yellow crust of pure sulfur. The sunken region between Ethiopia and Eritrea in East Africa is a wild volcanic area, packed with erupting craters, arid deserts, boiling mud, and pools with unusual colours caused by the presence of sulfur and many mineral salts.

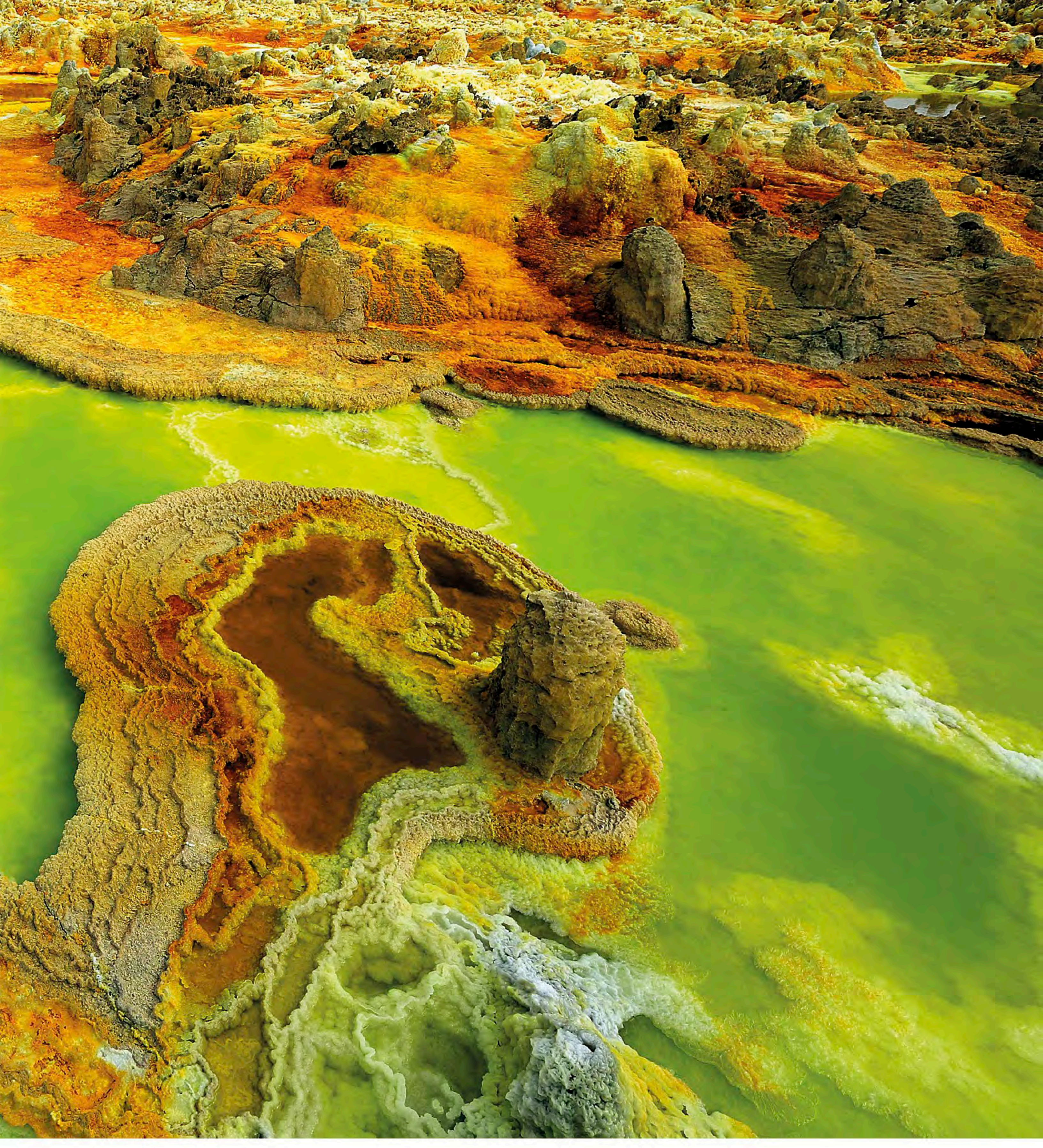

At more than 100 m (330 ft) below sea level, the Danakil Depression is one of the lowest points on Earth's surface. This area receives little or no rainfall and the weather is hot and dry, with temperatures soaring above 50°C (120°F). The scalding green water of the springs inside the depression contains pure sulfur as well as a toxic sulfur compound called sulfuric acid. As the water evaporates, sulfur deposits build up around the edges of the pools, making beautiful shapes across the vast landscape. Tourists visit to marvel at the remarkable sights at Danakil, even though the inhospitable conditions in the area give it the title of the "cruellest place on Earth".

34
Se

Selenium

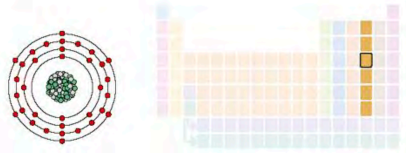

− 34 + 34 ○ 45

State: Solid
Discovery: 1817

Forms

This form of the element has a metallic sheen on its surface.

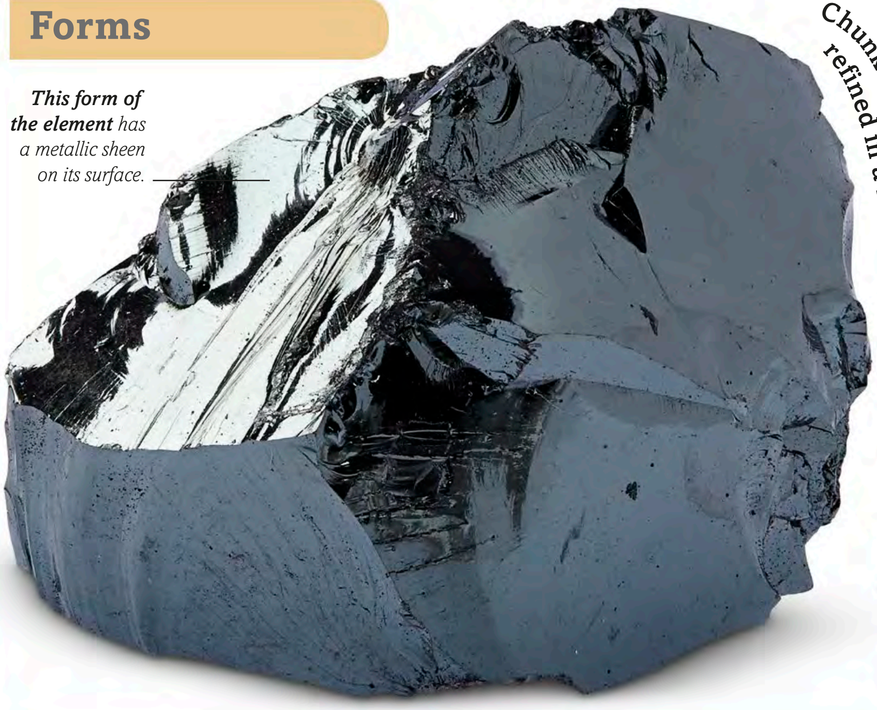

Chunk of pure grey selenium refined in a laboratory

Brazil nuts

These nuts are the richest food source of selenium.

Berzelianite

These dark areas contain selenium and copper.

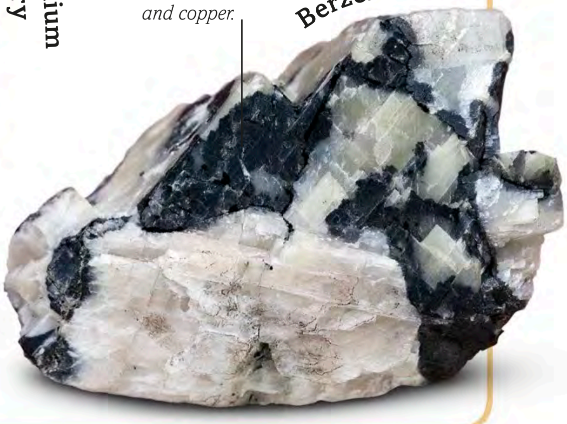

Uses

This calculator is powered by a solar cell made of selenium and nickel.

Calculator

Anti-dandruff shampoo

A selenium compound in this shampoo treats dandruff.

Ceramic vase

This bright colour comes from the red selenium in the glaze.

Photocopier

Many office photocopiers use selenium in powdered form.

Selenium is named after Selene, the Greek goddess of the Moon. This element is a semi-metal and so has the properties of both metals and non-metals. Selenium has two main pure forms: **grey selenium**, which is a hard substance, and red selenium, which is a soft powder. The most common use of selenium is as an ingredient that provides colour in glass and **ceramics**. Selenium is sensitive to light, so it is used in solar cells that convert sunlight into electricity. It is also utilized in **photocopy machines**.

52 **Te** Tellurium

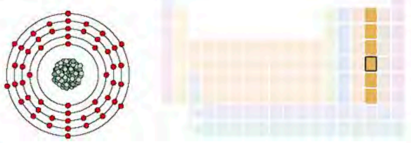

⊖ 52 ⊕ 52 ○ 76

State: Solid
Discovery: 1783

Forms

Melonite

This ore *is a soft but dense solid.*

Sylvanite

This metallic crust *contains tellurium, gold, and silver.*

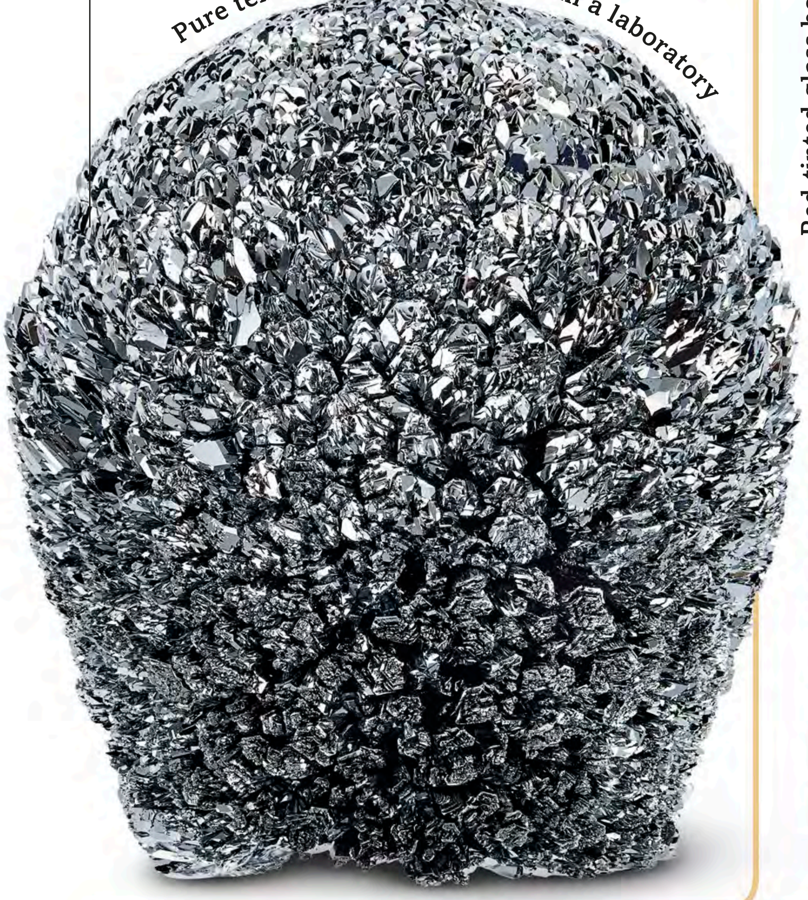

Pure tellurium crystals refined in a laboratory

This semi-metal *can form silvery white crystals.*

Uses

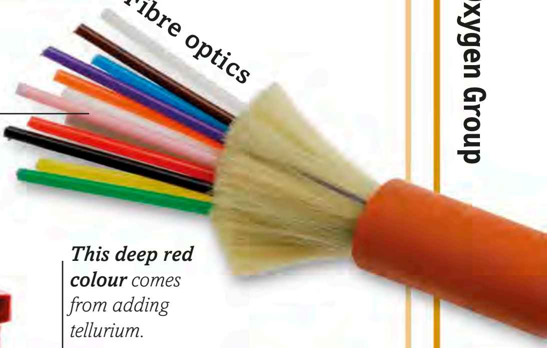

Fibre optics

These glass fibres *contain tellurium.*

Red-tinted glass bottle

This deep red colour *comes from adding tellurium.*

Tellurium **protects** bronze **from corroding** easily in air.

Topaz solar farm, California, USA

The solar panels *are linked to power cells containing tellurium.*

Tellurium is one of the 10 rarest elements on this planet. It gets its name from the Latin word *tellus*, which means Earth. This element is often found as a compound with another element, such as the metal nickel, as in the case of the ore **melonite**. Tellurium is also produced as a waste product when lead and copper are refined. **Pure tellurium** can take on two forms: a shiny, metallic solid or a brown powder. This element is mainly used in the glass of **fibre optics**, which carry high volumes of information much faster than copper cables.

84
Po

Polonium

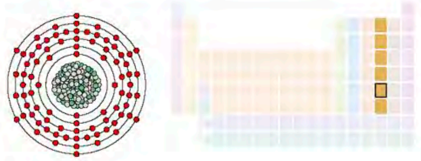

⊖ 84 ⊕ 84 ○ 125

State: **Solid**
Discovery: **1898**

Forms

This uranium ore contains **0.0000001 per cent** polonium.

This mineral *contains uranium atoms that break apart to form atoms of polonium.*

Uses

Anti-static brush

This brush *is used to remove static electric charge from camera lenses and music records.*

This bomb *can be detonated when the polonium inside it ignites.*

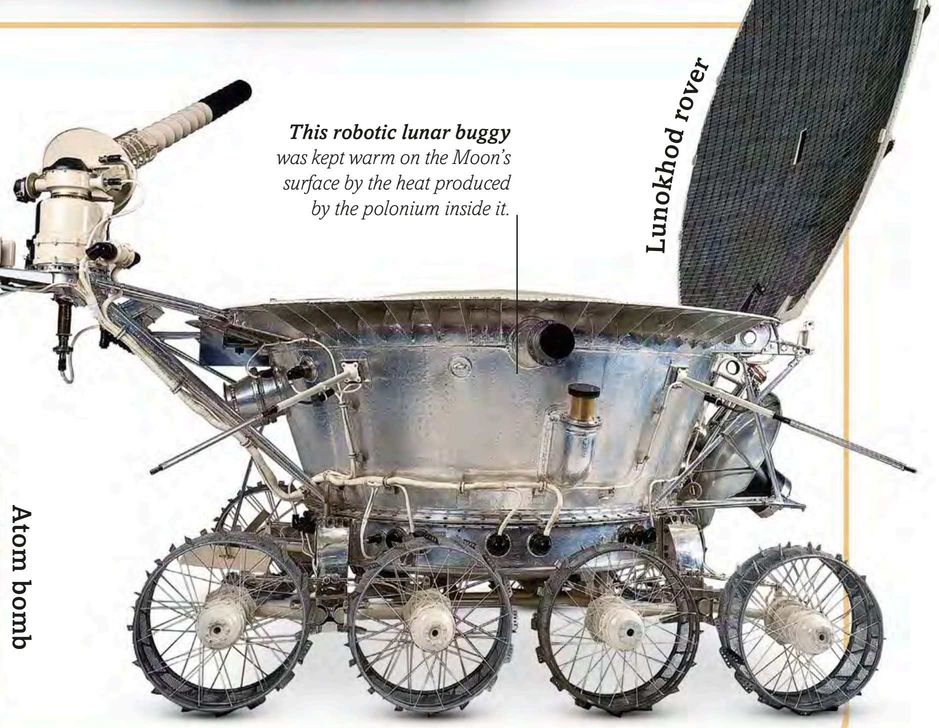

This robotic lunar buggy *was kept warm on the Moon's surface by the heat produced by the polonium inside it.*

Polonium is very radioactive: 1 g (0.03 oz) of this metal quickly heats up to 500°C (932°F) because of the radiation it emits. This element was discovered by Marie and Pierre Curie in 1898. Marie named it after Poland, her homeland. It is rare in nature, and is normally produced in nuclear reactors. Despite its radioactivity, this element is used in a few ways. It can trigger the explosion of **atom bombs**. It heats and powers spacecraft, such as the Russian **Lunokhod rovers**, which landed on the Moon in the 1970s.

116

Lv

Livermorium

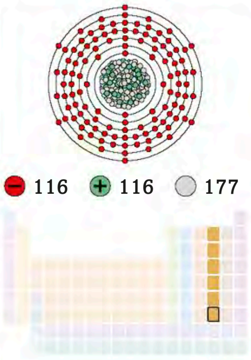

State: Solid
Discovery: 2000

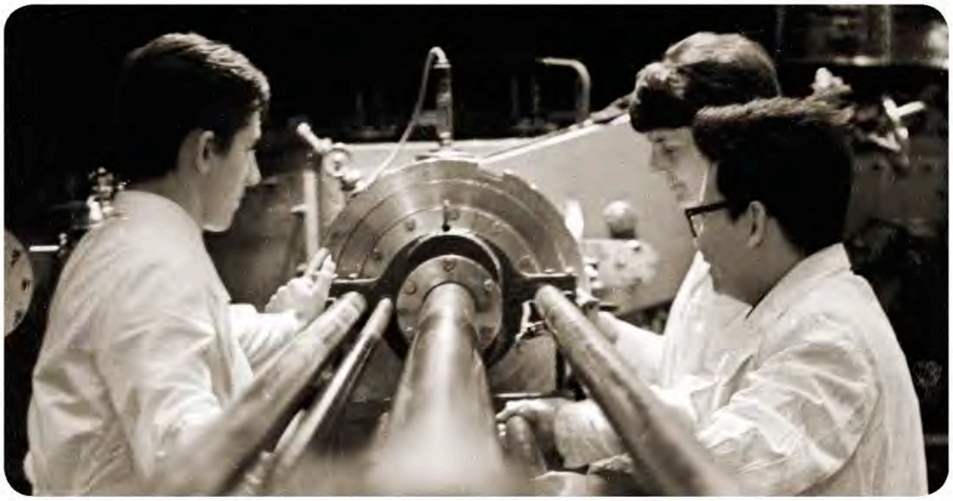

Heavy ion cyclotron,
Joint Institute of Nuclear Research, Dubna, Russia

Livermorium has been **named after** this **laboratory**.

Lawrence Livermore National Laboratory, California, USA

When livermorium atoms were first produced in 2000, they broke apart in a fraction of a second. The first successful attempt to create atoms of this element was made at the **Joint Institute of Nuclear Research** at Dubna, Russia. The team worked with material provided by the **Lawrence Livermore National Laboratory** in California, USA. This highly radioactive element was produced by firing calcium atoms at curium atoms in a particle accelerator (a machine in which atoms are smashed together).

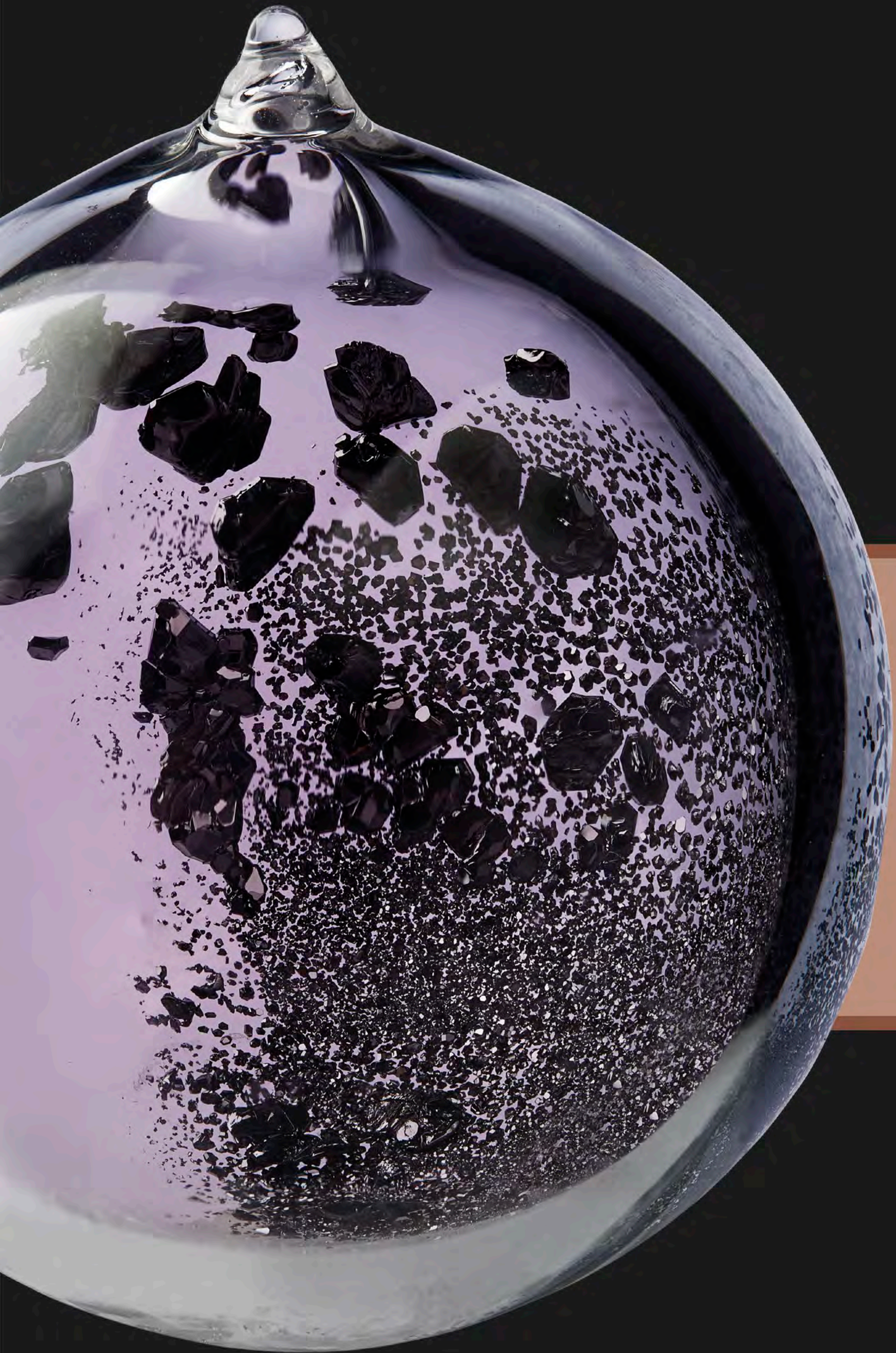

This glass sphere contains pure iodine (I).

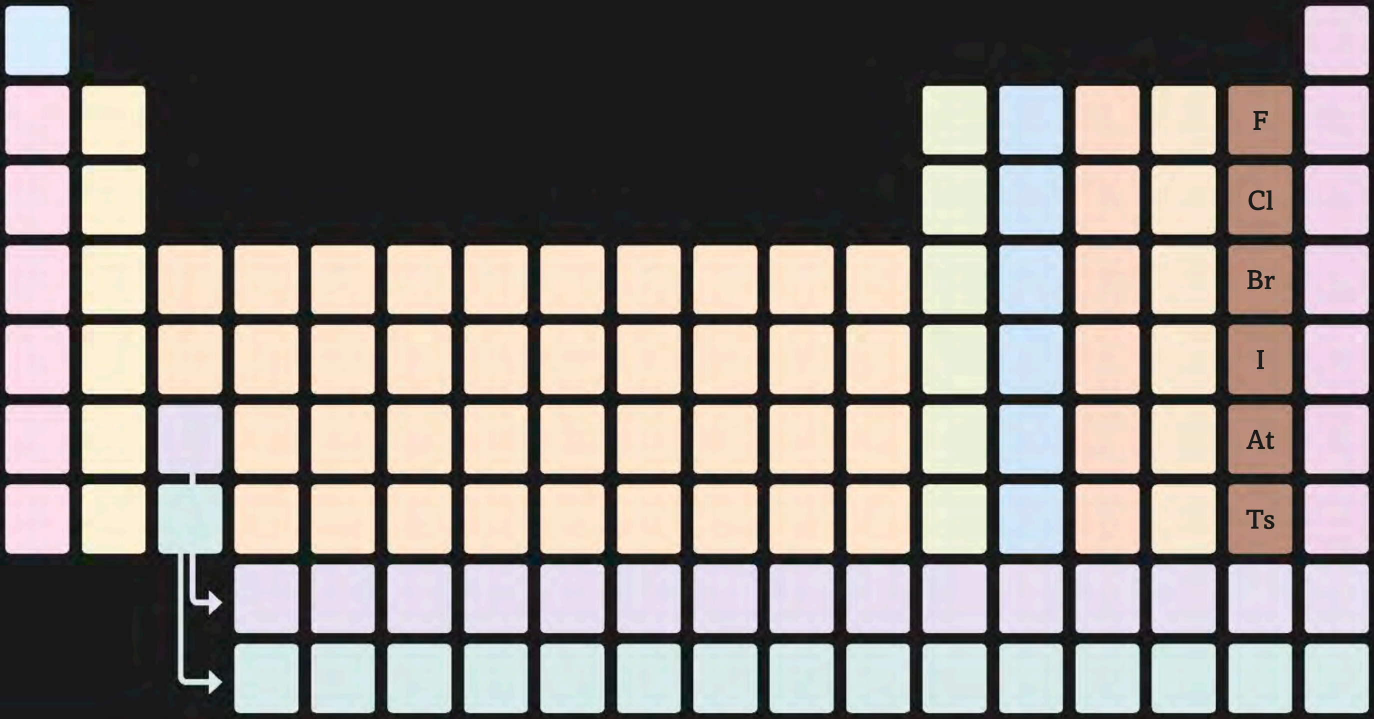

The Halogen Group

One of the most reactive groups in the periodic table, this set includes non-metals. The name “halogen” means “salt former”, which refers to the way that elements in this group react with metals to form salts, such as sodium chloride, widely known as common salt. Scientists don’t know much about tennessine (Ts), an artificial halogen.

Atomic structure
All members have seven electrons in the outer shell of each atom. There is space for one more electron in each outer shell.

Physical properties
Bromine (Br) is the only halogen that is liquid. Fluorine (F) and chlorine (Cl) are gases, while iodine and astatine (At) are solids.

Chemical properties
Every halogen atom receives one electron from other atoms to form a compound. Reactivity decreases down the group.

Compounds
The halogens react with hydrogen (H) to form acidic compounds. Halogen compounds are used in products such as bleach.

9 F Fluorine

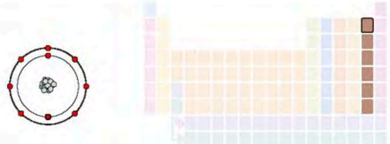

⊖ 9 ⊕ 9 ○ 10

State: Gas
Discovery: 1886

Forms

This soft mineral *is brittle, which means it breaks easily into lots of pieces.*

Cryolite

Laboratory sample

This sealed case *contains a mixture of fluorine and helium.*

Topaz **means “fire”** in the ancient Indian language of Sanskrit.

These cubic crystals *are green due to impurities.*

Fluorite

Topaz

This precious gemstone *contains 20.7% fluorine.*

This highly reactive element is incredibly dangerous when pure: just a tiny amount added to the air can kill a person. A pale yellow gas, fluorine reacts with brick, glass, and steel, burning a hole straight through them. Because it is so dangerous, pure fluorine is often stored in nickel containers that can resist its attack. Minerals such as **cryolite** and **fluorite** contain this element. This gas and its less harmful compounds have a wide variety of uses. Hydrofluoric acid is a toxic liquid used to etch patterns on glass, as seen in some **glass vases**.

Uses

HENRI MOISSAN

In the early 1800s, chemists in Europe realized that minerals such as fluorite contained an unknown element. However, it took another 70 years before the French chemist Henri Moissan extracted pure fluorine following a series of dangerous experiments that even poisoned him several times.

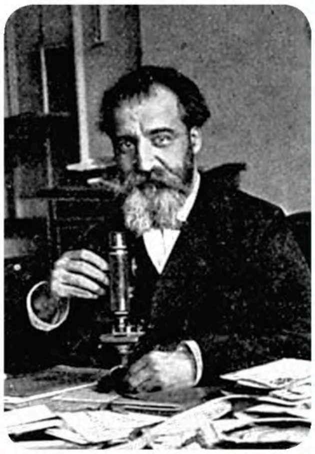

Etched glass vase

These patterns *form after the surface of the glass is burned by an acidic fluorine compound.*

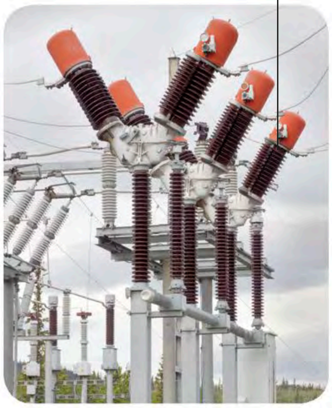

These circuit breakers*, containing a compound of fluorine and sulfur, cut electricity supply in an emergency.*

Circuit breakers

Ceramic pot

The shiny coating *on this ceramic dish is from a fluorine-containing glaze.*

Fluorine-rich plastic clothing *repels water.*

Waterproof clothing

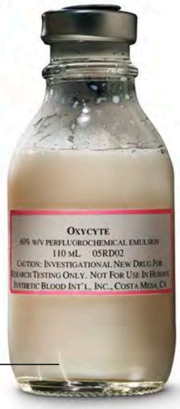
OXYCYTE
60% W/V PERFLUOROCHEMICAL EMULSION
110 mL 05RD02
CAUTION: INVESTIGATIONAL NEW DRUG FOR RESEARCH TESTING ONLY. NOT FOR USE IN HUMANS
SYNTHETIC BLOOD INT'L, INC., COSTA MESA, CA

Upon injection, this fluorine-rich liquid *heals damaged tissues by carrying oxygen to them.*

Oxycyte

PTFE was used by NASA to make **spacesuits** because it protected against heat.

This pan *has a PTFE coating that resists heat.*

Non-stick pan

Some toothpastes *contain fluorides that harden tooth enamel.*

Toothpaste

Some glazes used to coat ceramics contain fluorine minerals. When heated, these glazes release fluorine, which hardens the ceramic underneath. Another compound called polytetrafluoroethylene (PTFE) is commonly used to make **non-stick pans**: this material is slippery and prevents food that has burned while cooking from sticking to the pan. Thin fibres made of PTFE are also used to make lightweight, **waterproof clothing**. One of the most common uses of fluorine compounds is in **toothpaste**: they toughen teeth against decay.

17

Cl

Chlorine

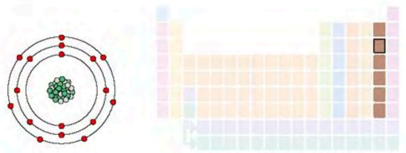

−17 +17 ○ 18

State: Gas
Discovery: 1774

Forms

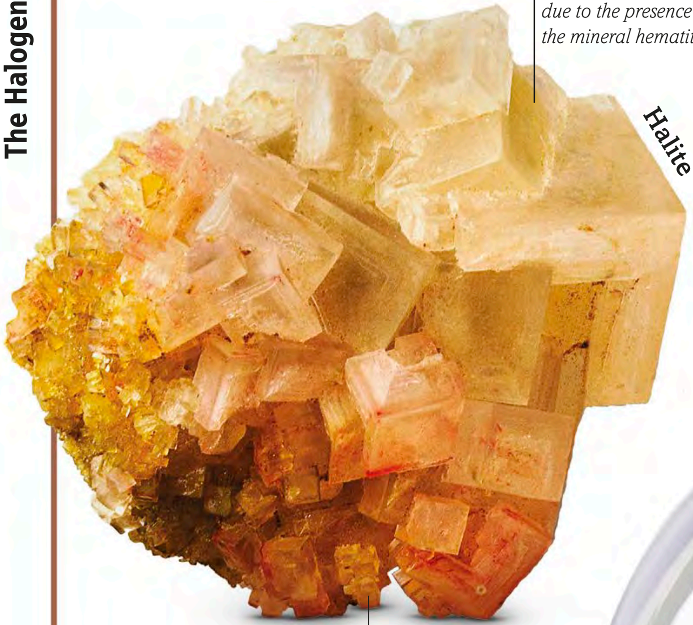

This orange colour *is due to the presence of the mineral hematite.*

Cube-shaped crystals

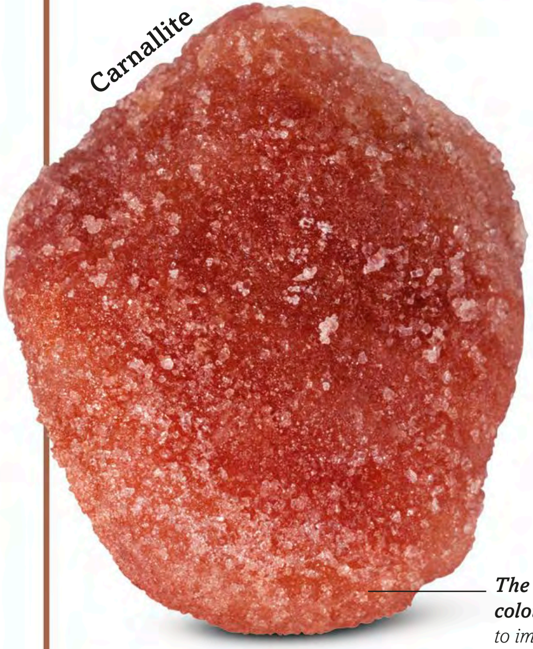

The intense red colour *is due to impurities.*

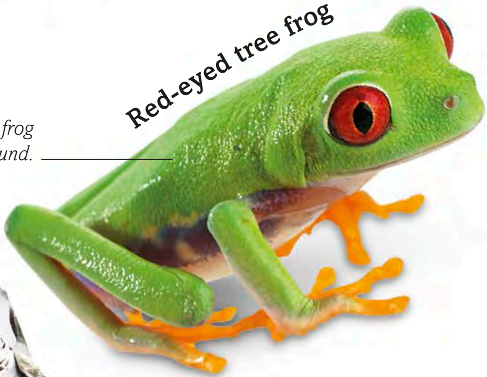

The skin *of this tree frog contains a chlorine compound.*

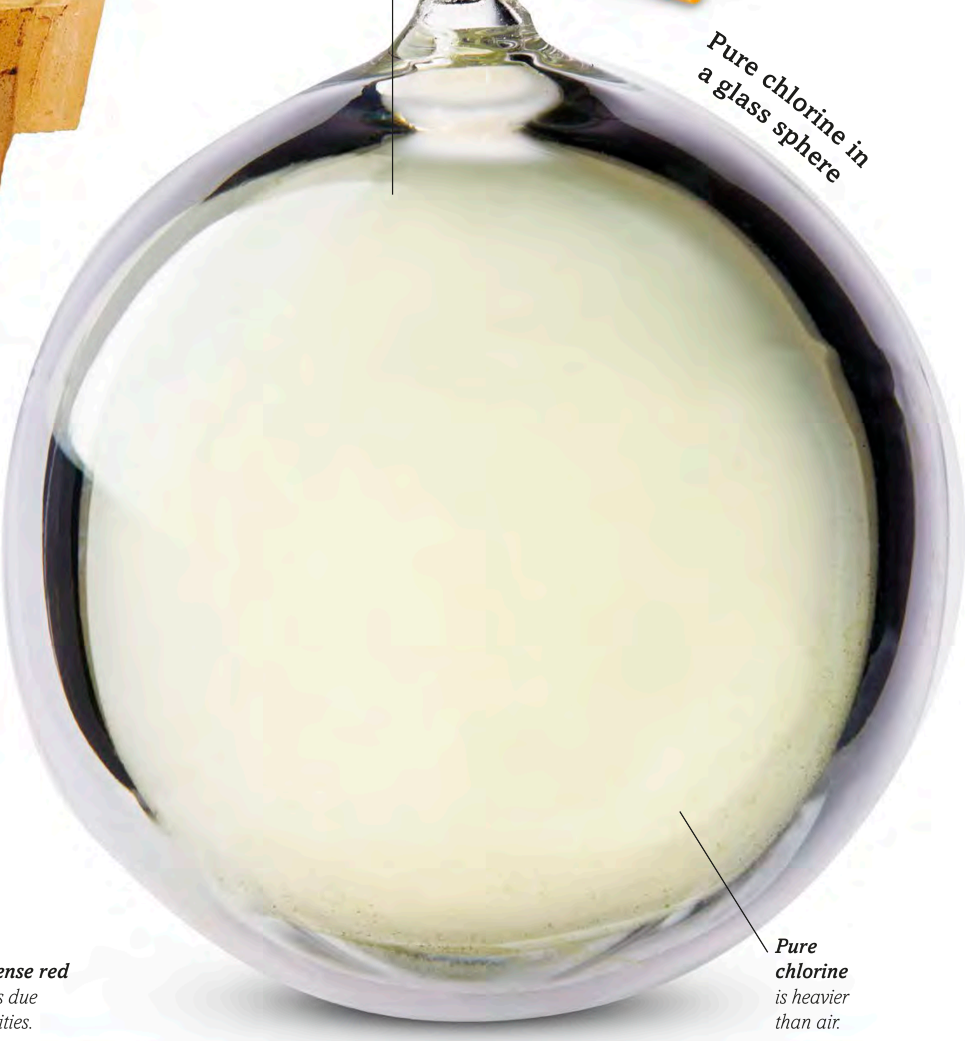

This glass sphere *traps pure chlorine so as to prevent any reactions with air.*

Pure chlorine *is heavier than air.*

Chlorine is named after the Greek word *chlóros*, which means "pale green", a reference to the colour of this gaseous element. Chlorine is a highly reactive gas that forms a number of compounds, and does not exist pure in nature. The most common chlorine compound is sodium chloride, found in nature as the mineral **halite**. Chlorine compounds are important for the body and are used by muscles and nerves. They are also present in sweat. As it is poisonous in its pure form, chlorine gas was used as a weapon during World War I: soldiers had to wear masks for protection

Uses

Running shoes

The soles of some running shoes *contain chlorine compounds.*

Common salt

Sodium chloride *is used to season meals.*

Chloroform

Breathing in this chlorine-infused liquid *makes people fall unconscious.*

PVC pipes

Strong water pipes *are composed of thick PVC.*

Safety goggles

This chlorine-rich plastic *is tough.*

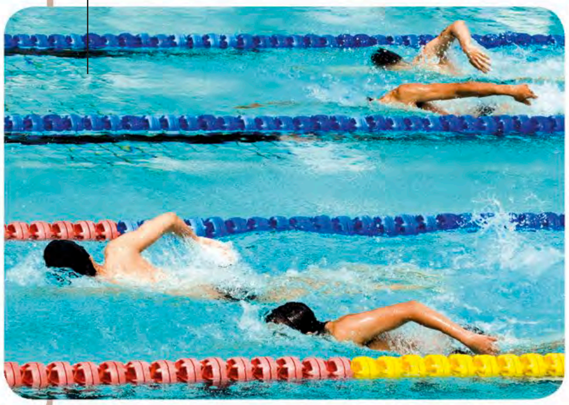

Swimming pool

The chlorine levels in this pool *need to be regulated carefully to maintain the quality of water.*

Bleach

This bleach cleaner *contains a compound called sodium hypochlorite.*

PVC suitcase

This case *is tough but flexible.*

CHLORINATION

The process of cleaning dirty water with chlorine is called chlorination. This method involves passing the water through a filter.

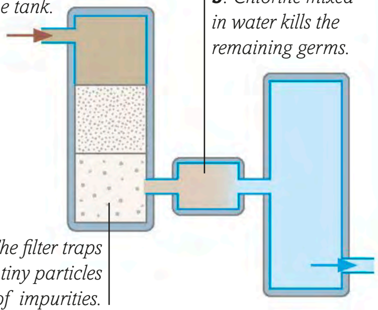

1. *Dirty water enters the tank.*
3. *Chlorine mixed in water kills the remaining germs.*
2. *The filter traps tiny particles of impurities.*
4. *Clean water for drinking, cooking, and washing is released.*

against this weapon. Today, chlorine is used in many ways. Its compounds are present in everything from **running shoes** to **choloroform**. It reacts with hydrogen to make hydrochloric acid, an industrial cleaner. This corrosive liquid eats away at most metals, releasing hydrogen gas. A weaker chlorine acid is used to clean water in **swimming pools**, while **bleach** and other cleaners use chlorine compounds to kill germs. One of the most widely used plastics, **polyvinyl chloride (PVC)**, contains chlorine. It is a tough plastic, used to make many rigid objects.

SPIRO
NARVAL

OCEAN CLEAN UP Chlorine is a common ingredient in cleaning products, and can be used for scrubbing everything from bathroom tiles to ocean floors. These divers are trying to remove harmful seaweed in the Mediterranean Sea using the power of chlorine. This green weed grows quickly and can potentially kill other sea plants by depriving them of their essential nutrients. Some fish are also poisoned if they eat this toxic weed.

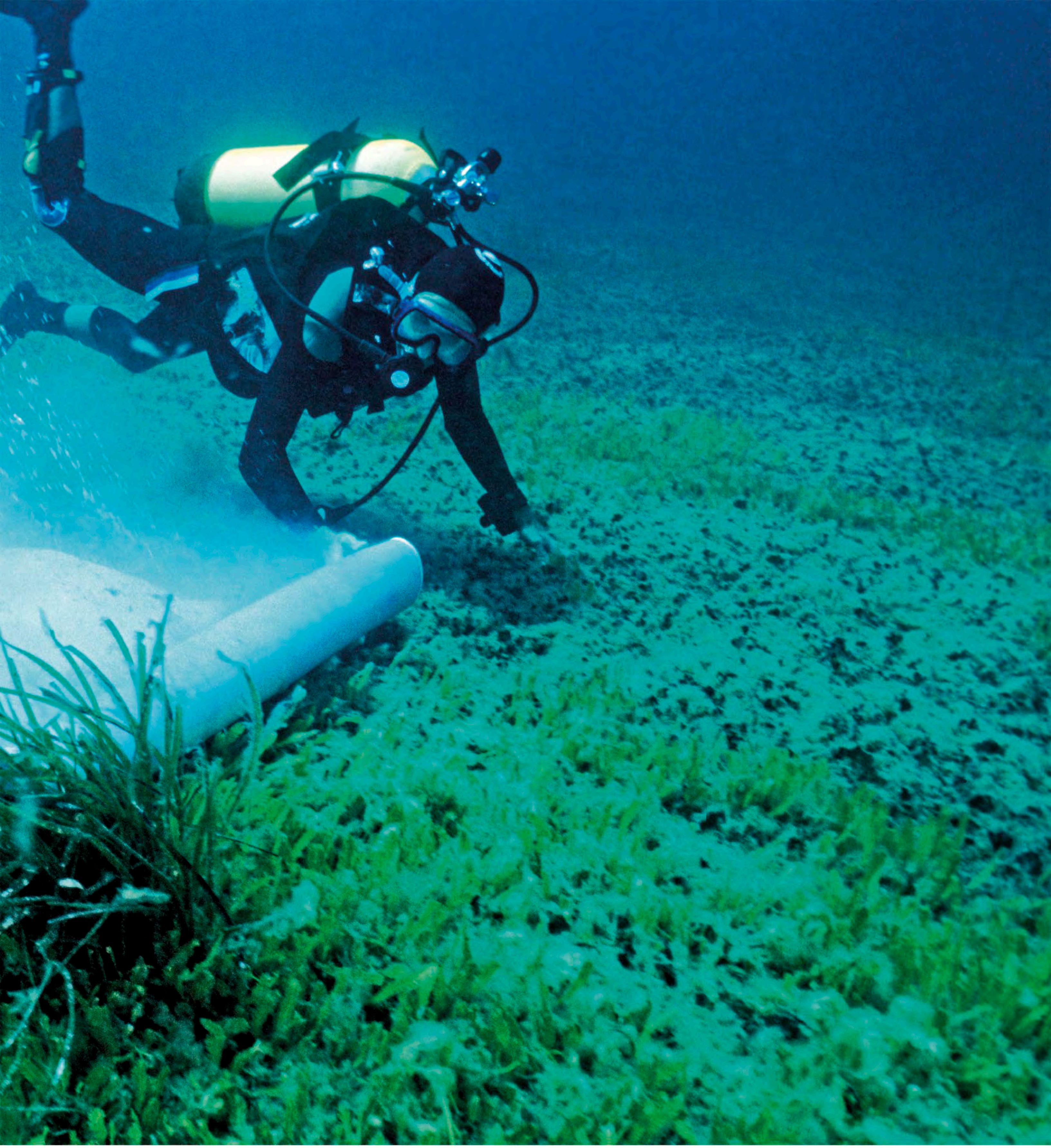

The two divers use chlorine twice in the cleaning process. First, they cover the thick seaweed with a sheet made of PVC, a tough plastic containing chlorine. Next, they pump a compound of sodium and chlorine called sodium hypochlorite under the sheet. This powerful liquid bleach kills the unwanted seaweed. Several weeks later, the divers return to remove the PVC sheets. The invading seaweed will not regrow, and the plants on the seabed will gradually return. Although chlorine is highly reactive and can damage skin and other body parts, divers are well-protected by their rubber wetsuits.

35
Br

Bromine

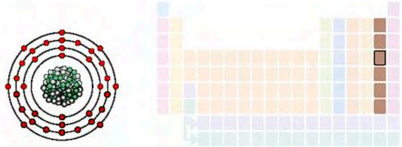

⊖ 35 ⊕ 35 ○ 45

State: **Liquid**
Discovery: **1826**

Forms

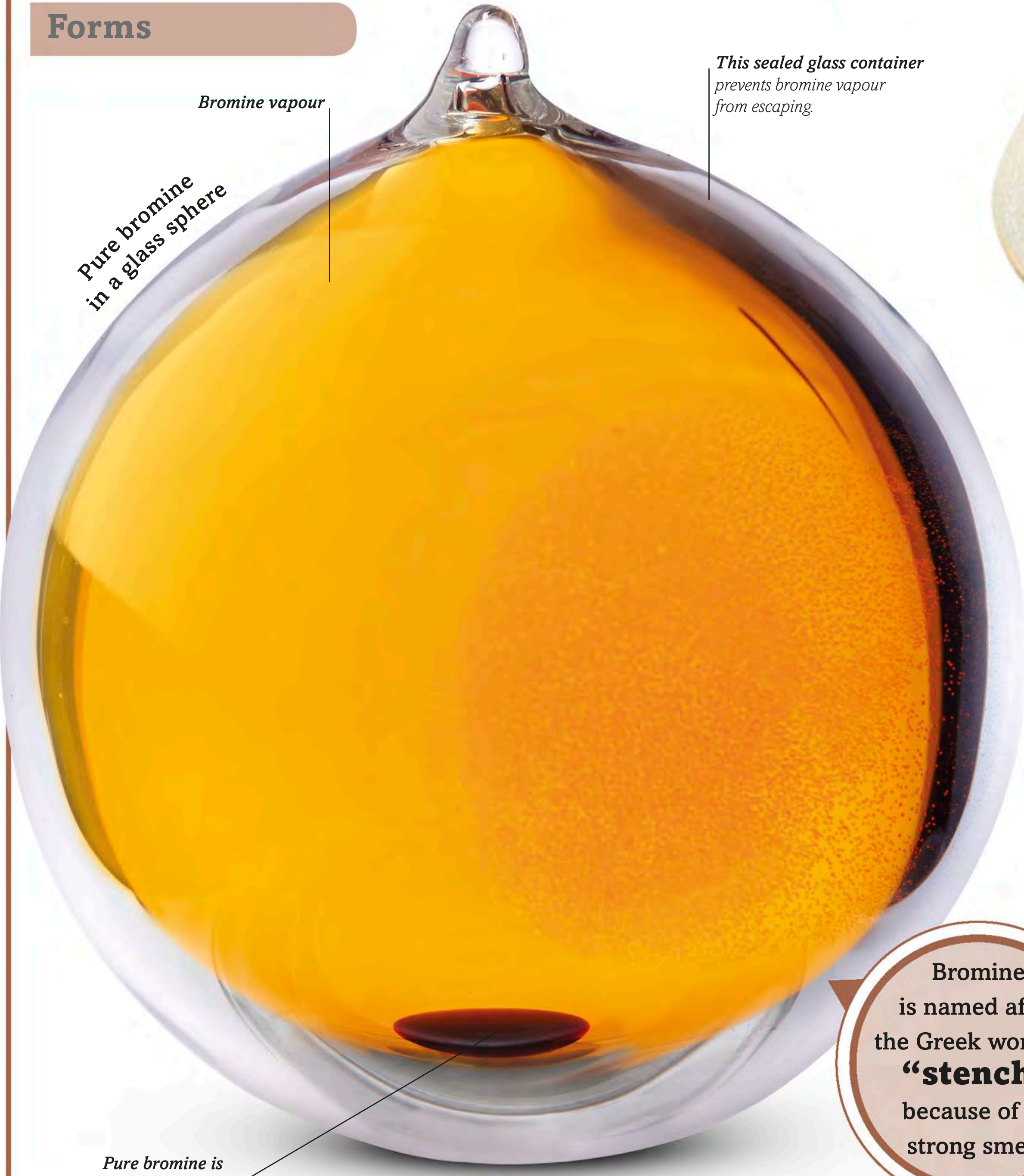

Pure bromine in a glass sphere

Bromine vapour

This sealed glass container *prevents bromine vapour from escaping.*

Pure bromine is *a red-brown liquid.*

Potassium bromide

Bromine is named after the Greek word for **"stench"** because of its strong smell.

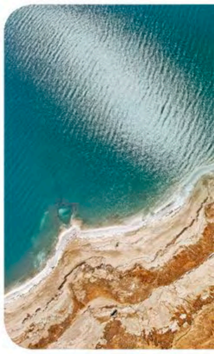

Bromine is the only non-metal that is a liquid at room temperature. A thick vapour given off by this liquid is dangerous if breathed in. **Pure bromine** is never found in nature. Its compounds can easily mix in water, and are found dissolved in seawater and extremely salty lakes, such as the **Dead Sea** in the Middle East. Solid bromine salts, including **potassium bromide**, collect as the water evaporates away, leaving behind crusts of white crystals. Bromine can then be extracted from the solid salts. A common

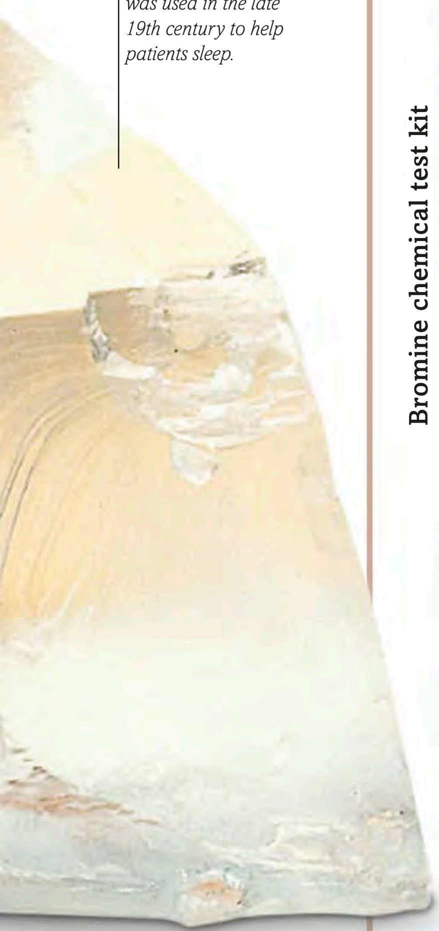

This bromine salt *was used in the late 19th century to help patients sleep.*

Uses

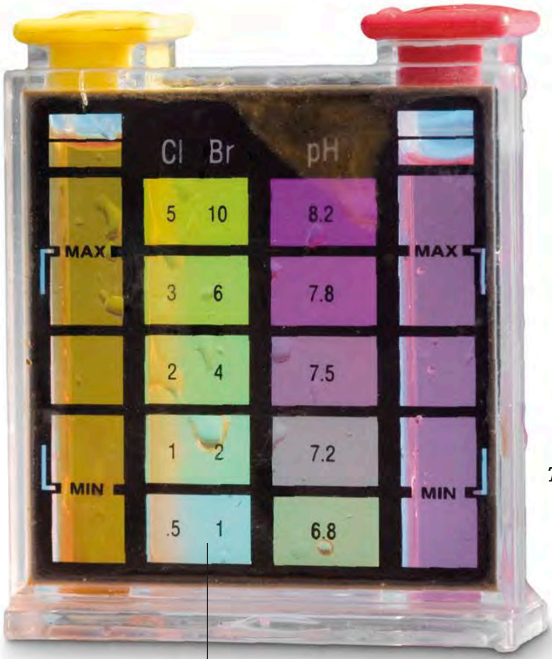

Bromine chemical test kit

The colours on this test kit *show how much bromine is in the water.*

Chubb Fire
HALON

Fire extinguisher

This fire extinguisher *uses a non-flammable, bromine-rich gas to extinguish fires.*

This image *was created when light reacted with silver bromide.*

Photograph negative

Bromine was used as a **weapon** in World War I.

The fabric *used to make this suit contains bromine compounds that make it fireproof.*

Fireproof suit

Crusts of bromine salts *form along the Israeli shoreline.*

The Dead Sea Coast

ANTOINE-JÉRÔME BALARD

In 1826, French chemist Antoine-Jérôme Balard discovered bromine. He heated seawater from salt marshes, and after most of the water had evaporated, he passed chlorine gas through what was left. The remaining liquid turned orange-red: this was bromine.

use of this element is as a disinfectant to clean water. It works better than chlorine in hot tubs as chlorine escapes into the air easily from the warm water. The concentration of bromine in swimming pools can be regulated using **chemical test kits**. Bromine compounds can be used in film photography in which images are printed using chemicals on **negatives**. Today, bromine is mainly used in **fireproof material**, such as firefighter suits or furnishings, because it doesn't catch fire easily.

53
I

Iodine

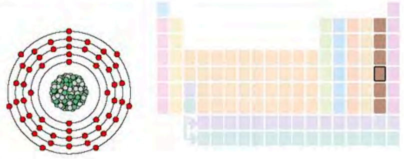

⊖ 53 ⊕ 53 ○ 74

State: Solid
Discovery: 1811

Forms

Pure iodine in a glass sphere

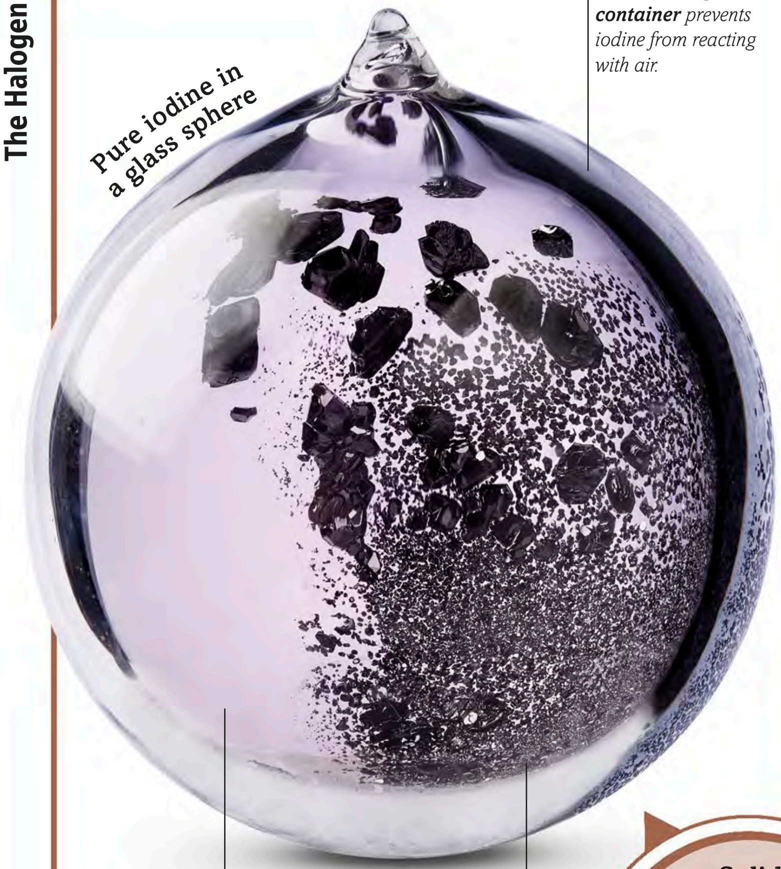

This sealed glass container *prevents iodine from reacting with air.*

Purple iodine vapour

Purple-black solid iodine

Solid iodine **does not melt** when heated, but turns into a vapour.

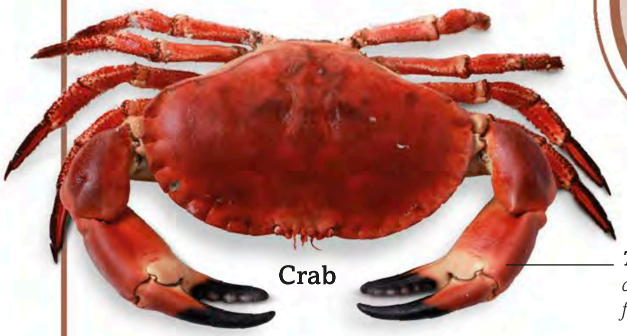

Crab

This crab *absorbs iodine from seawater.*

Uses

Printing ink

These coloured inks *are made using iodine compounds.*

Polarizing sunglasses

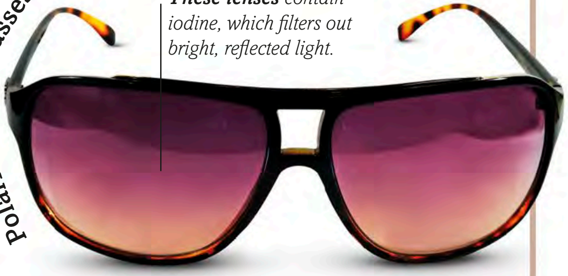

These lenses *contain iodine, which filters out bright, reflected light.*

Candied cherries

The bright red colour *of these cherries is due to an iodine dye.*

Betadine

This disinfectant *is applied to wounds to stop the spread of infection.*

Betadine® dermique 10%
Povidone iodée
Solution pour application locale
MEDA Pharma 08920.3 10 ml

Iodine is the only halogen that is solid at room temperature. The element forms a purple gas when heated, and is named after the Greek word *iodes*, which means "violet". Iodine was first discovered in seaweed, and many plants and animals in the sea have high levels of iodine. Seafood, including **crabs** and fish, provide the element in our diet. The human body needs small amounts of iodine to make an important substance called thyroxine, which helps us grow. Iodine is also used to make **printing ink**, red and brown food dyes, and disinfectants.

85
At

Astatine

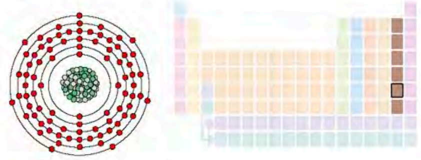

⊖ 85 ⊕ 85 ○ 125

State: Solid
Discovery: 1940

Atoms of astatine are unstable, and typically break down after just a few hours, into atoms of lighter elements, such as bismuth. This radioactive element itself forms in a similar way when atoms of a heavier element called francium break apart. Tiny amounts of this rare element are found in uranium ores, such as **uraninite**. The Italian physicist Emilio Segrè was one of the first scientists to isolate a sample of pure astatine. He was able to do so by using a particle accelerator: this is a machine that smashes together atoms and then studies the results.

***Inside this mineral**, unstable atoms of the element francium are breaking apart, forming astatine atoms.*

Uraninite

117
Ts

Tennessine

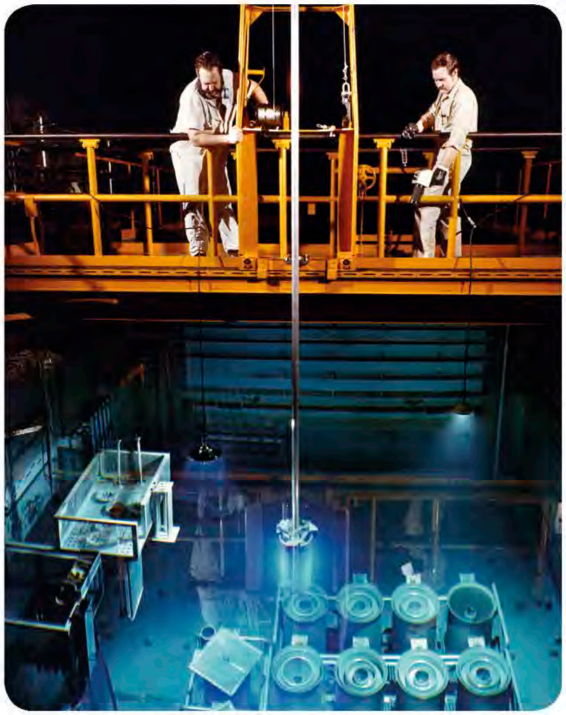

Nuclear Reactor, Oak Ridge National Laboratory, Tennessee, USA

Atoms of tennessine **existed for a few seconds** after they were formed.

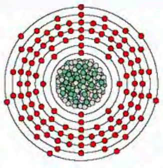

⊖ 117 ⊕ 117 ○ 177

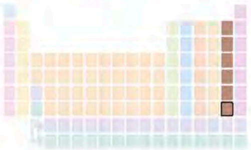

State: Solid
Discovery: 2011 (predicted)

Tennessine is the youngest element in the periodic table. It was produced in 2011, in the Russian city of Dubna. The element was named after the US state of Tennessee, home to the **Oak Ridge National Laboratory**, which houses one of the first, large-scale nuclear reactors ever built. Only a few atoms of this halogen element have ever been made. Even so, scientists have predicted it to be a semi-metal, not a non-metal like all the other halogens.

Krypton (Kr) becomes visible only when it is electrified.

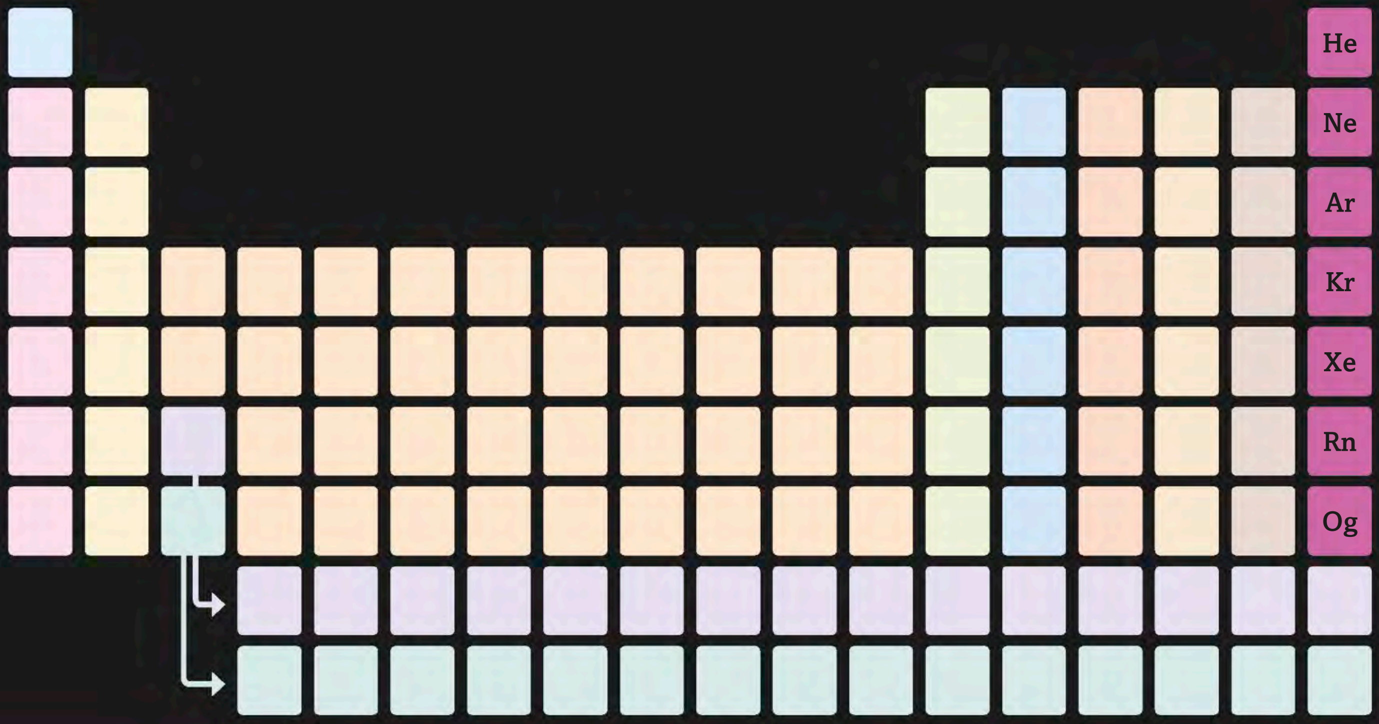

Noble Gases

The group on the far right of the periodic table belongs to the noble gases. These elements are described as “noble” because they do not react with the other “common” elements, such as oxygen (O). Their atoms never form bonds in nature, not even with atoms of their own kind, and so they are always gases at room temperature.

Atomic structure
Apart from a helium (He) atom that has two electrons in its outer shell, all other elements in this group have atoms with eight electrons.

Physical properties
All the members of this group are colourless gases. Going down the group, the density increases – radon (Rn) is 54 times denser than helium.

Chemical properties
Noble gases never react in nature. In the laboratory, heavier noble gases can be forced to form compounds with fluorine (F).

Compounds
These gases form no natural compounds. However, xenon (Xe), krypton (Kr), and argon (Ar) can be made to form compounds.

2 He Helium

⊖ 2 ⊕ 2 ○ 2

State: Gas
Discovery: 1895

Forms

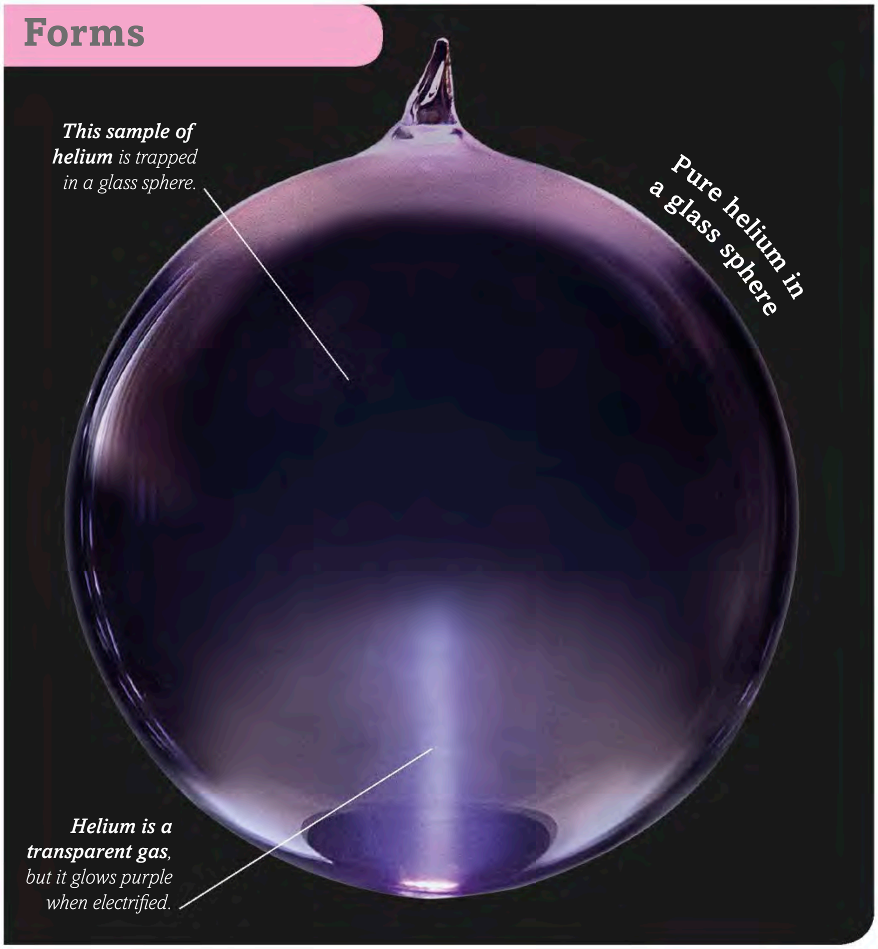

This sample of helium *is trapped in a glass sphere.*

Helium is a transparent gas*, but it glows purple when electrified.*

Pure helium in a glass sphere

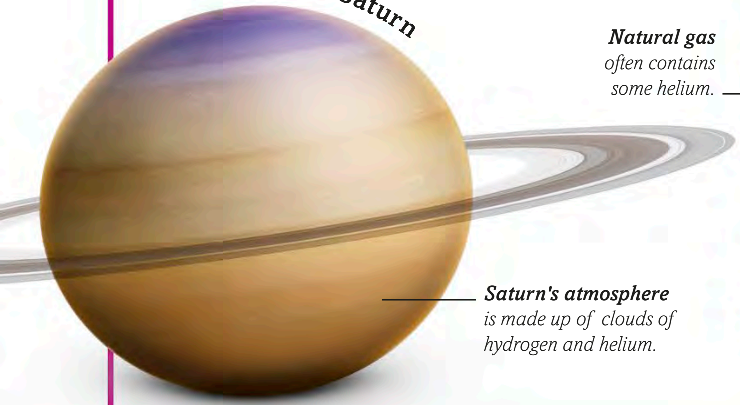

Saturn

Saturn's atmosphere *is made up of clouds of hydrogen and helium.*

Natural gas *often contains some helium.*

Gas flare rig

Uses

A particle accelerator *is a machine that smashes atoms together: this one uses liquid helium to cool its parts.*

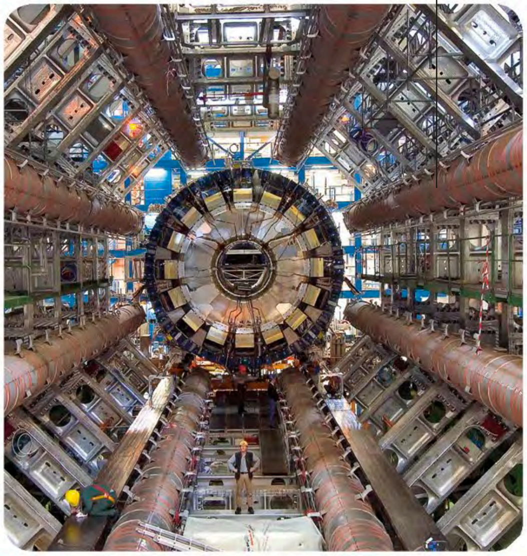

Large Hadron Collider, CERN, Switzerland

Helium-cooled MRI scanner

Helium is the second lightest element after hydrogen. This transparent gas was first discovered in 1868 by Sir William Ramsay, a Scottish chemist. Today, we know that a quarter of all the atoms in the Universe are helium. It is one of the main gases in the atmospheres of giant gas planets, such as **Saturn**. Being so light, however, helium is very rare on Earth: it escapes from our atmosphere into space. It was not until 1895 that chemists managed to collect a sample of helium gas coming from uraninite, a radioactive uranium mineral. Today, helium is

Airship

This airship *contains large quantities of helium to make itself lighter than air.*

SUN GAS

In 1868, during a total solar eclipse (when the Moon passes directly in front of the Sun), helium was discovered in the cloud of gas seen around the Sun. The yellow colour of this cloud showed it contained an unknown gas, which was named after Helios, the Greek god of the Sun.

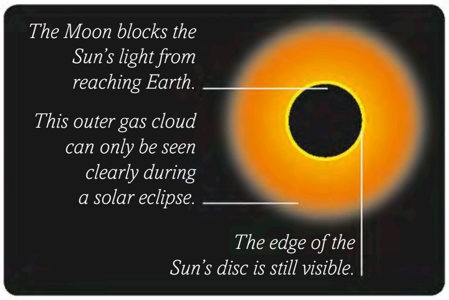

The Moon blocks the Sun's light from reaching Earth.

This outer gas cloud can only be seen clearly during a solar eclipse.

The edge of the Sun's disc is still visible.

Party balloon

This balloon *contains a mixture of helium and air.*

Helium-ion microscope

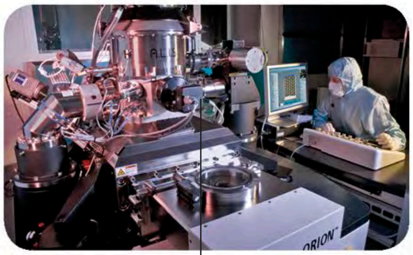

This powerful microscope *can zoom in to view much smaller details than most other microscopes.*

This high-speed train *uses a pair of magnets: one to move forward and one to float over the track.*

The track is lined with a magnet *that repels the one on the train, making it float.*

Helium-cooled maglev train

Rocket helium tank

Helium in this container *will fill up a rocket's fuel tanks as they empty out during liftoff.*

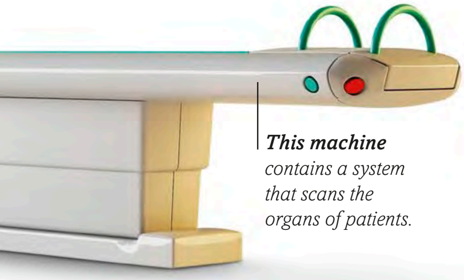

This machine *contains a system that scans the organs of patients.*

Helium has the **lowest melting point** of any element.

collected from underground reservoirs or is found mixed in natural **gas** and oil. Unlike hydrogen, which is very reactive, helium is a noble gas and does not react at all. This property makes it safe to use in objects such as **party balloons** and **airships**. To turn helium into a liquid, it must be cooled to an extreme temperature of –269°C (–452°F). Liquid helium is used to make things very cold, including the powerful magnets used to make **maglev trains** float along special tracks. **MRI scanners** also use liquid helium for cooling.

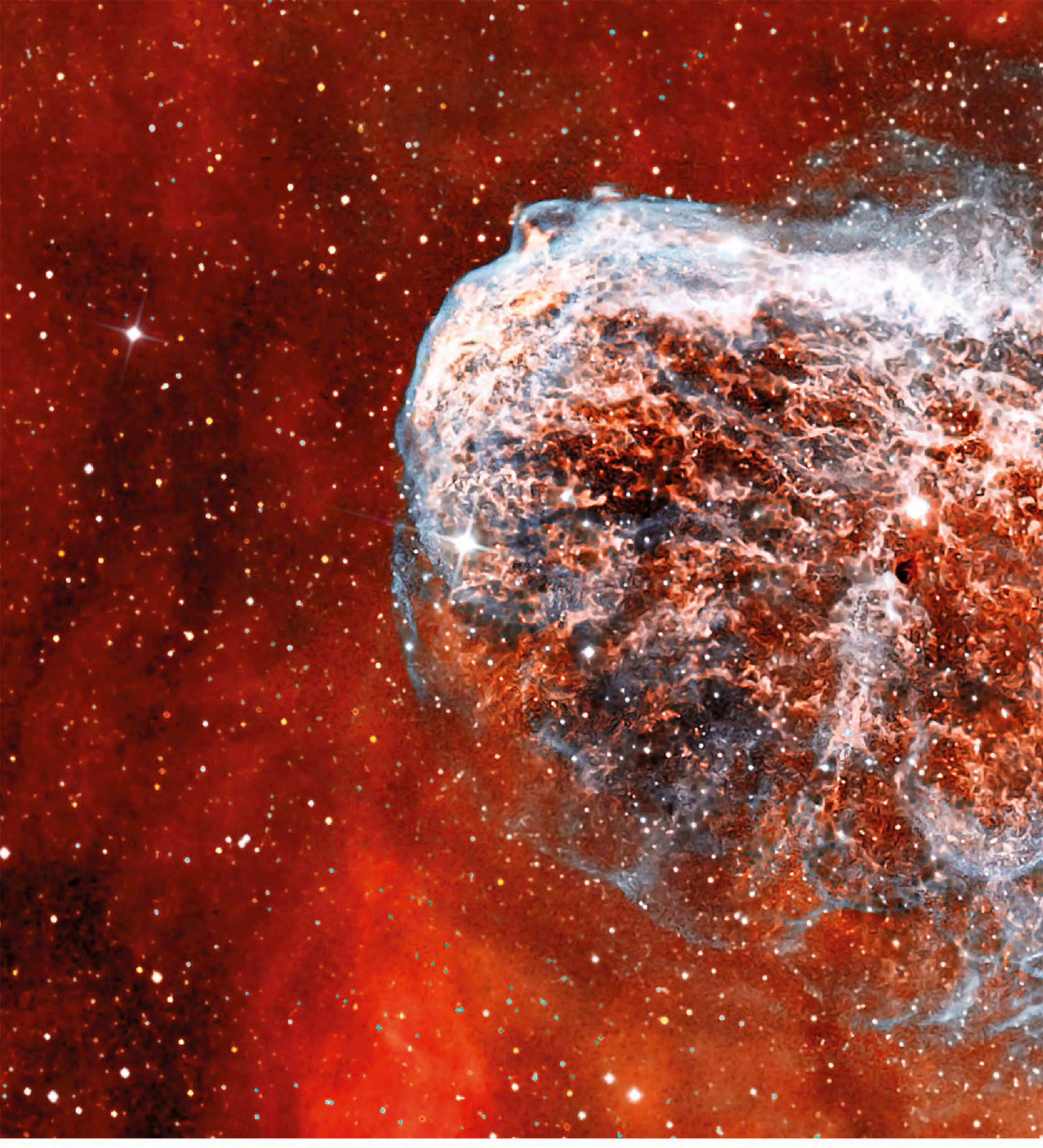

NEBULA This glowing nebula (cloud of gas and dust) is the Crescent Nebula. It is so vast that our entire Solar System would fit inside it seven times over. The nebula's light comes from a super-heated star at its centre. Known as WR 136, this star is 15 times heavier than our Sun and 250,000 times brighter. Its immense power comes from its fuel – helium.

Helium makes WR 136 hot and bright. The star once burned using hydrogen, like our Sun. Hydrogen atoms smashed together in the star's core until they became helium atoms, releasing energy in the process. However, the star ran out of hydrogen about 200,000 years ago. It began smashing together helium atoms instead, and ballooned into a gigantic red star, sending out a cloud of gas that spread around it. The star is producing a wind of electrified gases that hurtles out at 1,700 km (1,056 miles) every second. This wind continues to crash into the gas cloud, making it glow into the nebula we see. Eventually, WR 136 will run out of helium and its other fuels, and explode into an enormous fireball called a supernova.

10

Ne

Neon

🔴 10 🟢 10 ⚪ 10

State: Gas
Discovery: 1898

Forms

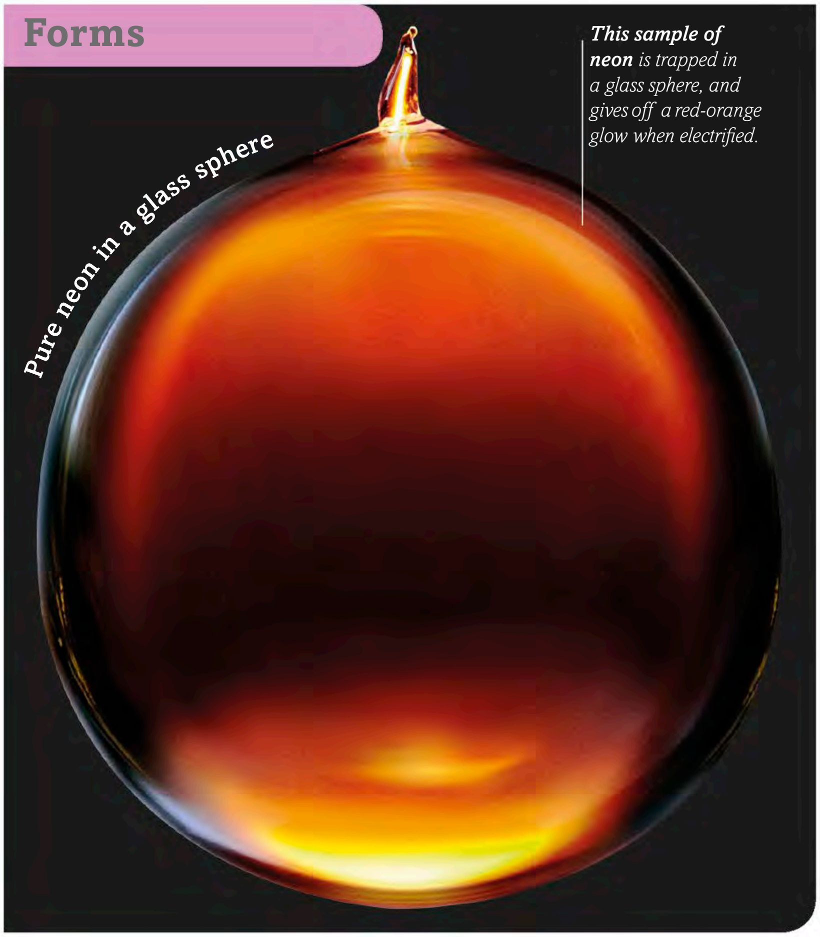

Pure neon in a glass sphere

This sample of neon *is trapped in a glass sphere, and gives off a red-orange glow when electrified.*

Volcanic eruption

Volcanic eruptions *release neon gas into the atmosphere.*

Neon lights may refer to lighting produced using any noble gas.

Uses

A deep red beam *is emitted by this laser.*

Helium-neon laser

Glass tubes filled with neon *are used as brightly lit signs.*

Neon sign

Neon is a rare element: it makes up just 0.001 per cent of our atmosphere. Some of it was locked in Earth's rocks when the planet formed, and this is released into the air by **volcanic eruptions**. **Pure neon**, a transparent gas, is extracted by cooling air to a temperature of −189.34°C (−308.81°F), at which point the neon gas in the air turns to liquid. Neon can be mixed with helium to create research **lasers**. However, it is most commonly used in lighting, such as in **illuminated signs** or as bright warning beacons in the path of aircraft at airports.

18

Ar

Argon

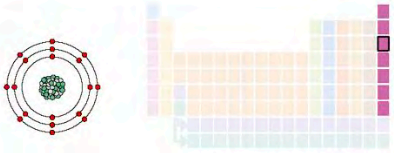

⊖ 18 ⊕ 18 ○ 22

State: Gas
Discovery: 1894

Forms

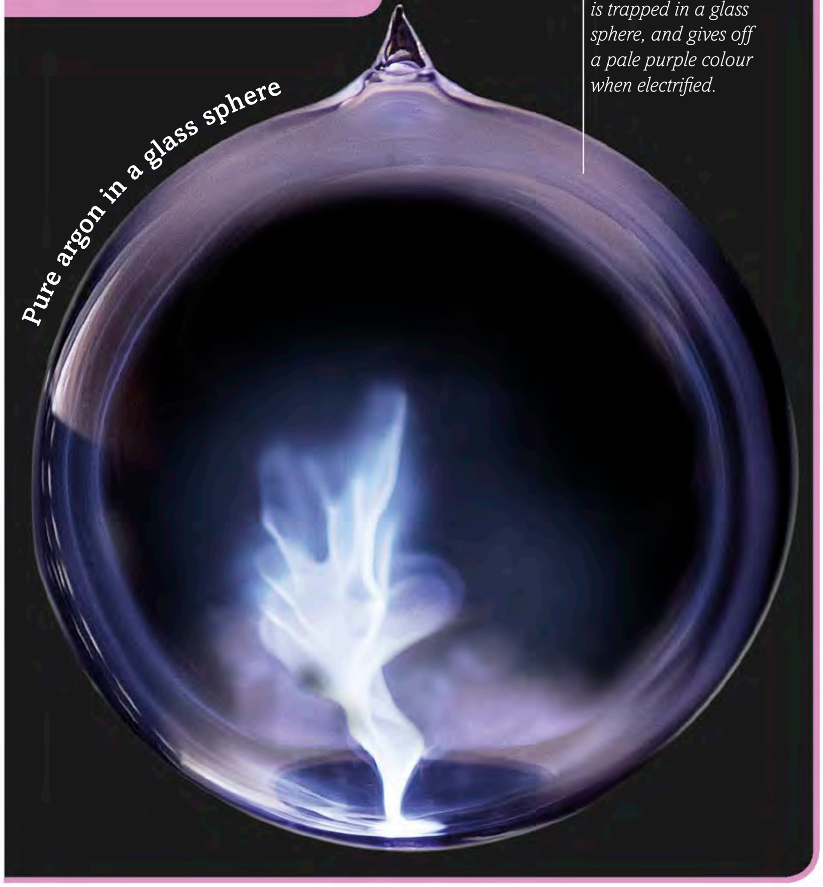

Pure argon in a glass sphere

This sample of argon *is trapped in a glass sphere, and gives off a pale purple colour when electrified.*

Argon-filled display

The Magna Carta*, a historical document, is stored in argon, which forces out oxygen and water vapour that would damage the parchment.*

Uses

Argon-filled suit

Some diving suits *are inflated with argon to retain heat in cold water.*

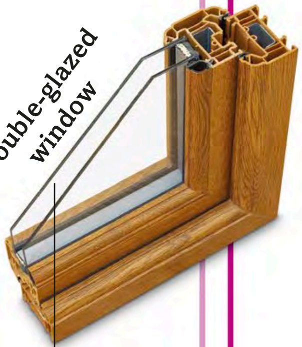

Double-glazed window

The space between the glass panes *is filled with argon to slow the loss of heat.*

Metal welding

Argon in this flame *prevents metals from reacting with oxygen*

Argon is the third most abundant gas in the atmosphere, after nitrogen and oxygen. It undergoes no reactions with any other element, and was named after the Greek word *argos*, meaning "idle". Argon does not conduct heat well so it is put in **double-glazed windows**, and in **diving suits** during cold, deep dives. Its lack of reactivity is useful. Argon is used in **museum displays** to protect delicate exhibits. It also stops metals reacting during hot **welding**. This element can also be useful in the production of titanium.

36

Kr Krypton

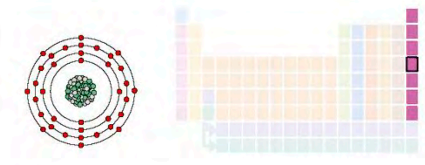

⊖ 36 ⊕ 36 ○ 48

State: Gas
Discovery: 1898

Forms

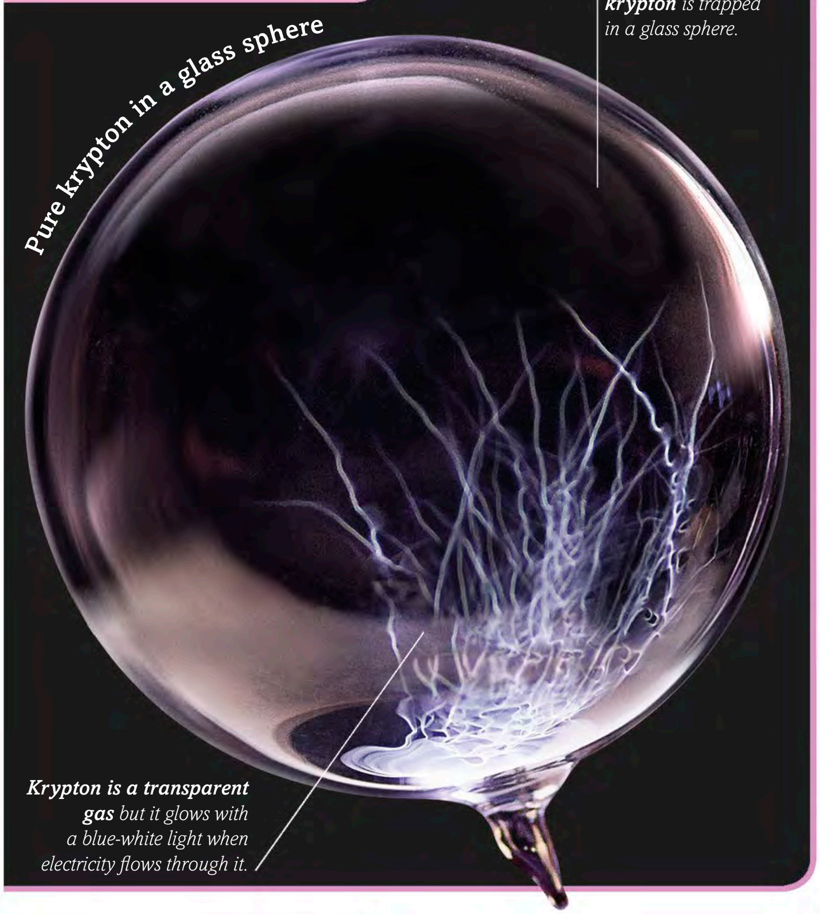

Pure krypton in a glass sphere

This sample of krypton *is trapped in a glass sphere.*

Krypton is a transparent gas *but it glows with a blue-white light when electricity flows through it.*

When this camera's flash *activates, it's a result of krypton being electrified by the camera's battery.*

Digital camera

Krypton-based lasers *illuminate this building.*

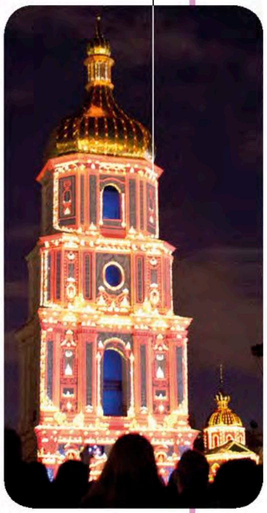

Laser lighting

Sir William Ramsey won a **Nobel Prize** in Chemistry for discovering the noble gases.

Uses

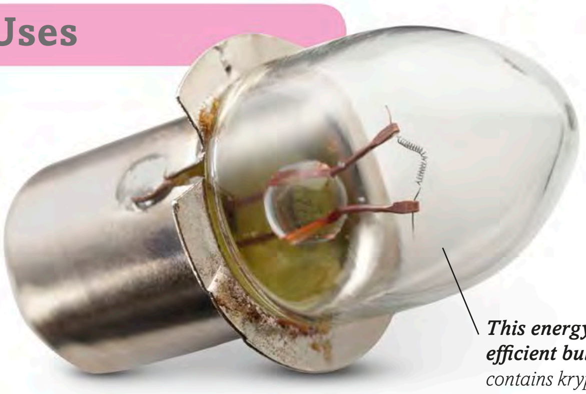

This energy-efficient bulb *contains krypton.*

Incandescent bulb

Plasma ball

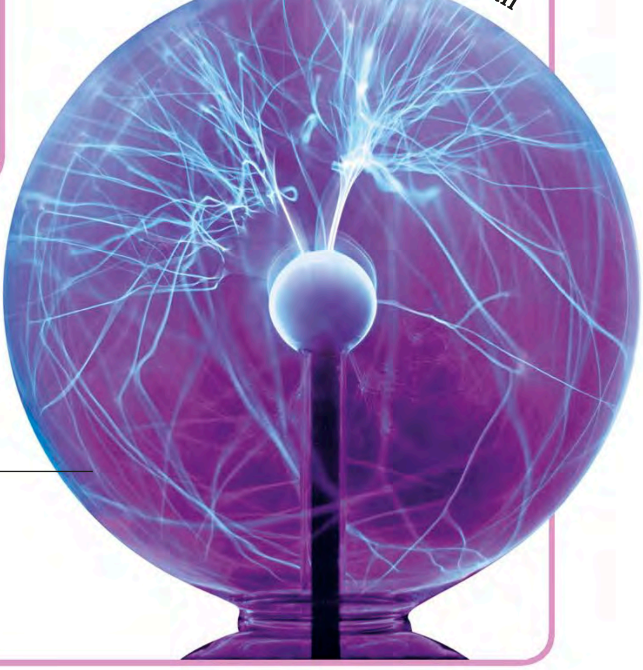

This globe *contains a mixture of noble gases, including krypton.*

The word krypton means the "hidden one" in Greek. This element exists as an inert gas in nature, which means that it does not react with almost any other element. Krypton is not found in any minerals and only tiny amounts of it can be found in the air. **Pure krypton** produces a very bright white light when electrified with a current, which makes it ideal for use in **flash bulbs**. Krypton can react with the element fluorine to form the compound krypton fluoride, which is used to power some kinds of **laser**.

54
Xe

Xenon

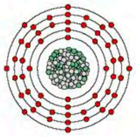

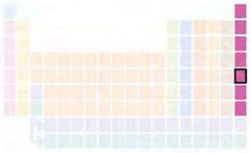

⊖ 54 ⊕ 54 ○ 77

State: Gas
Discovery: 1898

Forms

Pure xenon in a glass sphere

Xenon is a transparent gas *but it glows with a blue light when an electric current flows through it.*

This sample of xenon *is trapped in a glass sphere.*

Anaesthesia machine

The xenon produced by this device *makes a patient unconscious before an operation.*

Xenon is used in powerful **lasers** that can **kill bacteria**.

Car headlight

Xenon headlights *glow brighter than the more common halogen headlights.*

Xenon glow *disinfects the air in a room.*

Uses

High pressure inside this lamp *makes electrified xenon glow very brightly.*

Modern film projector lamp

Dawn space probe

Electrified xenon *blasts from the exhaust, pushing the probe forwards.*

Xenon is so rare that there is only one atom of this gaseous element for every 10 million atoms in the air. Like the other noble gases, xenon is colourless and odourless. It glows brightly when electrified, making it useful in very powerful lamps, such as those used in **film projectors** and **car headlights**. The gas is harmless when breathed in and can be used as an **anaesthetic**. When preparing food, **xenon lamps** can purify the air. To propel spacecraft, xenon is used in some rocket engines that produce streams of fast-moving, electrified atoms.

86 Rn Radon

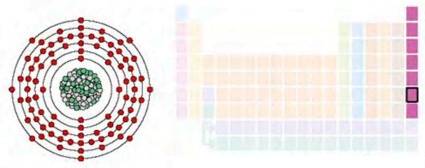

⊖ 86 ⊕ 86 ○ 136

State: Gas
Discovery: 1900

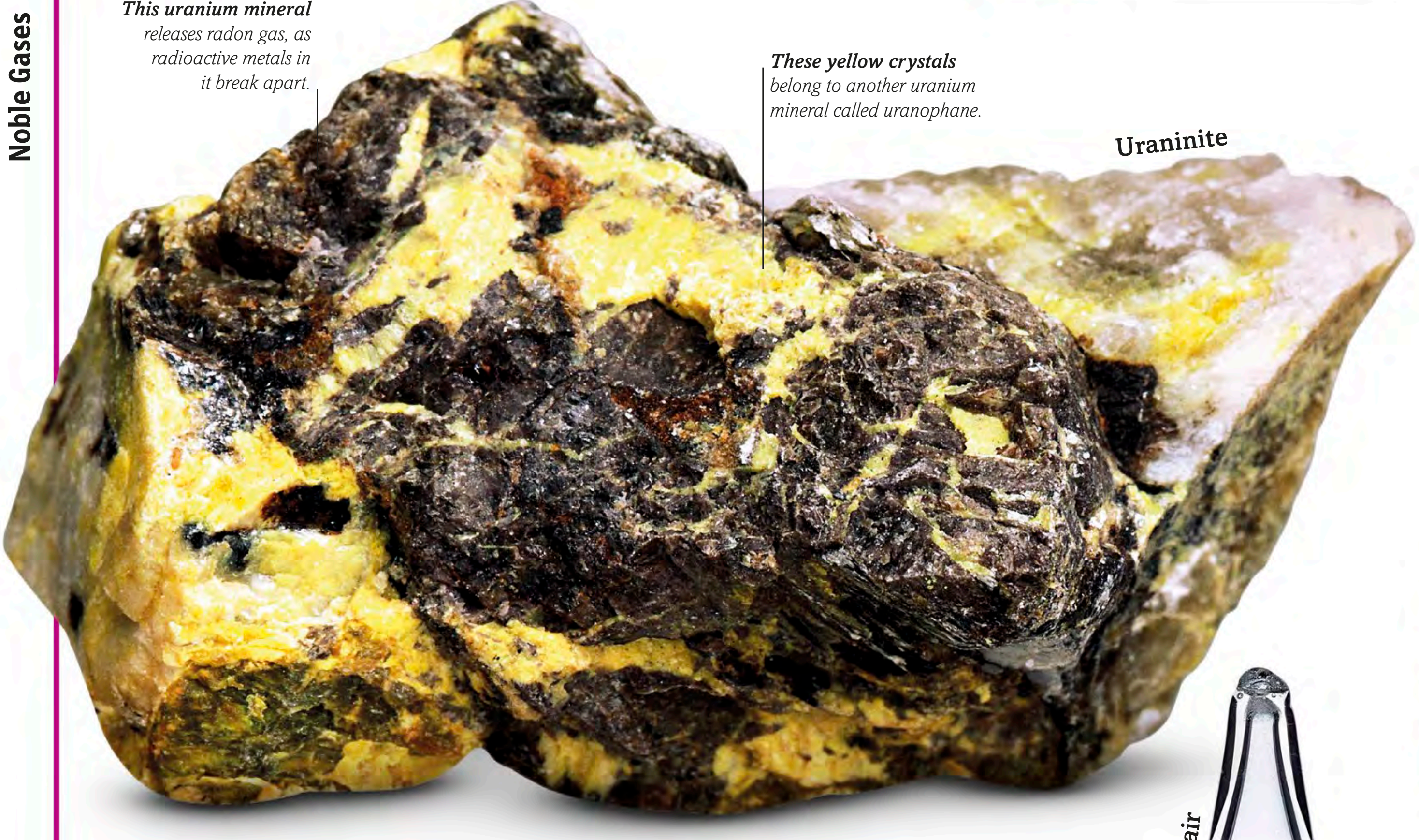

This uranium mineral *releases radon gas, as radioactive metals in it break apart.*

These yellow crystals *belong to another uranium mineral called uranophane.*

Uraninite

It takes only **3.8 days** for half of radon's atoms to split into atoms of other elements.

Radon is the only natural radioactive noble gas. This element is produced by the breakdown of uranium and other radioactive metals. Being a gas, radon escapes from minerals, such as **uraninite**, into the air. Radon is very radioactive and breathing it in can cause illness, such as lung cancer. In most places, the amount of radon in the air is incredibly tiny. However, its levels are high around **volcanic springs** and mud, where it bubbles out with other hot gases. Radon is also present in the water at **geothermal power plants**, which use heat energy from deep, volcanic rocks to make electricity. Radon is also more common in areas rich in granite rock. In these places, people use **test kits** to monitor their homes' radon levels.

Glass sphere containing radon and air

As it decays*, a compound called thorium dioxide emits radon.*

The muddy water *from volcanic springs contains radon.*

Hot springs in Lisvori, Greece

These pipes *draw water containing radon from deep under the ground, and this is then used to power the plant.*

Geothermal power plant

RADO
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Radon home test kit

This kit *collects radon from the air so the amount of the gas in the area can be measured.*

118
Og

Oganesson

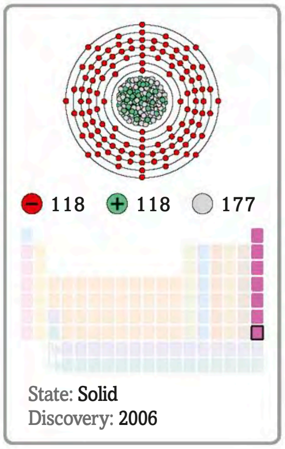

State: Solid
Discovery: 2006

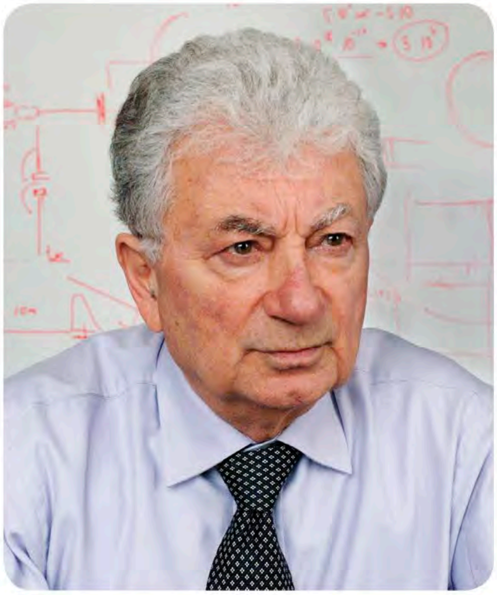

Yuri Oganessian

The heaviest element yet made is oganesson. Scientists think it would be solid at room temperature, but it may really be an unreactive, noble gas. However, only a few atoms have been created so far, so its properties are not well understood. Oganesson was first produced by a team of Russian and American scientists who smashed californium and calcium atoms together at the **Joint Institute for Nuclear Research** in Dubna, Russia. The element was named after **Yuri Oganessian**, the leader of the team.

Joint Institute For Nuclear Research, Russia

Glossary

Acid
A compound that contains hydrogen, and releases ions of hydrogen when it is dissolved in water. These ions make acids very reactive.

Actinide
A member of a group of radioactive metals with relatively large atoms.

Alchemist
People who experimented with chemicals before the science of chemistry began. Alchemists thought they could turn ordinary metals into gold.

Alkali
A compound that takes hydrogen ions from water molecules when it is dissolved in water. Alkalis react with acids.

Alkali metal
A group of metals that make alkalis when they react with water.

Alkaline earth metal
A group of metals that are found in nature, mainly in alkaline minerals.

Alloy
A material made by mixing a metal with tiny amounts of other metals or non-metals. Steel is a common alloy used in buildings and railways.

Artificial
Something that does not exist in nature. Several elements, including all that are heavier than uranium, are artificially produced by scientists in laboratories.

Atmosphere
The mixture of gases that surrounds a planet or moon. Earth's atmosphere is a mixture of nitrogen, oxygen, and argon, with tiny amounts of several other gases.

Atom
The smallest unit of an element. Atoms are composed of protons, neutrons, and electrons. The atoms of a particular element all have the same number of protons.

Atomic number
The number of protons in an atom of an element. Every element has a unique, unchanging atomic number.

Battery
A device containing chemicals that react to produce an electric current. There are two main kinds of battery: rechargeable and non-rechargeable.

Boiling point
The temperature at which a liquid gets hot enough to change into a gas.

Bond
The attraction between atoms that holds them together in an element or a compound.

Brittle
A way of describing a hard solid that shatters easily.

Carbonate
A compound that contains carbon and oxygen atoms, as well as atoms of other elements. Many minerals are carbonates.

Catalyst
A substance that speeds up a chemical reaction.

Chemist
A scientist who studies the elements, their compounds, and chemical reactions.

These vanadinite **crystals** contain the element vanadium.

Chemistry
The scientific study of the properties and reactions of the elements.

Chemical
Another word for a substance, generally meaning a compound made from several elements.

Combustion
A chemical reaction, involving oxygen, in which a fuel burns to produce heat and light in the form of flames.

Flames are the result of **combustion**.

Compound
A substance made of the atoms of one or more elements that are bonded together in a particular combination.

Conductor
A substance that lets heat or electricity flow easily through it.

Contract
To make or become smaller. Solids, liquids, and gases usually contract when the temperature goes down.

Corrosion
A chemical reaction that attacks a metal, or other solid object, usually due to the presence of oxygen and water.

Crystal
A naturally occurring solid substance whose atoms are arranged in a regular three dimensions pattern.

Decay
A process in which unstable atoms of radioactive elements break apart. The atoms of one element are transformed into those of another element during decay.

Density
The amount of matter held within a known volume of a material.

Dissolve
To become completely mixed into another substance. In most cases, a solid, such as salt, dissolves in a liquid, such as water.

Earthenware
A basic form of pottery, in which clay is heated to make it form hard structures.

Electrolysis
A process in which a compound is split into simpler substances using an electric current. Many elements, such as aluminium, are purified from their compounds in ores in this way.

Electrode
An electrical contact in an electric circuit. Electrodes can have a positive or negative charge.

Electron
A negatively charged particle inside an atom. Electrons orbit the atom's nucleus (or core) in layers called shells. They are also exchanged or shared by atoms to make bonds that hold molecules together.

Element
A pure substance that cannot be broken down into any simpler substances. Elements are the building blocks of matter. There are 118 known elements on Earth.

This **element** calcium is in crystal form.

Expand
To make or become bigger. Solids, liquids, and gases usually expand when the temperature rises.

Fission
A process in which the nucleus of an unstable atom splits in two when it collides with a neutron. It releases more neutrons that start the cycle again, and this continues as a chain reaction. Many unstable nuclei undergo fission spontaneously, without being hit by a neutron. Fission releases a lot of energy. The process is used to generate electricity in nuclear power plants, and it can trigger atom bomb explosions.

Flammable
A way of describing a material that can catch fire easily.

Fusion
A process in which small atoms, such as those of hydrogen, are fused together with such force that they merge to form larger atoms, while releasing a lot of energy. The Sun is powered by the fusion of hydrogen atoms into helium in its central core.

Gas
A state in which the particles of matter (atoms or molecules) are not attached to each other, and move freely. A gas can flow, take any shape, and fill any container.

Group
A set of elements in a column in the periodic table. Elements in a group have similar properties because each atom has the same number of electrons in its outer shell.

Halogen
A member of a group near the far right of the periodic table. Halogens form salts with metals. They are reactive, non-metallic elements.

Hardness
A measure of how easy it is to scratch or cut a substance with another substance.

Hydroxide
A type of compound containing hydrogen and oxygen, and normally a metallic element.

This is a chunk of ytterbium, a **lanthanide**.

Ion
An atom or a group of atoms that have an electric charge. While atoms have no overall charge, they become positive ions if they lose electrons or negative ions if they gain electrons.

Insulator
A substance that does not let heat or electricity flow easily through it.

Isotope
A form of an element with atoms that have the same number of protons but a different number of neutrons.

Lanthanide
A member of a set of metals with relatively large atoms. The elements in this series sit with the actinides, below the main part of the periodic table.

Laser
A beam of light with a single wavelength, in which the waves are all perfectly in step. Lasers are used in electronics and surgery.

Milk is a type of **mixture**.

LED
Short for light-emitting diode. An LED is a device that produces light when an electric current passes through it. The colour of its light depends on the compounds used in it.

Liquid
A state in which the particles of matter (atoms or molecules) are only loosely attached to each other, and move freely. A liquid can flow and take any shape, but has a fixed volume.

Mass
The amount of matter in a substance.

Matter
The material that makes up everything around us.

Maglev
Short for magnetic levitation. This refers to some kinds of high-speed train that use magnets to propel themselves while hovering over a track.

Magnet
A solid object that produces a magnetic field, which attracts certain materials to it and can attract or repel other magnets.

Magnetic
Relating to a magnet.

Magnetic field
The force field around a magnet.

Melting point
The temperature at which a solid gets hot enough to turn into a liquid.

Metal
A type of element that is likely to react by giving away the outermost electrons in its atoms. Most elements are metals, and they tend to be hard, shiny solids. Mercury is the only metal that is liquid at room temperature.

Mineral
A naturally occurring solid compound – or mixture of compounds – made up of different elements. Every mineral has particular characteristics, such as crystal shape and hardness. Minerals are mixed together to make the rocks in Earth's crust.

Mixture
A collection of substances that fill the same space but are not connected by chemical bonds. Examples of mixtures are seawater, milk, and mud. The contents of a mixture can be separated by a physical process, such as filtration.

Molecule
A single particle of a compound. Its two or more atoms are bonded together.

Neutron
A neutral particle in the nucleus of an atom. A neutron is about the same size as a proton but it does not have an electric charge.

Noble gases
A group of elements that are unreactive and generally form no compounds with the other elements. This is because the outermost shells in their atoms are filled with electrons. This group sits on the extreme right of the periodic table.

Non-metal
A type of element that is likely to react by acquiring electrons in the outermost shell of its atoms. Non-metals are usually crystalline solids, such as sulfur, or gases, such as oxygen. Bromine is the only non-metal that is liquid at room temperature.

Nucleus
An atom's core, which contains its protons and neutrons. Nearly all the mass of an atom is packed into its nucleus.

Ore
A rock or mineral from which a useful element such as a metal can be purified and isolated.

Oxide
A compound in which oxygen is bound to one or more other elements.

Particle
A basic unit of which substances are made. Sub-atomic particles are units of which atoms are made including protons, neutrons, electrons, and many other smaller ones.

Particle accelerator
A machine in which atoms or sub-atomic particles are made to collide at high speeds. These collisions are then studied by scientists. Particle accelerators are used to produce artificial elements as well as study particles smaller than atoms. A cyclotron is a type of particle accelerator.

These petal-like shapes may form when desert sand mixes with barite, an **ore** of barium.

Period
A set of elements in a row in the periodic table. Each atom of the elements in the first period have one electron shell. Atoms in the second period have two electron shells.

Periodic table
A table that identifies and classifies all known elements.

Photograph negative
A film or plate that has been exposed to light to show an image with reversed colours.

Photosynthesis
A complicated set of chemical reactions by which plants make their food. They use the energy of sunlight to convert water and carbon dioxide into sugar and oxygen.

Pollution
Harmful substances that are released into the environment. Pollution can be chemical – a gas, liquid, or solid added to the air, water, or soil.

Pressure
A measure of how hard a force pushes on a surface. Pressure depends upon the strength of the force and the area of the surface.

Proton
A positively charged particle in the nucleus of an atom. Protons attract electrons, and they circle the nucleus.

Radar
A system that detects the positions and speed of distant objects, such as aircraft.

Radiation
Energy released by atoms as light, infrared, ultraviolet (UV), and X-rays. The term "radiation" is also used to describe the rays given out by radioactive substances.

Radioactive
Describes a substance that contains unstable atoms, in which the nucleus breaks apart, or decays. When a nucleus decays, it releases at least one particle and its atomic number changes, so that the atom becomes a different element.

Reaction
A chemical process in which atoms or molecules form bonds with each other to form a new compound – or rearrange, to produce different compounds.

Renewable energy
A source of energy that will not run out, for example, wind.

Rust
The common name for the compounds that form when iron reacts with oxygen and water.

Salt
A compound that forms when an acid reacts with an alkali. Sodium chloride is the most familiar example of a salt.

Semi-metal
An element that has properties of both metals and non-metals.

Smelting
A chemical process that involves great heat in which a metal is extracted from its ore.

Solid
A state in which the particles of matter (atoms or molecules) are bound to each other, so they remain in fixed positions. A solid has a fixed shape and volume.

Stainless steel
An alloy of iron and carbon that also contains other metals, such as chromium, which stop the iron from rusting and increase its toughness.

Superconductor
A substance through which an electric current flows with no resistance; most substances resist the flow of electricity, and produce heat when current flows.

Synthetic
Another word for artificial. Out of the 118 known elements on Earth, more than 25 are synthetically made.

Toughness
A quality of a solid that shows how difficult it is to break. Steel is very tough – it may bend or twist, but is much harder to break.

Transition metal
A member of the set of metals that sit in the middle of the periodic table. Most metals belong to this set.

Toxic
Another word for poisonous or harmful.

Transparent
Another word for see-through. Glass, water, and air are transparent to light. Many materials are transparent to other forms of radiation.

Vacuum
An empty space that does not contain air or any other substance.

Vapour
A gas that can easily be changed back to a liquid, by cooling it or putting it under pressure.

Verdigris
The green-grey layer that forms on copper when it comes in contact with air.

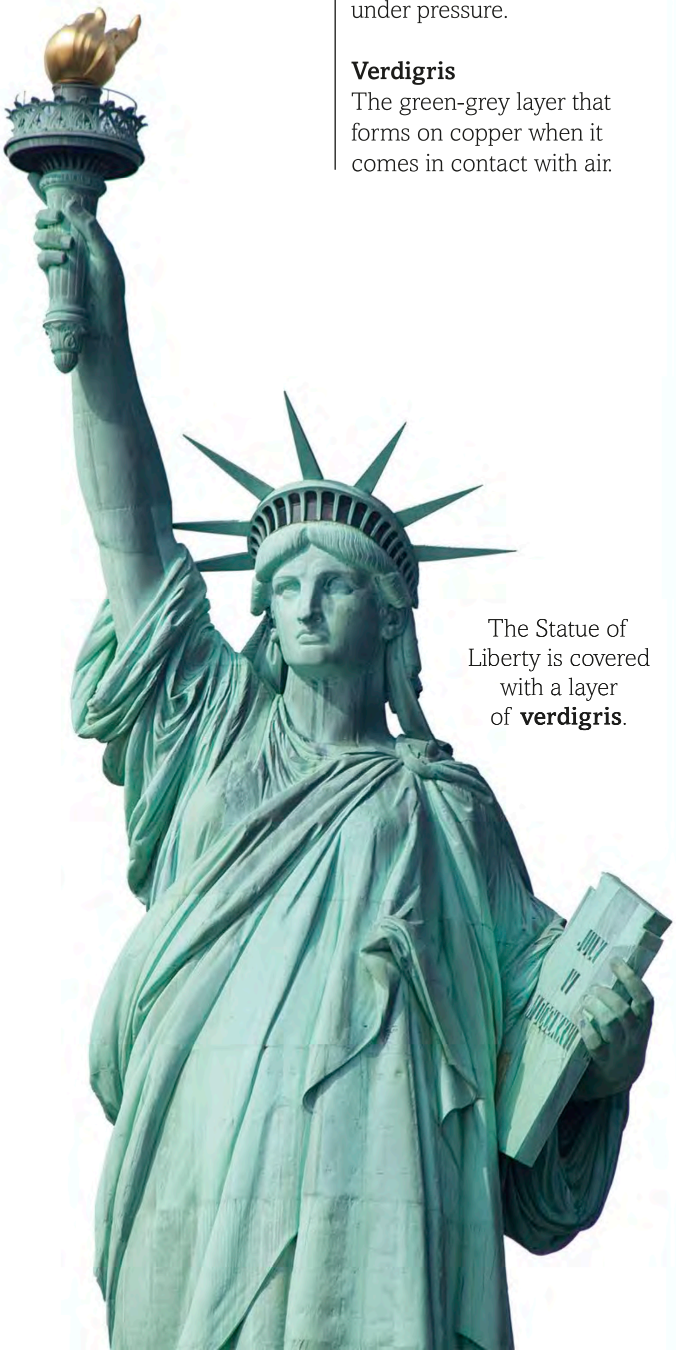

The Statue of Liberty is covered with a layer of **verdigris**.

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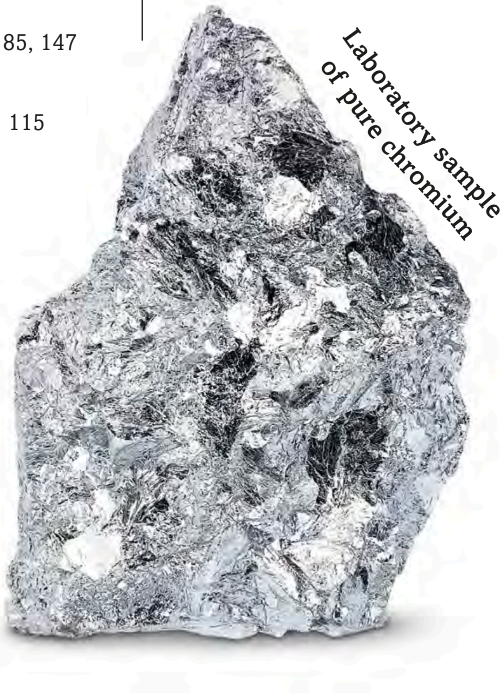

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ROCKS AND MINERALS

THE WORLD IN YOUR HANDS

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ROCKS
AND MINERALS

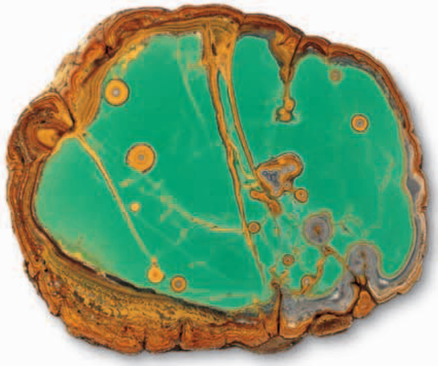

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NATURE GUIDE

ROCKS AND MINERALS

Ronald Louis Bonewitz

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HOW THE ROCK AND MINERAL PROFILES WORK

profile information (including illustration of crystal system in mineral entries)

name of mineral or rock group

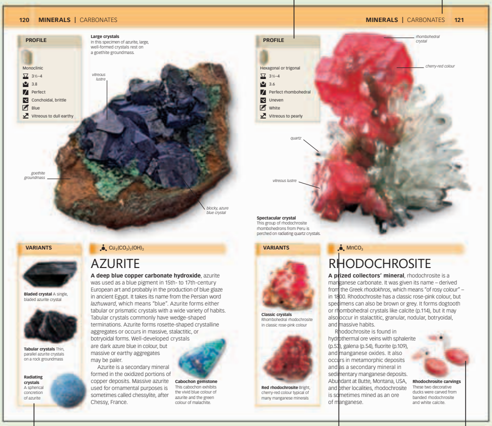

120 **MINERALS** | CARBONATES

PROFILE

Monoclinic
3½–4
3.8
Perfect
Conchoidal, brittle
Blue
Vitreous to dull earthy

Large crystals In this specimen of azurite, large, well-formed crystals rest on a goethite groundmass.

VARIANTS

Bladed crystal A single, bladed azurite crystal

Tabular crystals Thin, parallel azurite crystals on a rock groundmass

Radiating crystals A spherical concretion of azurite

$Cu_3(CO_3)_2(OH)_2$

AZURITE

A deep blue copper carbonate hydroxide, azurite was used as a blue pigment in 15th- to 17th-century European art and probably in the production of blue glaze in ancient Egypt. It takes its name from the Persian word *lazhuward*, which means "blue". Azurite forms either tabular or prismatic crystals with a wide variety of habits. Tabular crystals commonly have wedge-shaped terminations. Azurite forms rosette-shaped crystalline aggregates or occurs in massive, stalactitic, or botryoidal forms. Well-developed crystals are dark azure blue in colour, but massive or earthy aggregates may be paler.

Azurite is a secondary mineral formed in the oxidized portions of copper deposits. Massive azurite used for ornamental purposes is sometimes called chessylite, after Chessy, France.

Cabochon gemstone This cabochon exhibits the vivid blue colour of azurite and the green colour of malachite.

MINERALS | CARBONATES 121

PROFILE

Hexagonal or trigonal
3½–4
3.6
Perfect rhombohedral
Uneven
White
Vitreous to pearly

Spectacular crystal This group of rhodochrosite rhombohedrons from Peru is perched on radiating quartz crystals.

VARIANTS

Classic crystals Rhombohedral rhodochrosite in classic rose-pink colour

Red rhodochrosite Bright, cherry-red colour typical of many manganese minerals

$MnCO_3$

RHODOCHROSITE

A prized collectors' mineral, rhodochrosite is a manganese carbonate. It was given its name – derived from the Greek *rhodokhros*, which means "of rosy colour" – in 1800. Rhodochrosite has a classic rose-pink colour, but specimens can also be brown or grey. It forms dogtooth or rhombohedral crystals like calcite (p.114), but it may also occur in stalactitic, granular, nodular, botryoidal, and massive habits.

Rhodochrosite is found in hydrothermal ore veins with sphalerite (p.53), galena (p.54), fluorite (p.109), and manganese oxides. It also occurs in metamorphic deposits and as a secondary mineral in sedimentary manganese deposits. Abundant at Butte, Montana, USA, and other localities, rhodochrosite is sometimes mined as an ore of manganese.

Rhodochrosite carvings These two decorative ducks were carved from banded rhodochrosite and white calcite.

variants panel containing named varieties and additional specimens

chemical formula of mineral

example of rock or mineral application

KEY

Hardness
Specific gravity
Cleavage
Fracture
Streak
Luster
Type
Origin
Temperature of formation
Pressure of formation
Structure
Grain size
Major minerals
Minor minerals
Color
Precursor rock
Fossils

INTRODUCTION

WHAT IS A MINERAL?

A mineral is a naturally occurring solid with a specific chemical composition and a distinctive internal crystal structure. Most minerals are formed inorganically but some, such as those found in bone, are formed organically (by living organisms).

WHAT MINERALS ARE MADE OF

Most minerals are chemical compounds composed of two or more chemical elements. However, copper, sulfur, gold, silver, and a few others occur as single "native" elements. A mineral is defined by its chemical formula and by the arrangement of atoms within its crystals. For example, iron sulfide has the chemical formula FeS_2 (where Fe is iron and S is sulfur). Iron sulfide can crystallize in two different ways. When it crystallizes in the cubic system (pp.22–23), it is called pyrite; when it crystallizes in the orthorhombic system, it becomes the mineral marcasite. Minerals are classified by their chemical content: for example, those containing oxygen ions are called oxides and those having carbon and oxygen ions are called carbonates.

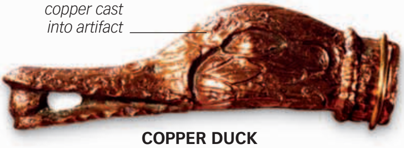

COPPER DUCK

Native elements
Native copper was probably the first metal used by humans. This duck's head was made in North Africa about 1,900 years ago.

Same composition but different structure
Though pyrite and marcasite have the same chemical composition and are both iron sulfide, their differing crystal structures make them different minerals.

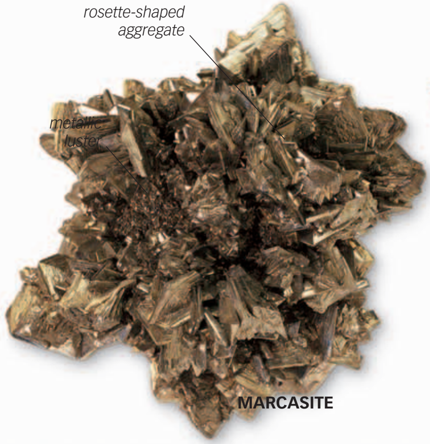

MARCASITE

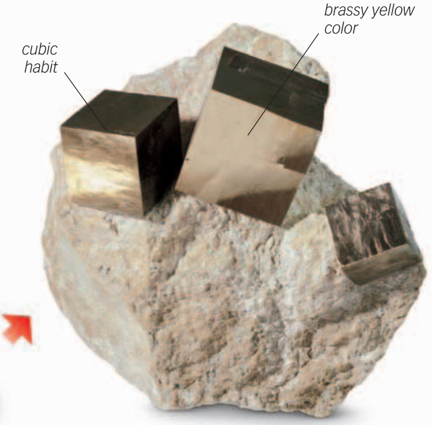

PYRITE

Native sulfur
Sulfur is mined at Kawah Ijen, Java. Volcanic gases escaping from small openings in the ground (fumaroles) carry sulfur vapors to the surface, where it is deposited as a yellow crust.

Volcanic rhyolite
The Rhyolite Hills in Iceland are formed of rhyolite, a silica-rich rock produced as a result of volcanic activity. Rhyolite is made up of crystals of high-silica minerals.

ELECTRICAL CHARGE AND COMPOUNDS

A mineral compound is based on an electrical balance between a positively charged metal and a negatively charged part. In many minerals, negative charge is carried by a "radical": a combination of atoms acting as a single unit. For example, carbon and oxygen combine in a 1:3 ratio to give the CO_3 radical, which acts as a single, negatively charged unit.

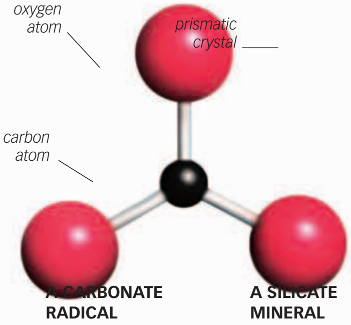
oxygen atom
prismatic crystal
carbon atom
A CARBONATE RADICAL
A SILICATE MINERAL

Simple and complex compounds
In carbonates, a simple carbon and oxygen group known as a radical combines with one or more metals.

COMMON MINERALS

There are more than 500 known minerals, but only about 100 of these are common. Silicon and oxygen make up about three-quarters of the crust by weight, and silicate minerals such as quartz, feldspar, and olivine are by far the most common minerals in rocks, making up 90 percent of the rocks at Earth's surface. The carbonates calcite and dolomite form sedimentary rocks, such as limestone.

Silicates
Silica tetrahedra link to form quartz. They can act as a radical to combine with one or more metals or semimetals to form other silicate minerals.

crystal face

QUARTZ CRYSTAL

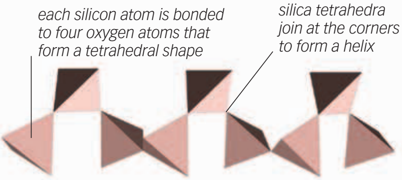
each silicon atom is bonded to four oxygen atoms that form a tetrahedral shape
silica tetrahedra join at the corners to form a helix

STRUCTURE OF QUARTZ

MINERAL GROUPS AND ASSOCIATIONS

Some minerals belong to chemical groups or series called solid solutions. In some circumstances, minerals are found together in groupings known as associations or assemblages. These patterns of occurrence can provide clues as to the minerals' origin.

SOLID SOLUTIONS

Some minerals do not have specific chemical compositions. Instead, they are homogenous mixtures of two minerals. These homogenous mixtures are known as solid solutions. For example, the olivine group of silicates includes forsterite and fayalite. Forsterite is a magnesium silicate, while fayalite is an iron silicate. Most olivine specimens are homogenous mixtures of the two, with the relative content of magnesium and iron varying in specimens. These minerals are described as part of a solid-solution series, in which forsterite and fayalite are the end-members.

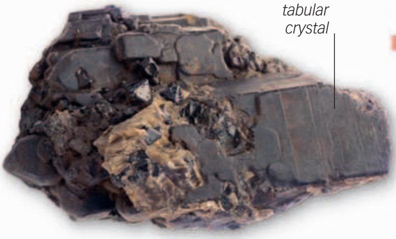

FAYALITE

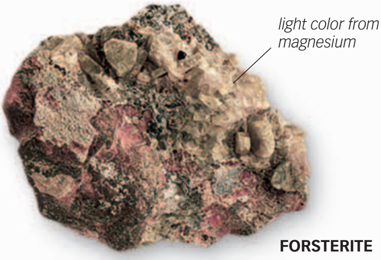

FORSTERITE

Fayalite and forsterite
The olivine minerals fayalite and forsterite form a solid-solution series, with magnesium-rich forsterite as one end-member and iron-rich fayalite as the other.

PRIMARY AND SECONDARY MINERALS

Primary minerals crystallize directly from magma and remain unaltered. They include essential minerals used to assign a classification name to a rock and accessory minerals that are present in lesser abundance and do not affect the classification of a rock. Secondary minerals are produced by the alteration of a primary mineral after its formation. For example, when copper-bearing primary minerals come into contact with carbonated water, they alter into secondary azurite or malachite.

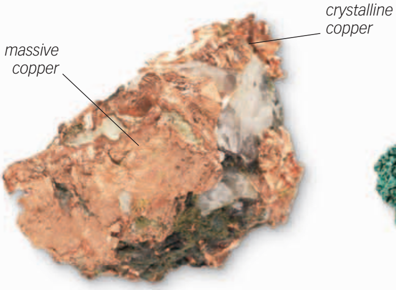

Primary copper mineral
Primary minerals, such as native copper, form directly in igneous rocks and remain unaltered. Their eventual alteration products are secondary minerals.

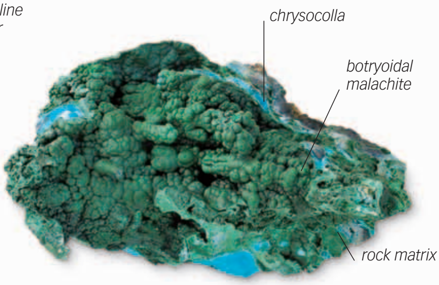

Secondary copper mineral
Chrysocolla and malachite are secondary minerals derived from the chemical weathering of primary copper minerals, such as native copper and bornite.

MINERAL ASSOCIATIONS

Some minerals are consistently found together over large areas because they are found in the same rock type. Other associations occur in encrustations, veins, cavities, or thin layers. The fact that certain minerals are likely to be found together can help in the discovery and identification of minerals. Lead and zinc ore minerals are often associated with calcite and barite, while gold is frequently found in association with quartz.

Associated minerals that form almost simultaneously and are usually present in a specific rock type make up an assemblage. Orthoclase, albite, biotite, and quartz form an assemblage for granite, and plagioclase, augite, magnetite, and olivine for gabbro. Assemblages are key indicators of the environments in which minerals form.

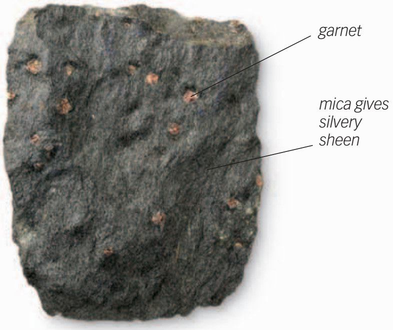

Metamorphic mix
The assemblage of garnet, quartz, and mica in this specimen indicates that this rock formed at moderate pressure and low temperatures (up to 400°F/200°C).

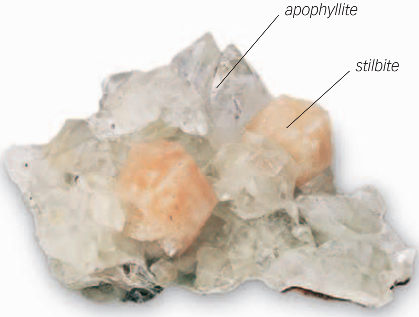

Zeolite association
Minerals belonging to the zeolite group of silicates, such as these crystals of apophyllite and stilbite, are often found in association with one another.

Layered rocks in the San Juan River
Erosion at this canyon in Utah, USA, has exposed layers of shale. Differences in the assemblage of minerals in various shale layers can reveal much about the geological history of the region.

CLASSIFYING MINERALS

Classification of minerals is an ongoing study among mineralogists—geologists who specifically study minerals. The ability to delve deep into the structure and chemistry of minerals has increased dramatically with advances in instruments and techniques.

MINERAL OR NOT?

The term “mineral” is commonly applied to certain organic substances, such as coal, oil, and natural gas, when referring to a nation’s wealth in resources. However, these materials are more accurately referred to as hydrocarbons. Gases and liquids are not, in the strict sense, minerals. Although ice—the solid state of water—is a mineral, liquid water is not; nor is liquid mercury, which can be found in mercury ore deposits. Synthetic equivalents of minerals, for example emeralds and diamonds produced in the laboratory, are not minerals because they do not occur naturally. The “minerals” referred to in foods are also not strictly minerals—they refer to elements, such as iron, calcium, or zinc.

Synthetic ruby boule
Rubies and other gems grown synthetically are not classified as minerals. Some gems, such as yttrium-aluminum garnet, do not even occur in nature.

CHEMICAL FORMULAE

A chemical formula identifies the atoms present in a mineral and their proportions. In some minerals, the atoms and their proportions are fixed. Pyrite, for example, is always FeS_2, denoting iron (Fe) and sulfur (S) in a 1:2 ratio. In solid solutions, the components may be variable. For olivine, where complete substitution is possible between iron and magnesium (Mg), the formula is $(Fe,Mg)_2SiO_4$, indicating that iron and magnesium are found in varying amounts.

CHEMICAL ELEMENTS

Symbol	Name	Symbol	Name	Symbol	Name	Symbol	Name
Ac	Actinium	Er	Erbium	Mo	Molybdenum	Sb	Antimony
Ag	Silver	Es	Einsteinium	N	Nitrogen	Sc	Scandium
Al	Aluminum	F	Fluorine	Na	Sodium	Se	Selenium
Am	Americium	Fe	Iron	Nb	Niobium	Si	Silicon
Ar	Argon	Fm	Fermium	Nd	Neodymium	Sm	Samarium
As	Arsenic	Fr	Francium	Ne	Neon	Sn	Tin
At	Astatine	Ga	Gallium	Ni	Nickle	Sr	Strontium
Au	Gold	Gd	Gadolinium	No	Nobelium	Ta	Tantalum
B	Boron	Ge	Germanium	Np	Neptunium	Tb	Terbium
Ba	Barium	H	Hydrogen	O	Oxygen	Tc	Technetium
Be	Beryllium	He	Helium	Os	Osmium	Te	Tellurium
Bi	Bismuth	Hf	Hafnium	P	Phosphorus	Th	Thorium
Bk	Berkelium	Hg	Mercury	Pa	Protactinium	Ti	Titanium
Br	Bromine	Ho	Holmium	Pb	Lead	Tl	Thallium
C	Carbon	I	Iodine	Pd	Palladium	Tm	Thulium
Ca	Calcium	In	Indium	Pm	Promethium	U	Uranium
Cd	Cadmium	Ir	Iridium	Po	Polonium	V	Vanadium
Ce	Cerium	K	Potassium	Pt	Platinum	W	Tungsten
Cf	Californium	Kr	Krypton	Pr	Praseodymium	Xe	Xenon
Cl	Chlorine	La	Lanthanum	Pu	Plutonium	Y	Yttrium
Cm	Curium	Li	Lithium	Ra	Radium	Yb	Ytterbium
Co	Cobalt	Lu	Lutetium	Rb	Rubidium	Zn	Zinc
Cr	Chromium	Lw	Lawrencium	Re	Rhenium	Zr	Zirconium
Cs	Cesium	Md	Mendelevium	Rh	Rhodium		
Cu	Copper	Mg	Magnesium	Rn	Radon		
Dy	Dysprosium	Mn	Manganese	S	Sulfur		

CLASSIFYING MINERALS

Minerals are primarily classified according to their chemical composition. Shown below are the major chemical groups, with an example of each. Minerals are further classified into subgroups, with each subgroup taking its name from its most typical mineral. A radical is a group of atoms that acts as a single unit.

GRAPHITE

Native elements
Minerals formed of a single chemical element—metals such as gold and copper and nonmetals such as sulfur and carbon—are called native elements.

BRUCITE

Hydroxides
Hydroxide minerals contain a hydroxyl (hydrogen and oxygen) radical combined with a metallic element. In brucite, the metallic element is magnesium.

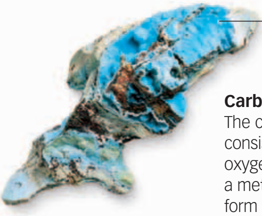

coating of blue smithsonite

SMITHSONITE

Carbonates
The carbonate radical, consisting of carbon and oxygen, combines with a metal or semimetal to form carbonate minerals. In smithsonite, the metal is zinc.

COLEMANITE

Borates and nitrates
Borates contain radicals of boron and oxygen, and nitrates, radicals of nitrogen and oxygen. In colemanite boron and oxygen combine with calcium and water.

AMETHYST

Silicates
In this group, silicon and oxygen form a silica radical that combines with metals or semimetals. Silica occurs alone as quartz, as in this amethyst specimen.

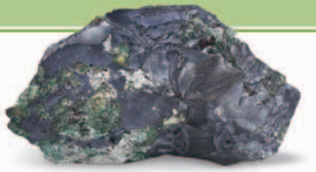

CHALCOCITE

Sulfides
The sulfides are formed when a metal or semimetal combines with sulfur. In chalcocite, the metallic element is copper.

RUBY

Oxides
When oxygen alone combines with a metal or semimetal, an oxide is formed. Corundum is aluminum oxide, with a red variety called ruby.

Halides
A halogen element (chlorine, bromine, iodine, or fluorine) combined with a metal or semimetal makes a halide. Sylvite is a compound of chlorine and potassium.

SYLVITE

APATITE

Arsenates, phosphates, and vanadates
In these minerals, a radical of oxygen and either arsenic, phosphorus, or vanadium combines with a semimetal or metal. Apatite is a phosphate.

Sulfates, chromates, tungstates, and molybdates
Sulfur, molybdenum, chromium, or tungsten form a radical with oxygen that combines with a metal or semimetal. Celestine is a sulfate.

CELESTINE

AMBER

Organic minerals
This group includes some naturally occurring substances, such as shell and coral, that are generated by organic means. Amber is a fossil resin.

IDENTIFYING MINERALS

There are certain physical properties determined by the crystalline structure and chemical composition of a mineral. These can commonly help to identify minerals without the use of expensive equipment. Even a beginner can readily use these pointers.

COLOR

Some minerals have characteristic colors—the bright blue of azurite, the yellow of sulfur, and the green of malachite allow for easy identification. This is not true of all minerals—fluorite occurs in virtually all colors, so it is best identified by other properties.

In minerals, color is caused by the absorption or refraction of light of particular wavelengths. This can happen for several reasons. One is the presence of trace elements—"foreign" atoms that are not part of the basic chemical makeup of the mineral in the crystal structure. As few as three atoms per million can absorb enough of certain parts of the visible-light spectrum to give color to some minerals. Color can also result from the absence of an atom or ionic radical from a place that it would normally occupy in a crystal. The structure of the mineral itself, without any defect or foreign element, may also cause color: opal is composed of minute spheres of silica that diffract light; and the thin interlayering of two feldspars in moonstone gives it color and sheen.

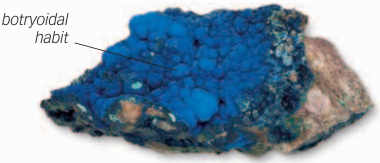

Azurite
Some minerals can be identified by their characteristic color. The copper carbonate azurite is always azure blue.

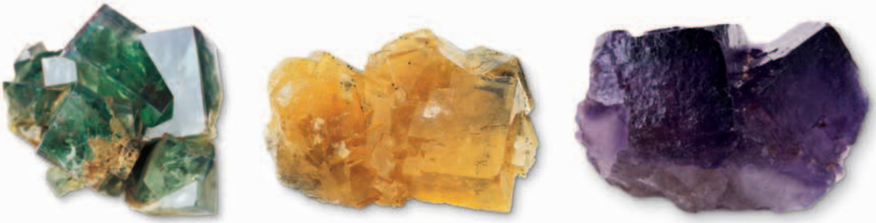

GREEN FLUORITE **YELLOW FLUORITE** **PURPLE FLUORITE**

Color range
These specimens show only a few of the many colors that can occur in fluorite. Different coloration depends on a number of factors.

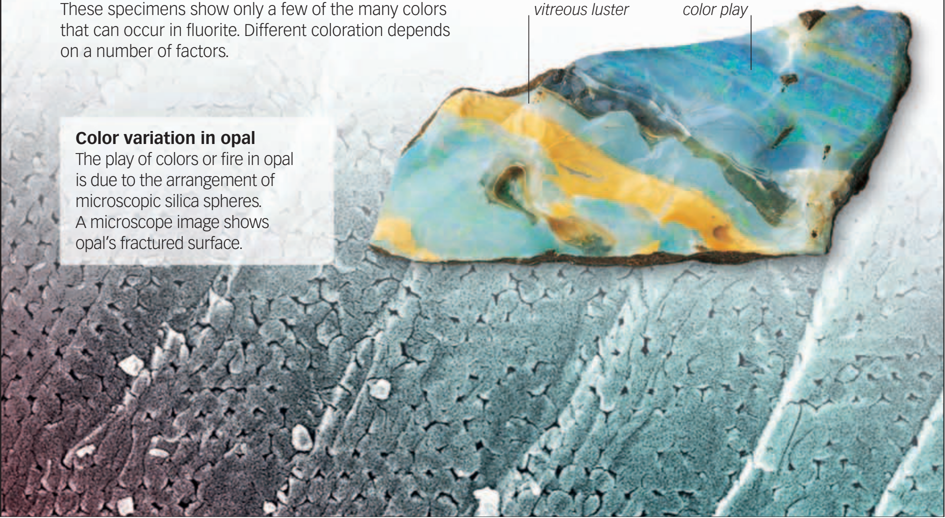

Color variation in opal
The play of colors or fire in opal is due to the arrangement of microscopic silica spheres. A microscope image shows opal's fractured surface.

LUSTER

A mineral's luster is the appearance of its surface in reflected light. There are two broad types of luster: metallic and nonmetallic. Metallic luster is that of an untarnished metal surface, such as gold, silver, or copper. These minerals tend to be opaque. Minerals with nonmetallic luster commonly show transparency or translucency. Vitreous describes the luster of a piece of broken glass; adamantine, the brilliant luster of diamond; resinous, the luster of a piece of resin; and pearly, the luster of mother-of-pearl or pearl. Greasy luster refers to the appearance of being covered with a thin layer of oil, and silky, the appearance of the surface of silk or satin. Dull luster implies little or no reflection, and earthy luster the nonlustrous look of raw earth.

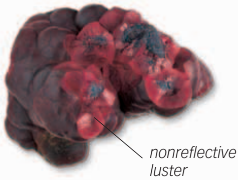

Dull
A dull luster is seen in this specimen of hematite. It is nonreflective but not as granular in appearance as earthy luster.

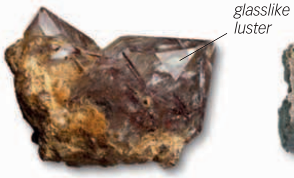

Vitreous
Many silicate minerals, such as this quartz crystal, have a vitreous luster. This luster appears similar to the surface of glass.

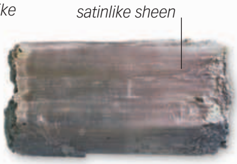

Silky
The borate ulexite exhibits a silky luster, with the surface sheen resembling a bolt of satin or silk.

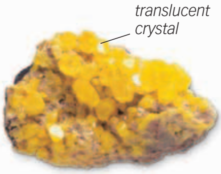

Resinous
Native sulfur crystals are transparent or translucent, with a resinous luster that resembles the surface of tree resin.

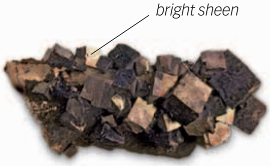

Metallic
The sulfide galena has a metallic luster and a distinctive cleavage. Metallic luster looks like the reflection from new metal.

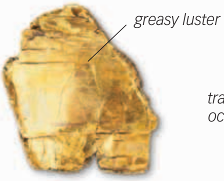

Greasy
Orpiment can appear greasy—resembling an oily surface—or resinous. The difference between the two lusters is subjective.

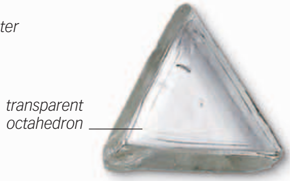

Adamantine
Adamantine is the brightest of lusters, with an appearance similar to the surface of this diamond. It is brighter than vitreous luster.

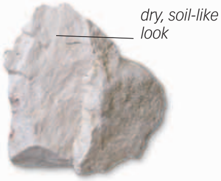

Earthy
Minerals with an earthy luster, such as this fine-grained calcite, have the look of freshly broken, dry soil.

STREAK

The color of the powder produced when a specimen is drawn across a surface such as unglazed porcelain is known as streak. A mineral's streak is consistent and is a more useful diagnostic indicator than its color, which can vary. Streak can help distinguish between minerals that are easy to confuse. For example, the iron oxide hematite has a red streak, while magnetite, another iron oxide, gives a black streak.

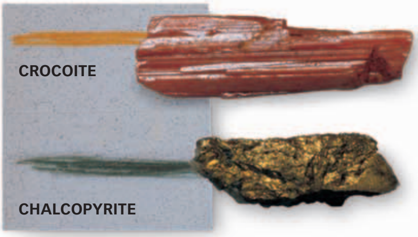

Consistent streak
The streak of a mineral is consistent from specimen to specimen, as long as an unweathered surface is tested. It is the same as the color of the powdered mineral.

CLEAVAGE

The ability of a mineral to break along flat, planar surfaces is called cleavage. It occurs in the crystal structure where the forces that bond atoms are the weakest. Cleavage surfaces are generally smooth and reflect light evenly. Cleavage is described by its direction relative to the orientation of the crystal and by the ease with which it is produced. If cleavage easily produces smooth, lustrous surfaces, it is called perfect. Distinct, imperfect, and difficult indicate less easy kinds of cleavage. Minerals may have different quality cleavages in different directions. Some have no cleavage at all.

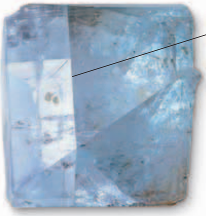

Perfect cleavage
This topaz crystal exhibits perfect cleavage. It breaks cleanly parallel to its base, and is thus said to have perfect basal cleavage.

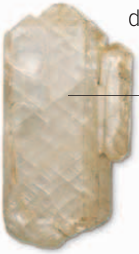

Clear breaks
The cleavage planes of this baryte crystal are clearly visible. Baryte has perfect cleavage in different directions, as seen in this specimen.

FRACTURE

Some minerals can break in directions other than along cleavage planes. These breaks, known as fractures, help in identifying minerals. For example, hackly fractures (with jagged edges), are often found in metals, while shell-like conchoidal fractures are typical of quartz. Other terms for fractures include even (rough but more or less flat), uneven (rough and completely irregular), and splintery (with partially separated fibers).

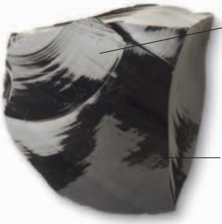

Conchoidal
This obsidian nodule shows conchoidal fracture, with fractures shaped like a bivalve seashell. It is commonly seen in silicates.

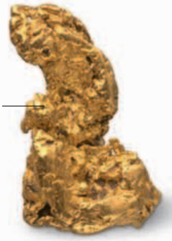

Hackly
This gold nugget shows hackly fracture, with sharp edges and jagged points. It is characteristic of most metals.

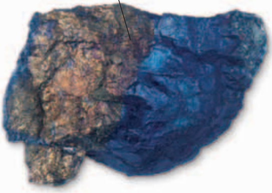

Uneven
This specimen of chalcopyrite shows uneven fracture. Its broken surface is rough and irregular, with no pattern evident.

TENACITY

The term tenacity describes the physical properties of a mineral based on the cohesive force between atoms in the structure. Gold, silver, and copper are malleable and can be flattened without crumbling. Sectile minerals can be cut smoothly with a knife; flexible minerals bend easily and stay bent after pressure is removed; ductile minerals can be drawn into a wire; brittle minerals are prone to breakage; and elastic minerals return to the original form after they are bent.

Ductile copper
Like many other native metals, copper is ductile. This means that it can be drawn into a wire without breaking.

Malleable gold
The malleability of gold allows it to be wrought into elaborate shapes. It can also be hammered into sheets thinner than paper.

HARDNESS

The hardness of a mineral is the relative ease or difficulty with which it can be scratched. A harder mineral will scratch a softer one, but not vice versa. Minerals are assigned a number between 1 to 10 on the Mohs scale, which measures hardness relative to ten minerals of increasing hardness. Hardness differs from toughness or strength; very hard minerals can be quite brittle. Most hydrous minerals—those that contain water molecules—are soft, as are phosphates, carbonates, sulfates, halides, and most sulfides. Anhydrous oxides—those without water molecules—and silicates are relatively hard.

Fingernail test
The fingernail is about 2½ on the Mohs scale and can scratch talc and gypsum. The hardness of other common items is also noted on the scale.

THE MOHS SCALE OF HARDNESS

Hardness	Mineral	Other materials for hardness testing
1	Talc	Very easily scratched by a fingernail
2	Gypsum	Can be scratched by a fingernail
3	Calcite	Just scratched with a copper coin
4	Flourite	Very easily scratched with a knife but not as easily as calcite
5	Apatite	Scratched with a knife with difficulty
6	Orthoclase	Cannot be scratched with a knife but scratches glass with difficulty
7	Quartz	Scratches glass easily
8	Topaz	Scratches glass very easily
9	Corundum	Cuts glass
10	Diamond	Cuts glass

REFRACTIVE INDEX

Light changes velocity and direction as it passes through a transparent or translucent mineral. The extent of this change is measured by the refractive index: the ratio of light's velocity in air to its velocity in the crystal. A high index causes dispersion of light into its component colors. Refractive indices can be found using specialized liquids or inexpensive equipment.

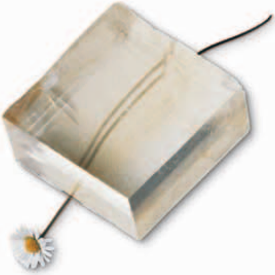

Double refraction
A calcite rhomb is said to be double refractive. It refracts light at two different angles, thus creating a double image.

FLUORESCENCE

Some minerals exhibit fluorescence—that is, they emit visible light of various colors when subjected to ultraviolet radiation. Ultraviolet lights for testing fluorescence can be obtained from dealers selling collectors' equipment. Fluorescence is an imperfect indicator of a mineral's identity because not all specimens of a mineral show fluorescence, even if they look identical and come from the same location.

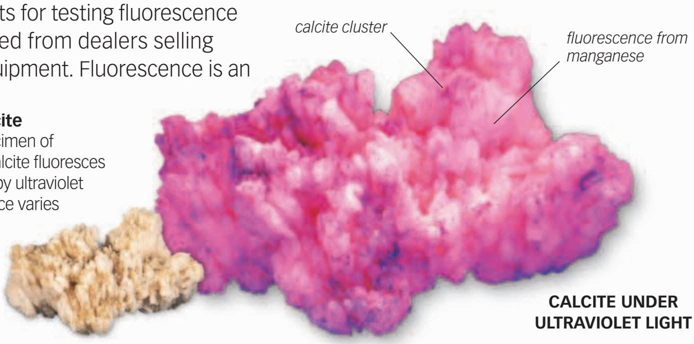
calcite cluster
fluorescence from manganese
CALCITE UNDER NATURAL LIGHT
CALCITE UNDER ULTRAVIOLET LIGHT

Manganoan calcite
This yellowish specimen of manganese-rich calcite fluoresces rose pink when lit by ultraviolet light. Its fluorescence varies with manganese concentration.

WHAT ARE CRYSTALS?

Virtually all minerals are crystalline—solids in which the component atoms are arranged in a particular, repeating, three-dimensional pattern. All crystals of a mineral are built with the same pattern. Some are 10 feet long; others can only be seen with a microscope.

ATOMIC STRUCTURE

A crystal is built up of individual, identical, structural units of atoms or molecules called unit cells. A crystal can consist of only a few unit cells or billions of them. The unit cell is repeatedly repeated in three dimensions, forming the larger internal structure of the crystal. The shape of the unit cell and the symmetry of the structure determine the positions and shapes of the crystal's faces.

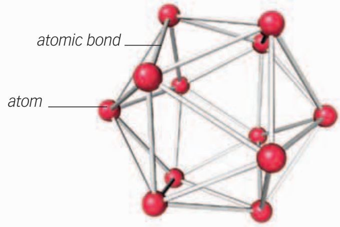

Crystal structure
Stick-and-ball diagrams, such as this one, show how each atom in the structure of a crystal is bonded to others.

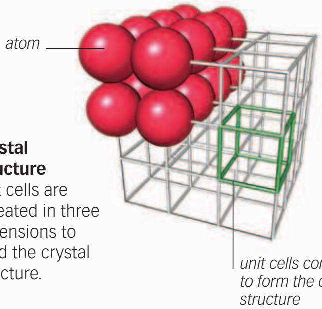

Crystal structure
Unit cells are repeated in three dimensions to build the crystal structure.

Crystals of many different minerals have unit cells that are similar in shape but are made of different chemical elements. The final development of the faces of a crystal is determined by the symmetry of the atomic structure and by the geological conditions at the time of its formation. Certain faces may be emphasized, while others disappear altogether. The final form taken by a crystal is known as its habit (pp.20–21).

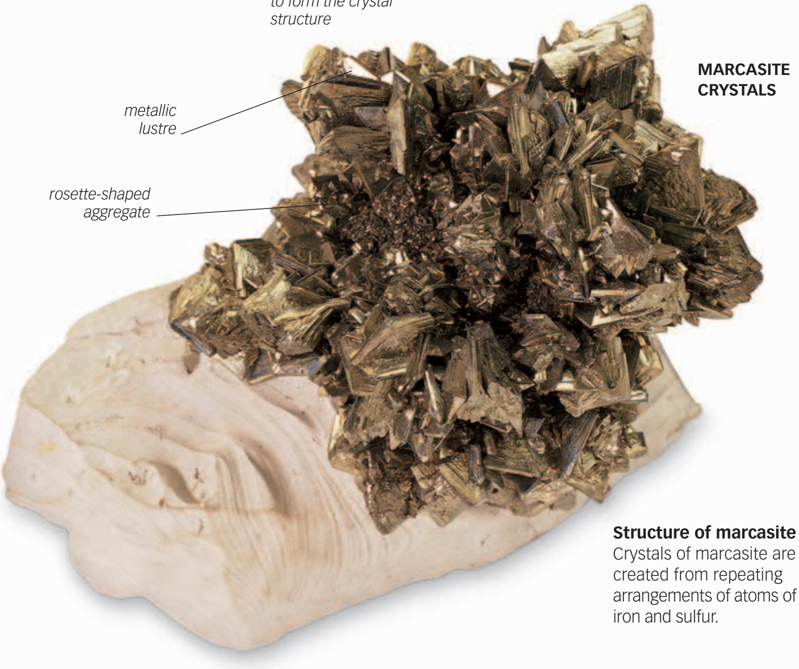

Structure of marcasite
Crystals of marcasite are created from repeating arrangements of atoms of iron and sulfur.

CRYSTAL SYMMETRY

All crystals exhibit symmetry because each crystal is built up of repeating geometric patterns. These patterns of crystal symmetry are divided into six main groups, or crystal systems (pp.22–23). The first of these symmetrical patterns is the cubic system, in which all crystals exhibit cubic symmetry. The characteristics of cubic symmetry may be explained as follows: if opposite face centers of a cube-shaped cubic crystal, such as halite, are held between the thumb and forefinger and the crystal is rotated through 360 degrees, the pattern of faces will appear identical four times as the different faces and edges come into view.

All cubic crystals have three axes of fourfold symmetry. They have other axes of symmetry, but these differ among classes within the cubic system. For example, cube-shaped crystals of halite have three axes of fourfold symmetry, in addition to its four axes of threefold symmetry.

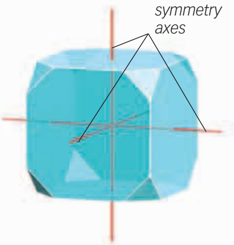

Cubic symmetry
All cubic crystals, such as those of halite (right), have three axes of fourfold symmetry.

cubic crystal
rock matrix

HALITE

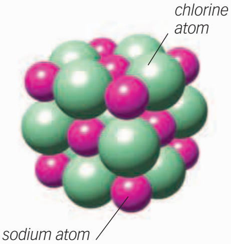

Halite atomic structure
This diagram shows the cubic arrangement of sodium and chlorine atoms in the halite structure.

TWIN CRYSTALS

When two or more crystals of the same species (a group of minerals that are chemically similar), such as gypsum or fluorite, form a symmetrical intergrowth, they are referred to as twinned crystals. Twins can be described as interpenetrating or contact. Penetration twinning may occur with individual crystals at an angle to one another—for example, forming a cross. It can also occur with individual crystals parallel to one another, as in Carlsbad twinning. If a twin involves three or more individual crystals, it is referred to as a multiple twin or a repeated twin. Albite often forms multiple twins. Many other minerals form twins, but they are particularly characteristic of some, such as the "fishtail" contact twins of gypsum or the penetration twins of fluorite.

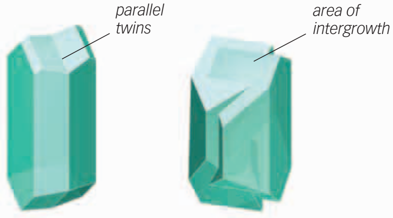

CONTACT TWIN

CARLSBAD PENETRATION TWIN

Contact and penetration twins
Parallel twinning is a kind of contact twinning in which two or more crystals share a common face or faces. Penetration twinning results from crystals growing into each other.

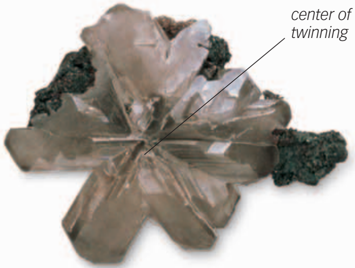

Cyclic twin
Cyclic twins occur when more than two crystals are twinned at a common center. This specimen of cerussite shows the cyclic twinning of three crystals all at 60° angles to each other.

CRYSTAL HABITS

Habit refers to the external shape of a crystal or an assemblage of intergrown crystals. It includes names of crystal's faces, such as prismatic and pyramidal, names of forms, such as cubic and octahedral, and descriptive terms, such as bladed and dendritic.

CRYSTAL FACES

The three types of crystal face—prism, pyramid, and pinacoid—are determined by a relationship to a crystallographic axis (p.22). Prism faces are parallel to the axis; pyramid faces cut through the axis at an angle; and pinacoid faces are at right angles to the axis. A crystal may have numerous sets of pyramid faces, each at a different angle to the c axis. Crystals may also have major and minor prism faces with edges parallel to each other. In most crystals, some faces are more developed than others.

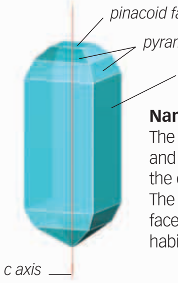

Naming crystal faces
The names of crystal faces and their relationship to the c axis are shown here. The predominant crystal face gives the crystal its habit name.

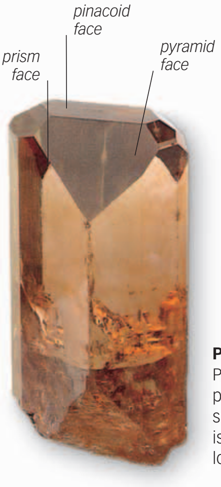

Prismatic topaz
Although this topaz crystal exhibits prismatic, pryamidal, and pinacoidal faces, the bulk of the crystal is defined by its prism faces and it is therefore called prismatic.

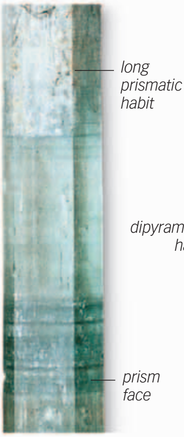

Prismatic
Prism faces clearly predominate in this long specimen of beryl. Its habit is therefore described as long prismatic.

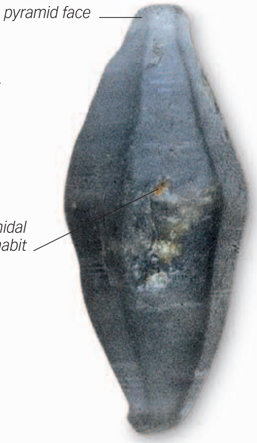

Pyramidal
If pyramid faces dominate in one direction, the habit is pyramidal. If pyramid faces dominate in both directions, as in this specimen of sapphire, the habit is dipyramidal.

CRYSTAL FORMS

Habits can be named after crystal forms: "cubic" implies crystallizing in the form of cubes; "dodecahedral," in the form of dodecahedrons; and "rhombohedral," in the form of rhombohedrons. When crystals of one system crystallize in forms that appear to be the crystals of another system, the habit name is preceded by the word "pseudo." When terminations take different forms in the same crystal, the habit is known as hemimorphic.

Octahedral
This magnetite specimen has crystallized as an octahedron and is said to have an octahedral habit.

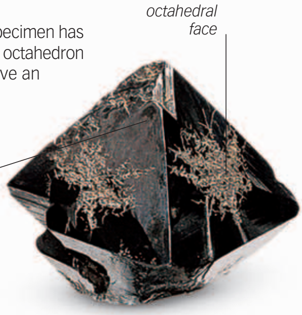

AGGREGATES

Aggregates are groups of intimately associated crystals. In general, aggregates are intergrowths of imperfectly developed crystals. In some aggregates, the crystals may be microscopic. The type of aggregation is often typical of a particular mineral species. Terms used to describe aggregates include granular, fibrous, radiating, botryoidal, stalactitic, geodic, and massive.

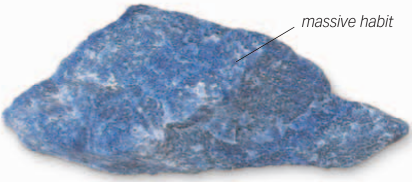

Massive
The massive habit occurs when there is a mass of crystals that cannot be seen individually, as in this specimen of dumortierite.

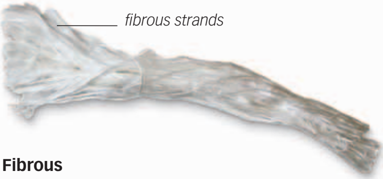

Fibrous
The fibrous habit is an aggregate, consisting of slender, parallel, or radiating fibers. This tremolite specimen is a good example.

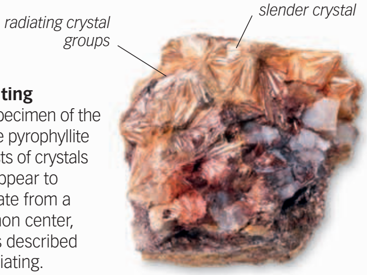

Radiating
This specimen of the silicate pyrophyllite consists of crystals that appear to originate from a common center, so it is described as radiating.

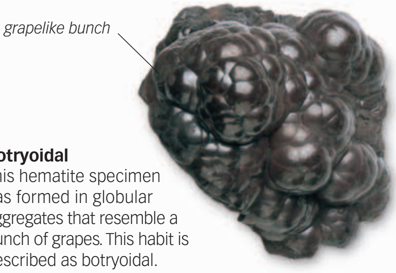

Botryoidal
This hematite specimen has formed in globular aggregates that resemble a bunch of grapes. This habit is described as botryoidal.

CRYSTAL APPEARANCE

Some habits are descriptions of the general appearance of a crystal. The term "tabular" describes a crystal with large, flat, parallel faces; "bladed" describes elongated crystals that are flattened like a knife blade; "stalactitic" describes crystal aggregates shaped like stalactites; and "blocky" or "equant" describes crystals with faces that are roughly the same size in all directions.

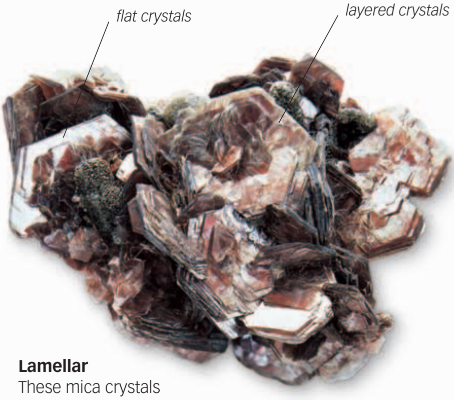

Lamellar
These mica crystals are described as having a lamellar habit. They are flat, platelike, individual crystals arranged in layers.

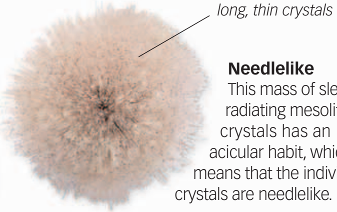

Needlelike
This mass of slender, radiating mesolite crystals has an acicular habit, which means that the individual crystals are needlelike.

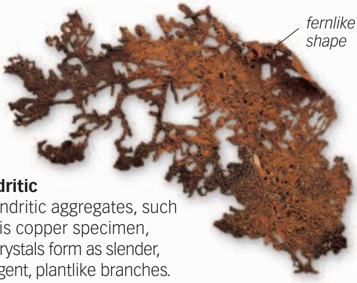

Dendritic
In dendritic aggregates, such as this copper specimen, the crystals form as slender, divergent, plantlike branches.

CRYSTAL SYSTEMS

Crystals are classified into six different systems according to the maximum symmetry of their faces. Each crystal system is defined by the relative lengths and orientation of its three crystallographic axes—imaginary lines that pass through the centre of an ideal crystal.

CUBIC

Cubic crystals have three crystallographic axes (a_1, a_2, and a_3) at right angles and of equal length, and four threefold axes of symmetry. The main forms within this system are cube, octahedron, and rhombic dodecahedron. Halite, copper, gold, silver, platinum, iron, fluorite, and magnetite crystallize in the cubic system, which is also known as the isometric system.

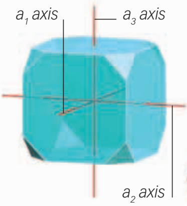

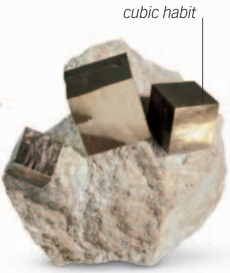

Cubic crystal system
Pyrite crystals commonly form as cubes, but they can also occur as pentagonal dodecahedra and octahedra, or combinations of all three forms.

TETRAGONAL

Tetragonal crystals have three crystallographic axes at right angles—two equal in length (a_1 and a_2), and the third (c) longer or shorter. These crystals have one principal, fourfold axis of symmetry. Crystals look like square or octahedral prisms in shape. Rutile, zircon, cassiterite, and calomel are minerals that crystallize in the tetragonal system.

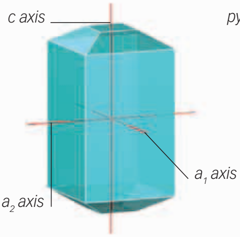

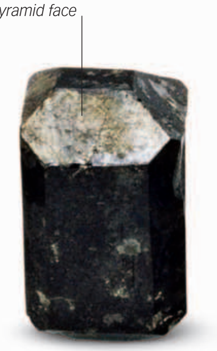

Vesuvianite
This vesuvianite crystal—with prismatic, pyramidal, and pinnacoid faces—shows a classic tetragonal form.

HEXAGONAL AND TRIGONAL

Some crystallographers consider hexagonal and trigonal crystals to comprise a single system, whereas others regard them as forming separate systems. Both crystalline forms have three crystallographic axes (a_1, a_2, and a_3) of equal length. These are at 120 degrees to one another and to a fourth axis (c), which is perpendicular to the plane of the other three axes. Trigonal crystals have only threefold symmetry, whereas hexagonal crystals have sixfold symmetry. Minerals that crystallize in the hexagonal system include beryl (emerald and aquamarine) and apatite. Some of the minerals that crystallize in the trigonal system are calcite, quartz, and tourmaline.

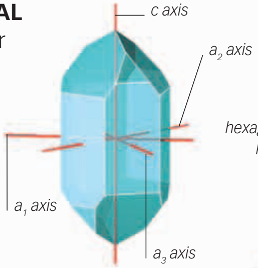

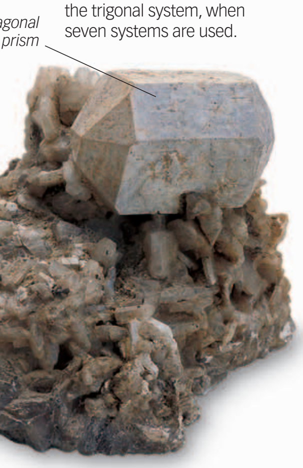

Apatite
Apatite forms hexagonal-shaped prisms, and its overall symmetry is hexagonal. Many "hexagonal" minerals fall into the trigonal system, when seven systems are used.

MONOCLINIC

The term "monoclinic" means "one incline." Monoclinic crystals have three crystallographic axes of unequal length. One (c) is at right angles to the other two (a and b). These two axes are not perpendicular to each other, although they are in the same plane. The crystals have one twofold axis of symmetry. More minerals crystallize in the monoclinic system than in any other crystal system. Examples are gypsum, orthoclase, malachite, and jadeite.

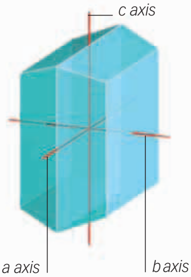

Gypsum
The parallelogram shape of this crystal of gypsum demonstrates the two unequal crystallographic axes and the third axis at right angles of the monoclinic system. Orthoclase, which belongs to the same system, often forms twinned crystals.

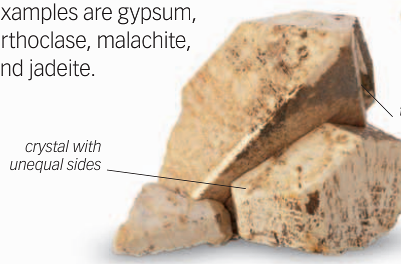

ORTHOCLASE

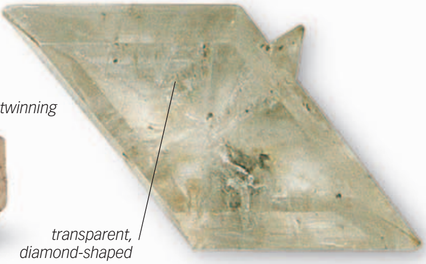

GYPSUM

ORTHORHOMBIC

Orthorhombic means "perpendicular parallelogram". Crystals in this system have three crystallographic axes (a, b, and c) at right angles, all of which are unequal in length. They have three twofold axes of symmetry. Minerals that crystallize in this system include olivine, aragonite, topaz, marcasite, and barite.

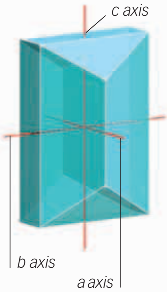

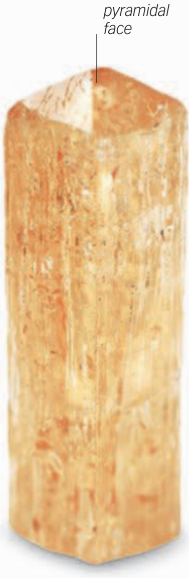

Topaz
The mineral topaz often forms beautiful, orthorhombic prismatic crystals that are usually terminated by pyramids or other prisms. The mineral barite also forms orthorhombic prisms.

TRICLINIC

Triclinic crystals have the least symmetrical shape, with three crystallographic axes of unequal length (a, b, and c) inclined at angles other than 90 degrees to each other. The orientation of a triclinic crystal is arbitrary. Minerals that crystallize in this system include albite, anorthite, kaolin, and kyanite.

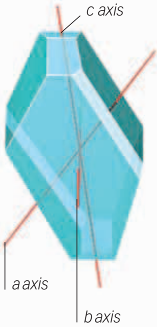

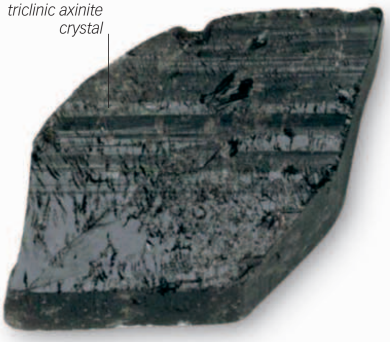

Axinite
The silicate axinite is a classic triclinic mineral. Several feldspars, including albite and microcline, are also triclinic.

GEMS

A gem is any mineral that is highly prized for its beauty, durability, and rarity. It is enhanced in some manner by altering its shape, usually by cutting and polishing. Most gems begin as crystals of minerals or as aggregates of crystals.

HISTORY OF GEMS

The use of gemstones in human history goes back to the Upper Paleolithic Period (25,000–12,000 BCE). People were initially drawn by the bright colors and beautiful patterns of gems. When the shaping of stones for adornment first began, opaque and soft specimens were used. As shaping techniques improved, harder stones began to be cut into gems. Beads of the quartz varieties hard carnelian and rock crystal were fashioned in Mesopotamia (now Iraq) in the 7th millennium BCE. Records of the time suggest that people thought that stones had a mystic value—a belief that persists to the present.

wings embedded with gems

Ancient masterpiece
This ancient Egyptian chest ornament is inlaid with gold, finely cut lapis lazuli, carnelian, and other gems. It is from the tomb of Tutankhamun (*c.*1361–1352 BCE).

lapis lazuli
etched carnelian

Iraqi carnelian necklace
This necklace was made in Mesopotamia (modern day Iraq) from lapis lazuli, carnelian, and etched carnelian. It dates from about 2500 BCE.

GEM MINING

Gemstone deposits form in different geological environments. Perhaps the best known are the "pipes" of kimberlite, from which most diamonds are recovered by the hard-rock methods of drilling and blasting. Other gems also recovered from the rock in which they form are quartz varieties, opal, tourmaline, topaz, emerald, aquamarine, some sapphires and rubies, turquoise, lapis lazuli, and chrysoberyl. Hard and dense gemstones that are impervious to chemical weathering are carried by water to placer deposits such as river beds, beaches, and the ocean floor. Placer mining techniques mimic the creation of the placer by separating denser minerals in running water. The simplest methods are panning and sieving, or passing gravel through a trough of flowing water with baffles at the bottom. The lighter material washes away but denser gemstones remain.

Gem panning
Many gemstone minerals, such as sapphire and ruby, are heavier than normal stream gravels. These can be recovered using the slow but thorough panning method.

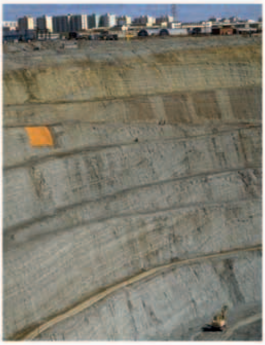

Diamond mine in Siberia
Russia has become a major supplier of diamonds. In this mine, diamonds are being recovered from a diamond pipe.

FACETING

Gemstones can be shaped in several ways. Opaque or translucent semiprecious stones, such as agate and jasper, are tumble-polished, carved, engraved, or cut with a rounded upper surface and a flat underside. Grinding and polishing of flat faces on the stone is called faceting. Facets are placed in specific geometric positions at specific angles according to the bending of light within a particular stone. Transparent stones, such as amethyst, diamond, and sapphire, are faceted to maximize their brilliance and "fire" or enhance color. Although much material is ground away while cutting, the final value is much enhanced.

Cutting a brilliant
While faceting gemstones, care must be taken to preserve the maximum material and produce the best brilliance and color.

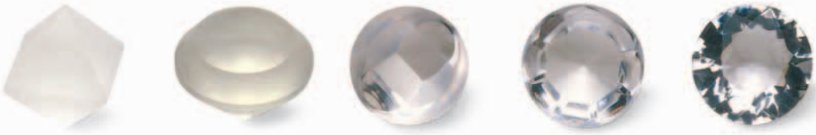

Rough choice
The faceter selects his rough based on color, clarity, and shape, which determine the cut for the final gem.

Sawn in two
The rough is sawn to roughly the final shape of the gem. Accurate sawing saves time in the grinding process.

Faceting begins
The major facets are first ground onto the gem. The accuracy of these determines the final brilliance.

Further facets
Smaller facets are cut after the major facets. Based on the cut, there may be only a few or dozens of these.

Finished off
After the first side of the stone is cut, it is reversed and facets are placed on the second side in the same order.

GEM CUTS

There are three basic types of facet cut: step (with rectangular facets), brilliant (with triangular facets), and mixed (a combination of the two). The first faceting probably involved diamond cutting in Italy prior to the 15th century. First, only the natural faces of octahedral diamond crystals were polished. The rose cut was developed in the 17th century. By about 1700, the brilliant cut (today's favorite for diamonds and other colorless gems) was created. The emerald cut was soon developed to save valuable material, as its rectangular cut conforms to the shape of emerald crystals. Today there are hundreds of possible gem cuts.

Gemstone shapes
A principal criterion for the cutter in choosing a gemstone shape is the shape of the rough gemstone. This ensures that a minimum of valuable material is lost.

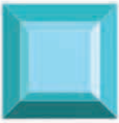

SQUARE

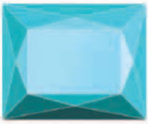

SCISSOR

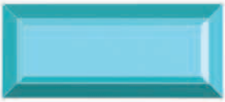

BAGUETTE

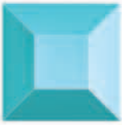

TABLE

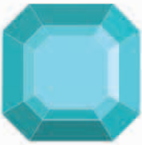

OCTAGONAL

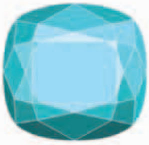

CUSHION

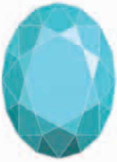

OVAL

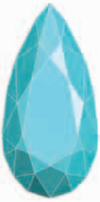

PENDELOQUE

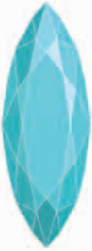

MARQUISE

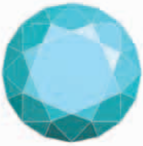

ROUND

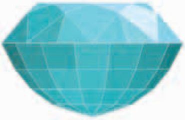

MIXED

WHAT IS A ROCK?

A rock is a naturally occurring and coherent aggregate of one or more minerals. There are three major classes of rock—igneous, sedimentary, and metamorphic. Each of these three classes is further subdivided into groups and types.

TYPES OF ROCK

Igneous rocks form from melted rock called magma. When magmas solidify underground, intrusive rocks such as granite are created. Intrusive rocks are also known as plutonic rocks. If the magma flows onto the surface of the land or ocean bed, extrusive rocks such as basalt, are formed.

Sedimentary rocks are usually made of deposits laid down on Earth's surface by water, wind, or ice. They almost always occur in layers or strata. Stratification survives compaction and cementation and is a distinguishing feature of sedimentary rocks. Some sedimentary rocks are of chemical origin, having been deposited in solid form from a solution. Others are of biochemical origin and are composed predominantly of the compound calcium carbonate.

When existing rocks are subjected to extreme temperatures or pressures, or both, their composition, texture, and internal structure may be altered to form metamorphic rocks. The original rocks may be igneous, sedimentary, or metamorphic.

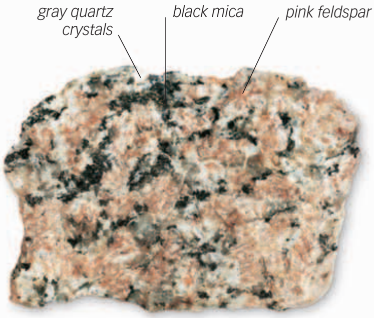

Pink granite
In this specimen of igneous pink granite, the three essential components of all granites can be seen: quartz, alkali feldspar, and mica.

Pegmatite dike
Light-colored bands of igneous hydrothermal pegmatite, composed principally of quartz, can be seen here cutting across darker bands of metamorphic gneiss.

Volcanic growth
The eruption of extrusive magmas can create volumes of igneous rock measured in cubic miles on the surface of Earth.

Marble quarry
This dazzling white marble being quarried at Carrara, Italy, is metamorphosed from a very pure limestone.

Meteorites are not considered igneous, sedimentary, or metamorphic but are a group of their own. Many are remnants of asteroids, which are themselves remnants of the formation of the Solar System. Some meteorites are remains of the nickel-iron cores of asteroids; some contain nickel-iron and minerals such as olivine from the mantles of asteroids; and others are made up principally of silicate minerals.

Sedimentary layers
The Colorado River cuts through layers of sedimentary rock in the Grand Canyon, USA. The highest layers are the youngest, while the deepest are the oldest.

THE ROCK CYCLE

The series of processes by which rocks are created, broken down, and reconstituted as new rocks is known as the rock cycle. These processes depend on pressure, temperature, time, and changes in environmental conditions in Earth's crust and surface. At various stages in the rock cycle, old rocks are broken down, new minerals form, and new rocks originate from the components of the old. Thus a rock that began at the surface as an igneous rock may be reworked into a sedimentary rock, metamorphic rock, or new igneous rock to continue the cycle again.

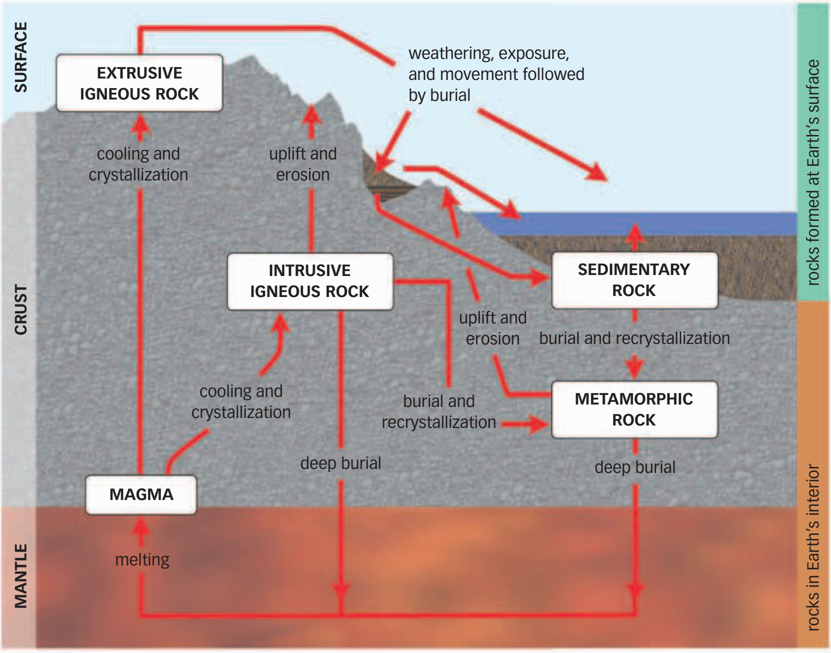
SURFACE
CRUST
MANTLE
EXTRUSIVE IGNEOUS ROCK
weathering, exposure, and movement followed by burial
cooling and crystallization
uplift and erosion
INTRUSIVE IGNEOUS ROCK
SEDIMENTARY ROCK
uplift and erosion
burial and recrystallization
cooling and crystallization
burial and recrystallization
METAMORPHIC ROCK
deep burial
deep burial
MAGMA
melting
rocks formed at Earth's surface
rocks in Earth's interior

The rock cycle
This diagram summarizes the various elements of the rock cycle, from the creation of fresh igneous rock through erosion, deposition, and its reconstitution into new rock.

COLLECTING ROCKS AND MINERALS

The world of rocks, minerals, gems, and fossils offers endless possibilities for the hobbyist. Only a small amount of specialized knowledge is required to open a whole world of enjoyment of some of nature's finest creations.

WHERE TO LOOK

Most collectors begin by just accumulating rocks, minerals, and fossils. As their collection grows, they start being more selective, keeping only specimens with better color and crystallization and more interesting crystal forms. A wide range of specimens can be purchased from dealers, but it is often more enjoyable to find your own. In many countries, there are guidebooks that give precise directions to collecting localities for rocks, minerals, and fossils.

Sample collection is not without its constraints: working mines and quarries have legal restrictions on people permitted on their premises; old mines are dangerous; old mine dumps have been gone over for decades by other collectors; and public access to land is often restricted. However, traditional collecting sites, such as road cuttings and eroded cliffs on shorelines, continue to provide excellent opportunities for collectors.

Field experience
Rock collecting can be a hobby for a lifetime, as the collector develops knowledge and skills to enhance the activity.

Road cutting
The bank of a road cut through this pegmatite rock reveals giant feldspar crystals. Many fine rock and mineral specimens are derived from road cuttings.

Looking for gold
The gold pan is an essential piece of kit for a collector. Many gemstones, such as garnet and sapphire, can be found by panning.

There is also an increasing number of collecting localities that are open to the public on the payment of a fee. Some clubs for collecting enthusiasts have their own collecting sites, and they also arrange trips to sites that are otherwise inaccessible to the public. Collectors should bear in mind that permission must always be sought to collect samples on private property.

Old working
While mine dumps are good sources of specimens, hidden workings and old machinery can pose a hazard to unwary collectors.

Tempting tunnels
Old mine shafts can be tempting, but are often highly dangerous places. In most cases better specimens are usually found in the mine dumps outside.

SAFETY AND THE COLLECTING CODE

While mineral collecting is generally a safe hobby, there are a few definite hazards that a collector needs to be aware of. The most dangerous collecting localities are around old mines and workings. Tunnels should never be entered—shoring timbers rot quickly, and cave-ins and rock falls are almost guaranteed to happen. Collectors must also pay attention to what is underfoot—old shafts are sometimes covered over. In any case, there is often remarkably poor collecting inside old mines because most material of value has usually already been removed by miners. Mine dumps, by contrast, can be a good source of specimens. However, caution should be exercized because mine dumps are often loosely piled and can be unstable.

When collecting in beach cliffs, road cuttings, and rock falls, pay attention not only to loose material underfoot but also to anything that may fall or roll from above. It is best to avoid a collecting locality if you are not sure that is safe.

TAKING NOTES

When they start out, new collectors often ignore the need to write down information about their finds. But experience soon shows that investing in a notebook and devoting the minimal amount of time it takes to keep at least basic notes is essential. It is especially important to make notes about exactly where specimens were found. A considerable time may go by before you revisit the locality, and by then, in the absence of notes, you will probably be unable to find the spot again. It is useful to make a sketch of important landmarks or outcrops, because these can help relocate a specific spot.

Map and compass
Tools such as a compass and a map or a GPS receiver are essential for identifying localities and relocating them at a later date.

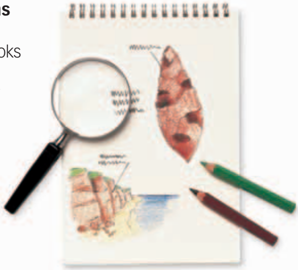

Drawing locations
It is useful to make drawings in notebooks of locations and the specimens they have yielded.

Correcting fluid
Number each specimen with a note about their find-spot. A dab of correction fluid makes a good label and can be removed if necessary.

EQUIPMENT

Mineral collecting is a safe hobby, but some simple pieces of equipment increase the safety factor dramatically. Just a few basics, such as the right hammer and chisel, a hard hat, goggles, gloves, and things you already have, will get you started.

FIELD EQUIPMENT

In addition to the basic collecting tools described here, safety equipment should be considered essential. Access to some collecting localities requires safety clothing such as a hard hat and fluorescent vest. Carry a cell phone with a fully charged battery with you even if you are only going a short distance from the car. A fall into a ravine or another low

HARD HAT
LEATHER GLOVES
SAFETY GOGGLES

Head and hand protection

Flying rock splinters and falling rocks cause injuries to collectors every year. Hands, eyes, and heads are particularly vulnerable areas. Goggles are recommended when breaking or splitting stone.

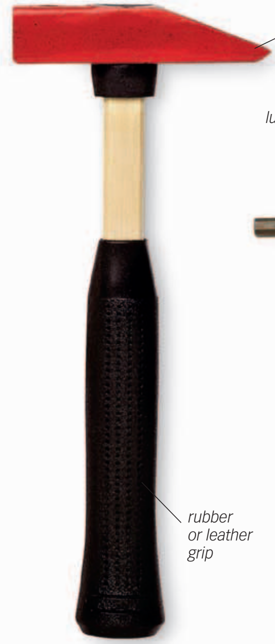
straight head for splitting hard rock
rubber or leather grip

GEOLOGISTS' HAMMER

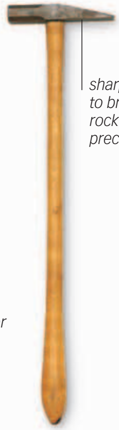
sharp end to break rock with precision

TRIMMING HAMMER

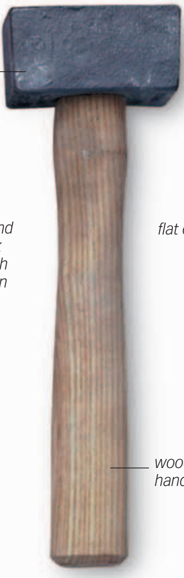
lump hammer head
wooden handle

CLUB HAMMER

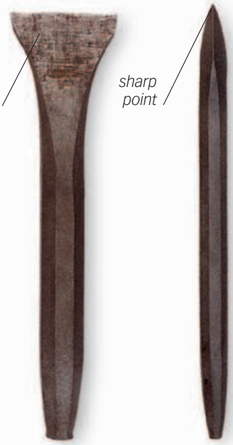
flat end
sharp point

SAFETY CHISELS

Hammers

Every year rock collectors are injured—sometimes blinded—by using the wrong hammers. Geologists' hammers are made of special steels. Their striking ends are beveled to prevent steel splinters from flying off.

Chisels

Like rock hammers, the chisels used by geologists are made from special steels that resist splintering. Not all are essential but having two or three of different sizes will make cutting rock safer.

brush for light cleaning
trowel
flat brush
sieve

Extra tools
The experienced collector has a range of equipment for all collecting possibilities, from sieves and pans to various brushes and trowels. Most of these can be bought a few at a time as new collecting localities are visited.

spot may take you out of sight of potential help and add hours to the time it takes to find you. In desert country, an adequate supply of water is essential, and if you are in snake country take an appropriate snake-bite kit. Clothing suitable to the weather and terrain is, of course, vital. Leave your low-cut shoes and sneakers at home. Leather boots offer better protection from snake bites, cactus spines, sharp stones, jagged metal, and rolling stones, and ensure much better traction.

MAGNIFICATION

There is an entire area of mineral collecting devoted to tiny crystals known as micromounts. Small crystals often develop superb forms and groupings that are obscured as the process of crystallization progresses. Micromount collectors need effective microscopes, or at the least large magnifiers, to examine and enjoy these minute specimens. For collectors not wishing to incur the expense of a microscope, a simple hand lens will reveal much of the beauty of the tiny micromounts.

scraper
trowel for removing soft sediments
PEN KNIFE

KNIVES AND SPATULAS

Cleaning tools
There are two types of cleaning tool: those for field use and those for cleaning specimens at home. Tools for field use are more robust and are used for separating specimens from adhering rock.

eyepiece
objectives
stage

MICROSCOPE

magnifying glass

HAND LENS

A closer look
Most collectors of small crystals have a microscope to examine their specimens. The field equipment of every geologist and collector should include a hand lens with a magnification of about 10 times.

ORGANIZATION, STORAGE, AND CLEANING

Finding mineral specimens is only the first stage of collecting. The number of specimens damaged in the course of the journey home or while cleaning can be large. Care must therefore be taken from the moment a specimen is collected.

TRANSPORTING SPECIMENS

Wrapping of some sort is essential when transporting newly collected specimens, whether they are being carried in a backpack or a car. Delicate specimens should be wrapped first in tissue and then in newspaper. If your wrapping material is used up, try leaves, grass, or pine needles as a natural alternative. Unwrap wet specimens and let them dry as soon as you get home. Cotton balls and cellulose wadding should be kept entirely away from specimens, because the fibers are almost impossible to remove.

In the bag
Rock samples can be carried in a cloth specimen bag. More sensitive specimens require elaborate wrapping so that they can be transported safely.

CLEANING SPECIMENS

As a general rule, clean specimens as little as possible, starting with the gentlest methods first. Begin by using a soft brush to remove loose soil and debris. Hard rock specimens, such as gneiss or granite, are unlikely to be damaged by vigorous cleaning. With delicate minerals, such as calcite crystals, it is essential to use a fine, soft brush. Never use hot water to wash a specimen, because the heat may cause some minerals to crack or shatter. Toothbrushes that use a pulsing water jet are useful cleaning tools. Soaps should be avoided, but if you must use them, choose liquid dishwashing soaps over hand or toilet soaps, which have additives that can penetrate specimens. The use of ultrasonic cleaners is not recommended—they can shatter delicate specimens even at low intensities. Certain

Muddy rocks
Many specimens will be muddy or dirty when collected. Most dirt is more easily removed when it is dry and can be lightly brushed off.

DISTILLED WATER
HYDROCHLORIC ACID

Cleaning liquids
Distilled (or deionized) water is good as a final wash for minerals. Weak hydrochloric acid is good for cleaning silicates, but always be aware of the risks involved.

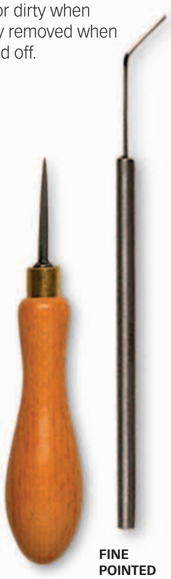

acids are suitable for cleaning specific minerals. Silicates are not harmed by weak acids, but carbonates and phosphates can be damaged by them. If you do use acids, seek specific information on their use from specialized books or other collectors.

Cleaning up
Removing rock with fine specialist tools is often necessary when collecting fossils. The mineral collector, by contrast, is more likely to brush or wash off dirt from specimens.

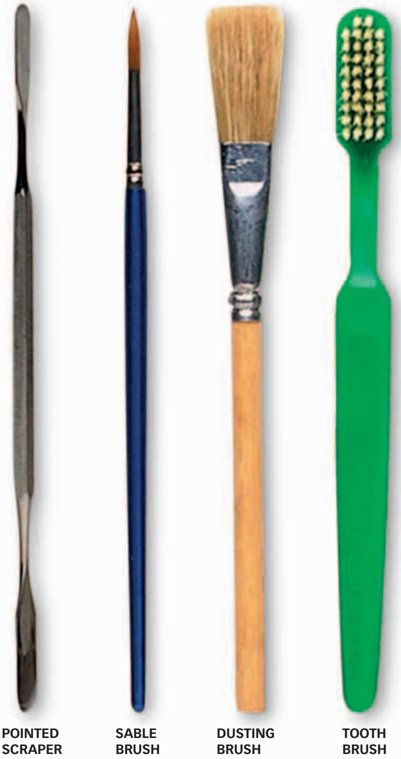

Cleaning tools
A variety of tools is useful for cleaning specimens. Each specimen will present a different cleaning problem, so a selection of tools is necessary.

STORAGE AND DISPLAY

Once specimens have been collected and cleaned, they need to be stored or, in the case of the most attractive pieces, displayed. Many collectors like to store specimens in card trays inside shallow drawers. Once collected, some minerals are liable to experience physical and chemical effects that may change or sometimes even destroy them. Fortunately, these problems are well known and preventative measures can be taken in advance.

Every specimen collected should be accompanied by a label with as much information about it as is feasible. For display, use a sturdy, preferably glass-fronted cabinet or shelf. Many guests will wish to handle specimens, but they may not be aware that handling can damage delicate examples.

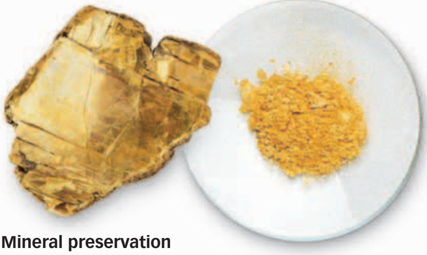

Mineral preservation
Minerals such as orpiment and realgar are sensitive to light and need special storage methods. Other minerals may require either dry or humid conditions.

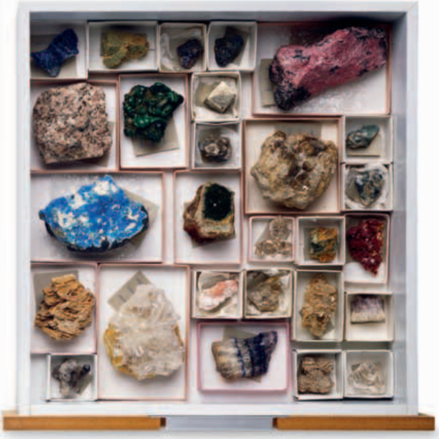

Informative display
People will admire your best specimens and also value information about them. Some collectors choose to provide museum-style information about specimens.

MINERALS

NATIVE ELEMENTS

There are 88 chemical elements known to occur in nature. Of these, less than two dozen are found uncombined with other elements. This group is called the native elements. Only eight of these native elements are found in significant quantities.

COMPOSITION

The native elements are classified into three groups: metals like copper and gold; semimetals like arsenic; and nonmetals like sulfur and carbon. The metals rarely form well-defined crystals; the semimetals typically occur as nodular masses; and the nonmetals form distinct crystals.

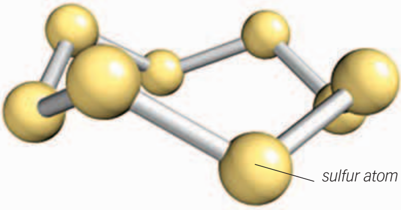

Sulfur crystal structure
In the orthorhombic crystal structure of sulfur, strongly bonded rings of eight sulfur atoms are weakly bonded to neighboring rings.

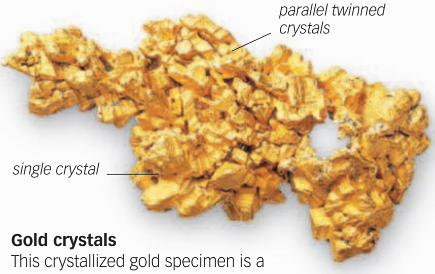

Gold crystals
This crystallized gold specimen is a rarity, because native metals rarely form well-defined crystals. Most occur in wirelike and branching forms or as nuggets.

OCCURRENCE AND USES

Native elements are known to form under a wide range of geologic conditions and in a variety of rock types. A native element can occur in several different environments. Some are found in sufficient concentrations to form economically important deposits.

Native gold and silver have been media of exchange for three millennia, and native copper and meteoric iron were among the first metals to be used by humans.

Industrial tools
This tool-maker is producing a diamond-edged industrial cutting tool. Although partly replaced by synthetic diamond, natural diamond continues to be used as an industrial abrasive.

Sulfur crust
Native sulfur builds up around fumaroles, where sulfur-rich gas is vented around volcanoes. These fumaroles often produce magnificently crystallized specimens.

PROFILE

Cubic

- ⧖ 2½–3
- 8.9
- None
- Hackly, ductile
- Rose
- Metallic

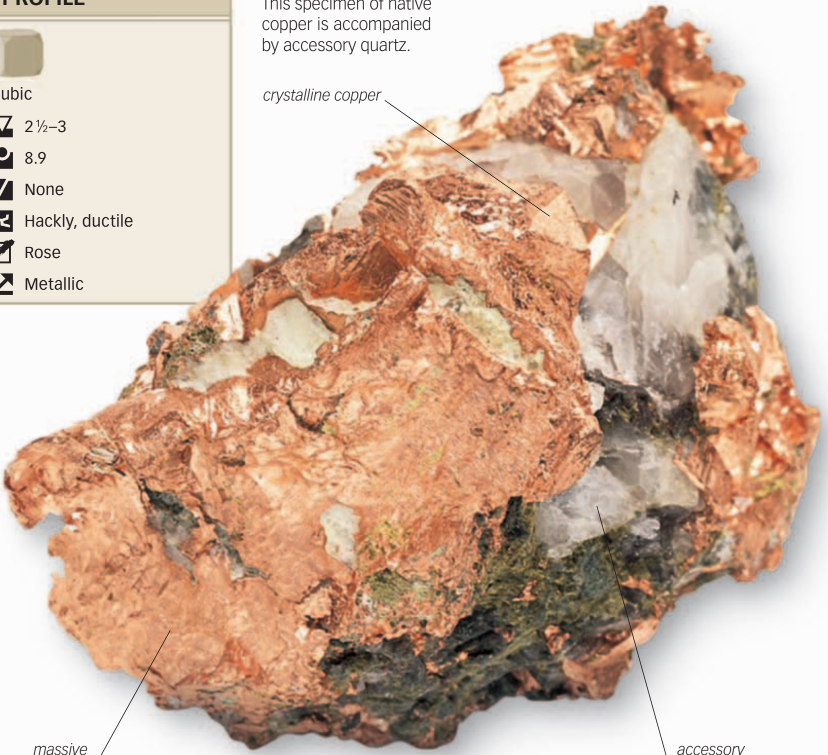

Native copper This specimen of native copper is accompanied by accessory quartz.

VARIANT

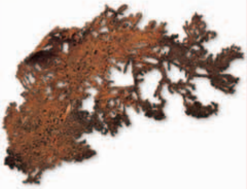

Dendritic copper A specimen of crystalline copper in the branching form

Cu

COPPER

In its free-occurring metallic state, copper was probably the first metal to be used by humans. Neolithic people are believed to have used copper as a substitute for stone by 8000 BCE. Around 4000 BCE, Egyptians cast copper in molds. By 3500 BCE, copper began to be alloyed with tin to produce bronze.

Copper is opaque, bright, and metallic salmon pink on freshly broken surfaces but soon turns dull brown. Copper crystals are uncommon, but when formed are either cubic or dodecahedral, often arranged in branching aggregates. Most copper is found as irregular, flattened, or branching masses. It is one of the few metals that occur in the "native" form without being bonded to other elements. Native copper seems to be a secondary mineral, a result of interaction between copper-bearing solutions and iron-bearing minerals.

Plumbing joint Because it is easy to shape and roll the metal, copper is widely used to make household pipes.

PROFILE

Cubic

4–4½

14.0–19.0

None

Hackly

Whitish steel-gray

Metallic

Platinum nugget Although most of the platinum mined from placer deposits occurs as small grains, sizeable nuggets are sometimes found.

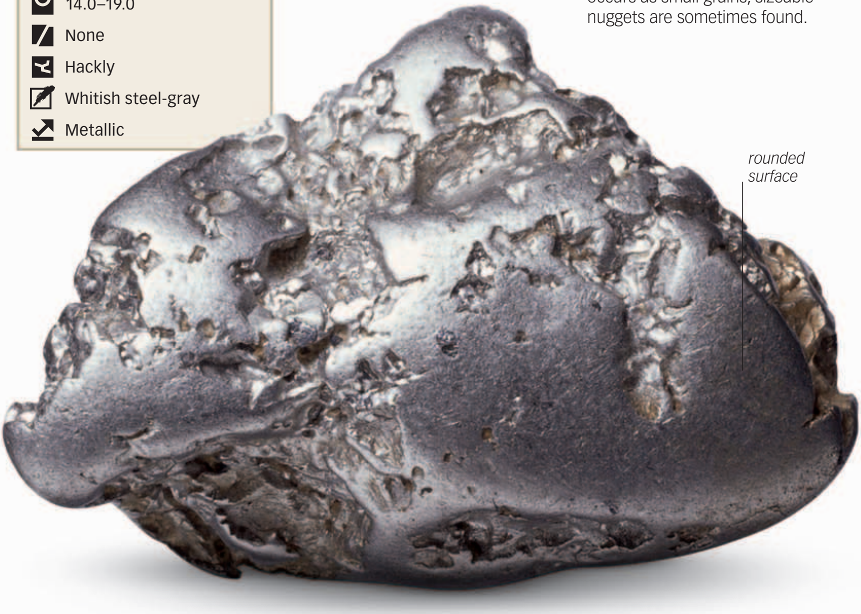

VARIANTS

Granular habit Most platinum is recovered as small grains

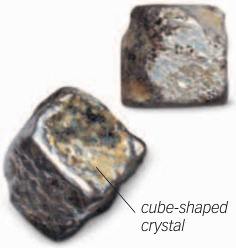

Platinum crystals Isolated cubic crystals of platinum

Pt

PLATINUM

The first documented discovery of platinum was by the Spaniards in the 1500s, in the alluvial gold mines of the Río Pinto, Colombia. They called it *platina del Pinto*, from *platina,* which means "little silver," thinking that it was an impure ore of silver. It was not recognized as a distinct metal until 1735. It is opaque, silvery gray, and markedly dense.

Platinum usually occurs as disseminated grains in iron- and magnesium-rich igneous rocks and in quartz veins associated with hematite (p.91), chlorite, and pyrolusite (p.80). When rocks weather, the heavy platinum accumulates as grains and nuggets in the resulting placer deposits. Crystals are rare, but when found they are cubic. Most platinum for commercial use is recovered from primary deposits. Native platinum typically contains iron and metals such as palladium, iridium, and rhodium.

Platinum ring A 2.5-carat, brilliant-cut diamond has been set in a platinum mounting in this ring.

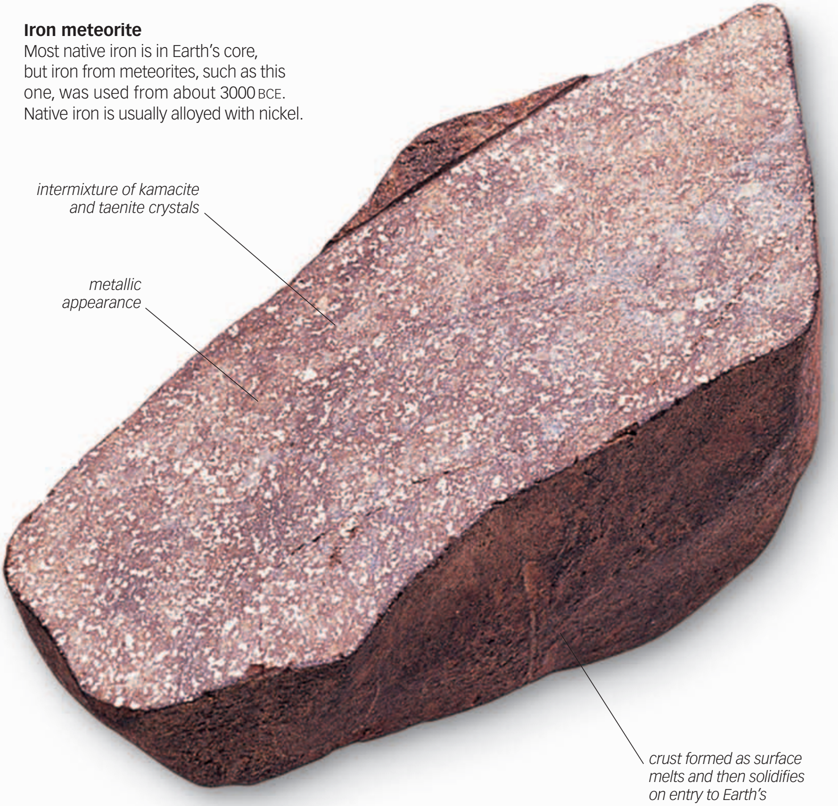
intermixture of kamacite and taenite crystals
metallic appearance
crust formed as surface melts and then solidifies on entry to Earth's atmosphere

Iron meteorite
Most native iron is in Earth's core, but iron from meteorites, such as this one, was used from about 3000 BCE. Native iron is usually alloyed with nickel.

PROFILE

Cubic
4
7.3–7.9
Basal
Hackly
Steel-gray
Metallic

Fe,Ni

IRON

Five percent of Earth's crust is made up of iron. Native iron is rare in the crust and is invariably alloyed with nickel. Low-nickel iron (up to 7.5 percent nickel) is called kamacite, and high-nickel iron (up to 50 percent nickel) is called taenite. Both crystallize in the cubic system. A third form of iron-nickel, mainly found in meteorites and crystallizing in the tetragonal system, is called tetrataenite. All three forms are generally found either as disseminated grains or as rounded masses.

Kamacite is the major component of most iron meteorites (p.335). It is found in most chondritic meteorites (p.337), and occurs as microscopic grains in some lunar rocks. Taenite and tetrataenite are mainly found in meteorites, often intergrown with kamacite. Iron is also plentiful in the Sun and other stars.

Viking axe head
This iron Viking axe head from Frykat, Denmark, has a shape commonly used in weapons.

PROFILE

Trigonal or hexagonal

2–2½

9.7–9.8

Perfect basal

Uneven

Silver-white

Metallic

Crystalline bismuth
This group of intergrown bismuth crystals shows typical metallic luster and iridescence.

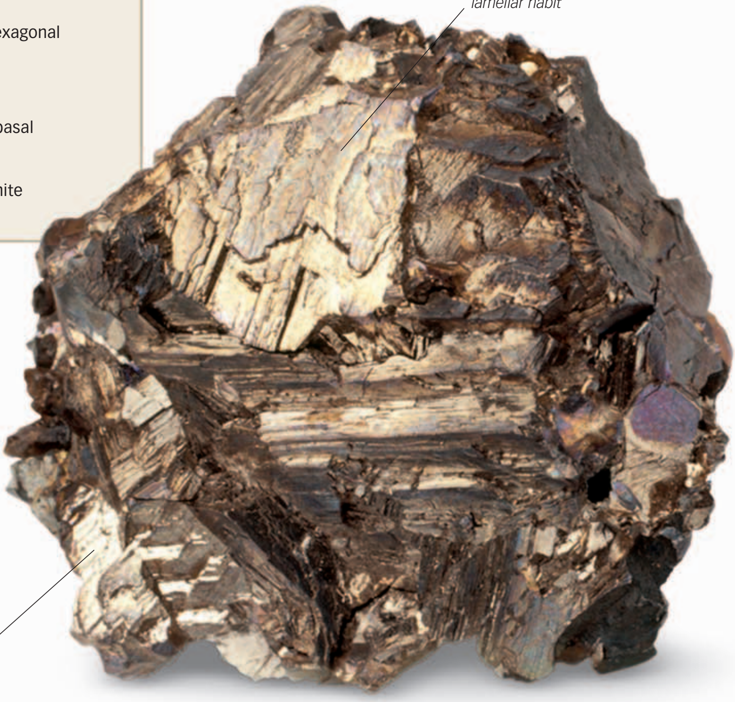

VARIANT

Native bismuth Partly crystalline bismuth on rock

Bi

BISMUTH

As a native metal, bismuth has been known since the Middle Ages. A German monk named Basil Valentine first described it in 1450. Bismuth is often found uncombined with other elements, forming indistinct crystals, often in parallel groupings. It is hard, brittle, and lustrous. It is also found in grains and as foliated masses. Silver-white, it usually has a reddish tinge that distinguishes it. Specimens may have an iridescent tarnish.

Bismuth is found in hydrothermal veins and in pegmatites (p.260) and is often associated with ores of tin, lead, or copper (p.37), from which it is separated as a by-product. Bismuth expands slightly when it solidifies, making its alloys useful in the manufacture of metal castings with sharp detailing. Bismuth salts are often used as soothing agents for digestive disorders.

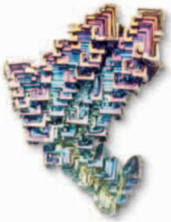

Hopper-shaped crystals Laboratory-grown bismuth crystals with cavernous faces like these exhibit an array of colors.

PROFILE

Hexagonal
3–3½
6.6–6.7
Perfect basal
Uneven
Gray
Metallic

Massive antimony This specimen of massive antimony has a pale silvery gray color and the occasional small crystal.

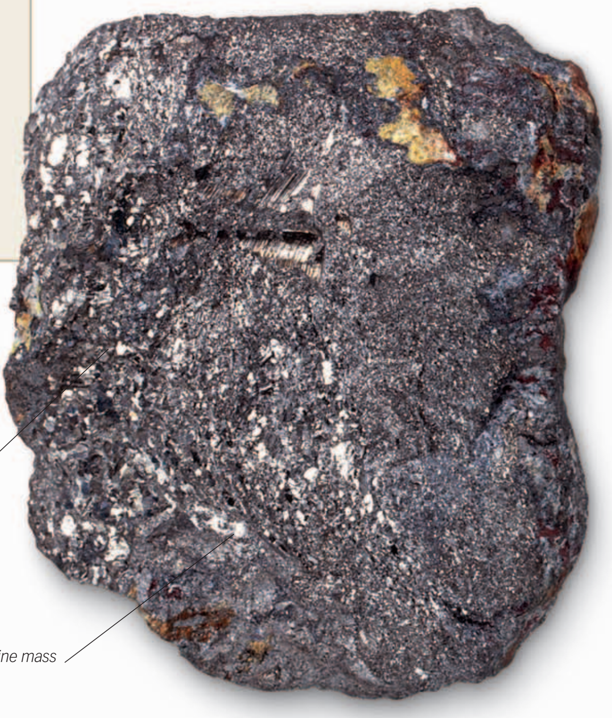

VARIANT

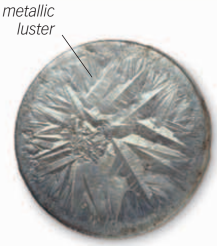

Antimony star A starry pattern of antimony formed when molten antimony is cooled

Sb

ANTIMONY

Although recognized as a metal since the 8th century or earlier, antimony was only identified as an element in 1748. Crystals are rare but when found are either psuedocubic or thick and tabular. Antimony usually occurs in massive, foliated, or granular form. It is lustrous, silvery, bluish white in color, and has a flaky texture that makes it brittle. It almost always contains some arsenic and is found in veins with silver (p.43), arsenic (p.45), and other antimony minerals.

Antimony is extremely important in alloys. Even in minor quantities, it imparts strength and hardness to other metals, particularly lead, whose alloys are used in the plates of automobile storage batteries, in bullets, and in coverings for cables. Combined with tin and lead, antimony forms antifriction alloys called babbitt metals, which are used as components of machine bearings. Like bismuth (p.40), antimony expands slightly on solidifying, making it a useful alloying metal for detailed castings.

PROFILE

Cubic

2½–3

19.3

None

Hackly

Golden yellow

Metallic

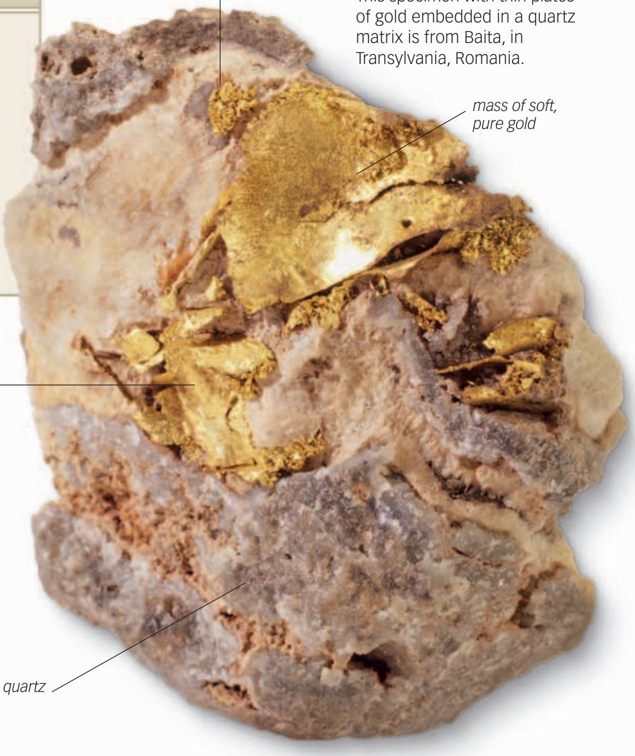

Scales of gold This specimen with thin plates of gold embedded in a quartz matrix is from Baita, in Transylvania, Romania.

VARIANTS

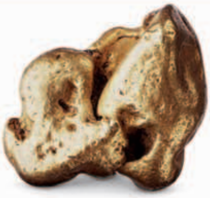

Gold nugget An irregularly shaped gold nugget

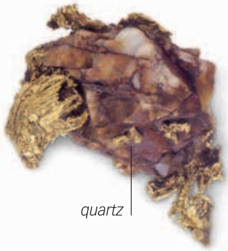

Gold crystals Crystalline gold in a dull quartz matrix

Au

GOLD

Throughout human history, gold has been the most prized metal. It is opaque, has a highly attractive metallic golden yellow color, is extremely malleable, and is usually found in a relatively pure form. It is remarkably inert, so it resists tarnish. These qualities have made it exceptionally valuable. Gold usually occurs as treelike growths, grains, and scaly masses. It rarely occurs as well-formed crystals, but when found these are octahedral or dodecahedral.

Gold is mostly found in hydrothermal veins with quartz (p.168) and sulfides. Virtually all granitic igneous rocks—in which it occurs as invisible, disseminated grains—contain low concentrations of gold. Almost all of the gold recovered since antiquity has come from placer deposits—weathered gold particles concentrated in river and stream gravel.

Garnet in gold This gold ring has an unusual demantoid (yellow-green) garnet set in it.

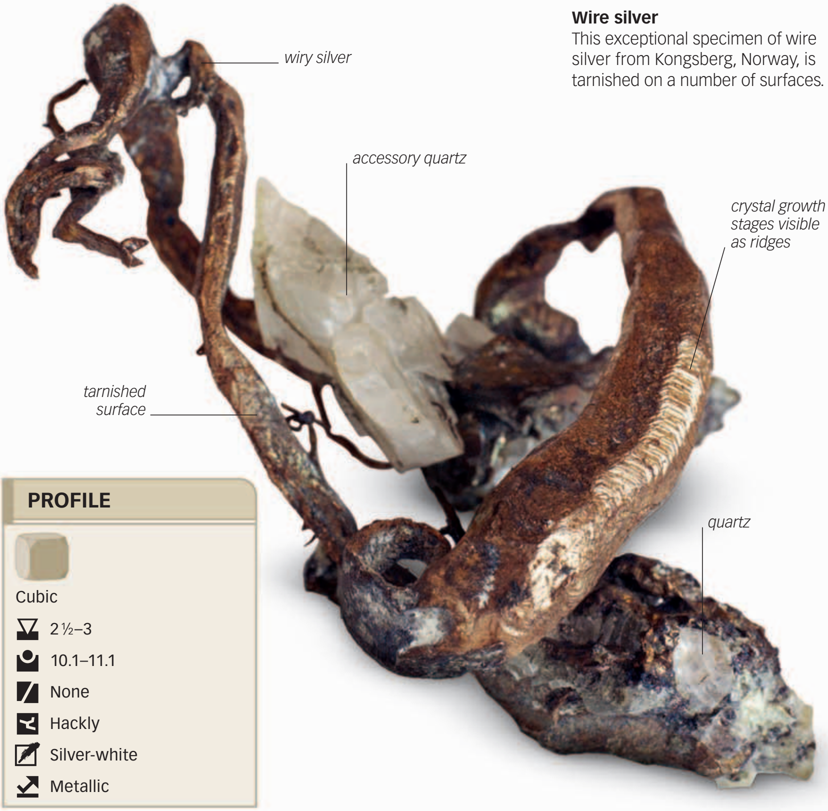

Wire silver This exceptional specimen of wire silver from Kongsberg, Norway, is tarnished on a number of surfaces.

PROFILE

Cubic
2½–3
10.1–11.1
None
Hackly
Silver-white
Metallic

VARIANTS

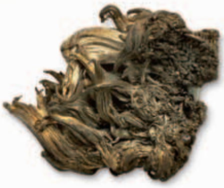

Tarnished silver A tarnished specimen of wiry silver

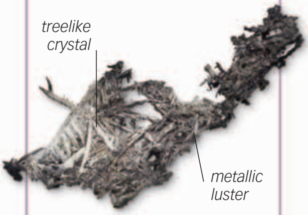

Dendritic silver Superbly crystalline, dendritic silver

Ag

SILVER

The earliest silver ornaments and decorations were found in tombs that date as far back as 4000 BCE. Silver coinage began to appear around 550 BCE. Opaque and bright silvery white with a slightly pink tint, silver readily tarnishes to either gray or black. Natural crystals of silver are uncommon, but when found they are cubic, octahedral, or dodecahedral. Silver is usually found in granular habit and as wiry, branching, lamellar, or scaly masses.

Widely distributed in nature, silver is a primary hydrothermal mineral. It also forms by alteration of other silver-bearing minerals. Much of the world's silver production is a by-product of refining lead, copper (p.37), and zinc. Silver is the second most malleable and ductile metal, and it is important in the photographic and electronic industries.

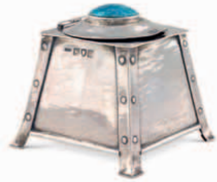

Silver inkwell This Guild of Handicraft textured silver inkwell of square, tapering form has a blue enamel cabochon.

PROFILE

Orthorhombic

1½–2½

2.1

Indistinct

Conchoidal to uneven, brittle

White

Resinous to greasy

Sulfur crystals Yellow orthorhombic crystals of sulfur are set in a rock matrix in this specimen from Conil, Andalucía, Spain.

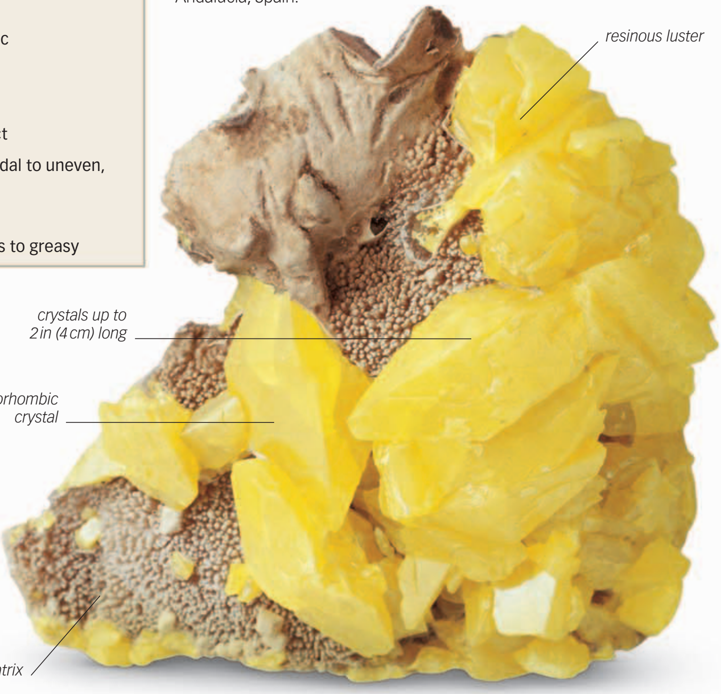

VARIANTS

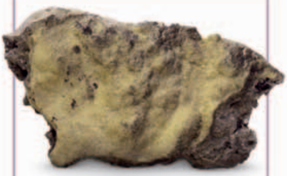

Fumarole crystals A crust of very small sulfur crystals from a fumarole in Java, Indonesia

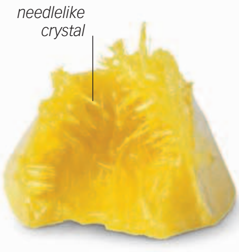

Acicular sulfur Elongated sulfur crystals on rock

S

SULFUR

The ninth most abundant element in the Universe, after oxygen and silicon, sulfur is the most abundant constituent of minerals. It occurs in the form of sulfides (pp.49–64), sulfates (pp.132–41), and elemental sulfur. The bright yellow or orangish color of sulfur makes the mineral easy to identify. Sulfur forms pyramidal or tabular crystals, encrustations, powdery coatings, and granular or massive aggregates. Crystalline sulfur may exhibit as many as 56 different habits.

Most sulfur forms in volcanic fumaroles, but it can also result from the breakdown of sulfide ore deposits. Massive sulfur is found in thick beds in sedimentary rocks, particularly those associated with salt domes. Sulfur is a poor conductor of heat, which means that specimens are warm to the touch.

Powdered sulfur Sulfur is used in a number of industrial and medicinal applications, including in the production of sulfuric acid.

PROFILE

Hexagonal

3 ½

5.7

Perfect, fair

Uneven, brittle

Gray

Metallic or dull earthy

Botryoidal arsenic In this specimen, native arsenic has a metallic luster and exhibits a typical botryoidal habit.

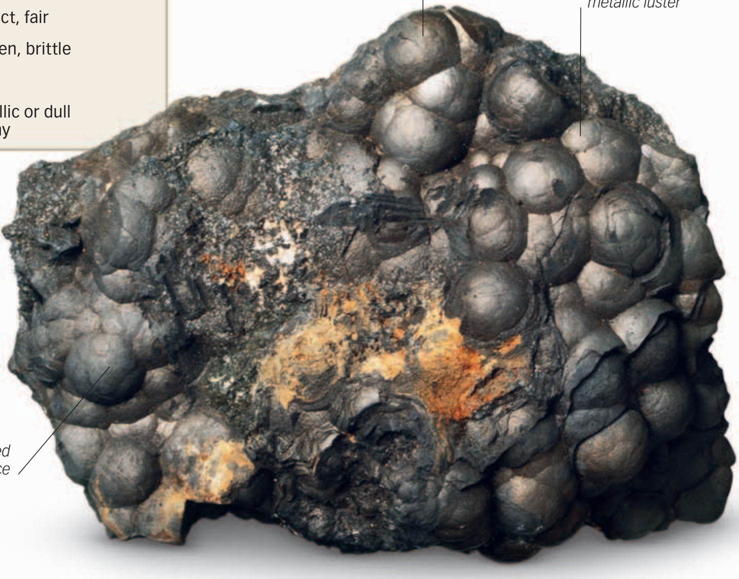

VARIANT

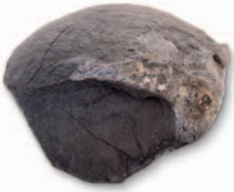

Massive arsenic A darkly tarnished, massive specimen of native arsenic

As

ARSENIC

Known since antiquity, arsenic is widely distributed in nature, although it is unusual in native form. It is classified as a semimetal, because it possesses some properties of metals and some of nonmetals. Crystals are rare, but when found they are rhombohedral. Arsenic usually occurs in massive, botryoidal to reniform, or stalactitic habits, often with concentric layers. On fresh surfaces, arsenic is tin-white, but it quickly tarnishes to dark gray.

Native arsenic is found in hydrothermal veins, often associated with antimony (p.41), silver (p.43), cobalt, and nickel-bearing minerals. It is highly poisonous, although it is used in some medicines to treat infections. Arsenic-based compounds can be used in alloys to increase high-temperature strength and as a herbicide and pesticide.

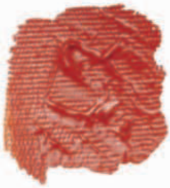

Arsenic paint Ancient Egyptian artists used orange-red colors made from powdered arsenic sulfide.

PROFILE

Hexagonal

1–2

2.2

Perfect basal

Uneven

Black to steel-gray, shiny

Metallic or dull earthy

Massive graphite As seen in this massive specimen, graphite has a soapy or greasy feeling when touched.

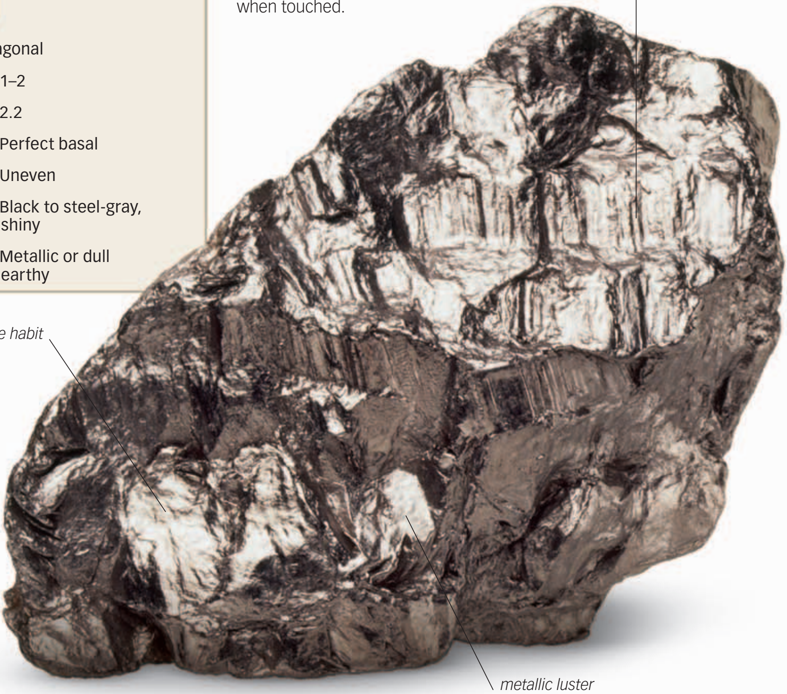

VARIANTS

Black graphite A lump of compact, black graphite

Crystalline graphite A graphite crystal exhibiting metallic luster

C

GRAPHITE

Like diamond, graphite is a form of native carbon. It takes its name from the Greek term *graphein*, which means "to write"—a reference to the black mark it leaves on paper. Graphite is opaque and dark gray to black. It occurs as hexagonal crystals, flexible sheets, scales, or large masses. It may be earthy, granular, or compact.

Graphite forms from the metamorphism of carbonaceous sediments and the reaction of carbon compounds with hydrothermal solutions. Graphite looks dramatically different from diamond and is at the other end of the hardness scale. Graphite's softness is due to the way carbon atoms are bonded to each other—rings of six carbon atoms are arranged in widely spaced horizontal sheets. The atoms are strongly bonded within the rings but very weakly bonded between the sheets.

Graphite pencil The familiar pencil "lead" contains graphite. The first use of graphite pencils was described in 1575.

PROFILE

Cubic
10
3.4–3.5
Perfect octahedral
Conchoidal
Will scratch streak plate
Adamantine

Diamond in a matrix
An octahedral diamond crystal rests in the kimberlite matrix in which it was found.

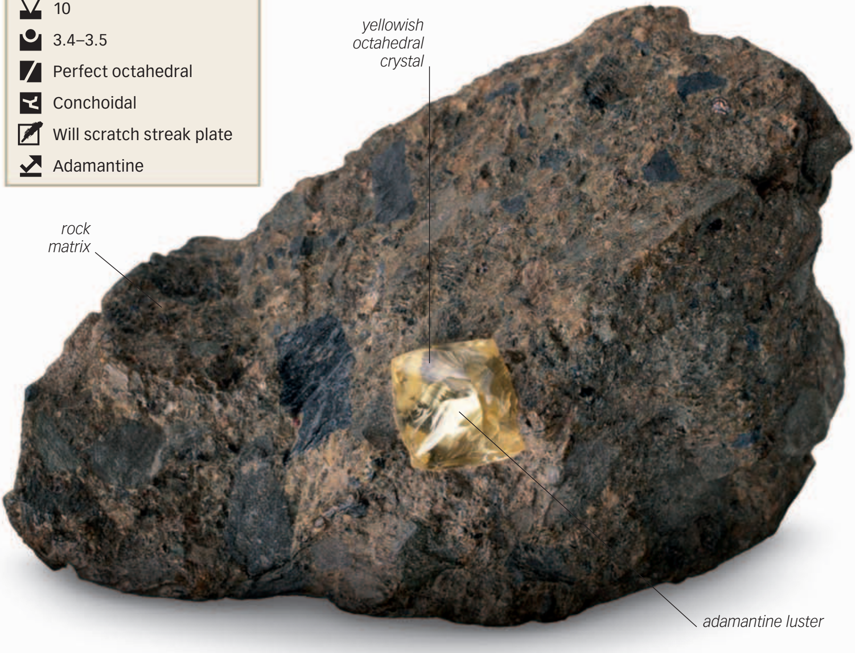

VARIANTS

Carbonado A form of black industrial diamond

Bort diamond A crystal of black bort diamond

Pink diamond A rare pink diamond crystal

C

DIAMOND

The hardest known mineral, diamond is pure carbon. Its crystals typically occur as octahedrons and cubes with rounded edges and slightly convex faces. Crystals may be transparent, translucent, or opaque. They range from colorless to black, with brown and yellow being the most common colors. Other forms include bort or boart (irregular or granular black diamond) and carbonado (microcrystalline masses). Colorless gemstones are most often used in jewelry.

Most diamonds come from two rare volcanic rocks—lamproite and kimberlite (p.269). The diamonds crystallize in Earth's mantle, generally more than 95 miles (150 km) deep, and are formed up to Earth's surface through volcanism. Diamonds are also found in sediment deposited by rivers or melting glaciers.

Hope Diamond
Blue in color, the 45.5-carat Hope diamond is probably the world's most famous diamond.

SULFIDES

Sulfides are minerals in which sulfur (a nonmetal) is combined either with a metal or a semimetal. Some sulfides are brilliantly colored, and most of them have low hardness and high specific gravity. Sulfides are common and are found widely in nature.

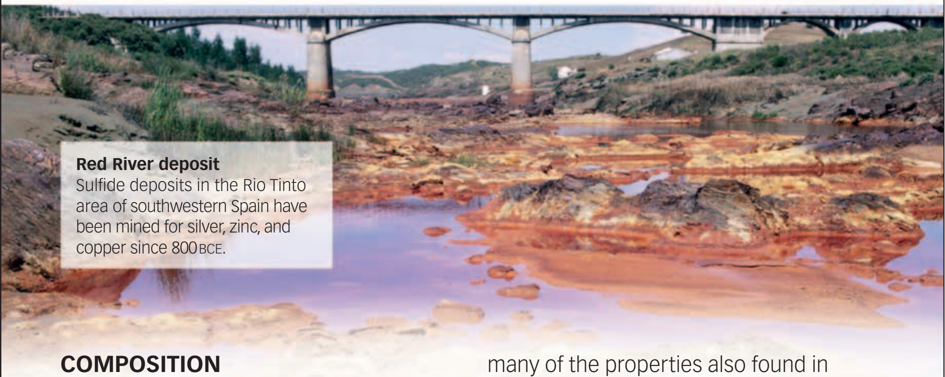

Red River deposit
Sulfide deposits in the Rio Tinto area of southwestern Spain have been mined for silver, zinc, and copper since 800 BCE.

COMPOSITION

Most sulfides have simple atomic structures, in which sulfur atoms are stacked alternately with metal or semimetal atoms and arranged as cubes, octahedra, or tetrahedra. This yields highly symmetrical crystal forms. Except in a few sulfides, such as orpiment and realgar, the symmetrical form also gives rise to many of the properties also found in metals, including metallic luster and electrical conductivity.

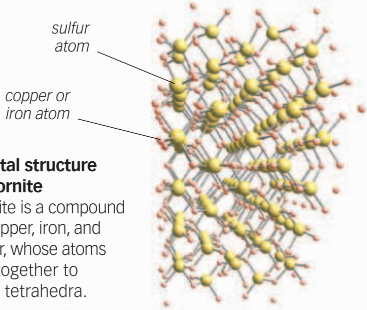

Crystal structure of bornite
Bornite is a compound of copper, iron, and sulfur, whose atoms link together to form tetrahedra.

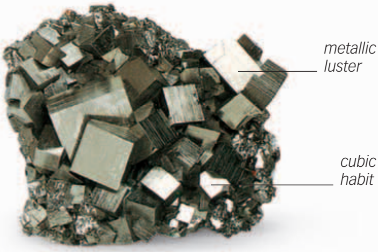

Crystalline pyrite
The iron sulfide pyrite, also called fool's gold, is one of the most common sulfides. The cubic crystals of pyrite reflect its simple atomic structure.

OCCURRENCE AND USES

Sulfides tend to form primarily in hydrothermal veins, from fluids circulating within fractures in Earth's crust. Sulfides such as pyrite and marcasite can form in sedimentary environments; others may form in magmas. It is common to find several sulfide minerals together.

Sulfides are the major ore minerals of many metals, including lead, zinc, iron, antimony, bismuth, molybdenum, nickel, silver, and copper—all of which have industrial uses. Gold is commonly found in sulfide deposits.

Die production
Sphalerite—a zinc sulfide—is the principal ore of zinc, which is used for die-cast components to galvanize, or coat, iron and steel.

PROFILE

Monoclinic

2–2½

7.2–7.4

Indistinct

Subconchoidal, sectile

Black

Metallic

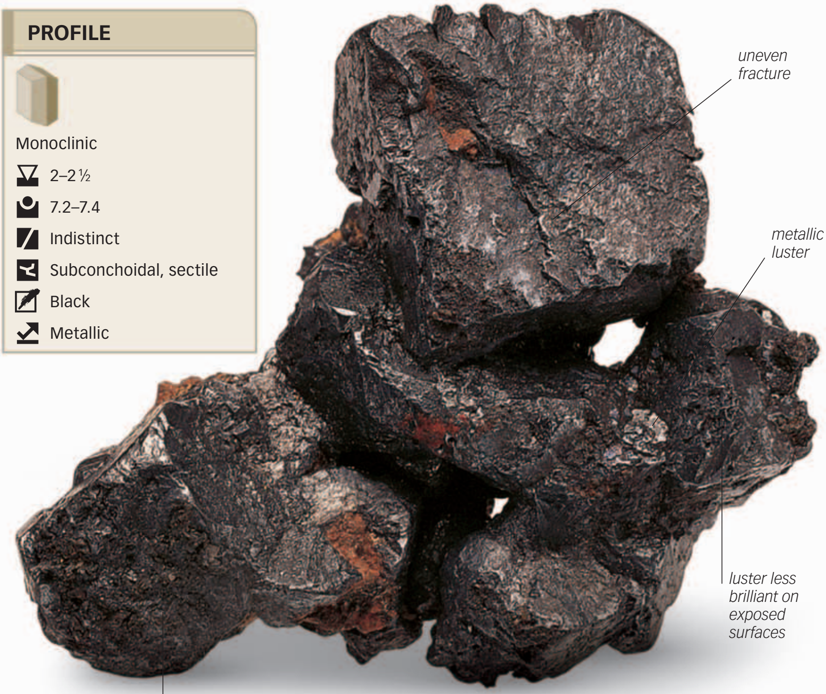

uneven fracture

metallic luster

luster less brilliant on exposed surfaces

darkened, weathered surface

Blocky, prismatic crystals In this pseudomorph specimen, argentite has replaced acanthite, while retaining the outward form of acanthite's cubic symmetry.

VARIANT

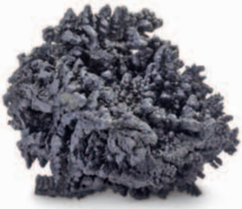

Thorny acanthite Dark, spiky acanthite crystals

Ag_2S

ACANTHITE

A silver sulfide, acanthite is the most important ore of silver. It takes its name from the Greek *akantha*, which means "thorn" and refers to the spiky appearance of some of its crystals. It also occurs in massive form and has an opaque, grayish black color. Above 350°F (177°C), silver sulfide crystallizes in the cubic system, and it used to be assumed that cubic silver sulfide—known as argentite—was a separate mineral from acanthite. It is now known that they are the same mineral, with acanthite crystallizing in the monoclinic system at temperatures below 350°F (177°C).

Acanthite forms in hydrothermal veins with other minerals, such as silver (p.43), galena (p.54), pyrargyrite (p.70), and proustite (p.72). It also forms as a secondary alteration product of primary silver sulfides. When heated, acanthite fuses readily and releases sulfurous fumes. The most famous locality of acanthite, the Comstock Lode in Nevada, USA, was so rich in silver that a branch of the US mint was established at nearby Carson City to coin its output.

PROFILE

Orthorhombic

3

5.1

Poor

Uneven to conchoidal, brittle

Pale grayish black

Metallic

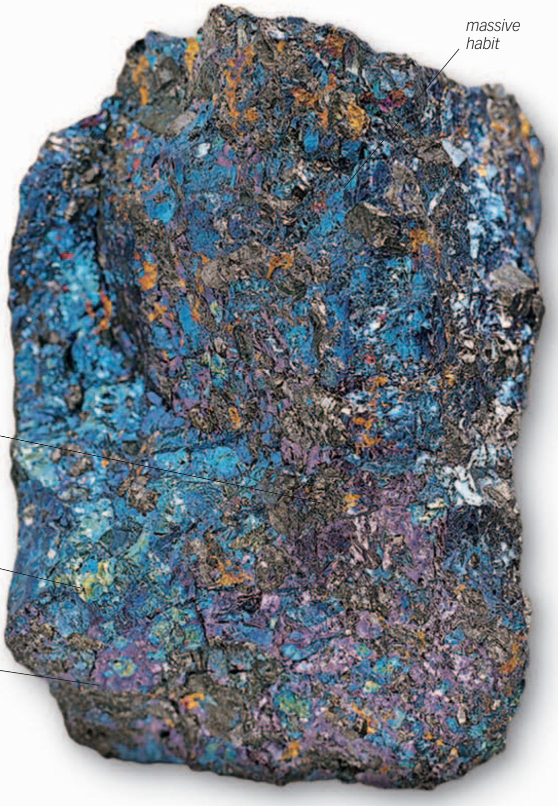

Massive bornite This specimen of tarnished bornite shows the oxidation colors that give it the names "purple copper ore" and "peacock ore."

VARIANT

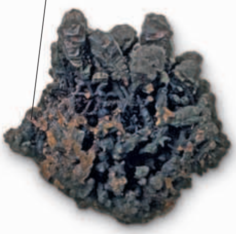

Bornite crystals Well-developed bornite crystals with curved faces

Cu_5FeS_4

BORNITE

One of nature's most colorful minerals, bornite is a copper iron sulfide named after the Austrian mineralogist Ignaz von Born (1742–91). A major ore of copper, its natural color can be coppery red, coppery brown, or bronze. It can also show iridescent purple, blue, and red splashes of color on broken, tarnished faces, which explains its common name, "peacock ore." Bornite is also known as "purple copper ore" and "variegated copper ore."

Bornite crystals are uncommon. Although they exhibit orthorhombic symmetry, crystals, when found, are cubic, octahedral, or dodecahedral, often with curved or rough faces. Bornite is frequently compact, granular, or massive and alters readily to chalcocite (p.51) and other copper minerals upon weathering. It forms mainly in hydrothermal copper ore deposits with minerals such as chalcopyrite (p.57), pyrite (p.62), marcasite (p.63), and quartz (p.168). It also forms in some silica-poor, intrusive igneous rocks and in pegmatite veins and contact metamorphic zones.

PROFILE

Monoclinic
2½–3
5.5–5.8
Indistinct
Conchoidal
Blackish lead gray
Metallic

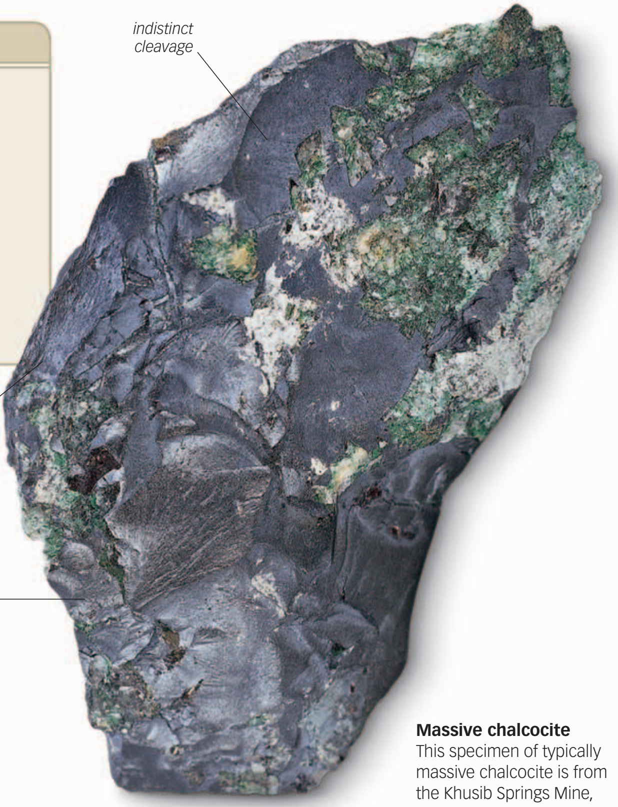

Massive chalcocite This specimen of typically massive chalcocite is from the Khusib Springs Mine, Otavi, Namibia.

VARIANT

Prismatic crystals Short, prismatic chalcocite crystals on dolomite

Cu_2S

CHALCOCITE

The name chalcocite is derived from the Greek word for copper, *chalcos*. Chalcocite is one of the most important ores of copper. It is usually massive but, on rare occasions, occurs in short, striated prismatic or tabular crystals or as pseudohexagonal prisms formed by twinning. It is opaque, dark metallic gray, and becomes dull on exposure to light. Chalcocite was formerly known as chalcosine, copper glace, and redruthite, but these names are now obsolete.

Chalcocite forms at relatively low temperatures (up to 400°F/200C°), often as alteration products of other copper minerals such as bornite (p.50). It is found in hydrothermal veins and porphyry copper deposits with other minerals—bornite, covellite (p.52), sphalerite (p.53), galena (p.54), chalcopyrite (p.57), calcite (p.114), and quartz (p.168). Deposits in Cornwall, England, have been worked since the Bronze Age. Concentrated in secondary alteration zones, chalcocite can yield more copper than the element's primary deposits.

PROFILE

Hexagonal
- 1½–2
- 4.6–4.7
- Perfect basal
- Uneven
- Lead gray to black, shiny
- Submetallic to resinous

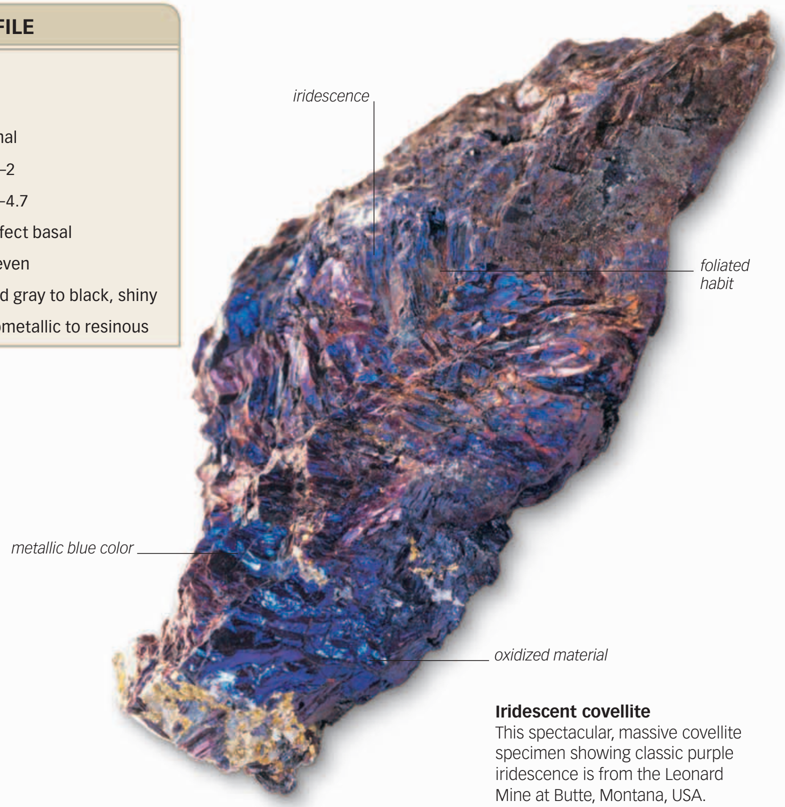

Iridescent covellite This spectacular, massive covellite specimen showing classic purple iridescence is from the Leonard Mine at Butte, Montana, USA.

VARIANT

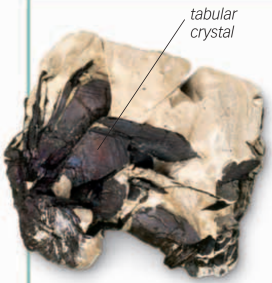

Tabular covellite Rare covellite crystals in their tabular habit

CuS

COVELLITE

Named in 1832 after the Italian minerologist Niccolo Covelli, who first described it, covellite is a copper sulfide. A minor ore of copper (p.37), covellite is opaque, with a bright metallic blue or indigo color. It is easy to recognize because of its brassy yellow, deep red, or purple iridescence. Covellite is generally massive and foliated in habit, although sometimes spheroidal. In crystalline form, it occurs as thin, tabular, and hexagonal plates, which are flexible when thin enough. Plates formed from its perfect basal cleavage are likewise flexible. It fuses very easily when heated, emitting a blue flame.

Covellite is a primary mineral in some places, but it typically occurs as an alteration product of other copper sulfide minerals such as bornite (p.50), chalcocite (p.51), and chalcopyrite (p.57). It sometimes forms as a coating on other copper sulfides. It rarely occurs as a volcanic sublimate, as on Mt. Vesuvius, where Niccolo Covelli first collected it. Covellite is abundant in the massive copper mines in Arizona, USA.

PROFILE

Cubic

3½–4

3.9–4.1

Perfect in six directions

Conchoidal

Brownish to light yellow

Resinous to adamantine, metallic

Sphalerite crystals These superbly formed sphalerite crystals occur with well-crystallized pyrite and quartz. They are from Casapalca, Lima, Peru.

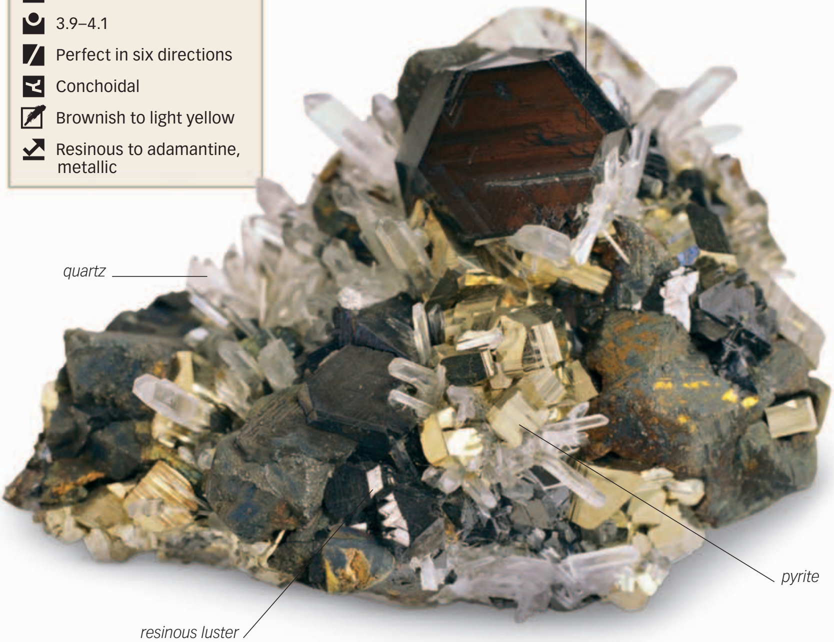

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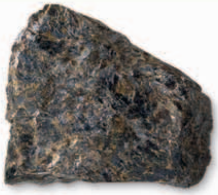

Massive sphalerite The most common habit of sphalerite

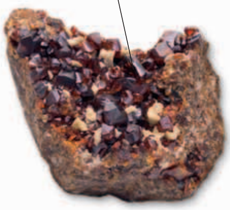

Ruby blende Brilliant red crystals of ruby blende sphalerite

ZnS

SPHALERITE

Sphalerite is the principal ore of zinc. Pure sphalerite is colorless and rare. Normally, iron is present, causing the color to vary from pale greenish yellow to brown and black with increasing iron content. Its complex crystals combine tetrahedral or dodecahedral forms with other faces. Sphalerite gets its name from the Greek *sphaleros*, meaning "deceitful," because its lustrous dark crystals can be mistaken for other minerals. It is often coarsely crystalline or massive, or forms banded, botryoidal, or stalactitic aggregates.

Sphalerite is found associated with galena (p.54) in lead-zinc deposits. It occurs in hydrothermal vein deposits, contact metamorphic zones, and replacement deposits formed at high temperature (1,065°F/575°C or above). It is also found in meteorites and lunar rocks.

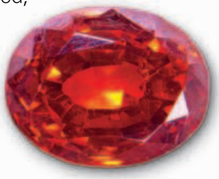

Oval cut This oval cut shows off the golden brown color of sphalerite. Such stones are cut for collectors.

PROFILE

Cubic

- 2½
- 7.6
- Perfect
- Subconchoidal
- Lead-gray
- Metallic

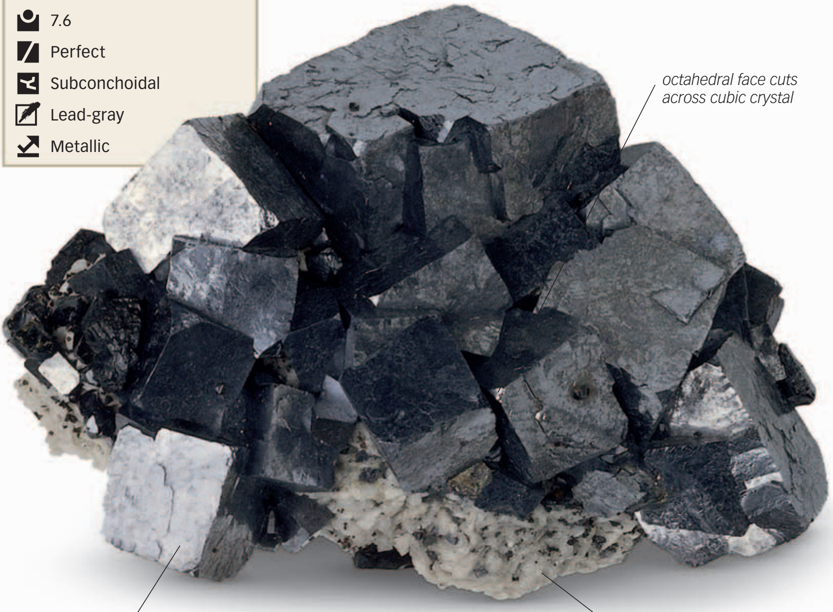

Galena crystals Galena is usually found in cube-shaped crystals, but the crystal shape can also incorporate the faces of octahedra, as here.

octahedral face cuts across cubic crystal

metallic luster

accessory dolomite

VARIANT

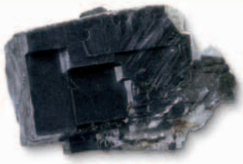

Perfect cleavage Cubic galena crystals with perfect cleavage in three directions

PbS

GALENA

There are more than 60 known minerals that contain lead, but by far the most important lead ore is galena, or lead sulfide. It is possible that galena was the first ore to be smelted to release its metal—lead beads found in Turkey have been dated to around 6500 BCE. Galena is opaque and bright metallic gray when fresh, but it dulls on exposure to the atmosphere. Its crystals are cubic, octahedral, dodecahedral, or combinations of these forms. Irregular, coarse, or fine crystalline masses are common.

Galena is common in hydrothermal lead, zinc, and copper (p.37) ore deposits worldwide and is often associated with sphalerite (p.53), chalcopyrite (p.57), and pyrite (p.62). It is also found in contact metamorphic rocks. Galena weathers easily to form secondary lead minerals, such as cerussite (p.119), anglesite (p.132), and pyromorphite (p.151). Galena is both the principal ore of lead and the main source of silver (p.43)—it often contains a considerable amount of silver in the form of acanthite as an impurity. It can also be a source of other metals.

Massive pentlandite
This typical massive specimen of pentlandite also contains pyrrhotite.

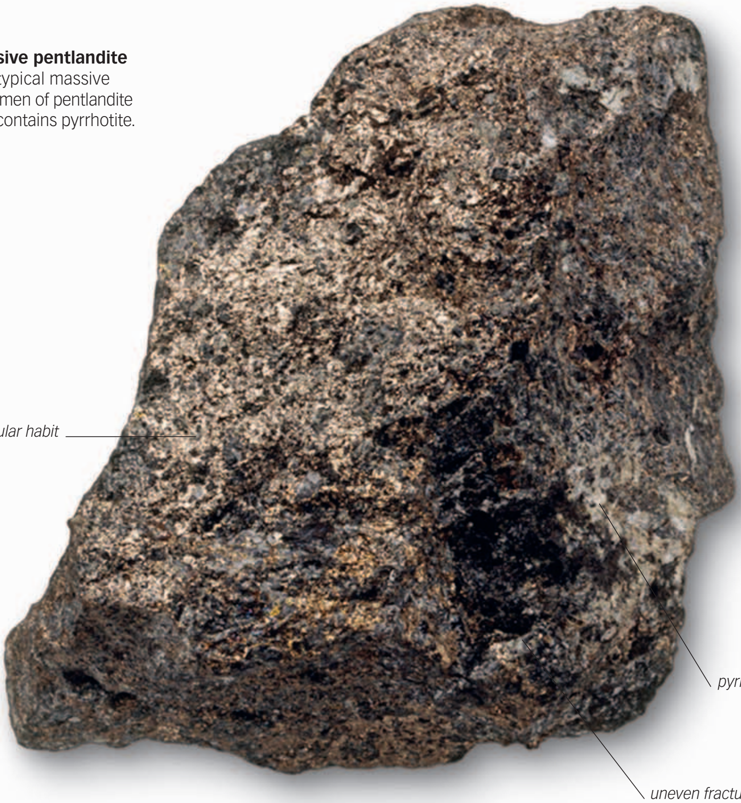

PROFILE

Cubic
3½–4
4.6–5.0
None
Conchoidal
Bronze-brown
Metallic

$(Fe,Ni)_9S_8$

PENTLANDITE

Named in 1856 after the Irish scientist Joseph Pentland, its discoverer, pentlandite is a nickel and iron sulfide. Nickel is usually a smaller component than iron, but both may be present in equal parts. Pentlandite mainly has a massive or granular habit, and its crystals cannot be seen by the naked eye. It is opaque, metallic yellow in color, and has a bronzelike tarnish.

Pentlandite occurs in silica-poor, intrusive igneous rocks. It is almost always accompanied by pyrrhotite, with other sulfides such as chalcopyrite (p.57) and pyrite (p.62), and with some arsenides. The chief ore of nickel, pentlandite is relatively widespread, but commercial deposits are scarce. In Ontario, Canada, nickel from an ancient meteorite is thought to have enriched the ore. Pentlandite is also found as an accessory mineral in some meteorites. Silver (p.43) can be present in the pentlandite structure, yielding the mineral argentopentlandite; when cobalt replaces the iron and nickel, the mineral becomes cobaltpentlandite.

PROFILE

Hexagonal
2–2½
8.0
Perfect
Subconchoidal to uneven
Scarlet
Adamantine to dull

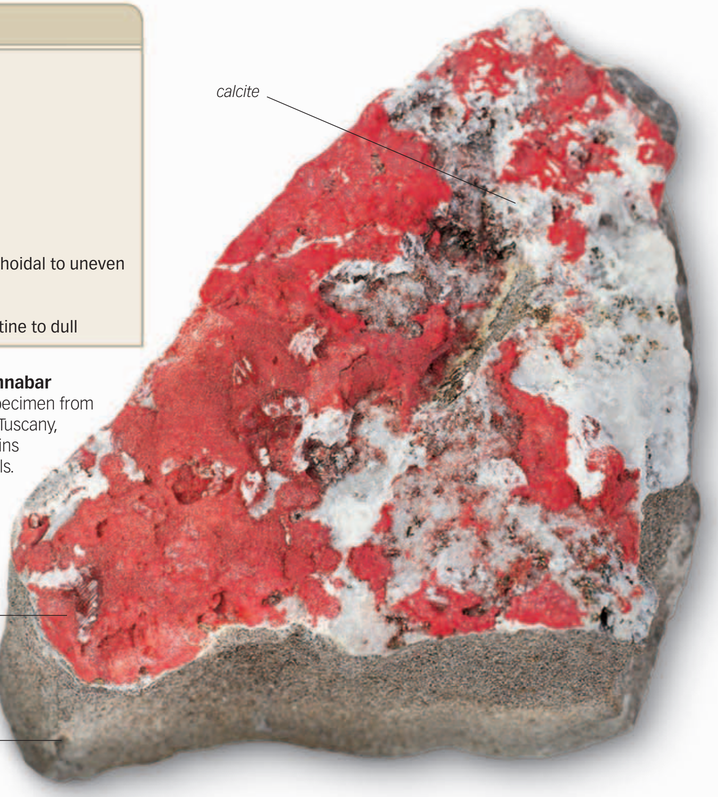

Crystalline cinnabar This massive specimen from Monte Amiata, Tuscany, Italy, also contains cinnabar crystals.

VARIANT

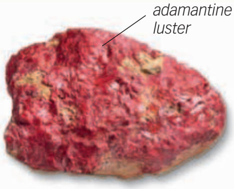

Massive cinnabar A specimen of massive cinnabar with a nonmetallic, adamantine luster

HgS

CINNABAR

A mercury sulfide, cinnabar takes its name from the Persian *zinjirfrah* and Arabic *zinjafr*, which mean “dragon’s blood.” It is bright scarlet to deep grayish red in color. It is the major source of mercury. Crystals are uncommon but when found they are rhombohedral, tabular, or prismatic. It usually occurs as massive or granular aggregates, but sometimes powdery coatings.

Cinnabar is often found with other minerals—such as stibnite (p.61), pyrite (p.62), and marcasite (p.63)—in veins near recent volcanic rocks. It is also found around hot springs. Cinnabar is believed to have been mined and used in Egypt in the early 2nd millennium BCE. It has also been mined for at least 2,000 years at Almadén, Spain. This site still yields excellent crystals.

Powdered cinnabar Since ancient times, artists have used bright red powdered cinnabar for the pigment vermillion.

PROFILE

Tetragonal

3½–4

4.2

Distinct

Uneven, brittle

Green-black

Metallic

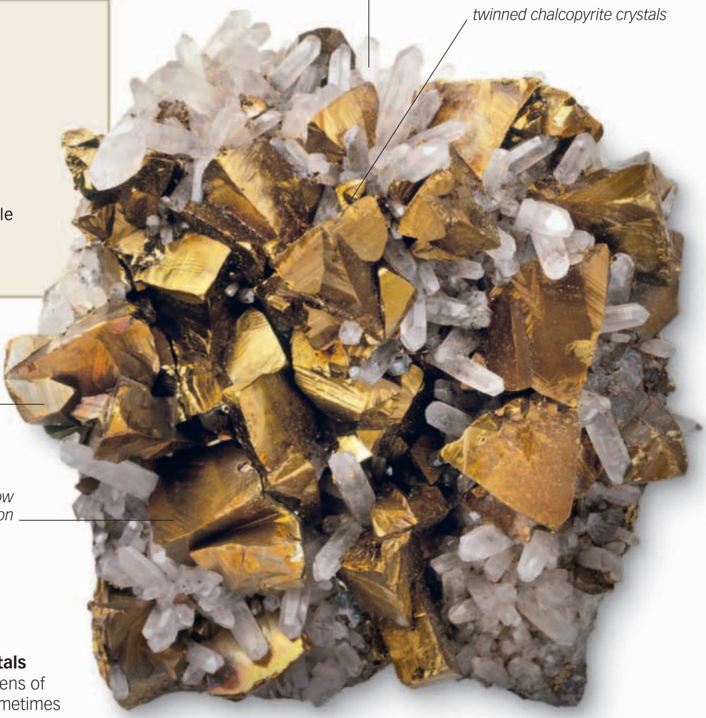

Chalcopyrite crystals Crystallized specimens of chalcopyrite can sometimes contain both twinned crystals and quartz crystals.

VARIANTS

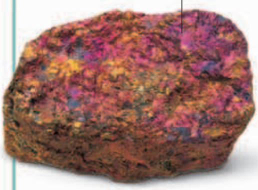

Massive chalcopyrite A specimen with an iridescent tarnish to it

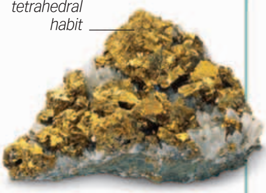

Brassy yellow chalcopyrite A specimen with an uneven fracture and tetrahedral habit

$CuFeS_2$

CHALCOPYRITE

One of the minerals worked at Rio Tinto, Spain, since Roman times, chalcopyrite is a copper and iron sulfide. It is opaque and brassy yellow when freshly mined, but it commonly develops an iridescent tarnish on exposure to the atmosphere. This tetragonal mineral forms tetrahedral crystals, which can be up to 4 in (10 cm) long on a face. It commonly occurs as massive aggregates and less frequently as botryoidal masses or as scattered grains in igneous rocks.

Chalcopyrite forms under a variety of conditions. It is mostly found in hydrothermal sulfide veins as a primary mineral deposited at medium and high temperatures (400°F/200°C or above), and as replacements, often with large concentrations of pyrite (p.62). It is also found as grains in igneous rocks and is an important ore mineral in porphyry copper deposits. Rarely, it occurs in metamorphic rocks. Chalcopyrite is an important ore of copper owing to its widespread occurrence. In some cases, selenium can replace a portion of the sulfur.

Realgar crystals
These bright red, prismatic realgar crystals are in a rock matrix and accompanied by gray quartz.

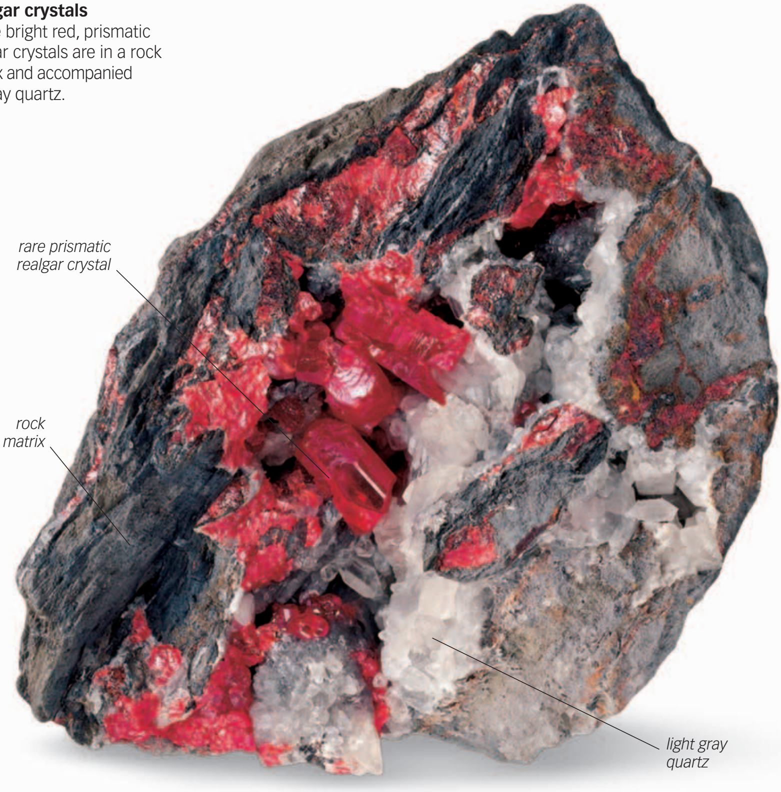

PROFILE

Monoclinic
1½–2
3.6
Good
Conchoidal
Scarlet to orange-yellow
Resinous to greasy

AsS

REALGAR

An important ore of arsenic, realgar is bright red or orange in color. Crystals are not often found, but when they occur they are short, prismatic, and striated. Realgar mostly occurs as coarse to fine granular masses and as encrustations. Realgar disintegrates on prolonged exposure to light, forming an opaque yellow powder, which is principally pararealgar. Therefore, specimens are kept in darkened containers.

Realgar is typically found in hydrothermal deposits at low temperature (up to 400°F/200°C) often with orpiment (p.59) and other arsenic minerals. It also forms as a sublimate around volcanoes, hot springs, and geyser deposits and as a weathering product of other arsenic-bearing minerals. Realgar is often found with stibnite (p.61) and calcite (p.114).

Powdered realgar
Scarlet to orange-yellow in color, powdered realgar was once used as a pigment and in fireworks.

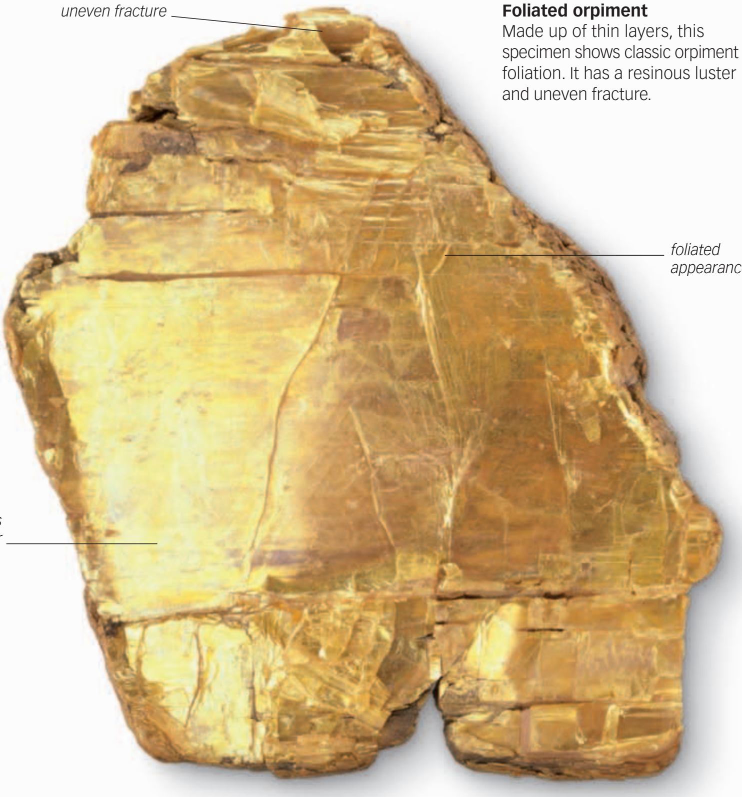

Foliated orpiment Made up of thin layers, this specimen shows classic orpiment foliation. It has a resinous luster and uneven fracture.

PROFILE

Monoclinic
1½–2
3.5
Perfect
Uneven, sectile
Pale yellow
Resinous

VARIANT

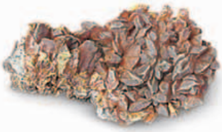

Crystalline orpiment Rare, stubby, prismatic crystals

As_2S_3

ORPIMENT

An arsenic sulfide, orpiment is a soft yellow or orange mineral. Widely distributed, it is typically powdery or massive, but it is also found as cleavable, columnar, or foliated masses. Distinct crystals are uncommon, but when found they are short prisms. Orpiment occurs in hydrothermal veins at low temperature (up to 400°F/200°C), hot spring deposits, and volcanic fumaroles, and it may occur with stibnite (p.61) and realgar (p.58). It also results from the alteration of other arsenic-bearing minerals.

When heated, orpiment gives off the garlic odor typical of arsenic minerals. The luster is resinous on freshly broken surfaces but pearly on cleavage surfaces. It was used as a pigment, mainly in ancient times in the Middle East. It was also used later in the West but soon replaced due to its toxicity.

Yellow pigment Powdered orpiment was used as a yellow pigment, especially to make gold-colored paint.

PROFILE

Hexagonal

3–3½

5.5

Perfect

Uneven, brittle

Greenish black

Metallic

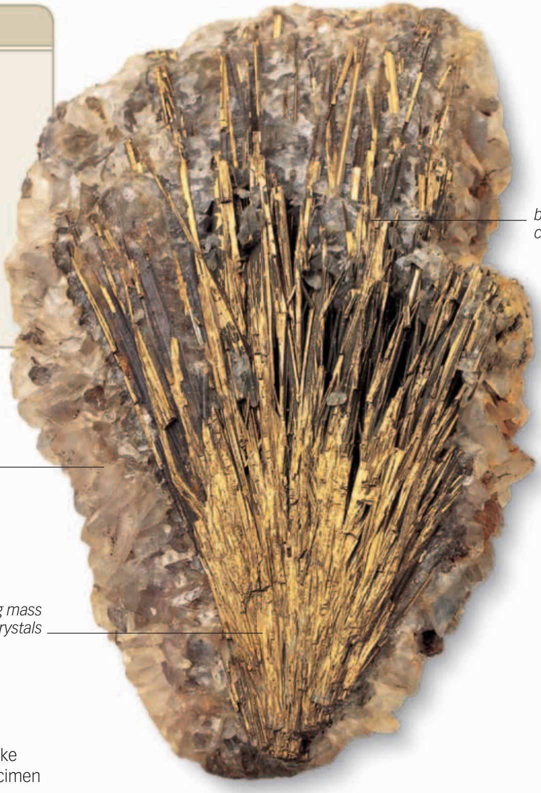

Millerite needles
The metallic yellow, needlelike crystals of this millerite specimen form a radiating spray.

VARIANT

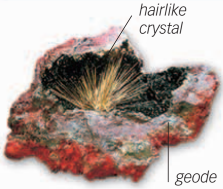

Millerite geode Thin, radiating crystals of millerite have formed in this hollow space

NiS

MILLERITE

A nickel sulfide, millerite commonly occurs as delicate, needlelike, opaque golden crystals. It can form free-standing, single crystals or occur as tufts, matted groups, or radiating sprays. It is also massive and frequently found with an iridescent tarnish. Nickel is more abundant in Earth's crust than copper (p.37), but it is generally more dispersed. Millerite is an ore of the element nickel, which is used in corrosion-resistant metal alloys, especially in the copper-nickel coinage that has replaced silver. It was named in 1845 after the English mineralogist W.H. Miller, who was the first person to study it.

Millerite normally forms at low temperatures (up to 400°F/200°C). It is often found in cavities in limestone (p.319) or dolomite (p.320), in carbonate veins and other associated rocks, within coal (p.253) deposits, and in serpentinite (p.298). It can occur as a later-formed mineral in nickel sulfide deposits and as an alteration product of other nickel minerals. Millerite is also found in meteorites and as a sublimate on Mount Vesuvius, Italy.

PROFILE

Orthorhombic

2

4.6

Perfect

Subconchoidal

Lead-gray to steel-gray

Metallic

Stibnite crystals This group of long, prismatic, striated stibnite crystals is on a quartz and barite matrix.

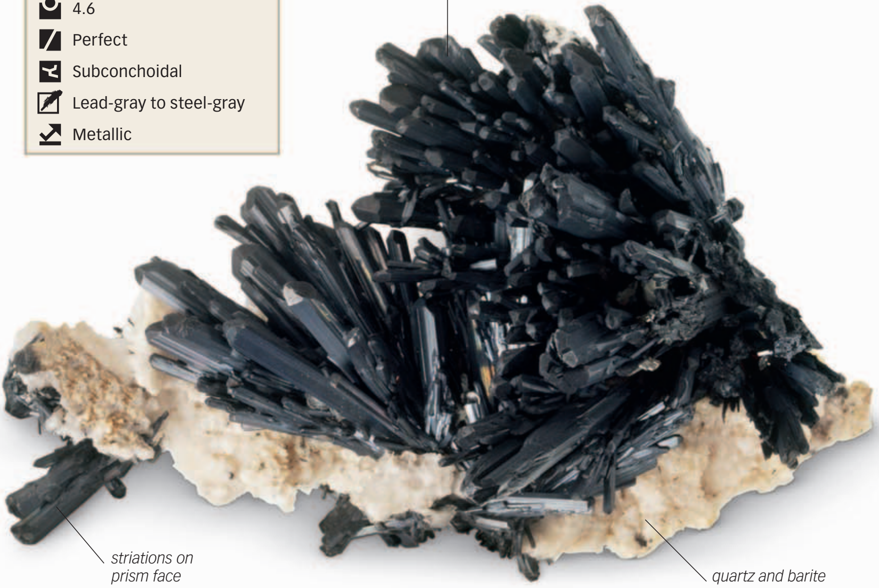

VARIANTS

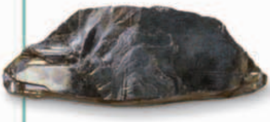

Stibnite sheets Thin layers of stibnite with sheetlike cleavage

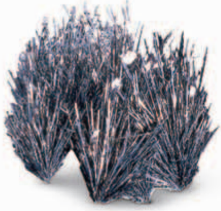

Acicular stibnite A mass of radiating, needlelike crystals

Sb_2S_3

STIBNITE

The principal ore of antimony, stibnite is antimony sulfide. Its name comes from the Latin *stibium*. Lead-gray to silvery gray in color, it often develops a black, iridescent tarnish on exposure to light. It normally occurs as elongated, prismatic crystals that may be bent or twisted. These crystals are often marked by striations parallel to the prism faces. Stibnite typically forms coarse, irregular masses or radiating sprays of needlelike crystals, but it can also be granular or massive.

A widespread mineral, stibnite occurs in hydrothermal veins, hot-spring deposits, and replacement deposits that form at low temperatures (up to 400°F/200°C). It is often associated with galena (p.54), cinnabar (p.56), realgar (p.58), orpiment (p.59), pyrite (p.62), and quartz (p.168). It is found in massive aggregates in granite (pp.258–59) and gneiss (p.288) rocks. Stibnite is used to manufacture matches, fireworks, and percussion caps for firearms. Powdered stibnite was used in the ancient world as a cosmetic for eyes to make them look larger.

PROFILE

Cubic

6–6½

5.0

None

Conchoidal

Greenish black to brownish black

Metallic

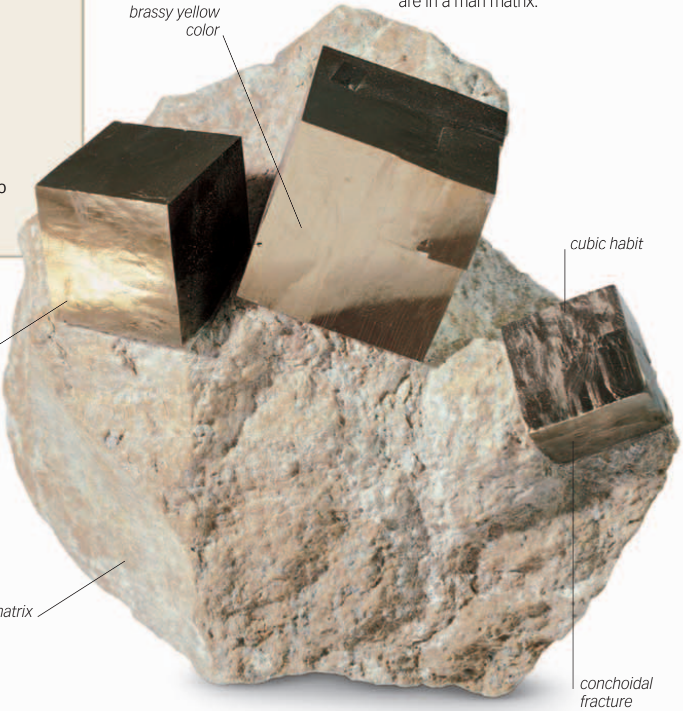

Cubic pyrite These three perfectly formed pyrite crystals—up to 1½in (3.5cm) wide—from Navajún, La Rioja, Spain, are in a marl matrix.

VARIANTS

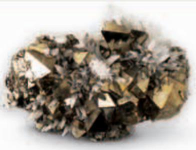

Octahedral pyrite A group of octahedral crystals with quartz

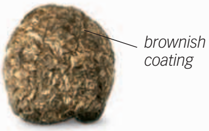

Pyrite nodule A ball-shaped, nodular group of pyrite crystals

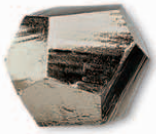

Pyritohedral pyrite A classic pyrite pyritohedral crystal

FeS_2

PYRITE

Known since antiquity, pyrite is commonly referred to as "fool's gold." Although much lighter than gold, its brassy color and relatively high density misled many novice prospectors. Its name is derived from the Greek word *pyr*, meaning "fire," because it emits sparks when struck by iron. It is opaque and pale silvery yellow when fresh, turning darker and tarnishing with exposure to oxygen. Pyrite crystals may be cubic, octahedral, or twelve-sided "pyritohedra," and are often striated. Pyrite can also be massive or granular, or form either flattened disks or nodules of radiating, elongate crystals.

Pyrite occurs in hydrothermal veins, by segregation from magmas, in contact metamorphic rocks, and in sedimentary rocks, such as shale (p.313) and coal (p.253), where it can either fill or replace fossils.

Pyrite beads With care, brittle pyrite can be ground into beads, such as those strung together in this necklace.

PROFILE

Orthorhombic

6–6½

4.9

Distinct

Uneven or irregular

Gray to black

Metallic

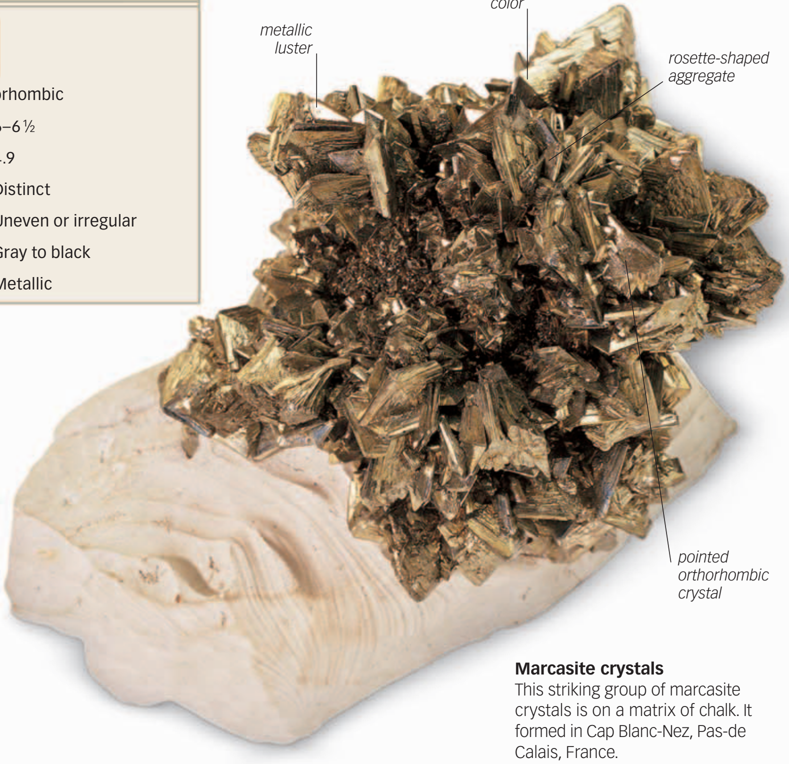
silvery yellow color
metallic luster
rosette-shaped aggregate
pointed orthorhombic crystal

Marcasite crystals
This striking group of marcasite crystals is on a matrix of chalk. It formed in Cap Blanc-Nez, Pas-de Calais, France.

VARIANT

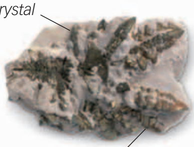
spear-shaped crystal
limestone matrix

Spear-shaped marcasite
Several groups of spear-shaped, twinned crystals

FeS_2

MARCASITE

An iron sulfide, marcasite is chemically identical to pyrite (p.62), but unlike pyrite it has an orthorhombic crystal structure. Marcasite is opaque and pale silvery yellow when fresh but darkens and tarnishes on exposure. It has a predominantly pyramidal or tabular crystal form. It is also found in characteristic twinned, curved, sheaflike shapes that resemble a cockscomb. Nodules with radially arranged fibers are common. Marcasite can also be massive, stalactitic, or reniform.

Marcasite is found near Earth's surface. It forms from acidic solutions percolating downward through beds of shale (p.313), clay, limestone (p.319), or chalk (p.321), where it often fills or replaces fossils. Marcasite also occurs as nodules in coal (p.253).

Art Deco jewelry
Marcasite was a popular choice for Victorian and Art Deco jewelry, although most of the material used was actually pyrite.

Layered masses
The crystallized molybdenite masses in this specimen show a typical layered structure.

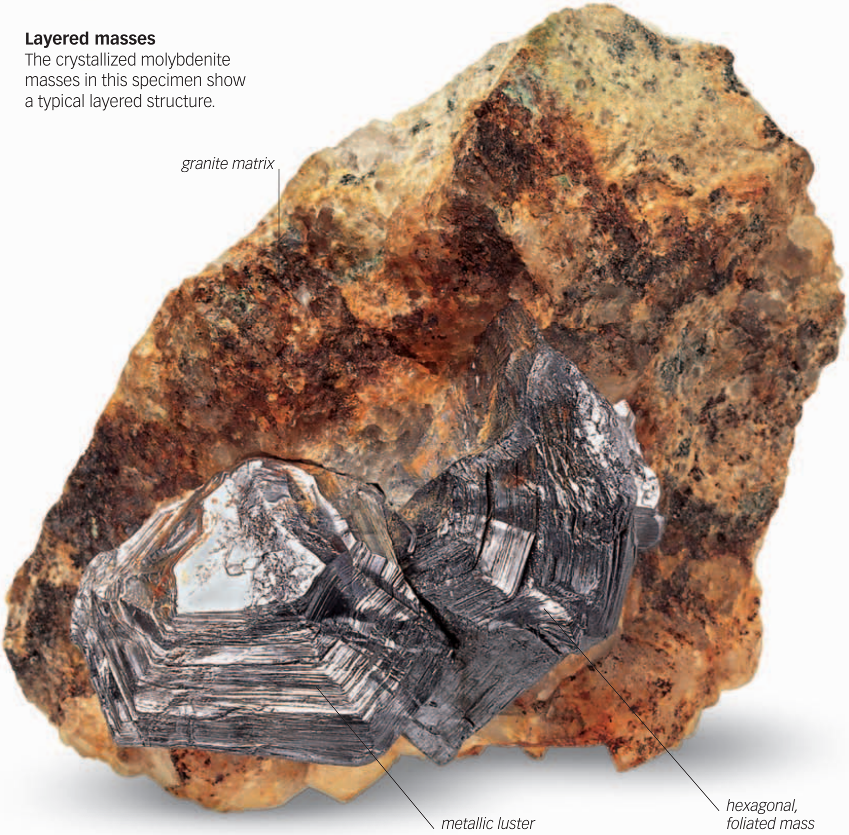

PROFILE

Hexagonal or trigonal
1–1½
4.7
Perfect basal
Uneven
Greenish or bluish gray
Metallic

MoS_2

MOLYBDENITE

A molybdenum sulfide, molybdenite is the most important source of molybdenum, which is an important element in high-strength steels. Molybdenite was originally thought to be lead, and its name is derived from the Greek word for lead, *molybdos*. It was recognized as a distinct mineral by the Swedish chemist Carl Scheele in 1778.

Molybdenite is soft, opaque, and bluish gray. It forms tabular hexagonal crystals, foliated masses, scales, and disseminated grains. It can also be massive or scaly. The platy, flexible, greasy-feeling hexagonal crystals of molybdenite can be confused with graphite (p.46), although molybdenite has a much higher specific gravity, a more metallic luster, and a slightly bluer tinge. Molybdenite occurs in granite (pp.258–59), pegmatite (p.260), and hydrothermal veins at high temperature (1,065°F/575°C or above) with other minerals—fluorite (p.109), ferberite (p.145), scheelite (p.146), and topaz (p.234). It is also found in porphyry ores and in contact metamorphic deposits.

SULFOSALTS

Sulfosalts are a group of mostly rare minerals that contain two or more metals in combination with sulfur (a nonmetal) and semimetals such as arsenic and antimony. Sulfosalt minerals have a high density, a metallic luster, and are usually brittle.

COMPOSITION

Sulfosalts have complex crystal structures. The structures of many sulfosalts appear to be based on fragments of simpler sulfur compounds. Metals commonly found in sulfosalts are lead, silver, thallium, copper, tin, bismuth, and germanium.

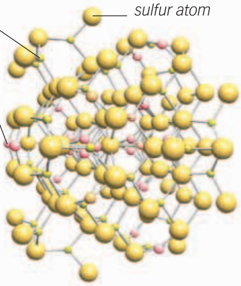

Crystal structure of tetrahedrite
The sulfosalt tetrahedrite is a complex compound of sulfur, copper, and antimony, and may contain silver, iron, zinc, and lead.

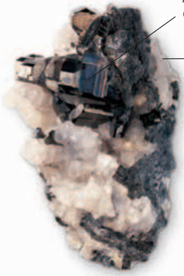

Bournonite
This specimen shows crystals typical of the sulfosalt bournonite. Twinned crystals growing parallel to each other give the mineral its informal name, cogwheel ore.

OCCURRENCE

Sulfosalts occur in small amounts in hydrothermal veins formed at low temperatures (up to 400°F/200°C). They are generally associated with the more common sulfides. A single Swiss deposit is known to have yielded up to 30 different sulfosalt minerals.

USES

Sulfosalts are typically found in small amounts but in a few deposits are economically important. Sometimes, they can constitute minor ores of silver, mercury, and antimony.

Silver coins
Pyragyrite, a sulfosalt mineral, yields the metal silver, which was used to produce the ancient coins seen here.

Sulfosalt deposit
Many sulfosalt minerals are found in Cornwall, England. These stone buildings once housed steam engines to pump water from mine shafts.

PROFILE

Cubic

4

4.6–4.7

None

Subconchoidal to uneven, brittle

Black

Metallic

Crystalline tennantite This mass of tetrahedral tennantite crystals is set in a rock matrix and has an iridescent tarnish.

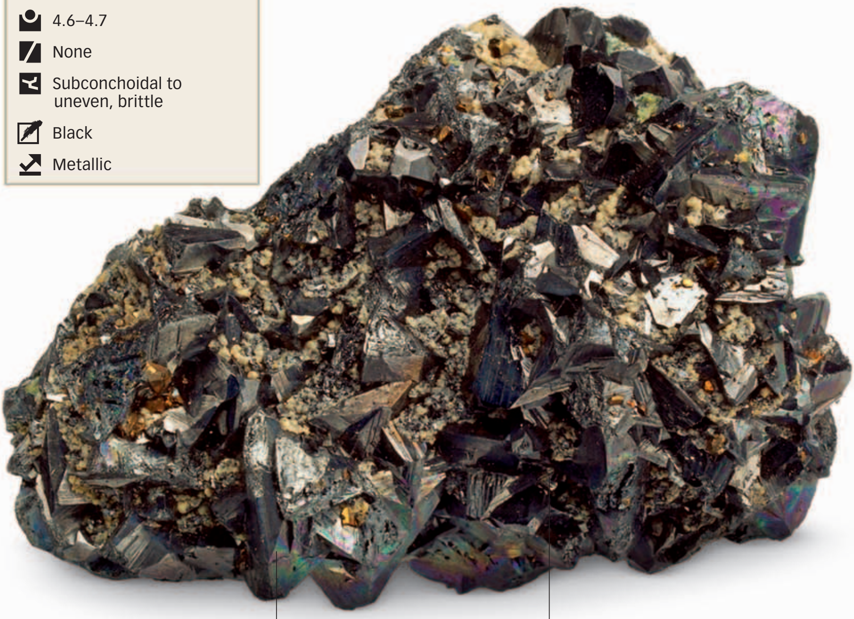

VARIANT

steel-gray coloring

Massive tennantite A specimen of massive tennantite from Cornwall, England

$(Cu,Fe)_{12}As_4S_3$

TENNANTITE

Named in 1819 after the English chemist Smithson Tennant, tennantite is a copper iron arsenic sulfide. Iron, zinc, mercury, bismuth, and silver may substitute for up to 15 percent of the copper in tennantite. Tennantite is gray-black, steel-gray, iron-gray, or black in color. It forms cubic and tetrahedral crystals. It may also occur in massive, granular, and compact forms. Tennantite is an end member of a solid-solution series with the similar mineral tetrahedrite (p.73). The two have very similar properties, making it difficult to distinguish between them. Their crystal habits are similar and both exhibit contact and penetration twinning.

Tennantite is found in hydrothermal and contact metamorphic deposits, often associated with sphalerite (p.53), galena (p.54), chalcopyrite (p.57), fluorite (p.109), barite (p.134), and quartz (p.168). Deposits are found in Freiberg, Saxony, Germany; Lengenbach, Switzerland; and Butte, Montana, and Aspen and Central City, Colorado, USA.

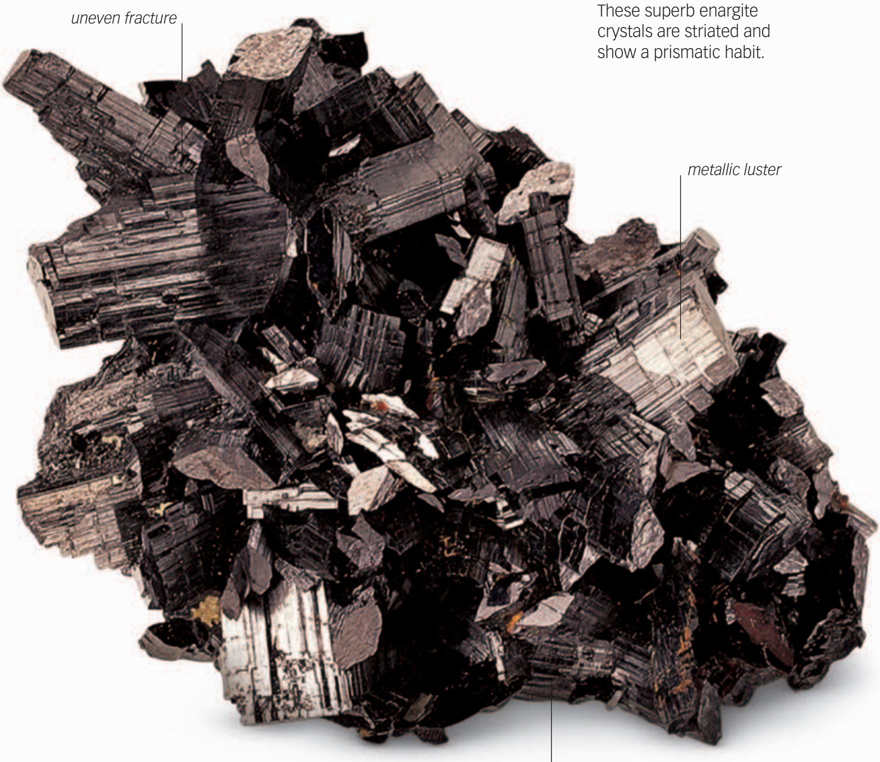

Enargite crystals
These superb enargite crystals are striated and show a prismatic habit.

PROFILE

Orthorhombic
3
4.4–4.5
Perfect
Uneven, brittle
Black
Metallic

Cu_3AsS_4

ENARGITE

A copper arsenic sulfide, enargite takes its name from the Greek word *enarge*, which means "distinct"—a reference to its perfect cleavage. An important ore of copper, it has a bright metallic luster, is opaque, and has a gray-black to iron-black to violet-black color when fresh. It turns dull black on exposure to light and pollutants. Enargite may occur in massive or granular habits. Crystals are usually small, either tabular or prismatic, sometimes pseudohexagonal or hemimorphic (with different terminations at each end), and have striations along the prism faces. Enargite crystals occasionally form star-shaped multiple twins.

Enargite forms in hydrothermal vein deposits at low to medium temperature (up to 1,065°F/575°C) and in replacement deposits, where it is associated with bornite (p.50), covellite (p.52), sphalerite (p.53), galena (p.54), chalcopyrite (p.57), pyrite (p.62), and other copper sulfides. It also occurs in the cap rocks of salt domes, with minerals such as anhydrite (p.133).

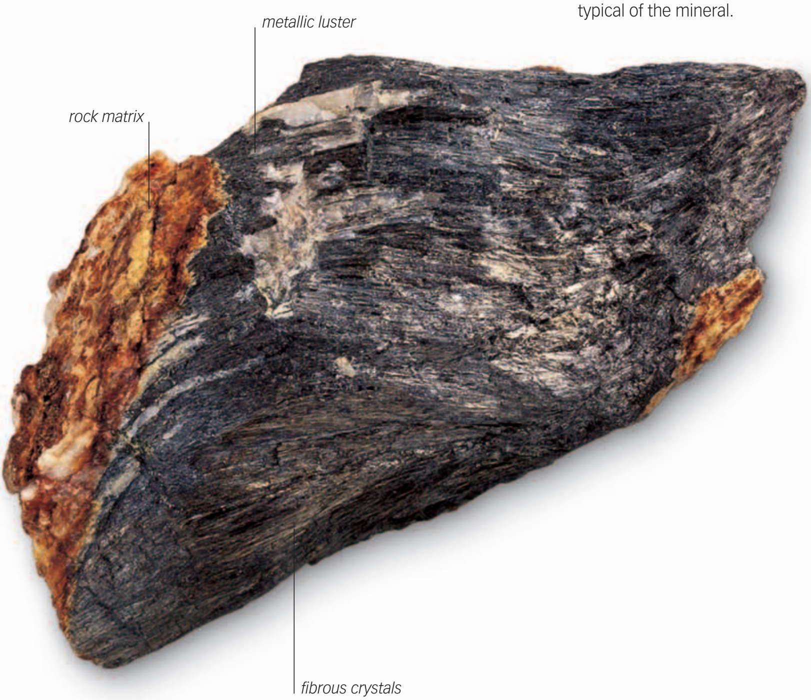

Fibrous habit
This jamesonite specimen, set in a rock matrix, has the fibrous habit typical of the mineral.

PROFILE

Monoclinic
2–3
5.5–6.0
Good
Uneven to conchoidal
Grayish black
Metallic

$Pb_4FeSb_6S_{14}$

JAMESONITE

Named in 1825 after the Scottish mineralogist Robert Jameson, jamesonite is a lead iron antimony sulfide. It is opaque lead-gray, but can often develop an iridescent tarnish. Jamesonite is normally found as needlelike or fibrous crystals combined together into columnar, radiating, plumose (featherlike), or feltlike masses.

Jamesonite occurs in hydrothermal veins at low or medium temperature (up to 1,065°F/575°C), where hot, chemical-rich fluids have permeated joints and fault lines, depositing minerals during cooling. In hydrothermal veins, it often occurs with other lead and antimony sulfides and sulfosalt minerals. Jamesonite also occurs in quartz associated with carbonate minerals, such as calcite (p.114), dolomite (p.117), and rhodochrosite (p.121). Jamesonite is a minor ore of antimony, which is used as a strengthening agent in alloys. It is widespread in small amounts, with good specimens coming from Freiburg, Saxony, Germany; Yakutia, Russia; Trepca, Serbia; Dachang, China; Cornwall, England; and Oruro, Bolivia.

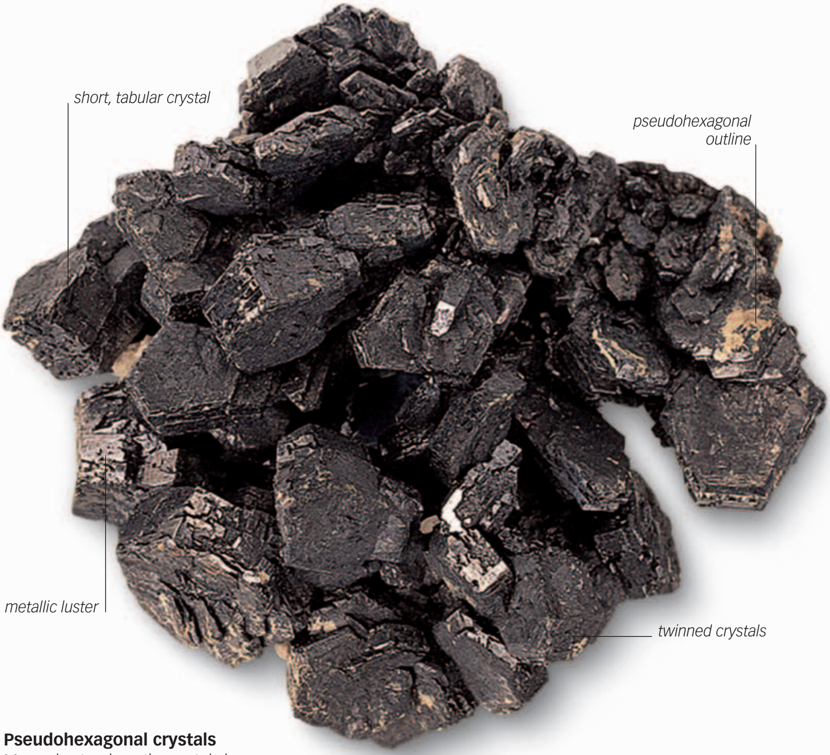

Pseudohexagonal crystals
Many short, prismatic crystals in this stephanite specimen show pseudohexagonal twinning.

PROFILE

Orthorhombic
2–2½
6.2–6.5
Imperfect
Subconchoidal to uneven, brittle
Iron-black
Metallic

Ag_5SbS_4

STEPHANITE

A silver antimony sulfide, stephanite was named in honor of Archduke Victor Stephan, the mining director of Austria, in 1845. It is sometimes called brittle or black silver ore. It is opaque, iron-black to black in color, and has a metallic luster on fresh faces. Stephanite crystals range from short prismatic to tabular and are repeatedly twinned to form pseudohexagonal groups. Stephanite may also occur in massive and granular habits.

Stephanite is generally found in small amounts in late-stage hydrothermal silver veins associated with native silver (p.43), sulfides, and other sulfosalts, such as acanthite (p.49) and tetrahedrite (p.73). It was found in sufficient quantity to be an ore of silver in Comstock Lode, Nevada, USA.

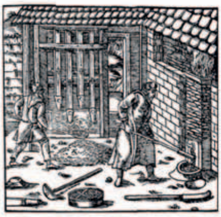

Historic silver processing
This 1550 woodcut from Georgius Agricola's treatise *De Re Metallica* shows silver ore being processed.

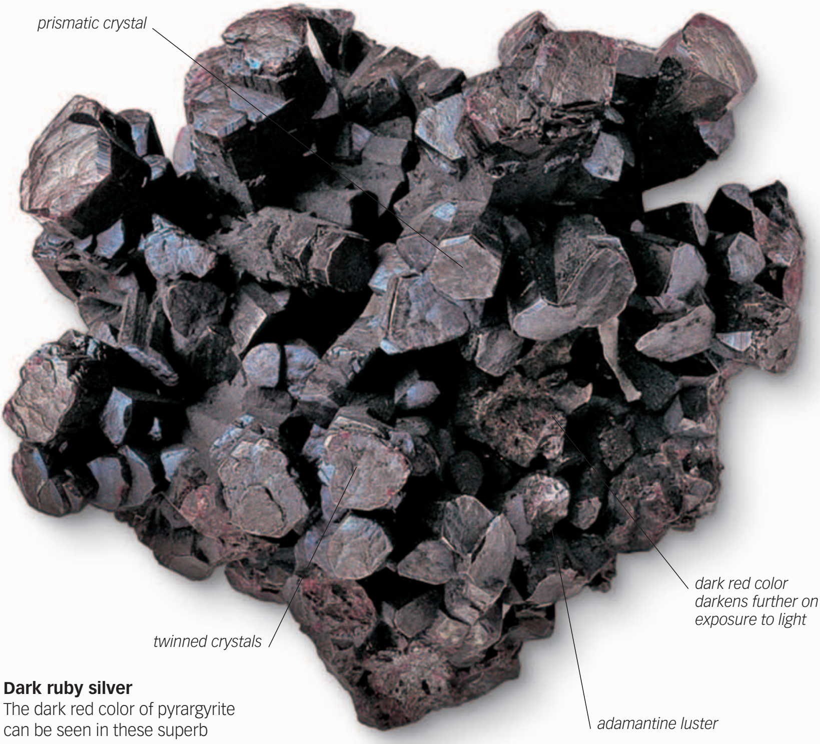

Dark ruby silver
The dark red color of pyrargyrite can be seen in these superb twinned, prismatic crystals.

PROFILE

Hexagonal

2½

5.8

Distinct

Conchoidal to uneven, brittle

Purplish red

Adamantine

Ag_3SbS_3

PYRARGYRITE

An important ore of silver, pyrargyrite takes its name from the Greek words *pyros*, which means "fire," and *argent*, which means "silver"—an allusion to its silver content and its translucent, dark red color. Also known as dark ruby silver, pyrargyrite turns opaque dull gray when exposed to light. Therefore, prized specimens are stored in the dark. Pyrargyrite is typically massive or granular. It can also occur as well-formed prismatic crystals with rhombohedral, scalenohedral, or flat terminations, different at each end and frequently twinned.

Pyrargyrite forms in hydrothermal veins at relatively low temperature (up to 400°F/200°C) with the minerals sphalerite (p.53), galena (p.54), tetrahedrite (p.73), proustite (p.72), and calcite (p.114). It also forms by the alteration of other minerals.

Roman silver
This Roman *denarius* (silver coin) of the first century BCE shows gladiators fighting.

PROFILE

Orthorhombic
2½–3
5.8
Indistinct
Subconchoidal to uneven
Steel-gray
Metallic

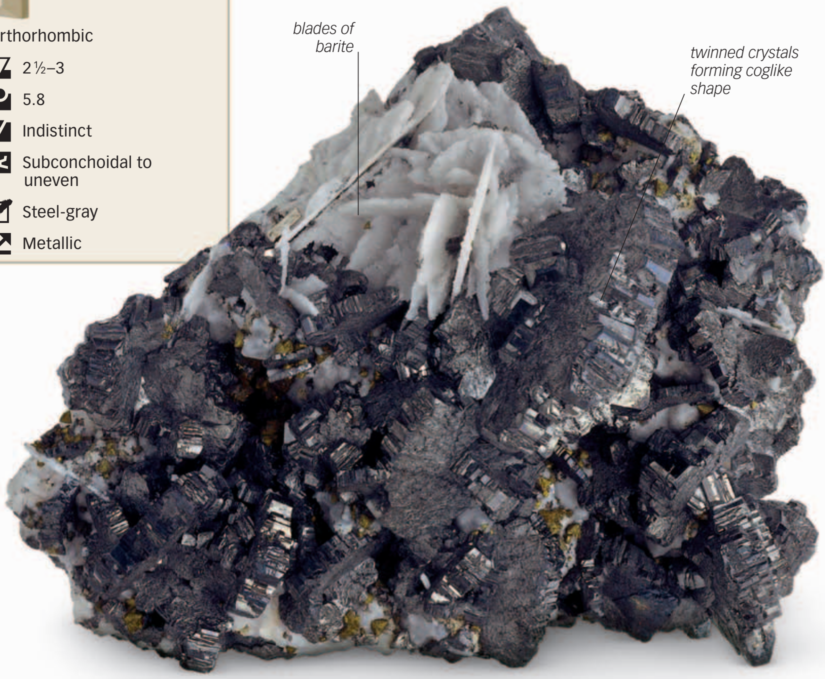

Cogwheel ore This specimen of bournonite, accompanied by white baryte, shows the twinned habit that gives the mineral its informal name.

VARIANT

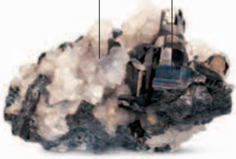

Prismatic bournonite A group of twinned prismatic crystals of bournonite

$PbCuSbS_3$

BOURNONITE

A lead copper antimony sulfide, bournonite occurs as heavy, dark crystal aggregates and masses, as well as interpenetrating cruciform (crosslike) twins. When repeatedly twinned, bournonite has the appearance of a toothed wheel, giving rise to the informal name cogwheel ore. Untwinned crystals of this opaque mineral are tabular or short prismatic and usually have smooth and bright faces. Bournonite was first mentioned as a mineral in 1797 but was named only in 1805 after the French mineralogist Count J.L. de Bournon.

A widely distributed mineral, bournonite is found in hydrothermal veins at medium temperatures (400–1,065°F/200–575°C) and associated with sphalerite (p.53), galena (p.54), chalcopyrite (p.57), pyrite (p.62), tetrahedrite (p.73), and other sulfide minerals. Particularly prized specimens of bournonite come from the Harz Mountains of Germany, where a few crystals exceed ¾ in (2.2 cm) in diameter. This mineral has been used as a minor ore of antimony (p.41).

PROFILE

Hexagonal

2–2½

5.8

Distinct rhombohedral

Conchoidal to uneven, brittle

Vermilion

Adamantine to submetallic

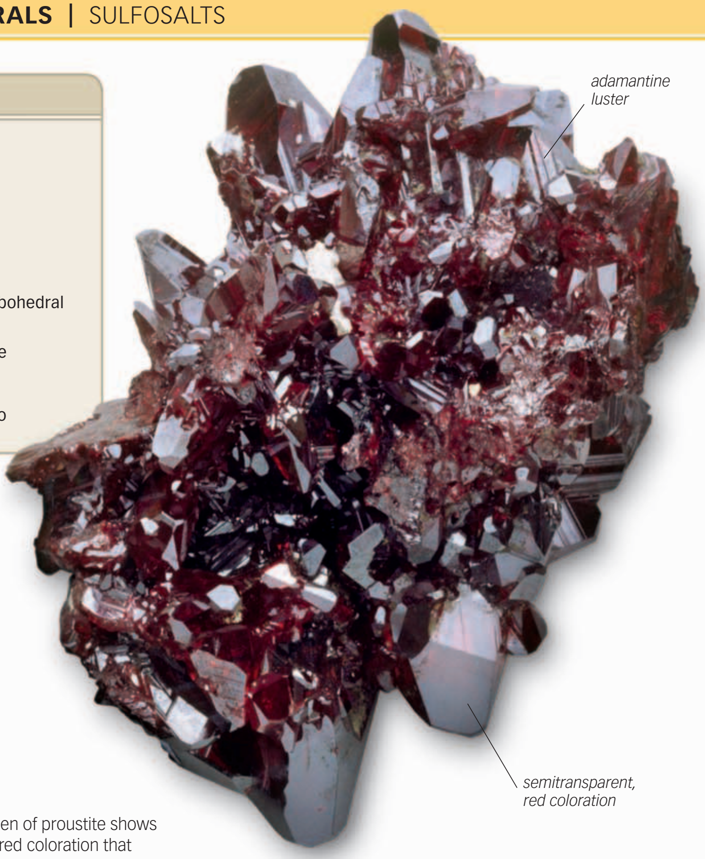

Ruby silver
This stunning specimen of proustite shows the semitransparent red coloration that gives it the name common ruby silver.

VARIANTS

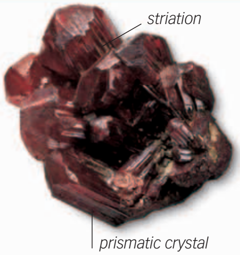

Striated proustite A prismatic, semitransparent crystal

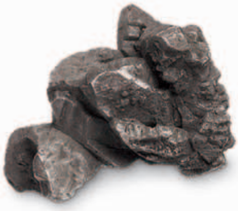

Dull proustite A dull, opaque specimen after exposure to light

Ag_3AsS_3

PROUSTITE

As its original name ruby silver ore suggests, proustite is translucent and red and is an important source of silver (p.43). It has also been called light red silver ore. The name proustite comes from the French chemist Joseph Proust, who distinguished it from the related mineral pyrargyrite (p.70) by chemical analysis in 1832. Its striated, often brilliant crystals are typically prismatic with rhombohedral or scalenohedral terminations, often resembling the dogtooth spar form of calcite (p.114) in habit. Proustite also occurs as massive or granular aggregates. The mineral turns from transparent scarlet to dull opaque gray in strong light, so specimens are stored in the dark.

Proustite forms in hydrothermal veins at low temperature (up to 400°F/200°C) with other silver minerals, such as acanthite (p.49), stephanite (p.69), and tetrahedrite (p.73), and with native arsenic (p.45), galena (p.54), and calcite (p.114). It also forms in the secondary zone of silver deposits. Large crystals come from Chañarcillo, Chile, and Freiburg, Saxony, Germany.

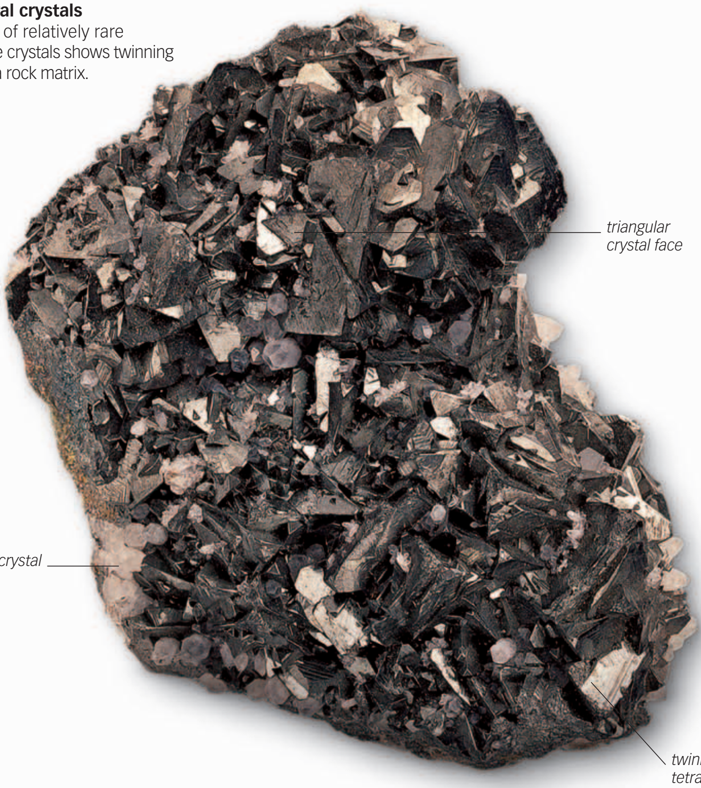

Tetrahedral crystals
This group of relatively rare tetrahedrite crystals shows twinning and coats a rock matrix.

PROFILE

Cubic

3–4

4.6–5.1

None

Subconchoidal to uneven

Brown to black to cherry-red

Metallic

$(Cu,Fe)_{12}Sb_4S_{13}$

TETRAHEDRITE

The name tetrahedrite comes from this mineral's characteristic tetrahedral crystals, although it also occurs as massive, compact, or granular aggregates. Tetrahedrite is opaque, metallic gray, or nearly black, and it sometimes coats or is coated with brassy yellow chalcopyrite (p.57). It forms a continuous solid-solution series with the similar mineral tennantite (p.66), in which arsenic replaces antimony in the crystal structure. Bismuth also substitutes for antimony and forms bismuthian tetrahedrite or annivite.

Tetrahedrite is an important ore of copper and sometimes silver. It forms in hydrothermal veins at low to medium temperatures (up to 1,065°F/575°C), often with bornite (p.50), galena (p.54), chalcopyrite, pyrite (p.62), barite (p.134), and quartz (p.168). It is also found in contact metamorphic deposits.

Copper ore
This 9th-century brass Arabic astrolabe is believed to have been made of copper extracted from tetrahedrite.

OXIDES

The minerals in this group have crystal structures in which metals or semimetals occupy spaces between oxygen atoms. The properties of oxides vary: the metallic ores and gemstone varieties tend to be hard and have a high specific gravity.

COMPOSITION

Oxides can be either simple or multiple. Simple oxides, such as cuprite (Cu_2O), contain only one metal or semimetal and oxygen. Multiple oxides have two different metal sites, both of which may be occupied by several different metals or semimetals. The minerals in the spinel ($MgAl_2O_4$) group are examples of multiple oxides.

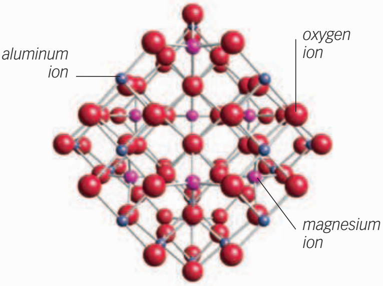

Spinel crystal structure
In spinel, magnesium and aluminum combine with oxygen. Other metals can replace magnesium and aluminum to form the spinel series of minerals.

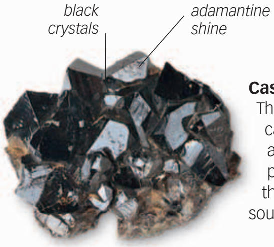

Cassiterite crystals
The simple tin oxide cassiterite, seen here as a group of twinned prismatic crystals, is the world's primary source of tin.

Queensland
The Queensland region of eastern Australia is a treasure trove of minerals. Several deposits of alluvial sapphire (aluminum oxide) are found here.

OCCURRENCE AND USES

Oxides occur as accessory minerals in many igneous rocks, especially as early crystallizing minerals in ultrabasic rocks, in pegmatites, and as decomposition products of sulfide minerals. Many resist weathering and are found concentrated in placers.

Many oxide minerals are important ores of chromium, uranium, tantalum, zinc, tin, cerium, tungsten, manganese, copper, and titanium. Other oxides, such as quartz and corundum, are important gemstone minerals.

Chrome bumper
The large, chrome-plated front bumper of this classic American 1956 Chevrolet is a dramatic example of chromium derived from the oxide chromite.

PROFILE

Hexagonal

Varies

1.0

Perfect, difficult

Conchoidal, brittle

White

Vitreous

Iceberg This small, beached iceberg still shows some of its original depositional layering.

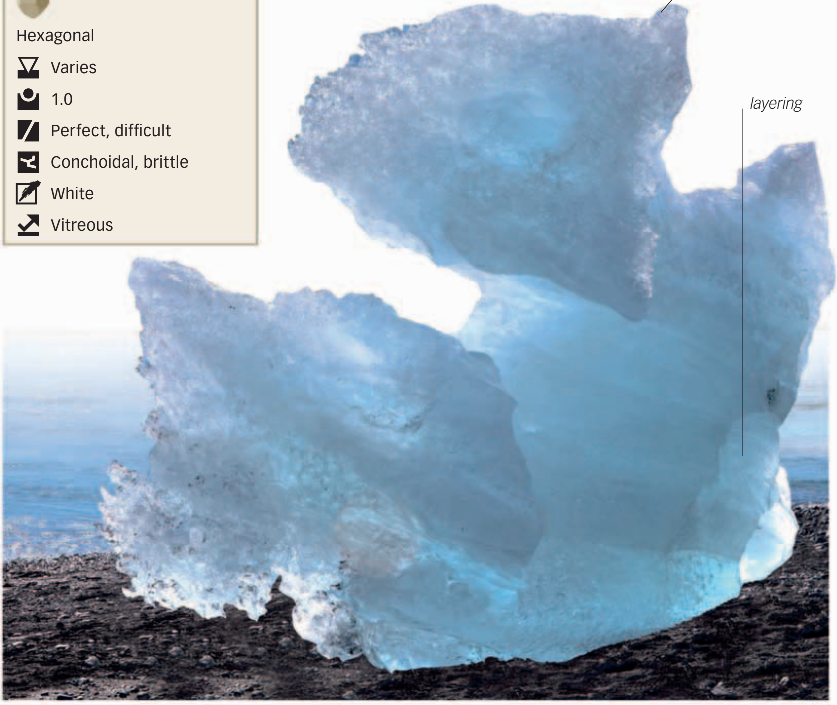

VARIANTS

Frost Crystalline ice in a frostlike form

Hailstone A huge (2 in x 3½ in / 5 cm x 9 cm) hailstone

H_2O

ICE

Although largely absent at lower latitudes, ice is probably the most abundant mineral exposed on Earth's surface. Liquid water is not classified as a mineral because it has no crystalline form. As snow, ice forms crystals that seldom exceed ¼ in (7 mm) in length, although as massive aggregates in glaciers, individual crystals may be up to 17½ in (45 cm) long. Other forms of ice include branching, treelike frost, skeletal, hopper-shaped, prismlike frost, and hailstones and icicles made up of many randomly oriented crystals.

Ice crystals are generally colorless, but the common white color of ice is due to gaseous inclusions of air that reflect light. There are at least nine polymorphs—different crystalline forms—of ice, each forming under different pressure and temperature conditions, but only one form exists at Earth's surface. The hardness of ice varies with its crystal structure, purity, and temperature. At temperatures found in the Arctic and high-alpine zones, ice is so hard it can erode stone when windblown.

PROFILE

Tetragonal

5½–6

3.9

Perfect

Subconchoidal

White to pale yellow

Adamantine to metallic

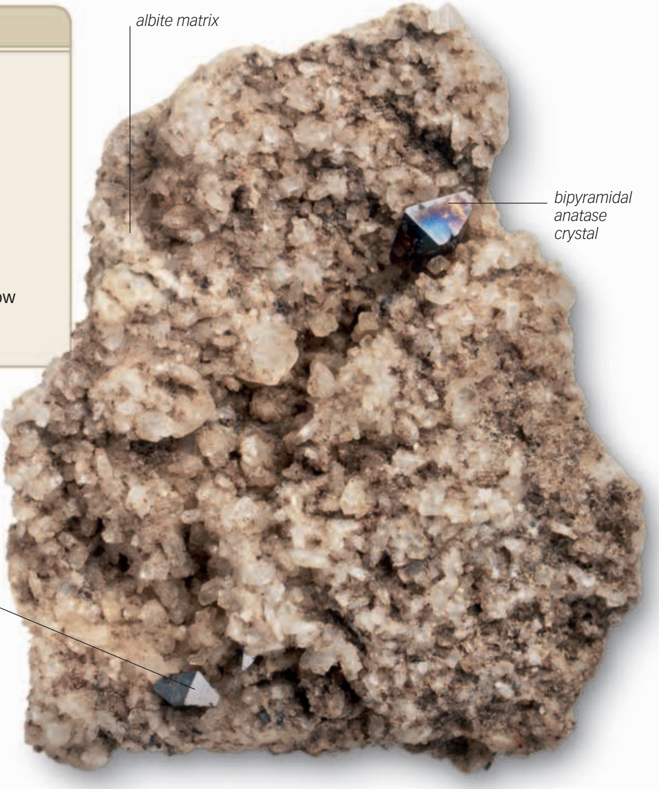

Bipyramidal anatase This specimen shows two bipyramidal anatase crystals perched on a matrix of albite crystals.

VARIANTS

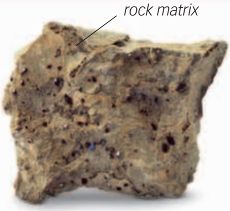

Black anatase Schist speckled with tiny black anatase crystals

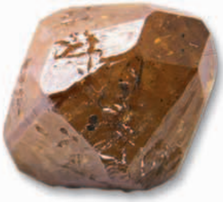

Octahedral crystal A perfectly formed, modified bipyramidal anatase crystal

TiO_2

ANATASE

Formerly known as octahedrite, anatase is a polymorph of titanium dioxide. Its name comes from the Greek word *anatasis,* which means "extension"—a reference to the elongate octahedral crystals that are the most common habit of anatase. Anatase crystals can also be tabular and, rarely, prismatic. Hard and brilliant, the crystals can be brown, yellow, indigo-blue, green, gray, lilac, or black in color.

Anatase forms in veins and crevices in metamorphic rocks, such as schists (pp.291–92) and gneisses (p.288), and is derived from the leaching of surrounding rocks by hydrothermal solutions. Anatase also forms in pegmatites (p.260), often in association with the minerals brookite (p.77), ilmenite (p.90), fluorite (p.109), and aegirine (p.209). It is found in sediments and is sometimes concentrated in placer deposits. Much anatase is formed by the weathering of titanite (p.234). Weathered anatase becomes rutile (p.78). Although rutile replaces anatase, it retains the anatase crystal shape.

PROFILE

Orthorhombic

5½–6

4.1

Indistinct

Subconchoidal to uneven

White, grayish, yellowish

Metallic to adamantine

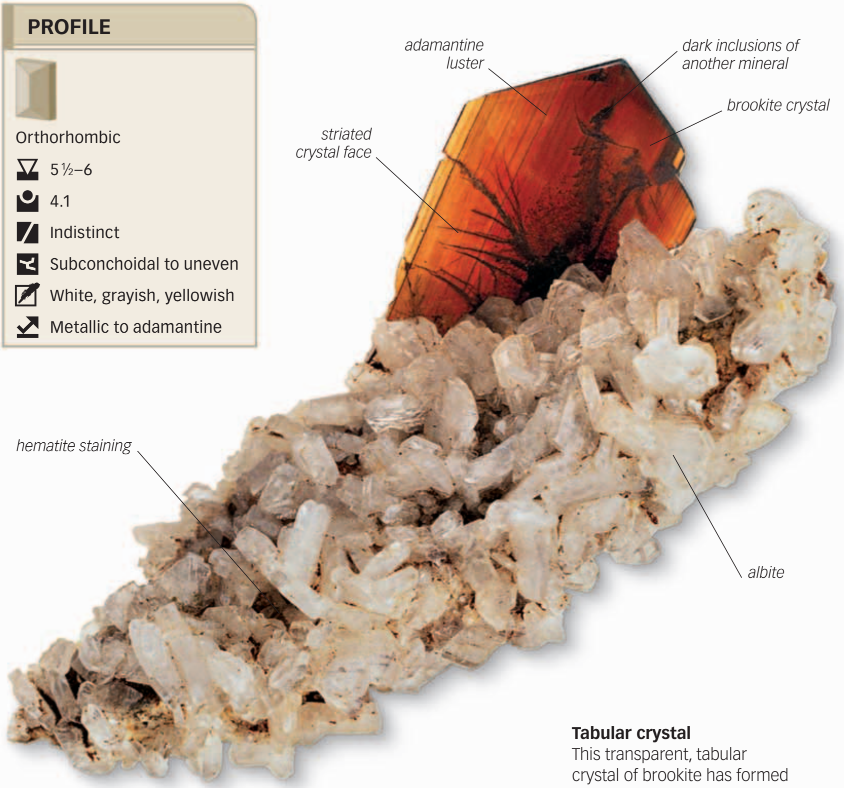

Tabular crystal This transparent, tabular crystal of brookite has formed on a mass of albite crystals.

VARIANT

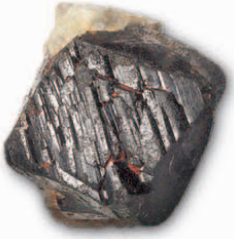

Dipyramidal crystal A black brookite specimen with metallic luster

TiO_2

BROOKITE

Named in 1825 after British crystallographer H.J. Brooke, brookite, like anatase (p.76) and rutile (p.78), is composed of titanium dioxide. However, unlike anatase and rutile, brookite exhibits orthorhombic symmetry. Usually brown and metallic, brookite may also be red, yellow-brown, or black. Crystals can be tabular or, less commonly, pyramidal or pseudohexagonal. They may be thin or thick and up to 2 in (5 cm) long. Iron is almost always present in this mineral's structure to a small degree, and brookite containing niobium is also known.

Brookite occurs in hydrothermal veins, in some contact metamorphic rocks, and as a detrital mineral in sedimentary deposits. Being relatively dense, it is common in areas with natural concentrations of heavy minerals, such as the diamond placer deposits of Brazil. It generally occurs with other minerals, including rutile, anatase, and albite (p.177). Brookite is widespread in mineral veins in the Alps. In the Fronolen locality in northern Wales, UK, it forms crystals on crevice walls in diabase rock.

PROFILE

Tetragonal

6–6½

4.2

Good

Conchoidal to uneven

Pale brown to yellowish

Adamantine to submetallic

Single crystal This large, semitransparent, and striated single crystal of rutile originates from Val di Vizze, Trentino-Alto Adige, Italy.

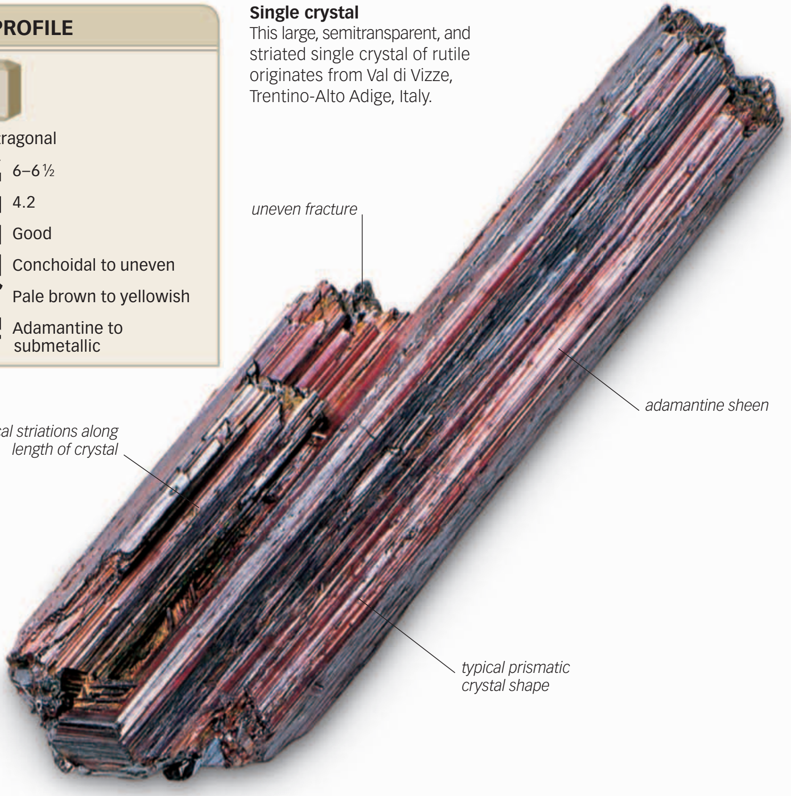
uneven fracture
adamantine sheen
vertical striations along length of crystal
typical prismatic crystal shape

VARIANTS

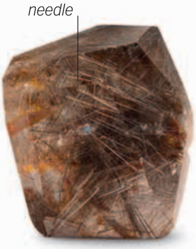
rutile needle

Rutilated quartz Pale-golden rutile crystals in polished quartz

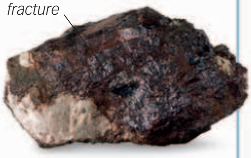
uneven fracture

Massive rutile Dark-hued crystals in rock matrix

TiO_2

RUTILE

A form of titanium oxide, rutile takes its name from the Latin *rutilis*, which means "red" or "glowing." It often appears as pale golden, needlelike crystals inside quartz (p.168). When not enclosed in quartz, it is usually yellowish or reddish brown, dark brown, or black. Crystals are generally prismatic but can also be slender and needlelike. Multiple twinning is common and is either knee-shaped, net- or latticelike, or radiating, forming wheel-like twins. Rutile may also radiate in starlike sprays from hematite crystals.

Rutile often occurs as a minor constituent of granites (pp.258–59), gneisses (p.288), and schists (p.291), and also in hydrothermal veins and in some clastic sediments. It commonly forms microscopic, oriented inclusions in other minerals, producing an asterism effect.

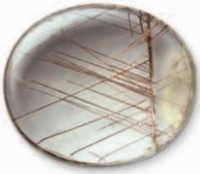

Quartz rutile cabochon Slender rutile crystals are clearly visible inside this polished, convex-cut, colorless quartz.

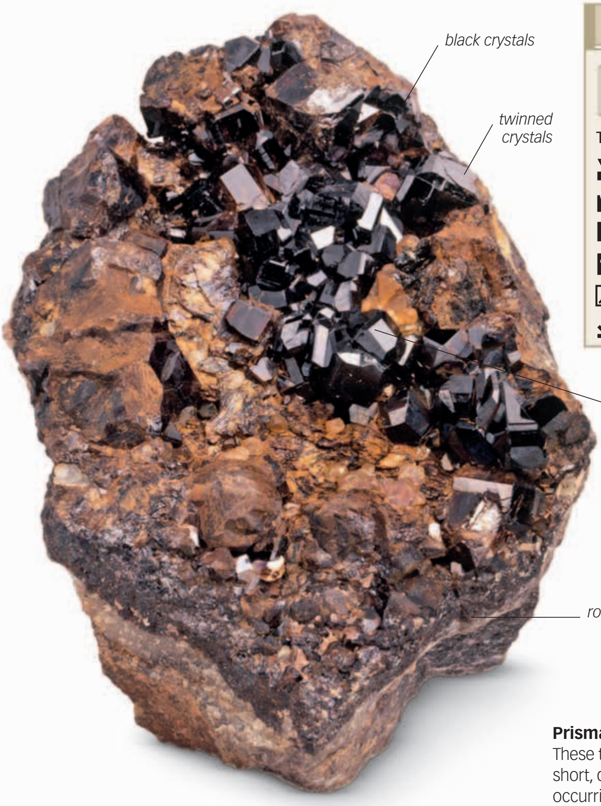

PROFILE

Tetragonal
6–7
7.0
Indistinct
Subconchoidal to uneven
White, grayish, brownish
Adamantine to metallic

Prismatic crystals These twinned cassiterite crystals are short, dark-colored, and prismatic, occurring on a rocky matrix.

VARIANT

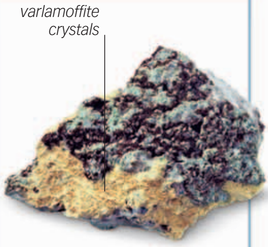

Varlamoffite cassiterite A specimen displaying the yellow variety of tin oxide

SnO_2

CASSITERITE

The tin oxide cassiterite takes its name from the Greek word for tin, *kassiteros*. Also called tinstone, it is the only important ore of tin. Colorless when pure, it commonly appears brown or black due to iron impurities. Rarely, it is gray or white. Its crystals are usually heavily striated prisms and pyramids. Twinned crystals are quite common. It can also be massive, occurring as a botryoidal, fibrous variety (wood tin) or as water-worn pebbles (stream tin).

Cassiterite forms in association with igneous rocks in hydrothermal veins at high temperature (1,065°F/575°C or above), with tungsten minerals such as ferberite (p.145), and with topaz (p.234), molybdenite (p.64), and tourmaline (p.224). Durable and relatively dense, it becomes concentrated in placer deposits after erosion from its primary rocks.

Brilliant gemstone This faceted, golden orange cassiterite gem is transparent with a resinous luster.

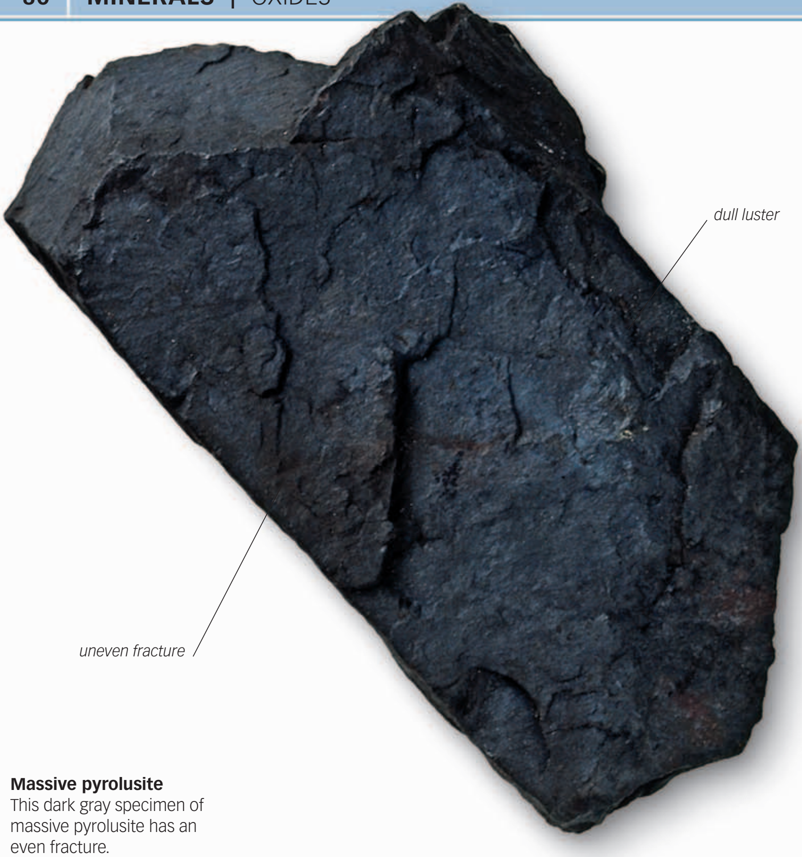

Massive pyrolusite
This dark gray specimen of massive pyrolusite has an even fracture.

PROFILE

Tetragonal
- 6–6½
- 4.4–5.1
- Perfect
- Uneven, brittle, splintery
- Black or bluish black
- Metallic to earthy

MnO_2

PYROLUSITE

Pyrolusite is the primary ore of the element manganese. Specimens are typically light gray to black in color. Pyrolusite usually occurs as massive aggregates. It also forms metallic coatings, crusts, fibers, nodules, botryoidal masses, concretions, and coatings that may be powdery or branching. Crystals are rare; when found, they are opaque and prismatic.

Pyrolusite forms under highly oxidizing conditions as an alteration product of manganese minerals, such as rhodochrosite (p.121). It has been found in bogs, lakes, and shallow marine environments and as a deposit laid down by circulating waters. Excellent crystals are found at Horni Blatna, Czech Republic, and at Bathurst, New Brunswick, Canada. The mineral is mined extensively in Russia, India, Georgia, and Ghana. Pyrolusite is used as a decolorizing agent in glass, as a coloring agent in bricks, and in dry cell batteries. It is also used in the manufacture of steel and saltwater-resistant manganese-bronze, which is used to make ships' propellers.

PROFILE

Orthorhombic

8½

3.7

Distinct

Uneven to conchoidal

Colorless

Vitreous

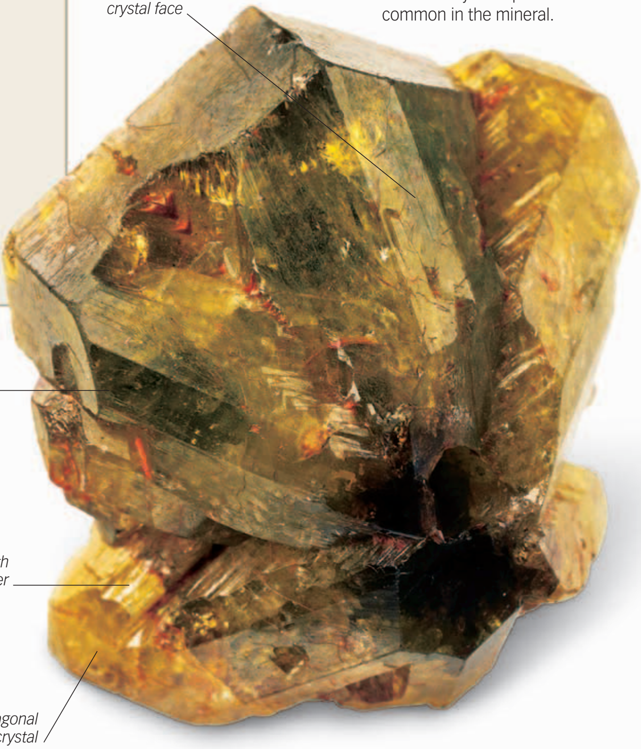
striation on crystal face
greenish yellow twinned crystal
transparent with vitreous luster
pseudohexagonal twinned crystal

Cyclic twin
The cyclic twinning of chrysoberyl exhibited by this specimen is common in the mineral.

VARIANTS

Siberian alexandrite A group of twinned alexandrite crystals with mica from Russia

Yellow gemstone Cat's eye chrysoberyl in the most desirable honey-yellow color

$BeAl_2O_4$

CHRYSOBERYL

A beryllium aluminum oxide, chrysoberyl is hard and durable. It is inferior in hardness only to corundum (p.95) and diamond (p.47). Chrysoberyl is typically yellow, green, or brown in color. It forms tabular or short prismatic crystals and heart-shaped or pseudohexagonal twinned crystals. Alexandrite, one of its gemstone varieties, is one of the rarest and most expensive gems. Another variety, cat's eye, is also prized as a gemstone. It contains parallel fibrous crystals of other minerals that reflect light across the surface of a polished gemstone—an effect known as chatoyancy.

Chrysoberyl occurs in some granite pegmatites (p.260), gneisses (p.288), mica schists, and marbles (p.301). Crystals that weather out of the parent rock are often found in streams and gravel beds.

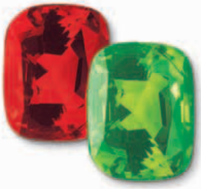

Color change
Alexandrite exhibits color change—from brilliant green in daylight to cherry-red under tungsten light.

PROFILE

Orthorhombic

6–6½

5.2–8.0

Distinct

Subconchoidal or uneven

Red, brown, or black

Submetallic to resinous

Ferrocolumbite This opaque, tabular crystal of ferrocolumbite exhibits a submetallic to resinous luster.

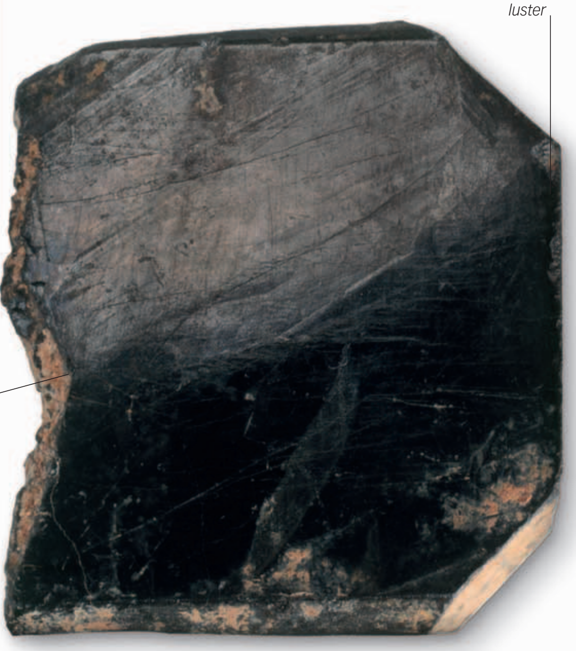

VARIANT

Yttrotantalite Dark crystals of the coltan series mineral yttrotantalite (yttrium-rich tantalite) in a light matrix

$(Fe,Mn)(Nb,Ta)_2O_6$–$(Fe,Mn)(Ta,Nb)_2O_6$

COLUMBITE–TANTALITE

Columbite forms the coltan series—a nearly complete solid-solution series—with the mineral tantalite. Minerals at the columbite end of this series are niobium-rich, and those at the tantalite end are tantalum-rich. Tantalite and columbite have similar crystal structures, but tantalite is denser, and tantalum atoms replace niobium atoms in the columbite crystal structure. The name of the mineral is prefixed with “ferro-” or “mangano-” depending on the content of iron or manganese. Ferrocolumbite is the most common mineral of the coltan group. Scandium and tungsten may also be present as minor constituents.

Coltan minerals are brown or black in color and are often iridescent. They are either massive or form tabular or short, prismatic crystals. They are the most abundant and widespread of the niobates and tantalates, and are the most important ores of niobium and tantalum. Coltan minerals mainly occur in granite pegmatite rocks (p.260) and in detrital deposits.

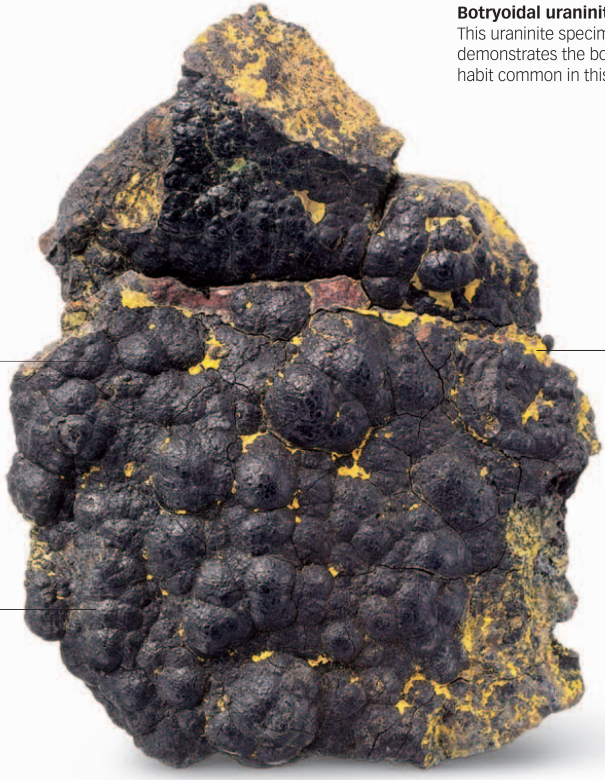

Botryoidal uraninite
This uraninite specimen demonstrates the botryoidal habit common in this mineral.

PROFILE

Cubic
5–6
6.5–11.0
None
Uneven to subconchoidal
Brownish black
Submetallic, pitchy, dull

UO_2

URANINITE

Discovered by the German chemist M.H. Klaproth in 1789, uraninite is a major ore of uranium. The pioneering work on radioactivity by Pierre and Marie Curie was based on uranium extracted from uraninite ores. It is black to brownish black, dark gray, or greenish. It commonly occurs in massive or botryoidal forms, or in banded or granular habits, and less commonly as opaque octahedral or cubic crystals.

Uraninite crystals occur in granitic pegmatites (p.260). Uraninite forms with cassiterite (p.79) and arsenopyrite in hydrothermal sulfide veins at high temperatures (1,065°F/575°C or above). It also forms at medium temperatures (400–1,065°F/200–575°C) as pitchblende. It also occurs as small grains in sandstones and conglomerates, where it may have weathered into secondary uranium minerals.

Uranium pellets
These ceramic pellets of enriched uranium are ready for use in nuclear reactors.

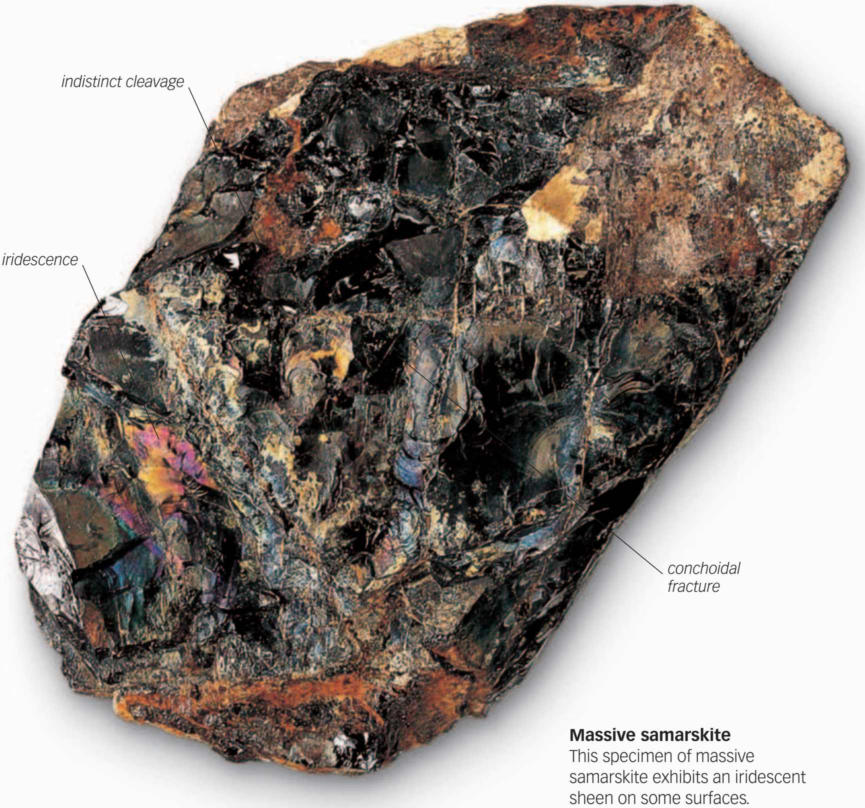

Massive samarskite
This specimen of massive samarskite exhibits an iridescent sheen on some surfaces.

PROFILE

Orthorhombic
5–6
5.7
Indistinct
Conchoidal, brittle
Dark reddish brown to black
Vitreous to resinous

$(Y,Fe,U)\ (Nb,Ta)O_4$

SAMARSKITE

Named in 1847 after Vasili Yefrafovich von Samarski-Bykhovets of Russia, samarskite is a complex oxide of yttrium, iron, tantalum, niobium, and uranium. Two types of samarskite are recognized—samarskite-(Y) or yttrium samarskite; and samarskite-(Yb) or ytterbium samarskite. The mineral is usually black and opaque but translucent in thin fragments. Crystals are stubby, opaque, and prismatic with a rectangular cross section—although samarskite is commonly found in the massive form. It is often brown or yellowish brown due to surface alteration. Specimens with high uranium content have a yellow-brown, earthy rind. Samarskite samples are usually radioactive.

Samarskite is usually found in rare, earth-bearing granitic pegmatites (p.260). It forms in similar conditions as columbite (p.82), so the minerals are closely associated. Samarskite is also associated with monazite (p.150), garnet, and other minerals. Yttrium from samarskite has been used in cathode-ray televisions, optical glass, and special ceramics.

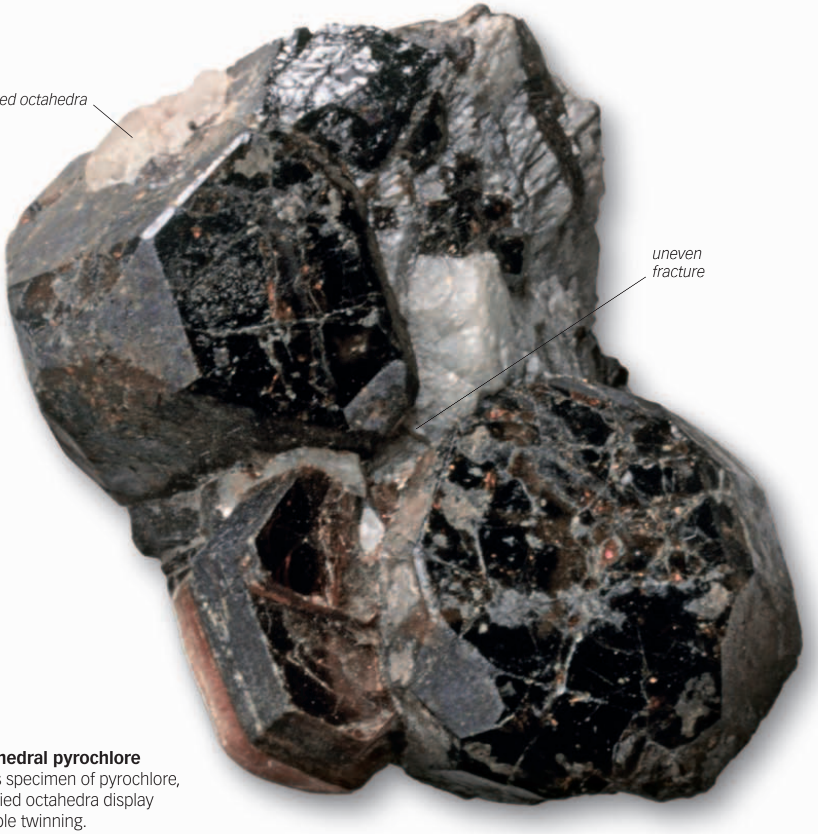

Octahedral pyrochlore
In this specimen of pyrochlore, modified octahedra display multiple twinning.

PROFILE

Cubic
5–5½
4.5
Distinct
Subconchoidal to uneven
Light brown, yellowish brown
Vitreous to resinous

$(Na,Ca)_2Nb_2(O,OH,F)_7$

PYROCHLORE

A major source of the element niobium, pyrochlore is a complex niobium sodium calcium oxide. Its name comes from the Greek *pyr* and *chloros*, which mean "fire" and "green" respectively—a reference to some specimens that turn green after heating. Pyrochlore is orange, brownish red, brown, or black in color. Crystals are typically well-formed octahedra with modified faces. They are frequently twinned or occur as either granular or massive aggregates. Pyrochlore often contains traces of uranium and thorium, and it may be radioactive. In such cases, its internal structure may be disrupted.

Pyrochlore forms in pegmatite rocks (p.260) and in igneous rocks dominated by carbonate minerals. It is an accessory mineral in silica-poor rocks, often occurring with magnetite (p.92), apatite (p.148), and zircon (p.233). It also accumulates in some detrital deposits. Niobium is a major alloying element in nickel-based superalloys. It has been used either alone or together with zirconium in claddings for nuclear-reactor cores.

Microlite crystals
This specimen of crystalline microlite contains tantalum in place of the niobium typically found in pyrochlore.

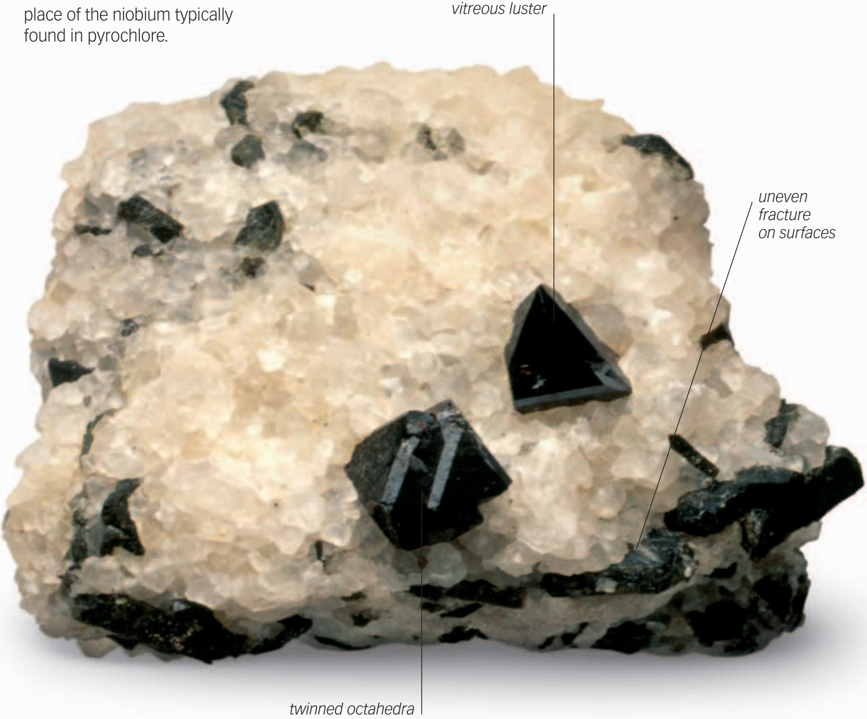

PROFILE

Cubic
5–5½
6.4
Distinct to difficult
Subconchoidal to uneven
Yellowish to brownish
Resinous to vitreous

$(Na,Ca)_2Ta_2O_6(O,OH,F)$

MICROLITE

Named in 1835, microlite takes it name from the Greek word *micros,* which means "small"—a reference to the small size of the crystals found in the locality where the mineral was first discovered. Microlite can, in fact, form excellent octahedral crystals, which can be up to ⅜in (1cm) on an edge. It also occurs as irregular grains. Specimens can be yellow, brown, black, green, or reddish. Microlite is related to pyrochlore (p.85), and both minerals are dominated by rare-earth elements: microlite by tantalum and pyrochlore by niobium.

Microlite is found in pegmatites (p.260), especially those rich in lepidolite (p.198) or other lithium-bearing minerals, and in albite (p.177). It is a major ore of tantalum, which is especially useful in high-capacitance electronic devices, particularly those used in miniaturized circuitry. Microlite is also used in corrosion-resistant chemical equipment. Excellent crystals are found at Dixon, New Mexico, USA; Shingus, Gilgit, Pakistan; Mattawa, Ontario, Canada; and at numerous localities in Brazil.

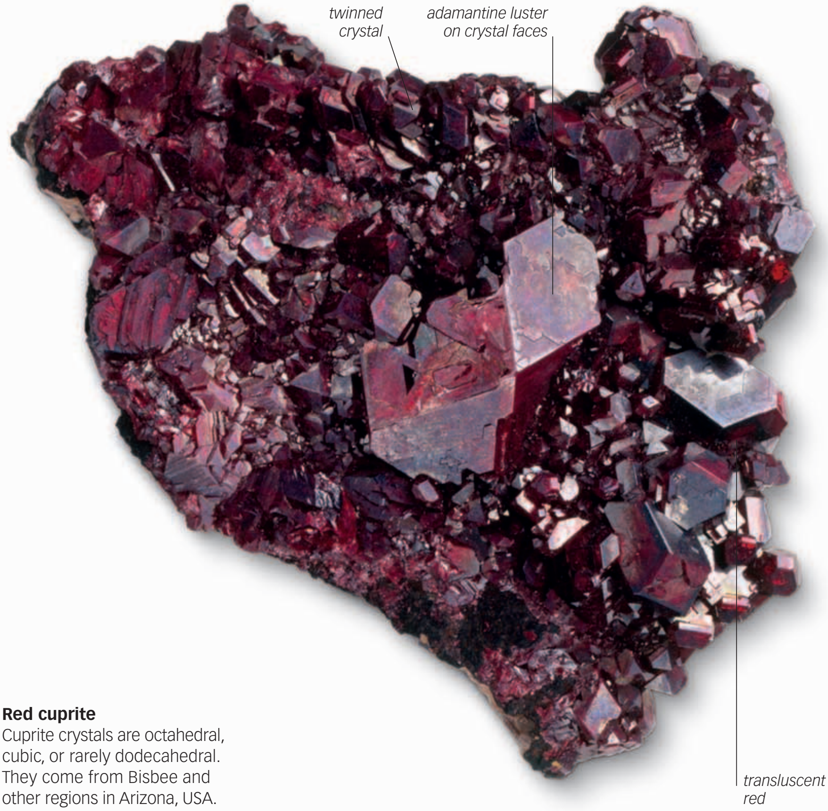

Red cuprite
Cuprite crystals are octahedral, cubic, or rarely dodecahedral. They come from Bisbee and other regions in Arizona, USA.

PROFILE

Cubic
3½–4
6.1
Distinct
Conchoidal, brittle
Brownish red, shining
Adamantine, submetallic

VARIANT

Chalcotrichite Bright red, hairlike crystals of the chalcotrichite variety

Cu_2O

CUPRITE

A relatively soft, heavy copper oxide, cuprite is an important ore of copper. Its crystals are either cubic or octahedral in shape and commonly striated. Massive or granular aggregates with the appearance of sugar are common. Cuprite is translucent and bright red when freshly broken but turns to a dull metallic gray color on exposure to light and pollutants. Cuprite is sometimes known as ruby copper due to its distinctive red color.

In the variety called chalcotrichite or plush copper ore, the crystals are a rich carmine color, fibrous, capillary, and are silky in appearance. They are found in loosely matted aggregates. Cuprite of the tile ore variety is soft, earthy, brick-red to brownish red in color, and often contains intermixed hematite (p.91) or goethite (p.102).

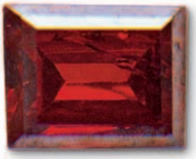

Step cut
Rare transparent cuprite is sometimes cut for collectors, as in this rectangular step cut.

Crystalline zincite This specimen of coarsely crystalline zincite in a white calcite matrix is from Sterling Hill, New Jersey, USA.

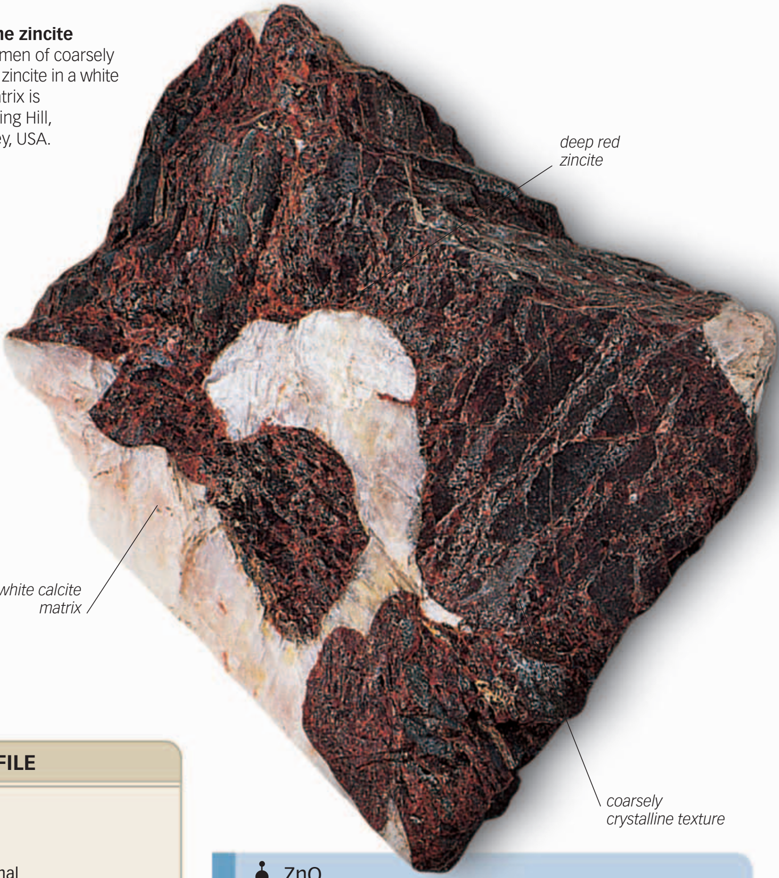

PROFILE

Hexagonal
- 4–5
- 5.7
- Perfect
- Conchoidal
- Orange-yellow
- Resinous, submetallic

VARIANT

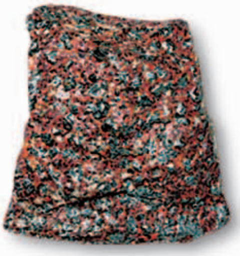

Granular habit Granular zincite with black franklinite

ZnO

ZINCITE

Red oxide of zinc is another name for zincite, which is a minor ore of zinc. Zincite occurs mostly as cleavable or granular masses. Natural crystals are rare, but when they occur they are pyramidal, pointed at one end and flat at the other. These crystals can be orange, red, yellow, or green.

Zincite is found mainly as an accessory mineral in zinc-ore deposits and is commonly associated with black franklinite and white calcite. It may also be a rare constituent of volcanic ash. Crystals are found only in secondary veins or fractures, where zincite forms by the chemical alteration or metamorphism of zinc deposits. Some so-called natural zincite crystals in the collectors' market are, in fact, large crystals that have formed in the chimneys of smelters. Natural crystals are rarely fluorescent; artificial crystals may range from fluorescent green to fluorescent yellow. The classic locality for fine zincite crystals is Franklin, New Jersey, USA. It is also found at Varmland and Nordmark, Sweden.

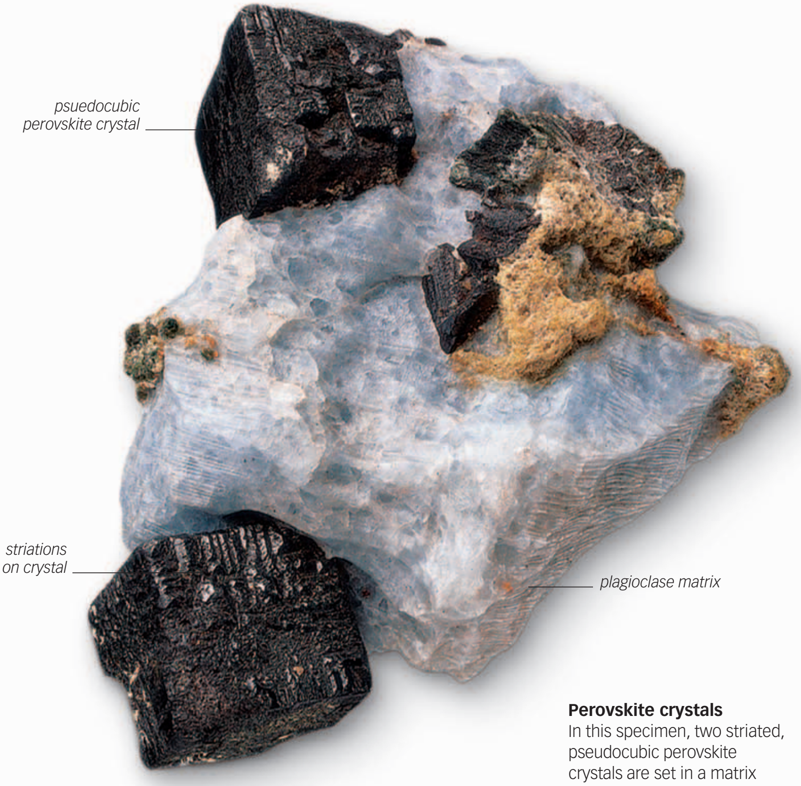

Perovskite crystals
In this specimen, two striated, pseudocubic perovskite crystals are set in a matrix of plagioclase feldspar.

PROFILE

Orthorhombic
5½
4.0
Imperfect
Subconchoidal to uneven
Gray to colorless
Adamantine or metallic

$CaTiO_3$

PEROVSKITE

A calcium titanium oxide, perovskite was named after the Russian mineralogist Count Lev Alekseevich Perovski in 1839. The composition of perovskite varies considerably: niobium can substitute for up to 44.9 percent titanium by weight, and cerium and sodium can substitute for calcium. When specimens are black, they have a metallic luster; when brown or yellow, they appear adamantine. Although perovskite is an orthorhombic mineral, its crystals are usually pseudocubic. Perovskite crystals can be pseudooctahedral in varieties where niobium or cerium has replaced a large amount of titanium. The crystals tend to be deeply striated and are frequently twinned.

Perovskite occurs in igneous rocks that are rich in iron and magnesium. It also occurs in contact metamorphic rocks associated with magnesium- and iron-rich intrusive igneous rocks and in some chlorite and talc schists. It is also found in carbonaceous chondrite meteorites (p.337).

PROFILE

Hexagonal

5–6

4.7

None

Conchoidal

Black to reddish brown

Metallic to submetallic

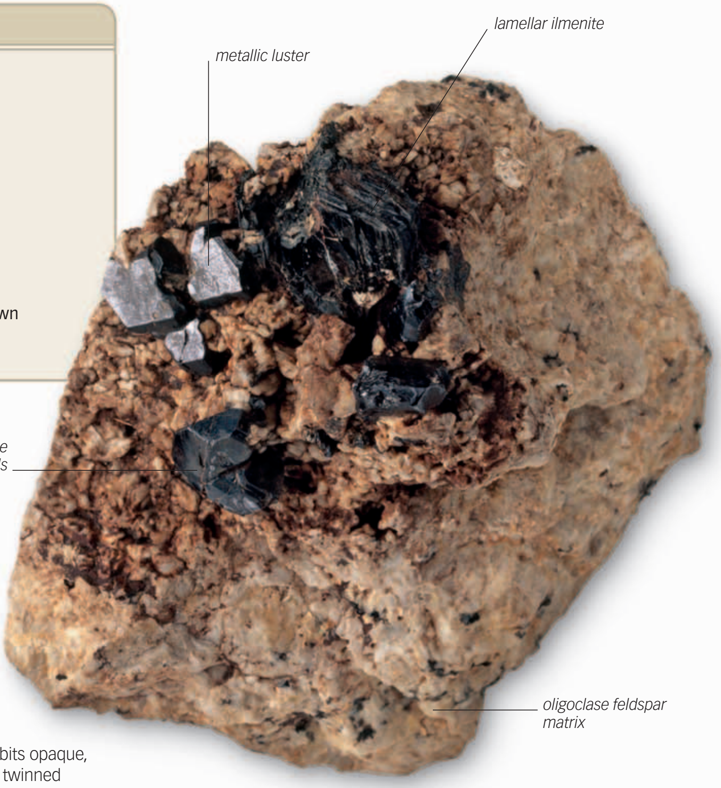

Ilmenite crystals This specimen exhibits opaque, black, lamellar, and twinned crystals of ilmenite.

VARIANT

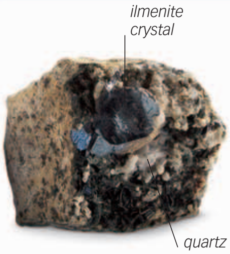

Tabular crystals Thin, gray, tabular ilmenite crystals with actinolite and quartz

$FeTiO_3$

ILMENITE

Named after the Il'menski Mountains near Miass, Russia, where it was discovered, ilmenite is a major source of titanium. Usually thick and tabular, its crystals sometimes occur as thin lamellae (fine plates) or rhombohedra. Ilmenite can also be massive, or occur as scattered grains. Intergrowths with hematite (p.91) or magnetite (p.92) are common, and ilmenite can be mistaken for these minerals because of its opaque, metallic, gray-black color. Unlike magnetite, however, ilmenite is nonmagnetic or very weakly magnetic; and it can be distinguished from hematite by its black streak. It may weather to a dull brown color.

Ilmenite is widely distributed as an accessory mineral in igneous rocks, such as diorite (p.264) and gabbro (p.265). It is a frequent accessory in kimberlite rocks (p.269), associated with diamond (p.47). It is also found in veins, pegmatite rocks (p.260), and black beach sands associated with magnetite, rutile (p.78), zircon (p.233), and other heavy minerals.

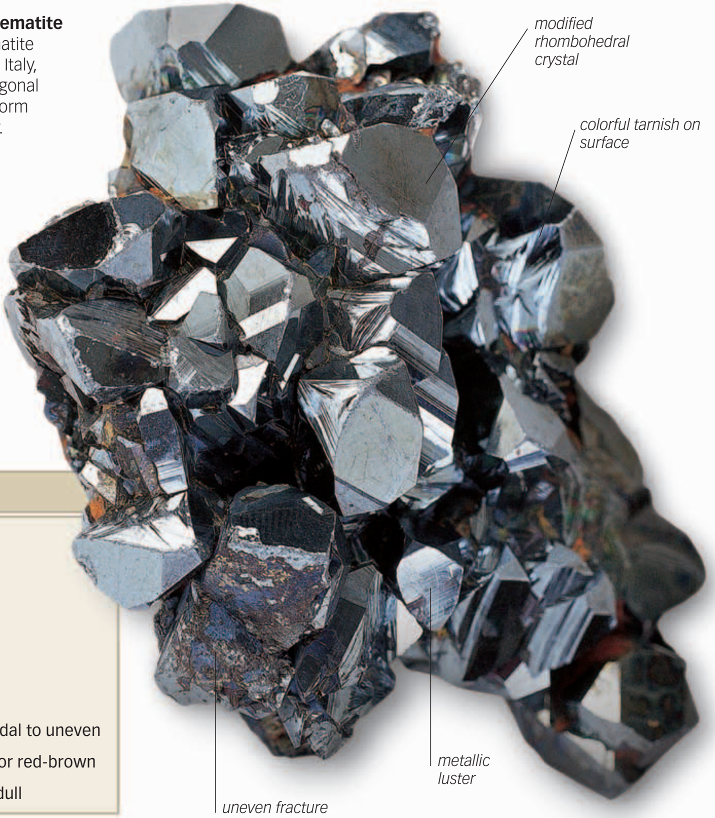

Rhombohedral hematite These superb hematite crystals from Elba, Italy, demonstrate hexagonal or rhombohedral form and metallic luster.

Fe_2O_3

HEMATITE

Dense and hard, hematite is the most important ore of iron (p.39) because of its high iron content and its abundance. The mineral occurs in various habits: steel-gray crystals and coarse-grained varieties with a brilliant metallic luster are known as specular hematite; thin, scaly forms make up micaceous hematite; and crystals in petal-like arrangements are called iron roses. Hematite also occurs as short, black, rhombohedral crystals and may have an iridescent tarnish. The soft, fine-grained, and earthy form of hematite is used as a pigment.

Important hematite deposits occur in sedimentary beds or in metamorphosed sediments. A compact variety known as kidney ore has a kidney-shaped surface. A form of ground hematite called rouge is used to polish plate glass and jewelry.

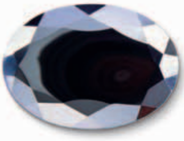

Oval cabochon This oval cabochon of black hematite is faceted on top. Hematite cabochons have been sold as "marcasites."

PROFILE

Hexagonal
5–6
5.3
None
Subconchoidal to uneven
Cherry-red or red-brown
Metallic to dull

VARIANTS

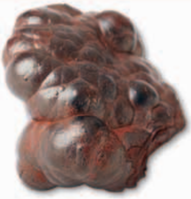

Kidney ore A perfect example of hematite's botryoidal habit

Specular hematite Brilliant platy crystals of specular hematite

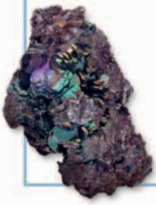

Iridescent hematite An iridescent crystal on rock

PROFILE

Cubic

5½–6

5.2

None

Conchoidal to uneven

Black

Metallic to semimetallic

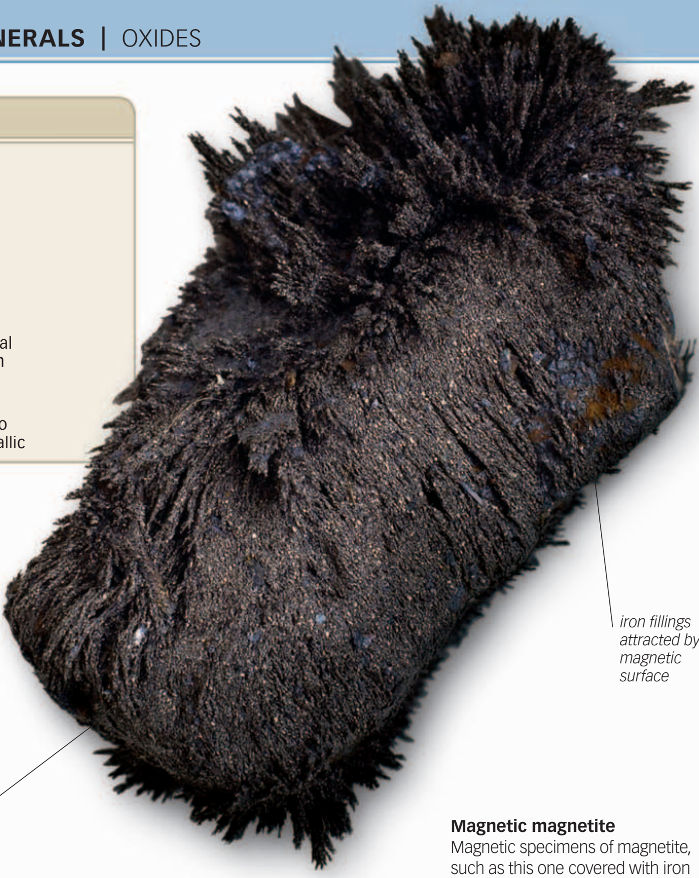

Magnetic magnetite Magnetic specimens of magnetite, such as this one covered with iron filings, are known as lodestones.

Fe_2O_4

MAGNETITE

An iron oxide, magnetite is named after the Greek shepherd boy Magnes, who noticed that the iron ferrule of his staff and the nails of his shoes clung to a magnetite-bearing rock. All magnetite can be picked up with a magnet, but some magnetite is itself naturally magnetic and attracts iron filings and deflects compass needles. Magnetite usually forms octahedral crystals, although it sometimes occurs as highly modified dodecahedrons. Specimens can also be massive or granular, occurring as disseminated grains and as concentrations in black sand. Magnetite is similar in appearance to hematite (p.91), but hematite is nonmagnetic and has a red streak.

Magnetite occurs in a range of geological environments. It forms at high temperatures (1,065°F/575°C or above) as an accessory mineral in metamorphic and igneous rocks and in sulfide veins. A major ore of iron (p.39), magnetite forms large ore bodies. Economically important deposits occur in silica-poor intrusions of igneous rocks and in banded ironstones (p.329).

VARIANTS

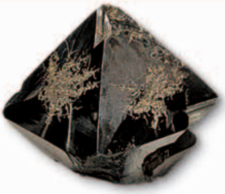

Octahedral crystal A magnetite crystal showing classic octahedral form

Magnetite crystals A cluster of black magnetite crystals

Swedish fergusonite
In this specimen from Ytterby, Sweden, fergusonite crystals rest on a matrix of feldspar.

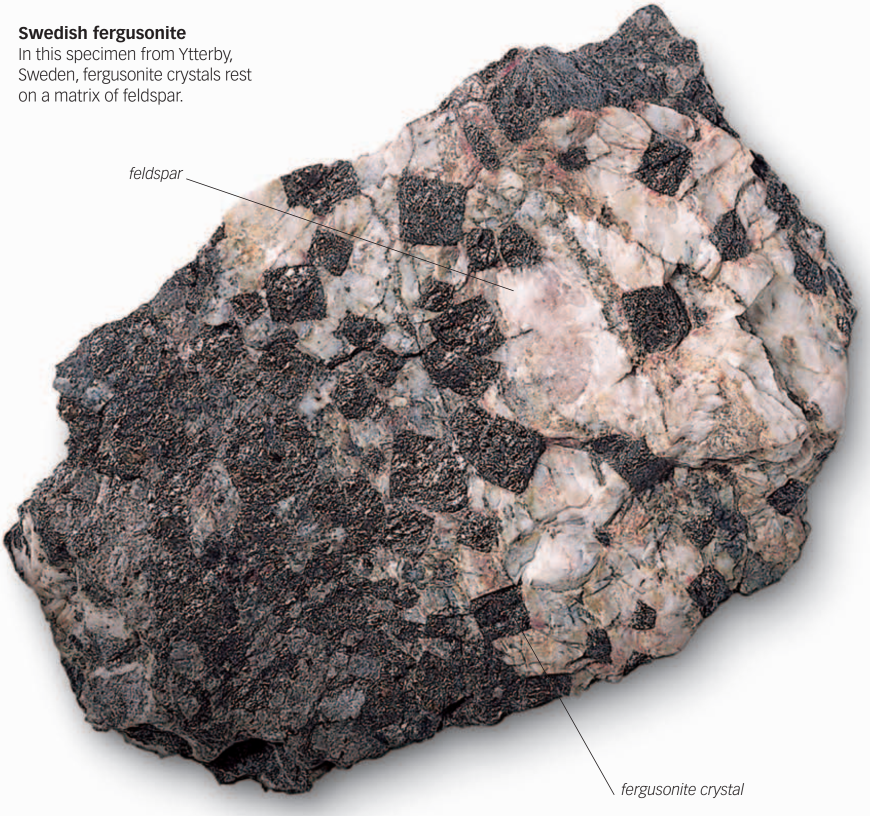

PROFILE

Tetragonal

5½–6½

4.2–5.7

Poor

Subconchoidal, brittle

Brown, yellow-brown, greenish gray

Vitreous to submetallic

$(Ce,Y,La,Nd)NbO_4$

FERGUSONITE

Named after the Scottish mineralogist Robert Ferguson (1767–1840), the fergusonite group contains several minerals. All fergusonites may be considered as sources of the rare metals they contain. The most common is fergusonite-(Y), which is rich in yttrium. Its crystals are prismatic to pyramidal in shape and black to brownish black. Fergusonite-(Ce) is cerium-rich, dark red to black in color, and forms prismatic dipyramidal crystals—although these are rare. Fergusonite-(Nd), a neodymium-bearing fergusonite, is usually granular. Another member of the fergusonites, formanite-(Y), is found as tabular crystals and anhedral pebbles. Yet other fergusonites, most of which appear in minor quantities, bear the prefix “beta.”

Fergusonites can also have varying amounts of erbium, lanthanum, niobium, dysprosium, uranium, thorium, zirconium, and tungsten. They can be found in granitic pegmatites (p.260) associated with other rare-earth minerals and in placer deposits.

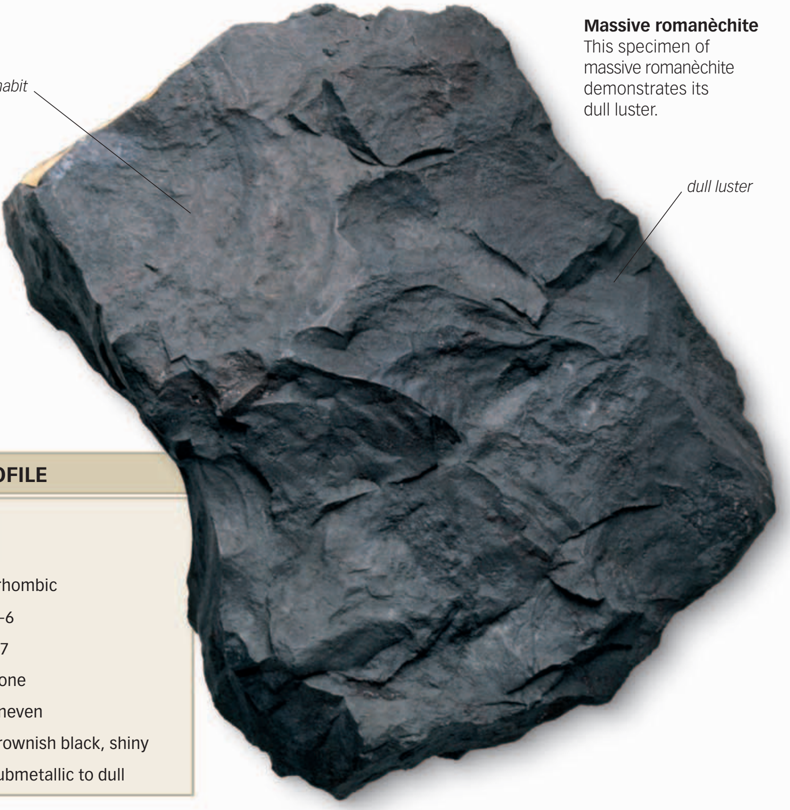

Massive romanèchite
This specimen of massive romanèchite demonstrates its dull luster.

PROFILE

Orthorhombic

5–6

4.7

None

Uneven

Brownish black, shiny

Submetallic to dull

VARIANT

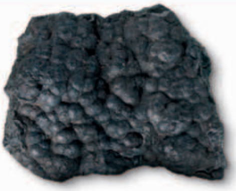

Botryoidal romanèchite
Dense, submetallic, botryoidal romanèchite

$(Ba, H_2O) (Mn_4+Mn_3+)_5O_{10}$

ROMANÈCHITE

A hard, black, barium manganese oxide, romanèchite is named for its occurrence at Romanèche-Thorins, France. It is one of the manganese oxides that were formerly grouped together under the name psilomelane, which has been applied to several distinct minerals. Although the name psilomelane is no longer used to refer to a particular mineral, it continues to be used as a term of convenience for a group of barium-bearing manganese oxides. Romanèchite specimens are usually fine-grained or fibrous. Crystals are rare; when found, they are prismatic.

Romanèchite forms as an alteration product of other manganese minerals and is an ore of manganese. The mineral also forms in bogs, lakes, and shallow seas. Although romanèchite is named after a French locality, it was first identified at Schneeberg, Saxony, Germany. Other important deposits of romanèchite are at Tekrasni, India; Pilbara, Australia; Cornwall, England; and Hidalgo County, New Mexico, USA.

PROFILE

Hexagonal
9
4–4.1
None
Conchoidal to uneven
Colorless
Adamantine to vitreous

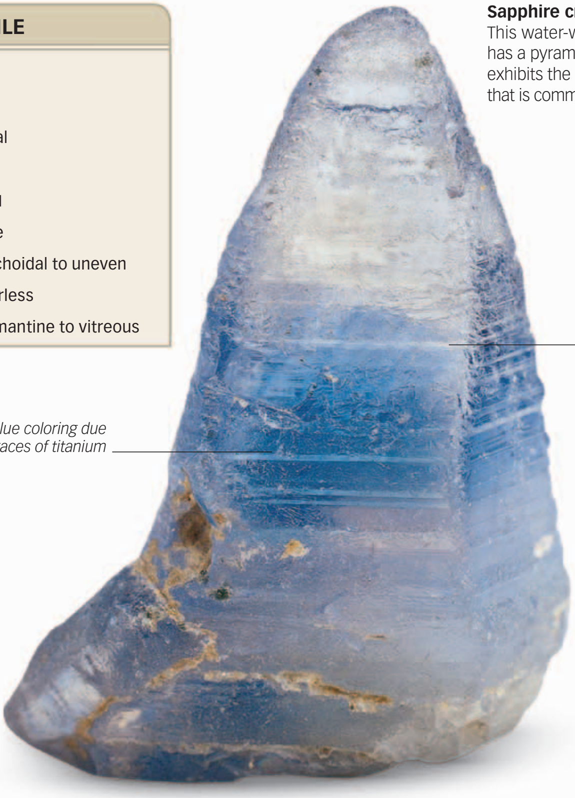

Sapphire crystal
This water-worn crystal has a pyramidal form and exhibits the color zoning that is common in sapphire.

VARIANTS

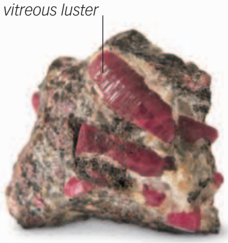

Ruby in matrix
Prismatic Kashmir rubies embedded in a rock matrix

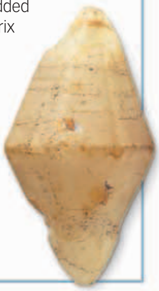

Common corundum
An opaque, dipyramidal crystal of common corundum

Al_2O_3

CORUNDUM

After diamond, corundum is the hardest mineral on Earth. The name corundum comes from the Sanskrit *kuruvinda*, meaning “ruby”—the name given to red corundum. Ruby and sapphire are gem varieties of corundum. An aluminum oxide, corundum is commonly white, gray, or brown, but gem colors include red ruby and blue, green, yellow, orange, violet, and pink sapphire. Colorless forms also occur. Ruby forms a continuous color succession with pink sapphire; only stones of the darker hues are considered to be ruby.

Corundum crystals are generally hexagonal, either tabular, tapering barrel-shaped, or dipyramidal. Corundum can also be massive or granular. It forms in syenites (p.262), certain pegmatites (p.260), and in high-grade metamorphic rocks. It is concentrated in placer deposits.

Antique ruby ring
In this ring, a square-cut ruby has been set at right angles to its square setting.

PROFILE

Cubic

7½–8

3.6–4.1

None

Conchoidal to uneven

White

Vitreous

Spinel octahedrons
In this specimen, octahedral crystals of pleonaste, or black spinel, are set in a quartz matrix.

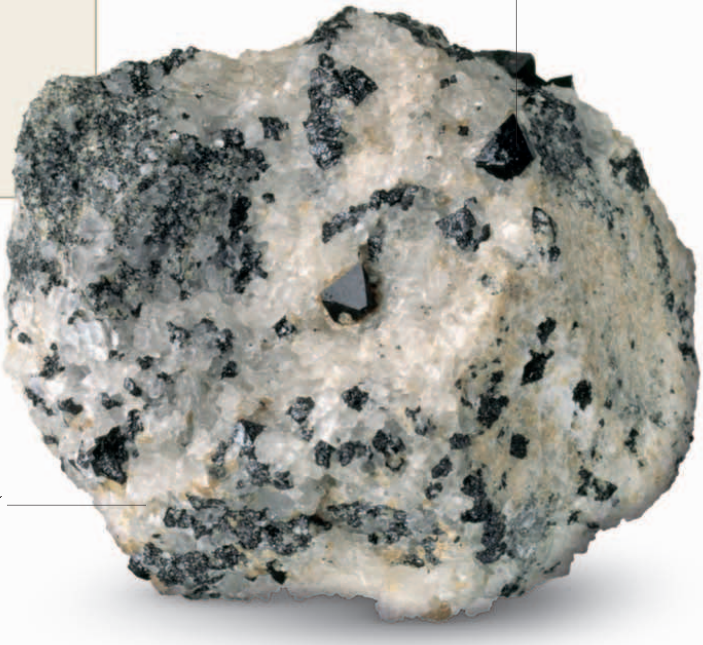

VARIANTS

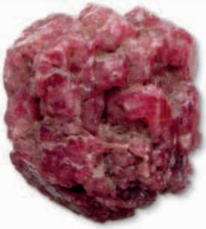

Spinel aggregate Numerous ruby spinel crystals

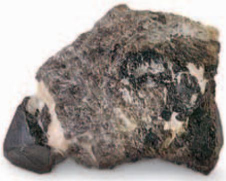

Black spinel A modified octahedron of black spinel on a rock matrix

$MgAl_2O_4$

SPINEL

Spinel is the name of both an individual mineral and of a group of metal-oxide minerals that share the same crystal structure. Minerals in this group include gahnite (p.97), franklinite, and chromite (p.99). Spinel is found as glassy, hard octahedra, or as grains or masses. Although familiar as a blue, purple, red, or pink gemstone, spinel also occurs in other colors. Red spinel is called ruby spinel; its blood-red color is due to the presence of chromium.

A minor constituent of peridotites (p.266), kimberlites (p.269), basalts (p.273), and other igneous rocks, spinel also forms in aluminum-rich schists (pp.291–92) and metamorphosed limestones. Water-worn crystals come from stream deposits. The earliest known spinel dates back to 100 BCE and was discovered near Kabul, Afghanistan.

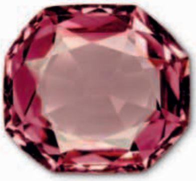

Spinel gemstone This superb faceted spinel shows excellent red-lavender color and good clarity.

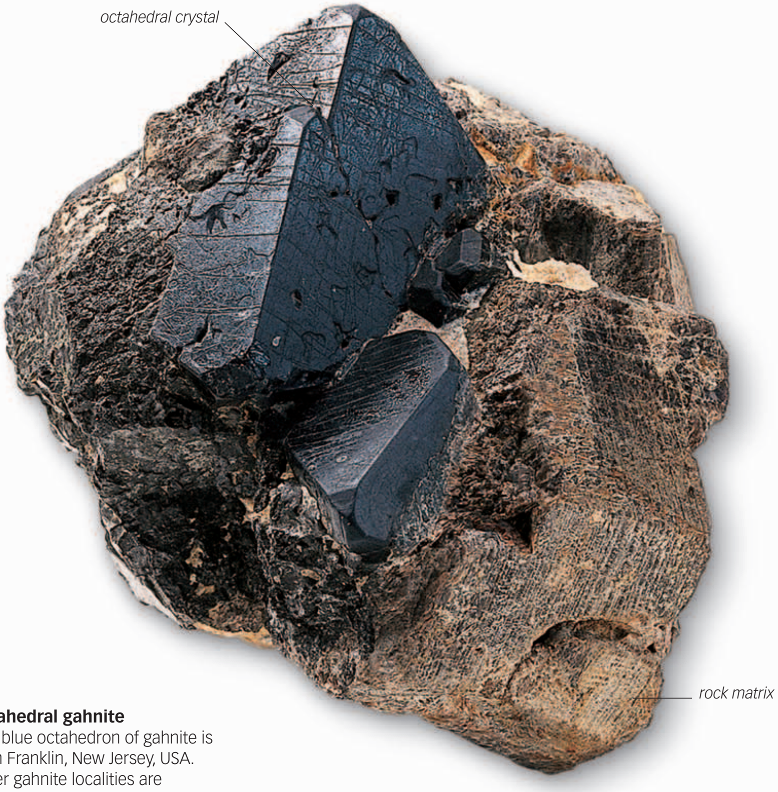

Octahedral gahnite
This blue octahedron of gahnite is from Franklin, New Jersey, USA. Other gahnite localities are Colorado and Maine, USA.

PROFILE

Cubic
7½–8
4.6
Indistinct
Conchoidal, irregular
Grayish
Vitreous

$ZnAl_2O_4$

GAHNITE

A zinc aluminum oxide, gahnite is a member of the spinel group and frequently forms the simple octahedral crystals typical of the group. Crystals usually show good external form. They may be striated on faces and cleavage surfaces. Usually dark green or blue to black in color, they can reach up to 4½in (12cm) on an edge. Crystals can sometimes be gray, yellow, or brown in color. Gahnite also occurs as irregular grains and masses, and in some lithium pegmatites (p.260) as gem-clear nodules.

Gahnite was named in 1807 after the Swedish chemist and mineralogist John Gottlieb Gahn. It is found in crystalline schists (pp.291–92) and gneisses (p.288), in granites (pp.258–59) and granitic pegmatites, and in contact metamorphosed limestones. It sometimes forms from the low-grade metamorphism of bauxite (p.101) and is also found in placer deposits. Superb crystals occur at Salida and Cotopaxi, Colorado, USA; at Falun, Sweden; and at Minas Gerais, Brazil.

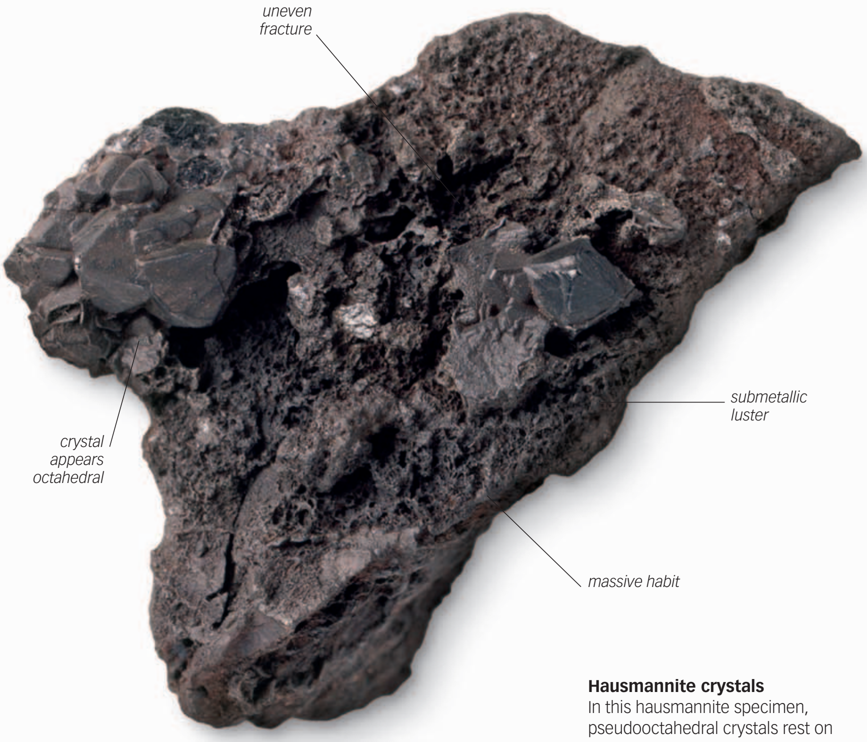

Hausmannite crystals
In this hausmannite specimen, pseudooctahedral crystals rest on a base of massive hausmannite.

PROFILE

Tetragonal
5½
4.8
Perfect
Uneven
Reddish brown
Submetallic

$Mn^{2+}Mn_2^{3+}O_4$

HAUSMANNITE

Named in 1827 after Johann Friedrich Ludwig Hausmann, a German professor of mineralogy, hausmannite is dark brown or black and is usually granular or massive. Well-formed crystals are uncommon yet distinctive. They are pseudooctahedral in shape but often have additional faces. Small amounts of iron and zinc may substitute for manganese in the hausmannite structure. Hausmannite forms in hydrothermal veins, and it also occurs where manganese-rich rocks have been metamorphosed. It is often found associated with other manganese oxides, such as pyrolusite (p.80), romanéchite (p.94), and the manganese–iron mineral bixbyite. Superb crystals, up to 1½in (4cm) long, come from Brazil, South Africa, and Germany.

Hausmannite is an ore of manganese, which is added to aluminum and magnesium alloys to improve corrosion resistance. Manganese oxides are important in the manufacture of steel, where they absorb the sulfur in iron ores and impart strength.

PROFILE

Cubic

5½

4.7

None

Uneven

Brown

Metallic

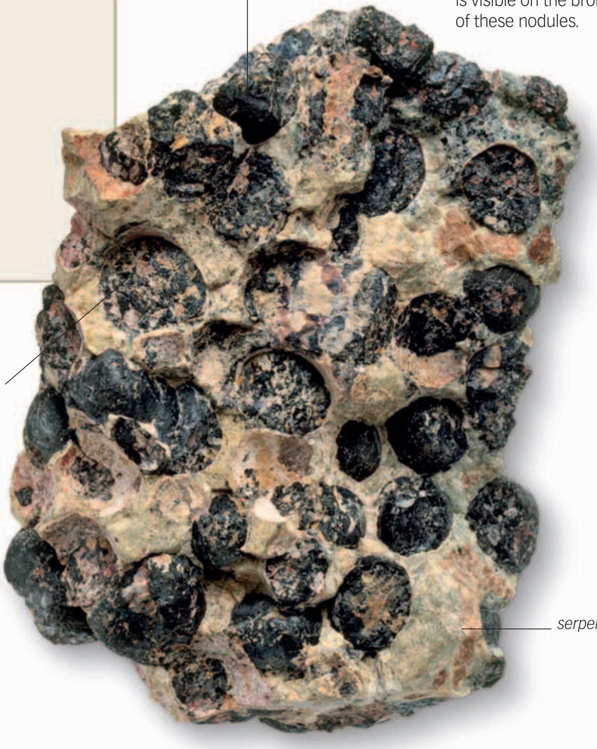

Nodular chromite The metallic luster of chromite is visible on the broken surfaces of these nodules.

VARIANT

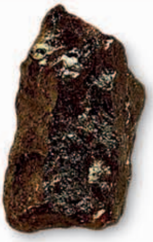

Massive chromite A glossy black specimen of chromite

$FeCr_2O_4$

CHROMITE

A member of the spinel mineral group, chromite is an iron chromium oxide and the most important ore of chromium. Crystals are uncommon, but when found they are octahedral. Chromite is usually massive or in the form of lenses and tabular bodies, or it may be disseminated as granules. It is sometimes found as a crystalline inclusion in diamond. Chromite is dark brown to black in color and can contain some magnesium and aluminum.

Chromite is most commonly found as an accessory mineral in iron- and magnesium-rich igneous rocks or concentrated in sediments derived from them. It occurs as layers in a few igneous rocks that are especially rich in iron and magnesium. Almost pure chromite is found in similar layers in sedimentary rocks. The layers are preserved when the sedimentary rocks metamorphose to form serpentinite (p.298). Referred to as chromitites, these rocks are the most important ores of chromium. The weathering of chromite ore bodies can also lead to its concentration in placer deposits.

HYDROXIDES

Hydroxides form when metallic elements combine with a hydroxyl radical. They are found predominantly as weathering products of other minerals. Hydroxide minerals are usually less dense and softer than oxide minerals. Many hydroxides are important ore minerals.

COMPOSITION

Nearly all hydroxides form at low temperatures (up to 400°F/200°C), when water reacts with an oxide. They contain the hydroxyl radical, which is a single chemical unit made up of one atom of hydrogen and one atom of oxygen.

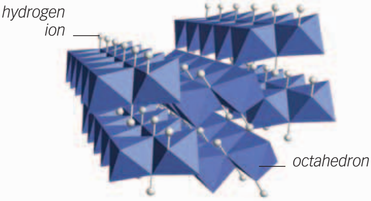

Crystal structure of diaspore
In the aluminum hydroxide diaspore, aluminum ions are in octahedral coordination with hydroxyl groups, forming strips of octahedra.

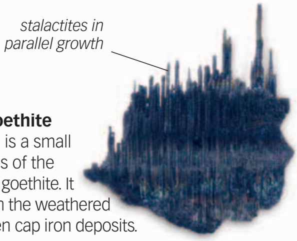

Stalactitic goethite
This specimen is a small stalactitic mass of the iron hydroxide goethite. It mainly forms in the weathered zones that often cap iron deposits.

OCCURRENCE AND USES

Hydroxide minerals are found in most places where water has altered primary oxides. Some hydroxides are also precipitated directly. They are often important ore minerals. The aluminum hydroxides diaspore, bohemite, and gibbsite constitute bauxite, the ore of aluminum. Goethite, an iron hydroxide, is an ore of iron.

UMBER
OCHER

Artists' pigments
Although now mostly replaced by synthetics, goethite (formerly called limonite) has provided the pigment in umbers and ochers for millennia.

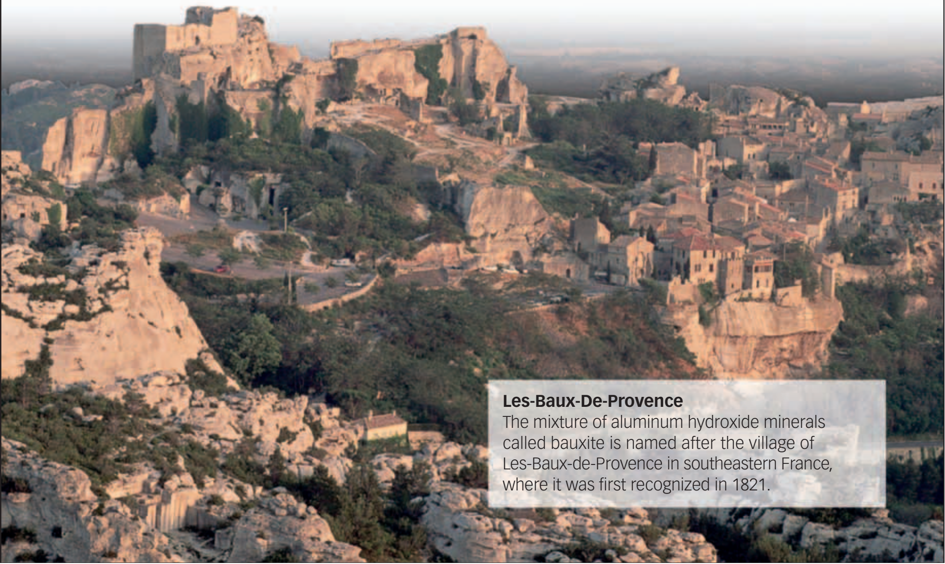

Les-Baux-De-Provence
The mixture of aluminum hydroxide minerals called bauxite is named after the village of Les-Baux-de-Provence in southeastern France, where it was first recognized in 1821.

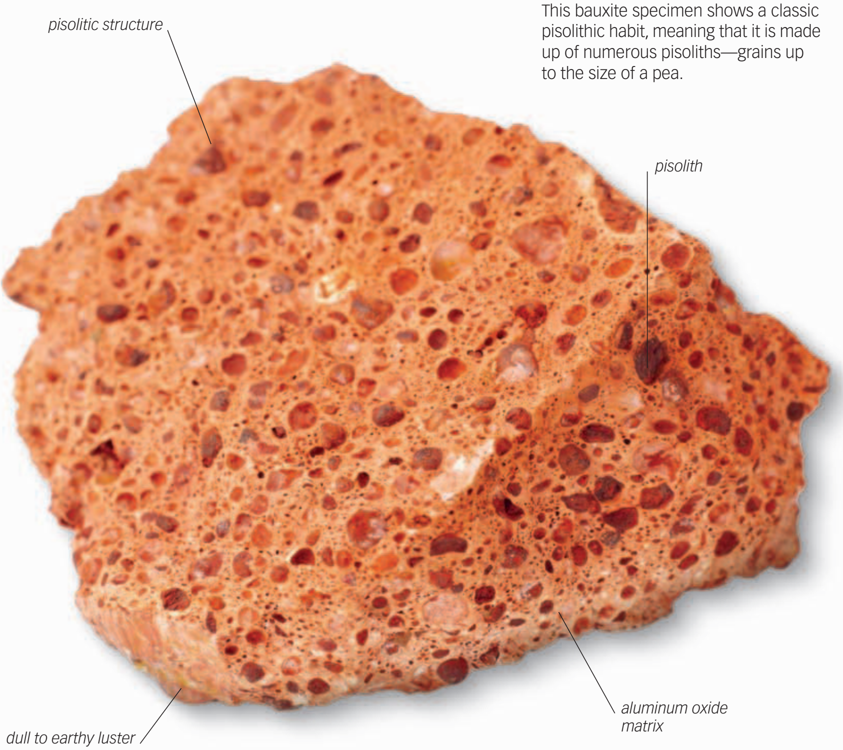

Pisolitic bauxite
This bauxite specimen shows a classic pisolithic habit, meaning that it is made up of numerous pisoliths—grains up to the size of a pea.

PROFILE

Crystal system None

1–3

2.3–2.7

None

Uneven

Usually white

Earthy

VARIANT

Bauxite as an ore Primary ore of the metal aluminum

Mixture of hydrous aluminum oxides

BAUXITE

Although bauxite is not a mineral, it is one of the most important ores because it is the sole source of aluminum. The product of weathering of aluminum-rich rocks, it contains several constituent minerals. Bauxite is variably creamy yellow, orange, pink, or red because of the presence of quartz (p.168), clays, and hematite (p.91) and other iron oxides in addition to several hydrated aluminum oxides.

Bauxite forms as extensive, shallow deposits in humid tropical environments. It may be nodular, pisolitic, or earthy. Deposits are soft, easily crushed, and textureless or hard, dense, and pealike. Bauxite may also be porous but strong and stratified, or it may retain the form of its parent rock.

Versatile aluminum
A key metal of the modern age, aluminum is used to make products ranging from takeout trays to spacecraft.

PROFILE

Orthorhombic

5–5½

4.3

Perfect

Uneven

Brownish yellow to ocher-red

Adamantine to metallic

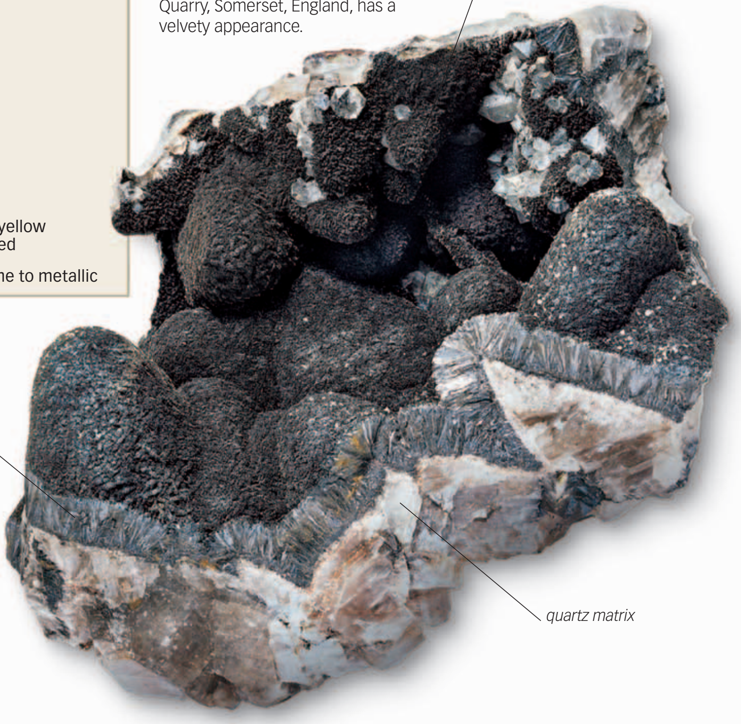

Velvety goethite This botryoidal mass of radiating goethite crystals from Merehead Quarry, Somerset, England, has a velvety appearance.

VARIANTS

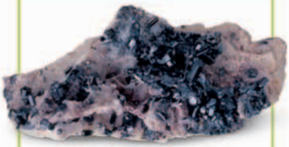

Prismatic crystals Striated crystals in quartz matrix

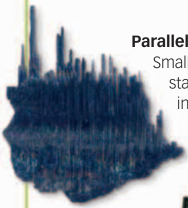

Parallel growth Small goethite stalactites in parallel growth

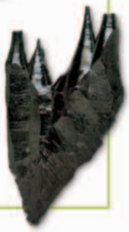

Stalactitic goethite Hard, glossy goethite in classic stalactitic habit

$FeO(OH)$

GOETHITE

Named after the German mineralogist Johann Wolfgang von Goethe in 1806, goethite is a common mineral. It can be brownish yellow, reddish brown, or dark brown in color, depending on the size of the crystal in the specimen—small crystals appear lighter, and larger ones darker. It can occur as opaque black, prismatic and vertically striated crystals; velvety, radiating fibrous aggregates; flattened tablets or scales; and reniform or botryoidal masses. Goethite can also occur in stalactitic or massive forms and in tufts and drusy coatings.

Goethite is an iron oxide hydroxide, although manganese can substitute for up to 5 percent of the iron. It forms as a weathering product in the oxidation zones of veins of iron minerals, such as pyrite (p.62), magnetite (p.92), and siderite (p.123). Goethite may occur with these minerals in the gossan, or iron hat, which is the weathered capping of an iron ore deposit. It also occurs in a form called bog iron ore, which can be produced by living organisms.

PROFILE

Monoclinic
4
4.3
Perfect, good
Uneven
Reddish brown to black
Submetallic

Prismatic manganite This specimen is a mass of pseudoorthorhombic prisms showing typical deep striations on the crystal faces.

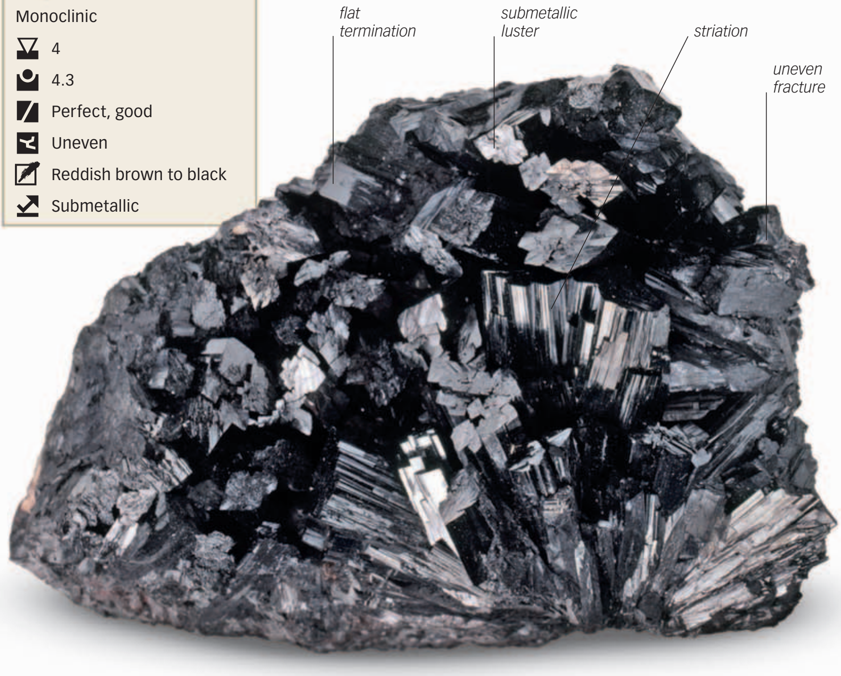

VARIANT

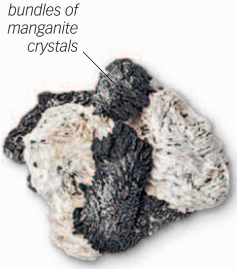

Crystal bundles Manganite crystals grouped in bundles

$MnO(OH)$

MANGANITE

A widespread and important ore of manganese, manganite is hydrated manganese oxide. The mineral had been described by a number of different names since 1772, but was finally given its current name, which it owes to its manganese component, in 1827. Opaque and metallic dark gray or black, crystals of manganite are mostly pseudoorthorhombic prisms, typically with flat or blunt terminations, and are often grouped in bundles and striated lengthwise. Multiple twinning is common. Manganite can also be massive or granular; it is then hard to distinguish by eye from other manganese oxides, such as pyrolusite (p.80).

An important ore of manganese, manganite occurs in hydrothermal deposits formed at low temperature (up to 400°F/200°C) with calcite (p.114), siderite (p.123), and barite (p.134), and in replacement deposits with goethite (p.102). Manganite also occurs in hot-spring manganese deposits. It alters to pyrolusite and may form by the alteration of other manganese minerals.

Dark red diaspore
In this specimen, a mass of dark red, thin, platy diaspore crystals rests in a matrix of corundum.

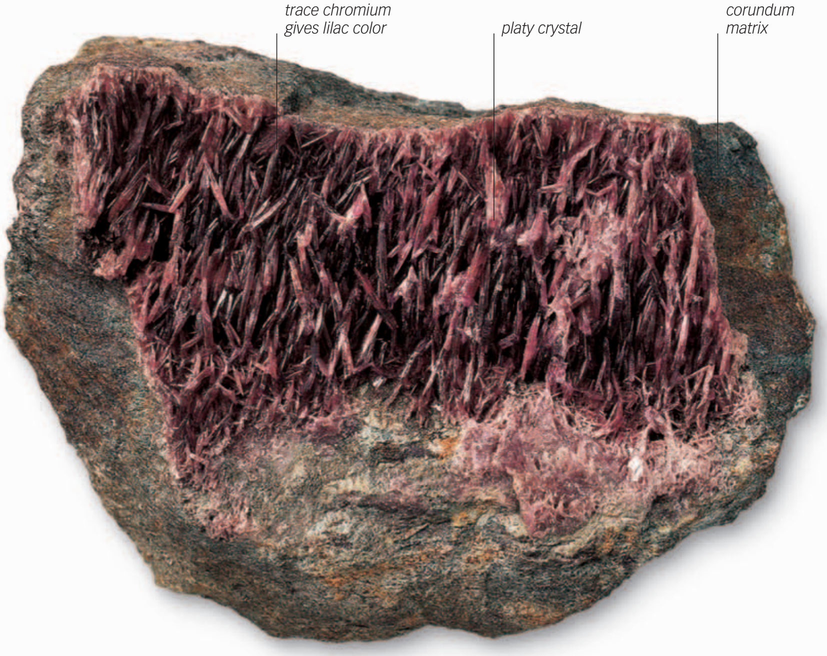

PROFILE

Orthorhombic
6½–7
3.4
Perfect, imperfect
Conchoidal, brittle
White
Vitreous

AlO(OH)

DIASPORE

Diaspore takes its name from the Greek word *diaspora*, which means “scattering”—a reference to the way diaspore crackles and depreciates under high heat. Its crystals are thin and platy, elongated, tabular, prismatic, or needlelike and are often twinned. Diaspore can be massive or can occur as disseminated grains. It may be colorless, white, grayish white, greenish gray, light brown, yellowish, lilac, or pink in color. The same specimen can appear to have different colors when viewed from different directions.

Diaspore forms in metamorphic rocks, such as schists (p.292) and marbles (p.301), where it is often associated with corundum (p.95), spinel (p.96), and manganite (p.103). It is widespread in bauxite (p.101), laterite (p.326), and aluminous clays.

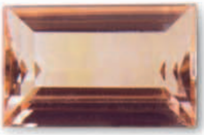
Faceted gem
Zultanite, which is a rare, transparent type of diaspore crystal from Turkey, is a collector’s gem.

PROFILE

Hexagonal

2½

2.4

Perfect

Uneven, sectile

White

Waxy to vitreous/pearly

Fibrous brucite
This fibrous mass of brucite with a vitreous luster is from Timmins, Ontario, Canada.

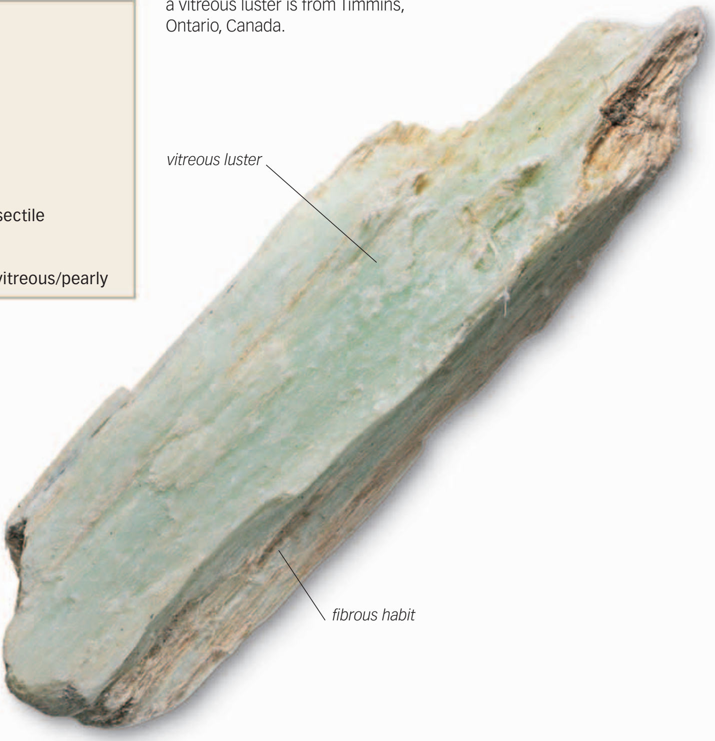

VARIANTS

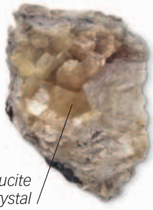

Tabular crystals Tabular brucite in a rock matrix

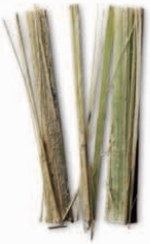

Nemalite A fibrous variety of brucite

$Mg(OH)_2$

BRUCITE

Named after the American mineralogist Archibald Bruce in 1824, brucite is magnesium hydroxide. Usually white, it can be pale green, gray, or blue. Manganese may substitute to some degree for magnesium, producing yellow to red coloration. Its crystals can be tabular or form aggregates of plates. They tend to be soft, and range from waxy to glassy in appearance. Fine large crystals have been collected from nemalite, a variety of brucite that occurs in fibres and laths. Brucite may also occur in massive, foliated, fibrous, or, more rarely, granular habits.

Brucite is found in metamorphic rocks, such as schist (p.292), and in low-temperature hydrothermal veins (up to 400°F/200°C) in marbles (p.301) and chlorite schists. It is used as a primary source of medical magnesia and as a fire retardant.

Kiln lining
Because of its high melting point, brucite is used to line kilns, such as the potter's kiln being used here.

HALIDES

Minerals in this group consist of metals combined with one of the four common halogen elements: fluorine, chlorine, iodine, or bromine. Halides tend to be soft and many crystallize in the cubic system.

COMPOSITION

Compositionally and structurally, there are three broad categories of halide mineral: simple halides, halide complexes, and oxyhydroxy-halides. Simple halides form when a metal combines with a halogen. Halite and fluorite are examples of simple halides. In halide complexes, the halide is usually bound to aluminum, creating a molecule that behaves as a single unit, which is in turn bound to a metal. For example, in cryolite, fluorine and aluminum are bound to sodium. Oxyhydroxy-halides are very rare. Atacamite is an example of these halides.

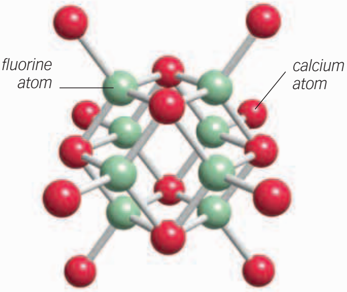

Fluorite crystal structure
In the crystal structure of fluorite, every calcium atom is coordinated with eight fluorine atoms at the corners of a cube. This yields cubic crystals.

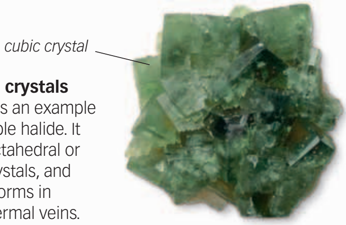

Fluorite crystals
Fluorite is an example of a simple halide. It forms octahedral or cubic crystals, and usually forms in hydrothermal veins.

OCCURRENCE

Many halides occur in evaporite deposits. Others occur in hydrothermal veins or form when halide-bearing waters act upon the oxidation products of other minerals.

USES

Halides are important industrial minerals. Halite, or table salt, is the classic example. Other halides are used as fertilizers, in glass making and metal refining, and as minor ores.

Fertilizing crops
The halides sylvite and carnallite are important sources of potash for fertilizers. Potash reduces many diseases, rot, and mildew of food plants.

Salt Lake
Thick, white crusts of the halide mineral halite encrust rocks along the edge of the Great Salt Lake, Utah, USA.

Granular carnallite
This granular mass of carnallite has a red color due to inclusions of hematite.

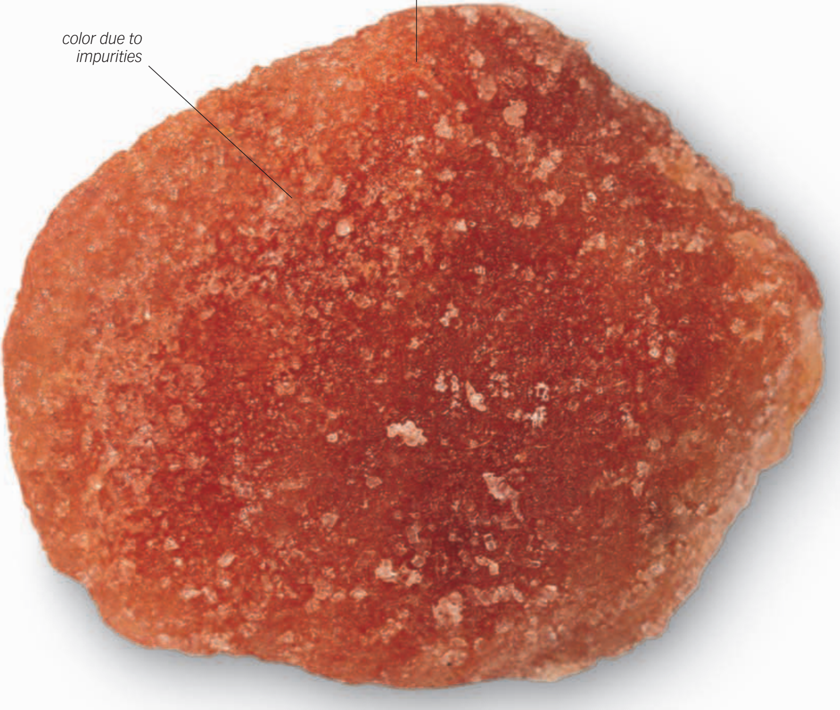

PROFILE

Orthorhombic

2½

1.6

None

Conchoidal

White

Greasy

$KMgCl_3 \cdot 6H_2O$

CARNALLITE

First discovered in Germany, carnallite was named after Rudolph von Carnall, a Prussian mining engineer, in 1856. It is usually white or colorless but may appear reddish or yellowish depending on the presence of hematite (p.91) or goethite (p.102) impurities. Hydrated potassium and magnesium chloride, carnallite is generally massive to granular in habit. Crystals are rare because they absorb water from the air and dissolve. When found, crystals are thick and tabular, pseudohexagonal, or pyramidal.

Carnallite forms in the upper layers of marine evaporite salt deposits, where it occurs with other potassium and magnesium evaporite minerals. The mineral is Russia's most important source of magnesium. Caustic potash, a potassium hydroxide, is produced from carnallite.

Potash fertilizer
Carnallite is an important source of potash, which is used in fertilizers, and caustic potash.

Cryolite crystals
This mass of translucent cryolite crystals on rock has patches of siderite on it.

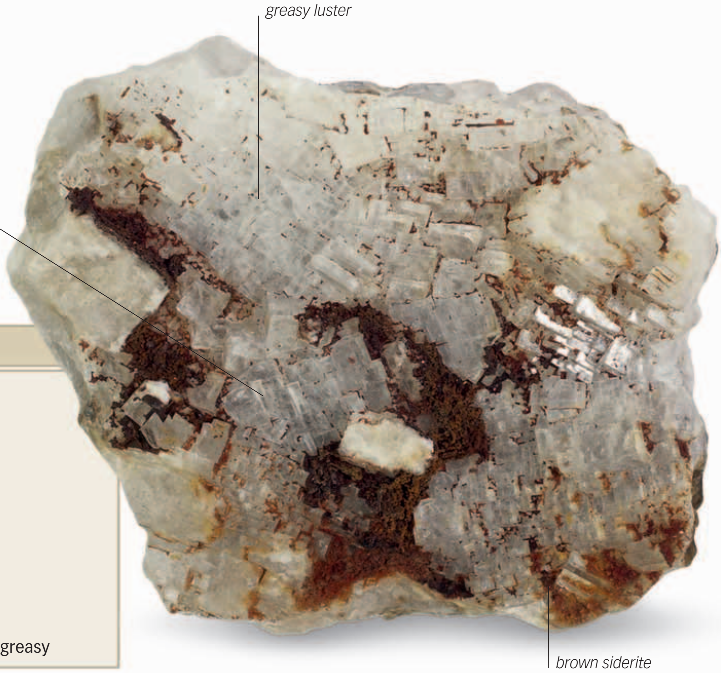

PROFILE

Monoclinic
2½
3.0
None
Uneven
White
Vitreous to greasy

VARIANT

pseudocubic outline
greasy luster

Massive cryolite specimen
A close-up of a massive cryolite fragment

Na_3AlF_6

CRYOLITE

Few people have heard of cryolite, but it is one of the most important minerals of our age. Aircraft could not fly without it, and modern engineering of all kinds would be stunted in its absence. Synthetic cryolite is an essential ingredient in aluminum production. The mineral takes its name from the Greek terms *kryos* and *lithos*, which mean “ice” and “stone”—an allusion to its translucent, icelike appearance. Cryolite is usually colorless or white. Rarely it can be brown, yellow, reddish brown, or black. It occurs commonly as coarse, granular, or massive aggregates and rarely, as pseudocubic crystals.

Cryolite forms mainly in certain granites (pp.258–59) and granitic pegmatites (p.260). The largest deposit of cryolite, at Ivigtut, Greenland, is now exhausted. Lesser amounts are found in Spain, Russia, and the USA.

Cryolite in aviation
Synthetic cryolite is used to separate aluminum—an indispensable metal in aviation—from its ores.

PROFILE

Cubic
4
3.0–3.3
Perfect octahedral
Flat conchoidal
White
Vitreous

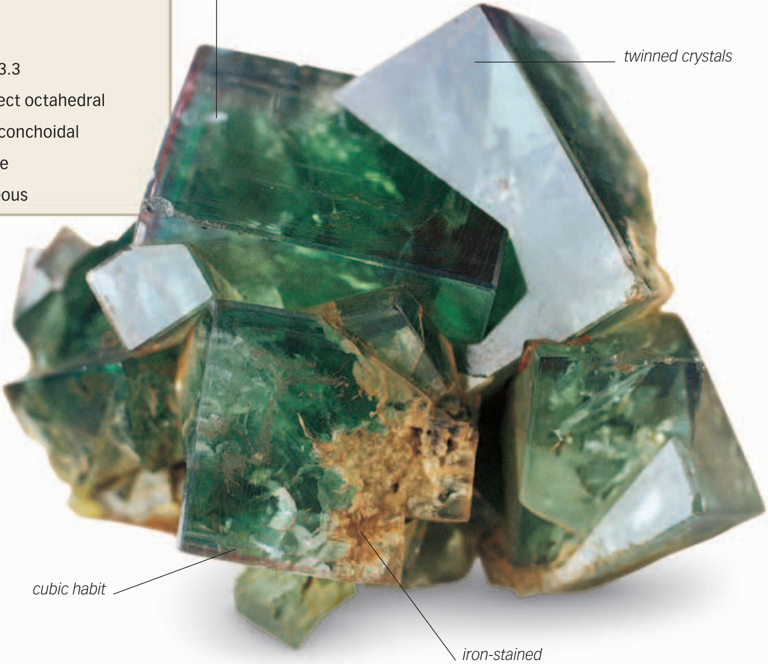

Twinned crystals
This group of fine, green cubic fluorite crystals exhibits the classic penetration twins, which are typical of this mineral.

VARIANTS

Pink octahedron An octahedral crystal of rare pink fluorite

Yellow fluorite A group of bright yellow fluorite cubes

Near-white fluorite A group of unusually colorless cubes

CaF_2

FLUORITE

An important industrial mineral, fluorite used to be known as fluorspar. The name fluorite comes from the Latin word *fluere*, which means “to flow”—a reference to its use in iron smelting to improve the fluidity of slags and the refining of metals. Fluorite commonly occurs as vibrant, well-formed crystals. A single crystal may have zones of different colors that follow the contour of the crystal faces. Fluorite crystals are widely found in cubes, while fluorite octahedra—which are often twinned—are much less common. The mineral can also be massive, granular, or compact.

Fluorite occurs in hydrothermal deposits and as an accessory mineral in intermediate intrusive and silica-rich rocks. It is used in the manufacture of high-octane fuels and steel and in the production of hydrofluoric acid.

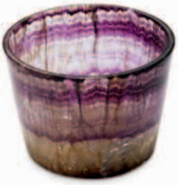

Blue John
Veins of banded purple, white, and yellow fluorite, known as Blue John, are visible in this vessel.

PROFILE

Cubic
2½
2.1–2.6
Perfect cubic
Conchoidal
White
Vitreous

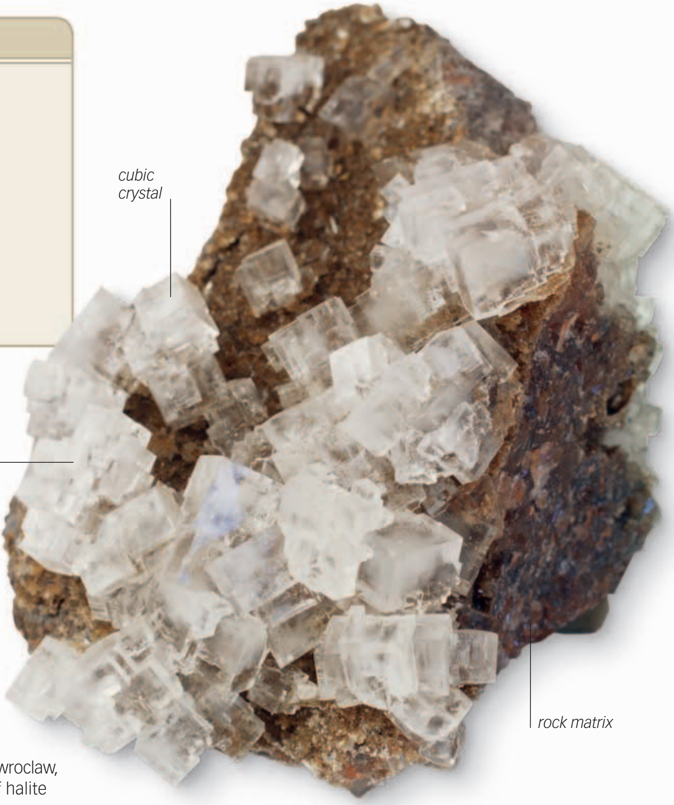

Halite crystals In this specimen from Inowroclaw, Poland, cubic crystals of halite cover a rock matrix.

VARIANTS

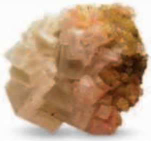
Cubic halite Twinned, cubic crystals on rock matrix

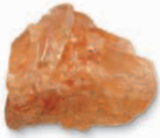
Massive halite A specimen of massive pink halite

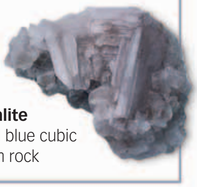
Blue halite Unusual blue cubic halite on rock

NaCl

HALITE

Culinary rock salt is actually halite. Its name is derived from the Greek word *hals*, which means “salt.” Most halite is colorless, white, gray, orange, or brown, but it can also be bright blue or purple. The orange color comes from inclusions of hematite (p.91), while the blue and purple colors indicate defects in the crystal structure. Halite is commonly found in massive and bedded aggregates as rock salt. It also occurs in coarse, crystalline masses or in granular and compact forms.

Halite crystals are usually cubic. Sometimes, halite may form “hopper” crystals—in which the outer edges of the cube faces have grown more rapidly than their centers, leaving cavernous faces. It is widespread in saline evaporite deposits.

Table salt Mined since ancient times and also used as a currency, common table salt is the mineral halite.

PROFILE

Cubic
2½
2.0
Perfect cubic
Uneven
White
Vitreous

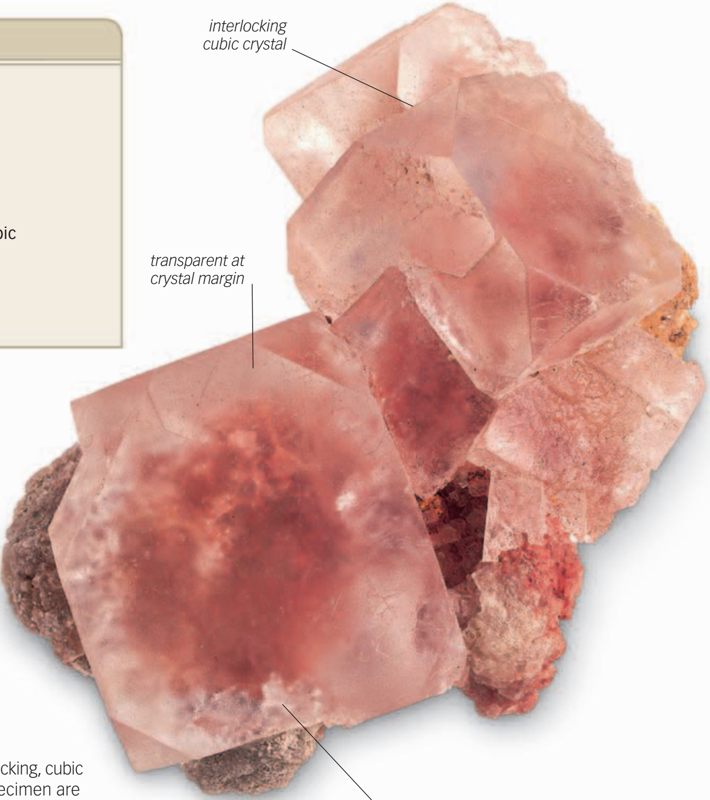

Sylvite crystals The pinkish, interlocking, cubic crystals in this specimen are typical of sylvite.

VARIANT

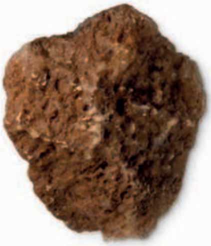

Sylvite in potash A specimen of massive potash containing the mineral sylvite

KCl

SYLVITE

Millions of tons of sylvite are mined annually for the manufacture of potassium compounds, such as potash fertilizers. Sylvite is also used to manufacture metallic potassium. The mineral was first discovered in 1823 on Mount Vesuvius, Italy, where it occurs as encrustations on lava. The name sylvite comes from its Latin medicinal name, *sal digestivus Sylvii*, which means "digestive salt," and it is also known as sylvine. Usually colorless to white or grayish, sylvite can be tinged blue, yellow, purple, or red. Sylvite crystals are cubic, octahedral, or both. It commonly occurs as crusts and as columnar, granular, or massive aggregates.

Sylvite is found in thick beds either mixed or interbedded with halite (p.110), gypsum (p.136), and other evaporite minerals, although it is rarer than halite.

Sylvite fertilizer Crushed potash, as seen here, is used as a fertilizer and comes from the mineral sylvite.

PROFILE

Tetragonal

1–2

6.5

Distinct

Conchoidal

Pale yellow-white

Adamantine

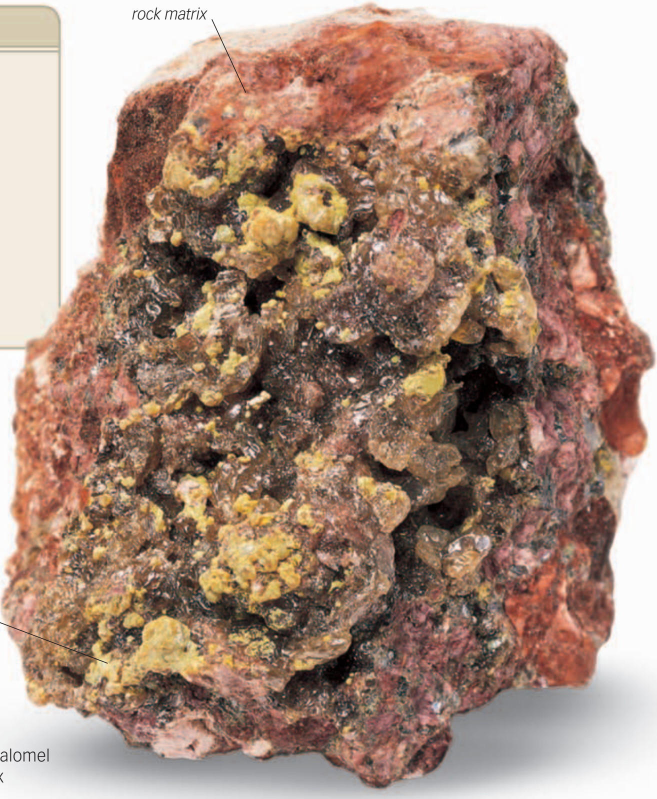

Calomel encrustations
A thin crust of yellowish calomel crystals coats a rock matrix in this specimen.

HgCl

CALOMEL

A mercury chloride, calomel takes its name from two Greek words: *ómorfi*, which means "beautiful," and *méli*, which means "honey"—an allusion to its sweet taste, although it is, in fact, toxic. Calomel is also referred to as horn quicksilver and horn mercury. Specimens are soft, heavy, and plasticlike, with crystals that are pyramidal, tabular, or prismatic, often with complex twinning. Calomel is also found as crusts and can be massive and earthy. It fluoresces brick red.

Calomel occurs as a secondary mineral in the oxidized zones of mercury-bearing deposits, together with native mercury, cinnabar (p.56), goethite (p.102), and calcite (p.114). It was used as a laxative and a disinfectant as well as in the treatment of syphilis from the 16th century until the early 20th century, when the toxic effect of its mercury component was discovered. Calomel's use as a teething powder in Britain was suspended only in 1954, following widespread poisoning. It is still used as an ore of mercury and in insecticides and fungicides.

VARIANT

black calomel crystal

Calomel in matrix Crystals of black calomel in a rock matrix

CARBONATES

There are approximately 80 known carbonate minerals. Most of them are rare, but the common carbonates calcite and dolomite are major rock-forming minerals. Carbonates form rhombohedral crystals and are soft, soluble in hydrochloric acid, and often vividly colored.

COMPOSITION

All carbonates contain the carbonate group CO_3 as the basic compositional and structural unit. This group has a carbon atom in the center of an equilateral triangle of oxygen atoms, giving rise to the trigonal symmetry of many carbonate minerals. This basic unit is joined by one or more metals or semimetals such as calcium, sodium, aluminum, manganese, barium, zinc, and copper.

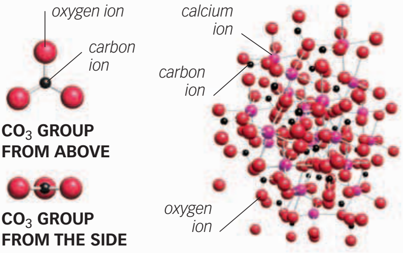

CO_3 GROUP FROM ABOVE

CO_3 GROUP FROM THE SIDE

Calcite crystal sructure
In calcite, three oxygen ions surround each carbon ion in a CO_3 group. Each calcium ion combines with six oxygen ions to form an octahedron.

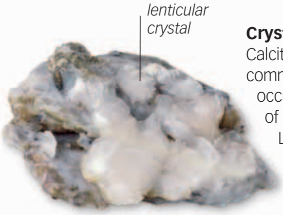

Crystalline calcite
Calcite is the most common carbonate and occurs in a wide range of crystalline forms. Lenticular and scalenohedral crystals are seen in this specimen.

OCCURRENCE

Calcite and dolomite are found in sediments such as chalk and limestone. They also occur in seashells and coral reefs, in evaporate deposits, and in metamorphic rocks, such as marble. Other carbonates, such as rhodochrosite, azurite, and malachite, are principally secondary minerals.

USES

The carbonate minerals calcite and dolomite are important in the manufacture of cement and building stone. Other carbonates find uses as ores of metals: witherite of barium; strontianite of strontium; siderite of iron; rhodochrosite of manganese; smithsonite of zinc; and cerussite of lead.

intricate growth pattern

Malachite jewel box
The copper carbonate malachite has been a favorite carving stone for three millennia.

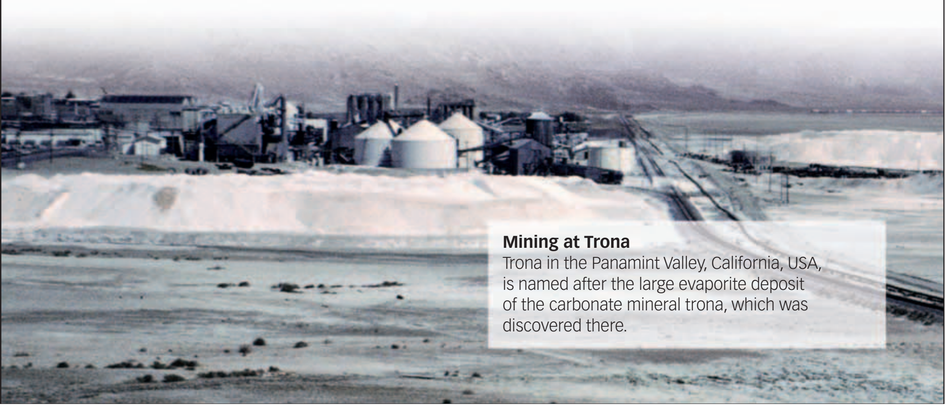

Mining at Trona
Trona in the Panamint Valley, California, USA, is named after the large evaporite deposit of the carbonate mineral trona, which was discovered there.

PROFILE

Hexagonal

3

2.7

Perfect rhombohedral

Subconchoidal, brittle

White

Vitreous

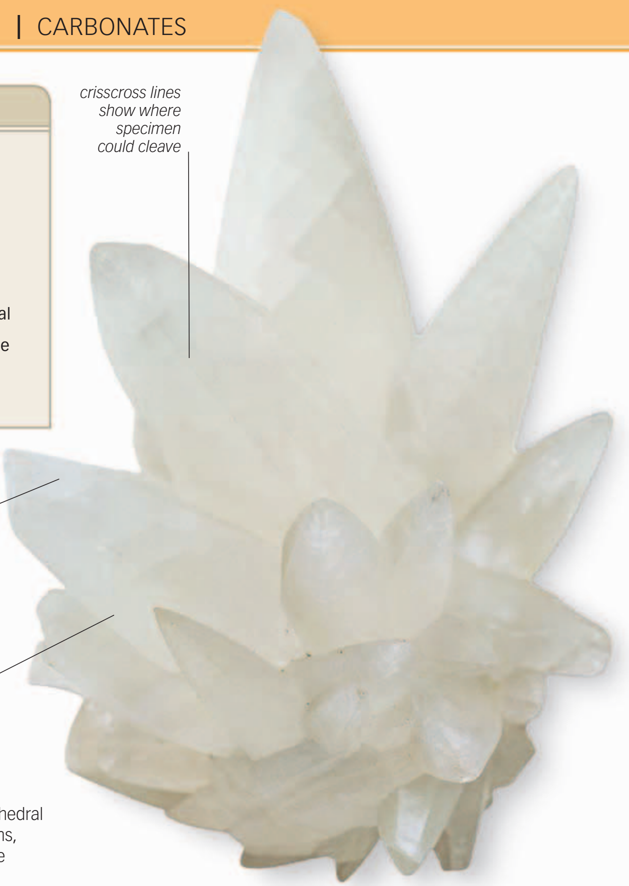
crisscross lines show where specimen could cleave
vitreous luster
group of dogtooth crystals

Dogtooth spar
Crystals with steep, rhombohedral or scalenohedral terminations, such as in this specimen, are known as dogtooth spar.

VARIANTS

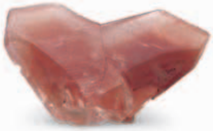

Butterfly twin A twinned, pink crystal of calcite

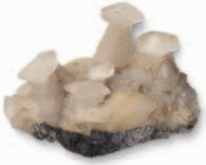

Nailhead spar A rhombohedral calcite crystal on galena

Scalenohedron A single scalenohedral calcite crystal

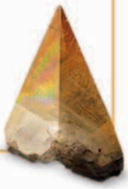

$CaCo_3$

CALCITE

The most common form of calcium carbonate, calcite is known for the variety and beautiful development of its crystals. These occur most often as scalenohedra and are commonly twinned, sometimes forming heart-shaped, butterfly twins. Crystals with rhombohedral terminations are also common; those with shallow rhombohedral terminations are called nailhead spar. Highly transparent calcite is called optical spar.

Although calcite can form spectacular crystals, it is usually massive, occurring either as marble (p.301) or as limestone (p.319). It is also found as fibers, nodules, stalactites, and earthy aggregates. Calcite specimens can occur in metamorphic deposits, igneous rocks, and hydrothermal veins.

Alabaster sphinx
Virtually all ancient Egyptian "alabaster," such as that used to make this small sphinx, was actually calcite.

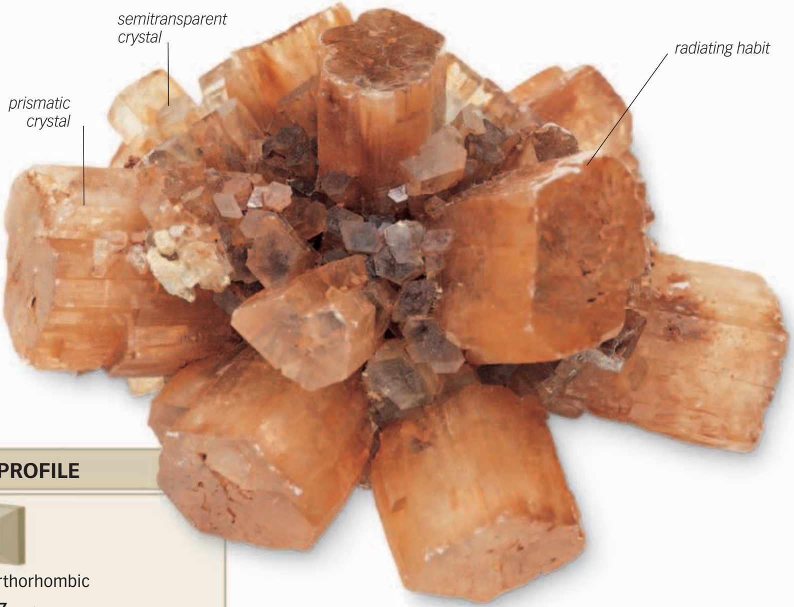

Pseudohexagonal crystals This specimen consists of a radiating group of prismatic, semitransparent, pseudohexagonal, twinned aragonite crystals.

PROFILE

Orthorhombic

3½–4

2.9

Distinct

Subconchoidal, brittle

White

Vitreous inclining to resinous

VARIANTS

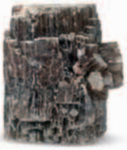

Intergrown crystals A mass of pseudohexagonal crystals of aragonite

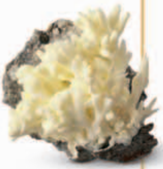

Flos ferri Coral-like aragonite crystals on rock matrix

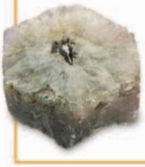

Cyclic twin A classic aragonite cyclic twin from Spain

$CaCo_3$

ARAGONITE

Although aragonite has the same chemical composition as calcite (p.114), its crystals are different. They are tabular, prismatic, or needlelike, often with steep pyramidal or chisel-shaped ends, and can form columnar or radiating aggregates. Multiple twinned crystals are common, appearing hexagonal in shape. Although aragonite sometimes looks similar to calcite, it is easily distinguished by the absence of rhombohedral cleavage. Specimens can be white, colorless, gray, yellowish, green, blue, reddish, violet, or brown.

Aragonite is found in the oxidized zones of ore deposits and in evaporites, hot spring deposits, and caves. It is also found in some metamorphic and igneous rocks. Banded stalactitic aragonite can be polished as an ornamental stone.

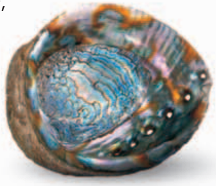

Mother of pearl Aragonite is also produced by some living animals. It is seen here forming the inner layer of a marine mollusk shell.

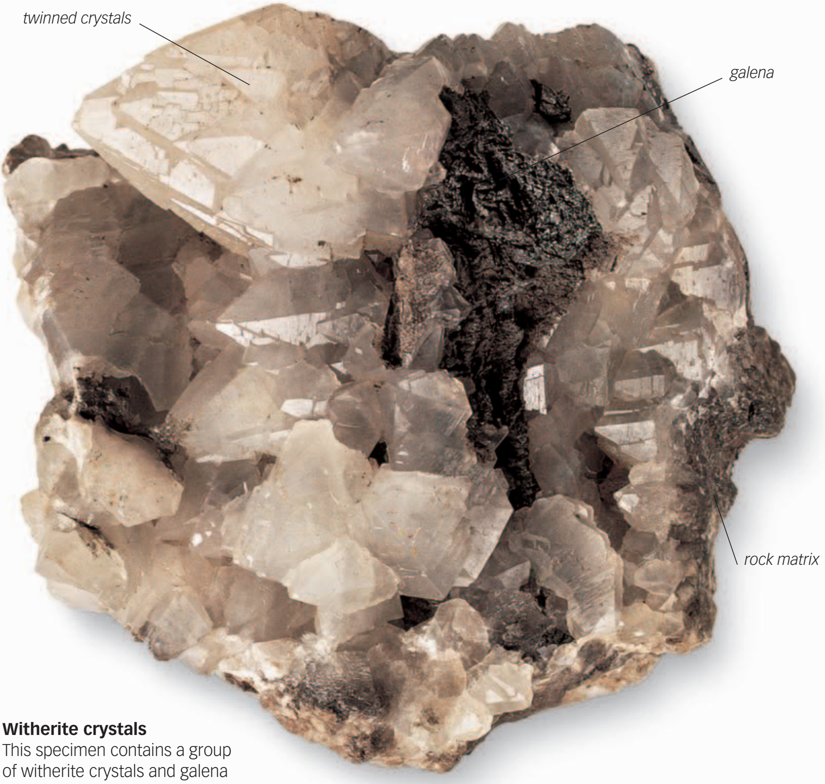

Witherite crystals
This specimen contains a group of witherite crystals and galena on a rock matrix.

PROFILE

Orthorhombic
3–3½
4.3
Distinct, imperfect
Uneven, brittle
White
Vitreous

$BaCo_3$

WITHERITE

This barium carbonate was named in 1790 after the English mineralogist William Withering. Witherite is white, colorless, or tinged yellow, brown, or green. Its crystals are always twinned, either as prisms which appear hexagonal in shape, or as pyramids, which are frequently paired. They can also be short to long prismatic or tabular and may have striations running across the prism faces. Witherite can also be fibrous, botryoidal, spherular, columnar, granular, or massive.

Most witherite comes from hydrothermal veins formed at low temperatures (up to 400°F/200°C), usually resulting from the alteration of baryte (p.134). Specimens feel relatively heavy for their size due to the presence of the high-density element barium. Witherite is preferred over the commonly found barium mineral barite for the preparation of other barium compounds because it is more soluble in acids. These compounds are used in case-hardening steel, in copper refining, in sugar refining, in vacuum tubes, and in many other applications.

PROFILE

Hexagonal

3½–4

2.8–2.9

Perfect rhombohedral

Subconchoidal

White

Vitreous

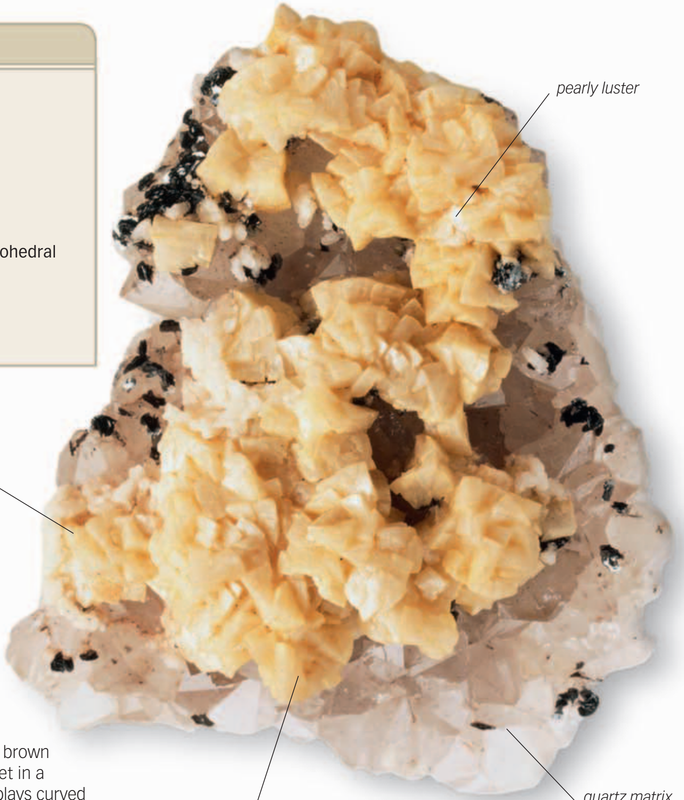

Pink dolomite This specimen of pale brown dolomite crystals is set in a quartz matrix and displays curved crystal faces.

VARIANT

saddle-shaped crystal

Tabular crystals Pink, saddle-shaped, tabular crystals of dolomite in a crustlike form

$CaMg(CO_3)_2$

DOLOMITE

An important rock-forming mineral, dolomite is named after the French mineralogist Déodat Gratet de Dolomieu. It is a colorless to white, pale brown, grayish, reddish, or pink mineral. Its crystals are commonly rhombohedral or tabular, often have curved faces, and sometimes cluster in saddle-shaped aggregates. Dolomite may be striated horizontally and twinned. Some crystals may be up to 2 in (5 cm) long. It can also be coarse to fine granular, massive, and, rarely, fibrous.

Dolomite is the main constituent in dolomite rocks and dolomitic marbles. It occurs as a replacement deposit in limestone (p.319) affected by magnesium-bearing solutions, in talc schists, and in other magnesium-rich metamorphic rocks. Dolomite is found in hydrothermal veins associated with lead, zinc, and copper ores. It is also found in altered, silica-poor igneous rocks, in some carbonatites (p.272), and in serpentinites (p.298). Crystals of dolomite frequently form in cavities in limestone and marble (p.301).

PROFILE

Hexagonal

4

3.0

Perfect rhombohedral

Conchoidal, brittle

White

Vitreous

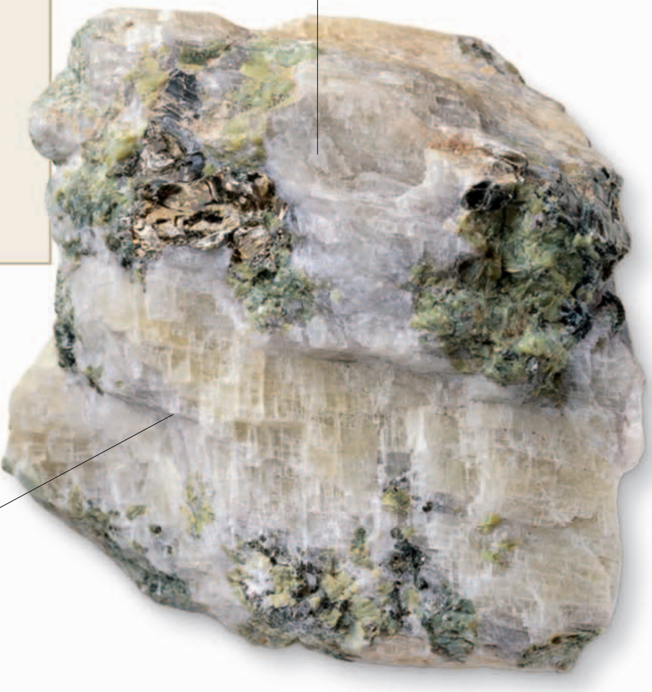

Magnesite crystals
This crystalline mass of magnesite is on a rock matrix.

VARIANT

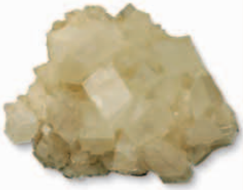

Rhombohedral magnesite
Rare, rhombohedral crystals of the colorless form of magnesite

$MgCO_3$

MAGNESITE

This carbonate of magnesium takes its name from its magnesium component. It is generally massive, lamellar, fibrous, chalky, or granular. Distinct crystals are rare, but when found they are either rhombohedral or prismatic. Most commonly white or light gray, magnesite can be yellow or brownish when iron substitutes for some of the magnesium.

Magnesite forms mainly as an alteration product in magnesium-rich rocks, such as peridotites (p.266). It can occur as a primary mineral in limestones (p.319) and talc or chlorite schists, in cavities in volcanic rocks, and in oceanic salt deposits. It is also found in some meteorites (pp.335–37). An important source of magnesium, magnesite is used as a refractory material, as a catalyst and filler in the production of synthetic rubber, and in the manufacture of chemicals and fertilizers. Magnesium derived from magnesite is alloyed with aluminum, zinc, or manganese for use in aircraft, spacecraft, road vehicles, and household appliances.

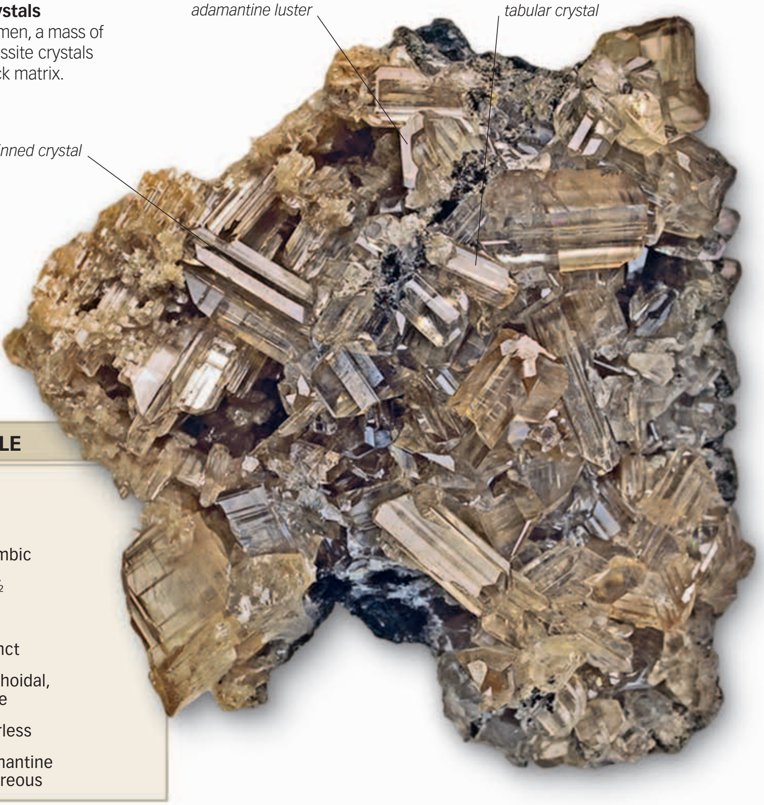

Tabular crystals
In this specimen, a mass of tabular cerussite crystals covers a rock matrix.

PROFILE

Orthorhombic

3–3½

6.5

Distinct

Conchoidal, brittle

Colorless

Adamantine to vitreous

VARIANTS

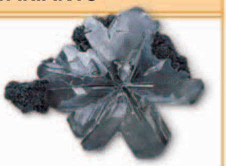

Cyclic twin A star-shaped, crystalline specimen of cerussite from Zambia

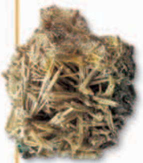

Jack-straw cerussite Delicate, needlelike crystals of jack-straw cerussite

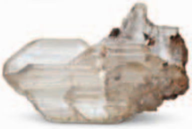

Prismatic crystal A striated, colorless, prismatic crystal of cerussite

$PbCO_3$

CERUSSITE

Known since antiquity, cerussite is named after the Latin word *cerussa*, which describes a white lead pigment. After galena (p.54), it is the most common ore of lead. Cerussite is generally colorless or white to gray, but may be blue to green due to copper impurities. Its crystal habits are highly varied. Cerussite forms tabular or pyramidal crystals or, sometimes, twins that may be star-shaped or reticulated (netlike) masses. Fragile aggregates of randomly grown prismatic crystals known as jack-straw cerussite are also common. The adamantine luster of cerussite crystals is particularly bright.

A widespread secondary mineral that occurs in the oxidation zones of lead veins, cerussite is formed by the action of carbonated water on other lead minerals, particularly galena and anglesite (p.132).

Collector's gem Faceted cerussite stones, such as this rare gem, are brilliant but too soft to be worn.

PROFILE

Monoclinic
3½–4
3.8
Perfect
Conchoidal, brittle
Blue
Vitreous to dull earthy

Large crystals
In this specimen of azurite, large, well-formed crystals rest on a goethite matrix.

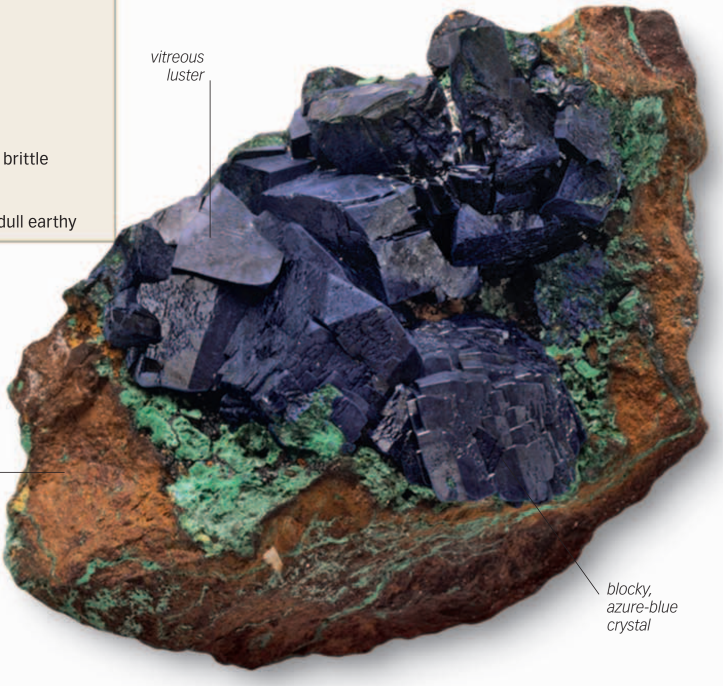

VARIANTS

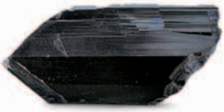

Bladed crystal A single, bladed azurite crystal

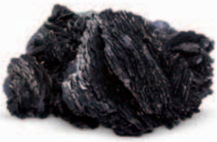

Tabular crystals Thin, parallel azurite crystals on a rock matrix

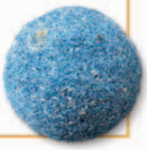

Radiating crystals A spherical concretion of azurite

$Cu_3(CO_3)_2(OH)_2$

AZURITE

A deep blue copper carbonate hydroxide, azurite was used as a blue pigment in 15th- to 17th-century European art and probably in the production of blue glaze in ancient Egypt. It takes its name from the Persian word *lazhuward*, which means "blue." Azurite forms either tabular or prismatic crystals with a wide variety of habits. Tabular crystals commonly have wedge-shaped terminations. Azurite forms rosette-shaped crystalline aggregates or occurs in massive, stalactitic, or botryoidal forms. Well-developed crystals are dark azure blue in color, but massive or earthy aggregates may be paler.

Azurite is a secondary mineral formed in the oxidized portions of copper deposits. Massive azurite used for ornamental purposes is sometimes called chessylite, after Chessy, France.

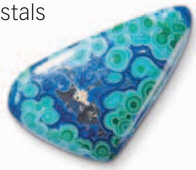

Cabochon gemstone This cabochon exhibits the vivid blue color of azurite and the green color of malachite.

PROFILE

Hexagonal
3½–4
3.6
Perfect rhombohedral
Uneven
White
Vitreous to pearly

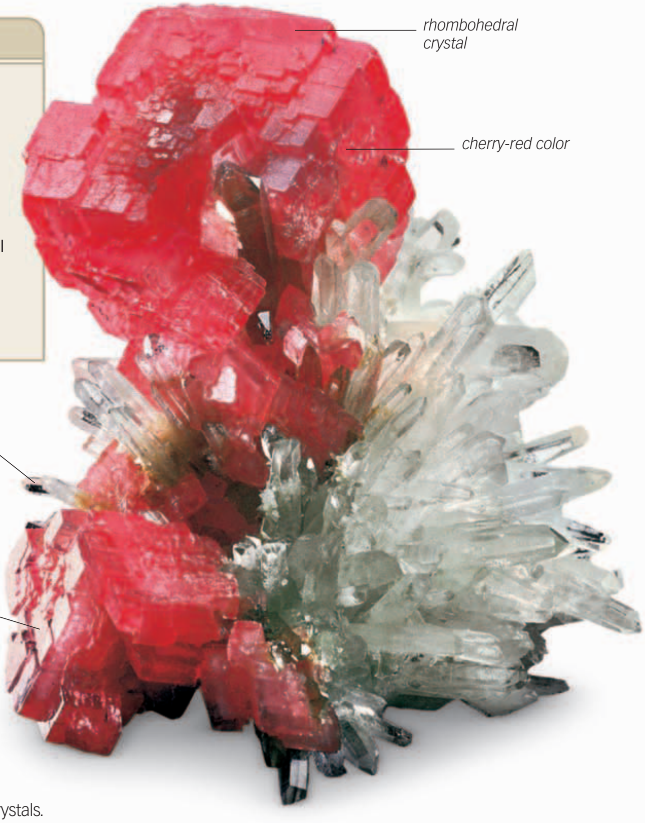

Spectacular crystal This group of rhodochrosite rhombohedrons from Peru is perched on radiating quartz crystals.

VARIANTS

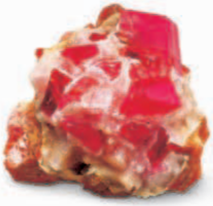

Classic crystals Rhombohedral rhodochrosite in classic rose-pink color

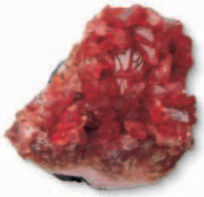

Red rhodochrosite Bright, cherry-red color typical of many manganese minerals

$MnCO_3$

RHODOCHROSITE

A prized collectors' mineral, rhodochrosite is a manganese carbonate. It was given its name—derived from the Greek *rhodokhros*, which means "of rosy color"—in 1800. Rhodochrosite has a classic rose-pink color, but specimens can also be brown or gray. It forms dogtooth or rhombohedral crystals like calcite (p.114), but it may also occur in stalactitic, granular, nodular, botryoidal, and massive habits.

Rhodochrosite is found in hydrothermal ore veins with sphalerite (p.53), galena (p.54), fluorite (p.109), and manganese oxides. It also occurs in metamorphic deposits and as a secondary mineral in sedimentary manganese deposits. Abundant at Butte, Montana, and other localities, rhodochrosite is sometimes mined as an ore of manganese.

Rhodochrosite carvings These two decorative ducks were carved from banded rhodochrosite and white calcite.

Ankerite rhombohedra
This group of ankerite rhombohedra is set in a rock matrix.

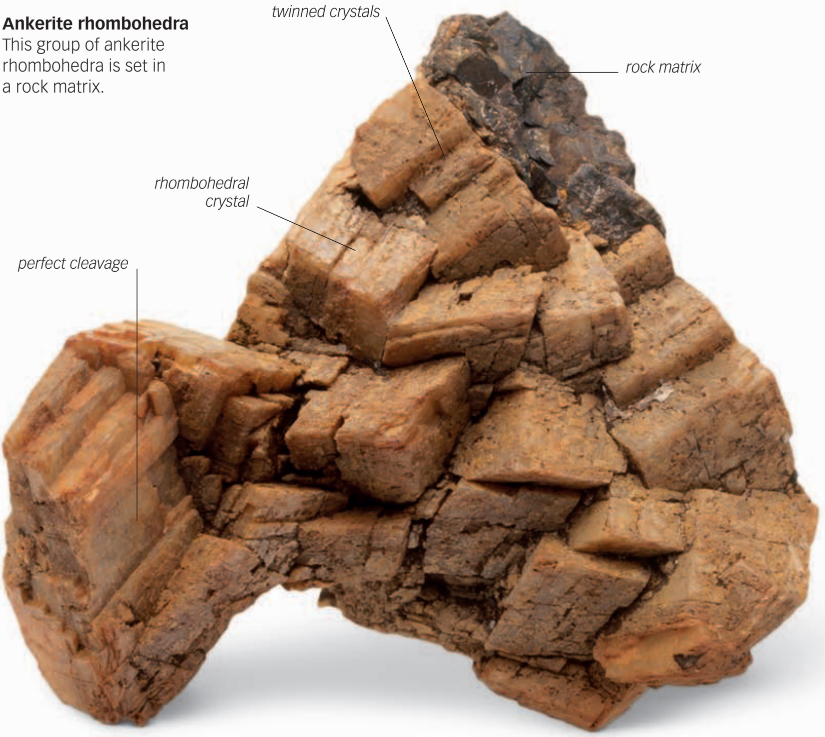

PROFILE

Hexagonal
3½–4
2.9
Perfect
Subconchoidal
White
Vitreous to pearly

$Ca(Fe,Mg,Mn,)(CO_3)_2$

ANKERITE

Considered a rock-forming mineral, ankerite is calcium carbonate with varying amounts of iron, magnesium, and manganese in its structure. It was named in 1825 after the Austrian mineralogist M.J. Anker. Although usually pale buff in color, ankerite can be colorless, white, gray, or brownish. Much ankerite becomes dark on weathering, and many specimens are fluorescent. Ankerite forms rhombohedral crystals similar to those of dolomite (p.117), often with similarly curved faces forming saddle-shaped groups; it can also form prismatic crystals. However, ankerite is more commonly massive or coarsely granular.

Ankerite forms as a secondary mineral from the action of iron- and magnesium-bearing fluids on limestone (p.319) or dolomite rock (p.320). It is a waste mineral in hydrothermal ore deposits and also occurs in carbonatites (p.272), low-grade metamorphosed ironstones, and banded ironstone formations (p.329). Ankerite is also found in iron ore deposits with siderite (p.123).

PROFILE

Hexagonal

3½–4

3.9

Perfect rhombohedral

Uneven or subconchoidal

White

Vitreous to pearly

Rhombohedral crystals This group of well-formed siderite rhombohedra with many twinned crystals rests on a rock matrix.

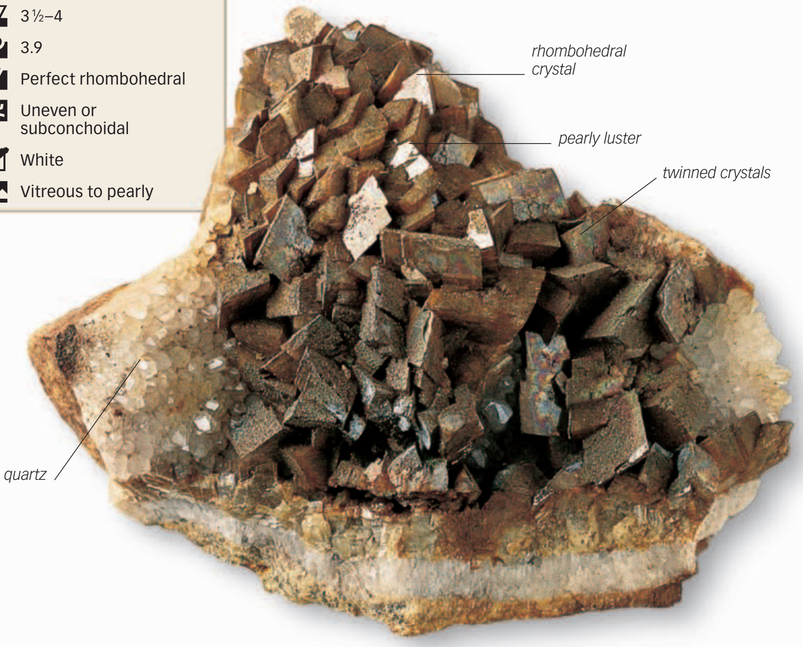

VARIANTS

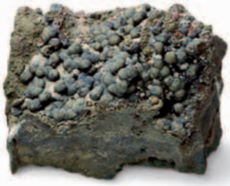

Botryoidal siderite Grapelike siderite bunches on a base of massive siderite

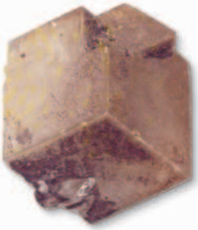

Single crystal A large, rhombohedral, single crystal of siderite

$FeCO_3$

SIDERITE

An ore of iron, **siderite takes its name** from the Greek word *sideros*, which means “iron.” Formerly known as chalybite, siderite can form rhombohedral crystals, often with curved surfaces. The mineral can also form scalenohedral, tabular, or prismatic crystals. Single crystals up to 6 in (15 cm) long are found in Quebec, Canada. However, siderite is more commonly massive or granular and sometimes botryoidal or globular in habit.

A widespread mineral, siderite occurs in igneous, sedimentary, and metamorphic rocks. In sedimentary rocks, siderite occurs in concretions (p.333) and in thin beds with coal (p.253) seams, shale (p.313), and clay. Well-formed crystals are found in hydrothermal metallic veins and in some granitic and syenitic pegmatites (p.260). An outcrop of siderite originally mined for iron by American colonists is still visible at Roxbury, Connecticut. Rare transparent siderite is sometimes cut as gemstones for collectors.

PROFILE

Hexagonal
4–4½
4.4
Perfect rhombohedral
Uneven to conchoidal
White
Vitreous to pearly

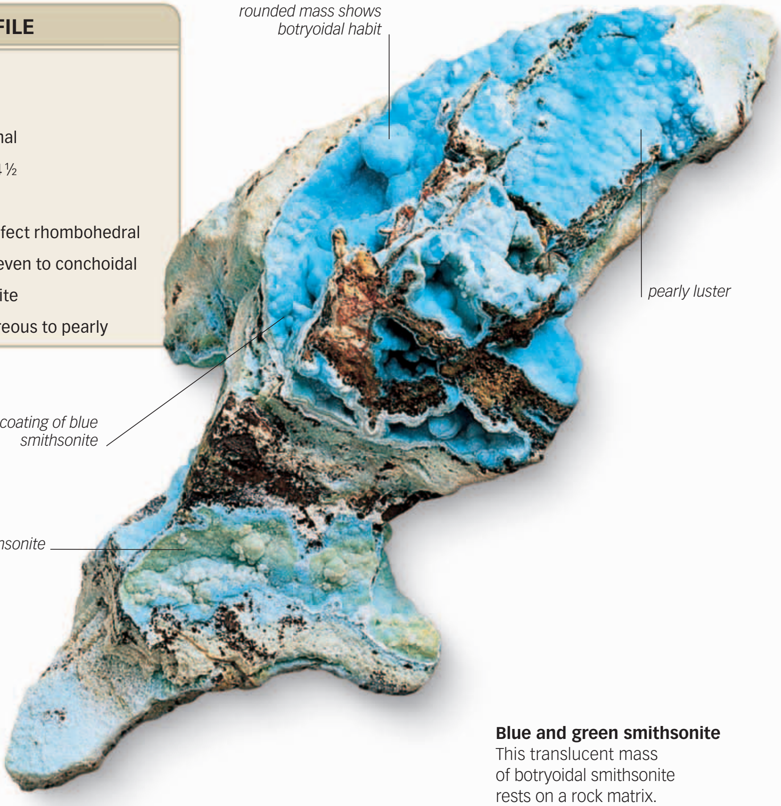
rounded mass shows botryoidal habit
pearly luster
coating of blue smithsonite
green smithsonite

Blue and green smithsonite This translucent mass of botryoidal smithsonite rests on a rock matrix.

VARIANT

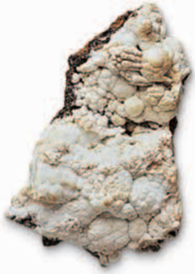

White smithsonite A mass of earthy smithsonite on a rock matrix

$ZnCo_3$

SMITHSONITE

An ore of zinc that continues to be frequently mined, smithsonite may have provided the zinc component of brass in ancient metallurgy. Specimens can be of various colors, such as yellow, orange, brown, pink, lilac, white, gray, green, and blue. Although smithsonite rarely forms crystals, when found, they are prismatic, rhombohedral, or scalenohedral and often have curved faces. A zinc carbonate, smithsonite commonly occurs as massive, botryoidal, spherular, or stalactitic masses, or sometimes, as honeycombed aggregates called dry-bone ore.

Smithsonite is a common mineral, found in the oxidation zones of many zinc ore deposits and in adjacent calcareous rocks. It is often found with malachite (p.125), azurite (p.120), pyromorphite (p.151), cerussite (p.119), and hemimorphite (p.227).

Cabochon Soft smithsonite is occasionally cut into cabochon gemstones for collectors.

PROFILE

Monoclinic

3½–4

3.9–4.0

Perfect

Subconchoidal to uneven, brittle

Pale green

Adamantine to silky

Botryoidal malachite
This specimen of malachite on chrysocolla is from Etoile du Congo Mine in Katanga province, Congo.

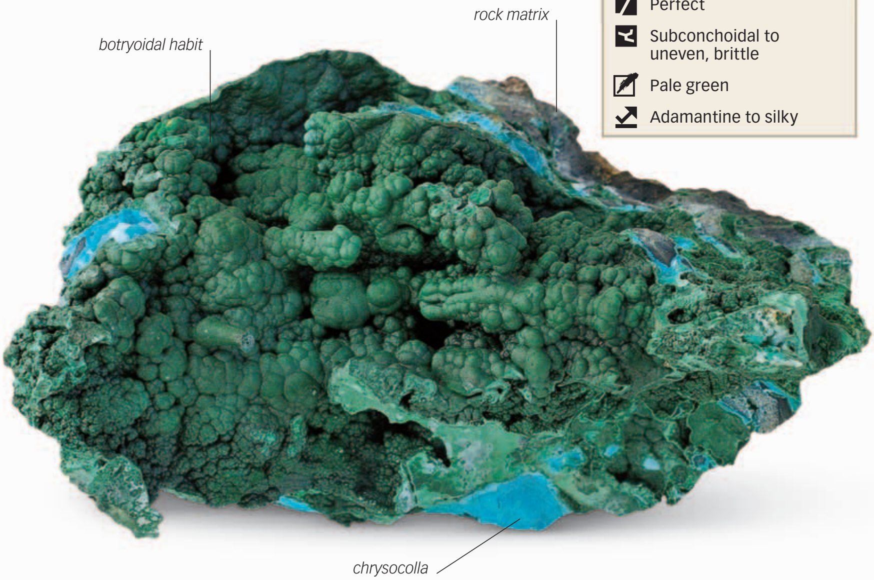

VARIANTS

Fibrous malachite
A radiating group of fibrous malachite crystals

Stalactitic malachite
A group of radiating, fibrous malachite crystals

Malachite section
A section cut through a malachite stalactite

$Cu_2CO_3(OH)_2$

MALACHITE

Possibly the earliest ore of copper, malachite is believed to have been mined in the Sinai and eastern deserts of ancient Egypt from as early as 3000 BCE. Single crystals are uncommon; when found, they are short to long prisms. Malachite is usually found as botryoidal or encrusting masses, often with a radiating fibrous structure and banded in various shades of green. It also occurs as delicate fibrous aggregates and as concentrically banded stalactites.

Malachite occurs in the altered zones of copper deposits, where it is usually accompanied by lesser amounts of azurite (p.120). It is primarily valued as an ornamental material and gemstone. Single masses that weighed up to 51 tons were found in the Ural Mountains of Russia in the 19th century.

Polished malachite
This specimen of the mineral malachite has been polished to show dark and light color bands.

BORATES

Borate minerals are compounds containing boron and oxygen. Most borate minerals are rare, but a few, such as borax, ulexite, colemanite, and kernite, form large, commercially mined deposits. Borates tend to be soft and either white or colorless.

COMPOSITION

Structurally, boron and oxygen may form a triangle (BO_3) or a tetrahedron (BO_4), each with a boron atom. These structures act as a single chemical unit that bonds to a metal, such as sodium in borax and calcium in colemanite. Borates tend to contain water molecules or a hydroxyl (OH) group, which acts as a chemical unit bonded into their structure. Some borates contain both.

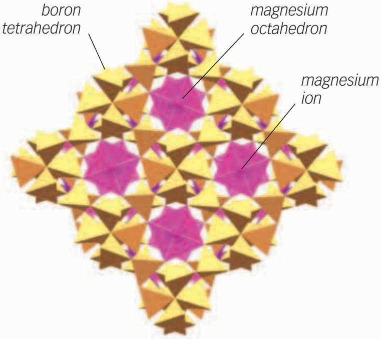

Crystal structure of boracite
In boracite, densely packed boron tetrahedra combine with the metals magnesium and iron (not shown). The borate radical is in the form of tetrahedra.

OCCURRENCE AND USES

Borates appear in two geologic environments. In the first, borate-bearing solutions that result from volcanic activity flow into a closed basin, where evaporation takes place. Basin deposits usually occur in desert regions, such as the Mojave Desert and Death Valley in California. Borax, ulexite, and colemanite occur in these evaporate deposits. In the second environment, borate minerals are formed as a result of rocks being altered by heat and pressure at relatively high temperatures (1,065°F/575°C or above).

Borates are used as pottery glazes, solvents for metal-oxide slags in metallurgy, welding fluxes, fertilizer additives, soap supplements, and water softeners.

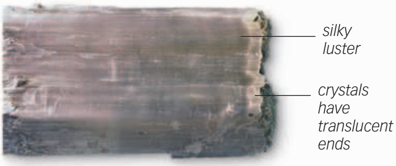

Ulexite
This is a classic evaporite borate. A hydrous sodium calcium borate, ulexite can form parallel, fibrous crystals that act as fiberoptics when viewed from an end.

Fireworks
Boron carbide is used to give a green color to fireworks, in place of the toxic barium compounds that were once used.

Borax crust
This crust formed at the edge of Searles Lake in southern California, USA, is principally composed of borax, a borate produced by evaporation.

Borax crystals
This group of prismatic borax crystals coated with an opaque layer of tincalconite is set on a rock matrix.

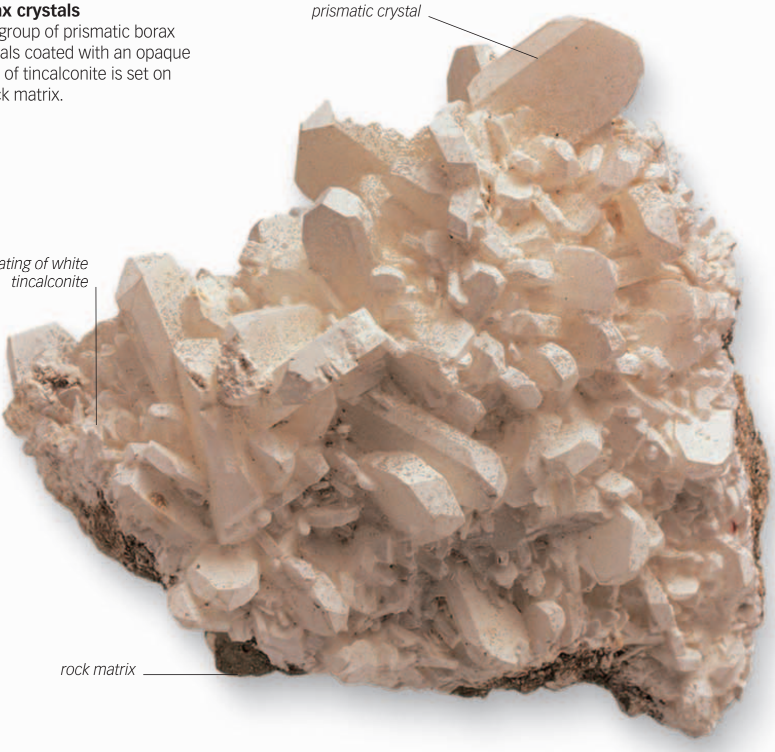

PROFILE

Monoclinic

2–2½

1.7

Perfect, imperfect

Conchoidal

White

Vitreous to earthy

$Na_2B_4O_5(OH)_4 \cdot 8H_2O$

BORAX

An important source of boron, borax has been mined since ancient times. A hydrated sodium borate, borax's colorless crystals dehydrate in air to become the chalky mineral tincalconite. Specimens can also be white, gray, pale green, or pale blue. Borax has short prismatic to tabular crystals, although in commercial deposits it is predominantly massive.

Borax is an evaporite formed in dry lake beds with halite (p.110) and other borates and evaporite sulfates and carbonates. It is used in metal-casting and steel-making. Molten borax beads were historically used to test the composition of other minerals—powdered minerals were fused with the beads, and color change in the beads revealed what the minerals contained.

Boron soap
Compounds derived from borax and, to a lesser extent, ulexite, are key components of many soaps.

PROFILE

Monoclinic

2½

2.0

Perfect

Uneven

White

Vitreous to silky

Ulexite slice This ulexite specimen has a fibrous structure and has been sliced and polished to show its fiberoptic effect.

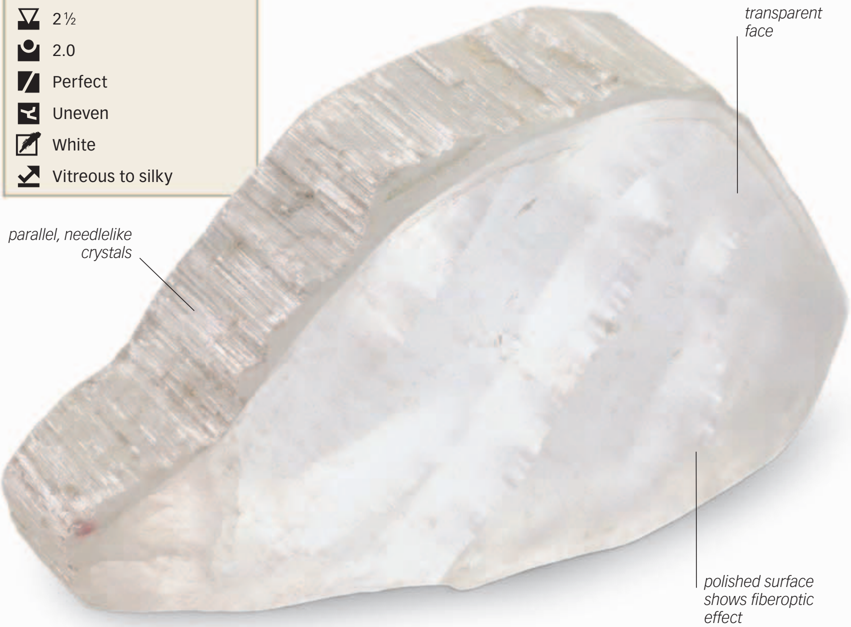

transparent face

parallel, needlelike crystals

polished surface shows fiberoptic effect

VARIANT

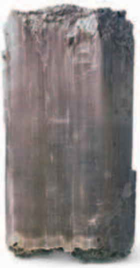

Fibrous crystals Parallel, fibrous ulexite crystals with a silky luster

$NaCaB_5O_6(OH)_6{\cdot}H_2O$

ULEXITE

An important economic borate mineral, ulexite is named after the German chemist George Ludwig Ulex, who determined its composition in 1850. It is either colorless or white and has a number of habits. It is commonly found in nodular, rounded, or lenslike crystal aggregates, which often resemble balls of cotton. Less commonly, ulexite is found in dense veins of parallel fibers known as television stone because the fibers transmit light from one end of the crystal to the other. Ulexite also occurs in radiating or compact aggregates of crystals.

Ulexite is found in playa lakes and other evaporite basins in deserts, where it is derived from hot, boron-rich fluids. The mineral commonly occurs with colemanite (p.130), anhydrite (p.133), and glauberite (p.141).

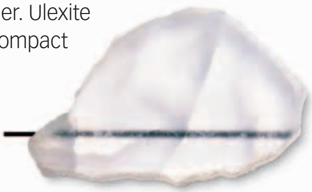

Television stone An unusual property of the form of ulexite shown above is its ability to "transmit" images.

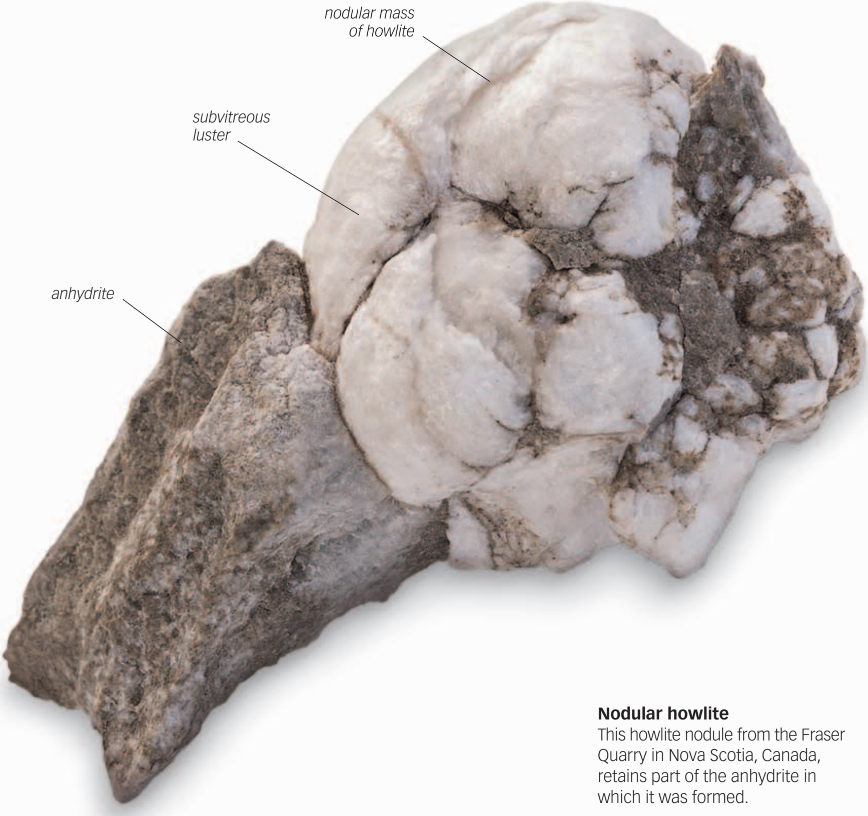

Nodular howlite
This howlite nodule from the Fraser Quarry in Nova Scotia, Canada, retains part of the anhydrite in which it was formed.

PROFILE

Monoclinic
3½
2.6
None
Conchoidal to uneven
White
Subvitreous

$Ca_2B_5SiO_9(OH)_5$

HOWLITE

Named in 1868 after the Canadian chemist, geologist, and mineralogist Henry How, howlite is a calcium borosilicate hydroxide. It generally forms cauliflowerlike nodular masses. The nodules are white, with fine gray or black veins of other minerals running across in an erratic, often weblike pattern. Crystals are rare, but when found they are tabular and seldom exceed 3/8 in (1 cm) in length. When dyed, howlite specimens resemble and are sometimes sold as turquoise (p.154), although they are easily distinguished by their inferior hardness and lighter color.

Howlite usually occurs associated with other boron minerals, such as kernite and borax (p.127). It is easily fused and is used to make carvings, jewelry components, and other decorative items.

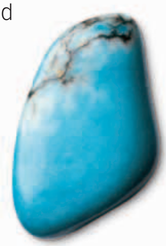

Stained howlite
This tumble-polished and dyed or stained piece of howlite looks similar to turquoise.

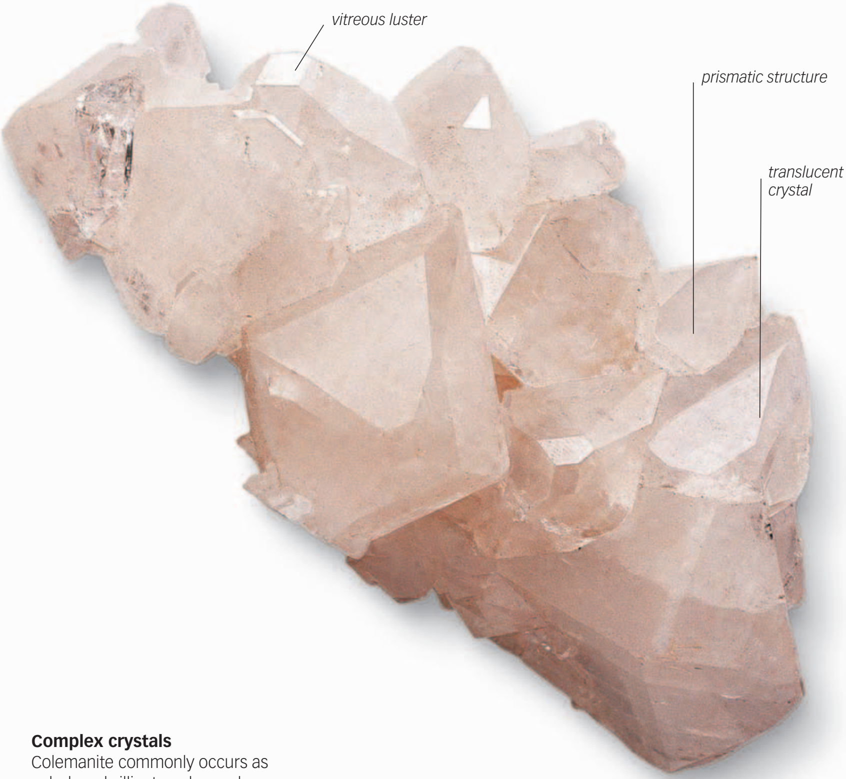

Complex crystals
Colemanite commonly occurs as colorless, brilliant, and complex crystals, as in this specimen.

PROFILE

Monoclinic
4–4½
2.4
Perfect, distinct
Uneven to subconchoidal
White
Vitreous to adamantine

$CaB_3O_4(OH)_3 \cdot H_2O$

COLEMANITE

An important source of boron, colemanite was named in 1884 after William Coleman, the owner of the mine in California where it was discovered. It is colorless, white, yellowish white, or gray. Colemanite occurs as short prismatic or equant crystals in nodules or as granular or coarse, massive aggregates. It is usually massive in commercial deposits, but individual crystals up to 8 in (20 cm) long have also been found.

Colemanite is found in playas and other evaporite deposits, where it replaces other borate minerals, such as borax (p.127) and ulexite (p.128), which were originally deposited in huge inland lakes. Borosilicates derived from colemanite and other minerals are used to make glass that is resistant to chemicals, electricity, and heat.

Heat-resistant glass
Borosilicate glass is used in car headlights, laboratory glassware, ovenware, and industrial equipment.

SULFATES, MOLYBDATES, CHROMATES, AND TUNGSTATES

Sulphates, molybdates, chromates, and tungstates share similar structures and chemical behavior. Sulfates are soft and lightweight, chromates are rare and brightly colored, and tungstates and molybdates are dense, hard, brittle, and vividly colored.

COMPOSITION

Sulfate minerals have a tetrahedral crystal structure, with four oxygen atoms at each corner and a sulfur atom in the center. The sulfate tetrahedron behaves chemically as a single, negatively charged radical or unit. All sulfates contain an SO_4 group.

The basic structural unit of the chromates, molybdates, and tungstates is also a tetrahedron formed from four oxygen atoms, with a central chromium (Cr), molybdenum (Mo), or tungsten (W) atom, respectively. The chromate minerals all contain a CrO_4 group, the molybdates an MoO_4 group, and the tungstates a WO_4 group.

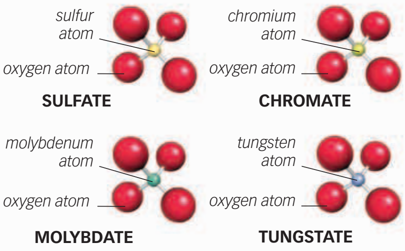

Crystal structure
Tetrahedra are the structural basis of the sulfates, chromates, tungstates, and molybdates. The central metal atom gives each group its name.

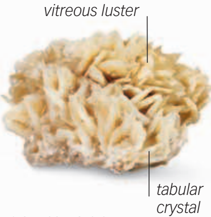

Barite crystals
This large group of tabular barite crystals is from the Wet Grooves mine, Yorkshire, England. Barite has important industrial and medicinal uses.

OCCURRENCE

Sulfates, such as gypsum, occur in evaporite deposits; others, such as barite, mainly occur in hydrothermal veins. Many tungstates are found in hydrothermal veins and pegmatites. Chromates and molybdates are often found as secondary minerals.

USES

The sulfates gypsum and barite are major industrial minerals. Chromates, tungstates, and molybdates are rare but when found concentrated are important ores of the metals they contain.

Plaster cast
About 75 percent of the calcium sulfate gypsum that is mined is used to make plaster of Paris. Most is used for wallboards, but some finds medical uses, such as making plaster casts.

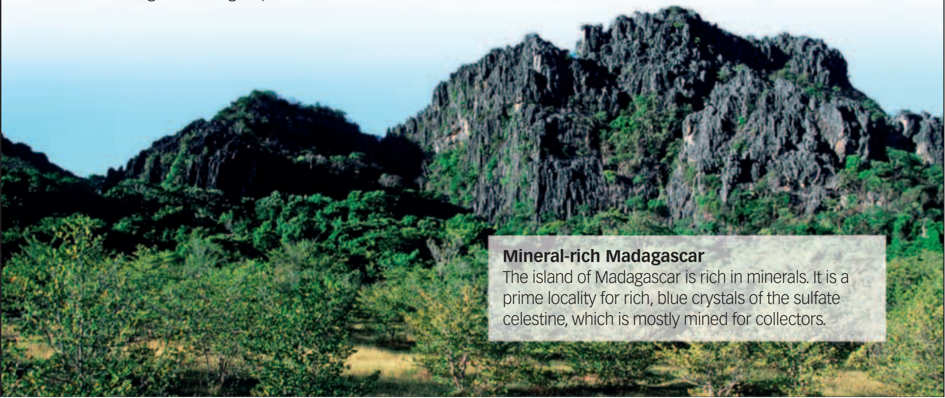

Mineral-rich Madagascar
The island of Madagascar is rich in minerals. It is a prime locality for rich, blue crystals of the sulfate celestine, which is mostly mined for collectors.

PROFILE

Orthorhombic

2½–3

6.4

Good, distinct

Conchoidal, brittle

Colorless

Adamantine to resinous, vitreous

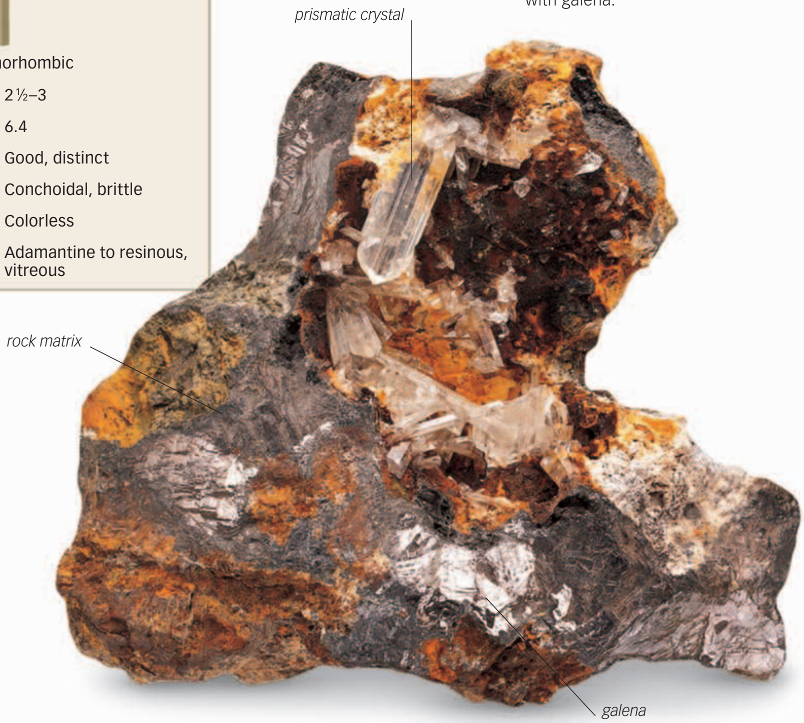

Anglesite crystals These striated prismatic crystals of anglesite are on a rock matrix with galena.

VARIANTS

Pyramidal crystal A pointed crystal of anglesite with galena

adamantine luster

Single crystal A crystal of anglesite that has an adamantine luster

$PbSO_4$

ANGLESITE

Named in 1832 after the large deposit of this mineral found on the island of Anglesey in Wales, anglesite is colorless to white, grayish, yellow, green, or blue and often fluoresces yellow under ultraviolet light. It commonly occurs in massive, granular, or compact forms. It has a number of crystal habits: thin to thick tabular, prismatic, pseudorhombohedral, and pyramidal with striations along the length. Exceptionally large crystals—up to 31 in (80 cm) long—have been found.

Used since ancient times as an ore of lead, anglesite forms in the oxidation zones of lead deposits. It is an alteration product of galena (p.54), formed when galena comes into contact with sulfate solutions. Anglesite is sometimes found in concentric layers with a core of unaltered galena.

Oval-cut anglesite Anglesite is soft and easily cleaved. It is one of the stones used to test the skills of master gem cutters.

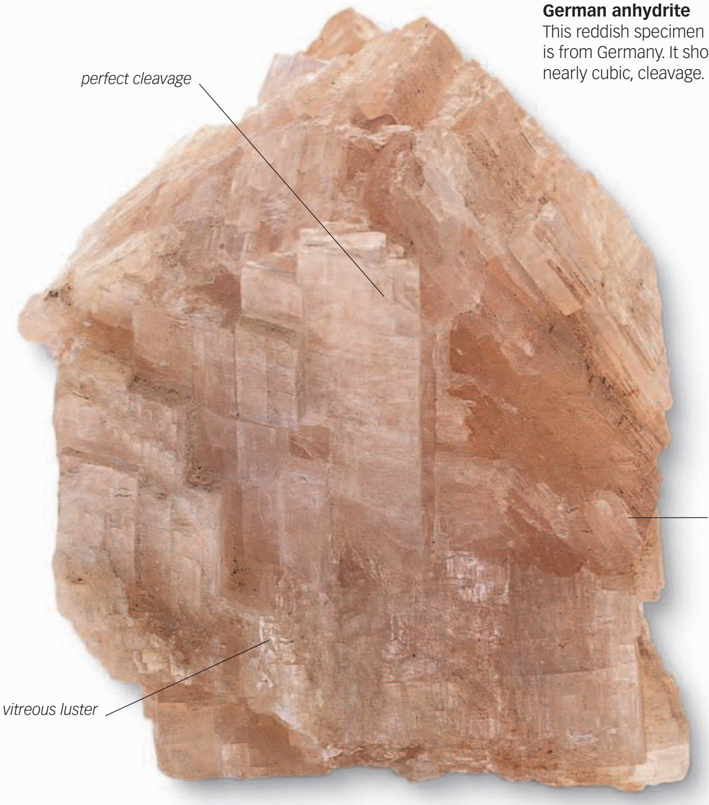

German anhydrite
This reddish specimen of anhydrite is from Germany. It shows perfect, nearly cubic, cleavage.

PROFILE

Orthorhombic
3½
3.0
Perfect, good
Uneven to splintery
White
Vitreous to pearly

$CaSO_4$

ANHYDRITE

An important rock-forming mineral, anhydrite is a calcium sulfate. It takes its name from the Greek word *anhydrous*, which means "without water." Anhydrite is usually colorless to white. Specimens can also be brownish, reddish, or grayish or pale shades of pink, blue, or violet. Individual crystals are uncommon, but when found they are blocky or thick tabular. Crystals up to 4 in (10 cm) long come from Swiss deposits. Anhydrite is usually massive, granular, or coarsely crystalline.

Anhydrite is one of the major minerals in evaporite deposits and commonly occurs in salt deposits associated with halite (p.110) and gypsum (p.136). It alters to gypsum in humid conditions. Anhydrite is often a constituent of cap rocks above salt domes that act as reservoirs for natural oil. It also occurs in volcanic fumaroles and in seafloor hydrothermal "chimneys." Anhydrite is used in fertilizers and as a drying agent in plasters, cement, paints, and varnishes.

PROFILE

Orthorhombic

3–3½

4.5

Perfect

Uneven

White

Vitreous, pearly, resinous

Barite crystals
This large group of tabular barite crystals is from the Wet Grooves Mine in Yorkshire, England.

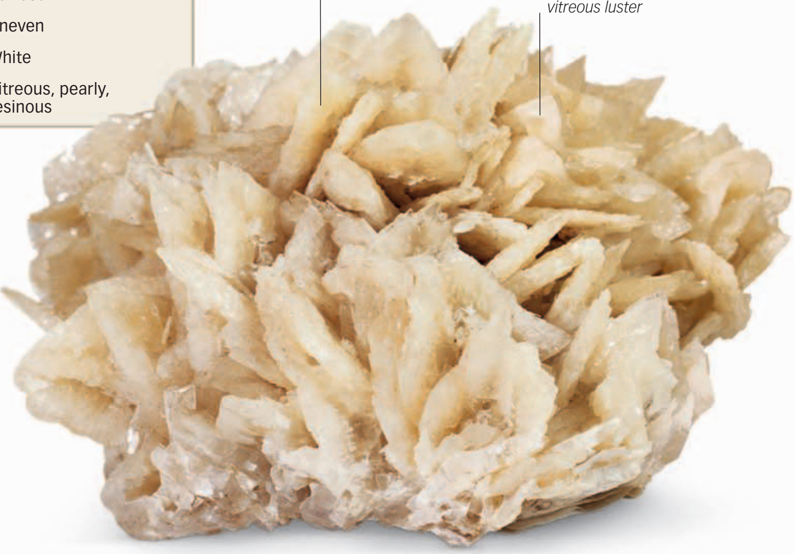

VARIANTS

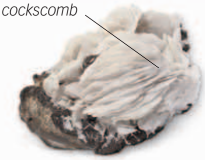

Cockscomb White cockscomb barite resting on sphalerite

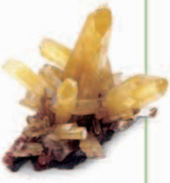

Prismatic crystals A group of yellow prismatic barite crystals

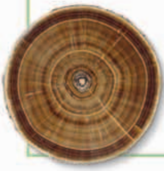

Stalagmite section Barite in a stalagmitic form

$BaSO_4$

BARITE

The barium sulfate barite takes its name from the Greek word *barys*, which means "heavy"—a reference to its high specific gravity. It has also been called heavy spar. Barite crystals are sometimes tinged yellow, blue, or brown. Golden barite comes from South Dakota. Crystals are well formed, usually either prismatic or tabular. Cockscomb (crested aggregates) and desert roses (rosette aggregates) of crystals are common. Transparent, blue barite crystals may resemble aquamarine but are distinguished by their softness, heaviness, and crystal shape. Barite can also be stalactitic, stalagmitic, fibrous, concretionary, or massive.

Barite is a common accessory mineral in lead and zinc veins. It is also found in sedimentary rocks, clay deposits, marine deposits, and cavities in igneous rocks.

Barite gemstone
Although transparent barite is soft and difficult to cut, it is sometimes faceted for collectors.

PROFILE

Orthorhombic

3–3½

4.0

Perfect

Uneven

White

Vitreous, pearly on cleavage

Celestine crystals
This superbly crystallized specimen of blue celestine crystals is from Madagascar. The largest crystal is more than 1½ in (3.5 cm) long.

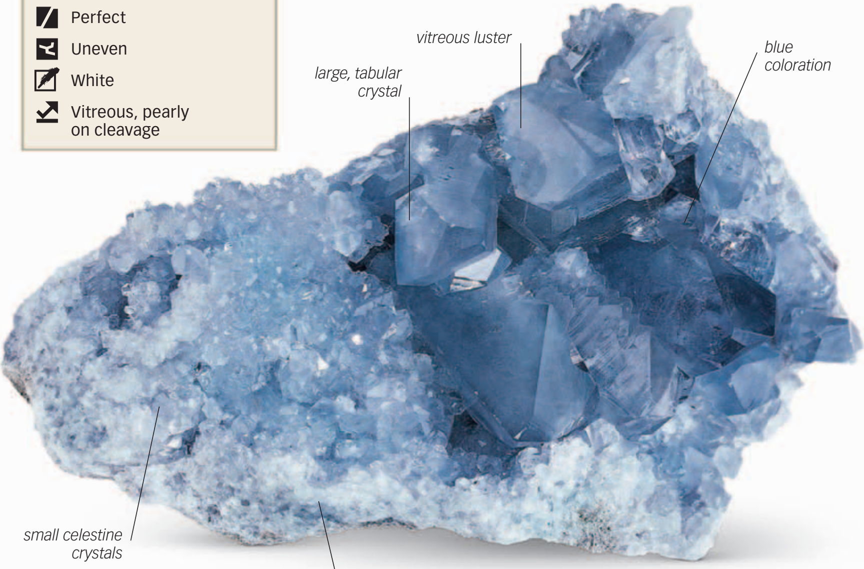

VARIANTS

Colorless celestine
Prismatic, colorless crystals on a sulfur matrix

Single crystal A light blue prismatic crystal of celestine

$SrSO_4$

CELESTINE

Often light blue in color, celestine takes its name from the Latin word *coelestis*, which means "heavenly"—an allusion to the color of the sky. Specimens can also be colorless, white, light red, green, medium to dark blue, or brown. Celestine crystals are commonly more than 4 in (10 cm) long. Well-formed, transparent, light- to medium-blue, tabular crystals are common, and some have been known to reach more than 30 in (75 cm) in length. Crystals can also be blocky, bladed, or form elongate pyramids. Celestine may also be massive, fibrous, granular, or nodular in habit.

Celestine forms in cavities in sedimentary rocks (pp.306–33). It commonly occurs in evaporite deposits and can also be precipitated directly from seawater. It can occasionally form in hydrothermal deposits. Celestine is an ore of strontium.

Collector's gem
Celestine is too soft to wear. Faceted celestine demonstrates the skills of master cutters.

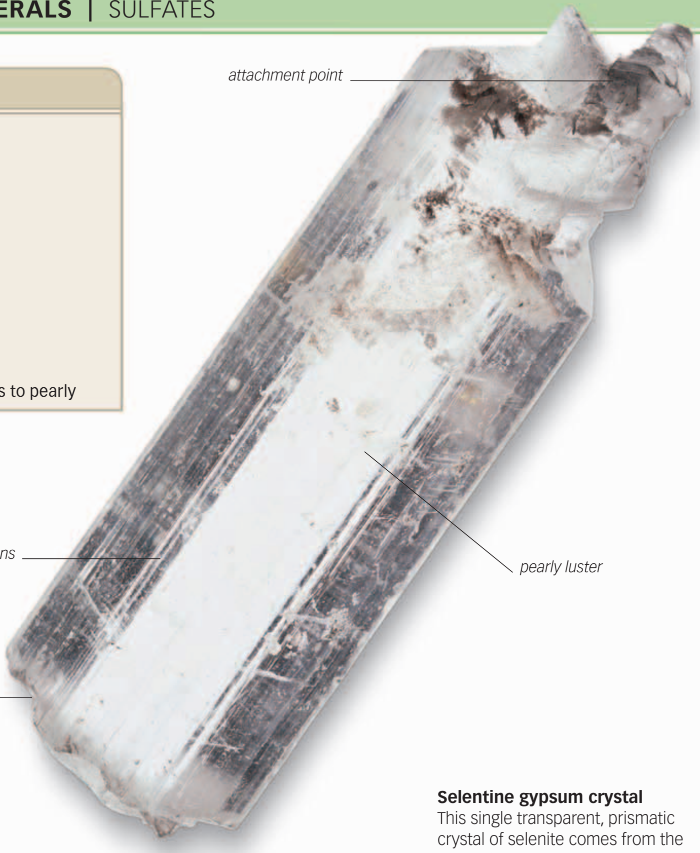

Selentine gypsum crystal This single transparent, prismatic crystal of selenite comes from the Cave of Swords in Mexico.

PROFILE

Monoclinic
- 2
- 2.3
- Perfect
- Splintery
- White
- Subvitreous to pearly

VARIANTS

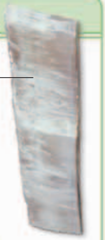

Gypsum satin spar Fibrous gypsum crystals

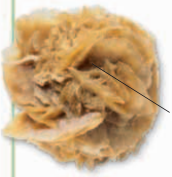

Desert rose Spherical clusters of bladed selenite

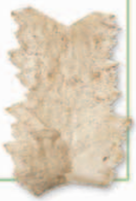

Fishtail twin Colorless, translucent selenite gypsum with fishtail twinning

$CaSO_4{\cdot}2H_2O$

GYPSUM

A widespread calcium sulfate hydrate, gypsum is found in a number of forms and is of great economic importance. It is colorless or white but can be tinted light brown, gray, yellow, green, or orange due to the presence of impurities. Single, well-developed crystals can be blocky with a slanted parallelogram outline, tabular, or bladed. Twinned crystals are common and frequently form characteristic “fishtails.” Numerous transparent, swordlike selenite gypsum crystals 6½ ft (2 m) or more long can be found at the Cave of Swords, Chihuahua, Mexico, one of the world’s most spectacular mineral deposits.

Gypsum occurs in extensive beds formed by the evaporation of ocean brine. It also occurs as an alteration product of sulfides in ore deposits and as volcanic deposits.

Cat’s eye sheen Satin spar, a fibrous variety of gypsum, can be cut into a cabochon gem with a cat’s eye sheen.

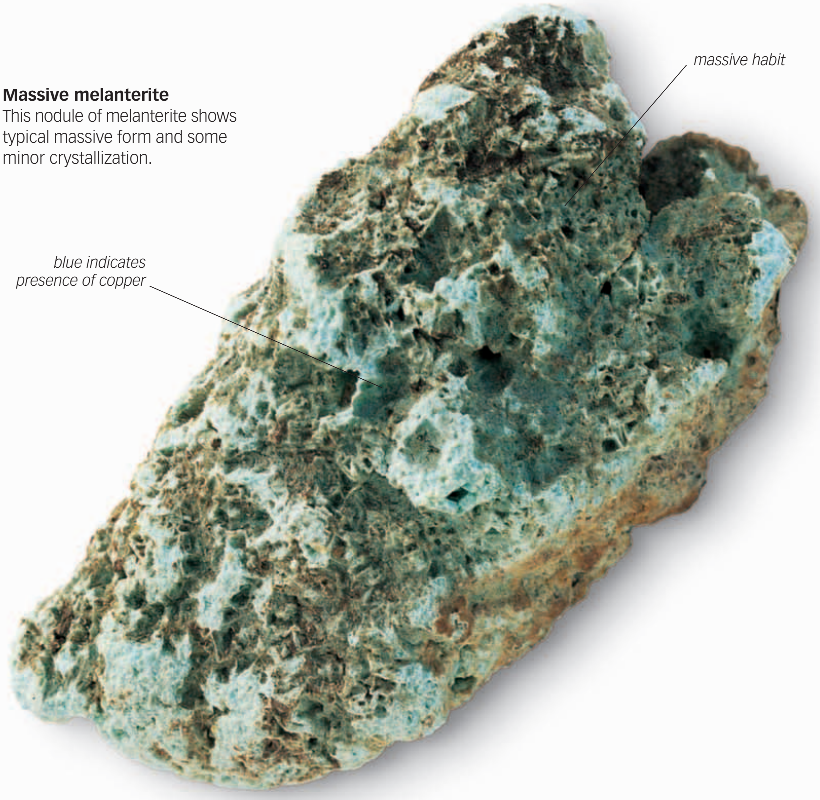

Massive melanterite
This nodule of melanterite shows typical massive form and some minor crystallization.

$FeSO_4 \cdot 7H_2O$

MELANTERITE

A hydrous iron sulfate, melanterite takes its name from the Greek word *melas*, which means "sulfate of iron." Melanterite is the iron analog of the copper sulfate chalcanthite, the two minerals having similar molecular structures. Most specimens of melanterite are colorless to white but can become green to blue as copper increasingly substitutes for iron. Melanterite is generally found in stalactitic or concretionary masses and rarely forms crystals. When crystals occur, they are short prisms or pseudo-octahedrons.

Melanterite is a secondary mineral formed by the oxidation of pyrite (p.62), marcasite (p.63), and other iron sulfides. It is frequently deposited on the timbers of old mine workings. Melanterite also occurs in the altered zones of pyrite-bearing rocks, especially in arid climates and in coal (p.253) deposits, where it is an alteration product of marcasite. Iron sulfate is used in water purification as a coagulant and also as a fertilizer.

PROFILE

Monoclinic
2
1.9
Perfect
Conchoidal, brittle
White
Vitreous

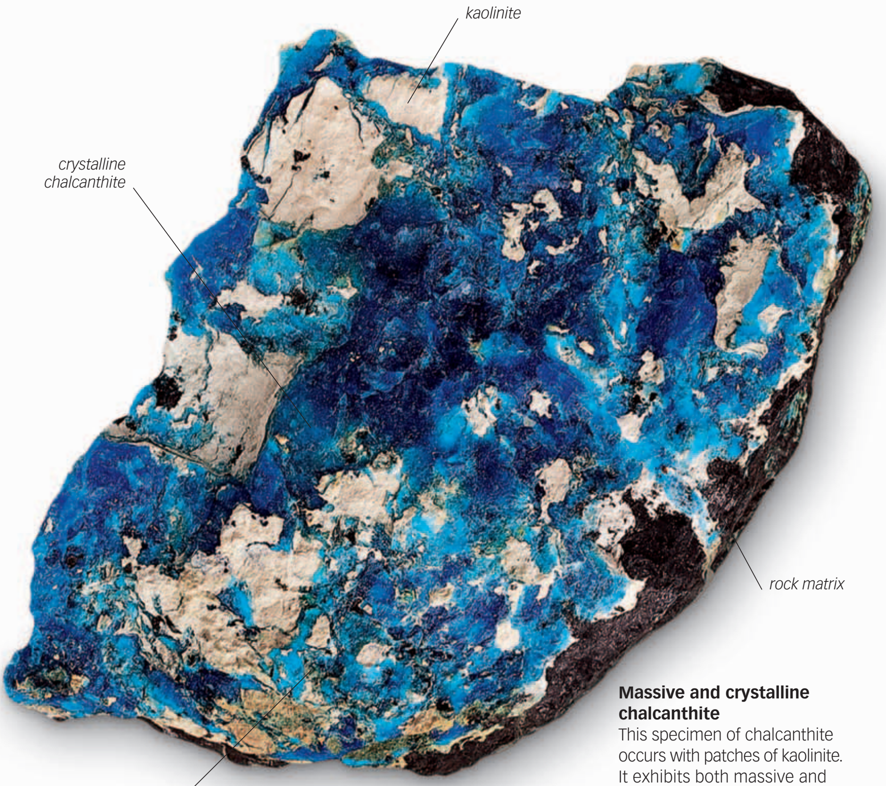

Massive and crystalline chalcanthite
This specimen of chalcanthite occurs with patches of kaolinite. It exhibits both massive and crystalline forms of the mineral.

PROFILE

Triclinic
2½
2.3
Not distinct
Conchoidal
Colorless
Vitreous

VARIANT

Stalactite Chalcanthite in the form of a stalactitic aggregate

$CuSO_4{\cdot}5H_2O$

CHALCANTHITE

A hydrated copper sulfate, chalcanthite takes its name from the Greek words *khalkos*, which means “copper,” and *anthos*, which means “flower.” It used to be known as blue vitriol. It is commonly peacock blue, although some specimens are greenish. Natural crystals are relatively rare. Chalcanthite usually occurs in veinlets and as massive and stalactitic aggregates.

This widespread, naturally occurring mineral forms through the oxidation of chalcopyrite (p.57) and other copper sulfates that occur in the oxidized zones of copper deposits. Being a water-soluble mineral, it is often found forming crusts and stalactites on the walls and timbers of mine workings, where it crystallizes from mine waters. In arid areas, such as Chile, chalcanthite concentrates in sufficient quantities without being dissolved away to constitute an important ore of copper. Although chalcanthite is a sought-after collectors’ mineral, its crystal structure disintegrates over time because it readily absorbs water.

PROFILE

Monoclinic
3½–4
4.0
Perfect
Uneven to subconchoidal
Pale green
Vitreous

Acicular brochantite
This brochantite specimen from Chile has needlelike crystals on a matrix of iron oxides.

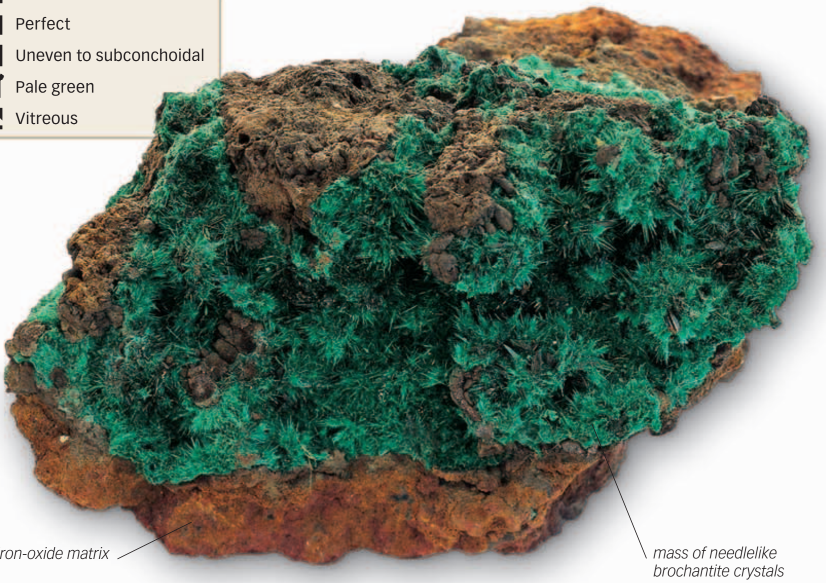

VARIANT

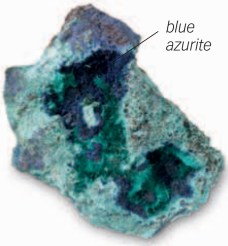

Brochantite on azurite
Green brochantite with blue azurite

$Cu_4SO_4(OH)_6$

BROCHANTITE

A hydrous copper sulfate, brochantite is emerald green, blue-green, or blackish green in color. It was named in 1824 after the French geologist and mineralogist A.J.M. Brochant de Villiers, who was the first pupil admitted to the École des Mines, Paris, and who later became its Professor of Geology and Mines. Brochantite usually forms prismatic or needlelike crystals, which rarely exceed a fraction of an inch in length. Twinning is common in crystals. Brochantite is also found in tufts and druse crusts and as fine-grained masses.

Brochantite forms in the oxidation zones of copper deposits, especially those that occur in the arid regions of the world. In these regions, brochantite is usually associated with azurite (p.120), malachite (p.125), and other copper minerals. In Arizona, and Chile, the mineral is abundant enough to be an ore of copper. Splendid specimens of brochantite come from Namibia, and Bisbee, Arizona, where prismatic crystals may exceed ⅜in (1 cm) in length.

PROFILE

Orthorhombic

2–2½

1.7

Perfect

Conchoidal

White

Vitreous to silky

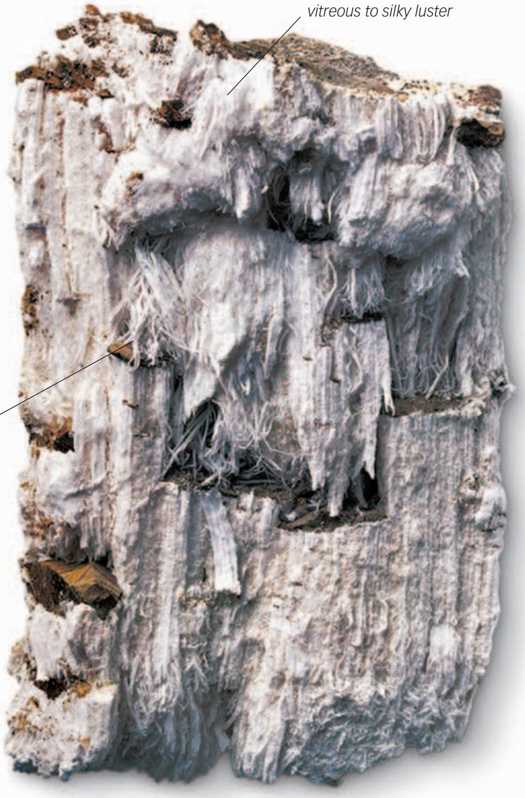

Fibrous epsomite This epsomite specimen occurs in a fibrous habit and shows a vitreous to silky luster.

VARIANT

Powdery mass Epsomite coating on a rocky matrix

$MgSO_4 \cdot 7H_2O$

EPSOMITE

Epsom salts is the common name for this hydrated magnesium sulfate mineral. It was first found around springs near the town of Epsom in Surrey, England, and was named after that locality in 1805. It is colorless, white, pale pink, or green. Epsomite crystals are rare; when found, they are either prismatic or fibrous. Epsomite usually occurs as crusts, powdery or woolly coatings, or sometimes as botryoidal or reniform masses.

Magnesium sulfate occurs in solution in seawater, saline lake water, and spring water. When the water evaporates, epsomite precipitates, forming deposits. It is also found with coal (p.253), in weathered magnesium-rich rocks, sulfide ore deposits, and dolomite (p.320) and limestone caves.

Refined epsom salt This widely used medication is derived from epsomite. One common use is as a natural laxative.

PROFILE

Monoclinic

2½–3

2.8

Perfect, indistinct

Conchoidal

White

Vitreous to waxy

Glauberite crystals
This group of dipyramidal glauberite crystals is from Ciempozuelos, Madrid, Spain.

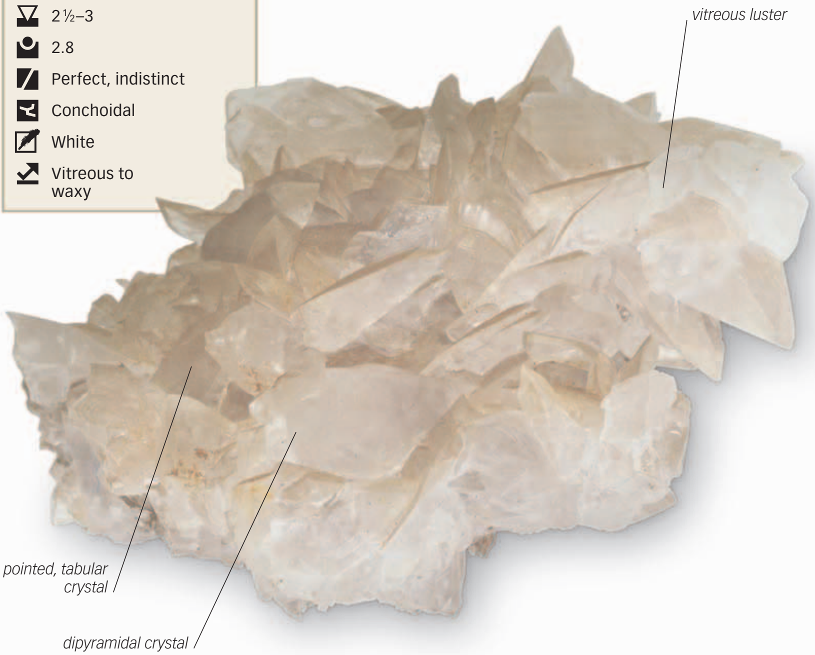

VARIANTS

Single crystal A single pyramidal crystal of glauberite

Pseudomorph A specimen with glauberite replaced by calcite

$Na_2Ca(SO_4)_2$

GLAUBERITE

This mineral was named in 1808 for its similarity to another chemical, Glauber's salt, which in turn was named after the German alchemist Johann Glauber. Glauberite is a sodium calcium sulfate. It can be colorless, pale yellow, reddish, or gray, and its surface may alter to white, powdery sodium sulfate. Crystals can be prismatic, tabular, and dipyramidal, all with combinations of forms and all of which may have rounded edges. Glauberite crystal pseudomorphs form when other minerals, such as calcite (p.114) and gypsum (p.136), replace it. Glauberite has a slightly saline taste, turns white in water, and fuses to a white enamel.

This mineral forms under a variety of conditions. It is primarily an evaporite, forming in both marine and salt-lake environments. It is also found in cavities in basaltic igneous rocks and in volcanic fumaroles. Molds and casts of quartz (p.168) and prehnite (p.205) formed from glauberite are frequently found in basalt cavities in Patterson, New Jersey, USA.

PROFILE

Monoclinic

2½–3

6.0

Distinct in one direction

Conchoidal to uneven, brittle

Orange-yellow

Vitreous

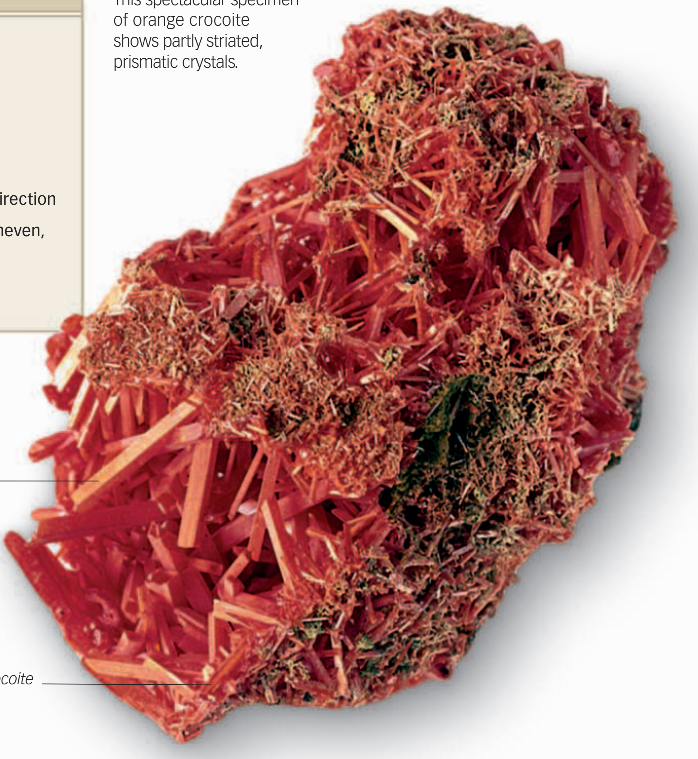
Prismatic crystals This spectacular specimen of orange crocoite shows partly striated, prismatic crystals.

VARIANTS

Red crocoite Red, prismatic crystals of crocoite in a rock matrix

Atypical crocoite An almost reticulated growth of crocoite

$PbCrO_4$

CROCOITE

One of the most eye-catching of minerals, crocoite is bright orange to red in color. It takes its name from the Greek word *krókos*, which means "saffron." Crocoite crystals are prismatic, commonly square-sectioned, slender and elongated, and sometimes cavernous or hollow. They may be striated along their length and may rarely show distinct terminations. Crystals usually occur in radiating or randomly intergrown clusters. Crocoite can also occur in granular or massive forms. On exposure to light, much of the translucence and brilliance of the mineral is lost.

Crocoite is a rare mineral, as specific conditions—an oxidation zone of lead ore and the presence of low-silica igneous rocks that serve as the source of chromium—are required for its formation. It is the official mineral emblem of Tasmania, where exceptional crystals, 3–4 in (7.5–10 cm) long and having a brilliant luster and color, are found. Crocoite is identical in composition to the pigment chrome yellow.

PROFILE

Tetragonal

2½–3

6.5–7.0

Distinct

Subconchoidal to uneven

White

Subadamantine to greasy

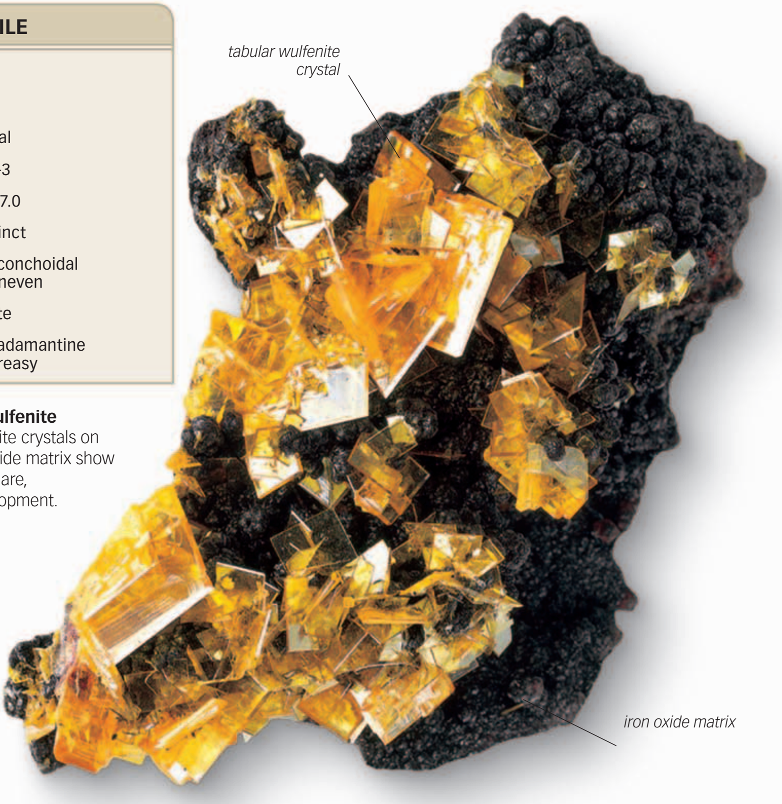

Yellow wulfenite The wulfenite crystals on this iron oxide matrix show classic, square, platy development.

VARIANTS

Square crystals Typical thin, tabular crystals of wulfenite

Red cloud wulfenite Crystals found in Red Cloud Mine in Arizona

$PbMoO_4$

WULFENITE

The second most common molybdenum mineral after molybdenite, wulfenite was named after F.X. Wülfen, an Austro-Hungarian mineralogist, in 1841. The color of specimens varies and can be yellow, orange, red, gray, or brown. Wulfenite usually forms as thin, square plates or square, beveled, tabular crystals. Crystals sometimes show different terminations on each end, probably due to twinning. Bright, colorful, and sharply formed crystals are popular with collectors. Wulfenite also occurs in massive, earthy, and granular forms.

Wulfenite is a minor source of molybdenum. Tungsten substitutes for the molybdenum, although in most specimens it is present only in trace amounts. Wulfenite is a secondary mineral formed in the oxidized zones of lead and molybdenum deposits, and it occurs with other minerals, including cerussite (p.119), pyromorphite (p.151), and vanadinite (p.155). It is relatively widespread and is often found in superb crystals, occasionally up to 4 in (10 cm) on an edge.

Hübnerite crystals
In this specimen, translucent hübnerite crystals grow on a quartz matrix with tarnished tetrahedrite.

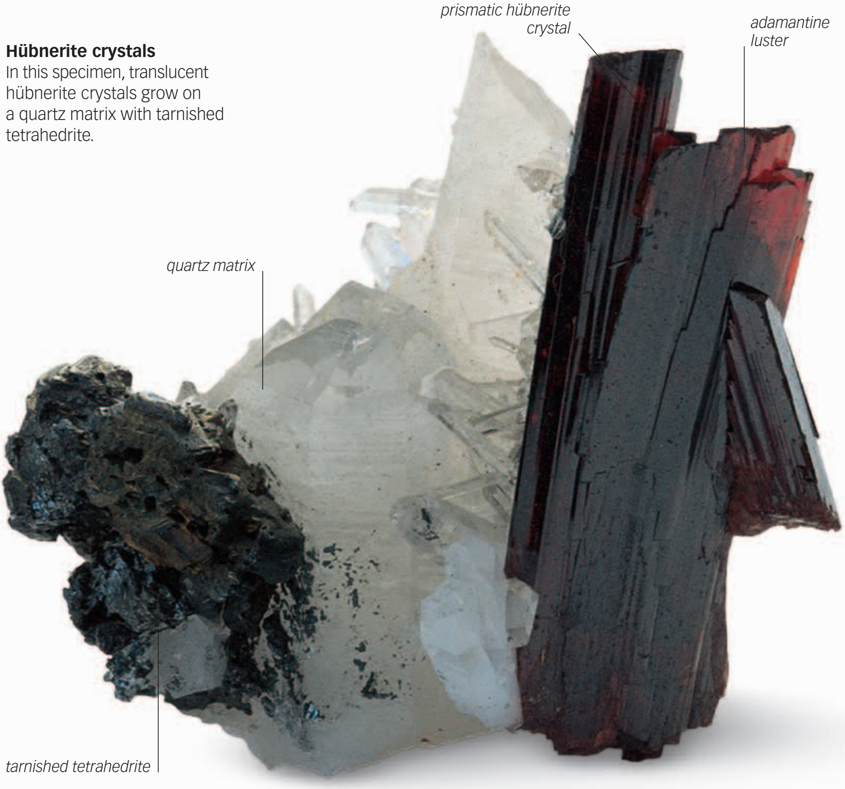

PROFILE

Monoclinic
4–4½
7.3
Perfect
Uneven
Yellow to brown
Submetallic/adamantine to resinous

$MnWO_4$

HÜBNERITE

Named after the German mineralogist Adolf Hübner, who first described it in 1865, hübnerite is an important ore of tungsten. It is found as prismatic, long prismatic, tabular, or flattened crystals with striations and is commonly twinned. It can also form groups of parallel or subparallel crystals or radiating groups. Hübnerite is generally reddish brown. In transparent crystals, it can change color when viewed from different directions and show strong internal reflection.

Hübnerite is the manganese end member of a manganese–iron solid-solution series. It occurs in granitic pegmatites (p.260) and in thermal veins at high temperatures (1,065°F/575°C or above). The mineral is also recovered from alluvial gravels, in which it can concentrate.

Bulb filament
Hübnerite is an ore of tungsten, which is mainly used in light bulb filaments.

Ferberite crystal
This ferberite crystal is from Cínovec, Czech Republic. It shows the prismatic habit of the mineral.

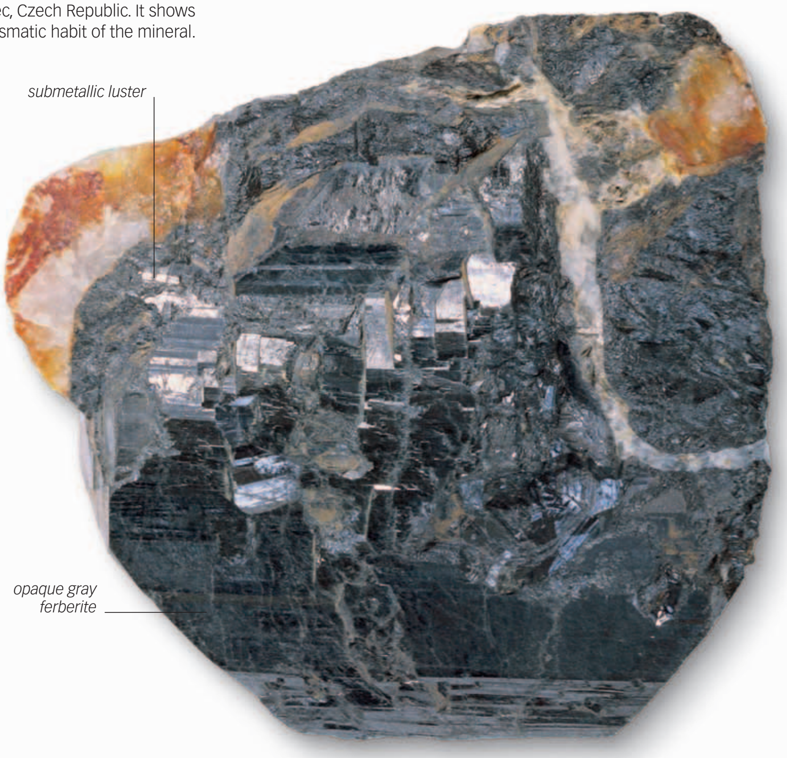

PROFILE

Monoclinic

4–4½

7.5

Perfect in one direction

Uneven, brittle

Black to brown

Submetallic

FeWO$_4$

FERBERITE

The principal ore of tungsten, ferberite is an iron tungstate. It was named in 1863 after Moritz Rudolph Ferber, a German industrialist and mineralogist. Ferberite forms black crystals, which are commonly elongated or flattened with a wedge-shaped appearance. Twinning and striations are common in crystals. Ferberite is also found as granular masses.

Ferberite is the iron end-member of a solid-solution series it forms with hübnerite (p.144), the manganese end-member. Together, they constitute the mineral formerly called wolframite. Ferberite occurs in hydrothermal veins at high temperatures (1,065°F/ 575°C or above) and in granitic pegmatites (p.260) with other minerals.

Tungsten steel
Rocket nozzles, such as those used in Saturn V, are made of heat-resistant, hard, and strong tungsten steel.

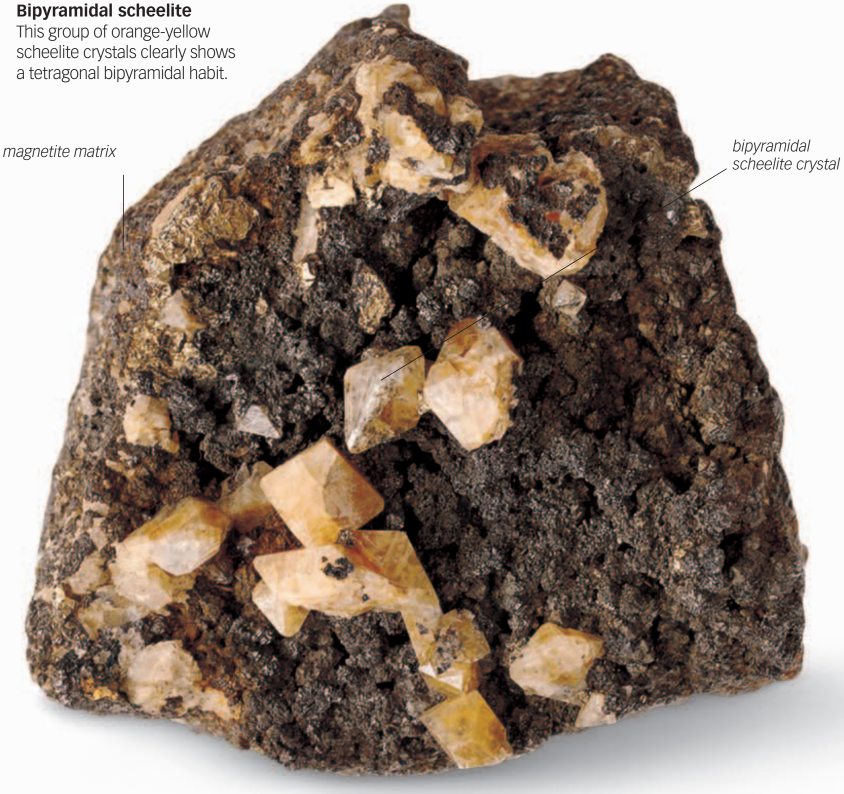

Bipyramidal scheelite This group of orange-yellow scheelite crystals clearly shows a tetragonal bipyramidal habit.

PROFILE

Tetragonal

4½–5

6.1

Distinct

Uneven to subconchoidal

White

Vitreous to greasy

$CaWO_4$

SCHEELITE

Named in 1821 after the Swedish chemist C.W. Scheele, scheelite is calcium tungstate. Its crystals are generally bipyramidal and twinned but also form in granular or massive aggregates. Irregular masses of colorless, gray, orange, or pale brown scheelite can be difficult to spot, but they fluoresce vivid bluish white under a short-wave ultraviolet light. Scheelite is sometimes associated with native gold (p.42), and its fluorescence is used by geologists in their search for gold deposits.

Scheelite commonly occurs in contact with metamorphic deposits, in hydrothermal veins formed at high temperatures (1,065°F/575°C or above), and less commonly in granitic pegmatites (p.260). Opaque crystals weighing up to 15½ lb (7 kg) come from Arizona. Scheelite is a major source of tungsten.

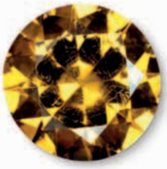

Brilliant cut scheelite Transparent scheelite is relatively rare. Stones faceted from it are only for gem collectors.

PHOSPHATES, VANADATES, AND ARSENATES

The phosphate, arsenate, and vanadate minerals are grouped together because their crystal structures are similar. The phosphates are the most numerous of the three groups, with more than 200 known minerals.

COMPOSITION

Phosphates contain phosphorus and oxygen in a 1:4 ratio, written as PO_4. The combined atoms act as a single unit that in turn combines with other elements to form phosphate minerals. Arsenates have a basic structural unit of arsenic and oxygen, written as AsO_4, which combines with other elements to form arsenate minerals. Most arsenates are rare and many are brilliantly colored. Vanadates mostly contain the same type of structural tetrahedra as the phosphates and arsenates, written as VO_4. The structures of vanadates are complex, and these minerals are relatively rare.

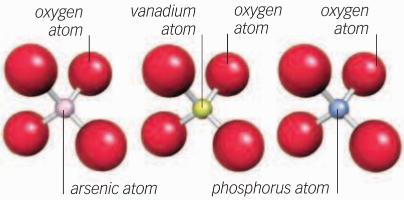

Crystal structure
The arsenate (AsO_4), vanadate (VO_4), and phosphate (PO_4) ions consist of a metal atom bonded to four oxygen atoms. Each ion acts as a single unit.

OCCURRENCE

Primary phosphates usually crystallize from aqueous fluids derived from igneous crystallization; secondary phosphates, when primary phosphates are altered in the presence of water; and rock phosphates, from phosphorus-bearing organic material.

USES

Phosphates are of major economic importance as fertilizers. Vanadates are minor ores of vanadium and have no other economic importance. The only exception is carnotite, an important source of uranium.

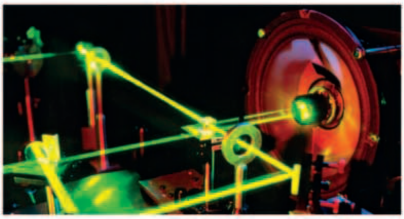

High-speed laser
Garnet-containing yttrium, which is derived from the yttrium phosphate xenotime, is used to make lasers. The direction of the laser beams is changed using mirrors.

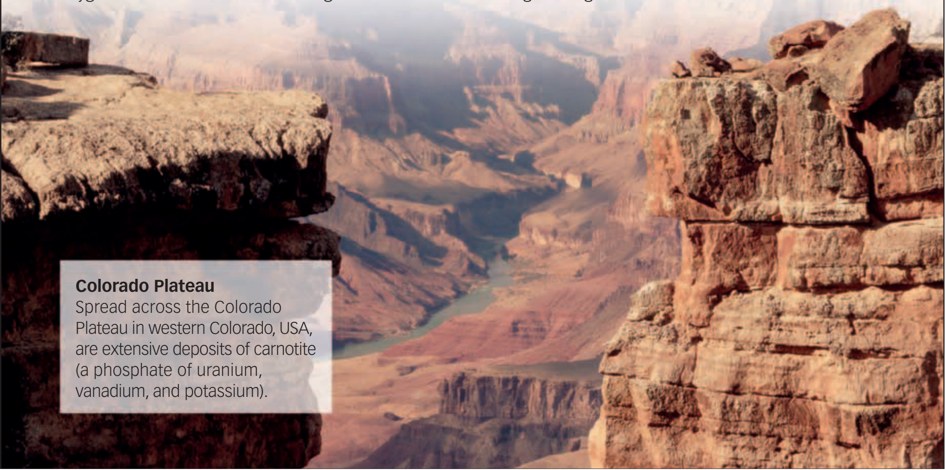

Colorado Plateau
Spread across the Colorado Plateau in western Colorado, USA, are extensive deposits of carnotite (a phosphate of uranium, vanadium, and potassium).

PROFILE

Monoclinic

- 5
- 3.1–3.2
- Indistinct, variable
- Conchoidal to uneven
- White
- Vitreous, waxy

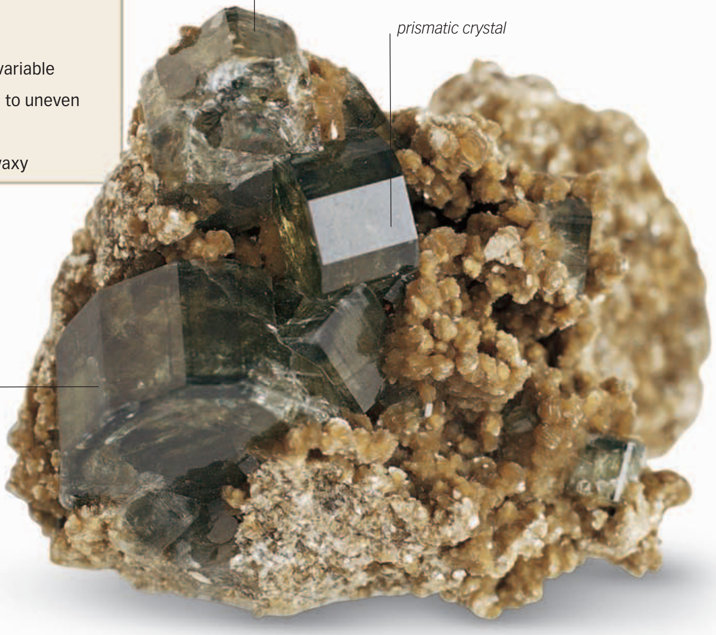

Apatite crystals These spectacular apatite crystals from Panasqueira Mine, Beira Baixa, Portugal, occur with muscovite and a small amount of arsenopyrite.

VARIANTS

Chlorapatite crystal Double-terminated chlorapatite

Brilliant apatite A single yellow crystal of hydroxylapatite

Hydroxylapatite A specimen with a waxy luster

$Ca_5(PO_4)_3(F,OH,Cl)$

APATITE

A series of calcium phosphate minerals that differ in composition are known as apatites. The name apatite is derived from the Greek *apate*, which means "deceit"—a reference to its similarity to crystals of aquamarine, amethyst, and olivine (p.232). Apatites can occur as green, blue, violet-blue, purple, colorless, white, yellow, pink, or rose-red specimens. All the apatites are structurally similar and are commonly found as transparent, well-formed, glassy crystals and in masses or nodules. Crystals are short to long prismatic, thick tabular, or prismatic with complex forms.

Apatites occur in marbles (p.301), skarns (p.302), and other metamorphic rocks. Rich deposits of apatite also occur in sedimentary rocks. As an accessory mineral, it occurs in a wide range of igneous rocks and in hydrothermal veins.

Step-cut gemstone Owing to the brittleness of apatite, an edge of one facet of this blue gemstone has become chipped.

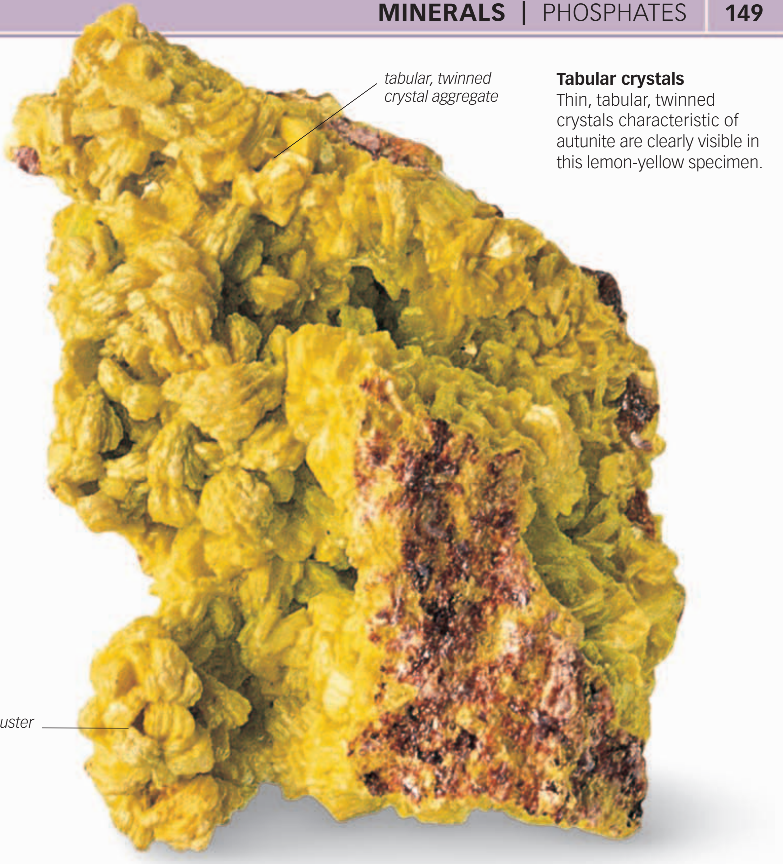

Tabular crystals
Thin, tabular, twinned crystals characteristic of autunite are clearly visible in this lemon-yellow specimen.

PROFILE

Tetragonal
2–2½
3.1–3.2
Perfect basal
Uneven
Pale yellow
Vitreous to pearly

$Ca(UO_2)_2(PO_4)_2\cdot 10\text{–}12H_2O$

AUTUNITE

A popular collector’s mineral, autunite is a calcium uranium phosphate. Greenish or lemon yellow in color, autunite specimens fluoresce green under ultraviolet light. Crystals of autunite have a rectangular or octagonal outline. Coarse groups are found, but scaly coatings are more common. Autunite is also found as crusts with crystals standing on edge, giving a serrated appearance.

Autunite is named after Autun, France, where this mineral was discovered. It is formed in the oxidation zones of uranium ore bodies as an alteration product of uraninite (p.83) and other uranium-bearing minerals. It also occurs in hydrothermal veins and in pegmatites (p.260). Since autunite contains uranium and is radioactive, it must be stored carefully and handled as little as possible. When mildly heated, tetragonal autunite dehydrates into orthorhombic meta-autunite. Most museum and collector specimens of autunite have been converted to meta-autunite. A moist atmosphere helps prevent dehydration.

PROFILE

Monoclinic

5

4.6–5.4

Perfect, good, poor

Conchoidal to uneven, brittle

White

Resinous, waxy, or vitreous

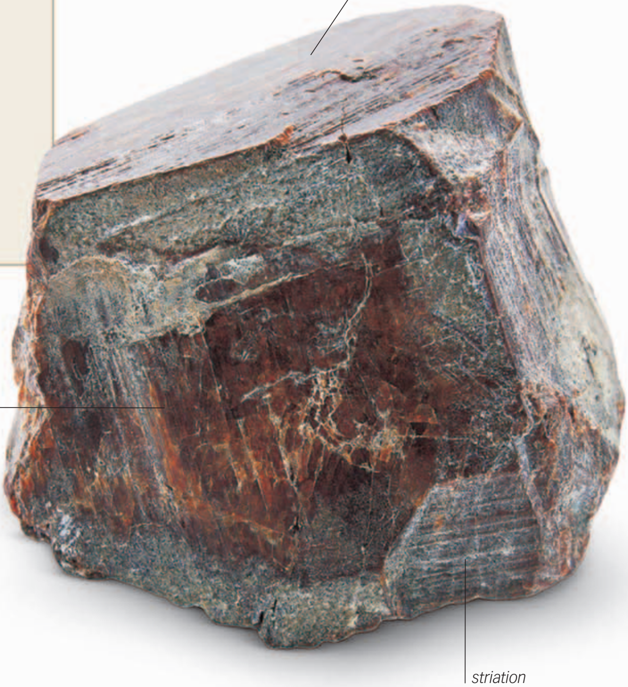

Monazite crystal This striated crystal of monazite is from Arendal, Aust-Agder, Norway, which is an important monazite locality.

VARIANT

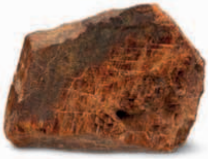

Monazite fragment A brown crystal fragment showing growth lamellae

$(Ce,La,Th,Nd)PO_4$

MONAZITE

The monazite group consists of three different phosphate minerals, all sharing the same crystal structure. The most widespread is monazite-(Ce), cerium phosphate, which is yellowish or reddish brown to brown, greenish, or nearly white. Monazite-(Ce) forms prismatic, flattened, or elongated crystals, which are occasionally large, coarse, and commonly twinned. Two other species of monazite are monazite-(La), which is lanthanum phosphate, and monazite-(Nd), which is neodymium phosphate.

Monazite is a common accessory mineral in granites (pp.258–59) and gneisses (p.288) and in pegmatites (p.260) and fissure veins. Detrital monazite can accumulate as monazite sands. Lanthanum is used in oil refining. Neodymium is used for coloring glass.

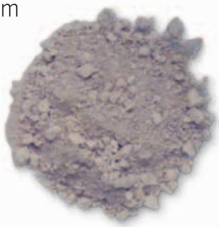

Cerium oxide Monazite-(Ce) is a source of cerium. Cerium oxide is used for polishing glass, stone, and gemstones.

PROFILE

Hexagonal

3½–4

7.0

Poor

Uneven to subconchoidal, brittle

White

Resinous

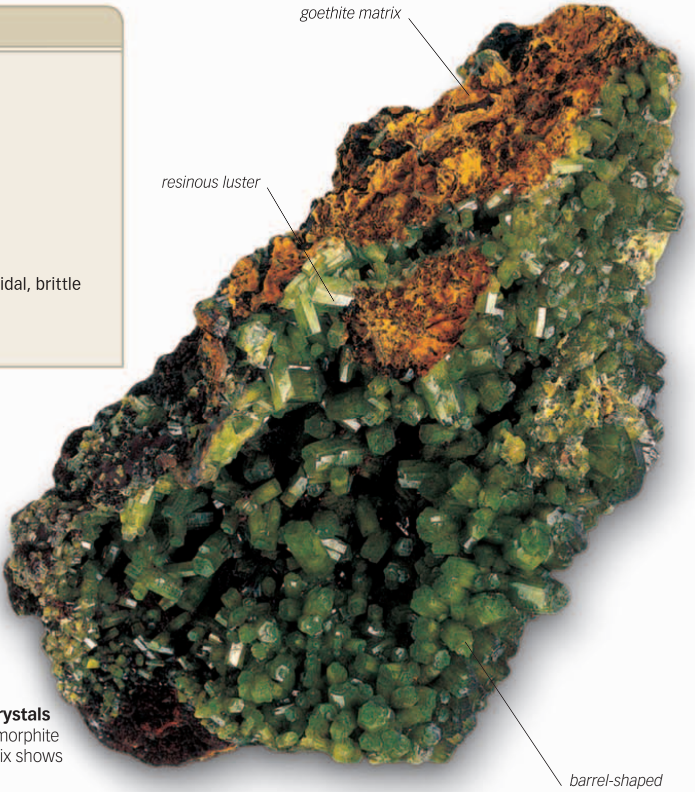

Barrel-shaped crystals This mass of pyromorphite on a limonite matrix shows its typical barrel-shaped crystals.

VARIANTS

Lime-green crystals Crystals showing pyromorphite's intense coloration

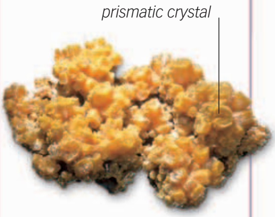

Yellow-green crystals A specimen of pyromorphite with yellow-green prismatic crystals

$Pb_5(PO_4)_3Cl$

PYROMORPHITE

A minor ore of lead but a popular collector's mineral, pyromorphite forms a continuous chemical series with mimetite (p.164) in which phosphorus and arsenic replace each other. Pyromorphite gets its name from the Greek words *pyr*, which means "fire," and *morphe*, which means "form"—an allusion to its property of becoming crystalline on cooling after it has been melted to a globule. It is dark green to yellow-green, shades of brown, a waxy yellow, or yellow-orange. Crystals may be either simple hexagonal prisms or rounded and barrel-shaped, spindle-shaped, or cavernous. Some crystals exhibit different colors when viewed from different directions and some produce electricity on application of mechanical stress. The mineral can also be globular, reniform, or granular in habit.

Pyromorphite occurs as a secondary mineral in the oxidized zones of lead deposits with galena (p.54), goethite (p.102), cerussite (p.119), smithsonite (p.124), and vanadinite (p.155). Pseudomorphs of pyromorphite after galena are common.

Torbernite crystals In this specimen, tabular crystals of torbernite rest on an iron-rich matrix.

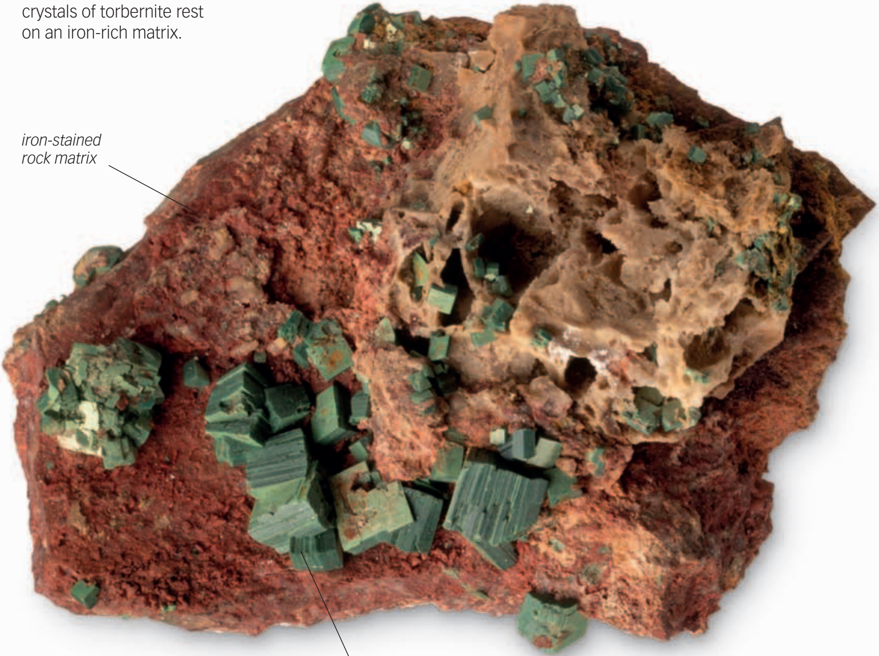

PROFILE

Tetragonal
2–2½
3.2
Perfect, basal
Uneven
Pale green
Vitreous to subadamantine

VARIANT

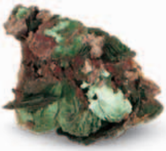

Metatorbernite Green sheaves of metatorbernite crystals in rock matrix

$Cu(UO_2)_2(PO_4)_2\cdot 8–12H_2O$

TORBERNITE

Named in 1793 after the Swedish mineralogist Torbern Olaf Bergmann, torbernite is a uranium-bearing mineral and a minor ore of uranium. Torbernite forms thin to thick tabular crystals that are commonly square in outline, foliated micalike masses, sheaflike crystal groups, or scaly coatings. Specimens are bright mid-green, emerald green, leek green, or grass green in color. Torbernite is chemically unstable, and with increased hydration it transforms to metatorbernite. In fact, all specimens are probably metatorbernite. It is also radioactive and needs to be handled with appropriate care.

Torbernite is found as a secondary mineral formed in the oxidation zones of deposits containing uranium and copper and is associated with other phosphate minerals. It forms as an alteration product of uraninite (p.83) or other uranium-bearing minerals. Torbernite is also associated with uraninite, autunite (p.149), and carnotite (p.159). Fine specimens occur in Cornwall, England, in the Flinders Range of Australia, and elsewhere.

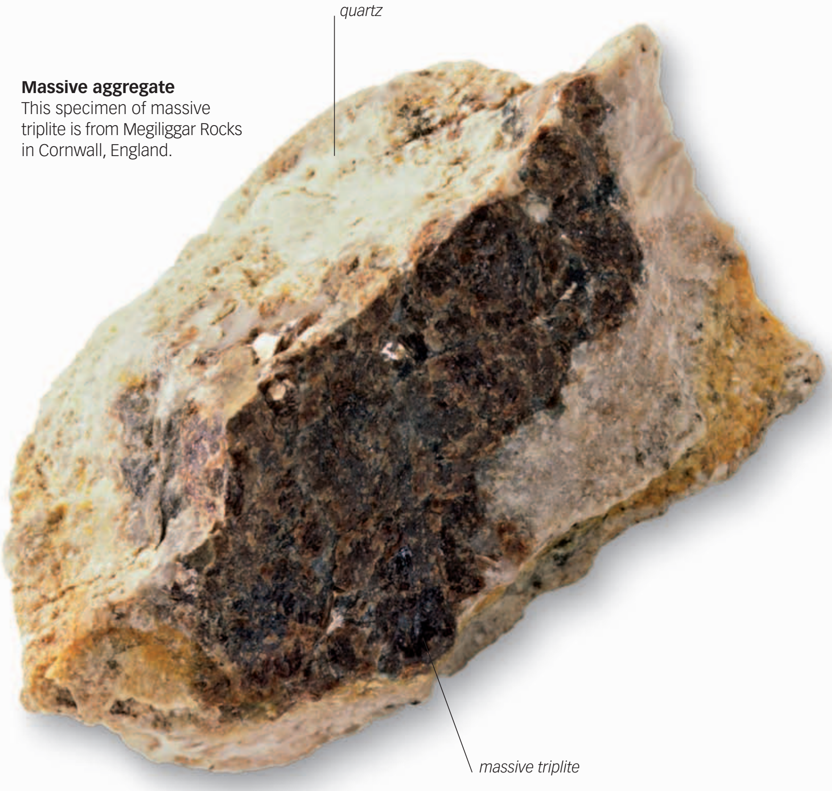

Massive aggregate
This specimen of massive triplite is from Megiliggar Rocks in Cornwall, England.

PROFILE

Monoclinic
5–5½
3.5–3.9
Good in three directions
Uneven to subconchoidal
White to brown
Vitreous to resinous

$(Mn,Fe,Mg)_2PO_4(F,OH)$

TRIPLITE

The first occurrence of triplite was described in 1813 in Chanteloube, Limousin, France. Although it is a fluoridated manganese phosphate, in most triplite samples iron partially replaces manganese. Triplite takes its name from the Greek word *triplos,* which means “triple”—a reference to its three cleavages oriented at right angles to each other. Its crystals are typically rough and poorly developed but may have many indistinct forms. Triplite is more commonly nodular or massive. Specimens may be chestnut brown, reddish brown, flesh red, or salmon pink in color. If altered, they may be brownish black to black. Translucent crystals may also exhibit different colors when viewed from different directions (a phenomenon known as pleochroism), going from yellow-brown to reddish brown.

Triplite is a primary mineral in granite pegmatites (p.260) with complex zones and in some hydrothermal tin veins. It may be accompanied by sphalerite (p.53), pyrite (p.62), apatite (p.148), and tourmaline (p.224).

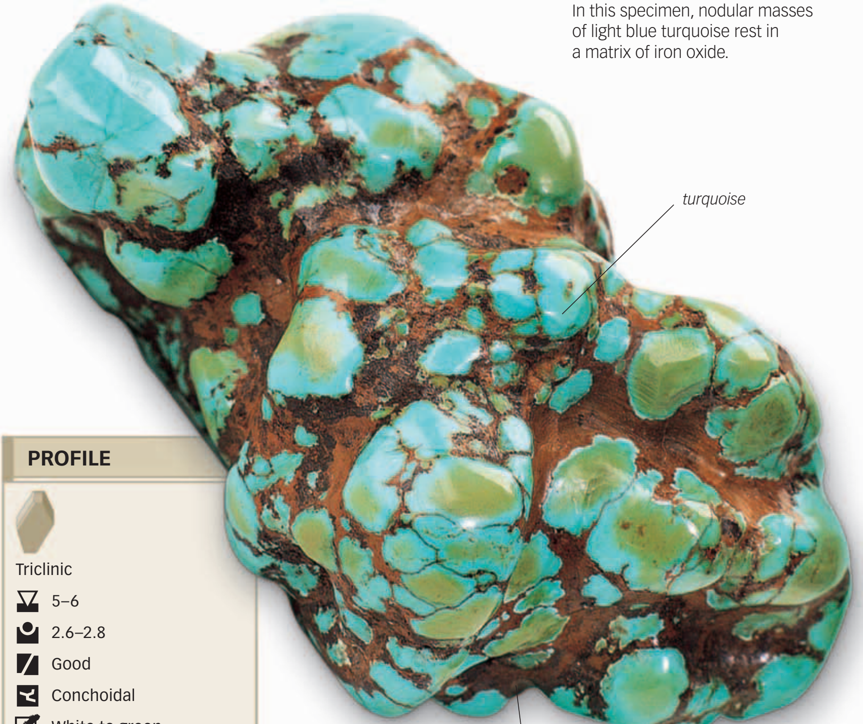

Blue turquoise In this specimen, nodular masses of light blue turquoise rest in a matrix of iron oxide.

PROFILE

Triclinic
5–6
2.6–2.8
Good
Conchoidal
White to green
Waxy to dull

VARIANTS

Turquoise vein Massive turquoise in a small vein

Green turquoise A hard, green nugget from the USA

Turquoise in rock Blue-green, massive turquoise in rock

$CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$

TURQUOISE

One of the first gemstones to be mined, turquoise is a hydrous copper aluminum phosphate. Beads made of turquoise that date back to *c.*5000 BCE have been recovered in Mesopotamia (present-day Iraq). This mineral usually occurs in massive or microcrystalline forms, as encrustations or nodules, or in veins. Crystals are rare; when found, they occur as short, often transparent prisms. Turquoise varies in color from sky-blue to green, depending on the amount of iron and copper it contains.

"Turquoise" is derived from the French word for "Turkey," because it was first transported to Europe through Turkey. Turquoise occurs in arid environments as a secondary mineral probably derived from the decomposition of apatite (p.148) and some copper sulfides.

Carved elephant Turquoise is a favorite of Chinese stone carvers, who produced this turquoise elephant.

Red vanadinite
Vanadinite crystals are often brilliantly colored in shades of red and yellow. This specimen has smooth-faced, prismatic crystals.

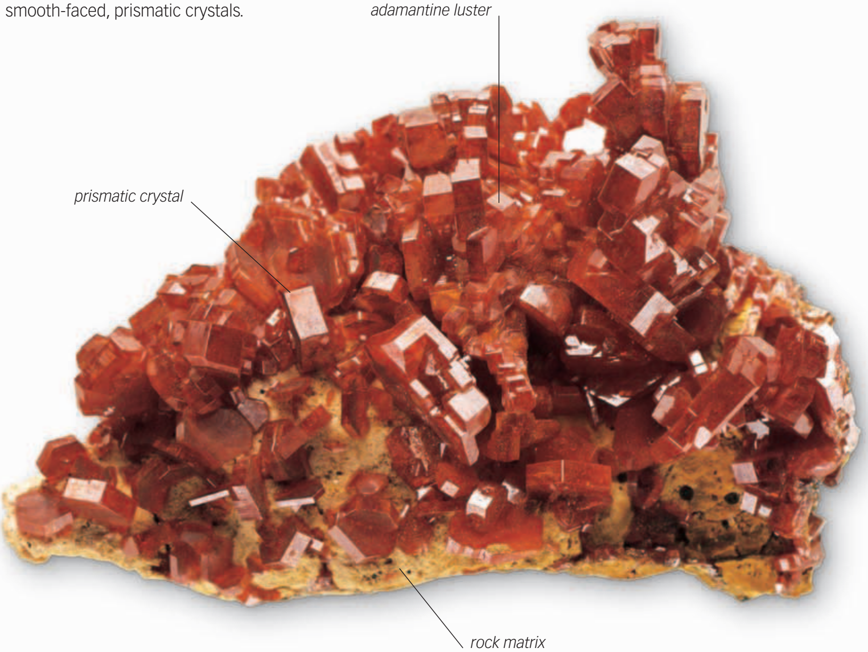

PROFILE

Hexagonal
3
6.9
None
Uneven, brittle
Whitish yellow
Adamantine

$Pb_5(VO_4)_3Cl$

VANADINITE

A relatively rare mineral, vanadinite is a lead chlorovanadate. The bright red or orange-red colors of vanadinite make it popular among mineral collectors, although it is sometimes brown, red-brown, gray, yellow, or colorless. Crystals are usually in the form of short, hexagonal prisms but can also be found as hexagonal pyramids or as hollow prisms. They can also be needlelike. Small amounts of calcium, zinc, and copper may substitute for lead, and arsenic can completely substitute for vanadium in the crystal structure to form the mineral mimetite (p.164). The mineral is also found as rounded masses or crusts.

Vanadinite forms as a secondary mineral in oxidized ore deposits containing lead, often associated with galena (p.54), goethite (p.102), barite (p.134), and wulfenite (p.143). Vanadium from vanadinite is used to make strong vanadium steels.

Steel spanner
Vanadium imparts strength and hardness to steel that is used to make high-stress tools, such as this spanner.

Concretionary variscite
Variscite is often found in nodules and concretions like the sliced specimen shown here. It can be sometimes mistaken for turquoise.

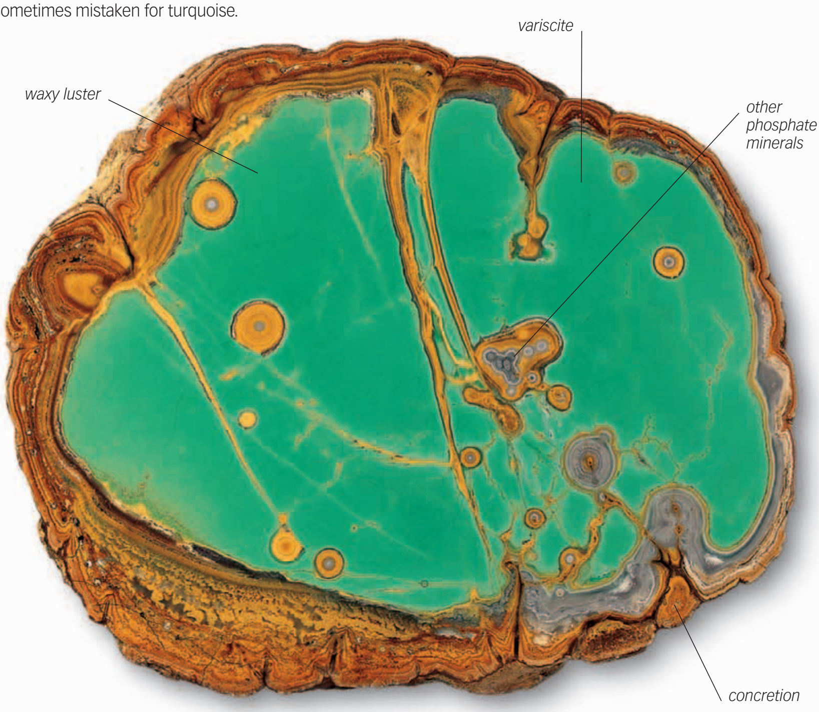

PROFILE

Orthorhombic
4½
2.6
Good but rarely visible
Splintery in massive
White
Vitreous to waxy

$AlPO_4 \cdot 2H_2O$

VARISCITE

This mineral was named after Variscia, the old name for the German district of Voightland, where it was first discovered, in 1837. Variscite is pale to apple green in color. It is predominantly found as cryptocrystalline or fine-grained masses and in veins, crusts, or nodules. It rarely forms crystals.

Variscite forms in cavities produced by the action of phosphate-rich waters on aluminous rocks. It commonly occurs in association with apatite (p.148) and wavellite (p.158). It is valued as a semiprecious gemstone and is used for carvings and as an ornamental material. Variscite is porous, and, when worn next to the skin, tends to absorb body oils, which discolor it. A mineral that appears to be turquoise (p.154) but is actually variscite is sometimes marketed by the name variquoise.

Cabochon
Variscite can be polished into inexpensive gems, but their softness makes them vulnerable to wear.

PROFILE

Monoclinic

1½–2

2.7

Perfect

Uneven

Bluish white

Vitreous to earthy

Needlelike vivianite This specimen of radiating vivianite crystals is set on a rock matrix.

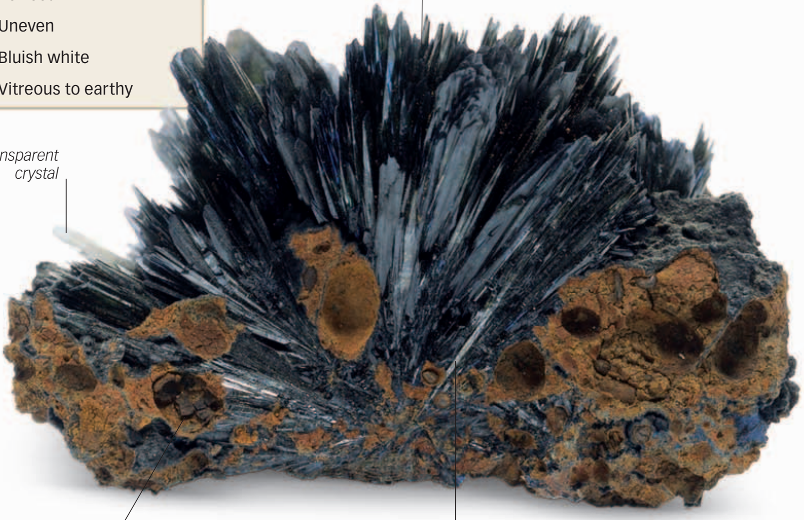
radiating, bladed crystal
thin, transparent crystal
crystals in cavity left by fossil shell
vitreous luster

VARIANT

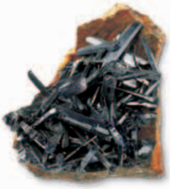

Prismatic crystal Blue-black, elongated prismatic crystals of vivianite

$Fe_3(PO_4)_2 \cdot 8H_2O$

VIVIANITE

Named in 1817 after the English mineralogist John Henry Vivian, vivianite occurs as elongated, prismatic, or bladed tabular crystals. Specimens may be rounded, corroded, concretionary, earthy, or powdery in form. Vivianite can also form starlike groups or encrustations or occur in massive or fibrous forms. Sometimes colorless when freshly exposed, vivianite becomes either pale blue to greenish blue or indigo blue on oxidation. Before the development of modern synthetic chemicals, vivianite was the source of the sought-after blue paint pigment blue ocher.

Vivianite is a widespread secondary mineral, forming in the weathered zones of iron ore and phosphate deposits and in complex granite pegmatites (p.260).

Blue ocher Powdered vivianite was used to make blue ocher, a rare and expensive pigment.

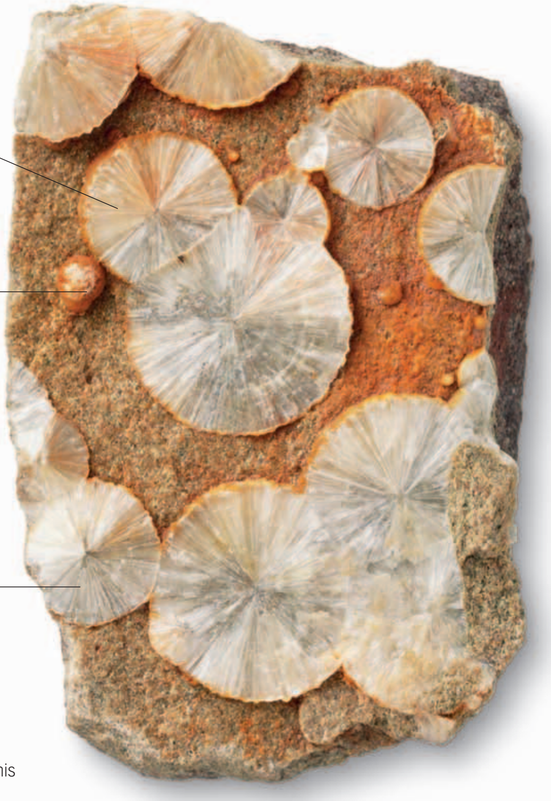

Radiating crystals
Needlelike crystals of wavellite form radiating aggregates on this rock matrix.

PROFILE

Orthorhombic
3½–4
2.4
Good
Subconchoidal to uneven
White
Vitreous to resinous

$Al_3(PO_4)_2(OH,F)_3 \cdot 5H_2O$

WAVELLITE

Named in 1805 after the amateur English mineralogist William Wavell, wavellite is a hydrated aluminum phosphate. Specimens are usually green but can also be white, greenish white, green-yellow, yellowish brown, turquoise-blue, brown, or black. They may exhibit color zoning. Crystals are uncommon but when found are short to long prismatic, elongated, and striated parallel to the prism faces. Wavellite is commonly found as translucent, greenish, globular aggregates of radiating crystals up to 1¼in (3cm) in diameter, as crusts, or as stalactitic deposits.

Wavellite is a secondary mineral that forms in low-grade, aluminous, metamorphic rocks; goethite (p.102) and phosphate rock deposits; and, rarely, in hydrothermal veins. It is also found in areas where phosphate minerals have been weathered in granites (p.258) and granitic pegmatites (p.260).

Match production
Phosphorous sulfate derived from wavellite and other phosphates is a major component of matches.

Carnotite crust
A crust of vivid yellow, powdery radioactive carnotite coats this fragment of sandstone.

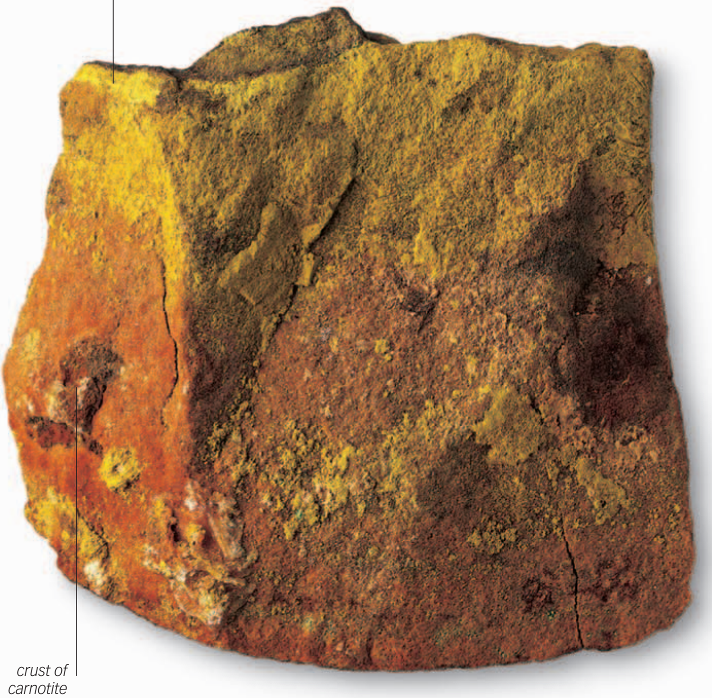

PROFILE

Monoclinic
2
4.7
Perfect
Uneven
Yellow
Pearly to dull

$K_2(UO_2)_2(VO_4)_2\cdot 3H_20$

CARNOTITE

A radioactive mineral, carnotite was named in 1899 after the French chemist and mining engineer Marie-Adolphe Carno. It is bright to lemon yellow or greenish yellow. Carnotite is generally found as powdery or microcrystalline masses; tiny, disseminated grains; or crusts. Crystals are platy, rhombohedral, or lathlike.

Carnotite is a secondary mineral formed by the alteration of primary uranium-vanadium minerals. It occurs chiefly in sandstone (p.308), either disseminated or in concentrations around fossil wood or other fossilized vegetable matter. Pure carnotite contains about 53 percent uranium by weight, which is used to generate nuclear energy and in atomic weapons. It has also been mined for vanadium and radium, from World War II onward.

Radium dial
Sourced from carnotite, radium has been used to create illuminated watch hands and dials.

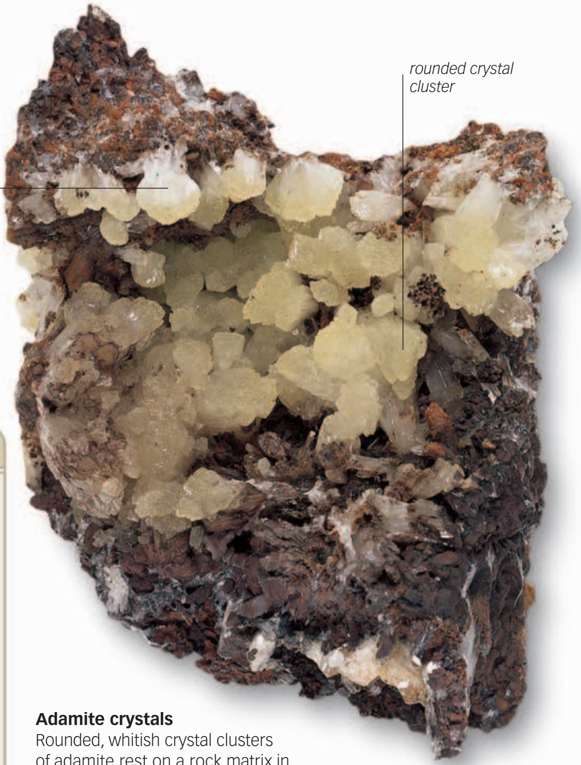

Adamite crystals Rounded, whitish crystal clusters of adamite rest on a rock matrix in this specimen.

PROFILE

Orthorhombic

- 3½
- 4.4
- Good
- Subconchoidal to uneven, brittle
- White
- Vitreous

VARIANTS

Reddish adamite Adamite crystals on a reddish orange iron-oxide matrix

adamite crystal

Spheroidal adamite A cluster of yellow, spheroidal adamite crystals on a limonite matrix

$Zn_2AsO_4(OH)$

ADAMITE

Named in 1866 after the French mineralogist G.J. Adam, who discovered adamite in Chile, this mineral is a zinc arsenate hydroxide. It is rarely colorless or white, and many specimens fluoresce green under ultraviolet light. Adamite is often brightly colored due to traces of other elements: copper commonly substitutes for zinc to yield yellow or green crystals depending on its concentration; manganese may substitute for zinc to yield crystals that are pink or violet. Adamite crystals are elongated, tabular, or blocky. This mineral also occurs as rosettes and spherical masses of radiating crystals.

Adamite forms as a secondary mineral in the oxidized zones of zinc and arsenic deposits, often associated with goethite (p.102), azurite (p.120), smithsonite (p.124), mimetite (p.164), scorodite (p.165), hemimorphite (p.227), and olivenite. Although adamite has no commercial uses, its bright and lustrous crystals are highly sought after by mineral collectors.

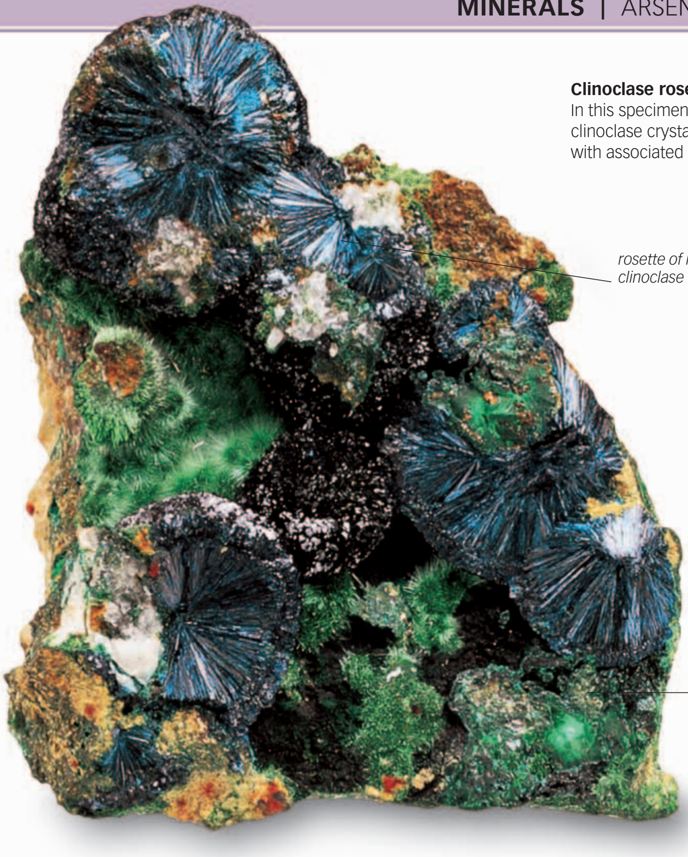

Clinoclase rosettes
In this specimen, rosettes of clinoclase crystals are seen with associated olivenite.

PROFILE

Monoclinic
2½–3
4.3
Perfect
Uneven, brittle
Bluish green
Vitreous to pearly

$Cu_3(AsO_4)(OH)_3$

CLINOCLASE

Discovered in 1830 in the Wheal Gorland mine in Cornwall, England, clinoclase was named in 1868. It takes its name from the Greek *me klísi*, which means "to incline," and *gia na spásei*, which means "to break"—a reference to its oblique basal cleavage. The vitreous crystals of clinoclase are translucent dark blue to dark greenish blue. They can be elongated or tabular or occur as single, isolated crystals that appear rhombohedral. Specimens can also form rosettelike aggregates or occur as crusts or coatings with a fibrous structure.

Clinoclase forms as a secondary mineral in the oxidized zones of deposits containing copper sulfides. Associated minerals include goethite (p.102), azurite (p.120), malachite (p.125), brochantite (p.139), adamite (p.160), quartz (p.168), and olivenite. Specimens come from Broken Hill, New South Wales, Australia; Tintic district, Utah, and Majuba Hill, Nevada, USA; the Vosges, France; and the Tsumeb Mine, Namibia.

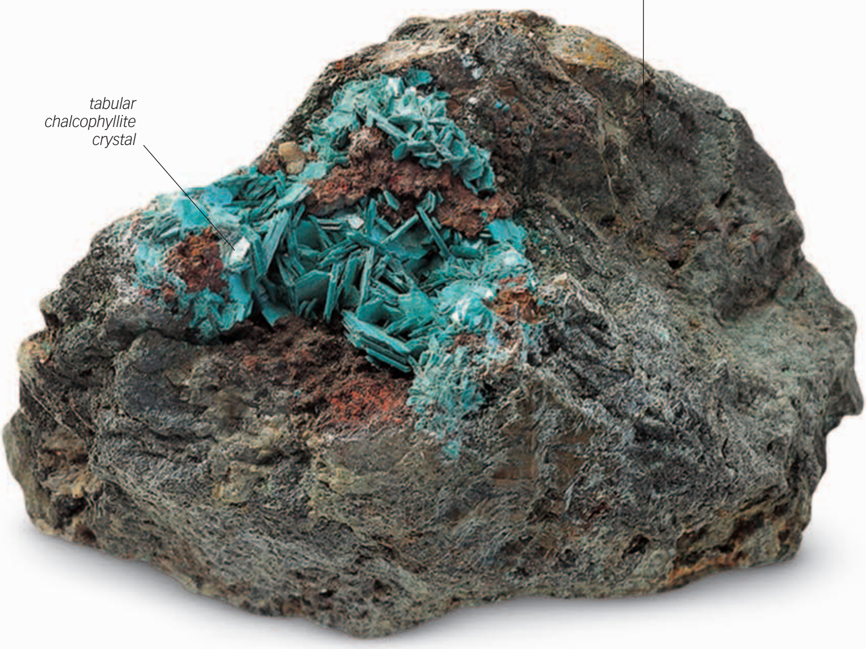

Tabular chalcophyllite
A mass of vivid blue, tabular chalcophyllite crystals rests on a rock matrix.

PROFILE

Hexagonal
2
2.7
Perfect basal
Uneven to subconchoidal
Pale green
Pearly to vitreous

$Cu_{18}Al_2(AsO_4)_2(SO_4)_3(OH)_{27}\cdot 33H_2O$

CHALCOPHYLLITE

A vivid blue-green in color, chalcophyllite takes its name from the Greek words *chalco*, which means "copper," and *phyllon*, which means "leaf"—an allusion to its copper content and its common foliated habit. Chalcophyllite was first described after material collected in Germany and named in 1847. Translucent crystals exhibit a blue-green color when viewed from one direction and appear almost colorless from another direction. Crystals are platy, six-sided, and flattened and may have triangular striations. Chalcophyllite may also be rosettelike, tabular, drusy, or massive.

This mineral occurs in hydrothermal copper deposits, often accompanied by cuprite (p.87), azurite (p.120), malachite (p.125), brochantite (p.139), and clinoclase (p.161).

Statue of Lamma
Chalcophyllite was used as an ore of copper when this copper statue was made in the period 1800–1600 BCE.

PROFILE

Monoclinic

1½–2½

3.1

Perfect

Uneven, sectile

Pale red

Adamantine to vitreous, pearly

Acicular crystals These brightly colored, needlelike crystals of erythrite are from Bou Azzer, Morocco.

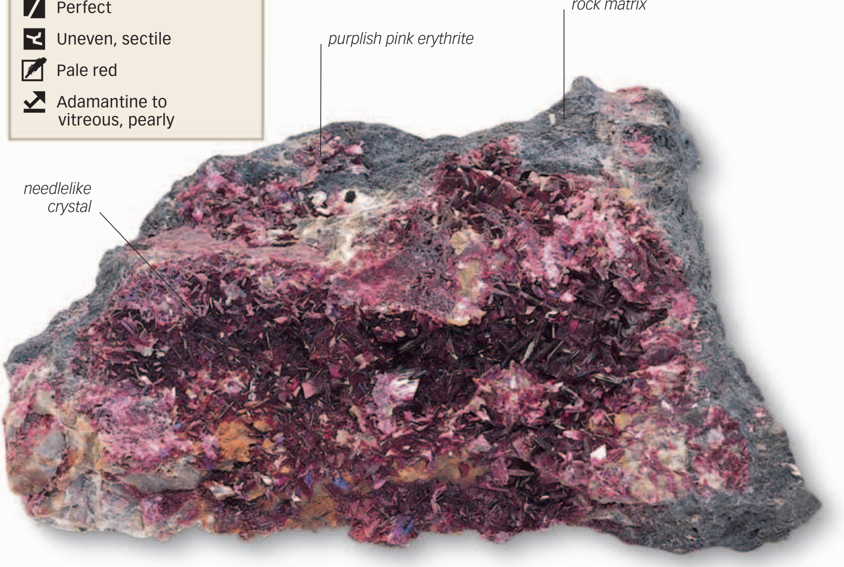

VARIANT

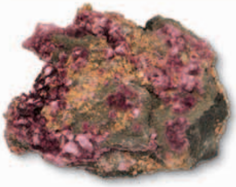

Erythrite crust A thin crust of erythrite on a brown rock base

$CO_3(AsO_4)_2 \cdot 8H_2O$

ERYTHRITE

Although of little commercial value, erythrite is an important tool for prospectors looking for cobalt and related silver deposits. The bright purplish pink color of erythrite in a rock indicates the presence of cobalt. This explains why miners call erythrite “cobalt bloom.” Erythrite is a cobalt arsenate hydrate. It forms a chemical replacement series with annabergite, in which nickel replaces cobalt in the erythrite structure. Its color may vary from crimson red to peach red, with the lighter colors indicating a higher nickel content. The coloration may also occur in bands. Well-formed crystals are rare, but when found they occur as deeply striated, prismatic to needlelike, commonly radiating, globular tufts of crystals, or as powdery coatings.

Erythrite is a secondary mineral found in the oxidized zones of cobalt-nickel-arsenic deposits. Fine specimens come from Canada and Morocco. Erythrite is also found in Mexico, France, southwestern USA, the Czech Republic, Germany, Australia, and elsewhere.

PROFILE

Hexagonal
3½–4
7.3
Poor
Conchoidal to uneven, brittle
White
Resinous

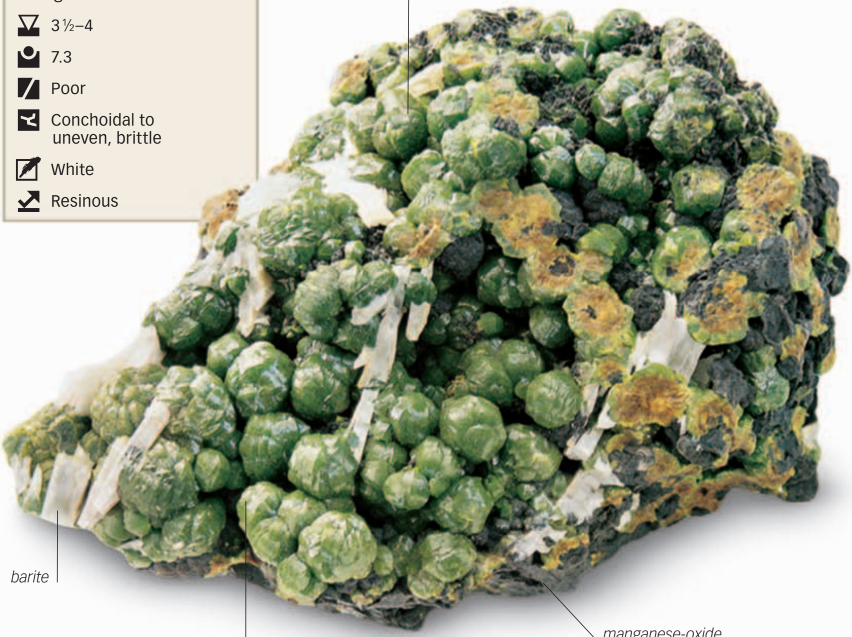

Mimetite on manganese oxide This specimen from England contains “campylite”—a rounded variety of mimetite—and barite on nodules of manganese oxide.

VARIANTS

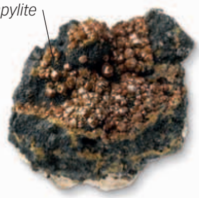

Campylite Massive and crystalline varieties of campylite set in a rock matrix

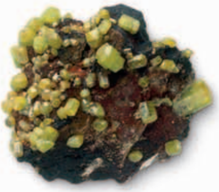

Prismatic crystals Mimetite in the form of prismatic, barrel-shaped crystals

$Pb_5(AsO_4)_3Cl$

MIMETITE

An arsenate mineral, mimetite is the end-member of a solid-solution series with pyromorphite (p.151). It is named after the Greek word *mimetes*, which means “imitator”—a reference to its resemblance to pyromorphite. Although similar in physical characterisitics and crystal form to pyromorphite, mimetite is a less common mineral. It forms heavy, barrel-shaped, hexagonal crystals or rounded masses, but is also found as botryoidal, granular, tabular, and needlelike aggregates. Mimetite specimens may be colorless or occur in shades of yellow, orange, brown, and green.

Mimetite is a secondary mineral, which forms in the oxidized zone of lead deposits and in other localities where the elements lead and arsenic occur together. Excellent specimens come from Chihuahua, Mexico; Saxony, Germany; Attica, Greece; Broken Hill, Australia; and Bisbee and Tombstone, Arizona, USA. A single crystal mined from Tsumeb in Namibia measured 2½ in (6.4 cm) in length.

PROFILE

Orthorhombic

3½–4

3.1–3.3

Imperfect

Subconchoidal

White

Vitreous to resinous or waxy

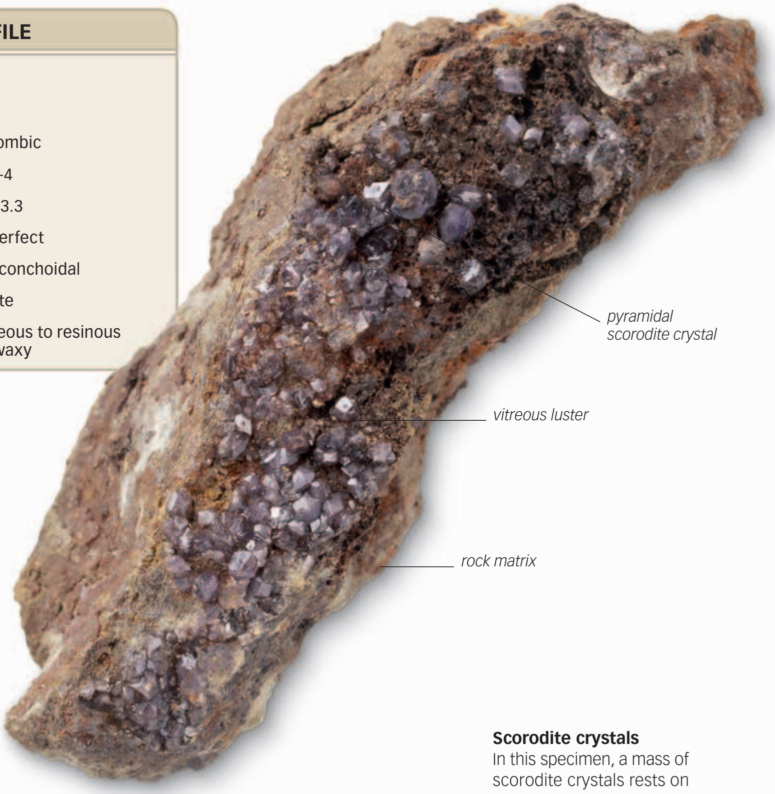

Scorodite crystals In this specimen, a mass of scorodite crystals rests on a rock matrix.

VARIANT

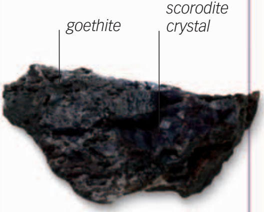

Crystal aggregate A specimen of scorodite with goethite

$FeAsO_4 \cdot 2H_2O$

SCORODITE

A hydrated iron arsenate mineral, scorodite takes its name from the Greek word *scorodion*, which means "garliclike"—an allusion to the odor emitted by the arsenic when specimens are heated. Scorodite can vary considerably in color depending on the light under which it is seen: pale leek green, grayish green, liver brown, pale blue, violet, yellow, pale grayish, or colorless. It may be blue-green in daylight but bluish purple to grayish blue in incandescent light; in transmitted light it may appear colorless to pale shades of green or brown. Crystals are usually dipyramidal, appearing octahedral, and may have a number of modifying faces. They may also be tabular or short prisms. Drusy coatings are common. Scorodite can also be porous and earthy or massive.

Scorodite is found in hydrothermal veins, hot spring deposits, and oxidized zones of arsenic-rich ore bodies. Associated minerals may be pharmacosiderite, vivianite (p.157), adamite (p.160), and various iron oxides.

SILICATES

The silicates constitute around 25 percent of all known minerals and nearly half of the most common ones. All silicates are built around a basic structure of silicon and oxygen. They are a major component of Earth and occur in lunar samples and meteorites.

COMPOSITION

The silicates make up about 95 percent of the crust and upper mantle of Earth. All silicates contain silicon and oxygen. Silicon is a lightweight, shiny metal; oxygen is a colorless, odorless gas.

rich purple coloring

Amethyst crystal
The tectosilicate mineral quartz occurs in several differently colored varieties. These include amethyst (above), rock crystal, smoky quartz, and citrine.

In silicates, silicon and oxygen combine to form structural tetrahedra, each with a silicon atom in the center and oxygen atoms at the corners. Silicate tetrahedra may exist as discrete, independent units and connect only with other silicate tetrahedra (as in quartz), or they may link with other elements such as iron, magnesium, and aluminum. Tetrahedra may also share their oxygen atoms at corners, edges, or, more rarely, faces, creating various structures. The different linkages also create voids of different sizes, which are occupied by ions of various metals. Substitutions can occur where atoms are of a relatively similar size. Silicates are divided into six main groups (see panel, below) according to the structural configurations that result from the different ways in which tetrahedra and other elements are linked. Within these main groups are further subdivisions based on chemistry—that is, the type and location of other atoms in the structure. Many groups are solid-solution series, such as the feldspars (see panel, opposite) and the garnets, in which the ions of various metals and semimetals substitute for each other within the silicate structure.

SILICATE GROUPS

The six silicate groups are based on the different ways in which the basic silica tetrahedra are linked. These differing linkages create voids of different sizes and configurations that allow positively charged atoms of different sizes to fit into the structure.

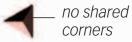

NESOSILICATES
Isolated groups of silica tetrahedra, with an SiO_4 unit in their formulae, are called nesosilicates.

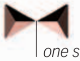

SOROSILICATES
These are double-tetrahedral groups with an oxygen atom shared by two tetrahedra.

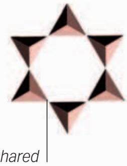

CYCLOSILICATES
These are closed, ringlike circles of tetrahedra that share corners.

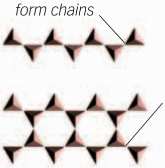
two shared corners form chains
two or three corners shared to form double chains

INOSILICATES (SINGLE-CHAIN AND DOUBLE-CHAIN)
Chains of silica tetrahedra with Si_2O_6 groups are called single-chain inosilicates.

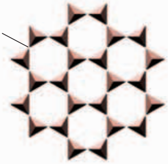

PHYLLOSILICATES
Flat sheets of silicate tetrahedra, with an Si_2O_5 unit in their chemical formulae, are called phyllosilicates.

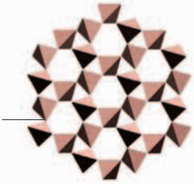

TECTOSILICATES
A three-dimensional network of silica tetrahedra, linked at each corner, makes up a tectosilicate.

THE FELDSPARS

The feldspars are a group of aluminosilicate minerals that contain calcium, sodium, or potassium. As shown here, there are three major solid-solution series within the group. Feldspars are the most abundant mineral in Earth's crust.

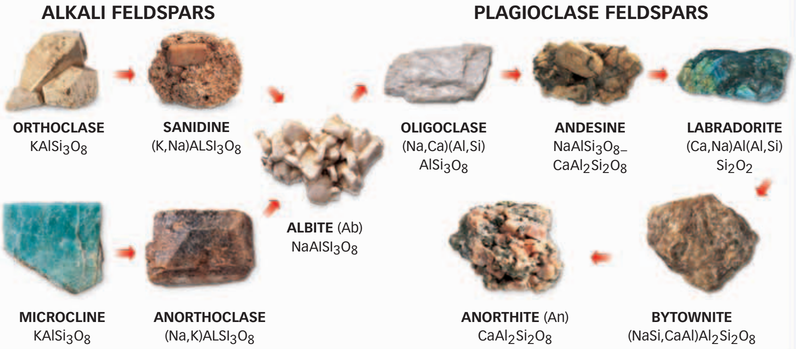
ALKALI FELDSPARS
PLAGIOCLASE FELDSPARS
ORTHOCLASE $KAlSi_3O_8$
SANIDINE $(K,Na)ALSI_3O_8$
ALBITE (Ab) $NaAlSI_3O_8$
OLIGOCLASE $(Na,Ca)(Al,Si)AlSi_3O_8$
ANDESINE $NaAlSi_3O_8$–$CaAl_2Si_2O_8$
LABRADORITE $(Ca,Na)Al(Al,Si)Si_2O_2$
MICROCLINE $KAlSi_3O_8$
ANORTHOCLASE $(Na,K)ALSI_3O_8$
ANORTHITE (An) $CaAl_2Si_2O_8$
BYTOWNITE $(NaSi,CaAl)Al_2Si_2O_8$

OCCURRENCE AND USES

The ultimate source of all silicates is igneous rock in which tectosilicate feldspar minerals are the major component. Silicates are found not only on Earth but also on the Moon and in meteorites. After feldspar, quartz is the most abundant mineral in the crust and upper mantle. It occurs in nearly all high-silica igneous, metamorphic, and sedimentary rocks. In silica-poor rocks where quartz does not form, other silicate minerals develop. Since many silicates, especially quartz and its varieties, are resistant to weathering, they form the major component of most detrital sediments. There are numerous uses of silicates. Quartz and its varieties find use as gemstones, in electronic and optical applications, and as abrasives. The feldspars are used in glass and ceramics, as gemstones, and as abrasives. Other silicates are ores, and yet others are important gem, ornamental, and industrial minerals. The tough rocks formed from silicate minerals are used as major building and industrial materials.

Jadeite mask
The inosilicate jadeite was one of the first minerals used by humans. Although difficult to shape, it has been used for tools and ornaments.

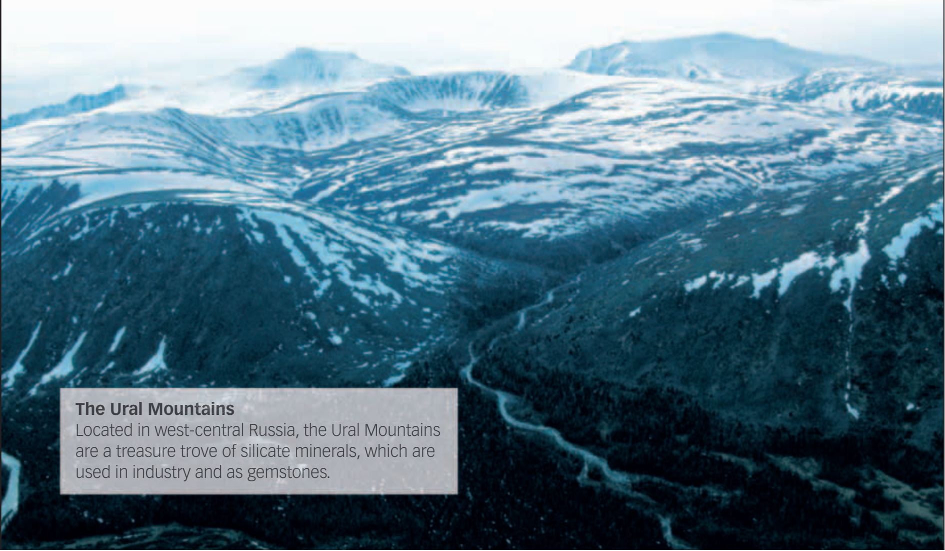

The Ural Mountains
Located in west-central Russia, the Ural Mountains are a treasure trove of silicate minerals, which are used in industry and as gemstones.

PROFILE

Hexagonal

7

2.7

None

Conchoidal

White

Vitreous

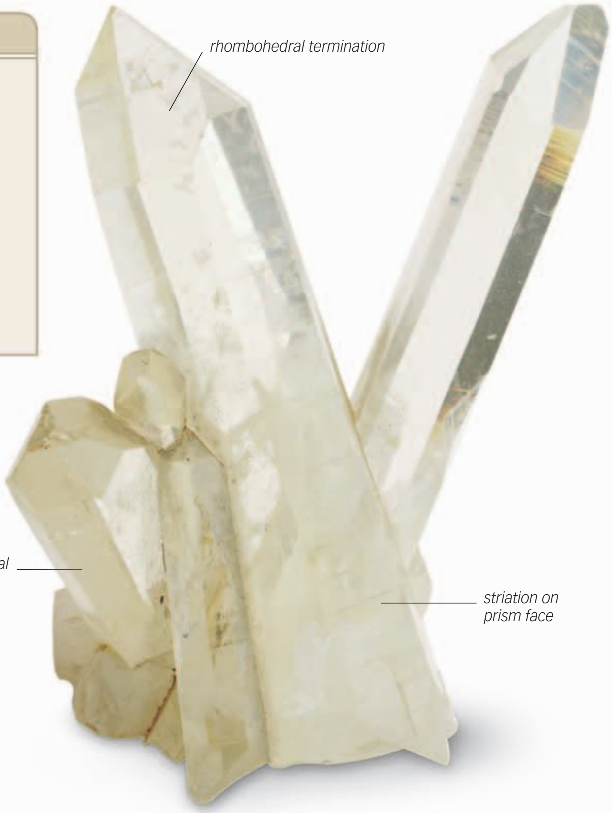

Prismatic quartz This group of long, prismatic quartz crystals is from the Dauphiné province of France.

VARIANTS

Pyramidal amethyst An amethyst specimen with pyramidal terminations

milky quartz
termination
smoky quartz

Smoky quartz Double-terminated smoky quartz in milky quartz

termination

Milky quartz A white, terminated quartz prism

SiO_2

QUARTZ

One of the most common minerals in Earth's crust, quartz has two forms: macrocrystalline (with crystals that can be seen by eye) and cryptocrystalline (formed of microscopic crystals). Macrocrystalline quartz is usually colorless and transparent, as in rock crystal, or white and translucent, as in milky quartz. Colored varieties include: pink and translucent rose quartz; transparent to translucent lavender or purple amethyst; transparent to translucent black or brown smoky quartz; and transparent to translucent yellow or yellow-brown citrine. All crystalline varieties form hexagonal prisms and pyramids.

Cryptocrystalline varieties of quartz include chalcedony (p.169), agate (p.170), and jasper (p.171). Quartz occurs in nearly all silica-rich sedimentary, igneous, and metamorphic rocks.

Oval citrine This large, oval-cut citrine is set in a silver brooch. It is encircled by silver leaves and faceted amethysts.

PROFILE

Hexagonal
7
2.7
None
Uneven
White
Waxy to dull

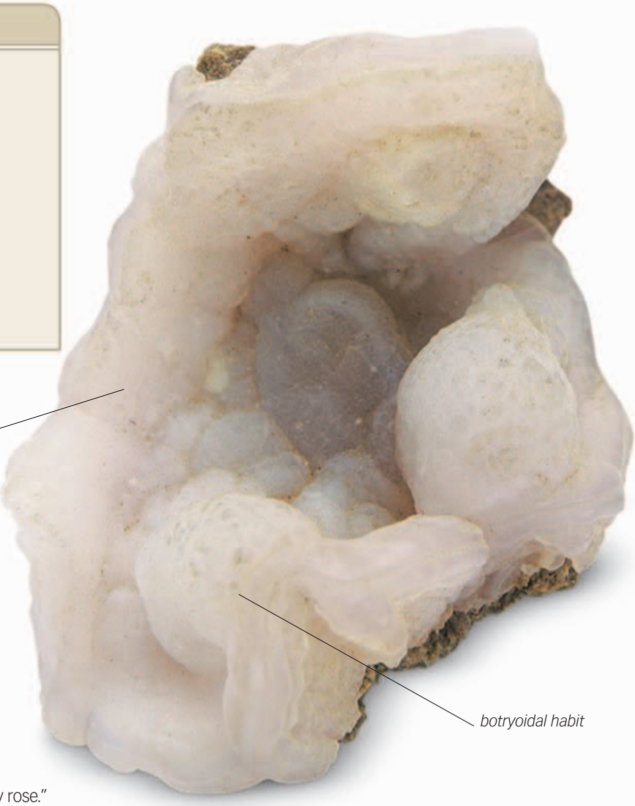

Pink chalcedony This form of botryoidal pink chalcedony is sometimes referred to as a "chalcedony rose."

VARIANTS

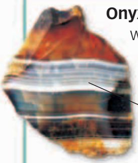

Onyx Chalcedony with straight banding

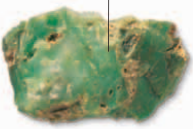

Chrysoprase Chalcedony colored green by nickel

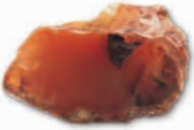

Carnelian A piece of red-orange chalcedony

SiO_2

QUARTZ: CHALCEDONY

A compact variety of microcrystalline quartz (p.168), chalcedony may have been named after the ancient port of Khalkedon in Asia Minor (now Turkey), where there were extensive deposits of this mineral. Chalcedony is white when pure, but it may contain microscopic inclusions of other minerals, which give it a range of colors. This mineral is composed of microscopic fibers and can be mamillary, botryoidal, or stalactitic.

Many chalcedonies are semiprecious gems and have their own names. Chalcedony with distinct banding is called agate (p.170). All varieties of chalcedony occur worldwide. It is found in veins, concretions, and geodes. It forms in cavities, cracks, and when silica-rich waters at low temperatures (up to 400°F/200°C) percolate through existing rocks.

Chalcedony blade This Aztec sacrificial knife has a finely chipped chalcedony blade and a mosaic handle.

PROFILE

Hexagonal
- 7
- 2.7
- None
- Conchoidal
- White
- Vitreous to waxy

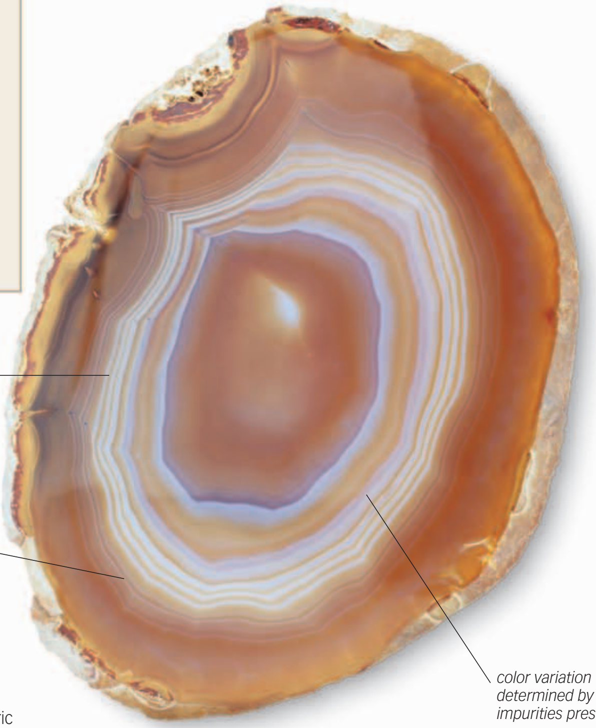
concentric bands of agate
shapes of bands follow outline of cavity
color variation determined by impurities present

Brazilian agate
This cross section of a Brazilian agate nodule shows the concentric layering typical of agate.

VARIANT

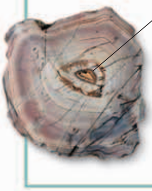
concentric bands

Fortification agate
Banded agate with angular bends

SiO_2

CHALCEDONY: AGATE

A common, semiprecious chalcedony, agate has been worked since prehistoric times. It is a compact, microcrystalline variety of quartz (p.168), and it has the same physical properties as quartz. Agate is characterized by concentric color bands in shades of white, yellow, gray, pale blue, brown, pink, red, or black.

Other names often precede the word agate to indicate the mineral's visual characteristics or place of origin. One of these is fire agate, which has inclusions of reddish to brown hematite that give an internal iridescence to polished stones. Another is fortification agate, which has concentric bands of color resembling an aerial view of an ancient fortress. Most agates are found in cavities in ancient lavas or other extrusive igneous rocks.

Snuff bottle
The 19th-century Chinese snuff bottle seen here has been carved from agate. It has a jade stopper.

PROFILE

Hexagonal
7
2.7
None
Conchoidal
White
Vitreous

Color variation
Hematite colors this example of jasper brownish red. Threads of white quartz veins make a crisscross pattern on this specimen.

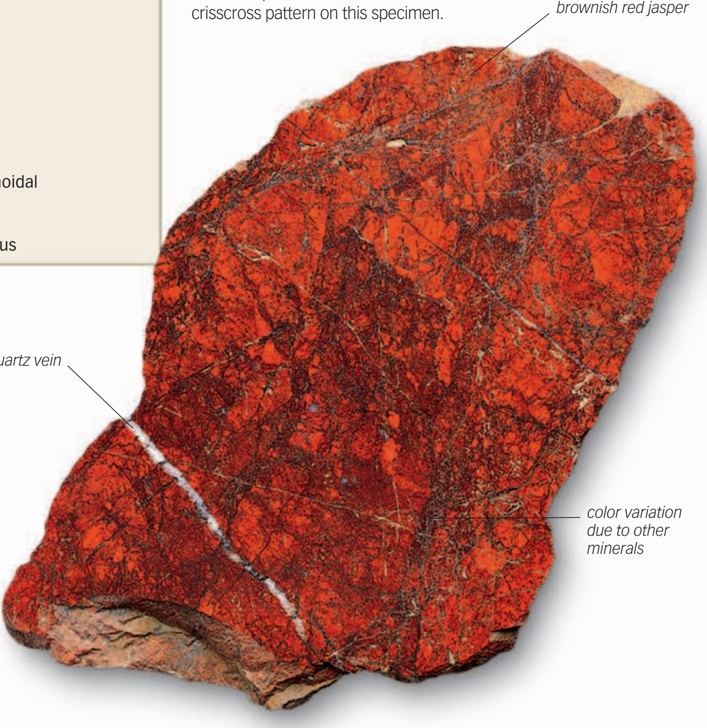

VARIANTS

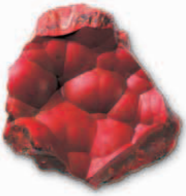

Mammillary jasper Red jasper in mammillary form

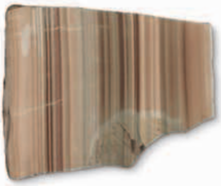

Ribboned jasper A specimen of jasper with parallel, reddish bands

SiO_2

QUARTZ: JASPER

An impure variety of cryptocrystalline quartz (p.168), jasper takes its name from the Greek word *iaspis*, which is probably of Semitic origin. It is fine-grained or dense, and it contains various amounts of other materials, which give it opacity and color. Hematite (p.91) gives jasper a brick-red to brownish red color; clay a yellowish white or gray color; and goethite (p.102) a brown or yellow hue.

Jasper forms when silica-rich waters at low temperatures (up to 400°F/200°C) percolate through cracks and fissures in other rocks, incorporating a variety of materials and leaving behind deposits. It is found worldwide wherever cryptocrystalline quartz occurs. The classification and naming of jasper varies greatly and often incorporates place names or colors. Only some of these are formally recognized as varieties of jasper, leaving great latitude in defining which jasper is which. Color names such as "red" or "green" can apply to a range of shades, while locality names, such as "Bruneau jasper" after a canyon in Idaho, tend to be more specific.

PROFILE

Crystal system Amorphous

5–6

1.9–2.3

None

Conchoidal

White

Vitreous

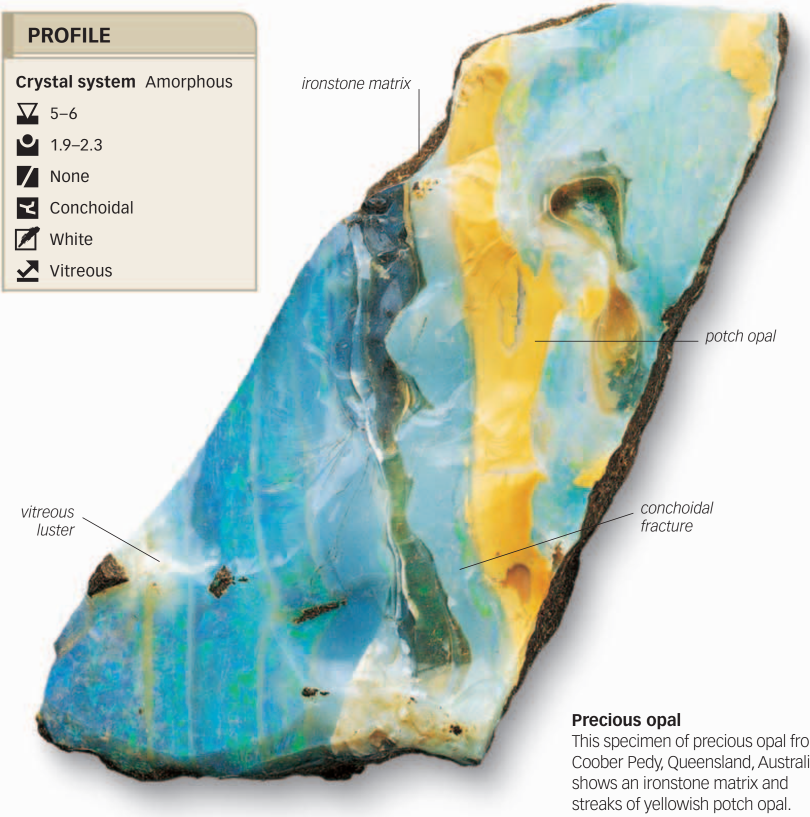

Precious opal
This specimen of precious opal from Coober Pedy, Queensland, Australia, shows an ironstone matrix and streaks of yellowish potch opal.

VARIANTS

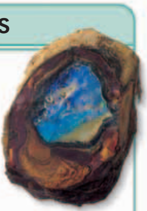

Boulder opal Blue mass of opal in an iron-oxide nodule

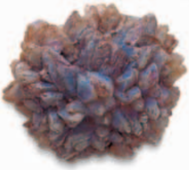

Opal pseudomorph Crystals of glauberite replaced by opal

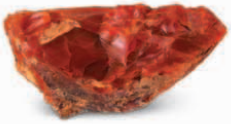

Fire opal Noniridescent, transparent opal

$SiO_2 \cdot nH_2O$

OPAL

Known since antiquity, opal derives its name from the Roman word *opalus,* which means "precious stone." Although it is colorless when pure, the vast majority of common opal occurs in opaque, dull yellows and reds. It varies from essentially amorphous to partially crystalline. Precious opal is the least crystalline form of the mineral, consisting of a regular arrangement of tiny, transparent, silica spheres. Regularly arranged spheres of a particular size create a diffraction effect called color play.

Opal is widespread and is deposited at low temperatures (up to 400°F/200°C) from silica-bearing, circulating waters. It is found as nodules, stalactitic masses, veinlets, and encrustations in most kinds of rocks. Opal constitutes important parts of many sedimentary accumulations, such as diatomaceous earth.

Victorian ring
Some cut opal dries and cracks with age and needs to be kept moist. The opal in this ring is well preserved.

PROFILE

Monoclinic

6–6½

2.5–2.6

Perfect

Subconchoidal to uneven, brittle

White

Vitreous

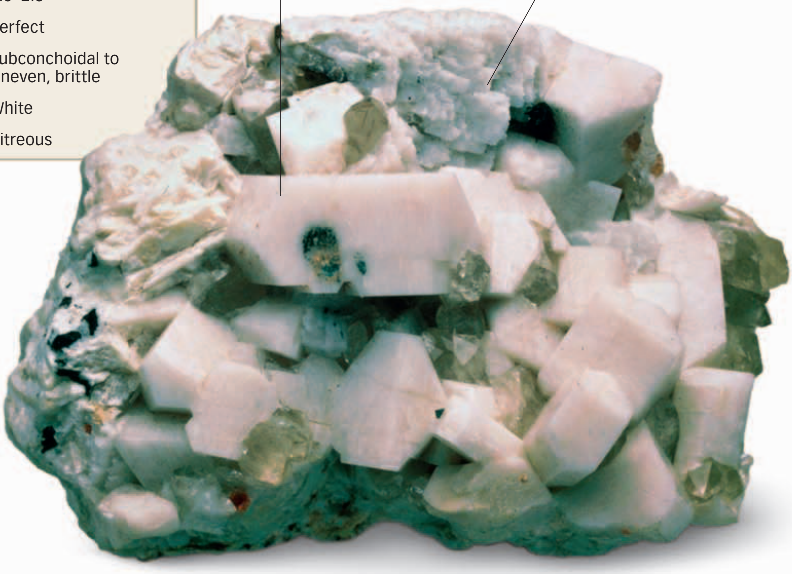

Orthoclase prisms In this specimen, white, blocky prisms of orthoclase are associated with cleavelandite albite and set in pegmatite.

VARIANTS

Yellow orthoclase A crystal of yellow orthoclase

Moonstone rough An opalescent variety of orthoclase

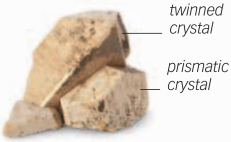

Orthoclase crystals Twinned orthoclase with smaller prism

KAlSi$_3$O$_8$

ORTHOCLASE

An important rock-forming mineral, orthoclase is the potassium-bearing end member of the potassium—sodium feldspar solid-solution series. It is a major component of granite (pp.258–59)—its pink crystals give granite its typical color. Crystalline orthoclase can also be white, colorless, cream, pale yellow, or brownish red. Orthoclase appears as well-formed, short, prismatic crystals, which are frequently twinned. It may also occur in massive form. Moonstone is a variety of orthoclase that exhibits a schiller effect.

Pure orthoclase is rare—some sodium is usually present in the structure. Specimens are abundant in igneous rocks rich in potassium or silica, in pegmatites (p.260), and in gneisses (p.288). This mineral is important in ceramics, to make the item itself and as a glaze.

Moonstone-set brooch Orthoclase exhibits the schiller effect which creates the shimmer seen on the moonstones in this brooch.

Prismatic sanidine
This single, well-formed prismatic crystal of sanidine rests in a matrix of the volcanic rock trachyte.

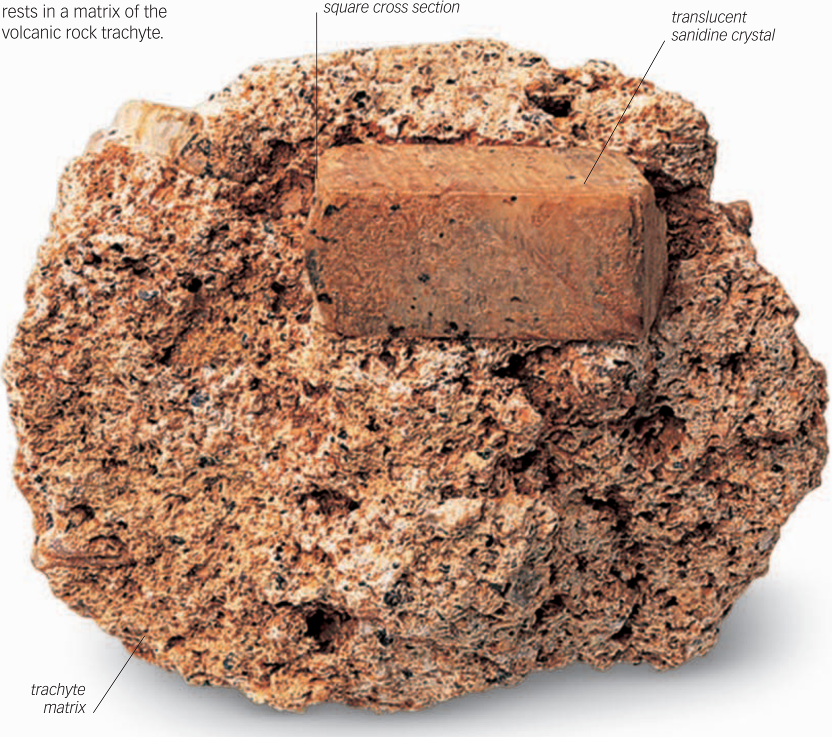

PROFILE

Monoclinic

6–6½

2.6

Perfect, good

Conchoidal to uneven

White

Vitreous

$(K,Na)AlSi_3O_8$

SANIDINE

A member of the solid-solution series of potassium and sodium feldspars, sanidine is the high-temperature form of potassium feldspar, forming at 1,065°F (575°C) or above. Crystals are usually colorless or white, glassy, and transparent, but they may also be gray, cream, or occur in other pale tints. They are generally short prismatic or tabular, with a square cross section. Twinning is common. Crystals have been known to reach 20in (50cm) in length. Sanidine is also found as granular or cleavable masses.

A widespread mineral, sanidine occurs in feldspar- and quartz-rich volcanic rocks, such as rhyolite (p.278), phonolite, and trachyte (p.279). It is also found in eclogites (p.299), contact metamorphic rocks, and metamorphic rocks formed at low pressure and high temperature. Sanidine forms spherular masses of needlelike crystals in obsidian (p.280), giving rise to what is called snowflake obsidian. Significant occurrences of sanidine are at the Alban Hills near Rome, Italy; Mont St.-Hilaire, Canada; and Eifel, Germany.

PROFILE

Triclinic

6–6½

2.6

Perfect, good

Conchoidal to uneven, brittle

White

Vitreous, dull

Prismatic microcline
Numerous prismatic crystals of light-colored microcline sit atop a pegmatite matrix, along with smoky quartz.

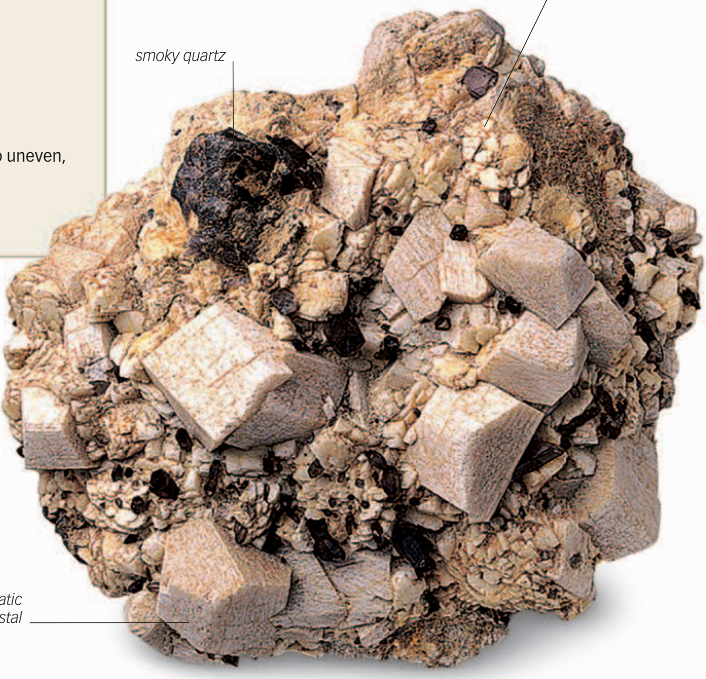

VARIANT

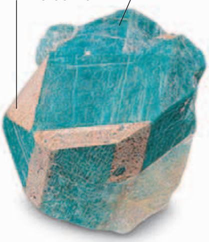

Amazonite A single crystal of blue-green amazonite, a variety of microcline

$KAlSi_3O_8$

MICROCLINE

Used in ceramics and as a mild abrasive, microcline is one of the most common feldspar minerals. It can be colorless, white, cream to pale yellow, salmon pink to red, or bright green to blue-green. Microcline forms short prismatic or tabular crystals that are often of considerable size: single crystals can weigh several tons and reach yards in length. Crystals are often multiply twinned, with two sets of fine lines at right angles to each other. This gives a "plaid" effect that is unique to microcline among the feldspars. Microcline can also be massive.

The mineral occurs in feldspar-rich rocks, such as granite (pp.258–59), syenite (p.262), and granodiorite (p.263). It is found in granite pegmatites (p.260) and in metamorphic rocks, such as gneisses (p.288) and schists (p.291–92).

Amazonite cabochon
This Arts and Craft ring exhibits an asymmetrically set cabochon of amazonite in a rose-and-foliage design.

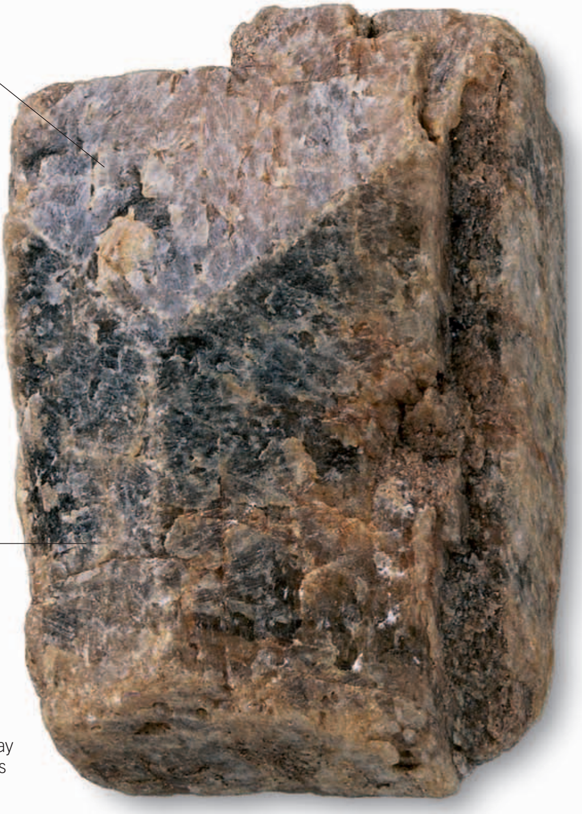

Prismatic anorthoclase
This specimen of pink and gray prismatic anorthoclase shows well-developed crystal faces.

PROFILE

Triclinic
- 6–6½
- 2.6
- Perfect, good
- Conchoidal to uneven, brittle
- White
- Vitreous

$(Na,K)AlSi_3O_8$

ANORTHOCLASE

This member of the sodium- and potassium-rich feldspar group takes its name from the Greek word *anorthos*, which means "not straight"—a reference to its oblique cleavage. Anorthoclase is colorless, white, cream, pink, pale yellow, gray, or green. Its crystals are prismatic or tabular and are often multiply twinned. Anorthoclase crystals can show two sets of fine lines at right angles to each other like microcline (p.175), but the lines are much finer. Specimens can also be massive or granular.

Anorthoclase forms in sodium-rich igneous zones. It commonly occurs with ilmenite (p.90), apatite (p.148), and augite (p.211). Much anorthoclase exhibits a gold, bluish, or greenish schiller effect, making it one of several feldspars known as moonstone when cut *en cabochon*. A type of the igneous rock syenite (p.262) called larvikite has large schillerized crystals of anorthoclase and is highly prized as an ornamental stone. Anorthoclase is widespread, but fine examples come from Cripple Creek, Colorado, USA; Larvik, Norway; and Fife, Scotland.

PROFILE

Triclinic

6–6½

2.6

Perfect, good

Conchoidal to uneven, brittle

White

Vitreous to pearly

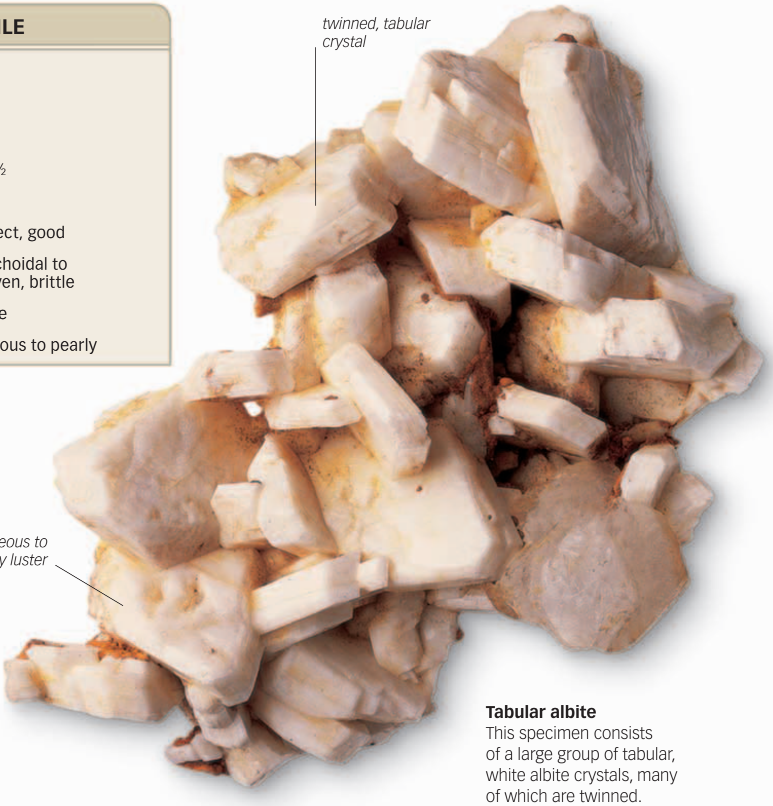

Tabular albite This specimen consists of a large group of tabular, white albite crystals, many of which are twinned.

VARIANT

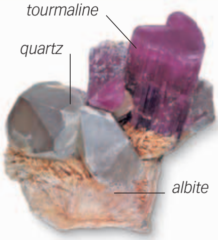

Albite base Tourmaline and quartz crystals on albite

$NaAlSi_3O_8$

ALBITE

A rock-forming mineral, albite takes its name from the Latin word *albus*, which means “white”—a reference to its usual color. Specimens can also be colorless, yellowish, pink, or green. Albite occurs as tabular or platy crystals that are often twinned, glassy, and brittle. It can also be massive or granular. Albite was named in 1707.

This mineral is the solid-solution end member of both the plagioclase and the sodium- and potassium-rich feldspars. It occurs in pegmatites (p.260) and in some feldspar- and quartz-rich igneous rocks. Albite also forms through chemical processes in certain sedimentary environments and occurs in low-grade metamorphic rocks. The cleavelandite variety occurs in complex pegmatites as thin plates or scales.

Facet-grade albite Faceted albite, although fragile, is sometimes used in jewelry, along with albite’s moonstone variety.

PROFILE

Triclinic

6

2.6

Perfect

Conchoidal to uneven, brittle

White

Vitreous

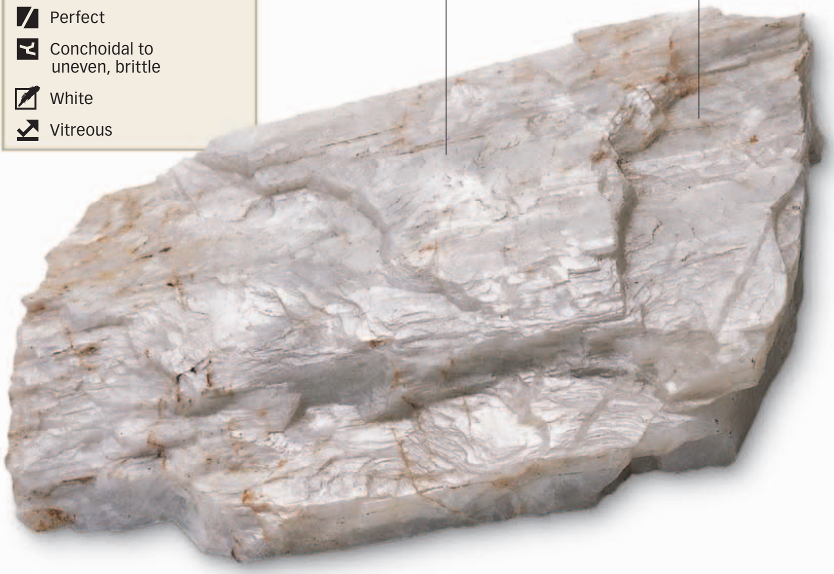

Massive oligoclase This typical massive specimen of oligoclase is from Penland, Mitchell County, North Carolina.

VARIANTS

Sunstone rough An uncut specimen of sunstone oligoclase

smoky quartz

Oligoclase crystal A pink crystal accompanied by smoky quartz

$(Na,Ca)Al_2Si_2O_8$

OLIGOCLASE

In 1826, the German mineralogist August Breithaupt named this mineral after two Greek words: *oligos*, which means "little," and *clasein*, which means "to break"—because it was thought to have a less perfect cleavage than albite (p.177). Oligoclase can be gray, white, red, greenish, yellowish, brown, or colorless. Its usual habit is massive or granular, although it can form tabular crystals that are commonly twinned.

Oligoclase is the most common of the plagioclase feldspars. It occurs in granite (pp.258–59), granitic pegmatites (p.260), diorite (p.264), rhyolite (p.278), and other feldspar- and quartz-rich igneous rocks. It also occurs in high-grade, metamorphosed gneisses (p.288) and schists (pp.291–92).

Semiprecious oligoclase Sunstone oligoclase, such as the oval example seen here, has hematite or goethite inclusions.

PROFILE

Triclinic

6–6½

2.7

Perfect

Conchoidal to uneven, brittle

White

Vitreous

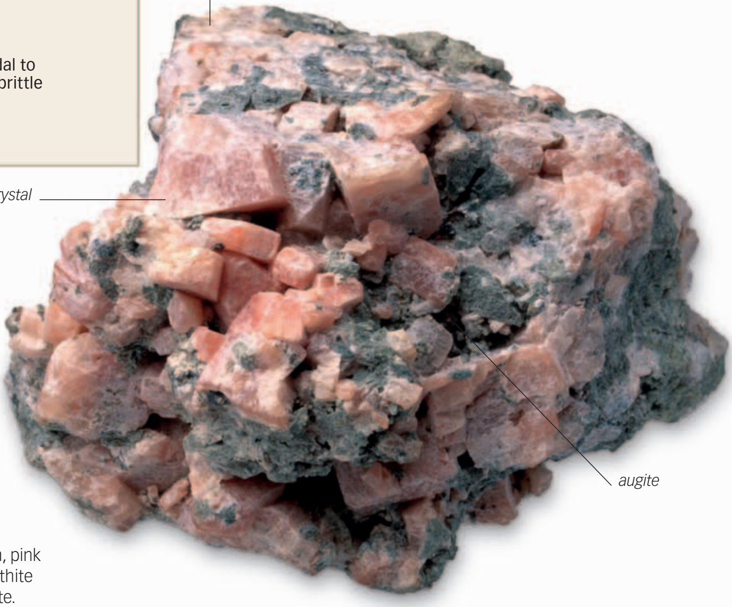

Pink anorthite
In this specimen, pink crystals of anorthite occur with augite.

VARIANT

Anorthite aggregate A mass of blue-gray anorthite

$CaAl_2Si_2O_8$

ANORTHITE

The calcium-rich end-member of the plagioclase-feldspar solid-solution series, anorthite takes its name from the Greek word *anorthos*, which means “not straight”—a reference to its triclinic form. Its brittle, short, glassy crystals are well-formed prisms that can be colored white or shades of gray, pink, or red. Specimens are also massive or granular. Anorthite is a calcium aluminosilicate and can contain up to 10 percent albite (p.177).

Anorthite is a major rock-forming mineral present in many magnesium- and iron-rich igneous rocks, contact metamorphic rocks, and chondroditic meteorites (p.337). Pure anorthite is uncommon; it weathers readily and is rare in rocks exposed at the surface for long periods. Anorthosite (p.261), a rock composed mainly of anorthite, makes up much of the lunar highlands. The so-called Genesis Rock, brought back by Apollo 15, is made of anorthosite and dates back to the formation of the Moon, which occurred about 4.1 billion years ago. Anorthite was also discovered in the comet Wild 2.

PROFILE

Triclinic
6–6½
2.7
Perfect
Uneven to conchoidal
White
Vitreous

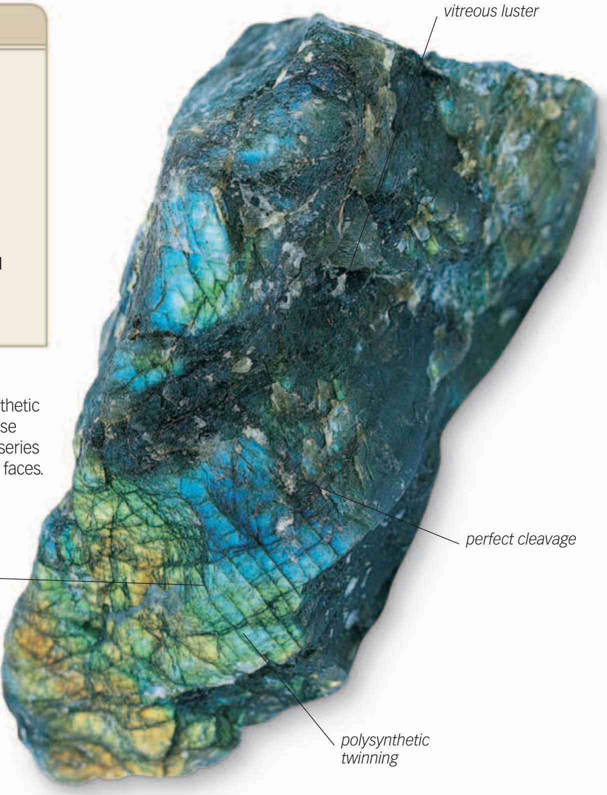

Blue labradorite This specimen shows polysynthetic twinning typical of plagioclase feldspars. This is evident as a series of parallel lines on the broken faces.

VARIANTS

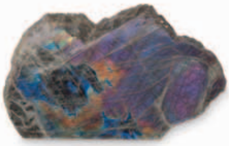

Schiller effect Orange, purple, and blue flashes visible in a specimen of labradorite

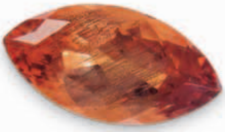

Orange sunstone Labradorite "sunstone" from Oregon

$NaAlSi_3O_8$–$CaAl_2Si_2O_8$

LABRADORITE

The calcium-rich, middle-range member of the plagioclase feldspars, labradorite is characterized by its schiller effect—a rich play of iridescent colors, mainly blue, on cleavage surfaces. Specimens are generally blue or dark gray but can also be colorless or white. When transparent, labradorite is yellow, red, orange, or green. This mineral seldom forms crystals, but when crystals do occur, they are tabular. It most often forms masses with crystals that can be microscopic or up to 3 ft (1 m) or more wide.

Labradorite is a major constituent of certain medium-silica and silica-poor igneous and metamorphic rocks, including diorite (p.264), gabbro (p.265), basalt (p.273), andesite (p.275), and amphibolite (p.296). Gem-quality labradorite from Finland is known as spectrolite.

Semiprecious gemstone The polished oval of labradorite in this choker beautifully displays the stone's rainbow iridescence.

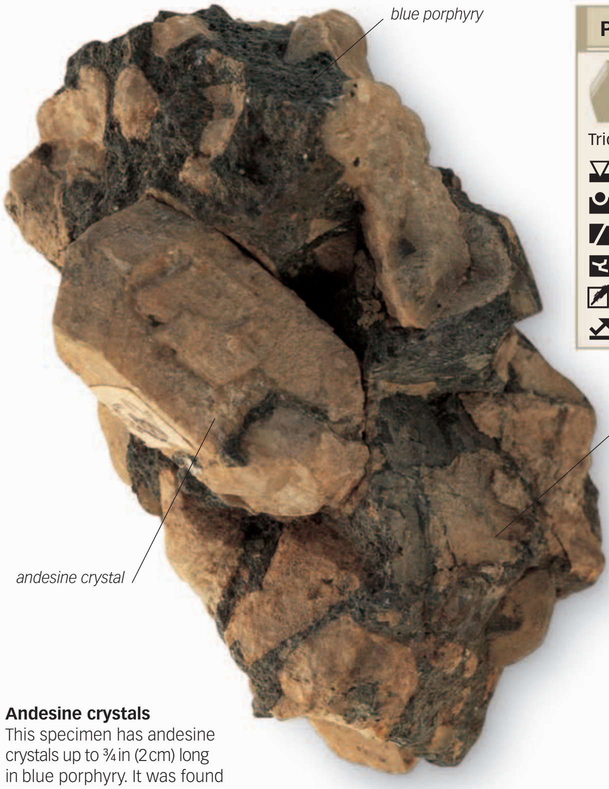

Andesine crystals
This specimen has andesine crystals up to ¾ in (2 cm) long in blue porphyry. It was found in Estérel, Var, France.

PROFILE

Triclinic
6–6½
2.7
Perfect
Conchoidal to uneven
White
Subvitreous to pearly

VARIANT

Andesite porphyry Andesite is a major constituent of this porphyry rock

$NaAlSi_3O_8$–$CaAl_2Si_2O_8$

ANDESINE

The plagioclase feldspar andesine is named after the Andes Mountains in South America, where it is abundant in andesite lavas. A white, gray, or colorless mineral, andesine often forms well-defined crystals that usually exhibit multiple twinning. It can also be massive or occur as rock-bound grains.

A sodium calcium aluminosilicate, andesine is an intermediate member of the plagioclase solid-solution series. It occurs widely in igneous rocks of medium silica content, especially in andesite (p.275). Andesine is also found in other intermediate igneous rocks, such as syenite (p.262) and diorite (p.264). Specimens are commonly associated with magnetite (p.92), quartz (p.168), biotite (p.197), and hornblende (p.218). Andesine typically occurs in metamorphic rocks formed under high pressure and temperatures (1,065°F/575°C or above). It is also found as detrital grains in sedimentary rocks. The accurate identification of individual specimens involves detailed study and analysis.

Massive nepheline This specimen of nepheline from Arkansas shows the mineral's most typical massive habit.

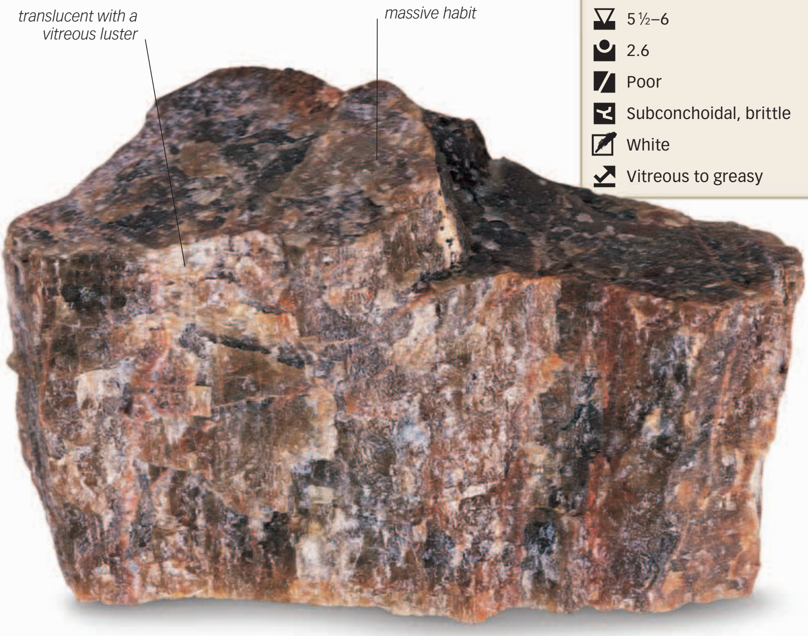

PROFILE

Hexagonal
5½–6
2.6
Poor
Subconchoidal, brittle
White
Vitreous to greasy

VARIANT

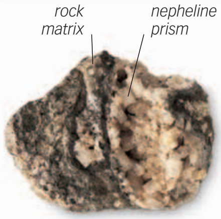

Nepheline crystals Well-developed crystals within cavities in a rock matrix

$(Na,K)AlSiO_4$

NEPHELINE

The most common feldspathoid mineral, nepheline takes its name from the Greek word *nephele*, which means "cloud"—a reference to the fact that the mineral becomes cloudy or milky in strong acids. Specimens are usually white in color, often with a yellowish or grayish tint. They can also be colorless, gray, yellow, or red-brown. Nepheline is generally massive. Crystals usually occur as hexagonal prisms, although they can exhibit a variety of prism and pyramid shapes. Nepheline also forms large, tabular phenocrysts in igneous rocks.

This rock-forming mineral is found in iron- and magnesium-rich igneous rocks with perovskite (p.89), spinel (p.96), and olivine (p.232). It also occurs in intermediate igneous rocks with aegirine (p.209) and augite (p.211) and in some volcanic and metamorphic rocks.

Ceramic bowl Nepheline is sometimes used as a substitute for feldspars in ceramics, such as this porcelain bowl.

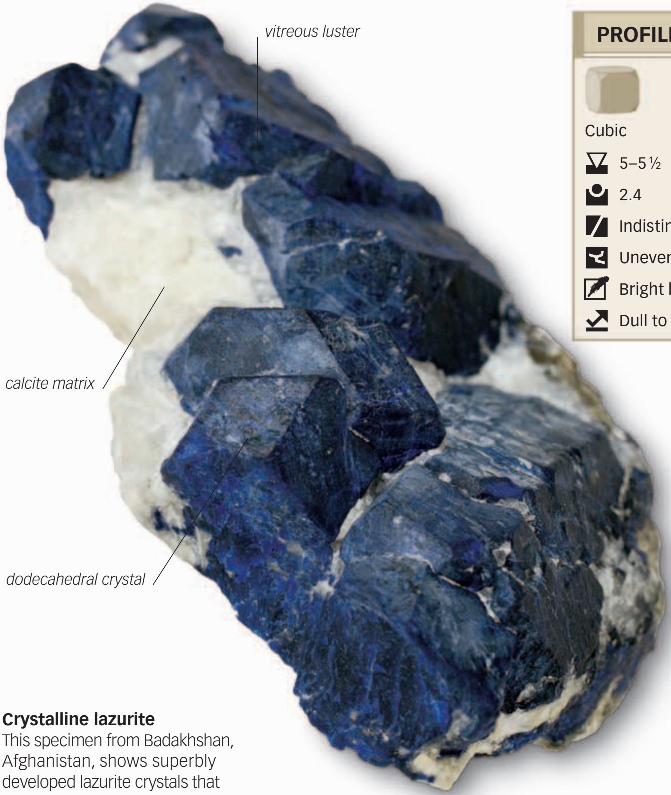

Crystalline lazurite This specimen from Badakhshan, Afghanistan, shows superbly developed lazurite crystals that are up to ¾ in (1.9 cm) long.

PROFILE

Cubic
5–5½
2.4
Indistinct
Uneven, brittle
Bright blue
Dull to vitreous

$Na_3Ca(Al_3Si_3O_{12})S$

LAZURITE

A sodium calcium aluminosilicate, lazurite is the main component of the gemstone lapis lazuli and accounts for the stone's intense blue color, although lapis lazuli also typically contains pyrite (p.62), calcite (p.114), sodalite (p.184), and haüyne. Lazurite specimens are always deep or vibrant blue. Distinct crystals were thought to be rare until large numbers were brought out of mines in Badakhshan, Afghanistan, in the 1990s. These are usually dodecahedral and are much sought after. Most lazurite is either massive or occurs in disseminated grains.

Lapis lazuli is relatively rare. It forms in crystalline limestones (p.319) as a product of contact metamorphism. The best quality lapis lazuli is dark blue with minor patches of calcite and pyrite. In addition to its use as a gemstone, lapis lazuli was used as one of the first eye shadows.

Expensive pigment Powdered lapis lazuli was once used to make ultramarine, one of the most expensive pigments.

VARIANTS

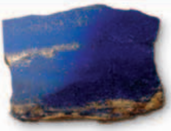

Polished slab A slice of lazurite showing intense color

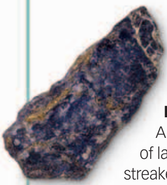

Lapis lazuli An uncut piece of lapis lazuli streaked with calcite

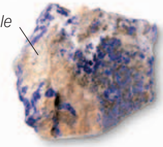

Lazurite in marble Lazurite dispersed in marble

PROFILE

Cubic

5½–6

2.1–2.3

Poor to distinct

Uneven to conchoidal

White to light blue

Vitreous to greasy

Massive sodalite This sodalite specimen shows intense blue color, which can sometimes lead to the mineral being mistaken for lapis lazuli.

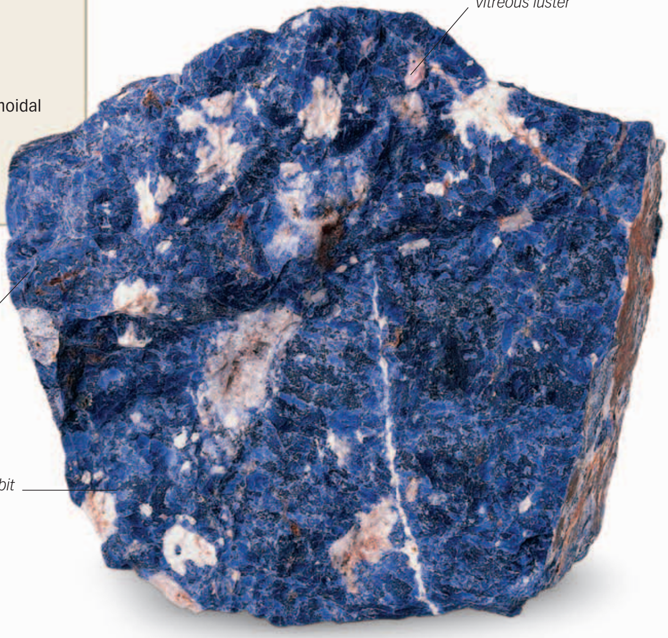

$Na_4Al_3Si_3O_{12}Cl$

SODALITE

Named in 1811 after its high sodium content, sodalite is sodium aluminum silicate chloride. Specimens can be blue, gray, pink, colorless, or other pale shades. They sometimes fluoresce bright orange under ultraviolet light. Sodalite nearly always forms massive aggregates or disseminated grains. Crystals are relatively rare; when found, they are dodecahedral or octahedral.

Sodalite occurs in igneous rocks and associated pegmatites (p.260). It is sometimes found in contact metamorphosed limestones (p.319) and dolomites (p.320) and in rocks ejected from volcanoes. Rare crystals are found on the Mount Vesuvius volcano in Italy. Uncommon transparent specimens from Mont St.-Hilaire, Canada, are faceted for collectors.

Sodalite beads This unusual modern Egyptian necklace has beads made of blue sodalite and red carnelian.

VARIANTS

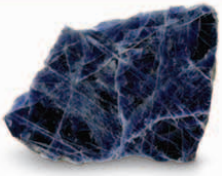

Polished sodalite A specimen that has been polished to bring out its color

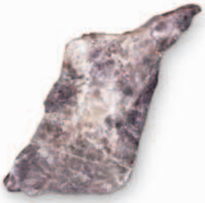

Indian sodalite A specimen of light blue sodalite found in India

PROFILE

Cubic

Tetragonal

5½–6

2.5

Poor

Conchoidal, brittle

White

Vitreous

Leucite crystals In this specimen formed at a high temperature, fine psuedotrapezohedral crystals of leucite rest in cavities in a rock matrix.

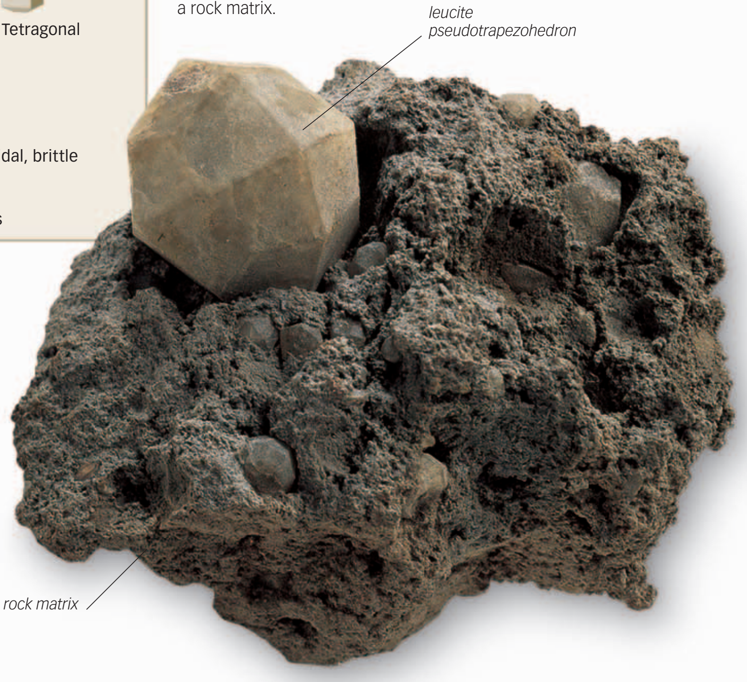

VARIANTS

Single crystal A single yellowish crystal of leucite

Italian leucite A crystal in pseudotrapezohedral form from Casserta, Italy

$KAlSi_2O_6$

LEUCITE

The name leucite comes from the Greek word *leukos*, which means "matt white"—a reference to the mineral's most common color. Specimens can also be colorless or gray. Crystals are common and can be up to 3½ in (9 cm) wide. More often, leucite occurs as massive or granular aggregates or as disseminated grains. It is tetragonal at temperatures below 1,155°F (625°C) and cubic with trapezohedral crystals at higher temperatures. The trapezohedral form is preserved as the mineral cools and develops tetragonal symmetry.

Leucite is found in potassium-rich and silica-poor igneous rocks. It is found with nepheline (p.182), sodalite (p.184), natrolite (p.186), analcime (p.190), and sodium- and potassium-rich feldspars, and occurs worldwide.

Potassium fertilizer Because of leucite's high potassium content, the mineral is used as a fertilizer in some countries.

PROFILE

Orthorhombic
5–5½
2.3
Perfect
Uneven, brittle
White
Vitreous to pearly

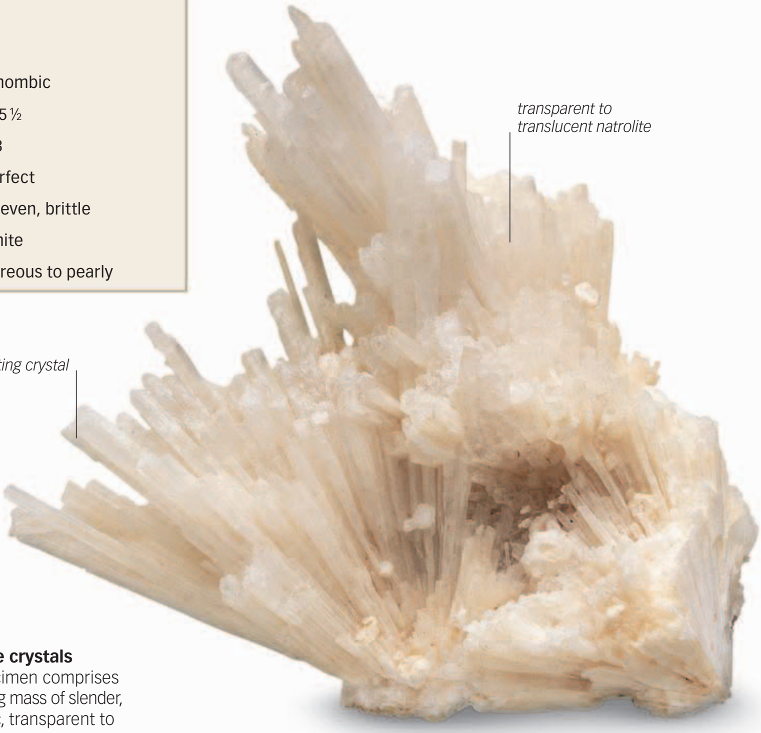

Natrolite crystals
This specimen comprises a radiating mass of slender, prismatic, transparent to translucent natrolite crystals.

VARIANT

natrolite
calcite

Natrolite and calcite
A specimen including white calcite and light orange natrolite

$Na_2Al_2Si_3O_{10}\cdot 2H_2O$

NATROLITE

A hydrated sodium aluminosilicate, natrolite takes its name from the Greek word *natrium*, which means “soda”—a reference to the sodium content of this mineral. Natrolite can be pale pink, colorless, white, red, gray, yellow, or green. Some specimens fluoresce orange to yellow under ultraviolet light. Natrolite crystals are generally long and slender, with vertical striations and a square cross section. They may appear tetragonal and can grow up to 3 ft (1 m) in length. Natrolite is also found as radiating masses of needlelike crystals and as granular or compact masses. This mineral produces an electric charge in response to both pressure and temperature changes.

Natrolite is found in cavities or fissures in basaltic rocks (p.273), volcanic ash deposits, and veins in granite (pp.258–59), gneiss (p.288), and other rocks. It also occurs in altered syenites (p.262), aplites, and dolerites (p.268). Specimens are often associated with quartz (p.168), heulandite (p.187), apophyllite (p.204), and other zeolites.

PROFILE

Monoclinic

3½–4

2.2

Perfect

Uneven, brittle

Colorless

Vitreous to pearly

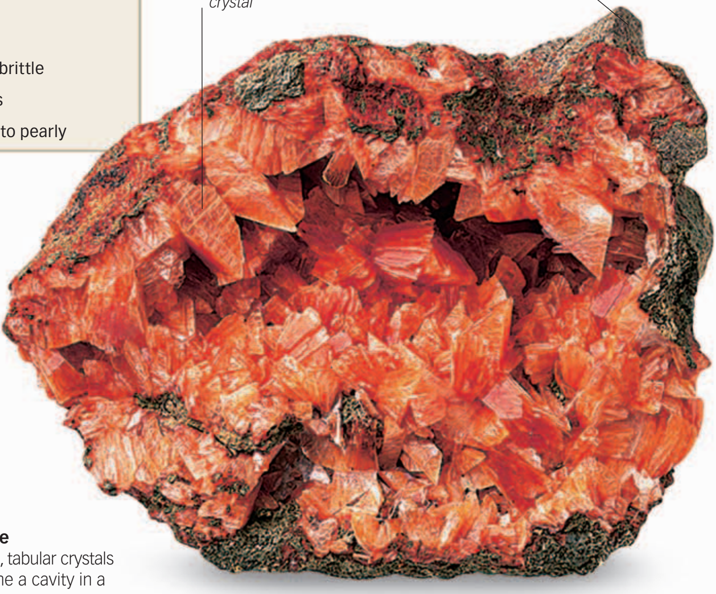

Red heulandite
In this specimen, tabular crystals of heulandite line a cavity in a basalt matrix.

VARIANT

Colorless crystals Typical, colorless, coffin-shaped heulandite crystals

$CaAl_2Si_7O_{18}\cdot 6H_2O$

HEULANDITE

The name heulandite is used to refer to a series of five zeolite minerals, all of which look the same but vary in composition. The group was named in 1822 after the British collector and mineral dealer J.H. Heuland. Heulandite is usually colorless or white but can also be red, gray, yellow, pink, green, or brown. When found, crystals are elongated, tabular, and widest at the center, creating a coffin shape. Occasionally, trapezohedral crystals are found. Heulandite specimens can also be granular or massive.

Heulandite forms at low temperatures (up to 400°F/200°C) in a wide range of environments: with other zeolites filling cavities in granites (pp.258–59), pegmatites (p.260), and basalts (p.273); in metamorphic rocks; and in weathered andesites (p.275) and diabases.

Oil refining
Heulandite and other zeolites are used to filter out unwanted molecules during oil refining.

PROFILE

Monoclinic
5
2.3
Perfect
Uneven, brittle
White
Vitreous to silky

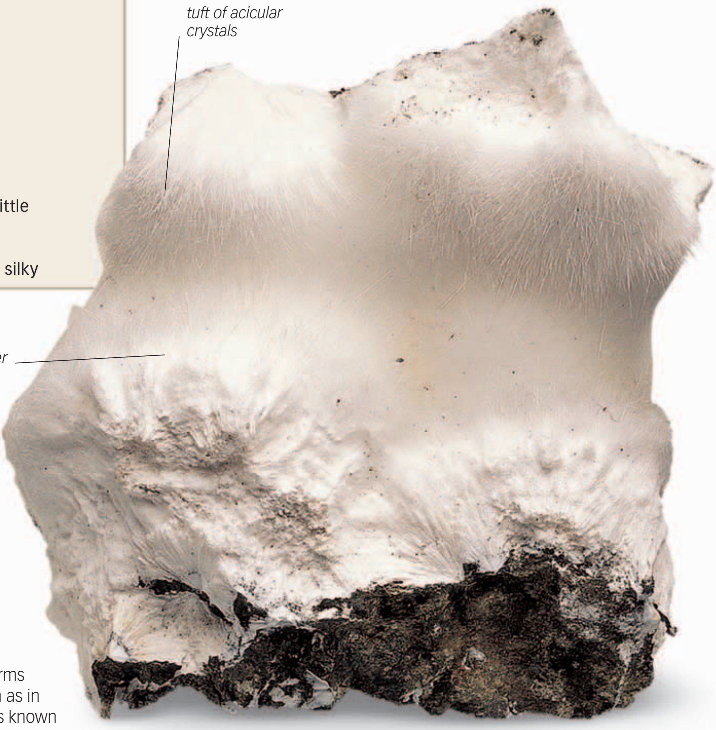

Cotton stone When mesolite forms hairlike tufts, such as in this specimen, it is known as cotton stone.

VARIANTS

White mesolite Needles of mesolite on green apophyllite

Acicular mesolite A radiating mass of needlelike crystals

$Na_2Ca_2(Al_6Si_9)O_{30}\cdot 8H_2O$

MESOLITE

First described in 1816, mesolite takes its name from two Greek words: *mesos*, which means "middle," and *lithos*, which means "stone"—a reference to the fact that this mineral is chemically intermediate in composition between scolecite and natrolite (p.186). Mesolite is structurally identical and similar in appearance to scolecite and natrolite, which makes it difficult to identify in hand specimens. Specimens can be white, pink, red, yellowish, green, or pale colored. It occurs as long, slender needles, radiating masses, prisms, and, less commonly, compact masses or fibrous stalactites.

Mesolite is found in cavities in basalts (p.273) and andesites (p.275), where delicate, glassy prisms can occur with stilbite, heulandite (p.187), and green apophyllite (p.204). It is also found in hydrothermal veins. Exceptional specimens occur in Ahmadnagar and Poona, India; Neubauerberg, the Czech Republic; Naalsoy in the Faroe Islands; Victoria Land, Antarctica; and in the states of Washington, Oregon, and Colorado.

Pseudocubic chabazite This group of pseudocubic chabazite crystals is from the Bay of Fundy in Nova Scotia, Canada.

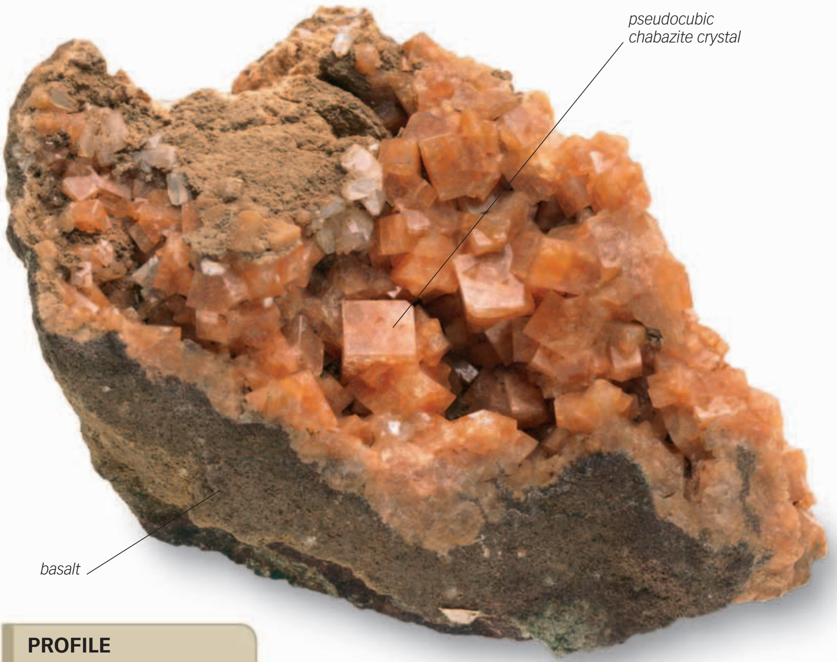

PROFILE

Triclinic (Pseudohexagonal)

- 4–5
- 2.0–2.2
- Indistinct
- Uneven, brittle
- White
- Vitreous

VARIANT

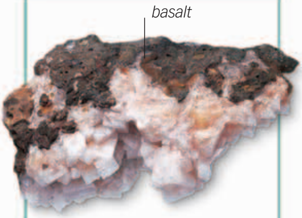

Chabazite in basalt A group of white chabazite crystals in a hollow in basalt

$(Na,Ca_{0.5},K)_4(Al_4Si_8O_{24})\cdot 12H_2O$

CHABAZITE

Common zeolites, the chabazite group consists of three distinct minerals that look alike: chabazite-Ca, chabazite-K, and chabazite-Na. The name is derived from the Greek *chabazios* or *chalazios*, both of which mean "hailstone." Specimens are colorless, white, cream, pink, red, orange, yellow, or brown. Chabazite crystals occur as distorted cubes or pseudorhombohedrons consisting of multiple twins. They may also be prismatic. Twinning is common in all forms of chabazite.

Chabazite is found in cavities in pegmatites (p.260), basalt (p.273), andesite (p.275), volcanic ash deposits, and granitic (pp.258–59) and metamorphic (pp.288–303) rocks. It is widespread, with crystals that are 1–2 in (2.5–5 cm) long occurring in several locations. Chabazite and some other zeolites have an open crystal structure that is sievelike and permits small molecules to pass through, while preventing the passage of larger molecules. This structure, for example, helps filter methane from gases emitted by decaying organic waste matter.

PROFILE

Cubic

- 5–5½
- 2.3
- None
- Subconchoidal, brittle
- White
- Vitreous

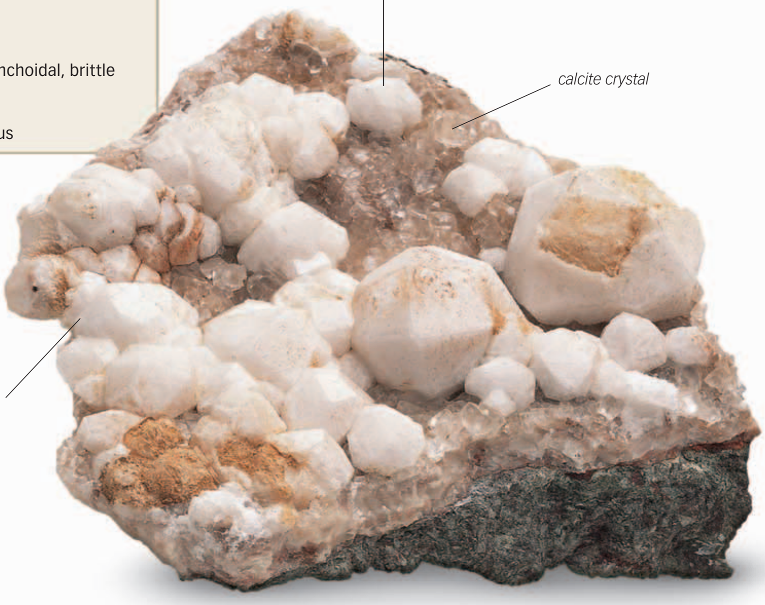

Analcime trapezohedrons This group of superbly crystallized analcime trapezohedrons from the Dean Quarry, Cornwall, England, rests on a bed of calcite crystals.

VARIANT

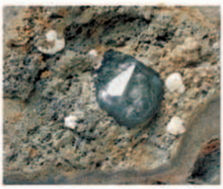

Colorless analcime A single crystal of colorless analcime on a rock matrix

$Na(AlSi_2)O_6 \cdot H_2O$

ANALCIME

Formerly grouped with the feldspathoids, analcime is now classified as a zeolite. A sodium aluminum silicate, analcime is named after the Greek word *analkimos*, which means "weak"—a reference to the weak electrical charge that this mineral produces when it is heated or rubbed. Specimens are usually colorless or white but can also be yellow, brown, pink, red, or orange. Most analcime crystals are trapezohedral. Variations in the ratio and order of the sodium–aluminum portion in analcime can lead to structural variations and variation in crystal system.

Analcime occurs in seams and cavities in granite (pp.258–59), basalt (p.273), gneiss (p.288), and diabase, associated with calcite (p.114), prehnite (p.205), and other zeolites. It also occurs in extensive beds formed by precipitation from alkaline lakes.

Silica dessicator Made from analcime, silica gel, such as in this dessicator, rapidly absorbs moisture and has many drying uses.

PROFILE

Monoclinic or triclinic

3½–5½

2.5–2.6

Perfect but not visible

Conchoidal to splintery

White

Subvitreous to greasy, resinous, earthy, dull

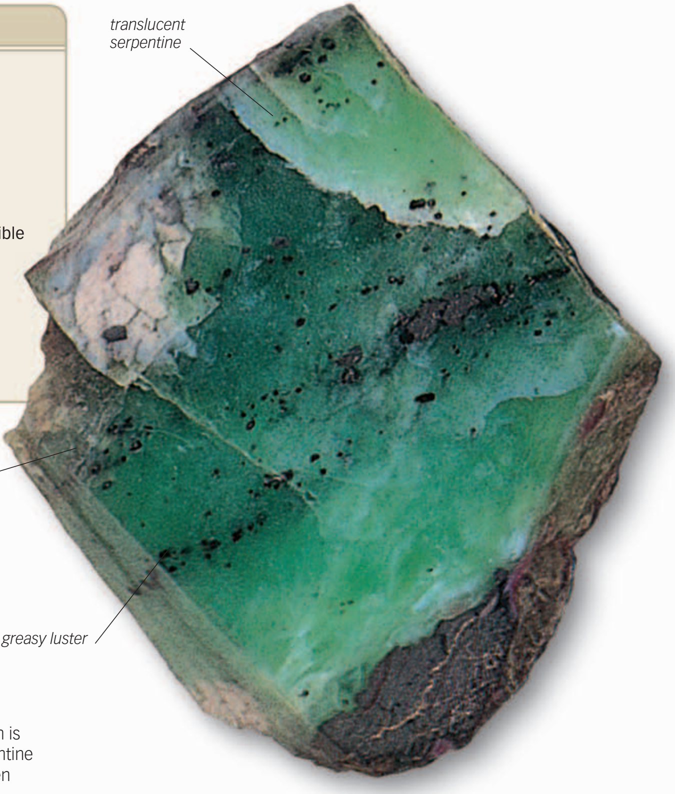

Precious serpentine This high-quality specimen is composed of many serpentine minerals. It is the kind often carved and sold as jade.

VARIANTS

Lizardite A specimen of this fine-grained serpentine mineral from Cornwall, UK

Antigorite A specimen of this serpentine mineral with characteristic, corrugated plates

$(Mg,Fe,Ni)_3Si_2O_5(OH)_4$

SERPENTINE

Resembling snakeskin in appearance, serpentine is a group of at least 16 white, yellowish, green, or gray-green magnesium silicate minerals. Although they usually form mixtures, individual members of the group can sometimes be distinguished. Four common serpentine minerals include chrysotile (p.192), antigorite, lizardite, and amesite, which occur in platy or pseudohexagonal, columnar crystals. Although their chemistry is complex, these minerals look similar.

Serpentines are secondary minerals derived from the chemical alteration of olivine (p.232), the pyroxenes, and the amphiboles. It is found in areas where highly altered, deep-seated, silica-poor rocks are exposed, such as along the crests and axes of great folds, in island arcs, and in Alpine mountain chains.

Williamsite cabochon A variety of serpentine, williamsite is an ornamental stone that is sometimes cut as an inexpensive gem.

PROFILE

Monoclinic or orthorhombic
2–3
2.6
Perfect
None
White
Subresinous to greasy

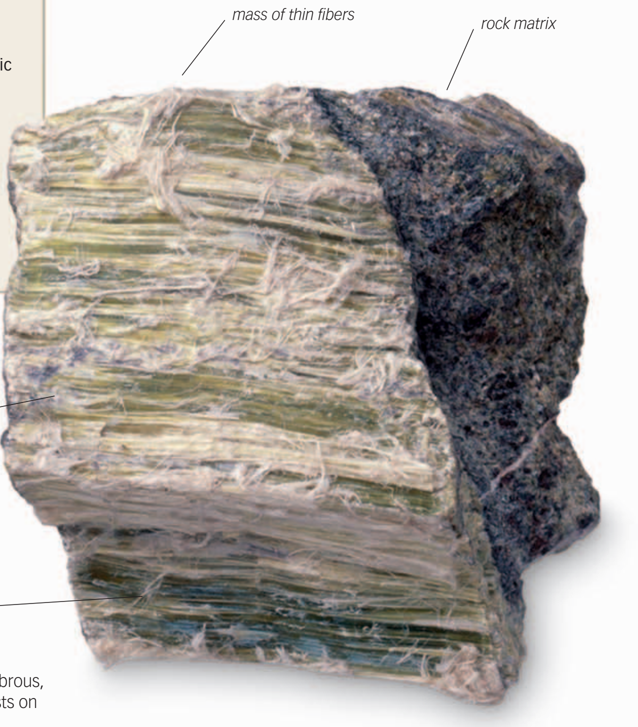

Chrysotile fibers In this specimen, a mass of fibrous, flexible chrysotile crystals rests on a rock matrix.

VARIANT

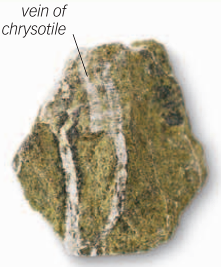

Asbestos mineral A specimen of fibrous chrysotile

$Mg_3Si_2O_5(OH)_4$

CHRYSOTILE

The fibrous serpentine mineral chrysotile is the most important asbestos mineral. Also known as white asbestos, it accounts for about 95 percent of all asbestos in commercial use. Chrysotile fibers are tubes in which the structural layers of the mineral are rolled in the form of a spiral. Individual chrysotile fibers are white and silky, while aggregate fibers in veins are green or yellowish. The fibers are generally oriented across the vein and less than ½ in (1.3 cm) in length, but they can be longer. The mineral sometimes appears golden, and its name is derived from the Greek for "hair of gold."

Chrysotile can take three different forms: clinochrysotile, orthochrysotile, and parachrysotile. These are chemically identical, but orthochrysotile and parachrysotile have orthorhombic rather than monoclinic crystals. These forms are indistinguishable in hand specimens, and clinochrysotile and orthochrysotile may occur within the same fiber. Specimens occur as veins in altered peridotite (p.266) with other serpentine minerals.

PROFILE

Triclinic or monoclinic

1

2.8

Perfect

Uneven to subconchoidal

White

Pearly to greasy

Foliated talc
This specimen of green, foliated talc exhibits its pearly luster and micalike cleavage.

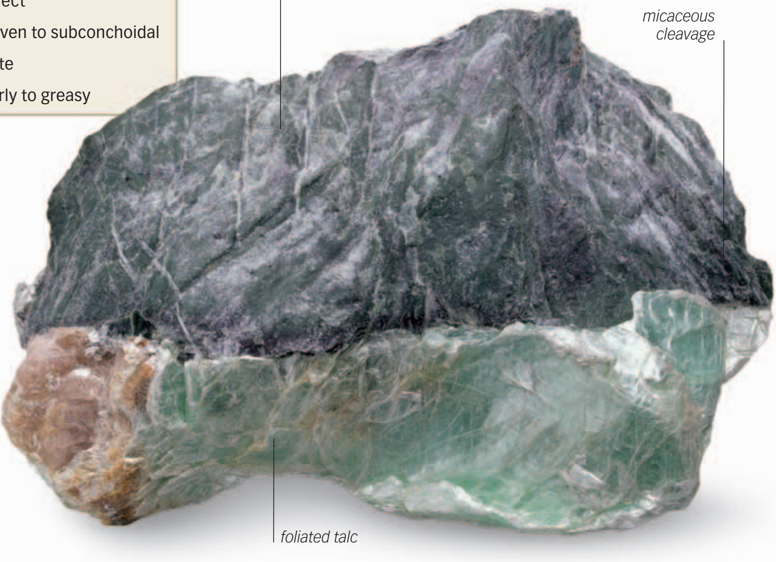

VARIANT

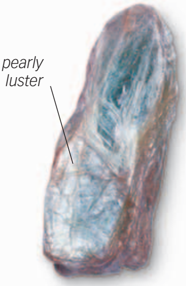

Pearly talc A pearly, toothlike piece of talc

$Mg_3Si_4O_{10}(OH)_2$

TALC

Easily distinguishable by its extreme softness, talc is white, colorless, pale to dark green, or yellowish to brown. Crystals are rare; talc is most commonly found in foliated, fibrous, or massive aggregates. It is often found mixed with other minerals, such as serpentine (p.191) and calcite (p.114). Dense, high-purity talc is called steatite.

Talc is a metamorphic mineral found in veins and magnesium-rich rocks. It is often associated with serpentine, tremolite (p.219), and forsterite (p.232) and occurs as an alteration product of silica-poor igneous rocks. Talc is widespread and is found in most areas of the world where low-grade metamorphism occurs. The name soapstone is given to compact masses of talc and other minerals due to their soapy or greasy feel.

WITH THE
Beatles
TALC

Talcum powder
Talc is the principal mineral used to make talcum powder. It acts as an astringent on the skin.

PROFILE

Triclinic or monoclinic

1–2

2.7–2.9

Perfect

Uneven

White

Pearly to dull

Pyrophyllite stars This aggregate of pyrophyllite displays radiating, starlike groups of laths with associated quartz.

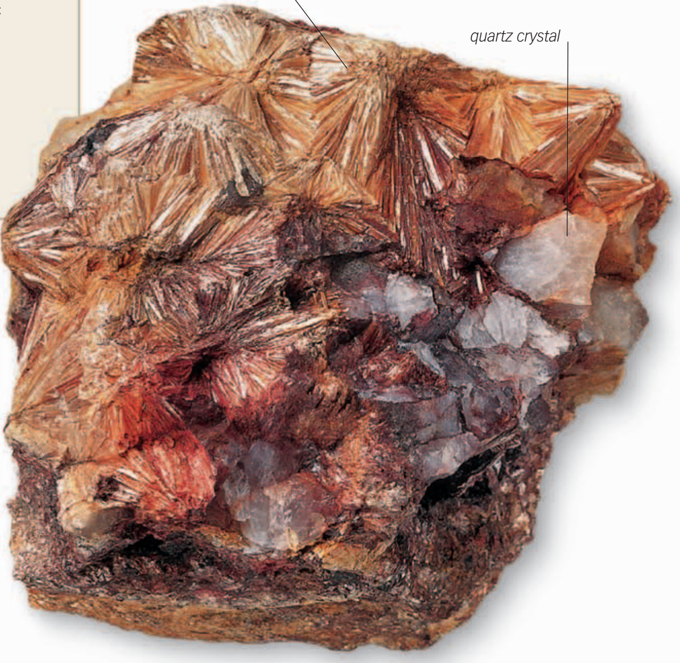

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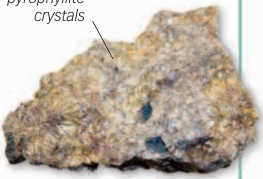

Pyrophyllite on rock Groups of pyrophyllite crystals on a rock matrix

$Al_2Si_4O_{10}(OH)_2$

PYROPHYLLITE

An aluminum silicate hydroxide, pyrophyllite takes its name from the Greek words *pyr* and *phyllon*, which respectively mean “fire” and “leaf”—a reference to the mineral’s tendency to exfoliate when heated. Pyrophyllite can be colorless, white, cream, brownish green, pale blue, or gray. It is usually found in granular masses of flattened lamellae. Pyrophyllite rarely forms distinct crystals, although it is sometimes found in coarse laths and radiating aggregates. Specimens are often so fine-grained that the mineral appears textureless.

Pyrophyllite forms by the metamorphism of aluminum-rich sedimentary rocks, such as bauxite (p.101). It is a good insulator and is used in heat-resistant applications, such as in making fire bricks.

High gloss Bright, reflective flakes of powdered pyrophyllite are added to lipstick to give it a high sheen.

Colorful fuchsite
Fuchsite is a minor variety of white muscovite. Specimens such as this one are colored by traces of chromium.

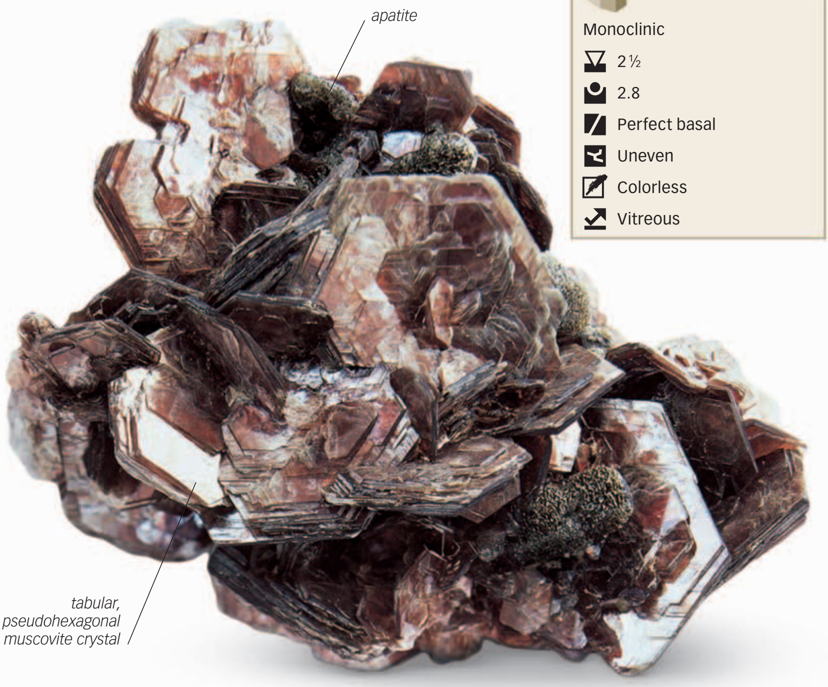

PROFILE

Monoclinic
2½
2.8
Perfect basal
Uneven
Colorless
Vitreous

VARIANTS

Tabular crystals Silver-brown crystals of tabular muscovite

Platy muscovite Crystals of muscovite in a rock matrix

Green fuchsite Bright green fuchsite in a rock matrix

$KAl_2(Si_3Al)O_{10}(OH,F)_2$

MUSCOVITE

Also called common mica, potash mica, or isinglass, muscovite is the most common member of the mica group. Specimens are usually colorless or silvery white but can also be brown, light gray, pale green, or rose red. Muscovite typically occurs as tabular crystals with a hexagonal or pseudohexagonal outline. Crystals can be up to 9¾ ft (3 m) in diameter. Muscovite can also form thin, flat sheets and fine-grained aggregates. Fine-grained muscovite is called sericite or white mica, while bright green specimens rich in chromium are called fuchsite.

A common rock-forming mineral, muscovite occurs in metamorphic rocks, such as gneisses (p.288) and schists (pp.291–92), and in granites (pp.258–59), veins, and pegmatites (p.260). It is also found in some fine-grained sediments. Muscovite has considerable commercial importance. Its low iron content makes it a good electrical and thermal insulator. In Russia, thin, transparent sheets of muscovite, called muscovy glass, were used as window panes.

PROFILE

Monoclinic

- 2
- 2.4–2.9
- Perfect basal
- Uneven
- Green
- Dull to earthy

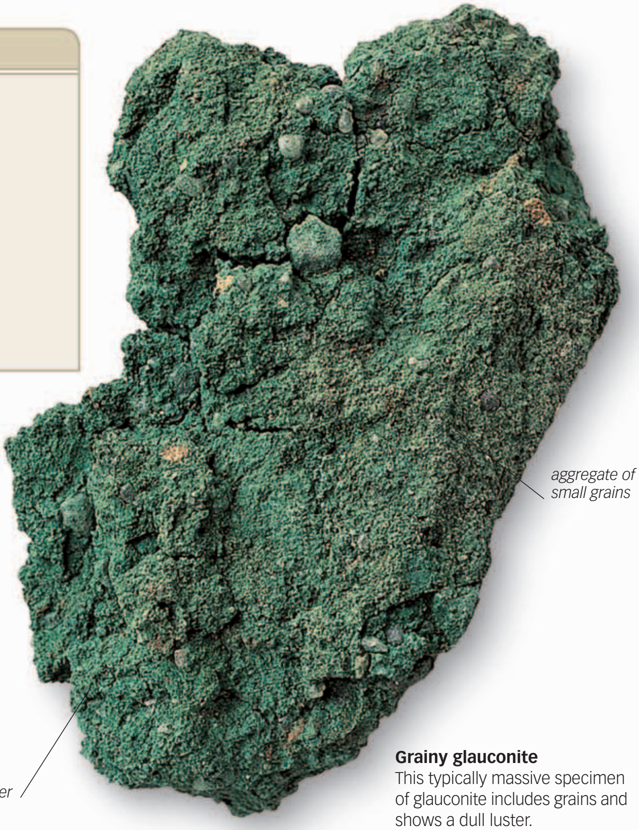

Grainy glauconite This typically massive specimen of glauconite includes grains and shows a dull luster.

VARIANTS

Glauconite sandstone Sandstone with a high percentage of glauconite

Nodular glauconite Light green nodules of glauconite

$(K,Na)\ (Mg,Al,Fe)_2(Si,Al)_4O_{10}(OH)_2$

GLAUCONITE

A member of the mica group, glauconite was named in 1828 after the Greek word *glaukos*, which means "blue-green"—a reference to the mineral's usual color. Specimens can also be olive green to black-green. The mineral usually occurs as rounded aggregates or pellets of fine-grained, scaly particles. It weathers readily and easily crumbles to a fine powder.

A widespread silicate, glauconite forms in shallow marine environments, where it is used as a diagnostic mineral to identify continental-shelf deposits with slow rates of accumulation. The sedimentary rock greensand (p.309) is so called because of the green color imparted by glauconite pellets, which in turn, may incorporate other minerals. Glauconite can also be found in impure limestone (p.319), chalk (p.321), and sand and clay formations. The mineral has long been used as a pigment in artists' oil paint, especially in the paintings of Russian icons. It has also been used in wall paintings dating back to Roman Gaul.

PROFILE

Monoclinic

2–3$\frac{3}{10}$

2.7–3.4

Perfect basal

Uneven

Colorless

Vitreous to submetallic

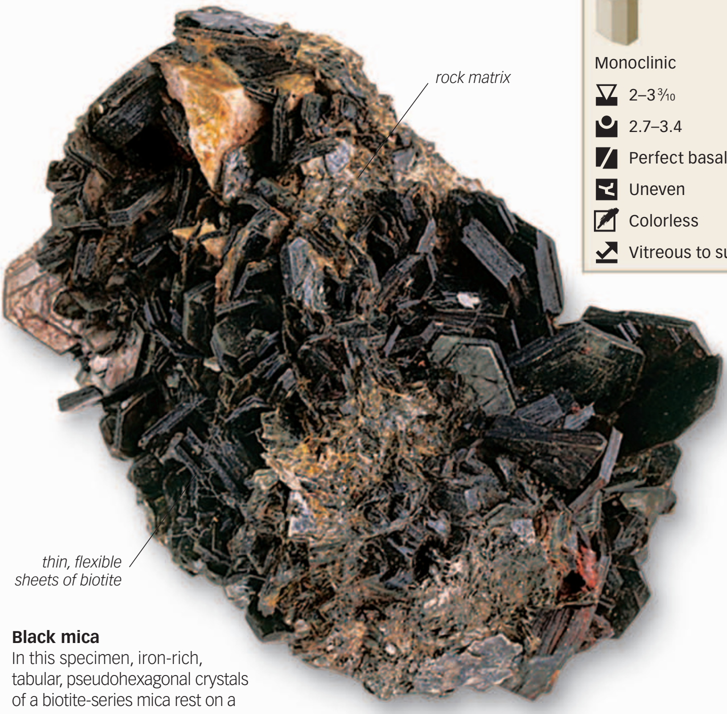

Black mica In this specimen, iron-rich, tabular, pseudohexagonal crystals of a biotite-series mica rest on a rock matrix.

VARIANT

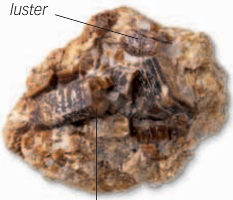

Phlogopite Crystals of the magnesium end-member of the biotite solid-solution series

$KFe_3,Mg_3(AlSi_3O_{10})(OH,F)_2$

BIOTITE

Once considered a mineral in its own right, biotite is now recognized as a solid-solution series with the mineral annite as the iron end-member and phlogopite as the magnesium end-member. It was named in honor of the French physicist Jean-Baptiste Biot in 1847. Micas of the biotite series usually form large, tabular to short, prismatic crystals that are often pseudohexagonal in cross section. They also occur in thin layers or as scaly aggregates or disseminated grains. Specimens are black when iron-rich, and brown, pale yellow to tan, or bronze with increasing magnesium content. They readily cleave into thin, flexible sheets.

Biotite-series micas are widespread. They are a key constituent of many igneous and metamorphic rocks, including granites (pp.258–59), nepheline syenites (p.262), gneisses (p.288), and schists (pp.291–92). They are also found in potassium-rich hydrothermal deposits and some clastic sedimentary rocks. Biotite is used extensively to date rocks.

PROFILE

Monoclinic
2½–3½
3.0
Perfect basal
Uneven
Colorless
Vitreous to pearly

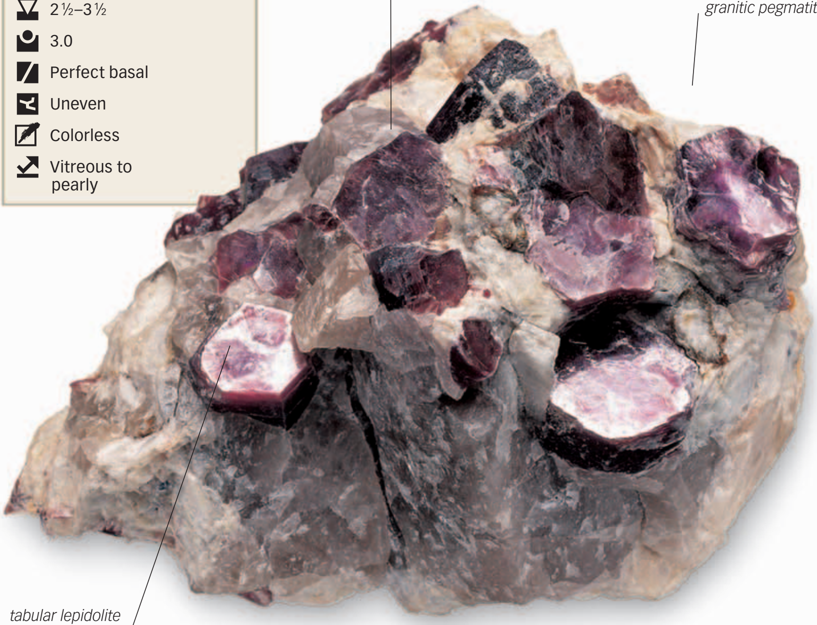

Distinctive color
Numerous violet pseudohexagonal lepidolite crystals protrude from this pegmatite specimen.

VARIANT

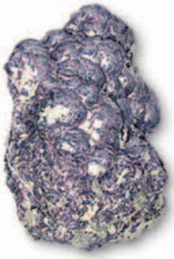

Botryoidal lepidolite
Lepidolite in botryoidal habit

$K(Li,Al_3)(AlSi_3)O_{10}(OH,F)_2$

LEPIDOLITE

A light mica, lepidolite is Earth's most common lithium-bearing mineral. Its name is derived from two Greek words: *lepidos*, which means "scale," and *lithos*, which means "stone." Although typically pale lilac, specimens can also be colorless, violet, pale yellow, or gray. Lepidolite crystals may appear pseudohexagonal. The mineral is also found as botryoidal or kidneylike masses and fine- to coarse-grained, interlocking plates. Its perfect cleavage yields thin, flexible sheets.

Lepidolite occurs in granitic pegmatites (p.260), where it is associated with other lithium minerals, such as beryl (p.225) and topaz (p.234). The mineral is economically important as a major source of lithium, which is used to make glass and enamels. It is also a major source of the rare alkali metals rubidium and cesium.

Lithium battery
Extracted from lepidolite, the metal lithium has many industrial uses, such as in lithium batteries.

Vermiculite layers
This specimen of vermiculite, mined in Pennsylvania, shows the mineral's foliated habit.

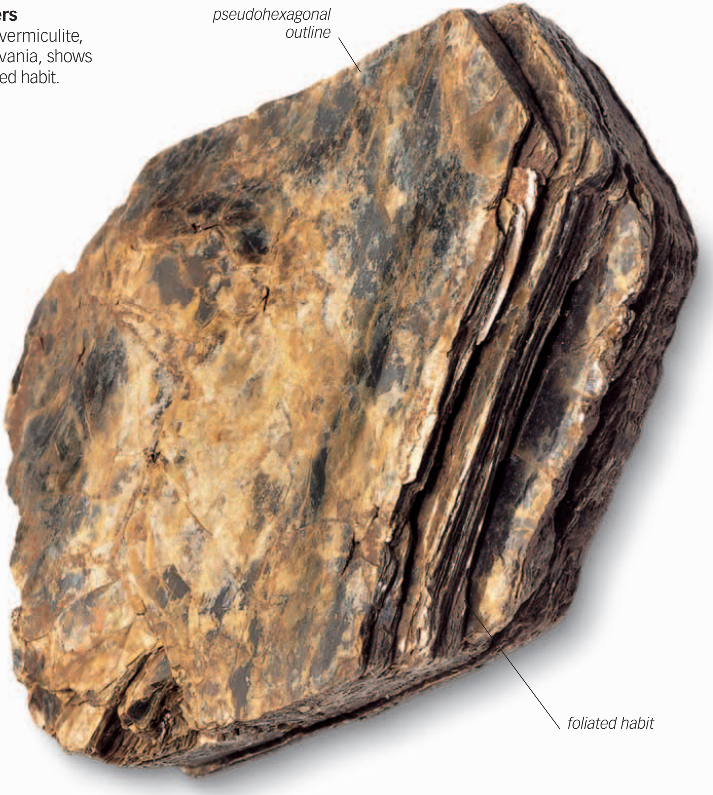

PROFILE

Monoclinic
1–2
2.6
Perfect
Uneven
White
Oily to earthy

$(Mg,Fe,Al)_3(Al,Si)_4O_{10}(OH)\cdot 4H_2O$

VERMICULITE

The name vermiculite is applied to a group of mica minerals in which various chemical substitutions occur in the molecular structure. Vermiculite may be completely interlayered with other micas and claylike minerals. Specimens are green, golden yellow, or brown in color. Vermiculite usually forms tabular, pseudohexagonal crystals or platy aggregates.

Vermiculite occurs as large pseudomorphs replacing biotite (p.197), as small particles in soils and ancient sediments, and at the interface between feldspar-rich and iron- and magnesium-rich igneous rocks. It also forms by hydrothermal alteration of iron-bearing micas. When heated to nearly 572°F (300°C), vermiculite can expand quickly and strongly to 20 times its original thickness.

Potting soil
Expanded vermiculite is a good growing medium for new plants; it retains water and offers good aeration.

PROFILE

Monoclinic
1–2
2.1
Perfect
Uneven
White to buff
Earthy

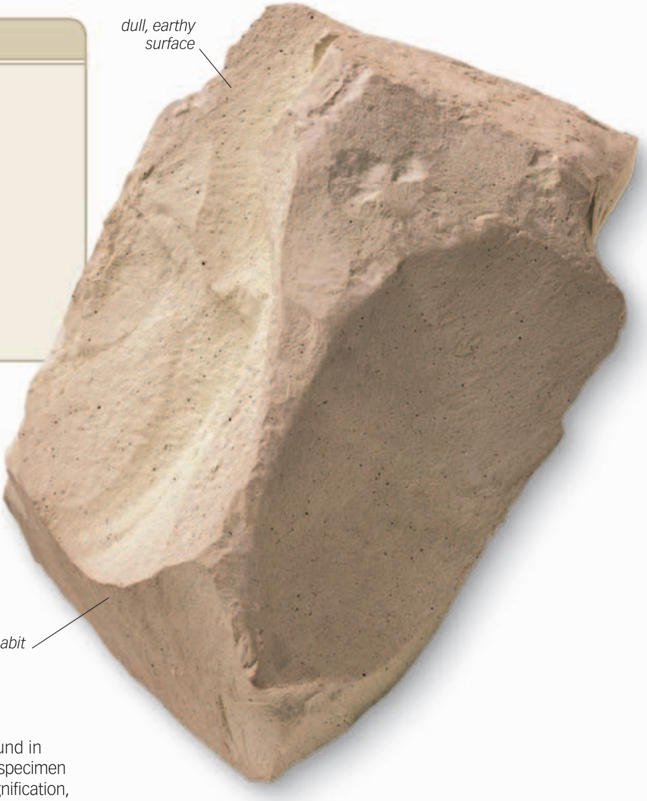

Massive bentonite
Bentonite is always found in massive form, as in the specimen shown here. Under magnification, tiny, hexagonal plates are visible.

VARIANTS

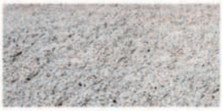

Desert cracking Loss of water from bentonite clays causes shrinkage and cracking

Bentonite sediments Layers of bentonite-rich clay

$(Na,Ca_{0.5})_{0.33}(Al,Mg)_2Si_4O_{10}(OH)_2\cdot nH_2O$

BENTONITE

This group of minerals are all kinds of clay that expand as they absorb water and shrink as they dry. In regions underlain by bentonites, this property causes immense problems with building foundations. There are three bentonite minerals, each named after the respective dominant element: potassium bentonite, sodium bentonite, and calcium bentonite. The minerals are generally yellow, white, or gray in color. They occur as microscopic crystals and are earthy and frequently stained.

Although the term bentonite has been used for clay beds of uncertain origin, this mineral group generally forms from volcanic ash that has weathered in the presence of water. Important industrial minerals, bentonites are used as sealants and in oil drilling.

Potting clay
The potting clay used to make this bowl contains bentonite, which is also used in bricks and ceramics.

PROFILE

Triclinic
2–2½
2.6
Perfect
Unobservable
White
Earthy

Powdery kaolinite In this specimen, powdery kaolinite coats a piece of granite.

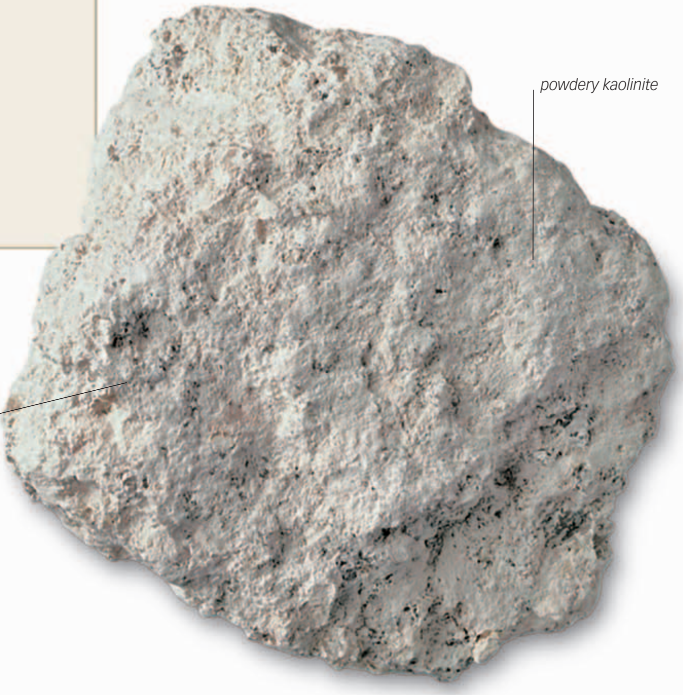

VARIANTS

Blocky kaolinite Blocky, typically white kaolinite

Iron staining A specimen of kaolinite mixed with iron oxides, which give it an orange color

$Al_2Si_2O_5(OH)_4$

KAOLINITE

Clay minerals are far removed in their outward appearance from more attractive and glamorous minerals, such as gold and diamond. Yet, by providing the raw material for brick, pottery, and tiles, they have played a vital part in the progress of human civilization. Important among these minerals is kaolinite. Kaolinite forms white, microscopic, pseudohexagonal plates in compact or granular masses and in micalike piles. Three other minerals—dickite, nacrite, and halloysite—are chemically identical to kaolinite but crystallize in the monoclinic system. All four have been found together and are often visually indistinguishable.

Kaolinite is a natural product of the alteration of mica, plagioclase, and sodium–potassium feldspars under the influence of water, dissolved carbon dioxide, and organic acids. It is used in agriculture; as a filler in food, such as chocolate; mixed with pectin as an antidiarrheal; as a paint extender; as a strengthener in rubber; and as a dusting agent in foundry operations.

PROFILE

Monoclinic
1–2
2.6–2.9
Perfect
None
White
Dull

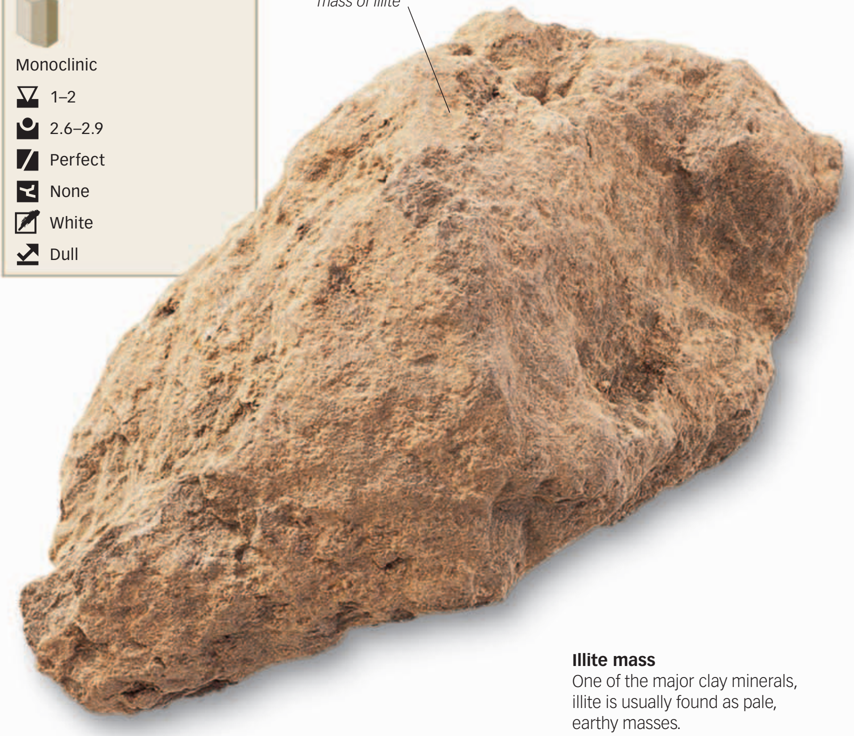

Illite mass
One of the major clay minerals, illite is usually found as pale, earthy masses.

VARIANT

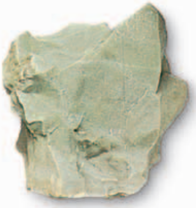

Solid illite Solid masses of illite are occasionally found

$K_{0.65}Al_2Al_{0.65}Si_{3.35}O_{10}(OH)_2$

ILLITE

Once regarded as a clay mineral, illite is now classified as a group of mica minerals that bear many structural similarities to the white mica muscovite (p.195). Illite takes its name from its type location in Illinois. It is white, but impurities may tint it gray and other pale colors. It occurs as fine-grained aggregates. Individual hexagonal crystals can only be seen using an electron microscope. Because of its minute crystals, illite can only be positively identified by x-ray diffraction. The degree of crystallization of illite has been used as an indicator of metamorphic grade in clay-bearing metamorphic rocks.

Illite is found in sedimentary rocks and soils. It is the most abundant clay mineral in shales (pp.313–14) and clays. It appears to be derived from the weathering of muscovite and feldspar (pp.173–81).

Mud bricks
Ancient buildings, such as the Funerary Temple in Egypt, were often made from clays bearing illite.

Chrysocolla with azurite
In this specimen, chrysocolla can be seen with the carbonate mineral azurite in a rock matrix.

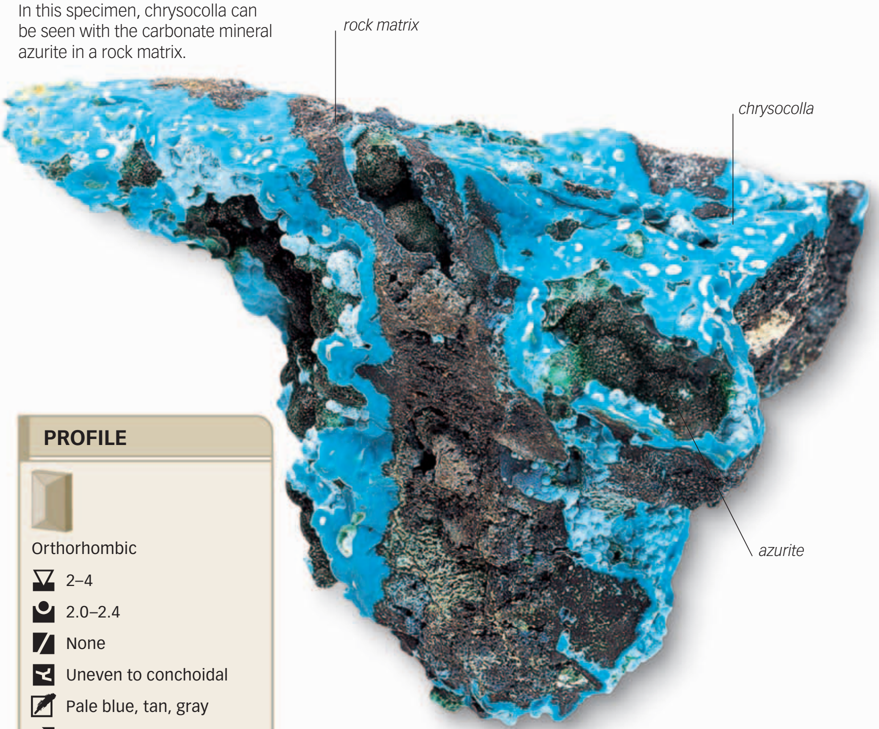

PROFILE

Orthorhombic
- 2–4
- 2.0–2.4
- None
- Uneven to conchoidal
- Pale blue, tan, gray
- Vitreous to earthy

VARIANTS

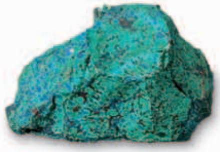

Rough chrysocolla
A specimen intergrown with turquoise and malachite

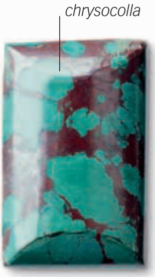

Cabochon Green chrysocolla within reddish iron oxide

$Cu_2H_2(Si_2O_5)(OH)_4 \cdot nH_2O$

CHRYSOCOLLA

The term chrysocolla was first used by the Greek philosopher Theophrastus in 315 BCE to refer to various materials used in soldering gold. The name is derived from two Greek words: *chrysos*, which means "gold," and *kolla*, which means "glue." A copper aluminum silicate, chrysocolla is generally blue-green in color. Specimens are commonly fine grained and massive. Crystals are very rare but when found occur as botryoidal, radiating aggregates.

An occasional ore of copper, chrysocolla is a decomposition product of copper minerals, especially in arid regions. It is frequently intergrown with other minerals, such as quartz (p.168), chalcedony (p.169), and opal (p.172), to yield a gemstone variety. Gemstones can weigh more than 5 lb (2.3 kg).

Chrysocolla bracelet
Rich blue-green chrysocolla, such as the cabochon in this antique bracelet, is highly prized as a gemstone.

Green apophyllite In this specimen, green apophyllite occurs in a basalt matrix with a white zeolite mineral.

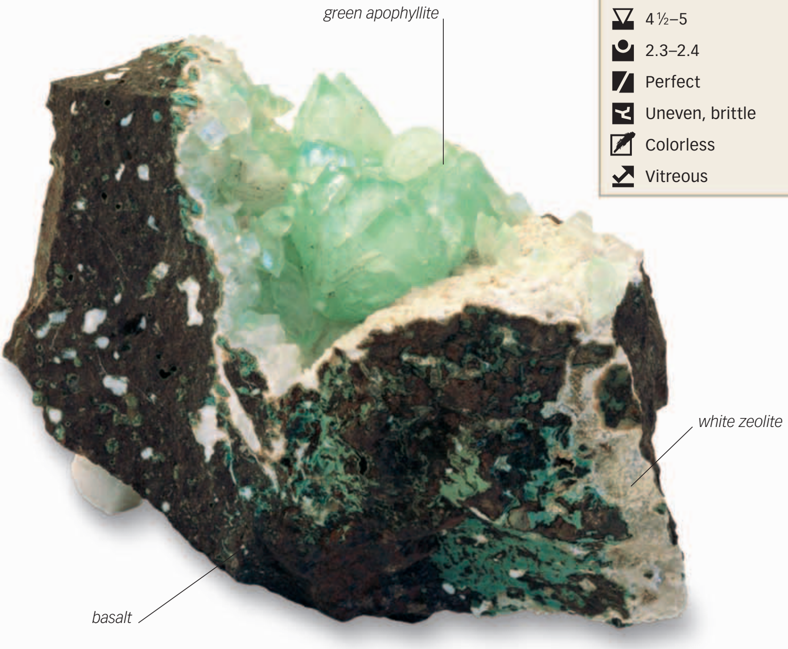

PROFILE

Tetragonal

4½–5

2.3–2.4

Perfect

Uneven, brittle

Colorless

Vitreous

VARIANTS

Pink crystal An unusual single crystal of pink apophyllite

Blocky crystals Green crystals on stilbite

apophyllite
stilbite

Reddish pink crystals Apophyllite with white stilbite

$KCa_4Si_8O_{20}(F,OH)\cdot 8H_2O$ (fluorapophyllite)

APOPHYLLITE

The name apophyllite comes from the Greek words *apo* and *phyllazein*, which mean “to get” and “leaf” respectively—a reference to the way in which the mineral separates into flakes or layers when it is heated. Once considered to be a single mineral, apophyllite is now divided into two distinct species—fluorapophyllite and hydroxyapophyllite. These species form a solid-solution series in which fluorine can predominate over oxygen and hydrogen, and vice versa. Apophyllite specimens are green, pink, colorless, or white. Crystals are transparent or translucent and up to 8 in (20 cm) in length. They occur as square-sided, striated prisms with flat ends and may appear cubic. Apophyllite crystals may also show steep pyramidal terminations.

The mineral frequently occurs with zeolite minerals in basalt (p.273) and less commonly in cavities in granites (pp.258–59). It is also found in metamorphic rocks and in hydrothermal deposits. Colorless and green specimens from India are faceted as collectors’ gems.

PROFILE

Orthorhombic
6–6½
2.9
Distinct basal
Uneven, brittle
White
Vitreous

Botryoidal prehnite
A group of radiating crystal masses of prehnite resting on a rock matrix gives a botryoidal form to this specimen.

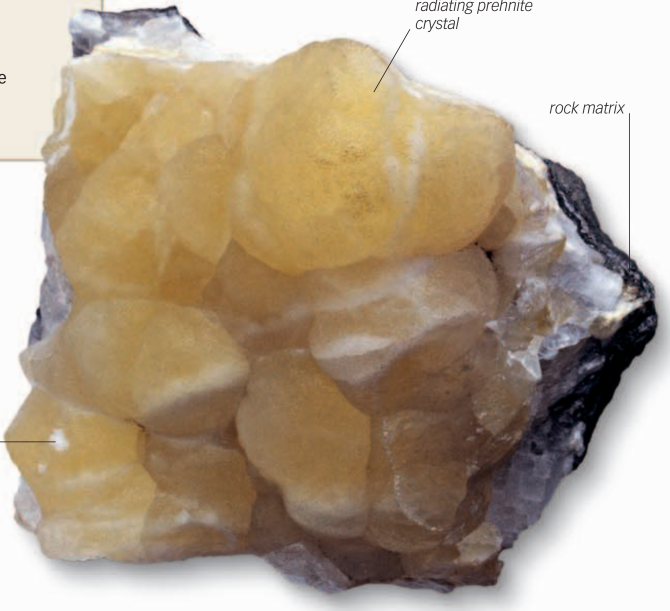

VARIANT

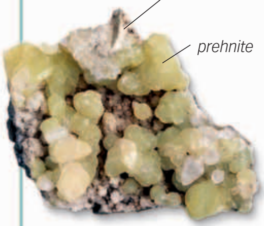

Green prehnite Spherical masses of prehnite occuring with white calcite on a rock matrix

$Ca_2Al_2Si_3O_{10}(OH)_2$

PREHNITE

A calcium aluminum silicate, prehnite was named in 1789 after its discoverer Hendrik von Prehn, a Dutch military officer. Specimens can be pale to mid-green, tan, pale yellow, gray, light blue, or white. Prehnite commonly occurs as globular, spherical, or stalactitic aggregates of fine to coarse crystals. Rare individual crystals are short prismatic to tabular with square cross sections. Many of these have curved faces.

Prehnite is often found lining cavities in volcanic rocks, associated with calcite (p.114) and zeolites (pp.185–90), and in mineral veins in granite (pp.258–59). Crystals up to several inches long come from Canada. Transparent specimens from Australia and Scotland are faceted for gem collectors.

White cabochon
Prehnite gems, such as this creamy white cabochon with dark inclusions, are almost too soft to wear.

PROFILE

Orthorhombic
2–2½
2.1–2.3
Good but rarely seen
Uneven
White
Dull to earthy

Massive sepiolite This specimen of massive sepiolite shows a characteristic dull, earthy luster.

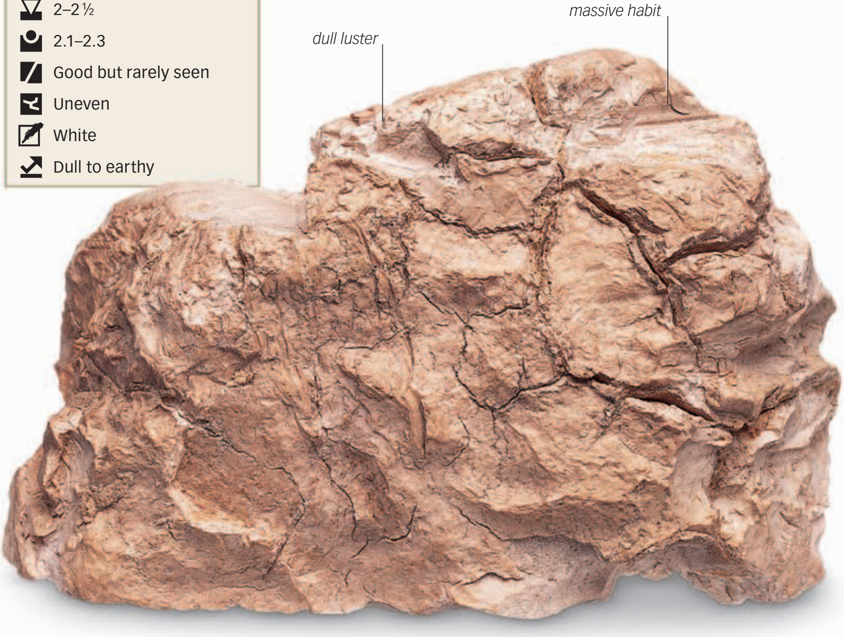

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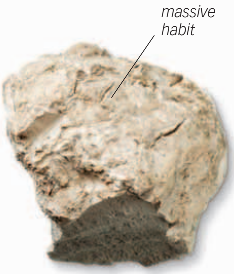

Meerschaum A specimen of massive white sepiolite

$Mg_4Si_6O_{15}(OH)_2.6H_2O$

SEPIOLITE

A compact, claylike, often porous mineral, sepiolite is best known by its popular name *meerschaum*, which is the German word for “sea-foam.” The name sepiolite comes from the mineral’s resemblance to the light and porous bone of cuttlefish from the genus *Sepia*. Sepiolite is usually white or gray and may be tinted yellow, brown, or green. It is usually found in nodular masses of interlocking fibers, which give it a toughness contrary to its mineralogical softness. Sepiolite also occurs in porous aggregates.

Sepiolite is an alteration product of minerals such as magnesite (p.118) and rocks, such as serpentinite (p.298). It is found as irregular nodules in Turkey and elsewhere, and in large sedimentary deposits.

Meerschaum cigar holder Sepiolite is used in carved tobacco pipes and cigar holders, which develop a brown patina when smoked.

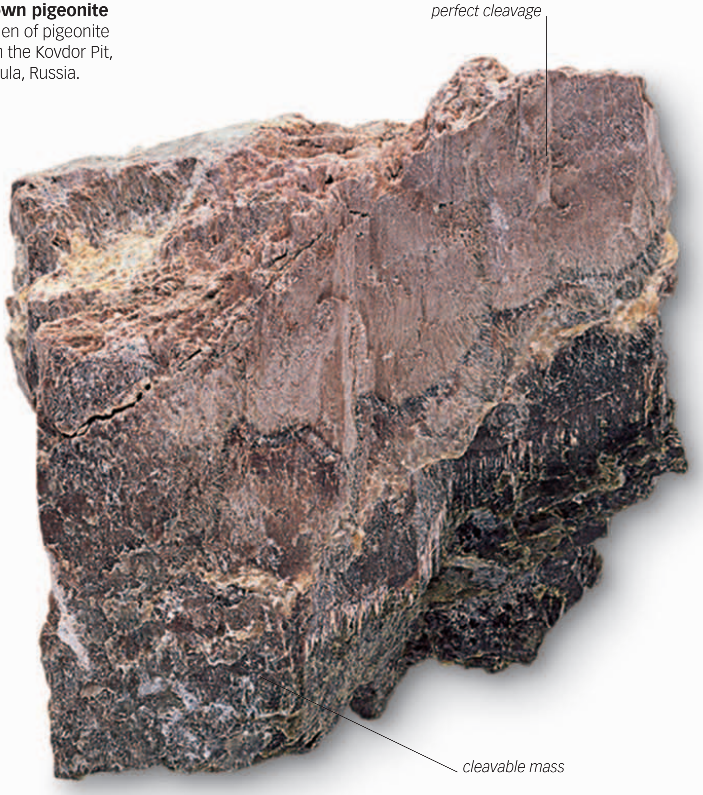

Purple-brown pigeonite
This specimen of pigeonite comes from the Kovdor Pit, Kola Peninsula, Russia.

PROFILE

Monoclinic
6
3.2–3.5
Good
Uneven to conchoidal, brittle
White to pale brown
Vitreous

$(Mg,Fe,Ca)_2(Si_2O_6)$

PIGEONITE

A member of the pyroxene group of minerals, pigeonite is named after Pigeon Point, Minnesota, USA—the locality where it was first identified. Specimens are brown, purplish brown, or greenish brown to black in color. Pigeonite is generally found as disseminated grains. Well-formed crystals are relatively rare. An iron-rich variety of pigeonite is sometimes called ferropigeonite.

Pigeonite is an important mineral in lunar rocks and also occurs in meteorites (pp.335–37). It is found in lavas and smaller intrusive rock bodies as the dominant pyroxene and as an important component of dolerites (p.268) and andesites (p.275). The temperature limit of pigeonite formation indicates the crystallization temperature of the magma from which it has originated. Mare—the large, dark, flat areas of the Moon once believed to be seas—are in fact basalts (p.273) containing pigeonite. Notable localities on Earth include Skaergaard, Greenland; Mull, Scotland; Labrador, Canada; Mount Wellington, Tasmania; and Goose Creek, Virginia, and New Jersey, USA.

PROFILE

Orthorhombic

5–6

3.1–3.9

Good to perfect

Uneven

Gray to white

Vitreous

Prismatic crystals This mass of small, prismatic enstatite crystals rests on a rock matrix.

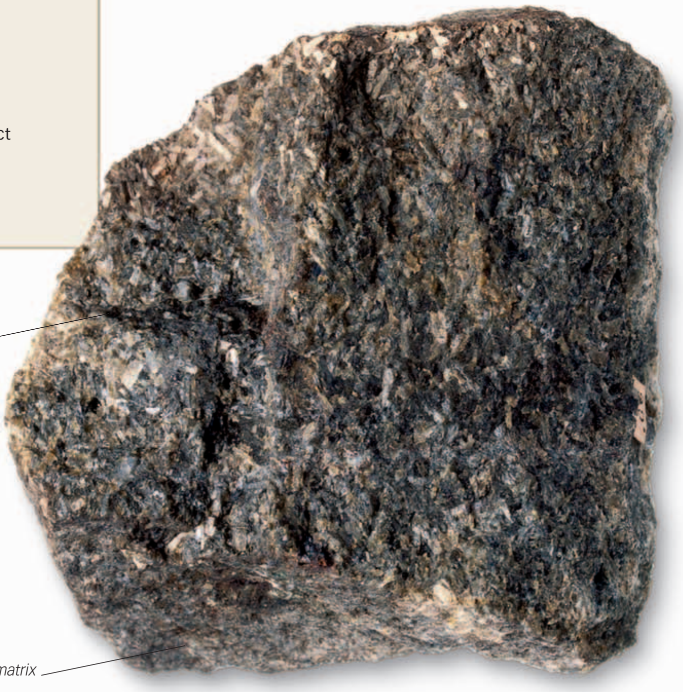

VARIANTS

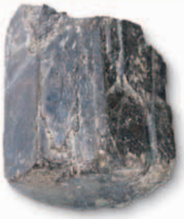

Single crystal A large crystal from Telemark, Norway

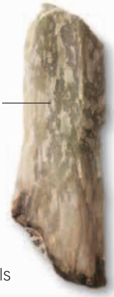

Fibrous enstatite A fibrous mass of parallel enstatite crystals

$Mg_2Si_2O_6$

ENSTATITE

The pyroxene mineral enstatite takes its name from the Greek word *enstates*, which means "opponent"—a reference to the use of this mineral as a refractory "opponent" of heat in the linings of ovens and kilns. Specimens are colorless, pale yellow, or pale green. They become darker and turn greenish brown to black with increasing iron content. Enstatite generally occurs as massive aggregates or disseminated grains. Well-formed crystals, when found, tend to be short prisms, often with complex terminations. Enstatite is also found as fibrous masses of parallel, needlelike crystals.

A widespread mineral, enstatite forms a solid-solution series with ferrosilite. The mineral usually occurs in magnesium- and iron-rich igneous rocks and in meteorites (pp.335–37).

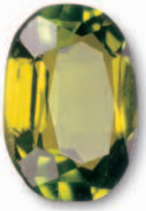

Mixed-cut enstatite Recovered from Myanmar and Sri Lanka, facet-grade enstatite, such as this gem, is mainly cut for collectors.

PROFILE

Monoclinic

6

3.5–3.6

Good to perfect

Uneven

Yellow-green to pale green

Vitreous

Terminated crystals This specimen is composed of a group of prismatic aegirine crystals with feldspar. The crystals have full terminations.

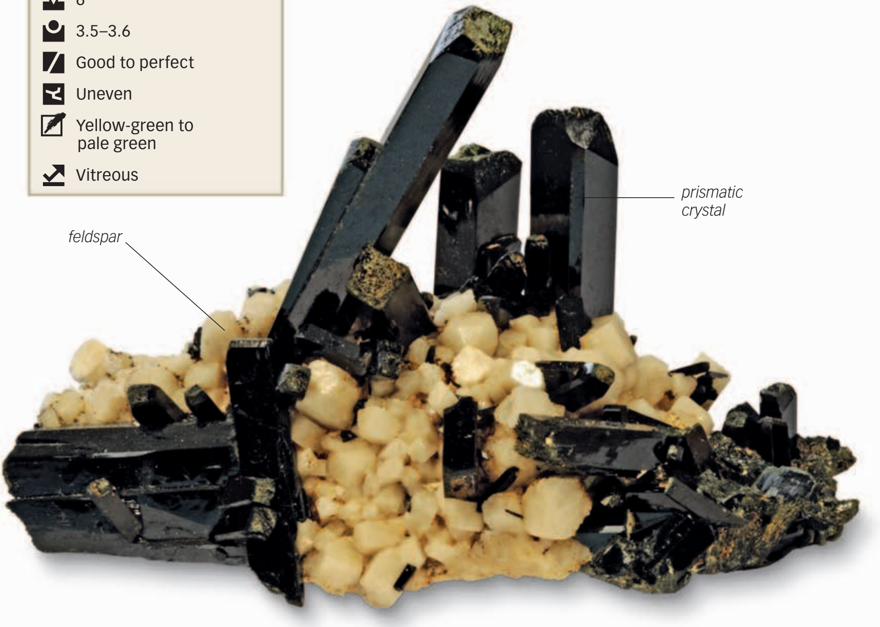

VARIANTS

Parallel crystals A mass of prismatic aegirine crystals aligned in parallel

Prismatic aegirine Prismatic crystals of aegirine in a rock matrix

$NaFe(Si_2O_6)$

AEGIRINE

The sodium iron silicate aegirine was discovered in Norway and named in 1835 after Aegir, the Scandinavian god of the sea. Aegirine is also known as acmite after the Greek word *acme*, which means "point" or "edge"—a reference to the mineral's typically pointed crystals. Specimens are dark green, reddish brown, or black in color. Aegirine occurs as needlelike or fibrous crystals that form attractive, radiating sprays. The crystals have steep or blunt terminations and are often striated along the length. Prism faces are often lustrous and striated, while the faces of terminations are often etched and dull.

A pyroxene, aegirine forms a solid-solution series with hedenbergite and diopside (p.210). It is found in magnesium- and iron-rich igneous rocks, especially syenitic pegmatites (p.260) and syenites (p.262). It is also found in schists (pp.291–92), metamorphosed iron-rich sediments, and metamorphic rocks altered by circulating fluids. Notable localities include Kongsberg, Norway, and Mont St.-Hilaire, Canada.

PROFILE

Monoclinic

6

3.3

Distinct in two directions at almost right angles

Uneven

White to pale green

Vitreous

Prismatic diopside This specimen of diopside in a rock matrix comes from St. Marcel, Valle d'Aosta, Italy.

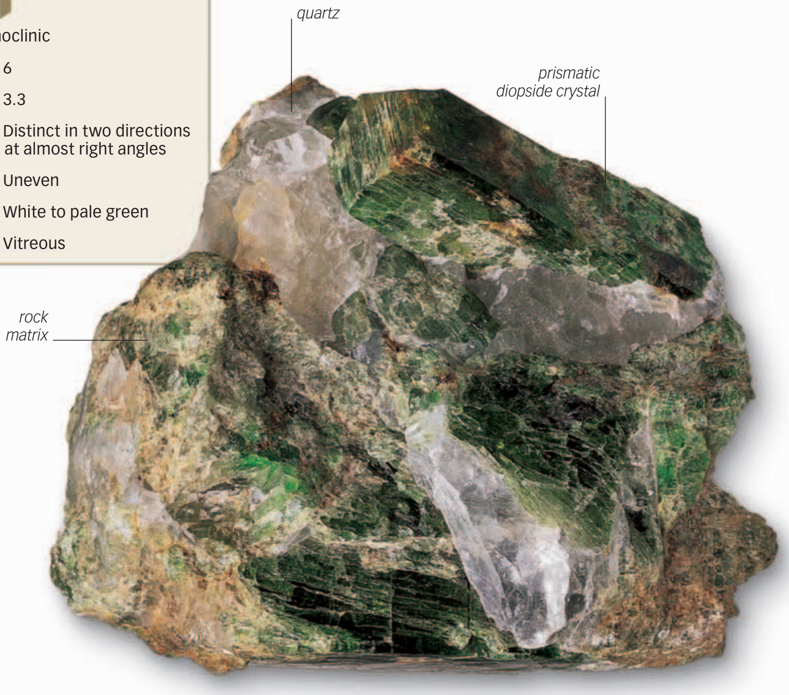

VARIANT

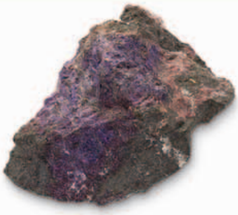

Violane A blue, crystalline variant of diopside

$CaMg(Si_2O_6)$

DIOPSIDE

A member of the pyroxene family, diopside takes its name from the Greek for "double" and "appearance," a reference to the variable appearance of the mineral. Specimens can be colorless but are more often bottle green, brownish green, or light green in color. Diopside occurs in the form of equant to prismatic crystals that are usually nearly square in section. Crystals are less commonly tabular. This mineral can also form columnar, sheetlike, granular, or massive aggregates.

Most diopside is metamorphic and found in metamorphosed silica-rich limestones (p.319) and dolomites (p.320) and in iron-rich contact metamorphic rocks. It also occurs in peridotites (p.266), kimberlites (p.269), and other igneous rocks.

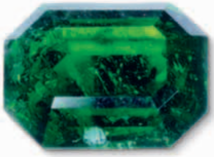

Chrome diopside Emerald-green diopside, such as the gem shown here, is chromium-rich and is also known as chrome diopside.

PROFILE

Monoclinic

5½–6

3.3

Distinct in two directions at almost right angles

Uneven to subconchoidal

Pale brown to greenish gray

Vitreous to dull

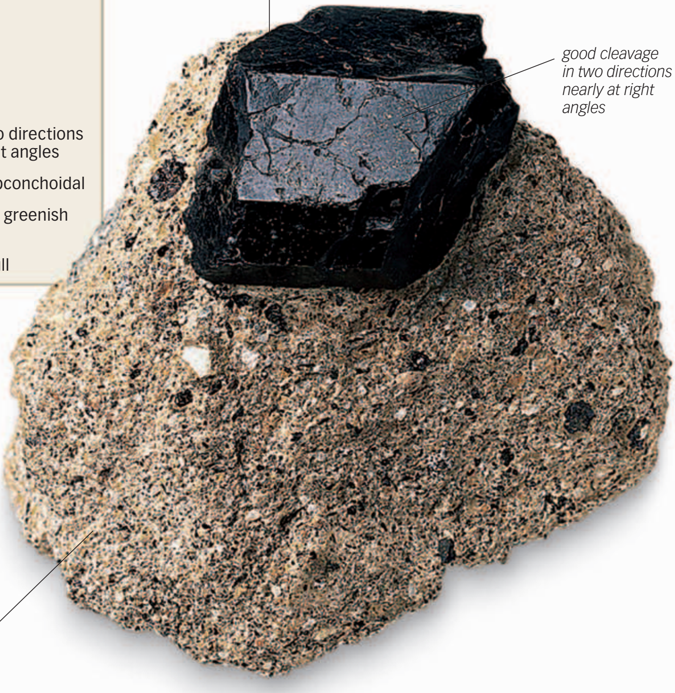
dark, nearly opaque crystal
good cleavage in two directions nearly at right angles
volcanic tuff

Single crystal
In this specimen, a single, large, dark-colored augite crystal rests on a matrix of volcanic tuff.

$(Ca,Na)(Mg,Fe,Ti,Al)(Al,Si)_2O_6$

AUGITE

The most common pyroxene, augite is named after the Greek word *augites*, which means "brightness"—a reference to its occasional shiny appearance. Most augite has a dull, dark green, brown, or black finish. Augite occurs chiefly as short, thick, prismatic crystals with a square or octagonal cross section and sometimes as large, cleavable masses. It occurs in a solid-solution series in which diopside (p.210) and hedenbergite are the end-members.

Augite is common in silica-poor rocks and various other dark-colored igneous rocks, as well as igneous rocks of intermediate silica content. It also occurs in some metamorphic rocks formed at high temperatures (1,065°F/575°C or above). Augite is a common constituent of lunar basalts and some meteorites (pp.335–37). Notable crystal localities are in Germany, the Czech Republic, Italy, Russia, Japan, Mexico, Canada, and USA. Because it is difficult to distinguish between augite, diopside, and hedenbergite in hand specimens, all pyroxenes are often identified as augite.

VARIANTS

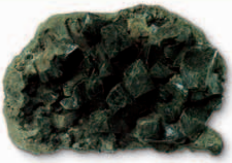

Greenish black augite A mass of greenish black, prismatic augite crystals

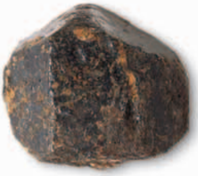

Prismatic crystal A short prismatic augite crystal from the Czech Republic

PROFILE

Monoclinic

6½–7

3.0–3.2

Perfect

Subconchoidal to splintery

White

Vitreous

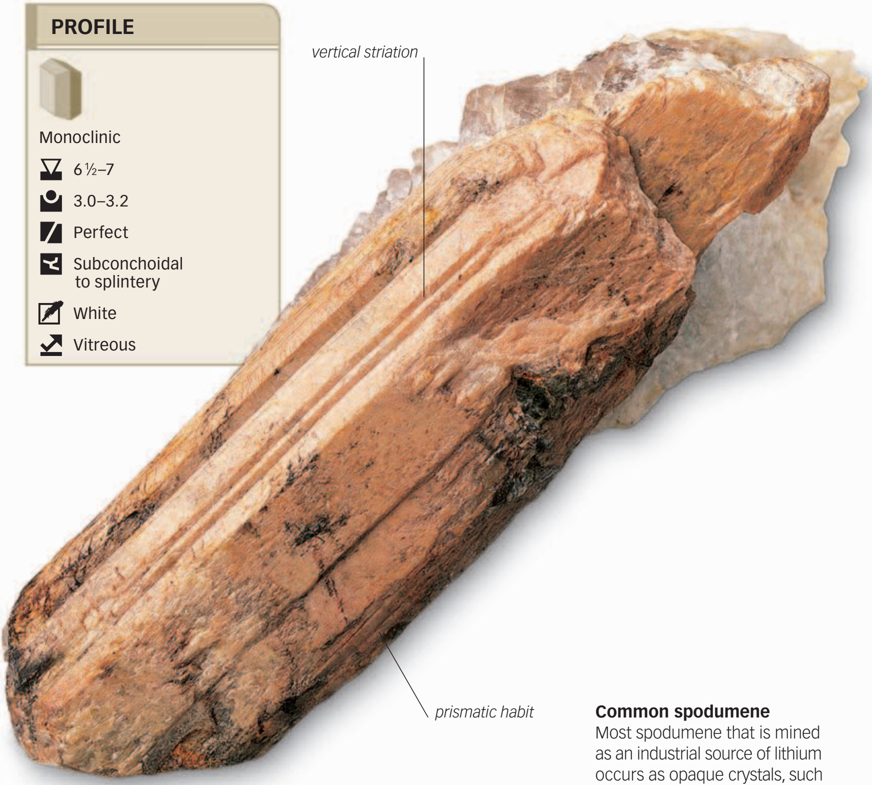

Common spodumene Most spodumene that is mined as an industrial source of lithium occurs as opaque crystals, such as the one shown here.

VARIANTS

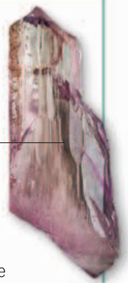

Kunzite The lavender gemstone form of spodumene

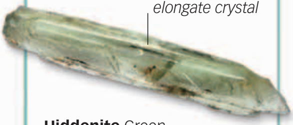

Hiddenite Green, gem-variety specimen of spodumene

$LiAl(Si_2O_6)$

SPODUMENE

A member of the pyroxene group, spodumene is named after the Greek word *spodumenos*, which means "reduced to ashes"—a reference to the mineral's common ash-gray color. It can also be pink, lilac, or green. Crystals are prismatic, flattened, and typically striated along their length. Gem varieties of the mineral usually exhibit strong pleochroism.

Spodumene is an important ore of lithium. It occurs in lithium-bearing granite pegmatite dykes, often with other lithium-bearing minerals, such as eucryptite and lepidolite (p.198). One of the largest single crystals of any mineral ever found was a spodumene specimen from South Dakota, USA, 47 ft (14.3 m) long and 90 tons in weight.

Strengthened glass Spodumene is a key source of lithium, which forms the lithium fluoride that is used to add strength to glass.

PROFILE

Monoclinic
6–7
3.2–3.4
Good
Splintery
White
Vitreous to greasy

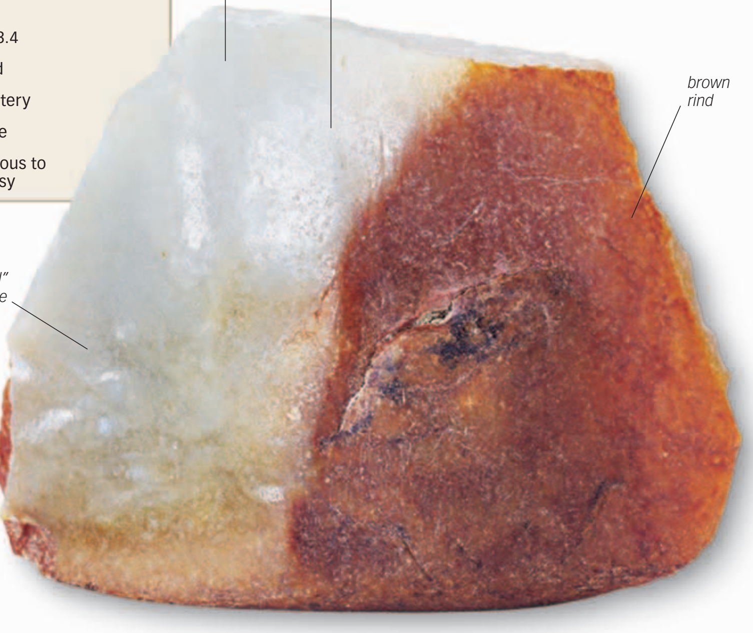

Weathered jadeite This massive jadeite specimen is colored lavender by impurities. It has been partly polished to show its characteristic brown "rind."

VARIANTS

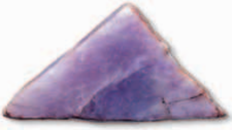

Lilac jadeite A rare and valuable variety of jadeite

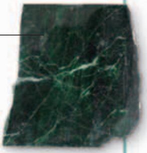

Imperial jade A rich green specimen of imperial jade

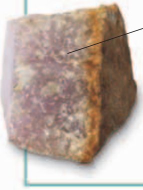

Violet jadeite A specimen of rare, valuable, violet jadeite

$Na(Al,Fe)Si_2O_6$

JADEITE

A pyroxene mineral, jadeite is one of the two minerals that are referred to as jade. The other is nephrite (p.217), which is a variety of either tremolite (p.219) or actinolite (p.220). Pure jadeite is white in color. Specimens can be colored green by iron, lilac by manganese and iron, or pink, purple, brown, red, blue, black, orange, or yellow by inclusions of other minerals. Jadeite is made up of interlocking, blocky, granular crystals and commonly has a sugary or granular texture. Crystals are short prisms. They are rare but when found are usually in hollows within massive material.

Jadeite occurs in metamorphic rocks formed at high pressure. Although usually recovered as alluvial pebbles and boulders, it is also found in the rocks in which it originally formed.

Jade mask Jadeite, such as that used in this 18th-century mask, had cultural value for Central and South American Indians.

PROFILE

Triclinic

4½–5

2.9

Perfect

Uneven to splintery

White

Vitreous to splintery

Crystalline wollastonite
The mass of parallel crystals in this specimen are shaped like coarse blades. They show silky luster and a splintery fracture.

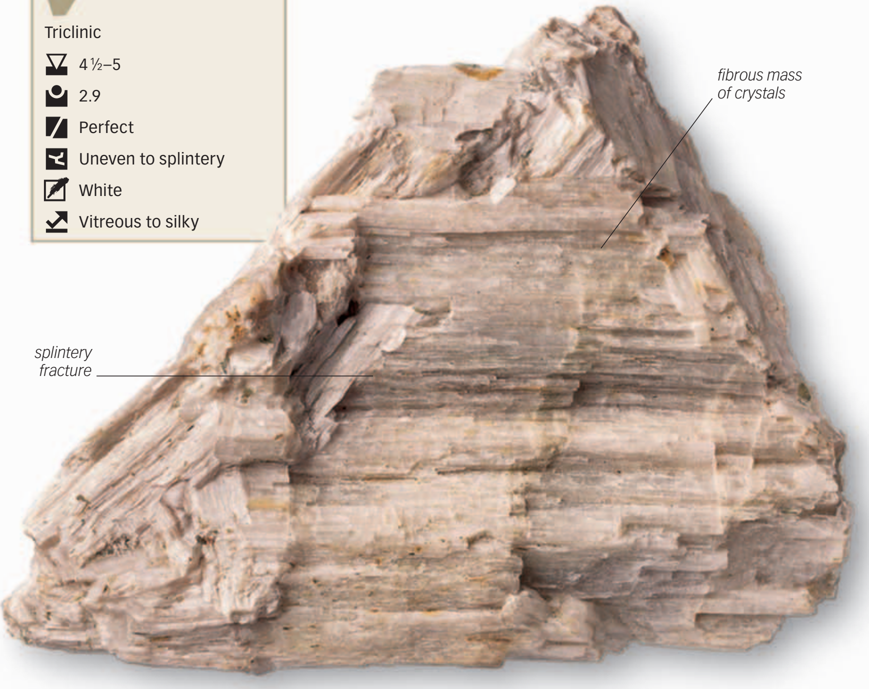

VARIANTS

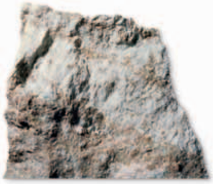

Massive wollastonite
A piece of massive wollastonite

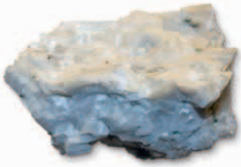

Coarse crytals A mass of coarsely crystalline wollastonite from New York

$CaSiO_3$

WOLLASTONITE

A valuable industrial mineral, wollastonite is white, gray, or pale green in color. It occurs as rare, tabular crystals or massive, coarse-bladed, foliated, or fibrous masses. Its crystals are usually triclinic, although its structure has seven variants, one of which is monoclinic. These variations are however, indistinguishable in hand specimens.

Wollastonite forms as a result of the contact metamorphism of limestones (p.319) and in igneous rocks that are contaminated by carbon-rich inclusions. It can be accompanied by other calcium-containing silicates, such as diopside (p.210), tremolite (p.219), epidote (p.230), and grossular garnet (p.245). Wollastonite also appears in regionally metamorphosed rocks in schists (pp.291–92), slates (p.293), and phyllites (p.294).

Ceramic tile
Wollastonite is widely used in ceramics, such as the tile shown here. It is also an ideal base for fluxes and glazes.

PROFILE

Triclinic

6

3.5–3.7

Perfect

Conchoidal to uneven

White

Vitreous

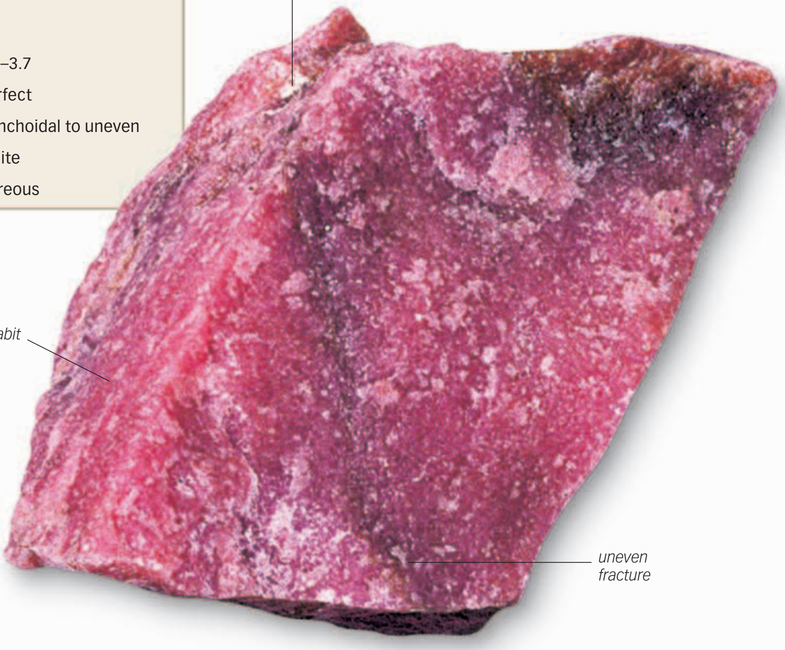

Massive rhodonite This specimen of rough rhodonite shows the intense coloring and fine texture of the best gem-quality material.

VARIANT

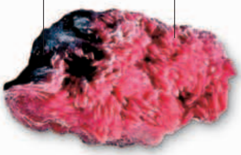

Tabular crystals Aggregates of tabular crystals

$(Mn,Ca)_5(Si_5O_{15})$

RHODONITE

The semiprecious gemstone rhodonite takes its name from the Greek word *rhodon*, which means “rose”—a reference to the mineral’s typical pink color. Crystals are uncommon but are rounded when found. Rhodonite usually occurs as masses or grains and is often coated or veined with manganese oxides.

Rhodonite is found in various manganese ores, often with rhodochrosite (p.121) or as a product of rhodochrosite that has undergone metamorphism. It has been used as a manganese ore in India but is more often mined as a gem and an ornamental stone. Rhodonite is primarily cut *en cabochon* as beads. Massive rhodonite is relatively tough and is good as a carving medium. Transparent rhodonite is rare. Although extremely fragile, it can be faceted for collectors.

Rhodonite box Black-veined rhodonite, such as that used here, is relatively tough and is preferred by many carvers.

Radiating crystals
This specimen is a mass of fibrous, radiating crystals of anthophyllite with vitreous luster.

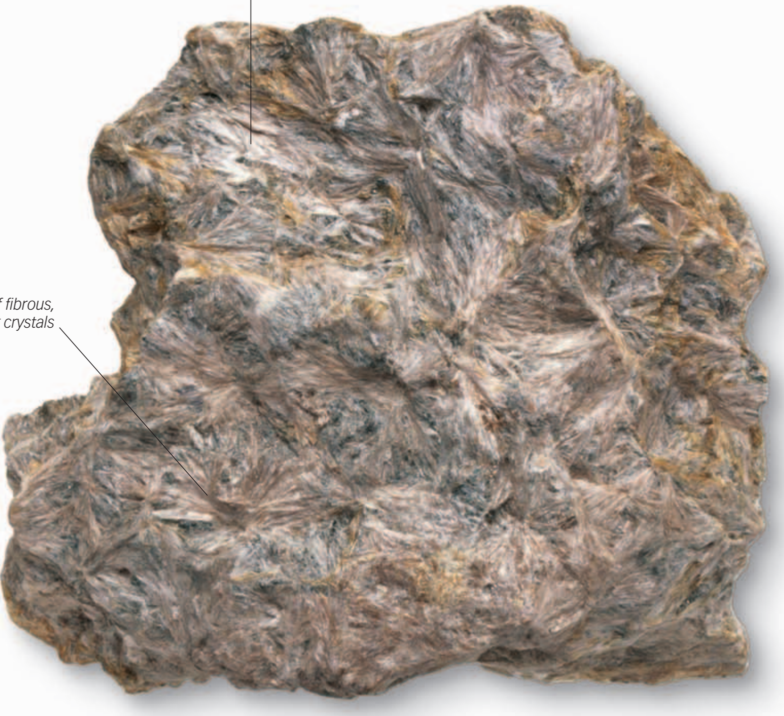

PROFILE

Orthorhombic

- 5½–6
- 2.8–3.6
- Perfect, imperfect
- Uneven
- Colorless to gray
- Vitreous

$(Mg,Fe)_7Si_8O_{22}(OH)_2$

ANTHOPHYLLITE

The name anthophyllite comes from the Latin word *anthophyllum*, which means "clove"—a reference to the mineral's clove-brown to dark brown color. Specimens can also be pale green, gray, or white. Anthophyllite is usually found in columnar to fibrous masses. Single crystals are uncommon; when found, they are prismatic and usually unterminated. The iron and magnesium content in anthophyllite is variable. The mineral is called ferroanthophyllite when it is iron-rich, sodium-anthophyllite when sodium is present, and magnesioanthophyllite when magnesium is dominant. Titanium and manganese may also be present in the anthophyllite structure.

Anthophyllite forms by the regional metamorphism of iron- and magnesium-rich rocks, especially silica-poor igneous rocks. It is an important component of some gneisses (p.288) and crystalline schists (pp.291–92) and is found worldwide. Anthophyllite is one of several minerals referred to as asbestos.

Polished nephrite
This small boulder of nephrite has been sliced and polished to reveal its quality.

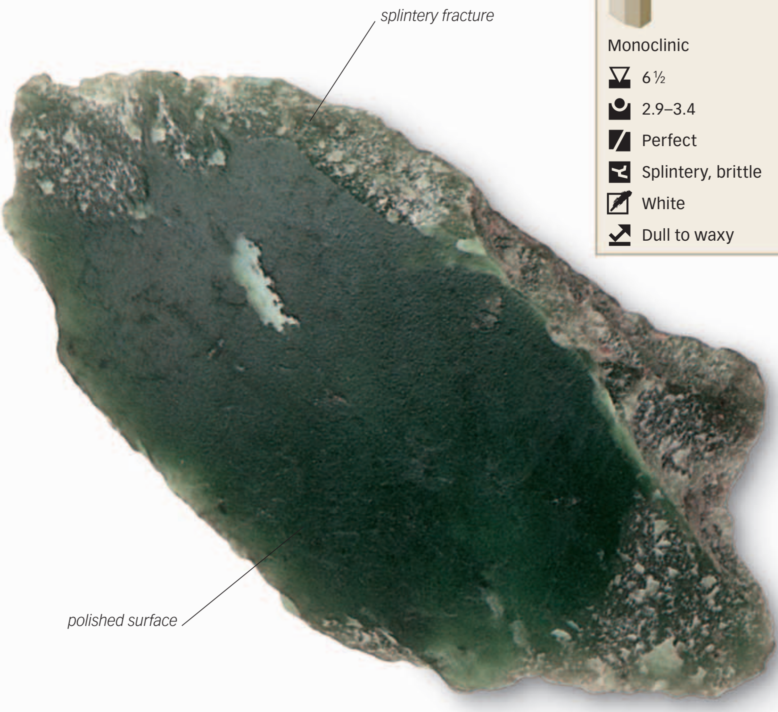

PROFILE

Monoclinic

6½

2.9–3.4

Perfect

Splintery, brittle

White

Dull to waxy

VARIANT

Light green nephrite A mass of light green nephrite

$Ca_2(Mg,Fe)_5(Si_8O_{22})(OH)_2$

NEPHRITE

Not a true mineral name, the term nephrite applies to the tough, compact form of either tremolite (p.219) or actinolite (p.220). Both are calcium magnesium silicate hydroxides and structurally identical, except that in actinolite some of the magnesium is replaced by iron. Nephrite is dark green when iron-rich and creamy white when magnesium-rich. Specimens are composed of a mat of tightly interlocked fibers, creating a stone that is tougher than steel.

Nephrite forms in metamorphic environments, especially in metamorphosed iron- and magnesium-rich rocks, where it is associated with serpentine (p.191) and talc (p.193). It is also found in regionally metamorphosed areas where dolomites (p.320) are intruded by iron- and magnesium-rich igneous rocks.

Nephrite tiki
Hei tikis, such as this one made of nephrite, are worn by the Maori of New Zealand.

PROFILE

Monoclinic

5–6

3.1–3.3

Perfect

Uneven, brittle

White to gray

Vitreous

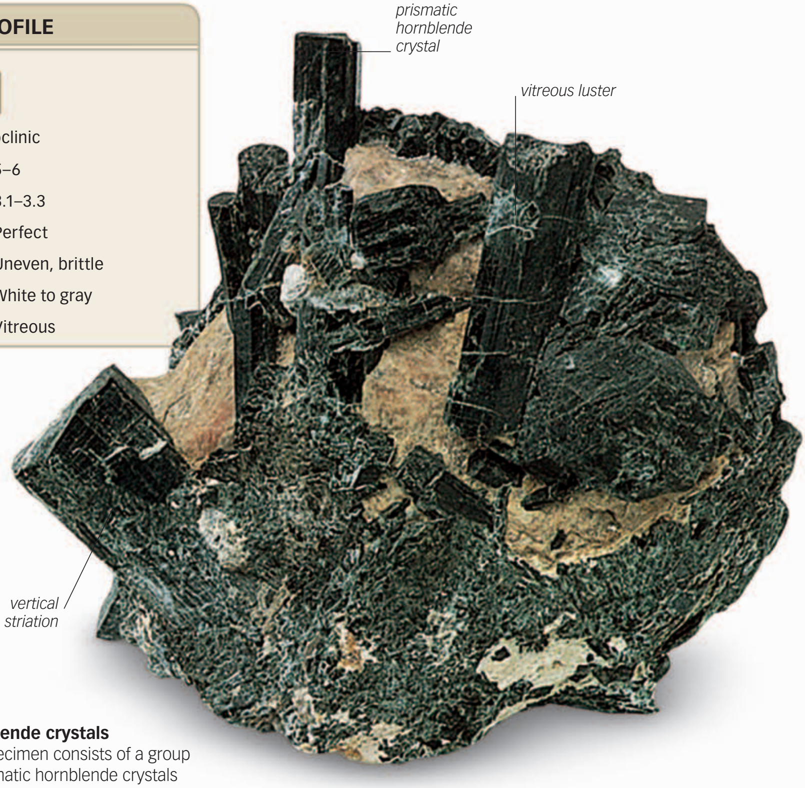

Hornblende crystals
This specimen consists of a group of prismatic hornblende crystals embedded in a rock matrix.

VARIANTS

white rock matrix

Prismatic hornblende Prismatic crystals in a rock matrix

Massive hornblende A piece of massive hornblende

six-sided crystal

Single crystal A single, short prismatic crystal of hornblende

eg: $Ca_2(Fe^2,Mg)_4(Al,Fe^3)(Si_7Al)O_{22}(OH,F)_2$

HORNBLENDE

The name hornblende is applied to a group of minerals that can be distinguished from each other only by detailed chemical analysis. The two end-member hornblendes—iron-rich ferrohornblende and magnesium-rich magnesiohornblende—are both calcium-rich and monoclinic in crystal structure. Other elements, such as chromium, titanium, and nickel, can also appear in the crystal structures of the group. The concentrations of these elements are an indicator of the metamorphic grade of the mineral.

Specimens are green, dark green, or brownish green to black in color. Hornblende crystals are usually bladed and unterminated, and they often show a pseudohexagonal cross section. Well-formed crystals are short to long prisms. Hornblende also occurs as cleavable masses and radiating groups. The mineral forms in metamorphic rocks, especially gneisses (p.288), hornblende schists, amphibolites (p.296), and magnesium- and iron-rich igneous rocks.

Tremolite crystals This specimen has plumelike aggregates of white, bladed tremolite crystals.

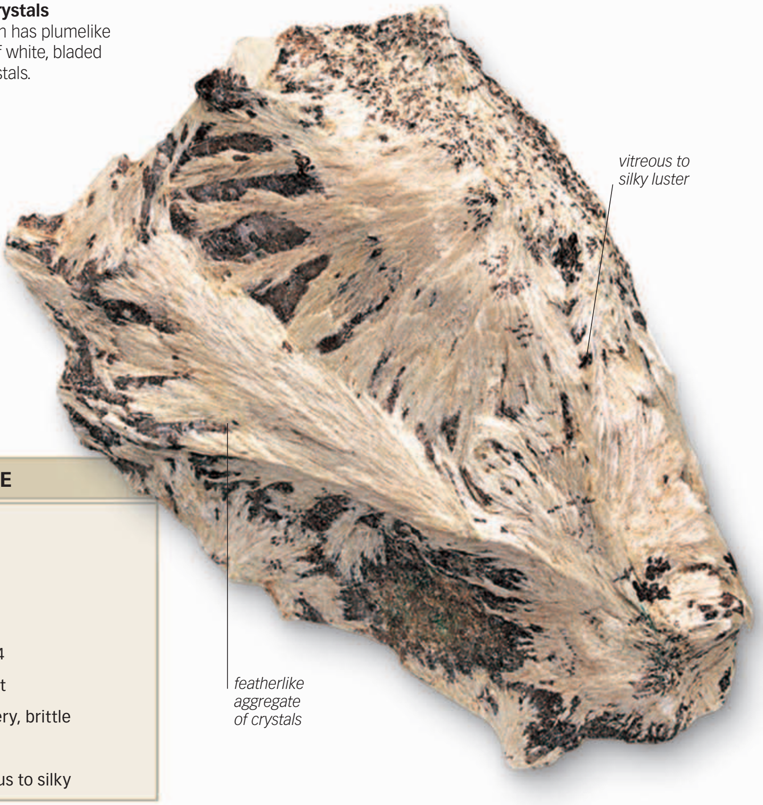

PROFILE

Monoclinic
5–6
2.9–3.4
Perfect
Splintery, brittle
White
Vitreous to silky

VARIANTS

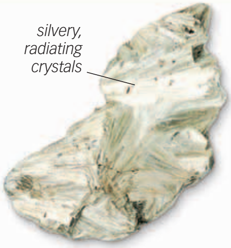

Radiating tremolite Radiating crystals of silvery tremolite

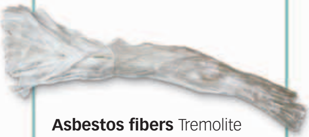

Asbestos fibers Tremolite in fibrous form

$Ca_2(Mg,Fe^2)_5Si_8O_{22}(OH)_2$

TREMOLITE

A calcium magnesium silicate, tremolite forms a solid-solution series with ferroactinolite (p.220), where iron substitutes in increasing amounts for magnesium. The color of tremolite varies with increasing iron content from colorless to white in pure tremolite to gray, gray-green, green, dark green and nearly black in other specimens. Traces of manganese may tint tremolite pink or violet. When well-formed, crystals are short to long prisms. More commonly, tremolite forms unterminated bladed crystals, parallel aggregates of bladed crystals, or radiating groups. Tremolite and actinolite both form thin, parallel, flexible fibers up to 10in (25cm) in length, which are used commercially as asbestos. Tremolite is known as nephrite jade when it is massive and fine-grained.

The mineral is abundant and widespread. It is the product of both thermal and regional metamorphism and is an indicator of metamorphic grade because it converts to diopside (p.210) at high temperatures (1,065°F/575°C or above).

PROFILE

Monoclinic

5–6

2.9–3.4

Good, crossing at 56° and 124°

Splintery, brittle

White

Vitreous or silky

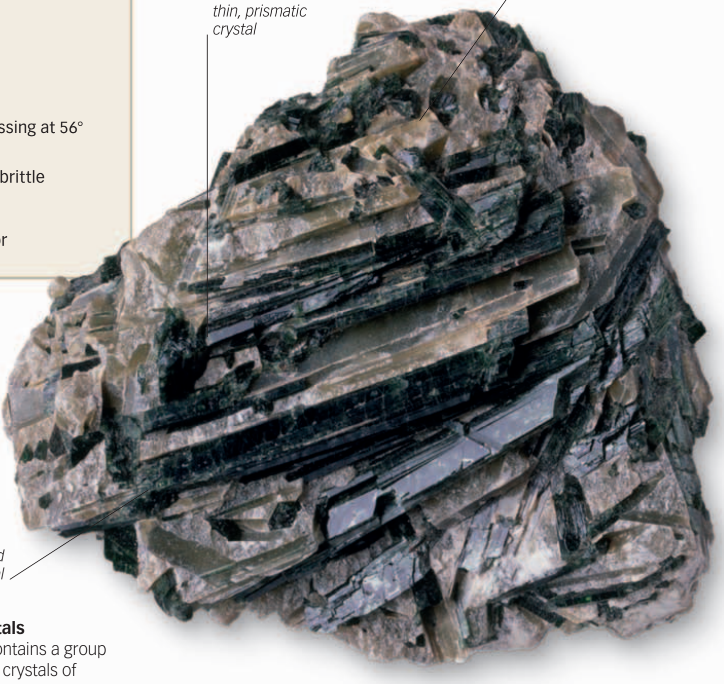

Actinolite crystals
This specimen contains a group of thin, prismatic crystals of actinolite in a talc matrix.

VARIANT

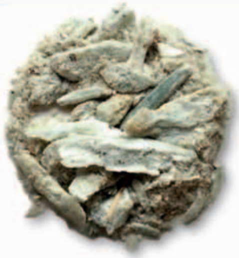

Gray-green actinolite
Crystals of actinolite, some of which have been powdered

$Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$

ACTINOLITE

Actinolite is an abundant mineral. It is in the middle of a solid-solution series of calcium, iron, and magnesium silicates that also includes ferroactinolite and tremolite (p.219). There is complete substitution in the series between iron and magnesium, but all have the same structure. Actinolite was named in 1794 after the Greek word *aktis*, which means "ray"—an allusion to its radiating, prismatic habit. Specimens range from green to dark green to black. Well-formed crystals are short to long prisms. Actinolite usually occurs as unterminated bladed crystals, parallel aggregates of bladed crystals, or radiating groups. It is sometimes found as needlelike or fibrous crystals up to 10 in (25 cm) long. When in this form, it is one of the minerals that are called asbestos. Massive, fine-grained actinolite and tremolite are both called nephrite jade.

Actinolite is an amphibole mineral and forms as a product of low- to medium-grade thermal and regional metamorphism. Good crystals come from Edwards, New York, USA, and Kantiwa, Afghanistan.

PROFILE

Monoclinic

6

3.2

Distinct

Uneven to conchoidal

Gray-blue

Vitreous to pearly

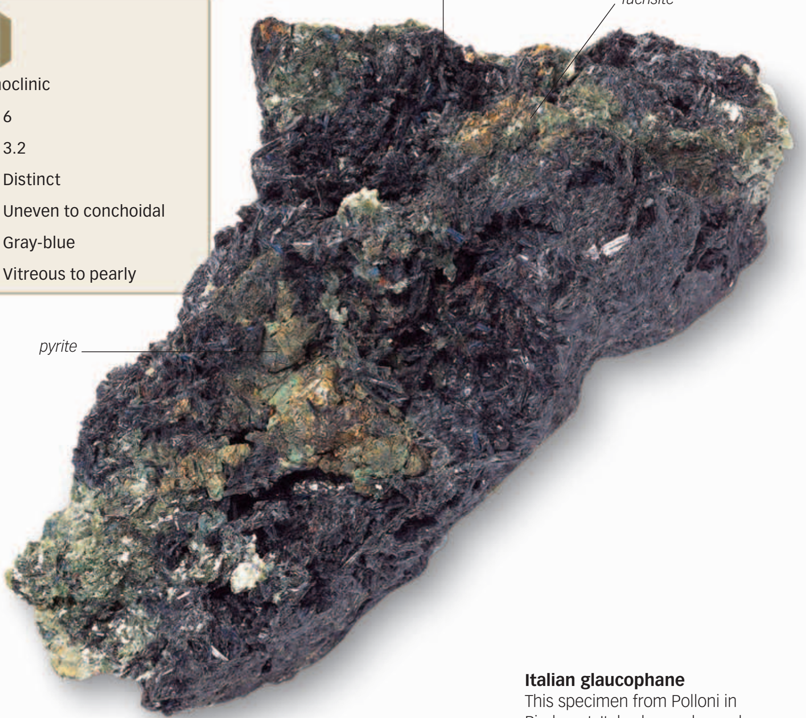

Italian glaucophane
This specimen from Polloni in Piedmont, Italy, shows glaucophane with fuchsite and pyrite.

VARIANT

prismatic crystal

Glaucophane crystals
Crystals of glaucophane in a rock matrix

$Na_2(Mg_3Al_2)Si_8O_{22}(OH)_2$

GLAUCOPHANE

The mineral is named after two Greek words: *glaukos*, which means "bluish green"; and *phainesthai*, which means "to appear." Specimens can be gray, lavender blue, or bluish black. Crystals are slender, often lathlike prisms, with lengthwise striations. Twinning is common. Glaucophane can also be massive, fibrous, or granular. When iron replaces the magnesium in its structure, it is known as ferroglaucophane.

Glaucophane occurs in schists (pp.291–92) formed by high-pressure metamorphism of sodium-rich sediments at low temperatures (up to 400°F/200°C) or by the introduction of sodium into the process. Glaucophane is often accompanied by jadeite (p.213), epidote (p.230), almandine (p.243), and chlorite. It is one of the minerals that are referred to as asbestos. Glaucophane and its associated minerals are known as the glaucophane metamorphic facies. The presence of these minerals indicates the range of temperatures and pressures under which metamorphism occurs.

PROFILE

Monoclinic

6

3.3–3.4

Perfect

Uneven

Blue-gray

Vitreous, silky

Riebeckite crystals The long, striated crystals characteristic of riebeckite are clearly visible in this specimen.

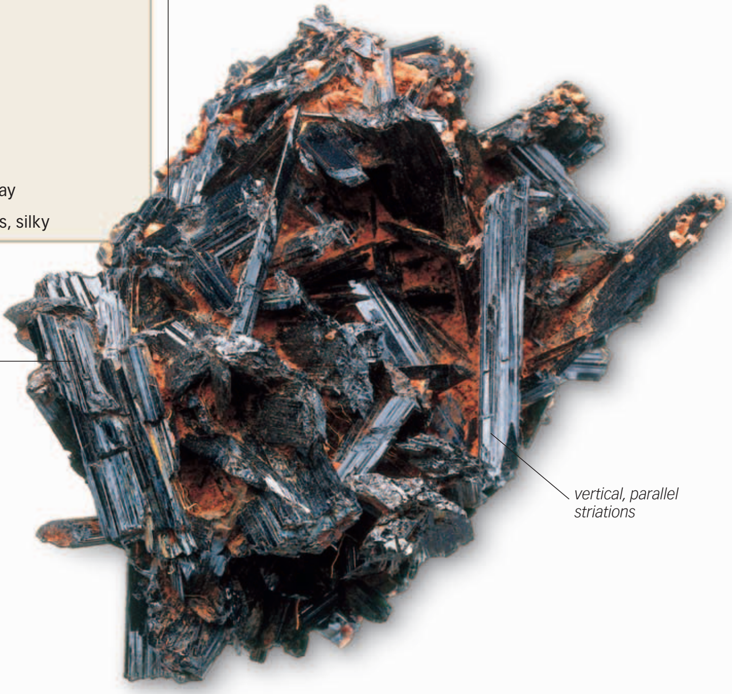

VARIANT

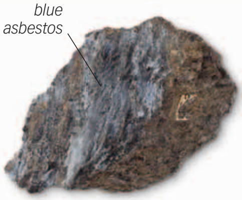

Crocidolite Fibers of blue riebeckite, which constitute blue asbestos

$Na_2(Fe^{2+}_3Fe^{3+}_2)Si_8O_{22}(OH)_2$

RIEBECKITE

A sodium iron silicate, riebeckite is one of the several minerals called asbestos. It was named after Emil Riebeck, a 19th-century German explorer. Although riebeckite specimens are generally grayish blue to dark blue, their color can vary depending on the concentration of iron in their structure. Riebeckite can occur as prismatic, striated crystals or sometimes as massive or fibrous aggregates.

This mineral occurs in feldspar- and quartz-rich igneous rocks. These include granites (pp.258–59), syenites (p.262) and, feldspar- and quartz-rich volcanic rocks, especially sodium-rich rhyolites (p.278). Riebeckite granite is found on the island of Ailsa Craig in western Scotland and is locally known as ailsite. Ailsite is used to manufacture stones used in the sport of curling.

Tiger's eye ring Crocidolite, a variant of riebeckite, forms the gemstone tiger's eye when it is silica-saturated.

PROFILE

Orthorhombic

7–7½

2.6

Moderate to poor

Conchoidal to uneven

White

Vitreous to greasy

Cordierite crystals This group of short prismatic, dark gray cordierite crystals occurs in a rock matrix.

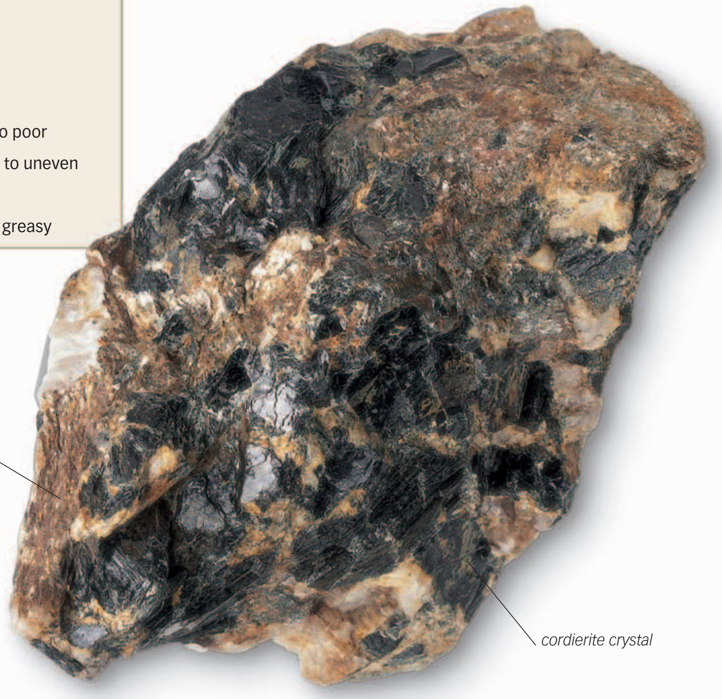

VARIANTS

Single crystal A large crystal of cordierite in matrix

Iolite A polished gemstone of cordierite called iolite

$(Mg,Fe)_2Al_4Si_5O_{18}$

CORDIERITE

The mineral is named after the French geologist Pierre L.A. Cordier, who first described it in 1813. Specimens can be blue, violet-blue, gray, or blue-green. Gem-quality blue cordierite or iolite is also known as water sapphire because of its color. Cordierite is pleochroic, exhibiting three different colors when viewed from different angles. Its crystals are prismatic, and the best blue color is seen along their length.

Cordierite occurs in high-grade, thermally metamorphosed, alumina-rich rocks. It is also found in gneisses (p.288) and schists (pp.291–92) and more rarely in granites (pp.258–59), pegmatites (p.260), and veins of quartz (p.168). Cordierite is important in the production of ceramics used in catalytic converters in cars.

Cordierite jewelry A variety of cordierite, iolite is used in ornaments because of its color and brilliance.

PROFILE

Hexagonal or trigonal

7–7½

3.0–3.2

Indistinct

Uneven to conchoidal

Colorless

Vitreous

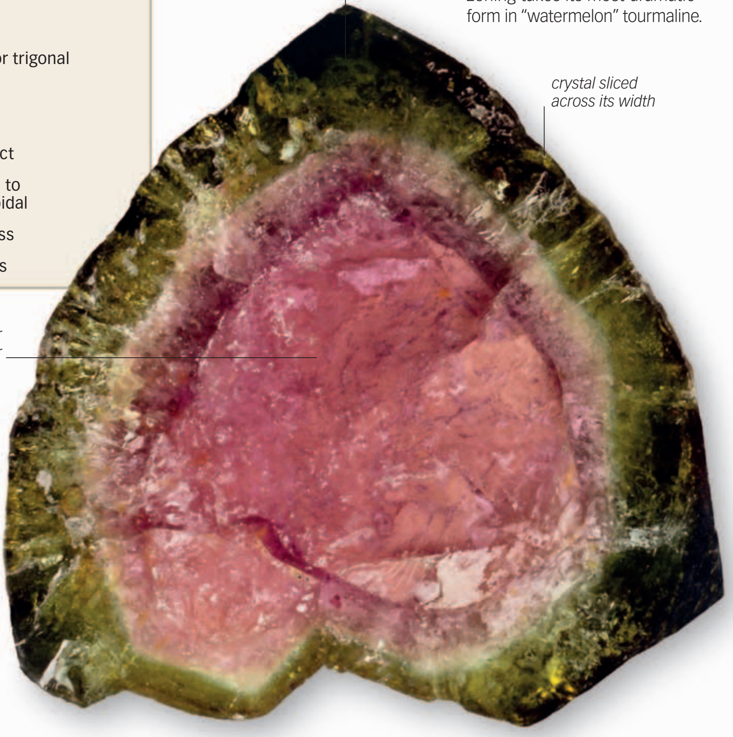

Watermelon tourmaline Color can vary either along or across a tourmaline crsytal. This zoning takes its most dramatic form in "watermelon" tourmaline.

$FeWO_4$

TOURMALINE

Tourmaline is the name given to a family of minerals of complex and variable composition, but all members have the same basic crystal structure. The 11 minerals in the group include elbaite, schorl, dravite, and liddicoacite. Gemstone varieties based on their color are also recognized, including indicolite (blue), rubellite (pink or red), verdelite (green), and achroite (colorless). These variety names can be applied to more than one mineral. Most tourmaline is dark, opaque, and not particularly attractive, but many of its transparent varieties are valued as gems.

Tourmaline is abundant, and its best formed crystals are usually found in pegmatites (p.260) and metamorphosed limestones (p.319) in contact with granitic magmas. It accumulates in gravel deposits and occurs as an accessory mineral in some sedimentary rocks.

Cut rubellite This specimen shows the rich red coloration and transparency found in some specimens of rubellite.

VARIANTS

Schorl Probably the most common tourmaline mineral

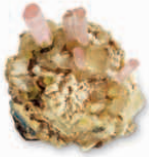

Elbaite A gemstone-quality variant of tourmaline

Indicolite A blue-colored variant of tourmaline

PROFILE

Hexagonal or trigonal

- 7½–8
- 2.6–2.8
- Indistinct
- Uneven to conchoidal
- White
- Vitreous

Aquamarine This mass of prismatic aquamarine crystals is from the Karakoram Range in Pakistan. The name aquamarine means "seawater."

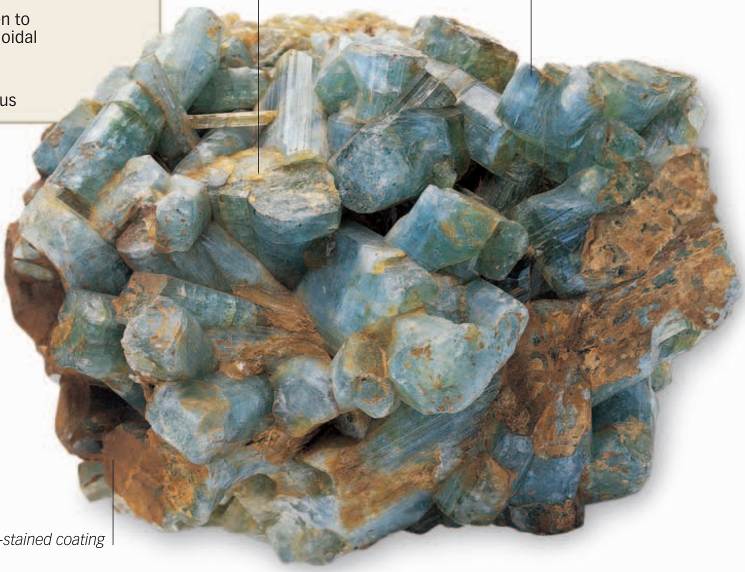

VARIANTS

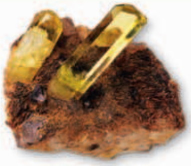

Heliodor Crystalline heliodor with hexagonal prisms

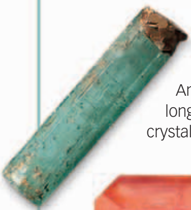

Emerald An unusually long prismatic crystal of emerald

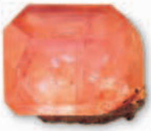

Morganite A variant with crystals in shades of pink

$MnWO_4$

BERYL

Few people have ever heard of the mineral beryl but almost everyone has heard of its principal gemstone varieties—emerald and aquamarine. Before 1925, beryl's solitary use was as a gemstone but since then many important uses have been found for beryllium. As a result, common beryl, which is usually pale green or white, has become widely sought after as the ore of this rare element. Most beryl is found in granites (pp.258–59), granite pegmatites (p.260), and rhyolites (p.278), but it can also occur in metamorphic rocks, such as schists (pp.291–92).

Emerald owes its grass-green color to the presence of traces of chromium and sometimes vanadium. Flawless emeralds are rare, but since 1937 the manufacture of synthetic crystals has become possible. Aquamarine is the most common gemstone variety of beryl. Nearly always found in cavities in pegmatites or in alluvial deposits, it forms larger and clearer crystals than emerald. Other gemstone varieties of beryl include heliodor, morganite, and goshenite.

PROFILE

Hexagonal
5
3.3
Perfect
Uneven to conchoidal
Pale greenish blue
Vitreous to greasy

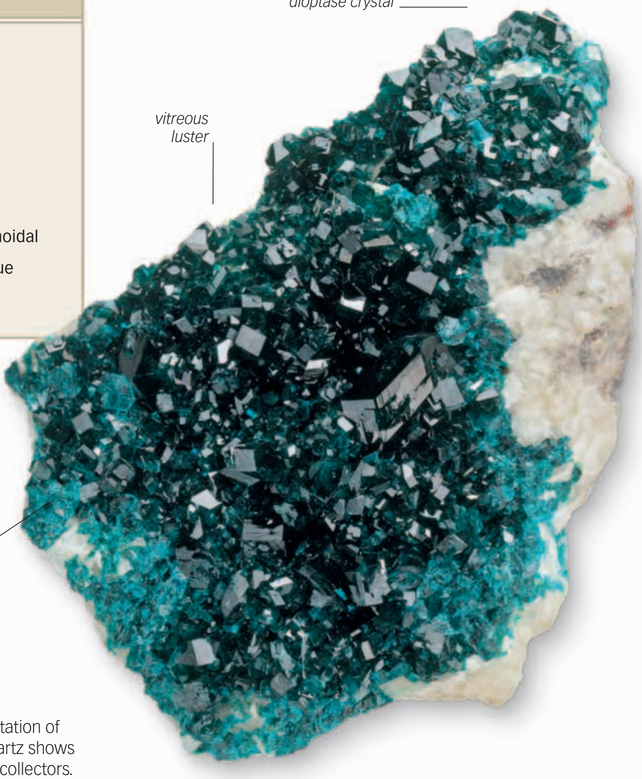

Prismatic dioptase This spectacular encrustation of dioptase crystals on quartz shows why it is a favorite with collectors.

VARIANTS

Clustered prisms A green dioptase specimen

Lustrous dioptase A specimen found in Central Africa

$CuSiO_2(OH_2)$

DIOPTASE

The bright green crystals of dioptase can superficially resemble emerald. Dioptase crystals mined from a rich deposit in Kazakhstan were wrongly identified as emerald when they were sent to Czar Paul of Russia in 1797. Were it not for its softness and good cleavage, dioptase would make a superb gemstone to rival emerald (p.225) in color. Its prismatic crystals, often with rhombohedral terminations, can be highly transparent. This explains why the name dioptase is derived from two Greek words: *dia*, which means “through,” and *optazein,* which means “visible” or “to see.” Transparent specimens of dioptase appear in different colors depending on the direction from which they are seen, and intensely colored specimens can be translucent. The mineral can also occur in granular or massive habits.

Dioptase forms in areas where copper veins have been altered by oxidation. Its vibrant color and its typical occurence as well-formed crystals make it popular with mineral collectors.

PROFILE

Orthorhombic
4½–5
3.4–3.5
Perfect, good, poor
Uneven, brittle
White
Vitreous

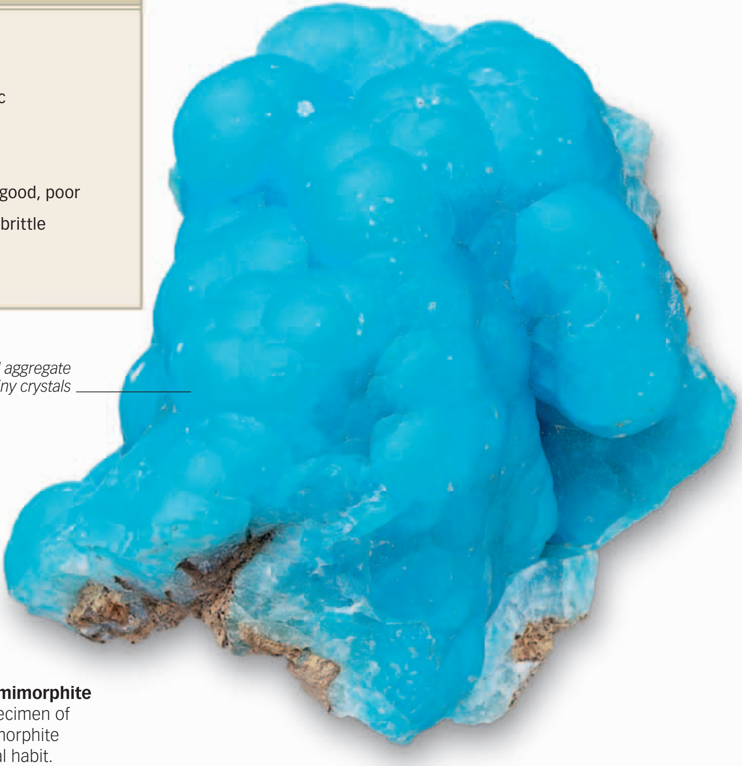

botryoidal aggregate of tiny crystals

Botryoidal hemimorphite This superb specimen of sky-blue hemimorphite has a botryoidal habit.

VARIANTS

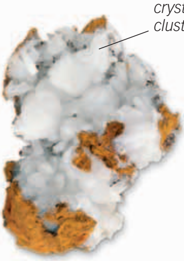

crystal cluster

White hemimorphite Tabular crystals on a rock matrix

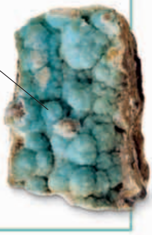

rounded mass

Crystalline aggregates A green specimen on a rock matrix

$Zn_4Si_2O_7(OH)_2 \cdot H_2O$

HEMIMORPHITE

One of two minerals formerly called calamine in the USA, hemimorphite takes its name from the Greek words *hemi*, which means "half," and *morphe*, which means "form"—a reference to its crystalline form. Hemimorphite crystals are double-terminated prisms with a differently shaped termination at each end—pointed at one and flat at the other. Crystals are often grouped in fan-shaped clusters. Hemimorphite can also be botryoidal, chalky, massive, granular, fibrous, or form encrustations. Usually colorless or white, specimens can also be pale yellow, pale green, or sky blue. Some specimens show strong, green fluorescence in shortwave ultraviolet light and weak, light pink fluorescence in longwave ultraviolet light.

Hemimorphite is a secondary mineral formed in the alteration zones of zinc deposits, especially as an alteration product of sphalerite (p.53). It can be half zinc by weight and is an important ore of that metal. Well-crystallized specimens come from Algeria, Namibia, Germany, Mexico, Spain, USA, and China.

PROFILE

Triclinic

6½–7

3.2–3.3

Good, poor

Uneven to conchoidal, brittle

Colorless to light brown

Vitreous

Axinite crystals This mass of well-formed, transparent, wedge-shaped, tabular axinite crystals rests on a rock matrix.

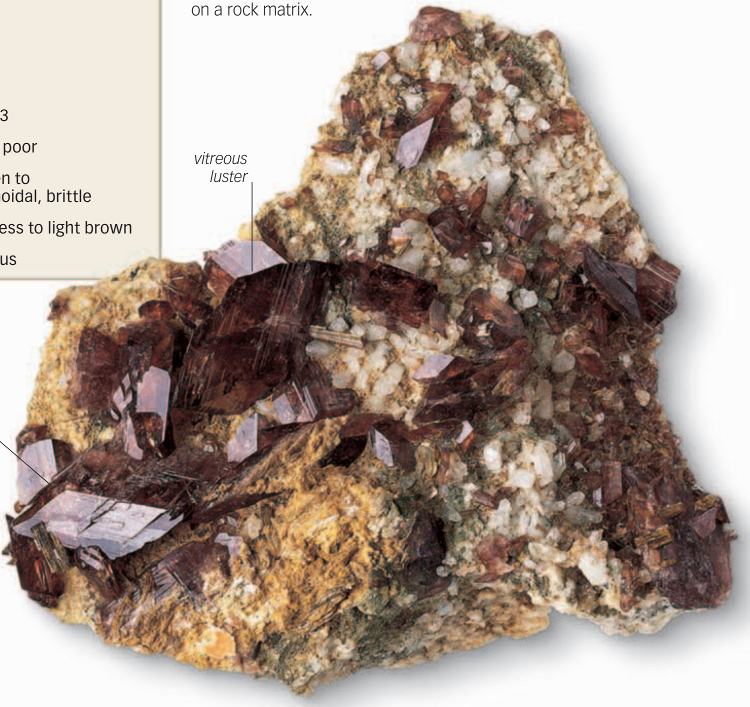

VARIANTS

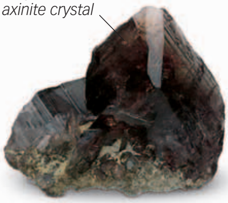

Gem quality Wedge-shaped crystals of brown axinite

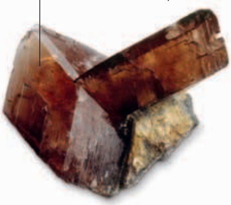

Unusual growth A small crystal growing on a larger one

$Ca_2FeAl_2(BSi_4O_{15})(OH)$

AXINITE

This group of minerals takes its name from the axehead shape of its crystals. Axinite minerals also occur as rosettes and in massive and granular forms. The most familiar color of axinite is clove brown. Varieties can also be gray to bluish gray; honey-, gray-, or golden-brown; violet-blue, pink, yellow, orange, or red. There are four minerals in the group: ferroaxinite, the most common; magnesioaxinite, in which magnesium replaces the iron in ferroaxinite; manganaxinite, in which manganese replaces the iron in ferroaxinite; and tinzenite, which is intermediate in composition between ferroaxinite and manganaxinite.

Axinite is commonly found in contact and low-temperature metamorphic rocks (those formed at up to 400°F/200°C) and in magnesium- and iron-rich igneous rocks.

Axinite gemstone Brilliant-cut axinite crystals, such as this specimen in an unusual shade of violet, are popular with collectors.

PROFILE

Tetragonal Monoclinic

6½

3.4

Poor

Subconchoidal to uneven, brittle

White to pale greenish brown

Vitreous to resinous

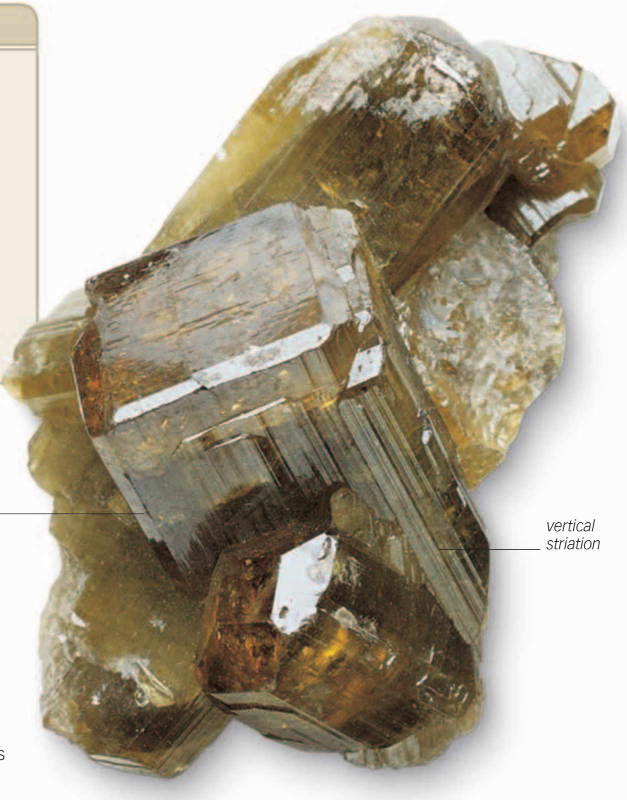

Striated vesuvianite
This superb specimen consists of prismatic, vertically striated vesuvianite crystals.

VARIANTS

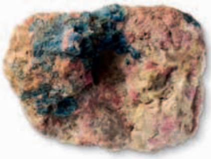

Cyprine A specimen of blue vesuvianite, or cyprine

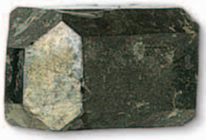

Tetragonal crystal
A single, well-formed crystal of vesuvianite

$Ca_{10}(Mg,Fe)_2Al_4(SiO_4)_5(Si_2O_7)_2(OH,F)_4$

VESUVIANITE

Formerly called idocrase, vesuvianite is named after its place of discovery—Mount Vesuvius in Italy. Usually green or yellow-green, it can also be yellow to brown, red, black, blue, or purple. A greenish blue copper-bearing vesuvianite is called cyprine. An unusual bismuth-bearing vesuvianite from Langben, Sweden, is bright red. The mineral forms pyramidal or prismatic and glassy crystals. Crystals 2¾ in (7 cm) or more long have been found.

Elements such as tin, lead, manganese, chromium, zinc, and sulfur may substitute in the vesuvianite structure. The mineral is formed by the metamorphism of impure limestones (p.319). It is also found in granulites (p.297) and marbles (p.301) accompanied by calcite (p.114), diopside (p.210), wollastonite (p.214), and grossular (p.245).

Vesuvianite gem
Occasionally, vesuvianite is found in translucent to transparent crystals suitable for cutting into gems.

PROFILE

Monoclinic

6–7

3.4

Good

Uneven to splintery

Colorless or grayish

Vitreous

Epidote crystals This superb group of striated epidote crystals, some reaching 1 in (2.5 cm) in length, shows typical prismatic development.

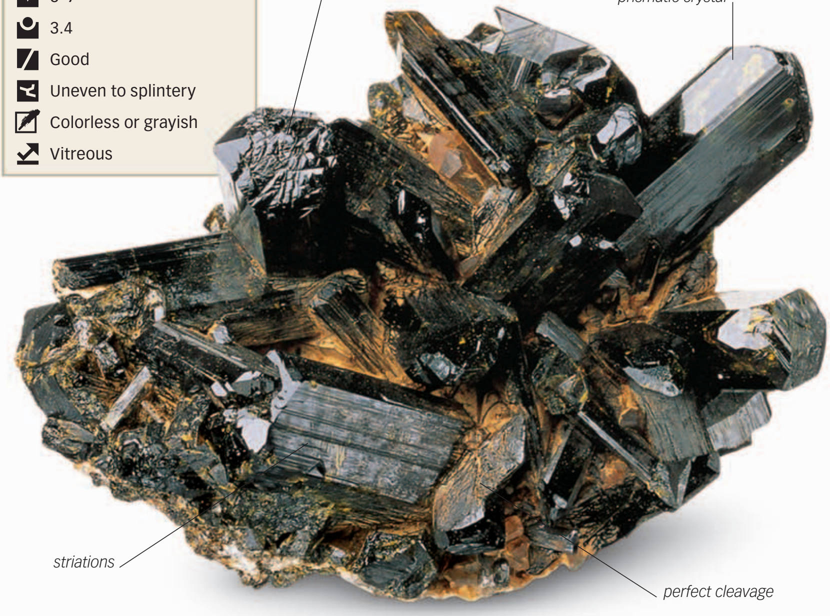

$Ca_2Al_2(Fe,Al)(SiO_4)(Si_2O_7)O(OH)$

EPIDOTE

An abundant rock-forming mineral, epidote derives its name from the Greek word *epidosis*, which means "increase"—a reference to the fact that one side of the prism is always wider than the others. Epidote is most easily recognized by its characteristic color—light to dark pistachio green. Gray or yellow specimens are also found. Epidote is pleochroic, exhibiting different colors when viewed from different directions. The mineral frequently forms well-developed crystals. These may be columnar prisms or thick, tabular crystals with faces that are finely striated parallel to the crystal's length. Twinning is common. Specimens can also be needlelike, massive, or granular.

Epidote is found in low-grade, regionally metamorphosed rocks. It also occurs as a product of the alteration of plagioclase feldspars (pp.173–81).

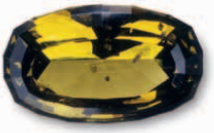

Epidote gemstone Clear, yellowish green to dark brown epidote gems are rare. Transparent crystals are cut for collectors.

VARIANTS

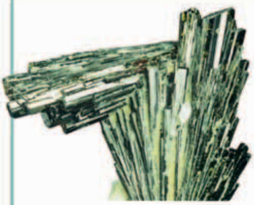

Pistachio epidote Long, striated crystals from Peru

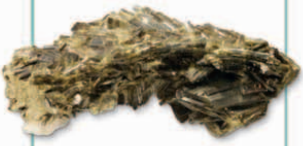

Acicular epidote Yellowish brown, needlelike crystals

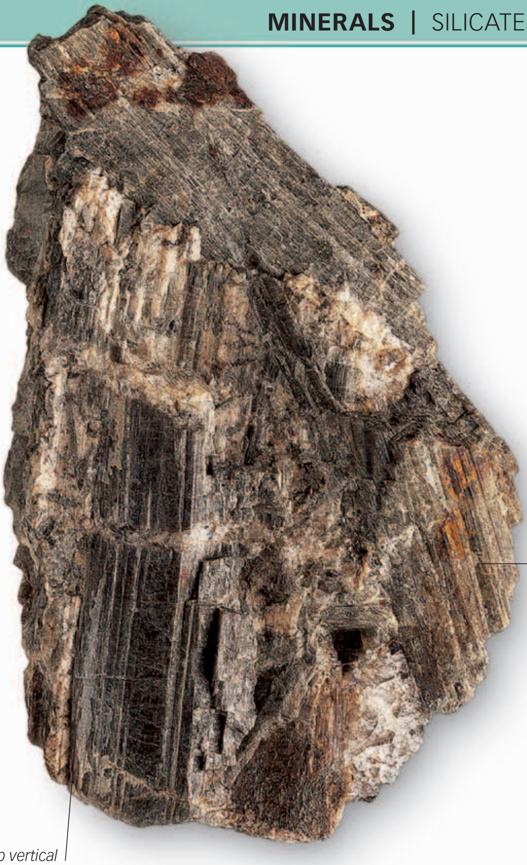

Zoisite crystals This specimen of ordinary zoisite shows a typical prismatic shape and vertical striations. The crystals are in a pegmatite matrix.

PROFILE

Orthorhombic
6–7
3.2–3.4
Perfect
Conchoidal to uneven, brittle
White
Vitreous

VARIANTS

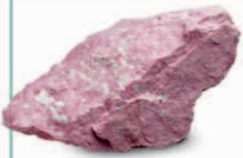

Thulite A pink, manganese-rich variety of zoisite

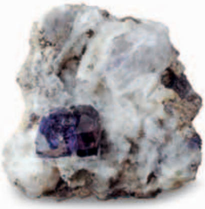

Tanzanite A rich purple gem-quality zoisite variety

$Ca_2Al_3(SiO_4)_3(OH)$

ZOISITE

A calcium aluminum silicate hydroxide, most zoisite is gray, white, light brown, yellowish green, or pale greenish gray. A massive, pinkish red variety is called thulite. A lilac-blue to sapphire-blue variety of zoisite is called tanzanite and is sometimes mistaken for sapphire (p.95). Zoisite with inclusions of ruby is called ruby-in-zoisite. Zoisite crystals exhibit gray, purple, or blue colors depending on the angle from which they are viewed. Zoisite is found as deeply striated, prismatic crystals and also as disseminated grains and columnar or massive aggregates.

The mineral is characteristic of regional metamorphism and hydrothermal alteration of igneous rocks. It results from metamorphism of calcium-rich rocks and typically occurs in medium-grade schists (pp.291–92), gneisses (p.288), and amphibolites (p.296). It is also found in veins of quartz (p.168) and pegmatites (p.260).

Ruby-in-zoisite Considered a good carving medium, ruby-in-zoisite has been used to make this 19th-century desk seal.

PROFILE

Orthorhombic

6½–7

3.3–4.3

Imperfect

Conchoidal

White

Vitreous

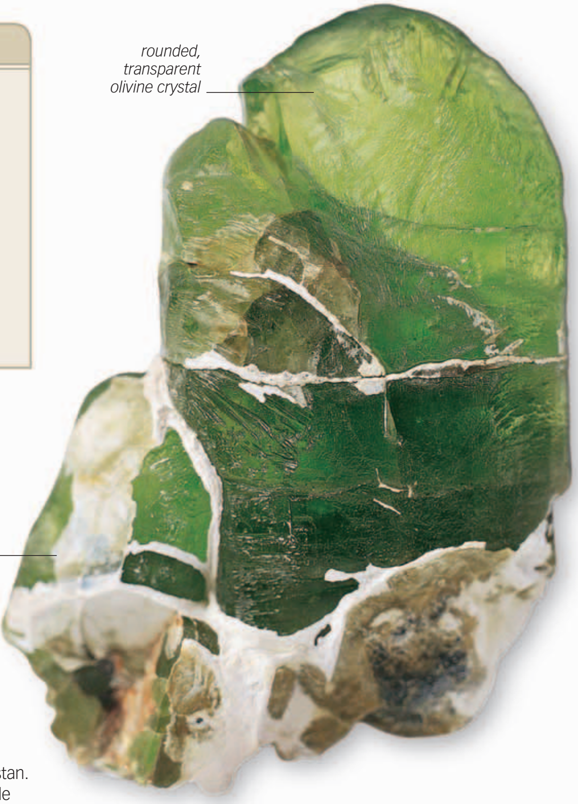

Peridot crystal This gem-quality specimen of olivine, or peridot, is from Pakistan. Other important sources include China and Myanmar.

VARIANTS

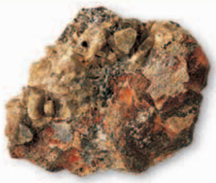

Forsterite Magnesium-rich olivine is called forsterite

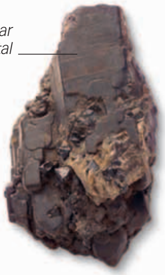

Fayalite Iron-rich olivine is called fayalite

$(Mg,Fe)_2SiO_4$

OLIVINE

The name olivine may be unfamiliar but most people know of its gemstone variety, peridot, which has been mined for over 3,500 years. The name olivine is applied to any mineral belonging to a solid-solution series in which iron and magnesium substitute freely in the structure. Fayalite is the iron end-member of the solid-solution series, and forsterite is the magnesium end-member.

Olivine specimens are usually yellowish green, but they can also be yellow, brown, gray, or colorless. Crystals are tabular, often with wedge-shaped terminations, although well-formed crystals of olivine are rare. Olivine may also occur in massive or granular habits. It is a major component of Earth’s upper mantle.

Peridot gemstone Green peridot, such as the one in this brooch, was used by Egyptians since the second millennium BCE.

PROFILE

Tetragonal

7½

4.6–4.7

Imperfect

Uneven to conchoidal

White

Adamantine to oily

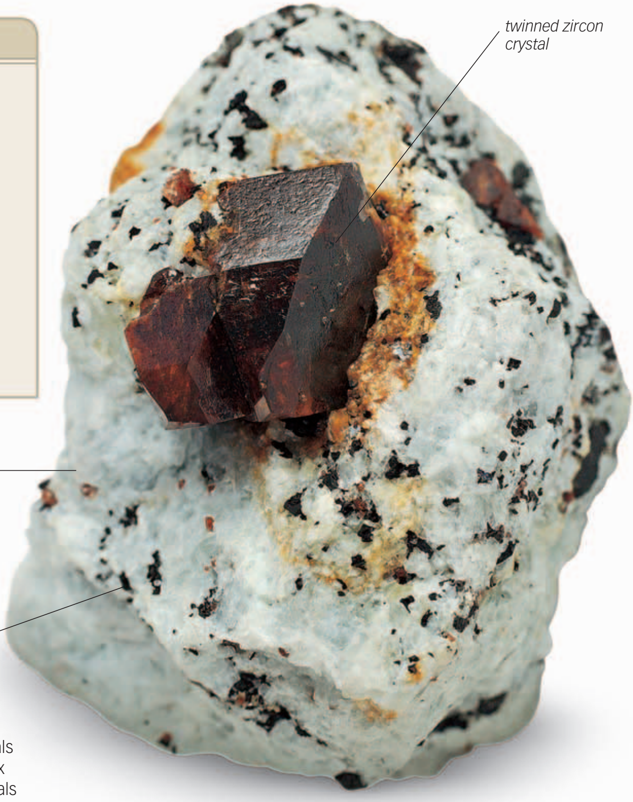

Afghan zircon
This specimen of zircon crystals in a feldspar-and-biotite matrix is from Afghanistan. The crystals are up to 1¼ in (3 cm) long.

VARIANTS

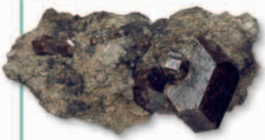

Purple zircon Crystals of zircon in a rock matrix

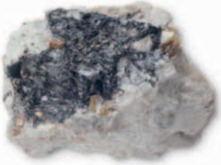

Crystalline cluster Zircon crystals that are embedded in pegmatite

$ZrSiO_4$

ZIRCON

A superb gem and one of the few stones to approach diamond (p.47) in fire and brilliance, zircon has a high refractive index and color dispersion. Known since antiquity, zircon takes its name from the Arabic word *zargun*, derived in turn from the Persian words *zar*, which means "gold," and *gun*, which means "color." Specimens can also be colorless, yellow, gray, green, brown, blue, and red. Brown zircon is frequently heat-treated to turn it blue. The mineral forms prismatic to dipyramidal crystals. Single crystals can reach a considerable size: specimens weighing up to 4½ lb (2 kg) and 8¾ lb (4 kg) have been found in Australia and Russia, respectively.

Zircon is found in metamorphic rocks and silica-rich igneous rocks. It resists weathering and, because of its relatively high specific gravity, concentrates in stream and river gravels and beach deposits.

Zircon bracelet
Gem zircons, such as the colorless, faceted zircons in this bracelet, have been mined for over 2,000 years.

PROFILE

Orthorhombic
8
3.4–3.6
Perfect basal
Subconchoidal to uneven
Colorless
Vitreous

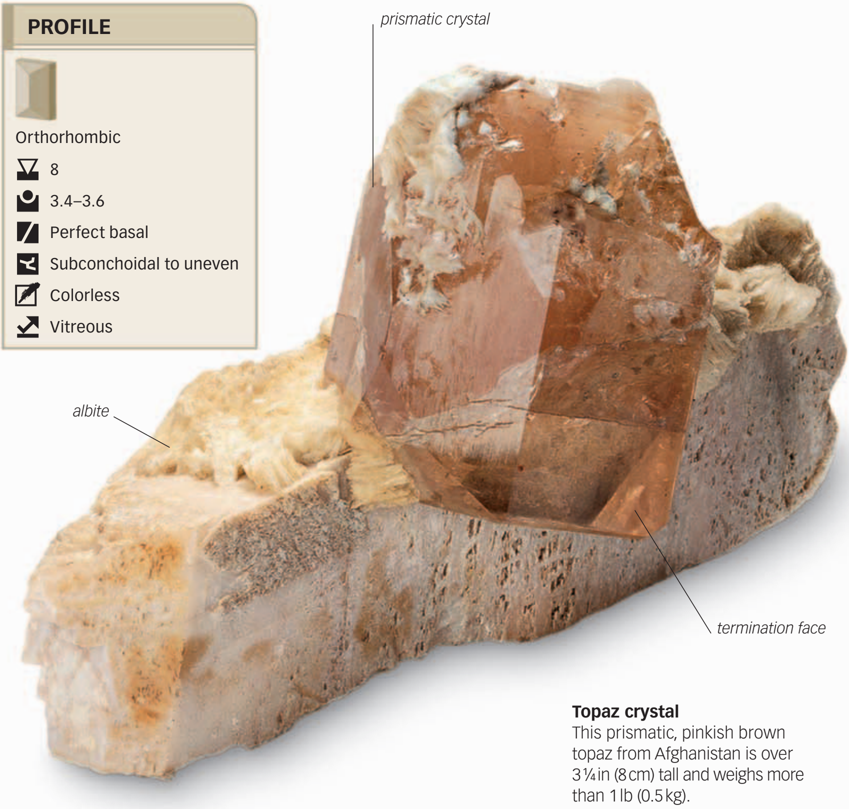

Topaz crystal
This prismatic, pinkish brown topaz from Afghanistan is over 3¼ in (8 cm) tall and weighs more than 1 lb (0.5 kg).

VARIANTS

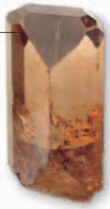

Brown topaz
A fine, natural crystal of brown topaz

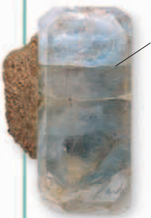

Light blue topaz
A specimen of blue topaz

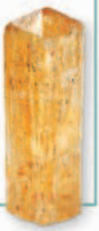

Imperial topaz
A golden imperial topaz from a deposit in Brazil

$Al_2SiO_4(F,OH)_2$

TOPAZ

The name topaz is thought to have been derived from the Sanskrit *tapaz*, which means "fire." Topaz occurs in a wide range of colors, with sherry-yellow and pink stones being particularly valuable. Colorless topaz has such a high refractive index that brilliant-cut specimens are mistaken for diamond (p.47). Well-formed prismatic crystals have a characteristic lozenge-shaped cross section and striations parallel to their length. The mineral is also found in massive, granular, and columnar habits.

Topaz is formed by fluorine-bearing vapors released in the late stages of crystallization of igneous rocks. It occurs in granites (pp.258–59), rhyolites (p.278), pegmatite dykes, and hydrothermal veins. Rounded pebbles are also found in river deposits. The world's largest faceted topaz weighs over 36,000 carats.

Pink topaz
A clear, octagonal step cut, pink topaz is set here in a gold ring. Natural pink topaz is rare.

Titanite crystals These interpenetrating, wedge-shaped titanite crystals, 1½ in (3.5 cm) long, are from Russia.

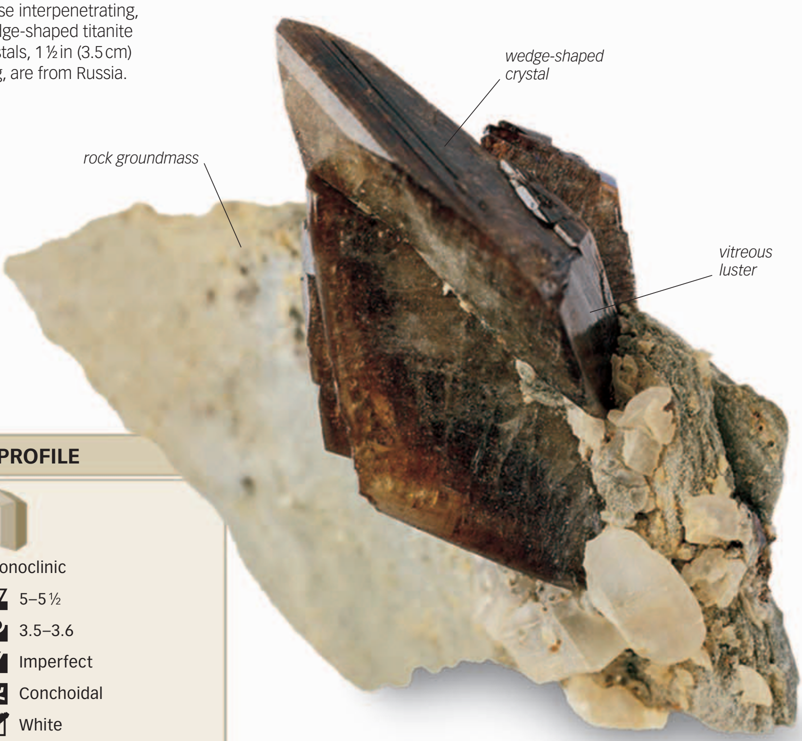

PROFILE

Monoclinic
5–5½
3.5–3.6
Imperfect
Conchoidal
White
Vitreous to greasy

VARIANT

Crystal group Wedge-shaped titanite crystals

CaTiSiO$_5$

TITANITE

Formerly called sphene, titanite is a calcium titanium silicate. The name sphene originates from the Greek word *sphen*, which means "wedge"—a reference to the typical wedge-shaped crystals of the mineral. Crystals can also be prismatic. Gem-quality crystals occur in yellow, green, or brown colors. Specimens can also be black, pink, red, blue, or colorless. Titanite is strongly pleochroic, exhibiting different colors when seen from different directions. The mineral can also be massive, lamellar, or compact. Faceted titanite is one of the few stones with a color dispersion higher than that of diamond (p.47).

Titanite is widely distributed as a minor component of silica-rich igneous rocks and associated pegmatites (p.260). It is also found in the metamorphic rocks gneiss (p.288), schist (pp.291–92), and marble (p.301).

Titanite ring Faceted titanites, such as the brilliant cut set in this gold ring, have superb fire and intense colors.

PROFILE

Orthorhombic

6½–7½

3.2

Good to perfect, poor

Conchoidal

White

Vitreous

Andalusite crystals This group of prismatic andalusite crystals from the Austrian Tyrol is in a matrix of quartz.

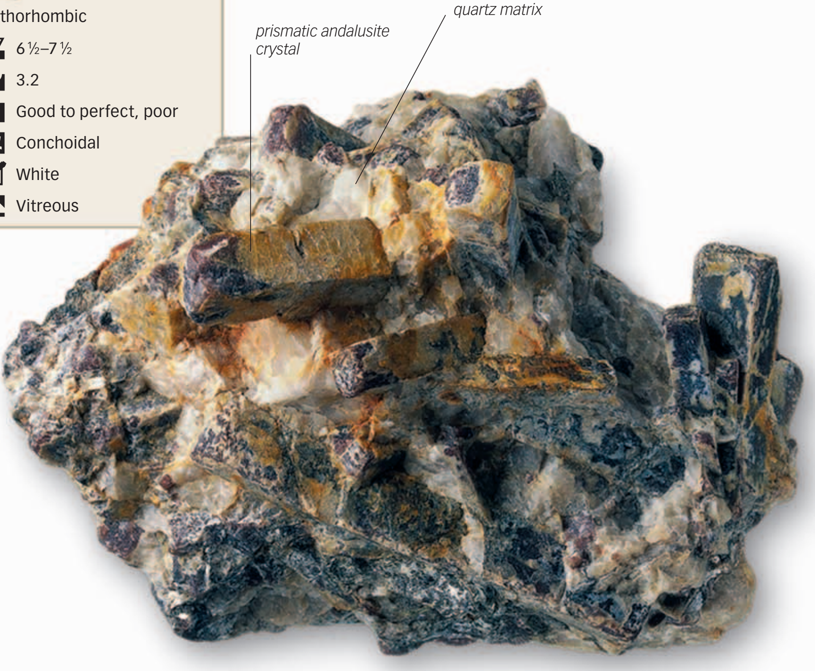

VARIANTS

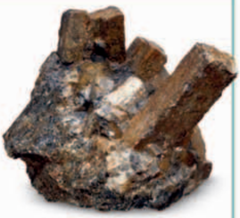

Brown andalusite Prismatic crystals on a rock matrix

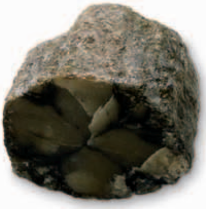

Chiastolite A yellowish brown andalusite crystal with cross-shaped inclusions of carbon

Al_2OSiO_5

ANDALUSITE

Named after the locality in Andalusia, Spain, where it was first described, andalusite is aluminum silicate. It is pink to reddish brown, white, gray, violet, yellow, green, or blue. Gem-quality andalusite exhibits yellow, green, and red colors when viewed from different directions. Andalusite crystals are commonly prismatic with a square cross section. They can also be elongated or tapered. Andalusite can also occur in massive form. A yellowish gray variety called chiastolite occurs as long prisms enclosing symmetrical wedges of carbon-rich material.

Andalusite is found in regional and low-grade metamorphic rocks, where it is associated with corundum (p.95), cordierite (p.223), sillimanite (p.237), and kyanite (p.238). It is rarely found in granites (pp.258–59) and granitic pegmatites (p.260) .

Rectangular step cut Relatively uncommon, transparent andalusite is too brittle to be worn. It is faceted for gem collectors.

PROFILE

Orthorhombic

7

3.2–3.3

Perfect

Uneven

White

Silky

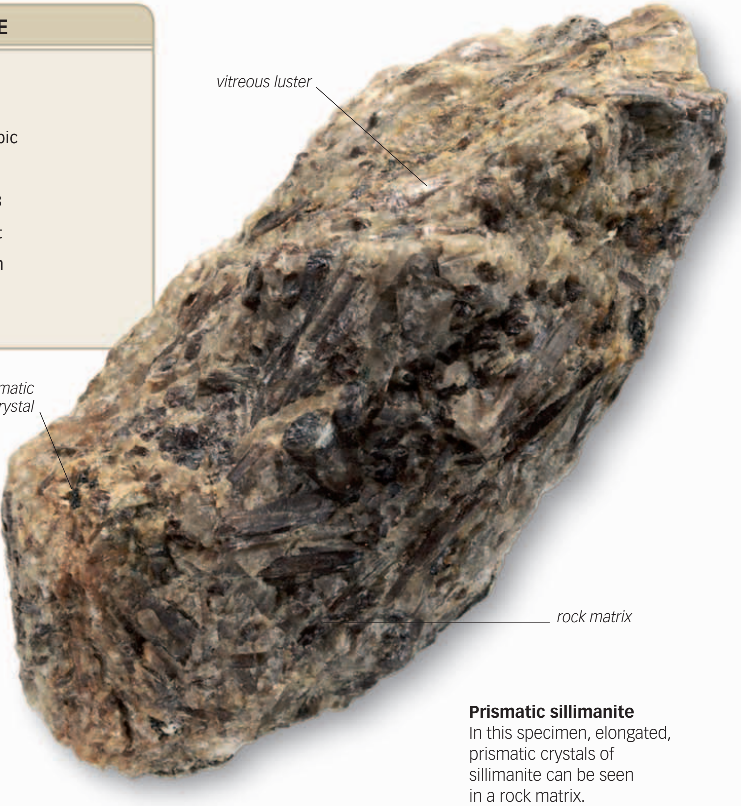

Prismatic sillimanite In this specimen, elongated, prismatic crystals of sillimanite can be seen in a rock matrix.

Al_2OSiO_5

SILLIMANITE

Named after the American chemist Benjamin Silliman, sillimanite is one of three polymorphs of aluminum silicate. Commonly colorless to white, sillimanite can also be pale yellow to brown, pale blue, green, or violet. A single specimen may appear yellowish green, dark green, or blue when seen from different angles. The mineral occurs in long, slender, glassy crystals or in blocky, poorly terminated prisms.

Sillimanite is characteristic of clay-rich metamorphic rocks formed at high temperatures (1,065°F/575°C or above). The mineral is often found with corundum (p.95), cordierite (p.223), and kyanite (p.238). Specimens also occur in gneisses (p.288), sillimanite schists, hornfels (p.303), and detrital sediments.

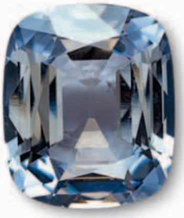

Collectors' gem Facet-grade sillimanite, such as this specimen, occurs in the gem gravels of Sri Lanka and Myanmar, and in Brazil.

VARIANTS

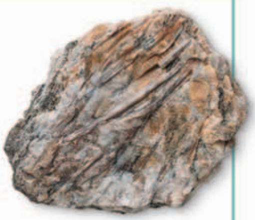

Crystals in rock Sillimanite in a rock matrix

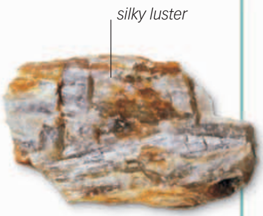

Fibrous sillimanite A mass of parallel, fibrous crystals

Blady kyanite
This specimen of kyanite with quartz from northern Brazil shows the characteristic elongated, bladed habit of kyanite crystals.

PROFILE

Triclinic
4½; 6
3.6
Perfect
Splintery
Colorless
Vitreous

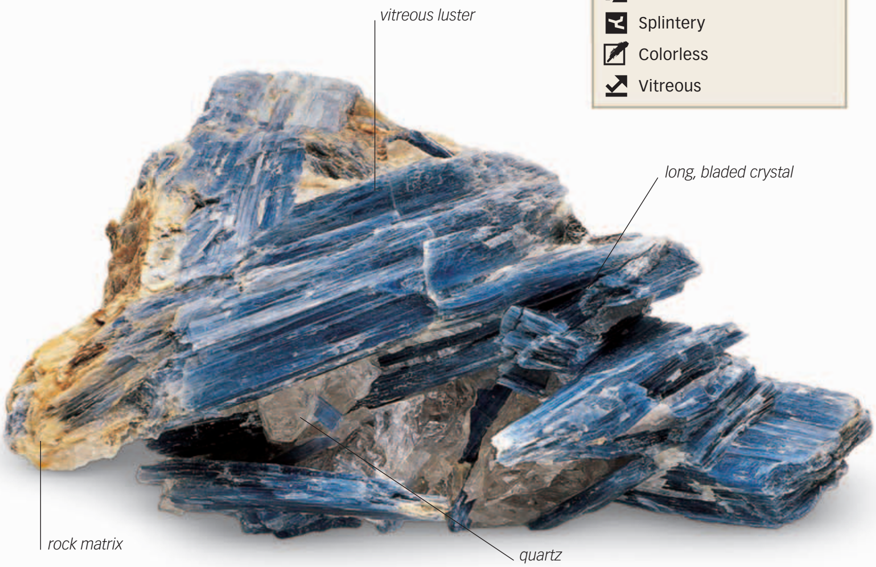

VARIANT

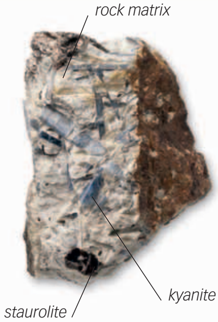

Kyanite in rock Kyanite crystals with staurolite in a rock matrix

Al_2SiO_5

KYANITE

Named after the Greek word *kyanos*, which means "dark blue," kyanite is blue and blue-gray, the colors generally zoned within a single crystal. Kyanite can also be green, orange, or colorless. Specimens have variable hardness: about 4½ when scratched parallel to the long axis but 6 when scratched perpendicular to the long axis. Kyanite occurs mainly as elongated, flattened blades that are often bent and sometimes as radiating, columnar aggregates.

Kyanite is formed during the regional metamorphism of clay-rich sediments. It occurs in mica schists, gneisses (p.288), and associated hydrothermal quartz veins and pegmatites (p.260). It is used to estimate the temperature, depth, and pressure at which a rock has metamorphosed.

Spark plugs
Kyanite is mined for the aluminum silicate mullite, which is used in spark plugs.

PROFILE

Monoclinic
7–7½
3.7
Distinct
Conchoidal
Colorless to gray
Vitreous to resinous

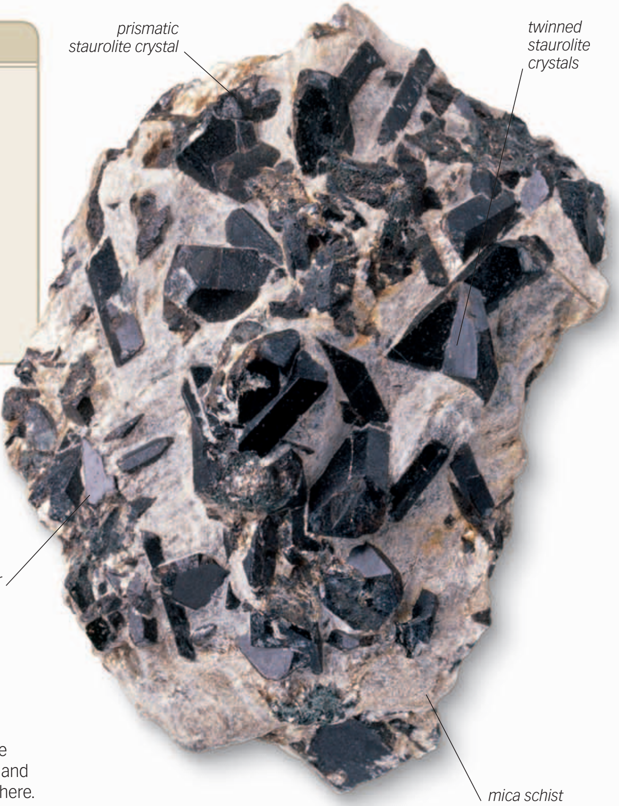

Staurolite crystals This is a specimen of staurolite in a mica schist matrix. Single and twinned crystals can be seen here.

VARIANTS

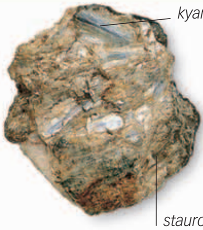

Staurolite in schist Kyanite and staurolite in schist

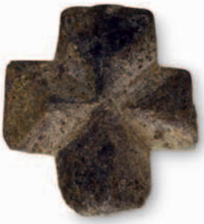

Fairy cross A twinned staurolite, or "fairy cross," crystal

$(Fe,Mg)_4Al_{17}(Si,Al)_8O_{45}(OH)_3$

STAUROLITE

A widespread mineral, staurolite takes its name from two Greek words: *stauros*, which means "cross," and *lithos*, which means "stone"—a reference to its typical crosslike twinned form. Cross-shaped penetration twins of the mineral are common and are in great demand as charms. Staurolite specimens are yellowish brown, reddish brown, or nearly black in color. The mineral normally occurs as prismatic crystals, which are either hexagonal or diamond-shaped in section and often have rough surfaces.

Staurolite occurs in mica schists, gneisses (p.288), and other metamorphosed, aluminum-rich rocks. It forms only under a specific range of pressure and temperature, which helps determine the various conditions under which the metamorphic rock formed.

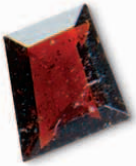

Trapeze-cut staurolite Transparent staurolite, as in this stone, is a rare faceting material because of its dark color and lack of brilliance.

PROFILE

Monoclinic

7½

3.0

Perfect

Conchoidal, brittle

White

Vitreous

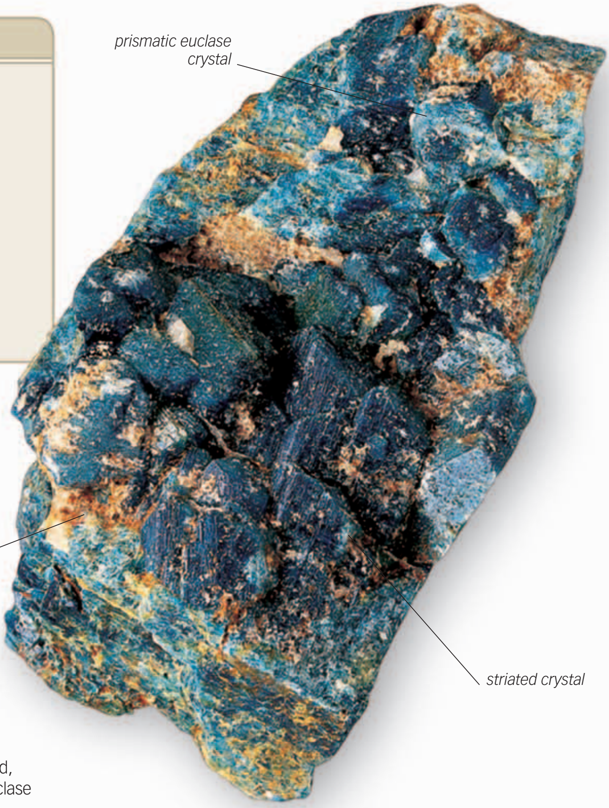

Blue euclase
This mass of well-developed, prismatic crystals of blue euclase is on a rocky matrix.

VARIANT

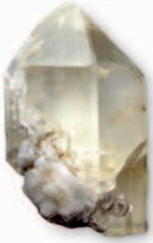

Transparent euclase
A near-transparent, striated euclase crystal

$BeAlSiO_4(OH)$

EUCLASE

Euclase takes its name from two Greek words: *eu*, which means "good," and *klasis*, which means "fracture"—a reference to its perfect cleavage. Generally white or colorless, euclase can also be pale green or pale to deep blue—a color for which it is particularly noted. It forms striated prisms, often with complex terminations. Massive and fibrous specimens are also found.

Euclase occurs in hydrothermal veins formed at low temperatures (up to 400°F/200°C), granitic pegmatites (p.260), and some metamorphic schists (pp.291–92) and phyllites (p.294). It is also found in stream gravels. Exquisite, colorless, and deep blue color-zoned crystals come from Karoi in Zimbabwe. Cut euclase resembles certain types of beryl (p.225) and topaz (p.234).

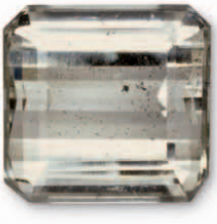

Euclase gemstone
This square-cut euclase gemstone shows small, dark inclusions of another mineral.

PROFILE

Orthorhombic

6–6½

3.2–3.3

Poor

Subconchoidal to uneven

Yellow to orange

Vitreous

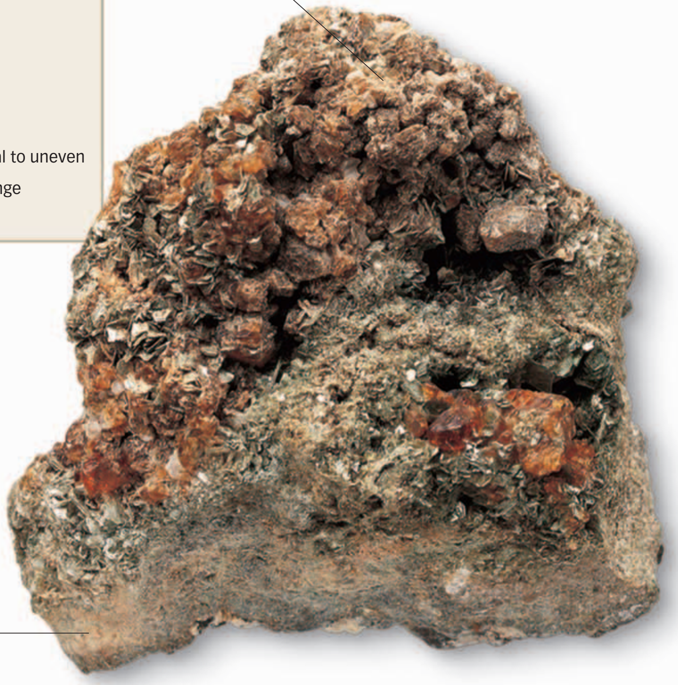

Humite crust
In this specimen, a crust of yellowish brown humite crystals covers a rock matrix that also contains accessory mica.

VARIANTS

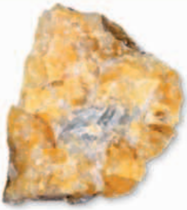

Yellow humite A specimen of massive, yellow humite

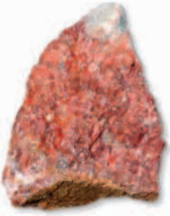

Orange humite Massive, orange humite with a brown weathering crust

$(Mg,Fe)_7(SiO_4)_3(F,OH)_2$

HUMITE

Named in 1813 after the English mineral and art collector Sir Abraham Hume (1749–1838), humite is a silicate of iron and magnesium. Manganese substitutes for iron in the structure to form a complete solid-solution series with manganhumite. Specimens are yellow to dark orange or reddish orange in color, tending toward brown with increasing manganese content. Humite is generally found in granular masses. Well-formed crystals are rare and grow in parallel with one another. Crystals rarely exceed ⅜ in (1 cm) in length and are occasionally twinned.

Humite is found with pyrite (p.62), cassiterite (p.79), hematite (p.91), quartz (p.168), tourmaline (p.224), and mica in contact and regionally metamorphosed limestones (p.319) and dolomites (p.320). Although this mineral occurs worldwide, noteworthy locations include Persberg and elsewhere in Sweden; Isle of Skye, Scotland; Mount Vesuvius, Italy; Valais, Switzerland; and Brewster, New York, USA.

PROFILE

Cubic
7–7½
3.6
None
Conchoidal, brittle
White
Vitreous

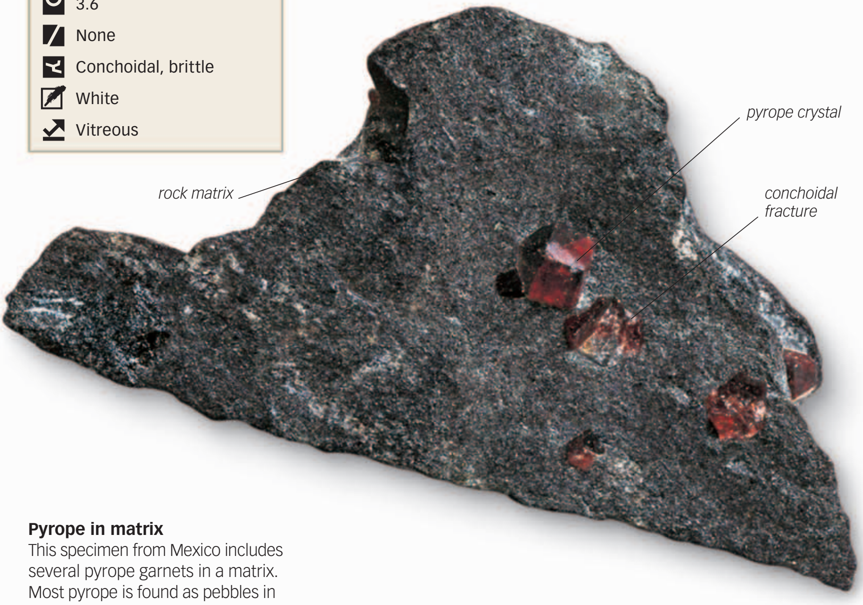

Pyrope in matrix
This specimen from Mexico includes several pyrope garnets in a matrix. Most pyrope is found as pebbles in placer deposits with other gems.

VARIANT

Gemstone rough Water-rounded pyrope recovered from a placer deposit

$Mg_3Al_2(SiO_4)_3$

PYROPE

The magnesium aluminum garnet pyrope was named in 1803 after the Greek words *pyr* and *ōps*, which mean “fire” and “eye” respectively—a reference to the typical fiery color of specimens. Manganese, chromium, iron, and titanium substitute in the mineral’s structure and act as coloring agents to some degree. Specimens can be rich red, dark red, violet-red, rose red, or reddish orange depending on the composition. Crystals are dodecahedral and trapezohedral, with hexoctahedra sometimes present. The mineral is most often found as rounded grains or pebbles.

Pyrope occurs as a high-pressure mineral in metamorphic rocks. It is also found in high-pressure, silica-poor igneous rocks and in detrital deposits derived from them.

Pyrope gemstones
Beautiful garnet jewelry comes from Bohemia, Czech Republic, where pyropes as big as hens’ eggs are found.

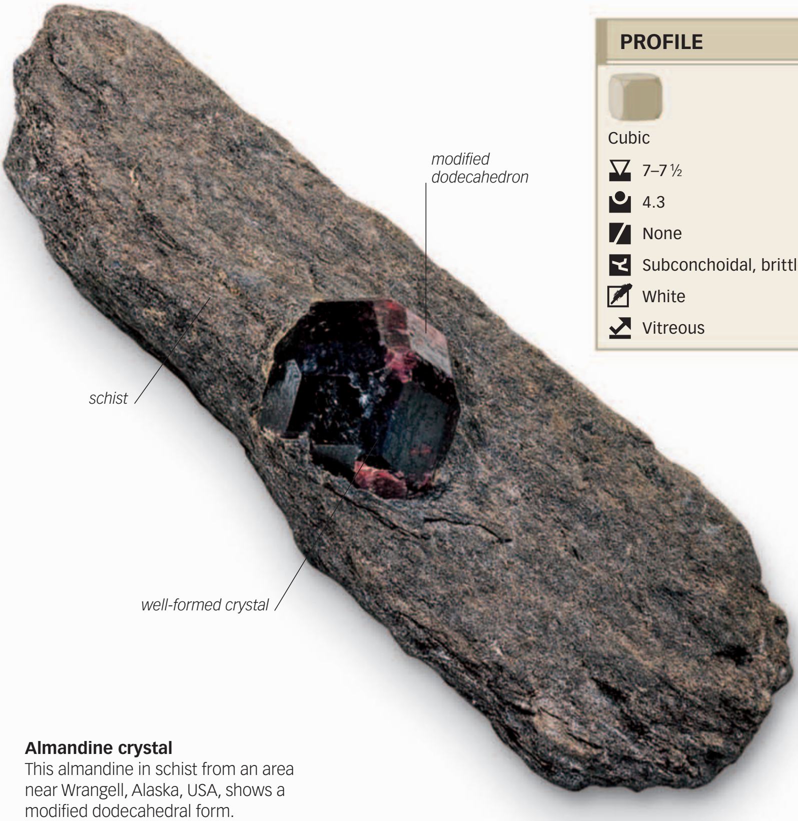

Almandine crystal
This almandine in schist from an area near Wrangell, Alaska, USA, shows a modified dodecahedral form.

PROFILE

Cubic
- 7–7½
- 4.3
- None
- Subconchoidal, brittle
- White
- Vitreous

VARIANTS

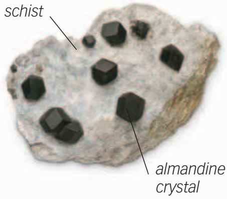

Crystals in schist Numerous almandine dodecahedrons rest on schist

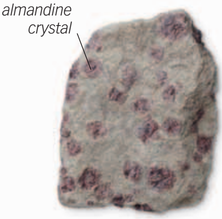

Almandine in granulite
Crystals of almandine in a granulite matrix

$Fe_3Al_2(SiO_4)_3$

ALMANDINE

The most common garnet, almandine is named after Alabanda (now Araphisar) in Turkey, where it has been cut since antiquity. Almandine is always red, often with a pink or violet tinge. Specimens can sometimes be nearly black. This mineral tends to be a pinker red than other garnets. Crystals often have well-developed faces and are dodecahedral or trapezohedral or have other more complex forms. Massive aggregates and rounded grains are also found. Rutile (p.78) needles can show as a four-rayed star when almandine is cut *en cabochon*.

Almandine occurs worldwide. It is found in gneisses (p.288) and mica schists, igneous rocks (pp.256–57), and occasionally as inclusions in diamond (p.47). When it occurs in metamorphic rocks, its presence indicates the grade of metamorphism.

Faceted almandine
Three faceted almandine gems and a seed pearl create a central flower motif in this antique gold brooch.

Spessartine crystals
In this specimen from Norway, well-formed dodecahedral crystals encrust a rock matrix.

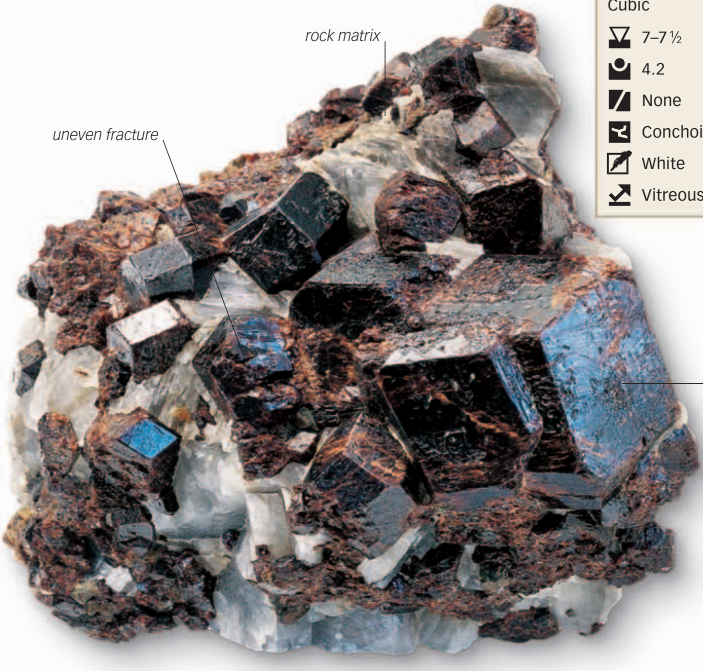

PROFILE

Cubic
7–7½
4.2
None
Conchoidal, brittle
White
Vitreous

VARIANT

Translucent spessartine
An attractive crystal of translucent spessartine

$Mn_3Al_2(SiO_4)_3$

SPESSARTINE

The manganese aluminum silicate spessartine is named after Spessart—the locality in Germany where it was first described. The mineral is pale yellow when nearly pure and orange to deep red, brown, or black in other specimens. A color change known as the alexandrite effect is occasionally found in spessartine grossular garnet. Crystals are dodecahedral or trapezohedral. Spessartine may also occur as either granular or massive aggregates.

Spessartine almost always contains some amount of iron (p.39). Pure spessartine is relatively rare and is found in manganese-rich metamorphic rocks, granites (pp.258–59), and pegmatite veins (p.260). The heaviest spessartine ever discovered weighs 6,720 carats.

Octagonal step cut
Because of spessartine's rich color, the liquid inclusions under the edge facets in this gem are not very noticeable.

PROFILE

Cubic

6½–7

3.6

None

Conchoidal

White

Vitreous

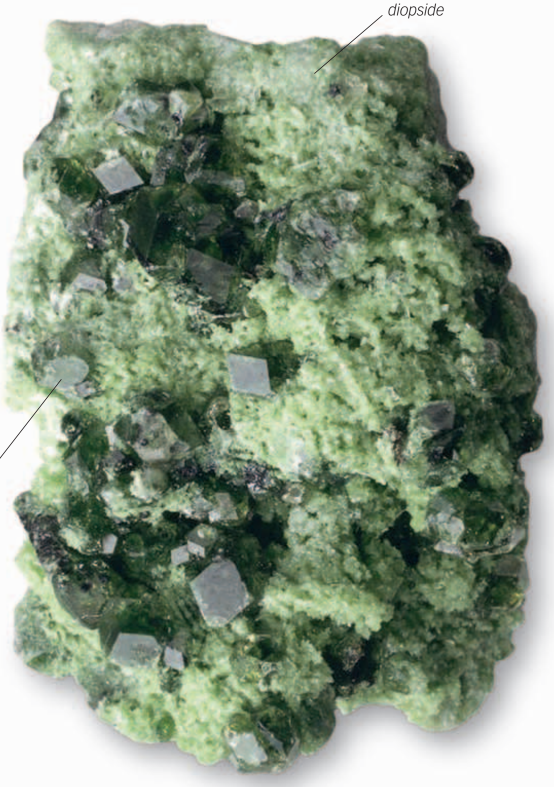

Grossular on diopside These grossular crystals from Piedmont, Italy, are set on a matrix of diopside.

VARIANTS

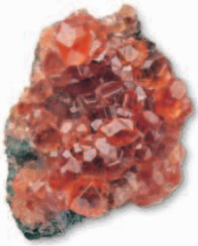

Hessonite Reddish brown dodecahedral grossular crystals

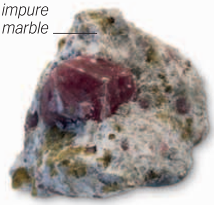

Pink grossular Rounded, pink grossular crystals in marble

$Ca_3Al_2(SiO_4)_3$

GROSSULAR

The calcium aluminum silicate grossular, a type of garnet, is named after the Latin word *grossularia*, which translates into "gooseberry"—a reference to the mineral's gooseberry-green color. Specimens can also be pale to emerald green, white, colorless, cream, orange, red, honey, brown, or black. Reddish brown or pink grossular is called hessonite or cinnamon stone. Grossular is usually translucent to opaque but can be transparent. It occurs as rounded dodecahedral or trapezohedral crystals that are up to 5 in (13 cm) wide. Specimens can also be granular or massive.

Grossular forms in impure calcareous rocks that have undergone regional or contact metamorphism, in some schists (pp.291–92) and serpentinites (p.298), and occasionally in meteorites (pp.335–37).

Grossular beads This strung group is made up of size-graded, round, luminescent green grossular beads.

ORGANICS

Generated by organic (biological) processes, the organics may or may not be crystalline. In some cases, they contain the same mineral matter—such as calcite or aragonite—as that generated through inorganic processes. Organics are sometimes used as gems.

COMPOSITION

The organics have a highly varied composition. Coral, pearl, and shell contain mineral matter generated by biological processes. Amber is fossilized resin, mainly from extinct coniferous trees, although amberlike substances from even older trees are also known. Copal is a modern equivalent of fossilized amber. Coal is derived from buried organic material, such as peat. Bitumen is a very heavy oil.

Shell
The shells of marine invertebrates capture large amounts of carbon in the form of aragonite. Their remains form extensive beds of carbonate rocks.

OCCURRENCE

The organics are relatively widespread. The shells of freshwater and marine organisms are part of a carbonate cycle that extracts carbon from the environment and returns it as carbonate sediment, either to be reincorporated into other organics or to be lithified. Other organics incorporate carbon in their essential composition.

USES

Coal and bitumen are the organics that find the widest use. Organically formed carbonate rocks are also extensively used as building stone and ballast and in the manufacture of cement. Other organics are used to make ornaments and jewelry.

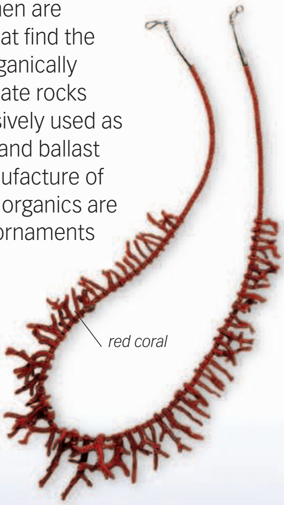

Coral necklace
This branchlike Native American necklace is made from small, polished branches and tiny beads of red coral.

Coral reef
A coral reef forms in shallow ocean areas. Corals are the most important part of the reef and form its main structural framework. Coral skeletons are made of aragonite.

PROFILE

Trigonal Orthorhombic

Amorphous

3½

2.6–2.7

None

Hackly

White

Dull to vitreous

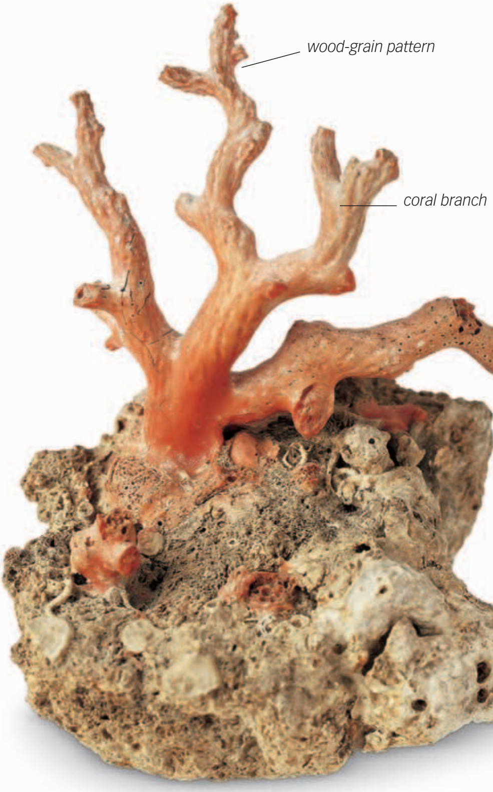

Red coral
The use of red coral dates back to the Iron Age. This specimen from the Mediterranean has a wood-grain pattern on its branches.

VARIANTS

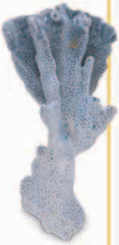

Blue coral
A type of coral used in artifacts and jewelry

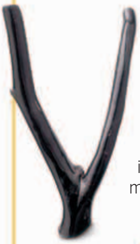

Black coral
A variant that is polished to make jewelry

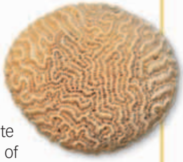

Brain coral
An elaborate confection of organic aragonite

Mostly $CaCO_3$

CORAL

According to Greek legend, coral came from the drops of blood shed when the mythic hero Perseus cut off the head of the monster Medusa. Coral is actually the skeletal material generated by marine animals also known as coral polyps. In most corals, this material is calcium carbonate, but in black and golden corals it is a hornlike substance called conchiolin. Coral has a dull luster when recovered, but it can be polished and brightened. It is sensitive even to mild acids and can become dull with extensive wear.

Coral is variable in color. Red and pink precious coral is found in the warm seas around Japan and Malaysia, in African coastal waters, and in the Mediterranean Sea. Black coral comes from the West Indies, Australia, and from around the Pacific Islands.

Coral necklace
This triple-stranded necklace from Morocco is made of coral, silver, and turquoise.

PROFILE

Orthorhombic

3

2.7

None

Uneven, brittle

White

Pearly

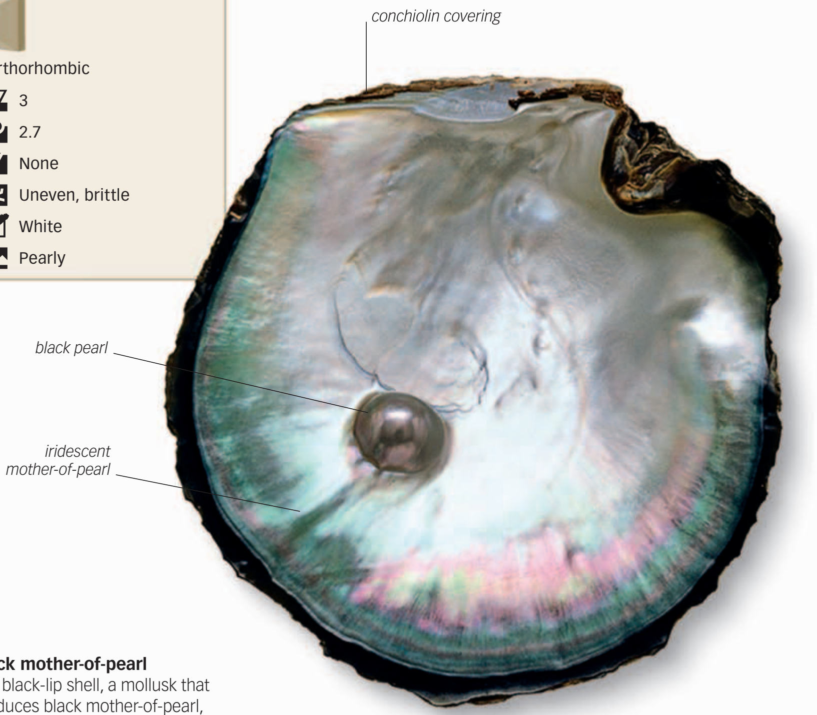

Black mother-of-pearl The black-lip shell, a mollusk that produces black mother-of-pearl, also produces black cultured pearls.

VARIANTS

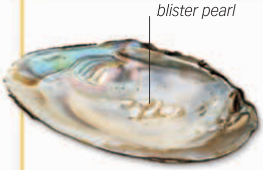

Blister pearls Attached to the shell, these are flat on one side

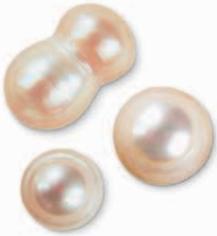

Freshwater pearls These have the same luster as marine pearls

Mostly $CaCO_3$

PEARL

A concretion formed by a mollusk, a pearl consists mainly of aragonite (p.115), the same material as the animal's shell (p.249). The shell-secreting cells are located in a layer of the mollusk's body tissue called the mantle. When a foreign particle enters the mantle, the cells build up concentric layers of pearl around it. Colors vary with the mollusk and its environment and can be any delicate shade from black to white, cream, gray, blue, yellow, green, lavender, or mauve.

The finest pearls are produced by limited species of saltwater oysters and freshwater clams. A pearl is valued by its translucence, luster, color, and shape. The most valuable pearls are spherical or droplike, with a deep luster and good play of color. Rose-tinted Indian pearls are highly prized.

Pearl bracelet This Cartier Art Deco bracelet has five strands of cultured pearls with a gold and oxidized-silver clasp.

PROFILE

Hexagonal Orthorhombic
Amorphous

- 2½
- About 1.3
- None
- Conchoidal
- White
- Dull to vitreous

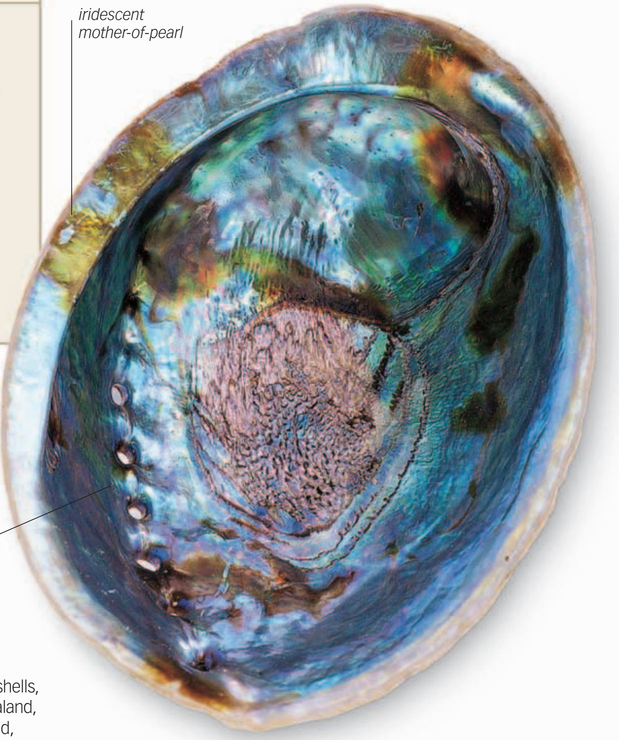

Abalone shell Found in warm seas, abalone shells, such as this one from New Zealand, are noted for their multicolored, iridescent, mother-of-pearl lining.

VARIANTS

Spider conch A type of shell widely used for ornamental purposes

Tortoise shell The shell of a hawksbill turtle

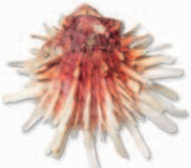

Thorny oyster A shell made up of organic aragonite

$CaCO_3$

SHELL

Like coral (p.247), shell is mineral matter generated by biological processes. The mineral component of shell is either calcite (p.114) or aragonite (p.115), both of which are calcium carbonate. Shell forms as the hard outer covering of many mollusks. It is secreted in calcareous layers by cells in the mantle—a skinlike tissue in the mollusk's body wall. Mollusk shells differ in the composition, number, and arrangement of calcareous layers. These layers form as distinct microstructures with different mechanical properties and, in some shells, different colors.

Both marine and freshwater shells are used for ornamentation. Shells with different colored layers have been carved into cameos since antiquity. Pearly shells were used widely in button making around the 19th century.

Shell perfume bottle This 19th-century perfume bottle is made of two shells glued together. It has a chain, ring, and pinchbeck stopper.

PROFILE

Crystal system None

2–2½

About 1.1

None

Conchoidal

White

Resinous

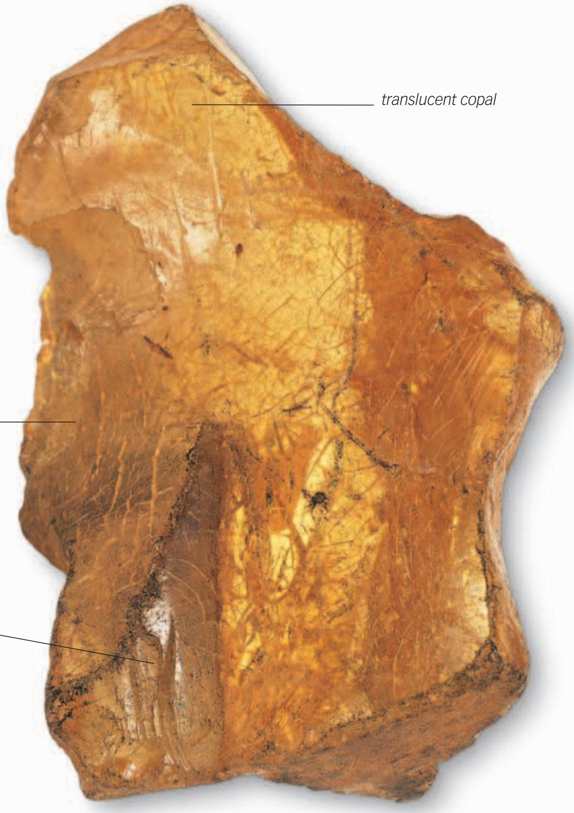

Copal nugget This specimen of copal closely resembles amber. Some copal is used as an amber substitute in jewelry.

VARIANTS

orange-yellow gum

Kauri gum Resin derived from the Kauri conifer

Copal lumps Lumps of resin from the Protium copal or copal tree

Various

COPAL

Named after the Nahuatl word *copalli*, which means "resin," copal is a yellow to red-orange resin obtained from various tropical trees. It can be collected from living trees and from accumulations in the soil beneath the trees. It can also be mined if it is buried. Copals from different sources usually have different chemical properties but can have similar physical properties. Copal has approximately the same hardness as amber (p.251) but unlike amber it is wholly or partially soluble in organic solvents. Buried copal is the nearest to amber in durability and is, in many cases, virtually indistinguishable from it.

Zanzibar in Tanzania is a major source of buried copal. This mineral is also found in China, Brazil, and other South American countries. It is used in varnishes, lacquers, and inks.

Copal beads In this necklace, beads of a tough and compact form of copal alternate with beads carved from seeds.

PROFILE

Crystal system None
2–2½
1.1
None
Conchoidal
White
Resinous

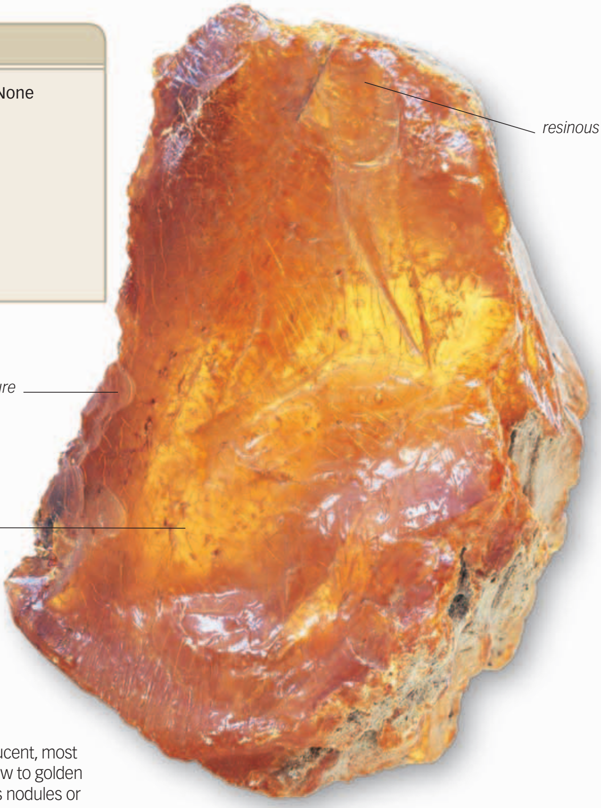

Amber nodule
Transparent to translucent, most amber is golden yellow to golden orange and occurs as nodules or small, irregularly shaped masses.

VARIANTS

Wave-rounded amber
A piece of wave-rounded Baltic amber

Lithuanian amber A group of amber pieces showing color variation

Hydrocarbon (C,H,O)

AMBER

The fossilized resin amber comes mainly from extinct coniferous trees, although amberlike substances from earlier trees are also known. It is generally found in association with lignite coal (p.253). Amber and other partially fossilized resins are sometimes given mineral-like names depending on where they are found, their degree of fossilization, or the presence of other chemical components. For example, resin that resembles copal (p.250) and comes from the London clay region is called copalite. At least 12 other names are applied to minor variants.

For thousands of years, the largest source of amber has been deposits along the Baltic coast, extending intermittently from Gdánsk right around to the coastlines of Denmark and Sweden. Amber has been traded since ancient times.

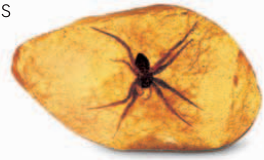

Preserved in amber
As resin dried 40–50 million years ago, insects were sometimes fossilized within the sticky substance.

PROFILE

Crystal system None
2½
About 1.3
None
Conchoidal
Black to dark brown
Velvety, vitreous, or waxy

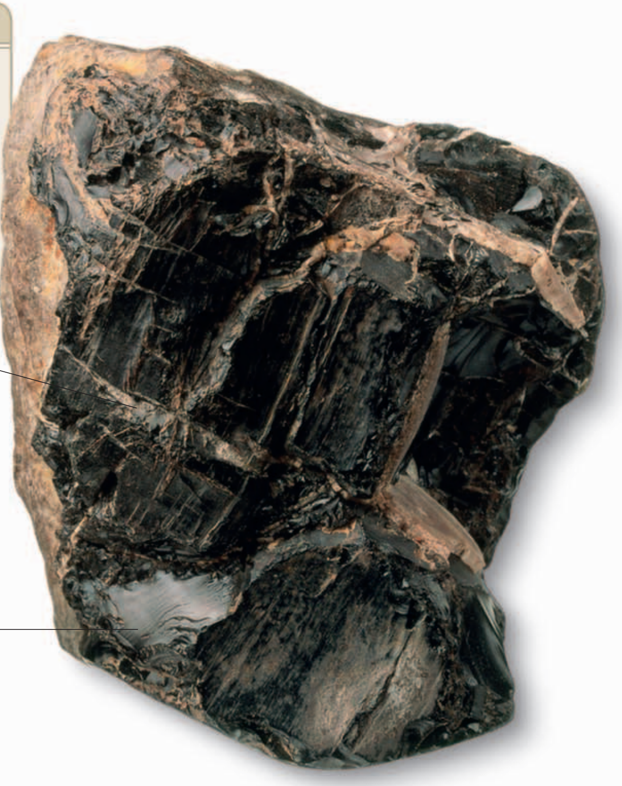

Woody structure This specimen of jet shows the layered, woody structure that is sometimes characteristic of the mineral.

VARIANT

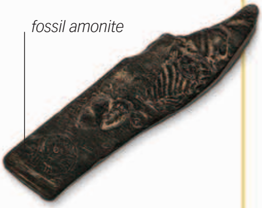

Jet fossil Jet with fossils of marine origin

Various

JET

Generally classified as a type of coal (p.253), jet has a high carbon content and a layered structure. It is black to dark brown in color. Specimens sometimes contain tiny inclusions of pyrite (p.62), which have a metallic luster. Jet is found in rocks of marine origin, perhaps derived from waterlogged driftwood or other plant material. It can occur in distinct beds, such as those at Whitby, England, from which jet has been extracted since the 1st century CE.

Jet has been carved for ornamental purposes since prehistoric times and has been found in prehistoric caves. The Romans carved jet into bangles and beads. In medieval times, powdered jet drunk with water or wine was believed to have medicinal properties.

Jet necklace This Native American necklace is made of high-quality, fine-grained jet, which shows velvety luster.

PROFILE

Crystal system None

2–2½

About 1.1

None

Conchoidal

Black

Nearly metallic

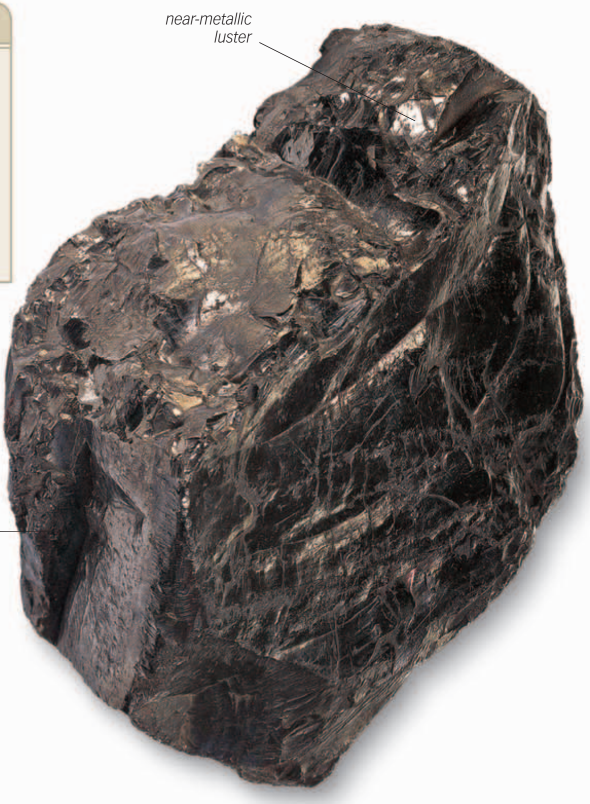

Anthracite
Hard to the touch, anthracite is naturally shiny. It takes a brilliant polish and is used for decorative as well as practical purposes.

VARIANTS

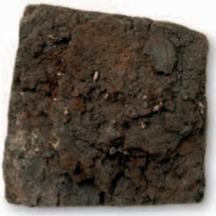

Lignite A variant having a composition between peat and bituminous coal

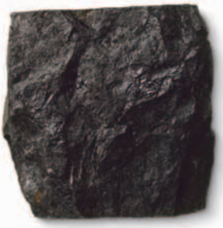

Bituminous coal The most common form of coal

Various

COAL

The fossilized remains of plants, coal usually occurs in layered, sedimentary deposits. It is brown or black and made up of an irregular mixture of chemical compounds called macerals, which are analogous to minerals in inorganic rocks. Unlike minerals, macerals have no fixed chemical composition and no definite crystalline structure.

Different varieties of coal are formed depending on the kinds of plant material, varying degrees of coalification (the process by which plant material is converted to coal), and the presence of impurities. Four varieties are recognized. Lignite is the lowest grade and is the softest and least coalified variety. It forms from peat under moderate pressure. Sub-bituminous coal is dark brown to black. Bituminous coal is the most abundant and is commonly burned for heat generation. Anthracite is the highest grade and the most highly metamorphosed form of coal. It contains the highest percentage of low-emission carbon and would be an ideal fuel if it were not relatively scarce.

ROCKS

IGNEOUS ROCKS

Igneous rocks are formed from magma—molten rock. They are classified as extrusive or intrusive depending on whether or not the magma emerged at Earth's surface before crystallizing. Extrusive rocks form on the surface; intrusive rocks form below it.

INTRUSIVE IGNEOUS ROCKS

Intrusive rocks are categorized as plutonic if formed deep inside the crust and hypabyssal if formed at shallow depths. Plutonic intrusive rocks are characterized by their large crystals and generally form geographically large bodies. For example, a batholith is a large igneous body with a surface exposure of at least 40 square miles (100 square km) and a thickness of about 6–9 miles (10–15 km). Batholiths form the cores of great mountain ranges, such as the Rockies and the Sierra Nevada in North America. Granite, diorite, peridotite, syenite, and gabbro are all plutonic igneous rocks.

Hypabyssal intrusive rocks are formed at shallower depths and are characterized by fine crystallization. They occur in sheetlike bodies called dikes and sills, volcanic plugs, and other relatively small formations. Dikes range from less than an inch to many feet in thickness and can be hundreds of miles in length. Sills are similar to dikes, except that they form parallel to the enclosing rocks and intrude between two strata.

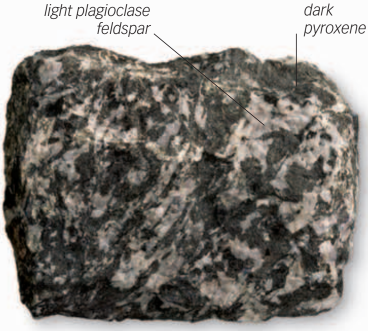
light plagioclase feldspar
dark pyroxene

Gabbro
Most gabbros form as plutonic intrusive rocks. This coarsely crystallized specimen contains light-colored crystals of plagioclase and dark crystals of pyroxene.

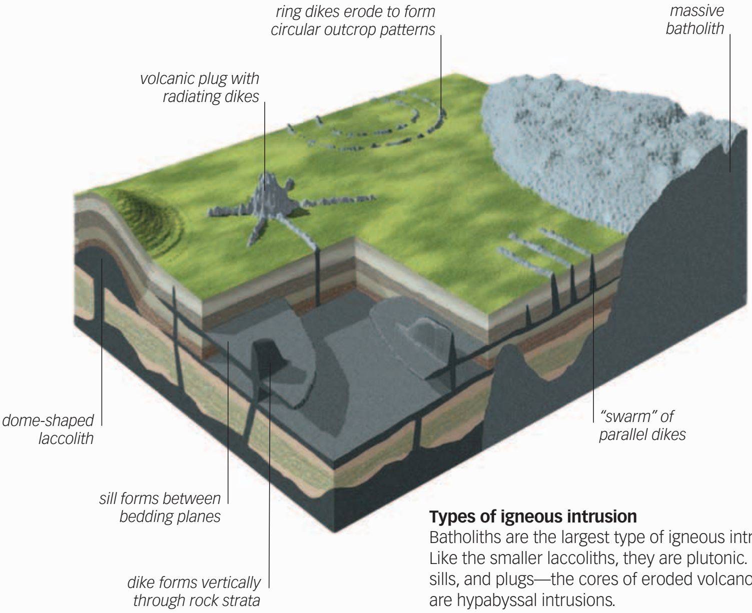
ring dikes erode to form circular outcrop patterns
massive batholith
volcanic plug with radiating dikes
dome-shaped laccolith
"swarm" of parallel dikes
sill forms between bedding planes
dike forms vertically through rock strata

Types of igneous intrusion
Batholiths are the largest type of igneous intrusion. Like the smaller laccoliths, they are plutonic. Dikes, sills, and plugs—the cores of eroded volcanoes—are hypabyssal intrusions.

EXTRUSIVE IGNEOUS ROCKS

Extrusive igneous rocks are also known as volcanic rocks. The principal rock types in this category include basalt, obsidian, rhyolite, trachyte, and andesite. All of these usually form from lava—a magma that has flowed either onto land or underwater. Other extrusive rocks, such as tuff and pumice, form in explosive volcanic eruptions. These "pyroclastic" rocks are porous because of the frothing expansion of volcanic gases during their formation. Basalt is the most common extrusive rock, forming the floor of most oceans and extensive plateaus on land, such as the Deccan Plateau of India and the Columbia River Basalts of Oregon, USA.

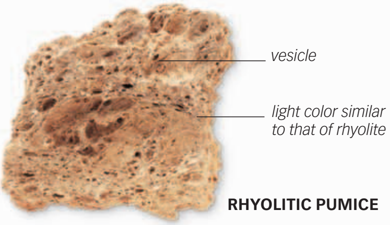

RHYOLITIC PUMICE

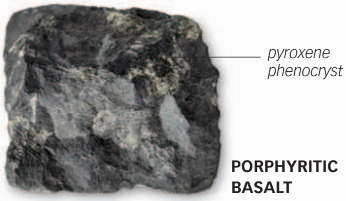

PORPHYRITIC BASALT

Grain size
The origin of igneous rocks is generally indicated by the grain size of their minerals. Small or microscopic grains are found in extrusives; large grains in intrusives.

COMPOSITION OF IGNEOUS ROCKS

Igneous rocks form from magma, which is essentially a silicate melt. Igneous rocks are classified on the basis of silica content. Felsic rocks have over 65 percent silica, intermediate rocks 55–65 percent, mafic rocks 45–55 percent, and ultramafic rocks less than 45 percent silica. The silicate minerals that develop from the melt depend on factors such as silica concentration in the melt, the presence and concentration of other elements such as aluminum, iron, magnesium, calcium, sodium, and potassium within the melt, and the temperature and pressure at which crystallization takes place.

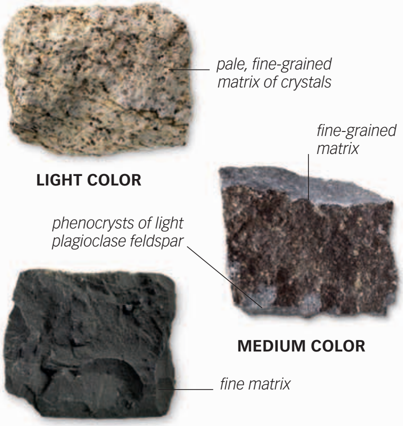
pale, fine-grained matrix of crystals
fine-grained matrix
phenocrysts of light plagioclase feldspar
fine matrix

LIGHT COLOR

MEDIUM COLOR

DARK COLOR

Color
Relatively few igneous rocks are identified by specific colors. Instead, they are generally described as light, intermediate, or dark.

Mount St. Helens
In 1980, Mount St. Helens in the USA erupted, sending thousands of tons of pyroclastic debris across northwestern USA. Extensive beds of pumice and tuff form from such eruptions.

PROFILE

- Silica-rich, plutonic
- Crystallization of a silica-rich magma in a major intrusion
- 1⁄16–3⁄16 in (2–5 mm), phenocrysts to 4 in (10 cm)
- Potassium feldspar, quartz, mica
- Sodium plagioclase, hornblende
- White, light gray, pink, red

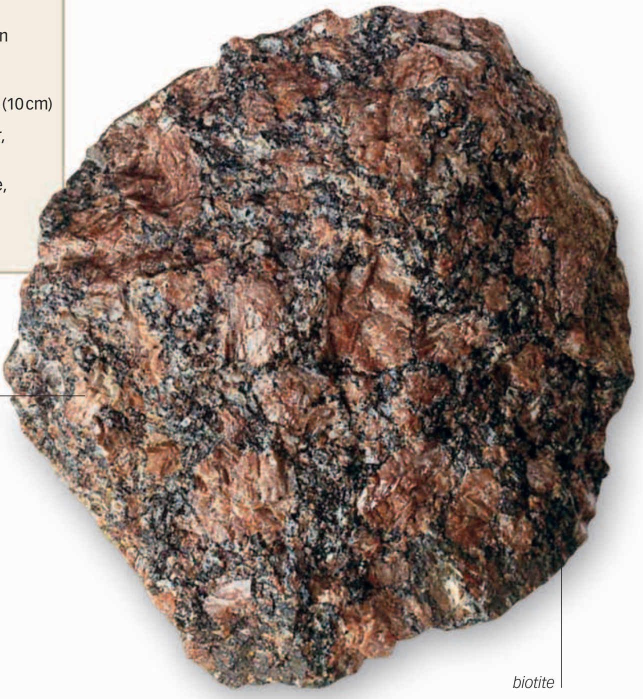

Dark granite This specimen of granite is dominated by large crystals of potassium feldspar, quartz, and biotite.

GRANITE

The most common intrusive rock in Earth's continental crust, granite is familiar as a mottled pink, white, gray, and black ornamental stone. It is coarse- to medium-grained. Its three main minerals are feldspar, quartz (p.168), and mica, which occur as silvery muscovite (p.195) or dark biotite (p.197) or both. Of these minerals, feldspar predominates, and quartz usually accounts for more than 10 percent. The alkali feldspars are often pink, resulting in the pink granite often used as a decorative stone.

Granite crystallizes from silica-rich magmas that are miles deep in Earth's crust. Many mineral deposits form near crystallizing granite bodies from the hydrothermal solutions that such bodies release.

Granite staircase Granite is used as a building stone. This stairway made of granite ascends to the Bom Jesus Church in Portugal.

VARIANTS

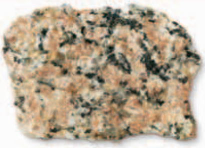

Pink granite Pink feldspars give this granite its color

White granite A specimen dominated by light-colored minerals

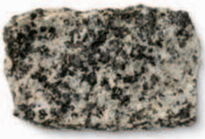

Hornblende granite Granite with black hornblende

PROFILE

- Intrusive
- Intrusive
- Medium to coarse
- Quartz, feldspar, mica
- Hornblende, plagioclase
- Pink, white

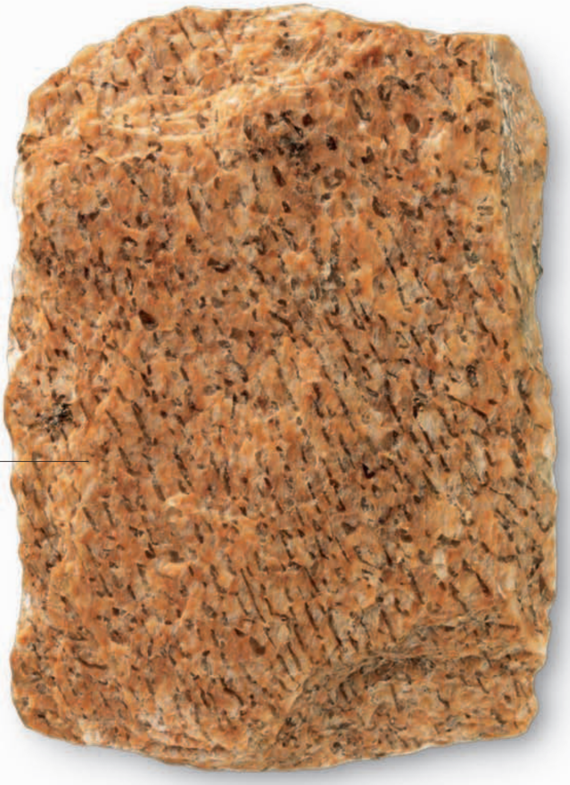

Graphic granite This specimen of granite shows simultaneous growth of quartz and feldspar, which produces a pattern.

VARIANTS

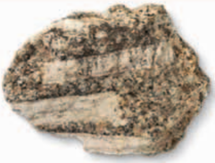

Porphyritic granite A specimen in which large feldspar phenocrysts are set in granite

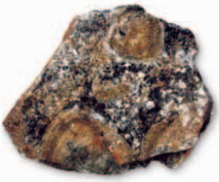

Orbicular granite Granite with spherical phenocrysts of feldspar

TEXTURED GRANITE

Granites with distinct patterns in their crystallization are known as textured granites and in some cases, graphic granites. Graphic granite consists of roughly 30 percent quartz (p.168) and 70 percent feldspar, with a few other minerals. These minerals are intergrown in such a way that straight-sided quartz crystals, which look like hieroglyphic characters, are set in a background of feldspar. The texture forms in pegmatites (p.260) when the main minerals crystallize from the magma at the same time.

Orbicular granite is an unusual but spectacular granite containing spheres (orbicules) of concentric layers of granitic minerals. The orbicules are about 2–4 in (5–10 cm) in diameter and often richer than the granite in darker minerals. They are usually restricted to small areas within the larger granite mass. In porphyritic granite, the feldspar crystals are larger and better formed than the surrounding mineral grains. These granites have been quarried and polished for use as ornamental and building stones.

PROFILE

Feldspar-rich, plutonic

Fluid-rich crystallization in the final stages of the formation of a granite

More than 3⁄16in (5mm) to many ft (m)

Quartz, feldspar, mica

Tourmaline, topaz

White, pink

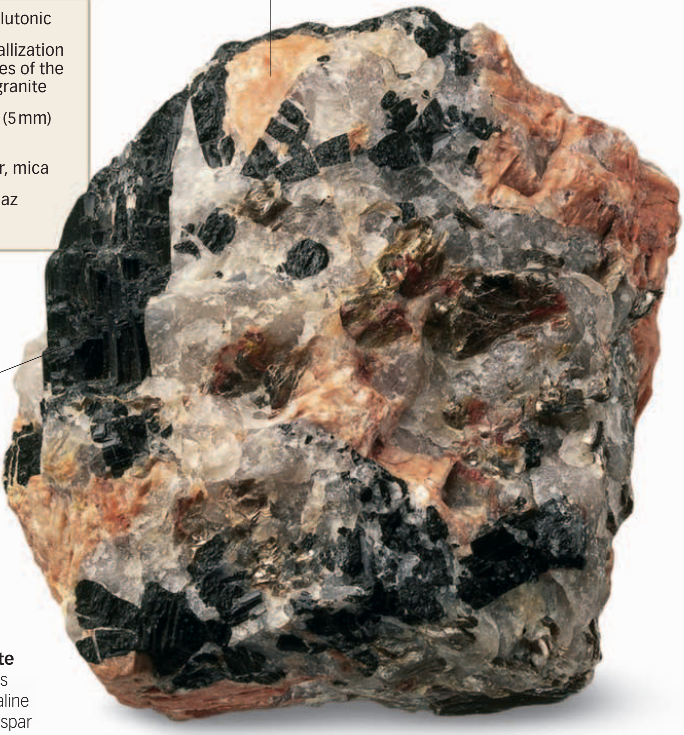

Tourmaline pegmatite
This specimen contains crystals of black tourmaline in a matrix of pink feldspar and white quartz.

VARIANTS

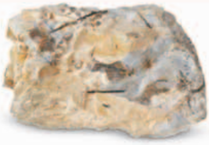

Granitic pegmatite
A specimen with feldspar, quartz, biotite, and needle-shaped tourmaline

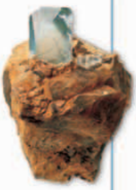

Blue topaz
A topaz crystal in a pegmatite matrix

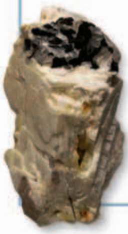

Feldspar pegmatite
A pegmatite dominated by white feldspar, with amphibole

PEGMATITE

Important sources of many gemstones, pegmatites are very coarse-grained igneous rocks, mostly of a granitic composition. Although crystals can be huge—over 33ft (10m) in some specimens—individual crystals usually average 3¼–4in (8–10cm) in length. The large crystals are due to the considerable amount of water in the magma rather than slow cooling. The most perfect crystals are typically found in openings or pockets. Quartz (p.168) and feldspar dominate, but many other minerals can form large, beautiful crystals. Muscovite (p.195) and other micas commonly occur in pegmatites in large, flat sheets known as books.

Pegmatites are light-colored rocks and occur in small igneous bodies, such as veins and dykes, or sometimes as patches in larger masses of granite (pp.258–59). Several gemstones—such as tourmaline (p.224) group minerals, aquamarine (p.225), rock crystal, smoky quartz, rose quartz, and topaz (p.234)—are mined from pegmatites.

PROFILE

- Ultramafic, plutonic
- Crystallization of a silica-poor magma in a major intrusion
- 1⁄16–3⁄16 in (2–5 mm)
- Calcium plagioclase
- Olivine, pyroxene, garnet
- Light gray to white

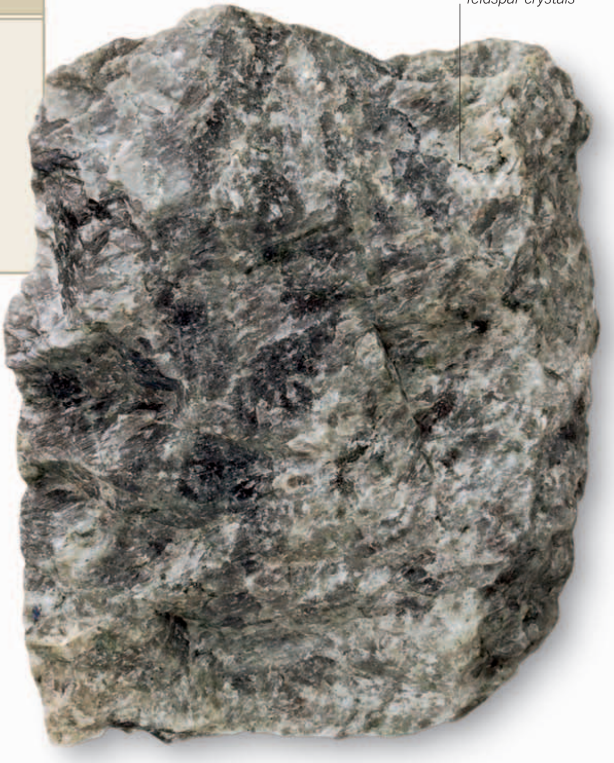
plagioclase feldspar crystals

Anorthosite
This specimen of anorthosite is dominated by light-colored plagioclase feldspars.

VARIANTS

Coarse anorthosite
A specimen with pyroxene and orthopyroxene

Lunar anorthosite Believed to be the first lunar rock to crystallize

ANORTHOSITE

An intrusive igneous rock, anorthosite is composed of at least 90 percent calcium-rich plagioclase feldspar—principally labradorite (p.180) and bytownite. Olivine (p.232), garnet, pyroxene, and iron oxides make up the remaining 10 percent. Anorthosite is coarse-grained and either white or gray. Specimens can also be green. Many anorthosites have an interesting “cumulate” texture, where well-formed crystals appear to have settled out of the liquid magma, in a similar way as large grains settling in a sediment.

Anorthosite is not a common rock, but where it does occur, it is found as immense masses, or as layers between iron- and magnesium-rich rocks, such as gabbro (p.265) and peridotite (p.266). Anorthosite is, however, common on the surface of the Moon.

Labradorite relief
Labrodorite occurs in anorthosite and is used in carvings, such as this 19th-century relief.

PROFILE

- Intermediate silica content, plutonic
- Crystallization of an alkaline intermediate magma in a major intrusion
- 1/16–3/16 in (2–5 mm)
- Potassium feldspar
- Sodium plagioclase, biotite, amphibole, pyroxene, hornblende, feldspathoids
- Gray, pink, or red

Pink syenite The pink color of this syenite specimen is due to the presence of alkali feldspar, which predominates in syenite.

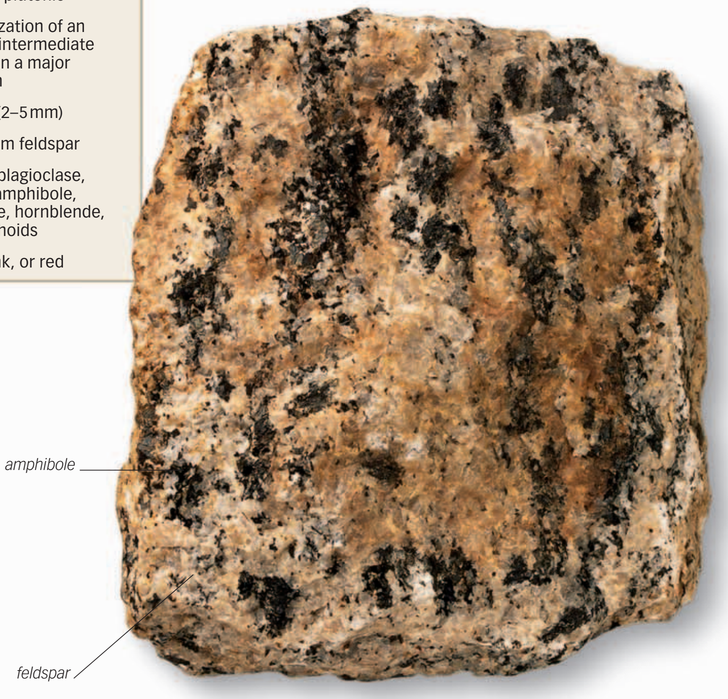

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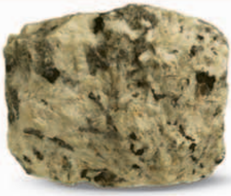

Nepheline syenite Nepheline crystals with black hornblende

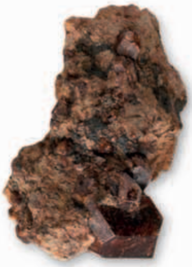

Syenite with zircon Zircon crystals in a syenite matrix

SYENITE

Visually similar to granite and often confused with it, syenites can be distinguished from granite by the absence or scarcity of quartz. A syenite is any one of a class of rocks essentially composed of: an alkali feldspar or sodium plagioclase (or both); a ferromagnesian mineral, usually biotite (p.197), hornblende (p.218), or pyroxene; and little or no quartz. The alkali feldspars can include orthoclase (p.173), albite (p.177), or less commonly, microcline (p.175). Syenites are attractive, multi-colored rocks—usually gray, pink, or red. Other minerals that occasionally occur in small amounts in syenite include titanite, apatite (p.148), zircon (p.233), magnetite (p.92), and pyrite (p.62). When syenites contain quartz, they are called quartz syenites.

Nepheline (p.182) and alkali feldspar are essential minerals in nepheline syenite, but this rock can contain other minerals, including unusual and attractive ones, such as eudialyte. If the rock includes a pyroxene, it is usually aegirine (p.209); if an amphibole it is usually arfvedsonite, both of which are rich in sodium.

PROFILE

- ▲ Feldspar-rich, plutonic
- 🌐 Intrusive
- 🔍 Coarse
- ◩ Plagioclase, alkali feldspar, quartz, mica
- ◳ Hornblende, augite
- ✻ Gray, white, or pink

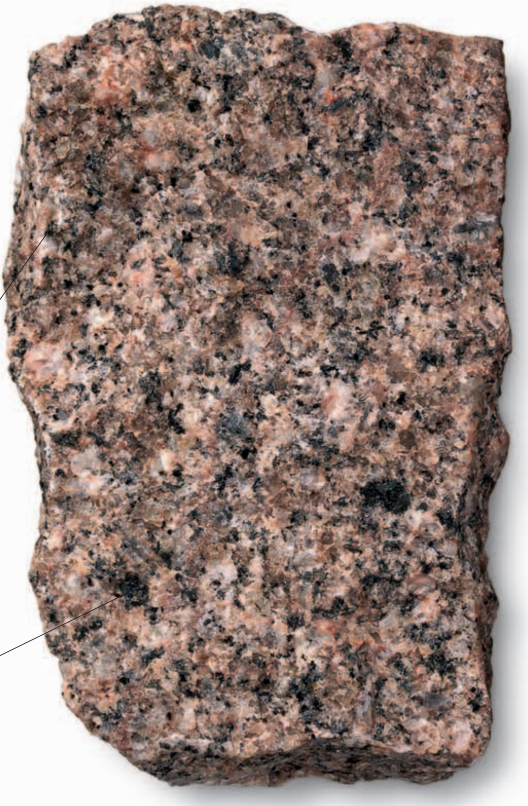

Speckled granodiorite This pink granodiorite has a speckled appearance because of the presence of darker minerals, such as mica and hornblende.

VARIANT

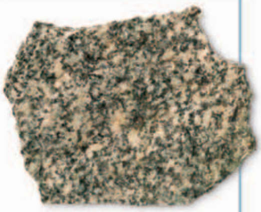

Pink granodiorite A specimen of granodiorite with dark mica and hornblende

GRANODIORITE

Among the most abundant of intrusive igneous rocks, granodiorite is a medium- to coarse-grained rock that is similar to granite (p.258) in texture. Granodiorite can be pink or white, with a grain size and texture similar to that of granite, but abundant plagioclase generally makes it appear darker than granite. The biotite (p.197) and hornblende (p.218) give it a speckled appearance. The mica may occur in well-formed hexagonal crystals, and the hornblende may be present in needlelike crystals. Twinned plagioclase crystals are sometimes wholly encased by orthoclase.

The quartz (p.168) present in granodiorite can be gray to white. With increased amounts of quartz and alkali feldspar, granodiorite grades to granite. With less quartz and alkali feldspar, it becomes diorite (p.264). The volcanic equivalent of granodiorite is dacite (p.274). Two historic stones are granodiorite: the Rosetta Stone was carved from it, and the Plymouth Rock is a glacial erratic boulder of granodiorite.

PROFILE

- Intermediate silica content, plutonic
- Crystallization of a magma with intermediate silica content in a major intrusion
- $\frac{1}{16}$–$\frac{3}{16}$ in (2–5 mm)
- Sodium plagioclase, hornblende
- Biotite
- Black or dark green mottled with gray or white

Two-toned diorite
This diorite specimen gets its two-toned appearance from light-colored plagioclase feldspar and black hornblende.

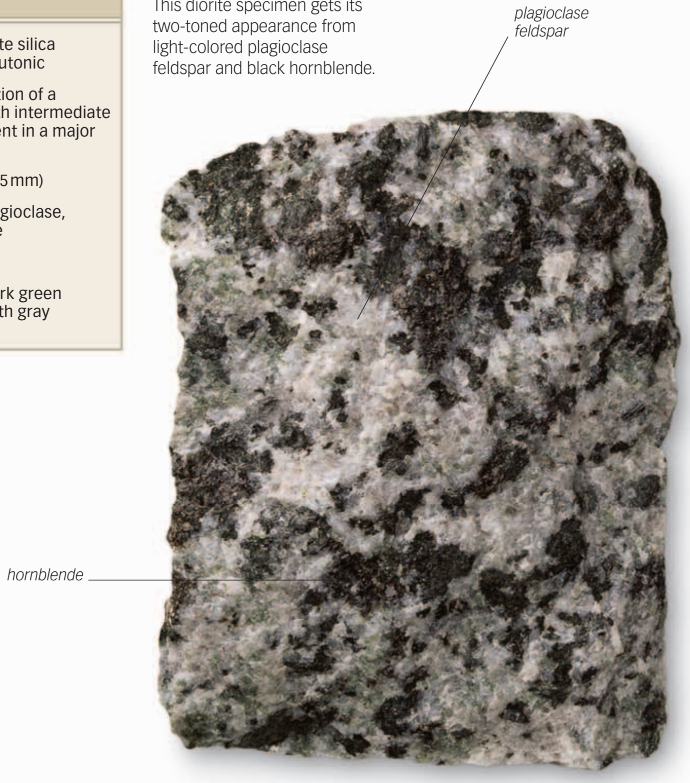

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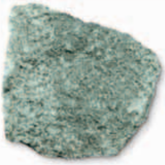

Light-colored diorite
A specimen of diorite with white plagioclase and a minor amount of hornblende

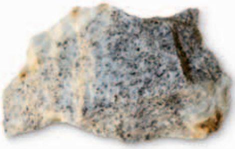

Fine-grained diorite
A specimen of fine-grained diorite with phenocrysts of hornblende

DIORITE

This medium- to coarse-grained intrusive igneous rock is sometimes sold as "black granite." In general, though, diorite is darker than granite (p.258). It is commonly composed of about two-thirds white plagioclase feldspar and one-third dark-colored minerals, such as biotite (p.197) and hornblende (p.218). The plagioclases in diorite—oligoclase (p.178) or andesine (p.181)—are rich in sodium. Diorite can be of uniform grain size or have large phenocrysts of plagioclase or hornblende.

The rock can occur as large intrusions or as smaller dykes and sills. Most diorite is intruded along the margins of continents. With small amounts of quartz (p.168) and alkali feldspar, it becomes a granodiorite (p.263); with larger amounts, it is classified as granite.

Neolithic axehead
Diorite can be extremely tough and was used to make ancient tools, such as this neolithic axehead.

PROFILE

- Mafic, plutonic
- Crystallization of a silica-poor magma in a major intrusion
- $\frac{1}{16}$–$\frac{3}{16}$ in (2–5 mm)
- Calcium plagioclase feldspar, pyroxene, ilmenite
- Olivine, magnetite
- Dark gray to black

Coarse-grained gabbro This specimen of gabbro has coarse grains, as produced by the formation of large crystals during slow cooling of a magma.

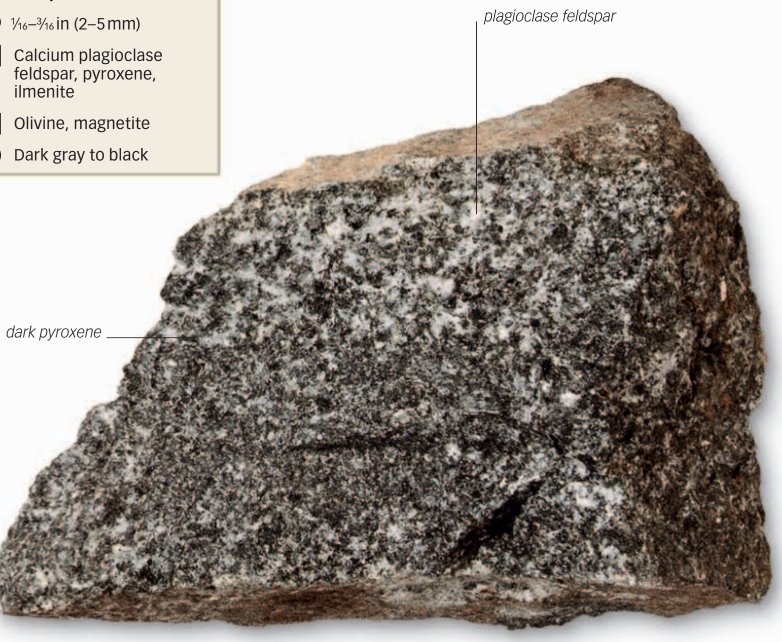

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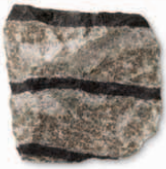

Layered gabbro Bands of light plagioclase and dark ferromagnesian minerals

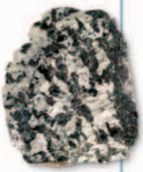

Leucogabbro A gabbro with feldspar-rich crystals

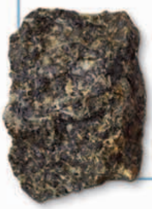

Olivine gabbro A gabbro containing olivine

GABBRO

Medium or coarse-grained rocks, gabbros consist principally of dark green pyroxene (augite and lesser amounts of orthopyroxene) plus white- or green-colored plagioclase and black, millimeter-sized grains of magnetite and/or ilmenite. A gabbro has an intermediate or low silica content and rarely contains quartz (p.168). Gabbro is essentially the intrusive equivalent of basalt (p.273), but unlike basalt gabbro has a highly variable mineral content. It often contains a layering of light and dark minerals (layered gabbro), a significant amount of olivine (olivine gabbro), or a high percentage of coarse crystals of plagioclase feldspar (leucogabbro).

Gabbros are widespread but not common on Earth's surface. They occur as intrusions and as uplifted sections of oceanic crust. Some gabbros are mined for their nickel, chromium, and platinum (p.38). Those containing ilmenite (p.90) and magnetite (p.92) are mined for their iron or titanium.

PROFILE

- Ultramafic, plutonic
- Crystallization of a silica-poor magma in a major intrusion, or Earth's mantle
- $\frac{1}{16}$–$\frac{3}{16}$ in (2–5 mm)
- Olivine, pyroxene
- Garnet, chromite
- Dark green to black

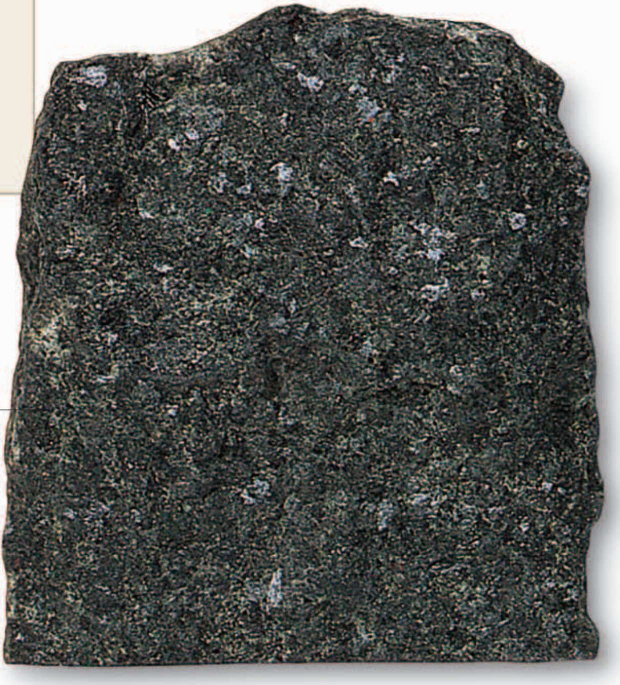

Coarse peridotite This is a specimen of dark, olivine- and pyroxene-rich peridotite from Odenwald, West Germany.

VARIANTS

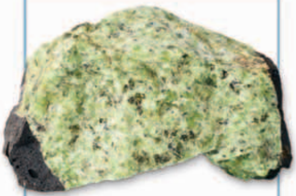

Green peridotite A specimen containing green olivine

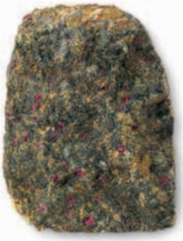

Garnet peridotite Peridotite with red phenocrysts of pyrope garnet

PERIDOTITE

An intrusive igneous rock, peridotite is coarse-grained and dense. It is light to dark green in color. Peridotite contains at least 40 percent olivine (p.232) and some pyroxene. Unlike the olivine grains, the pyroxene grains in peridotite have a visible cleavage when viewed under a hand lens. Peridotite forms much of Earth's mantle and can occur as nodules that are brought up from the mantle by kimberlite (p.269) or basalt (p.273) magmas.

The rock is usually found interlayered with iron- and magnesium-rich rocks in the lower parts of layered igneous rock bodies, where its denser crystals first form through selective crystallization and then settle to the bottom of still-fluid or semi-solid crystallizing mushes. A peridotite specimen that has been altered by weathering becomes serpentinite (p.298). Peridotite and pyroxenite (p.267) form in similar environments, but pyroxenite contains a higher percentage of pyroxene. Peridotites are important sources of chromium and nickel.

Pyroxenite
Pyroxene, the main component of pyroxenite, can be seen in this specimen, along with smaller amounts of plagioclase feldspar and accessory sulfide minerals.

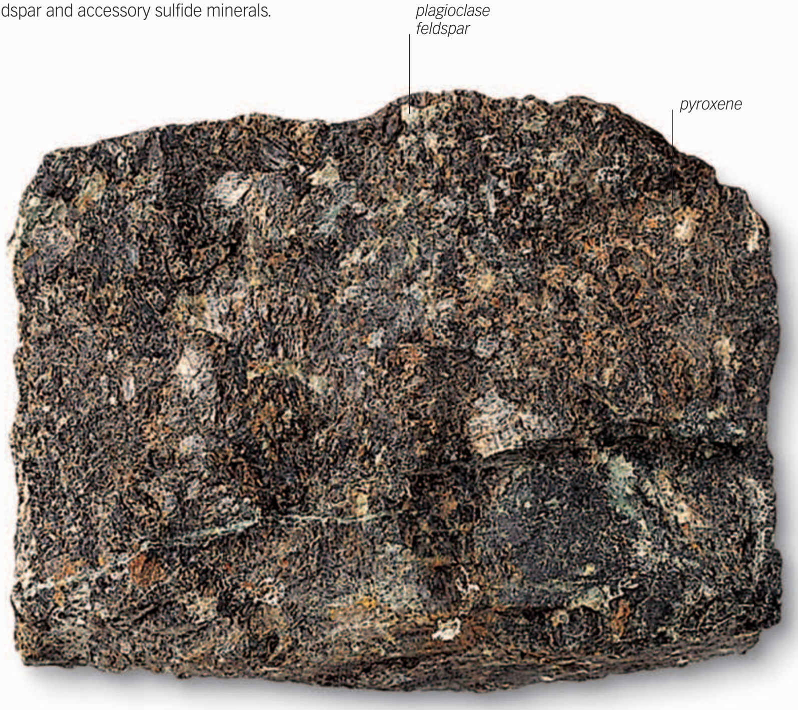

PROFILE

- Intrusive
- Crystallization of a silica-poor magma in a major intrusion
- 1/16–3/16 in (2–5 mm)
- Pyroxene
- Biotite, hornblende, olivine, plagioclase, nepheline
- Light green, dark green, or black

PYROXENITE

This is a coarse-grained, granular igneous rock that contains at least 90 percent pyroxene. Pyroxenite may also contain olivine (p.232) and oxide minerals when it occurs in layered intrusions or nepheline (p.182) when it occurs in silica-poor intrusions. A hard and heavy rock, it is light green, dark green, or black. Its surface often weathers to rusty brown. Individual crystals may be 3 in (7.5 cm) or more in length. Pyroxenites are usually found with gabbros (p.265) and peridotites (p.266). Unlike gabbros, pyroxenite contains almost no feldspars. Also, pyroxenite has less olivine than peridotites.

The principal minerals usually found accompanying pyroxenites, in addition to olivine and feldspar, are chromite (p.99) and other spinels (p.96), garnet, rutile (p.78), and magnetite (p.92). It has been proposed that large volumes of pyroxenite form in the upper mantle. Rare metamorphic pyroxenites are known and are described as pyroxene hornfels.

PROFILE

- Mafic, plutonic
- Crystallization of a silica-poor magma in a minor intrusion
- 1/256–1/16 in (0.1–2 mm)
- Calcium plagioclase, pyroxene
- Quartz, magnetite, olivine
- Dark gray to black, often mottled white

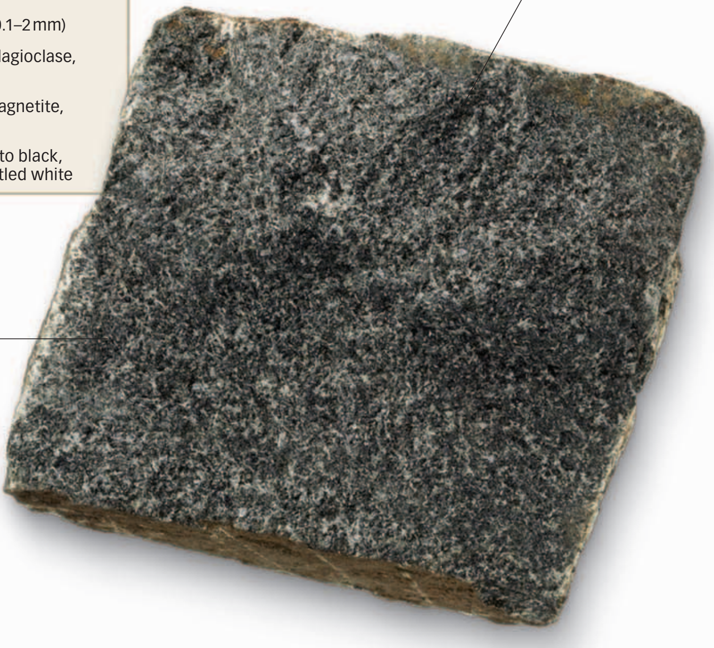

Dark gray dolerite Dolerite's characteristic medium texture and dark color can be seen in this specimen.

VARIANTS

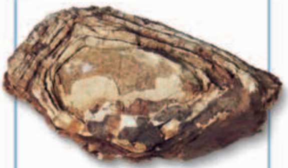

Weathered dolerite A dolerite specimen showing surface flaking from weathering

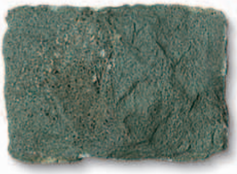

Fine-grained dolerite A specimen of dolerite with fine-grained texture

DOLERITE

A medium-grained rock, dolerite has the same composition as gabbro (p.265): one- to two-thirds is calcium-rich plagioclase feldspar, and the remainder is mainly pyroxene. Specimens can have up to 55 percent silica and up to 10 percent quartz (p.168). Plagioclase crystals commonly occur as tiny rectangular crystals within larger pyroxene grains in dolerite. Olivine (p.232) can occur as a constituent in the form of rounded grains that are often weathered orange-brown.

An extremely hard and tough rock, dolerite occurs in dykes and sills intruded into fissures in other rocks. It is a heavy rock that is often polished for use as a decorative stone. Dolerite is also used in its rough state for paving and is crushed for road stone. It is a stone sold under the name "black granite."

Stonehenge, England The inner circle at Stonehenge in England is made up of about 80 pieces of dolerite "bluestones."

PROFILE

- Silica-poor, volcanic
- Extrusion of a fluid part of Earth's mantle
- Wide range
- Olivine, pyroxene, mica, garnet, diopside
- Ilmenite, diamond, serpentine, calcite, rutile, perovskite, magnetite
- Dark gray

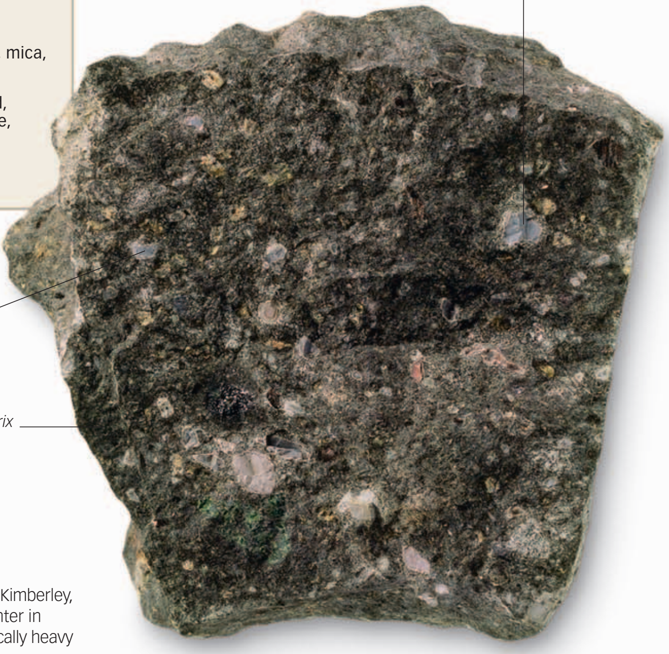

Brecciated kimberlite
Kimberlite is named after Kimberley, the diamond industry center in South Africa. This is a typically heavy and fragmented specimen.

VARIANTS

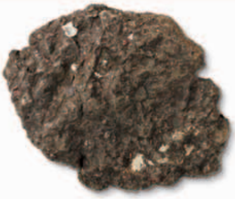

Weathered kimberlite
Heavily weathered kimberlite from Kimberley, South Africa

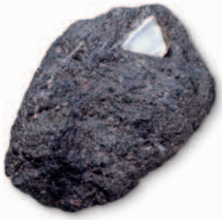

Diamond in kimberlite
An octahedral diamond in a kimberlite matrix

KIMBERLITE

The major source of diamonds (p.47), kimberlite is a variety of peridotite (p.266). It is rich in mica, often in the form of crystals of phlogopite, a type of mica. Other abundant constituent minerals include chrome-diopside (p.210), olivine (p.232), and chromium- and pyrope-rich garnet. Lesser amounts of rutile (p.78), perovskite (p.89), ilmenite (p.90), magnetite (p.92), calcite (p.114), serpentine (p.191), pyroxene, and diamond can also be present.

Kimberlite is typically found in pipes—structures with vertical sides roughly circular in cross section. The rock may have been injected from the mantle into zones of weakness in the crust. Fragments of mantle rock are often brought to the surface in kimberlites, making them a valuable source of information about inner Earth.

Diamond ring
This ring has an emerald-cut diamond on a gold shank. Kimberlites are the primary source rock for diamonds.

PROFILE

Extrusive

Crystallization of an alkaline magma in a minor intrusion

$\frac{1}{256}$–$\frac{1}{16}$ in (0.1–2 mm)

Orthoclase, plagioclase, biotite, hornblende

Hornblende, magnetite, axinite, amphibole, pyroxene

Dark brown to black

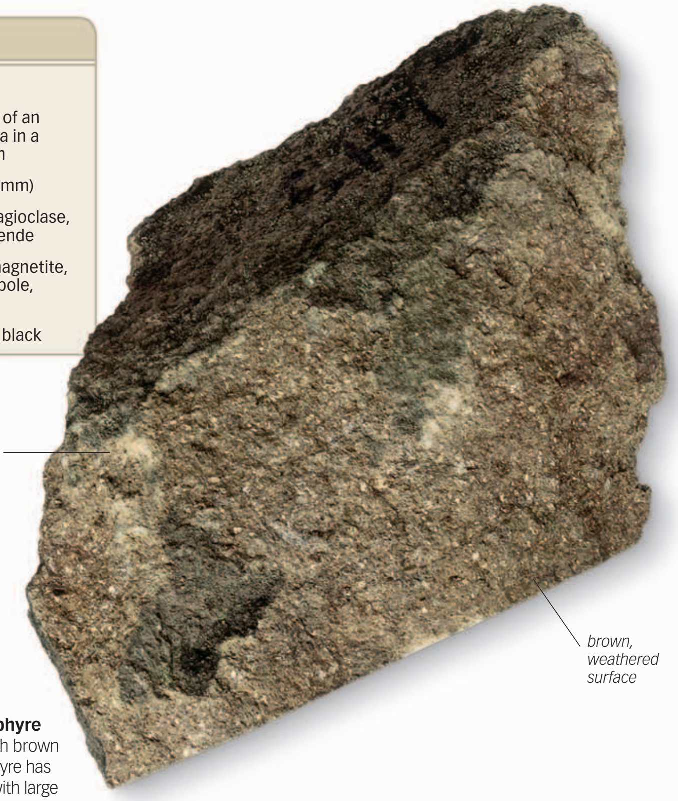

Weathered lamprophyre This weathered grayish brown specimen of lamprophyre has a porphyritic texture, with large crystals set in a fine matrix.

VARIANTS

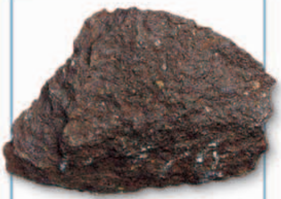

Dark brown lamprophyre A specimen of lamprophyre with mica flakes

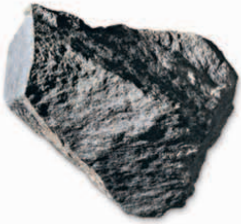

Fine-grained lamprophyre Lamprophyre with fine grains and no phenocrysts

LAMPROPHYRE

The term lamprophyre is used to refer to a group of igneous rocks with high potassium, magnesium, and iron content. Four minerals dominate these rocks: orthoclase (p.173), plagioclase, biotite (p.197), and hornblende (p.218). Amphibole and biotite tend to occur in a matrix of various combinations of plagioclase and other sodium- and potassium-rich feldspars, pyroxene, and feldspathoids (pp.182–84). Because of their relative rarity and varied composition, lamprophyres do not fit into standard geological classifications. In general, they form at great depth and are enriched in sodium, cesium, rubidium, nickel, and chromium, as well as potassium, iron, and magnesium. Some are also source rocks for diamonds.

The exact origin of lamprophyres is still debated. These rocks occur mainly in dykes, sills, and other small igneous intrusions. They form along the margins of some granites (pp.258–59) and are often associated with large bodies of intrusive granodiorite (p.263).

PROFILE

- Extrusive
- Two-stage crystallization of an igneous rock
- Less than $\frac{1}{256}$ in (0.1 mm); phenocrysts up to $\frac{3}{4}$ in (2 cm)
- Various
- Various
- Red, green, purple

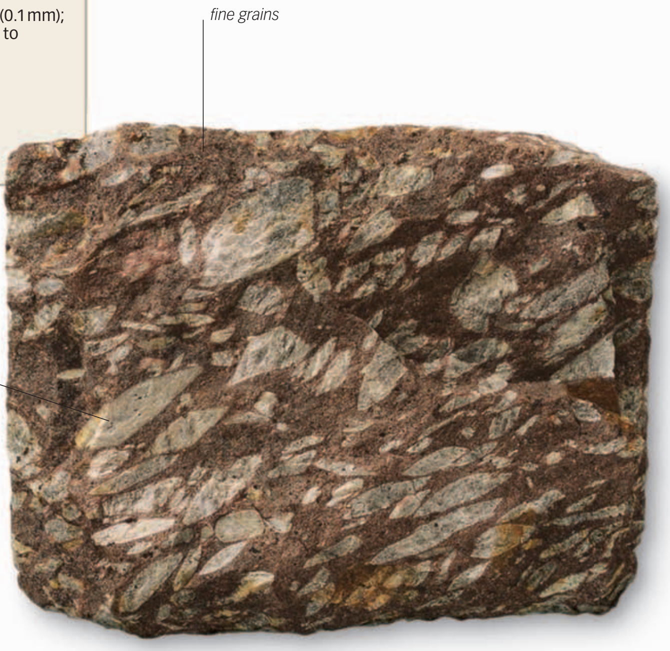

Rhomb porphyry
This porphyry has feldspar with rhombic cross sections in a fine-grained matrix.

VARIANTS

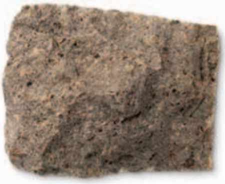

Quartz porphyry Porphyry with phenocrysts of quartz

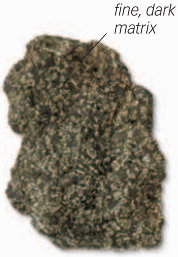

Feldspar porphyry
Phenocrysts of feldspar in a reddish brown matrix

PORPHYRY

The name porphyry is a general name and textural term for medium- to fine-grained igneous rocks that contain large crystals (phenocrysts) of other minerals, especially if these minerals are found in the smaller crystals of the matrix. It is most often used for rocks formed in lava flows or minor intrusions. The term porphyry is often prefixed with a reference to the minerals it contains, such as quartz–feldspar porphyry, which contains phenocrysts of the two minerals. Alternatively, the prefix can refer to the composition or texture of the rock. Examples are rhyolite porphyry or rhomb porphyry, respectively.

Porphyries form when crystallization begins deep in Earth's crust and cooling occurs quickly after rapid upward movement of magma. This results in the formation of very small crystals of the matrix. Historically, the name porphyry was used for the purple-red form of the rock, which has been valued since antiquity as an ornamental stone. Many Egyptian, Roman, and Greek sculptures used this type of porphyry.

PROFILE

- ▲ Intrusive and extrusive
- 🌐 Crystallization of a carbonate magma derived from Earth's mantle
- 🔍 Wide range
- ◪ Calcite, dolomite, siderite
- ◳ Magnetite, apatite, pyrochlore, phlogopite
- ✻ Cream, yellow, brown

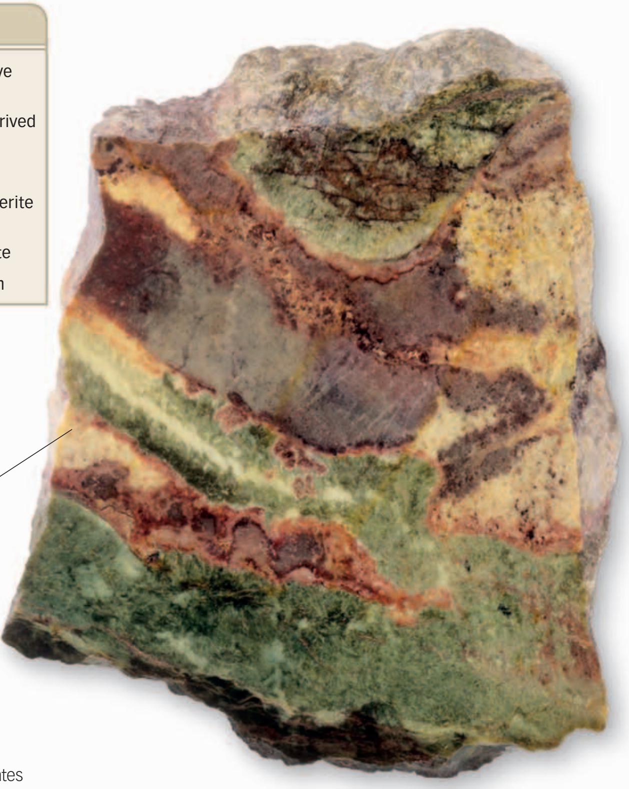

Carbonatite This carbonatite specimen contains a mixture of carbonates and other minerals.

VARIANT

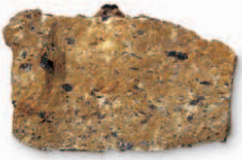

Carbonatite with magnetite A specimen of carbonatite with accessory black magnetite

CARBONATITE

An unusual rock type, carbonatite consists of over 50 percent carbonate minerals—usually calcite (p.114), dolomite (p.117), or siderite (p.123). Most carbonatites also contain some portion of silicate minerals and may contain magnetite (p.92), the brown mica phlogopite, and rare-earth minerals such as pyrochlore (p.85). Specimens are typically cream-colored, yellow, or brown. Carbonatite looks similar to marble (p.301). It may be coarse-grained if intrusive and fine-grained if volcanic.

The process by which carbonatites form is still a matter of conjecture. They are usually found in areas of continental rifting in veins, dykes, and sills around intrusions of sodium- and potassium-rich igneous rocks. The geochemistry of carbonatites is complex and can vary considerably in specimens. Many contain scarce and valuable ores of rare elements, such as niobium, cesium, tantalum, thorium, and hafnium. Some carbonatites also contain significant amounts of platinum (p.38), gold (p.42), silver (p.43), and nickel.

PROFILE

- Mafic, volcanic
- Extrusion of a silica-poor magma
- Less than 1⁄256 in (0.1 mm)
- Sodium plagioclase, pyroxene, olivine
- Leucite, nepheline, augite
- Dark gray to black

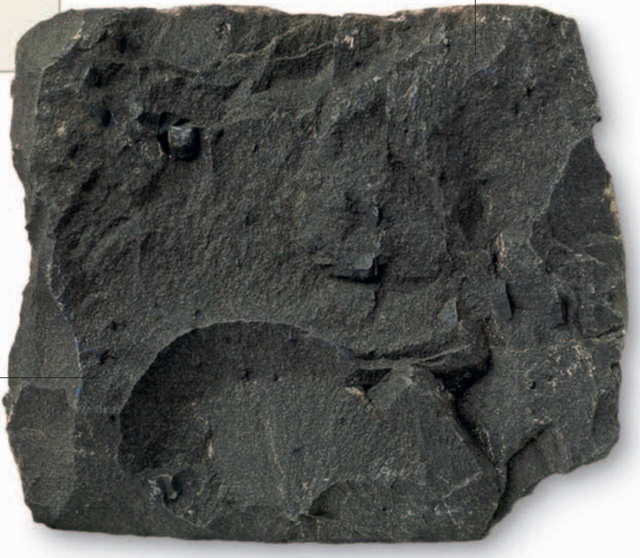

Fine-grained basalt This specimen of basalt shows its characteristic fine-grained texture.

VARIANTS

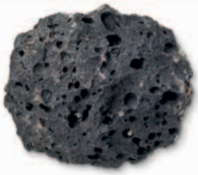

Vesicular basalt A basalt specimen with holes left by gas bubbles during cooling

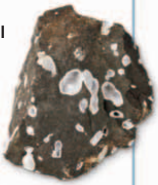

Amygdaloidal basalt A specimen with zeolite crystals in vesicules

Porphyritic basalt A basalt with phenocrysts of pyroxene

BASALT

Basalt is the most common rock on Earth's surface. Specimens are black in color and weather to dark green or brown. Basalt is rich in iron and magnesium and is mainly composed of olivine (p.232), pyroxene, and plagioclase. Most specimens are compact, fine-grained, and glassy. They can also be porphyritic, with phenocrysts of olivine, augite (p.211), or plagioclase. Holes left by gas bubbles can give basalt a coarsely porous texture.

Basalt makes up large parts of the ocean floor. It can form volcanic islands when it is erupted by volcanoes in ocean basins. The rock has also built huge plateaus on land. The dark plains on the Moon, known as maria, and, possibly, the volcanoes on Mars and Venus are made of basalt.

Basalt temple This magnificent, thousand-pillared temple in Andhra Pradesh, India, is made of gray basalt.

PROFILE

- Extrusive
- Extrusion of a magma with intermediate silica content
- Less than 1/256 in (0.1 mm)
- Quartz, plagioclase
- Biotite, hornblende, pyroxene
- Gray to pink

Porphyritic dacite This dacite specimen has a porphyritic texture, with prominent phenocrysts of plagioclase and biotite.

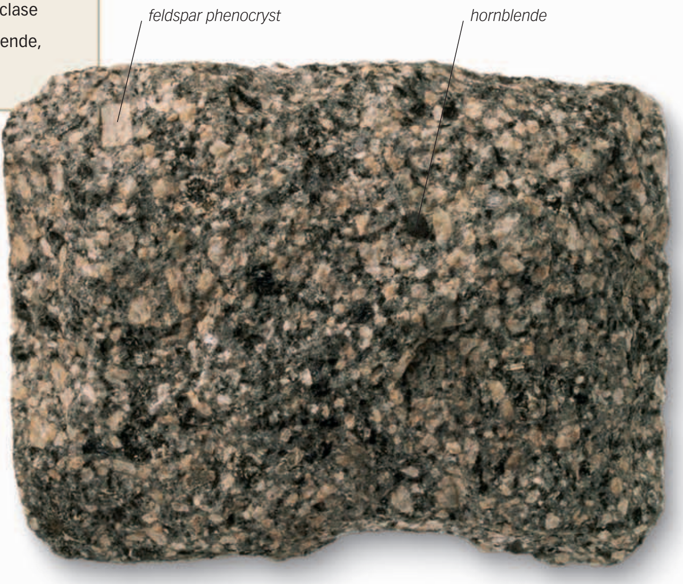

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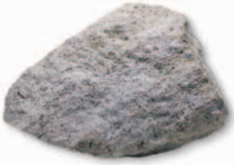

Fine-grained dacite A fine-grained specimen of dacite with small phenocrysts

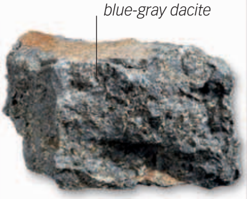

Blue-gray dacite A specimen of dacite with dark phenocrysts

DACITE

An extrusive igneous rock, dacite takes its name from Dacia (modern Romania)—the ancient Roman province where it was first found. The volcanic equivalent of granodiorite (p.263), dacite is usually pink or a shade of gray. It often has flowlike bands. Porphyritic varieties are common, with large crystals usually consisting of blocky plagioclase feldspar or rounded quartz (p.168), or both. Dacite matrix can be cryptocrystalline or glassy.

Dacite occurs with andesite (p.275) on continental margins, and with rhyolite (p.278) in continental volcanic districts. Along continental margins, dacite magmas form in areas where oceanic crust sinks beneath continental crust. Dacite magmas are chemically altered as they reach the mantle. Dacite lavas are quite viscous because of their moderate silica content, and thus can be quite explosive in eruptions. The explosion of Mount Saint Helens volcano in USA in 1980 was a result of dacite domes formed from previous eruptions. The mineral compositions of dacite lavas tell the history of the magma.

PROFILE

- Intermediate silica content, volcanic
- Extrusion of a magma with intermediate silica content
- Less than 1⁄256 in (0.1 mm)
- Plagioclase feldspars
- Pyroxene, amphibole, biotite
- Light to dark gray, reddish pink

Porphyritic andesite
This specimen of porphyritic andesite shows light feldspar phenocrysts in a dark andesite matrix.

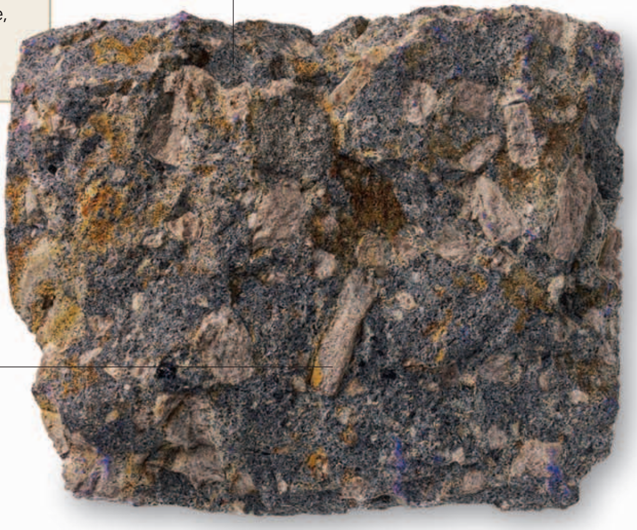

ANDESITE

This volcanic rock is named after the Andes Mountains. Intermediate in silica content, it is usually gray in color and may be fine-grained or porphyritic. Andesite is the volcanic equivalent of diorite (p.264). It consists of the plagioclase feldspar minerals andesine (p.181) and oligoclase (p.178), together with one or more dark, ferromagnesian minerals such as pyroxene and biotite (p.197).

Amygdaloidal andesite occurs when the voids left by gas bubbles in the solidifying magma are later filled in, often with zeolite minerals (pp.185–90). Andesite erupts from volcanoes and is commonly found interbedded with volcanic ash and tuff (p.282). Ancient andesites are used to map ancient subduction zones because andesitic volcanoes form on continental or ocean crust above these zones.

Volcanic andesite
Mount Fujiyama in Yamanashi Prefecture, Honshu, Japan, is the cone of an andesitic volcano.

VARIANTS

Fine-grained andesite
A specimen from the Solomon Islands, Pacific Ocean

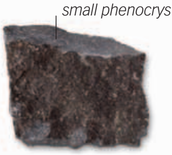

Andesite with plagioclase
A specimen of andesite with phenocrysts of light plagioclase

Amygdaloidal andesite Vesicles of andesite filled with a zeolite

PROFILE

- Extrusive
- Rubbly top of an extruded, silica-poor magma
- Less than $\frac{1}{256}$ in (0.1 mm)
- Plagioclase, pyroxene
- Apatite, magnetite, olivine
- Dark brown, black, or red

Vesicular scoria The large vesicles characteristic of scoria can be seen in this specimen.

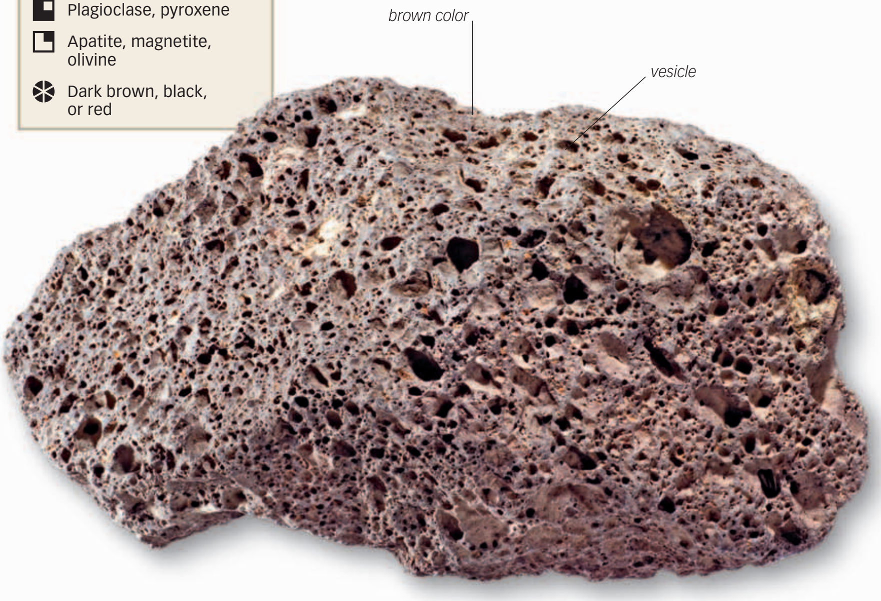

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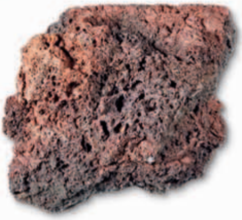

Rubbly scoria A specimen of rubbly scoria from the top of a lava flow

SCORIA

The top of a lava flow is made up of a highly vesicular, rubbly material known as scoria. It has the appearance of vesicular lava. When fresh, scoria is generally dark in color—dark brown, black, or red. Weathered scoria has a medium-brown color and forms piles of loose rubble with small pieces. Most scoria is basaltic or andesitic in composition. This rock forms when gases in the magma expand to form bubbles as lava reaches the surface. The bubbles are then retained as the lava solidifies. Scoria is common in areas of recent volcanism, such as the Canary Islands and the Italian volcanoes.

This rock is of relatively low density due to its vesicles, but it is not as light as pumice (p.277), which floats on water. Scoria also differs from pumice in that it has larger vesicles with thicker walls. Scoria has commercial use as a high-temperature insulating material. It also has applications in landscaping and drainage.

PROFILE

Volcanic

Solidification of a silica-rich lava with trapped gas bubbles

Less than $\frac{1}{256}$ in (0.1 mm)

Glass

Feldspar, augite, hornblende, zircon

Black, white, yellow, brown

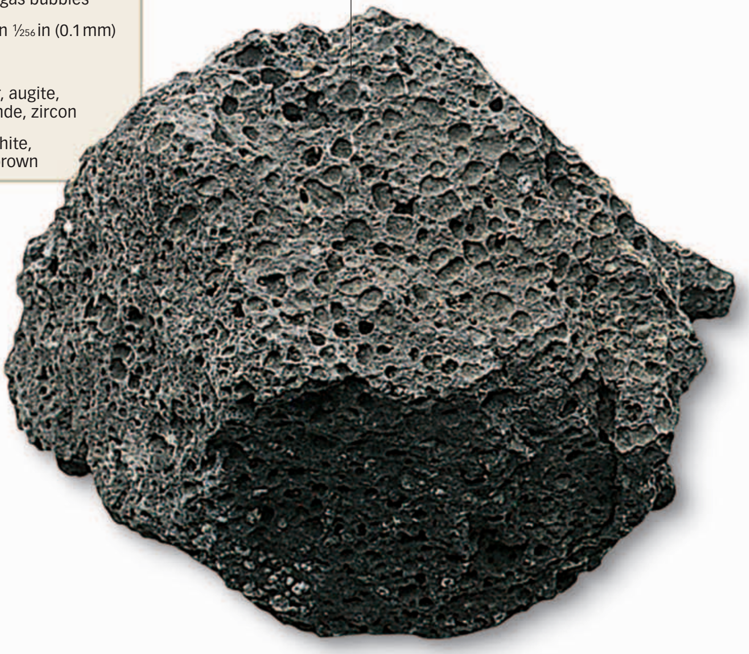

Frothy pumice The hollows (or vesicles) in this pumice clearly show its frothy nature. Vesicles may join together to form hollows or passages.

VARIANTS

Rhyolitic pumice A light-colored rhyolitic pumice with a frothy structure

Historic pumice A specimen of pumice from the Krakatoa eruption of 1883

PUMICE

A porous and frothlike volcanic glass, pumice is created when gas-saturated liquid magma erupts like a carbonated drink and cools so rapidly that the resulting foam solidifies into a glass full of gas bubbles. Pumices from silica-rich lavas are white, those from lavas with intermediate silica content are often yellow or brown, and rarer silica-poor pumices are black. The hollows in the froth can be rounded, elongated, or tubular, depending on the flow of the solidifying lava. The glassy material that forms pumice can be in threads, fibers, or thin partitions between the hollows.

Although pumice is mainly composed of glass, small crystals of various minerals occur. Pumice has a low density due to its numerous air-filled pores. For this reason, it can easily float in water.

Pumice stone Pumice is soft and easily shaped. Mildly abrasive, it is often used to remove rough skin.

PROFILE

- Feldspar-rich, volcanic
- Extrusion of a silica-rich magma
- Less than 1⁄256 in (0.1 mm)
- Quartz, potassium feldspar
- Glass, biotite, amphibole, plagioclase, pyroxene
- Light to medium gray, light pink

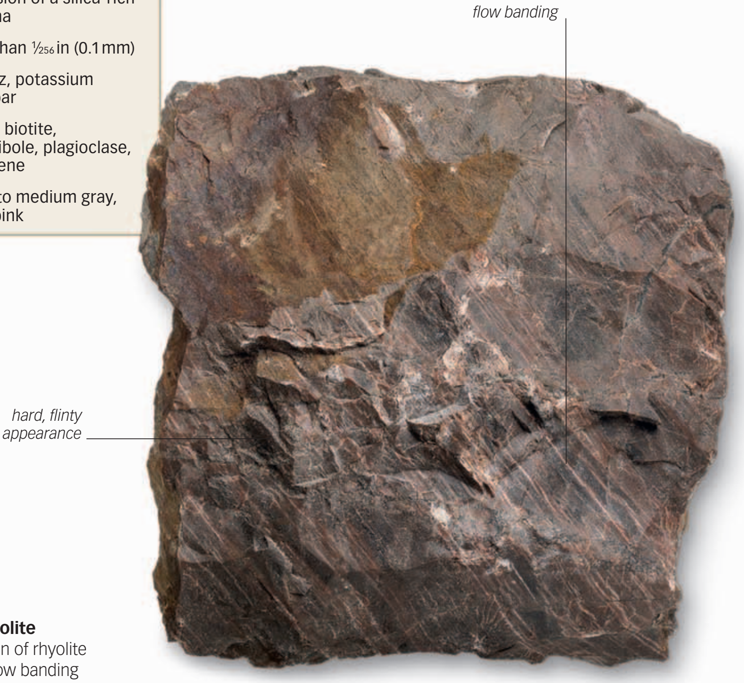

Banded rhyolite
This specimen of rhyolite has visible flow banding across its surface.

VARIANT

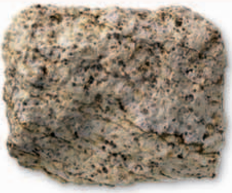

Porphyritic rhyolite
Light-colored rhyolite with phenocrysts of quartz

RHYOLITE

A rare volcanic rock, rhyolite is usually fine-grained. It is often composed largely of volcanic glass (pp.280–81). Individual grains of quartz (p.168), feldspar (pp.173–81), and mica may be present but are too small to be visible. The small size of these grains indicates that crystallization began before the lava flowed to the surface. Rhyolites sometimes have millimeter-scale phenocrysts of quartz, feldspar, or both. Specimens can also include iron- and magnesium-rich minerals, such as biotite (p.197) or pyroxene and amphibole. The granitic magma from which rhyolite crystallizes is very viscous. Therefore, flow banding is often preserved and can be seen on weathered surfaces. Banded rhyolites have few or no phenocrysts. A rhyolite variant with tiny crystals arranged in radiating spheres is called spherulitic rhyolite.

Rhyolite occurs with pumice (p.277), obsidian (p.280), and intermediate volcanic rocks, such as andesite (p.275). Rhyolites are almost exclusively confined to the interiors and margins of continents.

PROFILE

- Intermediate silica content, volcanic
- Extrusion of an alkaline intermediate magma
- Less than 1/256 in (0.1 mm)
- Sanidine, oligoclase
- Feldspathoids, quartz, hornblende, pyroxene, biotite
- Off-white, gray, pale yellow, pink

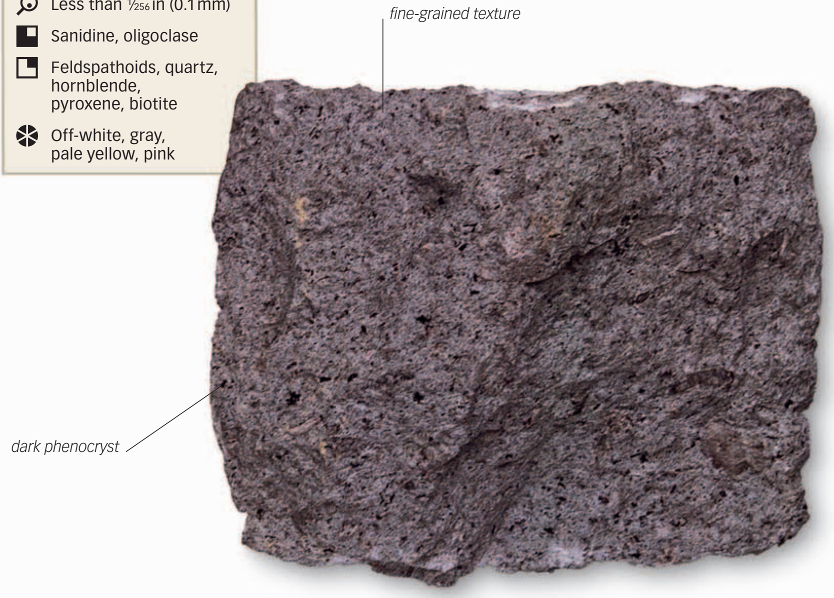

Porhyritic trachyte
This specimen of fine-grained trachyte has phenocrysts of a dark mineral.

VARIANTS

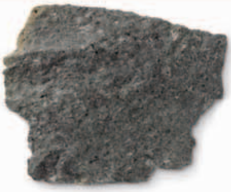

Gray trachyte A fine- to medium-grained specimen of trachyte

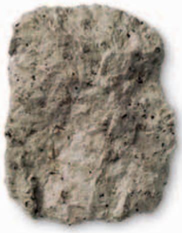

Porphyritic trachyte Light-colored trachyte with dark mineral phenocrysts

TRACHYTE

The name trachyte comes from the Greek word *trachys*, which means "rough"—a reference to the rock's typical rough texture. Trachyte's composition is dominated by alkali feldspar—a major component of the fine matrix and of the abundant phenocrysts that are common in the rock. Dark, iron- and magnesium-rich minerals, such as biotite (p.197), pyroxene, and amphibole, can be present in small quantities. Trachyte is similar to rhyolite (p.278) in color and occurence, but it contains little or no quartz (p.168).

Trachyte occurs on continents and oceanic islands with other volcanic rocks that are rich in alkali feldspars, have intermediate to high silica content, and are iron- and magnesium-rich.

Trachyte stonework
The cathedral in Morelia, in Mexico's Michoacán state, has ornate stonework of pink trachyte.

PROFILE

- Feldspar-rich, volcanic
- Extrusion and rapid cooling of a silica-rich magma
- Not granular
- Glass
- Hematite, feldspar
- Black, red, brown

Icelandic obsidian
This classic specimen of obsidian from Iceland perfectly demonstrates the rock's conchoidal fracture and vitreous luster.

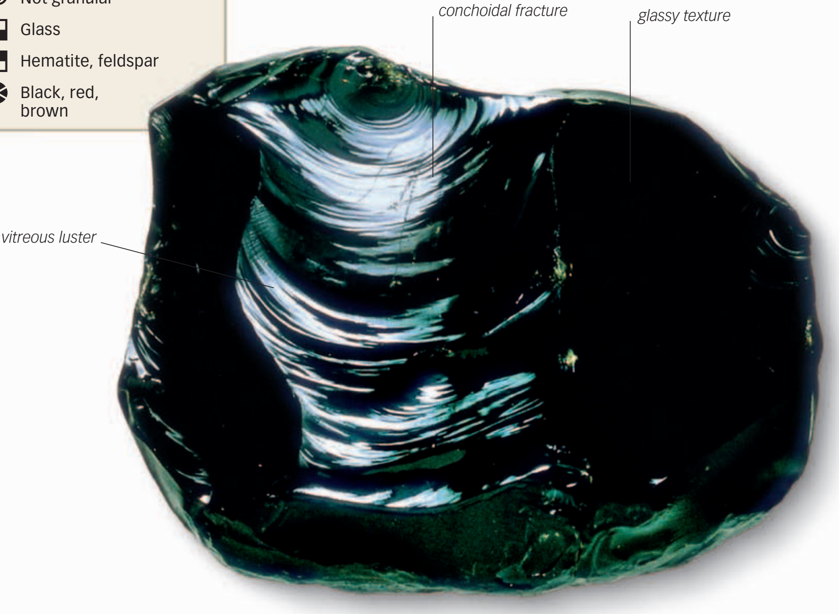

VARIANTS

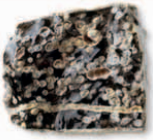

Vesicular obsidian
A specimen with white, silicate-filled vesicles

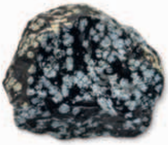

Snowflake obsidian
A specimen with needlelike crystals in spherical aggregates

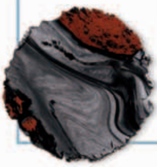

Banded obsidian
Obsidian with red hematite

OBSIDIAN

The natural volcanic glass obsidian forms when lava solidifies so quickly that crystals do not have time to form. Specimens are typically jet black, although the presence of hematite (p.90) can produce red and brown variants. The inclusion of tiny gas bubbles can sometimes create a golden sheen. Tiny crystals of feldspar (pp.173–81) and phenocrysts of quartz (p.168) can also be present. Obsidian can show flow banding.

Although obsidian can have any chemical composition, most specimens have a composition similar to rhyolite (p.278) and are found on the outer edges of rhyolite domes and flows. Like rhyolite, obsidian is also found along the rapidly cooled edges of sills and dykes. Most obsidian is relatively young, as the glass gradually crystallizes into minerals over a period of time.

Obsidian tear drop
These polished obsidian nodules are called Apache Tears after the tears of felled Apache warriors.

PROFILE

- Extrusive
- Rapid cooling of basalt in a lava fountain
- Up to 1⁄32 in (1 mm)
- Basaltic glass
- None
- Brown, black

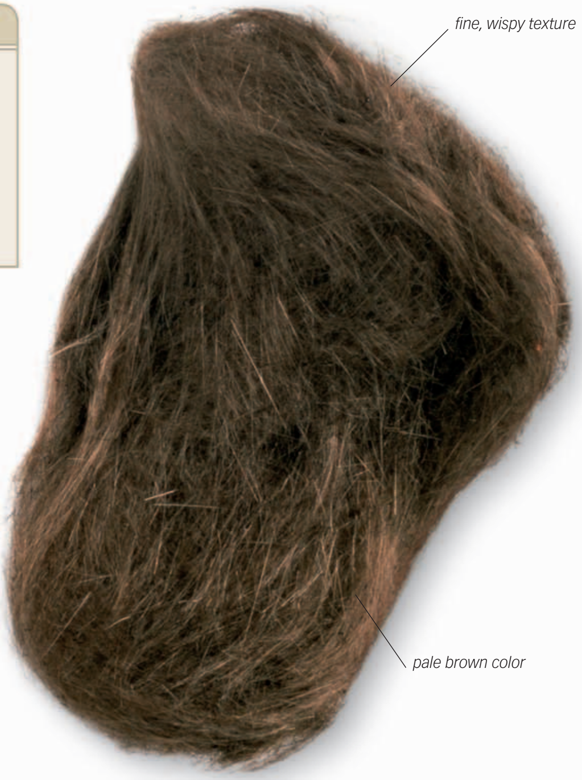

Pele's hair This unusual rock produced in volcanic eruptions is made up of hairlike fibers of volcanic glass.

PELE'S HAIR AND TEARS

Two of the more unusual kinds of extrusive volcanic rock are named after Pele, the Hawaiian goddess of volcanoes. The first of these is Pele's hair, which refers to threads or fibers of volcanic glass (pp.280–81) formed when small droplets of molten basaltic material are blown into the air and spun out by the wind into long, hairlike strands. Specimens are usually emitted from lava fountains, lava cascades, vents, and vigorous lava flows. They are generally deep yellow or golden in color. A single strand of Pele's hair with a diameter of less than 1⁄16 in (0.5 mm) can be as long as 6½ ft (2 m). Strands can be blown tens of miles away from the vent or fountain where they originated.

The second variety of volcanic extrusive named after Pele is Pele's tears, which are small blobs of volcanic glass formed in much the same way as Pele's hair. Specimens occur as spheres or tear drops that are jet black in color. They are frequently found on one end of a strand of Pele's hair.

VARIANTS

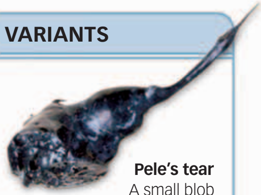

Pele's tear A small blob of volcanic glass elongated by airflow

Golden hair A mass of fine, golden volcanic glass

Long strands Particularly long strands of Pele's hair

PROFILE

- Volcanic
- Pyroclastic accumulation of fine material
- 1/256–1/16 in (0.1–2 mm)
- Glassy fragments
- Crystalline fragments
- Light to dark brown

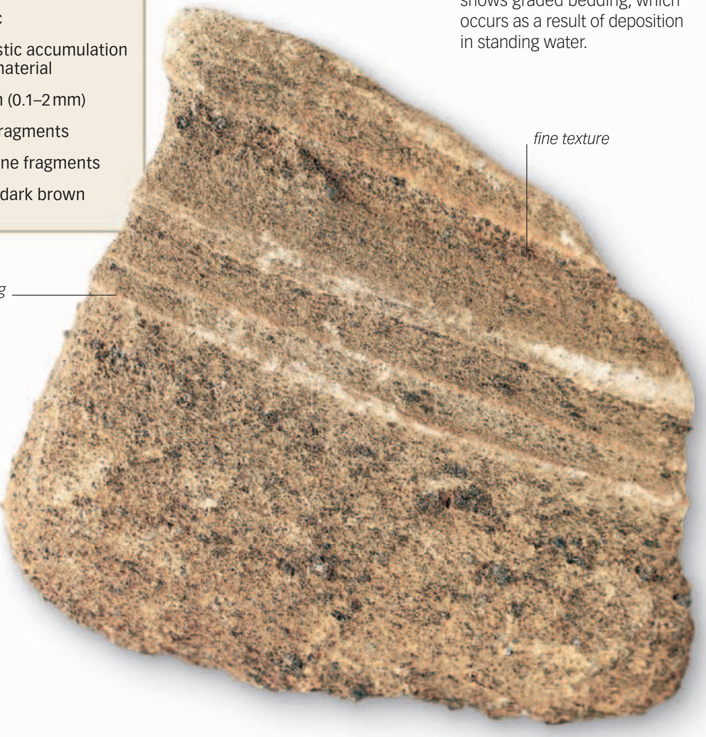

Tuff with graded bedding This tuff specimen from Ireland shows graded bedding, which occurs as a result of deposition in standing water.

VARIANTS

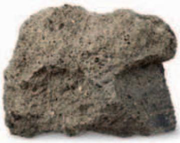

Lithic tuff A specimen of tuff containing a high percentage of small rock fragments

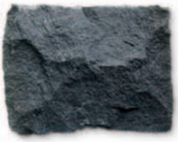

Crystal tuff A specimen of tuff containing a predominance of crystal fragments

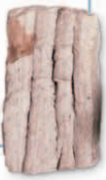

Bedded tuff A specimen of tuff that has fallen in distinct layers

TUFF

Any relatively soft, porous rock made of ash and other sediments ejected from volcanic vents that has solidified into rock is known as tuff. Most tuff formations include a range of fragment sizes and varieties. These range from fine-grained dust and ash (ash tuffs) to medium-sized fragments called lapilli (lapilli tuffs) to large volcanic blocks and bombs (bomb tuffs). Tuffs originate when foaming magma wells to the surface as a mixture of hot gases and incandescent particles and is ejected from a volcano.

The conditions under which the ejected ash solidifies determine the final nature of the tuff. Tuffs can vary both in texture and in chemical and mineralogical composition because of variations in the conditions of their formation and the composition of the ejected material. If the pyroclastic material is hot enough to fuse, a welded tuff (called ignimbrite) forms at once. Other tuffs lithify slowly through compaction and cementation, and can stratify when they accumulate under water.

PROFILE

- Extrusive
- Mixing of liquid and solid material during crystallization of a basic magma
- Less than $\frac{1}{256}$ in (0.1 mm), clasts $\frac{3}{16}$–8 in (0.5–20 cm)
- Various
- Various
- Red, brown, black

Rhyolite breccia This specimen of volcanic breccia incorporates angular fragments of reddish rhyolite.

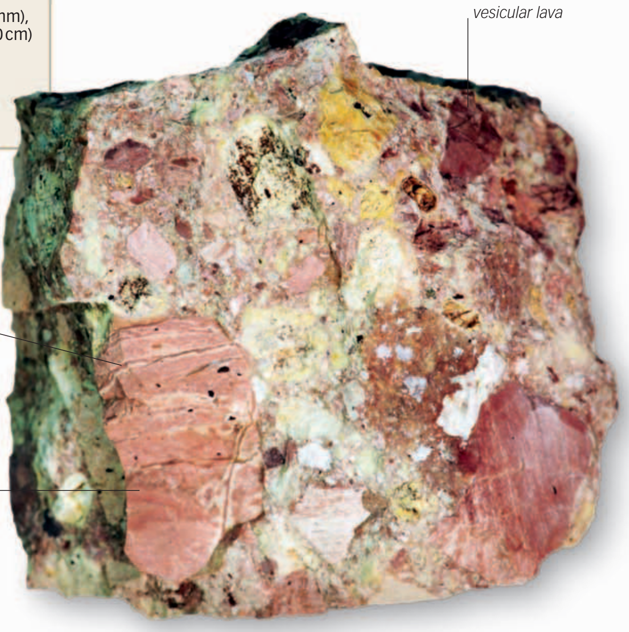
vesicular lava
flow banding from original rhyolite deposit
reddish rhyolite fragment

VARIANT

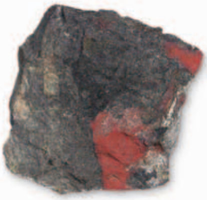

Volcanic breccia A specimen of volcanic breccia that contains large clasts of other volcanics

VOLCANIC BRECCIA

These igneous rocks are formed either by the interaction of lava and scoria (p.276) or by the mixing of cooled lava and flowing lava. Volcanic breccia takes the form of inch-scale angular clasts, which may be rocks broken off the side of a magma conduit or rocks picked up off the surface during a pyroclastic or lava flow. In certain types of lavas, especially dacite (p.274) and rhyolite (p.278) lavas, thick and nearly solidified lava is broken into blocks and then reincorporated into the flow of liquid lava. Flowing lavas can also pick up surface rocks and incorporate them into a solidified breccia. In explosive volcanoes, solidified lava may be reshattered numerous times to be reconstituted as breccias.

Flowtop breccia commonly forms at the top of a lava flow where the moving lava picks up loose debris from previous eruptions and flows. It is especially common between basaltic lava flows, which may occur some time apart. Breccias are different from agglomerates (p.284), in which the clasts are rounded.

PROFILE

- ▲ Extrusive
- Pyroclastic accumulation of coarse material
- Less than $\frac{1}{256}$ in (0.1 mm), clasts $\frac{3}{16}$–8 in (0.5–20 cm)
- Igneous rock fragments
- None
- Various

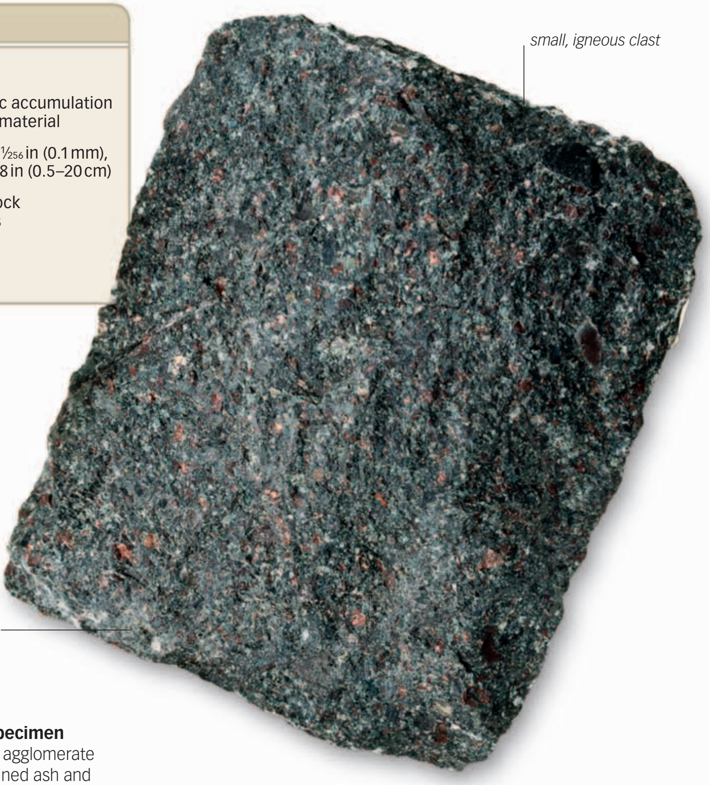

Agglomerate specimen
This specimen of agglomerate contains fine-grained ash and small clasts of other igneous rocks.

VARIANT

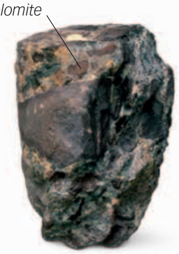

Carbonatite agglomerate
A specimen of carbonatite with clasts of red dolomite

AGGLOMERATE

An agglomerate is a pyroclastic rock in which coarse, rounded clasts up to several inches long are set in a matrix of lava or ash. The clasts are fragments that may be derived from lava, pyroclastic rock, or country rock (the rock that surrounds or lies beneath a volcano). The rounding of the clasts may have occurred either in the magma during eruption or by later sedimentary reworking. The rounded nature of these clasts is the key to designating the rock as an agglomerate rather than as a volcanic breccia (p.283). In a volcanic breccia, most of the clasts are angular.

One type of agglomerate, vent agglomerate, is the rock that plugs either the main vent or a satellite vent of a volcano. The outcrop of this rock is of limited extent and appears circular on a geological map. Like other agglomerates, vent agglomerate contains a variety of clasts of different sizes, shapes, and compositions from the lava, other volcanic rocks, or country rocks. These clasts lie in a matrix of fine-grained igneous rock.

PROFILE

- Extrusive
- Mid-air cooling of masses of silica-poor magma
- ¾ in–3¼ ft (2 cm–1 m)
- Basalt
- None
- Dark shades of red, brown, or green

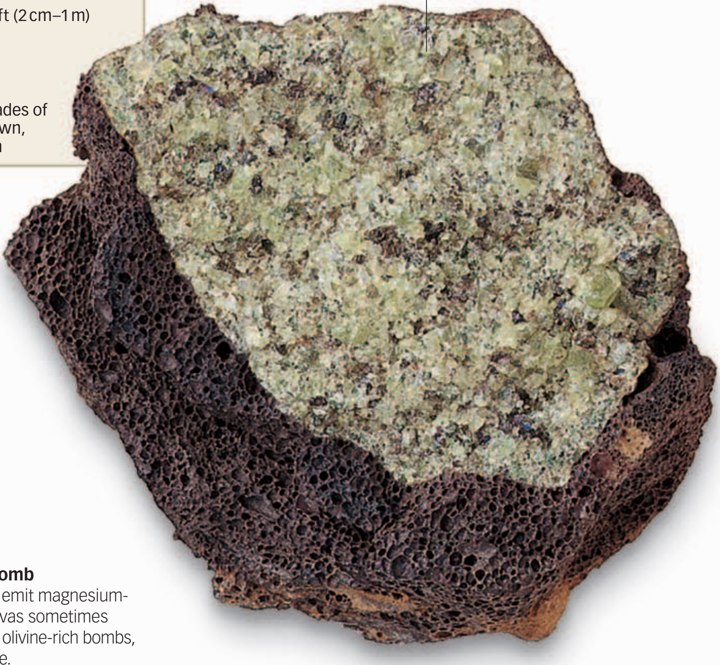

Olivine-rich bomb Volcanoes that emit magnesium- and iron-rich lavas sometimes explosively hurl olivine-rich bombs, such as this one.

VARIANTS

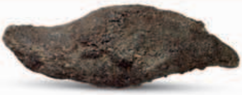

Spindle bomb Lava twisted by aerodynamic forces

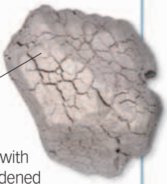

Breadcrust bomb Bomb with crust that hardened before landing

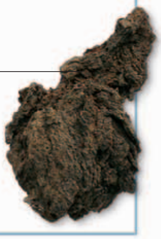

Spiky spindle A spindle bomb violently spun after ejection

VOLCANIC BOMB

Formed by the cooling of a mass of lava while it flies through the air after eruption, a volcanic bomb is a pyroclastic rock. To be called a bomb, a specimen must be larger than 2½ in (6.5 cm) in diameter; smaller specimens are known as lapilli. Specimens up to 20 ft (6 m) in diameter are known. Volcanic bombs are usually brown or red, weathering to a yellow-brown color. Specimens can become rounded as they fly through the air, although they may also be twisted or pointed. They may have a cracked, fine-grained, or glassy surface.

There are several types of volcanic bomb, which are named according to their outward appearance and structure. Spherical bombs are spheres of fluid magma pulled into shape by surface tension. Spindle bombs are formed by the same process as spherical bombs, except that their rotation in flight leaves them elongated. A breadcrust bomb forms if the outside of the lava bomb solidifies during flight and develops a cracked outer surface while the interior continues to expand.

METAMORPHIC ROCKS

Metamorphism occurs when an existing rock is subjected to pressures or temperatures very different from those under which it formed. This causes its atoms and molecules to rearrange themselves into new minerals in the solid state, without melting.

DYNAMIC METAMORPHISM

There are three different ways in which metamorphic rocks are formed. The first of these is dynamic metamorphism. This occurs as a result of large-scale movements in Earth's crust, especially along fault planes and at continental margins where tectonic plates collide. The resulting mechanical deformation produces angular fragments to fine-grained, granulated, or powdered rocks. These rocks are characterized by a foliated appearance, in which mineral grains align as parallel plates.

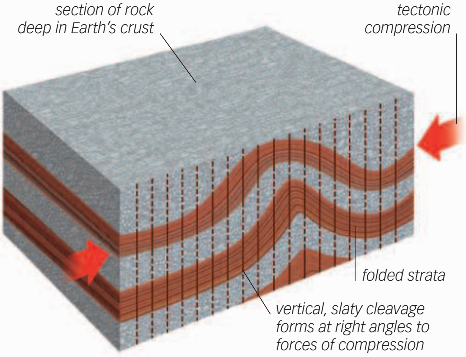
section of rock deep in Earth's crust
tectonic compression
folded strata
vertical, slaty cleavage forms at right angles to forces of compression

Dynamic metamorphism
Tectonic forces transform sedimentary rocks by dynamic metamorphism. Rock strata fold and cleavages develop as minerals align themselves due to the pressure.

REGIONAL METAMORPHISM

The second type of metamorphism is the formation of regional metamorphic rocks. These are associated with mountain building through the collision of tectonic plates. This process increases temperature and pressure over an area of thousands of square miles, producing widespread metamorphism. Important regional metamorphic rocks include slates, schists, and gneisses. Which rock forms depends on the existing rock, the temperatures and pressures to which it is subjected, and the time spent under those conditions. At the extremes, low temperature and pressure produces slates; high temperature and pressure produces gneisses.

Ancient metamorphic rocks
The Elk Mountains in Colorado, USA, have extensive areas of metamorphic rock, including schists and gneisses thought to have metamorphosed 1.7–1.9 billion years ago.

CONTACT METAMORPHISM

The third type of metamorphism is contact metamorphism or thermal metamorphism. This type occurs mainly as a result of increases in temperature, not in pressure. It is common in rocks near an igneous intrusion. Heat from the intrusion alters rocks to produce an "aureole" of metamorphic rock. The rocks nearest the intrusion are subjected to higher temperatures than those farther away, resulting in concentric zones of distinctive metamorphic rocks. The minerals of each zone depend on the original composition of the host rocks.

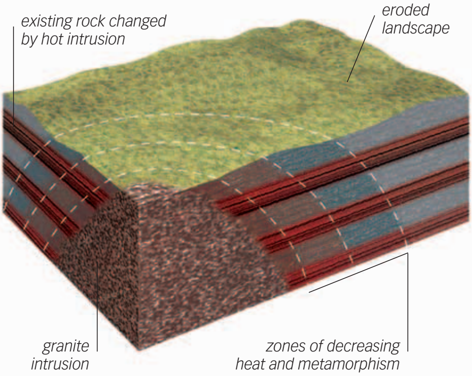
existing rock changed by hot intrusion
eroded landscape
granite intrusion
zones of decreasing heat and metamorphism

Contact metamorphism
A large intrusion of an igneous rock, such as granite, releases heat into the surrounding rocks, altering their mineral content.

CHANGING CHARACTERISTICS

Metamorphism is said to be low grade if it occurs at relatively low temperature and pressure and high grade at the intense end of the temperature and pressure range. The assemblages of minerals in rocks are affected differently depending on the grade of metamorphism and the relative importance of pressure and temperature in the reaction. In some low-grade reactions, the components of existing mineral assemblages are simply redistributed. In other reactions at higher temperatures and pressures, components combine with others present in the rock to form an entirely new set of minerals.

Shale to gneiss
This sequence shows how shale, a sedimentary rock, can be metamorphosed into various other rocks by the application of increasingly high degrees of heat and pressure (from left to right).

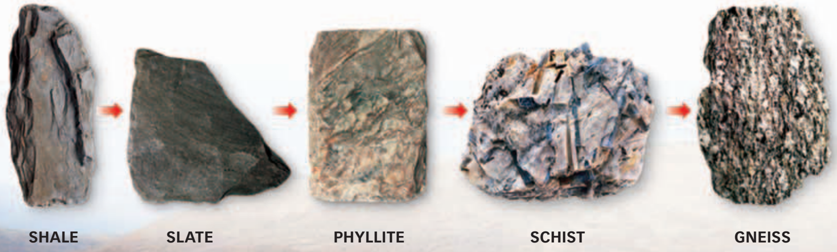

PROFILE

- Regional metamorphic
- High-grade metamorphism of rocks containing quartz and feldspar
- High
- High
- Foliated, crystalline
- 1/16–3/16 in (2–5 mm)
- Quartz, feldspar
- Biotite, hornblende, garnet, staurolite
- Gray, pink, multicolored
- Granodiorite, mudstone granite, shale, siltstone, or felsic volcanics

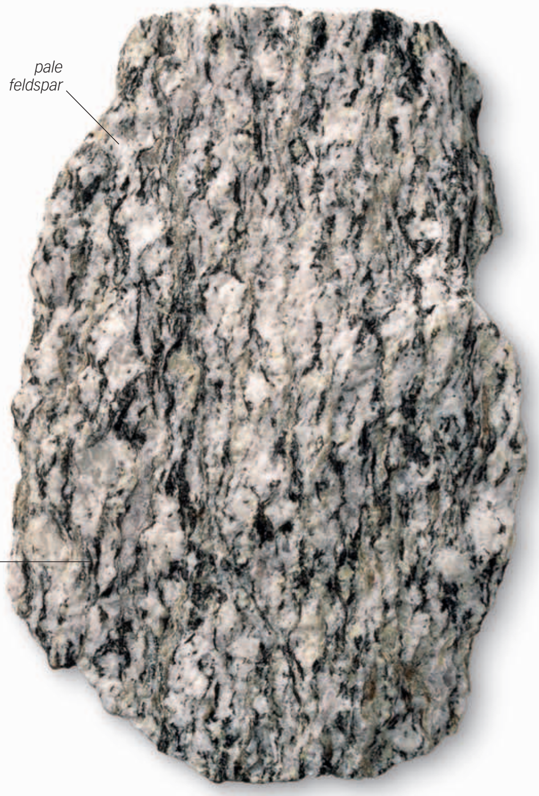

Banded gneiss
This specimen of classic gneiss shows foliated banding of light and dark minerals.

VARIANTS

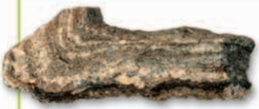

Folded gneiss A specimen with alternating mineral bands and typical folding

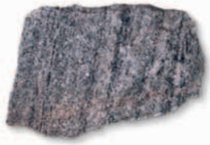

Orthogneiss Gneiss from metamorphosed igneous rocks

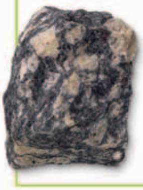

Augen gneiss A specimen with large "eyes" of light-colored feldspar

GNEISS

Distinct bands of minerals of different colors and grain sizes characterize this metamorphic rock. In most gneisses, these bands are folded, although the folds may be too large to see in hand specimens. Gneiss is a medium- to coarse-grained rock. Unlike schist (pp.291–92), its foliation is well developed, but it has little or no tendency to split along planes. Most gneisses contain quartz (p.168) and feldspar (pp.173–81), but neither mineral is necessary for a rock to be called gneiss. Larger crystals of metamorphic minerals, such as garnet, can also be present.

Gneiss makes up the cores of many mountain ranges. It forms from sedimentary or granitic (pp.258–59) rocks at very high pressures and temperatures (1,065°F/575°C or above). A variety called pencil gneiss has rod-shaped individual minerals or mineral aggregates. In augen gneiss, the augens or "eyes" are single-mineral, eye-shaped grains that are larger than other grains in the rock. Orthogneiss is gneiss derived from igneous rock, and paragneiss is gneiss derived from sedimentary rock.

PROFILE

- ▲ Dynamic thrust zones
- 🌐 Stretching of a rock in a large fault
- 🌡 Low
- ☰ Shearing stress
- ▦ Streaked out
- 🔍 Less than 1⁄16 in (2 mm)
- ◧ As surrounding rock
- ◰ As surrounding rock
- ✻ As surrounding rock
- ◀◀ Surrounding rock

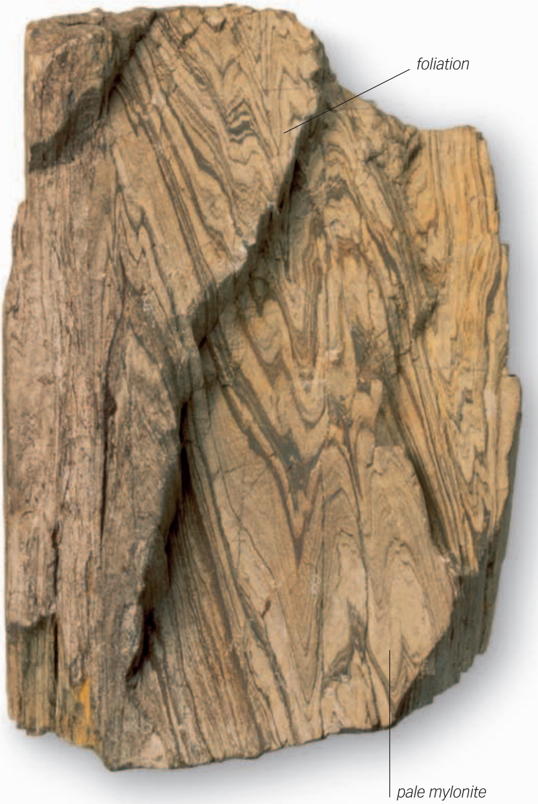

Deformed mylonite
The folded bands in this mylonite specimen indicate that it has been subjected to extreme deformation.

VARIANT

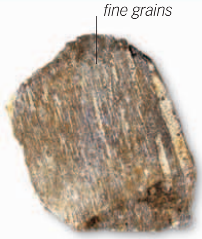

Granular mylonite
A specimen with stretched mineral grains

MYLONITE

The term mylonite refers to fine-grained rocks with streaks or rodlike structures produced by the ductile deformation, or stretching, of mineral grains. This classification is based only on the texture of the rock, and specimens can have different mineral compositions. Mylonite with a large percentage of phyllosilicate minerals, such as chlorite or mica, is known as phyllonite. When mylonite is hard, dark, and so fine that it has the appearance of streaky flint, it is known as ultramylonite. Although generally fine grained, a few mylonites are coarse grained and often sugary in appearance. These are referred to as blastomylonites.

There are many different views on the formation of mylonite. It is typically produced in a zone of thrusts or low-angle faults. Fine-grained mylonites may have been produced by recrystallization under pressure. The fact that mylonite grains are stretched rather than sheared makes it evident that the rock has softened in the metamorphic process.

PROFILE

- Regional metamorphic
- Partial melting of rocks containing quartz and feldspar
- High
- High
- Foliated, crystalline
- $\frac{1}{16}$–$\frac{3}{16}$ in (2–5 mm)
- Quartz, feldspar, mica
- Various
- Banded light and dark gray, pink, white
- Various, including granite

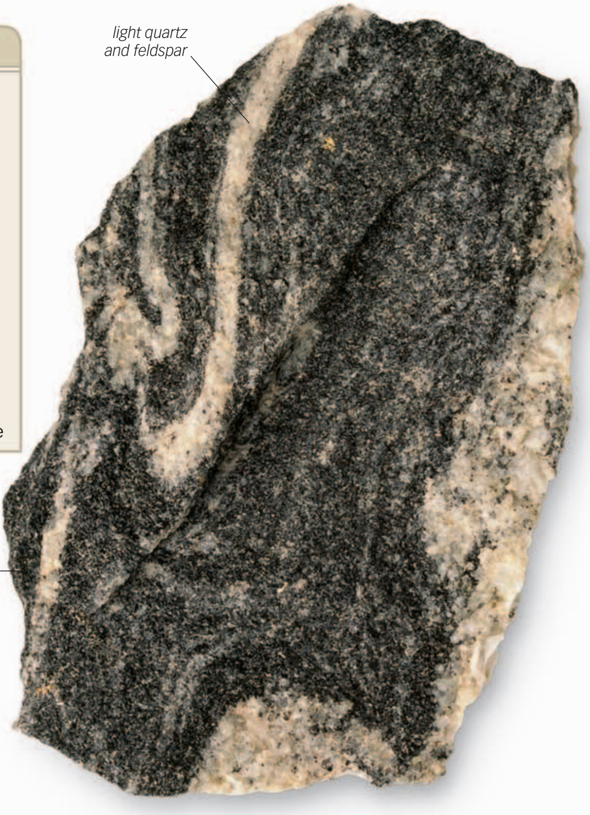

Mixed migmatite The mixing of light igneous and dark metamorphic mineral elements is evident in this specimen of migmatite.

VARIANTS

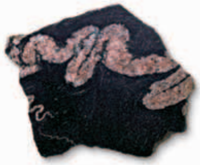

Partial melting Migmatite with a snakelike vein of granite, which indicates partial melting

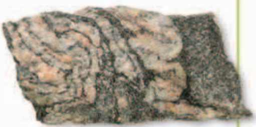

Migmatite folding A specimen of migmatite with distortions produced by extreme temperatures

MIGMATITE

The term migmatite means “mixed rock” and refers to rocks that consist of gneiss (p.288) or schist (pp.291–92) interlayered, streaked, or veined with granite (pp.258–59). The granitic parts consist of granular patches of quartz (p.168) and feldspar (pp.173–81), and the gneissic parts consist of quartz, feldspar, and dark-colored minerals. The granite streaks are a result of the partial melting of the parent rock at temperatures below the melting point of the schist or gneiss. The layering may be tightly folded as a result of softening during heating. Migmatites occur at the borderline between igneous and metamorphic rocks.

The rock forms near large intrusions of granite when some of the magma has intruded into the surrounding metamorphic rocks. Commonly, migmatite occurs within extremely deformed rocks that once formed the bases of eroded mountain chains. It forms deep in the crust at high temperatures (1,065°F/575°C or above) and pressures.

PROFILE

- Regional metamorphic
- Regional metamorphism of fine-grained sediments
- Low to moderate
- Low to moderate
- Foliated
- 1/256–1/16 in (0.1–2 mm)
- Quartz, feldspar, mica
- Garnet, hornblende, actinolite, graphite, kyanite
- Silvery, green, blue
- Mudstone, siltstone, shale, or felsic volcanics

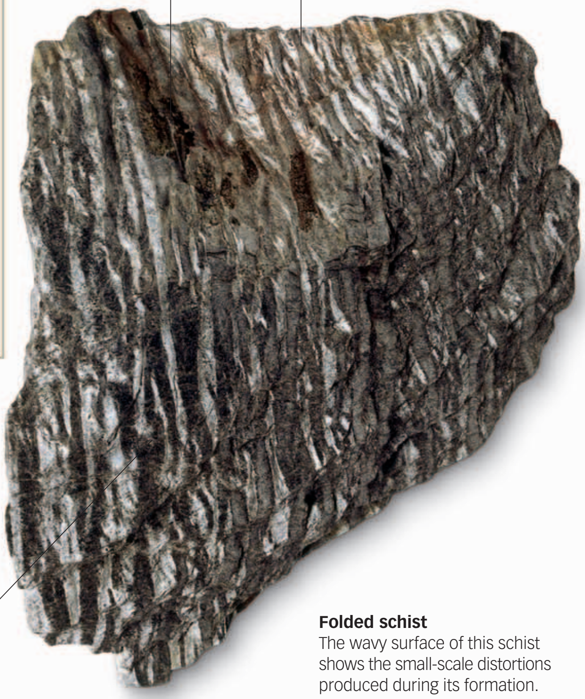

Folded schist The wavy surface of this schist shows the small-scale distortions produced during its formation. It has split along its mica bands.

VARIANTS

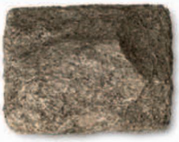

Muscovite schist A specimen of schist dominated by white muscovite mica

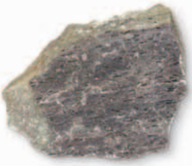

Blue schist Schist colored blue by glaucophane

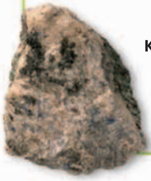

Kyanite schist Small, blue blades of kyanite in schist

SCHIST

This metamorphic rock has a flaky and foliated texture. Specimens have wrinkled, wavy, or irregular sheets as a result of the parallel orientation of the component minerals. Schist shows distinct layering of light- and dark-colored minerals. The mineral assemblage varies, but mica is usually present. Most schists are composed of platy minerals, such as chlorite, graphite (p.46), talc (p.193), muscovite (p.195), and biotite (p.197). The mineral composition of a schist depends on its protolith or original rock and its metamorphic environment. The mineral assemblage can thus be used to determine the metamorphic history of the rock.

Indian schist carving Although its texture and composition are often uneven, schist is sometimes used as a carving material.

PROFILE

- Regional metamorphic
- Medium-grade metamorphism of silica-rich rocks
- Low to moderate
- Moderate
- Foliated
- $\frac{1}{16}$–$\frac{3}{16}$ in (2–5 mm)
- Muscovite, biotite, garnet
- Feldspar, staurolite, sillimanite, kyanite, cordierite
- Light to dark
- Silica-rich rocks

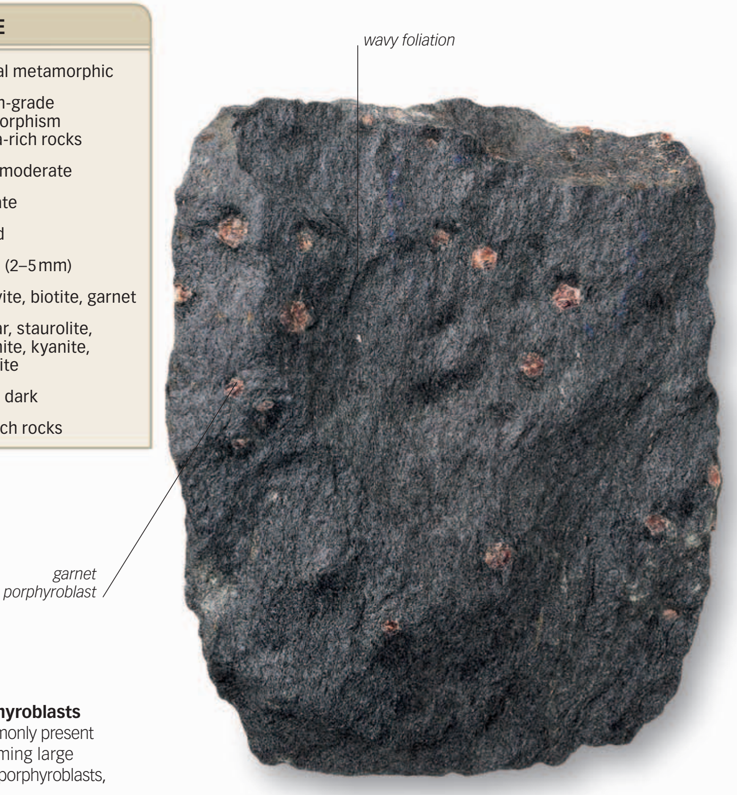

Garnet porphyroblasts Garnet is commonly present in schists, forming large crystals called porphyroblasts, as seen here.

VARIANTS

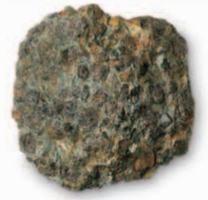

Garnet-chlorite schist Garnet porphyroblasts in chlorite schist

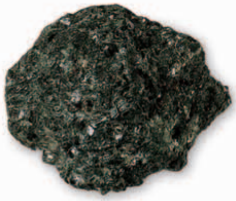

Garnet-muscovite-chlorite schist Garnet porphyroblasts in a specimen of muscovite-chlorite schist

GARNET SCHIST

Like other schists, garnet schist is a metamorphic rock with a characteristic texture: wrinkled, irregular, or wavy as a result of the parallel orientation of its component minerals, such as chlorite, graphite (p.46), talc (p.193), muscovite (p.195), and biotite (p.197). In garnet schist, garnet occurs as porphyroblasts, which are large crystals set in a metamorphic matrix with other smaller crystals. The resulting texture is called porphyroblastic. The equivalent texture in igneous rocks is called porphyritic.

Garnet schist is widespread and usually forms from the metamorphism of fine-grained sediments, especially during the formation of mountains. The mineral assemblage in garnet schist, like in other schists, helps determine both the environment in which the original rock formed and its metamorphic history. Other porphyroblastic schists—such as staurolite schist, corundum schist, kyanite schist, muscovite schist, biotite schist, and schists of other metamorphic minerals—are indicative of other metamorphic histories.

PROFILE

- Regional metamorphic
- Low-grade regional metamorphism of fine-grained sediments
- Low
- Low
- Foliated
- Less than 1/256 in (0.1 mm)
- Quartz, mica, feldspar
- Pyrite, graphite
- Various
- Mudstone, siltstone, shale, or felsic volcanics

Welsh slate This dark gray specimen is from Wales, Britain's principal source of slate. In the USA, slate is quarried in Pennsylvania and Vermont.

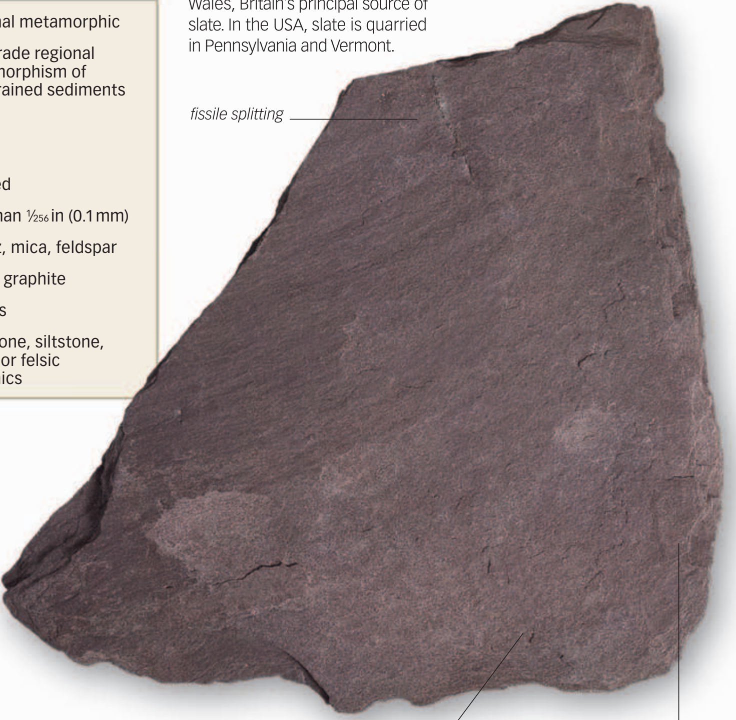

VARIANTS

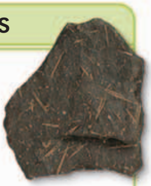

Chiastolite slate High-temperature slate with chiastolite crystals

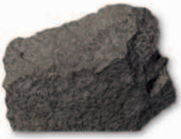

Spotted slate Slate with small aggregates of carbon

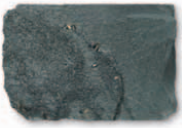

Pyrite Slate with pyrite grains and porphyroblasts

SLATE

A fine-grained metamorphic rock, slate occurs in a number of colors that depend on the minerals in the original sedimentary rock and the oxidation conditions under which that rock formed. Slate has a characteristic cleavage that allows it to be split into relatively thin, flat sheets. This is a result of microscopic mica crystals that have grown oriented in the same plane. True slates split along the foliation planes formed during metamorphism, rather than along the original sedimentary layers.

Slate is common in regionally metamorphosed terrains. It forms when shale (p.313), mudstone (p.316), or volcanic rocks rich in silica are buried as well as subjected to low pressures and temperatures (up to 400°F/200°C). The ability of slate to split into thin sheets makes it ideal as a durable roofing material.

School slate This child's school slate is from Victorian times. In the past, all school "blackboards" were made from slate.

PROFILE

- Regional metamorphic
- Regional metamorphism of fine-grained sediments
- Low to moderate
- Low
- Foliated
- Less than 1/256 in (0.1 mm)
- Quartz, feldspar, chlorite, muscovite mica, graphite
- Tourmaline, andalusite, cordierite, biotite, staurolite
- Silvery to greenish gray
- Mudstone, siltstone, shale, or felsic volcanics

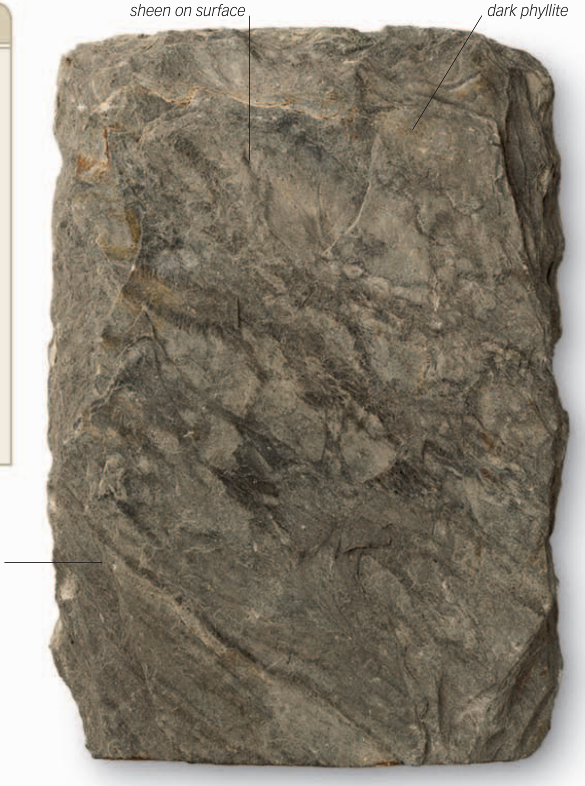

Irregular surface This example of phyllite shows bands of minerals and a cleaved surface that is more irregular than that found in slate.

VARIANTS

Coarse foliation An example of coarsely foliated phyllite

Alternating minerals Phyllite with bands of minerals

Garnet porphyroblasts Small, dark garnets on foliated surface

PHYLLITE

Like slate (p.293), phyllite is a fine-grained metamorphic rock that is usually gray or dark green in color. It has a shinier sheen than slate because of its larger mica crystals. The rock has a tendency to split in the same manner as slate because of a parallel alignment of mica minerals. However, the split surfaces are more irregular than in slate, and phyllite splits into thick slabs rather than thin sheets. Many phyllite specimens have a scattering of large crystals called porphyroblasts, which grow during metamorphism. The rock is often deformed into folds a couple of inches wide and is veined with quartz (p.168). Biotite (p.197), cordierite (p.223), tourmaline (p.224), andalusite (p.236), and staurolite (p.239) are commonly found in phyllite.

This rock occurs in both young and old eroded mountain belts in regionally metamorphosed terrains. It forms when fine-grained sedimentary rocks, such as shales (p.313) or mudstones (p.316), are buried and subjected to relatively low pressures and temperatures (up to 400°F/200°C) for a long period of time.

PROFILE

- Regional metamorphic
- Regional metamorphism of orthoquartzite
- High
- Low to high
- Crystalline
- 1⁄16–3⁄16 in (2–5 mm)
- Quartz
- Mica, kyanite, sillimanite
- Almost any
- Sandstone

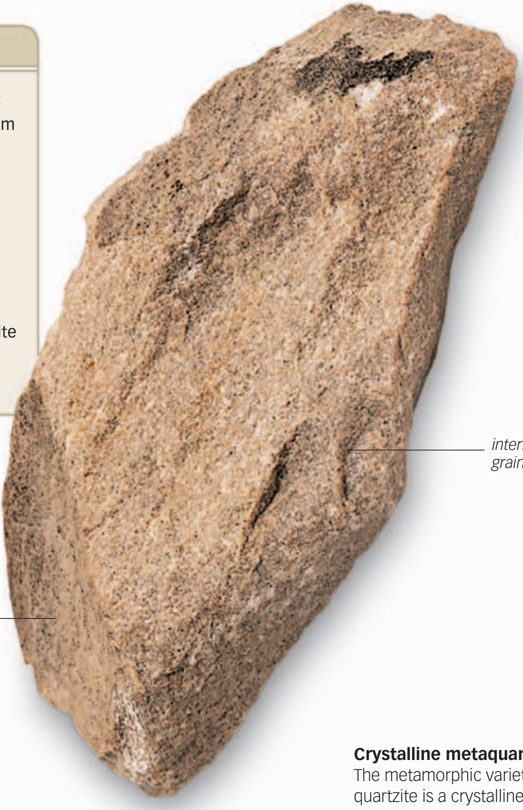

Crystalline metaquartzite The metamorphic variety of quartzite is a crystalline rock with over 90 percent quartz.

QUARTZITE

This quartz-rich metamorphic rock is usually white to gray when pure. Specimens can be various shades of pink, red, yellow, and orange when mineral impurities are present. Quartzite is very hard and brittle and shows conchoidal fracture. It usually contains at least 90 percent quartz (p.168).

Metamorphic quartzite, or metaquartzite, forms when sandstone (p.308) is buried, heated, and squeezed into a solid quartz rock. It is found with other regional metamorphic rocks formed during the shifting of Earth's tectonic plates. Quartzite can also refer to sedimentary sandstone converted to a much denser form through the precipitation of silica cement in pore spaces. The two types of quartzite can be distinguished by examining the grains under a microscope: metamorphic quartzite consists of interlocking crystals of quartz, whereas sedimentary quartzite, or orthoquartzite, contains rounded quartz grains. Crushed quartzite is often used as railroad ballast and in the construction of roads.

VARIANTS

Pale metaquartzite A specimen of metaquartzite with a very high percentage of quartz

Gray metaquartzite A specimen that reflects the color of the original sandstone

PROFILE

- Regional metamorphic
- High-grade metamorphism of silica-poor igneous rocks
- Low to moderate temperatures (up to 1,065°F/575°C)
- Low to moderate
- Foliated, crystalline
- 1⁄16–3⁄16 in (2–5 mm)
- Hornblende, tremolite, actinolite
- Feldspar, calcite, garnet, pyroxene
- Gray, black, greenish
- Basalt, graywacke, dolomite

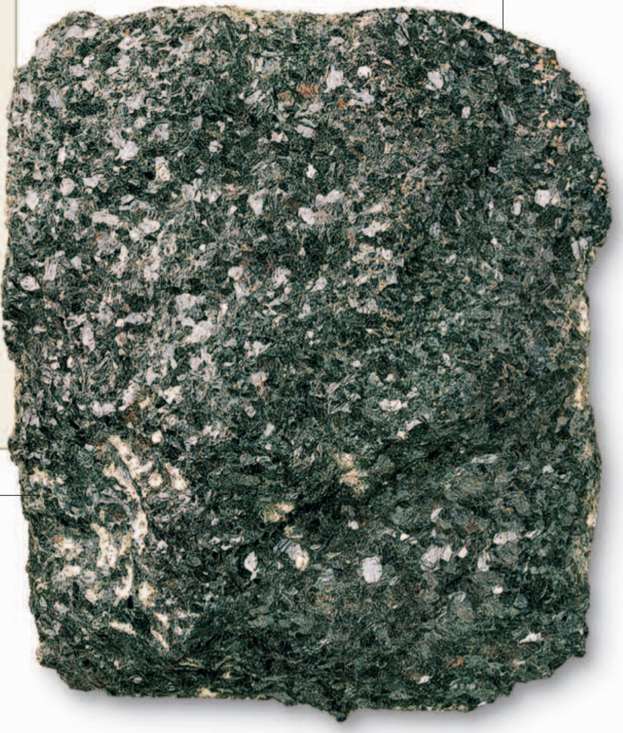

Amphibolite composition Although it comprises mainly amphibole minerals, amphibolite can also contain feldspar, garnet, pyroxene, and epidote.

AMPHIBOLITE

As the name suggests, amphibolites are dark-colored, coarse-grained rocks that are dominated by amphiboles: the black or dark green hornblende (p.218) and the green tremolite (p.219) or actinolite (p.220). Specimens may contain grains of calcite (p.114), feldspar (pp.173–81), and pyroxene and large crystals of minerals such as garnet. Except for garnet, the mineral grains in amphibolite are usually aligned. The rock can also show banding.

Amphibolites form from the metamorphism of iron- and magnesium-rich igneous rocks, such as gabbros (p.265), and from sedimentary rocks, such as graywacke (p.317). They comprise one of the major divisions of metamorphic rocks as classified by their mineral assemblages. These rocks form under conditions of low to moderate pressures and temperatures (up to 1,065°F/575°C). Amphibolites are used in building roads and in other aggregates where high degrees of strength and durability are required.

VARIANTS

Light-colored amphibolite An unusual amphibolite with light-colored minerals present

Hornblende-rich amphibolite A hornblende-rich specimen of amphibolite

Green amphibolite Amphibolite with many garnet porphyroblasts

PROFILE

- Regional metamorphic
- High-grade metamorphism of silica-poor igneous rocks
- High temperatures (1,065°F/575°C or above)
- High
- Crystalline
- 1/16–3/16 in (2–5 mm)
- Feldspar, quartz, garnet, pyroxene
- Spinel, corundum
- Gray, pinkish, brownish, mottled
- Felsic igneous and sedimentary rocks

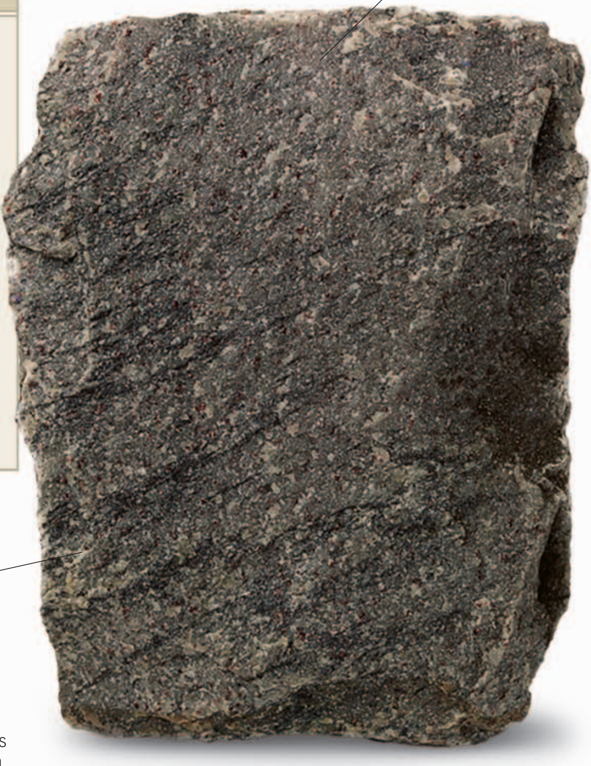

Unfoliated rock Unlike many other regionally metamorphosed rocks, granulite is characterized by a lack of foliation.

GRANULITE

This metamorphic rock is named for its even-grained, granular texture. Specimens are typically tough and massive. Granulite has a high concentration of pyroxene, with diopside (p.210) or hypersthene, garnet, calcium plagioclase, and quartz (p.168) or olivine (p.232). It has nearly the same minerals as gneiss (p.288) but is finer-grained and less perfectly foliated, and has more garnet.

Formed at high pressures and temperatures (1,065°F/575°C or above) deep in Earth's crust, granulites are characteristic of the highest grade of metamorphism. Rocks formed under these conditions belong to a category of metamorphic rocks known as the granulite facies. Mineral groups such as micas and amphiboles cannot survive at the high metamorphic grade under which granulites form and are converted into pyroxenes and garnets. Most granulites date from the Precambrian Age, which ended over 500 million years ago. They are of particular interest to geologists because many of them represent samples of the deep continental crust.

VARIANT

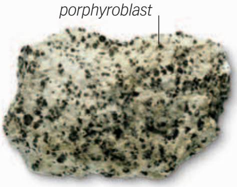

Light-colored granulite This specimen of granulite has numerous porphyroblasts

PROFILE

- Regional
- Water-rich, low-grade metamorphism of olivine-rich rocks
- Low temperatures (up to 400°F/200°C)
- Low
- Nonfoliated
- Less than 1/256 in (0.1 mm)
- Serpentine
- Chromite, magnetite, talc
- Medium to dark
- Olivine-rich igneous rocks

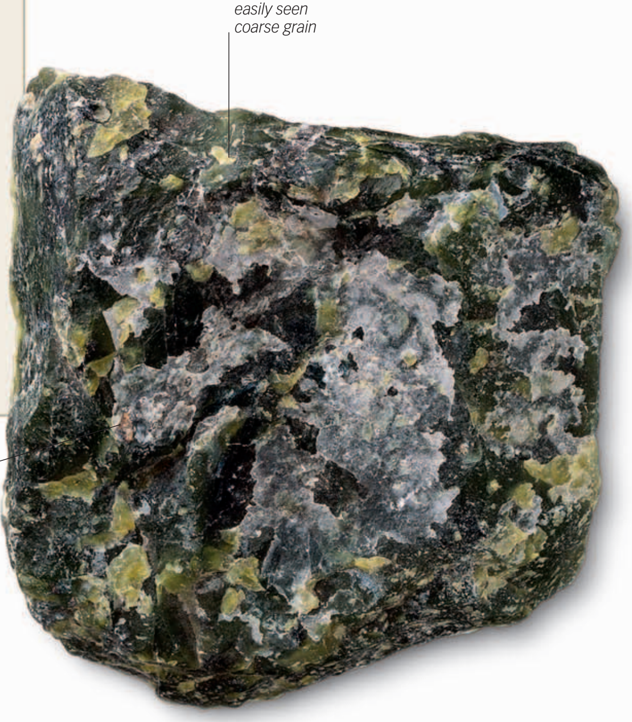

Grainy serpentinite This example of serpentinite clearly shows its fine grains.

VARIANT

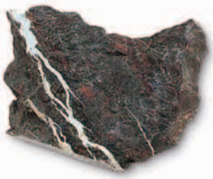

Alpine serpentine Red and green serpentinite streaked with calcite from the Alps

SERPENTINITE

An attractive rock, serpentinite is composed of serpentine (p.191) and other serpentine-group minerals. It commonly has flowing bands of various colors, especially green and yellow. Serpentine minerals form by a metamorphic process called serpentinization that alters olivine and pyroxene-rich, silica-poor igneous rocks. This process occurs at low temperatures (up to 400°F/200°C) and in the presence of water. The original minerals are oxidized to produce serpentine, magnetite (p.92), and brucite (p.105). The degree to which a rock undergoes serpentinization depends on the composition of the parent rock and the mineral composition of its components, especially its olivine (p.232). For example, fayalite-rich olivines serpentinize differently than forsterite-rich olivines.

Serpentinite is used as a decorative stone since it can be easily cut and polished. It is also mixed into concrete aggregate and used as a dry filler in the steel shielding jackets of nuclear reactors.

PROFILE

- Regional
- High-pressure metamorphism of silica-poor igneous rocks
- High temperatures (1,065°F/575°C or above)
- High
- Foliated, crystalline
- 1/16–3/16 in (2–5 mm)
- Pyroxene, garnet
- Kyanite, quartz, olivine, diopside
- Various colors
- Silica-poor igneous rocks

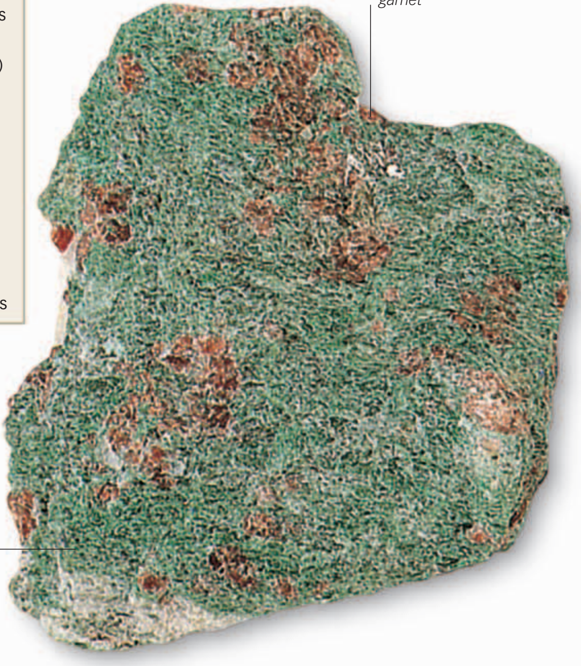

Distributed eclogite grains Eclogites, such as this one with red garnet and green pyroxene, are formed under great pressure, and are thought to originate in the mantle.

ECLOGITE

A rare but important rock, eclogite is formed only by conditions typically found in the mantle or the lowermost and thickest part of the continental crust. Its overall chemical composition is similar to that of igneous basalt (p.273). It is a beautiful, coarse-grained, dense rock of bright red garnet and contrasting bright green omphacite—a pyroxene characteristic of high-temperature metamorphism. Diopside (p.210) and olivine (p.232) are commonly present as well. Eclogite grains may be evenly distributed or banded.

Eclogite forms at very high temperatures (1,065°F/575°C or above) and pressures from silica-poor igneous rocks. Many investigators believe that eclogite is characteristic of a considerable portion of the upper mantle. When brought upward into the crust, eclogites are mainly found as xenoliths (foreign inclusions) in igneous rocks and as isolated blocks up to 330 ft (100 m) wide in other metamorphic rocks. Although rare, diamonds (p.47) may occur in eclogites.

VARIANTS

Mantle rock Eclogite with garnet porphyroblasts

Fine-grained eclogite Garnet- and pyroxene-rich specimen of eclogite

PROFILE

- Regional
- Metamorphism of serpentine in presence of water
- Low temperatures (up to 400°F/200°C)
- Low
- Foliated
- Less than 1/256 in (0.1 mm)
- Talc
- Chlorite, magnesite
- White, green, brown, black
- Serpentine

Soapstone specimen This specimen of soapstone shows the foliation of the original talc.

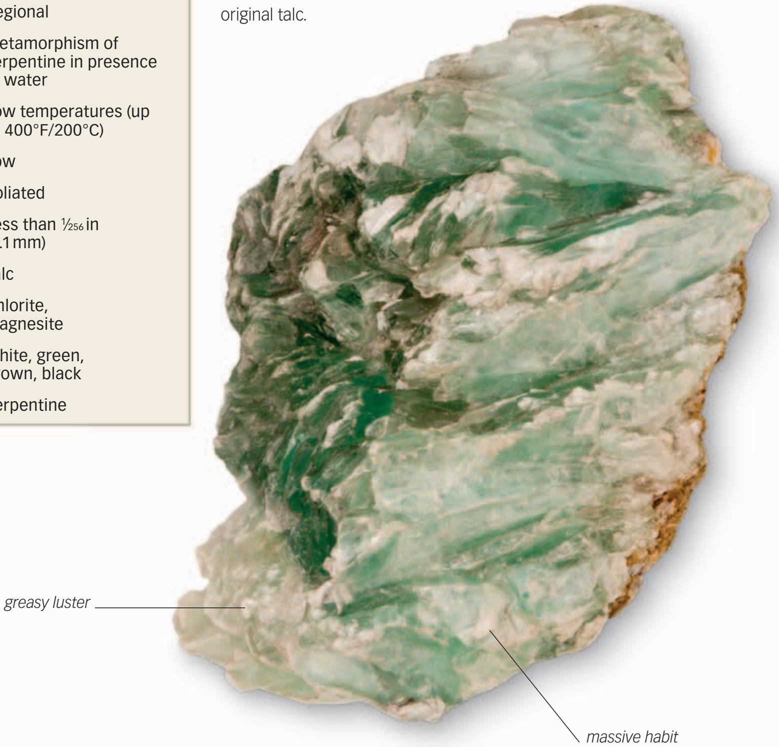

VARIANTS

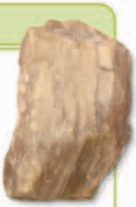

Foliated soapstone Soapstone with visible foliation

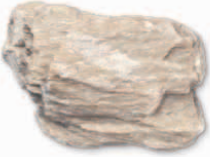

Flaky soapstone Soft soapstone with a flaky surface

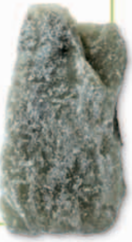

Green soapstone A specimen of soapstone consisting primarily of green talc

SOAPSTONE

Also known as steatite, soapstone is a fine-grained, massive rock. Talc (p.193), one of the softest minerals, is its principal component. Soapstone specimens are easily recognized by their softness: they have a greasy feel and can be scratched with a fingernail. Soapstone may also contain varying amounts of amphiboles, such as anthophyllite (p.216) and tremolite (p.219), and chlorites. Specimens can be green, brown, or black when polished, but they become white when scratched.

Soapstone is found associated with other metamorphosed silica-poor igneous rocks, such as serpentinite (p.298). It is used in fireplace surrounds because it absorbs and distributes heat evenly. It is also carved into molds for soft-metal casting.

Lion dog seal Soapstone, such as that used in this Chinese seal, has been used to carve ornaments for millennia.

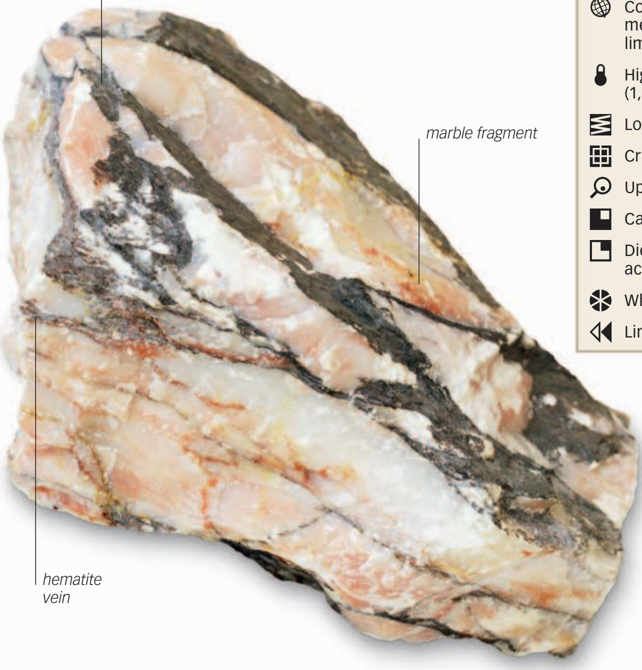

Marble breccia This specimen of marble has been cracked and shattered, the veins infilled, and fragments recemented with iron- and calcium-rich cement.

PROFILE

- Regional or contact metamorphic
- Contact or regional metamorphism of limestone or dolomite
- High temperatures (1,065°F/575°C or above)
- Low to high
- Crystalline
- Up to ¾ in (2 cm)
- Calcite
- Diopside, tremolite, actinolite, dolomite
- White, pink
- Limestone, dolomite

MARBLE

A granular metamorphic rock, marble is derived from limestone (p.319) or dolomite (p.320). It consists of a mass of interlocking grains of calcite (p.114) or the mineral dolomite (p.117).

Marbles form when limestone buried deep in the older layers of Earth's crust is subjected to heat and pressure from thick layers of overlying sediments. It may also form as a result of contact metamorphism near igneous intrusions. Impurities in the limestone can recrystallize during metamorphism, resulting in mineral impurities in the marble, most commonly graphite (p.46), pyrite (p.62), quartz (p.168), mica, and iron oxides. In sufficient amounts, these can affect the texture and color of the marble.

Taj Mahal, India The Taj Mahal is built of Makrana—a white marble that changes hue with the angle of the light.

VARIANTS

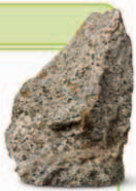

Olivine marble Marble with small crystals of olivine

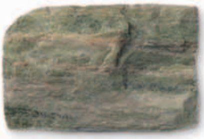

Green marble A specimen of marble colored by green silicate minerals

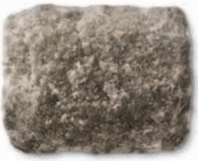

Gray marble Marble from relatively pure limestone

PROFILE

Contact

Contact metamorphism of limestone

High temperatures (1,065°F/575°C or above)

Low

Crystalline

1⁄256–3⁄4 in (0.1–20 mm)

Calcite

Garnet, serpentine, forsterite, vesuvianite

Variegated

Limestone, dolomite

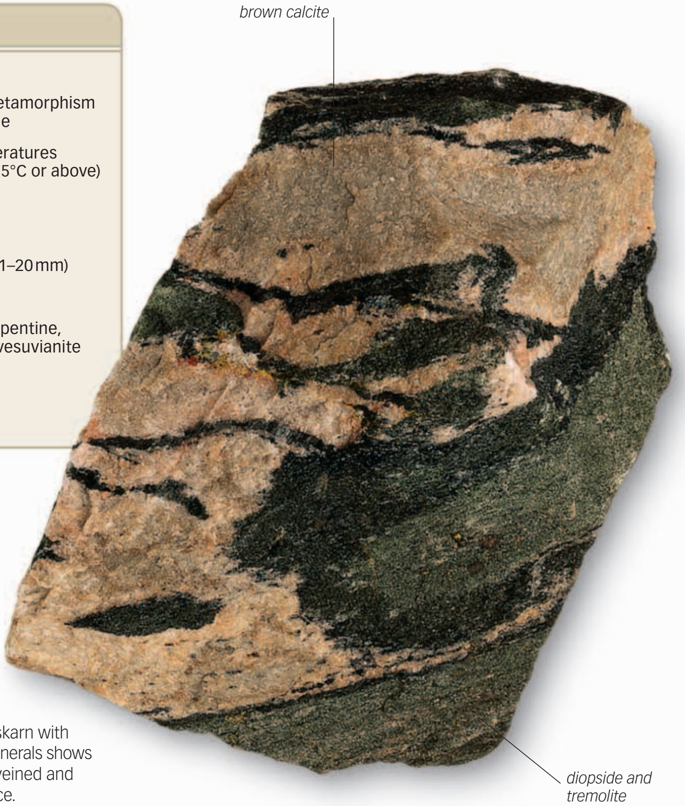

Skarn specimen This specimen of skarn with calcite and dark minerals shows the rock's typical veined and banded appearance.

VARIANT

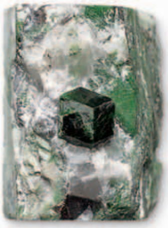

Garnet in skarn A uvarovite garnet porphyroblast in a skarn matrix

SKARN

This rock is a product of the contact metamorphism of limestone (p.319) or dolomite (p.320) by an igneous intrusion, often granite (pp.258–59), with an intermediate or high silica content. Hot waters derived from the granitic magma are rich in silica, iron, aluminum, sulfur, and magnesium. When limestone or dolomite is invaded by this high-temperature hydrothermal solution, the carbonate minerals calcite (p.114) and dolomite react strongly with the slightly acid solution. The elements carried in the solutions combine with the calcium and magnesium in the parent rock to form silicate minerals, such as diopside (p.210), tremolite (p.219), and andradite. The resulting rock is usually a highly complex combination of calcium-, magnesium-, and carbonate-rich minerals.

Skarn minerals can be fine- to medium-grained. They also occur as coarse, radiating crystals or bands. Some skarns are rich in metallic ores and form valuable deposits of metals, including gold (p.42), copper, iron, tin, lead, molybdenum, and zinc.

PROFILE

Contact metamorphic

Contact metamorphism of fine-grained sediment

Moderate to high temperatures (400°F/200°C or above)

Low to high

Crystalline

Less than 1⁄256 in (0.1 mm)

Hornblende, plagioclase, andalusite, cordierite, and others

Magnetite, apatite, titanite

Dark gray, brown, greenish, reddish

Almost any rock

dark, pyroxene crystals

Pyroxene hornfels In this specimen of hornfels, dark porphyroblasts of pyroxene can be seen.

VARIANTS

Garnet hornfels A specimen colored red by garnet crystals

Cordierite hornfels Hornfels with small grains of cordierite, quartz, and mica

Chiastolite hornfels Hornfels with elongated porphyroblasts of chiastolite (andalusite)

HORNFELS

Formed by contact metamorphism close to igneous intrusions at temperatures as high as 1,300°–1,450°F (700°–800°C), hornfels can form from almost any parent rock and is notoriously difficult to identify. Its composition depends on the parent rock and the exact temperatures and fluids to which the rock is exposed. Specimens are usually dense, hard, and hard to break. They are fine-grained and relatively homogeneous, with a conchoidal, flintlike fracture. The rock may sometimes appear glassy. The color is usually even throughout, although specimens may also be banded.

Hornfels is often categorized by the mix of minerals present in the specimen. Garnet hornfels, for example, is characterized by large crystals of garnet set into a rock matrix. Cordierite hornfels contains large crystals of cordierite (p.223) that can be up to several inches in diameter. An outcrop of hornfels rarely extends more than a few yards from the contact and may pass outward into spotted slate.

SEDIMENTARY ROCKS

Sedimentary rocks are formed at or near Earth's surface either by accumulation of grains or by precipitation of dissolved material. These rocks make up the majority of the rock exposed at Earth's surface, but are only about 8 percent of the volume of the entire crust.

LITHIFICATION

The transformation of loose grains of sediment into clastic sedimentary rock is known as lithification. The grains are often bound together by a cementing agent, which is generally precipitated from solutions that filter through the sediment. In some cases, the cementing agent is created at least in part by the breakdown of some rock particles of the sediment itself. The most common cement is silica (usually quartz), but calcite and other carbonates as well as iron oxides, barite, anhydrite, zeolites, and clay minerals also form cements. The cementing agent becomes an integral and important part of the sedimentary rock once it is formed. In some cases, clastic sedimentary rocks (see opposite) can also be formed by simple compaction—a process in which the grains bind together under extreme pressure.

Lithification can sometimes take place almost immediately after the grains have been deposited as sediment. In other cases, hundreds or even millions of years may pass by before lithification occurs. At any given time, there are large amounts of rock fragments that have been produced by weathering but have not been lithified and simply exist as a form of sediment.

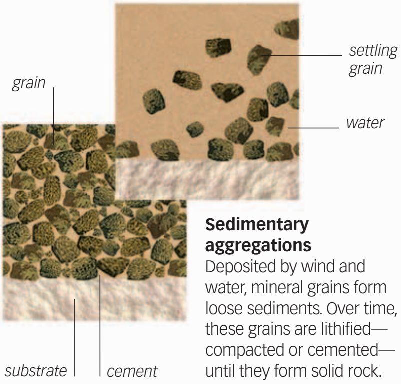
grain
settling grain
water
substrate
cement

Sedimentary aggregations
Deposited by wind and water, mineral grains form loose sediments. Over time, these grains are lithified—compacted or cemented—until they form solid rock.

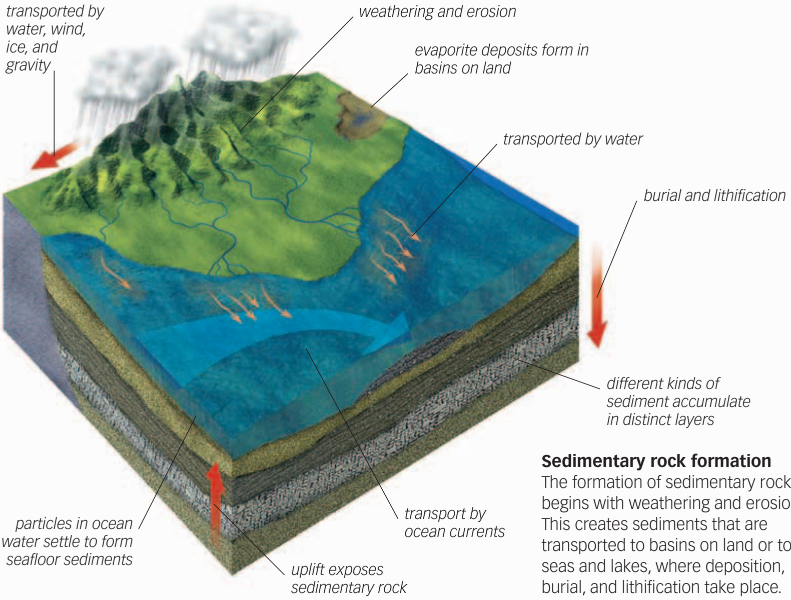
transported by water, wind, ice, and gravity
weathering and erosion
evaporite deposits form in basins on land
transported by water
burial and lithification
different kinds of sediment accumulate in distinct layers
particles in ocean water settle to form seafloor sediments
transport by ocean currents
uplift exposes sedimentary rock

Sedimentary rock formation
The formation of sedimentary rocks begins with weathering and erosion. This creates sediments that are transported to basins on land or to seas and lakes, where deposition, burial, and lithification take place.

CLASTIC ROCKS

Clasts are rock fragments ranging in size from boulders to microscopic particles. Clastic sedimentary rocks are grouped according to the size of the clasts from which they form. Larger clasts such as pebbles, cobbles, and boulder-sized gravels form conglomerate and breccia; sand becomes sandstone; and finer silt and clay particles form siltstone, mudstone, and shale. The mineral composition of clastic rocks can be subject to considerable change over time.

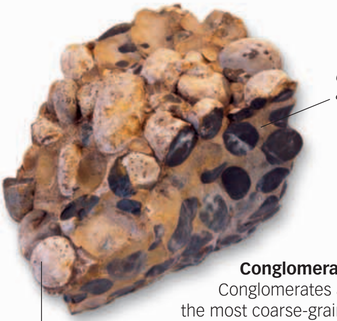

Conglomerate
Conglomerates are the most coarse-grained sedimentary rocks. They consist of pebble-sized or larger grains, bound together by a cementing matrix.

CHEMICAL ROCKS

Chemical sedimentary rocks are formed by the precipitation of the transported, dissolved products of chemical weathering. In some cases, the dissolved constituents are directly precipitated as solid rock. Examples include banded iron formations, some limestones, and bedded evaporite deposits—rocks and mineral deposits of soluble salts resulting from the evaporation of water. In other sedimentary rocks, such as limestone and chert, solid material first precipitates into particles or becomes the shells of organisms, which are then deposited and lithified.

White Cliffs of Dover
Located near the town of Dover in Kent, England, the celebrated White Cliffs of Dover are spectacular deposits of chalk many feet thick.

FOSSILS

A fossil is a remnant, impression, or trace of an organism that lived in a past geologic age. Fossils are preserved almost exclusively in sedimentary rocks. The most common fossils are of aquatic plants and animals. After an organism dies, the soft parts decompose, leaving behind only the hard parts—the shell, teeth, bones, or wood. Buried in layers of sediment, the hard parts gradually turn to stone. In a process known as permineralization, water seeps through the rock, depositing mineral salts in the pores of the shell or bone, thereby fossilizing the remains. In some cases, the organic matter is completely replaced by minerals as it decays. In other cases, circulating acid solutions dissolve the original shell or bone, leaving a cavity of identical shape, which is filled in as new material is deposited in the cavity, creating a cast.

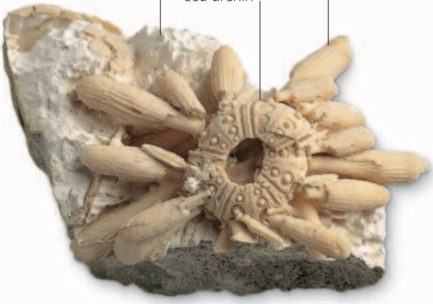

Fossil in chalk
Large sea urchin fossils, such as this well-preserved example, are usually found in chalk, which is itself made up of the fossils of tiny marine organisms.

PROFILE

- Detrital, from pebbles
- Marine, freshwater, glacial
- 1⁄16 in (2 mm) to several in (cm) in finer matrix
- Any hard mineral can be present
- Any mineral can be present
- Varies
- Very rare

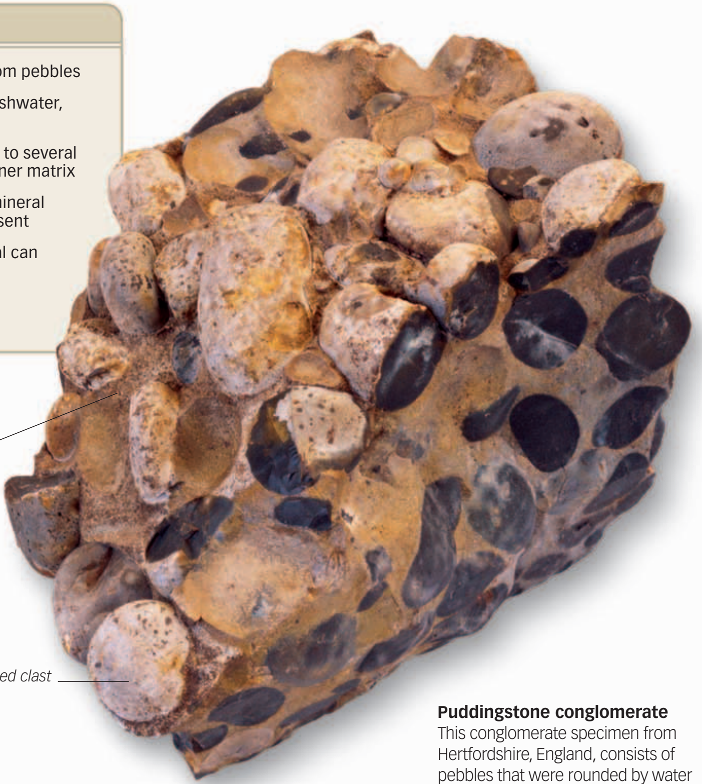

Puddingstone conglomerate
This conglomerate specimen from Hertfordshire, England, consists of pebbles that were rounded by water and then cemented together.

VARIANTS

Quartz conglomerate
A specimen with large clasts of quartz

Polygenetic conglomerate
A specimen with clasts of various rock types

alluvial diamond

Alluvial diamond
A diamond cemented into a conglomerate

CONGLOMERATE

Rocks formed by the lithification of rounded rock fragments that are over 1⁄16 in (2 mm) in diameter are known as conglomerates. They can be further classified by the average size of their constituent materials—pebble-conglomerate (fine), cobble-conglomerate (medium), and boulder-conglomerate (coarse). Conglomerate can also be known by the rock or mineral fragments in its composition; for example, a quartz pebble conglomerate.

Depending on the environment in which these fragments are deposited, these rocks may be of two types. Well-sorted conglomerates result from water flow over a long period. These have well-sorted pebbles (with a small size variation) generally of only one rock or mineral type, and a few small particles between the pebbles. Poorly sorted conglomerates form from rapid water flow and deposition. They have poorly sorted pebbles (of varying sizes) of mixed rock and mineral types with a number of small particles between the pebbles.

PROFILE

- Detrital, from coarse sediment
- Marine, freshwater, glacial
- 1⁄16 in (2 mm) to 1 in (several cm) in finer matrix
- Any hard mineral can be present
- Any mineral can be present
- Varies
- Very rare

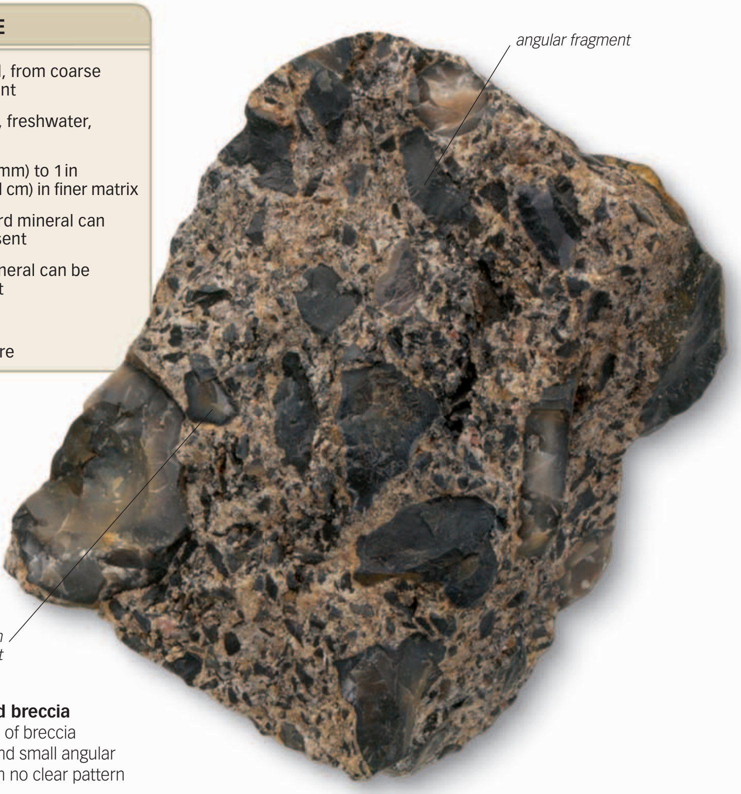

Poorly sorted breccia This specimen of breccia shows large and small angular fragments with no clear pattern of orientation.

VARIANTS

Limestone breccia Fragments of limestone in breccia

Polygenetic breccia A specimen with clasts of different types of rock

Fault breccia Cemented clasts shattered by faulting

BRECCIA

Lithified sediments with rock fragments that are more than 1⁄16 in (2 mm) in diameter but angular or only slightly rounded are called breccias. The lack of rounding indicates that little or no transportation took place before the fragments became incorporated in the rock.

Breccias can form in several ways. Rocks can shatter—for example, due to frost action or earth movement—and the fragments then become cemented in the new position. Shattered fragments may also move before being cemented—for example, they may accumulate at the base of a cliff or be carried by a flash flood. Breccias can also form in areas of active faulting. In areas where faulting occurs underwater, newly shattered material can also move in underwater landslides and become cemented to form breccia.

Breccia vase This ancient Egyptian carved vase made of breccia or mottle stone was used to store liquids.

PROFILE

- Detrital, from sand
- Terrestrial
- 1/256–1/16 in (0.1–2 mm)
- Quartz, feldspar
- Silica, calcium carbonate
- Cream to red
- Vertebrates, invertebrates, plants

Structure in sandstone This sandstone from Yorkshire, England, is derived from deposits of wind-blown sand. The bedding planes, which slumped after deposition, are well preserved.

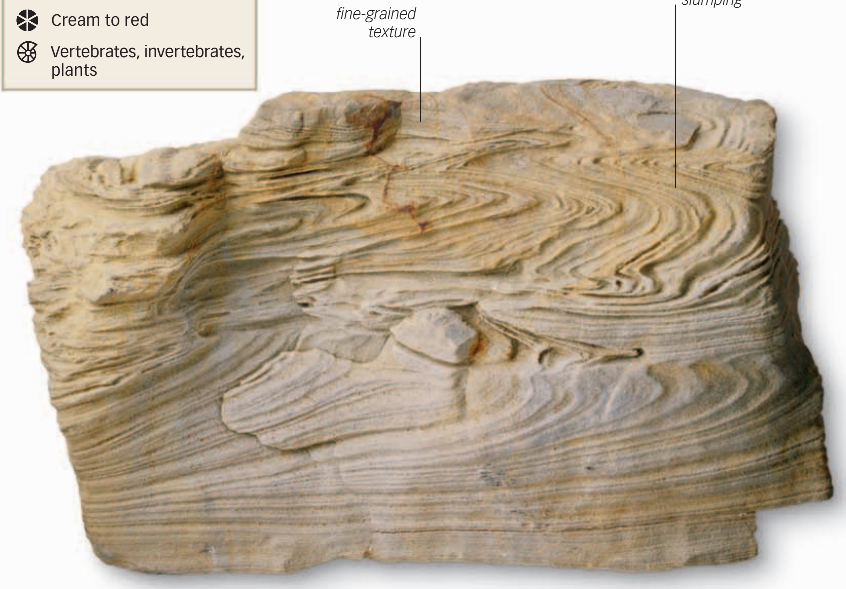

VARIANTS

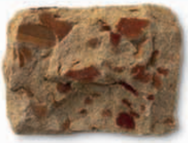

Micaceous sandstone A specimen with flakes of mica and patches of iron oxide

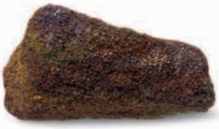

Goethite sandstone Sand grains with red goethite

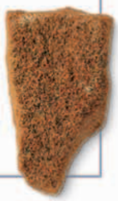

Red sandstone A specimen of quartz sandstone colored red due to the presence of iron oxides

SANDSTONE

The second most abundant sedimentary rock after shale (p.313), sandstone makes up about 10 to 20 percent of the sedimentary rocks in Earth's crust. Sandstones are classified according to texture and mineralogical properties into micaceous sandstone, orthoquartzite (p.310), and graywacke (p.317). They are usually dominated by quartz (p.168) and have visible sandy grains and other minerals present in varying amounts. Well-rounded grains are typical of desert sandstone, while river sands are usually angular, and beach sands somewhere in between.

Bedding is often visible in sandstones as a series of layers representing successive deposits of grains. Bedding surfaces may show either ripples or the cross bedding typical of dunes. Sandstone is an important indicator of deposition and erosion processes.

Sandstone platform This platform in the center of the courtyard pool at Fatehpur Sikri, India, is made from red sandstone.

Marine greensand
This specimen is from the Atlantic coastal plain of North America, where greensand is a common type of rock.

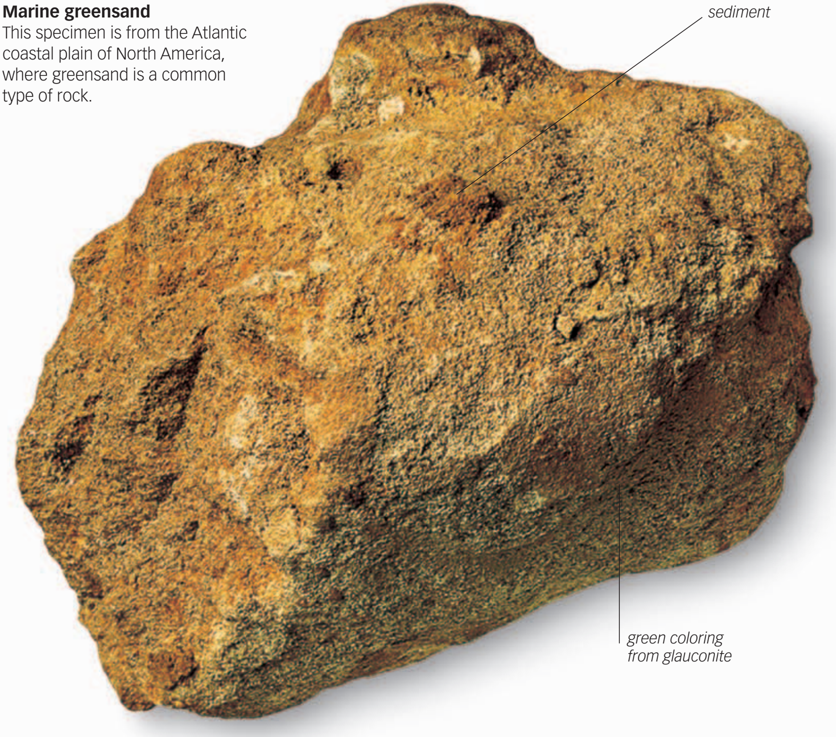

well-sorted sediment

green coloring from glauconite

PROFILE

- Detrital, from glauconite-rich marine sand
- Marine
- 1/256–1/16 in (0.1–2 mm)
- Quartz, glauconite
- Feldspar, mica
- Green
- Vertebrates, invertebrates, plants

VARIANT

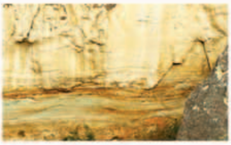

Greensand banding
A band of greensand within a rock outcrop

GREENSAND

A quartz sandstone with a high percentage of the green mica mineral glauconite (p.196) is known as greensand or glauconitic sandstone. The term glauconite is also loosely applied to any glauconitic sediment. Glauconite is believed to form in shallow, oxygen-poor marine environments that are rich in organic detritus. It forms as a result of a slow accumulation of sediments, by the replacement of calcite (p.114), or by primary deposition. It may contain shell fragments and larger fossils. Some glauconite pellets are biogenic, originating as fecal pellets.

Greensand tends to be weak and friable, although relatively hard greensand has been used as building stone. The soil derived from greensand varies, ranging from fertile to sterile. Glauconite is favored in organic cultivation as a natural source of potassium and phosphorus. Its potassium content is useful in radiometric age-dating. Due to its chemical-exchange properties, the glauconite in greensand is used as a water softener and in water-treatment systems.

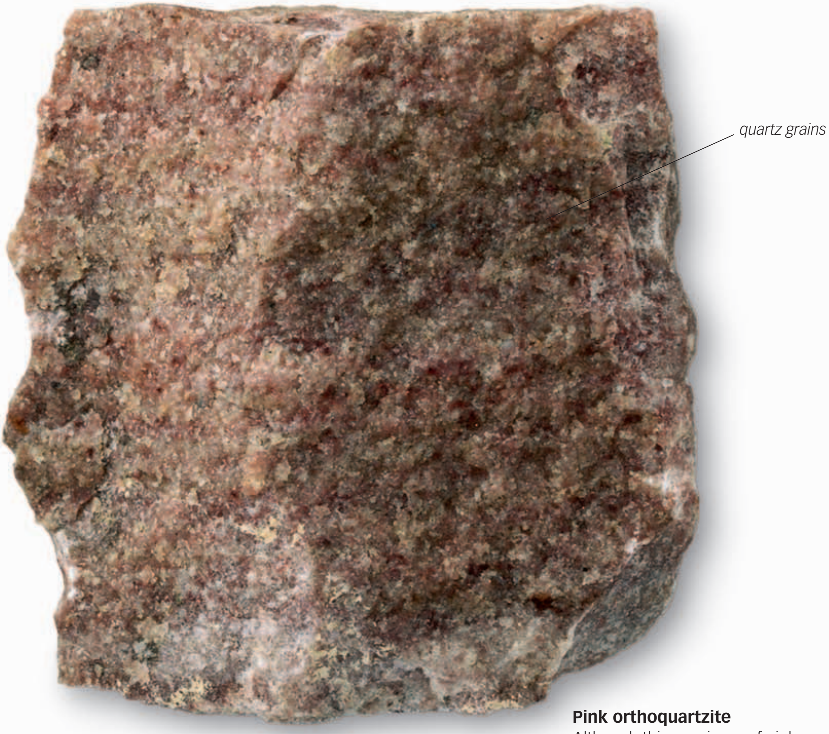

Pink orthoquartzite
Although this specimen of pink orthoquartzite is composed almost entirely of quartz, it is colored by small amounts of iron oxide.

ORTHOQUARTZITE

A pure quartz sandstone, orthoquartzite is usually composed of well-rounded quartz (p.168) grains cemented by silica. The high degree of rounding of the grains indicates that they have traveled some distance, which also accounts for the high degree of sorting. Some orthoquartzites are up to 99 percent quartz, with only minor amounts of iron oxide and traces of other erosion-resistant minerals, such as rutile (p.78), magnetite (p.92), and zircon (p.233). Lesser amounts of other minerals can color the generally white or pinkish specimens either gray or red. Orthoquartzites can be differentiated in hand specimens from other sandstones by their lighter color and absence of other minerals.

Orthoquartzites rarely preserve fossils, although the sedimentary structures are usually preserved. The presence of silica cement makes orthoquartzites durable. They tend to resist weathering and form prominent outcrops. Orthoquartzite is distinct from metamorphic quartzite, also known as metaquartzite (p.295).

PROFILE

- Detrital
- Terrestrial
- 1/256–1/16 in (0.1–2 mm)
- Quartz
- Heavy minerals, such as zircon and rutile
- Light to medium
- Rare, vertebrates

VARIANT

Gray orthoquartzite
A specimen colored gray by quartz grains

Gray arkose
Darker variants of arkose, such as this specimen, tend to be older than pink arkose.

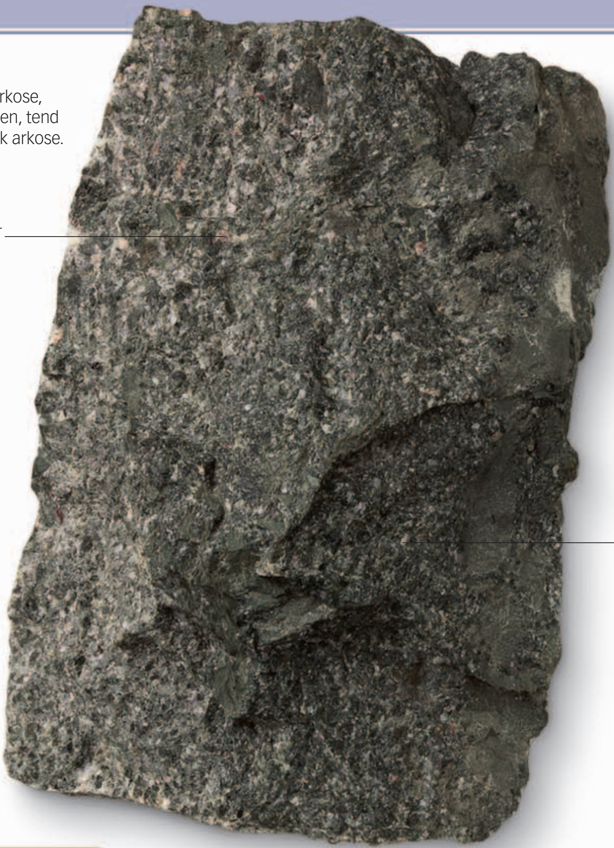

PROFILE

- Detrital, from feldspar-rich sand
- Terrestrial, marine, or freshwater
- 1/256–1/16 in (0.1–2 mm)
- Quartz, feldspar
- Mica
- Pinkish, pale gray
- Rare

VARIANT

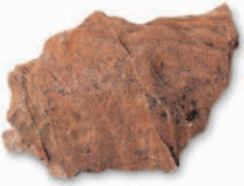

Pink arkose A variant of arkose formed more recently than gray arkose

ARKOSE

A pink sandstone, arkose is colored by an abundance of feldspars (pp.173–81), especially pink alkali feldspars. Its high feldspar content (more than 25 percent of the sand grains) sets it apart from other sandstones. Arkose specimens are relatively coarse and consist primarily of quartz (p.168) and feldspar grains, with small amounts of mica. The grains tend to be moderately well sorted and angular or slightly rounded. They are usually cemented with calcite (p.114) or sometimes with iron oxides or silica. The flat cleavage faces and angular grain shape of the feldspars reflect light under a hand lens. Sandstones with a feldspar content of 5–25 percent are called subarkoses.

Arkose forms from the quick deposition of sand weathered from granites (pp.258–59) and gneisses (p.288). The development of arkoses is thought to indicate either a climatic extreme or a rapid uplift and high relief of the source area. Arkoses are common along the front ranges of the Rocky Mountains.

PROFILE

Detrital, from grit
Freshwater
1/32–3/16 in (1–4 mm)
Quartz, feldspar
Garnet, rutile
White, pink, gray
Invertebrates, vertebrates, plants

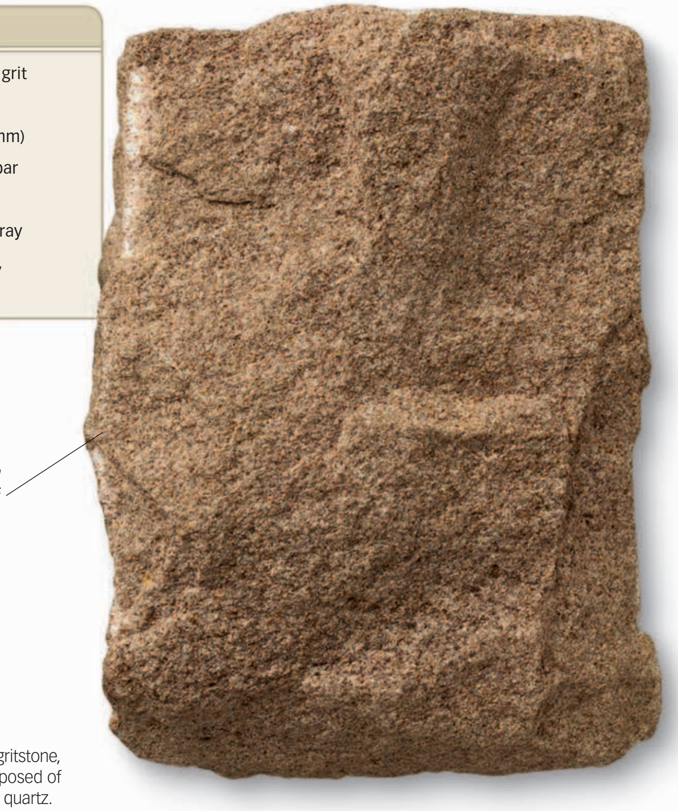

Quartz gritstone
Specimens of quartz gritstone, such as this, are composed of more than 75 percent quartz.

VARIANT

Feldspathic gritstone
A variant containing up to 25 percent feldspar

GRITSTONE

Providing material for grindstones and millstones, gritstone has, in the past, been a commercially important sedimentary rock. It is a porous rock composed of cemented, coarse, often angular sand grains, with occasional small pebbles. Quartz (p.168) is always the greatest component, but specimens often contain iron oxides that give them a yellow, brown, or red color. In some, the grains can be easily rubbed out; in others, strong cement makes the rock suitable for use as grinding stones.

Gritstones originate in river deposits and frequently show signs of cross-bedding or current bedding. The Millstone Grit, a gritstone deposit in northern England, was mined for millstones used in flour mills and for grindstones, which were used to make paper pulp from wood and sharpen tools. Gritstone is still quarried for use as building material worldwide. Large exposures of gritstone are favored by rock climbers because the rough surface provides outstanding friction, enabling them to grip the smallest features in the rock.

Gray shale
This specimen of shale from Runswick Bay, Yorkshire, England contains fossils of bivalves and ammonites.

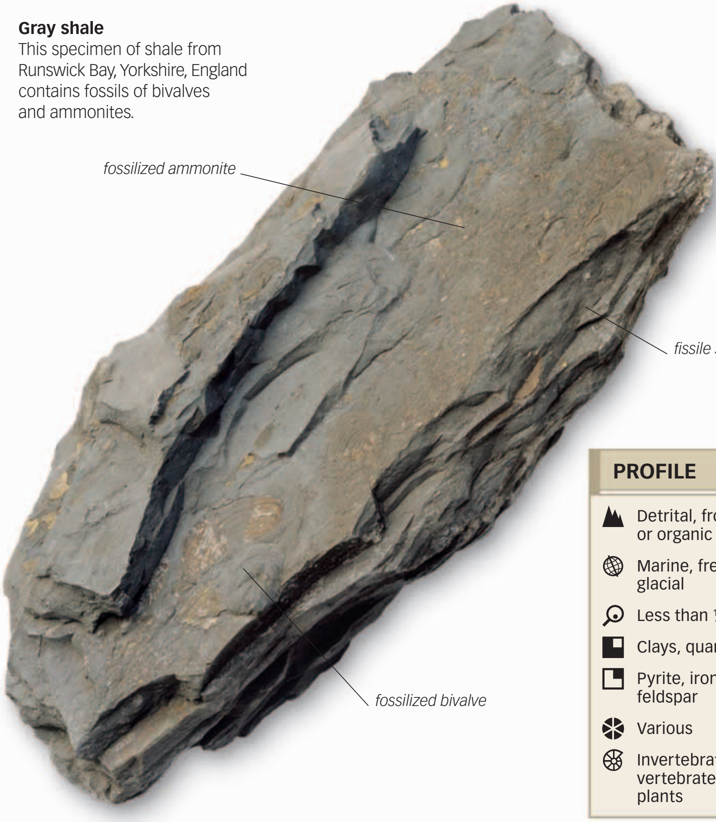

PROFILE

- Detrital, from mud, clay, or organic material
- Marine, freshwater, glacial
- Less than $\frac{1}{256}$ in (0.1 mm)
- Clays, quartz, calcite
- Pyrite, iron oxides, feldspar
- Various
- Invertebrates, vertebrates, plants

VARIANTS

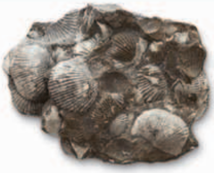

Fossiliferous shale Shale with numerous fossils of brachiopods

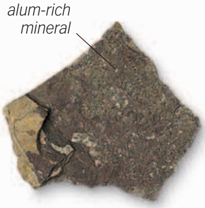

Light-colored shale
A specimen with alum-rich, light-colored areas

SHALE

The most abundant sedimentary rock, shale makes up about 70 percent of all sedimentary rocks in Earth's crust. It consists of a high percentage of clay minerals, substantial amounts of quartz (p.168), and smaller amounts of carbonates (pp.114–25), feldspars (pp.173–81), iron oxides, fossils, and organic matter. Shales are colored reddish and purple by hematite (p.91) and goethite (p.102); blue, green, and black by ferrous iron; and gray or yellowish by calcite (p.114). They split easily into thin layers.

Shales consists of silt- and clay-sized particles deposited by gentle currents on deep ocean floors, shallow sea basins, and river floodplains. They occur thinly interbedded with layers of sandstone (p.308) or limestone (p.319) and in sheets up to several yards thick.

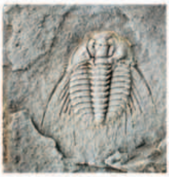

Fossil trilobite
Preserved in gray shale, this fossil trilobite is more than 400 million years old.

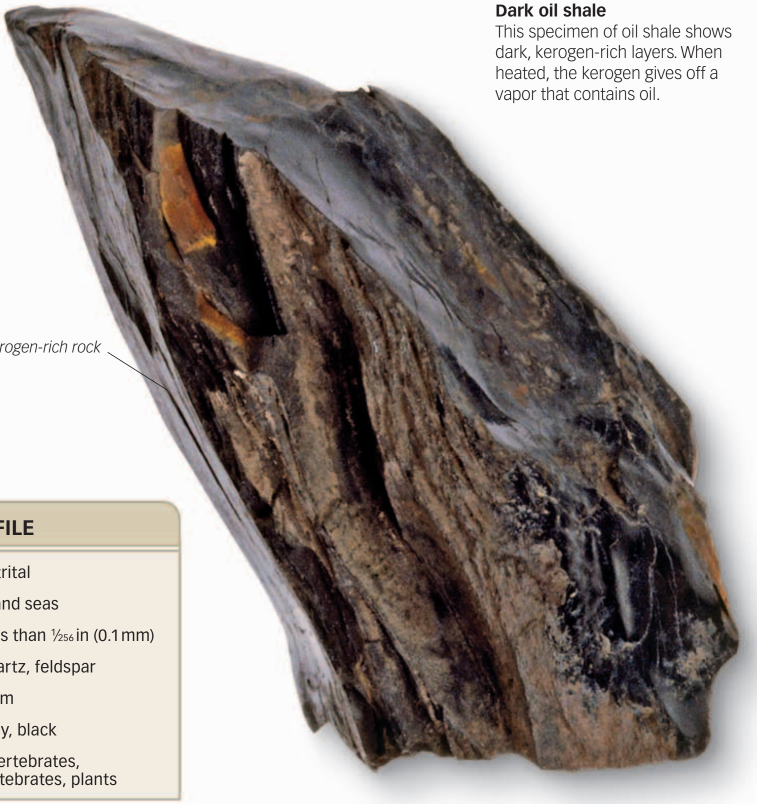

Dark oil shale
This specimen of oil shale shows dark, kerogen-rich layers. When heated, the kerogen gives off a vapor that contains oil.

PROFILE

- Detrital
- Inland seas
- Less than 1⁄256 in (0.1 mm)
- Quartz, feldspar
- Alum
- Gray, black
- Invertebrates, vertebrates, plants

VARIANT

Oily surface A specimen with condensed droplets of oil visible on the surface

OIL SHALE

The name oil shale is a general term for organic-rich sedimentary rocks that contain kerogen—a chemically complex mixture of solid hydrocarbons derived from plant and animal matter. When subjected to intense heat, these shales yield oil. Oil shales range from brown to black in color. They are flammable and burn with a sooty flame. Some oil shales are true shales in which clay minerals are predominant. Others are actually limestones (p.319) and dolomites (p.320). Much of the original organic material in oil shales is unrecognizable, but it is believed to be derived from plankton, algae, and microorganisms that live in fresh sediment.

In previous centuries, small amounts of oil have been successfully recovered from oil shales. During the past century, oil shales have been mined with rock types varying from shale (p.313) to marl (p.322) and other carbonate rocks. Various pilot plants have been built to extract oil from shales, but the commercial results have been modest so far.

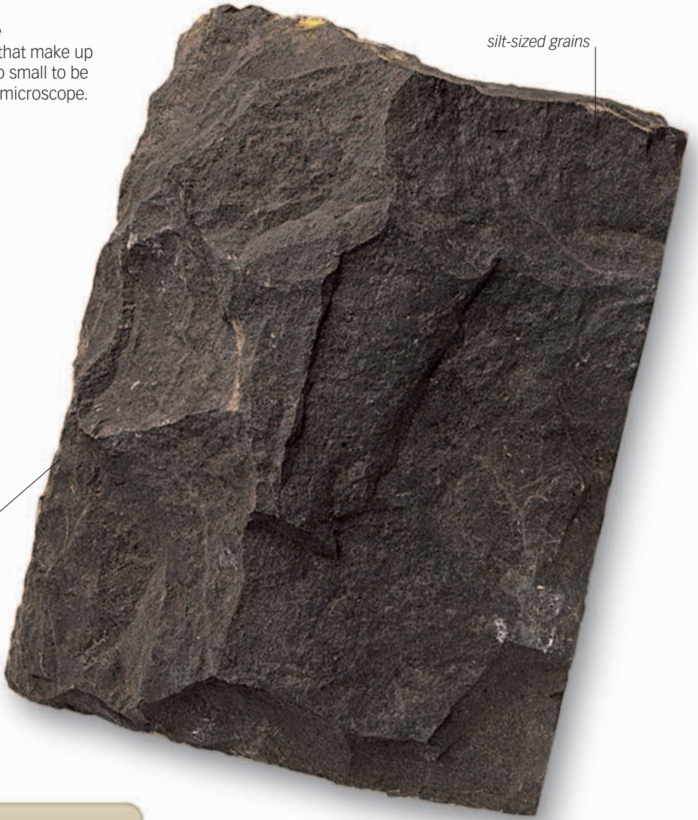

Gray siltstone
The tiny grains that make up siltstone are too small to be seen without a microscope.

PROFILE

- Detrital, from silt
- Marine, freshwater, glacial
- Up to 1/256 in (0.1 mm)
- Quartz, feldspar
- Mica, chlorite, mica-rich clay minerals
- Gray to beige
- Invertebrates, vertebrates, plants

VARIANT

Fossiliferous siltstone
A fern fossil enclosed in siltstone

SILTSTONE

Formed from grains whose sizes vary between that of sandstone (p.308) and mudstone (p.316), siltstone is a sedimentary rock. Like sandstone, it can form in different environments and have different colors and textures. Siltstones are typically red and gray with flat bedding planes. Plant fossils and other carbon-rich matter are common in darker-colored siltstones. Examples tend to be hard and durable and do not easily split into thin layers. However, the presence of mica may produce a siltstone that splits into thicker, flagstonelike sheets. In addition to mica, siltstone may contain abundant chlorite and other mica-rich clay minerals.

Although many shales (p.313) contain more than 50 percent silt, siltstones are usually chemically cemented and show cross-bedding, ripple marks, and internal layering. This indistinct layering tends to weather at oblique angles unrelated to bedding. Siltstone is less common than shale or sandstone and rarely forms thick deposits.

PROFILE

- Detrital, from mud
- Marine, freshwater, glacial
- Less than 1/256 in (0.1 mm)
- Clays, quartz
- Calcite
- Gray, brown, black
- Invertebrates, vertebrates, plants

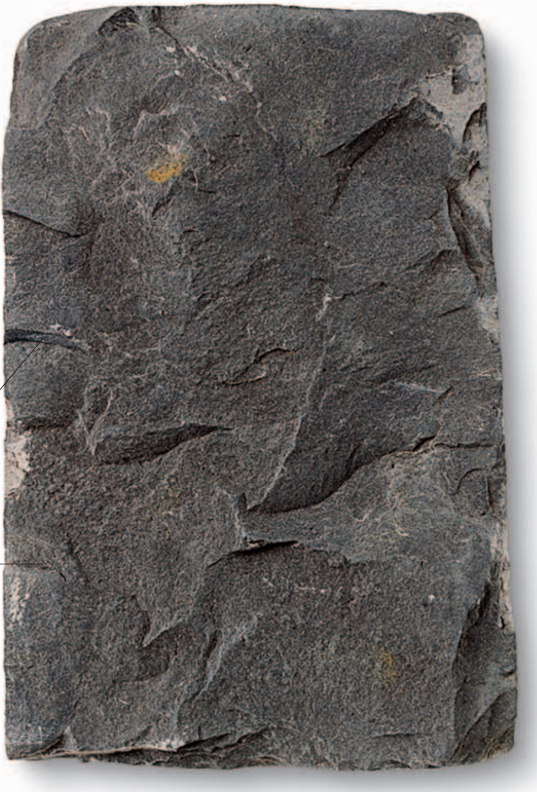

Mudstone specimen Mudstone is somewhat similar in appearance to siltstone, but its grains are smaller and it has a broken surface with a much finer texture.

VARIANTS

Fossiliferous mudstone A specimen of mudstone with numerous invertebrate fossils

Calcareous mudstone A mudstone variant with a substantial amount of calcite

MUDSTONE

A gray or black rock formed from mud, mudstone contains carbon-rich matter, clay minerals, and detrital minerals such as quartz (p.168) and feldspar (pp.173–81). Mudstones look like hardened clay and can show the cracks seen in sun-baked clay deposits.

As in shale (p.313), mudstone's individual grains are clay- and silt-sized particles that can only be seen under a hand lens. Mudstone generally has the same color range as shale, with similar associations between color and content. Unlike shale, mudstone is not laminated during lithification and is not easily split into thin layers. The lack of layering is either due to the original texture or the disruption of layering. Mudstone deposits may be up to 10 ft (several meters) in thickness.

Nautiloid fossil This fossil nautilus is preserved in mudstone. The iridescence of a part of its shell is still visible.

PROFILE

Detrital, from muddy sand

Marine

1⁄256–1⁄16 in (0.1–2 mm)

Quartz, feldspar, mafic minerals

Chlorite, biotite, clay, calcite

Mostly gray or greenish gray; also brown, yellow, or black

Rare

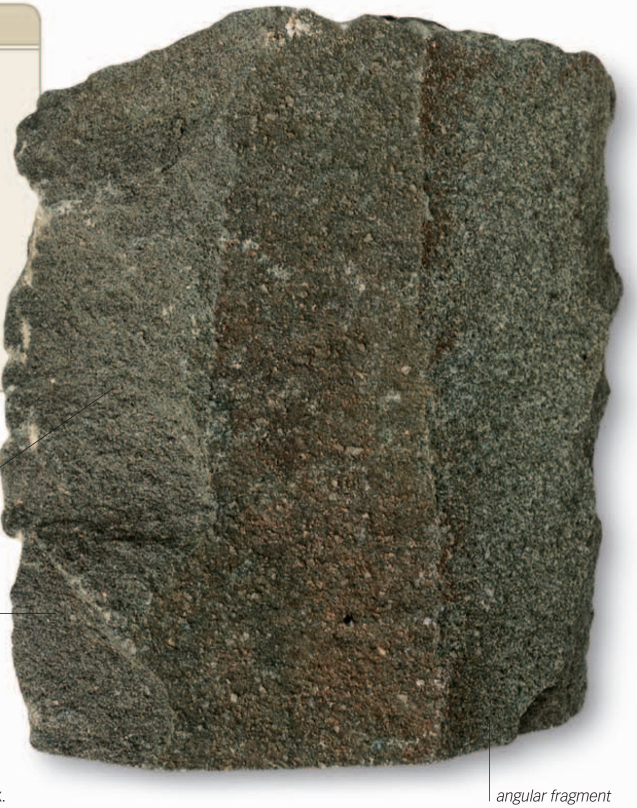

Fine-grained graywacke This specimen shows the poor sorting characteristic of graywacke. The angular clasts are set in a fine-grained matrix.

VARIANTS

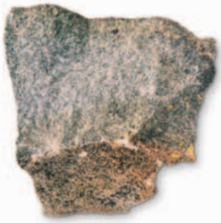

Dirty sandstone A specimen from Canada with typical dirty appearance and poor sorting

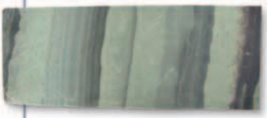

Turbidite A graywacke formed by undersea avalanches

GRAYWACKE

Easily confused with igneous basalt (p.273), graywacke is a turbidite—a rock resulting from rapid deposition in a turbulent marine environment. It gets its name from the German word *grauwacke*, which signifies a gray, earthy rock. Also called dirty sandstone, graywacke is hard, and mostly gray, brown, yellow, or black.

Graywacke is composed of poorly sorted, coarse- to fine-grained quartz (p.168), feldspar (pp.173–81), and dark-colored minerals such as amphibole and pyroxene, set in a fine-grained matrix of clay, calcite (p.114), or quartz. Graywackes may occur in thick or thin beds along with slates (p.293) and limestones (p.319). In ancient Egypt, this stone was used to make sarcophagi, vessels, and statues.

Graywacke carving This ancient Egyptian graywacke carving dates from 1370 BCE. It is an offering to the god of writing.

PROFILE

Detrital

Glacial

From less than 1⁄256 in (0.1 mm) to many ft (m)

Rock fragments

Rock fragments

Various

None

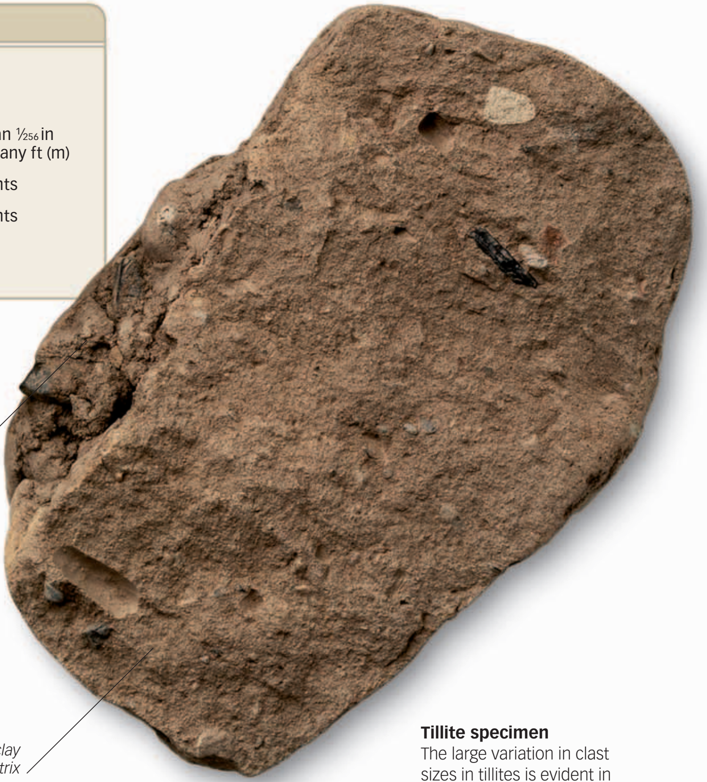

Tillite specimen
The large variation in clast sizes in tillites is evident in this specimen.

VARIANTS

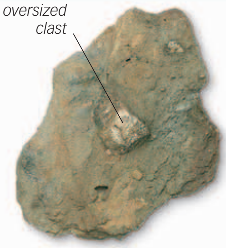

Large clast Tillite with a large clast in a finer matrix

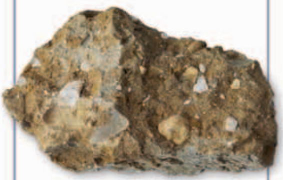

Differing clast sizes
A specimen of tillite with rounded clasts of differing sizes

TILLITE

Unsorted and unstratified rock material deposited by glacial ice that has later been lithified is called tillite. As glaciers move down valleys, they erode and transport rocks. On melting, they deposit this material, which is referred to as till. Glacial tills consist of preexisting rock fragments pushed forward or sideways by the glacier, newly eroded material ground or broken up by the glacier, or mixtures of the two.

Tillites are typically made of grains with a wide range of sizes. They include fragments ranging from clay-sized particles to large blocks. The largest pieces give rise to the rock's alternative name, "boulder clay." The matrix, which frequently comprises a large percentage of the rock, is often made from rock flour, an unweathered and finely ground rock powder. Matching beds of ancient tillites on opposite sides of the South Atlantic Ocean provided early evidence for continental drift—the idea that continents move relative to one another—which was an important precursor to the theory of plate tectonics.

Fossiliferous limestone This limestone specimen from Oxfordshire, England, includes several fossil invertebrates.

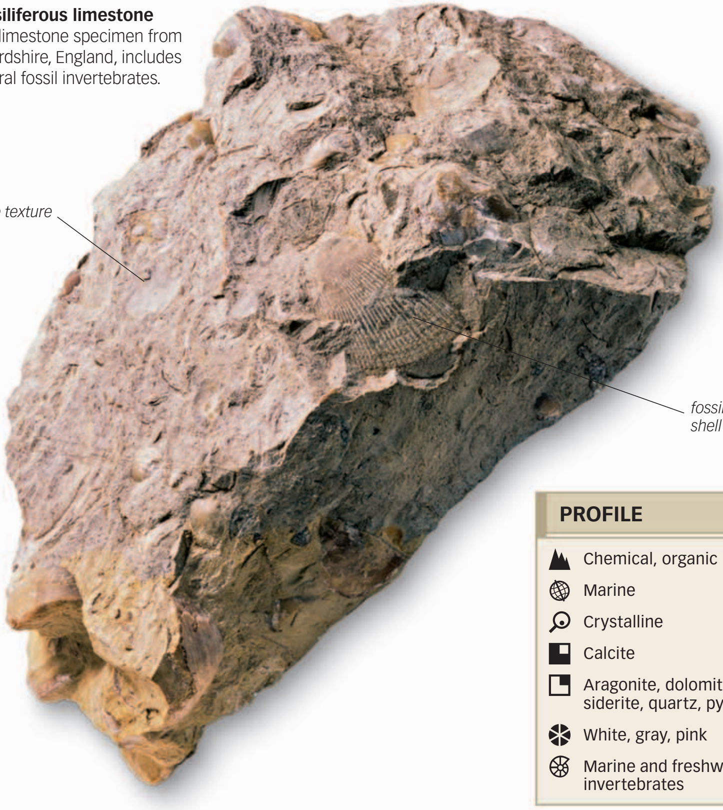

PROFILE

- Chemical, organic
- Marine
- Crystalline
- Calcite
- Aragonite, dolomite, siderite, quartz, pyrite
- White, gray, pink
- Marine and freshwater invertebrates

LIMESTONE

Composed mainly of calcite (p.114), this abundant rock forms multiple layers that are thick and extensive. It can be yellow, white, or gray. Specimens can be identified by the rapid release of carbon dioxide and a fizzing sound when they react with dilute hydrochloric acid. Limestones can be compact, grainy, or friable. Many have cross-bedding or ripple marks. The texture of limestone ranges from coarse and fossil-rich to fine and microcrystalline.

Limestone generally forms in warm, shallow seas either from calcium carbonate precipitated from seawater or from the shells and skeletons of calcareous marine organisms. It is used in construction, as a raw material in the manufacture of glass, as a flux in metallurgical processes, and in agriculture.

Limestone mask This face mask dating from the Neolithic Period has been carved out of mottled limestone.

VARIANTS

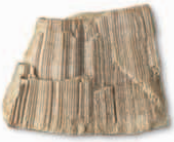

Coral limestone Limestone formed from fossil coral

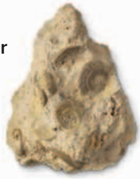

Freshwater limestone Uncommon variant of limestone

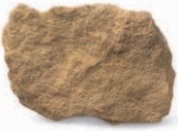

Oolitic limestone Round ooliths set in calcite cement

PROFILE

- Chemical
- Marine
- Crystalline
- Dolomite
- Calcite
- Gray to yellowish gray
- Invertebrates

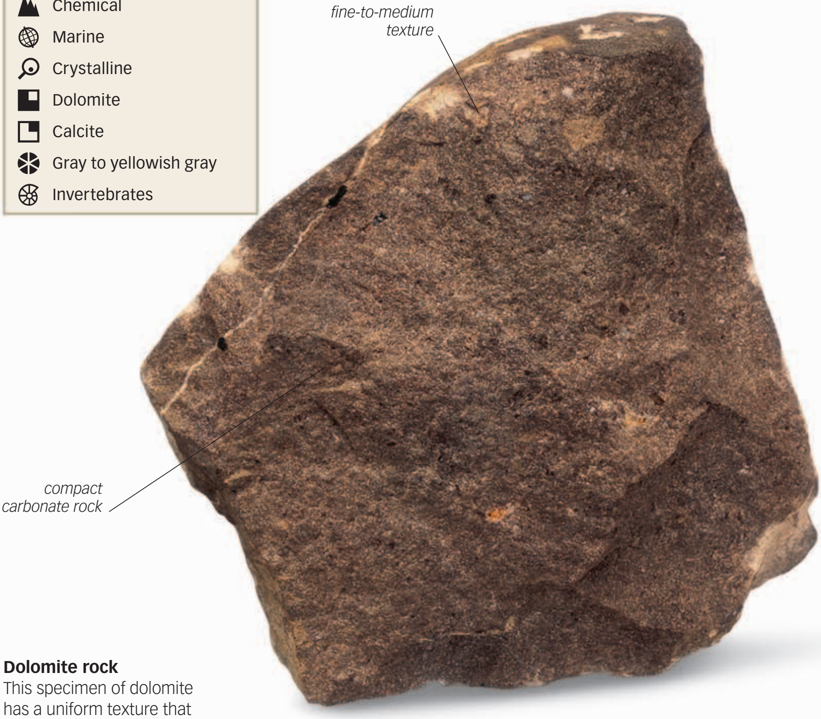

Dolomite rock This specimen of dolomite has a uniform texture that is typical of the rock.

VARIANT

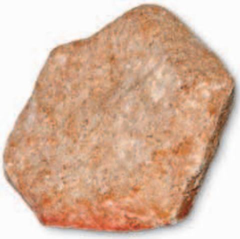

Red dolomite A specimen of dolomite colored with iron oxides and hydroxides

DOLOMITE

This rock, formed exclusively from the mineral dolomite (p.117), is also called dolostone. Most dolomite rocks are believed to be limestones (p.319) in which dolomite has replaced the calcite (p.114) in contact with magnesium-bearing solutions. This process is called dolomitization. Fresh dolomite looks similar to limestone, while weathered dolomite is yellowish gray. Dolomites have fewer fossils than limestones because fossils and other features are destroyed by the dolomitization process. Dolomite fizzes less violently than limestone when in contact with hydrochloric acid.

Dolomite typically occurs as massive layers. It is also present as thin layers or pods within limestone. Dolomite is used as a flux to make steel. It can also be used as a lightweight building aggregate, in breeze blocks, and in poured concrete.

Environment-friendly flux In contrast to other steel-making fluxes, dolomite produces slag that can be reused.

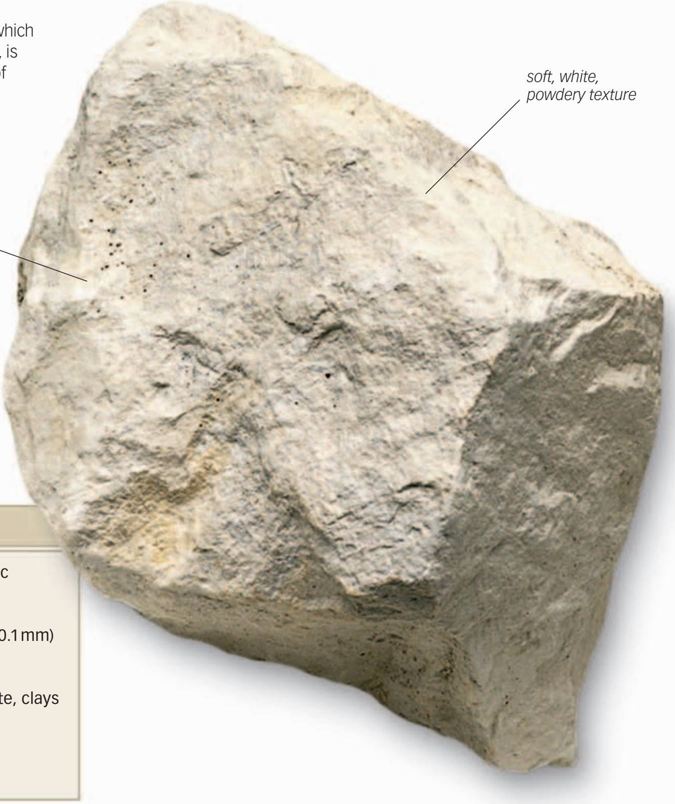

Microscopic fossils
This specimen of chalk, which is almost entirely calcite, is made up of tiny fossils of marine organisms.

PROFILE

- Chemical, organic
- Marine
- Less than 1⁄256 in (0.1 mm)
- Calcite
- Quartz, glauconite, clays
- White, gray, buff
- Invertebrates, vertebrates

VARIANTS

Red chalk A specimen of chalk that takes its color from incorporated hematite

Marine chalk A specimen of chalk pitted by the boring of marine animals

CHALK

A soft, fine-grained, easily pulverized, white to grayish variety of limestone is known as chalk. It is composed of calcite shells of minute marine organisms. Small amounts of other minerals, such as apatite (p.148), glauconite (p.196), and clay minerals, are usually present. Silica from sponge spines, diatom and radiolarian skeletons, and nodules of chert (p.332) and flint can also be present.

Extensive chalk deposits were formed during the Cretaceous Period (142 to 65 million years ago), the name being derived from the Latin word *creta*, which means "chalk." Chalk is used to make lime and cement and as a fertilizer. It is also used as a filler, extender, or pigment in a wide variety of materials, including ceramics and cosmetics.

Blackboard chalk
One of chalk's longstanding uses has been compression into sticks for writing on blackboards.

Green marl
Marls differ in color depending on their mineral content. Green marls, such as this one, are colored by either glauconite or chlorite.

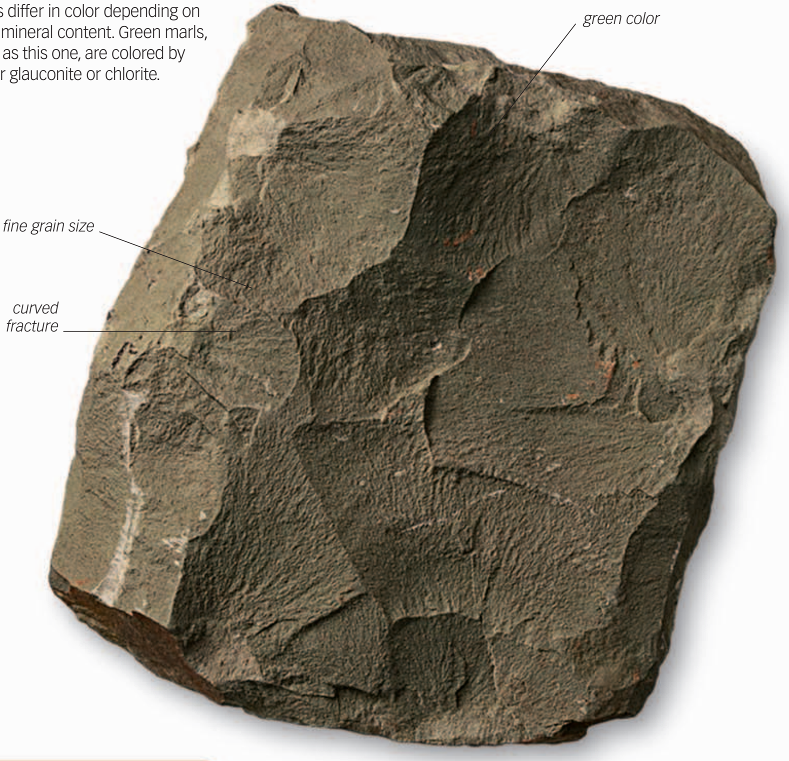

MARL

Calcareous mudstone or marl is a term applied to a variety of rocks that have a range of compositions but are all earthy mixtures of fine-grained minerals. In some countries, marl is referred to by the German terms *mergel* and *seekreide*, both of which mean "lake chalk." Marls usually consist of clay minerals and calcium carbonate. They form in shallow freshwater or seawater. The calcium carbonate content is frequently made up of shell fragments of marine or freshwater organisms or calcium carbonate precipitated by algae. The high carbonate content of marls makes them react with dilute acid.

Marls are whitish gray or brownish in color but can also be gray, green, red, or variegated. Greensand marls contain the green mineral glauconite (p.196), and red marls, iron oxides. Marl is much less easily split than shale (p.313) and tends to break in blocks. Specimens are often nodular, and the nodules are usually better cemented than the surrounding rock.

PROFILE

- Detrital, from lime mud
- Marine, freshwater
- Less than 1⁄256 in (0.1 mm)
- Clays, calcite
- Glauconite, hematite
- Various
- Vertebrates, invertebrates, plants

VARIANT

Red marl A specimen colored red by iron oxides

PROFILE

- Evaporite
- Marine
- Crystalline
- Gypsum
- Anhydrite
- White, pinkish, yellowish, gray
- None

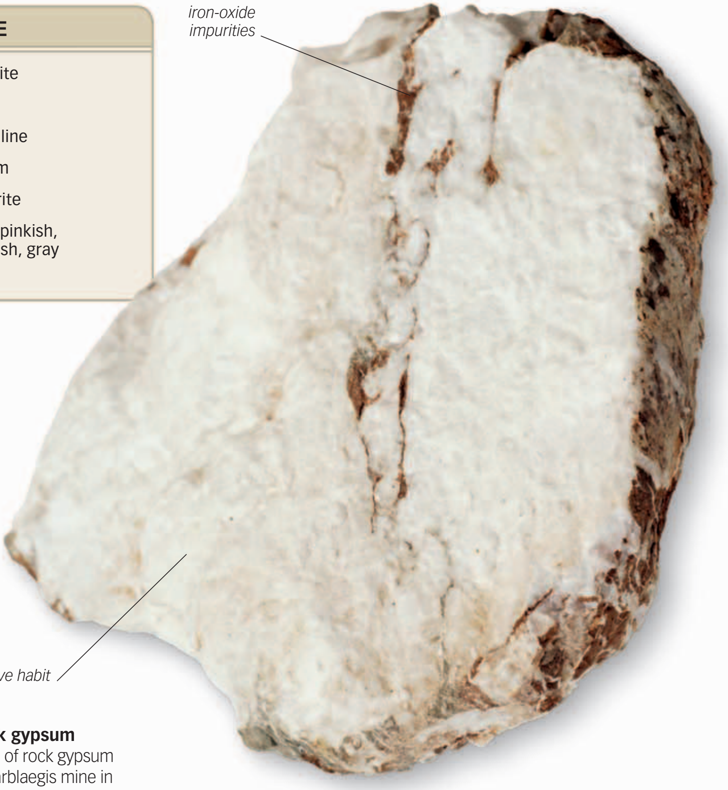

Massive rock gypsum This specimen of rock gypsum is from the Marblaegis mine in Nottinghamshire, England.

VARIANT

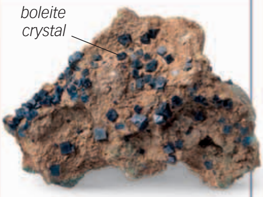

Gypsum with boleite Blue crystals of boleite seen in a matrix of gypsum

ROCK GYPSUM

Also called gyprock, rock gypsum is the sedimentary rock formed mainly from the mineral gypsum (p.136). Although it is commonly granular, it can also occur as fibrous bands. Rock gypsum occurs in extensive beds formed by the evaporation of ocean water, in saline lakes, and in salt pans. It also occurs in some shales (p.313), limestones (p.319), and dolomitic limestones. Rock gypsum is commonly interlayered with other evaporites, such as rock anhydrite (p.133) and salt (p.324).

Most of the gypsum that is extracted—about three-quarters of the total production—is calcined (heated to drive off some of its water) for use as plaster of Paris. Unaltered rock gypsum is used as a fluxing agent, fertilizer, filler in paper and textiles, and retardant in Portland cement.

Mesopotamian seal This ancient cylinder seal, with engravings of stags and scorpions, is made of alabaster gypsum.

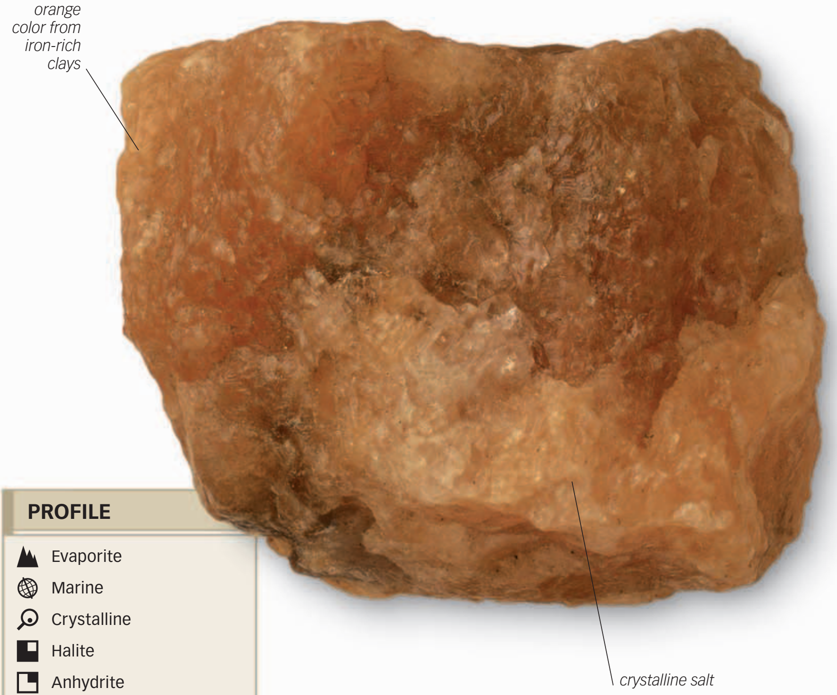

Crystalline rock salt This specimen of crystalline rock salt is colored orange by iron-rich clays incorporated during deposition.

PROFILE

Evaporite
Marine
Crystalline
Halite
Anhydrite
White, pinkish, gray, yellowish
None

ROCK SALT

Familiar as common table salt, rock salt is the massive rock form of the mineral halite (p.110). It occurs in beds that range in thickness from 3 ft (1 m) or so to more than 990 ft (300 m). Rock salt forms as a result of the evaporation of saline water in partially enclosed basins. It is commonly interlayered with beds of shale (p.313), limestone (p.319), dolomite (p.320), and other evaporites, such as anhydrite (p.133) and gypsum (p.136).

Rock salt often occurs in salt domes, which consist of a core of salt surrounded by strata of other rock. The domes can be 1 mile (2 km) or more thick and up to 6 miles (10 km) in diameter. They can occur with petroleum deposits: oil from oil-rich shales migrates up and gets caught on the underside of a salt dome.

Natural salt Many people prefer natural salt for their cooking. Much of it comes from evaporating brines.

VARIANTS

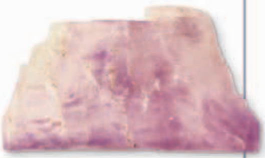

Pink rock salt A specimen colored pink by traces of iron oxides

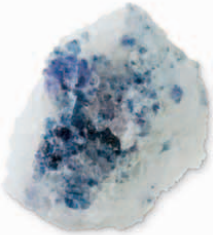

Massive rock salt Rock salt with coarse, white and blue crystals

Porous diatomite
This specimen of diatomite exhibits its typical porous structure and rough texture.

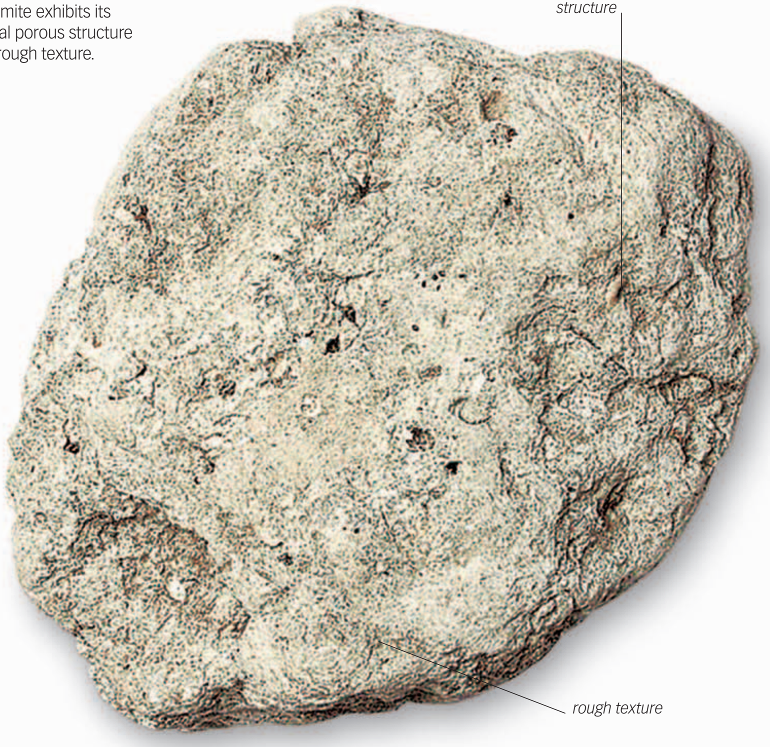

PROFILE

- Detrital
- Accumulation of silica-rich organisms
- Less than 1/256 in (0.1 mm)
- Opal
- None
- White
- Diatoms

DIATOMITE

Also called diatomaceous earth, diatomite consists of about 90 percent silica; the remainder is made up of compounds such as aluminum oxides and iron oxides. Diatomite is easily crumbled into a fine, white to off-white powder. It is made of the fossilized remains of organisms called diatoms. A form of algae, diatoms have hard shells made of amorphous silica (opal) and containing many fine pores. Most float on the surface of the sea. Occasionally, large quantities are deposited in ocean sediments, eventually forming diatomite. A few significant deposits of freshwater diatomite are also known. Diatoms are so small that diatomite specimens may contain millions of diatom shells per cubic inch.

An important industrial rock, diatomite is easily mined. It is used for the filtration of beverages, liquid chemicals, industrial oils, cooking oils, fuels, and drinking water. Its low-abrasive qualities find use in toothpastes, polishes, and nonabrasive cleaners. It is also used as a filler and extender in paint and paper.

PROFILE

- Chemical
- Postdepositional
- Not granular
- Hematite, goethite, calcite, chalcedony
- Sand, clay
- Red-brown or yellow
- None

Red-brown laterite
This specimen shows the intermixture of iron and aluminum oxides with sand or other rock detritus characteristic of laterites.

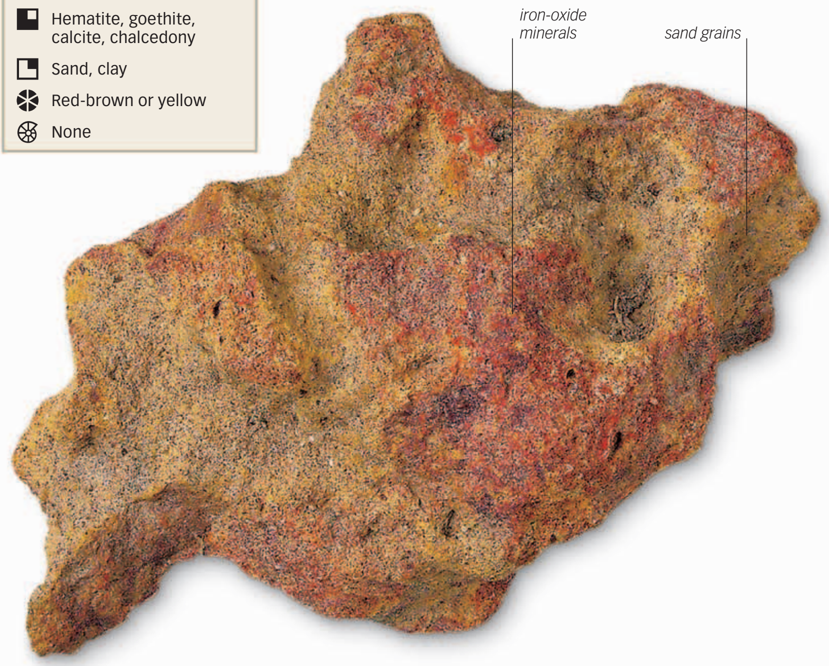

VARIANT

Desert-varnished laterite
A variant of laterite with a polished surface

LATERITE

Laterite is nodular soil rich in hardened iron and aluminum oxides and resembles bauxite (p.101) in composition. Nodules of laterite are red-brown or yellow and contain grains of sand or hardened clay. The rock forms in hot, wet tropical climates, where it develops by intensive and prolonged chemical weathering of the underlying rock. Evaporation and leaching of minerals from rock, loose sediment, and soil leaves behind insoluble salts. This results in a variety of laterites, which differ in their thickness, grade, chemistry, and ore mineralogy.

Laterite is a source of bauxite, which is an ore of aluminum and exists largely in clay minerals and various hydroxides. Laterite ores have also been a source of iron and nickel. Many laterites are solid enough to be used as building blocks. An example is the laterite seen at the famous temple in Angkor Wat, Cambodia. Crushed laterite has been widely used to make roads. Laterites are also being increasingly used in water treatment.

PROFILE

Chemical
Swamps, bogs
Less than 1/256 in (0.1 mm)
Hematite, goethite, calcite, chalcedony
Sand, clay
Light to dark
Plants

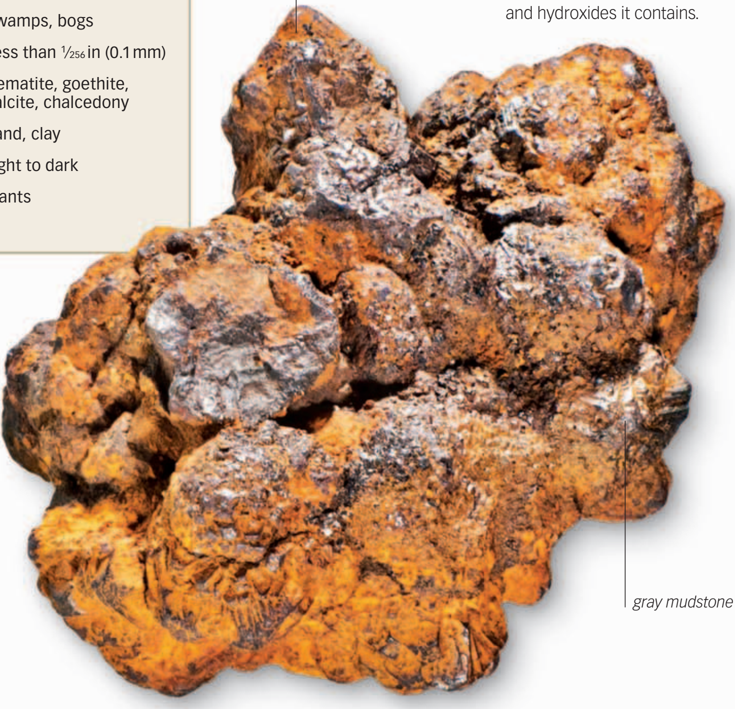

Bog iron nodule This nodule of bog iron shows varied coloration, which results from the various iron oxides and hydroxides it contains.

VARIANT

Bog iron ore Gray mudstone with oxides and hydroxides of iron

BOG IRON

Impure iron deposits that develop in bogs or swamps are known as bog iron. Bog iron is typically a brown-yellow mudstone with yellow, red, brown, or black concretions of iron oxides and hydroxides. In general, bog ores consist of iron hydroxides, primarily goethite (p.102). Bog iron can contain up to 70 percent iron oxide. It often contains carbon-rich plant material, which is sometimes preserved by iron minerals. Bog iron typically forms in areas where iron-bearing groundwater emerges as springs. As the iron encounters the oxygen-rich surface water, it oxidizes, and the iron oxides precipitate out.

Bog iron was formerly used as an ore and was widely sought in the preindustrial age. The Romans and the Vikings made extensive use of bog iron as a source of iron. Bog iron was also the principal source of iron in colonial USA. Although it is still forming today, the iron requirements of modern industry demand much larger sources of ore.

PROFILE

- Chemical
- Marine, terrestrial
- 1⁄256–1⁄16 in (0.1–2 mm)
- Hematite, goethite, chamosite, magnetite, siderite, limonite, jasper
- Pyrite, pyrrhotite
- Red, black, brown, yellow
- Invertebrates or plants

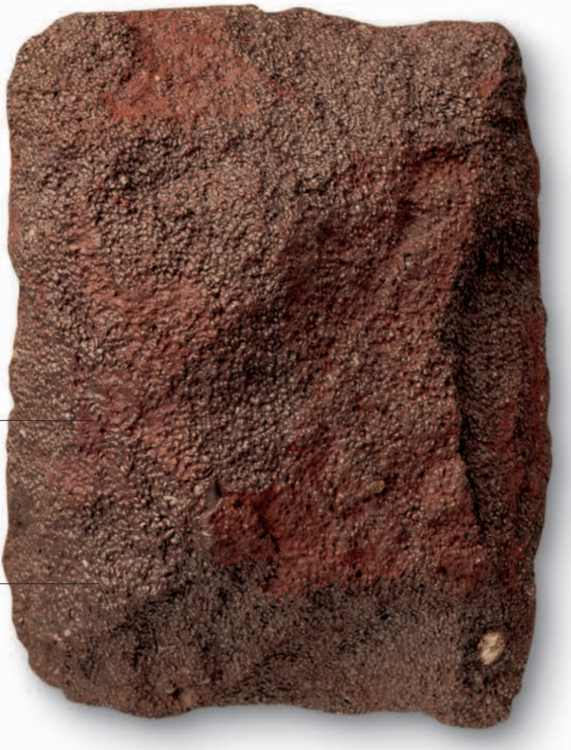

Oolitic ironstone
This specimen of ironstone is made up of small, rounded oolites, which are cemented by hematite.

VARIANT

Sandy ironstone A specimen of a leaf fossil beautifully preserved in ironstone

IRONSTONE

The term ironstone is applied to sandstones and limestones that contain more than 15 percent iron. Ironstones are rich in iron-bearing minerals such as hematite (p.91), goethite (p.102), siderite (p.123), and chamosite. These minerals give ironstones a dark red, brown, or yellow color.

Ironstone no longer appears to be forming; partly because of this, the process by which it forms is something of a mystery. Some ironstones seem to have formed early in Earth's history when oxygen was not as abundant in the atmosphere as it is now. Precambrian ironstones, which are more than 500 million years old, as well as slightly later ones, formed prior to 240 million years ago, are common. Many of the later ironstones consist of oolites (small spheres) of hematite and contain fossils. Although historically used as an iron ore, ironstone is too limited in quantity to be an economic modern source of iron.

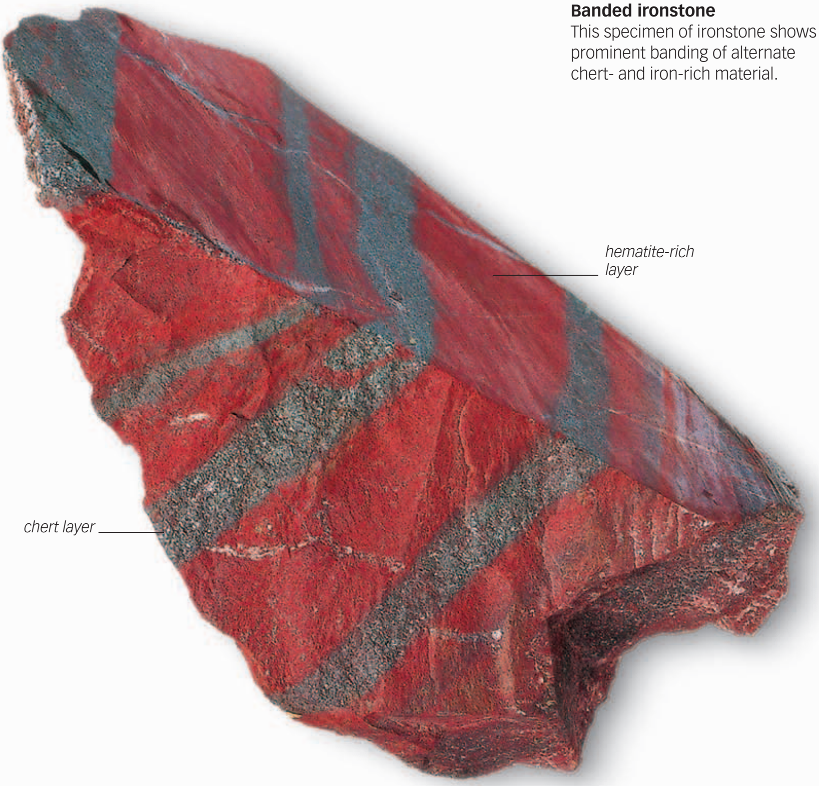

Banded ironstone
This specimen of ironstone shows prominent banding of alternate chert- and iron-rich material.

PROFILE

- ▲ Chemical
- 🌐 Marine
- 🔍 Neither granular nor very fine
- ◼ Siderite, hematite, chert
- ◻ Magnetite, pyrite
- ✳ Red, black, gray, striped
- ⊛ None

BANDED IRONSTONE

Also known as banded iron formations, banded ironstone is made up of thin layers of alternating red, brown, or black iron oxides, which may be hematite (p.91) or magnetite (p.92), and gray or off-white shale (p.313) or chert (p.332). It is a very fine-grained rock that breaks into smooth, splintery pieces. Particularly abundant in Precambrian rocks, which are more than 500 million years old, banded ironstone can form very thick sequences, such as in the Hammersley Range of Australia, where it is an economically important iron ore.

Banded iron layers are found in some of the oldest known rock formations, dating from more than 3,700 million years ago. These layers are believed to have formed in the seas as a result of dissolved iron combining with oxygen released by the green algae that flourished in the oceans at that time. This was then precipitated into oxygen-poor seafloor sediments that were forming shale and chert. The banding of ironstone is assumed to result from cyclic variations in the oxygen available.

PROFILE

- Chemical
- Terrestrial
- Less than 1/32 in (1 mm)
- Calcite or silica
- Aragonite
- White
- Rare

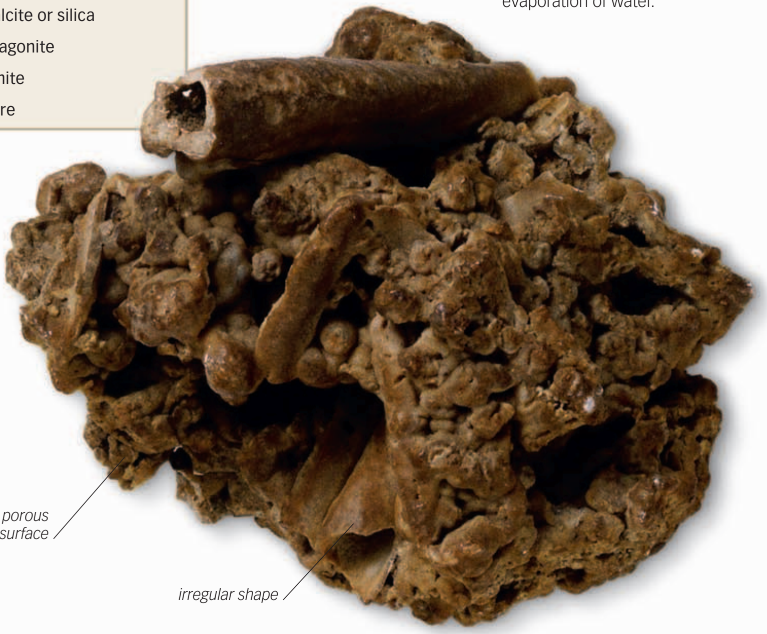

Calcareous tufa
This specimen of calcareous tufa is full of holes and irregular shapes. It was formed by the evaporation of water.

VARIANTS

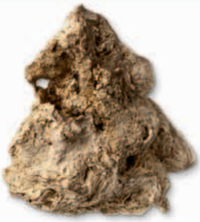

Yellow tufa Irregularly shaped tufa that lacks bedding

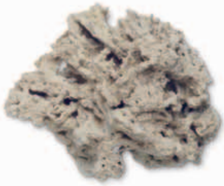

Fossilized tufa Tufa formed around plant remains

TUFA

Two different sedimentary rocks that precipitate from water are known as tufa. Calcareous tufa, or calc-tufa, is a soft, porous form of limestone deposit composed principally of calcium carbonate (calcite) that precipitates from hot springs, lake water, and groundwater. Calc-tufa is often stained red by the presence of iron oxides.

Siliceous tufa, which is also called siliceous sinter, is a deposit of opaline or amorphous silica that forms through the rapid precipitation of fine-grained silica as an encrustation around hot springs and geysers. It is believed to have been partly formed by the action of algae in the heated water. The term “sinter” means that it has several hollow tubes and cavities in its structure, which are often a result of organic matter that has decomposed later.

Stone Wedding
This pink tufa formation is in the Rhodope Mountains, Bulgaria. It is locally called the Stone Wedding.

PROFILE

- Chemical
- Post-depositional
- Fine
- Pyrite, marcasite
- Silica
- Various
- Occasional plants and animals

Flint nodule
This nodule shows a variation in color due to differences in the extraneous material enclosed while the silica making the rock solidified.

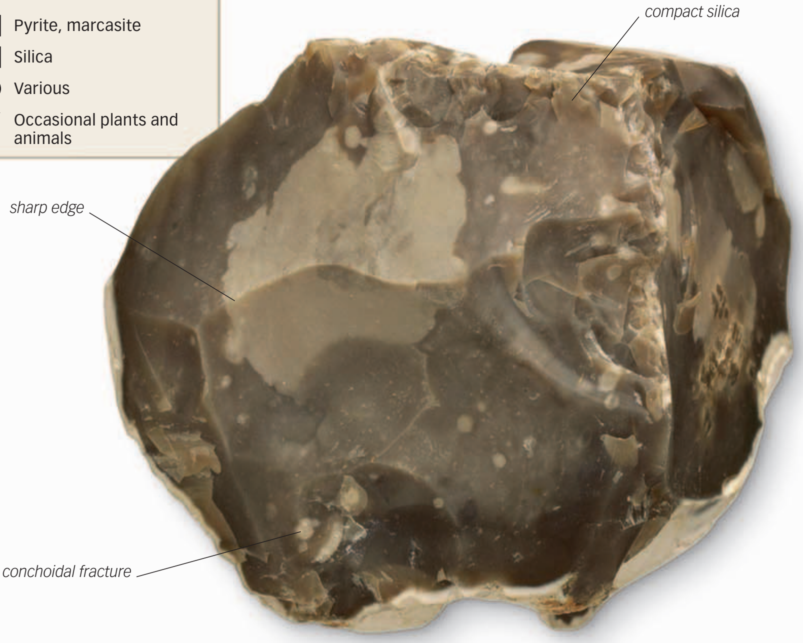

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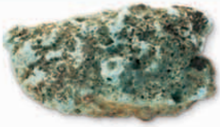
Melanterite A nodule of hydrous iron sulfate

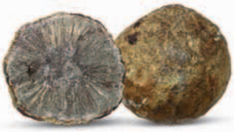
Pyrite nodule A nodule of radiating pyrite crystals

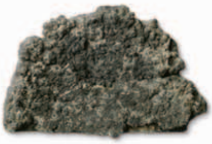
Marine nodule A nodule of manganese oxides

NODULES

A rounded mineral accretion that differs in composition from its surrounding rock is known as a nodule. Nodules are commonly elongated with a knobby irregular surface and are usually oriented parallel to the bedding of their enclosing sediment. Most nodules are formed by the accumulation of silica in sediments and its subsequent solidification. Nodules containing manganese, phosphorous, titanium, chromium, and other valuable metals develop on the seafloor but are uneconomical to mine. Other nodules form around plant and animal remains as part of the fossilization process.

Pyrite (p.62) is commonly found as nodules. It occurs as spheres, rounded cylinders of radiating crystals, and flat, radiating disks, or "suns." Clay ironstone, a mixture of siderite (p.123) and clay, sometimes occurs as layers of dark gray-to-brown nodules overlying coal seams. Chert (p.332) and flint often occur as nodules of nearly pure cryptocrystalline quartz (p.168) within beds of limestone (p.319) or chalk (p.321).

PROFILE

- Chemical
- Postdepositional
- Not granular
- Chalcedony
- None
- Gray, brown
- Invertebrates, plants

Grainy chert
This specimen of fine-grained chert shows the way the rock breaks along flat to rounded surfaces.

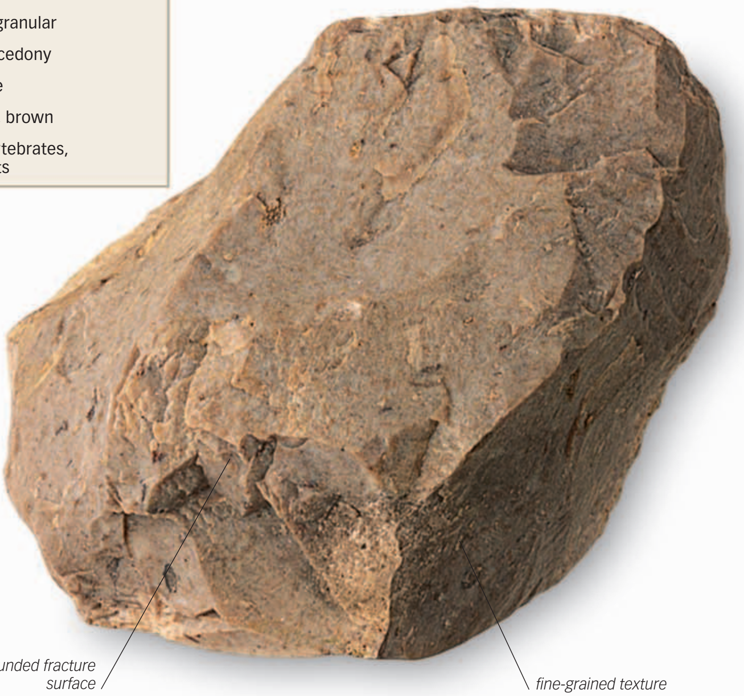

VARIANT

Fossiliferous chert
A specimen containing fossilized primitive plants

CHERT

A rock composed of microcrystalline silica is known as chert. It is commonly gray, white, brown, or black and may contain small fossils. Traces of iron (p.39) may give chert a light green to rusty-red color. Chert occurs as beds or nodules. It breaks along flat to rounded, smooth surfaces and has a glassy appearance. The rock forms by precipitation from silica-rich fluids and colloids.

Flint is chert that occurs in marly limestones (p.319) or chalk (p.321). It is generally gray in color. Flint is found as nodules, often in bands parallel to the bedding planes, and breaks with a conchoidal fracture. The nodules are irregular but rounded. Flint resists weathering, so it can form thick pebble beds on beaches and accumulate in soils that are derived from chalk.

Flint ax
A prized material for tool making, flint was one of the earliest rocks to be mined and extracted.

PROFILE

- Chemical
- Postdepositional
- Crystalline
- Calcite, silica
- Celestine
- Gray, brown
- Invertebrates, plants

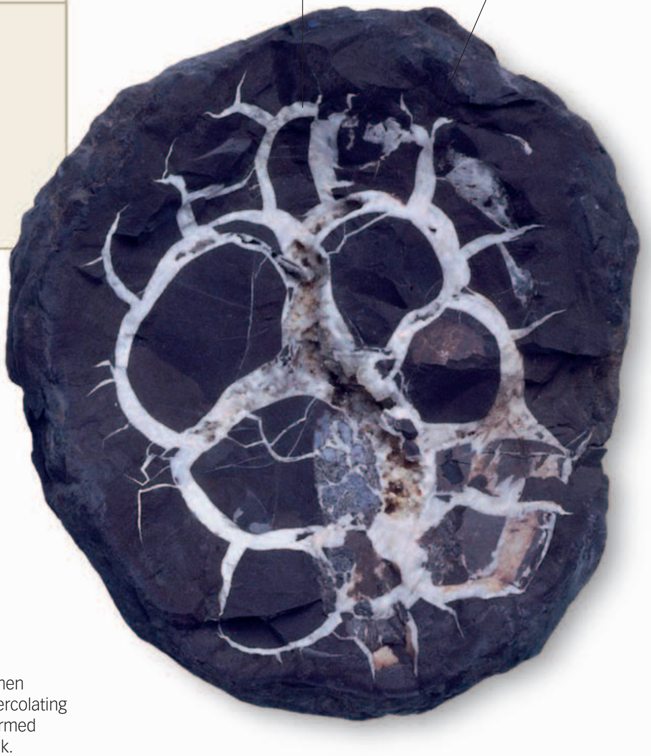

Septarian concretion
This concretion formed when crystals deposited from percolating brines filled cracks that formed inside a nodule as it shrank.

VARIANT

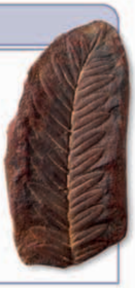

Ironstone concretion
Pteridosperm (seed fern) fossilized in an ironstone concretion

CONCRETIONS

Nodules and concretions are distinctly different geologically, although they have some visual similarities. Unlike nodules, which are of different compositions than their hosts, concretions are made of the same material as their host sediment and cemented by other minerals, mainly calcite (p.114), iron oxides, and silica. Concretions are often much harder and more resistant to erosion than their surrounding rock and can be concentrated by weathering. They usually form early in the burial history of the sediment before the rest of the sediment is hardened into rock.

Concretions vary in shape, hardness, and size. They can be so small that they need to be seen under a magnifying lens. Specimens can also be huge bodies 9¾ ft (3 m) or more in diameter and weighing several tons. In some localities, fossil collectors seek out concretions that have formed around plant and animal remains and perfectly fossilized them. The largest fossil from concretions was an almost complete hadrosaur—a type of dinosaur.

METEORITES

Meteorites are rocks that formed elsewhere in our Solar System and orbited the Sun before colliding with Earth and falling to its surface. The fragments most likely to survive are either very large (weighing ⅓oz/10g or more) or very small (1mg or less).

STRUCTURE

There are three basic types of meteorite: irons, composed mostly of metallic iron and varying amounts of nickel; stony-irons, composed of a mixture of iron and silicate minerals; and stony meteorites, which are further classified into chondrites and achondrites, depending on the presence or absence of small igneous, silicate spheres called chondrules. The most common type of stony-irons are pallasites, which are iron meteorites with centimetre-sized, translucent, olivine or pyroxene crystals scattered throughout.

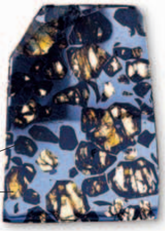

Pallasite section
The stony-iron meteorites known as pallasites are usually one part olivine crystals to two parts metal. In this specimen, olivine is more abundant.

small to medium grains

Achondrite
This stony meteorite found in Haryana, India, lacks chondrules, the small spheres of igneous minerals that would make it a chondrite.

OCCURRENCE

Meteorites are found on every continent. They are often found in environments where they are highly visible—ice caps and deserts being examples. They range in size from microscopic specimens to masses that weigh many tons. Rocks that have been melted by meteorite impacts called tektites, are also widespread.

THE ORIGIN OF THE SOLAR SYSTEM

Meteorites are of particular interest in the study of the origin of the Solar System. Nearly all meteorites are thought to be fragments of asteroids—rocky bodies that formed in the solar nebula at about the same time as Earth. Radiometric dating puts the age of most meteorites at about 4.5 billion years, the same age as Earth.

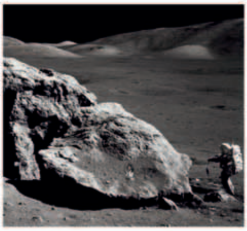

Lunar discoveries
Over 100 meteorites are now believed to be material dislodged from the Moon, providing a more representative sample of the lunar surface than those brought back by astronauts.

Barringer Crater
This well-preserved impact crater is in the Arizona Desert, USA, and is ¾ mile (1.2km) in diameter. The meteorite that created it fell about 50,000 years ago and was about 165ft (50m) across.

PROFILE

- 🔍 Small
- ◼ Iron, nickel
- ◻ Olivine, pyroxene, graphite
- ✲ Steel gray on fresh surfaces, black on the outside

Iron meteorite The kamacite and taenite crystals in this iron meteorite occur as fine, crosshatched lines, forming what is known as a Widmanstätten pattern.

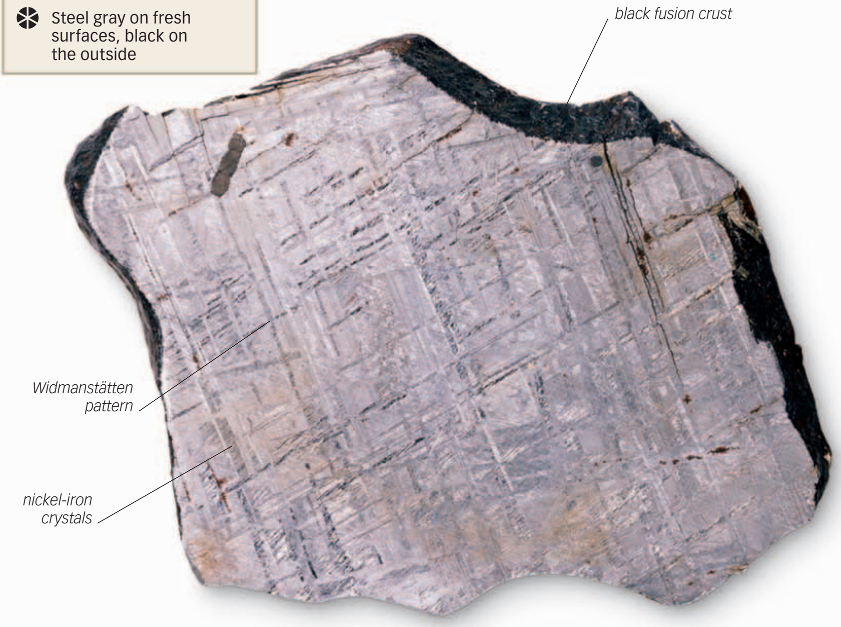

VARIANT

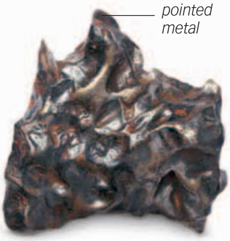

Fusion surface An iron meteorite with a partially vaporized surface

IRON METEORITE

These meteorites are believed to be the shattered fragments of the formerly molten cores of large, ancient asteroids. As the name suggests, iron meteorites are composed mostly of metallic iron (p.39) and up to 25 percent nickel, to produce two minerals, kamacite and taenite, which are otherwise rare on Earth. Other minerals present in minor amounts in iron meteorites include troilite, graphite (p.46), phosphides, and some silicates—most commonly olivine (p.232) and pyroxene. Iron meteorites are divided into a number of subgroups based on their chemical makeup.

Since iron meteorites are so different from most terrestrial rocks, they are recognized more often than other kinds of meteorites and tend to be over represented in meteorite collections. It is estimated that only about 6 percent of meteorites are iron meteorites. Chemical and isotope analysis of a number of iron meteorites indicates that at least 50 distinct parent asteroids were involved in their creation.

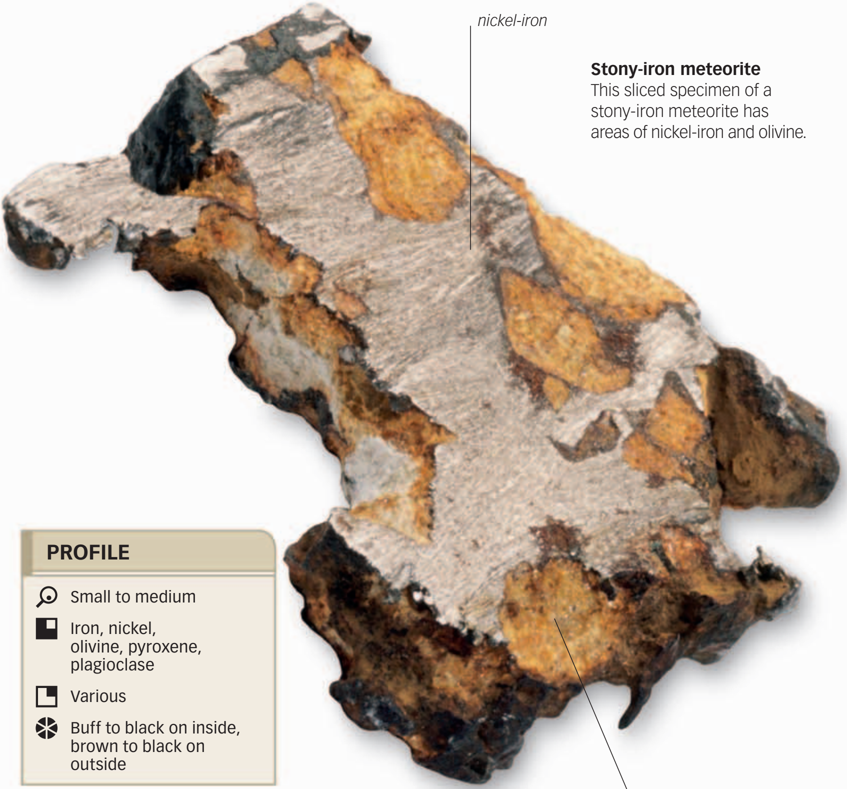

Stony-iron meteorite
This sliced specimen of a stony-iron meteorite has areas of nickel-iron and olivine.

PROFILE

- Small to medium
- Iron, nickel, olivine, pyroxene, plagioclase
- Various
- Buff to black on inside, brown to black on outside

VARIANTS

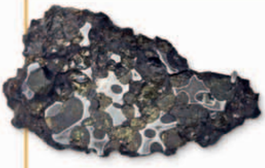

Meteorite from Antarctica
Stony-iron meteorite from the Thiel Mountains, Antarctica

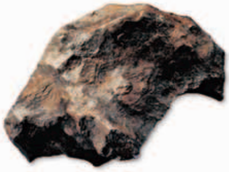

"Thumbprint" surface
Meteorite from Chile with a melted surface resembling a thumbprint

STONY-IRON METEORITE

Composed of a mixture of metallic nickel-iron and silicate minerals, stony-iron meteorites make up about 1 percent of recovered meteorites. Pallasites, the most common type of stony-iron meteorites, are iron meteorites with inch-sized, translucent crystals of olivine (p.232), or sometimes pyroxene, scattered throughout. Pallasites were believed to have originated along the boundaries of the iron cores and silicate mantles of large asteroids. But some experts now believe they are impact-generated mixtures of core and mantle materials.

The other main group of stony-iron meteorites are known as the mesosiderites. Relatively rare, these consist of about equal parts of metallic nickel-iron and silicate minerals, namely pyroxene, olivine, and calcium-rich feldspar (pp.173–81). They have an irregular, often brecciated texture, with the silicates and metal occurring as lumps, pebbles, or fine-grained intergrowths.

PROFILE

- Small to medium
- Olivine, pyroxene, plagioclase
- Various
- Buff to black on inside, brown to black on outside

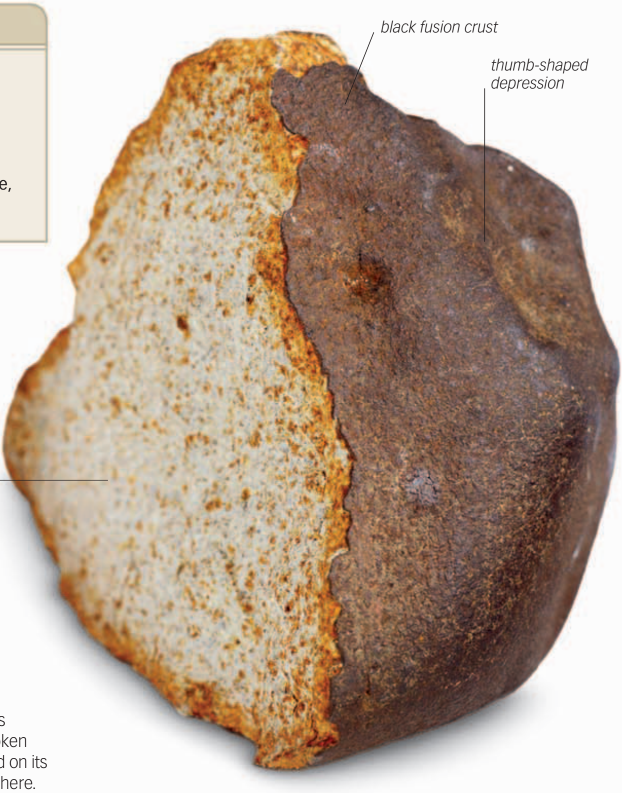

Stony meteorite
The stony composition of this meteorite is visible on its broken surface. Its outside has melted on its passage through the atmosphere.

VARIANTS

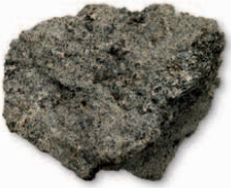

Achondrite A specimen with more varied composition than chondrites

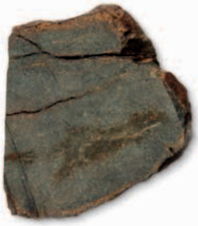

Chondrite Variant of stony meteorites usually composed of olivine and pyroxene

STONY METEORITE

These meteorites can be divided into chondrites and achondrites, which are named after chondrules—small, igneous, silicate spheres that dominate most chondritic meteorites. Chondrules are largely made up of pyroxene and olivine (p.232), with lesser amounts of glass, and may contain calcium-rich feldspar (pp.173–81). They can be up to ⅜in (1 cm) wide. Chondritic asteroids are some of the oldest and most primitive astronomical bodies in the Solar System. They may have formed by rapid heating in the cloud of dust from which the Solar System originated. More than 80 percent of the meteorites that fall to Earth are chondrites.

Achondritic meteorites, in which chondrules are absent, are believed to represent the crust or mantle of asteroids that developed separate mineral shells around an iron-nickel core. They are similar to igneous rocks (pp.258–85) and impact breccias on Earth. Although most achondrites appear to come from asteroids, about 20 of those recovered are believed to have originated on Mars and another 20 on the Moon.

GLOSSARY

ACCESSORY MINERAL
A mineral that occurs in a rock in such small amounts that it is disregarded in the definition of the rock.

ACICULAR HABIT
A needlelike crystal habit of some minerals. See also *habit.*

ADAMANTINE LUSTER
A type of bright mineral luster similar to that of diamond. See also *luster.*

AGGREGATE
An accumulation of mineral crystals or rock fragments.

ALKALINE ROCK
A class of igneous rocks abundant in potassium- and sodium-rich minerals.

ALTERATION
The chemical, thermal, or pressure process or processes by which one rock or mineral is changed into another.

ALTERATION PRODUCT
A new rock or mineral formed by the alteration of a previous one. See also *alteration.*

ALUM
Any of a group of hydrated double salts, usually consisting of aluminum sulfate, water of hydration, and the sulfate of another element.

AMYGDALE
A secondary in-filling of a void in an igneous rock. Minerals that occur as amygdales include quartz, calcite, and the zeolites.

ASSOCIATED MINERALS
Minerals found growing together but not necessarily intergrown. See also *intergrowth.*

AUREOLE
The area around an igneous intrusion where contact metamorphism has occurred.

BASAL CLEAVAGE
Cleavage that occurs parallel to the basal crystal plane of a mineral. See also *cleavage.*

BATHOLITH
A huge, irregularly shaped mass of igneous rock formed from the intrusion of magma at depth. See also *magma*.

BLADED HABIT
A crystal habit in which wide, flat crystals appear similar to knife blades. See also *habit*.

BOTRYOIDAL HABIT
A mineral habit in which crystals form globular aggregates similar to bunches. See also *aggregate*, *habit*.

BRECCIA
A sedimentary rock made up of angular fragments. See also *igneous breccia*.

CABOCHON
A gemstone cut with a domed upper surface and a flat or domed under surface; gemstones cut in this way are said to be cut *en cabochon*. See also *cut*, *gem*, *gemstone*.

CARAT
A unit of gemstone weight, equivalent to 0.007 oz (0.2 g). Carat (also spelled "Karat") is also a measure of gold purity, the number of parts of gold in 24 parts of a gold alloy: 24 kt is pure gold; 18 kt is three quarters gold. See also *gem, gemstone*.

CHATOYANCY
The cat's-eye effect shown by some stones cut *en cabochon*. See also *cabochon*.

CLAST
A fragment of rock, especially when incorporated into a sedimentary rock.

CLASTIC ROCK
A sedimentary rock composed of cemented clasts. See also *clast*.

CLAY
Mineral particles smaller than about 0.00008 in (0.002 mm).

CLEAVAGE
The way certain minerals break along planes dictated by their atomic structure.

COLLOID
Any substance that consists of particles substantially larger than atoms or molecules but too small to be visible to the unaided eye.

COLOR DISPERSION
The separation of white light into its constituent colors.

CONCHOIDAL FRACTURE
A curved or shell-like fracture in many minerals and some rocks. See also *fracture*.

CONCRETION
A rounded, nodular mass of rock formed from its enclosing rock and commonly found in beds of sandstone, shale, or clay.

CONTACT TWINNING
The phenomenon of two or more crystals growing in parallel contact with each other and sharing a common face. See also *twinned crystals*.

CRYPTOCRYSTALLINE HABIT
A mineral habit that is crystalline but very fine-grained. Individual crystallized components can be seen only under a microscope. See also *habit*.

CUT
The final shape of a ground and polished gem, as in emerald cut. See also *gem*, *gemstone*, *gem cutting*.

DENDRITIC HABIT
A type of habit in which crystals form branching, treelike shapes. See also *habit*.

DETRITAL ROCKS
Sedimentary rocks formed essentially of fragments and grains derived from existing rocks. See also *sedimentary rock.*

DIATOMACEOUS EARTH
A sedimentary rock composed of the siliceous shells of microscopic aquatic plants known as diatoms.

DIFFRACTION
The splitting of light into its component colors. See also *x-ray diffraction*.

DIKE
A sheet-shaped igneous intrusion that cuts across existing rock structures.

DISCOVERY/TYPE LOCALITY
The site where a mineral was first recognized as a new mineral.

DOUBLE REFRACTION
The splitting of light into two separate rays as it enters a stone.

DRUSY COATING
A sheet of numerous, often well-formed, small crystals covering a mineral.

DULL LUSTER
A type of luster in which little or no light is reflected. See also *luster*.

EARTHY LUSTER
A nonreflective mineral luster. See also *luster*.

EQUANT
A mineral habit that refers to a crystal that is of equal size in all directions; a rock composed of grains of equal size.

EUHEDRAL
A term describing crystals with well-formed faces.

EVAPORITE
A mineral or rock formed by the evaporation of saline water.

EXTRUSIVE ROCK
A rock formed from lava that either flowed onto Earth's surface or was ejected as pyroclastic material. See also *intrusive rock*, *lava*.

FACES
The external flat surfaces that make up a crystal's shape.

FELDSPATHOIDS
Minerals similar in chemistry and structure to the feldspars but with less silica.

FELSIC ROCK
An igneous rock with more than 65 percent silica and more than 20 percent quartz. It is also known as acidic rock.

FISSILE TEXTURE
A rock texture that allows the rock to be split into sheets. See also *texture*.

FLOW BANDING
Layering in a rock that originated when the rock was in a fluid, molten state.

FOLIATION
The laminated, parallel orientation or segregation of minerals.

FOSSIL
Any record of past life preserved in the crustal rocks. Apart from bones and shells, fossils can include footprints, excrement, and borings.

FRACTURE
Mineral breakage that occurs at locations other than along cleavage planes. See also *cleavage.*

FUMAROLE
In volcanic regions, an opening in the ground through which hot gases are emitted.

GARNET
A member of a group of silicates with the general formula A3B2(SiO4)3 in which A can be Ca, Fe^{2+}, Mg, or Mn^{2+}; and B can be Al, Cr, Fe^{3+}, Mn^{3+}, Si, Ti, V, or Zr.

GEODE
A hollow, generally rounded nodule lined with crystals. See also *nodule*.

GEM, GEMSTONE
A cut stone worn in jewelry, valued for its color, rarity, texture, or clarity. It may even be an unset stone cut for use as jewelry. See also *cut*, *rough gemstone*.

GEM CUTTING
The process of shaping a gemstone by grinding and polishing. See also *cut*, *gem*, *gemstone*.

GLASS
A solid substance showing no crystalline structure—in effect, a very thick liquid. See also *glassy texture*.

GLASSY TEXTURE
The smooth consistency of an igneous rock in which glass formed due to rapid solidification. See also *glass, texture*.

GRANULAR TEXTURE
A rock or mineral texture that either includes grains or is in the form of grains. See also *texture*.

GRAPHIC TEXTURE
The surface appearance of some igneous rocks in which quartz and feldspar have intergrown to produce an effect resembling a written script. See also *texture*.

HABIT
The mode of growth and appearance of a mineral. The habit of a mineral results from its molecular structure.

HACKLY FRACTURE
A mineral fracture that has a rough surface with small protuberances, as on a piece of broken cast iron. See also *fracture*.

HEMIMORPHIC FORM
A crystalline form with a different facial development at each end.

HOPPER CRYSTAL
A crystal whose incomplete growth has created a hopper-shaped concavity on one or more faces.

HYDROTHERMAL DEPOSIT
A mineral deposit that is formed by hot water ejected from deep within Earth's crust.

HYDROTHERMAL MINERAL
A mineral that is derived from hydrothermal deposition. See also *hydrothermal deposit*.

HYDROTHERMAL VEIN
A rock fracture in which minerals have been deposited by fluids from deep within Earth's crust. See also *hydrothermal deposit*, *pegmatite*, *vein*.

HYPABYSSAL
A term describing minor igneous intrusions at relatively shallow depths within Earth's crust.

IGNEOUS BRECCIA
An igneous rock made up of angular fragments. See also *breccia*.

IGNEOUS ROCK
A rock that is formed through the solidification of molten rock.

INCLUSION
A crystal or fragment of another substance within a crystal or rock.

INTERGROWTH
Two or more minerals that are growing together and interpenetrating each other. See also *associated minerals*.

INTERMEDIATE ROCK
An igneous rock that is intermediate in composition between silica-rich and silica-poor rocks.

INTRUSIVE ROCK
A body of igneous rock that invades older rock. See also *extrusive rock*.

IRIDESCENCE
The reflection of light from the internal elements of a stone, yielding a rainbowlike play of colors.

LAMELLAR HABIT
A type of crystal habit in which plates or flakes occur in thin layers or scales. See also *habit*.

LAVA
Molten rock that is extruded onto Earth's surface. See also *magma*.

LITHIFICATION
The process by which unconsolidated sediment turns to stone. See also *recrystallization*.

LUSTER
The shine of a mineral caused by reflected light.

MAFIC ROCK
An igneous rock with 45–55 percent silica. Such rocks have less than 10 percent quartz and are rich in iron-magnesium minerals.They are also known as basic rocks. See also *ultramafic rock*.

MAGMA
Molten rock that may crystallize beneath Earth's surface or be erupted as lava. See also *lava*.

MAMILLARY HABIT
A mineral habit in which crystals form rounded aggregates. See also *aggregate, habit*.

MASSIVE
A mineral form having no definite shape.

MATRIX
A fine-grained rock into which or on top of which larger crystals appear to be set. It is also known as a groundmass.

METAL
A substance that is characterized by high electrical and thermal conductivity as well as by malleability, ductility, and high reflectivity of light.

METALLIC LUSTER
A shine similar to the typical shine of polished metal. See also *luster*.

METAMORPHIC ROCK
A rock that has been transformed by heat or pressure (or both) into another rock.

METEOR
A rock from space that completely vaporizes while passing through Earth's atmosphere.

METEORITE
A rock from space that reaches Earth's surface.

MICA
Any of a group of hydrous potassium or aluminum silicate minerals. These minerals exhibit a two-dimensional sheet- or layerlike structure.

MICROCRYSTALLINE HABIT
A mineral habit in which crystals are so minuscule that they can be detected only with the aid of a microscope. See also *habit*.

MINERAL GROUP
Two or more minerals that share common structural and/or chemical properties.

MOONSTONE
A gem-quality feldspar mineral that exhibits a silvery or bluish iridescence. Several feldspars, especially some plagioclases, are called moonstone.

NATIVE ELEMENT
A chemical element that is found in nature uncombined with other elements.

NODULE
A generally rounded accretion of sedimentary material that differs from its enclosing sedimentary rock.

NONMETAL
An element, such as sulfur, which lacks some or all of the properties of metals. See also *metal*.

OOLITHS
Individual spherical sedimentary grains from which

oolitic rocks are formed. Most ooliths comprise concentric layers of calcite.

ORE
A rock or mineral from which a metal can be profitably extracted.

OXIDATION
The process of combining with oxygen. In minerals, the oxygen can come from the air or water.

PEGMATITE
A hydrothermal vein composed of large crystals. See also *hydrothermal vein*.

PENETRATION TWINNING
The phenomenon of two or more crystals forming from a common center and appearing to penetrate each other. See also *twinned crystals*.

PHENOCRYST
A large crystal set in an igneous rock matrix, creating a porphyritic texture. See also *porphyritic texture*.

PISOLITIC HABIT
A mineral habit characterized by pea-sized grains with a concentric inner structure. See also *habit*.

PLACER, PLACER DEPOSIT
A deposit of minerals derived by weathering and concentrated in streams or beaches because of the mineral's high specific gravity.

PLASTIC ROCK
A type of rock that is easily folded when subjected to high temperature and pressure.

PLATY HABIT
The growth habit shown by flat, thin crystals. See also *habit*.

PLAYA DEPOSIT
A mineral deposit formed in a desert basin that is intermittently filled with a lake.

PLEOCHROIC, PLEOCHROISM
The phenomenon of a mineral or gem presenting different colors to the eye when viewed from different directions.

PLUTON
A mass of igneous (plutonic) rock that has formed beneath Earth's surface by the solidification of magma.

POLYMORPH
A substance that can exist in two or more crystalline forms; one crystalline form of such a substance. See also *pseudomorph*.

PORPHYRITIC TEXTURE
An igneous rock texture in which large crystals are set in a finer matrix. See also *phenocryst*, *texture*.

PORPHYROBLAST
A relatively large crystal set in a fine-grained matrix in a metamorphic rock.

PORPHYROBLASTIC TEXTURE
A texture characterized by relatively large crystals in a fine-grained matrix. See also *texture*.

PRECIPITATION
The condensation of a solid from a liquid or gas.

PRIMARY MINERAL
A mineral that has crystallized directly from an igneous magma and is unaltered by rain, groundwater, or other agents. See also *secondary mineral*.

PRISMATIC HABIT
A mineral habit in which parallel rectangular crystal faces form prisms. See also *habit*.

PROTOLITH
A rock that existed prior to undergoing metamorphic transformation into a different rock type.

PSEUDOMORPH
A crystal with the outward form of another species of mineral. See also *polymorph*.

PYRAMIDAL HABIT
A crystal habit in which the principal faces join at a point. When two such pyramids are placed base to base, the crystal is said to be di- or bi-pyramidal. See also *habit*.

PYROCLASTIC ROCK
A rock consisting of airborne material ejected from a volcanic vent.

PYROXENE
A member of a group of 21 rock-forming silicate minerals that typically form elongate crystals.

RADIOMETRIC DATING
The determination of absolute ages of minerals and rocks by measuring certain radioactive and radiogenic atoms in them.

RARE-EARTH MINERAL
A mineral containing a significant portion of one or more of the 17 rare-earth elements, principally ytterbium, gadolinium, neodymium, praseodymium, cerium, lanthanum, yttrium, and scandium.

RECRYSTALLIZATION
The redistribution of components to form new minerals or mineral crystals; in some cases new rocks form. It occurs during lithification and metamorphism. See also *lithification*.

REFRACTIVE INDEX
A measure of the slowing down and bending of light as it enters a stone. It is used to identify cut gemstones and some minerals. See also *cut*, *gem*, *gemstone*.

RENIFORM HABIT
A mineral habit with a kidneylike appearance. See also *habit*.

REPLACEMENT DEPOSIT
A deposit formed from minerals that have been altered. See also *alteration product*.

RESINOUS LUSTER
A shine having the reflectivity of resin. See also *luster*.

RETICULATED
Having a network or a netlike mode of crystallization.

ROCK FLOUR
Very fine-grained rock dust, often the product of glacial action.

ROUGH GEMSTONE
An uncut gemstone. See also *cut, gem*, *gemstone.*

SALT DOME
A large, intrusive mass of salt, sometimes with petroleum trapped beneath.

SCHILLER EFFECT
The brilliant play of bright colors in a crystal, which is often due to minute, rodlike inclusions.

SCHISTOSITY
A foliation that occurs in coarse-grained metamorphic rocks. It is the result of platy mineral grains. See also *foliation*.

SCORIACEOUS
A term for lava or other volcanic material that is heavily pitted with hollows and cavities. See also *lava*.

SECONDARY MINERAL
A mineral that replaces another mineral as a result of weathering or alteration. See also *alteration*, *primary mineral*.

SECTILE
The property of a mineral that allows it to be cut smoothly with a knife. See also *fracture*.

SEDIMENTARY ROCK
A rock that either originates on Earth's surface as an accumulation of sediments or precipitates from water.

SEMIMETAL
A metal, such as arsenic or bismuth, that is not malleable. See also *metal*.

SILICA-POOR ROCKS
Rocks containing less than 50 percent silica. See also *silica-rich rocks*.

SILICA-RICH ROCKS
Rocks containing more than 50 percent silica. See also *silica-poor rocks*.

SLATY CLEAVAGE
The tendency of a rock, such as slate, to break along flat planes into thin, flat sheets. See also *cleavage*.

SOLID-SOLUTION SERIES
A series of minerals in which certain chemical components are variable between two end-members with fixed composition.

SPECIFIC GRAVITY
The ratio of the mass of a mineral to the mass of an equal volume of water. Specific gravity is numerically equivalent to density (mass divided by volume) in grams per cubic centimeter.

SPHEROIDAL HABIT
A crystal habit in which numerous crystals radiate outwards to form a spherical mass. See also *habit*.

STALACTITIC HABIT
A mineral habit in which the crystalline components are arranged in radiating groups of diminishing size, giving the appearance of icicles. See also *habit*.

STRIATION
A parallel groove or line appearing on a crystal.

SUBLIMATION, SUBLIMATE
The process by which a substance moves directly from a gaseous state to a solid state. A sublimate is the solid product of sublimation.

SUNSTONE
A gemstone variety of feldspar with minute, platelike inclusions of iron oxide oriented parallel to one another throughout. See also *gem*, *gemstone*.

TABULAR HABIT
A crystal habit in which the crystals have long, flat, parallel faces. See also *habit*.

TERMINATION
Faces that make up the ends of a crystal.

TEXTURE
The size, shape, and relationships between rock grains or crystals.

TWINNED CRYSTALS
Crystals that grow together as mirror images with a common face (contact twins) or grow at angles up to 90 degrees to each other and appear to penetrate each other (penetration twins).

ULTRAMAFIC ROCK
An igneous rock with less than 45 percent silica. It is also known as an ultrabasic rock. See also *mafic rock*.

VEIN
A thin, sheetlike mass of rock that fills fractures in other rocks.

VESICLE
A small, spherical or oval cavity produced by a bubble of gas or vapor in lava, left after the lava has solidified. See also *lava*.

VITREOUS LUSTER
A shine resembling that of glass. See also *luster*.

VOLCANIC PIPE
A fissure through which lava flows. See also *lava*.

WELL-SORTED ROCK
A sediment or sedimentary rock with grains or clasts that are roughly of the same size.

X-RAY DIFFRACTION
The passing of x-rays through a crystal to determine its internal structure by the way in which the x-rays are scattered. See also *diffraction*.

ZEOLITE
A group of hydrous aluminum silicates characterized by their easy and reversible loss of water.

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Blanchet et Associes (br). **Getty Images:** DEA/Photo 1 (cl). **218 Getty Images:** Mark Schneider (clb); Scientifica (cla). **222 Dorling Kindersley:** John Chase, Courtesy of The Museum of London (br). **223 Dorling Kindersley:** Judith Miller/ Lesley Craze Gallery (br). **226 Alamy Images:** Alan Curtis (bl); Greg C Grace (cl). **230 Getty Images:** Mark Schneider (cl); Visuals Unlimited/Scientifica (bl). **231 Dorling Kindersley:** Judith Miller/Woolley and Wallis (br). **232 Dorling Kindersley:** Judith Miller/ HY Duke and Son (br). **241 shutterstone.com:** (cl, bl). **243 Dorling Kindersley:** Judith Miller/ Joseph H Bonnar (br). **246 Dorling Kindersley:** Martin Strmiska (c) Alamy (b). **248 Dorling Kindersley:** Judith Miller/ Beaussant Lefevre (br). **249 Dorling Kindersley:** Judith Miller/ Wallis and Wallis (br). **252 Dorling Kindersley:** Colin Keates, Courtesy of the Natural History Museum, London (cl). **254-255 Corbis:** Chris Harris/All Canada Photos. **257 Corbis:** Gary Braasch (b). **259 Dorling Kindersley:** Neil Fletcher (bl). **261 Dorling Kindersley:** Judith Miller/N. Bloom & Son Ltd. (br). **Smithsonian Institution, Washington, DC:** (bl). **264 Corbis:** Visuals Unlimited (bl). **Getty Images:** Mark Schneider/Visuals Unlimited (cl). **269 Dorling Kindersley:** Judith Miller/HY Duke and Son (br). **270 Dorling Kindersley:** Neil Fletcher (cl). **Getty Images:** DEA/A. Dagli Orti (bl). **272 Alamy Images:** RF Company (t). **274 Alamy Images:** Susan E. Degginger (bl). **Getty Images:** DEA/R. Appiani (cl). **275 Dorling Kindersley:** Image Plan (c) Corbis (br). **276 Alamy Images:** Phil Degginger (t); Susan E. Degginger (b). **281 Alamy Images:** Photo resource Hawaii (clb). **Corbis:** (bl). **283 Dorling Kindersley:** Neil Fletcher (cl). **shutterstone.com:** (t). **286-287 Alamy Images:** Daniel Dempster Photography (b). **291 Dorling Kindersley:** Judith Miller/ Ormonde Gallery (br). **293 Dorling Kindersley:** Courtesy of the Blists Hill Museum, Ironbridge, Shropshire (br). **294 Alamy Images:** Susan E. Degginger (clb); RF Company (cla); geoz (bl). **296 Alamy Images:** geoz (cl); RF Company (bl); Fabrizio Troiani (clb). **297 Alamy Images:** The Art Archive (b). **300 Alamy Images:** Leslie Garland Picture Library (cl). **Corbis:** Scientifica/Visuals Unlimited (t, bl). **Dorling Kindersley:** Neil Fletcher (clb). **305 Corbis:** Ric Ergenbright (cr). **307 Dorling Kindersley:** Peter Hayman/The Trustees of the British Museum (br). **309 fotoLibra :** Brian G Burgess (b). **316 Dorling Kindersley:** Colin Keates, Courtesy of the Natural History Museum, London (cl). **317 The Bridgeman Art Library:** Detroit Institute of Arts, USA/Gift of Lillian Henkel Haass and Constance Haass (br). **319 Dorling Kindersley:** The Trustees of the British Museum (br). **320 shutterstone.com:** (bl). **323 Dorling Kindersley:** The Trustees of the British Museum (br). **326 Dorling Kindersley:** Neil Fletcher (bl, t). **327 fotoLibra :** John Cleare (t). **332 Dorling Kindersley:** Courtesy of the Pitt Rivers Museum, University of Oxford (br). **333 Dorling Kindersley:** Colin Keates, Courtesy of the Natural History Museum, London (cl). **334 Corbis:** (cr). **Smithsonian Institution, Washington, DC:** (c). **335 Dorling Kindersley:** Neil Fletcher (b). **336 Dorling Kindersley:** Colin Keates, Courtesy of the Natural History Museum, London (cl); Courtesy of the Oxford University Museum of Natural History (t). **337 Dorling Kindersley:** Neil Fletcher (bl)

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Sept. 7, 1965

L. G. SMITH

3,205,381

IONOSPHERIC BATTERY

Filed March 9, 1962

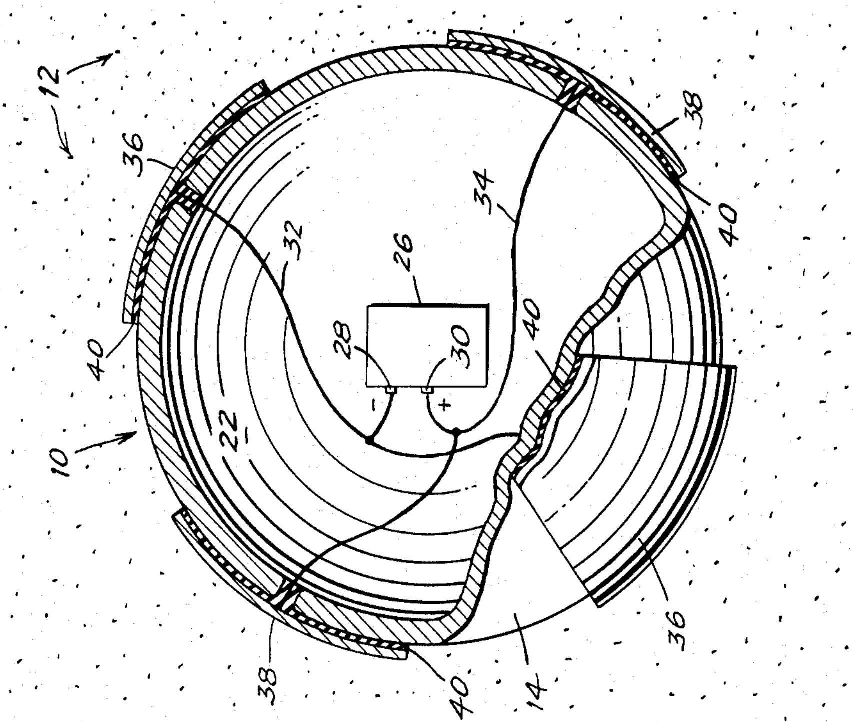
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Fig. 2

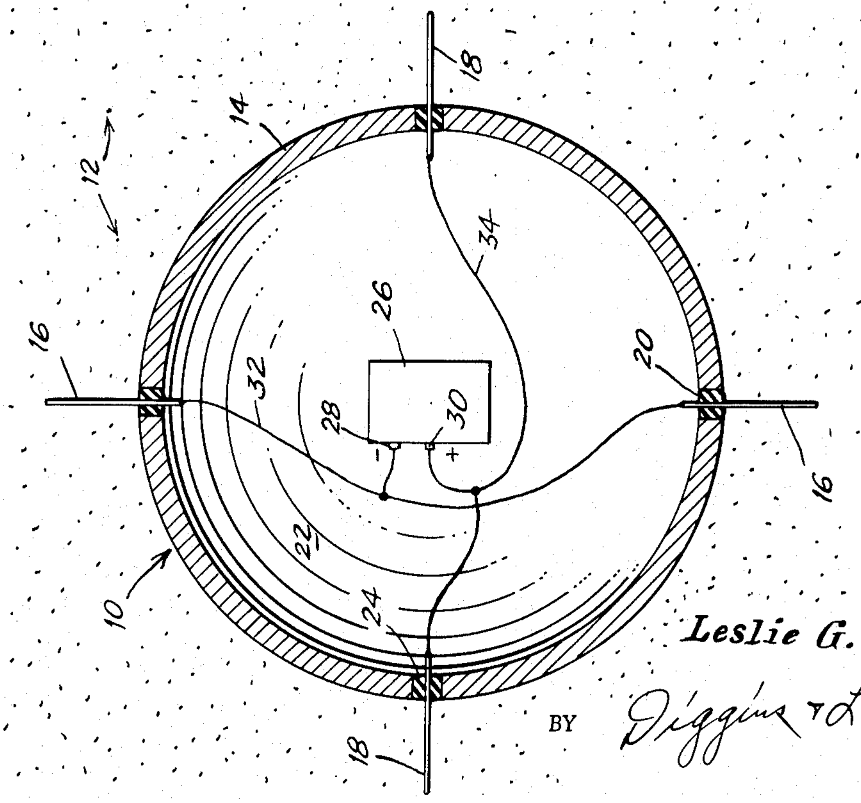
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Fig. 1

INVENTOR

Leslie G. Smith,

BY Diggins & Le Blanc

ATTORNEYS

United States Patent Office

3,205,381

Patented Sept. 7, 1965

3,205,381

IONOSPHERIC BATTERY

Leslie G. Smith, Waltham, Mass., assignor, by mesne assignments, to the United States of America as represented by the Administrator of the National Aeronautics and Space Administration

Filed Mar. 9, 1962, Ser. No. 178,721

11 Claims. (Cl. 310—5)

This invention relates to a method and apparatus for tapping the enormous reservoir of energy existing in the ionosphere and more particularly for furnishing electrical power to space vehicles.

Within recent years various space probes and space vehicles such as satellites have been launched by man in an effort to learn more about the earth and the solar system within which he lives. Each of these various space craft has employed numerous electrical circuits which are utilized to detect and transmit back to earth certain information ascertained by the craft as it moves through space. In view of the presence of such electrical circuits, some source of electrical power must be made available whereby these circuits can be energized. In the past there have been three main sources of electrical power carried by space vehicles for energizing these circuits, namely, (1) conventional storage batteries, (2) solar batteries and (3) a combination of the conventional storage and solar batteries. Although these various electrical power sources have functioned with some degree of success each has certain serious limitations which cannot be readily overcome.

In the first instance, the conventional storage battery may be of either the wet or dry type but, due to its superior storage capacity, the wet cell type is used nearly exclusively in space vehicles. This additional storage capacity of the wet cell battery is of great importance since the useful life of the vehicle is usually dependent upon the proper operation of its electrical circuits which are, in turn, directly dependent upon the capacity and life of the available power source. Use in space vehicles of a storage battery that utilizes a liquid electrolyte presents several problems that have not been completely solved, however, nor is there any apparent solution to some of these problems. For example, to increase the output capacity of the battery and thereby extend the useful life of the satellite a greater amount of electrolyte must be carried by the battery. But to increase the quantity of electrolyte carried by the battery results in both an increase in size and weight of the power source and space vehicle which cannot, in most instances, be tolerated. Furthermore, the electrolyte may not function correctly if it is subjected to the extreme conditions of space such as, for example, the changes in temperature that are normally encountered. Thus, to insure the proper operation of the wet cell battery involved in powering a space vehicle and to prevent any leakage that might occur should the battery be damaged, some shielding or insulating of the battery is usually involved which, needless to say, adds materially to the cost and weight of the vehicle.

To overcome the space, weight and leakage problems encountered when storage batteries of the conventional wet cell type are used, space engineers have turned to the recently developed solar cell or battery which converts the light rays received from the sun directly into electrical energy. While these solar batteries do not require any type of electroylte and are, therefore, relatively light in comparison to the wet cell storage battery, they are expensive and their inherent principle of operation presents one problem which cannot be overcome, namely, the inability of the solar cell to produce power while the space vehicle is shaded from the sun such as occurs when a satellite is in the shadow cast by the earth.

In an effort to overcome this loss of power which occurs each time a satellite passes into the shadow cast by the earth or some other heavenly body, a storage battery of the wet cell type was added to the vehicle. While the satellite is in the sunlight the solar battery powers the various electrical circuits and charges the storage battery so that, once the sunlight is no longer available, the storage battery can be switched on to furnish the necessary electrical power to the vehicle. While this combined system functions satisfactorily, there is added to the already existing problems of weight, size and electrolyte leakage the problem of incorporating a battery charging and switch-over system between the solar and storage batteries. The addition of this type of system to the power source is undesirable since it adds unduly to the complexity, sensitivity and cost of the space vehicle.

According to the present invention, it has been found that some of the foregoing disadvantages of space vehicle power sources can be overcome by employing an ionospheric type battery which utilizes the ionosphere or other ionized medium existing in outer space as a supplemental source of energy. Since power is a scarce commodity essential for the operation of the space vehicle and for the proper functioning of its experiments, any means for supplying additional power while adding only slightly to the weight of the vehicle, increases the efficiency and life of the space vehicle. Although it has been known for some time that the ionosphere contains an enormous reservoir of energy in the form of excited and ionized atoms and molecules, no practical method has heretofore been found whereby this energy could be utilized as a source of power for earth satellites even though much thought has been given to this problem. The operation of the present invention is based upon the discovery that the ionosphere can be utilized as a part of supplemental power source for the load circuit in a space vehicle when said vehicle is equipped with electrodes having different work functions which, in turn, are electrically connected through the load circuit.

Accordingly, a primary object of this invention is to provide a method of producing electrical power from ionized media existing in nature.

Another object of this invention is to provide a simple, highly reliable supplemental power source for space vehicles.

Yet another object of this invention is to provide an ionospheric battery for use by satellites.

Still another object of this invention is to provide an ionospheric battery which utilizes the ionosphere as an electrolyte.

A further object of this invention is to provide a supplemental power source for space vehicles that will operate when shielded from the sun.

Yet a further object of this invention is to provide a power source for a satellite that is light and inexpensive to produce.

Another object of this invention is to provide a satellite with various shaped electrodes constructed of metals having different contact potentials.

These and further objects and advantages of this invention will become more apparent upon reference to the following description, claims and the appended drawings wherein:

FIGURE 1 is a cross sectional view of an orbiting satellite equipped with a power source constructed in accordance with one embodiment of the present invention; and

FIGURE 2 is a view in partial section of an orbiting satellite equipped with a power source constructed in accordance with a second embodiment of the present invention.

With continuing reference to the accompanying drawings wherein like reference numerals designate similar parts throughout the various views, and with initial attention directed to the embodiment of FIGURE 1, reference numeral **10** is used to generally designate a space satellite which is orbiting or otherwise passing through an ionized layer or medium such as, for example, the ionosphere which surrounds the earth. As is well known, the ionosphere contains an enormous number of excited and ionized atoms and molecules which are generated or produced when the gasses surrounding the earth are subjected to bombardment by high energy particles and rays such as, for example, ultra-violet or cosmic rays that originate throughout the solar system. Although these various ionized particles created by this bombardment are invisible to the eye they are represented pictorially by the various dots **12** for purposes of clarity.

The satellite **10** consists of an envelope or outer skin surface **14** which may be constructed of metal, ceramic or any other like material which is suitable for space vehicles of this type. As seen in FIGURE 1, a plurality of electrically conductive electrodes **16–18**, which are shown in the form of rods and are constructed of materials having different contact potentials (work functions), are mounted in a spaced relationship in the medium **12** through apertures **20** in the envelope **14** of the satellite. In order to prevent a leak from occurring between the normally pressurized interior **22** of the satellite and the ionosphere, which is a near vacuum, and to insulate the electrodes in case a metal is used for the envelope **14**, vacuum tight insulator feed-through elements **24** are fitted around the electrodes **16–18** and are securely mounted within the aperture **20**. These feed-through elements may be of any suitable type so long as they are constructed to withstand the changes in environmental conditions encountered in space without losing their insulative and sealing qualities.

Carried within the cavity or interior **22** of the satellite **10** is a load circuit **26** which may be, for example, a transmitter or any other electrical device that requires a source of electrical power for its proper operation. The load circuit **26** is mounted to the interior wall of the satellite by suitable means (not shown) and has its positive and negative power input terminals **28–30** connected to the various electrodes **16–18** respectively, by suitable electrical conductors **32–34**.

The overall principle and operation of the ionospheric battery in relationship to the satellite **10** can be explained substantially in the following manner. While the satellite remains on earth prior to its being hurled into or through an ionized medium, the electrodes **16–18** are at substantially the same potential since very few ionized particles are present. Thus, no current will flow through the load circuit **26**. However, once the satelllite is launched and it enters an ionized medium a potential difference will be established between the electrodes **16–18** and an electrical current will begin to flow through the load circuit **26**. This difference in electrical potential that exists between the electrodes **16–18** while the satellite is in an ionized medium is attributed to the fact that the electrodes **16** are constructed of a material having a different contact potential or work function from that of the electrodes **18**. This difference in contact potential between the electrodes **16–18** will result in the free electrons of the ionized medium being collected on one group of electrodes, for example the electrodes **16**, while the positive ions produced when the gas is ionized will be collected on the other electrodes **18**. With the electrodes **16** charged to a negative potential in relationship to electrodes **18**, a predetermined amount of current will flow through the load circuit **26** and can thus be utilized to power an electrical circuit such as the transmitter mentioned above.

The exact material from which the two types of electrodes **16** and **18** are constructed will depend upon several factors such as, for example, the amount of output power desired, the material readily available for constructing the electrodes, the susceptibility of the material to damage or destruction when exposed to the environmental conditions existing in space, and various other considerations that will be readily apparent to a worker in the battery field.

While the electrodes **16–18** used in the ionospheric battery of FIGURE 1 have been described as rods or whiplike elements it is to be realized that the electrodes may take other shapes. By way of example, a plurality of flat, plate-like electrodes **36–38** are shown mounted on a satellite in FIGURE 2. These electrodes are constructed of materials having different contact potentials and are insulated from the outer surface **14** of the satellite when this is necessary by an insulative layer **40** of any suitable material having the desired insulative properties under the severe conditions existing in space. The use of these plate electrodes **36–38** has the advantage of increasing the surface area exposed to the ionized medium thus permitting a larger output current to be produced without the necessity of using excessively long electrodes as might be the case if the rod electrodes of FIGURE 1 were used.

The output current of the battery is dependent upon the degree to which the medium is ionized and to the extent that the electrode surface area is exposed to the medium. An increase in either results in an increase in the efficiency of the battery. From an analysis of various experiments it is expected that a current of about two microamps per cm.^{2} of electrode surface at a potential of one volt would be produced if the satellite is orbiting in the ionosphere at an altitude of approximately 350 km. and electrodes of gold and platinum are used.

It will also be readily apparent that the envelope of the satellite itself could be constructed in sectional form and of materials having different contact potential thus eliminating the necessity of attaching different electrodes to the satellite or the slight increase in weight necessarily involved. Of course the various sections of material making up the envelope of the satellite would have to be insulated from one another to prevent electrical shorting from occurring.

It will be apparent from the foregoing that the power source of this invention is extremely light, rugged and involves a minimum of cost to construct. By using the vast natural reservoir of energy existing in the form of ionized gases for producing the electrical power necessary to energize the various electrical circuits of a space vehicle a practically indefinite source of electrical power is made available to the vehicle. An ionospheric battery constructed in accordance with this invention is also much more reliable in operation than other heretofore known power sources since no liquid electrolyte is involved which can leak, deteriorate or otherwise become spent, nor is the operation of the battery dependent upon its position in relationship to a source of light.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respect as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. A space vehicle equipped with a generator of electrical energy operable in the ionosphere as a supplemental source of potential for a load thereof, said generator comprising at least two electrode means on said vehicle and positioned to contact said ionosphere when said vehicle is in said ionosphere, said two electrode means each having different contact potentials, one of said two electrode means being gold and the other being

platinum, and electrical connector means connecting said two electrode means to said load.

2. Apparatus for generating electrical energy from the ionosphere comprising, a pair of spaced electrode means having different contact potentials positioned to contact said ionosphere so that a direct-current electric potential is established between said electrode means, load circuit means, and means electrically connecting said load circuit means to said electrode means whereby said load circuit means is powered by the direct-current electrical potential existing between said electrodes.

3. Apparatus for generating electrical energy from the ionosphere comprising, carrier means, a first electrode having a first contact potential mounted on said carrier means, a second electrode having a second contact potential spaced from said first electrode and mounted on said carrier means, said first and second electrodes being positioned on said carrier means so that they will be in contact with said ionosphere when said apparatus is placed in the ionosphere so that a direct-current electric potential is established between said first and second electrodes, and an electrical load circuit connected between said first and second electrodes, said load circuit being powered by the direct-current potential produced by said first and second electrodes.

4. Apparatus according to claim 3 wherein said first and second electrodes extend away from said carrier means.

5. Apparatus according to claim 3 wherein said first and second electrodes form a portion of said carrier means.

6. In a space vehicle adapted to pass through ionized areas in space, a power source for said vehicle while it is passing through said ionized areas comprising, a plurality of electrode means located on the outer surface of said vehicle, said electrode means being constructed of materials having different contact potentials, and means connecting said electrode means together through a load circuit whereby said circuit receives a source of direct-current as said space vehicle passes through said ionized areas.

7. In a space vehicle according to claim 6 wherein said electrode means are rod shaped.

8. In a space vehicle according to claim 6 wherein said electrode means are plate shaped.

9. A satellite comprising an envelope, electrical load means carried in said envelope, apertures extending through said envelope at spaced points, electrode means having different contact potentials, said electrode means passing through said apertures, means in said aperture for insulating said electrode means from said envelope, and electrical conductor means connected between said electrode means and said electrical load means whereby said electrical load means is energized by the direct-current electric potential established when said electrode means passes through an ionized medium.

10. A space satellite comprising an envelope, an electrical load circuit carried in said envelope, a power supply for said electrical load circuit comprising a first electrode having a first contact potential connected to said electrical load circuit and extending through said envelope and a second electrode having a second contact potential connected to said electrical load circuit and extending through said envelope, said first and second electrodes being insulated from one another so that said electrical load circuit is powered by the direct-current electric potential established by said first and second electrodes coming in contact with an ionized medium.

11. The method of powering electrical circuit means carried by a space vehicle comprising the steps of positioning first and second electrode means having different work functions on said vehicle, passing said vehicle through the ionosphere so that said first and second electrode means are in contact therewith and produce a direct-current potential between them, and connecting said first and second electrodes to said electrical circuit means by means of electrical connector means, whereby said direct-current potential is made available for operating said circuit.

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LLOYD McCOLLUM, *Primary Examiner.*

JOHN H. MACK, *Examiner.*

Capacitors we used are electrolytic rated at 400 volts x 47 uF put in series to equal 6,000 volts, the diodes we used were silicon 1000 volt 2 amp placed in series to equal 6,000 volts......... Ground was connected to laboratory wall out let ground.

If you decide to try Tesla's experiment by pumping DC into the ground be careful, I tried this and it does work but is very dangerous to you or your neighbors. If someone is taking a shower or using water they can get killed or shocked. do this experiment far away from humans and animals. you can get far more energy out than you put in. I will not tell you much more because it is such a dangerous experiment.

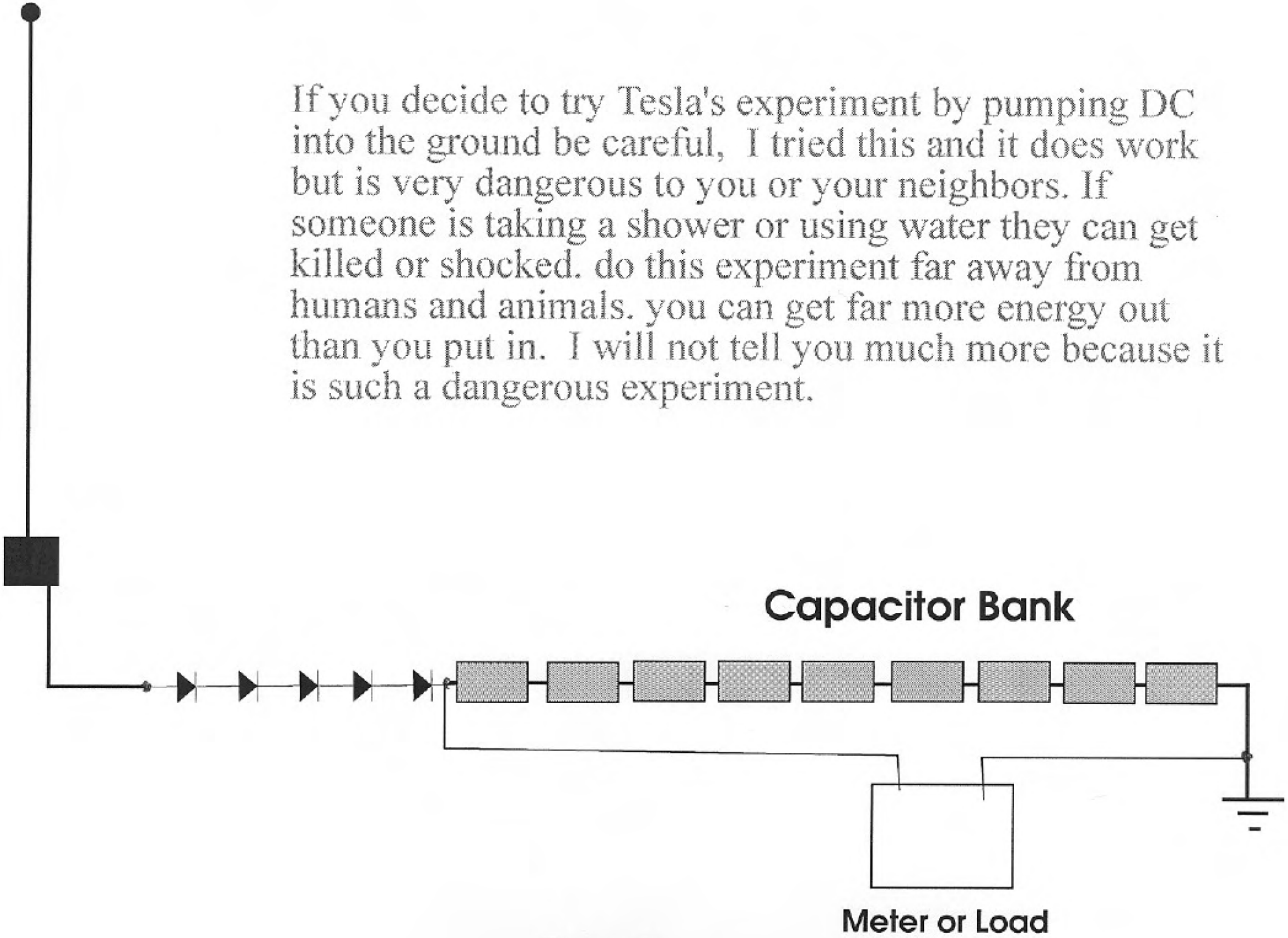

BUILDING A DIY VIDEO TRANSMITTER

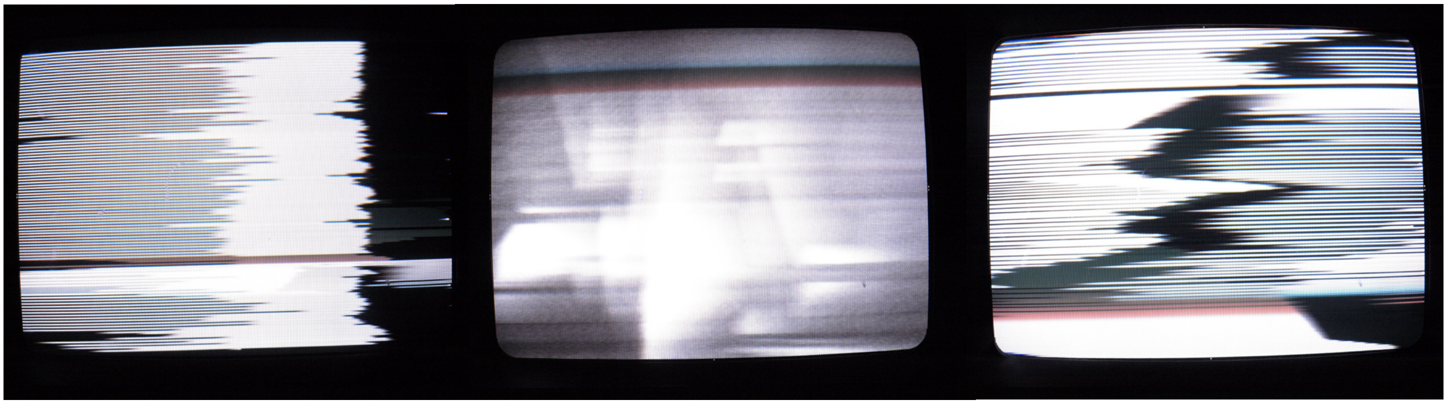

WHAT YOU NEED

- Blank PCB Copper Plate (jameco.com part #169279)
- Capacitors: 2x 0.1uf
  1x 100u
  2x 6-70pf Variable Caps (jameco.com part #32855)
- Resistors: 27kOhm
  10kOh
- Transistor-MPSA18 (jameco.com part #210681)
- 1k potentiometer
- Small amount (~4") of magnet wire 24 AWG or close (jameco.com part #2098419)
- Sand paper
- Stranded hookup wire
- Hacksaw or dremel tool
- Headphones with 1/8" plug (from iPod or MP3 player)
- Hot glue or super glue
- Soldering Iron
- CRT "tube" TV with an antenna (the transmitter won't transmit to newer flat screen TV's)

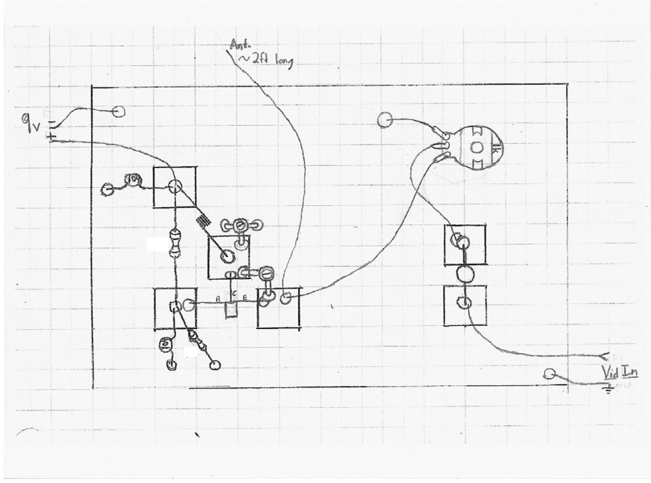

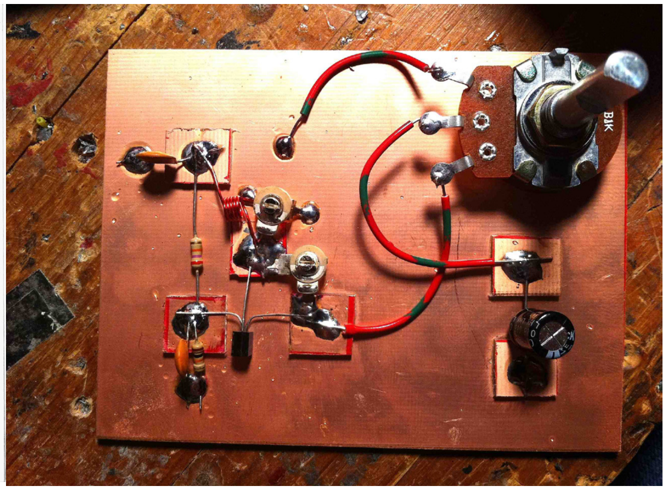

INTRODUCTION

This micro video transmitter was designed by the DIY radio and micro TV artist Tetsuo Kogawa. His website (http://anarchy.translocal.jp/) is full of great info on DIY radio, and all credit for this circuit goes to him.The transmitter can be used to transmit a relatively clear video signal or abstract visualizations, depending on the desired output. It will usually function at a distance of about 20 feet. If you have any previous experience with electronics or circuit building, you will notice that this method of building is different. The circuit is constructed on top of a copper "ground plate" which is common in radio applications. This tutorial uses step-by-step sketches and photos created based on Tetsuo Kogawa's design.

BUILDING THE TRANSMITTER

1. PREPARING THE COPPER PLATE

- Take the bare copper plate and cut off 1inch of material using a dremel tool or hacksaw.
- Use this material to cut out 6 square ½ in. x ½ in. pieces.
- Arrange the 6 pieces on the larger copper plate as shown in the image below…

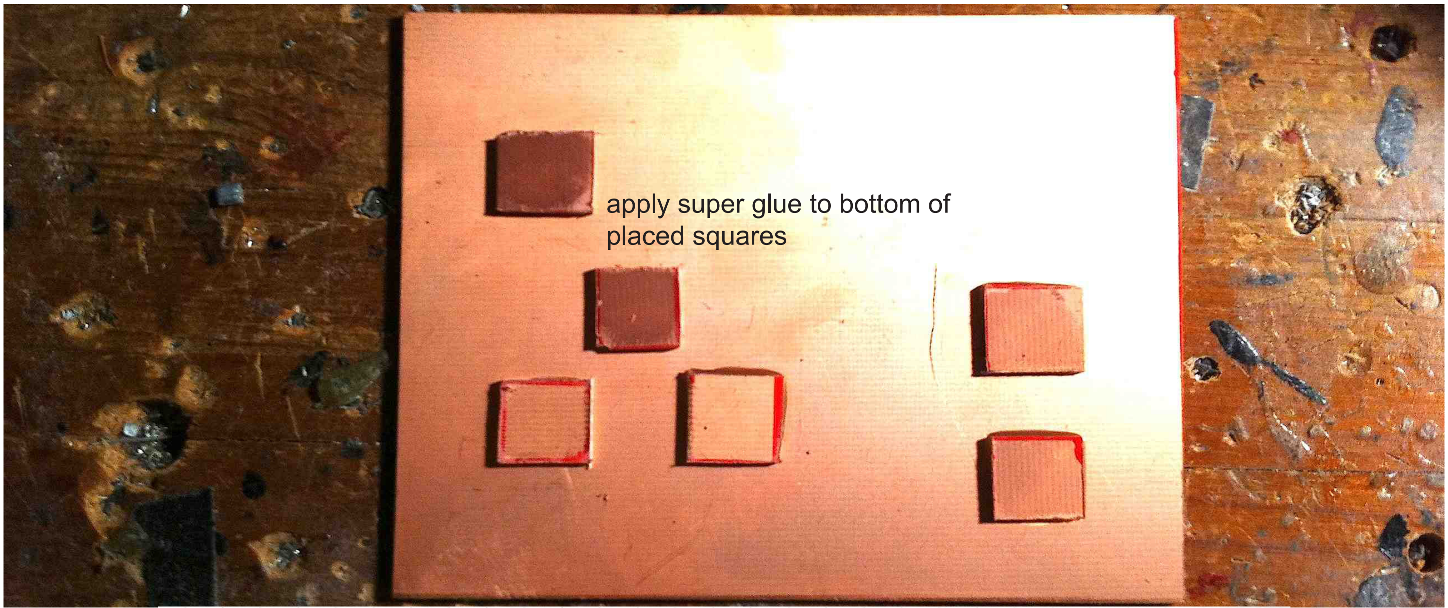

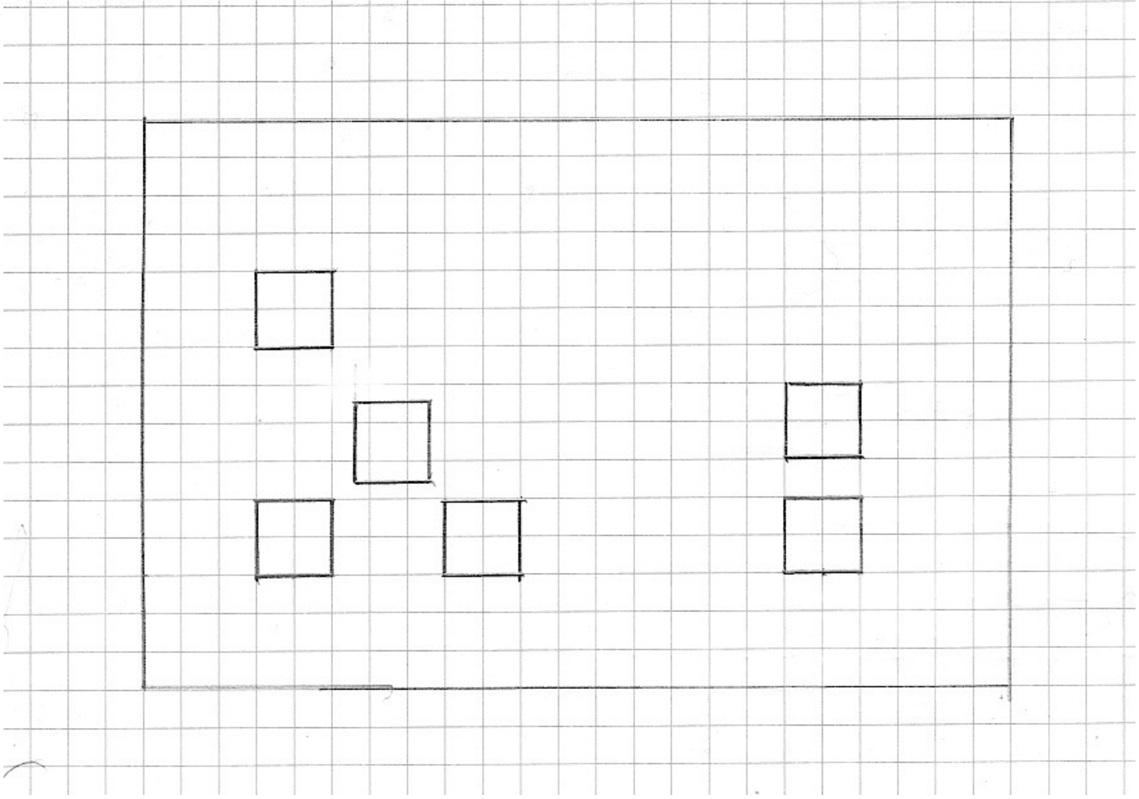

****NOTE**** Be sure to arrange them so that all the component leads will be able to reach the squares. Look ahead to see what components will go where so you know exactly how to space them.

- Once you have them arranged, put a dab of hot or super glue on the bottom of each square and stick them in place on the copper plate.

2. ADDING THE 100uF CAPACITOR (the cylinder with “100uF” written on the side)

- Melt a blob of solder onto the two squares furthest to the right. To do this, apply your iron to each square to transfer heat for an extended period of time until the solder flows onto the surface.

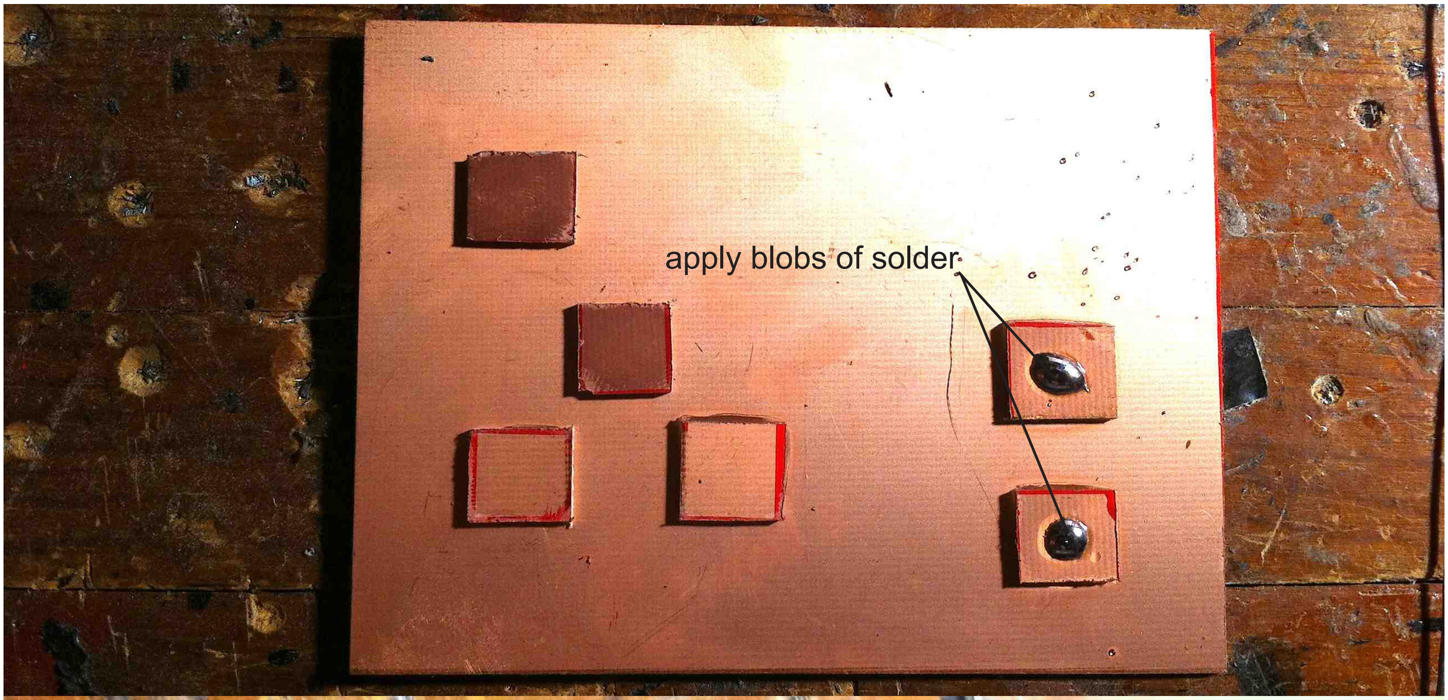
apply blobs of solder

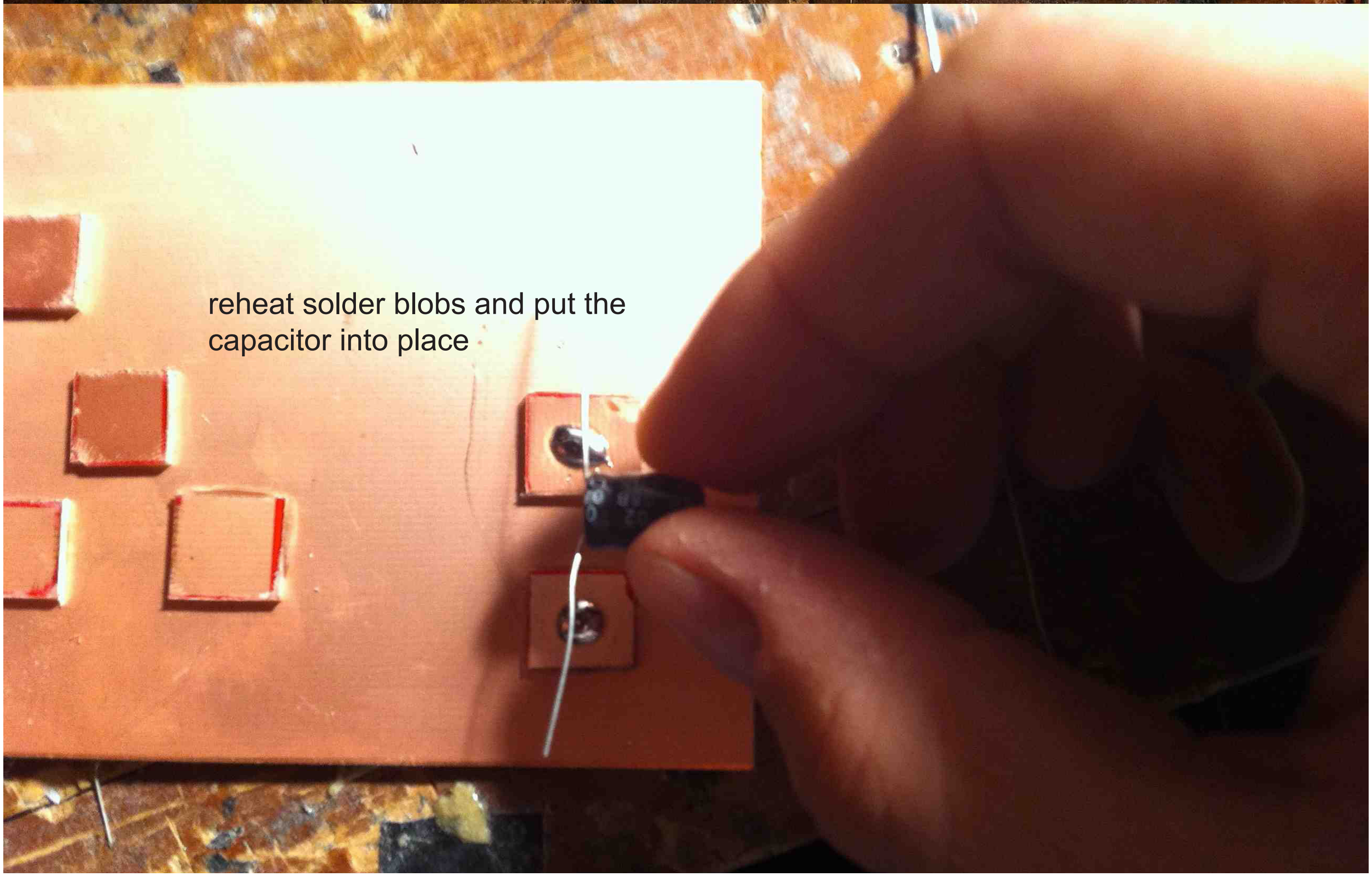
reheat solder blobs and put the capacitor into place

- Bend the legs out of the 100uf capacitor and straddle them between the two squares making sure that the leads are only touching the two small squares (not touching the ground plate).
- Cut the excess off of the leads.
- One at a time, re-heat the solder blobs and place the capacitor leads into them, allowing them to cool down until they stay in place.

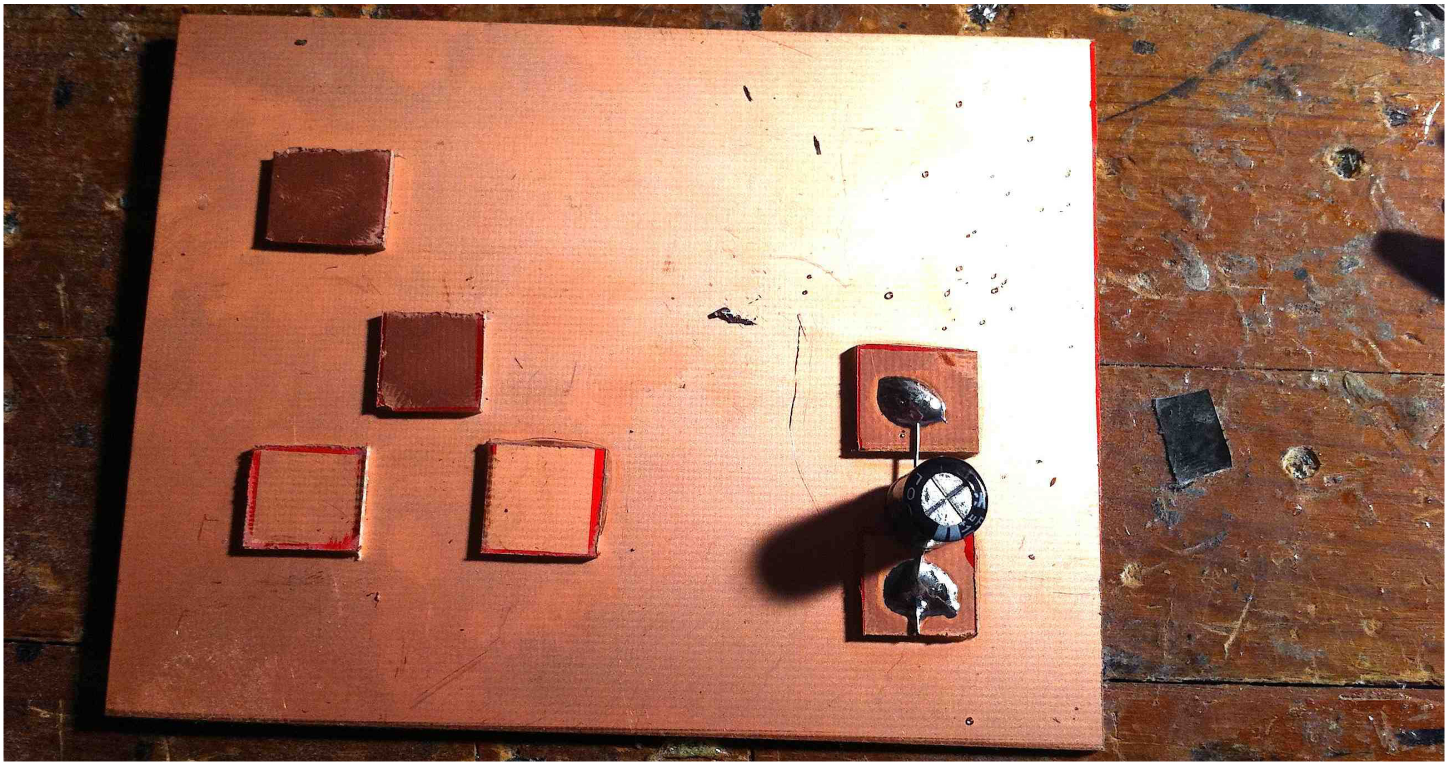

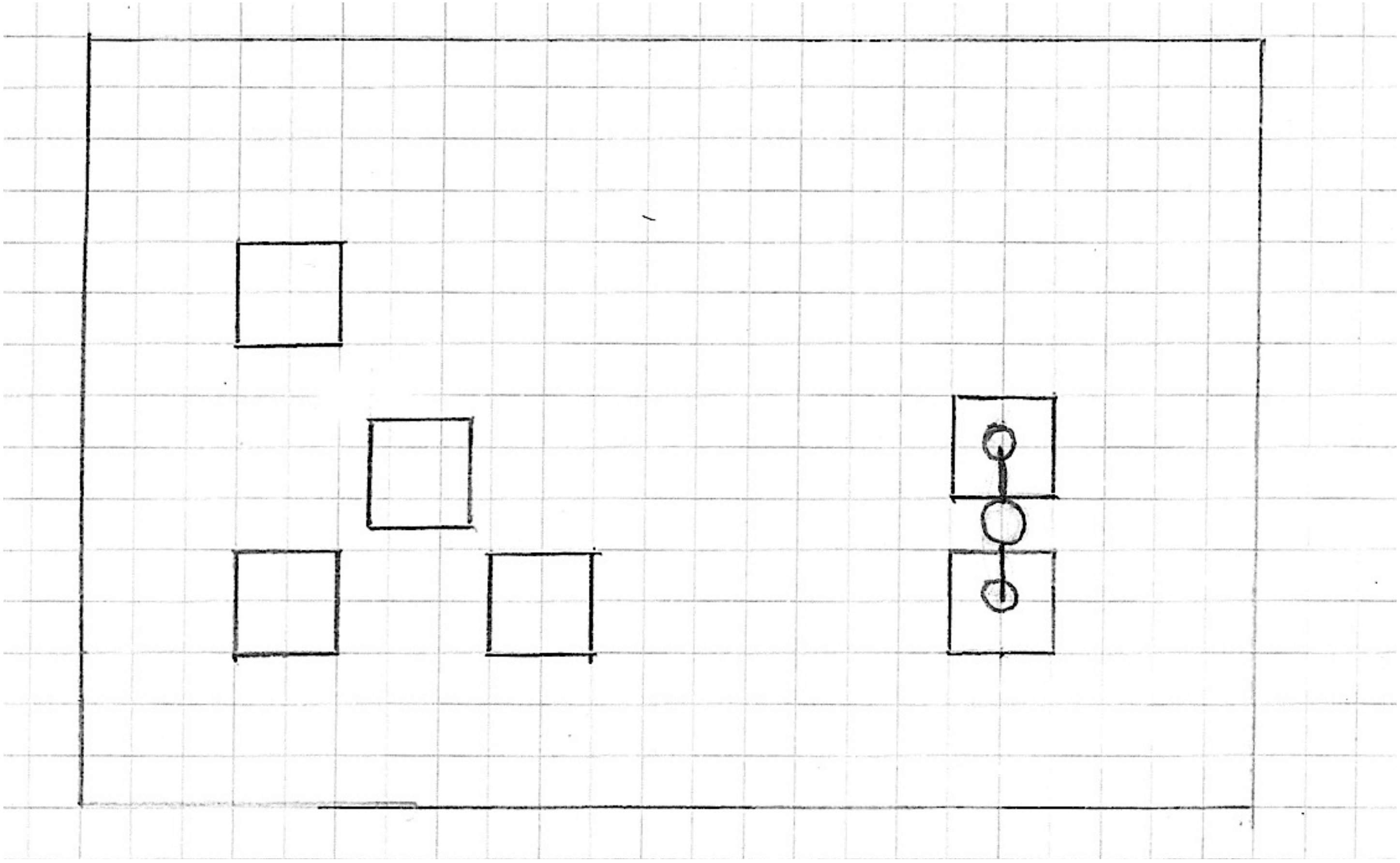

*****NOTE***** - This capacitor is polarized meaning that it has to be facing in the appropriate direction. Make sure you solder the NEGATIVE lead to the LOWER of the two squares. The negative side has the shorter lead and a vertical stripe along the side of the capacitor.

3. ADDING THE .1uF CAPACITORS (the two discs with “104” written on them)

- These capacitors will be positioned between the upper and lower left most squares and the ground plate. Melt a blob of solder on these two squares and two blobs on the ground plate beside each. (Reference the pictures for exact positioning).
- Re-heat the blobs and position the capacitors accordingly as in step 2.

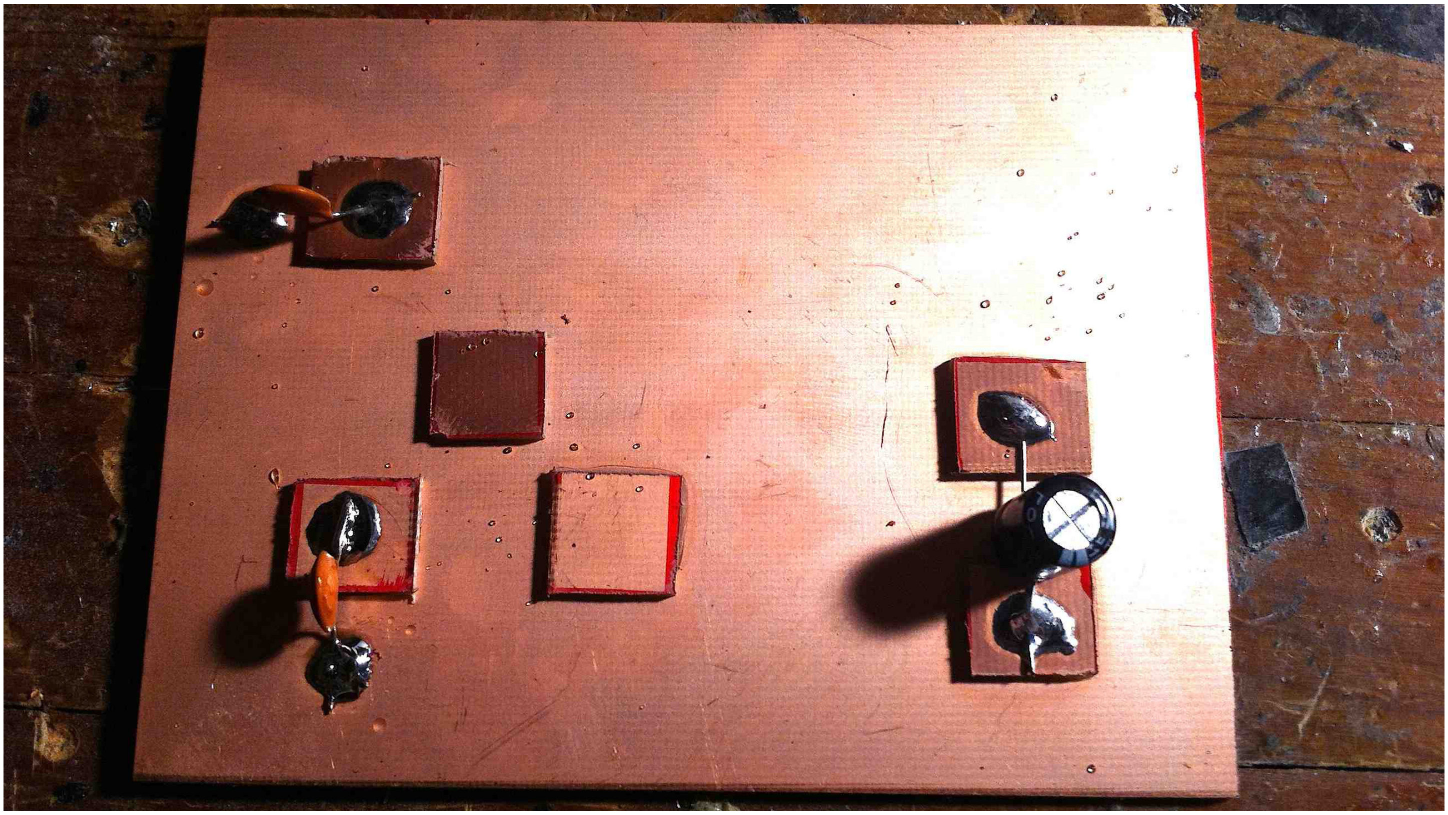

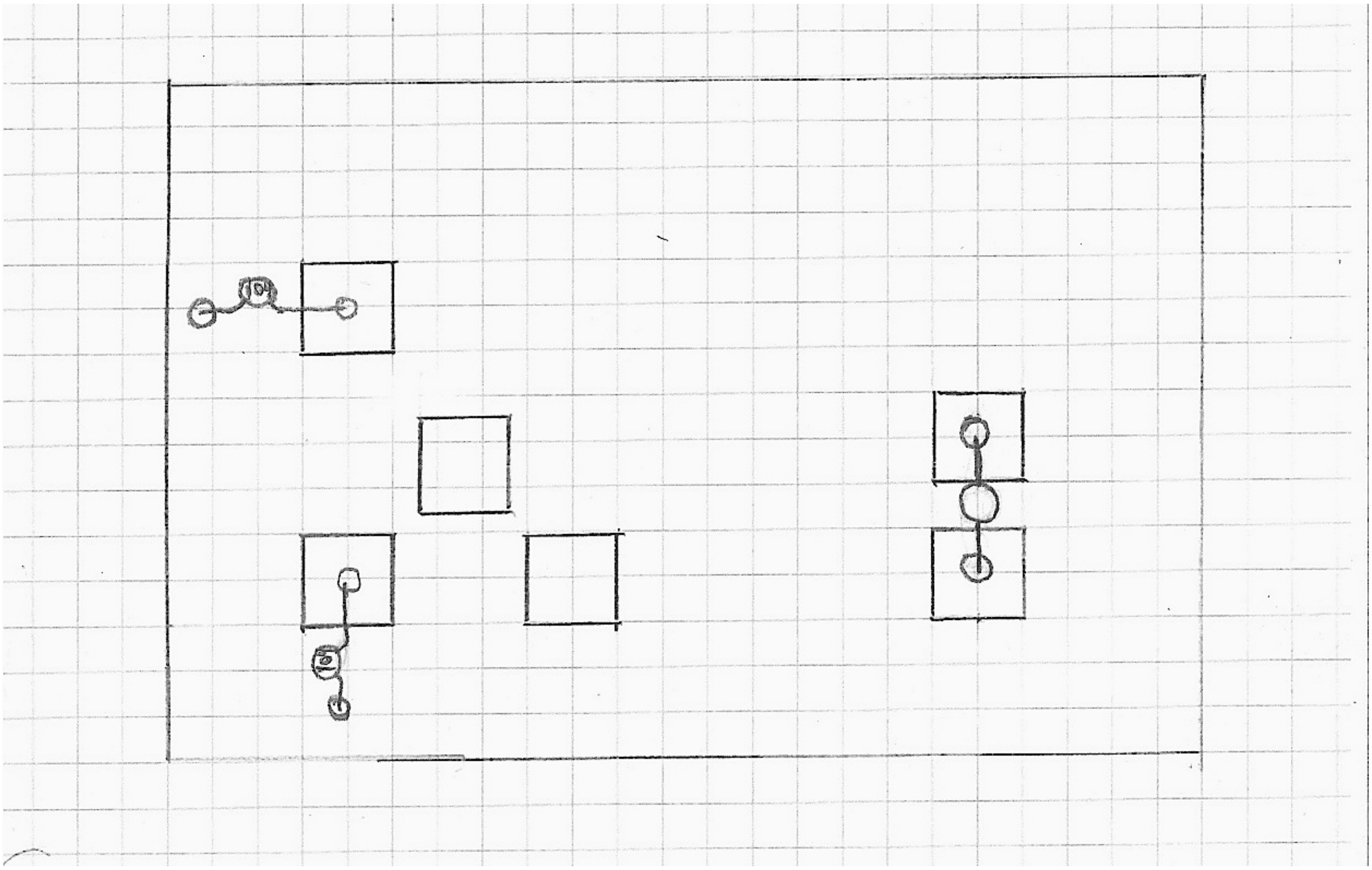

4. ADDING THE RESISTORS (10k and 27k)

- Solder the 10k resistor (brown, black and orange stripes) between the bottom left square and ground.
- Solder the 27k resistor (red, violate and orange stripes) between the two left squares.

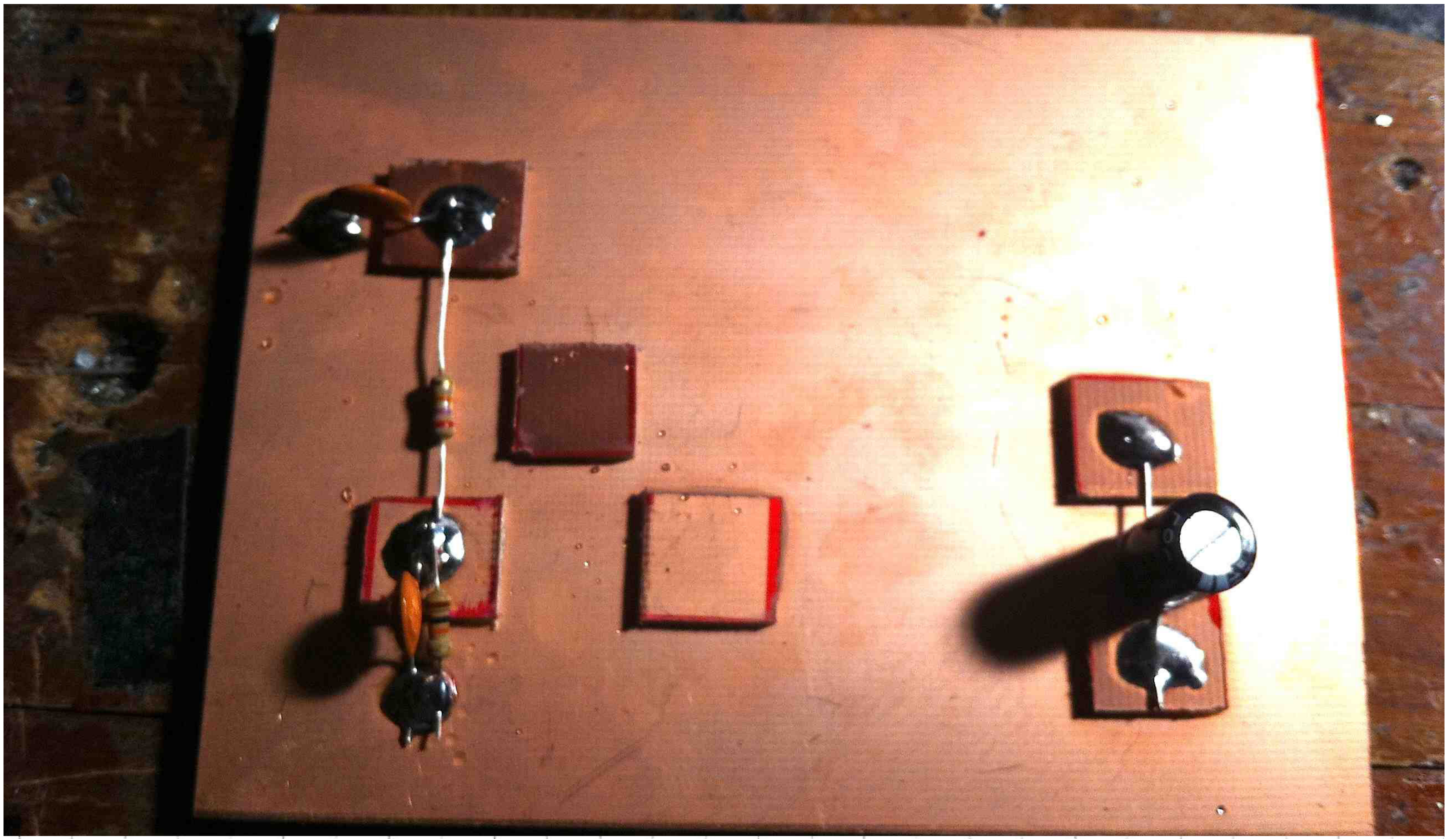

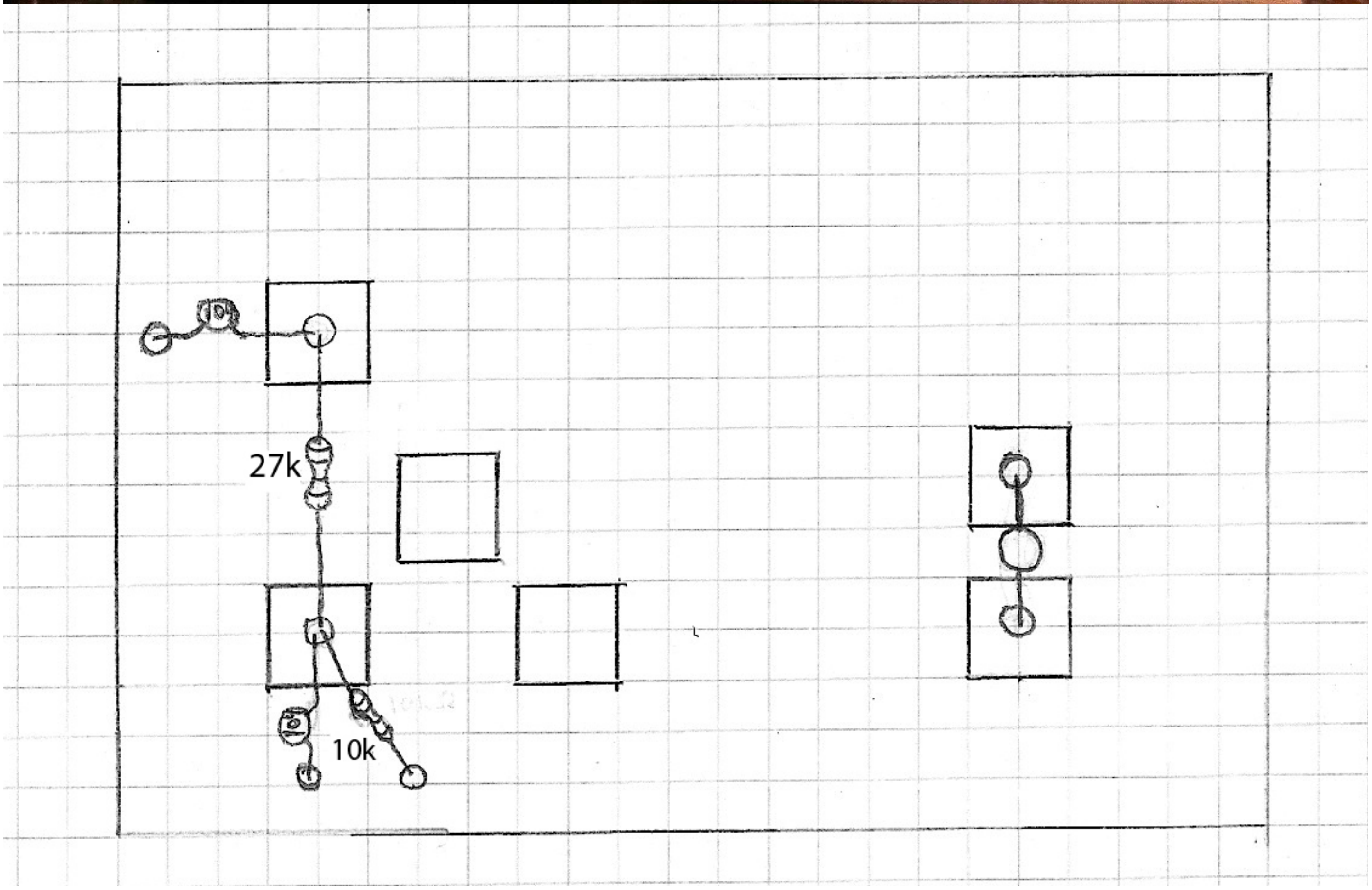

5. ADDING THE COIL

- Cut about 4” of the magnet wire (24 AWG or close)
- Use the plug from your headphones to wrap the wire around. Make 5 turns.

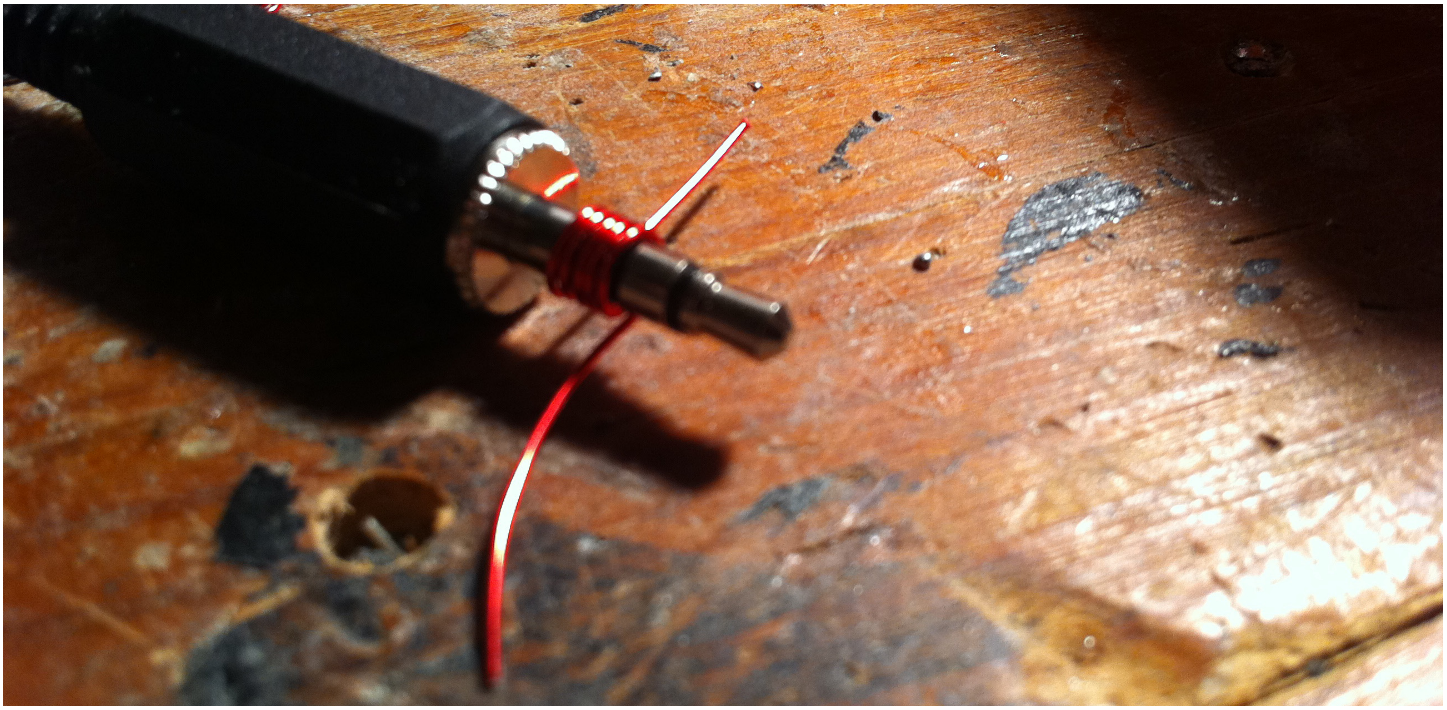

- With the wire still wrapped around the headphone plug, take a small piece of sand paper and rub off the colored insulation of each end until the bare copper is exposed (If the copper is not exposed, you won’t be able to make a connection).

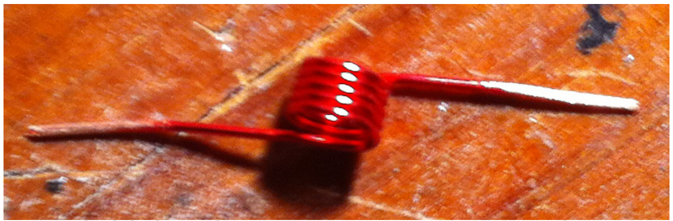

- Solder the coil into place bridging the two squares as seen below

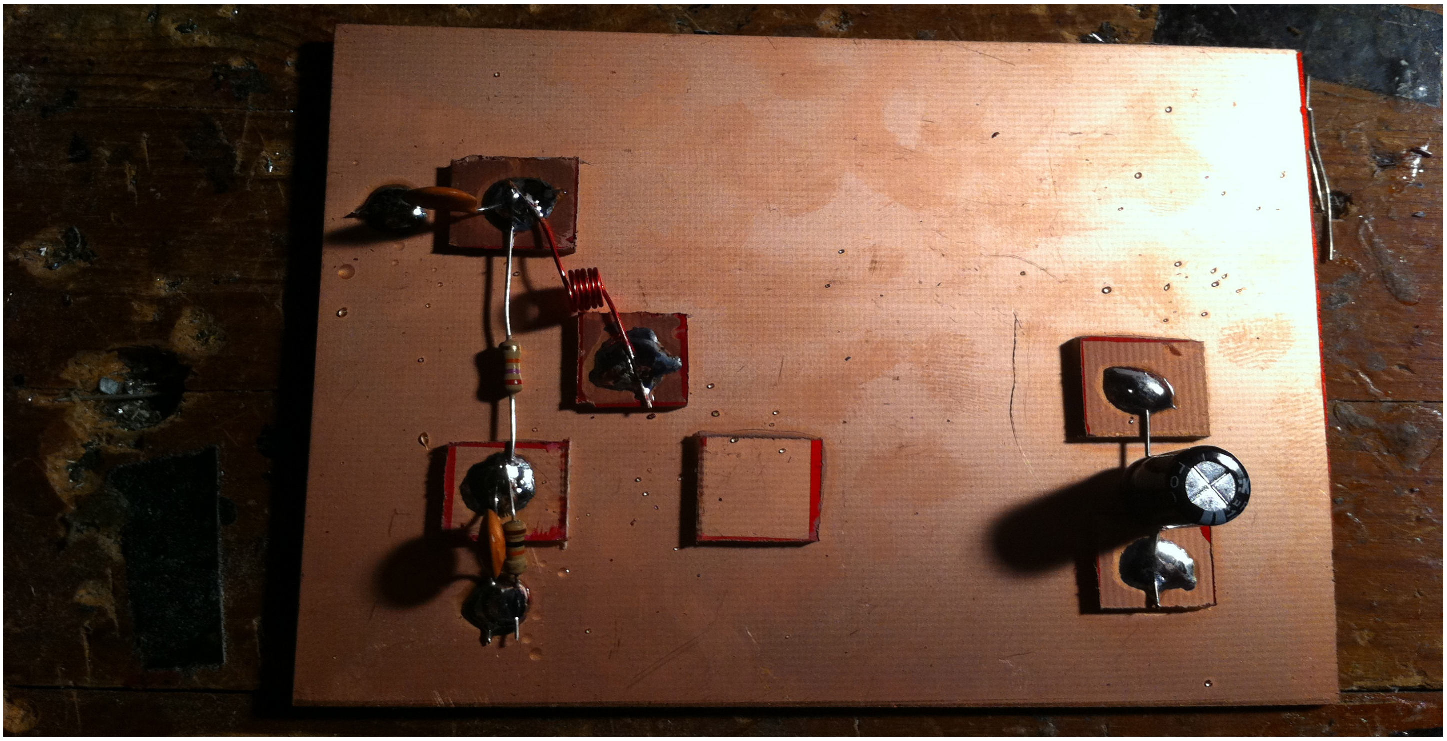

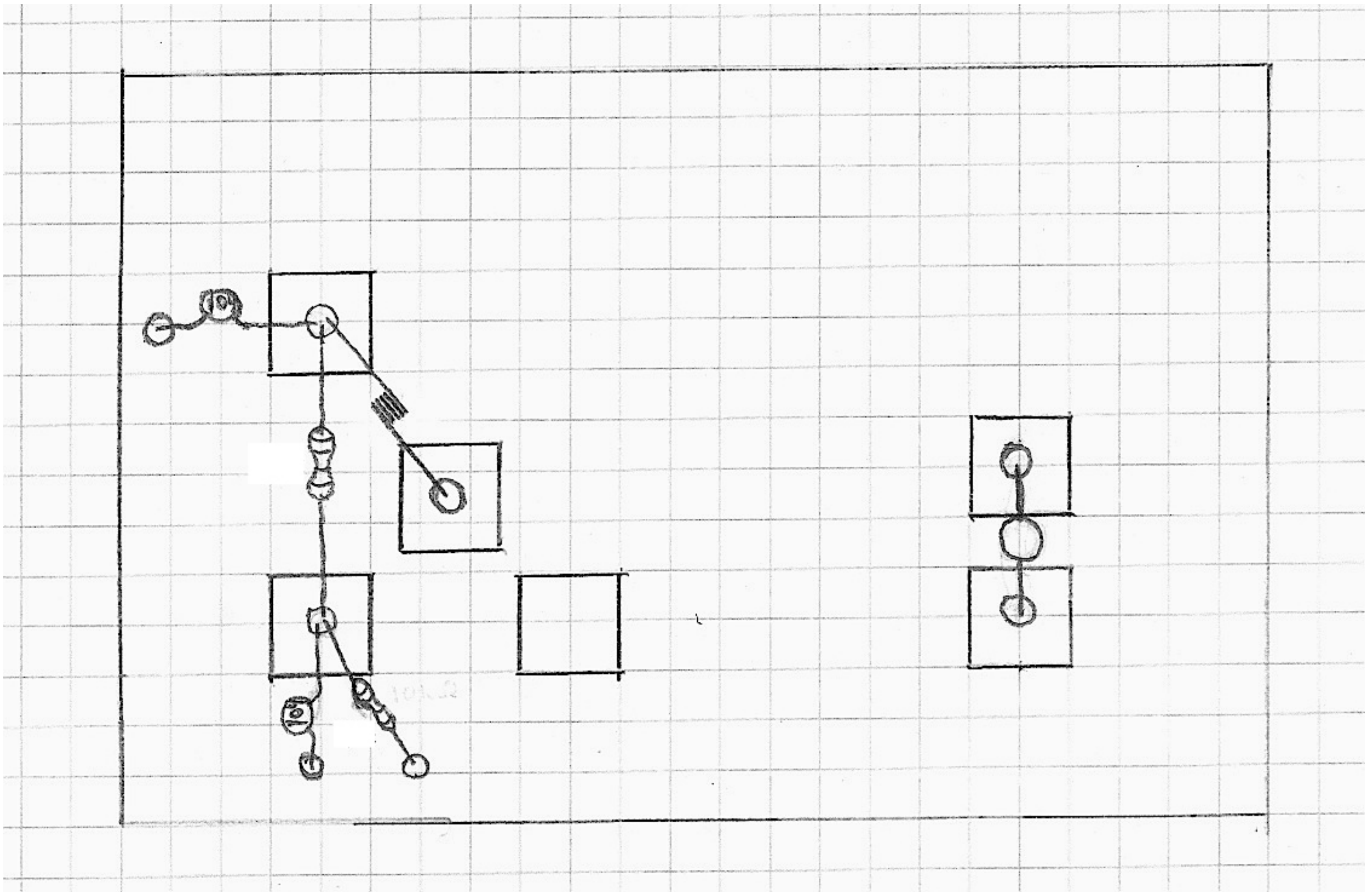

6. ADDING THE VARIABLE CAPACITORS

NOTE Once the component leads start to pile up on each other on each square, it helps to add additional solder.

- The first variable capacitor will be soldered between the top square of the three that make up the bottom triangle and the ground plate.

- Solder the “nose” of the capacitor (the lead that is different from the other two) to the square, and the other two side leads to the ground plate.

NOTE You will have to bend the leads in a certain way in order to get everything positioned properly. Just play around with it till you get it.

- The second variable capacitor will bridge between top and right squares of the triangle. Only two leads are needed here so use your clippers to remove one of the side leads, leaving the nose and only one side. (See the pic below)

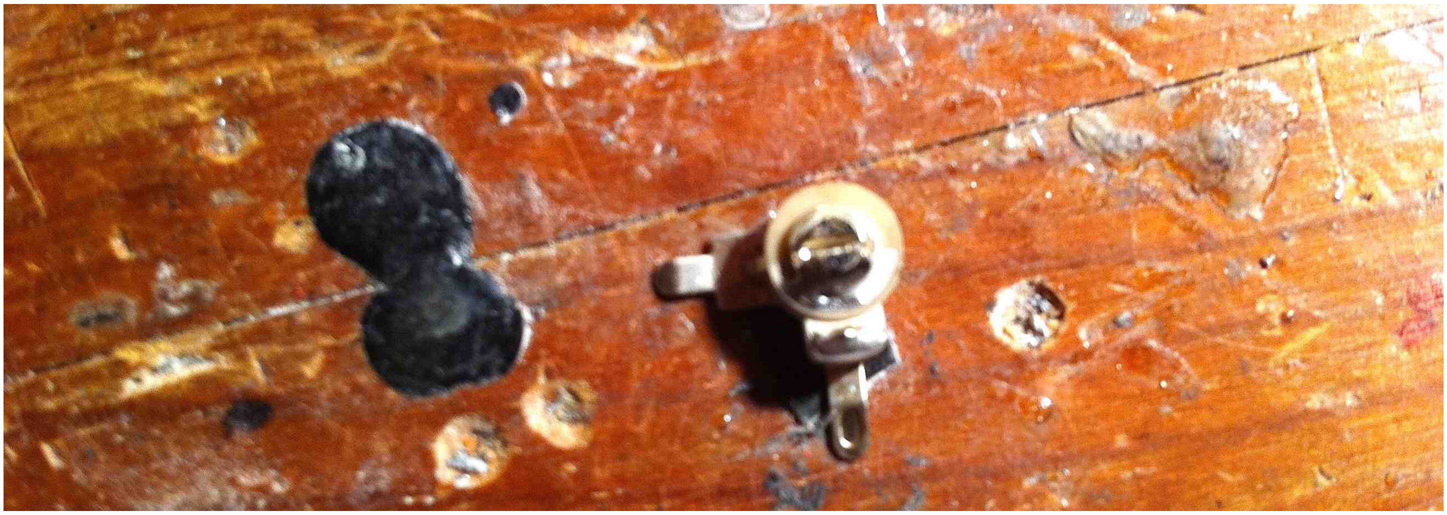

The variable capacitors soldered into place…

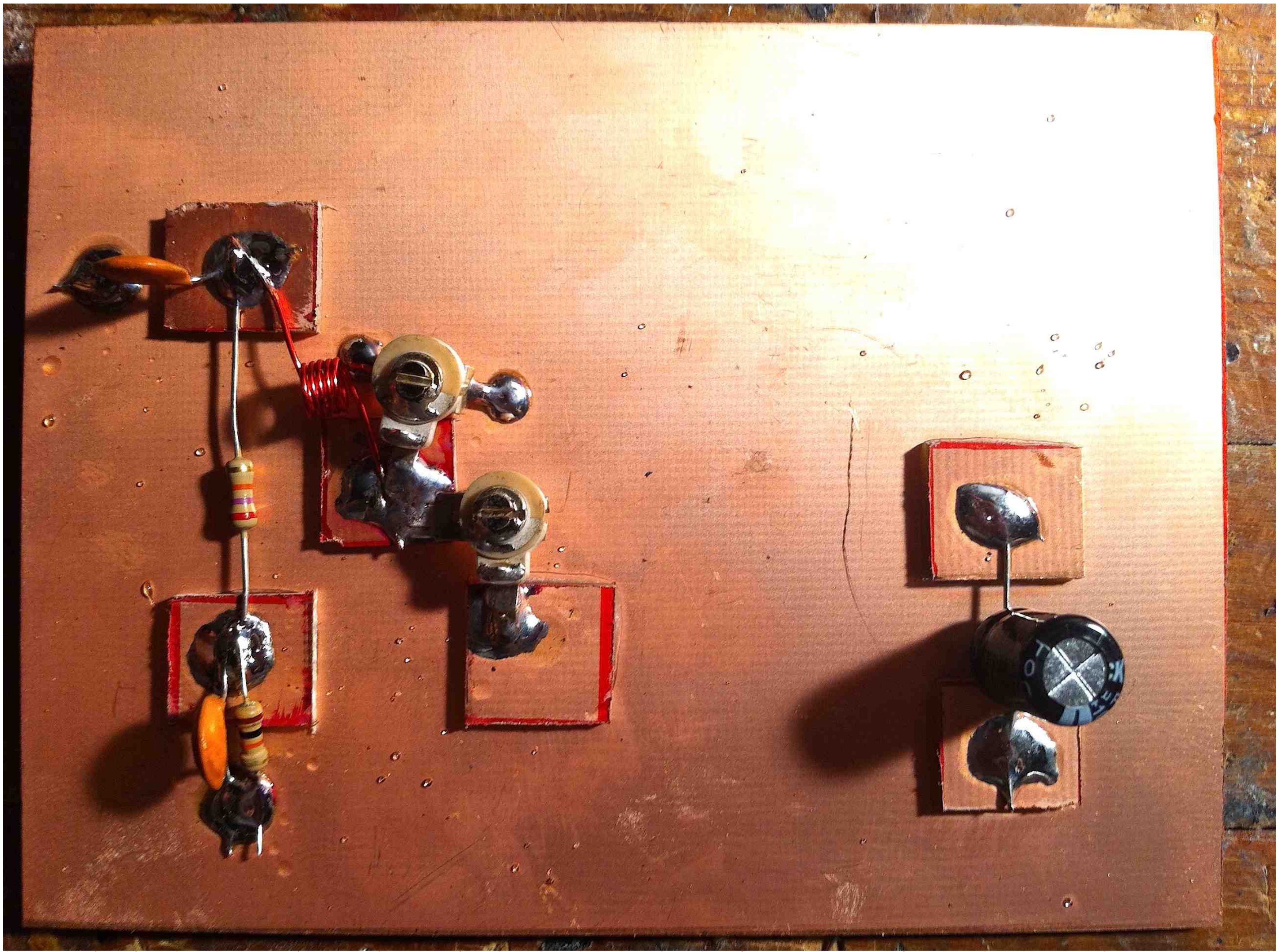

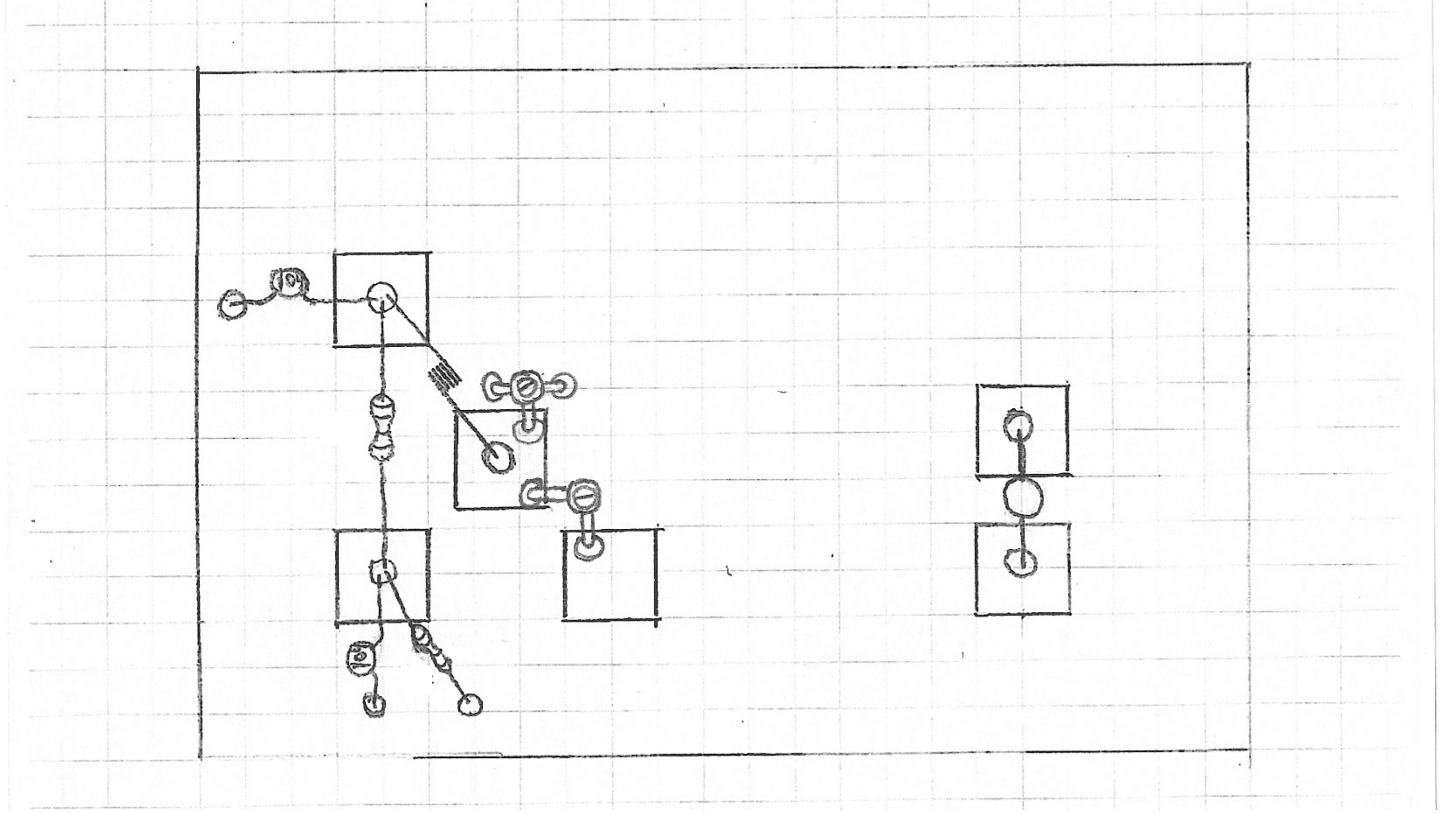

7. ADDING THE TRANSISTOR (MPSA18)

NOTE This transistor is sensitive to heat and can be destroyed by the heat from your iron. Be sure to follow the necessary precautions below. But don't worry if you do kill one, they are only ~$.10 a piece.

- The three leads of the transistor all do specific things and must go to the appropriate places. Here is a pic of the orientation of this transistor…

C=Collector B=Base E=Emitter

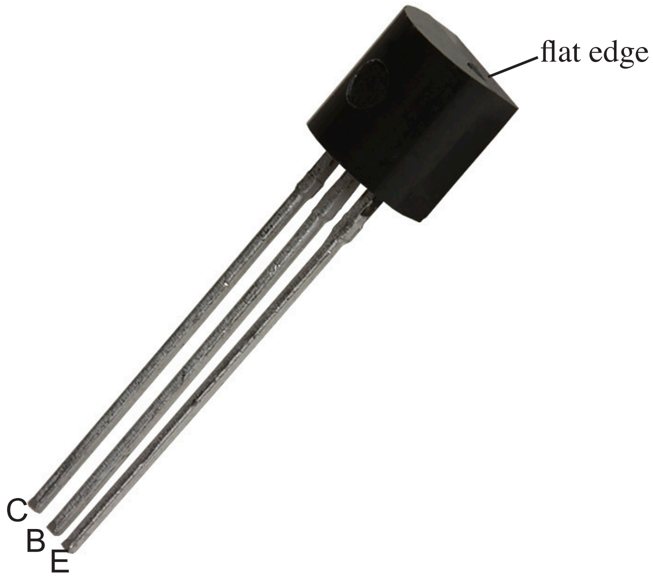

- Each lead from the transistor will be soldered to the three different squares that make up the triangle, so you will have to bend the leads accordingly.
- The B lead (base) goes to the left square of the triangle, the C lead (collector) goes to the top square, and the E lead (emitter) goes to the right square, as in the image below.

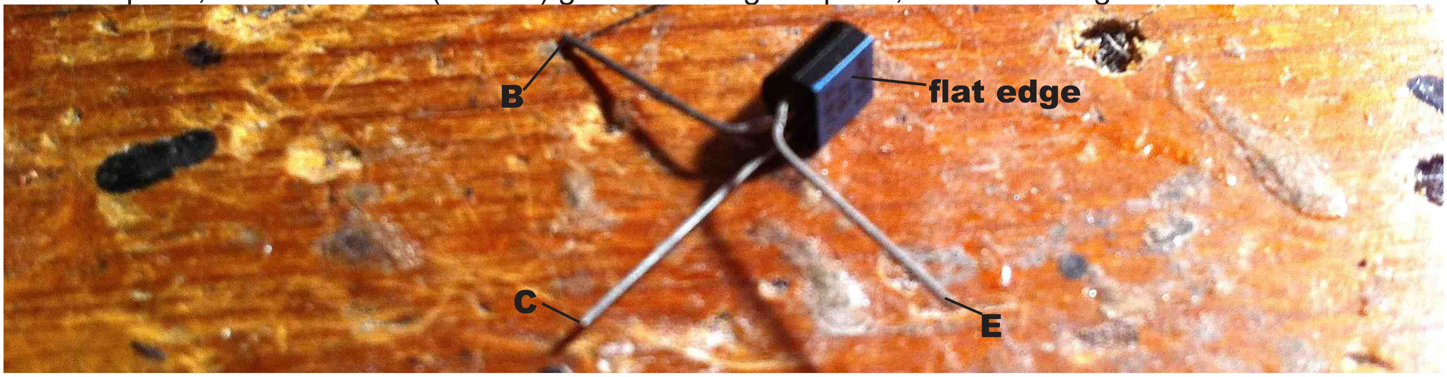

- Before you solder the transistor in place, you need to have a "heat sink" attached to protect it. This will draw some of the heat from the transistor to something else. To do this, simply take an alligator clip and attach it to the lead you are soldering…

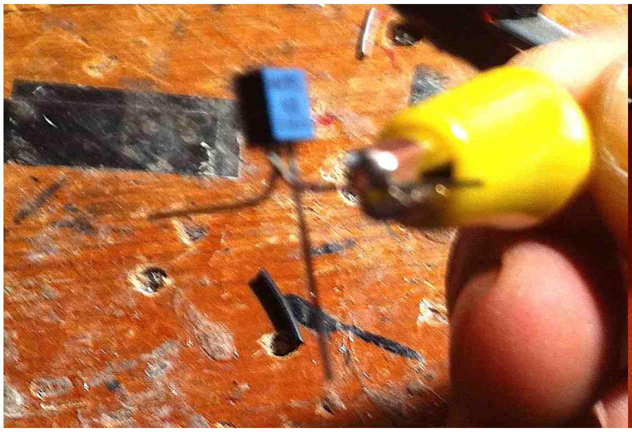

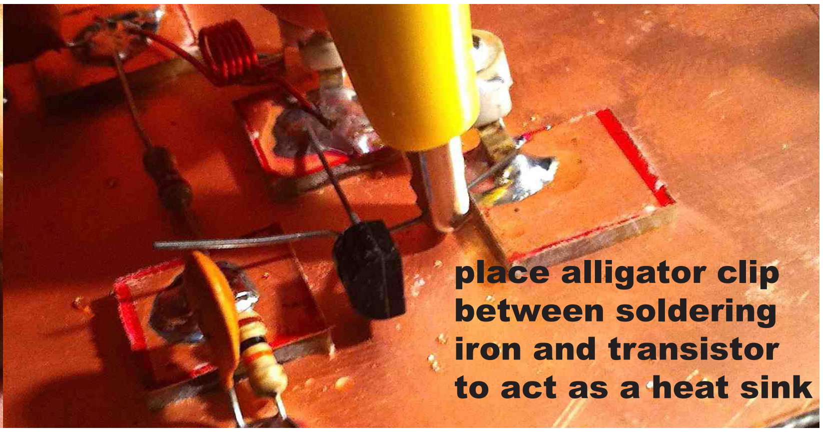

place alligator clip between soldering iron and transistor to act as a heat sink

- Solder each lead in place attaching the clip lead to each one before doing so.

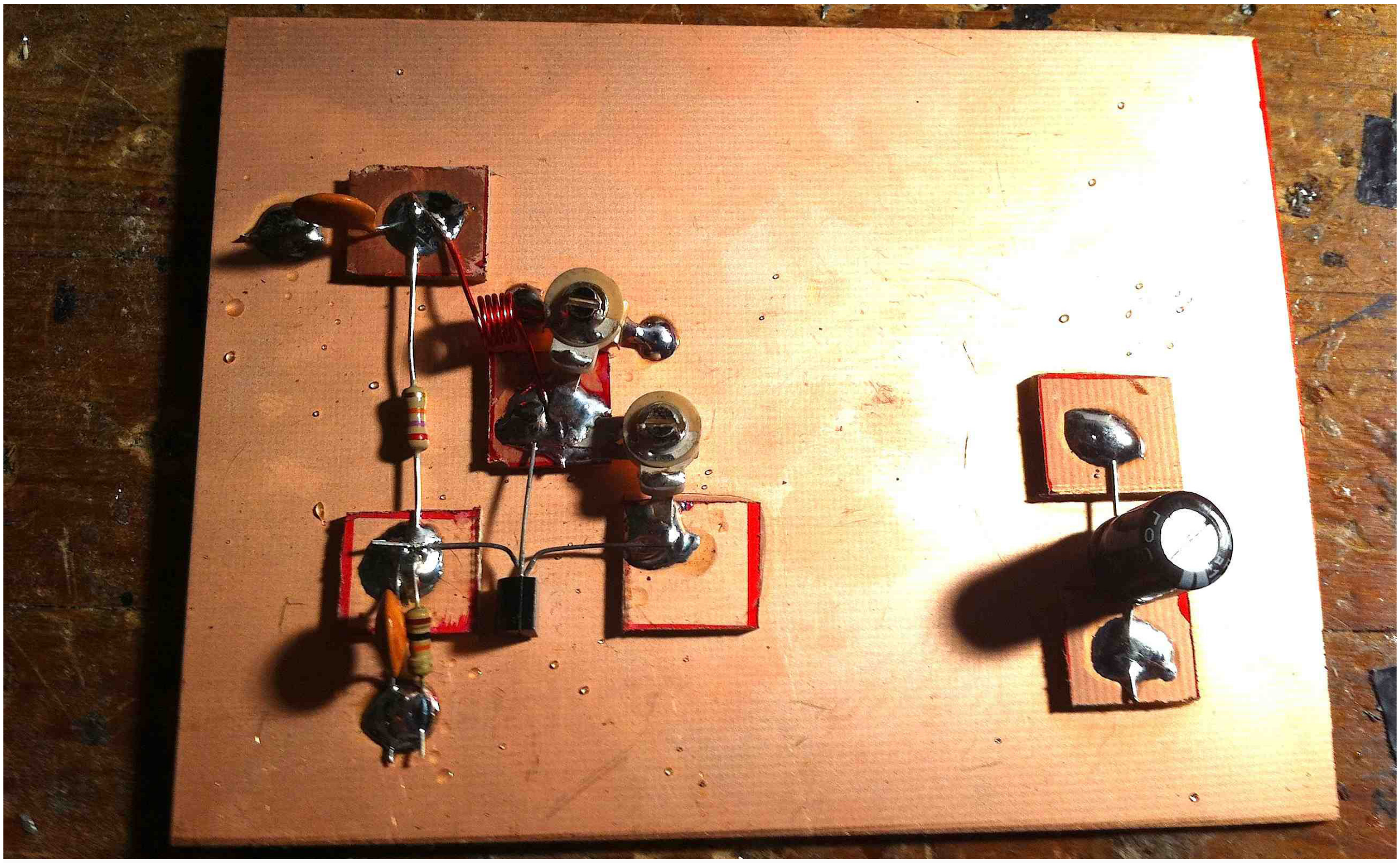

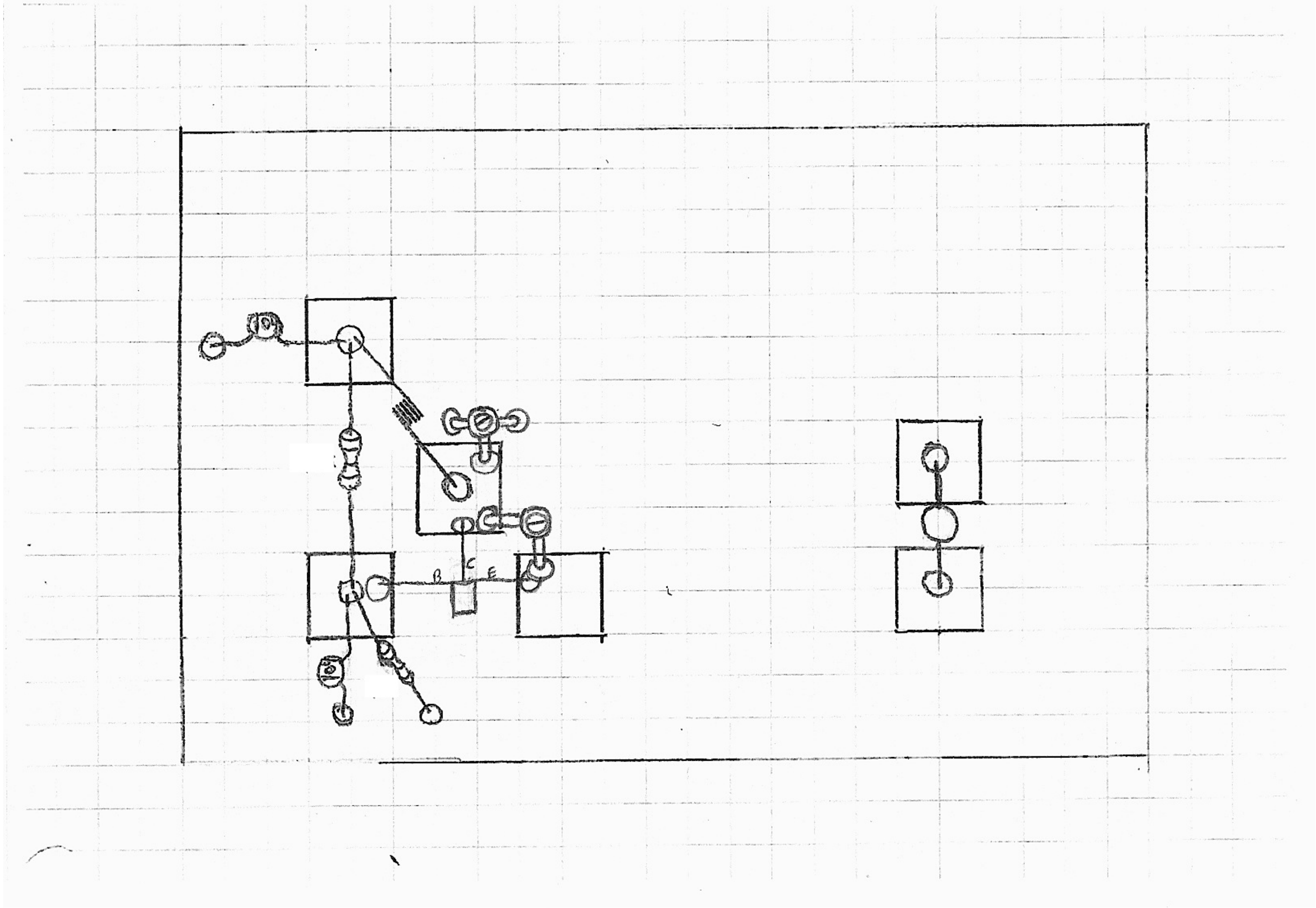

8. ADDING THE 1k POTENTIOMETER

- Put a bit of super glue or hot glue on the bottom of the potentiometer and stick it to the upper right corner with the leads facing towards the left of the plate.
- Take a small amount of stranded hookup wire and strip both ends. Solder one side to the upper most lead and the other side to the ground plate.
- Repeat the process by connecting the middle lead of the potentiometer to the upper most of the two right squares. Then connect the lower lead of the potentiometer to the right most square of the triangle.

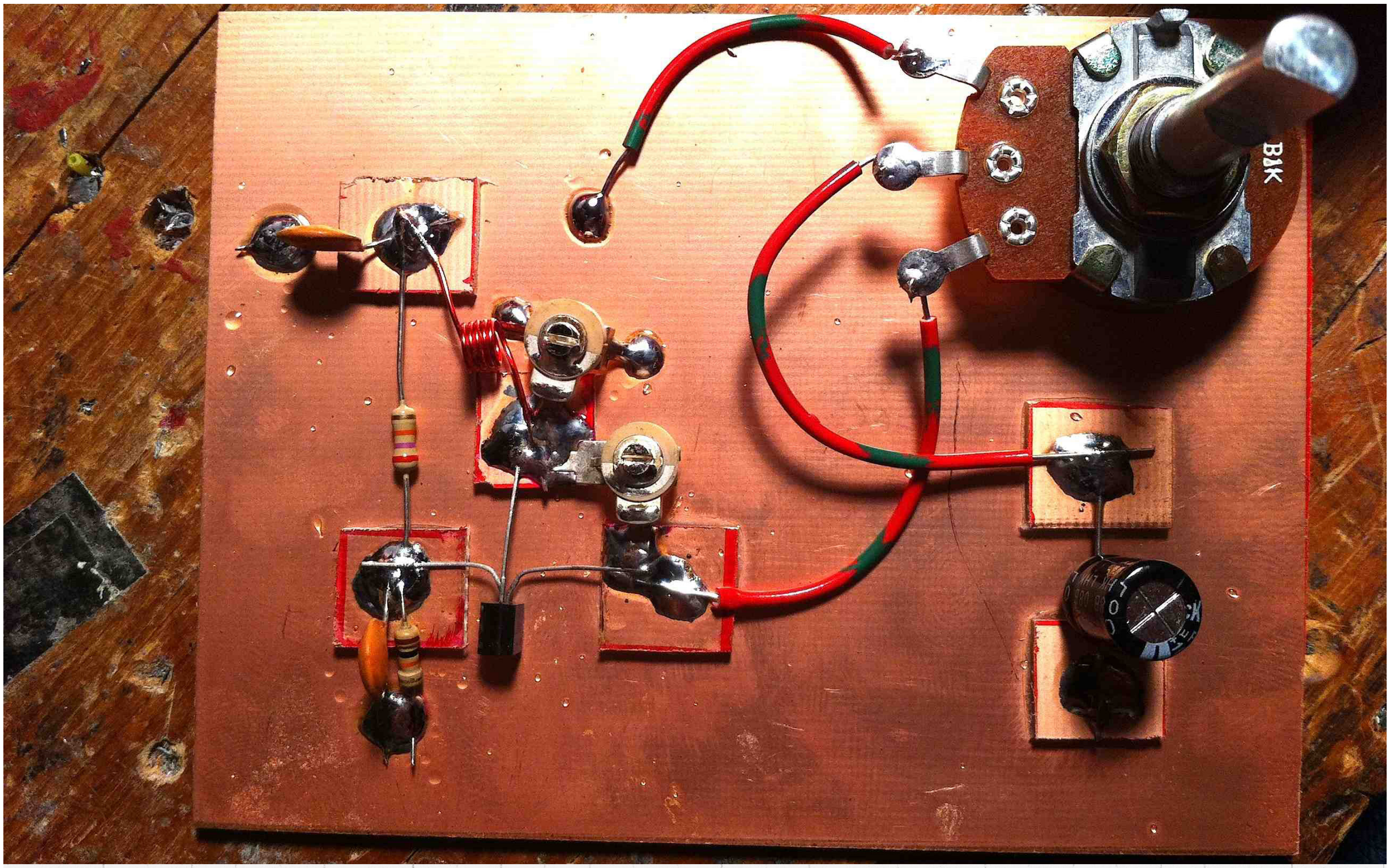

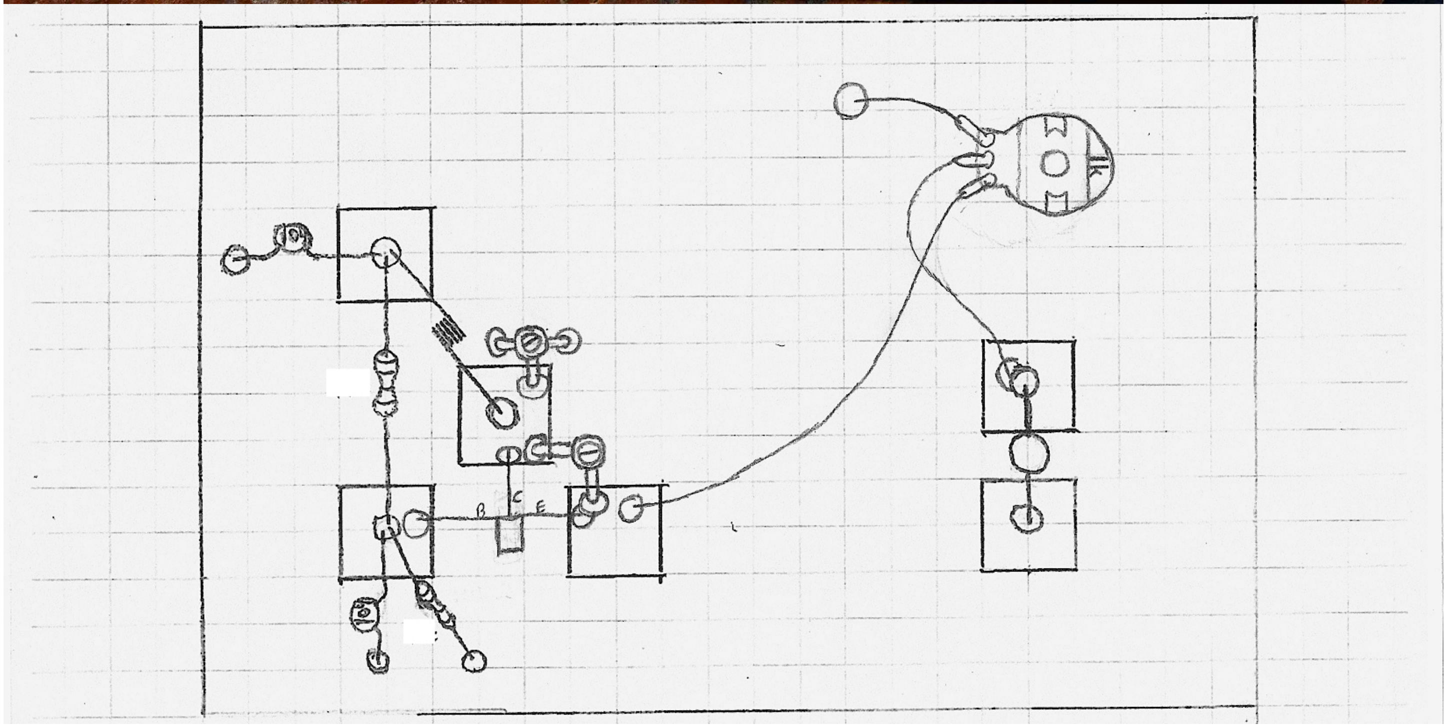

9. ADDING THE INPUT WIRES

- Cut two small lengths (~4-5”) of your stranded wire and strip both sides
- Solder one of the wires to the ground plate (this will be the ground input from your video source)
- Solder the other wire to the bottom square of the two right squares. (This will be the signal input from your video source)

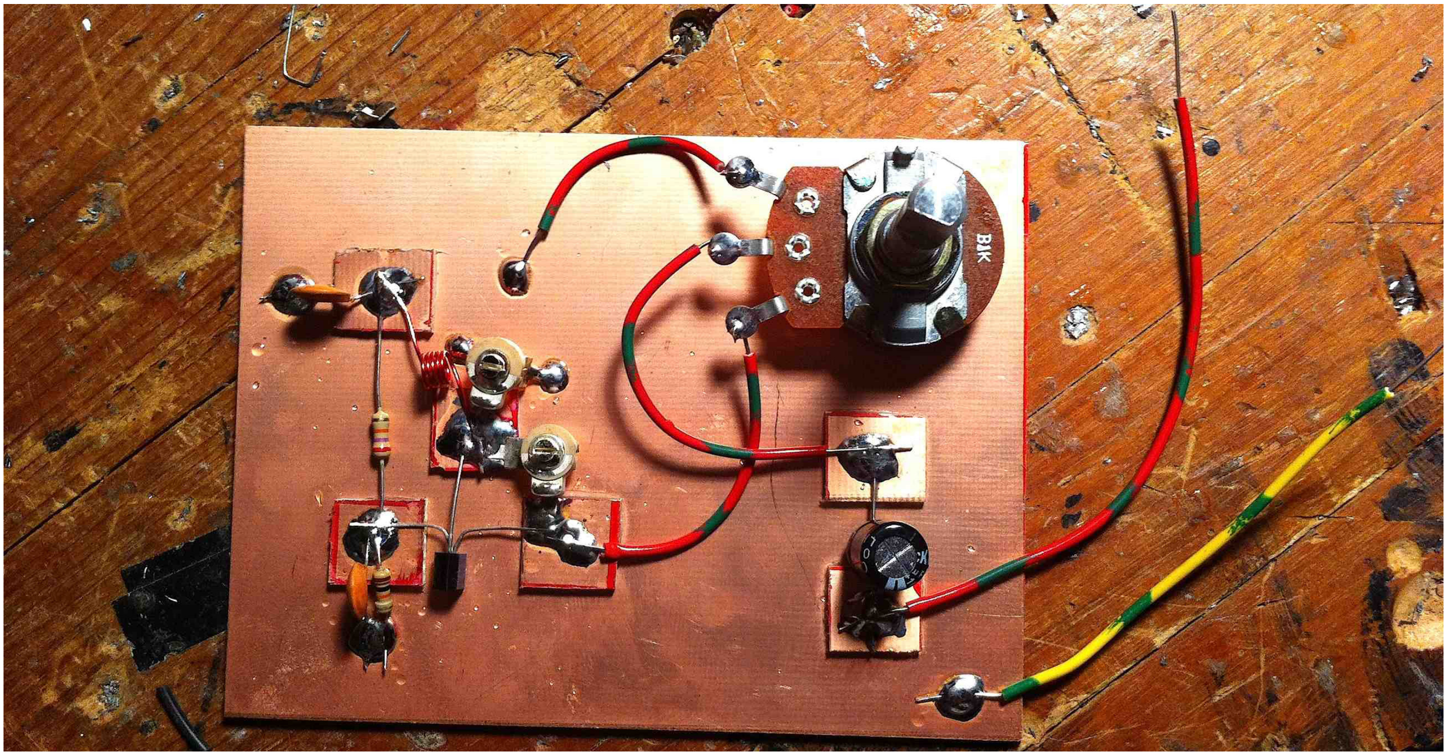

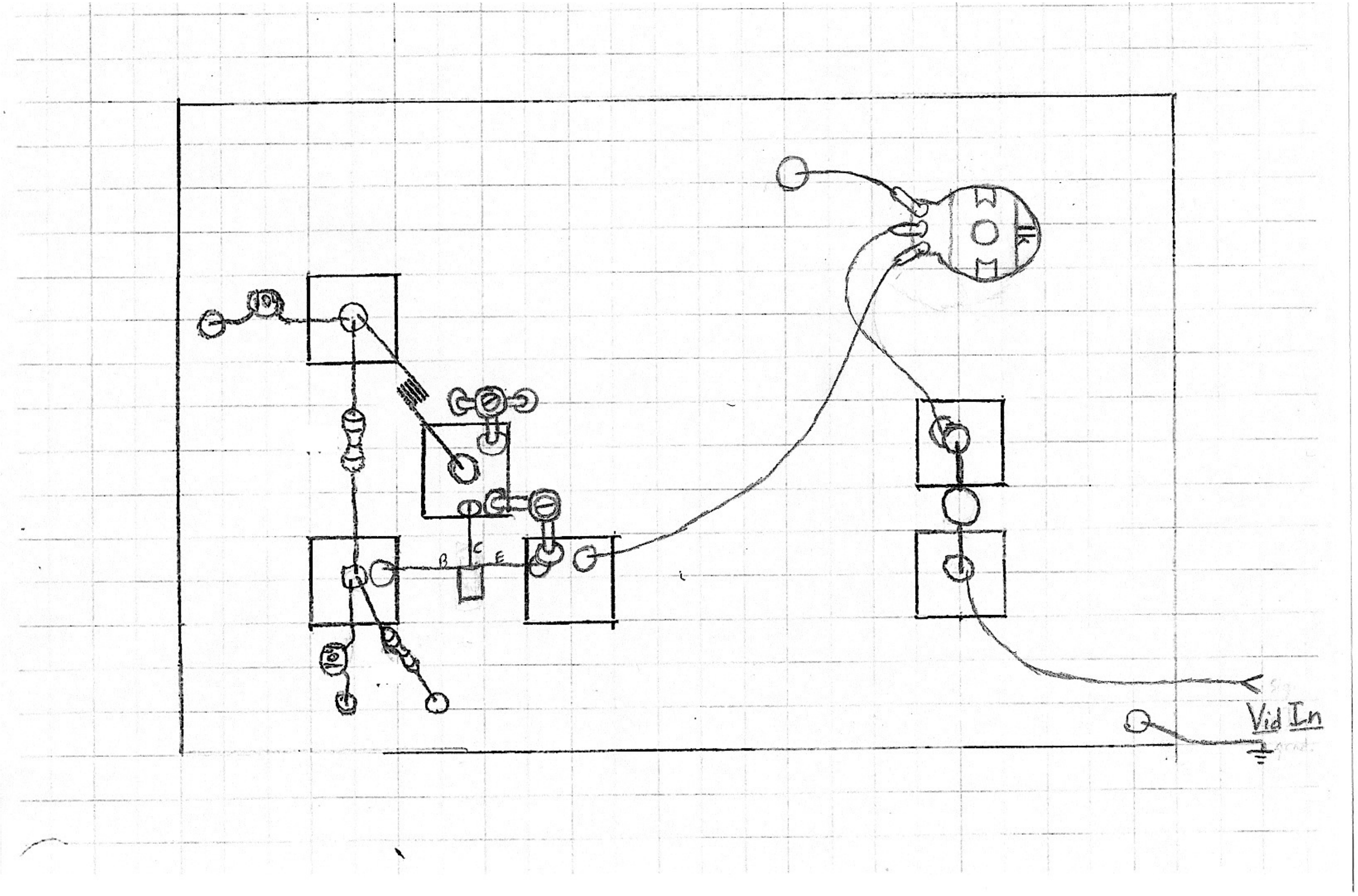

10. ADDING THE BATTERY INPUT WIRES

- Just like the last step, cut two shot pieces of wire and strip both ends.
- Solder one of the wires to the ground plate (this will be the negative input from your 9volt battery).
- Solder the other wire to the upper left square (this will be the positive input from your 9volt battery).

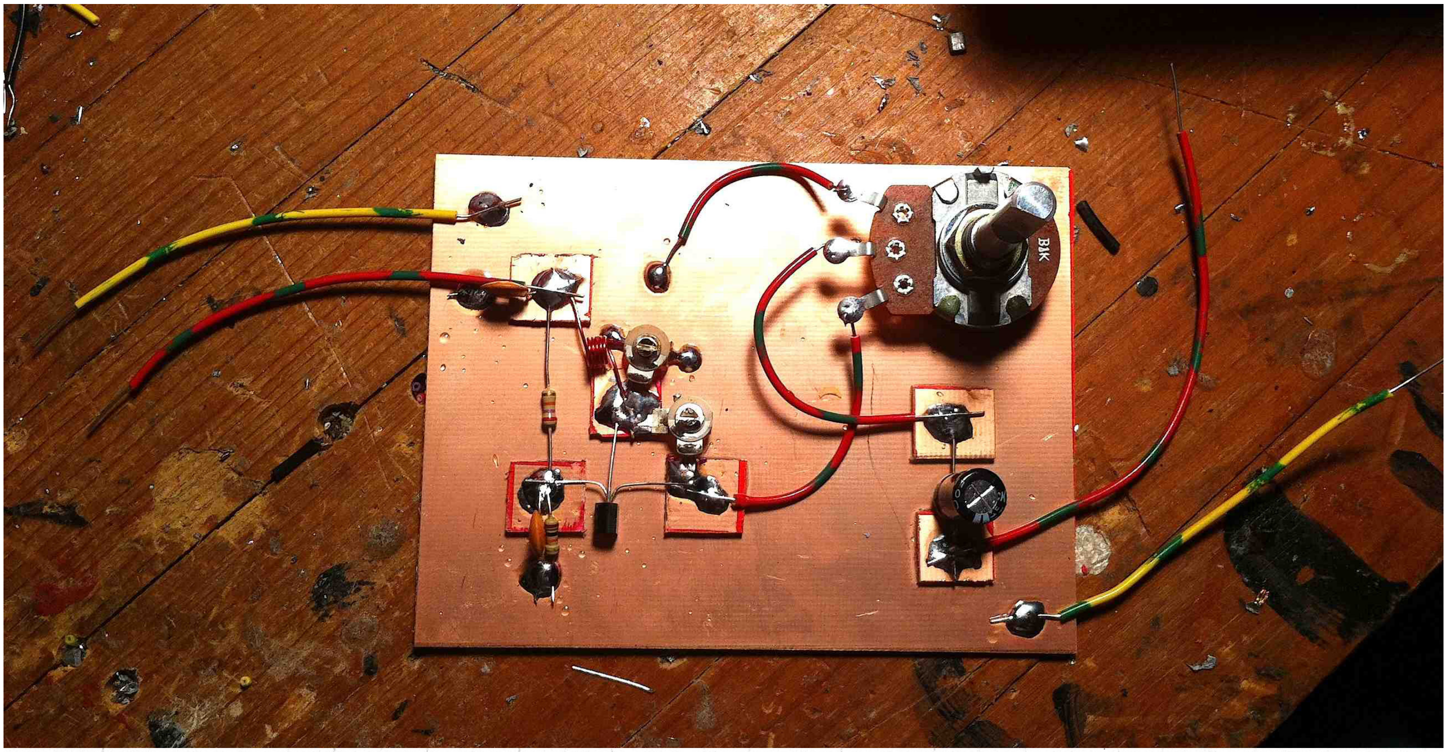

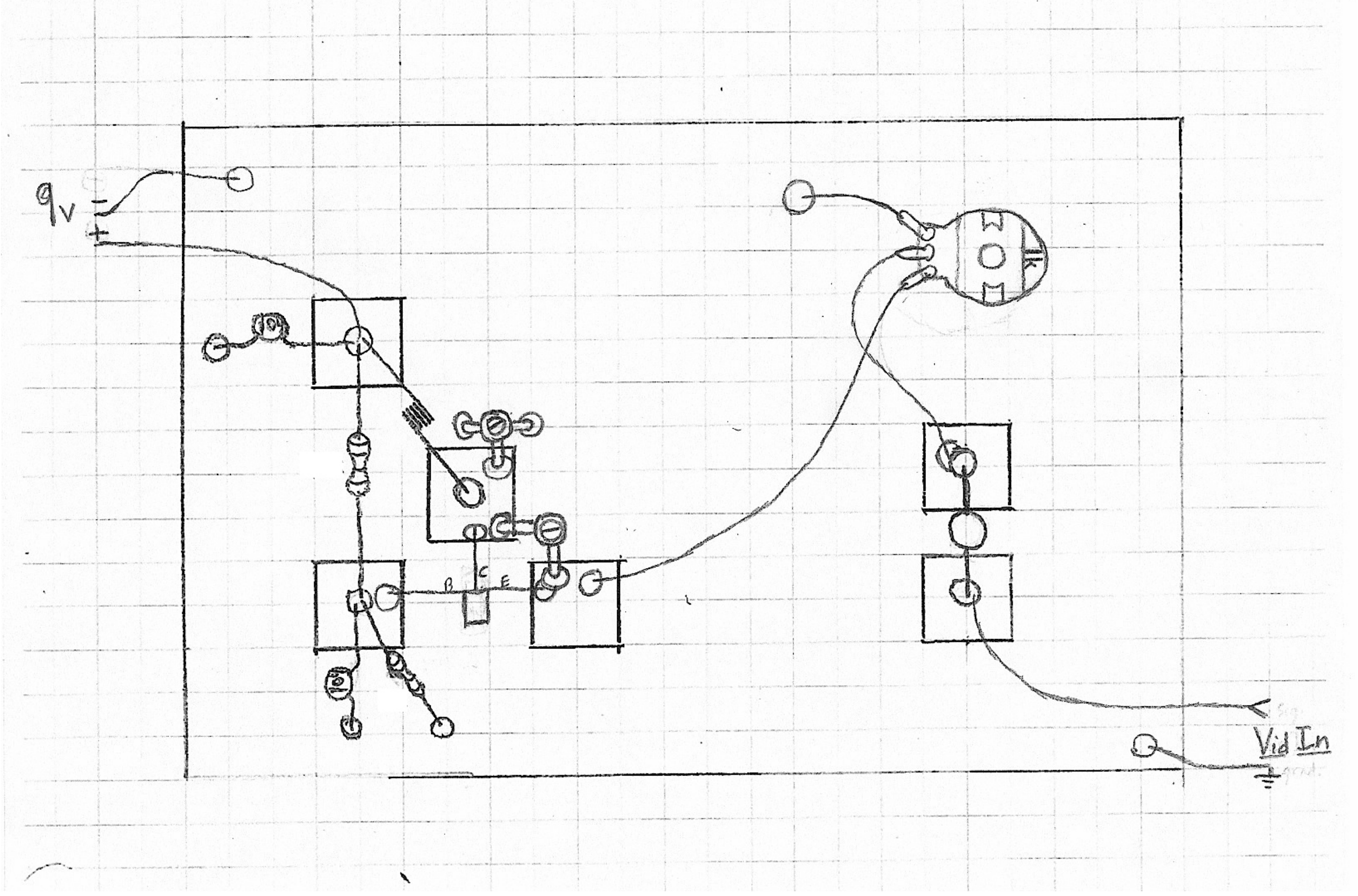

11. ADDING THE ANTENNA

- Cut about 2 feet of wire and strip one end.
- Solder the wire to the right most square of the triangle.

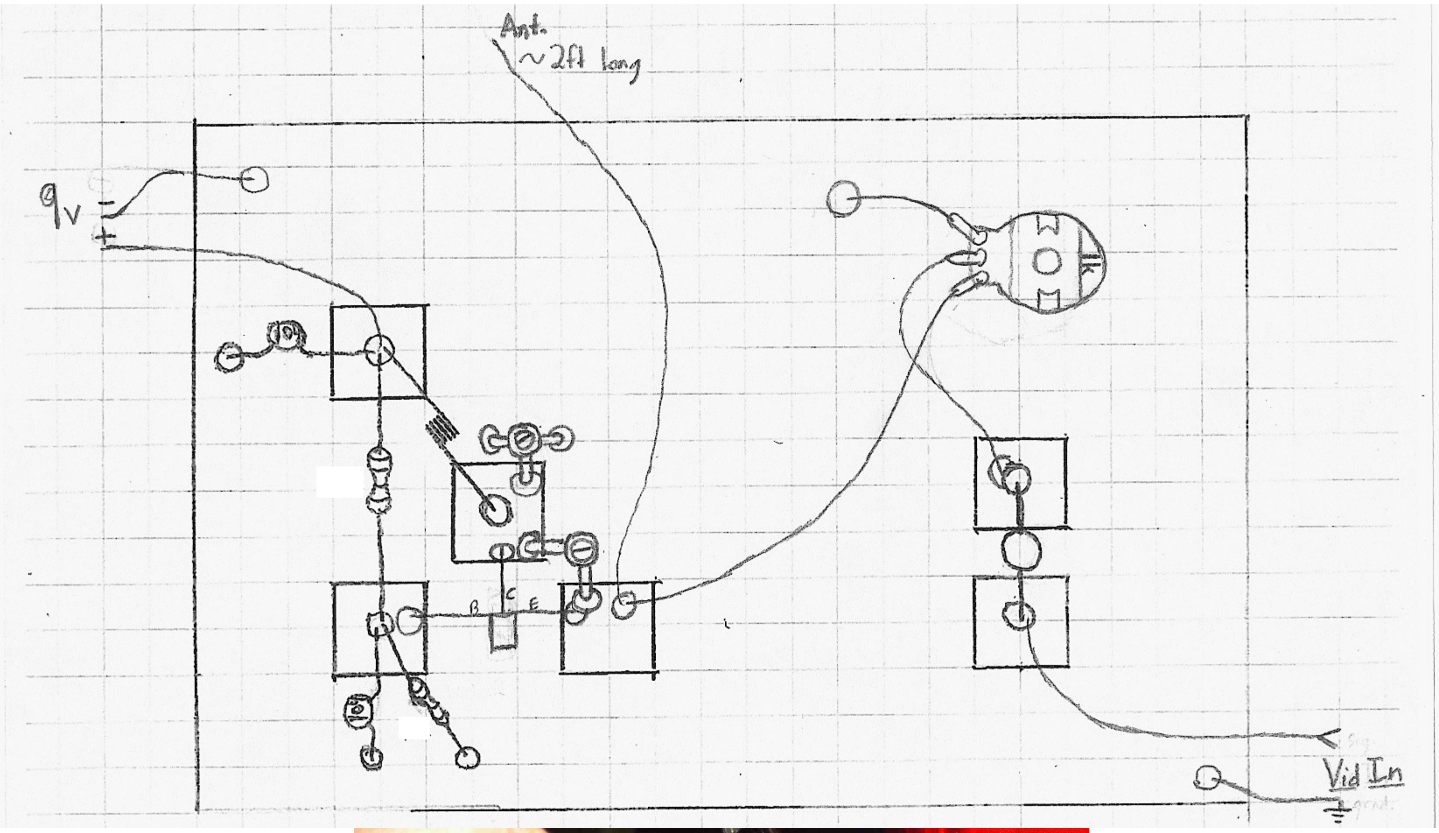
Ant.
~2ft long
9v
-
+
B
C
E
sig.
Vid In
gnd.

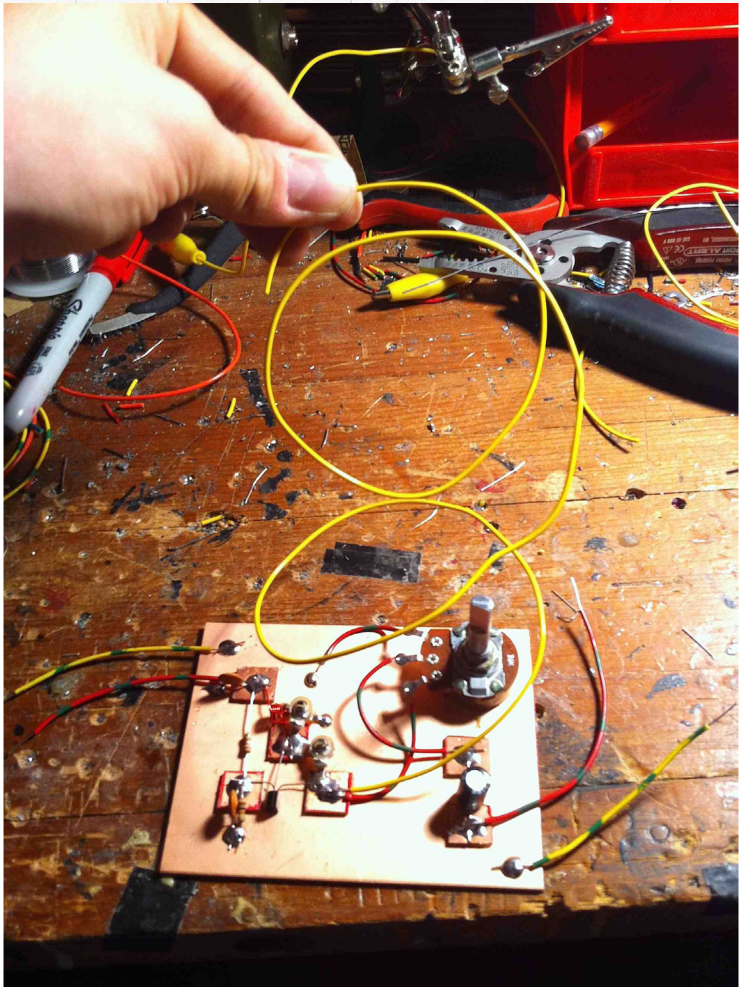

OPERATING

- Find a video source (DVD player, VHS player, iPod etc.) that has a composite video output.
- Use an alligator clip lead to connect the ground from your video source to the ground input of the transmitter. Using another alligator clip lead, attach the signal output from your source to the signal input of the transmitter.
- Use two more alligator clips to connect the positive and negative of a 9v battery to the positive and negative battery inputs of the transmitter.
- Turn on a CRT “tube style” TV and tune it to channel 2 or 3.
- Turn your potentiometer to somewhere around 50%
- Using a small screwdriver, tune the upper most variable cap slowly until you see the TV make a flicker or change.
- Tune the second variable capacitor until you start to see some strong signal coming through
- Tune the potentiometer and the two variable capacitors until you get the imagery you wan

Send any comments, questions or suggestions to yaktronix.online@gmail.com

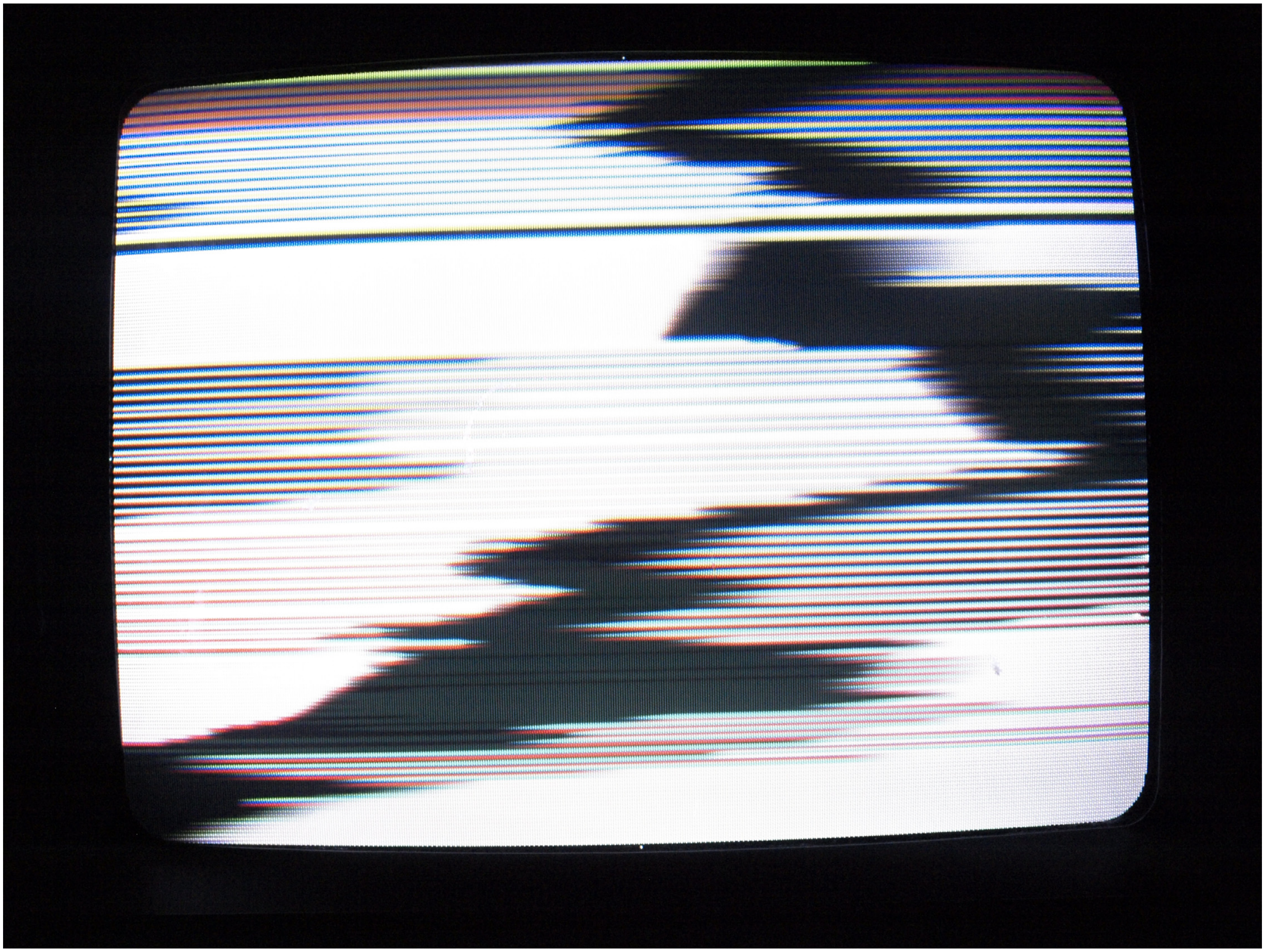

Ugly/Ground Plane Construction

The Method I Use in Building My Simple Receivers

Oct. 7, 2006 by Rick Andersen, KE3IJ

Occasionally I get emails from readers who want to know how I build these simple radio receiver circuits on an "L-shaped chassis" without cutting and scoring the copper, what I mean by "L-shaped chassis," or "what's all this about 10 megohm resistors?", etc. I tend to forget that not everybody has done this before, and I usually take it for granted that the reader is an accomplished "basement-tinkerer" and should therefore be able to just look at a schematic diagram and then come up with his own layout and method of construction. Sorry if I have annoyed anyone -- that wasn't my intention.

When I first design a circuit, I make what a friend of mine used to refer to as a "spider" (or, "spider-web")-- basically just construct the circuit by soldering the components together, lead by lead, into a reasonable facsimile of the schematic (no chassis or pc board necessary-- the stiffness of the soldered leads themselves hold the "spider" circuit together). This method is quick, and allows me to modify things fairly easily. It also grows rather quickly into a "haywire monstrosity" if I allow it.

Sometimes I do use a piece of copper-clad pc board as a ground plane, even during the "spider" stage, as the photo below illustrates:

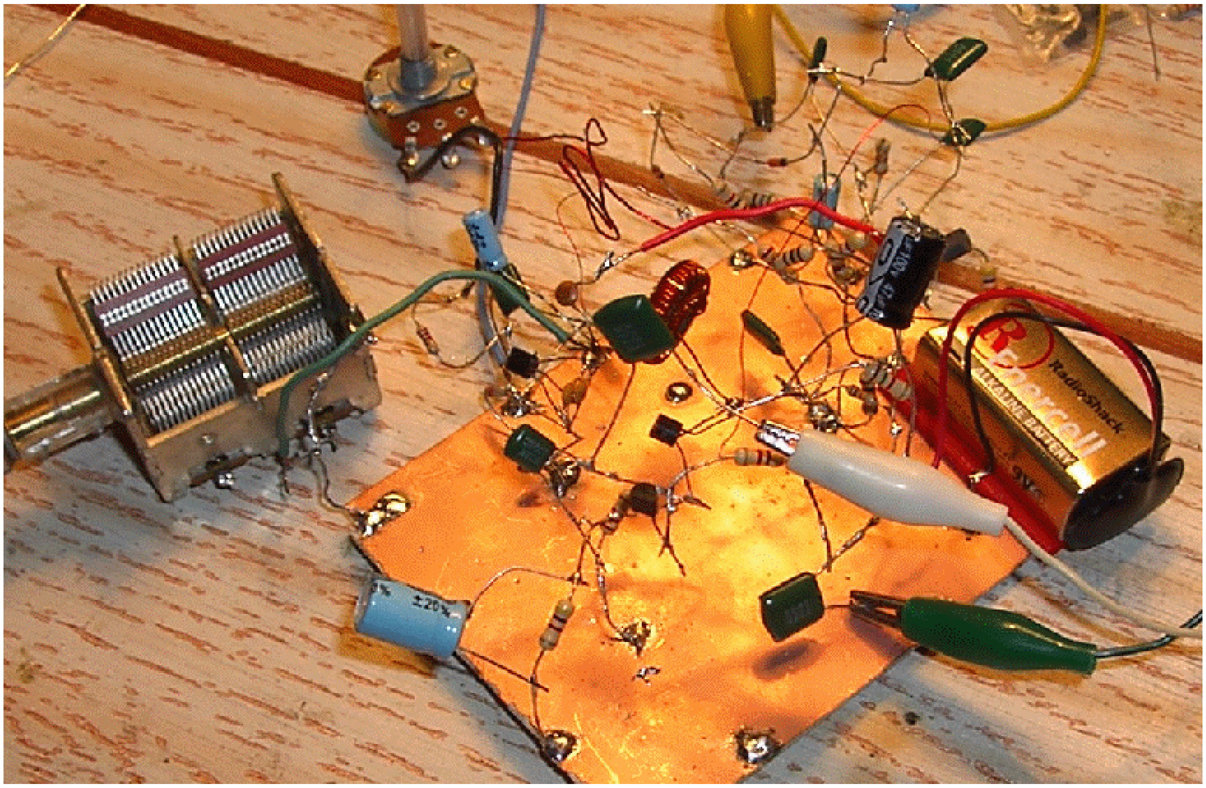

A "haywire" mess of my "AGC-80" Regen receiver in its early, experimental stage

To make things a bit clearer to you who have never built projects in this way before, I have attempted a free-hand diagram using Microsoft "Paint", which I converted to a .gif file and which you see below.

In the top-center of the diagram is the schematic for a simple common-emitter audio amplifier stage. The left side of the diagram illustrates how one might translate that schematic into an actual circuit on the copper-clad pc board. At right is a diagram of the "L-shaped Chassis." This is the style in which I build most of my circuits.

Basically, I use 2 pieces of 5x7 inch copper-clad pc board, available in the USA at **Radio Shack** [free plug]. One piece lies flat (the bottom piece), which is what I have shown in the diagram. I build my circuit on this bottom piece, using the copper floor as my ground connections ("ground plane"). Any resistors, caps, etc., that go to ground in the schematic, are literally soldered to this bottom ground plane and stood upright. At their top ends, the rest of the circuit is soldered, suspended up above the ground plane. Anywhere that I think I need some mechanical stability, I use a vertical 10 Megohm resistor, which acts to prop up and support the rest of the wiring above the ground plane. For most of the circuits I build, 10 Megohms is much higher a resistance value than any of the resistors in the circuit itself; therefore, the circuit pretty much ignores the 10M "posts", electrically, and they remain simply a mechanical "standoff insulator". The 2nd piece of copper clad board is drilled for switches, potentiometers, tuning caps, and earphone jacks, etc., and then is soldered at right angles to the flat bottom piece, making an "L-shaped chassis". It also helps to solder triangular pieces of copper-clad board as mechanical braces, at the corners where the front panel is soldered to the bottom ground plane.

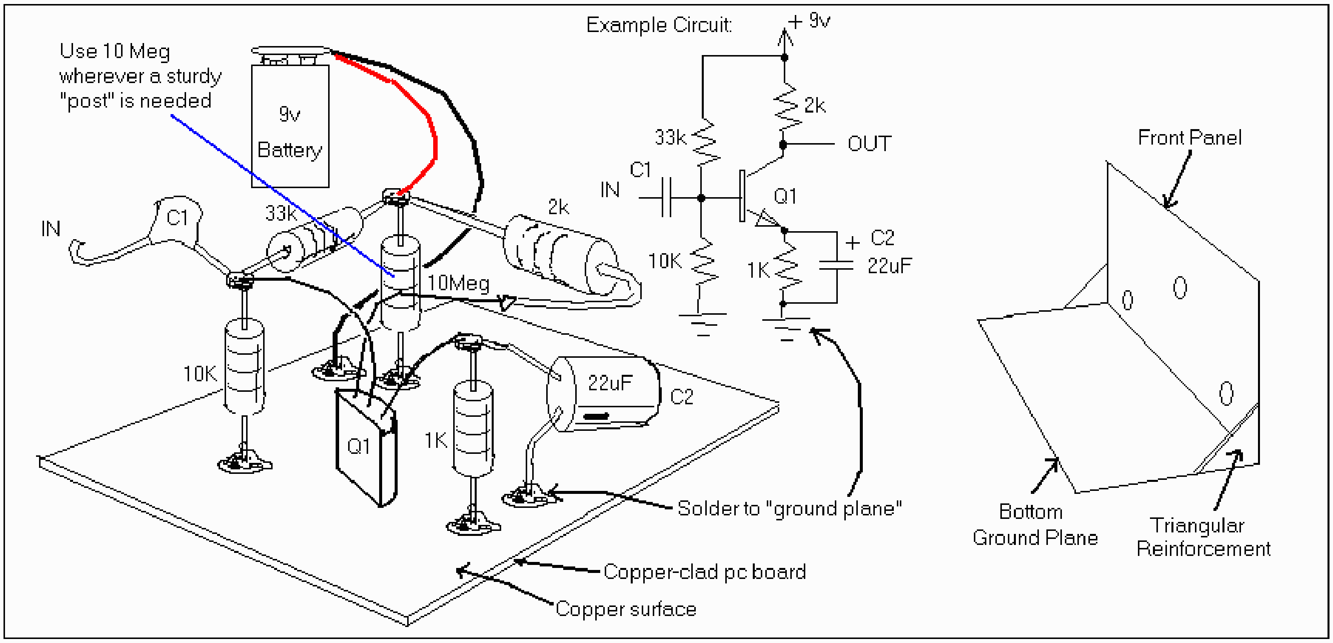
Use 10 Meg wherever a sturdy "post" is needed
9v Battery
IN
C1
33k
2k
10Meg
10K
Q1
1K
22uF
C2
Solder to "ground plane"
Copper-clad pc board
Copper surface
Example Circuit:
+ 9v
2k
OUT
33k
C1
IN
Q1
10K
1K
+ C2
22uF
Front Panel
Bottom Ground Plane
Triangular Reinforcement

Below is a photo of my 2006 creation, the "AGC-80", a Regen receiver for the 80 Meter ham band with audio-derived AGC. There's an article on this receiver elsewhere on this website; meanwhile, notice that it is built in the same way outlined above-- an "L-shaped" chassis made of a bottom piece of copper-clad board, soldered to a vertical piece of the same kind of board which is the front panel. [I also added a back wall to hold the antenna jack, and a right wall to hold the audio output jack, as well as a triangular reinforcement piece of copper-clad, at bottom-left between the front panel and bottom piece, although you can't see it in this photo.]

To the right of the AGC-80 is the infamous Radio Shack/Archer little beige Amplified Speaker that I'm always mentioning. I may knock Radio Shack for other reasons [for example, that they have pretty much left us hobbyists behind, and have become just another consumer electronics store] but I will always say good things about their little $12.95 beige-colored Amplified Speaker. It works like a charm for the kind of projects I build. I also run an audio cable out of the Radio Shack amp to a bigger speaker, for better-quality sound-- in the photo you can see a white "Optimus" computer speaker pressed into this service. While the Radio Shack's speaker does a fine job, the Optimus sounds quite a bit louder and way nicer. Of course, you may argue that a *real* Electronics Geek rolls his *own* audio amp rather than rely on a commercially-made, external one. Well, I'm often too impatient to build the audio power amp myself, after having spent hours or days getting the RF part of the radio to work the way I want. Also, homemade audio amps tend to oscillate (squeal, motorboat, howl) in mysterious ways once lovingly installed on the same circuit board as the RF circuitry.... After a while one grows tired of trying 50 ways to make it happy, and would rather just hook up an Amplified Speaker and be done with it.

To each his own.

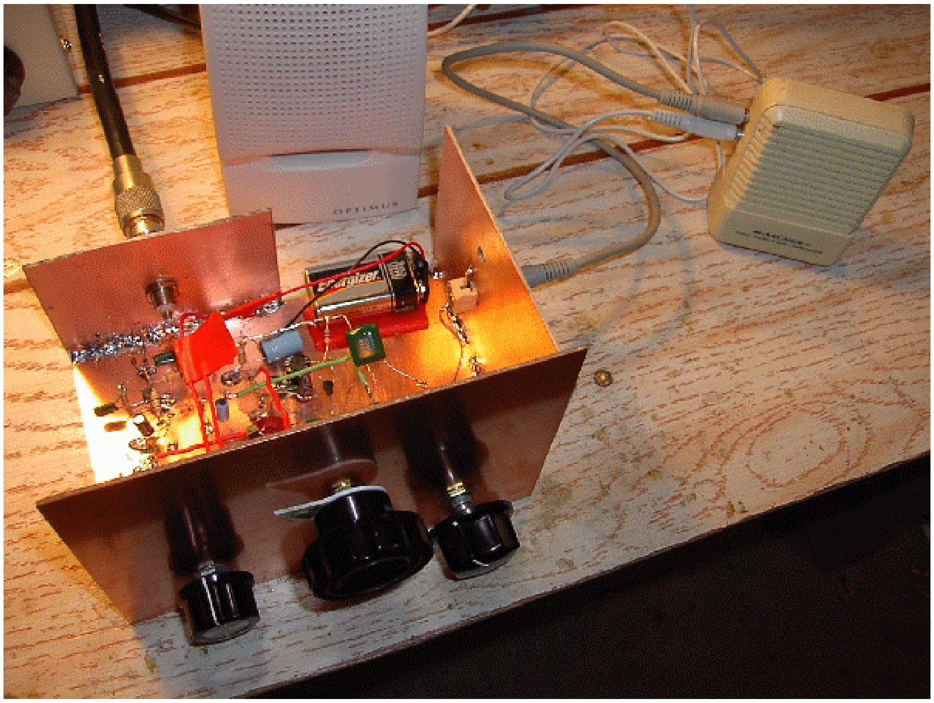

Please realize that you don't have to follow this method of construction (usually called "Ugly Construction" by hams), but I would advise you to make sure there is some equivalent of a copper ground plane in most of your radio projects... it helps to shield the circuit from outside influence (particularly when connected to earth ground) and contributes to stability.

I hope this has helped to give you a little better idea of the methods I use!
73 de Rick, KE3IJ

Back

The “Tree Antenna”

RCC Aug & Oct 2006 – Dave/WB7ESV

Aug 2006 Article

What is unique about this antenna is that it is only a tree. The tree is used as a Gamma or Shunt fed vertical. To make this work, we drove a 3 ½” deck screw into the tree (you need to make contact with the sap vein), at about 15’ above the ground (15’ to 20’ will work). We attached a wire to the screw, extended the wire 2’ perpendicular to the tree, tied a rope to the wire at the 2’ point, tied the other end of the rope to a tree limb and dropped the wire to the ground.

At the ground we drove a 3’ ground rod 2 feet out from the base of the tree and attached a rope to the ground rod and to the wire to keep the wire tight.

At the feed-point end of the wire we connected an MFJ-901B tuner strapped for “WIRE” operation and connected the tuner ground to the ground rod.

Coax was connected and run to the operating position in a tent. To tune the antenna, an MFJ-269 SWR Analyzer was connected to the tuner input and the tuner adjusted for minimum SWR at the center of the operating band. The antenna is capable of operation on 10 - 80 meters. Many contacts were made including: Hawaii, Texas, Oklahoma, Montana, Wyoming, Utah, Idaho, California, VE6 and VE7.

The tree height should be no shorter than 30 feet and any wire antenna tuner will work.

Oct 2006 Article

Those who are building or have built it are: Jeff, KB6IBB, in The Dalles, OR; Tom, KD7ZOS, in Portland, OR; Dave, W0OXB, in Stillwater,MN; and Larry, KE7HGC, in Vancouver, WA.

Those who have it up and running have made contacts all over the U.S. and have stated that: .If I can hear them, I can talk to them.

If you are in an area that frowns on antennas and you have a tree that is at least 30. tall, give it a try. What you will need to build the Tree Antenna is: A tree that is at least 30’ tall, a 3# nail or wood screw, (not galvanized), 20’- # 12 - # 16 AWG copper wire (can be solid or stranded, un-insulated or insulated), a 4’ ground rod, wire clamp for the ground rod, 2-egg insulators and an antenna tuner that can be remotely adjusted, (ICOM AH-4, SGC SmartTuner, Home Brew with small motors to operate the variable capacitor(s) and inductor, etc). If you decide to ‘Home Brew’ a tuner, there are several in the ARRL Amateur Radio Handbook that will work very well.

Solder one end of the copper wire to the nail/screw. At about 15’- 18’ up the side of the tree drive the nail/ screw into the tree so as to penetrate the sap vein of the tree. (This is important for RF conduction.) Draw the wire out 2’ perpendicular from where you drove the nail/screw and support the wire with an egg insulator tied to a rope which is tied off to a limb of the tree and let the rest of the wire drop down to the ground.

Drive the ground rod into the ground 2’ out from the base of the tree leaving about 3’ of the rod above ground level. Attach a short piece of rope to a egg insulator and attach the other end of the insulator to the copper wire so that the insulator/wire is about 6’ above the top of the ground rod. Leave enough wire to connect to the tuner.

Attach a short piece of rope to a egg insulator and attach the other end of the insulator to the copper wire so that the insulator/wire is about 6’ above the top of the ground rod. Leave enough wire to connect to the tuner.

Attach the rope to the ground rod and install the antenna tuner to the end of the wire and place the tuner in a plastic container to protect it from the weather.

Connect a short ground wire from the ground side of the tuner to the ground rod with a clamp and make sure all connections are tight and sealed from weather.

If you are wondering where the “Tree Antenna” Comes from, it’s from a WWI/WWII Army Signal Corps Emergency Communications Manual.

ANTENNA
TUNING UNITS
(ATUs)

Home | Contact | Site Map | Links

Radio Stations & Memorabilia | Loop & Frame Aerials | Copper Tube Antenna
DXing & Short Wave | Make A Signal Meter | Riding On A Radio Wave

ATUs - ANTENNA TUNING UNITS

THE ATU

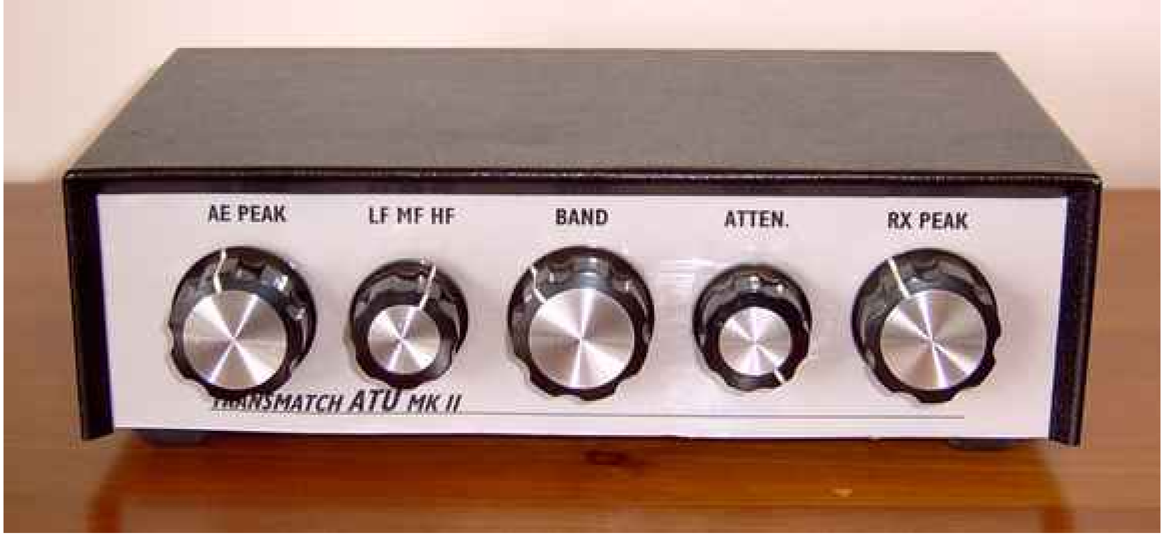
AE PEAK
LF MF HF
BAND
ATTEN.
RX PEAK
TRANSMATCH ATU MK II

An Antenna Tuning Unit

For good Short Wave reception long aerial really is required to dig those distant stations out of the ether. To effectively couple such an aerial to a radio a matching unit called an ATU (Antenna Tuning Unit) can often be extremely helpful. An ATU is relatively straightforward to construct and uses simple parts that are quite easy to obtain. The ATU shown above is of my own construction and is used with a Lowe HF-150 receiver.

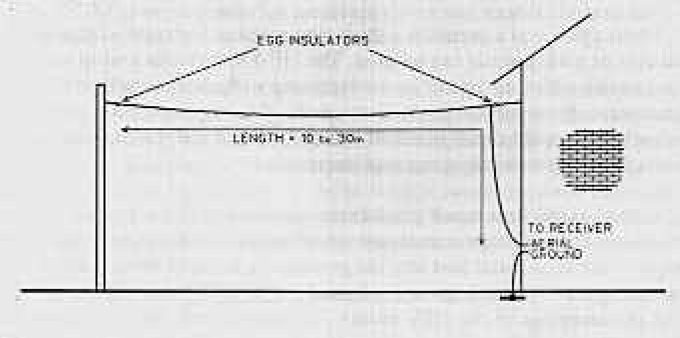
EGG INSULATORS
LENGTH = 10 to 30m
TO RECEIVER
AERIAL
GROUND

Typical Aerial Installation

AERIALS [or ANTENNAS]

AERIAL n. & adj. > n. a metal rod, wire or other structure by which signals are transmitted or received as part of a radio or television transmission or receiving system. > adj. 1. by or from or involving aircraft (aerial navigation; aerial photography). > 2 a existing, moving or happening in the air. b of or in the atmosphere, atmospheric. 3 a thin as air, ethereal. b immaterial, imaginary. c of air, gaseous

For the purpose of this page we'll choose the noun, I think. So the aerial can be:

A Random Length Of Wire Strung As High As Possible
OR -
A Carefully Designed Structure Whereby The Element (Or Elements) Is (Are) Tuned To Resonate At The Required Operating Wavelength (Frequency) Of The Station Or Waveband Being Received

(What??)

The advantage of a long random wire aerial to a listener is that it is easy to install in a loft or around a garden. Many Short Wave Listeners' (SWL's) aerials consist of such a long end fed wire of a random length perhaps between 10 and 50 meters, i.e. not cut to resonate at a specific wavelength. The disadvantage is that it is not tuned to a specific wavelength and therfore may not be particularly efficient at gathering the signals from a desired station. This is because a random wire aerial system will not present an even impedance* to the input of the radio receiver. This should generally be around 50 Ohms.

[* Impedance is the resistance to the flow of an alternating current (AC) - in this case a radio wave]

The impedance of a random wire aerial could swing from a few Ohms up to several thousand Ohms depending on what frequency is being used. This will present a serious mis-match to the receiver, which would prefer to 'see' a nice constant 50 Ohm load. This mismatch of impedance between aerial and radio can detrimentally effect the amount of signal transferred from the aerial to the radio, and therfore weaken reception of stations at some wavelengths.

An Antenna Tuning Unit (ATU) can help match the impedance of the aerial to the 50 Ohm impedance required by the radio. Once the impedance of the aerial matches the impedance at the input of the radio (after being tuned by the ATU) the greater the chance of the RF energy being effectively transferred.

Using an ATU will not always improve reception. If, by pure chance, the random wire aerial presents a 50 Ohm impedance to the radio on, say, the 41 meter band then no further improvement in signal strength will be obtained. But then if the radio is tuned to the 25 meter band, for instance, the aerial may have a 500 Ohm impedance and on this band the ATU will help to transfer more signal and improve reception.

WAVELENGTHS AND FREQUENCIES

This is the mathematical formula to calculate the wavelength of a particular frequency:

V/F = wavelength

E.G: V/F = 300,000,000/1,875,000Hz = 300/1.875MHz = 160m

The velocity of a radio wave when travelling through space is the same as the spped of light

i.e. 300,000,000 meters per second (186,000 miles per second). V = Velocity, F = Frequency in Hz. The result of the calculation is the wavelength in meters.

Once the wavelength of the radio wave is known, the relationship with the length of the aerial can be determined. An aerial that is 1/4 wavelength or an odd multiple of 1/4 wavelengths e.g. 5/8th or 7/8th wavelength, the impedance presented to the receiver will be quite low. If the aerial is a full or half wavelength long then the impedance will be much higher.

LOWE, JOHN WILSON AND THE SIX BAND SAGGER

Have a little look at the bottom of the LOWE HF-150 page since it includes an interesting article by John Wilson, formerly of Lowe Electronics, about aerials, specifically the "Six Band Sagger".

ATUs AND FILTERING

The ATU acts as an Impedance Matching Transformer with the ability to accept a wide range of input impedances and match them to the 50ohms that is required by the receiver. It also has the bonus of providing an certain amount of filtering, which can help overcome receiver overloading, by letting through the required frequency while attenuating the higher and lower frequencies. There are two types of ATU circuits described further down this page, the Pi type and the T type. The T type is particularly effective as a 'high pass' filter, and is very useful for filtering out interference on Short Wave caused by high power Medium Wave transmitters that can overload a short wave radio.

The graph below shows the effect that can be acheived:

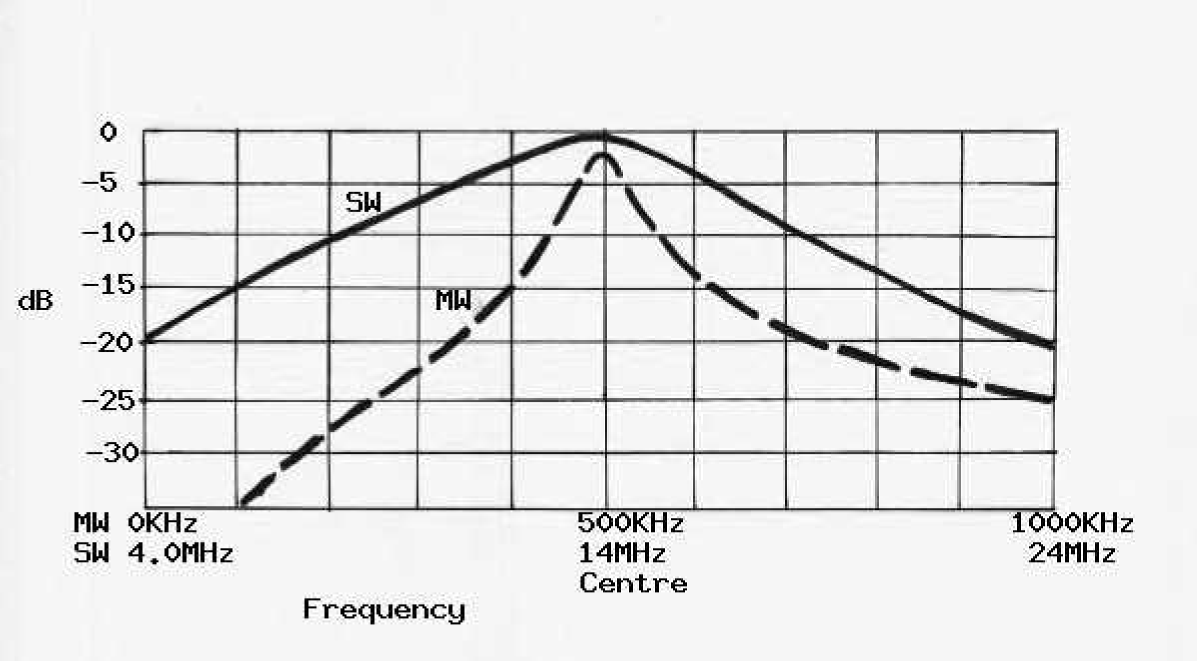

The solid line shows the filtering effect of an ATU at shortwave frequencies, while the broken line shows the filtering performance at medium wave frequencies

MAKE YOUR OWN ATU

The circuit diagram below shows the circuit for a typical Pi type ATU which seems to be a popular arrange ment for many ATUs. I have built ATUs using this Pi arrangement and although they work quite well and are certainly a useful improvement over no ATU at all, I have found in my own experience that the 'T' arrangement in the next circuit works even better, matching more easily over a wide range of frequencies and also seemingly offering improved filtering in my own circumstances.

Each aerial arrangement is different and you may find that this circuit performs best of all in your circumstances:

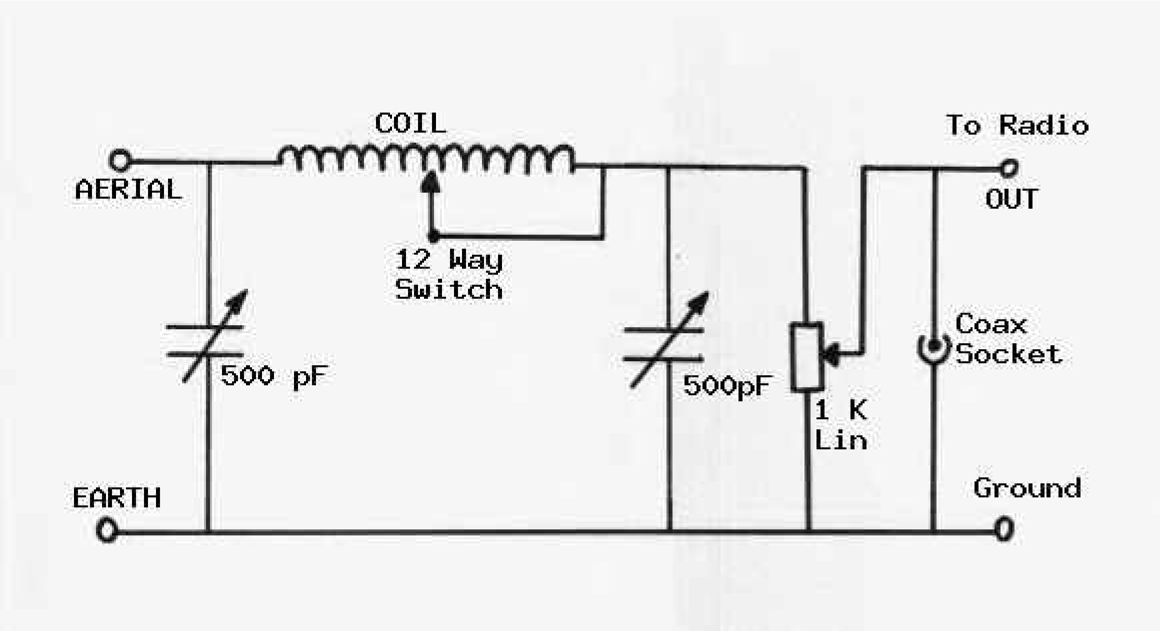

Pi type circuit - Very popular for many ATUs

Below is the circuit diagram for my preferred choice of a T type circuit which includes a variable attenuator and which could not be simpler to construct. This circuit, with the coil described, covers from 500kHz medium wave to 30MHz short wave. Tuning capacitor VC1 is adjusted to match the aerial side while tuning capacitor VC2 is adjusted to match the receiver side. This circuit is often referred to as a TRANSMATCH, particularly in the USA.

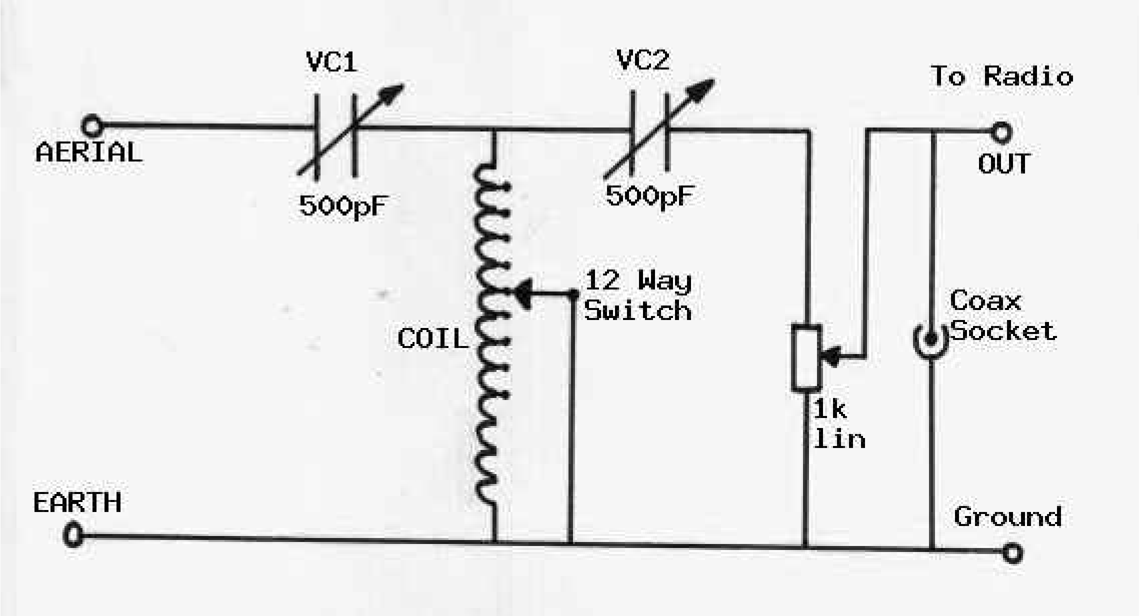

T type circuit, which I have found to be more effective than the Pi type at my listening post, possibly because this design acts as a 'high pass' filter, and is therefore very useful for filtering out interference to short wave reception caused by high power medium wave transmitters that can overload the short wave radio

All that is needed is:

1	**Self wound coil with 12 tapping points. See below**
1	**Reel of 22 s.w.g enamelled copper wire for coil**
1	**Coil former, eg the inside of a fax roll (30 mm diam approx)**
1	**12 way switch to select tapping pints on coil**
2	**500pF tuning capacitors (200pF or 365pF can also be used)**
1	**1 k ohm linear potentiometer for attenuator**
2	**Red terminal posts**
2	**Green terminal posts**
1	**Coaxial socket, e.g. 3.5mm jack (as used here) or SO239**
1	**Case 150 x 100 x 60 mm + with rubber feet**

See additional notes below >

SOURCES FOR TUNING CAPACITORS

Old broken radio sets - but don't smash a nice one up for the sake of a capacitor! Old radio sets, especially the old 'valved' wirelesses are very interesting and often sound superb and could be quite rare.

J BIRKETT RADIO COMPONENTS,. 25 THE STRAIT, LINCOLN, LN2 1JD. telephone (uk) 01522 520767 http://www.zyra.org.uk/birkett.htm

MAINLINE GROUP http://www.mainlinegroup.co.uk/jacksonbrothers/index.htm

COIL WINDING DETAILS

The coils that I have made for my ATUs have been wound around formers made from the plasic tube found inside a typical fax roll. This can be cut to a suitable length to fit inside the enclosure, in this case 150mm long with a 30mm diameter. If a plastic fax roll is not available then a strong cardboard tube could be used instead.

Two small holes can be drilled at each end of the tube to feed the start and finish portions of the 22 swg wire through in order to secure it. Then wind the required number of turns, putting a tight twist in the wire at each tapping point, taking care to scrape off the enamel so that the connecting wire can be soldered into place.

Alternatively, as I did in my first coil, I inserted printed circuit board (PCB) terminal pins into the tube to secure the wire to at the start and finish points of the coil and at each tapping point, as you can see in the photograph below. This involved drilling a hole in the soft plasic of the tube slightly smaller than the PCB pin and forcing the first pin in for a tight fit. The enamel must be scraped of the wire, wrapped arount the pin with a single turn and then soldered in place - quickly to avoid melting the plastc! Then the first turn of the coil is made, another hole drilled and pin inserted and wire scraped clean of enamel and soldered to the pin. Proceed until all the turns and tapping points have been made according to the diagram.

The diagram below shows the number of turns between each tapping point:

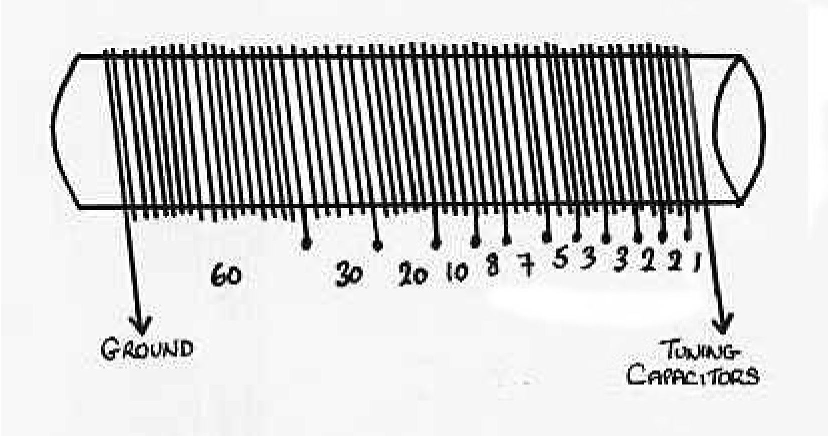

Once the coil is complete the tapping points can be wired to the 12 way switch by using short lengths of hook-up wire (e.g. 7/0.2mm pvc covered), being careful to wire the into the circuit exactly as in the diagram.

The Mk1 ATU using the T type circuit

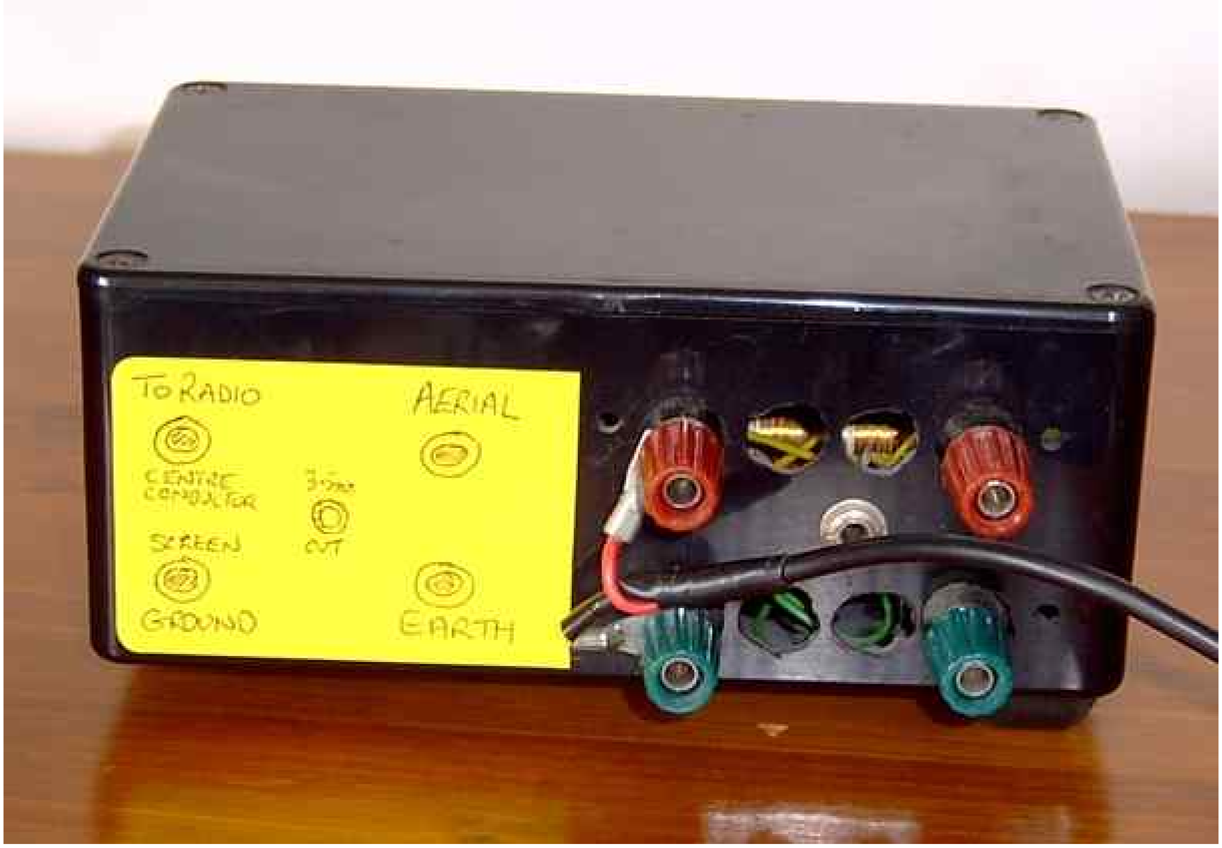
TO RADIO
CENTRE CONDUCTOR
SCREEN
GROUND
3.5mm
OUT
AERIAL
EARTH

The rear panel of the Mk1 ATU showing the aerial input and output terminal posts.
A 3.5mm jack socket is also included as an alternative output socket for convenient connection to a portable radio via a length of flexible 50 ohm coaxial cable

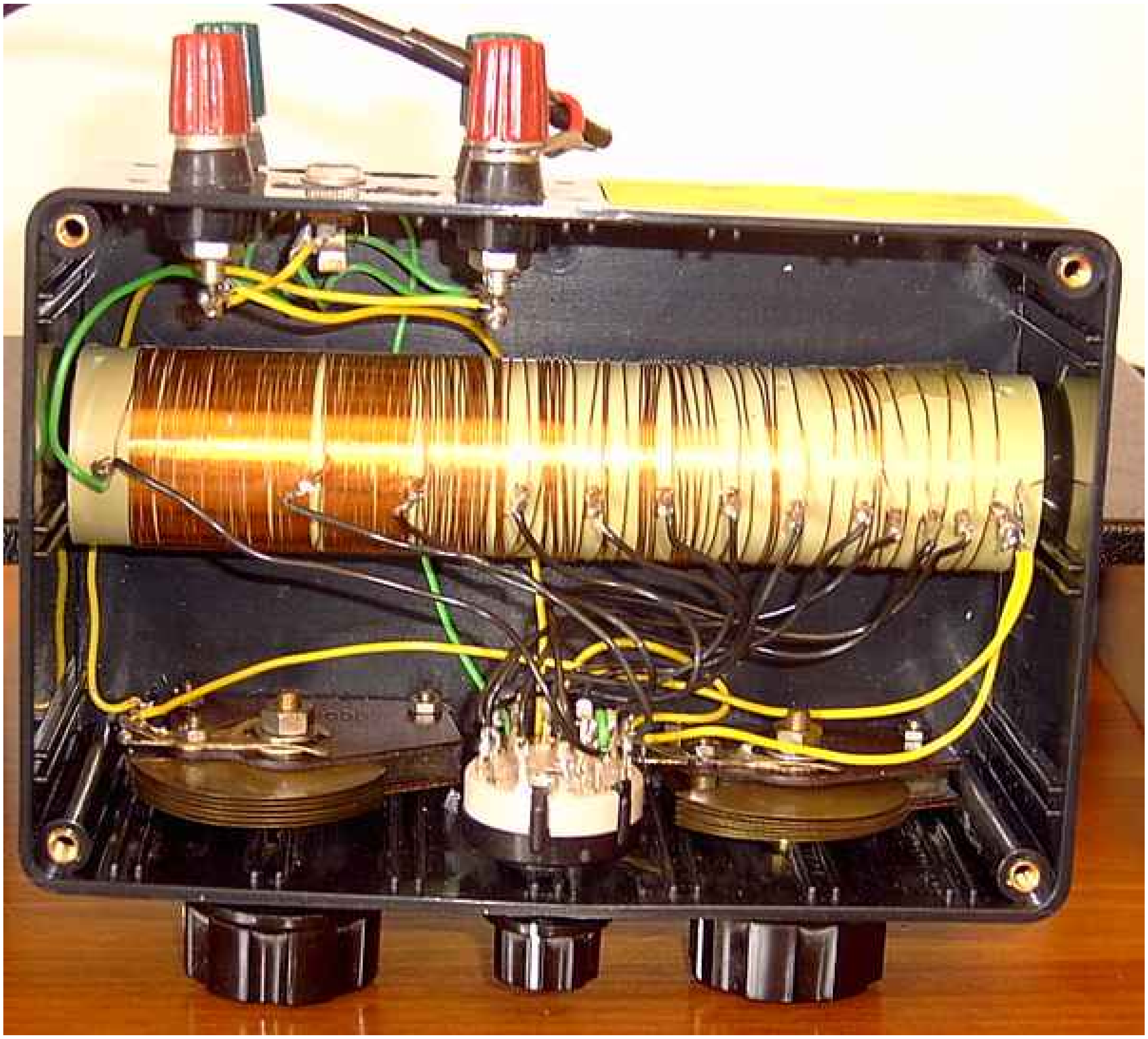

Internal view of the Mk 1 Antenna Tuning Unit showing the coil and its 12 tapping points, the range switch and two space-saving Jackson type solid dielectric tuning capacitors. The potentiometer that forms the variable attenuator is hidden from view by the range switch.

The Mark 2 Aerial Tuning Unit

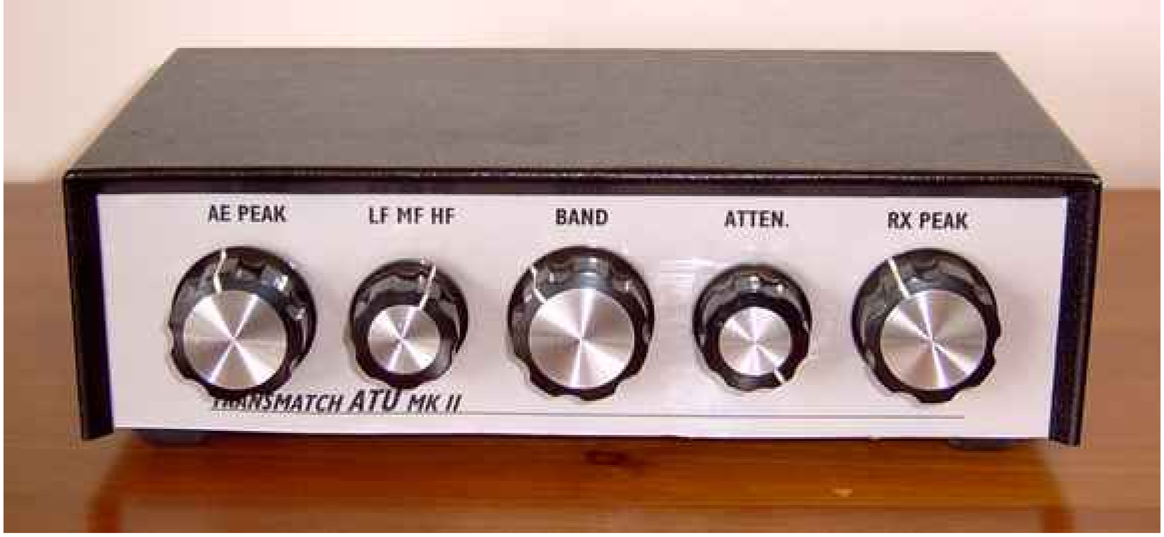
AE PEAK
LF MF HF
BAND
ATTEN.
RX PEAK
TRANSMATCH ATU MK II

The Mark 2 Antenna Tuning Unit

The Mark 1 ATU described above was initially made using the Pi match circuit and when I made this, the Mark2, I used the T match circuit design and when I found that it worked even better I modified the Mark 1 to also use the T match circuit layout.

The Mark 1 is used for a portable radio and therefore is more compact, the Mark 2 is used for the HF-150 so can be a bit larger. It is housed in an aluminium case and uses the larger air-spaced tuning capacitors and also has SO239 sockets are fitted for the input and output.

The coil is larger too, using the same former made from the centre of a fax roll but longer at 220mm to accommodate additional windings to enable coverage of long wave frequencies. An additional switch is also included to give plenty of adjustment while including the long wave range.

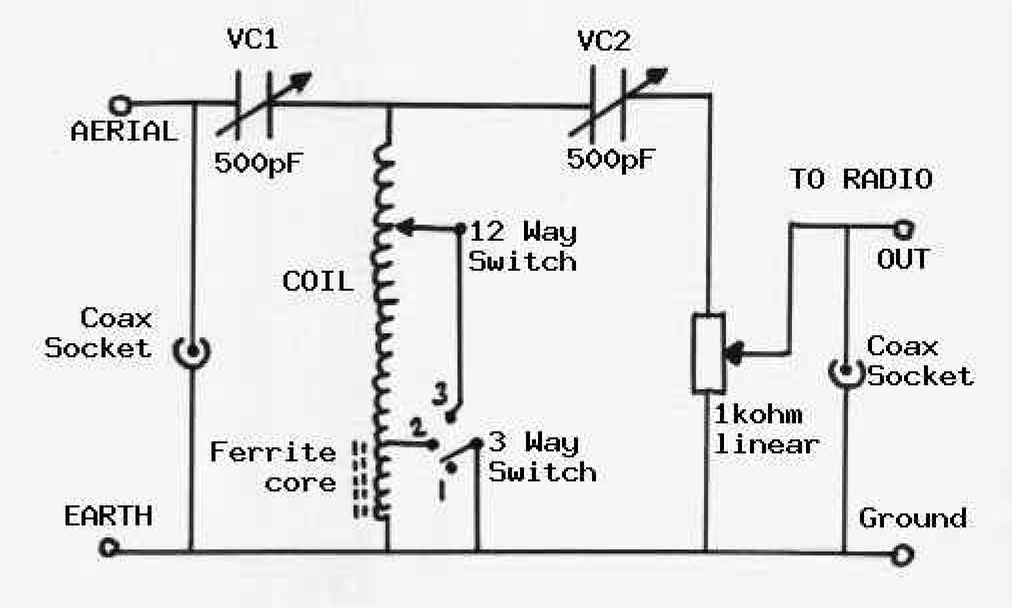

The circuit diagram showing the coil and the 12 way switch to adjust the Short Wave ranges and the additional 3 way switch to change to Medium Wave and Long Wave coverage*. The attenuator is simply a 1k ohm potentiometer.

* Position 1 is Long Wave; 2 Medium Wave; 3 Short Wave ranges - adjusted with 12 way switch

Tuning Capacitors: In these circuits, as is the general rule of thumb with radio projects, the moving vanes of tuning capacitors - and therefore the spindles/shafts - are connected to the earthy side of the circuit. Ensuring that the moving vanes are connected to the earthy side minimises 'hand capacitance' effects when touching the adjustment knobs. The fixed vanes are therefore connected to the 'hot' (top) side of the circuit.

You will have to determine which terminals on your particular capacitor are connected to the fixed vanes and which are connected to the moving vanes. It should be able to determine this visually from the physical construction of your particular component, but if you are unsure always use the continuity tester function of your multimeter.

With dual gang variable capacitors with smaller values per gang, it may be desirable to connect the two fixed sets of vanes together in parallel to increase maximum capacitance. For many metal framed air-spaced variable capacitors the moving vanes will effectively be connected together via the brass spindle to the main frame of the capacitor body. The fixed vanes and their associated terminals will be isolated from the metal frame by ceramic,

paxolin, or similar, insulators.

PARTS REQUIRED

1	Self wound coil with 13 tapping points
1	Reel of 22 swg enamelled copper wire
1	Reel of 30 swg enamelled copper wire (for longwave part)
1	Coil Former **220mm** long & approx **30mm** diameter
1	12 way switch
1	3 way switch
2	500pF tuning capacitors (200pF or 365pF can also be used)
1	1 k ohm linear potentiometer
2	Red Terminal posts
2	Green terminal posts
2	SO239 sockets
1	Aluminium case 220 x 130 x 65 mm + rubber feet

See additional notes below >

SOURCES FOR TUNING CAPACITORS

Old broken radio sets - but don't smash a nice one up for the sake of a capacitor! Old radio sets, especially the old 'valved' wirelesses are very interesting and often sound superb and could be quite rare.

J BIRKETT RADIO COMPONENTS,. 25 THE STRAIT, LINCOLN, LN2 1JD. telephone (uk) 01522 520767 http://www.zyra.org.uk/birkett.htm

MAINLINE GROUP http://www.mainlinegroup.co.uk/jacksonbrothers/index.htm]

COIL WINDING DETAILS

The coil is essentially the same as the coil described above being wound on the centre of a fax roll or any similar former approximately 30mm in diameter, but slightly longer at 220 mm long. In this case I secured the start and the finish of the windings by simply looping the 22 swg enamelled copper wire through two small holes at each ends of the former to secure it in place. The taps are formed by simply twisting the wire into a loop at each specified interval, to form the connection points to the range switch, making sure that all the enamel is scaped off so that the connecting wires to the switches can be properly soldered in place.

One difference with this coil is that it is designed to cover the Long Wave band too, and the final 110 turns are wound from slightly thinner 30 swg enamelled copper wire, this was done simply to save space. Inside the tube at this end are placed a couple of short lengths of ferrite rod, no longer than 50mm. These are then adjusted, once the ATU is functioning, to give the required tuning range. Alternatively more windings could be added to the final winding to increase its inductance until the desired range is achieved.

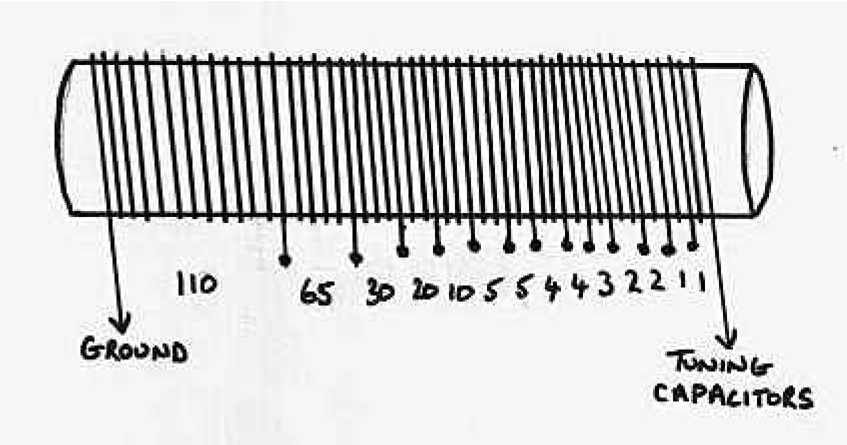
110
65
30
20
10
5
5
4
4
3
2
2
1
1
GROUND
TUNING CAPACITORS

Diagram showing the number of turns between each tapping point

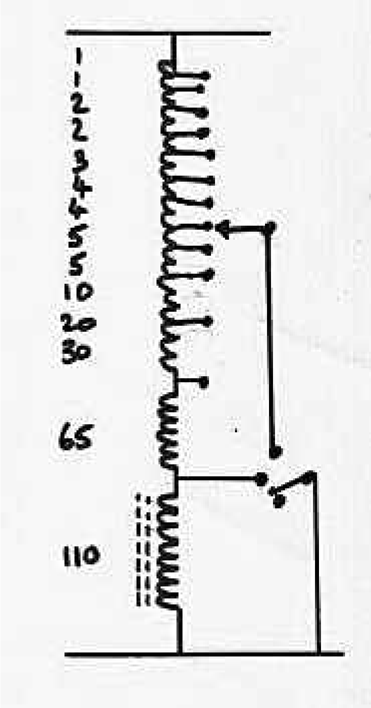
1
1
2
2
3
4
4
5
5
10
20
30
65
110

Detail of tapping point intervals and how the coil is wired into the circuit

ANTENNA
EARTH
RX

Detail of tapping point intervals and how the coil is wired into the circuit

The rear panel. On the left the input terminal posts for the aerial and earth wires, with the addition of a SO239 socket for the connection of coaxial cable. On the right the SO239 coaxial output socket for connection to a radio with a coaxial input socket also provided are the alternative terminal posts for single wire output and ground connections to the radio.

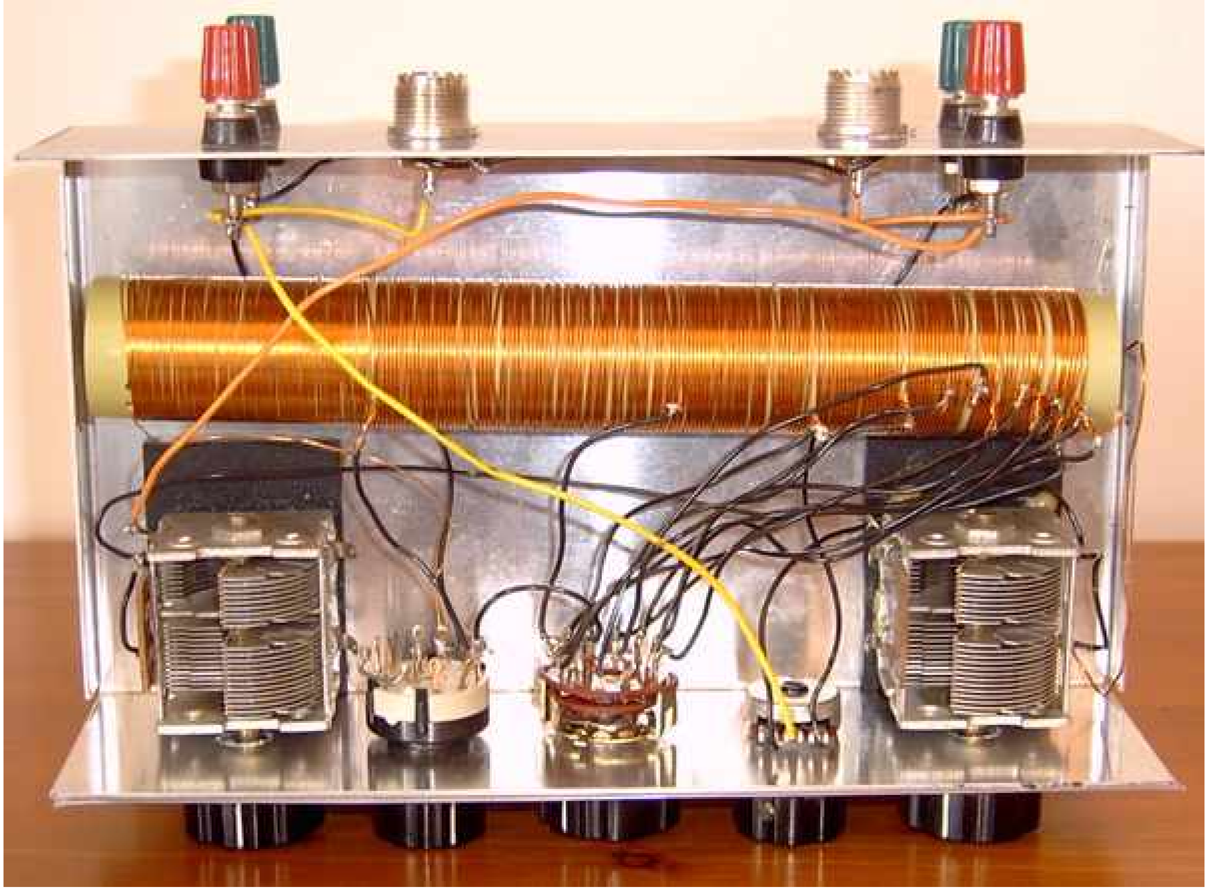

Photo showing the relatively straightforward internal construction of an ATU.
2 large air-spaced tuning capacitors, range switches, potentiometer, and coil with 14 tapping points.

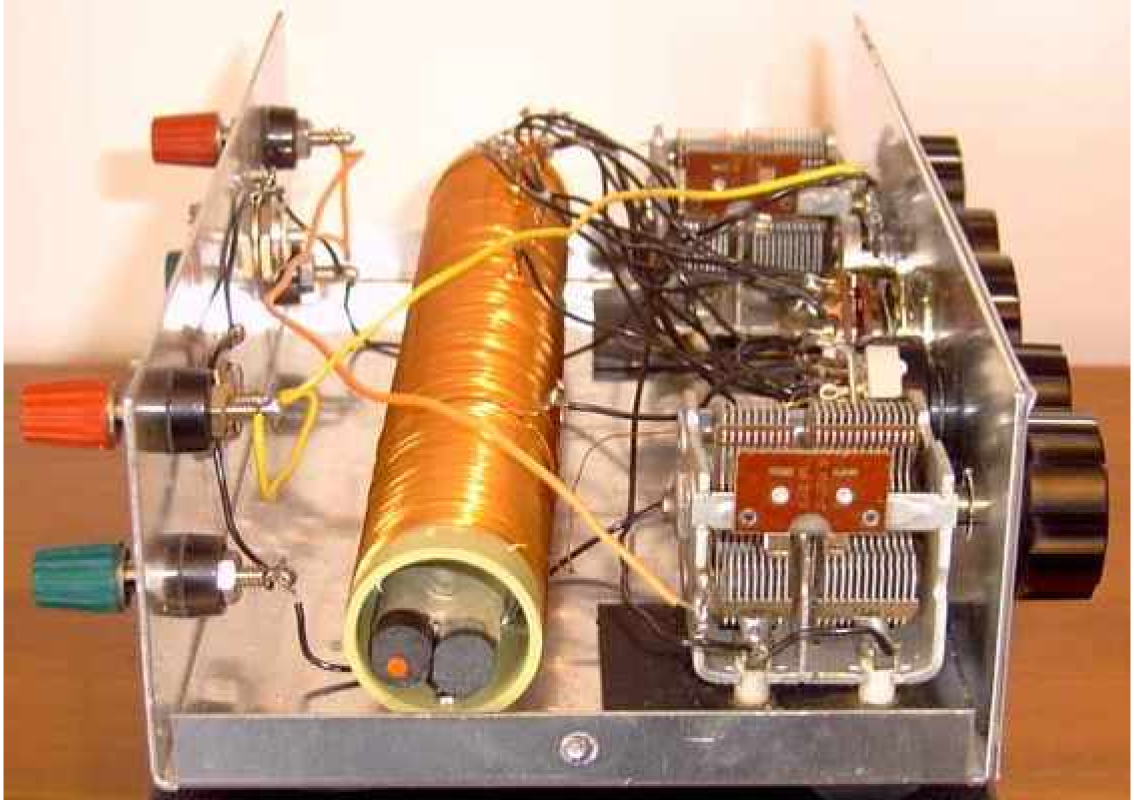

Photo showing how two 2 inch lengths of ferrite rod are put inside the coil at the longwave end of the coil to provide coverage of these low frequencies

ADDITIONAL NOTES:

Thank you to Dr Paul S Crawford who e-mailed us with this additional useful advice:

"You have basically have a capacitor input system connected to the antenna, my own preferance is always to put a 100K Ohm 'bleeder' resistor to GND on such an input just to stop any static build up on hot dry days, etc. Of course, you might also want to include a neon lamp across the input as a crude (but cheap) induced lightening surge arrestor as well.

Regards,
Paul "

Thanks Paul for taking the trouble to get in touch. The lightning arrestor is certainly an excellent safety feature, and if you are troubled with noise caused by a build up of static on the aerial wire, then the 100k resistor is a good tip.

A Question About The Daiwa CL-22 antenna coupler

Dear Sir, I hope you can answer a few questions for me, if you can help me, it will be gratefully appreciated, firstly i am 11 years old, and have just started SWL listening with a DX 394 radio, been using a end fed long wire about 25m long into back of radio.

Recently bought a Daiwa cl-22 coupler(atu) at a car boot sale for £3, it looks in mint condition, but didn't come with any operating instructions, and scoured the internet for some with no effect.
the ATU, has 3 controls on the front..... one marked Receiver, one marked Antenna, both theses are variable controls, and one marked band (A to G), i understand the Band control, also the Antenna control, what is mystifying me, is the variable control marked Receiver ?.

Also on the rear of ATU is 4 screw terminals, grouped in pairs, one marked Receiver, and the other marked Antenna, the Antenna screw terminals are coloured ,one black and one red, and the same for the Receiver terminals, they are very small screw terminals, looks like they only for very thin wire, my question is how do i connect my long wire to the ATU, and to which terminal?

I really hope you can help me with this, as your web site seems to be the only one, on the internet, which seems to want to help anyone like myself, looking forward to hearing your reply.

Thanking you, Ashley Griffiths. May 2012

Hi Ashley, I am not familiar with this particular unit, but most antenna matching units are similar in operation. One pair of terminals on the rear will be used to connect to the antenna and the other pair to the receiver.

Use RG58 coaxial cable to connect between the a.m.u. and receiver. The red to the centre conductor of the RG58 coaxial cable and the other terminal to the outer shield. Some antennas use coaxial cable to feed to the receiver or a.m.u., but in your case you are using a single random wire as an aerial, so simply connect this to the red terminal.

Often connecting the other (ground / GND) terminal to an earth / grounding stake driven in to soft damp soil outside can help reception. Possibly reducing interference or increasing signal strength. It's worth trying, but it does not always help in every case. I don't know without seeing the physical circuit what the actual circuit topography will be. It could be what is known as a "T" match or perhaps a
"Pi" match. Nevertheless the controls on your a.m.u. will perform the same functions and will likely be as described below.

All three controls will tend to interact with each other. The band control is most likely to be a multi-way switch that selects tapping points on an inductor (coil). This sets the general band of operation - usually from around 3MHz at the longer wavelength end of the short wave (H.F.) bands up to around 30MHz at the shortest wavelengths of the short wave (H.F.) band.

'A' will correspond to one end of the HF band (maybe the shortest wave / highest frequency end) and 'G' the other end (maybe the longest wave / lowest frequency end) - or the other way around. You will determine this by experimentation. The other two controls will normally be variable capacitors. One of these will be on the antenna side of the circuit, while the other will be in the output (receiver) side of the matching circuit.

All the controls have to be adjusted to provide the best impedance match between the receiver which always requires a 50 Ohm antenna impedance and the antenna which will present a complex and varying impedance of just several ohms to (perhaps) many hundreds of Ohms dependent on frequency being used.

For example if you want to listen to a radio station in the 31 metre band and your particular random wire antenna presents 50 Ohms to the receiver's antenna input socket then conditions are well matched and you will not need to use the matching unit, indeed it may have little or no effect and may even induces losses that actually weaken reception!

However if on the 31 metre band your random wire antenna presents an impedance (resistance to an alternating current) of several hundred Ohms or more, or a lot less than 50 Ohms then matching will be poor and some of the signal will be lost. This is when the matching unit can help. By adjusting the controls correctly better impedance matching can be achieved so that more of the signal is ransferred from the random antenna to the radio receiver.

Each band will be different and will need different amounts of matching. You will need to experiment with the controls and determine the best position of all three that produces the highest signal strength. Make a note of their positions for each HF band on a paper chart so that you can easily and quickly set the correct positions in the future as you hop from band to band on the receiver.

I think that's as much as I can tell you without knowing or seeing the actual a.m.u., but these basic principles are the same for any a.m.u. - I hope that helps!

73
Mike
M0MTJ

Hi Mike, Thanks for sharing your expertise and experience!

I am an American living in Mexico and want to use a longwire antenna of about 130 feet for shortwave listening. Am thinking to bring the signal into the house with a 9:1 unun and RG8x coax, then fine tune with your ATU MK II into my Yaesu FT-847.

I don't understand the use of the two ferrite rods.... do they simply enhance the effect of the wiring in the fax tube or do the rods have wires wound around them as well?   For the alternative of more windings around the fax tube (I assume that eliminates the need for the rods), about how many more windings?

If I cant find a fax paper tube (30 mm = 1.1811 inches) can I use pvc plumbing pipe that is either 3/4 nominal =1.050 inch outer diameter or 1 inch nominal = 1.315 inch outer diameter?

I cant find 500 pf tuning capacitors so will use 365pf instead...do you know which frequencies I will not be able to tune as a result?

I understand the longwire is directional, pointing toward the far end. Will it likely cover at least 22.5 degrees to each side of its direction?

Is a plastic enclosure just as good as metal, or is shielding an issue? Your photo seems to be of a plastic box, and I can source a plastic enclosure locally.

I wish I could find people like you here where I live in Mexico to share ideas, and passion for whatever hobby it might be, SWL, amateur radio, and so forth.

My great grandparents are British but I haven't visited your country, but will someday. I am envious because you have so many enthusiasts for many interesting activities in your country. I even have the idea that all your countrymen have amazing gardens in their backyards...

When I know what to order so can start to collect the parts...

Thank you Mike, Ransom Peek in Patzcuaro, Michoacan Mexico. (November 2014)

Hi Ransom,

Thanks for your email, it's nice to hear from you.

Using a 'long wire' (I prefer to use the term 'random wire') antenna fed via a 9:1 UnUn is a popular antenna to use at present. It's certainly not the ideal antenna for all circumstances, but as a compromise 'all around' antenna it is probably a pretty good choice.

The two ferrite rods are plain - no additional windings. I simply used them to increase the inductance of that section of the coil windings, therefore allowing use on the lower frequency bands. Their size and position within the tube will dictate the actual frequency range of that section. So - nothing critical, but you may need to experiment a little.

The same applies to the tube. The size is not critical, but it will effect the inductance and hence the frequencies that are covered. Anything (card / paper / PVC) of about 25 to 30 mm (i.e. about 1 inch) will be fine - but again you may need to experiment with the final tapping positions to ensure that your obtain the frequency coverage that you require. I cannot give you absolutes - but the rule is; the larger the diameter of the coil the higher the inductance and hence the lower the frequency - similarly the greater the number of turns on the coil the higher the inductance and hence the lower the frequency - and obviously the converse is true.

365pF cap's are fine and are, in fact, commonly used in ATU's. Naturally the frequency coverage will be a bit different using smaller value cap's, but this can likely be compensated for by adjusting the tapping points if necessary. Lower value cap's may need a few more turns on the coil to compensate.

A straight wire will have some directionality, but depending on the frequency of operation, the pattern will tend to break up into lobes causing some nulls in certain directions. As a rule of thumb, however, the deepest nulls will tend to be off the ends of the wire, while the greatest signal pick up will broadside to the wire.

Please also note that this is a receiving ATU, it has not been rated for transmitting, although it might be ok QRP operation (i.e. < 5watts).

If you have not already done so - just try the 9:1 fed antenna straight into the radio. It may be fine for your swl needs as it is. Then, if you feel that you need a bit of impedance matching, you could try making the ATU. Of course - there can be endless experiments with antennas!

A plastic case should be fine for a receiving ATU.

It is interesting to learn that your great grandparents were from the UK!

As for back gardens here - well they can be of all shapes and sizes, or, indeed, non existent!

Our garden is quite small - but the gardens of many older (1930's) suburban houses could be 100 feet long, or much more. The back gardens of newer houses tend to be very compact - even for larger houses - due to the VERY high cost of land nowadays. Small gardens are called "Postage Stamp" gardens. Of course, many people live in flats and apartments, some of which have shared/communal gardens, and some have no gardens at all. The radio enthusiast therefore has to devise all sorts of compact or 'stealthy' methods of installing an antenna! Maybe a wire aerial supported on a fibreglass fishing pole fixed to the balcony, perhaps.

I hope that helps! Good luck with your projects.

73
Mike
M0MTJ

More about Components / Aerials / UnUns and Baluns

Simplification: If do not need cover the long wave or medium wave bands then you can omit those windings. This will make construction and wiring simpler.

Variable Capacitors: The variable capacitors can be anything over 200pF in value - just bear in mind that smaller values will not give as much adjustment range as larger values. Using a smaller value capacitor, such as 200pF, should not be a problem but it may require some experimentation with different tapping spacings, or perhaps using a greater number of tapping points, to obtain the required band coverage.

The use the miniature polyvaricon cap's which have a value of around 200pF will help keep costs low and will work perfectly well in receiving ATU's. You might also find these in old junk pocket transistor radios that can be salvaged for these sorts of projects.

Aerials and Feeder arrangements:

This will be a case of experimentation to find what provides the best reception - whether that be best signal strengths from stations of most interest, or lowest noise - i.e. best Signal to Noise ratio (S/N).

Try a 'long wire' aerial to begin with. Actually the expression 'Random Wire' is a more accurate and better terminology. Connect the aerial wire directly to the ATU. This may give good signal strengths but may also be noisy.

If you are troubled with noise:

Try connecting coaxial antenna cable to the ATU with shield to the ground terminal and centre conductor to input terminal. Take the coax to the outside the house and connect the the inner conductor to the random ('long') wire aerial. This may lower noise - or may just lower signal strength! It is important to attempt to judge whether the Signal to Noise ratio has improved. It might be found that actual strengths have been lowered, but that the noise level may have reduced by a greater extent, so as long as the signals are still resovable the overall noise should be lower.

Further experiments: Experiment with connecting the far end of the coax inner conductor to the random aerial wire but also connect the shield of the coax to an earth stake in the back yard or garden. This will change the aerial system - possibly reducing local noise pick up - possibly not!

Also experiment with a matching transformer at the far end of the coax. The use of an UNbalanced to UNbalanced transformer would be the most appropriate for this purpose - so try winding a simple 4:1 ratio UNUN or perhaps try a 9:1 UNUN which may work even better.

There are numerous UNUN designs on the web often using a toroid core, while some designs also use a 10mm ferrite rod. The wire used to make the windings might be enamelled copper wire or even p.v.c. covered wire. Either method would be good for these experiments. Here are some links for constructing UnUns and BalUns:

UnUn designs

M0UKD - 9:1 Unun (so-called magnetic longwire balun):
http://www.m0ukd.com/Magnetic_Long_Wire_UnUn/index.php

How To Build an UNUN by G7LRR:
http://www.pcsystems-ss.co.uk/g7lrrweb/index.php?module=pagemaster&PAGE_user_op=view_page&PAGE_id=52&MMN_position=77:37

IW7EHC - Unun Design for Longwire antennas:
http://iw7ehc.altervista.org/ununEN.htm

Balun designs

Build An Air Wound 1:1 Choke Balun For HF: http://www.hamuniverse.com/balun.html

1:1 Balun for balanced dipole aerials : http://www.m0ukd.com/1to1_HF_Balun_for_dipole/index.php
http://warga11mc.blogspot.com/2010/07/balun-11-14.html

Cost Effective 1:1 Current Mode Balun:
http://www.arising.com.au/people/Holland/Ralph/cmbalun.htm

Inexpensive 1:1 Balun: http://oz1jux.dk/balun.htm

Build a 1:1 Coaxial Balun: http://www.iw5edi.com/ham-radio/?a-1-1-coaxial-balun,41

Broadband Balun Design: http://www.qsl.net/ta1dx/amator/broadband_baluns.htm

Step-By-Step Construction of a 4:1 Current-Type (Guanella) Balun:
www.n0ss.net/qrp_4-1_guanella-type_balun.pdf

Making Baluns 1:1 and 4:1 Baluns - Swindon and District Amateur Radio Club:
http://www.sdarc.net/wp-content/uploads/pdfs/Making_Baluns.pdf

Air Wound 4:1 balun: http://www.combotec.com/projects/balun14/balun14.html

Home brew a 4:1 balun: http://www.rason.org/Projects/balun/balun.htm

4:1 balun for 160 to 10 meters by Clay Wynn: http://www.hard-core-dx.com/nordicdx/antenna/feed/4_1balun.html

4:1 and 1:1 Balun ideas by PD7BZ
http://www.pd7bz.com/radioprogs/manuals/balun_transformer.htm

Balun Winding: http://users.catchnet.com.au/~rjandusimports/balun_winding.html

4:1 and 1:1 Balun construction by M0SCG: http://www.m0scg.org.uk/Projects/?p=207

QRP 4:1 Balun for 160 to 10m : http://www.dxzone.com/cgi-bin/dir/jump2.cgi?ID=16753

UK Source for Silver Plated PTFE (Teflon) covered wire for winding higher power baluns:
http://wires.co.uk/acatalog/ptfe_covered.html
14awg / 16 swg or 0.16 mm dia wire. 12awg / 14swg 0.2mm dia wire and larger toroid for higher

powers.

Balun using T200-2 toroid (17 turns of e.c.w.) or T200A-2 toroid (13 turns of e.c.w.) for 400 watt H.F. Balun.
T400-2 Toroid (14 turns of e.c.w.) for 1000 watt H.F. Balun.
Amidon ferrite & powdered iron cores & ferrites: https://www.amidoncorp.com
Bytemark ferrite & powedered iron cores & ferrites: http://www.cwsbytemark.com
http://www.bytemark.com

I hope you enjoy building one of these useful devices, and enjoy even more the benefits that an ATU can bring to your listening post with minimal expense.

73
Mike
MØMTJ

Radio Stations & Memorabilia | **Loop & Frame Aerials** | **Copper Tube Antenna**

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The Fredbox

2007-05-26

I first heard about The G3XBM Fredbox transceiver via Solder Smoke. As soon as I saw it I just had to give it a go. It is a very simple and elegant design. Of course it offers no bells or whistles, just a fixed TX and RX frequency, and a flea-power output on TX, but it has a special charm in its simplicity and the retro usage of AM on VHF.

Transmitter

I built the transmitter side first. BF199s were selected as a good candidate for the RF devices, but I lacked a crystal in the range specified in the original article. Instead, I used a common 16.384 MHz crystal and redesigned the circuit to be two triplers rather than two doublers. This crystal is a common "computer" crystal, but places the TX frequency in the high-end simplex segment. This is a bit too close to the pager-splattered end of the band for my liking, and doesn't match the band-plans. For now this is OK, I'll get a custom crystal cut eventually.

I didn't use shielded cans or variable inductors for the transmit coils (as specified by the article), rather I used fixed inductances wound on T37-6 toroid cores with bare 0.71 mm tinned copper wire. My LC resonance calculator and nH inductance meter were enormously helpful in making the selection and testing of the tripler and output stage resonators. Each stage was tuned with trimmer capacitors.

It was amazingly easy to get the TX-side working, I just built each stage from the crystal to the final amp in turn, testing as I went. Each stage is well behaved and peaks nicely.

Peter VK2TPM could hear the signal at his QTH several kilometres away when I connected the half-finished TX board into my flower-pot antenna. The DC input power was about 23 mW, and no special attempt was made to match the output into the load, in fact the series trimmer in the matching network was absent at this point, just a fixed 12 pF capacitor was used for DC blocking.

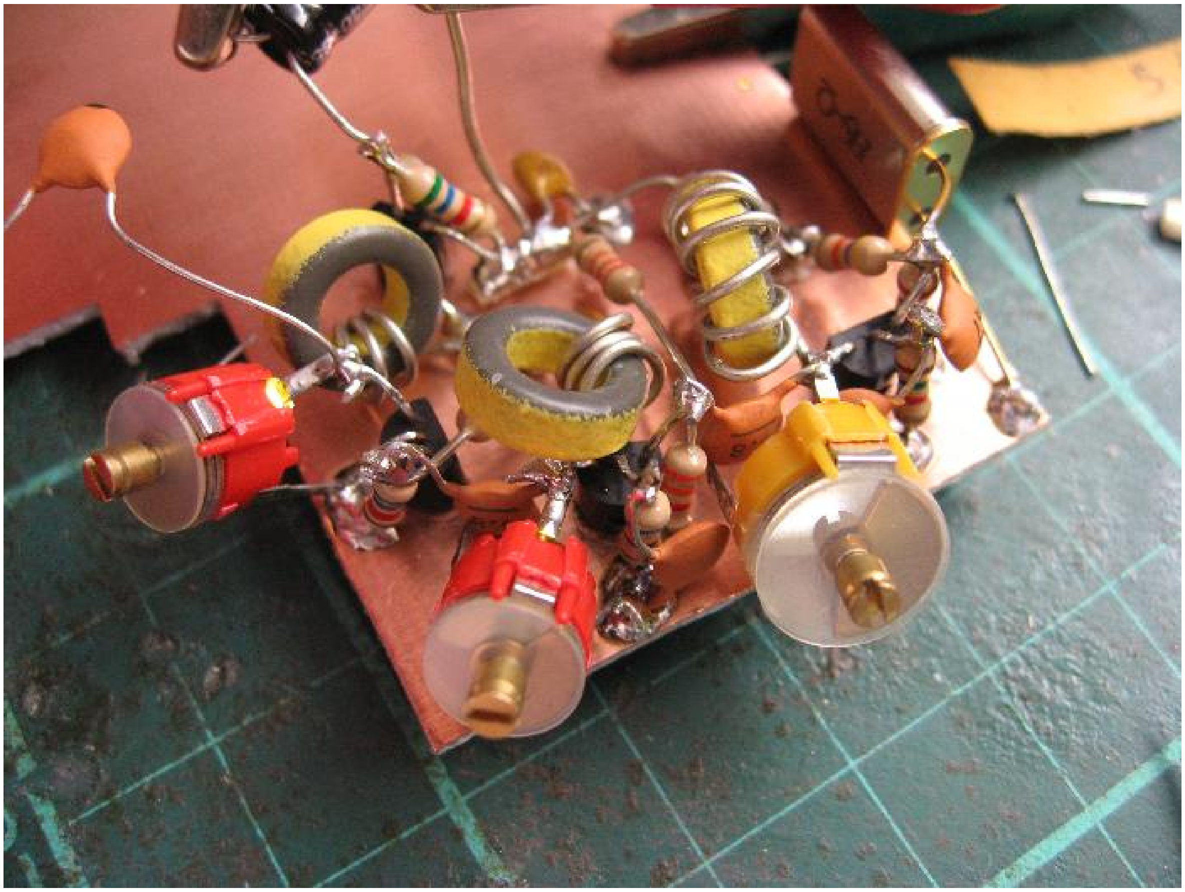

Upon finishing the TX circuit I did experience a bit of RF pick-up in the microphone amplifier 2nd stage. A 1 nF capacitor to ground discouraged its RF gain and eliminated the problem. The 2nd AF amp stage is located immediately adjacent the crystal oscillator stage and was picking up RF directly. The effect was not audible, but was visible on the spectrum analyser as weak 16.384 MHz sidebands either side of the carrier. This wasn't causing feedback, just high-frequency modulation of the signal. If nothing else it proved the bandwidth of the modulator, which is perhaps a surprise considering the 100 nF decoupling on the modulated rail, however the output impedance of the series modulator emitter is so low it could deliver a few tens of mVs of HF ripple into that kind of load.

Receiver

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As easy as the Transmitter was, the Receiver was hard. It fought me every inch of the way. I spent an entire day trying to work out why it was simply not super regenerating from about 130-160 MHz. It turned out to be a 10 nF decoupling capacitor on the cold-end of the detector resonator. The article specified 1 nF, and I originally intended to use this value, but I had a strip of 10 nF mono's on the bench, so I used them. At build time I did consider why 1 nF was specified in the first place, I figured it was avoid the exact problem that would befall my unit, decoupling resonance. (Lesson #1: Trust the original builder and your initial instinct.) When the unit wouldn't oscillate properly I assumed that I had damaged the capacitor on install - this is a pretty common fault, so I tested it in-place by ensuring it would shunt a HF signal (my standard decoupling cap test), it passed this test just fine. (Lesson #2: Test at the frequency of operation.)

My hubris about "modern components" being superior and likely "purely capacitive" at VHF turned out to be completely wrong. It took *hours* to work it out, but eventually I determined the entire decoupling network was resonant near the operating frequency. Much foul language later and I replaced the cap with a ceramic 1 nF, with its "flashing" broken off and scraped right back to the disc to minimise the lead length. This cured the problem.

For the longest time I had assumed it was the source coil - and in fact the first source RFC I used (a molded choke) was being operated above its self-resonant frequency and prevented any oscillation at all. I replaced it with a few turns on a ferrite bead which seems just fine now.

A couple of other minor annoyances/mistakes were worked through (like picking larger inductances and making the entire circuit so sensitive to stray capacitance it was a nightmare to tune - DUH!).

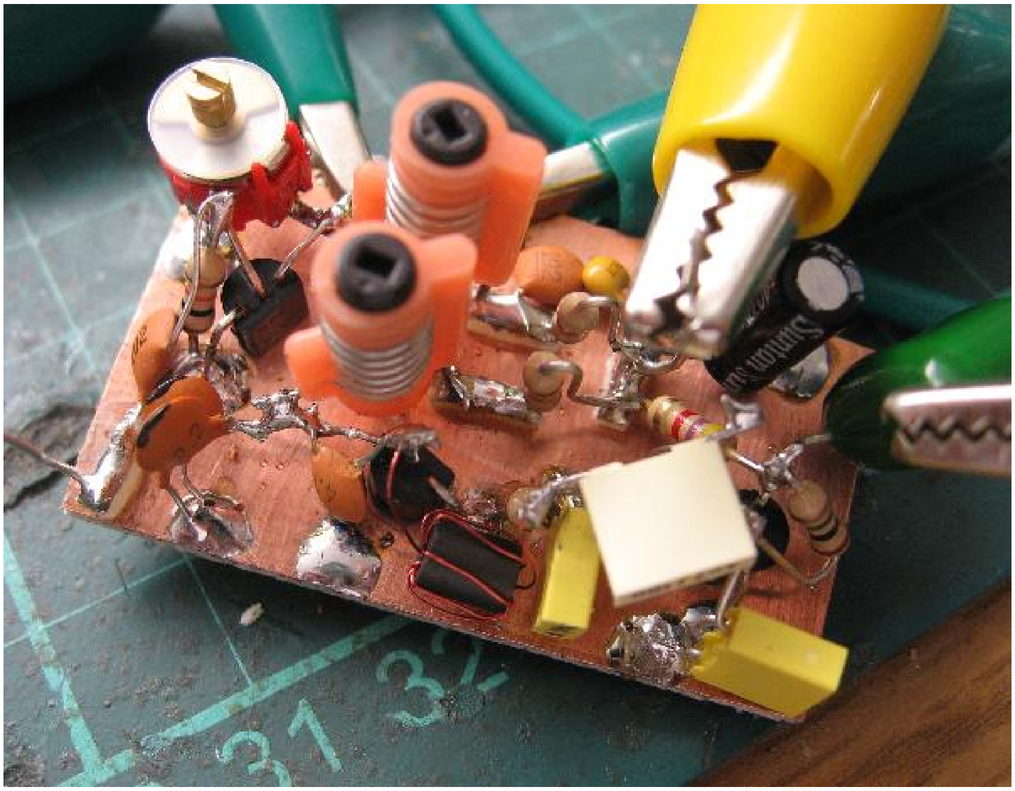

Eventually the unit super-regenerated right through the region of interest and the LNA stage was constructed. Initially I put the LNA drain coil too close to the detector coil and they over-coupled. This meant as I tuned through resonance on the LNA drain it would pull the detector so much it would shut down. Bugger! Moving the coils apart a little reduced this effect to acceptable levels, but the core of one still effects the other a little. I'm happy with the current coupling, and it is actually useful to help tuning the LNA resonator. As you rock it through resonance it will pull the detector, and by observing the wiggle on the spectrum analyser you can tell you've got it tuned up. The AGC action of the detector makes it hard to tune for maximum smoke otherwise, as the AF output doesn't change much at all even when the front-end isn't tuned up properly. Once you've got it nearly right you can use a weak signal to tune for best signal to noise.

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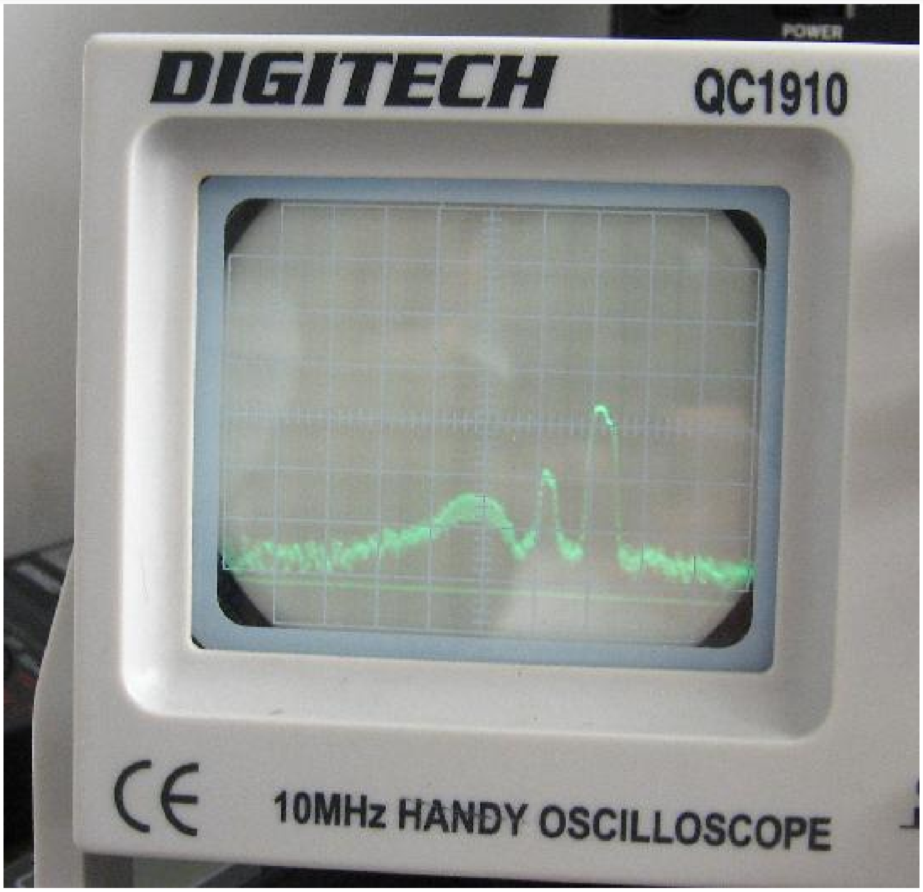

Note the pagers above the 2 metre band in this spectrogram. The hump in the noise floor is the receiver super-regeneration side bands. The smaller peak in between is the output of the Fredbox transmitter, the leakage from the unshielded prototype on my desk operating into a 47 Ohm load. It is rather disturbing that the pager signals are *larger* than this local signal just a foot or two from the spectrum analyser antenna.

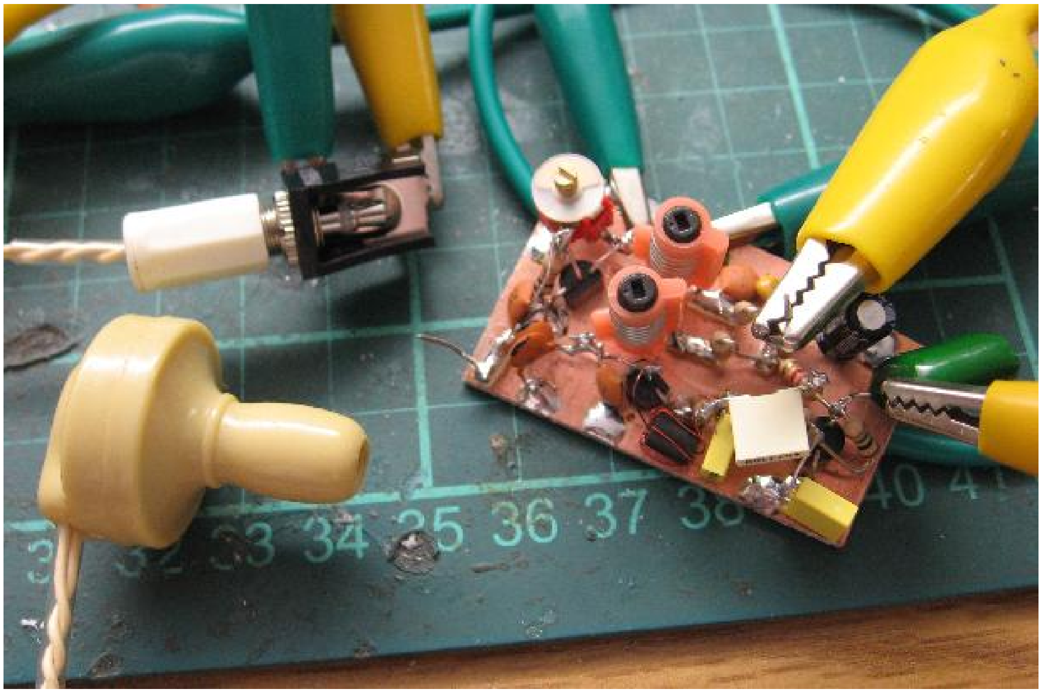

I used J310s for the receiver FETs, and a 2N3904 for the audio amp. Although the main design requirement for Roger appears to have been flea-power, I think a better AF amplifier that can drive modern low-impedance headphones would be preferable. Only Jaycar now carries crystal earphones with a nice soft silicone ear piece. The one I used comes from DSE and it is hard-plastic - not very nice on the ear. I really hate these kind of earphones anyway, I'll probably be rebuilding it for a low-Z output at some point, but it does work pretty well as-is.

BTW: While I was in the "Special Hell" of decoupling resonance I took the RX down to the FM broadcast band, and up to the VHF-hi TV band. It works wonderfully in both, which isn't a surprise. However, by adjusting the drain-source feedback (then a trimmer, now fixed) I

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Hall's regen on the FM band. The topology is more forgiving however, allowing grounding of the tuning cap. I also built several different oscillator topologies in desperation before I identified the decoupling fault, in one I got a Colpitts-like oscillator working with emitter coupled feedback to a tapped capacitor across the tank. This is something I should have thought about a *long* time ago, I'll probably build yet another FM broadcast regen using this topology for the detector, it seemed quite easy to control just by manipulation of the base voltage.

Boxing It Up

I am still tossing up between a cast Aluminium box, a custom box folded out of Aluminium sheet, or an Altoids tin. The circuit is small enough to just fit inside an Altoids tin but it probably won't fit with a battery. I'll pick up a centre-off momentary-one-side switch over the next week and finish off the radio one way or the other.

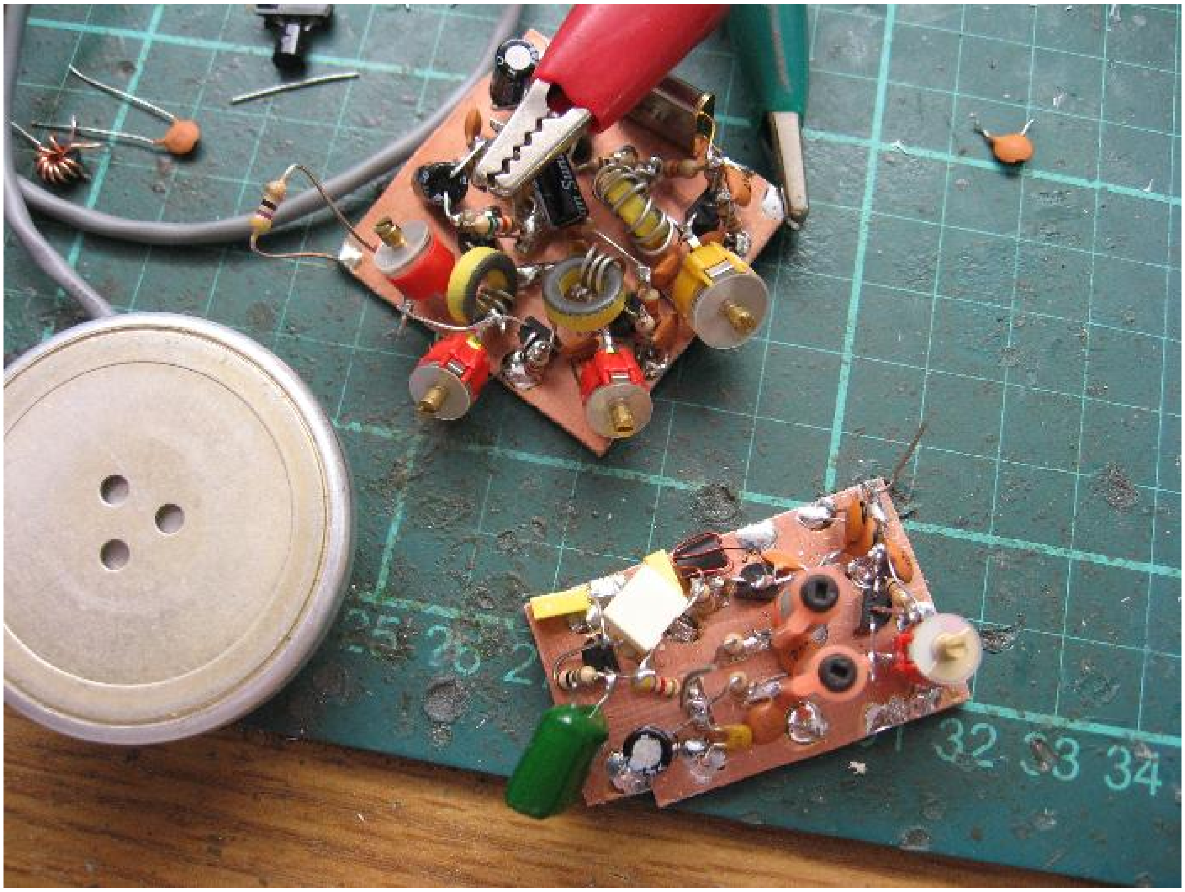

Note the use of an old telephone receiver as the microphone. It is nearly as large as the entire TX board. I'll have to find my electret mics, I know I have a bag of them somewhere that I got from a Rockby sale.

I'm strongly considering rebuilding the radio, perhaps through-the-hole to minimise its size. Although my prototype isn't too large as-is, it would be nice to neaten it up. Maybe I'll build it with fixed caps and variable inductors to save space too, although shielded cans are about the same size. It *might* be possible to tune the multiplier stages with stretched coils and fixed caps, this would make it much more compact and save money too if it ends up being kitted...

More TX Power

I am considering running the unit on 12 Volts to get a bit more RF out, and perhaps building in a small amplifier to get it up to 1 Watt region. This would probably involve a rebuild of the TX side to use a 2N4427 or similar final device, and a more robust series modulator transistor. This won't be efficient, but is probably easier to get going than a linear amp which would need careful drive adjustment.

I'll probably conduct some experiments around using a 2N7000 or VN10KM as the output device. The math suggests they may operate on 2 metres. I've already got them working on 6 metres in a brief experiment last month (must document that).

Comments

Working with VHF is fun! I find it a great learning experience, especially when you get problems like the resonant decoupling cap. That kind of thing really pushes your understanding of the physics and teaches you a lot.

I know a lot of HAMs won't touch anything above the bandwidth of their oscilloscopes. I can understand the frustration when something doesn't work, especially when you can't see why, but it really isn't that much worse at VHF. With just a diode probe you can achieve a lot. It does help enormously if you have VHF test equipment, for example I likely would have never noticed the HF modulation problem had I not had a spectrum analyser (although the HF was visible on the collector of the modulator drive amp, and most of us have a CRO that can see fine near 16 MHz).

A wavemeter can be helpful, if a bit retro, especially for making sure your multipliers are tuned up right and for looking for spurs. You can build one quite easily, it only needs to be a resonator with a detector and a LED or meter as a read-out. I'm a big fan of the biased 1N5711 through the decoupled bottom of the tank coil topology. For super-sensitivity you can use a MPSA18 as a DC amplifier. With a signal generator or dipper and a counter or scanner/receiver you can easily calibrate it. It can be used like a poor-man's spectrum

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My only advice when you get stuck is to trust the physics, do the math and follow your instinct when nothing is making sense. Rebuild parts of the circuit and test them independently. Measure what is actually happening and try to figure out what kind of misbehaviour in the circuit would cause the observed of behaviour. That will often solve an otherwise intractable problem.

Update 2007-06-05

I took the Fredbox boards to the local Homebrew Group meeting. I had both halves hooked up and talking across the room. Peter VK2TPM had brought along a digital audio recorder and did an interview with many of us in attendance. You can hear what I said about The Fredbox on Soldersmoke 62, and even a brief snippet of audio going through The Fredbox.

Also on the recording are Peter VK2EMU talking about the 80 meter challenge, John VK2ASU talking about his transmitter modules for the challenge (and an interesting diversion into IRF510 gate-modulation with some input from Brian VK2TOX - something I was thinking about back here, apparently Drew Diamond VK3XU has already produced a design doing just this). Mike VK2BMR also talks about his great VSWR/power meter project. His unit was absolutely beautiful, I was very much taken by the excellent job he did of cutting the PCB stock that made up the external directional coupler box, essentially flawless, perfectly square workmanship.

Update 2007-06-09

I've built a weak-signal source for aligning the receiver. One of the biggest weaknesses of the Fredbox receiver is that it drifts in frequency quite significantly with Vcc variations. Powered by a 9 Volt battery near the end of its life, it may drift enough to make the receiver completely off-frequency despite its poor selectivity. If I build this circuit again I'll probably put in a stabilized supply for the detector stage to avoid this problem.

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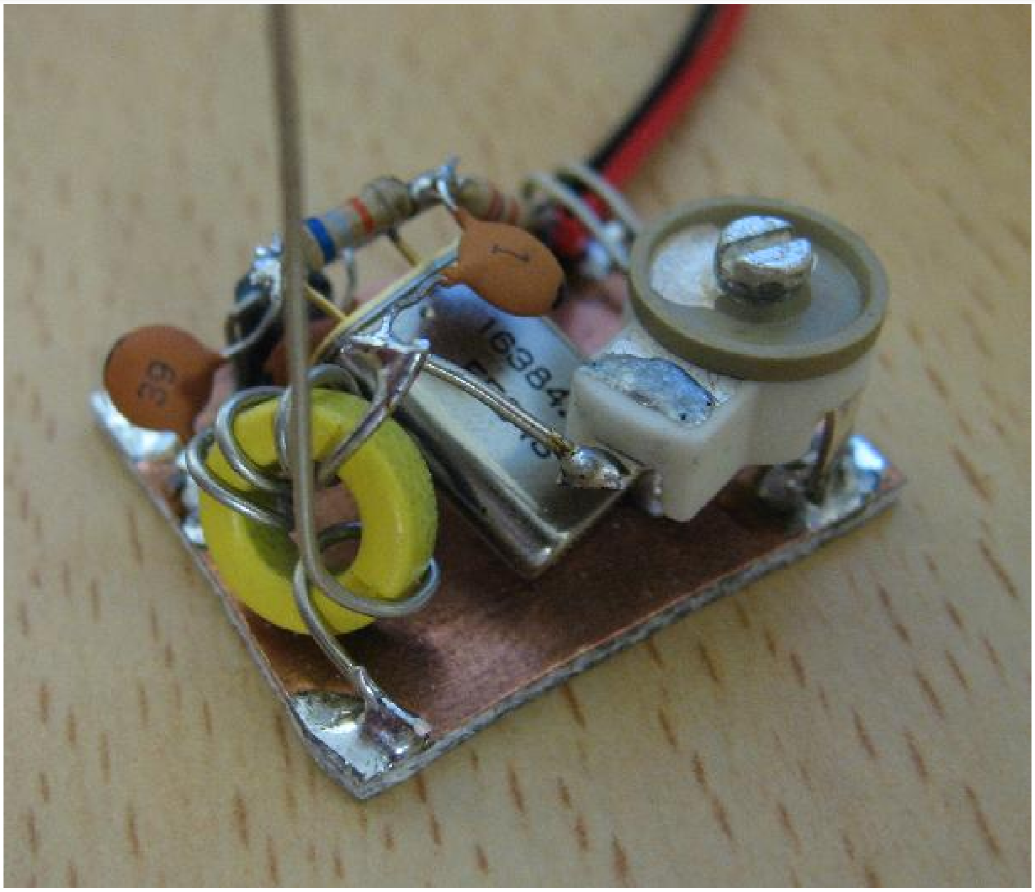

The signal source is a Pierce oscillator driving a tuned circuit which selects the VHF harmonic of interest. Because of the oscillator topology the crystal isn't pulled down as much as in the Fredbox circuit. The difference is fairly minor for my purposes, the poor selectivity of the receiver makes the difference in frequency of no real consequence. There is no active (or passive) multiplier, so the tuned circuit is merely extracting the harmonic energy from the oscillator. The harmonic energy available is very small, which is perfect for the application, giving an almost undetectable signal 1 metre away.

Update 2007-06-10

I've boxed up the Fredbox. As discussed earlier I went with the Altoids tin, despite this not allowing the battery to also fit inside the enclosure. I tossed up soldering an additional tin to the back to hold the batteries, but for now I've gone with the 9-volt battery snap just hanging out. It will work well with 6xAA battery holders which can just be held to the box with a rubber band.

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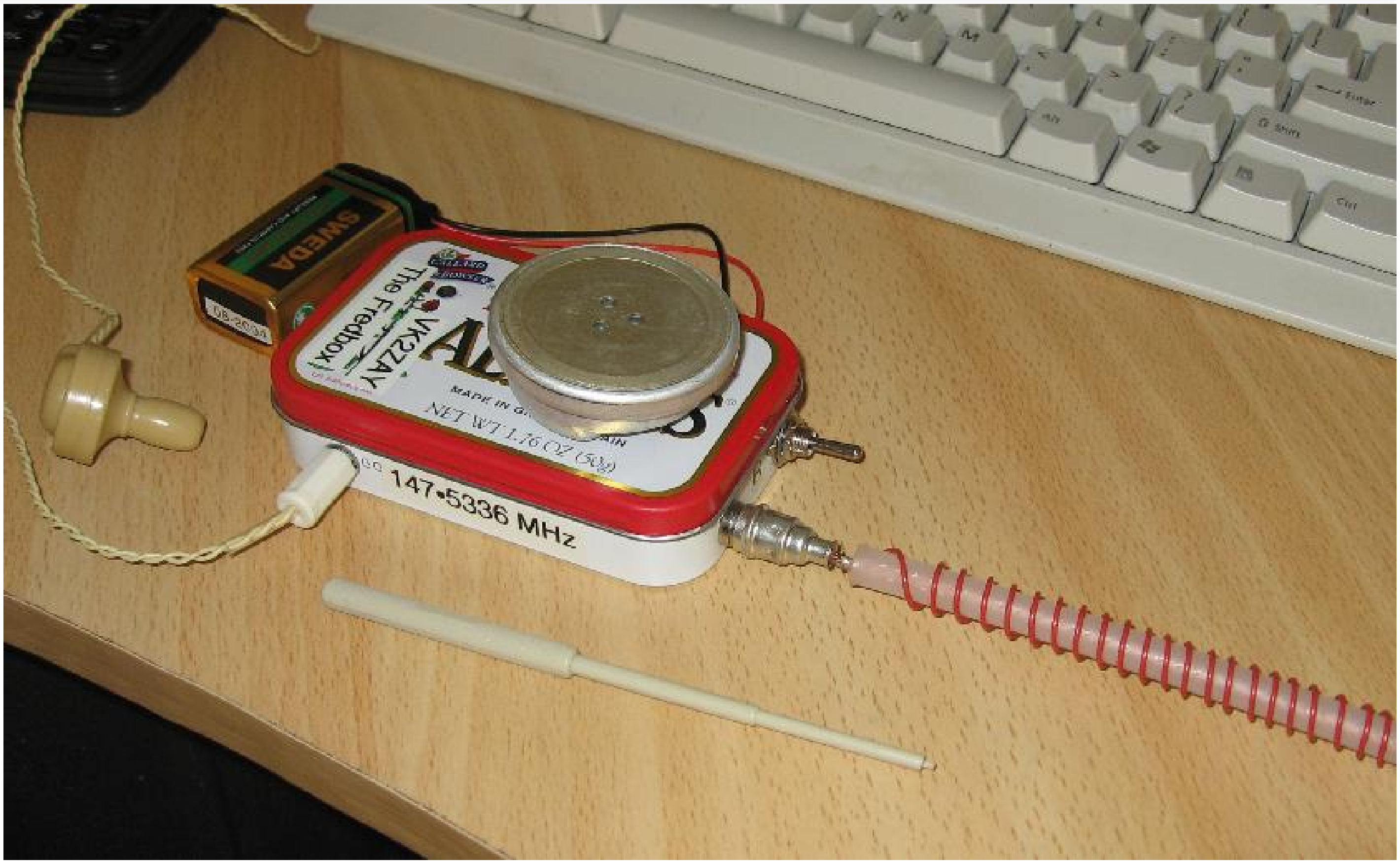

For the RF connector I chose an RCA. I can hear all the VHF engineers cringing, but for the purposes of this prototype it works just fine. The Antenna is a half-wave of wire helical which is quarter-wave resonant (with some pruning). The former is a piece of centre conductor and insulator from RG-213 coax. The centre conductor was left in place and is soldered into the RCA plug centre conductor, adding some capacitive loading and shortening the length of wire needed for resonance. I have no idea if this is good or bad, but it works.

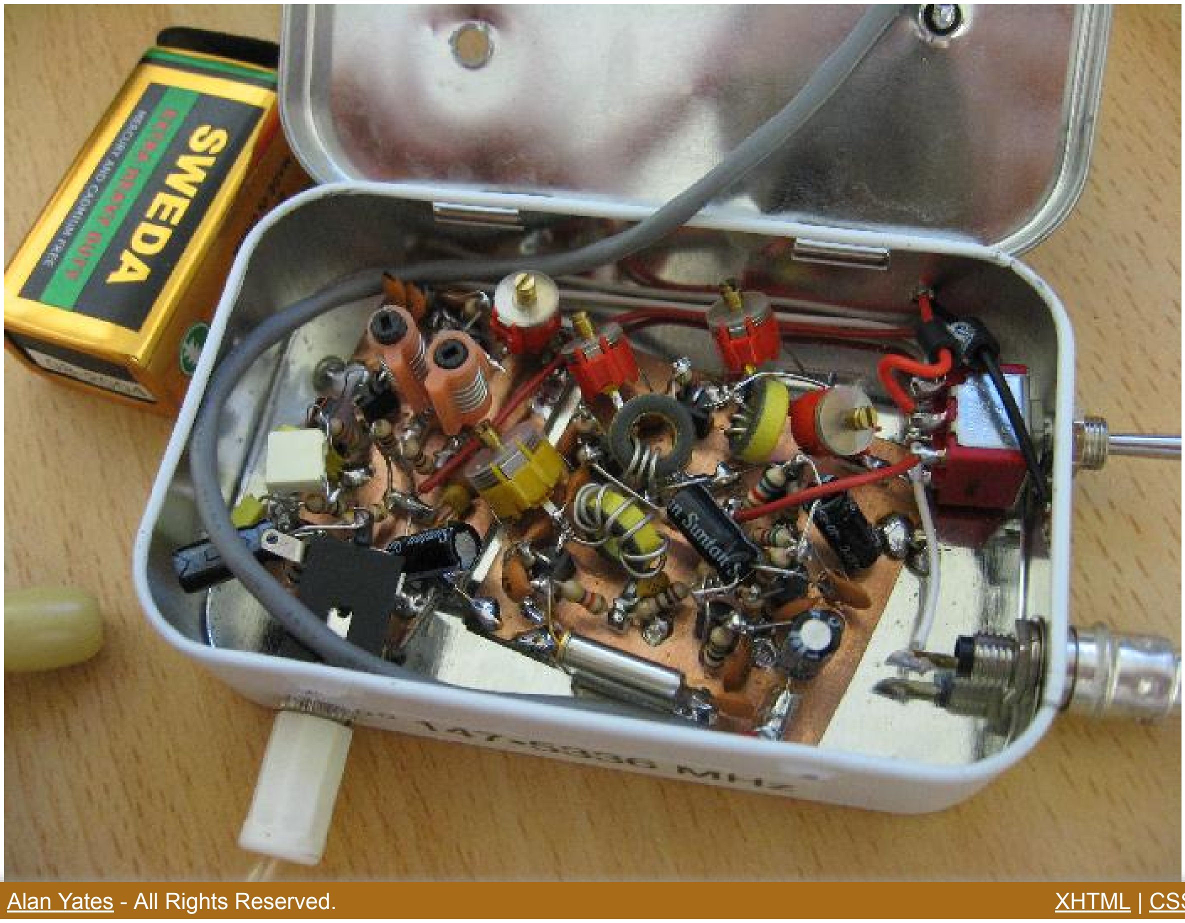

I didn't find my stash of electret microphones, so I ended up just soldering the telephone receiver into the top of the Altoids tin. Ugly as hell, but also kinda unique. It looks somewhat like those Vietnam-war era VHF-low walkie-talkies.

I couldn't find a momentary-one-side toggle switch, so a centre-off on-both-sides switch was used instead. A special dummy load/diode peak-voltage probe was assembled for the final alignment. The carrier power ended up being near 25 mW on 12 Volts, on 9 Volts 10 mW just like Roger says in the article.

Update 2007-06-11

The 2N7000 on 2 metres experiment was a failure, it simply doesn't produce useful power beyond 90 MHz or so. However, it is very usable below 70 MHz. My input network was far from optimal, so perhaps with some more work it would be possible to get it working higher up, and I haven't tried an VN10KM in the same circuit.

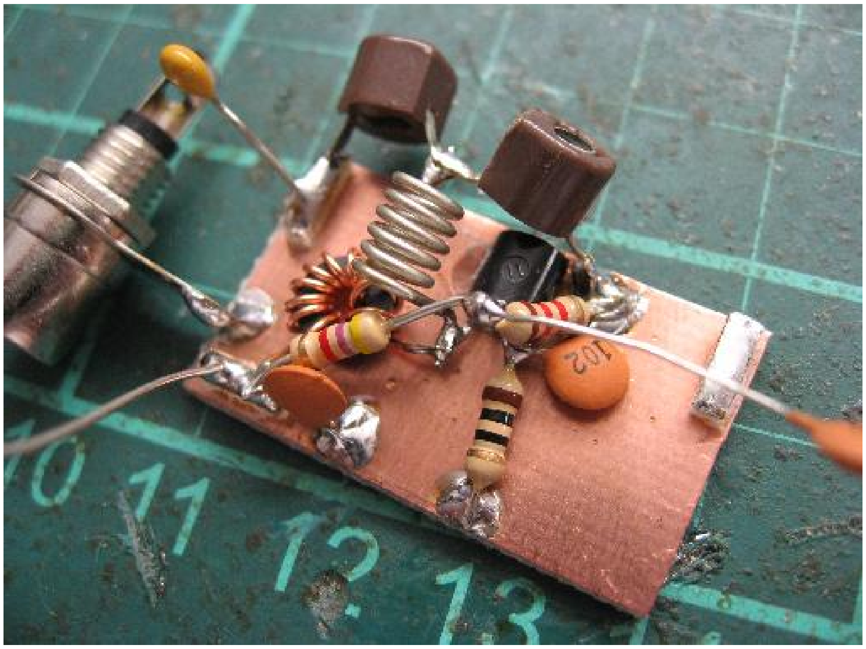

I've also been fiddling around with grounded-base class-C multipliers. (Not just decoupled, biased base, the base actually soldered directly to the ground plane.) At first this seems a little weird, but if you pull the emitter low with a link-coupling to the previous stage collector current will flow. The advantage is excellent reverse isolation, which might help with stability with less than ideal layouts and devices. Such a topology was apparently quite common years ago with the 2N918.

1 comment.

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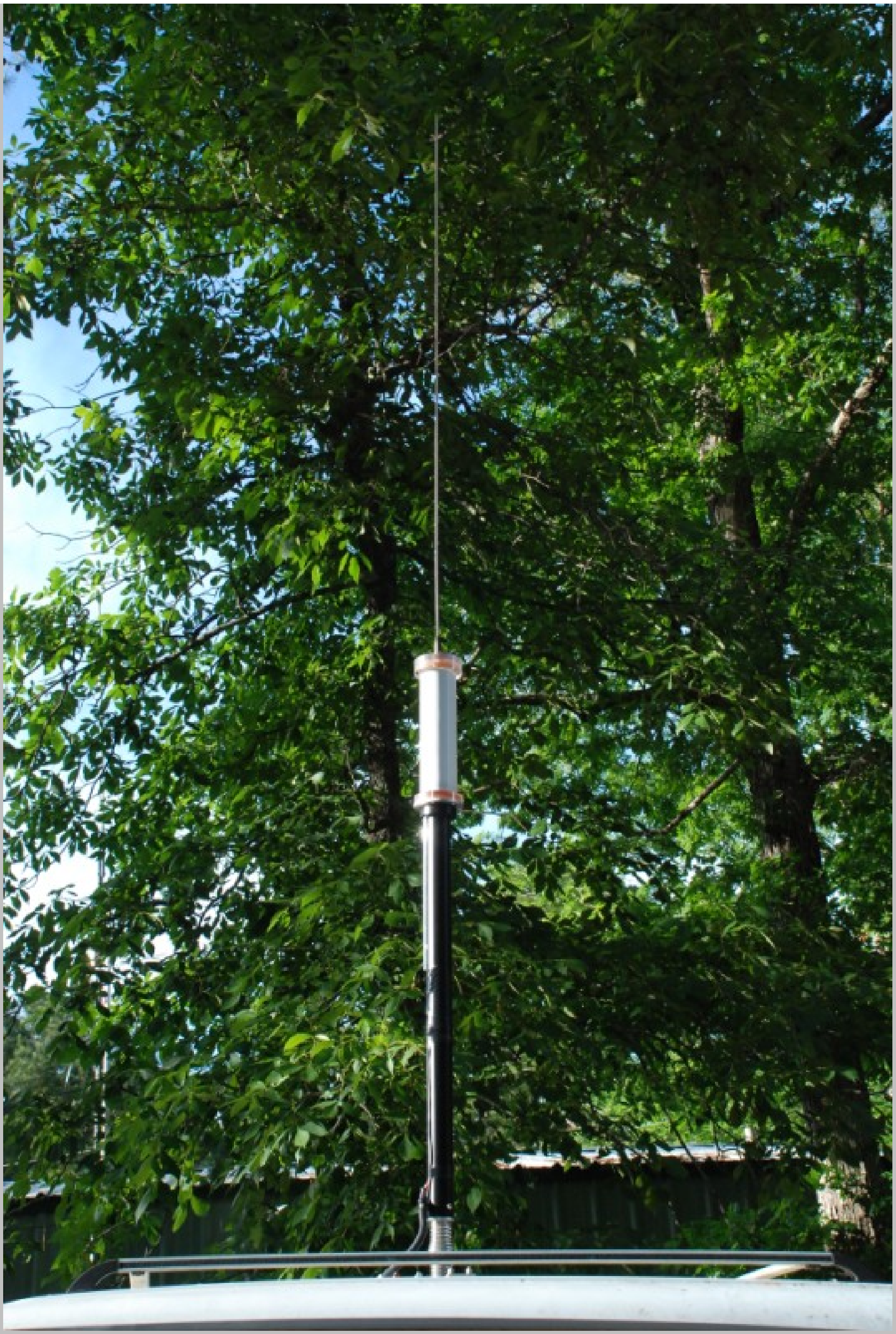

The GS3 antenna installation from the side of the van.

The lower base tube of the GS-series of antennas is made of a heavy gauge 2" diameter aluminum tube for strength and low RF resistance. (All the specifications for the antennas are on Gary's web site.) The loading coil is permanently and securely attached to a metal strengthening ring that is located at the bottom of the loading coil. The top whip that I chose to use with the GS3 is only 55 inches long. I needed to use a relatively short top whip to be able to have enough vertical clearance for obstructions. Ideally, the top whip should be at least a foot longer for better radiation efficiency and lower loading coil losses.

With a top whip this short, the lowest frequency the antenna will tune to is about 3700 kHz, but that is low enough for my use. (I do have a longer top whip that I can install that will allow the antenna to tune down below the bottom of the 80 Meter band.) With the 55 inch whip, the antenna requires about 1 to 2 turns of the loading coil to resonate on 10 meters. But at that frequency, the overall loss is quite low, and the antenna efficiency is fairly high. All things considered, the short top whip is a reasonable compromise for my use. Since the loss resistance of the loading coil is so much lower than the Bandspanner antenna, the overall results are better, plus I have the advantage of an antenna that I can retune on the fly from the drivers seat of the van.

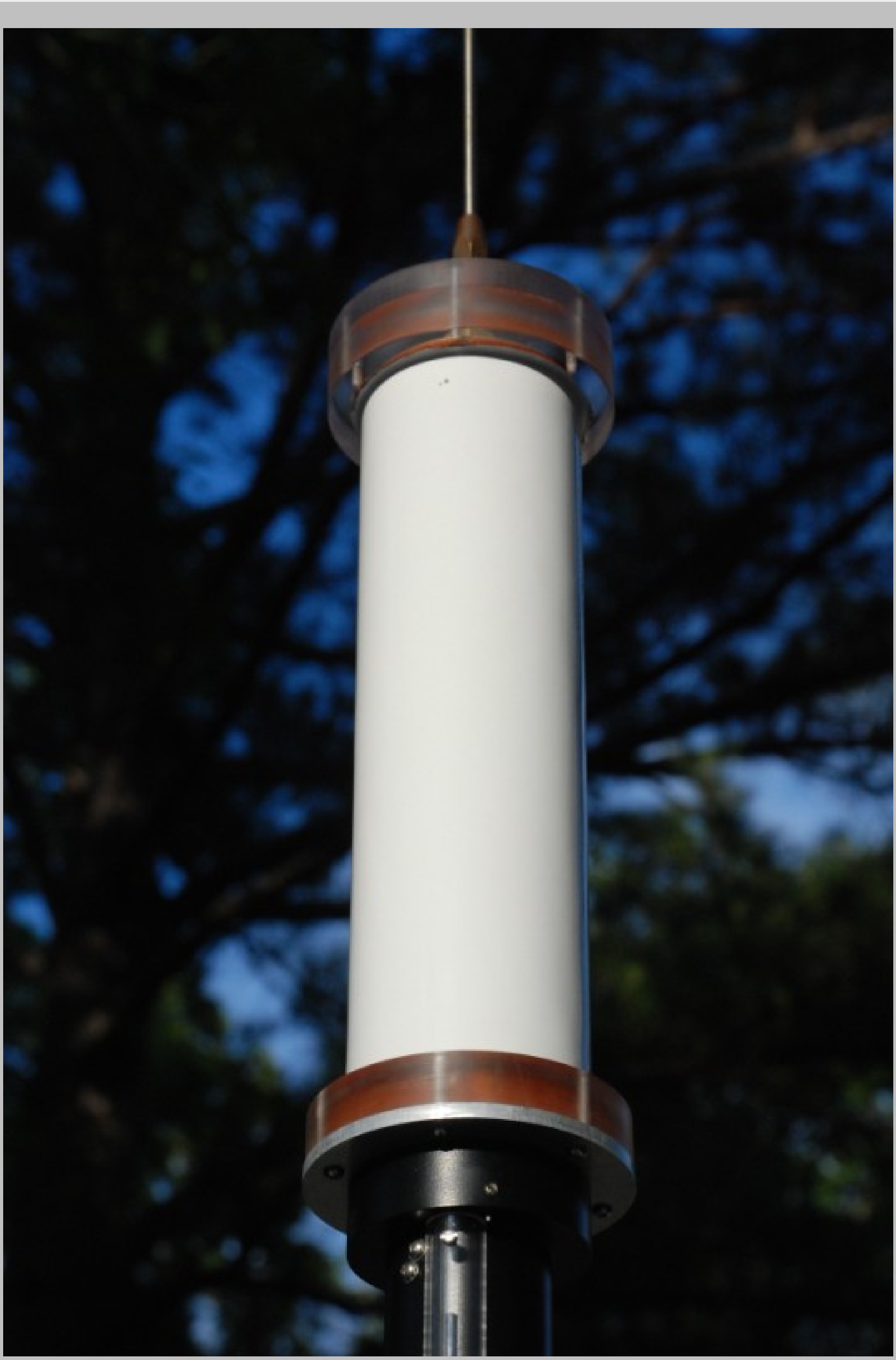

The loading coil of the GS3 antenna.

The GS3 loading coil is a real work of art. The antenna is strong enough to withstand almost any impact. The coil windings are inside the sturdy fiberglass tube, which Gary molds around the loading coil. Plastic end supports are used to eliminate the excessive RF losses that are common to many other screwdriver antennas that use metal end caps on their loading coils. Most of the RF loss in the loading coil will be at the top end of the loading coil, and Gary uses only plastic end caps at that point to minimize the losses. Gary builds his antennas as I build mine - engineering considerations first, for a better signal.

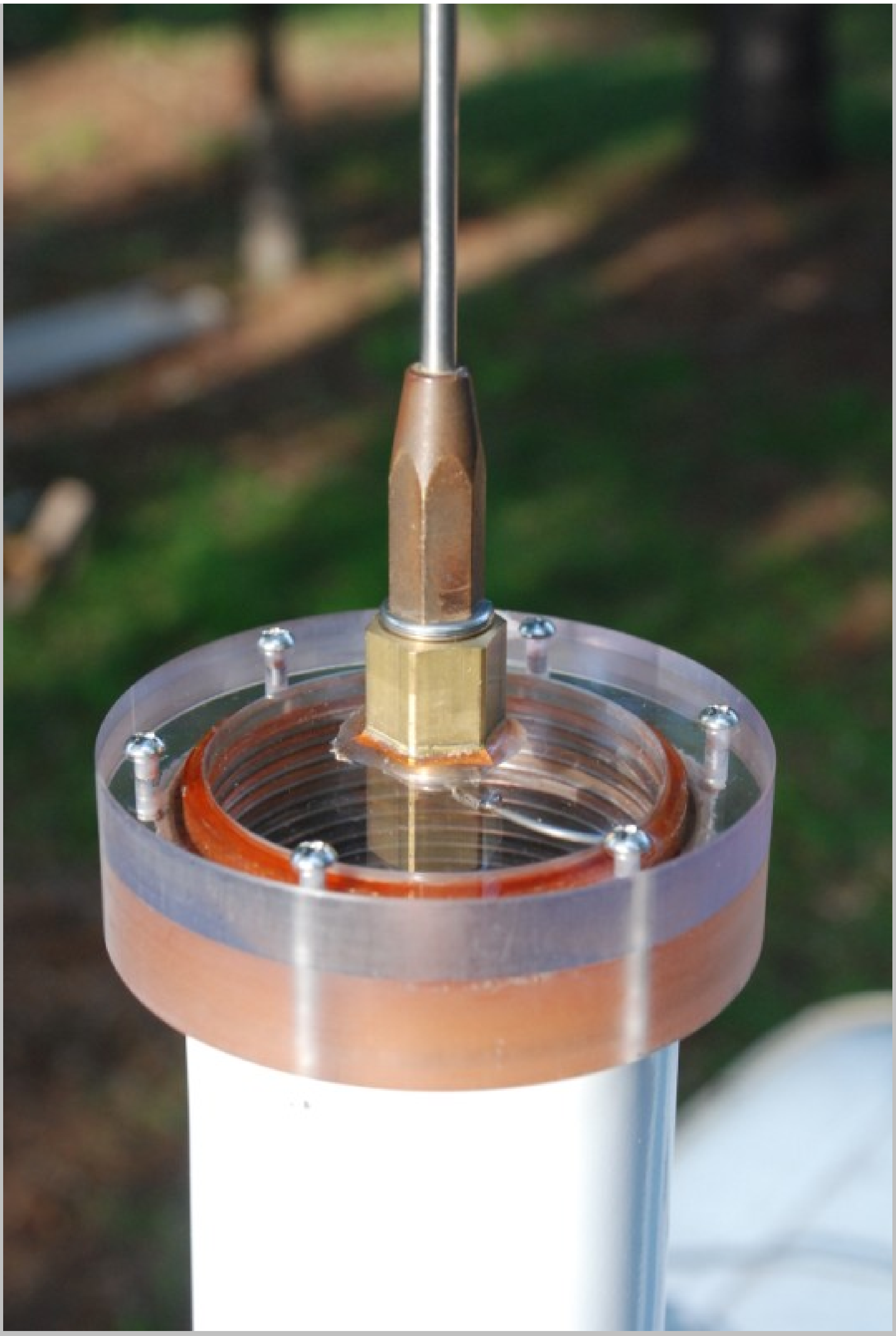

The top of the GS3 loading coil.

The topmost few turns of the 14 gauge wire loading coil can be seen in this picture. The wire is firmly and permanently embedded into the inside of the fiberglass tube. This construction protects the coil and the sliding contacts from deterioration due to the weather. A sturdy 3/8-24 thread brass fitting to accept the top whip is mounted in the center of the upper plastic coil cover. The whip seen here is one is one that I have used with various mobile installations since I had my first 1961 VW bug. It is cut for the 6-meter band, and it has survived at least five different vehicles. The base stud was originally chrome plated brass, while the whip itself is made from what is apparently indestructible 1/4" diameter stainless steel.

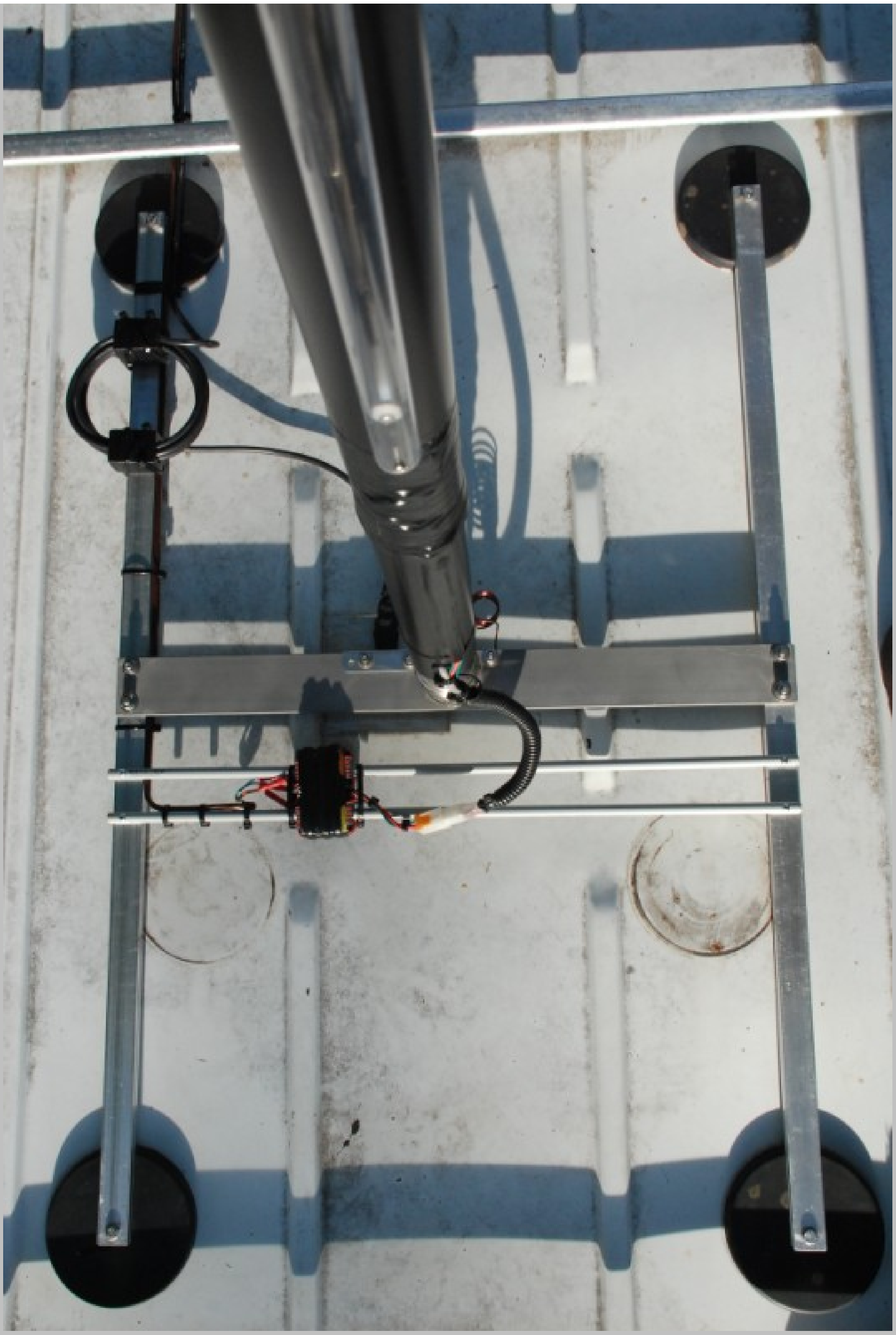

The rooftop magnet mount system as seen from the rear of the van.

In this picture, you are standing on the roof of the van looking down at the wide spaced magnet mount I constructed for this antenna. Engineering-wise, a magnet mount is not what you want to use with a mobile HF antenna. But since I have had very good results using magnet mounts on this van (probably because of the large mass of metal under the antenna) I decided to try it with the GS3 and see how it worked. I figured that if it failed to perform well enough for me, I would just drill a few more holes through the roof and install a permanent mount.

This magnet mount system was modeled after a magnet mount that I originally purchased from the Lakeview antenna company some years ago. The original design used four magnets arranged in a square pattern similar to this one but with a considerably smaller footprint. It always worked very well, and never once in over 50,000 miles of driving did it come loose from the roof. That includes the time when I had a HamStick antenna ripped from the mount when it became snagged in an overhead obstruction.

This magnet mount system uses four magnets, each one measuring 5 inches in diameter. Because the steel sheet roof of the van is fairly thick, the magnets stick extremely well. The metal bars connecting the magnets are each made of two lengths of hard aluminum stock. Each section measures 1 inch wide by 1/4 inch thick by 36 inches long. Because there are two of these strips in each bar, this gives a total thickness of 1/2 inch per bar. Making each bar from two sections of metal instead of one solid bar allows for slightly more flexibility so that as the antenna moves on the mount there is less tendency to detach the magnets from the roof of the vehicle. The horizontal plate that holds the antenna is made from 1/4 inch thick by 2 inch wide by 23 inch long hard aluminum stock. All the bolts and other hardware are stainless steel.

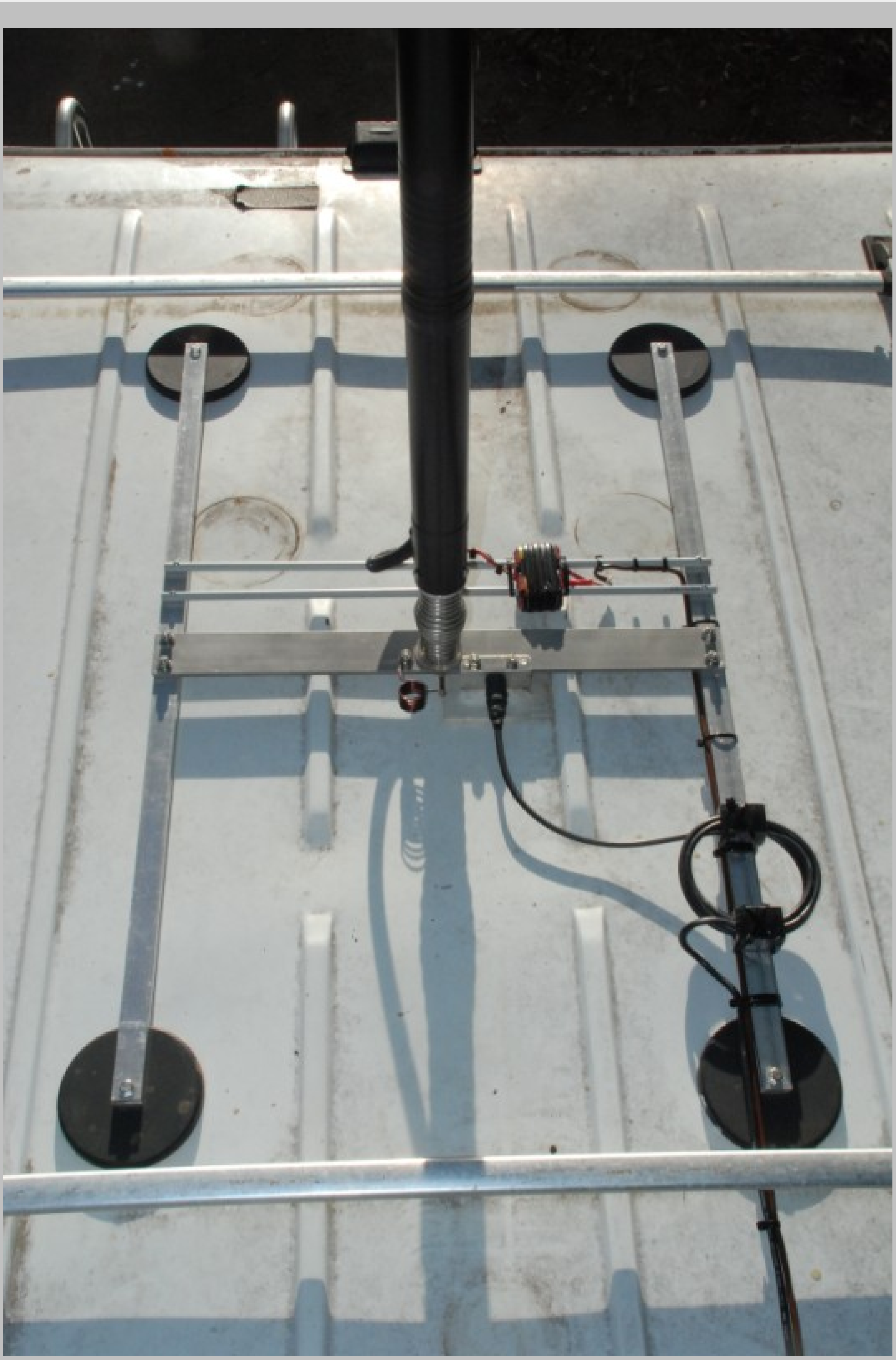

The rooftop magnet mount as seen from the front of the van.

In this view you are standing on the roof of the vehicle looking towards the back. The common mode RF choke for the coaxial feedline cable to the antenna may be seen near the lower right magnet. This is closest to the driver side door.

Slightly above and to the right of the antenna base spring mounted on the two parallel fiberglass support rods are the two common mode RF chokes for the motor power leads and the reed switch wires. Common mode RF is the biggest cause of troubles and tuning problems in HF mobile installations. (See K0BG's article.) You can also see the shunt coil that is mounted at the base of the antenna next to the base spring. This is required to compensate for the capacitive reactance of the short antenna at HF.

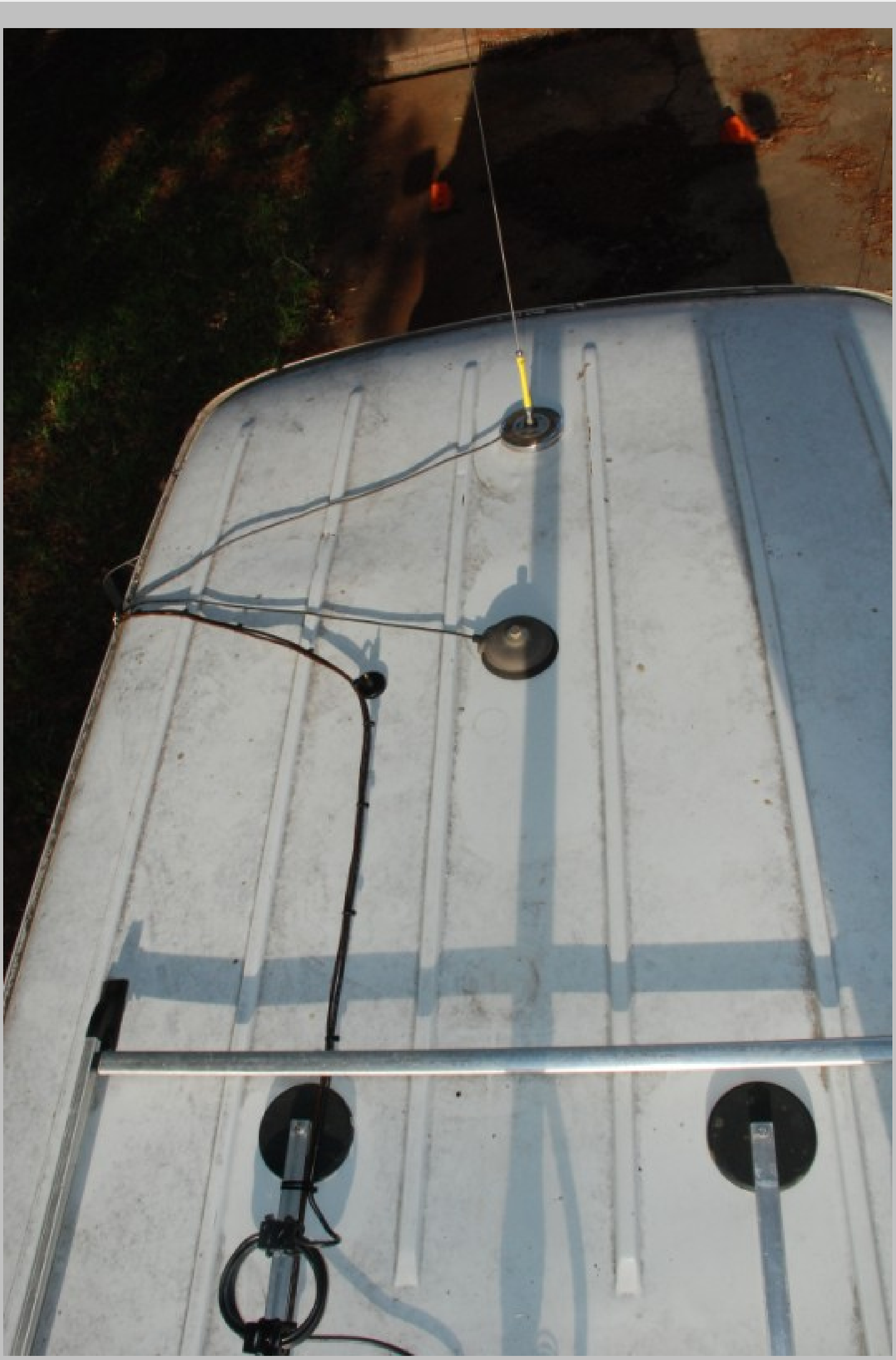

RF coax cable and control wires to inside of van and 6-meter antenna.

Near the front of the van is a quarter wave 6-meter antenna. Unfortunately the 6-meter antenna interacts somewhat with the GS3 antenna on 20 meters. The unwanted interaction occurs because the 6-meter antenna and it's coaxial cable are resonant slightly below the 20 meter band. This interaction affects the reactance of the GS3 antenna causing the SWR across of the

20 meter band to be about 3 to 1. However this isn't a real problem since the auto tuner in the TS-480SAT easily handles that much mismatch.

Below the 6-meter antenna (seen here positioned towards the rear of the vehicle) is another magnet mount. I can install a scanner antenna or a UHF antenna on this mount if needed.

The RF coax and control wires from the GS3 are fastened together with plastic ties. These lines come together with the coax feedlines from the other two antennas where they go over the edge of the roof and down into the passenger compartment of the vehicle. A small but powerful magnet is used to hold the wires for the GS3 antenna in place on the roof of the vehicle.

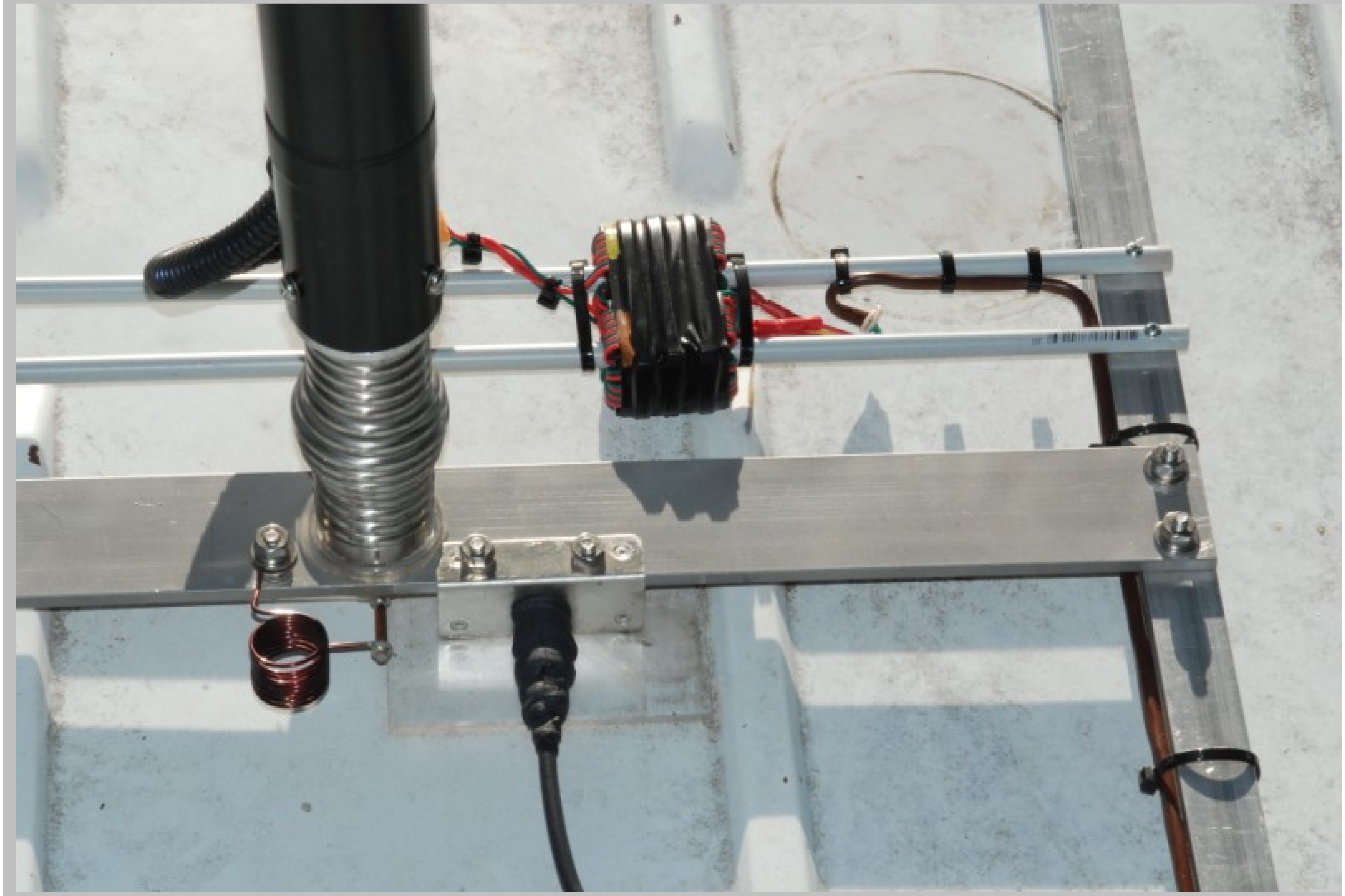

RF feed to base of antenna.

A small metal bracket holds an SO-239 connector for the RF feed going to the antenna. Installing a connector here makes it much easier to remove the antenna and the magnet mount from the roof of the vehicle should it be necessary. There is a small piece of 1/4 inch thick clear plastic placed between the metal bracket and the roof of the vehicle. This prevents the edge of the metal bracket from scraping the paint on the roof of the vehicle as the magnet mount flexes when the vehicle is bouncing up and down on our very bumpy country road.

When the GS3 antenna is used with a pickup truck or a sedan, it is usually attached to a fixed mount. However, I didn't think that was a good idea when the antenna was mounted on the roof of the van. I thought that mounting the antenna on a stiff spring would be a better and safer option. I had unpleasant visions of a firmly mounted antenna encountering a low hanging Oak tree branch! A base spring it would be.

The spring that I chose for mounting the GS3 is Cal-Av model MARK-5. This is a heavy spring, (Cal-Av makes much larger springs) and weighs slightly over 2 pounds. That's much heavier than your Radio Shack antenna spring. It takes a lot of force to bend it, and it works quite well with the rather heavy GS3 antenna. When I am driving, the antenna does not start to tilt back from the wind pressure until I reach a speed of between 45 and 50 m.p.h.. But the MARK-5 is flexible enough to still allow movement when the antenna encounters tree branches and other obstructions.

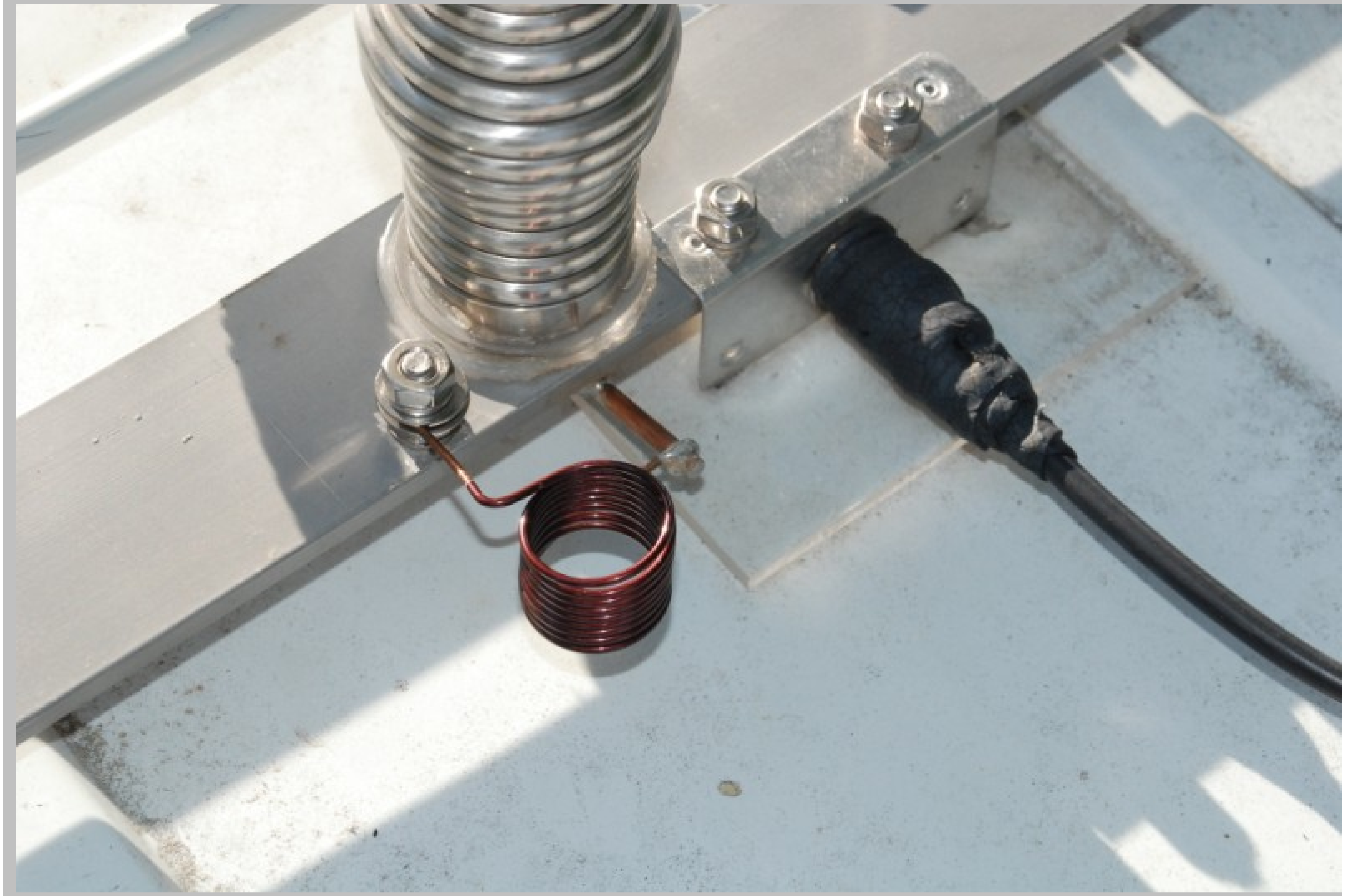

The shunt inductor at the RF feedpoint.

Gary supplies a shunt inductor to use with the GS3 antenna when you purchase his antenna, but Gary's inductor did not have quite enough inductance to properly tune the antenna on 75 meters when it was mounted on the roof of the van. I suspect that is because of the large amount of metal of the van under the antenna makes a better than usual (for a mobile system) ground plane. I made a new shunt inductor a little larger in diameter following the excellent suggestions on K0BG's web page about antenna matching. It worked perfectly, and the antenna tuned up nicely on all bands, 75 through 10 meters. I used my AIM-4170 to sweep the antenna when adjusting the shunt coil.

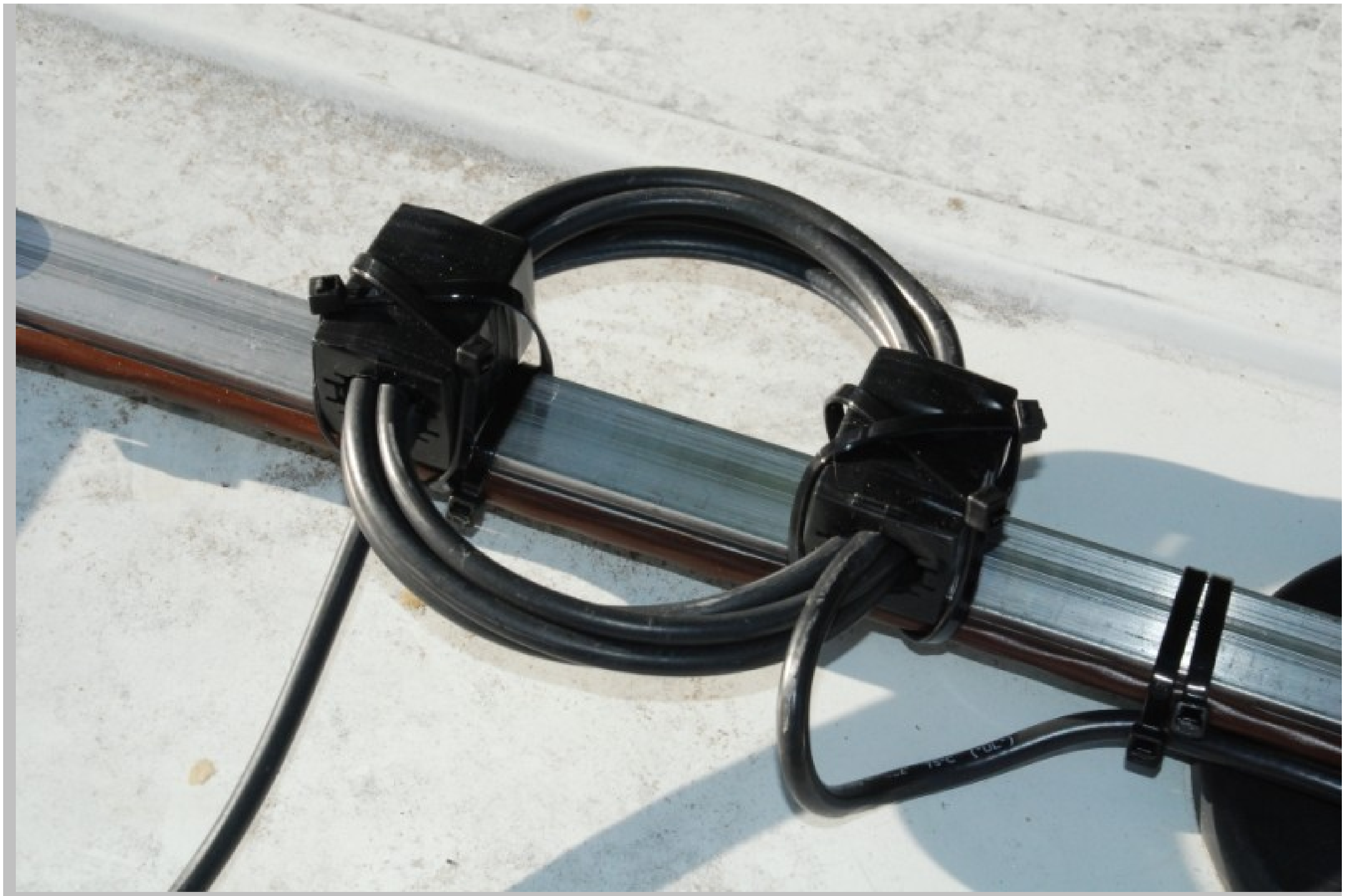

Common mode RF choke for RF coax.

To prevent RF feedback into the gear in the vehicle, it is necessary to use some common mode RF chokes on all the lines from the antenna. For the choke for the RF coax cable, I used two Mix 31 ferrite split beads and ran a total of 6 turns of RG-8X coax through the beads. That provided sufficient impedance to eliminate and problems. The ferrite beads are attached to the magnet mount support bars with plastic ties.

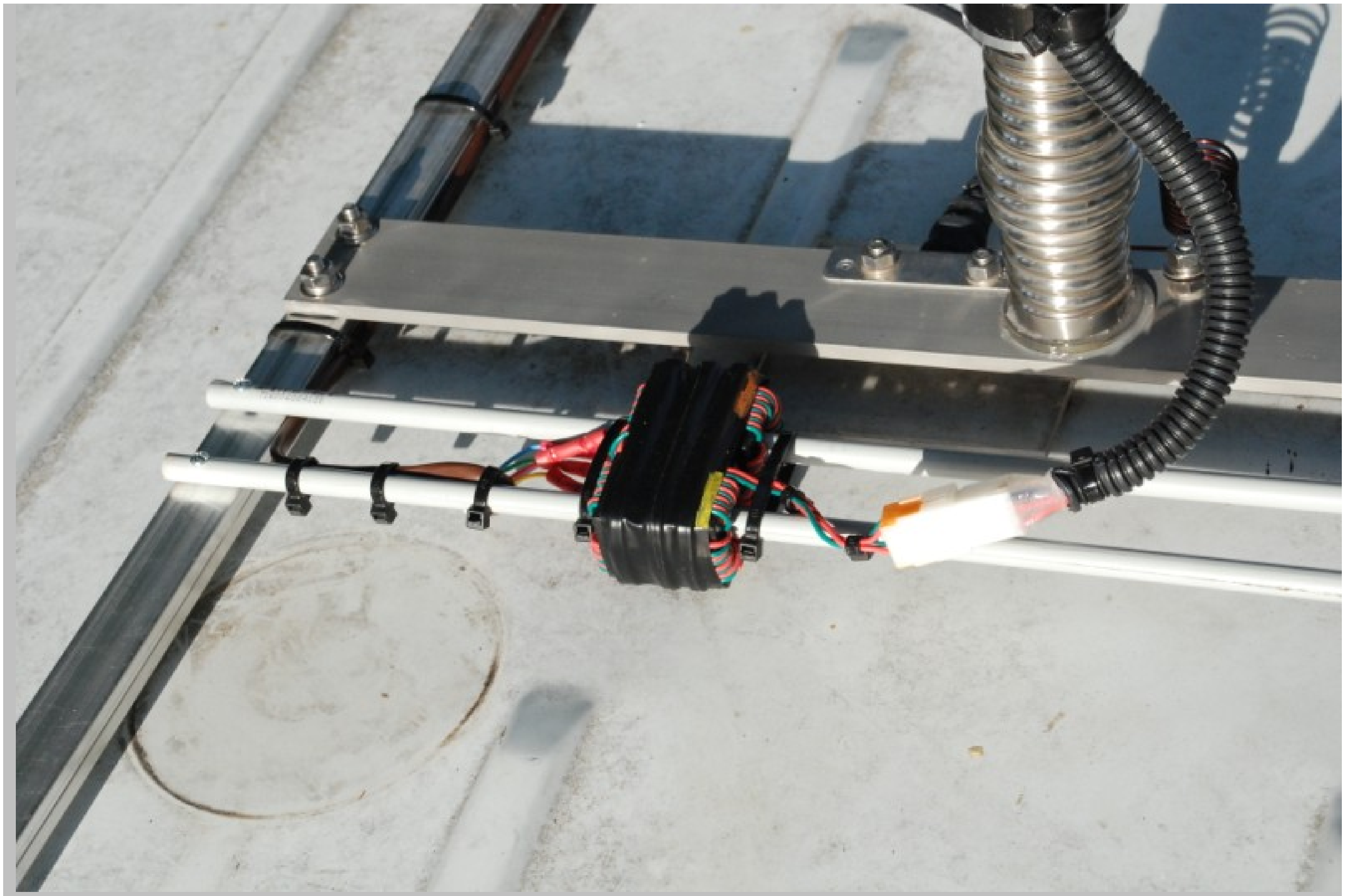

Common Mode RF chokes for motor power wires and reed switch.

I did the same thing with the motor power wires and the wires to the reed switch on the antenna. A single Mix 31 ferrite split bead was enough for each set of wires. There is one choke on the motor wires, and one choke on the reed switch wires. There are 16 bifilar turns of wire on each toroid. They were wound according to the directions on K0BG's web page. Because the wire in these choke coils covers the outside surface of the ferrite beads I did not want to mount these chokes against a metal surface. Instead, I mounted them on two fiberglass rods, one of which passes through the center of each choke. The fiberglass rods are fastened to the aluminum bars with stainless steel hardware. The rods themselves were cut from inexpensive electric fence support posts.

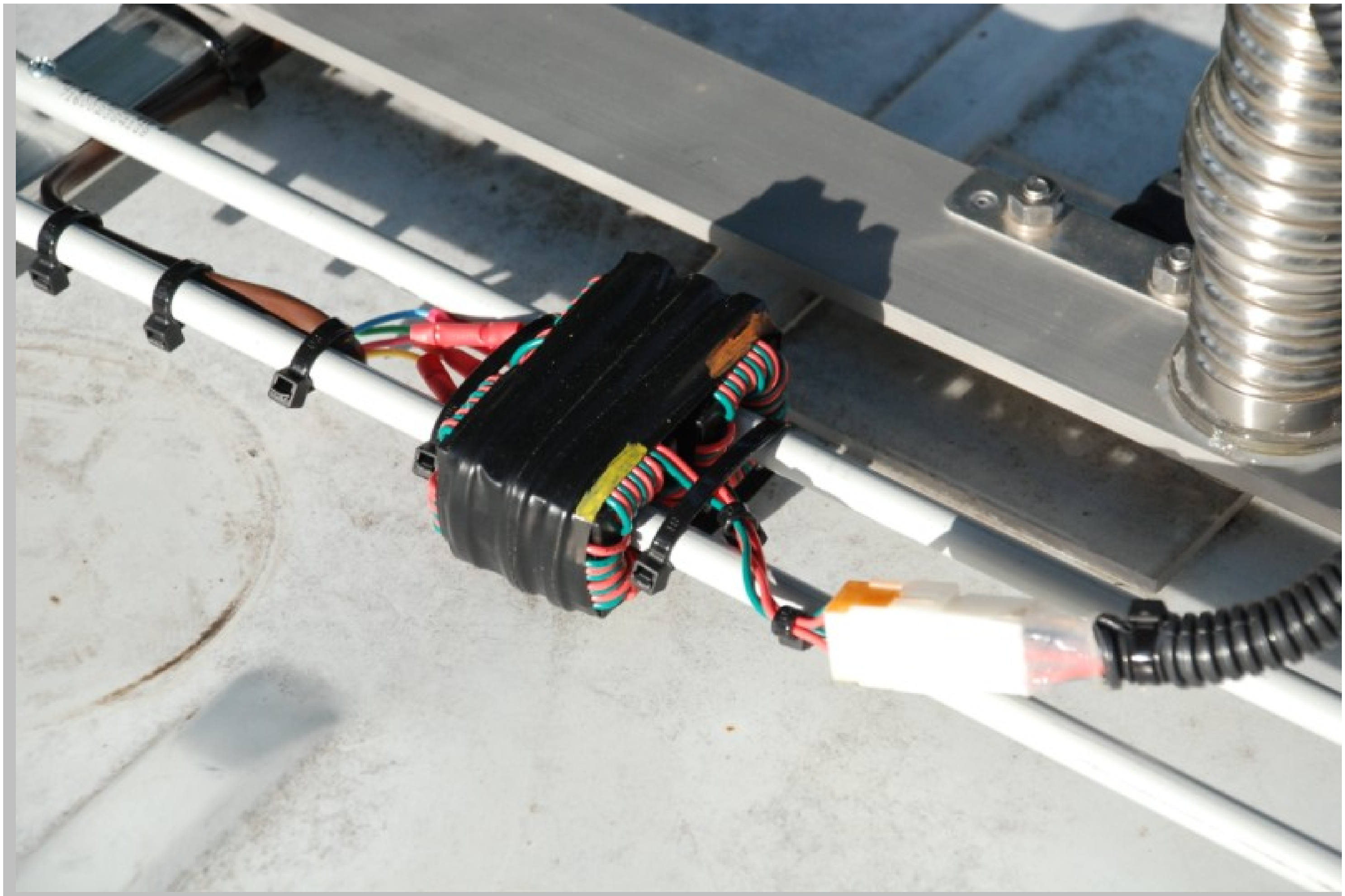

Common Mode RF chokes for motor power wires and reed switch.

The wires from the common mode RF chokes connect to the wires coming from the GS3 antenna through a Molex connector. The connector is sloped slightly downwards. The end of the Molex connector closest to the antenna is the highest end of the connector. That end of the connector is filled with silicone RTV sealer to prevent rain water and moisture from getting into the top of the connector. The bottom end of the Molex connector closest to the chokes is left open. That allows any moisture that does get into the connector to drain out. Although you can't easily see it in this picture, the end of the brown cable from the MFJ antenna controller inside the vehicle connecting to the RF chokes has the top open end of the insulation where the wires exit the cable bent over and pointed down. This is visible as a slight downward bend just past the plastic tie wrap to the left of the wire crimp splices by the RF chokes. This prevents any rainwater from getting into the cable and working its way downward and into the vehicle.

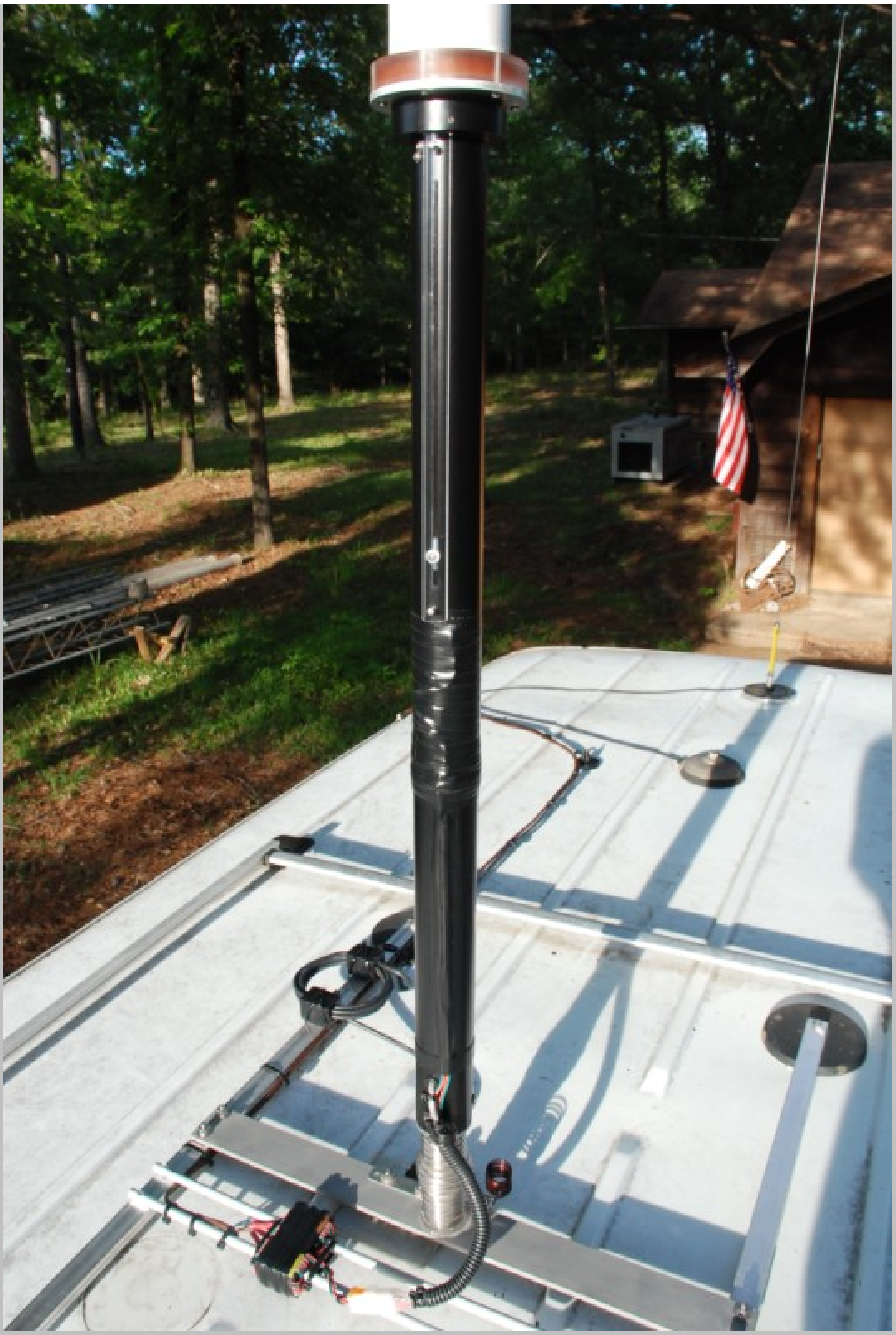

Magnetic reed switch mounting.

The reed switch that connects to the antenna controller is mounted under that mass of tape you see just below the plastic tuning position indicator cover below the loading coil.

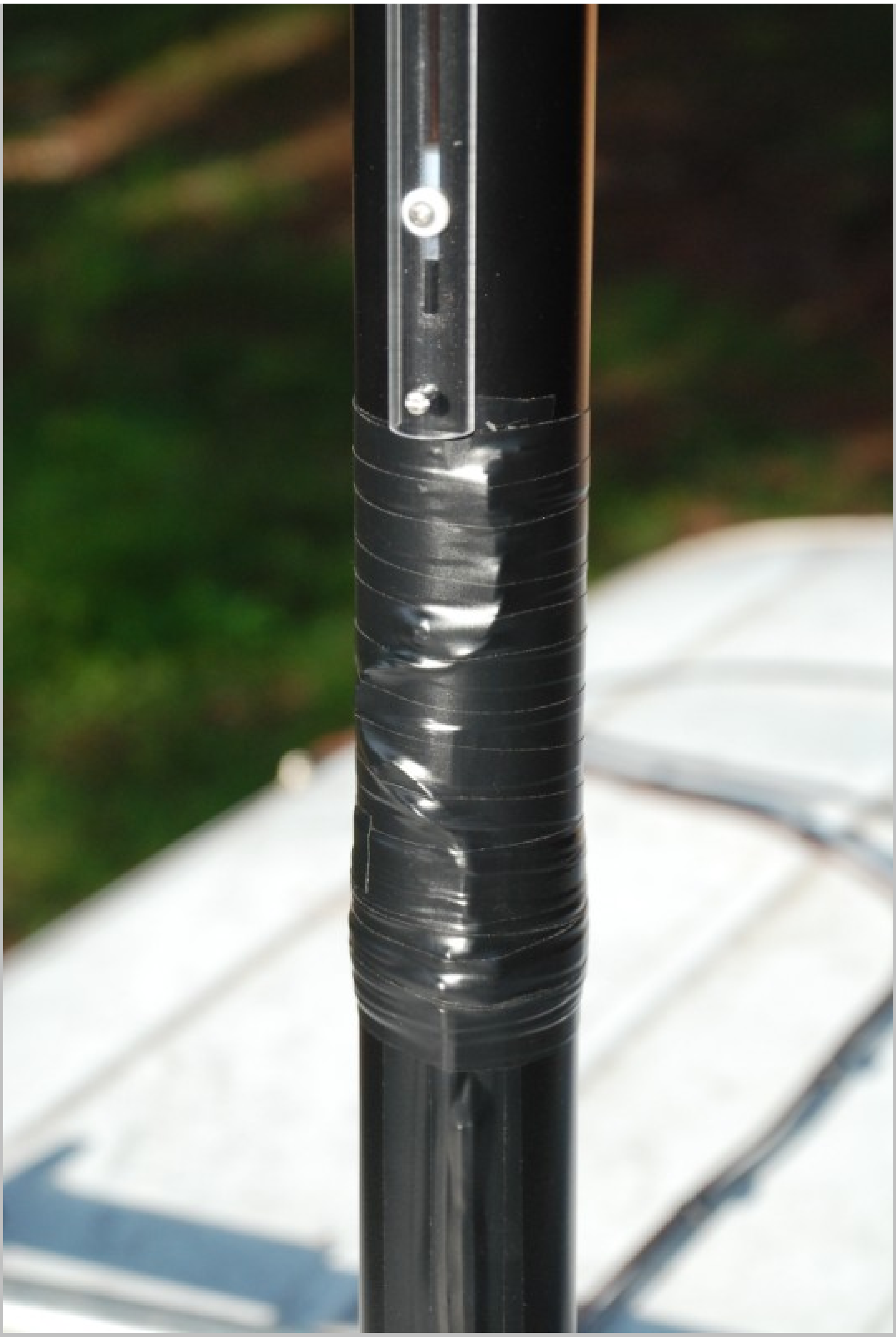

Magnetic reed switch mounting.

It's rather a sloppy looking job, but it does work. Gary does not supply the GS3 antenna with an internal reed switch. However he did mount a magnet on the motor shaft for me, so I was able to attach a reed switch to the outside of the antenna. If nothing else, having the switch on the outside of the antenna makes it easier to change the switch when it eventually fails. There's a lot of extra tape visible on the antenna where the switch is mounted. That's because there are several wire splices and some extra wire under the tape. I tried three different reed switches before I finally found one that worked satisfactorily. The reed switch that I ended up using is a Hamlin reed switch. The manufacturers part number is 5930011766643. Eventually I'll get around to removing the extra tape and straighten out the wiring to improve the appearance.

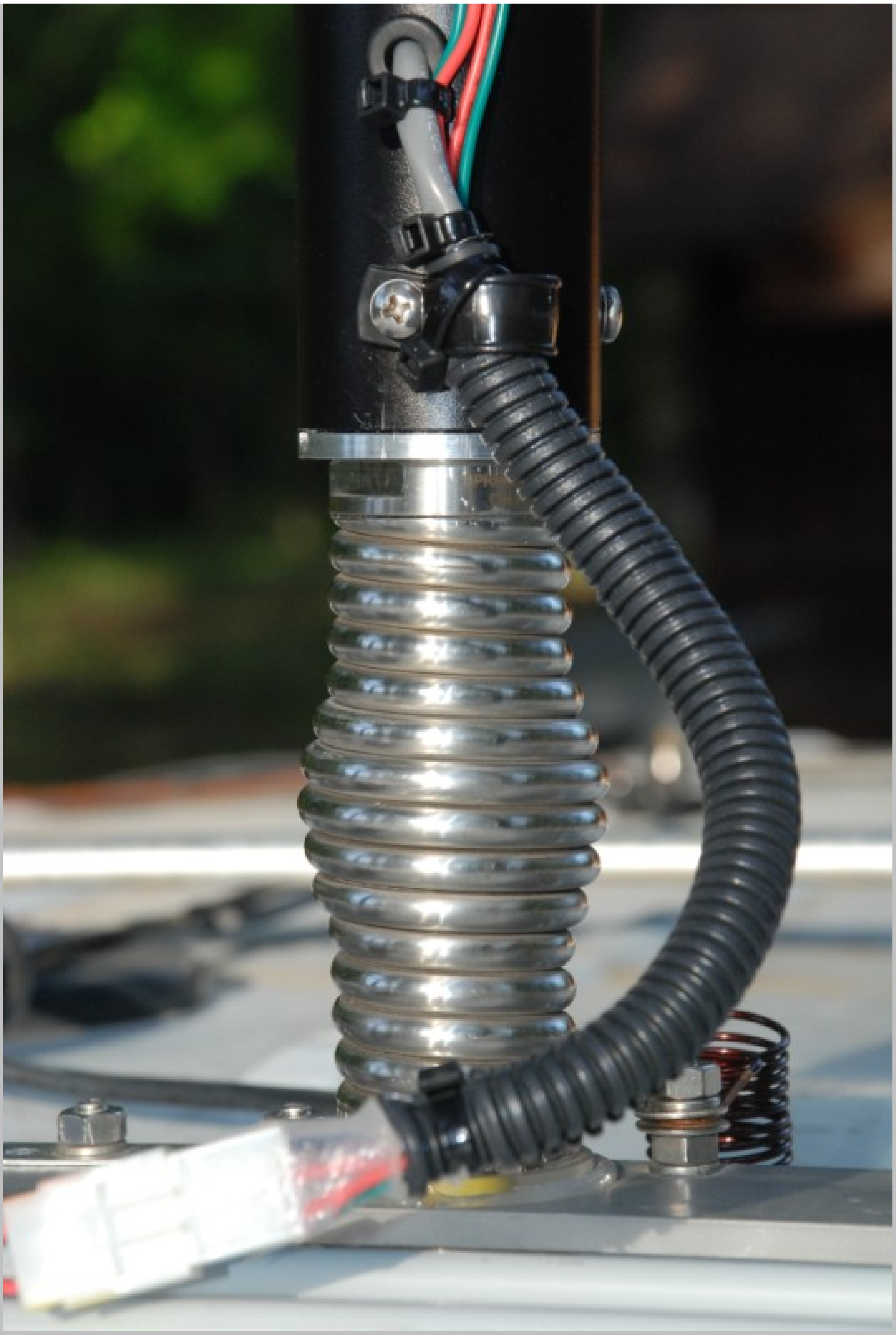

MARK-5 base spring.

This is one tough spring! But it's what this antenna needs because the weight of GS3 without a top whip is about 9 pounds. That's a lot of antenna to have mounted on top of a spring, but the MARK-5 handles it just fine.

I left enough slack in the motor and control wires from the antenna so that no matter what the position or tilt of the antenna is as it moves around on the base spring, the wire will not be flexed excessively. I also covered the wire with some convoluted tubing for additional protection from sun, wind, and weather.

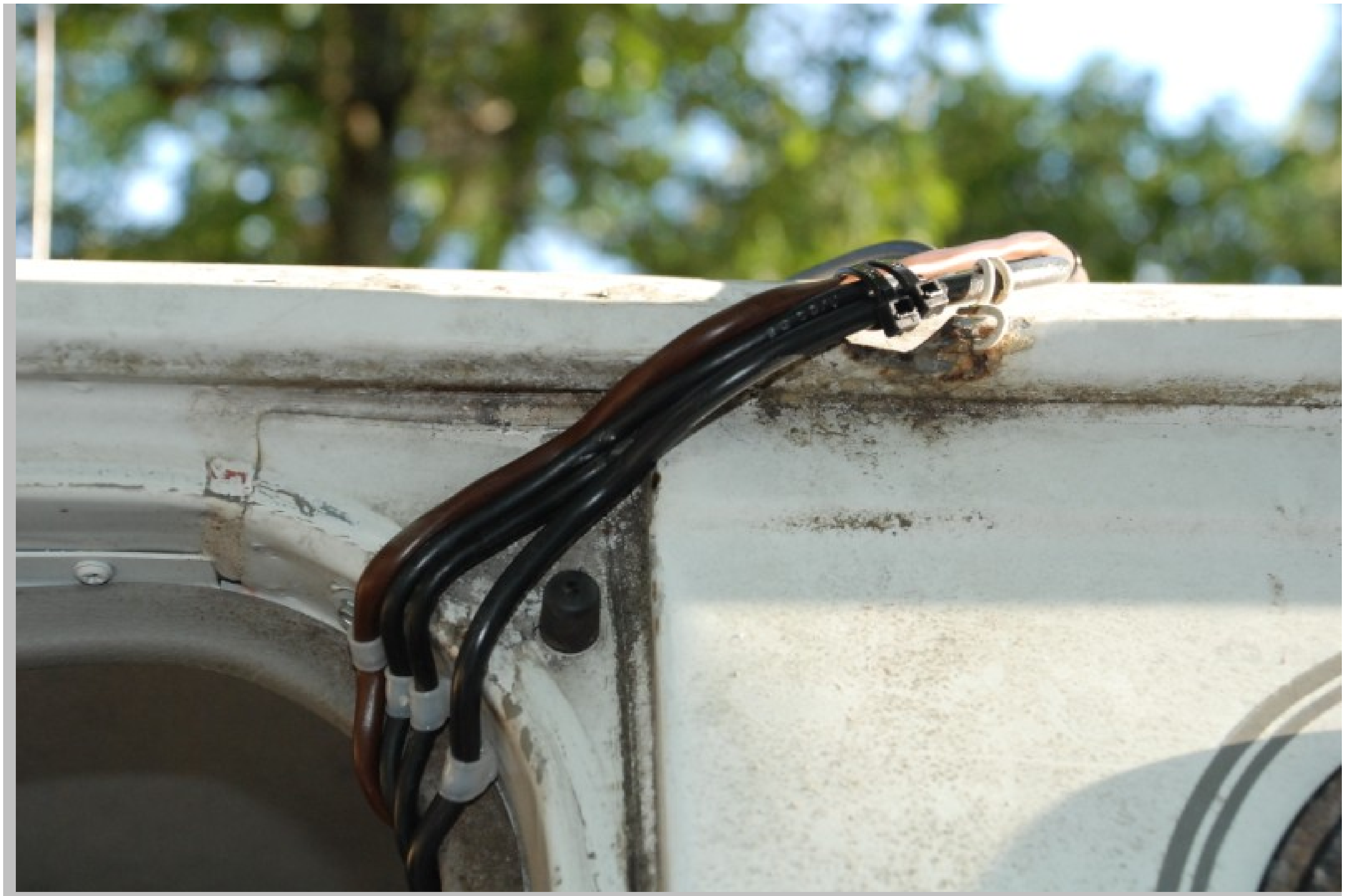

Yeah; I know - it sure needs a good wash job! Well, the van always gets parked in the same direction, and as you know, moss grows on the North side of the tree...

The coax cables from the antennas on the roof of the vehicle and the brown control wire from the GS3 antenna come down from the top of the roof over the rain gutter and into the vehicle through the door seal. What looks like a cut out in the rain gutter is actually placed there by the factory to allow rain water to drain at that spot instead of running down over the door entrance. It made a convenient place to bring the cables over the edge of the roof.

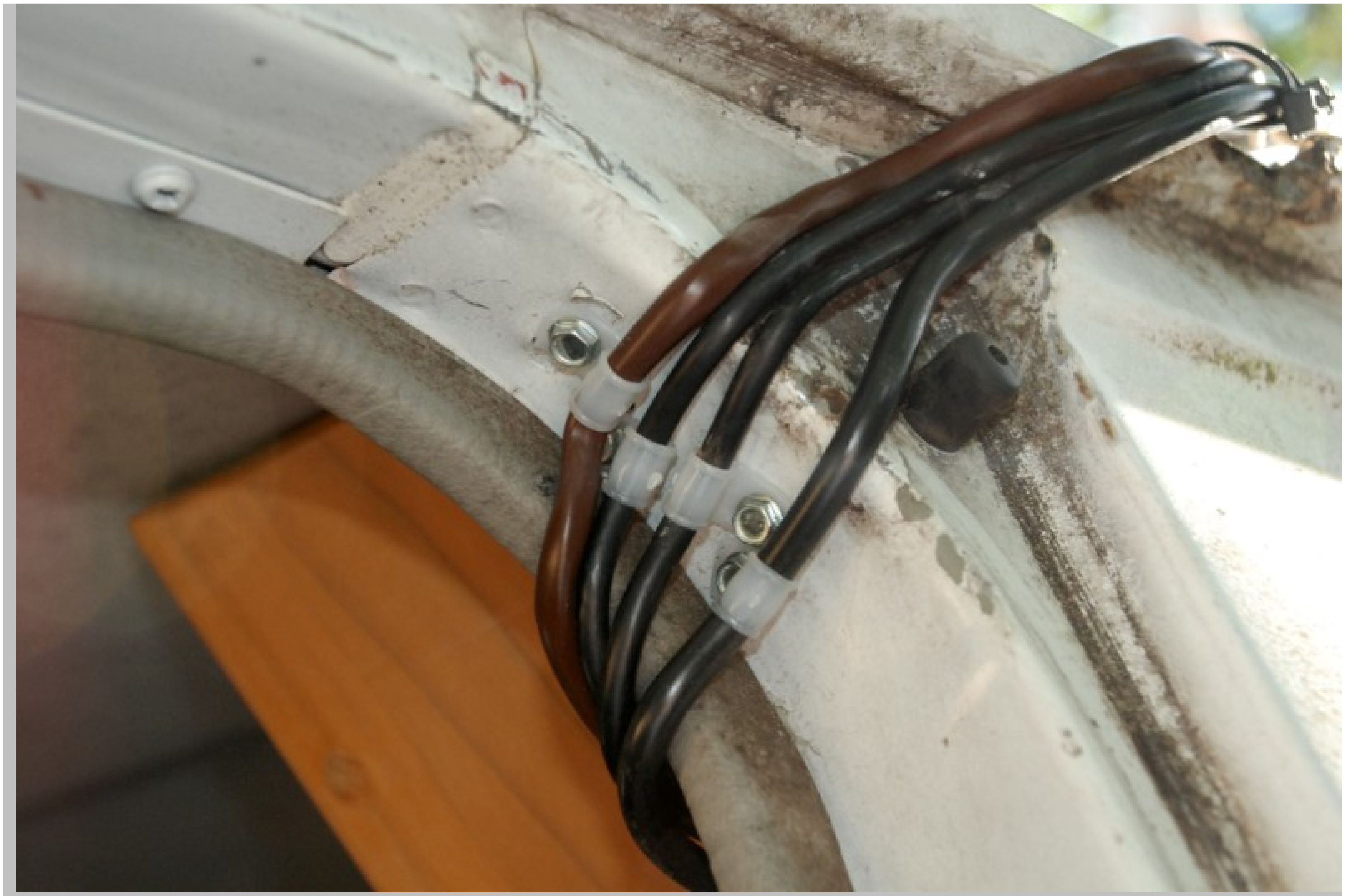

I decided the simplest way to keep the cables in place for the door seal as it closed against the frame was to use some cable ties and self tapping sheet-metal screws. This method keeps a cables firmly in place so that once the door seal has taken a set around the cables I don't get any water leakage into the vehicle.

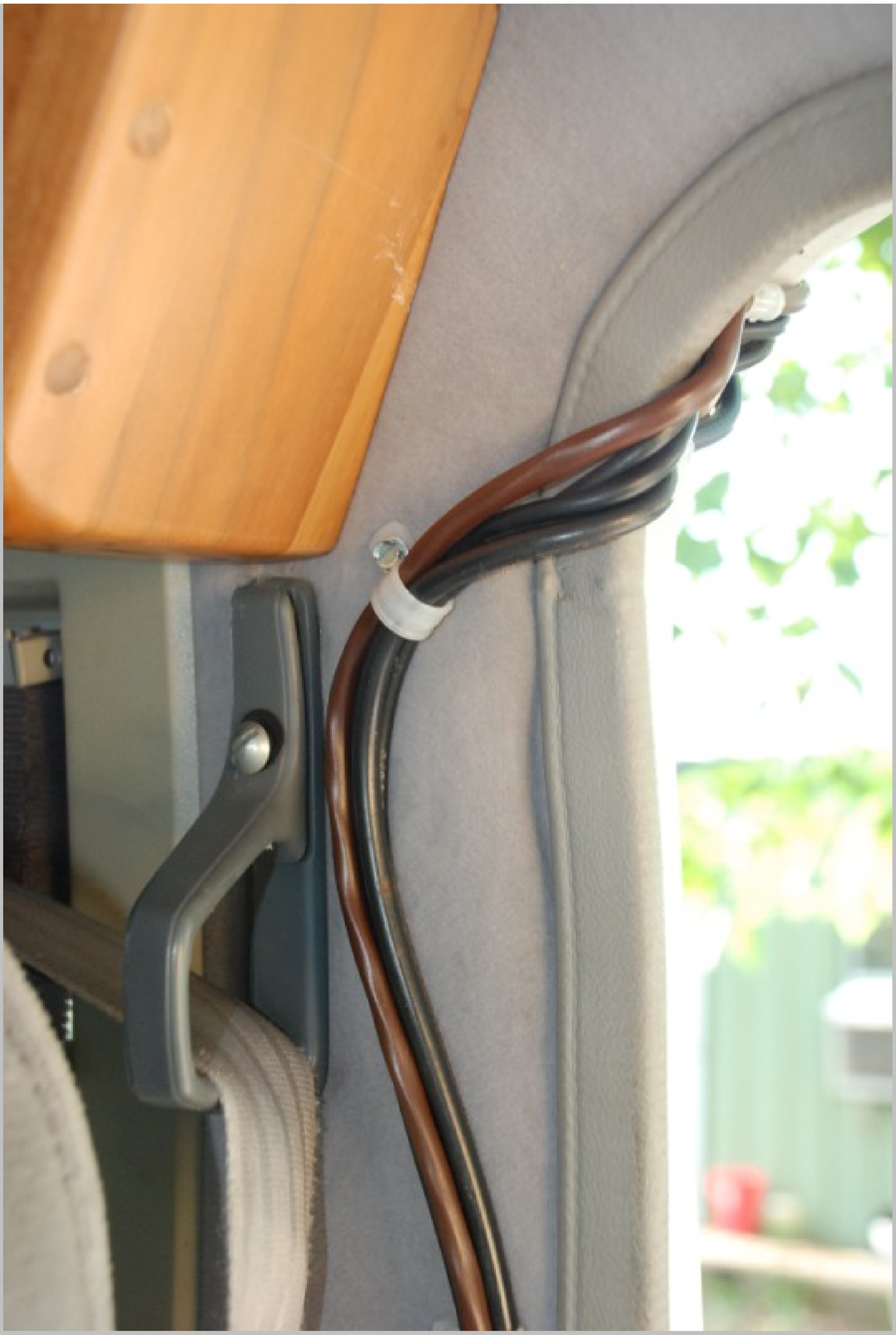

I use another cable clamp to keep the wires tightly against the door frame.

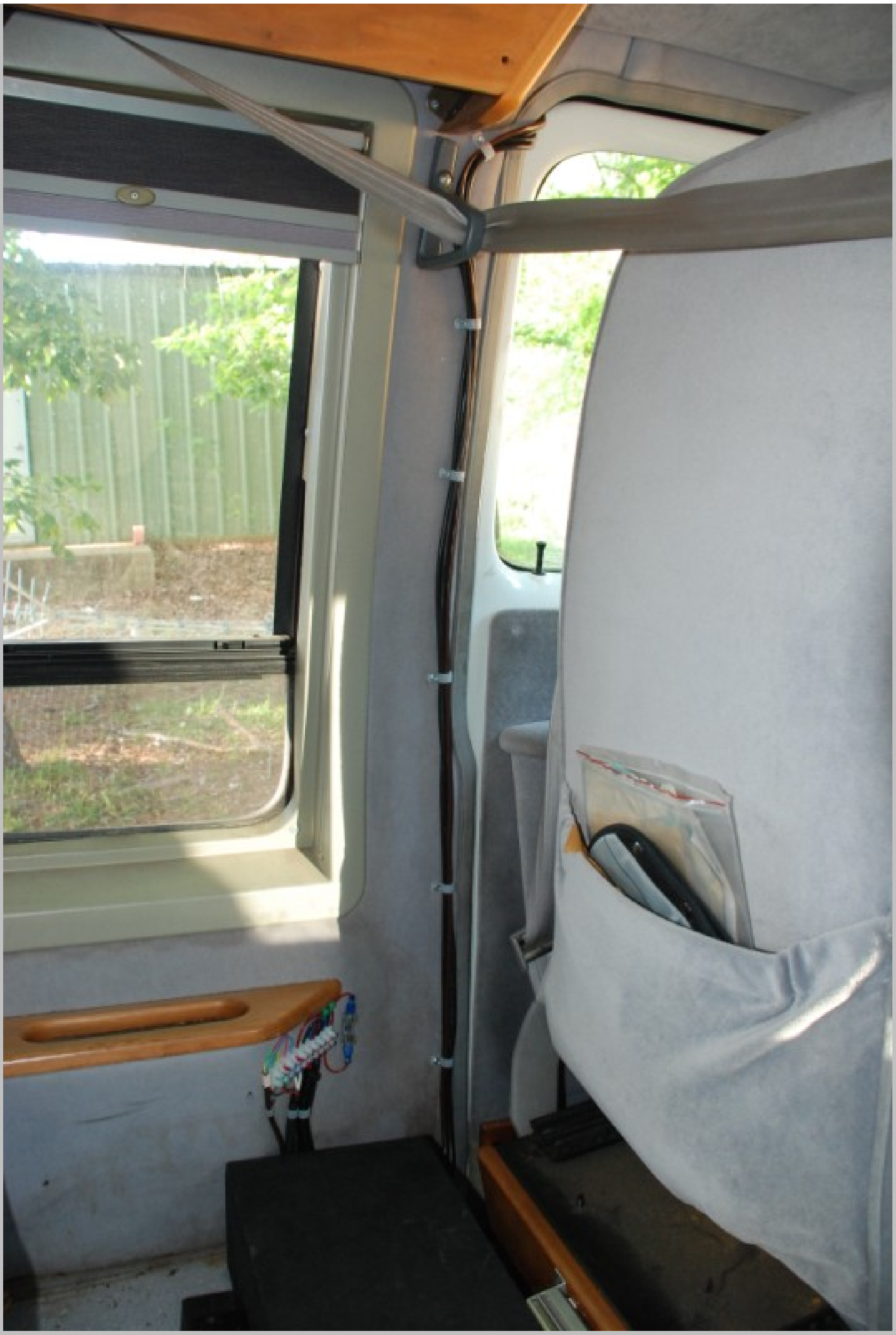

I use more cable clamps to bring all the wires straight down by the edge of the door frame.

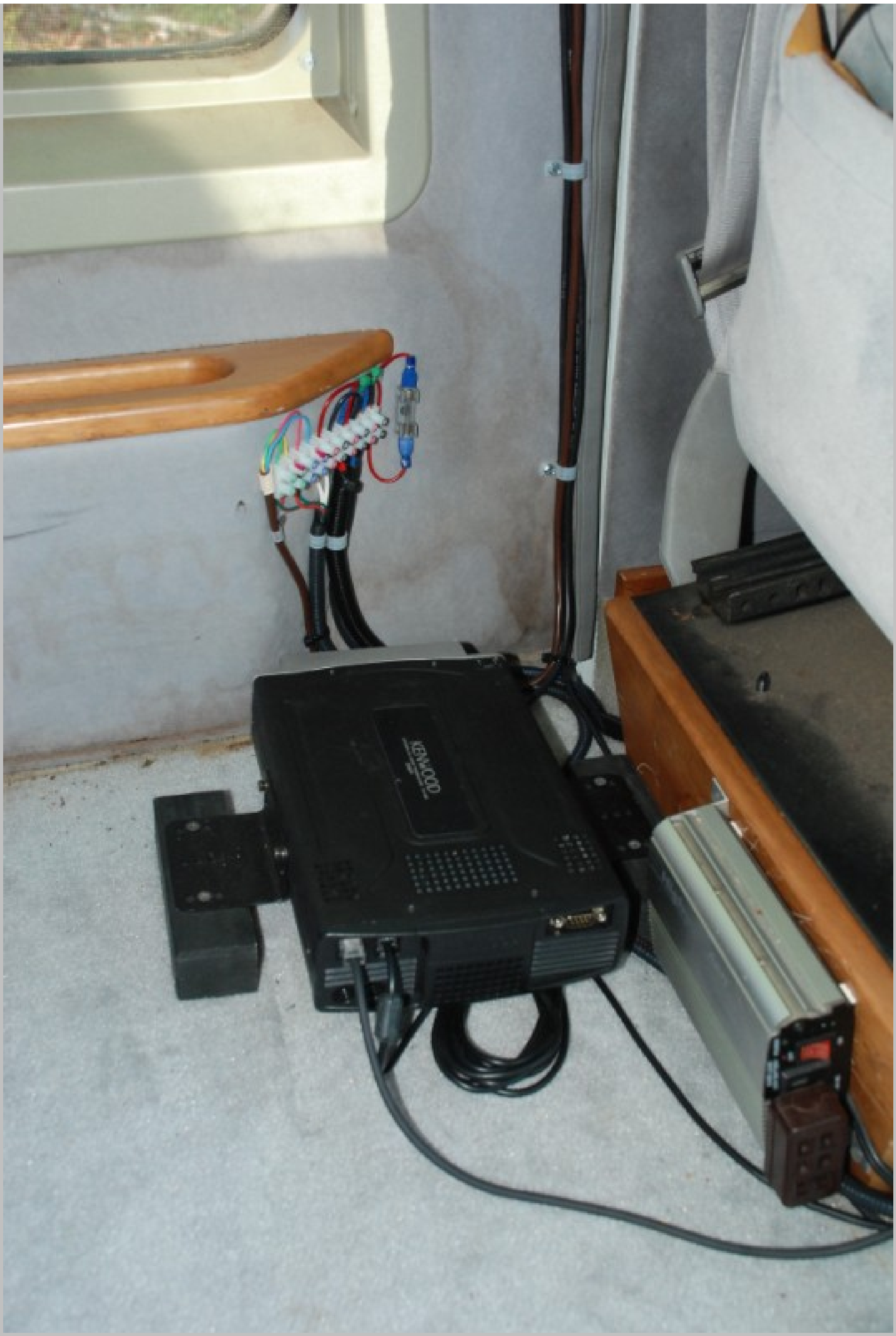

The electronics package is a Kenwood TS-480SAT. It is anchored to the floor behind the driver seat. I used two wooden blocks to elevate the radio slightly from the carpet to allow for plenty of ventilation space. The extra cable length is coiled up and stuffed under the bottom of the radio. A terminal strip is mounted on the wall of the vehicle to provide connections for primary DC power, MFJ controller power, GS3 antenna motor leads, and the antenna reed switch.

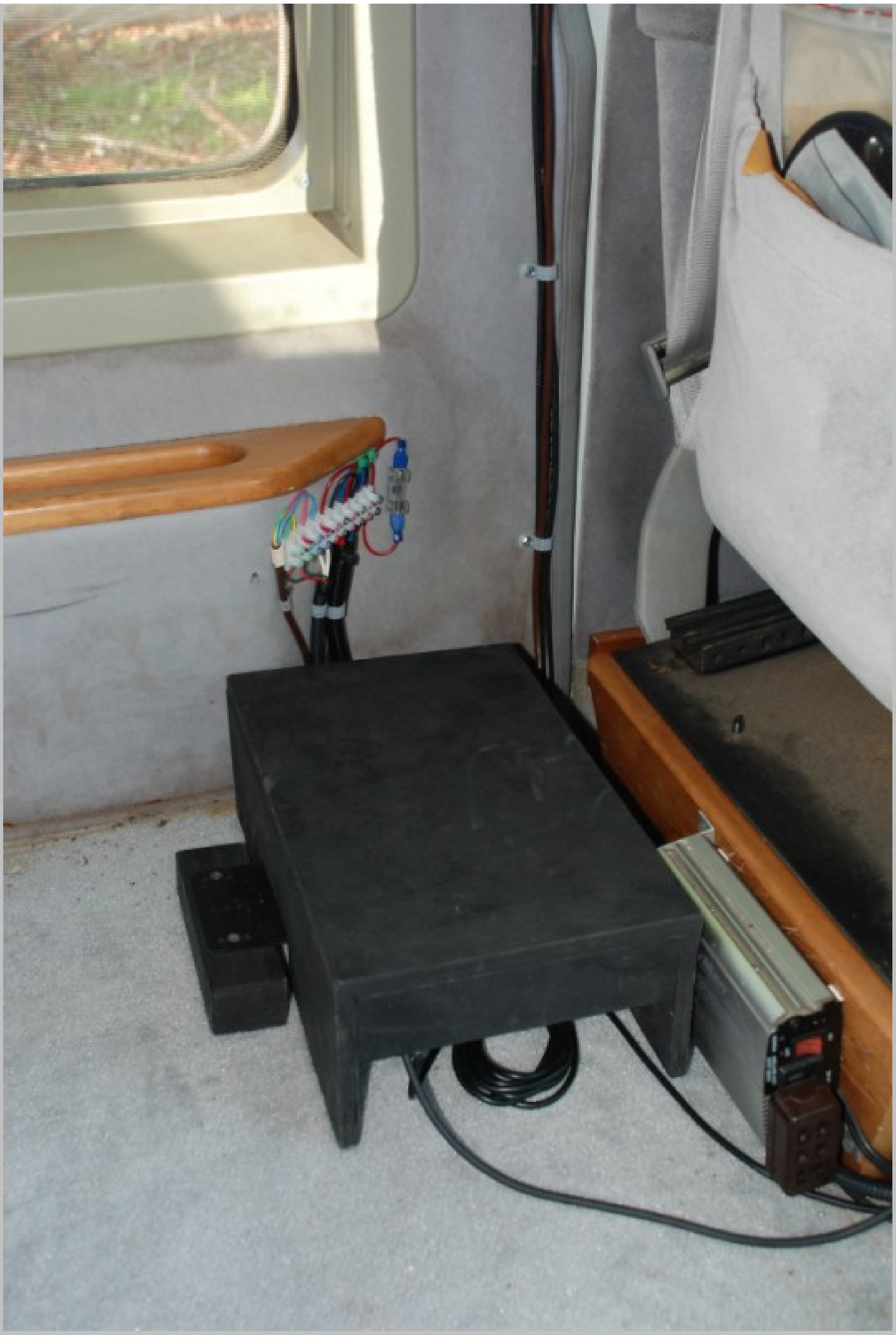

I made a slip over wooden cover and painted it flat black for low visibility. When the cover is placed over the radio, someone looking into the vehicle from outside can't see the radio. The case has plenty of clearance space around the radio for ventilating air to get in and out. The back of the wooden enclosure is open so the cooling fans and the TS-480SAT can exhaust the hot air with no restrictions.

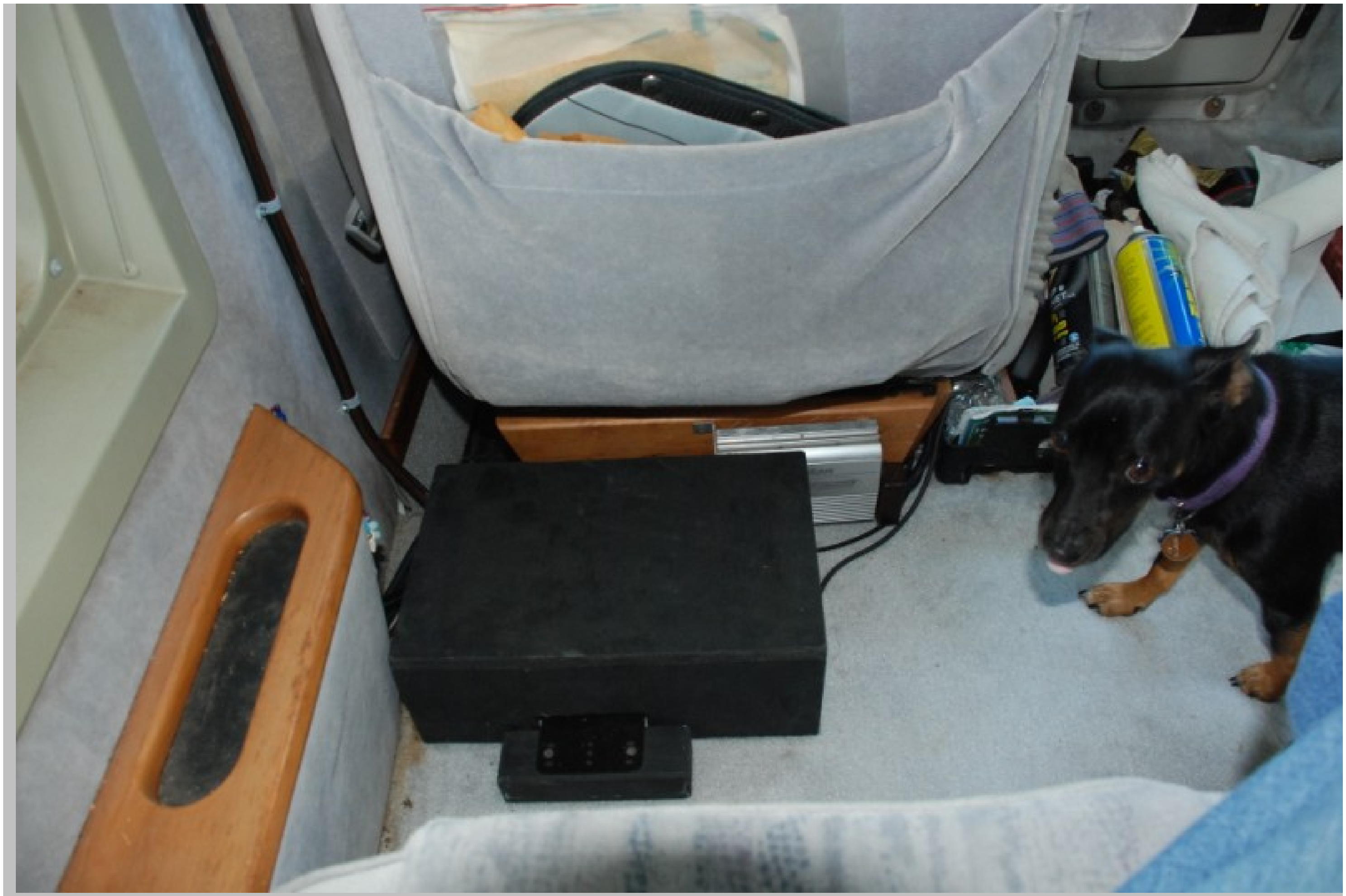

This is the view of the radio installation as seen from the rear passenger seat. (Note that the dog is an optional but self-installing feature of this vehicle.) The enclosure is sturdy enough that passengers can put their feet on the box with no damage.

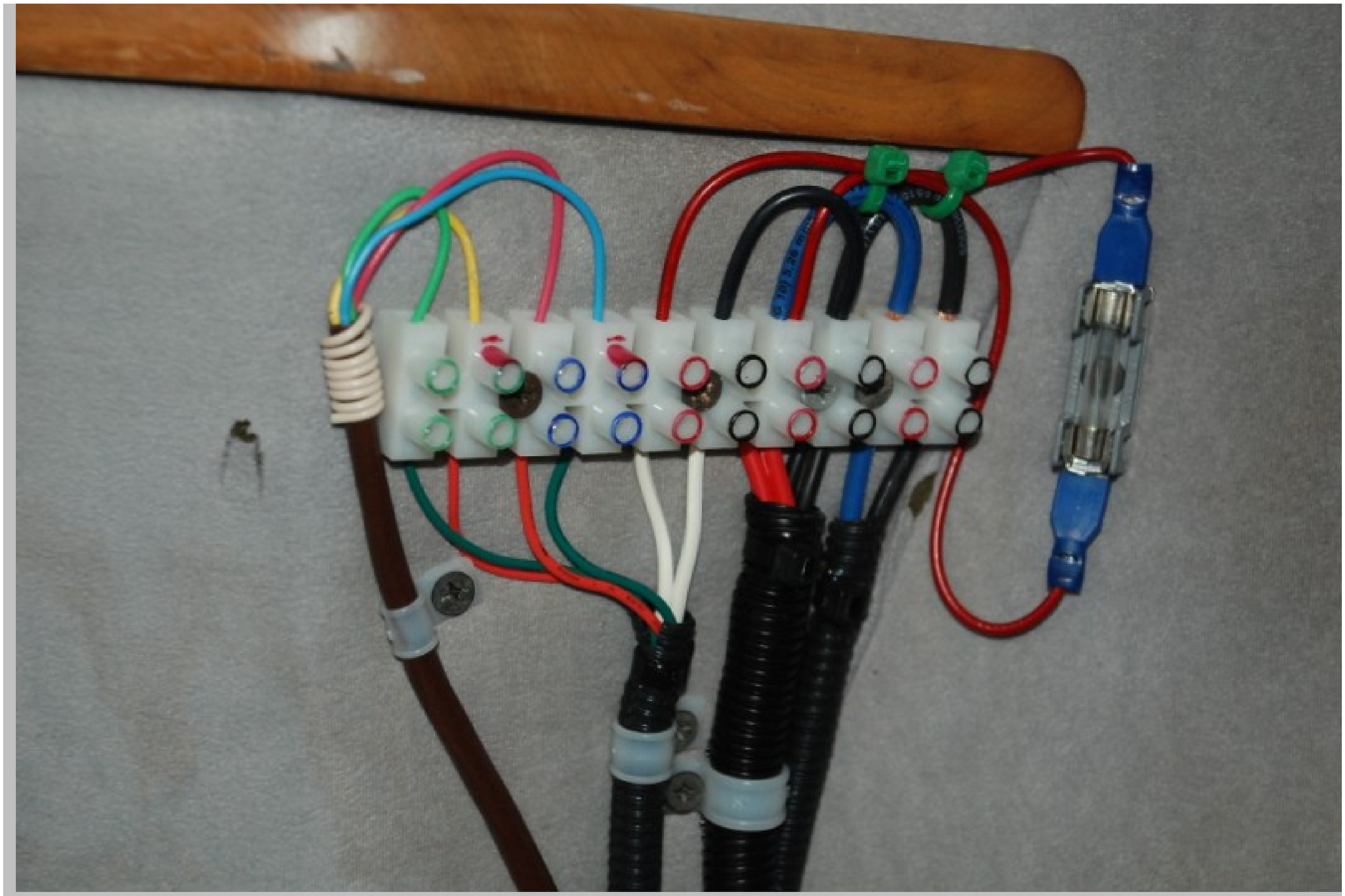

Terminal block connections (by pairs) from left to right: GS3 antenna reed switch, GS3 antenna motor, DC power to the MFJ-1924 antenna controller, DC power to TS-480SAT, fused DC power from vehicle battery. The fuse protects the +12 V DC power line to the antenna controller.

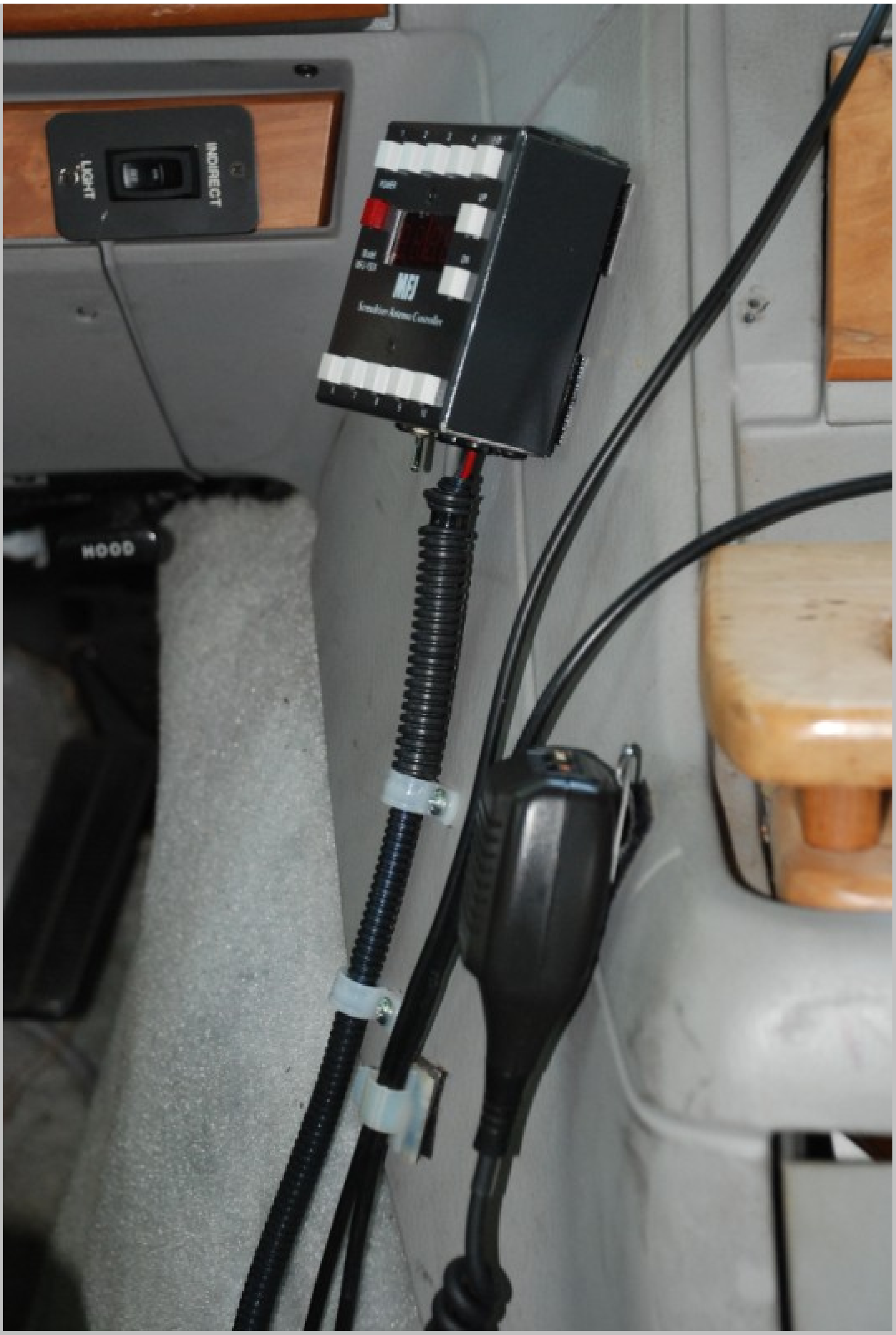

Modified MFJ-1924 Antenna Controller

One of the advantages of a screwdriver antenna is that you can control it from the operators position. The simplest control is simply a double pole double throw switch. Flip the switch one way, the antenna tunes up in frequency, flip the switch the other way, and the antenna tunes down in frequency. This is a simple and reliable method of controlling the antenna, but it has the disadvantage that you don't have any way to tell where the antenna is tuned at any given time. You need some sort of antenna controller for that.

The MFJ-1924 antenna controller is designed to remember 10 specific tuning settings. It does this by counting the number of revolutions that the shaft of the tuning motor makes. In order to do this, the MFJ assumes that there are two things available from the antenna.

The first thing the controller needs is a contact closure of some sort, usually from a reed switch mounted inside the antenna. This tells the controller how many turns the tuning system has made. Note that this does not directly correspond to the number of turns in the coil, but rather how many rotations the tuning shaft has made. It doesn't matter though because the tuning system will make only X number of turns from one end of the tuning range to the other.

The second thing the controller needs is some way to tell when the tuning system has reached the end of its travel range. Most screwdriver antennas simply run the tuning mechanism into mechanical end stops and jams the motor when the end of the tuning range is reached. This stalls the motor and causes the motor drive current to increase dramatically. The MFJ-1924 controller is designed to sense this increase in current. At that point, the controller shuts off power to the antenna tuning motor.

Sometimes, for reasons known only to Murphy, the controller will lose track of how many counts have gone by. For this reason, the MFJ controller has a function which enables you to "bottom" the antenna. This function tunes the antenna to the lowest frequency, stops the drive motor, and then zeroes the turns counter. So far, so good. It looks like the MFJ-1924 antenna controller is just what I need to control the GS3 antenna. Well, it was, almost.

First problem - no reed switch in the GS3 antenna. That one was fairly easily taken care of. Gary had already installed the magnet inside the antenna, so all I had to do was to mount a reed switch on the outside of the antenna, run the wires down the lower mast of the antenna, and then run them through a common mode RF choke.

Second problem - no stalled motor current for the controller to detect. In order to protect the tuning motor in the GS3 antenna Gary builds in a slip clutch arrangement. That means that when the antenna tuning mechanism reaches the end of its travel, the motor will continue to revolve but the tuning mechanism stops moving. Unfortunately for the MFJ antenna controller, this has the disadvantage of not allowing the tuning motor drive current to increase very much above the normal running current. The advantage is that it is impossible to damage the tuning mechanism or burn out the drive motor by running it into the end stops. I found that I was unable to get the MFJ controller to sense the end of travel of the tuning mechanism. I even went as far as to dig into the MFJ's internal circuitry and increase the sensitivity of the drive current detection circuit, but in the end, I found that there just wasn't enough difference in normal tuning and end of travel motor current to make the controller work reliably.

The solution ended up being a combination of electronics and brain power. I made a slight modification to the controller. Now, when I need to reset the controller and "bottom" the antenna and zero the counter, I place the MFJ controller in its counter reset mode. This starts tuning the antenna to the lowest frequency position. Meanwhile, I sit quietly and listen until I hear the "thunk-thunk-thunk" of the drive mechanism slipping when it reaches the lower end of the tuning range. Since the antenna is mounted on the metal roof, the sound is quite audible. At that point I press the little Magic Button on the bottom of the controller.

I drilled a small hole in the bottom of the controller case and installed a normally open push-button switch. I have the switch button protruding just slightly out of the hole so it can't be pressed accidentally. The switch is connected in series with a 50 ohm resistor. The resistor and switch were then wired directly across the tuning motor wires coming from the antenna controller. When the button is pushed, current flows through the resistor from the output of the MFJ controller. This extra current is added to the current being drawn by the tuning motor. This makes the MFJ controller "think" the motor has reached the end stop and has stalled. This tells the MFJ controller to turn off the power to the tuning motor and reset the counter to zero.

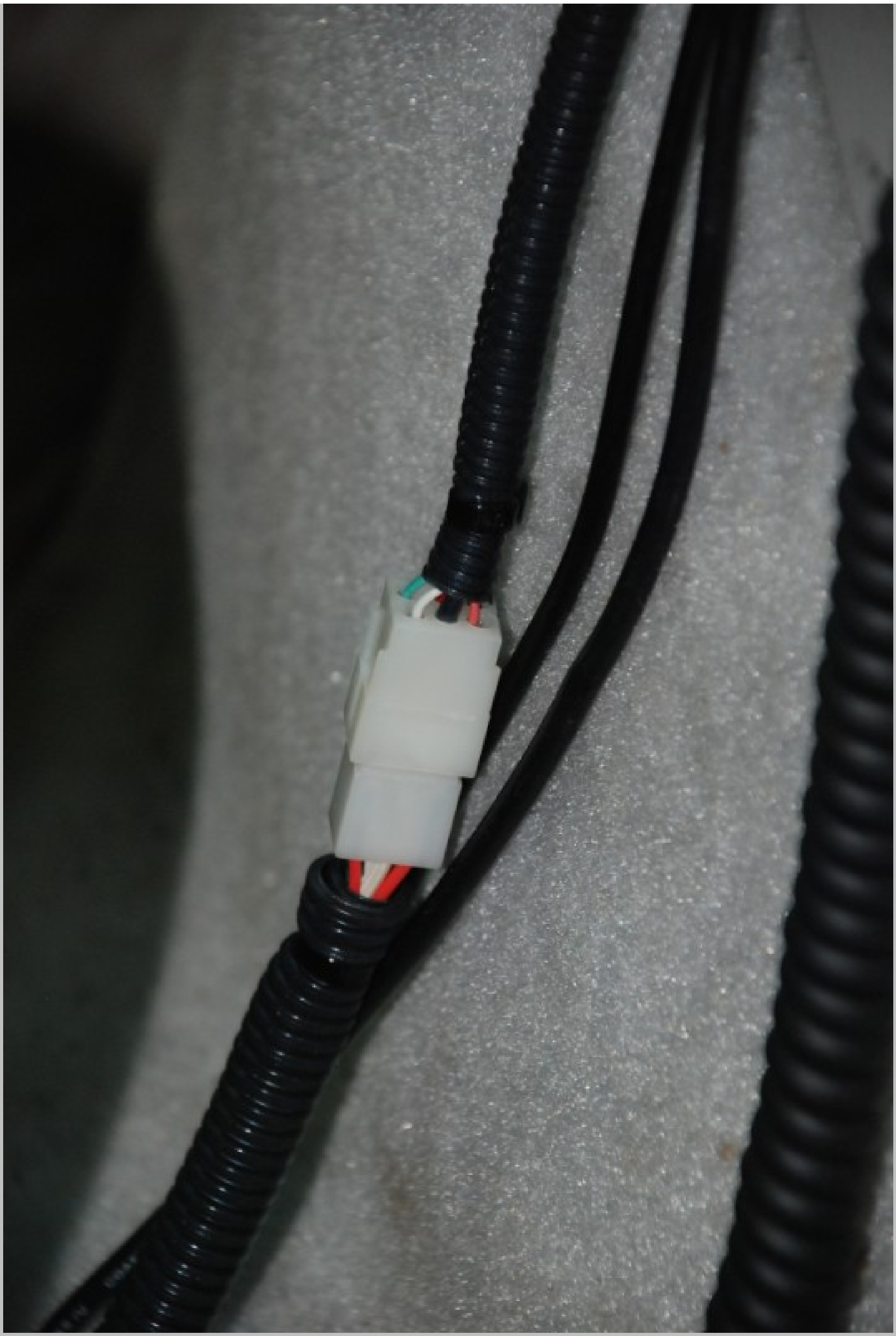

I knew I would have to take the MFJ antenna controller out of the vehicle from time to time, so I installed a Molex connector on the wires coming from the controller.

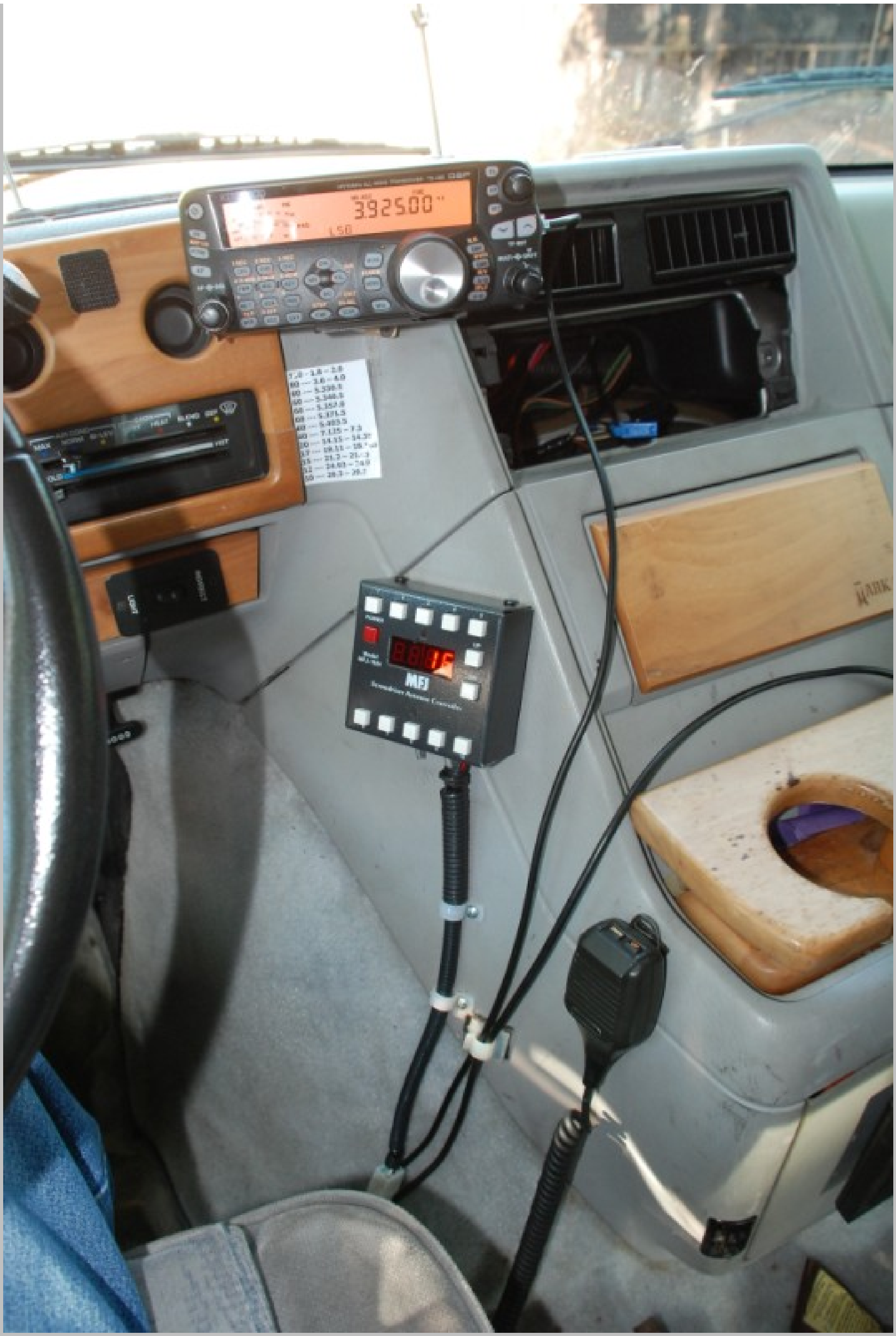

This is the mobile installation as seen the driver seat. Everything can be easily reached with one hand without stretching.

I used several cable clamps to secure the wires from the MFJ antenna controller. The controller itself is mounted to the vehicle with some adhesive backed high-strength hook and loop fastener material. The open spot in the dashboard is for the vehicle entertainment radio. I pulled the old radio out while I was doing the installation of the ham rig. I have a new entertainment radio ready to install. It will replace the old one which was killed by a nearby lightning strike. <!>

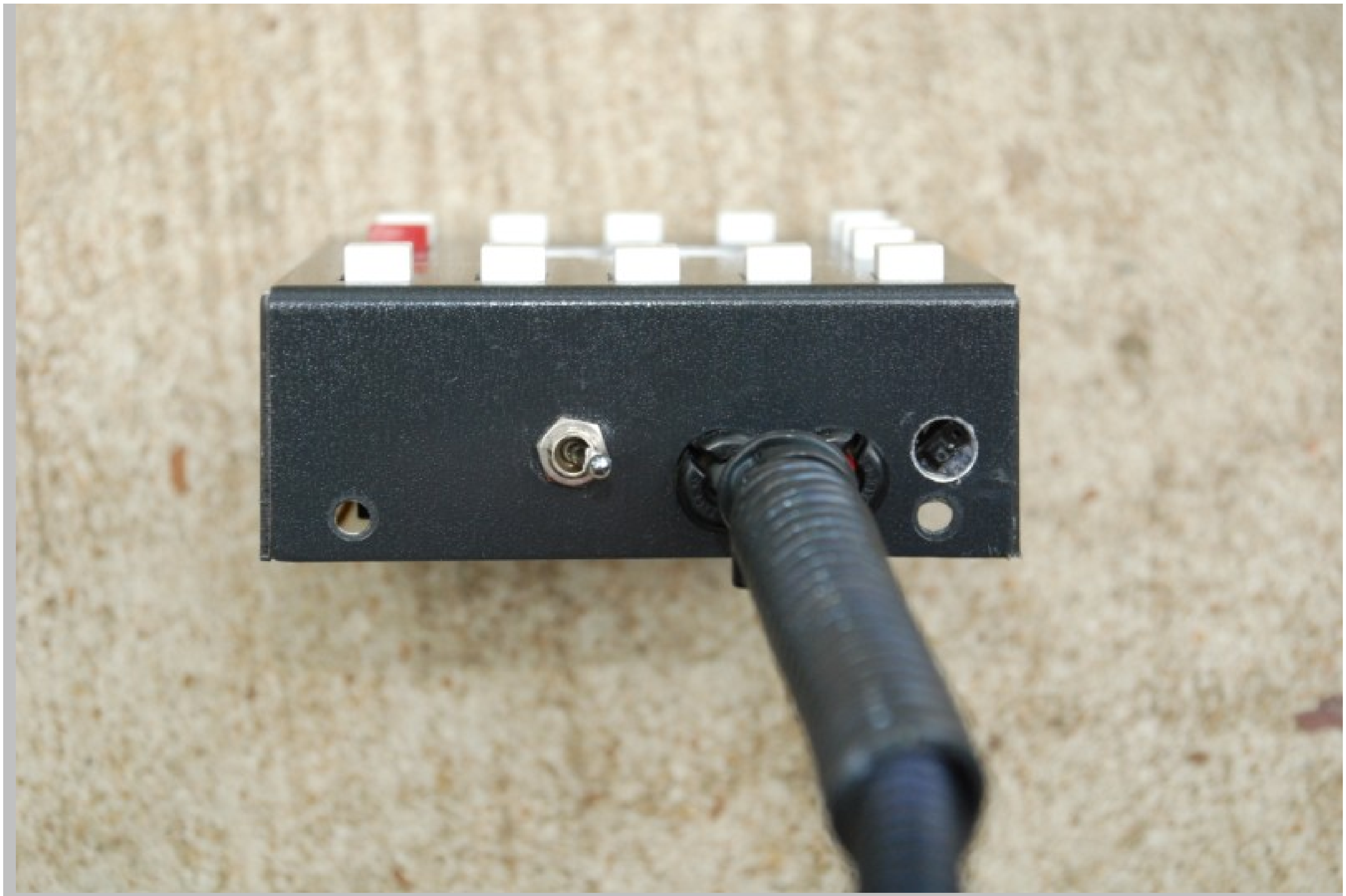

Here is a bottom view of the modified MFJ-1924 antenna controller. The Magic Button is at the far right of the controller. The switch was salvaged from a computer, and it's held inside the case with a blob of hot melt glue. Not fancy, but it works.

The silver switch is a single pole double throw switch. It inserts a 50 ohm 1 Watt resistor in series with the antenna tuning motor power wires. This cuts the speed of the drive motor by approximately half. If I need to tune the antenna manually, I can slow it down by using this switch. That makes it much easier to "tune by ear" if I need to tune to an odd frequency that is not programmed into the controller. It's also very useful if I am driving and want to manually change frequencies. I don't have to take my eyes off the road to adjust the antenna.

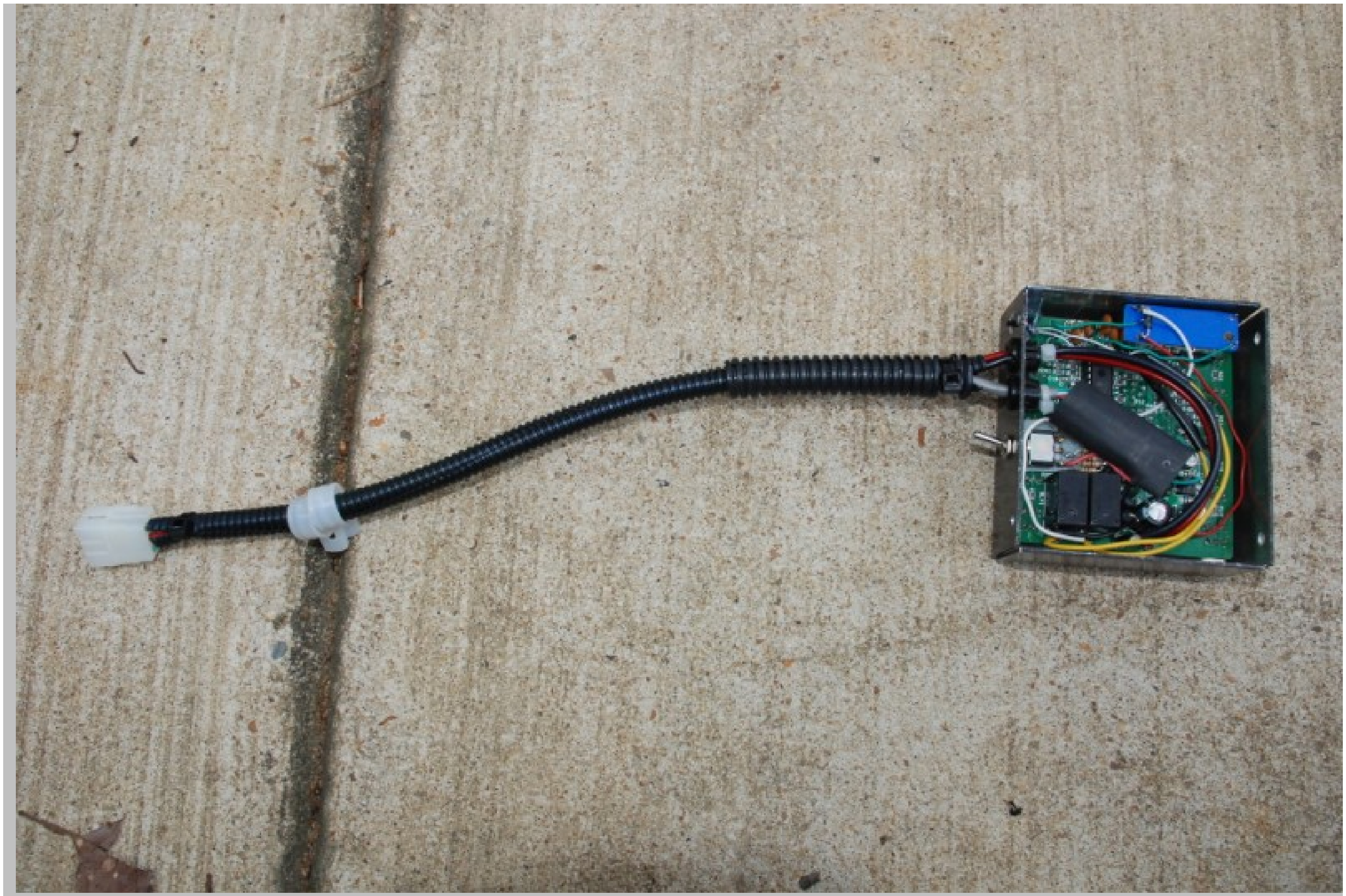

Here is the MFJ-1924 antenna controller after my modifications to it. After installing the Molex connector on the end of the wires, I use some convoluted tubing for protection. Hmm... I see a Blue Box inside the controller. That's not standard; I wonder what it's for?

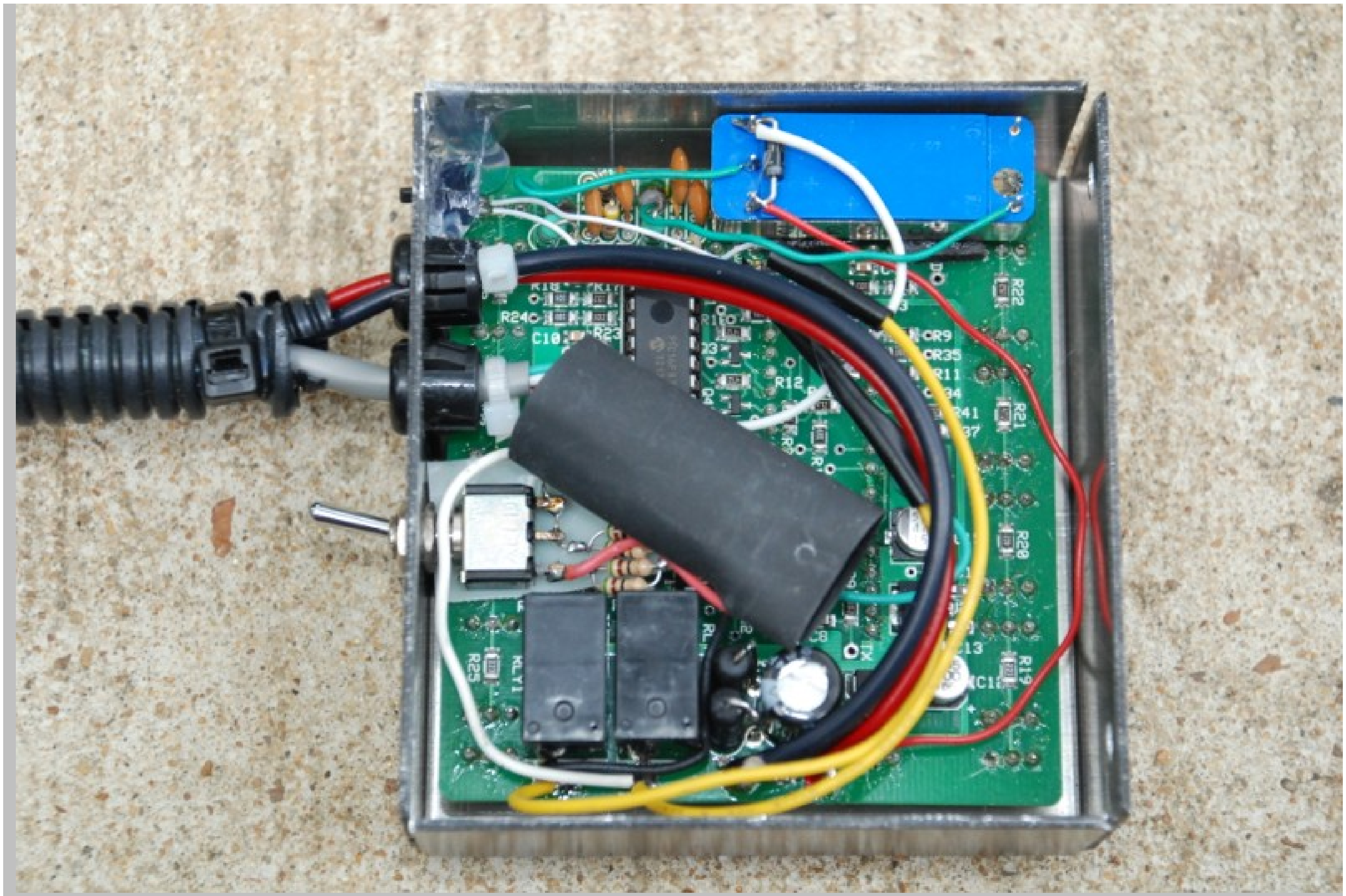

At the top left of the picture is the Magic Switch. It is pretty well buried under the blob of hot melt glue I used to hold it in place. Above the two black motor control relays you can see the extra toggle switch I installed to change the motor speed.

Oh, the blue box? That's a relay that I had to install to make the controller happy. It turned out that the MFJ controller occasionally missed counts from the reed switch. This caused the tuning to be off by a turn or two very often, resulting in a higher than desired VSWR reading. I spent some time looking at the reed switch pulses with an oscilloscope, and although I did not see anything wrong with them, the MFJ consistently miscounted. Installation of various types of RFI filters and RC networks failed to resolve the problem, which happened whether or not I was transmitting..Finally I decided that the CPU in the controller must be very sensitive to the rising and falling edges of the switch pulses. Perhaps adding a relay would fix the problem. Taking another page from K0BG (scroll down to the "Debouncer") I tried a small 12 volt relay and found that it did help resolve the problem. It was almost - but not quite - perfect.

Digging into my NOS parts junkbox, I found a Mercury wetted reed relay. (Sorry OSHA & RHOS) I managed to stuff it inside the MFJ controller. I took the relay coil DC power from the switched +12 volts DC, so as not to have a constant drain on the vehicle battery should the reed switch stay in the closed position at the end of the tune cycle. After installing the relay, the problem of miscounts went away. Perfect! I just have to remember that the controller - and the relay - must be operated in an upright position or the Mercury will roll around inside the relay and short out the relay contacts, resulting in no count pulses. I figure the reason this relay works so well is that unlike a normal relay, a Mercury wetted relay has virtually no contact bounce. Once the contacts close, they stay closed, and when they open, they open cleanly.

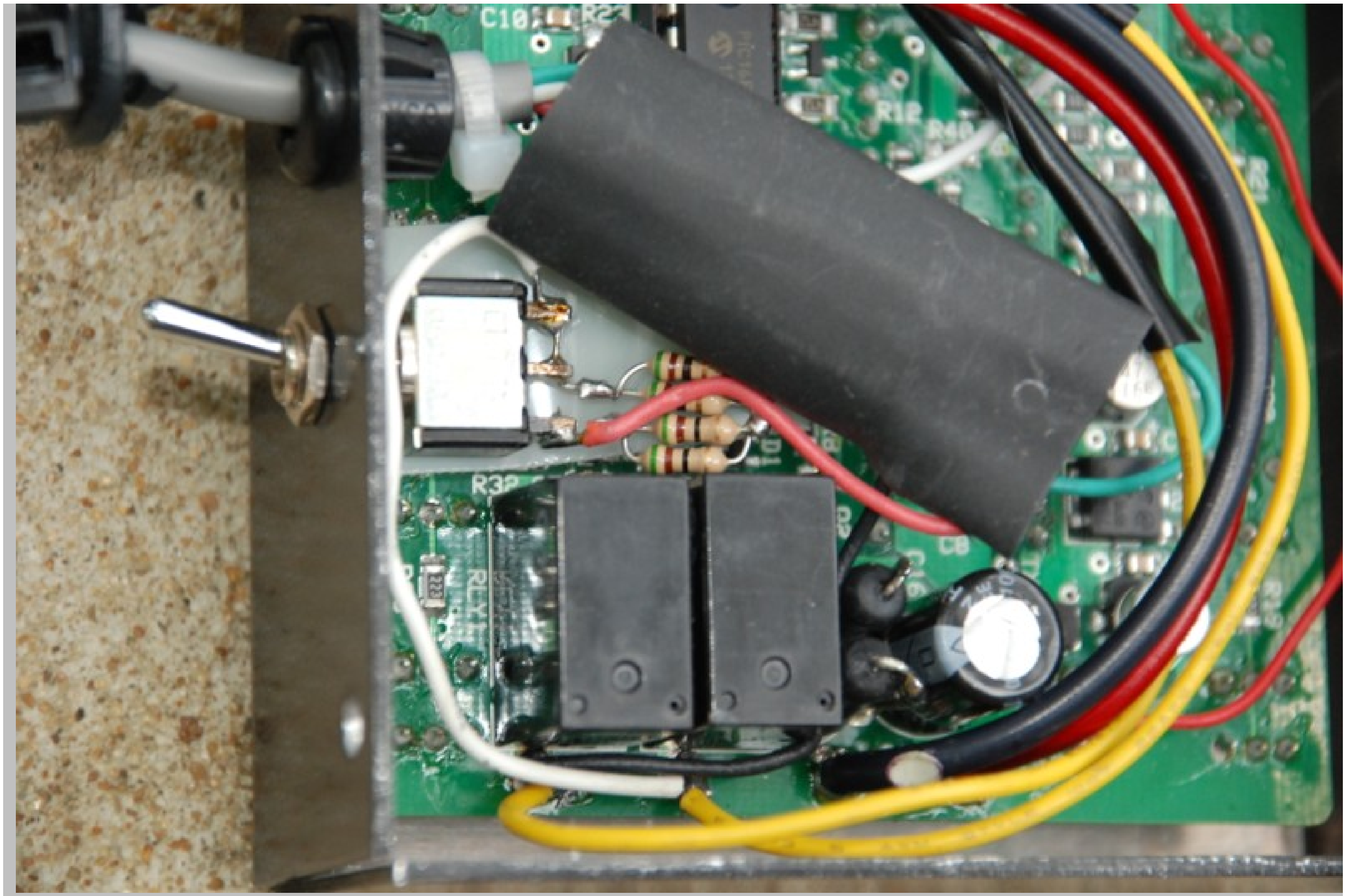

Because I didn't have a 50 ohm 1 Watt resistor on hand, I made one by connecting a total of 4 - 50 ohm 1/4 Watt resistors in a series parallel combination.

A Tree Antenna for the 600 Meter Band

Sept 8, 2007 - By W5JGV (updated January 01, 2008)

"Why put up an antenna when they're growing all around you?"

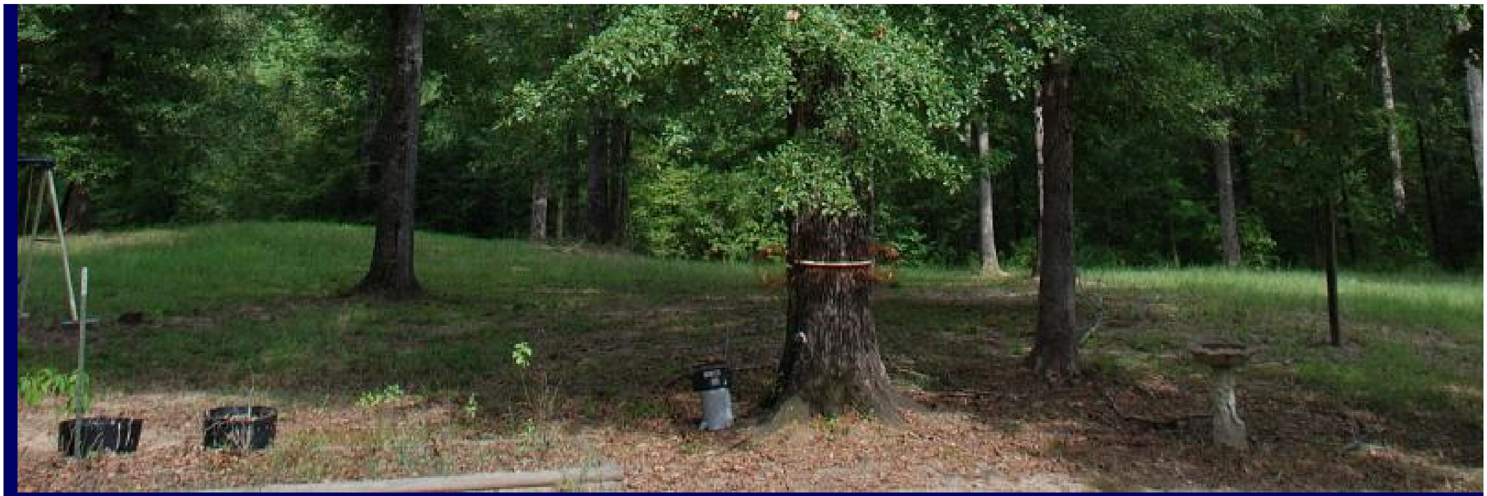

There are two antennas in this picture and one of them is not made of metal. Can you find them both?

If you look carefully, you can just see the horizontal single wire antenna in the background in the far right side of the picture. That is my 160 meter dipole antenna, which is about 20 feet above the ground. The other antenna is the large Oak tree in the center of the picture. Near the base of the tree trunk is the coupling coil which surrounds the trunk.

Yes, the tree IS the antenna!

My interest in tree antennas goes back many years, when I first read about some experiments using coils to couple RF energy to trees. Unfortunately, I neglected to save the article, and it was only much later that I was able to locate the source for the article.

Here are four articles that explain tree antennas - George O Squire Tree Antenna Patent.pdf - 1975 January Ikrath IEEE tree antennas.pdf - Robert Hand article.pdf and Signal Propagation at 400 kHz Using an Oak Tree with a HEMAC as an Antenna AD735330.pdf

It appears that there are two methods generally used to connect to a tree for using it as an antenna. The first is to drive a nail into the tree some distance up from the ground, and the second is to use a coupling coil around the trunk close to the ground. Since I prefer not to climb trees unless I really have to, I decided that the coupling coil would be the better approach.

Since little, if any, design data has been published on tree antenna coupling coils, I took a guess at what might work for the coil dimensions. I guesstimated that using a coil with about half the diameter of the tree trunk would be about right for the coil diameter. The length of the coil would be the diameter of the tree trunk. The number of turns was an unknown, but I figured that if the inductance was too small the tuning would be very sharp, and changing environmental conditions, rain, temperature, etc., might cause tuning problems. A larger inductance would be less sensitive to such things.

I decided on an inductance of about 175 uH as a starting point. That would require a coil of about 75 turns of about 10 inch diameter, or a total of about 195 feet of wire. Since I had a lot of #10 AWG bare copper wire available, that was used for the construction of the coupling coil.

Tuning the coil to resonance at 505 KHz would require approximately 575 pF of capacitance. At resonance, the coil losses would be about 10 Ohms, which would not be too good for transmitting, but for receiving, it should not pose a problem. At resonance, the impedance of the circuit would be about 30 Kohms so it would be a fairly good match for FET RF preamplifier.

Designing the coil was one thing, but how was I going to hold it in place against the tree? It had to be held away from the bark, or losses would increase when the tree got wet in the rain. After wearing out several pencils and using up the back of a lot of old envelopes, I finally hit on the idea of dropping each turn of the coil into a series of parallel slots cut into a length of plastic pipe. Then, when I bent the pipe around the tree, the flexing of the pipe would cause the slots to close up slightly and squeeze the wire tightly between the sides of each slot. At that point, all I'd have to do was to manhandle seven feet of flexible pipe and a hundred loose turns of copper wire into place while screwing the whole thing firmly to the tree trunk. I figured I'd work on that little problem after the coil was built.

Time to start construction!

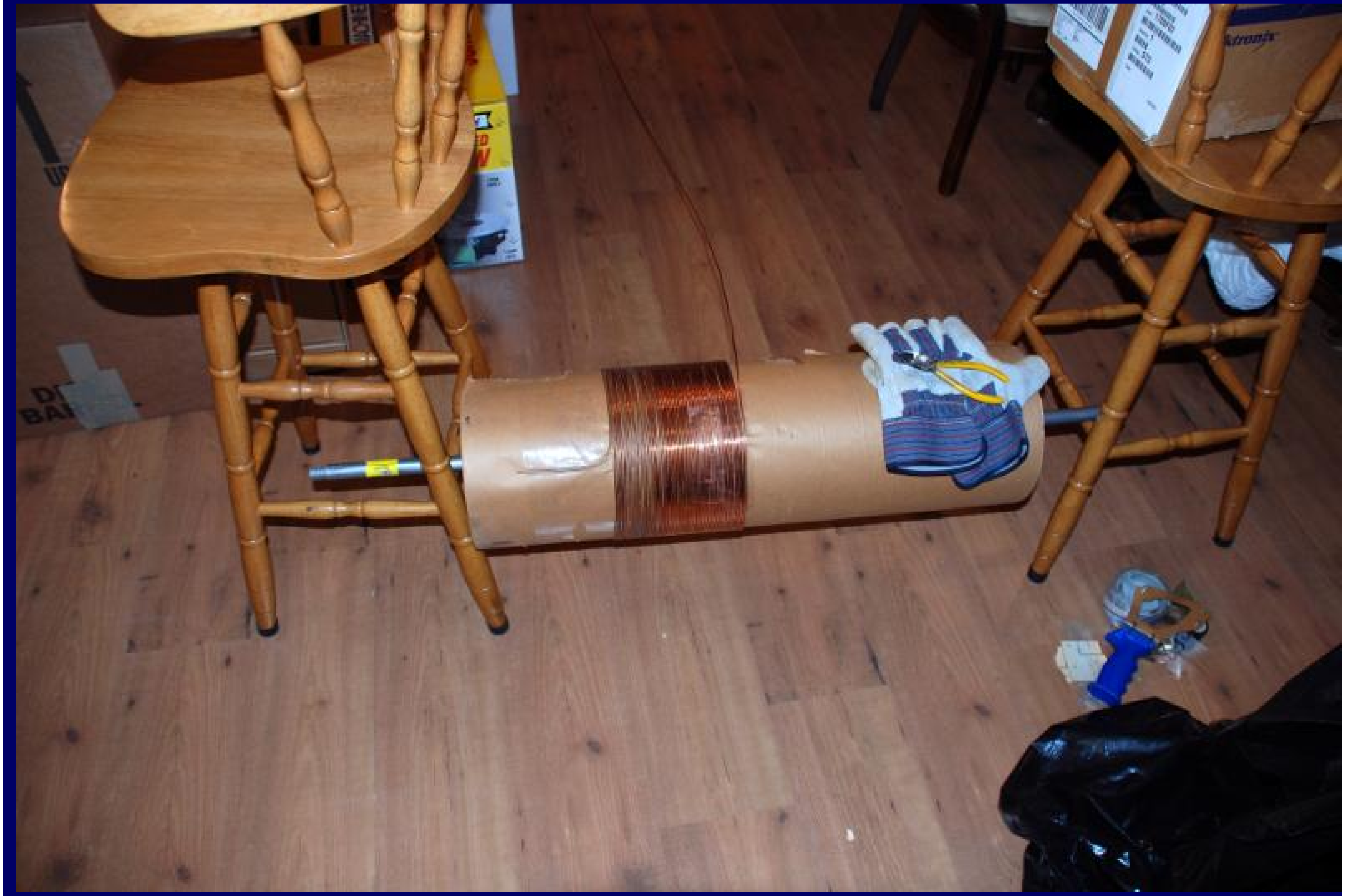

Construction of the coupling coil was started by running a broomstick through a roll of Bonnie, KB5YSE's art studio wrapping paper and supporting the roll between two wooden chairs. The roll measures about 9 inches in diameter, and made a solid form on which to wind the #10 AWG bare copper wire for the coil. The free end of the wire was simply taped to the roll of paper and winding was begun. After about 90 turns were wound on the form, the coil was carefully removed from the form and set aside for later installation.

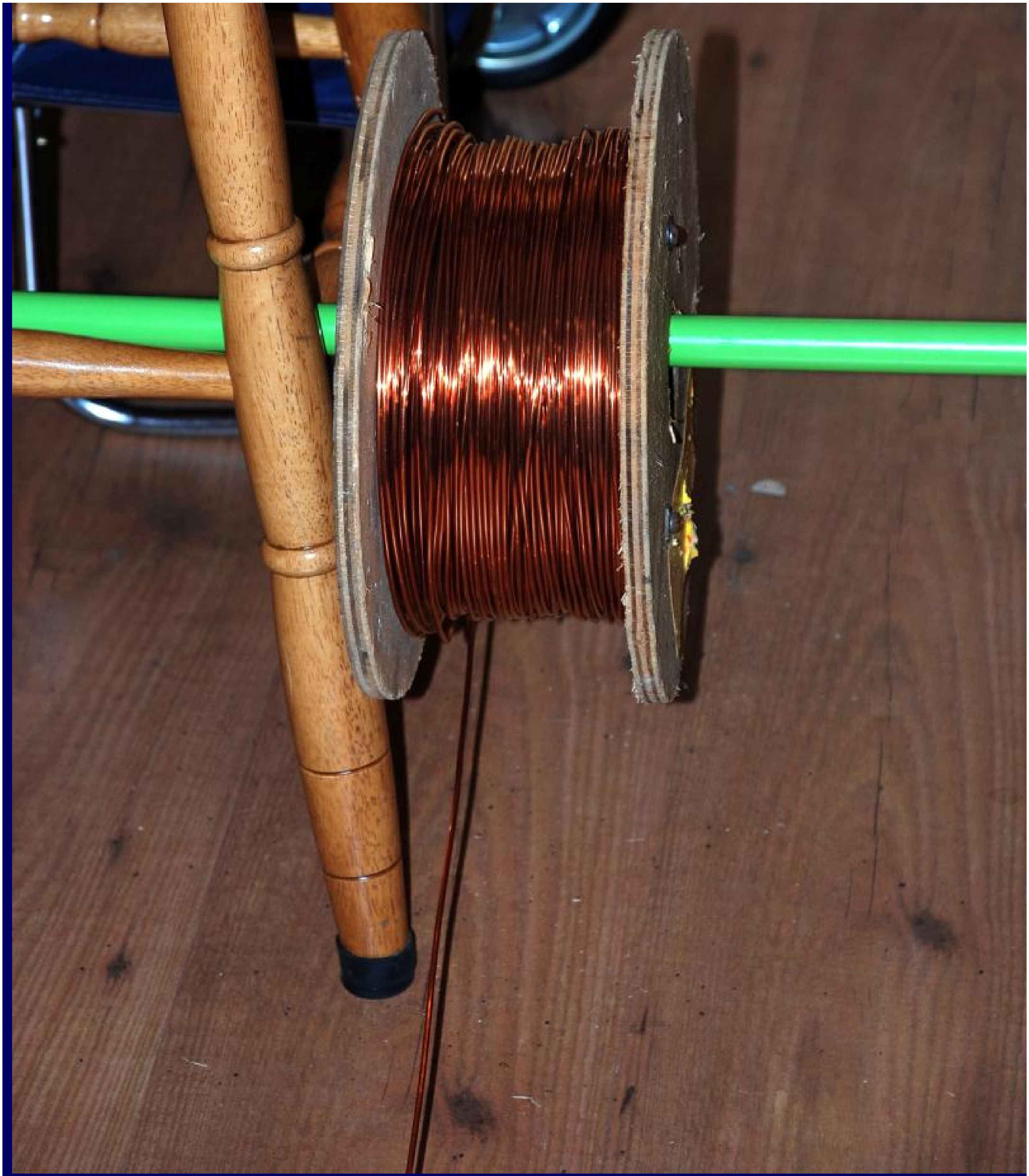

The wire I used was left over from a commercial AM broadcast antenna installation I did many years ago. It is bare, soft drawn, #10 AWG pure copper wire. It was just right for a coil of this size, since it is strong enough to hold its shape without any extra support.

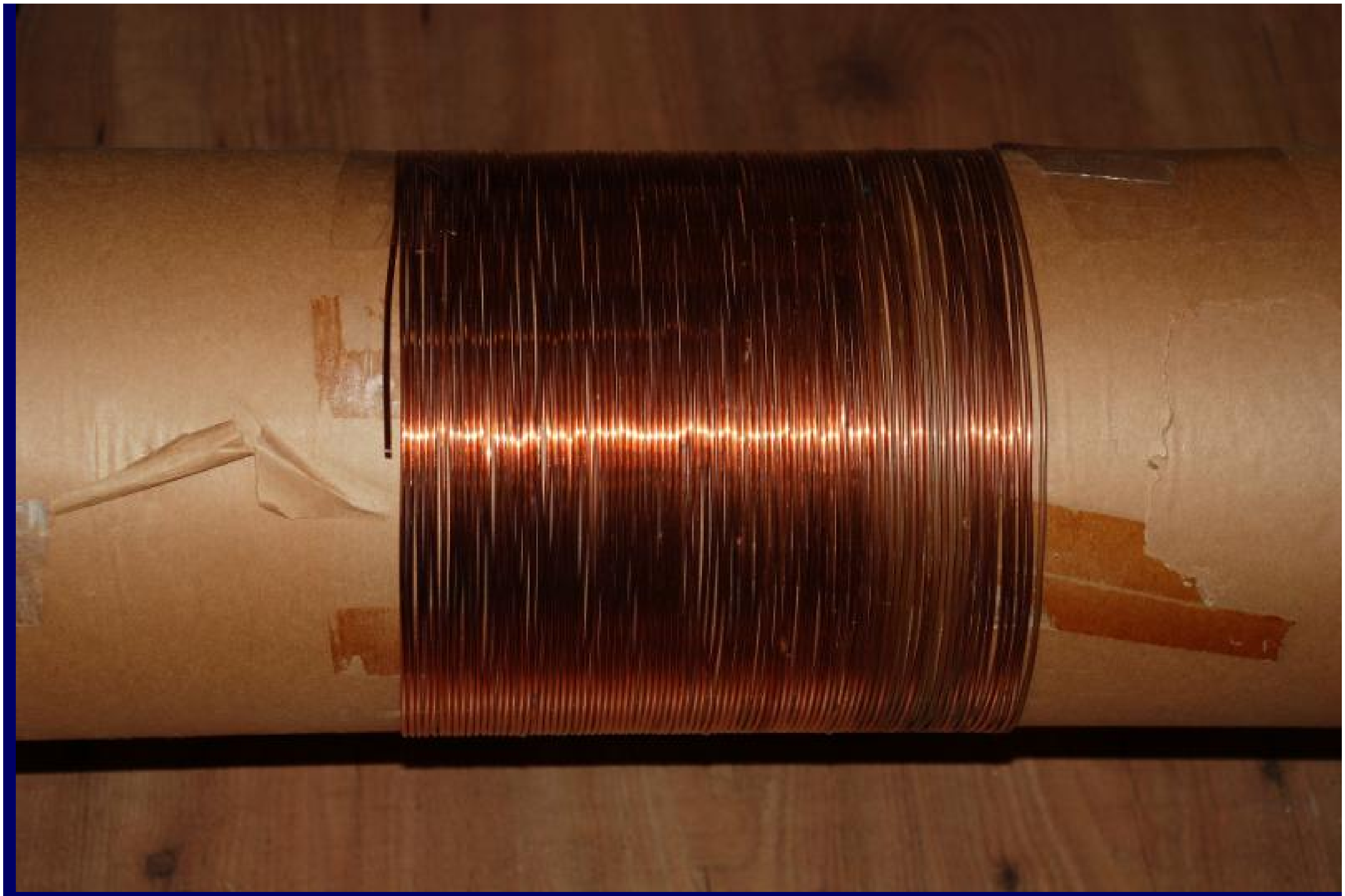

Here is the finished winding while it is still on the winding form. It looks neat at this point, but as soon as I loosened the wire to remove it from the form, it promptly sprang into action and unwound into a larger diameter shape, and instantly piled up into what appeared to be a massively tangled heap! Fortunately, it was very easy to unravel, and placement of the wire coil onto the supporting tube went along without any unexpected difficulty.

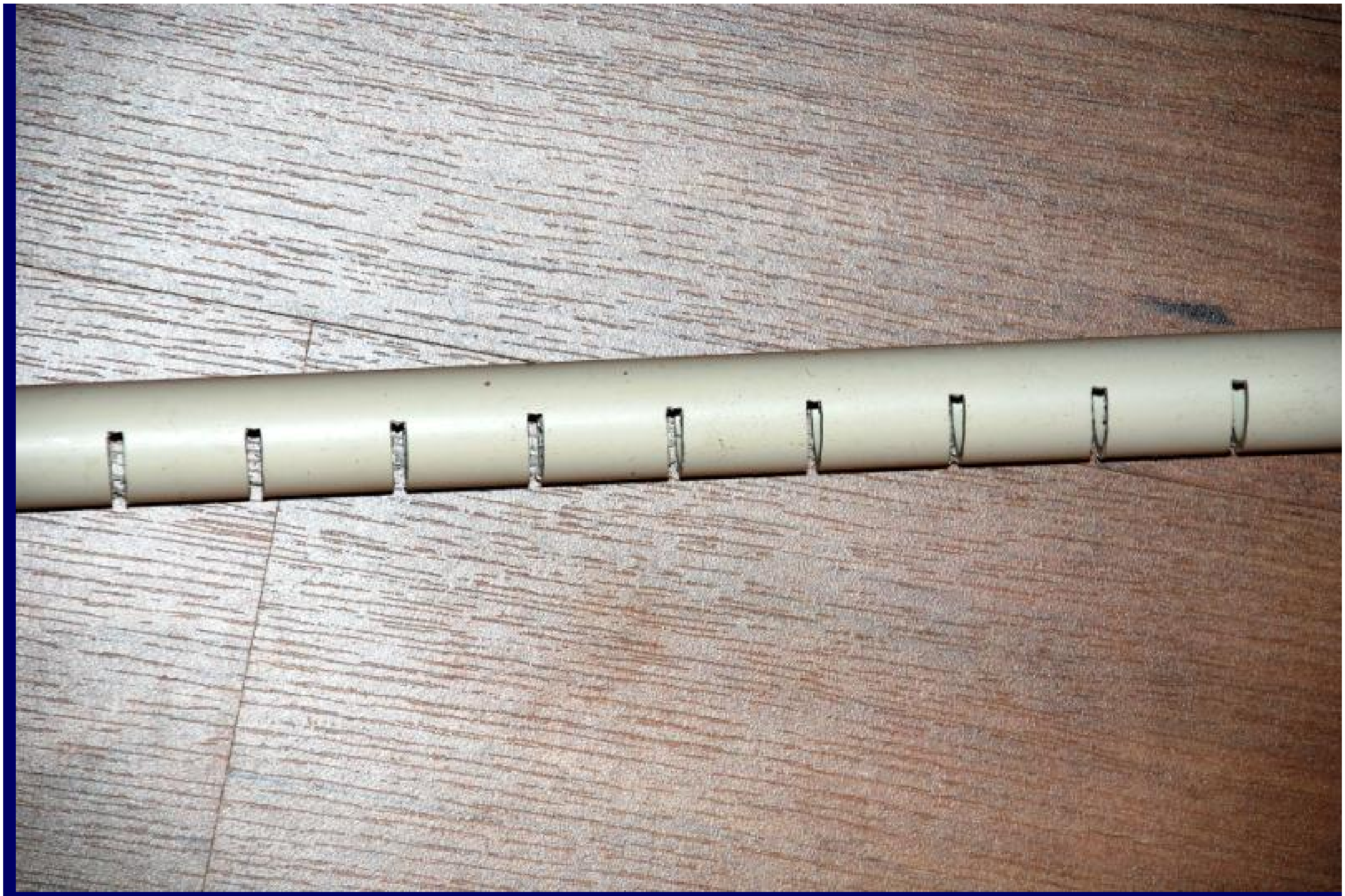

All that wire has to be supported somehow, and I figured the easiest and cheapest way would be to take a length of 1" diameter plastic pipe and cut an evenly spaced series of slots into the pipe. As the pipe was bent around the tree and fastened in place against the tree, the slots would close up slightly as the pipe was bent. This would "put the squeeze" on the wire and hold the coil firmly in place. I drew a series of pencil marks spaced one inch apart on the pipe. The slots were then cut a little more than halfway through the pipe using a carbide tipped saw blade on a table saw. I made a "sled" for the saw to hold the pipe tightly in position as I cut the slots. The use of the sled also kept my fingers well away from the saw blade during the cutting process.

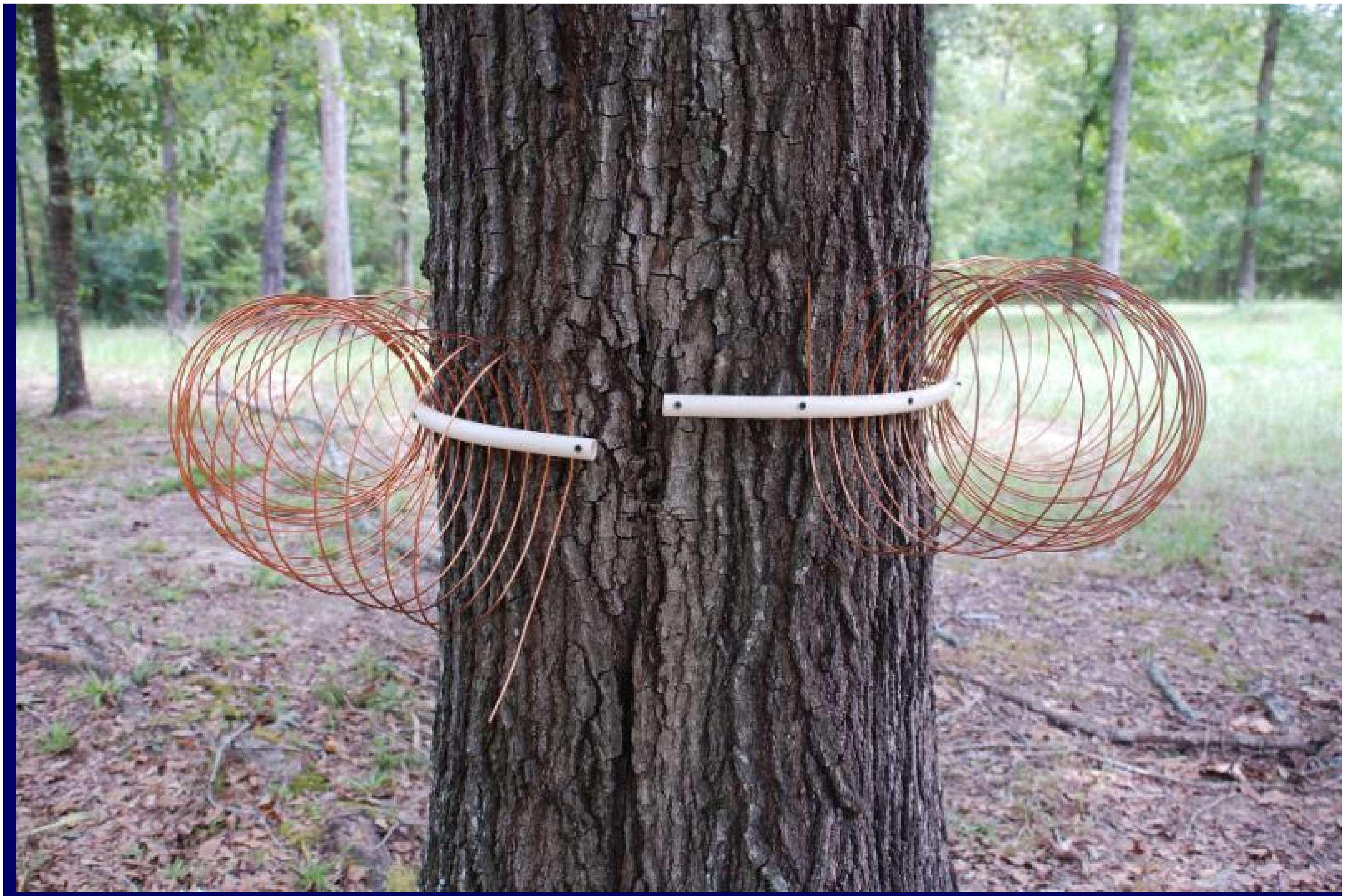

Well, here's the coil in place around the trunk of the tree. I'd like to say that the uneven placement of the ends of the tube were to ensure proper drainage of water from the tube when it rains, but in reality, I just screwed up a bit and didn't line things up quite right. (Hmm... I think I like the rain drain idea better!)

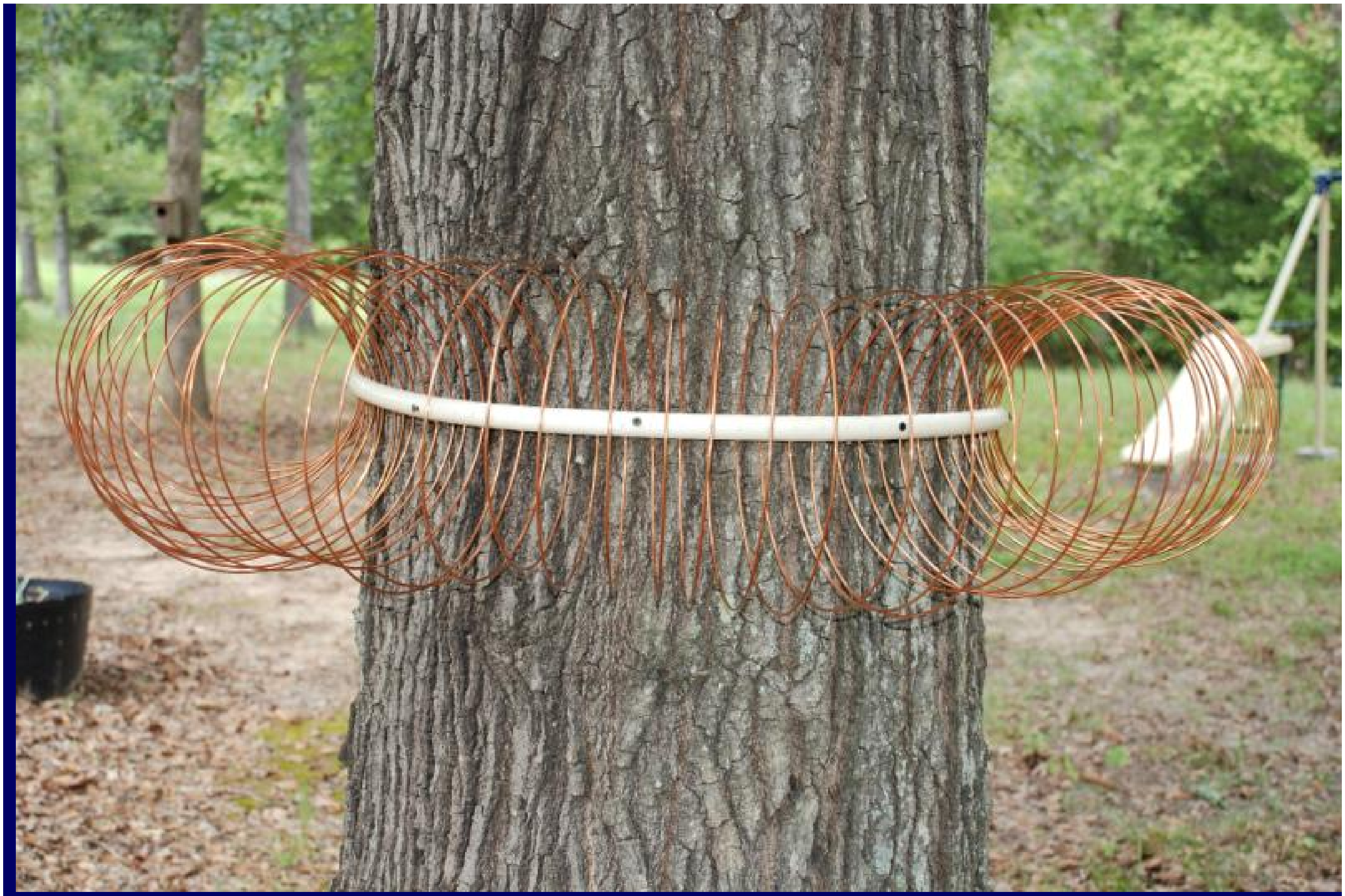

Seen from the other side of the tree, the coupling coil looks a bit better. The black screws that hold the pipe against the tree are not tightened up snugly. You must allow some slack here, or as the tree grows it will crush the pipe and eventually pull the screws right through the pipe, ruining the coil.

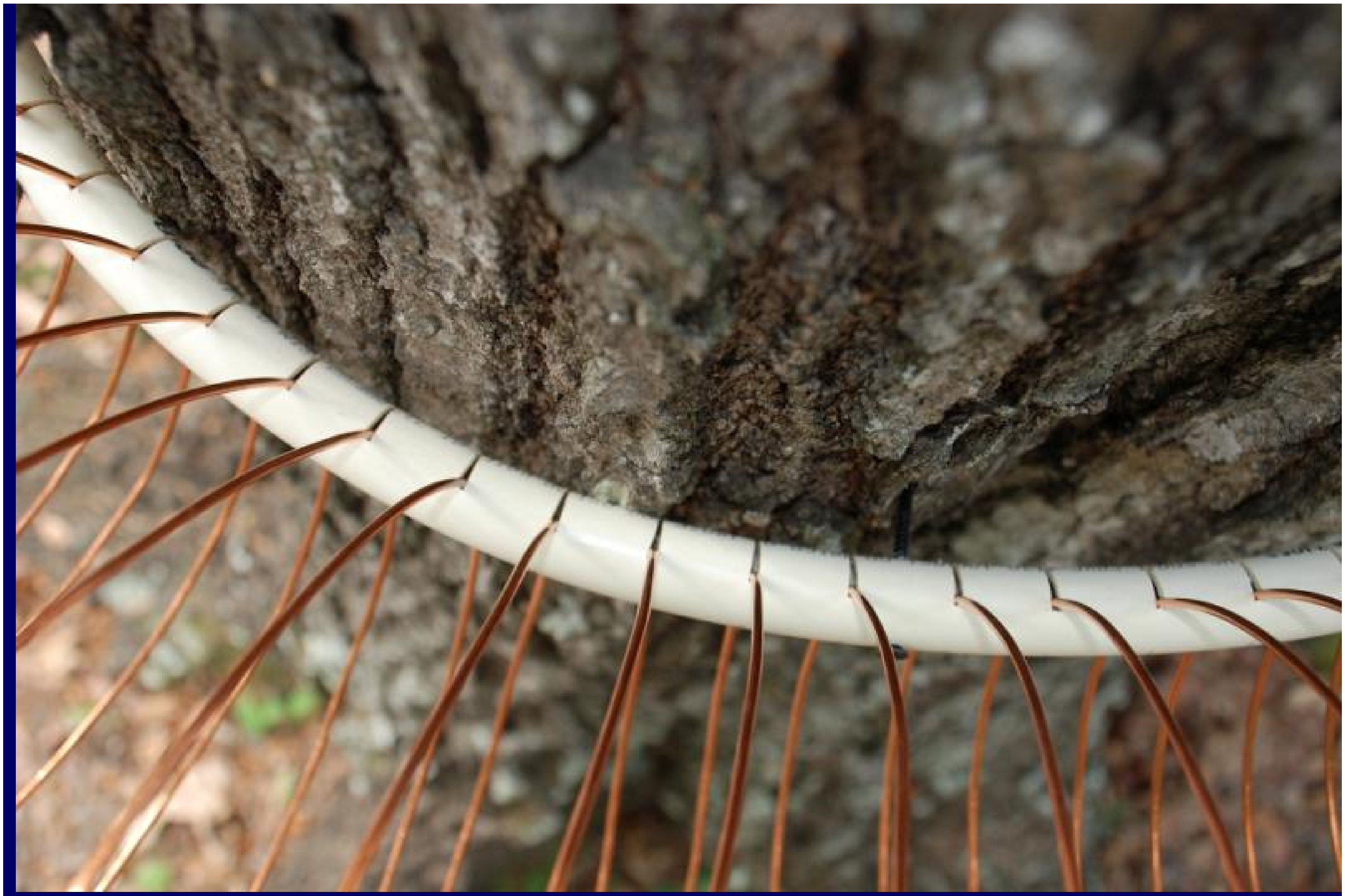

In this top view of the support pipe, you can see how the slots close up as the pipe is bent around the tree. As the slots close up, they pinch the turns of the coupling coil tightly. After the pipe is fastened in place, you cannot pull any of the turns through the slots. It's tight! The difficult part is that each turn of wire must be hand adjusted as the turns are placed into the slots. Of course, while I was doing this, about six other turns were trying to jump out of their slots. It turned out to be a real "juggling act" to get the turns to stay in place as I assembled the coil, but I finally beat the recalcitrant coils into their proper positions; order prevailed, and I got the coil finished at last.

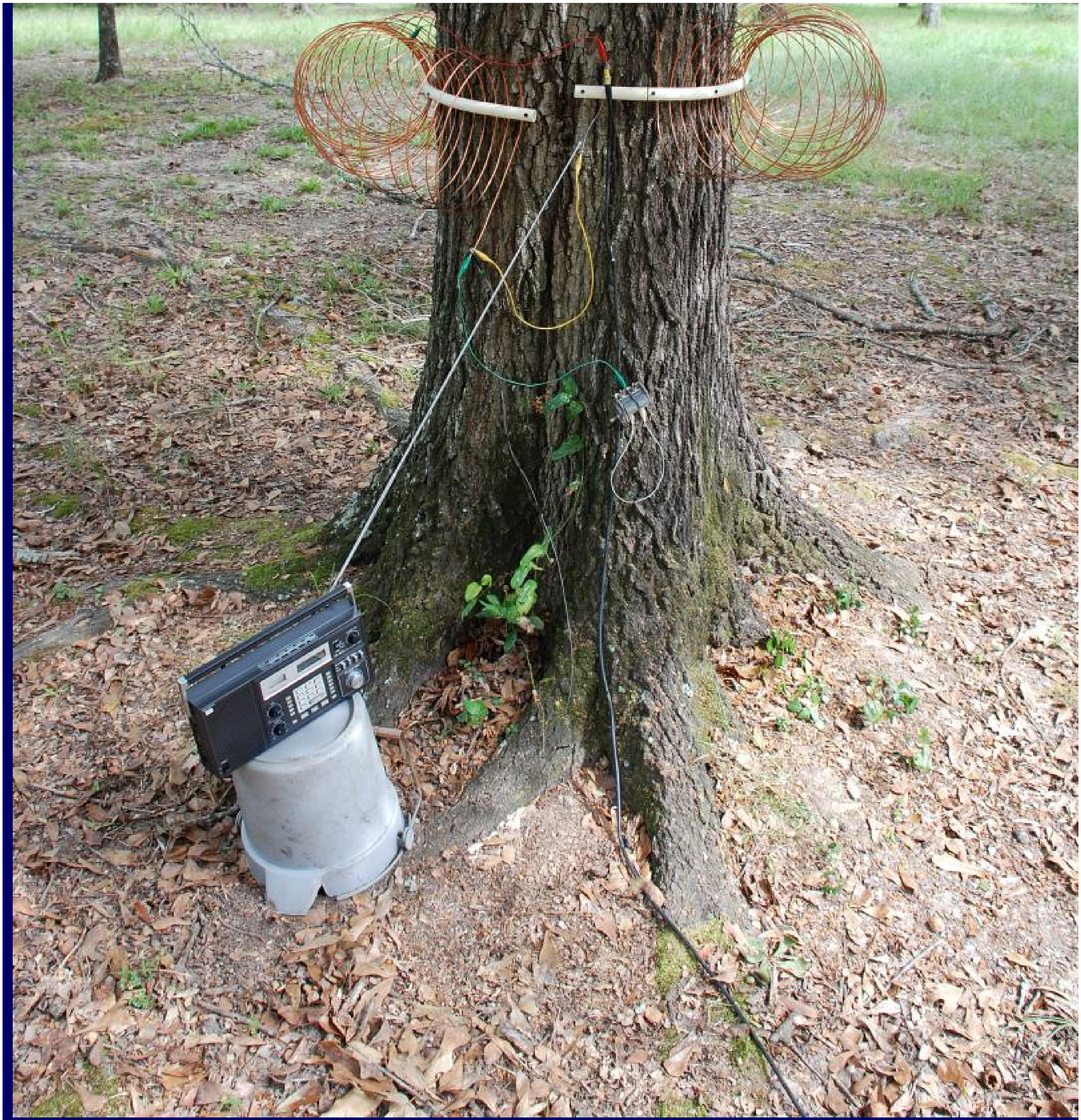

Tune up time! Does it actually work?

A quick test setup was made using a portable radio and an old 435 pF dual section variable capacitor salvaged from a defunct broadcast receiver. The coil resonated with the calculated amount of capacity connected across it. As it eventually turned out, this was about the easiest way to tune the antenna. All I have to do is to position the portable radio antenna close but not touching the coupling coil. The radio is then tuned to the frequency at which I want to tune the antenna. When the coupling coil is tuned to resonance, the signal (or background noise) in the radio increases, indicating that the system is tuned to resonance at that frequency.

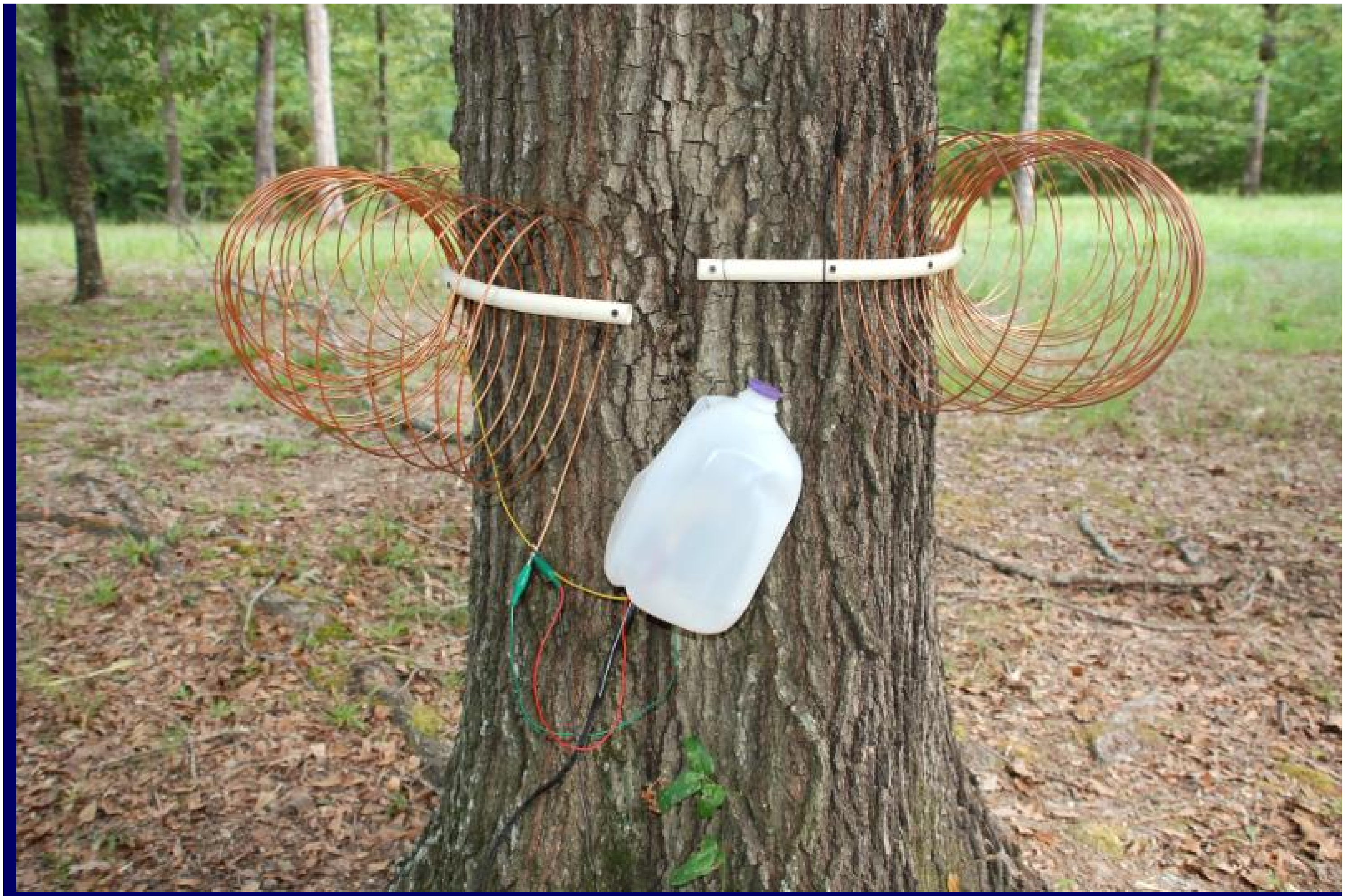

After the first tune up was so successful, I quickly constructed the elaborate weather cover you see here. Slits were cut into the bottom of an empty plastic water bottle and the tuning capacitor and feedline connections were stuffed into the bottle. This setup, complete with the Radio Shack clip leads, was used for several days before a more permanent enclosure was installed.

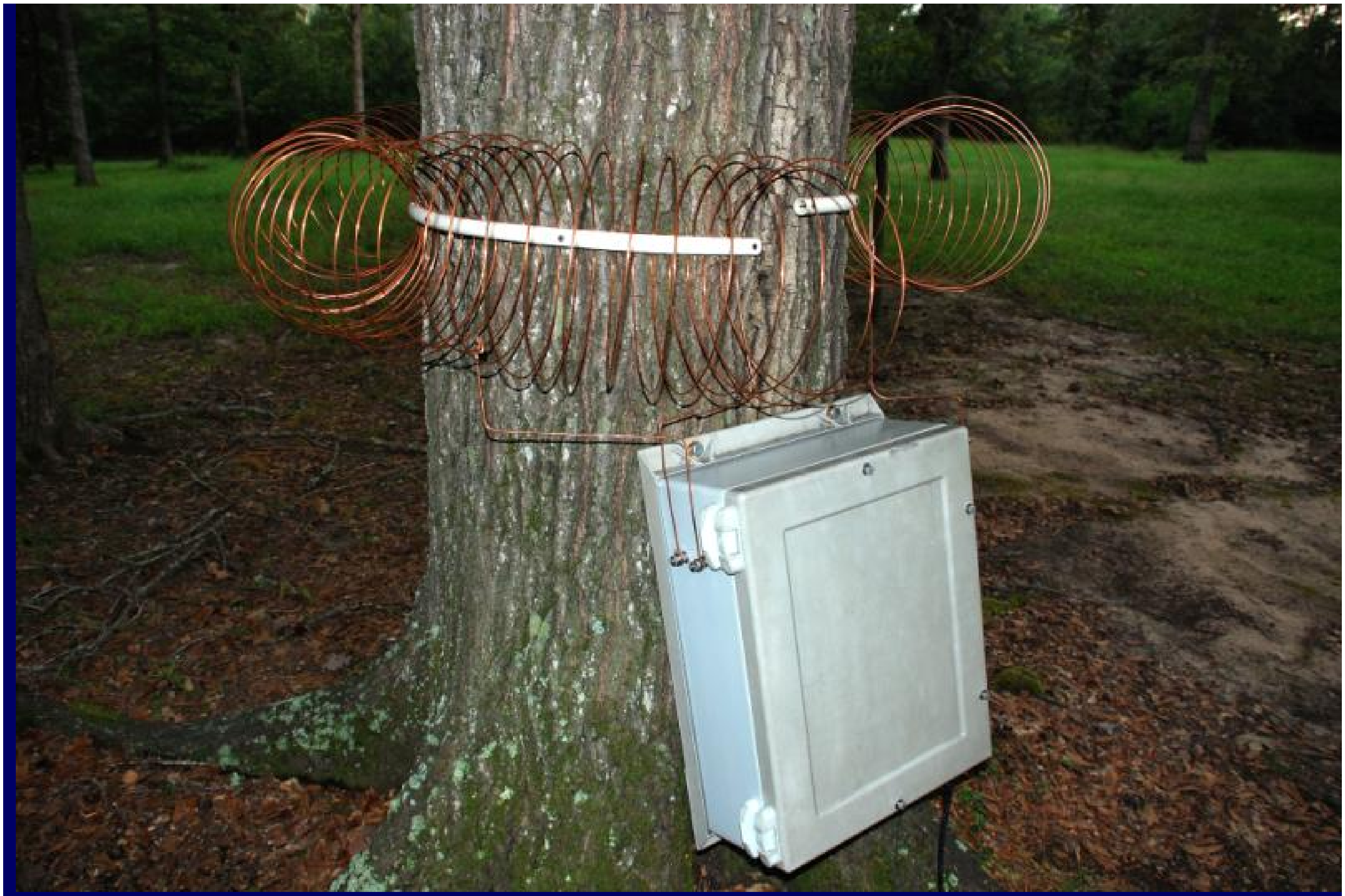

Now, this looks more like it! The enclosure is one that I salvaged from my Katrina-ravaged tower at my old QTH in New Orleans. The cabinet is at least 30 years old (Hoffman makes good stuff, you bet'cha!) and has been out in the sun and rain all those years. It is still weather tight using the original gaskets. It is Fiberglass and was starting to shed glass strands, so I refinished the outside of the enclosure.

There are two connections visible on the left side of the enclosure. The connection closest to the tree goes to the left ("cold") end of the coupling coil. This end of the coil is also connected to ground. The front-most connection goes to a tap on the coil that is 10 turns from the ground end of the coil. This is the feed point for the 75 Ohm coaxial cable that goes to the receiver in the shack.

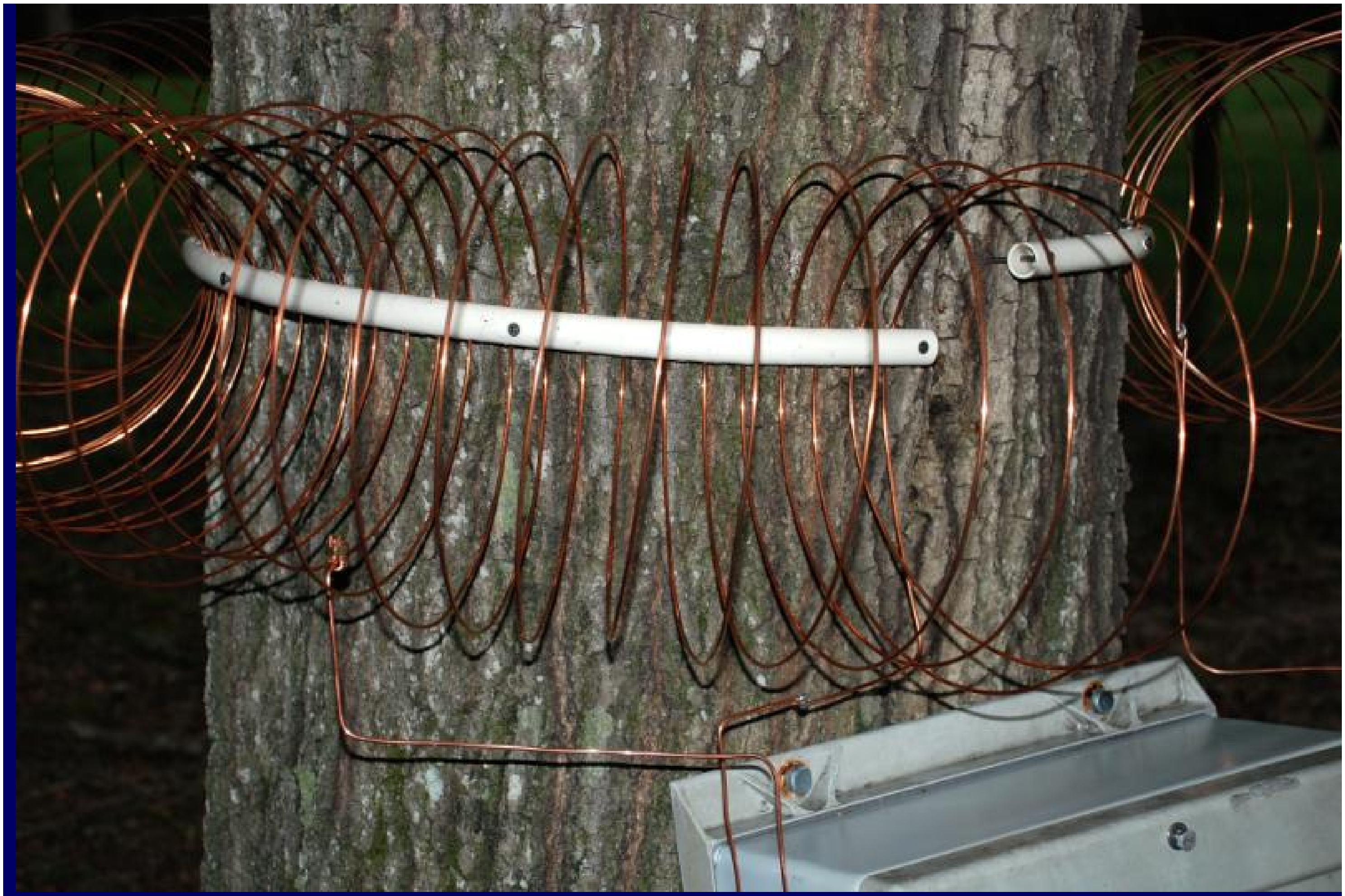

A close-up view of the tap and cold end of the coil connections.

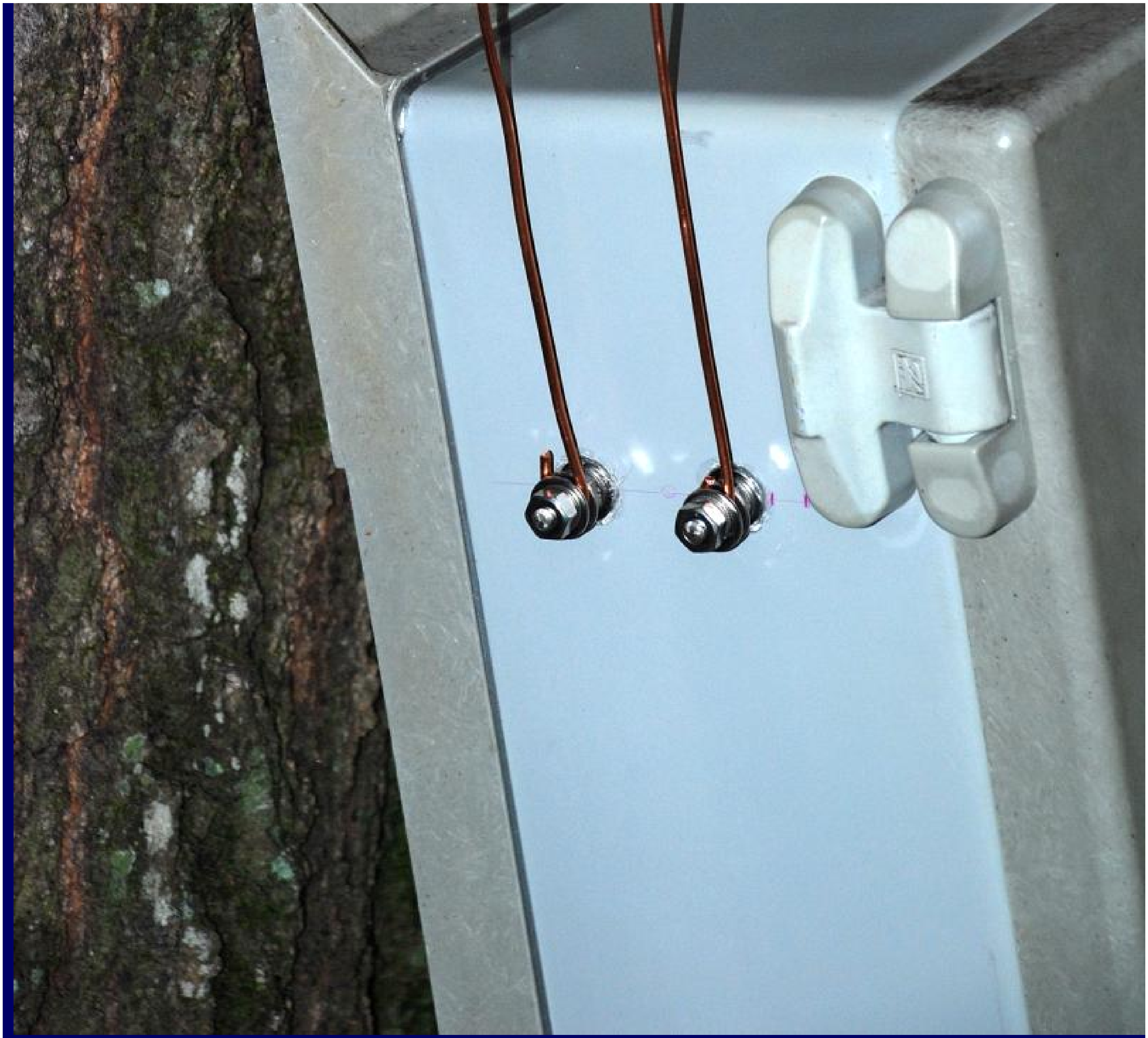

Stainless steel through bolts carry the signals through the Fiberglass walls of the enclosure. Sealer is applied to the bolts so that rain will not enter the enclosure. The bolts that hold the enclosure against the tree are not snugged up tight, there is room for the tree to grow. Both the bolts holding the enclosure to the tree and the screws holding the coupling coil in place will have to be backed out slightly every year or so.

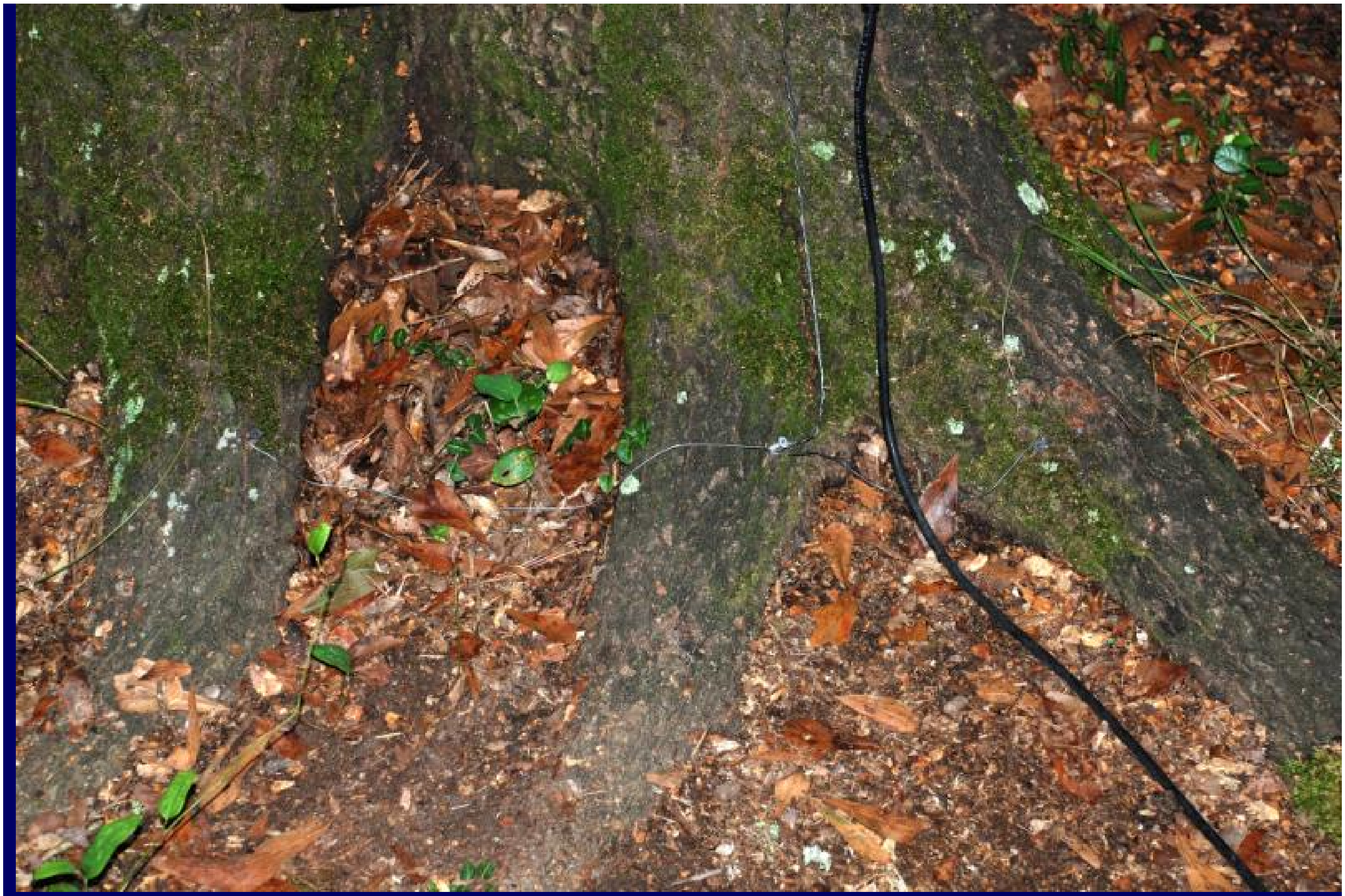

The ground system for the coupler uses three steel screws that are driven into the roots of the tree. I figured that the tree probably has a better connection to the ground than I could manage to get by driving a ground rod. After running the screws into the roots, the screws are removed and the end of an aluminum wire are pushed down into the holes. The screws are then replaced. This gives a good connection to the damp wood. Do NOT drive copper or brass wire or screws into a live tree, as the copper may kill the tree. Iron, steel or aluminum is OK.

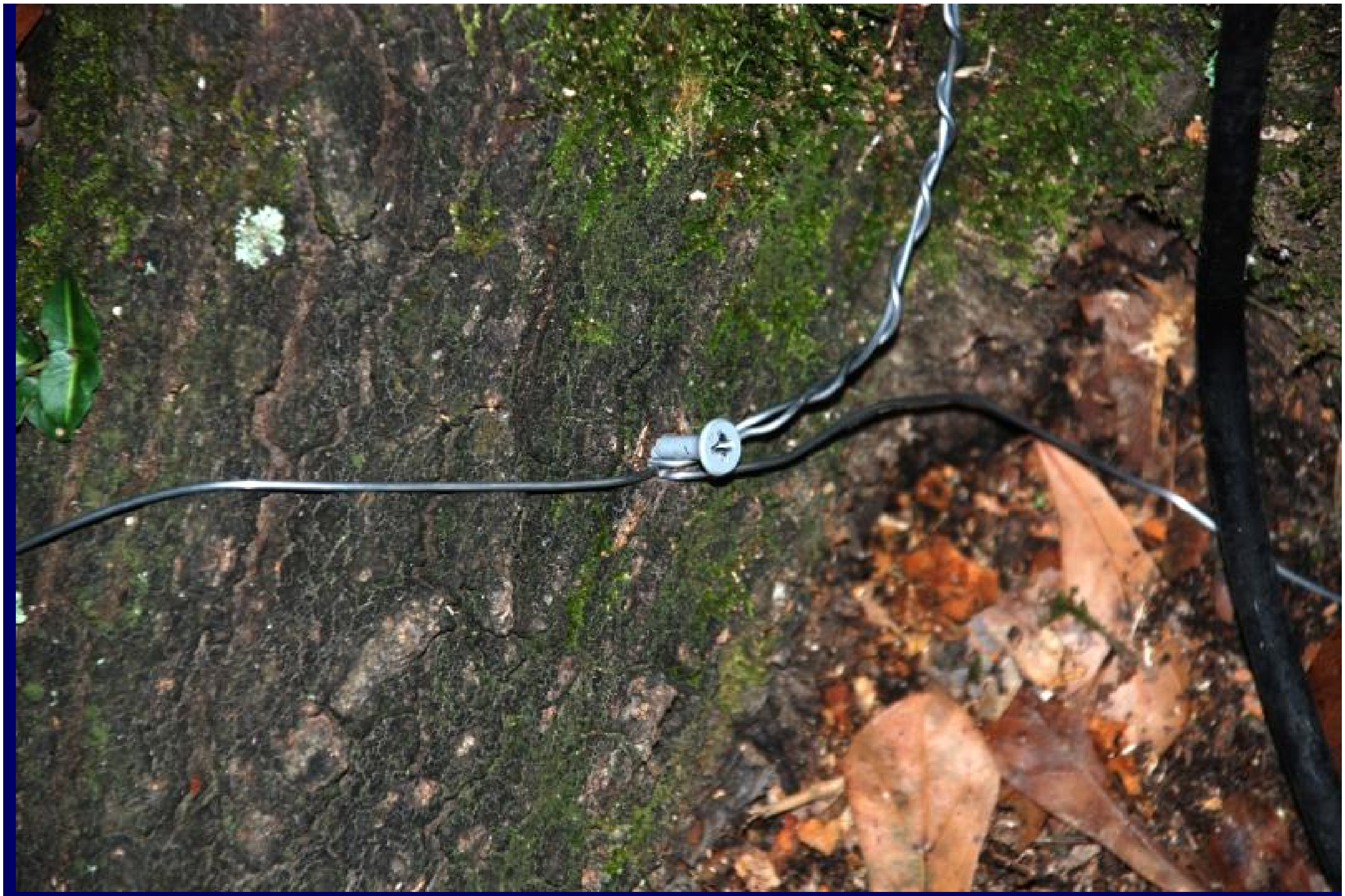

At the center ground-root, the wires from the other two ground-roots and the twisted pair of ground wires from the coupler circuit all come together. All the wires go about two and a half inches into the tree root. I used aluminum electric fence wire for the ground wires.

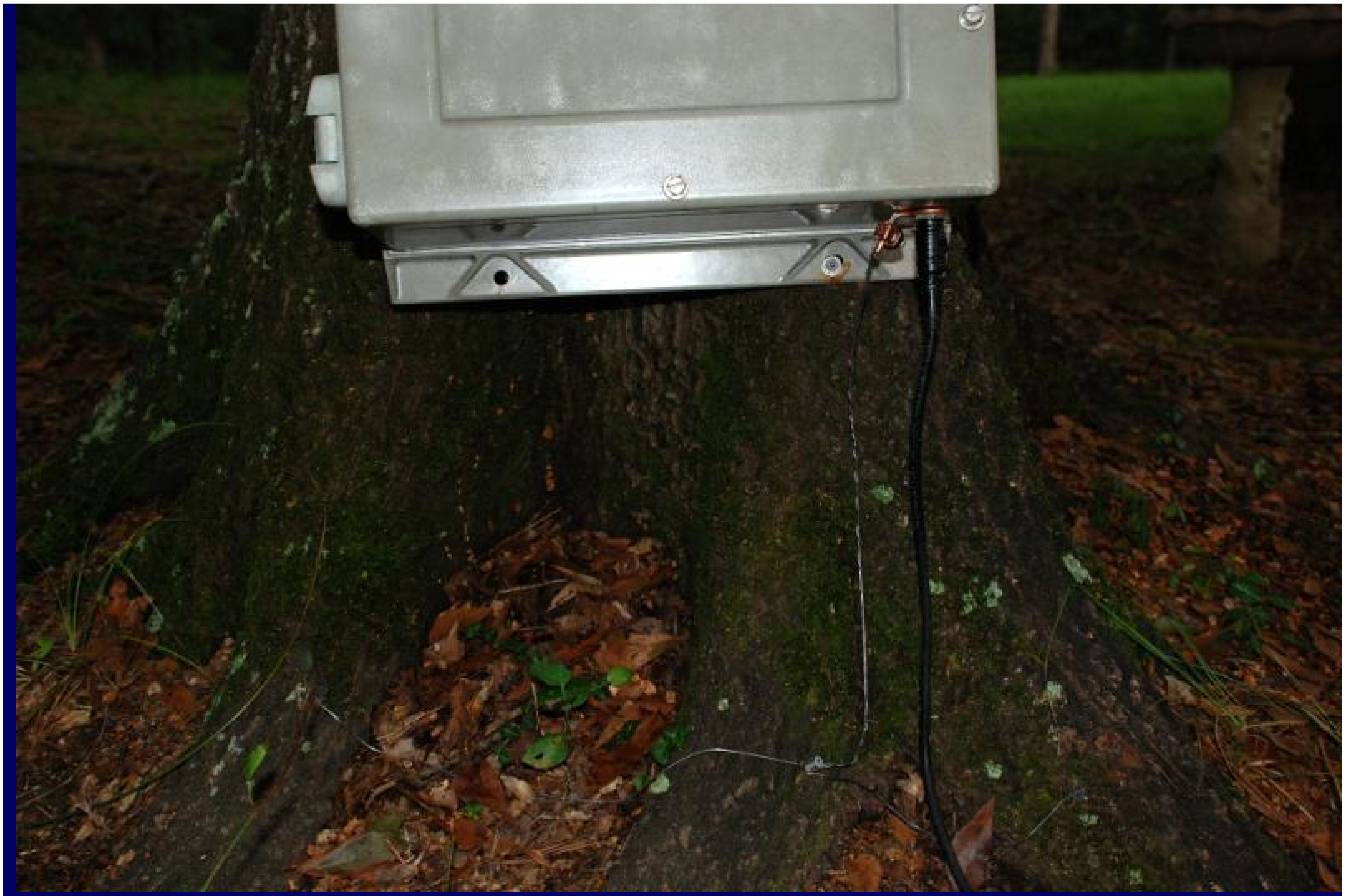

The ground wire goes from the tree roots to the coaxial connector on the bottom of the tuner enclosure.

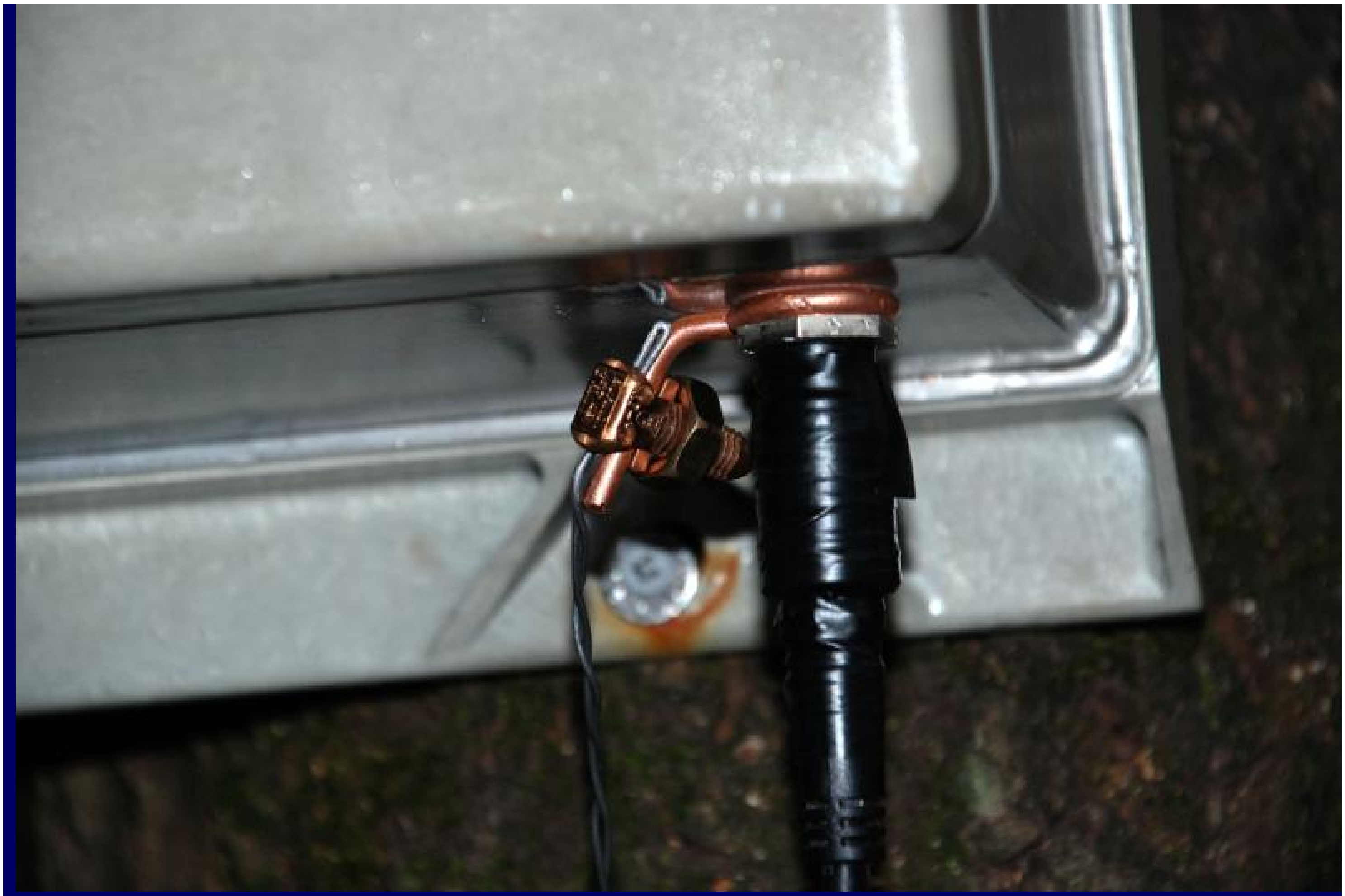

A split-bolt wire connector connects the ground wire to the pigtail coming from the connector.

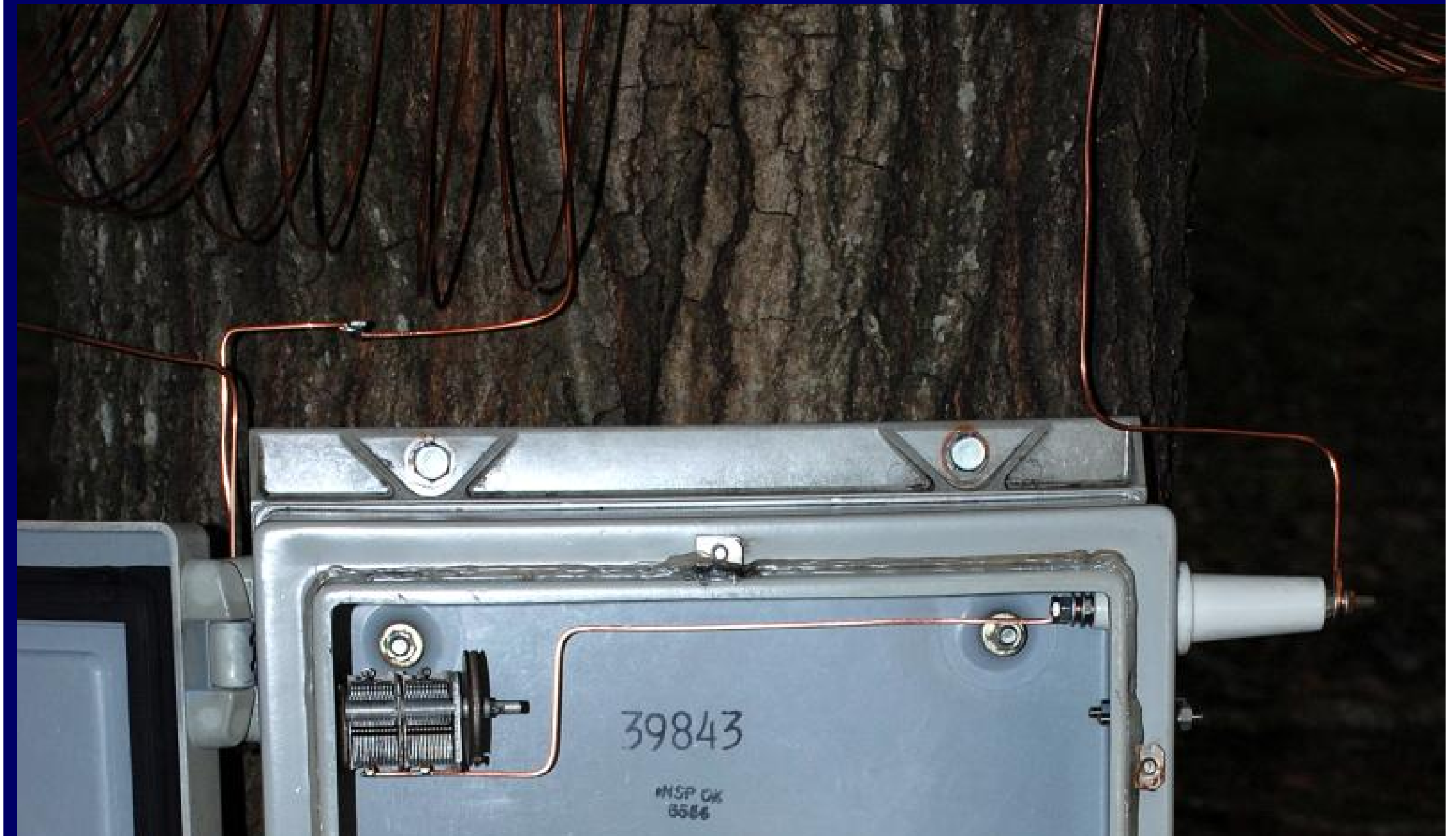

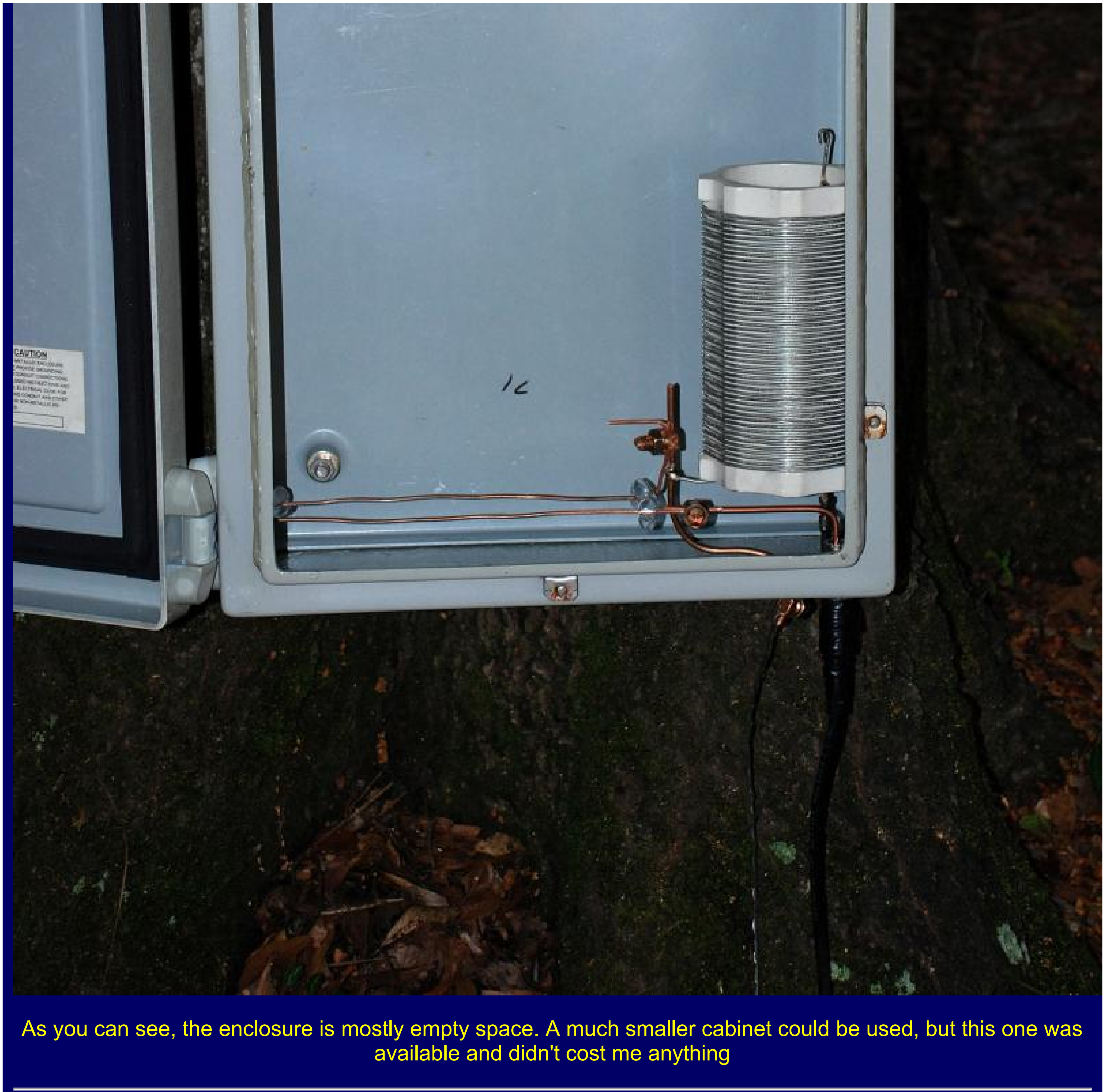

As you can see, the enclosure is mostly empty space. A much smaller cabinet could be used, but this one was available and didn't cost me anything

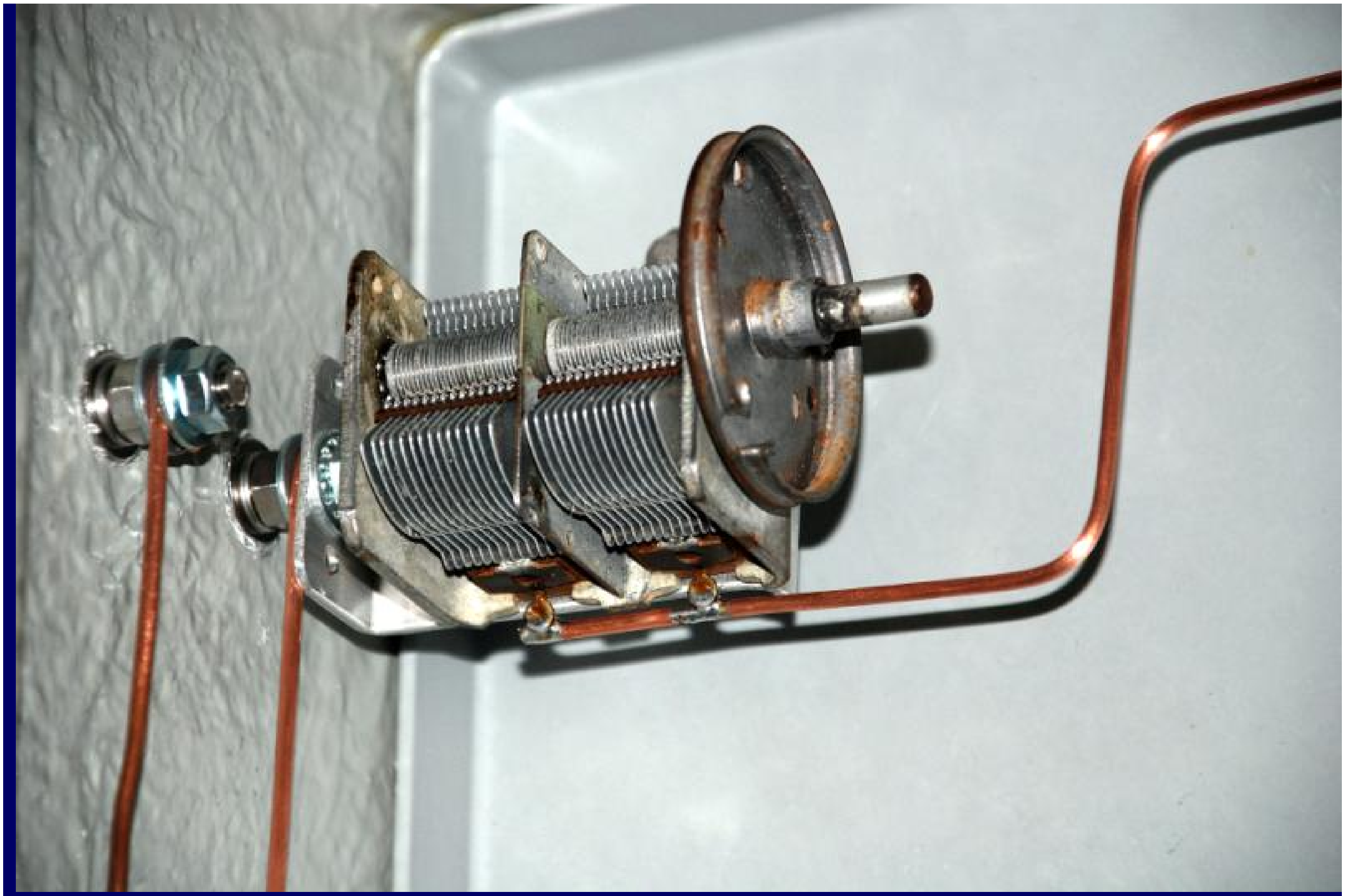

The frame of the tuning capacitor is simply bolted to an aluminum angle bracket and fastened directly to the grounded through bolt. Since the capacitor frame is grounded, I cam simply grab the dial cord drum on the end of the capacitor shaft and turn it as needed to adjust the capacitor.

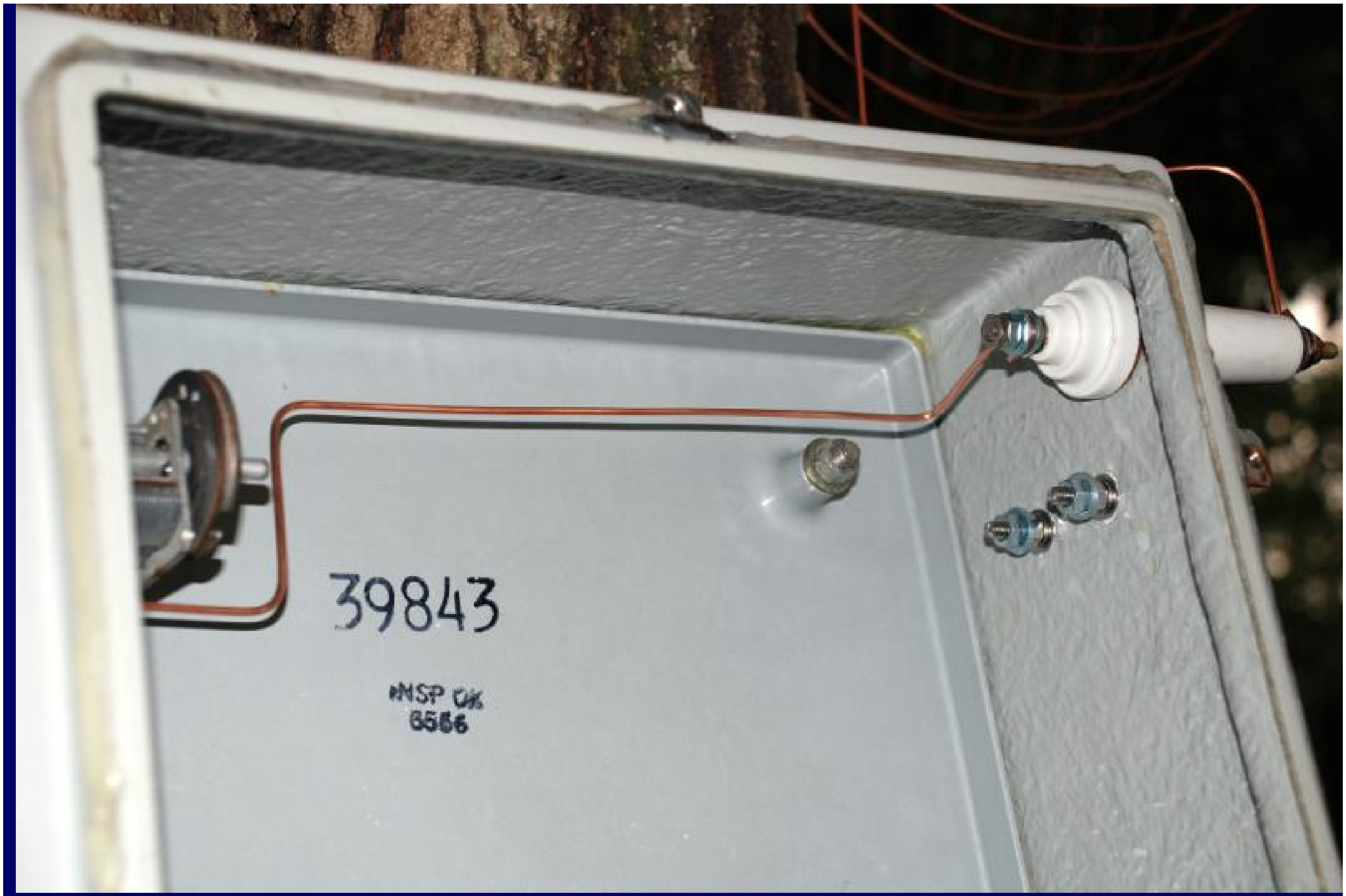

Both sections of the capacitor are in parallel, and connected to the wire leading off to the right of the picture. That wire goes through a ceramic feedthrough insulator on the right side of the enclosure and then connects to the hot side of the coupling coil.

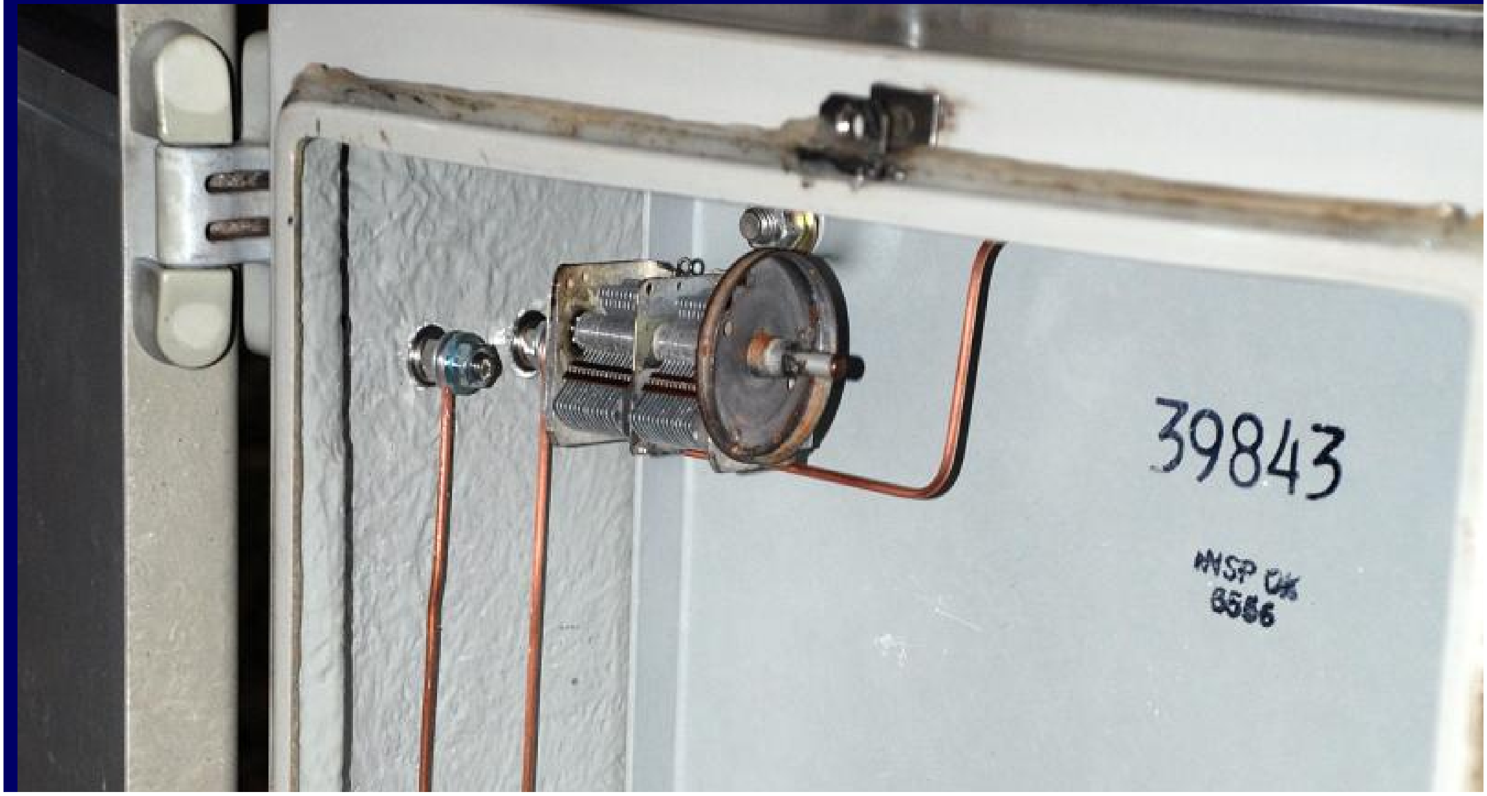

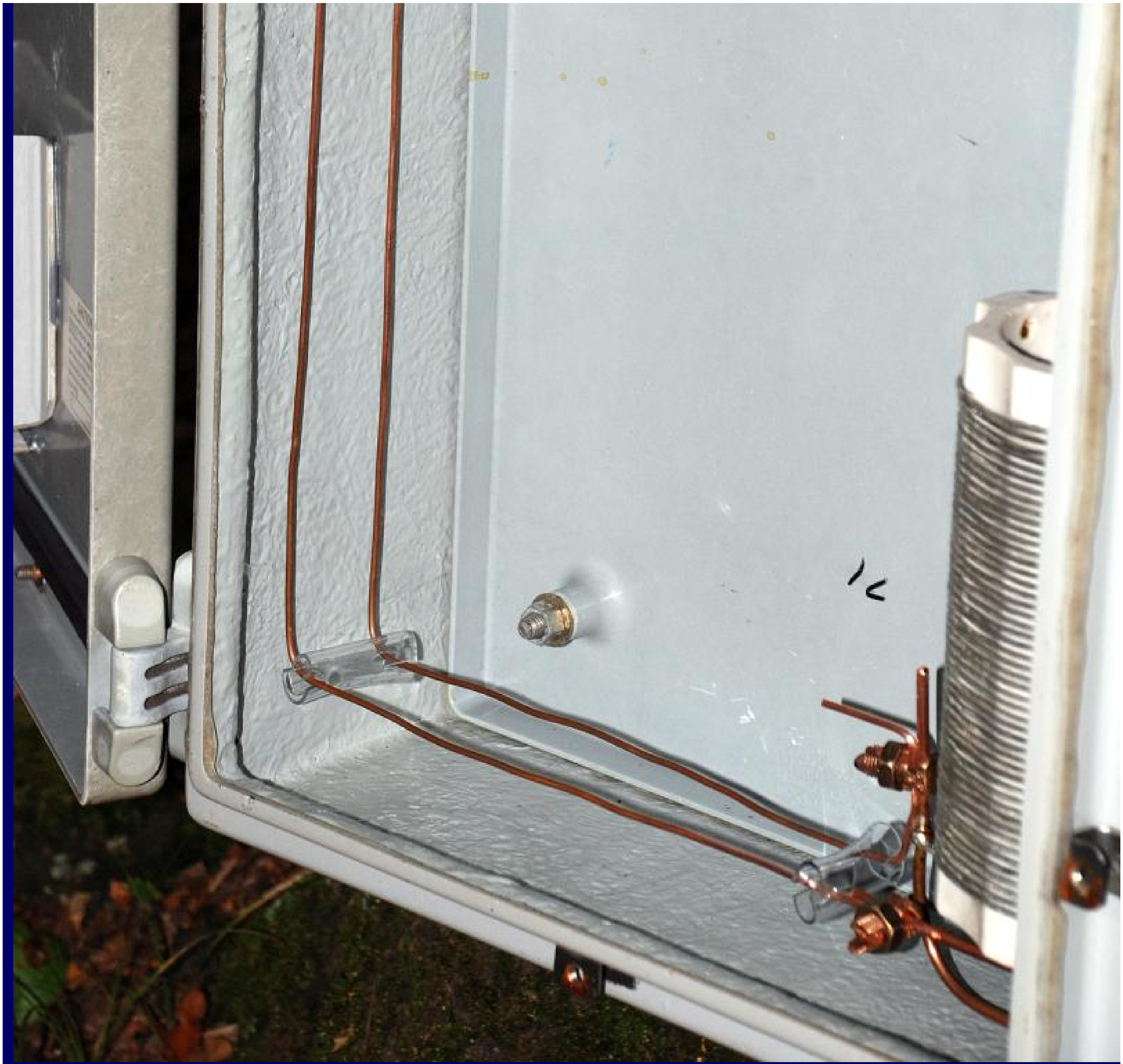

The wire closest to the back of the cabinet is the ground wire between the cold end of the coupling coil and earth ground. The wire nearest the front of the cabinet connects the coil tap to the center wire of the coaxial cable going back to the shack. Two spacers made from vinyl plastic tube that were used to hold the parallel wires in place.

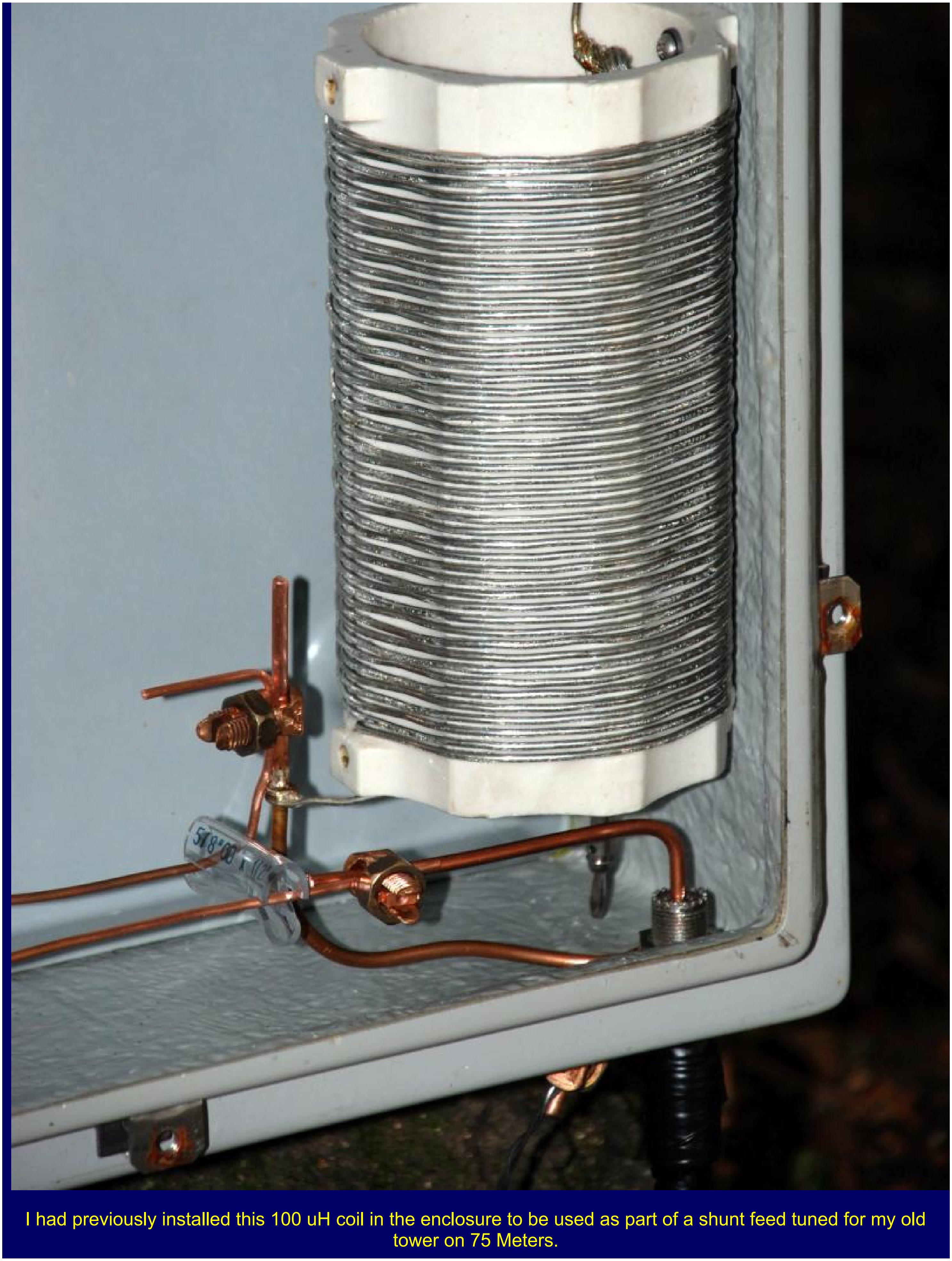

I had previously installed this 100 uH coil in the enclosure to be used as part of a shunt feed tuned for my old tower on 75 Meters.

However, even after much tinkering, it never worked properly, so I abandoned that project. It was only after removing the coil to refinish the enclosure for this tree antenna project that I realized that the cause of the problem was. It seems that when I wound the coil, I covered the winding with what apparently was a VERY good clear varnish, because it prevented the E. F. Johnson squeeze clips that I used from making contact with the wire! No wonder it would not work!! All I can figure out is that I must have had total brain fade when I built the tuner. I left the coil in the enclosure, since it just looks so nice. <G>

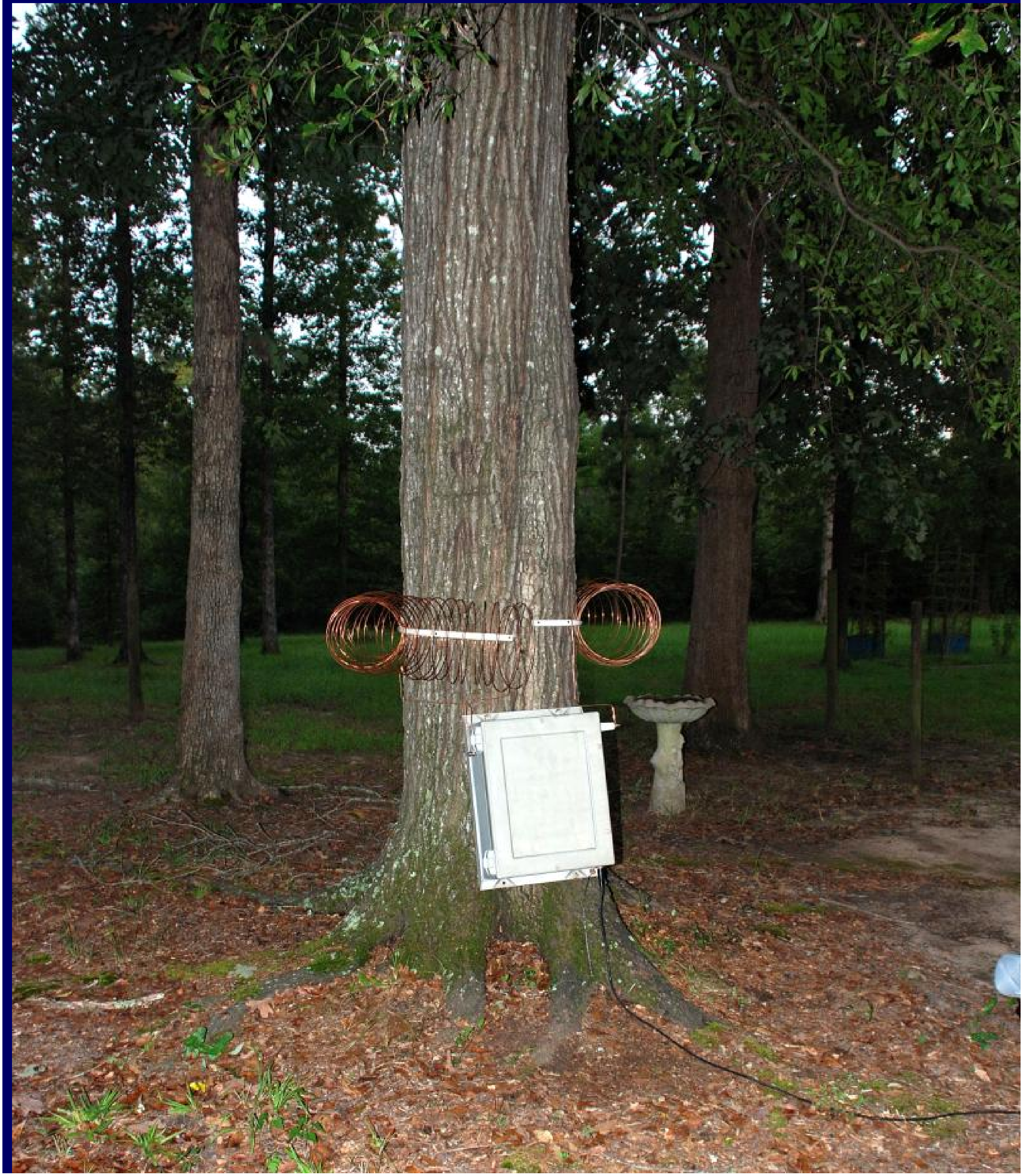

Except for the RF preamplifier, this is the finished system. I simply ran the coax cable over the ground and back to the shack. It's easy to change if I need to, and the lawn mower misses it. In a year or so, the grass will have grown over it and it won't be noticeable.

While working on the tuner, I noticed this little guy walking across the turns of the coupler coil. If he had been parallel to the turns, I probably would never have noticed him.

CLOSING THOUGHTS -

- The tree I chose for this project is about 90 feet tall. There are others available that are taller, or more in the clear, or both, but this one was in a good spot for testing. It is far enough from the house so as not to pick up much "house noise" but close enough so that I can get a long extension cord out to it to run test gear. I may try a different tree at some point.

- I suggest using aluminum electric fence wire or aluminum clothes-line wire for making the coil. That would make the coil lighter and easier to handle during construction, and the losses in the coil will not be enough greater to worry about. One advantage of the #10 bare copper wire is that it fits perfectly in the slot cut by the circular saw blade. Other types of wire may require a different width slot and considerably more construction effort.

- I strongly suggest that you drill the holes for the mounting screws through the plastic support pipe BEFORE you try to attach the coil to the tree, unless you have at least six hands to hold everything.

- Having an extra person available when you attach the coil to the tree is a great help. I did it all by myself, but I waited until the dark of the moon, on a Tuesday, and I held my tongue >just< so. ;)

- I did not use any isolation transformers between the coupling unit and the coax feedline going back to the ham shack. I did not see any extra noise pickup from the coax cable either with or without the cable grounded at the tree end of the cable. Your installation may be different, of course. I happen to have (finally!) a very low RF noise QTH.

- This coupling coil was designed for MF operation. The tuning range of the coil with the capacitor I used is from roughly 428 KHz to 1150 KHz. No detuning of the system is noticed unless you bring your hand within a few inches of the hot end of the coil. A coil with fewer turns would probably work better for HF work.

- The signal pickup of the tree antenna seems about equal to or a little less than using one side of my 160 meter dipole antenna, which is about 20 feet high. It does seem to pick up a little less noise than the dipole, so the S/N ratio appears better overall. I have not had the tree-tenna in use long enough to make any accurate conclusions.

- I have not noticed any difference in signal pickup from day to night, nor does rain seem to change the antenna characteristics.

- Tuning of the antenna may be done by using the variable capacitor or by shorting out one or more turns of the coil on the "cold" end. This raises the operating frequency but does not seem to change the sensitivity of the antenna appreciably. Since the "cold" end of the coil is grounded, a simple relay arrangement may be used to short out some of the coil turns to ground to make frequency shifts remotely.

- The antenna works even better since I installed my RF preamplifier.

73,

Ralph - W5JGV - WD2XSH/7

[BACK]

ON6MU's "Vipormutant" Antenna RE-AHFV14P

Versatile Inexpensive Portable Multi-band Tunable Antenna

de ON6MU

revision 2

AdChoices RF Antenna Design Antenna 2M 70CM Antenna

Features

- Only 3 meters high fully extended (effective radiating element height)
- Less then one meter inserted (no element is larger then one meter including the tunable section)
- Tunable without the use of an extra tuner (just switch till you get the best SWR)
- Covers all frequencies from UHF to 7 MHz without a tuner
- UHF (tuned by de- or increasing the length of the antenna) 3/4 2*5/8 4*5/8
- VHF (tuned by de- or increasing the length of the antenna) 1/4 5/8 2*5/8
- HF (tuned by switching)
  6 meters (1/4 1/2)
  10 meters (1/4)
  12 meters
  15 meters

  17 meters
  20 meters
  30 meters
  40 meters: with large counterpoise and/or with longer radiating element, or extra tuner
  80 meters: if radiating element is > 5 meters, or with large counterpoise and/or with extra tuner
- Works with or without cointerpoise
- Ideal as portable or balcony antenna
- Compact and extremly portable
- Not too critical on the material or sizes of the elements
- +- 50 watt input
- SWL's Note: tunable on all frequencies between the bands mentioned above

What you need to build the "Vipormutant"

- 5 (or more depending on how high you want your boom) alu tubes
- piece of hard insulating tube (+- 7 cm), examples: plastic, nylon, bamboo...
- some low loss RG174 50 Ohm coax
- carbon/ferrite bead or toroid (to act as a choke)
- a few meters of 0,75mm enamelled copper wire to make the coil
- SO239 (PL259 female)
- Paint, silicon, glue etc. to seal things up
- Plastic box to mount over the coil and where we'll put the switch and SO239 connector
- 12 position rotary switch
- a few innox hose clamps

About the "Vipormutant" antenna:

Well yes, one must have a name HI...It is nothing more then a base coil loaded antenna, but with a selector direct on the base to tune the antenna.
Most of us don't have the luxury of building a 1/4, 1/2 or even a 5/8 wavelength vertical antenna for HF. We have to settle for something a little shorter. (A lot shorter, in the case of people following the FCC's Part 15 rules, which limit them to 3 meters in size.) Shorter vertical antennas can give acceptable (but not spectacular) performance.
I needed a highly (HF) portable antenna to use with my FT-817 which should have the highest possible frequency range (also VHF) and still compact enough to take along almost anywhere! The antenna should be versatile enough to allow further experimenting, to allow being mounted on a balcony, caravan, outdoors etc... So I came up with a compact vertical (dismounted no higher then 1 meter) with a "tuner" directly connected to the antenna radiating element (the best possible place a tuner can be).
The "Vipormutant" tuning principle gets energy into the antenna on a wide range of frequencies, but the design of an antenna is what controls what happens to the RF energy from there. For some antennas, the antenna is simply not complete without a radial system, or at least a counterpoise. Other types of antennas need no RF ground system at all. Most reference books on antennas provide solid guidance on radials and counterpoises, but only for antennas cut to a specific frequency. When using the "Vipormutant" it will also act like tuner and at the best place a tuner should be: directly beneeth the antenna! So the rules have to change somewhat because the "Vipormutant" almost operates across the full range of HF frequencies unto UHF. It doesn't need a counterpoise to work, but the efficiency will increase when you do use it.

Considerations:

- If the length of the conductor is very short compared to a wavelength (< wave/4), the electric and magnetic fields will decrease dramatically within a distance of one or two wavelengths.
- It is impossible to make a small antenna to radiate as efficient like a big antenna.
- Ground losses affect radiation patterns and cause high signal losses for some frequencies. Such losses can be greatly reduced if a good conducting ground is provided in the vicinity of the antenna.

The coil/tuner

Wind 0,8mm enamelled copper wire around the isolator (+- 16mm diamter) and make a tap every xx turns (see fig. 2 and 3)

Fig.1

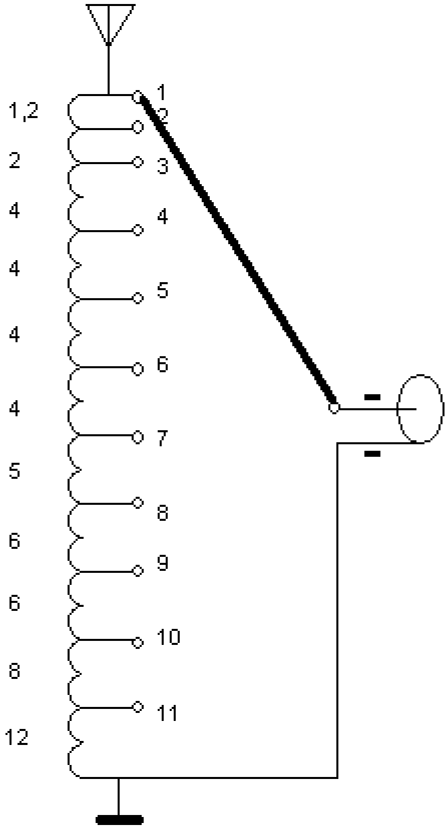

Fig.2 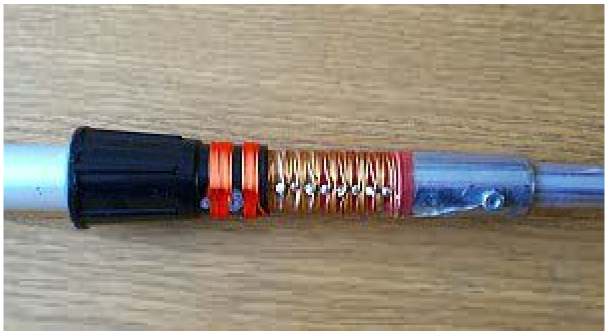 The coil dimensions isn't too critical.

Relatively short antennas behave like lossy capacitors and present a high impedance load to the transmitter due to the large amount of capacitive reactance that is present. The loading coil helps to tune out that reactance. Tuning out the reactance is important because a tuned antenna will accept and radiate much more power than a mismatched antenna.

When the loading coil is installed at the bottom of the vertical radiator, we call it a "base loaded" antenna. Base loading requires the smallest amount of inductance to achieve resonance.

The shoke

Is made out of miniature 50 Ohm coax (rg174) that goes a few turns through the carbon/ferrite bead or toroid. You can also use a Snap-Together Ferrite Choke Core.
If a ferrite is put over a cable which includes both signal and return lines, it will have no effect on the signal (differential-mode) current but it will increase the impedance to common-mode currents. This is because the differential currents, by definition, sum to zero in each wire pair and therefore there is no net magnetic field. If there is no field, the ferrite is invisible. But the common mode currents do produce a net magnetic flux and this flux is concentrated in the bulk of the ferrite, leading to an increased impedance for these currents only. The choke should prevent any mantle currents flowing and should decrease RFI.

The effectiveness can be increased by looping the cable several times through the core, but the benefit is limited at higher frequencies by the stray capacitance between the turns of the cable.

Fig 3.

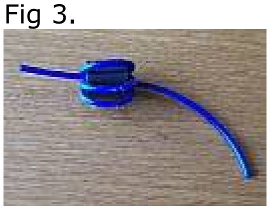

4 turns

Highlighted

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The base insulator

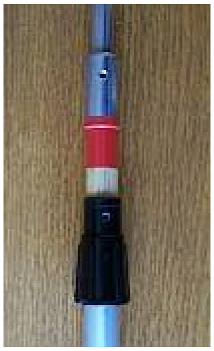

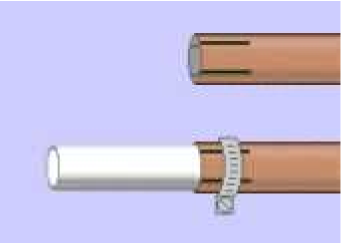

The vertical radiator "driver" element and tuning box

I used a plastic box of 130x70x40mm. On top and bottom I drilled a hole to fit the driver element (radiator of +/- 40cm length)and boom (also +/- 40cm length).
On the side I drilled a hole for the rotary switch and the SO239 connector, whilest on the opposite side I drilled a hole to fit a "ground" bolt where I can easily connect the counterpoise and/or ground to if needed.

Fig 4

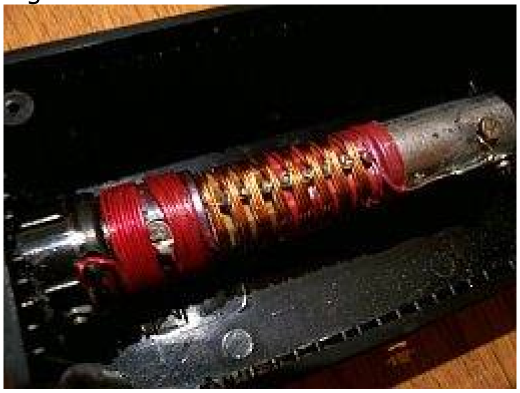

Fig 5

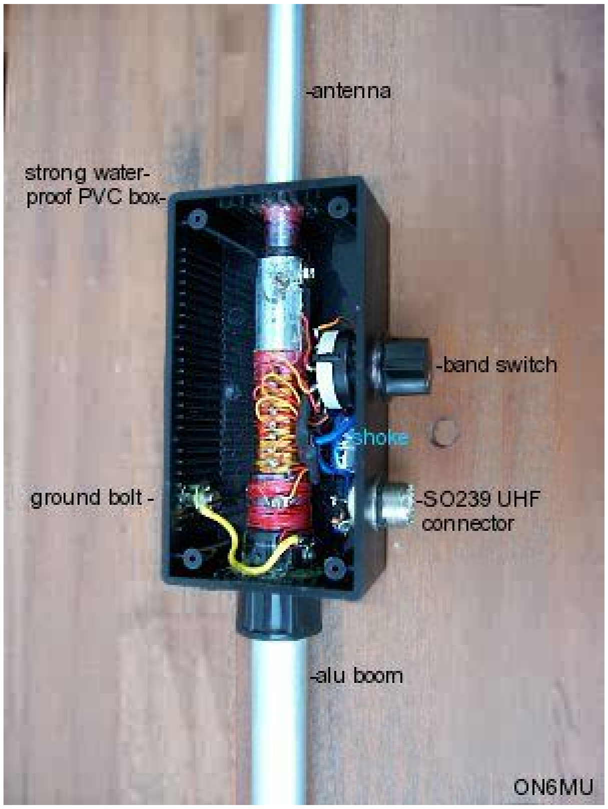
-antenna
strong water-proof PVC box-
-band switch
shoke
ground bolt -
-SO239 UHF connector
-alu boom
ON6MU

This is how things are connected inside the box:

Fig. 6

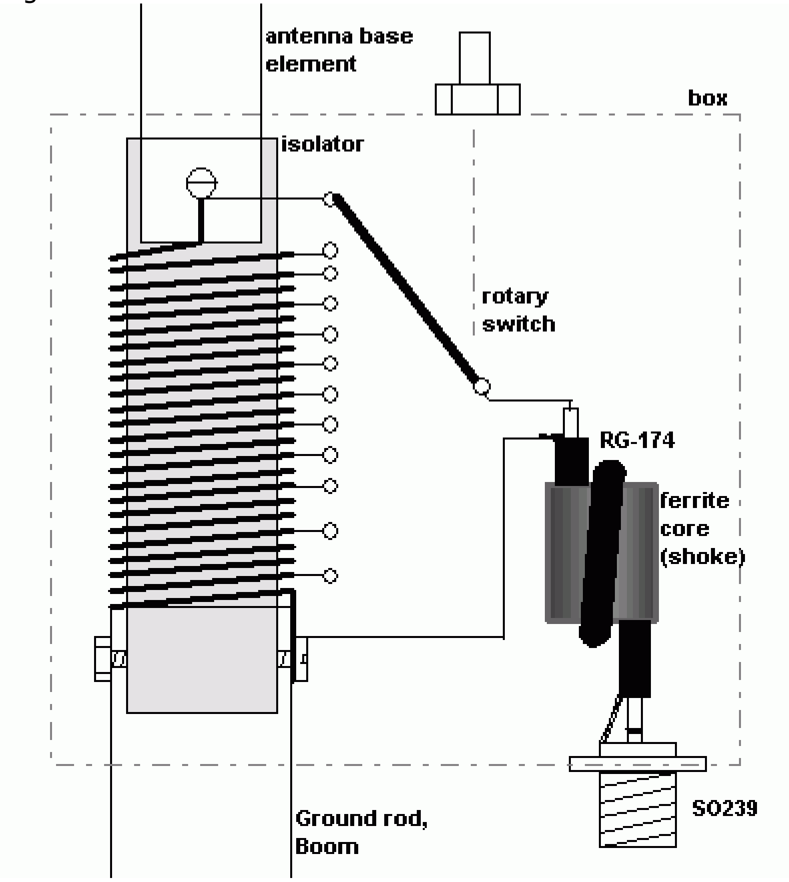
antenna base element
box
isolator
rotary switch
RG-174
ferrite core (shoke)
SO239
Ground rod, Boom

Example

The rotary switch is used for tuning the antenna on each band. The first position allows UHF/VHF ranges.
Tuning is done by sliding in/out of the elements.
The "lower" the switch (higher inductance) the lower the resonance frequency of the antenna.

Remember, and this is important too, to seal everything up so no moisture can penetrate the antenna!
Because the radiating vertical antenna elements are made out of separate pieces that fits inside each other and are tightened by hose clamps, the construction isn't waterproof.
If you use a hollow isolating piece you need to to prevent moisture from getting inside the box (via the places where the elements are hold together). I've used a rubber "stopper" that fits snugly on the bottom of the driver element and glued tight.

Black paint finishes the job:

fig. 7

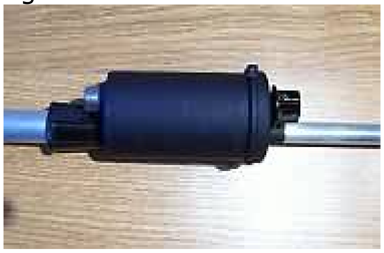

using a round box

In my first design I used a plastic box of 50mm diameter and 9 cm heigh. On top I drilled two holes: one for the driver element (radiator of 40cm) and a hole for the rotary switch (as was used in the first prototype).

fig.8: The main driver element and tuning unit finished

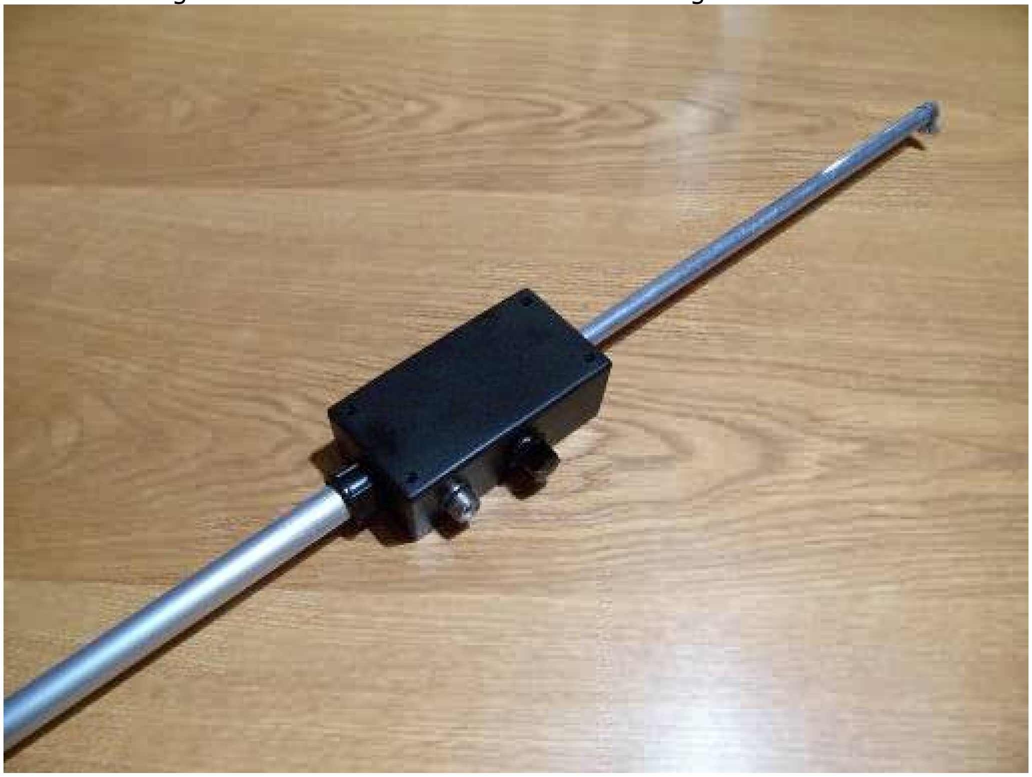

This allows it to be used on almost any boom or can be extended to use with or without vertical elements!
Ideal for experimenting!

Featuring Today

The antenna construction specs

All elements are made out of aluminum.
Fig. 9

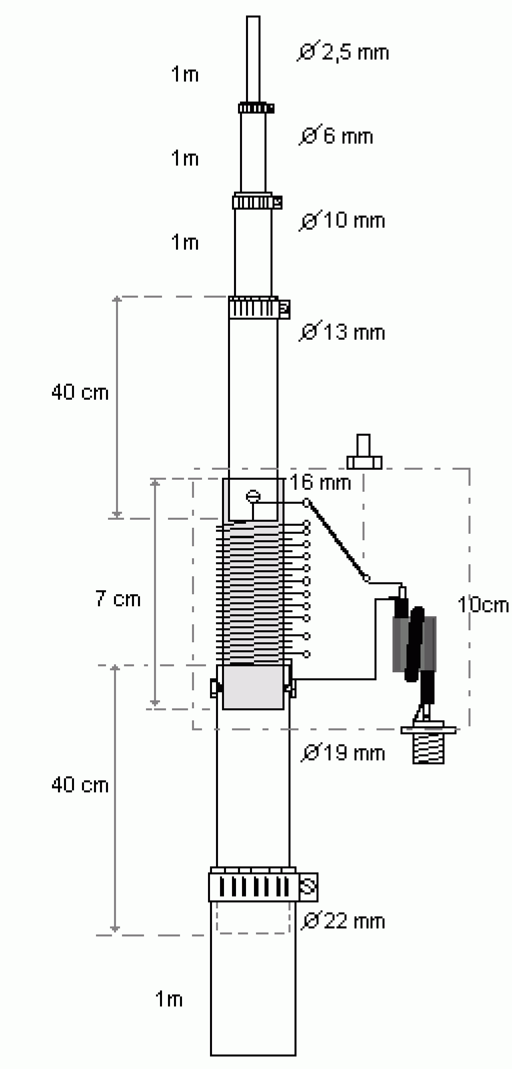
1m
Ø2,5 mm
1m
Ø6 mm
1m
Ø10 mm
40 cm
Ø13 mm
16 mm
7 cm
10cm
40 cm
Ø19 mm
Ø22 mm
1m

This makes the antenna effective radiating elements a total length of 3 meters. The boom elements can be chosen freely and on your needs. A short one (one element of a meter), a medium sized one of several 1 meter tubes or none at all! The bottom piece where the boom is "connected" too is 40 cm and can/could be put directly in the ground (if made pointed for sure). Or you could fix it in a umbrella stand. Use your imagination HI.

Examples of "Vipormutant's" utilization

Used it on a balcony:

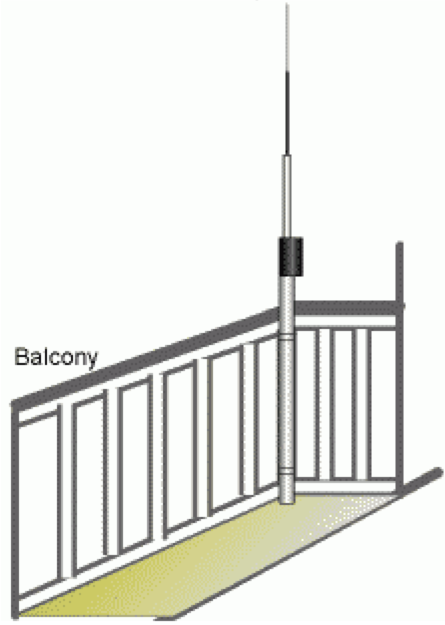

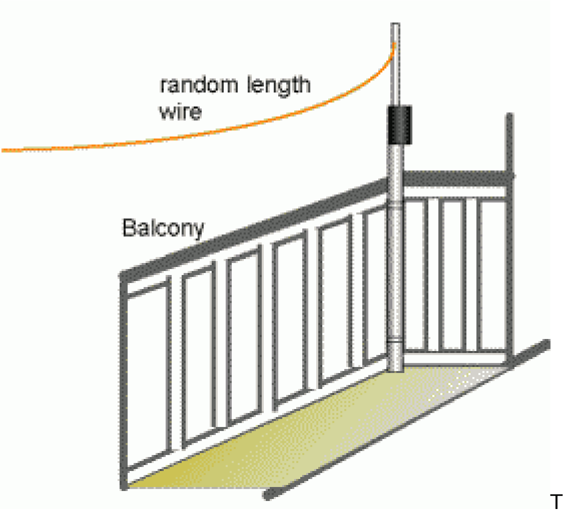
random length
wire
Balcony

This could cover even the lowest HF-bands!

Use it outdoors without grounding:

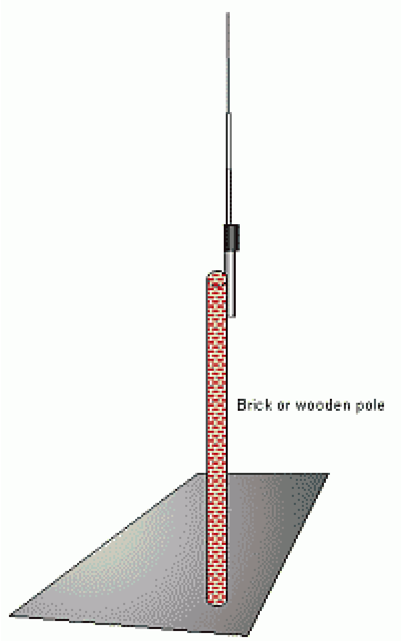
Brick or wooden pole

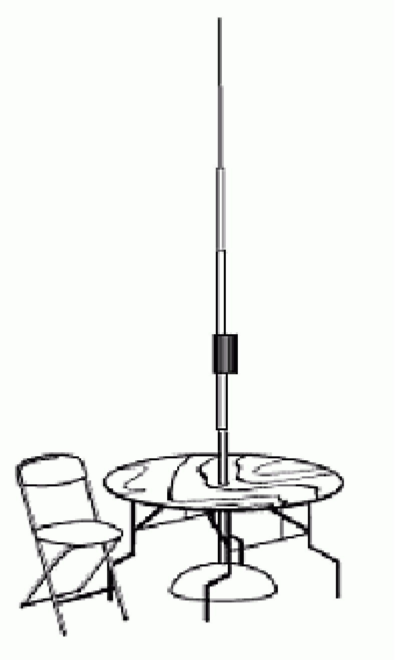

Use it outdoors as a shortened "dipole" balanced antenna (rotary switch set approx. in the middle):

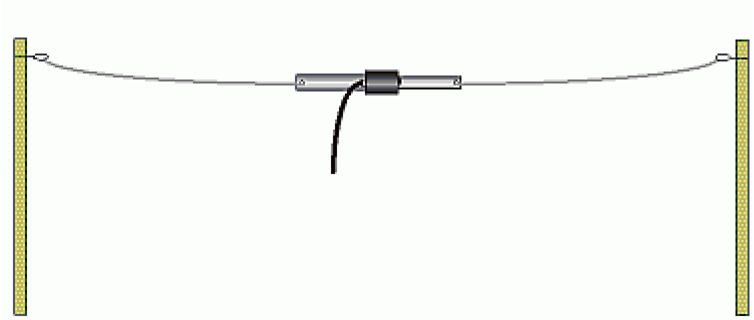

Frequencies below 7 MHz could easily be match 1:1 SWR if total length of the "dipole" > 4 meters
Further tuning can be done with selecting a different impedance using the rotary switch.
Different lengths of wire can be used (an example: one part 3 meter, the other 5 meter or more)

Use it outdoors with ground or counterpoise:

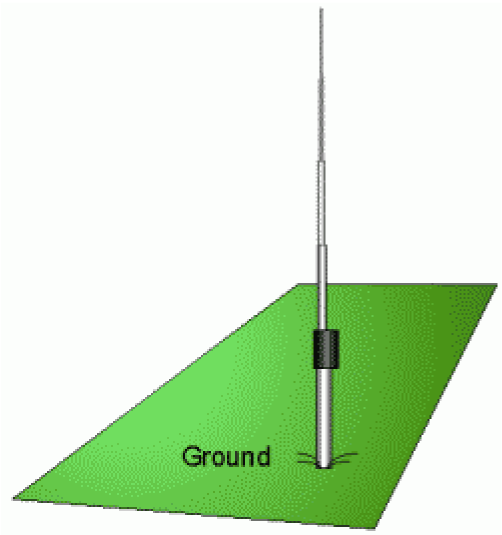

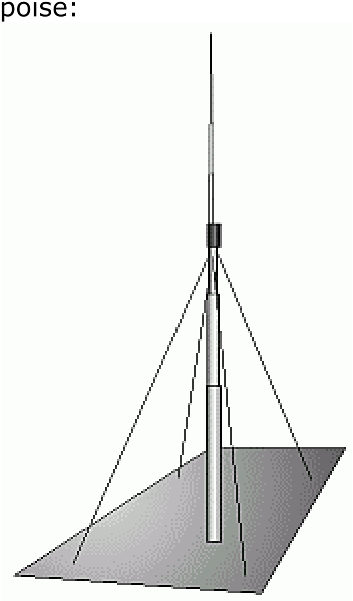

Radials and Counterpoises basic purposes:

1. To improve the RF ground conductivity for the ground current return path. Unless you live in a salt-water swamp, your ground conductivity makes a very poor path for the return of ground currents. This increases the ground losses and reduces the efficiency of an antenna that needs a good RF ground.

2. To provide a counterbalance for the feed point of the antenna to reduce RF radiation back to the radio room. The "Vipormutant" changes the rules because there is no single frequency that you will be operating on, so all of the thumb rules for 1/4 and 1/2 wavelength radials don’t apply. It is possible to be either a purist or a pragmatist in deciding what radials to put in place.

3. Number of radials: More is better, up to a point. In carefully controlled experiments, it has been proved that increasing the number of radials from 2 to 15, or from 4 to 16, produces significant increases in signal strength. Further increasing the number of radials to 60 only produces 1 to 2 dB of increase in field strength. Follow this link to see some of the empirical data.

4. Where to put the radials: For a semi-permanent installation, it is customary to bury the radials a few inches down in the soil. This makes it much easier to mow and walk in the area around the antenna. However, some experimenters have gotten an improvement in performance by raising the radials and the antenna base a few inches above the soil. Raising the antenna and ground system several meters above the earth, for example by installing the base of the antenna on a roof-top, can improve the antenna's performance by reducing capacitive earth losses.

While the "Vipormutant" will provide a good match with a poor RF ground system which will will able you to transmit, your antenna efficiency will be low. Nevertheless, by using a tuning circuit directly at the antenna radiating element losses are kept to a miminum. Getting the greatest efficiency out of your antenna system needs a proper RF ground unless you’re using a balanced antenna system

The efficiency of the antenna increases by using a counterpoise. However, the antenna can be tuned perfectly without!

Don't forget to check these out:

ON6MU Homebrew projects
Radioamateur related projects

ON6MU Ham mods
Modifications of transceivers

ALLIED ELECTRONICS & AUTOMATION
Allied Doesn't Take Lighting Lightly
MW MEAN WELL
SHOP NOW

73"

Have fun and my best 73"

Guy, ON6MU
http://www.qsl.net/on6mu

Comments, pictures or experiences with my antenna are always welcome!

ON6MU

9:1 Magnetic Longwire Balun / Unun

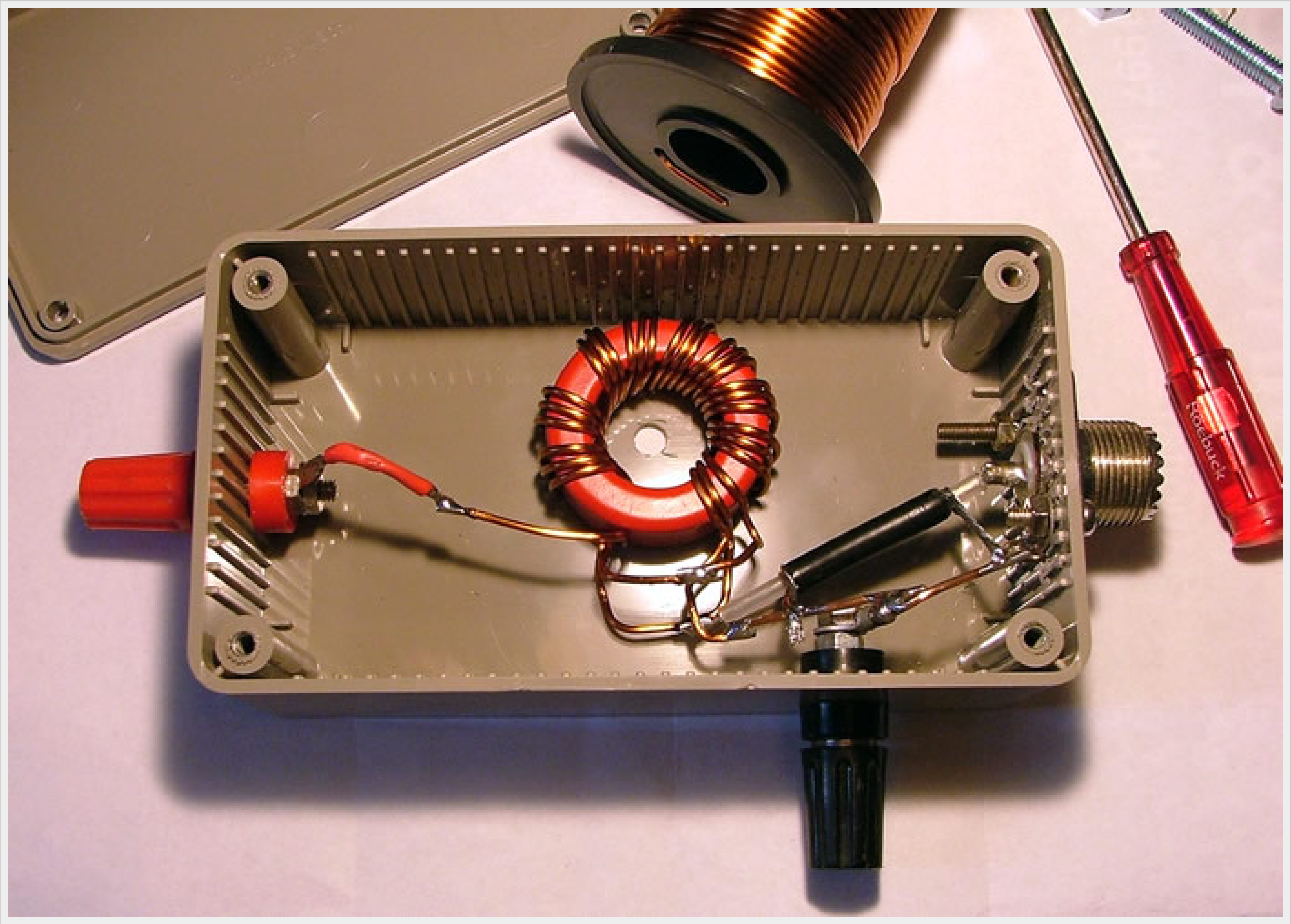

Completed 9:1 UnUn

These are sometimes known as a *Magnetic Longwire Balun*. Its really an impedance transformer (9:1) to feed a high impedance, end fed (unbalanced) random wire which is likely to be a few hundred ohms, and transform it into something closer to a 50Ω (unbalanced) coaxial input, hence UnUn. It can however also be used as a balun by not grounding the other half of the balanced output. The toroid is a T130-2 Iron Powder core, with 3 x 9 turns of 18SWG enammeled copper wire, and the connections can be seen below.

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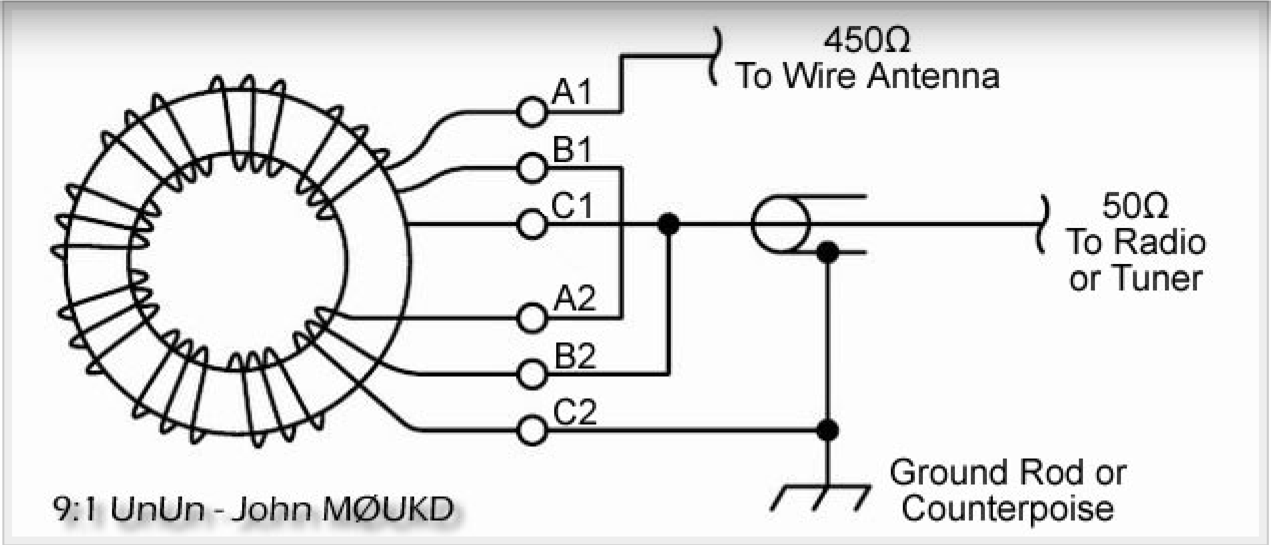
450Ω
To Wire Antenna
A1
B1
C1
A2
B2
C2
50Ω
To Radio
or Tuner
Ground Rod or
Counterpoise
9:1 UnUn - John MØUKD

The triple winding connections. 8 turns is shown here, but more turns is preferred. 10 would be ideal.

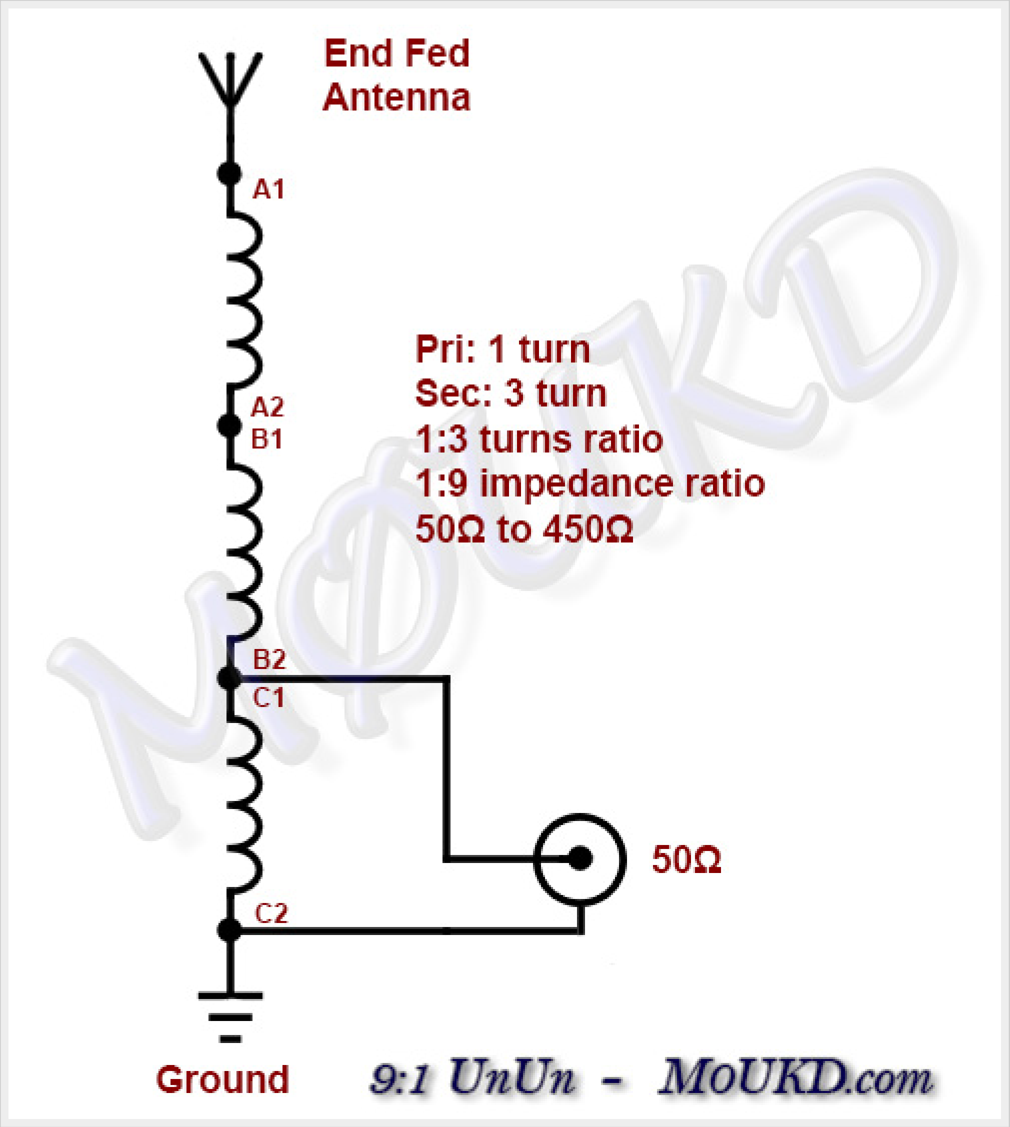
End Fed
Antenna
A1
A2
B1
B2
C1
C2
Pri: 1 turn
Sec: 3 turn
1:3 turns ratio
1:9 impedance ratio
50Ω to 450Ω
50Ω
Ground
9:1 UnUn - MOUKD.com
MØUKD

9:1 UnUn Schematic

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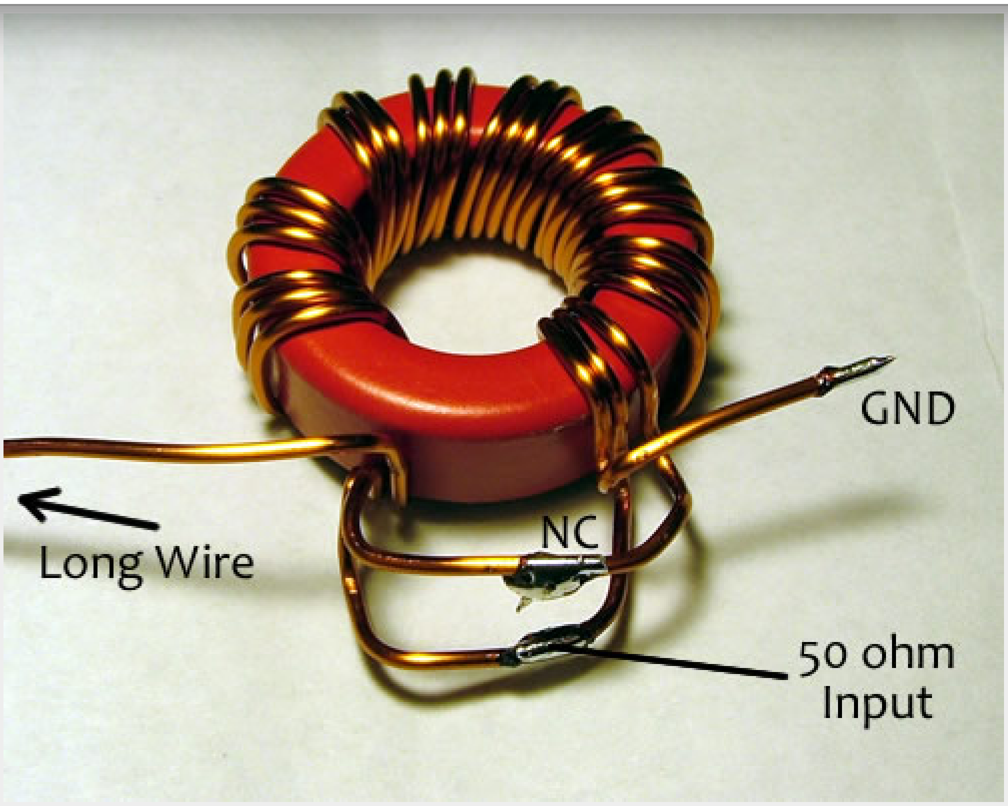
GND
Long Wire
NC
50 ohm
Input

Completed windings

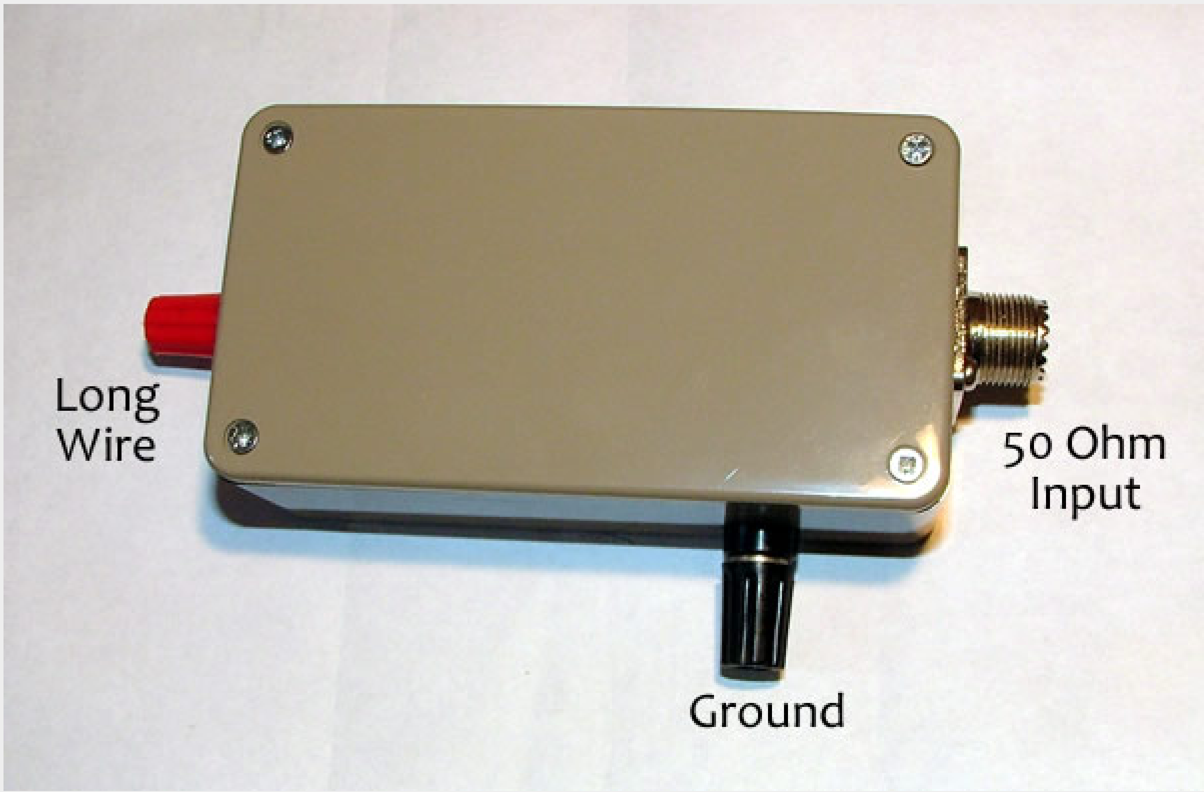
Long
Wire
50 Ohm
Input
Ground

The completed unit.

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1:1 Voltage Balun for HF wire dipoles

Heres a neat 1:1 50 ohm balun for use on HF horizontal wire dipoles. It uses an AM radio ferrite rod, with 3×14 turns of wire. 10-14 turns should be good for 2-30MHz. I used 18SWG enammeled copper wire. It all fits in a small project box. Great for setting up portable. For 20 metres, I started with 6 metres of wire per element, and trimmed each down until it has minimum S.W.R. I managed to get a 1:1.1 S.W.R. on my desired frequency. Bandwidth from the resonant frequency is about 200KHz either way, any more needs an ATU. The wire and ferrite core I had already, the box, terminal plugs and SO-239 came to about £6. The balun can also be built on a ferrite toroid such as an FT140-43 or FT240-43.

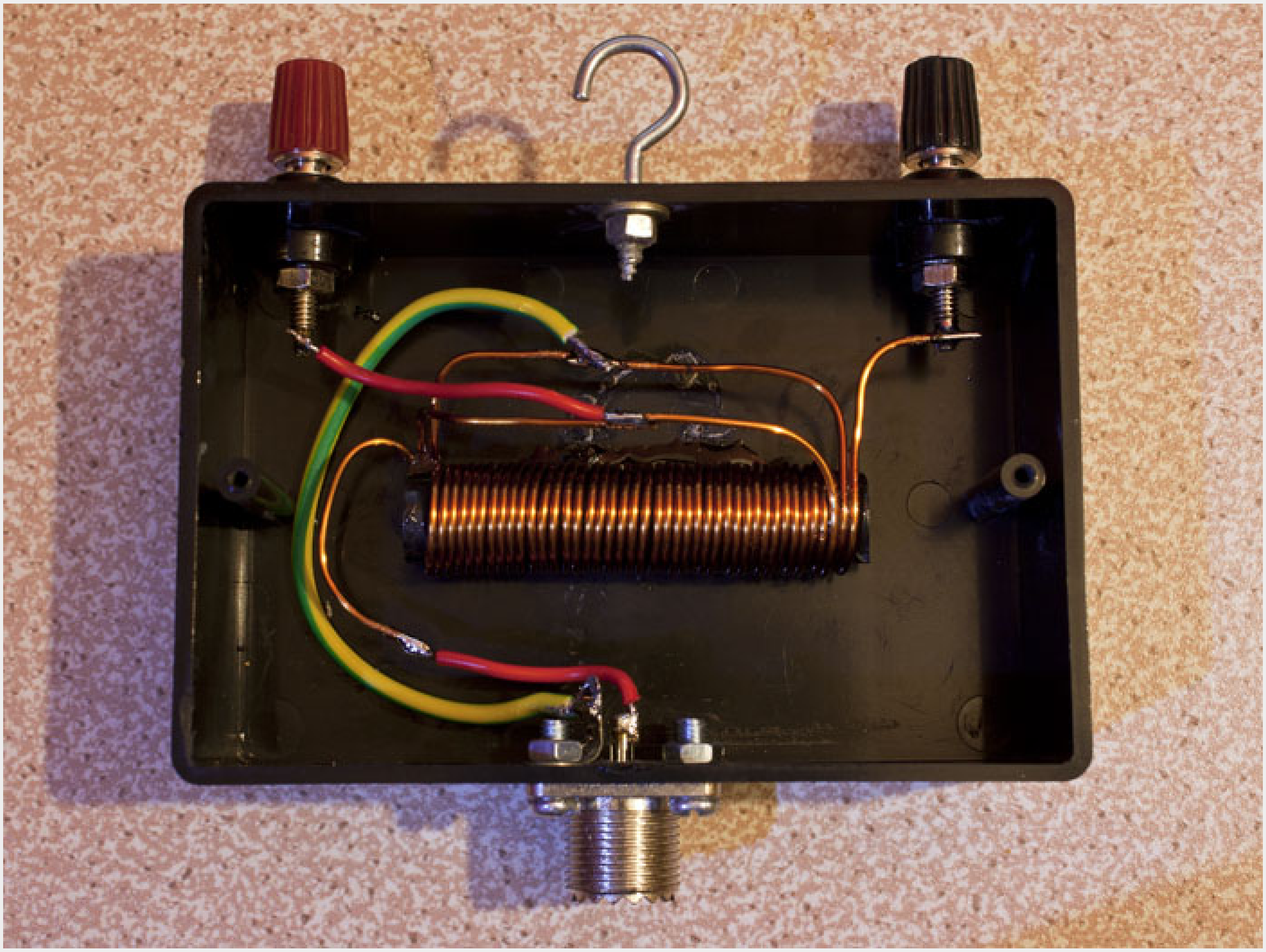

1:1 ferrite rod voltage balun

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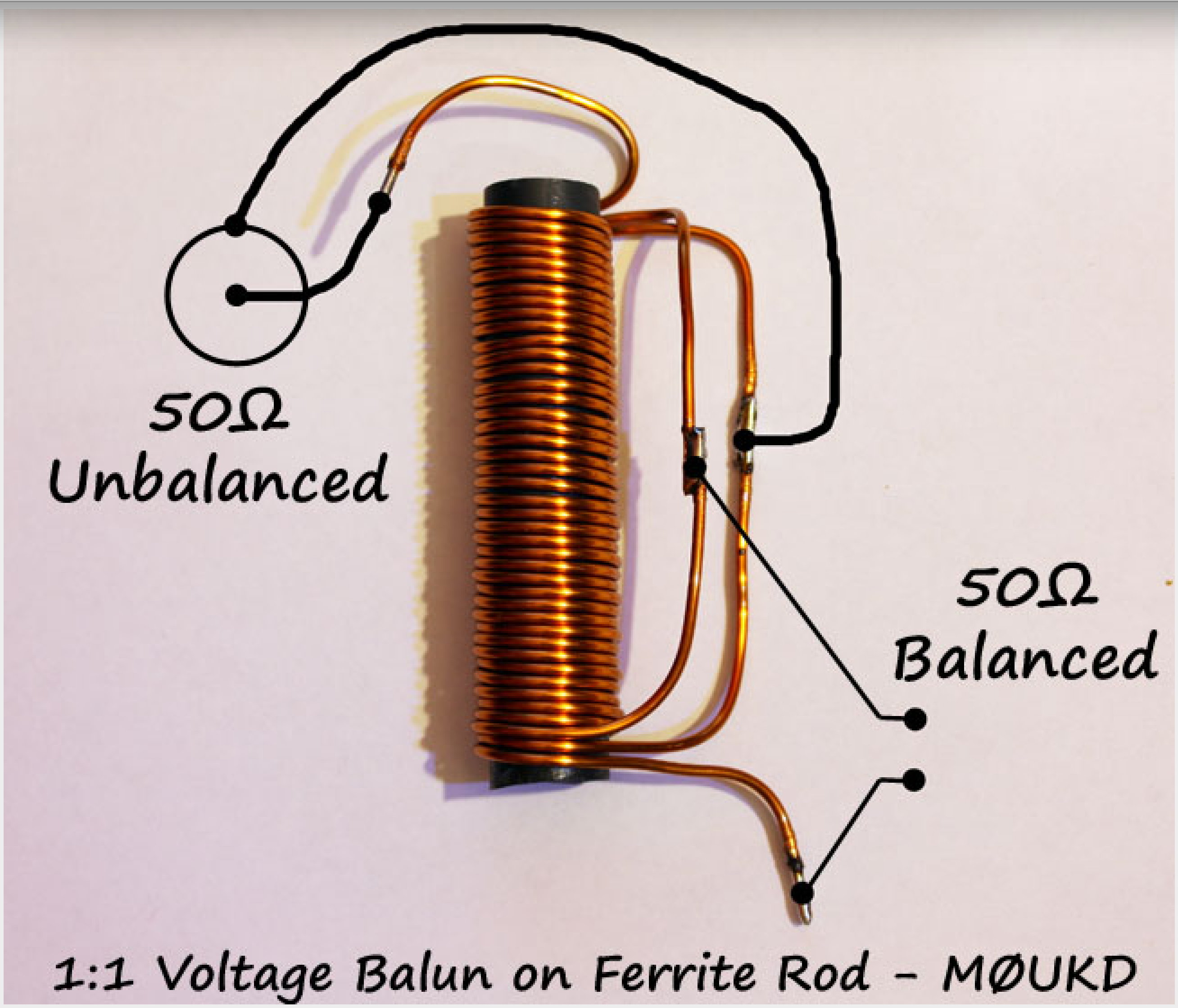
50Ω
Unbalanced
50Ω
Balanced
1:1 Voltage Balun on Ferrite Rod - M0UKD

Bandwidth may be increased by more spacing between each trifilar turn. I didn't have room on this tiny ferrite rod, but it performs OK.

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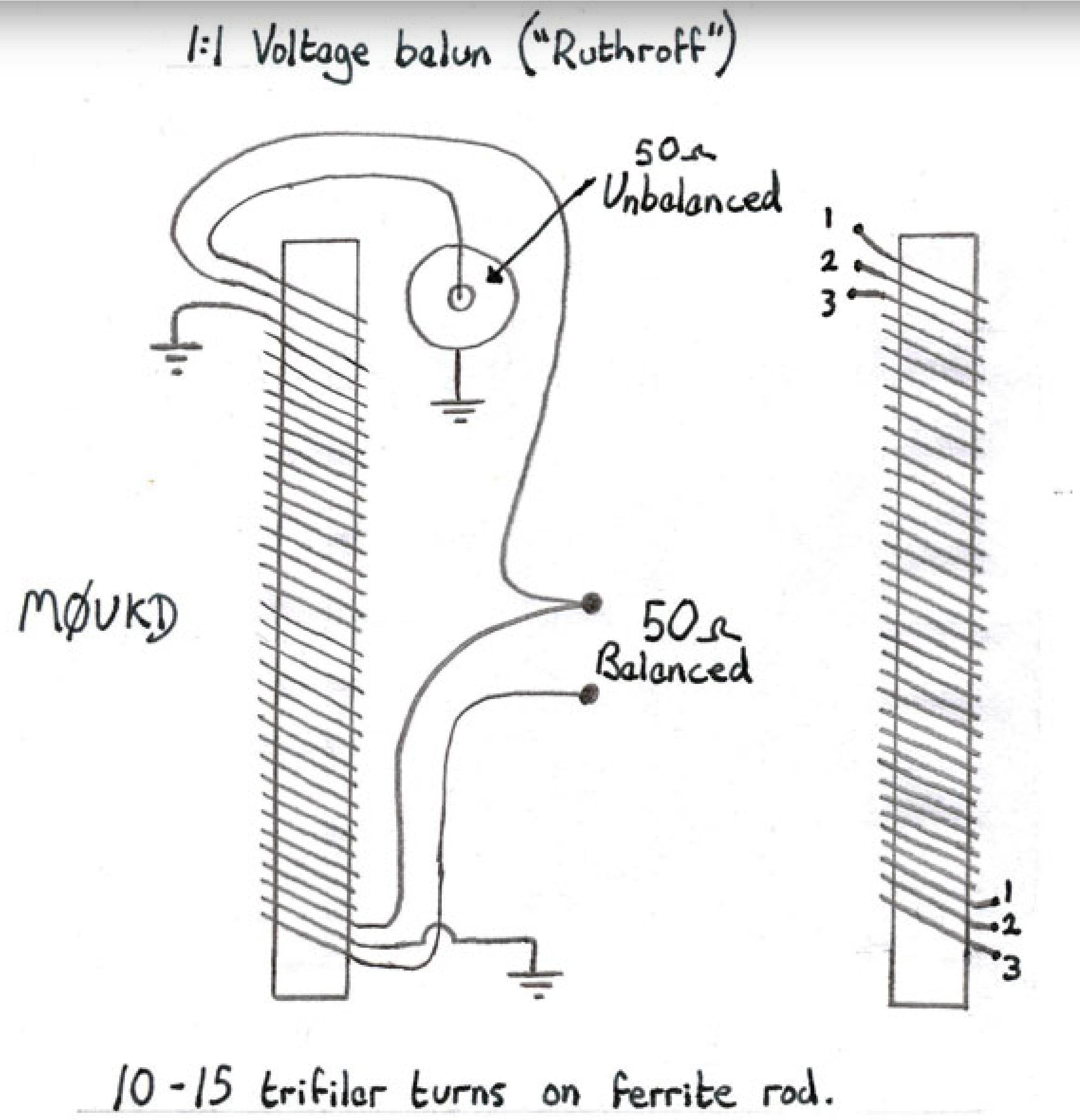
1:1 Voltage balun ("Ruthroff")
50Ω
Unbalanced
M0UKD
50Ω
Balanced
1
2
3
1
2
3
10-15 trifiler turns on ferrite rod.

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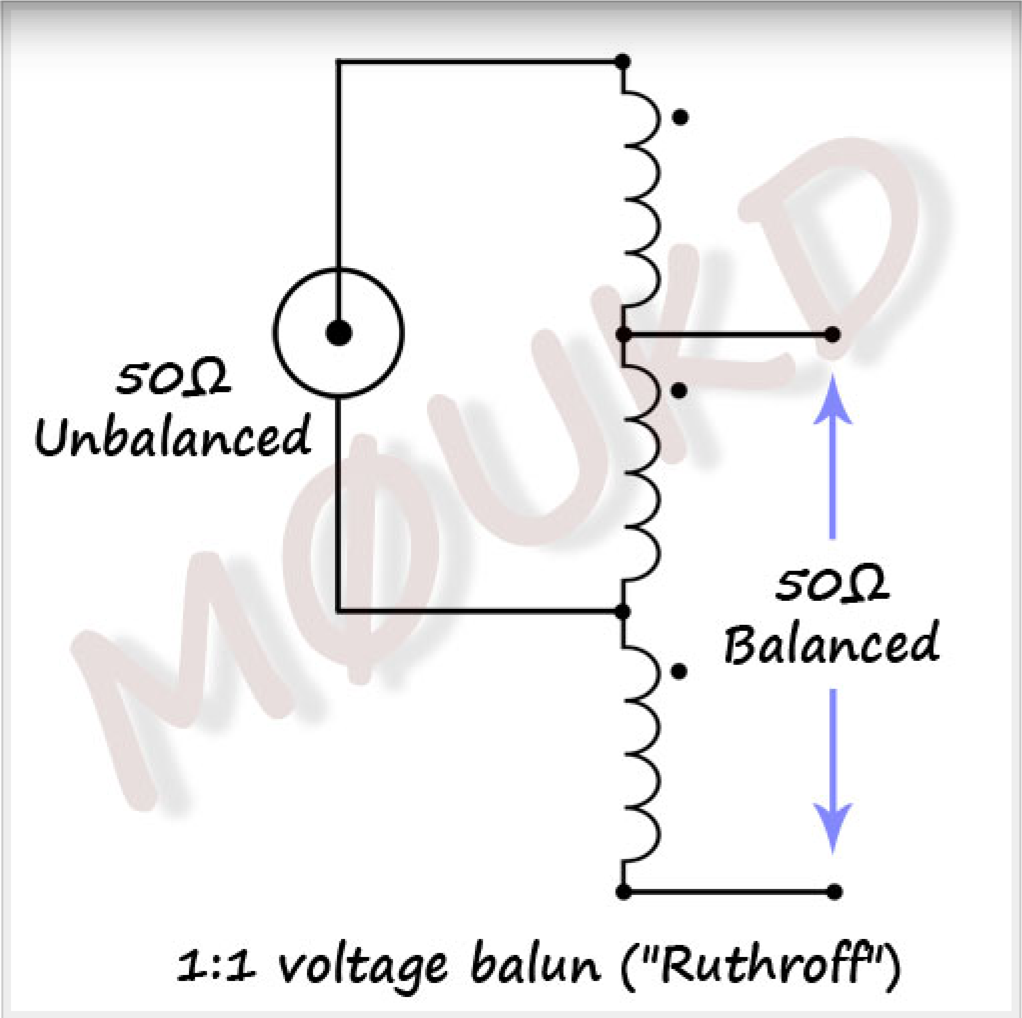
50Ω
Unbalanced
50Ω
Balanced
1:1 voltage balun ("Ruthroff")
M0UKD

Schematic Diagram

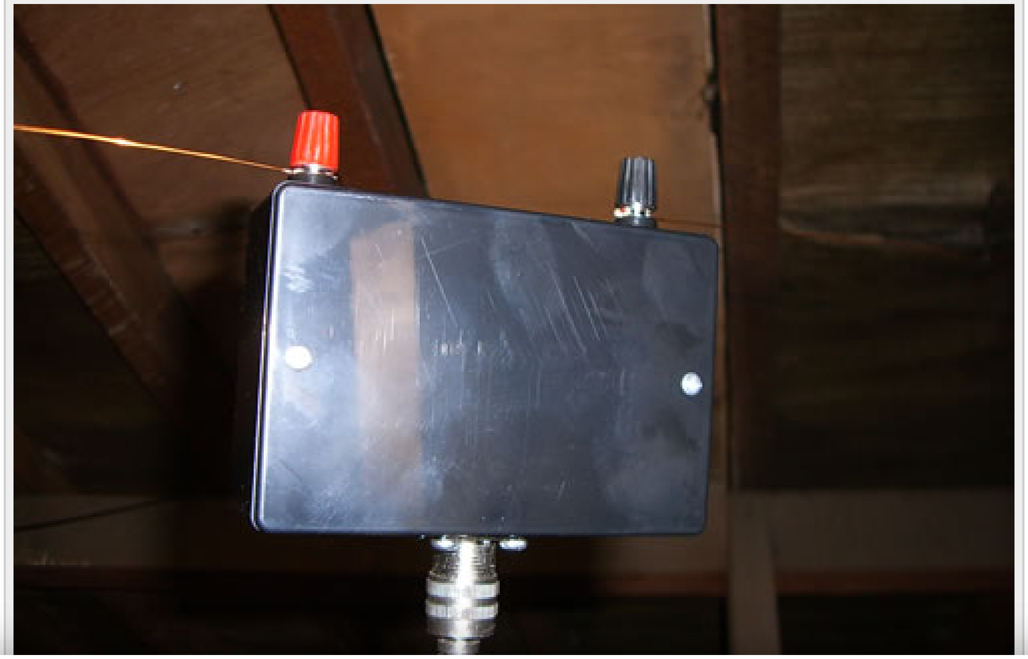

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End Fed Half Wave Antenna Coupler (EFHW)

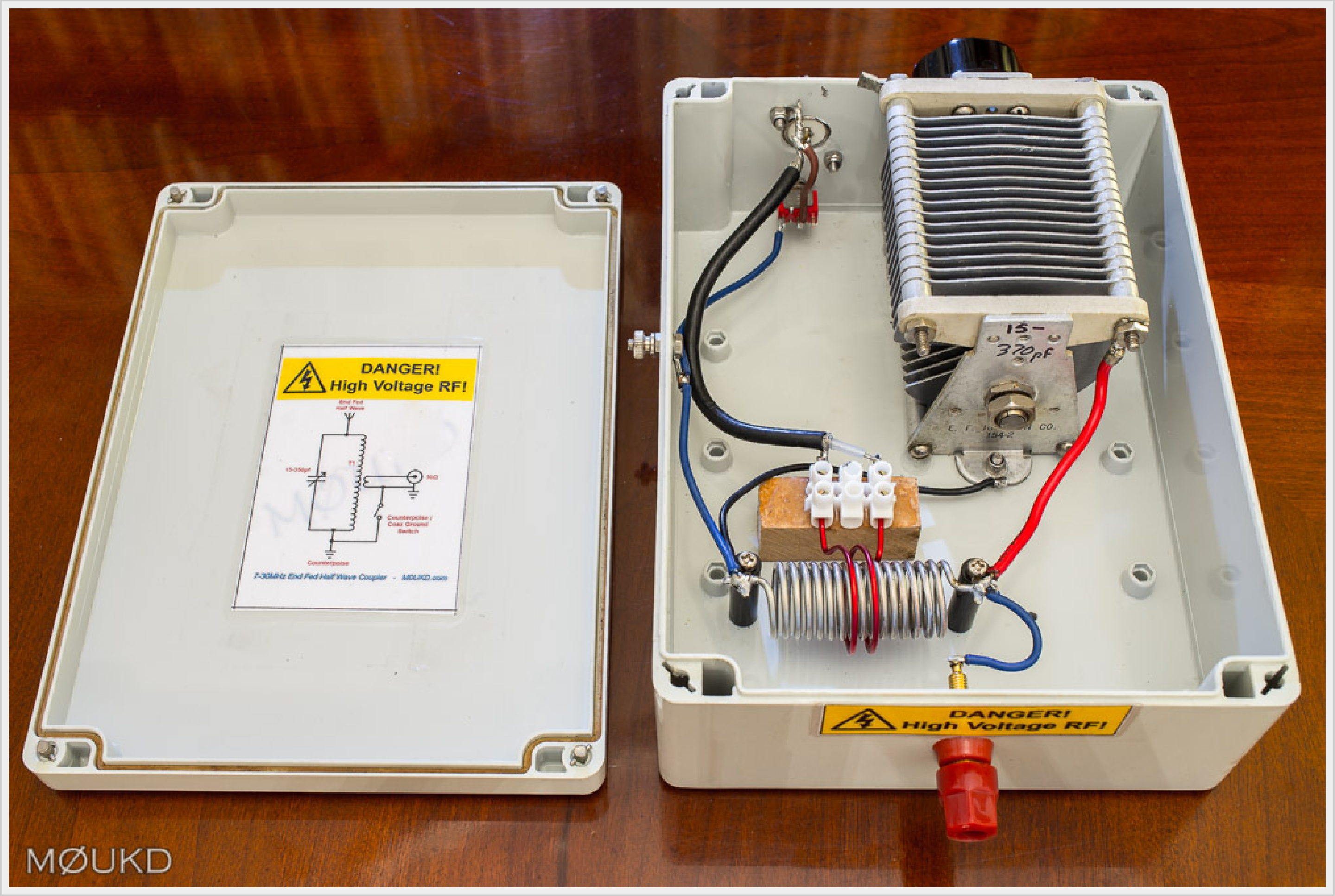

The finished End Fed Half Wave antenna coupler.

Centre fed half wave dipoles make great, simple and effective antennas for the HF bands. Sometimes however, the centre feed is not ideal, for example when you want to use it as a vertical. Being able to feed the dipole from one end gives you more options on how to erect an antenna and makes portable operation easier. A vertical, a sloper, a piece of wire hung in a hedge are all good examples. A ground mounted half wave vertical has a peak radiation angle of 20°, so it makes a good choice for DX.

I have been experimenting with feeding end fed half wave antennas matched by a parallel tuned circuit coupler. This article will explain my findings and reasons for constructing it the way I did.

A dipole can be fed anywhere along its length. A centre feed gives around 70Ω. A ‘Windom’ type off centre fed dipole (fed 38% along its length) provides around a 200Ω feed. The feed impedance at the very end of a half wave is thousands of ohms, usually somewhere between 2000Ω to 5000Ω, which we need to match to our 50Ω transceiver. The problem with end feeding a half wave is also its advantage. The high impedance means that the feedpoint has a very high voltage but low current, therefore very little ground is required. A very small counterpoise should be adequate from 7 to 30MHz, or you can even use the coax and transceiver

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Below is the schematic of the final build.

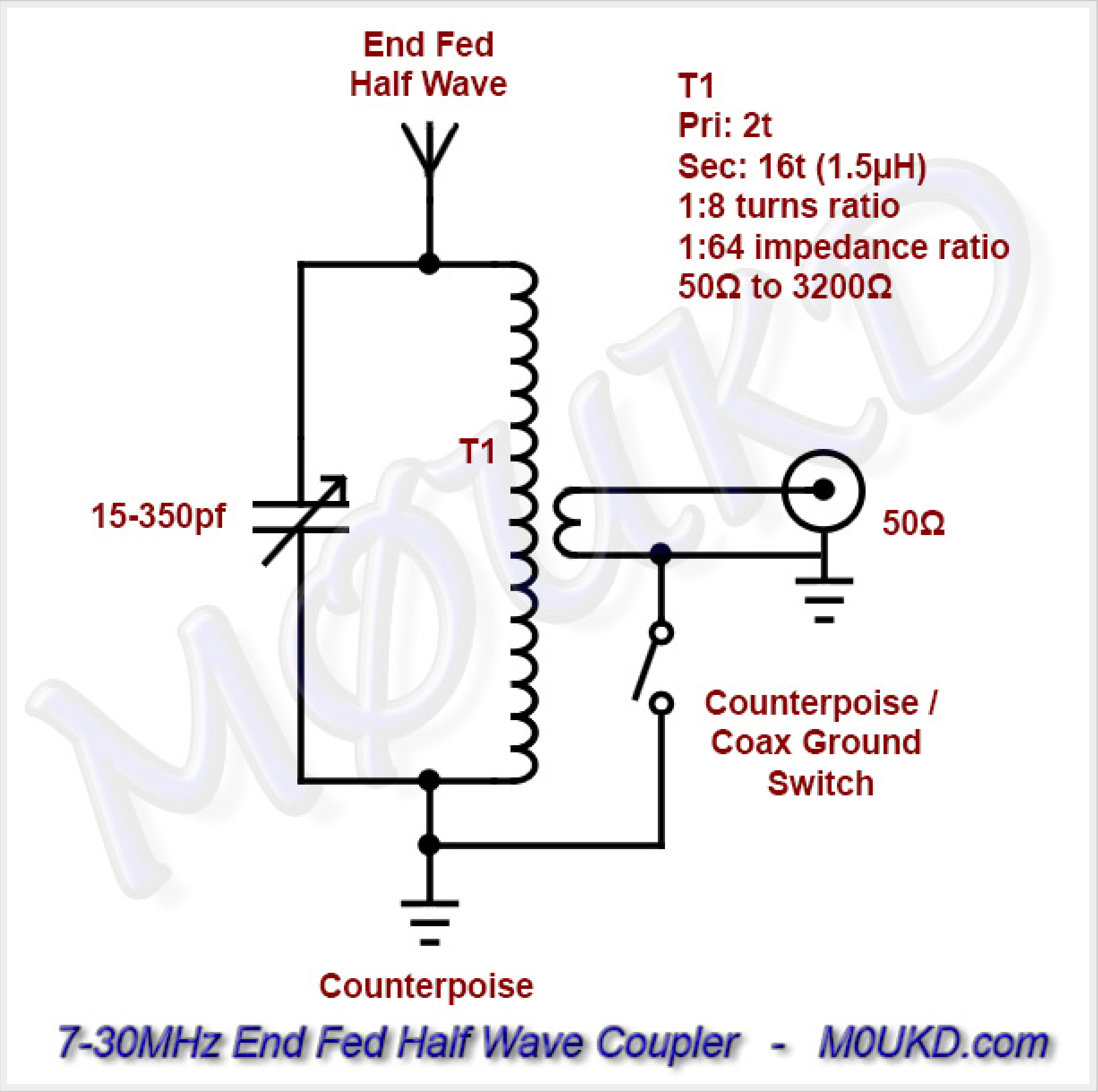
End Fed
Half Wave
T1
Pri: 2t
Sec: 16t (1.5µH)
1:8 turns ratio
1:64 impedance ratio
50Ω to 3200Ω
T1
15-350pf
50Ω
Counterpoise /
Coax Ground
Switch
Counterpoise
7-30MHz End Fed Half Wave Coupler - M0UKD.com
MØUKD

End Fed Half Wave Antenna Coupler Schematic – 7-30MHz

For calculating the length of a half wave in metres, I use 141÷*f* (MHz) for wire elements. These dimensions were derived from modelling the antenna in EZNEC. I have found this calculation to work well, however it depends on many factors such as wire used, location etc. I have made a javascript calculator below for simplicity with a 15m half wave ready to go!

Enter the frequency: 21.25 MHz

Calculate

Half Wave antenna is: Metres

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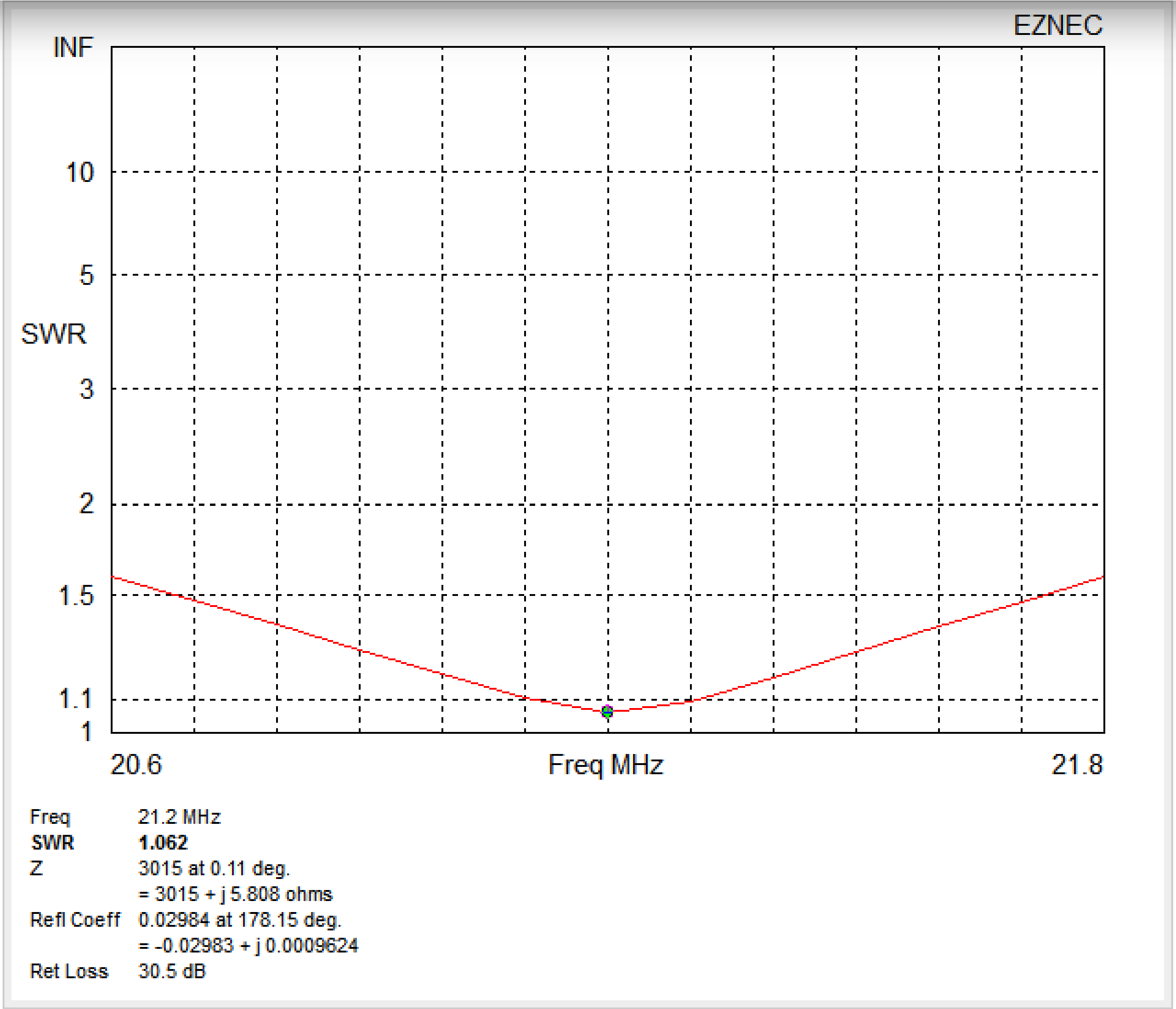

```
Freq        21.2 MHz
SWR         1.062
Z           3015 at 0.11 deg.
            = 3015 + j 5.808 ohms
Refl Coeff  0.02984 at 178.15 deg.
            = -0.02983 + j 0.0009624
Ret Loss    30.5 dB
```

End Fed Half Wave (6.65m @ 21.2MHz, ground mounted) SWR – Actual bandwidth on the 50Ω side of the coupler will be much narrower, due to the tuned circuit we are using. This is showing the feed point SWR at 3200Ω

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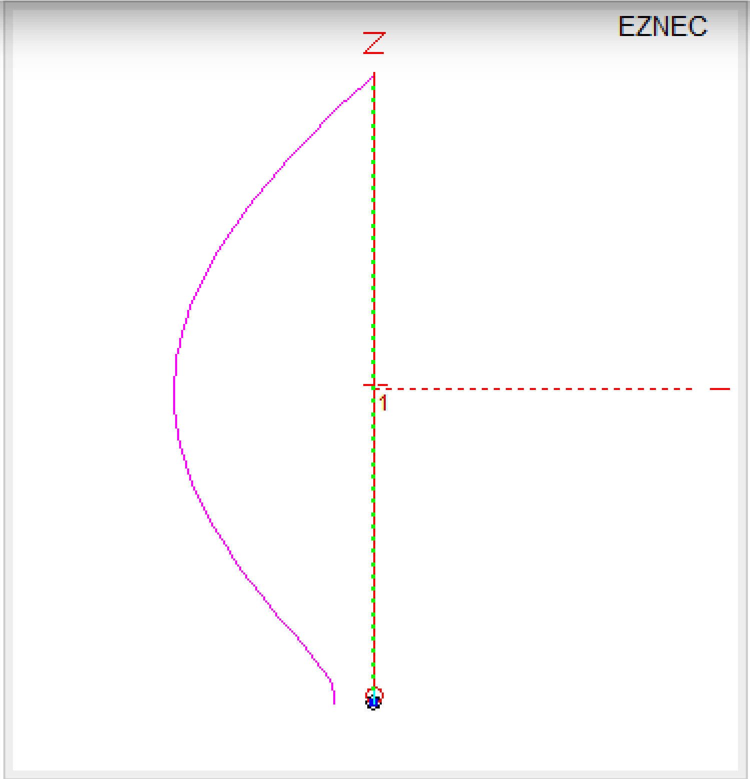

Current along the half wave. Notice how the feedpoint is not quite as high impedance as the top of the antenna.

First off, construction will be a juggle between available components and the desired band coverage. I had a capacitor that I wanted to use, which is a Johnson 154-2 air variable capacitor, with a range of 15-353pf. I would like to cover 7 to 30MHz with my coupler if possibe, so the next thing I needed to design was an inductor that would resonate in a parallel LC circuit at just above 30MHz when the capacitor is at minimum. Using this **Resonant LC Calculator**, I worked out that an inductance of 1.5μH will resonate at about 33MHz when the capacitor is at 15pf and 6.9MHz when the capacitor is at its maximum of 353pf. Sounds perfect to me! If you have a smaller value capacitor, for example 200pf maximum, it should still cover 10MHZ to 30MHz. A switch could be added to add a further capacitance of 150-200pf to include 7MHz operation.

So, lets build the secondary transformer inductor first. I wanted to transform 50Ω to around 3000Ω. This would require a 1:8 turns ratio. Impedance transformation is calculated by squaring the secondary turns ratio (note ratio, not actual turns) 8^2 is 64. 50×64=3200Ω (our input impedance x 8^2). I looked at using a **T200-6** iron powder toroid, but the problem was 1.5μH required *only* 12 turns. As I wanted a 1:8 turns ratio (for a 1:64 impedance ratio), I needed a primary of 1.33 turns, which was going to be impossible. I could have made it 16 turns and a 2 turn primary, but then the inductance would be too large for 30MHz.

So, I decided to use an air wound transformer. This way, I can build it with a 16 turn secondary, *and* at the inductance I wanted by altering the diameter and/or length of the coil. Using this **Air Inductance Calculator**, I worked out that a 19mm diameter, 52mm long, 16 turn inductor should give an inductance of 1.5uH, so this is what I built.

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drywipe marker
horizontally

Winding the secondary inductor

Once it was wound, I tested it on an LC meter, which confirmed it was around 1.5µH. You can expand or contract the inductor to fine tune the impedance to suit. The importance is that it remains 16 turns to match with the 2 turn primary. I then wound the primary coil, which had to be a slightly larger diameter so that it could fit over the secondary coil and provide inductive coupling. You can see the finished 2 turn primary and 16 turn secondary below.

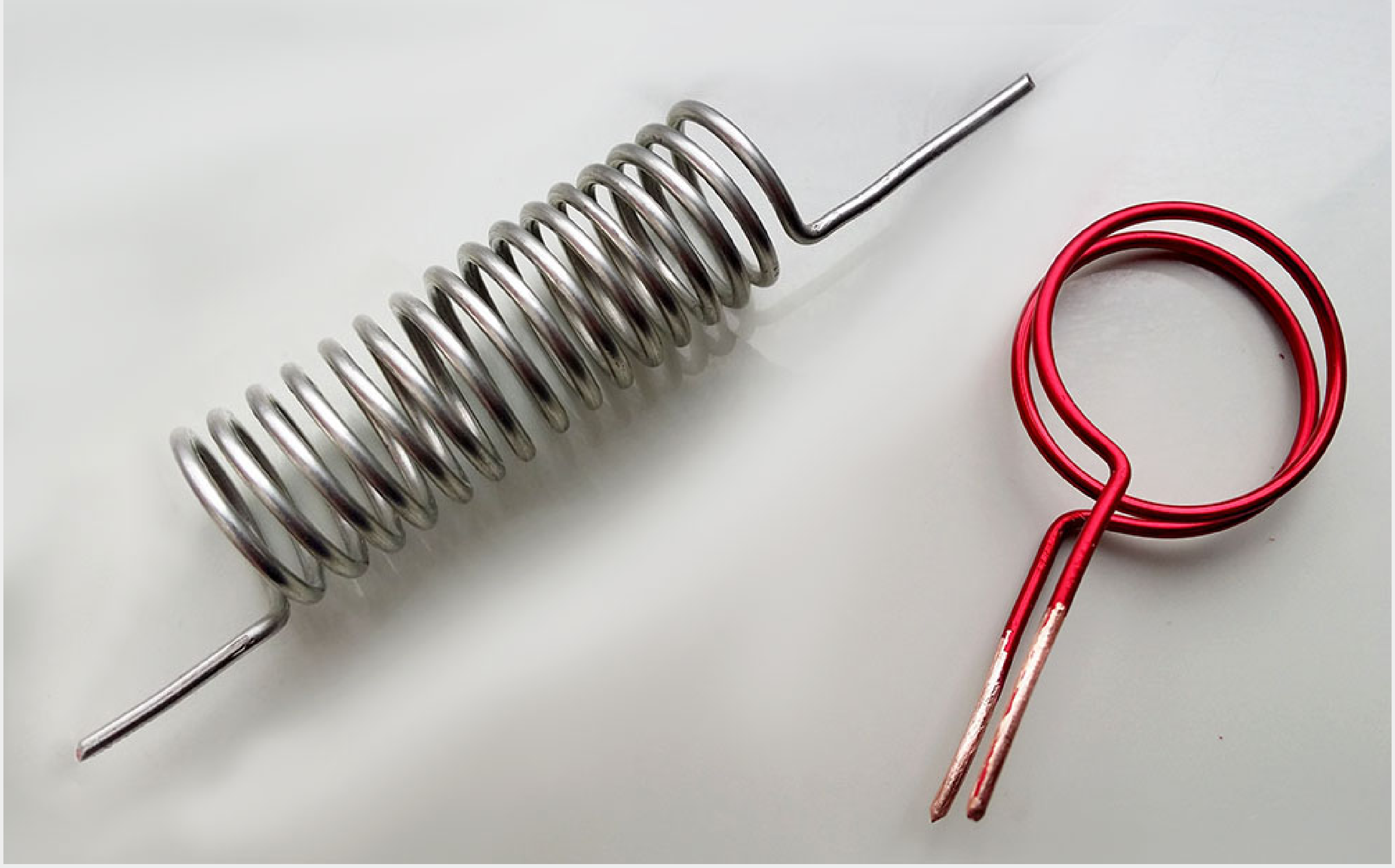

The completed inductors. They have their differences, but I will make them a happy 'couple'!

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secondary and a terminal block glued to a small block of MDF for the primary. The coax is soldered to the primary, the terminal block is just to hold it in place. There is a counterpoise connection on the side, the antenna connection on the front and the capacitor, SO239 and counterpoise/coax ground switch on the rear. Some photos of the completed unit are below.

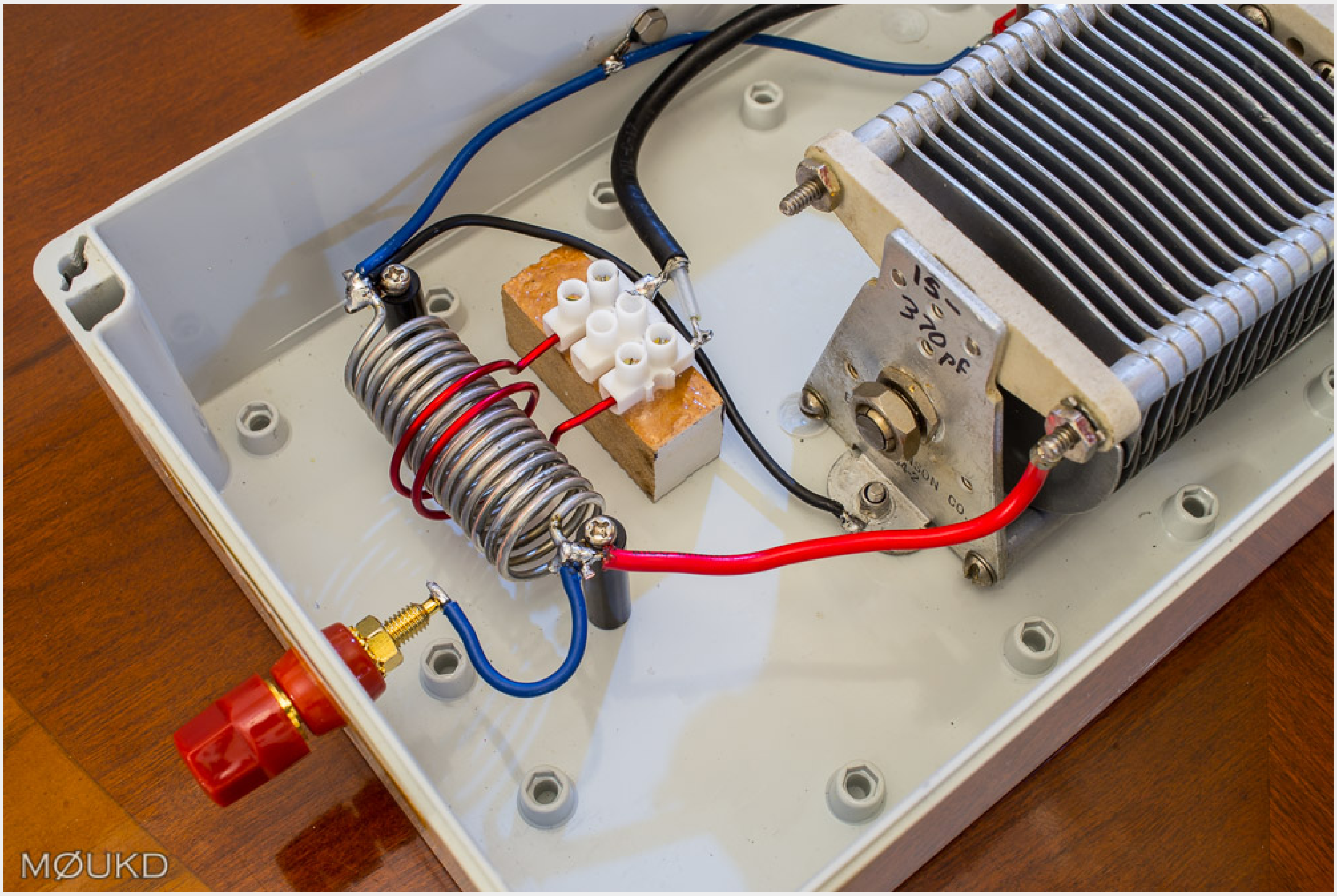

The completed End Fed Half Wave Coupler

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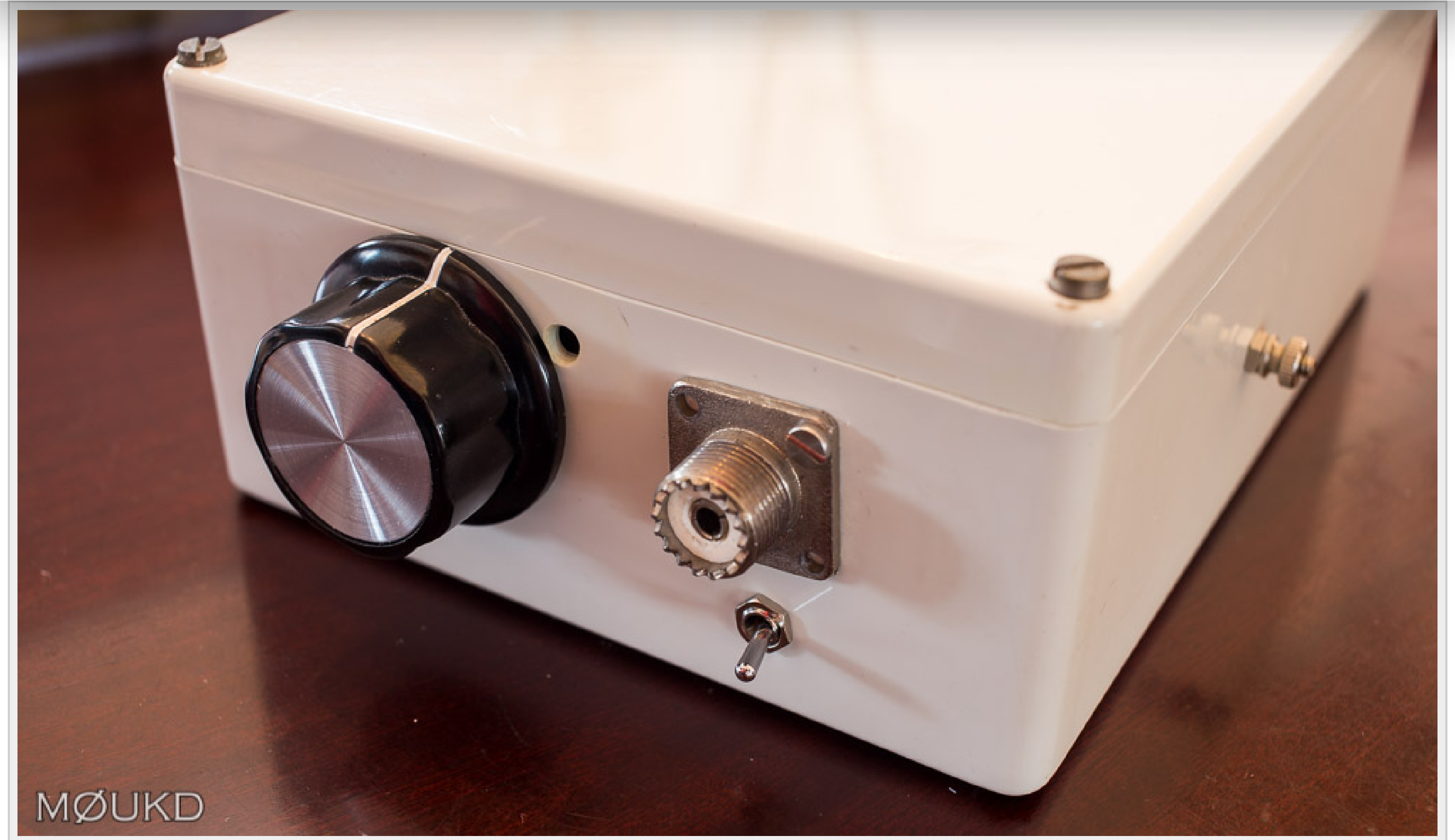

The tuning control, SO239, ground switch and on the right, the counterpoise connection.

DANGER!
High Voltage RF!
MØUKD

The antenna connection. The second hand box had a few holes in it, so I made this sticker to cover them up!

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this is due to extra stray capacitance. I tuned the coupler to resonance into a resistor (in my case 3.2kΩ) so a 1:1 SWR was obtained on my chosen frequency of 21.25MHz, then I removed the resistor and attached the half wave antenna (6.65m) and counterpoise (66cm) from the above calculator. Without adjusting the variable capacitor, I had a 1:1 SWR. This confirmed that I had a resonant half wave and that I was feeding it at or very close to the peak voltage point and the feed impedance was around 3200Ω. I found that a small counterpoise was required. Sometimes, the stray capacitance to ground was good enough on its own, especially on the higher bands and if the coupler was laying on the ground. If its all away from ground, I get consistent results using the above setup. I have had good success also by using the coax as the return, by connecting the 'bottom' of the primary and secondary together via a switch to use the coax shield and transceiver as a counterpoise.

You may be able to adjust the capacitor to match the antenna if its not a perfect half wave, but then it will be a higher current feed and the simple ground system will be inadequate. The coupler will also not be working as it was designed and will be inefficient, generating heat. The coupler is a tuned impedance transformer, not an antenna 'tuning' unit. Stick to the above, and it should be a sure thing!

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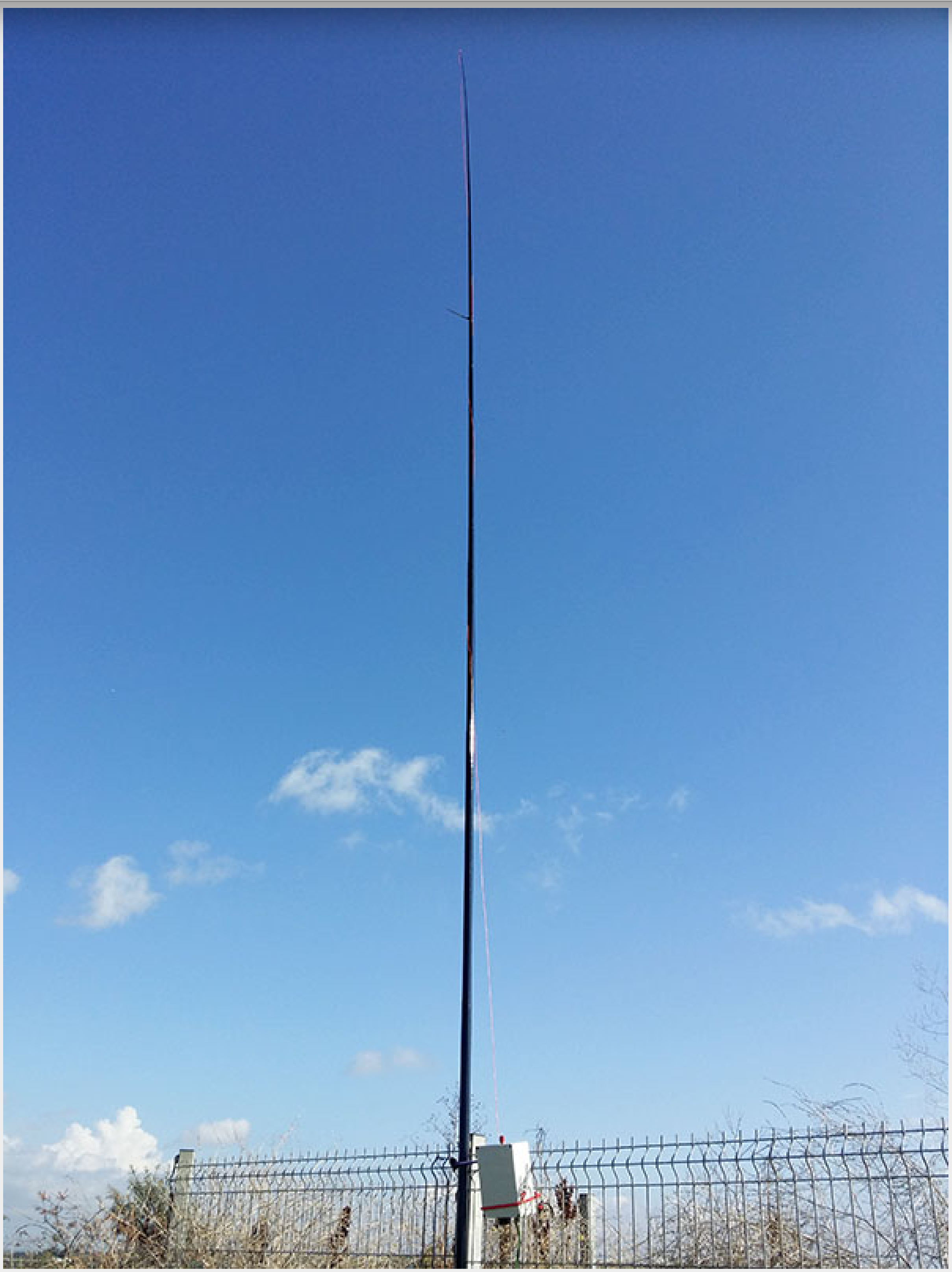

A half wave vertical for 21MHz. 6.65 metres of wire on a 9 metre fibreglass pole. The coupler is mounted 2 metres up and attached to the top of the fence. The 67cm counterpoise just hangs down in free air.

Below is a short video from my second test with the coupler, here on 17m.

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EARC
EMERGENCY
Amateur Radio Club

END FED 6–40 Meter Multiband HF Antenna

Introduction

This EARC project produces an inexpensive, multiband, end fed HF antenna matchbox that is quick and easy to setup and use. The end fed feature adds portable convenience, but does present another issue. The problem with an end fed half wave antenna is that the antenna presents high impedance, creating a significant miss match with the usual transceiver impedance of 50 ohms. This miss match is significantly greater than typical tuners can accommodate without a matching transformer.

This project creates a trifilar wound, 9:1 UNUN (unbalance to unbalance) toroid matching transformer that will match the high input impedance of an end fed antenna into the range where most antenna tuners can produce good performance. The matchbox handles 100 watts of power. ***This project requires an antenna tuner to achieve satisfactory SWR***. If you need an auto tuner, we recommend the LDG line of auto tuners, shown to work well with these matchbox antennas, and highly rated by users. They are reasonably priced and available at most ham stores.

The matchbox project uses readily available common hardware and materials listed below.

Matchbox Parts List

End Fed HF
Matchbox Antenna

1	small plastic enclosure (shown right)
1	powdered iron toroid T130-2
3	20” pieces of 18 AWG solid insulated copper wire in red, green, and black
2	# 8-32 x 3/4” hex head machine screws
2	# 8 lock washers
2	# 8 ring wire lugs
2	# 8 flat washers
2	# 8 lock washer/nut combination
2	# 8 wing nut
1	SO-239 panel mount connector to fit keyed enclosure opening

30’ # 18 AWG insulated stranded wire antenna with ring lug attached Small amount of clear silicone caulk to secure toroid in place

Preparing the MATCHBOX Plastic Enclosure

The enclosure needs one 5/8” hole for the SO-239 connector, and one 11/64” hole for the counterpoise wing nut on the lower side of the enclosure. An 11/64” hole on the upper right side of the box facilitates antenna connector mounting.

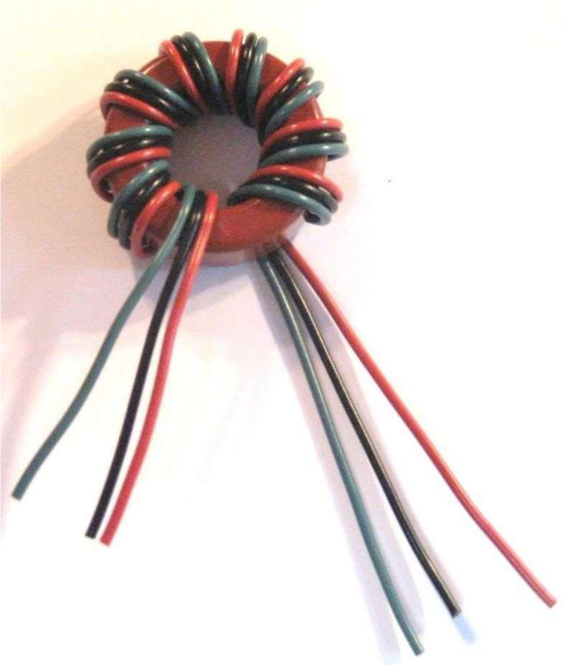

TOROID WINDING

First, wind the three 20” pieces of insulated solid wire onto the toroid. Place the wires as shown green-black-red, and wrap the toroid 9 turns so that it looks like the photo on the right. Notice there are three wires extending from the left winding and three wires extending from the right winding. As the connections are completed, the steps refer to the specific wires by left or right and color.

NOTE: Count turns by counting the number of times the wire goes thru the toroid center.

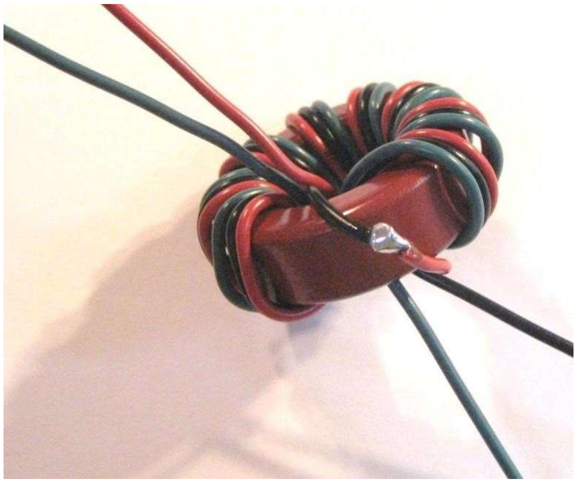

Crimp together and solder ***the left black wire*** with the ***right red wire*** When the step is completed, it will look like the right photo.

The next three steps should appear as shown in the first photo on page 3. Crimp and solder a # 8 lug to the ***left red*** wire about 2” from the toroid. The completed lug will later connect to the antenna connection bolt on the upper inside of the enclosure.

Twist the **left green** wire with the ***right black*** wire. Strip the ends of the two wires and twist together at about 2”. This twisted pair will solder to the center connection of the SO-239 connector in a later step.

Trim and strip the remaining ***right green*** wire at about 2”. Cut an additional 2” piece of green wire, and crimp and solder both wires to a # 8 lug. The 2” green wire will connect to the ground connector on the SO-239 already installed in the enclosure. Strip remaining green wire end 3/8" and bend into a hook for connection to the SO-239 ground connector.

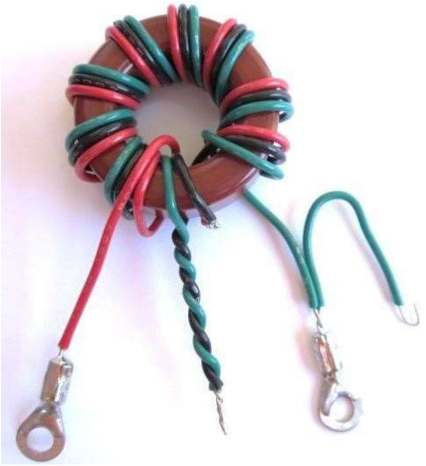

The SO-239 connector and ground lug should be installed through the keyed hole in the lower right with the mounting nut securely tightened.

Solder the green and black twisted pair to the SO-239 center connector. Solder the green wire hook to the ground lug on the SO-239 connector.

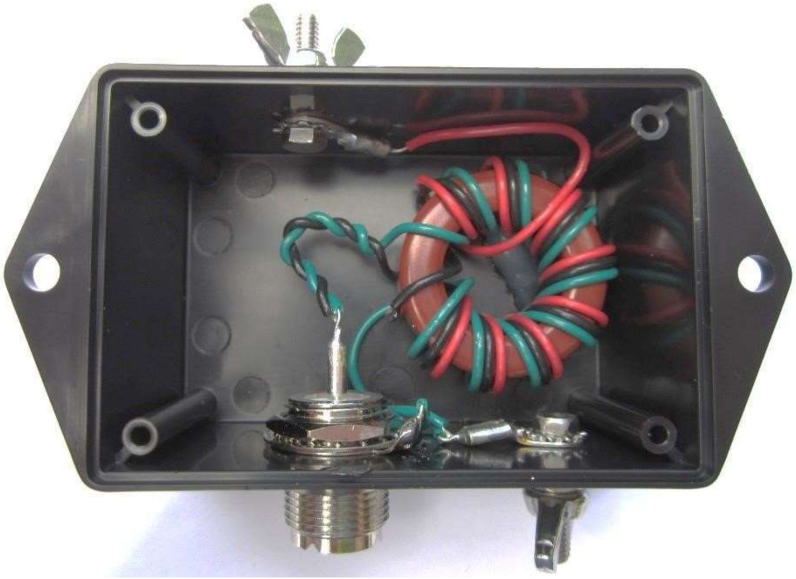

From inside the box, place an 8-32 machine screw through a lock washer, the # 8 lug on the green wire, then through the lower 11/64'" mounting hole. Place a flat washer on the outside protruding machine screw followed by # 8 lock washer/nut and tighten securely. Place a # 8 wing nut on the machine screw to finish the **counterpoise connector**.

Position the toroid inside the box to allow connection of the red antenna wire lug to an 832 machine screw and lock- washer on the upper box side. Place a flat washer on the outside of the box followed with a # 8 lock washer/nut. Tighten the nut securely. Next, place the wing nut on the **antenna connector** and your project appears as shown above.

A small spot of clear silicone compound is used to secure the toroid from movement in the enclosure. The final assembly step is to secure the box cover in place with four screws.

Preparing the Antenna Wire

Matchbox performance will be determined by two factors: The length of the antenna wire, and the capability of the tuner. The length of the antenna wire should be between 24 and 60 feet for best performance. Additional counterpoise is not normally required, as the coax shield provides the counterpoise function. Wires longer than 60 feet may have excessive impedance for some tuners to properly match. Wires shorter than 24 feet may not radiate as effectively. A 30 foot insulated 18 gauge stranded wire antenna and connecting lug is included with the project and should meet most requirements without need for any counterpoise.

Experience has shown that most external tuners and some internal tuners will tune 80–6 meters with an antenna length of 24’ to 30’. If a longer antenna is desired, the provided antenna can be lengthened.

Some tuners, in particular internal tuners, may not tune the full 80-6 meter range. You may need to try different wire lengths to optimize your antenna configuration. If you are having difficulty getting your rig to tune, start with a 26’ wire. This should produce good results on at least 40-6 meters using the narrowest performance range of internal tuners.

Best performance is achieved with a coax of 16’ or longer, with the coax shield providing the counterpoise function. Additional counterpoise is usually not required in this design, although the lower wing nut provides a convenient counterpoise connector if needed. The end fed antenna system works well in horizontal, sloper, and vertical configurations.

Observe established safety practices when working with antennas, and avoid proximity to power or utility wires. Permanent installations should be equipped with appropriate static and lighting protection.

Keep amateur radio safe and fun!

End Fed HF
Matchbox Antenna

Toroid Wiring Schematic

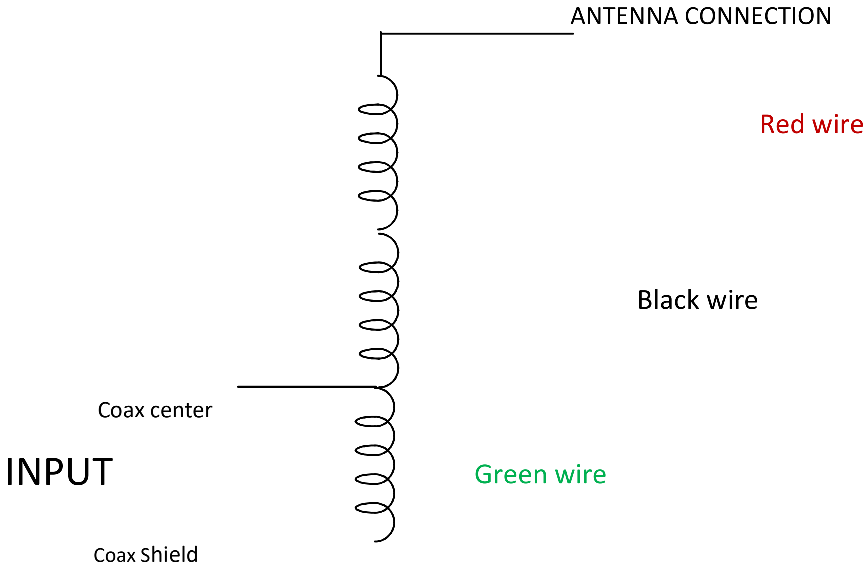
ANTENNA CONNECTION
Red wire
Black wire
Coax center
INPUT
Green wire
Coax Shield

Feedback on 6-40 End Fed Matchbox Antennas

The antenna is amazing. I receive fantastic signal report from DX stations as well as hams around the country. I previously used a short version GR5V that was in an inverted V configuration on the roof of our house. This antenna was noisy but worked. Your antenna out performs the prior antenna and is much quieter. Thanks again for the fine product that your club offers. ***May 2012***

It took me 10 minutes to install and WOW - within 10 minutes I made my first HF contact (from CT to GA). And in the span of 4 hours made 3 more !! I was transmitting just 5 Watts from Yaesu 857ND using this antenna. This antenna rocks ! Thanks a ton ! 73 ***May 2012***

The 6 - 40 Matchbox antenna works great! Easily tunes with the Z100 tuner - very low SWR's on 20m thru 10m. Antenna was up about 45 feet on tree branch - wire length was about 52.5 feet, slight slope, 55 feet of coax, line isolator at radio. ***Work Hawaii for the very first time. Guess the antenna wanted to call home :-) 57 report, 100 watts, 15 Meter band, Icom 718.*** A great portable antenna that I will use often at Montrose Harbor along the lakefront in Chicago. Thank you for a fine, well made product. ***April 2012***

It arrived today in fine shape. I got is up in the air this afternoon using a 31 foot radiator. Top is at 45 feet. Loads on all bands 80-10M with my LDG auto-tuner absolutely no problem, My first QSO was KH7X in the ARRL SS contest with 100W. Amazing. This thing rocks! It’s a great antenna! Nice job and a great buy. ***November 2011***

I set-up my jackite pole today and tried a 68' wire with the 9:1 unun matchbox. I set it up as an inverted L with about 26 feet vertical and 42 feet horizontal. With my IC-703 it tuned 80 through 6 all well below 1.5:1. I am going to leave the antenna up a few days and make a few contacts. I think the matchbox is terrific. ***October 2011***

My 6 – 40 meter end fed arrived through the UK holiday mail and I departed from my norm of a sloper and mounted it vertically on a 10m fishing pole. It is surprisingly effective and rewarded me with a surprise contact on 17m into the Falkland Islands at 20:30UT last night. ***January 2012***
When I attached it to a 10m fiberglass fishing pole and went vertical - wow! Easy 5/9 contacts out to 6,000+ miles when propagation was anything better than the worst. My simple ATU easily matches the antenna with SWR never greater than about 1.4 on any band it is built for. ***December 2012***

You can dither and procrastinate, but with this antenna, you'll be talking to the world in no time on any band that happens to be hot - and with your hard-earned cash hardly touched! ***January 2012***

Just wanted to report back that I have tossed the antenna into a tree about 20' up in an inverted vee shape and I am pleased to report that I can tune anywhere I need on 40-10M using the TS-590 internal tuner!! My first contact was on 40M within 10 minutes of erecting the antenna and was all the way to TX from my condo here in MI using just 10 watts. This is by far the best HAM related investment I have made in a long time. Living in a condo with strict association rules, I am able to conceal this wire in a tree out my bedroom window and talk all over. I'm very happy and would recommend this antenna to anyone in a similar situation. ***March 2013***

I have had your multiband end fed antenna installed here in Singapore for a few weeks now and am very pleased. I used the wire from my previous antenna which is 66 feet long. It works beautifully! I have it hanging vertically outside my 15th story apartment window on a 5 foot horizontal pole (to get it away from the reinforced concrete building). A couple of fish weights on the end keep it from blowing around too much. I would recommend this antenna to anyone who is facing a challenging QTH. ***April 2013*** I received my antenna yesterday, a quick 4 days since I ordered it. I attached it to a 31 foot pole and my IC-706MK2. Within minutes, I made my first contact with 9A4KW in Zagreb, Croatia on 20 meters. Being able to reach out over 4,000 miles gives me real confidence that I have found my portable antenna. Thanks for your rapid response and fine product. ***May 2013***

In only 2 weeks of casual on-air time. If you could see how I had to zig-zag it through a big tree above the roof of my RV, you'd be saying like I am, "how the heck can that work? I worked 90% of the stations I called, and just added Mexico City on 15m that gave me a 5x9. ***September 2013***

Just wanted to let you know how pleased I am with my ERAC matchbox antenna. I put the EARC antenna in the backyard with the feed point at 4 feet and the wire sloping up to 35 feet. I have 125 feet of coax feed line. My transceiver's built-in antenna tuner will adjust the SWR to below 1.2 to 1 on all bands 80-6 meters. Last weekend I worked 65 countries on 5 continents. I live in an antenna restricted community and this antenna has allowed me to enjoy ham radio again. ***February 2014***

I used the EARC Matchbox today. It works GREAT on 20m with a 30 ft radiator in vertical positioning, fed with 25ft of RG175/u coax. I've been talking up and down the east coast with 3W on SSB all afternoon! People ask me to repeat my power output again and again. I can't wait until I get the chance to use it at night, where I think it'll really shine! This has a permanent place in my portable kit. Thanks for the great product! ***April 2014***

I performed a simple install in Virginia making it vertical by using a 28 foot fiber glass kite pole. Within 30 minutes (NO KIDDING) I was receiving Lebanon on 17 meters! I also worked Russia and Eastern Europe that night on 20 meters. I love this antenna and I give it a 100% (5 STAR) rating. ***May 2014***

This little box is magic. NY, IA and NM from GA with ease on 100w ***June 2014***

Just wanted to let you guys know, this matchbox is wonderful. I built the matchbox, connected it to 55 feet of solid #14 about 20 feet in the air. My rig is a Yaesu FT-817ND connected to a MFJ-971 tuner with coax running between the tuner and the matchbox. So far I have worked Slovenia twice, Morocco, St. Helena Island, Cuba, Cost Rica, Vermont, Wyoming, Florida, North Dakota, Brazil, and Colombia. This setup works really well on the higher bands. Thank you for putting this design on the internet. I like it so much its become permanent here. ***September 2014***

This antenna continues to amaze me. It worked well U-shaped "indoors" with 50 watts, and now outdoors as a sloper. It easily loads 10-40m with my TS-570s internal tuner. I'm sold on it and own two of them now. I'm working at least 90% of the DX I chase. I have no RFI in the shack either. ***November 2014***

EARC Antennas are operating in virtually every state, these countries and more!

Argentina Australia Belgium Brazil Canada Chile Denmark Greece

Hong Kong India Ireland Israel Italy Mexico Mozambique New Zealand Russia Singapore
Sweden Tasmania United Kingdom

ORDERING A MATCHBOX ANTENNA FROM EARC

Volunteers of the Honolulu Emergency Amateur Radio Club (EARC) carefully assemble the 6-40 End Fed matchbox antennas for those who prefer not to build one. For a donation of **$56** (Including USPS priority mail shipping) club volunteers will build and deliver a 6-40 matchbox with a 30 foot antenna wire anywhere in the U.S., we do not ship internationally. Note that coax cable is not included.

Payment by PayPal

To pay via **PayPal**, make your payment to paypal@earchi.org using any major credit card. Include your name, mailing address, and email address with the order.

We will ship promptly and you will likely receive the order in the US in 7 days or less. If you have any questions about your order, please email webmaster@earchi.org

Thank you for your interest in the activities of Honolulu Emergency Amateur Radio Club and amateur radio.

2N6084 144MHz FM Power Amplifier

Power
TX
Off
144-146MHz 50w Amplifier
On

Simple 2m amplifier.

I built the PA board for this when I was a foundation licencee, but under the foundation licence, you must only use comercially made transmitters. Since getting my intermediate licence, I have put it in a box, and added an RF sensing switch so I can use it. It uses a 2N6084 RF transistor, and will produce 50w output max. It is a class C amplifier design, and therefore good for FM mode only. I have tried using the 2N6084 in class A, but amplifier gain was down to about 4dB and it seemed a but pointless!

2.5w	10w
4w	20w
7w	30w
10w	40w
13w	50w

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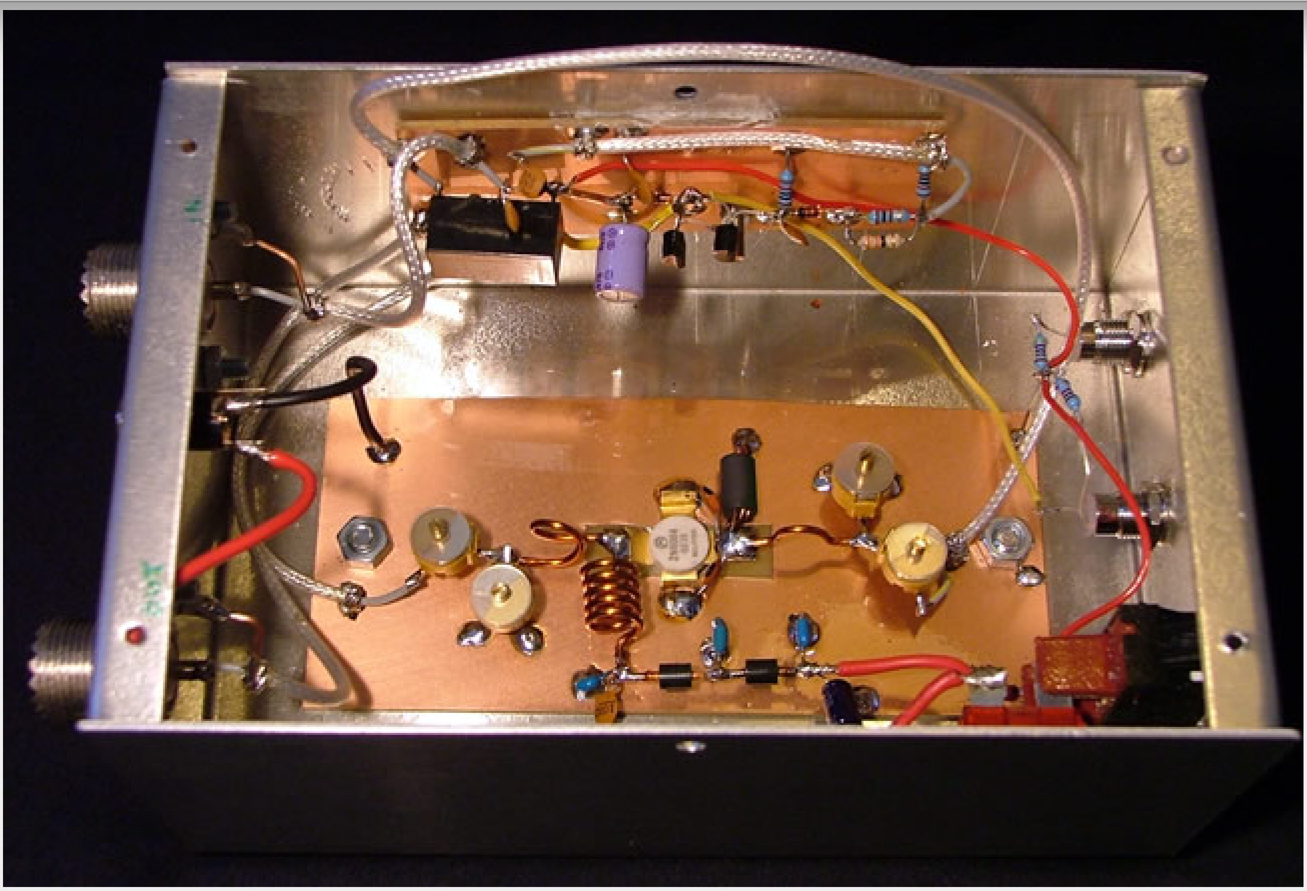

Inside the box

Accept

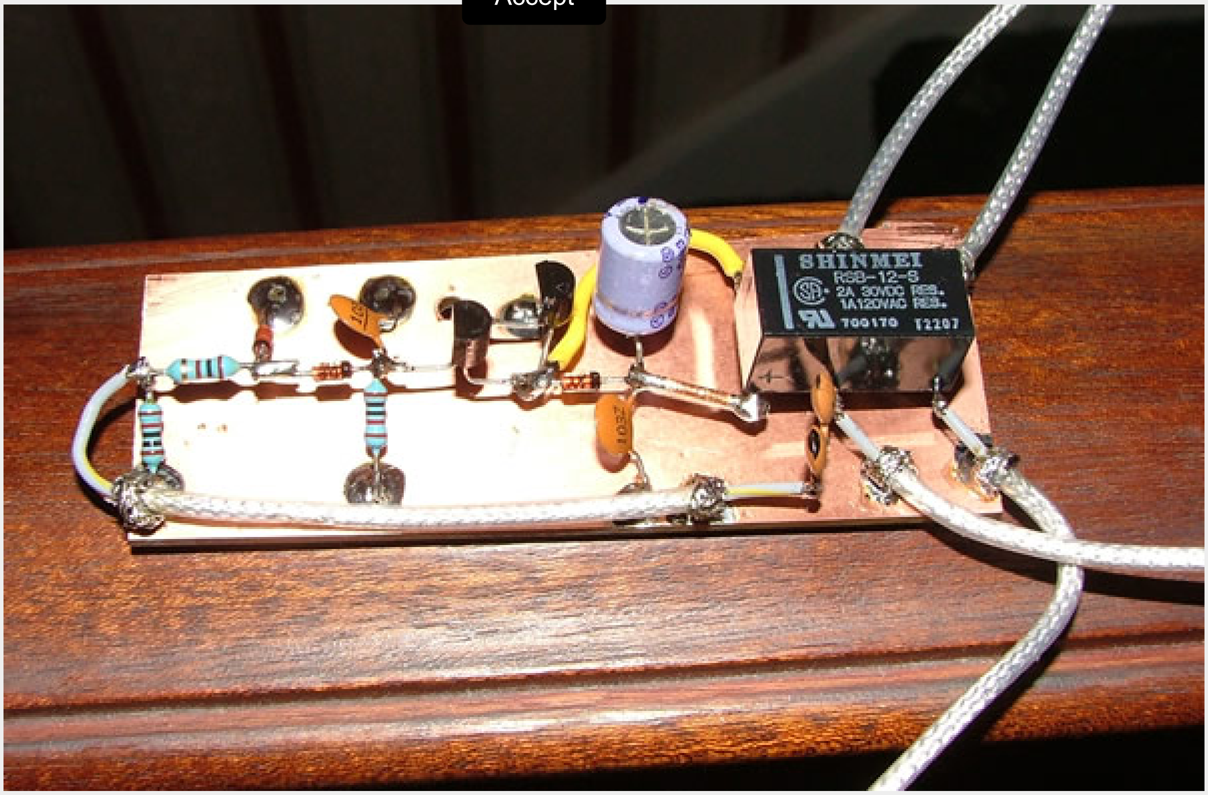
SHINMEI
RSB-12-S
2A 30VDC RES.
1A120VAC RES.

RF Sensing circuit & DPDT relay switch

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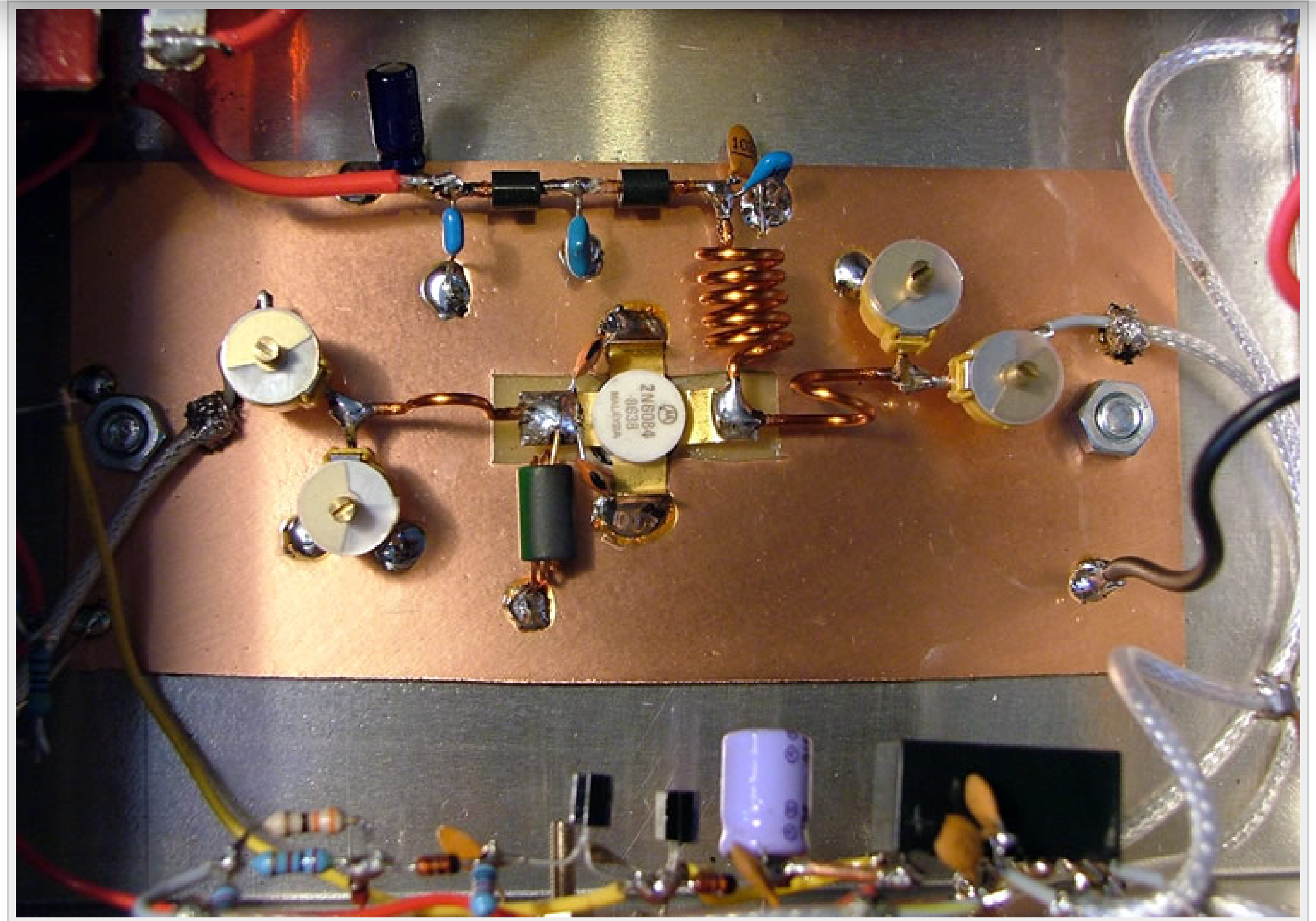

PA Stage

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Back

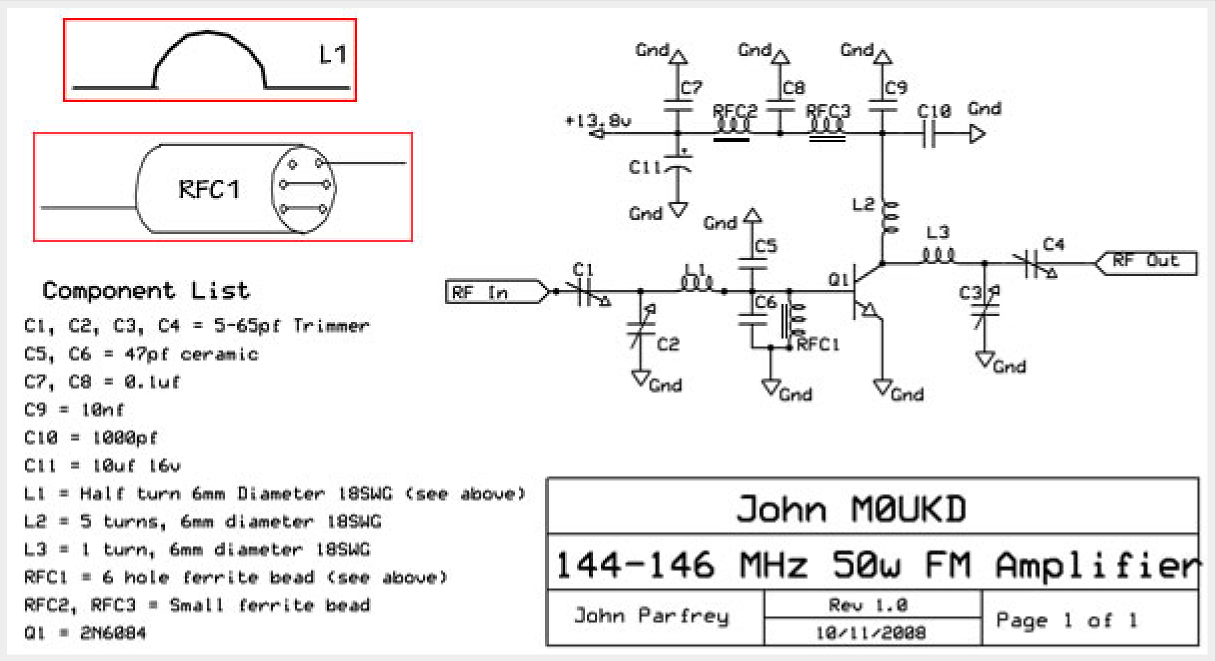
L1
RFC1
Gnd
Gnd
Gnd
C7
C8
C9
+13.8v
RFC2
RFC3
C10
Gnd
C11
Gnd
Gnd
C5
L2
L3
C4
RF Out
RF In
C1
L1
Q1
C6
C3
C2
RFC1
Gnd
Gnd
Gnd
Gnd

Component List

C1, C2, C3, C4 = 5-65pf Trimmer
C5, C6 = 47pf ceramic
C7, C8 = 0.1uf
C9 = 10nf
C10 = 1000pf
C11 = 10uf 16v
L1 = Half turn 6mm Diameter 18SWG (see above)
L2 = 5 turns, 6mm diameter 18SWG
L3 = 1 turn, 6mm diameter 18SWG
RFC1 = 6 hole ferrite bead (see above)
RFC2, RFC3 = Small ferrite bead
Q1 = 2N6084

John M0UKD
144-146 MHz 50w FM Amplifier
John Parfrey
Rev 1.0
10/11/2008
Page 1 of 1

Schematic of the PA board. CLICK IT FOR LARGE VERSION!

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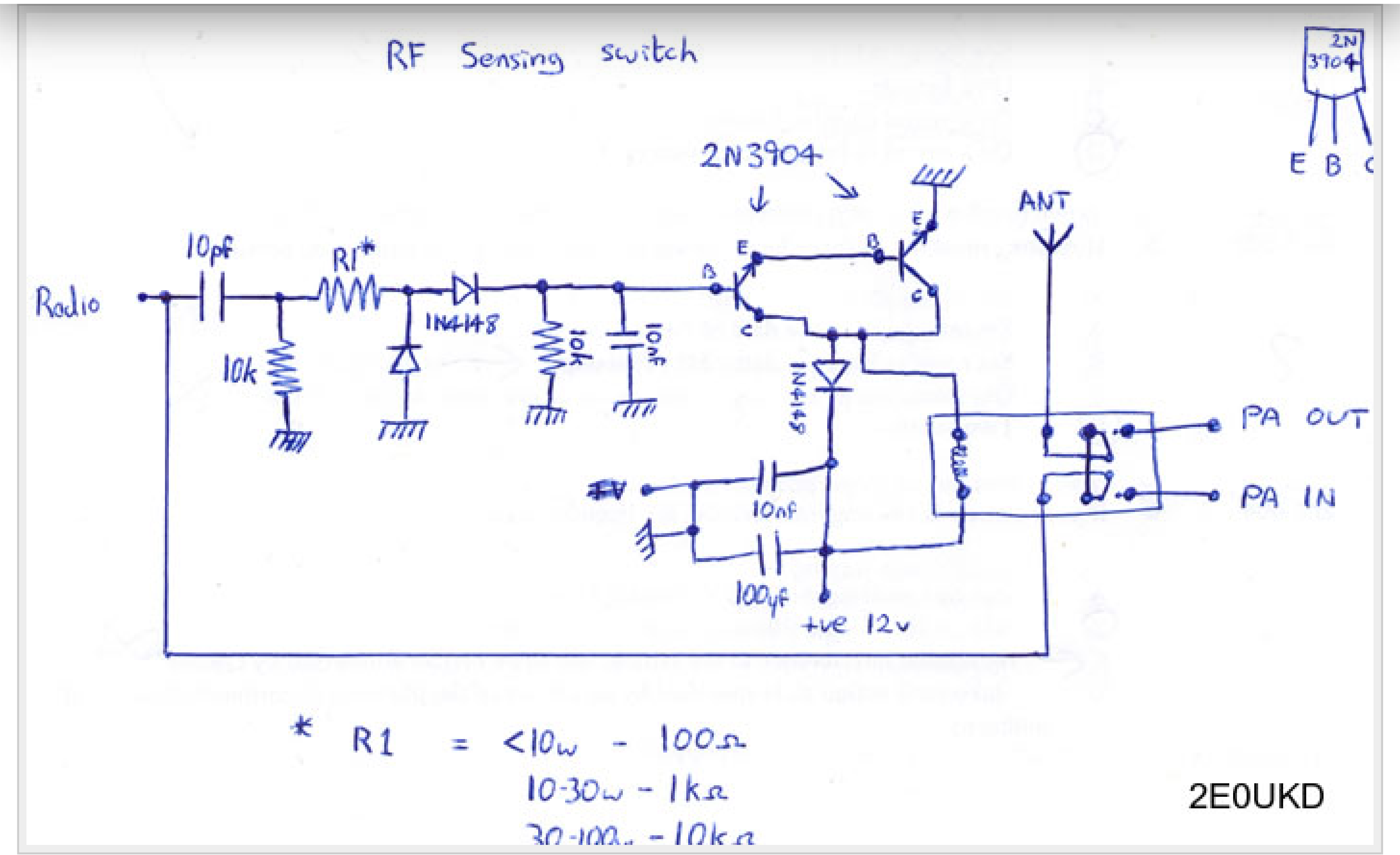
RF Sensing switch
2N 3904
E B C
2N3904
10pf
R1*
Radio
10k
1N4148
10k
10nf
B
E
C
B
E
C
ANT
1N4148
PA OUT
PA IN
10nf
100μf
+ve 12v
* R1 = <10w - 100Ω
10-30w - 1kΩ
30-100w - 10kΩ
2E0UKD

Schematic of RF sensing switch circuit.

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AERIALS (ANTENNAS) 2

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Antennas 1 : Aerials used at M0MTJ
Antennas 2 : Including ideas for compact aerkals for Top Band /160 metres
Antennas 3 : Felix Scerri VK4FUQ discusses Loop Antennas, baluns, masts & other antenna related topics
Antennas 4 : Many antenna ideas from various sources particularly for multi-band operation & also gives information about antenna trimming, knots for wire antennas and useful antenna rigging accessory ideas.
Antennas 5 : Half Wave End Fed aerials for 144 MHz VHF / 430 MHz UHF and 50 MHz 6 Metre band & J-Pole Aerials
Antennas 6 : Simple and effective H.F. Antenna ideas - Ground Plane and All Band Doublet
Antennas 7 : Omni-Directional - Circularly (Mixed) Polarized Aerial for VHF / 2 Meters.

Compact Top Band Antenna - An Inverted L for stealth with low(ish) visual impact

With a small back garden there is no way that I could accommodate an aerial for the 160m band that would be anything approaching full size. A full size dipole would be about 65 metres long and would need to be mounted at a very good height to be at its most effective. A full size vertical 1/4 wave would be about 37.5 meters tall. Impossible! Bending a 1/4 wave wire into an inverted L would still result in a very long wire - say 10 metres vertically and 27.5 metres horizontally. Still too large.

Full size top band antennas are big, far too big for my small plot, so I have tried a few different shortened 160m aerials. I really would prefer to use a balanced dipole not only for the radiation efficiency, but just as importantly for the lower noise on receive - like a ground mounted vertical aerial an inverted L can be rather noisy on RX. However I have to settle for a compromise, so shown in the drawings and photographs below is my current top band aerial, along with some previous experiments and ideas further down the page.

This incarnation of my Top Band aerial takes two forms. A compact Inverted L and, in its lower position, a less conspicuous sloping wire, shown below:

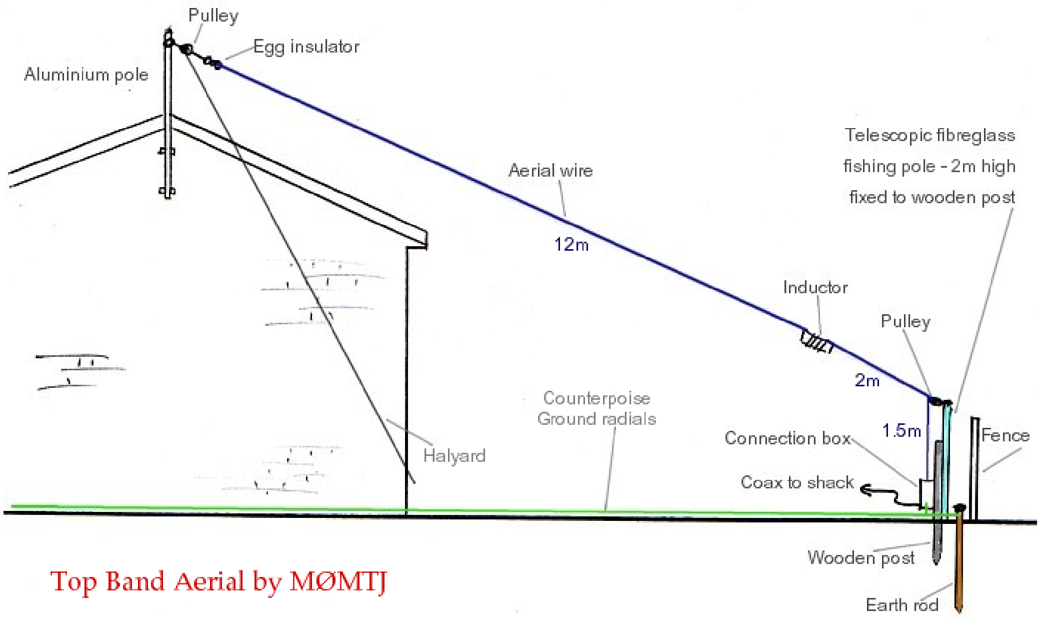

General layout of Top Band Aerial with fibreglass pole retracted to a height of 2 metres
Wire lengths are approximate: Inductor 5cm dia with approx 40 turns of 0.9mm e.c.w.

G-WHIP ANTENNAS

My first experiments were with a base loaded sloper which worked ok-ish for local ground wave, but could have been better. The first weak link that I wanted to change was moving the base loading coil further up the aerial wire so that it would be positioned on the more horizontal section.

It was also very low, so could surely benefit from some additional vertical height. However I could not realistically erect another permanent pole in the garden for fear of upsetting the XYL!

Therefore I decided that I needed a design that could be semi-permanent and offer two slightly different configurations: The idea is that, as a sloping wire, the aerial can be left in place at all times for RX and still be operable on TX. Since it is essentially just a wire sloping from fence height (2m) up to the roof apex it has fairly minimal visual impact. Alternatively, when required - at night - the telescopic pole can be extended to transform the aerial into the larger Inverted L.

The Earth and Radials: The aerial is fed against ground, so the ground needs to be as good as possible. At the base of the aerial a copper earth rod is driven into the ground. Additional ground radial wires are also added to provide a counterpoise and help reduce earth loss. The more the merrier.

The Support: A 10 metre long telescopic fibreglass fishing pole is used as part of the support. A wooden post was driven into the ground, adjacent to the earth rod. The connector box is screwed on to the post and the fishing pole was fixed to the post using nylon straps.

Since the top sections of a fishing pole are too thin to support the aerial wire, the last four sections were removed, leaving the pole 6 metres in length, which is a respectable height in a small back garden, though being even taller would be better.

A small lightweight pulley is fixed to the top of the fibreglass pole using two nylon ties - as seen in the photograph. As a sloping wire, the fishing pole is collapsed to 2m in height while being extended to 6 metres when being used as the 'full' Inverted L. The pole is quite flexible and so will tend to bend quite noticeably when 6 metres long with the wire attached to the top. This could be remedied by adding a back guy rope of required.

The far end of the aerial wire is tied to a egg type insulator and nylon halyard which is suspended through a pulley on a pole attached near the apex of the roof. The nylon halyard is tied off on a cleat hook near ground level to enable easy raising and lowering of the aerial wire.

The Wire: Aerial wire is PVC covered stranded wire of about 16/18 swg http://www.whwestlake.co.uk. The wires were cut for the maximum length that could be fitted into the available space - so as much wire was in the air as possible. This was about 3.5 metres from the feed point to inductor and around 12 to 13 metres from the inductor to the far end.

(If you make one of these get the vertical portion as high as possible and the horizontal section as long as possible and reduce the coil's inductance accordingly)**.**

The Inductor and Resonance:

The resonance of the aerial system was adjusted not by altering the length of the wires, but by changing the inductance of the loading coil.

I had some 0.9mm (20 s.w.g.) enamelled copper wire on a reel, so I used that to wind the coil. The coil former is 5cm in diameter and about 15 cm long, cut from an empty tube of silicone bath sealant (the 'gun' type). Two holes are drilled in the former for the fixing bolts and wing nuts that secure the aerial and coil wires.

I used an MFJ antenna analyzer to check resonance and adjust the number of turns. Initially the coil was wound with 60 turns, but the resonance was well below 1800 kHz. Turns were gradually removed until resonance was around 1940 kHz, leaving 39 turns on the coil. (Thicker e.c.wire might have been better, I would have preferred to use something like 18.swg 1.2mm diameter and this may possibly get changed in the future)

Enamelled copper wire:
http://www.esr.co.uk/electronics/cable-copper.htm

When the adjustments were finished the aerial wires and coil wires are terminated with lugs and fixed in place with the bolts and wing nuts. The winding was also covered in duck tape. All exposed connections should be suitably protected against the weather for a permanent installation.

When setting up any aerial an antenna analyzer is extremely useful - allowing all the measurements to be done in the garden or back yard thereby simplifying and speeding up the process considerably. These simple measurements can be made using the transceiver and VSWR meter, though that is obviously less convenient and will involve transmitting regular short burst of carrier, so it's very important to ensure that the power used is the absolute minimum and that the frequency being used is clear.

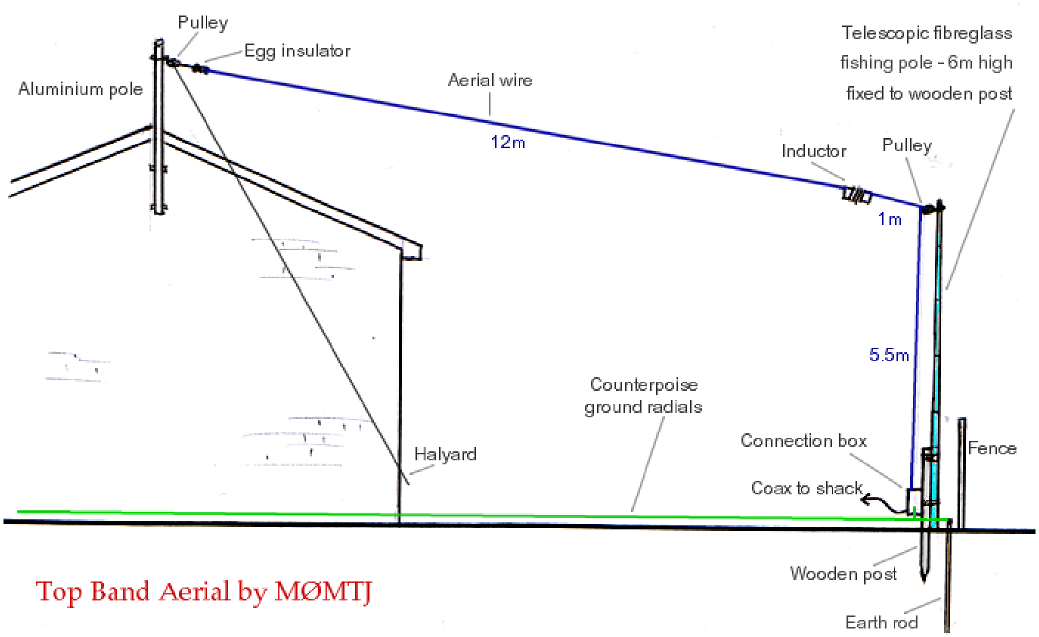

General layout of Top Band Aerial with a fibreglass pole extended to a height of 6 metres
Wire lengths are approximate: Inductor 5cm dia with approx 39 turns of 0.9mm e.c.w.

To transform the aerial to the Inverted L format (shown in the above diagram) I envisaged that changing the first length of wire, from a 3.5 metre length to 6.5 metre length, and the inductor would be necessary. I had assumed that a coil with less inductance (fewer turns) would be required due to the longer length of aerial wire used in the Inverted L arrangement.

I was, however, proved wrong. On first attempt I left the original coil in place, just adding the longer wire section (from connection box to coil) and raising the pole to its full 6 metres. The point of resonance was only about 20 kHz away from where it was as a sloper.

This, I think, can be explained by the fact that in the sloper configuration, the wire is close to the ground, other objects and vegetation which will in effect add loading to the aerial, Consequently a loading coil with less inductance than might otherwise be expected is required. So, by happy coincidence, the same coil is also suitable for the longer wire that is at a greater height (and therefore is influenced less by ground loading).

This, quite by chance, made the swap from Sloper to Inverted L a little easier since there was no need to wind a second coil - the change being made by merely adding the longer first wire section and pushing up the pole to its full 6 metre height.

If there are no concerns or objections to installing a tall pole at the bottom of the garden, then the Inverted L arrangement could be left as a permanent installation. In that case the pole need not be a fibreglass fishing pole, although it is still an attractive lightweight method, instead a couple of 3 metre long sections of treated timber could be joined together to form a 6 metre high post - the higher and longer the better though!

These links may be useful in helping to calculate loading coils:

Antenna Loading Coil Calculator : http://eweb.chemeng.ed.ac.uk/jack/radio/software/loading.html

Coil winding design program : http://ecosse.org/jack/radio/software/newcoil3.html

Loaded dipole calculator by K7MEM : http://www.k7mem.com/Electronic_Notebook/antennas/shortant.html

Ring Core Calculato r: http://www.dl5swb.de/html/mini_ring_core_calculator.htm

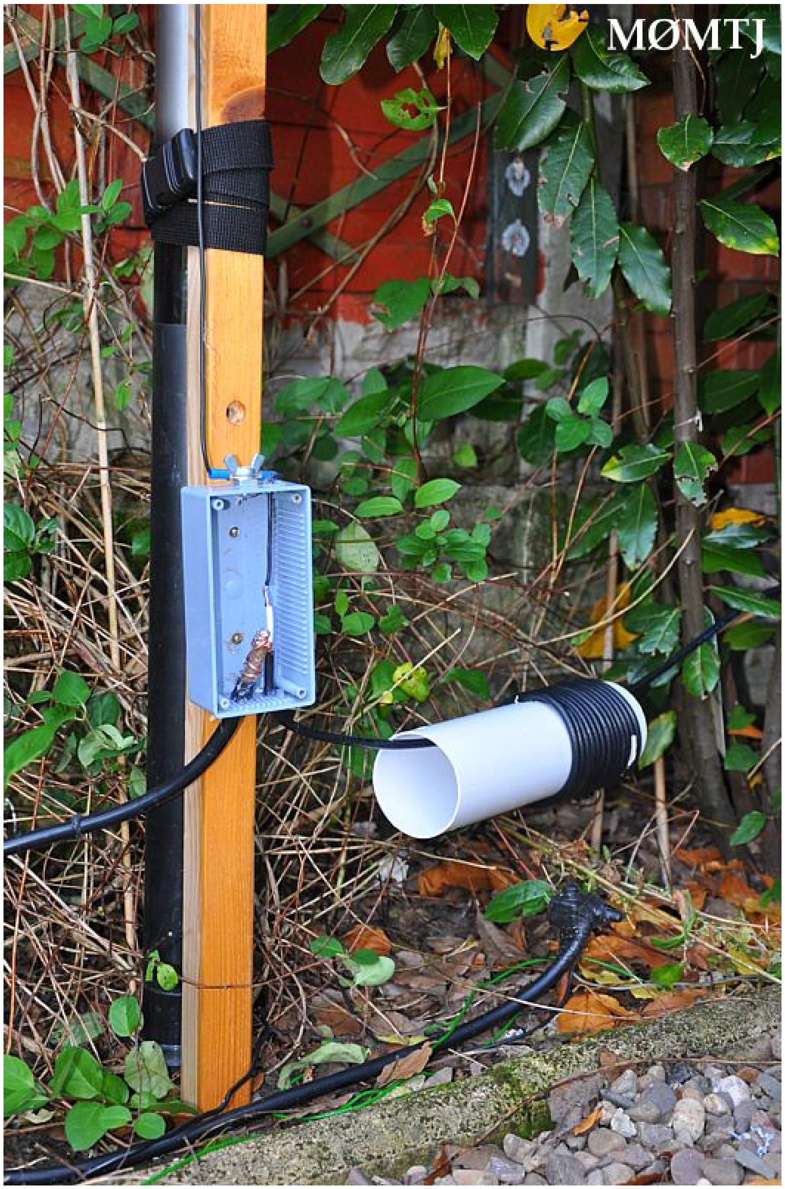

Top Band Inverted L - photograph showing the wooden support post with telescopic pole attached with connection box, cables and earth rod. The cable entering from the left is the earthing strap which is connected to ground rods and radial wires. The coaxial feeder cable exits from the bottom right of the box and is wound around a length of white plastic pipe to form a simple RF Choke.

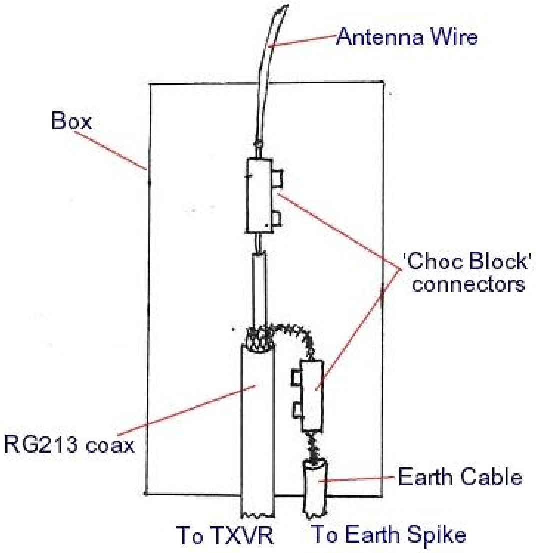
Antenna Wire
Box
'Choc Block' connectors
RG213 coax
Earth Cable
To TXVR
To Earth Spike

My original implementation which used 'choc block' connectors. The final design has all soldered joints with a stainless steel bolt and wing not at the top of the connecting box.

Top Band Inverted L - pulley on top of the 6m telescopic pole

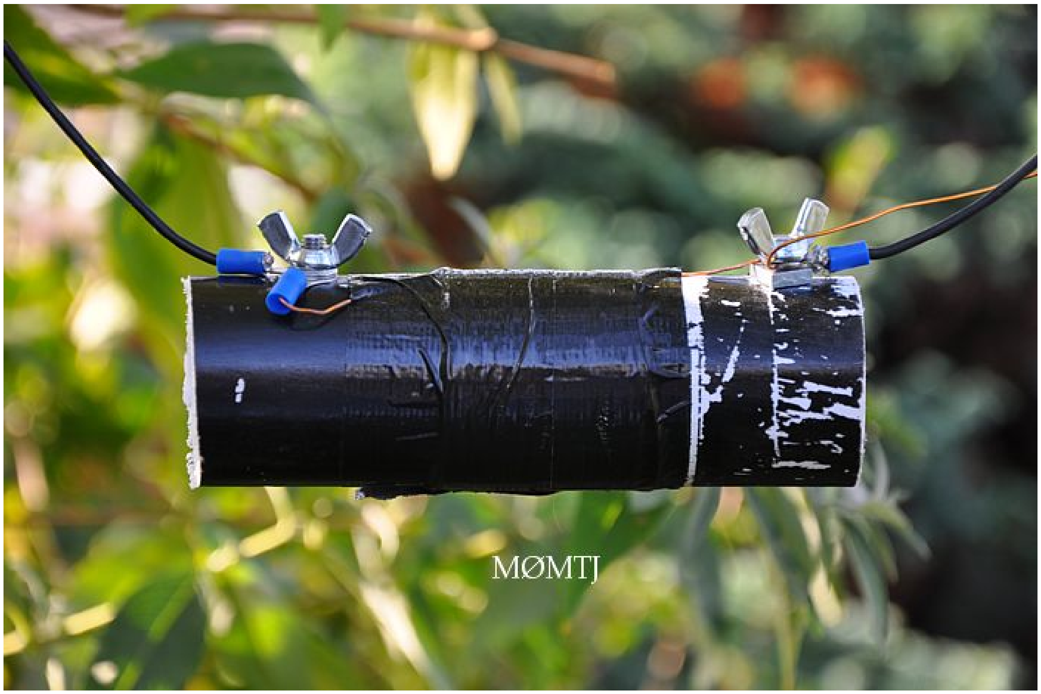

Top Band Inverted L - loading inductor.

This is the unfinished coil, the connections on the left are properly finished off using lugs, but the connections on the right are unfinished to allow adjustment of the number of turns. When that is settled the final lug is soldered to the end of the enamelled copper wire and held in place with the bolt and wing nut. The coil is 39 turns of 0.9mm e.c.w., wound on a 5cm diameter former made out of an empty silicone bathroom sealant tube. (I would have preferred to use slightly thicker e.c.w. of about 18 swg 1.2mm diameter, so that may get changed in the future)

Enamelled copper wire:
http://www.sycomcomp.co.uk
http://www.esr.co.uk/electronics/cable-copper.htm

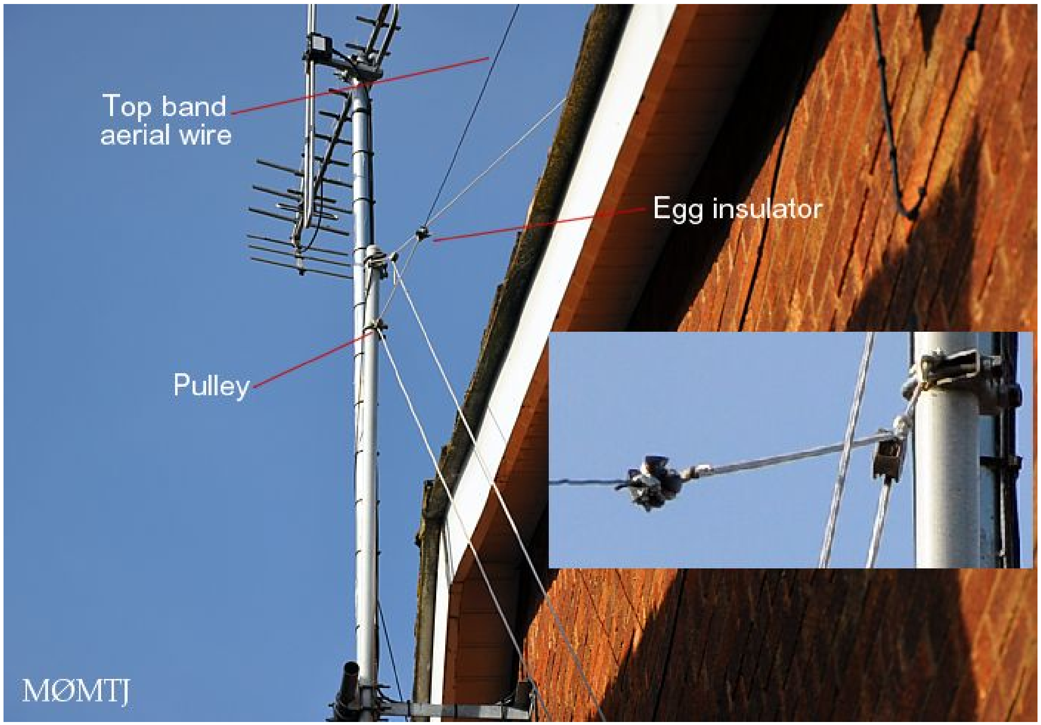

Top Band Inverted L - pulley, rope and insulator supporting the wire at the far end

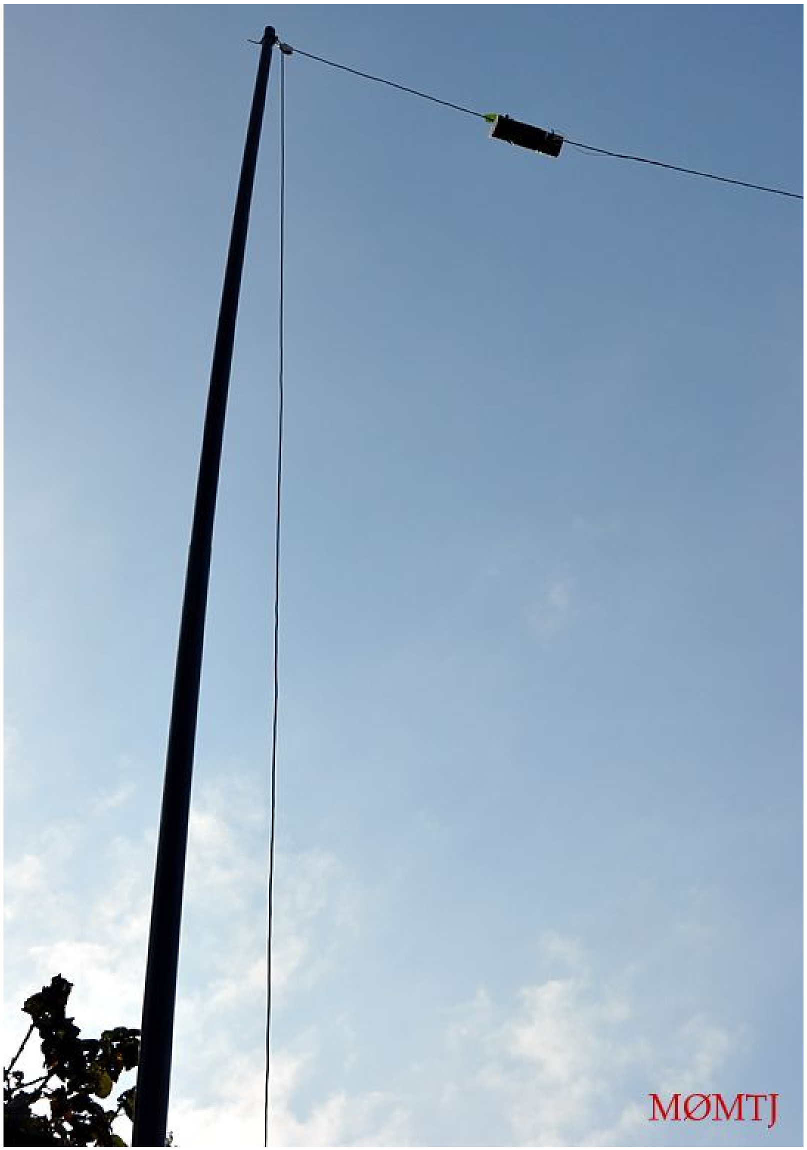

Top Band Inverted L - supported by a 6m long fibrelass (roach) pole

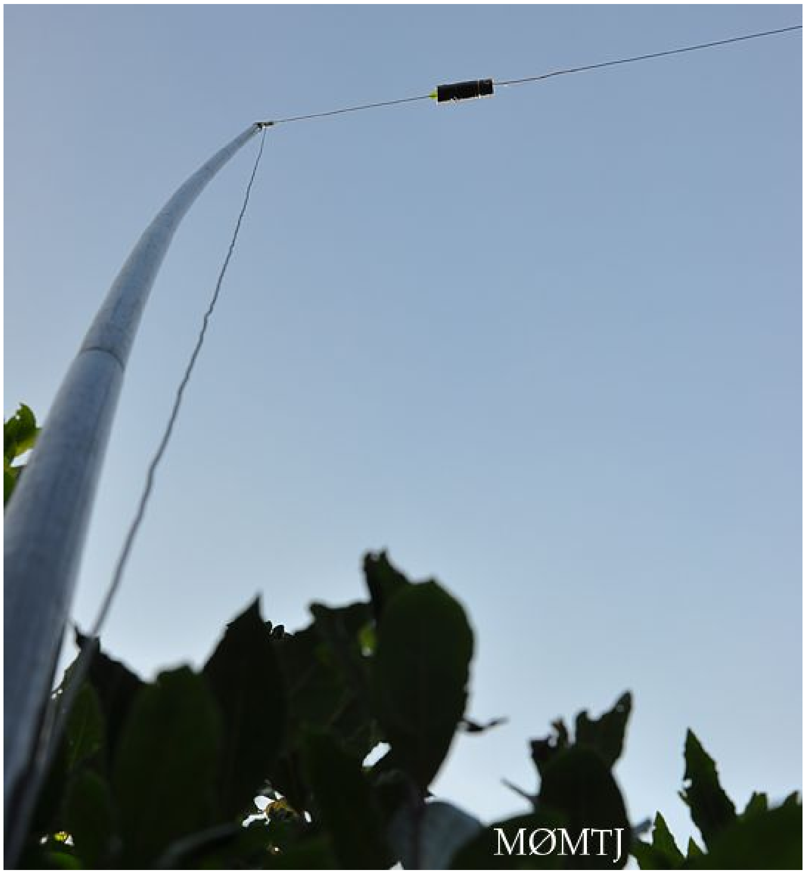

Top Band Inverted L - looking up!

The photo exaggerates the bend a little, but it's not enough to worry about. The bend could easily be corrected by adding a back guy to pull the pole back towards the vertical position, but for this job it's fine as it is.

DOES IT WORK?

Yes! This aerial does work, I am glad to say!

It works better than my initial short sloping wire shown further down this page, which is what one would expect!

Rather than merely settling for a local ground wave signal I was very pleased to contact Top Band enthusiast Steve G7KLJ on my first attempt. Steve is 170 miles distant from me and the night time sky wave provided a pretty good result. G7KLJ gave me a 5 / 8 with my 100 watts on 1843kcs using my small aerial. I gave G7KLJ 5 / 9+10 with Steve's large doublet and 400 watts (lovely audio too Steve!).

Admittedly that's potentially a 16dB difference, which is pretty huge, but G7KLJ had the benefit of 300 more watts - that's a 6dB advantage. It also depends on how the individual S meters compare. Steve seemed to indicate that his S meter was a bit on the lazy side - 1 S Point pessimistic? But maybe my S meter similarly pessimistic?

Compared to a full size inverted L my loaded aerial is less than half the size and is obviously going to lose out, but by how much? Half the size, half the effective power - 3dB down? Probably a lot more - 6dB? There's one S point lost already (Who wants to bet that it's a lot more than that?). Since I have a ground system that is far from ideal there's another few dB's lost - another 6dB? That would be 2 S Points lost before taking into account anything else. This is all pure guesswork and speculation admittedly and probably quite groundless (almost literally in my case), and might best be described as pointless ramblings! (Where did the delete key go?) The pessimist? The realist?

The only thing proved by this single event is that my aerial radiates at least something useful - and that G7KLJ has a great station! www.g7klj.com

Droitwich

OK so it's not Droitwich, but it does work and gets me on Top Band when otherwise there would be no chance.

I am happy - but as with anything improvements can always be made. The aerial could be taller perhaps, though I cannot make it any longer. The earth system could be far far better, though I would struggle to accommodate any improvements at the present QTH. I could use better coaxial cable and also (importantly) attempt to lower the received noise by experimenting with chokes or burying the feeder to reduce common mode currents.

Plenty to think about and plenty to play with!

Important notes on effective Grounding by Jim K8OZ

Mike - I was reading about your work on the 160 meter Inverted L, and it makes me want to go out and build some more antennas! Congratulations. Your story is fascinating, and very well documented.

The only thing I can offer as a suggestion is to get as much radial wire along the edge of your property as possible (assuming your XYL will not allow you to bury radial wire all over your yard). Even if you can only run multiple wires 1/8th of a meter apart from each other, and parallel to each other, your losses will be reduced. The ground losses have quite an impact on your transmitted signal, so any wire you can "hide" along the edge of your property will help improve your signal strength - little, by little...! { It may also affect your resonant frequency slightly, but that's easy to deal with by adjusting with an antenna tuner or slightly changing the loading coil. }

Good luck OM, and keep up the refinements on your antenna system. You're doing great! 73,

Jim, K8OZ
Albuquerque, NM

Top Band Antenna by Mark, G0MGX and Vince G0ORC

Mike, I've been reading with interest your musings on top band antennas and have tried to build a replica of yours today with a fellow ham G0ORC. Thanks very much for the information and the link. You can see the results of my attempts here:

Construction: http://g0mgx.blogspot.co.uk/2012/08/top-band-what-happens-there-then.html

It Works!: http://g0mgx.blogspot.co.uk/2012/08/well-this-top-band-twig-does-it-work.html

Mark. G0MGX

Mike,

I know you have been in contact with my good friend Mark G0MGX but I felt I needed to say thanks and acknowledge your work on a 160m sloper.

It works very well here and, thanks to Mark who built several inductors until one gave us an SWR of 1.1 on the CW end of the band and also braised several copper rods together for form a reasonable earth under a large pine tree. He has passed on to me details of the website of K7MEM which may well inspire me to try a sloper for 80m as well.

I've always wanted a top band antenna but felt that I didn't have the room - but thanks to your idea and Mark's enthusiasm for the project I now have what I wanted - I'm being heard (and can hear) into European Russia with it so it certainly works!

Thanks again - I enjoyed your website very much. (Just heard A65BP as well!)

73, Vince G0ORC http://www.qrz.com/db/G0ORC

Further Developments of this antenna...

Another Top Band Aerial by MØMTJ

After reading the article "Top Band in a Small Garden" in the August 2012 edition of Practical Wireless Magazine ('PW'), I investigated further development of my Top Band Sloper / Inverted L Antenna (shown above).

The article by Stuart Craigen G4GTX described a compact wire antenna for top band that could be accommodated in small gardens. The antenna is shunt fed at the base, the coax being connected across a 7 turn coil (wound on an off-cut of an empty silicone sealant cartridge), with the braid connected to the earth stake and radial ground wires. The centre conductor is connected to the aerial wire.

I could not quite accommodate the shape that Stuart suggested for the aerial wire, but it is very similar: For my version the feed point is at the bottom of the garden near the fence immediately adjacent the earth stake. The first section of aerial is about 9.14 metres long - the wire rises 3.5 metres vertically up the 6.5 metre tall telescopic pole, at the 3.5 metre point the wire is held in place on the mast by a small bungee and then folds over almost horizontally and runs for a further 5.64 metres where it connects to the loading inductor.

The inductor consists of 36 turns of 18 swg (1.2mm diameter) enamelled copper wire on a 50mm diameter, lightweight plastic former (again made from an off-cut of an empty silicone sealant cartridge). After the inductor there is a further 6 metres (approx) of wire rising to a dog-bone insulator, fixed to the end of a length of para cord that runs up to the pulley shown in a previous photograph. From the dog-bone insulator the aerial wire runs back, in the opposite direction, for about 12 metres, returning to the top of the 6.5 metre tall mast at the bottom of the garden, tied off to an egg insulator which is itself fixed to the top of the mast by a very short length of para-cord fixed to the mast by a thick nylon cable tie.

If the wire dimensions are changed, the number of turns on the inductor will have to be changed accordingly. Similarly my antenna is located quite near the 80m/40m Inverted L and the interaction of the antenna affects the tuning and hence the number of turns required on the loading coil.

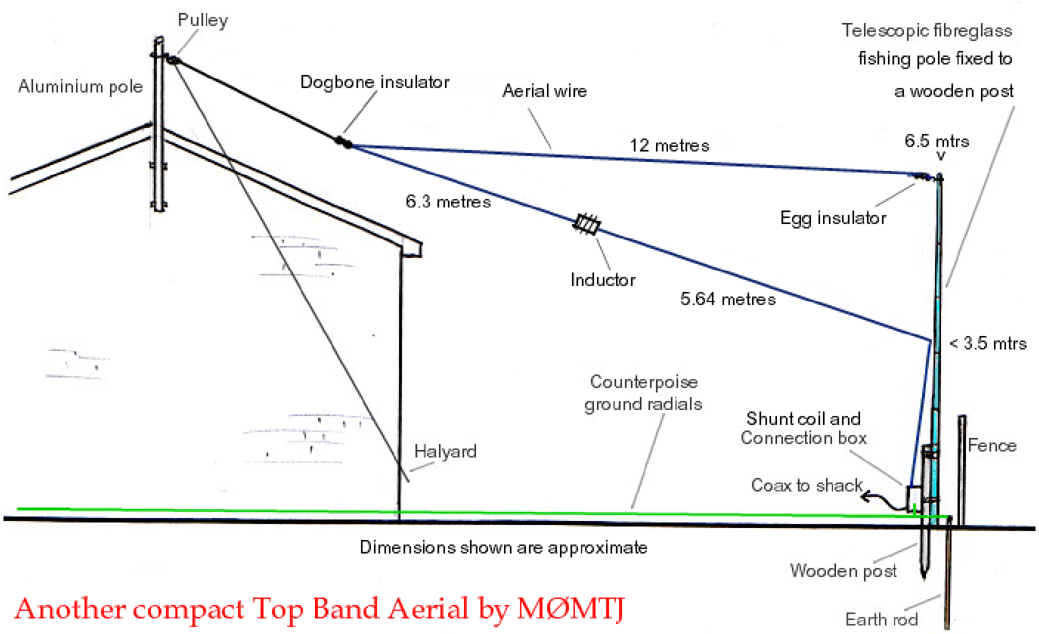
Pulley
Aluminium pole
Dogbone insulator
Aerial wire
Telescopic fibreglass
fishing pole fixed to
a wooden post
12 metres
6.5 mtrs
v
6.3 metres
Egg insulator
Inductor
5.64 metres
< 3.5 mtrs
Counterpoise
ground radials
Shunt coil and
Connection box
Fence
Halyard
Coax to shack
Dimensions shown are approximate
Wooden post
Another compact Top Band Aerial by M0MTJ
Earth rod

Another Top Band Aerial (drawing not to scale)
The inductor is 36 turns of 1.2mm diameter (18 swg) enamelled copper wire on a 2 inch former

With that arrangement there is about 27 metres of wire in the air. The point of resonance is 1900 kHz, but this can be adjusted by altering the number of turns on the inductor. As expected bandwidth is quite narrow. As with any antenna fed against ground the earthing needs to as extensive as possible - as noted previously, above. I suspect that it may be better that the top wire should be horizontal, or sloping slightly upwards, however with the available space and materials available the best that I could achieve had the top wire sloping slightly downwards to the post. Lowering the position of the dog-bone insulator or using a taller post could overcome this.

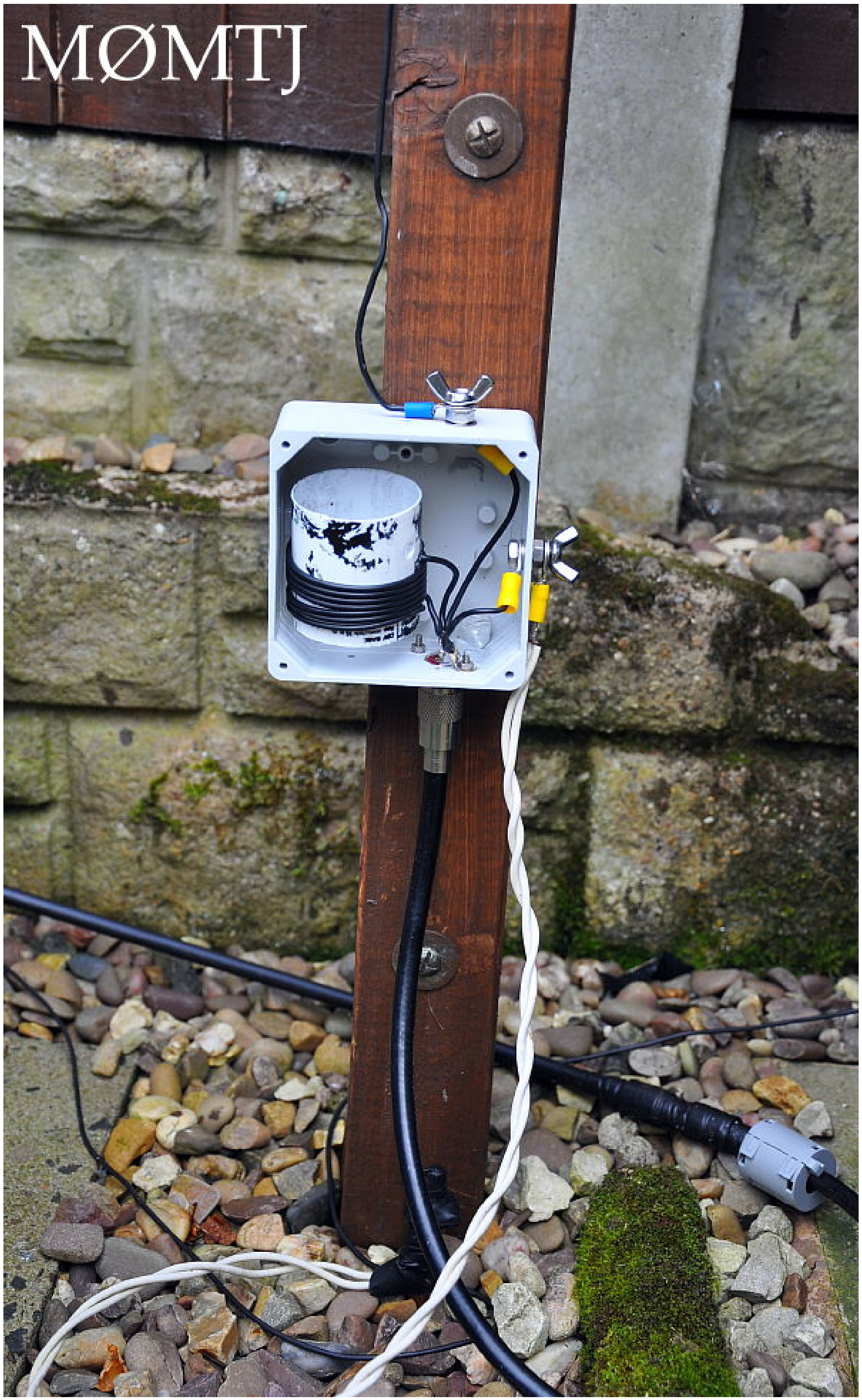

Photograph of the feed-point of the compact, folded, Top Band antenna showing the 7 turn shunt fed coil in the weatherproof housing. Nuts and bolts are stainless steel.

First Test: A brief on air test on 8th September 2012 between 2100 and 2130 UTC on 1.933 MHz brought in two prizes: Peter EI7JM near Malin Head and Tony M3LTD in Naseby, Leicestershire. EI7JM was a true 5/9 to me and he gave me a report of a true 5/9. M3LTD was 5/7. Many thanks to both stations for the useful contacts.

For different sized gardens the best idea might be to get as much aerial wire into the air and then make adjustments to the point of resonance by simply adjusting the number of turns on the inductor.

Practical Wireless Magazine
Obtain the article "Top Band in a Small Garden" by Stuart Craigen G4GTX from Practical Wireless Back Issues department

Stuart Craigen G4GTX comments:

Hi Mike, I have just been looking at your fascinating antenna page on top band antennas! Glad to see that you had a go at building my shunt fed wire vertical that I did for Practical Wireless! I found it tremendous. A few weeks ago I was talking to G3YFN in Newcastle at about 4pm when I was called by G4BIM in the Isle of Wight! I also got a QSL 5/9 from Luxembourg!. Have fun.with it!

Thanks for the nice comments about my shunt fed 160m aerial. I enclose some QSL cards which you might find interesting to look at! Note the times of the QSO's and the reports! At night I have been told that I sound like the BBC from some European stations!!

Note G4BIM Isle of Wight 5/7 from Sunderland at 4.30 pm and Aberdeen at night. It certainly works for me. I think that the shunt feeding is the answer as it taps into the aerial at the 50 ohm point. Putting the loading coil away from the base should increase efficiency hence approx midway. A chap near Newcastle built one of these a few years ago and his groundwave signal was 5/9+20 here in Sunderland 12 miles away!!!
73
Stuart G4GTX

More ideas....

Adding Top Band to the 40m / 80m Inverted L antenna using a switchable loading coil:

Due to an aborted house move in 2010 I had removed all the antennas. While re-establishing the aerials in 2011, and considering space limitations, I decided to experiment with adding a loading coil to the 40m / 80m Inverted L aerial. The loading coil has a link wire to short it out of circuit when using the aerial for 80 metres and 40 metres. The link wire is removed when Top Band is required. The coil consists of approximately 37 turns wound on a piece of 68mm (2.8 inch approx) diameter PVC pipe:

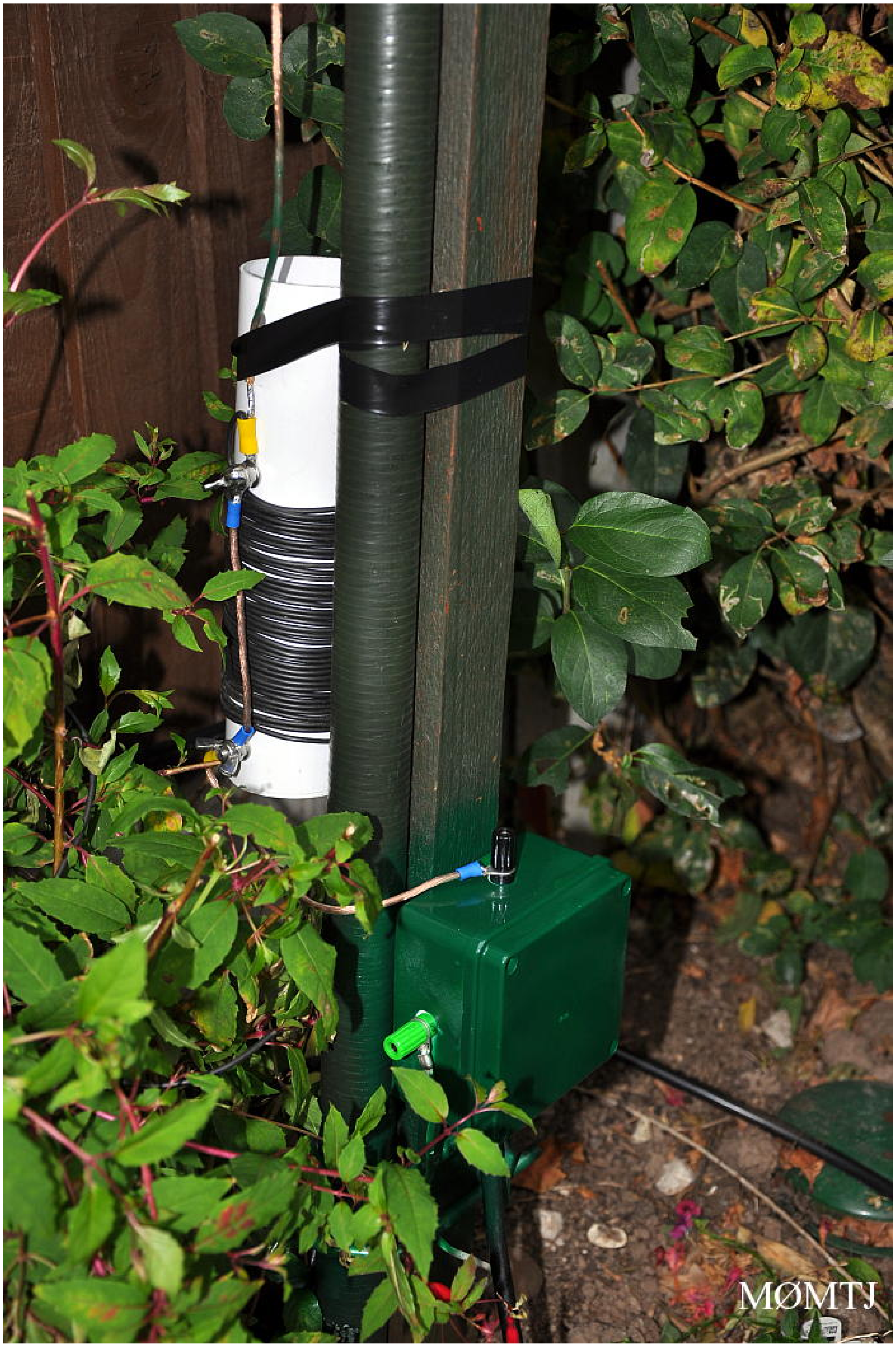

Work In Progress! - Adding 160 metre loading coil to the 80m / 40m Inverted L Aerial.
The loading coil has a link wire to short it out of circuit when using the aerial for 80 metres and 40 metres.
The link wire is removed when Top Band is required.
The coil consists of approximately 37 turns wound on a piece of 68mm (2.7 inch approx) diameter PVC pipe.

More about the 80 / 40 metre Inverted L Aerial on Antennas Page 1 >

Simple Vertical Top Band Aerial Using A Fibreglass Telescopic Fishing Pole (Roach Pole)?

If there really is no space to accommodate a top band dipole, inverted V or even the inverted L above, then another option could be a simple vertical. Again based on a 10 metre long fibreglass roach pole, this could be installed as a permanent aerial, or only deployed as and when required on a temporary and stealthy basis.

The 10 metre long fishing pole would be erected by standing it on the ground, using three or four nylon guy ropes as support, or tying it to a wooden ground stake driven into the ground. The vertical radiator would consist of about 9.5 metres of PVC covered wire fixed at the top of the pole and with a loading coil at the centre. As with the design above, the loading coil could be wound on a 5 cm diameter using 1.2 mm diameter enamelled copper wire. To make the former as light weight as possible, once again, the tube from an empty bathroom sealant (or silicone sealer etc) gun could be used. They are, conveniently, 50mm in diameter.

I have not experimented with the number of turns required for the centre loading coil, but from experience with the above aerial, the figure may lie somewhere between 50 and 100 turns.

The aerial would be fed with coaxial cable and would need a good earth rod at its base and a good number of ground radials, as along as possible.

Previous Top Band Aerial Experiments:

Top Band Inverted V

This is a considerably shortened dipole for 160 metres, using loading coils to reduce the length of each leg to about 7.5 metres length. Each coil is wound on a 5 cm diameter former and consists of approximately 120 turns of 1.2mm diameter enamelled copper wire. The dipole was arranged in an inverted V configuration.

Being as a dipole is a balanced aerial, it was fed at its centre using balanced twin feeder for lowest loss and, being balanced, lowest noise.

In this configuration it was very quiet, but did also appear to receive very well. At my QTH the noise on top band generally ranges from S7 to S9, on this inverted V the noise was S4 to S6. However it did not transmit well at all - I believe this to be not only because the dipole is very short (only 15m) but because the angle at which the wires at the top of the V was far too acute - only about 45 degrees. The angle at the top of the V really should be over well 90 degrees - maybe something like 110 degrees would be best. Clearly this seems to be a problem.

I had not got the space to separate the wires any further, but it was an interesting experiment that appeared to demonstrate that a balanced dipole fed with balanced twin feeder could help reduce noise. If more space was available this is an antenna that I would wish to pursue further.

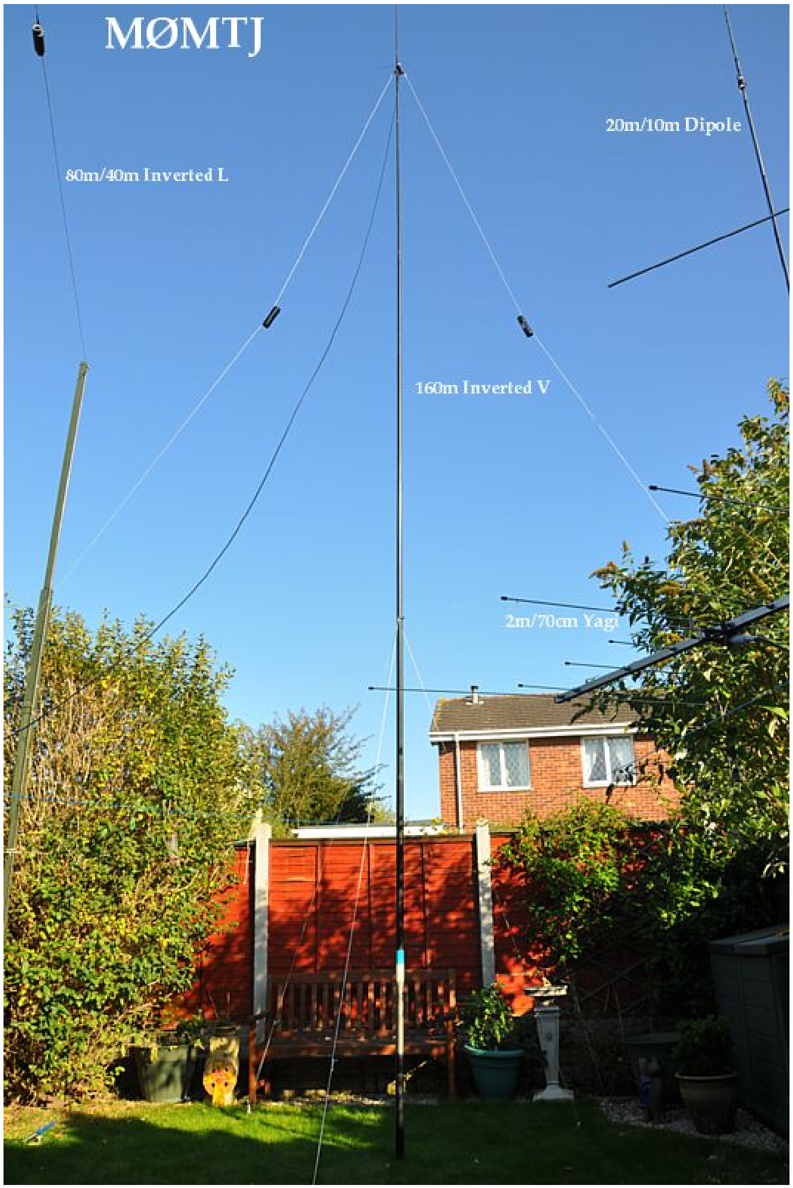
M0MTJ
20m/10m Dipole
80m/40m Inverted L
160m Inverted V
2m/70cm Yagi

Top Band Shortened (loaded) Inverted V

Short Base Loaded Sloper - a first attempt at a top band antenna

160m metres is probably the noisiest band, but I wanted to give it a go anyway even though space at my QTH is at a premium and fitting in a suitable antenna is quite challenging. The most promising candidate that I initially found, apart from small commercially available antennas, was the "Practical Antenna For 160 metres" described by Frank G3YCC and featured on the website of IW5EDI and linked to on the pages of www.dxzone.com

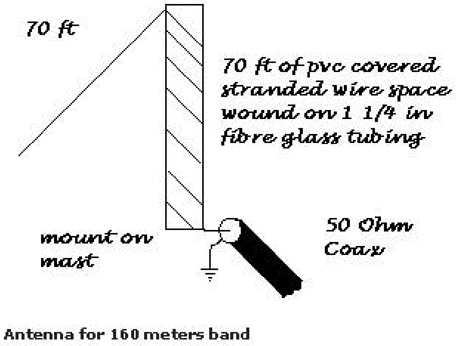
70 ft
70 ft of pvc covered stranded wire space wound on 1 1/4 in fibre glass tubing
mount on mast
50 Ohm Coax
Antenna for 160 meters band

G3YCC Top Band Antenna

This Top Band antenna consists of 140 feet of wire, 70 feet space wound around a non-conductive (fibreglass) pole or tube about 6 feet long, with remainder forming a sloping wire falling back to near ground level. The antenna is UN-Balanced and is therefore fed with unbalanced coaxial cable, with the braid connected to a ground stake at the base of the aerial.

The above design is intended to have the coil section mounted on top of a mast or pole with the wire running downwards. I could not accommodate that arrangement, so I adapted the design to produce the antenna shown below:

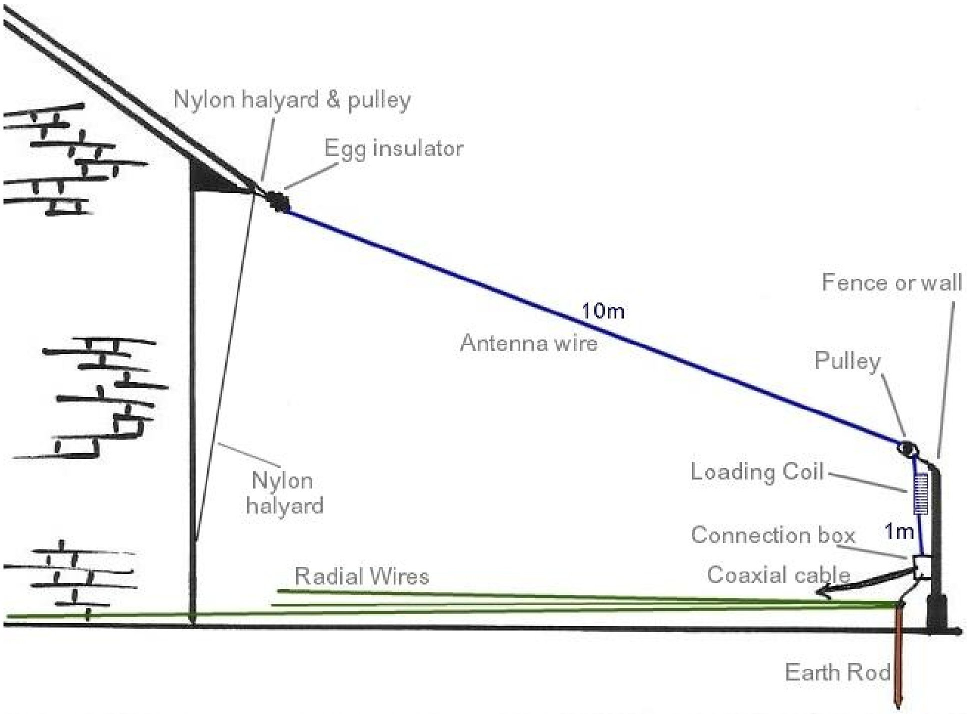
Nylon halyard & pulley
Egg insulator
Fence or wall
10m
Antenna wire
Pulley
Loading Coil
Nylon halyard
Connection box
1m
Radial Wires
Coaxial cable
Earth Rod

The drawing above shows the loaded Top-Band Antenna - a first attempt at an aerial for 160m - consisting of the radiating top wire, a base loading coil, earth stake and additional earth radials that act as a counterpoise: The top wire is about 10 metres long and slopes down to the loading coil which consists of 64 turns of the aerial cable wound around a 4" diameter PVC pipe and then falls vertically for about 1 metre where it enters the connection box. The halyard arrangement allows the antenna wire to be quickly dropped for adjustment and then raised back into position. There is an earth rod at the base of the antenna connected to several ground radials and a second earth rod a few metres away.After performing some tests I find that it does work reasonably well for local contacts ground wave contacts around the town, but it could be better and is certainly very disappointing for longer distance work.

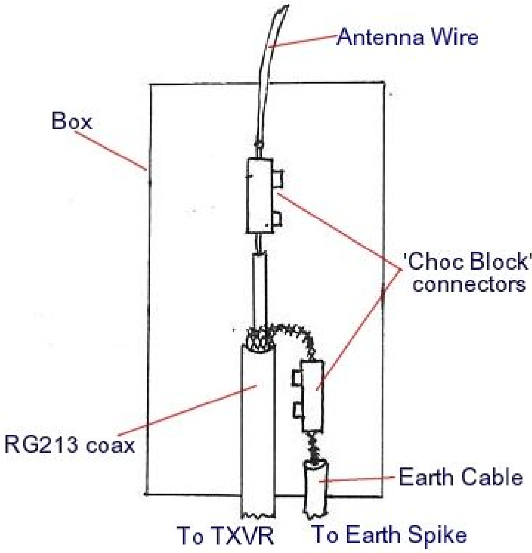
Antenna Wire
Box
'Choc Block' connectors
RG213 coax
Earth Cable
To TXVR
To Earth Spike

Above: The Connection Box

Read more developments here>

Efficiency

The aerial shown above is obviously very much shortened and therefore is very inefficient when compared to a full size resonant quater wave aerial. A shortened aerial still needs to make best use of the space - so the antenna wire needs to be as long as possible. Resonance is adjusted by varying the inductance of the loading coil. Also it is necessary to use the largest earth system as is practicable to obtain the best possible efficiency.

Performance

In my configuration described above it is admittedly a very low efficiency antenna - but at least it gets one on Top Band! It's ok for local working around a town or a city, but it's certainly not a DX aerial by any stretch of the imagination. I could hear many stations 100 to 200 miles away, but they could not read my signals. For local ground wave work it was adequate.

I suspect that if the original design by G3YCC was employed, i.e. the coil mounted at the top of a pole and the loading wire running down, that it may work rather better than my implementation. The problem that my implementation has is that the loading coil is at the bottom of the aerial, near the ground. Better efficiency may be acheived with centre loading. The longer the radiating wire the better too.

More Details

The antenna was fed by coaxial cable from the shack in the bedroom at the front of the house to the feed point at the base of the fence at the bottom of the back garden. The coaxial cable enters a small plastic box, screwed to the fence post, where it is terminated: The outer conductor of the coax is connected to the earth cable with a 'chock block' connecter, the earth cable going to a four foot long earth rod hammered into the ground near by. The centre conductor of the coax is connected to the antenna cable also using a 'choc block' connector.

The antenna wire runs vertically up the fence for about 1 metre to the loading coil which consists of 64 turns of the antenna wire wound around a piece of 4 inch diameter PVC pipe. About 32 turns a close wound and the other 32 turns space wound; The inductance, and therefore the point of resonance could be easily adjusted by altering the spacing of the windings. Once set at the required point of resonance the windings can be held in place with duck tape.

The antenna wire exits the coil at the top and passes through a pully secured to the top of the fence and then slopes upwards for about 10 metres to the fixing point at a convenient point on the house, in this case the eaves. The end of the wire is tied off to a plastic 'egg insulator'. The egg insulator is tied to a nylon halyard wich passes through a second pully at the fixing point. This allows the antenna wire to be quickly dropped for adjustment and then raised back into position.

The earth system should be as extensive as possible for better efficiency; e.g. earth stake and a number earth radials, as long as possible around the garden to provide a counterpoise.

Link:

Visit www.g7klj.com - the website of 160 metre entusiast Steve G7KLJ

OTHER THINGS

Antennas for HF

There are dozens, if not hundreds, of antenna designs from which to choose. All have their own proponents. Some are genuinely good while others might be considered as nothing more than glorified dummy loads! The key thing for me was to choose the most effective an antenna that could fit within the constrains of my small back garden and also one that would not be too ugly.

I decided that wire antennas, made from PVC covered stranded wire, would be least objectionable on visual grounds. After all they look like glorified washing lines and almost everyone has a washing line**!**

Knots to use when fixing Wire Antennas

It's important to use the correct knot for the job. I find that the Bowline is very useful for fixing end, egg and dog-bone insulators to the ends of the wire and/or ropes. The Round Turn & Two Hitches, Anchor Bend and Buntline Hitch knots are very good for tying a rope to a pole or a mast. A Double Sheet Bend can join two pieces of rope together - even if they are of unequal size. 'Animated Knots' will show you how to do them: http://www.animatedknots.com

The antenna or antennas really are the key to an effective amateur radio station. The most expensive radio will be of little value unless it is used with the best possible and most effective antenna; so I had to set about finding the best antennas that I could accommodate for HF and VHF work.

The dilemma facing most radio amateurs is that antennas for HF are often large and difficult to accommodate in modern small back gardens. Additionally there may be objections on the grounds of visual impact. Some people do not regard antennas as the beautiful creations that radio enthusiasts do!

Cables and Feeders

As I have learned by experience and from the tutorials I have studied as part of the licensing exam process, a very important consideration concerning the antenna system is the loss incurred in the cable that connects the radio to the antenna. A loss of 3dB sounds like a small amount when you say it quickly, but that equates to only HALF of your transmitter power reaching the aerial! We'd soon complain if our new 100 watt transceiver only produced 50 watts - so why stand the chance of losing this much power in the feed line?

Starting off as an M3 licensee I could only use 10dBw (10 watts) power at the antenna termination, so if I had a feeder with a loss of 3dB I would have to run the transmitter at 20 Watts to get 10 watts to the aerial!

Coaxial Cables

For HF using a single band resonant antenna, a dipole for example, Mini 8 or even RG58 is probably fine since the SWR should be between 1:1 and 2:1. However if one was to consider using the antenna on non resonant frequencies the VSWR will be higher, maybe very much higher, and the consequential losses in coaxial cable will be greatly magnified and power losses very significant. I did not want to run such an inefficient station.

For this reason I chose to use low loss RG213 coaxial cable for my Inverted L since I may need to use it on bands other than the 40 metre and 80 metres that it is intended for and where the SWR may be 4:1 or 5:1. RG213 will help keep feedline losses to a minimum. No lossy RG58 on Mini8 for me! Westflex 103 would be even better, of course.

For VHF and UHF I now consider Westflex103 as the minimum standard of cable to use, it's half the loss of even RG213. Losses at VHF are much higher than HF and at UHF they are even higher, so Westflex 103 helps preserve as much of that precious transmitter power as possible.

See more about Coaxial Cable Losses here >

Balanced Feeders = Low Noise

It's difficult to feed a centre fed wire dipole with RG213 or Westflex 103, both cables are really too thick and heavy. RG58 or Mini 8 are lighter and therefore more suitable for suspended wire dipoles, but to match the unbalanced coaxial cable to the balanced dipole would need a 1:1 'choke balun' at its centre, as I have learned. However, as mentioned above, when attempting to use the dipole at non-resonant frequencies the VSWR will be higher and the losses in the coaxial cable will be very much larger too, and hence much less of the precious transmitter power will be actually radiated by the antenna. Not an ideal situation

I have learned that the only really sensible way to feed dipole type antennas, which are 'balanced', is to use a balanced feeder such as 300 ohm ribbon cable, 450 ohm ladder line or the best option, it seems, might be 75 ohm Twin Feeder. All such twin feeders are extremely low loss, much much lower than any coaxial cable, so low that it could almost be considered lossless by comparison. Of course nothing is lossless, but twin feeder is as near as you'll get, so that's how I will feed my dipoles from now on! See the note on Doublet antennas below.

Tony Nailer of Spectrum Communications notes that: "75 ohm twin feeder is lower loss than coax. It allows the aerial to be properly balanced and the very close spacing of the wires prevents pickup or radiation from the feeder. It does not need to be spaced off, unlike ribbon feeder. Use of twin feeder makes this aerial much lower noise than one fed with coax. Also importantly it generates less TVI !! Note that the [trapped dipole] aerial is generally 72 ohms, and will need to be used with an ATU with transistorised rigs which are unforgiving about SWR mismatches."

Spectrum Communications are now supplying a new design of top quality, very low loss, twin feeder. It is rated at 2kW at 100 ohms. It can be supplied by 100 metre reel or by the meter, or in various lengths with the ends expertly terminated and made off. I can confirm the superior quality of this product and its low noise properties.

Spectrum Communications also supply a very high quality, well made 1:1 Balun that is perfect for connecting the twin feeder to the unbalanced input of an A.T.U. of transceiver.

Doublet or Dipole (Horizontal or Sloper)

I have also experimented with a second HF antenna - the 'doublet' style antenna. I fed this with low loss twin feeder and cut it for the lowest frequency of operation, in my case 20 metres (14 MHz).

Some initial experiments have shown that it is very effective on 20 metres, better than my Inverted L - which is designed essentially for 80m and 40m.

In theory a doublet antenna, when fed by twin feeder (NOT coaxial cable) and matched at the transmitter end via a

1:1 balun and an ATU (or to use a more correct term, Antenna Matching Unit) at the transceiver should be able to work on all bands with a higher frequency than the band that it is cut for.

On other bands such as 17m (18 MHz), 15m (21 MHz), 12m (24 MHz) and 10m 28 MHz) the doublet showed generally lower VSWR than the Inverted L .... however (and here is a nice lesson) it is actually not quite as effective as the Inverted L! I think that size may matter here - the overall length of the Inverted L is much longer.

This short 14 MHz doublet is only about 10 metres in total length and was suspended at about 25 feet high at one end from the same fibreglass pole fixed at the apex of the roof and taken down to another 16 foot high wooden pole installed on the other side of the back garden in somewhat of a 'sloper' style.

Trapped Horizontal Dipole or Vertical Antenna for 20m / 10m

I also experimented with a trapped wire dipole cut to be resonant for 20 metres and 10 metres, again fed with twin feeder and matched at the radio end via a 1:1 balun and the ATU (AMU !).

I may also try an antenna for 20m / 15m and 10m in a Vertical 'ground plane' arrangement which should give a lower angle of radiation than a horizontal dipole - therefore better for longer distance DX.

At the moment I am using the 20m / 10m trapped dipole in a rather unorthodox arrangement. I have installed a fibreglass fishing pole, mounted vertically on a stake on one side of the garden. Most of the wire dipole is fixed to the vertical pole, but being as the dipole is somewhat longer than 7 metres, a portion of the wire runs away from the pole horizontally along a fence panel about 1.5 meters above ground level. It's vaguely L shaped, but mostly vertical which should help with the angle of radiation. It seems to work very well indeed - I like the mostly vertical idea.
The antenna can be seen on this page >

Other Dipoles:

Spectrum Communications can supply a full size W3DZZ style antenna with a 7MHz trap for use on 40m and 80m and usable on 20m, 15m and 10m. A half size version with a 14 MHz trap for use on 40m and 20 metres, plus 15m and 10m is also available. As a special order an even shorter version using a 28 MHz trap is available for 20 metres and 10 metres. http://www.spectrumcomms.co.uk/G2DYM.htm Al versions designed to be used with balanced line feeder - lince they are balanced aerials - for low noise and lowest loss.

PDF Document - The W3DZZ Antenna -
http://www.users.icscotland.net/~len.paget/GM0ONX%20trap%20dipole.pdf (But rather than using coaxial cable with a 'choke balun' at the centre of the dipole, try using twin feeder with the Choke Balun at the radio end for less power loss!)

Links

Enamelled copper wire supply: http://www.esr.co.uk/electronics/cable-copper.htm

Loading coil calculators: http://www.k7mem.com/Electronic_Notebook/antennas/shortant.html

Ring Core Calculator: http://www.dl5swb.de/html/mini_ring_core_calculator.htm

Vertical Antenna For 50 MHz, 144 MHz and 430 MHz

Watson W-2000 on Telescopic Mast at the lowest position
more on this page

OTHER ANTENNAS

Our good friend in Australia Felix Scerri, VK4FUQ, uses Inverted V antennas but also highly recommends the Quad Loop style antenna for HF work. These are well worth investigating, and you can read more here: Antennas 3 see the antennas at the MØMTJ QTH here with many more antenna ideas on Antennas 4 and the Links Page here and here

Antennas 1 | Antennas 3 | Antennas 4 | Antennas 5 | Antennas 6 | Antennas 7

G Whip Antenna Products
G-Whip Antenna Products
Geoff G4ICD offers a multitude of high quality solutions for portable, mobile and permenant base installations

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WSPR Weak Signal Propagation Reporter

News, Developments, Events, Photographs and other 'Bits 'n' Bobs'

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M0MTJ

Amateur Radio; Ham Radio; Radio; Transceivers; HF; VHF; UHF; Data Modes; Morse Code; RTTY; PSK31; SSTV; FSTV; Amtor; Sitor Antennas; Aerials; Cable; Coaxial Cable; Twin Lead; Masts; Poles; Propagation; Computer; PC; USB Computer Interface; Microphone Loudspeaker; Filters; Noise Reduction; DSP; Digital Signal Processing; Morse Key; SWR ; Inverted L; Inverted V; Dipole; Doublet.

Amateur Radio MØMTJ

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AERIALS (ANTENNAS) 1

Antennas 2 | Antennas 3 | Antennas 4 | Antennas 5 | Antennas 6 | Antennas 7

"Success is 90% antenna and 10% rig. Hobby is 90% listening 10% transmitting" - *MM0HDW.*

AERIALS used by MØMTJ

This page shows some the antennas that I have used over the course of time.

Index To Other Antenna Pages:
Antennas 1 : Aerials used by M0MTJ
Antennas 2 : Including ideas for compact aerials for Top Band /160 metres
Antennas 3 : Felix Scerri VK4FUQ discusses Loop Aerials, baluns, masts & other antenna related topics
Antennas 4 : Many antenna ideas from various sources particularly for multi-band operation & also gives information about
antenna trimming, knots for wire antennas and useful aerial rigging accessory ideas.
Antennas 5 : Half Wave (physically end fed) aerials for 144 MHz VHF / 430 MHz UHF and 50 MHz 6 Metre band & J-Pole Aerials
Antennas 6 : Simple and effective H.F. Aerial ideas: The All Band Doublet, an All Band Sloper & a Ground Plane Aerial
Antennas 7 : Omni-Directional - Circularly (Mixed) Polarized Aerial for VHF / 2 Meters.

2014 : Current Set Up - as at September 2014:

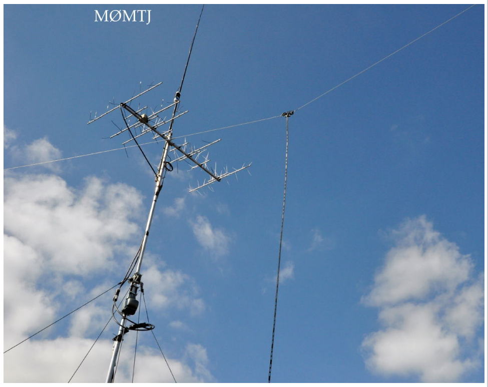

The Summer of 2014 has seen a few changes of aerials. The 80m/40m Inverted L was removed and replaced with a newly constructed Doublet Antenna fed with ladder line via a 4:1 G-Whip current balun and an LDG "ATU". The Tecadi support pole originally used for the Inverted L is now used to support one end of the Doublet. You have probably read this elsewhere, but I can confirm that the All Band Doublet (fed with ladder line *not coax*) is a superb all round HF aerial. Highly recommended.

The SGC-230 Automatic Antenna Coupler was moved from the original feedpoint of the Inverted L antenna to the second feed-point on the other side of the garden. This now feeds a sloping wire of approximately 20 meters length to ensure that the 80 Meter Band and Top Band (160 meters) remain available. This antenna will also 'tune' on most other bands, so remains a very useful second antenna, though the All Band Doublet is often considerably better, particularly on the higher frequencies. The old SGC-230 was also faulty and I replaced it with a new CG-3000 auto coupler from Martin Lynch and Sons.

The J-Pole for 4 Meters (70 MHz) was removed since it wasn't used much, being only connected to a 4m hand-held radio - it seemed to be a waste of precious antenna space. This was replaced with a newly constructed Half Wave "CFR" Antenna (Coaxial Dipole) for 6 Meters (50 MHz) connected to the main HF radio via Westflex 103 coax. The DK7ZB dual band Yagi antenna remains, as does the 10m / 6m Fan Dipole in the loft space. Also remaining in place at the apex of the house is the home-brew 2m / 70cm "CFR" Antenna (Coaxial Dipole) for VHF/UHF FM operation - this has been a particularly effective antenna.

To sumarise:

1) A 20 meter long doublet antenna fed with balanced ladder line for 40 meters to 6 meters. The 'old timers' really knew their stuff, this an excellent all round antenna that is easy and cheap to make and should be quite easy to accommodate and install. See photograph below and read more here

2) A Sloper Antenna consisting of two parallel wires - one wire being 20 meters long with a second parallel wire

Get on the air with
TOP QUALITY
BRITISH
G-WHIP
ANTENNAS

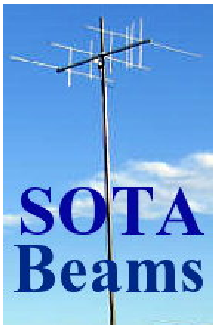

SOTA Beams
Lightweight 2 metre & 70cms Yagis, Dipole, Accessories & Poles
www.sotabeams.co.uk

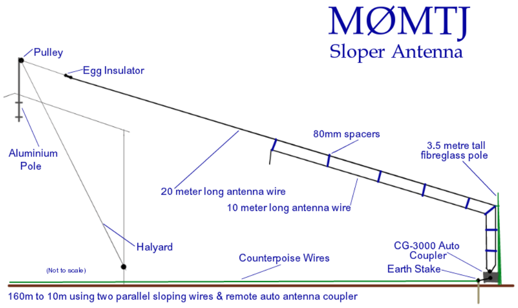
MØMTJ
Sloper Antenna
Pulley
Egg Insulator
Aluminium Pole
80mm spacers
3.5 metre tall fibreglass pole
20 meter long antenna wire
10 meter long antenna wire
Halyard
Counterpoise Wires
CG-3000 Auto Coupler
Earth Stake
(Not to scale)
160m to 10m using two parallel sloping wires & remote auto antenna coupler

that is 10 meters in length. The first 2.5 meters (approx) of wire runs vertically up a non metallic post, then the remainder slopes back towards the house being finished off with an insulator which is attached to a Para-Cord lanyard that runs through a pulley on a pole at the apex of the roof. The antenna wire can therefore easily be let down for maintenance or adjustment whenever required. For lowest possible loss, the antenna is fed via a GC3000 automatic antenna coupler located at the bottom of the garden. The antenna is primarily for lower HF bands including 160 meters, 80 meters and and 40 meters, but it also works very well on some higher bands. The GC3000 itself is mounted in a waterproof IP56 rated enclosure near ground level at the bottom of the garden. Grounding is achieved from two 4 foot long copper ground stakes and several radial grounding wires.

Read more about the Sloper Antenna and the CG3000 here.

3) A 'home-brew' omnidirectional, vertical dual band, end fed antenna for 2 metres and 70cm. This is of the Controlled Feeder Radiation design (CFR) by VK2ZOI; effectively an end fed half wave dipole on 2m with an aluminium sleeve dipole section to achieve 70cms with a few extra dB's of gain. It is mounted on an aluminium mast. It's feed-point is about 11 metres a.g.l. read more here

4) A DK7ZB design dual band Yagi antenna, with 5 elements for 2 metres and 8 elements for 70cms, mounted horizontally for SSB. A lightweight antenna rotator is employed and uses a push-up telescopic mast. Height above ground level is again approximately 7 metres. The DK7ZB is an excellent twin band Yagi antenna. read more here

5) A Half Wave End Fed / Controlled Feeder Radiation (CFR) antenna for 6 meters / 50 MHz. Supported by a 3 meter long telescopic fibreglass fishing pole attached to the top of the aluminium push up mast that supports the DK7ZB dual band yagi and rotator.

6) Dual Band Fan Dipole, made from thick loudspeaker wire, mounted horizontally in the loft space for 10 meters an 6 metres. Cheap & quite effective.

Other Options that can be deployed on an 'as required basis' :

7) A half wave Wire J-Pole fixed to a telescopic fibreglass fishing pole for 10m. Cheap and effective. more about J-Poles here and also here on Antenna page 5

8) Compact Loaded Top Band Antenna, based on a design idea by Stuart Craigen G4GTX more

9 & 10) G Whip End Fed Zepps (EFZ's) for either 20m, 15m or 17m or the G-Whip "WideBander" which is an 'UnTenna' style antenna that can be used for 20m through to 10m using good quality G Whip 9:1 UnUn; useful additions for antenna flexibility. more

11) N9TAX Dual Band Slim Jim (J-Pole) antenna mounted in the loft as a back-up antenna for 2m and 70cms. Very good. more

12) Delta Loop Antenna - 16 metre loop of wire in triangular Delta shape, hung from the top of the pole supporting the inverted L antenna and fed via RG213 coaxial cable via a 4:1 balun. The loop is really a single band antenna cut for one wavelength on the band of interest, however it also can be pressed into service for some higher bands - a good, cheap and easy to install aerial; Often works better than the inverted L on the higher bands, but on 10 metres the tuned 10 metre dipole in the loft is sometimes better. more

Knots: Knots for securing wire aerials and other things more here

H.F. ANTENNAS used by M0MTJ

All Band Doublet Antenna

The Doublet Antenna consists of two 10 meter long top wires to form the 20 meter long 'dipole' section. The centre is fed with Ladder Line rather than coaxial cable. A dipole fed with coaxial cable is essentially a single band (mono band) antenna. Feeding such an aerial with ladder line, or open wire twin feeder makes a much more effective multi-band antenna.

The ladder line runs down to a high efficiency 4:1 Current Balun (G-Whip) which is connected to an LDG AT-200 automatic antenna matching unit via a very short RG213 patch lead to ensure lowest losses. The Antenna tuner and balun are housed in a box which is itself contained in a small garden shed to protect it from the weather. The LDG antenna matching unit is then connected back to the 'shack' via a run of RG-213 coaxial cable. Read more about the All Band Doublet Antenna here.

A view of part of the MØMTJ All Band Doublet Antenna
Read more here

ANTENNAS FOR VHF and UHF - 2 m & 70 cms

The main antennas are as follows:

Home-Brew dual band end (physically end fed) half wave "Coaxial Dipole" for 2m & 70cm

For 2m and 70cm FM I use a mounted on a lightweight aluminium telescopic pole on the apex of the hose. The base of the antenna (the bottom of the radiating element) is approximately 11 metres above ground level. This antenna is based on the Controlled Feeder Radiation principle (CFR) and is described by VK2ZOI. Read more about its construction here. Also seen in the photograph below are the ropes that support the H.F. wire aerials.

Home brew dual band vertical antenna for 2 metres and 70 cms
Read more about its construction here

Dual Band Yagi for 2m & 70cm

For 2 metres and 70cms SSB there is a horizontal DK7ZB design dual band Yagi antenna. This has 5 elements for 2 metres and 8 elements for 70 cms. A lightweight antenna rotator is employed and uses the same push-up telescopic mast that the Home-Brew 70MHz J-Pole is mounted on. Height above ground level is again approximately 7 metres. The DK7ZB is an excellent twin band Yagi antenna**.**

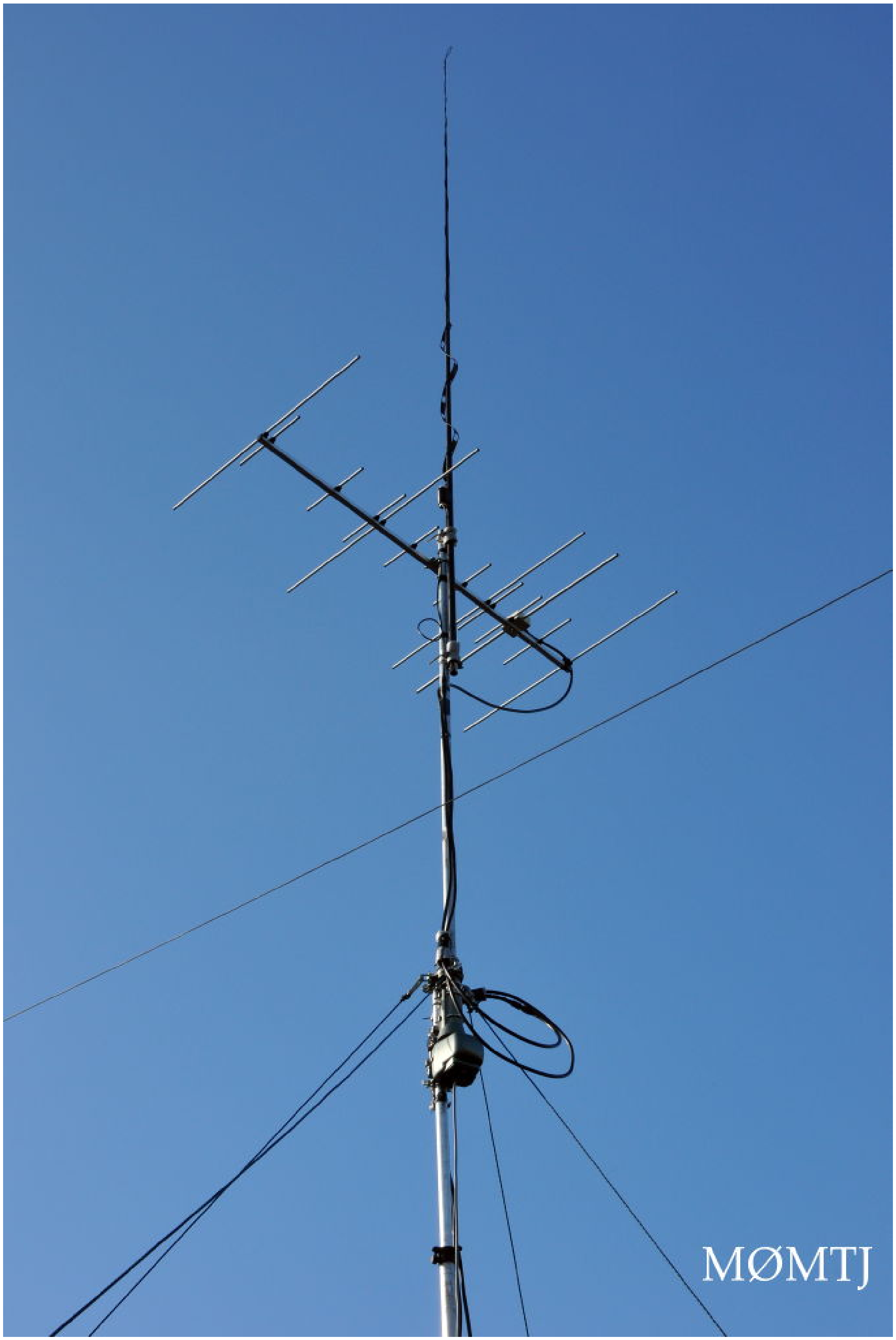

Push up aluminium mast with rotator, 2m / 70cm DK7ZB Yagi and a 4m J-Pole at the top

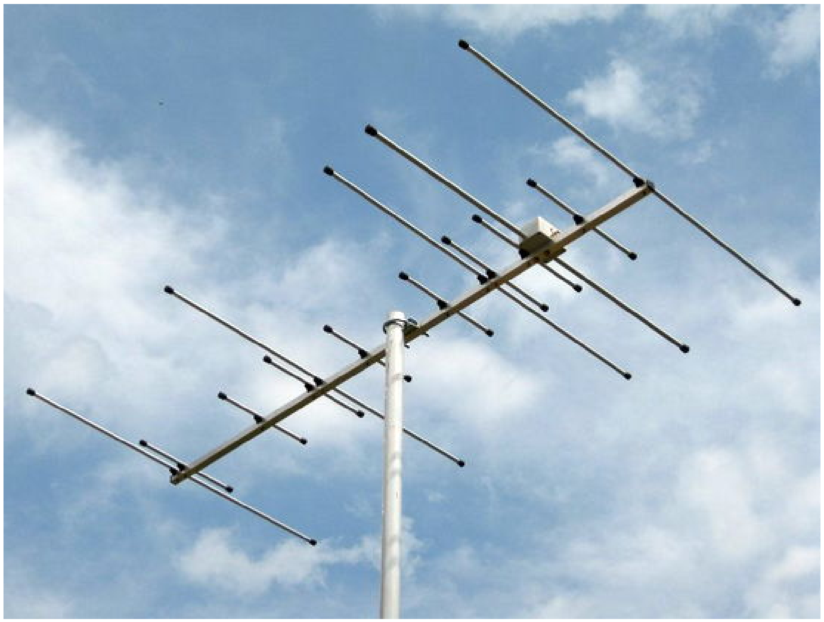

The DK7ZB 5 + 8 element dual band yagi for 2m and 70 cm - designed by Martin Steyer DK7ZB
Available from Arthur M0PLK (SQ2PLK) at Ham Radio Shop:
http://stores.ebay.co.uk/urbasket-eu
http://ham-radio.urbasket.eu
Also available from VPA SYSTEMS by SQ9VPA http://www.vpa-systems.pl
Kits available from NUXCOM.de : http://shop.nuxcom.de

2 Meter J-Pole Antenna for the garden shed - and other J-Pole antennas for 6 metres and 10 metres :

While experimenting with antennas in the garden in the summer of 2012 I thought that it would be good to have a hand-held radio in the shed to do some monitoring and make a few contacts. To improve upon the performance of the 'rubber duck' antenna I quickly made a J-Pole antenna for the 2 metre band.

It is made from a 47cm length of 450 ohm Wireman ladder line as the 1/4 wave matching section, plus a 97cm length of stranded wire as the 1/2 wave radiator. It is fed with 3 metres of Mil spec RG58 c/u coaxial cable that is soldered to the 1/4 wave matching section's impedance matching point at 3.5 cm from the bottom. The coax feeder is wound around some PVC tube to form a choke. The completed antenna is taped to a 2.2 metre long fibreglass fishing pole that I purchased from Poundland (for £1.00). It took about 20 minutes to make followed by some testing and adjustment with the antenna analyser. The fishing pole is lashed to the shed with some cable ties.

This simple antenna works pretty well, but being so low down signal strengths are not huge, but it's pleasing to get on the air with something so simple and cheap!

Find out how easy it is to construct J-Pole Antennas here

Now, if it was at the top of my 10 metre long fishing pole. . . . . (!)

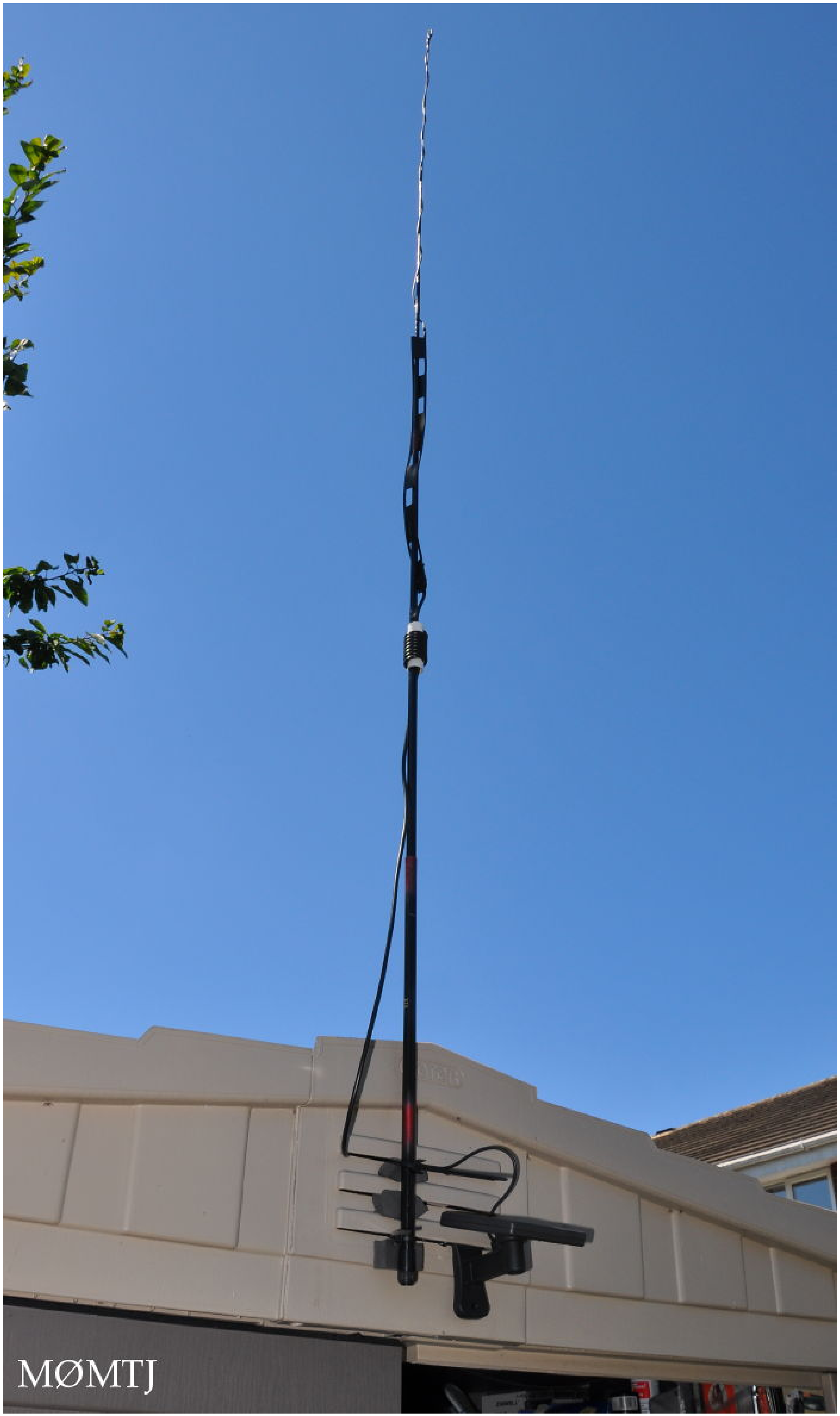

The Shed Antenna - a 2m J-Pole by M0MTJ
Note the simple choke balun at its base made by winding 8 turns
of the coaxial cable around a small off cut of white PVC water pipe.
Find out how easy it is to construct J-Pole Antennas here

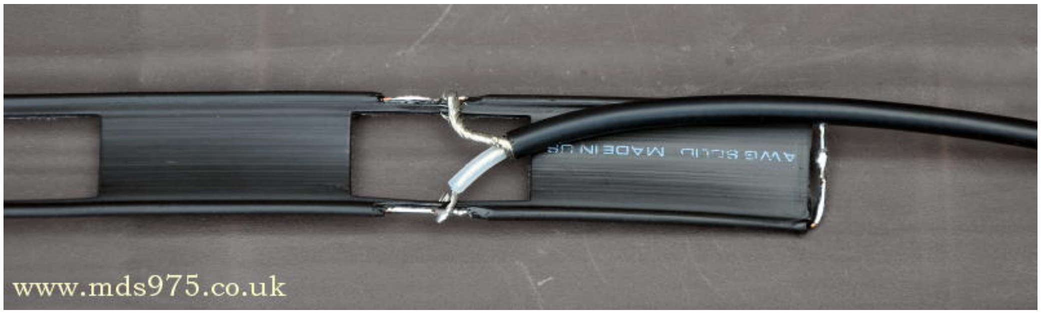

The feed point of a J-Pole antenna made from Wireman 450 ohm ladder line.
More here

More Antennas . . .

Inverted L Antenna for 80m and 40m (and some other HF Bands from 80m to 10m)

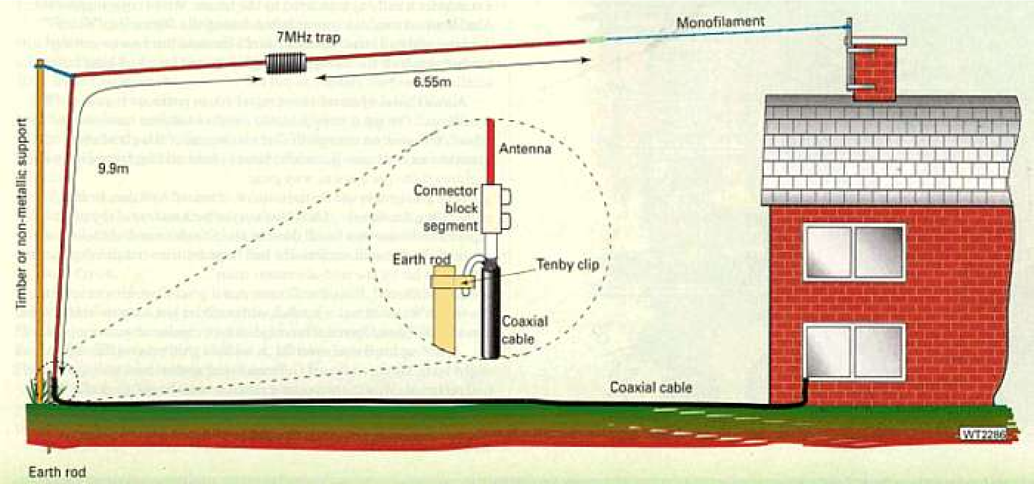

The basic layout of the Inverted L Antenna (Practical Wireless)

The first antenna that I installed was for HF. I decided on an Inverted L that incorporates a 7MHz trap so that it can be used on both 7MHz (40 metres) and 3.5 MHz (80 metres).

The design of this Inverted L is well known and a good design has been published previously in Practical Wireless by Len Paget GM0ONX. It is based on one half of the famous W3DZZ trapped dipole antenna.

It can be made entirely from scratch as a DIY project, or the 7MHz trap could be purchased commercially as a ready made item, or whole antenna can bought as a complete kit from Tony Nailer, G4CFY, at Spectrum Communications. I opted to buy the 7MHz trap from Spectrum Communications, as I already had most of the other materials required - rope, egg insulator, plastic box, and some good aerial wire. The Spectrum Communications trap is solid and well made and 'potted' to protect against the elements.

This antenna is tuned for 40 metres and 80 metres, but the VSWR is acceptable on several other bands being in the region of 2:1 to 5:1. The designer anticipated that this antenna would be usable on five of the H.F. bands between 80m and 10m.

I have found that with the use of the Antenna Tuning Unit it can be used on all of the H.F. bands. However the polar radiation pattern may very well be less predictable on bands other than the intended 40 and 80 metres, and it may well be less effective than might be desirable - but it does work!

The antenna is in the back garden, while the shack (radio room) is in a bedroom at the front of the house. It is fed by a 30 metre length of RG213 coaxial cable (it is not possible to use twin feeder for this type of antenna as the Inverted L is an UN-Balanced aerial, whereas twin feeder is balanced). With this length of cable I estimate the loss in the feeder alone to be about 1dB at 7MHz. The feed point of the aerial is located at the base of a 16 foot high wooden pole near the bottom of the garden. The horizontal top wire returns to a fibreglass pole installed at the apex of the roof.

+ 17 + 160: I have since added a separate sloping wire element for the 17 Metre Band and a switchable loading coil for Top Band - see notes below...

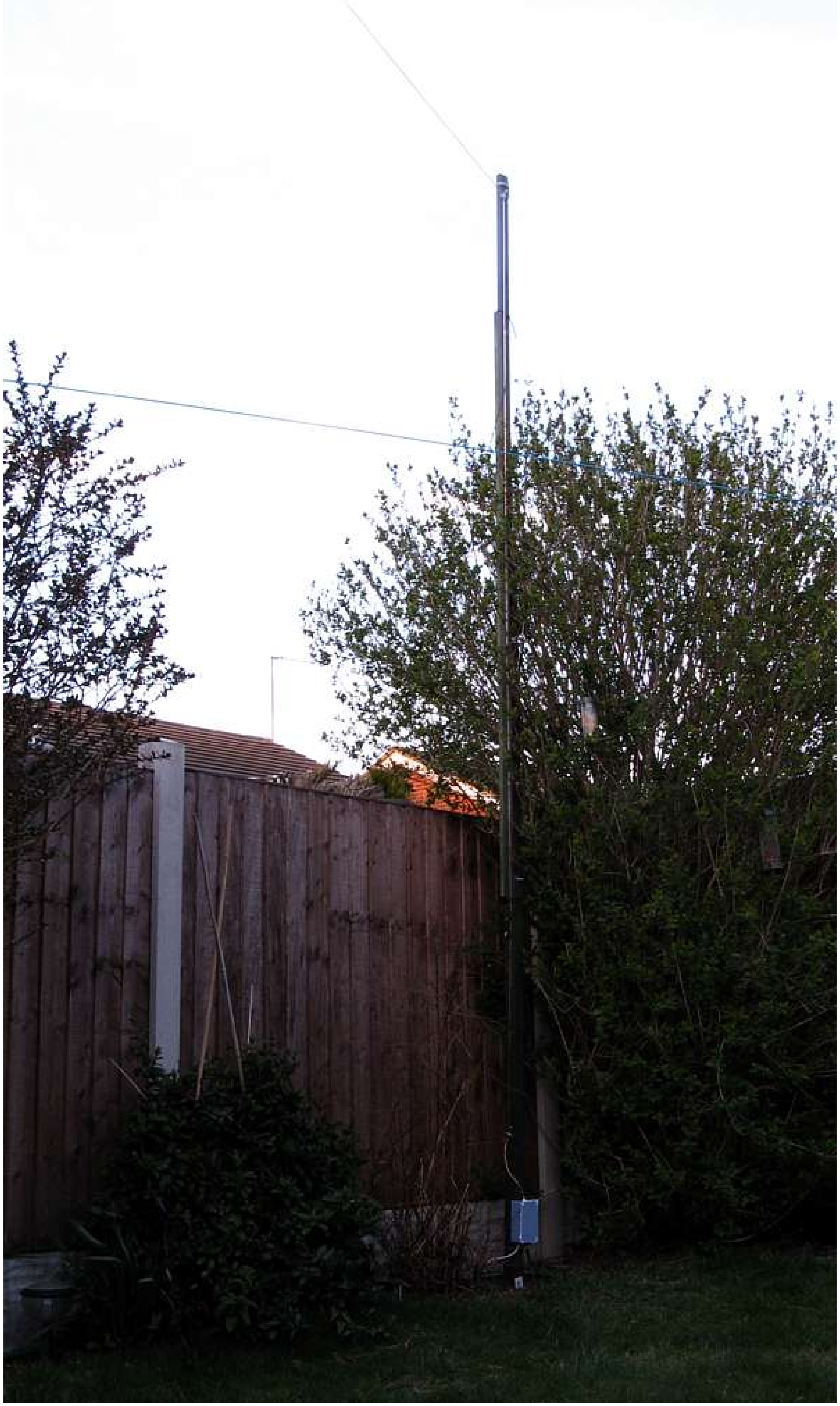

Photograph showing the wooden support post and termination point of the Inverted L antenna The post is coloured green with green fence treatment to mast it somewhat. I have also placed it near the bush to provide further camouflage.

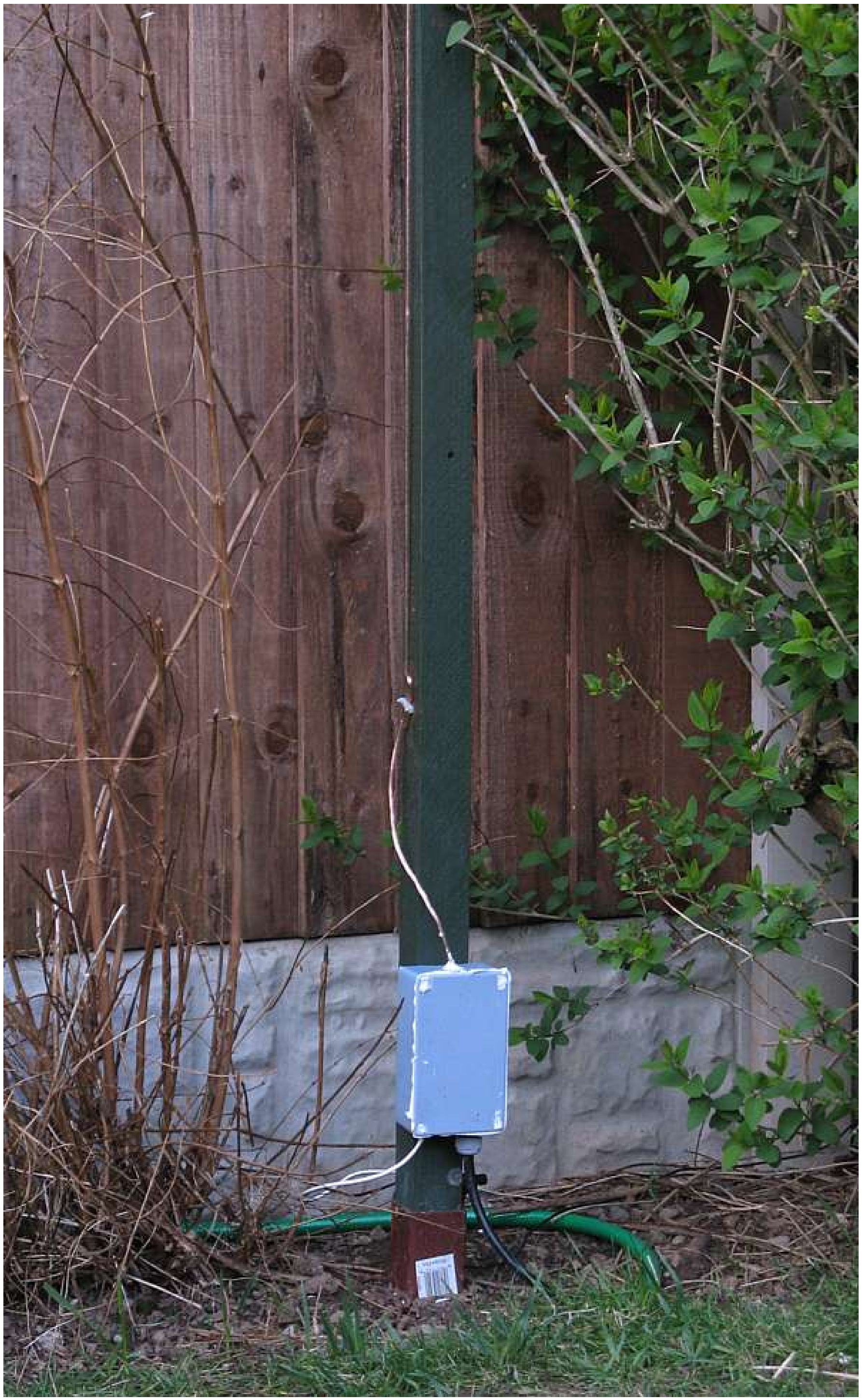

The low loss RG213 coaxial cable runs from the shack at the front of the house up into the loft and exits into the back garden down the rear wall, through some garden hose to offer some protection along the flower bed to the bottom of the garden where it is connected to the base of the Inverted L antenna.

The suspended Inverted L aerial with 7 MHz trap.

The Inverted L antenna - lower section now nicely camouflaged. The wooden support post is some 6 metres long.

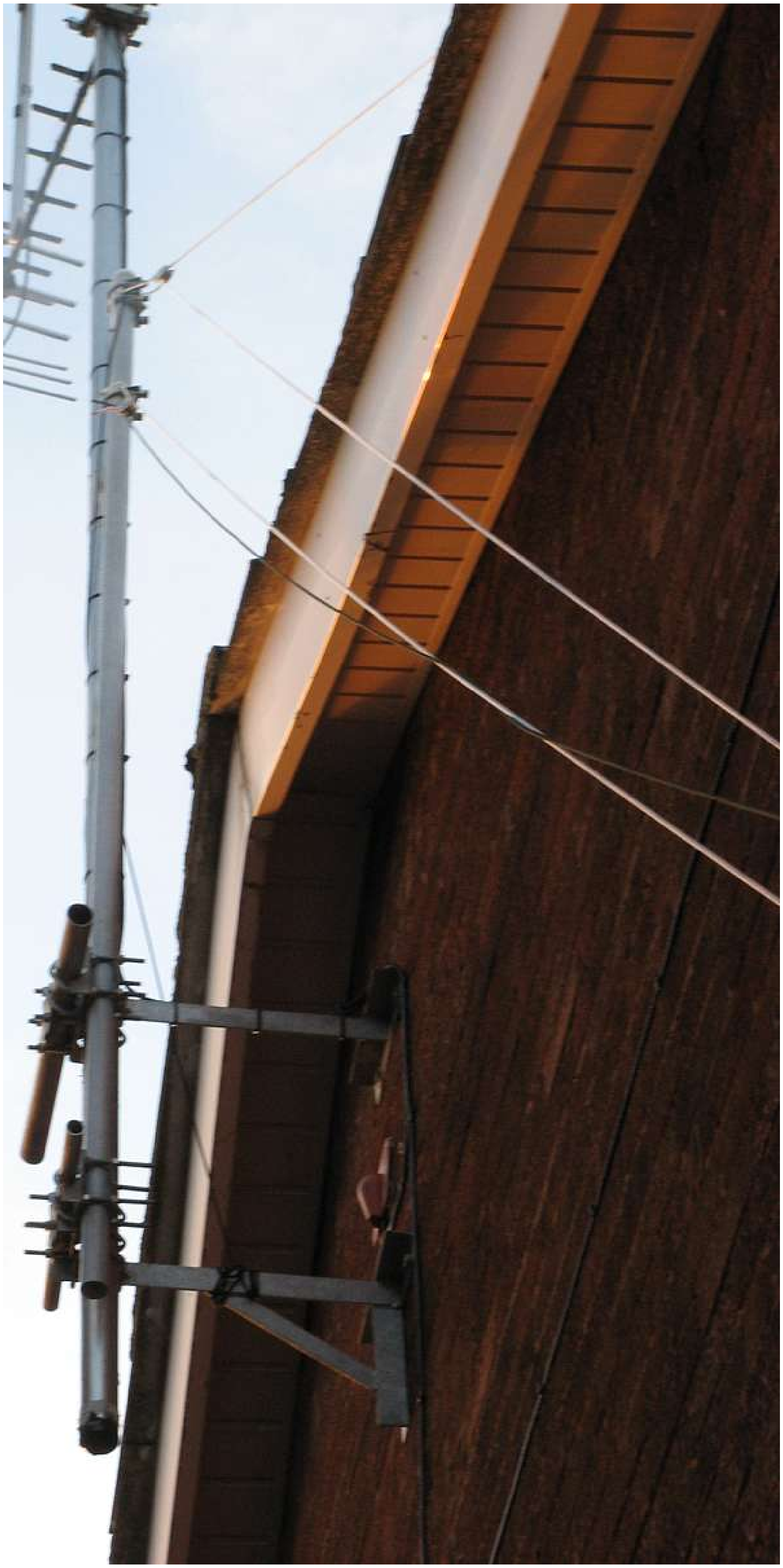

The photograph above shows the Dacron ropes supporting the ends of the Inverted L and Dipole antennas are held in place at the top of the fibreglass support mast by a pulley - one pulley for each support rope. This facilitates rapid lowering of either antenna for adjustment or replacement. This photograph also shows a second rope and pulley system that was originally used to support the 20m dipole and is now used for the top band inverted L wire aerial.

I needed a good reliable knot for securing ropes when installing wire antennas and have found the Bowline to be one of the most useful, it is strong and easy to tie. A Bowline will not slip in any circumstances and, usefully, the more load that is put on it, the tighter it gets.

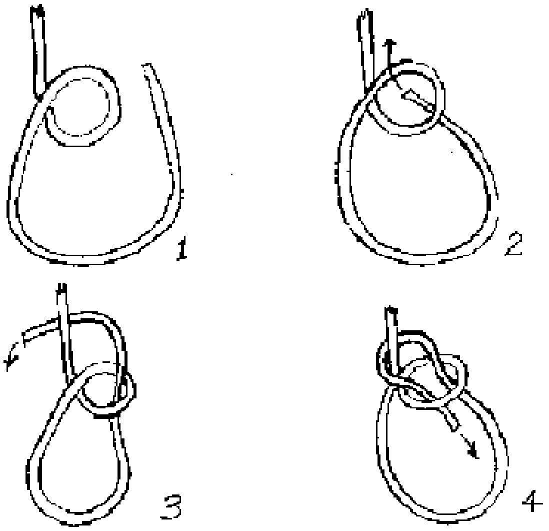

The Bowline Knot

A Bowline can be used to tie two ropes together and should be used to tie a support rope to a pulley, dipole centre and other antenna items.

It's important to use the correct knot for the job when fixing up wire antennas. I find the Bowline is a very useful for fixing end, egg and dog-bone insulators to the ends of the wire and/or ropes. The Round Turn & Two Hitches, Anchor Bend (Anchor Hitch) and Buntline Hitch knots are very good for tying a rope to a pole or a mast. A Double Sheet Bend can join two pieces of rope together - even if they are of unequal size. 'Animated Knots' will show you how to do them: http://www.animatedknots.com

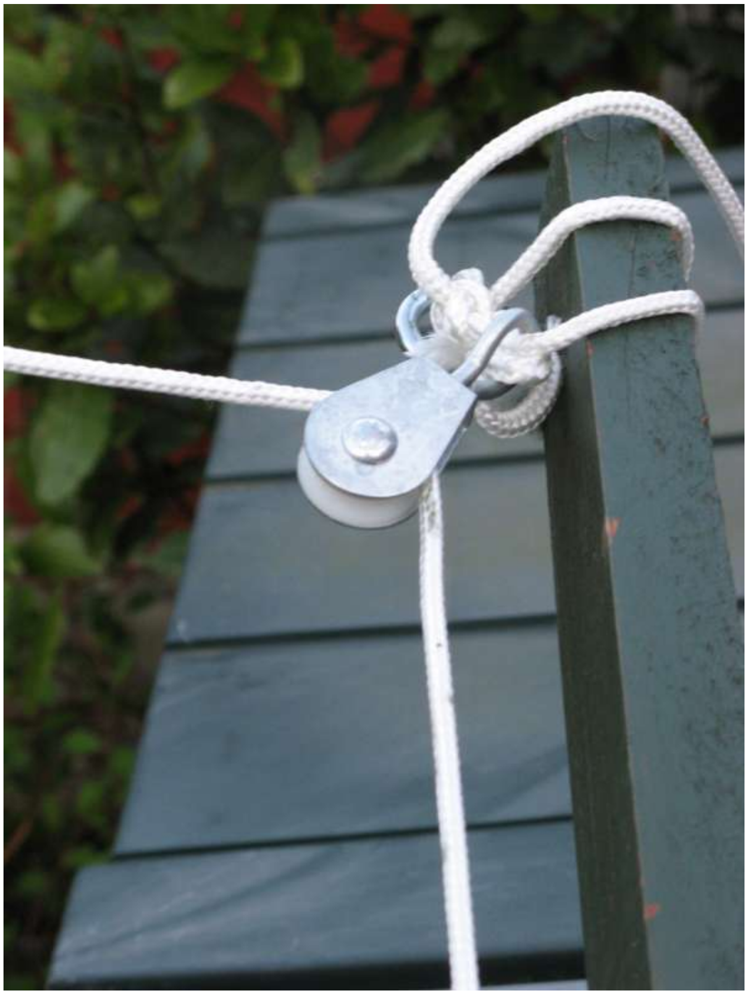

Photo showing pulley fixed to the top of the wooden support post and the aerial support rope that it holds in place.

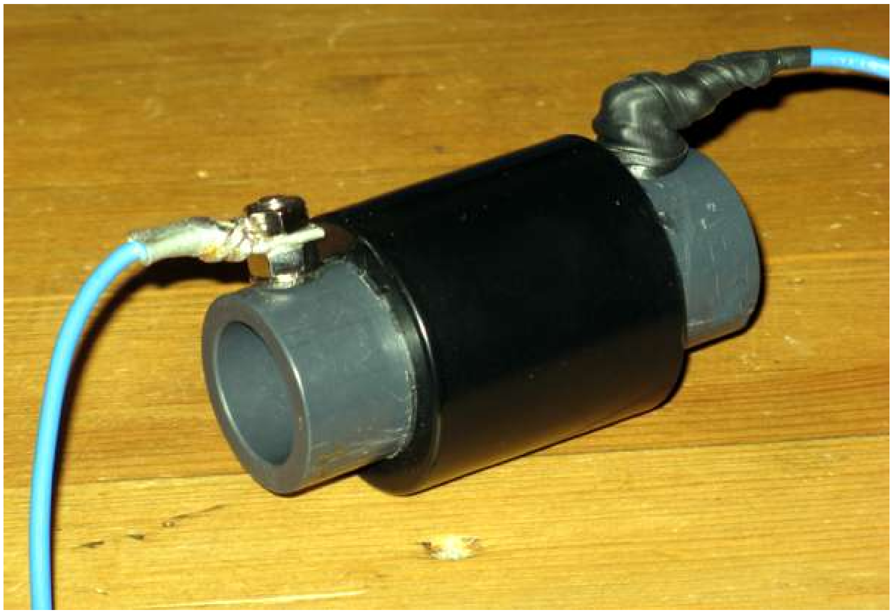

The Spectrum Communications Trap

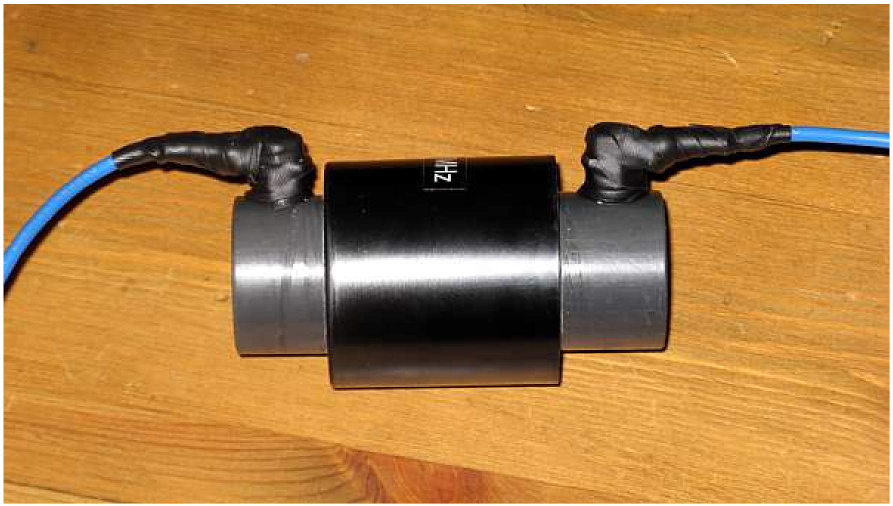

View of trap showing that the joints have been thoroughly sealed against the weather with self amalgamating tape and silicone sealant.

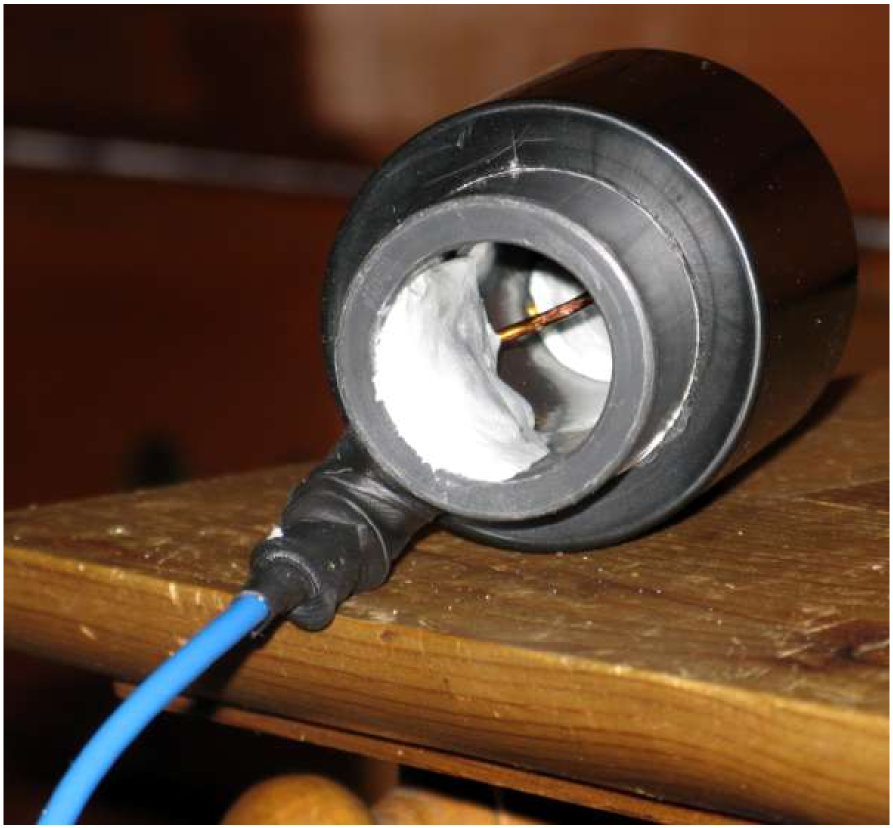

Just for good measure I sealed the internal side of the machine screw that forms the connection terminal against the weather with Watson sealant putty.

Adding Top Band to the 80 / 40 metre Inverted L Antenna:

Due to an aborted house move in 2010 I had removed all the antennas. While re-establishing the aerials in 2011, and considering space limitations, I decided to experiment with adding a loading coil to the 40m / 80m Inverted L aerial. The loading coil has a link wire to short it out of circuit when using the aerial for 80 metres and 40 metres. The link wire is removed when Top Band is required.

I also took the opportunity to replace the original wooden post with a strong 6 metre tall fibreglass pole.

The coil consists of approximately 37 turns of PVC covered antenna wire wound on a short piece of PVC pipe. Once the required points of resonance were set for 40 metres and 80 metres, the link wire was removed and number of turns on the coil were adjusted until the required point of resonance was found on the 160 metre band. I set it to around 1900 kHz - the bandwidth is quite narrow.

Once the work was done, the joints and connections were sealed with either Liquid Electrical Tape or self amalgamating tape, then the connecting box, V bolts and white PVC pipe were sprayed with green paint to help it all blend in with the surroundings a little better.

Adding the 17 Metre (18 MHz) Band to the 80 / 40 metre Inverted L Antenna:

The Inverted L is not too good for the 'WARC' bands so to obtain better performance on the 17 Metre band I added a single slightly sloping wire element cut for that band. The lower end of the wire is permanently connected to the feed terminal on the junction box, the other end is tied to a small dog bone insulator. This dog bone is then supported by a length of thin para-cord which is tied to the horizontal wire of the main Inverted L element. (N.B. The 17 metre modification is not currently shown in the photographs below.)

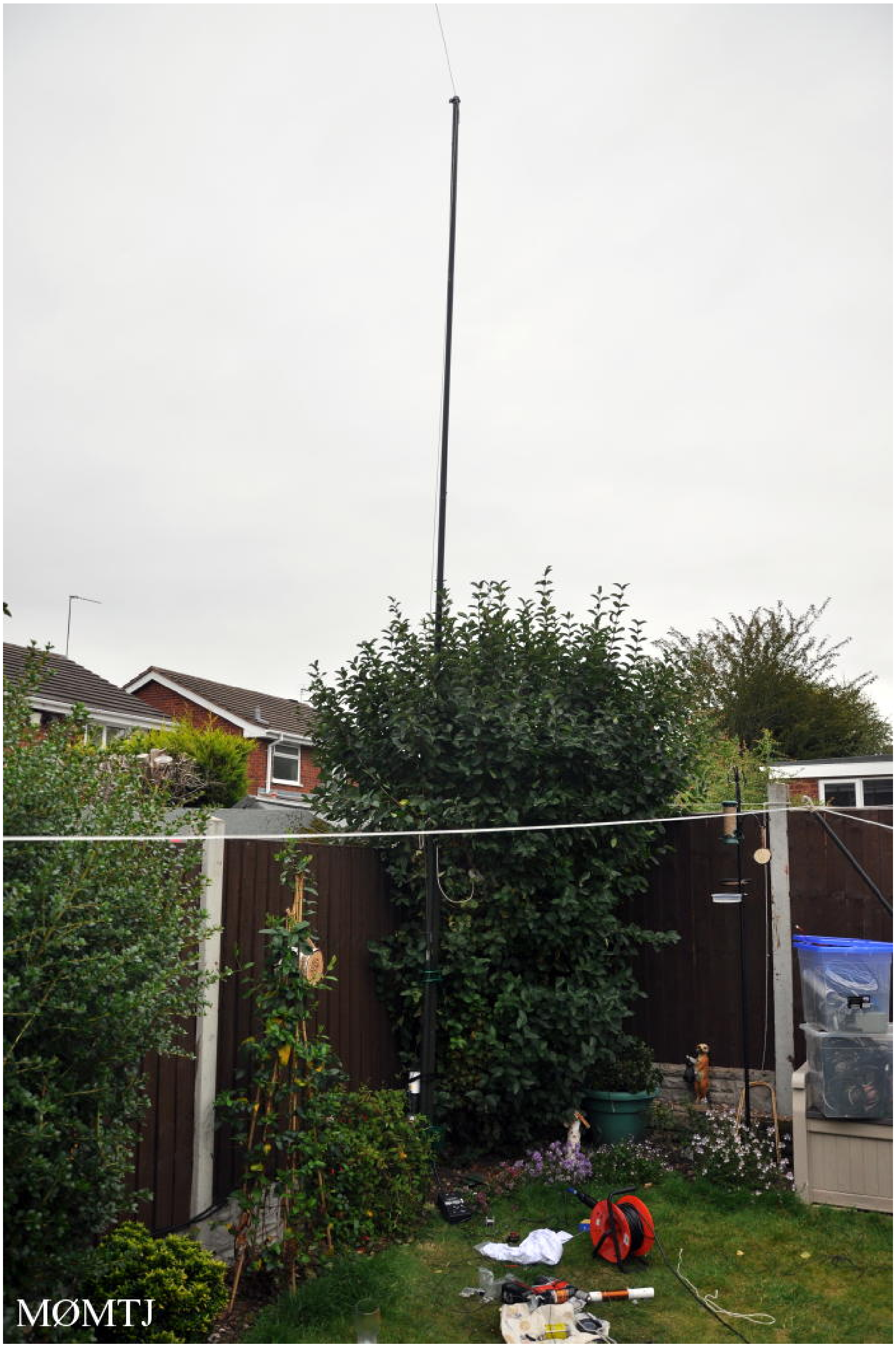

Work In Progress! - September 2011
Reconfiguring Inverted L with additional Top Band Loading Coil for 160 metres.
A strong 6 metre tall fibreglass pole replaces the original heavy wooden post.

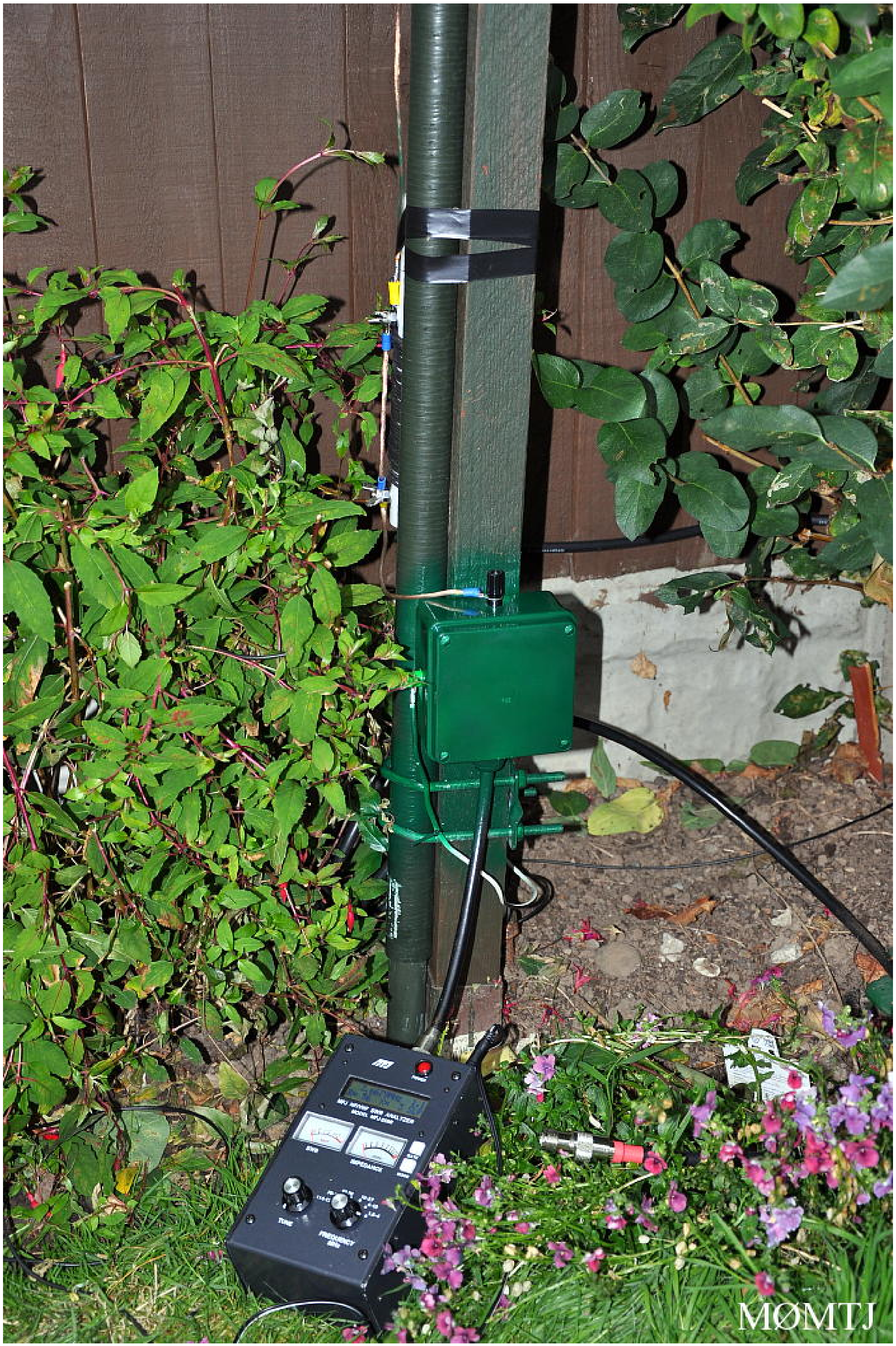

Adding 160 metre loading coil to the 80m / 40m Inverted L Aerial.
The loading coil has a link wire to short it out of circuit when using the aerial for 80 metres and 40 metres.
The link wire is removed when Top Band is required.
The coil consists of approximately 37 turns wound on a piece of PVC pipe.

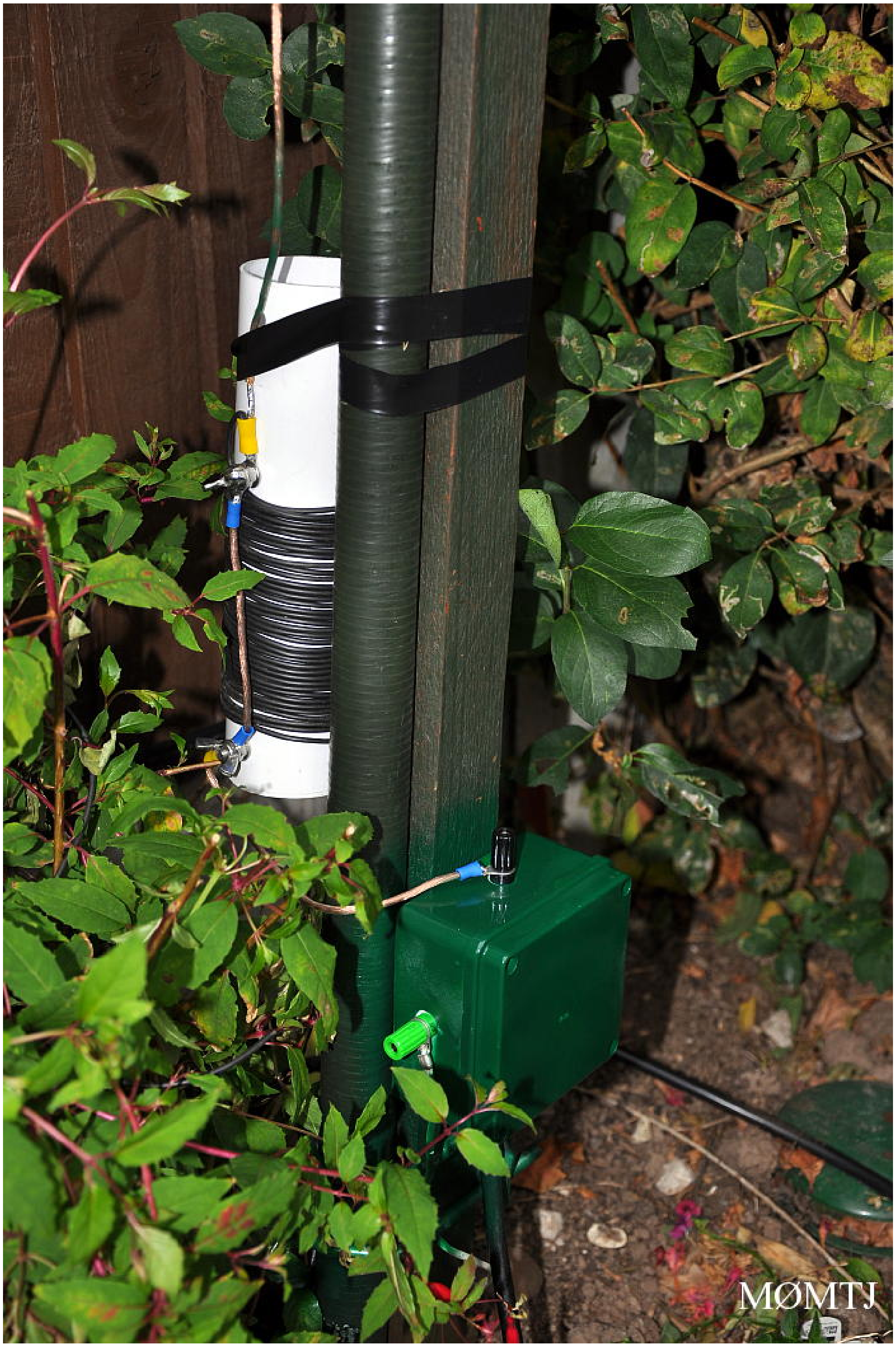

Adding 160 metre loading coil to the 80m / 40m Inverted L Aerial.
The loading coil has a link wire to short it out of circuit when using the aerial for 80 metres and 40 metres.
The link wire is removed when Top Band is required.
The coil consists of approximately 37 turns wound on a piece of PVC pipe.

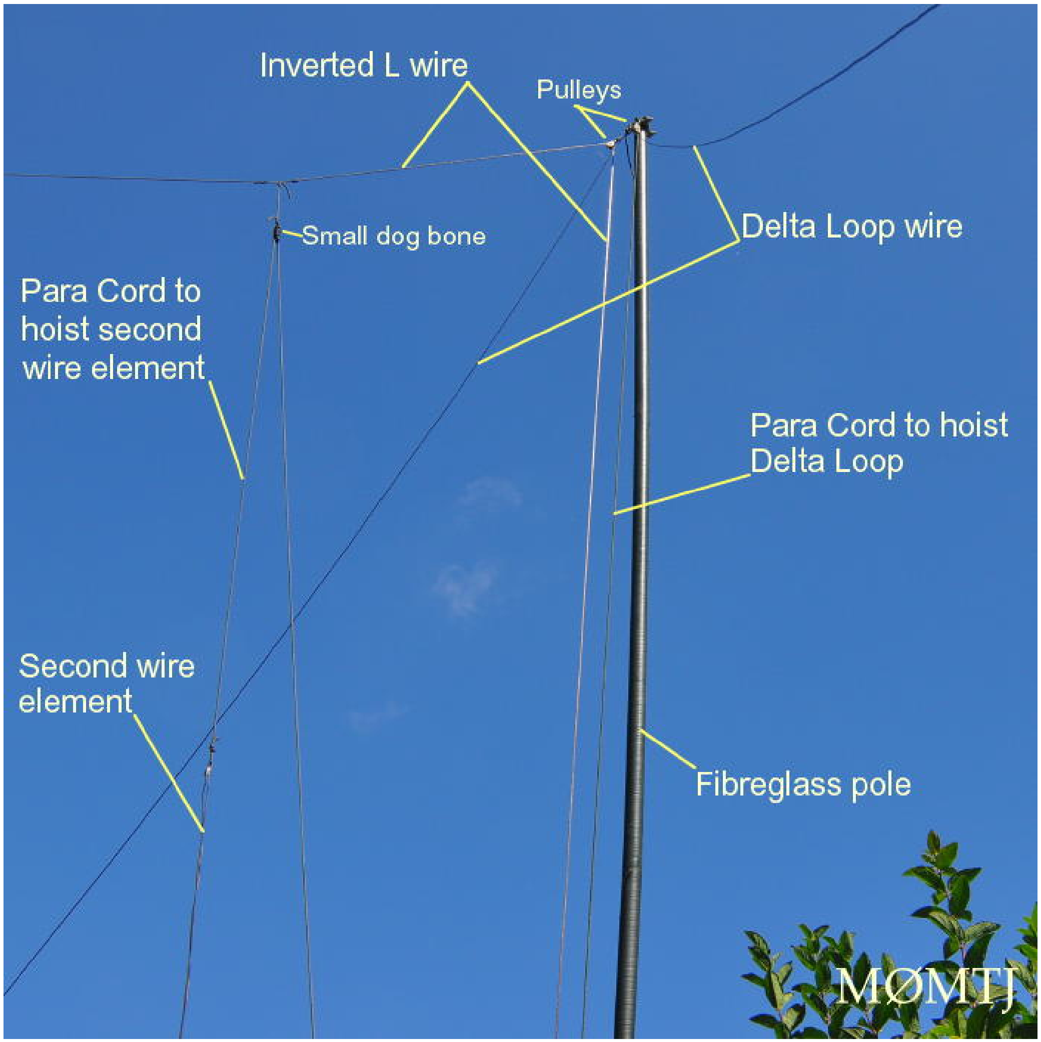
Inverted L wire
Pulleys
Small dog bone
Delta Loop wire
Para Cord to hoist second wire element
Para Cord to hoist Delta Loop
Second wire element
Fibreglass pole
MØMTJ

Photograph showing the Inverted L antenna with additional vertical wire element and position of Delta Loop

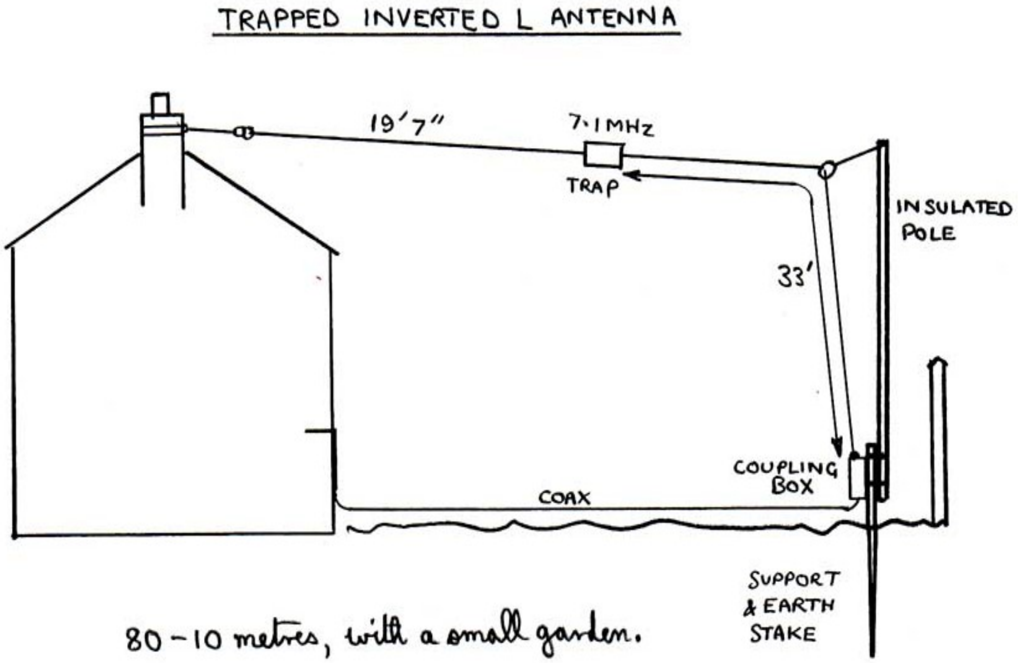
TRAPPED INVERTED L ANTENNA
19′7″
7·1 MHz
TRAP
INSULATED POLE
33′
COUPLING BOX
COAX
SUPPORT & EARTH STAKE
80-10 metres, with a small garden.

The commercial version of the basic 80m - 10m Inverted L is available from Tony Nailer at Spectrum Communications

Important notes on effective Grounding by Jim K8OZ

Mike - I was reading about your work on the 160 meter Inverted L, and it makes me want to go out and build some more antennas! Congratulations. Your story is fascinating, and very well documented.

The only thing I can offer as a suggestion is to get as much radial wire along the edge of your property as possible (assuming your XYL will not allow you to bury radial wire all over your yard). Even if you can only run multiple wires 1/8th of a meter apart from each other, and parallel to each other, your losses will be reduced. The ground lossses have quite an impact on your transmitted signal, so any wire you can "hide" along the edge of your property will help improve your signal strentgh - little, by little...! { It may also affect your resonant frequency slightly, but that's easy to deal with by adjusting with an antenna tuner or slightly changing the loading coil. }

Good luck OM, and keep up the refinements on your antenna system. You're doing great! 73,

Jim, K8OZ
Albuquerque, NM

Delta Loop Antenna - Tuned for the 17 metre band but also usable as a multi-band operation

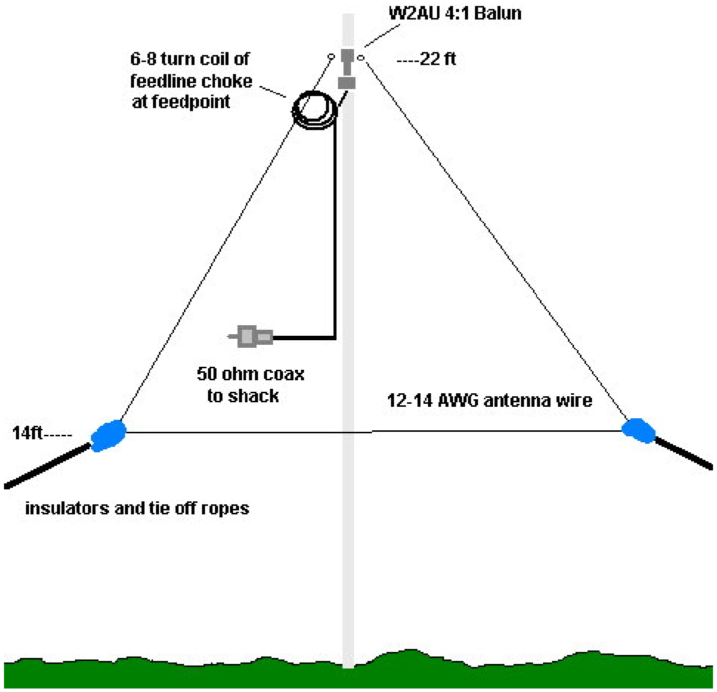

A typical Delta Loop antenna - diagram by W5SDC - gives multi-band operation with minimal cost.
My Delta Loop is fed near the bottom corner - it cannot be fed at the top, as in the diagram above, due to unwanted interaction with the antenna wire of the Inverted L antenna which is supported on the same pole.

My Delta Loop is fed near the bottom at one corner - it cannot be fed at the top, as in the diagram above, due to unwanted interaction with the antenna wire of the Inverted L antenna which is supported on the same pole.

It consists of a 16 metre long loop of wire in triangular Delta shape, hung from the top of the pole supporting the inverted L antenna and fed via RG213 coaxial cable via a home-brew 4:1 balun. A loop is really a single band antenna cut for one wavelength on the band of interest, however it can also work on higher bands with an ATU - as a good, cheap and easy to install multi-band H.F. aerial. Performance is a little better than the inverted L on the higher bands, but on 10 metres the tuned 10 / 6 metre wire 'fan' dipole in the loft can still be better.

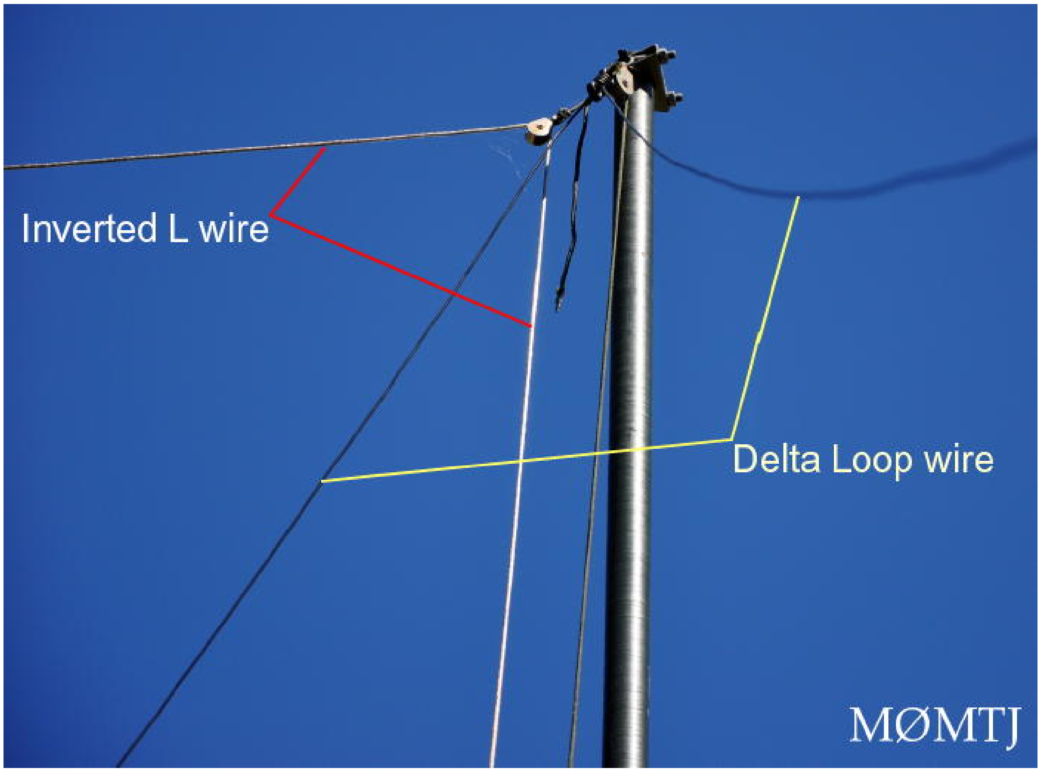
Inverted L wire
Delta Loop wire
MØMTJ

Apex of Delta Loop by M0MTJ

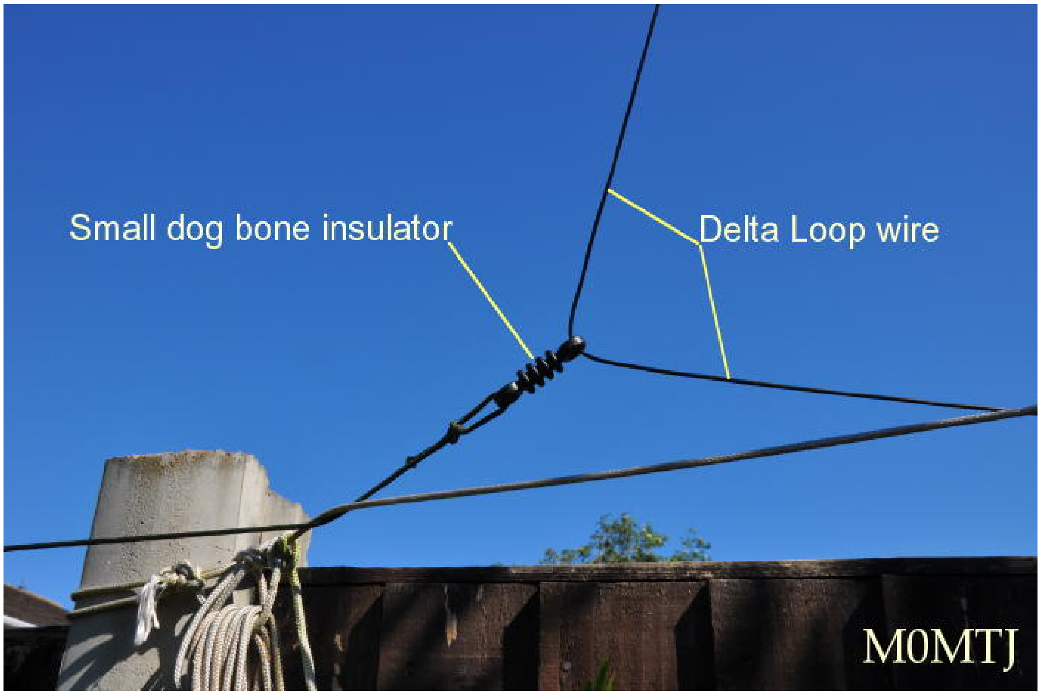
Small dog bone insulator
Delta Loop wire
M0MTJ

Bottom left corner of Delta Loop antenna by M0MTJ

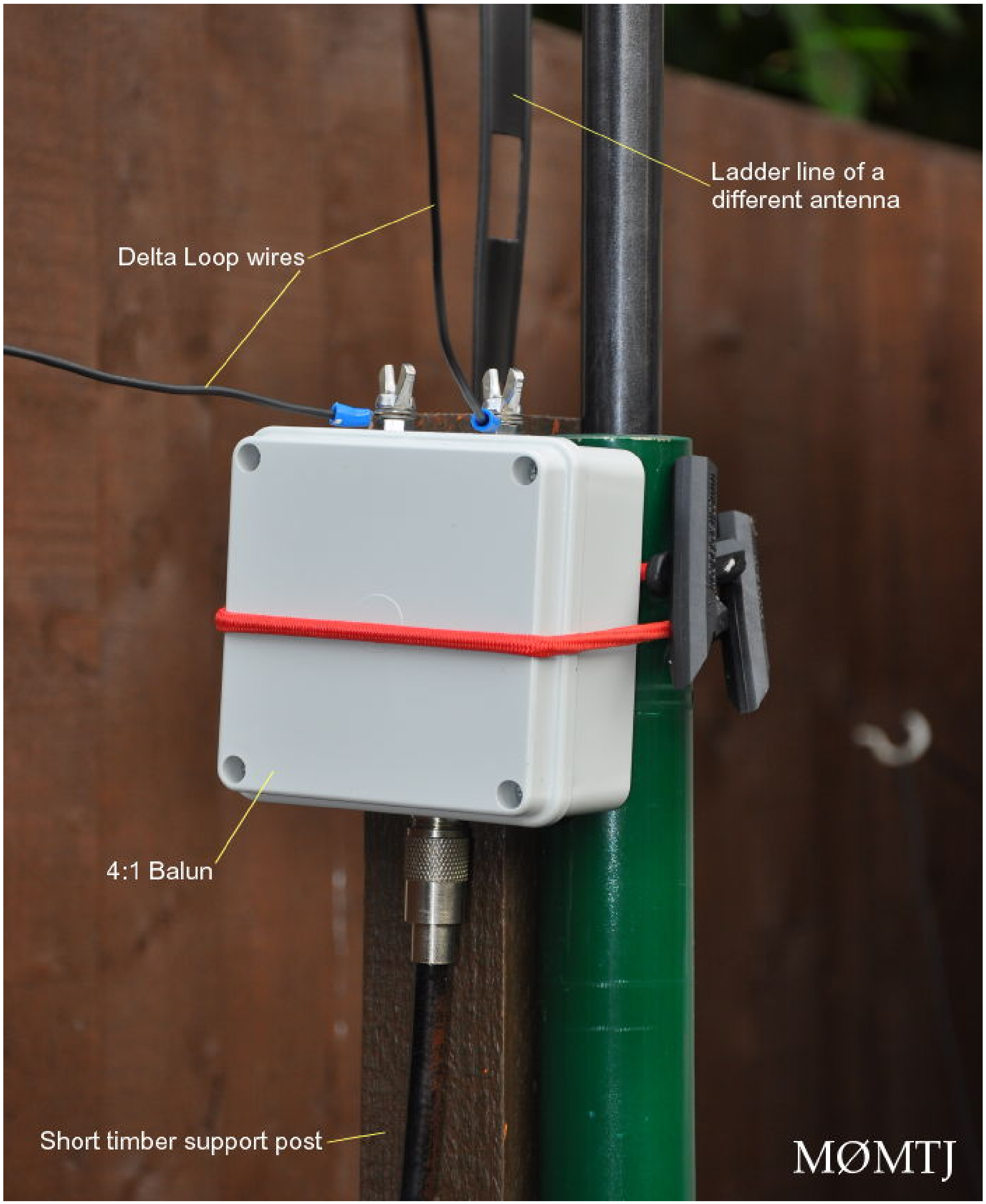
Ladder line of a different antenna
Delta Loop wires
4:1 Balun
Short timber support post
MØMTJ

Feed point of the Delta Loop at the bottom right hand corner

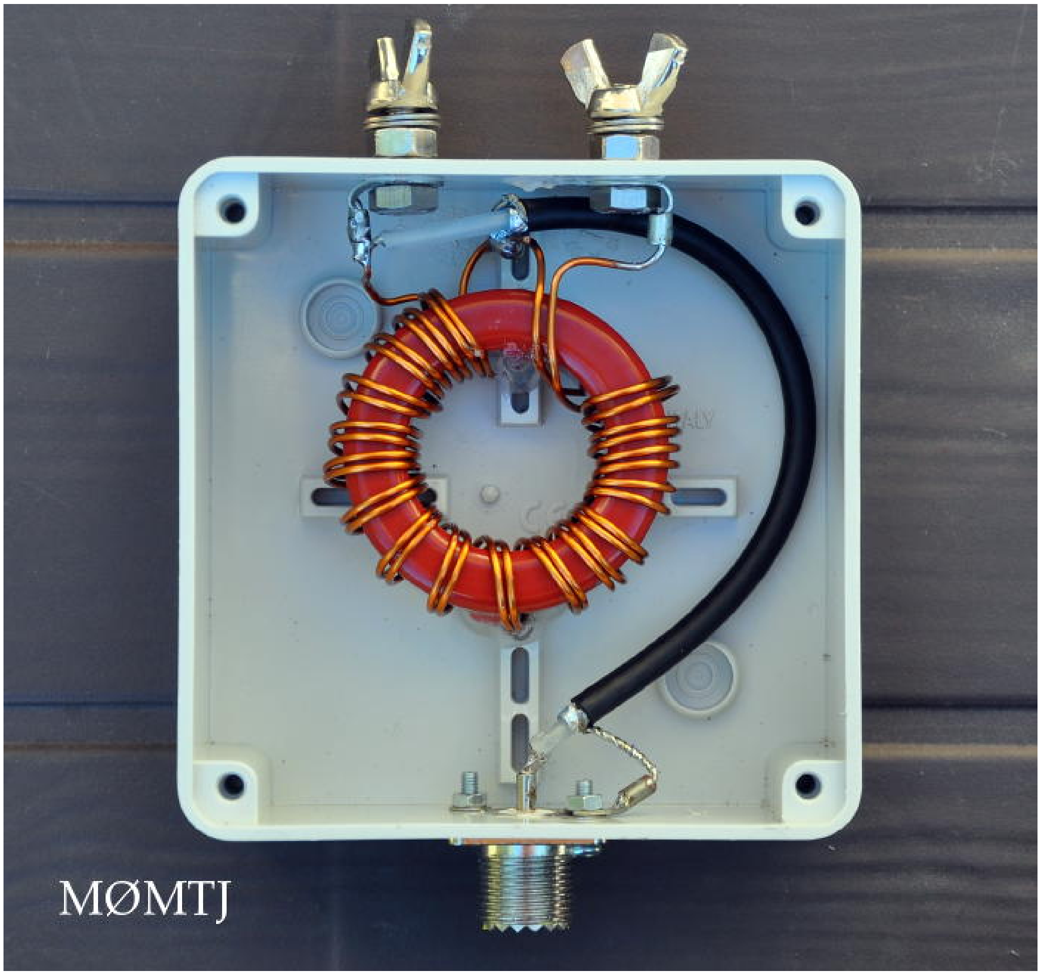

The Feed Point of the Delta Loop Antenna is at the bottom right hand corner
The Antenna is fed via a 'home brew' 4:1 balun by M0MTJ

Below are the VSWR measurements for the 16 metre long loop which has been measured an cut for resonance in the 17 metre band. For comparison are the measurements for the 12 metre long loop (which has not been optimised) and an 18 metre long loop which is of arbitrary length:

16 metre long loop of wire for the 17 Metre Band (optimised for 17m band)		
BAND	VSWR	VSWR
20m	14.0 MHz = 6.5	14.35 MHz = 4.9
17m	18.07 MHz = 1.2	18.16 MHz = 1.2
15m	21.0 MHz = 3.1	21.45 MHz = 3.7
12m	24.8 MHz = 5.9	25.9 MHz = 6.1
10m	28.0 MHz = 4.1	29.5 MHz = 4.4

12 metre long loop of wire for the 12 Metre Band (NOT optimised)		
BAND	VSWR	VSWR
20m	14.0 MHz = 22.1	14.35 MHz = 21.1
17m	18.07 MHz = 8.4	18.16 MHz = 8.1
15m	21.0 MHz = 5.0	21.45 MHz = 4.6
12m	24.8 MHz = 1.9	25.9 MHz = 2.0
10m	28.0 MHz = 5.0	29.5 MHz = 6.1

18 metre long loop of wire (An arbitary length between 20m & 17m)		
BAND	VSWR	VSWR
20m	14.0 MHz = 2.1	14.35 MHz = 1.4

17m	18.07 MHz = 2.6	18.16 MHz = 2.5
15m	21.0 MHz = 6.8	21.45 MHz = 8.4
12m	24.8 MHz = 6.3	25.9 MHz = 6.5
10m	28.0 MHz = 2.9	29.5 MHz = 2.5

Many users claim that loop aerials are quieter than typical vertical antennas. There are many plans available in the internet and given a suitable support or pole and a 4:1 balun it can take only a few minutes to install a loop antenna.

Arthur M0PLK (SQ2PLK) at Ham Radio Shop supplies an interesting lightweight self supporting Delta Loop antenna: http://ham-radio.urbasket.eu - see the review on the Polonia DX Award here: http://pdxa.one.pl/articles.php?article_id=17

LOOP ANTENNA LINKS: See lots more links to Loop Antennas on my links page here

Dipole or Doublet Antenna for 20m and 10m

This is an antenna trapped dipole for 20m and 10m. Currently it is fed by 75 ohm twin feeder to a 1:1 balun in the loft, then on to the ATU (AMU) via a short RG213 coaxial cable. Although it was initially installed horizontally, it is now installed with one leg supported vertically on a 7 metre fibreglass 'Sota' pole with the other leg supported horizontally about 2 metres above the ground. This is a rather unorthodox arrangement for a balanced dipole, but it seems to work ok and was inspired by another radio amateur's idea - although I don't recommend balanced feeder for this arrangement!

It looks much neater than the horizontally strung dipole and offers a more omnidirectional radiation pattern too.

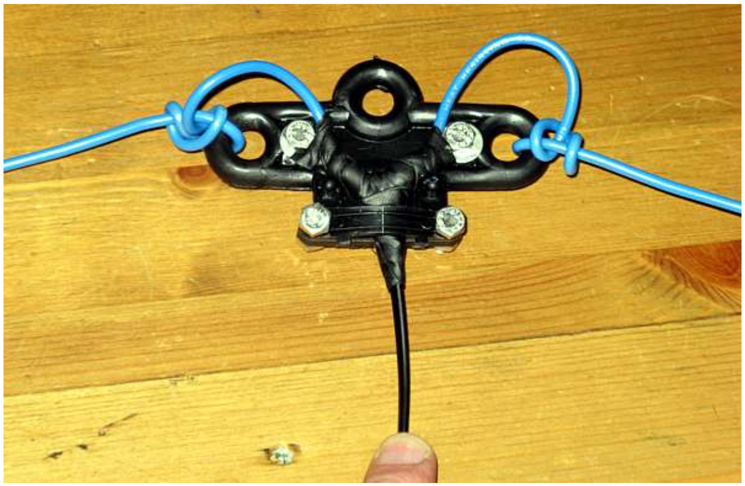

Dipole Centre with PVC covered wire and 75 ohm twin feeder attached.

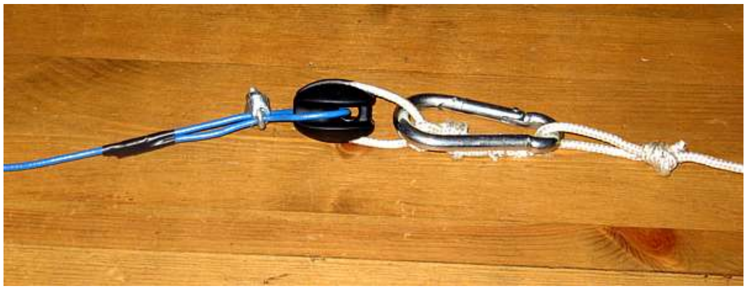

Removable end support method for wire dipole using a plastic antenna insulator, snap-hook and Dacron rope.

Photo showing how the wooden support posts are held in the ground by the steel Met Post.
This Met Post and wooden pole now supports the 7 metre high fibreglass Sota Pole (fishing pole).

The 'deformed dipole'.

A Dipole for 20m and 10m.

One leg is vertical, giving a more omnidirectional pattern and supported by the 7 metre long fibreglass fishing pole, while the other leg runs off horizontally at about 2 metres above the ground.

This antenna is fed by 75 ohm twin feeder.

The Deformed Dipole

Compact Antenna for Top Band

A Shortened Inverted L for 160 Metres

Despite the dreadful noise on top band caused by modern electronic gadgets and the difficulty in accommodating a necessarily large aerial in a small garden, I was keen to try to get on to top band. I experimented with some different ideas during 2009, some of which are shown on this page.

Eventually I settled on the design shown below. It is an Inverted L type aerial, shortened by the use of a loading coil. It uses a fibreglass telescopic fishing pole to allow it to be easily lowered out of sight when not in use. Read more on Antennas page 2 here>

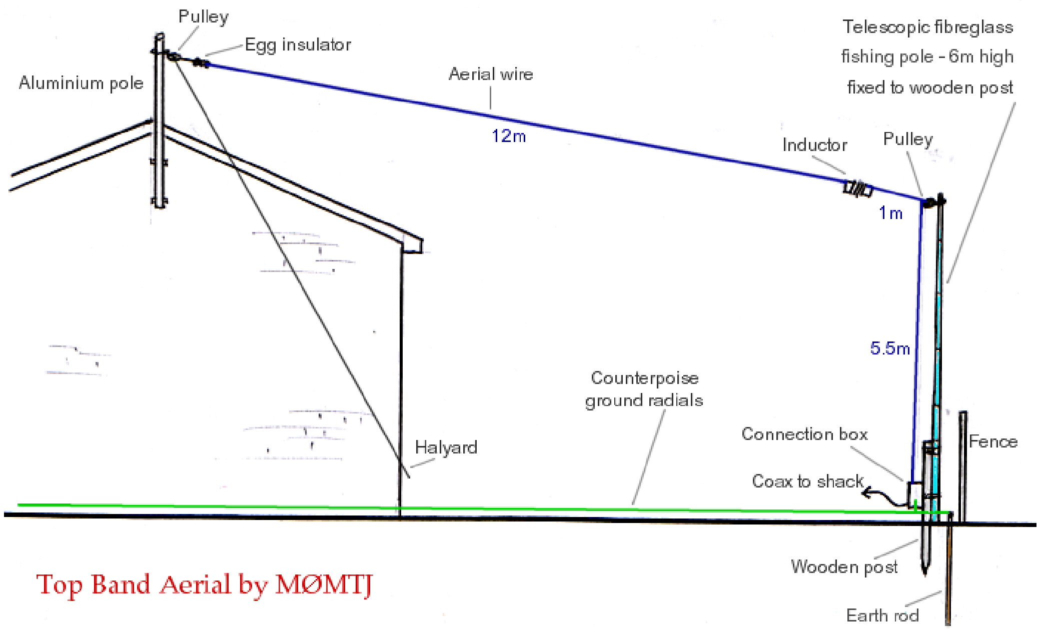
Pulley
Egg insulator
Aluminium pole
Aerial wire
12m
Telescopic fibreglass fishing pole - 6m high fixed to wooden post
Inductor
Pulley
1m
5.5m
Counterpoise ground radials
Halyard
Connection box
Fence
Coax to shack
Wooden post
Top Band Aerial by MØMTJ
Earth rod

Shortened Base Loaded Top Band Antenna For Small Gardens
uses a fibreglass telescopic fishing pole to allow it to be easily lowered out of sight when not in use.

Read more about Top Band Antennas on Antennas page 2 >

Other Antennas:

End Fed Zepp Antennas for 20m / 17m and 15m :

High quality commercially built Zepp antenna from G Whip Antenna Products.
http://www.gwhip.co.uk/

Above is a high efficiency, high quality commercially built Zepp style antenna using a half wave radiator. However there is a difference - unlike the traditional Zepp antennas, G4ICD's design dispenses with the long trailing 1/4 wave twin feeder matching section and counterpoise and, instead, uses a G-Whip's helical tuned unit.

The end fed Zepp is extremely versatile - it can simply be hung from the fascia board or guttering just outside one's window: The 1/2 wave wire radiator made of high strength Kevlar is easily sloped down the garden and is a camouflage green in colour so as to be almost invisible. The G-Whip Zepp is supplied with a fascia board insulator, a throwing line with plus cable strain relief and fittings, the IP65 waterproof resin potted box fitted with UHF connectors (SO239) for coax feeder. The Zepp can be mounted vertically (e.g. using a telescopic fibreglass pole), horizontally or sloping and can be ready in a matter of minutes.

I then decided to try an excellent new design developed by Geoff G4ICD - an End Fed Zepp antenna with a difference. The G-Whip End Fed Zepps are high efficiency, resonant mono band antennas utilising a half wave radiator, however this new G-Whip design by G4ICD dispenses with the long trailing 1/4 wave twin feeder matching section and counterpoise and, instead, uses a helical tuned unit. Using versions for 20m, 17m and 15m will enable me to get on the air with the minimum of fuss since the G-Whip end fed Zepp can simply be hung from the facia board or guttering just outside one's window. The high-strength Kevlar, camouflage green 1/2 wave wire radiator is easily sloped down the garden to be almost invisible.

G-Whip Widebander :

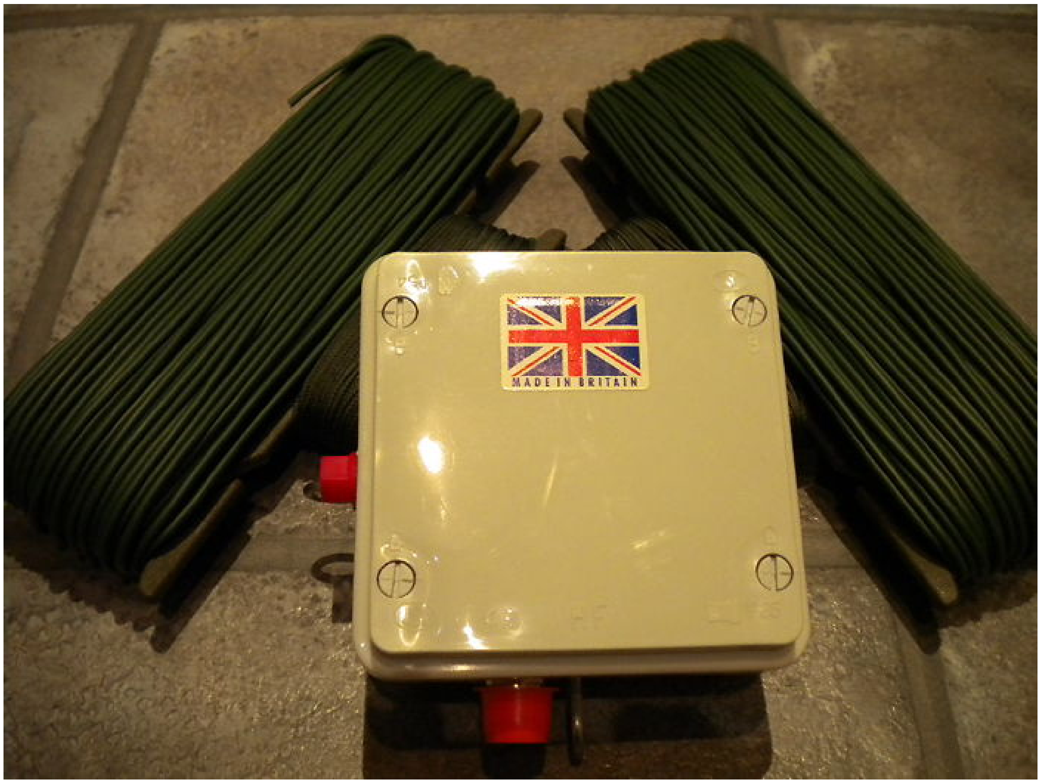

GWhip Widebander antenna.

Using the popular idea of feeding a large but non resonant antenna with an impedance converting 9:1 unun.

The G Whip wideband antenna consists of a 9:1 unun of GWhip's customary high quality for best efficiency, two 20metre lengths of kevlar wire for the radiator and counterpoise which provide operation from 3.6MHz to 50MHz. Feed with good quality low loss coax and use an ATU to match. The 20 metre radiator wire can be used as a sloper, or supported by convenient supports such as poles or trees in a straight line or 'dog legged'. I use a shorter radiator wire run up a telescopic fibreglass pole for operation on 20 metres an above.

Dual Band J-Pole :

There is a dual band vertical J-Pole antenna in the loft as a back up for the 2m and 70cm bands.

DUAL BAND SLIM JIM
BY N9TAX 2M-70CM

The excellent Dual Band N9TAX Slim Jim antenna that I use in the loft as a reserve antenna.
More information from Joe N9TAX at: www.n9tax.com
www.ebay.co.uk/itm/VHF-UHF-Slim-Jim-J-Pole-Dual-Band-2m-70cm-Antenna-jpole

Previous Antenna installations:

(2011 - 2013)

1) A trapped Inverted L for 80m and 40m with an SGC-230 auto antenna coupler at its feed-point at the bottom of the garden. RG213 coaxial cable is used to feed the output of the auto-coupler back to the shack. This can be used on all bands from 160 through to 10 metres. The support post is installed at the bottom of the garden with the end of the antenna wire being supported by Dacron rope that is attached to a pulley on a pole at the apex of the roof. A simple, single sloping wire element provides use on the 17 metre band. Although too short to be really effective on 160 metres, Top Band can be tuned by the SGC coupler. A pretty good all-round antenna. more

2) A half wave Wire J-Pole fixed to a telescopic fibreglass fishing pole for 10m. Cheap and effective. more about J-Poles

3) A 'home-brew' omnidirectional, vertical dual band, end fed antenna for 2 metres and 70cm. This is of the Controlled Feeder Radiation design (CFR) by VK2ZOI; effectively an end fed half wave dipole on 2m with an aluminium sleeve to achieve 70cms with a few extra dB's of gain. It is mounted on an aluminium mast 10 metres a.g.l. more

4) A DK7ZB design dual band Yagi antenna, with 5 elements for 2 metres and 8 elements for 70cms, mounted horizontally for SSB. A lightweight antenna rotator is employed and uses a push-up telescopic mast. Height above ground level is again approximately 7 metres. The DK7ZB is an excellent twin band Yagi antenna. more

5) Dual Band Fan Dipole, made from thick loudspeaker wire, mounted horizontally in the loft space for 10 meters an 6 metres. Cheap & effective.

6) (Installed late September 2013) Wire J-Pole antenna for 4 Metres (70 MHz) supported on a 3 metre long telescopic fibreglass pole to be attached to the top of the aluminium push up mast that supports the DK7ZB dual band yagi and rotator,

Other Options that can be deployed on an 'as required basis':

7) Compact Loaded Top Band Antenna, based on a design idea by Stuart Craigen G4GTX more

8 & 9) G Whip End Fed Zepps (EFZ's) for either 20m, 15m or 17m or the G-Whip "WideBander" which is an 'UnTenna' style antenna that can be used for 20m through to 10m using good quality G Whip 9:1 UnUn; useful additions for antenna flexibility. more

10) N9TAX Dual Band Slim Jim (J-Pole) antenna mounted in the loft as a back-up antenna for 2m and 70cms. Very good. more

11) Delta Loop Antenna - 16 metre loop of wire in triangular Delta shape, hung from the top of the pole supporting the inverted L antenna and fed via RG213 coaxial cable via a 4:1 balun. The loop is really a single band antenna cut for one wavelength on the band of interest, however it also can be pressed into service for some higher bands - a good, cheap and easy to install aerial; Often works better than the inverted L on the higher bands, but on 10 metres the tuned 10 metre dipole in the loft is sometimes better. more

(2011)

In mid 2011 I experimented with an excellent N9TAX designed dual band Slim-Jim (J-Pole) antenna for 2m and 70cms. This is made from lightweight 450 Ohm ladder line which can be fixed to the top of a 10m tall fibreglass, telescopic, fishing pole. The N9TAX works extremely well indeed. More information from Joe N9TAX at: www.n9tax.com and buy at: www.ebay.co.uk/itm/VHF-UHF-Slim-Jim-J-Pole-Dual-Band-2m-70cm-Antenna-jpole

N.B. I tried to home-brew the DJB-1 dual band J-Pole antenna using plans published by the ARRL in QST magazine. I wanted a neat antenna that could be enclosed in a protective tube to minimise weathering effects. However trying to tune this antenna at UHF frequencies proved to be frustratingly difficult to do and after two full days work I could not get the thing resonate accurately at the correct frequency. Sadly, for this reason, I cannot recommend the Dual Band J-Pole as a home-brew project.

The N9TAX antenna on the other hand works very well. However it cannot be enclosed in a tube due to the velocity factor effect de-tuning the antenna's resonant frequencies.

(Late 2011)

Due to difficulties with the stability of a lightweight fishing pole as a support I moved back to using the lightweight aluminium telescopic mast, with stays, to support a Watson W-50 vertical dual band collinear for 2 metres and 70 cms FM.

The excellent N9TAX dual band Slim Jim is now installed in the loft.

(Antennas used up until 2010)

1) A trapped Inverted L for 80m and 40m fed by RG213 coaxial cable to the LDG Z-11 Pro antenna matching unit in the shack. This can be used on all bands from 80 through to 10 metres. The support post is installed at the bottom of the garden with the end of the antenna wire being supported by Dacron rope that is attached to a pulley on a pole at the apex of the roof. This excellent antenna is still use. *more*

2) A trapped dipole for 20m and 10m. This was fed by 75 ohm twin feeder to a 1:1 balun then on to the AMU via RG213 coaxial cable. It was initially installed horizontally, but more latterly installed with one leg supported vertically on a 7 metre fibreglass 'Sota' pole with the other leg supported horizontally about 2 metres above the ground. A rather unorthodox arrangement for a balanced dipole, but it seemed to work ok, it looked much neater than a horizontally slung dipole and also offered a more omnidirectional radiation pattern. *more*

4) A compact Inverted L for the 160 metre band - Top Band - shortened with a loading coil. *more*

5) As N9TAX Dual Band Slim Jim (J-Pole) antenna for 2m and 70cms. This was fixed near the top of a 10m telescopic fibreglass fishing pole that I pushed up whenever it was required. *more*

(2008)

W-2000 - Vertical Collinear mounted on a temporary 10m telescopic pole:

I no longer have the Watson W-2000 but this is how it was used previously:

The Watson W-2000 covered VHF (2 metres / 144 MHz) and UHF (70 cms / 430 MHz) and also, rather usefully, 6 metres (50 MHz) too. The W-2000 is 2.5 metres long and enclosed in white fibreglass with three radial elements at the base.

Unfortunately I had nowhere practical to install a separate mast for the VHF / UHF antenna, so this was mounted on top of a 30 foot (10 metre) high telescopic aluminium mast in the back garden. The base of the mast was placed in a handy metal sleeved hole that was already present in a small wall in the garden. Very fortunate indeed!

The antenna is connected to the radio via the very low loss Westflex 103 coaxial cable. The cable was left in place permanently, running from the shack in the front bedroom, up into the loft and out of a small hole in the back of the house, down a drain pipe into the back garden. From there the aerial can be connected as an when required:

When VHF or UHF operation is required I have to connect the coaxial cable to the Watson W-2000, fix it to the top of the telescopic mast, which is very quick using two V bolts and 4 wing nuts, put the mast in the hole and raise it to a good height. I tend to extend it so that the bottom of the antenna is at about 24 feet in the air, the height of the apex of the house, so it is in fairly clear space.

A VHF and UHF aerial needs to be as high as possible since at these frequencies communication is essentially local and 'line of sight' - unless heightened propagation conditions, such as Sporadic E or a Temperature Inversion is prevailing at the time.

Even at 24 feet the mast is rather wobbly, so it was tied down using three nylon guy ropes.

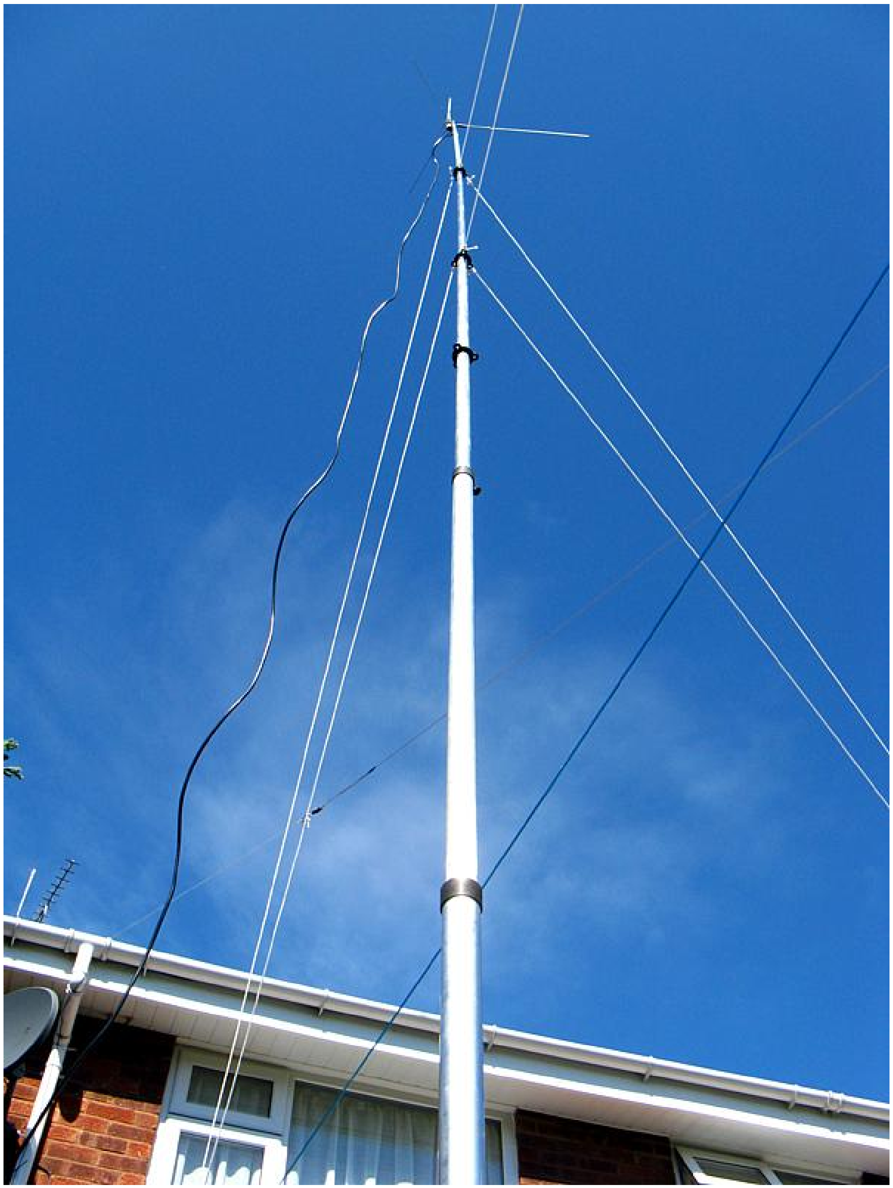

The Watson W-2000 on to of the extended telescopic pole - about 8 or 9 metres high.

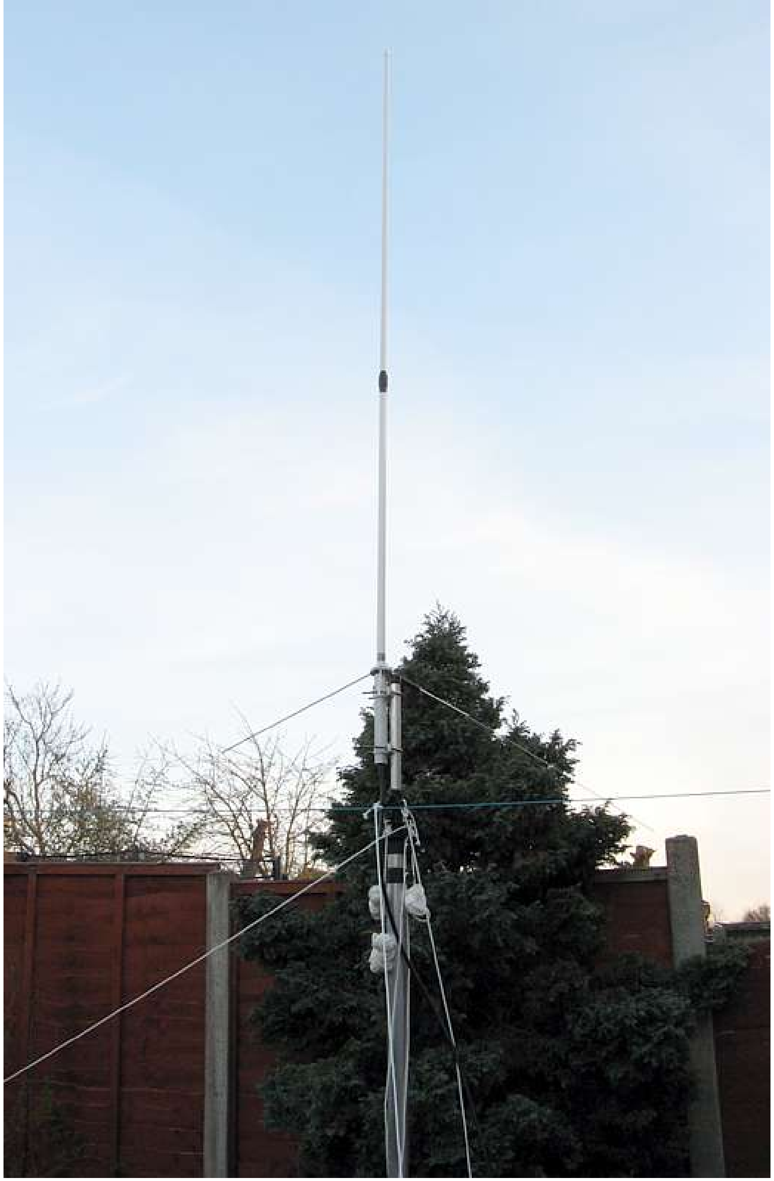

Photograph of a Watson W-2000 on Telescopic Mast at the lowest position.

MORE ANTENNAS

Our good friend in Australia Felix Scerri, VK4FUQ, uses Inverted V antennas but also highly recommends the Quad Loop style antenna for HF work. These are well worth investigating, and you can read more here: Antennas 3 with more antenna ideas on Antennas 2 and Antennas 4 and the Links Page here and here

KNOTS FOR SECURING WIRE ANTENNAS

I have found the Bowline to be one of the most useful, it is strong and easy to tie. A Bowline will not slip in any circumstances and, usefully, the more load that is put on it, the tighter it gets. Read more about good knots for amateur radio aerials here...

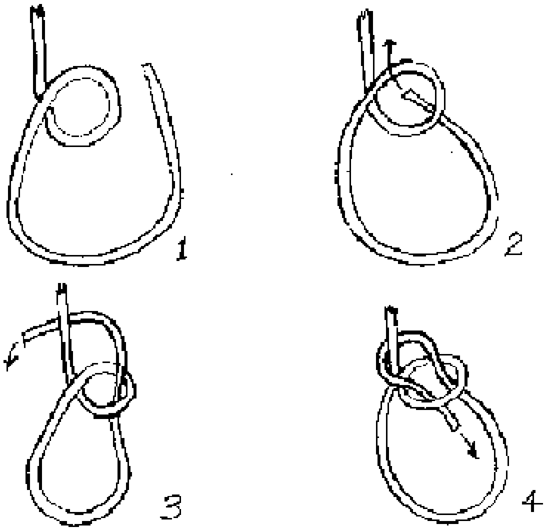

The Bowline Knot - Read more about knots here ...

Antenna Trimming Chart and useful Antenna Rigging Accessory ideas

On Antennas 4 I have included a helpful Antenna Trimming Chart and some useful ideas for Antenna Rigging Accessories

More project ideas here>

73

Mike, M0MTJ 2011 / 2012

Antennas 2 | **Antennas 3** | **Antennas 4** | **Antennas 5** | **Antennas 6**

Links to further reading:

Introducing The All Band Doublet: http://www.cebik.com/content/edu/edu6.html ***N.B. Create a free account at*** http://www.cebik.com

The All Band Doublet - http://www.cebik.com/wire/abd.html

The ALL Band HF Doublet on Ham Universe - http://www.hamuniverse.com/hfdoublet.html

Multi Band Dipoles Compared - by ARRL on QST and DX Zone:
http://www.arrl.org/tis/info/pdf/9611073.pdf http://www.dxzone.com/cgi-bin/dir/jump2.cgi?ID=7499

PDF Document - The W3DZZ Antenna -
http://www.users.icscotland.net/~len.paget/GM0ONX%20trap%20dipole.pdf (**!!! But don't use coaxial cable with a 'choke balun' at the centre of the dipole! Use twin feeder with the Choke Balun at the other end. Less power loss.!!!***)

See Practical Dipole Antennas Compared: http://www.qsl.net/ta1dx/amator/practical_dipole_antenna.htm

Practical Antenna For 160 Metres - http://www.iw5edi.com/ham-radio/?a-practical-antenna-for-160-metres,32
http://www.ik1mnj.net/id202.htm

More:

The website of GM0ONX http://www.gm0onx.co.uk/

The Inverted L - PDF document: http://www.users.icscotland.net/~len.paget/5%20band%20Inverted%20L.pdf

Adding Top Band To The Inverted L - PDF Document:
http://www.users.icscotland.net/~len.paget/Inverted%20L%20adding%20top%20band.pdf

The All Band Inverted L - http://www.antennex.com/preview/archive3/ltv.htm

Q.T.H. Move in 2010 !%*?"*!?!

We decided that we'd like to move house in 2009, we found a new property in early 2010. My amateur radio aerials were duly taken down and the ham shack packed away. However after months of delays we still had not moved by August 2010, but we were still hoping to move. However after months of messing about and stringing us along our buyer pulled out the very day before we were to exchange contracts later in August 2010.

This cost us a lot of time and a great deal of wasted money. Thank you Mrs xxxxxx :-(

After a wasted year we decided to stay where we were and take the house of the market. Instead we spent the next eight months remodelling and redecorating. No time for playing radio of course and besides everything was still all packed away in boxes!

In mid 2011 I was getting frustrated that I had no radio. So I suppose it's time to think about re-establishing the station and to start planning the installation of some antennas. Of course Jules, my XYL, understandably questions my antennas and experiments!

Due to time constraints I will probably start again with a somewhat temporary antenna. I was thinking along the lines of an "Untenna" - so I installed a 7.2 ish long wire supported on a vertical fibreglass pole with a horizontal 'counterpoise' connected via a 9:1 balun to the coax back to the shack. Of course it is a fairly low efficiency multi-band (wideband) antenna, but easy to get going quickly. The GWhip Widebander antenna by Geoff Brown G4ICD is possibly the highest quality antenna of this type available, using a very high efficiency, top quality 9:1 UnUn with a 17 meter wire radiator and 10 metre long counterpoise - a very useful, versatile 'all situations' antenna.

As time progressed I re-established my full size trapped Inverted L antenna for 80metres and 40 metres and added a switchable loading coil at its base for use on 160 meters, as described above.

Then I gradually re-established the 2 metres and 70 cms antennas with the vertical W-50 and horizontal dual band DK7ZB Yagi - as detailed above.

Antennas 2 | Antennas 3 | Antennas 4 | Antennas 5 | Antennas 6

Index To Other Antenna Pages:
Antennas 1 : Aerials used at M0MTJ
Antennas 2 : Including ..... Ideas for compact aerials for Top Band /160 metres
Antennas 3 : Felix Scerri VK4FUQ discusses Loop Antennas, baluns, masts & other antenna related topics
Antennas 4 : Including ...... Many antenna ideas from various sources particularly for multi-band operation & also gives information about
antenna trimming, knots for wire antennas and useful antenna rigging accessory ideas.
Antennas 5 : Including ..... Half Wave End Fed aerials for 144 MHz VHF / 430 MHz UHF and 50 MHz 6 Metre band & J-Pole Aerials
Antennas 6 : Including .... Simple and effective H.F. Antenna ideas - Ground Plane and All Band Doublet

G-Whip Antenna Products
Geoff Brown G4ICD offers a multitude of high quality solutions for portable, mobile and permanent base installations

G-WHIP
ANTENNA
PRODUCTS
PRO

G-WHIP G Pro Whip antennas
http://www.gwhip.co.uk/

G Whip Antenna News
New Products.
HF BASE ANTENNAS, PORTABLE ANTENNAS, MOBILE ANTENNAS, ZEPP ANTENNAS, BALUNS
WWW.GWHIP.CO.UK
G Whip Antenna Products
MADE IN BRITAIN

More products have been added to the range.. The Zepp range of antennas, these end fed antennas are absolutely superb, I personally took samples of them to GJ in December 2009 and had massive pileups of stations. At present there are models for 40/20/17/15/10/6 Mtrs, note that these are dedicated antennas for each band.

After many requests we now have a range of baluns, these are just wound components or top quality finished units. Several models are available for unbal to bal, or un to un. Most ratios are available like 1/1, 1/4, 6/1, 9/1 with power levels up to 1.5 kw.

http://www.gwhip.co.uk/

Just For Fun:

A tower that we may like to have to attach our antennas to - but I don't think that Health And Safety was taken into account here:

M0MTJ | Operating Conditions | Antennas / Aerials | /P Portable Operating | Accessories | Projects & Kits

Useful Information | Contact MØMTJ | Contact M6ORS | Links to Amateur Radio Sites

RSGB | QSL | The Amateur Radio Mini Site Map

WSPR Weak Signal Propagation Reporter

News, Developments, Events, Photographs and other 'Bits 'n' Bobs'

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Mike Smith - MDS975.co.uk © 2003 - 2016

M0MTJ

Amateur Radio; Ham Radio; Radio; Transceivers; HF; VHF; UHF; Data Modes; Morse Code; RTTY; PSK31; SSTV; FSTV; Amtor; Sitor Antennas; Aerials; Cable; Coaxial Cable; Twin Lead; Masts; Poles; Propagation; Computer; PC; USB Computer Interface; Microphone Loudspeaker; Filters; Noise Reduction; DSP; Digital Signal Processing; Morse Key; SWR ; Inverted L; Inverted V; Dipole; Doublet.

http://www.freeradio.co.uk/

Wire Antennas for Ham Radio

Iulian Rosu YO3DAC / VA3IUL,

http://www.qsl.net/va3iul

Note: *Dimensions of the antennas presented below are either in: feet ('), inch ("), meters (m), or centimeters (cm)*

01 - Tee Antenna
02 - Half-Lamda Tee Antenna
03 - Twin-Led Marconi Antenna
04 - Swallow-Tail Antenna
05 - Random Length Radiator Wire Antenna
06 - Windom Antenna
07 - Windom Antenna - Feed with coax cable
08 - Quarter Wavelength Vertical Antenna
09 - Folded Marconi Tee Antenna
10 - Zeppelin Antenna
11 - EWE Antenna
12 - Dipole Antenna - Balun
13 - Multiband Dipole Antenna
14 - Inverted-Vee Antenna
15 - Sloping Dipole Antenna
16 - Vertical Dipole
17 - Delta Fed Dipole Antenna
18 - Bow-Tie Dipole Antenna
19 - Bow-Tie Folded Dipole Antenna for RX
20 - Multiband Tuned Doublet Antenna
21 - G5RV Antenna
22 - Wideband Dipole Antenna
23 - Wideband Dipole for Receiving
24 - Tilted Folded Dipole Antenna
25 - Right Angle Marconi Antenna
26 - Linearly Loaded Tee Antenna
27 - Reduced Size Dipole Antenna
28 - Doublet Dipole Antenna
29 - Delta Loop Antenna
30 - Half Delta Loop Antenna
31 - Collinear Franklin Antenna
32 - Four Element Broadside Antenna
33 - The Lazy-H Array Antenna
34 - Sterba Curtain Array Antenna
35 - T-L DX Antenna
36 - 1.9 MHz Full-wave Loop Antenna
37 - Multi-Band Portable Antenna
38 - Off-center-fed Full-wave Doublet Antenna
39 - Terminated Sloper Antenna
40 - Double Extended Zepp Antenna
41 - TCFTFD Dipole Antenna
42 - Vee-Sloper Antenna
43 - Rhombic Inverted-Vee Antenna
44 - Counterpoise Longwire
45 - Bisquare Loop Antenna
46 - Piggyback Antenna for 10m
47 - Vertical Sleeve Antenna for 10m
48 - Double Windom Antenna
49 - Double Windom for 9 Bands
50 - Collinear Trap Antenna
51 - Short Dipole Antenna for 40m - 80m - 160m
52 - Center Fed-Zepp Antenna for 80m - 40m
53 - All Bands Antenna
54 - All-Bands Dipole Antenna
147 - KE4PT OCEF All-Band Dipole
148 - Wire Quad Antenna for 40m
149 - Inclined Dipole Antenna for 80m, 40m
150 - Pyramidal Wire Antenna for 80m
151 - Random Wire Antenna All Bands
152 - Multiband Dipole Antenna for 80m, 40m,15m, 10m
153 - Slim Jim Wire Antenna for 4m
154 - Delta Loop for 6m
155 - Re-Configurable Antenna for 160m and 80m
156 - Very Low Frequency Inverted-L Antenna
157 - Reduced Size Half Sloper Antenna for 160m
158 - Tree-Mounted HF Antenna
159 - Multiband Vertical Antenna for 80m, 40m, 20m
160 - Marconi Antenna for 136 kHz
161 - Simple Killer Antenna for 40m
162 - Stub-Directed V Antenna for 80m
163 - KT0NY Over-and-Under DX Antenna for 20m
164 - Horizontal Loop Antennas
165 - Ribbon J-Pole for 2m
166 - Dual Band Ribbon J-Pole for 2m, 70cm
167 - Square Vertical Loop Antenna for 40m
168 - Tri-Band Quad Antenna for 20m, 15m, 10m
169 - 3D Quad Antenna for 80m, 40m, 20m, 15m, 10m
170 - Sloping Wire Antenna for 30m, 20m, 17m, 15m, 12m, 10m
171 - Broadband Dipole Antenna with Coaxial Resonator for 80m
172 - Resonant Feedline Dipole Antenna for 80m
173 - Dual-Band Loading Wire Antenna for 80m, 30m
174 - Stub Matching Antennas
175 - J-Style Vertical Wire Antenna for 10m
176 - Dual Band Vertical with Zepp Feeders for 40m, 20m
177 - RCA Double Doublet for 40m to 12m
178 - RCA Spiderweb Antenna for 40m to 6m
179 - Folded Dipole with Shorted Straps
180 - Twin-Lead Marconi Antenna for 160m, 80m
181 - Broadband Antenna Quarter-Wave Balun for 80m
182 - Three-Quarter-Wave Folded Doublet for Dual-Band
183 - Three-Quarter-Wave Folded Doublet No-Switch for Dual-Band
184 - Wideband Omni-Directional Discone Antenna
185 - Wideband Rhombic Antenna for 40m to 10m
186 - Pre-Cut Linear Array Antenna 3dB-Gain for 40m
187 - X-Array Antenna 6dB-Gain for 20m, 15m, 10m
188 - Double-Bruce Array Antenna 5dB-Gain for 20m, 10m
189 - Bi-Square Broadside Array 4dB-Gain for 20m, 15m, 10m
190 - Six-Shooter Broadside Array 7.5dB-Gain for 20m, 15m, 10m
191 - Triplex Flat-Top Beam 4.5dB-Gain for 20m, 15m, 10m
192 - Dual-Band Tilt Antenna for 20m, 10m
193 - Super Space Multiband Dipole Antenna for 80m to 10m
194 - Bi-Square Beam Antenna Gain=5.5dB for 10m
195 - Cousin of G5RV Multiband Antenna for 40m to 10m
196 - Cayman Quad Antenna for 20m
197 - Hentenna Gain=3dB with Bazooka Match for 6m
198 - X-Beam Antenna Gain=3dB for 20m

55 - Multiband Z Antenna
56 - Multiband Dipole Antenna
57 - Five-Bands No-Tuner Antenna
58 - Dualband Full-wave Loop Antenna for 80m-40m
59 - Loop Antenna for 10m
60 - Lazy Quad Antenna for 10m
61 - Tri-band Delta Loop Antenna for 80m - 40m - 30m
62 - Dual-band Loop Antenna for 30m - 40m
63 - Wire-Beam Antenna for 80m
64 - Dual-Band Sloper Antenna
65 - Inverted-V Beam Antenna for 30m
66 - ZL-Special Beam Antenna for 15m
67 - Half-Sloper Antenna for 160m
68 - Two-Bands Half Sloper for 80m - 40m
69 - Linear Loaded Sloper Antenna for 160m
70 - Super-Sloper Antenna
71 - Tower Pole as a Vertical Antenna for 80m
72 - Clothesline Antenna
73 - Curtain Zepp Antenna for 160m, 80m, 40m
74 - Collinear Array Antenna for 40m, 30m, 20m
75 - 160m Inverted Delta Loop
76 - Half Rhombic Unidirectional Vertical for 20m to 6m
77 - Capacitance Loaded Vertical Antenna for 160m
78 - Fan Dipole Antenna for 80m to 6m
79 - Wire Ground Plane Antenna
80 - Inverted Delta Loop Antenna for 160m
81 - Inverted-L for 160m
82 - 300ohm-Ribbon Dual Band Dipole
83 - Tri-Band Beam for 20m, 15m, 10m
84 - Mini-Horse Yagi Antenna
85 - Backpack J-Pole Antenna for 10m, 6m, 2m
86 - Fan-Dipole Antenna for 80m, 40m, 20m
87 - Capacity Tuned Folded Loop Antenna for 20m
88 - Indoor Loop Antenna for 80m to 30m
89 - Indoor Loop Antenna for 80m
90 - Double-Delta Antenna 80m and 40m
91 - Inductance-Loaded Shortened Dipole for 160m
92 - V-Beam Antenna for 15m
93 - Picnic Vertical Wire Antenna
94 - Laid-Back Quad Antenna for 80m
95 - Phased Loop Antenna
96 - Loop Antenna for TX for 160m
97 - Morgain-Dipole Antenna for 160m and 80m
98 - ZL-Special for 20m, 15m, 10m
99 - Biconical Antenna
100 - Directive Delta-Birdcage Antenna for 20m to 10m
101 - Dual Polarization Antenna for 80m and 40m
102 - Directive 300-ohm-Ribbon Folded Dipole for 15m
103 - Miniature Directive Antenna for 10m
104 - Biquad Antenna 12dBi-Gain for 2.4GHz
105 - Dual-Rhomboid Antenna for 435MHz to 870MHz
106 - Double-Bazooka Antenna for 80m
107 - J-Style Antenna
108 - Vertical / Horizontal / Circular Polarization Antenna
109 - Coax Inverted-L Antenna for 80m
110 - Indoor Compact Loop Antenna for 80m
111 - Helix Antenna
112 - Novice Vertical Antenna for 80m, 40m, 15m, 10m
113 - Stub-Loaded Shortened Dipole for 80m
114 - Six-Band Wire-Stub Trap Antenna for 40m-10m
115 - Multiband Half-Wave Delta-Loop Antenna
199 - Twin Delta Loop Antenna Gain=6dB for 160m, 80m, 40m
200 - Inverted-V Beam Antenna for 30m
201 - FD4 Windom Antenna for 80m, 40m, 20m, 10m
202 - Two Elements Phased Delta Loop for 40m
203 - Three Elements Wire Yagi for 10m
204 - Low Radiation Angle Full-Wave Loop Antenna for 80m
205 - Collinear Antenna Gain=3dB for 2m
206 - X-Ray Monoband Antenna Gain=6.5dBd
207 - Broadside Collinear Curtain Array for 20m
208 - Shrunk Loop Antenna for 80m, 40m
209 - λ/3 Multiband Dipole for 40m, 20m, 17m, 15m, 13m, 10m
210 - K3LR Sloper Antenna Gain=3dB for 160m
211 - Mini Folded Vertical Monopole Antenna for 160m, 80m, 40m
212 - Three Band Dipole for 80m, 40m, 20m
213 - Stub Matched Dipole Antenna
214 - Inverted-Vee Antenna with Bazooka Match
215 - Multiband Long Wire Antenna for 40m, 20m, 15m, 10m
216 - Converted Vee Antenna for 80m, 40m
217 - Swiss Quad Antenna for 20m, 15m, 10m
218 - Japanese Quad Antenna for 20m, 15m, 10m
219 - Seven-Elements Triangle Beam Antenna for 20m
220 - Log Periodic Wire Antenna for 40m
221 - Three-Elements 90-degrees Wire Beam for 20m
222 - Two-Elements Wire Beam for 20m
223 - Suitcase-Fit Dipole Antenna for 80m, 40m, 20m
224 - Multiband Coaxial Dipole for 80m, 40m
225 - Vertical Log Periodic Antenna for 80m, 40m
226 - Inverted Vertical Log Periodic Antenna for 40m
227 - Double Extended Zepp Antenna Gain=7dB for 15m
228 - Double Lazy-H Antenna G=10dB for 70cm
229 - Wire Log Periodic Antenna G=12dB for 15m, 20m
230 - Five-Elements Vertical Log Periodic for 80m, 40m, 20m
231 - Sloping Delta Loop Antenna for 40m
232 - Doublet Antenna for 160m
233 - Log Periodic Wire Beam for 40m
234 - G3LDO Wire Beam Antenna for 20m, 15m, 10m
235 - Phased Delta Loop Array for 20m
236 - Dual Band V-dipole for 80m, 40m
237 - Collinear Array 5dB-Gain for 15m
238 - Two-Band Quad Loop Antenna 80m, 40m
239 - K7CW Quad Antenna
240 - Broadband Short Dipole for 80m
241 - Off-Center Fed Dipole for 40m, 20m, 10m
242 - Broadband Sloper Antenna for 80m
243 - Two-Frequency Dipole Antenna for 80m
244 - Top Loaded Vertical Antenna for 160m
245 - Two Loop Beam Antenna for 20m, 15m
246 - Corner-Fed Delta Loop Antenna for 80m, 40m, 20m
247 - Loaded Delta Loop Antenna for 40m, 20m
248 - Compact Size Dipole for 80m
249 - JAWS 3dB Gain Antenna for 40m
250 - Inverted-V Antenna for 160m
251 - Lazy-U Antenna for 160m
252 - AF3V Compact Antenna for 160m
253 - Hot Beam Wire Antenna for 40m
254 - Sloping Delta Loop for 40m
255 - K6FD Multiband Antenna with T-tuner
256 - Dual Band Dipole Antenna for 17m, 10m
257 - Compact Travel Dipole Antenna for 10m, 15m, 20m
258 - End-Fire Antenna for 160m, 80m, 40m, 20m
259 - Four Band Loop for 40m, 20m, 15m, 10m

116 - Hybrid Vee for 20m, 17m
117 - Six-Shooter Array Antenna, Gain=7.5dB
118 - Multiband Ground-Plane Antenna for 10m, 15m, 20m
119 - Wire Superbeam Antenna for 10m, 15m, 20m
120 - Two Elements Delta-Loop Antenna
121 - Sterba Curtain Antenna
122 - Half-Wave Vertical Zepp Antenna
123 - Lazy-Loop Antenna for 40m
124 - Terminated Folded Dipole for 80m, 40m
125 - Short-Fat Antenna for 15m
126 - Cobra Antenna for 80m
127 - Log-Periodic Wire Antenna for 20m, 15m, 10m
128 - 5-Element Log-Periodic Vertical Antenna for 80m, 40m, 20m
129 - 2m Vertical Wire Antennas
130 - Earth-Mover Inverted-V Antenna for 40m
131 - Coax-Cable Collinear Antennas
132 - Double Bobtail Antenna for 20m
133 - Collinear Zepp Antenna
134 - Taylor Vee Antenna for 20m
135 - Collinear Vertical Antenna 6dB-Gain for 2m, 1.3m, 73cm
136 - Bi-Loop Antenna for 20m
137 - Wire Beam 6dBd-Gain for 10m
138 - Sloping Diamond Antenna 4dB-Gain for 40m
139 - Twisted Loop Antenna for 160m
140 - DX RX Loop Antenna for 160m
141 - Hentenna 3dB-Gain for 10m, 6m, 2m
142 - VK2AAR Wire Antenna for 20m
143 - 2-Elements Quad Antenna for 6m
144 - Hula-Loop Bidirectional 6dB-Gain Antenna for 17m
145 - Moxon Rectangle Beam for 15m-10m
146 - Double-D Beam 4dB-Gain
260 - Carolina Windom Antenna for 80 to 10m
261 - Shortened Loaded Dipole for 40m
262 - Shortened Loaded Dipole for 80m
263 - Low Radiation Angle Inverted Delta Loop for 80m
264 - Compact Dipole Antenna for 40m, 15m
265 - Vertical Delta Loop for 40m to 10m
266 - Delta Loop Antenna for 17m
267 - Bi-Square Beam Gain=3dBd for 17m
268 -Trap Dipole Antenna for 17m,13m
269 - Hanging Unipole Antenna for 160m, 80m
270 - Wideband Sloping Vee Antenna - 30m to 6m
271 - 5/8 Wavelength Antenna
272 - C-Pole Vertical Antenna
273 - Bobtail Antenna for 30m
274 - Bobtail Antenna for 40m
275 - Two Elements Vertical Loop Antenna for 40m
276 - Double Extended Zepp Antenna for 40m
277 - Reversible Moxon Flip Beam for 40m
278 - Spitwire Antenna for 40m
279 - Fork Antenna for 40m
280 - Veebeam Antenna 3dB-Gain for All Bands
281 - Vertical Moxon Antenna for 10m
282 - Half-Square Antenna for 30m
283 - Rotatable Vertical Delta Loop for 20m
284 - Mini-Horse Antenna 10dB-Gain for 40m-to-2m
285 - Compact Moxon Antenna 5dB-Gain for 40m
286 - Two Elements Sloping Delta Loop 8dB-Gain for 10m
287 - Two Elements Phased Vertical Antenna 3dB-Gain for 40m

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01 - Tee Antenna

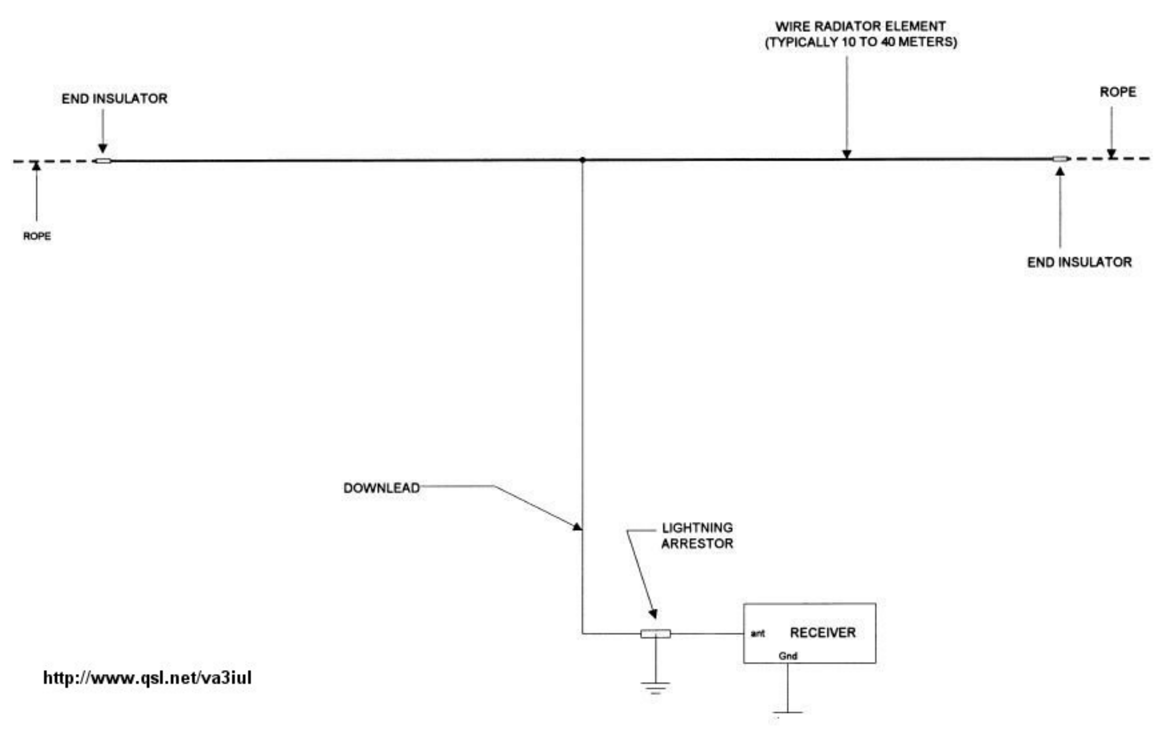
WIRE RADIATOR ELEMENT
(TYPICALLY 10 TO 40 METERS)
END INSULATOR
ROPE
ROPE
END INSULATOR
DOWNLEAD
LIGHTNING
ARRESTOR
ant
RECEIVER
Gnd
http://www.qsl.net/va3iul

02 - Half-Lamda Tee Antenna

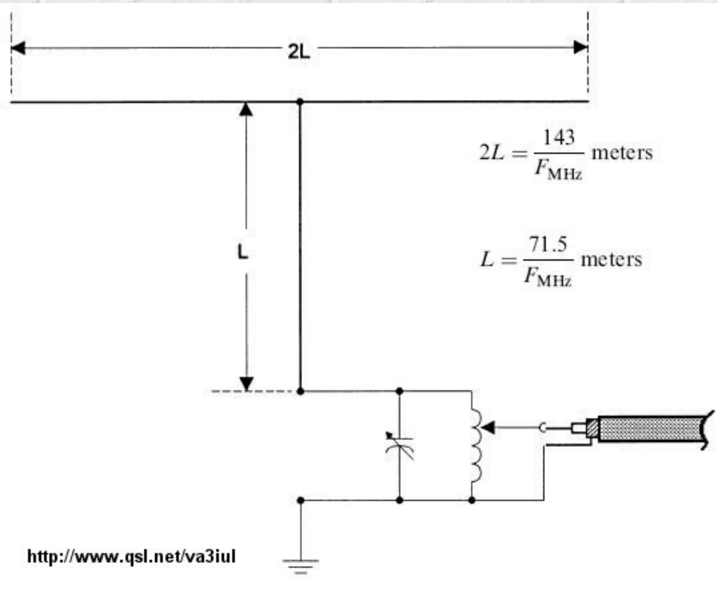
2L
$2L = \frac{143}{F_{\mathrm{MHz}}}$ meters
L
$L = \frac{71.5}{F_{\mathrm{MHz}}}$ meters
http://www.qsl.net/va3iul

03 - Twin-Led Marconi Antenna

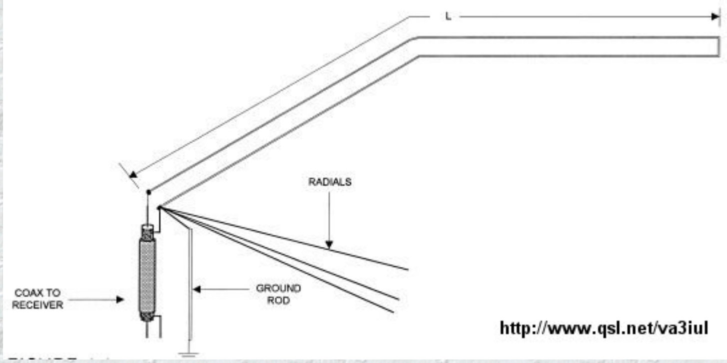
L
RADIALS
COAX TO
RECEIVER
GROUND
ROD
http://www.qsl.net/va3iul

04 - Swallow-Tail Antenna

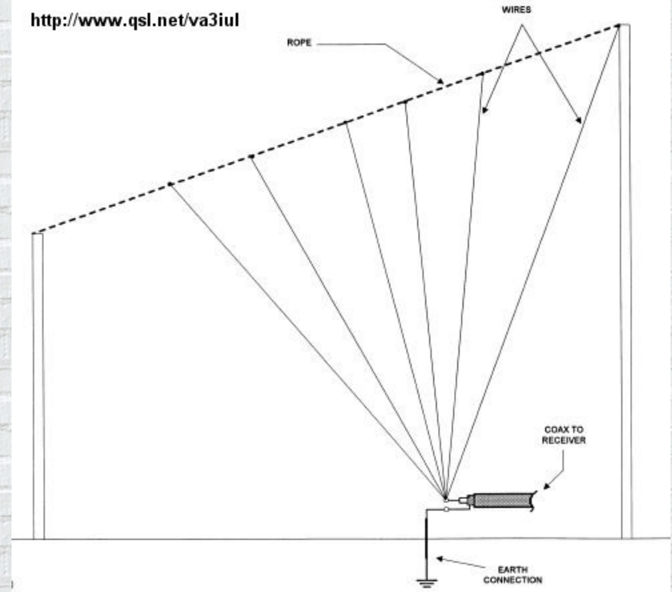
http://www.qsl.net/va3iul
WIRES
ROPE
COAX TO RECEIVER
EARTH CONNECTION

05 - Random Length Radiator Wire Antenna

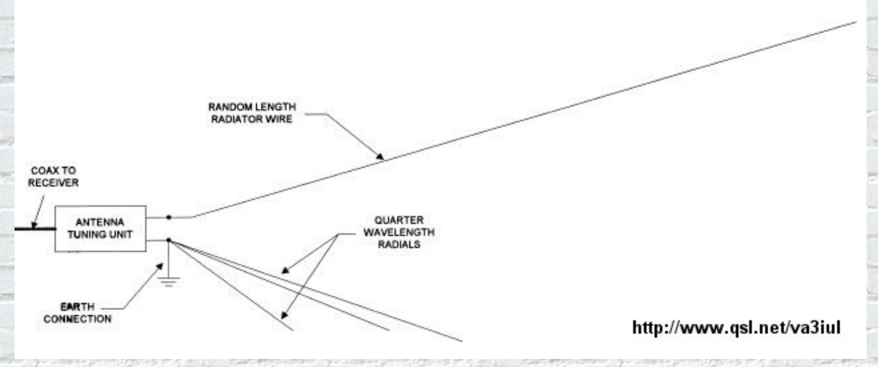
RANDOM LENGTH RADIATOR WIRE
COAX TO RECEIVER
ANTENNA TUNING UNIT
QUARTER WAVELENGTH RADIALS
EARTH CONNECTION
http://www.qsl.net/va3iul

06 - Windom Antenna

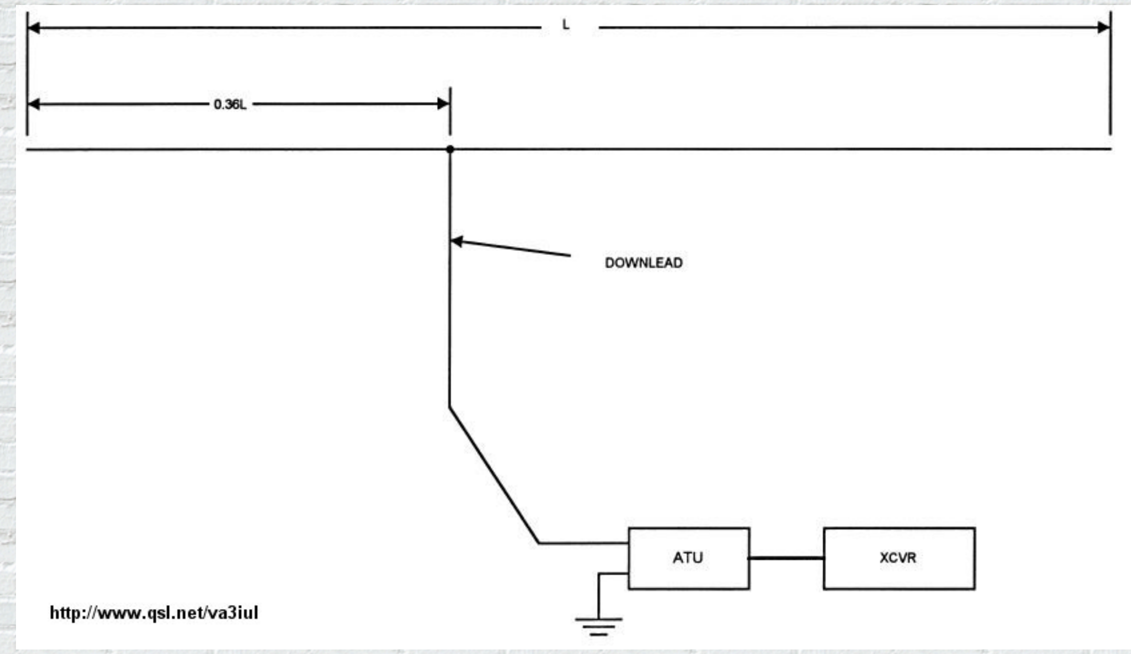
L
0.36L
DOWNLEAD
ATU
XCVR
http://www.qsl.net/va3iul

07 - Windom Antenna - Feed with coax cable

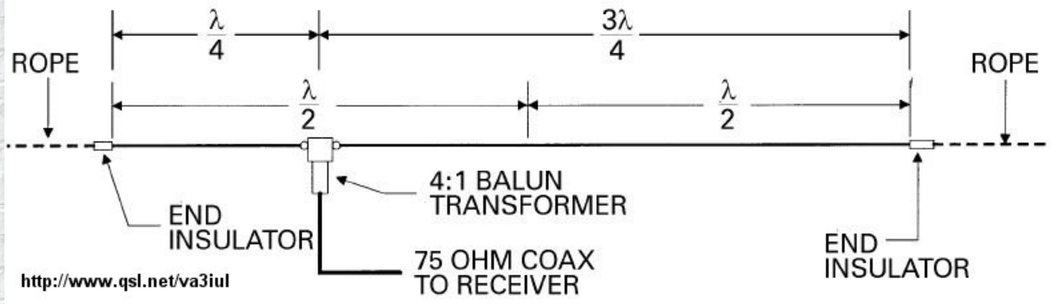
ROPE
$\frac{\lambda}{4}$
$\frac{3\lambda}{4}$
ROPE
$\frac{\lambda}{2}$
$\frac{\lambda}{2}$
4:1 BALUN TRANSFORMER
END INSULATOR
75 OHM COAX TO RECEIVER
END INSULATOR
http://www.qsl.net/va3iul

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08 - Quarter Wavelength Vertical Antenna

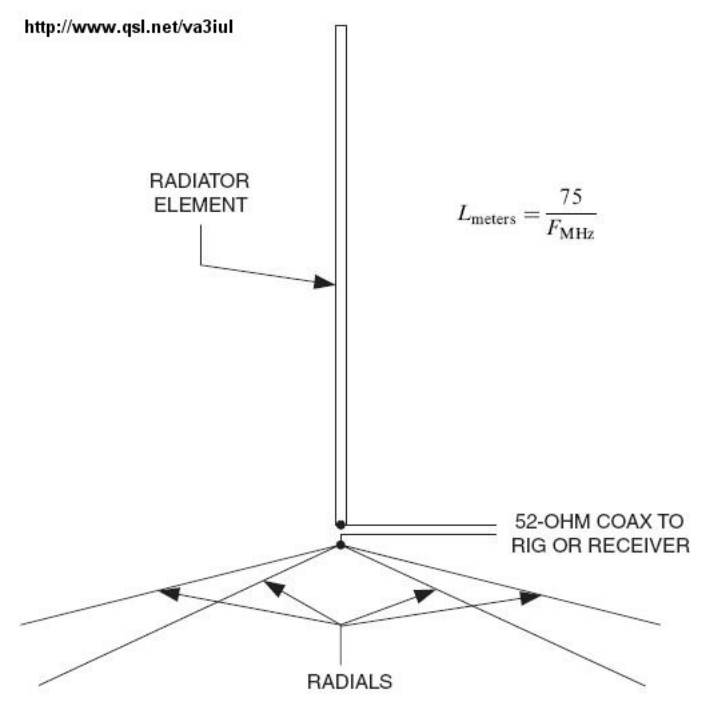
http://www.qsl.net/va3iul
RADIATOR ELEMENT
$L_{\text{meters}} = \frac{75}{F_{\text{MHz}}}$
52-OHM COAX TO RIG OR RECEIVER
RADIALS

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09 - Folded Marconi Tee Antenna

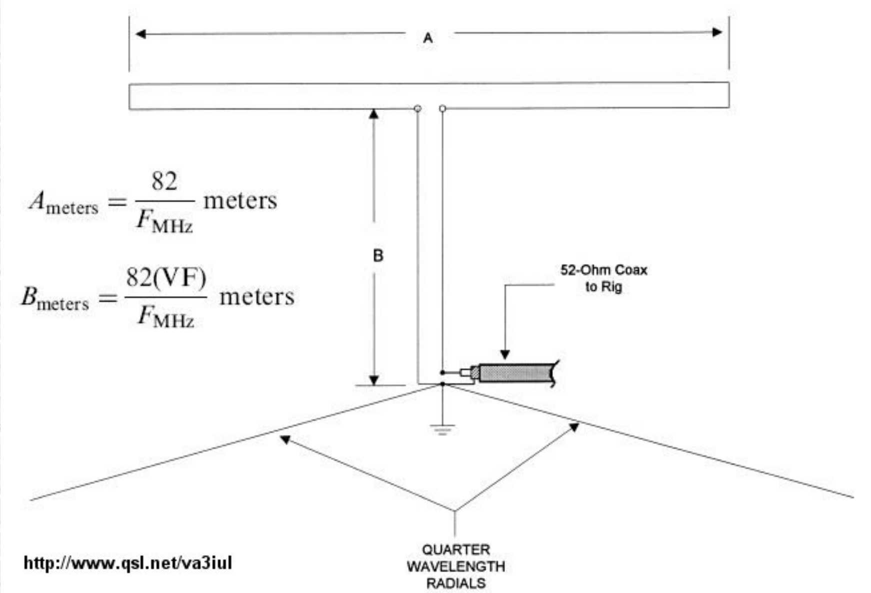
A
B
$A_{\text{meters}} = \frac{82}{F_{\text{MHz}}}$ meters
$B_{\text{meters}} = \frac{82(\text{VF})}{F_{\text{MHz}}}$ meters
52-Ohm Coax to Rig
QUARTER WAVELENGTH RADIALS
http://www.qsl.net/va3iul

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10 - Zeppelin Antenna

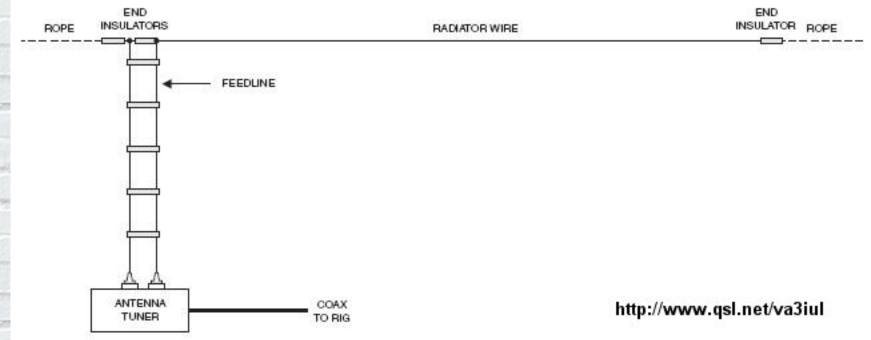
ROPE
END INSULATORS
RADIATOR WIRE
END INSULATOR
ROPE
FEEDLINE
ANTENNA TUNER
COAX TO RIG
http://www.qsl.net/va3iul

11 - EWE Antenna

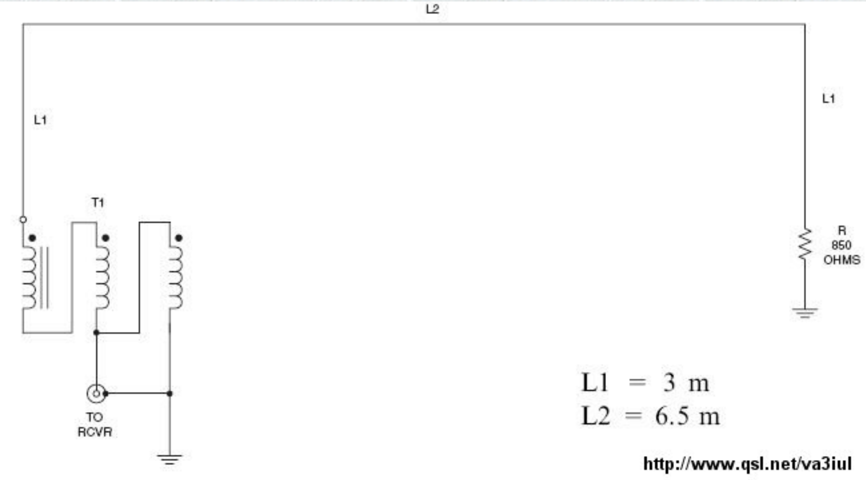
L2
L1
L1
T1
R 850 OHMS
TO RCVR
L1 = 3 m
L2 = 6.5 m
http://www.qsl.net/va3iul

12 - Dipole Antenna - Balun

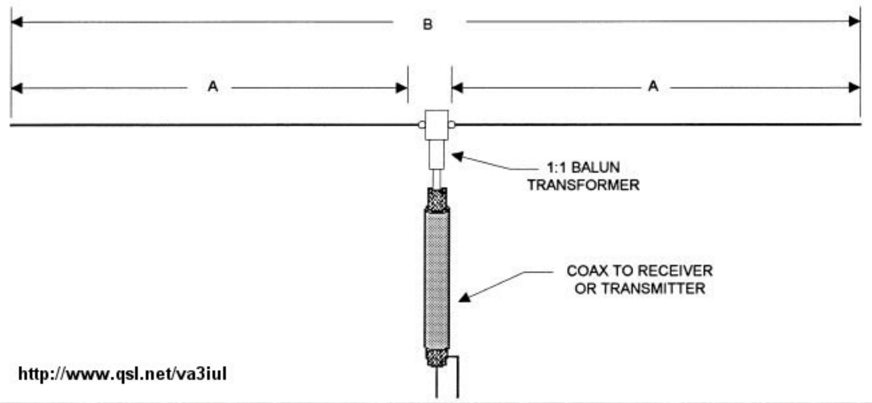
B
A
A
1:1 BALUN TRANSFORMER
COAX TO RECEIVER OR TRANSMITTER
http://www.qsl.net/va3iul

13 - Multiband Dipole Antenna

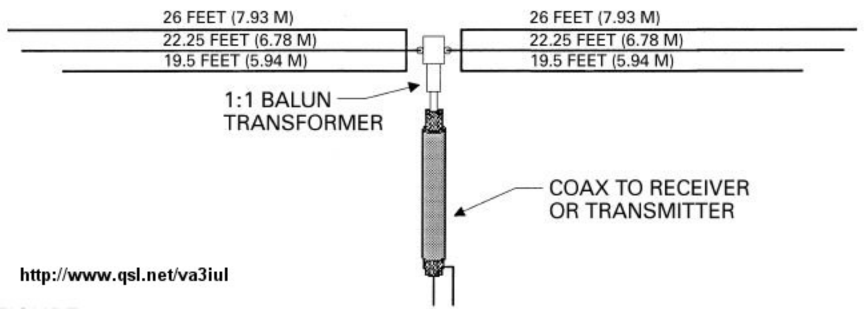
26 FEET (7.93 M)
22.25 FEET (6.78 M)
19.5 FEET (5.94 M)
26 FEET (7.93 M)
22.25 FEET (6.78 M)
19.5 FEET (5.94 M)
1:1 BALUN TRANSFORMER
COAX TO RECEIVER OR TRANSMITTER
http://www.qsl.net/va3iul

14 - Inverted-Vee Antenna

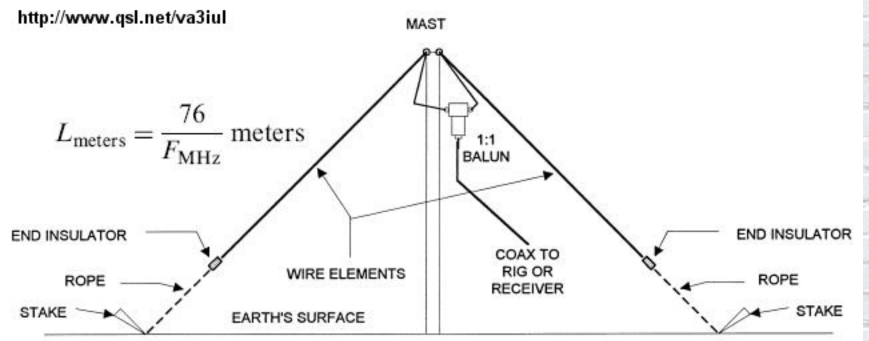
http://www.qsl.net/va3iul
MAST
$L_{meters} = \frac{76}{F_{MHz}}$ meters
1:1
BALUN
END INSULATOR
END INSULATOR
WIRE ELEMENTS
COAX TO
RIG OR
RECEIVER
ROPE
ROPE
STAKE
STAKE
EARTH'S SURFACE

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15 - Sloping Dipole Antenna

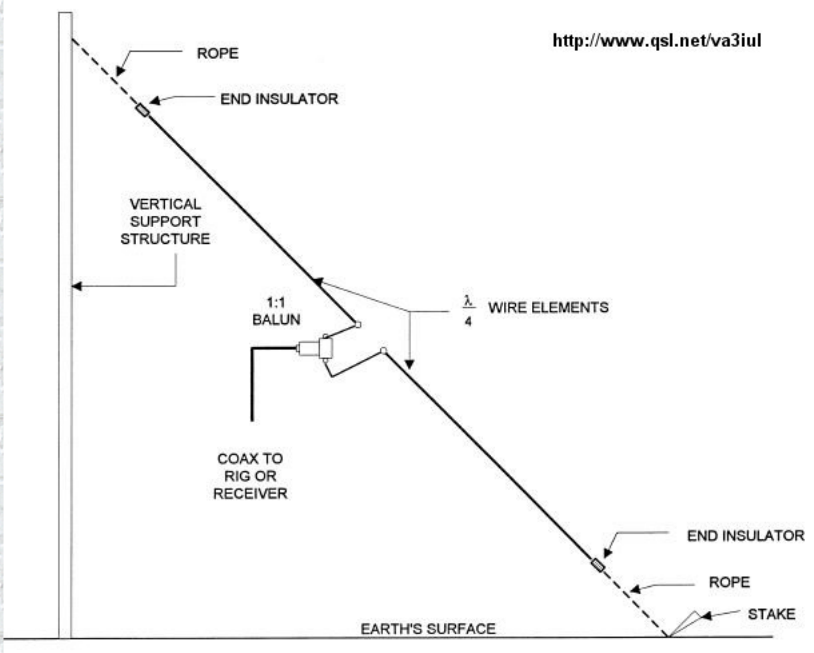
http://www.qsl.net/va3iul
ROPE
END INSULATOR
VERTICAL
SUPPORT
STRUCTURE
1:1
BALUN
λ/4 WIRE ELEMENTS
COAX TO
RIG OR
RECEIVER
END INSULATOR
ROPE
STAKE
EARTH'S SURFACE

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16 - Vertical Dipole

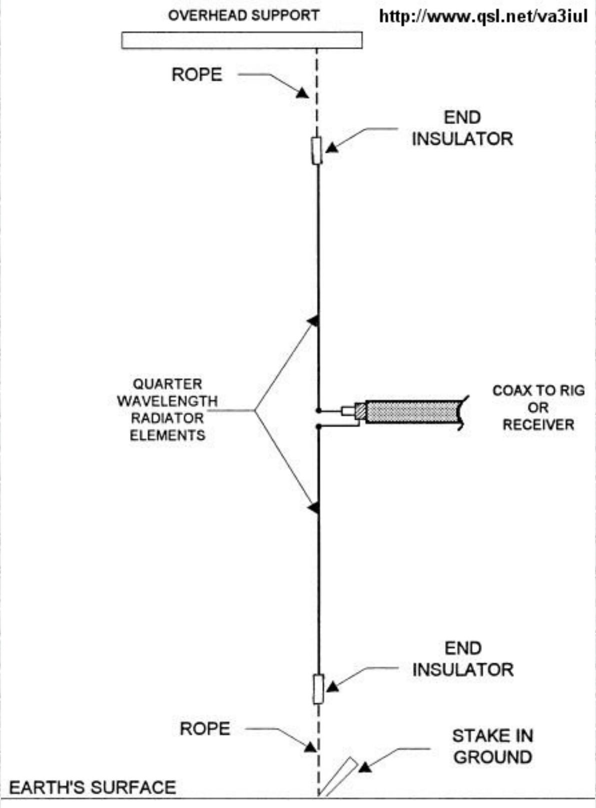
OVERHEAD SUPPORT
http://www.qsl.net/va3iul
ROPE
END INSULATOR
QUARTER WAVELENGTH RADIATOR ELEMENTS
COAX TO RIG OR RECEIVER
END INSULATOR
ROPE
STAKE IN GROUND
EARTH'S SURFACE

17 - Delta Fed Dipole Antenna

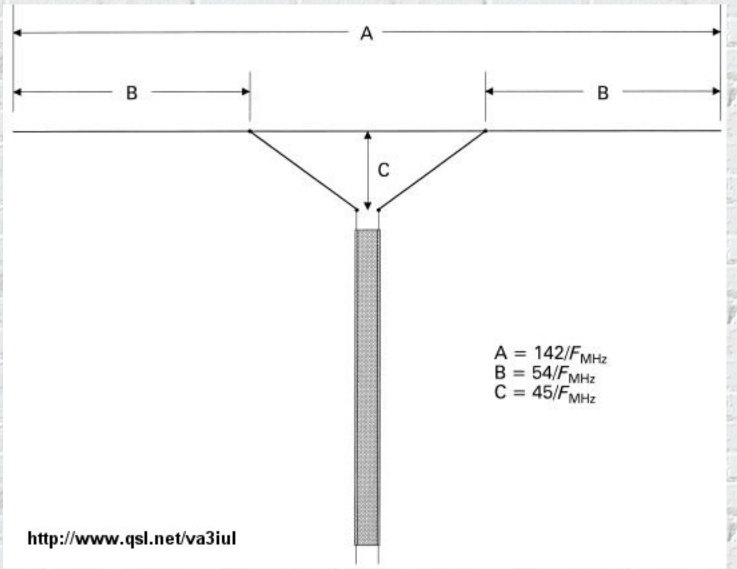
A
B
B
C
A = 142/F_MHz
B = 54/F_MHz
C = 45/F_MHz
http://www.qsl.net/va3iul

18 - Bow-Tie Dipole Antenna

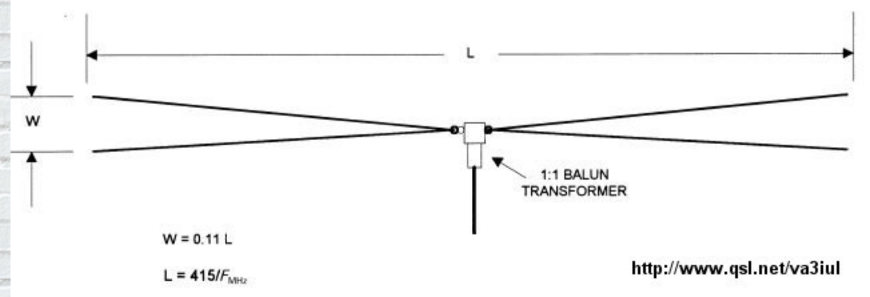
L
W
1:1 BALUN TRANSFORMER
W = 0.11 L
L = 415/F_MHz
http://www.qsl.net/va3iul

19 - Bow-Tie Folded Dipole Antenna for RX

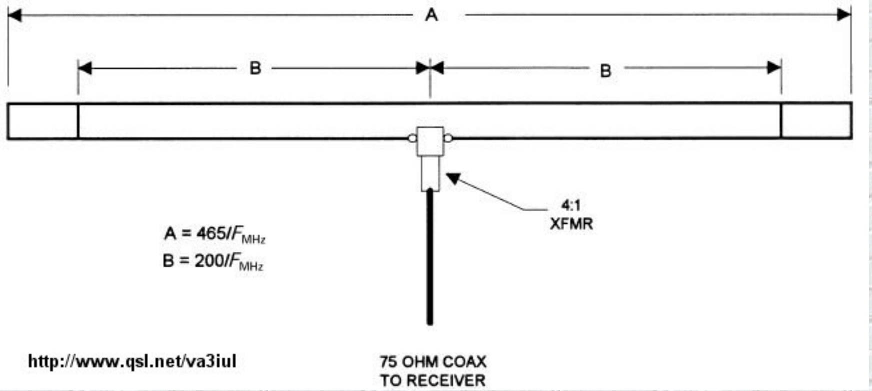
A
B
B
4:1
XFMR
A = 465/F_{MHz}
B = 200/F_{MHz}
http://www.qsl.net/va3iul
75 OHM COAX
TO RECEIVER

20 - Multiband Tuned Doublet Antenna

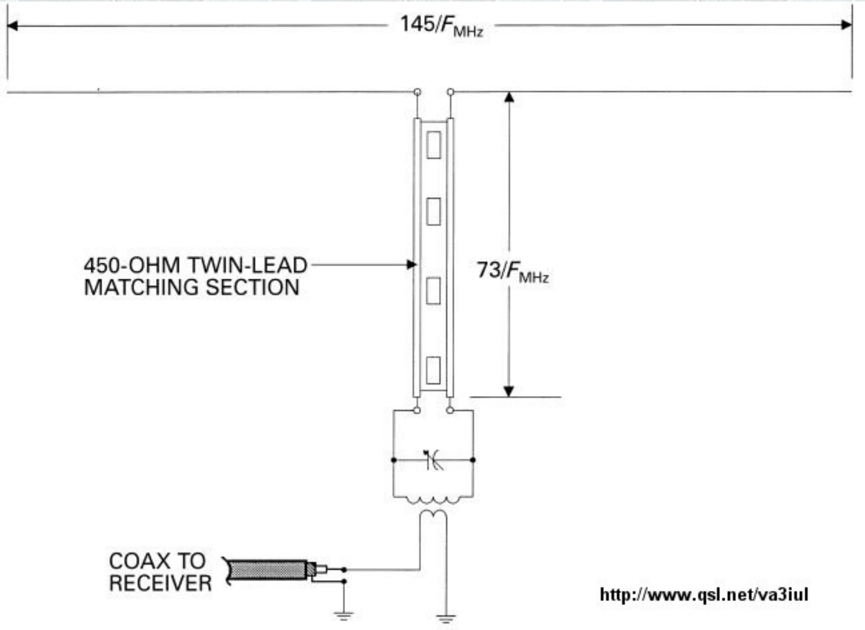
145/F_{MHz}
450-OHM TWIN-LEAD
MATCHING SECTION
73/F_{MHz}
COAX TO
RECEIVER
http://www.qsl.net/va3iul

21 - G5RV Antenna

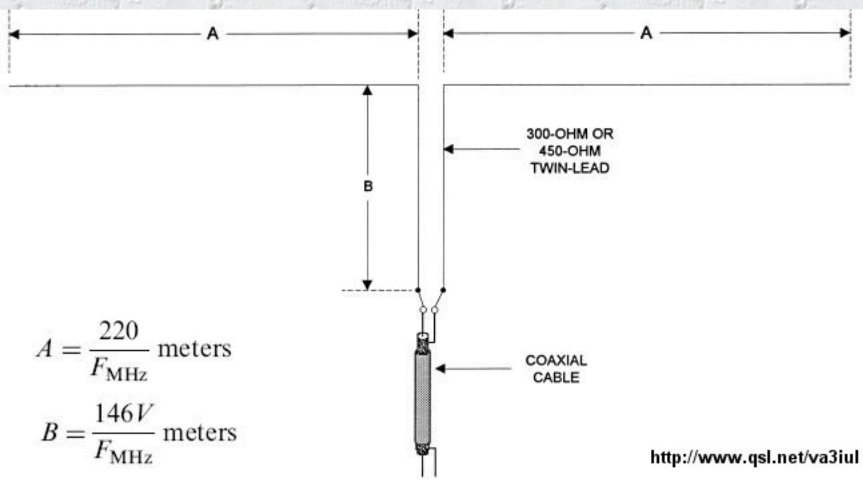
A
A
B
300-OHM OR
450-OHM
TWIN-LEAD
COAXIAL
CABLE
$A = \frac{220}{F_{\text{MHz}}}$ meters
$B = \frac{146V}{F_{\text{MHz}}}$ meters
http://www.qsl.net/va3iul

22 - Wideband Dipole Antenna

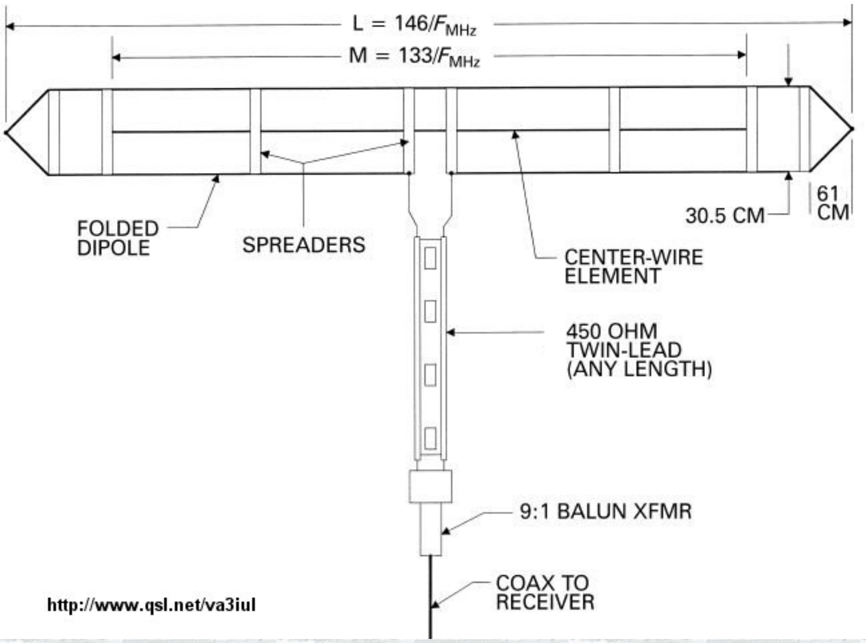
L = 146/F_MHz
M = 133/F_MHz
FOLDED DIPOLE
SPREADERS
30.5 CM
61 CM
CENTER-WIRE ELEMENT
450 OHM TWIN-LEAD (ANY LENGTH)
9:1 BALUN XFMR
COAX TO RECEIVER
http://www.qsl.net/va3iul

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23 - Wideband Dipole for Receiving

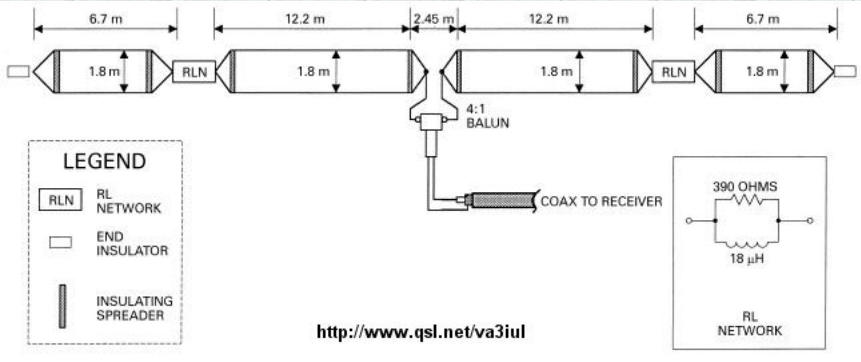
6.7 m
12.2 m
2.45 m
12.2 m
6.7 m
1.8 m
RLN
1.8 m
1.8 m
RLN
1.8 m
4:1 BALUN
LEGEND
RLN RL NETWORK
END INSULATOR
INSULATING SPREADER
COAX TO RECEIVER
390 OHMS
18 µH
RL NETWORK
http://www.qsl.net/va3iul

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24 - Tilted Folded Dipole Antenna

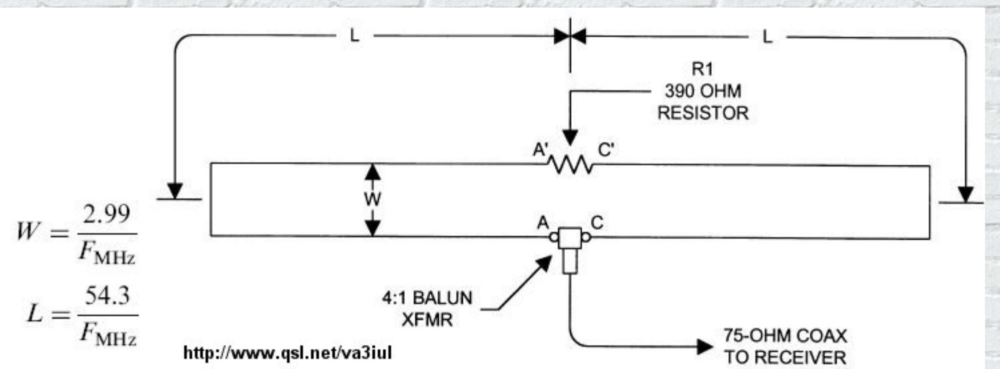
L
L
R1 390 OHM RESISTOR
A'
C'
W
A
C
W = 2.99/F_MHz
L = 54.3/F_MHz
4:1 BALUN XFMR
75-OHM COAX TO RECEIVER
http://www.qsl.net/va3iul

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25 - Right Angle Marconi Antenna

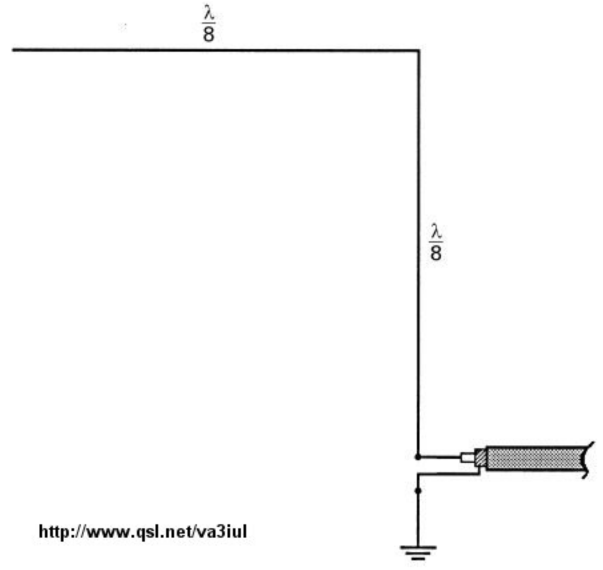
λ/8
λ/8
http://www.qsl.net/va3iul

26 - Linearly Loaded Tee Antenna

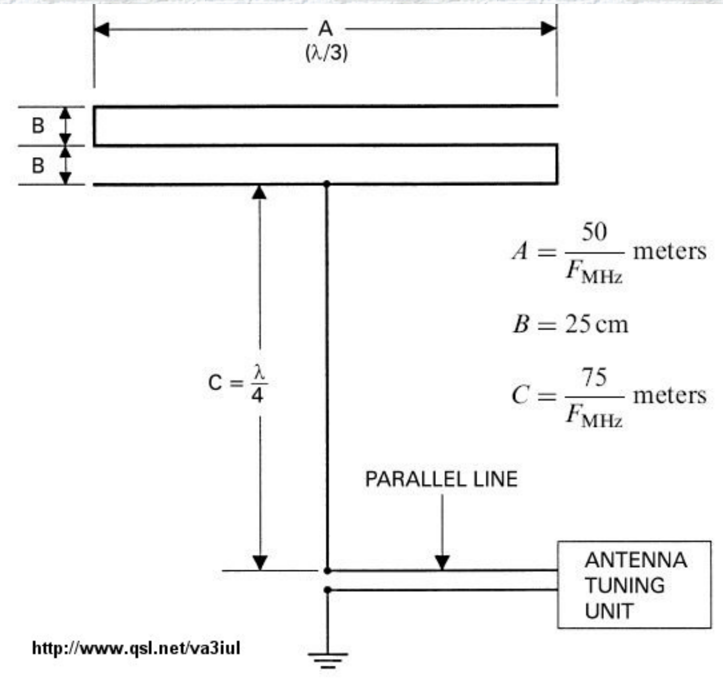
A
(λ/3)
B
B
C = λ/4
$A = \frac{50}{F_{\text{MHz}}}$ meters
$B = 25\,\text{cm}$
$C = \frac{75}{F_{\text{MHz}}}$ meters
PARALLEL LINE
ANTENNA TUNING UNIT
http://www.qsl.net/va3iul

27 - Reduced Size Dipole Antenna

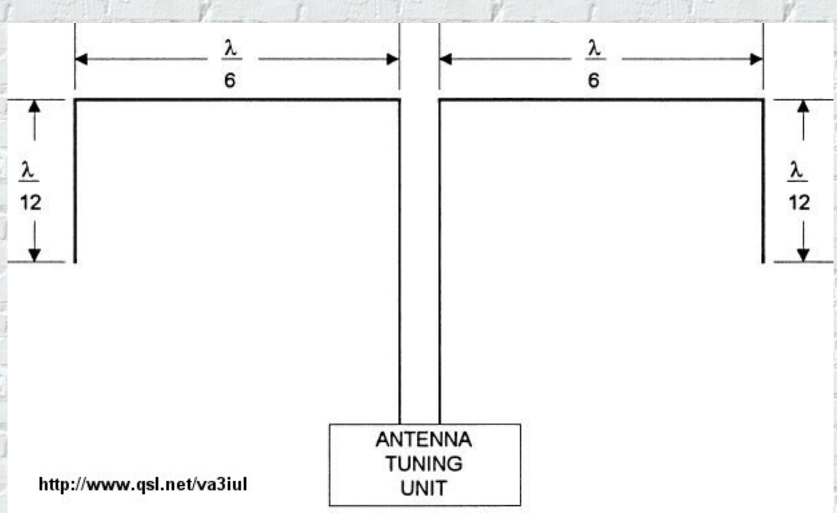
λ/6
λ/6
λ/12
λ/12
ANTENNA TUNING UNIT
http://www.qsl.net/va3iul

28 - Doublet Dipole Antenna

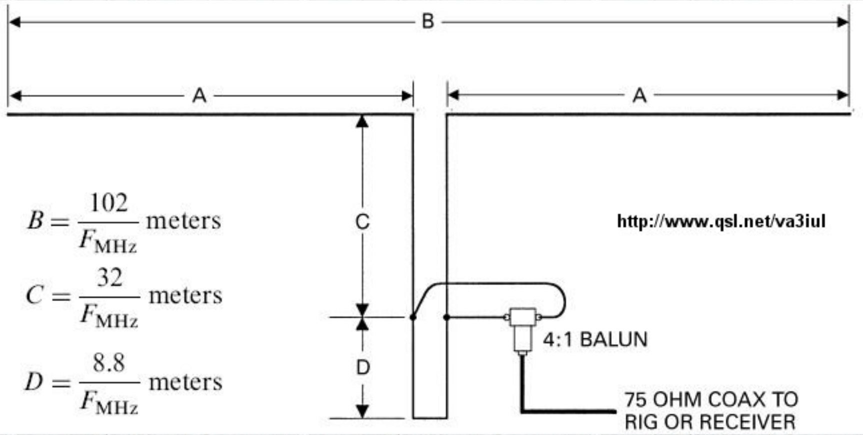
B
A
A
$B = \frac{102}{F_{\mathrm{MHz}}}$ meters
$C = \frac{32}{F_{\mathrm{MHz}}}$ meters
$D = \frac{8.8}{F_{\mathrm{MHz}}}$ meters
C
D
http://www.qsl.net/va3iul
4:1 BALUN
75 OHM COAX TO
RIG OR RECEIVER

---

29 - Delta Loop Antenna

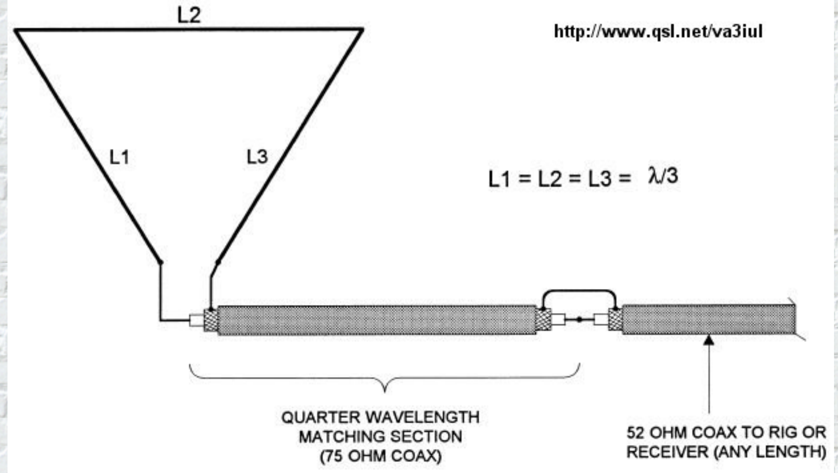
L2
http://www.qsl.net/va3iul
L1
L3
L1 = L2 = L3 = $\lambda/3$
QUARTER WAVELENGTH
MATCHING SECTION
(75 OHM COAX)
52 OHM COAX TO RIG OR
RECEIVER (ANY LENGTH)

---

30 - Half Delta Loop Antenna

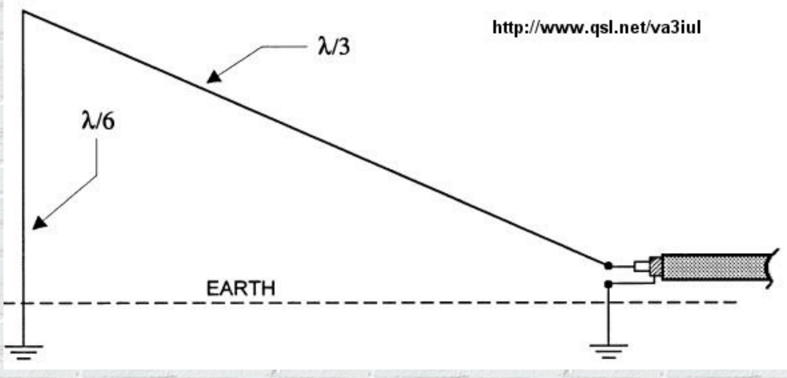
$\lambda/3$
http://www.qsl.net/va3iul
$\lambda/6$
EARTH

---

31 - Collinear Franklin Antenna

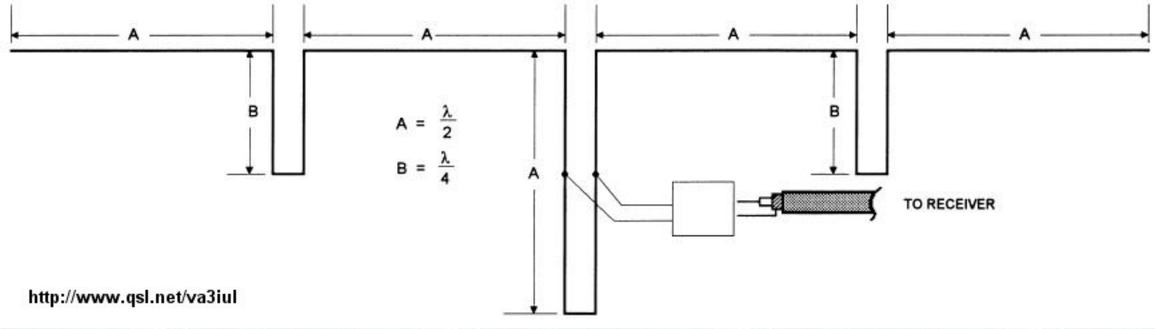
A
A
A
A
B
B
$A = \frac{\lambda}{2}$
$B = \frac{\lambda}{4}$
A
TO RECEIVER
http://www.qsl.net/va3iul

32 - Four Element Broadside Antenna

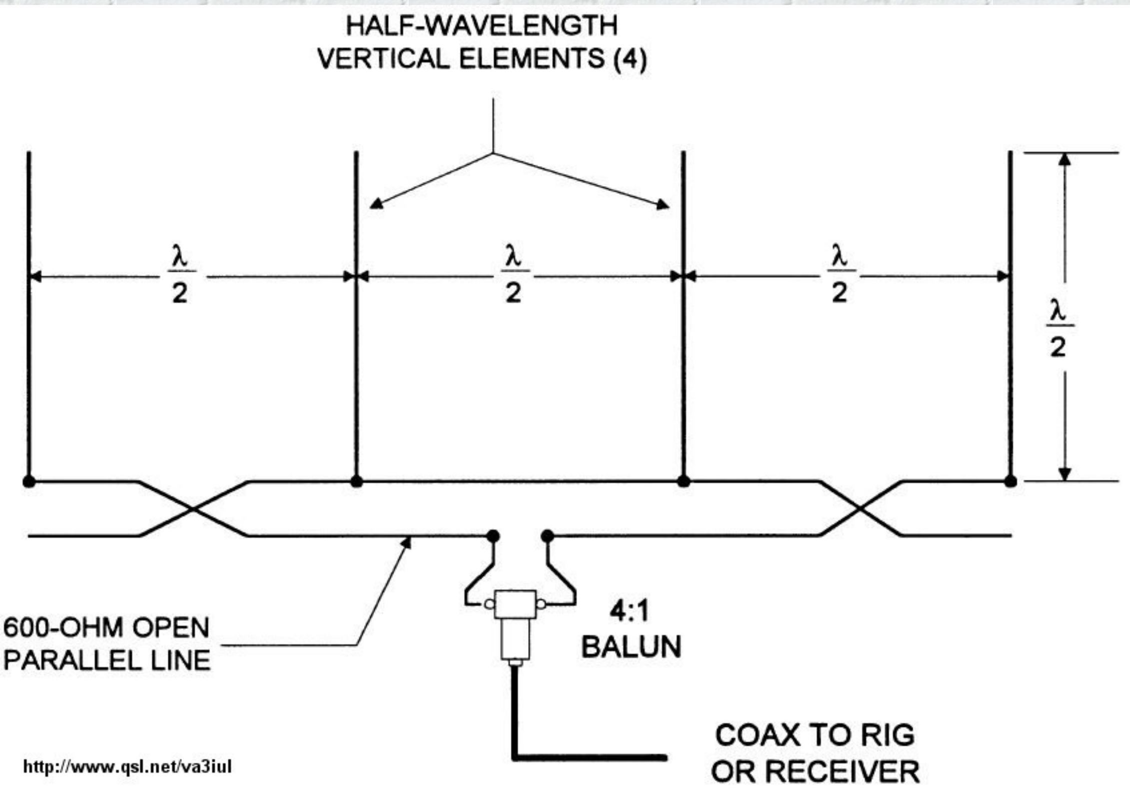
HALF-WAVELENGTH
VERTICAL ELEMENTS (4)
λ/2
λ/2
λ/2
λ/2
600-OHM OPEN
PARALLEL LINE
4:1
BALUN
COAX TO RIG
OR RECEIVER
http://www.qsl.net/va3iul

---

33 - The Lazy-H Array Antenna

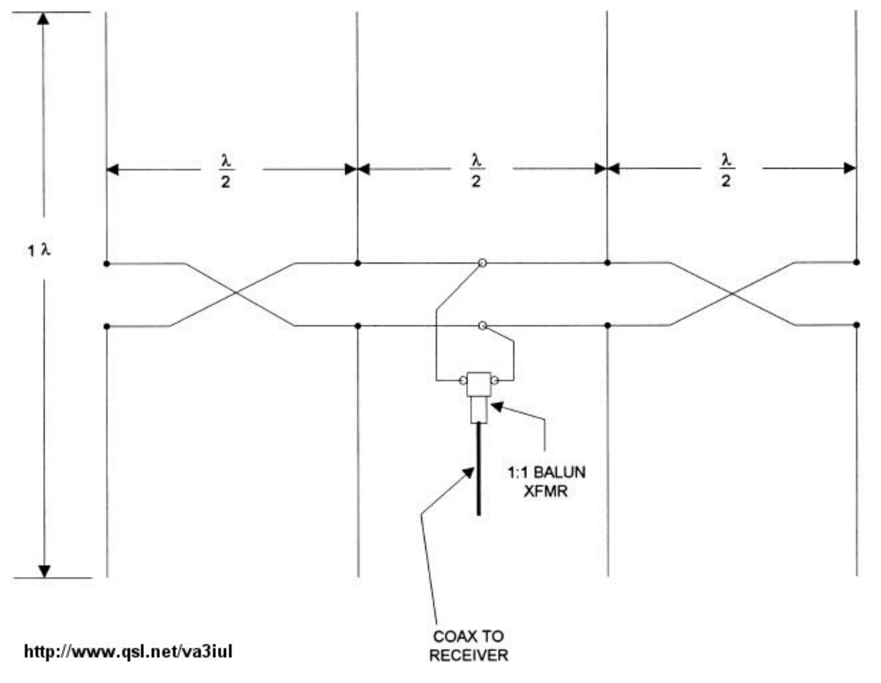
1 λ
λ/2
λ/2
λ/2
1:1 BALUN
XFMR
COAX TO
RECEIVER
http://www.qsl.net/va3iul

---

34 - Sterba Curtain Array Antenna

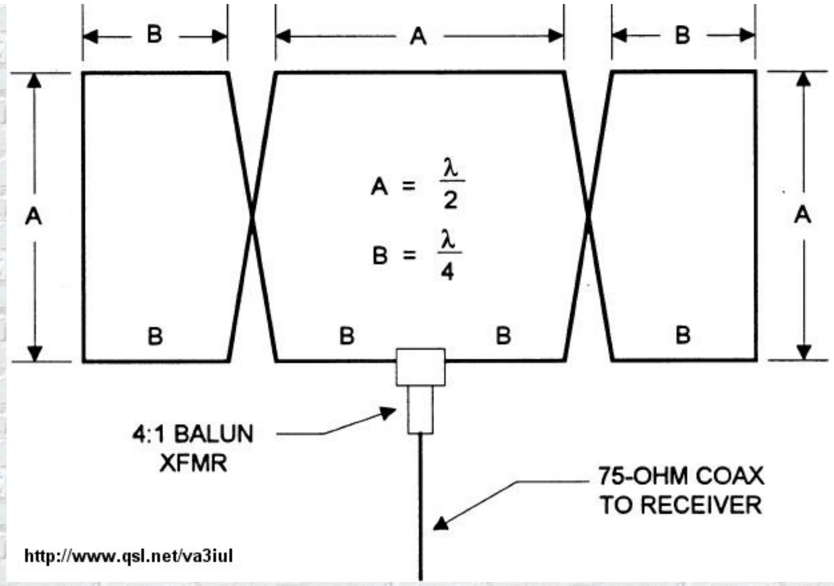
B
A
B
A
A
A = λ/2
B = λ/4
B
B
B
B
4:1 BALUN
XFMR
75-OHM COAX
TO RECEIVER
http://www.qsl.net/va3iul

35 - T-L DX Antenna

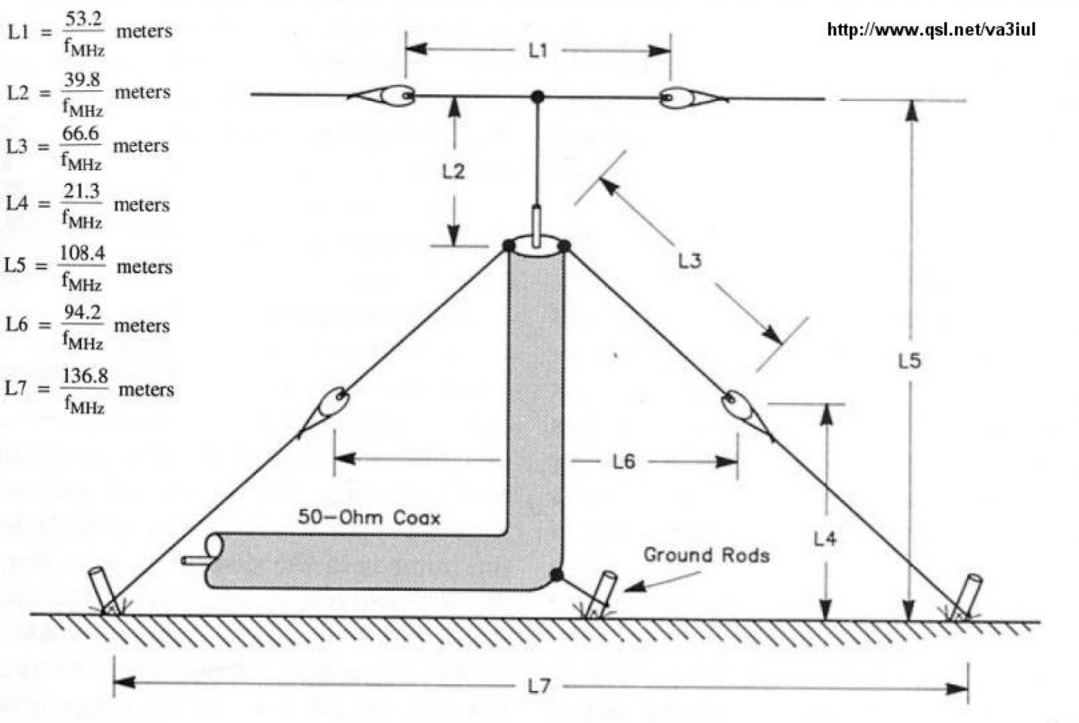
L1 = 53.2/fMHz meters
L2 = 39.8/fMHz meters
L3 = 66.6/fMHz meters
L4 = 21.3/fMHz meters
L5 = 108.4/fMHz meters
L6 = 94.2/fMHz meters
L7 = 136.8/fMHz meters
http://www.qsl.net/va3iul
L1
L2
L3
L5
L6
L4
50-Ohm Coax
Ground Rods
L7

36 - 1.9 MHz Full-wave Loop Antenna

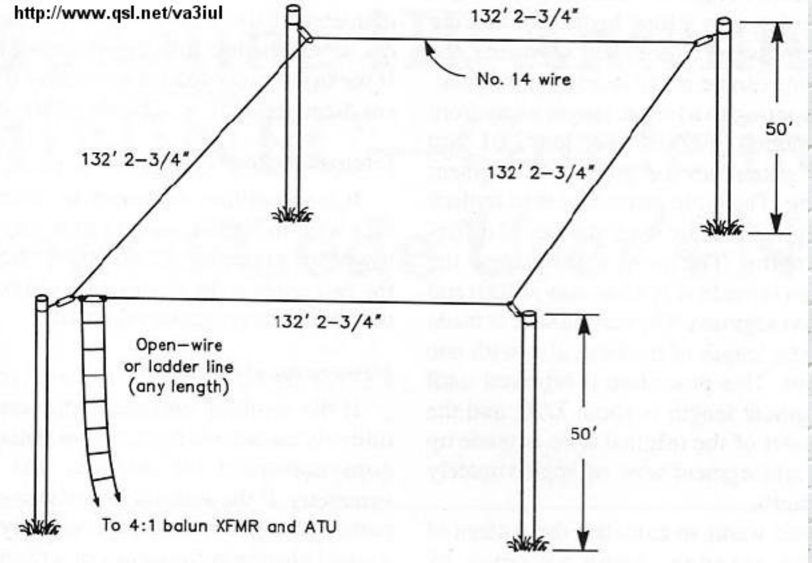
http://www.qsl.net/va3iul
132′ 2–3/4″
No. 14 wire
50′
132′ 2–3/4″
132′ 2–3/4″
132′ 2–3/4″
Open–wire
or ladder line
(any length)
50′
To 4:1 balun XFMR and ATU

---

37 - Multi-Band Portable Antenna

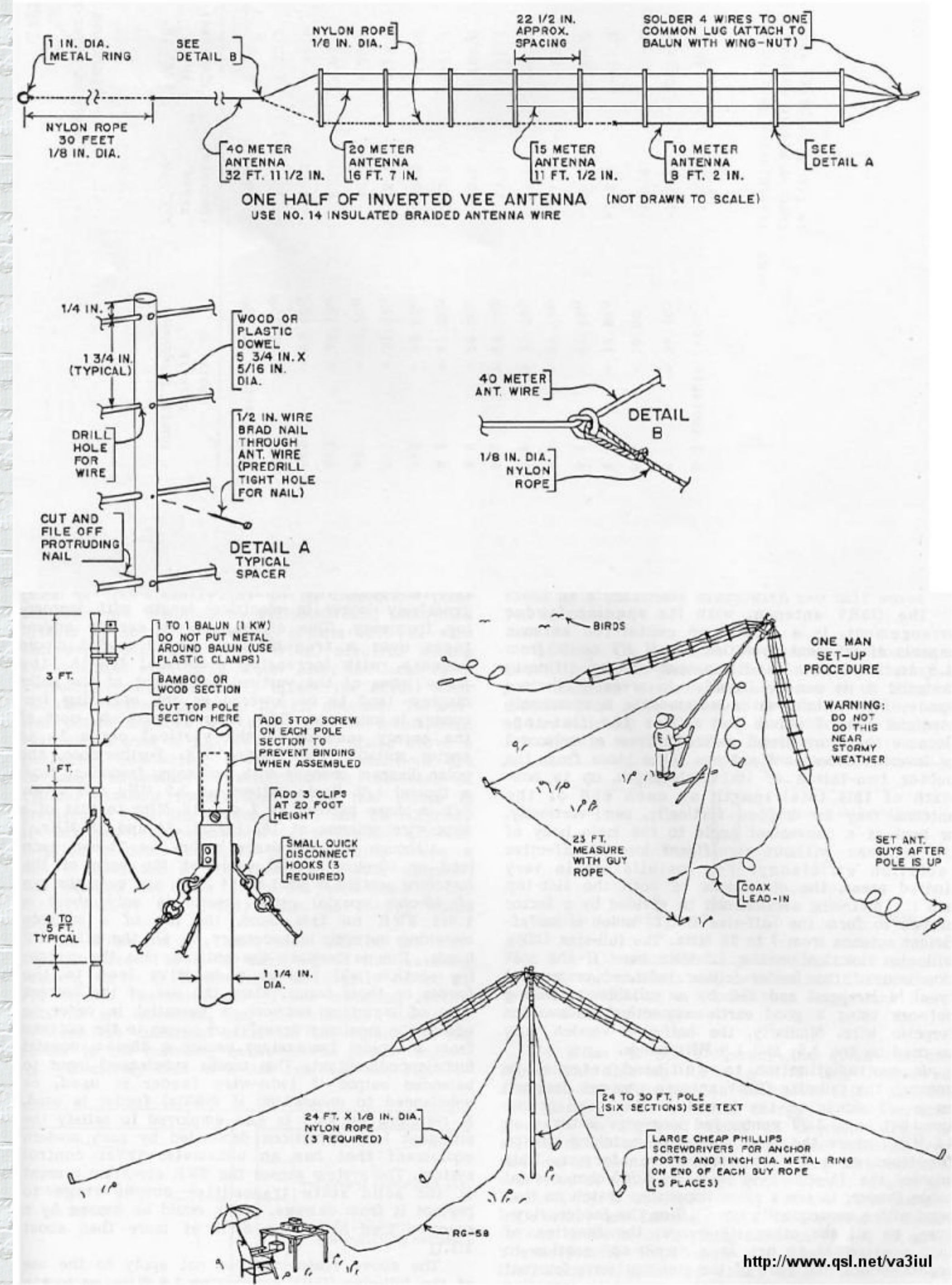
1 IN. DIA. METAL RING
SEE DETAIL B
NYLON ROPE 1/8 IN. DIA.
22 1/2 IN. APPROX. SPACING
SOLDER 4 WIRES TO ONE COMMON LUG (ATTACH TO BALUN WITH WING-NUT)
NYLON ROPE 30 FEET 1/8 IN. DIA.
40 METER ANTENNA 32 FT. 11 1/2 IN.
20 METER ANTENNA 16 FT. 7 IN.
15 METER ANTENNA 11 FT. 1/2 IN.
10 METER ANTENNA 8 FT. 2 IN.
SEE DETAIL A
ONE HALF OF INVERTED VEE ANTENNA
(NOT DRAWN TO SCALE)
USE NO. 14 INSULATED BRAIDED ANTENNA WIRE
1/4 IN.
1 3/4 IN. (TYPICAL)
WOOD OR PLASTIC DOWEL 5 3/4 IN. X 5/16 IN. DIA.
DRILL HOLE FOR WIRE
1/2 IN. WIRE BRAD NAIL THROUGH ANT. WIRE (PREDRILL TIGHT HOLE FOR NAIL)
CUT AND FILE OFF PROTRUDING NAIL
DETAIL A
TYPICAL SPACER
40 METER ANT. WIRE
DETAIL B
1/8 IN. DIA. NYLON ROPE
1 TO 1 BALUN (1 KW) DO NOT PUT METAL AROUND BALUN (USE PLASTIC CLAMPS)
3 FT.
BAMBOO OR WOOD SECTION
CUT TOP POLE SECTION HERE
ADD STOP SCREW ON EACH POLE SECTION TO PREVENT BINDING WHEN ASSEMBLED
1 FT.
ADD 3 CLIPS AT 20 FOOT HEIGHT
SMALL QUICK DISCONNECT HOOKS (3 REQUIRED)
4 TO 5 FT. TYPICAL
1 1/4 IN. DIA.
BIRDS
ONE MAN SET-UP PROCEDURE
WARNING: DO NOT DO THIS NEAR STORMY WEATHER
23 FT. MEASURE WITH GUY ROPE
COAX LEAD-IN
SET ANT. GUYS AFTER POLE IS UP
24 TO 30 FT. POLE (SIX SECTIONS) SEE TEXT
24 FT. X 1/8 IN. DIA. NYLON ROPE (3 REQUIRED)
LARGE CHEAP PHILLIPS SCREWDRIVERS FOR ANCHOR POSTS AND 1 INCH DIA. METAL RING ON END OF EACH GUY ROPE (5 PLACES)
RG-58
http://www.qsl.net/va3iul

38 - Off-center-fed Full-wave Doublet Antenna

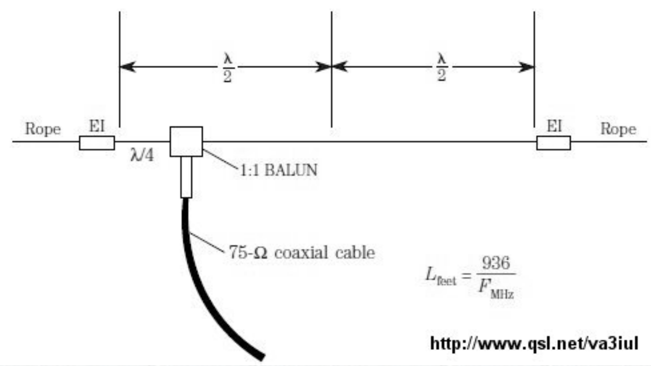
$\frac{\lambda}{2}$
$\frac{\lambda}{2}$
Rope
EI
EI
Rope
λ/4
1:1 BALUN
75-Ω coaxial cable
$L_{feet} = \frac{936}{F_{MHz}}$
http://www.qsl.net/va3iul

39 - Terminated Sloper Antenna

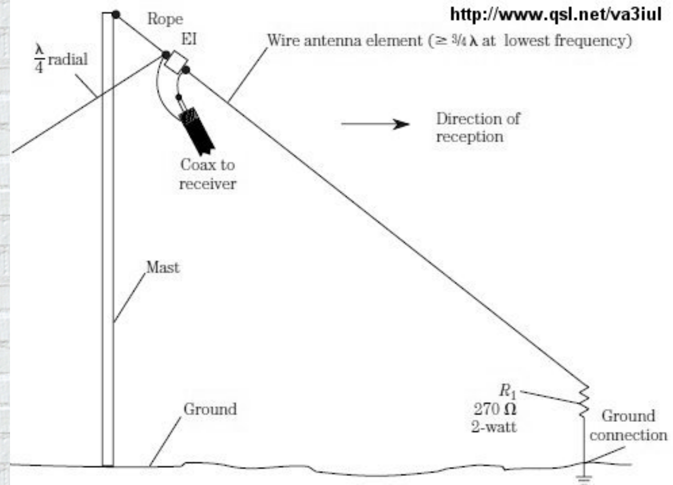
Rope
EI
http://www.qsl.net/va3iul
$\frac{\lambda}{4}$ radial
Wire antenna element (≥ 3/4 λ at lowest frequency)
Direction of reception
Coax to receiver
Mast
Ground
R_1 270 Ω 2-watt
Ground connection

---

40 - Double Extended Zepp Antenna

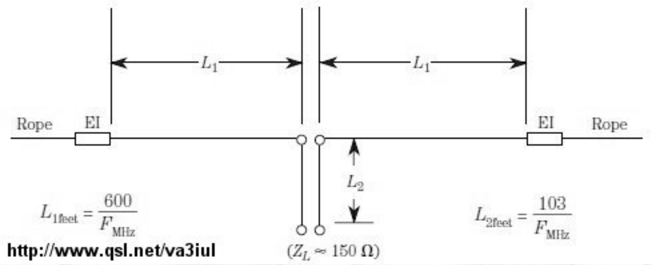
L_1
L_1
Rope
EI
EI
Rope
L_2
$L_{1\text{feet}} = \frac{600}{F_{\text{MHz}}}$
$L_{2\text{feet}} = \frac{103}{F_{\text{MHz}}}$
http://www.qsl.net/va3iul
$(Z_L \approx 150\ \Omega)$

---

41 - TCFTFD Dipole Antenna

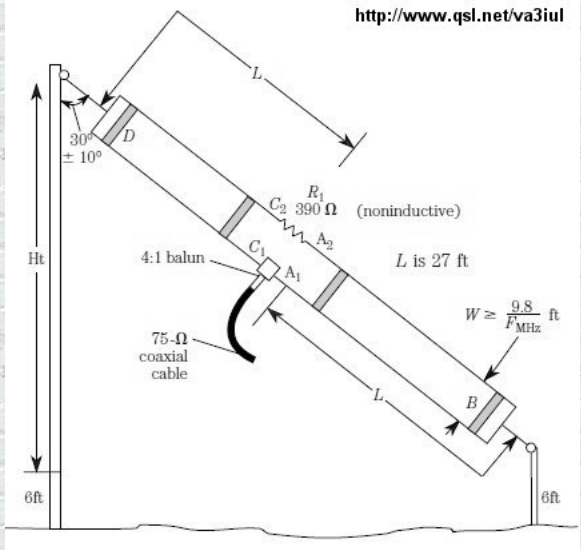
http://www.qsl.net/va3iul
L
30° ± 10°
D
R_1 390 Ω
(noninductive)
C_2
A_2
C_1
A_1
4:1 balun
Ht
L is 27 ft
$W \geq \frac{9.8}{F_{\text{MHz}}}$ ft
75-Ω coaxial cable
L
B
6ft
6ft

---

42 - Vee-Sloper Antenna

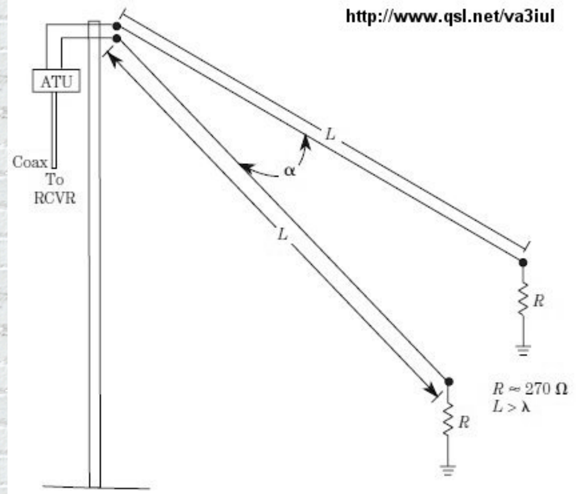
http://www.qsl.net/va3iul
ATU
Coax
To
RCVR
L
α
L
R
R
R ≈ 270 Ω
L > λ

---

43 - Rhombic Inverted-Vee Antenna

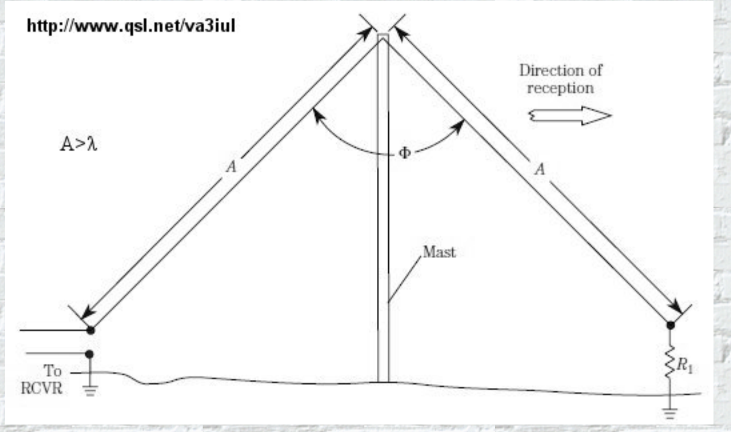
http://www.qsl.net/va3iul
A>λ
Direction of reception
A
Φ
A
Mast
To
RCVR
R1

---

44 - Counterpoise Longwire

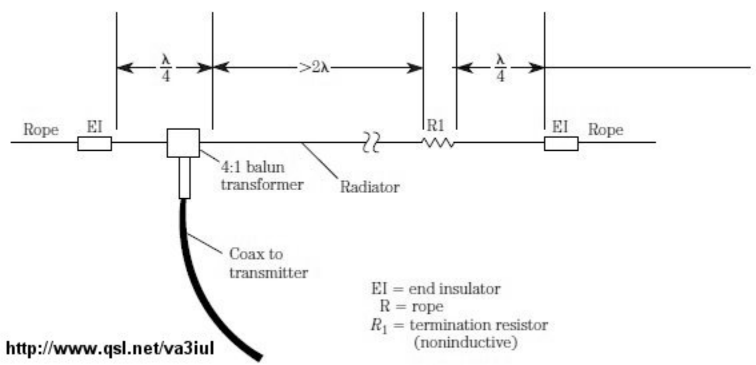
λ/4
>2λ
λ/4
Rope
EI
R1
EI
Rope
4:1 balun transformer
Radiator
Coax to transmitter
EI = end insulator
R = rope
R1 = termination resistor (noninductive)
http://www.qsl.net/va3iul

---

45 - Bisquare Loop Antenna

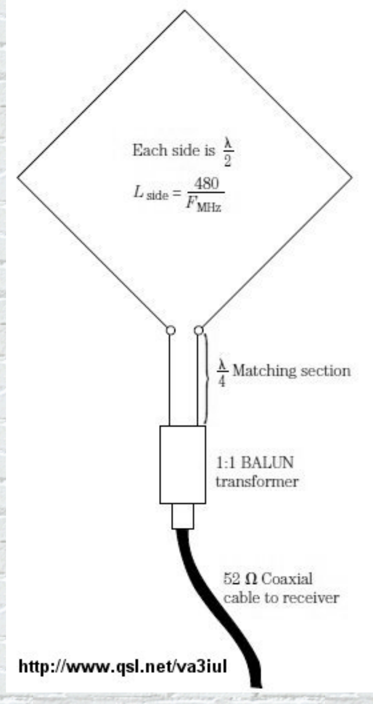
Each side is λ/2
L side = 480/F MHz
λ/4 Matching section
1:1 BALUN transformer
52 Ω Coaxial cable to receiver
http://www.qsl.net/va3iul

46 - Piggyback Antenna for 10m

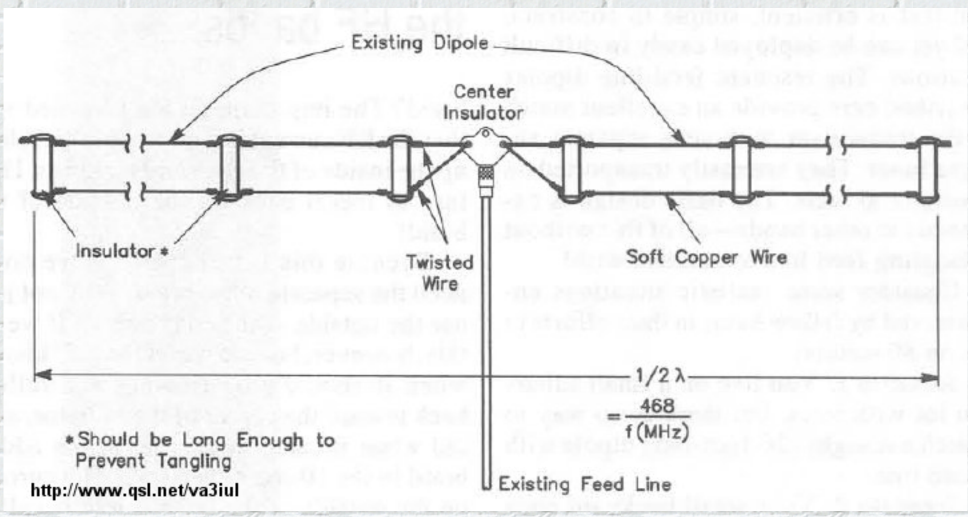
Existing Dipole
Center Insulator
Insulator *
Twisted Wire
Soft Copper Wire
1/2 λ = 468/f (MHz)
* Should be Long Enough to Prevent Tangling
Existing Feed Line
http://www.qsl.net/va3iul

47 - Vertical Sleeve Antenna for 10m

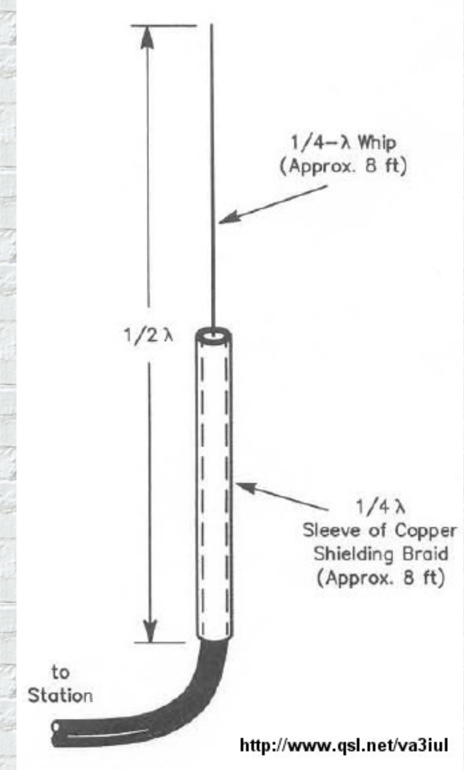
1/4–λ Whip
(Approx. 8 ft)
1/2 λ
1/4 λ
Sleeve of Copper
Shielding Braid
(Approx. 8 ft)
to
Station
http://www.qsl.net/va3iul

---

48 - Double Windom Antenna

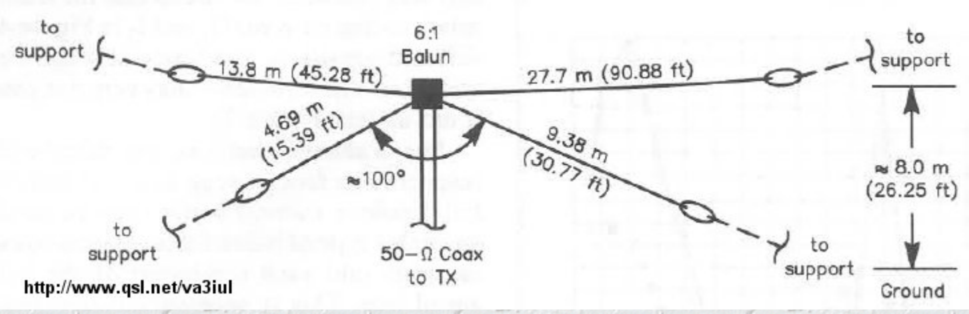
to
support
13.8 m (45.28 ft)
6:1
Balun
27.7 m (90.88 ft)
to
support
4.69 m
(15.39 ft)
≈100°
9.38 m
(30.77 ft)
≈ 8.0 m
(26.25 ft)
to
support
50–Ω Coax
to TX
to
support
Ground
http://www.qsl.net/va3iul

---

49 - Double Windom for 9 Bands

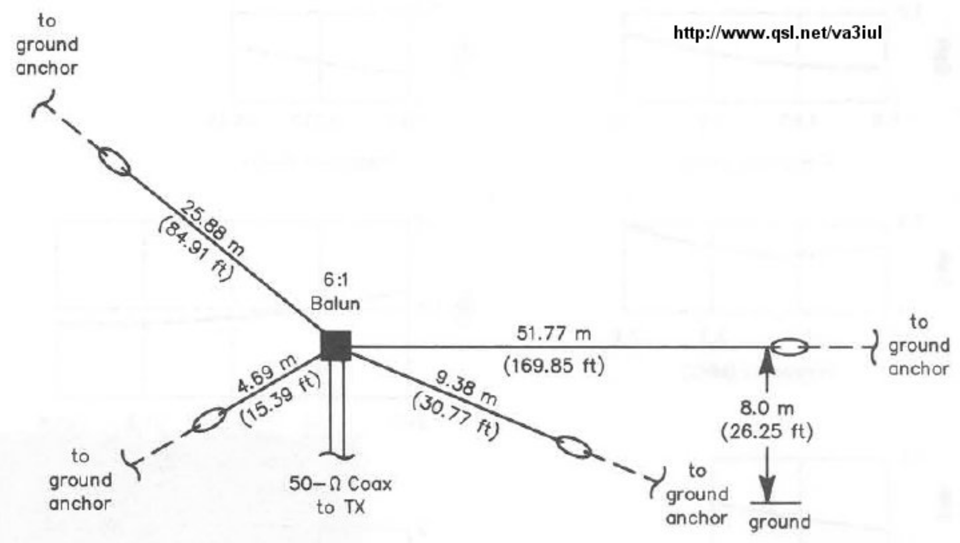
to
ground
anchor
http://www.qsl.net/va3iul
25.88 m
(84.91 ft)
6:1
Balun
51.77 m
(169.85 ft)
to
ground
anchor
4.69 m
(15.39 ft)
9.38 m
(30.77 ft)
8.0 m
(26.25 ft)
to
ground
anchor
50–Ω Coax
to TX
to
ground
anchor
ground

50 - Collinear Trap Antenna

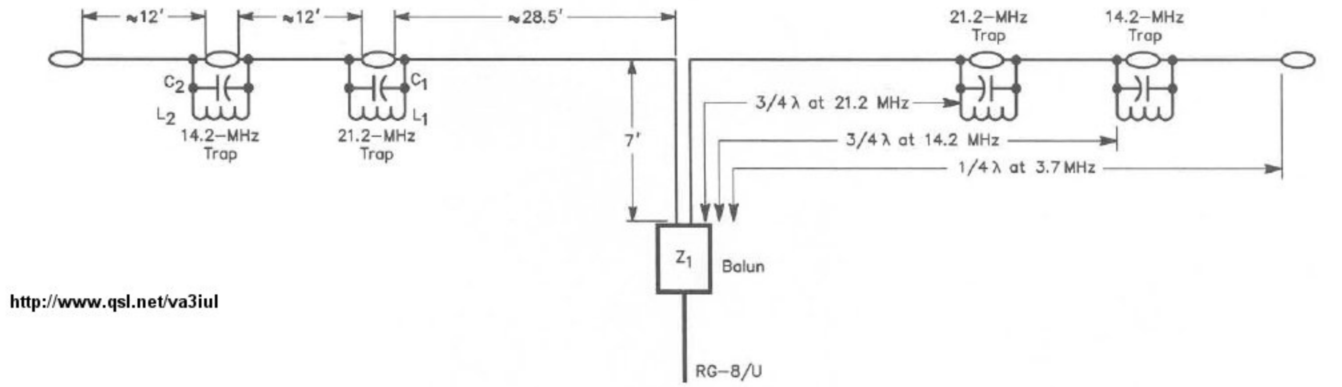
≈12′
≈12′
≈28.5′
21.2–MHz Trap
14.2–MHz Trap
C_2
L_2
14.2–MHz Trap
21.2–MHz Trap
C_1
L_1
7′
3/4 λ at 21.2 MHz
3/4 λ at 14.2 MHz
1/4 λ at 3.7 MHz
Z_1
Balun
RG–8/U
http://www.qsl.net/va3iul

C1, C2—25-pf. 6000-volt disk ceramic. See text.
L_1—Approx. 2 µH—4¾ turns No. 18, 2¼-inches diam., ⅜ inch long, or 5 turns No. 18, 2-inch diam., 16 tpi. See text.

L_2—Approx. 5 µH.—8 turns No. 18, 2¼-inch dia., ⅝ inch long, or 9 turns No. 18, 2-inch diam. 16 tpi. See text.
Z_1—1 to 1 balun.

51 - Short Dipole Antenna for 40m - 80m - 160m

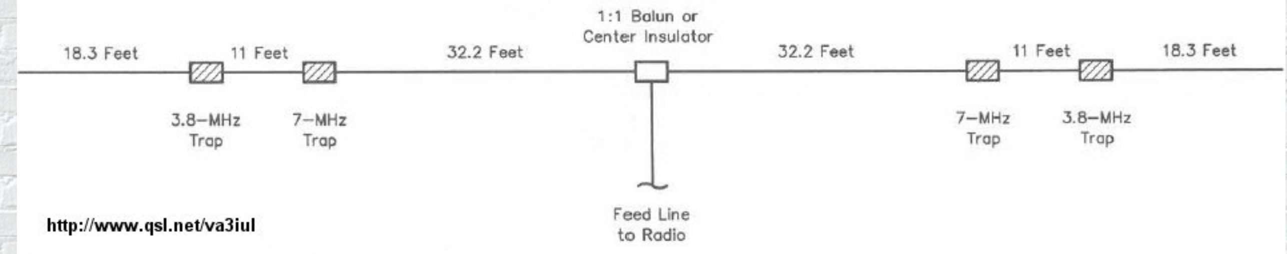
1:1 Balun or Center Insulator
18.3 Feet
11 Feet
32.2 Feet
32.2 Feet
11 Feet
18.3 Feet
3.8–MHz Trap
7–MHz Trap
7–MHz Trap
3.8–MHz Trap
http://www.qsl.net/va3iul
Feed Line to Radio

52 - Center Fed-Zepp Antenna for 80m - 40m

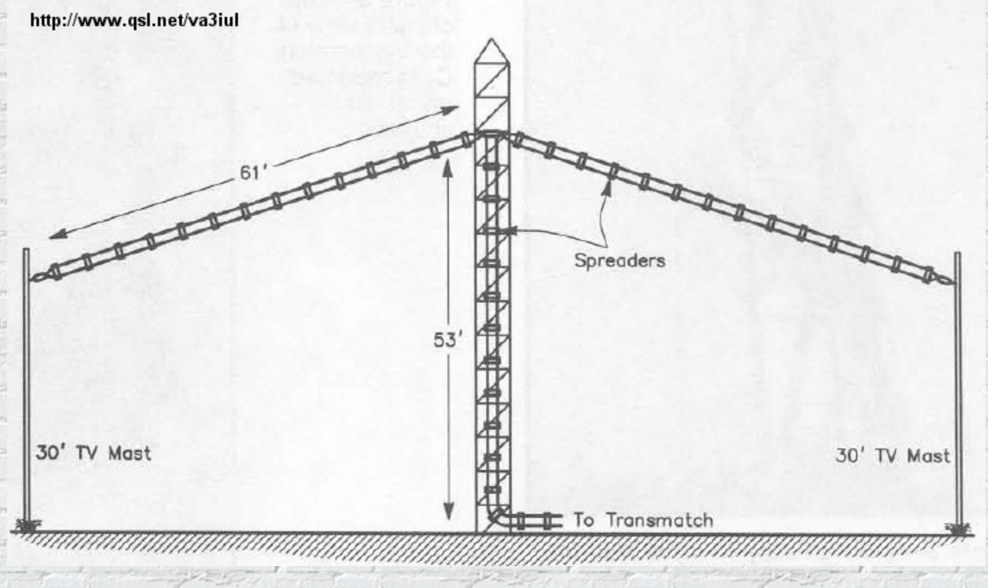
http://www.qsl.net/va3iul
61′
Spreaders
53′
30′ TV Mast
30′ TV Mast
To Transmatch

53 - All-Bands Antenna

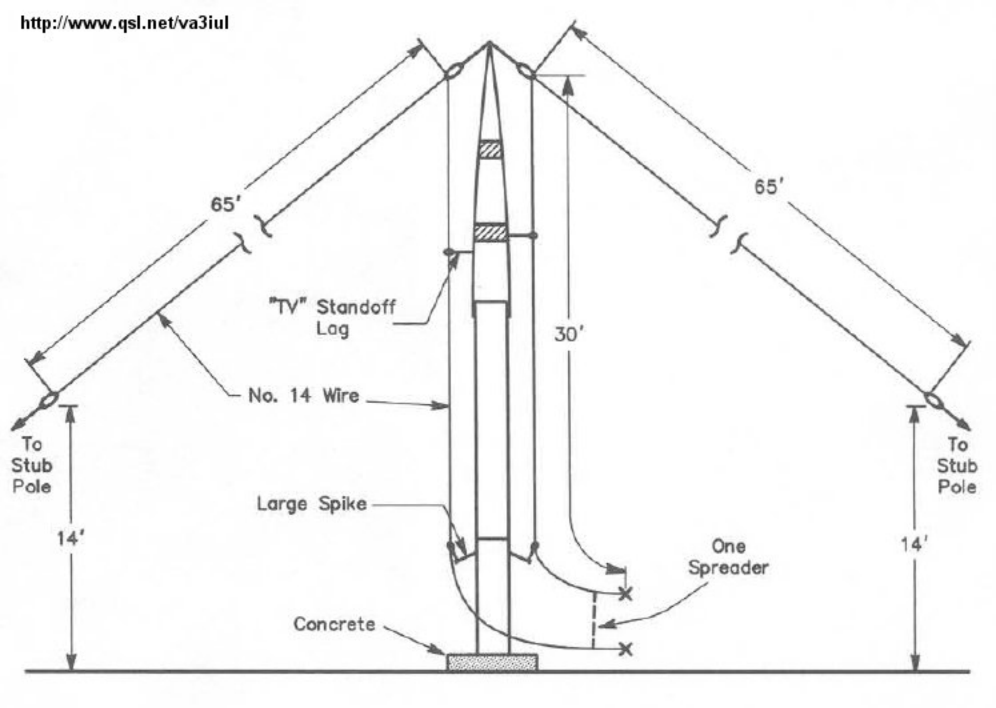
http://www.qsl.net/va3iul
65'
65'
"TV" Standoff Lag
30'
No. 14 Wire
To Stub Pole
To Stub Pole
Large Spike
14'
14'
One Spreader
Concrete

54 - All-Bands Dipole Antenna

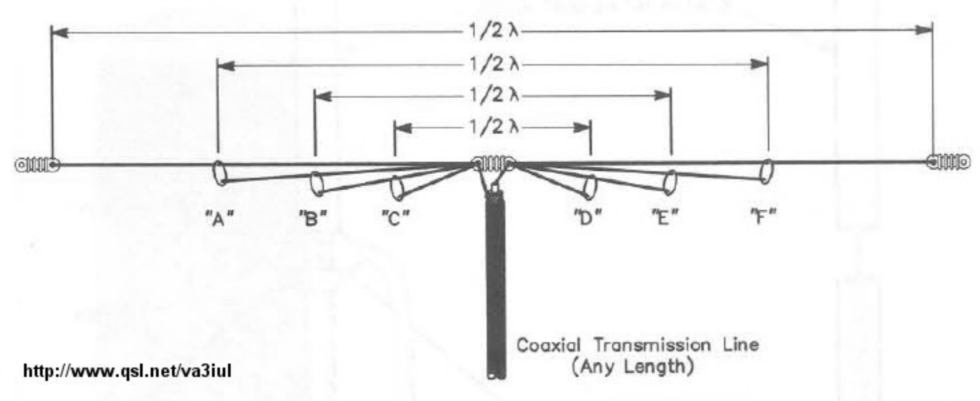
1/2 λ
1/2 λ
1/2 λ
1/2 λ
"A"
"B"
"C"
"D"
"E"
"F"
Coaxial Transmission Line (Any Length)
http://www.qsl.net/va3iul

55 - Multiband Z Antenna

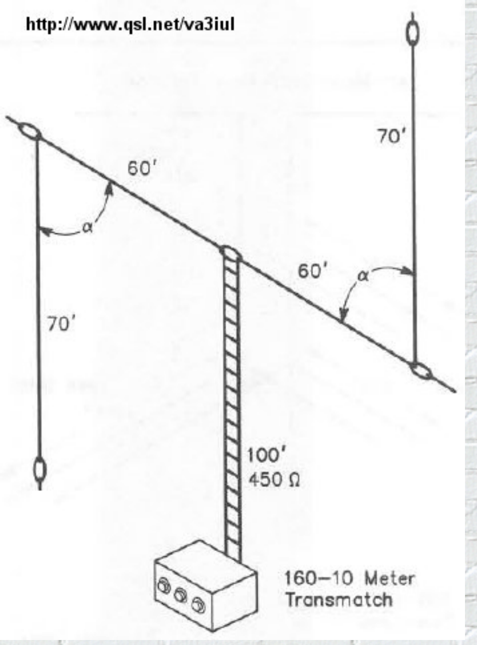
http://www.qsl.net/va3iul
70'
60'
α
60'
α
70'
100'
450 Ω
160–10 Meter
Transmatch

---

56 - Multiband Dipole Antenna

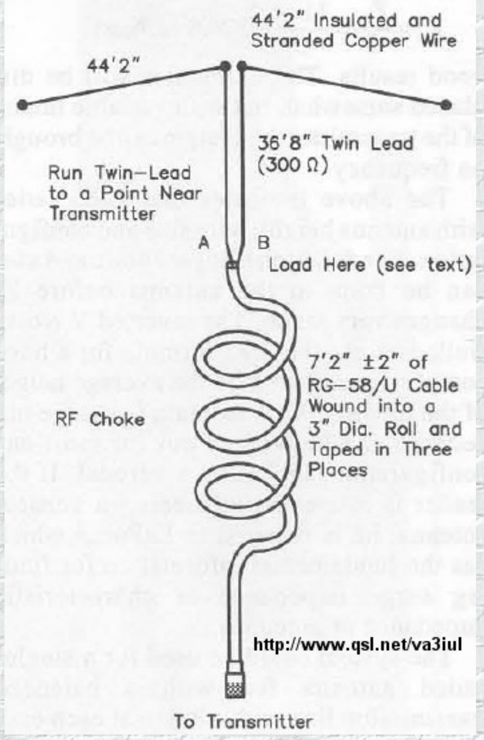
44'2" Insulated and
Stranded Copper Wire
44'2"
36'8" Twin Lead
(300 Ω)
Run Twin–Lead
to a Point Near
Transmitter
A
B
Load Here (see text)
7'2" ±2" of
RG–58/U Cable
Wound into a
3" Dia. Roll and
Taped in Three
Places
RF Choke
http://www.qsl.net/va3iul
To Transmitter

---

57 - Five-Bands No-Tuner Antenna

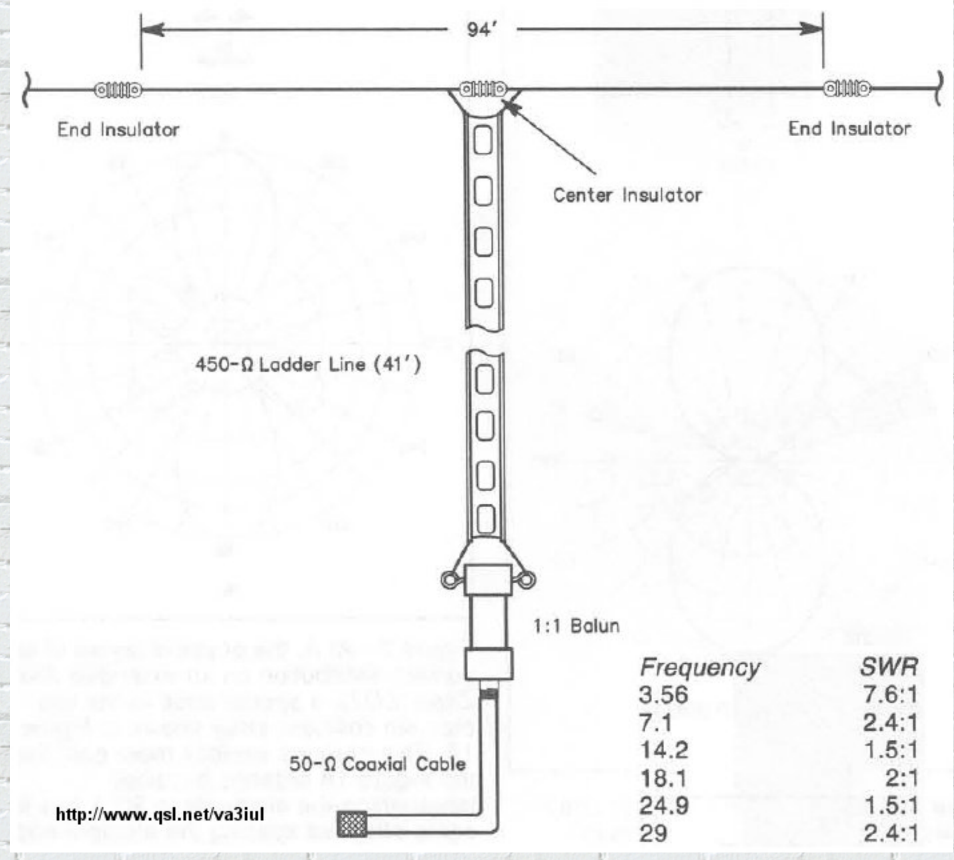
94′
End Insulator
End Insulator
Center Insulator
450-Ω Ladder Line (41′)
1:1 Balun
50-Ω Coaxial Cable
http://www.qsl.net/va3iul

Frequency	*SWR*
3.56	7.6:1
7.1	2.4:1
14.2	1.5:1
18.1	2:1
24.9	1.5:1
29	2.4:1

---

58 - Dualband Full-wave Loop Antenna for 80m-40m

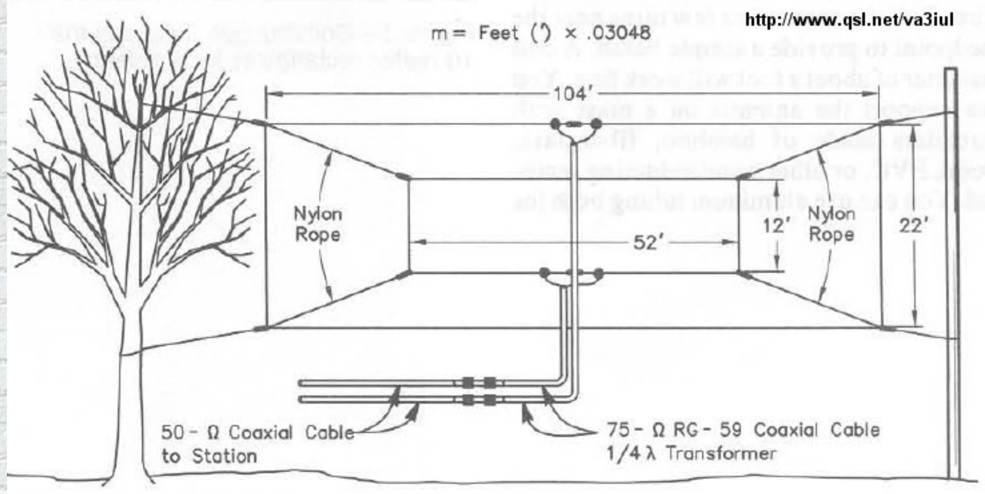
http://www.qsl.net/va3iul
m = Feet (′) × .03048
104′
Nylon Rope
52′
12′
Nylon Rope
22′
50 - Ω Coaxial Cable to Station
75 - Ω RG - 59 Coaxial Cable 1/4 λ Transformer

---

59 - Loop Antenna for 10m

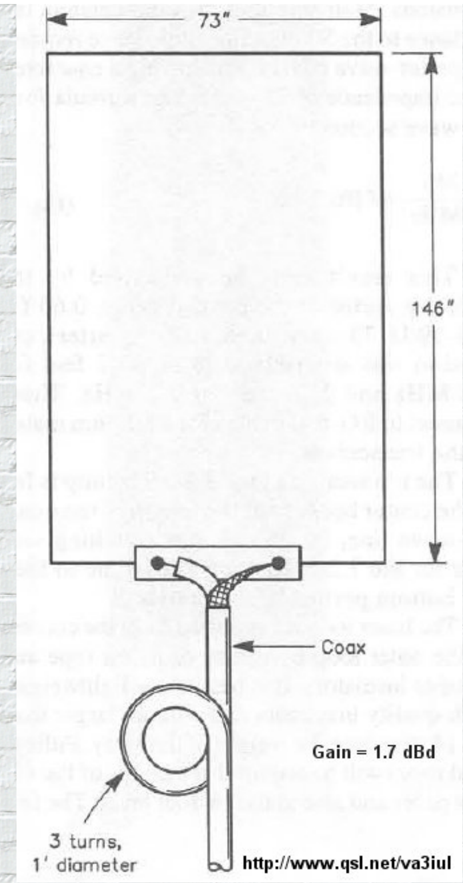
73"
146"
Coax
Gain = 1.7 dBd
3 turns,
1' diameter
http://www.qsl.net/va3iul

---

60 - Lazy Quad Antenna for 10m

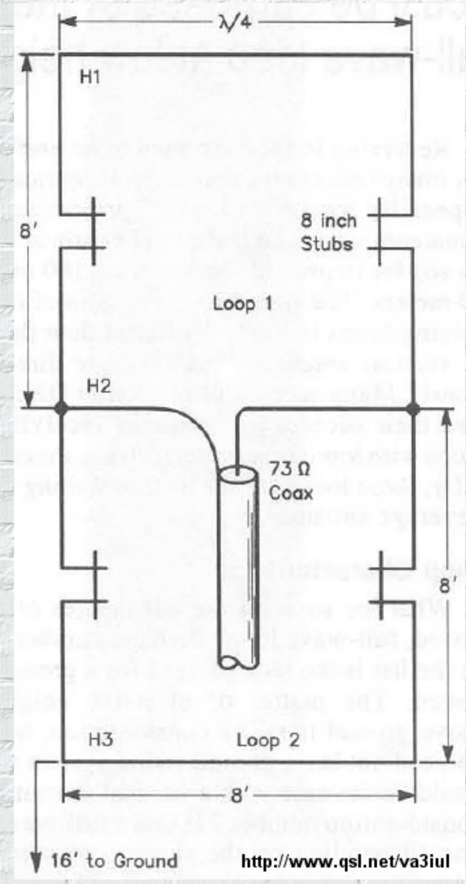
λ/4
H1
8'
8 inch
Stubs
Loop 1
H2
73 Ω
Coax
8'
H3
Loop 2
8'
16' to Ground
http://www.qsl.net/va3iul

61 - Tri-band Delta Loop Antenna for 80m - 40m - 30m

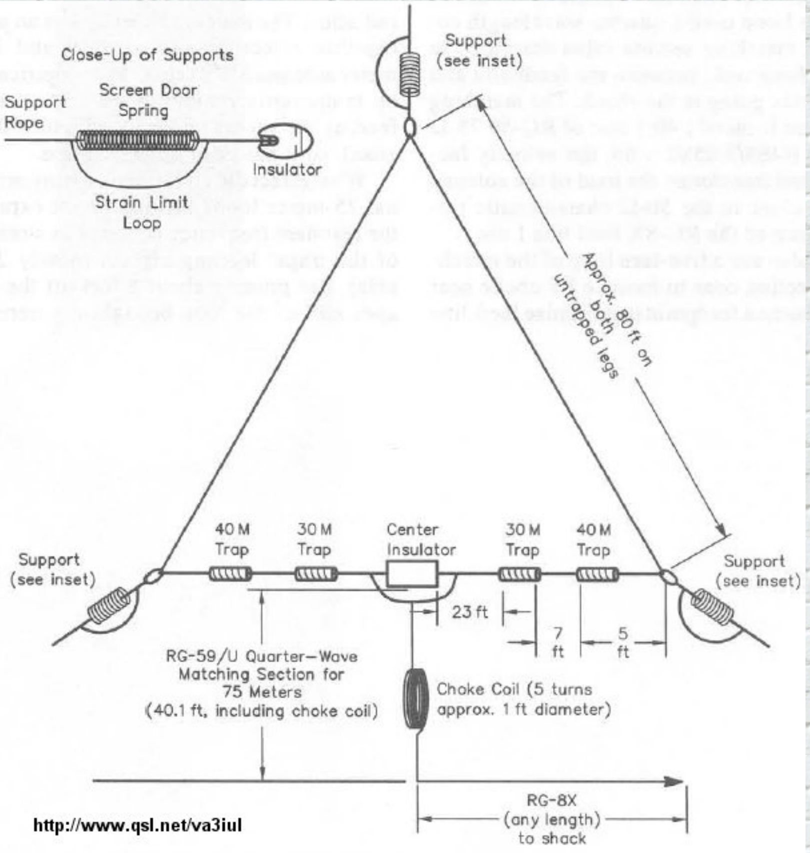
Close-Up of Supports
Support Rope
Screen Door Spring
Insulator
Strain Limit Loop
Support (see inset)
Approx. 80 ft on both untrapped legs
40 M Trap
30 M Trap
Center Insulator
30 M Trap
40 M Trap
Support (see inset)
Support (see inset)
23 ft
7 ft
5 ft
RG-59/U Quarter-Wave Matching Section for 75 Meters (40.1 ft, including choke coil)
Choke Coil (5 turns approx. 1 ft diameter)
RG-8X (any length) to shack
http://www.qsl.net/va3iul

---

62 - Dual-band Loop Antenna for 30m - 40m

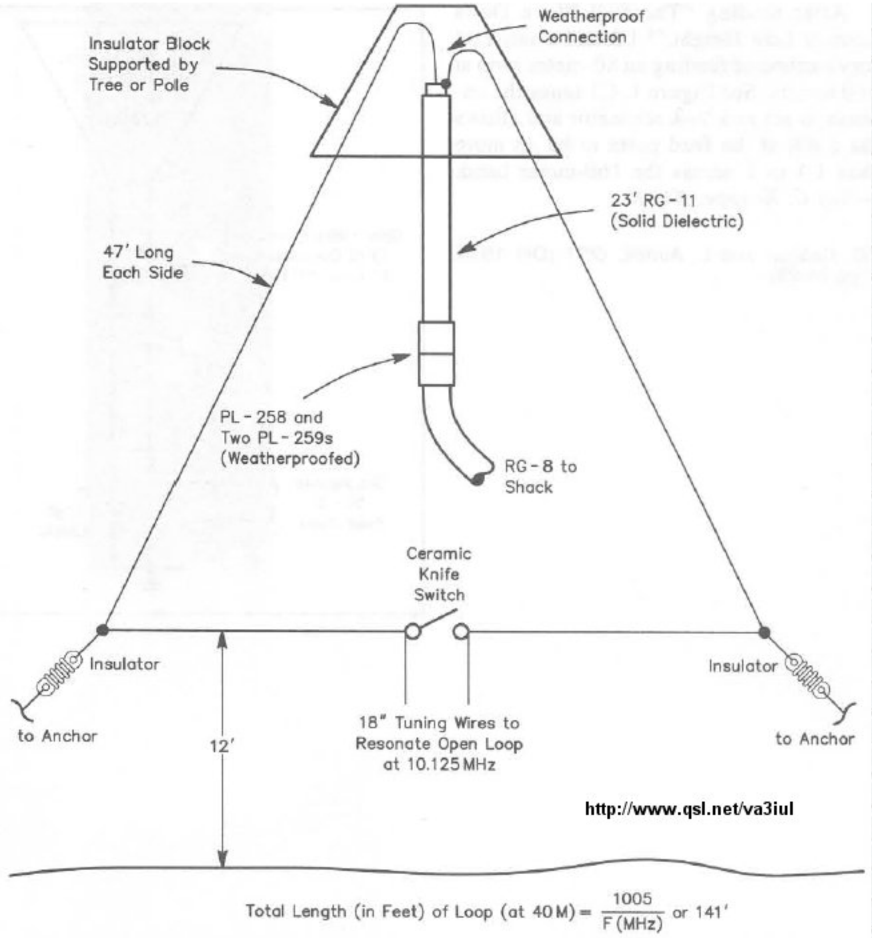
Insulator Block
Supported by
Tree or Pole
Weatherproof
Connection
23′ RG-11
(Solid Dielectric)
47′ Long
Each Side
PL-258 and
Two PL-259s
(Weatherproofed)
RG-8 to
Shack
Ceramic
Knife
Switch
Insulator
Insulator
to Anchor
to Anchor
12′
18″ Tuning Wires to
Resonate Open Loop
at 10.125 MHz
http://www.qsl.net/va3iul
Total Length (in Feet) of Loop (at 40 M) = 1005 / F (MHz) or 141′

63 - Wire-Beam Antenna for 80m

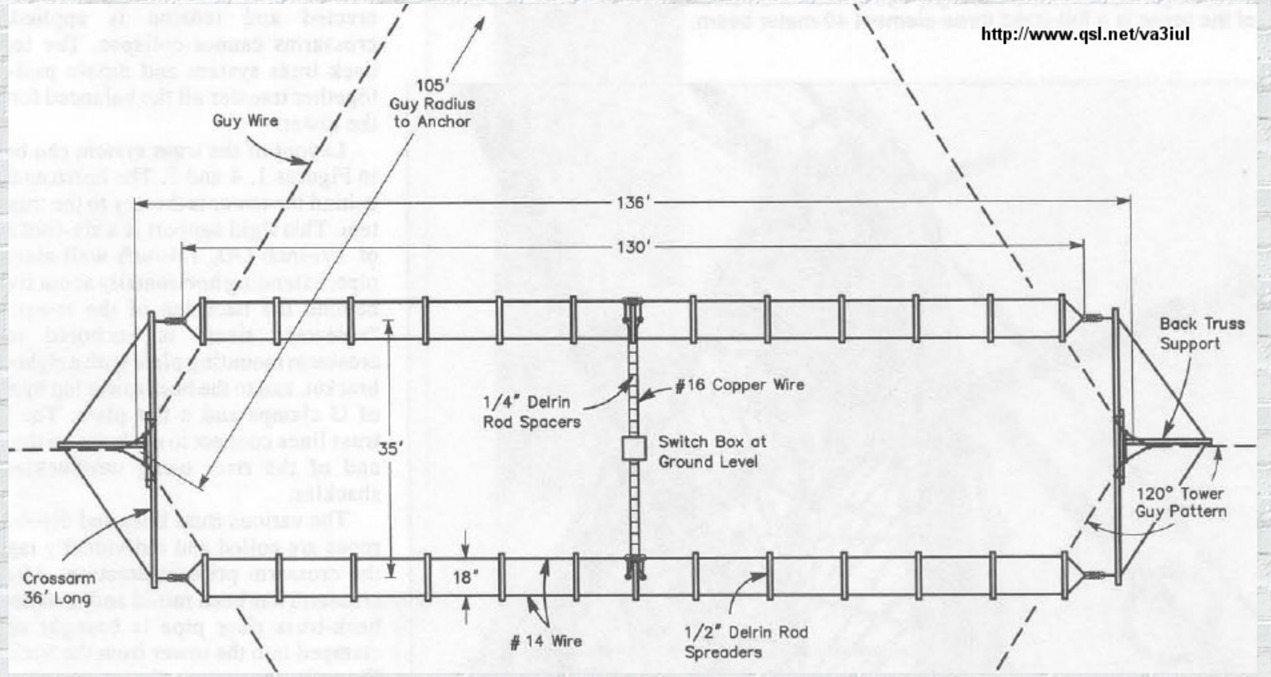
http://www.qsl.net/va3iul
105′
Guy Radius
to Anchor
Guy Wire
136′
130′
Back Truss
Support
#16 Copper Wire
1/4″ Delrin
Rod Spacers
Switch Box at
Ground Level
35′
120° Tower
Guy Pattern
Crossarm
36′ Long
18″
# 14 Wire
1/2″ Delrin Rod
Spreaders

64 - Dual-Band Sloper Antenna

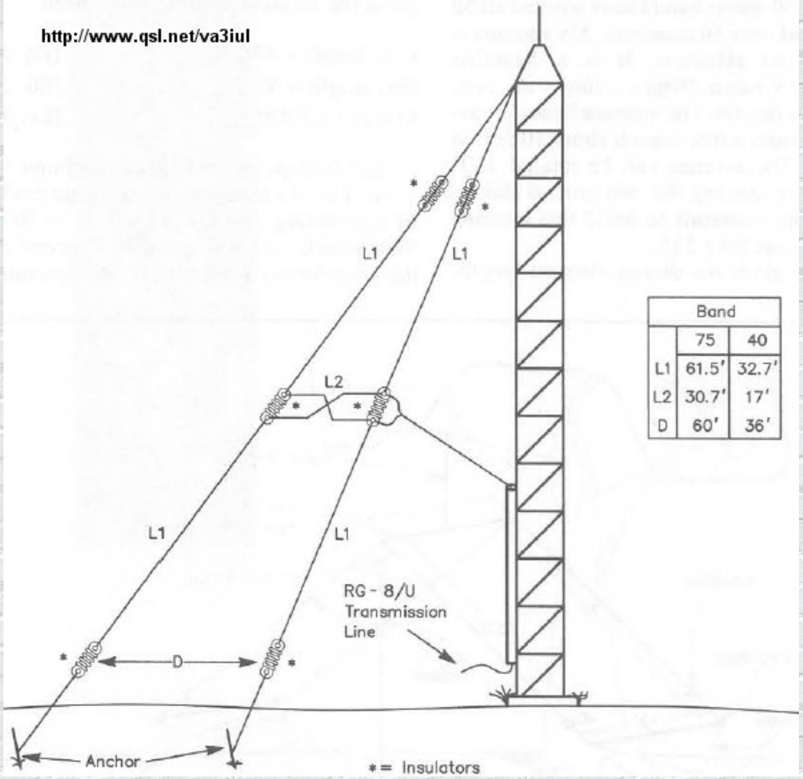
http://www.qsl.net/va3iul
L1
L1
L2
L1
L1
RG - 8/U
Transmission
Line
D
Anchor
* = Insulators

	Band	
	75	40
L1	61.5′	32.7′
L2	30.7′	17′
D	60′	36′

65 - Inverted-V Beam Antenna for 30m

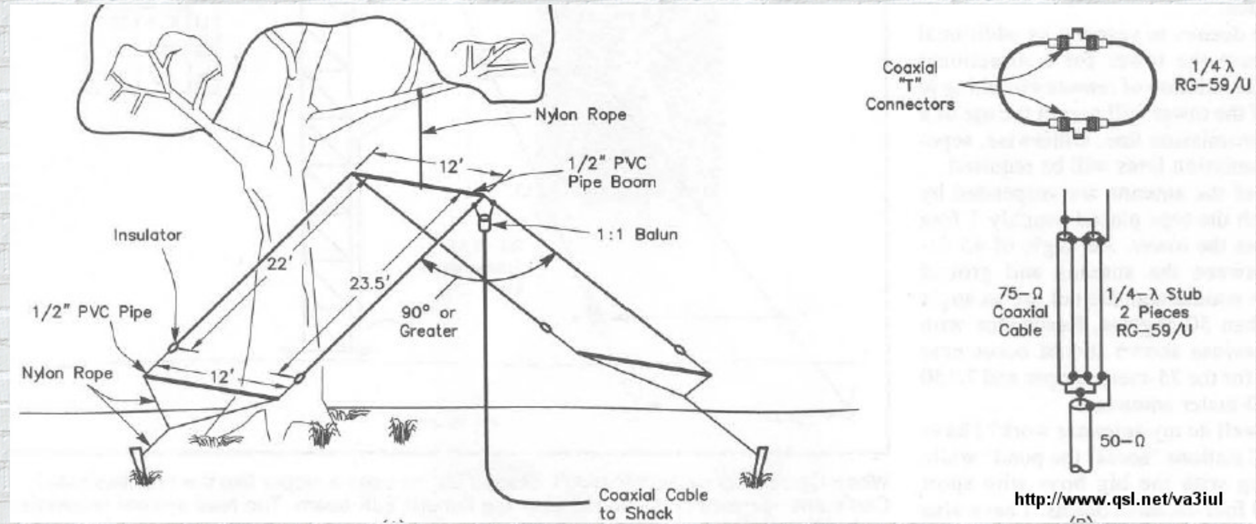
Nylon Rope
12′
1/2″ PVC
Pipe Boom
1:1 Balun
Insulator
22′
23.5′
90° or
Greater
1/2″ PVC Pipe
Nylon Rope
12′
Coaxial Cable
to Shack
Coaxial
"T"
Connectors
1/4 λ
RG-59/U
75-Ω
Coaxial
Cable
1/4-λ Stub
2 Pieces
RG-59/U
50-Ω
http://www.qsl.net/va3iul

66 - ZL-Special Beam Antenna for 15m

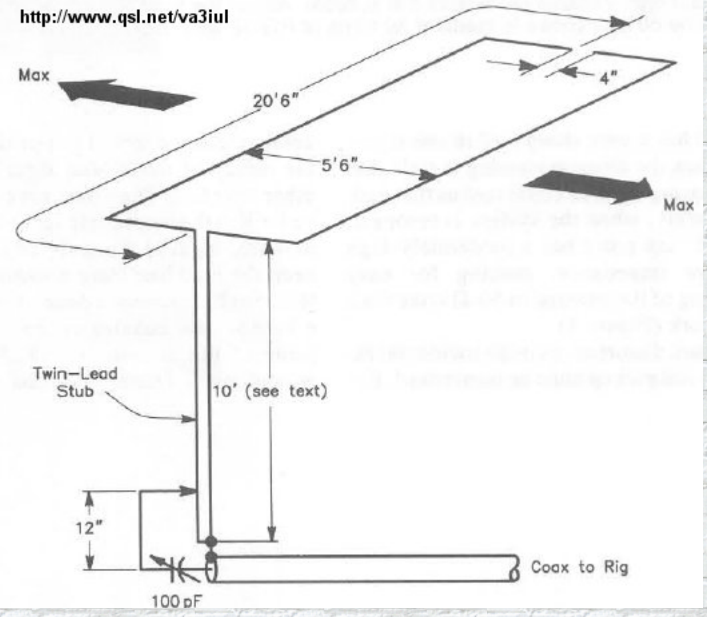
http://www.qsl.net/va3iul
Max
20'6"
4"
5'6"
Max
Twin-Lead Stub
10' (see text)
12"
100 pF
Coax to Rig

---

67 - Half-Sloper Antenna for 160m

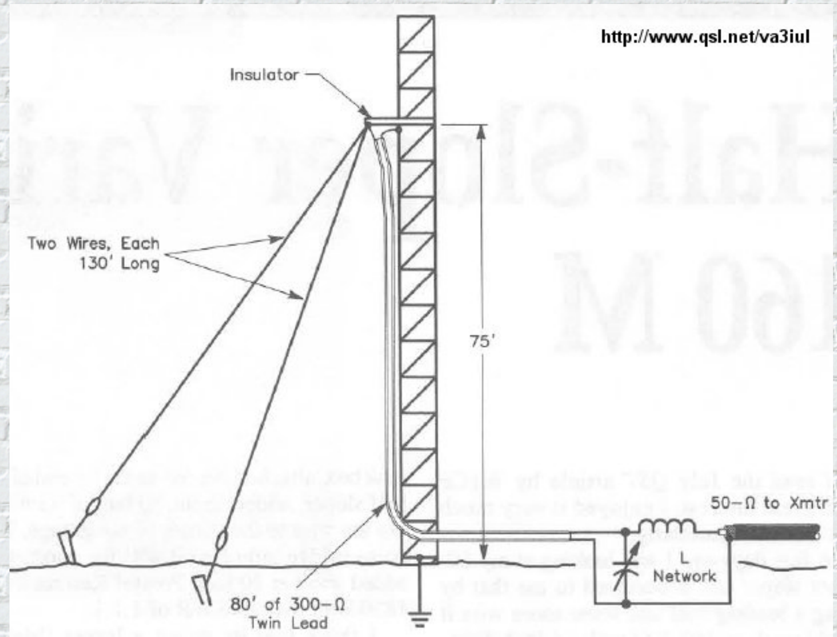
http://www.qsl.net/va3iul
Insulator
Two Wires, Each 130' Long
75'
50-Ω to Xmtr
L Network
80' of 300-Ω Twin Lead

---

68 - Two-Bands Half Sloper for 80m - 40m

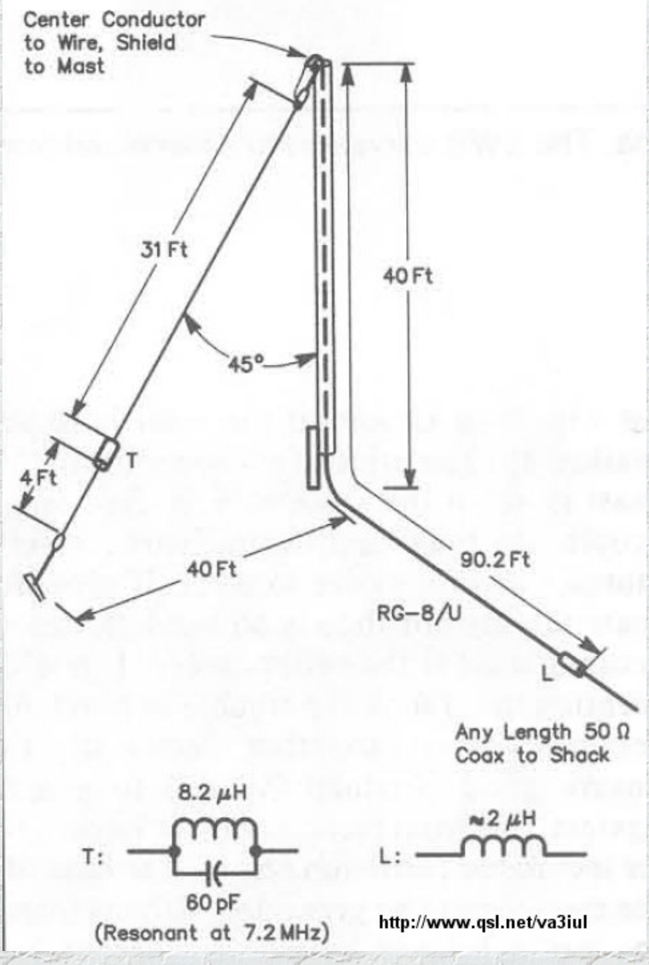
Center Conductor to Wire, Shield to Mast
31 Ft
40 Ft
45°
T
4 Ft
40 Ft
90.2 Ft
RG–8/U
L
Any Length 50 Ω Coax to Shack
8.2 µH
T:
60 pF
(Resonant at 7.2 MHz)
≈2 µH
L:
http://www.qsl.net/va3iul

69 - Linear Loaded Sloper Antenna for 160m

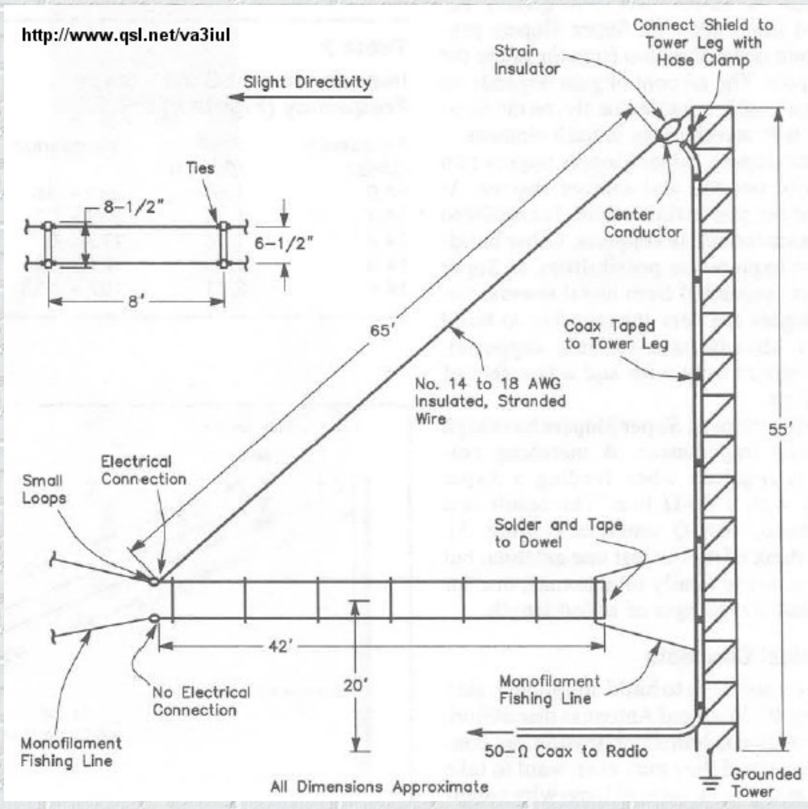
http://www.qsl.net/va3iul
Slight Directivity
Strain Insulator
Connect Shield to Tower Leg with Hose Clamp
Ties
8–1/2"
6–1/2"
8'
Center Conductor
65'
Coax Taped to Tower Leg
No. 14 to 18 AWG Insulated, Stranded Wire
55'
Small Loops
Electrical Connection
Solder and Tape to Dowel
42'
20'
No Electrical Connection
Monofilament Fishing Line
Monofilament Fishing Line
50–Ω Coax to Radio
Grounded Tower
All Dimensions Approximate

70 - Super-Sloper Antenna

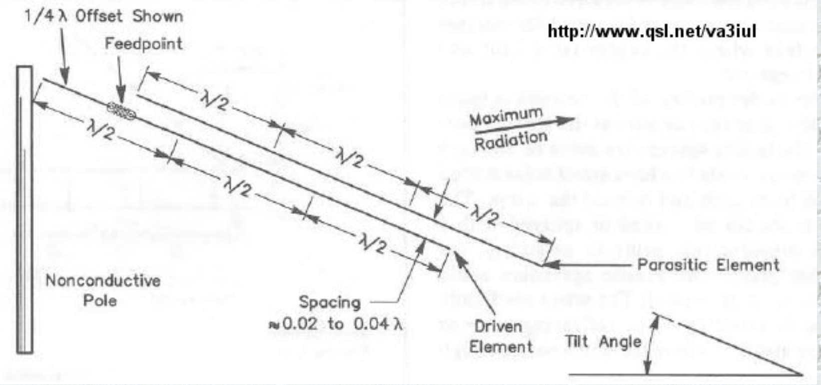
1/4 λ Offset Shown
Feedpoint
http://www.qsl.net/va3iul
λ/2
λ/2
λ/2
λ/2
λ/2
λ/2
λ/2
Maximum Radiation
Parasitic Element
Nonconductive Pole
Spacing ≈0.02 to 0.04 λ
Driven Element
Tilt Angle

---

71 - Tower Pole as a Vertical Antenna for 80m

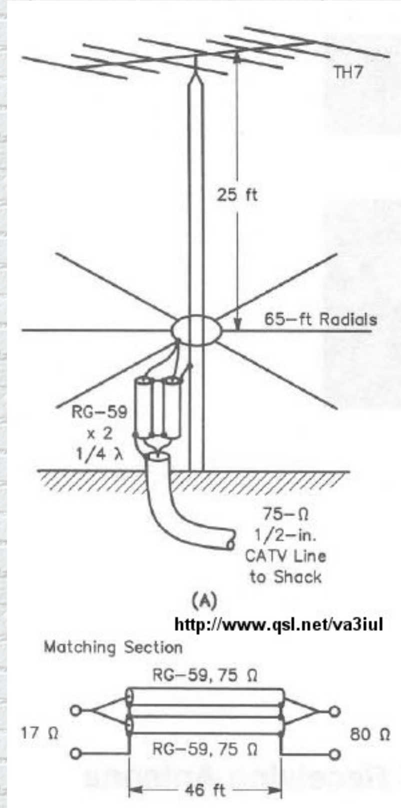
TH7
25 ft
65–ft Radials
RG–59 x 2 1/4 λ
75–Ω 1/2–in. CATV Line to Shack
(A)
http://www.qsl.net/va3iul
Matching Section
RG–59, 75 Ω
17 Ω
80 Ω
RG–59, 75 Ω
46 ft

---

72 - Clothesline Antenna

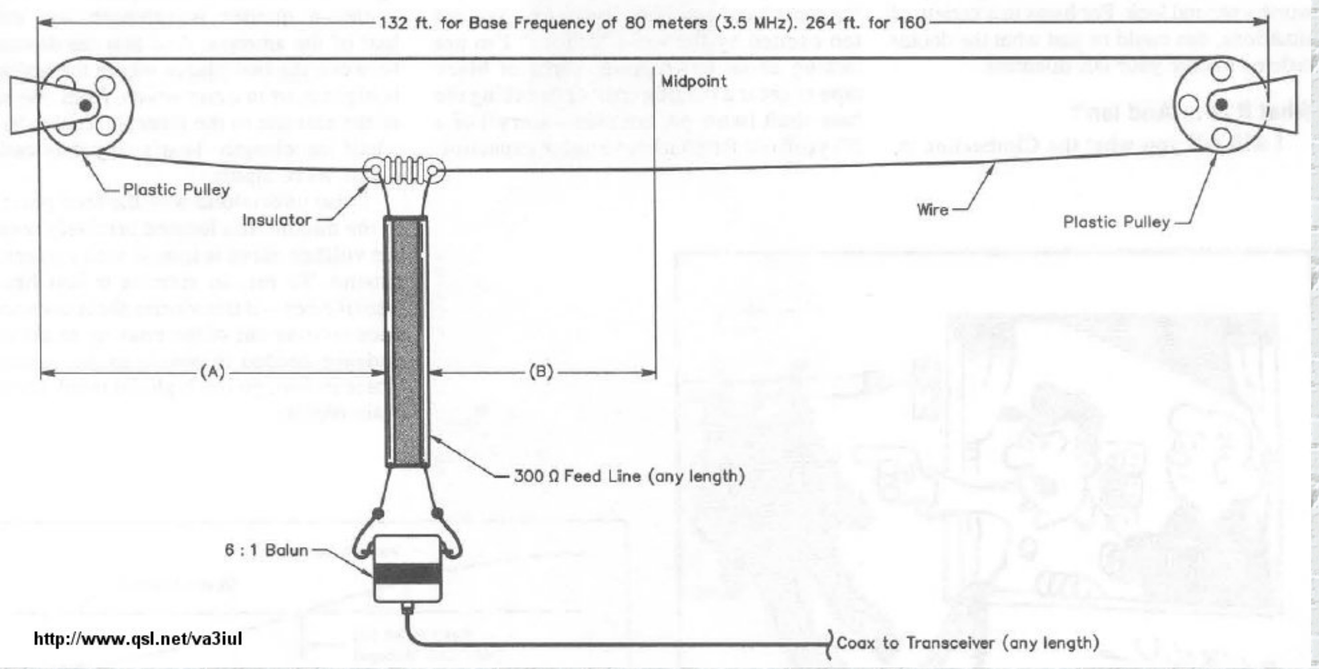
132 ft. for Base Frequency of 80 meters (3.5 MHz). 264 ft. for 160
Midpoint
Plastic Pulley
Insulator
Wire
Plastic Pulley
(A)
(B)
300 Ω Feed Line (any length)
6 : 1 Balun
Coax to Transceiver (any length)
http://www.qsl.net/va3iul

73 - Curtain Zepp Antenna for 160m, 80m, 40m

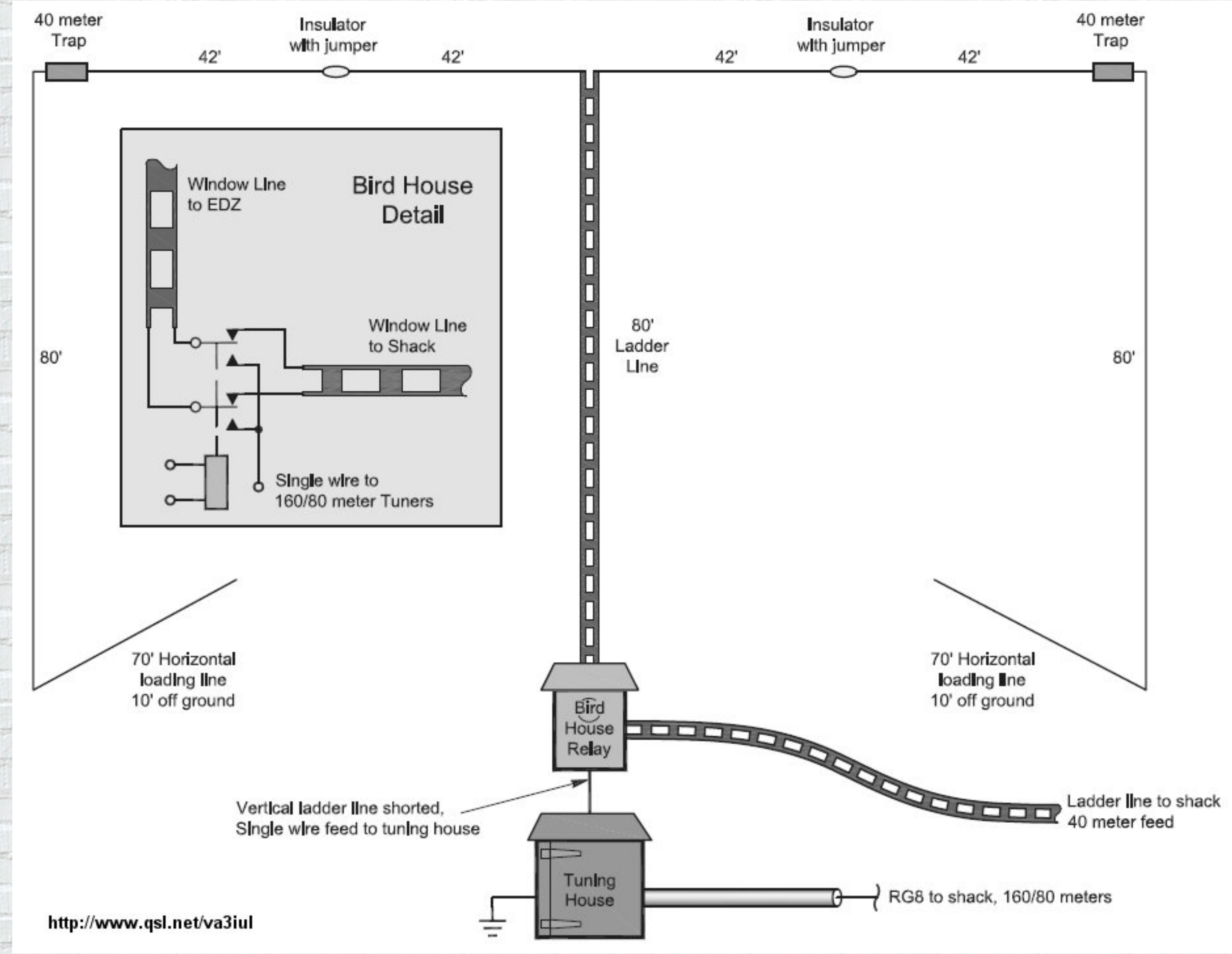
40 meter Trap
Insulator with jumper
42'
42'
42'
Insulator with jumper
42'
40 meter Trap
Window Line to EDZ
Bird House Detail
Window Line to Shack
Single wire to 160/80 meter Tuners
80'
80' Ladder Line
80'
70' Horizontal loading line 10' off ground
70' Horizontal loading line 10' off ground
Bird House Relay
Vertical ladder line shorted, Single wire feed to tuning house
Ladder line to shack 40 meter feed
Tuning House
RG8 to shack, 160/80 meters
http://www.qsl.net/va3iul

74 - Collinear Array Antenna for 40m, 30m, 20m

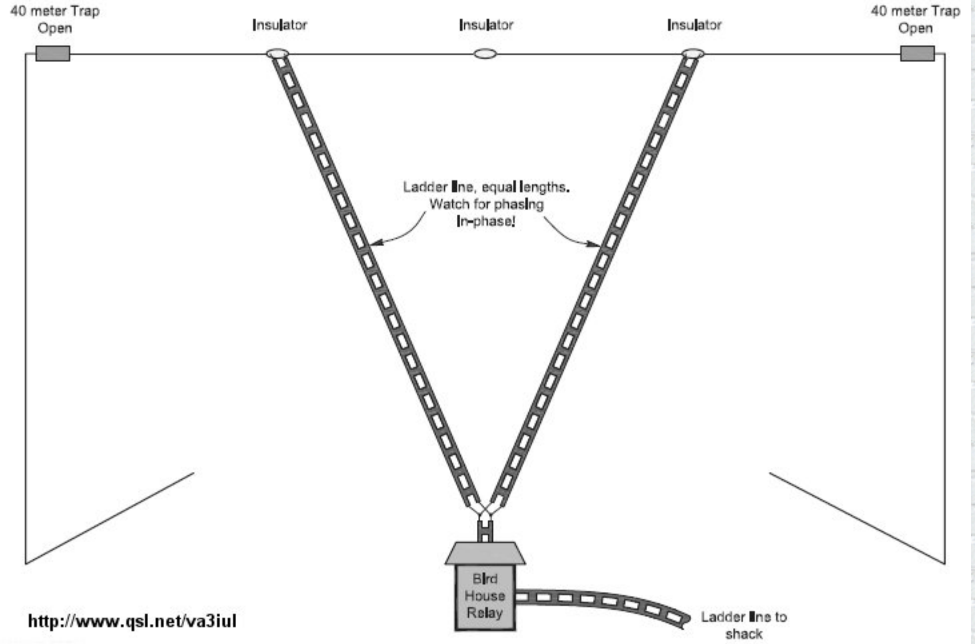
40 meter Trap
Open
Insulator
Insulator
Insulator
40 meter Trap
Open
Ladder line, equal lengths.
Watch for phasing
In-phase!
Bird
House
Relay
Ladder line to
shack
http://www.qsl.net/va3iul

---

75 - 160m Inverted Delta Loop

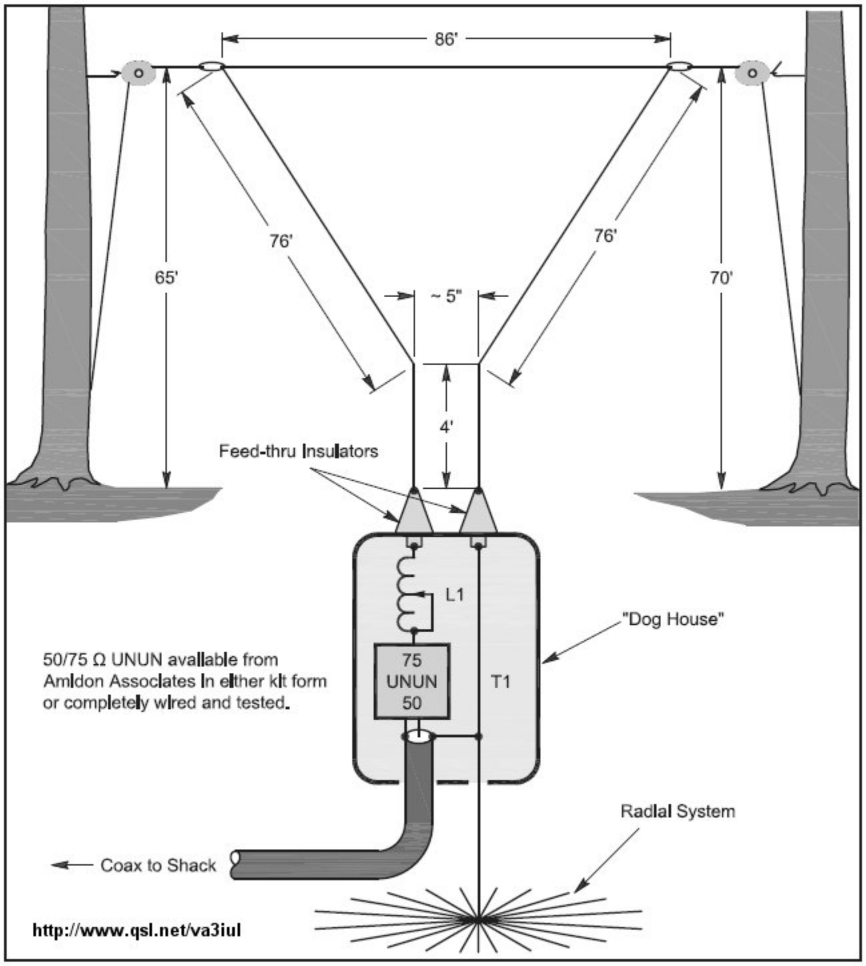
86'
76'
76'
65'
70'
~ 5"
4'
Feed-thru Insulators
L1
"Dog House"
75
UNUN
50
T1
50/75 Ω UNUN available from
Amidon Associates in either kit form
or completely wired and tested.
Radial System
Coax to Shack
http://www.qsl.net/va3iul

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76 - Half Rhombic Unidirectional Vertical for 20m to 6m

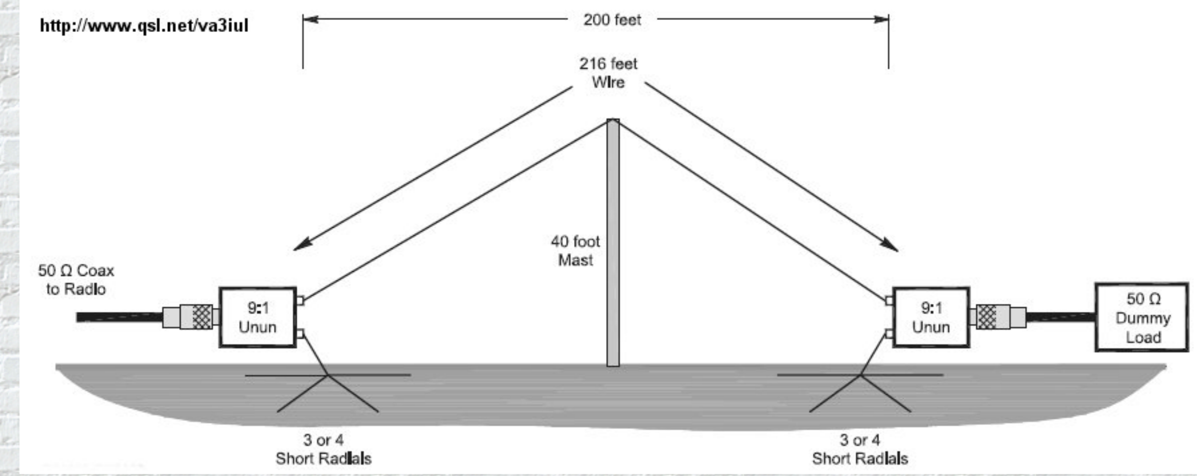
http://www.qsl.net/va3iul
200 feet
216 feet
Wire
40 foot
Mast
50 Ω Coax
to Radio
9:1
Unun
9:1
Unun
50 Ω
Dummy
Load
3 or 4
Short Radials
3 or 4
Short Radials

---

77 - Capacitance Loaded Vertical Antenna for 160m

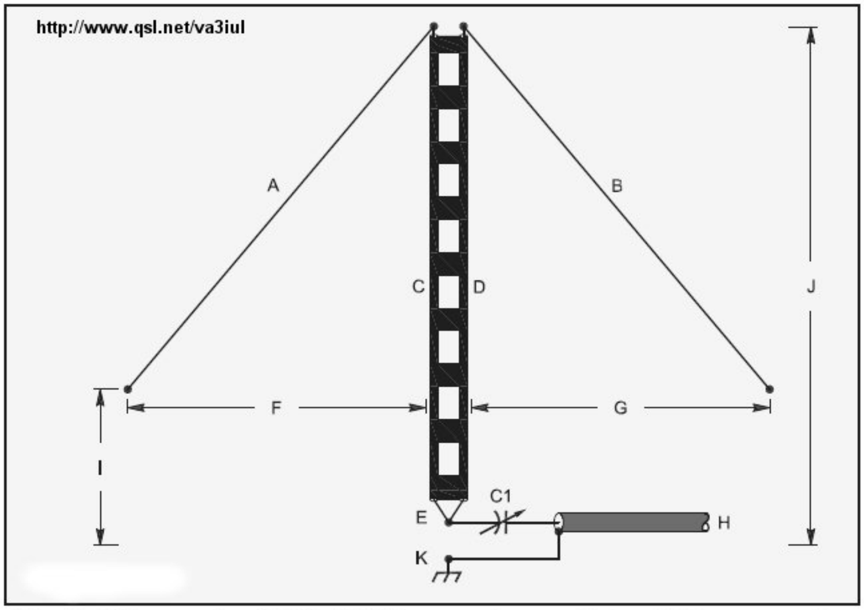
http://www.qsl.net/va3iul
A
B
C
D
J
F
G
I
C1
E
H
K

C1 — Variable capacitor, 0-1500 pF, 7 kV.

A, B — Sloping segments of 66 foot, 4 inch pieces of #16 AWG enameled copper wire soldered to the top of segments C and D and forming a 45° angle.

C, D — 59 feet of 450 Ω open wire or window line or, alternatively, two parallel lengths of #16 AWG enameled copper wire with a 1 inch separation.

E — 1 inch triangle formed by the bottom ends of the open wire line. Solder them tightly at the vertex and connect to C1.

F, G — Distance between the lower ends of segments A and B from segments C and D, 51 feet.

H — Any length of 50 Ω coaxial cable (RG-213 in this case). The central conductor must be soldered to C1, and the braid to the ground radials.

I — Approximately 16 feet from ground to lower ends of sloping segments A and B.

J — 60 feet from antenna top to bottom.

K — Ground radials, 60 ¼ λ (the more the better — 32 will form a reasonable ground).

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78 - Fan Dipole Antenna for 80m to 6m

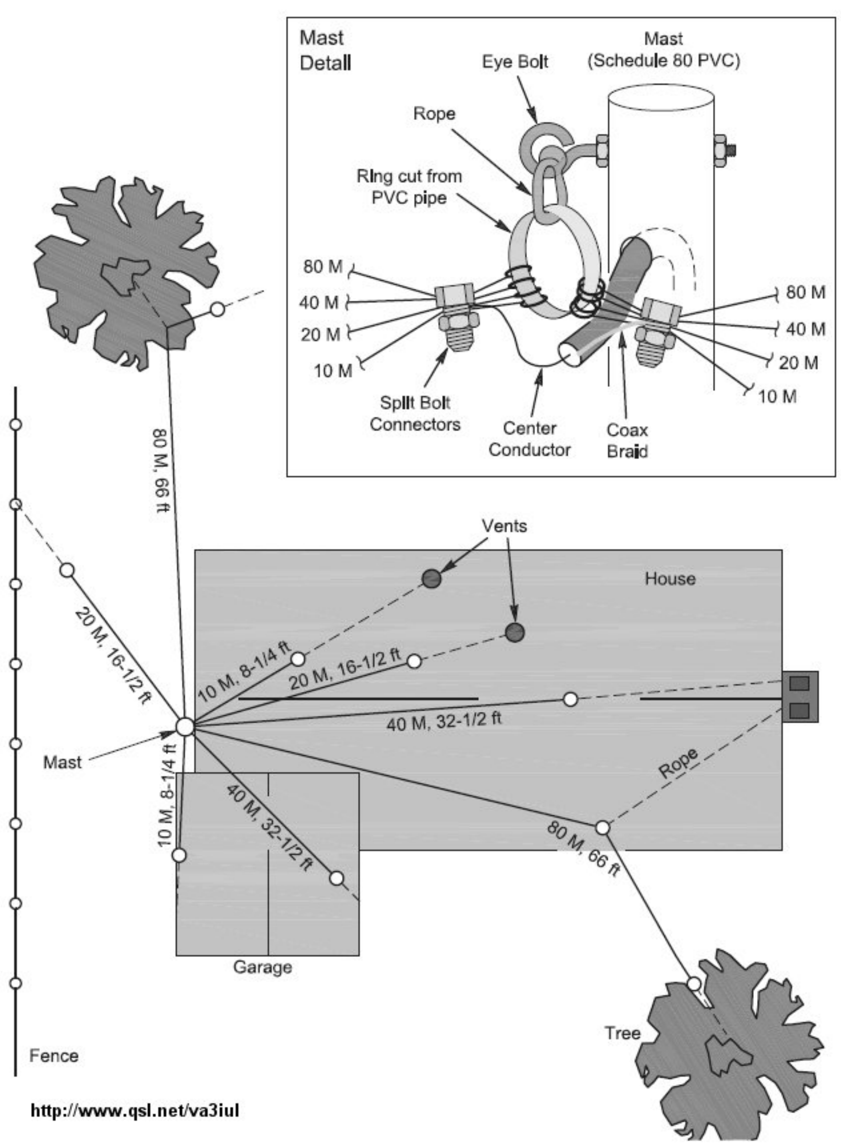
Mast
Detail
Eye Bolt
Mast
(Schedule 80 PVC)
Rope
Ring cut from
PVC pipe
80 M
40 M
20 M
10 M
80 M
40 M
20 M
10 M
Split Bolt
Connectors
Center
Conductor
Coax
Braid
80 M, 66 ft
Vents
House
20 M, 16-1/2 ft
10 M, 8-1/4 ft
20 M, 16-1/2 ft
40 M, 32-1/2 ft
Mast
Rope
10 M, 8-1/4 ft
40 M, 32-1/2 ft
80 M, 66 ft
Garage
Fence
Tree
http://www.qsl.net/va3iul

79 - Wire Ground Plane Antenna

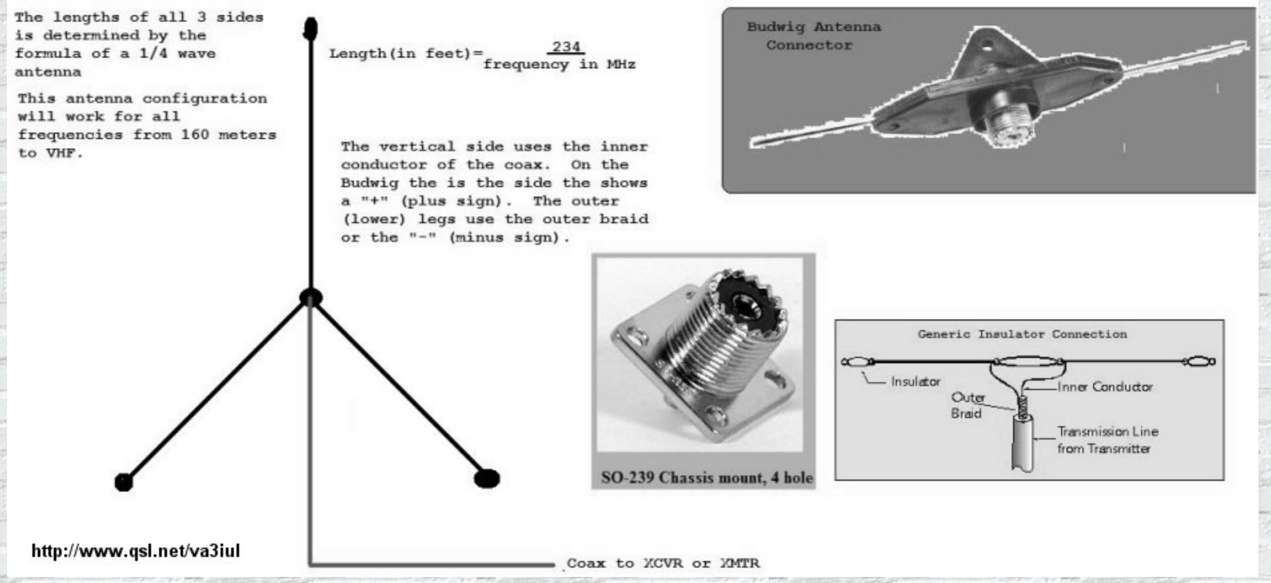

The lengths of all 3 sides is determined by the formula of a 1/4 wave antenna

This antenna configuration will work for all frequencies from 160 meters to VHF.

$$\text{Length (in feet)} = \frac{234}{\text{frequency in MHz}}$$

The vertical side uses the inner conductor of the coax. On the Budwig the is side the shows a "+" (plus sign). The outer (lower) legs use the outer braid or the "-" (minus sign).

SO-239 Chassis mount, 4 hole

Budwig Antenna
Connector
Generic Insulator Connection
Insulator
Inner Conductor
Outer
Braid
Transmission Line
from Transmitter
http://www.qsl.net/va3iul
Coax to XCVR or XMTR

80 - Inverted Delta Loop Antenna for 160m

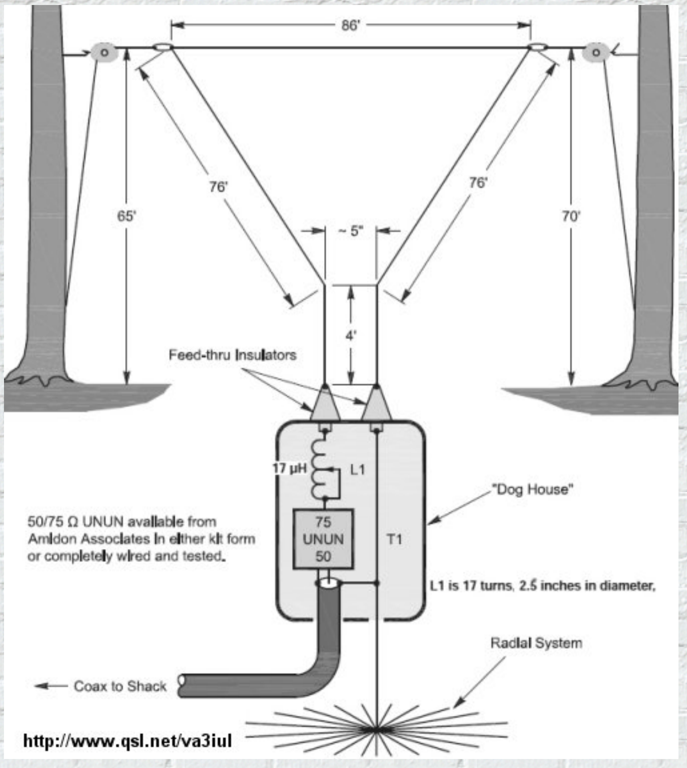
86'
76'
76'
65'
70'
~ 5"
4'
Feed-thru Insulators
17 µH
L1
"Dog House"
50/75 Ω UNUN available from Amidon Associates in either kit form or completely wired and tested.
75 UNUN 50
T1
L1 is 17 turns, 2.5 inches in diameter,
Radial System
Coax to Shack
http://www.qsl.net/va3iul

81 - Inverted-L for 160m

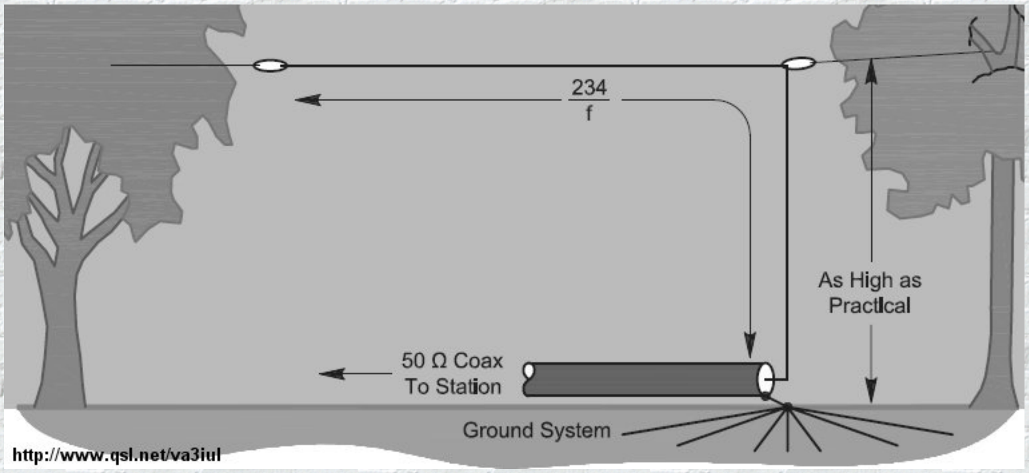
234 f
As High as Practical
50 Ω Coax To Station
Ground System
http://www.qsl.net/va3iul

82 - 300ohm-Ribbon Dual Band Dipole

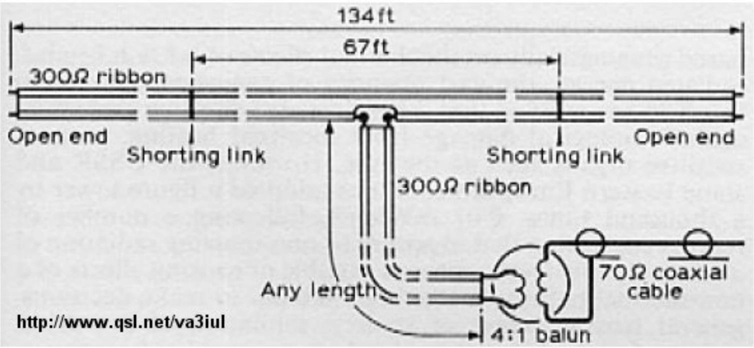
134 ft
67 ft
300Ω ribbon
Open end
Shorting link
Shorting link
Open end
300Ω ribbon
Any length
70Ω coaxial cable
4:1 balun
http://www.qsl.net/va3iul

83 - Tri-Band Beam for 20m, 15m, 10m

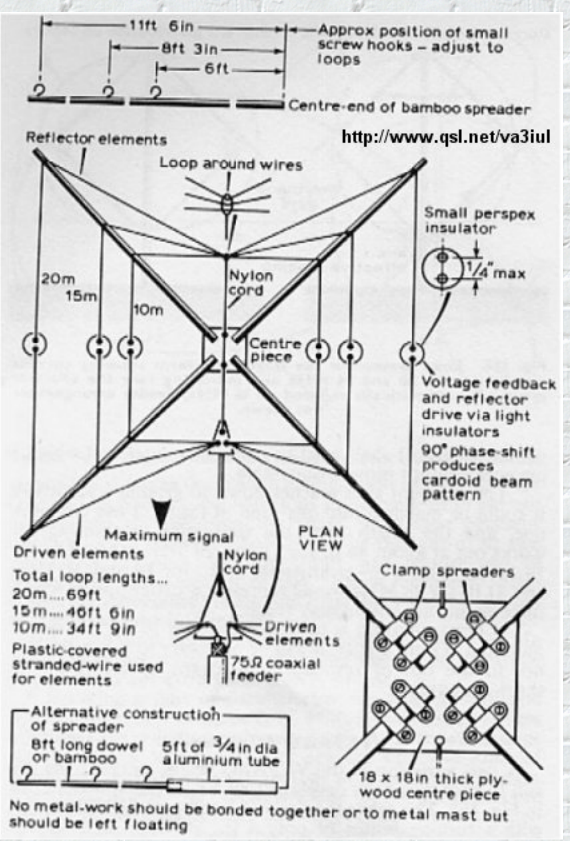
11ft 6in
8ft 3in
6ft
Approx position of small screw hooks – adjust to loops
Centre-end of bamboo spreader
http://www.qsl.net/va3iul
Reflector elements
Loop around wires
Small perspex insulator
1/4" max
20m
15m
10m
Nylon cord
Centre piece
Maximum signal
PLAN VIEW
Driven elements
Nylon cord
Driven elements
75Ω coaxial feeder
Clamp spreaders
18 x 18in thick ply-wood centre piece
Alternative construction of spreader
8ft long dowel or bamboo
5ft of 3/4in dia aluminium tube

Voltage feedback and reflector drive via light insulators

90° phase-shift produces cardoid beam pattern

Total loop lengths...
20m....69ft
15m....46ft 6in
10m....34ft 9in

Plastic-covered stranded-wire used for elements

No metal-work should be bonded together or to metal mast but should be left floating

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84 - Mini-Horse Yagi Antenna

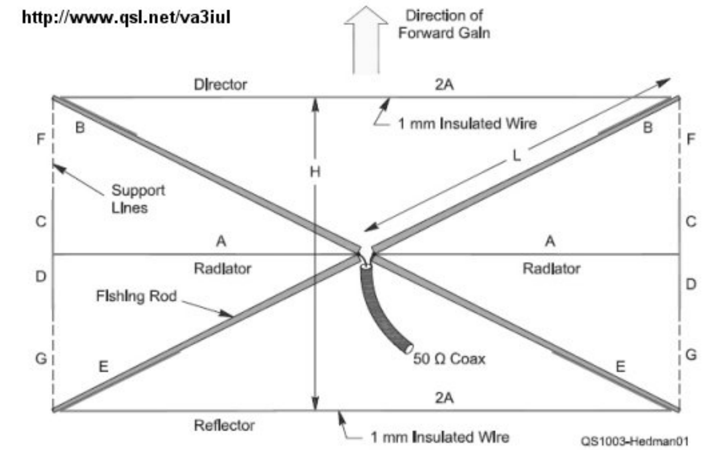
http://www.qsl.net/va3iul
Direction of Forward Gain
Director
2A
1 mm Insulated Wire
B
F
Support Lines
H
L
C
A
Radiator
A
Radiator
D
Fishing Rod
50 Ω Coax
G
E
E
2A
Reflector
1 mm Insulated Wire
QS1003-Hedman01

MHz	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*L*
144	1' 2.2"	0' 4.7"	0' 3.5"	0' 1.8"	0' 7.1"	0' 4.7"	0' 6.5"	1' 4.5"	1' 4.3"
28	5' 11.6"	1' 10.8"	1' 6.9"	0' 9.4"	2' 11.8"	1' 10.8"	2' 8.3"	6' 11.4"	6' 11.0"
21	7' 11.6"	2' 6.3"	2' 1.2"	1' 0.6"	3' 11.6"	2' 6.3"	3' 6.9"	9' 3.0"	9' 2.6"
14	11' 11.3"	3' 9.7"	3' 1.8"	1' 6.9"	5' 11.2"	3' 9.7"	5' 4.6"	13' 10.9"	13' 9.7"
7.1	23' 10.5"	7' 7.3"	6' 3.6"	3' 1.8"	11' 10.5"	7' 7.3"	10' 9.1"	27' 9.8"	27' 7.4"

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85 - Half-Rhombic Directive Antenna for 20m to 6m

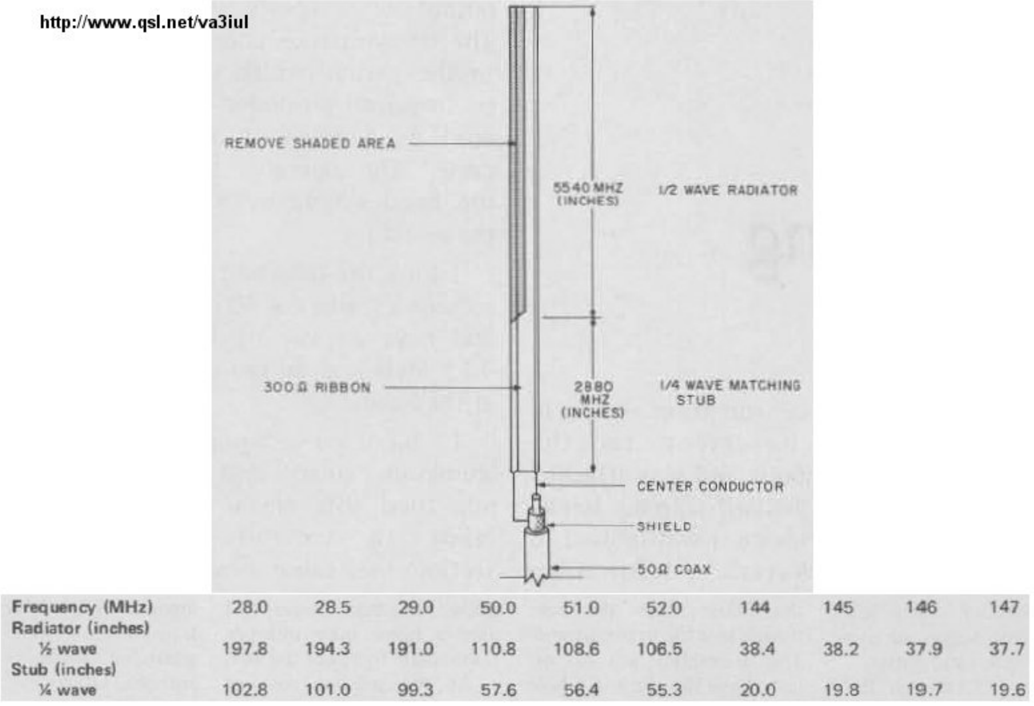
http://www.qsl.net/va3iul
REMOVE SHADED AREA
5540 MHZ (INCHES)
1/2 WAVE RADIATOR
300 Ω RIBBON
2880 MHZ (INCHES)
1/4 WAVE MATCHING STUB
CENTER CONDUCTOR
SHIELD
50Ω COAX

Frequency (MHz)	28.0	28.5	29.0	50.0	51.0	52.0	144	145	146	147
Radiator (inches) ½ wave	197.8	194.3	191.0	110.8	108.6	106.5	38.4	38.2	37.9	37.7
Stub (inches) ¼ wave	102.8	101.0	99.3	57.6	56.4	55.3	20.0	19.8	19.7	19.6

86 - Fan-Dipole Antenna for 80m, 40m, 20m

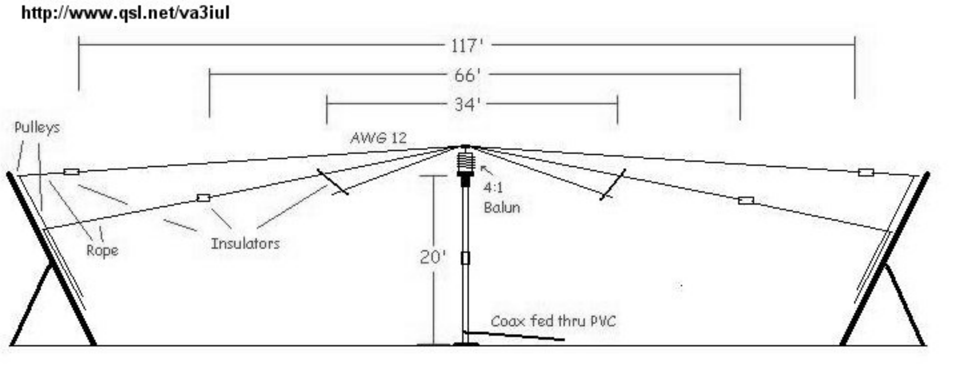
http://www.qsl.net/va3iul
117'
66'
34'
Pulleys
AWG 12
4:1
Balun
Rope
Insulators
20'
Coax fed thru PVC

87 - Capacity Tuned Folded Loop Antenna for 20m

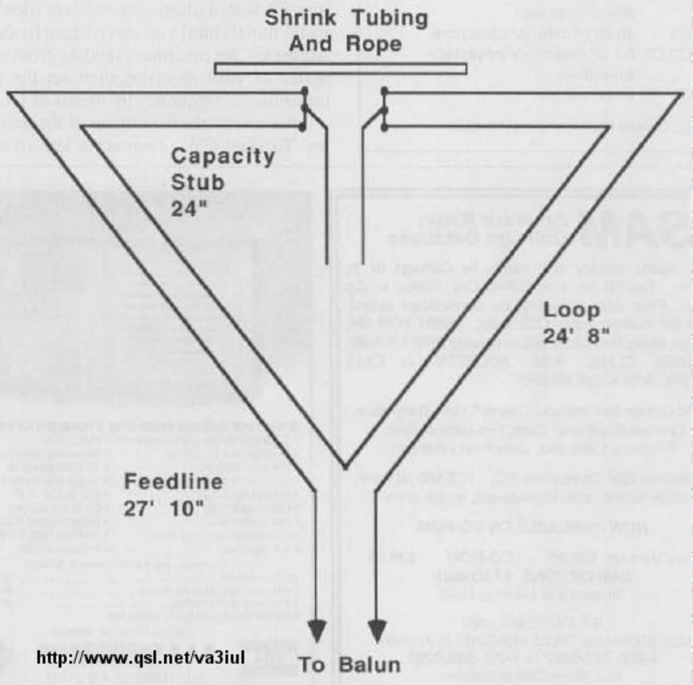
Shrink Tubing
And Rope
Capacity
Stub
24"
Loop
24' 8"
Feedline
27' 10"
http://www.qsl.net/va3iul
To Balun

88 - Indoor Loop Antenna for 80m to 30m

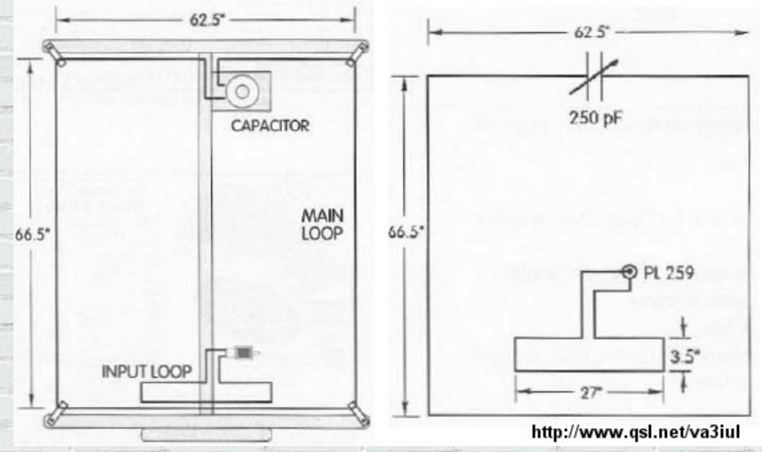
62.5"
CAPACITOR
MAIN
LOOP
66.5"
INPUT LOOP
62.5"
250 pF
66.5"
PL 259
3.5"
27"
http://www.qsl.net/va3iul

89 - Indoor Loop Antenna for 80m

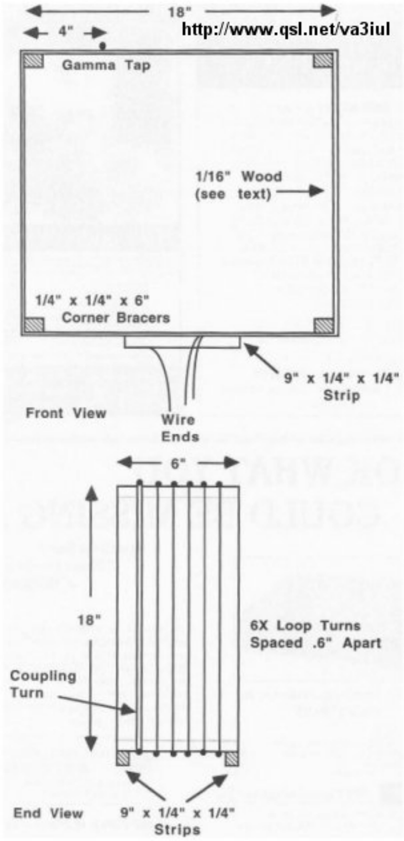
18"
4"
http://www.qsl.net/va3iul
Gamma Tap
1/16" Wood
(see text)
1/4" x 1/4" x 6"
Corner Bracers
9" x 1/4" x 1/4"
Strip
Front View
Wire
Ends
6"
18"
6X Loop Turns
Spaced .6" Apart
Coupling
Turn
End View
9" x 1/4" x 1/4"
Strips

90 - Double-Delta Antenna 80m and 40m

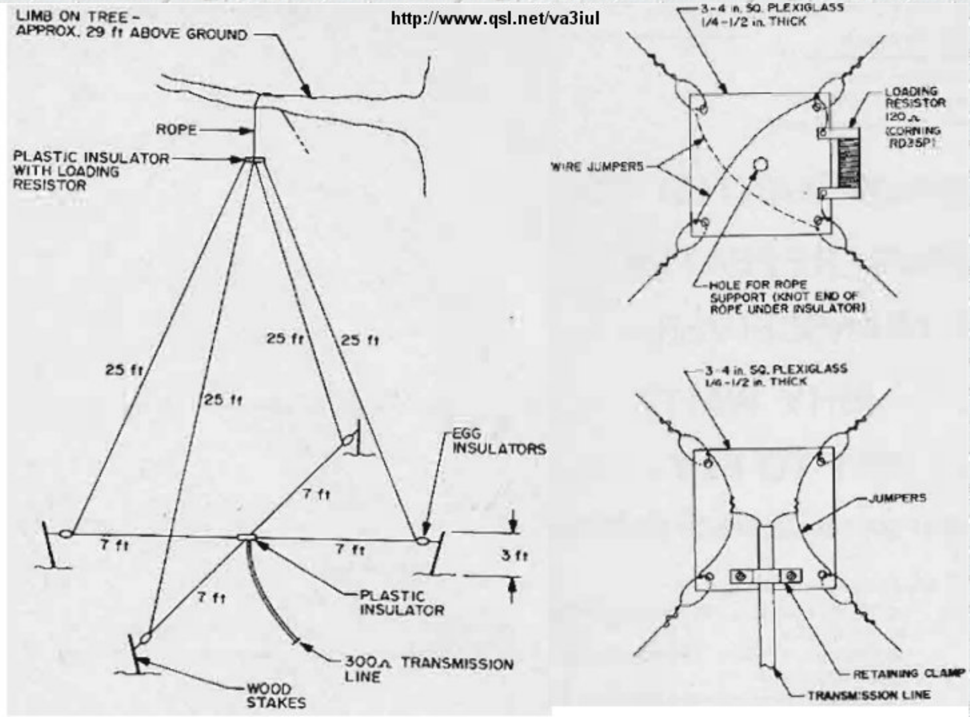
LIMB ON TREE -
APPROX. 29 ft ABOVE GROUND
http://www.qsl.net/va3iul
ROPE
PLASTIC INSULATOR
WITH LOADING
RESISTOR
25 ft
25 ft
25 ft
25 ft
EGG
INSULATORS
7 ft
7 ft
7 ft
7 ft
3 ft
PLASTIC
INSULATOR
300Ω TRANSMISSION
LINE
WOOD
STAKES
3-4 in. SQ. PLEXIGLASS
1/4-1/2 in. THICK
LOADING
RESISTOR
120 Ω
(CORNING
RD25P)
WIRE JUMPERS
HOLE FOR ROPE
SUPPORT (KNOT END OF
ROPE UNDER INSULATOR)
3-4 in. SQ. PLEXIGLASS
1/4-1/2 in. THICK
JUMPERS
RETAINING CLAMP
TRANSMISSION LINE

91 - Inductance-Loaded Shortened Dipole for 160m

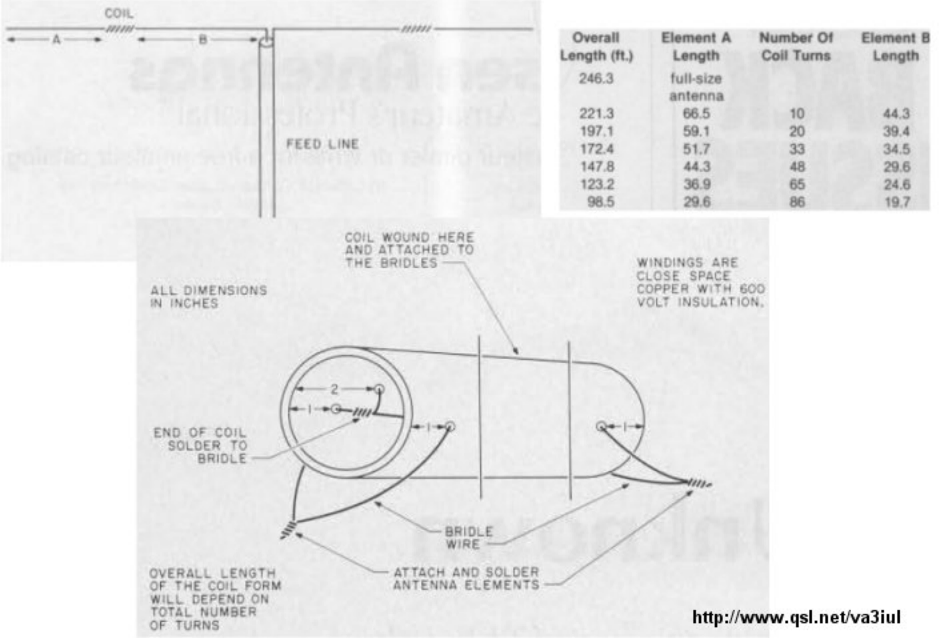

Overall Length (ft.)	Element A Length	Number Of Coil Turns	Element B Length
246.3	full-size antenna		
221.3	66.5	10	44.3
197.1	59.1	20	39.4
172.4	51.7	33	34.5
147.8	44.3	48	29.6
123.2	36.9	65	24.6
98.5	29.6	86	19.7

COIL
A
B
FEED LINE
ALL DIMENSIONS IN INCHES
COIL WOUND HERE AND ATTACHED TO THE BRIDLES
WINDINGS ARE CLOSE SPACE COPPER WITH 600 VOLT INSULATION.
2
1
1
1
END OF COIL SOLDER TO BRIDLE
BRIDLE WIRE
OVERALL LENGTH OF THE COIL FORM WILL DEPEND ON TOTAL NUMBER OF TURNS
ATTACH AND SOLDER ANTENNA ELEMENTS
http://www.qsl.net/va3iul

92 - V-Beam Antenna for 15m

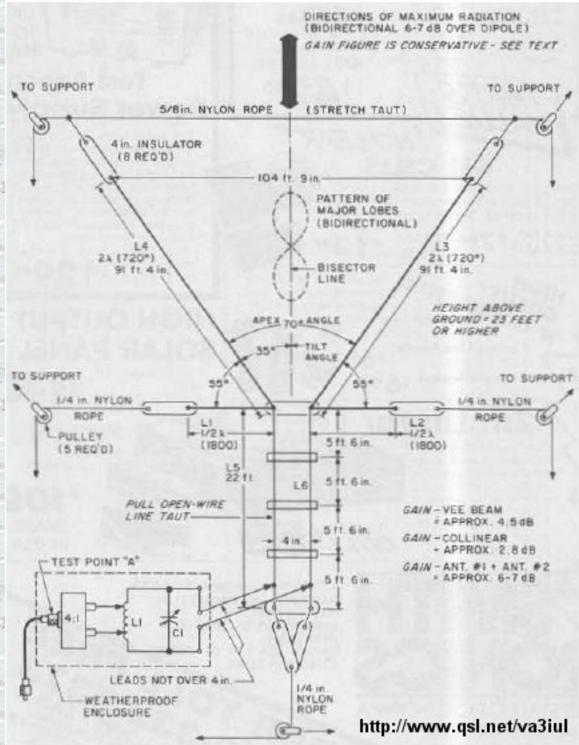

DIRECTIONS OF MAXIMUM RADIATION (BIDIRECTIONAL 6-7 dB OVER DIPOLE)
GAIN FIGURE IS CONSERVATIVE - SEE TEXT
TO SUPPORT
TO SUPPORT
5/8in. NYLON ROPE
(STRETCH TAUT)
4 in. INSULATOR (8 REQ'D)
104 ft. 9 in.
PATTERN OF MAJOR LOBES (BIDIRECTIONAL)
L4 2λ (720°) 91 ft. 4 in.
L3 2λ (720°) 91 ft. 4 in.
BISECTOR LINE
HEIGHT ABOVE GROUND = 23 FEET OR HIGHER
APEX 70° ANGLE
35° TILT ANGLE
55°
55°
TO SUPPORT
TO SUPPORT
1/4 in. NYLON ROPE
1/4 in. NYLON ROPE
PULLEY (5 REQ'D)
L1 1/2λ (180°)
L2 1/2λ (180°)
5 ft. 6 in.
L5 22 ft.
L6
5 ft. 6 in.
PULL OPEN-WIRE LINE TAUT
5 ft. 6 in.
4 in.
5 ft. 6 in.
GAIN - VEE BEAM = APPROX. 4.5dB
GAIN - COLLINEAR - APPROX. 2.8 dB
GAIN - ANT. #1 + ANT. #2 = APPROX. 6-7 dB
TEST POINT "A"
4:1
L1
C1
LEADS NOT OVER 4 in.
WEATHERPROOF ENCLOSURE
1/4 in. NYLON ROPE
http://www.qsl.net/va3iul

93 - Picnic Vertical Wire Antenna

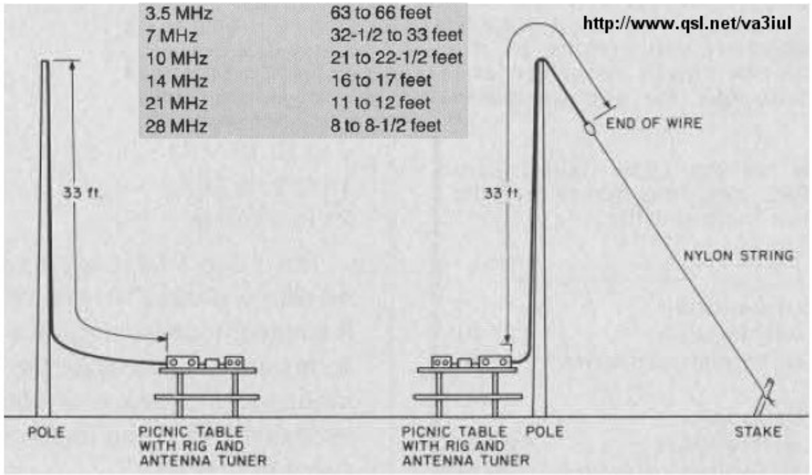

3.5 MHz	63 to 66 feet
7 MHz	32-1/2 to 33 feet
10 MHz	21 to 22-1/2 feet
14 MHz	16 to 17 feet
21 MHz	11 to 12 feet
28 MHz	8 to 8-1/2 feet

http://www.qsl.net/va3iul
33 ft.
33 ft.
END OF WIRE
NYLON STRING
POLE
PICNIC TABLE WITH RIG AND ANTENNA TUNER
PICNIC TABLE WITH RIG AND ANTENNA TUNER
POLE
STAKE

94 - Laid-Back Quad Antenna for 80m

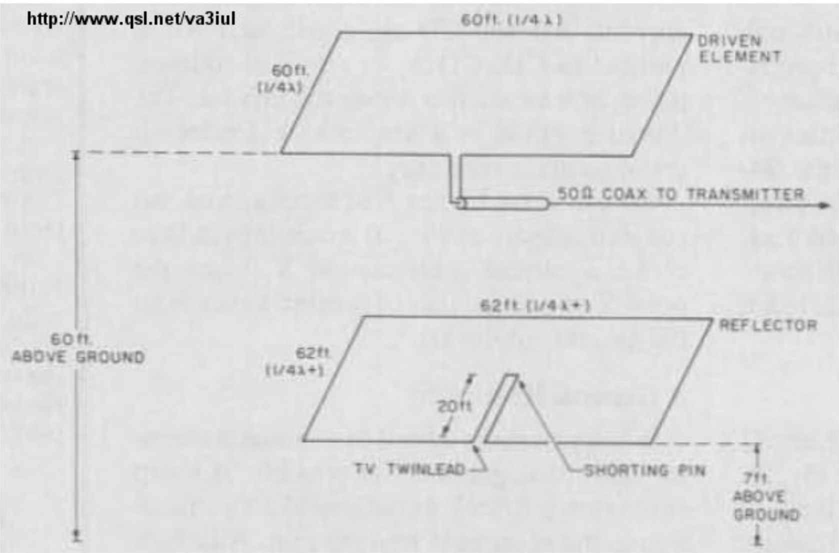
http://www.qsl.net/va3iul
60ft. (1/4 λ)
DRIVEN ELEMENT
60ft. (1/4λ)
50Ω COAX TO TRANSMITTER
60 ft. ABOVE GROUND
62ft. (1/4 λ+)
REFLECTOR
62ft. (1/4λ+)
20ft
TV TWINLEAD
SHORTING PIN
7ft. ABOVE GROUND

95 - Phased Loop Antenna

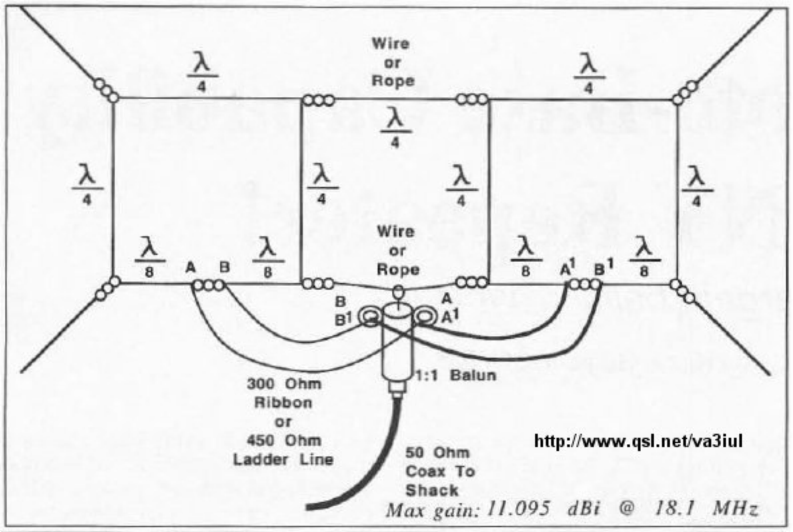
Wire or Rope
λ/4
λ/4
λ/4
λ/4
λ/4
λ/4
λ/4
Wire or Rope
λ/8
A
B
λ/8
λ/8
A1
B1
λ/8
B
B1
A
A1
1:1 Balun
300 Ohm Ribbon or 450 Ohm Ladder Line
50 Ohm Coax To Shack
http://www.qsl.net/va3iul
Max gain: 11.095 dBi @ 18.1 MHz

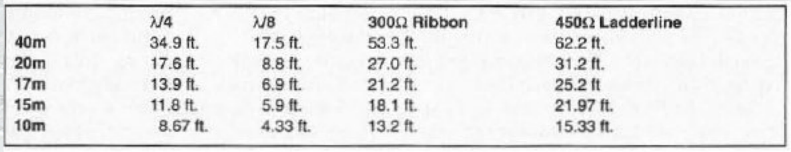

	λ/4	λ/8	300Ω Ribbon	450Ω Ladderline
40m	34.9 ft.	17.5 ft.	53.3 ft.	62.2 ft.
20m	17.6 ft.	8.8 ft.	27.0 ft.	31.2 ft.
17m	13.9 ft.	6.9 ft.	21.2 ft.	25.2 ft
15m	11.8 ft.	5.9 ft.	18.1 ft.	21.97 ft.
10m	8.67 ft.	4.33 ft.	13.2 ft.	15.33 ft.

96 - Loop Antenna for TX for 160m

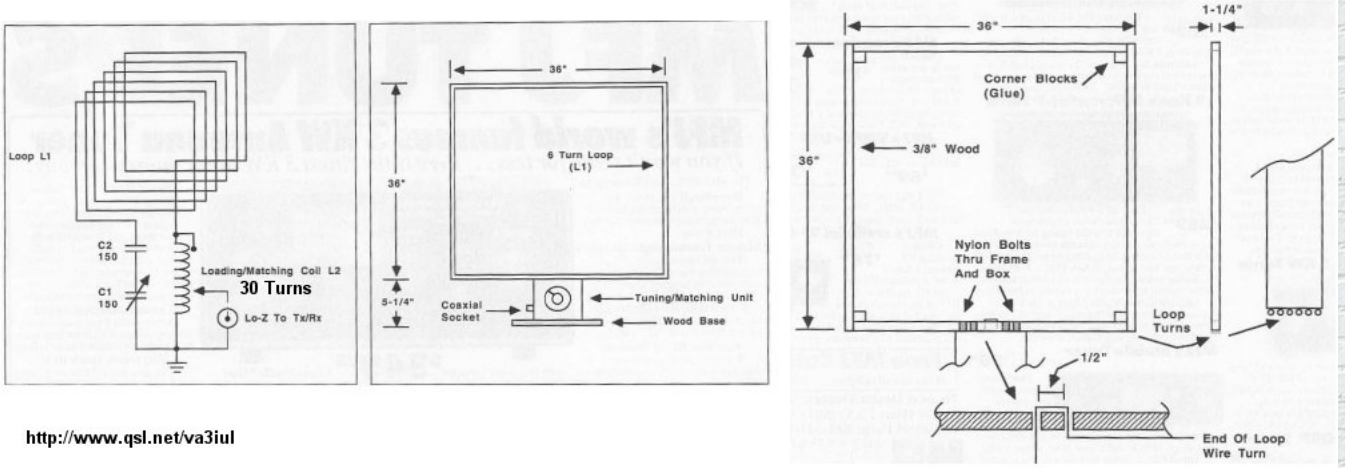
Loop L1
C2
150
C1
150
Loading/Matching Coil L2
30 Turns
Lo-Z To Tx/Rx
36"
36"
6 Turn Loop
(L1)
5-1/4"
Coaxial
Socket
Tuning/Matching Unit
Wood Base
36"
36"
1-1/4"
Corner Blocks
(Glue)
3/8" Wood
Nylon Bolts
Thru Frame
And Box
Loop
Turns
1/2"
End Of Loop
Wire Turn

http://www.qsl.net/va3iul

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97 - Morgain-Dipole Antenna for 160m and 80m

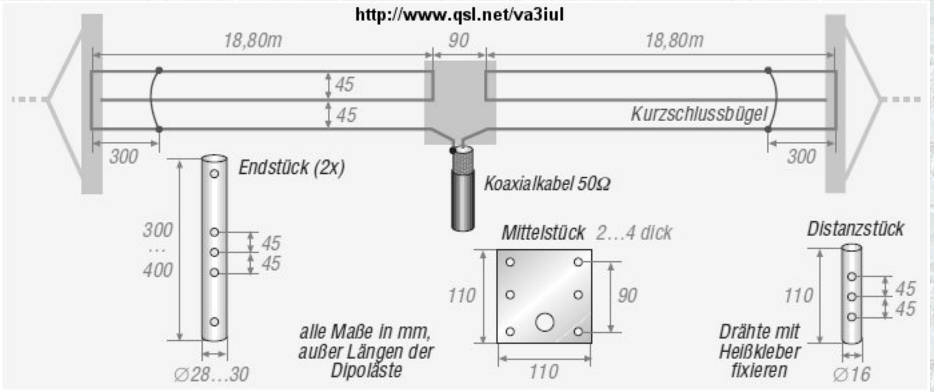
http://www.qsl.net/va3iul
18,80m
90
18,80m
45
45
Kurzschlussbügel
300
300
Endstück (2x)
Koaxialkabel 50Ω
300
...
400
45
45
Ø28…30
Mittelstück 2…4 dick
110
90
110
Distanzstück
110
45
45
Ø16
alle Maße in mm,
außer Längen der
Dipoläste
Drähte mit
Heißkleber
fixieren

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98 - ZL-Special for 20m, 15m, 10m

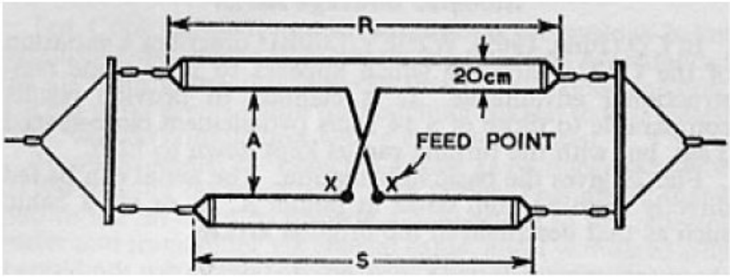
R
20cm
A
FEED POINT
X
X
S

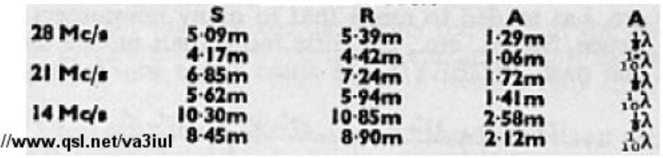

	S	R	A	A
28 Mc/s	5·09m	5·39m	1·29m	$\frac{1}{8}\lambda$
	4·17m	4·42m	1·06m	$\frac{1}{10}\lambda$
21 Mc/s	6·85m	7·24m	1·72m	$\frac{1}{8}\lambda$
	5·62m	5·94m	1·41m	$\frac{1}{10}\lambda$
14 Mc/s	10·30m	10·85m	2·58m	$\frac{1}{8}\lambda$
	8·45m	8·90m	2·12m	$\frac{1}{10}\lambda$

http://www.qsl.net/va3iul

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99 - Biconical Antenna

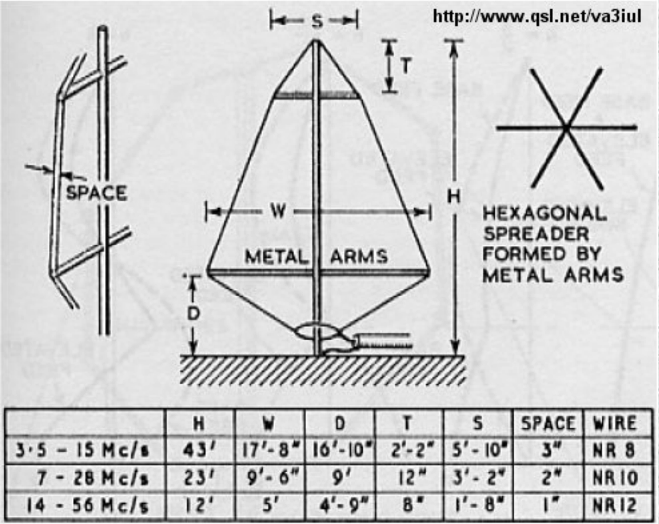
http://www.qsl.net/va3iul
S
T
SPACE
W
H
METAL ARMS
D
HEXAGONAL SPREADER FORMED BY METAL ARMS

	H	W	D	T	S	SPACE	WIRE
3·5 – 15 Mc/s	43′	17′-8″	16′-10″	2′-2″	5′-10″	3″	NR 8
7 - 28 Mc/s	23′	9′-6″	9′	12″	3′-2″	2″	NR 10
14 - 56 Mc/s	12′	5′	4′-9″	8″	1′-8″	1″	NR 12

100 - Directive Delta-Birdcage Antenna for 20m to 10m

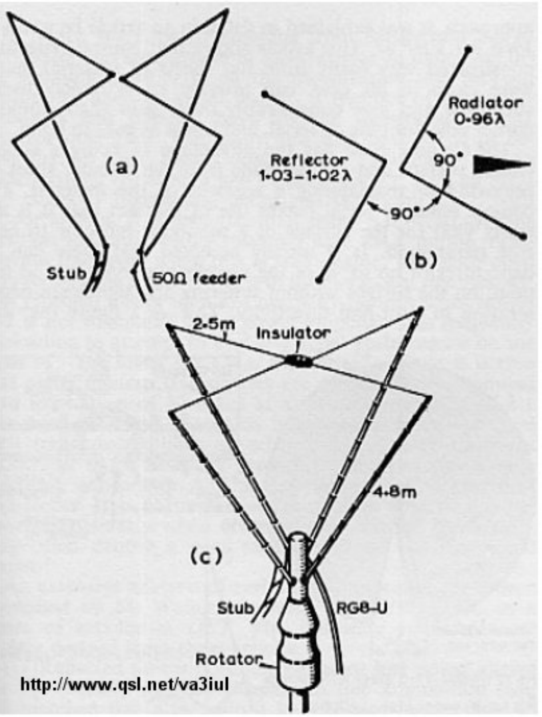
(a)
Stub
50Ω feeder
Reflector
1·03–1·02λ
Radiator
0·96λ
90°
90°
(b)
2·5m
Insulator
4·8m
(c)
Stub
RG8-U
Rotator
http://www.qsl.net/va3iul

101 - Dual Polarization Antenna for 80m and 40m

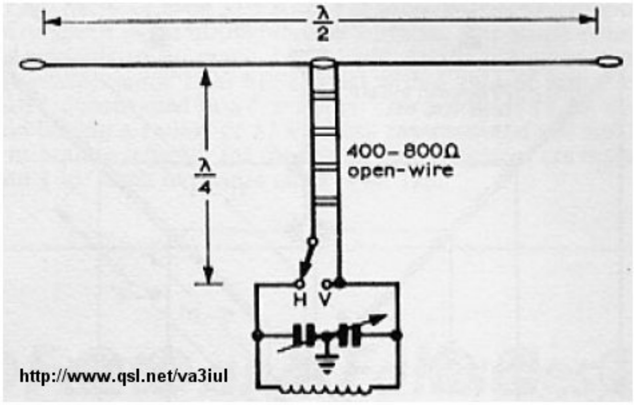
λ/2
λ/4
400–800Ω open-wire
H
V
http://www.qsl.net/va3iul

102 - Directive 300-ohm-Ribbon Folded Dipole for 15m

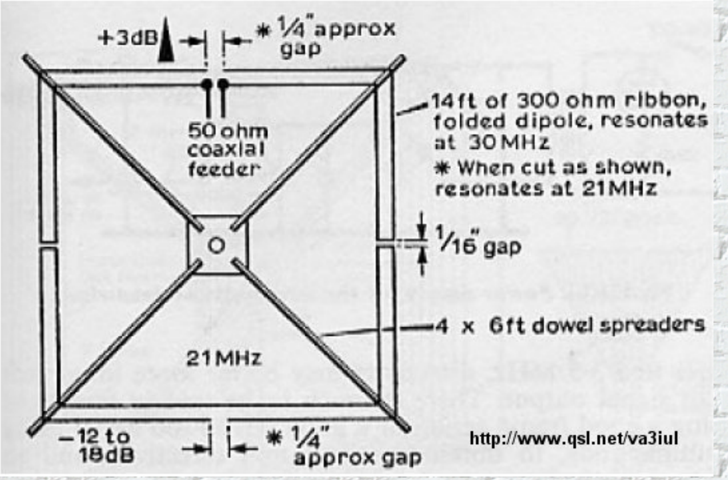
+3dB
✱ ¼" approx gap
50 ohm coaxial feeder
14 ft of 300 ohm ribbon, folded dipole, resonates at 30 MHz
✱ When cut as shown, resonates at 21 MHz
1/16" gap
4 x 6ft dowel spreaders
21 MHz
−12 to 18dB
✱ ¼" approx gap
http://www.qsl.net/va3iul

103 - Miniature Directive Antenna for 10m

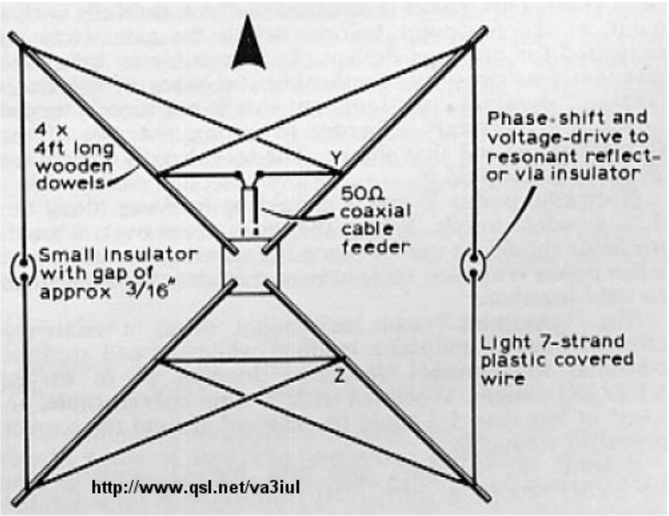
4 x 4ft long wooden dowels
Y
50Ω coaxial cable feeder
Phase-shift and voltage-drive to resonant reflector via insulator
Small insulator with gap of approx 3/16"
Light 7-strand plastic covered wire
Z
http://www.qsl.net/va3iul

104 - Biquad Antenna 12dBi-Gain for 2.4GHz

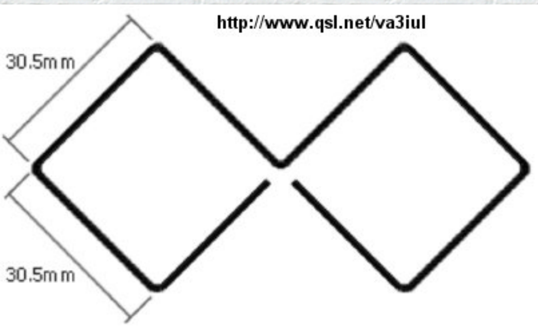
http://www.qsl.net/va3iul
30.5mm
30.5mm

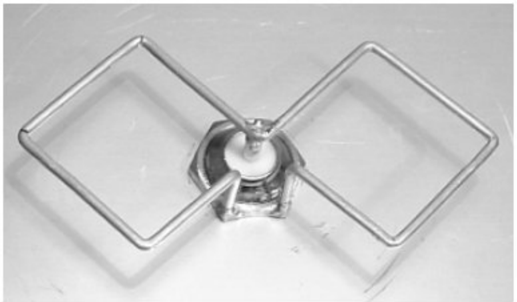

105 - Dual-Rhomboid Antenna for 435MHz to 870MHz

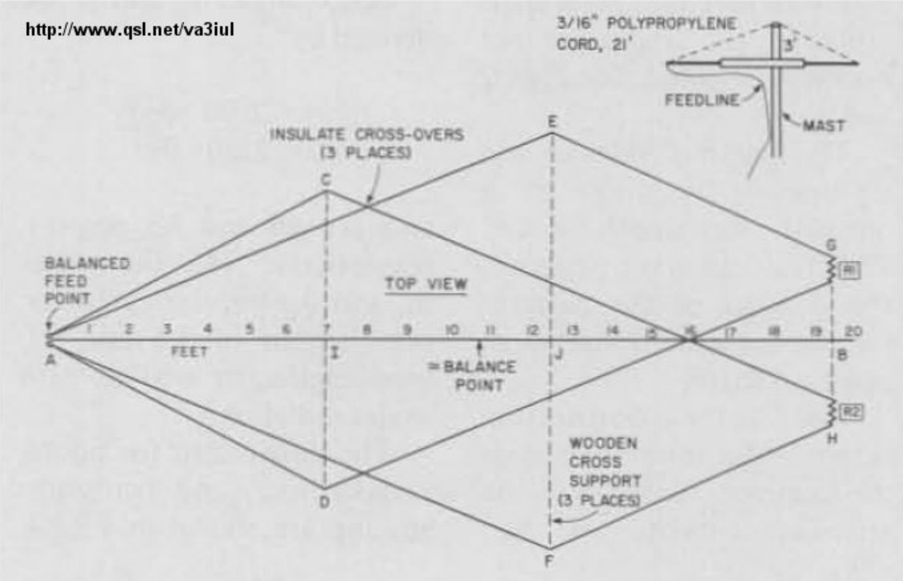
http://www.qsl.net/va3iul
3/16" POLYPROPYLENE CORD, 21'
3'
FEEDLINE
MAST
INSULATE CROSS-OVERS (3 PLACES)
E
C
BALANCED FEED POINT
TOP VIEW
G
R1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
FEET
A
I
J
B
≈ BALANCE POINT
R2
H
WOODEN CROSS SUPPORT (3 PLACES)
D
F

Dual rhomboid antenna for 435-870 MHz. Beamwidth ≈ 10° H x 6° V. Gain over DP ≈ 26 dB. Boom length: AB = 19'6". Support spacing : AI = 7'; IJ = 5'6"; JB = 7'. Support length: CD = 7'3"; EF = 10'3"; GH = 3'0". Rhomboid sides: AC, AD, EG, FH = 7'9.5"; AE, AF, CH, DG = 13'5.5". Feedline: Wire needed: 14 AWG formvar, ≈ 86'0". Boom material: AI, JB = wood; IJ = metal. Cross support: CD, EF, GH = wood. Terminators: R1, R2 = 600 Ohms; Watts

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106 - Double-Bazooka Antenna for 80m

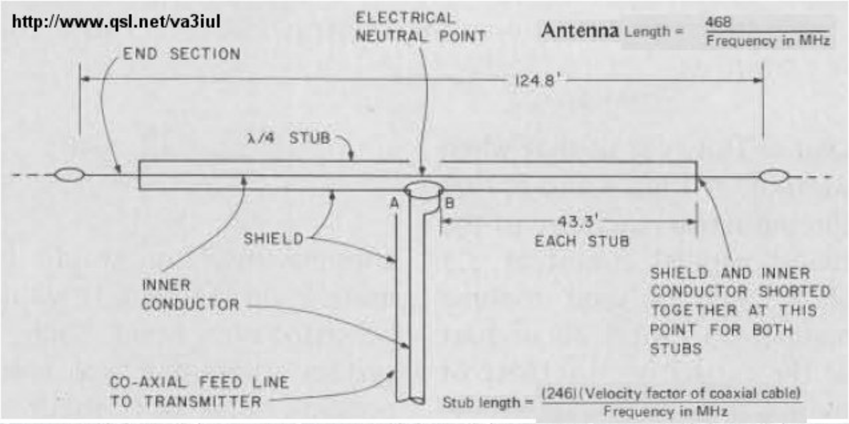
http://www.qsl.net/va3iul
END SECTION
ELECTRICAL NEUTRAL POINT
Antenna Length = 468 / Frequency in MHz
124.8'
λ/4 STUB
A
B
43.3' EACH STUB
SHIELD
INNER CONDUCTOR
SHIELD AND INNER CONDUCTOR SHORTED TOGETHER AT THIS POINT FOR BOTH STUBS
CO-AXIAL FEED LINE TO TRANSMITTER
Stub length = (246)(Velocity factor of coaxial cable) / Frequency in MHz

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107 - J-Style Antenna

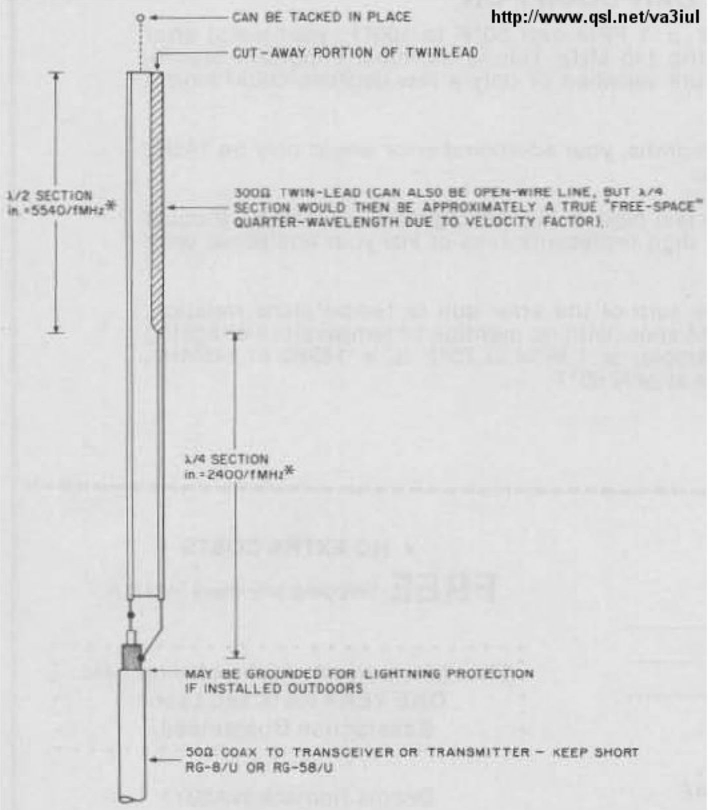
http://www.qsl.net/va3iul
CAN BE TACKED IN PLACE
CUT-AWAY PORTION OF TWINLEAD
λ/2 SECTION
in =5540/fMHz*
300Ω TWIN-LEAD (CAN ALSO BE OPEN-WIRE LINE, BUT λ/4 SECTION WOULD THEN BE APPROXIMATELY A TRUE "FREE-SPACE" QUARTER-WAVELENGTH DUE TO VELOCITY FACTOR).
λ/4 SECTION
in =2400/fMHz*
MAY BE GROUNDED FOR LIGHTNING PROTECTION IF INSTALLED OUTDOORS
50Ω COAX TO TRANSCEIVER OR TRANSMITTER — KEEP SHORT RG-8/U OR RG-58/U

108 - Vertical / Horizontal / Circular Polarization Antenna

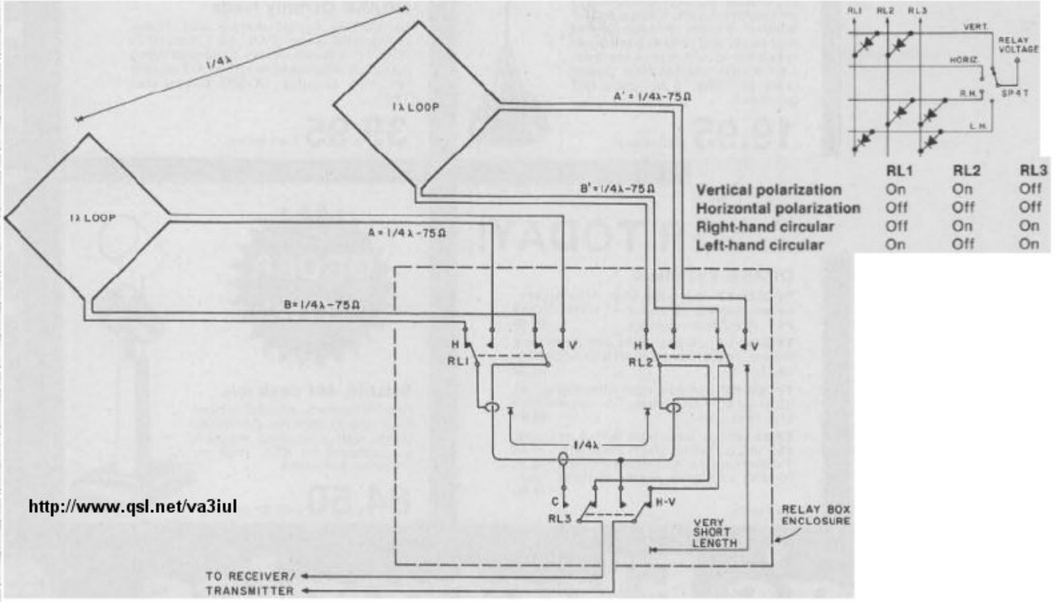
1/4λ
1λ LOOP
1λ LOOP
A' = 1/4λ-75Ω
B' = 1/4λ-75Ω
A = 1/4λ-75Ω
B = 1/4λ-75Ω
H
V
RL1
H
V
RL2
1/4λ
C
RL3
H-V
VERY SHORT LENGTH
RELAY BOX ENCLOSURE
TO RECEIVER/ TRANSMITTER
RL1 RL2 RL3
VERT.
HORIZ.
R.H.
L.H.
RELAY VOLTAGE
SP4T
http://www.qsl.net/va3iul

	RL1	RL2	RL3
Vertical polarization	On	On	Off
Horizontal polarization	Off	Off	Off
Right-hand circular	Off	On	On
Left-hand circular	On	Off	On

109 - Coax Inverted-L Antenna for 80m

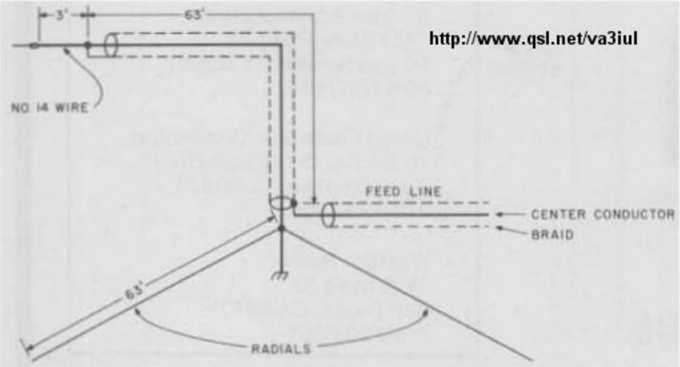
3'
63'
http://www.qsl.net/va3iul
NO 14 WIRE
FEED LINE
CENTER CONDUCTOR
BRAID
63'
RADIALS

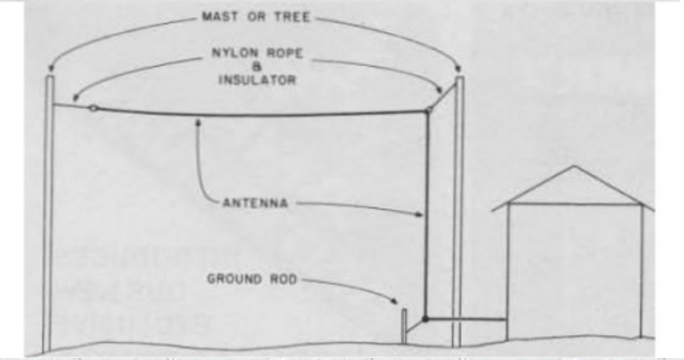
MAST OR TREE
NYLON ROPE
&
INSULATOR
ANTENNA
GROUND ROD

110 - Indoor Compact Loop Antenna for 80m

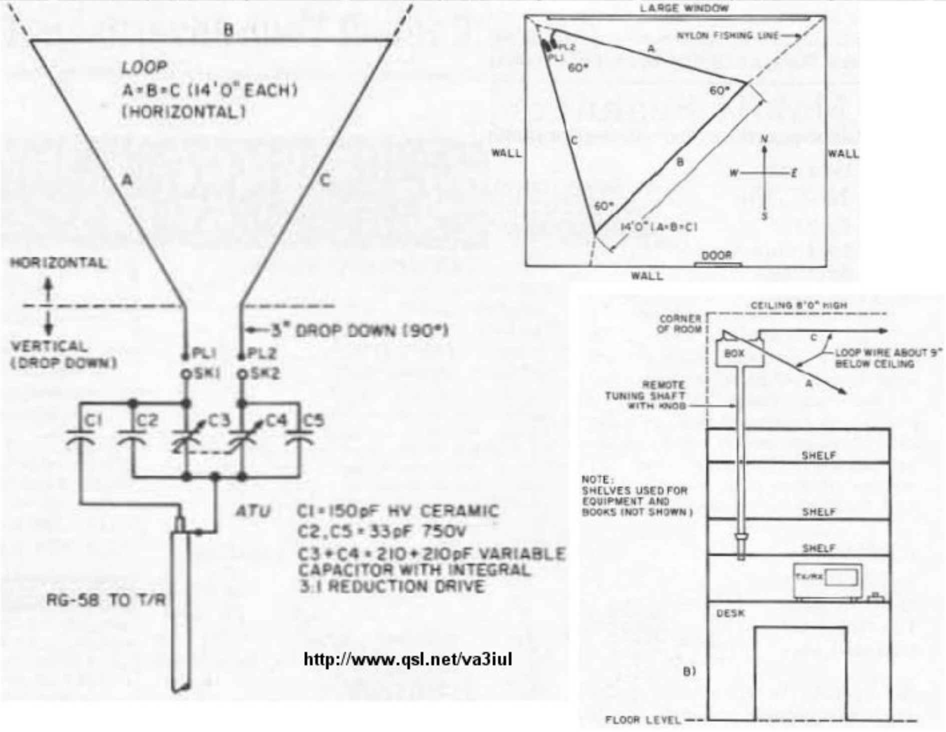
B
LOOP
A=B=C (14'0" EACH)
(HORIZONTAL)
A
C
HORIZONTAL
VERTICAL
(DROP DOWN)
3" DROP DOWN (90°)
PL1
PL2
SK1
SK2
C1
C2
C3
C4
C5
ATU
C1=150pF HV CERAMIC
C2,C5=33pF 750V
C3+C4=210+210pF VARIABLE
CAPACITOR WITH INTEGRAL
3:1 REDUCTION DRIVE
RG-58 TO T/R
http://www.qsl.net/va3iul
LARGE WINDOW
NYLON FISHING LINE
PL2
PL1
60°
A
60°
WALL
C
B
N
W
E
S
WALL
60°
14'0" (A=B=C)
DOOR
WALL
CEILING 8'0" HIGH
CORNER
OF ROOM
BOX
C
LOOP WIRE ABOUT 9"
BELOW CEILING
A
REMOTE
TUNING SHAFT
WITH KNOB
SHELF
NOTE:
SHELVES USED FOR
EQUIPMENT AND
BOOKS (NOT SHOWN)
SHELF
SHELF
TX/RX
DESK
B)
FLOOR LEVEL

111 - Helix Antenna

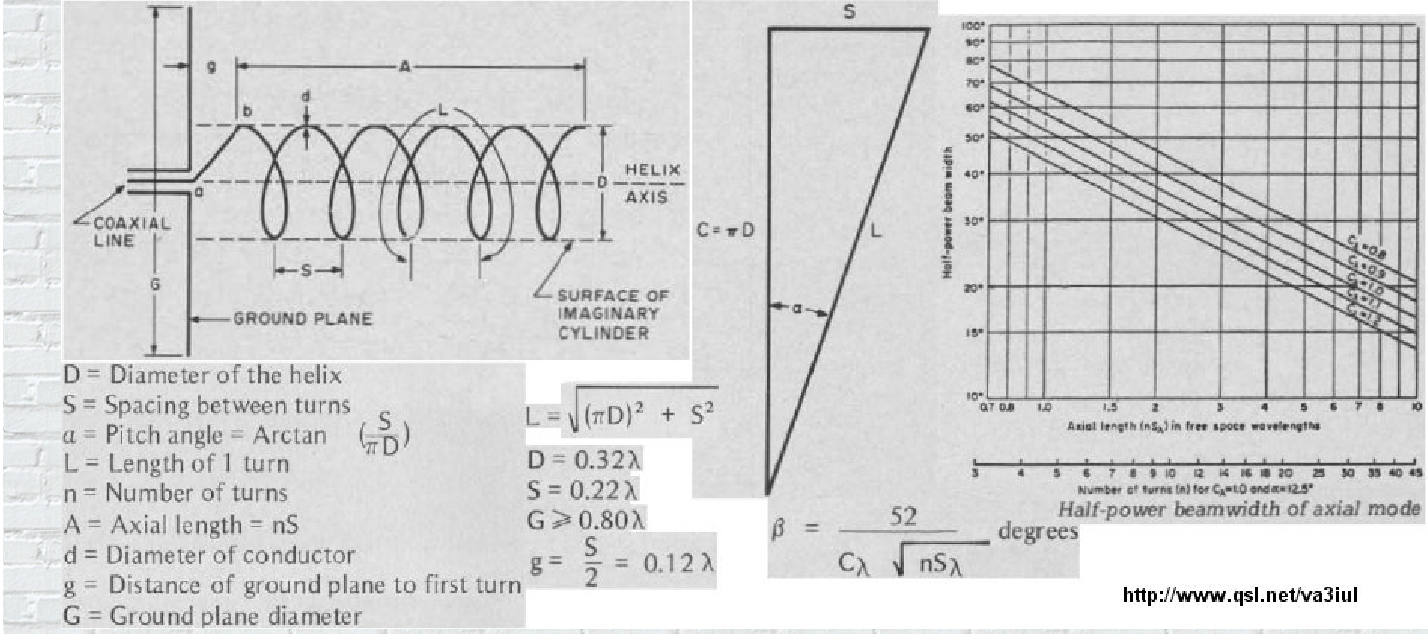
g
A
d
b
L
HELIX AXIS
D
COAXIAL LINE
a
S
G
GROUND PLANE
SURFACE OF IMAGINARY CYLINDER
S
C = πD
L
α
100°
90°
80°
70°
60°
50°
40°
30°
20°
15°
10°
Half-power beam width
0.7 0.8 1.0 1.5 2 3 4 5 6 7 8 10
Axial length (nSλ) in free space wavelengths
3 4 5 6 7 8 9 10 12 14 16 18 20 25 30 35 40 45
Number of turns (n) for Cλ=1.0 and α=12.5°
Cλ=0.8
Cλ=0.9
Cλ=1.0
Cλ=1.1
Cλ=1.2

D = Diameter of the helix
S = Spacing between turns
α = Pitch angle = Arctan $\left(\frac{S}{\pi D}\right)$
L = Length of 1 turn
n = Number of turns
A = Axial length = nS
d = Diameter of conductor
g = Distance of ground plane to first turn
G = Ground plane diameter

$$L = \sqrt{(\pi D)^2 + S^2}$$

$$D = 0.32\lambda$$

$$S = 0.22\lambda$$

$$G \geqslant 0.80\lambda$$

$$g = \frac{S}{2} = 0.12\lambda$$

$$\beta = \frac{52}{C_\lambda \sqrt{nS_\lambda}} \text{ degrees}$$

Half-power beamwidth of axial mode

http://www.qsl.net/va3iul

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112 - Novice Vertical Antenna for 80m, 40m, 15m, 10m

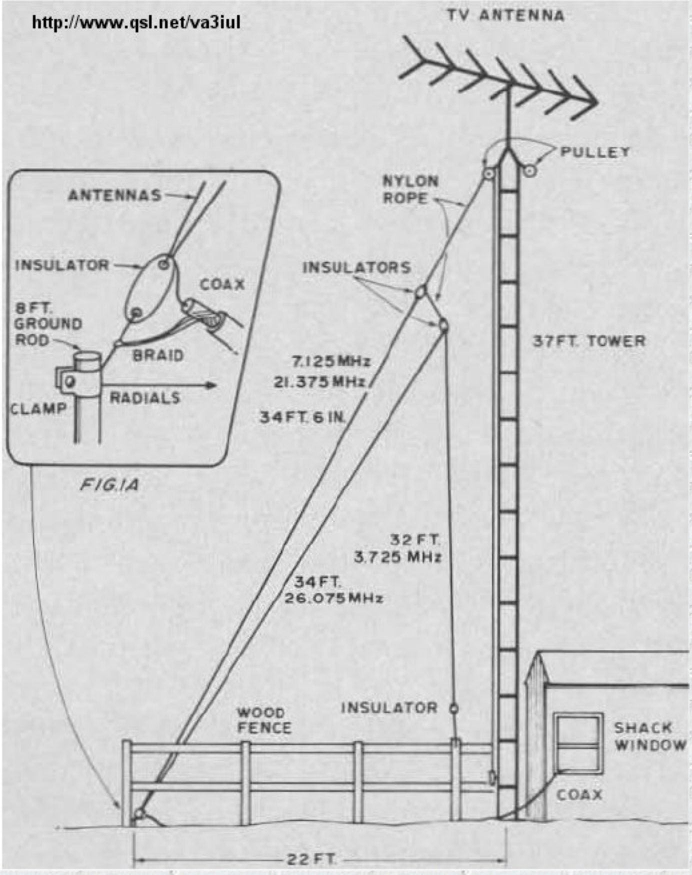
http://www.qsl.net/va3iul
TV ANTENNA
PULLEY
NYLON ROPE
ANTENNAS
INSULATOR
COAX
8 FT. GROUND ROD
BRAID
CLAMP
RADIALS
FIG.1A
INSULATORS
37 FT. TOWER
7.125 MHz
21.375 MHz
34 FT. 6 IN.
32 FT.
3.725 MHz
34 FT.
26.075 MHz
WOOD FENCE
INSULATOR
SHACK WINDOW
COAX
22 FT.

---

113 - Stub-Loaded Shortened Dipole for 80m

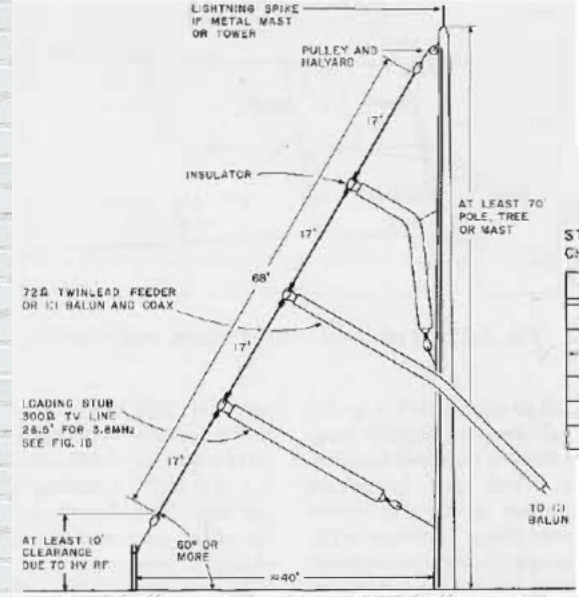
LIGHTNING SPIKE IF METAL MAST OR TOWER
PULLEY AND HALYARD
17'
INSULATOR
AT LEAST 70' POLE, TREE OR MAST
17'
68'
72Ω TWINLEAD FEEDER OR 1:1 BALUN AND COAX
17'
LOADING STUB 300Ω TV LINE 26.5' FOR 3.8MHz SEE FIG. 1B
17'
AT LEAST 10' CLEARANCE DUE TO HV RF
60° OR MORE
≈40'
TO 1:1 BALUN

http://www.qsl.net/va3iul

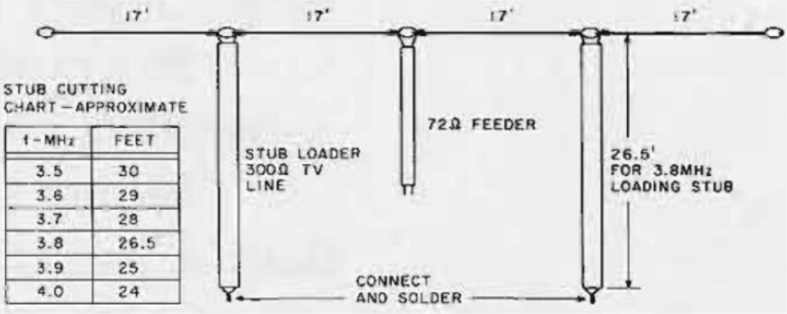
17'
17'
17'
17'
STUB LOADER 300Ω TV LINE
72Ω FEEDER
26.5' FOR 3.8MHz LOADING STUB
CONNECT AND SOLDER

STUB CUTTING CHART – APPROXIMATE

f-MHz	FEET
3.5	30
3.6	29
3.7	28
3.8	26.5
3.9	25
4.0	24

114 - Six-Band Wire-Stub Trap Antenna for 40m-10m

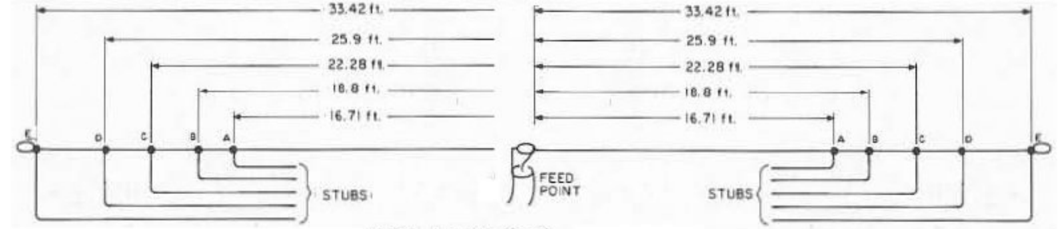
33.42 ft.
25.9 ft.
22.28 ft.
18.8 ft.
16.71 ft.
33.42 ft.
25.9 ft.
22.28 ft.
18.8 ft.
16.71 ft.
E
D
C
B
A
STUBS
FEED POINT
STUBS
A
B
C
D
E

Point	Length (feet)
A	8.37
B	9.40
C	11.14
D	12.95
E	16.72

40m
20m
17m
15m
12m
10m

http://www.qsl.net/va3iul

115 - Multiband Half-Wave Delta-Loop Antenna

http://www.qsl.net/va3iul

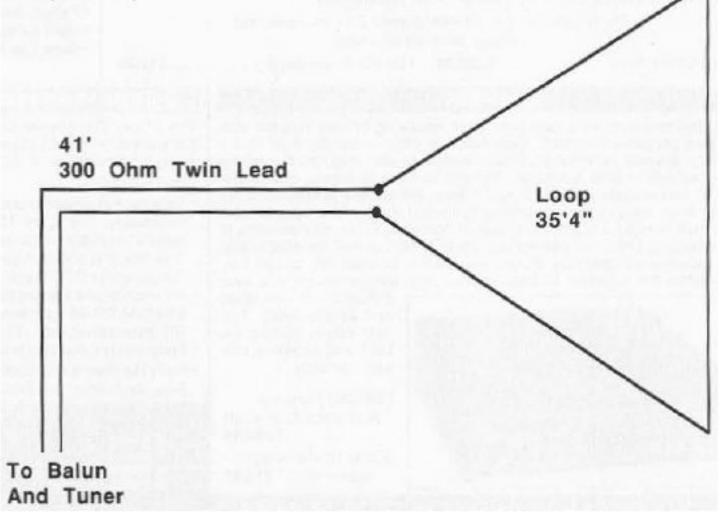
41'
300 Ohm Twin Lead
Loop
35'4"
To Balun
And Tuner

116 - Hybrid Vee for 20m, 17m

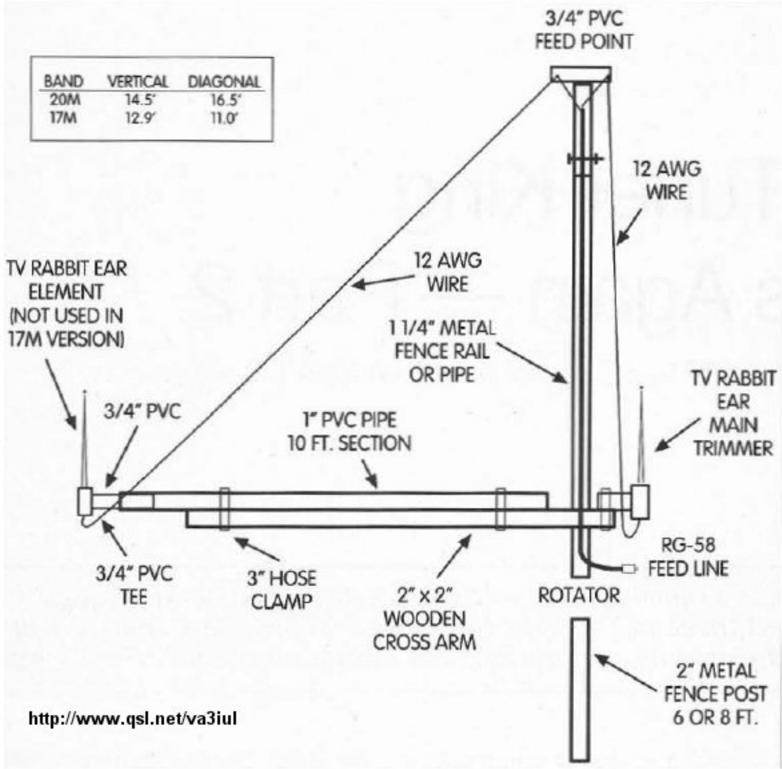
BAND VERTICAL DIAGONAL
20M 14.5' 16.5'
17M 12.9' 11.0'
3/4" PVC FEED POINT
12 AWG WIRE
12 AWG WIRE
TV RABBIT EAR ELEMENT (NOT USED IN 17M VERSION)
1 1/4" METAL FENCE RAIL OR PIPE
TV RABBIT EAR MAIN TRIMMER
3/4" PVC
1" PVC PIPE 10 FT. SECTION
RG-58 FEED LINE
3/4" PVC TEE
3" HOSE CLAMP
2" x 2" WOODEN CROSS ARM
ROTATOR
2" METAL FENCE POST 6 OR 8 FT.
http://www.qsl.net/va3iul

117 - Six-Shooter Array Antenna, Gain=7.5dB

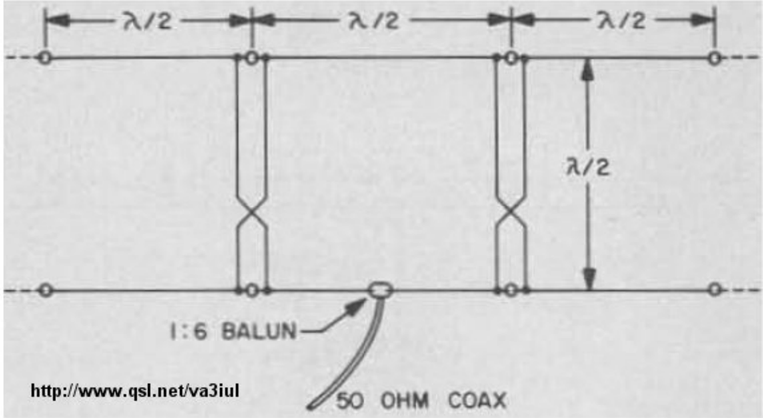
λ/2
λ/2
λ/2
λ/2
1:6 BALUN
50 OHM COAX
http://www.qsl.net/va3iul

118 - Multiband Ground-Plane Antenna for 10m, 15m, 20m

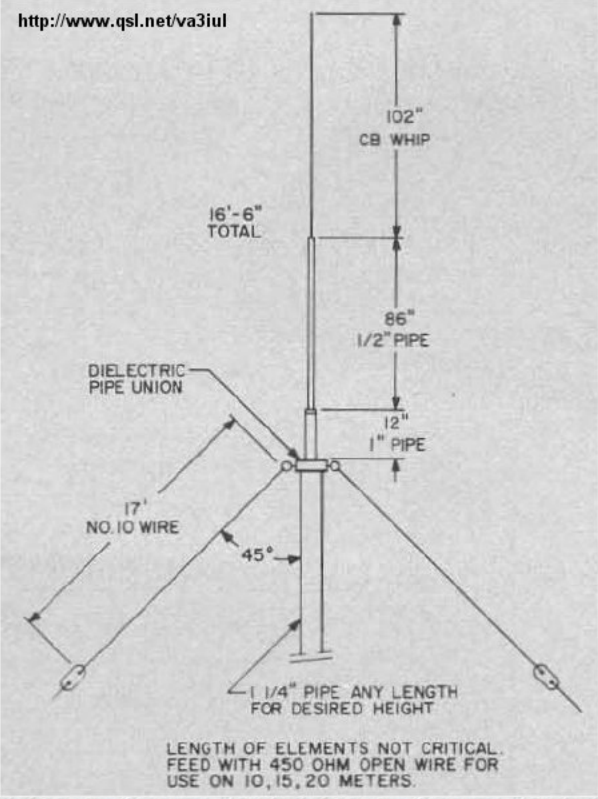
http://www.qsl.net/va3iul
102"
CB WHIP
16'-6"
TOTAL
86"
1/2" PIPE
DIELECTRIC
PIPE UNION
12"
1" PIPE
17'
NO. 10 WIRE
45°
1 1/4" PIPE ANY LENGTH
FOR DESIRED HEIGHT
LENGTH OF ELEMENTS NOT CRITICAL.
FEED WITH 450 OHM OPEN WIRE FOR
USE ON 10, 15, 20 METERS.

119 - Wire Superbeam Antenna for 10m, 15m, 20m

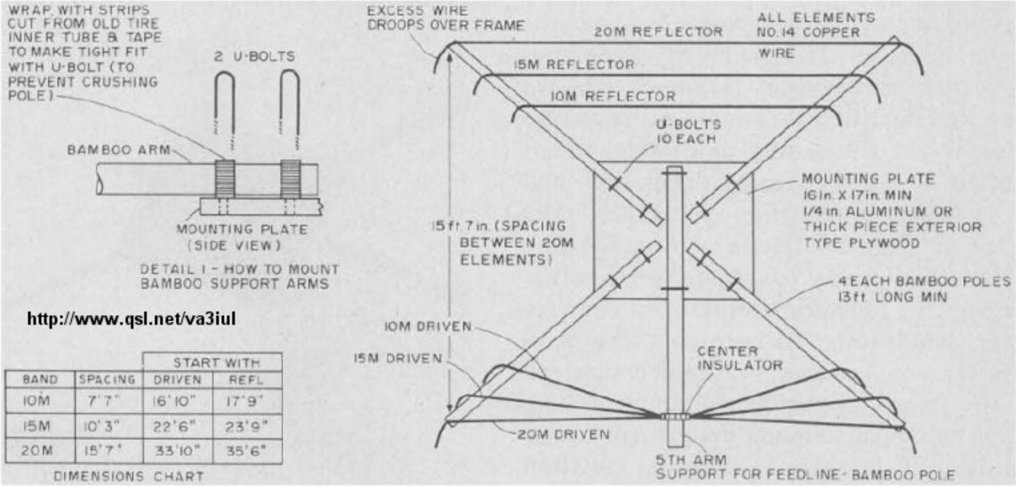
WRAP WITH STRIPS
CUT FROM OLD TIRE
INNER TUBE & TAPE
TO MAKE TIGHT FIT
WITH U-BOLT (TO
PREVENT CRUSHING
POLE)
2 U-BOLTS
BAMBOO ARM
MOUNTING PLATE
(SIDE VIEW)
DETAIL I - HOW TO MOUNT
BAMBOO SUPPORT ARMS
http://www.qsl.net/va3iul
EXCESS WIRE
DROOPS OVER FRAME
20M REFLECTOR
ALL ELEMENTS
NO.14 COPPER
WIRE
15M REFLECTOR
10M REFLECTOR
U-BOLTS
10 EACH
MOUNTING PLATE
16in. X 17in. MIN
1/4 in. ALUMINUM OR
THICK PIECE EXTERIOR
TYPE PLYWOOD
15 ft. 7 in. (SPACING
BETWEEN 20M
ELEMENTS)
4 EACH BAMBOO POLES
13 ft. LONG MIN
10M DRIVEN
15M DRIVEN
CENTER
INSULATOR
20M DRIVEN
5TH ARM
SUPPORT FOR FEEDLINE - BAMBOO POLE
DIMENSIONS CHART

		START WITH	
BAND	SPACING	DRIVEN	REFL
10M	7'7"	16'10"	17'9"
15M	10'3"	22'6"	23'9"
20M	15'7"	33'10"	35'6"

120 - Two Elements Delta-Loop Antenna

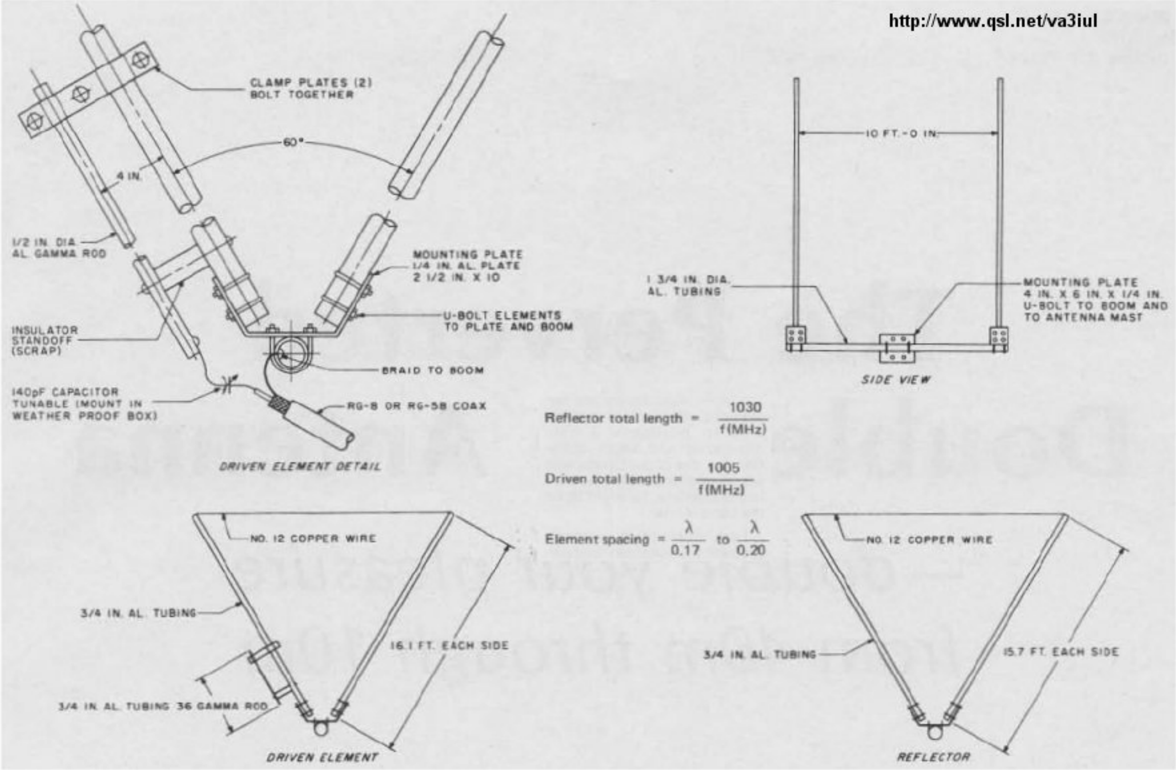
http://www.qsl.net/va3iul
CLAMP PLATES (2) BOLT TOGETHER
60°
4 IN.
1/2 IN. DIA AL. GAMMA ROD
MOUNTING PLATE 1/4 IN. AL. PLATE 2 1/2 IN. X 10
INSULATOR STANDOFF (SCRAP)
U-BOLT ELEMENTS TO PLATE AND BOOM
BRAID TO BOOM
140pF CAPACITOR TUNABLE (MOUNT IN WEATHER PROOF BOX)
RG-8 OR RG-58 COAX
DRIVEN ELEMENT DETAIL
10 FT.-0 IN.
1 3/4 IN. DIA. AL. TUBING
MOUNTING PLATE 4 IN. X 6 IN. X 1/4 IN. U-BOLT TO BOOM AND TO ANTENNA MAST
SIDE VIEW
Reflector total length = 1030/f(MHz)
Driven total length = 1005/f(MHz)
Element spacing = λ/0.17 to λ/0.20
NO. 12 COPPER WIRE
3/4 IN. AL. TUBING
16.1 FT. EACH SIDE
3/4 IN. AL. TUBING 36 GAMMA ROD
DRIVEN ELEMENT
NO. 12 COPPER WIRE
3/4 IN. AL. TUBING
15.7 FT. EACH SIDE
REFLECTOR

121 - Sterba Curtain Antenna

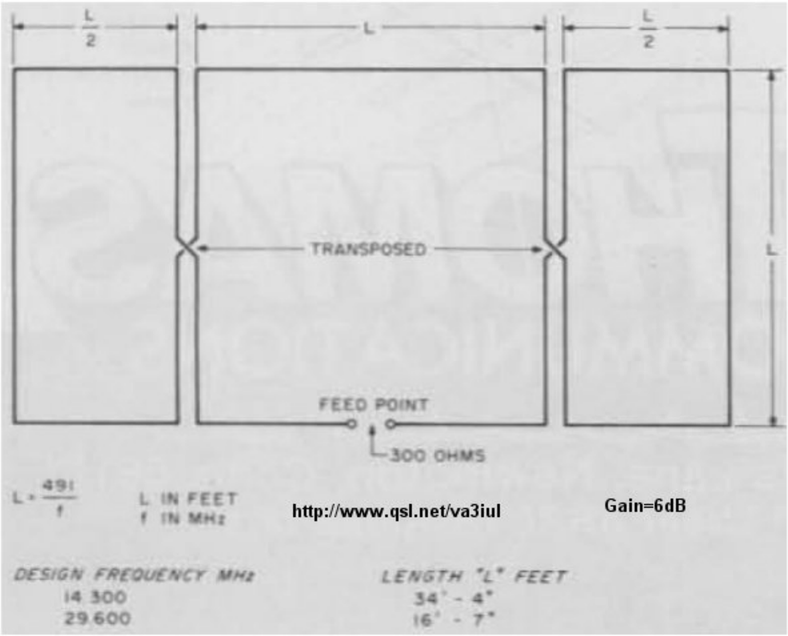
L/2
L
L/2
TRANSPOSED
L
FEED POINT
300 OHMS
L = 491/f
L IN FEET
f IN MHz
http://www.qsl.net/va3iul
Gain=6dB

DESIGN FREQUENCY MHz	LENGTH "L" FEET
14.300	34' - 4"
29.600	16' - 7"

122 - Half-Wave Vertical Zepp Antenna

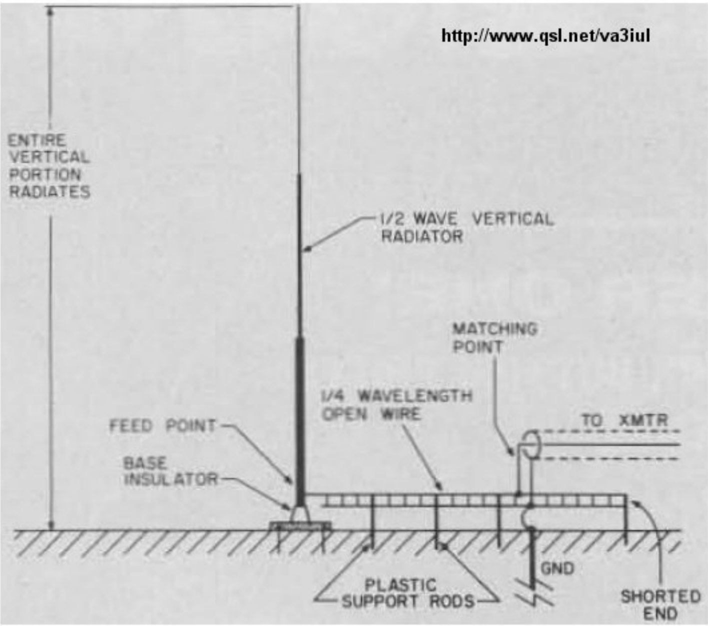
http://www.qsl.net/va3iul
ENTIRE VERTICAL PORTION RADIATES
1/2 WAVE VERTICAL RADIATOR
MATCHING POINT
1/4 WAVELENGTH OPEN WIRE
TO XMTR
FEED POINT
BASE INSULATOR
GND
PLASTIC SUPPORT RODS
SHORTED END

123 - Lazy-Loop Antenna for 40m

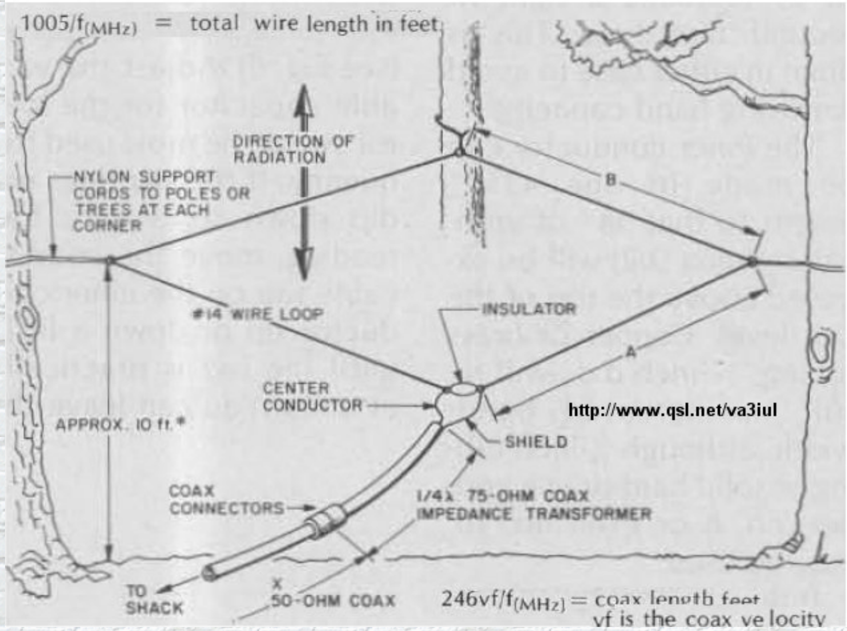
1005/f(MHz) = total wire length in feet
DIRECTION OF RADIATION
NYLON SUPPORT CORDS TO POLES OR TREES AT EACH CORNER
B
#14 WIRE LOOP
INSULATOR
A
CENTER CONDUCTOR
http://www.qsl.net/va3iul
SHIELD
APPROX. 10 ft.*
COAX CONNECTORS
1/4λ 75-OHM COAX IMPEDANCE TRANSFORMER
TO SHACK
X
50-OHM COAX
246vf/f(MHz) = coax length feet
vf is the coax velocity

124 - Terminated Folded Dipole for 80m, 40m

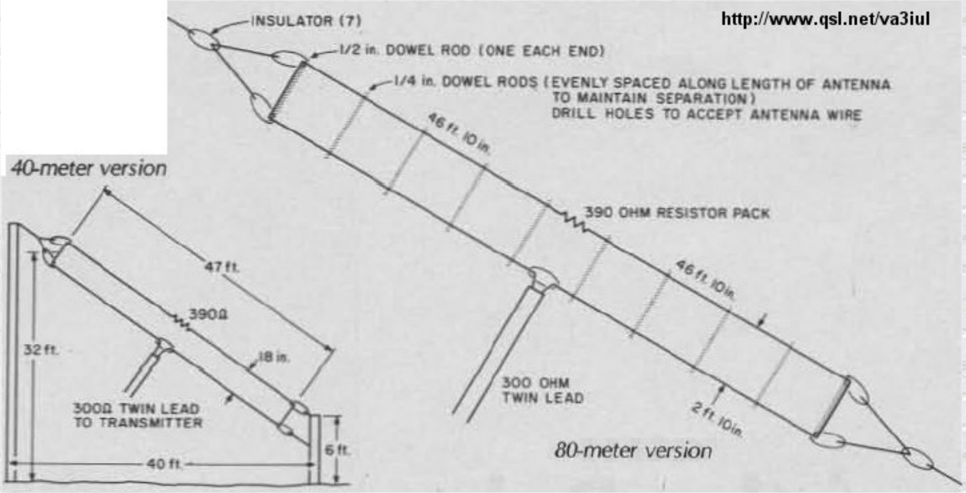
INSULATOR (7)
1/2 in. DOWEL ROD (ONE EACH END)
1/4 in. DOWEL RODS (EVENLY SPACED ALONG LENGTH OF ANTENNA TO MAINTAIN SEPARATION) DRILL HOLES TO ACCEPT ANTENNA WIRE
http://www.qsl.net/va3iul
46 ft. 10 in.
390 OHM RESISTOR PACK
46 ft. 10 in.
300 OHM TWIN LEAD
2 ft. 10 in.
80-meter version
40-meter version
47 ft.
390Ω
32 ft.
18 in.
300Ω TWIN LEAD TO TRANSMITTER
6 ft.
40 ft.

125 - Short-Fat Antenna for 15m

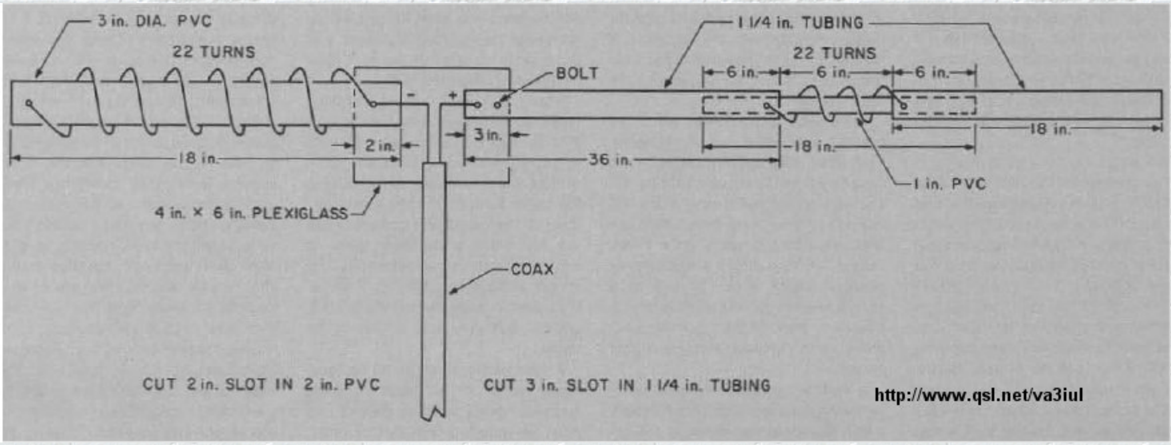
3 in. DIA. PVC
22 TURNS
BOLT
1 1/4 in. TUBING
22 TURNS
6 in.
6 in.
6 in.
2 in.
3 in.
18 in.
36 in.
18 in.
18 in.
1 in. PVC
4 in. × 6 in. PLEXIGLASS
COAX
CUT 2 in. SLOT IN 2 in. PVC
CUT 3 in. SLOT IN 1 1/4 in. TUBING
http://www.qsl.net/va3iul

126 - Cobra Antenna for 80m

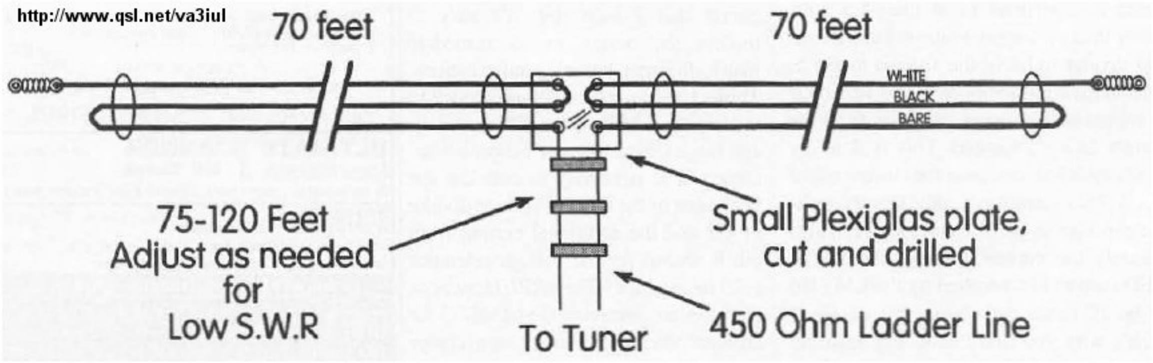
http://www.qsl.net/va3iul
70 feet
70 feet
WHITE
BLACK
BARE
75-120 Feet
Adjust as needed
for
Low S.W.R
Small Plexiglas plate,
cut and drilled
450 Ohm Ladder Line
To Tuner

127 - Log-Periodic Wire Antenna for 20m, 15m, 10m

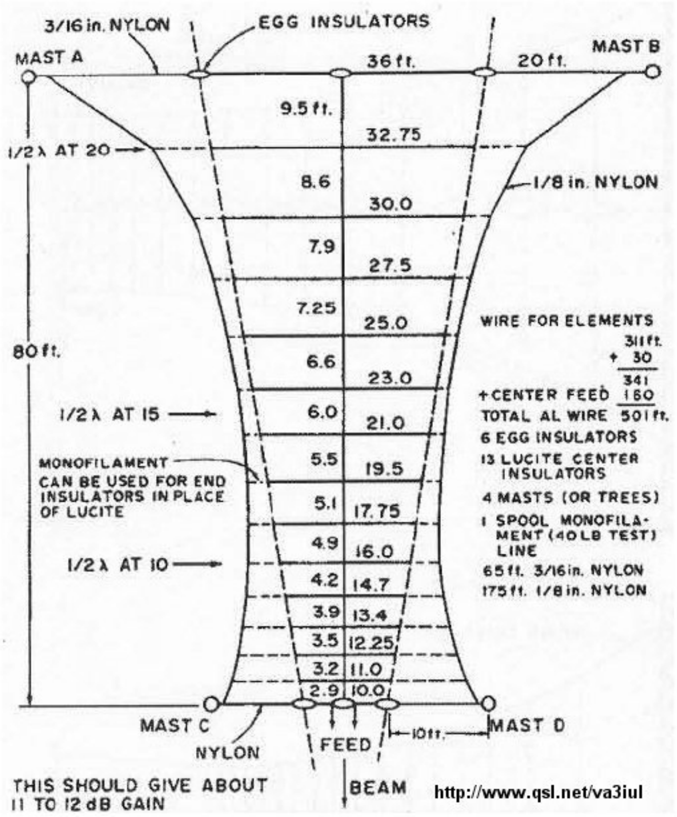
3/16 in. NYLON
EGG INSULATORS
MAST A
36 ft.
20 ft.
MAST B
9.5 ft.
32.75
1/2 λ AT 20
8.6
30.0
1/8 in. NYLON
7.9
27.5
7.25
25.0
80 ft.
6.6
23.0
6.0
21.0
1/2 λ AT 15
5.5
19.5
MONOFILAMENT
CAN BE USED FOR END
INSULATORS IN PLACE
OF LUCITE
5.1
17.75
4.9
16.0
1/2 λ AT 10
4.2
14.7
3.9
13.4
3.5
12.25
3.2
11.0
2.9
10.0
WIRE FOR ELEMENTS
311 ft.
+ 30
341
+ CENTER FEED 160
TOTAL AL WIRE 501 ft.
6 EGG INSULATORS
13 LUCITE CENTER INSULATORS
4 MASTS (OR TREES)
1 SPOOL MONOFILAMENT (40 LB TEST) LINE
65 ft. 3/16 in. NYLON
175 ft. 1/8 in. NYLON
MAST C
NYLON
FEED
10 ft.
MAST D
BEAM
THIS SHOULD GIVE ABOUT
11 TO 12 dB GAIN
http://www.qsl.net/va3iul

128 - 5-Element Log-Periodic Vertical Antenna for 80m, 40m, 20m

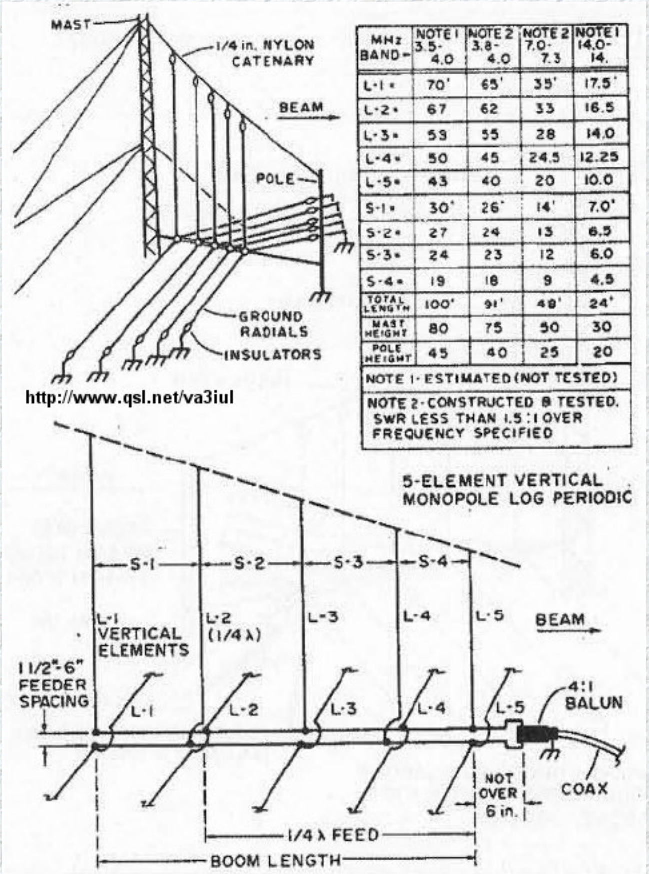
MAST
1/4 in. NYLON CATENARY
BEAM
POLE
GROUND RADIALS
INSULATORS
S-1
S-2
S-3
S-4
L-1 VERTICAL ELEMENTS
L-2 (1/4 λ)
L-3
L-4
L-5
BEAM
1 1/2"-6" FEEDER SPACING
L-1
L-2
L-3
L-4
L-5
4:1 BALUN
COAX
NOT OVER 6 in.
1/4 λ FEED
BOOM LENGTH

http://www.qsl.net/va3iul

MHz BAND -	NOTE 1 3.5-4.0	NOTE 2 3.8-4.0	NOTE 2 7.0-7.3	NOTE 1 14.0-14.
L-1 =	70'	65'	35'	17.5'
L-2 =	67	62	33	16.5
L-3 =	53	55	28	14.0
L-4 =	50	45	24.5	12.25
L-5 =	43	40	20	10.0
S-1 =	30'	26'	14'	7.0'
S-2 =	27	24	13	6.5
S-3 =	24	23	12	6.0
S-4 =	19	18	9	4.5
TOTAL LENGTH	100'	91'	48'	24'
MAST HEIGHT	80	75	50	30
POLE HEIGHT	45	40	25	20

NOTE 1 - ESTIMATED (NOT TESTED)

NOTE 2 - CONSTRUCTED & TESTED. SWR LESS THAN 1.5:1 OVER FREQUENCY SPECIFIED

5-ELEMENT VERTICAL MONOPOLE LOG PERIODIC

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129 - 2m Vertical Wire Antennas

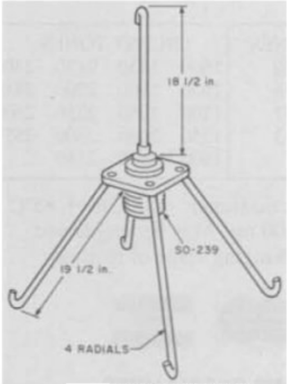
18 1/2 in.
SO-239
19 1/2 in.
4 RADIALS

Simple 1/4λ 2-meter ground-plane antenna.

http://www.qsl.net/va3iul

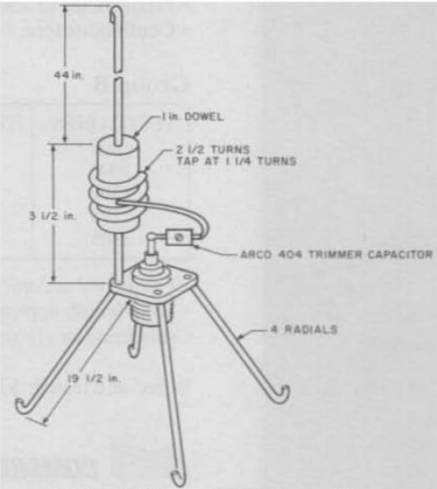
44 in.
1 in. DOWEL
2 1/2 TURNS TAP AT 1 1/4 TURNS
3 1/2 in.
ARCO 404 TRIMMER CAPACITOR
4 RADIALS
19 1/2 in.

Experimental 5/8λ vertical with 1/4λ ground plane.

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130 - Earth-Mover Inverted-V Antenna for 40m

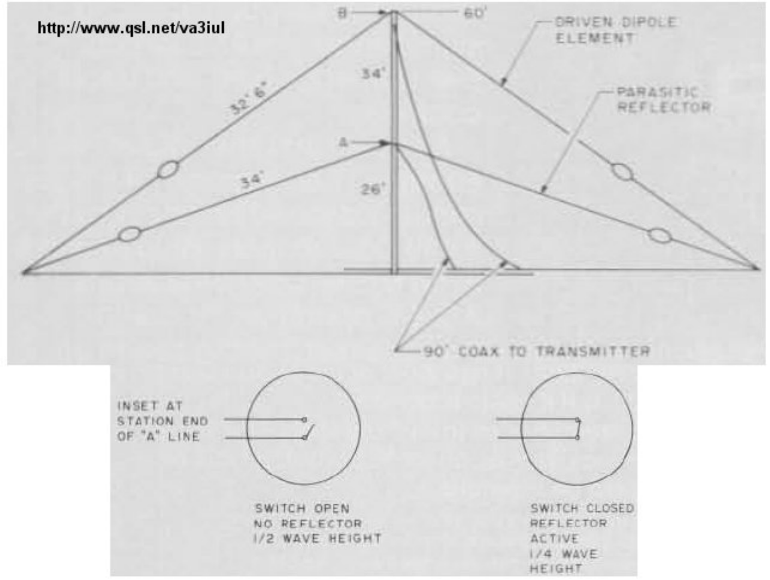
http://www.qsl.net/va3iul
B
60'
DRIVEN DIPOLE ELEMENT
34'
32' 6"
PARASITIC REFLECTOR
A
34'
26'
90' COAX TO TRANSMITTER
INSET AT STATION END OF "A" LINE
SWITCH OPEN NO REFLECTOR 1/2 WAVE HEIGHT
SWITCH CLOSED REFLECTOR ACTIVE 1/4 WAVE HEIGHT

131 - Coax-Cable Collinear Antennas

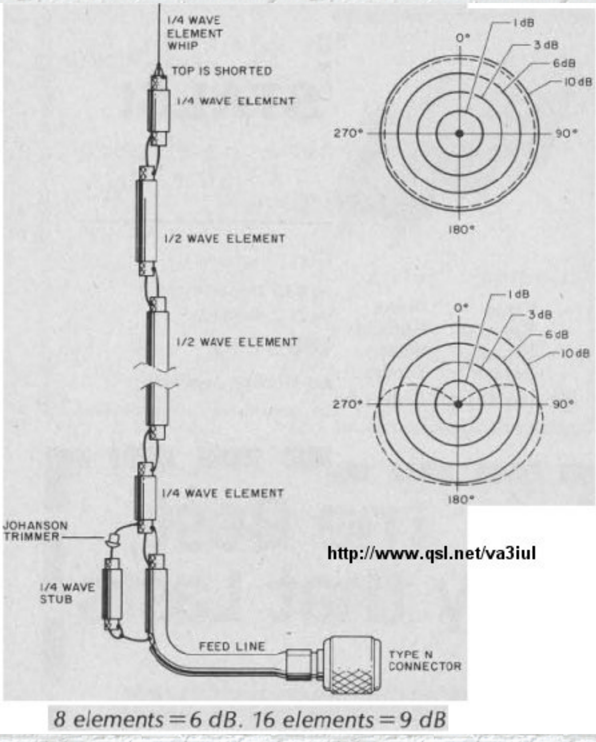
1/4 WAVE ELEMENT WHIP
TOP IS SHORTED
1/4 WAVE ELEMENT
1/2 WAVE ELEMENT
1/2 WAVE ELEMENT
1/4 WAVE ELEMENT
JOHANSON TRIMMER
1/4 WAVE STUB
FEED LINE
TYPE N CONNECTOR
0°
90°
180°
270°
1 dB
3 dB
6 dB
10 dB
0°
90°
180°
270°
1 dB
3 dB
6 dB
10 dB
http://www.qsl.net/va3iul

8 elements = 6 dB. 16 elements = 9 dB

132 - Double Bobtail Antenna for 20m

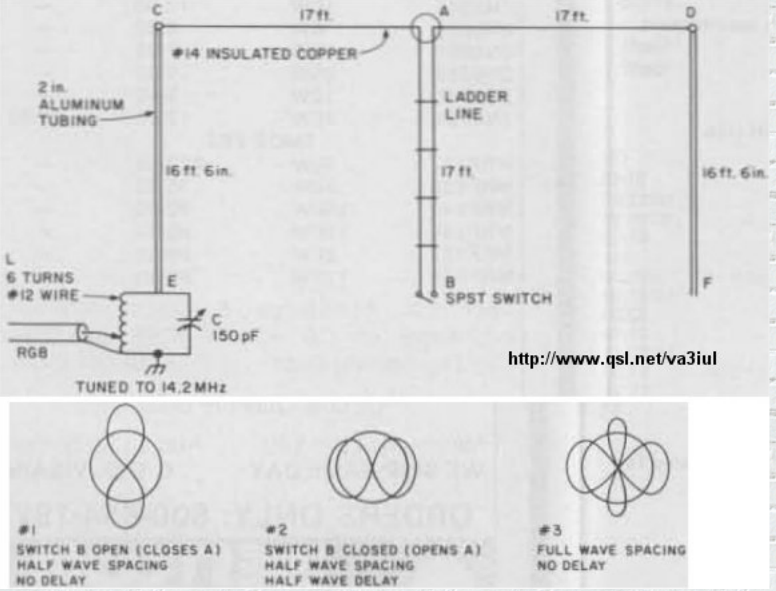
C
17 ft.
A
17 ft.
D
#14 INSULATED COPPER
2 in. ALUMINUM TUBING
LADDER LINE
16 ft. 6in.
17 ft.
16 ft. 6in.
L
6 TURNS
#12 WIRE
E
C
150 pF
RG8
TUNED TO 14.2 MHz
B
SPST SWITCH
F
http://www.qsl.net/va3iul
#1
SWITCH B OPEN (CLOSES A)
HALF WAVE SPACING
NO DELAY
#2
SWITCH B CLOSED (OPENS A)
HALF WAVE SPACING
HALF WAVE DELAY
#3
FULL WAVE SPACING
NO DELAY

133 - Collinear Zepp Antenna

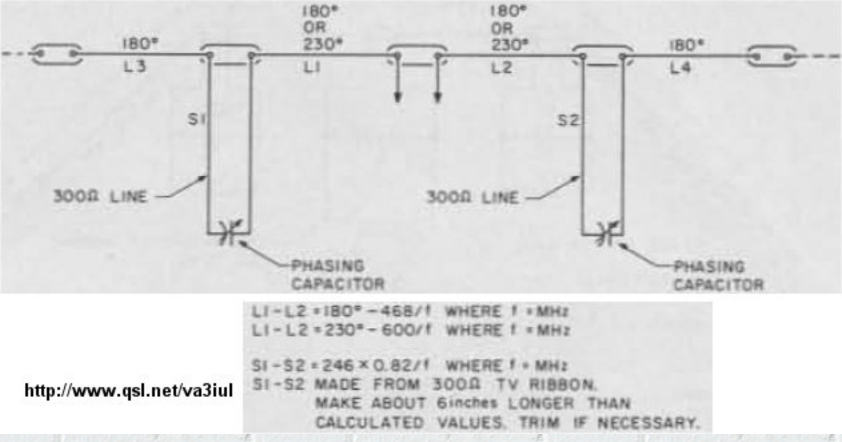
180°
L3
180° OR 230°
L1
180° OR 230°
L2
180°
L4
S1
S2
300Ω LINE
300Ω LINE
PHASING CAPACITOR
PHASING CAPACITOR
L1-L2 = 180° - 468/f WHERE f = MHz
L1-L2 = 230° - 600/f WHERE f = MHz
S1-S2 = 246 × 0.82/f WHERE f = MHz
S1-S2 MADE FROM 300Ω TV RIBBON.
MAKE ABOUT 6inches LONGER THAN
CALCULATED VALUES. TRIM IF NECESSARY.
http://www.qsl.net/va3iul

134 - Taylor Vee Antenna for 20m

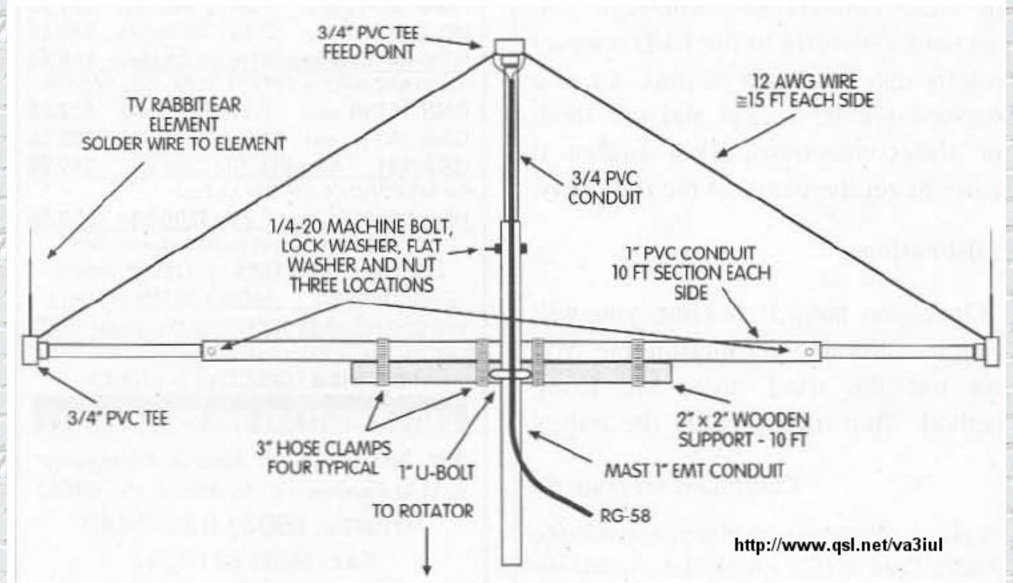
3/4" PVC TEE
FEED POINT
12 AWG WIRE
≅15 FT EACH SIDE
TV RABBIT EAR
ELEMENT
SOLDER WIRE TO ELEMENT
3/4 PVC
CONDUIT
1/4-20 MACHINE BOLT,
LOCK WASHER, FLAT
WASHER AND NUT
THREE LOCATIONS
1" PVC CONDUIT
10 FT SECTION EACH
SIDE
3/4" PVC TEE
3" HOSE CLAMPS
FOUR TYPICAL
1" U-BOLT
2" x 2" WOODEN
SUPPORT - 10 FT
MAST 1" EMT CONDUIT
TO ROTATOR
RG-58
http://www.qsl.net/va3iul

135 - Collinear Vertical Antenna 6dB-Gain for 2m, 1.3m, 73cm

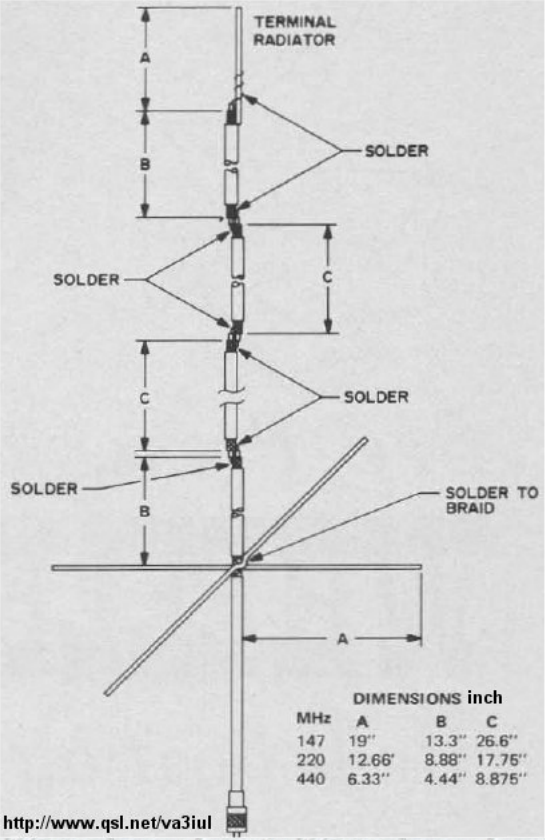
TERMINAL RADIATOR
A
B
SOLDER
C
SOLDER
C
SOLDER
SOLDER
B
SOLDER TO BRAID
A
DIMENSIONS inch
MHz A B C
147 19" 13.3" 26.6"
220 12.66' 8.88" 17.75"
440 6.33" 4.44" 8.875"
http://www.qsl.net/va3iul

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136 - Bi-Loop Antenna for 20m

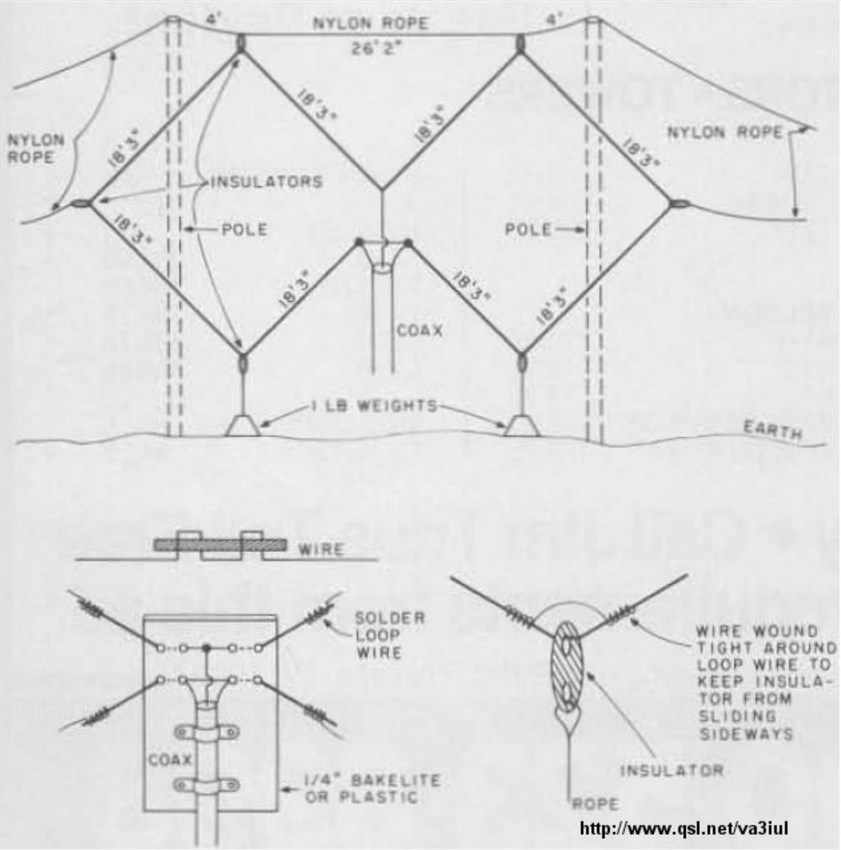
4'
NYLON ROPE
26' 2"
4'
NYLON ROPE
18' 3"
18' 3"
18' 3"
NYLON ROPE
18' 3"
INSULATORS
18' 3"
POLE
POLE
18' 3"
18' 3"
18' 3"
COAX
1 LB WEIGHTS
EARTH
WIRE
SOLDER LOOP WIRE
COAX
1/4" BAKELITE OR PLASTIC
WIRE WOUND TIGHT AROUND LOOP WIRE TO KEEP INSULATOR FROM SLIDING SIDEWAYS
INSULATOR
ROPE
http://www.qsl.net/va3iul

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137 - Wire Beam 6dBd-Gain for 10m

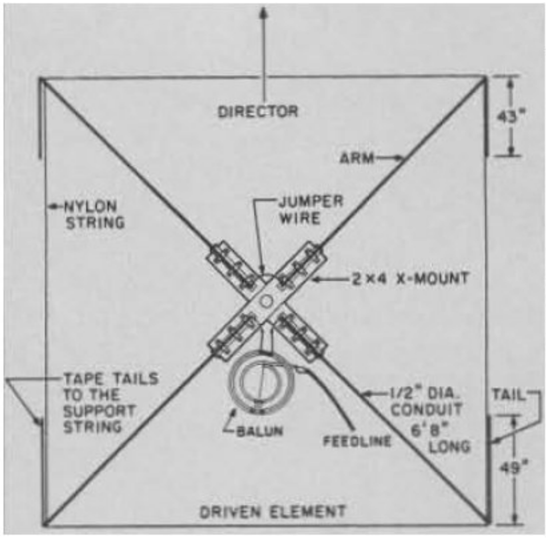
DIRECTOR
43"
ARM
NYLON STRING
JUMPER WIRE
2×4 X-MOUNT
TAPE TAILS TO THE SUPPORT STRING
BALUN
FEEDLINE
1/2" DIA. CONDUIT 6'8" LONG
TAIL
49"
DRIVEN ELEMENT

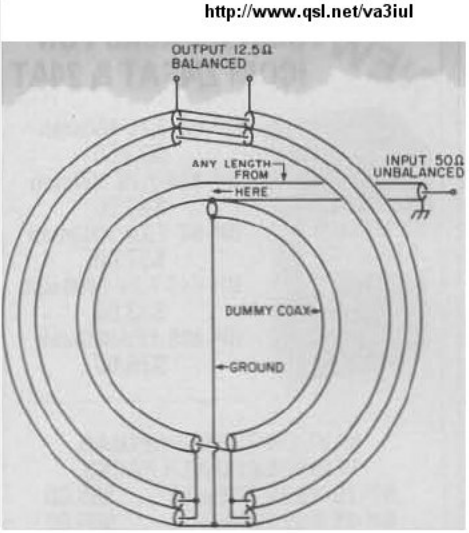
http://www.qsl.net/va3iul
OUTPUT 12.5Ω BALANCED
ANY LENGTH FROM HERE
INPUT 50Ω UNBALANCED
DUMMY COAX
GROUND

138 - Sloping Diamond Antenna 4dB-Gain for 40m

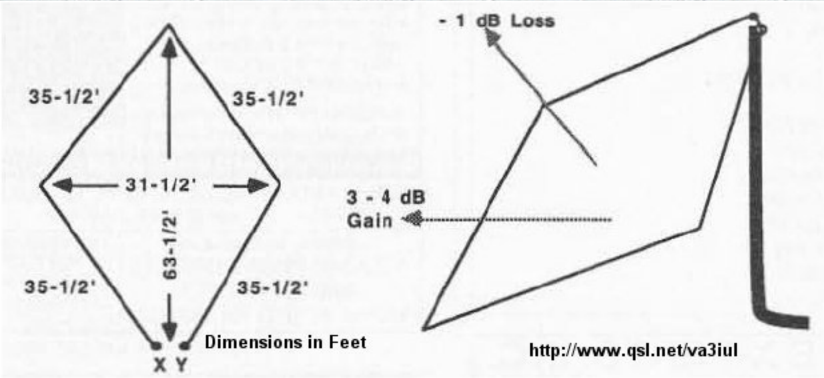
35-1/2'
35-1/2'
31-1/2'
63-1/2'
35-1/2'
35-1/2'
X Y
Dimensions in Feet
- 1 dB Loss
3 - 4 dB Gain
http://www.qsl.net/va3iul

139 - Twisted Loop Antenna for 160m

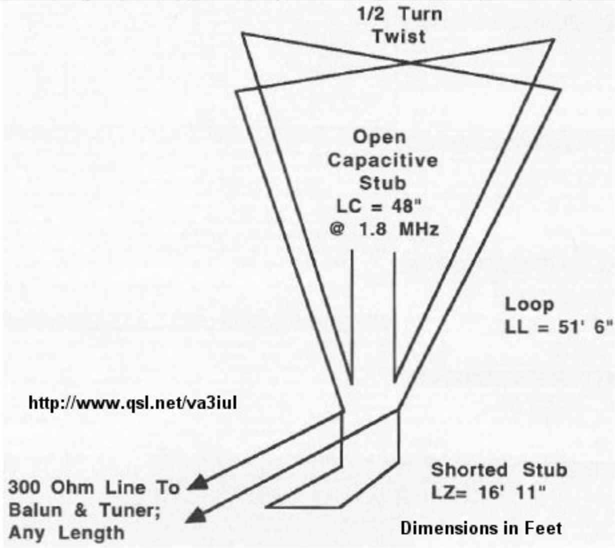
1/2 Turn Twist
Open Capacitive Stub LC = 48" @ 1.8 MHz
Loop LL = 51' 6"
http://www.qsl.net/va3iul
300 Ohm Line To Balun & Tuner; Any Length
Shorted Stub LZ= 16' 11"
Dimensions in Feet

140 - DX RX Loop Antenna for 160m

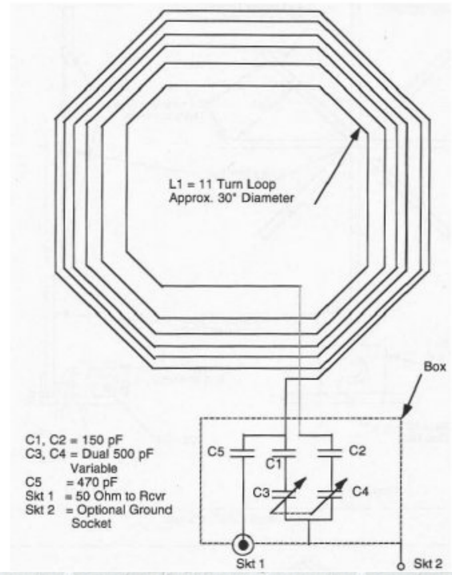
L1 = 11 Turn Loop
Approx. 30" Diameter
Box
C1, C2 = 150 pF
C3, C4 = Dual 500 pF
Variable
C5 = 470 pF
Skt 1 = 50 Ohm to Rcvr
Skt 2 = Optional Ground
Socket
C5
C1
C2
C3
C4
Skt 1
Skt 2

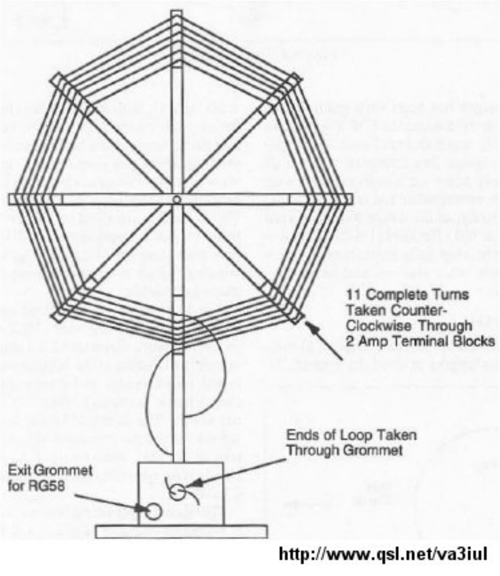
11 Complete Turns
Taken Counter-
Clockwise Through
2 Amp Terminal Blocks
Ends of Loop Taken
Through Grommet
Exit Grommet
for RG58
http://www.qsl.net/va3iul

141 - Hentenna 3dB-Gain for 10m, 6m, 2m

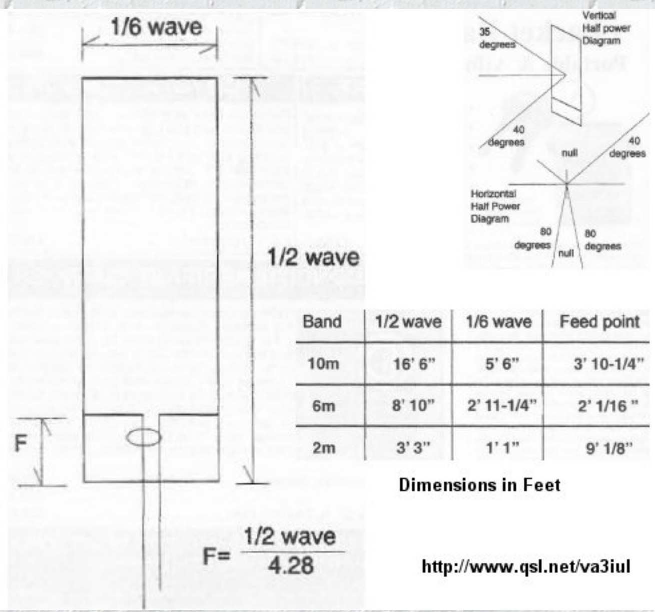
1/6 wave
1/2 wave
F
F= 1/2 wave / 4.28
Vertical
Half power
Diagram
35
degrees
40
degrees
null
40
degrees
Horizontal
Half Power
Diagram
80
degrees
null
80
degrees
http://www.qsl.net/va3iul

Band	1/2 wave	1/6 wave	Feed point
10m	16' 6"	5' 6"	3' 10-1/4"
6m	8' 10"	2' 11-1/4"	2' 1/16 "
2m	3' 3"	1' 1"	9' 1/8"

Dimensions in Feet

142 - VK2AAR Wire Antenna for 20m

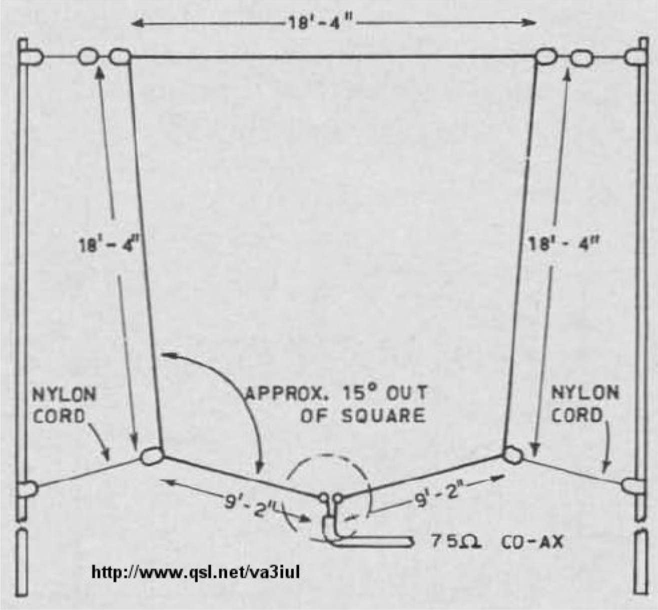
18'-4"
18'-4"
18'-4"
NYLON CORD
NYLON CORD
APPROX. 15° OUT OF SQUARE
9'-2"
9'-2"
75Ω CO-AX
http://www.qsl.net/va3iul

143 - 2-Elements Quad Antenna for 6m

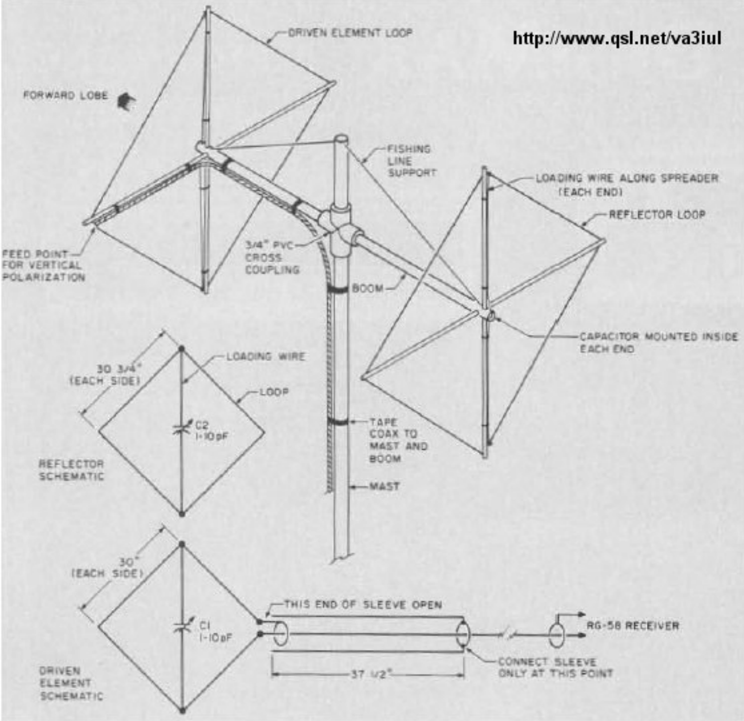
DRIVEN ELEMENT LOOP
http://www.qsl.net/va3iul
FORWARD LOBE
FISHING LINE SUPPORT
LOADING WIRE ALONG SPREADER (EACH END)
REFLECTOR LOOP
FEED POINT FOR VERTICAL POLARIZATION
3/4" PVC CROSS COUPLING
BOOM
CAPACITOR MOUNTED INSIDE EACH END
LOADING WIRE
30 3/4" (EACH SIDE)
LOOP
C2 1-10pF
REFLECTOR SCHEMATIC
TAPE COAX TO MAST AND BOOM
MAST
30" (EACH SIDE)
THIS END OF SLEEVE OPEN
C1 1-10pF
RG-58 RECEIVER
CONNECT SLEEVE ONLY AT THIS POINT
37 1/2"
DRIVEN ELEMENT SCHEMATIC

144 - Hula-Loop Bidirectional 6dB-Gain Antenna for 17m

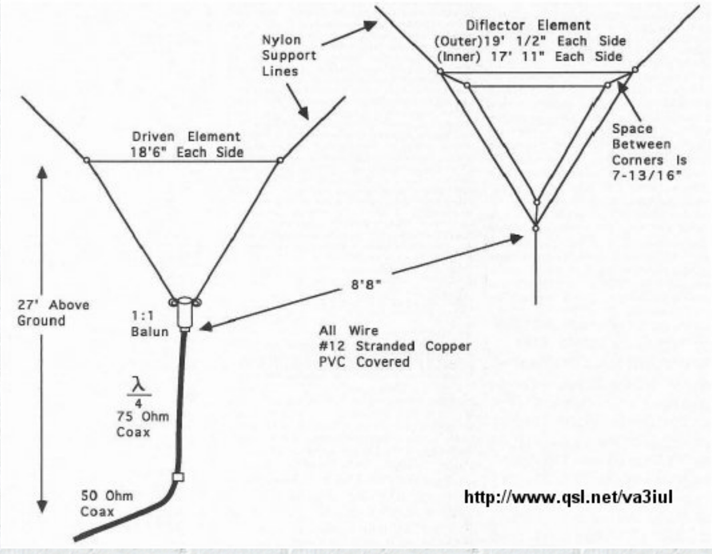
Nylon
Support
Lines
Diflector Element
(Outer)19' 1/2" Each Side
(Inner) 17' 11" Each Side
Driven Element
18'6" Each Side
Space
Between
Corners Is
7-13/16"
27' Above
Ground
1:1
Balun
8'8"
All Wire
#12 Stranded Copper
PVC Covered
λ
4
75 Ohm
Coax
50 Ohm
Coax
http://www.qsl.net/va3iul

145 - Moxon Rectangle Beam for 15m-10m

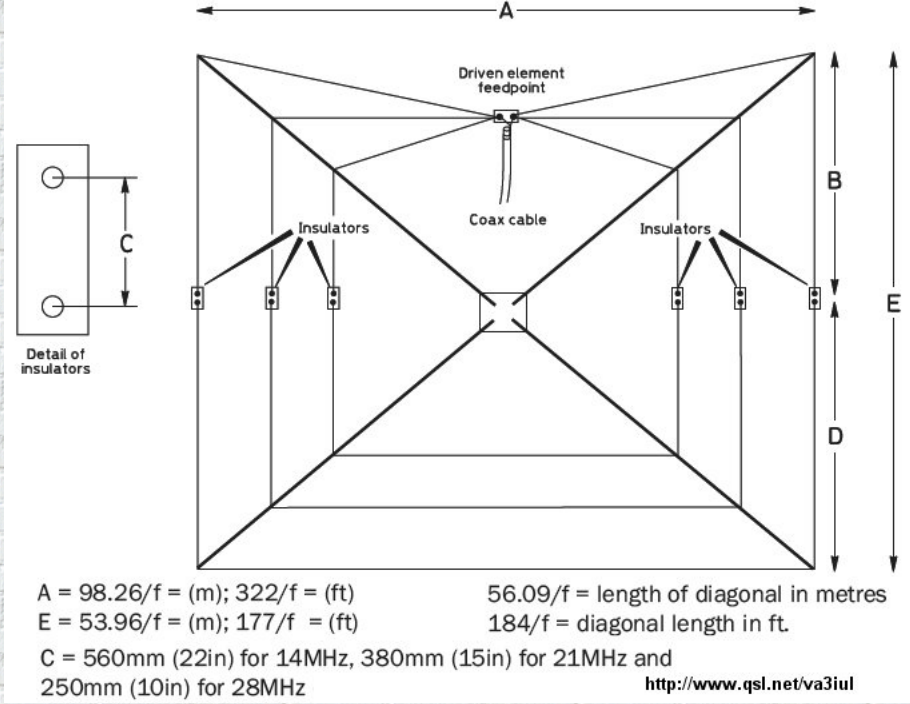
A
Driven element
feedpoint
B
C
Insulators
Coax cable
Insulators
E
Detail of
insulators
D
A = 98.26/f = (m); 322/f = (ft)
E = 53.96/f = (m); 177/f = (ft)
56.09/f = length of diagonal in metres
184/f = diagonal length in ft.
C = 560mm (22in) for 14MHz, 380mm (15in) for 21MHz and
250mm (10in) for 28MHz
http://www.qsl.net/va3iul

146 - Double-D Beam 4dB-Gain

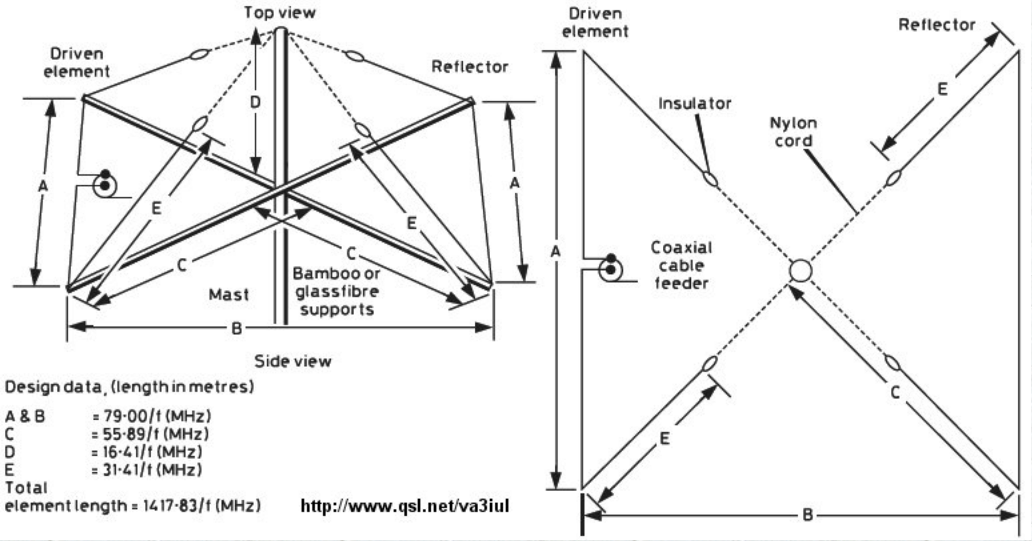
Top view
Driven element
Reflector
D
A
E
E
A
C
C
Mast
Bamboo or glassfibre supports
B
Side view
Driven element
Reflector
Insulator
Nylon cord
E
A
Coaxial cable feeder
C
E
B
http://www.qsl.net/va3iul

Design data, (length in metres)

A & B = 79·00/f (MHz)
C = 55·89/f (MHz)
D = 16·41/f (MHz)
E = 31·41/f (MHz)
Total element length = 1417·83/f (MHz)

147 - KE4PT OCEF All-Band Dipole

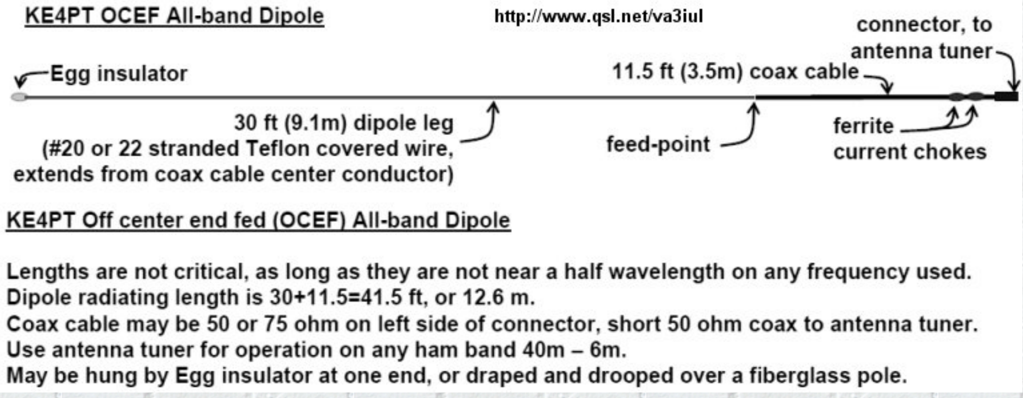
KE4PT OCEF All-band Dipole
http://www.qsl.net/va3iul
connector, to antenna tuner
Egg insulator
11.5 ft (3.5m) coax cable
30 ft (9.1m) dipole leg
(#20 or 22 stranded Teflon covered wire, extends from coax cable center conductor)
feed-point
ferrite current chokes

KE4PT Off center end fed (OCEF) All-band Dipole

Lengths are not critical, as long as they are not near a half wavelength on any frequency used.
Dipole radiating length is 30+11.5=41.5 ft, or 12.6 m.
Coax cable may be 50 or 75 ohm on left side of connector, short 50 ohm coax to antenna tuner.
Use antenna tuner for operation on any ham band 40m – 6m.
May be hung by Egg insulator at one end, or draped and drooped over a fiberglass pole.

148 - Wire Quad Antenna for 40m

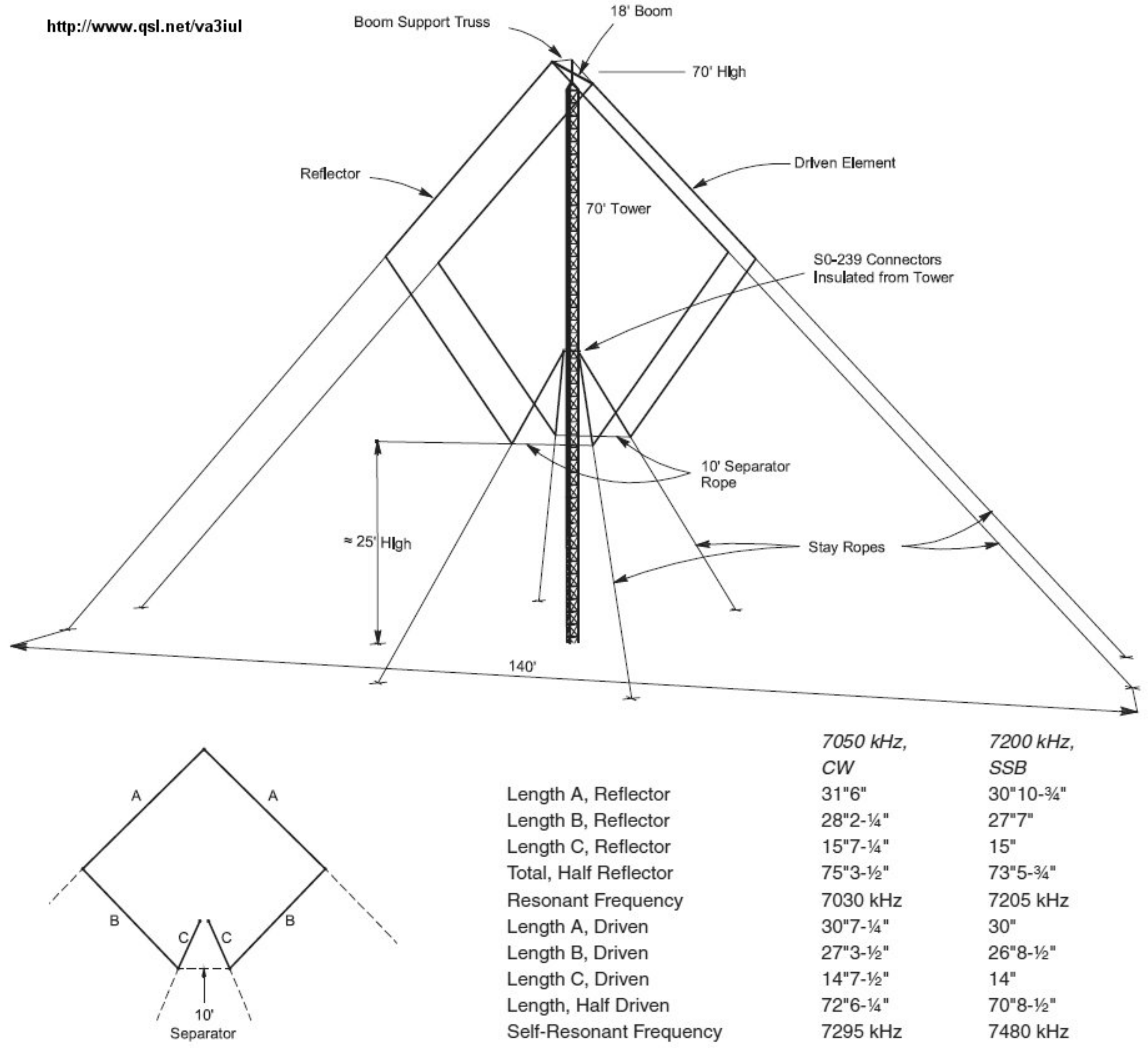
http://www.qsl.net/va3iul
Boom Support Truss
18' Boom
70' High
Reflector
Driven Element
70' Tower
S0-239 Connectors Insulated from Tower
10' Separator Rope
≈ 25' High
Stay Ropes
140'
A
A
B
C
C
B
10' Separator

	7050 kHz, CW	7200 kHz, SSB
Length A, Reflector	31"6"	30"10-¾"
Length B, Reflector	28"2-¼"	27"7"
Length C, Reflector	15"7-¼"	15"
Total, Half Reflector	75"3-½"	73"5-¾"
Resonant Frequency	7030 kHz	7205 kHz
Length A, Driven	30"7-¼"	30"
Length B, Driven	27"3-½"	26"8-½"
Length C, Driven	14"7-½"	14"
Length, Half Driven	72"6-¼"	70"8-½"
Self-Resonant Frequency	7295 kHz	7480 kHz

---

149 - Inclined Dipole Antenna for 80m, 40m

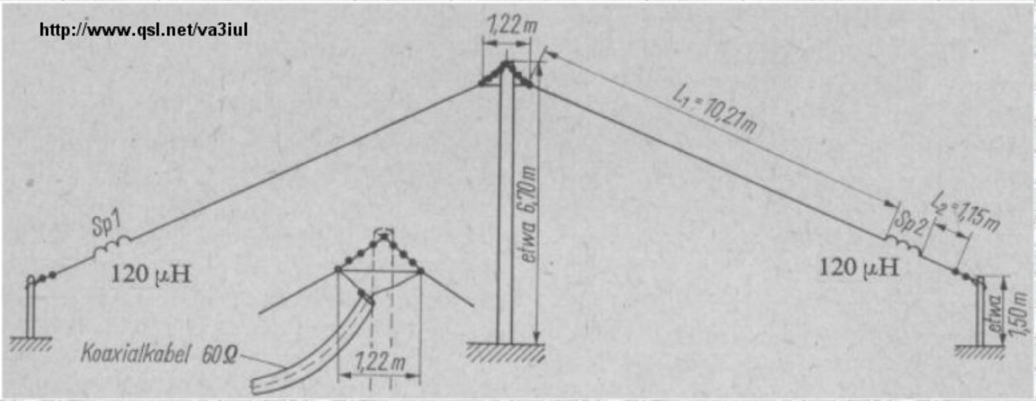
http://www.qsl.net/va3iul
1,22 m
L_1 = 10,21m
Sp1
120 µH
etwa 6,70 m
Sp2
L_2 = 1,15 m
120 µH
etwa 1,50 m
Koaxialkabel 60Ω
1,22 m

---

150 - Pyramidal Wire Antenna for 80m

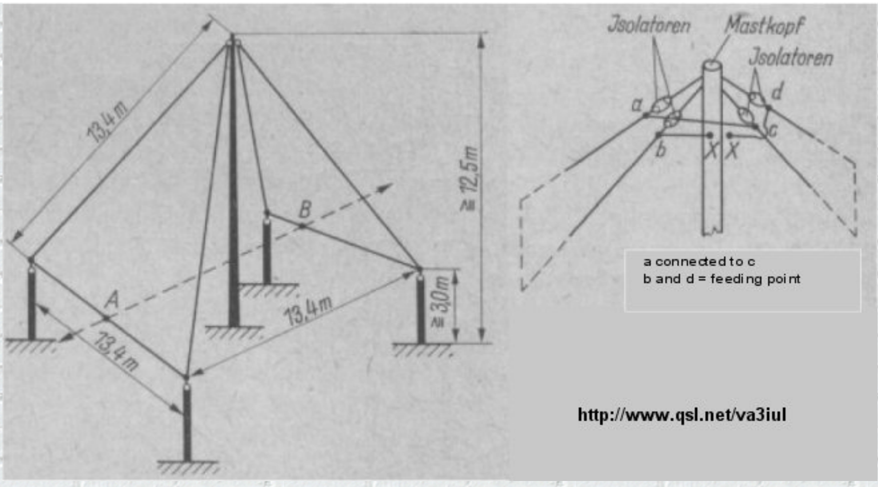
13,4 m
≥ 12,5 m
B
A
13,4 m
13,4 m
≥ 3,0 m
Jsolatoren
Mastkopf
Jsolatoren
a
b
c
d
X X
a connected to c
b and d = feeding point
http://www.qsl.net/va3iul

---

151 - Random Wire Antenna All Bands

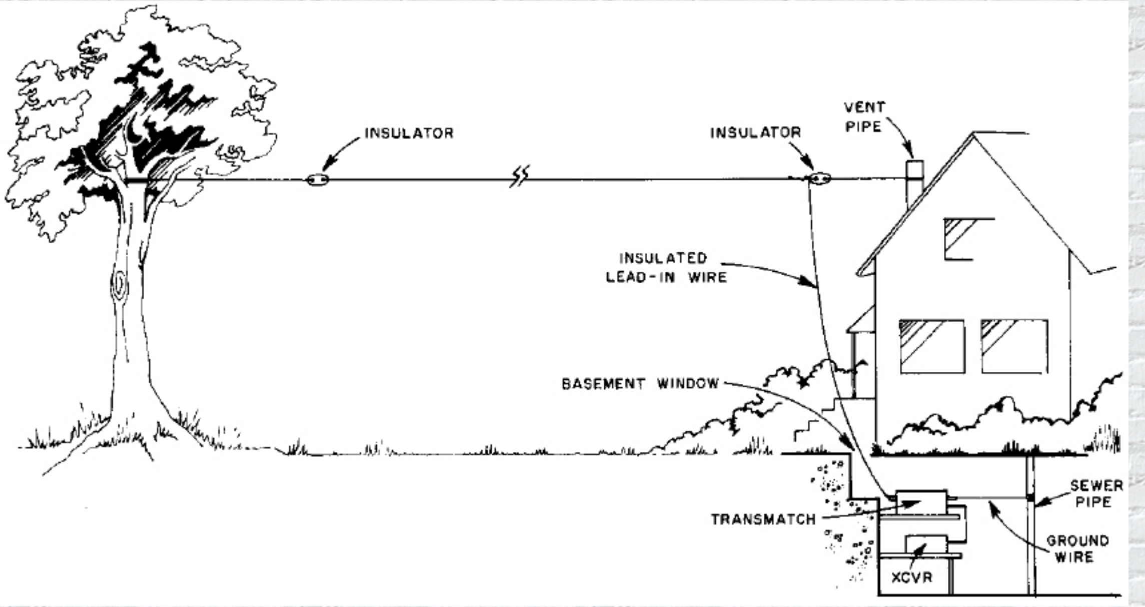
INSULATOR
INSULATOR
VENT PIPE
INSULATED LEAD-IN WIRE
BASEMENT WINDOW
SEWER PIPE
GROUND WIRE
TRANSMATCH
XCVR

---

152 - Multiband Dipole Antenna for 80m, 40m,15m, 10m

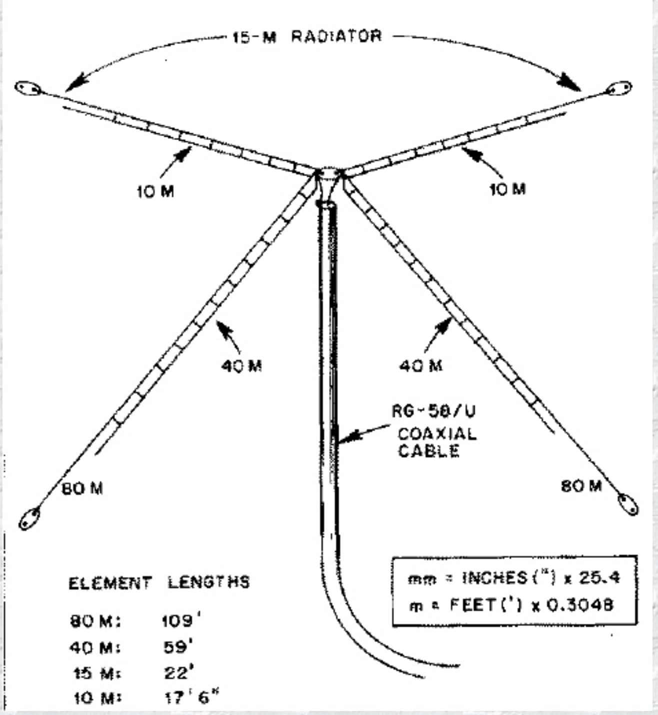
15-M RADIATOR
10 M
10 M
40 M
40 M
RG-58/U COAXIAL CABLE
80 M
80 M
mm = INCHES (") x 25.4
m = FEET (') x 0.3048
ELEMENT LENGTHS
80 M: 109'
40 M: 59'
15 M: 22'
10 M: 17' 6"

---

153 - Slim Jim Wire Antenna for 4m

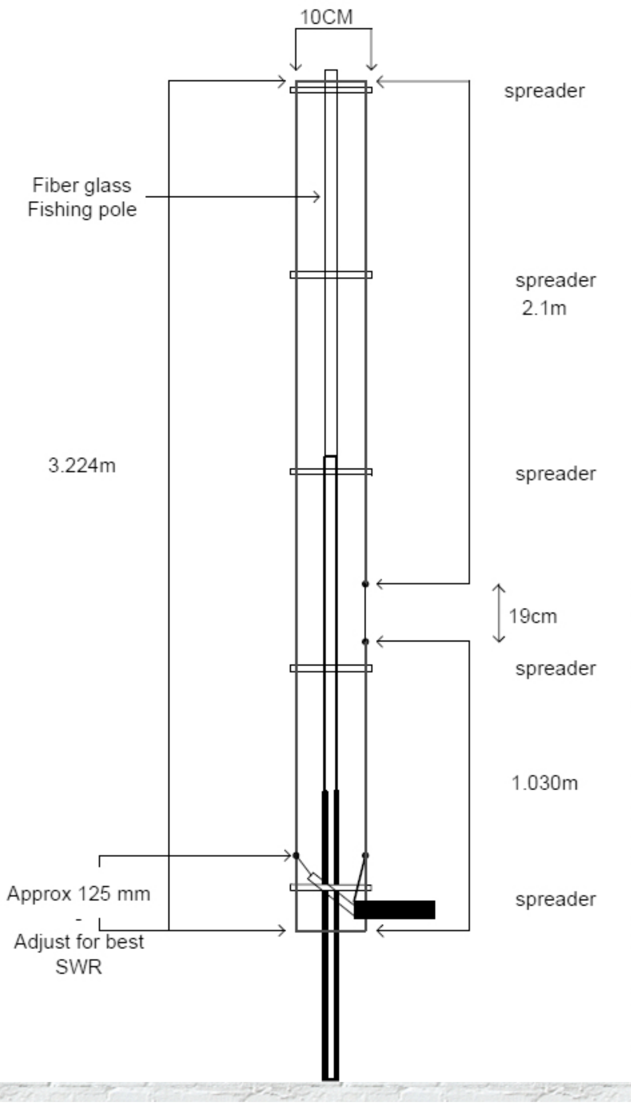
10CM
spreader
Fiber glass Fishing pole
spreader
2.1m
3.224m
spreader
19cm
spreader
1.030m
Approx 125 mm - Adjust for best SWR
spreader

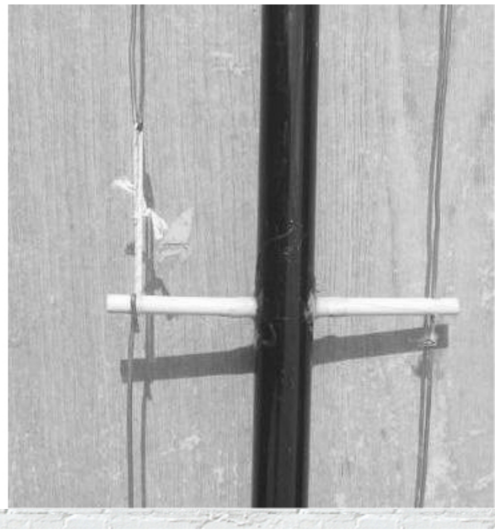

154 - Delta Loop for 6m

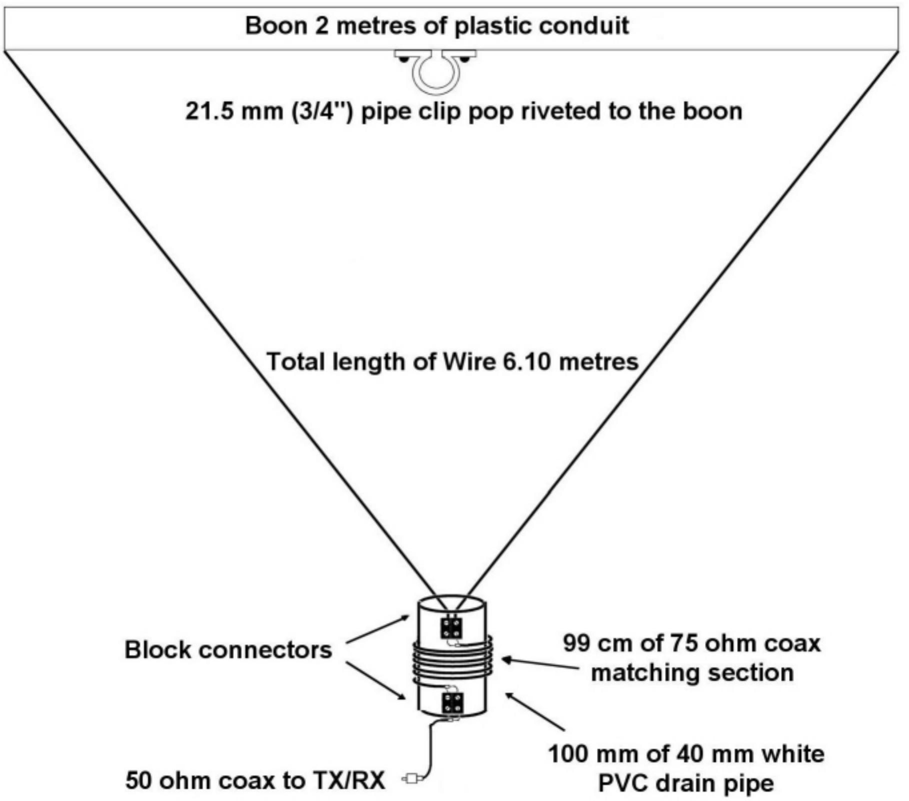
Boon 2 metres of plastic conduit
21.5 mm (3/4") pipe clip pop riveted to the boon
Total length of Wire 6.10 metres
Block connectors
99 cm of 75 ohm coax matching section
100 mm of 40 mm white PVC drain pipe
50 ohm coax to TX/RX

155 - Re-Configurable Antenna for 160m and 80m

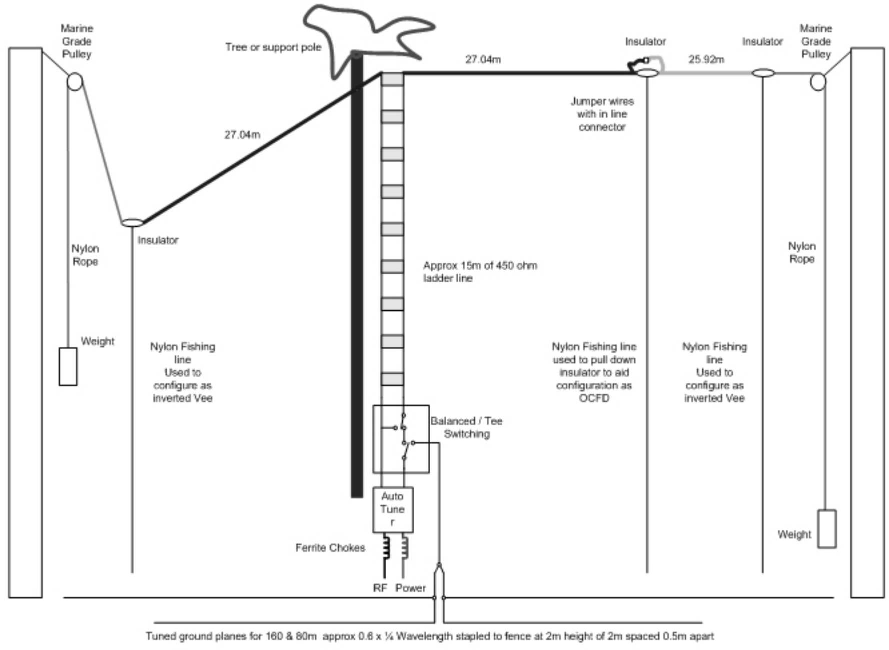
Marine Grade Pulley
Tree or support pole
27.04m
Insulator
25.92m
Insulator
Marine Grade Pulley
Jumper wires with in line connector
27.04m
Insulator
Nylon Rope
Approx 15m of 450 ohm ladder line
Nylon Rope
Weight
Nylon Fishing line Used to configure as inverted Vee
Nylon Fishing line used to pull down insulator to aid configuration as OCFD
Nylon Fishing line Used to configure as inverted Vee
Balanced / Tee Switching
Auto Tune r
Ferrite Chokes
Weight
RF Power
Tuned ground planes for 160 & 80m approx 0.6 x ¼ Wavelength stapled to fence at 2m height of 2m spaced 0.5m apart

156 - Very Low Frequency Inverted-L Antenna

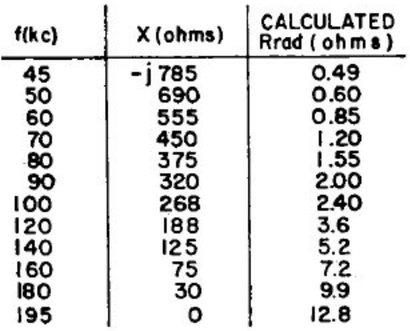

f(kc)	X (ohms)	CALCULATED Rrad (ohms)
45	-j 785	0.49
50	690	0.60
60	555	0.85
70	450	1.20
80	375	1.55
90	320	2.00
100	268	2.40
120	188	3.6
140	125	5.2
160	75	7.2
180	30	9.9
195	0	12.8

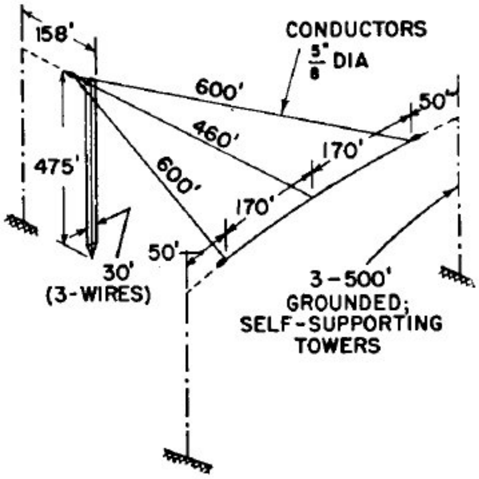
158'
CONDUCTORS
5/8" DIA
600'
460'
600'
50'
170'
170'
475'
50'
30'
(3-WIRES)
3-500'
GROUNDED;
SELF-SUPPORTING
TOWERS

157 - Reduced Size Half Sloper Antenna for 160m

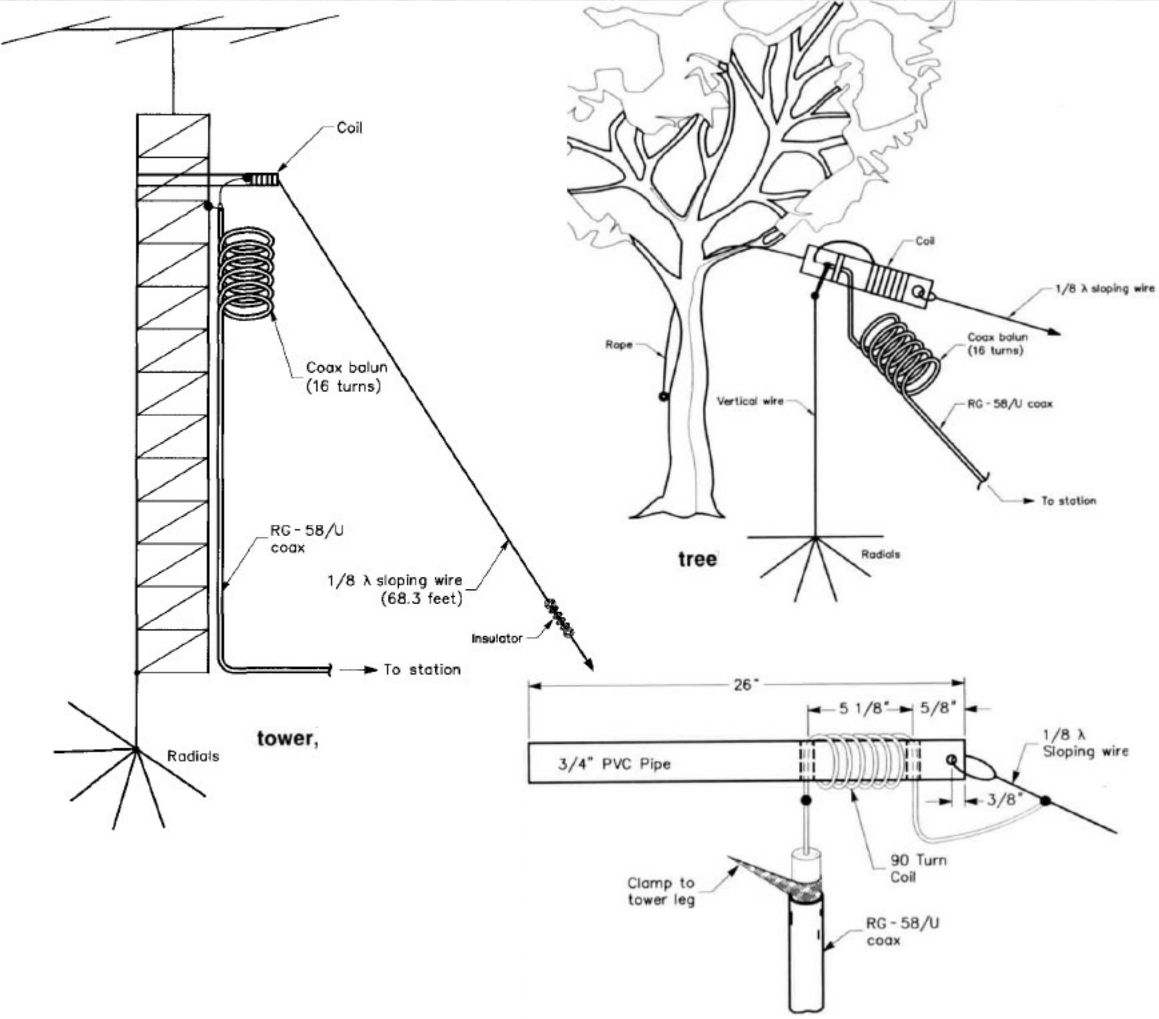
Coil
Coax balun
(16 turns)
RG-58/U
coax
1/8 λ sloping wire
(68.3 feet)
Insulator
To station
Radials
tower,
Coil
1/8 λ sloping wire
Rope
Coax balun
(16 turns)
Vertical wire
RG-58/U coax
To station
tree
Radials
26"
5 1/8"
5/8"
3/4" PVC Pipe
1/8 λ
Sloping wire
3/8"
90 Turn
Coil
Clamp to
tower leg
RG-58/U
coax

158 - Tree-Mounted HF Antenna

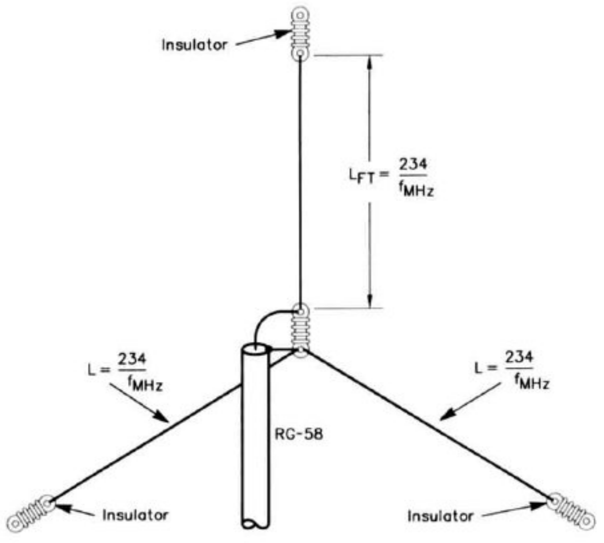
Insulator
L_FT = 234 / f_MHz
L = 234 / f_MHz
L = 234 / f_MHz
RG-58
Insulator
Insulator

---

159 - Multiband Vertical Antenna for 80m, 40m, 20m

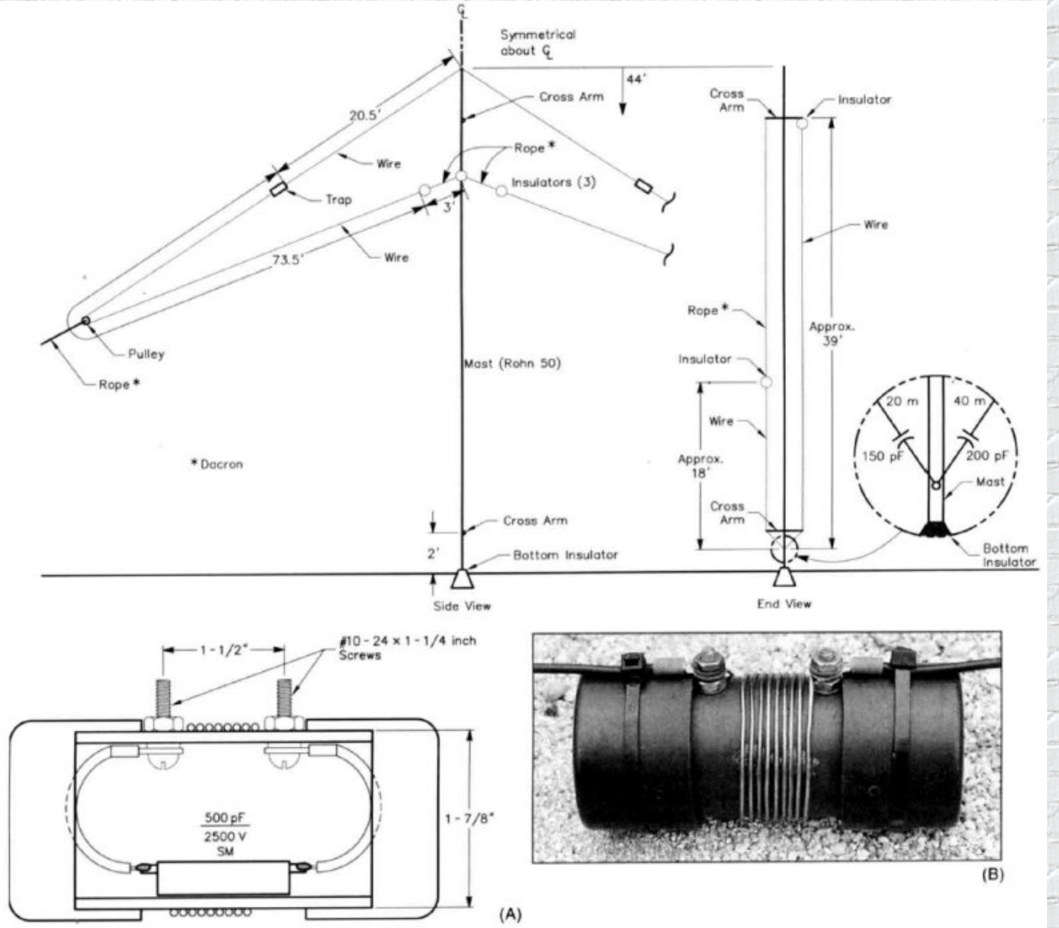
℄
Symmetrical about ℄
44'
Cross Arm
20.5'
Wire
Rope *
Insulators (3)
Trap
3'
73.5'
Wire
Pulley
Rope *
Mast (Rohn 50)
* Dacron
Cross Arm
2'
Bottom Insulator
Side View
Cross Arm
Insulator
Wire
Rope *
Approx. 39'
Insulator
Wire
Approx. 18'
Cross Arm
20 m
40 m
150 pF
200 pF
Mast
Bottom Insulator
End View
1-1/2"
#10-24 x 1-1/4 inch Screws
500 pF 2500 V SM
1-7/8"
(A)
(B)

---

160 - Marconi Antenna for 136 kHz

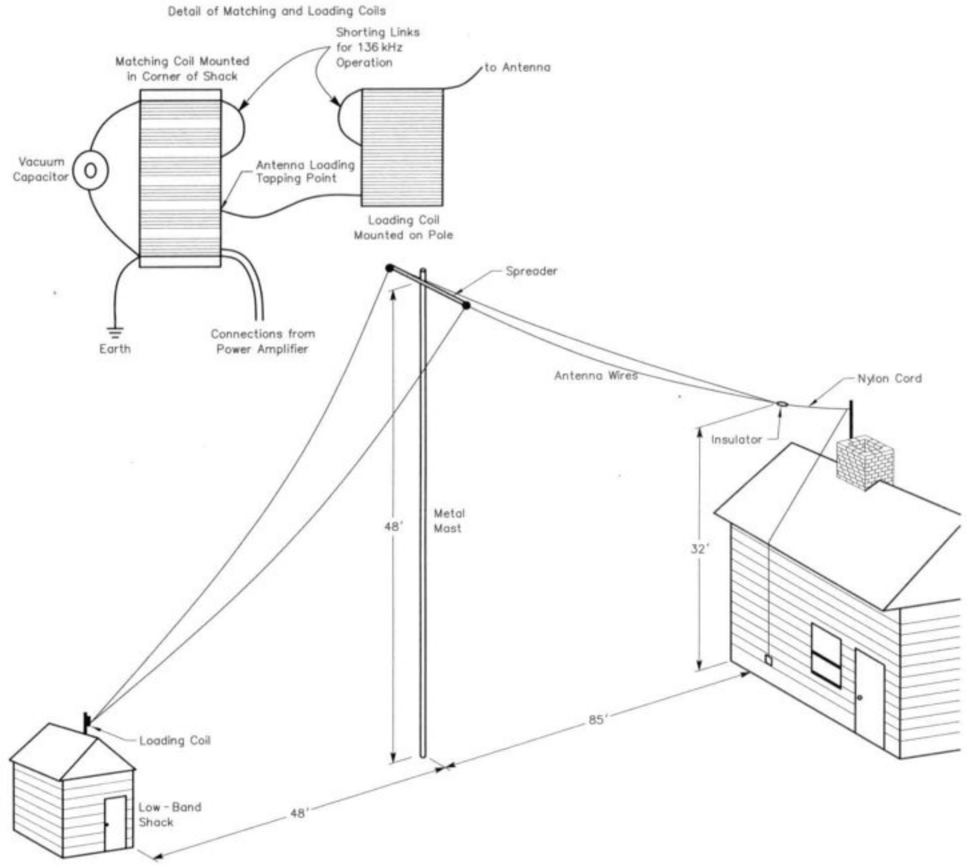
Detail of Matching and Loading Coils
Matching Coil Mounted in Corner of Shack
Shorting Links for 136 kHz Operation
to Antenna
Vacuum Capacitor
Antenna Loading Tapping Point
Loading Coil Mounted on Pole
Earth
Connections from Power Amplifier
Spreader
Antenna Wires
Nylon Cord
Insulator
48'
Metal Mast
32'
85'
Loading Coil
Low - Band Shack
48'

---

161 - Simple Killer Antenna for 40m

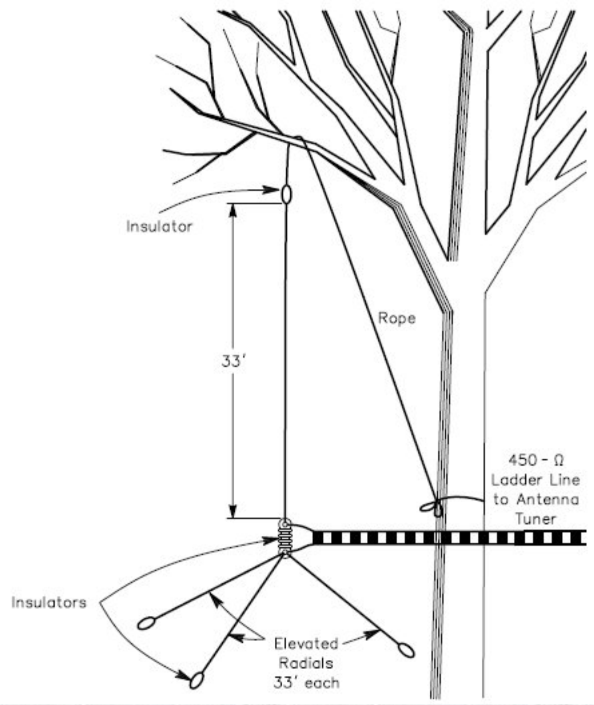
Insulator
33'
Rope
450 - Ω Ladder Line to Antenna Tuner
Insulators
Elevated Radials 33' each

---

162 - Stub-Directed V Antenna for 80m

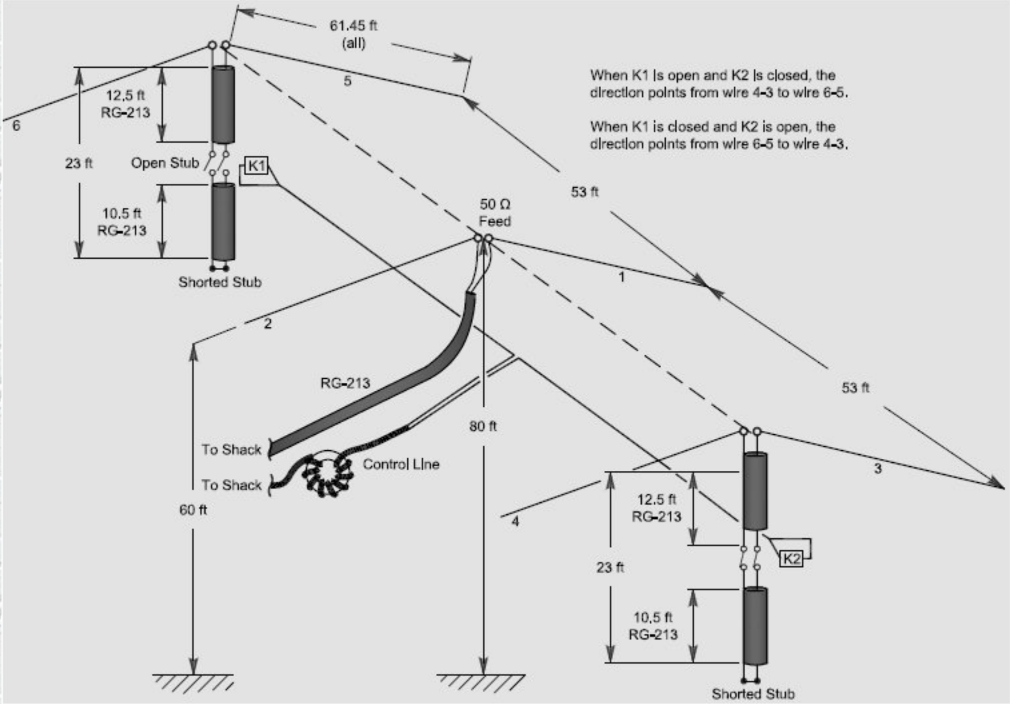
61.45 ft
(all)
5
6
12.5 ft
RG-213
23 ft
Open Stub
K1
10.5 ft
RG-213
Shorted Stub
When K1 is open and K2 is closed, the direction points from wire 4-3 to wire 6-5.
When K1 is closed and K2 is open, the direction points from wire 6-5 to wire 4-3.
53 ft
50 Ω
Feed
1
2
RG-213
To Shack
To Shack
Control Line
80 ft
60 ft
53 ft
3
4
12.5 ft
RG-213
K2
23 ft
10.5 ft
RG-213
Shorted Stub

163 - KT0NY Over-and-Under DX Antenna for 20m

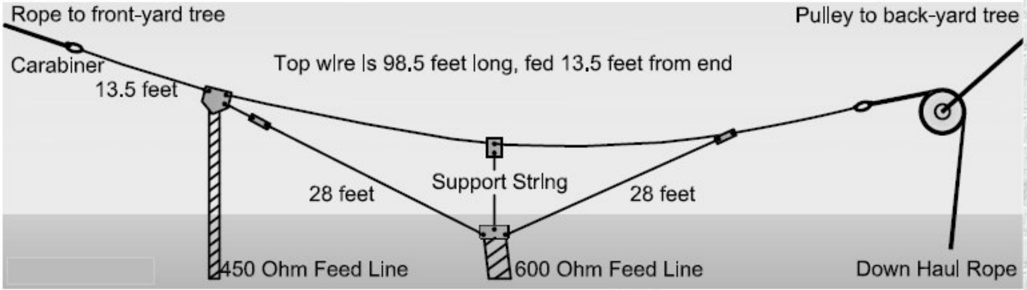
Rope to front-yard tree
Pulley to back-yard tree
Carabiner
13.5 feet
Top wire is 98.5 feet long, fed 13.5 feet from end
28 feet
Support String
28 feet
450 Ohm Feed Line
600 Ohm Feed Line
Down Haul Rope

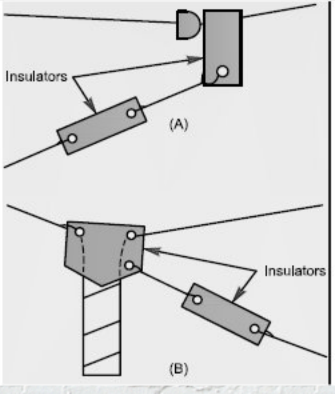
Insulators
(A)
Insulators
(B)

164 - Horizontal Loop Antennas

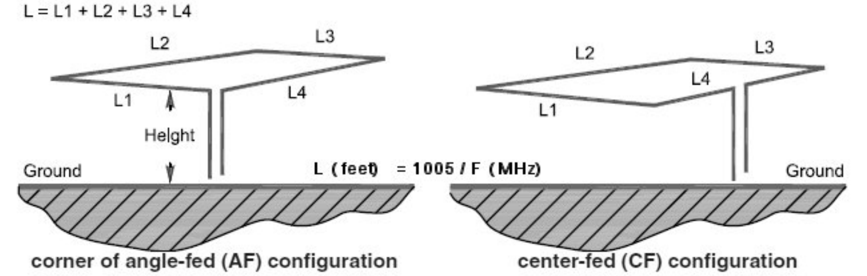
L = L1 + L2 + L3 + L4
L2
L3
L1
L4
Height
Ground
L (feet) = 1005 / F (MHz)
L2
L3
L4
L1
Ground
corner of angle-fed (AF) configuration
center-fed (CF) configuration

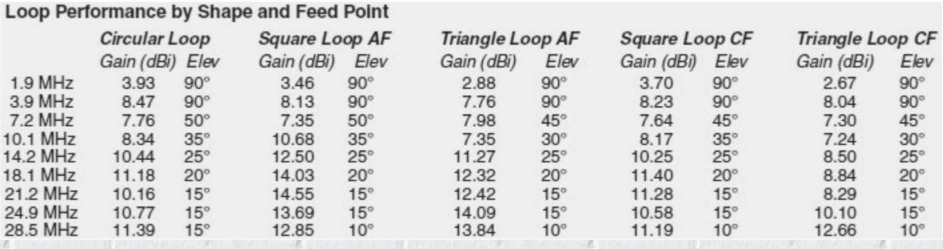
Loop Performance by Shape and Feed Point

	Circular Loop		Square Loop AF		Triangle Loop AF		Square Loop CF		Triangle Loop CF	
	Gain (dBi)	Elev	Gain (dBi)	Elev	Gain (dBi)	Elev	Gain (dBi)	Elev	Gain (dBi)	Elev
1.9 MHz	3.93	90°	3.46	90°	2.88	90°	3.70	90°	2.67	90°
3.9 MHz	8.47	90°	8.13	90°	7.76	90°	8.23	90°	8.04	90°
7.2 MHz	7.76	50°	7.35	50°	7.98	45°	7.64	45°	7.30	45°
10.1 MHz	8.34	35°	10.68	35°	7.35	30°	8.17	35°	7.24	30°
14.2 MHz	10.44	25°	12.50	25°	11.27	25°	10.25	25°	8.50	25°
18.1 MHz	11.18	20°	14.03	20°	12.32	20°	11.40	20°	8.84	20°
21.2 MHz	10.16	15°	14.55	15°	12.42	15°	11.28	15°	8.29	15°
24.9 MHz	10.77	15°	13.69	15°	14.09	15°	10.58	15°	10.10	15°
28.5 MHz	11.39	15°	12.85	10°	13.84	10°	11.19	10°	12.66	10°

---

165 - Ribbon J-Pole for 2m

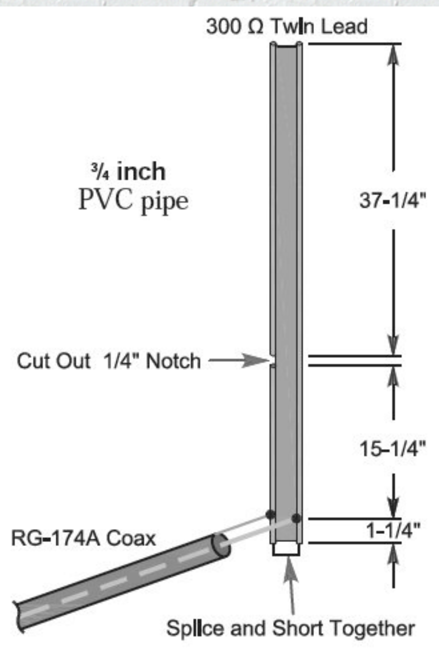
300 Ω Twin Lead
¾ inch PVC pipe
37-1/4"
Cut Out 1/4" Notch
15-1/4"
1-1/4"
RG-174A Coax
Splice and Short Together

---

166 - Dual Band Ribbon J-Pole for 2m, 70cm

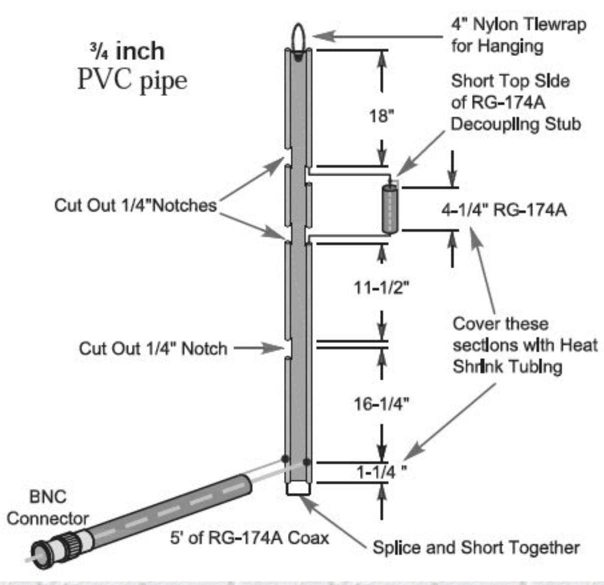
¾ inch
PVC pipe
4" Nylon Tiewrap for Hanging
18"
Short Top Side of RG-174A Decoupling Stub
Cut Out 1/4"Notches
4-1/4" RG-174A
11-1/2"
Cover these sections with Heat Shrink Tubing
Cut Out 1/4" Notch
16-1/4"
1-1/4 "
BNC Connector
5' of RG-174A Coax
Splice and Short Together

167 - Square Vertical Loop Antenna for 40m

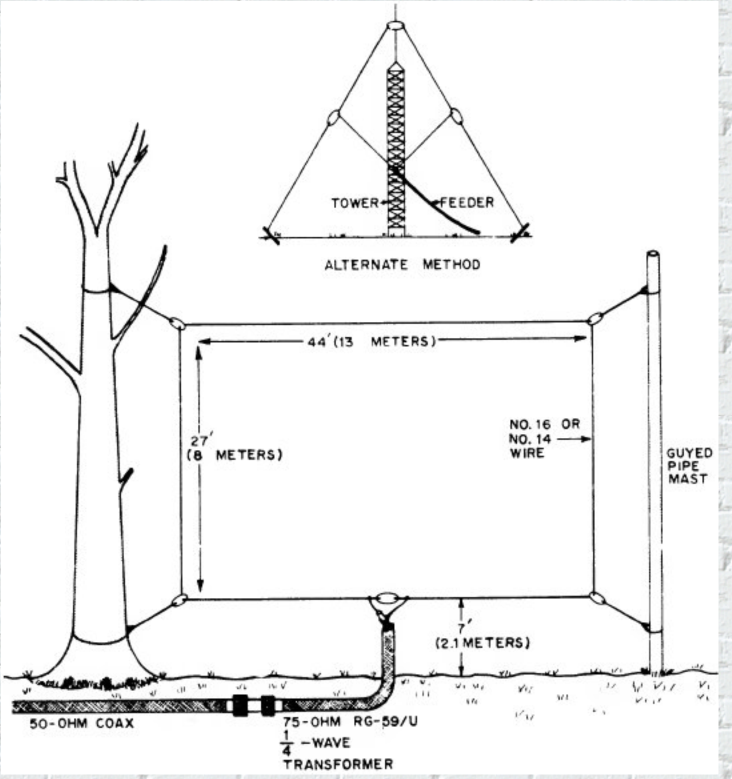
TOWER
FEEDER
ALTERNATE METHOD
44' (13 METERS)
27' (8 METERS)
NO. 16 OR NO. 14 WIRE
GUYED PIPE MAST
7' (2.1 METERS)
50-OHM COAX
75-OHM RG-59/U
1/4 -WAVE TRANSFORMER

168 - Tri-Band Quad Antenna for 20m, 15m, 10m

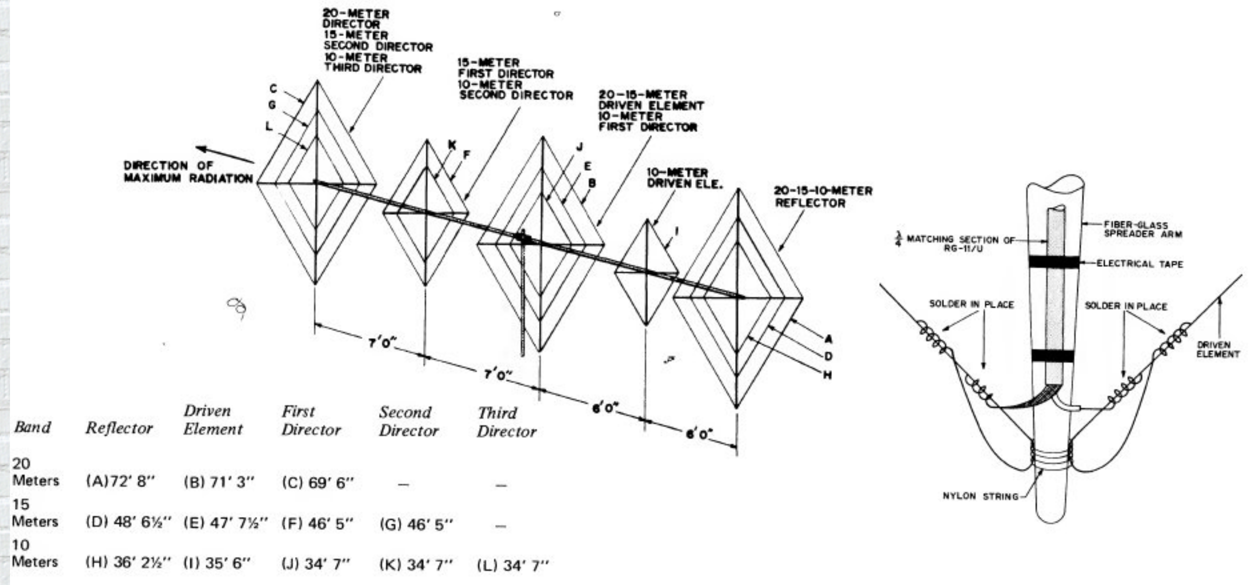
20-METER DIRECTOR
15-METER SECOND DIRECTOR
10-METER THIRD DIRECTOR
15-METER FIRST DIRECTOR
10-METER SECOND DIRECTOR
20-15-METER DRIVEN ELEMENT
10-METER FIRST DIRECTOR
10-METER DRIVEN ELE.
20-15-10-METER REFLECTOR
DIRECTION OF MAXIMUM RADIATION
C
G
L
K
F
J
E
B
I
A
D
H
7′0″
7′0″
6′0″
6′0″
¾ MATCHING SECTION OF RG-11/U
FIBER-GLASS SPREADER ARM
ELECTRICAL TAPE
SOLDER IN PLACE
SOLDER IN PLACE
DRIVEN ELEMENT
NYLON STRING

Band	Reflector	Driven Element	First Director	Second Director	Third Director
20 Meters	(A)72′ 8″	(B) 71′ 3″	(C) 69′ 6″	–	–
15 Meters	(D) 48′ 6½″	(E) 47′ 7½″	(F) 46′ 5″	(G) 46′ 5″	–
10 Meters	(H) 36′ 2½″	(I) 35′ 6″	(J) 34′ 7″	(K) 34′ 7″	(L) 34′ 7″

---

169 - 3D Quad Antenna for 80m, 40m, 20m, 15m, 10m

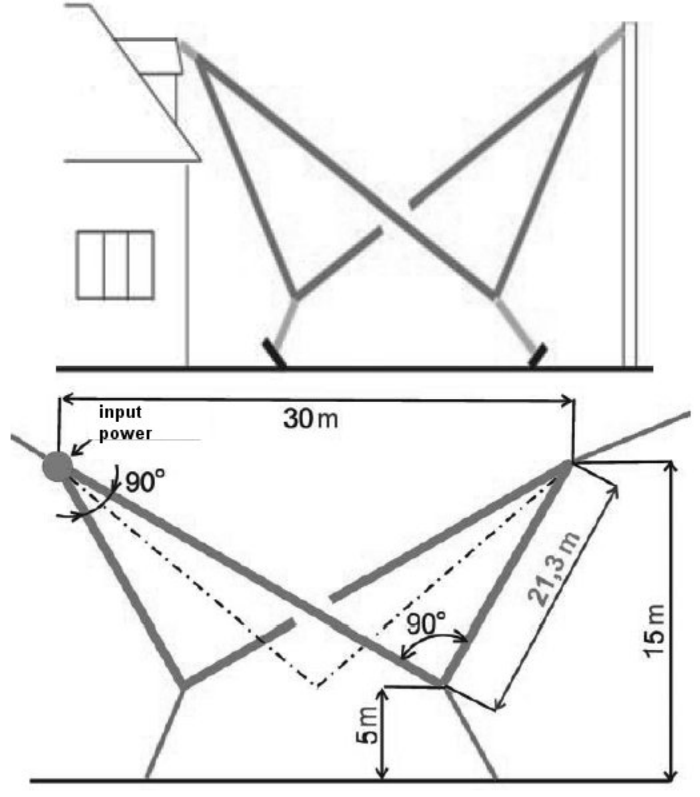
input power
30 m
90°
90°
21,3 m
15 m
5 m

---

170 - Sloping Wire Antenna for 30m, 20m, 17m, 15m, 12m, 10m

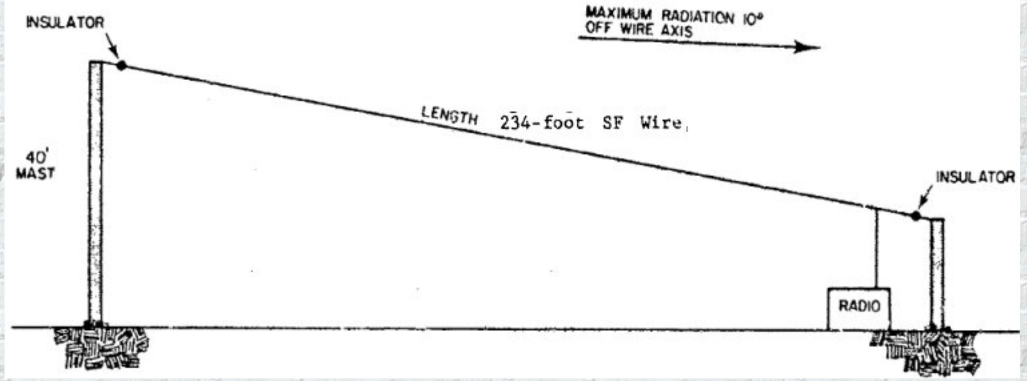
INSULATOR
MAXIMUM RADIATION 10°
OFF WIRE AXIS
LENGTH 234-foot SF Wire,
40'
MAST
INSULATOR
RADIO

171 - Broadband Dipole Antenna with Coaxial Resonator for 80m

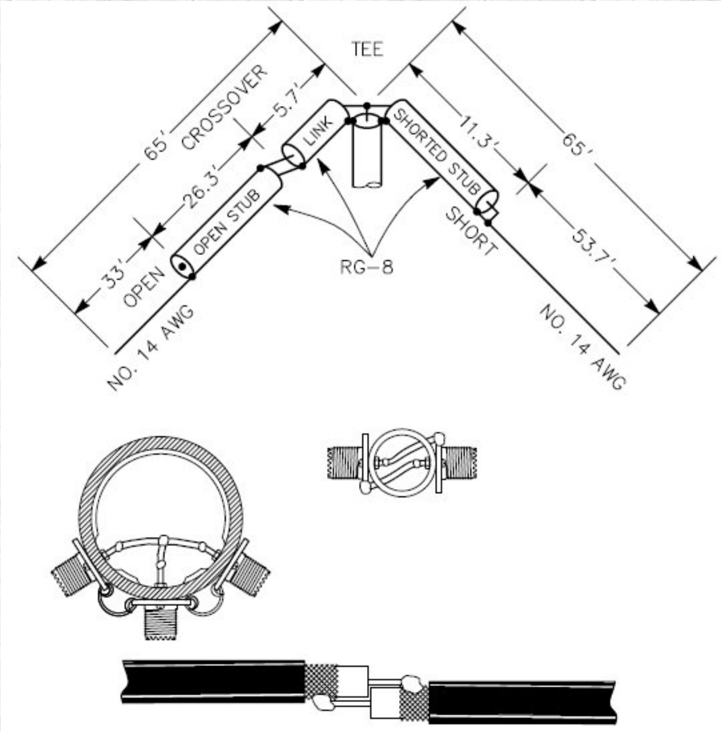
TEE
65' CROSSOVER
5.7'
26.3'
33'
LINK
OPEN STUB
OPEN
NO. 14 AWG
RG-8
SHORTED STUB
SHORT
11.3'
65'
53.7'
NO. 14 AWG

172 - Resonant Feedline Dipole Antenna for 80m

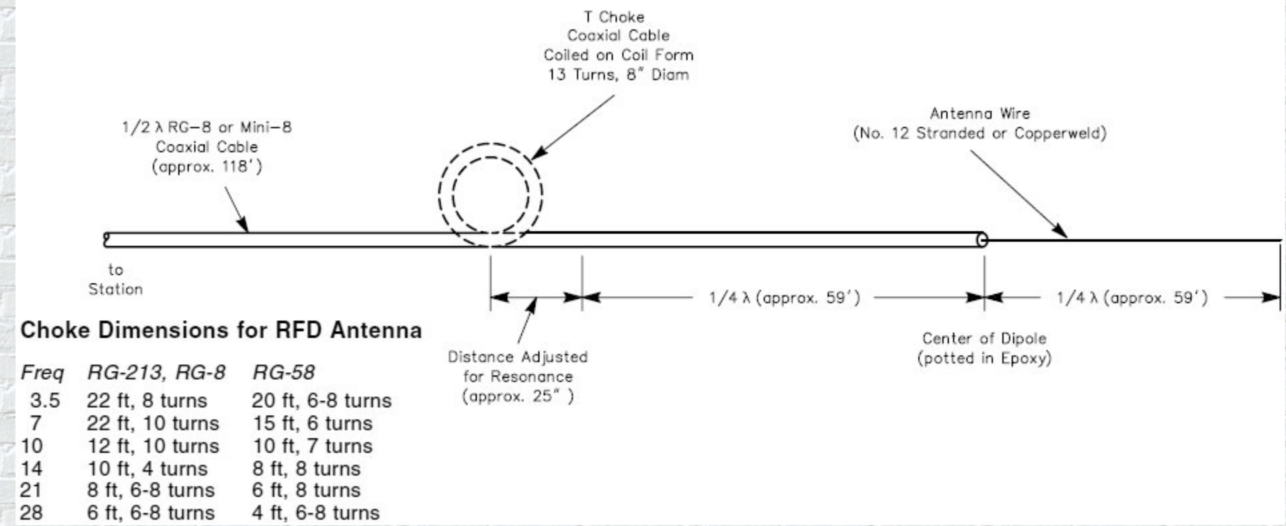
T Choke
Coaxial Cable
Coiled on Coil Form
13 Turns, 8" Diam
1/2 λ RG-8 or Mini-8
Coaxial Cable
(approx. 118')
Antenna Wire
(No. 12 Stranded or Copperweld)
to
Station
1/4 λ (approx. 59')
1/4 λ (approx. 59')
Distance Adjusted
for Resonance
(approx. 25")
Center of Dipole
(potted in Epoxy)

Choke Dimensions for RFD Antenna

Freq	*RG-213, RG-8*	*RG-58*
3.5	22 ft, 8 turns	20 ft, 6-8 turns
7	22 ft, 10 turns	15 ft, 6 turns
10	12 ft, 10 turns	10 ft, 7 turns
14	10 ft, 4 turns	8 ft, 8 turns
21	8 ft, 6-8 turns	6 ft, 8 turns
28	6 ft, 6-8 turns	4 ft, 6-8 turns

173 - Dual-Band Loading Wire Antenna for 80m, 30m

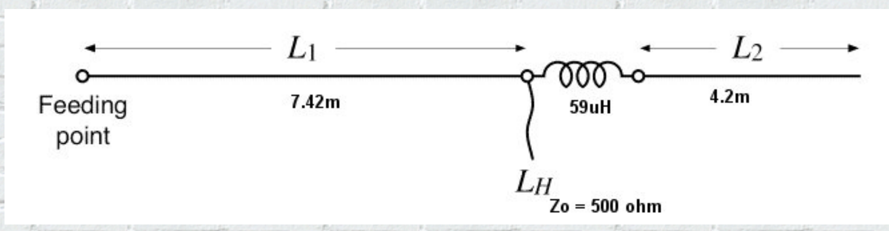
L_1
Feeding point
7.42m
59uH
L_2
4.2m
L_H
Zo = 500 ohm

---

174 - Stub Matching Antennas

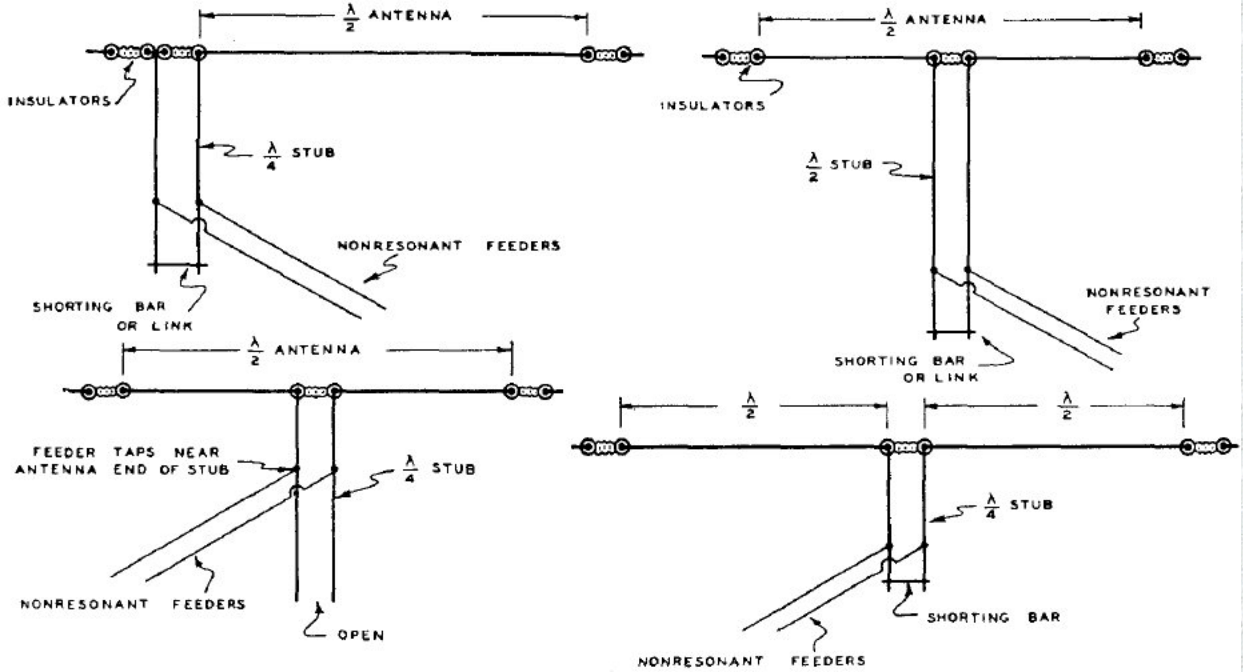
$\frac{\lambda}{2}$ ANTENNA
INSULATORS
$\frac{\lambda}{4}$ STUB
NONRESONANT FEEDERS
SHORTING BAR OR LINK
$\frac{\lambda}{2}$ ANTENNA
INSULATORS
$\frac{\lambda}{2}$ STUB
NONRESONANT FEEDERS
SHORTING BAR OR LINK
$\frac{\lambda}{2}$ ANTENNA
FEEDER TAPS NEAR ANTENNA END OF STUB
$\frac{\lambda}{4}$ STUB
NONRESONANT FEEDERS
OPEN
$\frac{\lambda}{2}$
$\frac{\lambda}{2}$
$\frac{\lambda}{4}$ STUB
SHORTING BAR
NONRESONANT FEEDERS

---

175 - J-Style Vertical Wire Antenna for 10m

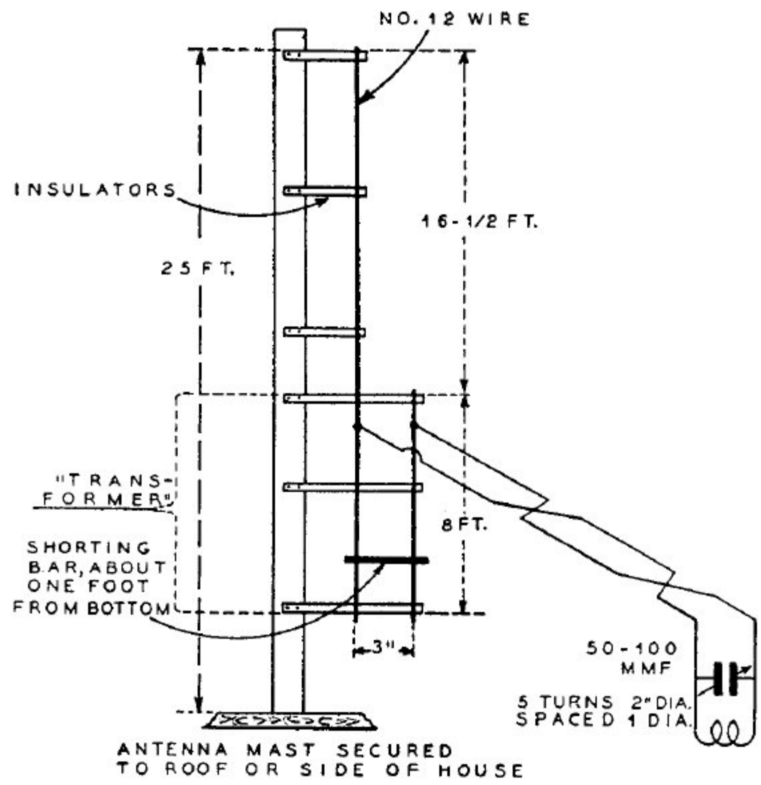
NO. 12 WIRE
INSULATORS
25 FT.
16-1/2 FT.
"TRANS-FORMER"
8 FT.
SHORTING BAR, ABOUT ONE FOOT FROM BOTTOM
3"
50-100 MMF
5 TURNS 2" DIA. SPACED 1 DIA.
ANTENNA MAST SECURED TO ROOF OR SIDE OF HOUSE

---

176 - Dual Band Vertical with Zepp Feeders for 40m, 20m

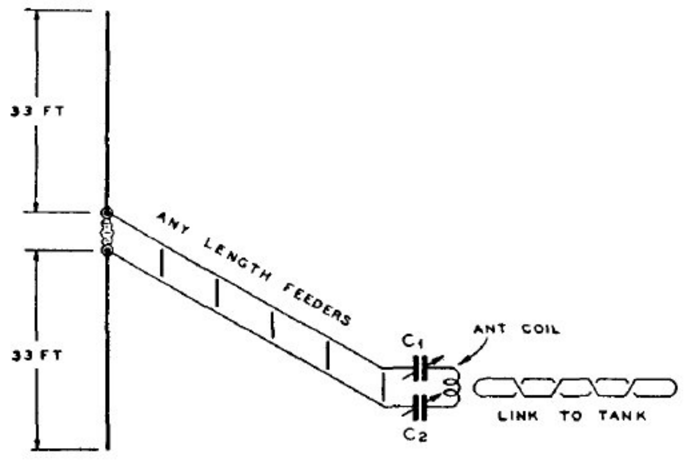
33 FT
33 FT
ANY LENGTH FEEDERS
C1
ANT COIL
LINK TO TANK
C2

---

177 - RCA Double Doublet for 40m to 12m

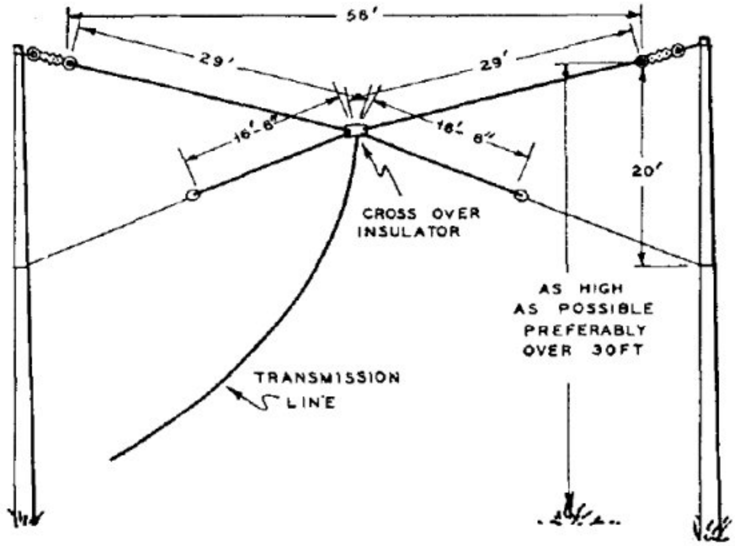
58'
29'
29'
16'-8"
16'-8"
20'
CROSS OVER INSULATOR
AS HIGH AS POSSIBLE PREFERABLY OVER 30FT
TRANSMISSION LINE

178 - RCA Spiderweb Antenna for 40m to 6m

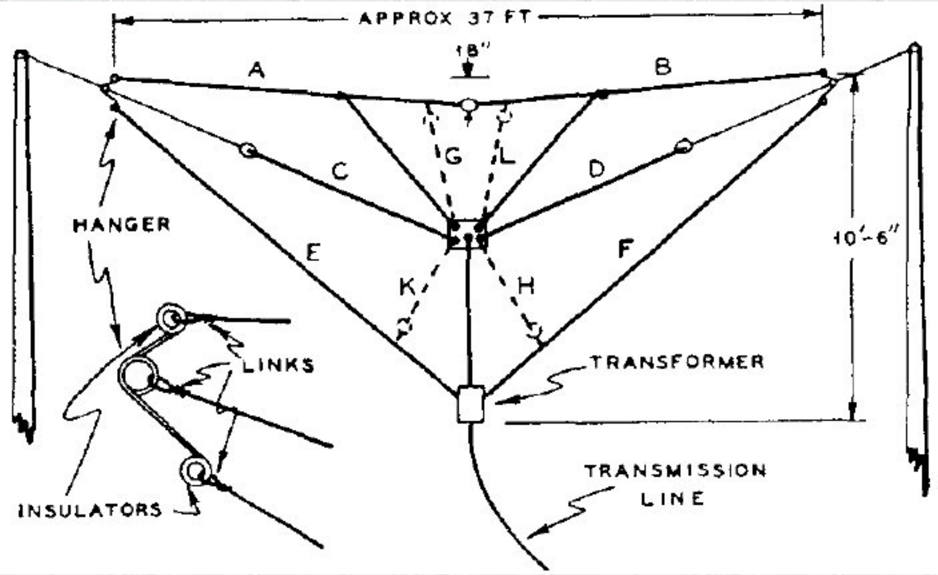
APPROX 37 FT
18"
A
B
G
L
C
D
HANGER
E
F
10'-6"
K
H
LINKS
TRANSFORMER
TRANSMISSION LINE
INSULATORS

179 - Folded Dipole with Shorted Straps

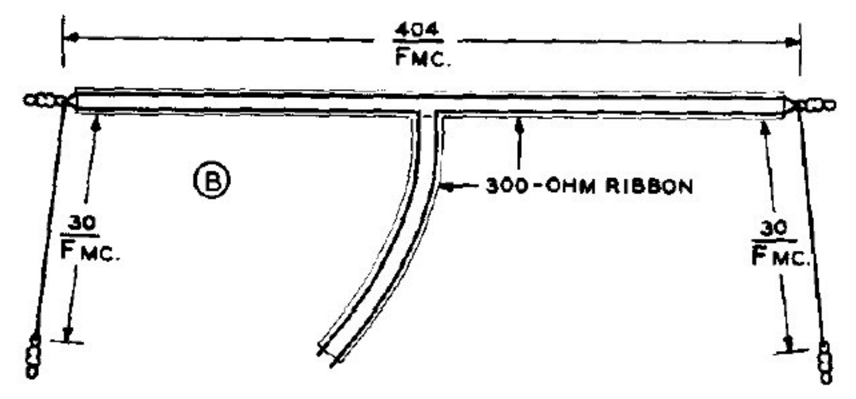
404/FMC.
B
300-OHM RIBBON
30/FMC.
30/FMC.

180 - Twin-Lead Marconi Antenna for 160m, 80m

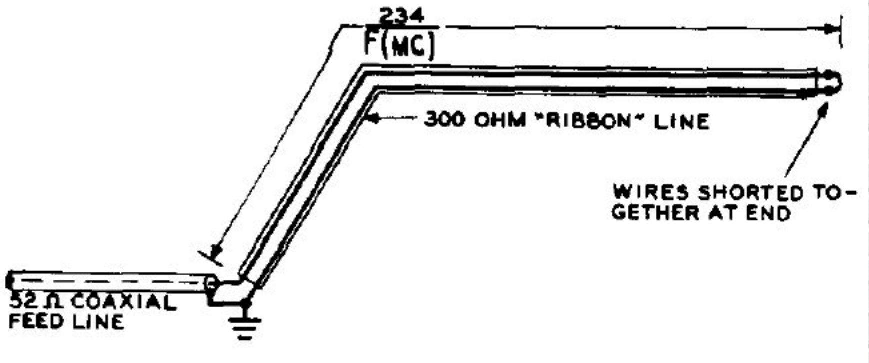
234
F(MC)
300 OHM "RIBBON" LINE
WIRES SHORTED TOGETHER AT END
52 Ω COAXIAL FEED LINE

---

181 - Broadband Antenna Quarter-Wave Balun for 80m

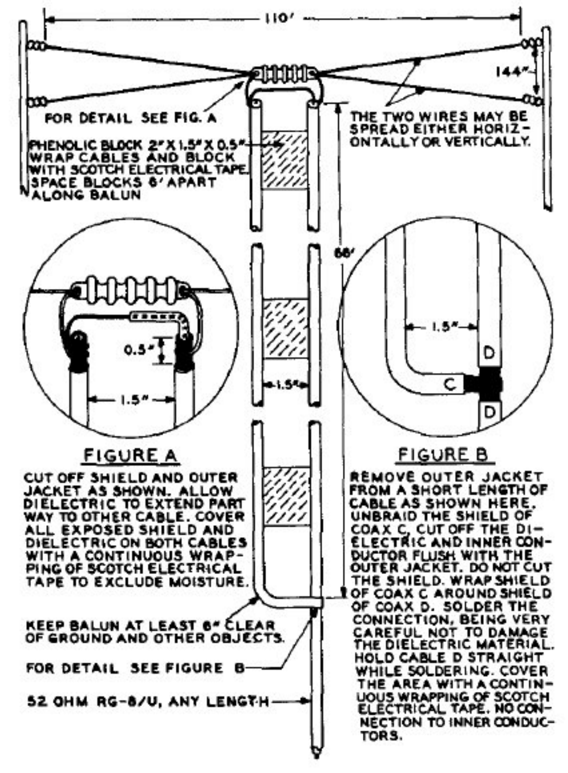
110'
144"
FOR DETAIL SEE FIG. A
THE TWO WIRES MAY BE SPREAD EITHER HORIZONTALLY OR VERTICALLY.
PHENOLIC BLOCK 2"X 1.5"X 0.5" WRAP CABLES AND BLOCK WITH SCOTCH ELECTRICAL TAPE. SPACE BLOCKS 6' APART ALONG BALUN
66'
0.5"
1.5"
1.5"
1.5"
C
D
D
FIGURE A
FIGURE B
KEEP BALUN AT LEAST 6" CLEAR OF GROUND AND OTHER OBJECTS.
FOR DETAIL SEE FIGURE B
52 OHM RG-8/U, ANY LENGTH

FIGURE A

CUT OFF SHIELD AND OUTER JACKET AS SHOWN. ALLOW DIELECTRIC TO EXTEND PART WAY TO OTHER CABLE. COVER ALL EXPOSED SHIELD AND DIELECTRIC ON BOTH CABLES WITH A CONTINUOUS WRAPPING OF SCOTCH ELECTRICAL TAPE TO EXCLUDE MOISTURE.

FIGURE B

REMOVE OUTER JACKET FROM A SHORT LENGTH OF CABLE AS SHOWN HERE. UNBRAID THE SHIELD OF COAX C, CUT OFF THE DIELECTRIC AND INNER CONDUCTOR FLUSH WITH THE OUTER JACKET. DO NOT CUT THE SHIELD. WRAP SHIELD OF COAX C AROUND SHIELD OF COAX D. SOLDER THE CONNECTION, BEING VERY CAREFUL NOT TO DAMAGE THE DIELECTRIC MATERIAL. HOLD CABLE D STRAIGHT WHILE SOLDERING. COVER THE AREA WITH A CONTINUOUS WRAPPING OF SCOTCH ELECTRICAL TAPE. NO CONNECTION TO INNER CONDUCTORS.

DIMENSIONS SHOWN HERE ARE FOR THE 80 METER BAND. THIS ANTENNA MAY BE BUILT FOR OTHER BANDS BY USING DIMENSIONS THAT ARE MULTIPLES OR SUBMULTIPLES OF THE DIMENSIONS SHOWN. BALUN SPACING IS 1.5" ON ALL BANDS.

---

182 - Three-Quarter-Wave Folded Doublet for Dual-Band

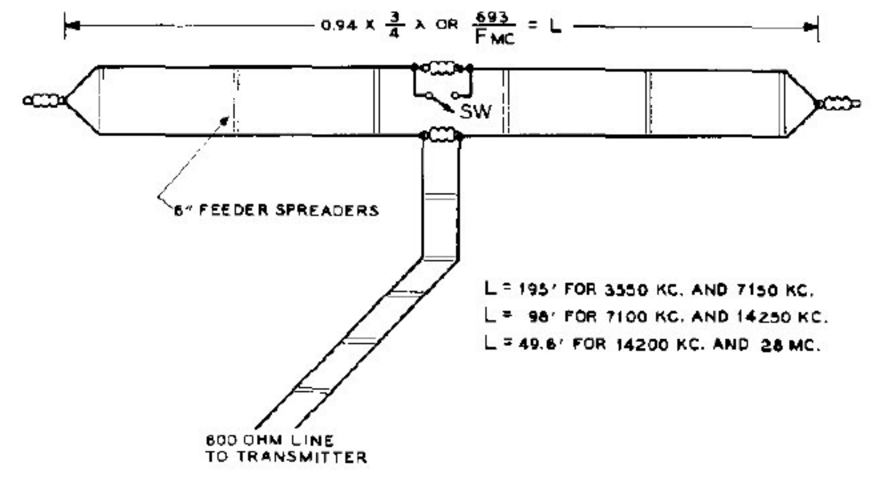
0.94 × 3/4 λ OR 693/F MC = L
SW
6" FEEDER SPREADERS
L = 195' FOR 3550 KC. AND 7150 KC.
L = 98' FOR 7100 KC. AND 14250 KC.
L = 49.6' FOR 14200 KC. AND 28 MC.
600 OHM LINE
TO TRANSMITTER

---

183 - Three-Quarter-Wave Folded Doublet No-Switch for Dual-Band

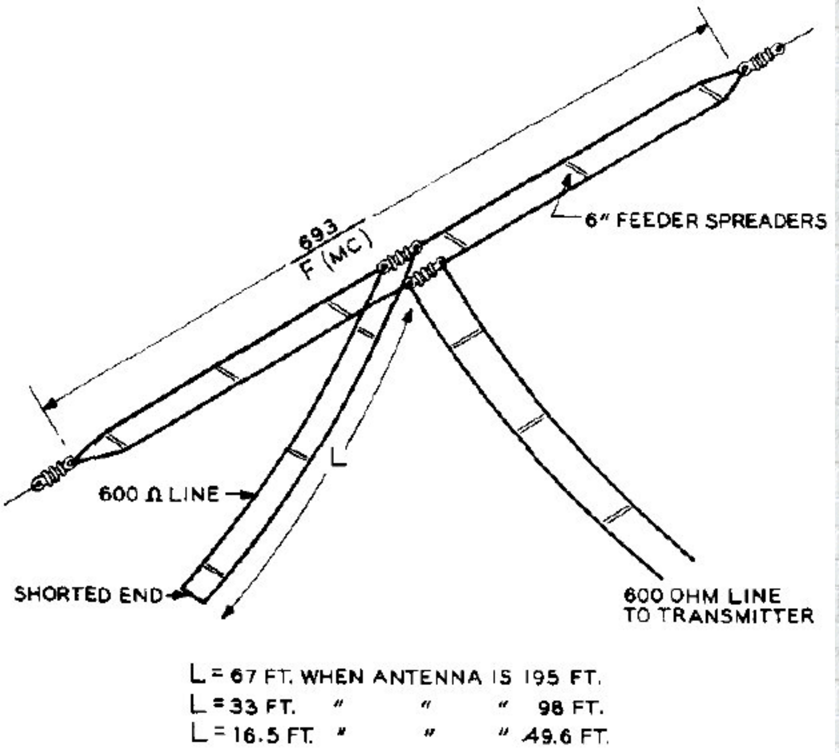
693/F (MC)
6" FEEDER SPREADERS
600 Ω LINE
L
SHORTED END
600 OHM LINE
TO TRANSMITTER
L = 67 FT. WHEN ANTENNA IS 195 FT.
L = 33 FT. " " " 98 FT.
L = 16.5 FT. " " " 49.6 FT.

---

184 - Wideband Omni-Directional Discone Antenna

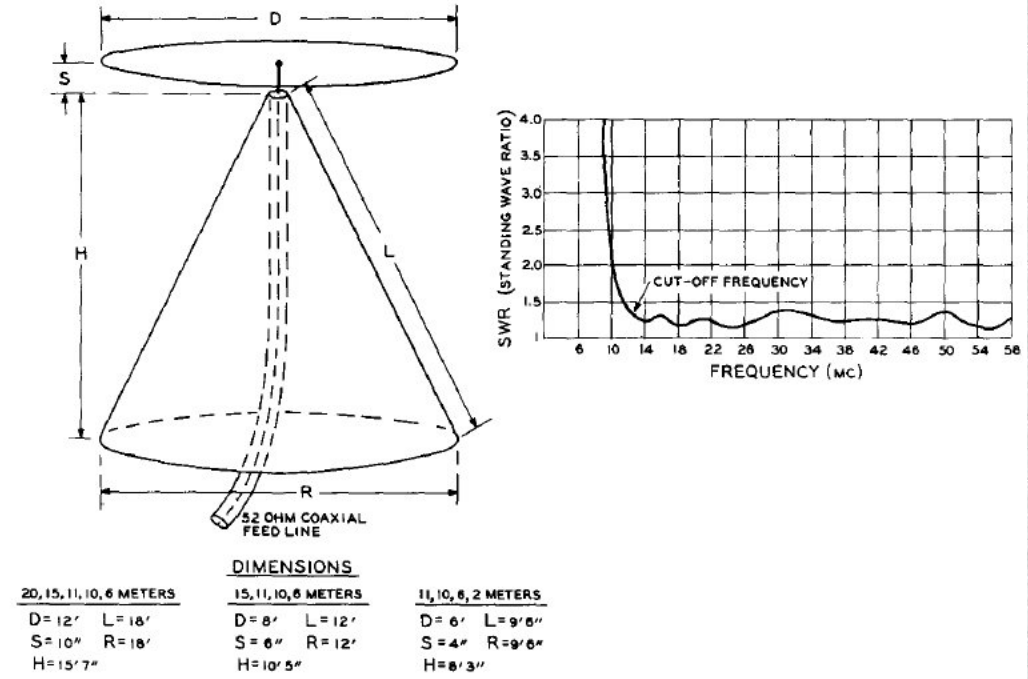
D
S
H
L
R
52 OHM COAXIAL FEED LINE
SWR (STANDING WAVE RATIO)
4.0
3.5
3.0
2.5
2.0
1.5
1
6 10 14 18 22 26 30 34 38 42 46 50 54 58
FREQUENCY (MC)
CUT-OFF FREQUENCY
DIMENSIONS
20, 15, 11, 10, 6 METERS
D= 12′ L= 18′
S= 10″ R= 18′
H= 15′ 7″
15, 11, 10, 6 METERS
D= 8′ L= 12′
S= 6″ R= 12′
H= 10′ 5″
11, 10, 6, 2 METERS
D= 6′ L= 9′ 6″
S = 4″ R = 9′ 6″
H= 8′ 3″

---

185 - Wideband Rhombic Antenna for 40m to 10m

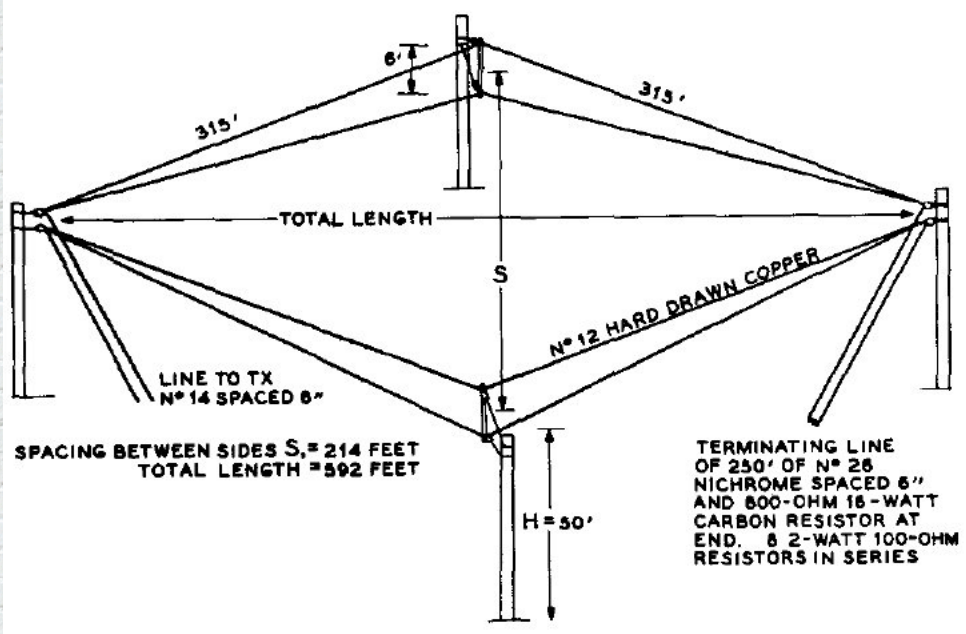
6′
315′
315′
TOTAL LENGTH
S
N° 12 HARD DRAWN COPPER
LINE TO TX
N° 14 SPACED 6″
SPACING BETWEEN SIDES S, = 214 FEET
TOTAL LENGTH = 592 FEET
H = 50′
TERMINATING LINE
OF 250′ OF N° 26
NICHROME SPACED 6″
AND 800-OHM 16-WATT
CARBON RESISTOR AT
END. 8 2-WATT 100-OHM
RESISTORS IN SERIES

---

186 - Pre-Cut Linear Array Antenna 3dB-Gain for 40m

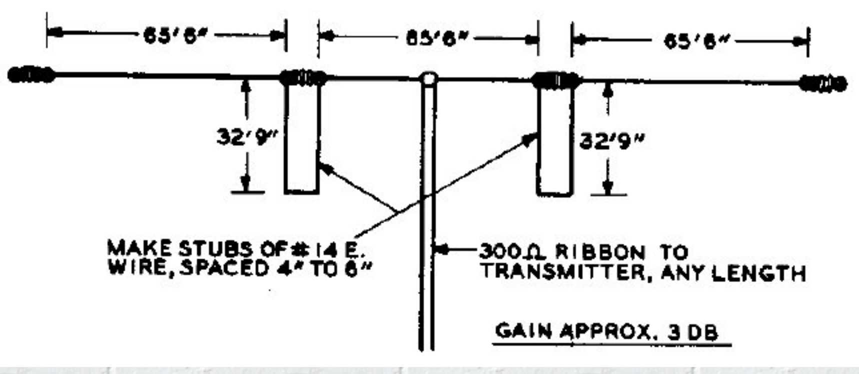
65′ 6″
65′ 6″
65′ 6″
32′ 9″
32′ 9″
MAKE STUBS OF # 14 E. WIRE, SPACED 4″ TO 6″
300Ω RIBBON TO TRANSMITTER, ANY LENGTH
GAIN APPROX. 3 DB

187 - X-Array Antenna 6dB-Gain for 20m, 15m, 10m

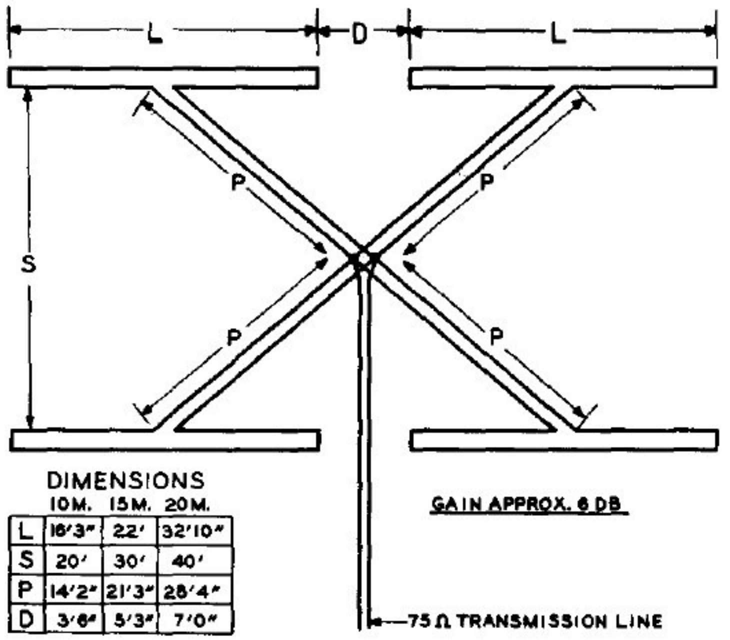
L
D
L
S
P
P
P
P
GAIN APPROX. 6 DB
—75 Ω TRANSMISSION LINE

DIMENSIONS

	10M.	15M.	20M.
L	16'3"	22'	32'10"
S	20'	30'	40'
P	14'2"	21'3"	28'4"
D	3'6"	5'3"	7'0"

The entire array (with the exception of the 75-ohm feed line) is constructed of 300-ohm ribbon line. Be sure phasing lines (P) are poled correctly, as shown.

188 - Double-Bruce Array Antenna 5dB-Gain for 20m, 10m

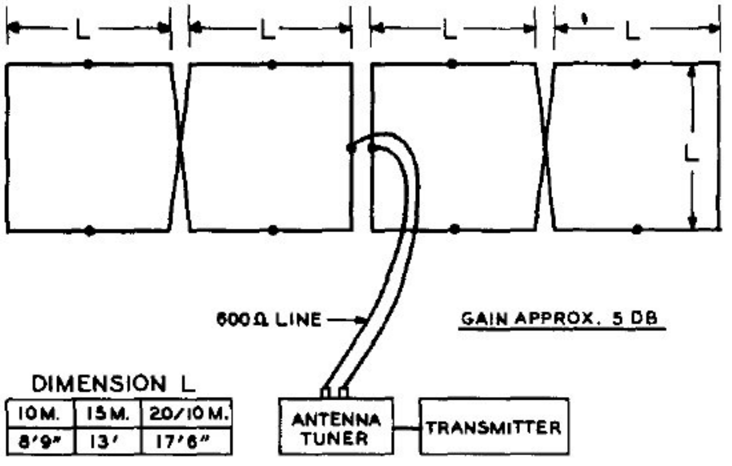
L
L
L
L
L
600Ω LINE
GAIN APPROX. 5 DB
ANTENNA TUNER
TRANSMITTER

DIMENSION L

10M.	15M.	20/10M.
8'9"	13'	17'6"

189 - Bi-Square Broadside Array 4dB-Gain for 20m, 15m, 10m

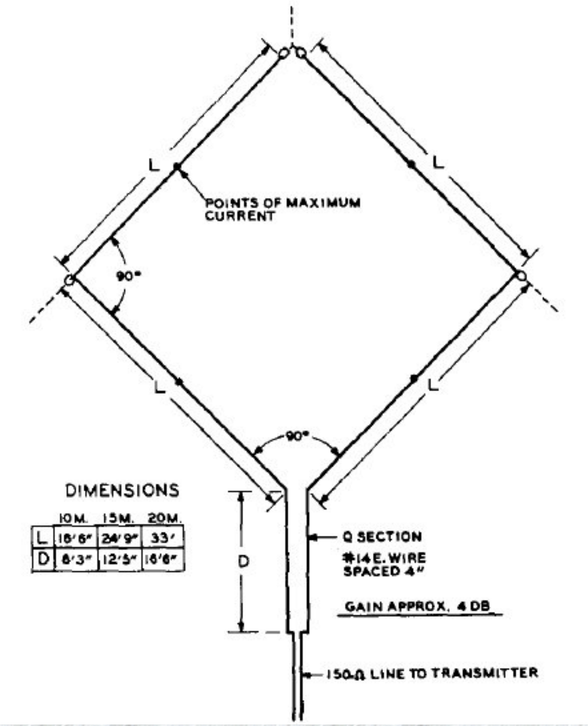
L
L
L
L
POINTS OF MAXIMUM CURRENT
90°
90°
D
Q SECTION
#14 E. WIRE SPACED 4"
GAIN APPROX. 4 DB
150Ω LINE TO TRANSMITTER

DIMENSIONS

	10M.	15M.	20M.
L	16'6"	24'9"	33'
D	8'3"	12'5"	16'6"

190 - Six-Shooter Broadside Array 7.5dB-Gain for 20m, 15m, 10m

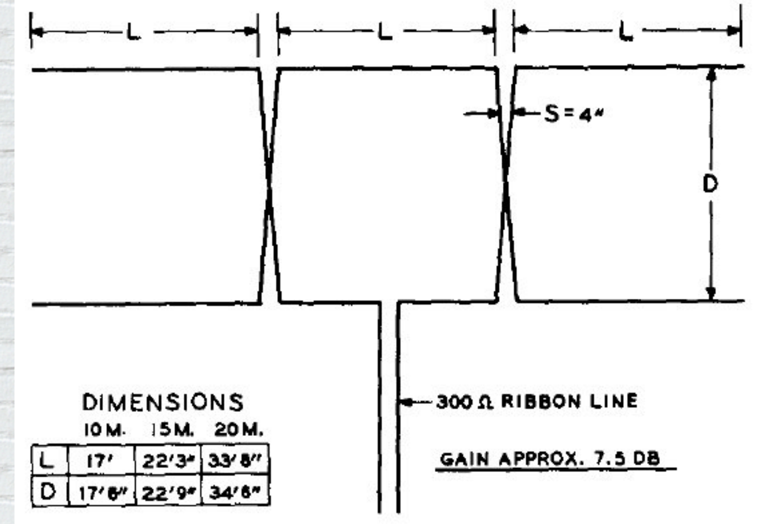
L
L
L
S = 4"
D
300 Ω RIBBON LINE
GAIN APPROX. 7.5 DB

DIMENSIONS

	10M.	15M.	20M.
L	17'	22'3"	33'8"
D	17'6"	22'9"	34'6"

191 - Triplex Flat-Top Beam 4.5dB-Gain for 20m, 15m, 10m

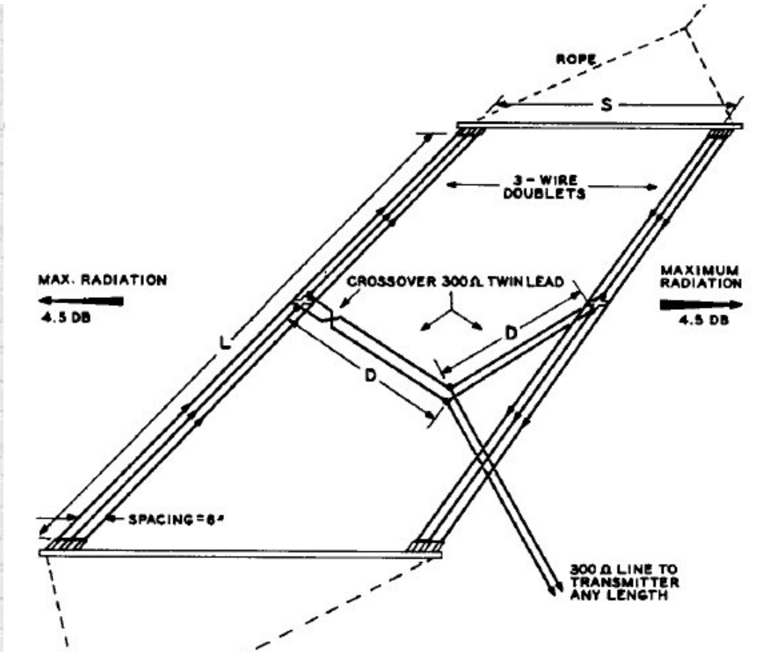
ROPE
S
3 - WIRE DOUBLETS
MAX. RADIATION
4.5 DB
MAXIMUM RADIATION
4.5 DB
CROSSOVER 300Ω TWIN LEAD
L
D
D
SPACING = 6"
300 Ω LINE TO TRANSMITTER ANY LENGTH

DIMENSIONS

	10M.	15M.	20M	MATERIAL
L	15'8"	21'5"	32'2"	THREE # 12 E. WIRES, SPACED 3"
S	5'6"	7'8"	11'	
D	7'2"	10'7"	14'4"	300 OHM RIBBON

---

192 - Dual-Band Tilt Antenna for 20m, 10m

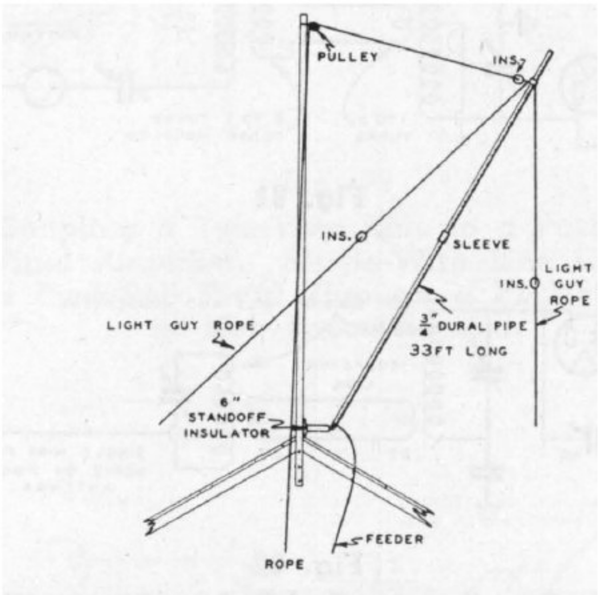
PULLEY
INS.
INS.
SLEEVE
LIGHT GUY ROPE
INS.
LIGHT GUY ROPE
3/4" DURAL PIPE
33FT LONG
6" STANDOFF INSULATOR
FEEDER
ROPE

TWO BAND (10-20 METER) TILT ANTENNA — VERTICAL FOR 20 METERS - TILT 54° FROM HORIZON FOR 10 METERS

---

193 - Super Space Multiband Dipole Antenna for 80m to 10m

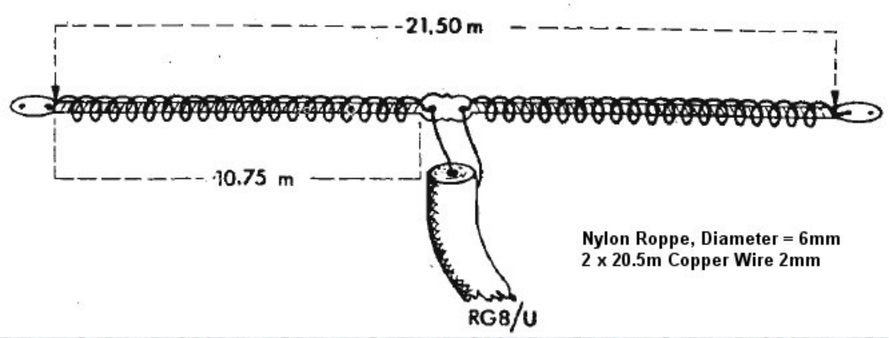
21,50 m
10.75 m
Nylon Roppe, Diameter = 6mm
2 x 20.5m Copper Wire 2mm
RG8/U

---

194 - Bi-Square Beam Antenna Gain=5.5dB for 10m

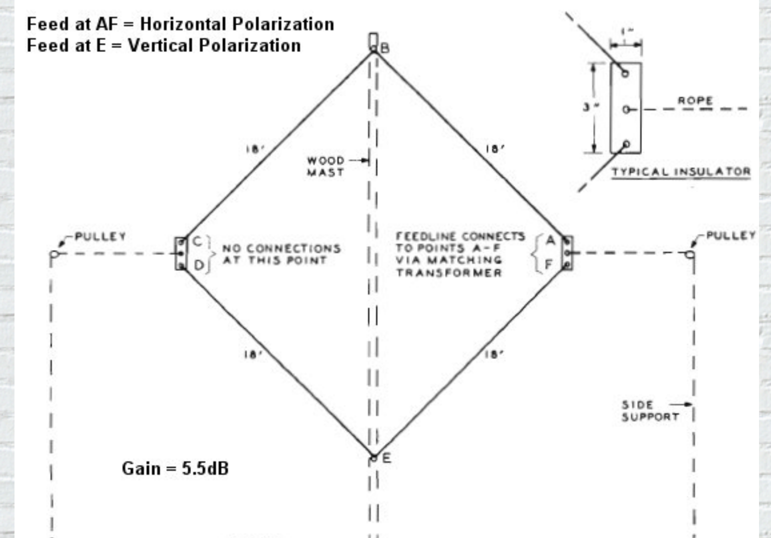
Feed at AF = Horizontal Polarization
Feed at E = Vertical Polarization
B
18'
18'
WOOD MAST
1"
3"
ROPE
TYPICAL INSULATOR
PULLEY
C
D
NO CONNECTIONS AT THIS POINT
FEEDLINE CONNECTS TO POINTS A-F VIA MATCHING TRANSFORMER
A
F
PULLEY
18'
18'
SIDE SUPPORT
E
Gain = 5.5dB
GROUND

---

195 - Cousin of G5RV Multiband Antenna for 40m to 10m

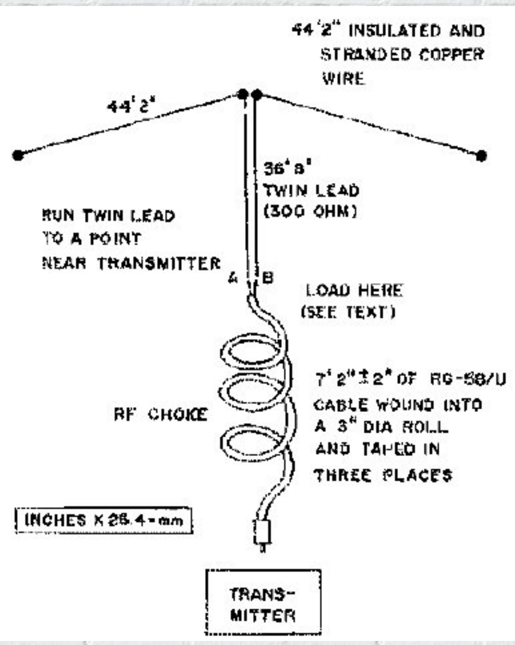
44'2" INSULATED AND STRANDED COPPER WIRE
44'2"
36'8" TWIN LEAD (300 OHM)
RUN TWIN LEAD TO A POINT NEAR TRANSMITTER
A
B
LOAD HERE (SEE TEXT)
7'2" ± 2" OF RG-58/U CABLE WOUND INTO A 3" DIA ROLL AND TAPED IN THREE PLACES
RF CHOKE
INCHES X 25.4=mm
TRANS-MITTER

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196 - Cayman Quad Antenna for 20m

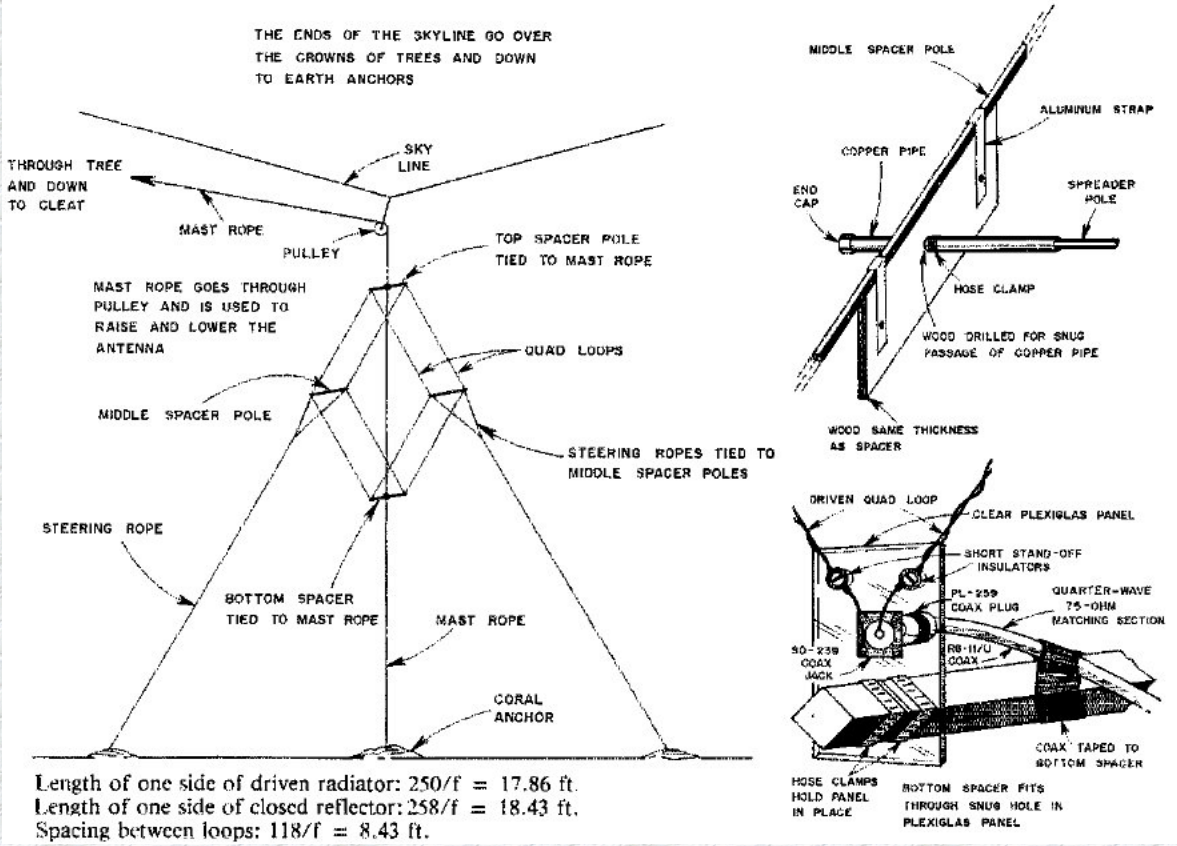
THE ENDS OF THE SKYLINE GO OVER THE CROWNS OF TREES AND DOWN TO EARTH ANCHORS
SKY LINE
THROUGH TREE AND DOWN TO CLEAT
MAST ROPE
PULLEY
TOP SPACER POLE TIED TO MAST ROPE
MAST ROPE GOES THROUGH PULLEY AND IS USED TO RAISE AND LOWER THE ANTENNA
QUAD LOOPS
MIDDLE SPACER POLE
STEERING ROPES TIED TO MIDDLE SPACER POLES
STEERING ROPE
BOTTOM SPACER TIED TO MAST ROPE
MAST ROPE
CORAL ANCHOR
MIDDLE SPACER POLE
ALUMINUM STRAP
COPPER PIPE
END CAP
SPREADER POLE
HOSE CLAMP
WOOD DRILLED FOR SNUG PASSAGE OF COPPER PIPE
WOOD SAME THICKNESS AS SPACER
DRIVEN QUAD LOOP
CLEAR PLEXIGLAS PANEL
SHORT STAND-OFF INSULATORS
PL-259 COAX PLUG
QUARTER-WAVE 75-OHM MATCHING SECTION
SO-239 COAX JACK
RG-11/U COAX
COAX TAPED TO BOTTOM SPACER
HOSE CLAMPS HOLD PANEL IN PLACE
BOTTOM SPACER FITS THROUGH SNUG HOLE IN PLEXIGLAS PANEL

Length of one side of driven radiator: 250/f = 17.86 ft.
Length of one side of closed reflector: 258/f = 18.43 ft.
Spacing between loops: 118/f = 8.43 ft.

197 - Hentenna Gain=3dB with Bazooka Match for 6m

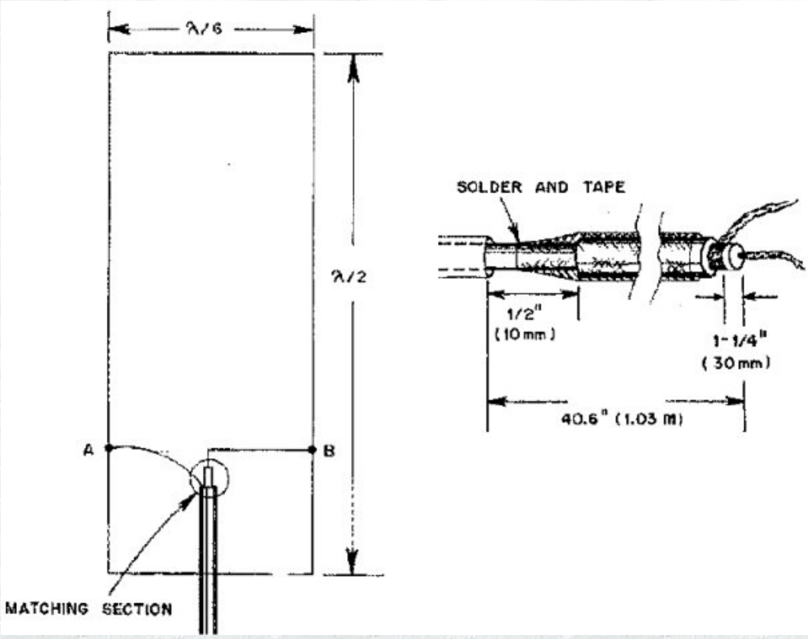
λ/6
λ/2
A
B
MATCHING SECTION
SOLDER AND TAPE
1/2" (10 mm)
1-1/4" (30 mm)
40.6" (1.03 m)

198 - X-Beam Antenna Gain=3dB for 20m

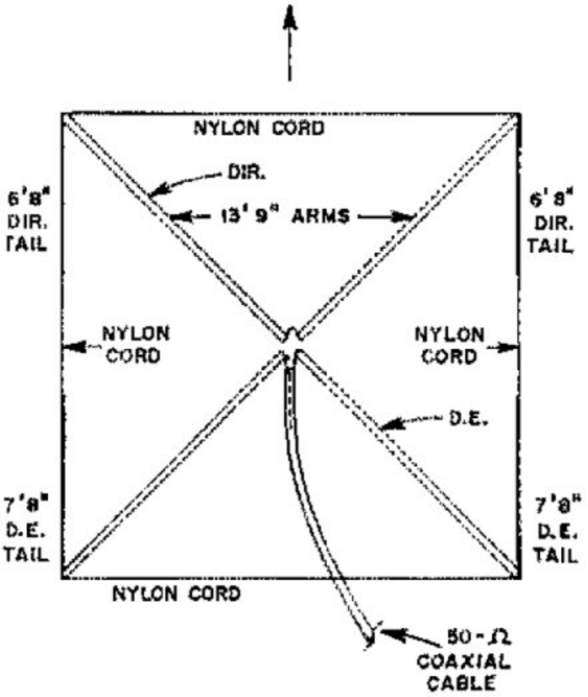
NYLON CORD
DIR.
13' 9" ARMS
6'8" DIR. TAIL
6'8" DIR. TAIL
NYLON CORD
NYLON CORD
D.E.
7'8" D.E. TAIL
7'8" D.E. TAIL
NYLON CORD
50-Ω COAXIAL CABLE

---

199 - Twin Delta Loop Antenna Gain=6dB for 160m, 80m, 40m

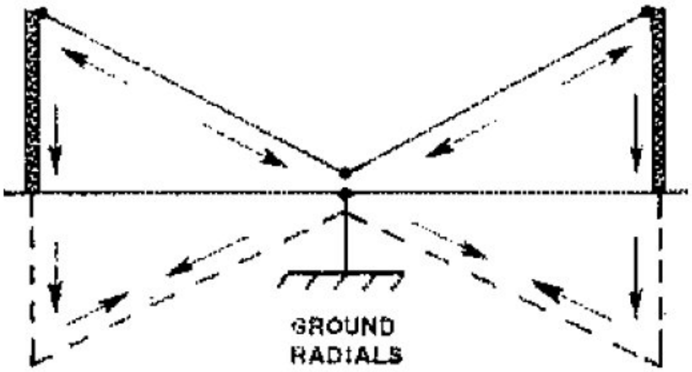
GROUND RADIALS

Twin- Delta Loop, with the image in the ground plane.

Band	*Tower Height (ft)*	*Length of Sloping Wires (ft)*
160 m†	102.03	204.06
80 m	49.86	99.72
40 m	25.92	51.84

---

200 - Inverted-V Beam Antenna for 30m

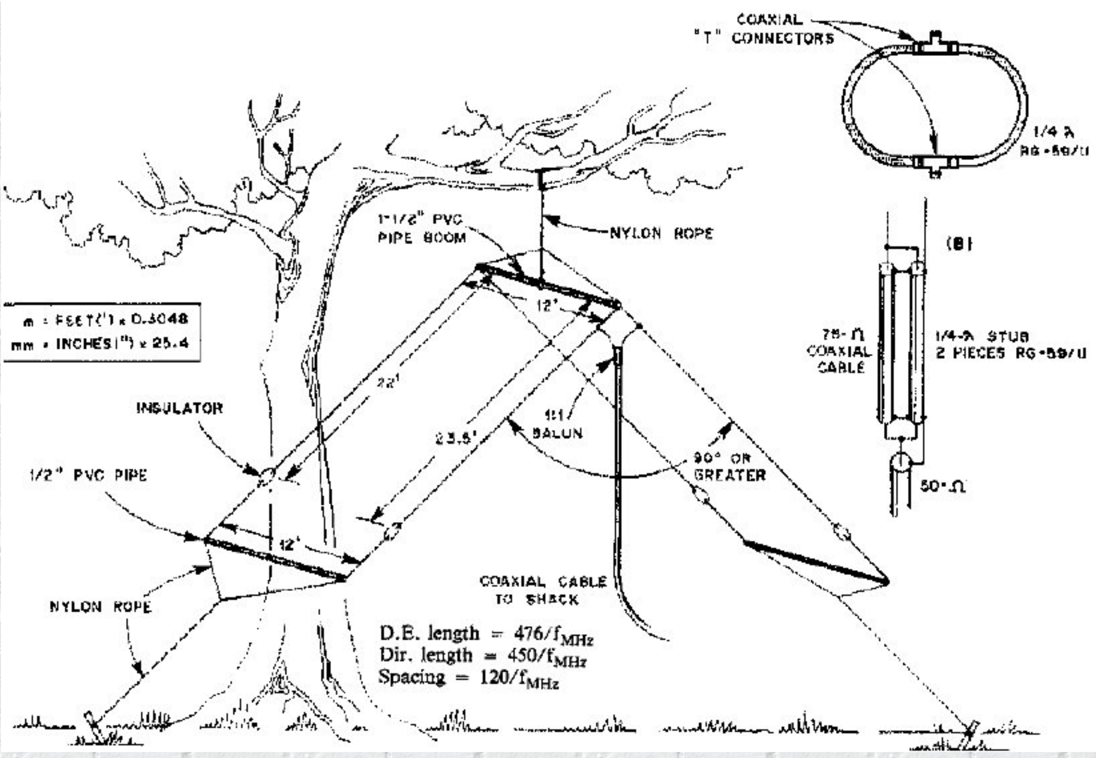
COAXIAL "T" CONNECTORS
1/4 λ RG-59/U
1-1/2" PVC PIPE BOOM
NYLON ROPE
(B)
m = FEET(') x 0.3048
mm = INCHES(") x 25.4
12'
22'
23.5'
1:1 BALUN
75-Ω COAXIAL CABLE
1/4-λ STUB 2 PIECES RG-59/U
INSULATOR
90° OR GREATER
1/2" PVC PIPE
50-Ω
12'
COAXIAL CABLE TO SHACK
NYLON ROPE
D.E. length = 476/f_MHz
Dir. length = 450/f_MHz
Spacing = 120/f_MHz

201 - FD4 Windom Antenna for 80m, 40m, 20m, 10m

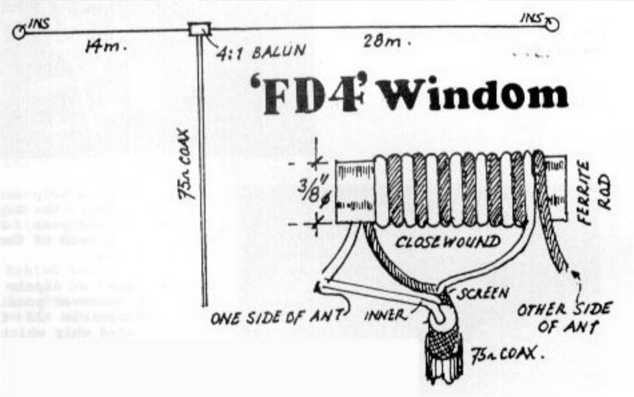
INS
14m.
4:1 BALUN
28m.
INS
'FD4' Windom
75Ω COAX
3/8" ϕ
FERRITE ROD
CLOSE WOUND
SCREEN
ONE SIDE OF ANT
INNER
OTHER SIDE OF ANT
75Ω COAX.

202 - Two Elements Phased Delta Loop for 40m

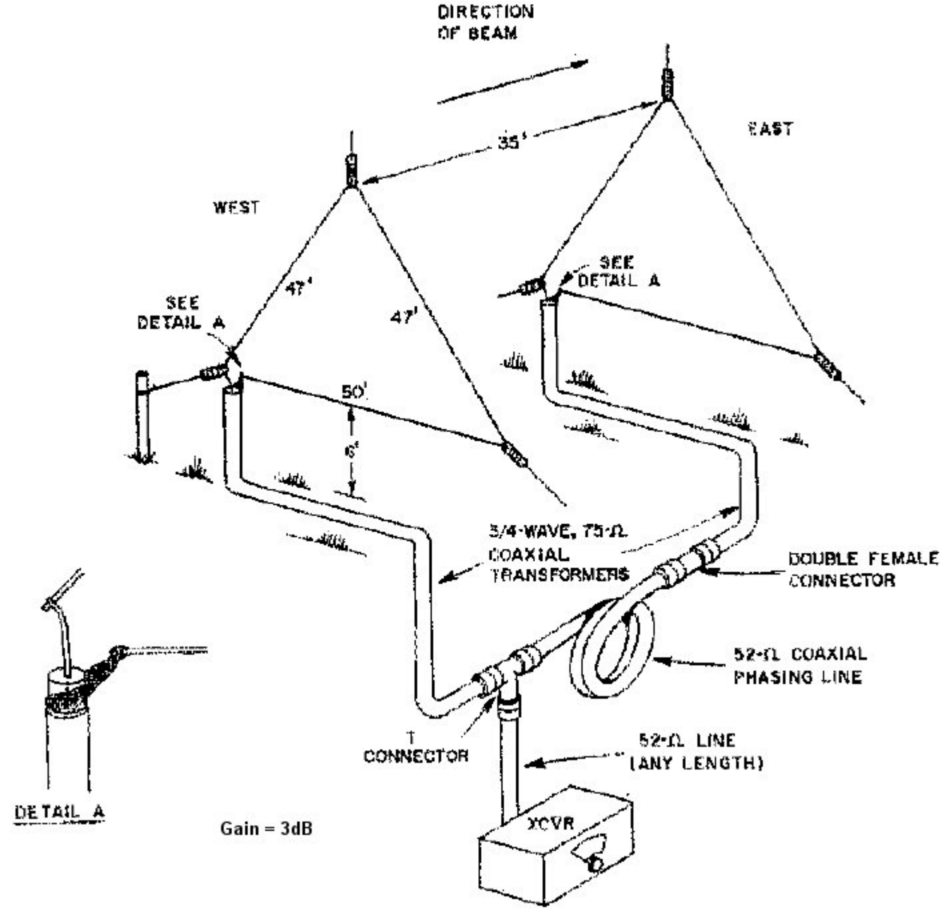
DIRECTION
OF BEAM
35'
EAST
WEST
SEE
DETAIL A
47'
47'
SEE
DETAIL A
50'
6'
3/4-WAVE, 75-Ω
COAXIAL
TRANSFORMERS
DOUBLE FEMALE
CONNECTOR
52-Ω COAXIAL
PHASING LINE
T
CONNECTOR
52-Ω LINE
(ANY LENGTH)
DETAIL A
XCVR
Gain = 3dB

203 - Three Elements Wire Yagi for 10m

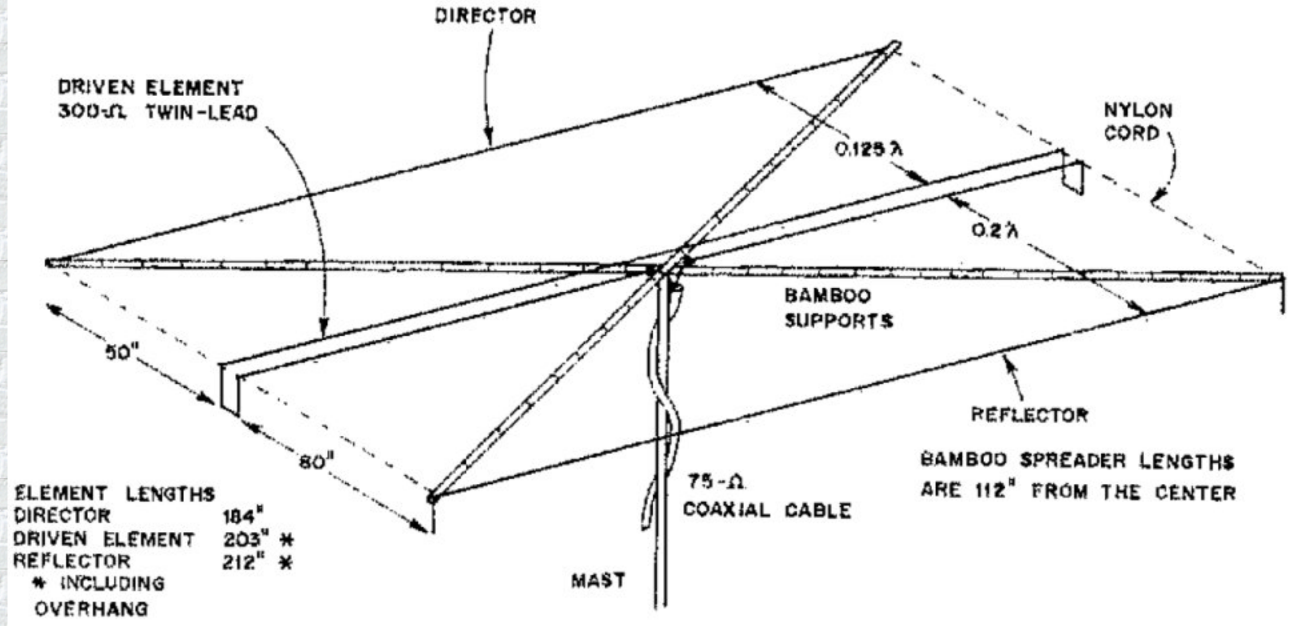
DIRECTOR
DRIVEN ELEMENT
300-Ω TWIN-LEAD
NYLON
CORD
0.125 λ
0.2 λ
BAMBOO
SUPPORTS
50"
80"
REFLECTOR
BAMBOO SPREADER LENGTHS
ARE 112" FROM THE CENTER
75-Ω
COAXIAL CABLE
MAST
ELEMENT LENGTHS
DIRECTOR 184"
DRIVEN ELEMENT 203" *
REFLECTOR 212" *
* INCLUDING
OVERHANG

204 - Low Radiation Angle Full-Wave Loop Antenna for 80m

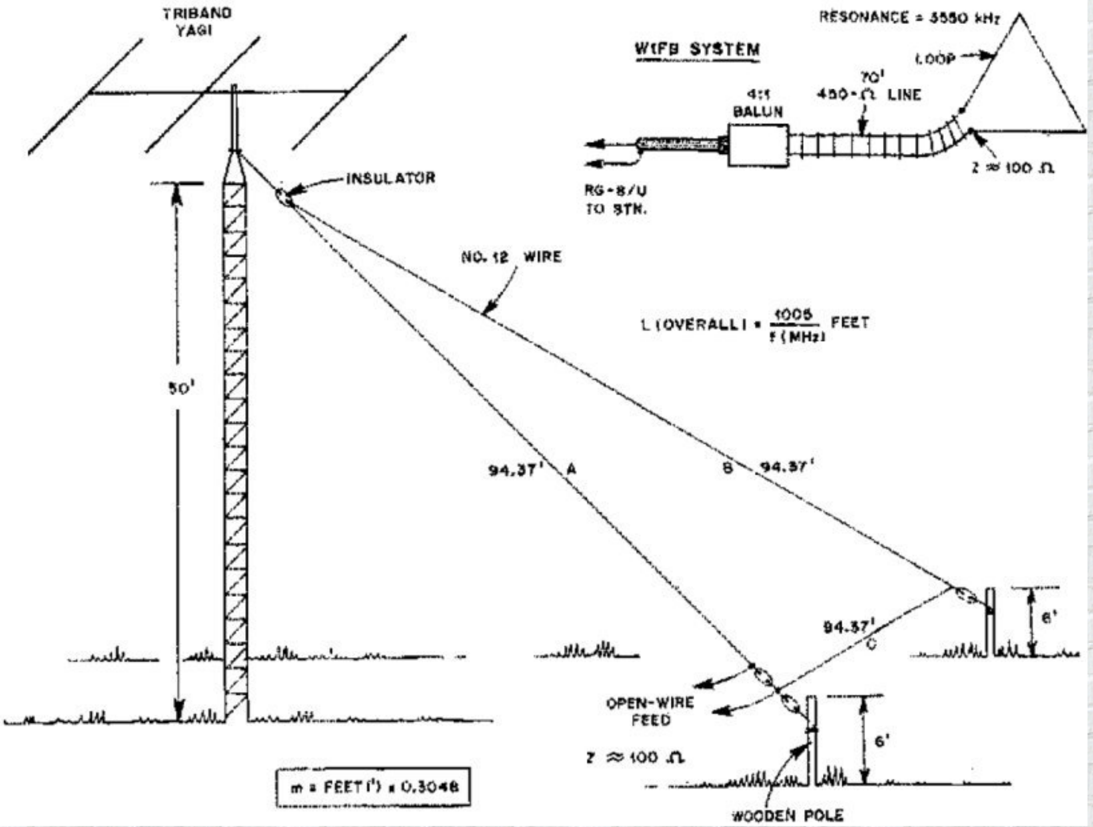
TRIBAND YAGI
RESONANCE = 3550 kHz
W1FB SYSTEM
LOOP
70'
4:1 BALUN
450-Ω LINE
Z ≈ 100 Ω
RG-8/U TO STN.
INSULATOR
NO. 12 WIRE
L (OVERALL) = 1005 / f (MHz) FEET
50'
94.37' A
B 94.37'
94.37' C
6'
OPEN-WIRE FEED
Z ≈ 100 Ω
6'
WOODEN POLE
m = FEET (') x 0.3048

205 - Collinear Antenna Gain=3dB for 2m

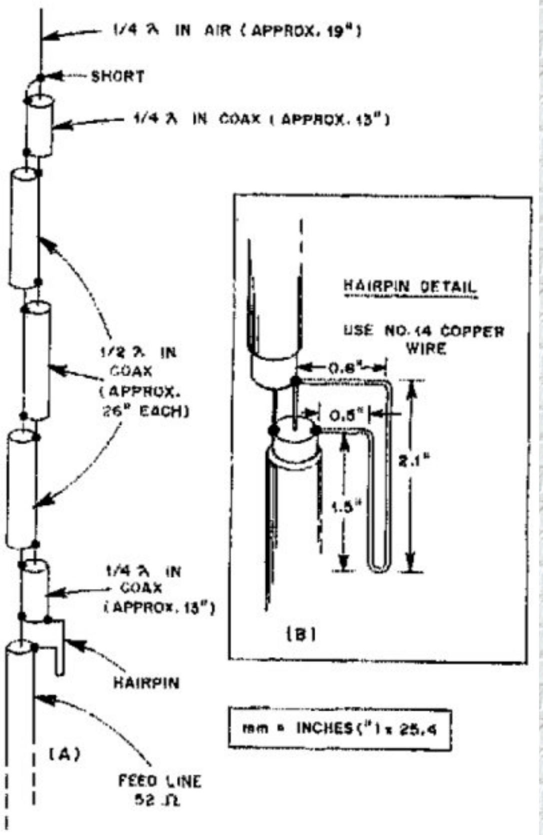
1/4 λ IN AIR (APPROX. 19")
SHORT
1/4 λ IN COAX (APPROX. 13")
1/2 λ IN COAX (APPROX. 26" EACH)
1/4 λ IN COAX (APPROX. 13")
HAIRPIN
(A)
FEED LINE 52 Ω
HAIRPIN DETAIL
USE NO. 14 COPPER WIRE
0.8"
0.5"
2.1"
1.5"
(B)
mm = INCHES (") x 25.4

206 - X-Ray Monoband Antenna Gain=6.5dBd

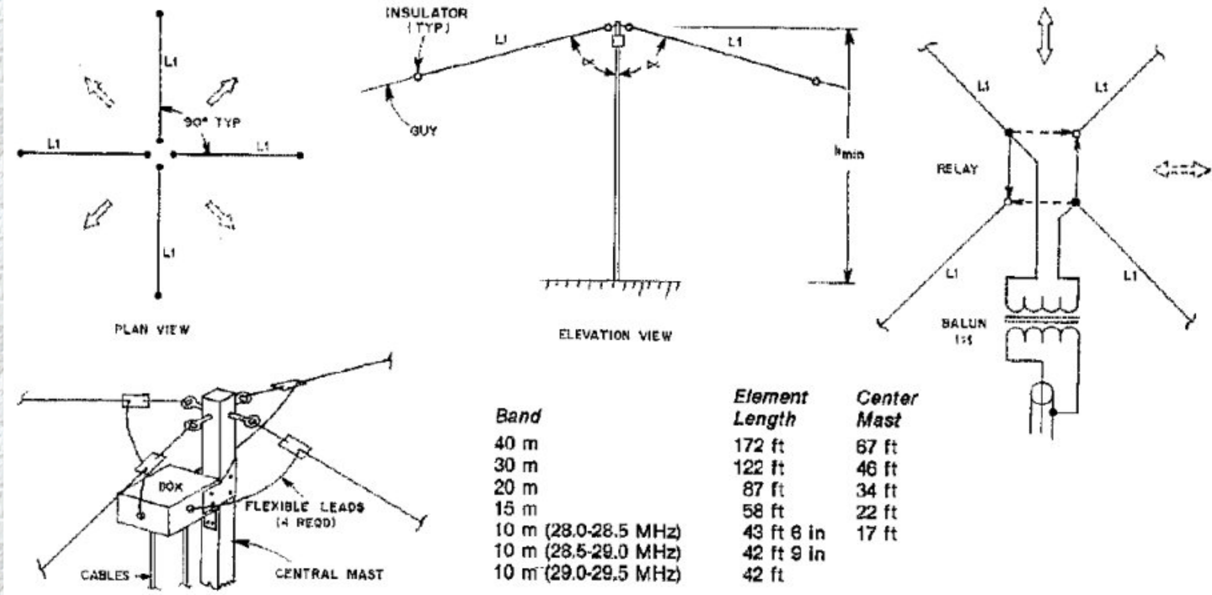
INSULATOR (TYP)
L1
GUY
α
h_min
ELEVATION VIEW
PLAN VIEW
90° TYP
RELAY
BALUN 1:1
BOX
FLEXIBLE LEADS (4 REQD)
CABLES
CENTRAL MAST

Band	Element Length	Center Mast
40 m	172 ft	67 ft
30 m	122 ft	46 ft
20 m	87 ft	34 ft
15 m	58 ft	22 ft
10 m (28.0-28.5 MHz)	43 ft 6 in	17 ft
10 m (28.5-29.0 MHz)	42 ft 9 in	
10 m (29.0-29.5 MHz)	42 ft	

207 - Broadside Collinear Curtain Array for 20m

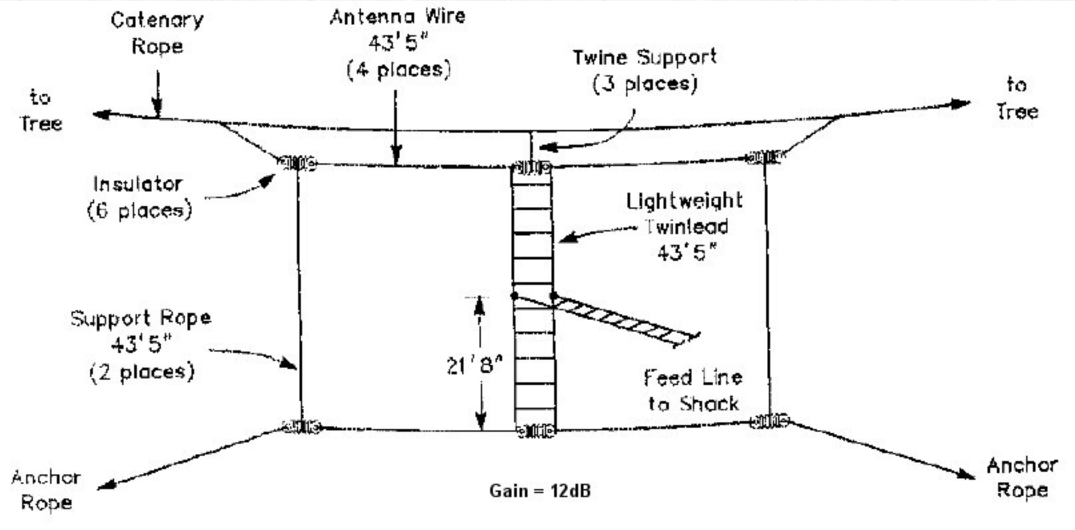
Catenary Rope
Antenna Wire 43'5" (4 places)
Twine Support (3 places)
to Tree
to Tree
Insulator (6 places)
Lightweight Twinlead 43'5"
Support Rope 43'5" (2 places)
21'8"
Feed Line to Shack
Anchor Rope
Anchor Rope
Gain = 12dB

208 - Shrunk Loop Antenna for 80m, 40m

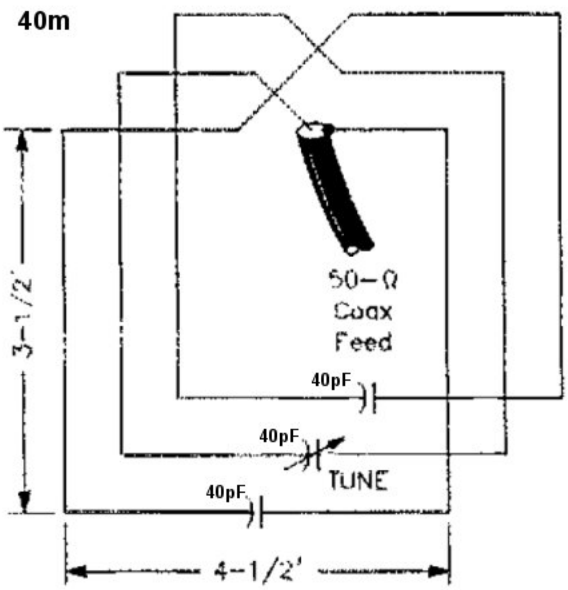
40m
3-1/2'
50-Ω
Coax
Feed
40pF
40pF
TUNE
40pF
4-1/2'

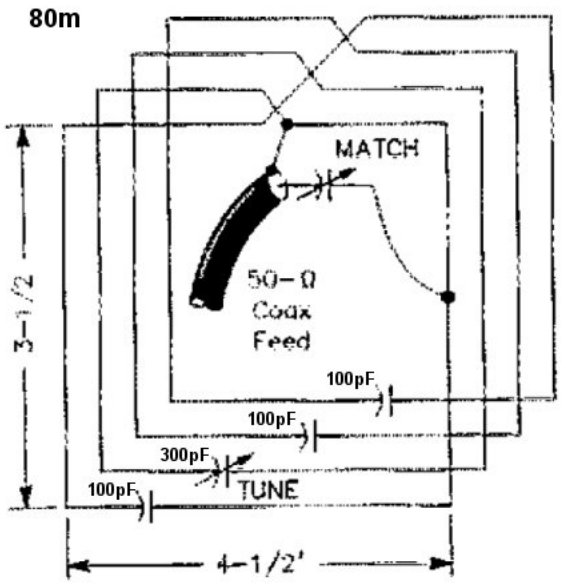
80m
MATCH
3-1/2'
50-Ω
Coax
Feed
100pF
100pF
300pF
TUNE
100pF
4-1/2'

209 - λ/3 Multiband Dipole for 40m, 20m, 17m, 15m, 13m, 10m

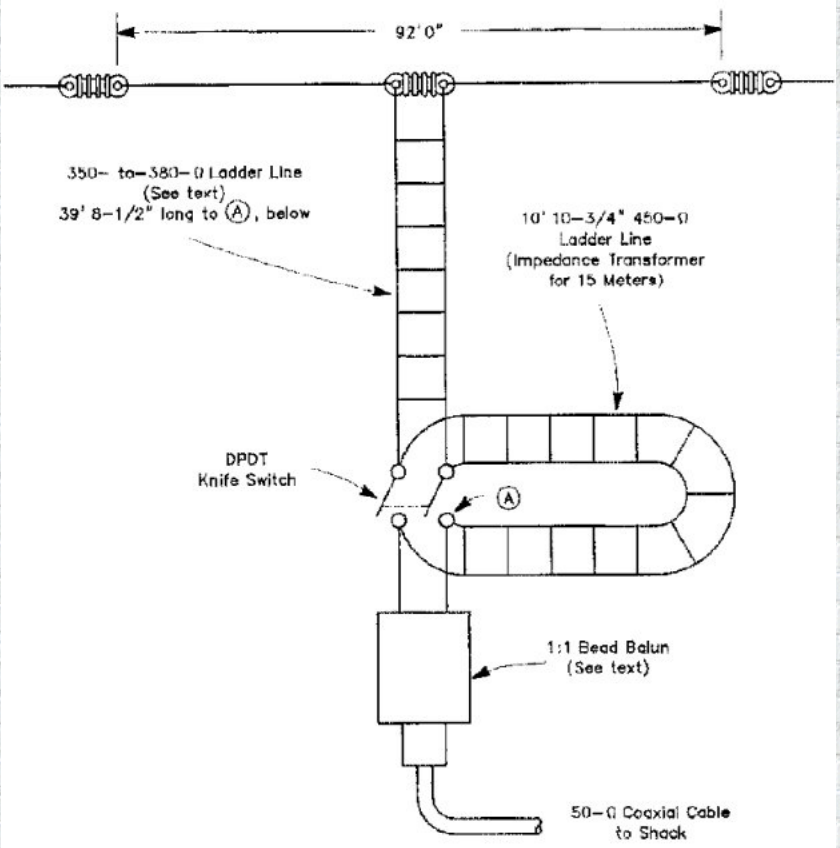
92' 0"
350- to-380-Ω Ladder Line
(See text)
39' 8-1/2" long to Ⓐ, below
10' 10-3/4" 450-Ω
Ladder Line
(Impedance Transformer
for 15 Meters)
DPDT
Knife Switch
Ⓐ
1:1 Bead Balun
(See text)
50-Ω Coaxial Cable
to Shack

210 - K3LR Sloper Antenna Gain=3dB for 160m

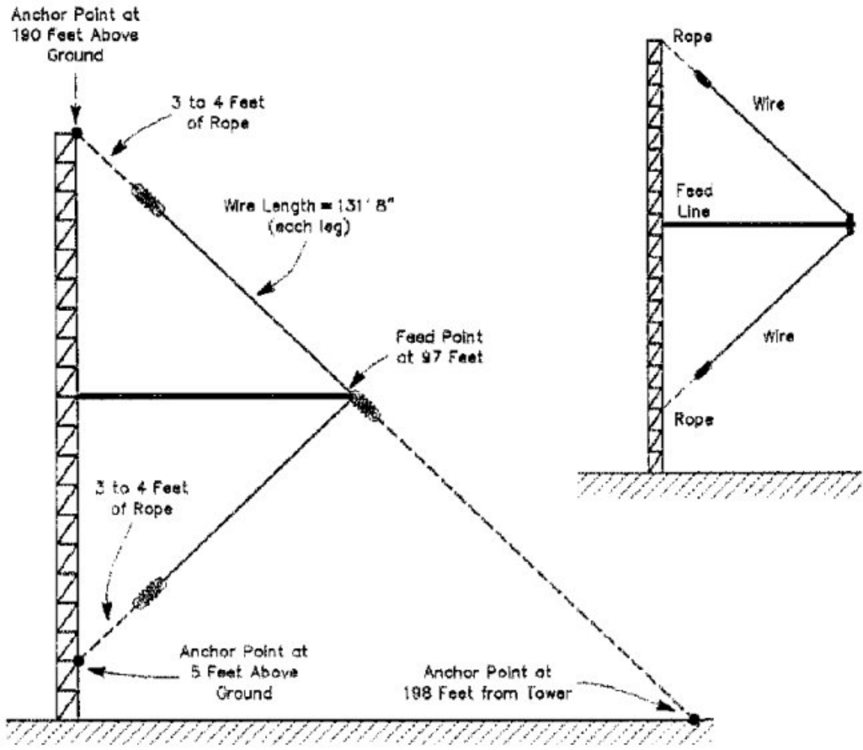
Anchor Point at
190 Feet Above
Ground
3 to 4 Feet
of Rope
Wire Length = 131' 8"
(each leg)
Feed Point
at 97 Feet
3 to 4 Feet
of Rope
Anchor Point at
5 Feet Above
Ground
Anchor Point at
198 Feet from Tower
Rope
Wire
Feed
Line
Wire
Rope

211 - Mini Folded Vertical Monopole Antenna for 160m, 80m, 40m

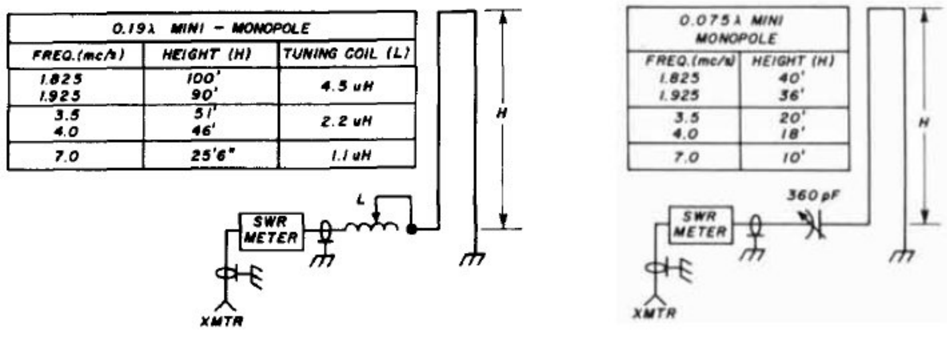
H
L
SWR METER
XMTR
H
360 pF
SWR METER
XMTR

0.19λ MINI - MONOPOLE		
FREQ.(mc/s)	HEIGHT (H)	TUNING COIL (L)
1.825 1.925	100' 90'	4.5 uH
3.5 4.0	51' 46'	2.2 uH
7.0	25'6"	1.1 uH

0.075λ MINI MONOPOLE	
FREQ.(mc/s)	HEIGHT (H)
1.825 1.925	40' 36'
3.5 4.0	20' 18'
7.0	10'

212 - Three Band Dipole for 80m, 40m, 20m

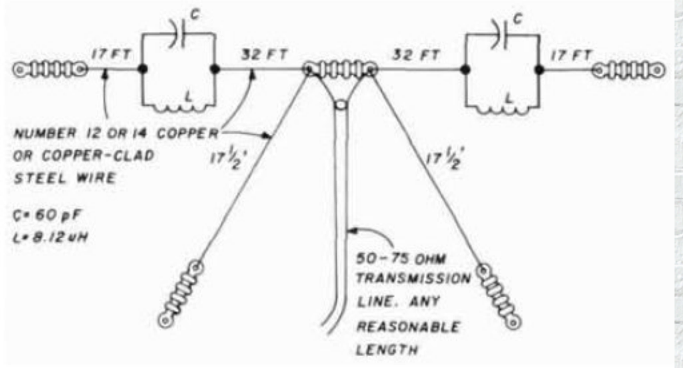
C
17 FT
32 FT
32 FT
C
17 FT
L
L
NUMBER 12 OR 14 COPPER
OR COPPER-CLAD
STEEL WIRE
17½'
17½'
C= 60 pF
L= 8.12 uH
50-75 OHM
TRANSMISSION
LINE. ANY
REASONABLE
LENGTH

213 - Stub Matched Dipole Antenna

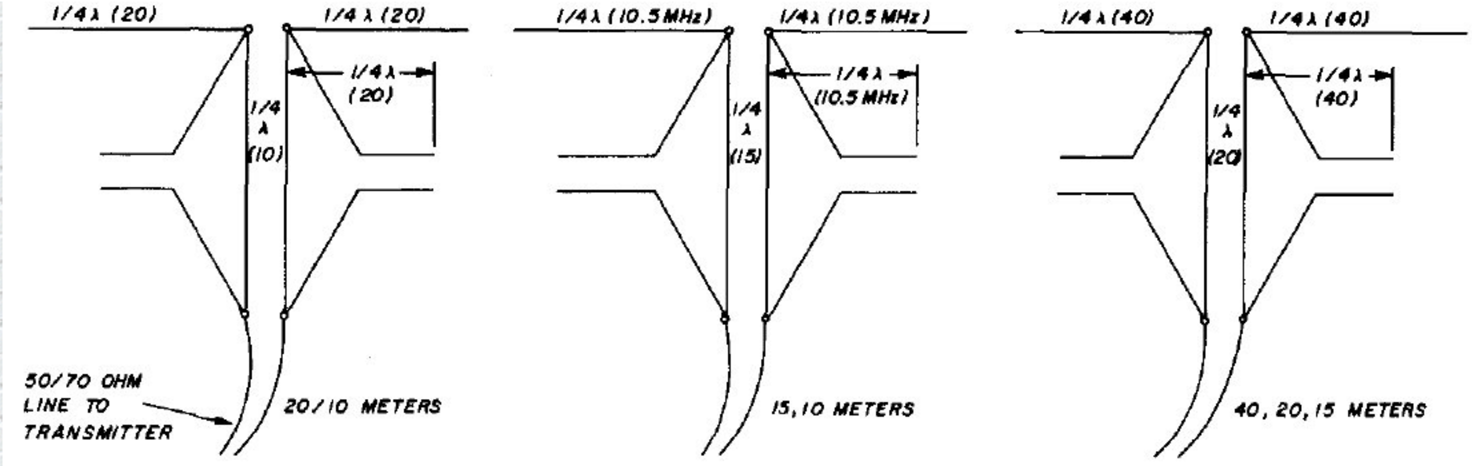
1/4 λ (20)
1/4 λ (20)
1/4 λ (20)
1/4 λ (10)
50/70 OHM LINE TO TRANSMITTER
20/10 METERS
1/4 λ (10.5 MHz)
1/4 λ (10.5 MHz)
1/4 λ (10.5 MHz)
1/4 λ (15)
15, 10 METERS
1/4 λ (40)
1/4 λ (40)
1/4 λ (40)
1/4 λ (20)
40, 20, 15 METERS

214 - Inverted-Vee Antenna with Bazooka Match

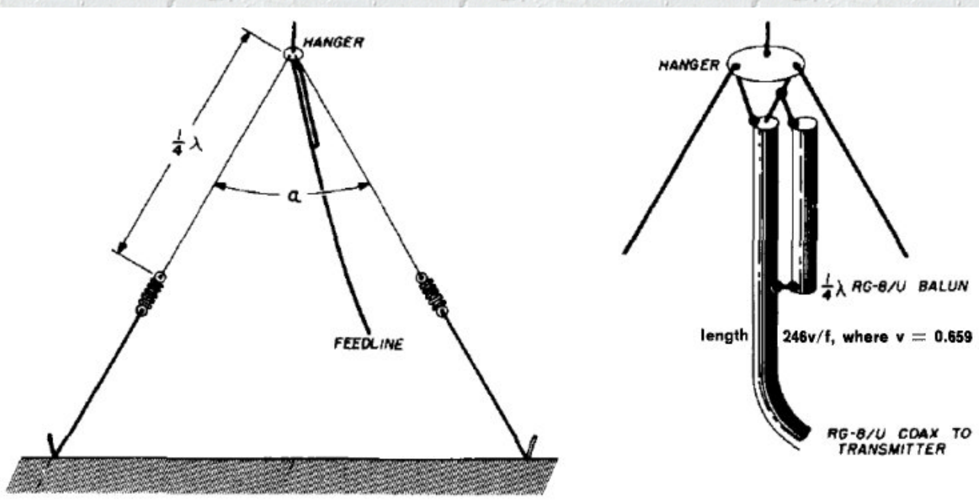
HANGER
$\frac{1}{4}\lambda$
a
FEEDLINE
HANGER
$\frac{1}{4}\lambda$ RG-8/U BALUN
length
246v/f, where v = 0.659
RG-8/U COAX TO TRANSMITTER

215 - Multiband Long Wire Antenna for 40m, 20m, 15m, 10m

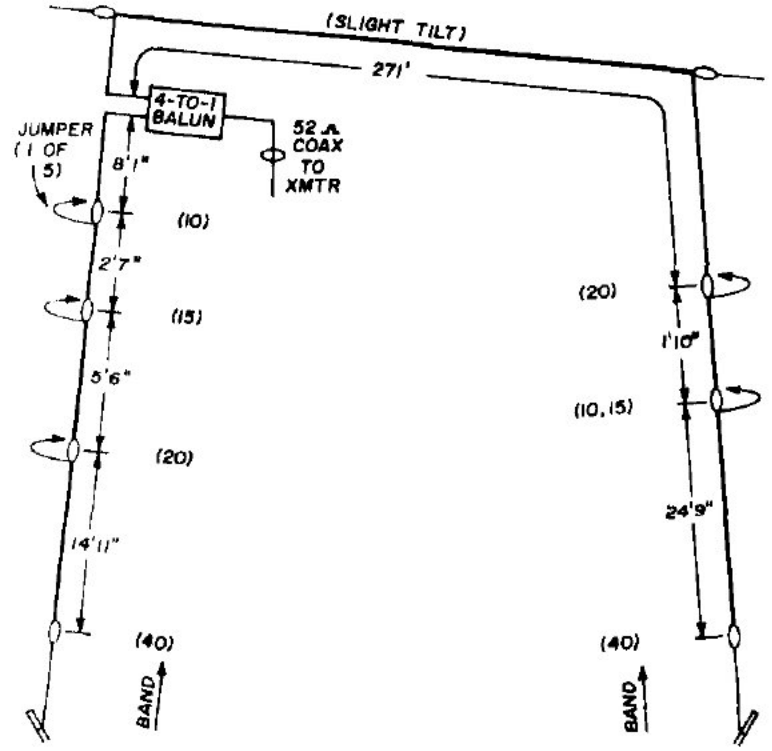
(SLIGHT TILT)
271'
4-TO-1 BALUN
52 Ω COAX TO XMTR
JUMPER (1 OF 5)
8'1"
(10)
2'7"
(15)
5'6"
(20)
14'11"
(40)
BAND
(20)
1'10"
(10, 15)
24'9"
(40)
BAND

216 - Converted Vee Antenna for 80m, 40m

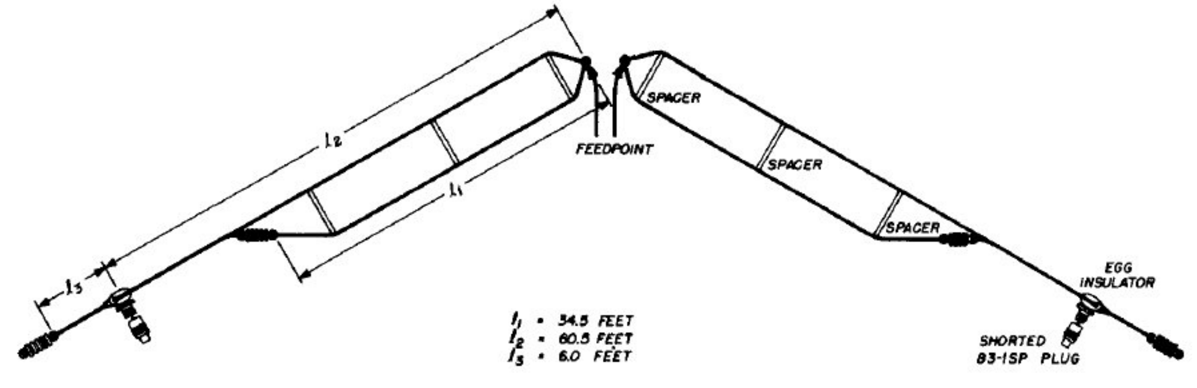
l_2
l_1
l_3
FEEDPOINT
SPACER
SPACER
SPACER
EGG INSULATOR
SHORTED 83-1SP PLUG
l_1 = 34.5 FEET
l_2 = 60.5 FEET
l_3 = 6.0 FEET

217 - Swiss Quad Antenna for 20m, 15m, 10m

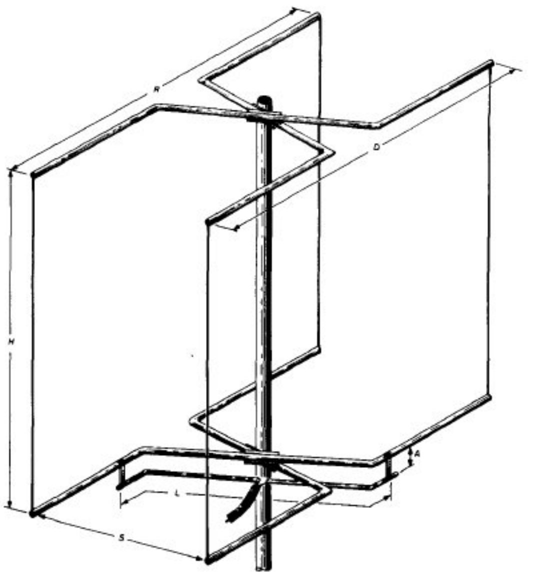

Dimensions for the Swiss quad (in inches).

frequency (MHz)	reflector horizontal (R)	radiator horizonal (D)	vertical (H)	spacing (S)	gamma length (L)	gamma spacing (A)
14.05	248	223½	236	84	188½	4¼
14.2	245	221	233	83	186½	4¼
21.05	165	149	157	56	126	2½
21.2	162½	148	155½	55½	124½	2½
28.05	124	112	118	42	94½	2
28.5	122	110	116	41½	93	2

218 - Japanese Quad Antenna for 20m, 15m, 10m

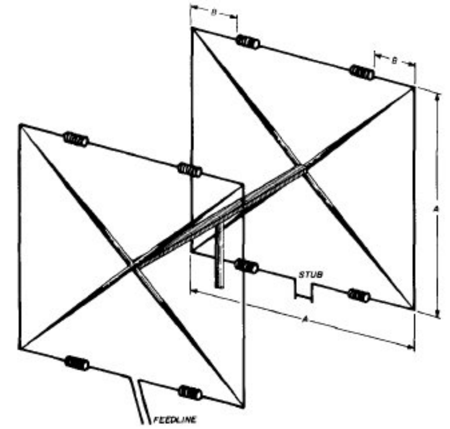
B
B
A
A
STUB
FEEDLINE

Construction details of the Japanese quad (in inches).

frequency (MHz)	quad side (A)	spacing	coil location (B)	coil (µH)	winding info
14	152	101	38	3.0	17½ turns no. 14, 1½" diameter, 5" long
21	98	67	24½	2.0	11 turns no. 14, 1½" diameter, 3½" long
28	77	50	19¼	1.5	9½ turns no. 14, 1½" diameter, 3½" long

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219 - Seven-Elements Triangle Beam Antenna for 20m

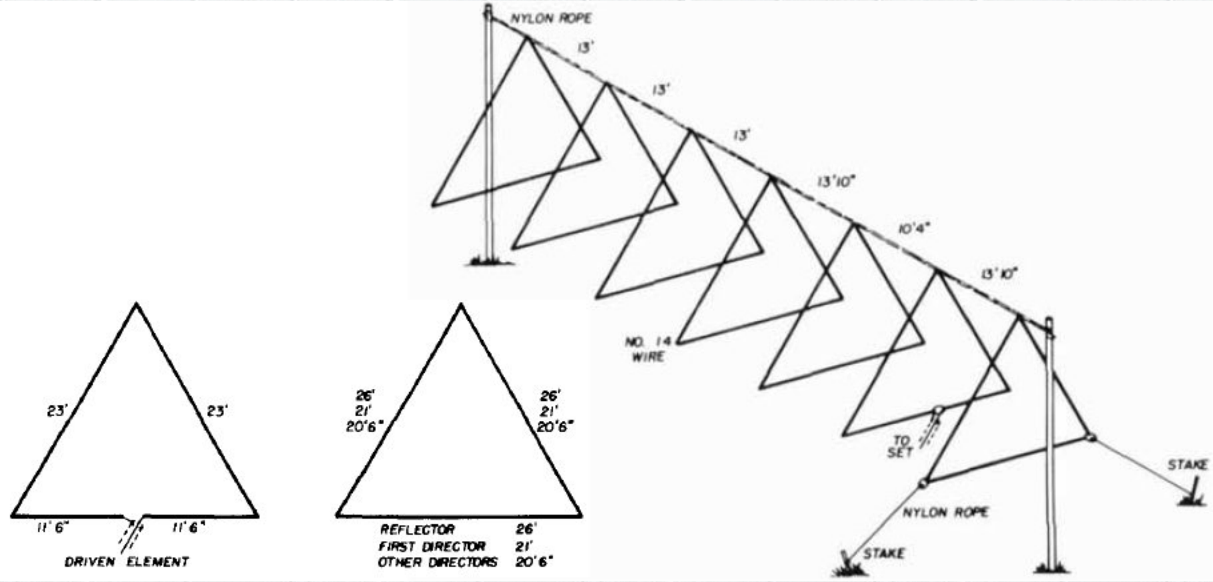
NYLON ROPE
13'
13'
13'
13'10"
10'4"
13'10"
NO. 14 WIRE
TO SET
STAKE
NYLON ROPE
STAKE
23'
23'
11'6"
11'6"
DRIVEN ELEMENT
26'
21'
20'6"
26'
21'
20'6"
REFLECTOR 26'
FIRST DIRECTOR 21'
OTHER DIRECTORS 20'6"

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220 - Log Periodic Wire Antenna for 40m

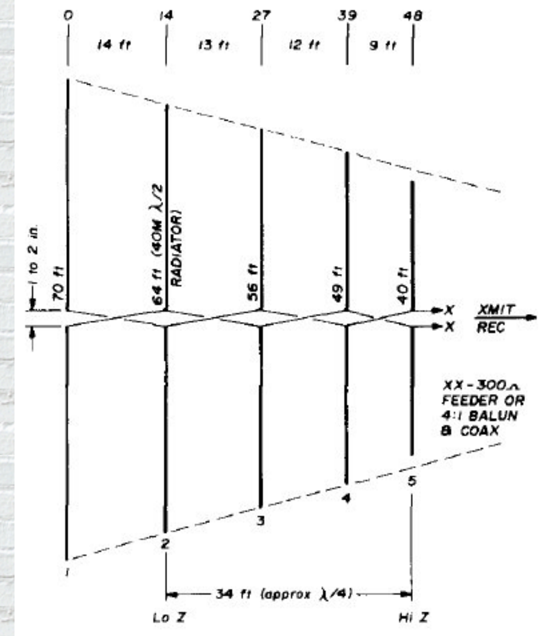
0
14
27
39
48
14 ft
13 ft
12 ft
9 ft
1 to 2 in.
70 ft
64 ft (40M λ/2 RADIATOR)
56 ft
49 ft
40 ft
X XMIT
X REC
XX-300Ω FEEDER OR 4:1 BALUN & COAX
1
2
3
4
5
34 ft (approx λ/4)
Lo Z
Hi Z

221 - Three-Elements 90-degrees Wire Beam for 20m

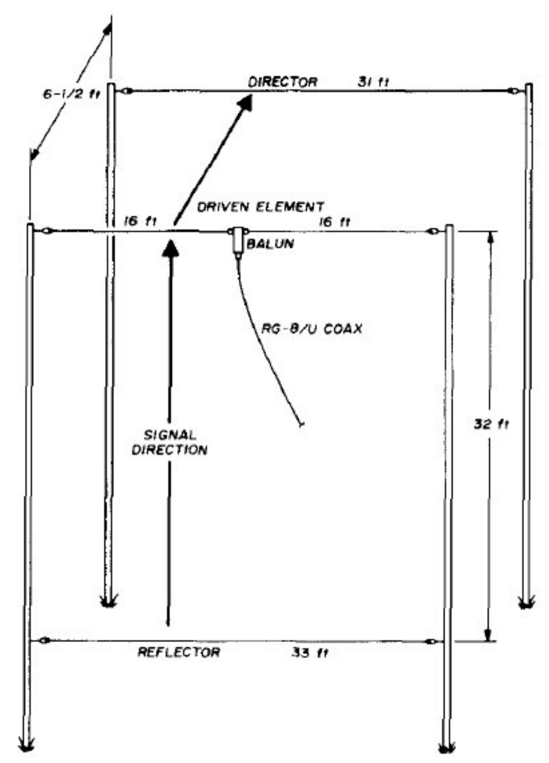
6-1/2 ft
DIRECTOR 31 ft
16 ft
DRIVEN ELEMENT
16 ft
BALUN
RG-8/U COAX
SIGNAL DIRECTION
32 ft
REFLECTOR 33 ft

222 - Two-Elements Wire Beam for 20m

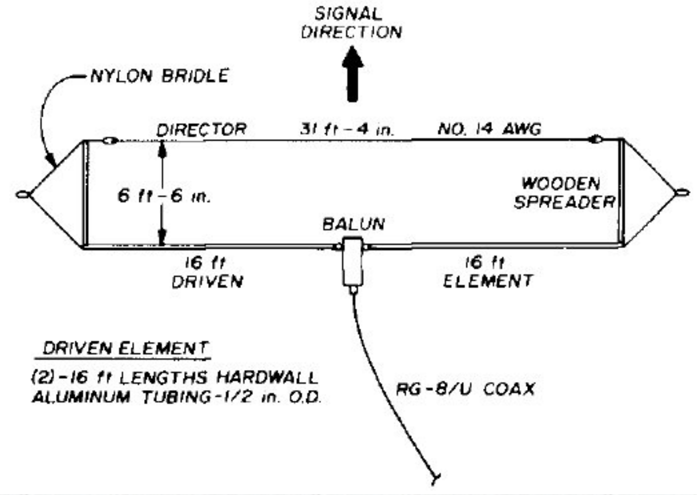
SIGNAL DIRECTION
NYLON BRIDLE
DIRECTOR 31 ft - 4 in. NO. 14 AWG
6 ft - 6 in.
WOODEN SPREADER
BALUN
16 ft DRIVEN
16 ft ELEMENT
DRIVEN ELEMENT
(2)-16 ft LENGTHS HARDWALL ALUMINUM TUBING-1/2 in. O.D.
RG-8/U COAX

223 - Suitcase-Fit Dipole Antenna for 80m, 40m, 20m

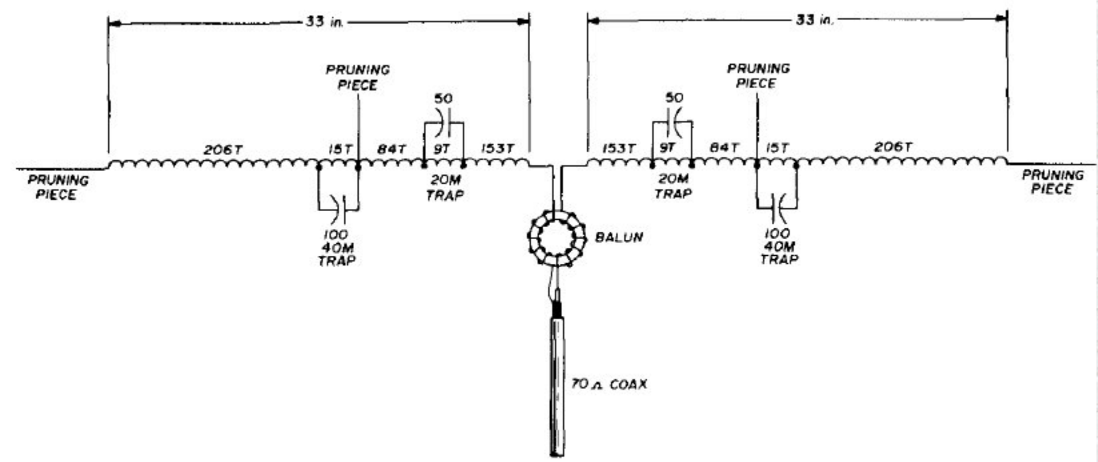
33 in.
33 in.
PRUNING PIECE
PRUNING PIECE
50
50
206T
15T
84T
9T
153T
153T
9T
84T
15T
206T
PRUNING PIECE
PRUNING PIECE
20M TRAP
20M TRAP
100 40M TRAP
100 40M TRAP
BALUN
70 Ω COAX

224 - Multiband Coaxial Dipole for 80m, 40m

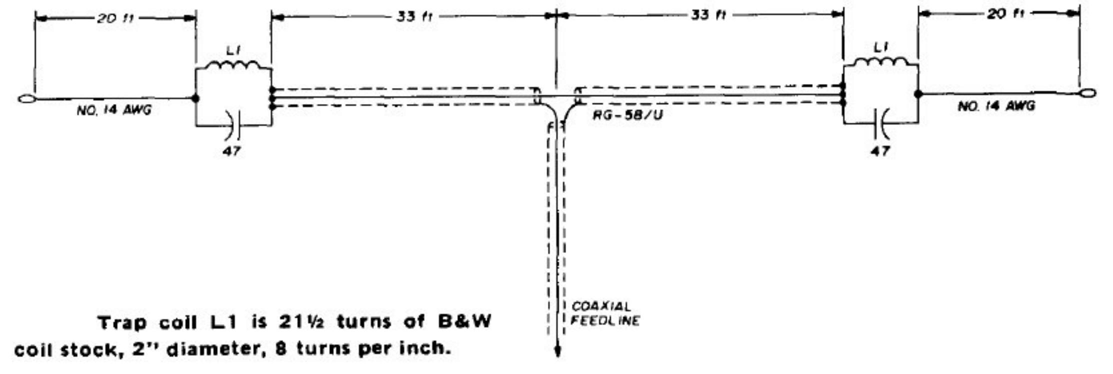
20 ft
33 ft
33 ft
20 ft
L1
L1
NO. 14 AWG
NO. 14 AWG
47
47
RG-58/U
COAXIAL FEEDLINE

Trap coil L1 is 21½ turns of B&W coil stock, 2" diameter, 8 turns per inch.

225 - Vertical Log Periodic Antenna for 80m, 40m

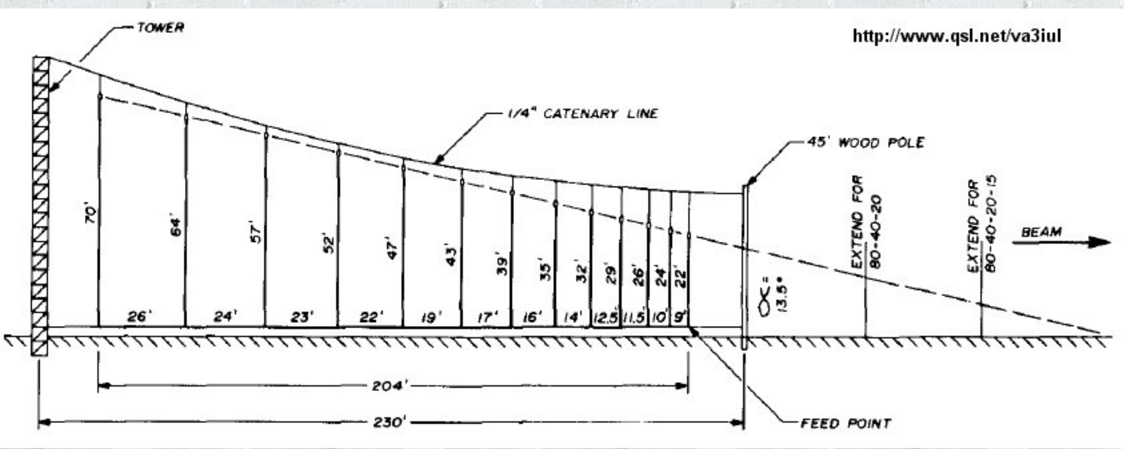
TOWER
http://www.qsl.net/va3iul
1/4" CATENARY LINE
45' WOOD POLE
70'
64'
57'
52'
47'
43'
39'
35'
32'
29'
26'
24'
22'
α = 13.5°
EXTEND FOR 80-40-20
EXTEND FOR 80-40-20-15
BEAM
26'
24'
23'
22'
19'
17'
16'
14'
12.5'
11.5'
10'
9'
204'
230'
FEED POINT

226 - Inverted Vertical Log Periodic Antenna for 40m

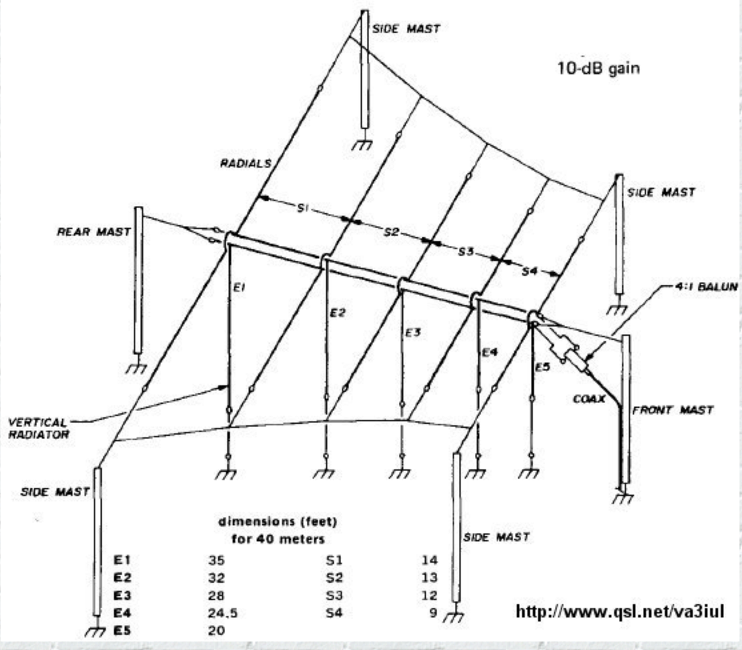
SIDE MAST
10-dB gain
RADIALS
SIDE MAST
REAR MAST
S1
S2
S3
S4
4:1 BALUN
E1
E2
E3
E4
E5
COAX
FRONT MAST
VERTICAL RADIATOR
SIDE MAST
SIDE MAST
dimensions (feet)
for 40 meters
E1 35 S1 14
E2 32 S2 13
E3 28 S3 12
E4 24.5 S4 9
E5 20
http://www.qsl.net/va3iul

---

227 - Double Extended Zepp Antenna Gain=7dB for 15m

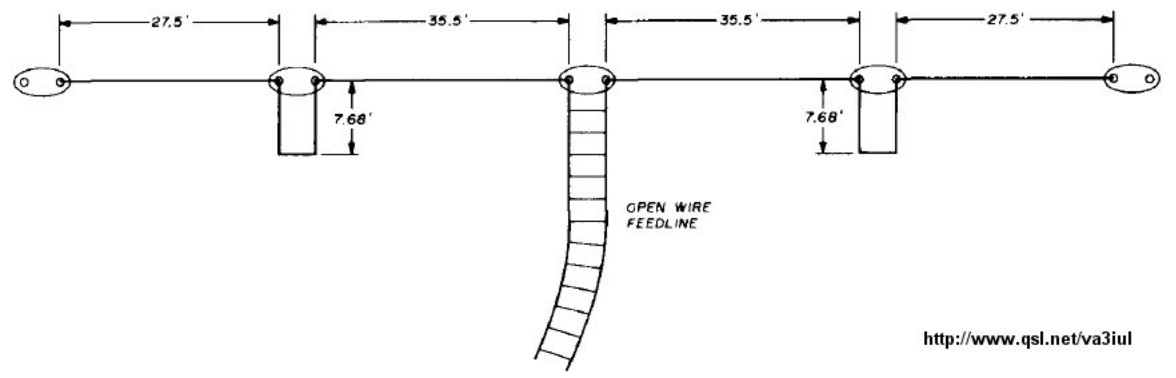
27.5'
35.5'
35.5'
27.5'
7.68'
7.68'
OPEN WIRE FEEDLINE
http://www.qsl.net/va3iul

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228 - Double Lazy-H Antenna G=10dB for 70cm

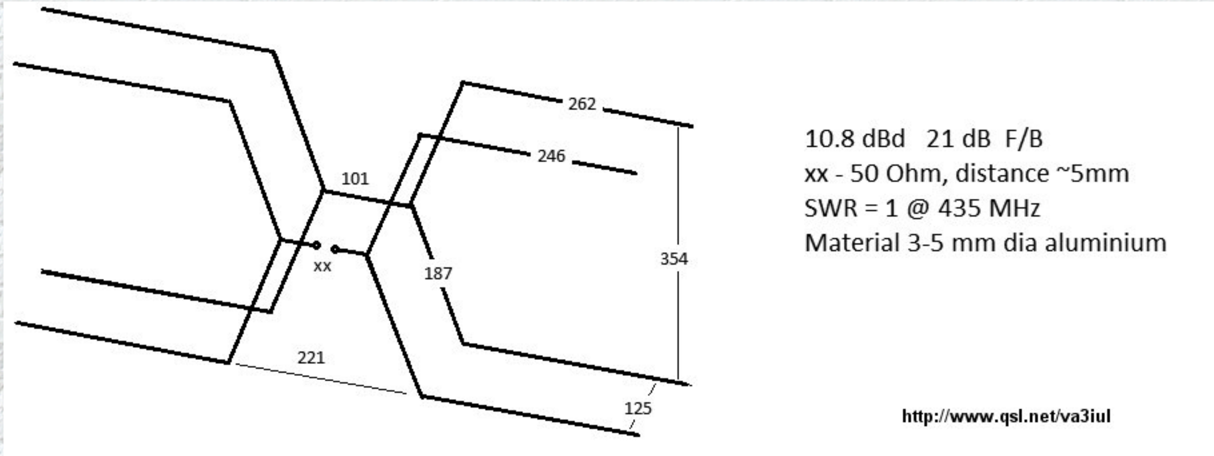
262
246
101
xx
187
354
221
125
10.8 dBd 21 dB F/B
xx - 50 Ohm, distance ~5mm
SWR = 1 @ 435 MHz
Material 3-5 mm dia aluminium
http://www.qsl.net/va3iul

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229 - Wire Log Periodic Antenna G=12dB for 15m, 20m

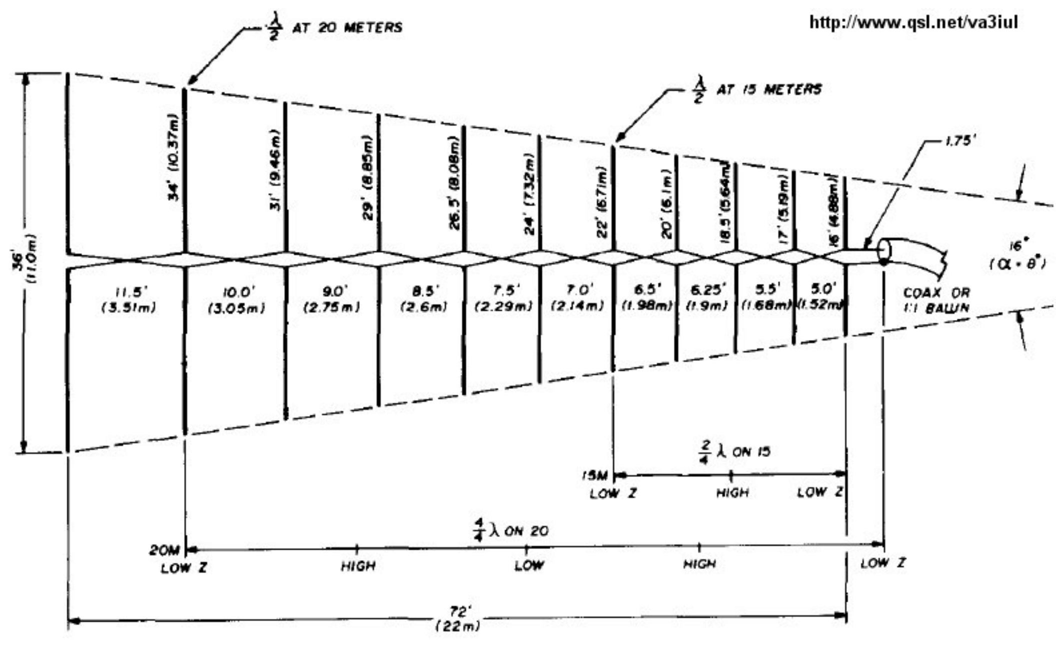
http://www.qsl.net/va3iul
λ/2 AT 20 METERS
λ/2 AT 15 METERS
1.75'
36' (11.0m)
34' (10.37m)
31' (9.46m)
29' (8.85m)
26.5' (8.08m)
24' (7.32m)
22' (6.71m)
20' (6.1m)
18.5' (5.64m)
17' (5.19m)
16' (4.88m)
11.5' (3.51m)
10.0' (3.05m)
9.0' (2.75m)
8.5' (2.6m)
7.5' (2.29m)
7.0' (2.14m)
6.5' (1.98m)
6.25' (1.9m)
5.5' (1.68m)
5.0' (1.52m)
COAX OR 1:1 BALUN
16° (α = 8°)
2/4 λ ON 15
15M LOW Z
HIGH
LOW Z
4/4 λ ON 20
20M LOW Z
HIGH
LOW
HIGH
LOW Z
72' (22m)

---

230 - Five-Elements Vertical Log Periodic for 80m, 40m, 20m

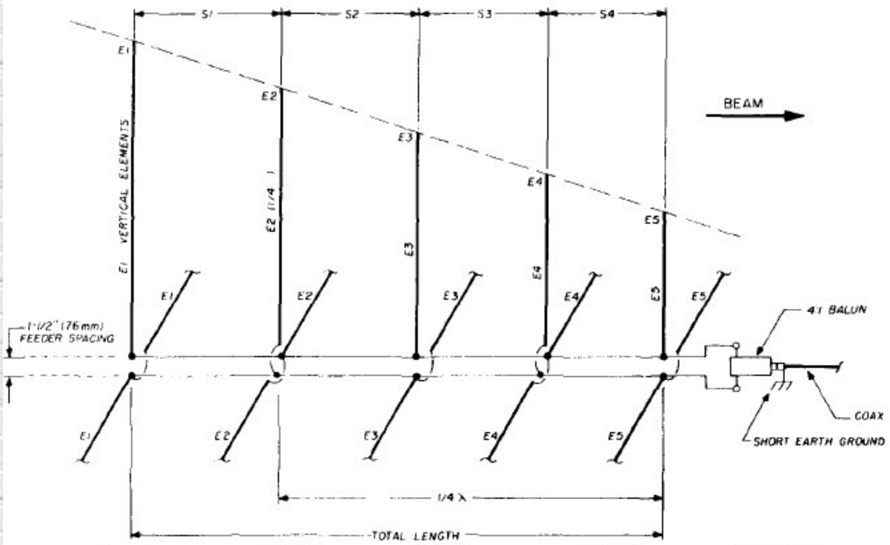
S1
S2
S3
S4
E1
E2
E3
E4
E5
BEAM
E1 VERTICAL ELEMENTS
E2 (1/4 λ)
E3
E4
E5
1-1/2" (76mm) FEEDER SPACING
4:1 BALUN
COAX
SHORT EARTH GROUND
1/4 λ
TOTAL LENGTH

element	3.5-4.0^1	3.8-4.0^2	7.0-7.3^2	14.0-14.35^1
E1	70' (21.4 m)	65' (19.8 m)	35' (10.7 m)	17.5' (5.3 m)
E2	67' (20.4 m)	62' (18.9 m)	33' (10.0 m)	16.5' (5.0 m)
E3	58' (17.7 m)	55' (16.8 m)	28' (8.5 m)	14.0' (4.3 m)
E4	50' (15.3 m)	45' (13.7 m)	24.5' (7.5 m)	12.2' (3.7 m)
E5	43' (13.1 m)	40' (12.2 m)	20' (6.1 m)	10.0' (3.0 m)
S1	30' (9.2 m)	26' (7.9 m)	14' (4.3 m)	7.0' (2.1 m)
S2	27' (8.2 m)	24' (7.3 m)	13' (4.0 m)	6.5' (2.0 m)
S3	24' (7.3 m)	23' (7.0 m)	12' (3.7 m)	6.0' (1.8 m)
S4	19' (5.8 m)	18' (5.5 m)	9' (2.7 m)	4.5' (1.4 m)
total length	100' (30.5 m)	91' (27.8 m)	48' (14.6 m)	24' (7.3 m)
mast height	80' (24.4 m)	75' (22.9 m)	50' (15.3 m)	30' (9.2 m)
pole height	45' (13.7 m)	40' (12.2 m)	25' (7.6 m)	20' (6.1 m)

http://www.qsl.net/va3iul

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231 - Sloping Delta Loop Antenna for 40m

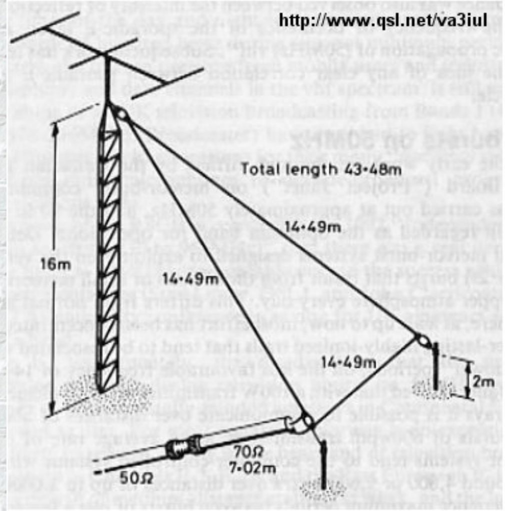
http://www.qsl.net/va3iul
Total length 43·48m
14·49m
16m
14·49m
14·49m
2m
70Ω
7·02m
50Ω

232 - Doublet Antenna for 160m

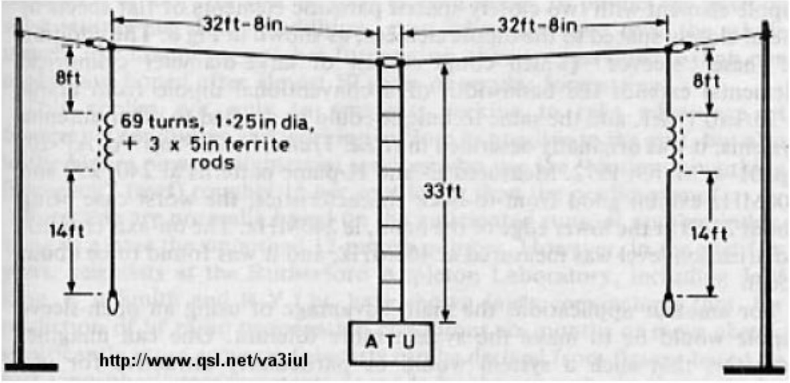
32ft-8in
32ft-8in
8ft
8ft
69 turns, 1·25in dia,
+ 3 x 5in ferrite
rods
33ft
14ft
14ft
A T U
http://www.qsl.net/va3iul

233 - Log Periodic Wire Beam for 40m

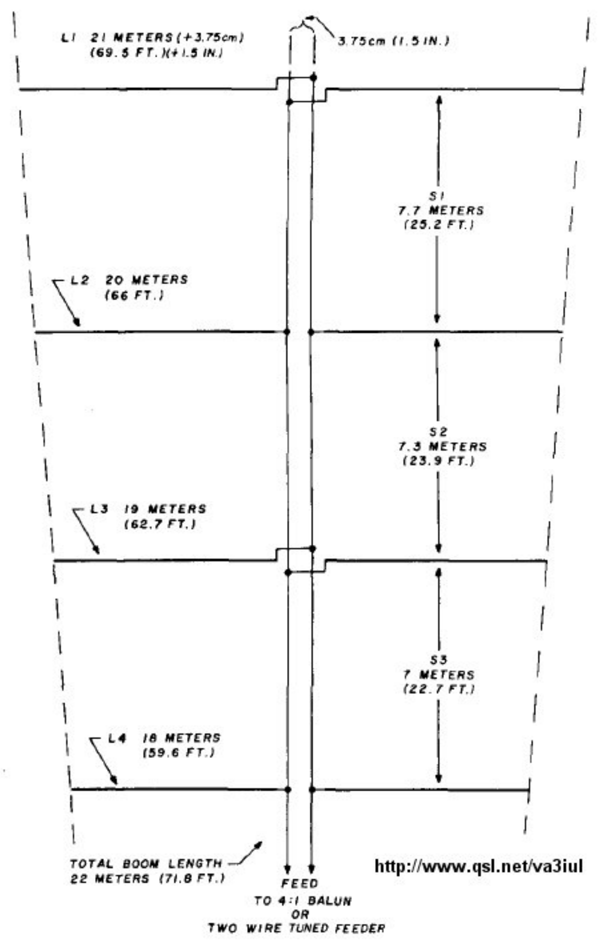
L1 21 METERS (+3.75cm)
(69.5 FT.)(+1.5 IN.)
3.75cm (1.5 IN.)
S1
7.7 METERS
(25.2 FT.)
L2 20 METERS
(66 FT.)
S2
7.3 METERS
(23.9 FT.)
L3 19 METERS
(62.7 FT.)
S3
7 METERS
(22.7 FT.)
L4 18 METERS
(59.6 FT.)
TOTAL BOOM LENGTH
22 METERS (71.8 FT.)
FEED
TO 4:1 BALUN
OR
TWO WIRE TUNED FEEDER
http://www.qsl.net/va3iul

---

234 - G3LDO Wire Beam Antenna for 20m, 15m, 10m

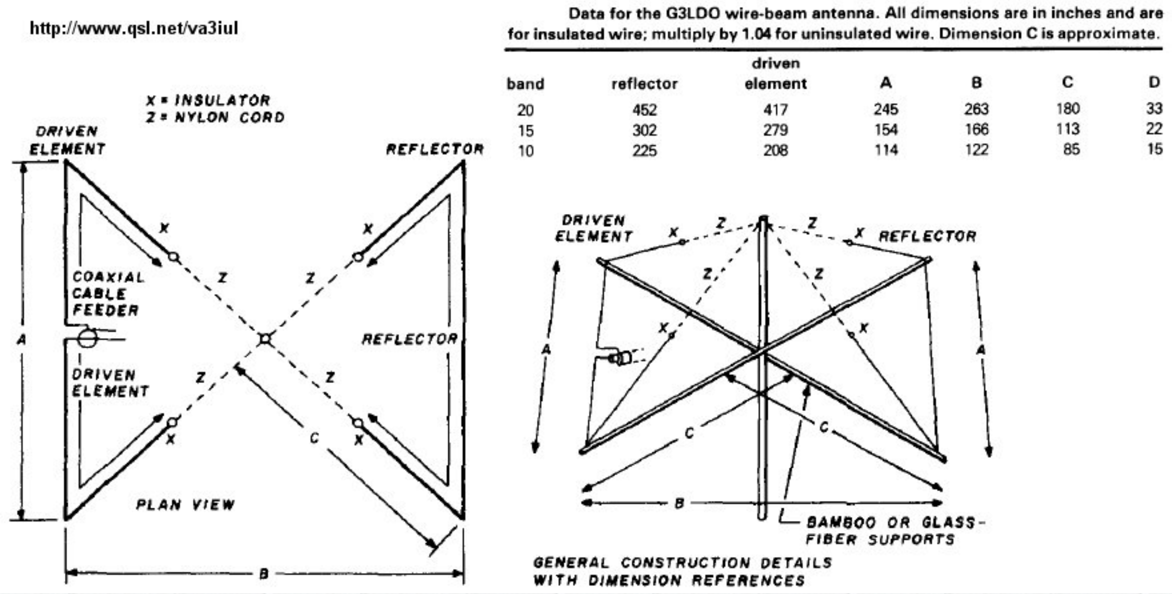
http://www.qsl.net/va3iul

Data for the G3LDO wire-beam antenna. All dimensions are in inches and are for insulated wire; multiply by 1.04 for uninsulated wire. Dimension C is approximate.

band	reflector	driven element	A	B	C	D
20	452	417	245	263	180	33
15	302	279	154	166	113	22
10	225	208	114	122	85	15

X = INSULATOR
Z = NYLON CORD
DRIVEN ELEMENT
REFLECTOR
COAXIAL CABLE FEEDER
A
B
C
X
Z
PLAN VIEW
BAMBOO OR GLASS-FIBER SUPPORTS
GENERAL CONSTRUCTION DETAILS WITH DIMENSION REFERENCES

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235 - Phased Delta Loop Array for 20m

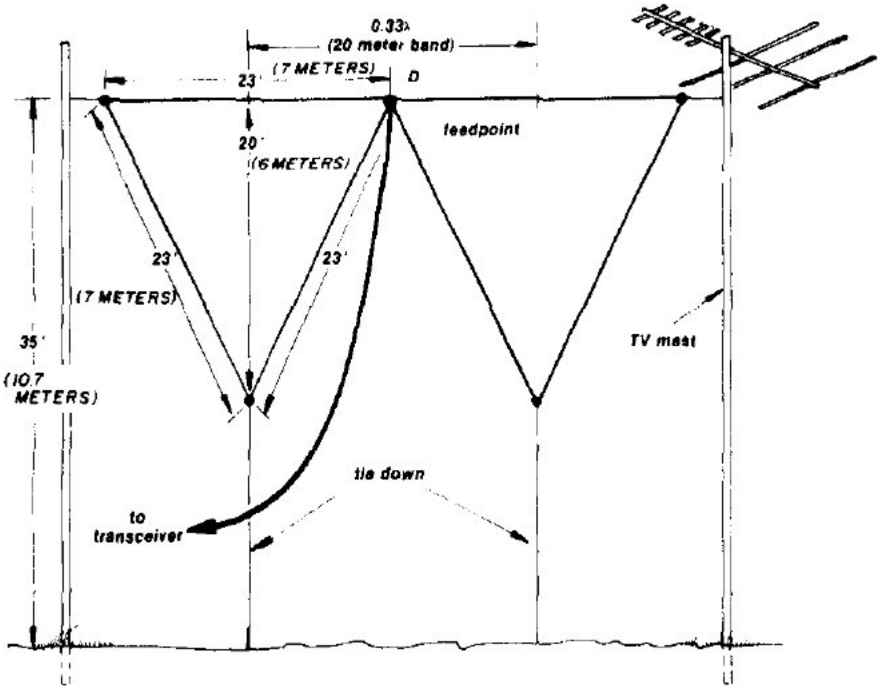
0.33λ
(20 meter band)
23'
(7 METERS)
D
20'
(6 METERS)
feedpoint
23'
23'
(7 METERS)
35'
(10.7 METERS)
TV mast
tie down
to transceiver

spacing wavelength	feet	(meters)	gain (dB)
0.33	23	(7)	2.0
0.40	27	(8)	2.8
0.50	34	(10)	4.0
0.65	44	(13)	4.8

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236 - Dual Band V-dipole for 80m, 40m

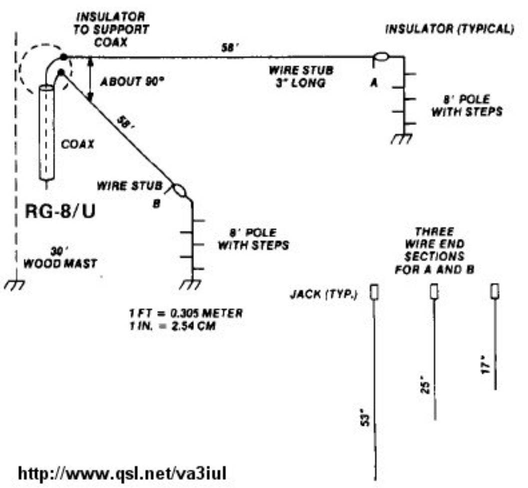
INSULATOR TO SUPPORT COAX
58'
INSULATOR (TYPICAL)
ABOUT 90°
WIRE STUB 3" LONG
A
8' POLE WITH STEPS
58'
COAX
WIRE STUB
B
RG-8/U
30' WOOD MAST
8' POLE WITH STEPS
THREE WIRE END SECTIONS FOR A AND B
JACK (TYP.)
1 FT = 0.305 METER
1 IN. = 2.54 CM
53"
25"
17"
http://www.qsl.net/va3iul

237 - Collinear Array 5dB-Gain for 15m

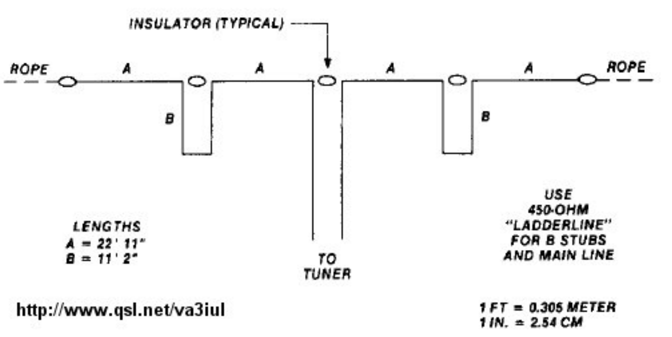
INSULATOR (TYPICAL)
ROPE
A
A
A
A
ROPE
B
B
LENGTHS
A = 22' 11"
B = 11' 2"
TO TUNER
USE 450-OHM "LADDERLINE" FOR B STUBS AND MAIN LINE
http://www.qsl.net/va3iul
1 FT = 0.305 METER
1 IN. = 2.54 CM

238 - Two-Band Quad Loop Antenna 80m, 40m

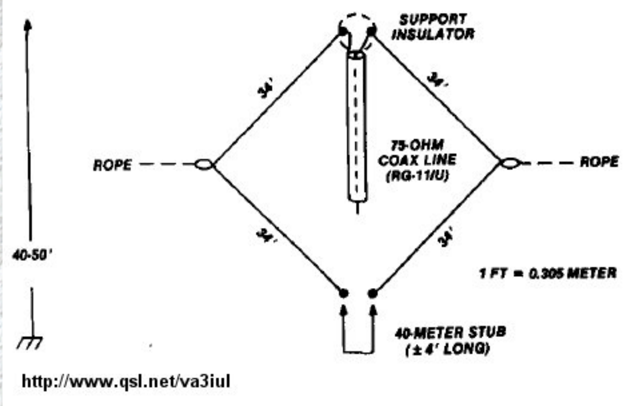
SUPPORT INSULATOR
34'
34'
34'
34'
ROPE
ROPE
75-OHM COAX LINE (RG-11/U)
40-50'
1 FT = 0.305 METER
40-METER STUB (±4' LONG)
http://www.qsl.net/va3iul

---

239 - K7CW Quad Antenna

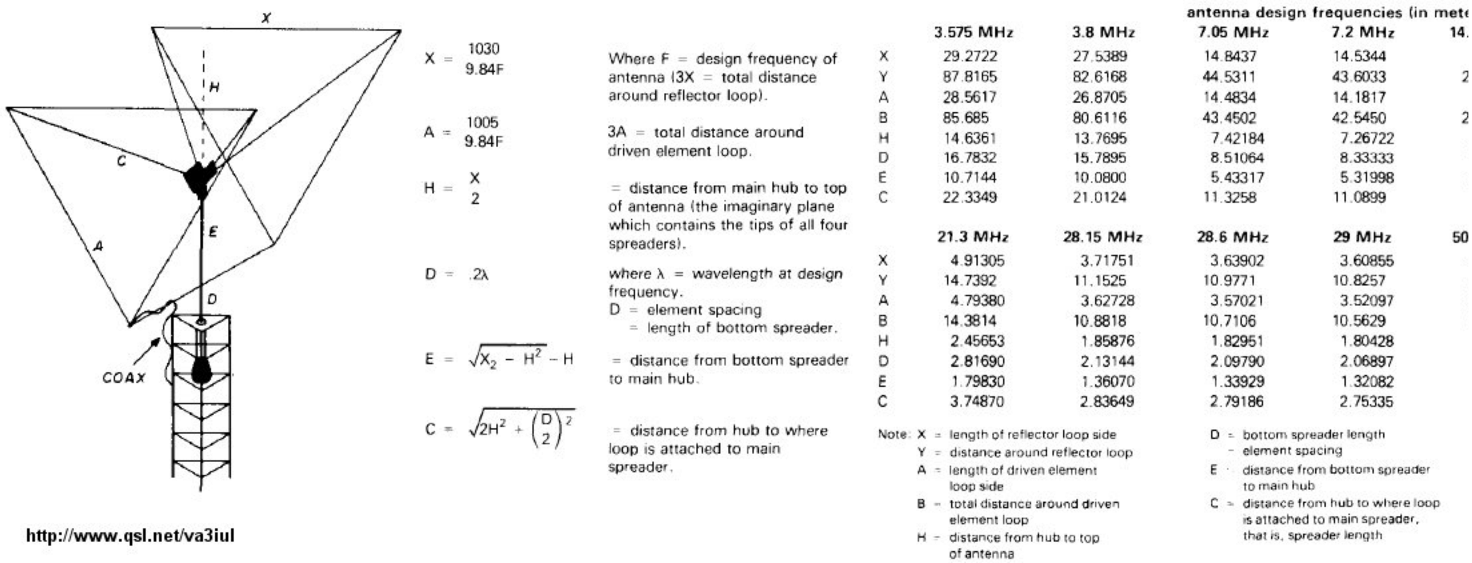
X
H
C
A
E
D
COAX
http://www.qsl.net/va3iul

$X = \frac{1030}{9.84F}$ Where F = design frequency of antenna (3X = total distance around reflector loop).

$A = \frac{1005}{9.84F}$ 3A = total distance around driven element loop.

$H = \frac{X}{2}$ = distance from main hub to top of antenna (the imaginary plane which contains the tips of all four spreaders).

$D = .2\lambda$ where λ = wavelength at design frequency.
D = element spacing
= length of bottom spreader.

$E = \sqrt{X_2 - H^2} - H$ = distance from bottom spreader to main hub.

$C = \sqrt{2H^2 + \left(\frac{D}{2}\right)^2}$ = distance from hub to where loop is attached to main spreader.

antenna design frequencies (in mete

	3.575 MHz	3.8 MHz	7.05 MHz	7.2 MHz	14.
X	29.2722	27.5389	14.8437	14.5344	
Y	87.8165	82.6168	44.5311	43.6033	2
A	28.5617	26.8705	14.4834	14.1817	
B	85.685	80.6116	43.4502	42.5450	2
H	14.6361	13.7695	7.42184	7.26722	
D	16.7832	15.7895	8.51064	8.33333	
E	10.7144	10.0800	5.43317	5.31998	
C	22.3349	21.0124	11.3258	11.0899	

	21.3 MHz	28.15 MHz	28.6 MHz	29 MHz	50
X	4.91305	3.71751	3.63902	3.60855	
Y	14.7392	11.1525	10.9771	10.8257	
A	4.79380	3.62728	3.57021	3.52097	
B	14.3814	10.8818	10.7106	10.5629	
H	2.45653	1.85876	1.82951	1.80428	
D	2.81690	2.13144	2.09790	2.06897	
E	1.79830	1.36070	1.33929	1.32082	
C	3.74870	2.83649	2.79186	2.75335	

Note: X = length of reflector loop side
Y = distance around reflector loop
A = length of driven element loop side
B = total distance around driven element loop
H = distance from hub to top of antenna
D = bottom spreader length
= element spacing
E = distance from bottom spreader to main hub
C = distance from hub to where loop is attached to main spreader, that is, spreader length

---

240 - Broadband Short Dipole for 80m

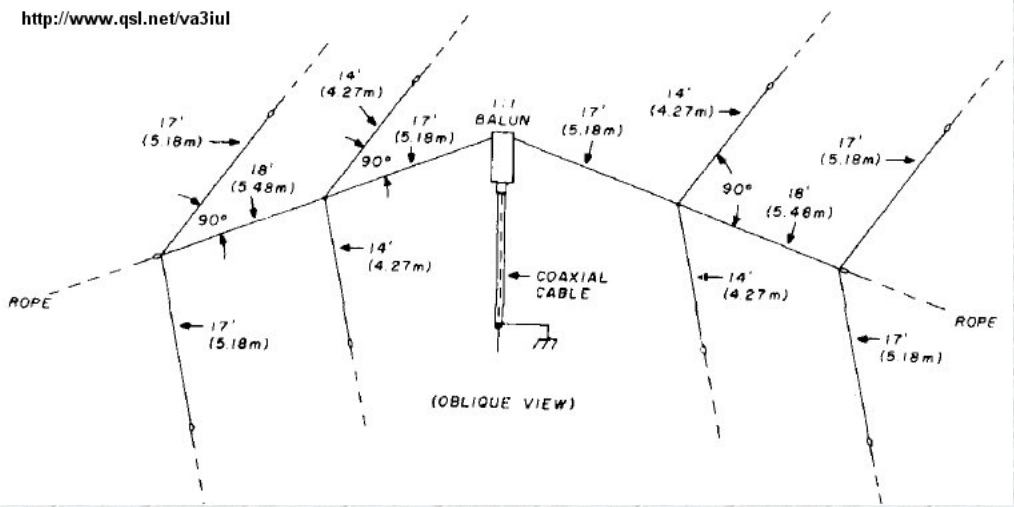
http://www.qsl.net/va3iul
14' (4.27m)
17' (5.18m)
17' (5.18m)
18' (5.48m)
90°
90°
1:1 BALUN
17' (5.18m)
14' (4.27m)
17' (5.18m)
90°
18' (5.48m)
ROPE
14' (4.27m)
COAXIAL CABLE
14' (4.27m)
ROPE
17' (5.18m)
17' (5.18m)
(OBLIQUE VIEW)

---

241 - Off-Center Fed Dipole for 40m, 20m, 10m

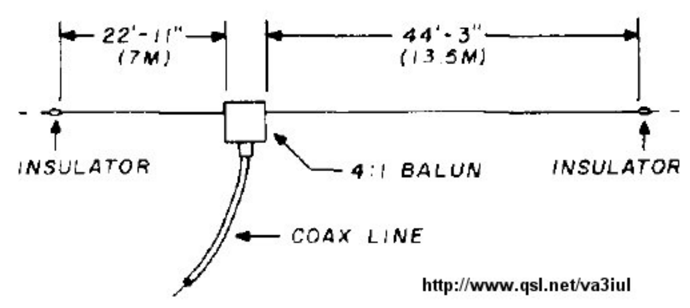
22'-11"
(7M)
44'-3"
(13.5M)
INSULATOR
4:1 BALUN
INSULATOR
COAX LINE
http://www.qsl.net/va3iul

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242 - Broadband Sloper Antenna for 80m

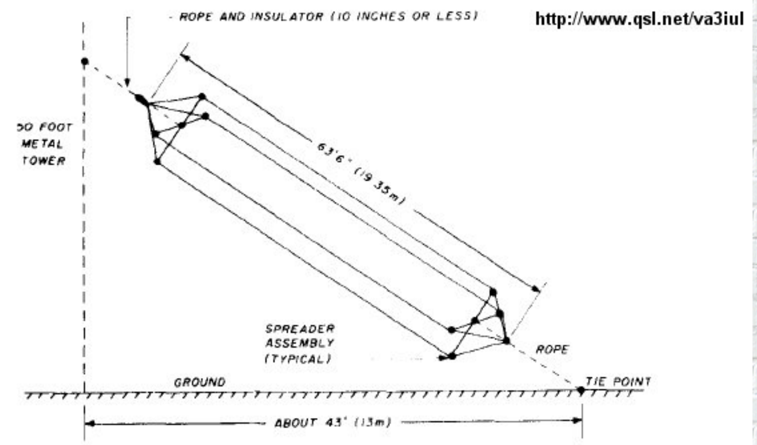
ROPE AND INSULATOR (10 INCHES OR LESS)
http://www.qsl.net/va3iul
50 FOOT
METAL
TOWER
63'6" (19.35m)
SPREADER
ASSEMBLY
(TYPICAL)
ROPE
GROUND
TIE POINT
ABOUT 43' (13m)

80-meter WD4FAB broadband sloper. Spreader assemblies are made of 36-inch long fiberglass tubes. The four antenna wires are tied together about 24 inches past each spreader assembly. A nylon line may be required from the crossover point of the spreader to the outer insulator to prevent bowing. The SWR plot of the antenna falls below 1.4-to-1 at 3.5 MHz; 1.25-to-1 at 3.8 MHz and 1.4-to-1 at 4.0 MHz. Feedpoint resistance of the antenna may be changed by altering the slope angle. The resonant frequency is adjusted by changing length — no climbing necessary!

---

243 - Two-Frequency Dipole Antenna for 80m

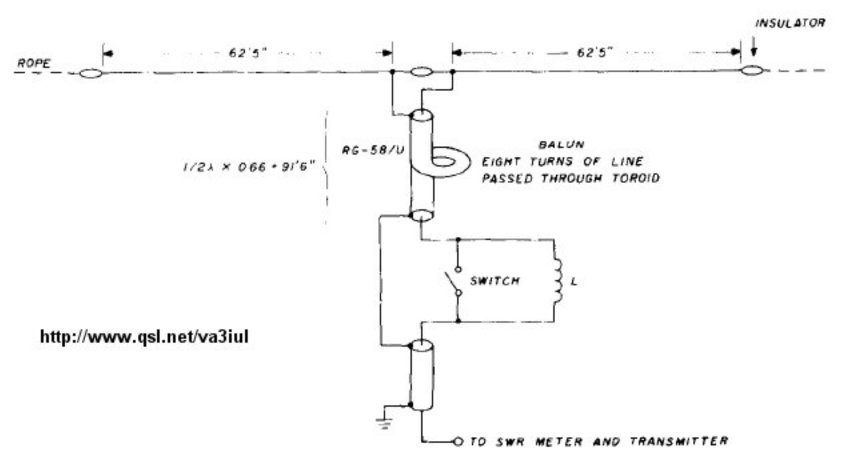
INSULATOR
ROPE
62'5"
62'5"
1/2λ × 0.66 = 91'6"
RG-58/U
BALUN
EIGHT TURNS OF LINE
PASSED THROUGH TOROID
SWITCH
L
http://www.qsl.net/va3iul
TO SWR METER AND TRANSMITTER

The W6TC two-frequency dipole for 80 meters. Antenna is cut for resonance at high frequency end of band. A single loading coil for operation at the low frequency end of the band is placed an electrical half-wavelength down the transmission line. The line is decoupled from the antenna by a simple balun placed directly at the antenna insulator. Toroid is powdered iron material T-200 (2″ OD) (1.25″ ID), 2-mix (red, μ = 10 (Amidon T-200-2), or equivalent.

---

244 - Top Loaded Vertical Antenna for 160m

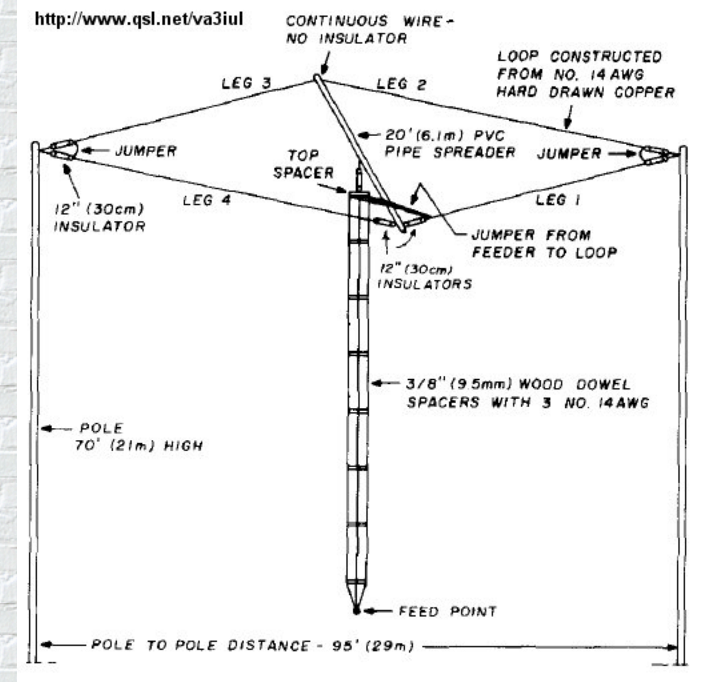
http://www.qsl.net/va3iul
CONTINUOUS WIRE - NO INSULATOR
LOOP CONSTRUCTED FROM NO. 14 AWG HARD DRAWN COPPER
LEG 3
LEG 2
20' (6.1m) PVC PIPE SPREADER
JUMPER
JUMPER
TOP SPACER
12" (30cm) INSULATOR
LEG 4
LEG 1
JUMPER FROM FEEDER TO LOOP
12" (30cm) INSULATORS
3/8" (9.5mm) WOOD DOWEL SPACERS WITH 3 NO. 14AWG
POLE 70' (21m) HIGH
FEED POINT
POLE TO POLE DISTANCE - 95' (29m)

245 - Two Loop Beam Antenna for 20m, 15m

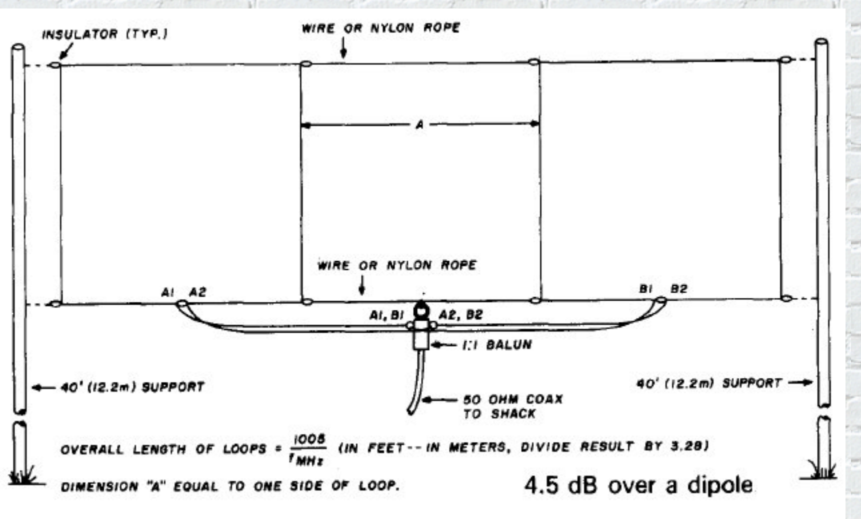
INSULATOR (TYP.)
WIRE OR NYLON ROPE
A
WIRE OR NYLON ROPE
A1 A2
B1 B2
A1, B1
A2, B2
1:1 BALUN
40' (12.2m) SUPPORT
40' (12.2m) SUPPORT
50 OHM COAX TO SHACK
OVERALL LENGTH OF LOOPS = 1005/f MHz (IN FEET--IN METERS, DIVIDE RESULT BY 3.28)
DIMENSION "A" EQUAL TO ONE SIDE OF LOOP.
4.5 dB over a dipole

The W2TBZ loop beam. The phasing lines are made of 300-ohm TV line. Length of phasing line = $\frac{468}{f_{MHz}}$ × velocity factor of 300-ohm line. Balun is supported at center of lower nylon rope.

http://www.qsl.net/va3iul

246 - Corner-Fed Delta Loop Antenna for 80m, 40m, 20m

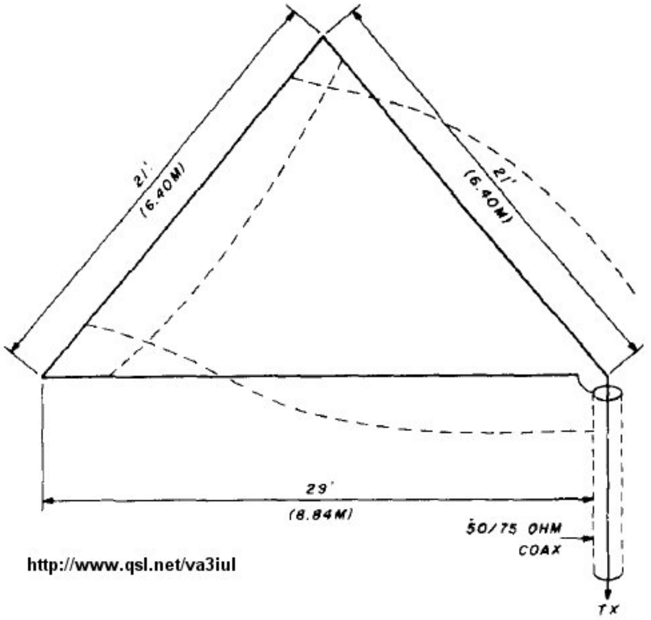
21'
(6.40M)
21'
(6.40M)
29'
(8.84M)
50/75 OHM
COAX
TX
http://www.qsl.net/va3iul

DIMENSIONS FOR FULL-SIZE CORNER-FED DELTA LOOPS

frequency (MHz)	total loop circumference (feet)	(meters)	length of each side (feet)	(meters)	length of base (feet)	(meters)
3.600	279 ft. 2 in.	(85.09)	82 ft.	(24.99)	115 ft. 2 in.	(35.10)
7.075	142 ft. 0 in.	(43.28)	42 ft.	(12.80)	58 ft. 0 in.	(17.68)
14.150	71 ft. 0 in.	(21.64)	21 ft.	(6.40)	29 ft. 0 in.	(8.84)

---

247 - Loaded Delta Loop Antenna for 40m, 20m

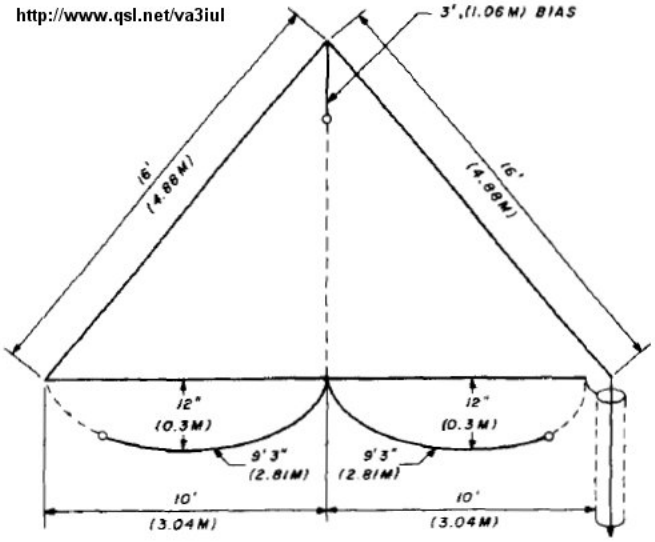
http://www.qsl.net/va3iul
3',(1.06M) BIAS
16'
(4.88M)
16'
(4.88M)
12"
(0.3M)
12"
(0.3M)
9'3"
(2.81M)
9'3"
(2.81M)
10'
(3.04M)
10'
(3.04M)

The final loaded loop for 14 MHz. All dimensions are doubled for operation on 7 MHz. Base loading wires are each 18 feet 4 inches (5.59 meters). The top loading wire is made taut by securing to base with thin light nylon cord.

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248 - Compact Size Dipole for 80m

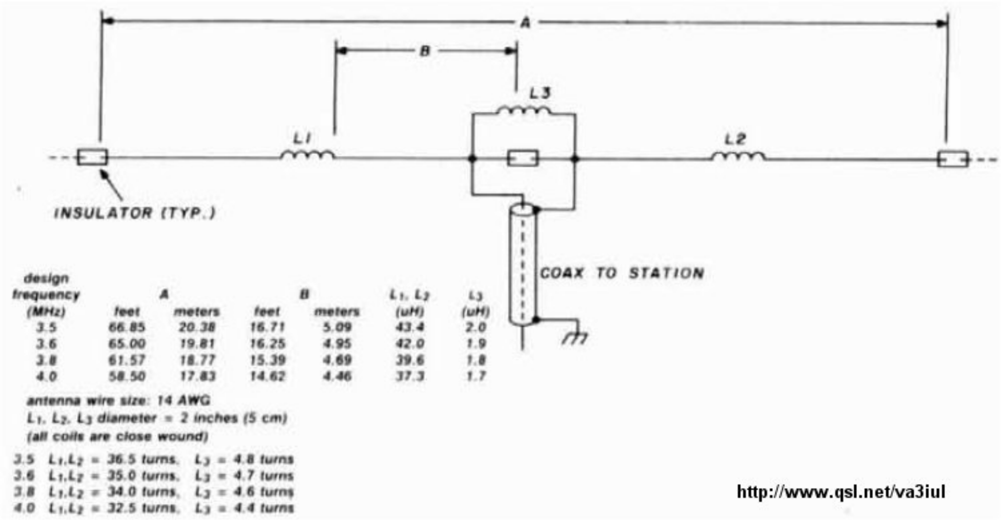
A
B
L3
L1
L2
INSULATOR (TYP.)
COAX TO STATION

design frequency (MHz)	A feet	A meters	B feet	B meters	L1, L2 (uH)	L3 (uH)
3.5	66.85	20.38	16.71	5.09	43.4	2.0
3.6	65.00	19.81	16.25	4.95	42.0	1.9
3.8	61.57	18.77	15.39	4.69	39.6	1.8
4.0	58.50	17.83	14.62	4.46	37.3	1.7

antenna wire size: 14 AWG
L_1, L_2, L_3 diameter = 2 inches (5 cm)
(all coils are close wound)

3.5 L_1, L_2 = 36.5 turns, L_3 = 4.8 turns
3.6 L_1, L_2 = 35.0 turns, L_3 = 4.7 turns
3.8 L_1, L_2 = 34.0 turns, L_3 = 4.6 turns
4.0 L_1, L_2 = 32.5 turns, L_3 = 4.4 turns

http://www.qsl.net/va3iul

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249 - JAWS 3dB Gain Antenna for 40m

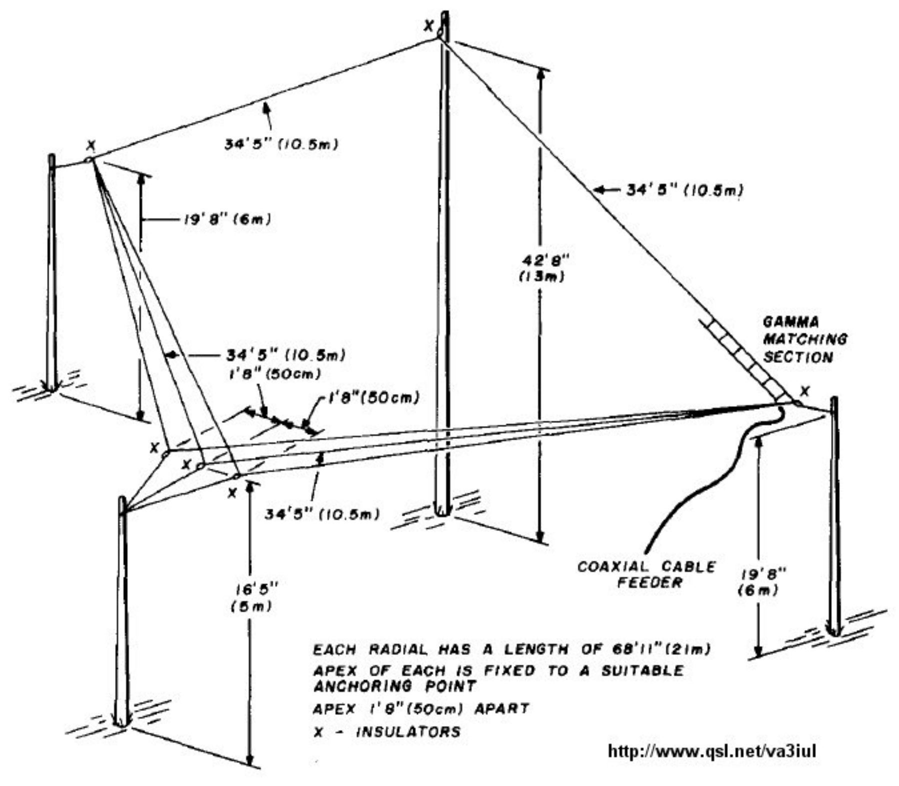
X
34' 5" (10.5m)
X
34' 5" (10.5m)
19' 8" (6m)
42' 8" (13m)
GAMMA MATCHING SECTION
34' 5" (10.5m)
1' 8" (50cm)
1' 8" (50cm)
X
X
X
X
34' 5" (10.5m)
COAXIAL CABLE FEEDER
19' 8" (6m)
16' 5" (5m)

EACH RADIAL HAS A LENGTH OF 68' 11" (21m)
APEX OF EACH IS FIXED TO A SUITABLE ANCHORING POINT
APEX 1' 8" (50cm) APART
X - INSULATORS

http://www.qsl.net/va3iul

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250 - Inverted-V Antenna for 160m

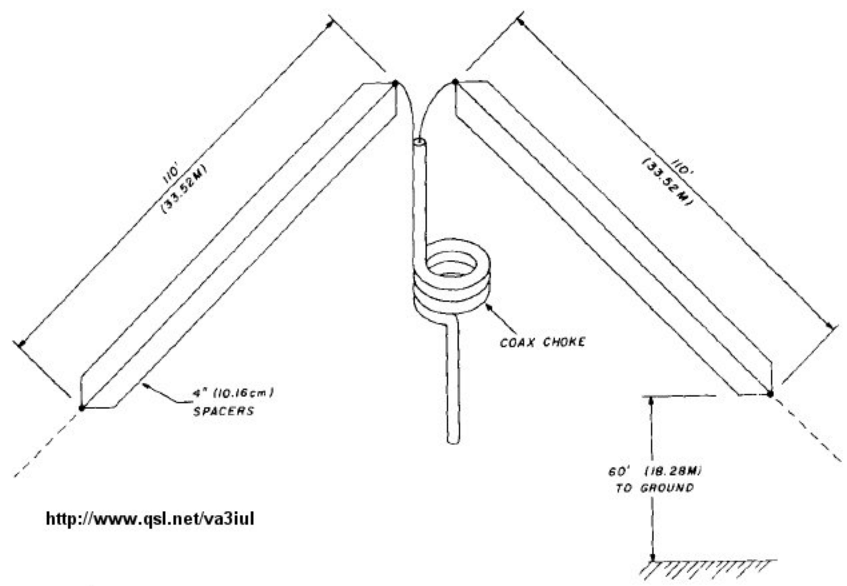
110'
(33.52M)
110'
(33.52M)
COAX CHOKE
4" (10.16cm)
SPACERS
60' (18.28M)
TO GROUND
http://www.qsl.net/va3iul

The inverted-V antenna for 160 meters at VE7BS. Wires all lie in the same plane. Apex is at 105 feet (32 meters).

---

251 - Lazy-U Antenna for 160m

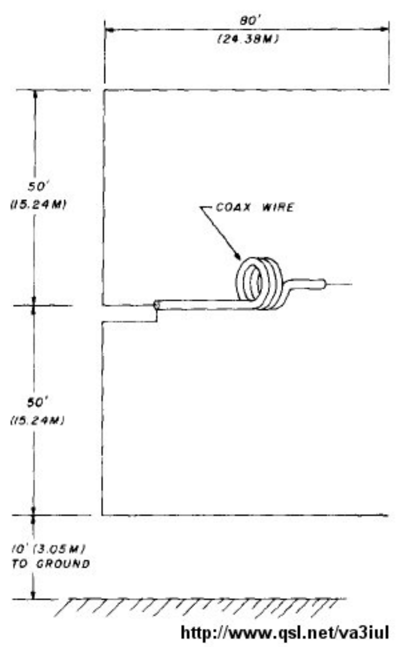
80'
(24.38M)
50'
(15.24M)
COAX WIRE
50'
(15.24M)
10' (3.05M)
TO GROUND
http://www.qsl.net/va3iul

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252 - AF3V Compact Antenna for 160m

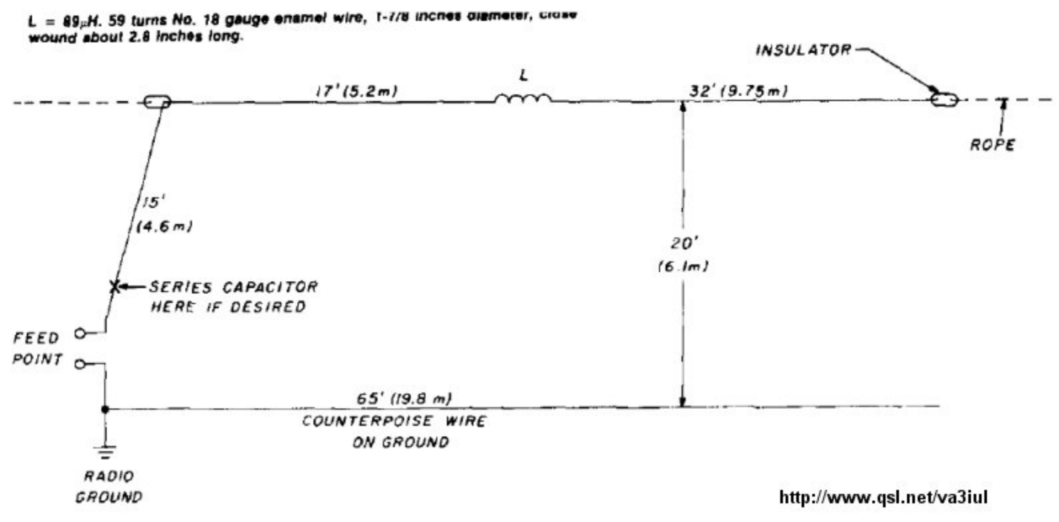
L = 89μH. 59 turns No. 18 gauge enamel wire, 1-7/8 inches diameter, close wound about 2.8 inches long.
INSULATOR
17' (5.2m)
L
32' (9.75m)
ROPE
15' (4.6m)
20' (6.1m)
SERIES CAPACITOR HERE IF DESIRED
FEED POINT
65' (19.8 m)
COUNTERPOISE WIRE ON GROUND
RADIO GROUND
http://www.qsl.net/va3iul

253 - Hot Beam Wire Antenna for 40m

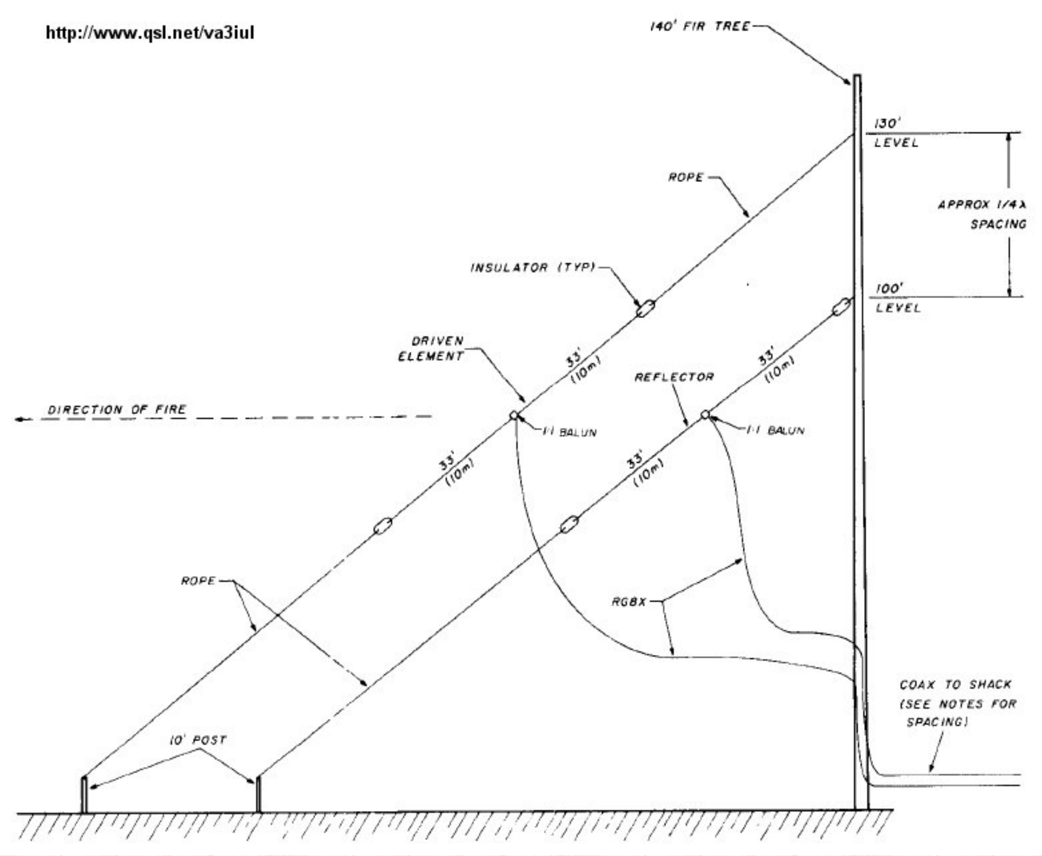
http://www.qsl.net/va3iul
140' FIR TREE
130' LEVEL
ROPE
APPROX 1/4λ SPACING
INSULATOR (TYP)
100' LEVEL
DRIVEN ELEMENT
33' (10m)
REFLECTOR
33' (10m)
DIRECTION OF FIRE
1:1 BALUN
1:1 BALUN
33' (10m)
33' (10m)
ROPE
RG8X
COAX TO SHACK (SEE NOTES FOR SPACING)
10' POST

254 - Sloping Delta Loop for 40m

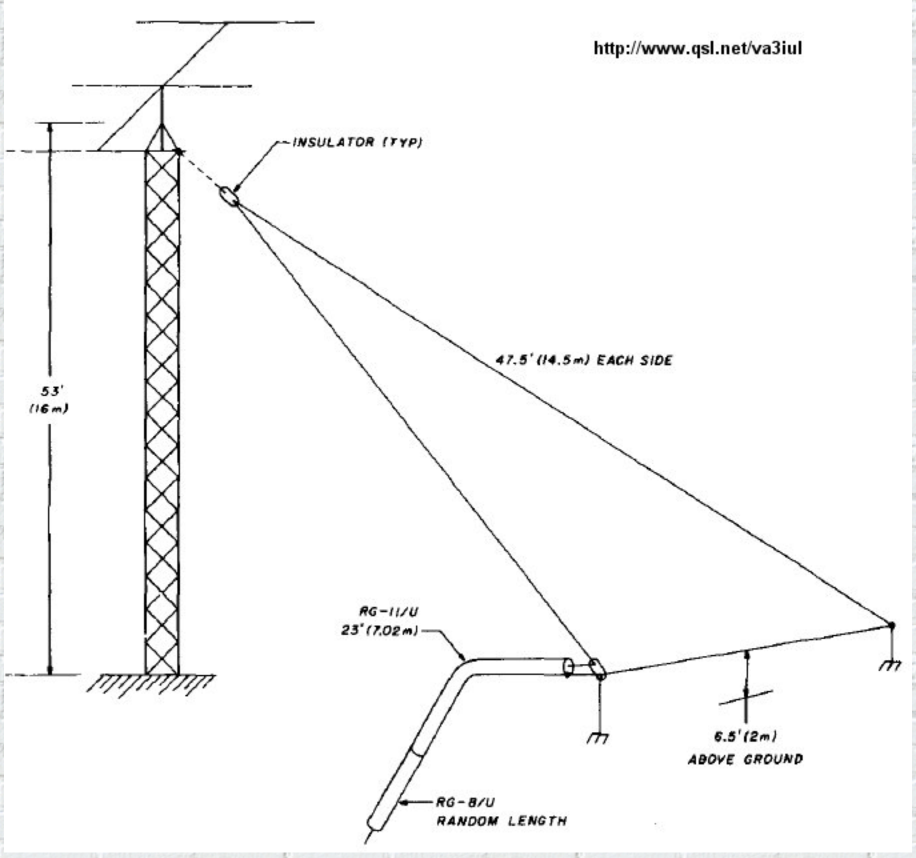
http://www.qsl.net/va3iul
INSULATOR (TYP)
53'
(16 m)
47.5' (14.5 m) EACH SIDE
RG-11/U
23' (7.02 m)
6.5' (2 m)
ABOVE GROUND
RG-8/U
RANDOM LENGTH

255 - K6FD Multiband Antenna with T-tuner

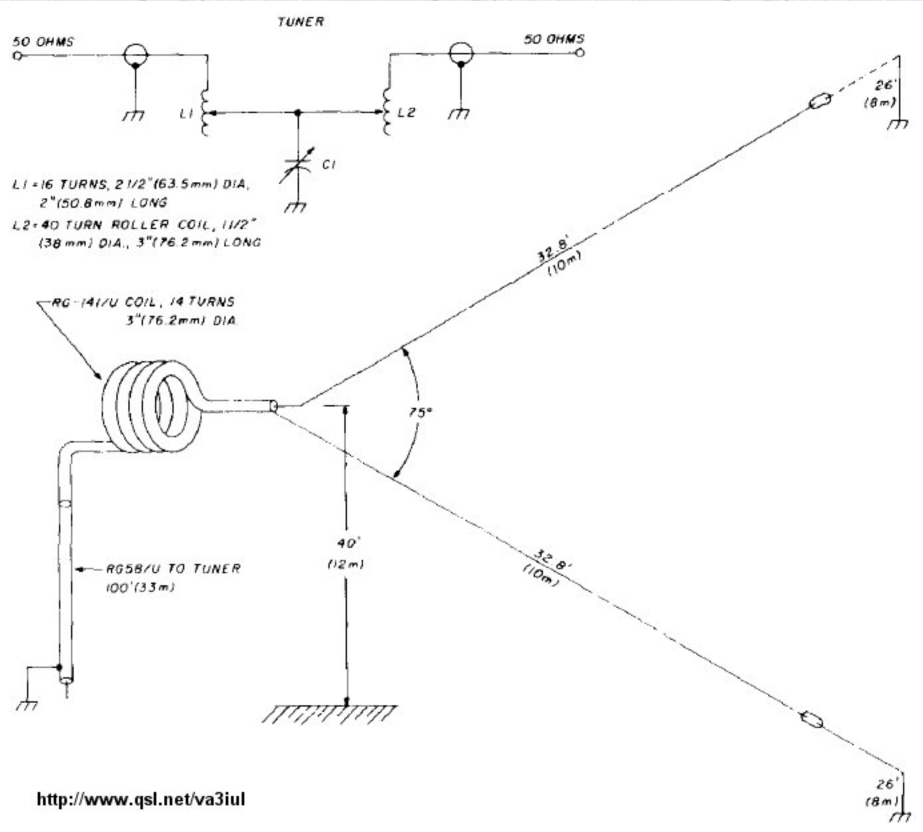
TUNER
50 OHMS
50 OHMS
L1
L2
C1
L1 = 16 TURNS, 2 1/2" (63.5 mm) DIA,
2" (50.8 mm) LONG
L2 = 40 TURN ROLLER COIL, 1 1/2"
(38 mm) DIA., 3" (76.2 mm) LONG
RG-141/U COIL, 14 TURNS
3" (76.2 mm) DIA
32.8'
(10 m)
26'
(8 m)
75°
40'
(12 m)
RG58/U TO TUNER
100' (33 m)
32.8'
(10 m)
26'
(8 m)
http://www.qsl.net/va3iul

256 - Dual Band Dipole Antenna for 17m, 10m

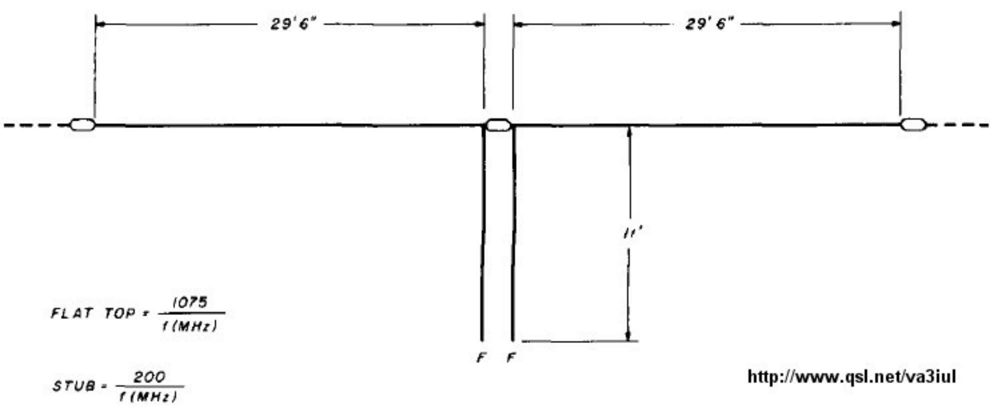
29'6"
29'6"
11'
FLAT TOP = 1075 / f(MHz)
STUB = 200 / f(MHz)
F F
http://www.qsl.net/va3iul

---

257 - Compact Travel Dipole Antenna for 10m, 15m, 20m

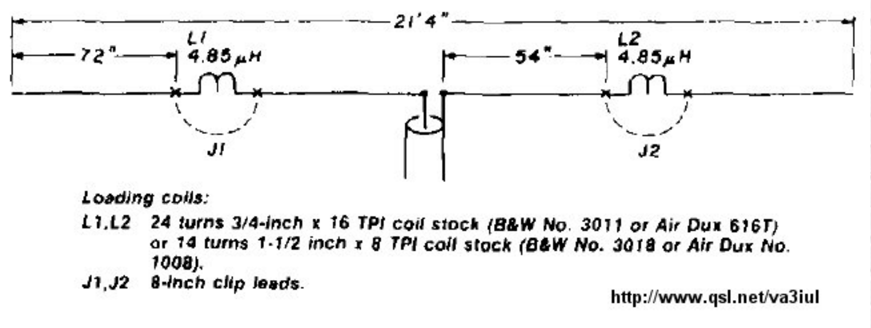
21'4"
72"
L1
4.85µH
54"
L2
4.85µH
J1
J2

Loading coils:

L1,L2 24 turns 3/4-inch x 16 TPI coil stock (B&W No. 3011 or Air Dux 616T) or 14 turns 1-1/2 inch x 8 TPI coil stock (B&W No. 3018 or Air Dux No. 1008).

J1,J2 8-inch clip leads.

http://www.qsl.net/va3iul

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258 - End-Fire Antenna for 160m, 80m, 40m, 20m

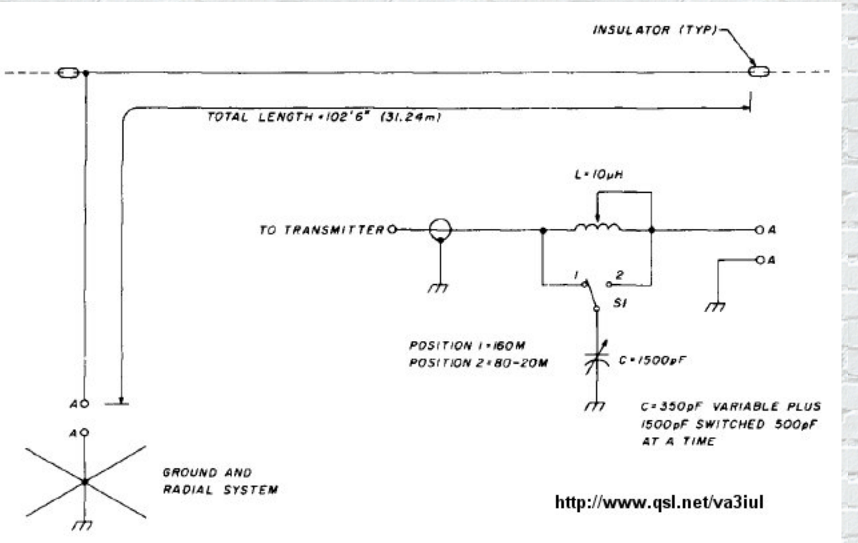
INSULATOR (TYP)
TOTAL LENGTH = 102'6" (31.24m)
L = 10µH
TO TRANSMITTER
A
A
1
2
S1
POSITION 1 = 160M
POSITION 2 = 80-20M
C = 1500pF
C = 350pF VARIABLE PLUS 1500pF SWITCHED 500pF AT A TIME
A
A
GROUND AND RADIAL SYSTEM
http://www.qsl.net/va3iul

---

259 - Four Band Loop for 40m, 20m, 15m, 10m

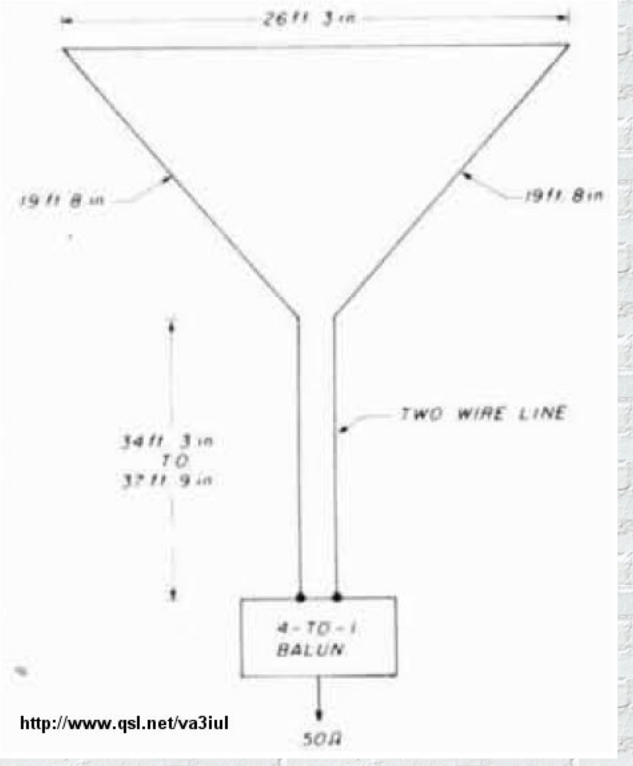
26 ft 3 in
19 ft 8 in
19 ft 8 in
34 ft 3 in
TO
37 ft 9 in
TWO WIRE LINE
4-TO-1
BALUN
http://www.qsl.net/va3iul
50Ω

---

260 - Carolina Windom Antenna for 80 to 10m

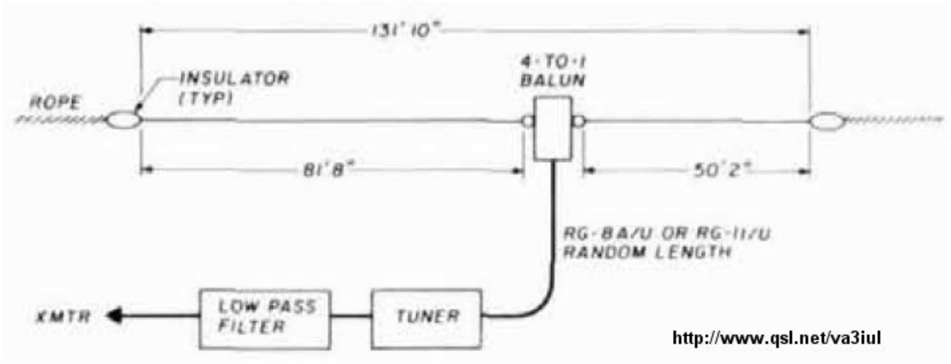
131' 10"
4-TO-1
BALUN
INSULATOR
(TYP)
ROPE
81' 8"
50' 2"
RG-8A/U OR RG-11/U
RANDOM LENGTH
XMTR
LOW PASS
FILTER
TUNER
http://www.qsl.net/va3iul

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261 - Shortened Loaded Dipole for 40m

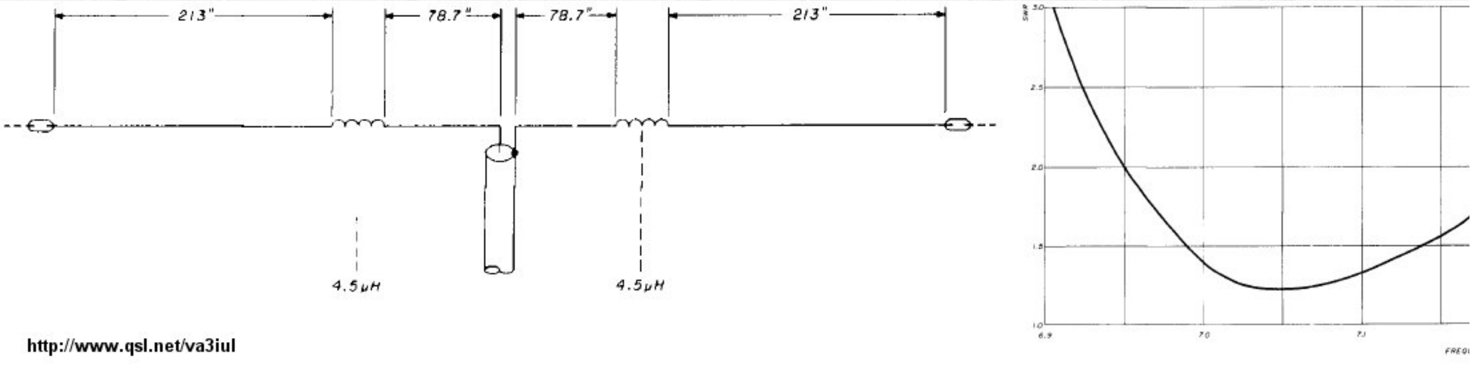
213"
78.7"
78.7"
213"
4.5μH
4.5μH
http://www.qsl.net/va3iul
SWR
3.0
2.5
2.0
1.5
1.0
6.9
7.0
7.1
FREQ

---

262 - Shortened Loaded Dipole for 80m

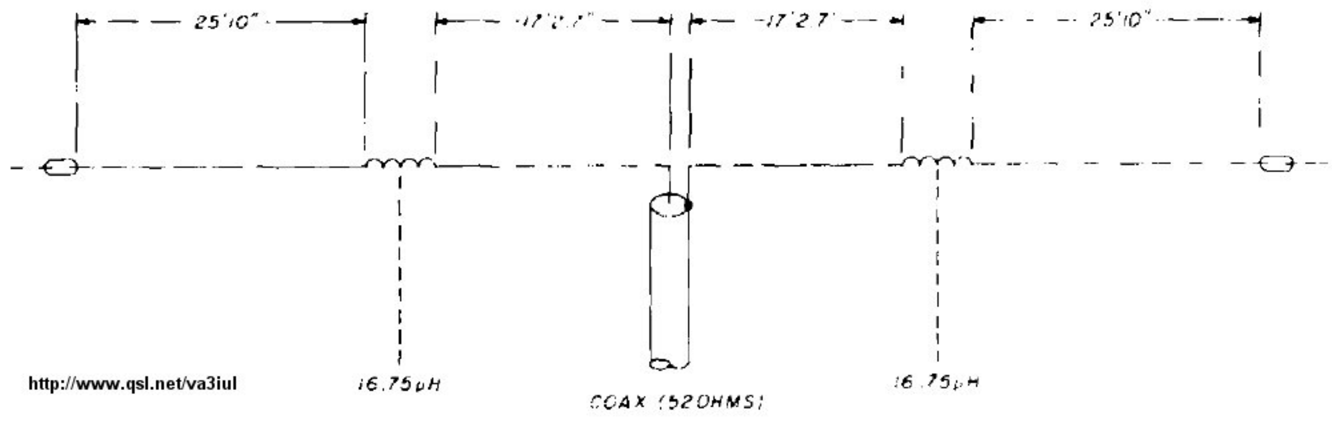
25'10"
17'2.7"
17'2.7"
25'10"
http://www.qsl.net/va3iul
16.75µH
COAX (52OHMS)
16.75µH

263 - Low Radiation Angle Inverted Delta Loop for 80m

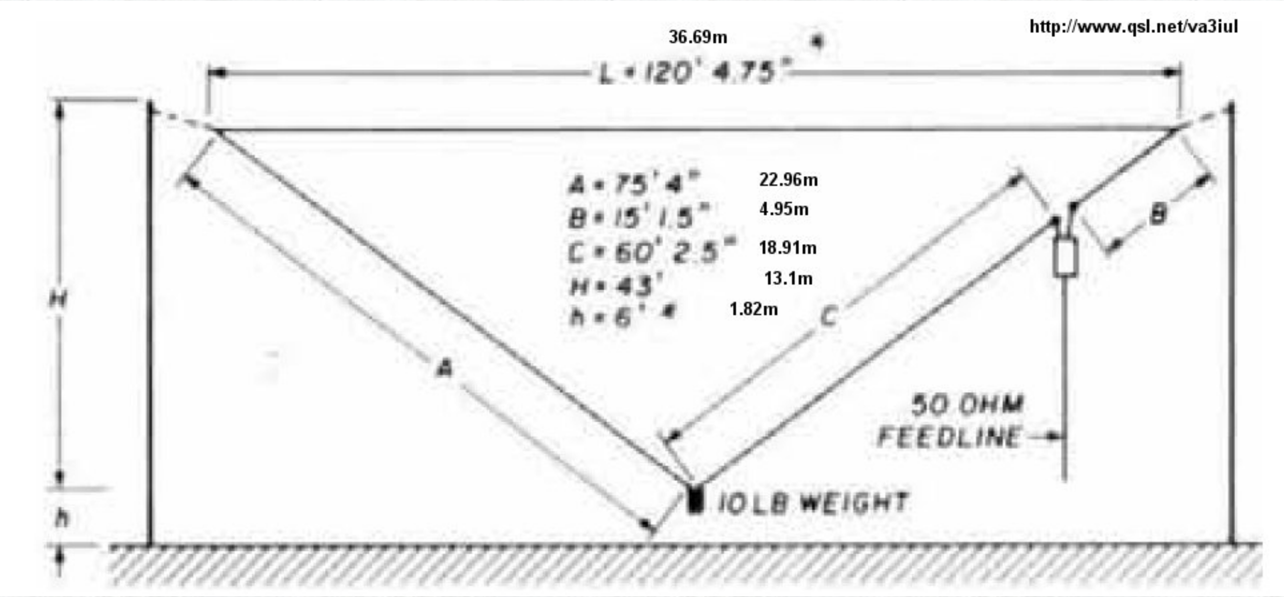
36.69m
L = 120' 4.75" *
http://www.qsl.net/va3iul
A = 75' 4" 22.96m
B = 15' 1.5" 4.95m
C = 60' 2.5" 18.91m
H = 43' 13.1m
h = 6' * 1.82m
H
h
A
B
C
50 OHM FEEDLINE
10 LB WEIGHT

264 - Compact Dipole Antenna for 40m, 15m

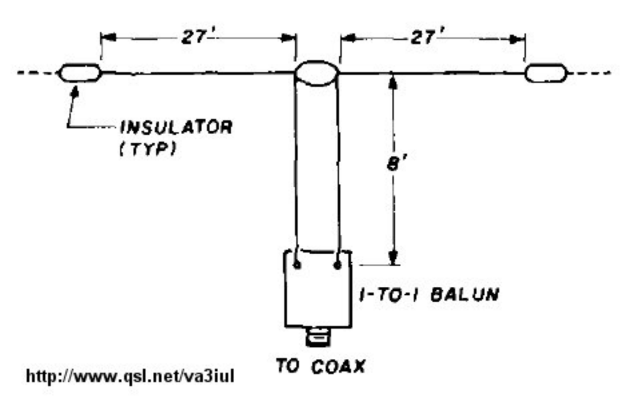
27'
27'
INSULATOR (TYP)
8'
1-TO-1 BALUN
TO COAX
http://www.qsl.net/va3iul

265 - Vertical Delta Loop for 40m to 10m

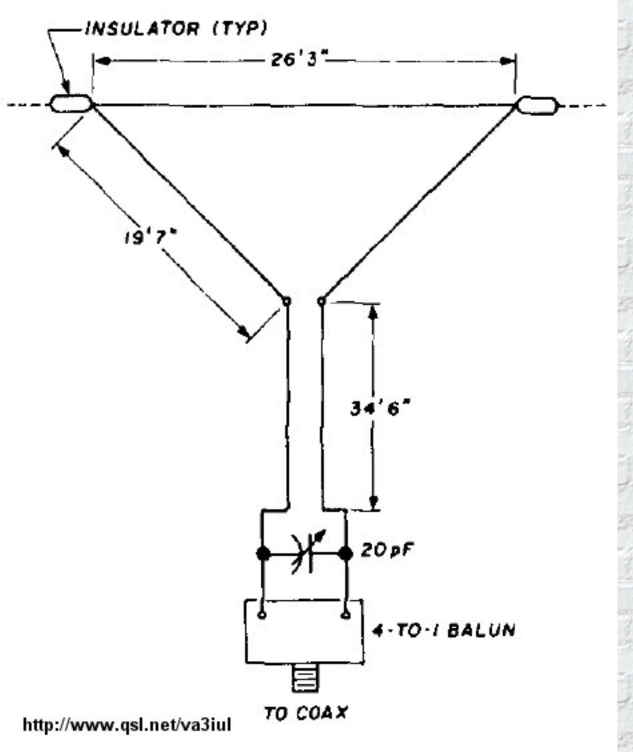
INSULATOR (TYP)
26'3"
19'7"
34'6"
20pF
4-TO-1 BALUN
TO COAX
http://www.qsl.net/va3iul

266 - Delta Loop Antenna for 17m

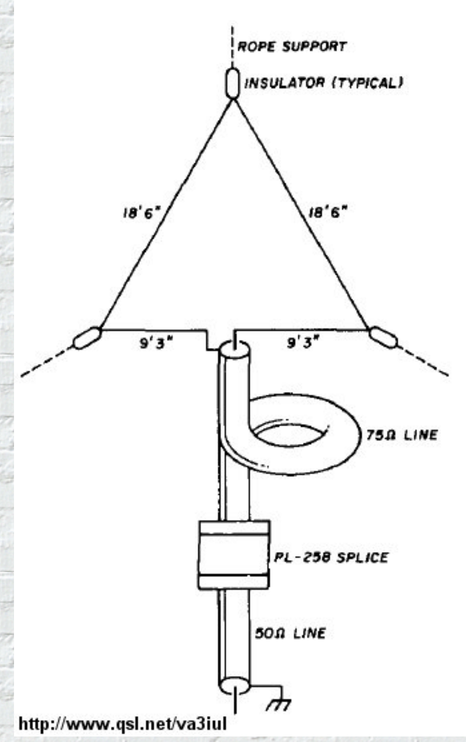
ROPE SUPPORT
INSULATOR (TYPICAL)
18'6"
18'6"
9'3"
9'3"
75Ω LINE
PL-258 SPLICE
50Ω LINE
http://www.qsl.net/va3iul

267 - Bi-Square Beam Gain=3dBd for 17m

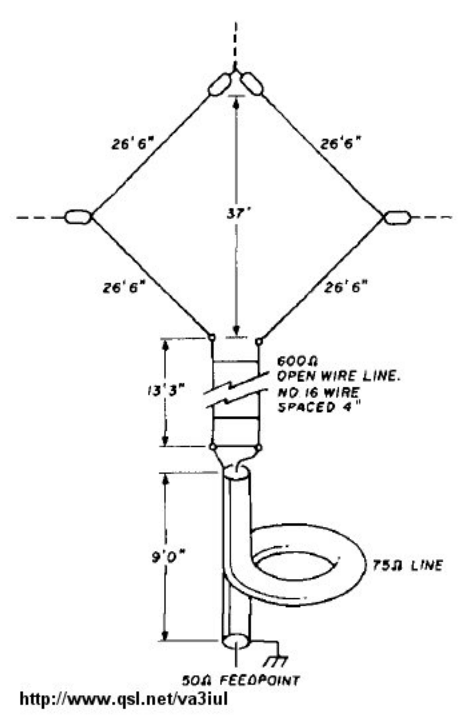
26'6"
26'6"
37'
26'6"
26'6"
600Ω
OPEN WIRE LINE.
NO 16 WIRE
SPACED 4"
13'3"
9'0"
75Ω LINE
50Ω FEEDPOINT
http://www.qsl.net/va3iul

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268 -Trap Dipole Antenna for 17m,13m

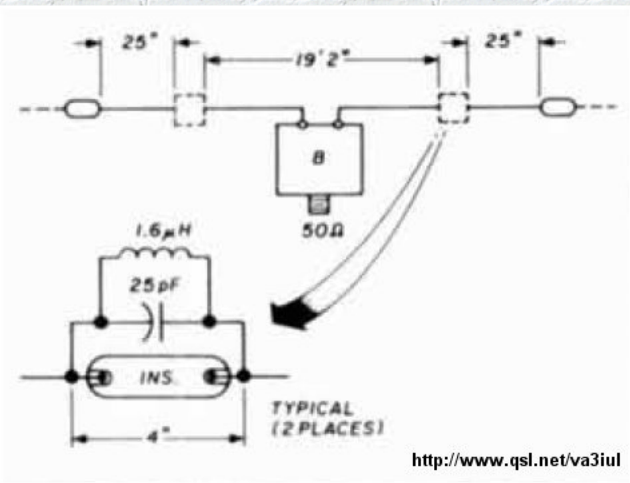
25"
19'2"
25"
B
50Ω
1.6μH
25pF
INS.
4"
TYPICAL
(2 PLACES)
http://www.qsl.net/va3iul

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269 - Hanging Unipole Antenna for 160m, 80m

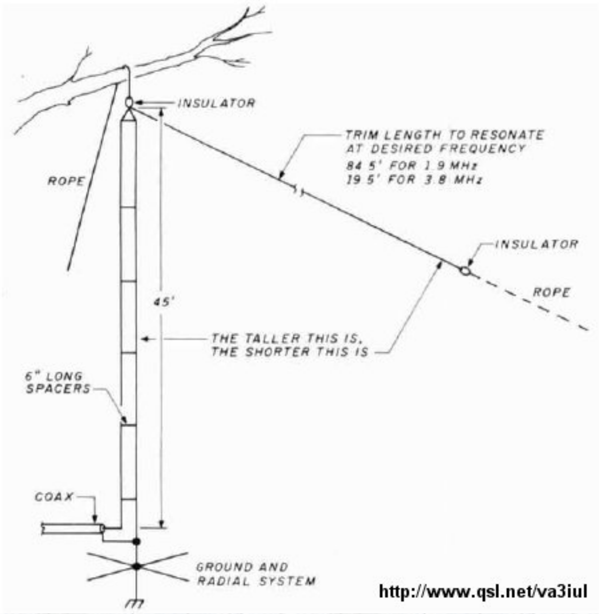
INSULATOR
TRIM LENGTH TO RESONATE AT DESIRED FREQUENCY
84.5' FOR 1.9 MHz
19.5' FOR 3.8 MHz
ROPE
INSULATOR
ROPE
45'
THE TALLER THIS IS, THE SHORTER THIS IS
6" LONG SPACERS
COAX
GROUND AND RADIAL SYSTEM
http://www.qsl.net/va3iul

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270 - Wideband Sloping Vee Antenna - 30m to 6m

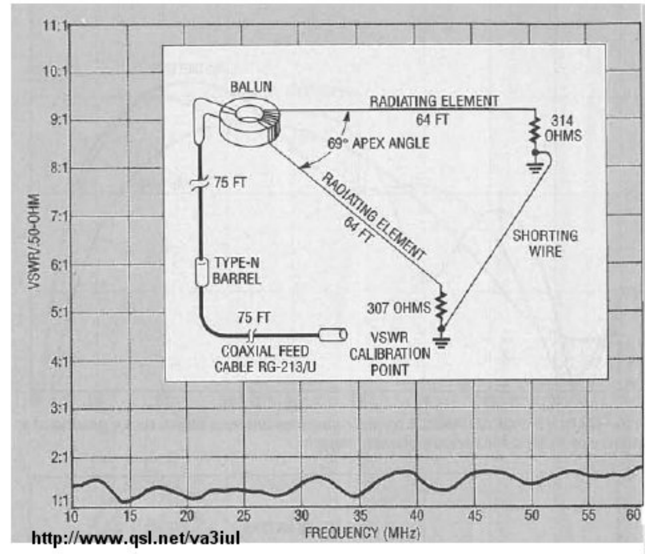

SOURCES OF MATERIALS

The following companies are sources for materials and computer software for this project:

- Toroidal ferrite cores (Part No. FT240-43)—Radio Kit, Inc., P.O. Box 973, Pelham, NH 03076, (603) 635-2235
- Film power resistors—Power Film Systems, Inc., Yellville, AR 72687, (501) 449-4091
- Antenna design software—Phadean Engineering Co., Inc., P.O. Box 611, Shrewsbury, MA 01545, (508) 869-6077
- Phosphor-bronze wire—Astro Industries, Inc., Dayton, OH 43432, (800) 543-5810
- Fiberglass tubing—J. T. Ryerson Co., P. O. Box 1111, Boston, MA 02103. (617) 782-6900

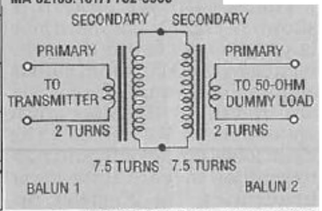
SECONDARY
SECONDARY
PRIMARY
PRIMARY
TO TRANSMITTER
TO 50-OHM DUMMY LOAD
2 TURNS
2 TURNS
7.5 TURNS
7.5 TURNS
BALUN 1
BALUN 2

-BACK-TO-BACK INSERTION LOSS TEST of baluns for sloping-vee antenna.

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271 - 5/8 Wavelength Antenna

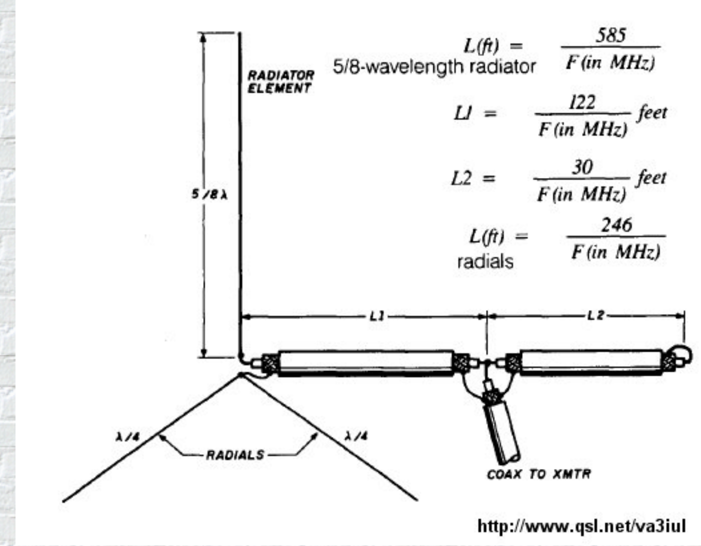
RADIATOR ELEMENT
5/8-wavelength radiator
$L(ft) = \frac{585}{F(in\ MHz)}$
$L1 = \frac{122}{F(in\ MHz)}$ feet
$L2 = \frac{30}{F(in\ MHz)}$ feet
$L(ft) = \frac{246}{F(in\ MHz)}$
radials
5/8 λ
L1
L2
λ/4
RADIALS
λ/4
COAX TO XMTR
http://www.qsl.net/va3iul

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272 - C-Pole Vertical Antenna

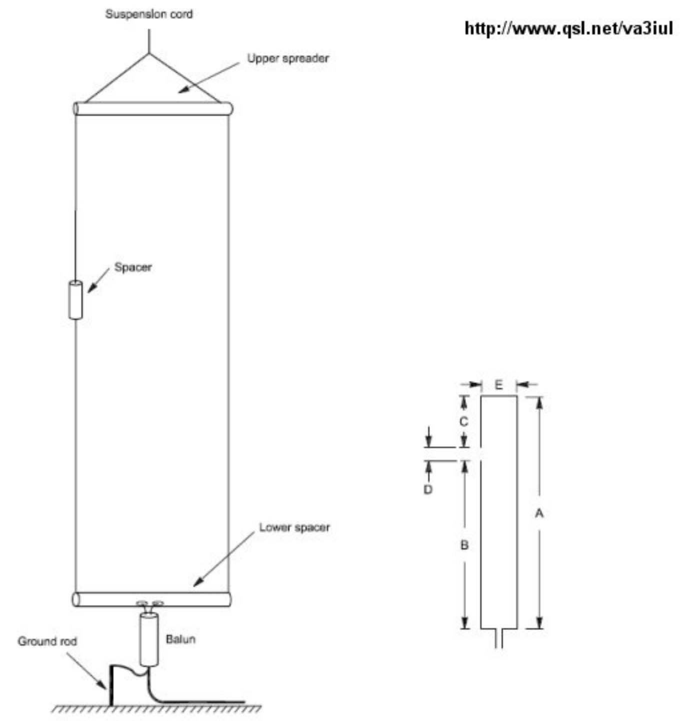
Suspension cord
http://www.qsl.net/va3iul
Upper spreader
Spacer
Lower spacer
Ground rod
Balun
E
C
D
A
B

Band (meters)	A (inches)	B (inches)	C (inches)	D (inches)	E (inches)	2:1 SWR bandwidth (kHz)
160	1666	924	994	60	80	58
80	840	460	360	30	40	120
60	591	322	249	20	26	250
40	450	240	190	20	20	260
30	320	167	139	14	14	360
20	177	85	84	8	40	400
15	124	60	60	4	20	600
10	87	46	37	4	20	800

Wire diameter is 1/16-inch. Height of the lower horizontal wire is 12 inches to 24 inches and is non-critical.

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273 - Bobtail Antenna for 30m

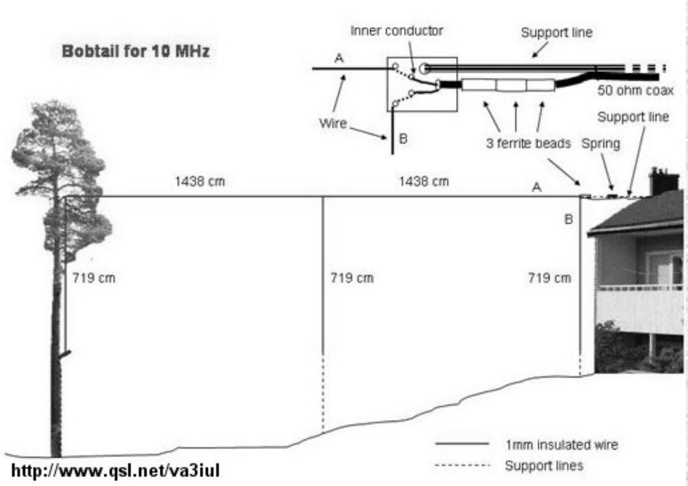
Bobtail for 10 MHz
Inner conductor
Support line
A
50 ohm coax
Wire
B
Support line
3 ferrite beads
Spring
1438 cm
1438 cm
A
B
719 cm
719 cm
719 cm
1mm insulated wire
Support lines
http://www.qsl.net/va3iul

274 - Bobtail Antenna for 40m

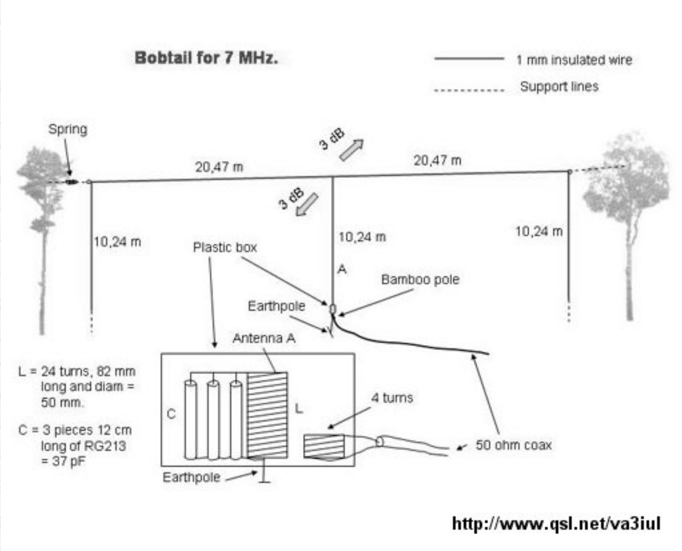
Bobtail for 7 MHz.
1 mm insulated wire
Support lines
Spring
3 dB
20,47 m
20,47 m
3 dB
10,24 m
10,24 m
10,24 m
Plastic box
A
Bamboo pole
Earthpole
Antenna A
L = 24 turns, 82 mm long and diam = 50 mm.
C = 3 pieces 12 cm long of RG213 = 37 pF
C
L
4 turns
50 ohm coax
Earthpole
http://www.qsl.net/va3iul

275 - Two Elements Vertical Loop Antenna for 40m

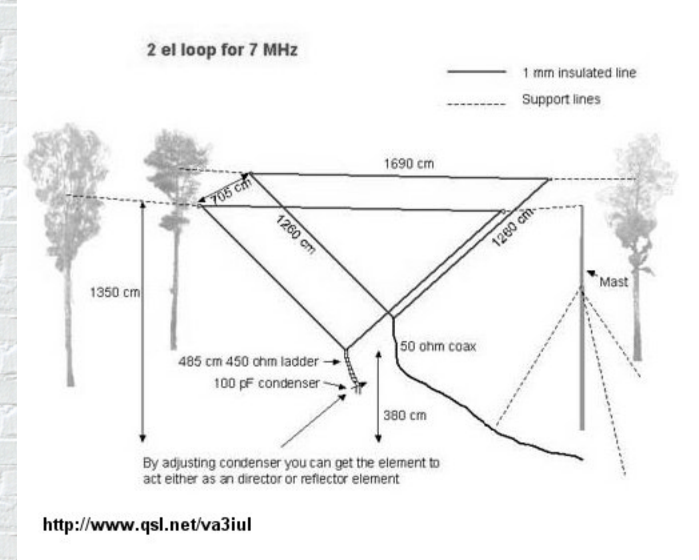
2 el loop for 7 MHz
1 mm insulated line
Support lines
1690 cm
705 cm
1260 cm
1260 cm
Mast
1350 cm
50 ohm coax
485 cm 450 ohm ladder
100 pF condenser
380 cm
By adjusting condenser you can get the element to act either as an director or reflector element
http://www.qsl.net/va3iul

276 - Double Extended Zepp Antenna for 40m

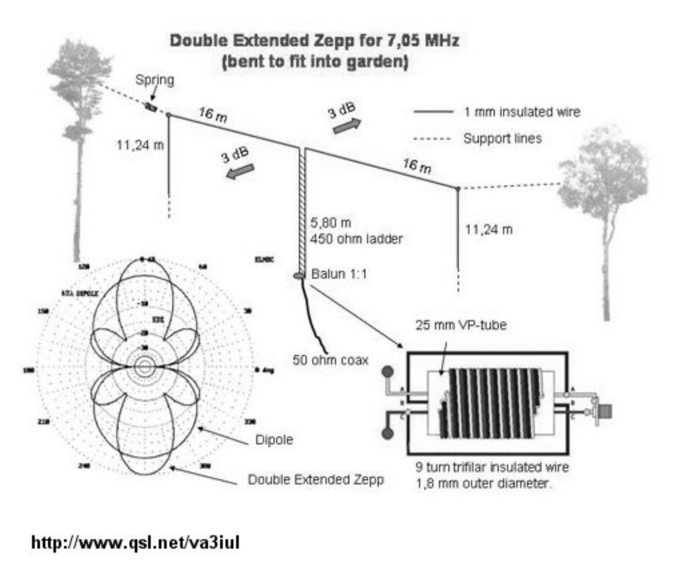
Double Extended Zepp for 7,05 MHz
(bent to fit into garden)
Spring
16 m
3 dB
1 mm insulated wire
Support lines
11,24 m
3 dB
16 m
5,80 m
450 ohm ladder
11,24 m
Balun 1:1
25 mm VP-tube
50 ohm coax
Dipole
Double Extended Zepp
9 turn trifilar insulated wire
1,8 mm outer diameter.

http://www.qsl.net/va3iul

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277 - Reversible Moxon Flip Beam for 40m

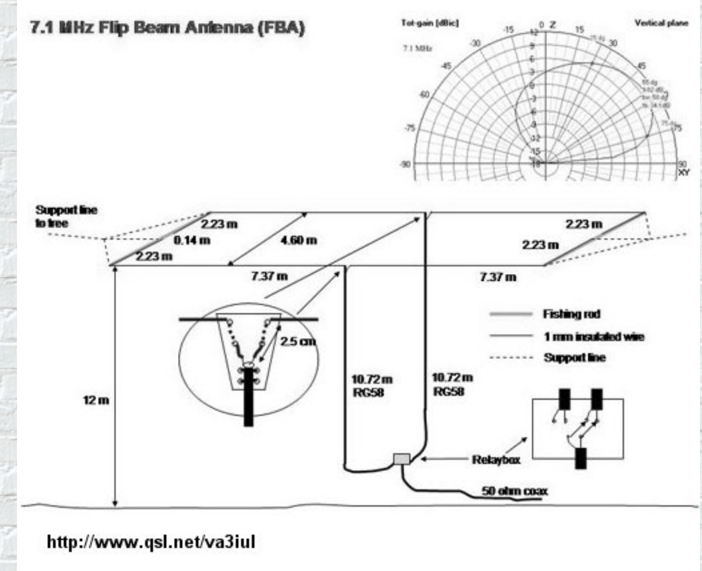
7.1 MHz Flip Beam Antenna (FBA)
Tot-gain [dBic]
Vertical plane
7.1 MHz
Support line to tree
2.23 m
0.14 m
4.60 m
2.23 m
7.37 m
2.23 m
2.23 m
7.37 m
2.5 cm
Fishing rod
1 mm insulated wire
Support line
12 m
10.72 m RG58
10.72 m RG58
Relaybox
50 ohm coax

http://www.qsl.net/va3iul

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278 - Spitwire Antenna for 40m

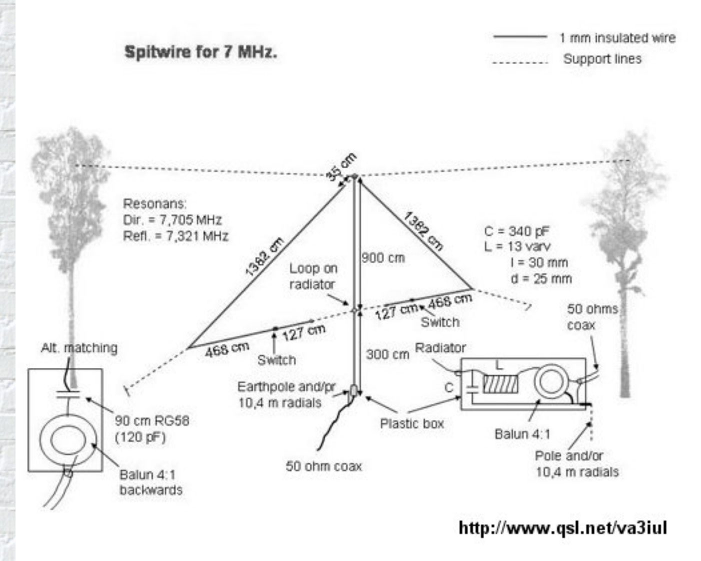
Spitwire for 7 MHz.
1 mm insulated wire
Support lines
Resonans:
Dir. = 7,705 MHz
Refl. = 7,321 MHz
35 cm
1382 cm
1382 cm
900 cm
Loop on radiator
C = 340 pF
L = 13 varv
l = 30 mm
d = 25 mm
127 cm
468 cm
127 cm
468 cm
Switch
Switch
50 ohms coax
Alt. matching
300 cm
Radiator
Earthpole and/pr 10,4 m radials
C
L
90 cm RG58 (120 pF)
Plastic box
Balun 4:1
Balun 4:1 backwards
50 ohm coax
Pole and/or 10,4 m radials
http://www.qsl.net/va3iul

279 - Fork Antenna for 40m

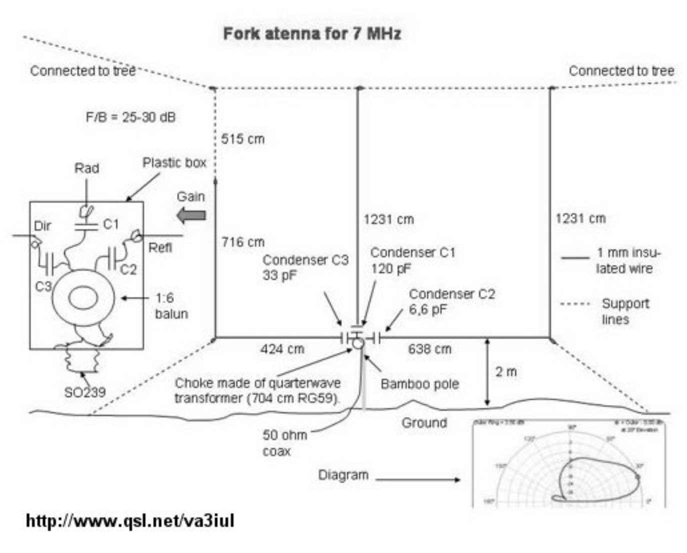
Fork atenna for 7 MHz
Connected to tree
Connected to tree
F/B = 25-30 dB
515 cm
Rad
Plastic box
Gain
Dir
C1
Refl
C2
C3
1:6 balun
716 cm
1231 cm
1231 cm
Condenser C3 33 pF
Condenser C1 120 pF
Condenser C2 6,6 pF
1 mm insu-lated wire
Support lines
424 cm
638 cm
2 m
SO239
Choke made of quarterwave transformer (704 cm RG59).
Bamboo pole
Ground
50 ohm coax
Diagram
http://www.qsl.net/va3iul

280 - Veebeam Antenna 3dB-Gain for All Bands

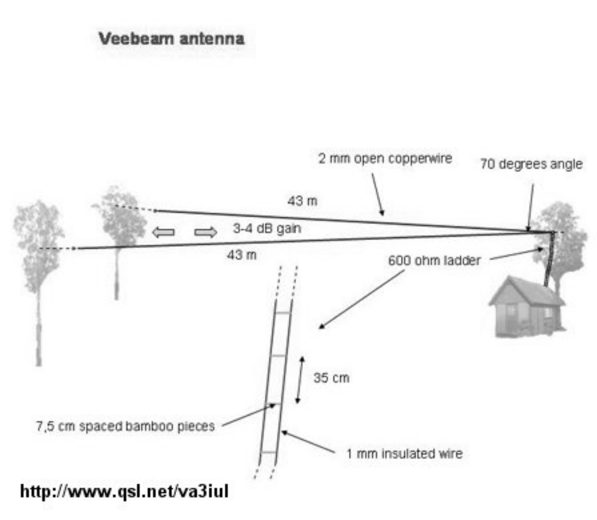
Veebeam antenna
2 mm open copperwire
70 degrees angle
43 m
3-4 dB gain
43 m
600 ohm ladder
35 cm
7,5 cm spaced bamboo pieces
1 mm insulated wire
http://www.qsl.net/va3iul

281 - Vertical Moxon Antenna for 10m

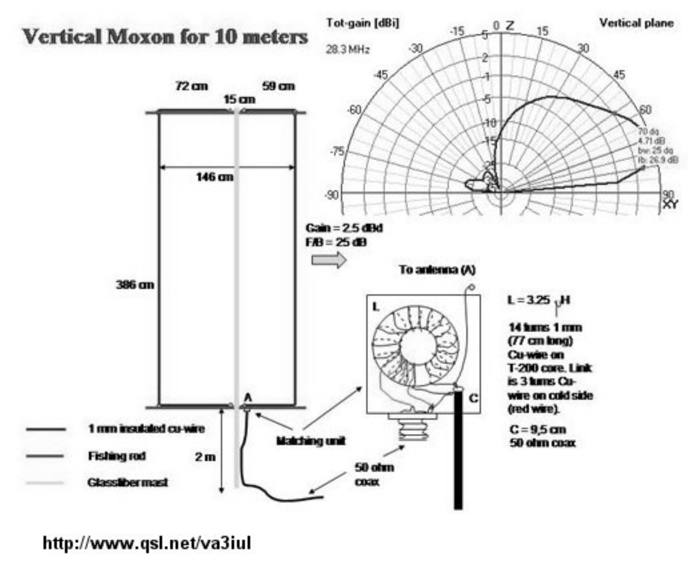
Vertical Moxon for 10 meters
72 cm
59 cm
15 cm
146 cm
386 cm
A
1 mm insulated cu-wire
Fishing rod
2 m
Glassfibermast
Matching unit
50 ohm coax
Tot-gain [dBi]
28.3 MHz
Vertical plane
Z
XY
70 dg
4.71 dB
bw: 25 dg
fb: 26.9 dB
Gain = 2.5 dBd
F/B = 25 dB
To antenna (A)
L
C
L = 3.25 μH
14 turns 1 mm (77 cm long) Cu-wire on T-200 core. Link is 3 turns Cu-wire on cold side (red wire).
C = 9,5 cm 50 ohm coax
http://www.qsl.net/va3iul

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282 - Half-Square Antenna for 30m

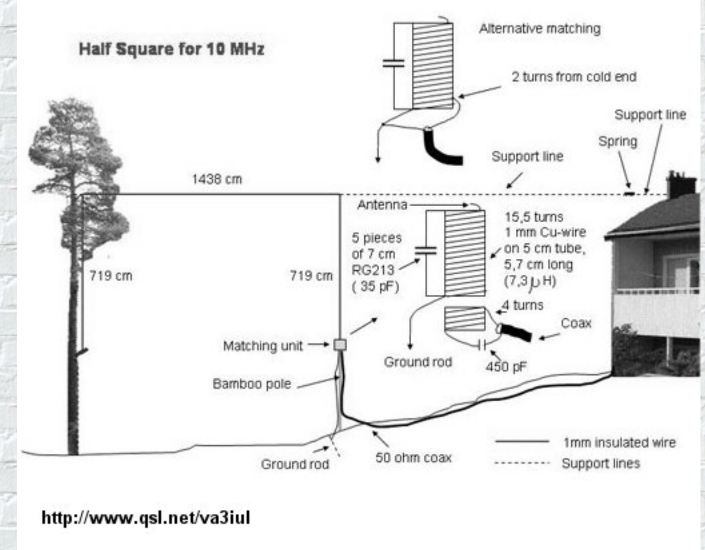
Half Square for 10 MHz
Alternative matching
2 turns from cold end
Support line
Spring
Support line
1438 cm
Antenna
719 cm
719 cm
5 pieces of 7 cm RG213 (35 pF)
15,5 turns 1 mm Cu-wire on 5 cm tube, 5,7 cm long (7,3 μH)
4 turns
Coax
Ground rod
450 pF
Matching unit
Bamboo pole
Ground rod
50 ohm coax
1mm insulated wire
Support lines
http://www.qsl.net/va3iul

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283 - Rotatable Vertical Delta Loop for 20m

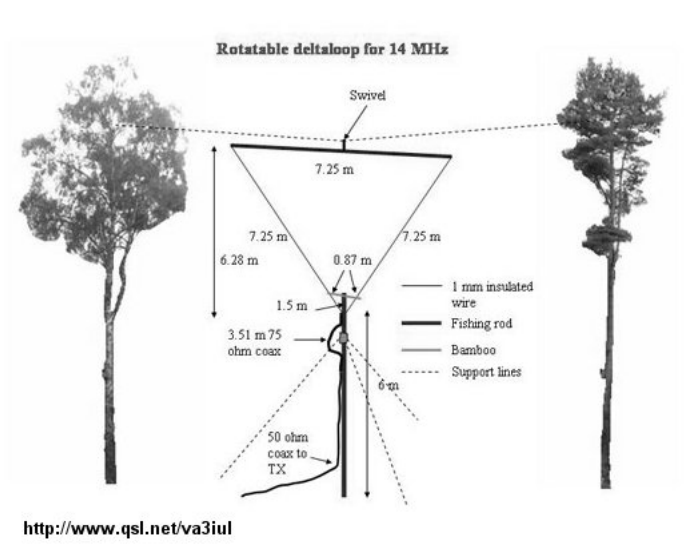
Rotatable deltaloop for 14 MHz
Swivel
7.25 m
7.25 m
7.25 m
6.28 m
0.87 m
1.5 m
3.51 m 75 ohm coax
6 m
50 ohm coax to TX
1 mm insulated wire
Fishing rod
Bamboo
Support lines
http://www.qsl.net/va3iul

284 - Mini-Horse Antenna 10dB-Gain for 40m-to-2m

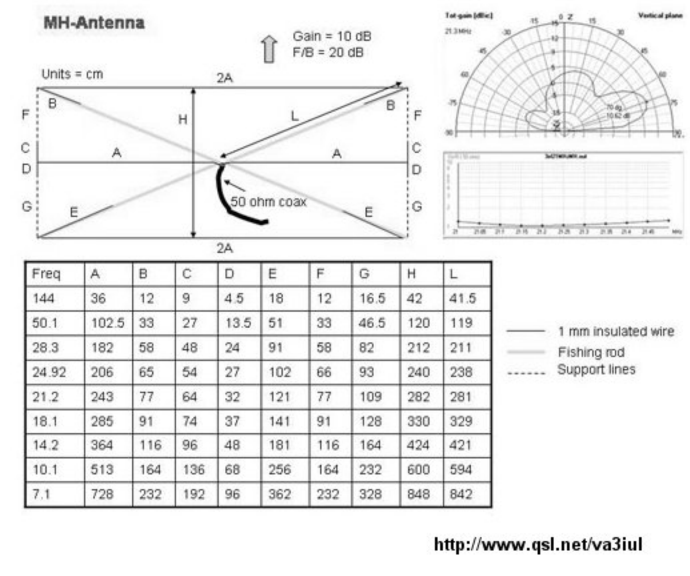
MH-Antenna
Gain = 10 dB
F/B = 20 dB
Units = cm
2A
B
H
L
B
F
F
C
D
A
A
C
D
G
E
50 ohm coax
E
G
2A
Tot gain [dBic]
21.3 MHz
Vertical plane
70 dg
10.62 dB
MHz
1 mm insulated wire
Fishing rod
Support lines
http://www.qsl.net/va3iul

Freq	A	B	C	D	E	F	G	H	L
144	36	12	9	4.5	18	12	16.5	42	41.5
50.1	102.5	33	27	13.5	51	33	46.5	120	119
28.3	182	58	48	24	91	58	82	212	211
24.92	206	65	54	27	102	66	93	240	238
21.2	243	77	64	32	121	77	109	282	281
18.1	285	91	74	37	141	91	128	330	329
14.2	364	116	96	48	181	116	164	424	421
10.1	513	164	136	68	256	164	232	600	594
7.1	728	232	192	96	362	232	328	848	842

285 - Compact Moxon Antenna 5dB-Gain for 40m

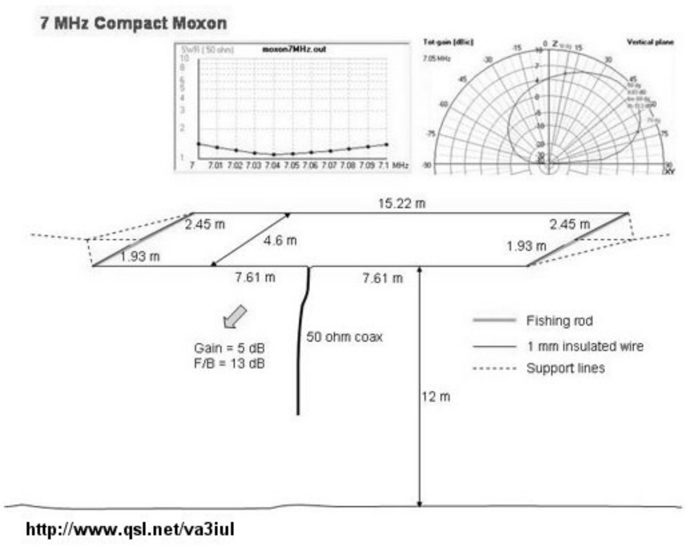
7 MHz Compact Moxon
SWR (50 ohm)
moxon7MHz.out
7
7.01
7.02
7.03
7.04
7.05
7.06
7.07
7.08
7.09
7.1
MHz
Tot gain [dBic]
7.05 MHz
Vertical plane
15.22 m
2.45 m
4.6 m
1.93 m
2.45 m
1.93 m
7.61 m
7.61 m
Gain = 5 dB
F/B = 13 dB
50 ohm coax
12 m
Fishing rod
1 mm insulated wire
Support lines
http://www.qsl.net/va3iul

286 - Two Elements Sloping Delta Loop 8dB-Gain for 10m

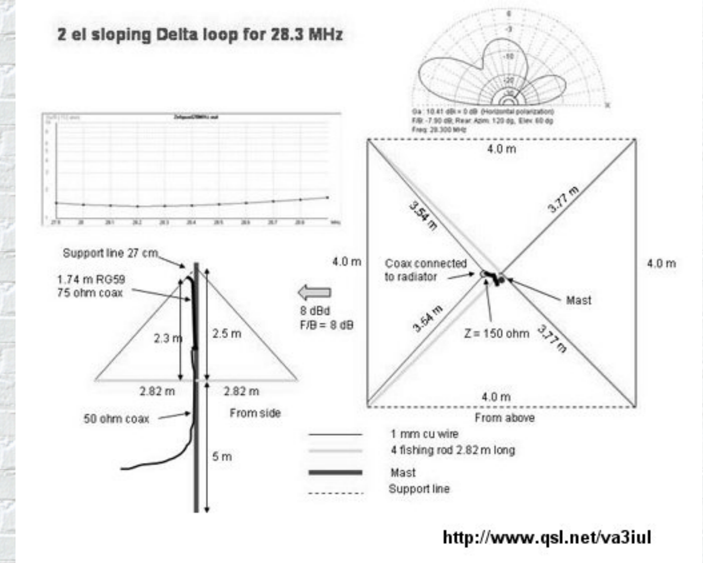
2 el sloping Delta loop for 28.3 MHz
Ga: 10.41 dBi = 0 dB (Horizontal polarization)
F/B: -7.90 dB; Rear: Azim. 120 dg, Elev. 60 dg
Freq: 28.300 MHz
Support line 27 cm
1.74 m RG59
75 ohm coax
2.3 m
2.5 m
2.82 m
2.82 m
50 ohm coax
From side
5 m
8 dBd
F/B = 8 dB
4.0 m
4.0 m
4.0 m
4.0 m
3.54 m
3.77 m
3.54 m
3.77 m
Coax connected
to radiator
Mast
Z = 150 ohm
From above
1 mm cu wire
4 fishing rod 2.82 m long
Mast
Support line
http://www.qsl.net/va3iul

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287 - Two Elements Phased Vertical Antenna 3dB-Gain for 40m

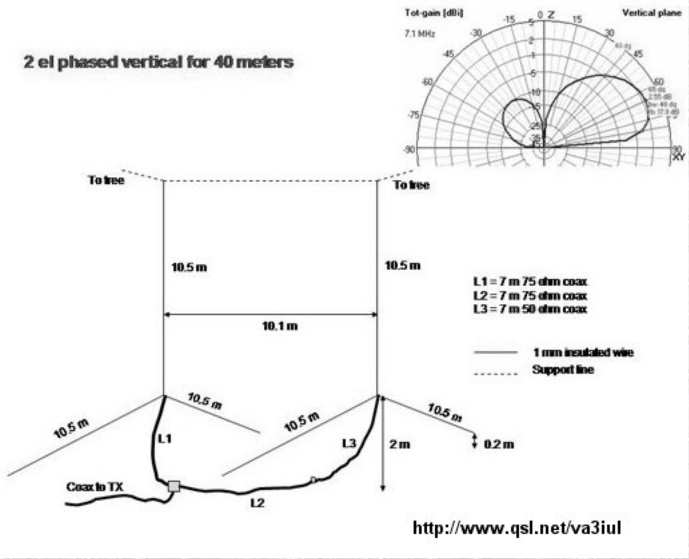
2 el phased vertical for 40 meters
Tot-gain [dBi]
7.1 MHz
Vertical plane
To tree
To tree
10.5 m
10.5 m
10.1 m
L1 = 7 m 75 ohm coax
L2 = 7 m 75 ohm coax
L3 = 7 m 50 ohm coax
1 mm insulated wire
Support line
10.5 m
10.5 m
10.5 m
10.5 m
L1
L3
2 m
0.2 m
Coax to TX
L2
http://www.qsl.net/va3iul

References:

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The Radio Handbook - W. Orr (editor), 15th edition
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SM0DTK - http://www.sm0dtk.se/antennas.htm
ARRL Antenna Handbook 1990-2007
ARRL Handbook 1937-2009
ARRL Antenna Compendium
73 Magazine 1970-2002
Funkamateur Magazine 1990-2011
RSGB Handbook - 2007 - 2010
QST Magazine - 1980 - 2010
Ham Radio Magazine - 1969 - 1990
Radio-Electronics Magazine - 1986 - 1990

home: ***http://www.qsl.net/va3iul***

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Antenna Technology

Zana Lane

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Chapter 1

Dipole Antenna

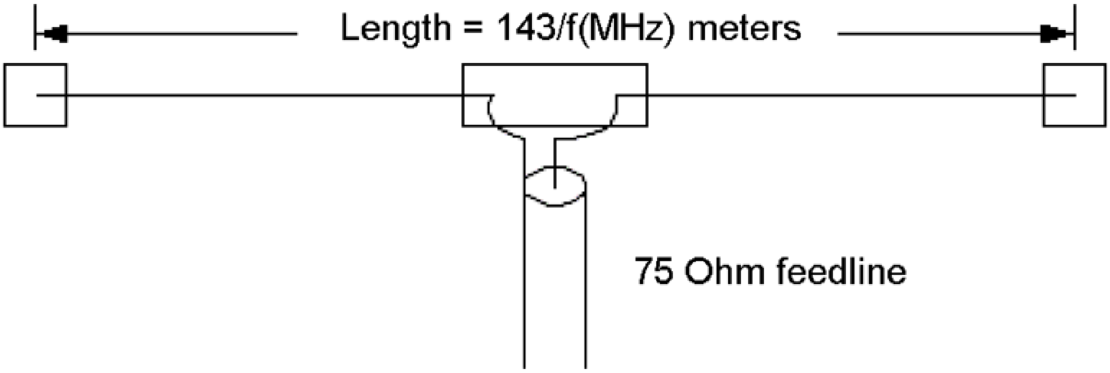

A schematic of a half-wave dipole antenna that a shortwave listener might build.

A **dipole antenna** is a radio antenna that can be made of a simple wire, with a center-fed driven element. It consists of two metal conductors of rod or wire, oriented parallel and collinear with each other (in line with each other), with a small space between them. The radio frequency voltage is applied to the antenna at the center, between the two conductors. These antennas are the simplest practical antennas from a theoretical point of view. They are used alone as antennas, notably in traditional "rabbit ears" television antennas, and as the driven element in many other types of antennas, such as the Yagi. Dipole antennas were invented by German physicist Heinrich Hertz around 1886 in his pioneering experiments with radio waves.

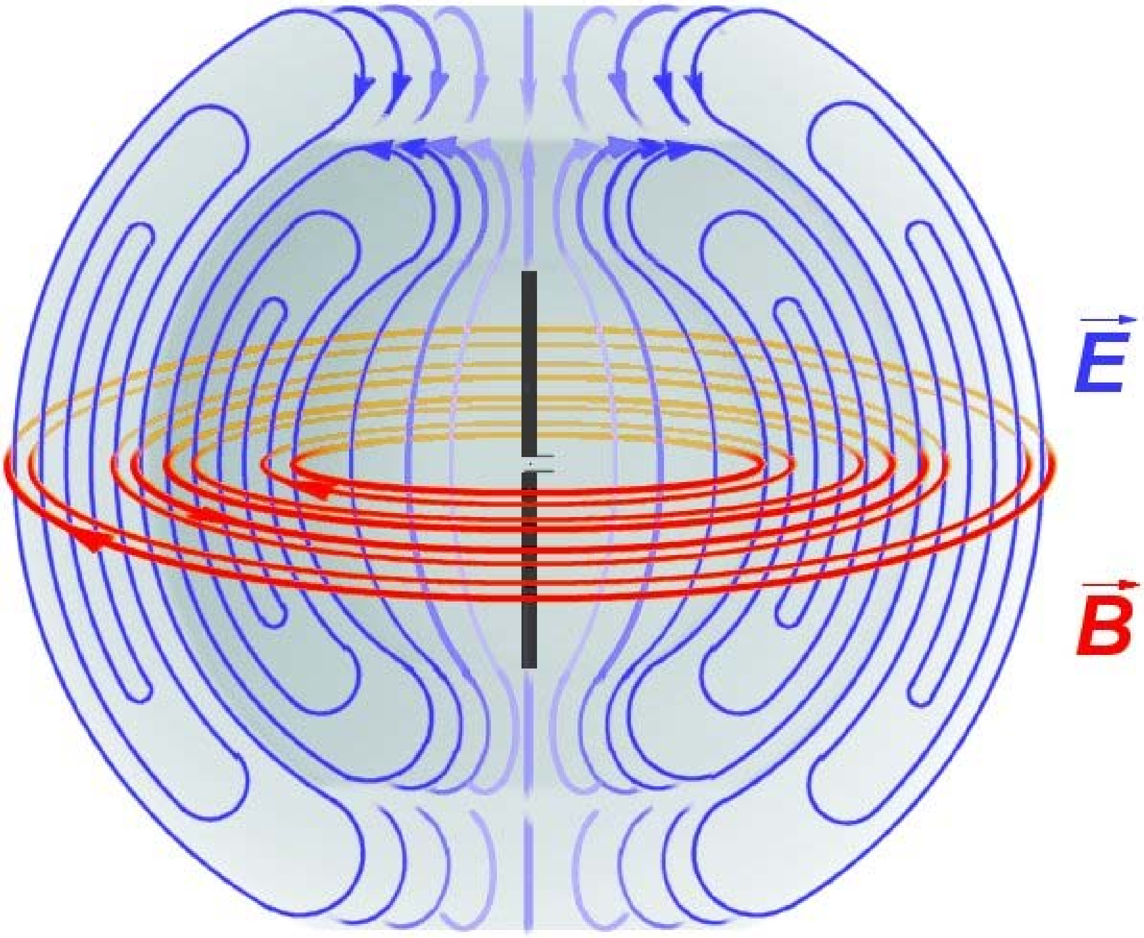

Electric fields *(blue)* and magnetic fields *(red)* radiated by a dipole antenna

Elementary doublet

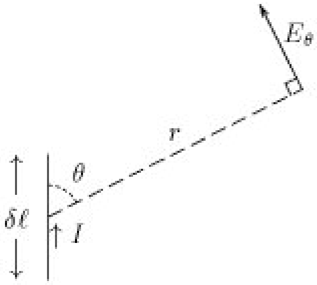

An elementary doublet is a small length of conductor $\delta\ell$(small compared to the wavelength λ) carrying an alternating current:

$$I = I_0 e^{i\omega t}.$$

Here $\omega = 2\pi f$is the angular frequency (and $f$the frequency), and $i$is $\sqrt{-1}$, so that $I$is a phasor.

Note that this dipole cannot be physically constructed because the current needs somewhere to come from and somewhere to go to. In reality, this small length of conductor will be just one of the multiple segments into which we must divide a real antenna, in order to calculate its properties. The interest of this imaginary elementary antenna is that we can easily calculate the electrical far field of the electromagnetic wave radiated by each elementary doublet. We give just the result:

$$E_\theta = \frac{-i I_\circ \sin\theta}{2\varepsilon_\circ c r}\frac{\delta l}{\lambda} e^{i(\omega t - kr)}$$

Where,

- $E_\theta$is the far electric field of the electromagnetic wave radiated in the θ direction.
- $\varepsilon_0$is the permittivity of vacuum.
- $c$is the speed of light in vacuum.
- $r$is the distance from the doublet to the point where the electrical field $E_\theta$is evaluated.
- $k$is the wavenumber $k=\frac{2\pi}{\lambda}$

The exponent of $e$accounts for the phase dependence of the electrical field on time and the distance from the dipole.

The far electric field $E_\theta$of the electromagnetic wave is coplanar with the conductor and perpendicular with the line joining the dipole to the point where the field is evaluated. If the dipole is placed in the center of a sphere in the axis south-north, the electric field would be parallel to geographic meridians and the magnetic field of the electromagnetic wave would be parallel to geographic parallels.

Near Field

The above formulas are valid for the far field of the antenna ($r \gg \lambda/(2\pi)$), and are the only contribution to the radiated field. The formulas in the near field have additional terms that reduce with r^2 and r^3. These are,

$$E_r = \frac{Z}{2\pi} I_0\, \delta l \left(\frac{1}{r^2} - i\,\frac{\lambda}{2\pi\, r^3}\right) e^{i(\omega t - kr)}\ \cos(\theta)$$

$$E_\theta = i\frac{Z}{2\lambda} I_0\, \delta l \left(\frac{1}{r} - i\,\frac{\lambda}{2\pi\, r^2} - \frac{\lambda^2}{4\pi^2\, r^3}\right) e^{i(\omega t - kr)}\ \sin(\theta)$$

$$H_\phi = i\frac{1}{2\lambda} I_0\, \delta l \left(\frac{1}{r} - i\,\frac{\lambda}{2\pi\, r^2}\right) e^{i(\omega t - kr)}\ \sin(\theta)$$

where $Z = \sqrt{\mu/\epsilon} = 1/(\epsilon c) = \mu c$. The energy associated with the term of the near field flows back and forward out and into the antenna.

Short dipole

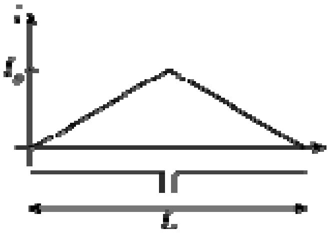

A short dipole is a physically feasible dipole formed by two conductors with a total length L very small compared with the wavelength λ. The two conducting wires are fed at the centre of the dipole. We assume the hypothesis that the current is maximal at the centre (where the dipole is fed) and that it decreases linearly to be zero at the ends of the wires. Note that the direction of the current is the same in both the dipole branches - to the right in both or to the left in both. The far field E_θ of the electromagnetic wave radiated by this dipole is:

$$E_\theta = \frac{-i I_0 \sin\theta}{4\epsilon_0 c r}\frac{L}{\lambda}e^{i(\omega t - kr)}.$$

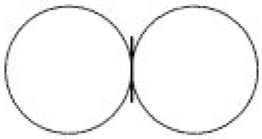

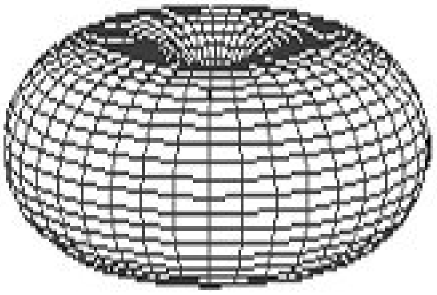

Emission is maximal in the plane perpendicular to the dipole and zero in the direction of wires which is the direction of the current. The emission diagram is circular section torus shaped (right image) with zero inner diameter. In the left image the doublet is vertical in the torus centre.

Knowing this electric field, we can compute the total emitted power and then compute the resistive part of the series impedance of this dipole due to the radiated field, known as the radiation resistance:

$$R_{series} = \frac{\pi}{6} Z_0 \left(\frac{L}{\lambda}\right)^2 \text{ (for } L \ll \lambda\text{).}$$

where Z_0 is the impedance of free space. Using a common approximation of $Z_0 = 120\pi$ ohms, we get:

$$R_{series} = 20\pi^2 \left(\frac{L}{\lambda}\right)^2 \text{ ohms}$$

Antenna gain

Antenna gain is the ratio of surface power radiated by the antenna to the surface power radiated by a hypothetical isotropic antenna:

$$G = \frac{\left(\frac{P}{S}\right)_{ant}}{\left(\frac{P}{S}\right)_{iso}}$$

The surface power carried by an electromagnetic wave is:

$$\left(\frac{P}{S}\right)_{ant} = \frac{1}{2} c \varepsilon_0 E_\theta^2 \simeq \frac{1}{120\pi} E_\theta^2$$

The surface power radiated by an isotropic antenna feed with the same power is:

$$\left(\frac{P}{S}\right)_{iso} = \frac{\frac{1}{2} R_{series} I_0^2}{4\pi r^2}$$

Substituting values for the case of a short dipole, final result is:

$$G = \frac{\pi\left(\frac{L}{\lambda}\right)^2}{c\varepsilon_0 \frac{2\pi}{3\varepsilon_0 c}\left(\frac{L}{\lambda}\right)^2} = 1.5 = 1.76 \text{ dBi}$$

dBi simply means decibels gain, relative to an **i**sotropic antenna.

Half-wave antenna

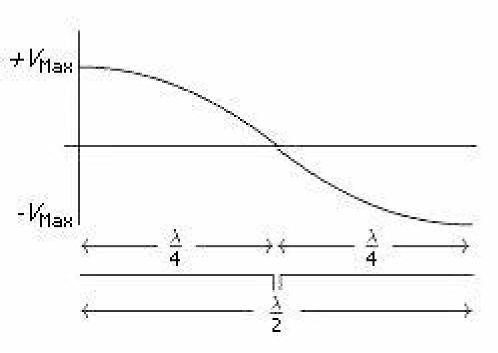

Typically a dipole antenna is formed by two quarter wavelength conductors or elements placed back to back for a total length of $\lambda/2$. A standing wave on an element of a length ~$\lambda/4$ yields the greatest voltage differential, as one end of the element is at a node while the other is at an antinode of the wave. The larger the differential voltage, the greater the current between the elements.

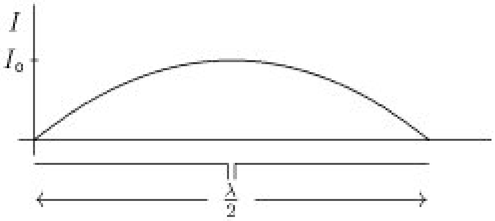

Assuming a sinusoidal distribution, the current impressed by this voltage differential is given by:

$$I = I_\circ e^{i\omega t} \cos k\ell$$

For the far-field case, the formula for the electric field of a radiating electromagnetic wave is somewhat more complex:

$$E_\theta = \frac{-iI_\circ}{2\pi\varepsilon_\circ cr} \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} e^{i(\omega t - kr)}$$

But the fraction $\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$ is not very different from $\sin\theta$.

The resulting emission diagram is a slightly flattened torus.

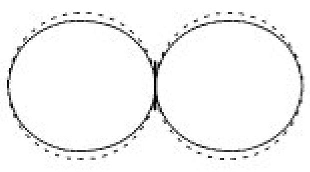

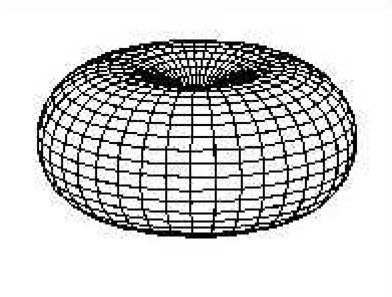

The image on the left shows the section of the emission pattern. We have drawn, in dotted lines, the emission pattern of a short dipole. We can see that the two patterns are very similar. The image at right shows the perspective view of the same emission pattern.

This time it is not possible to compute analytically the total power emitted by the antenna (the last formula does not allow), though a simple numerical integration or series expansion leads to the more precise, actual value of the half-wave resistance:

$$\begin{aligned} R_{\frac{\lambda}{2}} &= 60\mathrm{Cin}(2\pi) = 60\left[\ln(2\pi\gamma) - \mathrm{Ci}(2\pi)\right] = 120\int_0^{\frac{\pi}{2}} \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)^2}{\sin\theta}d\theta, \\ &= 15\left[2\pi^2 - \frac{1}{3}\pi^4 + \frac{4}{135}\pi^6 - \frac{1}{630}\pi^8 + \frac{4}{70875}\pi^{10} \ldots - (-1)^n\frac{(2\pi)^{2n}}{n(2n)!}\right], \\ &\approx 73.13\Omega; \end{aligned}$$

This leads to the gain of a dipole antenna, $G_{\frac{\lambda}{2}}$:

$$\begin{aligned} G_{\frac{\lambda}{2}} &- \frac{60^2}{30R_{\frac{\lambda}{2}}} - \frac{3600}{30R_{\frac{\lambda}{2}}} - \frac{120}{R_{\frac{\lambda}{2}}} - \frac{1}{\int_0^{\frac{\pi}{2}} \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)^2}{\sin\theta}d\theta}, \\ &\approx \frac{120}{73.1296} \approx 1.64 \approx 2.15\,\mathrm{dBi}; \end{aligned}$$

The resistance, however, is not enough to characterize the dipole impedance, as there is also an imaginary part——it is better to measure the impedance.

In the image below, the real and imaginary parts of a dipole's impedance are drawn for lengths going from $0.4\ \lambda$ to $0.6\ \lambda$, accompanied by a chart comparing the gains of dipole antennas of other lengths (note that gains are **not** in dBi but in natural number):

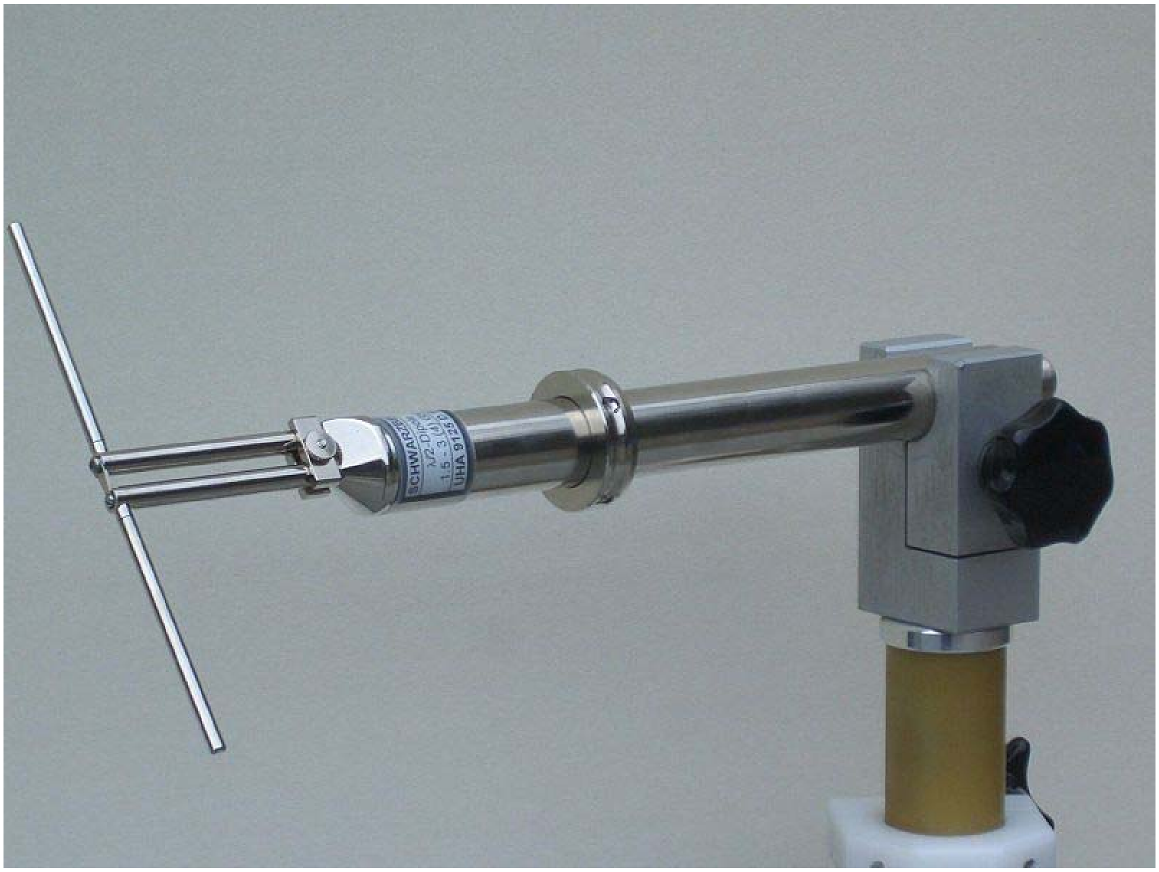
SCHWARZBE
λ/2-Dipol
1.5 - 3 (4)
UHA 9125

UHF–Half–Wave Dipole, 1.0–4 GHz

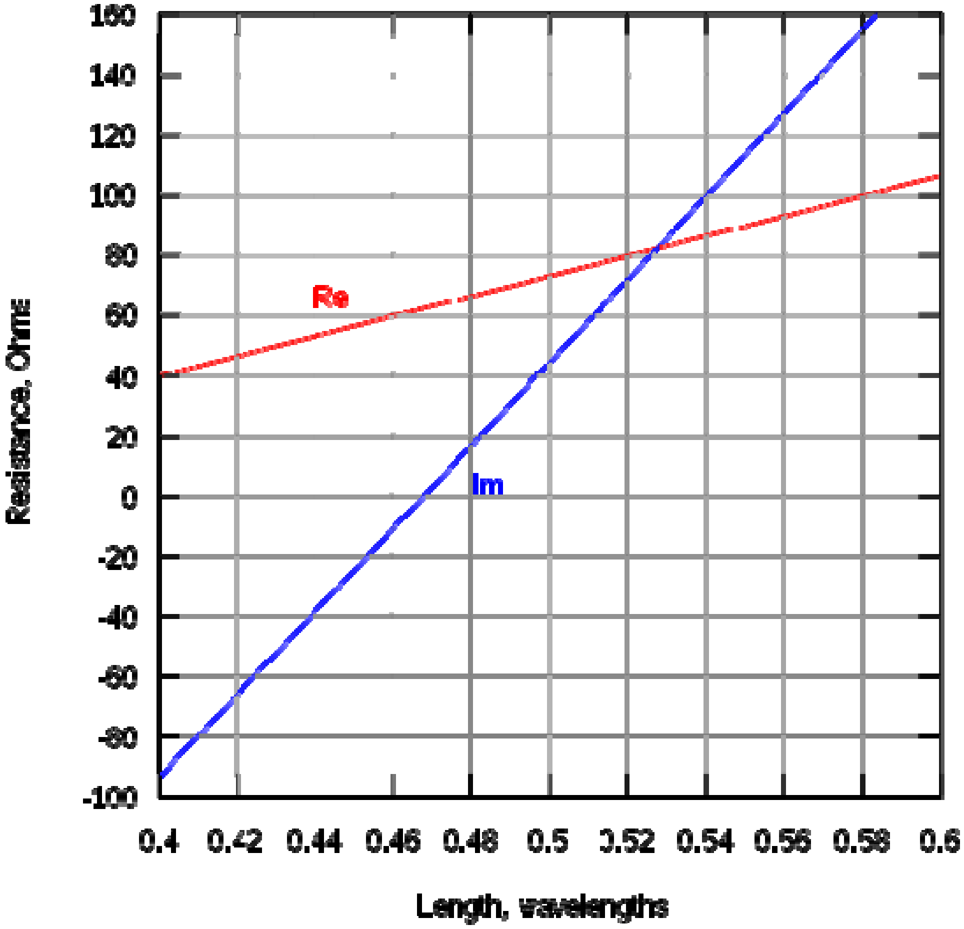

Gain of dipole antennas

length **L** in λ	Gain	Gain(dB)
≪0.1	1.50	1.76dB
0.5	**1.64**	**2.15dB**
1.0	1.80	2.55dB
1.5	2.00	3.01dB
2.0	2.30	3.62dB
3.0	2.80	4.47dB
4.0	3.50	5.44dB
8.0	7.10	8.51dB

Quarter-wave antenna

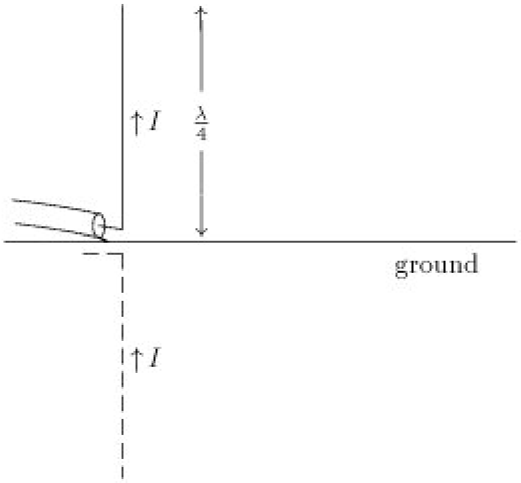

The antenna and its image form a $\frac{\lambda}{2}$dipole that radiates only upward.

The quarter wave monopole antenna is a single element antenna fed at one end, that behaves as a dipole antenna. It is formed by a conductor $\frac{\lambda}{4}$ in length. It is fed in the lower end, which is near a conductive surface which works as a reflector. The current in the reflected image has the same direction and phase as the current in the real antenna. The quarter-wave conductor and its image together form a half-wave dipole that radiates only in the upper half of space.

In this upper side of space the emitted field has the same amplitude of the field radiated by a half-wave dipole fed with the same current. Therefore, the total emitted power is one-half the emitted power of a half-wave dipole fed with the same current. As the current is the same, the radiation resistance (real part of series impedance) will be one-half of the series impedance of a half-wave dipole. As the reactive part is also divided by 2, the impedance of a quarter wave antenna is $\frac{73+i43}{2}=36+i21$ohms. Since the fields above ground are the same as for the dipole, but only half the power is applied, the gain is twice (3dB over) that for a half-wave dipole ($\frac{\lambda}{2}$), that is 5.14 dBi.

The earth can be used as ground plane, but it is a poor conductor: the reflected antenna image is only clear at glancing angles (far from the antenna). At these glancing angles, electromagnetic fields and radiation patterns are thus the same as for a half-wave dipole.

Naturally, the impedance of the earth is far inferior to that of a good conductor ground plane -- this can be improved (at cost) by laying a copper mesh.

When ground is not available (such as in a vehicle) other metallic surfaces can serve as a ground plane (typically the vehicle's roof). Alternatively, radial wires placed at the base of the antenna can simulate a ground plane. For VHF bands, the radiating and ground-plane elements can be constructed from rigid rods or tubes.

Dipole characteristics

Frequency versus length

Dipoles that are much smaller than the wavelength of the signal are called *Hertzian, short, or infinitesimal dipoles*. These have a very low radiation resistance and a high reactance, making them inefficient, but they are often the only available antennas at very long wavelengths. Dipoles whose length is half the wavelength of the signal are called *half-wave dipoles*, and are more efficient. In general radio engineering, the term *dipole* usually means a half-wave dipole (center-fed).

A half-wave dipole is cut to length l for frequency f MHz according to the formula $l = \frac{143}{f}$ where l is in metres or $l = \frac{468}{f}$ where l is in feet. This is because the impedance of the dipole is resistive pure at about this length. The length of the dipole antenna is about 95% of half a wavelength at the speed of light in free space.

The magic numbers above are derived from a one Hz wavelength which is the distance that light radio travels in one second. Speed of light in vacuum is 299,792,458 m/s, which is divided by 1 million to account for MHz rather than Hz, which is then divided by 2 for a half-wave dipole antenna. A fudge factor of approximately 0.95 is multiplied to account for the damping due to radiation, which results in the magic number of 143 m·MHz or 468 ft·MHz.

Radiation pattern and gain

Dipoles have an omnidirectional radiation pattern, shaped like a toroid (doughnut) symmetrical about the axis of the dipole. The radiation is maximum at right angles to the dipole, dropping off to zero on the antenna's axis. The theoretical maximum gain of a Hertzian dipole is 10 log 1.5 or 1.76 dBi. The maximum theoretical gain of a $\lambda/2$-dipole is 10 log 1.64 or 2.15 dBi.

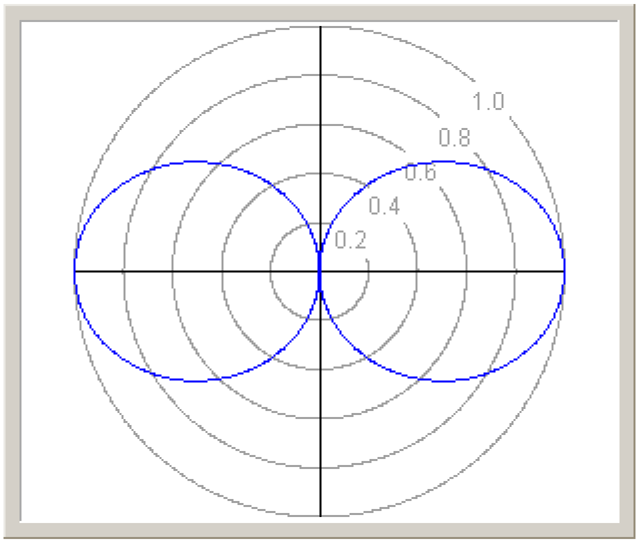

Radiation pattern of a half-wave dipole antenna. The scale is linear.

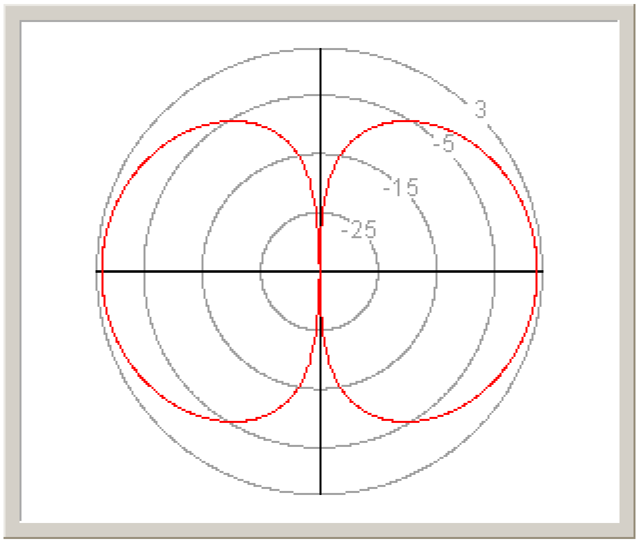

Gain of a half-wave dipole (same as left). The scale is in dBi (decibels over isotropic).

Feeder line

Ideally, a half-wave (λ/2) dipole should be fed with a balanced line matching the theoretical 73 ohm impedance of the antenna. A folded dipole uses a 300 ohm balanced feeder line.

Many people have had success in feeding a dipole directly with a coaxial cable feed rather than a ladder-line. However, coax is not symmetrical and thus not a balanced feeder. It is unbalanced, because the outer shield is connected to earth potential at the other end. When a balanced antenna such as a dipole is fed with an unbalanced feeder, common mode currents can cause the coax line to radiate in addition to the antenna itself, and the radiation pattern may be asymmetrically distorted. This can be remedied with the use of a balun.

Common applications

Set-top TV antenna

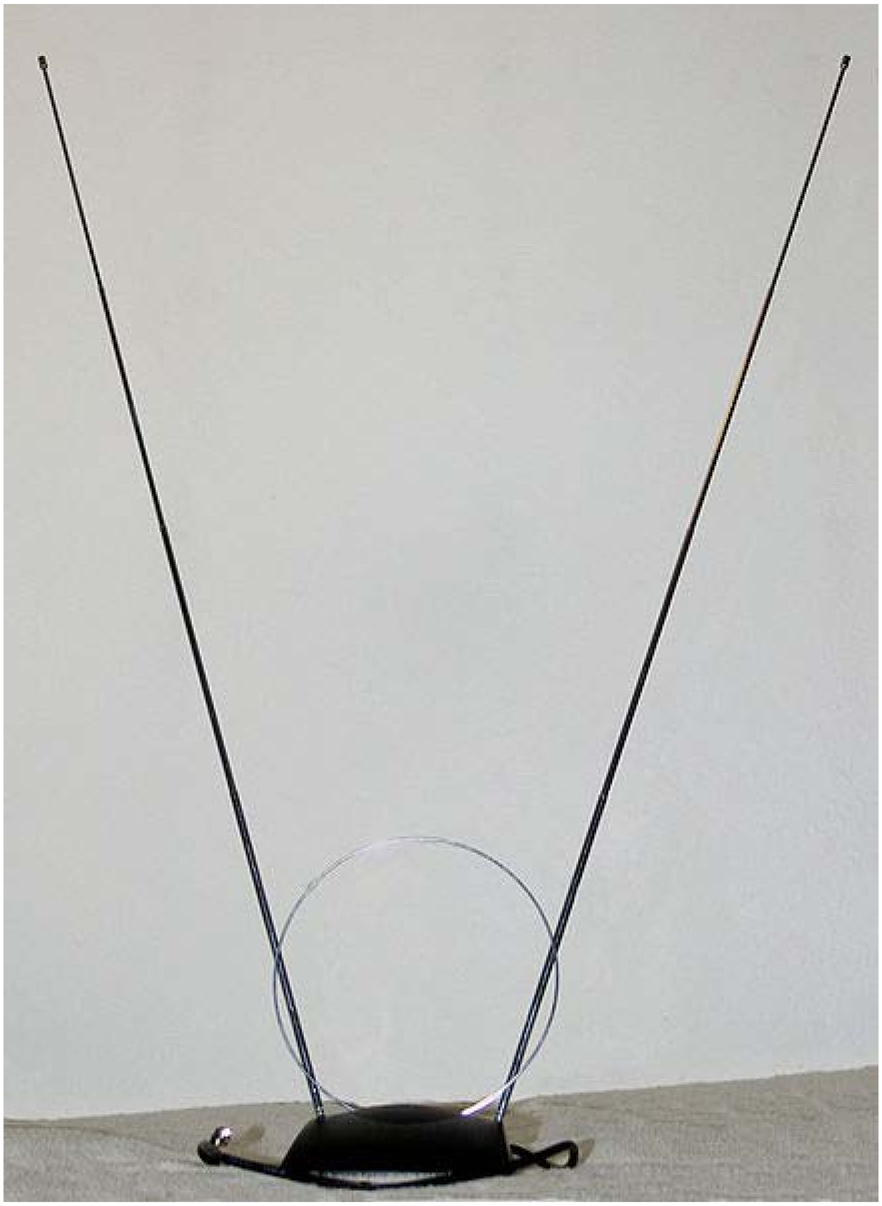

A "rabbit-ears" antenna with a UHF loop antenna.

The most common dipole antenna is the type used with televisions, often colloquially referred to as "**rabbit ears**" or "**bunny ears**." While in most applications the dipole elements are arranged along the same line, rabbit ears are adjustable in length and angle. Larger dipoles are sometimes hung in a V shape with the center near the radio equipment on the ground or the ends on the ground with the center supported. Shorter dipoles can be hung vertically. Some have extra elements to get better reception such as loops (especially for UHF transmissions), which can be turnable around a vertical axis, or a dial, which modifies the electrical properties of the antenna at each dial position.

Folded dipole

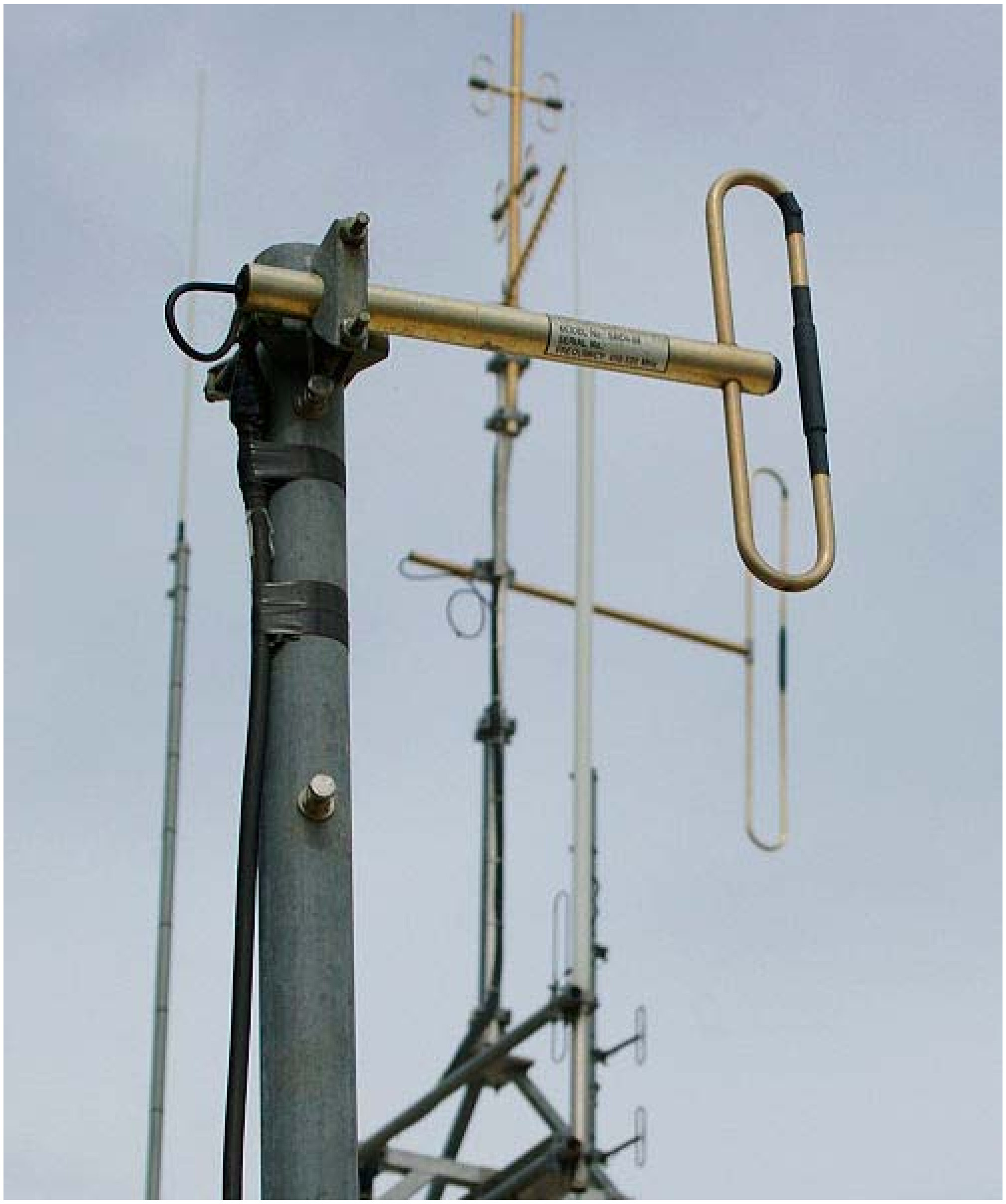

Folded dipole antenna

Another common place one can see dipoles is as antennas for the FM band - these are folded dipoles. The tips of the antenna are folded back until they almost meet at the feedpoint, such that the antenna comprises one entire wavelength. This arrangement has a greater bandwidth than a standard half-wave dipole. If the conductor has a constant radius and cross-section, at resonance the input impedance is four times that of a half-wave dipole.

Shortwave antenna

A DIY-made dipole antenna with mast

Dipoles for longer wavelengths are made from solid or stranded wire. Portable dipole antennas are made from wire that can be rolled up when not in use. Ropes with weights on the ends can be thrown over supports such as tree branches and then used to hoist up the antenna. The center and the connecting cable can be hoisted up with the ends on the ground or the ends hoisted up between two supports in a V shape. While permanent antennas can be trimmed to the proper length, it is helpful if portable antennas are adjustable to allow for local conditions when moved. One easy way is to fold the ends of the elements to form loops and use adjustable clamps. The loops can then be used as attachment points.

It is important to fit a good insulator at the ends of the dipole, as failure to do so can lead to a flashover if the dipole is used with a transmitter. Various purchased or improvised insulators can be used.

Whip antenna

The whip antenna is probably the most common and simplest-looking antenna. These are monopoles, and the most common and practical is the quarter-wave monopole which could be considered as half of a dipole using a ground plane as the image of the other half. The commonly referred-to end-fed dipole is actually just a half-wave monopole whip antenna.

Dipoles versus whip antennas

Dipoles are generally more efficient than whip antennas (quarter-wave monopoles). The total radiated power and the radiation resistance are twice that of a quarter-wave monopole. Thus, if a whip antenna were used with an infinite perfectly conducting ground plane, then it would be as efficient in half-space as a dipole in free space an infinite distance from any conductive surfaces such as the earth's surface.

Dipole towers

Large constructed half-wavelength dipole towers include the Warsaw radio mast — the only half-wave dipole for longwave ever built — and Blaw-Knox Towers.

Military

US Military personnel occasionally use a 'doublet' antenna, especially during dismounted unconventional warfare. A radio operator may choose to bring several doublet antennas for different frequencies, such as an antenna cut to length for the set MEDEVAC (medical evacuation) frequency, NCS (net control station) frequency, and tactical frequency (the frequency used by troops in the field). This approach may not be acceptable depending on the mission. Note that a doublet antenna will not work with the standard SINCGARS radio when using frequency hopping(FH) but is effective for single channel (SC). A doublet antenna is more practical for radios not intended for FH.

Collinear antenna systems based on dipoles

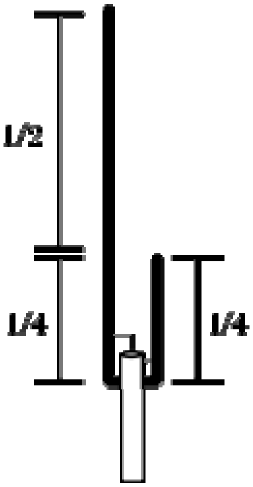

J-Pole Antenna

Dipoles can be stacked end to end in phased arrays to make collinear antenna arrays, which exhibit more gain in certain directions—the toroidal radiation pattern is flattened out, giving maximum gain at right angles to the axis of the colinear array.

Slim Jim or J-pole

A Slim Jim or J-pole is a form of end-fed dipole connected to a quarter-wave stub matching section.

Dipole types

Ideal half-wavelength dipole

This type of antenna is a special case where each wire is exactly one-quarter of the wavelength, for a total of a half wavelength. The radiation resistance is about 73 ohms if wire diameter is ignored, making it easily matched to a coaxial transmission line. The directivity is a constant 1.64, or 2.15 dB. Actual gain will be a little less due to ohmic losses.

If the dipole is not driven at the centre then the feed point resistance will be higher. If the feed point is distance *x* from one end of a half wave (λ/2) dipole, the resistance will be described by the following equation.

$$R_r = \frac{75}{\sin^2\left(\frac{2\pi x}{\lambda}\right)}$$

If taken to the extreme then the feed point resistance of a $\lambda/2$ long rod is infinite, but it is possible to use a $\lambda/2$ pole as an aerial; the right way to drive it is to connect it to one terminal of a parallel LC resonant circuit. The other side of the circuit must be connected to the braid of a coaxial cable lead and the core of the coaxial cable can be connected part way up the coil from the RF ground side. An alternative means of feeding this system is to use a second coil which is magnetically coupled to the coil attached to the aerial.

Folded dipole

A folded dipole is a half-wave dipole with an additional wire connecting its two ends. If the additional wire has the same diameter and cross-section as the dipole, two nearly identical radiating currents are generated. The resulting far-field emission pattern is nearly identical to the one for the single-wire dipole described above; however, at resonance its input (feedpoint) impedance R_{df} is four times the radiation resistance of a single-wire dipole. This is because for a fixed amount of power, the total radiating current I_0 is equal to twice the current in each wire and thus equal to twice the current at the feed point. Equating the average radiated power to the average power delivered at the feedpoint, we may write

$$\frac{1}{2}R_{\frac{\lambda}{2}}I_0^2 = \frac{1}{2}R_{fd}\left(I_0/2\right)^2 .$$

It follows that

$$R_{fd} = 4R_{\frac{\lambda}{2}} = 292.52\Omega.$$

The folded dipole is therefore well matched to 300-Ohm balanced transmission lines.

Hertzian dipole (current element)

The Hertzian dipole is a theoretical short dipole (significantly smaller than the wavelength) with a uniform current along its length. A true Hertzian dipole cannot physically exist, since the assumed current distribution implies an infinite accumulation of charge at its ends.

The radiation resistance is given by:

$$R_r = \frac{2\pi}{3}Z_0\left(\frac{\ell}{\lambda}\right)^2 .$$

where Z_0 is the impedance of free space. This is precisely four times the radiation resistance of the real short dipole with the linearly tapered current distribution.

The radiation resistance is typically a fraction of an ohm, making the infinitesimal dipole an inefficient radiator. The directivity D, which is the theoretical gain of the antenna assuming no ohmic losses (not real-world), is a constant of 1.5, which corresponds to

1.76 dB. Actual gain will be much less due to the ohmic losses and the loss inherent in connecting a transmission line to the antenna, which is very hard to do efficiently considering the incredibly low radiation resistance. The maximum effective aperture is:

$$A_e = \frac{3\lambda^2}{8\pi}$$

A surprising result is that even though the Hertzian dipole is minute, its effective aperture is comparable to antennas many times its size.

Dipole as a reference standard

Antenna gain is sometimes measured as "*x* dB above a dipole", which means that the antenna in question is being compared to a dipole, and has *x* dB more gain (has more directivity) than the dipole tuned to the same operating frequency. In this case one says the antenna has a gain of "*x* dBd". More often, gains are expressed relative to an isotropic radiator, which is an imaginary aerial that radiates equally in all directions. In this case one uses dBi instead of dBd. As it is impossible to build an isotropic radiator, gain measurements expressed relative to a dipole are more practical when a reference dipole aerial is used for experimental measurements. 0 dBd is often considered equal to 2.15 dBi.

From Babinet's principle, a dipole antenna is complementary to a slot antenna consisting of a slot the same size and shape as a dipole cut from an infinite sheet of metal; both give the same radiation pattern.

Dipole with baluns

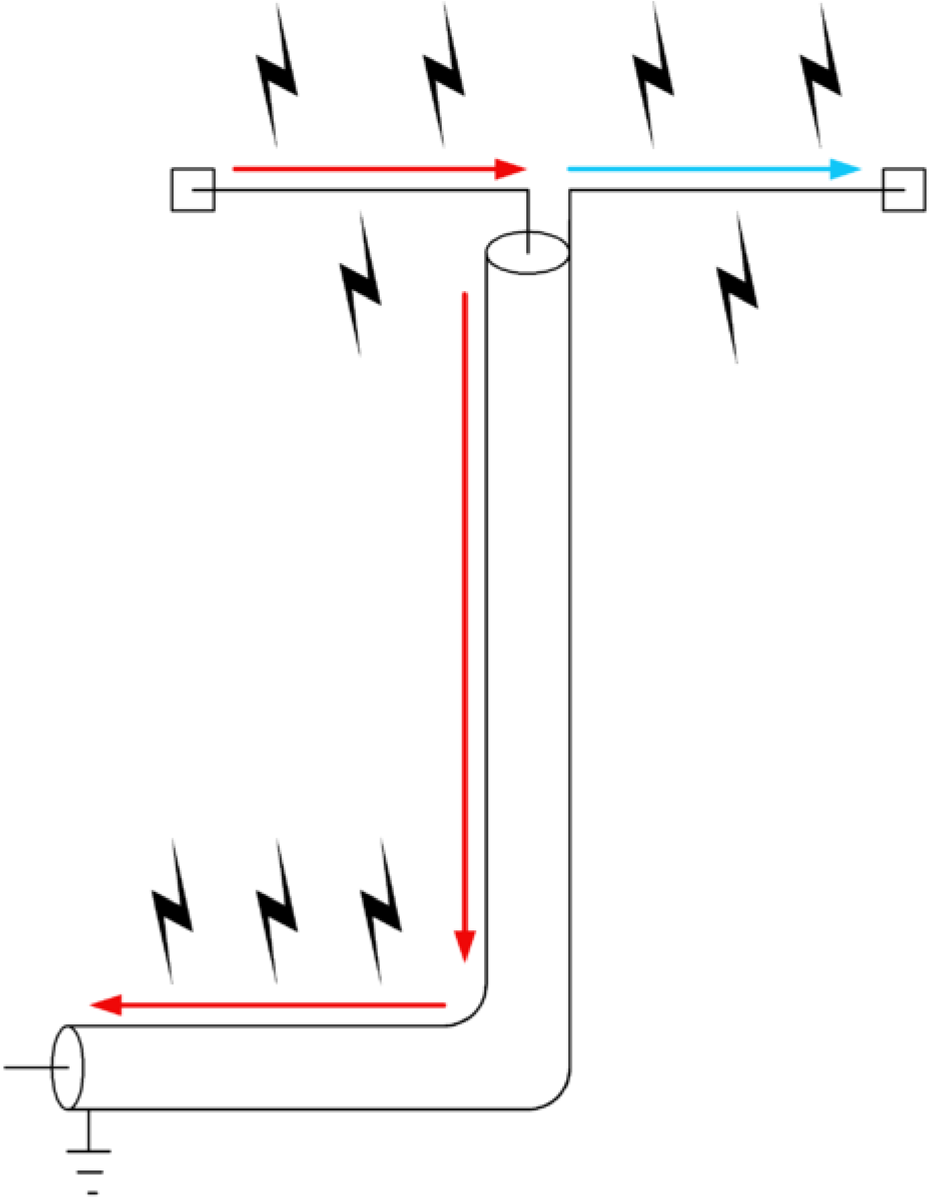

Coax and antenna both acting as radiators instead of only the antenna.

A dipole, being composed of two symmetrical ungrounded elements, works best when fed by a balanced transmission line, such as ladder line. When a dipole with an unbalanced feedline such as coaxial cable is used for transmitting, the shield side of the cable, in addition to the antenna, radiates. This can induce RF currents into other electronic equipment near the radiating feedline, causing RF interference. Furthermore, the antenna is not as efficient as it could be because it is radiating closer to the ground and its radiation (and reception) pattern may be distorted asymmetrically. At higher frequencies, where the length of the dipole becomes significantly shorter than the diameter of the feeder coax, this becomes a more significant problem. To prevent this, dipoles fed by coaxial cables have a balun between the cable and the antenna, to convert the unbalanced signal provided by the coax to a balanced symmetrical signal for the antenna.

Several type of baluns are commonly used to transmit on a dipole: current baluns and coax baluns.

Current balun

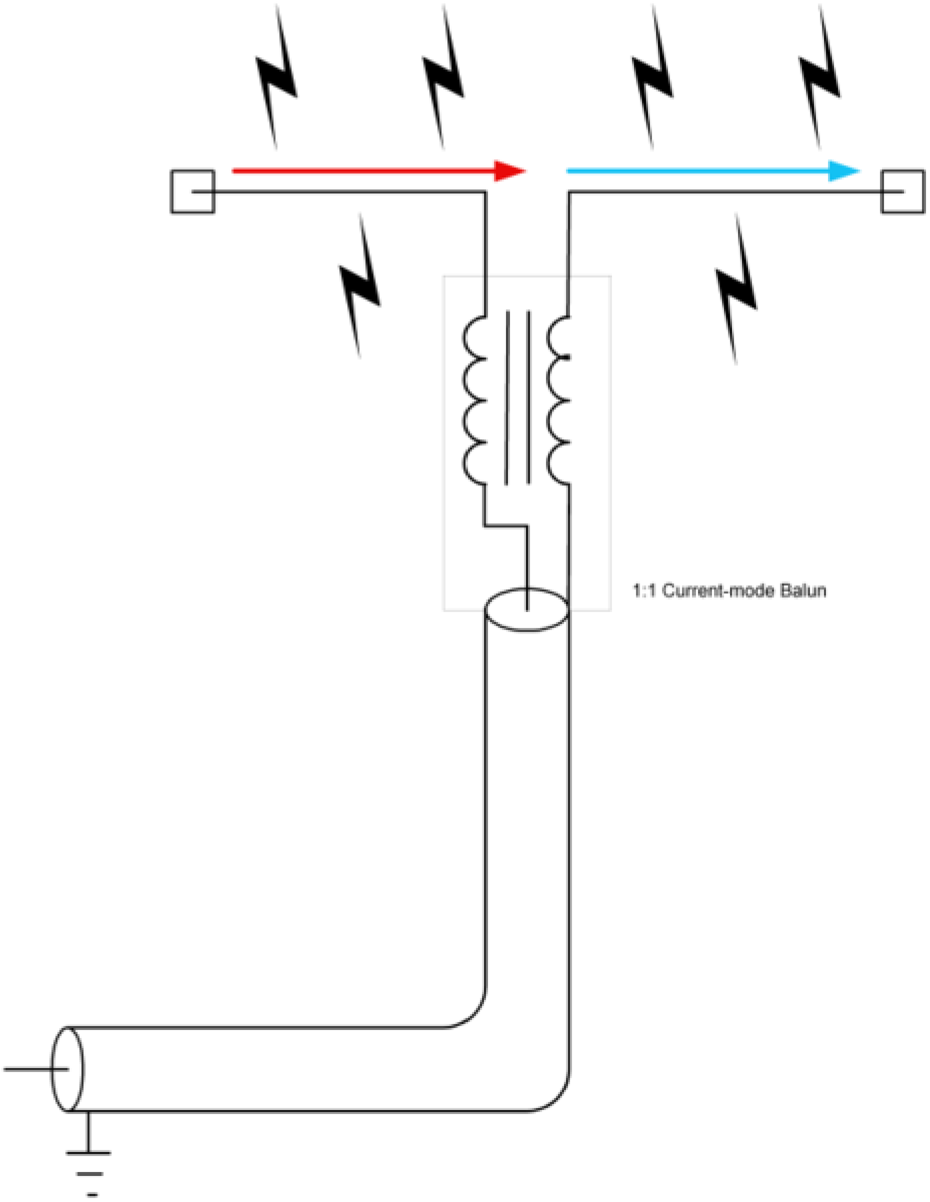

Dipole with a current balun.

A current balun is a bit more expensive but has the characteristic of being more broadband. It can also be as simple as winding the coax cable over a ferrite core. Or nothing but coax cable:

Coax balun

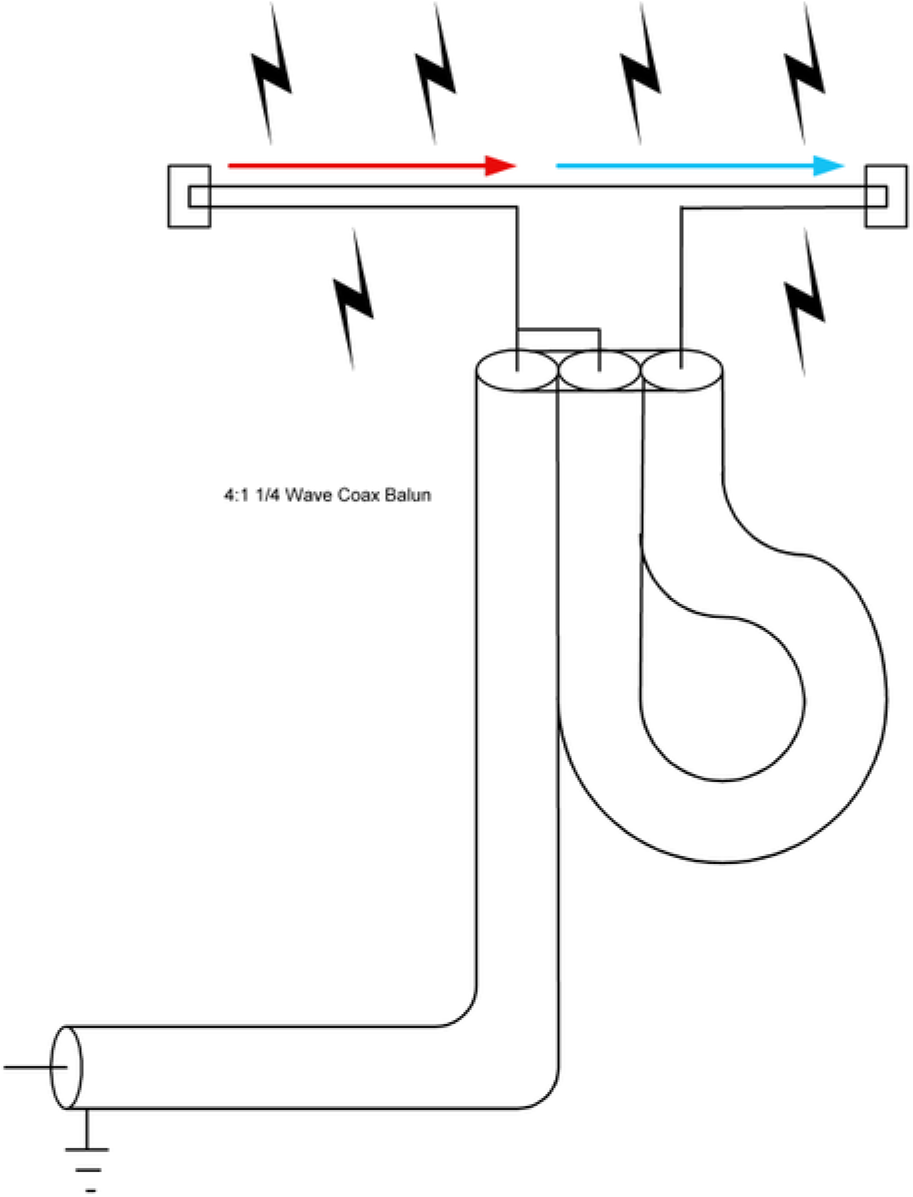

Here is a dipole using a coax balun.

A coax balun is a cost effective method to eliminate feeder radiation, but is limited to a narrow set of operating frequencies.

- One easy way to make a balun is a (λ/2) length of coaxial cable. The inner core of the cable is linked at each end to one of the balanced connections for a feeder or dipole. One of these terminals should be connected to the inner core of the coaxial feeder. All three braids should be connected together. This then forms a 4:1 balun which works correctly at only a narrow band of frequencies.

Sleeve balun

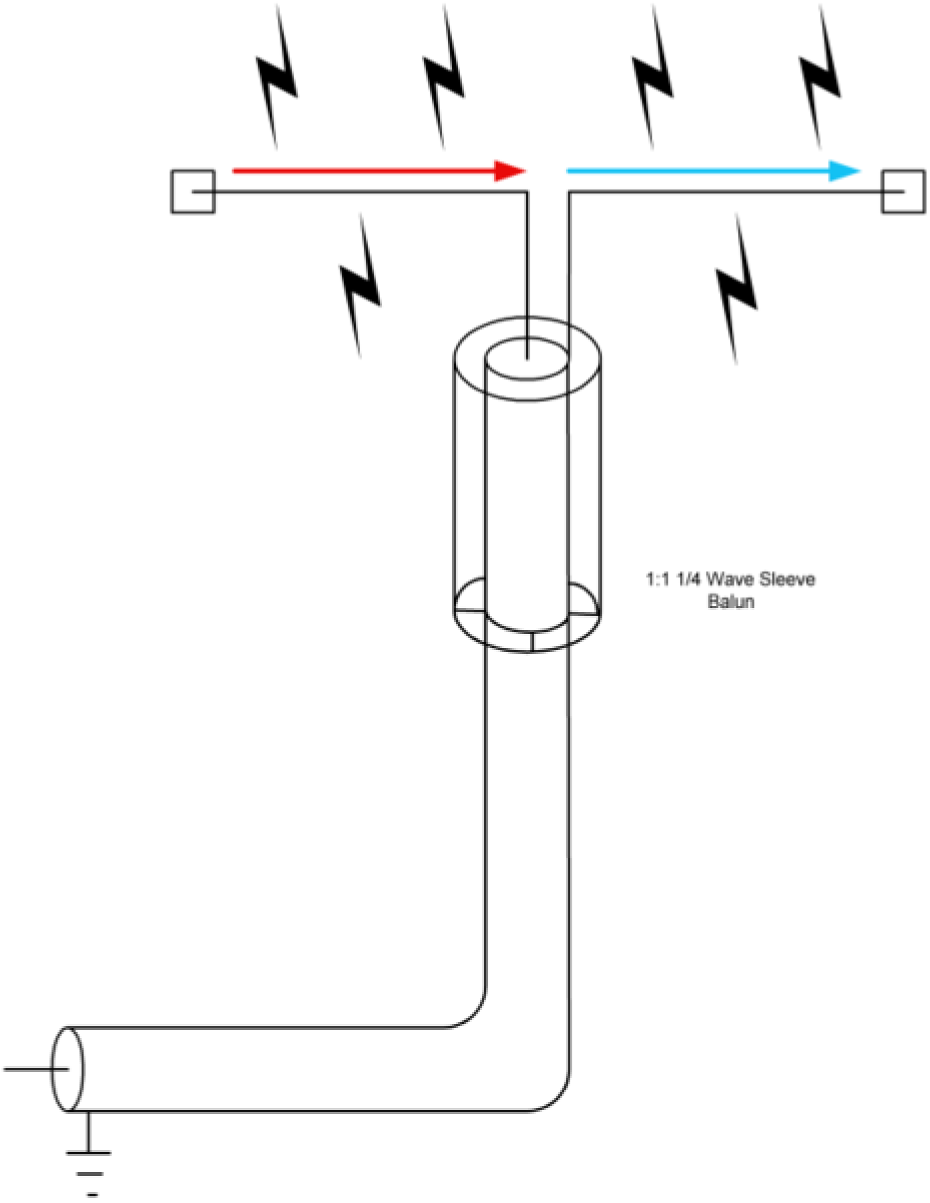

Here is a dipole using a sleeve balun.

At VHF frequencies, a sleeve balun can also be built to remove feeder radiation.

- Another narrow band design is to use a λ/4 length of metal pipe. The coaxial cable is placed inside the pipe; at one end the braid is wired to the pipe while at the other end no connection is made to the pipe. The balanced end of this balun is at the end where the pipe is wired to the braid. The λ/4 conductor acts as a transformer converting the infinite impedance at the unconnected end into a zero impedance at the end connected to the braid. Hence any current entering the balun through the connection, which goes to the braid at the end with the connection to the pipe, will flow into the pipe. This balun design is impractical for low frequencies because of the long length of pipe that will be needed.

Chapter 2

Horn Antenna

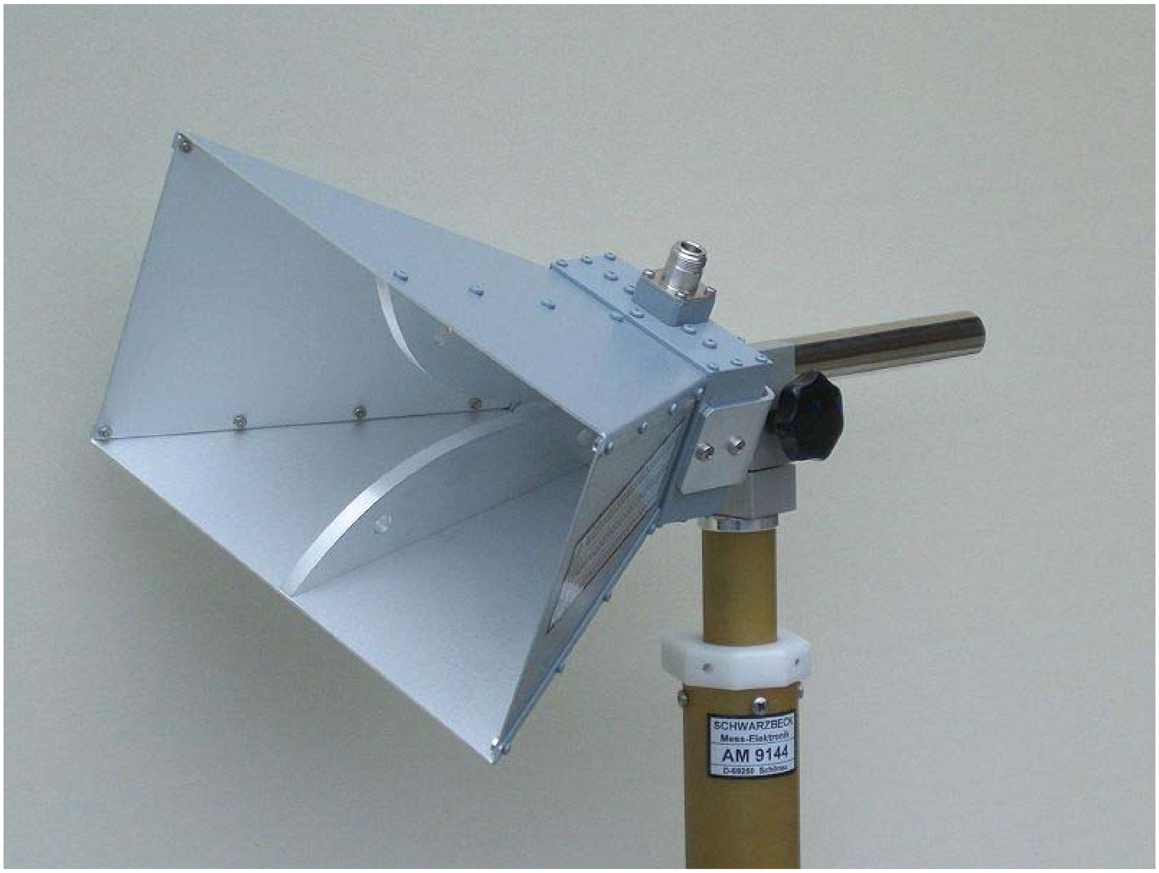

Pyramidal microwave horn antenna, with a bandwidth of 0.8 to 18 GHz. A coaxial cable feedline attaches to the connector visible at top. This type is called a ridged horn; the curving fins visible inside the mouth of the horn increase the antenna's bandwidth.

A **horn antenna** or **microwave horn** is an antenna that consists of a flaring metal waveguide shaped like a horn to direct the radio waves. Horns are widely used as antennas at UHF and microwave frequencies, above 300 MHz. They are used as feeders (called feed horns) for larger antenna structures such as parabolic antennas, as standard calibration antennas to measure the gain of other antennas, and as directive antennas for such devices as radar guns, automatic door openers, and microwave radiometers. Their advantages are moderate directivity (gain), low SWR, broad bandwidth, and simple construction and adjustment.

One of the first horn antennas was constructed in 1897 by Indian radio researcher Jagadish Chandra Bose in his pioneering experiments with microwaves. In the 1930s the first experimental research (Southworth and Barrow, 1936) and theoretical analysis (Barrow and Chu, 1939) of horns as antennas was done. The development of radar in World War 2 stimulated horn research. The corrugated horn proposed by Kay in 1962 has become widely used as a feed horn for microwave antennas such as satellite dishes and radio telescopes.

An advantage of horn antennas is that since they don't have any resonant elements, they can operate over a wide range of frequencies, a wide bandwidth. The useable bandwidth of horn antennas is typically of the order of 10:1, and can be up to 20:1 (for example allowing it to operate from 1 GHz to 20 GHz). The input impedance is slowly-varying over this wide frequency range, allowing low VSWR over the bandwidth. The gain of horn antennas ranges up to 25 dBi, with 10 - 20 dBi being typical.

Description

A horn antenna is used to transmit radio waves from a waveguide (a metal pipe used to carry radio waves) out into space, or collect radio waves into a waveguide for reception. It typically consists of a short length of rectangular or cylindrical metal tube (the waveguide), closed at one end, flaring into an open-ended conical or pyramidal shaped horn on the other end. The radio waves are usually introduced into the waveguide by a coaxial cable attached to the side, with the central conductor projecting into the waveguide. The waves then radiate out the horn end in a narrow beam. However in some equipment the radio waves are conducted from the transmitter or to the receiver by a waveguide, and in this case the horn is just attached to the end of the waveguide.

How it works

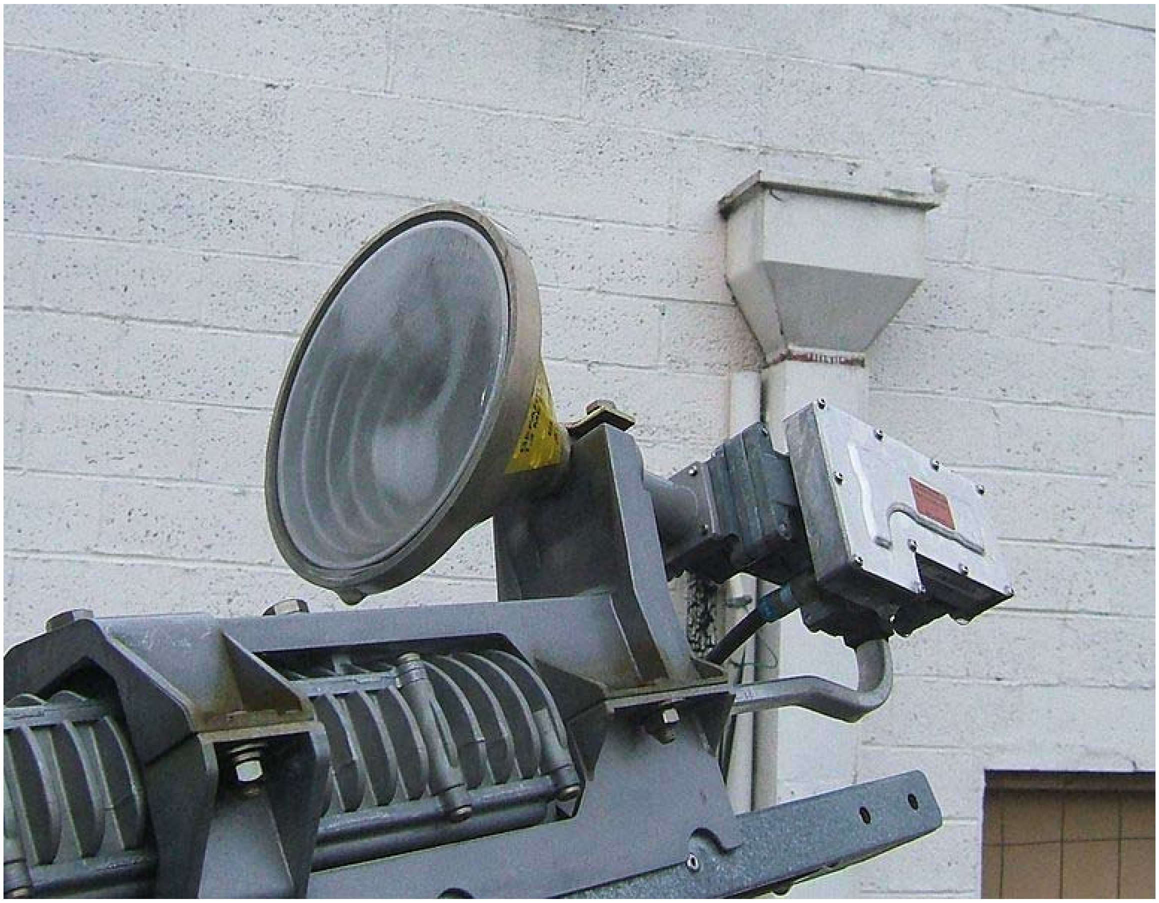

Corrugated conical horn antenna used as a feed horn on a Hughes Direcway home satellite dish.

A horn antenna serves the same function for electromagnetic waves that an acoustical horn does for sound waves in a musical instrument such as a trumpet; it provides a gradual transition structure to match the impedance of a tube to the impedance of free space, enabling the waves from the tube to radiate efficiently into space.

If a simple open-ended waveguide were to be used as an antenna, without the horn, the sudden end of the conductive walls causes an abrupt impedance change at the aperture, from the characteristic impedance of the waveguide to the impedance of free space, 377 ohms. When radio waves travelling through the waveguide hit the opening, it acts as a bottleneck, reflecting most of the wave energy back down the guide toward the source, so only part of the power is radiated. It acts similarly to an open-circuited transmission line, or to a boundary between optical mediums with a high and low index of refraction, like a glass surface. The reflected waves cause standing waves in the waveguide, increasing the VSWR, wasting energy and possibly overheating the transmitter. In addition, the small aperture of the waveguide (around one wavelength) causes severe diffraction of the waves issuing from it, resulting in a wide radiation pattern without much directivity.

To improve these poor characteristics, the ends of the waveguide are flared out to form a horn. The taper of the horn changes the impedance gradually along the horn's length. This acts like an impedance matching transformer, allowing most of the wave energy to radiate out the end of the horn into space, with minimal reflection. The taper functions similarly to a tapered transmission line, or an optical medium with a smoothly-varying refractive index. In addition, the wide aperture of the horn projects the waves in a narrow beam

The horn shape that gives minimum reflected power is an exponential taper. Exponential horns are used in special applications that require minimum signal loss, such as satellite antennas and radio telescopes. However conical and pyramidal horns are most widely used, because they have straight sides and are easier to fabricate.

Radiation pattern

The waves travel down a horn as spherical wavefronts, with their origin at the apex of the horn. The pattern of electric and magnetic fields at the aperture plane of the horn, which determines the radiation pattern, is a scaled-up reproduction of the fields in the waveguide. However, because the wavefronts are spherical, the phase increases smoothly from the center of the aperture plane to the edges, because of the difference in length of the center point and the edge points from the apex point. The difference in phase between the center point and the edges is called the *phase error*. This phase error, which increases with the flare angle, reduces the gain and increases the beamwidth, giving horns wider beamwidths than plane-wave antennas such as parabolic dishes.

At the flare angle, the radiation of the beam lobe is down about -20 dB from its maximum value.

The increasing phase error limits the aperture size of practical horns to about 15 wavelengths; larger apertures would require impractically long horns. This limits the gain of practical horns to about 1000 (30 dB) and the corresponding minimum beamwidth to about 5 - 10°.

Optimum horn

Large pyramidal horn used in 1951 to detect the 21 cm (1.43 GHz) radiation from hydrogen gas in the Milky Way galaxy.

For a given frequency and horn length, there is some flare angle that gives minimum reflection and maximum gain. The reflections in straight-sided horns come from the two locations along the wave path where the impedance changes abruptly; the mouth or aperture of the horn, and the throat where the sides begin to flare out. The amount of reflection at these two sites varies with the *flare angle* of the horn (the angle the sides make with the axis). In narrow horns with small flare angles most of the reflection occurs at the mouth of the horn. The gain of the antenna is low because the small mouth approximates an open-ended waveguide. As the angle is increased, the reflection at the mouth decreases rapidly and the antenna's gain increases. In contrast, in wide horns with flare angles approaching 90° most of the reflection is at the throat. The horn's gain is again low because the throat approximates an open-ended waveguide. As the angle is decreased, the amount of reflection at this site drops, and the horn's gain again increases.

This discussion shows that there is some flare angle which gives maximum gain and minimum reflection. This is called the *optimum horn*. Most practical horn antennas are designed as optimum horns. In a pyramidal horn, the dimensions that give an optimum horn are:

$$a_E = \sqrt{3\lambda L_E} \qquad a_H = \sqrt{2\lambda L_H}$$

For a conical horn, the dimensions that give an optimum horn are:

$$d = \sqrt{3\lambda L}$$

where

a_E is the width of the aperture in the E-field direction
a_H is the width of the aperture in the H-field direction
L_E is the slant length of the side in the E-field direction
L_H is the slant length of the side in the H-field direction.
d is the diameter of the cylindrical horn aperture
L is the slant length of the cone from the apex.
λ is the wavelength

An optimum horn does not give maximum gain for a given *aperture size*; this is achieved by a very long horn. It gives the maximum gain for a given horn *length*. Tables showing dimensions for optimum horns for various frequencies are given in microwave handbooks.

Gain

Horns have very little loss, so the directivity of a horn is roughly equal to its gain. The gain G of a pyramidal horn antenna (the ratio of the radiated power intensity along its beam axis to the intensity of an isotropic antenna with the same input power) is:

$$G = \frac{4\pi A}{\lambda^2} e_A$$

For conical horns, the gain is:

$$G = \left(\frac{\pi d}{\lambda}\right)^2 e_A$$

where

A is the area of the aperture,
d is the aperture diameter of a conical horn
λ is the wavelength,
e_A is a dimensionless parameter called the *aperture efficiency*,

The aperture efficiency ranges from 0.4 to 0.8 in practical horn antennas. For optimum pyramidal horns, $e_A = 0.511$., while for optimum conical horns $e_A = 0.522$. So an approximate figure of 0.5 is often used. The aperture efficiency increases with the length of the horn, and for aperture-limited horns is approximately unity.

Types of horn antennas

Aperture-limited corrugated horn, used as a feed horn in a radio telescope for millimeter waves.

These are the common types of horn antenna. Horns can have different flare angles as well as different expansion curves (elliptic, hyperbolic, etc.) in the E-field and H-field directions, making possible a wide variety of different beam profiles.

- Pyramidal horn - a horn antenna with the horn in the shape of a four-sided pyramid, with a rectangular cross section. They are the most widely used type, used with rectangular waveguides, and radiate linearly polarized radio waves.
- Sectoral horn - A pyramidal horn with only one pair of sides flared and the other pair parallel. It produces a fan-shaped beam, which is narrow in the plane of the flared sides, but wide in the plane of the narrow sides.
    - E-plane horn - A sectoral horn flared in the direction of the electric or E-field in the waveguide.
    - H-plane horn - A sectoral horn flared in the direction of the magnetic or H-field in the waveguide.
- Conical horn - A horn in the shape of a cone, with a circular cross section. They are used with cylindrical waveguides.
- Corrugated horn - A horn with parallel slots or grooves, small compared with a wavelength, covering the inside surface of the horn, transverse to the axis. Corrugated horns have wider bandwidth and smaller sidelobes and cross-

polarization, and are widely used as feed horns for satellite dishes and radio telescopes.

- Ridged horn - A pyramidal horn with ridges or fins attached to the inside of the horn, extending down the center of the sides. The fins lower the cutoff frequency, increasing the antenna's bandwidth.
- Septum horn - A horn which is divided into several subhorns by metal partitions (septums) inside, attached to opposite walls.
- Aperture-limited horn - a long narrow horn, long enough so the phase error is a fraction of a wavelength, so it essentially radiates a plane wave. It has an aperture efficiency of 1.0 so it gives the maximum gain and minimum beamwidth for a given aperture size. The gain is not affected by the length but only limited by diffraction at the aperture. Used as feed horns in radio telescopes and other high-resolution antennas.

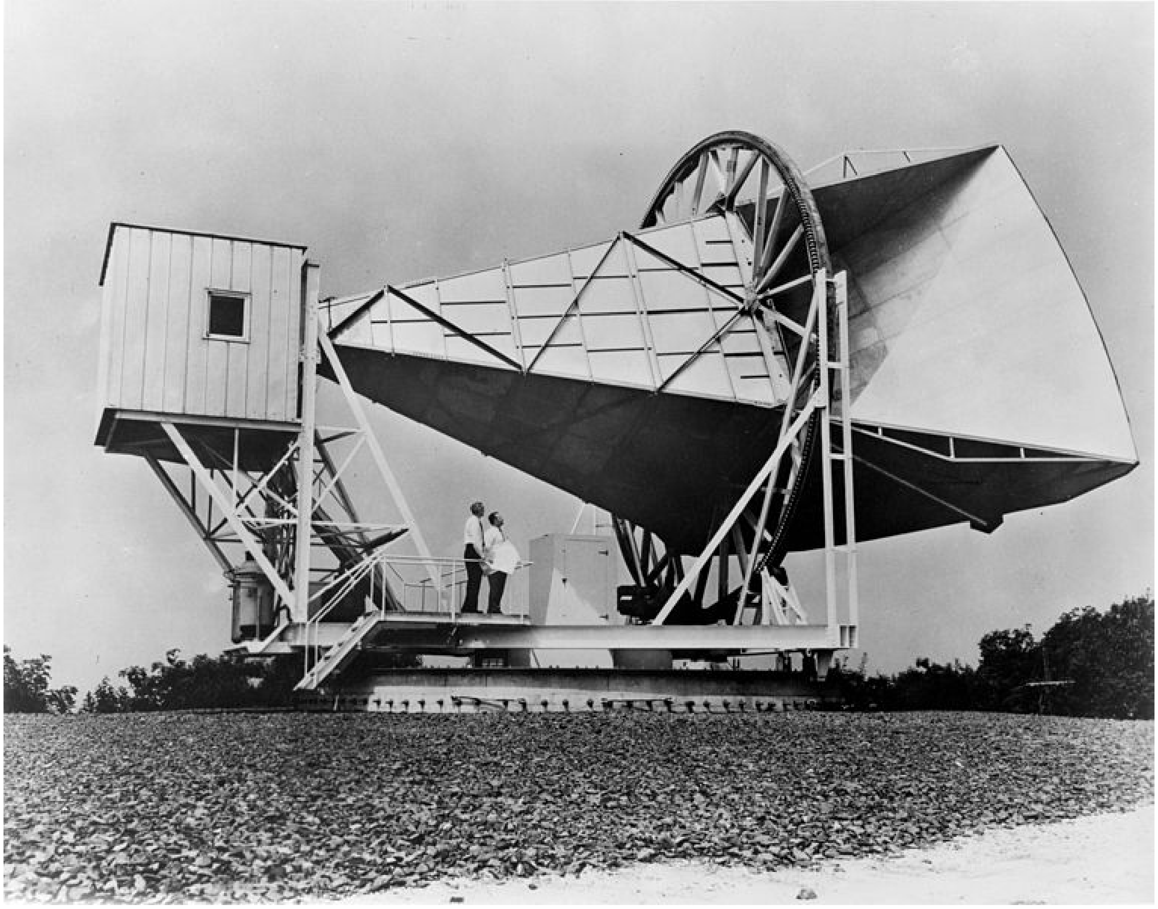

50 ft. Holmdel horn antenna at Bell labs in Holmdel, New Jersey, USA, with which Arno Penzias and Robert Wilson discovered cosmic microwave background radiation in 1964.

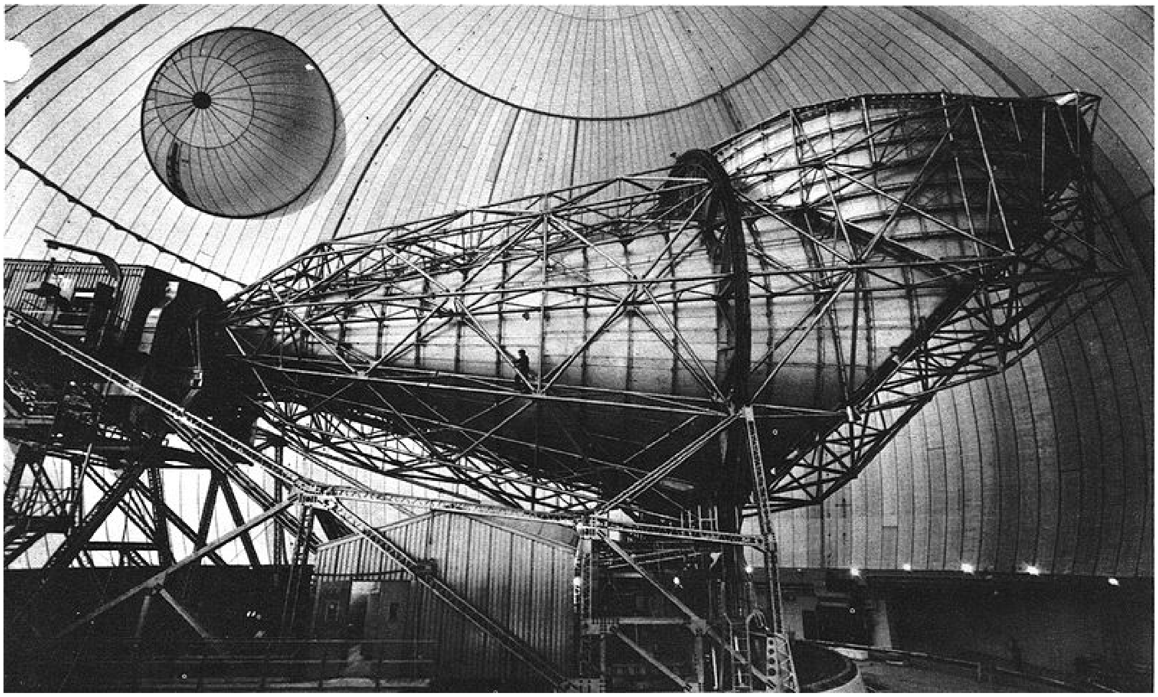

Large 177 ft. Hogg horn antenna at AT&T satellite communications facility in Andover, Maine, USA, used in 1960s to communicate with the first direct relay communications satellite, Telstar.

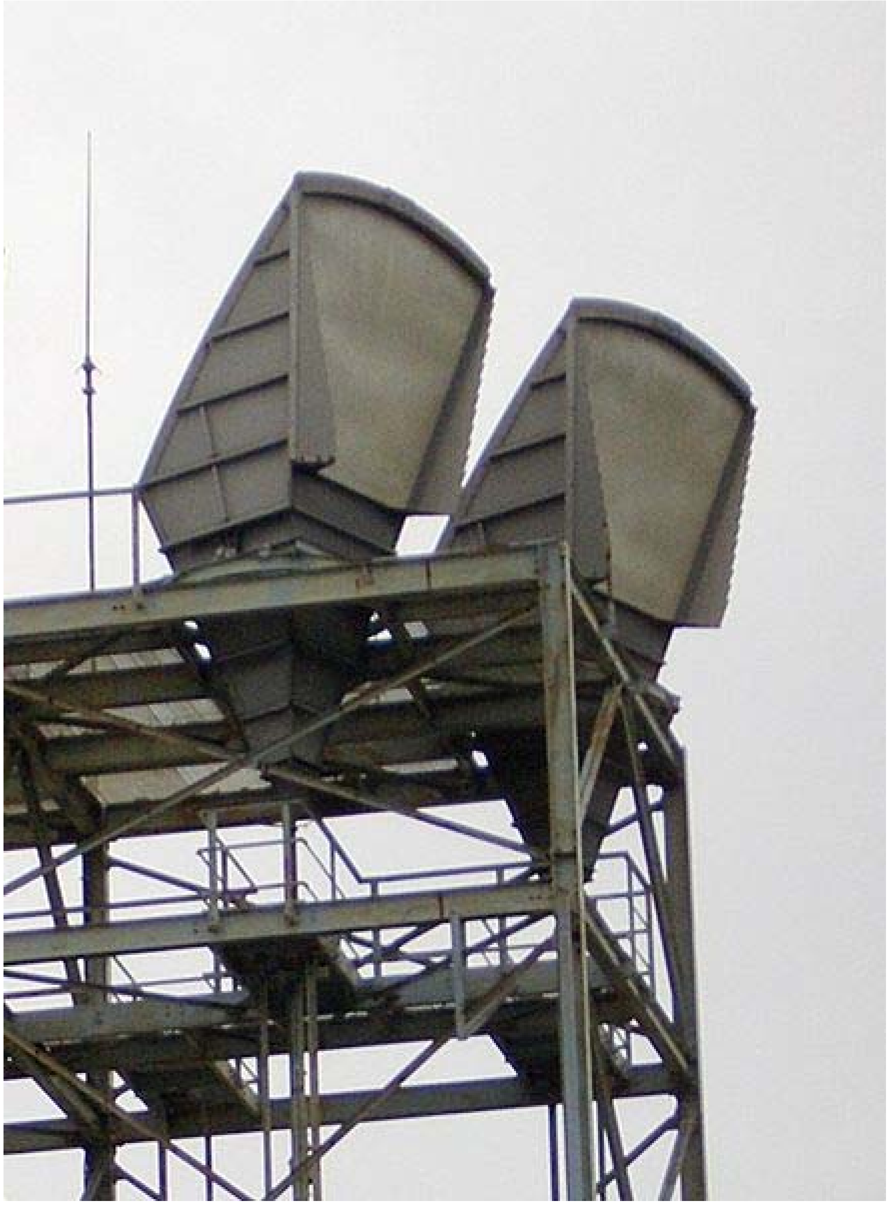

Hogg microwave relay antennas on roof of AT&T telephone switching center, Seattle, Washington, USA
Hogg antennas

Hogg horn antenna

A type of antenna that combines a horn with a parabolic reflector is the Hogg antenna, invented by D. C. Hogg at Bell labs around 1960. It consisted of a horn antenna with a reflector mounted in the mouth of the horn at a 45 degree angle so the radiated beam is at right angles to the horn axis. The reflector is a segment of a parabolic reflector, so the device is equivalent to a parabolic antenna fed off-axis. The advantage of this design over a standard parabolic antenna is that the horn shields the antenna from radiation coming from angles outside the main beam axis, so its radiation pattern has very small sidelobes.

Also, the aperture isn't partially obstructed by the feed and its supports, as with ordinary front-fed parabolic dishes. The disadvantage is that it is far larger and heavier for a given aperture area than a parabolic dish, and must be mounted on a cumbersome turntable to be fully steerable. This design was used for a few radio telescopes and communication satellite ground antennas during the 1960s. Its largest use, however, was as fixed antennas for microwave relay links in the AT&T Long Lines microwave network. Probably the most photographed and well-known example is the 15 meter (50 foot) long Holmdel Horn Antenna at Bell Labs in Holmdel, New Jersey, with which Arno Penzias and Robert Wilson discovered cosmic microwave background radiation in 1965, for which they won the 1978 Nobel Prize in Physics.

Chapter 3

Radio Telescope

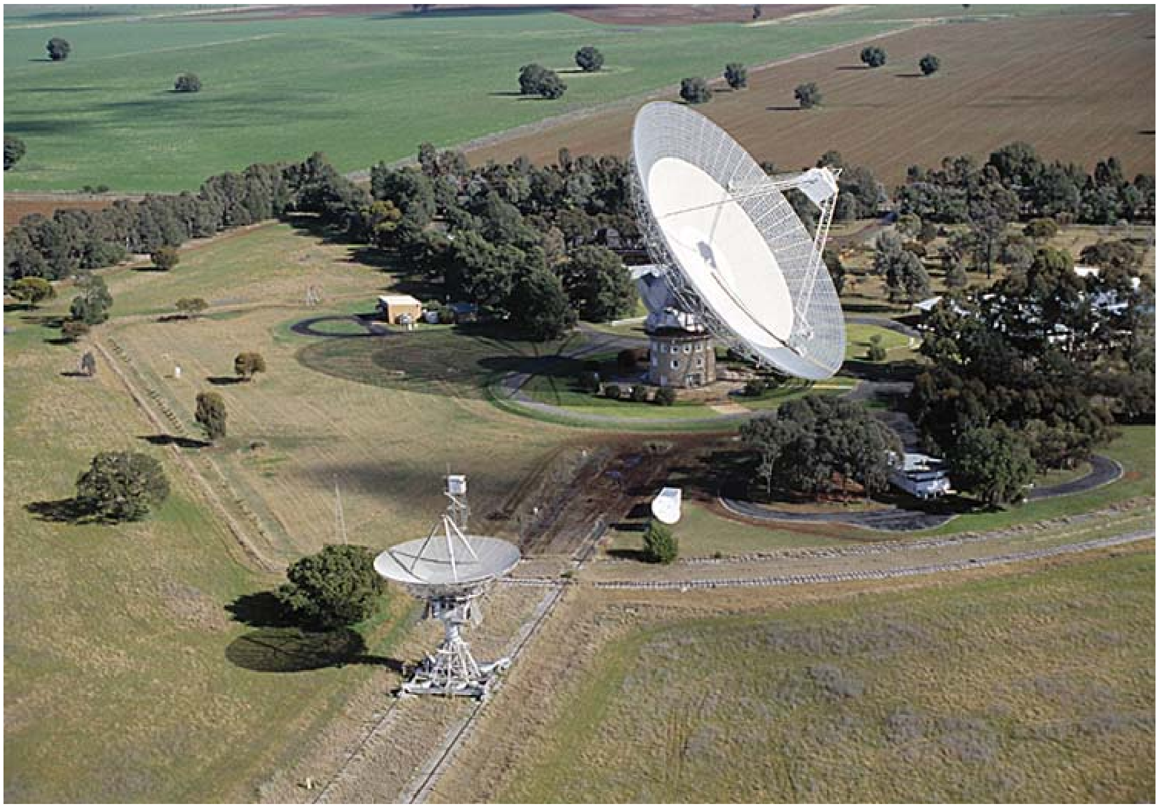

The 64 meter radio telescope at Parkes Observatory

A **radio telescope** is a form of directional radio antenna used in radio astronomy. The same types of antennas are also used in tracking and collecting data from satellites and space probes. In their astronomical role they differ from optical telescopes in that they operate in the radio frequency portion of the electromagnetic spectrum where they can detect and collect data on radio sources. Radio telescopes are typically large parabolic ("dish") antennas used singly or in an array. Radio observatories are preferentially located far from major centers of population to avoid electromagnetic interference (EMI) from radio, TV, radar, and other EMI emitting devices. This is similar to the locating of optical telescopes to avoid light pollution, with the difference being that radio observatories are often placed in valleys to further shield them from EMI as opposed to clear air mountain tops for optical observatories.

Early radio telescopes

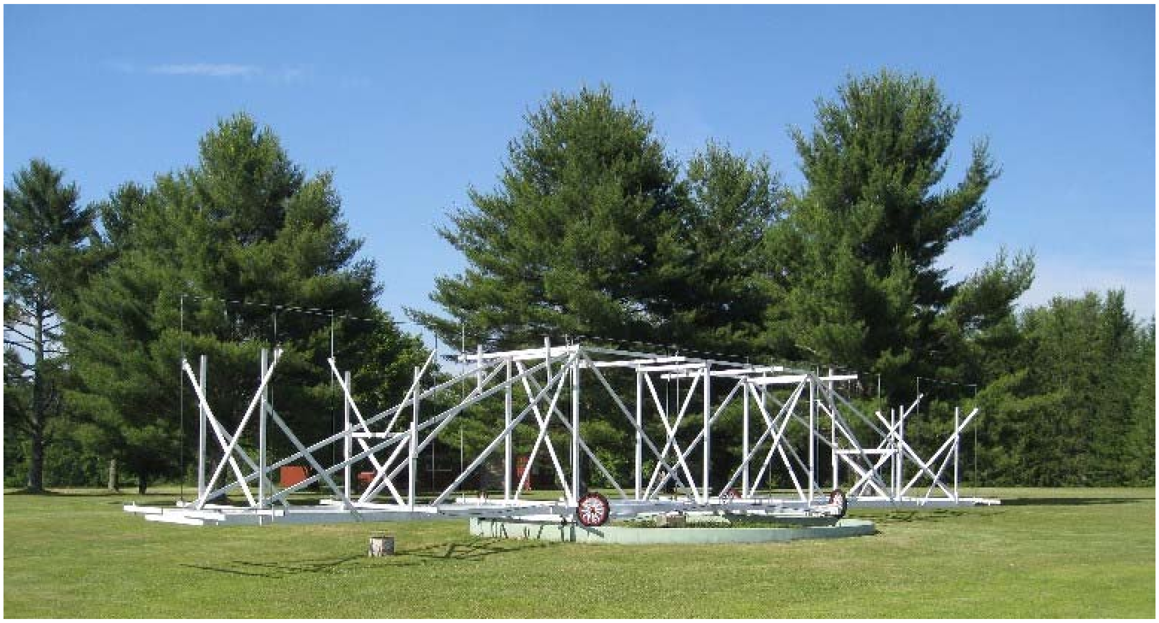

Full-size replica of the first radio telescope, Jansky's dipole array now at the US National Radio Astronomy Observatory

The first radio antenna used to identify an astronomical radio source was one built by Karl Guthe Jansky, an engineer with Bell Telephone Laboratories, in 1931. Jansky was assigned the job of identifying sources of static that might interfere with radio telephone service. Jansky's antenna was an array of dipoles and reflectors designed to receive short wave radio signals at a frequency of 20.5 MHz (wavelength about 14.6 metres). It was mounted on a turntable that allowed it to rotate in any direction, earning it the name "Jansky's merry-go-round". It had a diameter of approximately 100 ft (30 m). and stood 20 ft (6 m). tall. By rotating the antenna on a set of four Ford Model-T tires, the direction of the received interfering radio source (static) could be pinpointed. A small shed to the side of the antenna housed an analog pen-and-paper recording system. After recording signals from all directions for several months, Jansky eventually categorized them into three types of static: nearby thunderstorms, distant thunderstorms, and a faint steady hiss of unknown origin. Jansky finally determined that the "faint hiss" repeated on a cycle of 23 hours and 56 minutes. This period is the length of an astronomical sidereal day, the time it takes any "fixed" object located on the celestial sphere to come back to the same location in the sky. Thus Jansky suspected that the hiss originated well beyond the Earth's atmosphere, and by comparing his observations with optical astronomical maps, Jansky concluded that the radiation was coming from the Milky Way Galaxy and was strongest in the direction of the center of the galaxy, in the constellation of Sagittarius.

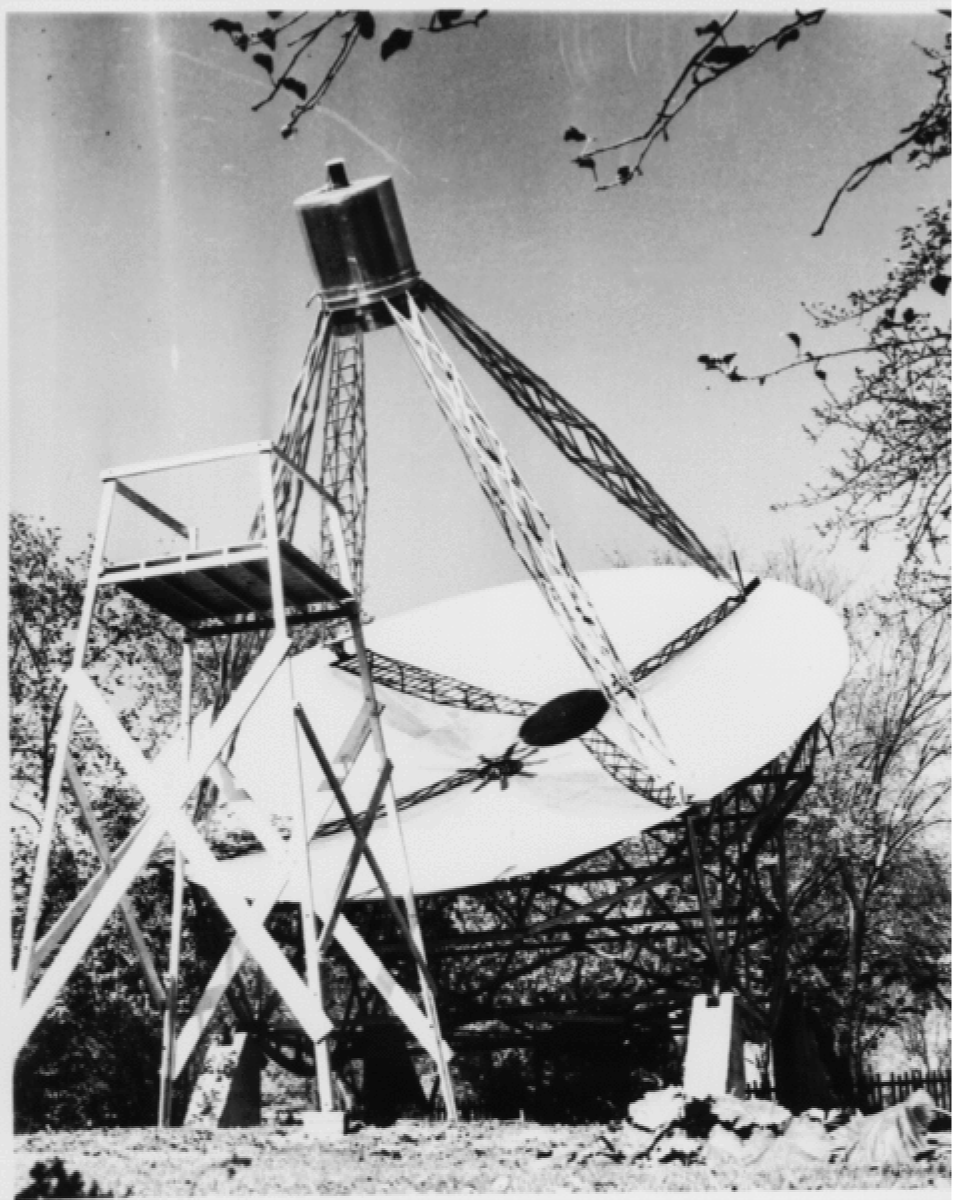

Reber's first "dish" radio telescope - Wheaton, IL 1937

An amateur radio operator, Grote Reber, was one of the pioneers of what became known as radio astronomy when he built the first parabolic "dish" radio telescope (9 metres (30 ft) in diameter) in his back yard in Illinois in 1937. He was instrumental in repeating Karl Guthe Jansky's pioneering but somewhat simple work at higher frequencies, and he went on to conduct the first sky survey at very high radio frequencies. The rapid development of radar technology during World War II was easily translated into radio astronomy technology after the war, and the field of radio astronomy began to blossom.

Types

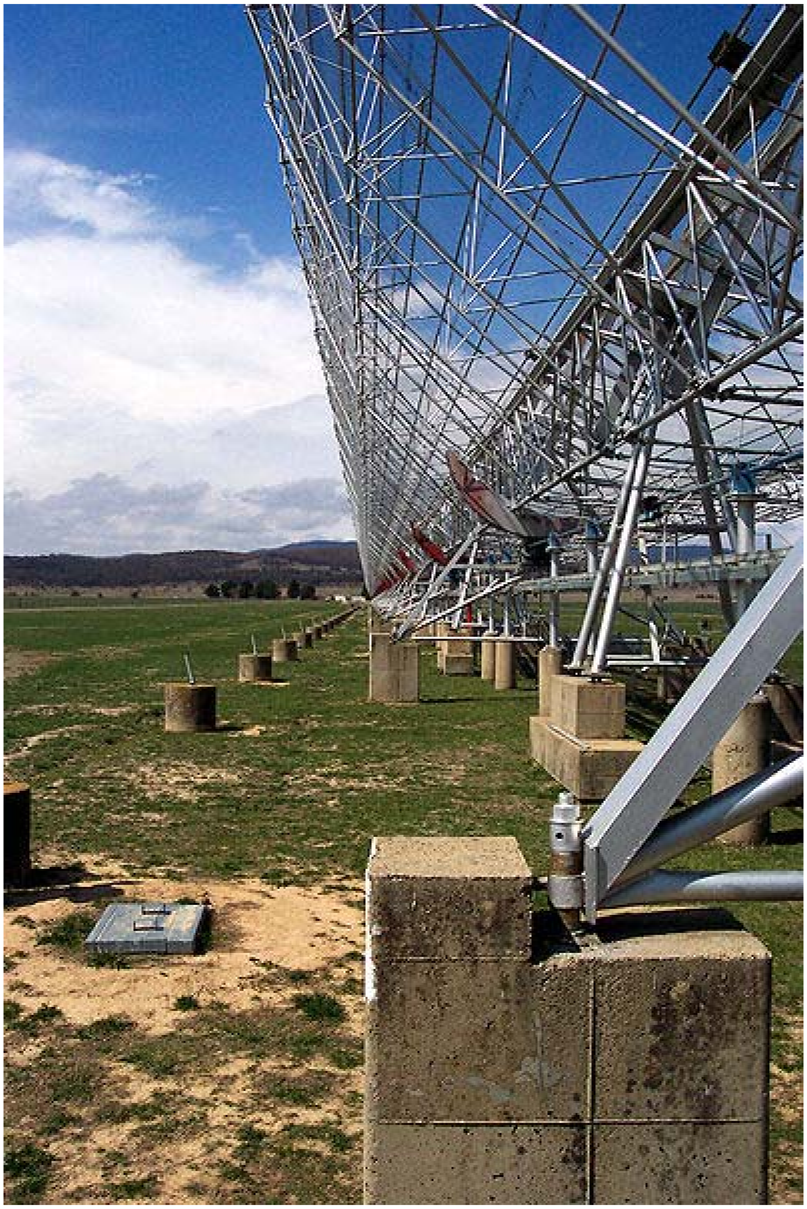

A *cylindrical paraboloid* antenna.

The range of frequencies in the electromagnetic spectrum that makes up the radio spectrum is very large. This means that the types of antennas that are used as radio telescopes vary widely in design, size, and configuration. At wavelengths of 30 meters to 3 meters (10 MHz - 100 MHz), they are generally either directional antenna arrays similar to "TV antennas" or large stationary reflectors with moveable focal points. Since the wavelengths being observed with these types of antennas are so long, the "reflector" surfaces can be constructed from coarse wire mesh such as chicken wire. At shorter wavelengths “dish” style radio telescopes predominate. The angular resolution of a dish style antenna is determined by the diameter of the dish expressed as a number of wavelengths of the electromagnetic radiation being observed. This dictates the dish size a radio telescope needs for a useful resolution. Radio telescopes that operate at wavelengths of 3 meters to 30 cm (100 MHz to 1 GHz) are usually well over 100 meters in diameter. Telescopes working at wavelengths shorter than 30 cm (above 1 GHz) range in size from 3 to 90 meters in diameter.

Big dishes

RT-70 planetary radar

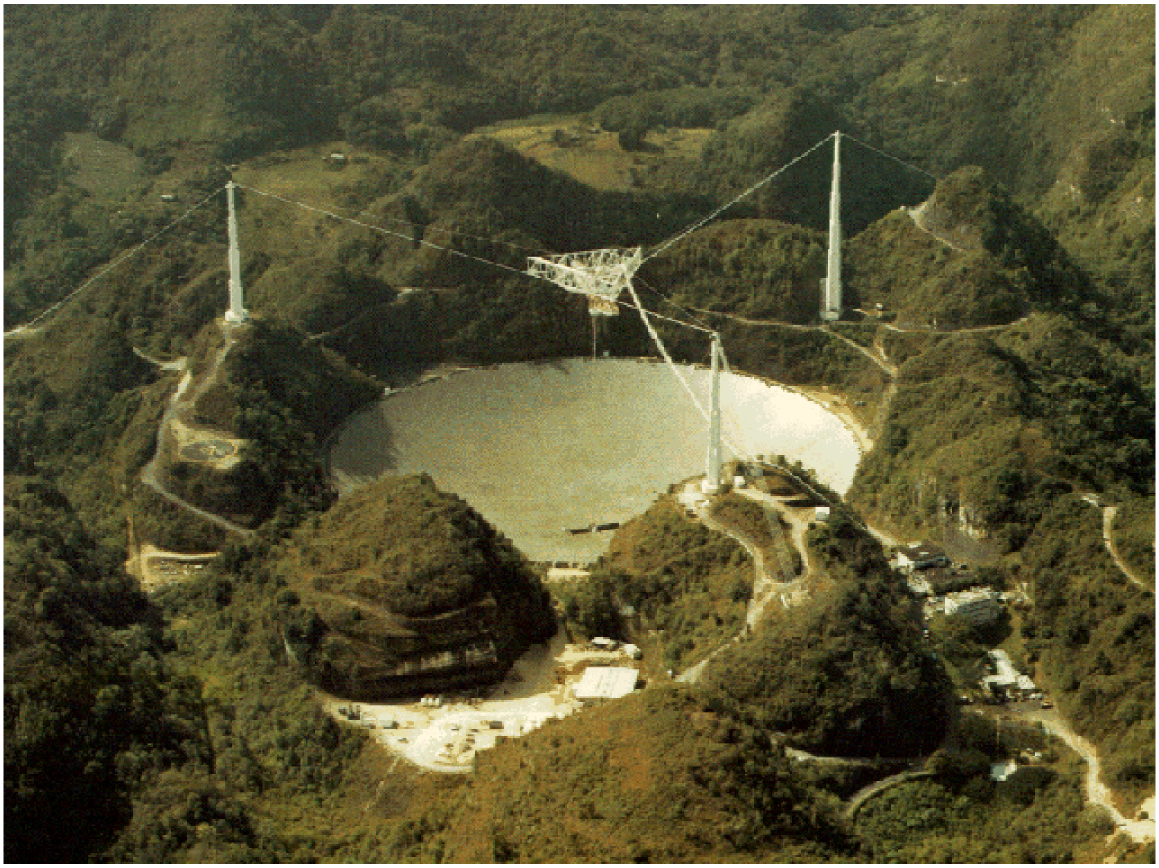

World's largest single-aperture radio telescope at Arecibo Observatory in Puerto Rico

ALMA construction site

The world's largest filled-aperture telescope (i.e., a full dish) is the Arecibo radio telescope located in Arecibo, Puerto Rico, whose 305 m (1,001 ft) dish is fixed in the ground. It was designed by engineer Bill Gordon (d. 2010). The suspension system was designed by George and Helias Doundoulakis, for which Helias Doundoulakis received a patent along with assignee William J. Casey, ex-Central Intelligence Agency Director under President Ronald Reagan. The antenna beam is steerable (by means of a moving receiver) within about 20° of the zenith. The largest individual radio telescope of any kind is the RATAN-600 located near Nizhny Arkhyz, Russia, which consists of a 576-meter circle of rectangular radio reflectors, each of which can be pointed towards a central conical receiver.

The largest radio telescope in Europe is the 100-meter diameter antenna in Effelsberg, Germany, which also was the world's largest fully-steerable telescope for 30 years until the slightly larger Green Bank Telescope was opened in West Virginia, United States, in 2000. The third-largest fully-steerable radio telescope is the 76-metre Lovell Telescope at Jodrell Bank Observatory in Cheshire, England. The fourth-largest fully-steerable radio telescopes is four the 70-metre radio telescopes: RT-70, Goldstone. Feature of these telescopes is that it is the world's largest planetary radars (except Suffa RT-70).

A typical size of the single antenna of a radio telescope is 25 meters. Dozens of radio telescopes with comparable sizes are operated in radio observatories all over the world.

China officially started construction of the world's largest single-aperture radio telescope in 2009, the FAST. The FAST, with a dish area as large as 30 football fields, will stand in a region of typical Karst depressions in Guizhou, and will be finished by 2013.

Radio interferometry

The Very Large Array, an interferometric array formed from many smaller telescopes, like many larger radio telescopes.

One of the most notable developments came in 1946 with the introduction of the technique called astronomical interferometry. Astronomical radio interferometers usually consist either of arrays of parabolic dishes (e.g., the One-Mile Telescope), arrays of one-dimensional antennas (e.g., the Molonglo Observatory Synthesis Telescope) or two-dimensional arrays of omni-directional dipoles (e.g., Tony Hewish's Pulsar Array). All of the telescopes in the array are widely separated and are usually connected together using coaxial cable, waveguide, optical fiber, or other type of transmission line. Recent advances in the stability of electronic oscillators also now permit interferometry to be carried out by independent recording of the signals at the various antennas, and then later correlating the recordings at some central processing facility. This process is known as VLBI (Very Long Baseline Interferometry). Interferometry does increase the total signal collected, but its primary purpose is to vastly increase the resolution through a process called Aperture synthesis. This technique works by superposing (interfering) the signal waves from the different telescopes on the principle that waves that coincide with the same phase will add to each other while two waves that have opposite phases will cancel each other out. This creates a combined telescope that is equivalent in resolution (though not in sensitivity) to a single antenna whose diameter is equal to the spacing of the antennas furthest apart in the array. A high quality image requires a large number of different separations between telescopes. Projected separation between any two telescopes, as seen from the radio source, is called a baseline. For example, the Very Large Array (VLA) near Socorro, New Mexico has 27 telescopes with 351 independent baselines at once, which achieves a resolution of 0.2 arc seconds at 3 cm wavelengths). Martin Ryle's group in Cambridge obtained a Nobel Prize for interferometry and aperture synthesis. The Lloyd's mirror interferometer was also developed independently in 1946 by Joseph Pawsey's group at the University of Sydney. In the early 1950s the Cambridge Interferometer mapped the radio sky to produce the famous 2C and 3C surveys of radio sources. The largest existing physically-connected radio telescope array is the Giant Metrewave Radio Telescope, located in Pune, India. A larger array, LOFAR (the 'LOw Frequency ARray') is currently being constructed in western Europe, consisting of 25 000 small antennas over an area several hundreds of kilometres in diameter. VLBI systems using post-observation processing have been constructed with antennas thousands of miles apart. Radio interferometers have also been used to obtain detailed images of the anisotropies and the polarization of the Cosmic Microwave Background, like the CBI interferometer in 2004.

Astronomical observations

Many astronomical objects are not only observable in visible light but also emit radiation at radio wavelengths. Besides observing energetic objects such as pulsars and quasars, radio telescopes are able to "image" most astronomical objects such as galaxies, nebulae, and even radio emissions from planets.

Chapter 4

Parabolic Antenna

A parabolic antenna at Erdfunkstelle Raisting, the biggest facility for satellite communication in the world, based in Raisting, Bavaria, Germany. It has a Cassegrain type feed.

A **parabolic antenna** is an antenna that uses a parabolic reflector, a surface with the cross-sectional shape of a parabola, to direct the radio waves. The most common form is shaped like a dish and is popularly called a **dish antenna** or **parabolic dish**. The main advantage of a parabolic antenna is that it is highly directive; it functions analogously to a searchlight or flashlight reflector to direct the radio waves in a narrow beam, or receive radio waves from one particular direction only. Parabolic antennas have some of the highest gains, that is they can produce the narrowest beam width angles, of any antenna type. They are used as high-gain antennas for point-to-point radio, television and data communications, and also for radiolocation (radar), on the UHF and microwave (SHF) parts of the radio spectrum. The relatively short wavelength of electromagnetic radiation at these frequencies allows reasonably sized reflectors to exhibit the desired highly directional response.

With the advent of TVRO and DBS satellite television dishes, parabolic antennas have become a ubiquitous feature of the modern landscape. They are also widely used for terrestrial microwave relay links, ground based and airborne radar antennas, wireless WAN/LAN links, satellite and spacecraft communication antennas, and radio telescopes.

History

The idea of using parabolic reflectors for radio antennas was taken from optics, where the power of a parabolic mirror to focus light into a beam has been known since classical antiquity. The designs of some specific types of parabolic antenna, such as the Cassegrain and Gregorian, come from similarly named analogous types of reflecting telescope, which were invented by astronomers during the 15th century.

German physicist Heinrich Hertz constructed the world's first parabolic reflector antenna in 1888. The antenna was a cylindrical parabolic reflector made of zinc sheet metal supported by a wooden frame, and had a spark-gap excited dipole along the focal line. Its aperture was 1.2 meters wide, with a focal length of 0.12 meters, and was used at an operating frequency of about 450 MHz. With two such antennas, one used for transmitting and the other for receiving, Hertz demonstrated the existence radio waves which had been predicted by James Clerk Maxwell some 22 years earlier.

The first parabolic antenna used for satellite communications was established in 1962 at Goonhilly in Cornwall, England, UK and was intended to communicate with Telstar.

Types

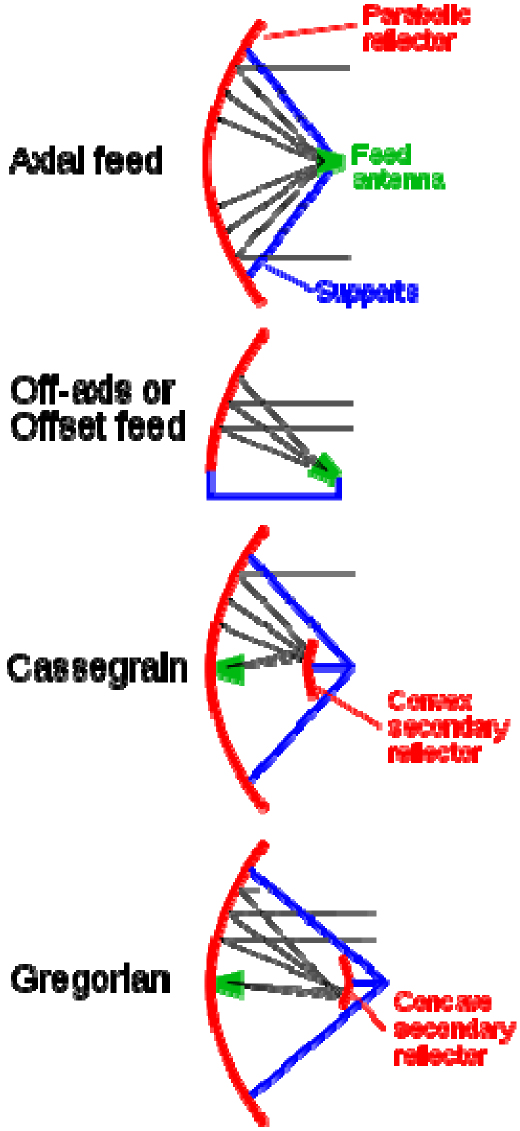
Parabolic reflector
Axial feed
Feed antenna
Supports
Off-axis or Offset feed
Cassegrain
Convex secondary reflector
Gregorian
Concave secondary reflector

Main types of parabolic antenna feeds.

Parabolic antennas are distinguished by their shapes:

- *Paraboloidal* or *dish* - The reflector is shaped like a paraboloid. This is the most common type. It radiates a narrow pencil-shaped beam along the axis of the dish.
    - *Shrouded dish* - Sometimes a cylindrical metal shield is attached to the rim of the dish. The shroud shields the antenna from radiation from angles outside the main beam axis, reducing the sidelobes. It is sometimes used to prevent interference in terrestrial microwave links, where several antennas using the same frequency are located close together. The shroud is coated

    - inside with microwave absorbent material. Shrouds can reduce back lobe radiation by 10 dB.
- *Cylindrical* - The reflector is curved in only one direction and flat in the other. The radio waves come to a focus not at a point but along a line. The feed is often a dipole antenna located along the focal line. It radiates a fan-shaped beam, narrow in the curved dimension, and wide in the uncurved dimension. The curved ends of the reflector are sometimes capped by flat plates, to prevent radiation out the ends, and this is called a *pillbox* antenna.
    - *"Orange peel"* - Another type is very long and narrow, shaped like the letter "C". This is called an *orange peel* design, and radiates an even wider fan beam. It is often used for radar antennas.

They are also classified by the type of *feed*; how the radio waves are supplied to the antenna:

- *Axial* or *front feed* - This is the most common type of feed, with the feed antenna located in front of the dish at the focus, on the beam axis. A disadvantage of this type is that the feed and its supports block some of the beam, which limits the aperture efficiency to only 55 - 60%.
- *Offset* or *off-axis feed* - The reflector is an asymmetrical segment of a paraboloid, so the focus, and the feed antenna, are located to one side of the dish. The purpose of this design is to move the feed structure out of the beam path, so it doesn't block the beam. It is widely used in home satellite television dishes, which are small enough that the feed structure would otherwise block a significant percentage of the signal.
- *Cassegrain* - In a Cassegrain antenna the feed is located on or behind the dish, and radiates forward, illuminating a convex hyperboloidal secondary reflector at the focus of the dish. The radio waves from the feed reflect back off the secondary reflector to the dish, which forms the main beam. An advantage of this configuration is that the feed, with its waveguides and "front end" electronics does not have to be suspended in front of the dish, so it is used for antennas with complicated or bulky feeds, such as large satellite communication antennas and radio telescopes. Aperture efficiency is on the order of 65 - 70%
- *Gregorian* - Similar to the Cassegrain design except that the secondary reflector is concave, (ellipsoidal) in shape. Aperture efficiency over 70% can be achieved.

Design

The operating principle of a parabolic antenna is that a point source of radio waves at the focal point in front of a parabolic reflector will be reflected into a collimated plane wave beam along the axis of the reflector. Conversely, an incoming plane wave parallel to the axis will be focused to a point at the focal point.

A typical parabolic antenna consists of a parabolic reflector with a small feed antenna at its focus, pointed back toward the reflector. The reflector is a metallic surface formed into a paraboloid of revolution and usually truncated in a circular rim that forms the diameter of the antenna.

The reflector dish can be of sheet metal, metal screen, or wire grill construction, and it can be either circular or various other shapes to create different beam shapes. A mesh screen reflects radio waves as well as a solid metal surface as long as the holes are smaller than 1/10 of a wavelength, so screen reflectors are often used to reduce weight and wind loads on the dish. To achieve the maximum gain, it is necessary that the shape of the dish be accurate within a small fraction of a wavelength, to ensure the waves from different parts of the antenna arrive in phase. Large dishes often require a truss structure behind them to provide the required stiffness.

The feed antenna at the reflector's focus is typically a low-gain type such as a half-wave dipole or more ofteh a small horn antenna called a feed horn. In more complex designs, such as the Cassegrain and Gregorian, a secondary reflector is used to direct the energy into the parabolic reflector from a feed antenna located away from the primary focal point. The feed antenna is connected to the associated radio-frequency (RF) transmitting or receiving equipment by means of a coaxial cable transmission line or waveguide.

Feed pattern

The radiation pattern of the feed antenna has a strong influence on the *aperture efficiency*, which determines the antenna gain. Radiation from the feed that falls outside the edge of the dish is called "*spillover*" and is wasted, reducing the gain and increasing the backlobes, possibly causing interference or (in receiving antennas) increasing susceptibility to ground noise. However, maximum gain is only achieved when the dish is uniformly "illuminated" with a constant field strength to its edges. So the ideal radiation pattern of a feed antenna would be a constant field strength throughout the solid angle of the dish, dropping abruptly to zero at the edges. However, practical feed antennas have radiation patterns that drop off gradually at the edges, so the feed antenna is a compromise between acceptably low spillover and adequate illumination.

Gain

The directive qualities of an antenna are measured by a dimensionless parameter called its gain, which is the ratio of the power received by the antenna from a source along its beam axis to the power received by a hypothetical isotropic antenna. The gain of a parabolic antenna is:

$$G = \frac{4\pi A}{\lambda^2} e_A = \frac{\pi^2 d^2}{\lambda^2} e_A$$

where:

- A is the area of the antenna aperture, that is, the mouth of the parabolic reflector
- d is the diameter of the parabolic reflector

- λ is the wavelength of the radio waves.
- e_A is a dimensionless parameter called the *aperture efficiency*. The aperture efficiency of typical parabolic antennas is 0.55 to 0.70.

The largest dish antenna in the world, the radio telescope at Arecibo Observatory, Puerto Rico, 305 meters (1000 feet) in diameter. It has a gain of 10 million, or 70 dBi, at 2.38 GHz.

It can be seen that, as with any *aperture antenna*, the larger the aperture is, compared to the wavelength, the higher the gain. The gain increases with the square of the ratio of aperture width to wavelength, so large parabolic antennas, such as those used for spacecraft communication and radio telescopes, can have extremely high gain. Applying the above formula to the 25-meter-diameter antennas used by the VLA and VLBA radio telescopes at a wavelength of 21 cm (1.42 GHz, a common radio astronomy frequency) yields an approximate maximum gain of 140,000 times or about 50 dBi (decibels above the isotropic level).

As of 2009, the largest "dish" antenna in the world is the Arecibo Observatory's radio telescope, at Arecibo, Puerto Rico, which has a diameter of 1,000 ft. (305 m). It has a gain of about 10 million, or 70 dBi, at 2.38 GHz. The dish is built into a valley in the landscape, so it is not steerable. To steer the beam to different points in the sky, the feed antenna is moved. For this reason, the dish actually has a spherical rather than a parabolic shape. A spherical reflector does not have a single focal "point", however, the Arecibo antenna is a three-reflector variety of Gregorian telescope, and uses its secondary and tertiary reflectors to focus the radio waves to a single point.

Aperture efficiency e_A is a catchall variable which accounts for various losses that reduce the gain of the antenna from the maximum that could be achieved with the given aperture. The major factors reducing the aperture efficiency in parabolic antennas are:.

- *Feed spillover* - Some of the radiation from the feed antenna falls outside the edge of the dish and so doesn't contribute to the main beam.
- *Feed illumination taper* - The maximum gain for any aperture antenna is only achieved when the intensity of the radiated beam is constant across the aperture area. However the radiation pattern from the feed antenna usually tapers off toward the outer part of the dish, so the outer parts of the dish are "illuminated" with a lower intensity of radiation. Even if the feed provided constant illumination across the angle subtended by the dish, the outer parts of the dish are farther away from the feed antenna than the inner parts, so the intensity would drop off with distance from the center. So the intensity of the beam radiated by a parabolic antenna is maximum at the center of the dish and falls off with distance from the axis, reducing the efficiency.
- *Aperture blockage* - In axis-fed parabolic dishes where the feed antenna is located in front of the dish in the beam path, the feed structure and its supports block some of the beam. In small dishes such as home satellite dishes, where the size of the feed structure is comparable with the size of the dish, this can seriously reduce the antenna gain. To prevent this problem these types of antennas often use an *off-axis* feed, where the feed antenna is located to one side, outside the beam area. The aperture efficiency for these types of antennas can reach 0.7 to 0.8.
- *Shape errors* - random surface errors in the shape of the reflector reduce efficiency. The loss is approximated by Ruze's Equation.

For theoretical considerations of mutual interference (at frequencies between 2 and c. 30 GHz - typically in the Fixed Satellite Service) where specific antenna performance has not been defined, a *reference antenna* based on Recommendation ITU-R S.465 is used to calculate the interference, which will include the likely sidelobes for off-axis effects.

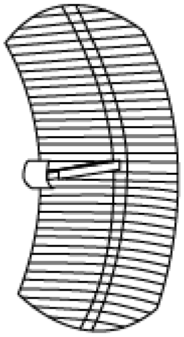

Wire grid-type parabolic antenna (Wi-Fi / WLAN antenna) at 2.4 GHz).

Beamwidth

C-band Satellite dish, Bucharest, Romania

The angular width of the beam radiated by high-gain antennas is measured by the *half-power beam width* (HPBW), which is the angular separation between the points on the antenna radiation pattern at which the power drops to one-half (-3 dB) its maximum value. For parabolic antennas, the HPBW θ is given by:

$$\theta = k\lambda/d$$

where k is a factor which depends on the shape of the reflector and the feed illumination pattern. For a "typical" parabolic antenna $k = 70$ when θ is in degrees.

For a typical 2 meter satellite dish operating on C band (4 GHz), like the one shown at right, this formula gives a beamwidth of about 2.6°. For the Arecibo antenna at 2.4 GHz the beamwidth is 0.028°. It can be seen that parabolic antennas can produce very narrow beams, and aiming them can be a problem. Some parabolic dishes are equipped with a boresight so they can be aimed accurately at the other antenna.

It can be seen there is an inverse relation between gain and beam width. By combining the beamwidth equation with the gain equation, the relation is:

$$G - \left(\frac{\pi k}{\theta}\right)^2 \epsilon_A$$

Chapter 5

Antenna (Radio)

Whip antenna on car

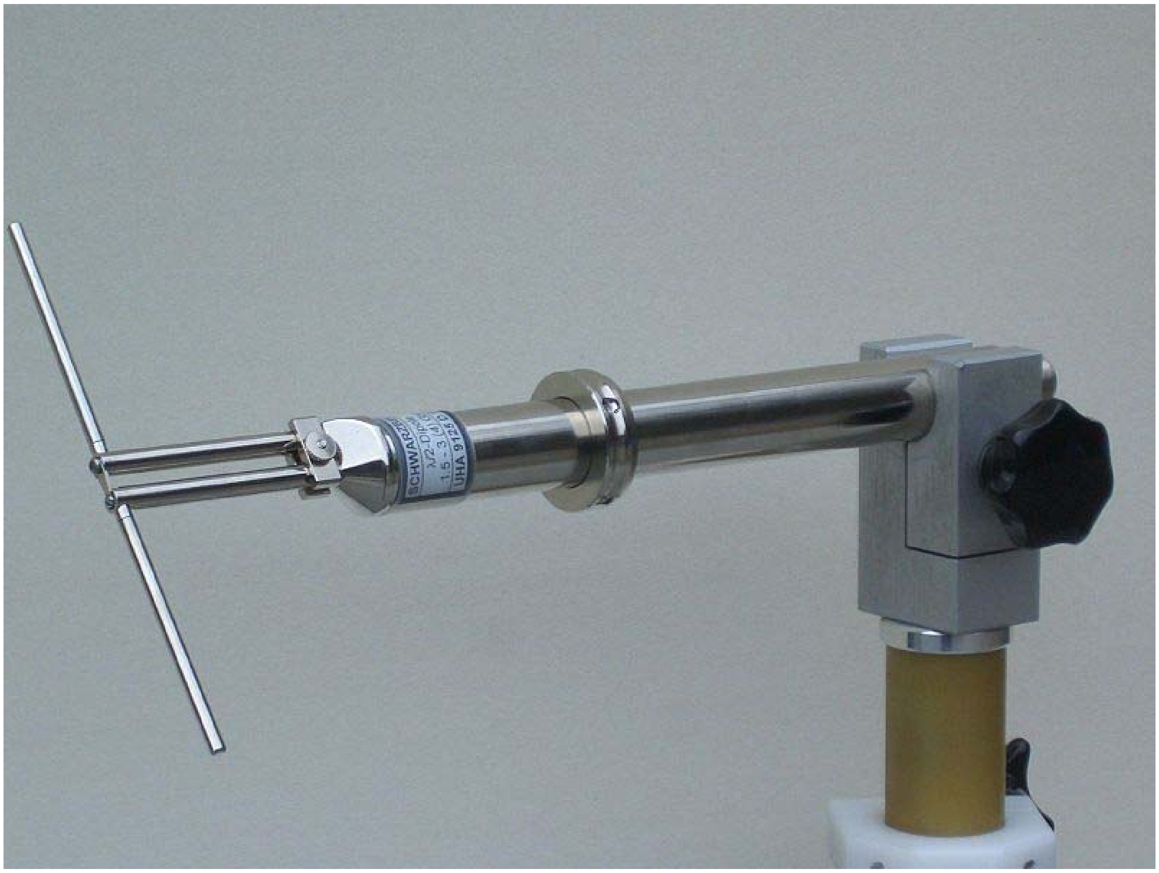
SCHWARZB
λ/2-Dip
1.5 - 3 (4)
UHA 9125

Half-wave dipole antenna

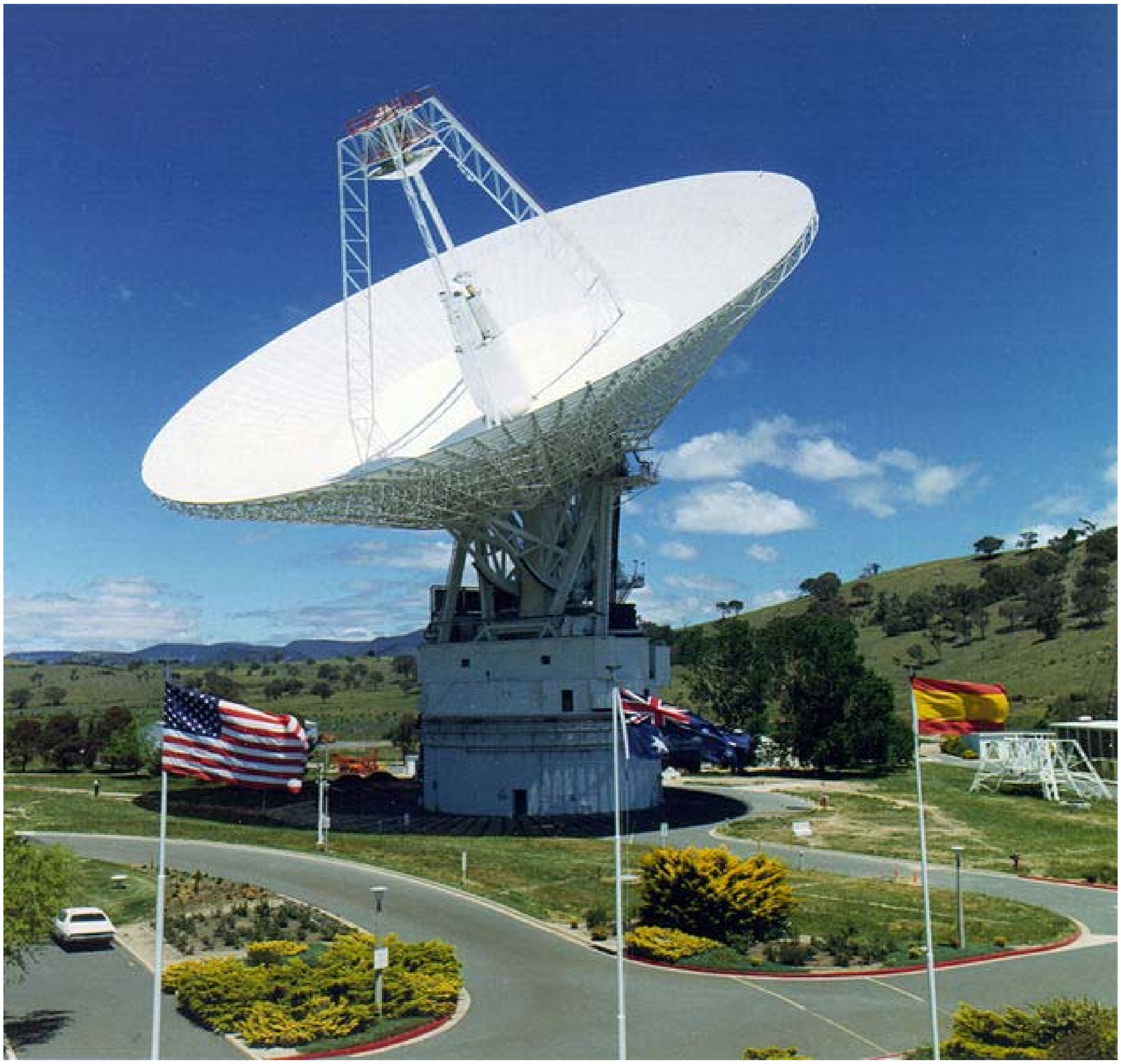

Large parabolic antenna for communicating with spacecraft

Rooftop directional antennas, typical for use at VHF and UHF frequencies

An **antenna** (or **aerial**) is an electrical device which couples radio waves in free space to an electrical current used by a radio receiver or transmitter. In reception, the antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage that the radio receiver can amplify. Alternatively, a radio transmitter will produce a large radio frequency current that may be applied to the terminals of the same antenna in order to convert it into an electromagnetic wave (radio wave) radiated into free space. Antennas are thus essential to the operation of all radio equipment, both transmitters and receivers. They are used in systems such as radio and television broadcasting, two-way radio, wireless LAN, mobile telephony, radar, and satellite communications.

Typically an antenna consists of an arrangement of metallic conductors (or "elements") with an electrical connection (often through a transmission line) to the receiver or transmitter. A current forced through such a conductor by a radio transmitter will create an alternating magnetic field according to Ampère's law. Or the alternating magnetic field due to a distant radio transmitter will induce a voltage at the antenna terminals, according to Faraday's law, which is connected to the input of a receiver. In the so-called far field, at a considerable distance away from the antenna, the oscillating magnetic field is coupled with a similarly oscillating electric field; together these define an electromagnetic wave which is capable of propagating great distances.

Light is one example of electromagnetic radiation, along with infrared and x-rays, while radio waves differ only in their much lower frequency (and much longer wavelength). Electronic circuits can operate at these lower frequencies, processing radio signals conducted through wires. But it is only through antennas that those radio frequency electrical signals are converted to (and from) propagating radio waves. Depending on the design of the antenna, radio waves can be sent toward and received from all directions ("omnidirectional"), whereas a directional or beam antenna is designed to operate in a particular direction.

The first antennas were built in 1888 by Heinrich Hertz (1857–1894) in his pioneering experiments to prove the existence of electromagnetic waves predicted by the theory of James Clerk Maxwell. Hertz placed dipole antennas at the focal point of parabolic reflectors for both transmitting and receiving. He published his work and installation drawings in *Annalen der Physik und Chemie* (vol. 36, 1889).

Terminology

The words *antenna* (plural: *antennas*) and *aerial* are used interchangeably; but usually a rigid metallic structure is termed an antenna and a wire format is called an aerial. In the United Kingdom and other British English speaking areas the term aerial is more common, even for rigid types. The noun *aerial* is occasionally written with a diaeresis mark—*aërial*—in recognition of the original spelling of the adjective *aërial* from which the noun is derived.

The origin of the word *antenna* relative to wireless apparatus is attributed to Guglielmo Marconi. In 1895, while testing early radio apparatuses in the Swiss Alps at Salvan, Switzerland in the Mont Blanc region, Marconi experimented with early wireless equipment. A 2.5 meter long pole, along which was carried a wire, was used as a radiating and receiving aerial element. In Italian a tent pole is known as *l'antenna centrale,* and the pole with a wire alongside it used as an aerial was simply called *l'antenna.* Until then wireless radiating transmitting and receiving elements were known simply as aerials or terminals. Marconi's use of the word *antenna* (Italian for *pole*) would become a popular term for what today is uniformly known as the *antenna*.

In common usage, the word *antenna* may refer broadly to an entire assembly including support structure, enclosure (if any), etc. in addition to the actual functional components.

Especially at microwave frequencies, a receiving antenna may include not only the actual electrical antenna but an integrated preamplifier and/or mixer.

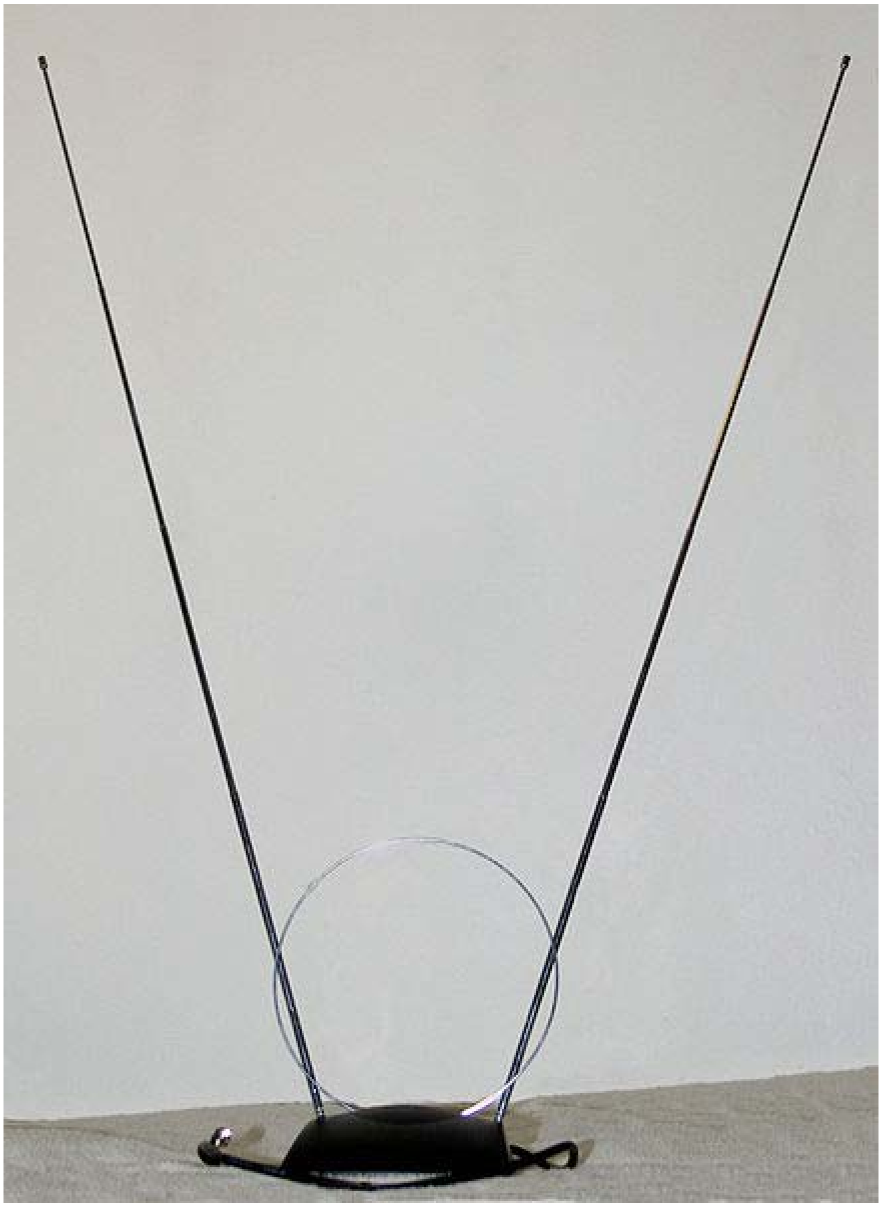

"Rabbit ears" dipole antenna for television reception

Cell phone base station antennas

Satellite link antenna used by Himalaya Television Nepal

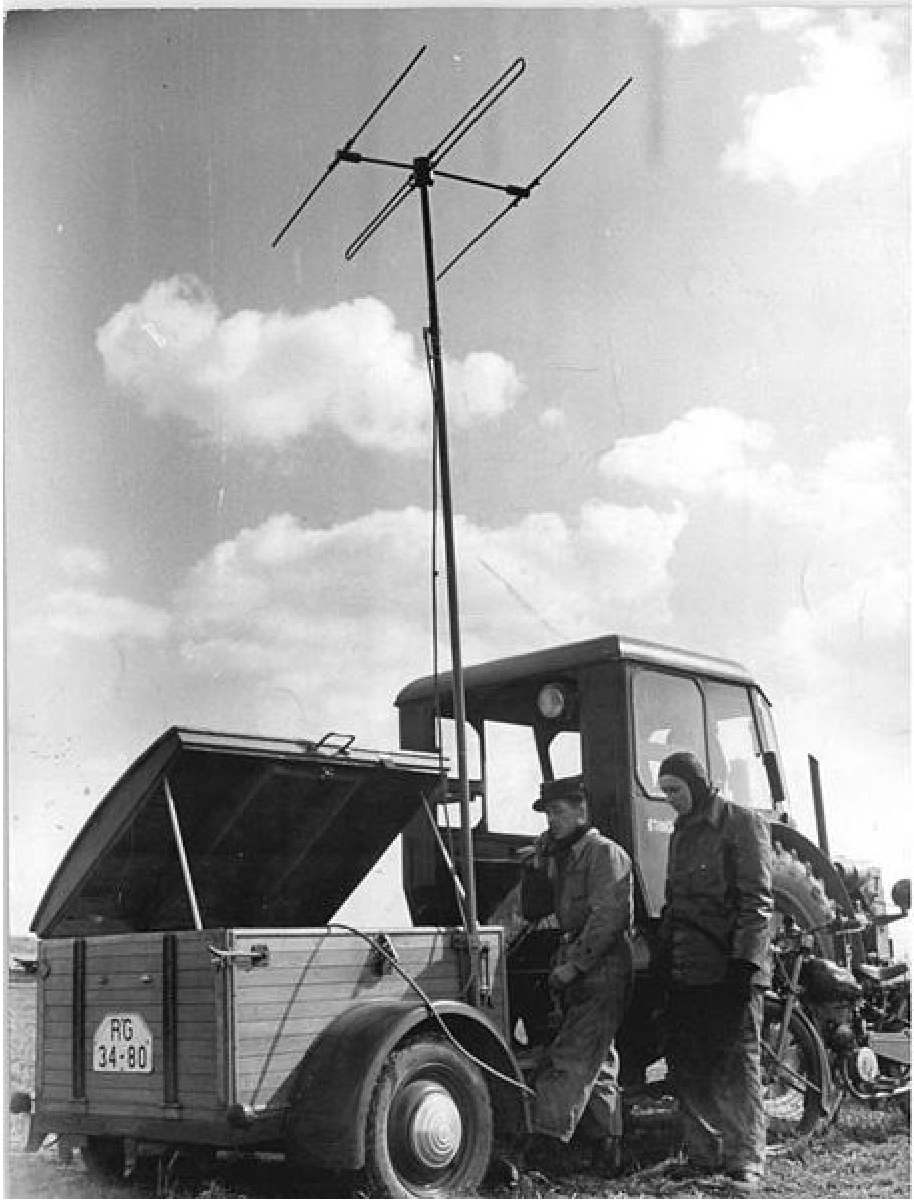

Bundesarchiv, Bild 183-29802-0001
Foto: Braun | April 1955

Yagi antenna used for mobile military communications station, Dresden, Germany, 1955

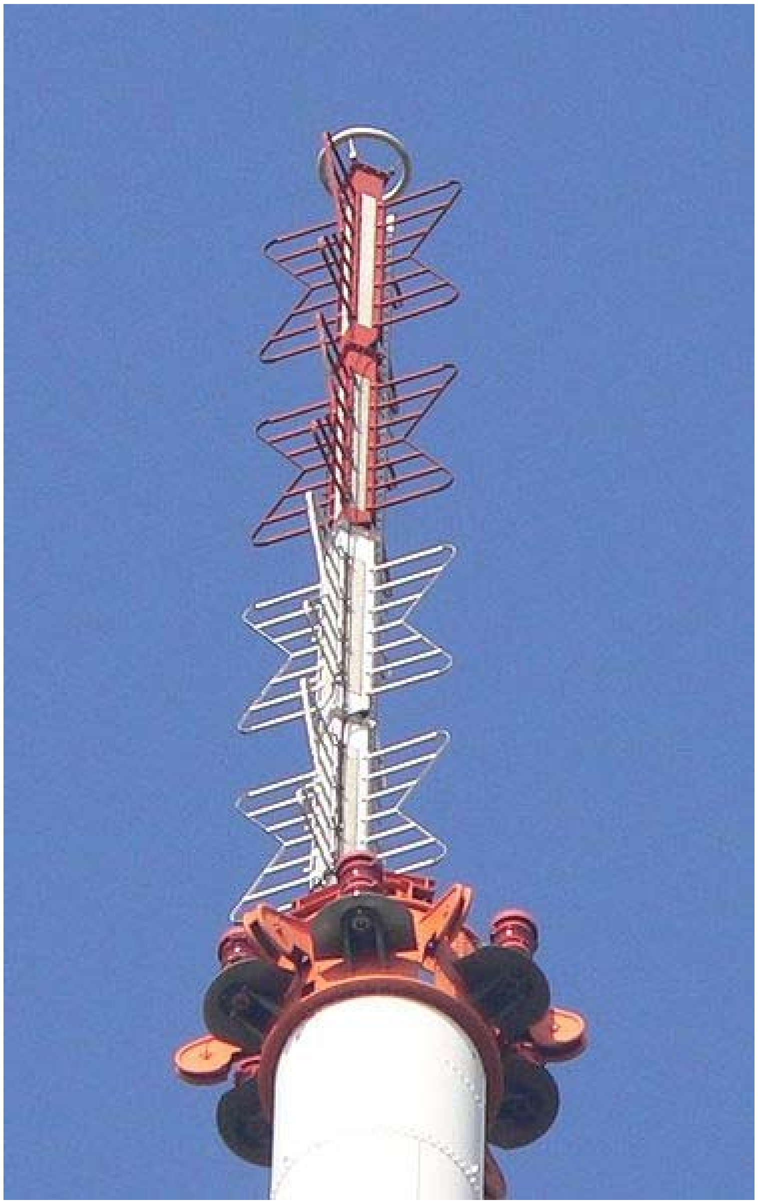

"Super Turnstile" type transmitting antenna for VHF low band television broadcasting station, Germany.

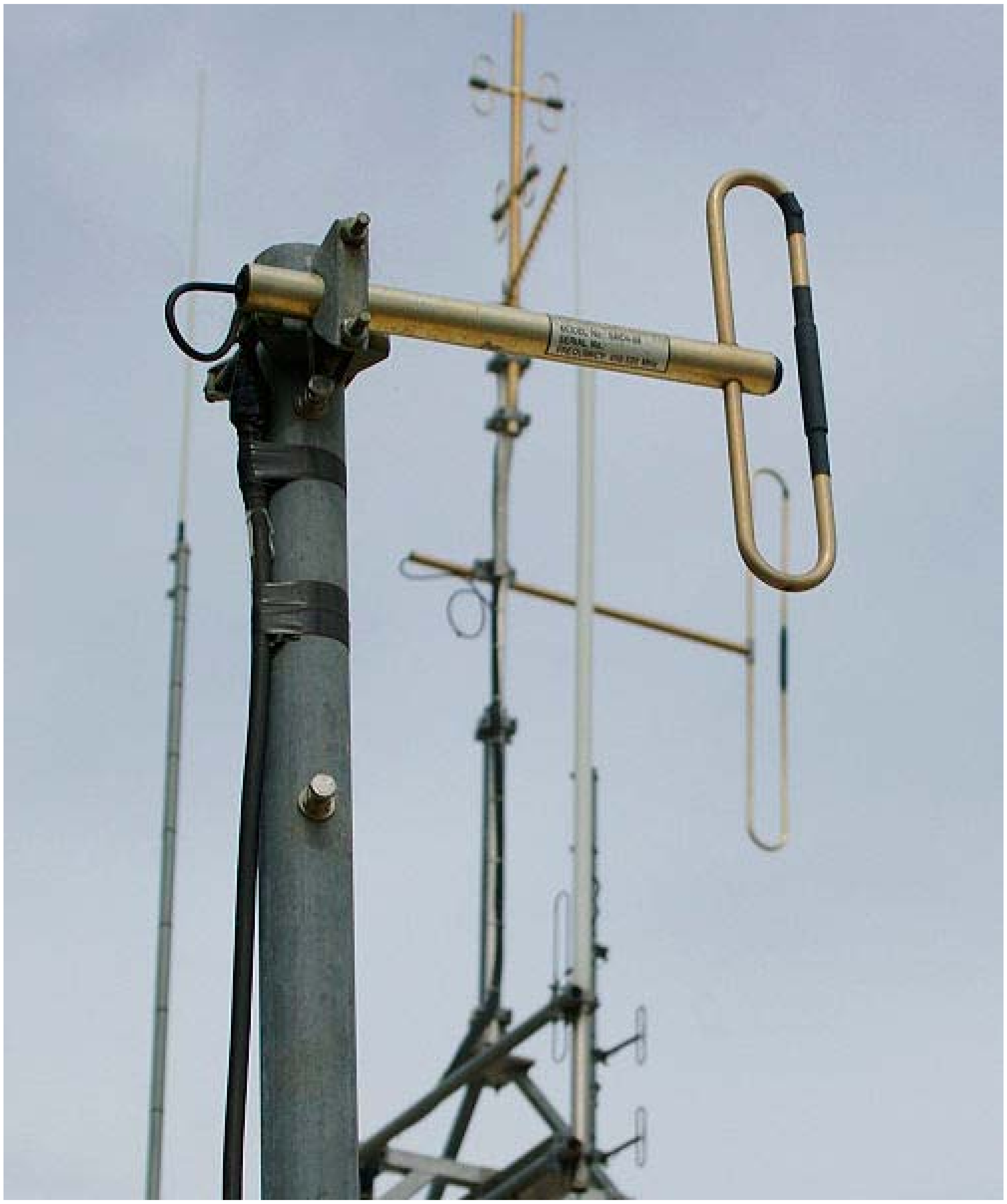
MODEL No.
SERIAL No.
FREQUENCY
MHz

Folded dipole antenna

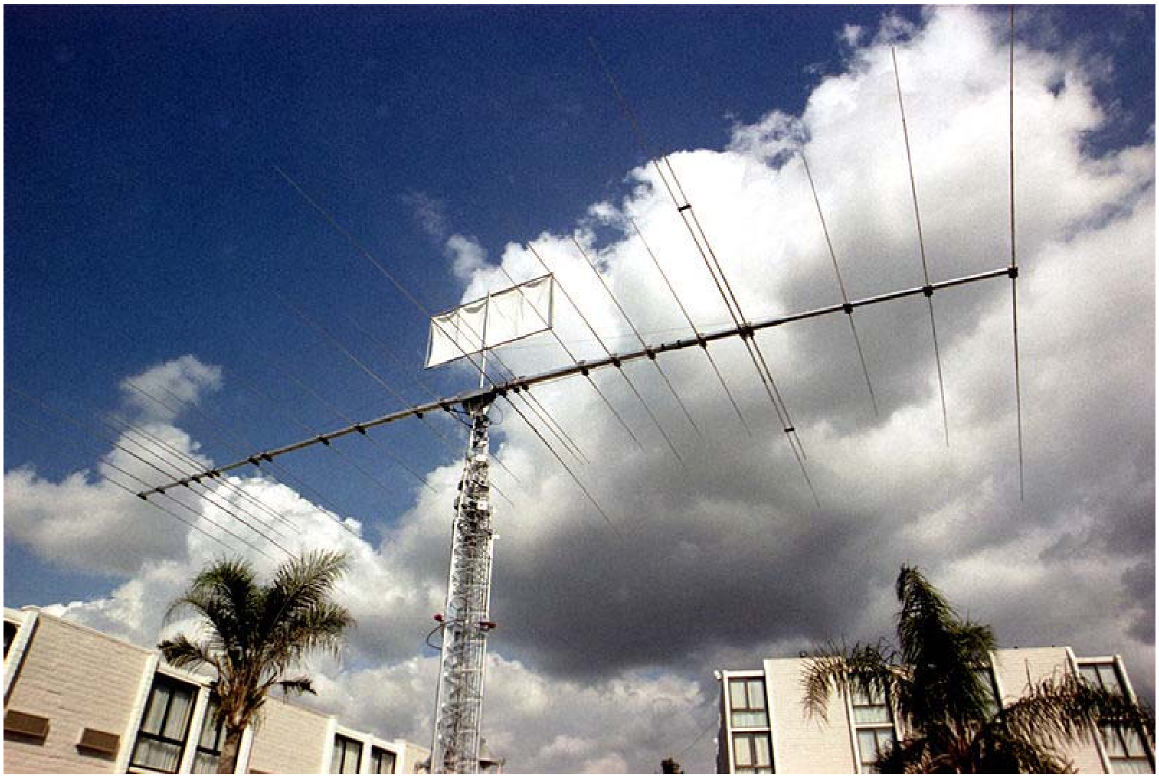

Large Yagi antenna used by amateur radio hobbyist

A vertical mast radiator, Chapel Hill, North Carolina

Overview

Antennas are required by any radio receiver or transmitter in order to couple its electrical connection to the electromagnetic field. Radio waves are electromagnetic waves which carry signals through the air (or through space) at almost the speed of light with almost no transmission loss. Radio transmitters and receivers are used to convey signals (information) in systems including broadcast (audio) radio, television, mobile telephones, wi-fi (WLAN) data networks, trunk lines and point-to-point communications links (telephone, data networks), satellite links, many remote controlled devices such as garage door openers, and wireless remote sensors, among many others. Radio waves are also used directly for measurements in technologies including RADAR, GPS, and radio astronomy. In each and every case, the transmitters and receivers involved require antennas, although these are sometimes hidden (such as the antenna inside an AM radio or inside a laptop computer equipped with wi-fi).

According to their applications and technology available, antennas generally fall in one of two catagories:

1. Omnidirectional or only weakly directional antennas which receive or radiate more or less in all directions. These are employed when the relative position of the other station is unknown or arbitrary. They are also used at lower frequencies where a directional antenna would be too large, or simply to cut costs in applications where a directional antenna isn't required.
2. Directional or *beam* antennas which are intended to preferentially radiate or receive in a particular direction or directional pattern.

In common usage "omnidirectional" usually refers to all horizontal directions, typically with reduced performance in the direction of the sky or the ground (a truly isotropic radiator is not even possible). A "directional" antenna usually is intended to maximize its coupling to the electromagnetic field in the direction of the other station, or sometimes to cover a particular sector such as a 120° horizontal fan pattern in the case of a panel antenna at a cell site.

One example of omnidirectional antennas is the very common *vertical antenna* or whip antenna consisting of a metal rod (often, but not always, a quarter of a wavelength long). A dipole antenna is similar but consists of two such conductors extending in opposite directions, with a total length that is often, but not always, a half of a wavelength long. Dipoles are typically oriented horizontally in which case they are weakly directional: signals are reasonably well radiated toward or received from all directions with the exception of the direction along the conductor itself; this region is called the antenna blind cone or null.

Both the vertical and dipole antennas are simple in construction and relatively inexpensive. The dipole antenna, which is the basis for most antenna designs, is a balanced component, with equal but opposite voltages and currents applied at its two terminals through a balanced transmission line (or to a coaxial transmission line through a so-called balun). The vertical antenna, on the other hand, is a *monopole* antenna. It is typically connected to the inner conductor of a coaxial transmission line (or a matching network); the shield of the transmission line is connected to ground. In this way, the ground (or any large conductive surface) plays the role of the second conductor of a dipole, thereby forming a complete circuit. Since monopole antennas rely on a conductive ground, a so-called grounding structure may be employed in order to provide a better ground contact to the earth or which itself acts as a ground plane to perform that function regardless of (or in absence of) an actual contact with the earth.

Antennas fancier than the dipole or vertical designs are usually intended to increase the directivity and consequently the gain of the antenna. This can be accomplished in many different ways leading to a plethora of antenna designs. The vast majority of designs are fed with a balanced line (unlike a monopole antenna) and are based on the dipole antenna with additional components (or *elements*) which increase its directionality.

For instance, a phased array consists of two or more simple antennas which are connected together through an electrical network. This often involves a number of parallel dipole antennas with a certain spacing. Depending on the relative phase introduced by the network, the same combination of dipole antennas can operate as a "broadside array" (directional normal to a line connecting the elements) or as an "end-fire array" (directional along the line connecting the elements). Antenna arrays may employ any basic (omnidirectional or weakly directional) antenna type, such as dipole, loop or slot antennas. These elements are often identical.

However a log-periodic dipole array consists of a number of dipole elements of *different* lengths in order to obtain a somewhat directional antenna having an extremely wide bandwidth: these are frequently used for television reception in fringe areas. The dipole antennas composing it are all considered "active elements" since they are all electrically connected together (and to the transmission line). On the other hand, a superficially similar dipole array, the Yagi-Uda Antenna (or simply "Yagi"), has only one dipole element with an electrical connection; the other so-called parasitic elements interact with the electromagnetic field in order to realize a fairly directional antenna but one which is limited to a rather narrow bandwidth. The Yagi antenna has similar looking parasitic dipole elements but which act differently due to their somewhat different lengths. There may be a number of so-called "directors" in front of the active element in the direction of propagation, and usually a single (but possibly more) "reflector" on the opposite side of the active element.

Greater directionality can be obtained using beam-forming techniques such as a parabolic reflector or a horn. Since the size of a directional antenna depends on it being large compared to the wavelength, very directional antennas of this sort are mainly feasible at UHF and microwave frequencies. On the other hand, at low frequencies (such as AM broadcast) where a practical antenna must be much smaller than a wavelength, significant directionality isn't even possible. A vertical antenna or loop antenna small compared to the wavelength is typically used, with the main design challenge being that of impedance matching. With a vertical antenna a *loading coil* at the base of the antenna may be employed to cancel the reactive component of impedance; small loop antennas are tuned with parallel capacitors for this purpose.

An antenna lead-in is the transmission line (or *feed line*) which connects the antenna to a transmitter or receiver. The *antenna feed* may refer to all components connecting the antenna to the transmitter or receiver, such as an impedance matching network in addition to the transmission line. In a so-called aperture antenna, such as a horn or parabolic dish, the "feed" may also refer to a basic antenna inside the entire system (normally at the focus of the parabolic dish or at the throat of a horn) which could be considered the one active element in that antenna system. A microwave antenna may also be fed directly from a waveguide in lieu of a (conductive) transmission line.

An antenna counterpoise or ground plane is a structure of conductive material which improves or substitutes for the ground. It may be connected to or insulated from the natural ground. In a monopole antenna, this aids in the function of the natural ground, particularly where variations (or limitations) of the characteristics of the natural ground interfere with its proper function. Such a structure is normally connected to the return connection of an unbalanced transmission line such as the shield of a coaxial cable.

An electromagnetic wave *refractor* in some aperture antennas is a component which due to its shape and position functions to selectively delay or advance portions of the electromagnetic wavefront passing through it. The refractor alters the spatial characteristics of the wave on one side relative to the other side. It can, for instance, bring the wave to a focus or alter the wave front in other ways, generally in order to maximize the directivity of the antenna system. This is the radio equivalent of an optical lens.

An antenna coupling network is a passive network (generally a combination of inductive and capacitive circuit elements) used for impedance matching in between the antenna and the transmitter or receiver. This may be used to improve the standing wave ratio in order to minimize losses in the transmission line (especially at higher frequencies and/or over longer distances) and to present the transmitter or receiver with a standard resistive impedance (such as 75 ohms) that it expects to see for optimum operation.

Reciprocity

It is a fundamental property of antennas that the characteristics of an antenna described in the next section, such as gain, radiation pattern, impedance, bandwidth, resonant frequency and polarization, are the same whether the antenna is transmitting or receiving. For example, the "*receiving pattern*" (sensitivity as a function of direction) of an antenna when used for reception is identical to the radiation pattern of the antenna when it is *driven* and functions as a radiator. This is a consequence of the reciprocity theorem of electromagnetics. Therefore in discussions of antenna properties no distinction is usually made between receiving and transmitting terminology, and the antenna can be viewed as either transmitting or receiving, whichever is more convenient.

A necessary condition for the above reciprocity property is that the materials in the antenna and transmission medium are linear and reciprocal. *Reciprocal* (or *bilateral*) means that the material has the same response to an electric or magnetic field, or a current, in one direction, as it has to the field or current in the opposite direction. Most materials used in antennas meet these conditions, but some microwave antennas use high-tech components such as isolators and circulators, made of nonreciprocal materials such as ferrite or garnet. These can be used to give the antenna a different behavior on receiving than it has on transmitting, which can be useful in applications like radar.

Parameters

There are several critical parameters affecting an antenna's performance that can be adjusted during the design process. These are resonant frequency, impedance, gain, aperture or radiation pattern, polarization, efficiency and bandwidth. Transmit antennas may also have a maximum power rating, and receive antennas differ in their noise rejection properties. All of these parameters can be measured through various means.

Resonant frequency

Many types of antenna are tuned to work at one particular frequency, and are effective only over a range of frequencies centered on this frequency, called the resonant frequency. These are called *resonant antennas*. The antenna acts as an electrical resonator. When driven at its resonant frequency, large standing waves of voltage and current are excited in the antenna elements. These large currents and voltages radiate intense electromagnetic waves, so the power radiated by the antenna is maximum at the resonant frequency.

In antennas made of thin linear conductive elements, the length of the driven element(s) determines the resonant frequency. To be resonant, the length of a driven element should typically be either half or a quarter of the wavelength at that frequency; these are called half-wave and quarter-wave antennas. The length referred to is not the physical length, but the electrical length of the element, which is the physical length divided by the velocity factor (the ratio of the speed of wave propagation in the wire to c_0, the speed of light in a vacuum). Antennas are usually also resonant at multiples (harmonics) of the lowest resonant frequency.

Some antenna designs have multiple resonant frequencies, and some are relatively effective over a very broad range of frequencies. or bandwidth. One commonly known type of wide band antenna is the logarithmic or log-periodic antenna.

The resonant frequency also affects the impedance of the antenna. At resonance, the equivalent circuit of an antenna is a pure resistance, with no reactive component. At frequencies other than the resonant frequencies, the antenna has capacitance or inductance as well as resistance. An antenna can be made resonant at other frequencies besides its natural resonant frequency by compensating for these reactances by adding a loading coil or capacitor in series with it. Other properties of an antenna change with frequency, in particular the radiation pattern, so the antenna's operating frequency may be considerably different from the resonant frequency to optimize other important parameters.

Gain

Gain is a parameter which measures the degree of directivity of the antenna's radiation pattern. An antenna with a low gain emits radiation with about the same power in all directions, whereas a high-gain antenna will preferentially radiate in particular directions. Specifically, the *antenna gain*, *directive gain*, or *power gain* of an antenna is defined as the ratio of the intensity (power per unit surface) radiated by the antenna in the direction of its maximum output, at an arbitrary distance, divided by the intensity radiated at the same distance by a hypothetical isotropic antenna.

The gain of an antenna is a passive phenomenon - power is not added by the antenna, but simply redistributed to provide more radiated power in a certain direction than would be transmitted by an isotropic antenna. An antenna designer must take into account the application for the antenna when determining the gain. High-gain antennas have the advantage of longer range and better signal quality, but must be aimed carefully in a particular direction. Low-gain antennas have shorter range, but the orientation of the antenna is relatively inconsequential. For example, a dish antenna on a spacecraft is a high-gain device that must be pointed at the planet to be effective, whereas a typical Wi-Fi antenna in a laptop computer is low-gain, and as long as the base station is within range, the antenna can be in any orientation in space. It makes sense to improve horizontal range at the expense of reception above or below the antenna. Thus most antennas labelled "omnidirectional" really have some gain.

In practice, the half-wave dipole is taken as a reference instead of the isotropic radiator. The gain is then given in **dBd** (decibels over **d**ipole):

NOTE: **0 dBd = 2.15 dBi**. It is vital in expressing gain values that the reference point be included. Failure to do so can lead to confusion and error.

Radiation pattern

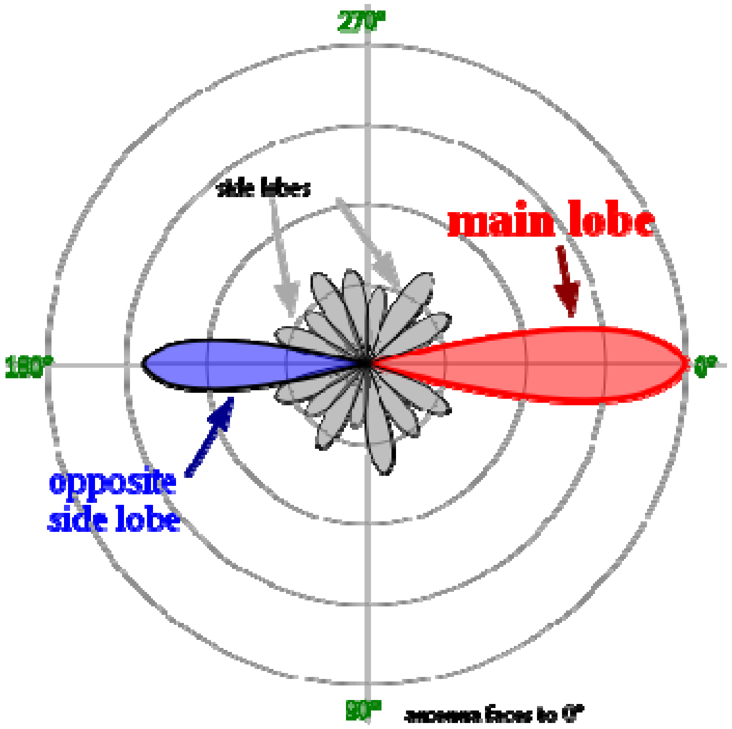

polar plots of the horizontal cross sections of a (virtual) Yagi-Uda-antenna. Outline connects points with 3db field power compared to an ISO emitter.

The radiation pattern of an antenna is a plot of the relative field strength of the radio waves emitted by the antenna at different angles. It is typically represented by a three dimensional graph, or polar plots of the horizontal and vertical cross sections. The pattern of an ideal isotropic antenna, which radiates equally in all directions, would look like a sphere. Many nondirectional antennas, such as monopoles and dipoles, emit equal power in all horizontal directions, with the power dropping off at higher and lower angles; this is called an omnidirectional pattern and when plotted looks like a torus or donut.

The radiation of many antennas shows a pattern of maxima or "*lobes*" at various angles, separated by "*nulls*", angles where the radiation falls to zero. This is because the radio waves emitted by different parts of the antenna typically interfere, causing maxima at angles where the radio waves arrive at distant points in phase, and zero radiation at other angles where the radio waves arrive out of phase. In a directional antenna designed to project radio waves in a particular direction, the lobe in that direction is designed larger than the others and is called the "*main lobe*". The other lobes usually represent unwanted radiation and are called "*sidelobes*". The axis through the main lobe is called the "*principle axis*" or "*boresight axis*".

Impedance

As an electro-magnetic wave travels through the different parts of the antenna system (radio, feed line, antenna, free space) it may encounter differences in impedance (E/H, V/I, etc.). At each interface, depending on the impedance match, some fraction of the wave's energy will reflect back to the source, forming a standing wave in the feed line. The ratio of maximum power to minimum power in the wave can be measured and is called the standing wave ratio (**SWR**). A SWR of 1:1 is ideal. A SWR of 1.5:1 is considered to be marginally acceptable in low power applications where power loss is more critical, although an SWR as high as 6:1 may still be usable with the right equipment. Minimizing impedance differences at each interface (impedance matching) will reduce SWR and maximize power transfer through each part of the antenna system.

Complex impedance of an antenna is related to the electrical length of the antenna at the wavelength in use. The impedance of an antenna can be matched to the feed line and radio by adjusting the impedance of the feed line, using the feed line as an impedance transformer. More commonly, the impedance is adjusted at the load (see below) with an antenna tuner, a balun, a matching transformer, matching networks composed of inductors and capacitors, or matching sections such as the gamma match.

Efficiency

Efficiency is the ratio of power actually radiated to the power put into the antenna terminals. A dummy load may have an SWR of 1:1 but an efficiency of 0, as it absorbs all power and radiates heat but very little RF energy, showing that SWR alone is not an effective measure of an antenna's efficiency. Radiation in an antenna is caused by radiation resistance which can only be measured as part of total resistance including loss resistance. Loss resistance usually results in heat generation rather than radiation, and reduces efficiency. Mathematically, efficiency is calculated as radiation resistance divided by total resistance.

Bandwidth

The *bandwidth* of an antenna is the range of frequencies over which it is effective, usually centered on the resonant frequency. The bandwidth of an antenna may be increased by several techniques, including using thicker wires, replacing wires with *cages* to simulate a thicker wire, tapering antenna components (like in a feed horn), and combining multiple antennas into a single assembly (array) and allowing the natural impedance of suitable inductive RF filter traps to select the correct antenna. All these attempts to increase bandwidth by adding capacitance to the surface area have a detrimental effect on efficiency by reducing the Q factor. They also have an adverse effect on the rejection of unwanted harmonics, on both received and transmitted signal frequencies. Small antennas are usually preferred for convenience, but there is a fundamental limit relating bandwidth, size and efficiency.

Polarization

The *polarization* of an antenna is the orientation of the electric field (E-plane) of the radio wave with respect to the Earth's surface and is determined by the physical structure of the antenna and by its orientation. It has nothing in common with antenna directionality terms: "horizontal", "vertical" and "circular". Thus, a simple straight wire antenna will have one polarization when mounted vertically, and a different polarization when mounted horizontally. "Electromagnetic wave polarization filters" are structures which can be employed to act directly on the electromagnetic wave to filter out wave energy of an undesired polarization and to pass wave energy of a desired polarization.

Reflections generally affect polarization. For radio waves the most important reflector is the ionosphere - signals which reflect from it will have their polarization changed unpredictably. For signals which are reflected by the ionosphere, polarization cannot be relied upon. For line-of-sight communications for which polarization can be relied upon, it can make a large difference in signal quality to have the transmitter and receiver using the same polarization; many tens of dB difference are commonly seen and this is more than enough to make the difference between reasonable communication and a broken link.

Polarization is largely predictable from antenna construction but, especially in directional antennas, the polarization of side lobes can be quite different from that of the main propagation lobe. For radio antennas, polarization corresponds to the orientation of the radiating element in an antenna. A vertical omnidirectional WiFi antenna will have vertical polarization (the most common type). An exception is a class of elongated waveguide antennas in which vertically placed antennas are horizontally polarized. Many commercial antennas are marked as to the polarization of their emitted signals.

Polarization is the sum of the E-plane orientations over time projected onto an imaginary plane perpendicular to the direction of motion of the radio wave. In the most general case, polarization is elliptical, meaning that the polarization of the radio waves varies over time. Two special cases are linear polarization (the ellipse collapses into a line) and circular polarization (in which the two axes of the ellipse are equal). In linear polarization the antenna compels the electric field of the emitted radio wave to a particular orientation. Depending on the orientation of the antenna mounting, the usual linear cases are horizontal and vertical polarization. In circular polarization, the antenna continuously varies the electric field of the radio wave through all possible values of its orientation with regard to the Earth's surface. Circular polarizations, like elliptical ones, are classified as right-hand polarized or left-hand polarized using a "thumb in the direction of the propagation" rule. Optical researchers use the same rule of thumb, but pointing it in the direction of the emitter, not in the direction of propagation, and so are opposite to radio engineers' use.

In practice, regardless of confusing terminology, it is important that linearly polarized antennas be matched, lest the received signal strength be greatly reduced. So horizontal should be used with horizontal and vertical with vertical. Intermediate matchings will lose some signal strength, but not as much as a complete mismatch. Transmitters mounted on vehicles with large motional freedom commonly use circularly polarized antennas so that there will never be a complete mismatch with signals from other sources.

Transmission and reception

All of the antenna parameters are expressed in terms of a transmission antenna, but are identically applicable to a receiving antenna, due to reciprocity. Impedance, however, is not applied in an obvious way; for impedance, the impedance at the load (where the power is consumed) is most critical. For a transmitting antenna, this is the antenna itself. For a receiving antenna, this is at the (radio) receiver rather than at the antenna. Tuning is done by adjusting the length of an electrically long linear antenna to alter the electrical resonance of the antenna.

Antenna tuning is done by adjusting an inductance or capacitance combined with the active antenna (but distinct and separate from the active antenna). The inductance or capacitance provides the reactance which combines with the inherent reactance of the active antenna to establish a resonance in a circuit including the active antenna. The established resonance being at a frequency other than the natural electrical resonant frequency of the active antenna. Adjustment of the inductance or capacitance changes this resonance.

Antennas used for transmission have a maximum power rating, beyond which heating, arcing or sparking may occur in the components, which may cause them to be damaged or destroyed. Raising this maximum power rating usually requires larger and heavier components, which may require larger and heavier supporting structures. This is a concern only for transmitting antennas, as the power received by an antenna rarely exceeds the microwatt range.

Antennas designed specifically for reception might be optimized for noise rejection capabilities. An *antenna shield* is a conductive or low reluctance structure (such as a wire, plate or grid) which is adapted to be placed in the vicinity of an antenna to reduce, as by dissipation through a resistance or by conduction to ground, undesired electromagnetic radiation, or electric or magnetic fields, which are directed toward the active antenna from an external source or which emanate from the active antenna. Other methods to optimize for noise rejection can be done by selecting a narrow bandwidth so that noise from other frequencies is rejected, or selecting a specific radiation pattern to reject noise from a specific direction, or by selecting a polarization different from the noise polarization, or by selecting an antenna that favors either the electric or magnetic field.

For instance, an antenna to be used for reception of low frequencies (below about ten megahertz) will be subject to both man-made noise from motors and other machinery, and from natural sources such as lightning. Successfully rejecting these forms of noise is an important antenna feature. A small coil of wire with many turns is more able to reject such noise than a vertical antenna. However, the vertical will radiate much more effectively on transmit, where extraneous signals are not a concern.

Basic antenna models

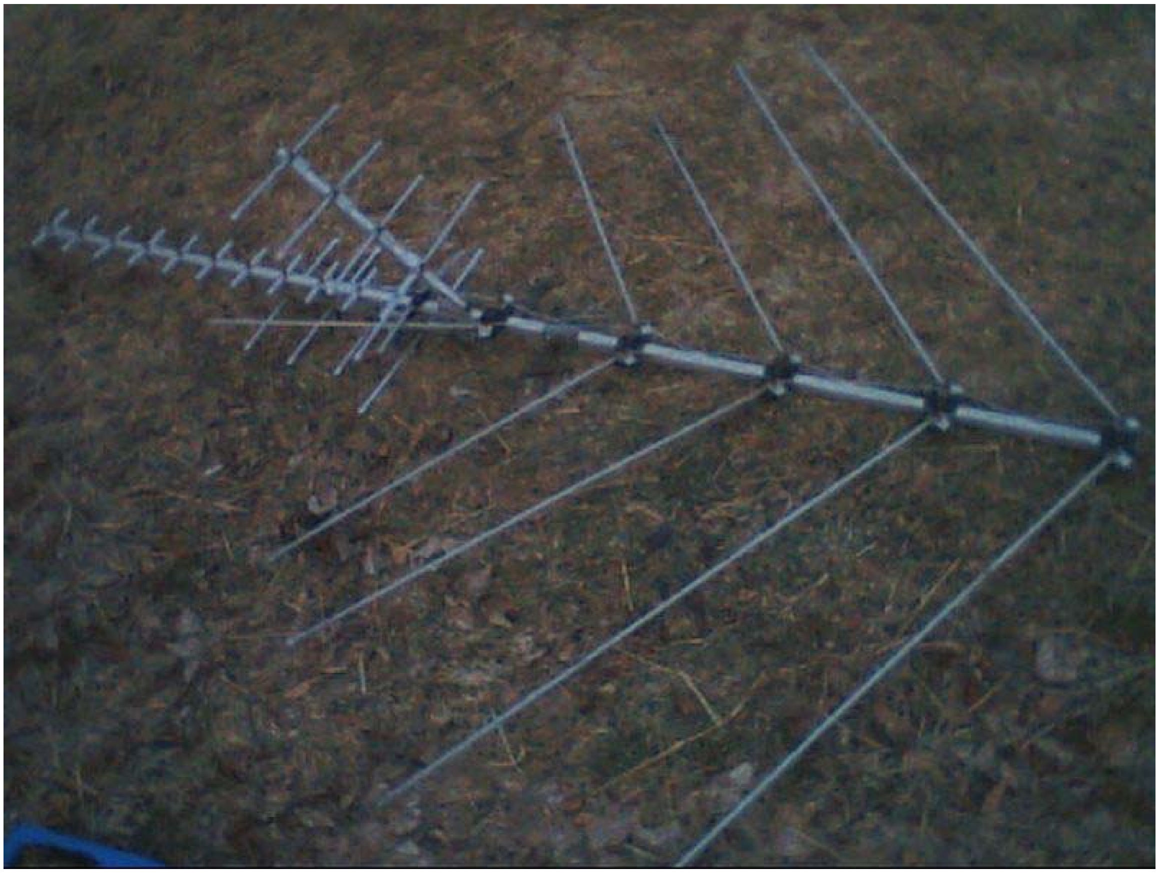

Typical US multiband TV antenna (aerial)

There are many variations of antennas. Below are a few basic models. More can be found in Category:Radio frequency antenna types.

- The isotropic radiator is a purely theoretical antenna that radiates equally in all directions. It is considered to be a point in space with no dimensions and no mass. This antenna cannot physically exist, but is useful as a theoretical model for comparison with all other antennas. Most antennas' gains are measured with reference to an isotropic radiator, and are rated in dBi (decibels with respect to an isotropic radiator).
- The dipole antenna is simply two wires pointed in opposite directions arranged either horizontally or vertically, with one end of each wire connected to the radio and the other end hanging free in space. Since this is the simplest practical antenna, it is also used as a reference model for other antennas; gain with respect to a dipole is labeled as dBd. Generally, the dipole is considered to be omnidirectional in the plane perpendicular to the axis of the antenna, but it has deep nulls in the directions of the axis. Variations of the dipole include the folded dipole, the half wave antenna, the ground plane antenna, the whip, and the J-pole.
- The Yagi-Uda antenna is a directional variation of the dipole with parasitic elements added which are functionality similar to adding a reflector and lenses (directors) to focus a filament light bulb.
- The random wire antenna is simply a very long (at least one quarter wavelength) wire with one end connected to the radio and the other in free space, arranged in any way most convenient for the space available. Folding will reduce effectiveness and make theoretical analysis extremely difficult. (The added length helps more than the folding typically hurts.) Typically, a random wire antenna will also require an antenna tuner, as it might have a random impedance that varies non-linearly with frequency.
- The horn is used where high gain is needed, the wavelength is short (microwave) and space is not an issue. Horns can be narrow band or wide band, depending on their shape. A horn can be built for any frequency, but horns for lower frequencies are typically impractical. Horns are also frequently used as reference antennas.
- The parabolic antenna consists of an active element at the focus of a parabolic reflector to reflect the waves into a plane wave. Like the horn it is used for high gain, microwave applications, such as satellite dishes.
- The patch antenna consists mainly of a square conductor mounted over a groundplane. Another example of a planar antenna is the tapered slot antenna (TSA), as the Vivaldi-antenna.

Practical antennas

"Rabbit ears" set-top antenna

Although any circuit can radiate if driven with a signal of high enough frequency, most practical antennas are specially designed to radiate efficiently at a particular frequency. An example of an inefficient antenna is the simple Hertzian dipole antenna, which radiates over wide range of frequencies and is useful for its small size. A more efficient variation of this is the half-wave dipole, which radiates with high efficiency when the signal wavelength is twice the electrical length of the antenna.

One of the goals of antenna design is to minimize the reactance of the device so that it appears as a resistive load. An "antenna inherent reactance" includes not only the distributed reactance of the active antenna but also the natural reactance due to its location and surroundings (as for example, the capacity relation inherent in the position of the active antenna relative to ground). Reactance diverts energy into the reactive field, which causes unwanted currents that heat the antenna and associated wiring, thereby wasting energy without contributing to the radiated output. Reactance can be eliminated by operating the antenna at its resonant frequency, when its capacitive and inductive reactances are equal and opposite, resulting in a net zero reactive current. If this is not possible, compensating inductors or capacitors can instead be added to the antenna to cancel its reactance as far as the source is concerned.

Once the reactance has been eliminated, what remains is a pure resistance, which is the sum of two parts: the ohmic resistance of the conductors, and the radiation resistance. Power absorbed by the ohmic resistance becomes waste heat, and that absorbed by the radiation resistance becomes radiated electromagnetic energy. The greater the ratio of radiation resistance to ohmic resistance, the more efficient the antenna.

Effect of ground

Antennas are typically used in an environment where other objects are present that may have an effect on their performance. Height above ground has a very significant effect on the radiation pattern of some antenna types.

At frequencies used in antennas, the ground behaves mainly as a dielectric. The conductivity of ground at these frequencies is negligible. When an electromagnetic wave arrives at the surface of an object, two waves are created: one enters the dielectric and the other is reflected. If the object is a conductor, the transmitted wave is negligible and the reflected wave has almost the same amplitude as the incident one. When the object is a dielectric, the fraction reflected depends (among others things) on the angle of incidence. When the angle of incidence is small (that is, the wave arrives almost perpendicularly) most of the energy traverses the surface and very little is reflected. When the angle of incidence is near 90° (grazing incidence) almost all the wave is reflected.

Most of the electromagnetic waves emitted by an antenna to the ground below the antenna at moderate (say < 60°) angles of incidence enter the earth and are absorbed (lost). But waves emitted to the ground at grazing angles, far from the antenna, are almost totally reflected. At grazing angles, the ground behaves as a mirror. Quality of reflection depends on the nature of the surface. When the irregularities of the surface are smaller than the wavelength reflection is good.

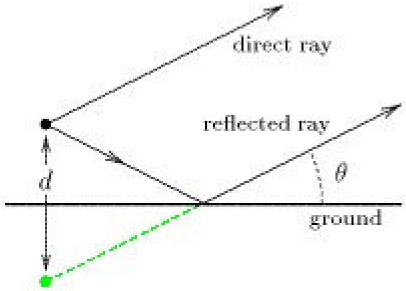

The wave reflected by earth can be considered as emitted by the image antenna

This means that the receptor "sees" the real antenna and, under the ground, the image of the antenna reflected by the ground. If the ground has irregularities, the image will appear fuzzy.

If the receiver is placed at some height above the ground, waves reflected by ground will travel a little longer distance to arrive to the receiver than direct waves. The distance will be the same only if the receiver is close to ground.

In the drawing at right, we have drawn the angle θfar bigger than in reality. Distance between the antenna and its image is d.

The situation is a bit more complex because the reflection of electromagnetic waves depends on the polarization of the incident wave. As the refractive index of the ground (average value $\simeq 2$) is bigger than the refractive index of the air ($\simeq 1$), the direction of the component of the electric field parallel to the ground inverses at the reflection. This is equivalent to a phase shift of πradians or 180°. The vertical component of the electric field reflects without changing direction. This sign inversion of the parallel component and the non-inversion of the perpendicular component would also happen if the ground were a good electrical conductor.

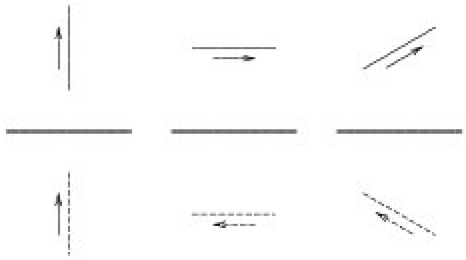

The vertical component of the current reflects without changing sign. The horizontal component reverses sign at reflection.

This means that a receiving antenna "sees" the image antenna with the current in the same direction if the antenna is vertical or with the current inverted if the antenna is horizontal.

For a vertical polarized emission antenna the far electric field of the electromagnetic wave produced by the direct ray plus the reflected ray is:

$$\left|E_{\perp}\right| = 2\left|E_{\theta_1}\right|\left|\cos\left(\frac{kd}{2}\sin\theta\right)\right|$$

The sign inversion for the parallel field case just changes a cosine to a sine:

$$\left|E_{=}\right| = 2\left|E_{\theta_1}\right|\left|\sin\left(\frac{kd}{2}\sin\theta\right)\right|$$

In these two equations:

- $E_{\theta_1}$is the electrical field radiated by the antenna if there were no ground.
- $k=\frac{2\pi}{\lambda}$is the wave number.
- $\lambda$is the wave length.

- d is the distance between antenna and its image (twice the height of the center of the antenna).

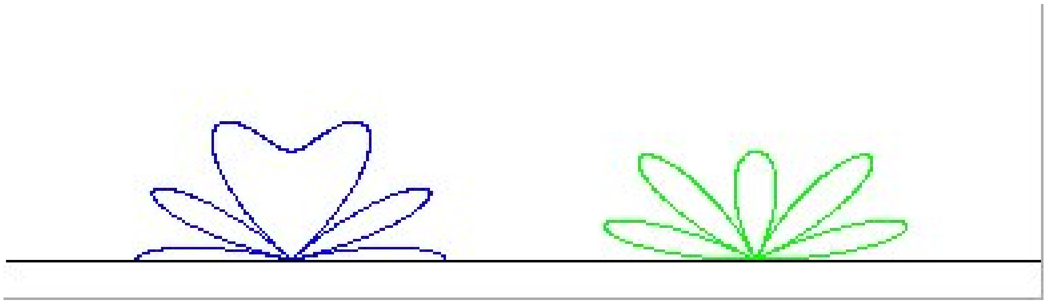

Radiation patterns of antennas and their images reflected by the ground. At left the polarization is vertical and there is always a maximum for $\theta=0$. If the polarization is horizontal as at right, there is always a zero for $\theta=0$.

For emitting and receiving antenna situated near the ground (in a building or on a mast) far from each other, distances traveled by direct and reflected rays are nearly the same. There is no induced phase shift. If the emission is polarized vertically the two fields (direct and reflected) add and there is maximum of received signal. If the emission is polarized horizontally the two signals subtracts and the received signal is minimum. This is depicted in the image at right. In the case of vertical polarization, there is always a maximum at earth level (left pattern). For horizontal polarization, there is always a minimum at earth level. Note that in these drawings the ground is considered as a perfect mirror, even for low angles of incidence. In these drawings the distance between the antenna and its image is just a few wavelengths. For greater distances, the number of lobes increases.

Note that the situation is different–and more complex–if reflections in the ionosphere occur. This happens over very long distances (thousands of kilometers). There is not a direct ray but several reflected rays that add with different phase shifts.

This is the reason why almost all public address radio emissions have vertical polarization. As public users are near ground, horizontal polarized emissions would be poorly received. Observe household and automobile radio receivers. They all have vertical antennas or horizontal ferrite antennas for vertical polarized emissions. In cases where the receiving antenna must work in any position, as in mobile phones, the emitter and receivers in base stations use circular polarized electromagnetic waves.

Classical (analog) television emissions are an exception. They are almost always horizontally polarized, because the presence of buildings makes it unlikely that a good emitter antenna image will appear. However, these same buildings reflect the electromagnetic waves and can create ghost images. Using horizontal polarization, reflections are attenuated because of the low reflection of electromagnetic waves whose magnetic field is parallel to the dielectric surface near the Brewster's angle. Vertically polarized analog television has been used in some rural areas. In digital terrestrial television reflections are less obtrusive, due to the inherent robustness of digital signalling and built-in error correction.

Mutual impedance and interaction between antennas

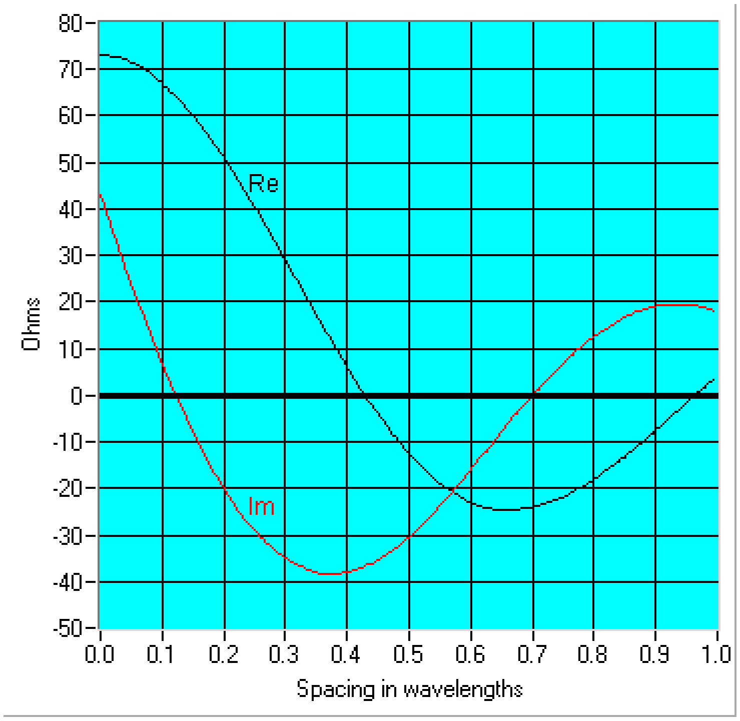

Mutual impedance between parallel $\frac{\lambda}{2}$dipoles not staggered. Curves **Re** and **Im** are the resistive and reactive parts of the impedance.

Current circulating in any antenna induces currents in all others. One can postulate a **mutual impedance** Z_{12}between two antennas that has the same significance as the $j\omega M$in ordinary coupled inductors. The mutual impedance Z_{12}between two antennas is defined as:

$$Z_{12} = \frac{v_2}{i_1}$$

where $i_1$is the current flowing in antenna 1 and $v_2$is the voltage that would have to be applied to antenna 2–with antenna 1 removed–to produce the current in the antenna 2 that was produced by antenna 1.

From this definition, the currents and voltages applied in a set of coupled antennas are:

$$\begin{array}{ccccccccc} v_1 & = & i_1 Z_{11} & + & i_2 Z_{12} & + & \cdots & + & i_n Z_{1n} \\ v_2 & = & i_1 Z_{21} & + & i_2 Z_{22} & + & \cdots & + & i_n Z_{2n} \\ \vdots & & \vdots & & \vdots & & & & \vdots \\ v_n & = & i_1 Z_{n1} & + & i_2 Z_{n2} & + & \cdots & + & i_n Z_{nn} \end{array}$$

where:

- v_i is the voltage applied to the antenna *i*
- Z_{ii} is the impedance of antenna *i*
- Z_{ij} is the mutual impedance between antennas *i* and *j*

Note that, as is the case for mutual inductances,

$$Z_{ij} = Z_{ji}$$

This is a consequence of Lorentz reciprocity. If some of the elements are not fed (there is a short circuit instead a feeder cable), as is the case in television antennas (Yagi-Uda antennas), the corresponding v_i are zero. Those elements are called parasitic elements. Parasitic elements are unpowered elements that either reflect or absorb and reradiate RF energy.

In some geometrical settings, the mutual impedance between antennas can be zero. This is the case for crossed dipoles used in circular polarization antennas.

Antenna

Antennas and antenna arrays

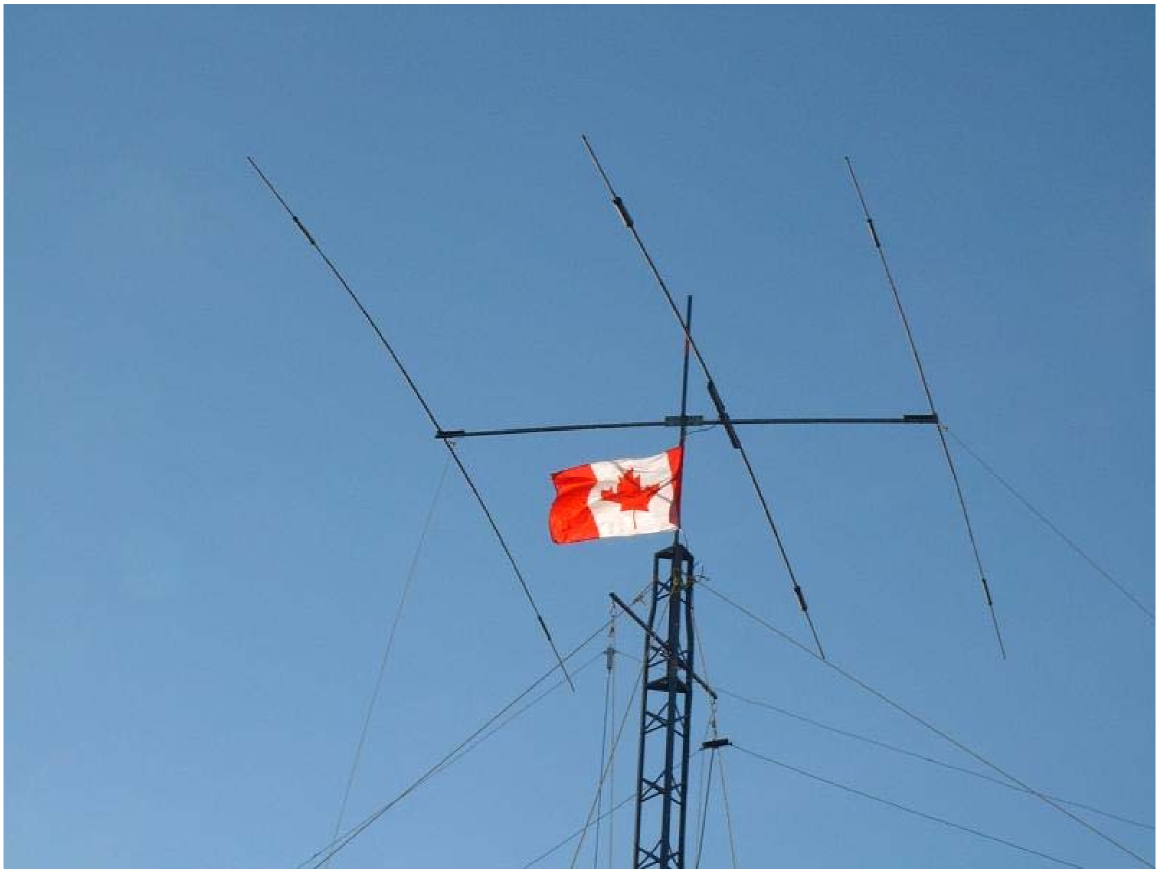

A Yagi-Uda beam antenna.

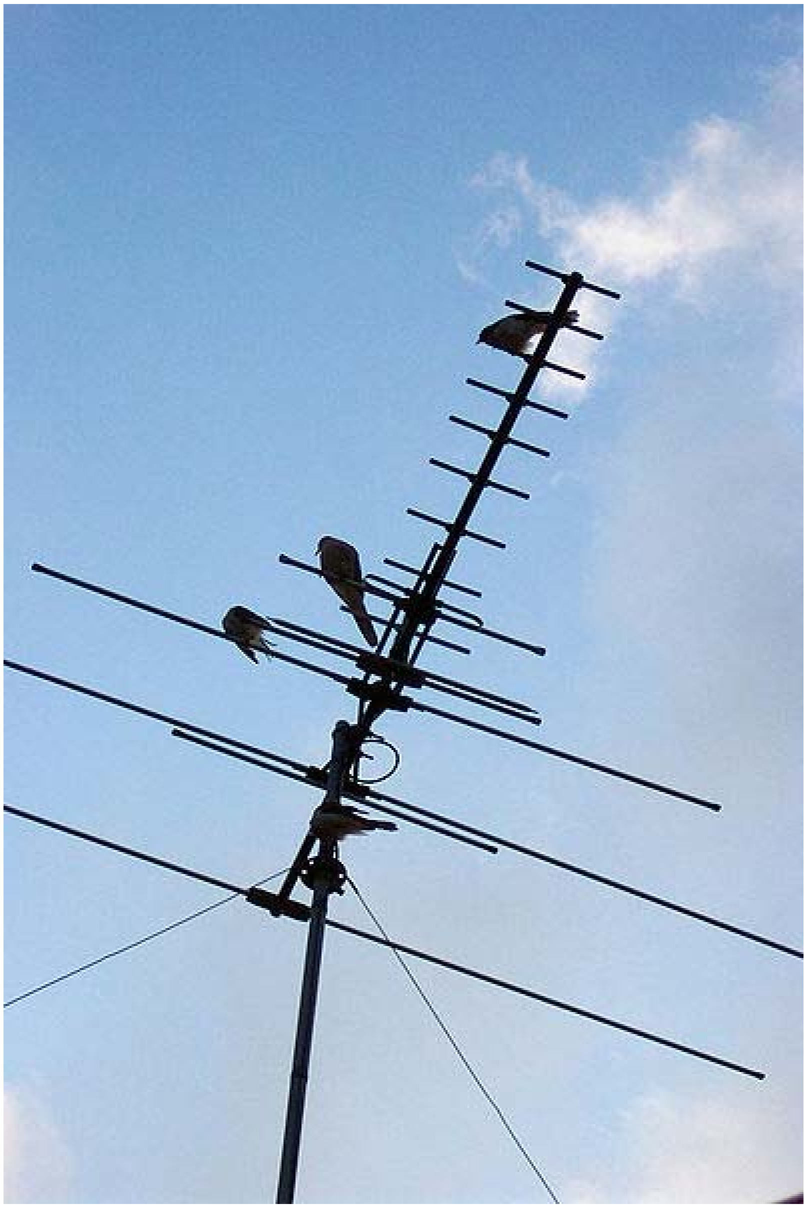

Rooftop TV antenna. It is actually three Yagi antennas. The longest elements are for the low band, while the medium and short elements are for the high and UHF band.

Examples of US 136-174 MHz base station antennas.

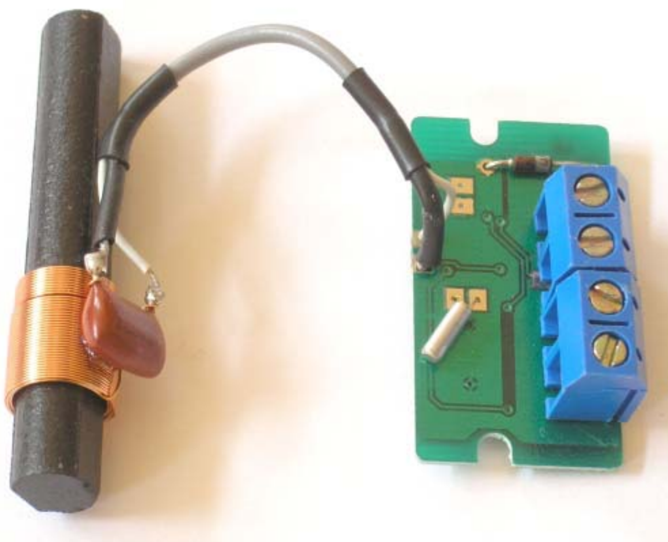

Low cost LF time signal receiver, antenna (left) and receiver (right).

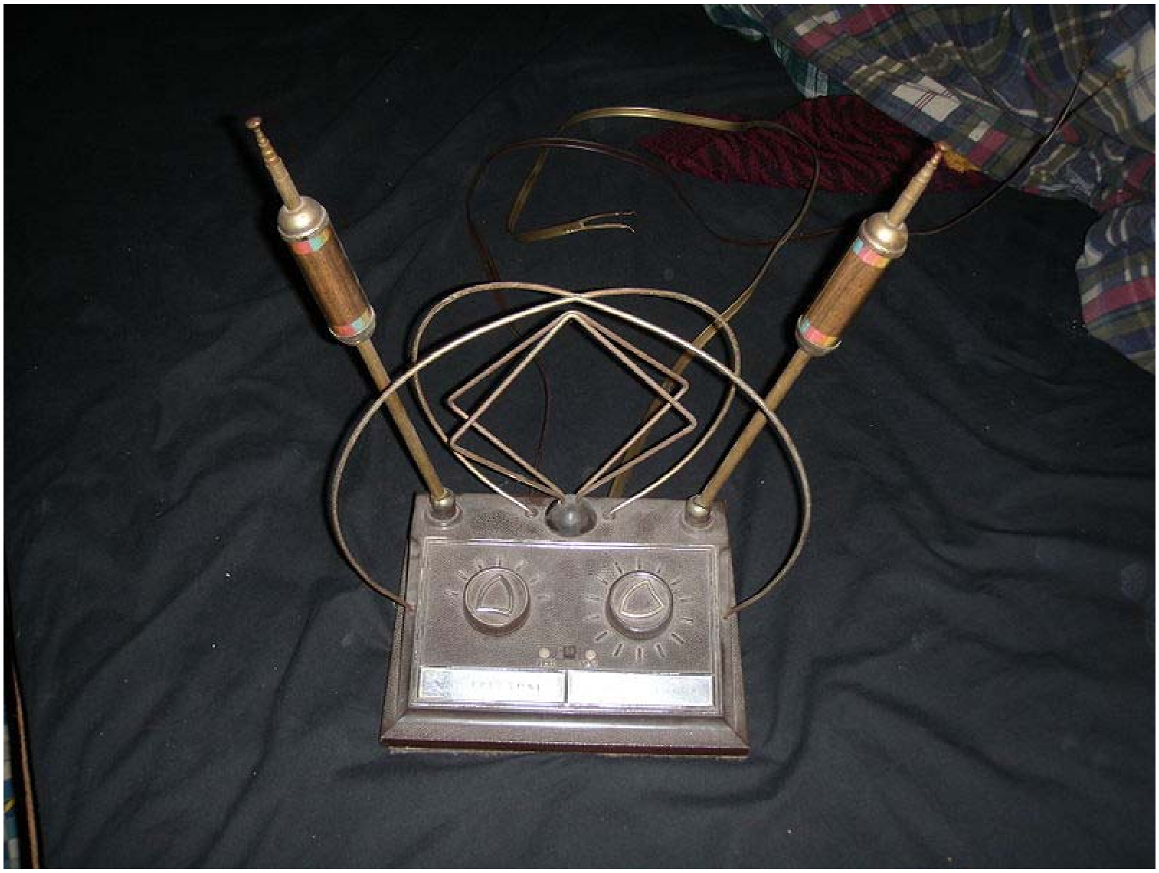

"Rabbit ears" antenna

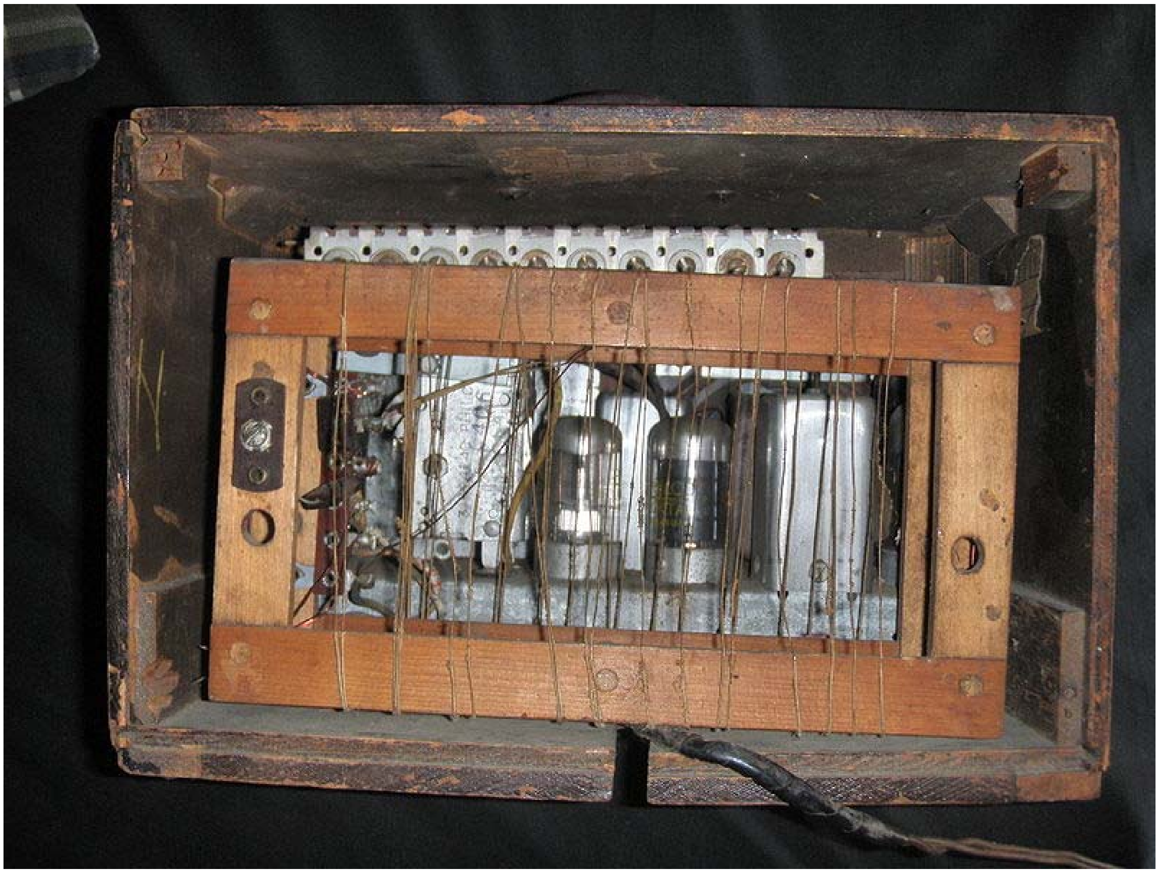

AM loop antenna

Antennas and supporting structures

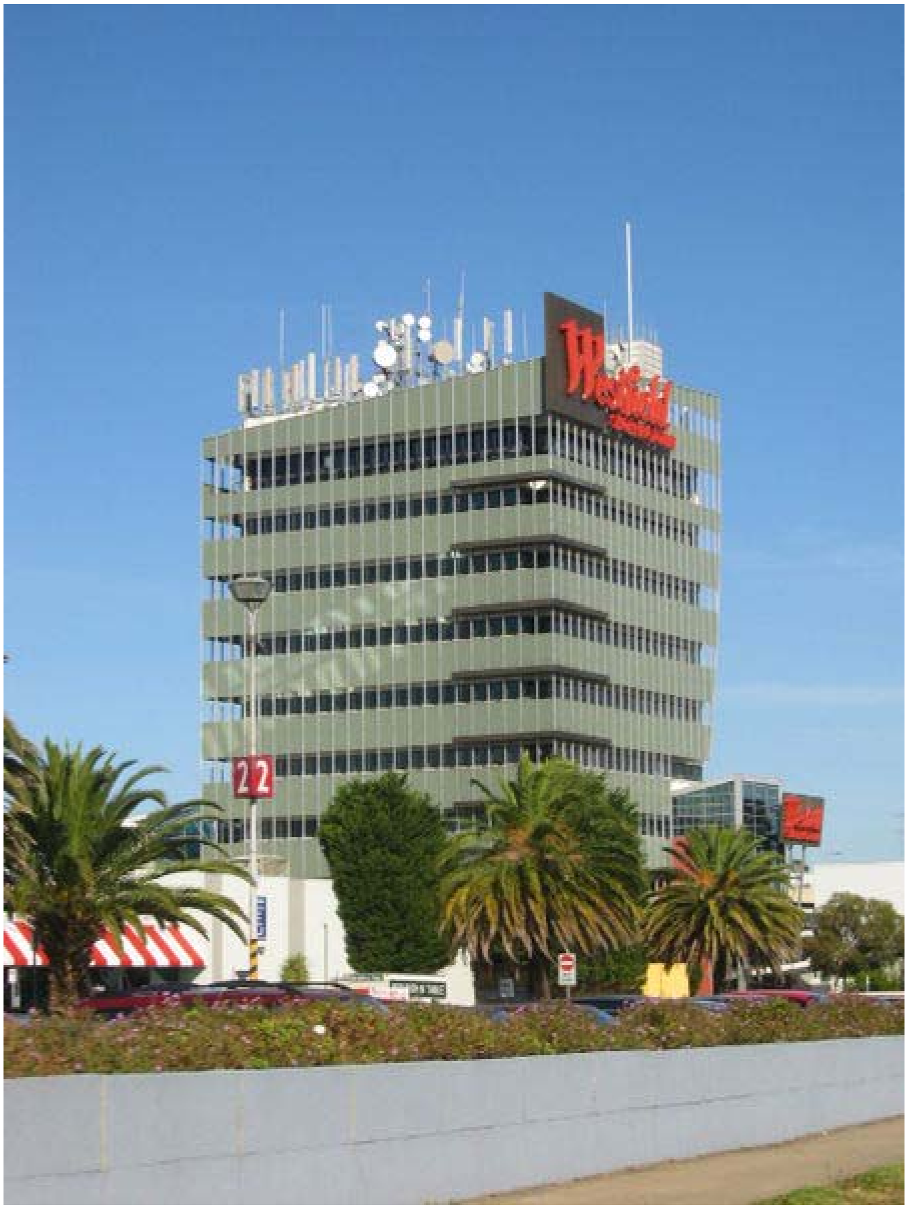

A building rooftop supporting numerous dish and sectored mobile telecommunications antennas (Doncaster, Victoria, Australia).

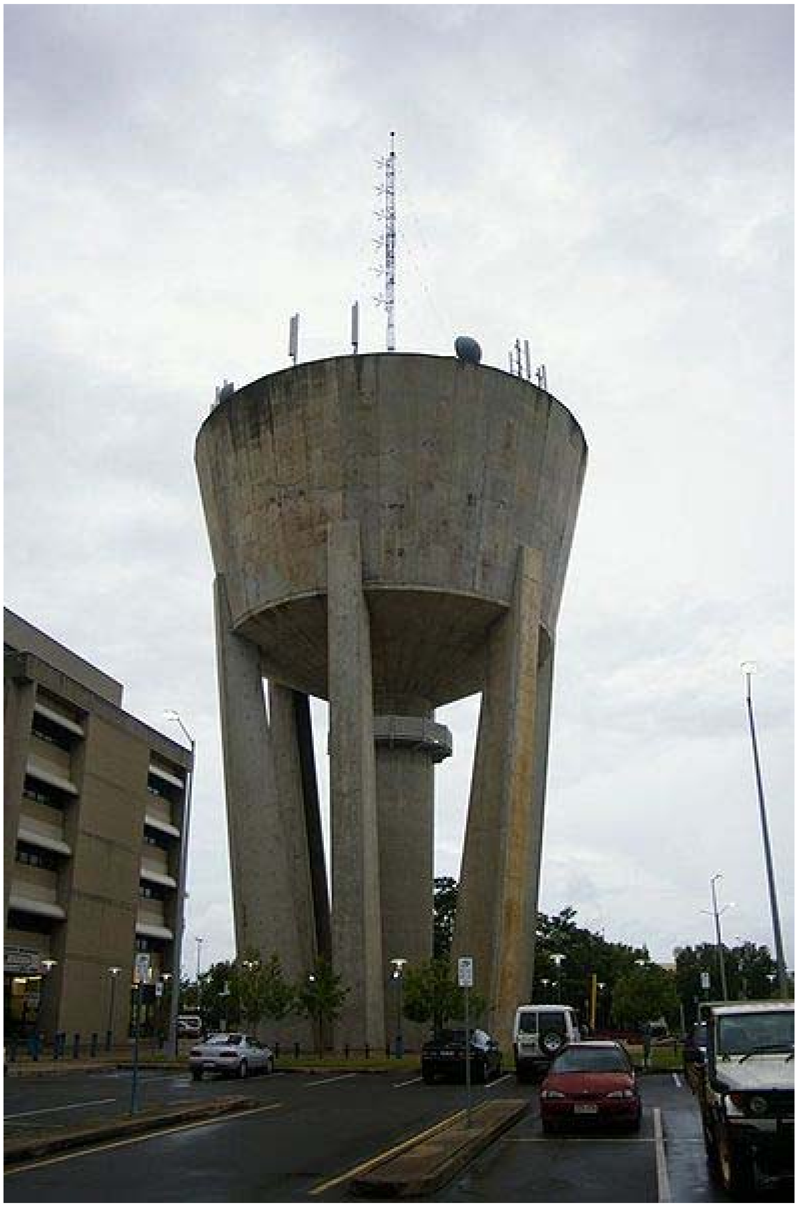

A water tower in Palmerston, Northern Territory with radio broadcasting and communications antennas.

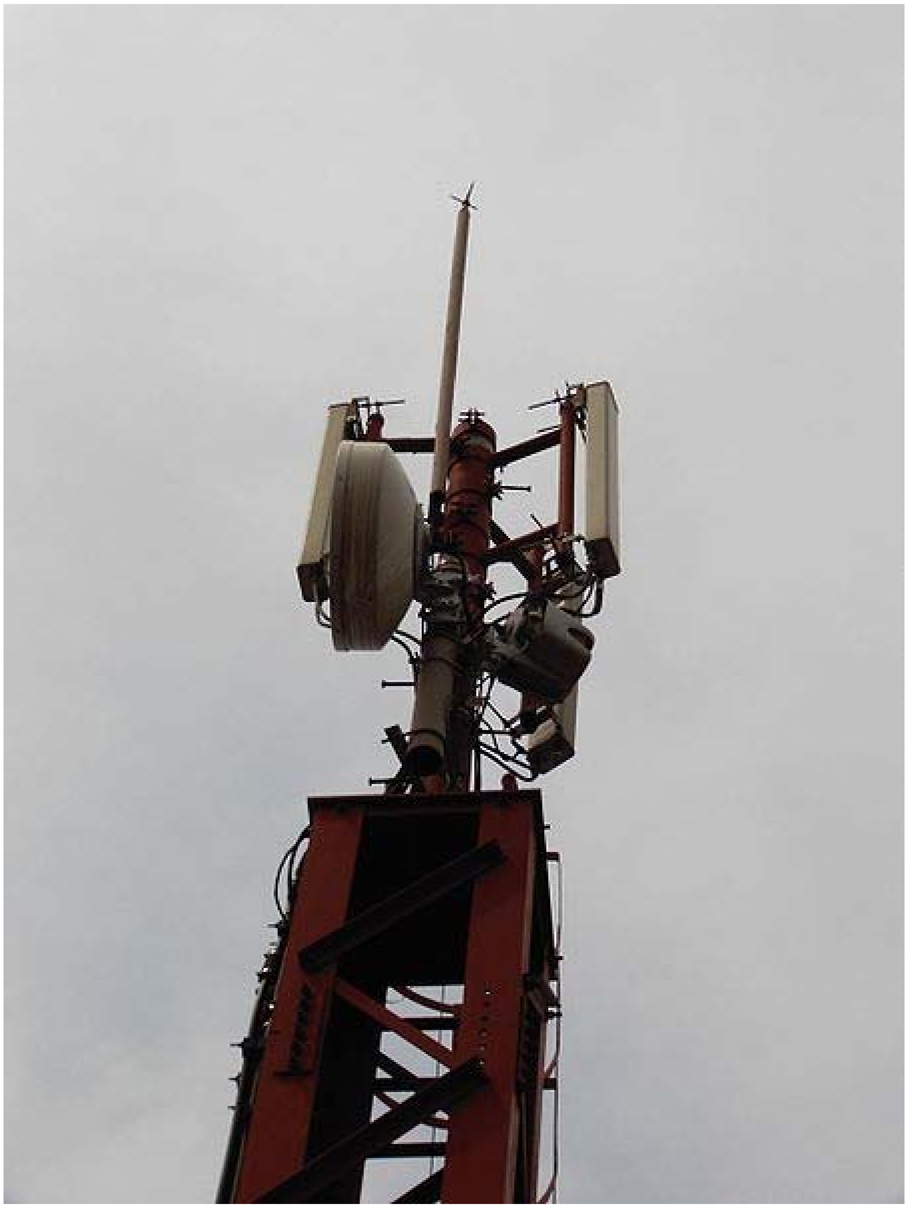

A three-sector telephone site in Mexico City.

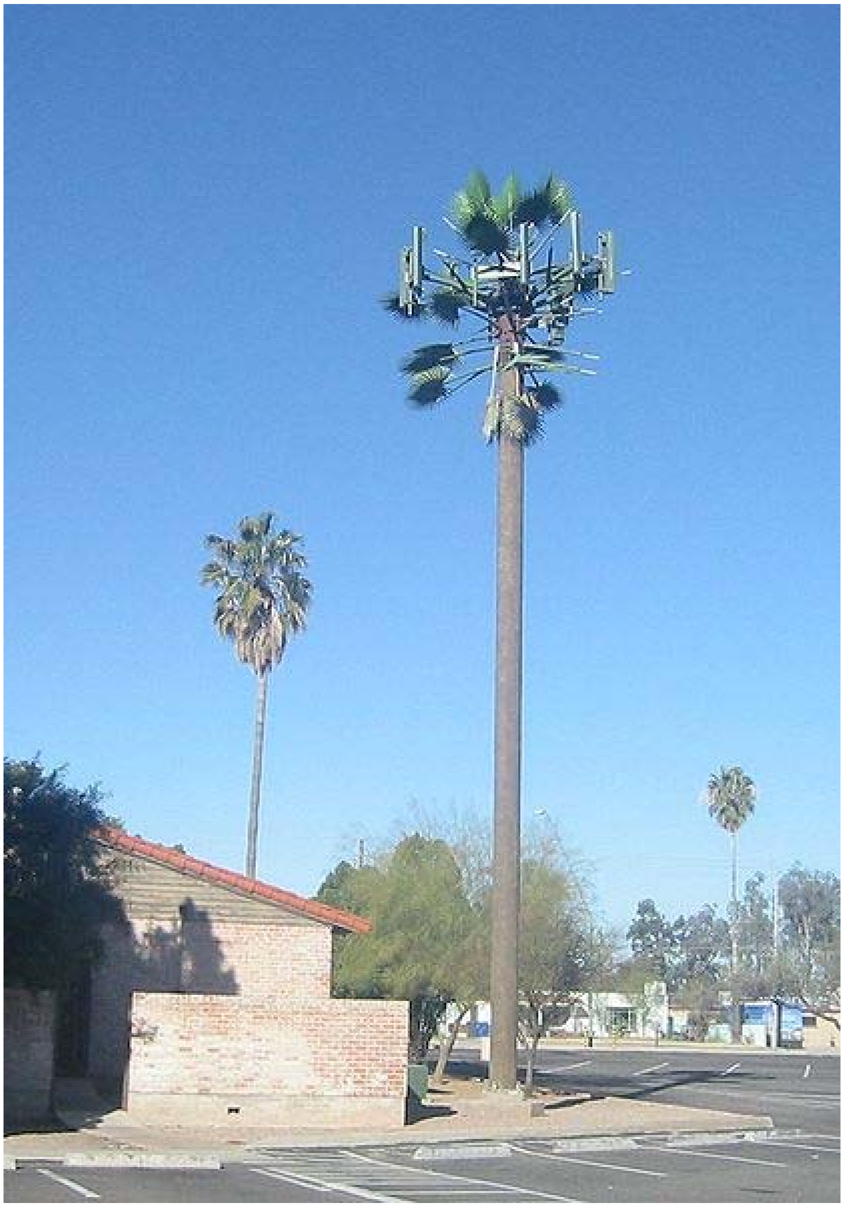

Telephone site concealed as a palm tree.

Diagrams as part of a system

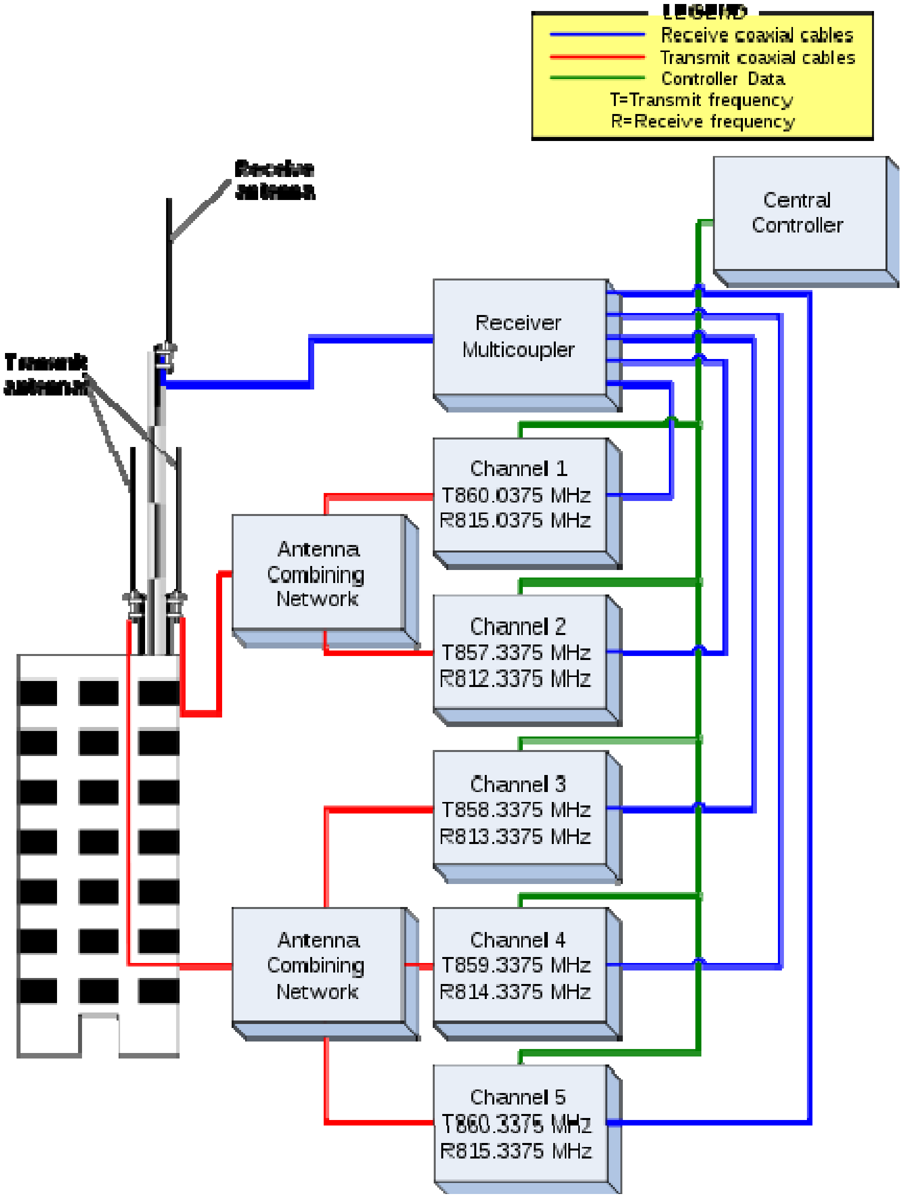
LEGEND
Receive coaxial cables
Transmit coaxial cables
Controller Data
T=Transmit frequency
R=Receive frequency
Receive antenna
Transmit antennas
Central Controller
Receiver Multicoupler
Channel 1
T860.0375 MHz
R815.0375 MHz
Antenna Combining Network
Channel 2
T857.3375 MHz
R812.3375 MHz
Channel 3
T858.3375 MHz
R813.3375 MHz
Antenna Combining Network
Channel 4
T859.3375 MHz
R814.3375 MHz
Channel 5
T860.3375 MHz
R815.3375 MHz

Antennas may be connected through a multiplexing arrangement in some applications like this trunked two-way radio example.

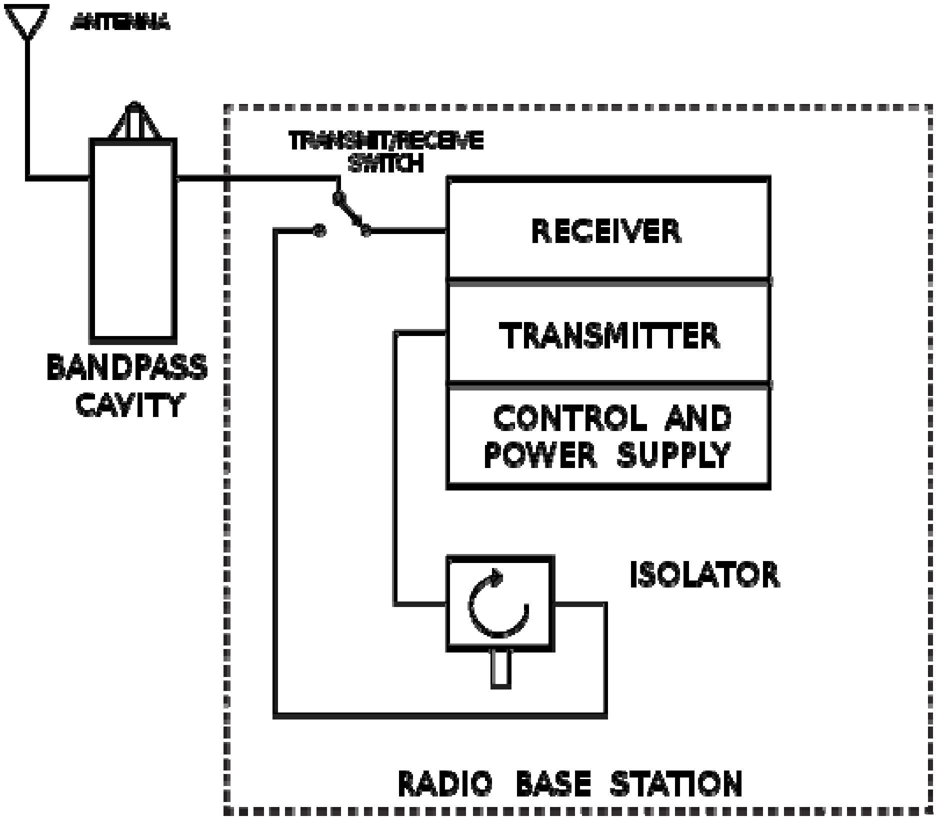
ANTENNA
TRANSMIT/RECEIVE SWITCH
RECEIVER
TRANSMITTER
CONTROL AND POWER SUPPLY
BANDPASS CAVITY
ISOLATOR
RADIO BASE STATION

Antenna network for an emergency medical services base station.

Chapter 6

Television Antenna

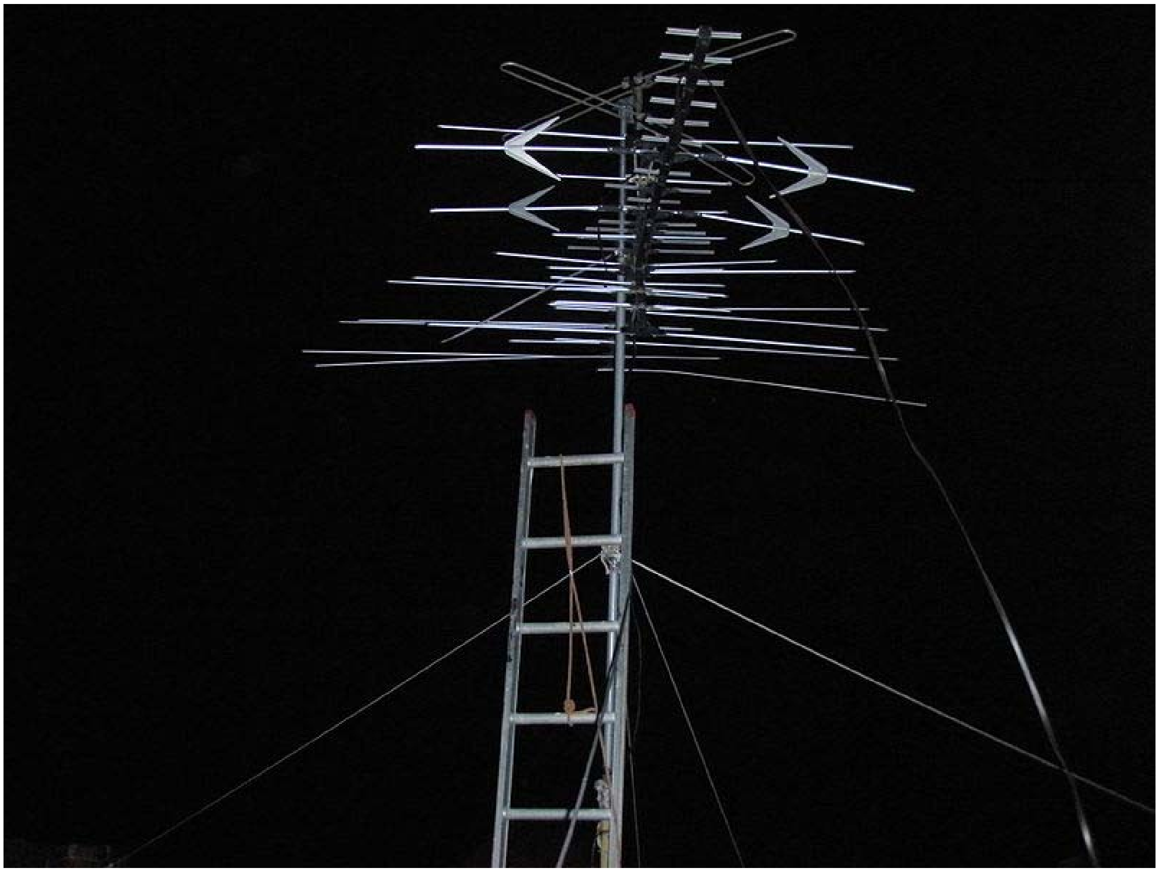

A Winegard HD-7084P 68 element VHF/UHF aerial antenna

A **television antenna**, or **TV aerial**, is an antenna specifically designed for the reception of over the air broadcast television signals, which are transmitted at frequencies from about 41 to 250 MHz in the VHF band, and 470 to 960 MHz in the UHF band in different countries. To cover this range antennas generally consist of multiple conductors of different lengths which correspond to the wavelength range the antenna is intended to receive. The length of the elements of a TV antenna are usually half the wavelength of the signal they are intended to receive. The wavelength of a signal equals the speed of light (c) divided by the frequency. The design of a television broadcast receiving antenna is the same for the older analog transmissions and the digital television transmissions which are replacing them Sellers often claim to supply a special "digital" or "high definition" antenna advised as a replacement for an existing analog antenna, even if satisfactory: this is misinformation to generate sales of unneeded equipment.

Simple/indoor

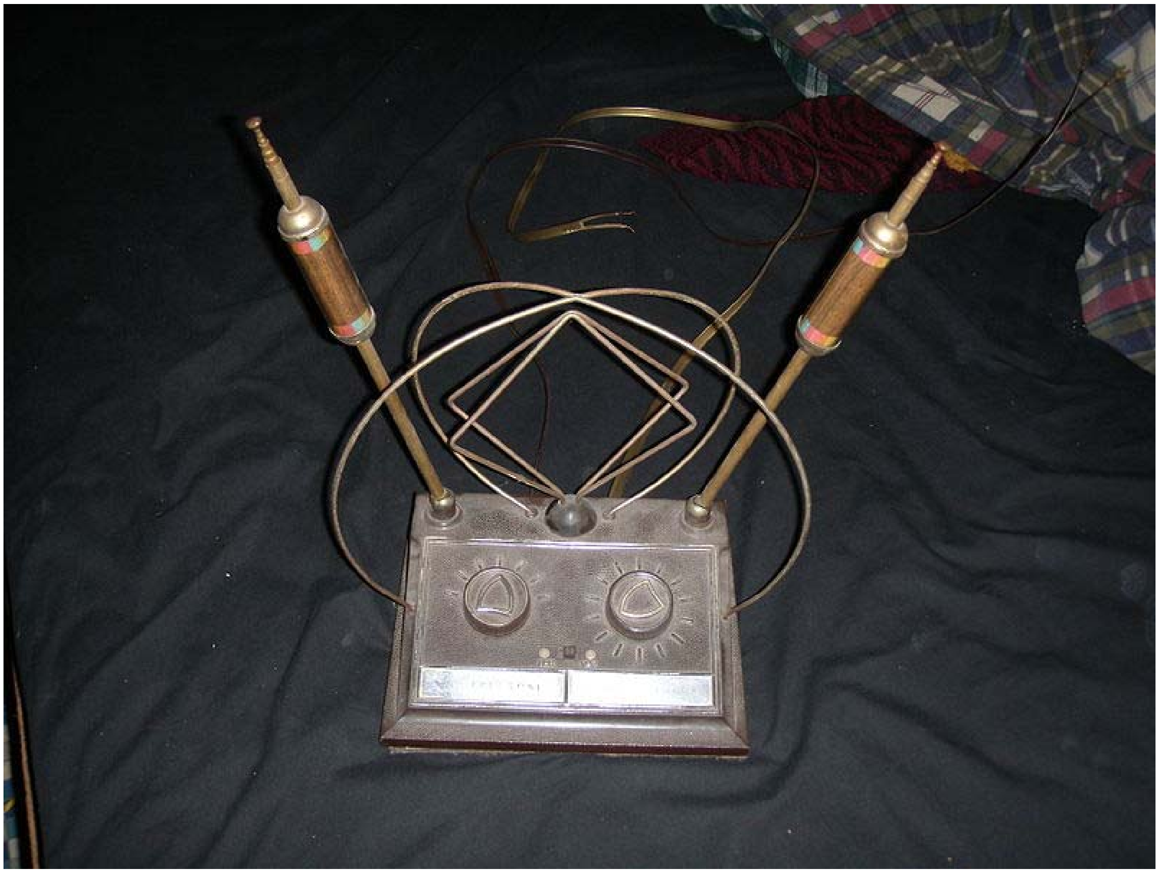

Very common "rabbit ears" set-top antenna of older model

Simple half-wave dipole VHF antennas or UHF loop antennas that are made to be placed indoors are often used for television (and VHF radio); these are often called "rabbit ears" or "bunny aerials". because of their appearance. The length of the telescopic "ears" can be adjusted by the user, and should be about one half of the wavelength of the signal for the desired channel. These are not as efficient as an aerial rooftop antenna since they are less directional and not always adjusted to the proper length for the desired channel. Dipole antennas are bi-directional, that is, they receive evenly forward and backwards, and also cover a broader band than antennas with more elements. This makes them less efficient than antennas designed to maximise the signal from a narrower angle in one direction.

Coupled with the poor placing, indoors and closer to the ground, they are much worse than multi-element rooftop antennas at receiving signals which are not very strong, although often adequate for nearby transmitters, in which case they may be adequate and cheap. These simple antennas are called set-top antennas because they are often placed on top of the television set or receiver.

The actual length of the ears is optimally about 91% of half the wavelength of the desired channel in free space. Quarter-wave television antennas are also used. These use a single element, and use the earth as a ground plane; therefore, no ground is required in the feed line.*a*

Outdoor

An aerial or rooftop antenna generally consists of multiple conductive elements that are arranged such that it is a directional antenna. The length of the elements is about one half of the signal wavelength. Therefore, the length of each element corresponds to a certain frequency.

In a combined VHF/UHF antenna the longer elements (for picking up VHF frequencies) are at the "back" of the antenna, relative to the device's directionality, and the much shorter UHF elements are in the "front", and the antenna works best when "pointing" to the source of the signal to be received. The smallest elements in this design, located in the "front", are UHF director elements, which are usually identical and give the antenna its directionality, as well as improving gain. The longest elements, located in the "back" of the antenna form a VHF phased array. Other long elements may be UHF reflectors Another common aerial antenna element is the corner reflector, a type of UHF reflector which increases gain and directionality for UHF frequencies.

An antenna can have a smaller or larger number of directors; the more directors it has (requiring a longer boom), and the more accurate their tuning, the higher its gain will be. For the commonly used Yagi antenna this is not a linear relationship. Antenna gain is the ratio of the signal received from the preferred direction to the signal from an ideal omnidirectional antenna. Gain is inversely proportional to the antenna's acceptance angle. The thickness of the rods on a Yagi antenna and its bandwidth are inversely proportional; thicker rods provide a wider band. Thinner rods are preferable to provide a narrower band, hence higher gain in the preferred direction; however, they must be thick enough to withstand wind.

Two or more directional rooftop antennas can be set up and connected to one receiver. Antennas designed for rooftop use are sometimes located in attics.

Sometimes television transmitters are organised such that all receivers in a given location need receive transmissions in only a relatively narrow band of the full UHF television spectrum and from the same direction, so that a single antenna provides reception from all stations.

Types of outdoor antenna

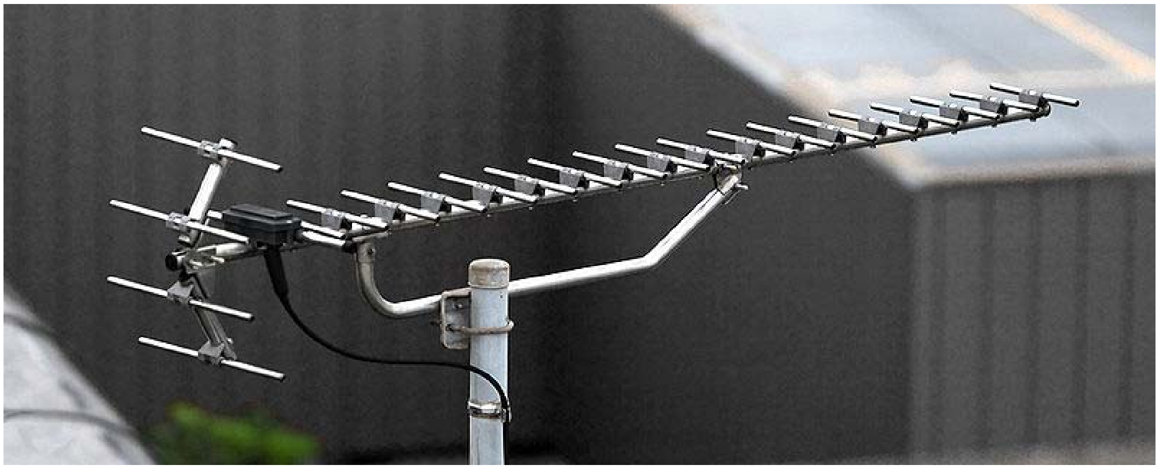

A UHF television antenna

An antenna pole setup in a chimney, reaching 35 feet (10.7 meters) off the ground

Small multi-directional: The smallest of all outdoor television antennas. They are designed to receive equal amounts of signal from all directions. These generally receive signals up to a maximum of thirty miles away from the transmitting station, greatly depending on the type. But, things such as large buildings or thick woods may greatly affect signal. They come in many different styles, ranging from small dishes to small metal bars, some can even mount on existing satellite dishes.

Medium multi-directional: A step up from the small multi-directional, these also receive signals from all directions. These usually require an amplifier in situations when long cable lengths are between the television receiver and the antenna. Styles are generally similar to small multi-directionals, but slightly larger.

Large multi-directional: These are the largest of all multi-directional outdoor television antennas. Styles include large "nets" or dishes, but can also greatly vary. Depending on the type, signal reception usually ranges from 30 to up to 70 miles.

Small directional: The smallest of all directional antennas, these antennas are multi-element antennas, typically placed on rooftops. This style of antenna receives signals generally equal to that of large multi-directionals. One advantage that small directionals hold, however, is that they can significantly reduce "ghosting" effects of television picture.

Medium directional: These antennas are the ones most often seen on suburban rooftops. Usually consisting of many elements, and slightly larger than the small directionals, these antennas are ideal for receiving television signals in suburban areas. Signal usually ranges from 30 to 60 miles away from the broadcasting station.

Large directional: The largest of all common outdoor television antennas, these antennas are designed to receive the weakest available stations in an area. Larger than the medium directional, this type of antenna consists of many elements and is usually used in rural areas, where reception is difficult. When used in conjunction with an amplifier, these antennas can usually pick up stations from 60 up to and over 100 miles, depending on the type.

The use of outdoor antennas with an amplifier can improve signal on low signal strength channels. If the signal quality is low repositioning the antenna onto a high mast will improve signal

Installation

A short antenna pole next to a house; this setup would only work well for receiving signals on that side of the house as they would not go through stone, especially.

Multiple Yagi TV aerials in Israel

Antennas are commonly placed on rooftops, and sometimes in attics. Placing an antenna indoors significantly attenuates the signal available to it. Directional antennas must be pointed at the transmitter they are receiving; in most cases great accuracy is not needed. In a given region it is sometimes arranged that all television transmitters are located in roughly the same direction and use frequencies space closely enough that a single antenna suffices for all. A single transmitter location may transmit signals for several channels.

Analog television signals are susceptible to ghosting in the image, multiple closely-spaced images giving the impression of blurred and repeated images of edges in the picture. This was due to the signal being reflected from nearby objects (buildings, tree, mountains); several copies of the signal, of different strengths and subject to different delays, are picked up. This was different for different transmissions. Careful positioning of the antenna could produce a compromise position which minimized the ghosts on different channels. Ghosting is also possible if multiple antennas connected to the same receiver pick up the same station, especially if the lengths of the cables connecting them to the splitter/merger were different lengths or the antennas were too close together. Analog television is being replaced by digital, which is not subject to ghosting.

Rooftop and other outdoor antennas

Aerials are attached to roofs in various ways, usually on a pole to elevate it above the roof. This is generally sufficient in most areas. In some places; however, such as a deep valley or near taller structures, the antenna may need to be placed significantly higher, using a lattice tower or mast.

The higher the antenna is placed, the better it will perform. An antenna of higher gain will be able to receive weaker signals from its preferred direction. Intervening buildings, topographical features (mountains), and dense forest will weaken the signal; in many cases the signal will be reflected such that a usable signal is still available. There are physical dangers inherent to high or complex antennas, such as the structure falling or being destroyed by the weather. There are also varying local ordinances which restrict and limit such things as the height of a structure without obtaining permits. For example, in the USA, the Telecommunications Act of 1996 allows any homeowner to install "An antenna that is designed to receive local television broadcast signals", but that "masts higher than 12 feet above the roof-line may be subject to local permitting requirements."

Indoor antennas

As discussed previously, antennas may be placed indoors where signals are strong enough to overcome antenna shortcomings. The antenna is simply plugged into the television receiver and placed conveniently, often on the top of the receiver ("set-top"). Sometimes the position needs to be experimented with to get the best picture. Indoor antennas can also benefit from RF amplification, commonly called a TV booster. Indoor antennas will never be an option in weak signal areas.

Attic installation

Sometimes it is desired not to put an antenna on the roof; in these cases, antennas designed for outdoor use are often mounted in the attic or loft, although antennas designed for attic use are also available. Putting an antenna indoors significantly decreases its performance due to lower elevation above ground level and intervening walls; however, in strong signal areas reception may be satisfactory. One layer of asphalt shingles, roof felt, and a plywood roof deck are considered to attenuate the signal to about half.

Multiple antennas, rotators

Two aerials setup on a roof. Spaced horizontally and vertically

It is sometimes desired to receive signals from transmitters which are not in the same direction. This can be achieved, for one station at a time, by using a rotator operated by an electric motor to turn the antenna as desired. Alternatively, two or more antennas, each pointing at a desired transmitter and coupled by appropriate circuitry, can be used. To prevent the antennas interfering with each other, the vertical spacing between the booms must be at least half the wavelength of the lowest frequency to be received (Distance=λ/2). The wavelength of 54 MHz (Channel 2) is 5.5 meters (λ x f = c) so the antennas must be a minimum of 2.25 meters, or ~89 inches apart. It is also important that the cables connecting the antennas to the signal splitter/merger be exactly the same length, to prevent phasing issues,which cause ghosting with analog reception. That is, the antennas might both pick up the same station; the signal from the one with the shorter cable will reach the receiver slightly sooner, supplying the receiver with two pictures slightly offset. There may be phasing issues even with the same length of down-lead cable. Bandpass filters or "signal traps" may help to reduce this problem.

For side-by-side placement of multiple antennas, as is common in a space of limited height such as an attic, they should be separated by at least one full wavelength of the lowest frequency to be received at their closest point.

Often when multiple antennas are used, one is for a range of co-located stations and the other is for a single transmitter in a different direction.

Safety

- TV antennas are large conductors of electricity and attract lightning, acting as a lightning rod. The use of a lightning arrestor is usual to protect against this. A large grounding rod connected to both the antenna and the mast or pole is required.

- Properly installed masts, especially tall ones, are guyed with galvanized cable; no insulators are needed. They are designed to withstand worst-case weather conditions in the area, and positioned so that they do not interfere with power lines if they fall.

- There is inherent danger in being on the rooftop of a house, required for installing or adjusting a television antenna.

Chapter 7

Radio Masts and Towers

Masts of the Rugby VLF transmitter in England

A dismantled radio mast in sections

Radio masts and towers are, typically, tall structures designed to support antennas (also known as aerials) for telecommunications and broadcasting, including television. They are among the tallest man-made structures. Similar structures include electricity pylons and towers for wind turbines.

Masts are sometimes named after the broadcasting organisations that use them, or after a nearby city or town.

The Warsaw Radio Mast was the world's tallest supported structure on land, but it collapsed in 1991, leaving the KVLY/KTHI-TV mast as the tallest.

In the case of a mast radiator or radiating tower, the whole mast or tower is itself the transmitting antenna.

Mast or tower?

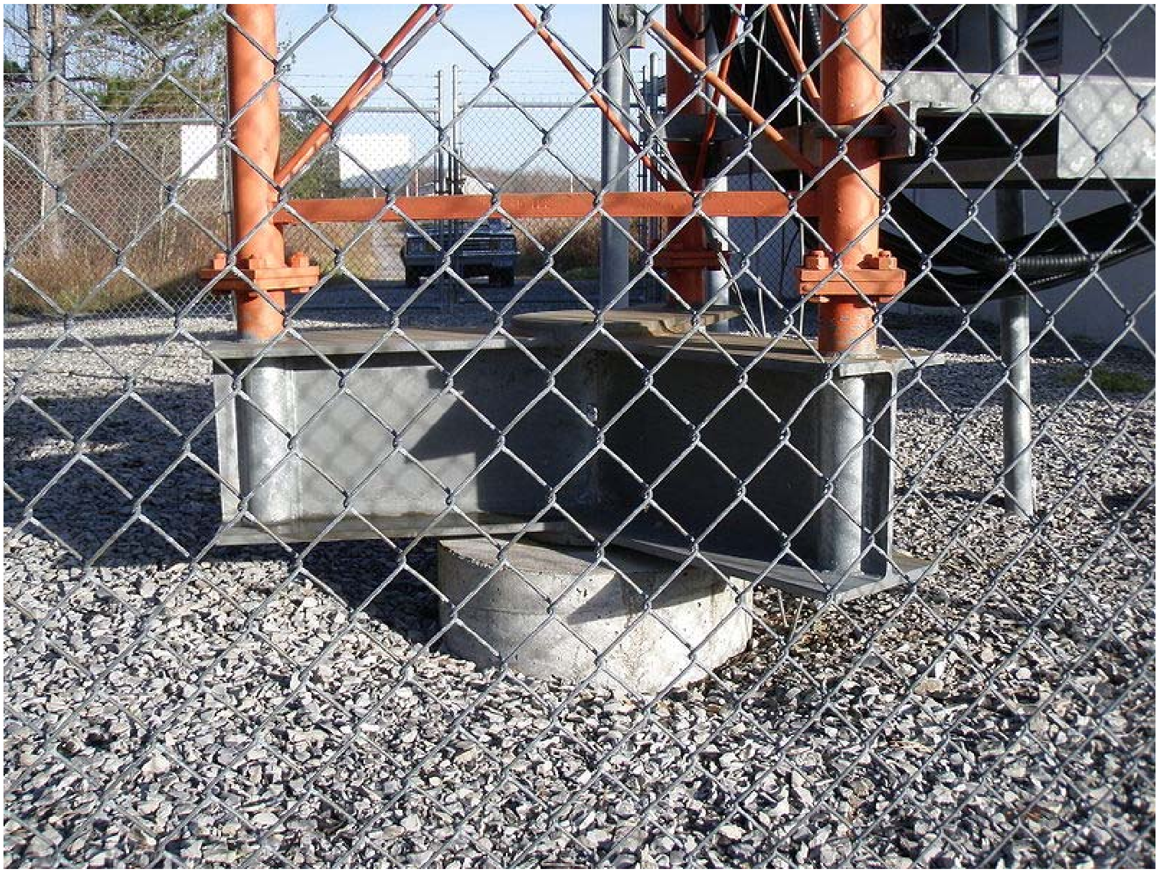

A radio mast base showing how virtually all support is provided by the guy-wires

The terms "mast" and "tower" are often used interchangeably. However, in structural engineering terms, a tower is a self-supporting or cantilevered structure, while a mast is held up by stays or guys. By contrast, in broadcast engineering, a tower is an antenna structure attached to the ground, whereas a mast is a vertical antenna support mounted on some other structure (which itself may be a tower, a building, or a vehicle). Masts (to use the civil engineering terminology) tend to be cheaper to build but require an extended area surrounding them to accommodate the guy wires. Towers are more commonly used in cities where land is in short supply.

There are a few borderline designs which are partly free-standing and partly guyed. For example:

- The Gerbrandy tower consists of a self-supporting tower with a guyed mast on top.
- The few remaining Blaw-Knox towers do the opposite: they have a guyed lower section surmounted by a freestanding part.
- Zendstation Smilde a tall tower with a guyed mast on top (guys go to ground)

- Torre de Collserola a guyed tower, with a guyed mast on top. (Tower portion is not free-standing.)

Materials

Steel lattice

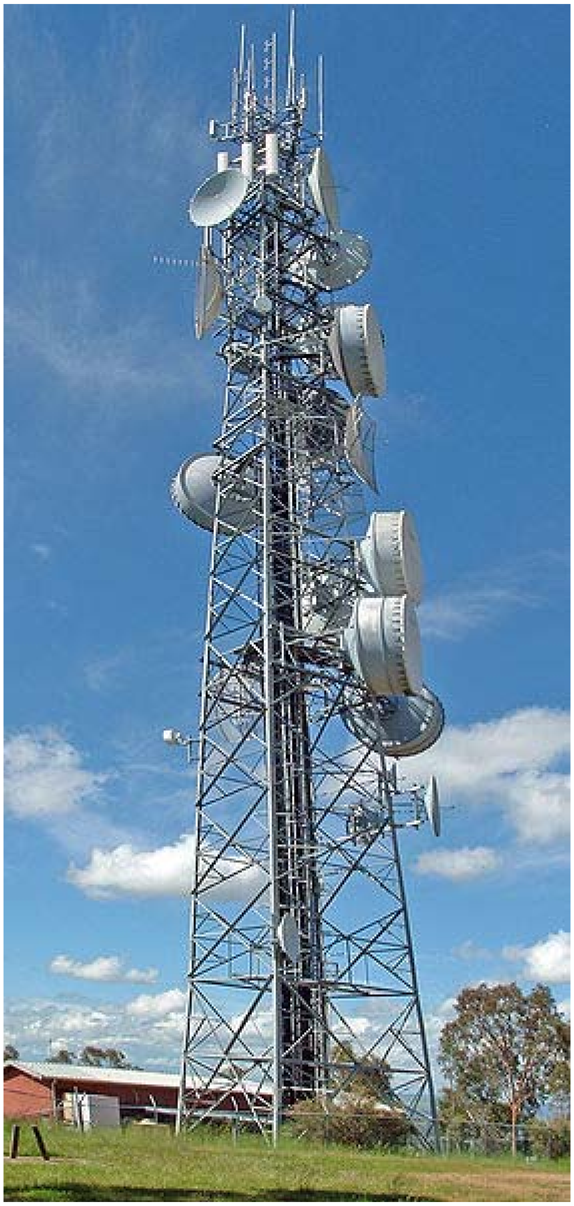

Steel lattice tower

The steel lattice is the most widespread form of construction. It provides great strength, low weight and wind resistance, and economy in the use of materials. Lattices of triangular cross-section are most common, and square lattices are also widely used.

When built as a stayed mast, usually the whole mast is parallel-sided. One exception is the Blaw-Knox type.

When built as a tower, the structure may be parallel-sided or taper over part or all of its height. When constructed of several sections which taper exponentially with height, in the manner of the Eiffel Tower, the tower is said to be an Eiffelized one. The Crystal Palace tower in London is an example.

Tubular steel

Guyed masts are sometimes also constructed out of steel tubes. This construction type has the advantage that cables and other equipment is protected from weather influence and that the structure may look nicer. They are mainly used for FM-/TV-broadcasting, but sometimes also as mast radiator, wherefore the big mast of Mühlacker transmitting station is a good example. A disadvantage of this mast type is that it is much more affected by winds than masts with open bodies. In fact several tubular guyed masts collapsed: in the UK, these were masts the Emley Moor and Waltham TV stations, which collapsed in the 1960s, in Germany that of Bielstein transmitter, which collapsed in 1985. Not in all countries such masts were built: while in Germany, France, UK, Czech, Slovakia and the former Soviet Union multiple tubular guyed masts were built, there are nearly none in Poland and North America.

At several cities in Russia and Ukraine, between 1960 and 1965 several tubular guyed masts with crossbars running from the mast structure to the guys were built. All these masts are exclusively used for FM and TV transmission and are except of the mast in Vinnytsia between 150 and 200 metres tall. The crossbars of these masts are equipped with a gangway and are equipped with smaller antennas. Their main purpose is oscillation damping.

First modern TV Tower in Stuttgart

Reinforced concrete

Reinforced concrete towers are relatively expensive to build but provide a high degree of mechanical rigidity in strong winds. This can be important when antennas with narrow beamwidths are used, such as those used for microwave point-to-point links, and when the structure is to be occupied by people.

In the 1950s, AT&T built numerous concrete towers, more resembling silos than towers, for its first transcontinental microwave route. Many are still in use today.

In Germany and the Netherlands most towers constructed for point-to-point microwave links are built of reinforced concrete, while in the UK most are lattice towers.

Concrete towers can form prestigious landmarks, such as the CN Tower in Toronto. As well as accommodating technical staff, these buildings may have public areas such as observation decks or restaurants.

The Stuttgart TV tower was the first tower in the world to be built in reinforced concrete. It was designed in 1956 by the local civil engineer Fritz Leonhardt.

Tokyo Tower

Fibreglass

Fibreglass poles are occasionally used for low-power non-directional beacons or medium-wave broadcast transmitters.

Wood

There are fewer wooden towers now than in the past. Many were built in the UK during World War II because of a shortage of steel. In Germany before World War II wooden towers were used at nearly all medium-wave transmission sites, but all of these towers have since been demolished, except for the Gliwice Radio Tower.

Ferryside Relay is an example of a TV relay transmitter using a wooden pole.

Other types of antenna supports and structures

Poles

Shorter masts may consist of a self-supporting or guyed wooden pole, similar to a telegraph pole. Sometimes self-supporting tubular galvanized steel poles are used: these may be termed monopoles.

Buildings

In some cases, it is possible to install transmitting antennas on the roofs of tall buildings. In North America, for instance, there are transmitting antennas on the Empire State Building, the Willis Tower ,and formerly on the World Trade Center towers. When the buildings collapsed, several local TV and radio stations were knocked off the air until backup transmitters could be put into service. Such facilities also exist in Europe, particularly for portable radio services and low-power FM radio stations.

Disguised cell-sites

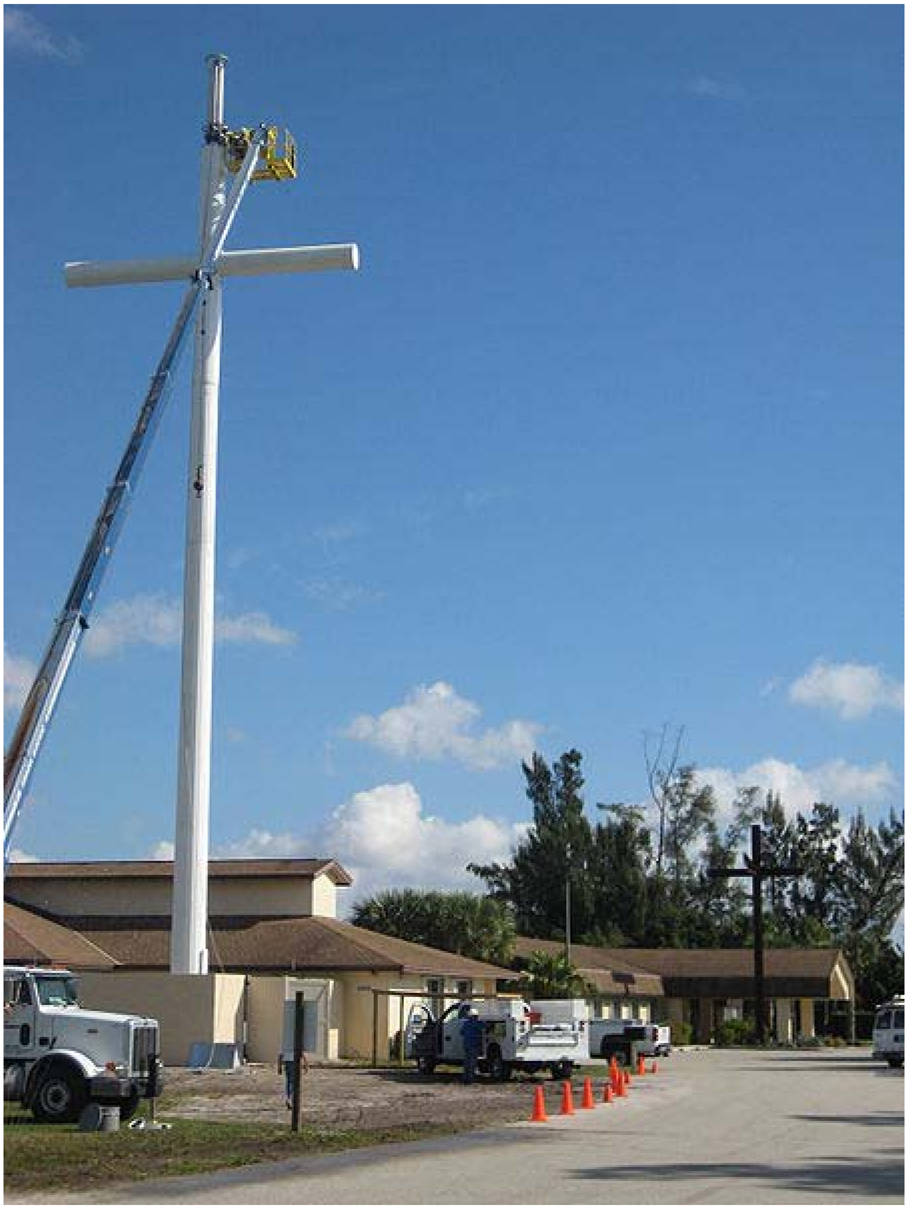

Completed in December 2009 at Epiphany Lutheran Church in Lake Worth, Florida, this 100' tall cross conceals equipment for T-Mobile.

Many people view bare cellphone towers as ugly and an intrusion into their neighbourhoods. Even though people increasingly depend upon cellular communications, they are opposed to the bare towers spoiling otherwise scenic views. Many companies offer to 'hide' cellphone towers in, or as, trees, church towers, flag poles, water tanks and other features. There are many providers that offer these services as part of the normal tower installation and maintenance service. These are generally called "stealth towers" or "stealth installations".

The level of detail and realism achieved by disguised cellphone towers is remarkably high; for example, such towers disguised as trees are nearly indistinguishable from the real thing, even for local wildlife (who additionally benefit from the artificial flora). Such towers can be placed unobtrusively in national parks and other such protected places, such as towers disguised as cacti in Coronado National Forest.

Even when disguised, however, such towers can create controversy; a tower doubling as a flagpole attracted controversy in 2004 in relation to the U.S. Presidential campaign of that year, and highlighted the sentiment that such disguises serve more to allow the installation of such towers in subterfuge away from public scrutiny rather than to serve towards the beautification of the landscape.

Mast radiators

A mast radiator is a radio tower or mast in which the whole structure works as an antenna. It is used frequently as a transmitting antenna for long or medium wave broadcasting.

Structurally, the only difference is that a mast radiator may be supported on an insulator at its base. In the case of a tower, there will be one insulator supporting each leg.

Telescopic, pump-up and tiltover towers

A special form of the radio tower is the *telescopic mast*. These can be erected very quickly. Telescopic masts are used predominantly in setting up temporary radio links for reporting on major news events, and for temporary communications in emergencies. They are also used in tactical military networks. They can save money by needing to withstand high winds only when raised, and as such are widely used in amateur radio.

Telescopic masts consist of two or more concentric sections and come in two principal types:

- Pump-up masts are often used on vehicles, and are raised to their full height pneumatically or hydraulically. They are usually only strong enough to support fairly small antennas.
- Telescopic lattice masts are raised by means of a winch, which may be powered by hand or an electric motor. These tend to cater for greater heights and loads than the pump-up type. When retracted, the whole assembly can sometimes be lowered to a horizontal position by means of a second tiltover winch. This enables antennas to be fitted and adjusted at ground level before winching the mast up.

Balloons and kites

A tethered balloon or a kite can serve as a temporary support. It can carry an antenna or a wire (for VLF, LW or MW) up to an appropriate height. Such an arrangement is used occasionally by military agencies or radio amateurs. The American broadcasters TV Martí broadcast a television program to Cuba by means of such a balloon.

Other special structures

For two VLF transmitters wire antennas spun across deep valleys are used. The wires are supported by small masts or towers or rock anchors. The same technique was also used for the Criggion VLF transmitter.

For ELF transmitters ground dipole antennas are used. Such structures require no tall masts. They consist of two electrodes buried deep in the ground at least a few dozen kilometres apart. From the transmitter building to the electrodes, overhead feeder lines run. These lines look like power lines of the 10 kV level, and are installed on similar pylons.

Design features

Economic and aesthetic considerations

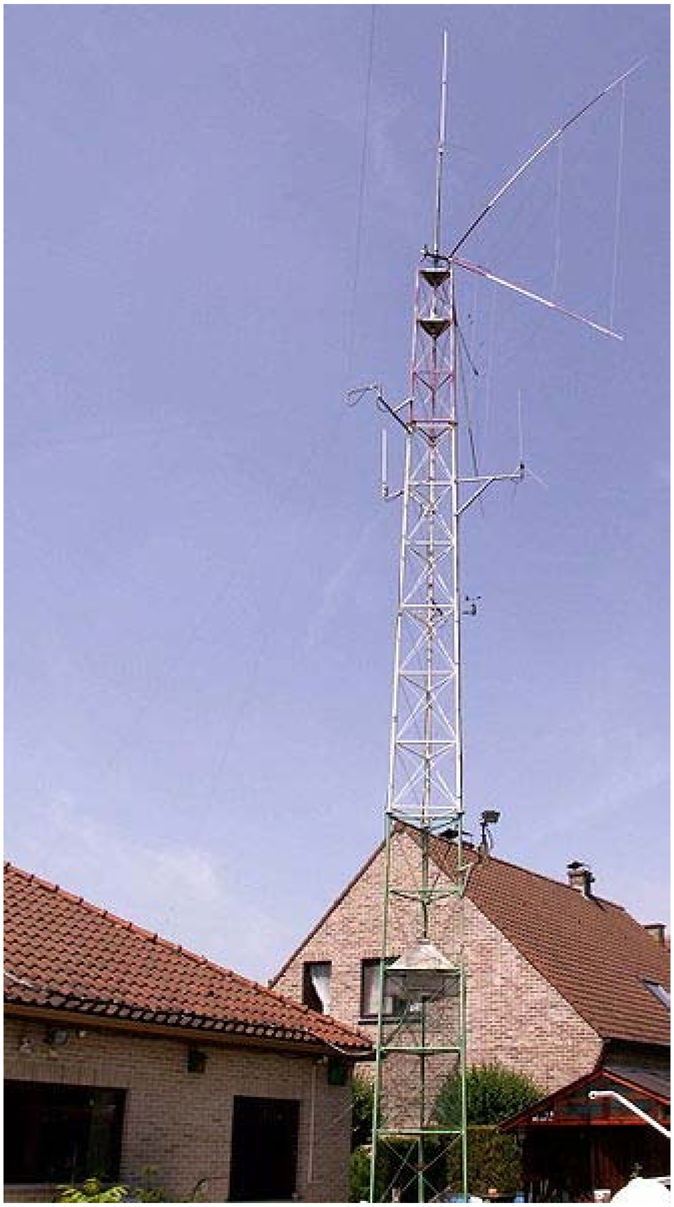

A radio amateur's do it yourself steel-lattice tower

Felsenegg-Girstel TV-tower

Uetliberg TV-tower

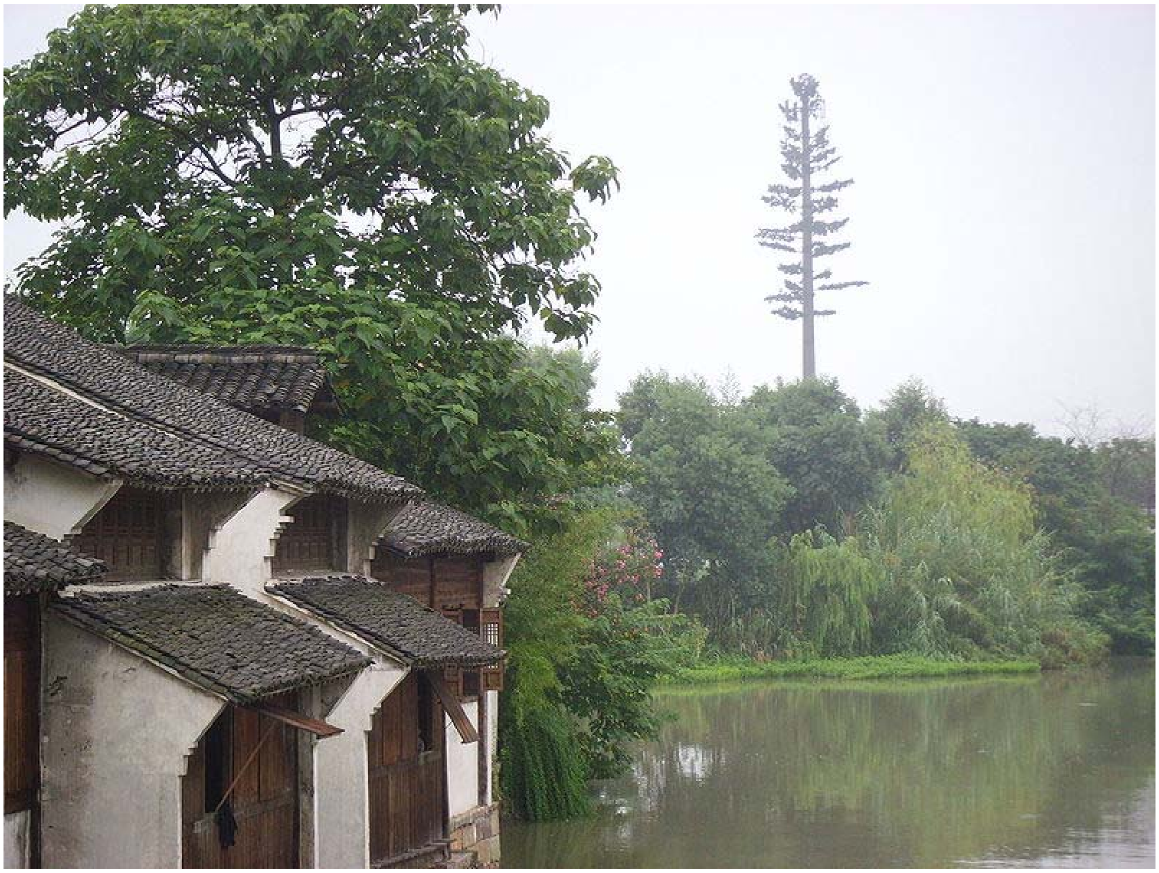

Communications tower, camouflaged as a slim tree

- The cost of a mast or tower is roughly proportional to the square of its height.
- A guyed mast is cheaper to build than a self-supporting tower of equal height.
- A guyed mast needs additional land to accommodate the guys, and is thus best suited to rural locations where land is relatively cheap. An unguyed tower will fit into a much smaller plot.
- A steel lattice tower is cheaper to build than a concrete tower of equal height.
- Two small towers may be less intrusive, visually, than one big one, especially if they look identical.
- Towers look less ugly if they and the antennas mounted on them appear symmetrical.
- Concrete towers can be built with aesthetic design - and they are, especially in Continental Europe. They are sometimes built in prominent places and include observation decks or restaurants.

Masts for HF/shortwave antennas

For transmissions in the shortwave range, there is little to be gained by raising the antenna more than a few wavelengths above ground level. Shortwave transmitters rarely use masts taller than about 100 metres.

Access for riggers

Because masts, towers and the antennas mounted on them require maintenance, access to the whole of the structure is necessary. Small structures are typically accessed with a ladder. Larger structures, which tend to require more frequent maintenance, may have stairs and sometimes a lift, also called a service elevator.

Aircraft warning features

Tall structures in excess of certain legislated heights are often equipped with aircraft warning lamps, usually red, to warn pilots of the structure's existence. In the past, ruggedized and under-run filament lamps were used to maximize the bulb life. Alternatively, neon lamps were used. Nowadays such lamps tend to use LED arrays.

Height requirements vary across states and countries, and may include additional rules such as requiring a white flashing strobe in the daytime and pulsating red fixtures at night. Structures over a certain height may also be required to be painted with contrasting color schemes such as white and orange or white and red to make them more visible against the sky.

Light pollution and nuisance lighting

In some countries where light pollution is a concern, tower heights may be restricted so as to reduce or eliminate the need for aircraft warning lights. For example in the United States the 1996 Telecommunications Act allows local jurisdictions to set maximum heights for towers, such as limiting tower height to below 200 feet and therefore not requiring aircraft illumination under U.S. Federal Communications Commission (FCC) rules. The limit is more commonly set to 190 or 180 feet to allow for masts extending above the tower.

Wind-induced oscillations

One problem with radio masts is the danger of wind-induced oscillations. This is particularly a concern with steel tube construction. One can reduce this by building cylindrical shock-mounts into the construction. One finds such shock-mounts, which look like cylinders thicker than the mast, for example, at the radio masts of DHO38 in Saterland. There are also constructions, which consist of a free-standing tower (usually from reinforced concrete), onto which a guyed radio mast is installed. The best known such construction is the Gerbrandy Tower in Lopik (the Netherlands). Further towers of this building method can be found near Smilde (the Netherlands) and Fernsehturm, Waldenburg, Baden-Württemberg, Germany).

Hazard to birds

Radio, television and cell towers have been documented to pose a hazard to birds. Reports have been issued documenting known bird fatalities and calling for research to find ways to minimize the hazard that communications towers can pose to birds.

Law

Since June 2010, Telecom operators in the USA can erect new telecom masts or towers as the government has lifted the moratorium, which was earlier placed on the issuance of permits for the construction of telecommunication towers.

Chapter 8

Omnidirectional Antenna & Directional Antenna

Omnidirectional Antenna

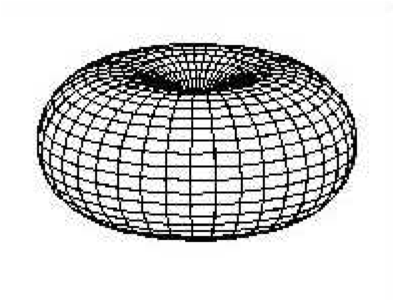

Omnidirectional radiation pattern of a vertical dipole antenna. In this graph the antenna is at the center of the "donut". Radial distance from the center represents the power radiated in that direction. The power radiated is maximum in horizontal directions, dropping to zero directly above and below the antenna.

An **omnidirectional antenna** is an antenna which radiates power uniformly in all directions in one plane, with the radiated power decreasing with elevation angle above or below the plane, dropping to zero on the antenna's axis. This radiation pattern is often described as "donut shaped". Note that this is different from an isotropic antenna, in which the gain is uniform in *all* directions ("spherical"). Omnidirectional antennas oriented vertically are widely used for nondirectional antennas on the surface of the Earth because they radiate equally in all horizontal directions, while the power radiated drops off with elevation angle so little radio energy is aimed into the sky or down toward the earth and wasted. Omnidirectional antennas are widely used for radio broadcasting antennas, and in mobile devices that use radio such as cell phones, FM radios, walkie-talkies, Wifi, cordless phones, GPS as well as for base stations that communicate with mobile radios, such as police and taxi dispatchers and aircraft communications.

Types

Common types of low gain omnidirectional antennas are the whip antenna, "Rubber Ducky", ground plane antenna, vertically oriented dipole antenna, discone antenna, mast radiator and the horizontal loop antenna (or halo antenna) (Sometimes known colloquially as a 'circular aerial' because of the shape).

Higher gain omnidirectional antennas can also be built. "Higher gain" in this case means that the antenna radiates less energy at higher and lower elevation angles and more in the horizontal directions. High gain omnidirectional antennas are generally realized using collinear dipole arrays. These arrays consist of half-wavelength dipoles with a phase shifting method between each element that ensures the current in each dipole is in phase. The Coaxial Colinear or COCO antenna uses transposed coaxial sections to produce in-phase half-wavelength radiatiors. A Franklin Array uses short U-shaped half-wavelength sections whose radiation cancels in the far-field to bring each half-wavelength dipole section into equal phase.

Types of higher gain omnidirectional antennas are the Coaxial Colinear (COCO) antenna and Omnidirectional Microstrip Antenna (OMA).

Some planar antennas (constructed from printed circuit board) are omnidirectional antennas.

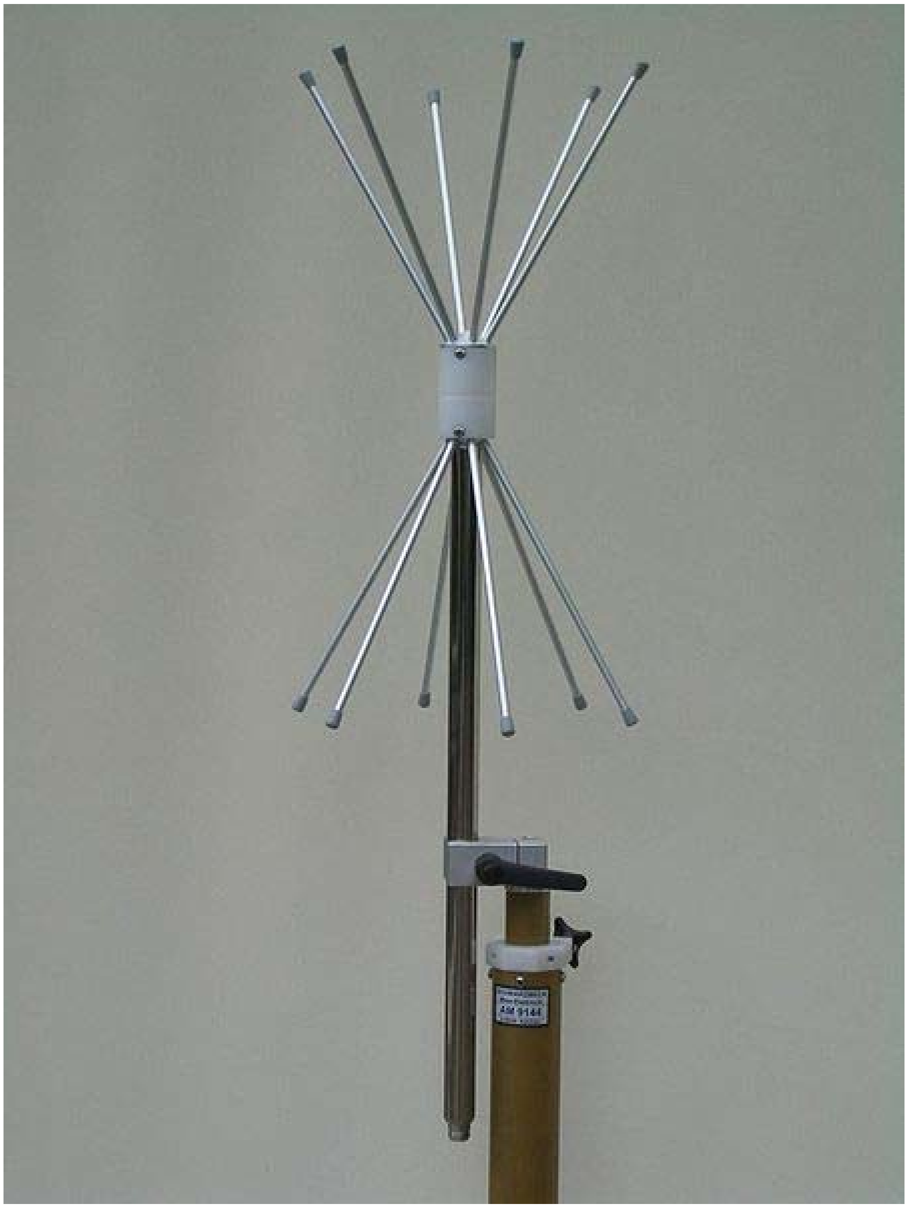

Vertical polarized VHF- UHF biconical antenna 170 – 1100 MHz with omni directional H-plane pattern.

Analysis

Omnidirectional radiation patterns are produced by the simplest practical antennas, monopole and dipole antennas, consisting of one or two straight rod conductors on a common axis. Antenna gain (G) is defined as antenna efficiency (e) multiplied by antenna directivity (D) which is expressed mathematically as: $G = eD$. A useful relationship between omnidirectional radiation pattern directivity (D) in decibels and half-power beamwidth (HPBW) based on the assumption of a $\sin b\theta / b\theta$ pattern shape is:

$$D = 10\log_{10}\left(\frac{101.5}{HPBW - 0.00272(HPBW)^2}\right)\ dB$$

Directional Antenna

Log-periodic dipole array

A **directional antenna** or **beam antenna** is an antenna which radiates greater power in one or more directions allowing for increased performance on transmit and receive and reduced interference from unwanted sources. Directional antennas like yagi antennas provide increased performance over dipole antennas when a greater concentration of radiation in a certain direction is desired.

All practical antennas are at least somewhat directional, although usually only the direction in the plane parallel to the earth is considered, and practical antennas can easily be omnidirectional in one plane.

The most common types are the yagi antenna, the log-periodic antenna, and the corner reflector, which are frequently combined and commercially sold as residential TV antennas. Cellular repeaters often make use of external directional antennas to give a far greater signal than can be obtained on a standard cell phone. Satellite Television receivers usually use parabolic antennas.

For long and medium wavelength frequencies, tower arrays are used in most cases as directional antennas.

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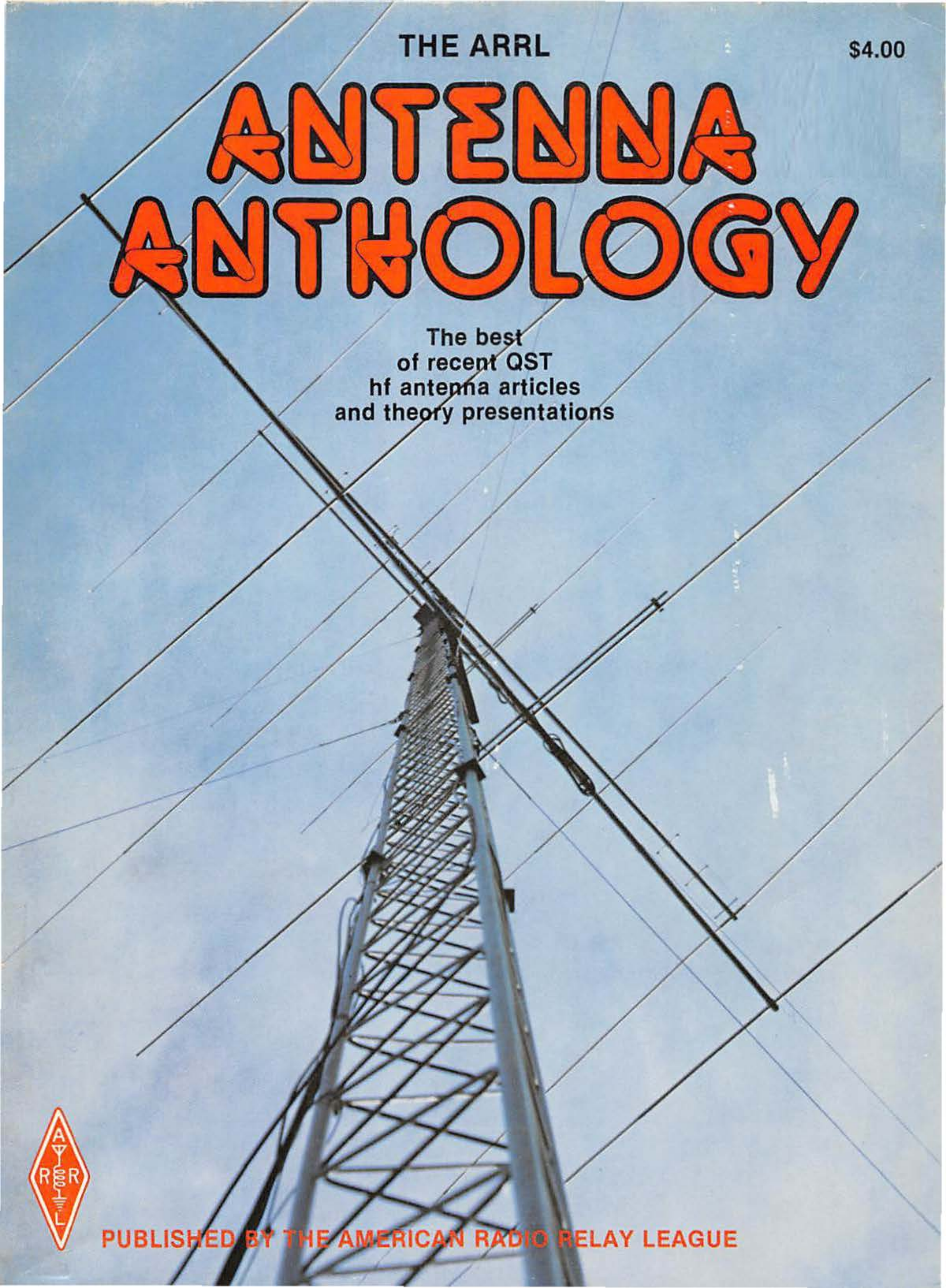

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Foreword

What type of amateur antenna best suits your needs? Does the available space on your property permit the installation of an effective DX antenna? Is there a compromise antenna system that will provide acceptable results over short and long distances while being reasonable in price and modest in complexity? No doubt you have come to grips with these matters repeatedly since obtaining your amateur license. So, where does one turn to find the answers to these sometimes perplexing questions? What one pre-eminent source might one consult among all of the antenna booklets published for amateurs? Why, *QST*, naturally!

This anthology contains what the ARRL hq. staff considers the best of the *QST* antenna articles and theory presentations in recent years. The contributions of numerous amateur authors and designers are contained in this volume for your convenience. This publication was developed not only to serve as a compilation of good articles, but to reach those amateurs who do not have access to past issues of the League's official monthly journal, *QST*.

The editors of this booklet have attempted to select the types of antennas that have greatest appeal to those who like to construct their own radiators, and for the many amateurs who can't justify the expense of purchasing commercial counterparts. A book of this type contains something for everyone who enjoys building and experimenting with antennas. But, if you aren't a builder you will still enjoy the hours of interesting reading provided by these works.

We wish to extend our gratitude to those *QST* authors whose articles have been selected for publication in this volume. Their enthusiasm, ability and generosity typifies clearly what Amateur Radio is all about. Should you have some original antenna ideas of proven performance, send an article to the ARRL, describing your work. Not only may your story be published in *QST* — it might appear in a future edition of this book.

Richard L. Baldwin, W1RU
General Manager

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Chapter 1

Vertical Antennas

One of the most practical antennas for use where limited space exists is the vertical. This type of antenna is particularly useful to amateurs who live in dense urban areas where city lots are traditionally small. The same general restriction prevails for those who dwell in apartment buildings. In such locations it is often easier to go "up" with an antenna than to erect one horizontally. But the virtues of vertical antennas extend beyond the foregoing considerations: "Verticals," as they often are called, are relatively inexpensive, easy to erect and are capable of performing well for local (stateside) and DX work. A vertical antenna exhibits a low angle of radiation when worked against a good ground system. This makes it an effective DX type of antenna.

This chapter contains reprints of some popular vertical-antenna systems that have appeared in *QST* during recent years. For the most part, the presentations contained herein have been "lifted" in their entirety, thus making it unnecessary for the reader to research the original articles for additional information.

A Two-Band Vertical for the Novice

Build this inexpensive Novice antenna. It is easy to construct and is made from readily available materials.

Knowing of a Novice who had space problems, the author set out to design an antenna for him that could be used on 40 and 15 meters. His previous antenna was a horizontal "V" whose performance wasn't worth the time it took to put it up. Because of his narrow property, the angle between the two wires was only around 40 degrees, no doubt causing considerable signal cancelation. Horizontal antennas were ruled out, so the best antenna for him was a vertical.

Knowing (or caring) little about multiband trap-loaded antennas, it was decided the simplest antenna would be a quarter-wavelength vertical on 40 meters. After a little paper work, and using formulas given in *The ARRL Antenna Book*, the correct length would be 31 feet 10 inches (9.70 m) for 7.175 MHz. This length would also work as a 3/4-wavelength antenna on 15 meters, providing two-band coverage. However, a 32-foot (9.75-m) vertical antenna made roof-mounting too difficult! Mounting the vertical to the side of the house alleviated many guying and support problems.

Materials

The first concern was what to use for antenna materials. Being almost 32 feet high, the vertical would need strength, so the writer thought of steel tubing, but that was much too expensive. With conduit there aren't enough sizes offered, and that left only one more material — aluminum tubing. The latter comes in just about any size desired, and the author had no trouble in finding just what he wanted. Going to the nearest aluminum dealer, the author found his stock to be more than ample.[1]

In order to keep the cost minimal, the author decided to make the base piece from 1-inch (25-mm) diameter thin-wall tubing. Into 12 feet (3.66 m) of this was inserted a 12-foot piece of 7/8-inch (22-mm) diameter thin-wall tubing. This piece was telescoped 2 feet (0.610 m), then bolted and clamped (after the end had been slit twice by a pair of tin snips). It was necessary to use hose clamps on the tubing because the galvanized bolts didn't provide a good bond between the pieces. The top section was 13-1/2-foot (4.11-m) piece of 3/4-inch (19-mm) diameter thin-wall tubing inserted far enough into the lower piece to make the overall antenna length about 31 feet, 10 inches (9.70 m). Because of its large size, all the work must be done while the antenna is

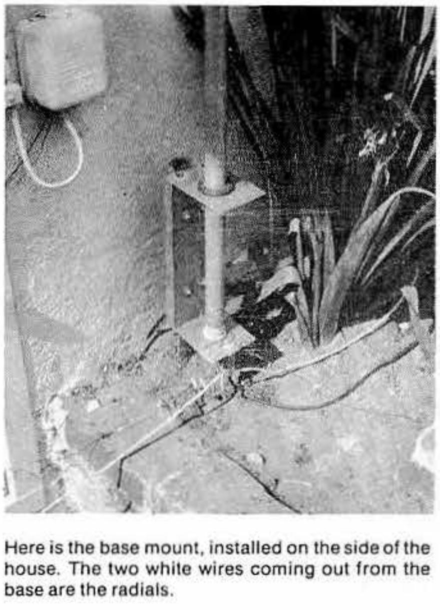

Here is the base mount, installed on the side of the house. The two white wires coming out from the base are the radials.

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[1] [Editor's Note: TV mast material is also well suited for verticals and comes in 10-foot (3.05-m) lengths, either steel or, preferably, aluminum.]

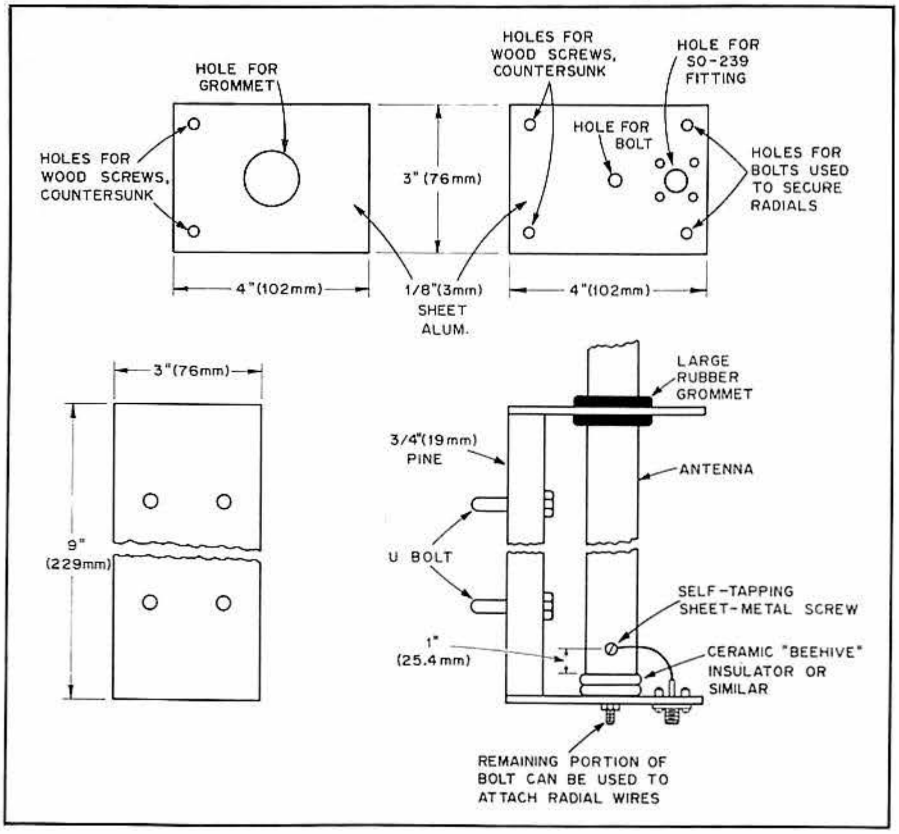
HOLE FOR GROMMET
HOLES FOR WOOD SCREWS, COUNTERSUNK
HOLES FOR WOOD SCREWS, COUNTERSUNK
HOLE FOR SO-239 FITTING
HOLE FOR BOLT
HOLES FOR BOLTS USED TO SECURE RADIALS
3" (76mm)
4"(102mm)
1/8"(3mm) SHEET ALUM.
4"(102mm)
3"(76mm)
9" (229mm)
LARGE RUBBER GROMMET
3/4"(19mm) PINE
ANTENNA
U BOLT
SELF-TAPPING SHEET-METAL SCREW
1" (25.4mm)
CERAMIC "BEEHIVE" INSULATOR OR SIMILAR
REMAINING PORTION OF BOLT CAN BE USED TO ATTACH RADIAL WIRES

Fig. 1 — Details for making the base-mounting section of the vertical.

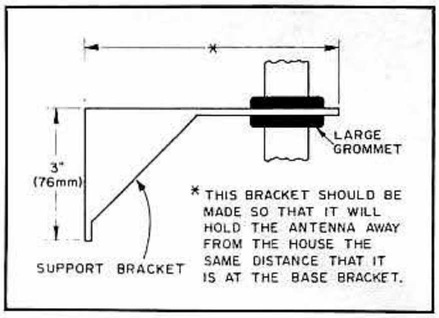
*
LARGE GROMMET
3" (76mm)
* THIS BRACKET SHOULD BE MADE SO THAT IT WILL HOLD THE ANTENNA AWAY FROM THE HOUSE THE SAME DISTANCE THAT IT IS AT THE BASE BRACKET.
SUPPORT BRACKET

Fig. 2 — Details for the support bracket.

lying on the ground. Then, the antenna must be disassembled and put up piece by piece. (Do not attempt to put the antenna up in one piece! While the weight isn't excessive, the tubing cannot stand the strain.)

Putting It Up

The original base bracket was made from 3/4-inch (19-mm) pine, but during the first rain the wood got wet and the bracket turned out to be a very poor insulator. So the unit was redesigned to use two pieces of 1/8-inch (3-mm) thick sheet aluminum, a large grommet, and a ceramic standoff insulator (see Fig. 1).

Assembling the two-band vertical was quite simple. First, a 4-foot (1.22-m) stake was driven into the ground about 2-1/2 feet (0.76 m), and about four or five inches (102 or 127 mm) away from the side of the house. Next, the bottom section (with the bracket attached) was slipped over the stake and tightened in place with the U bolts. Then the second section was inserted into the first, clamped and bolted in place. A support bracket was made from scrap aluminum, and a large grommet was installed on it to insulate the antenna from the brace (see Fig. 2). This assembly was then attached to the side of the house (near the gable) with wood screws. Last, the third section was forced through the grommet in the second bracket, and was then inserted into the second piece and clamped. (If adjustment of resonance is desired, it is better not to bolt the final section). A suitable cap was mounted on top of the antenna to keep out moisture.

Tune Up

RG-58/U coax was then connected between the transmitter and antenna with an SWR bridge in the line, and power was applied at 7175 kHz. The SWR was found to be 3:1. This was without any ground system on the antenna. In order to obtain a better match and reduce the SWR, it was apparent that a ground system was required.

According to *The ARRL Antenna Book*, two methods of making a suitable ground system can be used. One way is to connect the coax outer shield directly to ground at the base of the antenna, via a ground rod. However, this doesn't work too well unless the soil is extremely conductive (his wasn't). The other method is to make up some sort of artificial ground in the form of radials.

The author cut a radial from some surplus wire to the same length as the vertical section, attached the radial to the base plate and the SWR dropped to 2:1. Unknown to the author at the time, *The Antenna Book* says that the radials should be 2.5 percent longer than the vertical itself, so actually, they should have been made 32-feet 7-3/4-inches (9.95-m) long. A second radial, similar to the first, was attached and the SWR dropped further (to about 1.4:1). When the soil was wet, such as after a rain or after watering, the SWR takes a nose dive to less than 1.2:1. Since the property space was limited, two radials were all that could be used. Ideally, the most perfect system would consist of a metal disk, one quarter wavelength in radius, buried a few inches below the earth's surface, but this approach is rather impractical! But if the antenna was to be erected in an area *away* from buildings, and guyed, a ground system could be made of chicken wire or other similar material. However, the more radials, the better the artificial ground. Also, they should be laid out in as nearly a spoke-like pattern as possible. Hy-Gain recommended for their AVQ series antennas that a radial system be used consisting of at least two radials for *each* band used. However, for this installation the 40-meter radials operate on their third harmonic at 15 meters, requiring but one set of wires.[2]

The length specified makes the antenna resonant at about 7175 kHz on 40 meters. On 15 meters, at the third harmonic, the antenna is resonant at about 21,425 kHz, but power was applied as low as 21,105 kHz,

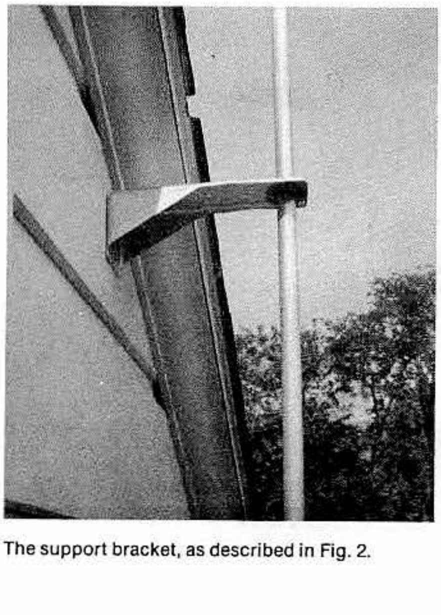

The support bracket, as described in Fig. 2.

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[2] [Editor's note: Actually, *any* radials, regardless of length, will help the performance of the system. Also when used on 15 meters, the antenna would be three quarter wavelengths long with low-impedance feed, approximately 50 ohms. However, the angle of radiation from the antenna will be higher than that of a quarter-wavelength vertical.]

and the SWR appeared to be only 1.4:1, well within tolerable limits. Bandwidth on both Novice bands was essentially flat.

Additional Information

Total cost will depend greatly on the individual's ability to scrounge parts. If the builder prefers to purchase the principal materials, this list will be useful.

3 — pieces thin-wall aluminum tubing, 1- (25-mm), 7/8- (22-mm), and 3/4-inch (19-mm) diameters. 12 (3.66 m), 12 (3.66 m) and 13-1/2 feet (4.11 m) long, respectively.
2 — U bolts.
1—SO-239 connector.

The other material, including three bolts and nuts, six wood screws, two grommets, two hose clamps, wood and aluminum for brackets, ground stake, and cap will vary from no cost to a few dollars, dependent on available materials. If used or surplus tubing is available one could save a substantial amount of money.

In this instance, the top of the antenna extends about 16 feet (4.88 m) above the peak of the roof, but because of the bracing no guy wires were necessary. If the antenna is to be erected in a high-wind area, guys made from nonconducting monofilament fishing line (or other nonconducting line) could be used.

The owner has received nothing but glowing reports so far. Running about 70 watts input, the first CQ on 40 meters raised W9SVJ in northern Indiana from Glendale, CA. His report, RST 589. On 15 meters the owner has worked ZL3JC, AX7SM and JH1EZZ, and received very good reports.

This vertical has no gain, and probably couldn't come near a Yagi or a quad in performance, but for an antenna costing less than $10 it does one heck of an FB job. This material was originally presented in *QST* by Jerry Arnold, WA6MBP.

Build This Novice Four-Band Vertical

Putting your first amateur station together can be an expensive proposition. One way to cut costs is to keep the antenna simple. Here's how to shave the price and provide four-band operation.

Is operation with one antenna acceptable if it covers the 80-, 40-, 15- and 10-meter bands? For a new Novice that's a reasonable approach. The author's backyard is smaller than that of most urban homes, so full-size dipole or inverted-V antennas were out of the question. Not owning a tower (yet!), it seemed that a ground-mounted vertical antenna would be worth trying.

After reading *The ARRL Antenna Book*, it was decided that a ground-mounted vertical antenna would be easiest to build. Some radial wires could be buried, and the metal fence which encloses the backyard could also be hooked up to enlarge the ground system. The author preferred this type of antenna to one installed above ground, because radials of specific lengths for each of the four bands would have been needed for a roof-mounted, groundplane type of vertical. The buried wires for the ground-mounted antenna could be any convenient length, as long as the available space would permit. From what was read about these antennas, the author believed that reasonable performance could be had even if the ground radials weren't numerous and long, although generally the more, the better.

With the help of W1FB some used aluminum tubing was purchased that would telescope together and give the author a 25-foot (7.62-meter) antenna. The wall thickness of the tubing is 0.058 inch (1.5 mm). Three 10-foot (3.05 m) sections are used. The largest diameter is 1 inch (25 mm). The center telescoping section has a diameter of 7/8 inch (22 mm) and the top piece of tubing has a 3/4-inch (19-mm) diameter. This material, plus hose clamps for holding the sections together, came to $8. An old ceramic rotary switch, a coaxial connector, a feed-through bushing, and a piece of Air Dux coil stock were acquired at a flea market for an additional $3. Two medium-size, ceramic standoff insulators were donated by W1FB. He said they cost him 50 cents each at a swap session. All that remained to collect was a weatherproof box for the loading coil, some 50-ohm coaxial cable and six U bolts. The author's OM, Bob, found some used 1-1/2-inch (38-mm) steel pipe which is 7 feet (2.13 m) long. It is used as a support for the vertical.

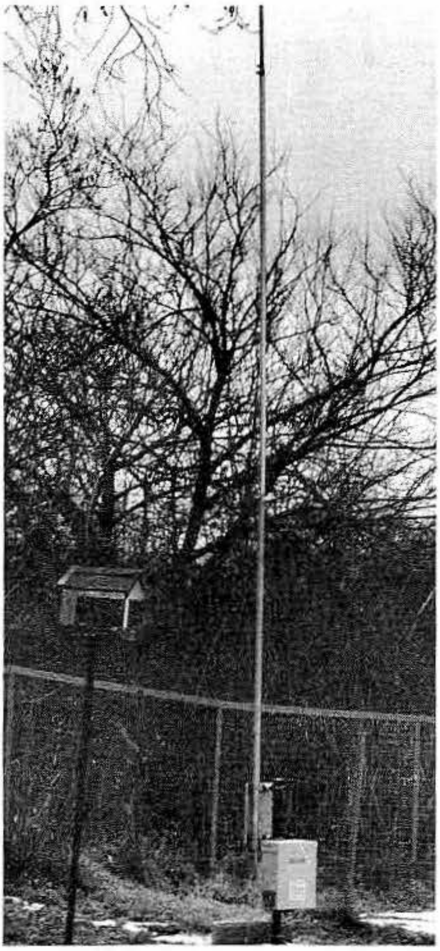

The completed 4-band vertical antenna used at WB1FSB. The box at the base of the antenna contains a loading coil.

Constructing the Antenna

A lawn-edger tool was used to make slits in the lawn, out from the base of the antenna toward the edges of the backyard. The slits were cut to a depth of 2 inches (51 mm). A total of 10 radials were buried in the slits. Some are only 15 feet (4.57 m) in length, while others are 25 feet (7.62 m) long. The metal yard fence was bonded together as needed, using wire jumpers between the fence sections. A single buried wire joined the fence to the common ground point at the base of the antenna.

The OM drove the steel pipe into the ground to a depth of 4 feet (1.22 m), leaving 3 feet (0.91 m) above ground for attaching the vertical antenna and weatherproof box. Construction details are shown in Fig. 3.

Although a wooden box could have been used to house the loading coil, switch and other hardware, an old electrical housing that the author's OM had in his junk box was used (Fig. 4.). It was drilled and

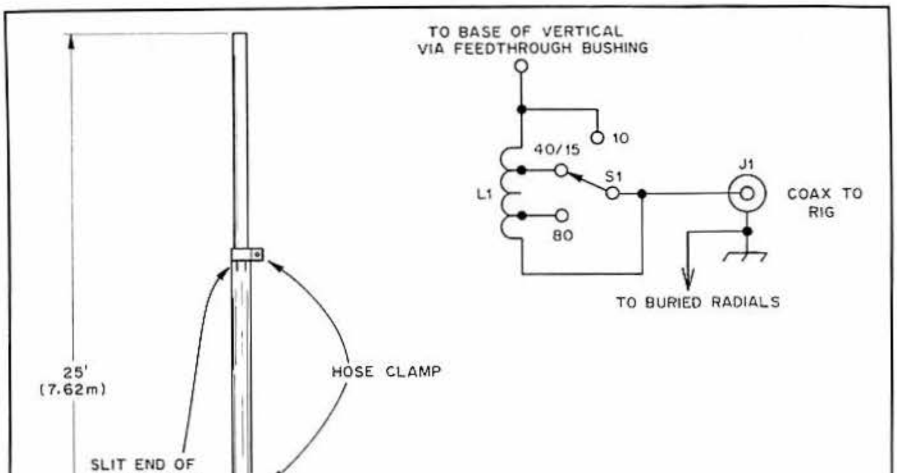
TO BASE OF VERTICAL
VIA FEEDTHROUGH BUSHING
10
40/15
S1
J1
L1
COAX TO RIG
80
TO BURIED RADIALS
25'
(7.62m)
HOSE CLAMP
SLIT END OF TUBING WITH HACK SAW (4 CUTS)
PLATES,1/4 X12X6-INCH(6X304X154mm)
SMALL METAL PLATE AND ONE U BOLT FOR EACH INSULATOR
STEEL PIPE
U BOLT
STANDOFF INSULATOR
METAL OR WOODEN BOX (ATTACHED TO PIPE WITH U BOLTS)
JUMPER WIRE TO VERTICAL
UNDERGROUND COAX CABLE TO RIG
FEEDTHROUGH BUSHING
BAND SWITCH
WIRE TO BURIED RADIALS

Fig. 3 — Dimensional drawing of the four-band Novice antenna. The top ends of the two lower tubing sections are slit four times each by means of a hack saw. This permits a tight joint when the hose clamp is compressed. The vertical is attached to one metal plate with U bolts. The large standoff insulators with metal feet connect this plate to a,pair of small ones. The latter are attached to the steel support pipe by means of two U bolts. The metal box is also affixed to the steel pipe with two U bolts. The band switch is a single-pole three-position ceramic wafer type. L1 can be a 5-inch (127-mm) length of B & W 3029 Miniductor, 2-1/2 inches (64 mm) in diameter, 6 turns per inch of no. 12 wire. See text for alternative mounting methods.

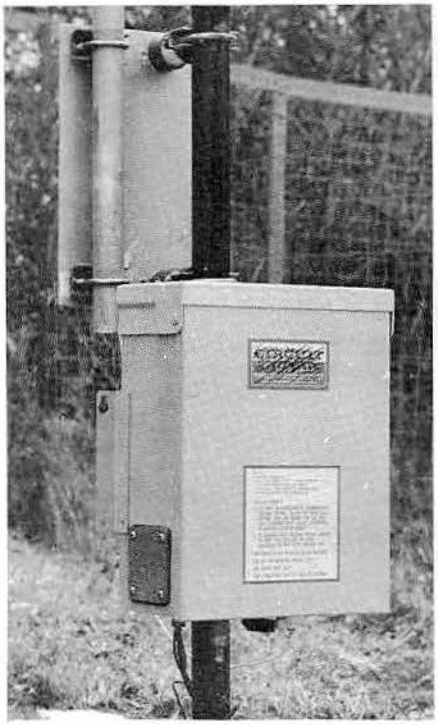

Fig. 4 — Closeup view of the base of the vertical. The aluminum tubing is affixed to a metal plate. The latter is attached to the iron support pipe by means of two surplus standoff insulators. Small aluminum plates are attached to the ends of the insulators to permit them to be fastened to the iron pipe by means of U bolts. The radial wires are connected to the bottom of the coil-housing box.

Fig. 5 — The author checks the SWR of the antenna during final adjustment of the system.

punched on the bottom surface to hold the feedthrough bushing, coaxial connector, switch and ground terminal for the radials.

W1FB designed the antenna, but he wasn't sure that an acceptable impedance match could be had on all four bands without a complex matching network. It was decided to try his idea, so the installation was completed.

Adjusting the Vertical

The author helped her OM install the antenna, then called W1FB for some assistance in tuning the system. He thought we could tune the vertical for 40 meters and make it work okay as a 3/4-wavelength vertical on 15 meters. For use on 80 meters it would be fairly short (63 feet or 19.20 m is the correct length for 3.7 MHz). With base loading it should offer adequate service out to a few hundred miles on 80 meters. Finally, it would operate as a 3/4-wavelength vertical on 10 meters.

A homemade SWR indicator was hooked in the coaxial line at the base of the vertical.[1] A small amount of transmitter power (5 W) was applied at 3725 kHz and the 80-meter switch lead was touched on the turns of the coil until minimum reflected power was indicated (Fig. 5). An SWR of 1:1 was obtained. The wire was then soldered in place on the coil. Next power was fed to the antenna on 7125 kHz, and the 40-meter switch lead was touched to the coil turns until an SWR of 1:1 was read. While using the same coil tap power was supplied to the antenna on 21.1 MHz and the SWR checked. It was approximately 3:1. By moving the coil tap just one turn we were able to get an SWR of 1.5:1 on 15 meters. A recheck on 40 meters followed. The SWR for that band was less than 2:1 — not a bad compromise! The coil was bypassed entirely for operation on 10 meters: an SWR of 2:1

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[1] DeMaw, "A QRP Man's RF Power Meter," *QST*, June 1973.

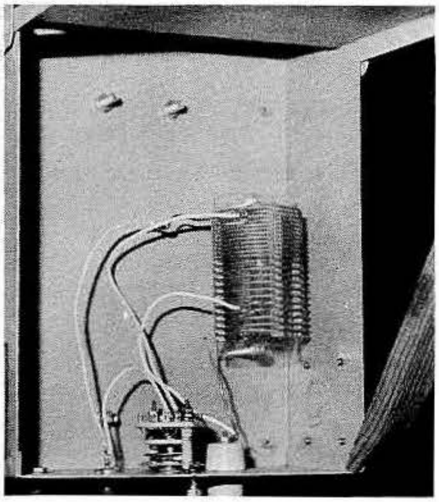

Fig. 6 — Interior view of the coil housing showing the switch, feedthrough bushing, coaxial connector, and ground post for the radials. The coil shown is a piece of Air Dux stock with a tapered pitch. It was obtained at a flea market.

was indicated at 28,000 kHz. The length of the overall antenna for operation on 28,100 kHz should be 25 feet or 7.62 m (3/4-wavelength radiator). However, the switch leads inside the coil housing add to the antenna length. If an SWR of less than 2:1 is desired, break the 10-meter switch lead and insert a 100-pF air variable capacitor. The unwanted reactance can be tuned out by this means and a low SWR will result.

Opening and closing the cover of the metal box had only a minor effect on the SWR. At last an on-the-air test of the system was possible. Fig. 6 shows the interior of the coil and switch housing.

Results

Good signal reports have been received on all bands. The first QSO on 40 meters netted an RST 599 report from North Carolina and many similar reports followed on 80, 15 and 10 meters. The author feels that a WAS award is not too far away now that this antenna is in operation.

An Alternative

There are many ways you can duplicate this design using substitute materials. For example, electrical conduit with couplers between the sections should be satisfactory in place of the aluminum tubing. The entire structure could be made from 2 x 4 inch (51 x 102-mm) lumber. If that is done, the radiator could even be a 25-foot (7.62 m) piece of no. 10 wire, supported on the side of the wood with standoff insulators.

Instead of the mounting method shown in Fig. 3, the vertical pipe could probably be inserted into a 2-foot (.61-m) length of PVC tubing, then clamped to the mounting plate. This would eliminate the need for the two standoff insulators. Better still, four or five wraps of Teflon sheeting (10 mil or 0.25 mm thickness) could be placed over the bottom end of the vertical before clamping it in place on the mounting plate. Teflon can be purchased at most plastic-supply houses.

The author hopes this idea is useful to other Novices who are trying to keep the budget within reasonable limits. This writer likes the way the antenna is working. Others should have good luck with this antenna also. Oh, by the way, the ground radials are made from various scraps of wire. The size isn't important, and they can be insulated or bare. There is quite an assortment of wire types buried in the lawn! This material was originally presented in *QST* by Marian Anderson, WB1FSB.

The Cheapie GP

Keeping an ear on 10 and 15 meters? With the trend of rising solar flux, 15 meters "opens" nearly every day — 10 meters occasionally. Don't miss these openings. Build a Cheapie GP!

Looking for an antenna to cover the 10- and 15-meter bands that won't pinch your pocketbook? Should it contain easy to obtain items and be relatively simple to construct while using ordinary hand tools? Must it be physically small and not a neighborhood eyesore? If your answer to these questions is "yup," you've turned to the right page! Detailed here is a duo-band coaxial-cable-fed, trap groundplane antenna system.

A groundplane antenna consists of a vertical quarter-wavelength radiator and an artificial metallic ground system extending radially from its base. For good results the antenna should be mounted at least one-quarter wavelength above ground. This is approximately 12 feet (3.66 m) on 15 meters. At this height and higher, only four radials for each band are necessary to provide a good ground system. If this antenna was ground mounted, many more radials would be needed to reduce earth losses to an acceptable low level. The antenna has an omnidirectional horizontal or *H*-plane pattern which means radiation from the antenna is essentially the same in all horizontal directions as shown in Fig. 7A. In Fig. 7B the approximate vertical or *E*-plane pattern of the antenna is shown for the antenna mounted one-quarter wavelength above ground. As can be seen, maximum radiation occurs at the low angles above the horizontal plane of the antenna. The antenna has an overhead null so little energy is radiated at high angles. This does not detract from the usefulness of the antenna, since DX signals seldom arrive at high angles on these bands. Instead, maximum radiation is concentrated at the *lower angles* where it will be more effective. Conversely, a horizontal dipole mounted one-quarter wavelength or less above ground will have maximum radiation straight up or nearly so. Lower-angle radiation will not occur unless the dipole is raised to a height of one-half wavelength or more above ground. If it is not possible to mount your horizontal antenna a half wavelength above ground, the vertically polarized groundplane is perhaps the logical choice over a dipole. As a general rule, the higher the groundplane can be located above power lines, gutters, house wiring and the like, the better it will perform.

A Duo-Band System

For the antenna to perform properly on two bands, it must function as a *separate* groundplane vertical on each band. This requirement is met quite simply in the case of the radials since four radials are used for each band. The 10-meter radials are 8 feet, 5 inches (2.56 m) long and the 15-meter radials are 11 feet, 7 inches (3.53 m). When the antenna is operated in the 10-meter mode, the 15-meter radials have little effect on the system. Similarly, when the antenna is used on 15 meters, the 10-meter radials do not appreciably alter the operation of the antenna. The effect of the additional radials is to change slightly the feed point resistance and the resonant frequencies of the antenna.

The vertical member of the antenna must act as a quarter-wavelength radiator on both 10 and 15 meters. To accomplish this a trap is inserted in the 15-meter vertical section. Its approximate location is a

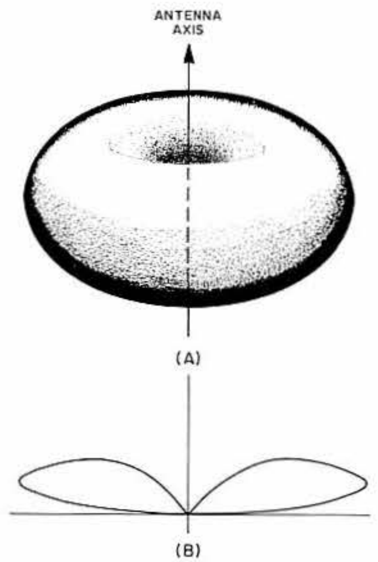

Fig. 7 — (A) Horizontal or H-plane pattern of the groundplane. (B) Approximate vertical or E-plane pattern of the antenna.

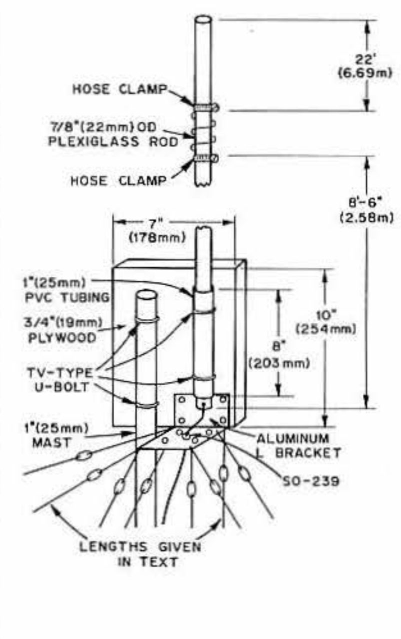

Fig. 8 — Constructional details of the duo-band antenna system.

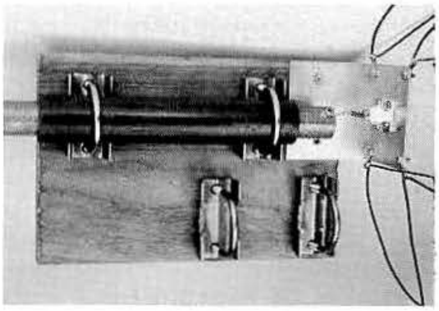

A photograph of the base assembly. The SO-239 coaxial connector and hood can be seen in the center of the aluminum L bracket. The U bolts are TV-type antenna hardware. The plywood should be coated with varnish or similar material.

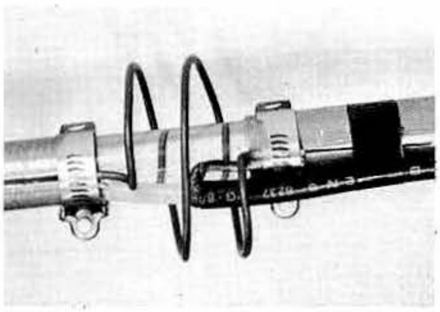

A close-up view of the trap. The leads from the coaxial-cable capacitor should be soldered directly to the pigtails of the coil. These connections should be coated with varnish after they have been secured under the hose clamps.

10-meter quarter wavelength above the base. The trap has a high impedance on 10 meters, thereby electrically divorcing the top section of the antenna when it is operated on that band. The length of the 10-meter section (section below the trap) is somewhat shorter than that of a simple 10-meter-only quarter-wavelength vertical. This is because the trap and top section of the duo-band system add top loading to the 10-meter portion of the antenna, reducing the length required for quarter-wavelength resonance. A coaxial-cable capacitor and a coil made from copper tubing form the trap which is resonant at approximately 28.150 MHz. On 15 meters the trap has a low impedance, effectively connecting together those portions of the antenna above and below the trap. The overall length of the 15-meter radiator is a bit shorter than a simple quarter-wavelength radiator would normally be for that band. This is because at 21 MHz the trap introduces inductance into the radiator — similar to the effects of a loading coil.

Construction

The vertical section of the antenna is mounted to a 3/4-inch (19-mm) thick piece of plywood board that measures 7 X 10 inches (178 mm X 254 mm). Several coats of exterior varnish or similar material will help protect the wood from inclement weather. Both the mast and the radiator are mounted to the piece of wood by means of TV U-bolt hardware. The vertical is electrically isolated from the wood with a piece of 1-inch (24-mm) diameter PVC tubing. A piece approximately 8 inches (203 mm) long is required, and it is of the schedule-80 variety. To prepare the tubing it must be slit along the entire length on one side. A hacksaw will work quite well. The PVC fits rather snugly on the aluminum tubing and will have to be "persuaded" on with the aid of a hammer. The mast is mounted directly to the wood with no insulation. An SO-239 coaxial connector and four solder lugs are mounted to an L-shaped bracket made from a piece of aluminum sheet. A short length of test probe wire, or inner conductor of RG-58/U cable, is soldered to the inner terminal of the connector. A UG-106/U connector hood is then slid over the wire and onto the coaxial connector. The hood and connector are bolted to the aluminum bracket. Two wood screws are used to secure the aluminum bracket to the plywood as shown in the drawing and photograph. The free end of the wire coming from the connector is soldered to a lug which is mounted to the bottom of the vertical radiator. Any space between the wire and where it passes through the hood is filled with GE silicone glue and seal or similar material to keep moisture out. The eight radials are soldered to the four lugs on the aluminum bracket. The two sections of the vertical member are separated by a piece of clear acrylic rod. Approximately 8 inches (203 mm) of 7/8-inch (22-mm) OD material is required. The aluminum tubing must be slit lengthwise for several inches so that the acrylic rod may be inserted. The two pieces of aluminum tubing are separated by 2-1/4 inches (57 mm).

The trap capacitor is made from RG-8/U coaxial cable and is 30.5 inches (775 mm) long. RG-8/U cable has 29.5 pF of capacitance per foot and RG-58/U has 28.5 pF per foot. RG-8/U cable is recommended over RG-58/U because of its higher breakdown-voltage characteristic. The braid should be pulled back 2-inches (51 mm) on one end of the cable, and the center conductor soldered to one end of the coil. Solder the braid to the other end of the coil. Compression-type hose clamps are placed over the capacitor/coil leads and put in position at the edges of the aluminum tubing. When tightened securely, the clamps serve a two-fold purpose — they keep the trap in contact with the vertical members and prevent the aluminum tubing from slipping off the acrylic rod. The coaxial-cable capacitor runs upward along the top section of the antenna. This is the side of the antenna to which the braid of the capacitor is connected. A cork or plastic cap should be placed in the very top of the antenna to keep moisture out.

Installation and Operation

The antenna may be mounted in position using a TV-type tripod, chimney, wall or vent mount. Alternatively, a telescoping mast or ordinary steel TV masting may be used, in which case the radials may be used as guys for the structure.

Any length of 50-ohm cable may be used to feed the antenna. The SWR at resonance should be on the order of 1.2 to 1.5:1 on both bands. The SWR is not 1 because the feedpoint resistance is something other than 50 ohms — closer to 35 or 40 ohms. Nearby metallic objects may also have an effect on the impedance of the antenna. The antenna is resonant at approximately 21.150 MHz and 28.150 MHz.

Some amateurs place too much importance on obtaining a "no reflected power" reading on their SWR indicators. Most ham transmitters will load into lines which exhibit an SWR of up to 2:1, the exception being some of the new broadband, no-tuning transmitters. To demonstrate how little effect an SWR of 1.5 or 2:1 will have on the system, consider the following: If the antenna is fed with 100 feet (30.48 m) of RG-8/U cable and if the antenna is perfectly matched to the line (an SWR of 1), the power loss along the cable will be approximately 0.98 dB on 10 meters. If the SWR on the line is increased to 1.5:1, the additional loss on the line due to the higher SWR is less than 0.1 dB. If the SWR is increased to 2:1, the additional loss over that of the matched condition will be on the order of 0.2 dB. This amount of loss is insignificant, and for this reason a complicated matching network is not necessary. This material was originally presented in *QST* by Jay Rusgrove, W1VD.

A High-Performance, 20-, 40- and 80-Meter Vertical System

Urban dwellers with small lots take heart! Here are the details for building your own DX-effective three-band mini-vertical antenna. Cost-conscious amateurs will be happy with the low cost of this system.

In another article on vertical antennas,[1] we tried to point out some fundamental characteristics of ground-mounted verticals, namely: (1) a good image plane is necessary for efficient operation, (2) a vertical over a good image plane compares favorably with a dipole at an elevation of one-half to one wavelength, (3) a short vertical compromises little in the way of performance.

This paper describes a highly efficient, three-band vertical system for 20, 40 and 80 meters, using elements of the order of an eighth wavelength. The system consists of an 80-meter vertical in parallel with a 20/40-meter trap vertical. Actually, either the 80-meter or the 20/40-meter vertical can be constructed and used alone if one is not interested in triband operation. The input impedances of both antennas are 12-1/2 ohms and they use the same 4:1 matching transformer.[2] The antennas also use the same radial system consisting of 100 radials of no. 15 aluminum wire 50 feet (15.24 m) in length (a lesser number of radials can be used as is discussed later in the article). Because of expected lower sunspot activity and, hence. poorer propagation conditions on the higher bands, the 40- and 80-meter portions of this antenna system, in particular, should prove very effective in DX communication over the next few years.

The first part of this paper deals with the design and tune-up considerations of the 80-meter element; the second part with the 20/40-meter element and the way it is used with the 80-meter vertical forming an efficient triband system. This is followed by reports on performance. Reference is also made to other alternatives for a multiband vertical system.

80-Meter Vertical

The two considerations in designing the 80-meter element of this vertical system were: (1) a good bandwidth for a reasonable height (a height one person can handle); and (2) proper spacing between the 80 and 20/40 portions such that coupling is negligible and both can be used over the same radial system.

Prior to building the shortened vertical described in this article, two others were constructed and tested on the air. One was a 22-foot (6.71 m) vertical[3] which had a 65-kHz bandwidth. The other was a trap vertical[4] with only a 20-kHz bandwidth. Both of these antennas were used separately over the same image plane of 100 radials and were efficient radiators. Therefore, the main reason in going to a slightly longer antenna was simply *to obtain a broader bandwidth.* The eighth-wavelength vertical on 40 meters from the previous work[5] promised considerable improvement by adding only a few feet. The results are shown in Figs. 9 and 10. The total height turned out to be 29 feet (8.83 m). This resulted in a bandwidth of about 140 kHz, a little more than twice the bandwidth of the 22-footer (6.71 m).

The vertical, in Fig. 9, uses a 20-foot (6.10-m) section of thick-wall aluminum tubing. (It was used some years ago as a gin pole for erecting a beam on a 40-foot (12.2 m) tower.) An 8-foot (2.44 m) extension was constructed with 1-inch (25-mm) tubing bolted in place using spacers for centering. The insulator at the bottom is phenolic tubing with a canvas base.[6] It has a 1/2-inch (13-mm) thick wall, is 9 inches

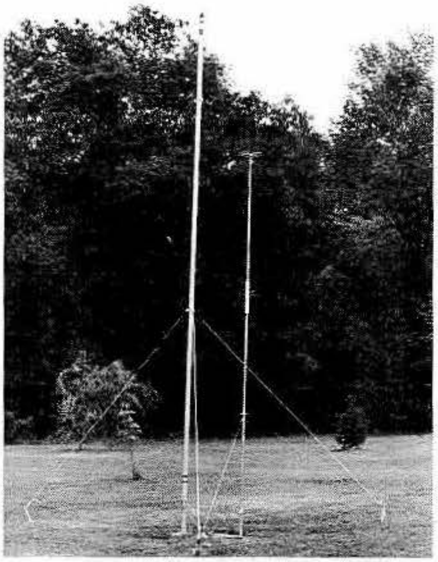

The triband vertical showing the polypropylene guys which provide an extra margin of support.

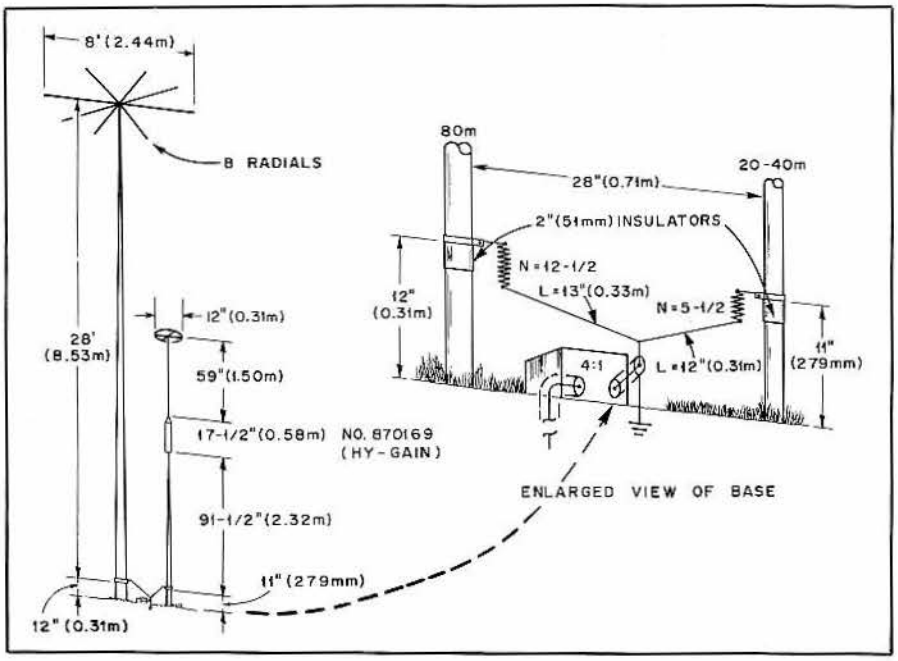

Fig. 9 — The 20-, 40- and 80-meter vertical antenna system. Tuning and construction details are given in the text.

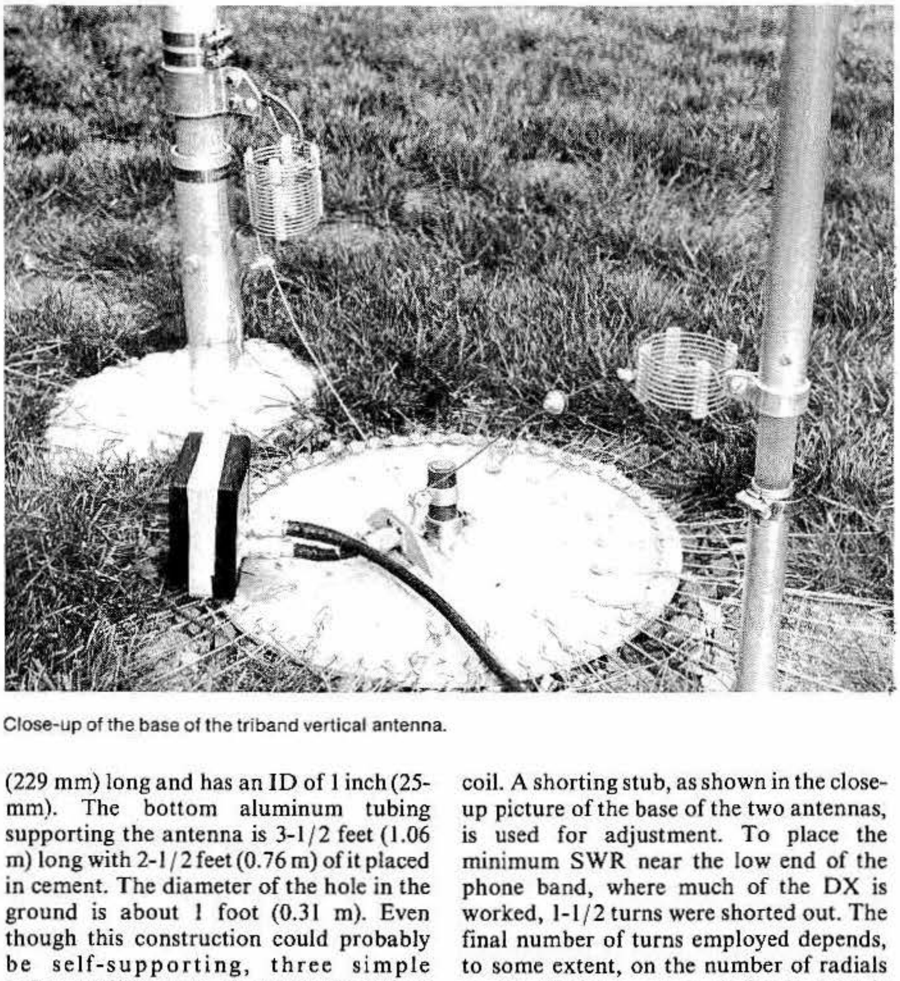

Close-up of the base of the triband vertical antenna.

(229 mm) long and has an ID of 1 inch (25-mm). The bottom aluminum tubing supporting the antenna is 3-1/2 feet (1.06 m) long with 2-1/2 feet (0.76 m) of it placed in cement. The diameter of the hole in the ground is about 1 foot (0.31 m). Even though this construction could probably be self-supporting, three simple polypropylene guys at about the 7-foot (2.13-m) level are used for extra margin of support. The radials at the top use 1/2-inch (13-mm) aluminum tubing.[7] The base loading consists of 12-1/2 turns of a B&W 3029 coil.[8] Actually, 14 turns are on the coil. A shorting stub, as shown in the close-up picture of the base of the two antennas, is used for adjustment. To place the minimum SWR near the low end of the phone band, where much of the DX is worked, 1-1/2 turns were shorted out. The final number of turns employed depends, to some extent, on the number of radials used in the image plane. A simple check is to set the shorting tap at some convenient point, like 12 or 13 turns, and plot the SWR. If the minimum value appears too high in frequency, then add about a half a turn of coil. This half turn chould change the position of the minimum SWR value by about 50 kHz. As can be seen in Fig. 10, the minimum value of SWR is practically 1:1 and occurs at 3.840 MHz. This also verifies the input impedance value of 12-1/2 ohms, as expected from the previous work on short verticals.

20/40-Meter Vertical

In extending the operation of a vertical system over other bands, many alternatives are available. A trap vertical with a 12-1/2-ohm input impedance can be connected in parallel with the 80-meter vertical. Alternatively, the trap vertical can be designed to present an impedance of 50 ohms and thus be connected to the input side of the 4:1 transformer.[9] If broadband operation is desired on only 80 and 40 meters, then one-eighth wavelength verticals on both bands can be used.[10]

For this work, a 20/40-meter trapped vertical having an input impedance of 12-1/2 ohms was used. It offered a rather simple mechanical form of parallel operation as is shown in Fig. 9 and the close-up picture. The bandwidth on 40 meters of 155 kHz appeared acceptable. This bandwidth can be extended by about 50 percent by using the 50-ohm design of a trap vertical.

In the first attempt of parallel operation, the 20/40-meter vertical was placed only 14 inches (355 mm) away from the 80-meter vertical. The coupling appeared excessive. The 80-meter vertical was detuned by approximately 50 kHz. The 20/40-meter vertical also required excessive base loading in order to present an acceptable input impedance. By doubling the spacing between the verticals to 28 inches (711 mm), the interaction between them became negligible. The final values of heights and loadings were practically the same as if the elements were operating alone.

The adjustment of the 20/40-meter vertical is somewhat more complicated than the 80-meter vertical. An impedance bridge, as described in the *ARRL Handbook*, is of considerable help. In this case, there are two degrees of freedom: (1) varying the number of turns at the base, and (2) adjusting the lengths of the vertical sections.

Basically, the tuning is as follows: The tap is set at about 5-1/2 turns and the 20-meter section adjusted to give an acceptable value of SWR, both in position in the band and in magnitude. If the impedance is too high, it can be lowered by increasing the number of turns and lowering the height of the 20-meter section for resonance. After this, the 40-meter portion is then tuned. A plot of the SWR vs. frequency can immediately give an indication of the necessary adjustment of the section above the 20-meter trap. If the minimum value appears too low in frequency, a shortening of the top section is required. In no case should large adjustments be made. A change of a few

Table 1

Some Results With Triband Vertical

Date	*Station Contacted*	*W2FMI Signal Report*	*Freq.(MHz)*	*Input Power SSB (Peak)*	*Comments*
3/13	K5LWL/YV6	59 + 10 dB	7	2 kW	very, very strong signal, only one signal stronger — he used a Yagi at 120 feet (36.58 m)
4/3	WB5HJY	59 + 40 dB	7	2 kW	superior to anything on band
4/4	ZF1SP	59 +	14	2 kW	very, very nice signal
4/4	WA4MUR/4	59 + 40 dB	14	2 kW	best signal on whole band
4/18	KV4HW	59 + 10 dB	7	2 kW	loudest on band
5/9	K6YIY	59	4	2 kW	K1GZL and I are only ones they hear
5/9	W9LZX	59 + 30 dB	4	2 kW	strongest (very consistent signal)
5/12	W2DU	59 +	4	2 kW	tremendous signal
5/17	VK5PB	56-7	4	2 kW	remarkably strong
5/17	W4JNY	59 + 20 dB	4	2 kW	outstanding, certainly one of best
5/22	VK5PB	59 + 10 dB	7	2 kW	really amazing
5/23	ZL3RJ	57-8	4	2 kW	one of the strongest he's heard for some time — pinned the S meter
5/27	WA2BQL	59 + 30 dB	4	200 W	very potent — Stronger than most locals — couldn't believe you were using 200 W

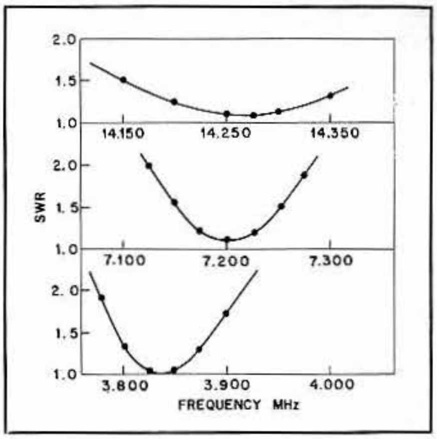

Fig. 10 — Standing wave ratio vs. frequency for the 20-, 40-, and 80-meter vertical antenna system.

inches has considerable effect. If the input impedance on 40 meters appears too low, then the 20-meter section has to be lengthened. This requires that the whole procedure be repeated. In any case, the initial adjustment should be started on the highest band of the trap vertical.

Results

Short verticals have been used by the author during the past year with considerable success. Many DX contacts were made on 40 meters with antennas varying in length from 6 to 33 feet (1.83 to 10.05 m). Since an extensive ground system was used, very little difference in effectiveness was noticed between the antennas.[11] This even includes redesigned trap verticals. As was stated before, the objective of the present investigation was to design a three-band vertical system which not only yielded competitive antennas on the lower bands, but one that was capable of covering a considerable portion of 80 meters. As was seen, a separate one-eighth wavelength antenna connected in parallel with a trap vertical not only gave a bandwidth on 80 meters of 140 kHz where the SWR was less than 2:1, but was short enough to not require considerable help in erection.

During all this time of operation of short verticals on 40 meters, and as of this writing, including several months on 80 meters, very few signal reports were received which did not indicate one of the best signals on the band. Table 1 gives some of the reports and comments received. In only three specific cases on 40 meters have the short verticals been bested by other antenna systems. One is shown in Table 1 where K5LWL/YV6 reported a stronger stateside signal by an amateur using a Yagi at 120 feet (36.58 m). The other cases include a comparison with W2GO of Linden, NJ. On 40 meters, VK5PB reported 6 dB and VK2WC 10 dB in favor of W2GO's signals. He was using a two-element Yagi at 60 feet (18.28 m). The elements were 44-1/2 feet (13.56 m) in length and the boom, 20 feet (6.10 m). On 80 meters, only one other station received a stronger report on direct comparison. This was by W2HCW, when comparing my signals with VK5PB. The difference was 2 to 3 S units. His antenna was an 80-meter Yagi at 120 feet (36.58 m).

Invariably, most amateurs were surprised by the performance of these verticals. In many instances, questions were asked regarding the minimum number and length of radials required for efficient operation of ground-mounted verticals. As was noted in previous articles,[12] the answer depends to some extent on the conductivity of the soil at the respective locations. Poorer soils not only require more radials, but ones that are also considerably longer. Although more experimental work is required in this area, it appears that about 50 radials, 0.2 wavelength long, should generally give good operation. The loss in this case will be approximately 1 to 2 ohms. Doubling the number to 100 radials should reduce the loss to less than 1 ohm. It should be noted that even 1 to 2 ohms of loss are appreciable with these short antennas since their radiation resistances are only 12-1/2 ohms.

Again, the author would like to acknowledge the help, encouragement, and interest shown by the many amateurs during our experimental studies on verticals. Very few antenna laboratories can boast of a greater number of willing and competent field stations. In particular, we would like to thank Al Jones, W2GO, for his considerable help in obtaining comparative reports in Australia and New Zealand. This material was originally presented in *QST* by J. Sevick, W2FMI.

References

[1] Sevick, "The W2FMI Ground-Mounted Short Vertical," *QST*, March 1973. Also appears elsewhere in this chapter.

[2] Sevick, "The W2FMI 20-Meter Vertical Beam," *QST*, June 1972.

[3] See footnote 1.

[4] Commercial unit.

[5] See footnote 1.

[6] Cadillac Plastic and Chemical Co., P. O. Box 810, Detroit, MI 48232

[7] Construction details on the top hat are also given in the reference in footnote 1.

[8] 2-1/2-inch (64-mm) diameter, 6 tpi, no. 12 wire.

[9] The characterization and design of these trap verticals will be published later.

[10] See footnote 1 for details on the 40-meter vertical.

[11] See footnote 1.

[12] See footnote 1.

A Multiband Vertical Radiator

An efficient multiband radiator with no traps and no loading coils? Impossible; you can't build one without them and have it work! "Oh, yes, sure you can." I doubt it. "You wanna bet? Come on, I'll show you."

What would you say if the author told you this vertical antenna system was 89-percent efficient but had only six radials? (Efficiency is defined as the ratio of radiated power to total power delivered to the antenna.) No, it's no joke. The vertical antenna that is described here is designed to work against ground systems that are less than optimum.

By increasing the radiation resistance by about 200 ohms, we have been able to improve the effectiveness substantially of a vertical radiator with a poor ground system. The value of 200 ohms was selected as the feed-point radiation resistance because a toroid autotransformer with a 1:4 ratio will match 50-ohm coax line very nicely. An added bonus when using such an arrangement is the Faraday screen effect that reduces noise pickup from being transferred to the feed line. The noise reduction over a conventional network was determined to be about 6 dB. See Figs. 11 and 12.

The system is based on a 135-degree antenna height. The radiation resistance at the base of the structure is about 200 ohms,[1] ideal for our matching system. And at the same time the radiation pattern retains a reasonable form. The 10-meter groundplane on top of the structure acts as a top hat. On 7 MHz the phase loops cause the antenna to look like a fat radiator and between the two, top hat and phase loops, the electrical height of the antenna is raised to within the tuning range of the toriodal loading network. On 14 and 21 MHz the phase loops keep the instantaneous current on the structure in phase and eliminate high-angle lobes. When the system is switched to operate on 28 MHz, the groundplane at the top of the structure is fed through the coax line running up the lower portion of the structure.

Construction and Tuning

The photographs and the drawings show how the antenna is constructed. The system was designed so that "storebought" items could be used for the assembly, rather than fabrication of the antenna components. A list of required parts is given in Table 2.

The tuning adjustments of the system are very noncritical. Tuning can be done with an SWR indicator. The best sequence is to start with the highest frequency and work down. The 28-MHz groundplane used as a top hat can be adjusted before it is attached to the rest of the antenna. The Radio Shack 11-meter groundplane that we used comes with a hairpin or "beta" match. With a short length of 50-ohm coax for the feed line, the groundplane should be adjusted for the lowest SWR in the 10-meter band. After the groundplane has been adjusted and attached to the top of the antenna, the entire system can be raised into position for final tune-up on the lower frequencies.

At this point the SWR indicator should be inserted in the 50-ohm feed line from the transmitter, as close to the antenna matching network at the base of the structure as possible. All that remains is the adjustment of the 200-pF capacitor. The

This multiband radiator, just over 36 feet (10.97 m) tall, operates on five amateur bands, 80 through 10 meters.

Table 2

Parts Required for the Multiband Vertical Radiator

3 —10-ft (3.05 m) lengths TV mast; Radio Shack 15-5066.
1 —27-MHz ground plane; Radio Shack 21-901.
3 —100-ft (30.48 m) rolls of 22-gauge hook-up wire; Radio Shack 278-1295.
1 —Amidon Balun kit (see Fig. 12).
1 —Aluminum box for tuner.
1 —28-ft (8.53 m) length of RG-8/U coax line.
4 —8-ft (2.44 m) sections of aluminum tubing (see Fig. 11).
1 —Base insulator; soft drink or (?) bottle.
1 —200-pF capacitor, air variable, surplus.
Misc. — See text and figures.

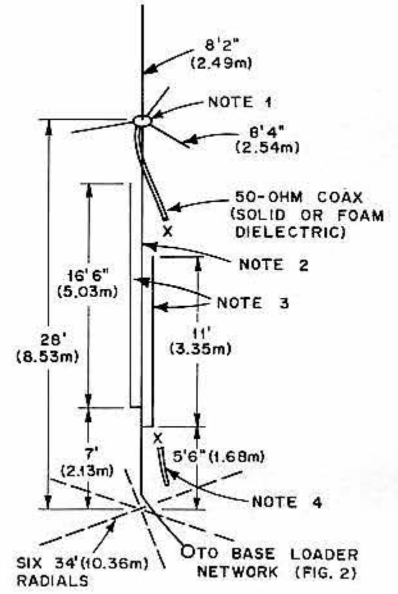

Notes

1) Radio Shack 27-MHz groundplane cut to dimensions shown. Radials are at right angle and connected to mast.
2) Three heavy-duty 10-ft (3.05-m) sections TV mast.
3) Phase loops, sections of telescoping 5/8- (16-mm) and 1/2-inch (13-mm) aluminum tubing spaced 4-1/2 inches (114 mm) from mast. See text.
4) 50-ohm coax such as RG-8/U. At upper end connect center conductor to top element, braid to ground-plane elements. Connect lower end to base loader network (Fig 12).

Fig. 11 — Details of the multiband radiating structure. See Table 2 for parts list. It is very important that a uniform spacing be maintained for the phasing loops, which may be supported at the bottom by shelf brackets. To support the upper portions of these loops, the author used homemade wooden spacers, 1/2 X 1 inch (13 X 25 mm), which were soaked in paraffin and held in place by screws passing through the loop tubing and the main radiator tubing. Homemade Plexiglas spacers may also be used.

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[1] *The ARRL Antenna Book*, 13th Ed. See Fig. 2-74 and the accompanying text on page 60.

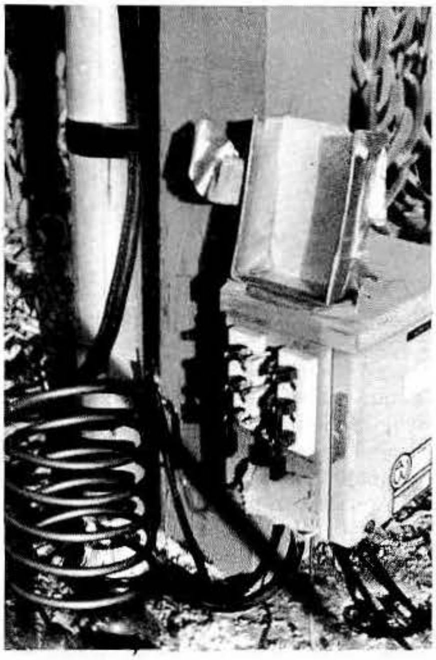

The base of the multiband antenna system. The 200-pF capacitor of the matching network is mounted inside a weatherproofed box, and the 80-meter loading coil is mounted outside. The porcelain knife switches for bandswitching are mounted outside the aluminum box under a homemade hinged cover. The structure itself is supported by a 10-foot (3.05-m) wooden post set 2 feet (0.61 m) in the ground (concrete optional).

Although heavy-duty insulators were used to support the radiating mast from the post as shown here, experience has indicated that insulators are not required. The author suggests that a modified pair of chimney-mount brackets be fastened to the post with lag screws. A short length of PVC pipe or Mylar film may be placed around the mast where it is supported, if you feel it necessary to have the mast insulated from the post.

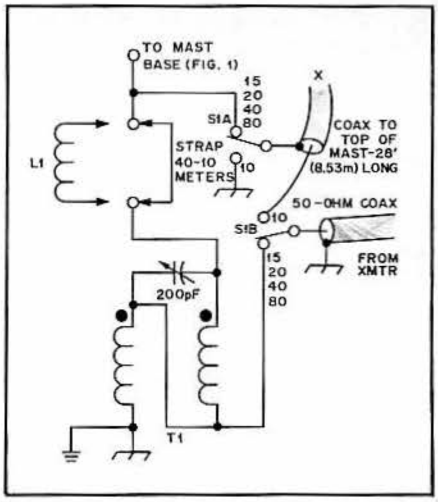

Fig. 12 — Schematic diagram of the base loading network. The connection to the mast base should be made with a short wire, no longer than one foot (0.31-m). The 200-pF capacitor should have a minimum of 1/16-inch (1.6-mm) plate spacing.

L1 — 80-meter loading coil, 0.67 μH; 4 turns of aluminum grounding wire, 3-inch (76-mm) diameter, 1 turn per inch, air core.

S1 — Dpdt, heavy-duty type. Two porcelain knife switches from the local hardware store will suffice, one for each pole.

T1 — Bifilar-wound toroidal autotransformer, 1:4 ratio; 11 turns spaced around 2-inch (51-mm) ID toroidal core: Amidon Balun Kit or equiv. (Amidon Associated, 12033 Otsego St., North Hollywood, CA 91607).

tuning will be different for each band. On 21 MHz the capacitor will be only about five percent meshed, on 14 MHz about half, and on 7 MHz nearly fully meshed. The capacitor on 3.5 MHz, along with the 3.5-MHz coil, can be adjusted to whatever section of the band you wish to work. The bandwidth will be about 400 kHz with less than 2:1 VSWR. To switch bands, all that is required is to set the double-pole, double-throw switch for the proper band and adjust the 200-pF variable capacitor.

All of the antennas constructed so far were cut to the dimensions shown in Fig. 11 and have not required any change. They have been installed in a wide variety of locations and the system design has been broad enough in tolerance to handle all of them. The writer's antenna has been in operation since 1972 and has performed exceptionally well. In the first year on the air, I managed to work 100 countries with less than 250 watts. In several experiments with just the six radials, we made comparative tests between this design and a properly matched quarter-wave vertical over the same radial system. The radiation efficiency was about 60 percent for the quarter wave vs. 89 percent for the "little monster." In the far field the signal improvement was better than 6 dB.

Now there are eight of these antennas on the air, and several more are under construction. All of the hams who have built the antenna have had comparable results to mine.

There are three hams to whom this author would like to give credit. They helped in testing and measuring the system and encouraged me to get it down on paper. They are Bob Crawford, WA6RYZ; Frank Scott, W6WOP and John Campbell, W6NVV. This material was presented originally in *QST* by A. E. Collins, K6VV.

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A Triband Vertical Antenna

Keep your vertical antenna simple. Operate three bands without using traps!

The most common vertical is the quarter-wave type, which radiates well and is easily matched to a coax feed line, but has the weakness that it is a single-band antenna. Methods of adapting a vertical for multiband operation include the use of traps, loading coils and elements of different length fed in parallel. The antenna system to be described here was arrived at by treating separately the problems of designing the antenna and of designing the matching system.

The antenna design was easy. A height of 22 feet (6.71 m) is optimum for a vertical antenna for 10, 15 and 20, and several commercial verticals are of this height. It corresponds to about five-eighths wavelength on 10 meters. Greater height results in reduced low-angle radiation on 10, besides being more difficult to erect. A 22-foot (6.71-m) vertical gives better low-angle radiation than a quarter-wave vertical on all three bands and is especially good on 10 meters.

The antenna consists of 22 feet (6.71 m) of 300-ohm twin-lead, with both conductors tied together, held about an inch from a bamboo pole by means of small blocks of insulating material spaced every two feet or so along the pole and held in place with plastic electrical tape. The pole is guyed with nylon fishing line, and the antenna is operated against a groundplane of four quarter-wave radials for each band. The use of twin-lead rather than a single wire simulates a thicker conductor and reduces the impedance, making the antenna easier to match. Even so, the antenna impedances are vastly different on the three bands. The presumed values of impedance are listed in Table 3. These values are taken from published data[1] and assume a cylindrical antenna of specific radius operated against a perfect ground. The antenna is not cylindrical, and it operates against a wire groundplane, so that the impedances listed must be considered approximate only. The results obtained indicate that they are at least fairly close.

Table 3

Approximate impedances at base of 22-foot (6.71-m) ground-plane vertical antenna

Frequency	*Resistance*	*Reactance*
14.250 MHz	100 ohms	+200 ohms
21.375 MHz	1200 ohms	−500 ohms
28.500 MHz	60 ohms	−220 ohms

Table 4

Impedances at input end of 27.8-foot (8.47 -m) matching section of 300-ohm twin-lead terminated by the impedances listed in Table 3.

Frequency	*Resistance*	*Reactance*
14.250 MHz	93 ohms	+177 ohms
21.375 MHz	63 ohms	0 ohms
28.500 MHz	75 ohms	−282 ohms

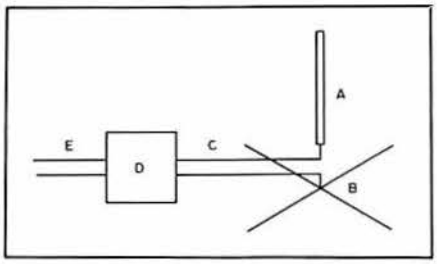

Fig. 13 — The triband vertical antenna system.

A — Vertical radiator, 22 ft (6.71 m) of 300-ohm twin-lead with conductors in parallel.
B — Four radials, each consisting of 1/4λ of wire, for each band (12 wires in all).
C — Matching section, 27.8 ft (8.47 m) of 300-ohm twin-lead.
D — Reactance unit; see Fig. 14.
E — 75-ohm coax to transmitter, any length.

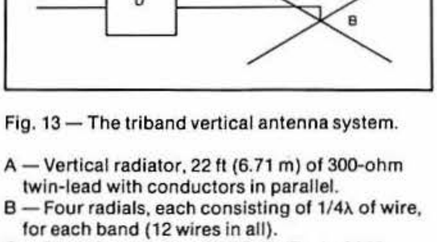

Fig. 14 — Reactance-unit circuit.

L1 — 0.86 μH; 7 turns no. 16 (or heavier). 1-inch (25-mm) dia, 1-inch (25-mm) winding length.
C1 — 30-pF air trimmer set to 23.1 pF.
C2 — 100-pF air trimmer set to 41.7 pF.

If the three antenna matching impedances are normalized to 300 ohms and plotted on a Smith chart, it can be seen that it is possible to obtain a reasonably good match to a coax line on any of the three bands by using an appropriate length of 300-ohm line as a matching section connected between the antenna and the coax line. What is not possible is to find a single length of line that will provide suitable matching on all three bands.

It turns out, however, that a 27.8-foot (8.47 m) section of 300-ohm line having the 0.82 velocity factor which is usual for twin-lead has interesting characteristics. Such a section of line, connected to an antenna having the impedances listed in Table 3, has the input impedances listed in Table 4. This combination of antenna and matching section is shown in Fig. 13.

It will be noted, first of all, that this combination may be used as it stands on 15 meters and fed with any usual coax. What is even more interesting, however, is that the input resistance is near 75 ohms on all three bands, though on 10 and 20 there is also considerable reactance. If a reactance unit could be made which had just the correct value of reactance to cancel out the input reactance of the matching section on all three bands, the unit could be connected in series with the matching-section input and the system fed with 75-ohm coax on all three bands.

Reactance Units

Can such a unit be made? Certainly! It's not hard at all. It consists of a simple seven-turn coil and two trimmer capacitors and is shown in Fig. 14. The trimmers are most easily adjusted with the aid of a grid-dip meter before the reactance unit is installed. C1 should be set so that L1C1 resonates at 35.85 MHz, and C2 can be subsequently adjusted by temporarily connecting it in parallel with L1C1 and varying it until the combination resonates at 21.37 MHz.

With the reactance unit adjusted as described, the antenna when first assembled showed SWRs of 2.1, 1.4, and 1.5 on 10, 15, and 20 meters respectively. Connecting the unit into the feed system apparently increased its shunt capacitance somewhat, for a small reduction in the value of C1 changed the SWR readings to 1.3, 1.5, and 1.4. These values could probably have been improved still more by further adjustment of C1 and C2, but it was not considered worth the trouble. If it is undertaken it should be borne in mind that the adjustments interact, but that C1 has its greatest effect on 10 meters and C2 on 20 meters. In any case it is not possible to obtain a perfect 1:1 match with this antenna system.

An SWR of 2, however, which can easily be bettered on all three bands, is within the loading capability of almost any transmitter and causes an *additional* loss over a perfectly matched line of less than half a dB even when the transmission line is very long. Since such a change in signal strength is undetectable, an SWR of 2 is in practice as good as an SWR of 1, as far as losses are concerned.

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[1] Jordan, E. C., *Electromagnetic Waves, and Radiating Systems*, Figs. 13-12 and -13, New York: Prentice-Hall, Inc., 1950, pp. 482-3.

A Few Notes

A few observations are in order. The matching section has a fairly high SWR (between 4:1 and 8:1), and it should be spaced well clear of metal objects and should not have sharp bends. TV standoffs are useful here. It is important that the same side of the matching section be connected to the coax shield and to the groundplane. If such a thing were available, 300-ohm coax would probably be preferred for the matching section, but for medium power (180 watts PEP) TV-type twin-lead for the matching section and receiving-type trimmers in the reactance unit have proved satisfactory. The parallel circuit L1C1 does not operate at its resonant frequency, and thus high circulating currents are not encountered. High power might necessitate heavier components. The reactance unit needs protection from the weather and can be built into a small plastic box and sealed with plastic electrical tape.

Although the antenna is matched at three widely separated frequencies, it is not matched at intermediate frequencies and is thus not a broad-band antenna in the usual sense. Nevertheless, it is broad enough for normal ham use. The SWR remains below 2:1 over the entire 15- and 20-meter bands, and also between 28.3 and 29.4 MHz on 10.

All SWRs mentioned in this article have been measured at the transmitter and are thus probably a little optimistic. Transmission-line losses are not known, but the line is not long (about 40 ft. [12.19 m]), and it is doubtful that the SWRs at the reactance unit are much higher than those measured at the transmitter.

This antenna is no match for a quad or a Yagi, but it has provided numerous transatlantic QSOs on all three bands. Because of its effectiveness, convenience, and the cheapness and availability of everything used in its construction, it should appeal to many hams. This material was originally presented in *QST* by Frank A. Regier, OD5CG.

A Multiband Groundplane Vertical Antenna with Tuned Feeders

Who says tuned feeders are used only with horizontal wire antennas? Go multiband with a simple vertical radiator by using a tuned-feeder system — and do it with ease!

For several years, the author has experimented with several versions of this antenna and has found them to be most satisfactory. The antenna shown in Fig. 15 provides not only outstanding performance on 10, 15 and 20 meters, but performance on 40 and 80 meters equivalent to most mobile-antenna installations. Full efficiency on these latter bands can be realized by making the vertical and radial portions proportionately longer.

The antenna system consists of the radiating element, groundplane radials, an open-wire feeder of any convenient length, a Transmatch capable of either series or parallel tuning, and an antenna SWR bridge. This combination is shown in Fig. 16.

Antenna and Radial Lengths

The author preferred to cut the antenna for resonance on one particular ham band (20 meters), but it is not necessary that the antenna be resonant on any band. Efficiency will suffer, of course, on bands where the length is significantly shorter than one-quarter wavelength. Whatever the length chosen for the antenna, the radials should be of about the same length.

Construction

Constructional details are shown in the sketch of Fig. 15. In the event the specified aluminum tubing is not available, thin-walled galvanized electrical conduit, aluminum conduit, or copper pipe may be used.

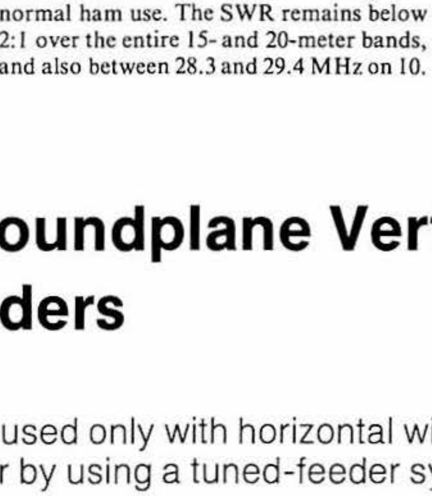

Fig. 15 — Sketch of W4VON's simple multiband antenna.

It is recommended that the vertical element not be supported by drilling holes through the tubing, as this will substantially weaken the structure. An alternative mounting arrangement is shown in Fig. 17. The insulators are porcelain standoff types with a lag-screw insert. They will be found at electrical supply houses (also at Sears), and are sometimes referred to as "saddle" type insulators. The hose clamps are stainless-steel gear type.

Adjustment

Operation of the antenna is simple. The Transmatch (a suitable one, including SWR bridge, is described in the ARRL *Handbooks)* and SWR bridge are connected, and the tuning network adjusted for

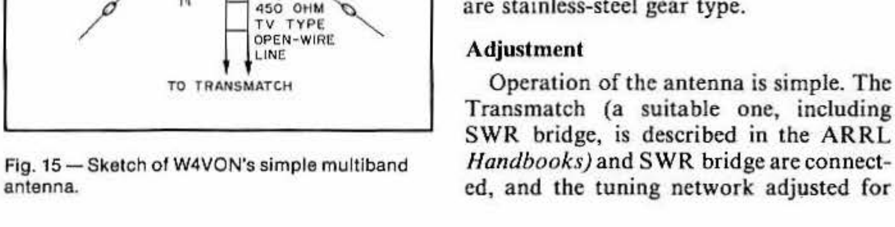

Fig. 16 — Recommended setup for coupling antenna line to low-impedance transmitter output.

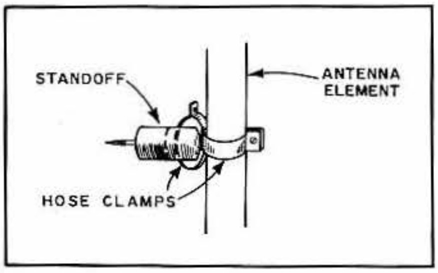

Fig. 17 — Suggested method of mounting radiator element without drilling holes in aluminum tubing.

maximum forward and minimum reflected power. Initially, it will be necessary to determine experimentally whether series or parallel tuning is required for the particular combination of band, feeder length, and antenna length selected.

The tuned-line-fed groundplane vertical antenna gives excellent performance, can be easily constructed in just a few hours even by a beginner, requires a minimum of installation space and costs less than $5, excluding the Transmatch and SWR bridge. The tuned circuit of the Transmatch provides excellent discrimination against harmonic output from the transmitter. Ease of construction and portability make this antenna an ideal one for Field Day use.

In case one wonders about the mismatch between the line and the antenna, the secret is in the use of open-wire line. The loss in such a line with an SWR of 25:1, at 10 meters, is less than the loss in RG-58/U when the latter is matched. This material was originally presented in *QST* by Arthur S. Gillespie, Jr., K4TP.

A Helically Wound Vertical Antenna for the 75-Meter Band

"Around and around she goes, and where she comes out — nobody knows." True, perhaps, with a wheel of fortune, but with a helically wound vertical the rf comes out effectively for DX and local work!

In order to have a full-size vertical antenna for the 75-meter band, the antenna would have to be around 65 feet (19.81 m) tall. That, alone, would require guying, or some other means of support which would result in a structure with no aesthetic appeal to any nonhams (who comprise almost 100 percent of the author's neighborhood). By using a helical configuration, the overall antenna height is reduced, thus eliminating the need for guying. With the helically wound antenna, more equal current and voltage distribution is accomplished (as compared with a lumped impedance from a loading coil). As a result, a better radiation pattern is produced. With this system very little reactance has to be cancelled out, eliminating the need for an overly large "top hat."[1] This antenna will easily take the full legal power limit.

Construction details for the antenna are shown in Fig. 19. The following is a list of parts used in constructing the antenna system.

1 — 20-ft (6.10-m) section of 4-inch (102-mm) OD plastic pipe (obtained at a local plumber)

130 ft. (39.62 m) no. 12 plastic-insulated

The dark pole to the immediate left of the tower is the WA0WHE helically wound vertical antenna.

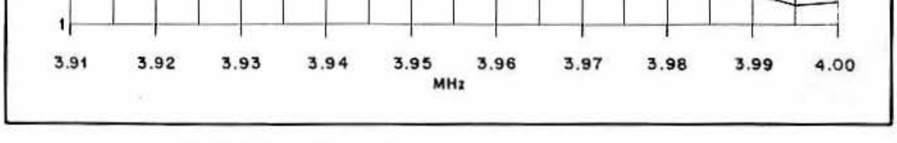

Fig. 18 — Measured SWR of the vertical antenna.

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[1] [Editor's Note: Some form of metal top hat should be connected to the last turn of the driven element at the high-impedance end of the radiator. Extremely high levels of rf voltage can develop at the end of the helix, sometimes causing the tip of the antenna to burn. The top hat tends to lower the Q of the antenna, thus reducing the voltage level at the far end. An aluminum pie tin mounted on a ceramic cone insulator works well in this application.]

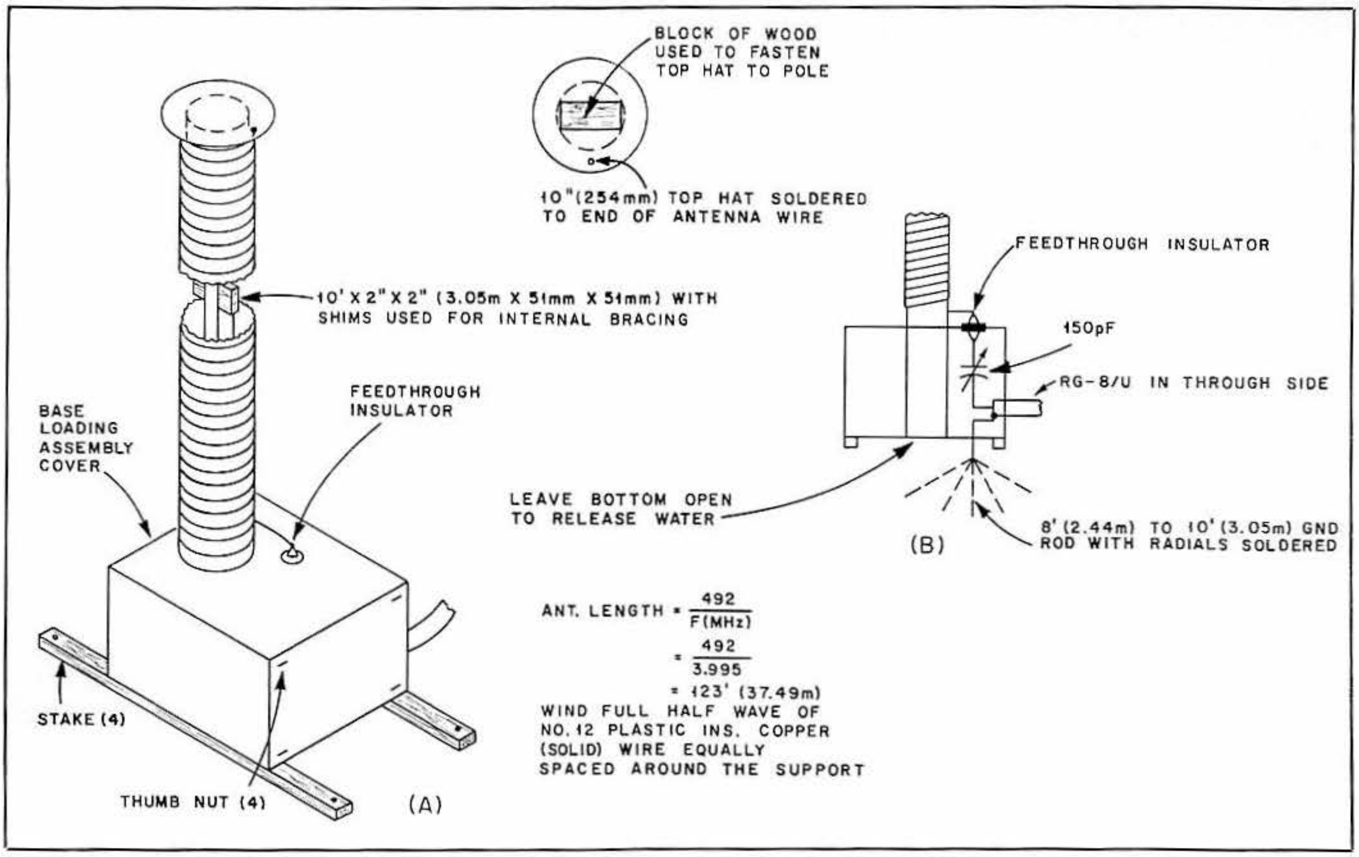
BLOCK OF WOOD USED TO FASTEN TOP HAT TO POLE
10"(254mm) TOP HAT SOLDERED TO END OF ANTENNA WIRE
10' X 2" X 2" (3.05m X 51mm X 51mm) WITH SHIMS USED FOR INTERNAL BRACING
BASE LOADING ASSEMBLY COVER
FEEDTHROUGH INSULATOR
STAKE (4)
THUMB NUT (4)
(A)
LEAVE BOTTOM OPEN TO RELEASE WATER
ANT. LENGTH = 492/F(MHz) = 492/3.995 = 123' (37.49m)
WIND FULL HALF WAVE OF NO. 12 PLASTIC INS. COPPER (SOLID) WIRE EQUALLY SPACED AROUND THE SUPPORT
FEEDTHROUGH INSULATOR
150pF
RG-8/U IN THROUGH SIDE
8' (2.44m) TO 10' (3.05m) GND ROD WITH RADIALS SOLDERED
(B)

Fig. 19 — Construction details of the helically wound antenna.

solid copper wire (allow a little extra, about 2 ft. [0.61 m])

1 — 10-in. (254-mm) disk of sheet metal (top hat; stop at a sheet metal or furnace repairman — I got this free)

260 ft. (79.25 m) no. 14 solid bare copper wire (I used only four radials in this system; use as many as you have room or money for)

20 sq. ft. (1.86 sq. m) of marine plywood for base

2 — 2 × 2 10-ft. (3.05 m) sections, for internal bracing

1 — 8-ft (2.44-m) copper ground rod (for radial junction)

The cost can be reduced considerably if all materials are readily located or already owned.

Fig. 18 shows the results of SWR measurements. The SWR indicator used to make the measurements was a Midland model. The antenna was adjusted for minimum SWR at resonant frequency with the tuning capacitor at the base. The frequency for this antenna is 3995 kHz with 123 feet (37.49 m) of wire wound on the support and one 8-ft. (2.44-m) ground rod and four 65-ft. (19.81-m) radials. There are numerous configurations possible with this system including a broadcasting favorite such as phasing two or more structures. I forgot to mention . . . give the entire structure one or two coats of marine varnish to seal the turns. This material was originally presented in *QST* by Gary L. Ellingson, WA0WHE.

The Ground-Image Vertical Antenna

The name of the game with vertical antennas is the "ground system." Not just any hastily contrived radial ground will do the job right. Read these details for building an effective ground that provides positive results.

Even though a beam antenna supported at the modest height of 40 feet (12.19 m) is a compromise (a 20-meter beam should be higher to be really effective), it still can be an obstacle to good neighborly relations, at least if your neighbors don't appreciate the ecological beauty of such an installation. Moreover, even that modest sort of an installation presents quite a number of engineering problems.

This report presents the results of the first phase of an investigation to find a less conspicuous but equally effective antenna for use at a new location. The author hopes it will provide suggestions for those faced with a similar problem. At the least, it may be of some value to those with a general interest in the subject of antennas.

This first part of this section deals briefly with theoretical considerations, the second with experimental results on quarter-wavelength and five-eighths-wavelength verticals, and the third on the test equipment. It should be pointed out at the outset that the information presented here is the work of a hobby and as such cannot be exhaustive. It is hoped that others will repeat some of the experiments, extend the work, and report the effect in practice of a groundplane system above 3 MHz. To my knowledge such practical data have not been reported.

Theoretical Considerations

A beam antenna possesses the advantage of gain and directivity. Nevertheless, its DX capability is determined primarily by its vertical radiation pattern. A large portion of the radiated energy should be directed between 5 and 25 degrees from the horizon.[1,2] Horizontally polarized antennas yield lower angles of radiation with increase in height above the ground. This is a result of the interference pattern created by reradiation from the earth's surface. Since the earth is a somewhat conducting medium, the electric field tangential to the surface must be approximately zero. This "boundary" condition is brought about by the induced surface currents which create an electric field of opposite phase. This field then combines constructively and destructively with the initial radiation from the antenna. A model for this condition is an image antenna of opposite phase below the earth's surface as a depth equivalent to the height above the surface.[3] In order to get a lobe below 15 degrees, the antenna height must exceed a wavelength. This is greater than 60 feet (18.29 m) on 20 meters.

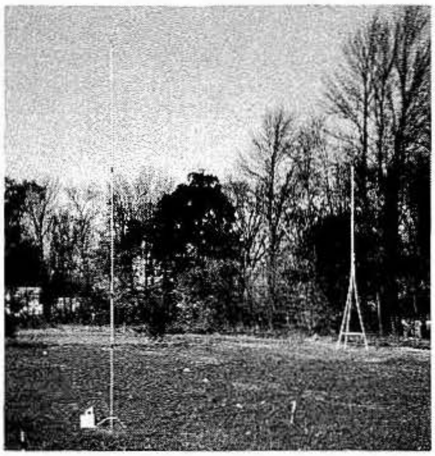
The 20-meter vertical antenna in the foreground, and the 26-foot (7.93-m) test tower.

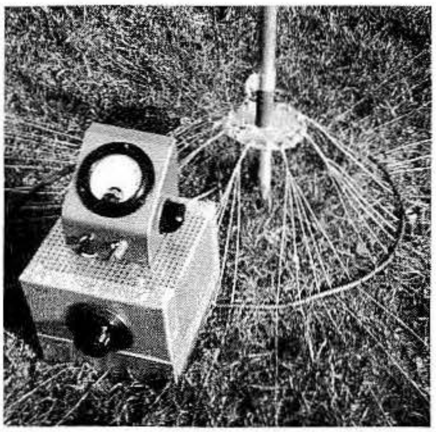
The base of the vertical element of the antenna and the impedance bridge. Forty radials, in bundles of five are fastened to the aluminum base plate and are tied down with a ring made from copper tubing.

On the other hand, a vertical antenna, in the ideal case, possesses an image which is in phase to produce a lobe tangential to the earth's surface. Only when the antenna length is increased to a wavelength, or multiple thereof, does the tangential lobe disappear. This is true whether the antenna is on the ground or suspended in space. Therefore, a vertical beam, i.e., an array of vertical antennas coupled together with an appropriate feed system, on the surface of the earth, seemed to be the logical choice for the new installation since it would appear to meet the following objectives: The system should

1) Exhibit a minimum profile.
2) Be easy to install and tune.
3) Offer a low angle of radiation.
4) Not require a large outlay of money.

The author proceeded, therefore, to construct an array with four vertical elements. When the tests were begun, it immediately became apparent that the simple procedures the writer was using were inadequate to cope with such a complex system. The author had to start anew to develop a test procedure and to build some suitable test equipment. The logical step was to backtrack to a single vertical antenna and use it as a standard on which to develop some basic test standards. As discussed subsequently, the writer found that relatively simple equipment, e.g., a simple impedance bridge, a field-strength meter, and a test oscillator, gave this author all of the data about the system that he needed.

It is important to note that a true ground-image antenna differs substantially from a ground-plane antenna system which relies merely on a few λ/4 radials above the ground. A true ground-image system results when a sufficient number of radials are used and an image of only the vertical section is sufficient to describe it. Considerable information[4,5] is available on ground-image systems for verticals operating below 3 MHz. The results have shown that some

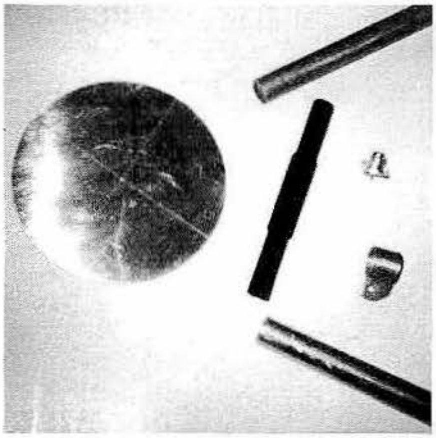
Base hardware for the antennas being tested. The insulator was made from 1-inch (25-mm) maple dowel, turned down to accept the 7/8-inch (22-mm) inside diameter of the ground and antenna tubing.

Table 5

Comparison of responses of 1/4-wavelength and 5/8-wavelength vertical antennas at low radiation angles. Data were taken by field-strength meter mounted on a wooden tower at a distance of 7.5 wavelengths at 14.25 MHz. Field strength (E) is normalized to maximum value obtained with 5/8-wavelength case.

θ	$E(\lambda/4)$	$E(5/8\lambda)$	GAIN OF 5/8-λ ANTENNA
0.1°	0	0.58	∞
0.4°	0	0.62	∞
0.75°	0.62	0.80	3.4 dB
1.1°	0.69	1.0	3.2 dB
1.5°	0.62	0.92	3.4 dB
2.25°	0.48	0.80	4.3 dB
3°	0.41	0.69	4.5 dB

The triband trap vertical antenna, which has an overall height of only 12.5 feet (3.81 m). With the system of 40 radials, performance of this antenna on 20 meters was about the same as that of the 1/4 and 5/8-wavelength vertical elements.

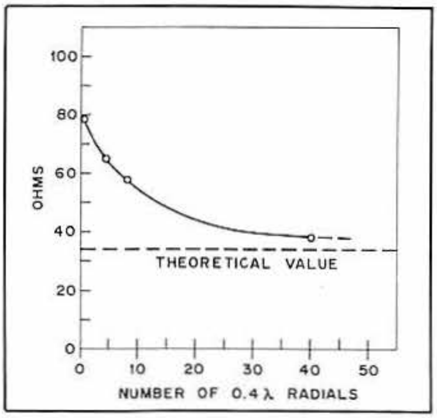

Fig. 20 — The input impedance of a 20-meter quarter-wave vertical antenna as a function of the number of radials 0.4-wavelength long. The four and eight radials consisted of bundles of five wires of no. 18 guage. The 40-radial point was obtained by fanning out the eight bundles.

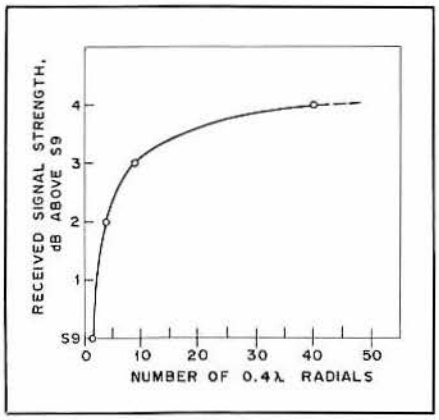

Fig. 21 — The improvement of low-angle radiation of a quarter-wavelength vertical antenna on 20 meters as a function of the number of added radials. A test oscillator was mounted on a wooden tower four wavelengths away at an elevation angle of six degrees from the base of the vertical.

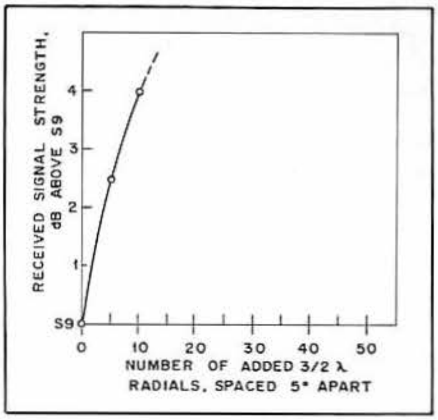

Fig. 22 — The result of interlacing 3/2-wavelength radials in a particular direction. Data were obtained by using a test oscillator on a wooden tower eight wavelengths away, at an elevation angle of 3 degrees from the base of the vertical. The results indicate the advantage of longer wires and the possibility of directional properties of a nonsymmetrical radial system.

100 radials of $\lambda/2$ in length, buried just below the surface, provide an adequate ground system. At higher frequencies, the dielectric effect of the earth becomes important, resulting in severe discrimination of radiation or reception at very low angles.[6,7] At low angles, the waves not only suffer by absorption, but also by a change in phase which results in destructive interference. Since little specific information was available at higher frequencies, the objective of the present work was to measure the input impedance and vertical radiation pattern at low angles of a vertical antenna as a function of the number of radials, in order to determine the feasibility of a vertical-array system as a competitor to beams at high elevation. The results of the tests were most gratifying. The author found that many of the "rules of thumb" which have developed and have been perpetuated to the point where they are practically taken for granted were more myth than truth.

Experimental Results

The classical paper on radial systems, which reports experimental results at 1 and 3 MHz, indicates that a large number of radials 0.4λ long should be used.[8] This appeared to be a good starting point for a 20-meter vertical. Accordingly, to check the number of radials needed, this author used eight bundles of wires, each 25 feet (7.62 m) long, and each made up of five no. 18 copper wires. Each bundle was bolted to a 5 × 1/4-inch (127 × 6-mm) aluminum plate as shown in the photograph. The writer was then able to use each bundle as a radial, measure the input impedance of the system, and then separate the bundles, wire by wire, to increase the number of radials in the system.

Fig. 20 shows the input impedance as a function of the number of radials used. Measurements were made with a simple impedance bridge. (Its construction is discussed later.) The antenna was resonated before each measurement was made, and the difference between the 40-radial system and the 8-radial system resulted only by fanning out the bundles of wires. This technique points out another important feature of ground systems and refutes one of the old myths: since the current carried by the radial system is equally divided among n radial elements, each radial is required to carry only 1/n of the total current. This means that relatively small diameter wire is perfectly adequate.

Moreover, it was found that at the higher frequencies it is best to keep the radials near the surface of the ground. Radials buried more than a few feet become less effective! Thus, you should not rely on the old admonition that radials should be 6 feet (1.83 m) down to be effective. This writer found that burying the wires slightly below the surface is the best way of installing the system. Mechanically the radials can be nailed down, electrically they are most effective, and esthetically they provide little interference to a healthy stand of grass.

It will be seen from Fig. 20 that the input impedance for a vertical antenna is drastically affected by the number of radials. Many radial wires are necessary to prevent an excessive loss of power and to provide a convenient input impedance. Fig. 20 also shows the theoretical impedance limit for an antenna having an effective height-to-radius ratio of 300:1.[9]

Fig. 21 shows the effect on low-angle radiation as a function of the number of radials. These data were obtained by placing a test oscillator on a wooden tower, four wavelengths away. A photograph shows the 20-meter vertical and the 26-foot wooden test tower.

The effect of using longer radials in a particular direction is shown in Fig. 22. Radials of no. 18 wire, 3/2 wavelengths long, were put down between the existing 40 radials. The spacing between the longer wires was five degrees. The considerable improvement indicates the need for longer wires and the directional properties a groundplane could give.

A 5/8-wavelength vertical was also constructed and tested. It consisted of a 40-ft. (12.19-m) telescoping aluminum pole and a loading coil of eight turns of no. 12 wire with a diameter of 2.5 inches (64 mm). The comparison in low-angle radiation at a distance of 7.5 wavelengths is presented in Table 5. A field-strength meter was mounted at different heights on the 26-foot (7.93-m) tower. The groundplane for these data consisted of the 40 0.4-λ radials plus the 11 3/2-λ ones. Measurements were taken in the direction of the added longer radials. The results show the improvement in low angle radiation offered by the 5/8-λ vertical. The input impedance of this longer antenna was found to be 76 ohms.

On-the-Air Checks

From these experiments and measurements the author decided to settle on a 1/4-λ antenna with approximately 40 radials. The installation is shown in the photograph. This writer then proceeded to make on-the-air tests to compare its effectiveness with an inverted-V antenna having its apex at 0.4 wavelength, and with a 5/8-λ vertical using the same ground system. Surprisingly, the 1/4-λ vertical seemed to perform just as well as the much taller 5/8-λ vertical. This could result from the fact that most signals arrive after several hops and the optimum lobe angle is probably as high as 15 to 20 degrees.[10] At that angle, the λ/4 antenna actually enjoys an advantage. With practically all DX contacts, the verticals had a 6- to 8-dB improvement over the inverted V! The only exceptions were at intermediate distances and for local contacts. At about 500 or 600 miles, the inverted V with its higher angle of radiation gave better results. Locally, the verticals gave far superior performance. Improvements of 10 to 15 dB were recorded. A triband trap vertical antenna was also tested on 20 meters and found to be practically the same in impedance and performance. This antenna had an overall height of only 12.5 feet (3.81 m)!

Test Equipment

A most interesting aspect of antenna measurements is that the equipment can be rather simple and in many cases constructed from items most amateurs have in their junk boxes. All that is really needed is some standard to compare with, such as a wattmeter or an S meter that is known to have reasonable accuracy. This writer has used both — the wattmeter in a Drake L-4B linear amplifier and the S meter in a R-4B receiver.

The impedance bridge shown in the photograph was patterned after the one shown in the *ARRL Handbook*. Care was taken in shielding the input and output circuits. The meter was mounted externally in order to minimize stray pickup. A calibration curve was obtained at 14.25 MHz by using many carbon resistors of known values as the load.

The field-strength meter is a simple diode detector and dc amplifier. The instrument was constructed to cover the 10-, 15- and 20-meter bands. Its meter was also mounted externally. The antenna length for the field-strength meter was determined by the strength of the available field. In addition to these pieces of test equipment, a 20-meter transistorized crystal oscillator was used for many of the tests.

Conclusion

The performance of a vertical antenna on the ground is highly dependent upon a good ground system, and, properly installed, the antenna can be a very good performer indeed for DX and local contacts. This is particularly true at the higher frequencies where the dielectric property of the earth plays a major role. Forty radials of no. 18 wire, 0.4λ long, will increase the total radiated power by about 3 dB. Radials can be thin if a sufficient number are used. The thought of using thick wires buried deeply, probably a carryover from lightning grounds, is not valid at higher frequencies. The idea of using only four buried radials, as commonly recommended, is a serious error, and if this article does nothing more than eliminate that misconception, this author will be satisfied. Since the electric field only penetrates the ground for a foot or two at the higher frequencies, the radial wires need be buried only as deep as necessary to escape children's feet and the lawn mower. Finally, these results from the single vertical antenna indicate that a vertical array could be a competitor to the more elaborate horizontal beams and warrants further investigation. This material was originally presented in *QST* by Jerry Sevick, W2FMI.

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[1] Terman, *Radio Engineering*, McGraw-Hill, New York, 1947, p. 651.

[2] Friis, Feldman, and Sharpless, "The Determination of the Direction of Arrival of Short Radio Waves," *Proceedings of the IRE*, Vol. 22, No. 1, January 1934.

[3] Williams, "Antenna Theory and Design," *The Electrical Design of Antennae*, Vol. 2, Second Edition, Sir Isaac Pitman and Sons Ltd., London, p. 126.

[4] Brown, Lewis, and Epstein, "Ground Systems as a Factor in Antenna Efficiency," *Proceedings of the IRE*, Vol. 25, No. 6, June 1937.

[5] Wait, "Input Resistance of L. F. Unipole Aerials," *Wireless Engineer*, May 1955.

[6] Feldman, "The Optical Behavior of the Ground for Short Radio Waves," *Proceedings of the IRE*, Vol. 21, No. 6, June 1933.

[7] Jager, "Effect of the Earth's Surface on Antenna Patterns in the Short Wave Range," *Internat Elektron Rundschau 1970*, Nr. 4.

[8] See footnote 4.

[9] King and Harrison, "The Impedance of Short, Long, and Capacitively Loaded Antennas with a Critical Discussion of the Antenna Problem," *Journal of Applied Physics*, Vol. 15, February 1944.

[10] See footnote 2.

The W2FMI Ground-Mounted Short Vertical

Just because the vertical is physically short doesn't mean it won't provide excellent results in DX work. Theory says it can be done. Here's how!

A short vertical antenna, properly designed and installed, approaches the efficiency of a full-size resonant quarter-wave antenna. Even a six-foot (1.83 m) vertical on 40 meters can produce an exceptional signal. Theory tells us that this should be possible, but the practical achievement of such a result requires an understanding of the problems of ground losses, loading, and impedance matching. This paper covers design principles which are applicable to all of our amateur bands.

Background

Earlier work by the author[1] on the radiation efficiency of a ground-mounted vertical resulted from the desire to design a simple, inexpensive, low-profile DX beam for 20 meters. This first work reviewed the theoretical considerations involved and pointed out that a good ground system is essential to achieve efficient operation of a resonant quarter-wave antenna. The second work applied these results to a 20-meter beam.[2] In the process of trying to extend the results of these investigations to the 40-, 80- and 160-meter bands, and to possible multiband operation, the need arose to understand the operation of a shortened vertical and the effects of different loading schemes on the input impedance.

The first part of this paper deals with the theoretical considerations of a short vertical antenna and the experimental procedures involved in measuring the various parameters. This is followed by experimental results which show the trade-offs involved in shortening antennas by various loading schemes. Finally, specific designs are given for the 40- and 80-meter bands.

Theoretical and Experimental Considerations

There are several old familiar axioms in Amateur Radio that are not completely understood by the amateur. The author refers specifically to the two sayings: *Make the antenna as long as possible and erect it as high as possible,* and, *A full-size beam is better than a smaller beam, and a tall vertical is always better than a short one.* The first axiom is particularly relevant to horizontal antennas, where height is most important for reliable DX operation.[3] Increasing the length tends to increase the gain in certain directions. But with the vertical antenna, taking it off the ground and feeding it at a voltage point (like the J antenna) in order to eliminate radials can result in poorer performance because of increased earth loss.[4,5] More experimental work remains to be done on this phase of vertical antennas. The second axiom noted above is generally true, but misinterpreted by many. The author refers to those important properties: power gain — important in transmitting and capture cross-section — important in receiving. (Power gain is the gain, in magnitude, compared to an isotropic radiator; cross-section is a fictitious area related to the ability of the antenna to intercept the radiated power and make it available to the receiver for detection.) As will be seen below, very little is compromised in these properties by shortening the antenna.

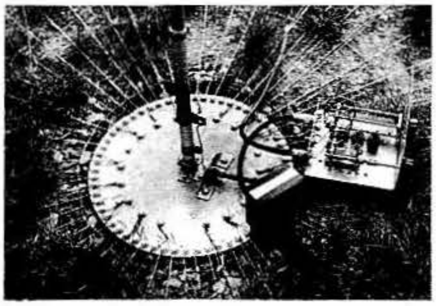
The matching network and base hardware showing 115 radials with the 6-foot (1.83-m) vertical. The pi network is covered with a plastic bag.

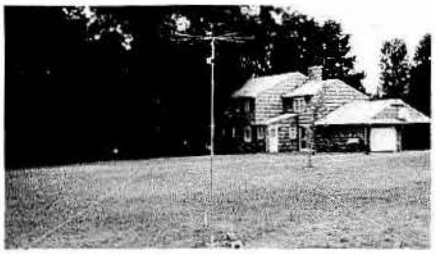
The 10-foot (3.05-m), 40-meter vertical designed for an input impedance of 12.5 ohms in order to use a 4:1 step-up bifilar transformer. The top hat has a diameter of 4 feet (1.22 m) and the coil, placed one foot (0.31 m) below, has 14 turns. Shown at the base is the transformer and impedance bridge.

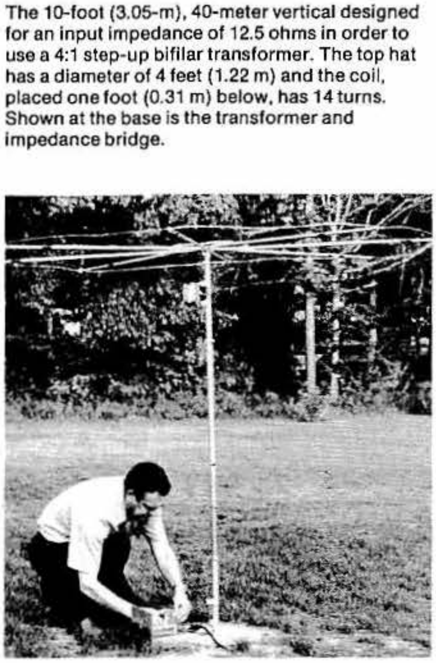
The author with the 6-foot (1.83-m), 40-meter vertical.

The short antenna has been defined as one that is small compared to a wavelength. In a more exact form, it is defined in such a manner as to simplify the mathematics in the theoretical calculations. King[6] has used the following inequality as the definition where

$$\beta_0 h = \leq 0.5$$

$$\beta_0 = \frac{2\pi}{\lambda}$$

h = half-length of a center-fed antenna or the height of a ground-mounted vertical.

λ = the wavelength

$\beta_0 h$ is actually a quantity which is used to express the height of an antenna in terms of an angle in radians. Thus, this quantity is independent of the frequency. Since 40

Table 6

Inductive Loading

	No. of Turns*	h		$R_{rad.}$
1) *Base Loading*				
a)	7	24 ft	3 in.	14.5 ohms
b)	10	18 ft	9 in.	7.5 ohms
c)	12	15 ft	7 in.	5.5 ohms
d)	14	13 ft		4 ohms
e)	18	8 ft	10 in.	2 ohms
2) *Midpoint Loading*	*No. of Turns**	*h*		$R_{rad.}$
a)	6	28 ft	5 in.	28.5 ohms
b)	11	24 ft	3 in.	25.2 ohms
c)	15	19 ft	8 in.	16.5 ohms
d)	18	15 ft	8 in.	12.3 ohms
e)	24	14 ft	6 in.	10.5 ohms
3) *Three-Quarter Point Loading*	*No. of Turns**	*h*		$R_{rad.}$
a)	10	29 ft	4 in.	32.5 ohms
b)	18	23 ft		26 ohms
c)	23	21 ft	2 in.	23.5 ohms
d)	24	19 ft	2 in.	22 ohms

*B & W 3029, 2-1/2 in. dia, 6 TPI, no. 12 wire.

1 ft = 0.3048 m

Table 7

Top Hat and Distributed Loading

1) *Top Hat Loading* (4-spoked wheel with 1/8-inch Al wire rim)

	Diameter	*h*	$R_{\text{rad.}}$
a)	1 ft	30 ft 10 in.	34 ohms
b)	2 ft	28 ft 7 in.	32.5 ohms
c)	4 ft	24 ft	30 ohms
d)	7 ft	19 ft 2 in.	23.5 ohms
e)	4 ft*	23 ft 4 in.	29.4 ohms

2) *Distributed Loading* (Helical Antenna)

	No. of Turns	*h*	$R_{\text{rad.}}$	*Top Hat at 1.5 ft Above Coil*
a)	111	12 ft	8 ohms	1 ft dia.
b)	105	12 ft	10 ohms	2 ft dia.
c)	113	7 ft	6 ohms	2 ft dia.
d)	75	7 ft	7.5 ohms	4 ft dia.

*8-spoked wheel
1 ft = 0.3048 m

Table 8

Parameters of the 40-Meter Short Vertical Designs

Total Height	$R_{\text{rad.}}$ (ohms)	*No. Turns**	*Dia. Top* (ft)	*Bandwidth*
6 ft	3.5	14	7	100 kHz
8-1/2 ft	7.5	at 6 in. below top hat		
8-1/2 ft	7.5	75 on 7 ft dowel 1-5/8 in. in dia.	4	100 kHz
10 ft	12.5	14 1 ft below top hat	4	125 kHz
15 ft 10 in.	12.5	7 at base	4	540 kHz

*Except for helical antenna, coil wire is same as shown in Table 6.
1 ft = 0.3048 m

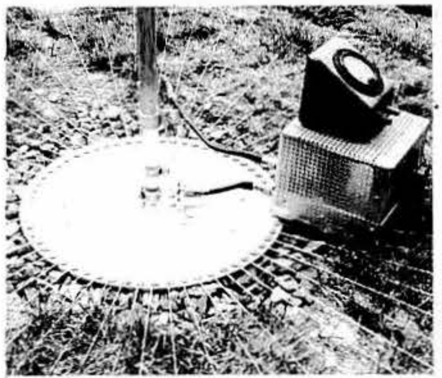

Base of the vertical antenna with 60 radials. The aluminum disk is 15 inches (0.38 m) in diameter and 1/4 inch (6 mm) thick. Sixty tapped holes for 1/4-20 aluminum hex-head bolts form the outer ring and 20 form the inner ring. The insulator is polystyrene material with a 1-inch (25-mm) diameter. Also shown is the impedance bridge for measuring input resistance.
Originally, circular wires were used to connect all radials together. These were positioned every 2 feet (0.61 m), starting from the antenna base. Then, one at a time, they were removed, meanwhile keeping a check on the antenna radiation resistance. There was no apparent change in the radiation resistance, so it was concluded that the interconnecting rings of wire were not needed in the ground system.

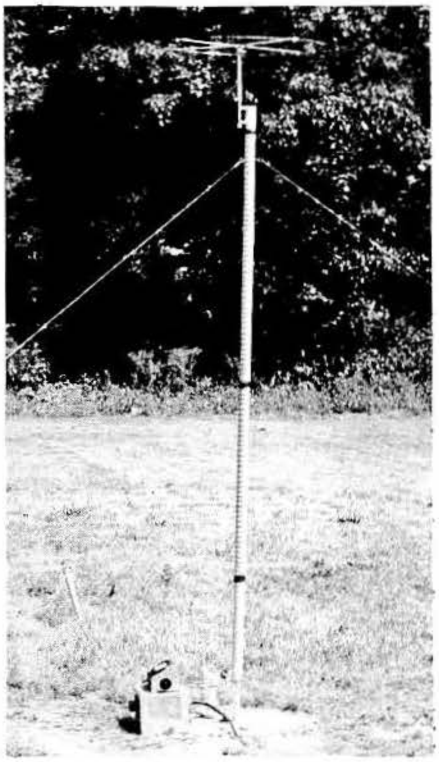

Eight-and-one-half-foot (2.59-m) helical antenna using a 2-foot (0.61-m) top hat 1-1/2 feet (0.46 m) above the 7-foot (2.13-m) helix. The 75 turns have approximately a 3-inch (76-mm) pitch below the midpoint and 1.5-inch (38-mm) pitch above. Very little difference was noted in reversing the pitches. The input impedance was 7.5 ohms.

meters was used mostly for experimental results presented in this article, the inequality above assures accurate theoretical calculations for verticals of 11 feet (3.35 m) or less.

The theoretical results show that the power gain for a *very* short antenna, even less than 1-foot (0.31-m) high on 40 meters, is 1.5.[7] This increases slowly to 1.513 for an 11-foot (3.35-m) antenna. These gains are to be compared to about 1.62 for a resonant quarter-wave vertical. It can be seen that this difference amounts to less than 0.4 dB or 0.07 S unit, based on 6 dB per S unit.

In a similar fashion, the capture cross-sections differ by relatively small amounts. For the *very* short antenna, a cross-section value is $0.119\,\lambda^2$, while for the quarter-wave vertical it is $0.13\,\lambda^2$. This is surprising to many since it is difficult to visualize a vertical of a foot or two (0.31 or 0.61 m) in height on 40 meters, having practically the same receiving ability as a 33-foot (10.06-m) quarter-wave antenna!

But the important property of a short vertical that makes its capture cross-section nearly the equivalent of a full $1/4$-λ antenna is its *very small value of input resistance.* Fig 23 shows the theoretical curve and the 40-meter experimental results for the input resistance of a ground-mounted vertical as a function of height.[8] The experimental data were obtained by essentially canceling out the capacitive reactance of the vertical by an inductance at the base of the antenna and measuring the resistive value with an impedance bridge. Since an extensive, low-loss radial system was used, the resistance measured was actually that of the antenna itself, which is called the *radiation resistance.*

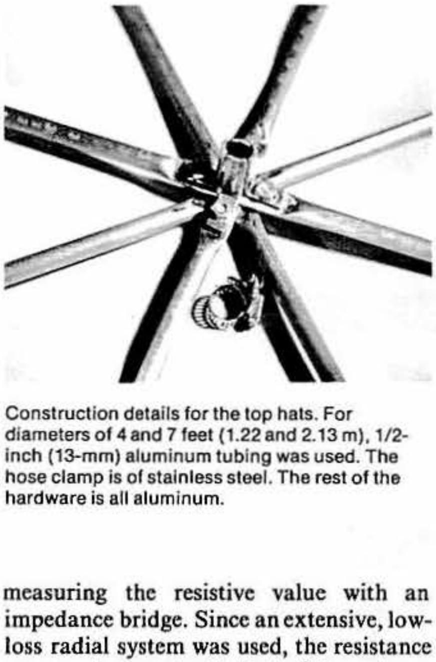

Construction details for the top hats. For diameters of 4 and 7 feet (1.22 and 2.13 m), 1/2-inch (13-mm) aluminum tubing was used. The hose clamp is of stainless steel. The rest of the hardware is all aluminum.

Fig. 24 shows the input resistance of a quarter-wave resonant vertical as a function of the number of radials. At the 115-radial point, the input resistance approaches the theoretical value of 35 ohms, which strongly indicates low earth loss and, hence, reliable data in short antenna measurements. The picture also shows the base hardware for 60 radials. The wire is 15-gauge aluminum. There is nothing sacred about 15 gauge. No. 22 wire, or even no. 28, would be just as good.

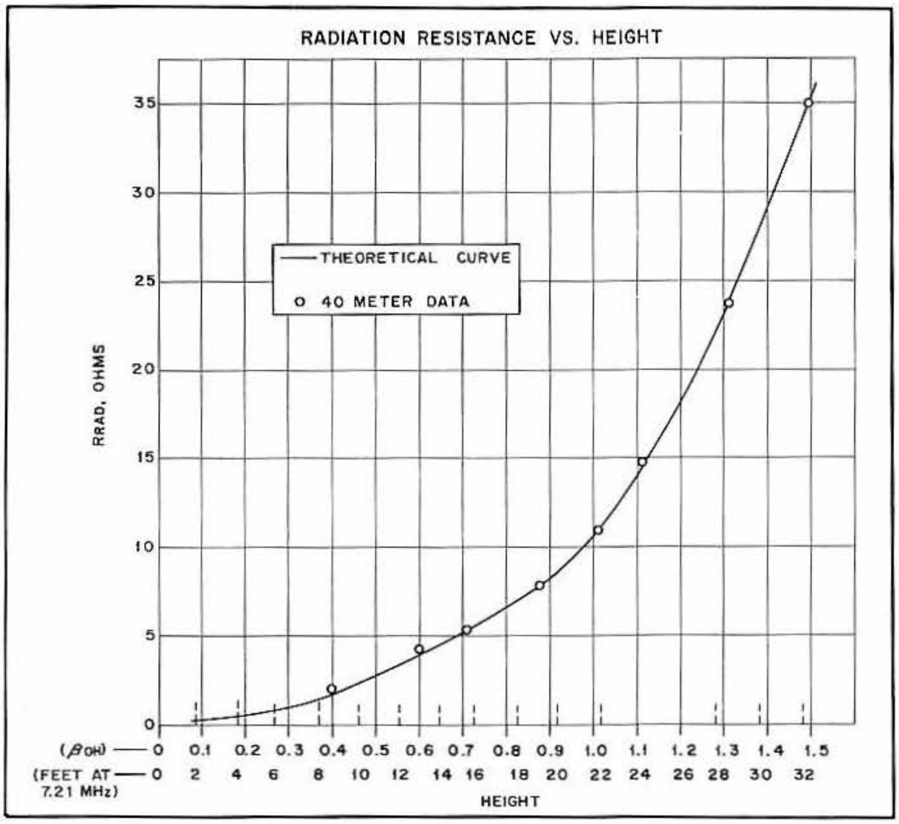

Fig. 23 — Theoretical curve and experimental results for the radiation resistance as function of height.

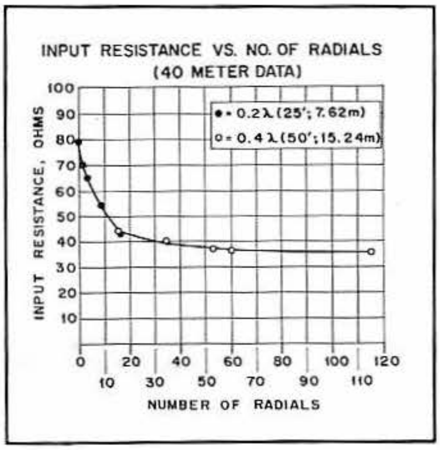

Fig. 24 — Input resistance of a quarter-wave ground-mounted resonant vertical as a function of the number of radials.

It should also be noted that very little difference was noted whether 0.2-λ or 0.4-λ radials were used. At 16 radials, the results are practically identical. In fact, this curve is also similar to the one obtained on 20 meters which was reported earlier.[9] More work remains to be done on the trade-offs in performance versus length of radials for ground-mounted verticals.[10]

Experimental Results

In designing a shortened vertical beam for 40, 80 or 160 meters, a most important consideration is the value of the input impedance of the driven element. As seen in Fig. 23, a shortened vertical using base loading has an extremely low value, particularly at one-eighth wavelength and less. This input impedance is then usually lowered in the presence of other elements in a beam array. The resulting very low value of input impedance makes it difficult to design matching networks. Therefore, an experimental investigation was undertaken to see what increases in radiation resistance could be obtained by other methods of loading, i.e., top hat, three-quarter point, midpoint, and distributed (helical antenna). The results of these experiments are shown in Fig. 25. Table 6 shows the individual points for inductive loading and Table 7 for top hat and distributive loading. Several interesting points were brought out by these experimental results. Fig. 25 shows that top-hat loading yielded the largest value of radiation resistance for a particular height. Surprisingly, the helical antenna[11] yielded a value less than midpoint loading. The three-quarter point and midpoint loading curves were not extended to lower values of height because data were very difficult to obtain below the points shown on the respective curves. The combinations of inductances and lengths below the heights shown on these two curves were probably beyond resonant conditions at the frequency used in the measurements. The other curves were extended by dashed lines indicating no difficulties were encountered in the measurements and other lengths were very possible.

Another interesting aspect of the top-hat loading curve is that a four-spoked wheel approaches to a good degree a solid disk. Doubling to eight spokes only improves the loading by about nine percent as noted in Table 7. Thus, *a few radials on the top of a vertical are very effective.*

Four radials at the base, approximating a ground system, are practically *useless* as noted in Fig. 24. Also, it can be seen from Table 7 that the reduction in length because of top-hat loading is approximately equal to twice the diameter of the disk.

On 160 meters, top hats have been made with sloping wires or struts with success.[12] Because of the sloping nature of this top hat, some cancellation of the antenna current takes place, thus reducing the radiation resistance further.

Although the curves in Fig. 25 were obtained from experiments at 7.21 MHz, these data can be applied to the other bands by proper scaling. For example, by doubling all dimensions, including the number of turns of the loading coils, the radiation resistance values would apply at a frequency of 3.6 MHz. By increasing the dimensions by only 1.85 instead of 2, the results would then apply to a frequency of 3.9 MHz. In like manner, a proper scaling factor could be used to apply these results to a portion of any of the amateur bands.

40- and 80-Meter Short-Vertical Designs

As was stated before, a most important consideration in designing short verticals is a knowledge of the input resistance and how it varies with different types of loading. The objective is to obtain a resistance value large compared to earth losses, so that efficient operation is obtained. In the author's specific case, using 115 radials, practically no earth loss was measured, and, hence, any radiation resistance above a few ohms assured good operation and an opportunity to verify the theoretical predictions for very short vertical antennas.

Since a broad-band, bifilar, 4:1 step-up transformer was available from previous work,[13] the first design was for the shortest vertical having an input resistance of 12.5 ohms. From the curves of Fig. 25, it appeared that a 16- or 17-foot (4.88- or 5.18-m) antenna with a coil of some 13 turns (extrapolated from Table 6) at 8 or 9 feet (2.44 or 2.74 m) from the base would provide the proper impedance at 40 meters. Further, it was decided that some 7 or 8 feet (2.13 or 2.44 m) of length above the coil could be replaced by an eight-spoked top hat having a diameter of 4 feet (1.22 m). The actual design that resulted, after proper tuning, is shown in the picture. The antenna had a total height of only 10 feet (3.05 m) and a 14-turn coil placed 1 foot (0.31 m) below the top hat. This height was about one foot (0.31 m) higher than first expected, but upon careful examination it was noted that the top hat also reduced the radiation resistance, while replacing a section of the vertical portion. Therefore, the height had to be increased somewhat when considering top-loading effects. Also shown in a picture are the construction details for the top hat.

Two other shortened verticals for 40 meters were investigated. One was an 8-1/2-foot (2.59-m) helical using a 4-foot (1.22-m) top hat and 75 turns on a 1-5/8-inch (41-mm), 7-foot (2.13-m) long, wooden dowel. The input impedance was 7.5 ohms and it was matched with a standard pi network. Pictures are shown with the network. Several tests were made by doubling the winding pitch below and above the midpoint, keeping the number of turns constant, with very little difference in results.

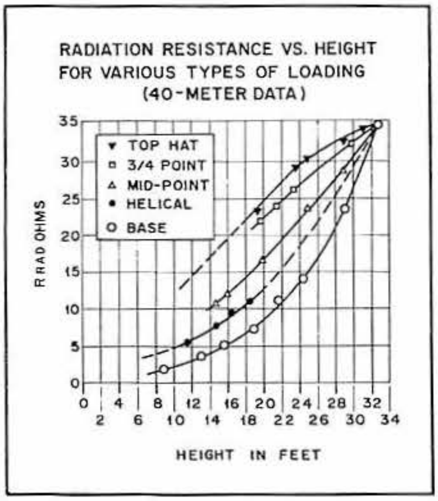

Fig. 25 — Experimental results of radiation resistance as a function of height of antenna for various types of loading (40-meter data).

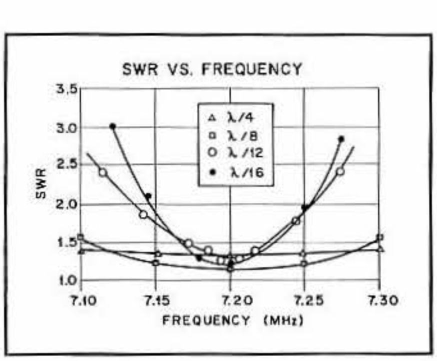

Fig. 26 — Standing wave ratio of various short verticals compared to a resonant quarter-wave antenna. The sixteenth-wavelength antenna is the 8-1/2-foot (2.59-m) helical design, the twelfth-wavelength is the 10-foot (3.05-m) antenna, and the eighth-wavelength is the 15-foot 10-inch (4.83-m) antenna. (All three are described in the text.)

The second antenna, also for 40 meters, using a 7-foot (2.13-m) top-hat, resulted in a matched vertical only 6 feet (1.83 m) high. It had a 14-turn coil, 6 inches (152 mm) below the top hat and an input impedance of only 3.5 ohms. Matching was accomplished with the 4:1 transformer and the pi network. A picture of the antenna and matching network is shown.

A larger 40-meter vertical antenna was also investigated. It had a 4-foot (1.22-m) top hat and 7 turns of base loading which resulted in a height of 15 feet 10 inches (4.83 m) (approximately 1/8 wavelength) and an input impedance of 12.5 ohms. The purpose of this design was to compare its low-angle radiation and bandwidth[14] with the other antennas. Table 8 shows the parameters of these various short vertical designs. Fig. 26 shows the SWR curves of three of the short antennas compared to a quarter-wave resonant vertical and Fig. 27 shows the SWR of the 6-foot (1.83 m) antenna.

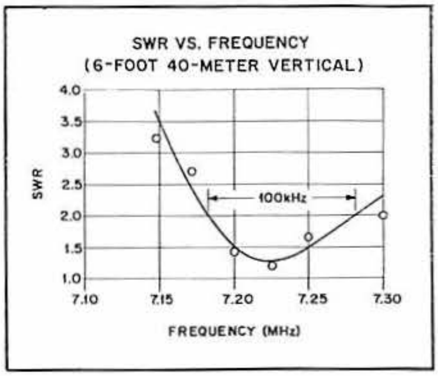

Fig. 27 — Standing wave ratio of the 6-foot (1.83-m) vertical using a 7-foot (2.13-m) top hat and 14 turns of loading 6 inches (152 mm) below the top hat.

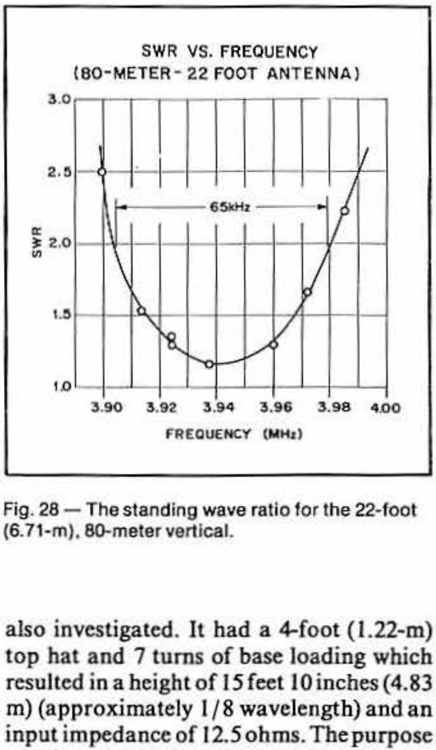

Fig. 28 — The standing wave ratio for the 22-foot (6.71-m), 80-meter vertical.

As can be seen by the SWR curves, shortening an antenna generally decreases its bandwidth. Also by comparing the 8-1/2- and 6-foot (2.59 and 1.83-m) antennas top-hat loading appears to affect the SWR the least. It should also be noted that an eighth-wavelength antenna appears to have a reasonable bandwidth and would probably result in a practical beam design.[15]

And finally, the four short-vertical designs described above were compared with a resonant quarter-wavelength antenna for low-angle radiation and on the air with other amateurs signals. The low-angle radiation measurements were made at three wavelengths in distance and at heights of 1, 3, 6 and 8 feet (0.31, 0.91, 1.83, 2.44 meters). This relates to vertical angles of 0.15, 0.45, 0.90 and 1.2 degrees, respectively. All measurements were made under matched conditions and with a constant 100 watts fed into the antennas under test. In no case were there any appreciable differences noted in the field strength measurements. In fact, the 6-foot (1.83-m) antenna seemed to give slightly higher readings! These measurements certainly tend to verify the theory on the power gain predicted for short verticals. On-the-air checks were again very gratifying and exciting. Over 200 contacts with the 6-foot (1.83-m) antenna strongly indicated the efficiency and capability of a short vertical. Invariably at distances greater than 500 or 600 miles, the short verticals yielded excellent signals.

As was stated previously, all of the results obtained by measurements on 40 meters can be scaled, by the appropriate ratios of frequencies, to other bands. This was tried out on 80 meters. Since a 7-foot (2.13-m) top hat was available (instead of an 8-foot [2.44-m] one), the height turned out to be 22 feet (6.71 m) instead of 20 (6.10 m). The loading coil had 24 turns and was placed 2 feet (0.61 m) below the top hat. On-the-air results duplicated those on 40 meters. The bandwidth was 65 kHz (half of the 40-meter value) as shown in Fig. 28.

Conclusions

Several interesting results came out of this investigation which, even to one schooled in antenna theory, are difficult to believe. The author refers specifically to the ability of very short verticals to radiate and receive as well as a full-size quarter-wave antenna. The differences are practically negligible. But, as was seen, the trade-offs are in lowered input impedances and bandwidths. However, with a good image plane and a proper design, these trade-offs can be entirely acceptable.

As a result of this investigation, other problems were noted which indicate the need for further experimentation. The writer refers specifically to the trade-offs encountered when shortening the radials (to 0.1 wavelength, for example), the efficiency of ground-mounted versus elevated verticals as a function of height above ground, the characteristics of a multiband vertical over a low-loss image plane, and a shortened vertical beam using elements of the order of an eighth wavelength.

Another point should be mentioned in relation to the results reported here. Even though they were obtained on short, ground-mounted verticals, they are valid for center-fed verticals or horizontal antennas as well. The only differences are that the impedance values should be doubled and the effect of the image antenna accounted for.

The author would like to acknowledge the support of many amateurs for their fine words of encouragement and excellent reporting during on-the-air contacts. In this study, some 350 amateurs reported on comparisons between signals from these short verticals and those of other stations. This material was originally presented in *QST* by Jerry Sevick, W2FMI.

References

[1] Sevick "The Ground-Image Vertical Antenna," *QST*, July 1971. Also appears elsewhere in this chapter.

[2] Sevick, "The W2FMI 20-Meter Vertical Beam," *QST*, June 1972.

[3] See footnote 1.

[4] Miller, Poggio, Burke, Seldon, "Analysis of Wire Antennas in the Presence of a Conducting Half-Space. Part II. The Vertical Antenna in Free Space," *Canadian Journal of Physics*, Vol. 50, 1972.

[5] Feldman, "The Optical Behavior of the Ground for Short Radio Waves," *Proc. of the Inst. of Radio Engineers*, Vol. 21, no. 6, June 1933.

[6] King, *The Theory of Linear Antennas*, Harvard Univ. Press, Cambridge, MA, 1956.

[7] See reference in footnote 6, p. 497.

[8] See reference in footnote 6, p. 190.

[9] See footnote 1.

[10] Weeks, *Antenna Engineering*, McGraw-Hill Book Company, 1968, p. 48.

[11] The diameter of the helical antenna was 1-5/8 inches (41 mm). Each helical antenna had a top hat 18 inches (457 mm) above the helix in order to terminate the upper turns with sufficient capacitive reactance.

[12] See reference in footnote 10, p. 44.

[13] See footnote 2.

[14] Bandwidth is defined as the range in frequency where SWR is less than 2:1.

[15] See footnote 2.

Optimizing Vertical Antenna Performance

Do you have tower restrictions, a small yard or patio, almost no room for antennas? If so, here are some suggestions for making your signal bigger in spite of the handicaps.

Antennas never cease to be a hot topic of conversation among amateurs; the interesting articles by John Stanley, K4ERO/HC1[1] and Roger Hostenback, W5EGS,[2] on the optimum grounding of vertical antennas have led the author to communicate these thoughts on the subject. Obstacles at the author's present location (typical of many suburban dwellings) place severe limitations upon where ground wires can be placed. These obstacles are large boulders, areas of concrete, the house, vegetable and flower beds, and the neighbors' property lines. It has not been possible to lay out radials of uniform length or of uniform angular distribution. Nevertheless, the author has had successful results with vertical antennas. Although the writer must make a number of statements which are based upon fragmentary evidence and are lacking in scientific rigor, they should be useful for suggesting how others might proceed to optimize their particular situations.

The writer has three very dissimilar vertical antennas. Much of the discussion will pertain to their individual ground systems, although strictly speaking they cannot be independent; a change of the grounding conductors of one vertical is bound to affect the others. For brevity the writer shall not discuss the methods of impedance matching of the antennas as this is a topic thoroughly covered elsewhere. The author *shall* mention some problems of using dissimilar antennas in a phased array, although the results are preliminary.

The three antennas are (1) a shunt-fed crank-up tower having a three-element triband Yagi on top, the height being variable from 27 to 41 feet (8.23 to 12.50 m); (2) a 40-foot (12.19-m) insulated base-loaded antenna consisting of a 30-foot (9.14-m) pipe mast topped by a whip, located approximately 70 feet (21.34 m) south of the tower and hereafter referred to as the "south antenna"; (3) about 20 feet (6.10 m) east of the tower, a vertical antenna termed the "north antenna," which was described in an earlier *QST* article.[3] Fig. 29 shows the layout. The north antenna has been used with various heights up to 40 feet (12.19 m) but in the present experiments it is used in its "summer" configuration with a height of 25 feet (7.62 m) and with a 7/14-MHz trap located 10 feet (3.05 m) from the base. For 3.5-MHz operation additional loading is supplied at the base.

The Grounding Systems

None of the three verticals have anything approaching an optimum ground system; while the south antenna has the best on paper, it is not necessarily the best in performance. When the south antenna was first placed into operation the grounding system consisted of about 200 feet (60.96 m)

How do you ground a vertical antenna when there is no ground?

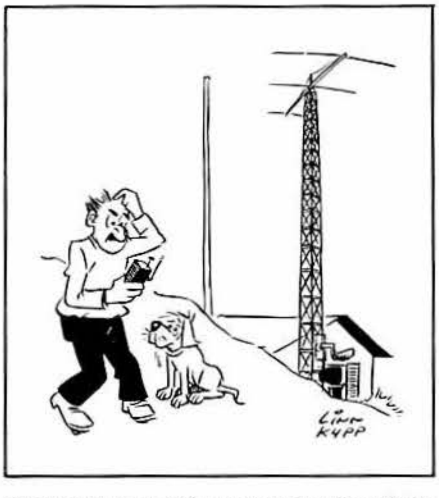

Optimizing ground-wire currents is well worth the time and effort required.

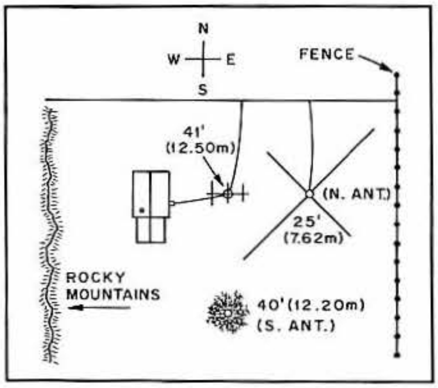

Fig. 29 — The W0JF backyard, with antenna farm.

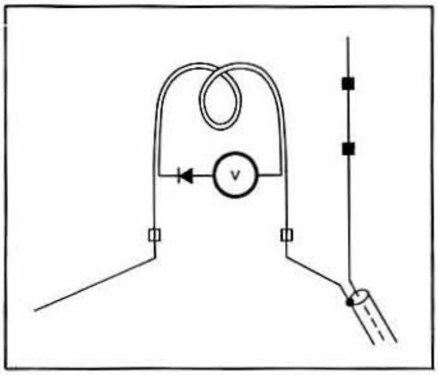

Fig. 30 — Suggested substitute for a thermocouple ammeter.

of wire distributed among a few conductors which went out more or less radially. One was about 60 feet (18.29 m) long, the others 30 feet (9.14 m) or less. On 7 MHz the performance was generally inferior to that of a horizontal half-wave dipole 30 feet (9.14 m) above ground. Later, the ground system was augmented to utilize about 1000 feet (304.80 m) of wire, and the vertical then began outperforming the dipole.

While the author foresaw Stanley's statement that possibly not all of this additional wire would be effective, it was assumed that any wires added at least would do no harm, and the writer tried to put wires in the entire immediate area of the antenna, subject to the constraints mentioned above. Several of the radials have bends to avoid obstacles. In a few cases a single wire goes out from the antenna to a junction some distance away, and then several wires fan outward from the junction. Three wires are connected at the far ends to a few square feet of chicken wire. Where the wires are in shrubbery they are above ground; otherwise they are an inch or two (25 or 51 mm) below. None of the additional wires were as long as 60 feet (18.29 m), and the lengths were generally determined by the obstacles they encountered. Haphazard as this system was, the improvement was spectacular.

While making this change in the south antenna's grounding, the author carried out two simple experiments. First, when operating at 7 MHz, a 33-foot (10.06-m) piece of wire was added, which in free space would be 1/4-λ long, but which when laid on the ground would be longer (in wavelengths). The writer connected it to the rest of the ground system through a thermocouple ammeter, and read the current while applying power. With this wire then cut in half and laid out as separate radials in opposite directions, it was found that the total current increased. Cutting these 1/8-λ pieces in half and distributing the resulting fragments as four radials in directions at 90 degrees to each other caused the total current to decrease. These observations led the author to conclude that for a given total amount of wire the most efficient layout would be radials having lengths of about 1/8 a free-space wavelength. This conclusion is consistent with Stanley's Table 1.[1]

In the other experiment, the author also used a 33-foot (10.06-m) piece of wire, but half of it was no. 34 and half no. 12 wire. With the thick end adjacent to the antenna, the current was higher than with the wire turned around so that the thin end was adjacent. The experiment showed that wire diameter is of some consequence, and it is more important to have heavy conductors close to the antenna.

The Tower and the North Antenna

Grounding of the tower is very heterogeneous; first of all, of course, the bottom of the tower is buried in the ground some 8 feet (2.44 m). There are two radials about 25 feet (7.62 m) long going in a more or less southerly direction, then a short wire going to a water faucet on the wall of the house. Finally, and probably most important, there is a wire that goes northward about 20 feet (6.10 m) and makes a junction with the middle of a 120-foot (36.58-m) east/west wire. The eastern end of this wire is located at the common corner with the property of the neighbor to the northeast and at that point is bonded to his extensive chain link fence. About 25 feet (7.62 m) west of this bond to the fence, there is a junction with a southward wire which is connected to the base of the north antenna. Otherwise, the grounding system of the north antenna, consisting of a few radial wires, is as described in the earlier *QST* article.

Some observations were made by connecting a thermocouple ammeter and a selection of capacitors and inductors in series with various conductors connected to the base of the tower. On 3.5 MHz, with the wire that goes to the fence, the author found a very strong resonance using a 300-pF capacitor. No such resonance was found with this wire of 7 MHz nor on 1.8 MHz, nor did there seem to be any resonance with any of the other wires.

No attempt has been made to bond the upper and lower sections of the tower (where they telescope) together. No such bonding seems necessary, except in the rare case of an extremely strong wind, when there is some receiver noise resulting from poor conductivity between the sections. Cranking the tower up and down seems to have little effect upon the degree of impedance mismatch.

On 3.5 MHz, using a power of about 150 watts, the author had contacts all over the world using this shunt-fed tower, usually not cranked all the way up. The south antenna has also given fairly good account of itself, but with its thousand feet (304 m) of radial wires its performance is still not quite as good as that of the tower with its meager "black magic" grounding.

On 7 MHz, the behavior of the tower is the reverse even though the impedance match is somewhat superior to that on 3.5 MHz. The performance, despite the good match, is far inferior to the south antenna or even the north antenna. Offhand, one would expect the performance, such as it is, to be better with the tower cranked down to minimum height, when it would be close to 1/4λ, but the few reports received on the air indicate better performance is obtained at maximum height. The overall performance of the tower on 7 MHz is a complete mystery.

The author has used the tower on 1.8 MHz only rarely, but has worked as far as 1000 miles, even though there is a very bad impedance mismatch on the feed line. One of the author's future projects is to cure that, since the tower may be magic on the top band, too!

What if You Don't Have a Thermocouple Ammeter?

The preceding discussion has, the author hopes, suggested that individuals may be able to optimize their ground systems by measuring the currents in individual ground wires. In this regard the writer has been fortunate in having available a number of thermocouple ammeters, instruments not commonly available in ham shacks. However, it was found easy to make a substitute which can serve to measure relative current and to detect resonances. Take a short length of twin-lead, speaker cord or similar cable, about a foot (0.305 m) long. Connect one wire of the pair in series with the circuit to be studied (the ground wire). Connect the two ends of the other wire of the pair to a semiconductor diode and a sensitive dc meter in series (Fig. 30). For convenience and for reproducibility in results, coil the cable up and secure it to a terminal board.

Using Dissimilar Antennas in a Phased Array

The author can use any two of the three verticals as a phased array by connecting the feed lines in parallel at the transmitter. In the shack the author has a switchboard that can switch additional lengths of line in series with one antenna or the other. The writer does not attempt to change the impedance match at the bases of the individual antennas, but does generally retune the transmitter as the phasing is changed. Some of the effects observed must be attributed to variations in impedance mismatches rather than to basic changes in directivity. Nevertheless, some gain can usually be obtained by combining the verticals in one way or another.

In the use of two dissimilar antennas, two questions arise which may not apply when identical antennas are used. First, is there really an advantage in using the two of them in a phased array over using the better of the two alone? The relevance of this question may be seen by considering the extreme case where one is very much better than the other. In such a case the field strength of the poorer one is so much less that there is little difference whether it is in or out of phase with the field of the better one, and there can be little or no observable directional effect when the two are used together. Furthermore, the power supplied to the better antenna is cut in half while the other half of the power is largely wasted.

This simple argument suggests that in most cases the two antennas should be nearly equal in the field strengths they produce if they are to be effective in a phased array. However, the actual situation is sufficiently complex that exceptions may be found. For one thing, the better antenna may have "blind" directions in its pattern because of obstructions, and the poorer one may help to fill those in. Also, the impedance effects which have been mentioned before are hard to predict. The author can only suggest that one may find it worthwhile to try using two such antennas together, and may find unexpected advantages in some directions.

On 3.5 MHz the north antenna is generally much poorer than the tower. However, in some directions observers have consistently reported a small gain in using the two together over the tower alone. Incidentally, it should be mentioned that observations made on receiving are not reliable tests, partly because of impedance effects. Also, some of the noise received may be generated locally and its effect may mask the true pattern of the array. The only reliable evaluation is by transmitting to distant observers.

The second question concerning dissimilar antennas involves solving for an unknown quantity: the relative phase of the two antennas. The relative phase of the field of an antenna is *not* determined solely by the length of the transmission line connecting it to a transmitter. The impedance of the antenna usually contains a reactive component, and its presence gives rise to a phase shift. With two identical antennas these phase shifts are the same and do not affect the relative phase between the two antennas, which is determined only by the difference in feed-line lengths. With dissimilar antennas these phase shifts are generally not identical, and they may vary in different ways with shifts in frequency or with variations in the moisture content of the earth. Not unrelated was a discovery made when changing the grounding of the south antenna from 200 feet (60.96 m) of wire to 1000 (304.80 m). There was a substantial change in the phasing when it was used in an array with the tower.

The author has experimentally answered this phasing question by setting up a small probe antenna at a point equally distant from the two antennas and connecting it to a field-strength meter. The line lengths are varied until a minimum (usually quite sharp) is observed. Then it is known that the antennas are 180 degrees out of phase, and the array is a bidirectional end-fire one (W8JK). If the author adds or subtracts 1/2 λ of line from one antenna, the antennas should be in phase and a maximum should be observed. The experimental observations are in agreement with such predictions. If a length of line equal in electrical wavelengths to the spacing between the antennas is then added or subtracted from the feed line of one of them, the combination approximates a unidirectional end-fire array. The favored direction is away from the element which has the longer equivalent feed line (larger phase shift from the transmitter).

To reiterate, the results with phasing dissimilar verticals are very preliminary, and there is little that can be said about them except for the fact that at times very noticeable gains over using the better single antenna are observed.

Vertical Versus Horizontal Antennas

The author used some *horizontal* antennas and observed the differences in performance between them and the vertical antennas at a particular location. Horizontal antennas were not tried on 7 and 3.5 MHz any higher than 30 feet (9.14 m) above ground, however.

The first foothills of the Rocky Mountains rise up immediately to the west of the author's QTH, the nearest ones subtending a vertical angle of about 10 or 15 degrees. As expected, propagation to the west is usually difficult. To the east there are some power wires running north and south. The land slopes off to the north, and has a line-of-sight view for 12 miles from the base of the antenna tower.

The writer finds a tendency for horizontal antennas to be superior to the west, over the mountains, and for verticals to be superior to the east. Standard theory explains these findings as follows: Probably many of the signals coming over the mountains are scattered by the surface of the ground. Those familiar with advanced electromagnetic theory remember that according to the Fresnel equations, the reflection coefficient is greater when the wave is polarized with the electric vector parallel to the surface (i.e., horizontal). Therefore, this scattered radiation is probably horizontally polarized. On the other hand, the electric field from the vertical antenna is perpendicular to the direction of the power wires and is less disturbed by them than the field of a horizontal antenna.

Although very few firm results were presented, the author hopes he has suggested some procedures which will help those facing restrictions on grounding systems they can use. With a little persistence and ingenuity, they should be able to build effective antennas. It *is* possible to evaluate simple arrays yourself and to improve their performance according to your own communication requirements. This material was originally presented in *QST* by Yardley Beers, W0JF.

References

[1] Stanley, "Optimum Ground Systems for Vertical Antennas," *QST*, December 1976.

[2] Hoestenback, "Improving Earth-Ground Characteristics," *QST*, December 1976.

[3] Beers, "Short Antennas for the Lower Frequencies," *QST*, September 1970.

Some Plain Facts about Multiband Vertical Antennas

Does engineering jargon, page-long equations and references to the *IEEE Proceedings* have you gnawing your nails in frustration? Take heart, for these bits of knowledge about multiband vertical antennas are given in plain lingo.

During discussions with newcomers, and old-timers for that matter, it becomes apparent that there is considerable confusion as to what exactly a multiband vertical antenna is. The confusion concerns the method of feed, how much mismatch one can expect, how many radials are required, how the particular antenna is built for multiband use, plus some other points.

This article breaks the subject into simple language and provides the reader with sufficient expertise to assure him that he won't wind up with a system he really doesn't want. Before going into a discussion of the different types of multiband "verticals" we will offer some simple antenna facts.

Some Basic Theory

The term "multiband antenna" has come to mean many things to hams. With trap antennas, tapped coils, random wires, and so forth, there is plenty of reason for the confusion. Simply, a multiband antenna is one that can be used on more than one band. How we make it work on different bands is another story.

Basically, any piece of wire of *any* length can be classed as a multiband antenna. For example, a length of wire 4 feet (1.22 m) long *could* by used on *any* amateur band, from 160 meters on up. But how well the piece of wire would work is a completely different matter.

In the feed point of any antenna there is *radiation resistance.* The energy supplied to an antenna is dissipated in the form of radio waves and in heat losses in the wire and nearby insulating materials. The radiated energy is the useful part, but so far as the transmitter is concerned it represents a power consumption just as much as does the energy lost in heating the wire. In either case the dissipated power is equal to I^2R; in the case of heat losses, R is a real resistance (ohmic losses), but in the case of radiation, R is an *assumed* resistance. This fictitious resistance is the radiation resistance. This brings us to our first important point about multiband antennas.

Whenever one reduces the size (length) of an antenna physically, the radiation resistance is reduced also. As an example, assume we have a 20-meter quarter-wave antenna, which is approximately 16 feet (4.88 m) long. Let's imagine we made it out of no. 40 wire, which has a resistance of about 1 ohm per foot, (0.31 m). The radiation resistance of a resonant quarter-wave vertical operated against a perfect ground is on the order of 35 ohms. In this case, the feed-point impedance of our antenna would be roughly 35 ohms in radiation resistance plus 16 ohms in ohmic resistance. If we were to feed 51 watts into this antenna 16 watts would be dissipated as heat (lost power) and the remainder — 35 watts — would be radiated. Now, suppose we use this same antenna on 80 meters. As mentioned above, when we reduce the size of an antenna physically the radiation resistance is also reduced. On 80 meters our 16-foot (4.88-m) antenna would have a radiation resistance on the order of 1 ohm! However, we would still have the ohmic resistance of 16 ohms. It doesn't take much figuring to realize that just about all of our power would be lost as heat.

Of course we wouldn't use no. 40 wire for such an antenna. More likely the antenna would be made from aluminum tubing and the ohmic losses would be very low, but probably still more than the radiation resistance. There is an old axiom in Amateur Radio that offers some pretty good advice: Always make the antenna as long as possible and erect it as high as possible. Also, there is a joke that goes with that axiom — if such an antenna stays up, it is too small!

At this point we have only mentioned radiation and ohmic resistance in the antenna feed point. These are the two resistances that exist when the antenna is resonant. When the antenna is not resonant, there is reactance present in the feed point. Reactance is also expressed in ohms, but it isn't a real resistance in the sense that power can be dissipated therein. We won't go into a long discussion on reactance because it would take up too much space. An excellent explanation can be found in the League publication, *Understanding Amateur Radio.* Simply, reactance can be likened to a gate or door that stops or hinders the flow of current into a circuit. When an antenna is operated at some frequency other than the resonant frequency there will always be reactance present. Keep in mind that with *any* antenna, multiband or otherwise, we always have a condition on some band or frequency where the antenna is not resonant. Therefore, there will be reactance at the feedpoint.

Types of Vertical Antennas

The basic and most popular type of vertical is one that is a quarter wavelength long and is operated against ground or in a groundplane configuration. The antenna is usually made from tubing and the radials are wire. An ideal groundplane (simulated earth ground) would be a sheet of metal with

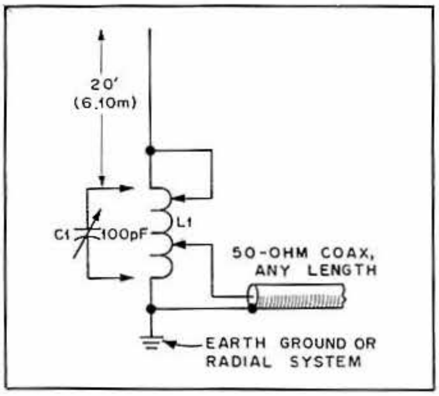

Fig. 31 — A typical multiband vertical antenna. A description of the system is given in the text.

a radius of one-quarter wavelength or more. However, this is only practical at vhf so the customary method is to use wires as the radials. Probably the number one question asked about groundplane antennas is, "how many radials are required?" The answer is simply, the more radials used, the better the antenna will perform, at least up to a certain point. This should not be construed to mean that an antenna with only two or three radials won't work. Such an antenna will work, but for *maximum* performance one should consider 40 or more radials. If the reader is interested in performance data for a few radials versus many, he should read the article in *QST* by Sevick.[1]

The feed-point impedance of quarter-wave groundplane is on the order of 35 ohms. The impedance can be raised by drooping the radials down until a 50-ohm match is obtained. Exactly how much droop is required depends on the number of radials.

The quarter-wave groundplane is essentially a single-band antenna. However, a 40-meter quarter-wave vertical can also be used on 15 meters, a happy circumstance for the Novice. In this case, a 40-meter quarter wave works out to be three quarter waves on 15 and any *odd* multiple of quarter waves will provide a relatively low-impedance feed.

Multiband Verticals

When we get into the field of multiband verticals we find that considerable confusion exists. As pointed out previously, *any* antenna can be *called* a multiband antenna, but how we get power into such an antenna is another matter.

Up until the '50s any amateur multiband antenna was a system that usually consisted of an antenna, tuned feeders, and an antenna coupler. In the early '50s more and more amateurs started to use coaxial cable for feeders, along with band-switching transmitters. The next logical step was the use of a multiband antenna system that required no adjustments and always presented a matched condition to the feed line — in other words, an antenna that had a 50-ohm feed-point impedance on every desired band and frequency within a given band. A logical development was the multiband trap antenna.

By inserting traps in an antenna it was possible to make an antenna "look" like a resonant half-wave dipole in whichever band was used; or, in the case of multiband verticals, making the vertical look like a resonant quarter-wave antenna for the desired band. However, and this is important as far as the newcomer is concerned, to our knowledge there is *no* multiband trap antenna that will provide a perfect match on all bands, *regardless* of what some antenna manufacturers may tell you. Many hams have spent countless hours trying to adjust trap antennas for that "perfect" match when actually, it is just about impossible to obtain such a condition.

Nontrap Multiband Verticals

Several antenna manufacturers sell multiband antennas that consist of a vertical piece of tubing, usually 16 to 20 feet (4.88 to 6.10 m) long. The tubing is used with a loading coil at the ground end. By making appropriate taps and adjustments on the coil the antenna can be matched (or closely matched) on any given band. This type antenna has *no* traps. This in turn means that the coil taps and adjustments *must* be altered when one changes bands. Some misguided amateurs buy these antennas expecting all they need do is put them up and the antenna will work on all bands, automatically. Let's make one point clear: such an antenna *is* a multiband antenna, but requires adjustment *at the antenna* when one changes bands.

Of course, the next question should be, "If the antenna is that simple can't I build my own?" Yes, it is a very simple multiband antenna to make and install. Two or three sections of inexpensive 10-foot (3.05-m) TV mast sections can serve as the vertical radiating element. The mast can be supported on an insulator, such as a beverage bottle, and the mast guyed with nylon line. Fig. 31 shows a diagram of the antenna system. L1 should be a coil made of bare wire, no. 12 or 14, so that it can be tapped at every turn. A convenient coil size is 2-1/2 inches (64 mm) in diameter, six turns per inch (25 mm), such as B & W 3905-1 stock. The number of turns required, assuming 80 meters as the lowest band to be used, should be about 30 turns with an antenna length of 25 feet (7.62 m).

Adjustment of the antenna requires the use of an SWR bridge. Connect the coax line across a few turns of L1 and make a trial position of the shorting tap. Measure the SWR, then try various positions of the shorting tap until the SWR reaches its lowest value. Then vary the line tap similarly. This should bring the SWR down to a low value. Small adjustments of both taps should provide an SWR close to 1. If not, try adding C1 and repeat the adjustment procedure, varying C1 each time until a match is achieved. Radials will enhance the performance of the antenna. The number of radials is up to the individual amateur.

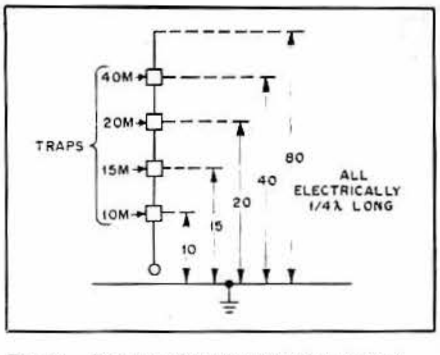

Fig. 32 — Drawing of the theoretical multiband trap vertical. In commercial practice, certain traps may be grouped together, giving the impression that only a single trap is used.

Trap Verticals

As mentioned earlier, traps can be installed in a multiband vertical. These traps are usually parallel-tuned circuits and the objective is to make each section of the antenna work as a quarter-wave vertical or odd multiple thereof on the desired band. Fig. 32 shows an example of this type antenna.

The purpose in using this type antenna is to provide a system that always presents a matched condition for the feed line. Unfortunately, there is so much interaction between various sections of the antenna that it is impossible to come up with a *perfect* match on each band. What is an *acceptable* match is another story.

Amateurs as a whole are inclined to attach too much importance to an SWR of 1. They feel that if their SWR bridge isn't showing an absolute zero reflected power that something is horribly wrong and they won't work out. The plain fact is that using a feed line such as RG-8/U (assume a 100-foot [30.48 m] length) one could have an SWR of as much as 5:1 and have *no* appreciable loss in the system. However, there is one clinker in this thinking!

In many instances commercially made transmitters and transceivers are designed by the manufacturer to work into a 50-ohm load only. They don't allow much leeway from this figure. When there is a mismatch in the antenna system, it can become impossible to load and tune the final amplifier of the transmitter. There just isn't enough tuning range in the tank circuit of the amplifier to handle the reactance that may be present in the load. There is a way around this problem however, and that is using a Transmatch in the feed line to disguise the mismatch.[2] The Transmatch can be adjusted so that the transmitter "sees" a 50-ohm load regardless of the mismatch at the antenna.

The Harmonic Problems

Another consideration should be mentioned. As pointed out earlier, *any* antenna can be a multiband antenna. By the same token any harmonics generated in the transmitter that reach the antenna can be radiated. It is true that a single-band antenna will reject harmonic energy, but *not* completely. In the case of a multiband trap antenna there is no rejection of some harmonics, simply because the antenna is designed to be resonant on all hf amateur bands. The solution to this problem is the use of a selective circuit installed in the feed line. A Transmatch is such a circuit and should provide adequate harmonic rejection.

Some Other Thoughts

The question is frequently asked, "Should I mount my vertical on the ground, or get the base up in the air?" Getting the antenna up in the clear is always better than having it mounted at earth level and surrounded by rain gutters, house wiring, trees, power lines and so forth. However, getting the vertical antenna up in the air also means that radials, as many as possible, should be used. The average installation (if there is such a thing) usually consists of three or four radials (or more) cut for the lowest operating frequency. Such a system should give a good performance.

Another important matter is that of the earth ground. When verticals are mounted at ground level the ground losses can be very important. Too many amateurs buy their verticals, get a 5-foot (1.52-m) long TV-type ground rod and drive it into the earth at the base of the antenna. They think this provides a good ground connection. As a matter of fact, the TV-type ground rods are practically worthless for amateur work. A *good* ground rod is the type used by the power company for home installations. This is a rod that is heavily galvanized, 5/8 inch (16 mm) in diameter, and about 10 feet (3.05 m) long. The amateur should be able to buy these rods from any wholesale electrical supply house. If possible, tie your ground connection to the water-system piping, assuming metal piping is used.

You'll hear the statement from fellow hams that verticals are poor antennas and radiate poorly in all directions. This isn't true, because a vertical *can* by a good antenna, but you have to give it a fighting chance. This material was originally presented in *QST* by Lewis McCoy, W1ICP.

References

[1] Sevick, "The Ground-Image Vertical Antenna" *QST*, July 1971. Also appears elsewhere in this chapter.

[2] A suitable Transmatch is described in the transmission-line chapter of any edition of *The Radio Amateur's Handbook*.

Shunt-Feeding Towers for Operation on the Lower Amateur Frequencies

The 160- and 80-meter DX antenna you've dreamed about may already be standing on your property — just waiting to be used as a DX vertical. Read this presentation and learn how to shunt-feed your tower on 1.8 and 3.5 MHz!

Shunt-feeding a tower used to support beam antennas for 14 MHz or higher frequencies has obvious advantages for the amateur who wants to work all lower bands. If a good ground system is installed, the result may be a very effective antenna for DX work on 80 and 160. The shorter tower installations may work very well on 40 meters, if the effective height above ground is less that 5/8 wavelength. Beyond this height the radiation angle goes higher, and the effectiveness for DX goes down.

The shunt-fed tower is at its best on 160, where a full quarter-wavelength vertical antenna is rarely possible. Almost any tower height can be used. If the beam structure provides some top loading, so much the better — but anything can be made to radiate, if it is fed properly. A self-supporting, aluminum, crank-up, tilt-over tower is used at W5RTQ with a TH6DXX tribander mounted at 70 feet (21.34 m). Measurements showed that the entire structure has about the same properties as a 125-foot (38.10-m) vertical. It thus works quite well on 160 and 80 in DX work requiring low-angle radiation. It can also be used on 40, but results are rather poor because of high radiation angle. WB5FKX, with a 37-foot (11.28-m) tower and a 21-MHz beam, finds that shunt feed on 40 enables him to work DX that he never knew existed before.

Close-up view of the base of the shunt-fed tower, showing the two bottom arms and their insulators.

Preparing the Structure

Usually some work on the tower system must be done before shunt-feeding is tried. Metallic guys should be broken up with insulators. They can be made to simulate top loading, if needed, by judicious placement of the first insulators. Don't overdo it; there is no need to "tune the radiator to resonance" in this way. If the tower is fastened to a house at a point more than about one-fourth of the height of the tower, it may be desirable to insulate the tower from the building. Plexiglas sheet, 1/4-inch (6-mm) or more thick, can be bent to any desired shape for this purpose, if it is heated in an oven and bent while hot.

All cables should be taped tightly to the tower, preferably on the inside, and run down to the ground level. It is not necessary to bond shielded cables to the tower

Table 9

Shunt-Feed Details for Several Towers Used on 160 Meters

Station	*Height of Tower (ft)*	*"Top-Hat" (Beams)*	*Average Height of Beam (ft)*	*Height of Wire-to-Tower Connection (ft)*	*Wire-to-Tower Spacing (in.)*	*Tuned Value of Gamma Capacitor*
W5RTQ	69	TH6DXX	70	68	30	150 pF
K5PFL	86	Stacked 40, 20, 15, 10 M beams	95	75	24	125 pF
K4PUZ	64	TH6DXX	66	63	8	300 pF
K8KAS	70	TH6DXX	77	68	24	225 pF
W1CER	50	QST 20-M DX Weasel	55	47	44	400 pF

1 ft = 0.3048 m
1 in. = 25.4 mm

electrically, but there should be no exceptions to the down-to-the-ground rule.

No rf problems have developed with rotators, beam traps, or even TV sets where the TV antenna is part of the radiating structure, as is the case at WB5FKX. His only precaution was use of coax on the TV antenna. It would be well to proceed with caution, as every installation could be different in this respect.

Though the effects of ground losses are less severe with the shunt-fed vertical than with the simple quarter-wave antenna, a good system of buried radials is very desirable. The ideal would be 120 radials, each 250 feet (76.20 m) long, but fewer and/or shorter ones must often suffice. You can sneak them around corners of houses, along fences or sidewalks, wherever they can be put a few inches under the surface, or even on the earth surface. Aluminum clothesline wire is used extensively at W5RTQ, and it stands up well. Neoprene-covered aluminum wire may be safer in highly acid soils. Contact with the soil is not important. Deep-driven ground rods, and connection to underground copper water pipes, are good, if usable.

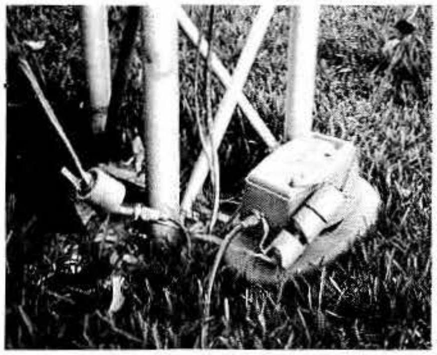

Though variable capacitors are shown in Fig. 33, they were all replaced with fixed-value units except one, which is inside a plastic box at the tower base.

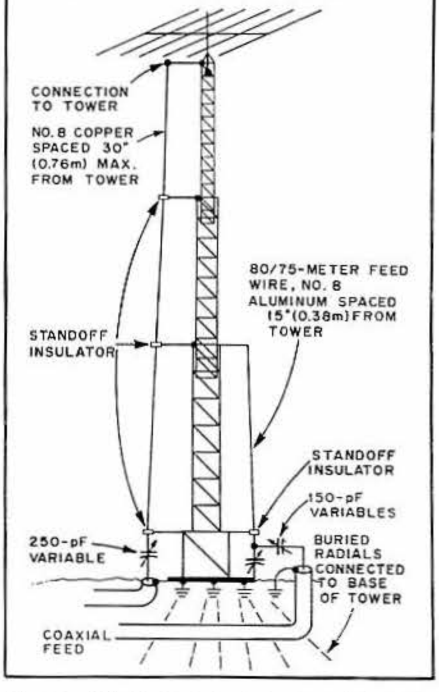
CONNECTION TO TOWER
NO. 8 COPPER SPACED 30" (0.76m) MAX. FROM TOWER
80/75-METER FEED WIRE, NO. 8 ALUMINUM SPACED 15"(0.38m) FROM TOWER
STANDOFF INSULATOR
STANDOFF INSULATOR
150-pF VARIABLES
250-pF VARIABLE
BURIED RADIALS CONNECTED TO BASE OF TOWER
COAXIAL FEED

Fig. 33 — Principal details of the shunt-fed tower at W5RTQ. The 160-meter feed, left side, connects to the top of the tower through a horizontal arm of 1-inch (25-mm) diameter aluminum tubing. The other arms have stand-off insulators at their outer ends, made of 1-foot (0.31-m) lengths of plastic water pipe. The connection for 80/75, right, is made similarly, at 28 feet (8.53 m), but two variable capacitors are used, to permit adjustment of matching with large changes in frequency.

Installing the Shunt Feed

Principal details of the shunt-fed tower for 80 and 160 meters are shown in Fig. 33. Rigid rod or tubing can be used for the feed portion, but heavy gauge aluminum or copper wire is easier to work with. Flexible stranded no. 8 copper wire is used for the 160-meter feed at W5RTQ, because when the tower is cranked down, the feed wire must come down with it. Connection is made at the top, 68 feet (20.73 m), through a 4-foot (1.22-m) length of aluminum tubing clamped to the top of the tower, horizontally. The wire is clamped to the tubing at the outer end, and runs down vertically through standoff insulators. These are made by fitting 12-inch (0.31-m) lengths of PVC plastic water pipe over 3-foot (0.91-m) lengths of aluminum tubing. These are clamped to the tower at 15 to 20-foot (4.57 to 6.10-m) intervals, with the bottom one about 3 feet (0.91 m) above ground. The lengths given allow for adjustment of the tower-to-wire spacing over a range of about 12 to 36 inches (0.31 to 91 m), for impedance matching.

The gamma-match capacitor for 160 is a 250-pF variable with about 1/16-inch (1.6-mm) plate spacing, which is adequate for the power levels presently authorized. The omega match used for 80 and 75 permits retuning for large excursions in frequency encountered in using both cw and phone on this band. Two capacitors are required, each about 150 pF, with plate spacing of about 3/16 inch (4.8 mm), if full power is used. They can be mounted in plastic refrigerator containers for protection against the weather. Use well-insulated knobs to avoid rf burns during the adjustment process.

Separate 50-ohm lines run underground to the station. The shield side of their connectors should be grounded to the base of the tower and to the buried radials as directly as possible.

Tuning Procedure

It is suggested that the 160-meter wire be connected to the top of a structure 75 feet (22.86 m) tall or less. Note, from Table 9, that the monster at K5PFL was fed at 75 feet (22.86 m) above ground. Mount the standoff insulators so as to have a spacing of about 24 inches (0.61 m) between wire and tower. Pull the wire taut and clamp it in place at the bottom insulator. Leave a little slack below to permit adjustment of the wire spacing, if necessary.

Adjust the series capacitor in the 160-meter line for minimum reflected power, as indicated on an SWR meter connected between the coax and the connector on the capacitor housing. Make this adjustment at a frequency near the middle of your expected operating range. If a high SWR is indicated, try moving the wire closer to the tower. Just the lower part of the wire need be moved for an indication as to whether reduced spacing is needed. If the SWR drops, move all insulators closer to the tower, and try again. If the SWR goes up, increase the spacing. There will be a practical range of about 12 to 36 inches (0.31 to .91 m). If going down to 12 inches (0.31 m) does not give a low SWR, try connecting the top a bit farther down the tower. If wide spacing does not make it, the omega match shown for 80-meter work should be tried. No adjustment of spacing is needed with the latter arrangement which may be necessary with short towers or installations having little or no top loading.

The two-capacitor arrangement is also useful for working in more than one 25-kHz segment of the 160-meter band. Tune up on the highest frequency, say 1990 kHz, using the single capacitor, making the settings of wire spacing and connection point permanent for this frequency. To move to the lower frequency, say 1810 kHz, connect the second capacitor into the circuit and adjust it for the new frequency. Switching the second capacitor in and out then allows changing from one segment to the other, with no more than a slight retuning of the first capacitor.

The omega match is recommended for 80-meter operation, because of the wide tuning range required. It was found that the point of connection could be at 28 feet (8.53 m), using a single support at the top of the first tower section. This served as a mount for the second standoff insulator for the 160-meter feed, as well.

A 40-meter feed, not shown, was connected at about 20 feet (6.10 m) up, with about 8 inches (203 mm) spacing between wire and tower.

Substituting Fixed-Value Capacitors

Depending on the frequencies used and the matching problems in a given installation, it may be possible to put fixed-value capacitors in place of some or all of the variables shown in Fig. 33, and then switch them remotely, or by hand, when changing frequency. This was done at W5RTQ. The 160-meter gamma capacitor is now a fixed-value, 150-pF type designed for high rf current service. It does not have to be weatherproofed, and it gives a satisfactory match over the small frequency range used on this band.

Two or three similar capacitors connected in series are used in covering the cw and phone frequencies in the 80-meter band. Operation around 3800 kHz requires about 50 pF in the omega (parallel) capacitor, so the three 150-pF units are used in series. Moving to cw operation near 3500 kHz requires about 75 pF, so only two 150-pF capacitors are used in series. The only variable now in the system is the 150-pF capacitor mounted in the plastic refrigerator box at the base of the tower. It is the series or gamma capacitor in the 80-meter feed. Even this could be replaced with a fixed unit, as it has been found unnecessary to adjust it in the course of normal operation of the station, if only small changes in frequency are made in using the two modes.

Because every tower installation is likely to be different from every other one in some respects, the values and dimensions given here may be subject to change, but the general principles should hold. Proof of this was found in the May 1975 issue of *Ham Radio*,[1] wherein W4OQ describes shunt-feeding in very similar terms. He also presented estimates of the electrical height of various tower-beam combinations that prospective shunt-feed users should find of interest.

It is hoped that this information will inspire others to try shunt-feeding their towers. This method offers an effective way to fire up on the lower frequencies that is useful to many who may have wanted to work these amateur frequencies but have shied away from doing so because of limited antenna space. This material was originally presented in *QST* by Earl W. Cunningham, K6SE.

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[1] True, "Shunt-Fed Vertical Antennas," *Ham Radio*, May 1975.

The Minooka Special

This 160-meter vertical antenna could be just the one for you, if you reside on property of city-lot size or are a mobile operator. You can make it from readily available, inexpensive material.

Inspiration for the design offered here resulted in part from the author's survey of antennas in use by 160-meter operators, worldwide. An extensive report was compiled, which filled a loose-leaf notebook! A boil-down of the most useful information resulted in an 11-page report which was made available to numerous amateurs. Subsequently, the writer was encouraged to submit some of the data for publication. Approximately 60 operators were polled. The following information from that inquiry should be of interest to those who are curious about "preferred" antennas for top-band use.

Question 1: "If you could put up any antenna for 160, what would it be?" *Result:* 60% favored verticals, 30% said horizontals, and 10% indicated mixed feelings. (The term "vertical" includes various configurations — 1/4, 1/2, and 5/8 wavelength, vertical arrays, and inverted Ls.)

Question 2: "Comparing antennas that an average ham could build, do you prefer verticals or horizontals for 160?" *Result:* 70% said vertical, 17% favored horizontal, 5% inverted L, 2% horizontal and vertical, 2% inverted V, and 3% had no opinion. Reasons given for the responses were, "Because of signal comparisons and past experience. A backyard-compatible vertical is more effective than a backyard-compatible horizontal."

Question 3: "Do you operate mobile on 160? If so, what is the antenna used?" *Result:* Three used base-loaded verticals, eight used center-loaded ones, and one employed a Heliwhip. Some of the operators used capacitance hats. Other questions in the survey dealt with receiving antennas, types of soil and terrain, besides requesting complete details of the present transmitting antenna.

Fig. 34 shows some of the vertical systems used when the poll began in 1969. Additional configurations used by successful 160-meter operators are illustrated in Fig. 35. It can be seen that a great deal of useful "backyard theory" is represented in the systems shown. The experience and trials of others can save countless years of experimenting with antennas (not that some of us can't use the exercise)! It is hoped that these data will be of value to future 160-meter operators.

The Minooka Special

The following is a description of an effective vertical antenna for 160 meters, designed with these objectives in mind:

1) Highly effective for 160-meter DX and local work.
2) Easy to build and adjust.
3) Very economical.
4) Fits neatly into back yard.
5) Reasonable bandwidth.
6) Good for portable and DXpedition work.
7) Can be scaled down for mobile operation.

The resultant antenna (Fig. 36) is top loaded inductively and can be built by anyone from readily available material. Only a dip meter and SWR indicator are needed for tune-up. Many versions were built and tested, ranging from 7-foot (2.13-m) mobile types to 60-foot (18.29-m) backyard

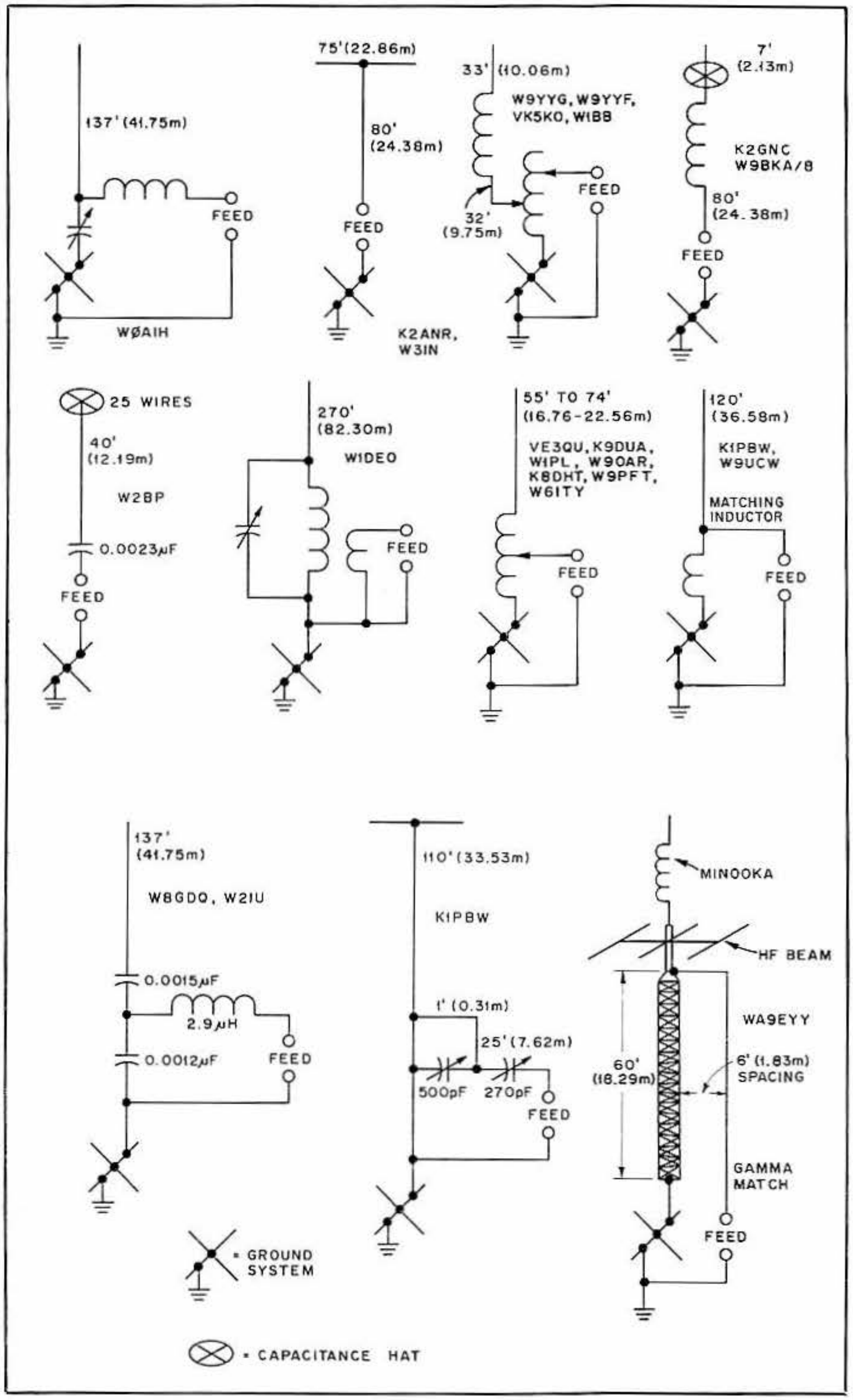
137' (41.75m)
FEED
WØAIH
75'(22.86m)
80'
(24.38m)
FEED
K2ANR,
W3IN
33' (10.06m)
W9YYG, W9YYF,
VK5KO, W1BB
FEED
32'
(9.75m)
7'
(2.13m)
K2GNC
W9BKA/8
80'
(24.38m)
FEED
25 WIRES
40'
(12.19m)
W2BP
0.0023µF
FEED
270'
(82.30m)
W1DEO
FEED
55' TO 74'
(16.76-22.56m)
VE3QU, K9DUA,
W1PL, W9OAR,
K8DHT, W9PFT,
W6ITY
FEED
120'
(36.58m)
K1PBW,
W9UCW
MATCHING
INDUCTOR
FEED
137'
(41.75m)
W8GDO, W2IU
0.0015µF
2.9µH
0.0012µF
FEED
110' (33.53m)
K1PBW
1' (0.31m)
25' (7.62m)
500pF
270pF
FEED
MINOOKA
HF BEAM
WA9EYY
60'
(18.29m)
6' (1.83m)
SPACING
GAMMA
MATCH
FEED
= GROUND
SYSTEM
= CAPACITANCE HAT

Fig. 34 — Illustrations of vertically polarized 160-meter antennas used by various operators for DX and local work. L and C values are not specified in some of the examples because the data were not furnished by the users.

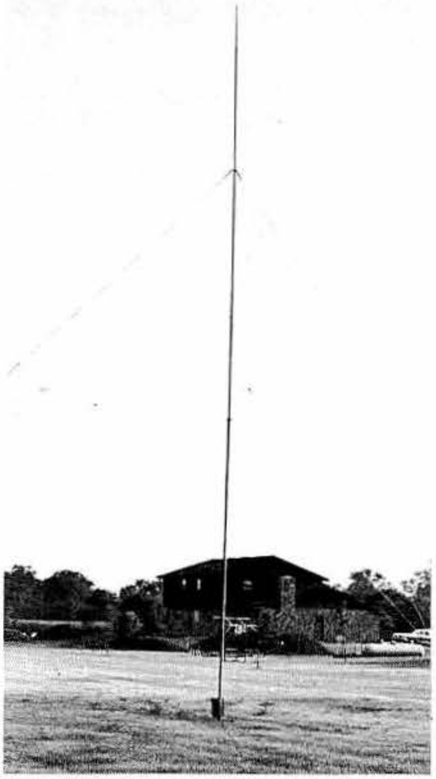

Here is a 50-foot (15.24-m) version of the Minooka Special. It is tuned remotely at K9SKX, and is used on 160 through 20 meters. Nylon or polypropylene guy lines should be used.

or DXpedition models. They have been used with good results from 20-foot (6.10-m)-wide backyards in cluttered Chicago, to vast beaches on Carribean islands, and in South America. The fixed-tuned bandwidths vary from 10 kHz for mobile versions, to 50 kHz for the larger fixed-station models (SWR 2:1 or better).

Construction

The physical layout of the antenna is centered around the use of 3/4-inch (19-mm) diameter rigid PVC water pipe. This sturdy tubing has an outside diameter of 1 inch (25 mm). The inner diameter provides an "interference fit" for 1/2-inch (13-mm) EMT conduit (thinwall). A 3/8-24 nut is driven into a 5-inch (127-mm) length of conduit, then aligned and braized into position. Next, the conduit is taper-ground and polished on the opposite end, then driven into the PVC tubing (see table of dimensions).

In the construction of mobile antennas another piece of conduit is driven into the bottom of the PVC coil form and a 3/8-24 bolt is brazed into the bottom end. The bolt will mate with standard mobile antenna mounts. For larger versions of the antenna the PVC material can be mounted in TV masting, or whatever. A standard 8-foot (2.44-m) stainless-steel whip between 3 and 8 feet (0.91 and 2.44 m) in length can be screwed into the top section. For home-installed versions of the antenna a

Table 10

	No. 1	*No. 2*	*No. 3*	*No. 4*	*No. 5*	*No. 6*
X	5 ft (1.52 m)	8 ft (2.43 m)	4 ft (1.22 m)	4 ft (1.22 m)	19 ft (5.79 m)	3 ft 3 in. (0.99 m)
Y	2 ft (0.61 m)	15 in. (381 mm)	3 ft 6 in. (1.07 m)	4 ft (1.22 m)	11 in. (279 mm)	3 ft (0.91 m)
Z	As long as possible					
Wire Size	No. 20	No. 19	No. 18	No. 16	No. 19	No. 22

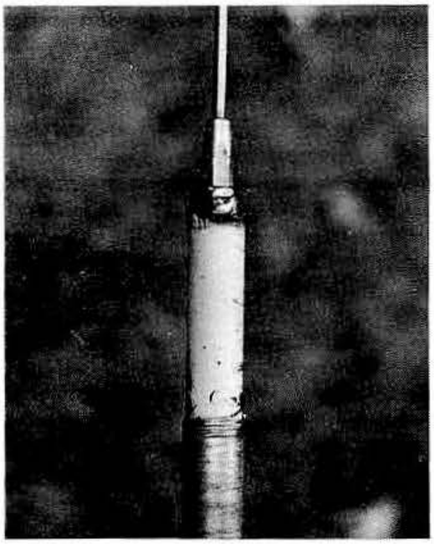

Close-up view of the top section of a coil assembly. This unit was used during mobile operation for over three years (40,000 miles or 64,374 km).

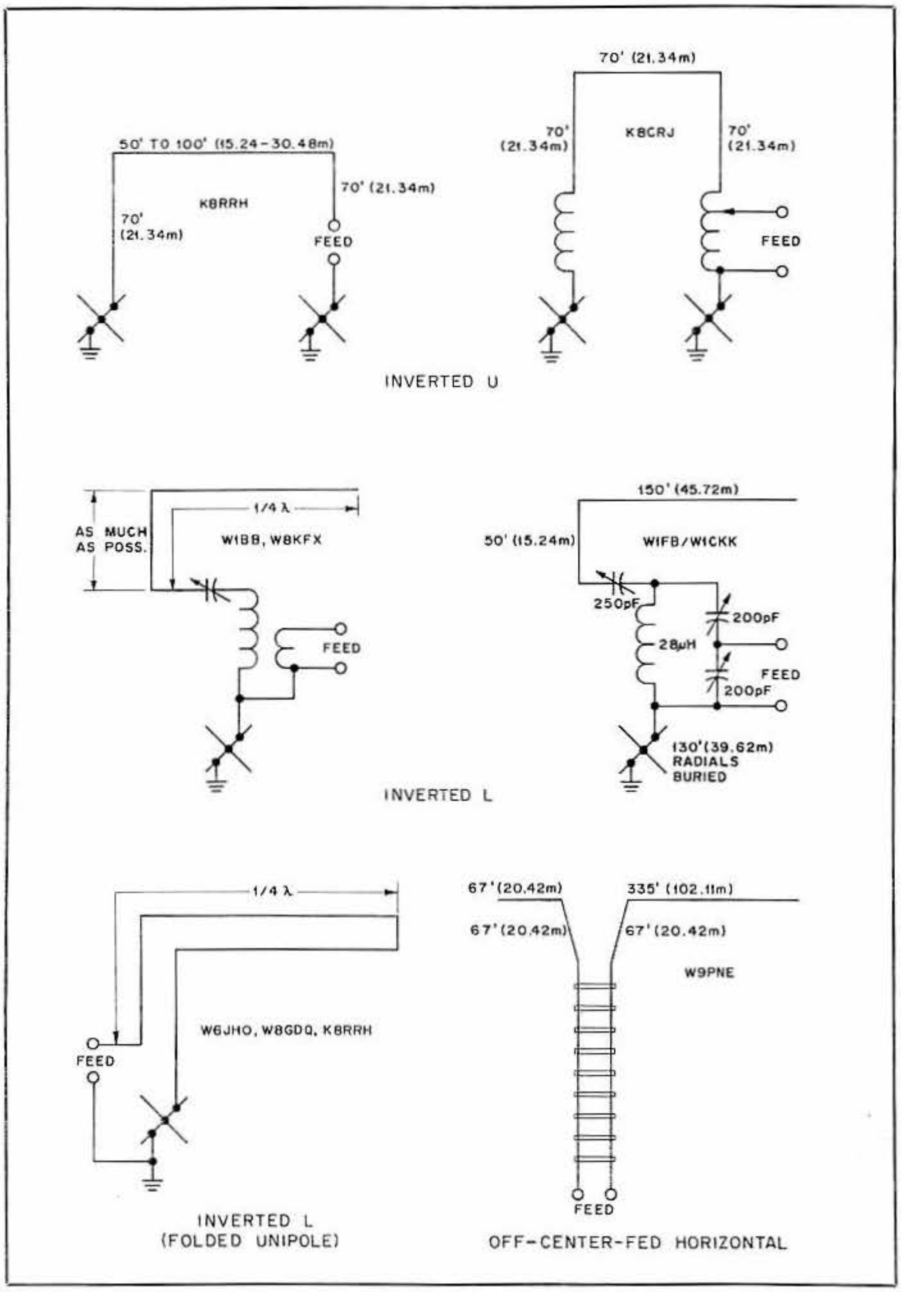
50' TO 100' (15.24-30.48m)
K8RRH
70' (21.34m)
70' (21.34m)
FEED
70' (21.34m)
70' (21.34m)
K8CRJ
70' (21.34m)
FEED
INVERTED U
AS MUCH AS POSS.
1/4 λ
W1BB, W8KFX
FEED
150' (45.72m)
50' (15.24m)
W1FB/W1CKK
250pF
200pF
28μH
FEED
200pF
130'(39.62m) RADIALS BURIED
INVERTED L
1/4 λ
W6JHO, W8GDQ, K8RRH
FEED
INVERTED L (FOLDED UNIPOLE)
67'(20.42m)
335' (102.11m)
67'(20.42m)
67'(20.42m)
W9PNE
FEED
OFF-CENTER-FED HORIZONTAL

Fig. 35 — Examples of additional antennas for 160 meters which proved effective for long-haul work.

A mobile version of the Minooka Special is shown mounted on the author's car.

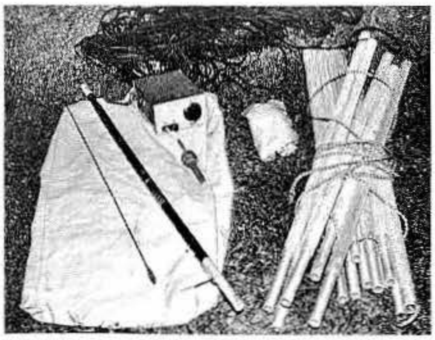

A portable version of the 160-meter vertical antenna. It was used by W9YYG and W9UCW at HK0BKX in January 1974.

3- or 4-foot (0.91- or 22-m) piece of thin-wall tubing can be used in place of the whip. This will save on the cost of materials, and will eliminate the need to have brazing done. The coil wire should be soldered to the conduit to assure a good electrical connection.

Adjustment

Pick a set of dimensions from the table which suits your application, but add a few inches more of coil turns (all turns close wound) than are recommended. This will allow leeway for pruning the system to resonance.

To simplify adjustment it is suggested that the system be assembled first with only the coil and top section (no base section). Place the antenna where it is in the clear (on the car or fixed-station site), and where it can be tuned against the proposed ground system — car body or ground radials.

A three-turn link should be connected temporarily between the lower end of the coil and the ground system. This will permit rough tuning of the system to resonance by inserting a dipper coil into the link and adjusting the coil turns on the antenna until a dip is noted in the desired part of the band. Upon completion of the pruning the constructor can, if he wishes, cover the coil with weatherproof tape or shrink tubing. The antenna should be tuned for roughly 2000 kHz if the entire band is to be used. Adjust the resonance for 1850 kHz if only the low segment will be utilized.

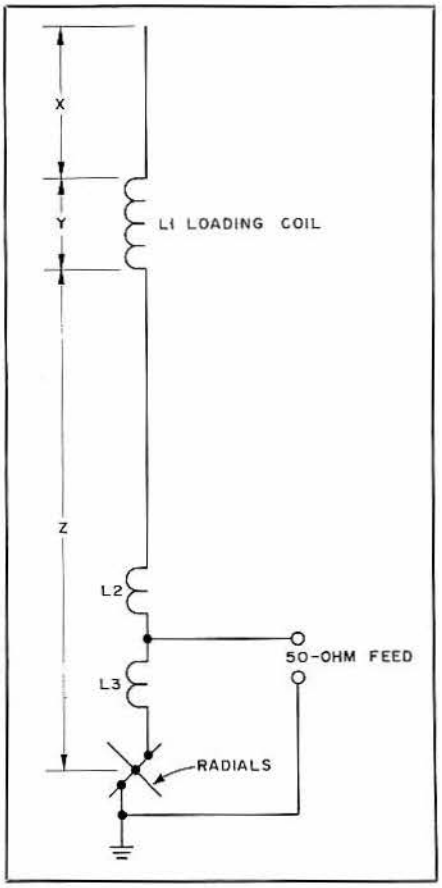

Fig. 36 — Electrical details of the Minooka Special. Table 10 gives specific information concerning dimensions X, Y and Z. L2 may vary in size from 1 to 20 turns, and L3 will contain between 5 and 10 turns, typically. L2 and L3 are made from no. 18 wire, spaced 1/8 inch (3 mm) between turns. The coil diameter is 1-1/2 inches (38 mm). Refer to text for tuning instructions.

Erect the antenna with all of its parts — coil, top and bottom section — and insert inductors L2 and L3 of Fig. 36 as shown. With L3 temporarily out of the system, adjust L2 for the lowerest value of SWR obtainable at the desired operating frequency. Then, place L3 back in the circuit and adjust it for an SWR reading of 1. Addition of the base section later on will not affect the resonant frequency of the overall system materially, provided the base section does not exceed, say, 60 feet (18.29 m).

The foregoing steps are used also in adjusting the mobile version of the antenna. However, because of the small size it is possible to adjust the antenna in completely assembled form. Only L3 of Fig. 36 is needed for mobile antennas. The main coil, L1, is adjusted for resonance, then L3 is set for lowest SWR. L3 can be mounted inside the trunk or under the bumper in a weatherproof enclosure.

For fixed-station operation it is recommended that a good ground system be employed. One should use at least 10 radials of, say, no. 18 or larger wire, 10 to 50 feet (3.05 to 15.24 m) in length. If you can manage 40 radials, 60 feet (18.29 m) in length, all the better.[1]

Concluding Comments

Three fixed-station versions of the Minooka Special have been tested and used at W9UCW. Each was compared against the regular antenna, which is a one-quarter wavelength vertical (130 feet [39.62 m] high), and operates against a radial system that contains 12,000 feet (3657.6 m) of wire. The short verticals were always inferior to the big antenna by approximately 5 dB.

Using version no. 4 from the table (4-foot [1.22-m] base section), the author worked W1s through W6s from the mobile setup. The rig was an HW-18 transceiver. Contacts were also made with VP9 and KV4 stations from the car.

While DXing from San Andres (HK0) reports were received of signal strengths exceeding S9 plus 20 dB from Maine to Washington. Good reports were received from Europe also.

Because the loading coil acts as an rf choke at 3.5 MHz and above, several versions of the antenna have been used successfully from 160 through 20 meters with an appropriate L-network matching section installed at the base of the system.

Acknowledgements

The author wishes to express his gratitude to all who helped make this article possible, . . . particularly K9SKX, WA9EYY, and W9YYF, who assisted with the initial experiments on the Minooka Special. The participants in the antenna survey (a list too large to include here) deserve considerable thanks for their help as well. This material was originally presented in *QST* by Barry A. Boothe, W9UCW.

[1] [Editor's Note: The reader should be aware that 1/4-wavelength radials (or longer ones) are recommended for best efficiency in a system of this kind. Detailed information on the subject is given in *The ARRL Antenna Book*, 13th Edition. The recommendations given by the author are no doubt based on the lack of space available in the typical urban lot, around which his design was established. See Hills, "The Grounds Beneath Us." *RSGB Bulletin*, June 1966.]

Inexpensive 5/8-Wave Vertical Antenna with Coaxial Transformer

The author's hastily constructed 5/8-wave vertical antenna (inspired by W0JF's results[1]) consists of a supporting structure made from sections of 2 x 2-inch (51 x 51-mm) lumber on which four lengths of 300-ohm TV ribbon are affixed. Each section of ribbon line is 41 feet 6 inches (12.65 m) long. A length of this line is attached to each side surface of the 2 x 2 support mast, then the ends (top and bottom) of all four line sections are connected in parallel to form a single vertical conductor. The coax-line dimensions are near those of W2JTJ,[2] and are shown in Fig. 37. The SWR varies from a flicker of reflected power at 14,000 kHz to 1.5:1 at 14,350 kHz. (The next task is to get that lowest-SWR point shifted to 14,275 kHz.) The whole thing is leaning against a tree, almost vertical, and seems to work well. This material was originally presented in *QST* by Robert J. Earl, W1DRV.

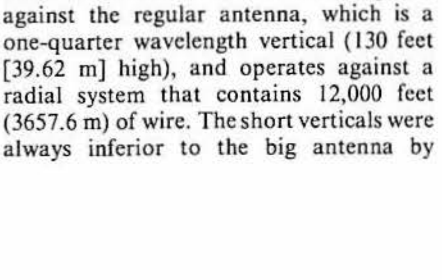

Fig. 37 — Coax-line transformer for 20-meter 5/8-wave vertical antenna.

References

[1] Beers, "Short Antennas for the Lower Frequencies," *QST*, August and September 1970.
[2] Czerwinski, "Coaxial Transformer for Voltage-Fed Antennas," *QST*, June 1961.

A Backyard 160-Meter Vertical

A 160-meter band was the favorite one at the author's QTH this winter. The same could be said for many other amateurs and the simple antenna described here may be of interest.

Some of the old-timers will tell the newcomer to 160 meters that the best antenna for local and DX work is the vertical. Since a full-size vertical would be very large, the question is finding a type that will fit into a closely packed residential area.

As a starter, the writer took an old 40-foot (12.19-m) telescoping mast and insulated it from the ground. (This can be done by setting it on top of a large soft-drink bottle, or clamping it to a wooden post.) The antenna was fed at the base with RG-58A/U 52-ohm coaxial cable. The shield was wired to a radial system and a ground rod. A hint for the radials — buy some aluminum clothesline and cut a number of slits in your yard with a flat spade. Next, push the wire into the slits and tamp the grass back together. If there are any swampy parts of the yard, these seem to make the best ground areas.

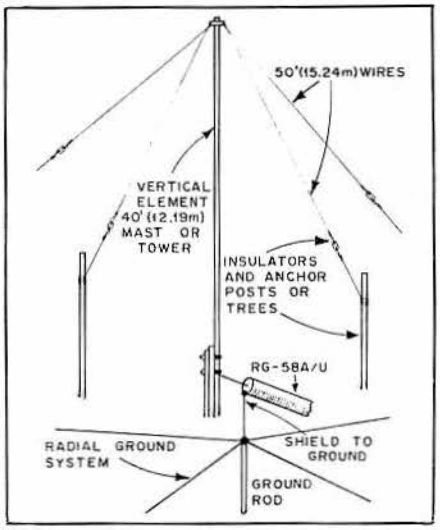
50'(15.24m)WIRES
VERTICAL ELEMENT 40' (12.19m) MAST OR TOWER
INSULATORS AND ANCHOR POSTS OR TREES
RG-58A/U
RADIAL GROUND SYSTEM
SHIELD TO GROUND
GROUND ROD

Fig. 38 — A space-saving vertical for 160 meters. While not always possible, it is desirable to have the wires for the top hat run off at right angles to the mast.

Rather than using a loading network at the base of the antenna, the author constructed a capacitive hat to load it at the top instead. The top hat was made from four 50-foot (15.24-m) pieces of wire strung out from the top of the mast in guy-wire fashion. They are connected electrically to the top, and stretched until they are as close as possible to a 90-degree angle with respect to the mast.

The system described works well with a 40-foot (12.19-m) mast, but other lengths could be used instead. However, the top hat may have to be adjusted in order to bring the system to resonance. While my vertical occupies very little space, it seems to perform as well as do many "full-size" antennas on 160 meters. This material was originally presented in *QST* by Mike Mussler, WB8JJA.

Chapter 2

Yagi Antennas

The antenna systems treated in this chapter are variations of the basic directional gain antenna devised many years ago by Yagi and Uda. Over the years the fundamental design and its variations have been referred to simply as the Yagi. How Mr. Uda was excluded from the credits remains a mystery, as he was a co-developer of the antenna under discussion.

Yagi types of antennas appeal to all manner of hf- vhf- and uhf-band operators. The primary response characteristic of the Yagi is unidirectional, discounting minor response lobes off the front, sides and rear of the antenna. The major lobe concentrates the radiated energy in a desired direction to provide gain in dB and discrimination against interference from unwanted directions.

Yagis can be used singly or in array combinations. In the latter case, each time the size of an array is doubled the system gain can be made to increase by 3 dB — assuming that the phasing, impedance matching, and aperture parameters are correct. Thus, a pair of 3-element Yagis which are "stacked" in an array to meet the foregoing criteria will exhibit 3 dB more gain than a single 3-element Yagi. To effect another 3 dB increase in gain, four 3-element Yagis would need to be placed in a given array of Yagis, and so on.

This chapter deals with the cream of the Yagi crop, so to speak, as taken from past issues of *QST*. When zoning laws and available property permit, the Yagi is preferred over the single-element vertical antennas described in chapter 1.

The 20-Meter DX Weasel

Short antennas have always captured the interest of amateurs.

The antenna presented here is a monoband version of the Bite-Size Beam for 20 and 15 meters published elsewhere in this chapter. It is designed for 20-meter operation only. Most of the parts were "lifted" from the original array.

The reader is cautioned against attempting to figure why some of the dimensions were selected. As a point of interest, they just happened that way. One new twist was added to this system — capacitance hats. The hats provided one noticeable improvement in performance which became obvious during the initial tune-up phase of the project. The hats lowered the Q of the elements and hence broadened the overall response of the system. While only conjecture, one might say that it is this broad tuning which causes the parasitic elements to perform as they do. Element tuning on the Bite-Size Beam[1] was critical. If the dimensions given here are followed carefully, the antenna should provide excellent characteristics for gain and pattern. Front-to-back measurements indicate approximately 20 dB. The front-to-side ratio was measured in excess of 25 dB. There are no objectionable side lobes. The SWR is less than 2:1 at each end of the band when the gamma capacitor and rod are set for proper operation at 14.1 MHz. There is no need to select phone or cw as the primary mode of operation.

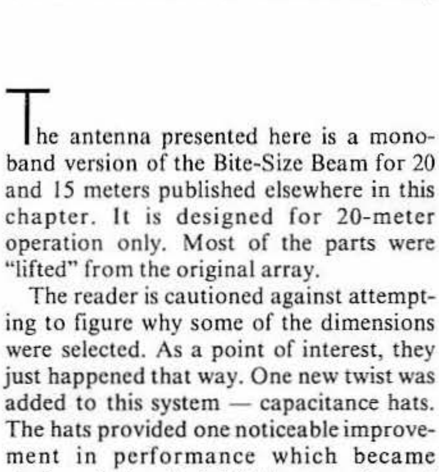

Details of the loading coil and capacitance hat on one of the elements.

Construction

The boom and all the elements are made from 1-1/4-inch (32-mm) diameter alumimun tubing available at most hardware stores. The two boom sections and the two pieces which make up the center portion of the driven element are coupled using 15-inch (0.38-m) sleeves of 1-3/8-inch (35-mm) OD aluminum tubing. Sheet-metal screws should be used to secure the sections within the coupling sleeves.

The loading coils are wound on 1-1/8-inch (29-mm) diameter Plexiglas rod. Details are shown in Fig. 1. Be sure to slit the ends of the aluminum tubing where the compression clamps are placed. The coils are made from no. 14 enameled wire. The specified number of turns are equally spaced to cover the entire 9 inches (229 mm) of Plexiglas.

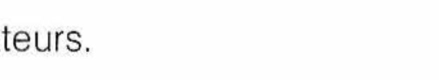

Fig. 1 — Details for joining sections of aluminum tubing and Plexiglas rod.

The capacitance hats are constructed from 3/4-inch (19-mm) angle aluminum. Two pieces 2 feet (0.61 m) in length are required for each hat. The model shown in the diagrams has the angle aluminum

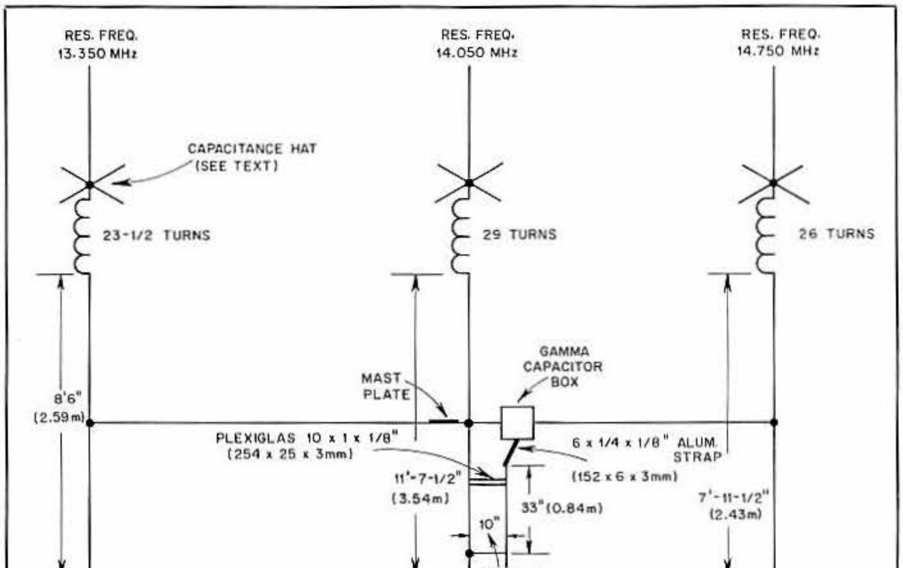

Fig. 2 — Constructional details for the 20-meter beam. The coils on each side of the element are identical. The gamma capacitor is a 140-pF variable unit manufactured by E. F. Johnson Co.

Table 1

Complete Parts List for the Short Beam

Qty	*Material*
2	10-foot (3.05-m) lengths of 1-1/4-inch (32-mm) dia. aluminum tubing (one for the reflector center section, one for the reflector end sections).
3	8-foot (2.44-m) lengths of 1-1/4-inch (32-mm) dia. aluminum tubing (two lengths for the boom, one length for the director element center).
4	6-foot (1.83-m) lengths of 1-1/4-inch (32-mm) dia. aluminum tubing (two lengths for the driven element center, two lengths for the director and driven element ends).
2	15-inch (0.38-m) lengths of 1-5/8-inch (41-mm) dia. aluminum tubing.
1	40-inch (12.19-m) length of 1-3/8-inch (10-mm) dia. aluminum tubing.
4	6-foot (1.83-m) lengths of 3/4-inch (19-mm) angle aluminum.
6	12-inch (0.31-m) lengths of 1-1/8-inch (29-mm) dia. Plexiglas rod.
1	9-inch (229-mm) square, 1/4-inch (6-mm) thick aluminum plate.
8	U bolts.
12	Compression hose clamps.
8	Crutch caps.
38 ft	No. 12 enameled copper wire.
60 ft	No. 14 enameled copper wire.

fastened to the element using aluminum strips and no. 8 sheet-metal screws, but sheet-metal screws alone can be used. Solder lugs are fastened to the ends of the angle aluminum and no. 12 or 14 wire connects the ends of the aluminum, resulting in a square loop. The wires should be soldered at each of the solder lugs.

All of the elements are secured to the boom with TV U-bolt hardware. Plated bolts are desirable to prevent rust from forming. An aluminum plate 9 inches (229 mm) square by 1/4-inch (6-mm) thick was used as the boom-to-mast plate.

A boom strut is recommended because the weight of the elements is sufficient to cause the boom to sag. A 1/8-inch (3-mm) diameter nylon line is plenty strong. A U-bolt clamp is placed on the mast several feet above the antenna and provides the attachment point for the center of the truss line. To reduce the possibility of water accumulating in the element tubing and subsequently freezing, crutch caps are placed over the ends. Rubber feet suitable for keeping furniture from scratching hardwood floors would serve the same purpose.

A piece of Plexiglas was mounted inside an aluminum Minibox to provide support and insulation for the gamma capacitor. A plastic refrigerator box would serve the purpose just as well. The capacitor housing is mounted to the boom by means of a U bolt. The gamma rod is made of 3/8-inch (10-mm) aluminum 40 inches (1.016 m) long and is connected to the gamma capacitor by a 6-inch (152-mm) length of strap aluminum.

Tune-Up and Operation

The builder is encouraged to follow the dimensions given in Fig. 2 as a starting point for the position of the gamma rod shorting strap. Connect the coaxial cable and install the antenna near or at the top of the tower. The gamma capacitor should be adjusted for minimum SWR at 14.1 MHz as indicated by an SWR meter (or power meter) connected in the feed line at the gamma capacitor box. If a perfect match cannot be obtained, a slight repositioning of the gamma short might be required.

Evaluation of performance is always a difficult task. The 20-Meter DX Weasel is mounted on top of a 50-foot (15.24-m) high tower at the QTH of W1FB. The transmitter input power for the testing period was 3 watts. Many European stations as well as a ZL have been contacted with ease. In fact, the Weasel has been responsible for cracking a few pileups on the first call!

Obtaining the Material

Table 1 lists all of the major parts used in the 20-meter Weasel. Most of the U-bolt hardware as well as the aluminum tubing should be available from large hardware stores. The Plexiglas rod, however, presents a bit more of a problem as indicated by mail received by the ARRL Technical Department. Many large plastic supply dealers stock the cast rod. The problem is that there are not very many large dealers! Additionally, Plexiglas is a petroleum-base product which means the cost is no doubt higher than one would expect. Those amateurs who are unable to locate aluminum hardware or Plexiglas should consult the yellow pages to see who their nearest supplier is. This material was originally presented in *QST* by Robert Myers, W1XT and Jay Rusgrove, W1VD.

[1] See page 45.

The HW-40 Micro Beam

A helically wound 2-element 40-meter Yagi.

Disconsolate pleas from apartment dwellers and other amateurs who live on property that is too small in area to permit the use of large 40-meter antennas prompted the authors to develop the antenna described here. The particular dimensions represented in this design were dictated primarily by the kind of fiberglass tubing that was immediately available. Kirk quad spreaders were obtained for use as forms on which to wind the helical elements. Longer (or shorter) elements can be used with good results. This article is intended as a guide in the design of similar antennas.

The HW-40 is scaled down to 28 percent of full size. Two elements are used, each being 18 feet (5.49 m) in length, tip-to-tip. Thus, the elements are just 2 feet (0.61 m) longer than those of a full-size 10-meter Yagi. A 16-foot (4.88-m)-long Reynolds aluminum-tubing boom (two 8-foot [2.44-m] lengths joined) provides 0.12-wavelength spacing between the driven element and reflector. The weight of the array is approximately 25 pounds, making it practical to use a TV-type antenna rotator with the system.

Design Considerations

Some may argue that helically wound antennas will tend to radiate off the ends of the elements (axial mode), and that the condition will prevent the Yagi from exhibiting normal front-to-side and front-to-back characteristics. It was established by Kraus,[1] that axial-mode radiation occurs only when a helix is one wavelength or greater in circumference. Generally, when the circumference is less than two-thirds wavelength, a nearly sinusoidal type of current distribution exists. This is effected by alternate reinforcement and cancellation of the two traveling waves which are directed oppositely. Each is of nearly identical current amplitude (I_0), hence the T_0 transmission mode results for both traveling waves on the helix. Because of the foregoing condition the helices of this antenna radiate in the *normal mode* and will exhibit linear polarization characteristics. The diameter of these helices is merely 0.0009469 wavelength, eliminating any opportunity for axial-mode radiation. Front-to-side and front-to-back checks of the beam indicate, indeed, that normal-mode radiation is occurring. A number of relative tests were performed locally at distances up to 20 miles, and the front-to-back characteristics indicate a 10-dB figure. Front-to-side checks confirm a figure of approximately 28 dB. The effect is not so pronounced when receiving high-angle incoming signals. Depending upon the time of day, distance involved, and other propagation factors, various directivity traits will be observed.

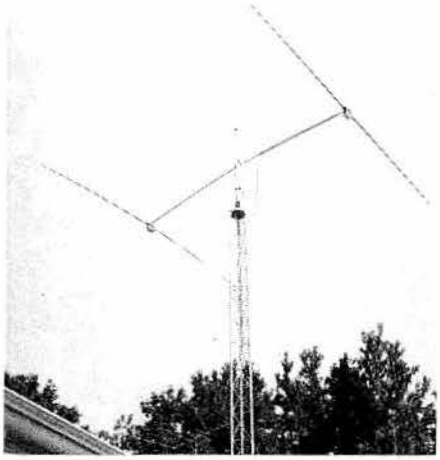
The HW-40 beam, just 28 percent of full-size, is light enough to require only a TV-rotator.

Helically wound elements were chosen in preference to lumped-inductance elements in order to obtain linear voltage and current distribution across the elements, and to make the matching technique less difficult. Even if end-loaded elements with capacitance hats were used, the 18-foot (5.49-m) dimension would make it impossible to use. a gamma match of conventional design. Because of the very low value of radiation resistance of short loaded antennas, other conventional matching schemes would not lend ease to matching a 50-ohm coaxial feeder to the system.

There are certain penalties one must accept when using physically shortened antennas of this kind, and an in-depth treatment of the subject was given by Sevick in *QST*.[2] It was a fortunate circumstance in this case that the feed-point impedance of the beam turned out to be approximately 12 ohms. Therefore, a 4:1 toroidal balun was installed at the feed point to provide a near-perfect match to the 50-ohm transmission line. In addition to encountering low values of feed impedance, the bandwidth of loaded elements is greatly less than with full-size antennas. This beam was tuned for operation at a center frequency of 7050 kHz. It works well from 7025 to 7075 kHz, with an SWR no greater than 2:1. It is flat at 7050 kHz. Those wishing to duplicate this Yagi should be willing to accept this design tradeoff in the interest of having an effective directional antenna. It is recommended, therefore, that it be tuned for one's favorite part of the 40-meter band. The use of a Transmatch will, however, permit excursions into portions of the band where the SWR becomes greater than 1:1.

Construction Details

The construction of the 40-meter beam is very simple and requires no special tools or hardware. Two fiberglass 15-meter quad arm spreaders are mounted on an aluminum plate with U bolts, as shown in the photograph. A wooden dowel is inserted approximately 6 inches (152 mm) in the end of each fiberglass arm to prevent the U bolts from crushing the poles. The aluminum mounting plate is equipped with U-bolt hardware for attachment to the 1-1/4-inch (32-mm) diameter boom.

A plastic refrigerator box is mounted on each element support plate and is used to house a Miniductor coil. No. 14 copper wire is used for the elements. The wire is wound directly on the fiberglass poles at a density of *40 turns per foot* (not turns per inch!) for a total of 360 evenly spaced turns. The wire is attached at each end with an automotive hose clamp of the proper size to fit the fiberglass rods. Since the fiberglass is tapered, care must be taken to keep the turns from sliding in the direction of the tips. Several pieces of plastic electrical tape were wrapped around the pole and wire at intervals of 1 foot (0.31 m). All of the element half sections are identical in terms of wire and pitch. Coil dimensions and type are given in Fig. 3.

The driven-element matching system consists of a 4:1 balun transformer and a link tightly coupled to the Miniductor. Complete details are given in Fig. 4.

Mounted at the end of each element (held in place by the hose clamp) is a short section of stiff copper wire used to allow for final tuning of the system as well as to broaden the frequency response of the antenna. Since the overall antenna is very small in relation to a full-sized array, the SWR points of 2:1 are rather close to each other, as mentioned earlier. The antenna shown in the photograph provides an SWR of less than 2:1 within about 25 kHz either side of resonance. Tuning the antenna for phone-band operation should not be difficult and the procedure outlined below should be suitable.

Tuning

The parasitic element is adjusted to be about four percent lower in frequency than

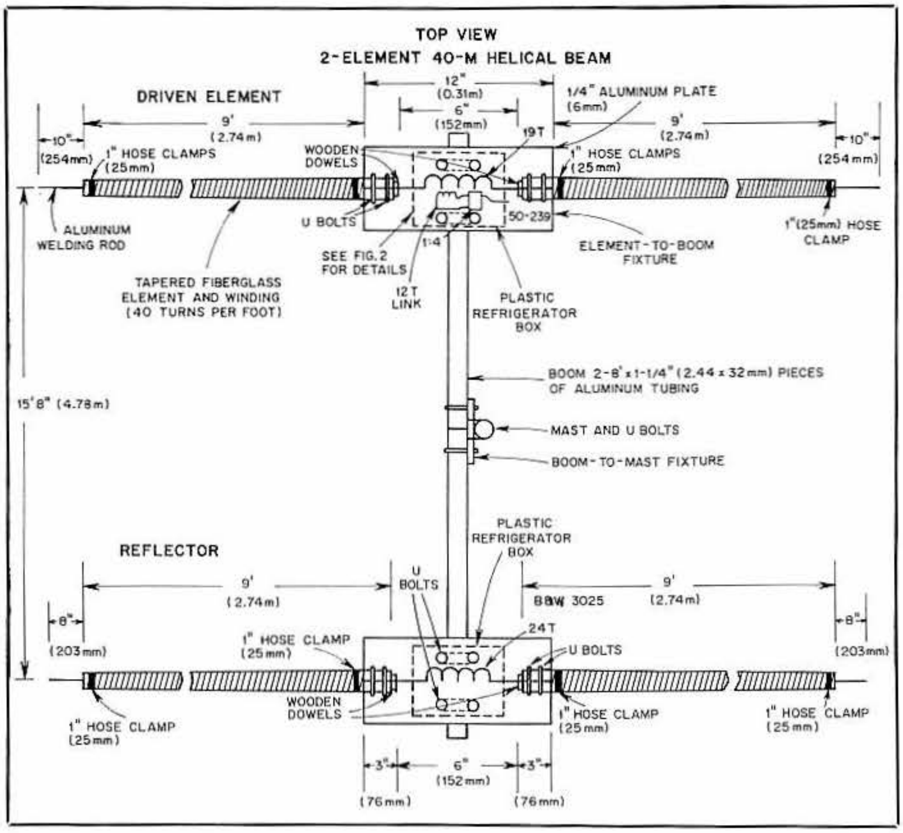
TOP VIEW
2-ELEMENT 40-M HELICAL BEAM
DRIVEN ELEMENT
12" (0.31m)
6" (152mm)
1/4" ALUMINUM PLATE (6mm)
9' (2.74m)
9' (2.74m)
10" (254mm)
10" (254mm)
1" HOSE CLAMPS (25mm)
WOODEN DOWELS
19T
1" HOSE CLAMPS (25mm)
U BOLTS
L
1:4
50-239
ALUMINUM WELDING ROD
TAPERED FIBERGLASS ELEMENT AND WINDING (40 TURNS PER FOOT)
SEE FIG. 2 FOR DETAILS
12 T LINK
PLASTIC REFRIGERATOR BOX
ELEMENT-TO-BOOM FIXTURE
1"(25mm) HOSE CLAMP
BOOM 2-8' x 1-1/4" (2.44 x 32mm) PIECES OF ALUMINUM TUBING
15' 8" (4.78m)
MAST AND U BOLTS
BOOM-TO-MAST FIXTURE
PLASTIC REFRIGERATOR BOX
REFLECTOR
9' (2.74m)
U BOLTS
B&W 3025
9' (2.74m)
8" (203mm)
8" (203mm)
1" HOSE CLAMP (25mm)
24T
U BOLTS
WOODEN DOWELS
1" HOSE CLAMP (25mm)
1" HOSE CLAMP (25mm)
1" HOSE CLAMP (25mm)
3" (76mm)
6" (152mm)
3" (76mm)

Fig. 3 — Overall dimensions for the 40-meter short beam. The boom consists of two pieces of standard 1-1/4-inch (32-mm) dia do-it-yourself aluminum tubing.

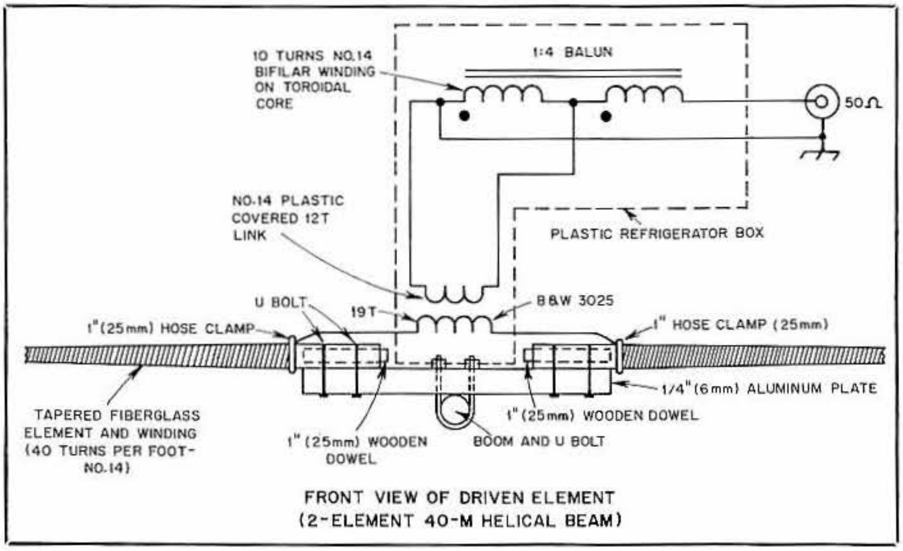
10 TURNS NO.14 BIFILAR WINDING ON TOROIDAL CORE
1:4 BALUN
50Ω
NO.14 PLASTIC COVERED 12T LINK
PLASTIC REFRIGERATOR BOX
U BOLT
19T
B&W 3025
1"(25mm) HOSE CLAMP
1" HOSE CLAMP (25mm)
1/4"(6mm) ALUMINUM PLATE
TAPERED FIBERGLASS ELEMENT AND WINDING (40 TURNS PER FOOT-NO.14)
1" (25mm) WOODEN DOWEL
1" (25mm) WOODEN DOWEL
BOOM AND U BOLT
FRONT VIEW OF DRIVEN ELEMENT
(2-ELEMENT 40-M HELICAL BEAM)

Fig. 4 — Schematic diagram of the balun assembly mounted inside the plastic utility box. The core is a single T-200-2 Amidon. The 12-turn link is wound directly over the 19-turn Miniductor.

the driven element. A grid-dip oscillator was coupled to the center loading coil and the element tips were trimmed (a quarter of an inch [6 mm] at a time!) until the GDO indicated resonance to be at 6.678 MHz. For phone-band use, the ends could be snipped for 6.840 MHz. Adjusting the driven element is simple. Place an SWR meter or power meter at the input connector and cut the end wires (or add some if necessary) to obtain a proper match between line and antenna.

Performance Characteristics

Once the initial near-ground tuning of the elements was completed, the HW-40 was carried aloft and mounted on the 40-foot (12.19-m) tower at W1FB. Final touching up of the matching and element resonances was effected after the beam was in place on the tower. It is important to realize that shortened antennas are sensitive to changes in environment because of their narrow-band characteristics. Thus, height above ground and distance from nearby objects will cause some change in resonance of the elements. The resonant frequency of the HW-40 changed some 150 kHz between tuning at several feet above ground to final tweaking atop the tower.

It should be noted that the 40-meter beam has yet to be tested at an ideal height above ground. A distance of 40 feet (12.19 m) above the earth is not much more than one-quarter wavelength at 7 MHz, though performance thus far has been better than one might expect when using a beam or dipole less than one-half wavelength above ground.

Comparisons were made between the beam and three types of wire antennas . . . an inverted V, a 3/4-wavelength end-fed wire, and a full-wave 40-meter loop (with its theoretical 2-dB gain).[3] The results have been interesting, though at times rather confusing. The confusion results from the time-of-day/propagation syndrome mentioned earlier. At no time, however, did the inverted-V or 3/4-wavelength antennas surpass the performance of the HW-40. The beam was always as good as or better than the other two radiators, regardless of band conditions or time. During contacts with European or South American DX stations, the beam was always the best antenna, usually by two S units or more. During daytime contacts out to, say, 1000 miles, the wire antennas equalled the beam at times.

When comparing the beam to the full-wave loop, results became less easy to evaluate. That is, the antennas took turns being best. Frequently, the loop outperformed the beam (in the favored direction of the loop) both on short-haul and DX contacts. At other times the beam had the edge by a couple of S units. At this time it is impossible to say which antenna would provide the best all-year, all-around service. But, it has been observed that the beam is far less subject to pickup of man-made and atmospheric noise because of its narrow-band characteristics (the loop exhibits the opposite bandwidth trait— broad). Reduction in noise during reception can be a blessing, especially when working with the weaker signals! Another beneficial effect of the narrow-band feature is that strong, near-frequency signals do not so severely affect the receiver with respect to overloading and cross modulation, as is the situation with other types of antennas. The proof of this came when trying to operate while W1AW (two blocks away from W1FB) was transmitting code practice. Until the beam was erected it was impossible to use the 40-meter band, but with the beam connected to the receiver, and with the antenna pointed away from W1AW, it became possible to operate within 10 kHz of W1AW without knowing that station was on the air! So, if some kW operator lives down the street from you, this little beam could put you back in business.

While running approximately 80 watts output, the short beam has been extremely effective in working DX. DX stations now answer our CQs, whereas with the wire antennas (loop excepted) this seldom happened. Signal reports from DX stations average 579, with many 589 and 599 reports. During QRP operation with the beam (2 watts output), a number of DX stations have been raised and worked. The signal reports are lower of course, but RST 559 and 569 indicates that something good must be happening! One unrelated event occurred while testing the beam and loop with the QRP setup: a station in the 4th call area called CQ and was answered. He came back and said, "No QRP lids, CQ kWs only." It's unlikely that the HW-40 beam can be blamed for that, especially since we went on to work five European stations later that day with the 2-watt equipment!

Acknowledgements

The authors wish to express gratitude to those who helped construct, test and erect the 40-meter beam. Special thanks to K1JX, who "clomped" up and down the ARRL test tower and the W1FB station tower numerous times with test gear (and the beam) until the final design goals were met. Thanks also to W1NPG (SK) who labored silently while winding the helices, and subsequently endured the unbearable Connecticut heat-wave temperatures of August, while putting two coats of exterior spar varnish on the completed elements. The element dimensions and turns information were developed by K1TD to test a newly developed calculator program. This material was originally presented in *QST* by Robert Myers, W1XT and Doug DeMaw, W1FB.

References

[1] Kraus, *Antennas*, First Edition, McGraw-Hill Book Co., Chapter 7.
[2] Sevick, "The Ground-Mounted Short Vertical," *QST*, March 1973, p. 13. (See Chapter 1.)
[3] DeMaw, "The Novi-Loop," *QST*, October 1973. (See Chapter 4.)

A Bite-Size Beam for 20 and 15 Meters

Do you want to work DX from your space-restricted QTH with increased effectiveness? If the answer is yes, perhaps this two-band Yagi system is just the one for you.

There is no doubt that a hundred-foot (30.48-m) tower with stacked monobanders for 20 and 15 meters is one way to generate an effective signal in the pileups. But what are the characteristics of this big system which make it perform better than a dipole strung between two trees? First, the tall tower places the antenna up in the clear, away from most of the surrounding ground clutter. Even a relatively short tower (40-foot [12.2-m] variety) provides this advantage in many instances. The ability to point the major radiation lobe of the antenna in the correct direction is another reason the high monobanders outperform the kinky wire. But if the antenna is capable of supporting its own elements, the directional characteristics can be used to good advantage whether the beam is mounted at 100 feet (30.5 m), or at 40 feet (12.2 m). And without any question, the ability to reject interference aids substantially in the reception of weak signals.

A typical one-foot (0.31-m)-per-side triangle tower is self-supporting (when properly installed) to 40 feet in height and requires less than one square foot of property. For many amateurs, the major limiting factor is the inability to turn a monoband beam (or even a large tribander) without hitting some object like a tall tree. Hesitation on behalf of the amateur to place what might be considered by his neighbors an offensive amount of hardware in the sky near his home is another reason beams are ruled out. The 2-element-per-band, 20- and 15-meter, interlaced Yagi presented here, overcomes these problems. It is lightweight and is less than 16-feet (4.88-m) square. And it's probably no more obtrusive than a large TV antenna.

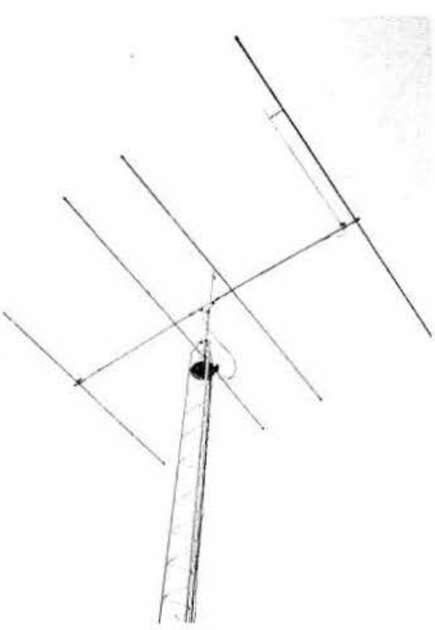

So What if It's Short!

A popular misconception among amateurs is that any element short of full size is no good in an antenna system. Reducing the size of an antenna by 50 percent does lower the efficiency by a decibel or two, but the gain capability of a parasitic array outweighs this small loss in efficiency. Mounting the antenna above the interference-generating neighborhood can greatly reduce susceptibility to man-made noise and certainly aids in the reduction of rf heating to trees, telephone poles, and buildings. It has been said that a brick wall, or dense foliage, can attenuate a signal passed through it by as much as 20 dB. Placing the antenna above these energy-absorbing objects is very desirable.

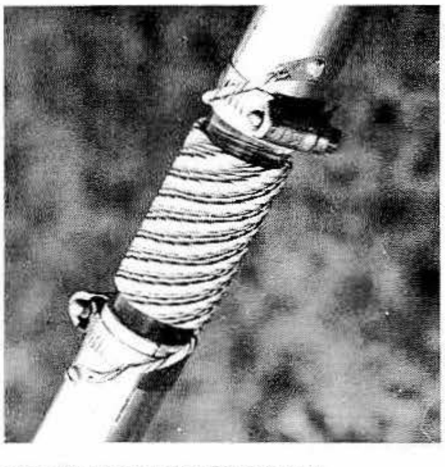

The coils are wound on Plexiglas rod. Compression clamps are used to hold the Plexiglas in position. Sheet-metal screws and solder lugs provide attachment points for the ends of the loading coils.

View of the short beam from the front yard at W1FB.

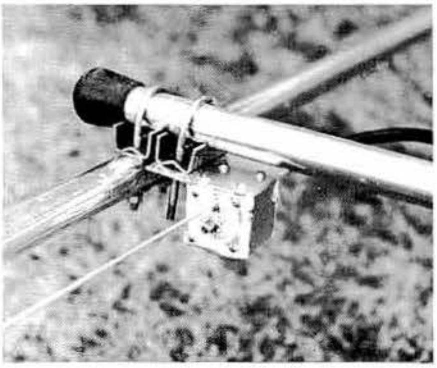

The gamma assembly is held in place by means of a small U bolt. The capacitors are mounted on etched circuit board.

It is a generally accepted fact that traps are difficult to build and adjust, as well as their being lossy. Loading coils, on the other hand, are easy to wind and require essentially no adjustment. If the wire size is large, losses are not a major factor. W2FMI lauded the merits of short antennas in an earlier article explaining that in reality, short (50 percent) elements do not materially depreciate the gain.[1] With these ideas in mind, the authors designed and built a shortened-element, but wide spaced, director array for 20 meters interlaced with a similar 15-meter reflector configuration also having optimum spacing for maximum gain. By placing the 15-meter driven element in front of the 20-meter array, the longer 20-meter elements tend to act as reflectors on 15 meters. There are no unwanted reflectors "in front" nor any directors "behind" the active array — elements which could cause pattern distortion and poor front-to-back ratio.

Construction

The dual-band beam has four elements, the longest of which is 16 feet (4.88 m). All of the elements and the boom are made from 1-1/4-inch (32-mm) diameter aluminum tubing available at most hardware stores. Element sections and boom pieces are joined together by slotting a 10-inch (254-mm) length of 1-1/4-inch (32-mm) tubing with a nibbling tool and compressing it for a snug fit inside the element and boom tubing. Coupling details are shown in Fig. 6.

The loading coils are wound on 1-1/8-inch (29-mm) diameter Plexiglas rod. The rod slips into the element tubing and is held in place with compression clamps. Be sure to slit the end of the aluminum where the compression clamps are placed. The model shown in the photographs has coils made of surplus Teflon-insulated miniature audio coaxial cable with the shield braid and inner conductor shorted together. A suitable substitute would be no. 14 enameled copper wire wound to the same dimensions as those given in Fig. 5.

All of the elements are secured to the boom with common TV U-bolt hardware. Plated bolts are desirable to prevent rust from forming. A 1/4-inch (6-mm) thick boom-to-mast plate is constructed from a few pieces of sheet aluminum cut into 10-inch (254-mm) square sheets and held together with no. 8 hardware. Several cookie tins could be used if sheet aluminum is not available. One local amateur used a plate from a large electrical box as a boom-to-mast bracket. Since it is galvanized, it is quite resistant to the harsh New England winters.

A boom strut (sometimes called a truss) is recommended because the weight of the elements is sufficient to cause the boom to sag a bit. A 1/8-inch (3-mm) diameter nylon line is plenty strong. A U-bolt clamp is

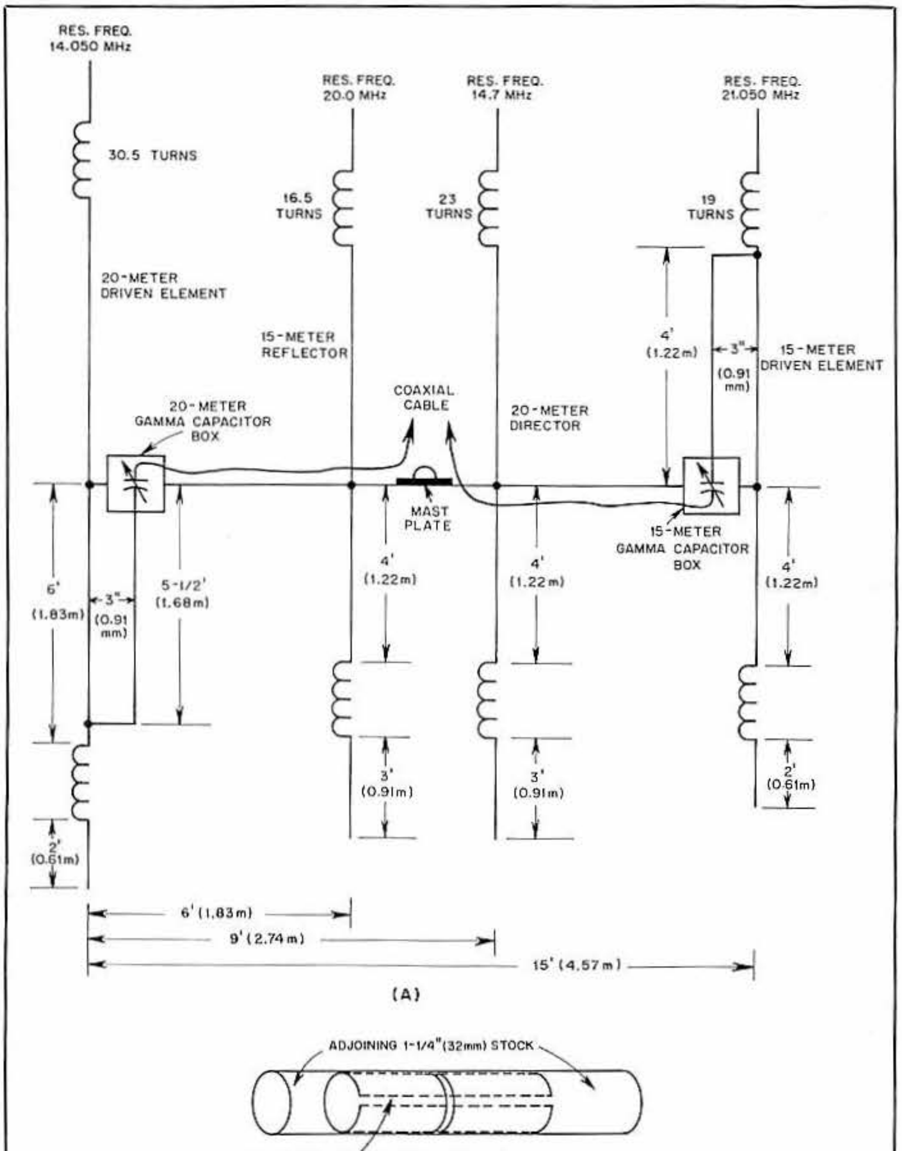
RES. FREQ. 14.050 MHz
RES. FREQ. 20.0 MHz
RES. FREQ. 14.7 MHz
RES. FREQ. 21.050 MHz
30.5 TURNS
16.5 TURNS
23 TURNS
19 TURNS
20-METER DRIVEN ELEMENT
15-METER REFLECTOR
4' (1.22m)
3" (0.91 mm)
15-METER DRIVEN ELEMENT
COAXIAL CABLE
20-METER GAMMA CAPACITOR BOX
20-METER DIRECTOR
MAST PLATE
15-METER GAMMA CAPACITOR BOX
6' (1.83m)
3" (0.91 mm)
5-1/2' (1.68m)
4' (1.22m)
4' (1.22m)
4' (1.22m)
3' (0.91m)
3' (0.91m)
2' (0.61m)
2' (0.61m)
6' (1.83m)
9' (2.74m)
15' (4.57m)
(A)
ADJOINING 1-1/4"(32mm) STOCK
1/4-INCH(6mm) SLOT IN 1-1/4"(32mm) SHORT SECTION OF TUBING
(B)

Fig. 5 — Constructional details for the 20- and 15-meter beam. The coils for each side of the element are identical. The gamma capacitors are each 140-pF variable units manufactured by E. F. Johnson Co. The capacitors are insulated from ground within the container. Since the design is one-half size for each band, the tuning is somewhat critical. The builder is encouraged to follow carefully the dimensions given in the text.

Table 2

Complete Parts List for the Short Beam

Qty	*Material*
9	8-foot (2.44-m) lengths of aluminum tubing, 1-1/4-in. (32 mm) dia
11	U bolts
2	Variable capacitors, 140 pF (E. F. Johnson)
4 ft	Plexiglas cast rod, 1-1/8-in. (29 mm) dia
16	Stainless steel hose clamps, 1-1/2-in. (38 mm) dia
1	Aluminum plate, 8-in. (203 mm) square
10 ft	Aluminum solid rod, 1/4-in. (6 mm) dia
2	Refrigerator boxes, 4 X 4 X 4 in. (102 X 102 X 102 mm)
25 ft	Nylon rope, 1/8-in. (3 mm) dia
16	No. 8 sheet metal screws
16	No. 8 solder lugs
8	Plastic (or rubber) end caps, 1-1/4-in. (32 mm) dia

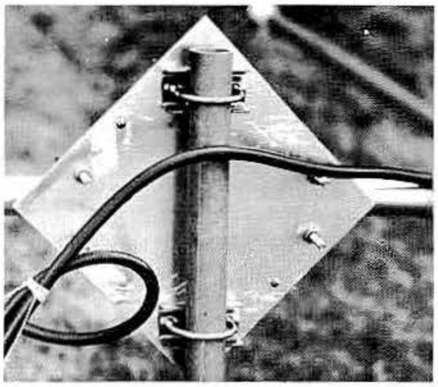

The boom-to-mast plate.

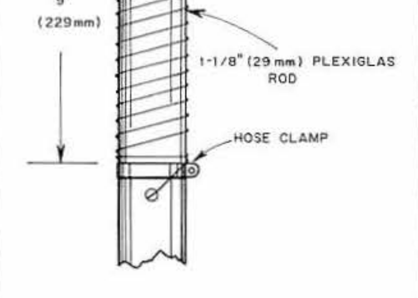

Fig. 6 — Coupling details for joining sections of aluminum tubing.

placed on the mast several feet above the antenna and provides the attachment point for the center of the truss line. To reduce the possibility of water accumulating in the element tubing and subsequently freezing (rupture may be the end result), crutch caps are placed over the element ends. Rubber feet suitable for keeping furniture from scratching hardwood floors would serve the same purpose. In fact, the rubber tips prevent the element ends from damaging surrounding objects during installation.

A heavy-duty steel mast should be used, such as a 1-inch (25-mm)-diameter galvanized water pipe. Steel TV mast is also acceptable. Any conventional TV-type antenna rotator should hold up under load conditions presented by this antenna. Nevertheless, certain precautions should be taken to assure continued trouble-free service. For instance, whenever possible, mount the rotator inside the tower and extend the mast through the tower top sleeve. This procedure relieves the rotator from having to handle lateral pressures during windy weather conditions. A thrust bearing is desirable to reduce downward forces on the rotator bearings.

Hookup and Operation

The monoband nature of the beam requires the use of two coaxial feed lines. The coaxial cable is attached to the 15-meter element (at the front of the beam) at the gamma-capacitor box. The other end of the cable is connected to a surplus 28-V dc single-pole coaxial switch.[2] The cable for the 20-meter element is connected in a similar fashion. The switch allows the use of a single feed line from the shack to a point just below the antenna where the switch is mounted. It is a simple matter to provide voltage to the switch for operation on one of the two bands. At the price of coaxial cable today, a double run of feed line represents a substantial investment and should be avoided if possible.

An etched-circuit board was mounted inside an aluminum Minibox to provide support and insulation for each of the gamma tuning capacitors. Plastic refrigerator boxes available from most department stores would serve just as well. The capacitor housing is mounted to the boom by means of U bolts.

The builder is encouraged to follow the dimensions given in Fig. 5 as a starting point for the position of the gamma rods and shorting bar. Placing the antenna near the top of the tower and then tilting it to allow the capacitors to be reached makes it possible to adjust the capacitors for minimum SWR as indicated by an SWR meter (or power meter) connected in the feed line at the relay. If the SWR cannot be reduced below some nominal figure of approximately 1.4:1, a slight repositioning of the gamma short might be required. The dimensions given are for operation at 14.050 MHz and 21.050 MHz. The SWR climbs above 2:1 about 50 kHz in either direction from the center frequency. Although tests were not conducted at more than 150 watts input to the transmitter there is no reason why the system would not operate correctly with a kilowatt of power supplied to it.

After many months of testing at the QTH of W1FB, several characteristics were noted. First, the antenna withstood several wind and ice storms common to Connecticut. Performance turned out to be what can be expected from a 2-element Yagi. Since the 20-meter portion of the antenna is a director array, the front-to-back ratio is a bit less than 10 dB. On 15 meters, where the system operates with a reflector parasitic element, the front-to-back ratio is considerably better — on the order of 15 dB.

This antenna was mounted atop a 40-foot (12.2-m) tower where previously there was connected a 20-meter sloping dipole pointed at Europe (a multielement array for 2 meters graced the top of the tower!). The number of European stations contacted increased rather dramatically with the installation of the beam. Except in pileups on rare DX stations, DX is now worked as a routine, even though W1FB is a QRP fan and typically runs less than 2 watts of output power.

No doubt the increased effectiveness of the signal was caused by several factors. The antenna certainly has gain (although at ARRL hq. we have no way of making accurate measurements) and is well above the nearby small trees. More importantly, the antenna is now far from the aluminum house siding which once was directly in the pattern of the 20-meter "sloper." Of course, the front-to-back characteristic has the tendency of making DX signals louder in relation to stateside stations and therefore makes receiving much easier.

If previously you've felt that a beam and tower were not possible at your QTH, perhaps re-evaluation of the situation is in order. This antenna, as shown in the photograph, does not appear offensive when viewed from the front yard. Yet the overall amount of property occupied (at ground level) is less than one square foot. And the turning radius is slightly over 11 feet (3.35 m)! This material was originally presented in *QST* by Robert Myers, W1XT and Clarke Greene, K1JX.

References

[1] Sevick, "The W2FMI Ground-Mounted Short Vertical," *QST*, March 1973. (See Chapter 1.)

[2] Purchased from Fair Radio Sales, Lima, OH.

Linear Loaded 20-Meter Beam

Build this novel minibeam for 20 meters . . . it works!

Full-sized antennas are fine if you have the height and room for them. But much of the advantage is usually lost with average installations. So why bother with a sad-looking monster a few feet atop the house when a trim, smaller model will do the job. This article deals with a method that eliminates the messy and expensive loading coils as well.

Having built an HW-32A transceiver, the author's 20-meter activity was restricted to the phone band. A homemade vertical antenna did a fair job in the states, but not for DX. This writer's thoughts ran to a beam and the aluminum tubing that could be obtained for full-size construction. A 2-element beam was constructed, using a gamma match and information found in the *Handbook*. The beam worked electrically, but the mechanical construction left much to be desired. It flopped in the wind like a wounded butterfly. The author tried to correct this with a wooden framework, but it was just as bad. Something with shorter elements was desired, something that was rigid and would still perform well. But all of the author's research turned up only loading coils or other methods involving a loss compromise.

The author's aluminum supply included four 12-ft (3.66-m) lengths of 7/8-inch (22-mm) diameter tubing. This would give two elements of 24 ft (7.32-m) length and a minimum of sag. The problem was how to mount them and make up the difference in physical and electrical length for a half-wave length. Loading coils were ruled out. The possibility of folding wire under the elements seemed to have merit. (Later, this was found to be called linear loading.) This dictated a split element and standoff supports for the tubing.

Two 2-ft (0.61-m) lengths of aluminum channel were obtained for the element supports (Fig. 7). each 12-ft (3.66-m) section was attached using 1-in. (25-mm) ceramic standoff insulators. A 34-in. (19-mm) birch dowel was used to stiffen and prevent crushing of the tubing where the attachment was made. Element supports were grooved and attached to a 10-ft (3-m) TV mast section using a single 5/16-in. (8-mm) U bolt.

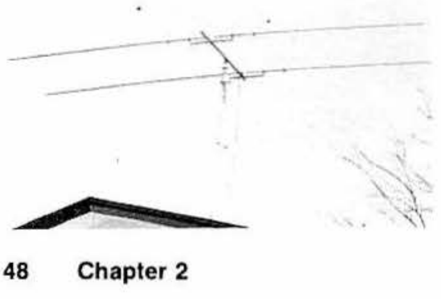

The folded additional loading wire was no. 12 copper house wire with the insulation stripped off, and was supported by two bakelite blocks on each element section. The blocks were anchored to the tubing by small sheet metal screws. Ends of the wire sections were formed into a loop to hold their position.

Tune-Up and Adjustments

My thinking in regard to coaxial-cable-fed dipoles is that they should use a balun or matching device of some kind. This beam, having a split driven element, seemed to call for a 1:1 balun since it was to be fed with RG-58/U (Fig. 8). Formulas found in handbooks for beam-element lengths did not seem to work for the linear-loading design, so cut-and-try was used many times. In final tests, a grid-dip meter was utilized with a calibrated receiver to determine the driven-element total length of 35 ft (10.67 m). A reflector with 10-ft (3.05-m) spacing was used.

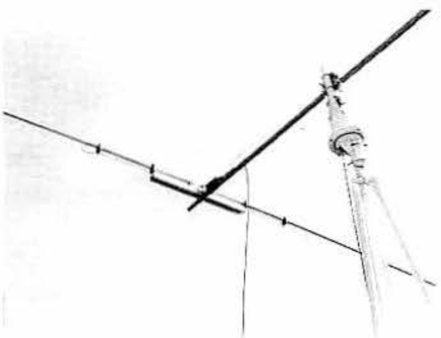

The beam atop the author's tower.

It was found that adding a reflector of five-percent greater length lowered the frequency (with the beam near the ground) but on raising the beam to rooftop, the frequency had increased. The 10-ft spacing gave a 3:1 VSWR which was very difficult to reduce. Testing this arrangement on the air seemed to indicate more gain in the back direction than in the front. After many tests and much rebuilding of the wire lengths, the director element approach seemed to give the most encouraging results. The VSWR was down to 1.5:1 and the five-percent shorter director raised the frequency to the phone band. Spacing was reduced to 7 ft 6 in. (2.29 m).

More research brought out the possibility of inductive matching to get the VSWR

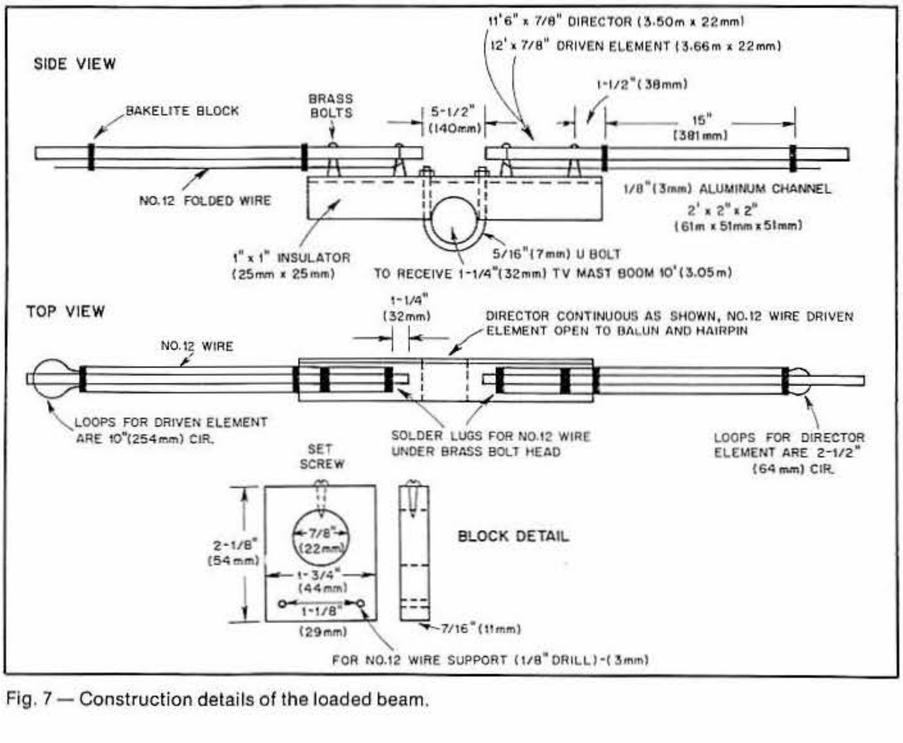
11'6" x 7/8" DIRECTOR (3.50m x 22mm)
12' x 7/8" DRIVEN ELEMENT (3.66m x 22mm)
SIDE VIEW
1-1/2" (38mm)
BAKELITE BLOCK
BRASS BOLTS
5-1/2" (140mm)
15" (381mm)
NO.12 FOLDED WIRE
1/8" (3mm) ALUMINUM CHANNEL
2' x 2" x 2"
(61m x 51mm x 51mm)
1" x 1" INSULATOR
(25mm x 25mm)
5/16" (7mm) U BOLT
TO RECEIVE 1-1/4" (32mm) TV MAST BOOM 10' (3.05m)
TOP VIEW
1-1/4" (32mm)
DIRECTOR CONTINUOUS AS SHOWN, NO.12 WIRE DRIVEN ELEMENT OPEN TO BALUN AND HAIRPIN
NO.12 WIRE
LOOPS FOR DRIVEN ELEMENT ARE 10" (254mm) CIR.
SOLDER LUGS FOR NO.12 WIRE UNDER BRASS BOLT HEAD
LOOPS FOR DIRECTOR ELEMENT ARE 2-1/2" (64 mm) CIR.
SET SCREW
2-1/8" (54mm)
7/8" (22mm)
1-3/4" (44mm)
1-1/8" (29mm)
BLOCK DETAIL
7/16" (11mm)
FOR NO.12 WIRE SUPPORT (1/8" DRILL)-(3mm)

Fig. 7 — Construction details of the loaded beam.

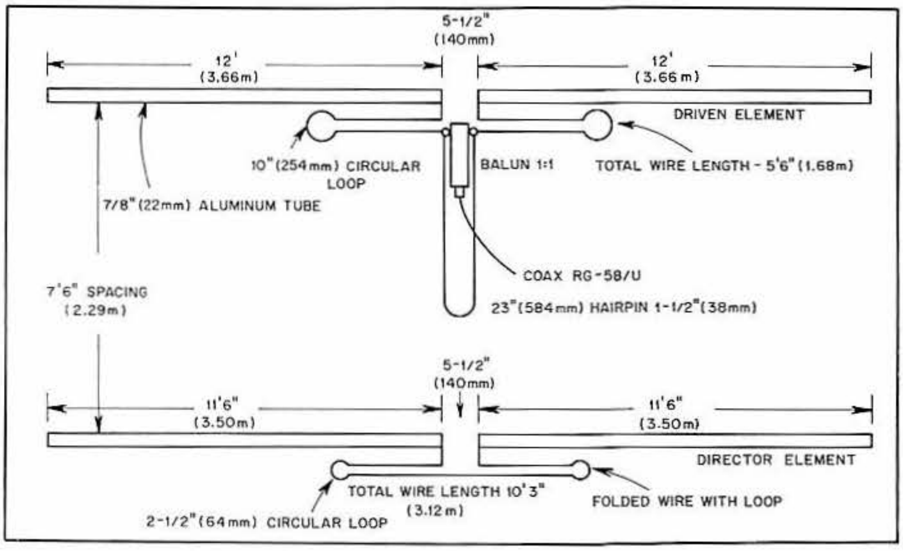

Fig. 8 — Critical electrical dimensions.

down to a more reasonable level. Many hairpin lengths and widths were tried with varying results. The final hairpin was 23-in. long by 1-1/2 in. (580 × 38 mm) wide with a slight fan shape to fit the balun connections. This reduced the VSWR at 14,200 kHz and 14,350 kHz with a flat response in between.

On-the-Air Tests

The help of other amateurs in tests for front-to back ratio was very helpful. Average reports have been 2.5 S units in the forward position over the back position. The author did not have a reference dipole for gain tests, but has heard and worked more DX than in the past 20 years. The beam is mounted on a rooftop 10-ft (3-m) steel tower 38 ft (11.6-m) above the ground. It weighs around 20 pounds and is rotated by an older-type TV rotator. This material was originally presented in *QST* by Cole Collinge, W0YNF.

The Log-Yag Array

The Yagi antenna array has been around for years and years. A relative newcomer to hams is the log-periodic dipole array (LPDA), which offers nearly constant gain over a greater bandwidth than the Yagi. Guess what happens when you cross a Yagi with an LPDA . . . .

With the decline in sunspot activity, a number of amateurs have considered monoband Yagi arrays. The first problem encountered seems to be array length, that is, overall size for a desired gain and bandwidth. The Log-Yag principle, as will be discussed shortly, has produced a system which will provide the amateur with another alternative to the long-boom Yagi, stacked Yagis, or loop-antenna systems. The L-P Yagi (Log-Yag) array is not a new system; many such arrays have been designed and developed by Oliver Swan[1] and others.[2] This article, however, will provide the basic theory of operation, design procedure, and the construction of a practical antenna.

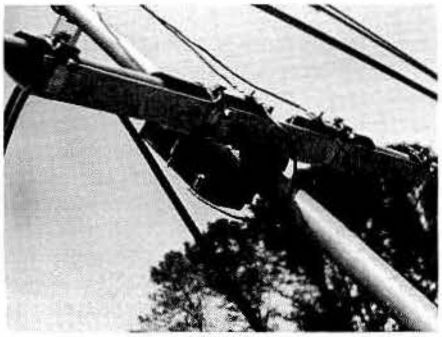

The attachment of the elements to the boom.

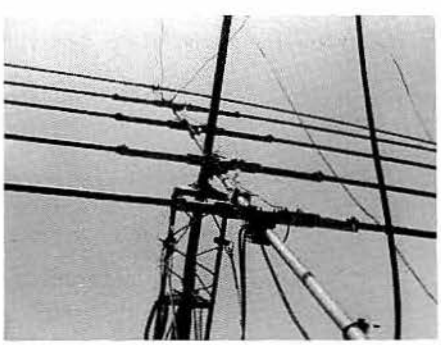

From the front to the back of the Log-Yag array. Note the truss provides lateral and vertical support.

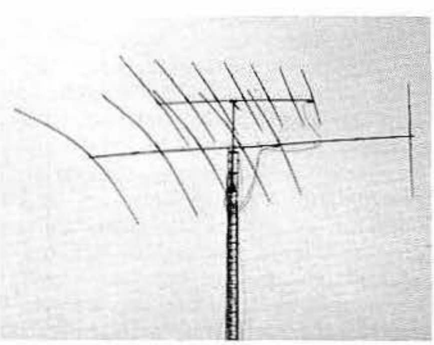

The completed Log-Yag array ready for use. The array mounted above the Log-Yag is a 7-element LPDA for 21 to 30 MHz.

Theory of Operation

The Log-Yag array utilizes an LPDA-driven[3] group of elements, designed to cover a desired bandwidth, in conjunction with parasitic elements to achieve higher gains and greater directivity than would be realized with either the LPDA or Yagi array alone. The Yagi array requires a long boom and wide element spacing for wide bandwidth and high gain. This is because the Q of the Yagi system increases as the number of elements is increased and/or as the spacing between adjacent elements is decreased.[4,5] An increase in the Q of the Yagi array means that the total bandwidth of that array is decreased; optimum gain, front-to-back ratio, and side lobe rejection are obtainable only over small portions of the band. Dr. I. L. Morris, using a high-speed digital computer, has completed extensive research on 4-, 8-, and 10-director Yagi-Uda arrays.[6] His work is comprehensive and is recommended reading for all technically minded amateurs. The parameters varied in his study were element length, spacing, radius and number. As can be seen in Fig. 9, the forward gain and front-to-back ratio

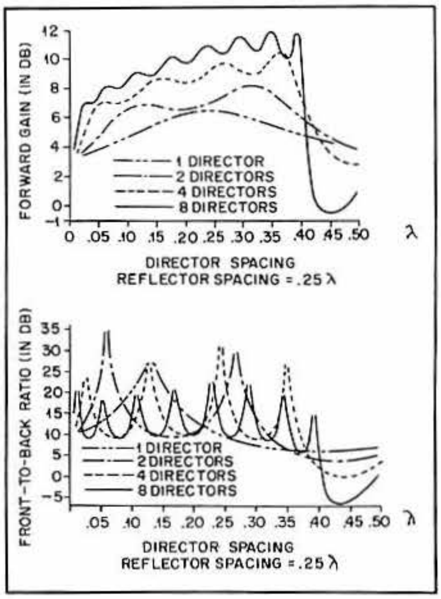

Fig. 9 — The effects of director spacing on various Yagi arrays. The change in gain and front-to-back ratio is plotted for the change in director spacing. The reflector spacing has been held constant.

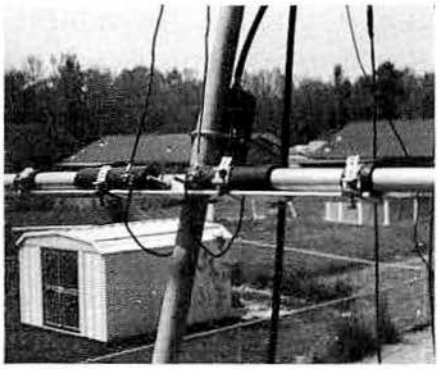

The connections between the balun and the input terminals.

deteriorate sharply as element spacings decrease. If the elements are closely spaced, then as the frequency is shifted either side of the array design frequency the electrical spacing between adjacent elements changes rapidly. This causes a higher SWR and a deterioration of forward gain and front-to-back ratio.

The Log-Yag system overcomes this difficulty by using a multiple driven element "cell" designed in accordance with the principles of the log-periodic dipole array.[7,8] Since this log cell exhibits both gain and directivity by itself, it is a more effective radiator than a simple dipole driven element. The front-to-back ratio and gain of the log cell can be improved with the addition of a parasitic reflector and director. It is not necessary for the parasitic element spacings to be large with respect to wavelength, as in the Yagi array, since the log cell is the determining factor in the array bandwidth. In fact, the element spacings within the log cell may be small with respect to a wavelength without appreciable deterioration of the cell gain. For example, decreasing the relative spacing constant (σ) from 0.1 to 0.5 λ will decrease the gain by less than 1 dB. Hence, a further reduction in boom length. It can be seen that the Log-Yag array will exhibit high theoretical gain (11 dBd), high front-to-back ratio (30 dB), high cross polarization (front-to-side ratio — 45 dB), and a wideband response utilizing boom lengths approximately one half that of a Yagi with similar characteristics.[2]

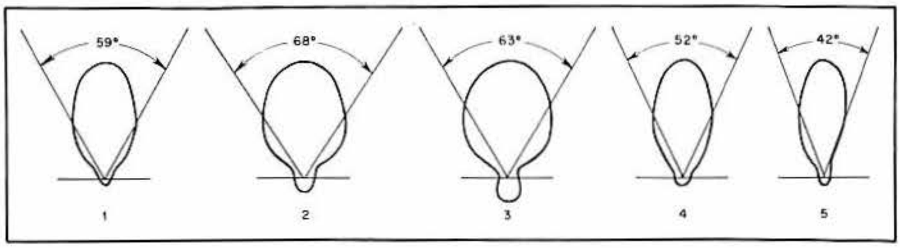

Fig. 10 — Beam patterns of 20-meter arrays.
No. 1 — 3-el. log cell, dir. @ 0.1λ, ref. @ 0.2λ.
No. 2 — 5-el. log periodic, σ = 0.1.
No. 3 — 3-el. log cell, 1st dir. @ 0.1λ, 2nd dir. @ 0.2λ.
No. 4 — 4-el. log cell, ref. @ 0.15λ.
No. 5 — 4-el. log cell, dir. @ 0.15λ, ref. @ 0.085λ (described in this article).

The author has built many monoband 14-MHz Log-Yag arrays in an attempt to find an optimum combination of elements, while holding the boom length to that of a full-sized, three-element monobander Yagi. Relative radiation patterns for various element combinations are found in Fig. 10. The final array design takes the form of a four-element log cell, parasitic reflector spaced at 0.085 λ_{max} and parasitic director spaced at 0.15 λ_{max} where λ_{max} is the longest free-space wavelength within the array passband. It has been found that array gain is almost unaffected with reflector spacings from 0.08 λ to 0.25 λ and the increase in boom length is not justified.[9] The function of the reflector is to improve the front-to-back ratio of the log cell while the director sharpens the forward lobe and decreases the half-power beamwidth. As the spacing between the parasitic elements and the log cell decreases, the parasitic elements must increase in length.[10]

The log cell is designed to meet upper and lower band limits with σ = 0.05λ. The design parameter τ is dependent on the structure bandwidth, B_s. When the log-periodic design parameters have been found, the element length and spacings can be determined. A review of the "Log-Periodic Dipole Array" is recommended though not necessary for the design of the Log-Yag array.[3,7,8]

The method of feeding the antenna is identical to that of feeding the log-periodic dipole array without the parasitic elements. As shown in Fig. 11, a balanced feeder is required for each log-cell element, and all adjacent elements are fed with a 180° phase shift by alternating connections. Since the Log-Yag array will be covering a relatively small bandwidth, the radiation resistance of the narrow-band log cell will vary from 80 to 90 ohms (tubing elements) depending on the operating bandwidth. The addition of parasitic elements lowers the log-cell radiation resistance. Hence, it is recommended that a 1-to-1 balun be connected at the log-cell input terminals and 52-ohm coaxial cable be used for the feed line. The measured radiation resistance of the 14-MHz Log-Yag installed at the author's QTH is 37 ohms, 14.0 to 14.35 MHz. It is assumed that tubing elements will be used. However, if a wire array is used then the radiation resistance R_o and antenna-feeder input impedance Z_o must be calculated so that the proper balun and coax may be used. The procedure is outlined in detail in *The ARRL Antenna Book*.[3,7]

Design Procedure

The following step-by-step design procedure may be used to design any monoband Log-Yag for any desired bandwidth.

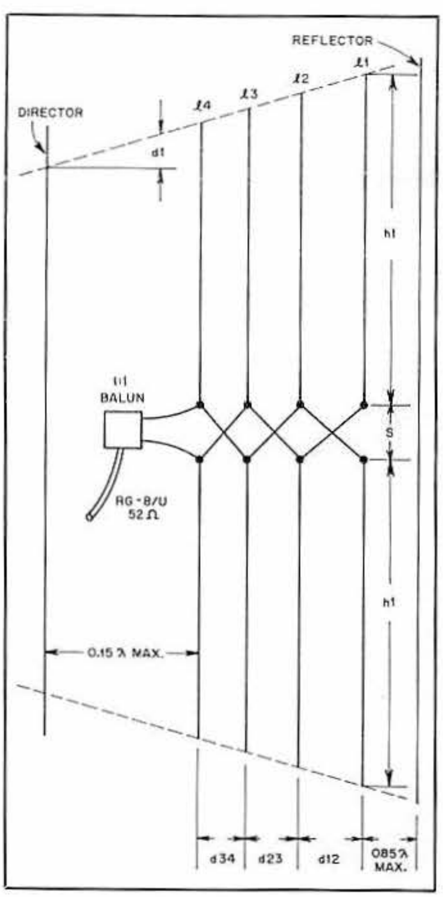

Fig. 11 — Layout of the Log-Yag array.

1) Determine the operating bandwidth, B, between f_1, lowest frequency (band edge), and f_n, highest frequency (band edge).

$$B = \frac{f_n}{f_1}$$

2) Determine the structure bandwidth (log-cell array) B_s.

$$B_s = 1.15B$$

3) Determine the design parameter τ (based on 4-element log cell, note 1).

$$\tau = \frac{1}{\sqrt[3]{B_s}}$$

Note 1. The design parameter τ is chosen for a four-element log cell since it provides the best bandpass for most amateur bands. For log cells with any number of elements

$$\tau = \frac{1}{\sqrt[(n-1)]{B_s}}$$

where n = number of elements within the log cell.

4) Determine the apex half-angle α: Since $\sigma = 0.05$ (relative spacing constant), then

$$\cot \alpha = \frac{0.2}{1-\tau}$$

5) Determine the longest free-space wavelength λ_{max}, log-cell boom length, L (ft) and longest element length within the log cell l_1 (ft).

$$\lambda_{max} = \frac{984}{f_1 \, \mathrm{MHz}}$$

$$L = \left[\frac{1}{4}\left(1 - \frac{1}{B_s}\right) \cot \alpha\right] \lambda_{max}$$

and

$$l_1 = \frac{492}{f_1 \, \mathrm{MHz}}$$

$$l_2 = \tau l_1$$

$$l_3 = \tau l_2$$

$$l_4 = \tau l_3$$

6) Determine the element spacing (d_{12}), distance between elements l_1 and l_2 (ft).

$$d_{12} = \frac{1}{2}\left(l_1 - l_2\right) \quad \cot \alpha$$

and

$$d_{23} = \tau d_{12}$$

$$d_{34} = \tau d_{23}$$

7) Determine the parasitic element lengths (ft) and spacings (ft).

$$l_{REF} = \frac{509.6}{f_1 \, \mathrm{MHz}}$$

$$d_{REF} = \frac{84}{f_1 \, \mathrm{MHz}}$$

$$l_{DIR} = \frac{450.8}{f_1 \, \mathrm{MHz}}$$

$$d_{DIR} = \frac{148}{f_1 \, \mathrm{MHz}}$$

This completes the design.

The Finished Log-Yag

The proof is always to be found in the completed and operating product. The

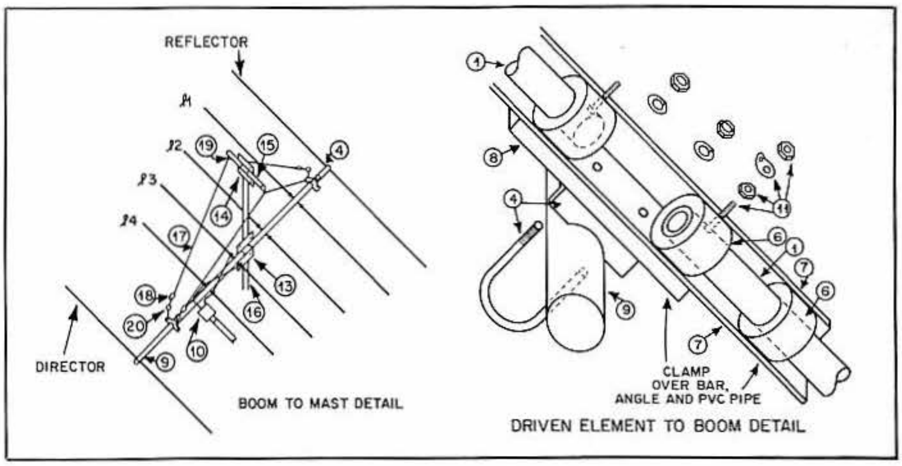

Fig. 12 — Assembly details. The numbered components refer to Table 6.

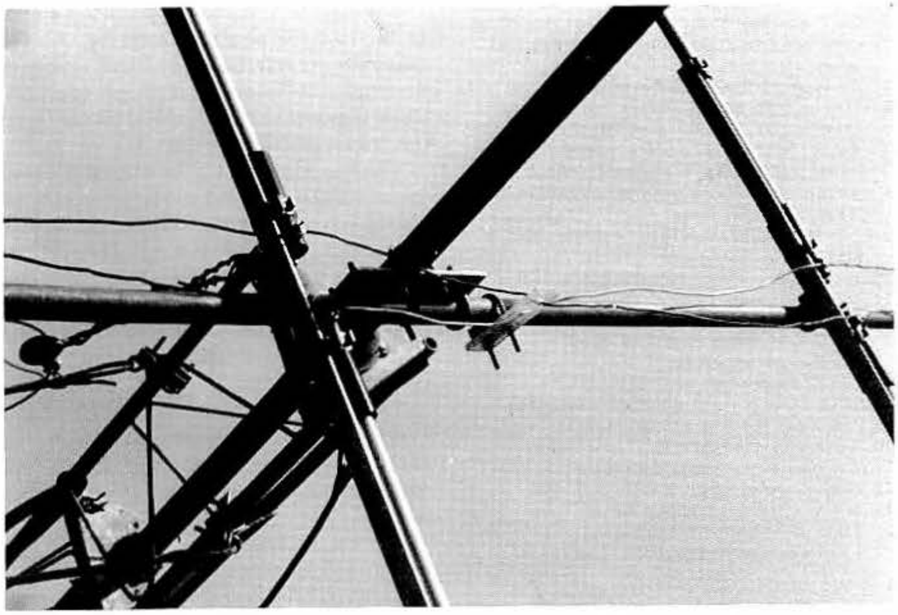

The interconnection between the elements of the log cell changes sides between each element.

Table 3

Array Characteristics

1. Frequency range	14-14.35 MHz
2. Operating bandwidth	B = 1.025
3. Design parameter	τ = 0.946657
4. Apex half angle	a = 14.92°, cot = 3.753
5. Half-power beam width	42° (14-14.35 MHz)
6. Bandwidth of structure	B_s = 1.17875
7. Free-space wavelength	λ_{max} = 70.28 ft
8. Log cell boom length	L = 10.0 ft
9. Longest log element	l_1 = 35.14 ft (a tabulation of element lengths and spacings given in Table 2)
10. Forward gain over dipole	11.5 dB (theoretical)
11. Front-to-back ratio	32 dB (theoretical)
12. Front-to-side ratio	45 dB (theoretical)
13. Input impedance	Z_0 = 37 ohms
14. SWR	1.3 to 1 (14-14.35 MHz)
15. Total weight	96 pounds
16. Wind-load area	8.5 sq. ft
17. Feed-point impedance	Z_0 = 37 ohms
18. Reflector length	36.4 ft @ 6.0 ft spacing
19. Director length	32.2 ft @ 10.5 ft spacing
20. Total boom length	26.5 ft

The mechanical construction of the log cell is identical to that described in *The ARRL Antenna Book*, except for the lengths and spacings.[3,7] Fig. 12 shows how the log cell is constructed as well as the addition of the parasitic elements.

1 ft = 0.30478 m

Table 4

Array Dimensions

Element	*Length Ft*	*Spacing Ft*
Reflector	36.4	6.0 (Ref. to l_1)
l_1	35.14	3.51 (d_{12})
l_2	33.27	3.32 (d_{23})
l_3	31.49	3.14 (d_{34})
l_4	29.81	10.57 (l_4 to dir.)
Director	32.2	

1 ft = 0.30478 m

Table 5

Element Material Requirements

Element	*1-in. Tubing Length (Ft)*	*Qty.*	*7/8-in. Tubing Length (Ft)*	*Qty.*	*3/4-in. Tubing Length (Ft)*	*Qty.*	*1 1/4-in. Angle Length (Ft)*	*1 X 1/4-in. Bar Length (Ft)*
Reflector	12	1	6	2	8	2	None	None
l_1	6	2	6	2	8	2	3	1
l_2	6	2	6	2	8	2	3	1
l_3	6	2	6	2	6	2	3	1
l_4	6	2	6	2	6	2	3	1
Director	12	1	6	2	6	2	None	None

1 ft = 0.30478 m

Table 6

Materials List

1. Aluminum tubing — 0.047 in. wall thickness
    1 in. — 12 ft lengths, 24 lin. ft
    1 in. — 12 ft or 6 ft lengths, 48 lin. ft
    7/8 in. — 12 ft or 6 ft lengths, 72 lin. ft
    3/4 in. — 8 ft lengths, 48 lin. ft
    3/4 in. — 6 ft lengths, 36 lin. ft
2. Stainless steel hose clamps — 2 in. max., 8 ea.
3. Stainless steel hose clamps — 1-1/4 in. max., 24 ea.
4. TV-type U bolts — 1-1/2 in., 6 ea.
5. U bolts, galv. type: 5/16 in. X 1-1/2 in., 4 ea.
6. U bolts, galv. type: 1/4 in. X 1 in., 2 ea.
7. 1 in. ID water-service polyethylene pipe 160 lb/in.^{2} test, approx. 1-3/8 in. OD, 7 lin. ft
8. 1-1/4 in. X 1-1/4 in. X 1/8 in. aluminum angle — 6 ft lengths, 12 lin. ft
9. 1 in. X 1/4 in. aluminum bar — 6 ft lengths, 6 lin. ft
10. 1-1/4 in. top rail of chain-link fence, 26.5 lin. ft

11 1:1 toroid balun, 1 ea.

12. No. 6-32 X 1 in. stainless steel screws, 8 ea.
    No. 6-32 stainless steel nuts, 16 ea.
    No. 6 solder lugs, 8 ea.
13. No. 12 copper feed wire, 22 lin. ft

14 12 in. X 6 in. X 1/4 in. aluminum plate, 1 ea.

15. 6 in. X 4 in. X 1/4 in. aluminum plate, 1 ea.
16. 3/4 in. galv. pipe, 3 lin. ft
17. 1 in. galv. pipe — mast, 5 lin. ft
18. Galv. guy wire, 50 lin. ft
19. 1/4 in. X 2 in. turnbuckles, 4 ea.
20. 1/4 in. X 1-1/2 in. eye bolts, 2 ea.
21. TV guy clamps and eyebolts, 2 ea.

1 in. = 25.4 mm
1 ft = 0.30478 m

author's 14-MHZ Log-Yag on-the-air performance on cw and ssb substantiates the theory. The characteristics of the array are given in Table 3.

The materials needed are given in Table 5. In the construction diagram, Fig. 12, the materials are referenced by their respective material list number. The photographs show the overall construction picture, and the drawings show the details.

The materials should be available from most hardware and electronic stores. However, some have found difficulty in obtaining aluminum tubing. This can be solved by writing to the manufacturer and asking for the name of their distributor nearest your locality. Commercial antenna manufacturers will sell their tubing, but the cost is at a premium.

This array is in operation at K4EWG and W4BBP. The results on the air are nothing short of fantastic! It will give the stacked Yagis and long-boom Yagis a run for their money.

It is the authors' hope that this antenna design will stimulate additional work and research by other amateurs. The field seems wide open, and Yag-Log combinations are endless. The optimum design is by no means achieved in this article. It does seem, however, that a log cell of more than four elements would be necessary only where the array bandwidths, B, exceed 1.03 ($B = f_n/f_1$).

The authors wish to thank George Smith, W4AEO, for his work in substantiating a consideration for log periodic gain.[8] This material was originally presented in *QST* by P. D. Rhodes, K4EWG and J. R. Painter, W4BBP.

References

[1] "The Swan Multidrive 2-Meter Antenna," *QST*, Oct. 1969.

[2] Orr, *Radio Handbook*, 18th edition, pp. 547-548.

[3] Rhodes, "The Log-Periodic Dipole Array," *QST*, November 1973.

[4] *The ARRL Antenna Book*, 13th edition, p. 151.

[5] See ref. 2 above, p. 558.

[6] King, Mack and Sandler, "Arrays of Cylindrical Dipoles," *Yagi-Uda Programme Apdx. V*, 1968, pp. 218-232,468-470.

[7] See ref. 4 above: pp. 160-164, 208-210, and Fig. 9-18.

[8] Smith, "Yes, I've Built Sixteen Log Periodic Antennas!" *73*, March 1975. See pp. 98-99.

[9] Orr, "Antennas," *CQ*, March 1975. See section headed "The KLM Antenna."

[10] See ref. 4 above, p. 204 and Fig. 9-5.

Chapter 3

Quad Antennas

A currently popular form of directional gain antenna is called the "quad." In general performance principles, it compares favorably to the Yagi beams discussed in chapter 2. The proper name for this antenna is the "cubical quad." It was developed by Clarence Moore, W9LZX, in 1942 when he was an engineer for HCJB in Quito, Ecuador. The design came as a solution to large corona discharges at the ends of existing beam-antenna elements. The problem was caused by the highly ionized air at the transmitter location, some two miles above sea level. Operation was in the commercial 25-meter band, which for the intentions of the broadcaster, required a gain type of antenna.

Moore concluded that a gain antenna with no ends was required to handle the 10-kW power without corona or flashover. Thus, the quad was born. Not only did it handle the power without difficulty, it later became a popular amateur antenna after he developed a model for use on 20 meters.

The primary limitation of quad antennas is the unwieldy nature of the "beast," especially at 40 and 20 meters, compared to a Yagi. The supporting framework is subject to extreme stress from ice and wind loading. Nonetheless, the quad has proven to be one of the most effective DX beams that an amateur can build at modest cost. This chapter contains data on various types of quads for a number of amateur bands. It is a compendium of the best on the subject, as published in past issues of *QST*.

Quads and Yagis: Comparisons, Patterns and Working Dimensions

Want a fresh look at the Yagi vs. quad question? This is "must" reading for the antenna-minded.

The material in the following sections will present a discussion of two time-tested antenna arrays.

In this class of arrays the Yagi (more properly the Yagi-Uda) antenna is the grandfather of them all. There are very few antennas which can compete with the electrical operation and simplicity of construction of this array. However, in the early 1940s C. C. Moore, of radio station HCJB, brought into being a parasitic array of loop elements with properties very comparable to those of the Yagi-Uda array. Since its conception this array has become very popular in Amateur Radio circles. It has come to be known as the "cubical quad" or "quad" antenna because of the common use of square loops and box-like construction.[1]

The material to follow will attempt to present an unbiased comparison of these two arrays based upon the experimental and theoretical results of many workers. This material is prefaced by a short section of introductory antenna concepts and definitions so that certain terms and notation will have more meaning when the comparisons between the quad and Yagi antennas are made. Finally, in the last section, some of the experimental patterns of modeled quad and Yagi arrays are presented. A compilation of some of the working dimensions for both types of arrays are also given. This latter material should be of interest to the builder and experimenter.

Introductory Antenna Theory and Definitions: Polarization

Inspection of the radiation field of an antenna will show it to have plane-wave character and to be made up of electric and magnetic field lines which are perpendicular to each other. Polarization of an electromagnetic wave is defined as that direction in which the electric field lines are oriented. If the electric field vector is fixed (in direction) in a plane it is said to be linearly polarized. For example, the polarization of a dipole is linear. If the plane in which this dipole lies is horizontal or parallel to some reference plane (e.g., the surface of the earth), it is called a horizontally polarized antenna. Vertical polarization would result if the dipole were placed perpendicular to the reference plane. It should be noted that if the electric vector does not stay fixed in position but rotates (its tip tracing out an ellipse), then the wave is said to be elliptically polarized. Circular polarization is a special case of elliptical polarization. Elliptical polarization will have a right- or left-hand sense, depending upon the direction of rotation of the electric vector.

Directivity and Gain of an Antenna

The degree to which a particular antenna can concentrate the antenna pattern into a beam is known as *directivity*. Mathematically, it is the ratio of the power density (in watts per square unit of measure) that would be available at an observation point to the power density one would have if the total radiated power were radiated *equally* well in *all* directions.[2] Directivity is a function of the antenna pattern alone and does not take into account antenna efficiency or losses.

The gain of an antenna can be defined in terms of directivity when antenna efficiency is taken into consideration. If K is the antenna efficiency, a number between 0 and 1, then antenna gain is given by

$$G = KD$$

where

G = antenna gain
K = antenna efficiency
D = directivity

The gain in decibels is then given by

$$\text{dB gain} = 10 \log_{10} G.$$

Please note that the above definition has been such that it is a function of the observation point. In amateur circles gain is usually measured at that observation point where the maximum power density is observed. Further, when considering practical Yagi and quad arrays for the hf range, K is normally taken as 1. Gain measured in the above manner is normally called gain with respect to an isotropic antenna. It is interesting to note that since a half-wave dipole concentrates its pattern into certain directions, it will have some gain with respect to an isotropic antenna. This gain with respect to isotropic is found to be

$$G = 1.64$$

or, in dB,

$$G_{dB} = 2.15 \text{ dB}$$

If the vertical and horizontal half-power beam widths are known for a given antenna the following formula will give (somewhat on the generous side) the gain of the antenna with respect to an isotropic antenna

$$G = \frac{40{,}000}{\theta_H \theta_V}$$

where

θ_H = horizontal half-power beam width in degrees.

θ_V= vertical half-power beam width in degrees.

This formula assumes low-side and back-lobe levels for the antenna pattern. If the gain with respect to isotropic is known then the gain with respect to a half-wave dipole is obtained by subtracting 2.15 dB.

Antenna Aperture or Area

This concept is of most use when discussing a receiving antenna. It is a measure of the antenna's ability to gather in available radiated power at some receiving position. Antenna area and gain are *directly* related

$$G = 4\pi \frac{A}{\lambda^2}$$

where

G = antenna gain

λ = operating wavelength

A = area (based upon square units of length measurement, with the length measurement the same as that assumed for λ). It should be noted that one *cannot* have two antennas with the same gain and different areas. One hears this concept misused (in the sense of the above sentence) quite often on the amateur bands. That is to say, if you feel that one antenna has more capture area than another, then it must also have more gain.

Antenna Patterns

The pattern of an antenna may be plotted by recording the received electric field strength or power density as a function of viewing (observation) angle. The properties of most antennas used by radio amateurs (below 30 MHz) can be described by two basic patterns. Consider a pattern due to a radiating half-wave dipole, this pattern to be obtained by moving a sampling or test antenna about the dipole in the horizontal plane which contains the dipole. This pattern is called the horizontal-plane or E-plane pattern (the pattern was taken in a plane containing the electric E-lines, hence the name E-plane pattern). If the sampling antenna is placed directly in front of the horizontal dipole (and in the horizontal plane) and moved up over the top of the dipole (in a plane perpendicular to the horizontal plane), and on around until it returns to the starting position, the result is the vertical-plane or H-plane pattern (since the test antenna moved in a plane parallel to the magnetic H-lines it is called an H-plane pattern).

For Yagi and quad arrays these two patterns will give enough essential information to determine their expected radiating properties.

Comparison of Quad and Yagi Arrays

The cubical quad antenna was first introduced to the radio world in 1942 by Clarence C. Moore at HCJB to alleviate a serious corona problem occurring on a large commercial shortwave Yagi array. It is a parasitic array formed with loop elements which are approximately one wavelength in circumference.

Important to proper operation of a quad antenna are considerations of proper element sizes, spacing between elements, boom length, feed impedance and so forth. The following material presents a discussion of these considerations and a comparison of the quad and Yagi arrays.

Polarization of a Quad Antenna

The polarization of a quad antenna can be determined by considering the current distribution on the driven element. To stress the point that square, diamond, or circular loop all produce essentially the same polarization, consider the current distribution shown in Fig. 1. A little thought reveals that fact that the vertical components of current produce radiated fields that cancel each other, and the horizontal components of current produce a radiated field (broadside to the loop) with all components adding. The polarization of any of these loops is then linear and parallel to an imaginary horizontal line drawn through the current minima. Hence, if a quad loop is fed at the bottom it produces horizontal polarization, and if fed on the side it will have vertical polarization. The geometrical form of the loop, square, diamond or circular, does not mean that the (broadside) radiation has a possible combination of both horizontal and vertical polarization or circular polarization. This seems to be a common misconception in amateur circles. The linear polarization properties introduced above can be verified easily experimentally. It should be further noted that there are no noticeable differences in the radiating properties or impedance of a loop 1 wavelength in circumference whether it be of the circle, diamond or square configuration.

Angle of Radiation for a Horizontally Polarized Quad Antenna

Placement of an antenna above a conducting ground will alter its free-space radiation pattern, positioning the maximum of its main lobe at possibly a new angle with respect to a horizontal reference line. The angular position of this main lobe is called the *angle of radiation*. The angle of radiation of an antenna is a function of its height above the conducting ground and its polarization. Given the height and the polarization, the angle of radiation can be determined by using the concept of the antenna's virtual image or ray theory and reflection of the wave by the ground.

The following conclusions can now be drawn:

The angle of radiation of a *horizontally* polarized quad antenna, at a given boom height, is essentially the *same* as that of a *horizontally* polarized Yagi at the same boom height.

This must be so because the boundary conditions imposed upon the electromag-

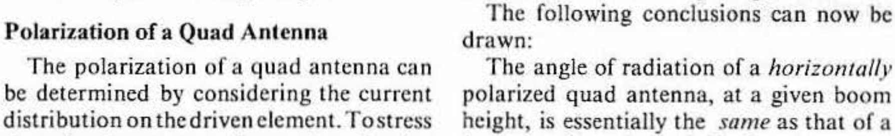

Fig. 1 — Current distribution on circular, diamond and square loops 1 wavelength in circumference.

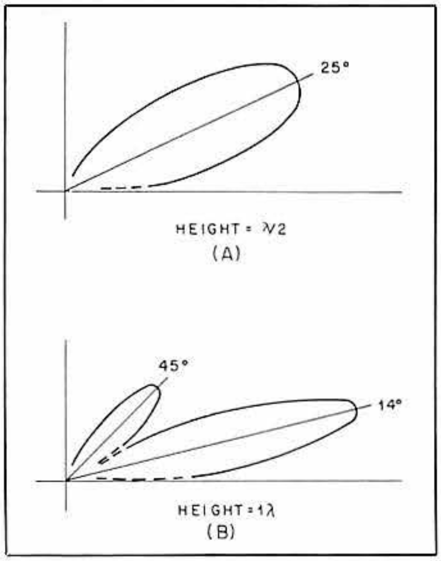

Fig. 2 — Vertical-plane radiation patterns for a horizontally polarized quad or Yagi array above perfectly conducting ground.

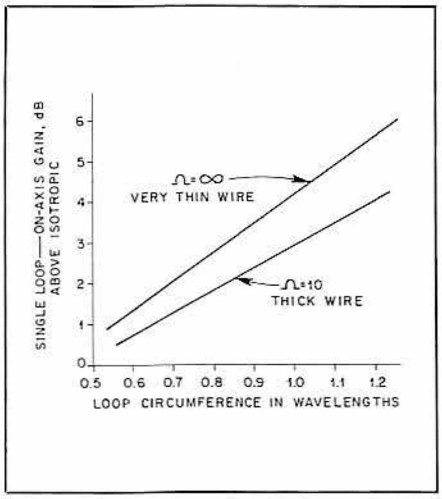

Fig. 3 — On-axis gain of a single loop as a function of loop circumference. (From "Studies of Large Circular Loop Antennas" by S. Adachi and Y. Mushiake *Sci. Rep. Ritu*, B-[Elect. Comm.] vol. 9, no. 2, Tohoku Univ., Sendai, Japan, 1957.)

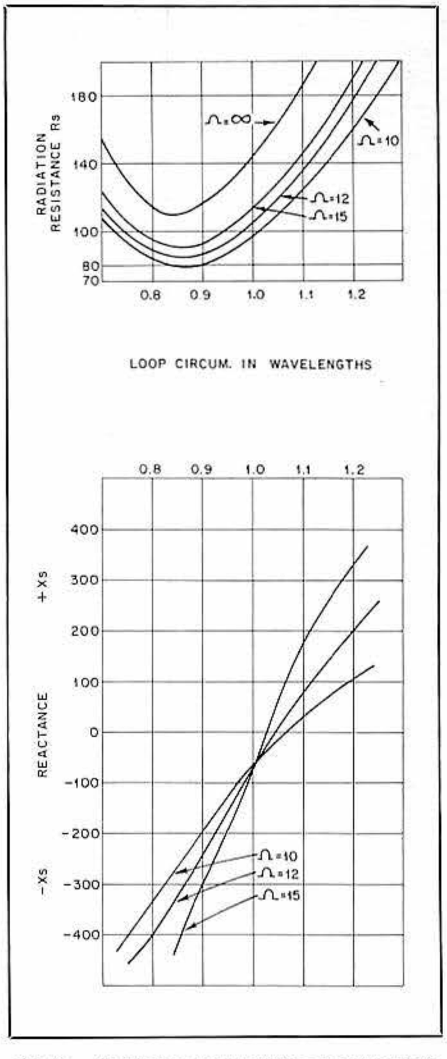

Fig. 4 — Reactance and radiation resistance of a single loop versus circumference. Note: Ω is a measure of the ratio of loop circumference to wire diameter. $\Omega = 2\ln 8a/\rho$ where a = loop radius and ρ = wire radius.

netic wave at the surface of ground are completely insensitive to the fact that the wave is produced by a quad antenna as opposed to the wave produced by a Yagi antenna.

Typical patterns of a quad *or* Yagi antenna placed at a height of $1/2\ \lambda$ or $1\ \lambda$ above a perfect ground are shown in Fig. 2 at A and B.

Gain Comparisons of the Quad Antenna with the Yagi Antenna

The gain of a quad array (of given boom length) seems to be somewhat higher than that of a Yagi array of the same boom length. This gain difference can be explained by considering the theoretical work of Adachi and Mushiake of Tohoku University in Japan. In 1952 and 1957 they published two papers which discussed the current distribution, impedance, and radiating properties of loops of large circumference.[3]

Fig. 3 shows the gain of a single loop as a function of wavelength and wire diameter. Fig. 4 shows the variation of reactance and radiation resistance for a single loop. Please note the dependence upon the circumference-to-wire-diameter ratio in these two figures. They showed that the broadside gain of a single loop 1λ in circumference was approximately 2 dB above that of a half-wave dipole. This result implies that a parasitic array of loop elements should have the same gain advantage when compared to a Yagi array of comparable boom length.

This gain differential for the quad array does appear and can be verified experimentally. Fig. 5 demonstrates this comparison. The points on the figure were obtained as follows: For the antenna under consideration E and H plane patterns were made. The gain was then calculated using the E and H-plane half-power beam widths of these radiation patterns and the formula discussed above. This gain and the boom length of the antenna were then used to determine a point on the graph given in Fig. 5, where gain and boom length represent the parameters under consideration. The data points for many, many antennas, both quad and Yagi, were then placed on the graph and a smooth curve representing an average for each type of antenna was then drawn.

The expected gain difference of 2 dB does indeed appear in favor of the quad antenna. This gain differential is essentially that predicted by the results of the Japanese workers cited above.

The measurements used to obtain the above gain comparisons were performed at 440 MHz. A measuring frequency of 440

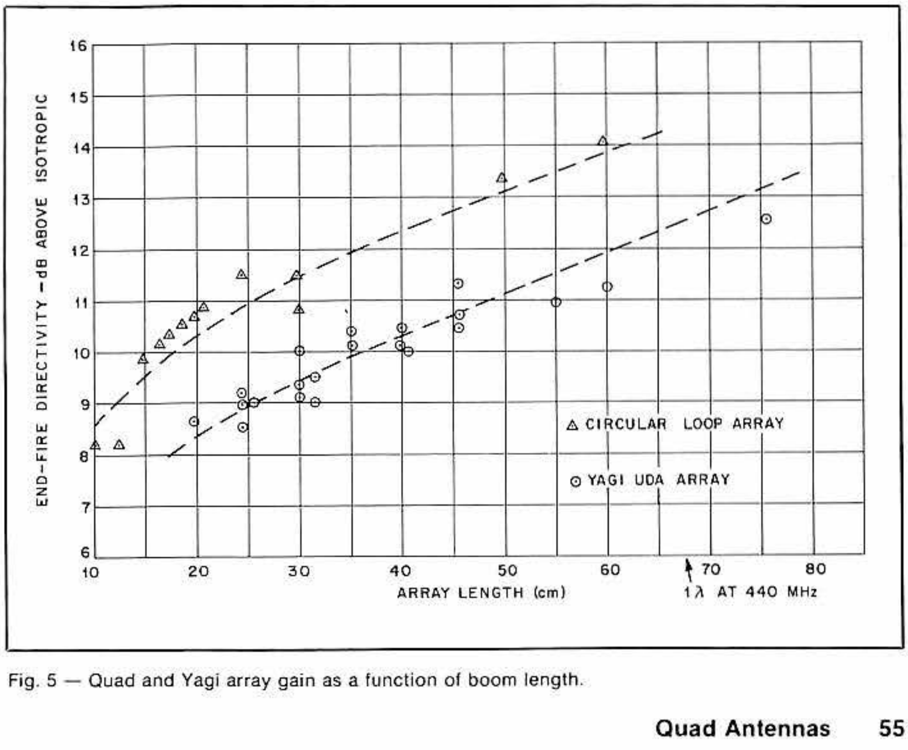

Fig. 5 — Quad and Yagi array gain as a function of boom length.

Table 1

Quad Dimensions

2-element Quad (W0HTH)
Spacing (given below)
Boom length (given below)

Band	*40 M*	*20 M*	*15 M*	*10 M*
Reflector	144 ft 11-1/2 in.	72 ft 4 in.	48 ft 8 in.	35 ft 7 in.
Driven Element	140 ft 11-1/2 in.	70 ft 2 in.	47 ft 4 in.	34 ft 7 in.
Spacing	30 ft	13 ft	10 ft	6 ft 6 in.
Boom length	30 ft	13 ft	10 ft	6 ft 6 in.
Feed method	Directly with 23 ft of RG-11, then any length RG-8 coax.	Directly with 11 ft 7 in. RG-11, then any length RG-8 coax.	Directly with 7 ft 8-1/2 in. RG-11, then any length RG-8 coax.	Directly with 5 ft 8 in. RG-11, then any length RG-8 coax.

(Note that a spider or boomless quad arrangement could be used for the 10/15/20 meter parts of the above dimensions yielding a triband antenna)

4-element Quad* (W0AIW [20 M] /W0HTH** /K0KKU/K0EZH/W6FXB)
Spacing: equal; 10 ft
Boom length: 30 ft

Band	*20 M*		*15 M*	*10 M*
	Phone	CW		
Reflector	72 ft 1-1/2 in.	72 ft 5 in.	48 ft 8 in.	35 ft 8-1/2 in.
Driven Element	70 ft 1-1/2 in.	70 ft 5 in.	47 ft 4 in.	34 ft 8-1/2 in.
Director 1	69 ft 1 in.	69 ft 1 in.	46 ft 4 in.	33 ft 7-1/4 in.
Director 2	69 ft 1 in.	69 ft 1 in.	46 ft 4 in.	33 ft 7-1/4 in.
Feed Method	Directly with 50-ohm coax.		Directly with 50-ohm coax.	Directly with 5 ft 9 in. RG-11, then any length RG-8 coax.

*Common boom used to form a triband array.
**The 2-element 40-meter quad given above is added to form a four-band quad array.

4-element Quad (W0HTH/K8DYZ*/K8YIB*/W7EPA*)
Spacing: equal; 13 ft 4 in.
Boom length: 40 ft

Band	*20 M*	*15 M*	*10 M*
Reflector	72 ft 5 in.	48 ft 4 in.	35 ft 8-1/2 in.
Driven Element	70 ft 5 in.	47 ft 0 in.	34 ft 8-1/2 in.*
Director 1	69 ft 1 in.	46 ft 1 in.	(Directors 1-3 all
Director 2	69 ft 1 in.	46 ft 1 in.	33 ft 7 in.)*
Feed method	Directly with 50-ohm coax.	Directly with 7 ft 9 in. RG-11, then any length 50-ohm coax.	Directly with 50-ohm coax.

*For the 10-meter band the driven element is placed between the 20/15 reflector and 20/15 driven element. The 10-meter reflector is placed on the same frame as the 20/15-meter reflectors and the remaining 10-meter directors are placed on the remaining 20/15-meter frames. The 10-meter portion is then a 5-element quad.

6-element Quad (W0YDM, W7UMJ)
Spacing: equal; 12 ft
Boom length: 60 ft

Band: 20 M	
Reflector	72 ft 1-1/2 in.
Driven Element	70 ft 1-1/2 in.
Directors 1, 2 and 3	69 ft 1 in.
Director 4	69 ft 4 in.
Feed Method	Directly with 50-ohm coax.

1 ft = 0.3048 m

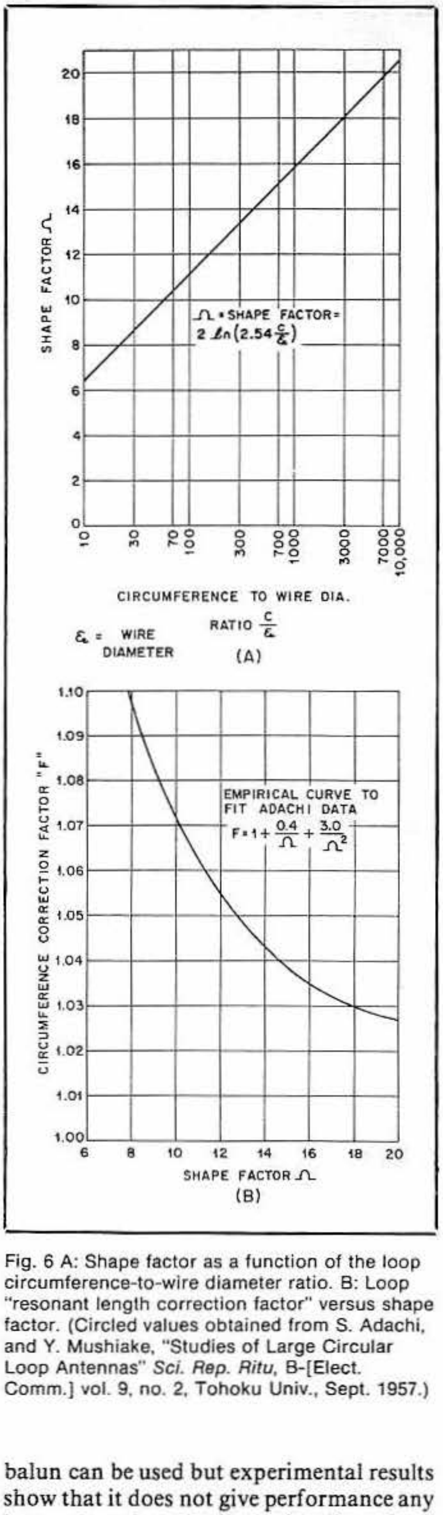

Fig. 6 A: Shape factor as a function of the loop circumference-to-wire diameter ratio. B: Loop "resonant length correction factor" versus shape factor. (Circled values obtained from S. Adachi, and Y. Mushiake, "Studies of Large Circular Loop Antennas" *Sci. Rep. Ritu*, B-[Elect. Comm.] vol. 9, no. 2, Tohoku Univ., Sept. 1957.)

MHz was chosen so that 1 cm (at this frequency) is equivalent to 1 foot of measurement at 14 MHz. Hence, to relate these results directly to the 20-meter amateur band, boom length in cm from the curve can be read as boom length in feet. For example, the gain of a quad on a 40-foot (12.19-m) boom should be slightly more than 1 dB above a quad on a 25-foot (7.62-m) boom. Comparison of the signals from these two antennas at a receiving station will not reveal much difference; however, in the DX pile-ups the longer antenna should have a slight advantage. Another interesting interpretation of these results is to note that a quad on a 30-foot (9.14-m) boom is equivalent to a Yagi on a 55-foot (16.76-m) boom. Hence the boom of a Yagi antenna must be about 1.8 times longer than the boom of a quad in order for the two gains to be comparable.

Impedance Properties and Matching

The driving-point impedance of a quad antenna depends upon the element spacing and number of elements. For 2-element quad antennas the results of Bill Orr in his *Quad Antenna* handbook can be used to determine the driving-point impedance. For multielement quads (3 or more elements)[4] the impedance will range from 40 to 60 ohms. Matching of these multielement quads is most easily done by direct feed with a 50-ohm coaxial line. A 1:1 balun can be used but experimental results show that it does not give performance any better than that obtained with direct feed. A gamma match can be used to obtain an exact match to any chosen coaxial line. For details of using a gamma match on a quad antenna see Bill Orr's *Quad Antenna* handbook.

If a single boom is used to construct a multiband quad antenna, then it is recommended that a separate feed line to each driven element be used.

Approximate Formulas for Quad Antenna Element Lengths

The multielement quad antenna gained its first real popularity following the work of Lee Bergren, W0AIW, in the early 1960s. He published the results of his work in *QST* in 1963.[5] Many experimentalists have used his dimensions for antennas in the 20-meter amateur band and have scaled them to other bands. Based upon Bergren's work and others the following empirical formulas can be used to determine the element lengths of a quad antenna

$$\text{Circumference of driven element} = \frac{1005}{f_{MHz}} \text{ feet}$$

$$\text{Circumference of reflector element} = \frac{1030}{f_{MHz}} \text{ feet}$$

$$\text{Circumference of director elements} = \frac{975}{f_{MHz}} \text{ feet}$$

These results should only be used for quad antennas operating below 30 MHz. It is interesting to note that for quad antennas the reflector and directors are only 2-1/2 to 3 percent different in length from the driven element. This is a smaller change than that normally encountered in Yagi arrays.

The above figures should not be used for vhf or uhf quad antennas. At these higher frequencies the circumference-to-wire-diameter ratio becomes small enough that its effect upon the resonant properties of the loop must be considered. Here again, the results of Adachi and Mushiake are useful and the effects of wire size on the resonant length of the loop can be taken into account. These results are given in graphical form in Fig. 6 where, based upon the circumference-to-wire-diameter ratio, a circumference correction factor can be obtained. Once the correct size of the driven element is determined (using the results of Fig. 6) a quad antenna can be designed by making the reflector approximately 3 percent longer and the directors 3 percent shorter.

The above results can be used to obtain workable dimensions but, just as with approximate formulas for Yagi antenna element lengths, the "best" dimensions would have to be determined experimentally by tuning the array.

A Collection of Quad and Yagi Patterns and Dimensions: E and H Plane Patterns for Quad and Yagi Arrays

The previous section referred to a group of experimental tests, where a series of model antennas were constructed and the E and H plane patterns obtained.

It should be noted that these patterns have direct interpretation in light of the 20-meter band. Recall that the experiments were performed at 440 MHz, where dimensions for boom length, element size, and spacing in cm are directly equivalent to dimensions in feet for the 20-meter band. For example, the patterns for a 440-MHz, 5-element Yagi on a 55-cm boom can also be taken as the pattern for a 14-MHz, 5-element Yagi on a 55-foot boom.

Perusal of these patterns will give a

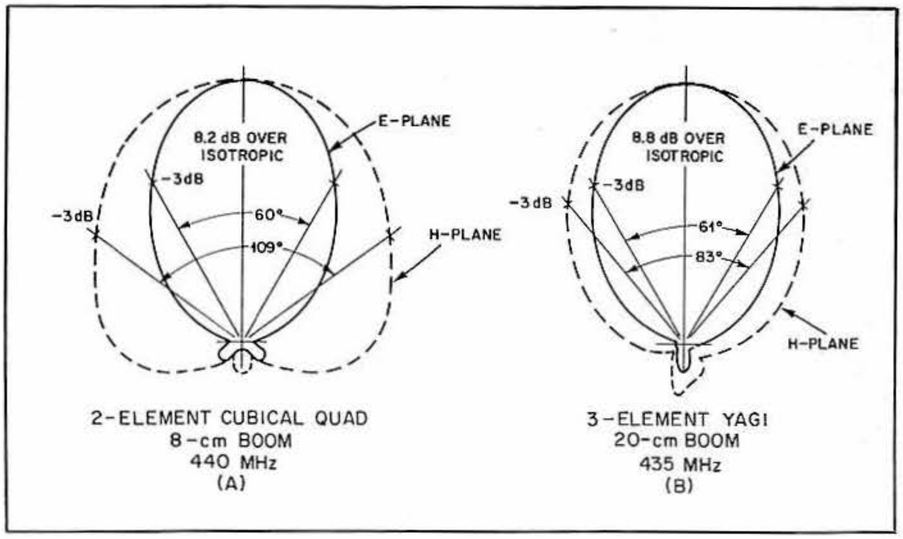
8.2 dB OVER ISOTROPIC
-3dB
-3dB
60°
109°
E-PLANE
H-PLANE
2-ELEMENT CUBICAL QUAD
8-cm BOOM
440 MHz
(A)
8.8 dB OVER ISOTROPIC
-3dB
-3dB
61°
83°
E-PLANE
H-PLANE
3-ELEMENT YAGI
20-cm BOOM
435 MHz
(B)

Fig. 7 — E and H plane radiation patterns for (A) 2-element quad antenna and (B) 3-element Yagi antenna.

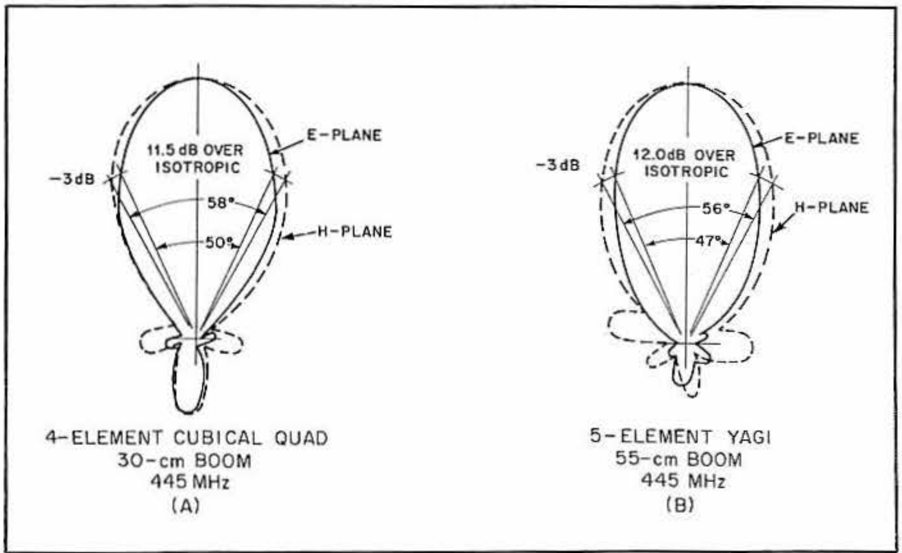
11.5 dB OVER ISOTROPIC
-3dB
58°
50°
E-PLANE
H-PLANE
4-ELEMENT CUBICAL QUAD
30-cm BOOM
445 MHz
(A)
12.0dB OVER ISOTROPIC
-3dB
56°
47°
E-PLANE
H-PLANE
5-ELEMENT YAGI
55-cm BOOM
445 MHz
(B)

Fig. 8 — E and H plane radiation patterns for (A) 4-element quad antenna and (B) 5-element Yagi antenna.

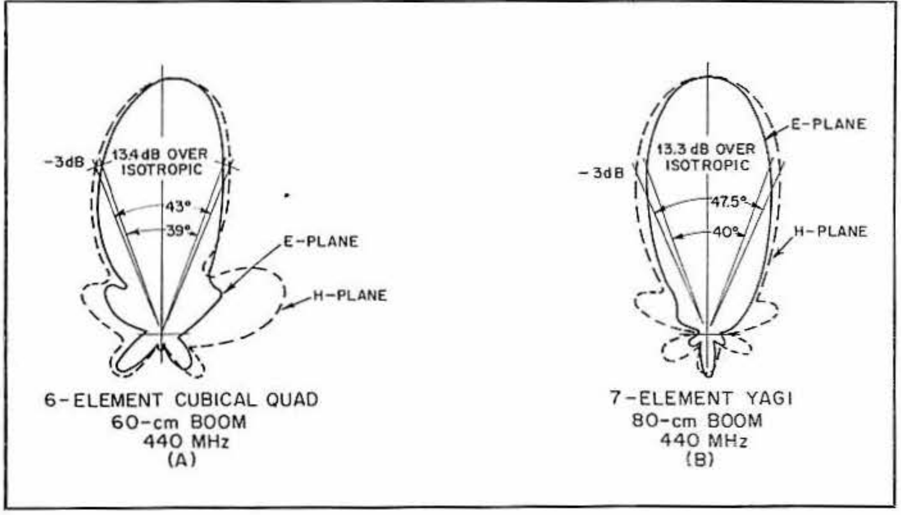
13.4dB OVER ISOTROPIC
-3dB
43°
39°
E-PLANE
H-PLANE
6-ELEMENT CUBICAL QUAD
60-cm BOOM
440 MHz
(A)
13.3 dB OVER ISOTROPIC
-3dB
47.5°
40°
E-PLANE
H-PLANE
7-ELEMENT YAGI
80-cm BOOM
440 MHz
(B)

Fig. 9 — E and H plane radiation patterns for (A) 6-element quad antenna and (B) 7-element Yagi antenna.

visual means of comparing the quad and Yagi arrays. It is interesting to note the dependence of gain and pattern beam width upon array boom length. Without further comment, typical patterns for both types of antennas are given in Figs. 7 through 9.

A Tabulation of Dimensions of Working Arrays

Presented in tabular form are a few representative dimensions for both quad and Yagi antennas. These are dimensions presently in use by a number of amateurs. Most of the Yagi dimensions are due to amateurs across the country who sent their dimensions to Mr. Hal Wolff or the author to be modeled on the antenna range at the University of Denver. The quad dimensions also are those now in use by a number of amateurs in this country and abroad. It should be noted that most of these dimensions, and the resulting model antennas, provided the necessary data used in the previous section to compare the quad and Yagi. Where known, either the user(s) or the originator of a set of dimensions is indicated. The first set of dimensions is for quad antennas, the second set for Yagi antennas.

Summary

A comparison between the quad and Yagi antennas, on the basis of gain, has been given, this comparison being based upon both theoretical and experimental results. The results indicate that if both antennas have the same boom length the gain of the quad array will be about 2 dB higher than that of the Yagi. For either antenna, gain is a function of boom length and will increase approximately 2.5 dB each time the boom length is doubled. Hence, a 2-dB gain advantage is equivalent to a boom-length advantage of 1.8. In other words, for the quad and Yagi arrays to have comparable gain, the boom length of the Yagi antenna must be 1.8 times longer than that of the quad.

The size of the wire used for the loop element (relative to the loop circumference) will have an influence upon the resonance and radiating properties of the loop. The influence of this shape factor — i.e., the ratio of loop circumference to wire diameter — can be accounted for by using the referenced results of Adache and Mushiake.

In conclusion, it might be stated that one type of antenna (quad or Yagi) is not necessarily better than the other. The choice between a quad or Yagi array will depend critically upon many factors. For example, if single-band operation is of main importance and the geographical area where the antenna is to be used does not have high-wind problems, the best and simplest choice would be a long-boom Yagi antenna. If multiband operation is desired, or if wind problems were to limit the length of the boom to some nominal value, then the quad antenna would be a good choice. Likewise, the choice of available materials in your locale, and the acceptance of the appearance of the antenna by your neighbors or family, constitute other determining factors. The best approach is to survey your requirements and

Table 2

Yagi Dimensions

3-element Yagi (W6SAF)
Boom length: 24 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	34 ft 10-3/4 in.	R—DE: 13 ft 9-1/2 in.
Driven Element	33 ft 2-1/2 in.	DE—D: 10 ft 4-1/2 in.
Director	31 ft. 9-1/2 in.	

3-element Yagi (W0OKC)
Boom length: 26 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 6 in.	R—DE: 14 ft
Driven Element	33 ft 4 in.	DE—D: 12 ft
Director	31 ft 7 in.	

3-element Yagi (W0CM, formerly W0JYW)
Boom length: 30 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 4-1/2 in.	R—DE: 13 ft
Driven Element	32 ft 2-1/2 in.	DE—D: 17 ft
Director	31 ft 10 in.	
Feed Method	Folded dipole	

4-element Yagi (K0KKU)
Boom length: 30 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 6 in.	(all elements equally spaced)
Driven Element	33 ft 4 in.	
Director 1	31 ft 9-1/2 in.	
Director 2	31 ft 2 in.	

4-element Yagi (W4PLL)
Boom length: 30 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 4-1/2 in.	(all elements equally spaced)
Driven Element	33 ft 4-1/2 in.	
Director 1	31 ft 9-1/2 in.	
Director 2	31 ft 9-1/2 in.	

4-element Yagi (K6VIZ)
Boom length: 32 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 6 in.	R—DE: 10 ft
Driven Element	32 ft 8 in.	DE—D1: 10 ft
Director 1	31 ft 8 in.	D1—D2: 12 ft
Director 2	31 ft 1 in.	

4-element Yagi (W0OKC)
Boom length: 36 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 6 in.	R—DE: 14 ft
Driven Element	33 ft 4 in.	DE—D1: 10 ft 8 in.
Director 1	31 ft 8-1/2 in.	D1—D2: 11 ft 4 in.
Director 2	31 ft 1 in.	

4-element Yagi
Boom length: 40 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 6 in.	R—DE: 14 ft
Driven Element	33 ft 4 in.	DE—D1: 12 ft
Director 1	31 ft 7 in.	D1—D2: 14 ft
Director 2	31 ft 0 in.	

5-element Yagi (WA6ZZK)
Boom length: 40 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	34 ft 10 in.	R—DE: 10 ft
Driven Element	33 ft 4 in.	DE—D1: 9 ft
Director 1	32 ft 6 in.	D1—D2: 10 ft 6 in.
Director 2	32 ft 2 in.	D2—D3: 10 ft 6 in.
Director 3	31 ft 10 in.	

5-element Yagi
Boom length: 46 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 7-3/4 in.	
Driven Element	34 ft 5-3/8 in.	(All elements equally spaced at 11 ft 6 in.)
Director 1	33 ft 2 in.	
Director 2	31 ft 9-1/2 in.	
Director 3	30 ft 4-1/2 in.	

1 ft = 0.3048 m

5-element Yagi (K6EVR)
Boom length: 46 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 4 in.	R—DE: 12 ft
Driven Element	33 ft 5 in.	DE—D1: 10 ft
Director 1	31 ft 8 in.	D1—D1: 12 ft
Director 2	31 ft 8 in.	D2—D3: 12 ft
Director 3	31 ft 8 in.	

5-element Yagi (W8PWH)
Boom length: 52 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 11 in.	R—DE: 13 ft 10 in.
Driven Element	33 ft 4-1/2 in.	DE—D1: 10 ft 5 in.
Director 1	32 ft 10 in.	D1—D2: 13 ft 10 in.
Director 2	31 ft 2 in.	D2—D3: 13 ft 10 in.
Director 3	30 ft 9 in.	

5-element Yagi (W4EX, formerly W4DQH)
Boom length: 54 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 0 in.	R—DE: 13 ft 6 in.
Driven Element	33 ft 4 in.	DE—D1: 11 ft 6 in.
Director 1	32 ft 3 in.	D1—D2: 13 ft
Director 2	32 ft 1 in.	D2—D3: 16 ft
Director 3	31 ft 11 in.	

5-element Yagi (W6RR, formerly W6ITA)
Boom length: 55 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	34 ft 9 in.	R—DE: 16 ft 9 in.
Driven Element	33 ft 7 in.	
Director 1	31 ft 11 in.	(All elements
Director 2	31 ft 9-1/2 in.	equally spaced)
Director 3	31 ft 8 in.	

6-element Yagi
Boom length: 46 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 5 in.	
Driven Element	34 ft 5-1/2 in.	(All elements
Director 1	32 ft 7 in.	equally spaced
Director 2	32 ft 3 in.	at 9 ft 2-3/8 in.)
Director 3	31 ft 4-1/2 in.	
Director 4	31 ft 1/2 in.	

6-element Yagi (W0OKC)
Boom length: 46 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 4 in.	R—DE: 10 ft
Driven Element	33 ft 4 in.	DE—D1: 8 ft
Director 1	31 ft 11 in.	D1—D2: 9 ft
Director 2	31 ft 3-1/2 in.	D2—D3: 9 ft 6 in.
Director 3	31 ft 1/2 in.	D3—D4: 9 ft 6 in.
Director 4	30 ft 11 in.	

6-element Yagi (W0OKC)
Boom length: 74 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 5 in.	R—DE: 16 ft 6 in.
Driven Element	33 ft 4 in.	DE—D1: 9 ft 9 in.
Director 1	31 ft 9-1/2 in.	D1—D2: 14 ft
Director 2	31 ft 2-1/2 in.	D2—D3: 17 ft 6 in.
Director 3	30 ft 11 in.	D3—D4: 21 ft
Director 4	30 ft 8 in.	

7-element Yagi (W6HAW)
Boom length: 80 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	35 ft 5 in.	R—DE: 14 ft
Driven Element	33 ft 4 in.	DE—D1: 11 ft
Director 1	31 ft 8 in.	D1—D2: 12 ft
Director 2	31 ft 4 in.	D2—D3: 13 ft
Director 3	30 ft 8 in.	D3—D4: 14 ft
Director 4	30 ft 8 in.	D4—D5: 16 ft
Director 5	30 ft 8 in.	

8-element Yagi (WA6EKD)
Boom length: 100 ft
Band: 20 M

	Element Length	*Spacing*
Reflector	34 ft 9 in.	(All elements
Driven Element	33 ft 5 in.	equally spaced
Director 1	32 ft 2 in.	at 14 ft 4 in.)
Director 2	31 ft 11-3/4 in.	
Director 3	31 ft 9-7/8 in.	
Director 4	31 ft 8 in.	
Director 5	31 ft 2 in.	
Director 6	30 ft 11-3/4 in.	

environmental restrictions, make your choice and proceed accordingly.

Acknowledgements

It is very difficult to acknowledge systematically and completely all those who have made the quad antenna a successful communications antenna. However, surely credit must be given to C. C. Moore, the father of the quad antenna, to William Orr, who presented the first written material on the theory and construction of 2-element quads; to Lee Bergren, who showed the feasibility and advantages of using multielement quad arrays; to the Japanese workers, Adache and Mushiake, of Tohoku University, who presented a detailed analysis and experimental verification of the electromagnetic properties of loop antennas of large circumference; and finally, to all the radio amateurs, in all corners of the world, who developed constructional and design techniques and proved or disproved their validity.

The author would like also to acknowledge the help of Mr. Hal Wolff (WA0IOR) for his aid in constructing the model Yagi and quad arrays and running the patterns. These patterns were obtained by using the antenna range of the Denver Research Institute of the University of Denver.[6] Many Denver-area amateurs have entered into these quad experiments, notably Messrs. Jim Snyder (K0ZCM), Butch Ford (WA0IMX), Ed Wood (K0KKU), Keith Farris (W0YDM), Warren Wheeler (W0R-EQ) and many others. The author gratefully acknowledges their assistance, help and encouragement. This material originally presented in *QST* by J. E. Lindsay, Jr., W7ZQ.

References

[1] For a colorful description of C. C. Moore's invention of the cubical quad antenna see the introduction of W. I. Orr's *Quad Antennas*, Radio Publications, Inc.

[2] An antenna which radiates equally well in all directions is called an isotropic radiator or isotropic antenna.

[3] Adachi and Mushiake, "Theoretical formulation for large circular loop antennas by integral equation method," *Repts. of the Research Institute of Elec. Commun.*, Tohoku University, Sendai, Japan, Sci. Rept. Ritu, B(Elec. Commun.), vol. 9, no. 1, 1957.

Idem., "Studies of large circular loop antennas," *Repts. of the Research Institute of Elec. Commun.*, Tohoku University, Sci. Rept. Ritu, B(Elec. Commun.), vol. 9, September 1952.

[4] Element spacing of 0.14λ to 0.2λ being considered.

[5] Bergren, "Multielement Quads," *QST*, May 1963.

[6] At the time these tests were performed (1962-64), the author was head of the Antenna Laboratory, Denver Research Institute, University of Denver. Mr. Hal Wolff was the research technician at this facility.

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Jasik, *Antenna Engineering Handbook*. New York: McGraw-Hill, 1961, pp. 16-25.

Lindsay, "A circular loop antenna with non-uniform current distribution," *IRE Trans. Antennas and Propagation (Communications)*, vol. AP-8, pp. 439-441, July 1960.

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A Triband One-Loop Cubical Quad Element

Why not trade gain for economy and structural reliability? This three-band "DX Getter" consists of a single quad loop. It will stay aloft in high winds and won't look like an ugly monster to those who dwell nearby.

The advantages of a rotatable beam antenna are well known to all DXers. A problem arises in many situations regarding just how a reasonable compromise between antenna performance and cost, size and weight can be obtained. Because this author likes to live in peace with the XYL, the neighbors and the local council, the antenna must not be considered dangerous or an eyesore as far as appearance is concerned. In addition, the antenna must not hang over the fence of the 50- × 150-foot (15- × 46-m) block, half of which is already occupied by buildings. With these limitations firmly implanted in mind, the author added such factors as cost and difficulty of erecting and supporting a full-size, 20-meter Yagi or cubical quad. After weighing all the facts, it was felt that the only way out was to construct an economy-style, reduced-size antenna.

A single-loop, cubical-quad triband element is shown in Fig. 10. Such a cubical quad has only one-fourth the weight and wind resistance of a full-sized, three-element cubical quad of the same mechanical strength. The mechanical and installation difficulties are many times smaller; the cost of mast and rotor are also considerably reduced. Yes, the antenna is a compromise and the gain is less than that of a 3-element quad, but this antenna still puts a signal in good DX company. This quad, because of its smaller physical size, will be tolerated in many more locations than its big brother. If desired, this quad could be used as an indoor antenna strung between two opposite room walls.

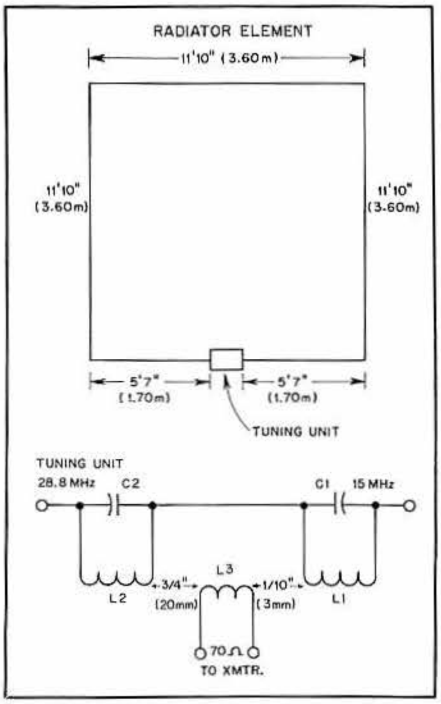

Fig. 10 — Single-loop triband cubical-quad element. Metric dimensions are shown; approximate English-unit dimensions are given in parentheses. Frequencies shown for C1L1 and C2L2 are those to which these circuits are tuned when disconnected from the loop.

C1 — 55 pF.

C2 — 49 pF.

L1 — 7 turns, No. 12, 38-mm (1-1/2-inch) diameter, space wound to 16 mm (5/8-inch) length.

L2 — 4 turns, No. 12, 38-mm (1-1/2-inch) diameter, space wound to 18 mm (11/16-inch) length.

L3 — 4 turns, No. 12, 38-mm (1-1/2-inch) diameter, space wound to 10-mm (3/8-inch) length.

Rather than going to a complicated switching arrangement to change bands, it was decided to apply what the author called the "triband-antenna principle" to this antenna. The theory behind this principle evolves around the same general ideas outlined by Pichitino in *QST*[1] several years ago. Antennas constructed along these guidelines do not operate harmonically and have only the desired resonances. The quad that was built is shortened only at the lowest operating frequency. It is full size at the middle operating frequency and much longer at the highest operating frequency. In addition, no heavy blocking tuned circuits are used near the element ends.

With C1 giving 20-meter resonance depends mainly on the total element length and L1. Fifteen-meter resonance is controlled principally by C1 and L2. Ten-meter resonance is determined by C2 and L2. Once the antenna is constructed, it may be fine-tuned on each band by varying the constants that control the resonant frequencies. After the quad was tuned up, the author found the SWR on each band to be very satisfactory. On 20 meters, the antenna resonated at 14.15 MHz with a resulting SWR of approximately 1:1. With a 15-meter resonance at 21.3 MHz, an SWR of 1.3:1 was measured. On 10 meters, 28.6 MHz was selected as the resonant frequency. The resulting SWR at resonance on this band was 1.5:1. The phase relationship of the fields in L1 and L2 varies from band to band so that too much direct coupling between these coils should be avoided.

Although the author used copper wire to make the loop element, you may desire to use aluminum tubing. The actual constructional details are left to the builder. The materials used and the methods of supporting the antenna are limited only by your imagination. The techniques employed may be as simple or as sophisticated as you may desire. DJ2UT used short pieces of coaxial cable as capacitors and placed them inside the tubing which he used for the element. The coils and inner capacitor ends were sealed and molded in resin. Fifteen- and 10-meter resonances are obtained by shifting copper rings over the ends of L1 and L2. This can be done without affecting the sealed coils in any way.

The author concluded this antenna to be rather efficient based on observations that the tuning network does not become warm and a low SWR has been measured across each of the three bands. This writer wishes to thank OM Sommer, DJ2UT, and his co-workers for the very considerable amount of work carried out, and the many practical ideas which have made successful antennas with the triband principle possible. This material was originally presented in *QST* by Hans F. Ruckert, VK2AOU.

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[1] Pichitino, "A New Principle in Two-Band Rotary-Beam Design," *QST*, October 1948.

A 2-Element, 15-Meter Quad for the Novice

Why not build this 2-element quad for 15 meters? It is easy to construct, inexpensive and in many ways quite novel.

Not being blessed with a large area for antennas, the author decided on an optimum-spaced, 2-element monoband quad. The standard formulas were used for sides and spacing, and the antenna is fed with 50-ohm cable through a quarter-wave "Q" section of 75-ohm coax cut to the standard formula. The reflector has a tuning stub.

The driven element grid-dips at 21,150 kHz and the reflector was tuned by using the grid-dip oscillator as a signal generator. The grid-dip meter was placed in a neighbor's home. Then, the back of the quad was aimed at the dip meter, and the reflector was tuned for the lowest indication on the S-meter.

One of the checks made on the antenna was with VE5XH, in Swift Current, SK. Doug gave the following information: The quad has 2 S-units gain over my 1/4-wave groundplane which was at the same height. Strength off the front was S9 and to the rear was S2, indicating a good front-to-back ratio. Because the constructional details are rather novel, the author felt that other hams might be interested in how this antenna was built.

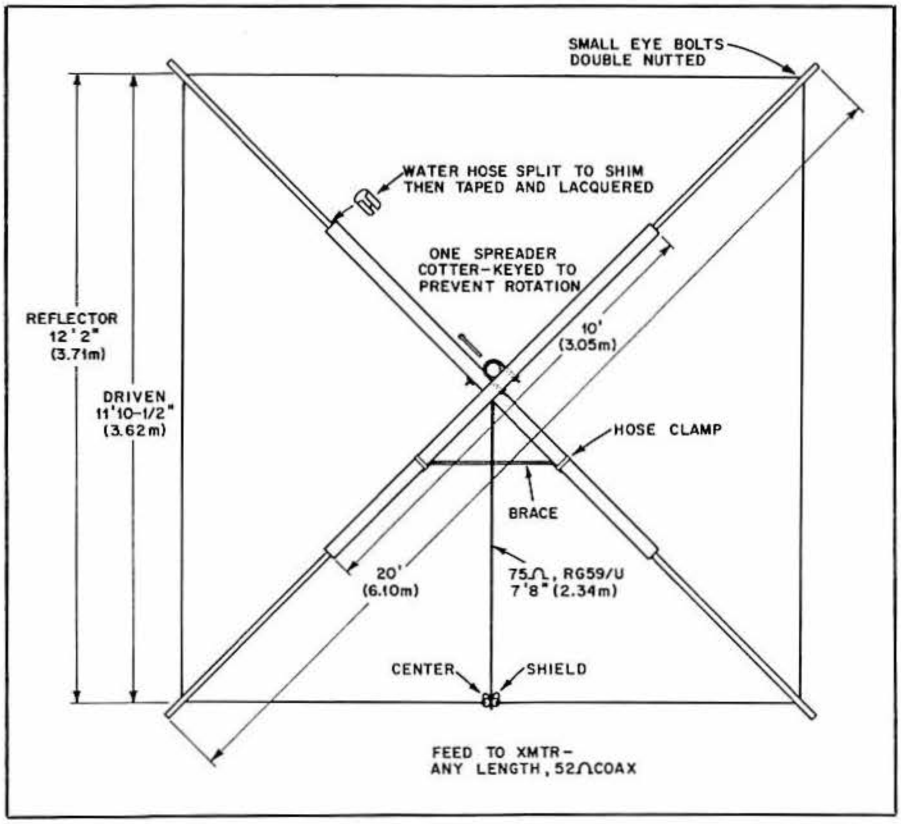
SMALL EYE BOLTS DOUBLE NUTTED
WATER HOSE SPLIT TO SHIM THEN TAPED AND LACQUERED
ONE SPREADER COTTER-KEYED TO PREVENT ROTATION
REFLECTOR 12' 2" (3.71m)
DRIVEN 11'10-1/2" (3.62m)
10' (3.05m)
HOSE CLAMP
BRACE
20' (6.10m)
75Ω, RG59/U 7'8" (2.34m)
CENTER
SHIELD
FEED TO XMTR - ANY LENGTH, 52Ω COAX

Fig. 11 — Detailed drawing of the quad. The cotter pin and cross-brace are required to prevent shifting of the spreaders. Small sections of split water hose are used for shims between the aluminum tubing and the plastic water pipe.

Construction

The author used 1-1/4-inch (32-mm) TV steel mast pipe, 10 feet (3 m) long, for the boom. Also, 10-foot lengths of TV mast sections, but aluminum, are used for the spreaders. However, 10-foot long spreaders are not long enough for a 15-meter quad; 20-foot (6.1-m) lengths are required. In order to obtain the required length, 20-foot lengths of one-inch (25 mm) diameter, ridged plastic water pipe were run completely through the 10-foot aluminum pipe sections. Pieces of rubber hose were used as shims between the aluminum pipe and the plastic pipe and these were taped where the plastic pipe emerges from the aluminum.

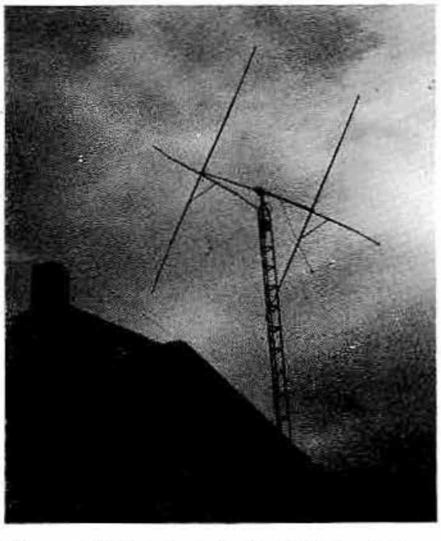

The completed quad on the tower. For tune-up, the quad was temporarily mounted on the garage roof.

The plastic water pipe comes in 20-foot lengths, 80 feet (24.4 m) being required. This pipe was purchased from a local plumbing and lighting outlet; the cost was $10 for the 80 feet. It is ridged plastic, but is not strong enough to support itself; so the aluminum mast pipe is used for the center portion of the spreaders.

The spreaders are clamped to the boom with standard U bolts, and one spreader in each element is pinned to the boom with a 5/16-inch (8 mm) cotter key. Additionally, a piece of one-inch (25 mm) conduit is used in each element as a cross-brace, to hold the correct angle between the spreaders.

The formulas and element lengths for 21,150 kHz are as follows

Driven element

$$\frac{1005}{f\,(\mathrm{MHz})} = 47 \text{ feet, 6 inches (14.48 m)}$$

Reflector

$$\frac{1030}{f\,(\mathrm{MHz})} = 48 \text{ feet, 8 inches (14.83 m)}$$

Boom spacing

$$0.2 \text{ wavelength} = 0.2 \times \frac{984}{f\,(\mathrm{MHz})} = 9 \text{ feet, 3 inches (2.84 m)}$$

75-ohm matching section

$$\frac{246 \times V}{f\,(\mathrm{MHz})} = \frac{162.4}{f\,(\mathrm{MHz})} = 7 \text{ feet, 8 inches (2.34 m)}$$

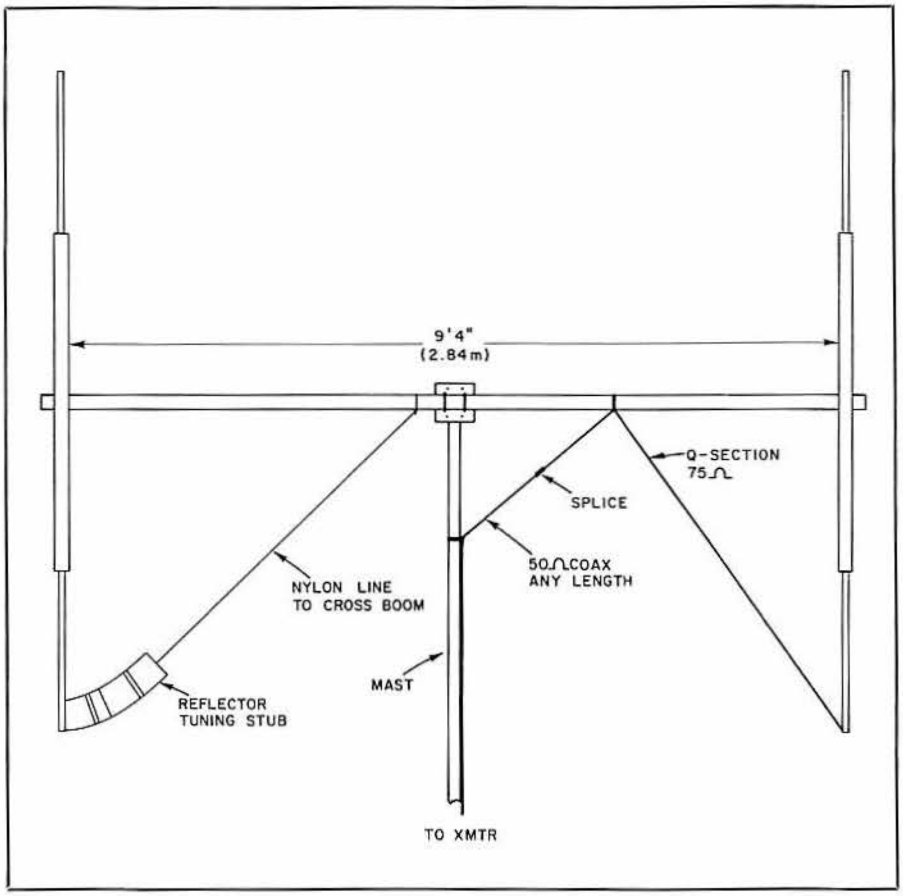

Fig. 12 — Side view, showing the mounting plate, Q matching section, and coax feed.

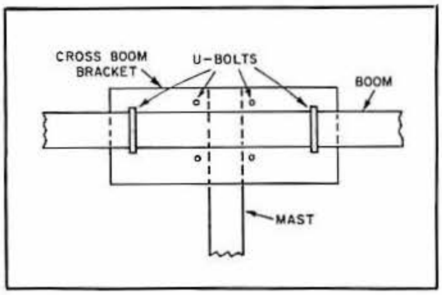

Fig. 13 — The cross-boom bracket, made from 3/8-inch (10 mm) aluminum plate. Ordinary TV U bolts are used to secure it to the boom and mast.

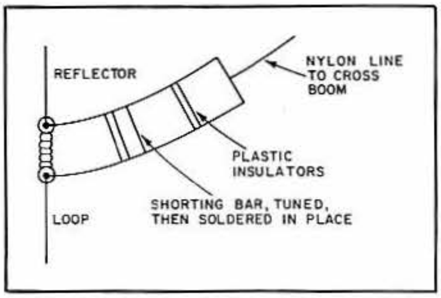

Fig. 14 — The reflector tuning stub is 36 inches (0.91 m) long. The shorting bar, a short piece of wire the same size as used in the stub was approximately 10 inches (254 mm) from the insulator when adjusted for maximum front-to-back ratio. Spacing between wires of the stub may be of the order of a few inches; this spacing is not critical since the stub length is adjusted by the shorting stub in the tune-up procedure.

The author used no. 14 soft-drawn enameled wire for loops and they were secured to the plastic pipe with double-nutted eye bolts. The reflector tuning stub was made from no. 12 copperweld wire. The total length of my stub is 36 inches (0.91 m), and after tuning, the shorting bar ended up approximately 10 inches (254 mm) from the loop.

The SWR showed almost a perfect match across the entire band. Since the quad was put up, the author has worked all continents and 35 countries on the Novice band. Stateside contacts always run S8 to S9. The total cost of the antenna was $28 at the time the system was built. This material was originally presented in *QST* by John Daebelliehn, WA9BJC.

A Practical 40-Meter Quad

One of the most perplexing problems continuously plaguing Field Day committees is how to install a good antenna system. For most clubs, finding a good location is generally the easiest job. The location must then be surveyed by the club antenna specialists. Deciding how many transmitters to use depends mostly on how many indivudual antennas can be set up for simultaneous operation as well as how many operators are available for the 24-hour stretch. Of course, an abundance of equipment is desirable.

Propagation conditions for Field Day and Sweepstakes generally favor the lower bands since they usually remain open all night. Success on the higher frequency bands (10 and 15 meters) depends primarily on catching the short-duration openings. The old trick of tying a rock to the end of a long piece of wire, tossing it into the tallest tree and loading it with a coupler just won't "cut the mustard" anymore. Gain and directivity into the dense population areas is the goal. However, the antenna must be simple to construct, easy to tune, and moderately stable against the wrath of Murphy and Mother Nature.

Our club decided to try a 2-element full-sized cubical quad for 40 meters. The immediate reaction within the more conservative ranks of our club was, "A 40-meter quad? It'll never work — the first breeze will knock it down!" With these objections in mind, we went ahead with our plans. Our location was approximately rectangular in shape, 60 feet wide, 500 feet long (18 × 152 m) and above the rest of the terrain. Of course, it just happened to be one of the highest locations in Winnebago County, IL!

The sketch illustrates the basic construction of the quad. Dimensions were estimated using the formula

$$L(\text{feet}) = \frac{248}{f(\text{MHz})}$$

where L is the length of one side of the diamond.

The parasitic element was constructed as a reflector using an extra long stub. A small relay shorts out the stub, thus converting the parasitic element from a reflector to a director (see Fig. 15).

The resonant frequency of the driven element is 7150 kHz, the middle of the band. The distance L for the driven element is 34 feet 8 inches (10.57 m). The parasitic element dimension is 5 percent smaller than the driven element. The stub is constructed so that the total circumference of the parasitic element with stub in the line is 5 percent greater than the driven element. L for the

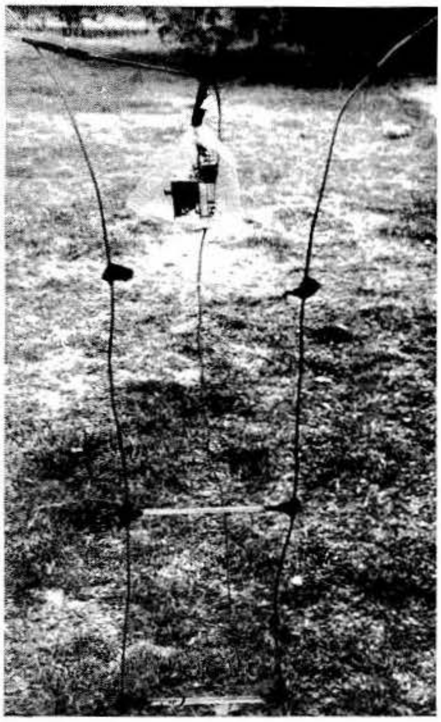

Fig. 15 — A simple relay arrangement is used to short out the stub and change the pattern of the antenna from one direction to another. A small plastic bag provides weatherproofing in the event it rains. (Doesn't it always?)

director is 33 feet (10.06 m). The stub length is 6 feet 9 inches (2.06 m). Eight-inch (203-mm) plastic spacers are placed between the two wires of the stub.

Supporting the quad is very simple. The mast is 50 feet (15.24 m) high, and guyed with nylon ropes. The boom is constructed from two telescoping sections of electrical conduit and is 18 feet (5.49 m) long. The elements are made from no. 14 stranded wire. The driven element is fed directly with RG-58/U coaxial cable. Location of the stub short is determined by the point of maximum front-to-back ratio. The boom-to-mast construction utilizes the support base from a Ham-M rotator. All it takes is a couple of U bolts and the boom-to-mast assembly is complete (see Fig. 16). The wire is strung from the end of the boom and is supported by a small piece of nylon rope and an egg insulator.

Results

Orientation for the quad was east and west. Favoring the eastern direction was the driven element/reflector combination, whereas the driven element/director combination was broadside to the western direction. A local amateur, approximately 5 miles (8 km) west of the Field Day site, assisted in tuning the quad for maximum front-to-back ratio. The end result was approximately 25 dB.

Results were a tremendous surprise! The antenna worked just as planned. The class of entry for simultaneous operation of two transmitters was used. One transmitter operated on 20 and 80 meters; the second transmitter was set up for 15 and 40 meters. Our club, W9AXD/9, scored third place in the two-transmitter class. Our biggest totals came from 40 meters — 693 contacts, over one third of our total number. For the first four hours of the contest, the antenna was aimed east. A rate of 90 contacts per hour prevailed for five solid hours. From that point on it was a steady decline after a sharp drop to about 45 contacts per hour. It was later surmised that the reason for the drop in contact rate was lack of activity and difficulty in finding stations that hadn't been worked before. The East Coast QRM was drastically reduced by changing the switch from "east" to "west." By midmorning we were surprised to find only a dozen W5 stations listed in the log. The antenna may not have been too effective in the southern direction.

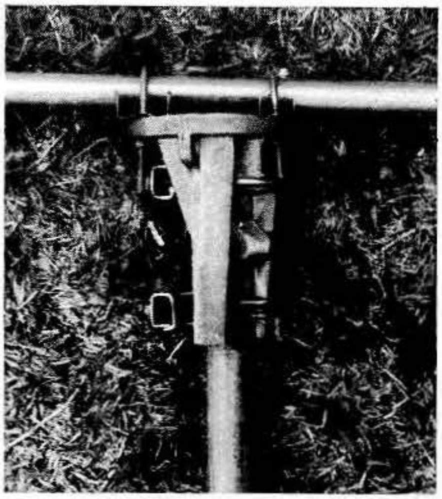

Fig. 16 — The bottom section of a CDE Ham-M rotor can be adapted to serve as a boom-to-mast bracket.

There is no reason why this arrangement could not be used for DX operating. The antenna could be positioned just underneath a beam for the higher frequency bands with the peak of the diamond supported from a boom placed through the top section of the tower.

This material was originally presented in *QST* by Peter H. Grillo, W6RTT.

Build This C-T Quad Beam for Reduced Size

This quad-beam antenna, while smaller in size than a conventional quad, performs like a veteran. The trade secret is to use capacitive tuning.

One of the main drawbacks of the quad beam is its large size compared to the Yagi beam. Previous efforts to reduce the size of the quad have utilized systems of inductive tuning. Loading coils have been used on one or two sides[1] or in the corners. Linear inductors on the vertical sides have also been used.[2] The purpose of this article is to explain a simple method of capacitive tuning to reduce the size of the quad. The C-T (capacitor-tuned) loop is diagrammed in Fig. 17.

It is well-known that the physical size of the dipole antenna can be reduced by replacing a portion of the antenna with a capacitive body and adding an inductor to restore the system to resonance. It seems less well-known that the full-wave loop antenna also may be reduced in physical size while holding the resonant frequency of the system constant by adding capacitance at the voltage loops. No inductors are needed. The capacitance may be added by any of the methods shown in Fig. 18.

The outside dimensions of the C-T loop may be anything chosen by the builder with the larger limit being the full-size, full-wave loop. The limit on the amount of size reduction effectively attainable depends both upon the electrical resistance in the circuit and upon the tendency in loop antennas for the current to become equal at all points in the circuit when the loop becomes very small in proportion to the free-space wavelength at the frequency under consideration. The geometrical shape of the loop is unimportant to basic operation provided that the capacitance is placed at or between the voltage loops. The bottom half of the chart in Fig. 21 shows the effective dimensional range of the C-T loop. The top half shows the tuning range that can

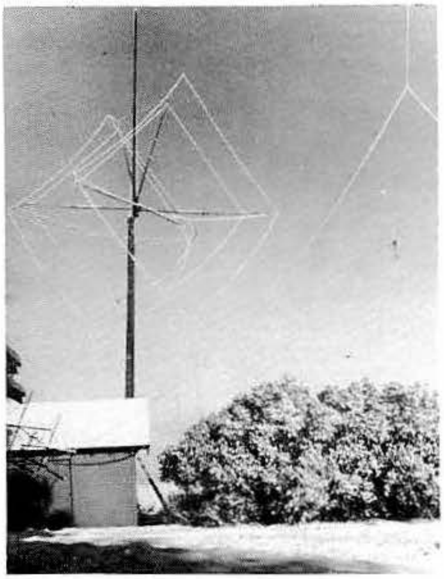

A winter snow sets the scene and accentuates the diamonds of the C-T quad-beam antenna at W7WKB.

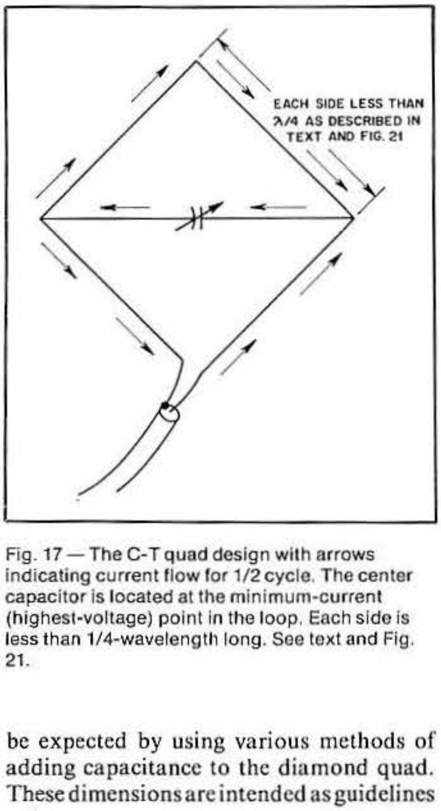

Fig. 17 — The C-T quad design with arrows indicating current flow for 1/2 cycle. The center capacitor is located at the minimum-current (highest-voltage) point in the loop. Each side is less than 1/4-wavelength long. See text and Fig. 21.

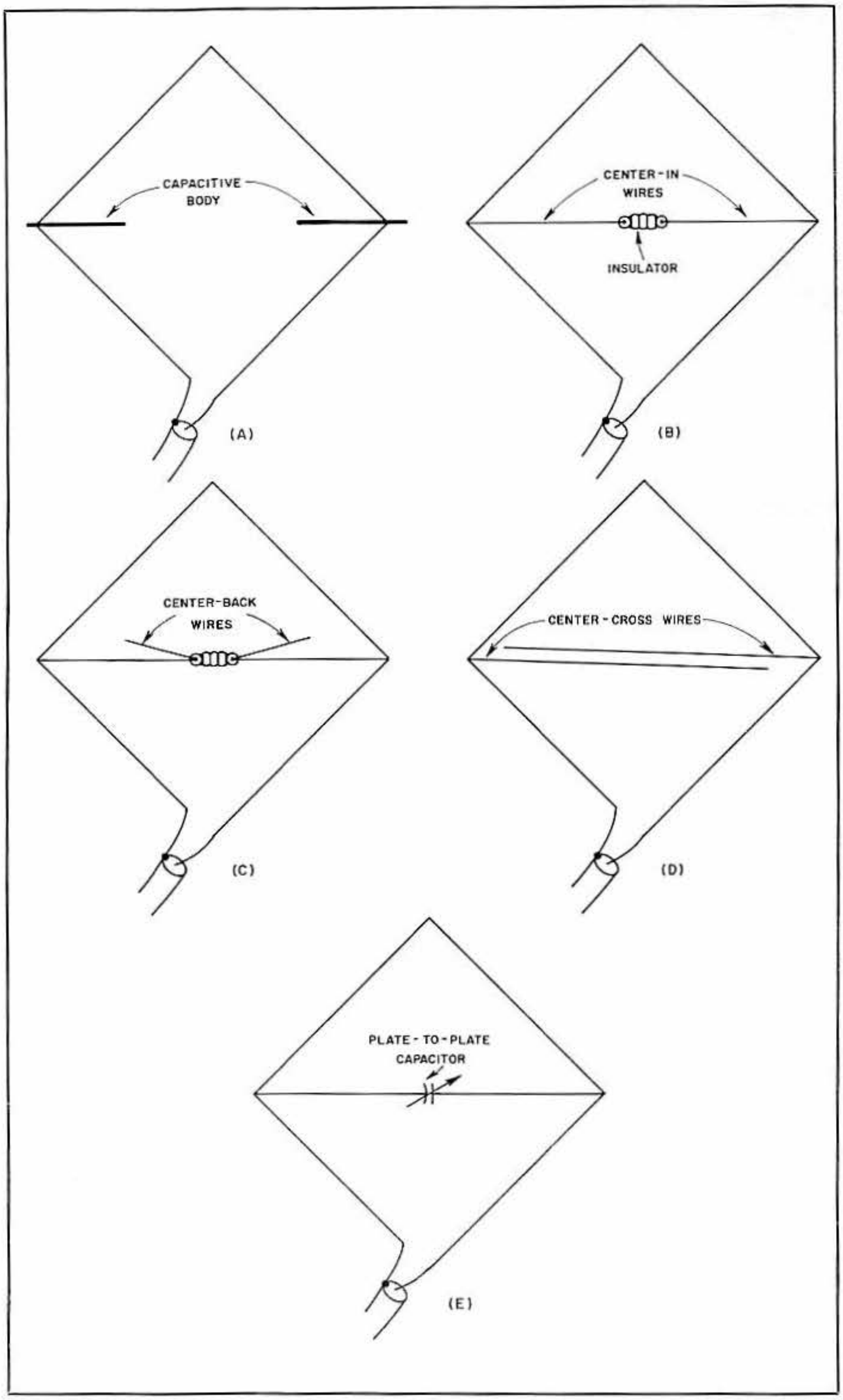

Fig. 18 — Methods of adding capacitance to the C-T loop are shown here. In Fig. 18C, if the center-back wires are placed too closely to the center-in wires, they become ineffective. A 12-inch (0.3048 m) spacing from the end of the center-back wire to the center-in wire is satisfactory. Wires running back toward the loop center may be attached to the outside ends of the center-back wires if more capacitance is needed. In Fig. 18D, the capacitance added by the center cross wires varies with both the length of wire and spacing between wires.

be expected by using various methods of adding capacitance to the diamond quad. These dimensions are intended as guidelines only.

The feedpoint resistance of the full-size, 1-wavelength loop is about 100 ohms. The feedpoint resistance of the C-T loop decreases as it is made smaller but will offer a good match to a 50-ohm coaxial line over the entire usable range as shown in the chart. A gamma match may be used if an exact match is desired.

More than one C-T loop may be used to form the C-T quad beam. A parasitic reflector was used in this installation because of the higher radiation resistance attainable while maintaining good gain. Maintaining the radiation resistance as high as possible is particularly important in small beams, both to keep efficiency high and to prevent the bandwidth from becoming too narrow.

Tuning and Mounting

The use of a grid-dip meter to attain initial band resonance is very helpful. By using a grid-dip oscillator, this beam was tuned initially with the driven element to resonate at the center of the band of interest. The reflector was then tuned to resonate at a frequency three percent lower than the driven element. Final adjustments were made using a test oscillator located about 1000 feet (300 m) away as a reference signal.

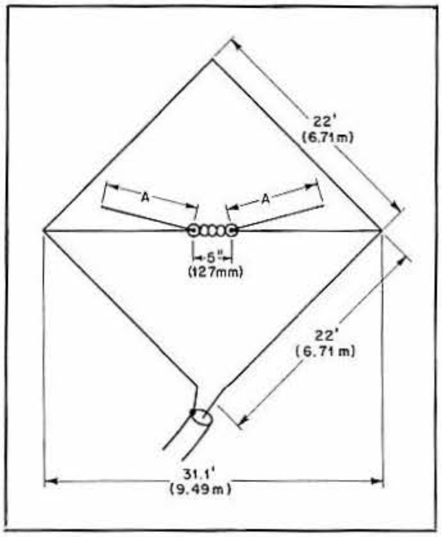

Fig. 19 — Dimensions for the 40-meter C-T quad are shown above. For the 2-element beam the spacing between the driven element and the reflector is 20 feet (6.10 m). The length of the center-back wire (dimension A) is 12 feet, 9 inches (3.89 m) for the reflector, and 9 feet, 11 inches (3.02 m) for the driven element.

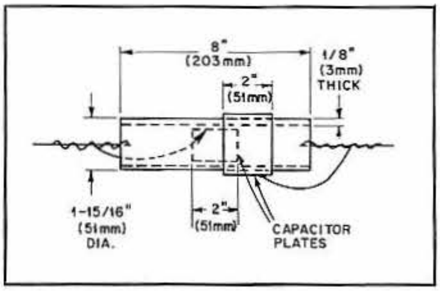

Fig. 20 — A variable capacitor is illustrated here. It can be used to tune the C-T quad. The eight-inch (203-mm) tubular portion is made from plastic water pipe. The cylindrical capacitor plates are formed from a copper sheet. One plate slides inside the eight-inch (203-mm) tube and the other over the outside of the tube. Maximum capacitance is approximately 25 pF.

The director was tuned for lowest SWR and the reflector for best gain. If you lack a grid-dipper, initial resonance can be established by listening to your station receiver for a strong signal while making the adjustments. A dramatic increase in signal strength will be noticed at resonance. Tuning is accomplished by shortening or lengthening the capacitance wires.

The single loop or beam may be mounted either horizontally or vertically for horizontal or vertical polarization, but in either case it should be mounted as high above the ground as possible. Loop antennas operating close to ground will show a much higher feedpoint resistance than normal and will waste considerable power in groundheating effects. A rough guideline is to mount the antenna so that the bottom point is at least half the loop diameter above the ground.

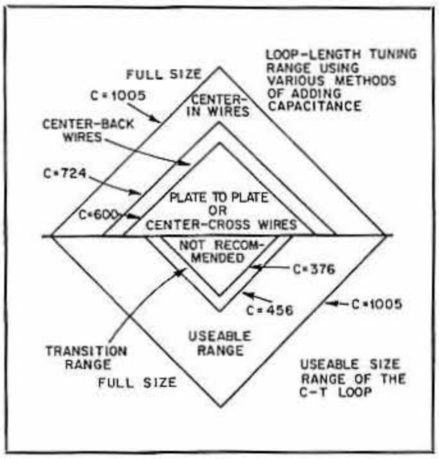
LOOP-LENGTH TUNING RANGE USING VARIOUS METHODS OF ADDING CAPACITANCE
FULL SIZE
C=1005
CENTER-IN WIRES
CENTER-BACK WIRES
C=724
C=600
PLATE TO PLATE OR CENTER-CROSS WIRES
NOT RECOM-MENDED
C=376
C=456
C=1005
USEABLE RANGE
TRANSITION RANGE
FULL SIZE
USEABLE SIZE RANGE OF THE C-T LOOP

Fig. 21 — The chart shown above, providing dimensional guidelines for a single C-T loop, is based on the equation LF = C, where L is the outside dimension in feet, F is the frequency in MHz, and C is a constant chosen for the size of the C-T loop to be constructed. Use the largest size possible for the best electrical results. This is particularly true when using C-T loop elements to form a parasitic beam.
To use the chart, pick the largest C (up to C = 1005) feasible for your application. Use bottom half of the chart to see if the C-T loop will operate at the dimensional size selected. Then refer to the top half of the chart for the recommended capacitance method.

Table 3

Data for plotting SWR curve. Information in this table is used for plotting the SWR curve for the 40-meter C-T quad beam, as described in the text.

Frequency (MHz)	*SWR*
7.500	4.87
7.450	4.00
7.400	3.08
7.350	2.33
7.300	1.82
7.275	1.78
7.250	1.94
7.200	3.44
7.150	5.25
7.100	8.08

The working 40-meter version of the C-T quad beam had a diamond configuration because of the greater mechanical strength and because of the longer center wire for tuning purposes. Final dimensions are shown in Fig. 19. A good quality center insulator should be used because of the high voltages present at the center.

A tubular tuning capacitor was originally installed in the driven element and worked well until the kW power level was reached. It then promptly arced over, leaving a conductive carbon deposit. A version using 2-inch (51-mm) plates as shown in Fig. 20 adequately tuned the reflector even at the kW level for some time. The capacitors, as shown, were not tried under wet conditions, but would probably be satisfactory at power levels up to 400 watts. For long-term use, the method shown in Fig. 18D is preferred over plate-to-plate capacitors because the high voltages are handled more easily.

Because some dielectric heating was noticed in this capacitor, the wire-tuned version was adopted. The wire version is recommended over the methods shown in Fig. 18D and 18E, any time the loop is large enough to be tuned by no more than one doubled-back wire (as shown in Fig. 18C). Tuning wires eliminate the capacitor with its heat loss and allow somewhat better current distribution. Less center radiation occurs because of partial canceling effects in the doubled-back wires. It would be wise initially to cut each center-back wire 12 inches (0.31 m) longer than shown to allow tuning. Pruning each center-back wire by 1 foot (304.8 m) increases the resonant frequency by roughly 100 kHz in the 40-meter version. No. 14 Copperweld wire was used throughout.

Performance

The antenna described performed up to expectations and has prompted many complimentary reports. The SWR curve information shown in Table 3 was attained using a 75-ohm coaxial feed line without any matching network. The SWR would be lower if a 50-ohm line or if a matching network were used. Forward signal strength as compared to the strength to the rear showed a maximum 30-dB difference as measured by means of the receiver S meter. Typical difference, as finally adjusted, was 12 dB.

The gain of the C-T quad over a comparable double Zepp (full wave on 40) was typically at least one S unit better when both antennas were at a height of 45 feet (13.7 m). The Zepp was better on very short skip but the C-T quad consistently was favored on longer skip. When elevated to 65 feet (19.8 m), the C-T quad gave outstanding results. At this height, two S-units improvement over a vertical antenna at distant points was noted many times.

The C-T quad may be built for any band. It should be most useful in meeting requirements for an inexpensive easily tuned wire-beam antenna where the full-size quad is unsuitable for mechanical or economic reasons. This material was orginally presented in *QST* by Roger Sparks, W7WKB.

References

[1] Pinner, "The Short Quad," *QST*, February 1964.
[2] Courtier-Dulton, "Some Notes on a 7-MHz Linear-Loaded Quad." See Chapter 4.

A Nearly Full-Size, Rotatable, 2-Element Quad for 80 Meters

We don't expect readers to rush right out and duplicate this antenna system — but this doesn't mean a lot of hams wouldn't like to!

Many hams have been thinking about new 80-meter antennas to improve their DX capabilities. On the higher amateur frequencies, antenna gain is relatively easy to acquire with a compact Yagi or quad. It is much harder in this respect on 40 meters. On 80 meters, however, the problem of securing any increase in antenna gain over a conventional dipole or groundplane is very difficult indeed, particularly where space is limited. Rhombics, Vs or multi-element collinear arrays become completely impractical on the normal urban or suburban lot. Even a phased vertical array is hard to handle on a city lot, and too often, performance is marginal because it is impossible to install an optimum ground system at such a location.

The author solved this problem at his QTH by constructing an almost full size 2-element quad for 80 meters. A unique tuning arrangement permits this antenna to be operated at any frequency within the 80-meter band with an SWR of close to 1. While certainly not adaptable to every individual's situation or pocketbook, a description of this antenna should be of interest to many amateurs. As far as it is known, this is the first and only set of beams, on one rotatable tower, covering all bands from 2 to 80 meters. By connecting the 2 quad elements in series to form a rotatable, bidirectional loop, the frequency coverage has been extended to 160 meters.

At this point, a few comments might be in order on the circumstances which led to this sizeable 80-meter antenna project. In June 1965, the writer returned to ham radio activity after a QRT of almost 30 years. During the first year of operation, the antennas of K3JH were a conventional commercial tribander for 10, 15 and 20 meters mounted on a 60-foot (18.3-m) tilt-over tower, and a trapped, inverted V for 40 and 80 meters. A bit of DX chasing soon led to the conclusion that better antennas were needed. Since the QTH is on a suburban lot about 175-feet (53.3-m) square, and heavily wooded, a "Christmas tree" array seemed the best alternative. Consequently, in the summer of 1966, with a great deal of help from Bob Scully, W2FXN, a 115-foot (35-m) rotary tower was installed along with full-size monoband beams for all bands from 2 through 40 meters.

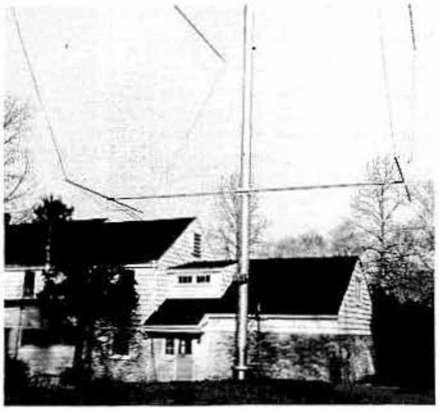

The bottom support of the quad elements is shown in this view, along with the tuning-network box, which is mounted on the mast.

This rotary steel tower is 16 inches (0.41 m) OD at the base with 1-inch (25-mm) thick walls. The tower rests in a 1/2-inch thick steel bearing-tube 15 feet (4.57 m) long and 20-inches (0.51-m) OD. The bearing tube is imbedded in a block of concrete 8 × 8 × 16 feet (2.44 × 2.44 × 4.88 m) which weighs 70 tons. The tower tapers to 5-1/2 inches (140 mm) at the top, and was designed to carry nine full-size monoband beams through 125-mph winds.

Initially, the antenna complement was as follows

2/6meters — Vert. groundplane at 115 feet (35 m)
6 " — 6 el at 113 feet (34.5 m)
2 " — 15 el at 109 feet (33.2 m)
20 " — 5 el at 104 feet (31.7 m)
15 " — 5 el at 96 feet (29.3 m)
10 " — 6 el at 86 feet (26.2 m)
40 " — 3 el at 77 feet (23.5 m)

A rotary ball-bearing ring and clamp at the 70-foot (2.13-m) level on the tower was used to support one end of an inverted L for 80 meters. This long wire, which could be used also on the higher frequencies, was fed through a Matchbox at the base.

Performance on 40 through 2 meters with this antenna system was generally excellent. The L and inverted V on 80, however, left much to be desired, especially when compared to the antenna performance on the other bands.

In attempts to improve this situation, several different 80-meter antennas were installed at various times between 1966 and the spring of 1969. Included in this effort were a top-loaded groundplane and a pair of phased verticals. None of these antennas provided sufficient improvement in DX performance on 80 to be considered satisfactory.

With the advent of the 5-Band DXCC, the question of how to do better on 80 meters again became a matter of concern. It was at this time that the concept of a quad of some sort, to be mounted on the rotary tower, began to emerge. Since 40-meter quads had been constructed previously, and were mechanically feasible, the thought at first was to build a half-size quad for 80 meters, using loading coils. Preliminary calculations indicated the possibility of achieving some gain over a dipole in addition to the obvious advantage of being able to rotate the array.

It was quickly determined that a half-size quad mounted at 57 feet (17.4 m) would fit underneath the 40-meter Yagi. Construction could be quite conventional using fiberglass X frames in each element, and a spacing of 0.15 wavelength.

Design Considerations

The proposed design was discussed with a number of amateurs including Jim Lindsay, W0HJ, Dunc Carter, W5IOU, and Claus Moeller, DL7CM, who were most helpful with advice and suggestions. A search of the literature disclosed that a number of loaded antennas of various types had been built. In most cases, however, performance had been judged empirically, and there was little in the way of specific comparative data on the performance of loaded versus unloaded configurations, or versus a reference dipole. Because of this, the decision was made to build and test a 14-MHz model of a half-size quad. This would enable a direct comparison between the performance of a miniaturized quad and other antennas. Of particular interest was a comparison with a dipole, since this was the more normal antenna used by amateurs on 80 meters.

Henry Pemberton, W3PN, who had become interested in the project, provided the X frames and supports from an old 20-meter quad, for use in the test model. Tom Consalvi, W3EOZ, provided some suitable coil stock for the test design. With this help, the 14-MHz model was quickly constructed. No trouble was experienced in pruning the coils and resonating the loops. Except for one bad piece of insulation on one coil, which promptly burst into flame when rf power was applied to the antenna, the driven element could be fed with a full kilowatt at an SWR of 1. The SWR, however, would rise sharply when the coils, which had no protection from the weather, became wet from rain. All testing, therefore, had to be done on dry days.

Since the 80-meter version was to be mounted on the tower one-quarter wavelength above ground, the 14-MHz model was mounted for the tests at the same relative height. Standard procedures for tuning up the quad were used, and will not be detailed here. Impedance of the loaded loop was measured at 60 ohms, so it could be driven nicely with a 50-ohm line. The bandwidth was 125 kHz, measured between frequencies each side of the resonant frequency where the SWR was 3:1. This was the result expected, due to the heavy loading.

Extensive on-the-air comparisons were made between the model and various other antennas. These included a dipole at the same height above ground as the model, a 3-element tribander at 60 feet (18.3 m), two different inverted Vs at 50 feet (15.2 m) and a 5-element monoband Yagi at 104 feet (31.7 m). The regular antenna switching arrangements in the station were such that almost instantaneous comparisons could be made between the different antennas, minimizing QSB differences in the receiver. In the transmit mode, many amateurs compared signal differences between the test model and the other antennas. It is impossible to list the calls of all those who helped in this way.

After considerable testing, adjustment, readjustment, and minor configuration changes in the model, the results were found to be quite discouraging. The simple conclusion was that a loaded half-size quad had insufficient gain compared to a dipole to warrant proceeding any further with an 80-meter version.

Further Exploration

Before abandoning the 80-meter project, however, we decided to explore some practical ways to increase the size of the elements, preferably without using the normal-type quad X frames, which would be difficult if not impossible to handle when the antenna grew too large. This thinking developed the concept of using the 14-MHz boom at 104 feet (31.7 m) to support diamond-shaped elements at the top, and using a boom and spreaders rather than an X frame to hold the elements at the center. The bottom of the quad elements could be supported easily with a relatively light boom and spreaders near the base of the tower.

In order to reduce the size of the center boom and spreaders, the first model was kite-shaped with an included angle at the top of about 50 degrees. Unfortunately, the results were poor, and compared to a dipole there was no gain. We concluded that this configuration was so squashed together that the antenna was acting like a dipole instead of a quad. A series of configurations was then drawn up on paper. The boom and spreader sizes were varied, but the included angle at the top of each diamond element was kept at 75 degrees or more. This helped to pin down a configuration which would be mechanically feasible, and which would be a reasonable compromise among the various considerations to be taken into account. The one selected is shown in Fig. 22.

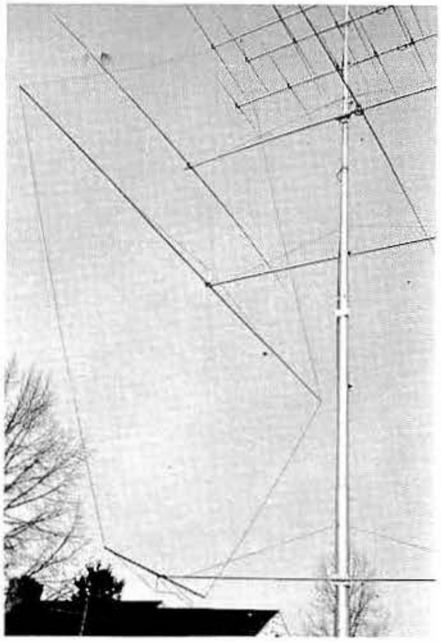

A detailed view of one of the quad elements, showing the method of supporting the loop.

Because these elements are almost full size at 4 MHz, making a 20-meter model quite large, it was decided to build and test a model of this configuration on 15 meters. The test procedures for this model were the same as those previously described for the 20-meter model of the half-size quad. This model showed substantial gain compared to the reference dipole at the same height. Also, the model mounted only 15 feet (4.6 m) above the ground compared favorably in performance with the tribander at 60 feet (18.3 m). The 5-element monobander at 96 feet (29.3 m) consistently provided better gain, as was to be expected. The impedance of the driven element was about 80 ohms. Bandwidth between SWR points of 3:1 was 250 kHz, or about twice what was measured on the half-size model.

Mechanical Considerations

After a lengthy test period, during which many on-the-air comparisons were made, the results were good enough to make the decision to build an 80-meter version of this antenna. Because of the size of the proposed antenna, considerable thought had to be given to the mechanical design to assure longevity comparable to the other beams which are rated for 125-mph winds. The wire in the quad elements is no. 12 stranded copperweld. All other metal in the antenna is aluminum or stainless steel. The two quad elements are suspended from the 20-meter boom at 104 feet (31.7 m). The insulators are five glazed porcelain knobs. Spacing is one-eighth wavelength, 36 feet (10.97 m). The 20-meter boom is 46 feet (14.02 m) long, and is made from 4-inch (102-mm) OD, 1/4-inch (6-mm) wall T-6 aluminum tubing at the center, and similar material tapering from 3-1/2 inches (89 -mm) to 3-inch (76-mm) OD at the ends. A 1/4-inch stainless steel cable supports the boom 18 feet (5.49 m) out from each side of the tower. Originally, the plan was to slide the quad elements down this cable from the tower. Unfortunately, the steel plates holding the Yagi elements to the boom on the other beams were found to be rusting because of poor plating. Rather than dismantle the beams, a crane was brought in so that these plates could be cleaned and painted by a man carried up in a boatswain's chair. At the same time, the elements were hung from the 20-meter beam, and the center boom and spreaders for the quad were installed with relative ease.

Dimensions

The 36-foot (10.97-m) center boom at the 57-foot (17.37-m) level of the tower is made of a single 24-foot (7.32-m) section of 3-1/2-inch (13-mm), 1/4-inch (6-mm) wall, T-6 tubing with 7-foot (2.13-m) sections of 3-inch (76-mm) OD pipe telescoped and bolted at each end. The boom is supported from the tower with a 3/16-inch (4.76-mm) stainless-steel cable. The spreaders at each end of this boom are 70 feet (21.34 m) long. Each consists of a 24-foot (7.32-m) piece of 2-1/2-inch (64-mm) OD, 1/8-inch (3-mm) wall, T-6 tubing at the center, with two short pieces of 2-1/8 × 1/8-inch (54 mm × 3-mm) tubing telescoped and bolted at each end to make up a length of 30 feet (9.14 m). To complete the spreaders, 20-foot (6.10-m) sections of 1-1/2- and 1-1/4-inch (38- and 32-mm) fiberglass poles are attached to each end of the aluminum centerpiece. Use of the fiberglass reduces weight and eliminates a one-quarter wavelength piece of metal from the middle of the quad element. A 1/8-inch (3-mm) cable and strut supports each spreader to minimize sag, which is very slight as may be noted in the photograph. A welded aluminum T structure and stainless steel clamps are used to hold the spreaders on to the ends of the boom. A stainless steel clamp and Teflon grommet is attached to the ends of each spreader to hold the element wires in place. The only function of the spreaders is to hold the two opposite sides of each quad element apart without too much fore and aft flopping around when the antenna is rotated. The length of the spreaders, wind loading, and safety factor dictates the heavy mechanical design.

The lower boom, which is 23 feet (7 m) off the ground, is made of a 24-foot (7.32-m) section of 2-1/4 × 1/4-inch (57- × 6-mm) T-6 tubing with shorter 2- × 1/4-inch (51- × 6-mm) pieces telescoped and bolted at each end to make the total length of 36 feet (10.97 m). To maintain symmetry, 17-foot (5.18-m) spreaders are attached to each end of the lower boom. These spreaders are made of 1-1/2-inch (38-mm) fiberglass. They are attached to the boom with aluminum angles and stainless-steel clamps. A light stainless-steel cable and strut holds the lower spreaders firm against the pull of the quad-element wires, which are attached to each end of the lower spreaders with stainless-steel clamps. The wires are taped along the fiberglass almost to the center of the spreaders, and then go off at right angles to the tuning box, which is mounted on the tower 13 feet (4 m) above ground. The distance from the end of the lower boom to the tower is about 18 feet (5.5 m), and the 36 feet (11 m) of wire which connects the quad proper to the tuning box represents loading.

Tuning

Each element, including the 36 feet (10.97 m) of connecting wire just mentioned, resonates at 4050 kHz. Thus, a small amount of additional inductive loading is required to tune the antenna to resonance within the 80-meter band. This is accomplished by putting two relatively small motor-driven coils in series with each loop of the antenna. The reversible motor for each pair of coils in each loop is controlled by a two-way toggle switch mounted on the antenna control panel in the shack. In the case of the driven element, tuning is accomplished simply by applying power to the antenna and then adjusting the loading inductances by the motor-control switch to the point where the SWR is minimum, usually very close to 1. Tuning the reflector can be accomplished by turning the back of the quad toward a distant signal, and adjusting the reflector loading coils for minimum received signal. This seemed a bit cumbersome to do each time the operating frequency was changed from cw to ssb and vice-versa, so a microswitch was added to the reflector coils and motor assembly. Each revolution of the coils flicks the microswitch, which actuates a light on the control panel in the shack. By counting the blinks of the light, and referring to a chart which shows the resonant frequency of the reflector versus the number of turns of inductance in the loop, the reflector can be tuned to any desired frequency. With this tuning scheme, it is quite easy to tune the quad for best performance at any point in the 80-meter band. The bandwidth between the 3:1 SWR points is close to 200 kHz, so retuning is required only for large frequency changes within the band. Frequency flexibility otherwise is quite good.

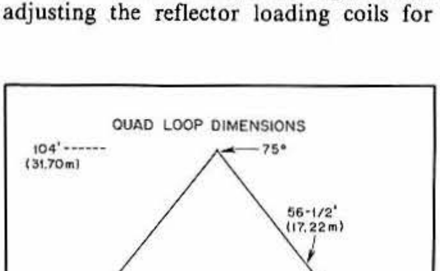
QUAD LOOP DIMENSIONS
104'
(31.70m)
75°
56-1/2'
(17.22m)
57'
(17.37m)
70' ACROSS
(21.34m)
105°
44-1/2'
(13.56m)
23'
(7.01m)
7'
(2.13m)
18' (5.49m)
THESE TWO WIRES RUN OFF AT NEARLY 90° TO THE PLANE OF LOOP TO THE TUNING BOX
252' (76.81m) OF WIRE IN EACH LOOP, INCLUDING LEADS TO TUNING BOX

Fig. 22 — Dimensions of one of the quad loops.

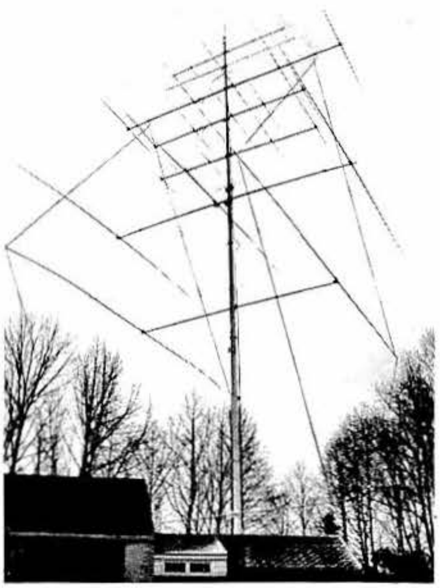

Here is the complete antenna system, 2 through 160 meters, all rotatable, directional arrays.

The impedance of the driven element measures about 75 ohms. The antenna is coupled to the transmitter through a balun and 50-ohm line. The difference between the resonant frequency of the driven element and the reflector, when the latter is tuned for maximum front-to-back ratio, is in the order of only 1-1/2 percent. This probably results from the quad being only a one-quarter wavelength above the ground. The front-to-back ratio is about 20 dB, and the front-to-side, 50 dB. All measurements have an indicated gain over a dipole in the order of 6 to 7 dB. No degradation in performance, or SWR, has been observed during heavy rain. The small loading coils are protected from the weather, of course, in their aluminum tuner box, so the problem, which was encountered with unprotected load coils in the 20-meter test model, has been eliminated.

Tests were conducted with the second element tuned as a director instead of a reflector; there was no noticeable improvement in gain, whereas the front-to-back ratio was diminished. It is felt that the best results are obtained with the reflector.

Some thought was given to driving both elements at a 135-degree phase difference to obtain a cardioid pattern. It is felt, however, that the conventional quad pattern, with deep nulls on each side, and a reasonably good front-to-back ratio, is more desireable for DX. So, nothing further has been done with such a phasing arrangement.

Results

DX results on 80 meters have improved considerably since the new antenna was put on the air. On cw, the gain seems to drop off somewhat as compared to the phone end of the band. Probably this is due to the fact that the relative size of the antenna is smaller at the cw operating frequencies. Nevertheless, reports usually are from one to several S units higher than other U.S. stations with comparable power input, and conventional antennas. In most instances during pile-ups in a recent cw contest, it took only a call or two to get through, whereas, previously, the station was usually last. It was found also that contacts could be made earlier, as the band opened. In several instances like this, it was amazing to get a response from a DX station, and then to hear other U.S. stations calling without success.

Reports from overseas on ssb are outstanding. During a recent phone contest, several dozen DX contacts were made in just a few hours — everyone on the first call.

During the day, on 80 meters, it is quite easy to work into Canada or the Carolinas with good signals at both ends of the circuit. On a dipole, very often the other station is completely unreadable, if not inaudible. This points up the fact that one notices great improvement in reception with the quad compared to a dipole, which on 80 is just as important as being able to transmit a better signal.

Once it was determined that the quad worked well on 80 meters, the possibility of operating the antenna on 160 meters was explored. Since the loops independently resonated at 4050 kHz, and there was considerable inductive loading available in the coils, it was felt that it might be possible to resonate the antenna on 1.8 MHz by putting the two loops in series. Actually, with the load coils tuned to minimum, the series-connected loops resonated at 1775 kHz because of the mutual coupling. By shortening out the coils entirely, the pair of loops were resonated at 1805 kHz. Therefore, the SWR at the low end of the 160-meter band is very low.

Domestic reports on 160 meters have been excellent. Consistent directional effects have been noted by several observers when the two-turn loop is rotated. The pattern is the typical figure eight, with deep nulls off each side of the loop. It remains to evaluate how well the antenna works on 160-meter DX.

Following completion of the antenna in September, there have been several severe storms, with winds gusting as high as 65 mph. These velocities barely moved the wires and spreaders around. It is apparent that the heavy construction is adequate to handle the winds of much higher velocity for which the antenna was designed. Although it is probably one of the largest quads in existence, it certainly appears as though it will stay up a long time, even through rough weather.

In conclusion, this project could never have been completed successfully without the help of many domestic and overseas amateurs. Their reports, advice, and assistance will always be appreciated. Although this has been a sizeable and difficult antenna task, a great deal of satisfaction has been derived from carrying it through from concept to on-the-air operation. The simple lesson has been relearned with regard to antennas — that one cannot get something for nothing. Mini-size antennas are better than no antennas, but there is no substitute for full-size antennas if one wants full-size results. This material was originally presented in *QST* by Joe Hertzberg, N3EA.

The Folded Mini Quad

A full-wavelength loop can take a variety of forms. Despite the shape suggested here, the author claims good results.

An unusual type of full-wavelength wireloop antenna is in use here on 2 and 15 meters. The design, which the author had not seen previously, provides an antenna that occupies minimum space; the antenna is omnidirectional, vertically polarized, broadbanded and requires no ground-plane.

It evolves from a full-wavelength loop.[1] The loop, if fed on the side (x-y) as in Fig. 23A, radiates a vertically polarized signal. The radiation pattern is bidirectional, with maximum radiation broadside to the plane of the loop and with the highest field strength in the plane A-A′.

The loop can be deformed into a square, such as in the elements of a quad, and without much loss of efficiency into a rectangle (Fig. 23C). Vertical polarization, bidirectional signal pattern and maximum radiation from the plane A-A′ are retained.

A 90 degree bend at A-A′ and two further right angle bends at B-B′ and C-C′ transforms the flat loop into a cube. The circumference is still a full wavelength and each side of the cube measures 1/10 wavelength. Again, vertical polarization is retained, but the appreciable bidirectional radiation from the sides of the cube adjacent to A-A′ leads to a nearly omnidirectional radiation pattern.

My 2-meter antenna was constructed from aluminum clothesline wire; the length in feet was chosen by 1005/f MHz. It is fed with 50-ohm coaxial cable through a Pomona Electronics no. 1699 adapter and no matching device is used. The SWR is less than 1.2:1 from 144 to 146.5 MHz and climbs to 1.4:1 at 148 MHz. The radiation pattern was measured with a simple field-strength meter, using a half-wave dipole as pickup element and a 20-kΩ resistance in series with the 20-μA meter to improve linearity.[2] The front-to-back ratio is 1.8 dB with no prominent sidelobes apparent, but a rather sharp 3-dB dip is caused by the "shadow" of the feed line and hardware.

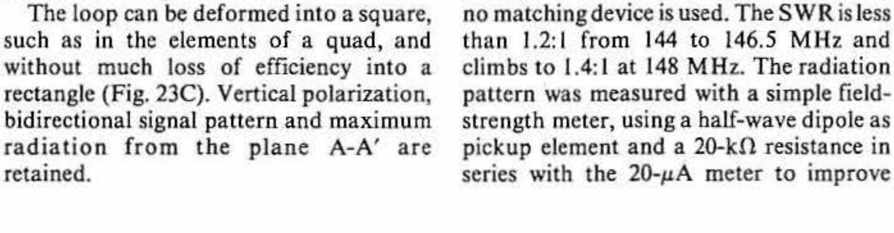

Fig. 23 — Conversion of the full-wavelength loop to the space-saving cubical configuration. The length of the wire and the vertical polarization remain but the pattern changes from bidirectional to omnidirectional. The spacing between the feed point and the adjacent side is not critical. The spacing on 2 meters is about 1-1/2 inches (38 mm), and on 15 meters is about 4 inches (102 mm).

Performance

Fed with 10 watts and used as an indoor antenna, it gives consistent communication with 2-meter fm base and mobile stations within a 10- to 15-mile radius. It performs better on receive and transmit than a 1/4-wave whip at the same location.

A 15-meter version of the antenna was then constructed and suspended in the attic with string and tacks. It is operated with 100 watts and the rig loads almost as well as the 2-meter version, but with a slightly higher SWR. The first contacts were with California and it has since given excellent performance to the West, Midwest and South as well as to South America and Europe.

The close proximity of antenna sections radiating out of phase may lower the efficiency over that of a loop, yet, in terms of space requirement, construction cost and ease of installation (no radials!) and tuning, the antenna is hard to beat. As a full-wave loop it should have a slight edge over a vertical. The author recommends further experimentation and modification, e.g., into the even more space-saving configuration of a cylinder. This material was originally presented in *QST* by Max Blumer, WA1MKP, SK.

References

[1] *The ARRL Antenna Book*, 13th ed., 1974, p. 65.

[2] *The Radio Amateur's Handbook*, 46th ed., 1969, p. 553.

A Convenient Stub-Tuning System for Quad Antennas

The cubical quad has been a popular antenna with amateurs for a number of reasons — relatively light weight, small turning radius, low cost, and good DX performance at rather low heights when compared to other antennas. The authors' experience with quads has demonstrated, however, that best possible performance requires careful parasitic-element tuning. Cutting elements according to various "established" length formulas has often yielded less than satisfactory results. While adjustments for maximum forward gain are generally uncritical, a mediocre front-to-back ratio often results unless time and care are taken to tune the parasitic elements. Factors such as spacing between elements, proximity of the antenna to ground, or influence of other objects (including the other concentric loops in a multiband array) require that the electrical length of the parasitic elements be adjusted using empirical methods if optimum performance is to be realized from the system. It was felt that if one was going to the trouble of erecting a good antenna system, it was worth seeing to it that the antenna was delivering the performance of which it was capable.

These considerations led to the development of the parasitic-element tuning system described here. While the scheme is applicable to quads in general, whether rotary or fixed, the original intended application was in a fixed two-element, full-size 40-meter quad. The descriptions here apply to this 40-meter system, but the general information allows one to follow the same scheme with a quad for any band.

A 40-Meter System

This 40-meter antenna consisted of two non-rotatable full-wave wire loops suspended from a boom which was mounted near the top of a tower. Spacing between elements was 22 feet (6.71 m). The corners of the loops were tied down to convenient anchor points by means of ropes, thereby eliminating the need for spreaders. With the elements thus fixed in place, the antenna was oriented in one general direction and could not be steered elsewhere. A driven-element and reflector combination was used.

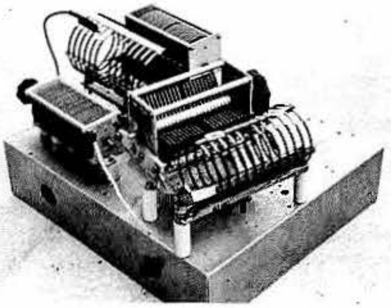

The matching network built by the authors for the modified 40-meter system. Relays, used in the switching circuitry, are not visible. The builder is left to choose a suitable network of his own to meet his operating requirements. Basic design information can be found in *The Radio Amateur's Handbook* or *The ARRL Antenna Book*.

Early experiments with the antenna demonstrated the need for careful reflector tuning. Several trips were made up the tower to alternately prune and add wire to the reflector before the antenna exhibited good performance at the frequencies of interest. But when tuned properly, the quad really performed! In many instances signals which were inaudible while using an 80-foot (24.4-m) high reference dipole were perfectly readable with the quad (at a median height of about 100 feet [30.5 m]). Reception was further enhanced by rejection of unwanted signals off the back of the quad.

Now if only the quad could be made rotatable. . . . Unfortunately, a full-size rotating system (spreaders would be needed) was out of the question. The cost, difficulties of construction and installation, and the severe effects of New England winters discouraged such ideas. The authors, being avid contesters and DXers, were willing to settle for the next best alternative — keeping the fixed quad, but electrically switching its pattern.

The solution involved a tunable stub attached to one of the elements to lengthen or shorten it electrically. With the appropriate stub switched in, the single element could be made to look like either a reflector or director and thus cause the pattern to be reversed. In order that adjustments be made quickly, easily, and from a convenient location (such as the shack or the bottom of the tower), it involved more than the conventional short stub often used with quads. Rather, the situation called for a long stub — long enough to reach the desired remote location — terminated in a variable reactance. Tuning the element, then, involved nothing more than adjustment of the value of reactance which could be provided conveniently by means of a variable capacitor.

The electrical principle is simple. One adds inductive reactance to lengthen an element electrically, or capacitive reactance to shorten it. Typically, the former arrangement is used with quads in a driven-element and reflector combination in which both elements are cut to the same physical length. A stub, shorted at the end, is attached at the center of the bottom section of the reflector. By varying the position of a shorting bar along the stub, the amount of inductive reactance presented to the element can be varied and the electrical length altered correspondingly. Because the stub is short in length, this adjustment must be made at the antenna itself, preferably near or at its final height.

Now, if the stub is cut to some different length which happens to be longer than in the above case, the parasitic element can still be made to see the proper amount of inductive reactance (if it is a reflector) provided the stub is terminated properly with some other reactance (in general, something other than a short). Varying the reactive termination is then equivalent to moving the shorting bar along the conventional stub. This is a consequence of the impedance-transforming property of transmission lines. The long stub can be treated as a transmission line. If we know its characteristic impedance, its length, and the impedance that must be seen at the parasitic-element end of the line, the Smith Chart can tell us what kind of termination is required at the opposite end.

A reflector cut to the same physical dimensions as the driven element — self-resonant at the desired operating frequency — must "see" roughly 150 ohms of inductive reactance at the terminals where the stub is attached. Although little information is available about the use of directors with quads, it is assumed initially that a director, also cut to the same length as the driven element, must see a roughly equal but opposite amount of reactance, or about 150 ohms of capacitive reactance. If one desires to make the termination at the end of the stub a variable capacitor for convenience of tuning, which was the case in the 40-meter system under consideration, the problem can be rephrased slightly: what length of line of a given characteristic impedance is required so that a variable capacitor (a 10- to 350-pF unit was used) causes the parasitic element to see the above reactances? This is easily solved with a Smith Chart. Two somewhat different systems evolved from these ideas. The second, a modification of the first, will be described last.

The design procedure for the 40-meter version went as follows: The driven and parasitic elements were cut to the same length, given by the more or less standard formula, $L = 1005/f$, where L is the length in feet, and f the frequency in MHz. This resulted in a loop circumference of 143 feet, 6 inches (43.74 m) at a frequency of 7.0 MHz. In the practical installation, the loops were triangular in shape rather than

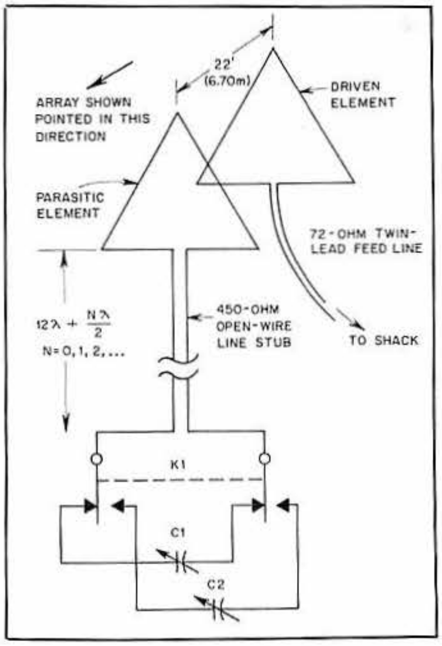
22'
(6.70m)
ARRAY SHOWN POINTED IN THIS DIRECTION
DRIVEN ELEMENT
PARASITIC ELEMENT
72-OHM TWIN-LEAD FEED LINE
12λ + Nλ/2
N=0, 1, 2,...
450-OHM OPEN-WIRE LINE STUB
TO SHACK
K1
C1
C2

Fig. 24 — Configuration of 2-element switchable 40-meter quad. Triangular loops are shown, although square or diamond loops can be used too. Both elements are cut to the same dimensions: 143 feet, 6 inches (43.74 m) for 7.0-MHz operation. The selection of either C1 or C2 by means of K1 determines which direction the array is pointed. Switching components K1, C1 and C2, can be installed inside the shack or on the ground. The stub line is cut long enough to reach them. Feeding the driven element with 72-ohm Twin Lead results in a low SWR.

C1 — 10- to 350-pF air-variable capacitor, adjusted for director operation as described in text.

C2 — Same as C1, except adjusted for reflector operation.

K1 — Dpdt relay (Potter and Brumfield KA11DG or equivalent).

square or diamond. Shape is relatively uncritical — performance is approximately equivalent for the various geometric configurations, and ease of installation was considered more important. The triangle has the advantage of requiring only three tie-off points — one at the top where it hangs from the boom and two at the bottom — whereas the other two forms require support at four corners. Furthermore, the triangle requires less vertical height — approximately 41 feet (12.5 m) on 40 meters, assuming equal-length sides — as opposed to the diamond which needs about 50 feet (15.25 m). The square requires the least vertical height but is the most difficult to support mechanically. The resultant configuration is shown in Fig. 24.

The stub line was made from 450-ohm open-wire transmission line because of its relatively low cost in commercially made form and its low-loss characteristics. The reactance range of the 10- to 350-pF capacitor by itself at 7 MHz was then plotted on the Smith Chart as shown in Fig. 25. (Recall that $X^L = 2\pi fL$ and $X^C = 1/2\pi fC$ where X^L and X^C represent values of inductive and capacitive reactance respectively, given in ohms, L and C the corresponding values of inductance in henrys and capacitance in farads, and f, the frequency in hertz.) The low-capacitance end of the range is indicated as point B in Fig. 25 with the Smith Chart normalized to 450 ohms in this example, while the other extreme comes out at point A. If the capacitor was then connected at the end of a 0.12-wavelength section of the 450-ohm line (approximately 16 feet [4.88 m] in open-wire line), the impedance seen at the other end of the line would vary between the range of slightly greater than +j300 to -j300, represented by points C and D. This would meet the +j150 and -j150 reactive loading requirements of the parasitic element for reflector and director operation, respectively. Actually a stub length of 0.12 wavelength, plus any multiple of a half wavelength, would work too, because any half-wavelength section of transmission line merely repeats at one end the impedance that appears at the other. Thus, the distance to the desired remote location dictates the minimum required line length. Another advantage of using 450-ohm line, as opposed to a line with a lower characteristic impedance, becomes apparent when working examples on the Smith Chart — for a given capacitor tuning range, the 450-ohm line produces a greater range of reactance change at the antenna end of the line. A 300-ohm line would serve almost as well, however, providing only slightly less tuning flexibility.

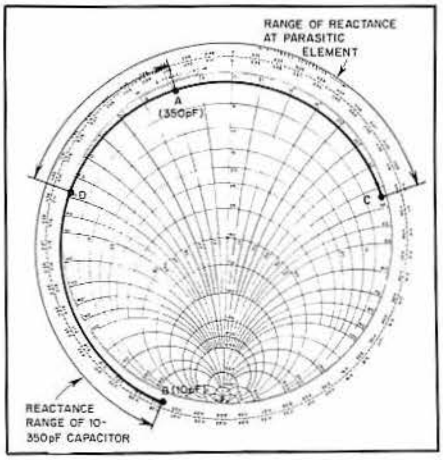

Fig. 25— Example of Smith Chart calculations required to arrive at correct stub dimensions. A 10- to 250-pF capacitor is used as the variable-reactance element which terminates the 450-ohm transmission line used for a parasitic-element stub. The chart is normalized to 450 ohms. The arc between points A and B represents the range of reactance of the capacitor as it is tuned between the extremes of its range. If the capacitor is connected to a 0.12-wavelength long stub (plus any multiple of one-half wavelength) with a 450-ohm characteristic impedance, the range of reactance represented by the arc between points C and D is presented to the parasitic element. This range is sufficient to cause a properly cut parasitic element to look like either a director or reflector. Further discussion of Smith Chart calculations can be found in the latest edition of *The ARRL Antenna Book.*

The stub was terminated at a dpdt relay which was controlled from the station operating position and which was used to select one of two variable capacitors — one adjusted to provide reactance for reflector operation and the other for director operation, as shown in Fig. 24. In this manner, the pattern could be flipped around 180 degrees instantly from the shack. The driven element was fed directly with 72-ohm transmitting-type Twin-Lead. A low SWR was obtained with no special provisions made for matching.

The director and reflector tuning should be done empirically, as was stated before. Experience has shown that quads tune rather broadly for maximum forward gain. It was found that fairly large changes in the settings of the variable capacitors did not alter the gain significantly. It is best, therefore, to tune for maximum front-to-back ratio, on which the settings had considerably more effect. On-the-air signals arriving from the rear direction can be nulled by tuning the capacitors. The nulls should be fairly pronounced if the

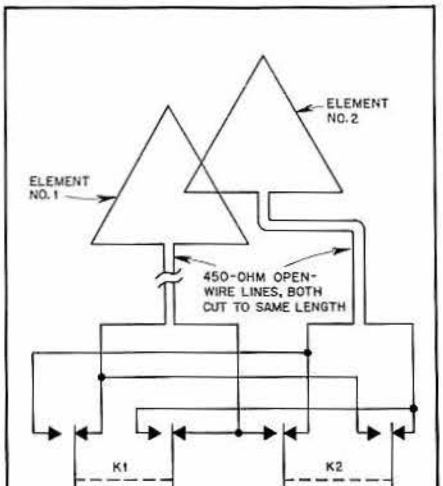
ELEMENT NO. 2
ELEMENT NO. 1
450-OHM OPEN-WIRE LINES, BOTH CUT TO SAME LENGTH
K1
K2
C1
MATCHING NETWORK
COAXIAL FEED LINE (RG-8/U, RG-11/U, ETC.) TO STATION

Fig. 26 — Configuration of modified 2-element switchable 40-meter quad. The lines from each element are both cut to the same length, which can be the same as the parasitic element line in Fig. 24 or other suitable length. Both elements are cut to the same dimensions as in Fig. 24. The positions of K1 and K2 determine whether an element is fed as a driven element or terminated as a reflector. The array pattern can be switched by determining which element operates as a reflector or driven element. Only one tuning capacitor is required, but a matching network is needed to match a coaxial feed line.

C1 — 10- to 250-pF air-variable capacitor, adjusted for reflector operation.

K1, K2 — Dpdt relays operated simultaneously, or both may be replaced by a single four-pole, double-throw relay (Potter and Brumfield KA11DG or equivalent).

system is set up as described here. The exact amount of attenuation of signals off the back of the antenna varies from signal to signal. It was observed that the 40-meter antenna exhibited the greatest front-to-back ratio for signals arriving from distant locations (at low radiation angles). Alternatively, field-strength measurements can be made to determine the proper settings for minimum radiation or reception off the rear of the antenna. In this fashion, one capacitor is adjusted for director operation and the other for reflector operation.

When making large excursions in operating frequency on 40 meters, it is necessary to touch up the tuning. A director tuned for operation in the low end of the cw segment is self-resonant approximately in the middle of the phone portion and provides little usable gain at those higher frequencies. Retuning is done easily, however — something which is not possible using fixed-tuned elements.

A Modified 40-Meter System

The 40-meter system described above provided very good results over a period of months, including stateside and DX contest work and casual DXing. After some thought, however, a modified system was constructed. The new configuration provided some advantages over the orginal scheme.

The same principle of operation was retained. The new system shown in Fig. 26, used only a reflector-type parasitic element, but the switching system now allowed either element to operate as the driven element or reflector. In this manner, the antenna pattern could still be reversed by choosing the appropriate element for the desired function.

Several factors prompted the change. It was found with the original system that a considerably higher front-to-back ratio could be had using a reflector rather than a director. The latter yielded no more than about 10-dB discrimination against signals received off the back of the antenna, even with careful tuning, whereas with the former the figure was approximately as high as 25 dB. Although most available literature made little mention of quad performance using a director, this observation agreed with what little published data could be found on the subject.[1] The reflector-only model also had the advantage that just one tuning adjustment was required, since one stub reflector served both elements in an identical fashion. Furthermore, because the system behaved the same no matter which direction the array was switched, the SWR did not change when switching, and the transmitter was thus always tuned properly. With the original scheme the antenna feed-point impedance changed when switched between director and reflector operation. Although the resultant SWR was not objectionable in either case (it did change, though), it was necessary to retune the transmitter after switching, or tolerate a moderate amount of mistuning.

The design procedure for the new arrangement is basically the same as before. Both elements are cut to the same length. Only the stub requirements for a reflector need be considered now in doing the Smith Chart calculations. Once the stub line length is determined, two such identical-length lines, both made from the same type of transmission line, are cut, one for each element. A four-pole, double-throw relay, or two dpdt relays operated simultaneously, are required in the hookup shown in Fig. 26, to switch the two lines between the parasitic-element termination and the main feed-line matching network.

The new system has one disadvantage, however. A matching network is required between the transmitter and driven element because of the mismatch between the main feedline, which is presumably coax, and the driven-element open-wire feed line. The original system required no special matching. This presented no problem in the 40-meter system considered here since a suitable network was easily constructed. The builder is left to choose a suitable matching network of his own as there are numerous possibilities to take care of the varied matching requirements which may arise under different situations. Depending upon one's preferences and requirements, the modified scheme may or may not prove more attractive.

Additional Remarks

A few general comments can be made at this point. Although a variable capacitor has been designated thus far as the termination for the stub, there is no reason for not using a coil or some other combination of inductance and capacitance if it will work with a stub length which happens to be convenient. The builder can choose for himself. The 10- to 350-pF capacitor described earlier had approximately 0.05-inch (1.27 mm) spacing between plates. While it is difficult to predict the voltages present in the parasitic element (and across the capacitor), no arcing between plates was observed during transmitting periods, even while running one kilowatt transmitter dc input. This suggested the plate spacing was adequate.

The lines from each element should be brought away perpendicular to the elements as much as possible, and open-wire line should be kept reasonably clear of nearby objects, especially metal ones. Also, the velocity factor of the line being used (0.95 for "ladder" line) must be remembered when computing physical lengths.

The authors erected a single diamond-shaped 80-meter quad loop with its bottom close to the ground. The antenna was tried as both a vertically and horizontally polarized radiator. For DX work, the vertically polarized version yielded unquestionably superior results in terms of greater signal strengths at long distances and the beneficial feature of rejection of unwanted high-angle radiation from stateside stations when receiving. A parasitic element to accompany the single loop was not tried. These observations suggest interesting possibilities for vertically polarized ground-mounted quads for low frequencies.

The ideas presented here are applicable to any quad antenna, but should be especially useful in designing large arrays which cannot be turned physically. The design procedure is simple in any case. The feature of continuously variable tuning eliminates the guesswork in cutting fixed-length, fixed-tuned elements. The system will serve well in any situation where, say, climbing the tower to work on the antenna is not convenient.

A fixed, switchable array is an asset to the contestant or DXer who finds it necessary to change antenna headings in a hurry. From the northeastern U.S., a single such array provides good coverage of Europe and Africa in one direction and of the western U.S. and the Pacific in the other. If two suitable supports spaced a reasonable distance apart are available, two arrays of this type, perpendicular to each other, can provide a wide range of coverage. This material was originally presented in *QST* by John E. Kaufmann, WA1CQW and Gary E. Kopec, K8RX.

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[1] "Technical Topics," *Radio Communication*, February 1973, p. 101.

Some Notes on a 7-MHz, Linear-Loaded Quad

If you like to experiment with antennas, here are enough new ideas about the construction of quad antennas to keep you going.

Most amateurs who have a serious interest in working DX in the 3.5- to 28-MHz bands would like to have antennas providing them with forward gain on all of these bands. Today, a triband trap Yagi or cubical quad may be employed to achieve this objective on 14, 21 and 28 MHz. Rotary beams are, for all practical purposes, out of the question for 3.5 MHz, but it is possible to achieve some gain with a 7-MHz rotary beam without having to pay a fortune for a supporting structure.

The Hy-Gain linear-loaded 2-element Yagi or the Mosley inductively loaded beam for 7 MHz can achieve this objective. The writer, however, prefers quads to Yagis, based on his own experience. Difficulties often arise when one seeks to mount beams for several different bands on the same tower without marked loss of performance on any band. The primary problem is, of course, that a full-sized cubical quad for 7 MHz is a monstrous structure. Such antennas have been erected, but they are not suited for the average amateur with a limited budget.

The first step in building a 7-MHz quad is, therefore, to design a single 7-MHz quad loop of reasonable size which is mechanically strong enough to survive most weather conditions.

Linear Loading

As a general rule, a reduction in antenna size to two-thirds of full size can be effected without a noticeable drop in performance, providing care is taken to limit the losses introduced by the loading devices. This means that one can think in terms of a loop for 7 MHz with 24 feet (7.32 m) on a side instead of 36 feet (10.97 m) on a side. An additional factor in choosing a 24-foot-per-side length was that the longest bamboo spreaders that the writer could obtain were 18 feet (5.5 m). Attempts were made to lengthen these spreaders, but results were not satisfactory mechanically.

If a 24-foot loop is to be used, the next questions are where to put the loading and what form of loading to use. A full-sized quad loop has symmetrical current distribution. The current maxima occur in the middle of the horizontal sections, and the current minima develop in the middle of the vertical sections. The current distribution in the vertical elements is such that most vertical radiation is canceled out. It is desirable to retain this current distribution in the shortened loop. It is also desirable not to put the loading in the center of the horizontal elements, since maximum radiation occurs at the current maxima, and it does not make sense to cut out the portion of an antenna that does the most effective work. The writer, therefore, chose to put the loading in the vertical sides.

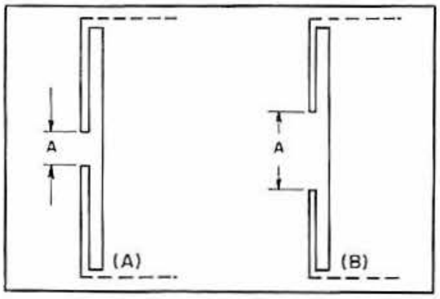

Fig. 27 — A method for linear-loading of one side of a quad element.

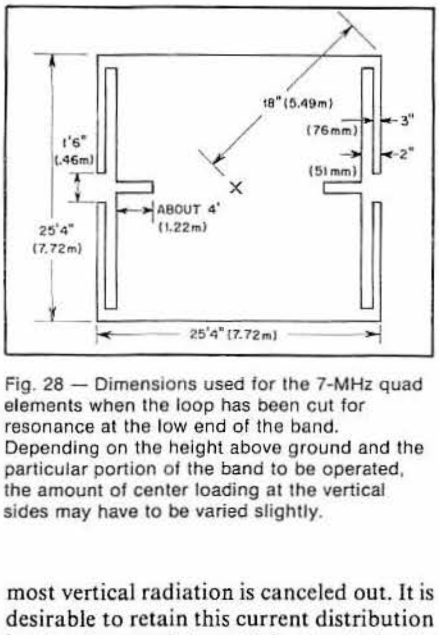

Fig. 28 — Dimensions used for the 7-MHz quad elements when the loop has been cut for resonance at the low end of the band. Depending on the height above ground and the particular portion of the band to be operated, the amount of center loading at the vertical sides may have to be varied slightly.

There are two popular methods of loading, stubs or coils. The writer dislikes coils for loading since, if they are wound with a heavy-gauge wire (desirable in order to avoid undue losses), they are bulky and difficult to weatherproof. The choice was therefore stub loading. It would have been possible to insert a stub at each corner of the loop, tied back to the spreaders. But, the current flowing in such stubs would be unbalanced, and radiation in unwanted directions would take place from the stubs themselves. There is also the consideration that if the same spreaders are used for 14-, 21- and 28-MHz loops, stubs at the corners of the 7-MHz loop would have to be mounted well clear of the loops for the other bands.

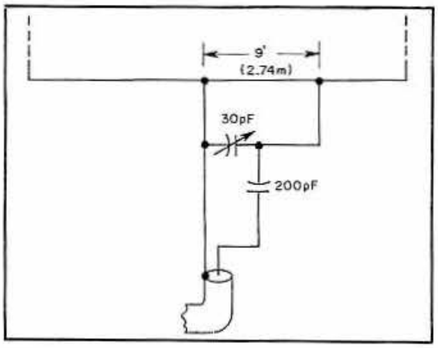

Fig. 29 — Diagram of the matching section used on the 40-meter driven element. The gamma capacitor employs a 100-pF air variable and a 100-pF high-voltage silver mica connected in parallel.

The original linear-loaded 7-MHz quad element was tried by the writer in a four-band quad some years ago. A single stub in the center of each vertical side was used. The loading stubs were made 14 feet (4.27 m) long and were tied on to a point near the center of the boom. Performance of this quad on 7 MHz was excellent, but the 21-MHz quad mounted on the same boom was almost useless, probably due to pickup at 21 MHz by the 7-MHz loop with subsequent reradiation. An attempt was made to find an efficient method of loading which did not involve long stubs "floating around." The next step was to try folding the wires in the vertical sections back on themselves as shown in Fig. 27A. Current distribution either side of the center part of the vertical elements is symmetrical, as desired. This change resulted in a loop that was resonant near 7 MHz, although its resonant frequency was slightly high. Shortening of the stubs slightly, as shown in Fig. 27B, was tried. This had virtually no effect on resonant frequency. This is no doubt because the increased end-loading effect of the portion A almost equalled the reduction in stub length. Short stubs (abour 4 feet [1.22 m] long) were then

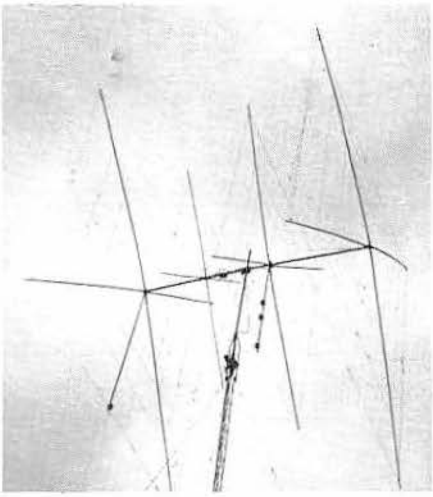

G3FPQ's compact 4-band quad has 2 elements for 7 MHz, 3 elements for 14 MHz, and 4 elements for 21 and 28 MHz. Pairs of Yagi-type directors are used in place of the usual loop director for the three higher frequency bands.

inserted at the center of the vertical sides, at right angles to the vertical sides as shown in Fig. 28, and resonance at 7 MHz was achieved.

A four-band quad for 7, 14, 21 and 28 MHz was then constructed. Much to the writer's delight, there appeared to be no noticeable interference with the pattern of the 21-MHz quad by the 7-MHZ elements. The loading effect of the stubs would be different at 21 MHz since they would include current maxima; the result is to give a loop which, while resonant at 7 MHz, does not appear to have a third-harmonic resonance in or near the 21-MHz band.

Yagi-Type Directors

The reader can probably see from the photograph that the directors for 14, 21 and 28 MHz consist of pairs of stacked Yagi-type elements level with the driven elements. There are two pairs of Yagi directors for the 10- and 15-meter elements at approximately 6-foot, 6-inch (2 m) spacing, and one pair of Yagi directors for 20 meters at approximately 13-foot (4 m) spacing. The overall length of the directors is 31 feet, 3 inches (9.52 m) on 20 meters; 20 feet, 10 inches (6.35 m) on 15 meters; and 15 feet, 2-1/2 inches (4.63 m) on 10 meters. Performance of the author's array on 10, 15, and 20 meters at the moment is little, if any, better than an ordinary 2-element quad. The writer has only recently had an opportunity to start checking out the directors to see what adjustment they need. Current indications are that they require lengthening, but there is a good deal more experimental work to be done. Anyone who wants to try this system must be prepared to do a good deal of cut and try to tune the directors, if any real increase in performance over a standard two-element quad is to be achieved.

One also has to bear in mind that when dealing with multiband quads the resonant frequency of Yagi-type directors is likely to be affected to a far greater extent by the proximity of other elements than would be the case for a quad-loop director. This is because a Yagi director is a comparatively high-Q element. From the theoretical point of view, the drawback to quad-loop directors is that the reactances involved are such that there is a comparatively low degree of mutual coupling between the quad-driven element and the quad-loop director. This, of course, reduces the efficiency of the loop as a director. This problem should not apply to the same extent with Yagi-type directors, and, in theory at least, they should prove to be more efficient than quad-loop directors. The question now is whether practice follows theory or not. This writer won't have an opportunity to conduct any detailed experiments until the summer. When deciding the original length for the Yagi directors, allowance was made for a rise in frequency of approximately 100 kHz. But, the only way to cope with the effects on the director resonant frequency of the proximity of other elements is by field-strength measurements, coupled with a good deal of cut and try. As in any multiband quad, separate feed lines should be used for each band to minimize interaction between bands.

The author's quad has been up for six months now, and final tuning remains to be done to the 7-MHz reflector loop to achieve maximum front-to-back ratio. But the results, even on a cut-and-try basis, are well worth the work that went into the array. This material was originally presented in *QST* by David. L. Courtier-Dutton, G3FPQ.

Spider Quad Mount: Simplified

There seems to be a growing interest in the spider quad. The photograph shows a version of a hub or "spider" mount. Using a 2-foot (0.61-m) length of 2-inch (51-mm) diameter steel pipe, a mount can be constructed easily. Two cuts, 10 inches (254 mm) long, are made through the diameter at each end of the pipe. This leaves 4 inches (102 mm) in the middle for the boom. The cut ends are then bent to an angle to suit the desired spacing. The unit shown in the photograph is bent to 108 degrees. The spreaders may be attached to the boom mount with hose clamps, bolts or wire.

The beauty of this design is that it can be made to any size desired. Also, it can be enlarged to a 4-element version, as shown in Fig. 30.

Fig. 30

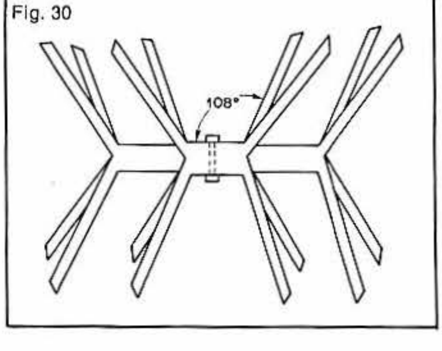

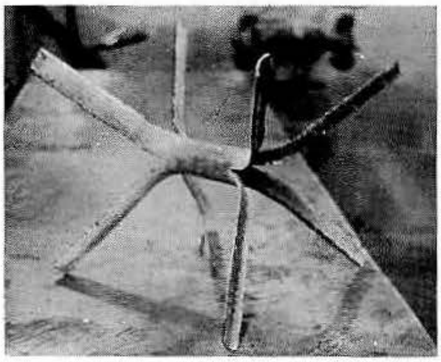

One of these spider mounts is in use at KP4DJI (constructed by KP4DIO and KP4DJI) using bamboo spreaders. The results have been excellent. This material originally presented in *QST* by Lynda B. Crowley, KP4DIP.

Two-Band Quad Matching

While experimenting with a 2-element, 2-band cubical quad antenna the problem of matching the antenna to a 50-ohm transmission line arose. The antenna is a "plain vanilla" quad built around information in W6SAI's book, *Quad Antennas*. The author's method of feeding the antenna *did not* produce fantastic front-to-back ratio or forward gain. It merely made the standing-wave ratio more acceptable to the 32S-3B used at the home QTH.

After building the 2-band quad, the author checked it with a General Radio 1606 impedance bridge and found the 10-meter antenna to be about 118 ohms and the 15-meter antenna to be about 91 ohms at resonance. This is 2.36:1 and 1.82:1, or approximately 2:1 for a 50-ohm transmission line. The feed system described here made the VSWR much nearer the desired 1:1.

The heart of the system is a ferrite-core autotransformer. The measured impedance ratio is very close to 50:107 ohms. The insertion loss is less than 0.2 dB from 15 to 30 MHz when terminated in 107 ohms. When it is terminated in 50 or 200 ohms the insertion loss is less than 0.35 dB from 15 to 30 MHz. Several transformers were built before these figures were obtained, and after a suitable design was achieved it was connected to the quad as shown in Fig. 31. You do not have to sacrifice F/B ratio for a more acceptable VSWR by detuning the reflector stubs; simply adjust the tuning stubs for maximum F/B ratio and then design the transformer for the proper impedance ratio. Also, lowering the VSWR places a larger portion of the desired band within an impedance range the average pi-section tuner will accept.

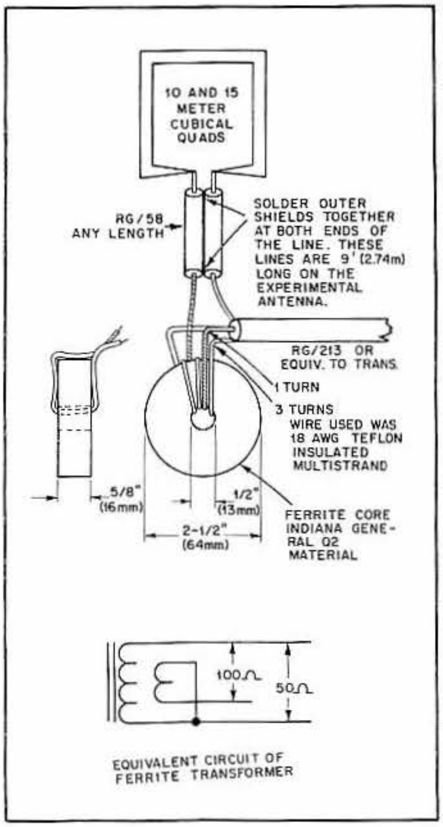
10 AND 15 METER CUBICAL QUADS
RG/58 ANY LENGTH
SOLDER OUTER SHIELDS TOGETHER AT BOTH ENDS OF THE LINE. THESE LINES ARE 9' (2.74m) LONG ON THE EXPERIMENTAL ANTENNA.
RG/213 OR EQUIV. TO TRANS.
1 TURN
3 TURNS WIRE USED WAS 18 AWG TEFLON INSULATED MULTISTRAND
5/8" (16mm)
1/2" (13mm)
2-1/2" (64mm)
FERRITE CORE INDIANA GENERAL Q2 MATERIAL
100Ω
50Ω
EQUIVALENT CIRCUIT OF FERRITE TRANSFORMER

Fig. 31 — Two-band quad matching.

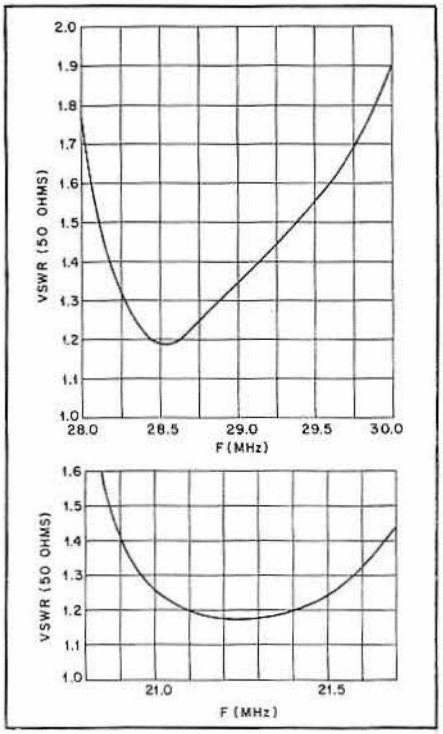

Fig. 32 — Standing-wave ratio curves taken with a laboratory-type VSWR bridge. Measurements were made at the transmitter ends of the transmission line with the antenna array mounted on a steel tower 44 feet (13.4 m) above ground.

In answer to on-the-air inquiries: Yes, performance of the antenna varies considerably from one end of the band to the other.

This antenna feed system is a broadband device, so don't forget to use a low-pass filter. This material was originally presented in *QST* by Toney L. Magnino, W5MVK.

Chapter 4

Miscellaneous Antenna Types

Here is a potpourri of useful antennas for the hf-band enthusiast. This chapter contains information on how to build and operate loop antennas, limited-space antennas and variations of the quad. Once again, the work of numerous *QST* authors has been collected for a timeless volume of useful construction details that can benefit amateurs whose operating objectives are numerous and varied.

For the most part, the antennas described in this section are simple and inexpensive to build. The performance characteristics are consistent with the operating needs of ragchewers, contesters and DX-chasers alike, assuming that the builder does not strive to have the loudest signal on the amateur bands.

Beat the Noise with a "Scoop Loop"

Operators on 160 and 80 meters fight a common foe — noise. Atmospheric QRN is compounded by the presence of man-made noise. Loop antennas for receiving may offer an economical solution to your noise problems. Here are some timely details.

If you've been tempted to massage your receiver with a 10-pound hammer because you can't copy some of the weak signals being heard by your colleagues, you may need a receiving loop! A high ambient noise level on 160 meters has stifled the author's DX work for several years, and more than once was ready to capitulate in favor of the man-made and atmospheric noises that the 75-foot (22.9-m) shunt-fed vertical responded to. "Grrrr," would be the snarl as the author listened to stations with Beverage antennas: They were handing out RST 579 signal reports to DX stations, and the author couldn't find the DX signals in the noise, let alone copy them.

Something had to be done. It was a matter of giving up on 1.8-MHz efforts toward DXCC, or putting forth a zealous attempt toward an improved signal-to-noise ratio. Some effective outdoor receiving antennas were erected (half-wavelength open loop — parallel to the ground, and a 200-foot [61-m] end-fed wire a few feet off the ground), but they did not always respond well to DX signals: It depended on band conditions. Also, there was the danger of receiver front-end damage caused by unwanted excitation of the large receiving antennas (resonant) during the transmit period. They were in close proximity to the vertical antenna, which was used for transmitting purposes. Lethargy prevented the author from installing a protective circuit at the receiver front end, and as a consequence the writer "blew" a JFET preamp and two protective diodes in the front end of the FT-301D transceiver.

Revisiting the Past

While for many years experimenting with small receiving loops for 40, 80 and 160 meters, the efforts were casual. The best of the loops was an outdoor one of the shielded variety, five feet (1.52 m) on a side, and fashioned from RG-59/U coaxial cable.[1] However, it was necessary to go out-of-doors each time to rotate it, and the author wasn't enthusiastic about investing in a rotator to use with the loop.

Recently, it seemed that some work could be done with indoor types of receiving loops. After all, loops of that kind have been around since radio was invented, and plenty of amateurs are using them effectively. After scanning available literature (Terman, Kraus, Jasik and Keen),[2] the author set about the task of building a framework for the chosen design. This time a multiturn loop would be tested (Fig. 1).

Construction

The photograph shows the general structure of the loop. In Fig. 2 are the dimensions of the wooden frame used to contain the antenna wires. There is nothing magic about the size of the antenna: Two pieces of wood that were stored in the workshop were used, each being 48 inches long, 1-1/2 inches wide and 3/8 inch thick (1.22 m × 38 mm × 10 mm).

Arbitrarily, the author decided to make L1 of Fig. 1 a five-turn winding. Holes were drilled (five) in each end of the cross-frame to accommodate the loop turns and hold them in place. Actually, there should be six holes at the bottom point of the frame to permit the final end of L1 to be secured during the threading-through process.

Five additional holes were drilled (Fig. 2) 3/4 inch (19 mm) below the holes for L1. These are used to contain L2, the one-turn output link of the antenna. L2 requires two holes at the bottom member of the frame — again to provide an anchor point for the ends of L2. Alternatively, V-shaped notches can be filed on the ends of the cross-frame. The wire for L1 can be laid in the grooves rather than threaded through the holes shown in Fig. 2. L2 should, however, be wound inside L1, through the five holes shown in the drawing.

A mounting base for the assembled antenna can be made to the builder's specifications. This writer used a piece of 3/4-inch (19 mm) plywood which has dimensions of 30 × 12 inches (0.76 m × 305 mm). A 1-inch (25 mm) diameter hole was drilled in the center of the board to accept an 18-inch (457 mm) length of 1-inch diameter dowel rod. The latter is lashed to the framework of the loop to enable the

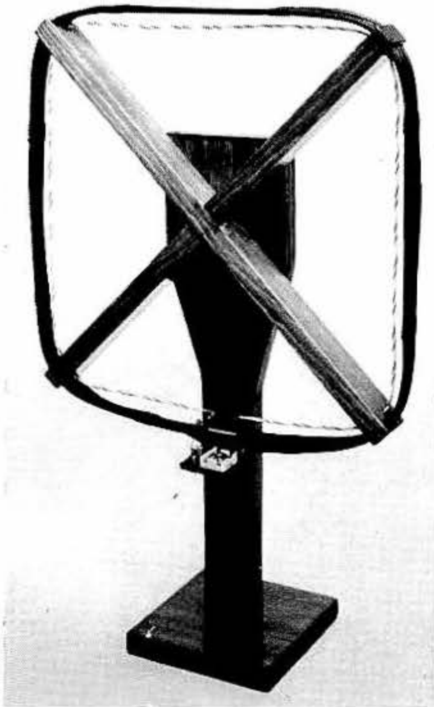

The silhouette is of an indoor version of the four-turn shielded loop described in this article. A wooden framework is used to support the main loop winding and the one-turn pickup link. The resonating capacitor is mounted on an aluminum L bracket along with a phono jack and an 860-pF disk capacitor. The latter is used between the output link and the phono jack instead of a trimmer capacitor. The framework was built by Technical Secretary Marian Anderson's OM, Bob. It has been stained and coated with clear lacquer.

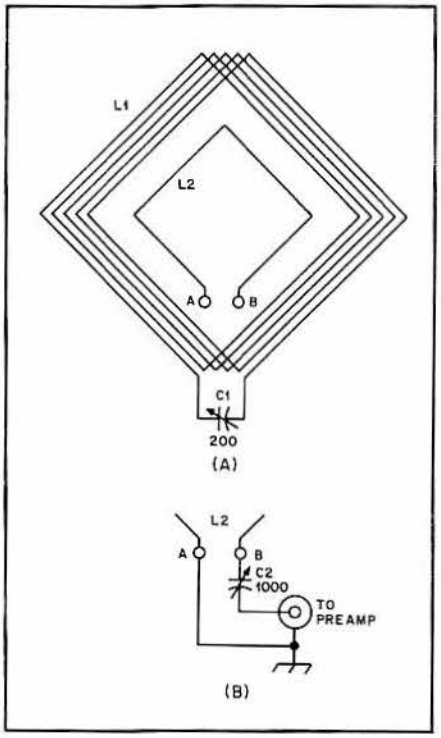

Fig. 1 — Schematic diagram of the receiving loop. C1 and C2 are mica compression trimmers. The illustration at A shows the 1-turn link inside the 5-turn one. At B is an expanded diagram of the feed point for L2.

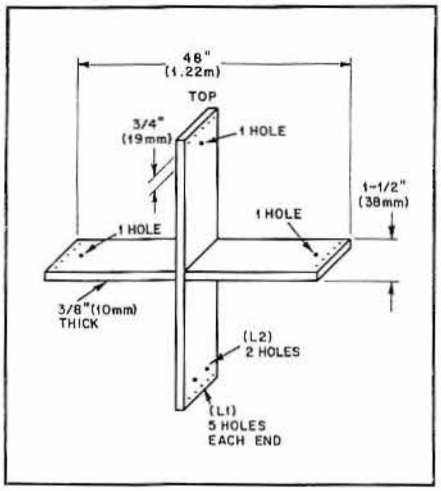

Fig. 2 — Dimensional drawing of the wooden frame which contains the Scoop Loop. Further information concerning the structure is given in the text.

operator to rotate the loop as desired. Although this is a "kluge" type of assembly, it serves its purpose adequately. A *carpenter* should be able to conceive a more practical base and support system for the antenna!

Number 22 insulated hookup wire was used for the loop turns. There is nothing critical about the wire size, but it is best to use the larger gauges. This will make the loop more rugged.

Performance

A variety of feed systems were tried before the author settled for the method illustrated in Fig. 1. Direct connection to the terminals of L1 required careful balancing to assure a uniform loop-response pattern. Unbalance causes pattern distortion, and if it's bad enough the maximum response can occur off the broad side of the loop rather than in the plane of the antenna.

Addition of a one-turn coupling loop, L2, proved to be the easiest method for assuring good balance. Bandwidth of the loop is dependent upon the Q. The latter can be controlled by the amount of capacitance used at C2: the lighter the coupling, the greater the loaded Q. Loop resonance is effected by means of C1. Since there is interaction between L1 and L2, it is necessary to readjust C1 each time C2 is tweaked. In this application it should be stressed that C2 is not used for the purpose of obtaining an SWR of 1. It is purely a *coupling* device. Hence, a 50-ohm condition does not necessarily exist at the loop output terminals.

During initial experiments the pickup loop, L2, was connected directly to the 50-ohm input port of a 40-dB broadband preamplifier which was designed by W7ZOI (Fig. 3). Without C2 in the circuit the coupling was excessive. This resulted in low Q, and the loop bandwidth was approximately 150 kHz at the 3-dB points of the response curve. After C2 was added and adjusted to provide a bandwidth of 25 kHz, the loop gain increased 10 dB. Alternatively, one might make L2 smaller and locate it closer to the center of the loop frame in order to lighten the coupling between the two windings. This could be a somewhat tedious mechanical procedure: The writer's inherent lassitude favored the addition of C2 for the purpose!

Performance Characteristics

A test range was set up for checking the null properties and relative gain of the loop. The equipment was arranged in an outdoor location, well away from power wiring and other station antennas. A crystal-controlled weak-signal source (2N2222A oscillator and 9-volt battery) was placed some 100 feet (30.48 m) from the test loop. It contained a 36-inch (0.91-m) whip antenna (vertically mounted) for radiation of the test signal. The 75-foot (22.86-m) transmitting vertical was shorted out at the feed point to prevent it from being resonant and affecting the loop antenna during the test period.

A 50-ohm Tektronix step attenuator was placed in the coaxial line between the loop and the receiver. The attenuator was used to measure accurately the changes in S-meter reading on the FT-301D transceiver which was used as a detector during the measurements.

A null depth of —21 dB was obtained with the loop. An extremely sharp null was noted. As the broad side of the loop was moved toward the signal source, the null began slowly, then fell deeply to —21 dB over the final 10 degrees of rotation. No evidence of pattern distortion was observed. The null was dead off the broad side of the antenna, and maximum response was directly off the thin side of the loop.

A comparison between the 75-foot (22.86-m) transmitting vertical (shunt-fed tower, top loaded and with buried radials) and the wire loop indicated that on groundwave signals the loop (without preamp in line) was —18 dB respective to the vertical. This suggested that in a practical installation a single JFET or dual-gate MOSFET preamp would provide unity gain with the transmitting vertical.

Using the Loop Indoors

The author's home has aluminum siding, and as is the case with all modern homes there is a network of water pipes, phone wires, TV lead-in conductors and house wiring. The author wondered how well the loop would perform within all of these unwanted signal obstacles, some of which form loops by themselves! The ham shack is at ground level inside the family room, and the loop was placed on a stand at floor level. The clutter of unwanted conductors disturbed the directivity of the loop somewhat, but the signal-pickup ability of the antenna was not impaired.

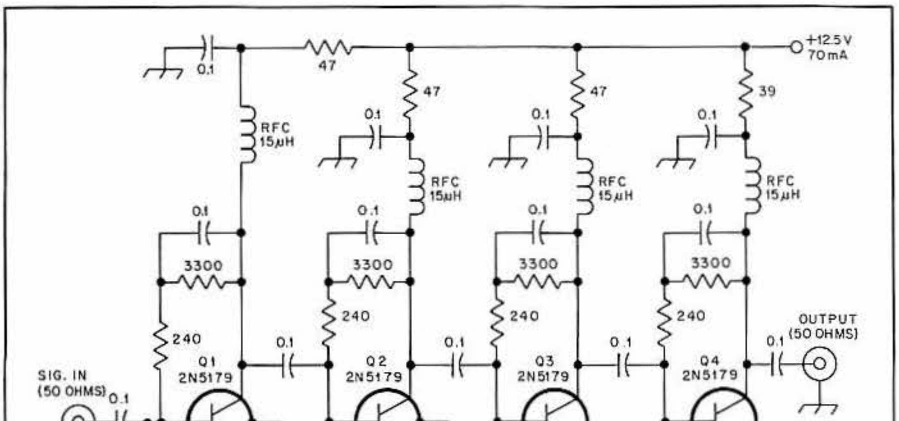
+12.5 V
70 mA
0.1
47
RFC 15μH
39
3300
240
SIG. IN (50 OHMS)
Q1 2N5179
Q2 2N5179
Q3 2N5179
Q4 2N5179
OUTPUT (50 OHMS)
1000
10
150
120
91
(A)
EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (μF); OTHERS ARE IN PICOFARADS (pF OR μμF); RESISTANCES ARE IN OHMS; k = 1 000, M = 1000 000.
1.8 – 1.9 MHz
50 OHMS
68
220
50 S.M.
C1 200
1000 S.M.
C2 200
L1
L2
-1 dB
5.8
870
BWL = 100 kHz IL = 0.5 dB
f₀ = 1.85 MHz
S.M. = SILVER MICA
(B)
(C)

Fig. 3 — The W7ZOI broadband 40-dB preamplifier is shown at A. Capacitors are disk ceramic or chip types. Resistors are 1/4-w composition. The upper 3-dB point of the amplifier is at 65 MHz. Heavy feedback is used to stabilize gain and provide a 50-ohm characteristic. At B is a 1-dB attenuator pad which can be used between an antenna of unknown impedance and the filter at C to provide a proper load for the filter. The Butterworth band-pass filter at C is suitable for use with the preamp at A. It will help reject out-of-band signals to improve the IMD characteristics of the preamp. When the preamp is used with nonresonant receiving antennas, it will be necessary to employ the filter to protect the preamp from signals across its response range (bc band through vhf). The preamp and filter would be fine for use with Beverage antennas. C1 and C2 are mica trimmers. L1 and L2 consist of 31 turns of no. 22 enameled wire on Amidon T68-6 toroid cores (5.1 μH).

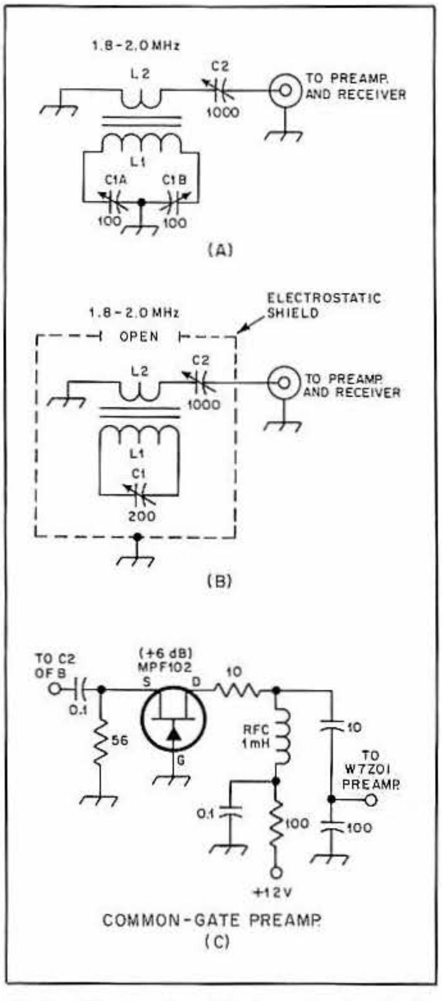
1.8 - 2.0 MHz
L2
C2
1000
TO PREAMP. AND RECEIVER
L1
C1A
C1B
100
(A)
ELECTROSTATIC SHIELD
OPEN
C1
200
(B)
TO C2 OF B
(+6 dB)
MPF102
S
D
G
0.1
56
RFC 1mH
10
TO W7ZOI PREAMP.
100
+12V
COMMON-GATE PREAMP.
(C)

Fig. 4 — The drawing at A shows the circuit of a 7 X 5/8-inch (178 X 16-mm) ferrite-rod loop (see text). At B is the final version which employs an electrostatic shield. C1 and C2 are mica compression trimmers (see text for other details). The circuit at C was used ahead of the W7ZOI preamplifier to improve the system noise figure.

A step attenuator was inserted between the W7ZOI preamplifier and the station receiver so that unity gain could be established between the loop and the 160-meter vertical (22 dB of gain had to be gotten rid of). An antenna switch was added to the system to permit rapid comparisons between the antennas.

Extensive tests proved that the loop outperforms the vertical by a substantial margin when it comes to digging weak signals out of the noise (man-made and atmospheric). The author has copied PA0HIP, PY0ZAE, G3MYI, W6RW, W6BLZ, W5AB and others perfectly Q5 on the loop (indoors) when they couldn't be found, or were unreadable on the vertical. It is only fair to say that on some occasions the vertical was the better antenna for receiving. Propagation conditions and ambient noise levels at a given time will determine which antenna can provide the best reception. Typically, the ambient noise level from the W1FB vertical is S3 on a receiver that is calibrated to indicate S9 on a 50-μV signal.[3] The same receiver shows no noise response when the loop is connected to it. However, static crashes (atmospheric noise peaks) are as loud with the loop as they are with the vertical when a storm is in the immediate area. Noise from distant storms can be discriminated against by turning the loop null toward the storm front. It appears that the major part of the author's ambient noise is man-made in nature. At times it peaks as high as S8.

When the loop is used indoors it responsds to unwanted 15.750-kHz TV spurs, and when appliances are actuated the transients kick the receiver S meter rather hard. This is because the loop is contained within loops formed by house wiring. This type of interference has not been observed while using the vertical antenna, even though it is affixed to the rear of my house. To prove that the house wiring was causing the problem with TV birdies and transients, the loop was located out-of-doors for two nights. The interference vanished!

Some Other Loop Experiments

Ferrite-rod loops have been used to advantage for many years (bc-band radios, direction-finder receivers for boats and aircraft, etc.), so it seemed worthwhile to investigate a model of that type of antenna before concluding the tests. Two versions were tried, each with a preamplifier.[4] The first consisted of a single 7 × 5/8-inch (178 × 16 mm) Amidon Assoc. ferrite rod on which was wound a 40-turn solenoidal coil of no. 22 insulated hookup wire. The loop was tuned to resonance by means of a 100-pF per section split-stator variable. A four-turn output link was wound over the center

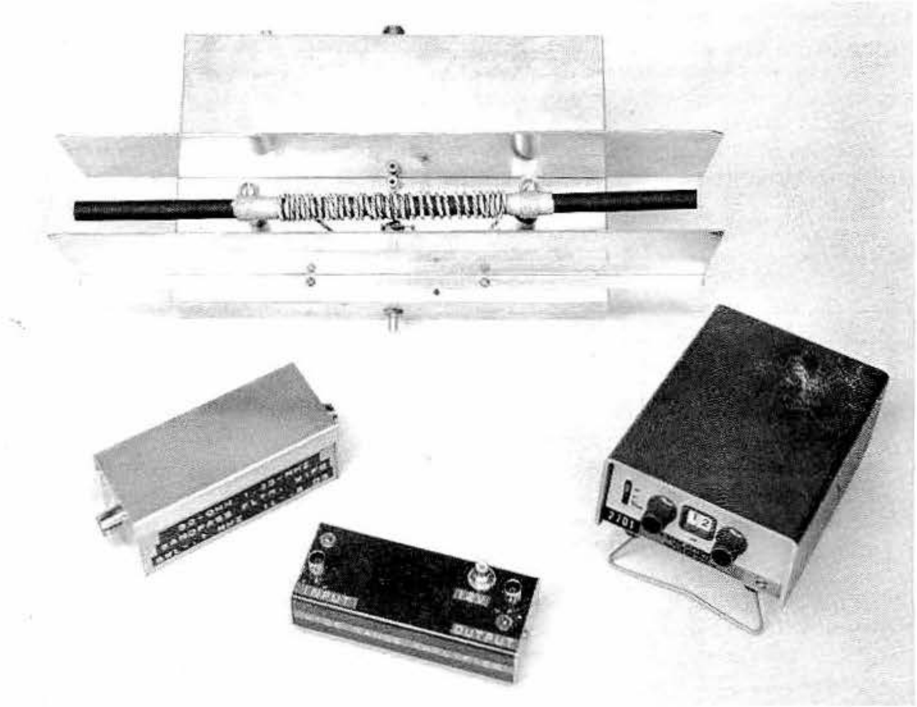

View of the ferrite-rod loop and test setup accessories. In the foreground (left) is the Butterworth band-pass filter. Below it at the center is the broadband preamplifier, and the Tektronix 2701 step attenuator is at the far right.

of the primary winding. The latter occupied approximately 3 inches (76 mm) of the center portion of the rod. A small aluminum chassis served as the foundation for the antenna, and the rod was spaced some 3 inches (76 mm) above the chassis. Performance tests showed the antenna to be less efficient than the large 5-turn wire loop. As referenced to the 75-foot (22.86-m) vertical, the ferrite loop was —38 dB. Furthermore, it was prone to the same induction effects which plagued the wire loop when both were used indoors. The rod-loop null was dismal — some 10 dB!

An improved model of the loop was built by using epoxy cement to join together a pair of 7-inch (178-mm) ferrite rods, end to end. The sensitivity (μV per meter) increases with the length of the rod, but is dependent upon the length of the coil which is wound on the rod. A multilayer coil contained at the center of the rod should be considerably better than a solenoidal coil spread over the major portion of the rod: The shorter the coil, the higher the Q of the antenna.

The author did not have Litz wire available, and was unable to build a multilayer coil, so a short solenoidal winding was placed on the center 5 inches (127 mm) of the 14 × 5/8-inch (356 × 16 mm) rod. It consisted of 32 turns of no. 12 insulated wire, spaced one wire diameter between each turn. The ferrite rods are made of Q2 material (μ = 125).

Fig. 4 shows the schematic diagram of the rod loop. A four-turn output link is wound over the center of L1. C1 is a mica compression trimmer which tunes the loop to resonance. C2 is used as a coupling capacitor to control the loop loading.

It seemed worthwhile to try shielding the loop, so a pair of aluminum L brackets were bolted to the chassis as shown in the photograph. Each bracket is 16 × 3-3/4 inches (406 × 95mm). The shields are spaced 1 inch (25 mm) either side of the loop.

The top of the U-shaped channel must be left open to prevent the shield from acting as a shorted turn. Proof of the effect can be seen by shorting across the open end of the trough (over the center of the rod) with a screwdriver. The received signal will vanish! An electrostatic shield, when used with a loop antenna, should minimize induced fields from nearby conductors and precipitation static, thereby making the system better for indoor use.

Rod-Loop Tests

The same outdoor test setup was employed for checking the performance of the rod loop. The nulls occur off the ends of the rod, and maximum response is found off the broad sides of the rod. A null of —23 dB was obtained with the loop, but efficiency was less than that obtained with the 5-turn wire loop. When compared to the 75-foot (22.86-m) vertical a reading of —31 dB was obtained, 13 dB inferior to the wire loop. The noise figure of the W7ZOI broadband preamplifier was too high for use with the new antenna, so a common-gate JFET pre-preamplifier was added between the loop output and the input to the 'ZOI unit. Ideally, a 30- or 35-dB preamplifier (two JFETs) should be used with the rod loop to assure a low noise figure and ample gain.

With the coupling set for maximum loop gain, the bandwidth (measured with an HP spectrum analyzer) is 10 kHz at the 3-dB points. The loop was measured independent of the shields and preamp for unloaded

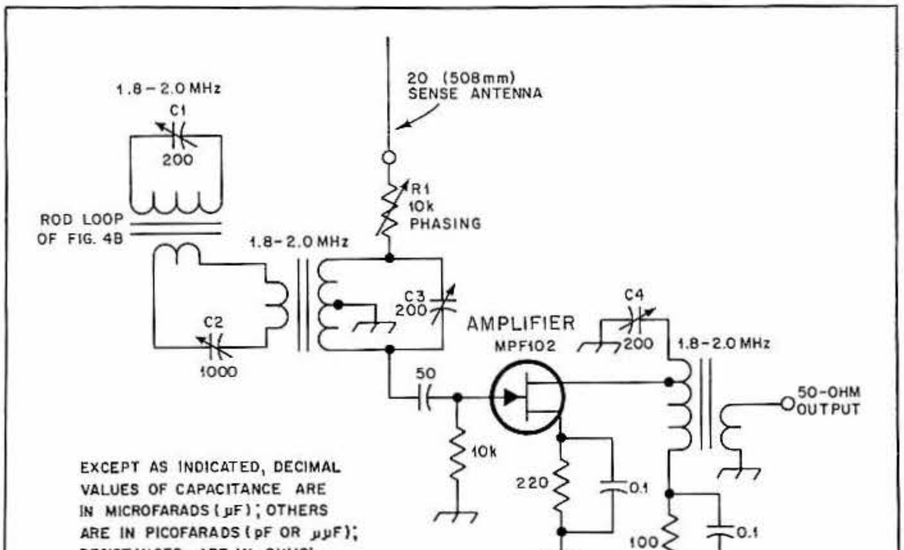

Fig. 5 — Suggested circuit for using a sense antenna with the rod loop. The sense antenna can be mounted 6 to 10 inches (152 to 254 mm) in front of the broadside of the rod loop (centered). C1, C2, C3 and R1 are adjusted alternately for the deepest null possible off the rejection side of the loop (side opposite the sense antenna). It may be necessary to experiment with the length of the sense antenna to obtain the best null in the cardioid response pattern. The tuned circuits for the JFET preamp can be wound on T-68-2 toroid cores.

Q by means of an HP Q meter. A reading of 430 was obtained.

The electrostatic shield cured the unwanted pickup of TV spurs and appliance transients during indoor use. The author would like to mention that the wire and rod loops are affected to some extent by the presence of the 75-foot (22.86-m) vertical. The latter is only 20 feet (6.10 m) away from the operating position. It tends to reradiate noise and signals. Some of that energy is picked up by the loop antennas. If an indoor loop is to be used regularly, or if it is outdoors, but within 100 feet (30.48 m) or so of the vertical, the latter should be shorted out or detuned during the receive period. An spst relay could be slaved to the regular antenna change-over relay to accomplish this.

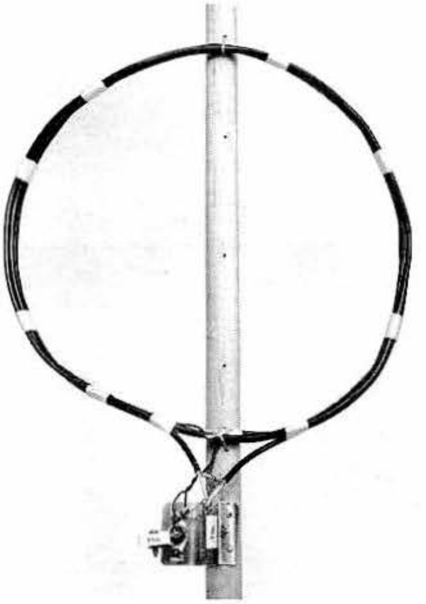

The 4-turn coax loop with electrostatic shielding. The trimmers are visible on aluminum brackets below the loop.

An improvement in performance for either type of loop could be had by adding a sense antenna and appropriate phasing circuit (Fig. 5). This would provide a cardioid pattern and result in a unidirectional response. Greater reduction of QRN and QRM would be effected through that technique. A weatherproof system of that type could be placed out-of-doors for year-round use. A TV type of rotator would be useful for changing the loop position, as desired.

The W1FB 4T-ES Loop

During a final investigation of loop types and performance characteristics, an attempt was made to devise a shielded loop small enough to be practical indoors. The primary objective was to develop a loop from ordinary materials — something that was inexpensive and easy to build. It should have efficiency comparable to that of the 5-turn wire loop described earlier in this report. A reasonable null depth and an undistorted pattern were sought also. From these criteria evolved the 4T-ES (four turn, electrostatic shield) loop shown in Fig. 6.

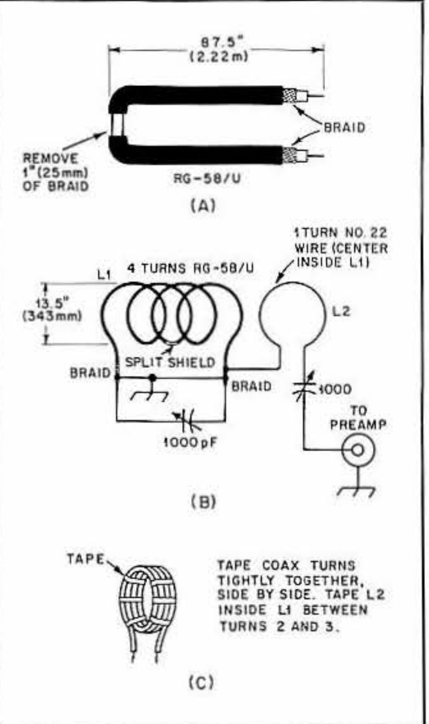

Fig. 6 — Structural details of the W1FB 4T-ES loop antenna. At A is an illustration of the total length of RG-58/U before the loop is formed. An expanded view of the loop turns and pickup link is given at B. Drawing C shows how the loop turns are taped together side by side as the antenna takes its final form.

It consists of four turns of RG-58/U cable which are formed into a circular configuration to provide a diameter of 13-1/2 inches (343 mm). There is nothing critical about the diameter, and RG-59/U coaxial cable could be used instead of the type specified. The turns are formed side by side, then taped at several points to maintain the loop form.

It is necessary to split the shield braid at the electrical midpoint of the loop. This prevents the shield from acting as a shorted turn. The principle is the same as that described for the ferrite-rod loop with its aluminum-channel shield. The braids are joined at the loop feed point and made common to one end of L2. The three grounded elements are then attached to the coaxial connector ground terminal on the loop support frame.

Loop performance was checked by using the test procedure discussed earlier. A null depth of —26 dB resulted. There was no discernible pattern warping, and the null occurred deeply over just a few degrees of rotation. The 4T-ES was 18 dB inferior to the 75-foot (22.86-m) vertical antenna when checking distant signals. The unloaded Q was measured by means of the HP Q meter. A value of 85 was obtained. Because C2 was set for light loading of the loop, a bandwidth (3-dB points) of 20 kHz was obtained when the preamplifier and receiver were connected to the antenna.

Numerous comparisons were made on DX signals from Europe and the Caribbean area during the ARRL DX Contest in March of 1977. In all instances the 4T-ES was as good as or better than the 75-foot (22.86-m) vertical. Ambient noise was considerably lower in amplitude while using the loop, even though all tests were performed with the loop indoors at ground level. There was no reduction in atmospheric noise (which was high that weekend) because the maxima of the loop favored the N.E. and S.W. directions: The storm front was S.W. of Connecticut. However, rotation of the loop caused a drop of 26 dB in the static crashes when the loop nulls were S.W. and N.E. Because of the electrostatic shielding there was minimum noise induction from the house wiring — a contrast to the performance characteristics of the unshielded 5-turn wire loop. The W7ZOI broadband preamplifier and an attenuator were used during the tests. There were some instances when the loop provided a stronger signal response than the vertical, even though the two systems were adjusted for unity gain.

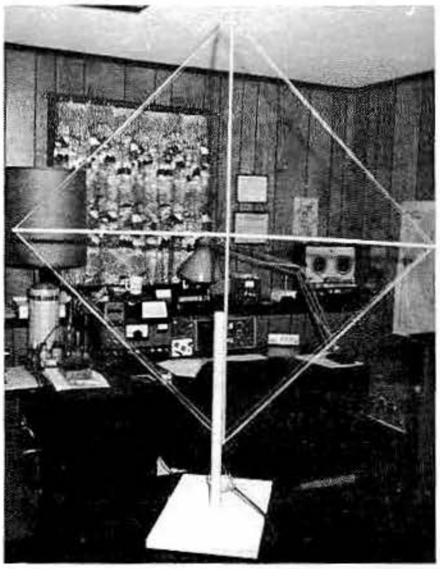

Close-up view of the 160-meter indoor receiving loop at W1FB. The antenna is resting on a piano bench, and is situated near the operating position so that it can be hand-rotated as necessary.

The 4T-ES is suitable for use indoors,

but it could be weatherproofed for outside installations. Epoxy cement could be used to seal the open ends of the coaxial cable of L1, and the trimmer capacitors would survive the natural elements if housed in a metal or plastic container.

In Summary

The loops that have been discussed here should be suitable for use on 40 or 80 meters if scaled accordingly. They may not show much directivity on sky-wave signals because of the "tumbling effect" at the higher frequencies. But QRM from nearby amateurs could be reduced greatly, and man-made noise sources could be rejected significantly by correct orientation of the loop.

The author has attempted to discuss some of the characteristics of small loops which are not treated in most of the references contained in amateur journals. There is plenty of latitude remaining for experimentation, and the reader is encouraged to apply his or her skills in developing better loops for amateur use. Meanwhile, why not build a small loop and scoop those weak signals out of the noise? It could mean some new countries for you on "top band" or 80 meters. This material was originally presented in *QST* by Doug DeMaw, W1FB.

References

[1] DeMaw, "A Receiving Loop for 160 Meters," *QST*, March 1974.

[2] Terman, *Electronic & Radio Engineering*, McGraw-Hill. Kraus, *Antennas*, McGraw-Hill. Jasik, *Antenna Engineering Handbook*, McGraw-Hill. Keen, *Wireless Direction Finding*, 3rd Edition, Iliffe & Sons, Ltd.

[3] DeMaw, "His Eminence — the Receiver," Parts 1 and 2, *QST*, June and July 1976. Receiver used in combination with an Autek Research QF-1 RC active audio filter.

[4] DeMaw, "Build This Quickie Preamp," *QST*, April 1977.

The Half Square Antenna

Do those 100 countries still elude you for 80-meter DXCC? In terms of dollars versus decibels, a half-square antenna may be your best bet for putting punch into your signal.

With 5-band DXCC as bait, considerable interest has arisen in DX and antennas for the lower frequency ham bands. The author's attempts to get a decent 80-meter DX antenna have gone through an evolutionary cycle with a lot of iterative tries and with steadily improving results. The half-square antenna that is the latest of these has some interesting properties and gives about as many "dBs per buck" as any this author has seen.

Before describing this configuration, it might be interesting to cover briefly the different antennas tried which didn't work as well. The writer's available options were set up by (1) a yard full of tall trees and (2) very little money to spend. The first antenna was an inverted V hung on the 75-foot (22.9-m) tower. This is really a quite good antenna — primarily because it has the high current part of the antenna at the highest support point. It provided a standard against which all succeeding antennas were checked. The next step was to add a parasitic element (director) which didn't seem to help at all. This is perhaps not so surprising with the ground so close. Viewed simply, normal parasitic coupling is dependent upon a fair proportion of the current in the driven element being coupled to the parasitic element. When they are both close to the ground, the reverse polarity of the image of the driven element starts to couple heavily to both the driven element and the parasitic element, making it practically impossible to get the desired parasitic current at any useful spacings.

This effect has been shown experimentally to be less with closed-loop type antennas such as the quad. Based on this supposition, the author next constructed a 2-element quad, supported at the corners by ropes tied off to trees. With only 75-foot (22.9-m) trees and the consequent sag, the bottom was only about 6 feet (1.83 m) off the ground. However, the quad did work, had an acceptable feedpoint impedance, and gave a few dB (about 1/2 an S unit) improvement over the inverted V on European contacts. Obviously, the only useful low-angle radiation in this antenna came from the upper half of it, the lower half serving to feed or excite the upper half. A major problem with the quad was keeping it up. It had to be very tightly stretched between trees to keep it from sagging to the ground and as a result the wire often broke.

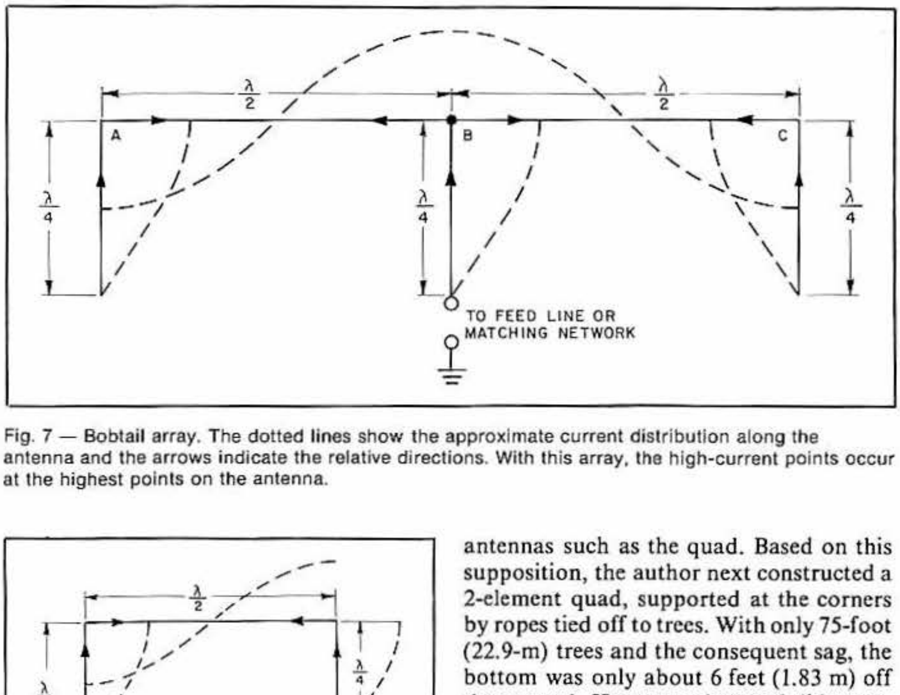

Fig. 7 — Bobtail array. The dotted lines show the approximate current distribution along the antenna and the arrows indicate the relative directions. With this array, the high-current points occur at the highest points on the antenna.

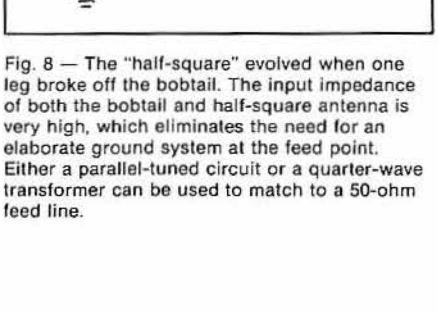

Fig. 8 — The "half-square" evolved when one leg broke off the bobtail. The input impedance of both the bobtail and half-square antenna is very high, which eliminates the need for an elaborate ground system at the feed point. Either a parallel-tuned circuit or a quarter-wave transformer can be used to match to a 50-ohm feed line.

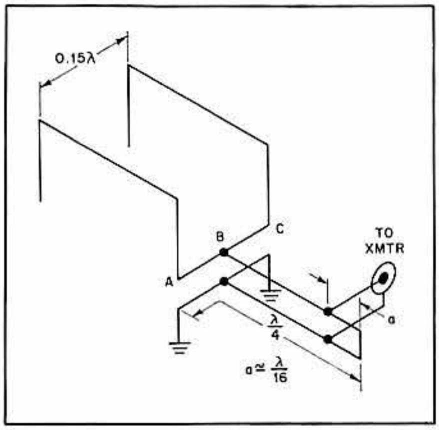

Fig. 9 — Two-element half square array gives greater gain and a very wide bandwidth.

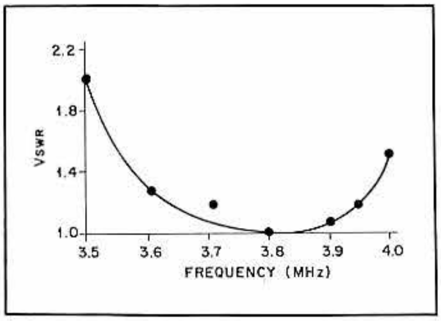

Fig. 10 — Measured SWR of the antenna shown in Fig. 9.

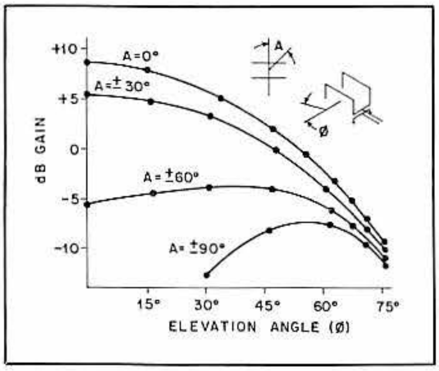

Fig. 11 — Computer-pattern plot for a 2-element half square array with 0.15-wavelength spacing between elements. The angles referred to in the drawing are shown in the inset.

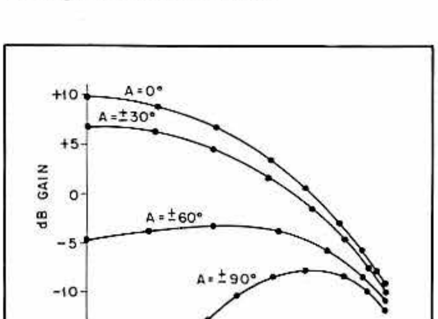

Fig. 12 — Computer-pattern plot for the antenna of Fig. 11 with 0.25-wavelength spacing.

To try another tack which would avoid the parasitic coupling problem an 8JK array with four half-wave elements was tried, all elements being fed. With the span of this being so long and with lots of high-voltage points which had to be kept from touching the trees, the author only managed to get it to a height of about 40 feet (12.19 m). The signal-report results with this were essentially identical to the quad on the path to Europe. The horizontal beamwidth was noticeably less than the quad. It probably would have done better if the writer could have gotten it to 75 or 80 feet (22.86 or 24.38 m) in height.

The next antenna tried was the so-called bobtail which is shown in Fig. 7. This is a broadside vertical array with approximately twice the current in the center leg as the two outer legs and with current distribution in the horizontal wires which tend to cancel horizontally polarized emission.[1] A major reason for trying this was the author's frustration with trying to use the maximum available height of the trees and still be able to feed the antenna and keep the high-voltage points clear of the tree branches. The author had avoided vertical antennas before because of the difficulty in getting a good low-loss ground. Also, the trees looked like great vertically polarized rf energy eaters. The bobtail is particularly nice for tree hanging since its highest support points (A, B, and C in Fig. 7) are all at low impedance and looked as if they could be directly slung over a tree limb with no insulators. It is fed from the bottom at a high-impedance point so the ground system doesn't need to be as good as it does with low-impedance feedpoints. Also, like the inverted V, the bobtail has its maximum current at the highest support point. It can be excited from a parallel-resonant tank circuit or a quarter-wavelength stub.

The bobtail has been an outstanding performer. It's at least an S unit better than the inverted V and works great on DX paths to the Far East (JA, KG6, and VS6). The author put up two of these at right angles and found their interaction to be practically nil even though their center legs are quite close. When switching, the author ground the feed point of the one not in use.

The Half-Square Antenna

With such fine results, it was thought the ultimate "tree-hung" antenna had been discovered. However, after a particularly bad storm, it was noticed that one leg of the bobtail had broken off and yet the antenna feed impedance hadn't changed noticeably. Furthermore, the results compared with the inverted V seemed about the same as the full bobtail. Fig. 8 shows the configuration. It is a 2-element (instead of 3) vertical broadside array with the same current in both legs. It has all the advantages of the bobtail except that the radiation from the horizontal part of the antenna doesn't cancel as well in all directions and some end-fire, horizontally polarized energy does spill off. This might be considered an advantage or a disadvantage, depending on whether you're seeking coverage or discrimination! In discussing this with Ed Watters, WA3LGX, he pointed out the kinship this antenna has with the bisquare array. It's sort of half of a bisquare laid sideways with the ground image antenna making up the other half. That, plus its obvious shape, led the author to dub it the half-square antenna.

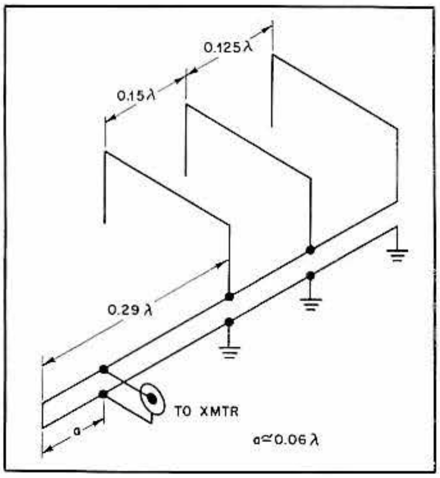

Fig. 13 — A 3-element half-square array.

After using a single half-square for awhile, it was decided to add another element with about 0.15-wavelength spacing. With the new element in place, a check was made to see what parasitic coupling there might be between elements. With several hundred watts fed into the driven element there was no evidence of rf on the parasitic element (using a neon bulb). This was a very gross measurement which tended to confirm what was expected. The very close proximity of the antenna to ground tends to reduce greatly parasitic coupling to a nearby element. Being puzzled why it should appear so small, the only hope was to devise a means of measuring this coupling more accurately.

Having had to tear down the 8JK antenna to get enough wire for this antenna, as a first try for feeding it, the author just used the 8JK open-wire line and stub match as it existed. The one wavelength of wire for each element was taken directly from the 8JK also. Fig. 9 shows the configuration. Unlike the 8JK, which was narrowband (centered around the middle of the band), this configuration gave the very flat SWR shown in Fig. 10 — on the first try! The SWR was not very different whether the feed-line stub was connected to point A, B, or C (Fig. 9). B gives a bidirectional characteristic while connection to A or C gives some unidirectivity. The author is still suspicious of the wide bandwidth and suspects the two elements may be different effective lengths, giving a stagger-tuned effect. If the spacing between these two were increased to a quarter wave and fed at point A or point C, it should theoretically add another couple of dB gain

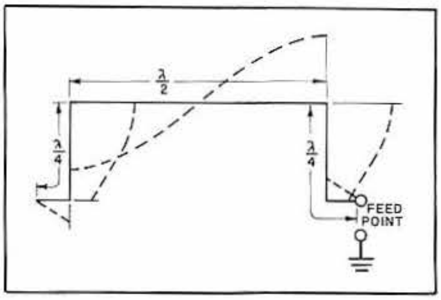

Fig. 14 — Any of the antennas mentioned can be bent as shown in order to keep the current loops at the upper corners.

and give a more significant front-to-back ratio than with the 0.15-wavelength spacing. WA3LGX plugged the dimensions and shape of this antenna into a generalized computer program he has developed for wire antennas and got the curves shown in Figs. 11 and 12. Fig. 11 defines the forward pattern for 0.15-wavelength spacing assuming a perfectly conducting earth. Fig. 12 is for quarter-wave spacing. The actual patterns will be modified at angles below 10° to 15° by the earth's resistivity[2] as is the case with any vertical antenna. The 0.15-wavelength-spaced antenna was used for some time and consistently gave better results than the bobtail on the path to Europe.

The writer took one other step beyond the 2-element array and added another element at 1/8-wavelength spacing (see Fig. 13). The extra element is fed, as are the other two, with an extension of the same open wire line. This antenna is considerably quieter (less QRN) than any of the other 80-meter antennas the writer had and has better than half an S unit advantage over the bobtail on European signals. It doesn't require any retuning to cover the whole band.

With these antennas not insulated at their support points, one might expect some effects when the tree sap rises or in wet conditions. The author hasn't been able to notice any differences from dry weather to monsoon-type rains or wet snow covering everything. The trees are slightly over 1/4-wavelength high on 80 meters. Considered as antennas or absorbers, they would look like grounded 1/4-wavelength vertical radiators. The vertical sections of the half-square antenna that run close to the trees are just the opposite. That is, at the bottom of the antenna the voltage is high and at the top, the voltage is low. This should minimize coupling to the trees, as opposed to, for example, using 1/4-wavelength grounded verticals for the antenna elements.

160-Meter Operation

Now if you look closely, you can see that the 80-meter half-square whether 1, 2 or 3 elements, should make a good antenna for 160 meters. Each element is 1/2-wavelength long on 160 meters, voltage fed on the end, and the high current part of the antenna is at the maximum height. True, a higher impedance part of the antenna touches the tree, but you can't have everything free! While not having managed to work any DX with the few watts available on 160 meters, the author can *hear* Central European ham stations quite well on this band for the first time ever at this location. Of course, a different stub or tuning arrangement is necessary for getting a low SWR on 160 meters. The writer just unshorted the stub and put a tapped coil (about 14 microhenries) in series with the coax feed line to tune it.

Construction Details

These antennas were all built with no. 14 soft-drawn copper wire. The elements are pulled over the top limbs of trees that have approximately the correct spacing and tied to nylon strings at about shoulder level. If your trees aren't a full quarter wave high, the extra wire can be stretched out parallel to the ground at each end as shown in Fig. 14. Note that you still get the maximum current point at the highest support point you have.

The best technique found for getting a line over the highest tree is to use a fisherman's casting reel (I use a Zebco 202) with an 8-pound nylon line and a 1- or 1-1/2-ounce sinker. The reel is put in the RELEASE position and a sling shot is used to shoot the sinker and line over the desired tree. This is a very accurate technique and you can easily put a line over 90-foot (27.43-m) trees. The light fishing line is used to pull over a heavier line. It's a good idea to paint the sinker a bright color since the line is almost invisible. You can waste a lot of time looking for the sinker at the end of the line.

Be sure to leave enough droop in the horizontal section of the antenna to allow for tree motion in high winds. The open-wire feed line used for the harness and stub sections is made with the same no. 14 wire spaced 3-1/2 inches (89 mm).

The avid Field Day or camping fan will notice the obvious advantages of the half-square antenna for that type of operation. It uses minimum materials, goes up very quickly, will really put out a booming signal on 80 meters, and can be taken down in just a few minutes. You can also make good use of the fishing rod in between your turns at the key. This material was originally presented in *QST* by Ben Vester, K3BC.

References

[1] [Editor's Note: While complete cancellation of the horizontally polarized component occurs at a point broadside to the array, some radiation from the flat-top portion will exist at other angles. This is because of incomplete cancellation of the components from the opposite ends of the flat top.]

[2] *The ARRL Antenna Book*, 12th Edition, p. 46.

The HRH Delta-Loop Beam

Here's an antenna that should excite the interest of the amateur fraternity. The Delta-Loop beam has all the features of a quad without many of the disadvantages.

The evolution and design of the antenna shown in the photographs came about primarily because of a lack of confidence in the mechanical durability of quads. Anyone who has ever built and used quads knows how difficult it is to keep them up in icing and high wind conditions.

The author being an old-time mechanic, felt there had to be a better design for an antenna that used full-wave elements in a parasitic array, so some years ago a start was made to find that better design. One thing that nearly all readers will agree is that Mother Nature is about the best designer there is. Along these lines, just observe the growth of branches on tree limbs. You'll find that many of the smaller branches will grow up in a semivertical pattern from the limb; see Fig. 15. It takes a considerable amount of icing and wind to break such branches, indicating the soundness of the design. This same idea should apply to elements mounted on a boom.

To test the idea, an element of aluminum tubing was mounted on a boom. The element was mounted as shown in Fig. 17. The boom was then secured to the family car with the element in a vertical position. The assembly was then tested at 65- to 75-mph. Even though the element was only secured to the boom as shown in Fig. 17, there was no "set" or permanent bending. This test opened the door to several possibilities in beam design.

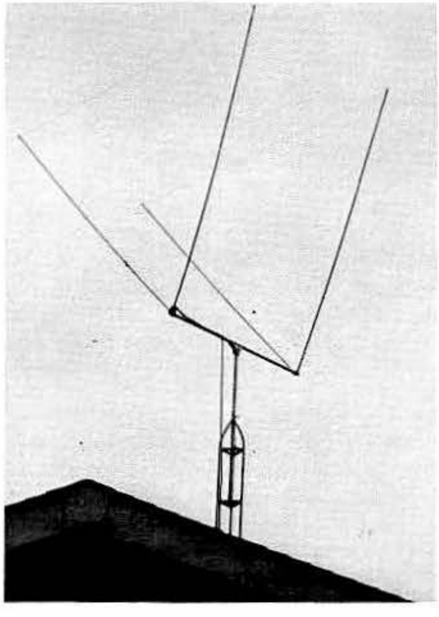
This is a 10-meter, 2-element Delta Loop that is very similar in construction to the antenna described in the article.

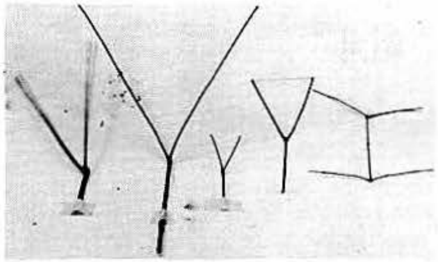
Fig. 15 — The basic idea for the Delta-Loop beam was conceived from the growth of tree limbs and branches. Here are just a few of nature's configurations that lend themselves to antenna design!

A loop aerial can take many shapes. Anyone who studies the history of the quad will find that many different configurations have been used. Why not use a triangle?[1] It should be possible to achieve a very good design using a vertical triangle. See Fig. 16. This shape appears ideal for a beam with full-wave elements, and has most of the advantages of the quad without many of the disadvantages. This led to the construction of several antennas of the type shown in the photographs, and some of these advantages become quickly apparent.

First, the entire antenna is *above* the boom. Second, the antenna is constructed primarily of aluminum tubing, which provides extra strength as compared with wire elements. Third, the antenna has Plumber's Delight type construction, meaning that the antenna is at ground potential for lightning protection, plus the fact that this type construction lends itself to gamma matching of the feed point, eliminating the need for a balun. Last, but not least, we find the antenna is very attractive in its symmetry. Of course, the important point is how well does the antenna perform?

Several 10-meter models have been tested and the unit shown in the roof-mounted position is 20-meter Delta Loop. Using a gamma match with 50-ohm coaxial feed, a 10-meter model was matched at 28.8 MHz. The antenna consisted of a driven element plus reflector with the elements spaced 6-1/2 feet (2 m) apart, or approximately 0.2 wavelength. Surprisingly, the antenna was extremely flat across the entire 10-meter band, the worst mismatch being *less* than 1.2 to 1.[2]

The author has no means of measuring gain or front-to-back ratios. However, with the spacing and element sizes the same as a quad, the gain should be the same, or at least so close the difference would be insignificant. On-the-air tests have shown the antenna to be as good as or better than quads the author has had up. Front-to-back and front-to-side reports have been outstanding, both on ground wave and skip.

Element Lengths

Many tests have been made on driven elements to determine the effect of element lengths on SWR. It was found that the flattest curve was obtained with the formula

$\frac{1005}{f_{MHz}}$ (feet)

for the driven element. The reflector should be about three percent longer, or

$\frac{1030}{f_{MHz}}$

If directors are desired it would appear that a length three percent shorter than the driven element would be adequate.

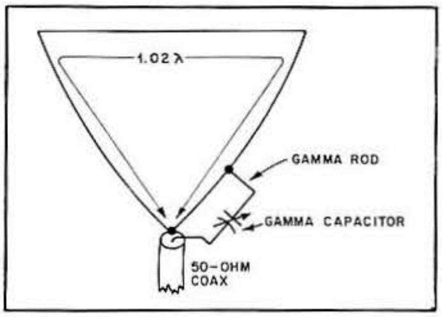

Fig. 16 — This drawing shows the driven element and feed method of the Delta Loop. Tests have shown that the overall length of the antenna is slightly longer than a wavelength (1.02λ). Each side of the antenna is approximately 1/3 wavelength long. The top, or wire section, is made slightly shorter to put tension on the vertical members.

Table 1

Bill of Materials

Tubing used is 6061 T6.
4 — 12-foot lengths of 3/4-inch OD, 0.035 wall (elements).
1 — 12-foot length 1-3/4-inch OD, 0.065 wall (boom).
8 — 3/4-inch diameter stainless steel hose clamps.
1 — 9-inch length of 3/8-inch OD by 5/16-inch ID.
1 — 9-inch length of 1/2-inch OD to slide over 3/8-inch section.
25 feet of copper wire no. 12 or 14, or equivalent in stranded wire.

Feet X 0.3048 = m.
Inches X 25.4 = mm.

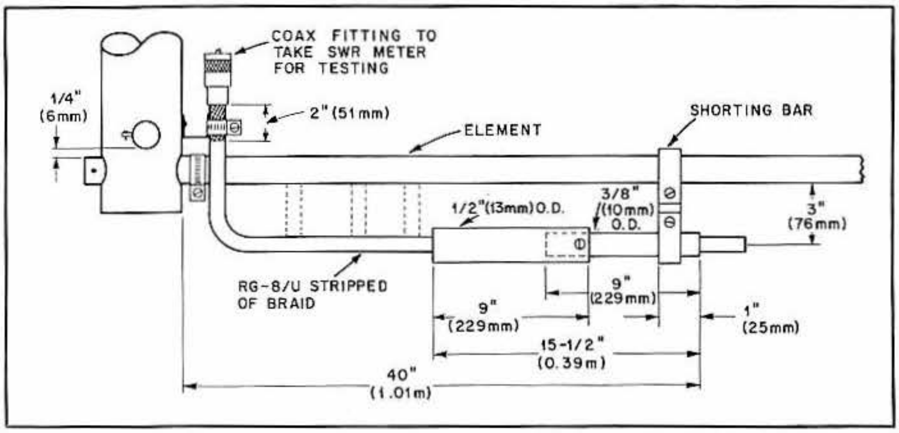

Fig. 18 — Here are the details on the gamma-matching section. As mentioned in the text, the coax fitting can be a female type SO-239, mounted on a small bracket which is mounted on the boom. Spacing insulators for spacing the gamma line from the element can be made up from pieces of Lucite or Plexiglas.

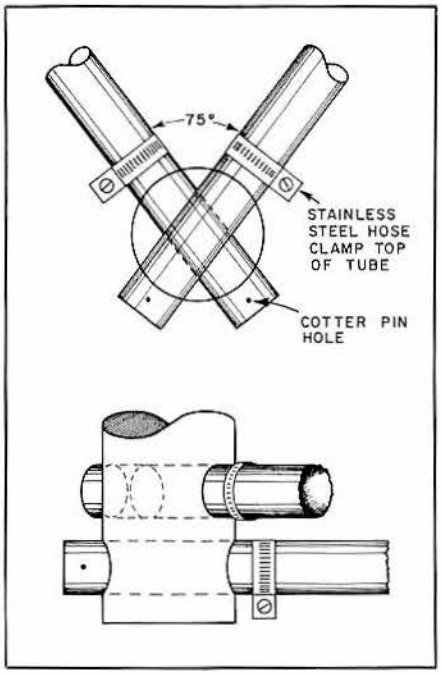

Fig. 17 — This drawing shows the method of mounting the element to the boom. A cotter pin is used on the under side of the boom and a hose clamp on the top to hold the element securely to the boom.

Here is our roof-mounted 20-meter Delta-Loop beam that is now undergoing a series of tests.

As to element spacing, the author has long been an advocate of wide spacing (0.17 to 0.2 wavelength) whenever possible. In the 10-meter tests 0.2 wavelength spacing was used.

For readers who are interested, complete construction information on a 10-meter model, including a list of the required tubing, follows.

Construction Notes

Fig. 17 shows the method of mounting the element tubing to the boom. The angle between the semi-vertical elements is shown as 75 degrees but this can vary a few degrees either way without any appreciable effect on the performance of the array. It is difficult to drill and line up the element support holes in the boom and come out to *exactly* 75 degrees.

There are a couple of methods of making the holes in the boom to hold the elements. One of the simplest is to use a Greenlee-type chassis punch. This makes a clean hole in the boom. Another method is to drill holes large enough to take the end of a 3/4-inch (19-mm) reamer and then ream out the holes to the necessary diameter.

One not accustomed to working with angles might find it difficult to drill holes at a 75-degree angle. A simple method is to first drill holes to take a single element. Next, make a jig from a piece of stiff cardboard or similiar material, using a protractor to get the 75-degree angle. Then insert the single element into the boom and lay the jig along the element; this will give you the correct alingment for the other element.

The elements are inserted through the boom just far enough to take a cotter pin on the underside of the boom. On the top side, a hose clamp is used to hold the element to the boom and prevent slippage. A length of copper wire can be wrapped around both elements just below the clamp to insure a good contact between the elements and the boom. Hose clamps are also used at the tops of the elements to hold the horizontal wire.

Fig. 18 shows the details of the gamma matching section. The gamma section is made up from the inner conductor of the coax, including its insulation, and two sections of telescoping aluminum tubing. The outer covering and braid is removed from a 52-inch (1.32-m) length of RG-8/U coax. In Fig. 18, a male coax fitting is shown with a short length of braid, 2 inches (51 mm) long, which is grounded to the boom via a clamp and bracket. If desired, a chassis-type coax fitting, type SO-239, could be mounted on the boom with a small metal bracket. The capacitor section is made of two lengths of tubing 3/8-inch (10 mm), and 1/2-inch (13 mm) diameter, respectively, and both 9 inches (229 mm) long. The 3/8-inch (10 mm) tubing fits over the insulation around the coax inner conductor while the 1/2-inch (13 mm) tubing slides over the 3/8-inch (10 mm) material. The larger tube is drilled and tapped to take a locking screw. Spacing of the section from the element is 3 inches (76 mm).

In adjusting the gamma, figures given in

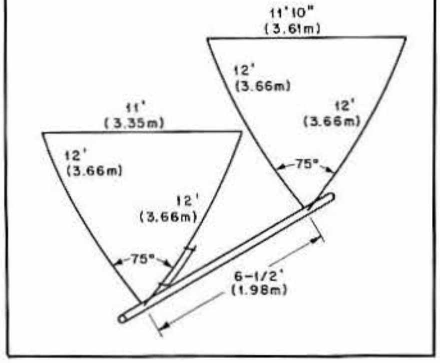

Fig. 19 — For those interested in exact figures, this sketch provides the element and boom lengths for a Delta-Loop beam for 28.8 MHz.

Fig. 19 can be used as a guide. In order to avoid matching errors, the gamma should be adjusted with the SWR bridge right at the beam. Set the shorting bar to the dimension given in the diagram and slide the 1/2-inch (13 mm) tubing over the smaller tubing, looking for a setting that gives a match. If one cannot be obtained, move the shorting bar and sliding tubing assembly a short distance, say an inch (25 mm), and then try different settings of the 1/2-inch (13 mm) tubing until you find a match. We found that the settings were not critical in getting a match. Once the beam is matched, the regular feed line to the station can be attached to the feed point. The connection should be taped to prevent moisture from getting into the fitting and coax.

As stated earlier, the antenna is extremely flat across the entire 10-meter band. The present model was designed for 28.8 MHz and matched at this frequency. The SWR at the highest point, at 29.7 MHz, was about 1.2 to 1. This dropped to 1 to 1 at about 29 MHz and stayed at 1 to 1 all the way down to 28 MHz. This feature of the antenna certainly is a help when using a transceiver designed for 50-ohm output. The beam has proved its ruggedness through winds and icing conditions. All in all, we think the Delta-Loop beam is one of the best performers we have seen. This material was originally presented in *QST* by Harry R. Habig, K8ANV.

References

[1] [Editor's Note: A triangular loop configuration also was described in *QST* in April 1968, "Technical Correspondence" by Norman Watson, W6DL, independently of K8ANV's design. Mr. Habig has been working for some years on this design and has a patent pending.]

[2] [Editor's Note: A 10-meter model of the Delta Loop beam tested at ARRL headquarters was matched at 28.8 MHz and an SWR curve was made using a Bird Wattmeter. The largest mismatch also was less than 1.2 to 1 MHz (at 29.7 MHz).]

The Delta-Loop Beam on 15

DX capability, low SWR and readily available construction materials are highlights of this 15-meter beam antenna. Similar to a quad, but rugged as a Yagi — those are the virtues of the Delta Loop.

Some of the features of the 15-meter beam described in this article include a very low SWR across the entire band, use of readily available materials, "Plumber's Delight" type construction — which is always an appealing feature of any beam antenna — and last but not least, excellent performance. On the last point, the antenna shown in the photographs was tested during a DX contest with a transmitter input power of 100 watts. The boom of the antenna was mounted only eight feet (2.44 m) above the ground, but in about five hours of contest operation 58 different countries were worked — and, believe it or not, the majority of the reports received were 59. Possibly conditions were above par, but even so the antenna shows it can do a real job under crowded band conditions.

As stated above, the beam uses Plumber's Delight type construction. For the newcomer's information, this type of construction has the antenna elements connected directly to the boom which in turn can be connected directly to earth ground without having any effect on the performance of the antenna. This is desirable because of the lightning protection offered by the system.

Fig. 20 is a drawing of the Delta-Loop driven element. The overall length around the driven element is slightly over one wavelength. Each side is approximately 1/3 wavelength long. The reason we say "approximately" is that the top section of the antenna is made of wire and is slightly shorter than 1/3 wavelength in order to put tension on the wire. A gamma-match feed system is used, eliminating the need for a balun.

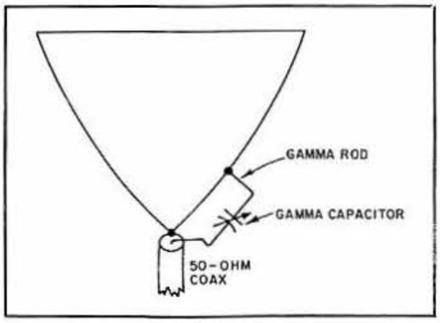

Fig. 20 — Basic configuration of the Delta-Loop driven element. Each side is approximately 1/3-wavelength long.

The formula used in figuring the driven element length is

$$\frac{1005}{f_{\mathrm{MHz}}},$$

where f is the desired resonant frequency of the driven element. The answer will be in feet. The reflector length formula is

$$\frac{1030}{f_{\mathrm{MHz}}}.$$

For a frequency of 21.2 MHz this figures out to a driven element 47 feet 5 inches (14.45 m) long and a reflector that is 48 feet 7 inches (14.81 m) long. Element spacing is approximately 0.2 wavelength or about 9 feet (2.74 m). Fig. 21 shows the two elements with the lengths of each segment.

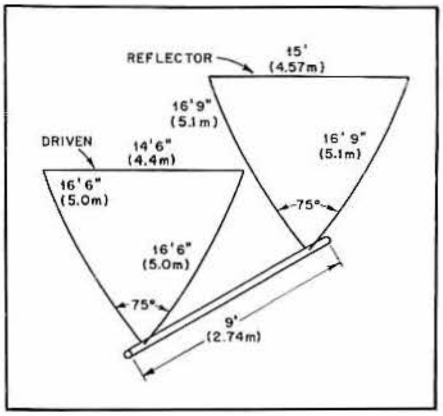

Fig. 21 — The element dimensions and the boom length. All measurements on the elements are made from where the element enters the boom; the portion of the element extending through the boom is not counted.

Material Requirements

The beam elements were built primarily from Reynolds Do-It-Yourself aluminum tubing, which *should* be available from most hardware dealers. The reason we say "should" is because in some sections of the country hardware stores don't stock the tubing. However, most dealers will order the tubing for you. If you live in an area near or in a city of reasonable size, a look through the Yellow Pages will show any aluminum tubing dealers. The Reynolds

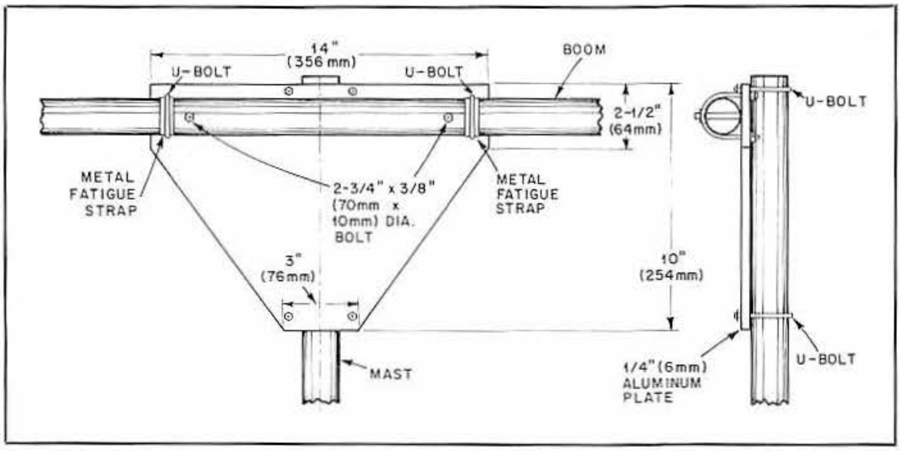

Fig. 22 — Construction details for the boom-to-mast mounting bracket. The U bolts holding the boom are 2-inch (51-mm) type. Those holding the mast will depend on the mast diameter — we used 1-1/2-inch (38-mm) U bolts for a 1-1/2-inch diameter mast.

Table 2

Shopping List

Quantity	*Length (ft)*	*Diameter (in.)*	*Reynolds no.*
4	8	1	4242
4	8	3/4	4222
2	6	7/8	4231
1	9	2	See Text.

3 feet of 3/8- or 1/2-inch diameter aluminum tubing.
12, 1-inch diameter hose clamps, stainless steel.
35 feet of no. 12 or 14 copper wire, solid or stranded.
1 variable capacitor, 100 pF maximum, 0.025 spacing or greater.
1 one-quart freezer container.
1 SO-239 Coax chassis connector.
5 1/4-inch diameter aluminum nuts and bolts, 1-1/4-inches long.

Feet X 0.3048 = m.
Inches X 25.4 = mm.

Do-It-Yourself tubing comes in 8-foot (2.44-m) lengths but most of the commercial tubing available from metal distributors comes in 12-foot (3.66-m) lengths. If you obtain the 12-foot types, be sure to specify type 6061 (61S) alloy as this material affords excellent strength for antenna elements. The boom used in this antenna was made from this alloy and is 2 inches (51 mm) in diameter with a 0.065-inch (1.65-mm) wall. Another source of aluminum or steel tubing is electrical supply houses; although this type of aluminum is a little too soft for the elements it would be suitable for a boom. Also, electrician's thin-wall steel tubing is available in various sizes, including the 2-inch diameter, for a boom. In a pinch, the boom could be made of wood, such as a length of 2 × 4. In such a case, the bottoms of the elements could be connected together with a length of wire to maintain the Plumber's Delight feature. The shopping list included here should prove of help in purchasing the parts.

Construction

The first step in building the antenna is to make up the vertical elements. The description given here is based on using the Reynolds tubing. Using a hack saw, cut the 7/8-inch (22-mm) tubing into 2-foot (0.61-m) sections. This particular type is made by Reynolds for the purpose of telescoping the 1- and 3/4-inch (25-mm and 19-mm) diameter sections together and comes in 6-foot (1.83-m) lengths. After cutting off four 2-foot (0.61 m) lengths you'll have one 4-foot (1.22-m) piece remaining. Cut this into four 1-foot (0.31-m) lengths and set these pieces aside for the time being.

Next, cut two lots, the thickness of the hacksaw blade, about 2 inches (51 mm) deep in one end of each of the 1-inch (25-mm) and 7/8-inch (22-mm) diameter lengths. Slide the 7/8-inch tubing inside the 1-inch diameter to a length of about 6 inches (152 mm) and then slip the hose clamps over the slots and tighten them. The 3/4-inch (19-mm) tubing can then be inserted into the slotted ends of the 7/8-inch (22-mm) tubing and these sections clamped with hose clamps. Two of the elements should be adjusted to the proper length for the driven element and two for the reflector, as per Fig. 21 (or whatever length you wish from the formulas). Some amateurs may prefer to cut their antennas for the cw portion of the band and others for the phone section.

The next step is to cut the 1-inch (25-mm) holes in the boom to take the ends of the 1-inch diameter elements. We used a 1-inch chassis punch to make the holes, but a 1-inch metal reamer could also be used. The aluminum is easy to cut or punch so making the holes should be no problem. What can be a problem is lining up the holes so that the 75-degree angle between the elements is obtained. We made a jig from a piece of cardboard, using a protractor. Once one set of holes for the director and reflector were made the elements were temporarily mounted in the boom. The cardboard jig was laid on the elements and the 75-degree holes were marked off and drilled.

When the holes are all drilled, the boom can be laid on the ground and the element ends inserted into the boom holes. We allowed about 1/4-inch (6-mm) extension of the base of the elements through the boom so as to allow space for cotter-pin holes. However, before drilling the cotter-pin holes, insert the four 1-foot (0.31-m) lengths of the 7/8-inch (22-mm) tubing into the elements at the boom. This will serve to give added strength to the elements at the support point. Drill each of the four ends to take the cotter pins and install the pins. Tighten down the hose clamps on the top side of the boom to secure the elements in place.

Drill the tops of the elements to take the 1/4- × 1-inch (6-mm × 25-mm) aluminum bolts. The top wires can then be installed.

The close-up view shows the gamma installation. The gamma capacitor is mounted inside a plastic freezer container which is held in place by a small metal L-shaped plate mounted on the box and the boom, using four self-tapping screws. This plate also holds an SO-239 coax chassis fitting to take the feed line. We like to install an SWR bridge directly at the beam when making SWR or matching tests to reduce matching errors, and having the fitting there simplifies the procedure. The gamma rod, made from a length of 3/8-inch (10-mm) aluminum tubing 36 inches (0.91 m) long, is flattened at one end for a length of 1-1/2 inches (38 mm).The flatted portion is bent over at right angles and drilled to take one of the 1/4- × 1-1/4-inch (6-mm × 32-mm) aluminum bolts, which is mounted through the top of the freezer box. The gamma rod is held in place by this bolt and by the shorting bar between the rod and the element. The shorting bar is made from a piece of aluminum, 1 inch (25 mm) wide and long enough to fit around the two pieces of tubing and provide a separation of 3 inches (76 mm) between the rod and the elements.

How you mount the antenna boom to the supporting mast will depend a great deal on what type of tower or supporting structure you have. The method shown in the photo is a fairly simple one, and easy to make up. Fig. 22 shows details of the construction of the mounting unit. The one shown in the photo supporting the beam was made from two pieces of 1/16-inch (2 mm) thick aluminum plate. However, we found that even with the double plate there was still too much "give" in the mounting setup, so a replacement was made from 1/4-inch (6 mm) thick aluminum. This made the mount competely steady. Either a plate of 1/4-inch aluminum or 1/8-inch (3 mm) steel should be adequate for the jobs. The 2-inch (51 mm) U bolts that hold the boom to the mounting plate were adequate, but just for added insurance, 3/8-inch (10 mm), 2-3/4-inch (70 mm) long machine bolts (two required) were installed through the boom and mounting plate for greater holding strength.

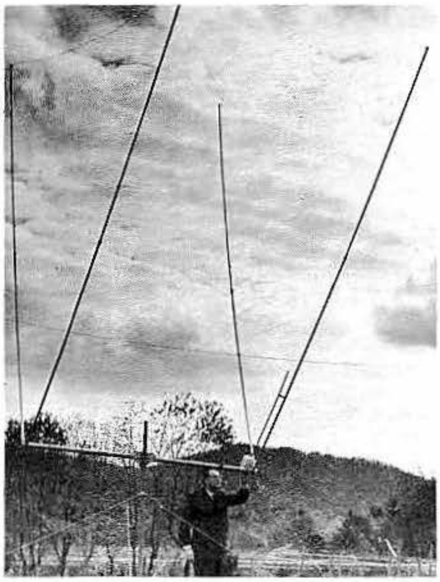

This view shows the completed antenna being matched.

During our tests, a weather front moved through the area and we had wind gusts up to 40 mph plus icing and snow loading on the antenna. The antenna and elements showed very little movement in these winds, and the entire antenna appeared very strong.

Adjustments

Adjustment of the gamma section is quite simple. Install an SWR bridge at the gamma feed point and tune up the rig on the desired frequency, Set the gamma shorting bar 24 inches (0.61 m) from the base of the gamma rod and tighten the gamma-bar nuts and bolts just enough to make electrical contact. Set the SWR bridge to read reflected power and adjust the gamma capacitor for a dip. The object is to find a setting of the capacitor and the gamma bar that gives a reading of zero in the reflected position. This may take a few tries, but you'll find the settings are not critical. If you adjust the antenna near the ground you may find it will require a new adjustment when it is up in its permanent location.

How you mount the antenna in its permanent location will depend on what you have to hold the antenna. If you use a boom mounting-plate-to-mast assembly such as already described, the U bolts holding the boom could be left slightly loose and the 3/8-inch (10-mm) bolts left out. The antenna could then be installed in an upside-down position and then rotated into place. Two men are better than one for this job, but one man *can* do the job. If a hole, say 1/2-inch (13-mm) diameter, is drilled through the boom a 1/2-inch rod could be slid through to serve as a lever to rotate the boom and antenna into an upright position and the U bolts and hardware could be then tightened down.

We think the Delta-Loop beam is an excellent antenna and offers many possibilities. Certainly the results obtained to this point prove the antenna is a real performer. Our tower is a crank-up job, making antenna testing a fairly simple project. The antenna was first matched at the 8-foot (2.44 m) level (boom height) and at the cranked-up height, about 55 feet (16.76 m) above ground. A very slight readjustment of the gamma capacitor was required at the greater height in order to get down to a 1-to-1 SWR. However, the change in SWR from the 8-foot to 55-foot (2.44- to 16.76-m) heights was very small. Also, the highest SWR was at 21,450 kHz, the top end of the band, with a mismatch no worse than 1.2 to 1. At 21,300 kHz the SWR dropped to 1 to 1 and remained at that figure all the way to the lower band edge.

The entire antenna weighs about 15 pounds (using the aluminum boom) so the antenna could be rotated with a heavy-duty TV rotator. One last note: We sprayed the cotter pins and hose clamps with a clear acrylic spray to reduce corrosion. This simple precaution should be taken in all antenna construction to prevent or reduce rusting. This material was originally presented in *QST* by Lewis G. McCoy, W1ICP.

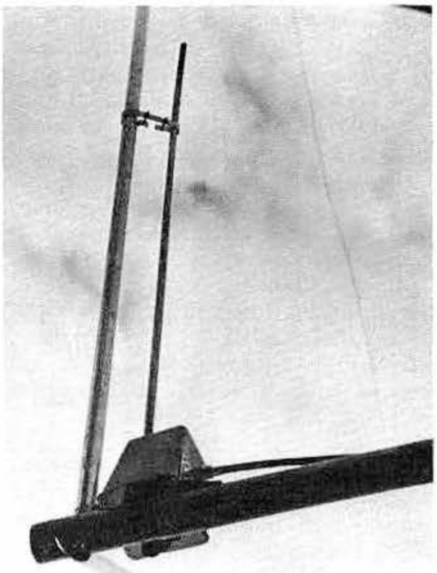

The plastic freezer box is held in place by the small metal bracket which is attached to the boom with self-tapping screws. Also on the bracket is a coax fitting to take the RG-8/U coaxial feed line. The gamma rod is mounted on top of the box and is held to the element with the shorting clamp.

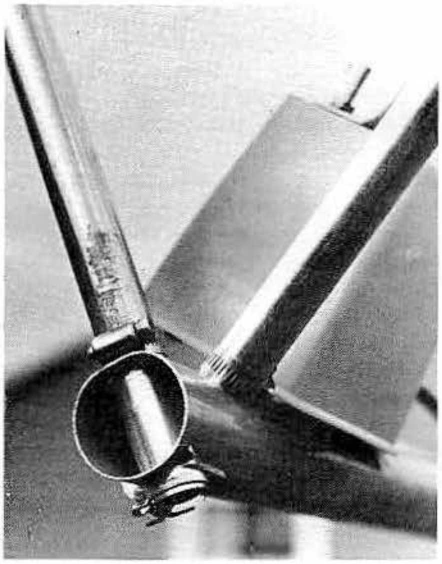

In this close-up view of the end of the boom, the mounting of the element ends are clearly shown. Cotter pins are used on the bottom end of the element and hose clamps on the top side of the boom. This secures the elements to the boom. The plastic freezer box that houses the gamma capacitor is clearly visible behind the elements.

Antennas for Travel Trailers and Campers

Pounding brass and rendering "lip service" from an RV or mobile home can be disappointing as all get-out if the antenna doesn't "play" well. Here are some tips for rig-mounted radiators that get the job done.

Who knows why so many hams like to go camping? Perhaps it's their Field Day training; perhaps it's the next logical step after mobile operation, or perhaps they just cannot leave home without their rigs. At any rate, it is nice to have your own means of communication with the outside world when you are away from home in the Maine woods, at the Grand Canyon, or even down in Mexico.

One thing all hams know is that no matter how good a transmitter you may have, you cannot get out without an antenna; and the better the antenna is, the better you get out. The antenna is usually no problem for the home station. The sky is the limit, so to speak. A 65-foot (19.81 m) crank-up tilt-over tower with a triband beam on top, and a couple of inverted Vs for 40 and 75 are not at all uncommon. But did you ever contemplate transporting such an antenna system to a state park, or some other campground, and setting it up while your XYL cooked suppper? Obviously, the mobile operator is faced with vastly different problems than those confronting the ham who stays at home, when it comes to antennas.

In 1929, the author built a 14-foot travel trailer, which was christened "Black Maria." Shortly thereafter, the writer got a ham license, and one of the first thoughts was toward a rig for the trailer. This was in the days when mobile operation was still a novelty, and the story of Black Maria was the author's first contribution to *QST*, in 1933. The rig used a pair of 33s in parallel operating from a B-battery pack.

Over the ensuing 35 years, many portable antenna designs have been tried, and much has been learned about their relative performance. The degree to which a trailer traveler is restricted in a choice of an antenna varies widely, of course, depending upon the facilities available at each stopping point. These are seldom known in advance, but to get the most out of the equipment, the trailer operator should be prepared to take maximum advantage of whatever facilities he may find on each occasion.

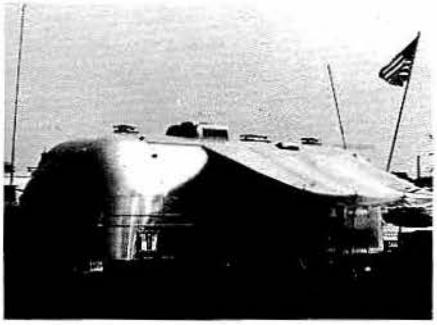

The author's 30-foot (9.14 m) Airstream trailer with the 75-meter Airstream Loop in place. The "tuning" mast is the one carrying the flag.

Dipole Antennas

Long ago, it was found that a simple dipole for 40 or 75 would far outperform the author's mobile whip, even with the dipole only a few feet above ground. While writing this, sitting in the latest Black Maria — a 30-foot Airstream job — up in Port Colburne, ON, the author was listening to the 75-meter phone band. The dipole is only 8 feet (2.44 m) above ground. When checking into the Airstream Travel Trailer Net, which meets every Sunday on 3963 kHz at 8 A.M. local time, the writer worked other trailer stations in Connecticut, New Jersey, Maryland, Pennsylvania, New York and Ohio. Several times the author switched to the mobile whip and could not be heard through the QRM. Such a dipole can be prefabricated and, when rolled up, occupies very little storage space.

When the length of the stay warrants it, and trees or other supports are available, the antenna will be even more effective when raised to a respectable height. A bow and arrow is kept on hand for shooting lines over taller trees. Incidentally, Hy-Gain makes a deluxe portable dipole consisting of two stainless-steel tapes in a double plastic housing. The tapes are calibrated in meters, and can be quickly reeled out to the proper length for use on any desired band. The unit is fitted with a coax connector, making installation very easy.

If only a single support is available, the dipole can be used in "inverted-V" fashion. A convenient way of putting up such an antenna is to use three or four 5-foot (1.52 m) lengths of 1-1/4-inch (32 mm) aluminum TV masting as a center pole, mounting it on the front of the trailer. The author has a mounting for such an arrangement clamped to the bumper, as shown in one of the photographs. The mast can be equipped with light nylon halyards for hoisting the center of the dipole. The ends of the dipole can be attached to whatever may be handy, but the higher, the better.

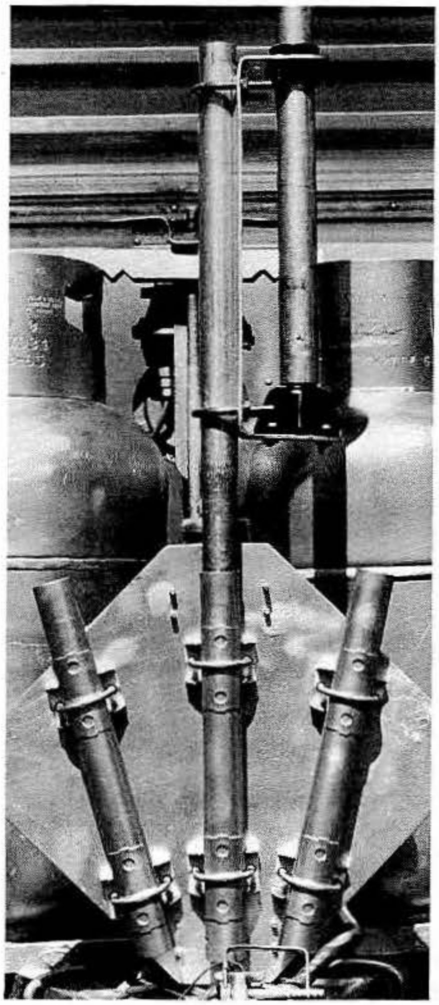

Insulated mounting at one end of the "Airstream Loop" 75-meter antenna. The "tuning" mast can be mounted directly in one of the other sockets. The tuning will vary with the spacing between masts as well as the length of the "tuning" mast. The insulated mounting can be transferred to one of the side sockets to obtain maximum spacing.

Loaded Antennas

Of course, there are many times when the surroundings, or the shortness of the stopover, make erection of a conventional dipole impractical. On these occasions, the author used one or another of several arrangements shown in the accompanying photographs and sketches. Where the

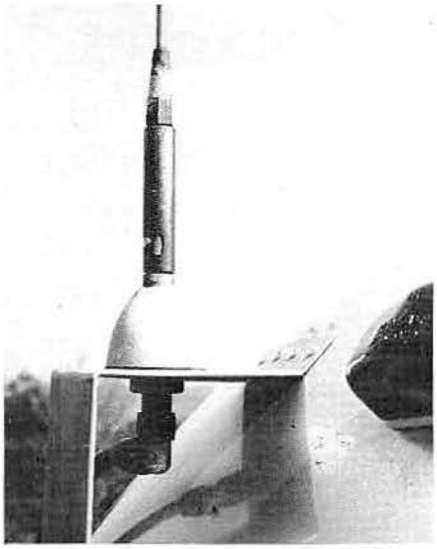

An elevated mounting for a mobile whip at a top rear corner of the trailer body. The bracket is fastened by pop rivets. This point may also be used, with the whip removed, for feeding wire dipoles.

A check with a 20-watt fluorescent lamp by W1WKZ indicates the "hot" points on the Airstream Loop 75-meter antenna system.

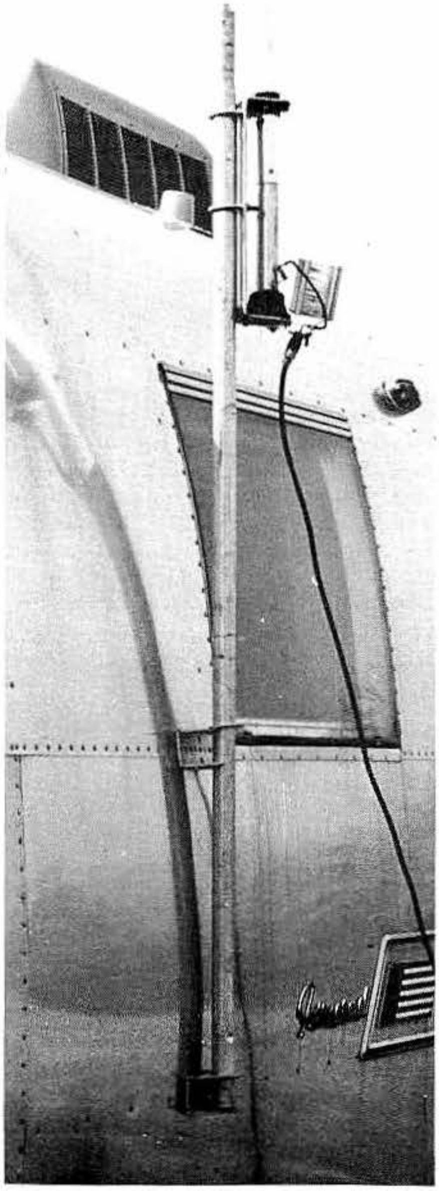

A 25-foot (7.62 m) base-loaded antenna mounted on brackets attached to the side of the trailer.

antenna system is one that requires a ground for operation, it was found that a quarter-wave wire counterpoise connected to the trailer, and strung out a few feet above ground, is usually a much better "ground" than the trailer alone, even if the trailer is actually grounded to a driven rod. The author carries two each of wires cut to lengths of 8, 16, 32 and 60 feet (2.44, 4.88, 9.75 and 18.29 m) for use as counterpoise on the 10-, 20-, 40- and 75-meter bands, respectively. One end of each wire is fitted with a large battery clip, while the other is terminated in an insulator. Trailer awning poles come in handy as counterpoise supports when nothing else is available.

"Airstream Loop" Antenna

Of particular interest is the 75-meter folded configuration shown in the sketch of Fig. 23, which is called the "Airstream Loop," although, strictly speaking, it does not function as a true loop. With the fittings that are provided, this antenna can be put up in a few minutes, and its performance seems to be about equal to that of a low dipole. It has the advantage that it is completely supported by the trailer, and requires no external supports. It is contained entirely within your own campsite. There are no wires strung out for you or your neighboring campers to trip over or be garroted by in the dark. A 30-foot (9.14-m) length of wire is strung between, and connected to, two poles made of aluminum TV mast sections. A third mast (A), of approximately the same length as the others, and connected to the trailer, is an essential part of the system. This arrangement appears to work as a folded half-wave antenna, the 30-foot (9.14-m) wire and the two poles connected to it forming one half of the antenna, while the other half is formed by the trailer body and mast (A). Probing with a fluorescent lamp shows that the end of the trailer opposite the feed point is "hot" while the feed-point end is "cold." The system can be tuned by adjustment of the length of pole A, and/or changing the spacing between A and the adjacent pole. The spacing can be changed by a selection of the pole mounting sockets shown in one of the photographs. In this manner, the resonant frequency can be changed by almost 150 kHz. For any adjustment, the transmitter can be tuned about 30 kHz either side of the resonant point before the SWR exceeds 3 to 1. Since the "hot" end of the trailer is the front end in my case, the tow car must be unhitched, and an insulating block used under the customary supporting jack.

In a similar arragement for 40 meters, mast A is omitted, and a wire approximately 21 feet (6.40 m) long is connected to the pole at the feed-point end. The open end of the wire is supported from the pole at the opposite end of the trailer by a length of nylon rope.

40-Meter Monopole

Another 40-meter antenna that has been used with considerable success is a 34-foot (10.36 m) length of 300-ohm ribbon line connected as a folded monopole, and strung up in the same manner as the antenna just described. One conductor of the ribbon is grounded to the trailer at the feed point, while the other conductor is connected to the center conductor of the coax line. The two ribbon conductors are connected together at the far end.

Matching

Standing-wave ratios up to 5 or 6 to 1 are hardly worth worrying about at 4 MHz so

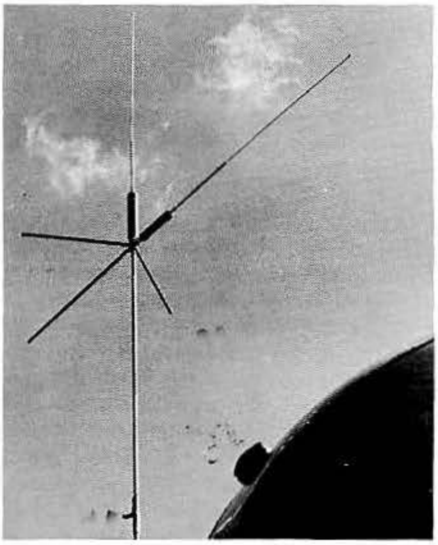

A five-band antenna system. A New-Tronics mobile antenna base section is fitted with a Waters Add-a-Band adapter. The short resonators for 10, 15 and 20 meters are Waters. The 80-meter resonator (top) is New-Tronics. A threaded stud has been added to the vacant side of the adapter to take a New-Tronics 40-meter resonator. The system is fed at the base with a single coax line.

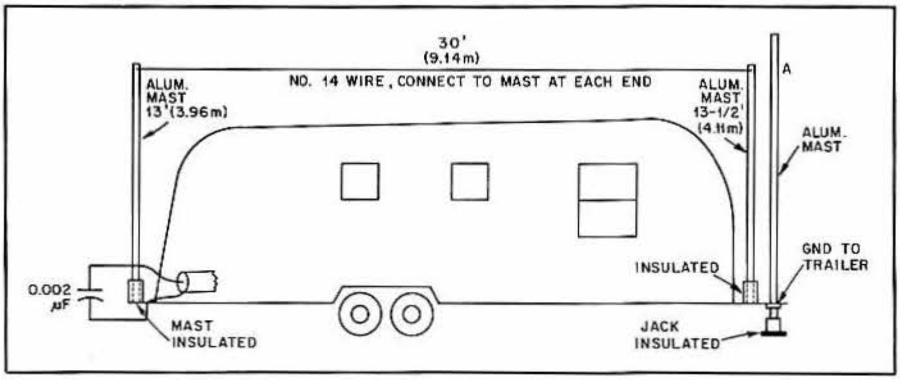

Fig. 23 — 75-meter "Airstream Loop"

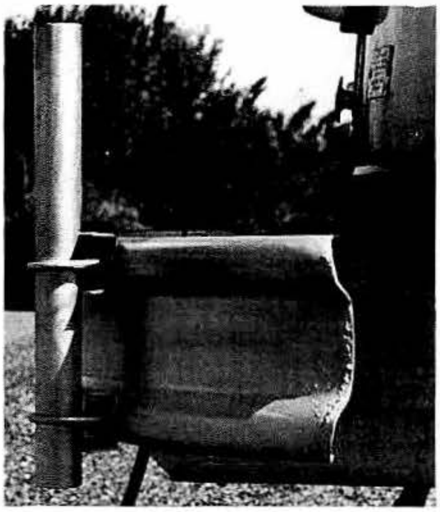

A bumper-mounted socket for TV masting.

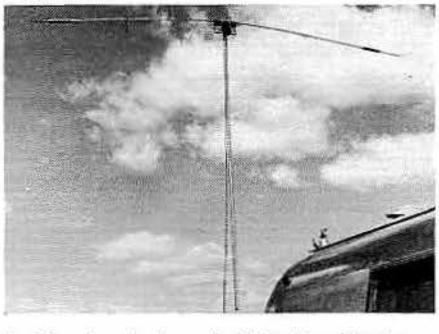

An 80-meter dipole made of two New-Tronics 75-meter mobile whip back to back. The 15-foot (4.57 m) mast is bumper-mounted. A 1-to-1 balun is mounted on the center insulating panel, which is secured to the mast with U bolts. This antenna is quite narrow-band when operated on 75 meters, making it necessary to retune the antenna for excursions of more than 30 or 40 kHz.

far as additional power loss is concerned. However, an SWR greater than 1 to 1 causes the line input impedance to vary, depending on the length of the line. The output circuits of many transmitters and transceivers are not designed to work into loads departing significantly from 50 ohms. With these units, it may not be possible to load the final stage, or components in the output stage not designed for the voltages that develop with higher-impedance loads may be damaged. Use a Monimatch, or other reflectometer, and adjust the antenna for minimum SWR. The author carries along several mica capacitors ranging in value from 50 pF to 0.002 μF with battery clips attached, which are used to shunt the line at the feed point. Start out with the lowest value, and double the capacitance in steps until you get an SWR of 1 to 1 somewhere in the band, and then adjust the antenna length for resonance at the desired frequency.[1]

To get some idea of the relative performances, a series of checks was made at 3825 kHz on several of the antennas described. A receiver with a horizontal antenna was set up at a distance of eight miles from the trailer, and S-meter readings were taken with the results shown in the accompanying tabulation. All readings were made with identical input power to the transmitter, and with the antennas adjusted for an SWR of 1 to 1.

To sum it all up:

1) Carry a complete set of mobile whips for lunch stops, or other occasions where you just do not have the time or room for anything better.

2) If at all possible, use a 1/4-wave counterpoise clipped to the trailer when using a mobile whip.

3) If you have the time or space, clip a 1/4-wave wire, instead of a whip, to your mobile antenna mount, and run it out to a bush or tree.

4) In addition to (3), clip a 1/4-wave counterpoise to the trailer, and run it in the opposite direction.

5) If you are stopping for a short time, or for the night, rig up the 5-band mobile whip with five 1/4-wave counterpoises, one of appropriate length for each band.

6) If you want to concentrate on one band, put up the 16-foot (4.88 m) mobile-whip dipole, if your space is limited.

7) If you have plenty of room, put up a 1/2-wave dipole for your favorite band.

8) If you want to work all bands, and space for dipoles is limited, then put up your trap vertical with the 75-meter resonator tuned to your favorite frequency.

9) If you are going to spend a week in a particular campground, shoot some lines over a couple of high trees with a bow and arrow, and get your dipoles up in the air as high as possible.

10) The use of balloons and kites is good, but depends completely on the wind.

11) Next best to a high dipole, put up the "Airstream Loop" antenna for 75 meters.

12) If all else fails, bring your 2-kW PEP linear and your 2.5 kW ac gas generator along. This will at least keep the other campers awake. Don't forget a low-pass filter for TVI! This material was originally presented in *QST* by Philip S. Rand, W1DBM.

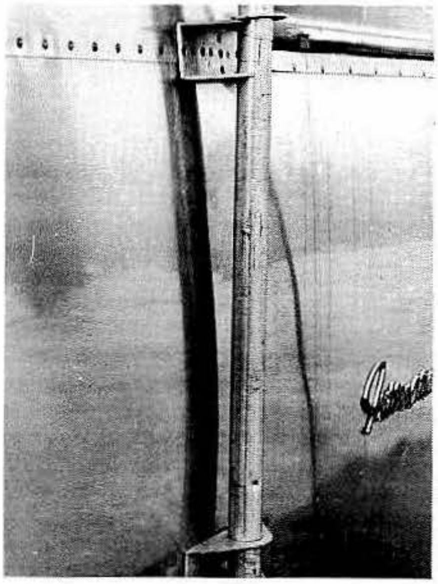

Brackets for mounting TV masting on the side of the trailer. The upper bracket is fitted with a removable U-shaped yoke bolted to the bracket. The brackets are fastened to the trailer with pop rivets.

Table 3

Hustler 75-meter mobile whip mounted vertically on top rear corner of trailer	S7
Same as above, with 60-foot counterpoise wire connected to trailer	S9
Two Hustler 75-meter mobile whips back to back as a horizontal loaded dipole	S9 + 5 dB
60-foot horizontal wire 8 feet high, using trailer as ground	S9 + 10 dB
Hustler 4BTV trap vertical with 75-meter resonator	S9 + 10 dB
120-foot dipole, 15 feet high at center	S9 + 20 dB
"Airstream Loop" antenna	S9 + 20 dB
Home-station dipole 50 feet high ...	S9 + 30 dB

Feet = 0.3048 = m.

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[1] [Editor's Note: This method is equivalent to the use of a stepdown L network. It can be used when the antenna feed-point impedance is lower than the line impedance. To obtain a match, the antenna length must be somewhat longer than a resonant length, so that the antenna shows inductive reactance at the feed point. (This reactance serves as a substitute for the reactance of the coil of a conventional L network.) For an accurate match, it is necessary to adust the antenna length and the value of the capacitor until the appropriate transformation ratio is obtained.]

The Apartment Dweller's Dilemma

Having trouble getting a signal out from "concrete city"? Nonresonant, random-length wires can provide surprising results if a Transmatch is used to make the rig happy with the load it sees.

It is apparent that many would-be amateurs living in apartment buildings believe it is impossible to get an effective signal on the air. They feel the need to have an outdoor antenna in order to make contacts. This isn't true. Of course, the apartment dweller can always go mobile, but there comes a time when the amateur wants a home station. This article treats the problem and, hopefully, will get a few more hams on the air.

Some General Considerations

There are exceptions to the following rules but, in general, they can be depended upon.

1) An outdoor antenna will work better than an indoor one.

2) An antenna inside a frame building with wood exteriors is better than the same antenna in a steel-and-concrete building.

3) The higher above ground, inside or out, the better the antenna will work.

4) The bigger (or longer) you can make an indoor antenna, the better — even if it means running the wire around corners.

5) Even a poor antenna *should* produce some contacts.

The Coupling Problem

Most transmitters are designed to work into a 50-ohm load, and contain little or no provision for adjusting the transmitter when the load is other than 50 ohms. Unfortunately, there is no random-length wire antenna that will present a 50-ohm load on all bands. What is required is a Transmatch. A Transmatch is simply an adjustable LC network that converts the unknown antenna impedance to 50 ohms. This unit, shown in Fig. 24 and the photographs, will cover the 80- through 10-meter bands and can handle 1 kW of rf power. In addition to matching the transmitter to the antenna load, the Transmatch helps reduce harmonic radiation. Many Novices get in trouble with the FCC because of 2nd-harmonic radiation from the 80-meter signal. This unit should reduce such harmonic radiation. Also, the use of a Transmatch can provide better front-end selectivity for the receiver. Some receivers are subject to severe cross modulation when operated near a broadcast station. The Transmatch should reduce this effect.

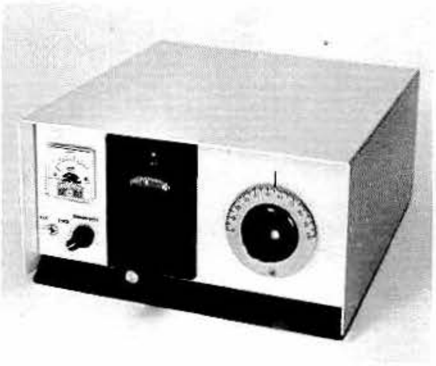

The completed Transmatch. The counter dial and knob are James Millen Mfg. Co., Inc. products. Check with G. R. Whitehouse, Amherst, NH 03031.

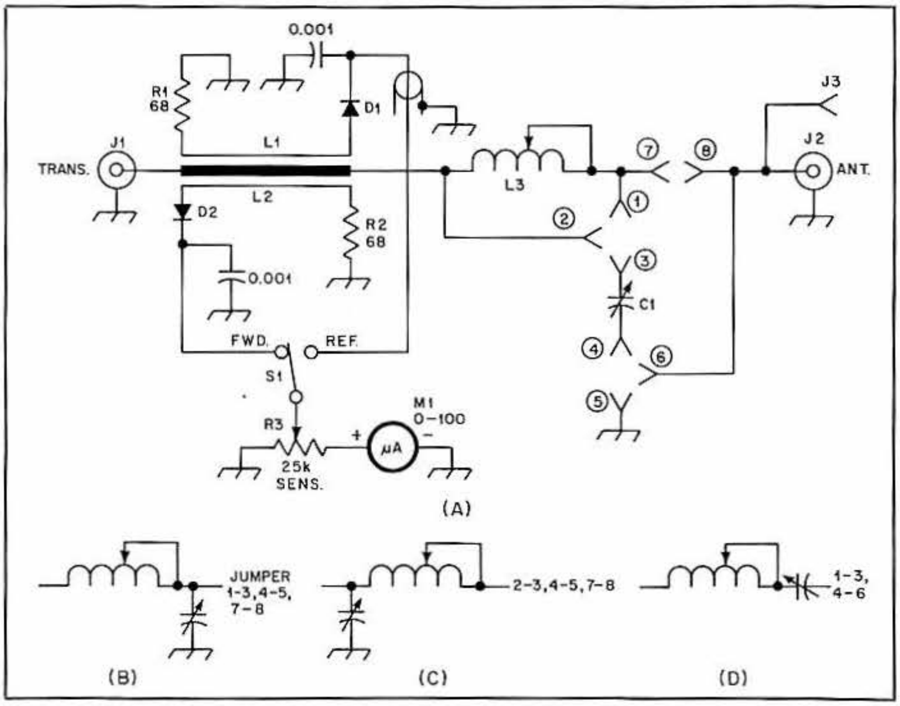

Fig. 24 — Circuit diagram of the L-network Transmatch. The eight banana jacks are E. F. Johnson type 108-900, and three dual banana plugs are required, E. F. Johnson type 108-200.

C1 — Variable capacitor, 350 pF (E. F. Johnson 154-10).

D1, D2 — 1N34A germanium diode.

J1, J2 — Chassis connector, type SO-239.

J3 — Feedthrough terminal, isolantite.

L1, L2 — See Fig. 25, part of etched circuit assembly.

L3 — Variable inductor, 28 μH (E. F. Johnson 220-203).

M1 — 100-μA meter.

R1, R2 — 68-ohm, 1/2-watt carbon or composition, *not wirewound.*

R3 — 25,000-ohm carbon control, linear taper.

S1 — Spst toggle.

Circuit Details

The unit shown in Fig. 24 is designed to be used in three configurations. They are shown at B, C and D. With one of the three hookups, it should be possible to match practically any antenna to the transmitter.

In order to get complete band coverage and avoid the complexities of bandswitching, banana and jack plugs are used to change the circuit to the configuration needed. For example, if one wanted the setup shown at B, he would jumper terminals 7 and 8, 1 and 3, and 4 and 5. Using the banana plugs makes for easy changing of the circuit.

Whenever a Transmatch is used, the operator should have a way of knowing when the unit is adjusted correctly. The answer to this need is a Monimatch or other SWR indicator. If you have an SWR meter, it can be connected in the line between the transmitter and the coupler. If

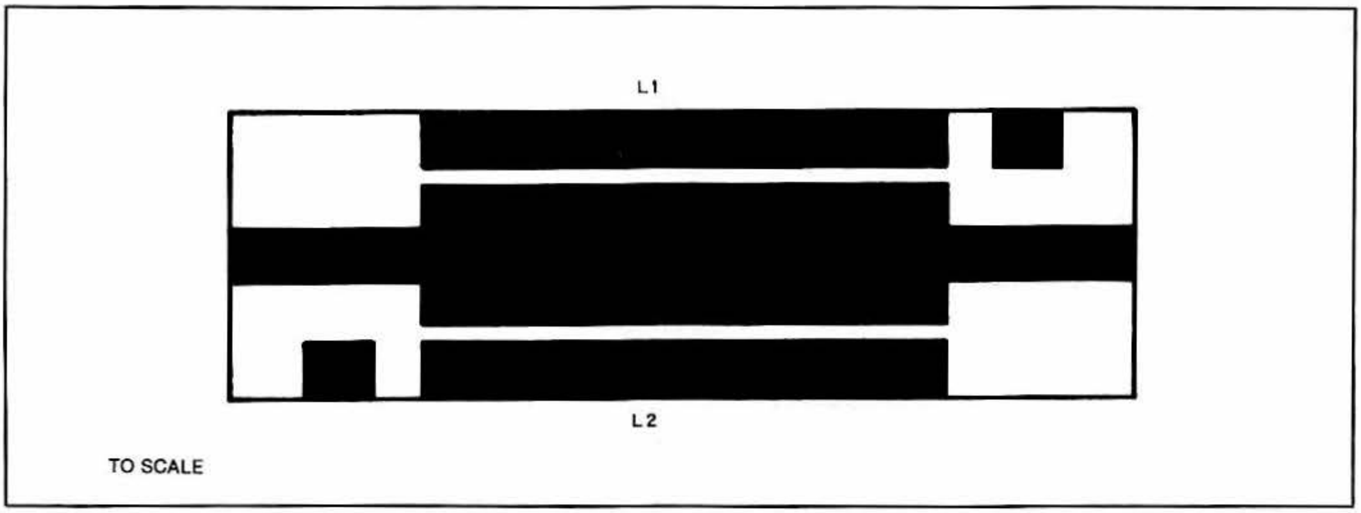

Fig. 25 — Etched circuit-board template. The foil side is shown, with etched portion shaded.

not, you can build the Monimatch[1] shown in Fig. 24, and include it in the cabinet with the Transmatch.

Construction Details

The chassis for mounting the Transmatch is made from a piece of aluminum measuring 10 × 19 inches (254 × 482 mm). The ends of the 19-inch length of aluminum are bent up to form a U-shaped chassis, the ends being 4-1/2 inches high to form a chassis 10 × 10 × 4-1/2 inches (254 × 254 × 114 mm). The back side of the U has an opening cut out, 3-1/4 inches high by 4-1/2 inches (83 × 114 mm) long. A piece of Plexiglas is mounted over this opening. The jack-plug sockets are installed directly on the plastic. Connections from the roller inductor, L3, and variable capacitor, C1, are made to the banana jacks. Be careful when drilling the holes for the jacks to insure that they will mate with the plugs. Fig. 25 shows the details for a pc-board Monimatch.

Methods for making etched circuit boards are given in detail in the construction chapter of The Radio Amateur's Handbook, so we won't treat the process here. When installing D1 and D2 on the board, be sure to use a heat sink while soldering the leads. Too much heat can ruin the diodes. Shielded leads are used from the circuit board to S1 to prevent unwanted rf pickup.

Today's equipment builder soon finds out that locating parts can be a tough problem. Fortunately, we have found a distributor who will furnish all the parts. With the exception of the chassis, the parts for the Transmatch can be purchased from Barry Electronics.[2]

Some Antenna Ideas

With this Transmatch one should be able to match any random-length antenna to his transmitter. To test the system, we strung up 25 feet (7.62 m) of wire in the ARRL lab (a steel-and-concrete building, first floor). The Transmatch provided the desired 50-ohm impedance on all bands. We didn't get any "60-over-9" reports, but we *did* make contacts.

As to your antenna installation, we suggest running the wire up to the ceiling, around the room, perhaps into the next room, making the antennas as long as possible. If the XYL objects to the wire, use an invisible antenna. Nope, we're not

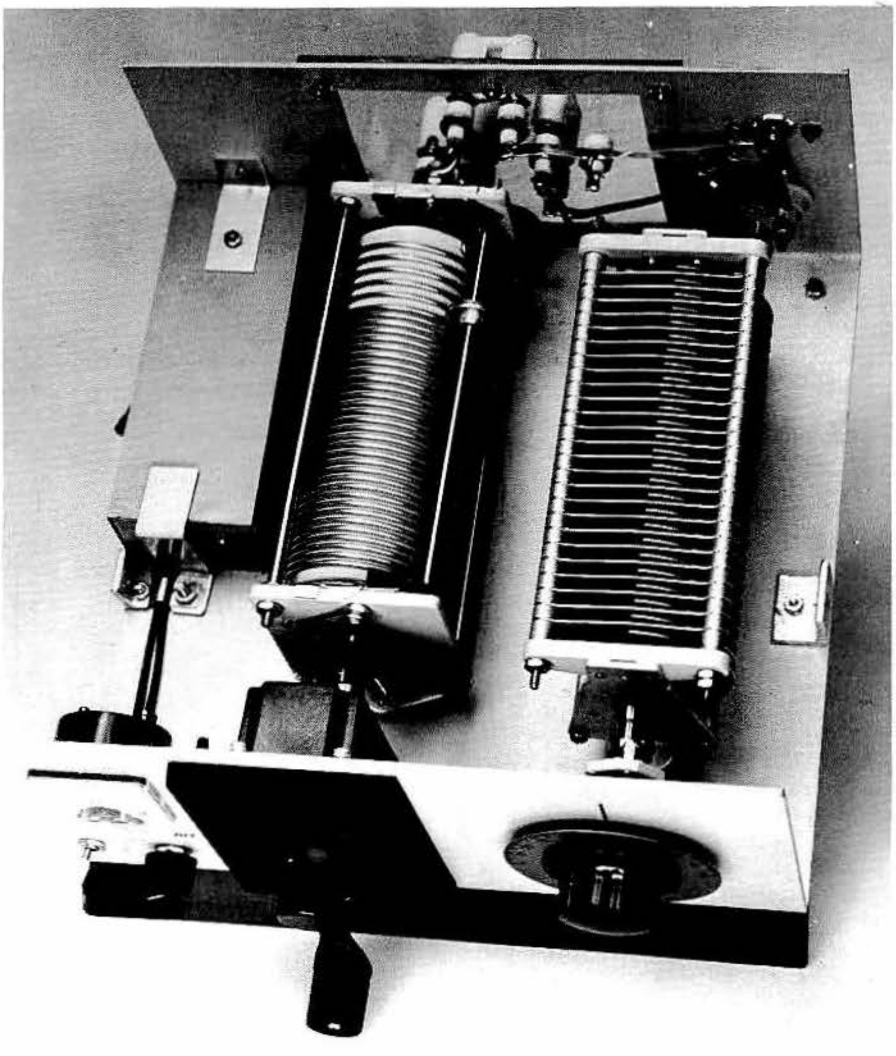

The Monimatch is at the upper left, covered by a metal enclosure. Connections from the roller inductor and the variable capacitor to the terminals on the jacks are made with thin strips of copper, although no. 12 or 14 wire can be used instead. The two antenna terminals are at the rear right. The top terminal is for use with a coax-fed antenna, if desired.

joking! You can make the antenna from no. 26 or 28 wire, which will be practically invisible. Also, you can conceal the wire behind molding. Be sure to insulate the wire if it runs near any metal. In some cases, it is impossible to get the wire outside. However, if you have a screen in one of your windows, terminate the end of the antenna at the screen. The screen *is* outside and it will help the system radiate. While it may be difficult to install, the antenna length to shoot for is approximately 120 to 130 feet (36.58 to 39.62 m) because this is a good length for multiband operation.

If you cannot put an antenna on the apartment roof, there is still a trick or two for having an outside antenna. You can drop a wire out the window and let it hang down. How long the wire should be will depend on how high up you are. You can make the wire long enough to reach nearly to the earth, but high enough to be beyond the reach of passersby. *Safety first*, always! There is no electrical law that states that a vertical must be fed at the bottom. Just connect the end of the wire to your Transmatch and tune up the system. You can use small-diameter wire. Use a lead sinker on the end of the wire and possibly imbed the sinker in a small sponge-rubber ball. (That way, you won't break your neighbor's window.)

If there is a support to which you can attach the far end of the antenna you can use the invisible-wire trick. Use rubber bands for insulators. Erect no. 26 or 28 wire. Don't be too discouraged if the wire gets broken by passing birds!

We know one ham who lived in a basement flat. He ran a wire through the wall to the bottom of a rain gutter, tuned up the system, and managed to work DXCC. (Safety first, again. The downspout should be beyond the reach of human beings!) The general idea is to use ingenuity. With a Transmatch you never can tell *what* will prove to be a useful antenna.

How to Tune Up

Using the Transmatch is not complicated. Although it takes some time to find the correct combination of settings, once determined, they can be logged for later reference. Use a short length of 50-ohm coax to connect the Transmatch to the transmitter. Attach the antenna to the Transmatch. Tune up your transmitter on the desired band, making sure that the final amplifier is resonated, but with the power output reduced. With the Monimatch in the forward-reading position, set the sensitivity control for a full-scale reading. You may have to increase the output of the transmitter to get full deflection, but be sure to keep the final amplifier tank in resonance. Switch the meter to the reflected position, and then adjust L1 and C1, until you get the lowest indication of reflected power. It should be possible to get the meter to read zero. When you have a zero reading in the reflected position, versus full scale in the forward setting, the Transmatch is correctly adjusted, and the SWR is 1. You may have to change the circuit to one of the other configurations in order to get a match, but one combination should work. Once you have the Transmatch set properly, you can then adjust the transmitter to its rated power input. One other point: It isn't always possible to get a good ground connection in an apartment. Therefore, a connection to a cold-water pipe or earth ground should be used. This material was originally presented in *QST* by Lewis G. McCoy, W1ICP.

References

[1] McCoy, "An Etched-Circuit Monimatch for Checking Your Antenna System," *QST*, October 1969. (See Chapter 5.)

[2] Barry Electronics, 512 Broadway, New York, NY 10012.

A 40-Meter DDRR Antenna

This antenna consists of a 1/4-wavelength element grounded at one end and wound into a single-turn coil, a few conductor diameters above the ground (see Fig. 26).

Shortly after the author's article on a practical DDRR Antenna appeared,[1] a number of inquiries were received regarding low-frequency versions of this antenna for operation at ground level. After a little experimenting, the author came up with this version of a 40-meter DDRR which works quite well. In early tests very fine QSOs were held with stations as far away as Phoenix, while the antenna was located inside the garage and surrounded by myriad metallic objects. When the antenna was relocated to the backyard, marked improvement was noted, even though this antenna site was marred by a sharp rise of 4 feet (1.22 m) in ground elevation, plus close proximity to house wiring and power lines. In spite of these obstacles solid contact was easily achieved with stations up and down the West Coast. Encouraged by these results, we moved the antenna to a rooftop location which put it well in the clear insofar as metallic objects above the groundplane were concerned. In this location, the DDRR really proved its worth. In spite of its low profile, a little over 1 foot (0.31 m), and its very small span, a few inches over 9 feet (2.74 m), it was more than adequate when competing with any signal on the band. The obvious conclusion from my experiments is that the 40-Meter DDRR is the apartment-dweller's dream. It is principally for that group that this article is prepared. Other interested amateurs might be those who are limited, as this author is, by too much house on too little real estate; or those who for other reasons cannot cope with high towers, masts and guy wires.

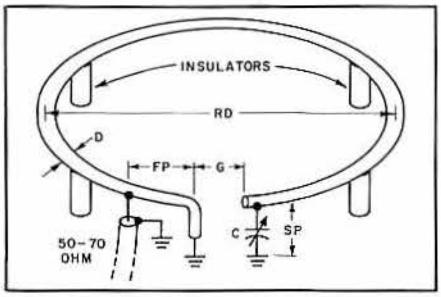

Fig. 26
RD = 0.078 λ (28°)
SP = 0.11D (2.5°)
FP = 0.25 h (See Note 1)
C = (See Note 2)
D = (See Note 3)
G = (See Table 4)

Notes: (1) Actual dimension must be found experimentally. (2) Value to resonate the antenna to the operating freq. (3) d ranges upward from 1/2" (13 mm). The larger "d" is the higher efficiency is. Use largest practical size, e.g., 1/2" (13 mm) for 10 meters, 5" (127 mm) or 6" (152 mm) for 80 or 160 meters.

Before this writer's enthusiasm sends you out to rip down your inverted V or to dismantle your beam, remember this: The DDRR, for all of its capabilities, will not supplant a full-size single-frequency antenna which is properly erected over clear terrain. What it will do is provide an

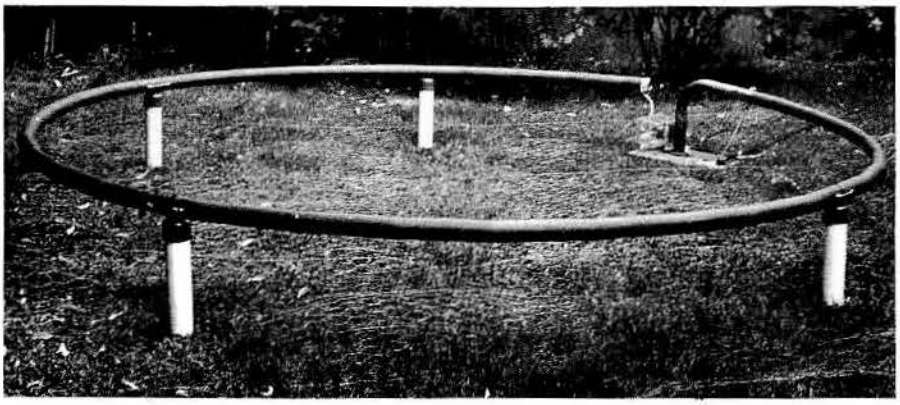

The chicken-wire groundplane is evident in the background. The base plate can be seen at lower right. Note the relative positions of the 52-ohm coaxial feed at the left end of the plate, the flange on the foot of the post, and the tuning unit at the right-hand end of the plate.

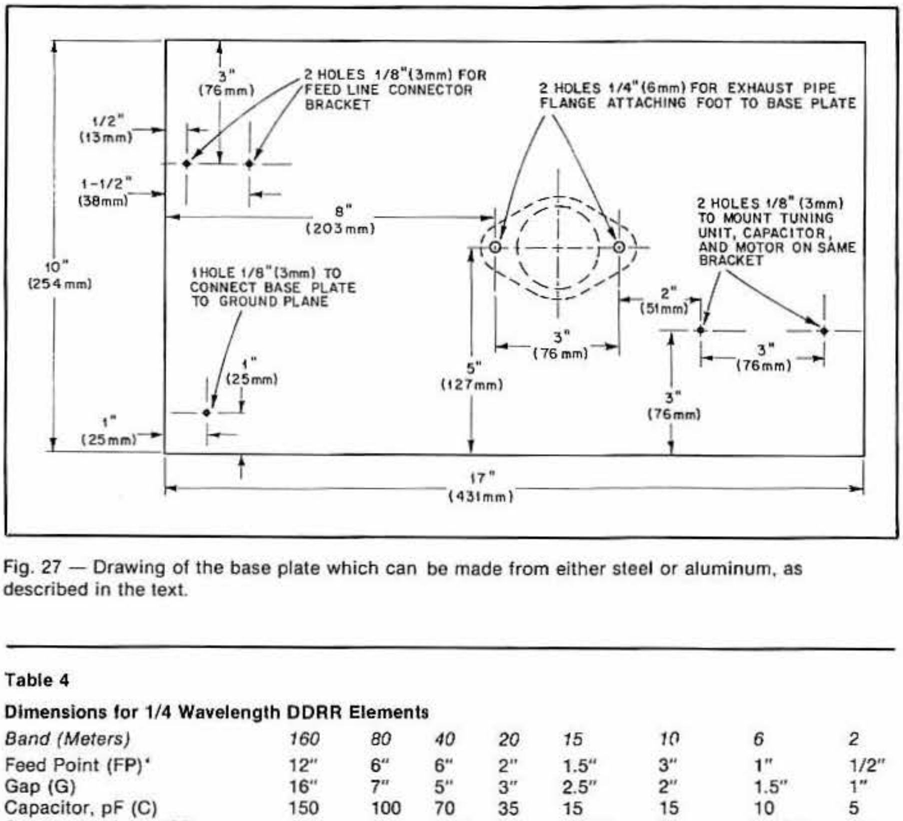
3" (76mm)
2 HOLES 1/8"(3mm) FOR FEED LINE CONNECTOR BRACKET
2 HOLES 1/4"(6mm) FOR EXHAUST PIPE FLANGE ATTACHING FOOT TO BASE PLATE
1/2" (13mm)
1-1/2" (38mm)
8" (203mm)
2 HOLES 1/8" (3mm) TO MOUNT TUNING UNIT, CAPACITOR, AND MOTOR ON SAME BRACKET
10" (254mm)
1 HOLE 1/8"(3mm) TO CONNECT BASE PLATE TO GROUND PLANE
2" (51mm)
3" (76 mm)
3" (76mm)
1" (25mm)
5" (127mm)
3" (76mm)
1" (25mm)
17" (431mm)

Fig. 27 — Drawing of the base plate which can be made from either steel or aluminum, as described in the text.

Table 4

Dimensions for 1/4 Wavelength DDRR Elements

Band (Meters)	*160*	*80*	*40*	*20*	*15*	*10*	*6*	*2*
Feed Point (FP)*	12"	6"	6"	2"	1.5"	3"	1"	1/2"
Gap (G)	16"	7"	5"	3"	2.5"	2"	1.5"	1"
Capacitor, pF (C)	150	100	70	35	15	15	10	5
Spacing (Height) (SP)	48"	24"	11"	6"	4 3/4"	3"	1 1/2"	1"
Tubing Diameter (D)	5"	4"	2"	1"	3/4"	3/4"	1/2"	1/4"
Ring Diameter (RD)	36'	18'	9'	4.5'	3'4"	2'4"	16 1/4"	6"

*See Fig. 26 for explanation of designations.

Feet X 0.3048 = m.

Inches X 25.4 = mm.

The braided lead across the flared joint is to assure electrical continuity. The screws used are self-tapping sheet-metal screws. The top end of the insulator (2-inch [51 mm] diameter PVC pipe) is a standard PVC pipe cap; the bottom is closed off with a cap from an aerosol can (2-inch [51 mm] ID).

antenna which will enable communications of respectable quality, where heretofore it has been impossible because of inadequate space to erect a 40-meter antenna.

Some consideration should also be given to the fact that the high-Q nature of the DDRR and its resultant narrow-band characteristics serve to reduce the noise level. Boyer[2,3] reports that in the initial experiments it was found that DX stations which could copy signals from either a vertical or a DDRR could only be heard on the DDRR due to the reduction in background noise. So if you have a noisy location, it might be to your benefit to try the DDRR, regardless of what antenna you are presently using.

Constructing the 40-Meter DDRR

In this application, 2-inch (51 mm) diameter automobile exhaust pipe was used as the radiating element. The local muffler shop not only supplied the material, but also undertook to bend it to specifications. This was an obvious course since the material and the power bender were right at hand.

The dimensions for 40 meters are:

Ring — 9 foot (2.74 m) diameter, center to center.

Height — 12 inches (0.31 m) from ground plant to element center.

Gap — 6 inches (152 mm) from upright post center to open end of ring.

In forming the ring to these dimensions, four 10-foot (3.05 m) lengths of tubing were used. A 10-degree bend was made at 9-inch (229 mm) intervals in three of the lengths. The fourth length was similarly treated, except for the last 18 inches (0.46 m) which were bent at right angles to form the upright leg of the ring. One end of each section was flared so that the sections could be coupled together by slipping the end of one into the flare of its mate.

The required flares are easily made at the muffler shop with the aid of the forming tools. Another task which can best be completed at the shop is to weld a flange onto the end of the upright leg. This flange is to facilitate attaching the leg to the mounting plate which provides a chassis for the tuning mechanism and the coaxial-feed coupler. After bending and flaring is complete, the ring is assembled and minor adjustments made to bring it into round and to the proper dimensions. This can best be done by drawing a circle on the floor with chalk and fitting the ring inside the circle. The circle must be slightly larger than the center-to-center diameter so that the reference line can be seen easily. For example, with two-inch (51-mm) tubing the actual diameter of the reference circle must be 9 feet, 2 inches (2.79 m). When you

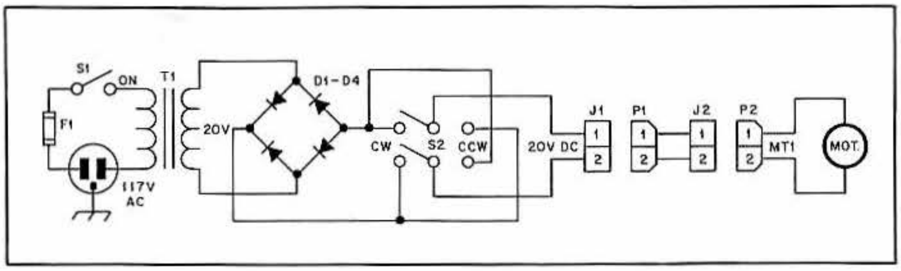

Fig. 28 — Circuit diagram of the power supply and control motor.

D1 through D4 — 1 A, 50 PRV, or equiv.
F1 — Fuse, 1 A.
J1, J2 — Two-terminal jack.
MT1 — Motor (see text).
P1, P2 — Two-terminal plug.
S1 — Spst.
S2 — Dpdt, center off.
T1 — Transformer (see text).

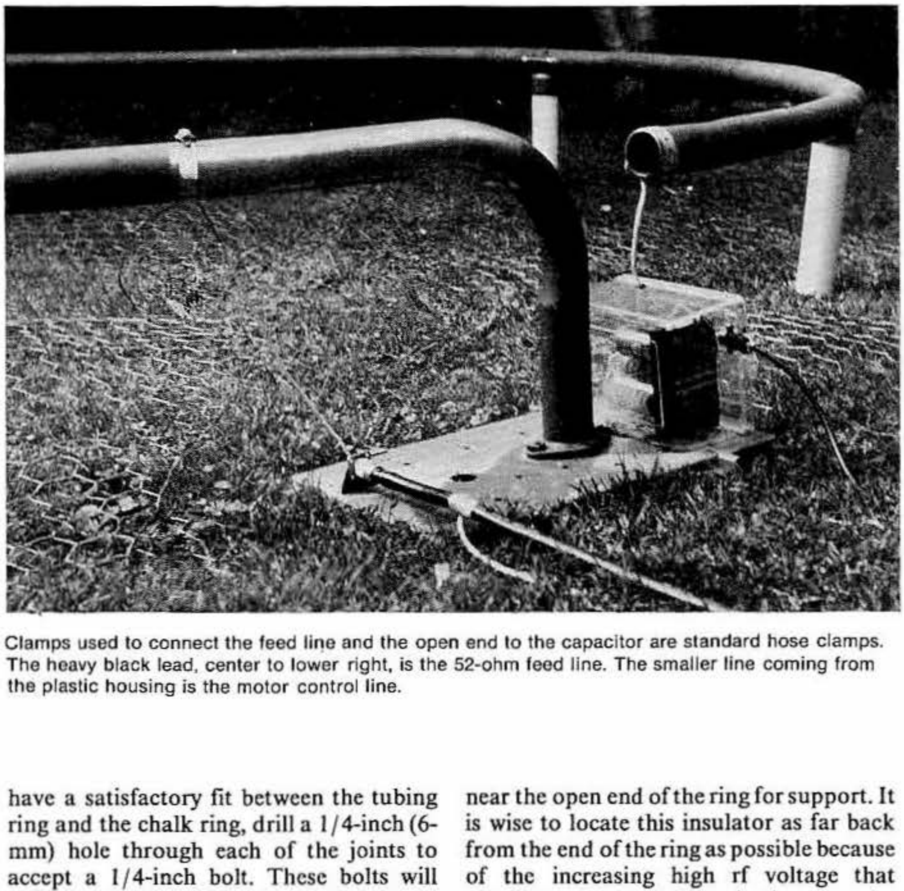

Clamps used to connect the feed line and the open end to the capacitor are standard hose clamps. The heavy black lead, center to lower right, is the 52-ohm feed line. The smaller line coming from the plastic housing is the motor control line.

have a satisfactory fit between the tubing ring and the chalk ring, drill a 1/4-inch (6-mm) hole through each of the joints to accept a 1/4-inch bolt. These bolts will clamp the sections together. Also, they can be used to attach the insulators which support the ring at a fixed height above the groundplane.

Making and Attaching the Insulators

Insulators for the antenna were made from 11-inch (279-mm) lengths of 2-inch (51-mm) PVC pipe inserted into a standard cap of the same material. The PVC caps are first drilled through the center to accept the 1/4-inch (6-mm) bolt previously installed at the joints. The caps are then slipped onto the bolts and nuts are installed and tightened to secure the caps in place. The 11-inch length of pipe, when inserted into the cap and pressed firmly until it touches bottom, results in a total insulator length of 12 inches (0.31 m). Four insulators are required: one at each of the joints and one near the open end of the ring for support. It is wise to locate this insulator as far back from the end of the ring as possible because of the increasing high rf voltage that develops as the end of the ring is approached.[4] As a final measure, the bottom ends of the insulators were sealed to prevent moisture from forming on the inside surfaces. Standard PVC caps could be used here, but we found that plastic caps from 15-ounce aerosol cans fit well.

Making the Mounting Plate

The mounting plate is required to provide good mechanical and electrical connections for the grounded leg of the radiator, the coaxial feed-line connection, and the tuning mechanism. If you are using aluminum tubing, you should use an aluminum plate, and for steel tubing, a steel plate to lessen corrosion from the contacting of dissimilar metals. Dimensions for the plate are shown in Fig. 27. The important consideration here is that good, solid mechanical and electrical connections are made between the ground side at the coaxial connector, the ring base, and the tuning capacitor.

The Tuning Unit

We found that the 9-foot (2.74 m) ring resonated easily with approximately 20 pF of capacitance between the high end of the ring and the base plate or ground. A 35-pF double-spaced variable from the junk box was pressed into service here (Cardwell NG-35-DS). Any variable which will tune the system to resonance and which will not arc under full power should be satisfactory. Remember, the rf voltage at the high impedance end of this antenna can reach 20 to 30 kV with high power, so if you are using the maximum legal limit, you would do well to consider using a vacuum variable capacitor. Since we limited our power to 500 watts PEP, the double-spaced Cardwell unit was satisfactory. To provide for full band coverage, the capacitor was coupled to a reversible, slow-speed motor which enabled the antenna to be remotely tuned from the operating position. An indicated SWR of 1.1 to 1 was easily achieved over the entire 40-meter band. The motor used was a surplus item made by Globe Industries of Dayton, OH.[5] At 20 volts dc the shaft of this motor turns at about 1 rpm which is ideal for DDRR tuning. The gears used were surplus items. If you cannot obtain gears, string and pulley drive will do almost as well, or you can mount both the motor and the capacitor in line and use direct coupling. Of course, if you operate on a fixed frequency or within a 40- to 50-kHz segment of the band, you can dispense with the motor entirely and simply tune the capacitor manually. In any case, the tuning unit must be protected from the weather. We used a plastic refigerator box to house the tuning capacitor and its drive motor.

Fig. 28 shows the electrical connection for the motor. A small train transformer or power supply for toy slot-cars will work admirably as a tuning motor power source. Standard ac zip cord was used for the connection between the control unit and the motor.

Electrical Connections and the Groundplane

The connection between the open end of the ring and the tuning capacitor is made with no. 12 wire or larger. On the end of the base plate opposite the tuning unit, and directly under the ring about 8 inches (203 mm) from the grounded post, install a bracket for a coaxial connector. The connector should be oriented so that the feed line will lead away from the ring at close to 90 degrees. Install a clamp on the ring directly above the coaxial connector. Connect a lead of no. 12 or larger wire from the coaxial connector to the clamp. This wire must have a certain amount of flexibility to accommodate the movement necessary when adjusting the match. The matching point must be found by experimentation. It will be affected by the nature and quality of the groundplane over which the antenna is operating. The antenna will function over earth ground; however, in our location we found the electrical ground to be unpredictable. A groundplane surface of chicken wire (laid under the antenna and bonded to the base plate) provided a constant ground reference and improved performance. In a rooftop location sheet metal roofing should provide an excellent groundplane. A poor ground usually results in a matching point for the feed line far out along the circumference of the circle. In our installation a near-perfect match was obtained with the feed line connected to the ring about 12 inches (0.31 m) from the grounded post. During testing, when the antenna was set up on a concrete surface without the groundplane, a match was found when the feed line was connected nearly 7 feet (2.13 m) from the post!

As shown in photos, the compactness of the antenna is readily apparent. The groundplane is made up of three 12-foot (3.66-m) lengths of chicken wire, each 4 feet (1.22 m) wide, which are bonded along the edges at about 6-inch (152-mm) intervals. In our installation the antenna, with the groundplane, could be dismantled in about 30 minutes. If portability is not important, it is best to bond all of the joints in the tubing so that good electrical continuity is assured.

After all construction is completed, the antenna should be given a coat of primer paint to minimize rust. If it suits you, there is no reason why a final coat of enamel could not be applied.

Tuning Procedures

Once the mechanical construction is completed, the antenna should be erected in its intended operating location. Coupling to the station may be accomplished with either 52-ohm or 72-ohm coaxial cable. Tune and load the transmitter as with any antenna. While observing an SWR meter in the line, operate the tuning motor. Indication of resonance is the noticeable decrease in indicated reflected power. At this point, note the loading of the transmitter; it will probably increase markedly as antenna resonance is approached. Retune the transmitter and move the feed-point tap on the antenna for a further reduction in indicated reflected power. There is interaction between the movement at the feed tap and the resonance point; therefore, it will be necessary to operate the tuning motor each time the tap is adjusted until the lowest SWR is achieved. Don't settle for anything less than 1.1 to 1. With a good ground and proper tuning and matching, this ratio can be achieved and maintained over the entire band. Once the proper feed point has been located, the only adjustment necessary when changing frequency is retuning the antenna to resonance by means of the motor. If the antenna is to be fixed tuned, provide an insulated shaft extension of 18 inches (457 mm) or so to the tuning-capacitor shaft for manual adjustment. This not only provides insulation from the high rf voltage but also minimizes body-capacitance effects during the tuning process.

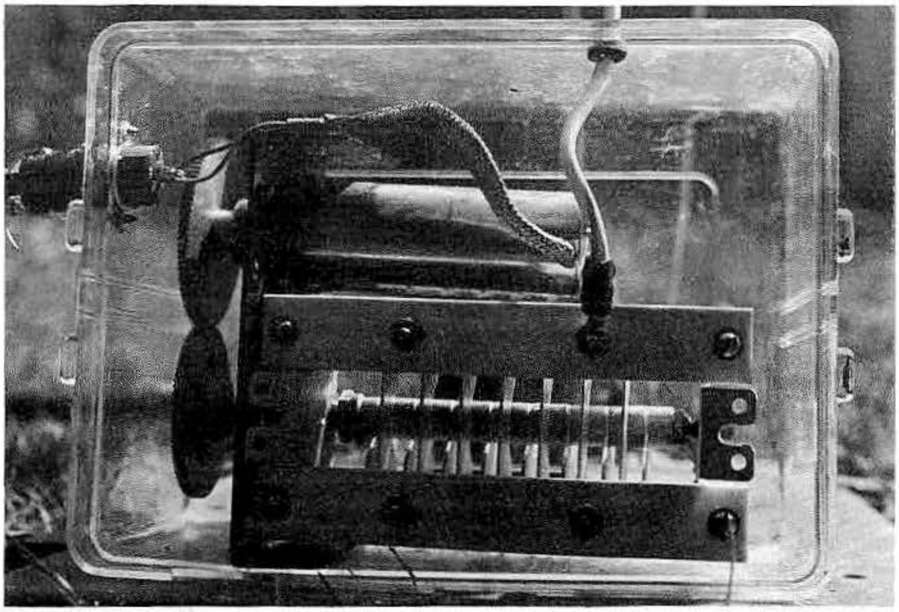

The tuning motor, above the capacitor, couples to the capacitor shaft through the gears at left. Both the motor and the capacitor are mounted on a common bracket which attaches to the base plate by two bolts through the weatherproof housing. The lead passing upward through the grommet connects the stator of the capacitor to the open end of the ring.

Alternatives

A number of materials other than the steel tubing used here are well suited for the ring element. Standard E.M.T. or electrical conduit would work as well with a slight increase in weight. One advantage to be gained through the use of conduit is the elimination of the flaring operation since standard couplings would serve to connect each segment of the ring to its adjacent member. Another suitable material is copper tubing. This material is superior to either exhaust pipe or conduit in terms of its conductivity characteristics. Another advantage of copper is that it is available in continuous lengths and the joints could be omitted entirely.

The 2-inch (51 mm) dimension is by no means mandatory. Smaller diameter tubing has been used with satisfactory results.[6] In fact, DDRR antennas have been fabricated with wire elements. But, if the element diameter is reduced, the antenna tunes more *sharply*. Some experimenters may wish to go in the other direction and use a larger diameter. The author recommends the use of aluminum downspout with a diameter of about 4 inches (2 mm). This material does not lend itself to bending, however, and the ring must be configured as a regular polygon of eight or more sides. Because of the large number of joints involved, welding is about the only practical means of joining the segments. Unless you are equipped to do this work yourself, the cost of welding might be prohibitive. Anyone who undertakes to make a DDRR antenna of a large element diameter will be rewarded in terms of improved performance.

Performance

Results have been quite encouraging, and it is hoped that more and more hams will equip themselves with the DDRR in the future. The antenna has proved its worth and deserves more investigation by the amateur fraternity than it has been given in the past. No intensive efforts have been made to work DX with the antenna described here: however, a low angle of radiation is conducive to DX, and this antenna demonstrates a low radiation angle. It was found that distant areas, such as the East Coast, are more easily contacted than are stations nearby. All of the results could be attributed to peculiarities of individual stations or skip conditions, but since they are charateristics which can be anticipated with high-efficiency antennas having low radiation angle, we prefer that interpretation. Besides, where else will you find an antenna for 40 meters that is small enough to fit into a corner of the backyard and not protrude above the fence; or for that matter, which could be mounted on the roof of an apartment building or even a ranch-type house and not be visible from the street?

Nearly everyone who listened to the description of this new antenna was enthusiastic. The author hopes to hear many hams on the air working with the DDRR in the near future. This material was originally presented in *QST* by W. E. English, W6WYQ.

Parts List

4 — 10-ft (3.05 m) lengths of 2-in. (51 mm) tubing, exhaust pipe, conduit or copper tubing.
1 — base plate 7-1/2 X 19 X 1/8 inches (191 X 482 X 3 mm), steel, aluminum, or copper to match tubing.
4 — PVC pipe caps for 2-inch (51 mm) pipe.
4 feet (1.22 m) of 2-inch PVC pipe.
2 clamps for 2-inch tubing.
4 — 1/4 X 4-inch (6 X 102 mm) bolts with nuts.
1 reversible motor with 1-rpm shaft output.
1 wide spaced variable capacitor. 5 to 35 pF (Millen 16550 or equiv.).
1 coaxial connector SO-239.
2 sets 2-connector plug and socket for motor control.
36 feet (10.97 m) of 4-foot (1.22 m) chicken wire or equivalent.
1 flange to attach tube to base plate.
2 — 1/2 X 1-inch (13 X 25 mm) bolts with nuts (flange mounting).
8 — 3-inch (76 mm) bonding strips no. 8 braided wire.
4 plugs 2-inch (51 mm) ID for insulator bases.

References

Hicks, "The DDRR Antenna: A New Approach to Compact Antenna Design," *CQ*, June 1964.
Horn, "The Half Wavelength DDRR Antenna," *CQ*, September 1967.
The Radio Amateur's Handbook, 46th ed., The American Radio Relay League.

Notes

[1] English, "A Practical DDRR Antenna," *73*, June 1970.
[2] Boyer, U.S. Patent Nos. RD 26196, RE 3,151,328 (All rights assigned to the Northrop Corporation.)
[3] Boyer, "Hula-Hoop Antennas: A Coming Trend?" *Electronics*, January 11, 1963.
[4] Editor's Note: Because of the danger of rf burns, in the event of accidental contact with the antenna, precautions should be taken to prevent random access to the completed installation.
[5] Globe C-5A-1106 (available from Lectronic Research Labs Inc., 75 Arch St., Philadelphia, PA 19106).
[6] See footnote 1.

Novi-Loop

A medium-size roll of wire, some insulators and a day of good antenna "puttin' up" weather can net you a Novi Loop. What will it do for you? Well, follow these instructions and get set to work 40-meter DX. Nuff said!

One of the sad facts of life for many beginners is the matter of poor antenna performance. Many enthusiastic Novices have fallen behind in their efforts to work DX because of bitter disappointment caused by poor performance in the antenna department. All too often it is suggested that a simple end-fed hunk of wire is ample for all-around Novice band operation, or that a dipole will suffice for most Novice operation. Sure, almost any kind of radiator that can be tuned to the operating frequency and marched to the impedance of the feed line and transmitter will enable the operator of a low-power station to make some contacts from time to time. It depends on how high the system is above ground, how free and clear it is of surrounding objects that can detune the radiator and absorb the energy radiated from it, and upon the condition of the band at a given time. It should stand as a firm rule, then, that any amateur who wants good results should erect the best antenna system he can, consistent with available space, finances and structural practicality. It is possible to advance beyond the plateau of simple dipoles and random-length wires in the quest for better performance, and without going to the expense and effort of erecting large directional beams such as the cubical quad or Yagi.

What will be described here can be applied to any of the high-frequency amateur bands. However, the example given relates to only the 40-meter Novice band. The antenna is a full-wave loop of wire, mounted through necessity at W1FB in a rectangular format, and matched with a simple quarter-wavelength coaxial transformer. It has given excellent performance in DX work and for making "solid" stateside contacts. Total cost for the antenna system (wire, matching transformer and insulators) is under $12, exclusive of the feed line used to connect the antenna to the rig.

Antenna Features

Full-wave, closed-loop antennas are broadband, low-Q devices. This is a handy feature because it permits the operator to move his transmitter frequency within a particular band without need to compensate for an increase in standing-wave ratio (SWR) which might otherwise occur if other types of antennas were used. (The higher the Q of an antenna, the narrower its bandwidth, even though an SWR of 1 can be obtained at some frequency within the band for which it is built.) The foregoing rules out the need for a Transmatch with the loop antenna, provided the feed method recommended here is applied.

Another interesting feature of this kind of antenna is the theoretical gain of approximately 2 dB it exhibits over a half-wave dipole. The angle of radiation from a properly erected full-wave loop is considered to be lower than that of a dipole when both are less than one-half wavelength above ground. This feature suggests the superiority of the loop in situations where significant height above ground is not a practical goal for the chap wishing to put up a 40-meter antenna.

A full-wavelength closed loop need not be square. It can be trapezoidal, rectangular, circular, or some distorted configuration in between those shapes. For best results, however, the builder should attempt to make the loop as square as possible. The more rectangular the shape, the greater the cancellation of energy in the system, and the less effective it will be. The effect is similar to that of a dipole whose effectiveness becomes impaired as the ends of the dipole are brought closer and closer together. The practical limit can be seen in the "inverted-V" antenna, where a 90-degree apex angle between the legs is the minimum value used. Angles that are less than 90 degrees cause serious cancellation of the rf energy.

The loop can be fed in the center of one of the vertical sides if vertical polarization is desired. For horizontal polarization it is necessary to feed either of the horizontal sides at the center. At the time of this writing there have been no data compiled to provide a comparison between the performance, vertical versus horizontal. Such an experiment could be interesting (and possibly productive) for the Novice.

Erecting the Antenna

Optimum directivity occurs at right angles to the plane of the loop, or in more

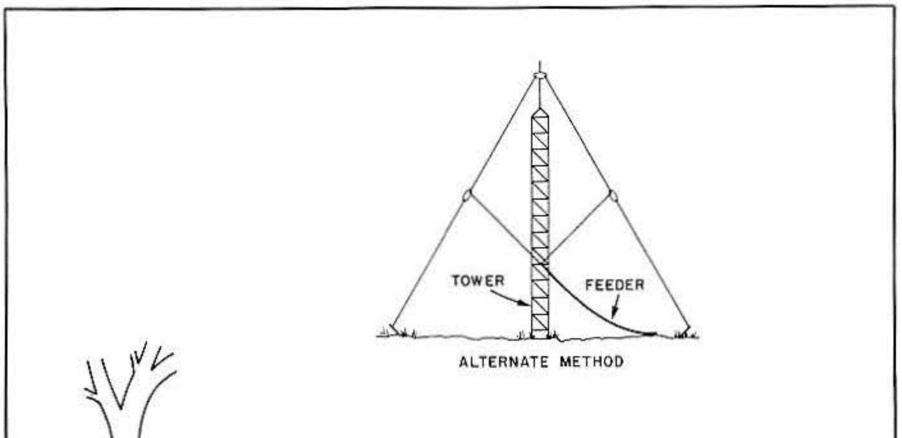

Fig. 29 — Details of the full-wave loop. The dimensions given are for operation at the low end of 40 meters (7050 kHz). The height above ground was 7 feet (2.13 m) in this instance, though improved performance should result if the builder can install the loop higher above ground without sacrificing length on the vertical sides. The inset illustrates how a single supporting structure can be used to hold the loop in a diamond-shaped configuration. Feeding the diamond at the lower tip provides radiation in the horizontal plane. Feeding the system at either side will result in vertical polarization of the radiated signal.

simple terms, broadside from the loop. Therefore, one should try to hang the system from available supports which will enable the antenna to radiate the maximum amount in some favored direction. The bidirectional pattern is maximized NE and SW at the writer's QTH. This gives good results in working Europeans and the stations "down under." Excellent signal reports have been obtained off the sides of the loop when working within the USA.

Just how the wire is erected will depend on what is available in one's yard. Trees are always handy for supporting antennas, and in many instances the house is high enough to be included in the lineup of solid objects from which to hang a radiator. If only one supporting structure is available it should be a simple matter to put up an A frame or pipe mast to use as a remaining support. (Also, tower owners see Fig. 29 inset.)

The overall length of the wire used in a loop is determined from the formula

$$\frac{1005}{\text{f (MHz)}}.$$

Hence, for operation at 7125 kHz the overall wire length will be 141 feet (42.98 m). The matching transformer, an electrical quarter wavelength of 75-ohm coax cable, can be computed by dividing 234 by the operating frequency in MHz, then multiplying that number by the velocity factor of the cable being used. Thus, for operation at 7125 kHz

$$\frac{234}{7.125\ (\text{MHz})} = 32.84 \text{ feet}$$

If coax with solid polyethylene insulation is used, a velocity factor of 0.66 must be employed. Foam-polyethylene coax has a velocity factor of 0.80. Assuming we are to use the solid dielectric coax, RG-59/U, the length of the matching transformer becomes 32.84 (feet) × 0.66 = 21.67 feet, or 21 feet 8 inches (6.605 m). The transformer will convert the 100-ohm feed-point impedance of the loop to 50 ohms, a convenient value for connecting the system to the transmitter. The loop described here was measured with the K1TD Macromatcher[1] and found to exhibit an impedance of 110 ohms. Some inductive reactance was indicated. By removing 1 foot (0.31 m) of wire from the overall loop the reactance dropped to zero, though the antenna loaded up fine prior to the final trimming. The feed impedance at 21 MHz was also 110 ohms, but considerable inductive reactance was observed. Most certainly one could use the antenna on 15 meters with reasonable success, despite the SWR which might be present.

Results

During two weeks of testing the loop gave an excellent account of itself. It was compared with the writer's two-element short beam for 40 meters, and the results indicated that the loop was better than the beam on some occasions. At other times the beam provided better performance, or was at least equal to the loop. The differences noted were the result of band conditions and the time of day. High-angle signals can cause misleading results when comparing antennas for hf-band use. More meaningful tests can be made on ground-wave contacts, however, and several checks made between the loop and the beam indicated that radiation at right angles to the plane of the loop compared closely with that from the front of the beam. The beam is rotatable and installed 40 feet (12.19 m) above ground.

With 150 watts dc input to the transmitter PA, and operating at the low end of 40 meters (loop was cut for 7050 kHz), the first night of operation resulted in the logging of three Russian stations, two Polish ones, two Yugoslavians, one Italian station and two English ones. The lowest report was RST 549. The highest report was RST 599. Generally speaking, the loop has outperformed the beam during most long-haul contacts. Though no effort has yet been made to work South American stations (off the side of the loop), they have been heard loud and clear, as have some VK stations via long path at approximately 2300 UTC.

It is quite likely that the Novice who chooses to erect his own Novi-Loop will have a commanding signal on 40 meters. If backyard space permits, it should be a worthwhile venture. Don't forget, the formulas and guidelines given here are applicable to the other hf Novice bands as well. This material was originally presented in *QST* by Doug DeMaw, W1FB.

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[1] Hall, "The Macromatcher," *QST*, January 1972.

Chapter 5

Antenna Theory and Test Methods

In order to obtain top performance from a given style of amateur antenna, it is important to understand the basic principles of operation. Additionally, some test procedures are necessary if one is to ensure that his or her antenna is functioning at its best. This chapter contains assorted data on antenna theory, plus a number of common-sense test methods.

These reprints of popular *QST* articles were chosen for all amateurs, regardless of their technical-aptitude levels. There's something to honor in the phrase, "Learn by doing." This chapter will help to make that philosophy a reality.

Quad vs. Triband Yagi

The controversy about quads working better than Yagis, or vice versa, may never end. But, we'll bet our newest roll of RG-8/U that you'll find some interesting reading on the subject in this report.

While stationed in Japan, a sort of DX crossroads of the world, this writer had the opportunity to observe, firsthand, the excellent performance of the cubical quad in competition with the Yagi, dipoles and an assortment of other antenna systems. In pursuing this undertaking certain steps were necessary to insure than any conclusions made would be meaningful. With this in mind a play emerged.

Objectives

In the many articles written on the cubical quad, it is noteworthy that only on a few occasions have the authors been privileged to compare the quad with other types of antennas on a real-time basis, and from the same operating location. Furthermore, when such comparisons were made, the authors generally compared against some type of monoband antenna system. A casual scanning of the 10-, 15- and 20-meter phone bands would lead one to conclude that the triband Yagi enjoys a rather high position of popularity among the antennas in general use. This being the case, it appeared that a worthwhile contribution to the data already available on the Yagi and quad might be made by conducting a series of controlled comparative tests, employing the triband Yagi and the quad. The test objectives were then defined: to compare various configurations of a cubical quad antenna with a representative commercial triband Yagi; such tests to be conducted over short, medium, and long transmission paths, and to arrive at conclusions regarding the relative merits of each antenna.

Table 1

	Mod. 1	*Mod. 2*	*Mod. 3*	*Mod. 4*
Reflector Element	72'3"	70'4"	72'5"	72'5"
Driven Element	69'	70'4"	70'5"	70'5"
Director Element	—	—	—	69'1"
Spacing "A"	7'6-1/2"	8'5"	13'4"	13'
Spacing "B"	—	—	—	13'
Stub	20-30"	34-38"	—	—

Feet X 0.3048 = m.
Inches X 25.4 = mm.

Test Plan and Procedure

Every effort was made to conduct the tests in a manner which would lessen the possibility of compromising the techniques employed by either the writer or participating stations:

1) The test to be performed by establishing communications with Amateur Radio stations located throughout the world on a random and scheduled basis.

2) Amateur Radio stations volunteering to assist in this effort to be briefed on conduct of test and data desired.

3) A voice ssb transmission to be made to the participating station, identifying the first antenna used as antenna "A."

4) The voice transmission to be followed immediately by an unmodulated carrier for a period of approximately 5 seconds.

5) The antennas would be switched, and a voice transmission made identifying the antenna as "B," and the procedures above repeated.

6) Participating stations will note signal strength related to each antenna, and provide a numerical value as observed on his S meter or other indicating device. These values to be logged, and the test reinitiated with another volunteer station.

Equipment Preparation

1) Antenna heights to be as nearly identical as possible.

2) Center of antenna horizontal lobe patterns to be as nearly identical as possible when pointing the antennas toward a participating station.

3) Resonant frequency of each antenna to be matched as closely as possible.

4) Transmission lines to be matched to antennas and transmitter loading to be as nearly identical as possible with each antenna.

5) Instantaneous transfer of antennas.

6) Relative power and SWR to be monitored continuously.

7) Prior to and after each data gathering session, equipment parameters will be verified. If a significant deviation in any parameter is noted, data collected will be discarded.

Antenna performance conclusions to be based on an analysis of data derived from a minimum of 50 unmodulated-carrier observations with each antenna configuration, and supplemented with data gathered during conventional ssb QSOs.

Table 2

	Mod. 1	*Mod. 2*	*Mod. 3*	*Mod. 4*
Total Observations	50	60	60	52
Less than 2100 miles	12	2	3	3
2100 to 4800 miles	33	31	33	32
Greater than 4800 miles	5	27	24	17
Signal Difference				
More than 1 S unit better	—	—	—	—
Less than 1 S unit better	—	—	7	9
No discernible difference	1	5	51	43
Less than 1 S unit poorer	27	46	2	—
More than 1 S unit poorer	22	9	—	—

Antenna Selection

This writer had been using a four-element commercial triband Yagi (boom length 24 feet [7.32 m], and 55 feet [16.76 m] above ground) for approximately 1-1/2 years, so the properties of this antenna were fairly well established. Furthermore, in on-the-air comparisons with competitive models of triband Yagis in use by other U.S. amateurs operating from the Tokyo area, the antenna appeared representative of commercial triband antennas in general use by the amateur community. Therefore, the Yagi in use at the author's station was selected as the reference antenna.

Text material concerning quad antennas, available to the author in Japan, was reviewed. It became evident that there are almost as many variations in quad design as there are writers on the subject. After much deliberation, and many discussions with amateurs throughout the world, the decision was made to test three models of the quad (a fourth model was tested as will be noted later). Since the physical characteristics of the quad are fairly standard, only the dimensions of the elements and the spacing between them was considered. The dimensions for the three models tested were obtained from a Japanese manufacturer of cubical quads, from Orr's book, *All About Cubical Quad Antennas,*[1] and from Dr., J. E. Lindsay, Jr., W0HJ.[2]

Preliminary Testing

Several days were spent "dry running" the test plan to validate the concept, and to smooth out the operating procedures and techniques. Of particular concern was the possible time required to make a valid data-gathering observation. If data were to be reasonably accurate, the transmission path had to be stable, and the signal-strength observations must be taken on each antenna during a short period of time. The dry runs were valuable in this respect.

A problem became evident during the first day of testing. It appears that those of us who speak and understand English do not always convey the same message when using the same words. As a result it was necessary to modify the verbal format, utilizing simple sentences and placing them in a logical sequence.

It also became apparent that the test could not be conducted under all transmission-path conditions; that even under ideal conditions several observations were often necessary before a conclusive report could be compiled. It was decided to conduct the tests only on 20 meters. The operating time available to the writer favored openings on 20 meters to Europe via the long path, and to Australia, the U.S. and various islands in the Pacific. It was also decided to orient the test antennas so that the topography and obstructions seen by each antenna would be essentially the same. (Physical separation between the two antennas was in the order of one wavelength.)

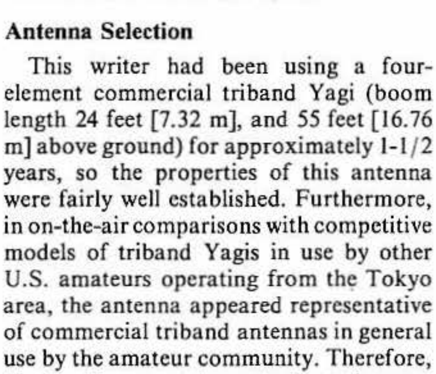

Fig. 1 — Element spacing information for Table 1.

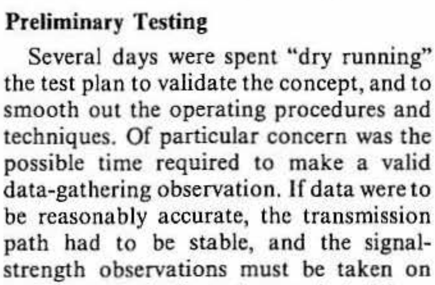

Fig. 2 — CLOSE SPACING IS FOR THE BIRDS!

Testing

Dimensions of the first quad model selected were furnished by a Japanese manufacturer of cubical-quad antennas. (see Table 1). The antenna was assembled, utilizing commercially manufactured heavy-duty hardware and fiberglass spreaders. It was tuned to a center frequency of 14,200 kHz. Testing of the first model began in November 1967 and continued for one month. The results for this period are given in Table 2.

In mid-December 1967 the first quad was replaced by a model constructed according to the formula and dimensions given in Orr's book. The results obtained with model 2 are contained in Table 2.

Construction of the third model (with wider element spacing) was carried out next. Two matching systems (Gamma and Q-section) were experimented with on this antenna. A satisfactory match could be had with either system. However, the Q-section was used for the test because it was the technique used with the previous two quad models (SWR with each antenna was never more than 1.3:1 with a difference between antennas no greater than 0.1). The results conducted with this model were most enlightening, as shown in Table 2. The model antenna was also used extensively during the first weekend of the 1968 ARRL DX Contest. Though these contacts were not used in tabulating test samplings, it is interesting to observe that openings to the U.S. (using the quad) lasted 15 to 30 minutes longer on each end of the period than with the Yagi. It is assumed that this phenomenon would also apply to each of the other quad models.

The fourth quad tested was a 3-element wide-spaced model constructed according to more dimensions furnished by W0HJ. The results of the samplings were somewhat disappointing and are given in Table 2. (Frankly, the author felt that the 3-element quad would show a substantial improvement over the Yagi in every case.) The 3-element model did appear to have a better front-to-back and front-to-side ratio than either the Yagi or the other quad models. One positive comment: The 3-element model is a monster to assemble and put up! In the author's opinion the difference in performance isn't worth the small improvement. Perhaps, on the other hand, if one accepts the 2-element model as the departure point between a simple mechanical structure and a major project, a 4-element model might be more worth the effort. However, this is purely conjecture on the part of the author.

Summary

The antenna tests indicate that:

1) One can expect to achieve the same or better results with a 2-element quad of proper dimensions than with a 3- or 4-element triband Yagi.

2) A wide-spaced quad will perform substantially better than a close-spaced quad.

3) Dollar for dollar, the quad appears to be a better investment than a Yagi.

Acknowledgements

The writer wishes to thank all of the amateurs who participated in the series of tests, particularly the VK gang, who night after night tolerated the request for observations. The support couldn't have been better, and on many occasions, upon completing a check with a particular station, several other stations would call to give their observations (which were taken during the same transmission test). This material was originally presented in *QST* by Col John H. Parrott, Jr., W4FRU.

References

[1] Orr, *All About Cubical-Quad Antennas*, Radio Publications, Wilton, CT 06897.

[2] Dimensions later published: Lindsay, "Quads and Yagis," *QST*, May 1968. (See chapter 3).

High Versus Low Antennas Performance Tests Using Identical Arrays

This section compares the performances of identical antennas mounted side-by-side at different heights, and produces some experimental evidence to support the practical importance of antenna height for most types of Amateur Radio communication.

"The higher the better" is the traditional rule of thumb for ham radio antennas. Few amateurs would disagree with this axiom, and most experienced antenna builders can recall how much better they got out after "raising the beam another 15 feet (4.57 m)." However, few empirical studies of the effect of antenna height on signal strength have been published in amateur circles.

This is unforunate, since several amateurs have studied the question methodically, including Dr. J. E. Lindsay, who has now published his definitive treatise on quads and Yagis[1] but not his excellent work in this area. And while both *The ARRL Antenna Book* and Orr's *Beam Antenna Handbook*[2] discuss the importance of antenna height in theoretical terms, neither reports the results of practical studies in the field.

With this in mind, the author set out to study the effect of height on signal strength at various distances, on several bands, and with various forms of propagation. Only amateur equipment was available for the study, but in other respects, the author strived to keep the methodology as rigorous as possible.

The Method

The author's approach was to erect identical antennas atop two towers of different heights and obtain comparative signal reports — with some safeguards to minimize reporting errors and to assure proper statistical treatment for the resulting data. For the main tests, one tower was 72 feet (21.95 m) high (the practical maximum for the author's residential backyard at the time of the tests), while the other stood 34 feet (10.36 m) high (about the minimum usable height for DX work, according to Orr). The two towers were placed as far apart as possible without trespassing — about 50 feet (15.24 m). With this separation, no interaction was evident on any band.

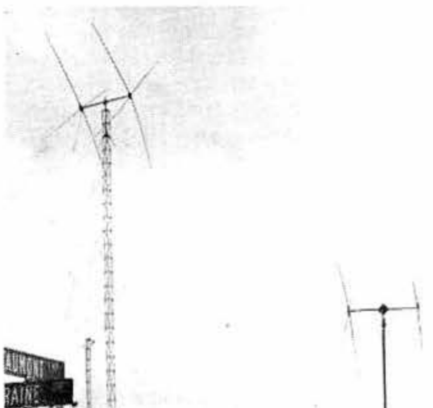

The two cubical quads used by the author to study the effects of antenna height on performance. The antenna at right is atop a 34-foot (10.36 m) tilt-over mast described by the author in June 1969 *QST*. The quad at left is on a 72-foot (21.95 m) tower.

A pair of 2-element cubical quads were selected for the 10-, 15- and 20-meter experiments. Each had an eight-foot (2.44 m) boom with all elements mounted concentrically on two sets of spreaders, and each antenna was fed with a single feed line (85 feet [25.9 m] of RG-8/U in both cases). This design obviously involves some compromises in element spacing and impedance matching, but both quads developed good SWR curves and front-to-back ratios when tuned. And, more important for our study, whatever compromises existed were essentially the same for both the high and low antennas.

It became apparent during the tests that many amateurs regard cubical quads as exceptional performers at low heights, but (unlike Yagis) not much better if raised higher. This popular impression is contrary to Lindsay's findings, which suggest that quads and Yagis respond quite comparably to changes in their height. Accepting Lindsay's conclusions, we assumed that our findings would be roughly the same if Yagis had been used for the primary experiments.

Table 3

Comparative Performance Data for High and Low Antennas

Band/path	No. reports	No. favoring high antenna	No. favoring low antenna	No. reporting no difference	Mean high-antenna advantage
20/DX	16	16	0	0	2.1 S units
20/U.S.	18	15	0	3	1.4 S units
15/DX	12	12	0	0	1.8 S units
15/U.S.	36	20	0	16	0.9 S units
15/ground-wave	12	12	0	0	2.2 S units
10/DX	8	7	0	1	1 S unit
6/ground-wave	5	5	0	0	2 S units
6/E-skip	10	2	7	1	−1.3 S units
2/ground-wave	16	16	0	0	3.3 S units

The author wanted to determine how well high and low antennas would perform not only on DX work, but on "Stateside" F-layer communications, ground-wave work, and E-skip as well. Thus, separate tabulations were kept for DX reports (i.e., those from stations more than 4000 miles away) and for reports from "Stateside" stations (i.e., F-layer reports over 1500—3000-mile paths) on each frequency band.[3] The author was careful to avoid seeking reports during anything that resembled an E-skip opening on 10, 15, and 20 meters, in the interest of studying E skip vs. antenna height separately on 6 meters.

To study the effect of height on vhf groundwave signals, the author replaced the cubical quads on the two towers with two pairs of seven-element 2-meter Yagis, each fed in phase with ratio-dipole driven elements. A move to a new home prevented the use of the same two towers for 6-meter experiments, but the author later set up two 3-element 6-meter Yagis — one atop a new 90-foot (27.43 m) tower, and the other on a 42-footer (12.8 m) — to continue the study.

On each band, the tests were conducted on ssb (except on 2 meters, where a-m was used), with an audio tone serving as a reference signal. The author switched between the high and low antennas repeatedly on each test, in an effort to counteract the effects of QSB.

This test procedure does introduce some sources of error, including the variability of hams' skills in observing the results, and the lack of receiver S-meter standardization. To cope with this kind of sampling fluctuation, the author obtained a number of reports on each band and then used t-distribution statistical methodology to evaluate the resulting data. Even with these efforts to make the study as rigorous as possible, however, the author makes no claim to finality for the results obtained. The findings on each band did prove to be statistically significant (at the 0.05 level of significance or better), but you don't "prove" things or arrive at exact parameters this way. The only claim the author makes for his results is that they suggest general trends that will probably be confirmed if this study is replicated elsewhere. There is no implication here that a 72-foot (21.95 m) high antenna produces "12-dB gain" over a 34-foot (10.36 m)-high antenna in 20-meter DX work just because the mean advantage in our tests was about two S units in this instance.

The Results

The results of these tests, summarized in the accompanying table, were interesting in several respects. With the exception of one case on 10 meters, every single DX station reported a substantially better signal from the high quad than the low one. This is thoroughly predicted in the literature, but we also found that the high quad produced a significantly stronger signal (taking the mean, or average, figure) on "Stateside" work. And on ground-wave work, the high antennas were absolutely consistent in outperforming lower ones. However, E-skip contacts proved to be another story, a point to be covered in detail later. The mean advantage of the high quad over the low quad in DX work was 2.1 S units on 20 meters, 1.8 S units on 15, and one S unit on the 10-meter band.

Since the author's linear amplifier (a commercial unit using two 3-400Zs) produces a signal gain of about two S units over the exciter alone on most S meters, it became apparent that many DX stations could not distinguish the kilowatt feeding the lower quad from the exciter "barefoot" with the higher array. The implications of this dramatic difference in signal strength for DX-contest operations are obvious: it's no wonder the "big guns" using antennas 130 feet (39.62 m) high get through the pileups quickly, with or without big linears.

On Stateside F-layer work, the pattern was less consistent, although the high array continued to hold a significant edge. While a majority of the reports still favored the high quad by one or two S units, more than a third of the stations dissented, reporting equal or virtually equal signals from the two quads. No one reported a stronger signal from the lower antenna, perhaps because of the author's effort to avoid E-ship contacts in this phase of the study. The mean advantage of the higher quad was 1.4 S units on 20-meter Stateside work, and 0.9 S unit on 15 — still a substantial advantage, but not enough to render a low antenna useless for portable work, as generations of Field Day operators can attest. In fact, the author previously described a portable quad[4] that stood only 19 feet (5.79 m) high, but nevertheless worked very well for "back-home" contacts during a long vacation. An antenna only 19 feet (5.97 m) high is clearly undesirable, but if higher antennas are not feasible, much successful hamming can still be done. (This is especially true on an occasion like Field Day, when almost everyone's antenna is low, and the few beams that are 40 [12.19 m] or more feet high seem to dominate the bands; if the competition is using a low antenna you can too!)

Ground-wave Tests

Although the plan was to study the effect of antenna height on ground-wave communication only on vhf bands, a number of stations within 100 miles volunteered reports on the hf bands. These reports were not tabulated except on 15 meters, but they consistently favored the higher array by at least two S units.

In the vhf experiments, height again proved decisive for gound-wave work. On both 2 and 6 meters, every station favored the high antenna. On two meters, the mean advantage was an amazing 3.3 S units. Surprisingly, the higher array appeared to be equally superior on contacts with San Bernardino-Riverside stations (some 30 miles from Beaumont, CA, where these tests were conducted) and on contacts into the Los Angeles basin (almost 100 miles away).[5]

After moving and acquiring the 90-foot (27.43 m) tower, the author put a single 7-element 2-meter Yagi up and took an S-meter reading on a nearby repeater with the new tower cranked down. As the tower ascended to its full height, the signal rose from S8 to 15 dB over S9 on a popular transceiver's S meter.

On 6 meters, only a few ground-wave tests were conducted, but the results were similar: Everyone favored the higher antenna substantially.

6-Meter E-Skip Tests

However, on 6-meter E skip an entirely different relationship developed: The *lower* antenna had the advantage in seven out of 10 tests during single-hop openings.[6] Only one station favored the high antenna, and the low array had a mean advantage of 1.3 S units over the high array!

Although this finding is surprising and contrary to every other test conducted, it is consistent with the one previous practical study of antenna height vs. signal strength the author could locate in ham radio literature. Working in the late 1940s, Leroy May[7] set up identical 6-meter Yagis at heights of 35 and 75 feet (10.67 and 22.8 m), and compared 350 received signals on the two arrays. He found that the low array was superior for distances below 1000 miles while the higher array began to pull ahead at distances exceeding 1100 miles.

The author made no attempt to fully replicate May's work, but all of our 6-meter E-skip experience supports him: For contacts into many major cities from greater Los Angeles, a high antenna is a handicap! Much to his chagrin, the author has frequently seen his 90-foot (27.43 m) - high Yagi outperformed on 6-meter E skip by a beam sitting 10 feet (3.05 m) above somebody's roof on a TV mast.

Conclusions and Recommendations

It is customary when reporting a study such as this to conclude by summarizing the findings and making some recommendations. The conclusion here must be that, for every application except E-skip work, there are worthwhile advantages of having an antenna at least 70 feet (21.34 m) high. This height advantage is most pronounced on ground-wave and long-haul DX work.

The only logical recommendation we can make, then, is that all hams should own towers 70 feet (21.34 m) high. May all of the XYLs, frightened neighbors, bill collectors, and zoning-conscious city officials of the world forgive us!

Alternately, maybe we should suggest that all hams (except the author) use 35-foot (10.67 m) towers to give the author a better chance in DX contests. Or better yet, how about an antenna-height multiplier for the DX contests? Let's see, that's 1.5 if your antenna is below 75 feet (22.86 m), 2.0 if it's below 40 feet (12.19 m), and 3.0 if you bury it in the ground . . . This material was originally presented in *QST* by Wayne E. Overbeck, N6NB.

References

[1] Lindsay, "Quads and Yagis," *QST*, May 1968 (See chapter 3).

[2] Orr, William I., *Beam Antenna Handbook*, 3rd Edition.

[3] No 10-meter "Stateside" tests are reported because the muf was too low for reliable F-layer work across the U.S. when these tests were run.

[4] Overbeck, "The 20-Minute Portable Quad," *QST*, May 1967.

[5] On the hf bands, it is normally assumed that a high antenna has a greater advantage over a low antenna on long-haul DX than it does on shorter paths, but the opposite may well be true for vhf ground-wave work. This is suggested in the *ARRL VHF Manual*, (1st Edition, pages 24,25). Thus, one would expect that an increase in height would result in greater improvement in signals over the 30-mile path than over the 100-mile path.

[6] At the time of the 6-meter tests, E skip was barely "in season." The author is continuing this study during seasons of more frequent E-skip openings.

[7] May, "Some Practical Results on the Question of Antenna Height," *CQ*, April 1953.

Limited-Space Antennas and Methods Of Coupling

When short, random-length wire antennas prove disappointing, chances are the installer didn't follow a few basic rules for good performance. These tips should lead the way to better results with "randoms."

One very popular type of antenna, probably because of its simplicity, is a wire of either a predetermined or random length, fed at one end. It is common procedure among amateurs these days to refer to such an antenna as a "long wire." Actually, this term is usually incorrect because, by definition, a long-wire antenna is a wire that is several wavelengths long at the operating frequency. But no matter what you call it, the end-fed wire can be a very simple antenna to put up and use, if certain steps are taken.

Transmitter Loads

Nearly all transmitters described these days are designed to work into 50- to 70-ohm loads, with little thought given to any load that departs very far from these figures. If the load is something different than the above figure it may be impossible to get the amplifier in a transmitter to load up. In order for the final amplifier stage to operate at its best efficiency, the load (the antenna system) must be within the design range of the amplifier.

An end-fed wire may present a load of 50 to 70 ohms, but if it does it will be a case of pure luck on the part of the user — and what's more important, that load won't stay the same across a band. In other

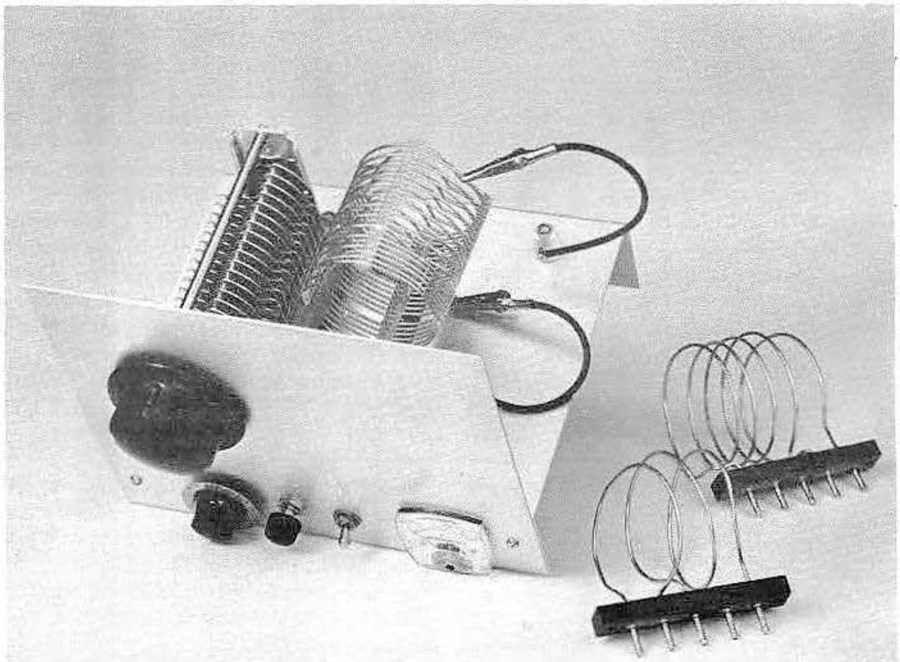

The completed transmatch with the 80/40-meter coil plugged in. At the rear is the 20-meter coil and the 10/15-meter unit is to the front. In regular operation, the antenna would be attached to the standoff insulator at the top rear of the chassis. The clip lead visible below the coil is the one attached to the jack bar.

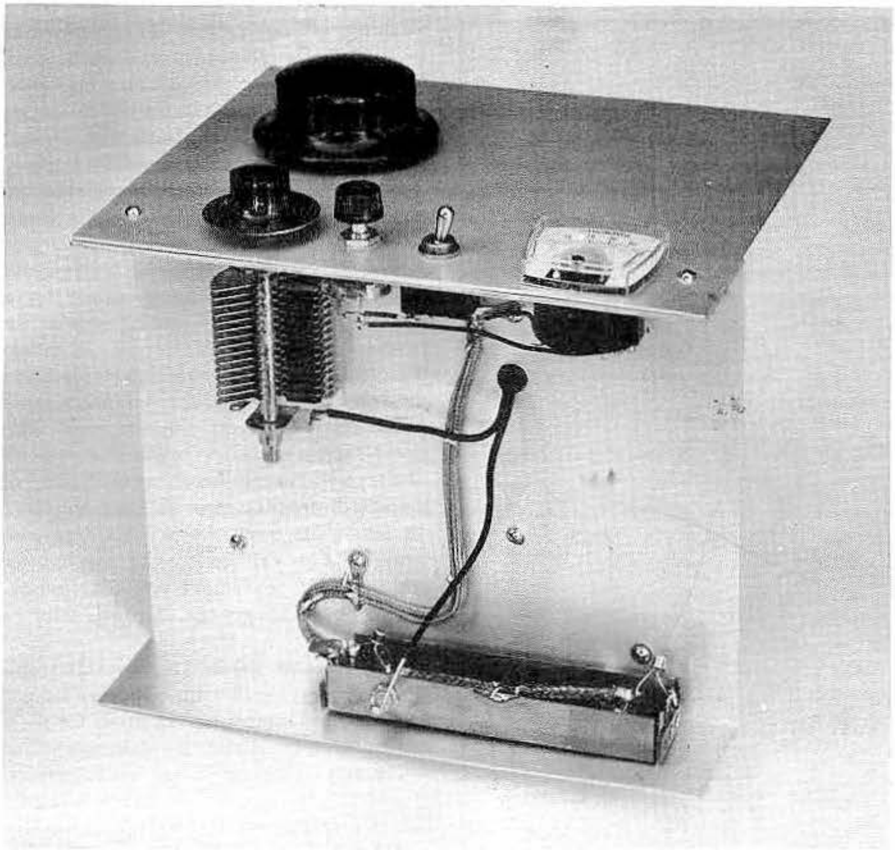

The wiring below deck. At the rear of the chassis is the Varimatcher section. C2 is at the left front of the chassis.

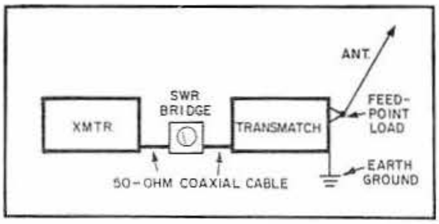

Fig. 3 — This block diagram shows the set-up for using a Transmatch. Not shown is an antenna relay which normally would be inserted in the coaxial line. If a low-pass filter is used, it should be the last item in the line before the Transmatch.

words, the antenna will present a 50- to 70-ohm load for only a very limited frequency range. Once we QSY the load may change to where it is no longer within the tuning range of the amplifier. Our problem boils down to having the transmitter *always* see a load of 50 to 70 ohms, regardless of the band or frequency in use. This in turn means we must make the antenna system look like a 50- to 70-ohm load, no matter which band we use it on.

The Transmatch, an Adjustable RF Transformer

Let's make one point clear about end-fed wires, or any antenna, for that matter: There is no way of predicting what the feed-point impedance (load) will be before making and installing the antenna. We can come close, but there are many factors that get into the act to determine what the impedance will be. The antenna's height, its proximity to nearby objects, its length, and the antenna's relation to earth ground are just a few of the factors. If we don't know what the feed-point impedance is, how can we make the transmitter always work into a 50-ohm load? The easiest way is to insert a Transmatch between the transmitter and the feed point. A Transmatch is simply an adjustable rf transformer that takes our unknown feed-point load and converts it to a desired load, 50 ohms in the case shown in Fig. 3.

Note in Fig. 3 that we show a random-length antenna and an earth ground connection. In this case, our unknown load exists between the end of the antenna and ground. On the transmitter side of the Transmatch we have 50-ohm coaxial cable and inserted in this cable is a 50-ohm reflectometer or SWR (standing-wave-ratio) bridge. The reflectometer is simply a measuring instrument that tells us when our Transmatch is properly adjusted to convert our unknown load to a 50-ohm load. If the Transmatch has adequate matching range, we can convert any feed-point load to 50 ohms. And this means that we can take any random length wire and make a working antenna out of it for any amateur band or frequency. There are some practical limits as to how short a wire we can use, but actually the antenna can be quite short in relation to a wavelength and still work.

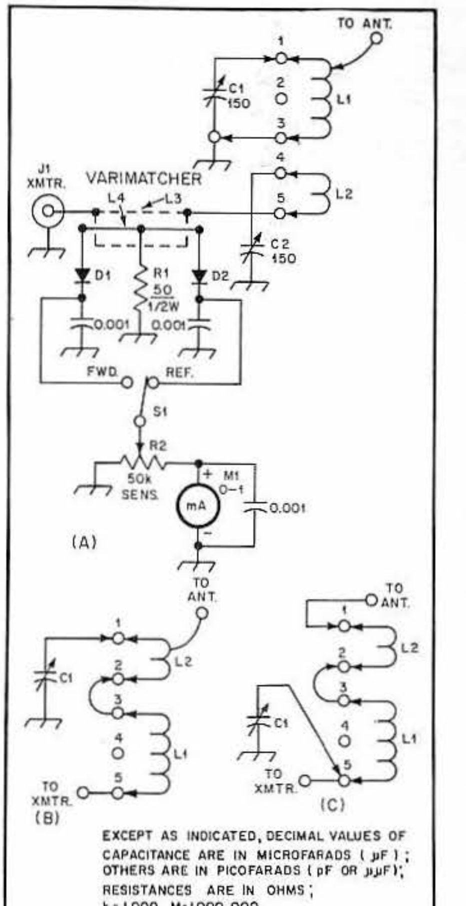
TO ANT.
1
2
3
4
5
C1 150
L1
J1 XMTR.
VARIMATCHER
L4
L3
L2
C2 150
D1
R1 50 1/2W
D2
0.001
0.001
FWD.
REF.
S1
R2 50k SENS.
M1 0-1
mA
0.001
(A)
TO ANT.
C1
L2
L1
TO XMTR.
(B)
TO ANT.
L2
C1
L1
TO XMTR.
(C)
EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF) ; OTHERS ARE IN PICOFARADS (pF OR µµF); RESISTANCES ARE IN OHMS ; k = 1 000, M = 1 000 000.

C2 — 150-pF variable (Millen 19140 or similar).
D1, D2 — 1N34A germanium diode.
J1 — Coax chassis fitting, type SO-239.
L1, L2 — See Fig. 7.
L3, L4 — See Fig. 6.
C1 — 150-pF variable, (air gap 0.077 inch [2 mm] or larger for high power, Millen 12515 or similar; air gap 0.040 inch [1 mm] for low power, Millen 19140W or similar).
M1 — 0-1 milliammeter (more sensitive meter can be used).
R1 — 50-ohms, 1/2-watt carbon or composition, not wire-wound.
R2 — 50 kΩ control, linear taper.
S1 — Single-pole, single-throw toggle switch.

Fig. 4 — Circuit diagram of the Transmatch and Varimatcher. All 0.001-µF capacitors are disk ceramic.

Limited-Space Antennas

Many hams live in apartments or locations where it is impossible to put up an "antenna farm" or even a half-wave dipole for 80 or 40 meters. Random-length wires are sometimes the best bet in these circumstances. For hams who live under such conditions there are some general rules that can be followed for best performance. If possible, always get the antenna up on the roof. If not, get the antenna as high as possible. Make the wire as long as possible, even if it has to go around corners. Don't overlook existing antenna possibilities, such as rain gutters or roof flashing. In a moment we are going to describe a Transmatch that can be used to couple practically any wire or metal structure to the transmitter, including rain gutters.

If it is impossible to get an outdoor antenna up (and don't overlook "invisible" antennas[1]). an indoor antenna will work, but not as well as an outdoor one. With the Transmatch to be described, you can run a wire around the ceiling molding and couple the wire to the rig, maintaining that 50-ohm load we mentioned earlier. When you hear hams talking about loading up the bed spring, don't laugh — many a ham has made contacts that way. All you need is some method of coupling the bed spring to the rig; that's what our Transmatch will do.

The Transmatch

Shown in Fig. 4 is the circuit for a Transmatch that will do the job we've been talking about. This unit will match practically any wire to our 50-ohm rigs on any band from 80 through 10 meters. Depending on which capacitor plate spacing you use for C1 the Transmatch can be used for Novice powers or up to the legal limit of 1 kW. Actually, the closer-spaced capacitor will handle 200 watts or so. The same type coil stock is used for either power level, high or low.

Also included in the Transmatch shown in Fig. 4 and the photographs is an SWR bridge. This is a necessary item in order to know when the Transmatch is correctly adjusted. If you already have a Monimatch or reflectometer, the unit described can be eliminated from the Transmatch.

With the random-wire antenna we'll be dealing with various loads, depending on the frequency and band in use. Shown in Fig. 5 are the three basic circuit configurations used with the Transmatch. The circuit can be changed to conform with type A, B, or C by reversing the plug-in coil in the jack bar or by changing the capacitor C1 from the output side of the L configuration, as in B, to the input side, as in C. The capacitor is changed by means of a clip lead connected to the stator.

Some loads may require the circuit setup of A. In this configuration, a link-coupled parallel-tuned circuit is used, the antenna being tapped onto L1.

Construction Details

The chassis used to hold the parts is 2 × 7 × 9 inches (51 mm × 178 mm × 229 mm) and the panel measures 7 × 9 inches (178 mm × 229 mm). Any chassis large enough to hold the parts can be used. C1 and the jack bar for the plug-in coils are mounted on top the chassis, and the Varimatcher reflectometer and C2 are mounted below the chassis top. The remaining components are mounted on the chassis front.

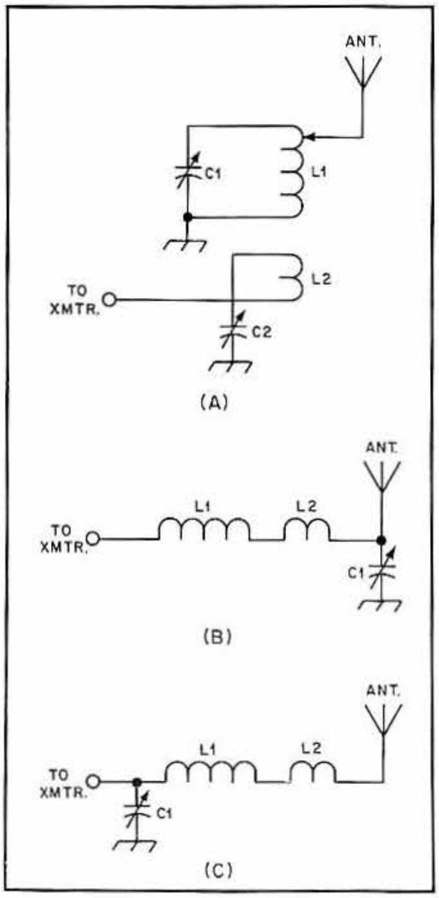

Fig. 5 — Three possible configurations with the Transmatch as described in the text. To set up types B or C the plug-in coil is reversed in the jack bar and terminal no. 3 of the jack is clipped to terminal no. 2.

A 4-inch (102 mm) length of RG-58/U coaxial cable is used for the pickup and conductor sections of the SWR bridge. Details for making this section are given in Fig. 6. Study these details and the photograph of the bottom view carefully before starting construction. The black outer covering of the coax is removed, leaving the braid and inner conductor with its insulation. The outer braid will be L3 and the inner conductor L4. You'll notice that there is an open area at the center of the coax braid. This is to allow room for the connection of one end of the 50-ohm resistor to the center of the inner part of the coaxial line. Use a probe or pointed instrument to open up the area in the braid and then carefully tin the edges of the opening with solder so as to prevent any of the hair-like wires from shorting to the resistor lead or inner conductor. The ends of the braid can be wrapped with a few turns of solid wire and tinned. The wire ends will provide a support for the connection to the feed-through terminal and the inner pin of J1.

The metal trough that houses the bridge section is made from a piece of copper flashing, although tin or aluminum could be used. It is a good idea to drill the holes for J1 and the feed-through bushing before bending up the trough into a U. Also, when soldering the leads for the diodes, D1 and D2, use a heat sink between the body of diode and the point being soldered, because too much heat can ruin the diode.

Using the Transmatch

In making the antenna, shoot for a length of at least 1/4 wavelength at the lowest operating frequency. In other words, if you plan on working 80 meters as the lowest band, then the antenna should be 60 feet (18.29 m) long, at least. This doesn't mean that shorter wires won't work — they will, but not nearly as well. A lot of hams will say they can't get up a length of 60 feet! The wire doesn't *have* to run straight. You can go around corners, up and down, or what have you. The important point is to get up as much wire as possible.

By the same token, many hams think (mistakenly) that they have to have a good earth ground connection in order for their station to work. It's fine if you have one but if you don't, forget it. If you have access to a water pipe or other earth ground connection make a connection to the rig and the Transmatch, but if you can't, don't worry. The antenna will still work.

With the antenna connected and the rig on the desired frequency, feed enough power through the system to get at least a half-scale reading on the Varimatcher meter, and have the Transmatch set up as in (A). Tap the antenna onto the first turn of the coil L1 at the "hot" end, or end opposite the ground. Incidentally, always turn the rig off when making any adjust-

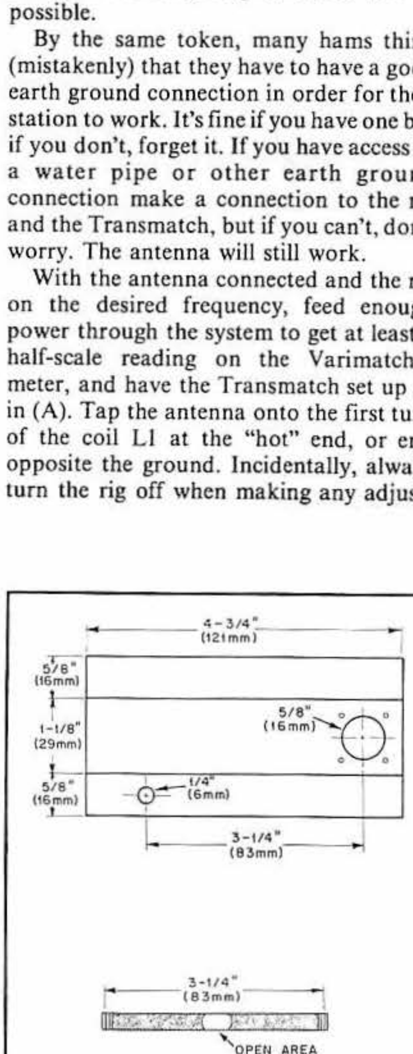

Fig. 6 — Constructional details of the Varimatcher bridge section. The braided portion of the coax is L3 and the inner portion is L4.

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[1] Any wire that is no. 28 or smaller is practically impossible to see when strung up as an antenna. Many hams use "invisible" antennas to prevent a touchy landlord situation.

ments on the Transmatch. There may not be any dc voltages present but some very, very high rf voltages can be developed on the Transmatch coils and can cause a nasty rf burn.

With the antenna tapped on near the hot end of L1 switch S1 to read reflected power and adjust C1 and C2 for a dip or minimum reading. If you cannot get the reflected reading down to zero, or close to it, turn off the power and move the antenna tap closer to the ground end of the coil. You'll eventually find a tap point that will give a reading of zero in the reflected position versus full scale in the forward position of S1. If you find that the tap point on L1 is very close, say within 25 percent, to the ground end, you may want to try configuration B or C.

In eight of these configurations, start at the antenna end of the coil and, using another short clip lead, short out turns or portions of turns as you move the antenna tap towards the transmitter end of the circuit. In other words, the antenna is always on the end of the coil, but you may have some of the coil shorted out in order to get a match as indicated by M1.

Once you get a match for any given band, make a chart of the taps and so forth so you can return to the setup when you change bands.

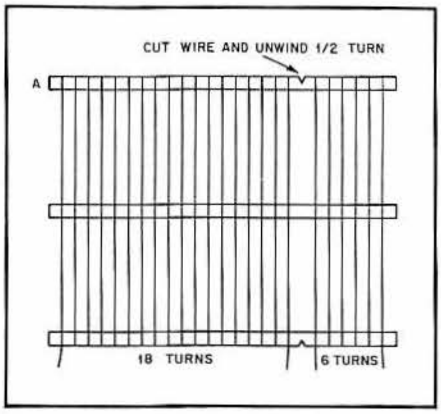

Fig. 7 — The 80/40-meter coil. To use the coil on 40 meters, short out 10 turns, counting from the "A" end of the coil. Shorting clips should be copper and the shorting leads should be insulated. Coil stock is no. 14 wire, 8 turns per inch (25 mm), 2-1/2 inches (64 mm) in diameter (Air Dux 2008T, B & W 3906-1, or Polycoils 1775).
The 20-meter coil consists of 4 turns of no. 12 solid wire, 2-1/2 inches in diameter, with the turns spaced so that L1 is 1-1/2 inches (38 mm) long. L2 is one turn of no. 12, same diameter as L1, spaced 1/2 inch (13 mm) from the end of L1. The 15/10-meter L1 coil is 2 turns of no. 12 solid wire, 2-1/2 inches (64 mm) in diameter, turns spaced to cover 1-1/2 inches (38 mm). L2 is a single turn, same diameter as L1, spaced 1/2 inch (13 mm) from L1.
All coils are mounted on Millen type 40305 plugs and the socket (jack bar) is a Millen 41305. See G. R. Whitehouse ads in *QST*.

The main reason for using configurations B and C is that if the antenna is tapped near ground on L1 in configuration A, extremely high rf voltages can develop across C1 even with Novice powers. We don't recommend playing around with "arcs" from coils but it might be wise to prove to yourself just how much voltage can be developed. With the antenna tapped near the ground end of L1, take a pencil and hold it by the wood, not at the eraser end but in the center. With the key closed and the rig loaded up to about 75 watts, touch the lead end of the pencil to the stator of C1. You'll quickly see why caution is necessary. Such an arc can make a very nasty and painful burn.

If you want to try using antennas that are *very* short for the frequency, such as 10 feet (3.05 m) long on 80 meters (similar to a mobile whip) certain additional steps may be required to obtain a match with the Transmatch. When you make the coil for 80 and 40 meters you'll have some coil stock left over. With very short antennas, this can be used as a "loading" coil. Connect the antenna to one end of the coil and connect the other end to the antenna terminal on the Transmatch. Then go through the tune-up procedure. You may have to use a clip lead to short out turns on the coil but you'll find a setup that will permit matching with the Transmatch. Again, avoid coming in contact with the series loading coil because very high rf voltages can develop in such a setup.

Some beginners may not be aware of it, but a fluorescent lamp or neon bulb will light up when in an rf field, if the rf voltage is high enough. If you have a fluorescent lamp (a burned-out one is OK), the lamp can be laid along the antenna wire where it leaves the Transmatch. This makes a good output indicator, showing when power is flowing in the antenna. This material was originally presented in *QST* by Lewis G. McCoy, W1ICP.

Off-Center-Loaded Dipole Antennas

So you can't manage a buried radial system on your city lot, eh? Then why not scrap those plans for a vertical antenna and try K1TD's version of a short dipole? Here are the design tips you need.

In these times when much of our amateur population lives in urban areas, the subject of shortened antennas for the lower frequency amateur bands is a very popular one. Physically short ground-mounted vertical antennas with lumped-constant loading to make them resonant can be quite efficient radiators, if a good radial system has been installed. This has certainly been evidenced in Sevick's series of *QST* articles.[1] To many amateurs, however, the "hitch" in constructing such a system is the installation of a good radial system. It must be admitted that for the "top" amateur bands, 160 and 80/75 meters, an efficient system of buried radials requires a sizable amount of real estate, even for a physically short radiator. On the average city-size lot, 50 or 75 by 120 to 150 feet (15.24 - 22.86 m by 36.58 - 45.72 m), it's almost impossible to install a highly efficient radial system for 80/75 meters, much less for 160 meters, when structures like a house and perhaps a separate garage exist. Or to some amateurs, just the thought of burying hundreds or maybe thousands of feet of wire is enough to turn off any enthusiasm for the project.

What's the alternative? A dipole type of antenna with lunped-constant loading. At modest heights, 30 or 40 feet (9.14 or 12.19 m), such an antenna will prove to be quite satisfactory if it is physically longer than about 0.2 wavelength. Shorter lengths may also be used, at reduced efficiency. Such an antenna can be fed directly with 50-ohm coaxial line, and it can be operated with no earth ground. (Of course the chassis of the transmitter and/or receiver should be grounded adequately for protection against shock hazard.)

Nearly all of us are familiar with the concept behind the use of inductive loading. A vertical antenna which is shorter than a quarter wave (or a dipole antenna which is

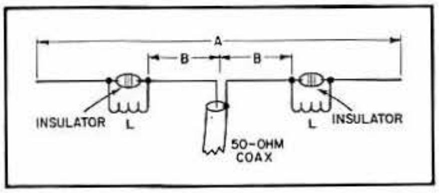

Fig. 8 — A dipole antenna lengthened electrically with off-center loading coils. For a fixed dimension A, greater efficiency will be realized with greater distance B, but as B is increased, L must be larger in value to maintain resonance.

(Eq. 1):

$$L_{\mu H} = \frac{10^6}{68\pi^2 f^2}\left\{\frac{\left[\ln\frac{24\left(\frac{234}{f}-B\right)}{D}-1\right]\left[\left(1-\frac{fB}{234}\right)^2-1\right]}{\frac{234}{f}-B}-\frac{\left[\ln\frac{\left(24\,\frac{A}{2}-B\right)}{D}-1\right]\left[\left(\frac{\frac{fA}{2}-fB}{234}\right)^2-1\right]}{\frac{A}{2}-B}\right\}$$

where

$L_{\mu H}$ = inductance required for resonance
ln = natural log
f = frequency, MHz
A = overall antenna length, feet
B = distance from center to each loading coil, feet
D = diameter of radiator, inches

shorter than a half wave) will exhibit capacitive reactance at its base (or center) feed point. To cancel such capacitive reactance, a coil having the proper inductive reactance may be connected in series with the base feed point of the vertical. The same result will be obtained through the use of two such coils for a dipole, one coil connected in series with each half. It is not necessary for the inductor to be installed at the feed point, however. In fact greater radiating efficiency results through improved current distribution if the inductor is located along the radiator some distance away from the low-impedance feed point, *viz,* in the manner of a center-loaded mobile whip antenna. Fig. 8 shows this concept extended to a dipole element, with off-center loading. The inductors resonate the antenna to the operating frequency, but do little actual radiating themselves. (This is in contrast to helically wound or continuously loaded elements, where a long thin inductor is the radiator as well as the loading element.)

In the antenna represented by Fig. 8, there are many variable factors to be considered when a practical antenna for a given frequency is being constructed. Of primary consideration from an efficiency standpoint is the overall length, shown as dimension A. Another consideration for efficiency is the distance of the coils from center, dimension B. The longer the overall length (A), up to a half wave, and the farther the loading coils are placed from the center (B), the greater is the efficiency of the antenna. However, the greater is distance B (for a fixed overall antenna size), the larger the inductors must be to maintain resonance. Theoretically, if the coils were placed at the outer ends of the dipole, they should be infinite in value to maintain resonance. Capacitive loading of the ends, either through proximity of the antenna to other objects or through the addition of capacitance hats, will reduce this requirement to a more practical value.

What Inductance Values?

As a matter of personal interest, this writer has been doing experimental work for a number of years with off-center-loaded antennas. One big drawback to such experimentation was the ever-present need for a large amount of cut-and-try work to arrive at resonance whenever a new set of dimensions was to be used. Probably the number of pruned-off turns from coil stock from such experiments, if straightened out and soldered end to end, would make up several full-sized half-wave antennas for the 160-meter band. Therefore, most of the writer's work of late in this area has been in going through paperwork exercises, looking for a way whereby at least "ball-park" values of inductance needed for a particular system could be calculated.

The equation contained in the Mobile chapter of *The ARRL Antenna Book* for determining the capacitance of a vertical antenna shorter than a quarter wavelength looked promising in early computations, and, indeed, it became the basis for the calculation procedure which finally resulted. This procedure has been found to produce results much closer than mere "ball-park" values for the necessary inductance — for wire antennas "in the clear" at moderate heights, the final inductance values found by cut-and-try pruning for lowest SWR at the desired frequency have been so close to the value from calculations that a laboratory bridge was necessary to measure the difference. The results are equally good for elements using tubing. Once the needed inductance value is determined by calculations, it is generally found sufficient to obtain coil dimensions from an ARRL L/C/F Calculator (see LaPlaca[2]) or by equation. Any significant pruning which has been found necessary could always be attributed to objects in proximity to the ends of the antenna.

The complete set of calculations is expressed in the mathematical relationship as Eq. 1, presented here primarily for mathematics buffs or those having access to electronic computers. This equation yields the inductance required, in microhenrys, for single-band resonance of a shortened antenna of a particular physical size at a given frequency, for a specific position of the loading coils from the center of the antenna. To spare the reader the task of performing some rather tedious calculations, Fig. 9 has been prepared from Eq. 1. The curves of the chart have been normalized, and may be used for any frequency of resonance. The chart is based on a half-wavelength/diameter ratio of the radiator of approximately 24,000. (This corresponds to no. 14 wire on 80 meters or no. 8 wire on 160 meters.) For "thinner" conductors, the required inductance will be somewhat greater than that determined from Fig. 9, and less inductance will be required for "thicker" conductors.

The use of the chart is as follows: At the intersection of the appropriate curve from the body for dimension A and the proper value for the coil position from the horizontal scale at the bottom of the chart, read the required inductive reactance for resonance from the scale at the left. Dimensions A and B are shown in Fig. 8, and for use with the chart are expressed as percentages. Dimension A is taken as percent length of the shortened antenna with respect to the length of a resonant half-wave dipole of the same conductor material. Dimension B is taken as the percent of coil distance from the feed point to the end of the shortened antenna. For example, resonating an antenna which is 50 percent or half the size of a half-wave dipole (one-quarter wavelength overall), with loading coils positioned midway between the feed point and each end (50 percent out), would require loading coils having an inductive reactance of approximately 950 ohms at the operating frequency. If the antenna is hung "in the clear," and if the length/diameter ratio of the conductor is near 24,000, inductance values as determined from the chart will be very close to actual values required. (Eq. 1 above takes the diameter of the radiator into account, and thus may be used for any length/diameter ratio.) For practical

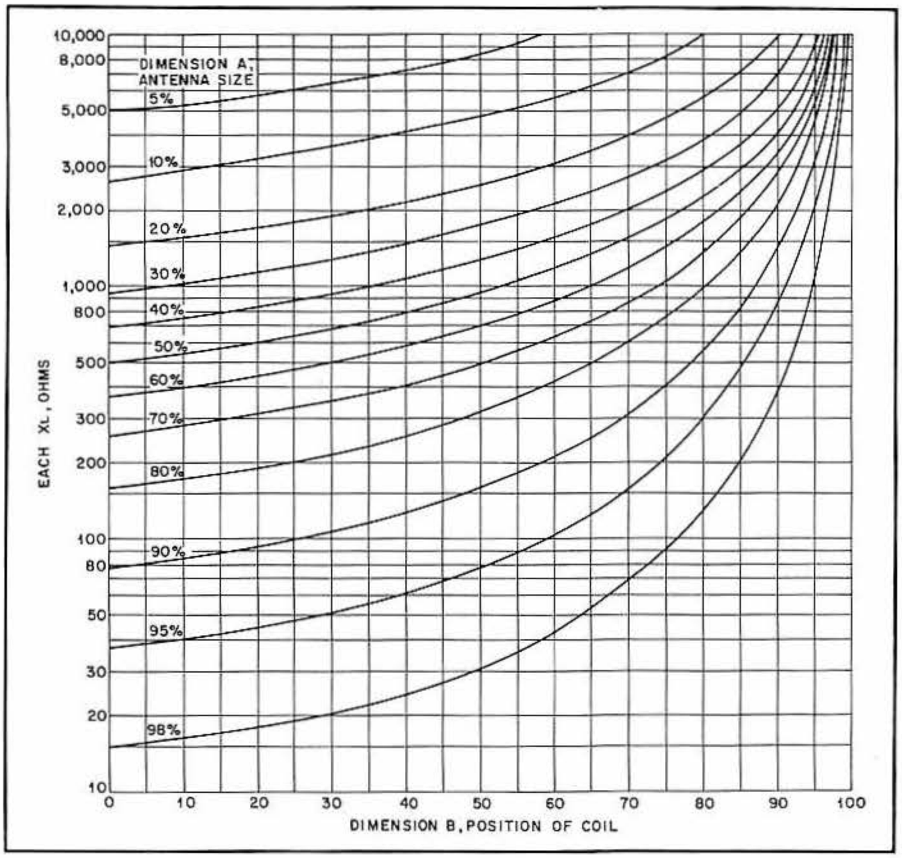

Fig. 9 — A chart for determining approximate inductance values for off-center-loaded dipoles. At the intersection of the appropriate curve from the body of the chart for dimension A and the proper value for the coil position from the horizontal scale at the bottom of the chart, read the required inductive reactance for resonance from the scale at left. See Fig. 8 regarding dimensions A and B.

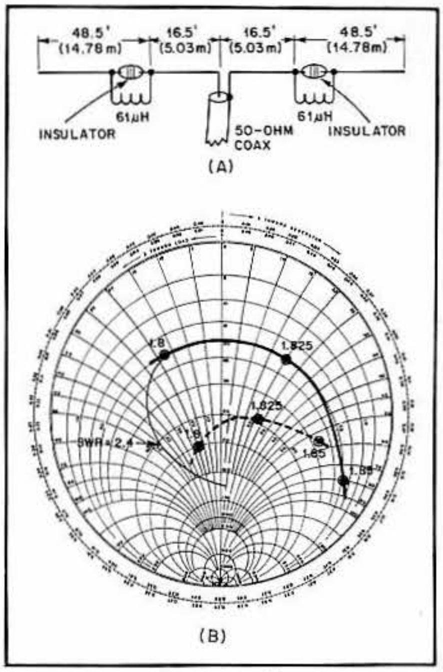

Fig. 10 — At A, an 80-meter dipole loaded for 160-meter operation. The inductors are 37 turns of coil stock having a 3-inch (76 mm) dia and 10 turns per inch (25 mm) (B & W 3035). At B, the impedance plot of this antenna installed at a height of 50 feet (15.24 m) (solid curve), and the plot of a 160-meter half-wave dipole (broken curve).

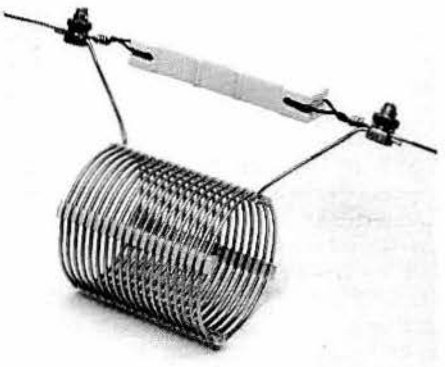

Fig. 11 — Copper electrical service connectors, sold under one trade name of Servit, provide a simple means of installing the loading coils. The antenna wire and the ends of the coil wires should be tinned to prevent corrosion. In addition, a protective coating of acrylic spray may be used at each connection.

purposes, dimension B may be taken as that distance from the center of the feed-point insulator to the inside eye of the loading-coil insulator, and dimension A as the eye-to-eye distance inside the end insulators (which are not drawn in Fig. 8).

Proximity of surrounding objects in individual installations may require some pruning of the coils, and the exact amount of final inductance required should be determined experimentally. If the antenna is hung in inverted-V style, with the ends brought near the earth, the required inductance will almost always be somewhat less than that determined from the chart or equation. A grid-dip meter, Macromatcher (see Hall and Kaufmann[3]), or SWR indicator may be used during the final adjustment procedure.

Practical Antennas

Although one might erect an inductively loaded antenna that is cut for a single amateur band, it is possible to use the antenna itself for two, three or more bands of operation, if provision is made to lower the antenna for band changes. A simple rope halyard and pulley arrangement at one of the supports will do the trick. Fig. 10A shows a three-band antenna of this nature, for 160, 80 and 20 meters. If the insulators shown are left open, with nothing bridging them, the antenna is a simple half-wave dipole cut for 14.18 MHz. (The 48.5-foot [14.78 m] lengths act merely as support wires, and have negligible effect on operation of the antenna.) If the insulators are bridged with short lengths of antenna wire, the antenna becomes a center-fed 80-meter dipole, resonant at about 3.6 MHz. For 160-meter operation the 20-meter insulators may be bridged with loading coils to resonate the antenna at 1.8 MHz, as shown in Fig. 10A. Burndy or other manufacturers' "Servit" type of electrical connectors may be used for ease in making band changes quickly, as shown in Fig. 11.

The calculation procedure for determining loading-coil values for the antenna of Fig. 10A, using the chart of Fig. 9, goes like this. If operation is desired on 1.8 MHz, the length of a full-sized half-wave dipole is found from the relationship 468/f to be 260 feet (79.25 m). The 130-foot (39.62 m) length of Fig. 10A represents 50 percent of this size, meaning that the dimension-A curve marked "50 percent" in Fig. 9 is to be used. The position of the coils is $16.5/(16.5 + 48.5) \times 100$, or 25 percent of the distance out from center, dimension B. From the intersection of 25 (horizontal scale at bottom) and the 50 percent curve, the required inductive reactance is read from the scale at the left of Fig. 9 to be 650 ohms. The inductance, L, is $650/2\pi f$ or 57.5 microhenrys, if no. 8 wire is to be used. For smaller diameter wire, the inductance should be somewhat larger. (Calculations from Eq. 1 for no. 12 wire indicate the required inductance is 60.99 μH.)

The radiation resistance of a shortened antenna loaded to resonance is less than that of a full-sized antenna. Further, the shortened antenna is "sharper," meaning that the change in reactance versus frequency is greater. In other words, the shortened antenna acts as a tuned circuit having a higher Q than a full-sized antenna.

To check these characteristics, the line input impedances for the antenna of Fig. 10A were measured with a laboratory bridge, and the electrical line length at the measurement frequency was then taken into account to determine the impedance at the antenna feed point. The antenna was constructed of no. 12 wire and hung at a height of 50 feet (15.24 m) as a "flat-top" radiator.

The solid curve of Fig. 10B is a plot of the feed-point impedance versus frequency for this antenna. The plot on Smith Chart coordinates is more meaningful than a simple SWR-vs.-frequency curve because the magnitudes of the resistive and reactive components are shown, as well as the sign of the reactance. (Capacitive reactance is negative, plotted to the left of the vertical center line, and inductive reactance is positive, plotted to the right.) In this presentation, a 50-ohm nonreactive impedance will appear at the exact center of the chart. The SWR in 50-ohm line for a given frequency may be determined by first noting the distance from the center of the chart to the particular impedance plot on the curve, and next measuring this same distance down the vertical center line from chart center (a drawing compass is helpful for this task), and finally dividing 50 into the value read at that point on the center line. For example, the SWR at 1.8 MHz equals 120/50 or 2.4, as indicated by the segment of the 2.4 SWR circle in Fig. 10 B. It may be seen that resonance (zero reactance) occurs at approximately 1810 kHz, where the resistance is about 22 ohms. The SWR at resonance is 2.33:1, and climbs to 3:1 at 1825 kHz. At 1850 kHz, the SWR is 10:1. Without any matching provisions the antenna is relatively sharp, as mentioned earlier. If one sets the usable bandwidth as the frequency range where the SWR is 3:1 or less, it is approximately 35 kHz, or 1.9 percent of the resonant frequency. As far as efficiency is concerned, ohmic losses are low, and the antenna is a good performer on 160 meters. Because of its horizontal polarization, it has proved to be most effective at night, and stations several hundred miles away have been worked with S 9 reports received for the 50-watt signal.

For a comparison of impedances, the broken curve of Fig. 10B is a plot of measured impedances of a full-size half-wave dipole, 260 feet (79.25 m) long overall, hung in place of the shortened antenna. From this curve it may be seen that resonance occurs at 1810 kHz, where the resistance is 59 ohms. The 3:1-SWR bandwidth for the half-wave antenna is in the order of 60 kHz, or 3.3 percent of the resonant frequency. It is interesting to note on this curve that the SWR at resonance is 1.18:1, and that it is a somewhat lower value, 1.15:1, at a frequency a few kilohertz above resonance. (Measurements were made every 5 kHz across this band, but plot points are shown only for 25-kHz increments to avoid crowding of the data.) This evidence refutes the oft-heard statement that the SWR-vs.-frequency curve is *always* lowest at antenna resonance. Points to remember are that the SWR in a transmission line is completely dependent upon the characteristic-impedance value of the line in use. Using a line of different impedance may shift the position of the SWR curve along the frequency axis in a simple SWR-vs.-frequency plot. This is definitely true in this case — if the 160-meter half-wave dipole were to be fed with 75-ohm line, the lowest SWR would occur at a frequency about 5 kHz *below* antenna resonance, whereas with 50-ohm line the lowest SWR is at a frequency slightly *above* resonance. The reason this happens is that the resistive component of the impedance, which consists of the radiation resistance plus any loss resistance, is not constant with frequency, even over a rather narrow frequency range. It must be acknowledged that the differences here are very slight, however, and for practical purposes the frequency of lowest SWR is (within a few kilohertz) the resonant frequency of the antenna.

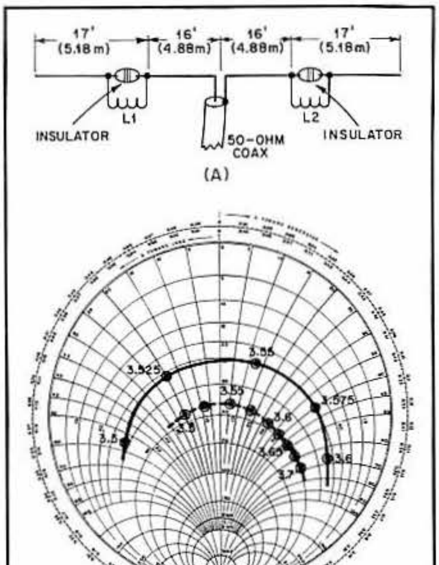

Fig. 12 — At A, a 40-meter dipole loaded for 80-meter operation. For resonance at 3.55 MHz the coils should be approximately 40 μH (27 turns of stock); 3.75 MHz, 35 μH (24 turns); 3.9 MHz, 31 μH (22 turns); and 4.0 MHz, 29 μH (21 turns). These are calculated inductance values for no. 12 antenna wire. Coil stock referenced above is 3-inch (76 mm) diameter, 10 turns per inch (25 mm) (B & W 3035). At B, the impedance plot of the 3.55-MHz version (solid curve) and of an 80-meter half-wave dipole (broken curve).

Another point concerning the SWR values bears noting. The values as determined from the plots in the manner described above are quite accurate, having been determined by measurements with laboratory equipment. In contrast, measurements with simple SWR indicators usually cannot be relied upon for anywhere near the equivalent accuracy.

For example, the author owns a commercially manufactured SWR indicator of the Monimatch type (see McCoy[4]) which, under a particular set of conditions, indicates a 2.5:1 SWR in a line where laboratory measuring equipment shows the *true SWR to be 4:1.* A significant difference! Herein lies another reason why impedance plots on Smith Chart coordinates are more meaningful than a simple SWR-vs.-frequency curve — greater accuracy may generally be expected.

A Half-Size 80-Meter Antenna

Fig. 12A shows the 3-band concept described earlier as it can be applied to 80, 40 and 20 meters. Its overall length is 66 feet (20.12 m), not a difficult length to use on a small lot. This antenna was constructed for 80-meter operation with a design-center frequency of 3.55 MHz, using no. 12 antenna wire and 40-μH loading coils — 27 turns of stock having a diameter of 3 inches (76 mm) and a pitch of 10 turns per inch (25 mm) (tpi). Feed-point impedances versus 80-meter frequency for the antenna, hung at a height of 50 feet (15.24 m), are shown by the solid curve at B of Fig. 12. Actual resonance occurred at 3.54 MHz, where the resistance was about 26 ohms. The bandwidth within which the SWR is 3:1 is 60 kHz, or 1.69 percent of the resonant frequency.

Also shown in Fig. 12B, by the broken curve, are the feed-point impedances of a half-wave dipole, 132 feet (40.23 m) overall length, hung in place of the shortened antenna. Resonance occurs at 3.54 MHz, where the resistance is 43.5 ohms and the SWR is 1.15:1. The broader nature of the half-wave antenna is exhibited by the "tighter" curve which swings closer to the 50-ohm center point of the chart than the shorter, loaded antenna. The SWR at 3.5 MHz is 1.6:1, and remains below 3:1 to 3.67 MHz.

Capacitive and Inductive Loading

One would assume that a combination of capacitive and inductive loading might provide a different feed-point impedance than would inductive loading alone, because of different current distributions in the radiators. To check out this assumption, the antenna of Fig. 12A was used as a "test bed" for comparative measurements. Capacitance hats were attached at different points along the 17-foot (5.18 m) lengths of wire outside the coils, and the coils were pruned to reresonate the antenna at about the same frequency as before. The impedance measuremnts were then repeated.

Dangling End Sections

First, "hats" consisting of 18 inches (457 mm) of no. 12 wire were affixed to the antenna ends and permitted to dangle. This lowered the resonant frequency to 3435 kHz. By calculations, this was approximately the same effect as that of extending the 17-foot portions of the antenna by the same amount as the dangling lengths, so it

Table 4

Characteristics of Various Loading Techniques, 66-Foot, 80-Meter Dipole

Loading	*Approx. feed-point resistance, resonance*	*SWR at resonance*	*3:1-SWR bandwidth, % of resonant freq.*
40-μH coils only	26 ohms	1.92:1	1.69
36.5-μH coils, 18" dangling ends	26	1.90:1	1.79
36" hats outside 32.5-μH coils	23	2.15:1	1.68
30-μH coils, 36" hats at ends	25	1.98:1	2.05
None (λ/2 dipole)	43.5	1.15	Greater than 3.6

Coil positions for each loaded antenna were 16 feet from antenna center. All antennas were constructed of no. 12 wire and installed at a height of 50 feet.

Feet X 0.3048 = m.

Inches X 25.4 = mm.

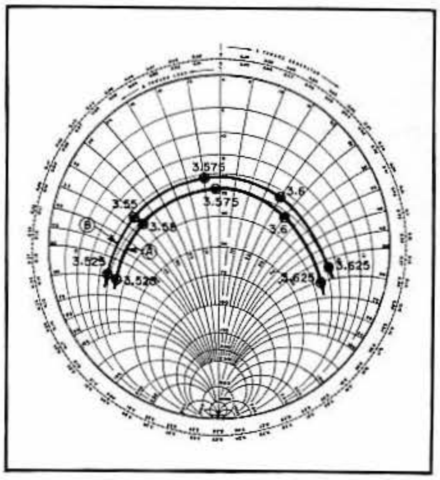

Fig. 13 — Curve A is the impedance plot of the antenna of Fig. 12A with 18-inch (457 mm) dangling end sections added and the coil trimmed to restore resonance near the original frequency. Curve B is a plot of the same antenna with X-shaped capacitance hats added at a point just outside the loading coils (dangling sections removed and coils trimmed to reestablish resonance.).

would seem to make little difference whether short sections of extra length are added inside the supporting insulators or are at the ends, suspended at right angles to the main antenna wire.

The inductors were reduced from 40 to 36.5 μH (25-turn coils replaced the original 27-turn coils), and resonance occurred at about 3575 kHz. At this frequency the resistance was 26 ohms and the SWR 1.90:1. The 3:1-SWR bandwidth, 64 kHz, is 1.79 percent of the frequency of resonance. The impedance plot for this arrangement is shown as Curve A in Fig. 13. The resistance at resonance for this antenna is identical to that with the coils alone, and the bandwidth is only 4 kHz greater, 64 kHz vs. 60. From these results, one would conclude that the main advantage offered by the "danglers" is a small saving of space over a flat-top antenna.

Capacitance Hats near Loading Coils

Next the dangling end sections were removed and a pair of capacitance hats was formed, each from two 36-inch (0.91 m) lengths of no. 12 solid wire. The two wires for a single hat were attached at their centers to the antenna wire at a point just outside one of the loading coils. The hat wires were then bent radially to form an X at right angles to the antenna wire, like four spokes of a wheel with the main antenna wire at the hub. The diameter of the X-shaped hat was thus 36 inches. The second hat was placed in a like manner just outside the second coil. Burndy connectors were used to affix the hat wires. The resonant frequency of this configuration with the original 40-μH loading coils was found to be 3290 kHz. The effect of adding the hats was about the same as that of extending the 17-foot (5.18 m) lengths to 19 feet (5.79 m).

When the inductors were replaced with 23-turn coils (32.5 μH), the antenna resonated at about 3.575 MHz, the resistance being 23 ohms. The SWR at resonance is 2.15:1, and the 3:1-SWR bandwidth for this configuration is 60 kHz, 1.68 percent of the resonant frequency. The impedance of this arrangement versus frequency is shown by Curve B of Fig. 13.

It is surprising to note that, by the standards of most amateurs, the characteristics of this antenna are not as good as those of the same length antenna with loading coils alone. The SWR at resonance for the antenna with combination capacitive and inductive loading is higher (2.15 vs. 1.92), and the 3:1-SWR bandwidths are the same, 60 kHz. Perhaps a significant factor here, though, is that the diameter of the capacitance hats used for these measurements was small, only 0.011 wavelength. Supporting much larger hats presents mechanical problems with wire antennas, however, as even these were a bit flimsy and would require reshaping after gusty weather.

Capacitance Hats at Antenna Ends

Finally, the X-shaped capacitance hats were moved to the outside ends of the antenna, just inside the end insulators. With the original 40-μH coils, resonance appeared at 3215 kHz. From calculations, it was as if the 17-foot (5.18 m) end sections were actually 21 feet (6.40 m) long. With 30-μH coils (22 turns) in place, the resonant frequency was 3560 kHz. At this frequency the resistance was 25 ohms and the SWR 1.98:1. The 3:1-SWR bandwidth is 73 kHz, or 2.05 percent of the resonant frequency. The impedance plot of this antenna is given in Fig. 14.

It is interesting to note that the position and shape of the plot for this antenna on Smith Chart coordinates is nearly identical to that for the same length antenna with loading coils only, the solid curve of Fig. 12B. For this antenna, however, the plot points for 25-kHz frequency increments appear closer together, which accounts for the increased bandwidth.

Conclusions

The measured characteristics of these various configurations of loading for the 80-meter antennas are tabulated in Table 4. Remember that the overall "flat-top" length of each antenna arrangement is 66 feet (20.12 m), and that the loading coils are always positioned 16 feet (4.88 m) each side of the center of the antenna, being pruned for resonance at approximately 3550 kHz. For comparison, information for a half-wave dipole is also included.

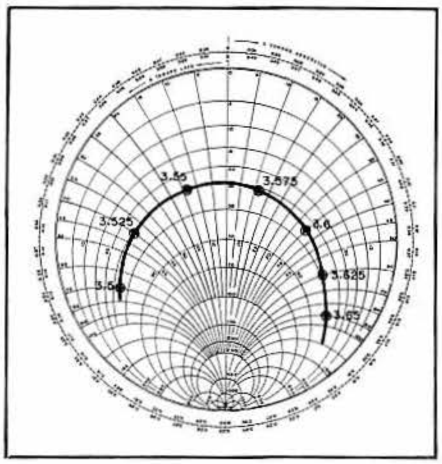

Fig. 14 — Impedance plot of a 66-foot (20.12 m) dipole using a combination of off-center inductive loading and capacitive end loading. Of all the shortened configurations tried, this arrangement offered the greatest bandwidth.

Of the various arrangements, capacitive end loading decidedly provides the greatest bandwidth, excepting the full-size half-wave antenna, of course. Although there are slight differences in the resistance value at resonance, all are of the same order of magnitude. These values, as well as those for the 160-meter antenna discussed earlier, tend to confirm a *broad* rule of thumb that the writer has formulated for this type of antenna: The feed-point impedance value at resonance is roughly proportional to the length of the antenna. That is, a loaded antenna which is half the size of a half-wave dipole will have approximately half the radiation resistance of the full-sized antenna.

Eq. 1 given earlier or the chart of Fig. 9 allows one to calculate loading-coil values for antennas with loading coils only. Additional capacitive loading is not taken into account. Calculating the effects of various capacitive loading arrangements appears to be difficult, and work remains to be done in this area.

Multiband Antennas with Loading Coils

All of the foregoing material has been devoted to the loading of an antenna for resonance at a single frequency. Resonated as described, the antenna is electrically a half wave in length. It will, however, operate well on higher frequencies — frequencies at which it is an odd multiple of half waves in *electrical* length . . . three half waves, five half waves, etc. Because of the lumped loading of the shortened antenna, these higher frequencies will likely not be closely related to odd-order harmonics of the fundamental frequency, as the case would be for a nonloaded radiator. (For example, it is a well-known fact that a 7-MHz half-wave dipole operates well on its third harmonic, 21 MHz.)

A loaded dipole will become an electrical 3/2-λ antenna at some frequency below that which is three times the fundamental resonant frequency. Depending upon the overall antenna length, coil value, and coil position, it is possible for an 80-meter loaded dipole to become a 3/2-λ performer on 40 meters. With such an arrangement, one would have a dual-band antenna without requiring the use of traps. The idea can be expanded upon to arrive at a loaded antenna without traps which will operate on more than two bands. This scheme offers considerable constructional simplification as compared with trap arrangements.

The multiband loading-coil concept has been recognized for better than half a century, but little use of the technique has been made by amateurs. Some years ago a very good article on the subject was published by William Lattin, W4JRW.[5] That article is recommended reading for anyone interested in more details on the concept. Supplemental information has been published by Buchanan.[6] Attempts by this writer to calculate antenna sizes and coil values for dual-band antennas have met with some success. From calculations and experiments to date, it appears that with only two loading coils (one each side of center), the antenna must always be greater than a half wave in physical length for the higher of the two frequency bands. In other words any 80/40 meter arrangement, for example, apparently would need to be longer than 66 feet (20.12 m) from tip to tip. However, much work also remains to be done in this area. This material was originally presented in *QST* by Jerry Hall, K1TD.

References

[1] Sevick, "The Ground-Image Vertical Antenna," *QST*, July 1971. (See chapter 1.) Also, "The W2FMI Ground-Mounted Short Vertical," *QST*, March 1973. (See chapter 1.) "A High Performance 20-, 40- and 80-Meter Vertical System," *QST*, December 1973. (See chapter 1.) "The Constant-Impedance Trap Vertical," *QST*, March 1974, p. 29.

[2] LaPlaca, "Using the ARRL L/C/F Calculator," *QST*, December 1973, p. 26.

[3] Hall and Kaufmann, "The Macromatcher, An Rf Impedance Bridge for Coax Lines," *QST*, January 1972, p. 14. Information also contained in *The Radio Amateur's Handbook* and *The ARRL Antenna Book*.

[4] McCoy, "Monimatch, Mark II," *QST*, February 1957, p. 38. Also, "An Etched-Circuit Monimatch For Checking Your Antenna System," *QST*, October 1969. (See chapter 4.)

[5] Lattin, "Multiband Antennas Using Loading Coils," *QST*, April 1961, p. 43.

[6] Buchanan, "An Inexpensive 40- and 80-Meter Antenna, Hints and Kinks," *QST*, September 1962, p. 62.

Efficient Short Radiators

If you're cramped for space to put up a beam antenna, you'll want to investigate these ideas as one way to shrink 'er down to usable size.

Shortened antennas have been popular with amateurs for either esthetic, space limitation or economic reasons. And most are inefficient radiators with narrow bandwidth. This section will first define some limitations and problems of conventinal short antenna designs. A design for a half-size 2-element Yagi, the performance of which is competitive with its full-size equivalent, will follow.

It has been proved that no appreciable difference exists between the directive patterns of "short" and full half-wave horizontal dipoles. Since the gain of a half-wave dipole over an isotropic radiator is determined by the dipole directive pattern and since the length of the dipole (up to λ/2) has negligible effect on its directive pattern, the length of the dipole (up to λ/2) has a negligible effect on its gain. An assumption is made that the efficiencies of both the short and half-wave dipoles are equal. The efficiency of an antenna can be expressed as

$$\text{Eff} = \frac{R_r}{R_r + R_{loss}} \qquad \text{Eq. 1}$$

where R_r = radiation resistance
R_{loss} = loss resistance of conductors, coils, etc.

The radiation resistance (R_r) of a horizontal dipole is determined by its length and height above ground. In free space, the R_r of a half-wave dipole is 73 ohms. As the length of the dipole is reduced, the R_r decreases as the square of the length. Thus, for a half-size dipole (as compared with λ/2), the R_r decreases to a value one-fourth that of the λ/2 dipole or approximately 13 ohms.

The efficiency of a half-wave dipole is very high, being on the order of 95 percent. The R_r is large and R_{loss} small by comparison. If we reduce the overall length by a factor of two, the R_r decreases by a factor of four. Input impedance at the center of the dipole is comprised of a low resistance and large capacitive reactance, so inductive loading is required in order to resonate the dipole. The inductive reactance needed to center-load the antenna will be approximately 1 kΩ (depending on conductor size used for the antenna). Assuming a coil Q of 200 and computing efficiency using Eq 1: This means that 28 percent of the transmitting power applied to the antenna is dissipated in the loading coil. The author has neglected any additional losses in the matching network which would result if the above antenna were driven by a 50-ohm source.

Let's suppose we decide to build a 2-element Yagi using shortened center-loaded elements. The driven element by itself has an R_r of 13 ohms. Adding a close-

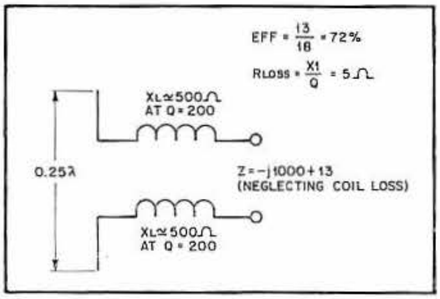

Fig. 15 — Electrical equivalent for the center-loaded dipole discussed in the text. Efficiency is 72 percent, as determined by Eq. 1.

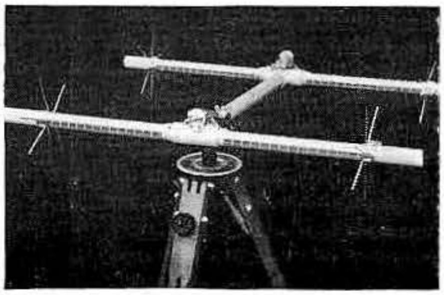

The 100-MHz "model" used by the author for testing shortened elements in a Yagi antenna design.

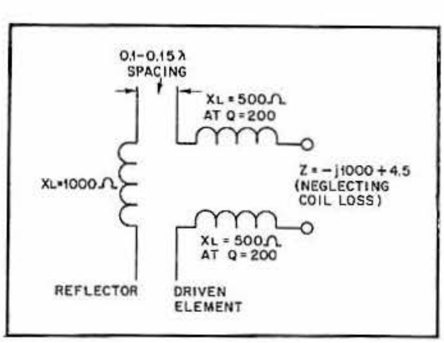

Fig. 16 — Electrical equivalent of a loaded 2-element antenna. The efficiency is 47 percent.

spaced parasitic element reduces the radiation resistance by approximately a factor of three. Thus, the driven element has an impedance composed of approximately 4.5 ohms resistive and 1 kΩ reactive. Loading both the driven and parasitic elements with the same inductors that were used for the dipole and computing efficiency

$$\text{Eff} = \frac{4.5}{4.5 + 5} = 47 \text{ percent}$$

This efficiency equates to slightly more than a 3-dB power loss in the driven element. The writer has neglected the sizable loss in the matching network since it must transform the 50-ohm source to the 9.5-ohm impedance of the antenna at resonance. In addition, the loading coil of the parasitic element will contribute approximately 1 dB of loss.

Taking into account the losses on loading coils of both the driven and parasitic elements and the loss on the driven element to feed-line matching network, we can easily account for a 5-dB power loss. Such a power loss would nullify the gain of a properly tuned Yagi, making it little better than a full-size dipole.

It should be obvious from the previous examples that the poor performance of short dipoles, and particularly Yagis, is a direct result of losses in loading inductors. If we can reduce these losses while raising the radiation resistance, the increase in efficiency will (might?) make the short dipole or Yagi competitive with its full-size counterpart.

Test Antenna

The helically wound whip antenna has always been appealing because the R_r tends to be higher than that of the base-loaded whip. This is because it is continuously loaded. In fact, using end-loading (large capacitance hats), the current distribution will be much more constant, yielding an R_r of up to four times that of a base-loaded whip. The author decided to use the helical design for a short test dipole and investigate the properties of this antenna versus that of a full-size dipole.

Conventional design for a helically wound antenna uses a form (wood, bamboo, fiberglass) wound with approximately $\lambda/2$ of no. 14 wire per $\lambda/4$ element. The writer felt that the resistive R_{loss} of this large amount of wire would be as great as that of the loading coils in the center-loaded dipole, making the helical design ineffective. As it is desirable to reduce conductor resistance, the surface area of the conductor must be substantially increased. Tubing is not mechanically suitable, and because skin depth is only on the order of 0.001 inch (0.03 mm),[1] the use of tubing is not required. Some 1/2-inch (13 mm) wide copper tape[2] was on hand and a study of its skin resistance revealed a loss per unit length of 12 percent less than that of the no. 14 wire.

A helically wound dipole was constructed (using the 1/2-inch [13 mm] wide tape) for use at 100 MHz. This frequency was chosen so that field-strength measurements could be performed using a local fm broadcast station as the signal source. A 28-inch (711 mm) length of 3/4-inch (19 mm) CPVC tubing (plastic water pipe) was wound with 38 equally spaced turns of the 1/2-inch (13 mm) wide tape. Using a grid-dip meter, resonance was measured at 104 MHz. Next, two 5-1/2-inch (140 mm) diameter six-spoke capacitance hats were attached to the ends. Resonance was again measured and found to be 84 MHz. A C-match[3] was constructed to transform the low impedance of the short dipole to 50 ohms. The C-match requires that the element be made to look inductive by lowering its resonant frequency. A variable capacitor is then shunted across the feed point and adjusted for resonance. This L/C ratio determines the impedance transformation. A 100-pF variable capacitor was shunted across the feed point of the test dipole and a 50-ohm coaxial cable was attached. Since the dipole is a balanced antenna, feed-line decoupling was necessary. The author used a quarter-wave sleeve (bazooka).

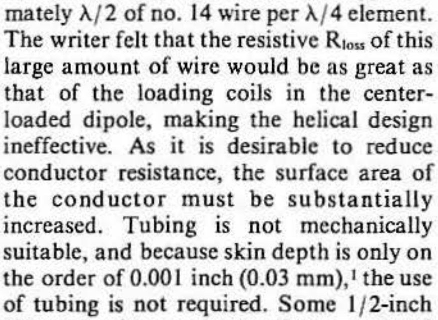

Fig. 17 — Curves depicting gain and FBR (front-to-back ratio) vs. frequency when the Yagi antenna is tuned for operation at 100 MHz.

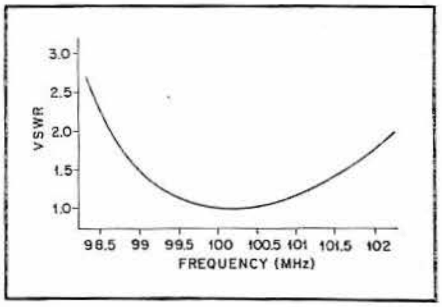

Fig. 18 — VSWR vs. frequency when the Yagi antenna is tuned for operation at 100 MHz.

Antenna Tuning

Rf power was applied to the test antenna through an SWR meter (measurements were taken in a screen room). Turns were removed, one at a time, and the shunt capacitor adjusted until a 1:1 match occurred. The capacitance hats were always installed at the tips of the element. When adjusted for a 1:1 match, the dipole consisted of 32 turns of copper tape, center fed, with 40 pF shunting the feed point and an overall element length of 21 inches (533 mm) which is 37 percent of the length of a full-size dipole. Tuning was very simple and took but 15 minutes to complete.

Measurements

The feed-point impedance was measured (with C-match disconnected) to be 20 ohms. The skin depth resistance was computed to be 0.24 ohm. Computing efficiency

$$\text{Eff} = \frac{20}{20 + 0.24} = 98 \text{ percent}$$

which is essentially the same as a full-size dipole. Bandwidth between 2:1 SWR points was measured to be greater than 6 percent of the operating frequency. Large capacity hats (for 100 MHz) and wide tape play an equally important role in reducing the Q of the antenna sufficiently to obtain a wide bandwidth. Next, a low-level signal generator and dipole were set up 5 wavelengths away from the test antenna. Using an Empire NF-105 noise and field-strength meter, a comparison was made on field strength between the test antenna and a full-size dipole. Results indicated no apparent measurable difference between the short helically wound dipole and a full-size dipole. Field-strength measurements were then taken on the signal from a local fm broadcast station. Again, there was no apparent difference; not bad for an antenna that is less than half size. The next question to be answered was whether gain could be secured by the addition of a parasitic element.

A boom and a parasitic element were added to the shortened test dipole. Although a director might provide better gain and front-to-back ratio (FBR), the decrease in radiation resistance, to a very low value (dipole by itself equals 20 ohms) because of the close spacing, was thought to decrease efficiency and bandwidth. A parasitic reflector was constructed, similar to that of the driven element. The element was split in the center and a 100-pF capacitor installed for tuning purposes. Element spacing was adjusted to 0.15 λ. With the capacitor fully meshed, the six-spoke capacitance hats were physically positioned on the element (both equidistant from element center) so that the reflector resonated at 93 MHz. Nominal reflector tuning calls for reflector resonance approximately 5-percent lower in frequency than the driven element, or 95 MHz. With the above configuration, the author was able to adjust reflector resonance, using the variable capacitor, anywhere in the range of 93 to 96.5 MHz or 3.5 to 7 percent lower in frequency than the driven element.

Using the same field-strength measurement set up as with the dipole, the reflector was aimed at the source signal and adjusted (using the variable capacitor at element center) for minimum pickup. The driven element was then readjusted for a 1:1 SWR and the process repeated until minimum rear pickup and a 1:1 SWR occurred simultaneously. Gain and FBR measurements were made at the design frequency and at points two percent of the design frequency on either side. The results are described in Fig. 17. The bandwidth measurements are given in Fig. 18.

As can be seen from the curves in Fig. 17, a gain of 4 dBd, and a 15-dB FBR can be secured quite easily with a physically short Yagi. As with other Yagis, the gain is relatively constant over a wide frequency range. However, the FBR drops quite fast especially when trying to use the antenna below its design frequency. From curves given in Fig. 18, the bandwidth between the 2:1 VSWR points is shown to be about 3.7 percent. Translated to 20 meters this bandwidth would be 500 kHz, equal to or greater than the average 3-band trap Yagi. If indeed the design were scaled to 14 MHz, the antenna would have element lengths of slightly over 12 feet (3.66 m) and a boom length of 10 feet, 6 inches (3.20 m).

Adapting Design to Ham Bands

Since it has been shown that a physically short Yagi can provide significant gain and FBR, a few design pointers are in order. First, make the element length no shorter than physically necessary for your particular situation. Bandwidth and efficiency will improve with greater lengths. Second, the use of large capacitance hats is recommended, as this reduces the helical conductor length and thus R_{loss}. Third, use large forms of good dielectric quality (fiberglass). The larger the form diameter, the greater the length reduction for a given number of turns. Also, with large diameter forms, 1.5 inch (38 mm), the width of the conductor can be increased, thus reducing R_{loss}. Fourth, regardless of the matching network used, construction of capacitance hats, etc., *solder all* joints and *seal* with silicone rubber. *Do not rely on pressure joints.* Fifth, to secure a reasonable FBR with any Yagi using a split driven element and fed with coaxial cable, some form of balun transformer is required to keep currents from flowing on the outside of the coax braid. Sixth, the use of a grid-dip meter is the only practical method to secure resonance with a fixed physical length. Construction will require some cut and try. Proximity to surrounding objects will affect resonance, and should be avoided when tuning the array.

No doubt the author has left out items, which may prove to be a problem for the reader. This article was intended to be more thought provoking than constructional, although there should be enough information here to build your own antenna with a reasonable amount of experimental effort. My current plans call for construction of a 2-element 10-meter Yagi (for reception of OSCAR signals) with 6-foot (1.83 m) elements and a 5-foot (1.52 m) boom. The author wishes to thank Mike Povlich, WB9HGS and Russ Mills for their assistance with measurements. This material was originally presented in *QST* by Ronald J. Gorski, N9AU.

References

[1] Kuecken, *Antennas and Transmission Lines*, Howard W. Sams and Company, Indianapolis, IN, 1st Edition (1969), p. 274.

[2] Copper tape available from Minnesota Mining and Mfg. Check Yellow Pages for the address of a local distributor.

[3] Orr, *Beam Antenna Handbook*, Radio Publications Inc., Wilton, CT, 3rd Edition, p. 63.

Simple Arrays of Vertical Antenna Elements

Work DX with a vengeance! Simple arrays of vertical elements will provide good low-angle radiation. DXCC may be closer than you think if you can manage a system like this one!

Because of the excellent low-angle radiation properties of vertical antenna elements and because of the benefits to be gained by horizontal-plane directivity, it is interesting to attempt to determine "optimum" arrangments of elements to produce "beam" antenna arrays. Because of the enormous variety of configurations possible, and the great difficulty of either experimental modeling or calculating exact theoretical performance, it has not been practical in the past to arrive at valid conclusions. However, it is now quite easy to simulate such antenna arrays by computer programs, and these can produce relatively quick and precise answers to a very large number of postulated configurations. After a number of computer trial runs, "optimum" configurations can be found quite readily. Such a computer program for quarter-wave elements has been written and supplied by H. Hurwitz, WA2VBW. Using a modification of this program, the author has investigated a

Table 5

Case	Element	Current	Phase	X	Y	Beam Direction	Beam Gain	Back Radiation	Minor Lobes
1	1	1	0	0	0	0°	3 dB	-3 dB	-α
	2	1	-90	0.25	0				
2	1	1	0	0	0	0°	4.1 dB	5.7 dB	-11.5
	2	1	-120	0.25	0				
3	1	1	0	0	0	90°	1.1 dB	0 dB	0 dB
	2	1	0	0.25	0				

Table 6

I1	*I2*	*φ1*	*φ2*	Beam Gain	Back Radiation	Minor Lobes
1	0.8	0	-120	4.0 dB	-5.5 dB	-10.8 dB
1	1	0	-120	4.1	-5.7	-11.5
1	1.2	0	-120	4.1	-5.6	-12.5
1	1	0	-100	3.4	-3.8	-11.1
1	1	0	-120	4.1	-5.7	-11.5
1	1	0	-140	4.6	-6.6	-6.6

Table 7

Element	Current	Phase	X	Y	Beam Direction	Beam Gain	Back Radiation	Minor Lobes
1	1	0	0	0	0°	5.6 dB	-8.7 dB	-8.7 dB
2	1	-120	0.25	0				
3	1	-240	0.5	0				

Table 8

Element	Current	Phase	X	Y	Beam Direction	Beam Gain	Back Radiation	Minor Lobes
1	1	0	0	0	90°	2.7 dB	0 dB	0 dB
2	1	0	0.25	0				
3	1	0	0.5	0				

Table 9

Element	Current	Phase	X	Y	Beam Direction	Beam Gain	Back Radiation	Minor Lobes
1	0.5	0	0	0.145	0°	4.35 dB	-6.1 dB	-15. dB
2	1	-110	0.25	0				
3	0.5	0	0	0.145				

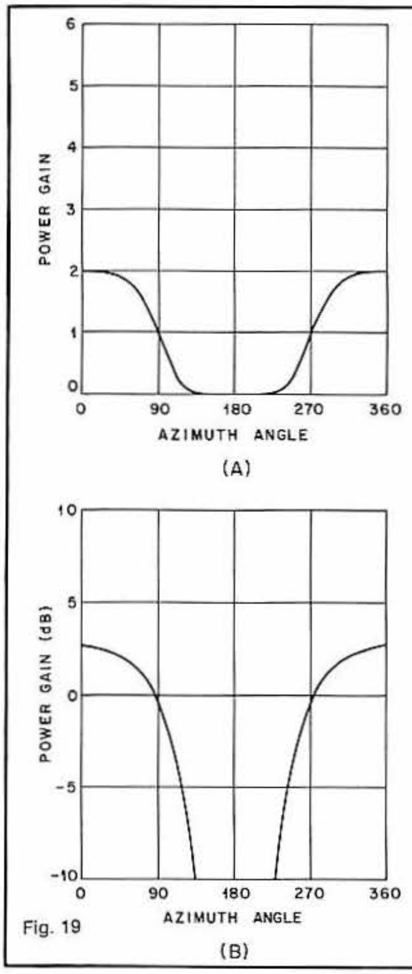

Fig. 19

large number of simple array configurations, which are potentially quite useful at the lower amateur frequencies, with the salient results given here. It is hoped that these will prove interesting to those considering construction of such arrays.

Technique for Optimizing Arrays

We must first try to define the problem and the parameters leading to an optimum design. The horizontal-plane pattern of an array of (vertical) elements depends only on the magnitudes of the individual element currents and their phases, and not on the way the currents are produced (e.g., driven or parasitic). The computer program allows one to specify the locations (x,y coordinates) of any number, n, of quarter-wave elements; also one must specify the magnitude of current and its phase in each element (usually normalized to unity current and zero phase for a given fiducial element). With these data inputs the radiation pattern is calculated and plotted out, giving the relative power gain in each azimuth angle interval, say, 5 or 10 degrees. The power gain is normalized to that power which would have been radiated at the same azimuth by a *single* vertical element using the same input electrical drive power. By using trial values of the current in all elements, in both amplitude and phase, one soon develops a feel for the behavior of the system, and can usually arrive at a "best" value for all the currents and phases. One can then try different geometrical separations of the elements and in this way arrive at the "best" spacing. Usually this best configuration is a compromise between power gain and good pattern control, e.g., front-to-back ratio, or more generally, main lobe to minor lobe (side or back) ratio.

In addition to the optimization described above it must be noted that if the array is to be used primarily to produce a "beam" in a given general direction with little emphasis on other directions, one usually finds a linear array of elements best (equivalent to an end-fire Yagi array). However, if the array is to be used for all directions, a more (circularly) symmetrical array should be considered. These points will become clear in the discussion of results.

Two-Element Array

In the case of two elements there is only one possible configuration. Consider one element at the origin of the x,y plane (coordinates 0,0) and the other element along the x axis (coordinate x,0). The parameters available are x, which we specify in units of wavelength, λ, the rf currents I1 and I2 in each element (we shall normalize one of the currents, e.g., I1, to unity) and the phases, $\phi1$ and $\phi2$, of the currents (we shall generally normalize the phase of the current in element 1 as zero and specify the relative phase of the current in element 2 in electrical degrees, either positive for leading currents or negative for lagging currents). It soon becomes apparent that the region of main interest is where the spacing x is in the neighborhood of 0.25, i.e. λ/4, and there the currents are nearly equal in magnitude. The reasons are that, for spacings of 0.5 or greater, other strong lobes appear in the pattern, and for grossly unequal currents relatively poor

Table 10

Element Spacing	Optimum $\phi 2$	Beam Gain	Back Radiation	Minor Lobes
0.2	-130°	4.65 dB	-6.5 dB	-18 dB
0.25	-120°	4.6	-6.5	-16
0.3	-110°	4.4	-6.2	-14
0.35	-110°	4.2	-5.8	-12

Table 11

Element	Current	Phase	X	Y	Beam Direction	Beam Gain	Back Radiation	Minor Lobes
1	1	0	0	0	0°	7.4 dB	-9.9 dB	-9.9 dB
2	1	-120	0.25	0				
3	1	-240	0.5	0				
4	1	0	0.75	0				

Table 12

Element	Current	Phase	X	Y	Beam Direction	Beam Gain	Back Radiation	Minor Lobes
1	1	0	0	0	90°	4.2 dB	0 dB	0 dB
2	1	0	0.25	0				
3	1	0	0.5	0				
4	1	0	0.75	0				

Table 13

Element	Current	Phase	X	Y	Beam Direction	Beam Gain	Back Radiation	Minor Lobes
1	1	0	0	0	45°	6.4 dB	-18 dB	-18 dB
2	1	-110	0.25	0				
3	1	-220	0.25	0.25				
4	1	-110	0	0.25				

Table 14

Element	Current	Phase	X	Y	Beam Direction	Beam Gain	Back Radiation	Minor Lobes
1	1	0	0	0	0°	5.1 dB	-11.5 dB	-11.5 dB
2	1	-120	0.25	0				
3	1	-120	0.25	0.25				
4	1	0	0	0.25				

Table 15

Square side Length (inλ)	ϕA opt.	ϕB opt.	Beam Gain	Back Radiation	Minor Lobes
0.167	-130	-260	6.6 dB	-22 dB	-22 dB
0.25	-110	-220	6.4	-18	-18
0.333	-80	-160	5.6	-18	-18

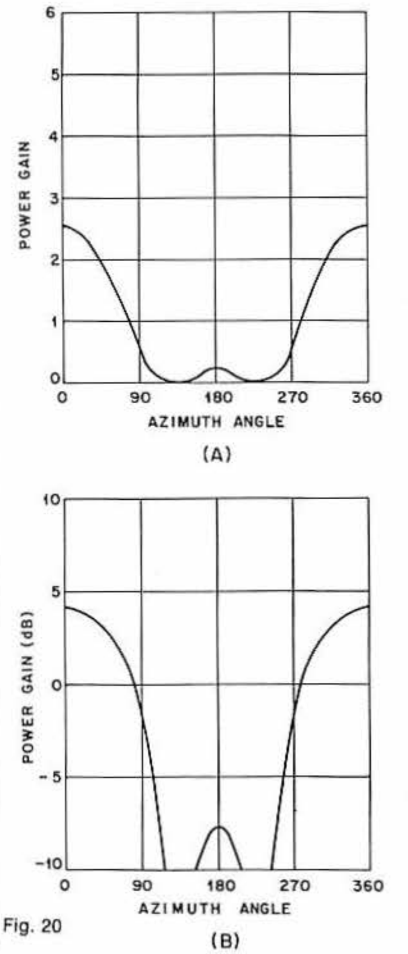

Fig. 20

peak gain and pattern discrimination result. Although the spacing x is not especially critical in the neighborhood of 0.25 (one can essentially compensate by adjustment of phase angle) we shall now examine the case where x = 0.25, and where I1 = I2 = 1. Best overall pattern discrimination (minimum back lobe) for the endfire case occurs where $\phi 1 = 0$, and $\phi 2 = 90$ degrees, and the power-gain pattern is shown in Fig. 19A.

Peak gain is 2 (or 3 dB) and occurs along the x-axis direction. Fig. 19A shows the power pattern of the array, i.e., it shows quantitatively where the radiated power goes. However, if one is looking at what an S meter would indicate, one can present exactly the same information on a vertical *logarithmic* scale as shown in Fig. 19B.

The vertical scale is shown in dB relative to the value for a single vertical radiator. This type of display is useful in judging excellence of pattern with respect to minor lobes. For all future cases discussed here, both displays will be shown.

It is possible to increase the gain of this array at the expense of some back lobe by increasing the phase lag in element 2, e.g., if $\phi 2 = -120$ degrees the peak gain, again along the x axis, is 2.59 (or 4.1 dB) and the entire pattern is shown again in Figs. 20A and B.

Note that the back lobe now shows a gain of 0.186, which is −11.5 dB relative to the forward lobe.

These two elements can be used to form either a beam along the +x axis as shown, or reversed along the −x axis (by reversing the phase $\phi 2$, i.e., making it +120 instead of −120 degrees) or if the two elements are driven in the same phase, i.e., $\phi 1 = \phi 2 = 0$, one produces a bilateral broadside beam as shown in Fig. 21.

Here the peak gain is 1.1 dB, but there is a "back" lobe of equal magnitude to the front lobe. Note that all patterns will be symmetrical around the x axis, or more generally around the line of any set of linearly-positioned elements. This example has illustrated some of the aspects of all of the results to be presented; namely, that:

a) The best element spacing will be found to be in the neighborhood of 0.25 wavelength.
b) Current ratios and phases can be adjusted to produce either a best *pattern discrimination* (minor lobe rejection) or best *main lobe gain*. It is generally not possible to get both at the same time, and a compromise must be made.

It may be useful to tabulate the salient results of each "best" case by noting the coordinates of the elements in the x,y plane, the individual drive currents, the individual phases, main beam heading in the x,y plane, main beam gain, and the

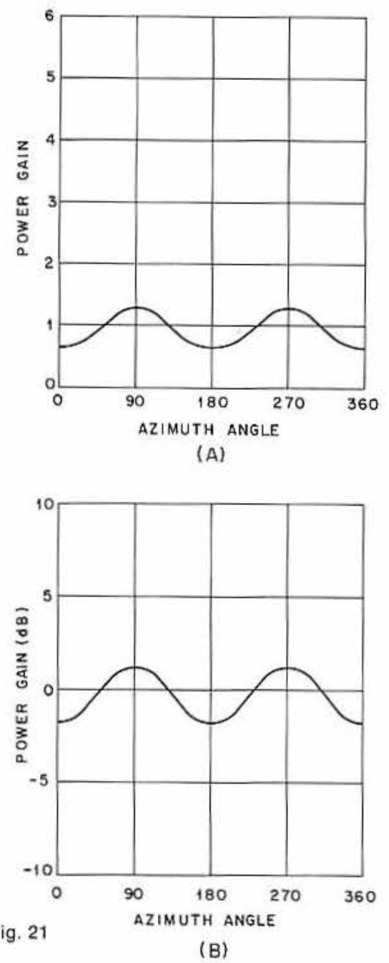

Fig. 21

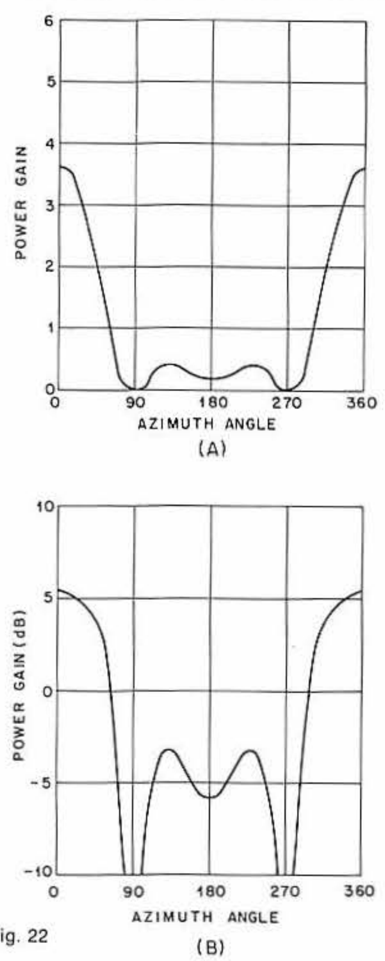

Fig. 22

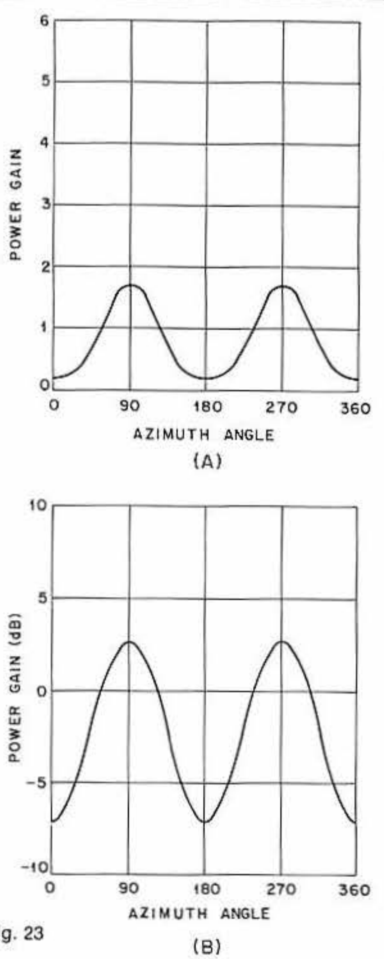

Fig. 23

largest pattern gain (such as given by either the side of the main lobe or by minor lobes) observed anywhere in the entire 180-degree sector centered just opposite in direction to the main lobe. We shall designate this quantity as "back radiation" and express it in dB relative to the main lobe gain. We shall also tabulate the largest minor lobe in this sector and label it "minor lobe," again expressed in dB relative to the main lobe. Thus for the cases just described, Table 5 is presented.

The sensitivity of these results to variations of currents and phases is not high. For example, one can summarize case 2 above with somewhat altered I2, or $\phi 2$, as shown in Table 6.

The author feels that end-fire case 2, where $\phi 2 = -120$ degrees, probably represents the "best" design with a good pattern and gain. Other more complicated cases presented below are optimized in this same way and only the "best" configuration will be shown with actual results.

Three-Element Arrays

For three elements, two different geometries suggest themselves: the linear array, best for a single preferred directional line, and an equilateral triangle configuration, the closest approach to circular symmetry. The latter, as we shall see, could be switched to give "beams" in any one of six angular positions (every 60 degrees). Let us consider first the linear array.

Linear Array — As in the 2-element linear array just discussed, the optimum arrangement seems to center around an element spacing of about 0.25 wavelength with approximately equal current drives. The optimum end-fire case is shown in Table 7; the broadside case is shown in Table 8.

The patterns for these cases are shown in Figs. 22 and 23.

Remember that for the end-fire case, which one can think of as a 3-element Yagi on its side, the rather large side lobe results because the pattern lies in a plane perpendicular to the elements. Side radiation is hard to avoid, as one cannot take advantage of the nulls off of the ends of excited elements.

Equilateral Triangular Array — For this case, the optimum situation appears to be as shown in Table 9. The behavior is very similar to the case of two elements in end-fire. See Table 5 (we have just split one of the two elements and have moved the separate pieces to the triangle corners). The pattern is shown in Fig. 24.

Reversing the phases will reverse the beam direction, and by rotating the drive currents (and phases) around the triangle, one can produce six beam directions (every 60 degrees). This is an attractive feature, but it does not come free; the maximum gain of the system is somewhat less than one obtains with the three linearly-disposed elements (which are chiefly useful in a direction along the line of the array).

The exact size of the triangular array is not critical — one must simply choose the best phase angle for the particular geometry. The "best" phase angles, $\phi 2 (\phi 1 = \phi 3 = 0)$, as determined by computer runs, for different spacings (triangle side lengths expressed in terms of λ) are shown in Table 10.

Four-Element Arrays

With four elements, there are at least three configurations which are interesting to investigate. As before, the linear array with a preferred beam direction is one type, but there are two configurations which possess a measure of circular symmetry. One of these is described by three antenna elements at the corners of an equilateral triangle with the fourth element at the geometric center of the triangle. This one we shall designate as a center-filled triangle. The other type is a square array.

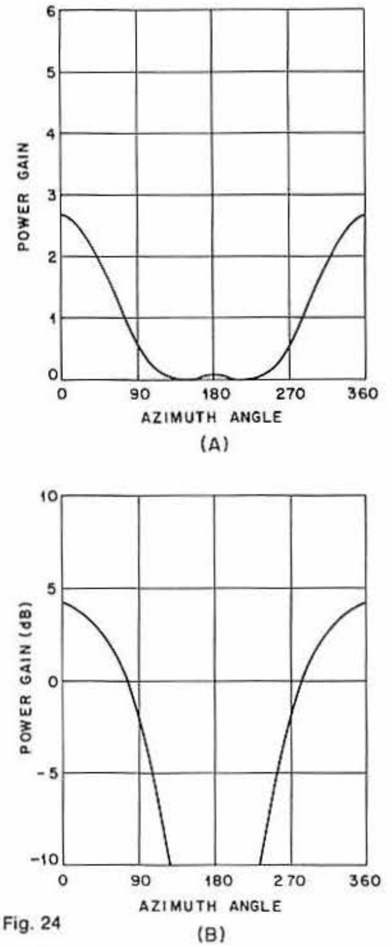

Fig. 24

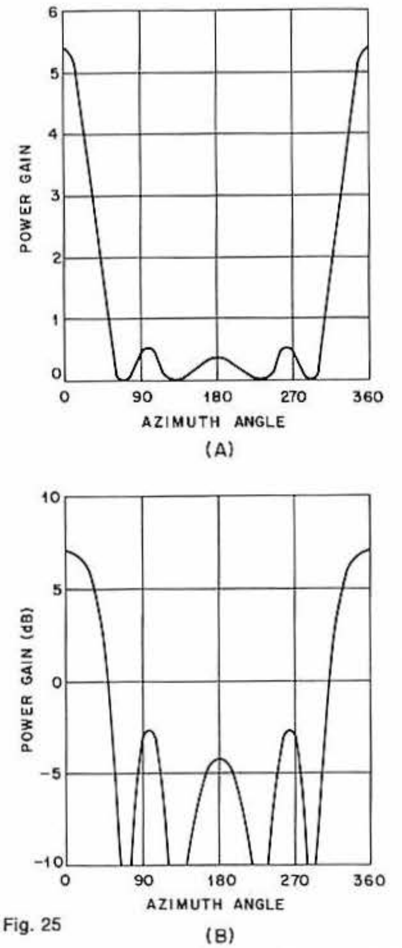

Fig. 25

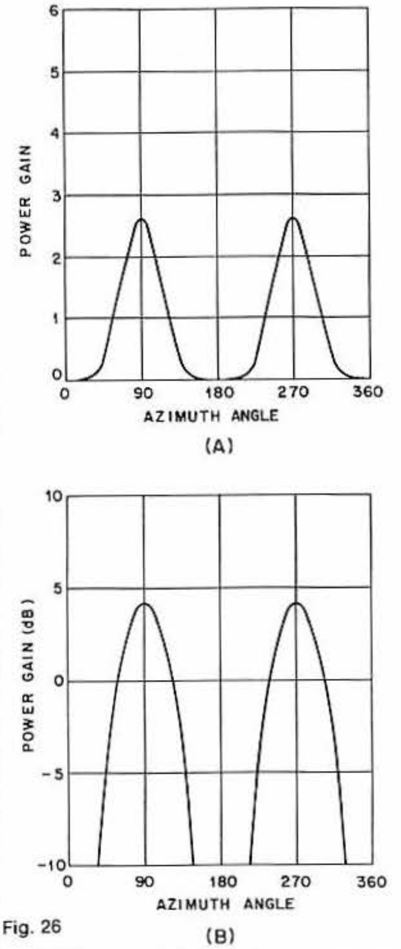

Fig. 26

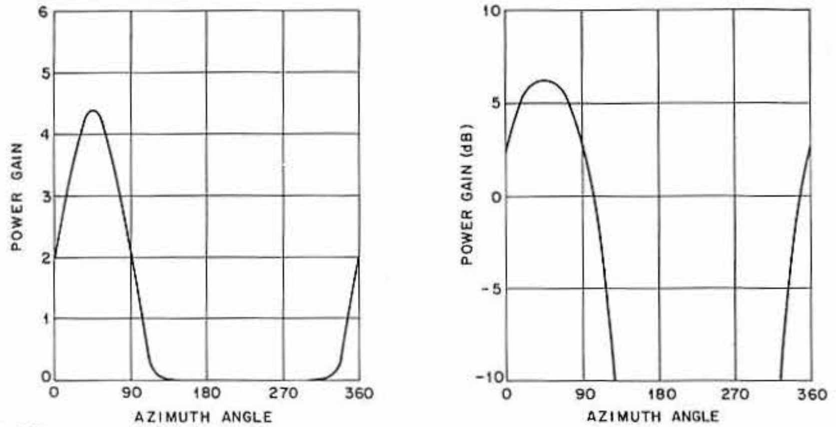

Fig. 27

Let us take these three types in order.

Four-Element Linear Array — For this case the optimum end-fire solution appears to be as shown in Table 11. The gain and major lobe shape of this configuration seems to be excellent. The broadside case is shown in Table 12. Patterns for this case are shown in Figs. 25A, B, and 26A, B.

Note that for this array there is poor coverage in some azimuthal directions (e.g., ±45 degrees) if only the two tabulated phase arrangements are used.

Center-Filled Triangle — A large number of situations were examined for this configuration, but unfortunately no combinations of spacing, currents or phases were found that looked very good. The best pattern was not particularly better than that of the three-element triangle alone, and was substantially inferior to that of the 4-element square to be discussed next.

Four-Element Square Array — For this case the best situation appears to be as shown in Table 13. Note that this arrangement fires diagonally and produces a respectable gain and excellent pattern. The "broadside" arrangement for the same square is shown in Table 14. The computed patterns are shown in Figs. 27 and 28.

The diagonal-fire pattern is exceptional, providing extremely low back radiation and minor lobes. The broadside pattern is not nearly as good, somewhat superior but reminiscent of the end-fire pattern obtainable with just 2 elements (see Fig. 20). In fact, the power-gain coverage at all angles (including the broadside angle) just using the switched four diagonal beams is large enough that it probably is not worthwhile using the broadside arrangement at all even to "fill" between diagonal beams.

This square array is superior to the center-filled triangle, and to all other simpler configurations (circular) in both gain and pattern discrimination. It is sufficiently good that one might ask what particular properties of the square have led to the nearly ideal performance. The

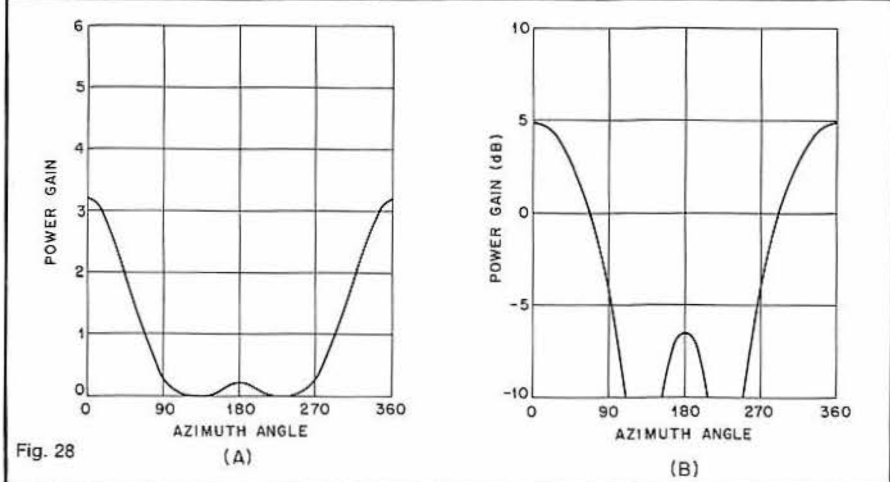

Fig. 28

author believes that there are two parameters which are noteworthy: first, the gain is respectable in diagonal fire because one can view the square along its diagonal as a three-element linear array in which the center element is split, each half being displaced to the other corners of the square. Thus the array behaves something like a 3-element (Yagi-like) linear array which is known to have a good gain. Secondly, the lobes are much smaller than the linear array due to the tendency for the phase cancellation of waves produced by the spatially-separated corner elements.

Again, as in previous examples, the actual dimensions of the square are not very critical, as long as one adjusts the phase (delay), ϕA in elements 2 and 4 and the larger phase delay, ϕB, in element 3 to the "best" value. Examples of such "best" phase values for different size squares are shown in the Table 15.

It turns out that the calculated gain figures for the smaller arrays are actually slightly larger than the gain for the larger squares, but as a practical matter this fact is probably offset by the larger (reactive) currents required for radiation. The larger currents are necessary because of the mutual coupling and phase relations between elements and the required phase relationships; in practice with the inefficiencies usually caused by ground currents when using vertical antennas, the gain differences for the various squares are probably inconsequential. The patterns for all cases are quite good, but the best pattern is obtained for the $\lambda/4$ square. Incidentally, the 0.167λ and 0.33λ square allows the possibility that a single square can be used for two amateur bands, and this has indeed become the subject of a practical antenna system.[1]

Conclusion

Computer trial runs, through a program developed by WA2VBW, have facilitated the investigation of a large number of $\lambda/4$ vertical antenna-array configurations. "Best" configurations, drive conditions, power gains and patterns have been found for the cases of two, three and four elements. Especially interesting is the case of four elements arranged in a square whose side dimension is about one-quarter wavelength.

Cases using more than 4 elements have been investigated, but the complexity, probable cost, and difficulty of installation of such configurations, reduces their utility and so they will not be reported here.

The author wishes to acknowledge the contribution of Henry Hurwitz, WA2VBW, who supplied the original computer program for this investigation. This material was originally presented in *QST* by James L. Lawson, W2PV.

References

[1] Lawson, W2PV, "75/80 Meter Vertical Antenna Square Array," *QST*, March 1971.

360-Degree Steerable Vertical Phased Arrays

Microwave power-splitting and phasing techniques were applied to the design of this 80-meter array. It has established an outstanding record for performance on long and difficult paths.

The possibility of providing effective 360-degree horizontal coverage with an array switched electrically, rather than rotated mechanically, has long intrigued many designers. Such a solution to the directional antenna problem is of particular interest to amateurs operating on the lower frequencies, where any mechanical rotation system is difficult and expensive to build. One of the authors, now W1CF, writing under his old call, W1HKK, described an 80-meter switchable phased array of four quarter-wave in-line elements more than 10 years ago.[1] The present article describes several novel array designs, using up-to-date technology, which provide greatly improved operation. Also covered are techniques used for effective power division, the beam-forming phasing system, switching, and impedance matching. Ground radials, cable and connector selection, and dc continuity testing are discussed.

One of these arrays recently constructed for 80-meter use has a single 97-degree lobe with a gain over a single vertical of approximately 7 dB at low angles. Its front-to-back ratio is 25 dB, and its front-to-side ratio is more that 12 dB, over the whole 80-meter band. It is switchable over 360 degrees in four 90-degree steps.

Computer-Modeled Arrays and Patterns

In the spring of 1975, while sitting over a cup of coffee, the three authors discussed the possibility of rebuilding the 1965 4-

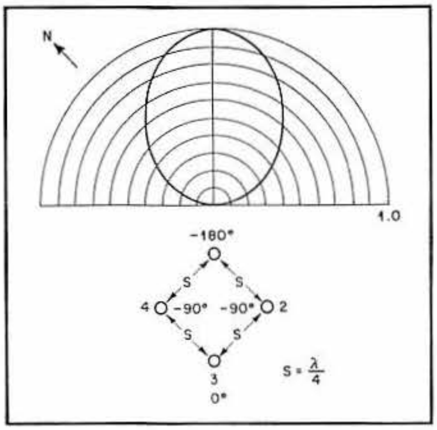

Fig. 29 — Polar plot of relative power, and planar view of the four-element diamond array showing the pattern obtained with no dc voltage on the switching relays, as in Fig. 31. Minor lobes are too far down to show on this scale.

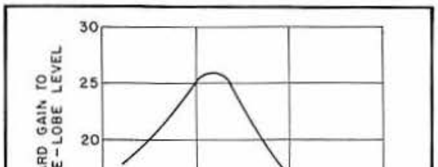

Fig. 30 — Bandwidth and side-lobe study of the four-element diamond array.

element array, using many improvements in technology that have evolved in the last 10 years. Dr. Joseph White accelerated the effort by coming up with a computer program written in Fortran IV, called ARRAY, which allows the user to plot patterns of arrays of from 2 to 99 elements in various spacings and combinations of phase and power, without ever leaving the computer terminal. Over 30 iterations using 4 elements were explored, and the computer-printed polar plots and other gain data analyzed, before we arrived at a configuration which provided good forward gain over a broad beamwidth, with no measurable unwanted lobes.

The configuration selected has four quarter-wavelength vertical elements in a square, with quarter-wave spacing between adjacent elements, as shown, with its predicted pattern, in Fig. 29. All elements are fed with equal amplitudes, the rear element at 0°, the two side elements at -90° and the lead element at -180°. The beam is transmitted along the diagonal from the rear to lead element. Gain due to horizontal beam formation alone is about 5.3 dB over a single vertical element. Front-to-back ratio is 25 dB. Front-to-side ratio is 12 dB, at 90° either side, increasing to much higher levels at 135° either side. Since most of the vertical energy is concentrated at low angles by the array, as much as 4 dB of gain additional to the predicted 5.3 dB in the horizontal plane can be achieved in theory, with perfectly conducting ground. The authors estimate that a good radial system and less-than-perfect ground yield an additional gain of 2 dB, or a total gain just over 7 dB for the system described.

The computer predicts a half-power beamwidth of 97°, so a suitable switching matrix can be used to direct the beam to four different quadrants, with only a slight loss of forward gain at the cross-over points, and virtually no deterioration of the front-to-back and front-to-side suppression. A computer study of the effect of variations in element spacing on forward-gain to maximum side-lobe level, plotted in Fig. 30, led to selection of $\lambda/4$ spacing of the corners of the square array. The 80-meter beam erected according to the computer-synthesized array design has proven to be remarkably successful. On-the-air results clearly approximate the performance anticipated by the program.

RF Power Dividers

Good power splitters are essential to the operation of phased arrays. Two-way and three-way power dividers will be discussed. Amateurs in broadcasting are well aware that tapped coils are the mainstay for power division in their industry. This reactive technique presents many problems.[2] The authors, being more versed in microwave techniques, thought it logical to scale up in wavelength the methods of power division used most successfully in the microwave region, particularly what is now known as the Wilkinson Power Divider,[3] shown in Fig. 31. Power from the transmitter is fed through a 50-ohm line of any length to a coaxial T, feeding two quarter-wavelength 70-ohm lines, W1 and W2. The two inner conductors of the 70-ohm lines are connected through a 100-ohm noninductive resistor, R1. This type of divider gives an equal power split, matches to 50-ohm loads at the two outputs, and has the unique property that any energy returning to the two outputs out of phase, due to mismatches or mutuals, is absorbed in the 100-ohm resistor.

The 90-degree phase-delay cable (DL) used in one side of each of the three power-splitting hybrids serves to assure that equal power reflections from the antennas are absorbed. Theoretically the resistors absorb none of the forward power. This technique provides approximately 30 dB of isolation from one output terminal to the other, to unwanted energy.

Reference is made in the 1965 article to difficulty in adjusting a phased array, because of element interaction due to mutual impedances between elements. The Wilkinson Power Divider, when used to feed phased arrays, reduces these problems and those resulting from imperfect match at the antenna inputs, and contributes to the realization of the predicted patterns. The "Wilkinson," is a remarkably simple and uncritical solution to the problem of power division. The 3-element vertical array described later uses a three-way "Wilkinson," shown in Fig. 33. It is constructed by splitting the 50-ohm input three ways, into three quarter-wave lengths of 93-ohm coaxial cable. The center conductors are connected together through 150-ohm noninductive resistors. An alternative approach is to return each center conductor to an ungrounded common point, through 50-ohm noninductive resistors.

Feeding, Switching and Phasing

The 4-element diamond array erected at W1CF uses three Wilkinson two-way

Terminations and switching relays at the center of W1CF array.

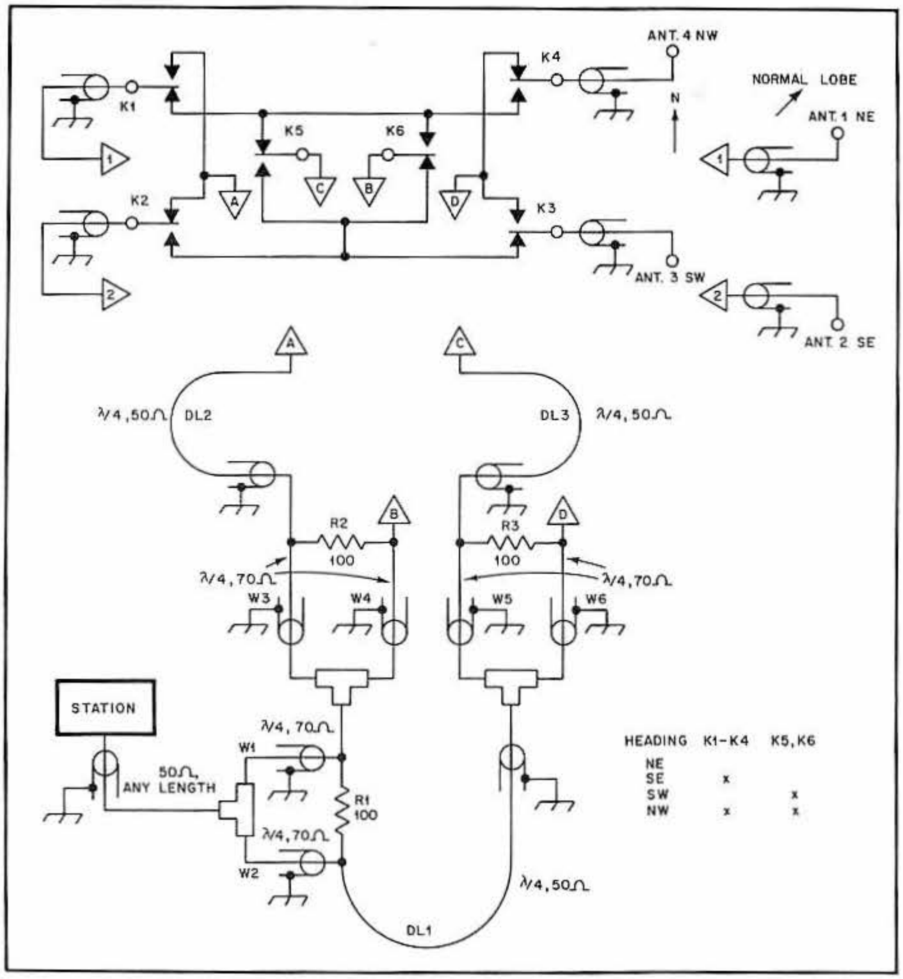

Fig. 31 — Schematic diagram of the Wilkinson Power Dividers, phasing lines, and switching relays (rf connections) for the four-element array. Dc switching commands for the four pattern headings are given at the lower right.

power dividers, as shown in Fig. 31. Phasing is accomplished with three 90-degree sections of RG-8/U cable, DL1, DL2, DL3. The four outputs are at 0°, -90°, -90° and -180° respectively in phase relationship, with power from the transmitter divided into four equal parts. Every effort was made to preserve symmetry throughout the system, in the hybrids, phase shifters, rf switching, feeds, and antenna placement, in order to have the array perform uniformly as it is switched between the four headings.

The switching can be done with six spdt coaxial relays, as in Fig. 31, or with one transfer relay and four spdt relays. With no voltage on the relay coils, the arms are in the positions shown in Fig. 31, giving northeasterly directivity (57° true, on Paris) the heading used most of the time at W1CF. The array is about 500 feet (152.40 m) from the transmitter, necessitating use of remote relays. A prospective user should consider the tradeoff between cable and relay costs. If the array is close to the station, four equal lengths of 50-ohm line can be brought into the station, and the switching done with a 4-pole, 4-position switch.

The long run of line here was dictated by the desire to take advantage of ground qualities and concealment afforded by swampland 500 feet (152.4 m) from the house. Not wanting to be electrocuted, we used 28 volts dc for operation of the switching relays. By judicious use of binary arithmetic, the switching commands require only three wires. Selection of the four beam headings is done at the operating position with a 4-wafer, 4-position switch. Relays should be selected for reliability and ease of weatherproofing. The cluster of relays and teminations shown in the photograph is at the geometrical center of the W1CF array. The connectors are protected against moisture by 3/4-inch (19 mm) heat-shrink tubing, which should extend from the bottom half inch (13 mm) of the connector 2 inches (51 mm) down the cable. In addition, wide plastic wastebaskets are used to protect these components. The expensive precautions were taken as the result of hard experience with moisture in the cables and connectors in the 1965 array.

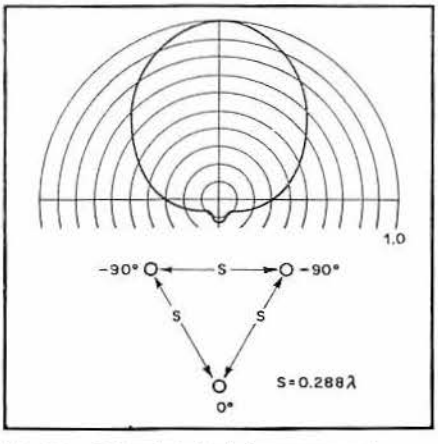

Fig. 32 — Polar plot of relative power, and planar view of the three-element triangular array.

Radiators and Radials

Relays K1 through K4 (Fig. 31) connect to their respective radiators through equal lengths of 50-ohm line, with no special attempt made for matching. The radiators are 57.5 feet (17.53 m) tall, above the base insulators. Constructional details follow the 1965 article, except as outlined below. Base insulators are 2-inch (51-mm) ID PVC pipe, 1/4 inch (6-mm) wall, 18 inches (457 mm) long, affixed to the aluminum with PVC cement and self-tapping screws. Each radiator is guyed at three levels with 3/16-inch (5-mm) galvanized cable, broken every 30 feet (9.14 m) with egg insulators.

Though 120 radials are considered to be the optimum number, only 40 per element are used here. Most are 65 feet (19.81 m) long, no. 12 galvanized wire, lying directly on the ground. This presents no hazard, as there is no foot traffic through the swamp area. The center radials are interconnected to two common busses in the central region, as recommended in reference 2. The authors feel intuitively that the square geometry of the array, in addition to providing considerable symmetry of the mutuals, allows a higher packing density for the radials, reducing ground losses.

Though the array has quarter-wavelength elements, all the feedpoints are at 50 ohms, and any type of vertical element can be used, provided an effort is made to match the inputs, and networks used for matching are *the same for all 4 elements.* Obviously, a height of 5/8 wavelength would be desirable, particularly for arrays built for higher frequencies. An indication of match would be to put rf voltmeters across the 100-ohm resistors, and tune the matching networks simultaneously for minimum voltage across the resistors. A nice thing about the λ/4 case is that the match is close enough that this step has not been necessary.

Testing

Before the array is fired up somebody should go to each element and short the input, while another person watches an ohmmeter placed across the main line at the station end. Make sure that a very low dc resistance is measured. Then, with the array in the normal position, as in Fig. 31, make sure that the resistance across the

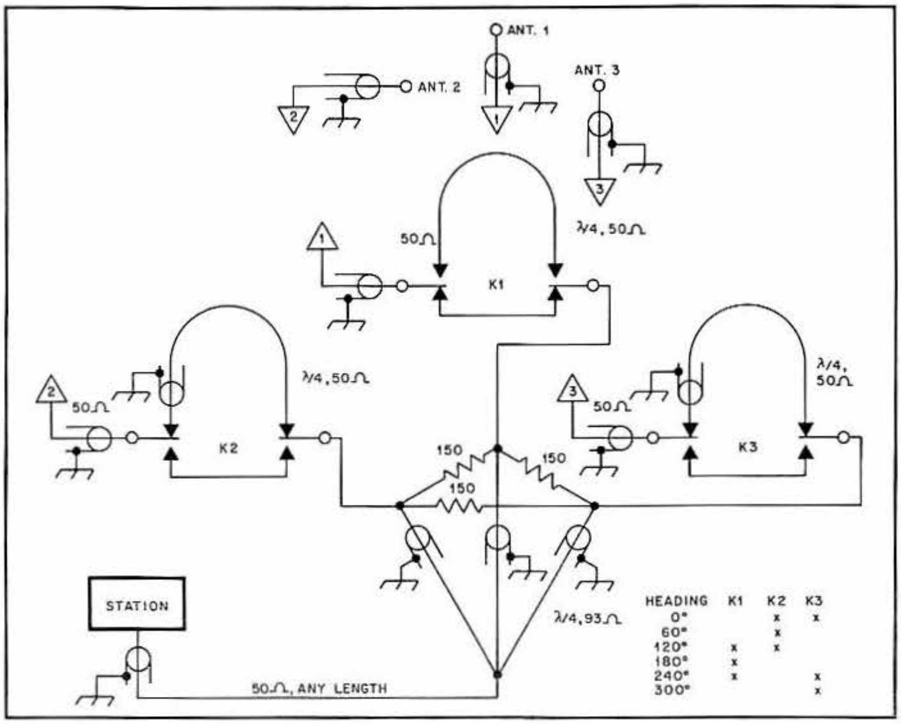

Fig. 33 — Schematic diagram of a three-element vertical array and its directivity switching and power dividing circuitry. Interconnecting leads should be as short and symmetrical as possible. The 50-ohm lines between the relays and antenna elements should be all the same length.

input is high. If it is low, check for moisture in the cables or connectors or for other leakage resistance. Silicone grease in the connectors is a good moisture preventive measure. It is recommended that these resistance checks be repeated periodically to be sure that all is well.

When the array is ready for use, go easy at first, as any reflected energy will be dissipated in the 100-ohm resistors. If they become hot, better matching is necessary, and if they blow up, perhaps higher-wattage resistors are needed. At W1CF, resistor banks were made up of 6, 20-watt, 150-ohm surplus resistors in series-parallel to give 100 ohms. These handle the dissipated power when the system is driven from a 4CX1000A amplifier, and after a month of operation there was no evidence of resistor damage. No attempt should be made to hot-switch the directivity. This was done inadvertently, and the result was the need for extensive emergency repairs — in midwinter.

Performance

In the short time that the array has been in use, all continents have been worked on 80-meter phone, including several stations in Japan and India, tough paths from New England. Gain and side and back rejection on all signals except those arriving from very high angles are just what the computer program predicted.

In receiving in the "search" mode, one hand tunes the receiver while the other operates the lobe selector switch, to see which position "listens" best. The big W1CF rotary array for 10, 15 and 20 takes 45 seconds to rotate 360°, which tends to discourage frequent directional checks. With the phased array a complete scan takes but a few seconds. The high front and side rejection eliminates most of the interference from signals in unwanted directions, and in transmitting the clean patterns help to prevent ruffled feathers.

A surprising by-product has been the reduced atmospheric noise pickup from unwanted directions. In particular, when listening toward Europe atmospheric noise coming from electrical storms in the southwest is greatly reduced, improving the signal-to-noise ratio on signals arriving from across the pond. The array is an order of magnitude better on both transmitting and receiving than any antenna previously used on 80 at W1CF. It has more than held its own with the competition, in all four quadrants. Of special interest to operators who like to use both phone and cw on 80 is the fact that the SWR is close to unity, from 3.5 to 4 MHz.

Triangle 3-Element Array

Anticipating that some amateurs may wish to use three rather than four elements, the ARRAY program was used to explore equilateral triangle configurations. Though it was not reduced to practice, a 3-element vertical array with 0.288λ spacing between adjacent radiators looks promising. The lead element is driven at 0° and the two side elements at -90°. The forward lobe is 135° wide, with a gain of close to 5.5 dB, including an estimated 1 dB contributed by vertical focusing. Front-to-back ratio is 12 dB. With suitable switching, the pattern can be aimed in six different directions, again providing 360-degree coverage. The three-way Wilkinson mentioned earlier must be used with three 90-degree sections of 50-ohm line, to provide the proper phase relationships. Several other configurations appear promising, but involve more complex switching and power-dividing circuitry.

Applications for Other Frequencies

The diamond and triangle antenna configurations may find uses at other frequencies, as was done with the 1965 design.[4] Formulas are given below for determining the line lengths and element spacings. A 2-meter phased array can be mounted on the roof of a car and wafer-switched to the desired directions. For people who like to experiment with logic and rf switching with semiconductors, circuits can be devised so that the receiver can scan periodically, and the antenna steered to the desired signal.

The authors wish to thank the many people who have contributed to the success of this project, including W1FRR, K1GXT, W1HMV, W1FXT, K1CCK, M. E. Hines, F. Howe, H. Wells, R. Rearwin, H. P. Scott, and many others. We also wish to thank Microwaves Associates, Inc., for the use of their superb computer facilities.

Formulas for length of quarter-wave (90°) phasing lines, and spacing of radiators, are given below:

Electrical λ/4, solid-dielectric coaxial line, 50 or 70 ohms (RG-8, -11, -58, -59):

$$L_{ft} = \frac{162.36}{f_{MHz}}$$

Electrical λ/4, solid-dielectric coaxial line, 93 ohms (RG-62, -71):

$$L_{ft} = \frac{206.64}{f_{MHz}}$$

300-ohm Twin-Lead — parallel three λ/4 sections to approximate 93-ohm cable (requires 1 input and 3 output 1:1 baluns):

$$L_{ft} = \frac{201.72}{f_{MHz}}$$

Radiator spacing, diamond array:

$$S_{ft} = \frac{246}{f_{MHz}} > 0.25\lambda$$

Radiator spacing, triangular array:

$$S_{ft} = \frac{283.4}{f_{MHz}} > 0.288\,\lambda$$

This material was originally presented in *QST* by Dana W. Atchley, Jr., W1CF, Harold E. Stinehelfer and Joseph F. White, Ph.D.

References

[1] Atchley, "Switchable 4-Element 80-Meter Phased Array," *QST*, March 1965.

[2] National Association of Broadcasters, *Engineering Handbook*, 6th Edition.

[3] Wilkinson, "An N-Way Hybrid Power Divider," *IRE Transactions on Microwave Theory and Techniques*, January 1960.

[4] Botts, "A Four-Element Vertical Beam for 40/15 Meters," *QST*, June 1975.

An Etched-Circuit Monimatch for Checking Your Antenna System

Why buy an expensive SWR indicator when you can build this slick little unit at home? Not only will you save money, but you'll learn something about how SWR meters operate. Try the W1ICP circuit — you'll like it!

A Novice who reads the instruction manual that comes with his transmitter and uses a 50-ohm dummy antenna can follow the tune-up procedures fairly accurately. With the dummy antenna he will find that the settings for the tuning controls will be fairly close to those specified by the manufacturer. However, when an antenna system is attached to the rig, in many instances the adjustments are far removed from any "book" setting. When this happens the Novice finds that he cannot get proper tuning of the rig, or worse yet, actually damages the equipment by trying to "force" it to work.

Nearly every transmitter these days, whether commercial or home-built, has a final amplifier stage that is designed to work into a 50-ohm load. If the load is something other than 50 ohms it may be impossible to tune the amplifier stage correctly. Of course, an important part of the problem is finding out what the load is — or, rather, how far from 50 ohms it happens to be. The piece of measuring gear described in this article is a device for doing just this. However, before describing the Monimatch and what it can do, let's take a little closer look at antenna-system loads.

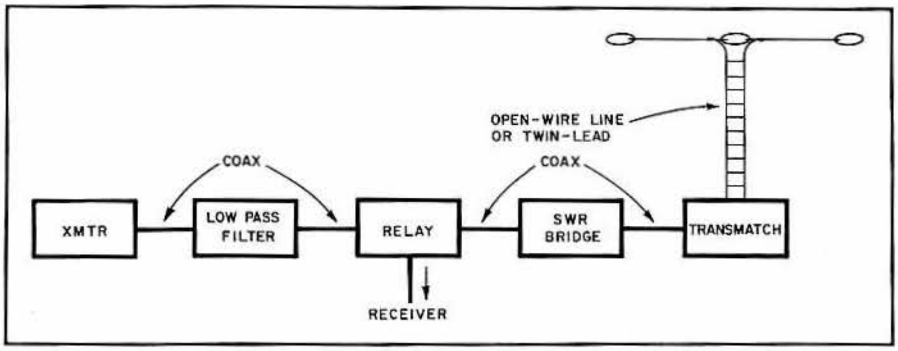

Fig. 34 — A typical setup for using a Monimatch in a multiband antenna system using a single dipole. The length of the dipole is not critical but it should be at least 1/4 wavelength overall at the lowest operating frequency for good efficiency. The feed line can be any length. The antenna relay and low-pass filter may be omitted if not needed.

The "50-Ohm" Load

The evolution of transmitter design since WW II has been influenced by several factors that have led to design that is more or less standard these days. First off, television came along right after the war and the hams quickly discovered that extremely tight shielding of a transmitter was needed to prevent undesired radiation that could cause TVI. However, when tight shielding was installed, band changing without band-switching became a real chore because there were so doggone many screws to unscrew and rescrew.

The one type of tank circuit that lent itself very well to the problem was the pi network. It was a fairly simple job to design a tightly shielded bandswitching transmitter, using the pi network, that would work into a 50-ohm load. Why 50 ohms? Simply because at this time 50-ohm coaxial cable had become a very popular type of transmission line. During the war, techniques were developed that made the manufacture of flexible coaxial cable a

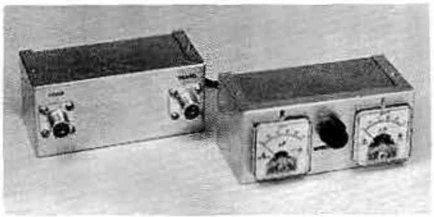

Here is the completed Monimatch with the two meters and the sensitivity control in the box at the right. The sensing unit is at the left.

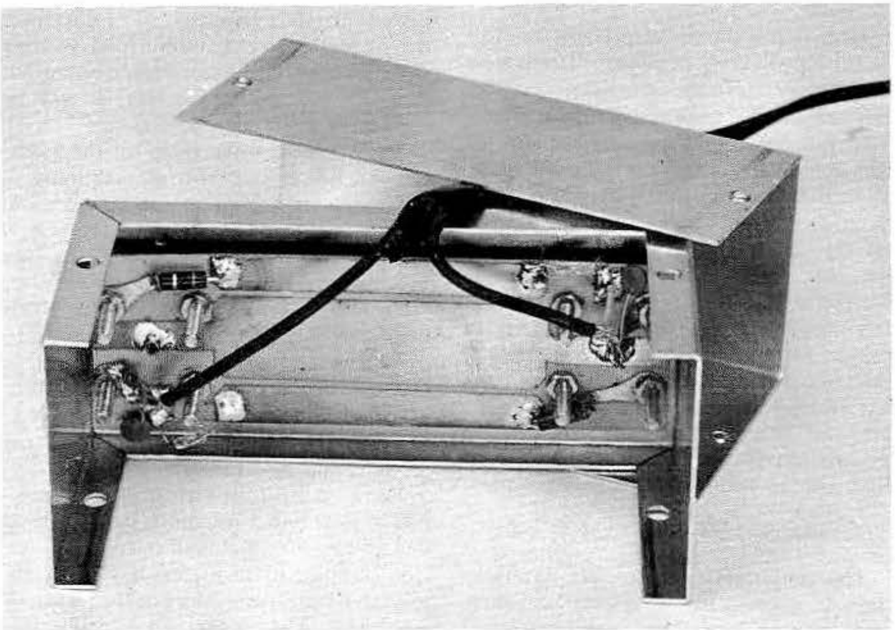

This is the sensing unit of the etched circuit Monimatch. As pointed out in the text, be sure to use a heat sink when soldering the diodes and resistors to the circuit board. The two shielded pickup leads are routed out the back of the Minibox, through a rubber grommet.

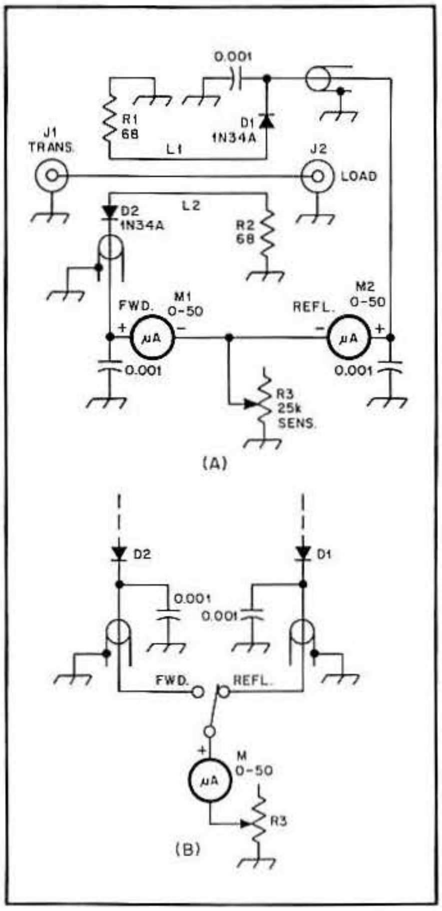

Fig. 35 — Circuit details of the etched-circuit Monimatch. The 0.001 µF capacitors are disk ceramic.
D1, D2 — 1N34A germanium diodes.
J1, J2 — Coax chassis fittings, type SO-239.
L1, L2 — See text and Fig. 36.
M1, M2 — 0-50 µA meter (Lafayette 99 H 5049).
R1, R2 — 68-ohm, 1/2-watt carbon or composition.
R3 — 25 kΩ control, linear taper.
S1 — Spdt switch.

reliable and economical process. So TVI and the availability of coax feed lines were the primary contributing factors that led to our present-day transmitter design.

If the load that is attached to the transmitter is something other than 50 ohms then the transmitter may be difficult to load, depending on a couple of other factors. While it is possible to design a pi network that will handle quite a wide variety of loads, many present day manufacturers, in order to compete in given price ranges, use a minimum number of parts in the tank circuit of the amplifier. For such rigs to operate properly the load must be between 25 and 75 ohms. This of course means that the user *must* furnish a load that will fall within this range.

Transmission Lines

The output terminal on all rigs these days is a coax fitting, which of course implies that a coaxial line must be attached to the rig. This doesn't mean that the coaxial line has to go all the way to the antenna. It could be connected to a Transmatch or a balun. What is important is that the first thing in the antenna system is the coaxial line that is attached to the rig.

Many Novices mistakenly believe that if you attach a 50-ohm coaxial cable to rig you *automatically* have a 50-ohm load. This is not true. The 50-ohm designation on the cable merely means that 50 ohms is the *characteristic impedance* of the cable. The characteristic impedance of a transmission line is determined by the size of the conductors used, the spacing of the conductors, and the dielectric material used to separate and support the conductors. The only time you would have a 50-ohm load using 50-ohm cable is when the line is terminated in its characteristic impedance. In other words, if the antenna has an impedance of 50 ohms then you will have a 50-ohm load on the rig. If the antenna has an impedance of other than 50 ohms then the load at the transmitter will be something other than 50 ohms. This in turn leads us up to a short discussion of standing-wave ratio.

SWR

If a transmission line is terminated in its characteristic impedance, all the power fed into the line from the transmitter will be delivered to the load end — in this case, the antenna. Actually, not quite all the power will reach the antenna because there is always some loss in the transmission line itself. However, what is important is that when the line is terminated in its characteristic impedance none of the power that reaches the end is reflected back toward the transmitter; all of it is used up in the antenna.

When the antenna impedance is different from the line impedance some of the power will be reflected back toward the transmitter end. Standing waves of voltages and currents will then exist on the transmission line. When this happens, the transmitter will no longer "see" a 50-ohm load. Exactly what the load will be will depend on several factors,[1] but suffice to say it will be something other than 50 ohms.

The standing-wave ratio on the transmission line is the ratio of maximum to minimum voltage or maximum to minimum current that exists along the line. If the line were matched in its characteristic impedance the voltage would be the same along the line and of course the SWR would be 1 to 1. The SWR is determined by dividing the resonant antenna impedance into the line impedance, or vice versa. For example, if the antenna impedance were 25 ohms and a 50-ohm line were used, the SWR would be 2 to 1.

For a moment, let's assume that regardless of how bad a mismatch exists, we are still able to tune and load our transmitter. The question then arises, how does the mismatch affect the losses in the transmission line? The answer to the question depends on how efficient the transmission line is.

Remember earlier we said there are always some power losses in every transmission line. If we have a mismatch at the antenna end, some of the power that reaches the end will be reflected back down the line. In traveling back, some of this power will be dissipated in the line, and the higher the SWR the higher these additional losses will be, because a higher SWR means that a greater proportion of the power will be reflected. In a transmission line that is 100 percent efficient (one that has no losses) it follows that regardless of how high an SWR exists, we wouldn't have any losses due to the SWR. Unfortunately, there "ain't no such" line, although some types of lines are much less lossy than others.

Also unfortunately, coaxial lines fall into the class that can be considered to be lossy lines. Just as an example, let's assume that you are using 100 feet (30.48 m) of RG-58/U on the Novice 15-meter band, and you are getting 50 watts out of your 75-watt Novice rig. This 50 watts is what is leaving your transmitter on the way to antenna via the 100 feet (30.48 m) of line. The loss for 100 feet (30.48 m) of RG-58/U at 21 MHz is 1.9 decibels. Translating this figure to power, we would lose about 20 of our 50 watts in the losses in the feed line, leaving only 30 watts to reach the antenna and be radiated. This is assuming the antenna impedance to be 50 ohms, the same as that of the line. If there is a mismatch the losses will be higher, as pointed out earlier. Suppose the SWR is 3 to 1, using the same setup. The *additional* loss in the system because of the SWR would be 1 dB, or a total of close to 3 dB. A 3-dB loss represents almost exactly one-half the power — that is, only 25 watts reach the antenna to be radiated. RG-8/U cable has the same characteristic impedance as RG-58/U but has less loss because it has larger conductors and more spacing between the conductors (and of course is more expensive).

The closest thing to a lossless transmission line is open-wire line. An open wire line on 21 MHz has only 0.08 dB loss per 100 feet (30.48 m). Even with a very high mismatch — for example, an SWR of 20 to 1, the additional losses are still less than 1 db!

This should not be interpreted to mean that coax is an undesirable type of line to use. For beam antennas it is difficult to beat the ease and convenience of using coax. However, for a single antenna, such as a dipole that is to be used on all bands and all frequencies, the best system is one consisting of a Transmatch and a feed line of open-wire line, such as shown in Fig. 34. With this system you can forget about line losses, SWR on the line, and mismatches between the antenna and feed line. By correctly adjusting the Transmatch, you can always give your rig a 50-ohm load regardless of what the load is on the antenna side of the Transmatch. If we use an SWR bridge in the short length of 50-ohm coaxial line that connects the rig to the

Transmatch, we can adjust the Transmatch so that the 50-ohm line shows a match, or SWR of 1 to 1, and the transmitter always sees a 50-ohm load.

The SWR bridge in the photographs and drawings is simple to build, and when installed in 50-ohm cable, will show the relative mismatch in the line, and also will indicate when you get the Transmatch properly adjusted for a match. The SWR bridge can also be used as an output indicator, which is very handy when tuning up the rig.

SWR Bridge Circuit Details

The etched-circuit Monimatch shown here is a reflectometer that samples the forward and reflected voltage in a 50-ohm line. Fig. 35 shows the circuit diagram. L1 and L2 are the pickup lines. In operation, a very small amount of power is coupled into the pickup lines and the rf voltages are rectified by D1 and D2. The rectified voltages are then fed to the two meters, M1 and M2, and the SWR then determined from the readings.

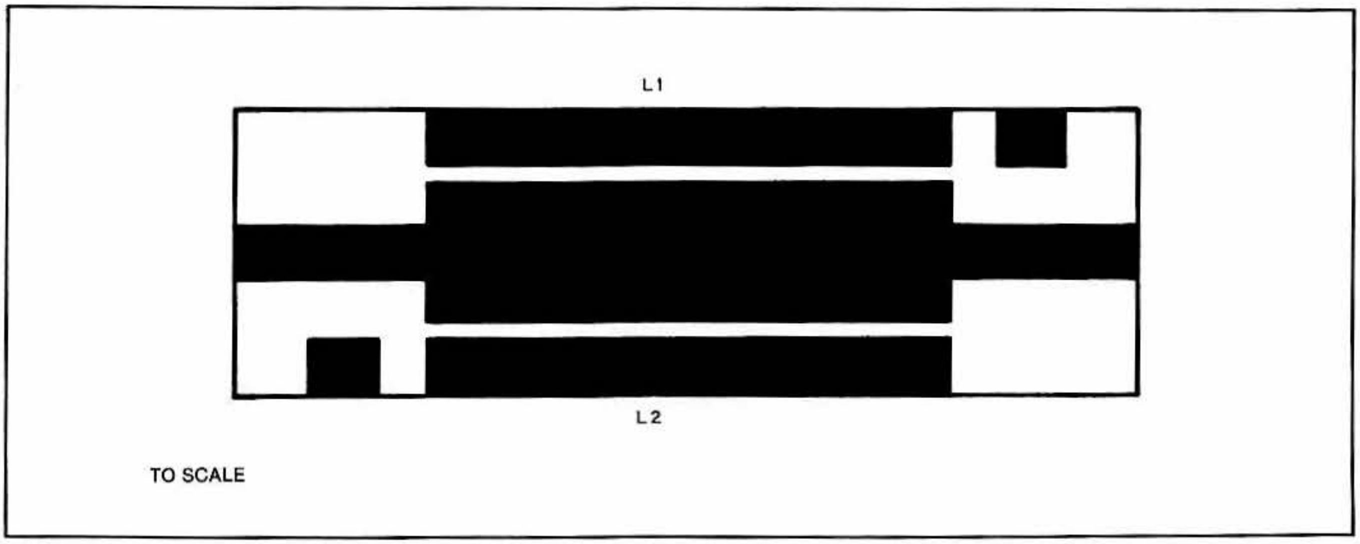

Fig. 36 — Etched circuit board template. The foil side is shown; the etched portion is shaded.

While a Monimatch is not a precise piece of measuring equipment, the SWR readings will be close enough for practical purposes. In order to determine the SWR, the forward-reading meter is set to full scale by adjusting R3, the sensitivity control, and then the reading on the "reflected" meter is noted. The formula for the SWR using this system is

$$\frac{F+R}{F-R}.$$

For example, let's assume the "reflected" reading is 5, with the "forward" reading being 10. Then 15 divided by 5 (that is, 10 + 5 divided by 10 − 5) would mean the SWR is 3 to 1. The closer the "reflected" reading is to zero, versus full-scale reading on "forward," the closer you come to 1 to 1, or a matched condition.

In the unit shown, two meters are used, one for the forward and the second for the reflected reading. However, if desired a single meter can be used and switched as shown in Fig. 35 at B. We used two meters in the indicator as this permits constant monitoring of what is happening in the line. The meters are inexpensive ones made in Japan.

Construction Details

Fig. 36 is a full-sized template of the etched circuit board. A *QST* article[2] went into detail showing simple methods for making etched circuits, so we won't treat the process here. In making this board, it is suggested that the board be covered with masking tape and then the pattern of Fig. 36 transferred to the tape. Using a sharp knife edge or razor blade and a straight edge, the masking tape can be carefully and accurately cut to the pattern.

After the board is etched, it can be positioned in the Minibox over the chassis connector holes and the board can then be marked at the drilling points for the mounting holes and the center conductor pins of the coax fittings. When installing the mounting screws, be sure they don't short to the center — conductor portion of the foil on the board.

There are a couple of other construction points that should be stressed. The lead lengths on R1 and R2 should be kept as short as possible. Also, be sure to use carbon or composition resistors, *not* wire-wound. When mounting the resistor and diode ends to the pickup sections, L1 and L2, the connections should be at the very ends of the sections. Also, use a heat sink when soldering the leads on any of the components mounted on the board, as too much heat from the iron can ruin the component.

The Monimatch and meters are mounted in separate Miniboxes, 2-1/4 × 2-1/4 × 5 inches (57 mm × 57 mm × 127 mm). The two connectors on the Monimatch sensing unit, J1 and J2, are mounted with their center pins 3-3/4 inches (95 mm) apart, center-to-center. In order to avoid an impedance "bump" in the feed line when the bridge is inserted in the line, the circuit board should be mounted 1/4 inch (6 mm) above the base of the Minibox. Quarter-inch (6 mm) spacers can be used under the circuit board at the screws holding both the board and the coax fittings to position the board accurately.

Shielded conductors should be used for the connections from the diodes to the meter enclosure. The shields should be grounded to the chassis at both boxes. These lead lengths are not critical, and the Monimatch can be remote from the meter indicator.

Using the Bridge

If you are using coax feed from the rig to the antenna, the bridge can be installed at any convenient spot in the line. If you are using a Transmatch, similar to the system as shown in Fig. 34, the Monimatch should be installed on the transmitter side of the Transmatch. Any relays or filters should be installed between the bridge and the transmitter, as shown.

Set R3 so that the arm of the control is at the top of the resistance — in other words, with all the resistance in series with the meter circuit. Tune up your rig in the normal fashion, and once tuned up adjust the sensitivity of the "forward" meter by moving the arm of R3 until the meter reads full scale. You can then determine the SWR by the formula mentioned earlier.

When adjusting a Transmatch, feed just enough power through the system to obtain about half-scale reading on the "forward" meter and then adjust the Transmatch controls for a match, as indicated by zero reflected power. You may have to adjust R3 as you adjust the Transmatch to keep the "forward" meter from reading more than full scale. Once you have the Transmatch adjusted for a 1-to-1 ratio as indicated by the bridge, the transmitter can be loaded up in the normal manner. We usually reduce the forward reading to about half scale, and then tune the rig for maximum output, as indicated by the meter. When doing this, you may notice that maximum output as indicated by the bridge meter occurs at some setting other than the normal transmitter plate meter "dip" reading. (Normally, the instruction manuals tell you to tune for a plate dip if the transmitter has no output meter.) However, the amplifier stage will work better if you tune for maximum output rather than the dip — keeping the plate loading within the transmitter ratings, of course.

Once you become familiar with the use of the bridge and interpreting the readings, you'll find it a very valuable device in your station. This material originally presented in *QST* by Lewis G. McCoy, W1ICP.

References

[1] [Editors Note: It is recommended that the newcomer obtain a copy of *The ARRL Antenna Book* for more detailed information on transmission line operation than can be provided in this article.]

[2] Schiebold, "Fast'n' Easy Printed Circuit Boards," *QST*, August 1969.

In-Line RF Power Metering

Problems are frequently encountered in designing and building reflected-power meters and SWR bridges. Examples of practical in-line rf wattmeters are given here, along with complete details for building a unit that will provide two power ranges, forward and reflected, for use from 3.5 to 30 MHz.

It is neither costly nor difficult to build an rf wattmeter. And, if the instrument is equipped with a few additional components it can be switched to read reflected power as well as forward power. With the foregoing feature the instrument can be used as an SWR meter for antenna matching and Transmatch adjustments.

Perhaps the most difficult task faced by the constructor is that of calibrating the power meter for whatever wattage range he desires to have. The least difficult method is to use a commercial wattmeter as a standard. If one is not available, the power output of the test transmitter can be computed by means of an rf ammeter in series with a 50-ohm dummy load, using the standard formula, $P = I^2R$. Or, if one is not interested in obtaining power readings the bridge can be used solely as an SWR indicator, as is done with the Monimatch-style SWR bridge.[1]

ANTENNA
RFL
FWD
µA

The advantage of the circuits shown here over those of Monimatch bridges is that these instruments are not frequency-sensitive. Monimatch indicators become more sensitive as the operating frequency is increased, thus making it impractical to calibrate them in watts for more than one band, or for more than one portion of a given band. The units described here are more sensitive than Monimatches are. This makes it possible to calibrate them for power levels as low as 1 watt, full scale, in any part of the hf spectrum.

All of the circuits shown in this article are similar to the basic one which was described in *QST*.[2] Some of the circuits are those of commercial power meters, and are used to illustrate variations in the basic Bruene design. The reader may wish to experiment with some of these circuits.

Design Philosophy

Referring to the circuit of Fig. 37B, the circuit used by Collins Radio Company, the transmission-line center conductor passes through the center of a toroid core and becomes the primary of T1. The multiturn winding on the core functions as the transformer secondary. Current flowing through the line-wire primary induces a voltage in the secondary which causes a current to flow through resistors R5 and R6. The voltage drops across these resistors are equal in amplitude, but 180 degrees out of phase with respect to common or ground. They are thus, for practical purposes, respectively in and out of phase with the line current. Capacitive voltage dividers, C3C7 and C4C8, are connected across the line to obtain equal-amplitude voltages *in* phase with the line voltage, the division ratio being adjusted so that these voltages match the voltage drops across R5 and R6 in amplitude. (As the current/voltage ratio in the line depends on the load, this can be done only for a particular value of load impedance. Load

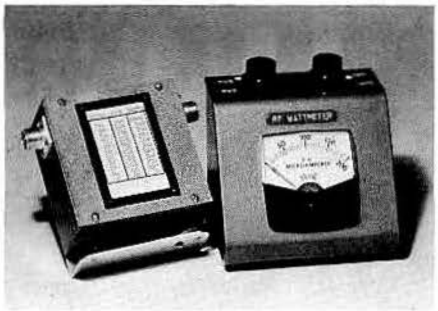

values chosen for this standardization are pure resistances that match the characteristic impedance of the transmission line with which the bridge is to be used, usually 50 or 75 ohms.) Under these conditions, the voltages rectified by D1 and D2 represent, in the one case, the vector *sum* of the voltages caused by the line current and voltage, and in the other, the vector *difference*. With respect to the resistance for which the circuit has been set up, the sum is proportional to the forward component of a traveling wave such as occurs on a transmission line, and the difference is proportional to the reflected component.

The Collins circuit uses two 8-µF capacitors, C5 and C6, to permit the meter to approach the PEP level during ssb operation. The dc voltages in the forward and reflected lines charge the capacitors to permit a near-peak reading. The discharge rate is set by the series calibrating resistors, R1 through R4, and is dependent upon which of them is switched into the metering line at a given time. The circuit of Fig. 37B uses two 43-pF capacitors, C1 and C2, to cancel the inductive reactances of R5 and R6. Such reactance may become manifest at the high end of the range for which the instrument is built. If reactance is present in that part of the circuit the meter readings may not be accurate, especially at 10 and 15 meters. The capacitors were not needed in the circuit of Fig. 38, perhaps because the resistor leads were very short when they were mounted on the etched-circuit board.

Some Design Hints

It is important that the layout of any rf bridge be as symmetrical as possible if good balance is to be had. The circuit-board layout for the instrument of Fig. 38 meets this requirement. Also, the input and output parts of the equipment should be isolated from the remainder of the circuit so that only the sampling circuits feed voltage to the bridge. A shield across the end of the box which contains the input and output jacks, and the interconnecting line between them, is necessary. If stray rf gets into the bridge circuit it will be impossible to obtain a complete zero reflected-power reading on M1 even though a 1:1 SWR exists.

Referring again to Fig. 38, resistors R1 and R2 should be selected for the best null reading when adjusting the bridge into a resistive 50- or 75-ohm load. Normally the value will be somewhere between 10 and 47 ohms. The 10-ohm value worked well with the homemade instruments shown here. It was found that half-watt resistors exhibited somewhat less inductive reactance at 30 MHz than did some 1-watt units tried. R1 and R2 should be as closely matched in resistance as possible. They need not be exactly 10 ohms, so a VTVM can be used to match them. The resistors used for the circuit of Fig. 38 were actually 10.5 ohms each, and were chosen from an assortment of "10-percenters" on hand.

Silver-mica capacitors C3 and C4 were close enough in value so that special selection was not required. There should be enough leeway in the ranges of C1 and C2 to compensate for any difference in the values of the 330-pF capacitors. Ideally, however, C3 and C4 should be matched in value.

Diodes D1 and D2 should also be matched for best results. An ohmmeter can be used to select a pair of diodes whose forward dc resistances are within a couple of ohms of being the same. Similarly, the back resistances of the diodes can be matched. The matched diodes will help to assure equal meter readings when the bridge is reversed. (The bridge should be perfectly bilateral in its performance characteristics.) Germanium diodes are used in the bridges described here, but

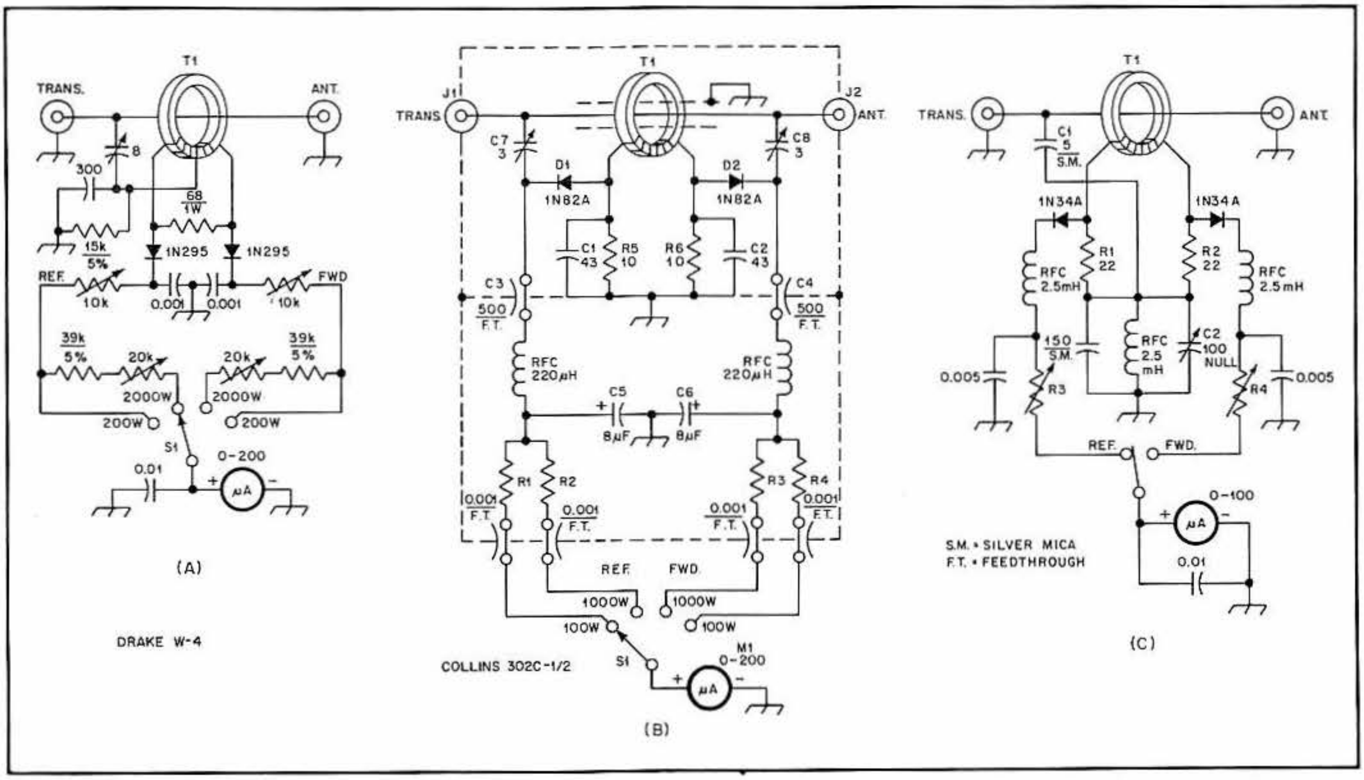

Fig. 37 — Schematic diagrams of typical in-line power meters. At A, the R. L. Drake W-4 instrument. It uses a center-tapped transformer at T1 and has but one capacitive voltage divider in the sensing circuit. The circuit at B is discussed in the text, and is used by Collins Radio Company. The capacitive voltage dividers in this circuit use two 500-pF feedthrough capacitors in place of the silver-mica capacitors specified in Fig. 38. Capacitors C5 and C6 permit a charge time that enables the meter to read near-peak power on ssb. Calibrating resistances R1 through R4 are factory selected. The circuit at C is similar to one used by Comdel in their power meter. In this circuit C1 is a fixed-value (small) capacitor, and the bridge is nulled by the larger capacitor in the divider, C2.

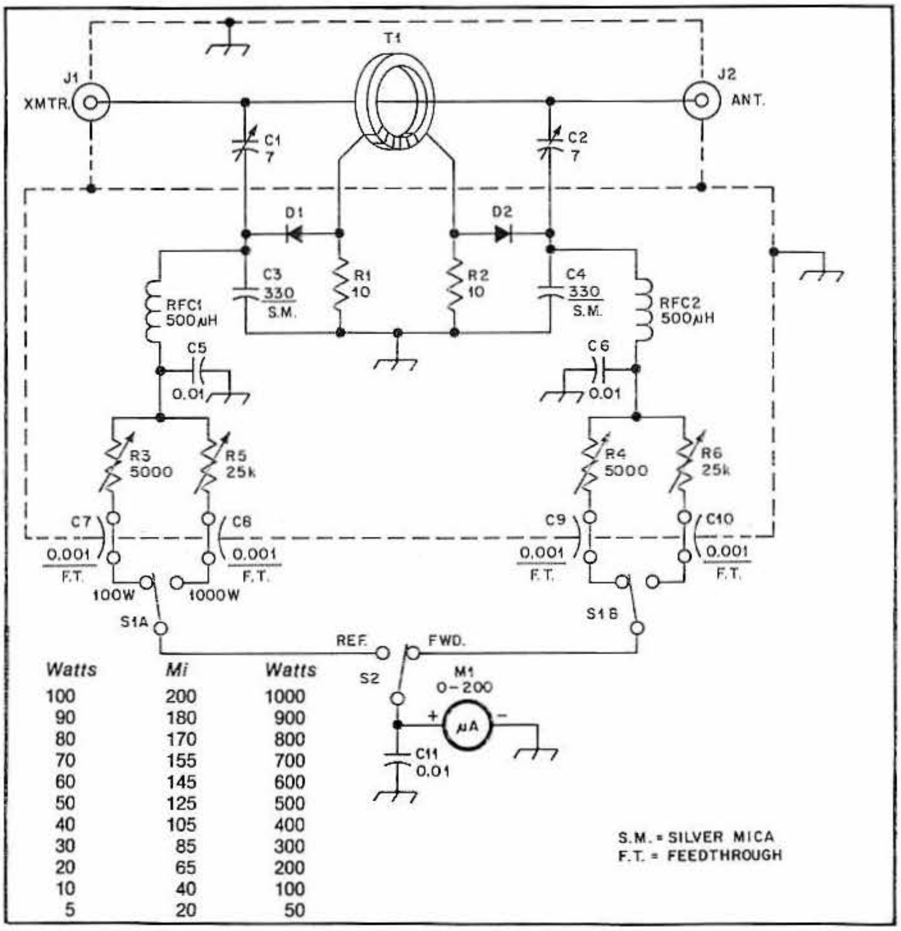

Watts	*Mi*	*Watts*
100	200	1000
90	180	900
80	170	800
70	155	700
60	145	600
50	125	500
40	105	400
30	85	300
20	65	200
10	40	100
5	20	50

Fig. 38 — Schematic diagram of a practical power wattmeter. A calibration scale for M1 is shown also. Fixed-value resistors are 1/2-watt composition. Fixed-value capacitors are disk ceramic unless otherwise noted. Decimal-value capacitances are in µF. Others are pF. Resistance is in ohms; k = 1000.

C1, C2 — 1.3- to 6.7-pF miniature trimmer (E. F. Johnson 189-502-4. Available from Newark Electronics, Chicago, IL).
C3-C11, incl. — Numbered for circuit-board identification.
D1, D2 — Small-signal germanium diode. IN34A, etc. (see text).
J1, J2 — Chassis-mount coax connector of builder's choice. Type SO-239 used here.
M1 — 0- to 200-µA meter (Triplett type 330-M used here.)
R1, R2 — Matched 10-ohm resistors (see text).
R3, R4 — 5000-ohm printed-circuit carbon control (IRC R502-B).
R5, R6 — 25,000-ohm printed-ciruit carbon control (IRC R253-B).
RFC1, RFC2 — 500-µH rf choke (Millen 34300-500 or similar).
S1 — Dpdt single-section phenolic wafer switch (Mallory 3222J).
S2 — Spdt phenolic wafer switch (Centralab 1460).
T1 — Toroidal transformer; 35 turns of no. 26 enam. wire to cover entire core of Amidon T-68-2 toroid (Amidon Assoc., 12033 Otsego St., No. Hollywood, CA 91607).

silicon diodes can also be used. Silicon diodes conduct at a higher voltage than germanium diodes do — approximately 0.7 volt — and will not work too well in low-power wattmeters. Some silicon diodes were tried, but ceased to conduct at approximately 8 watts in the circuit of Fig. 38. This effect can cause misleading results when low values of reflected power are present during antenna adjustments. The SWR can appear to be zero when actually it isn't. The germanium diodes conduct at approximately 0.3 volt, making them more suitable for low-power readings.

Any meter whose full-scale reading is between 50 microamperes and 1 milliampere can be used at M1. The more sensitive the meter, the more difficult it will be to get an absolute reflected-power reading of zero. Some residual current will flow in the bridge circuit no matter how carefully the circuit is balanced, and a sensitive instrument will detect this current flow. Also, the more sensitive the meter, the larger will have to be the calibrating resistances, R3 through R6, to provide high-power readings. A 0- to 200-microampere meter represents a good compromise for power ranges between 100 and 2000 watts.

Construction

The power meter of Fig. 38 is built in two sections. The rf circuit and the calibrating resistors are housed in a 4 × 4 × 2-inch (102 × 102 × 51 mm) aluminum utility box. All components other than J1, J2, and the feedthrough capacitors, are assembled on the etched-circuit board.[3] Switches S1 and S2, and the meter, M1, are installed in a sloping-panel utility box which measures 5 × 4 inches (127 × 102 mm). Four-conductor shielded cable — the shield serving as the common lead — is used to join the two pieces. There is no reason why the entire instrument cannot be housed in one container, but it is sometimes awkward to have coaxial cables attach to a unit that occupies a prominent place in the operating position. Built as shown, the two-piece instrument permits the rf pickup head to be concealed behind the transmitter, while the control head can be mounted where it is accessible to the operator.

Toroidal transformer T1 fits into a cutout area on the circuit board. A 1-inch (25 mm) long section of RG-8/U cable — vinyl jacket and shield braid removed — provides a snug fit in the center hole of the toroid, and is used to complete the line between J1 and J2. The inner conductor of the RG-8/U section solders to the circuit board, thus holding T1 in place.

A flashing-copper shield divides T1 and its center-conductor line from the remainder of the circuit. This partition is shown in dotted lines in Fig. 38. It is mounted on the non-foil side of the circuit board and is secured at each end to solder lugs which are mounted under the retaining screws for J1 and J2.

The circuit board is held in place, at the end near T1, by means of an aluminum L bracket. The circuit-board end nearest the feedthrough capacitors is held in place by a no. 6 spade bolt. A solder lug is mounted under the no. 6 nut (outside the case) which secures the spade bolt. The lug serves as a connection point for the common lead between the rf head and the control box. Two solder lugs are mounted under the bottom two retaining screws of each coax connector. The free ends of the lugs are soldered to the copper foil of the circuit board.

A partition is visible in the foil-side view of the rf head. It can be eliminated if desired, since it did not prove necessary when the unit was tested. Similarly, an extra shield partition is shown on the top side of the board. It too can be eliminated, for it turned out to be unnecessary. The flashing-copper shield discussed earlier is the only one required for the circuit of Fig. 38.

Checkout and Tune-up

Once the instrument is wired and ready to test it should be inspected for unwanted solder bridges between the circuit-board foils. It is usually a good idea to scrape out the rosin buildup between the foils, and this can be done with the blade of a small screwdriver. A continuity check for "opens" and "shorts" should also be made before power is applied to the unit. Make certain that the diodes are installed for the correct polarity — the banded ends (cathodes) toward C1 and C2.

Connect a noninductive 50-ohm dummy load to J2. A Heath Cantenna or similar load will serve nicely for adjustment purposes. Place S2 in the FORWARD position, and set S1 for the 100- range. An rf ammeter or calibrated power meter

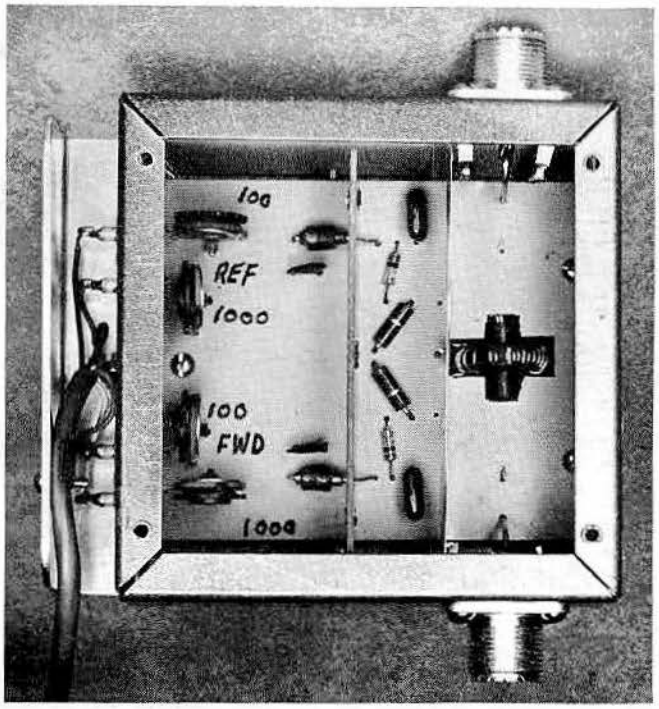

Top view of the rf head for the circuit of Fig. 38. A flashing-copper shield isolates the through-line and T1 from the rest of the circuit. The second shield (thicker) is not required and can be eliminated from the circuit. If a 2000-watt scale is desired, fixed-value resistors of approximately 22 kΩ can be connected in series with high-range printed-circuit controls. Or, the 25 kΩ controls shown here can be replaced by 50 kΩ units.

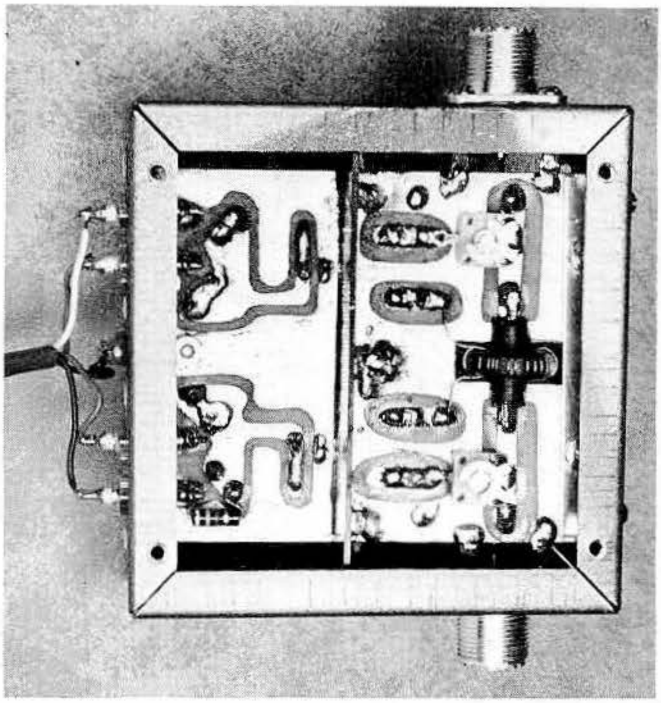

Bottom view of the rf head for the circuit of Fig. 38. The fixed-value resistor at the lower left does not belong in the circuit, but was added as a shunt for one of the calibrating controls which was too high in value — a 50 kΩ unit that was on hand. The shield partition shown here proved unnecessary and can be eliminated.

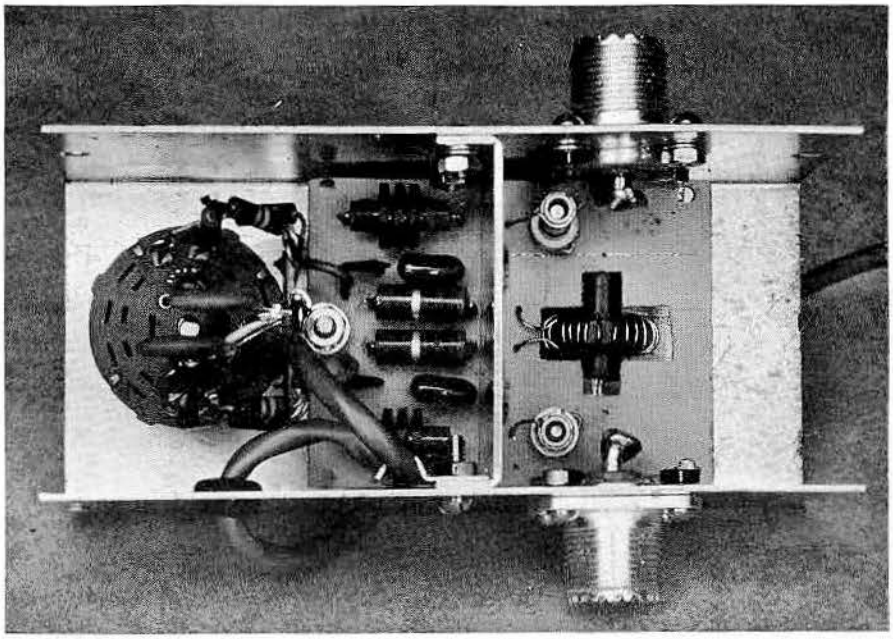

Fig. 39 — Inside view of the 5- and 50-watt power meter rf head. Component values are the same as in the circuit of Fig. 38, except for the calibrating resistances (see text). An aluminum shield isolates the through-line and toroid from the remainder of the circuit. A 50-μA meter is used in this model.

should be connected between J2 and the dummy load during the tests, providing power calibration points against which to plot the scale of M1. Apply transmitter output power to J1, gradually, until M1 begins to deflect upward. Increase transmitter power and adjust R4 so that a full-scale meter reading occurs when 100 watts is indicated on the rf ammeter or other standard in use. Next, switch S2 to REFLECTED and turn the transmitter off. Temporarily short across R3, turn the transmitter on, and gradually increase power until a meter reading is noted. With an insulated screwdriver adjust C2 for a null in the meter reading.

The next step is to reverse the coax connections to J1 and J2. Place S2 in the REFLECTED position and apply transmitter power until the meter reads full scale at 100 watts output. In this mode the REFLECTED position actually reads forward power because the bridge is reversed. Calibrating resistance R3 is set to obtain 100 watts full scale during this adjustment. Now, switch S2 to FORWARD and temporarily place a short across R4. Adjust C1 for a null reading on M1. Repeat the foregoing steps until no further improvement can be obtained. It will not be necessary to repeat the nulling adjustments on the 1000-watt range, but R5 and R6 will have to be adjusted to provide a full-scale meter reading at 1000 watts. If insufficient meter deflection is available for nulling adjustments on the 100-watt range, it may be necessary to adjust C1 and C2 at some power level higher than 100 watts. If the capacitors tune through a null, but the meter will not drop all the way to zero, chances are that some rf is leaking into the bridge circuit through stray coupling. If so, it may be necessary to experiment with the shielding of the through-line section of the rf head. If only a small residual reading is noted it will be of minor importance and can be ignored. In the circuit of Fig. 38 there remained approximately one-half a meter division when the null was reached, and this occurred only on the 1000-watt range. Since this was representative of less than 2 watts of power, it was deemed inconsequential.

With the component values given in Fig. 38 the meter readings track for both power ranges. That is, the 10-watt level on the

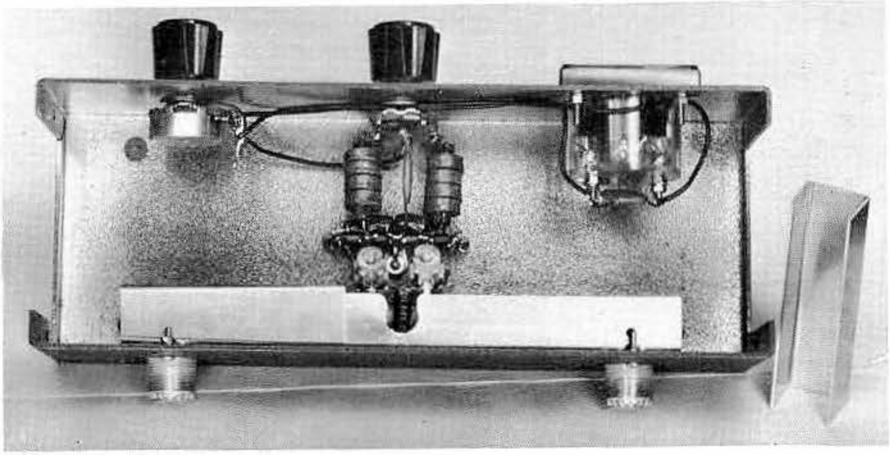

Inside view of the modified Heath HM-15 bridge. The new components are grouped at the center of the chassis on a 5-lug terminal strip. The nulling capacitors are connected between the inner line and the terminal strip. Press-fit aluminum shield covers are slipped over the trough line to aid in rf isolation. One cover is in place; the other is at the right of the photo. Improved shielding might be effected by installing an aluminum plate between the terminal strip and the two nulling capacitors.

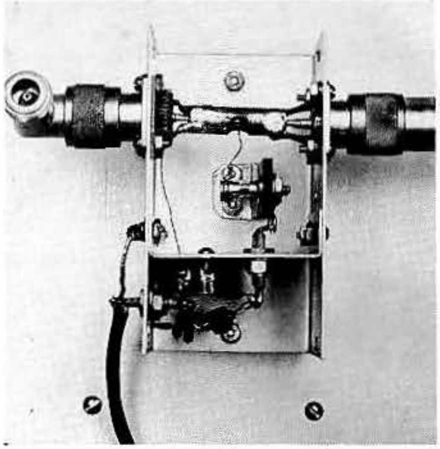

Inside view of a 2000-watt power meter built by N1RM. This bridge is patterned after the circuit of Fig. 37B. Point-to-point wiring is used throughout, thus avoiding the need for a circuit board. Two piston trimmers are used for the nulling capacitors and are mounted one above the other on a phenolic block. The two 500-pF feedthrough capacitors are part of the capacitive voltage dividers.

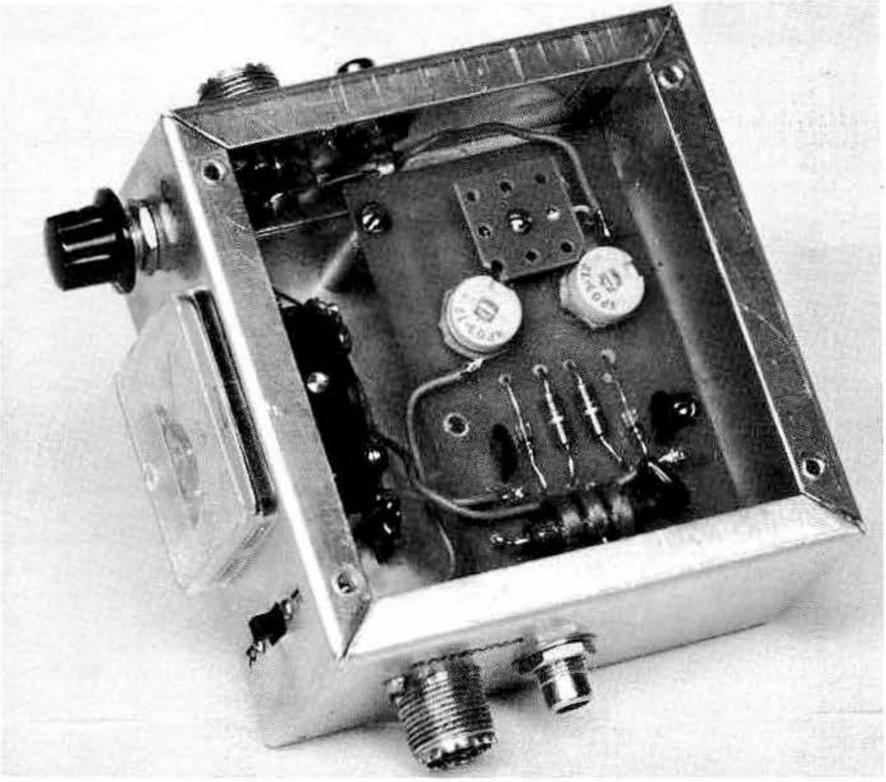

Fig. 40 — Inside view of a 3-watt power meter for QRP rigs. Its circuit is given on page 16 of June 1969 *QST*. Ceramic trimmers are used for nulling the bridge. Type SO-239 connectors are paralleled with phono jacks to add versatility. A 4 X 4 X 2 inch (102 X 102 X 51 mm) utility box houses the entire unit.

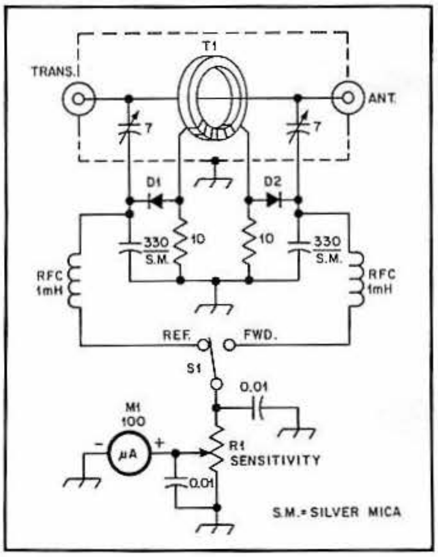

Fig. 41 — Schematic diagram of the modified Heath HM-15 SWR meter. D1, D2, M1, R1 and S1 are original components from the HM-15. T1 is the same as in Fig. 38. See text for additional details.

100-watt range, and the 100-watt point on the 1000-watt range fall at the same place on the meter scale, and so on. This no doubt results from the fact that the diodes are conducting in the most linear portion of their curve. Ordinarily, this desirable condition does not exist, making it necessary to plot separate scales for the different power ranges.

Tests indicate that the SWR caused by insertion of the power meter in the transmission line is negligible. It was checked at 28 MHz and no reflected-power could be noted on a Bird wattmeter. Similarly, the insertion loss was so low that it could not be measured with ordinary instruments.

Other Circuits

Additional circuits and photos are shown for variations in the basic design used at Fig. 38. A low-power model, having scales for 5 and 50 watts, is shown in Fig. 39. It uses fixed-value resistors for meter calibration. The required values of resistance were first determined by temporarily inserting a potentiometer in the meter line, obtaining the required full-scale reading, then substituting fixed-value resistances of the proper ohmage. The meter readings for the two power ranges do not track in this model.

A low-power meter was designed for use with the QRP transmitter described in June 1969 *QST*. It is shown in Fig. 40, and has a full-scale calibration of 3 watts. To obtain additional sensitivity, the primary of the toroidal transformer consists of a one-turn link instead of the single wire that would normally pass through the hole in the toroid core.

Some experiments were conducted to see if a Heath HM-15 SWR bridge (a Monimatch type) could be modified to work in a Bruene circuit. The results were satisfactory, and the circuit is given in Fig. 41. No attempt was made to obtain a calibration scale for the meter. The unit is being used as a simple SWR indicator, but now has better sensitivity in the lower part of the hf spectrum — 7 watts, full scale, from 3.5 to 30 MHz. Also, the instrument is no longer "frequency-conscious" as was the case before modification. The original pickup lines were discarded, the FWD-REV panel switch was rotated 180 degrees so that the labels were correct for the new circuit, and press-fit shield covers were installed on the trough line as shown in the photo. A power scale could be plotted by setting the sensitivity control in a fixed position — possibly replacing the existing control with a screwdriver-adjust type. A new 100-μA meter could be installed to provide a better scale for calibration in watts.

It was necessary to dismantle the trough line so that the toroidal transformer could be slipped over the inner line. A few wraps of mylar tape were wound over the center of the inner line to insulate the toroid winding from the line, and to provide a snug fit to keep the toroid in place. The trough was notched out with a nibbling tool to allow clearance for the toroidal transformer. Additional shielding can be added between the line and the rest of the circuit to further assure a zero meter reading in the reflected position.

It is hoped that the experimenter will find sufficient information here to enable him to build a power meter that will satisfy his specific needs. This material was originally presented in *QST* by Doug DeMaw, W1FB.

References

[1] "Monimatch Mark II," *QST*, February 1957.

[2] Bruene, "An Inside Picture of Directional Wattmeters," *QST*, April 1959.

[3] The etched-circuit board pattern and parts layout sheet for this power meter are available from ARRL hq. Send 25 cents and an s.a.s.e. Check with Circuit Board Specialists, P. O. Box 969, Pueblo, CO 81001 for negative and circuit boards.

A Resistive Antenna Bridge — Simplified

SWR indicators are neat, but when it comes to making measurements of resonant impedances, you need a true bridge type of instrument. Measure those low antenna resistances directly with this W2FMI circuit, and do it up to 30 MHz with ease!

As shown previously,[1] a bridge using a single variable capacitor can be used to measure resonant impedances of antennas and losses in coils with reasonable accuracy. With addition of an L/C network, the bridge can also be very useful in adjusting antennas for resonance conditions. Recently it was brought to the author's attention that a bridge using a variable resistance could also perform well. This is possible because the range of antenna impedances is generally low enough to allow for low values of resistance in the arms of the bridge. Under these conditions parasitic capacitances are negligible up to 30 MHz.

Resistive bridges have the advantages of small size, readily available components, and dial calibrations which can be made practically linear. Two bridges are shown with their respective calibration curves. The first is a linear device. The second expands the lower portion of the calibration curve, 0 to 30 ohms, to measure lower values of antenna impedance and coil losses more accurately.

Bridge Details

The resistive bridge with a variable resistance in one arm and equal resistances in the other two is shown in the photographs, and schematically in Fig. 42A. The nonlinear bridge is similar mechanically. The small enclosures and compact layout minimize lead lengths. With the linear version the dial practically reads directly in

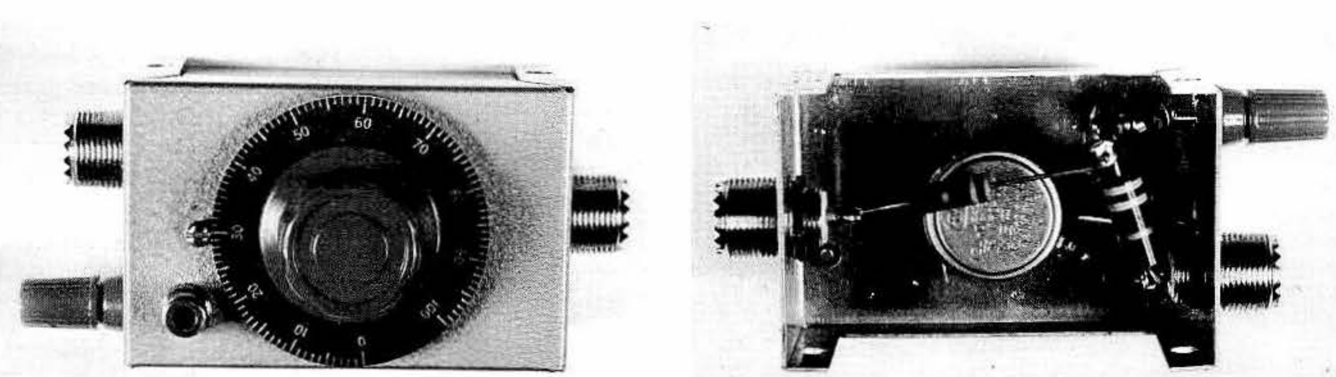

Exterior and interior view of the resistive bridge. Appearance and component arrangement are essentially the same for the two types described.

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[1] Sevick, "Simple RF Bridges," April 1975 *QST*, page 11.

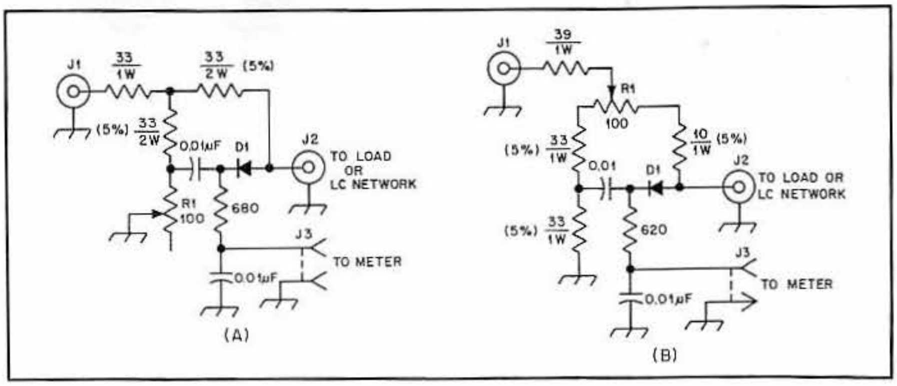

Fig. 42 — Schematic diagram and parts information for the linear (A) and nonlinear (B) resistance bridges. Resistor wattages are the minimum recommended.

D1 — Germanium diode.
J1, J2 — Coaxial connector, chassis type.
J3 — Phono jack.
R1 — 100-ohm, 2-watt linear control (Allen-Bradley, Type J).

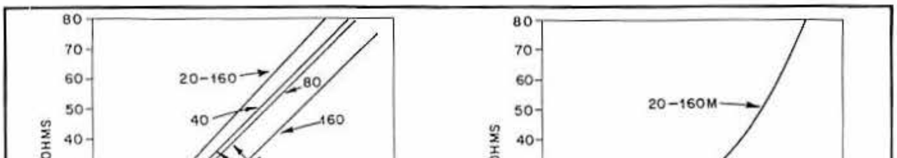

Fig. 43 — Calibration curves for the linear (A) and nonlinear (B) resistance bridges. The add-on L/C network used was described in the author's *QST* article on capacitive bridges.

ohms. In using the L/C network described in the previous article, a constant offset occurs, because of ohmic loss in the coils. This can be as high as 20 ohms, as is shown by the 160-meter curve with the L/C network, Fig. 43A.

The variable resistor used in the bridges has a parasitic (stray) capacitance of the order of 10 to 20 pF, which has little effect even at 14 MHz. Other potentiometers of similar design can probably be substituted. The calibration curves provide a good check. If the difference between the calibrations for the lowest and highest frequencies to be used is greater than an ohm or two, parasitic capacitances are probably excessive.

The nonlinear bridge uses most of the same components, but the control is connected in the differential mode, as shown in Fig. 42B. Resistance is subtracted from one arm and added to the other, tending to spread out the low end of the resistance scale for increased accuracy. In this version, the dial can be read easily to 0.5 ohm.

Results

The author has found these resistance bridges to be entirely satisfactory for measurements in the range of 1.8 to 30 MHz. Because of their greatly expanded scales, as compared with the capacitive bridges, and generally lower values of resistance in all arms of the bridge, they tend to have less marked nulls when used with very low-power signal sources. Increasing the minimum power to 20 or 30 milliwatts, when using the sensitive meter described previously, should take care of this.

In closing, the writer wishes to thank Roger A. Sykes, W1PP, for bringing the resistive bridge to the author's attention. This material was originally presented in *QST* by Jerry Sevick, W2FMI.

Why a Transmatch?

Let's cut away some of the mumbo jumbo about antennas. Here's some basic information to help the newcomer make the decision that best suits his need.

These days, nearly all transmitters have a pi-network tank circuit in the final amplifier. There are good reasons for this. With the pi tank it is possible to design a band-switching transmitter with excellent shielding (in order to prevent undesired harmonic radiation as far as TVI is concerned) and to accomplish the job with a minimum of complications. Additionally, the tank circuit easily can be set up to work into 50- or 70-ohm loads, the characteristic impedance of the popular types of coaxial feed lines. However, as we will see, this is where a "clinker" can get into the act.

When a pi network is designed to work into a 50-ohm load, the load *must* be 50 ohms in order for the transmitter to work at full efficiency. Merely connecting 50-ohm coax to the tank circuit does *not* accomplish this. For the tank to "see" a 50-ohm load, the far end of the coax — the load or antenna end — must also have the same impedance as the coax, 50 ohms. If the load is not 50 ohms the pi network will see some other value than 50 ohms. Usually, too, the tank will see reactance as well as resistance when the line is not matched. While reactance is expressed in ohms, it isn't a true resistance, and what it does is make it more difficult to put power into the line unless certain steps are taken to compensate for it.

Pi-Network Tank Circuits

In the conventional transmitter pi tank we have two controls, customarily referred to as the "tuning" and "loading" controls. The tuning control is the one that resonates the tank circuit to the desired frequency. The loading control, when adjusted properly, permits the final amplifier stage to be loaded to the desired input. To a limited extent it can also be used to compensate for the reactance in the load.

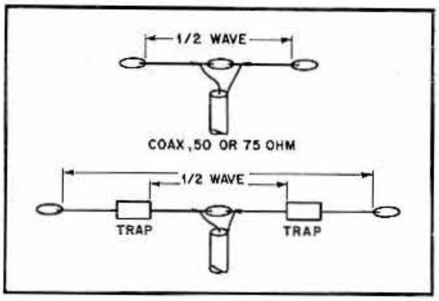

Fig. 44 — At the top is a simple half-wave dipole using coax feed. At the bottom is a drawing of a trap dipole. When a signal is fed to this antenna, for example an 80-meter one, the feed line "sees" a more-or-less resonant antenna on 80. When the transmitter is switched to 40, the traps "divorce" the 80-meter portion and the feed line sees a resonant 40-meter half-wave.

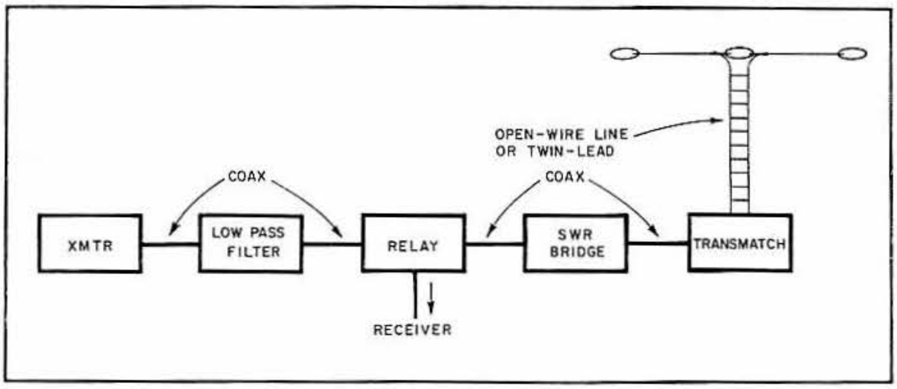

Fig. 45 — This drawing shows an ideal multiband antenna system. The units can be connected together by either 50- or 70-ohm coaxial line. The SWR bridge must match the line used. By putting the antenna relay in this section of the line, the Transmatch can be used to advantage for receiving as well as transmitting.

The clinker in this is that the reactance of many antenna-system loads may have too wide a range for the loading capacitor to handle. If you've ever been in the situation where is was impossible to load (or unload) the amplifier stage, the likely reason is that the load is too reactive to be handled by the tank circuit.

Such a condition can lead to some serious difficulties. While a correctly tuned pi network will offer good harmonic attenuation, an improperly adjusted tank may provide *no* harmonic attenuation. In fact, many Novices who receive second-harmonic violation notices for their 80-meter operation can lay the blame on poor loads and incorrectly adjusted tank circuits. This leads us to the real crux of the problem. How do we get a 50-ohm load on the various bands and frequencies desired?

Antenna Loads

As we said earlier, in order for a transmitter to see a 50-ohm load the far end of the 50-ohm coax must also see 50 ohms. The point where you feed the antenna has a certain impedance; in a half-wave dipole, for example, the impedance will be in the neighborhood of 50 ohms, depending somewhat on the dipole's height above ground. Also, at resonance there will be no reactance in the impedance. When we change frequency, the antenna is no longer resonant and reactance is introduced into the impedance. In turn, reactance is present at the transmitter end of the line. Whether or not the transmitter tank circuit can compensate for it will depend on the range of the loading capacitor.

How do we go about getting an antenna that will look like 50 ohms over a wide range of frequencies within a band — and, for that matter, on several bands? It isn't exactly easy.

For example, if we cut an 80-meter half-wave dipole for the center of the band, 3750 kHz, it is possible to obtain a fairly good match for 50-ohm coax at that frequency and approximately 50 kHz each side of 3750 kHz. However, at the band edges, 3500 and 4000 kHz, the impedance will be very reactive and the mismatch between the coax and the feed point may be as high as 10 to 1. It would be difficult, if not impossible, for our pi network to handle that type of mismatch. Actually, there is no "simple" antenna, by ham standards, that can be coax fed on 80 meters and cover the entire band with a reasonable match. The 40-, 20- and 15-meter bands are narrow enough so that the pi tank will handle a coax-fed dipole under normal circumstances. However, a coax-fed dipole is essentially a one-band system so such an antenna is not the answer if we want to work "all" bands and all frequencies with a single antenna.

Trap Antennas

One type of multiband antenna with coax feed is the trap antenna, either horizontal or vertical. The horizontal variety is essentially a dipole with traps added to divorce parts of the antenna so the coax "sees" an electrically resonant dipole on the band in use. However, the trap dipole is no "broader" than a single dipole. Fig. 44 shows such a trap dipole antenna.

There are a couple of drawbacks to trap dipoles. First, a coax-fed single-band dipole is essentially a selective circuit, in that it tends to discourage undesired harmonics from being accepted and radiated. For example, a 40-meter harmonic would have a tough time in an 80-meter coax-fed dipole because the antenna and line are badly mismatched on 40. A trap system, however, does not discriminate against such undesired signals. Also, traps introduce power loss — probably not a great deal, but nevertheless loss. But if you want to use coax line and have multiband operation, the trap dipole is an answer. On the other hand, a Novice may ask, "Is there a better multiband system, one without the trap losses and harmonic problems?" The answer is yes, but before describing it let's take a look at feed lines.

Feed Lines

Three common types of feed lines are used by amateurs: coaxial, twin-lead, and open-wire. Each has a certain amount of loss, with coax the lossiest, twin-lead next, and open-wire line the most efficient. An important point to keep in mind is that the greater the mismatch, or standing-wave ratio, on the transmission line, the greater the line loss. Also, the loss in any line increases with frequency: The loss will be least at 80 meters and will become progressively greater as we approach vhf or uhf. As an example, the loss in 100 feet (30.48 m) of RG-58/U line at 144 MHz is about 6 decibels. Translating this to power, if we had a transmitter that was putting out 100 watts only about 25 watts would reach the antenna, at the end of a 100-foot (30.48 m) line, to be radiated. The remaining 75 watts would be dissipated as heat in the line! And, most important, this figure is based on the coax being *matched* at the antenna end. The mismatch or SWR will depend entirely on the impedance of the transmission line and the impedance of the antenna. If there is a mismatch, the losses increase. On 80 meters, this same coax has a loss of less than 1 dB for 100 feet (30.48 m) of line, so we could tolerate more of a mismatch.

But don't overlook the fact that if the line and antenna are mismatched it may be impossible to make the amplifier load, even if the extra loss can be tolerated. The question that then comes to mind is if we use a low-loss line so we can tolerate a high degree of mismatch, how can we make the transmitter see a 50-ohm load? The answer to this is to use a Transmatch between the transmitter and antenna.

The Transmatch

A Transmatch is simply an adjustable rf transformer that converts an unknown load (antenna side) to a desired load (transmitter side). It consists of inductances and capacitances which can be adjusted to provide a perfect 50-ohm load for the transmitter on any band or frequency.

Let's take an example to show how a Transmatch can do the job. The impedance at the center of an 80-meter dipole is

Approximate Attenuation in Decibels/100 ft. (30.48 m)

Type	Z_0	3.5	7.0	14.0	21.0	28.0	50.	144	220	420
RG-58/U	52.5	0.68	1.0	1.5	1.9	2.2	3.1	5.7	7.2	10.4
100W. Output		8	18	28	35	38	51	72	81	92
RG-8/U	52.	0.30	0.45	0.66	0.83	0.98	1.35	2.5	3.3	4.8
RG-59/U	73	0.64	0.90	1.3	1.6	1.8	2.4	4.2	5.2	7.2
RG-11/U	75	0.38	0.55	0.80	0.98	1.15	1.55	2.8	3.8	4.9
Twin-lead	300	0.18	0.28	0.41	0.52	0.60	0.85	1.55	1.9	2.8
Open-wire	—	0.03	0.05	0.07	0.08	0.1	0.13	0.25		

This chart shows the attenuation figures in decibels for common types of feed lines. Z_0 is the nominal impedance. In the case of open-wire line, the impedance will depend on the size of the conductors and their spacing. The second line of the chart indicates the amount of power that would be lost in a 100-foot (30.48 m) run of RG-58/U when properly matched. For example, on 21 MHz, the loss per 100 feet (30.48 m) is 1.9 dB. With 100 watts output from the transmitter, 1.9 dB represents a loss of 35 watts in the line. A mismatch will increase the line loss.

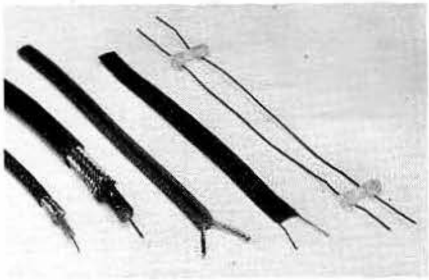

At the left are two examples of coaxial feed lines. The three lines at the right are balanced-type lines, 70-ohm, 300-ohm twin-lead, and TV open-wire line.

between 50 and 70 ohms on 80 meters. On 40 meters, the impedance at the same point on this same antenna is about 4000 ohms. If we feed this antenna with 300-ohm twin-lead the mismatch on 40 would be on the order of 13 or 14 to 1. However, bear in mind that 300-ohm line has relatively low loss, so we can probably tolerate the high SWR if the line is fairly short — less than 100 feet (30.48 m). Our only problem in making this antenna work on 40 is to take care of coupling the line to the transmitter. To do this the feed line is connected to the Transmatch and the Transmatch is then adjusted so that the transmitter sees a 50-ohm load. What we have now is an 80-meter dipole being used efficiently on 40, and our transmitter is working into the load it was designed for.

Now let's suppose that we feed this same antenna with 50-ohm coax. On 40, the mismatch would be 4000/50, or about 80 to 1! Because coax is not a low-loss line, the loss in the transmission line would be prohibitive. However, with twin-lead — or, even better, open-wire line — the loss is usually insignificant.

Also, and most important, a Transmatch adds selectivity at the output of the transmitter. It will discriminate against any undesired harmonics or spurious signals. And, if the antenna switching is set up so that the Transmatch is in the circuit on receiving, it will provide more selectivity for the receiver. In fact, a common problem for hams who live near broadcast stations is cross-modulation of 80- and 40-meter ham signals by the strong bc signal. A Transmatch will provide enough selectivity in most cases to eliminate bc cross modulation when it occurs in the receiver's front end.

Many hams are reluctant to use a Transmatch because it requires additional adjustments. However, the advantages are so great in a multiband system that any additional adjustments are more than worth the effort. With a Transmatch, the antenna doesn't have to be a half wave long to work on any band. For example, we described a complete multiband system just recently[1] using an antenna only 100 feet (30.48 m) long. Most hams can manage to get up a 60-foot (18.29-m) dipole, either horizontal or in an inverted-V configuration, and such an antenna also will work on 80 through 10. One method of putting up a multiband system is to find two supports for each end of the antenna, cut a wire long enough to run between them, put an insulator in the center of the antenna and at each end, and attach open-wire or twin-lead feeders long enough to reach the station. That's all there is to it. Bear in mind that a dipole fed this way doesn't have to be a half wave long; it can be any length, and it will work. Of course it is always a good idea to make it as long as possible and get it up as high as possible. Also, if possible, make it at least 1/4-wavelength long at its lowest operating frequency — about 60 feet (18.29 m) for 80 meters, for example.

A Few Notes

Many hams are reluctant to use open-wire line because of the problems in getting it into the shack from outdoors. One simple answer to this is to bring the line to the entrance — window sill, doorway, or whatever — and at that point attach 300-ohm twin-lead (which is insulated) and run the twin-lead in to the Transmatch. The fact that the two lines are not alike is of no concern because the load at the antenna side of the Transmatch is going to be some unknown value anyhow.

You may have read or heard that you must use coaxial lines in order to avoid TVI. Don't believe it. If you have a well-shielded transmitter and use a low-pass filter with it you won't have any harmonics coming out. Ask youself this simple question: "If there are harmonics, what difference can the kind of transmission line make?" The answer is, of course, "No difference."

One of the beauties in using a Transmatch is that the coaxial line between it and the rig can always be matched, and this matched section is where you put your low-pass filter. This eliminates any danger to the filter from excessive voltage or current caused by a mismatch.

One typical Novice question is "If my transmitter loads properly and I have no TVI problem, do I need more matching between the transmitter and antenna? I am using coax feed. What good would it do me to pay for the additional complexity of changing from band to band?" The answer to such a question depends on several factors. Is the harmonic attenuation — not TVI, but low-frequency harmonics — adequate? This could be a problem the Novice isn't aware of. As to the complexities of band changing, this will depend on how much the Novice desires to work other bands.

What we have tried to do in this article is to show the reader the problems and the recommended cure. There is nothing new about the multiband system using tuned feeders; it has been used for many years, and the interesting thing about it is that it is still the best multiband system. For further information it is recommended that the newcomer study *Understanding Amateur Radio* and *The ARRL Antenna Book* to gain a better insight as to how antennas work. This material was originally presented in *QST* by Lewis G. McCoy, W1ICP.

References

[1] McCoy, "A Complete Multiband Antenna System," *QST*, November 1967.

The Ultimate Transmatch

Most hams would like to own a Transmatch that could cover 80 through 10 meters, and work during coax-to-coax or balanced-lines conditions. Here is just such a unit. It will match the proverbial bedsprings, or any other nonresonant or resonant antenna — without plug-in coils or band switching — even on 160 meters.

Some amateurs assume that because they use coaxial feed lines they don't need a Transmatch. This can be an incorrect assumption.

The Harmonic Problem

A large number of hams have found to their sorrow that the harmonic suppression in their transmitters may leave much to be desired. The FCC issues many citations to Novices each year for second-harmonic violations.

A typical Novice station might consist of a transmitter and receiver, with direct coax feed to a trap dipole or vertical antenna. In a properly adjusted transmitter of typical design, often there is insufficient attenuation of the second-harmonic energy. This can mean that the second harmonic of the signal can reach the antenna and be radiated. What is required to eliminate or reduce the second harmonic, and higher-order harmonics, is more selectivity between the transmitter and the antenna. A Transmatch is an excellent aid in taking care of the harmonic problem.

The 50-Ohm-Load Problem

Still another reason for using a Transmatch is that nearly all manufacturers of transmitters design their rigs to work into a nonreactive, 50-ohm load. Any departure from this load impedance causes difficulty in tuning and loading the final-amplifier stage. It might be pertinent to point out that simply because a ham uses 50-ohm coax, it doesn't necessarily follow that he will have a 50-ohm load. Basically, in order to have a 50-ohm load when using 50-ohm coax, the coax must be terminated in a 50-ohm resistive impedance. In other words, the antenna impedance must be 50 ohms.

When the terminating impedance of the coaxial cable is other than 50 ohms, then the transmitter will be "looking" at some value other than 50 ohms. It is practically impossible to design a single antenna that will have an impedance of 50 ohms on all of the bands a ham might want to use. One answer to the problem is to employ a device that will "match" the unknown load to the 50-ohm impedance required by the transmitter. One such circuit or device is a Transmatch, simply an adjustable rf transformer that can match the unknown load presented by the transmitter end of the feed line to the required 50-ohm transmitter impedance.

The kW version of the Ultimate Transmatch. The knobs and dial counter are standard Millen components. The front bottom of the cabinet is tilted by means of two 2-inch (51 mm) standoff insulators used as feet.

Receiver Cross-Modulation

In addition to taking care of the problems just outlined, a Transmatch can serve another very useful function at the receiver. Some receivers are susceptible to what is known as cross-modulation, or front-end overloading, by strong nearby radio stations. This is particularly true on 160 or 80 meters when a broadcast station is nearby. The bc station overloads the front end of the communications receiver, causing "birdies" and other unwanted responses across the band. A Transmatch will eliminate or greatly reduce this problem in nearly all instances.

The Ultimate Transmatch

We shall describe two Transmatches — one for the Novice power limit, and another for the legal 2-kW PEP limit. We have found that many amateurs on the verge of taking their General, or higher-class licenses, would rather invest initially in a unit that will take care of all of their future needs.

Some years ago, a Transmatch was described that was designed for use with coaxial feed lines.[1] It was called "the 50-Ohm Transmatch." This unit handles mismatches on the order of 4:1. It can transform a load of about 200 ohms, or 12 ohms, to a 50-ohm impedance. The circuit of the Transmatch described in this article, Fig. 46, is similar, but with two notable exceptions. In place of a tapped, switched inductor, a variable inductor is used. (The idea for this innovation came from Al LaPlaca, K2DDK.) The variable inductor is a coil wound on an insulated form that can be rotated so that a movable wheel shorts out and grounds the unused portion of the coil. Using the roller inductor, along with the two variable capacitors, the Transmatch provides an almost unlimited matching range, plus the feature of 80- through 10-meter coverage without band switching. With the values shown in the units, it is even possible to add one fixed capacitor to obtain 160-meter coverage.

The other exception is the use of a 1:4 (unbalanced-to-balanced) balun transformer on the output side of the Transmatch, which permits the use of balanced feed lines. This means that a Transmatch can cover 160 through 10 meters (including the MARS frequencies). It can be used to match into coaxial lines, random-length end-fed wires, or balanced feeders, and can do the job without using switches.

The two units shown in the photographs underwent extensive tests as to efficiency, power-handling capabilities, and methods of adjustment. In coax-to-coax tests, power inputs and outputs through the Transmatch were carefully measured while using Bird Thruline wattmeters and an adjustable dummy load. As carefully as could be measured, and with indicated mismatches of up to 15:1, the Transmatches showed an efficiency of over 95 percent. This small loss in efficiency more than outweighs the usefulness of the device.

Many tests were made with the high-power version to check heating of the roller inductor and the balun. Under a key-down condition, with 1200 watts indicated power through the Transmatch, the transmitter was kept on for 15-minute periods. In one test, the measured rf current through the coil was in excess of 15 amperes. The roller inductor used in the unit is rated at 5 amperes, so this was considered a fairly rugged test. The coil did get warm, but not enough to be a cause for concern. Keep in mind that in regular amateur work, 15

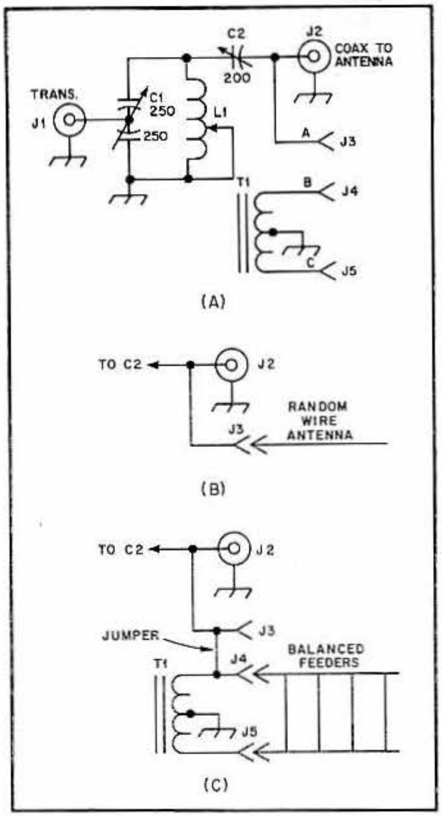

Fig. 46 — Circuit diagram of the Ultimate Transmatch.
C1 — Split-stator variable, 250 pF per section; see text. For low-power version, E. F. Johnson type 16250; or similar, for high-power version, Millen type 16250, or similar.
C2 — 200-pF variable, for low power, E. F. Johnson type 167-12 or similar, for high power, Millen type 16520 0.171-inch (0.43 cm) spacing, 16520A, 0.077-inch (2 mm) spacing, or similar.
J1, J2 — Coax chassis fitting, type SO-239.
J3, J4, J5 — Feed through insulators.
L1 — Roller inductor, see text. If 160-meter operation is desired, total inductance should be 28 μH, E. F. Johnson type 229-203; otherwise, 18 μH is adequate, E. F. Johnson type 229-202.
T1 — 1-to-4 balun; see text for details, cores are Amidon type T-200-2.

minutes would be a ridiculous figure for continuous operation.[2] In cw and ssb operation, the duty cycle would be in terms of seconds or even fractions of seconds.

The balun used for balanced operation in the high-power unit was made up from three Amidon 1-kW cores — more about that in a moment. N1RM has made extensive checks on a single-core balun. It was found that a single core would easily handle 500 watts of power during severe mismatch conditions. Failure of the core, most likely due to saturation and heating, took place at the 700-watt level. In the high-power Transmatch shown here, three cores are used. They are wrapped with glass insulating tape and then wound with Teflon covered wire. Wire insulation material can be important because of the extremely high rf voltages that may be developed with some load conditions. In many tests of long duration, using up to 1400 watts output into a dummy load, it was almost impossible to detect any heating of the balun.

Bear in mind that the balun would only be needed if balanced-line operation were desired. For coax-to-coax or random-wire feed, the balun can be omitted.

Construction Information

A look at Fig. 46, at A, will show that the circuit is a very simple one. The input line from the transmitter is connected to the rotor of C1, a split-stator capacitor. This means that the capacitor must be insulated from the chassis, using standoff pillars, and from the panel by means of an insulated shaft coupler. The same is true for C2. In the kW unit shown, we have installed a power bridge. Construction details are not given here for the bridge because such a unit was described in detail in *QST*[3]. Also, many amateurs already have a Monimatch[4] or some other type of SWR indicator. An SWR bridge or matching indicator is needed in the 50-ohm line between the rig and the Transmatch to show when the Transmatch is correctly adjusted.

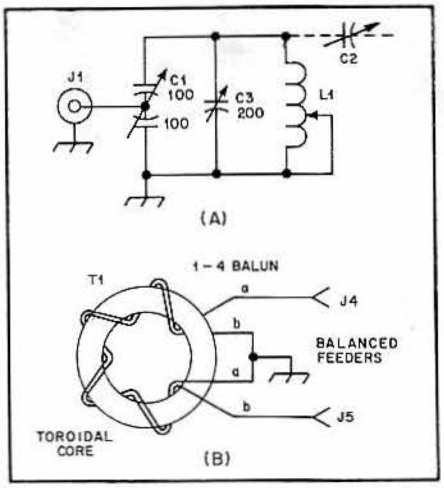

Fig. 47 — At A, details for padding a low-value variable for C1 by installing a second variable, C3, the same value as the low-power unit C2. In the case of tuning 160 meters, using an inductor of 28 μH for L1, and 250 pF per section for C1, a fixed capacitor of 100 pF can be used at C3, Centralab type 850-100N, or similar. At B, details for connecting the bifilar windings on the balun are given. The ungrounded leads a and b are connected to J3 and J4, the feedthrough insulator terminals.

Layout of the components should follow the same arrangement shown in the photographs — C1 at the input side, the roller inductor at the center, and then C2. If a balun is going to be installed, allow enough room behind the roller coil for mounting the balun. In the two units shown, the cabinets are made up from aluminum sheet stock. If desired, a commercial chassis and cabinet can be used. In the low-power Transmatch, leave at least 1/2-inch (13 mm) spacing between the edges of the capacitors and any part of the chassis and cabinet. Allow 1-inch (25 mm) spacing in the kW unit.

Balun Details

For the low-power Transmatch, a single toroid core will more than handle the power. Incidentally, the low-power unit was tested under all conditions at about 100 watts through the Transmatch. The

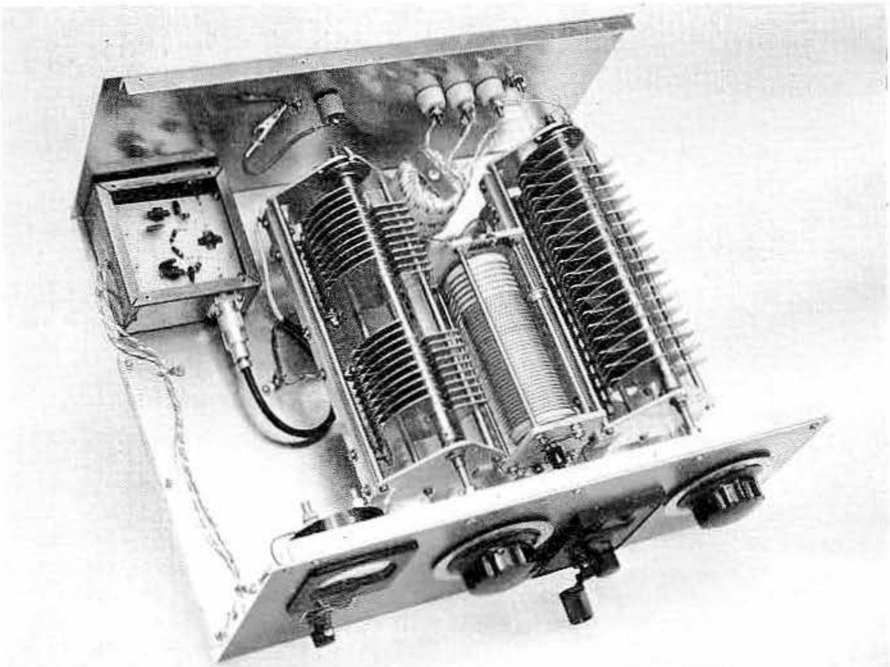

At the rear of the roller inductor is the 1:4 balun. The balun is set on top of a standoff insulator and is held in place with a piece of insulated board and a screw. The fixed capacitor mounted on the rear wall is the 160-meter unit. Both the variable capacitors and inductor are mounted on 1-inch (25 mm) high standoff insulators.

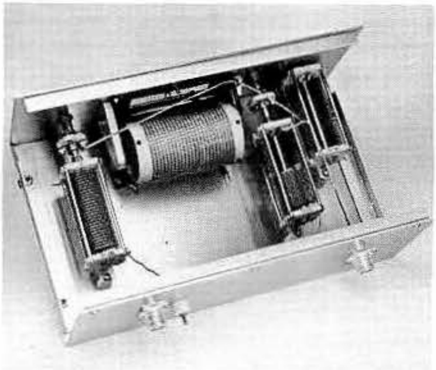

This is the low-power Transmatch. The salvaged roller inductor is mounted on the front panel, making use of the original mounting brackets.

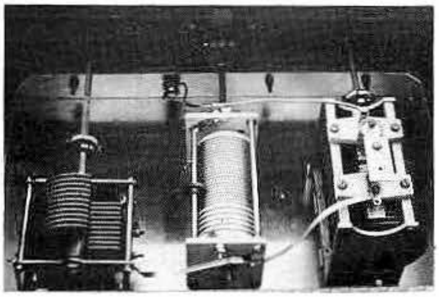

Here is an inside view of the Ultimate Transmatch as built by Al LaPlaca, K2DDK, who came up the idea of using the roller inductor. The installation on top the right-hand capacitor is the homemade 160-meter switch and fixed loading capacitor.

power-handling capabilities of the units depend primarily on the plate spacing used for C1 and C2, aside from the balun requirements mentioned earlier. At the 100-watt level, a plate spacing of 0.03 inch (0.8 mm) is adequate. A 0.045-inch (1 mm) spacing should handle 500 watts. In the kW unit shown, C1 has a 0.077-inch (2 mm) spacing. While a 0.077-inch spacing capacitor wasn't tried at C2, such plate spacing should work at the kW level.

In making the low-power balun, wind two layers of Scotch brand electrical tape around the core before putting on the wire. This will provide extra insulation, and will protect the edges of the wire to prevent the enamel from being scraped away. Fig. 47, at B, shows a sketch of the winding. The winding consists of 10 bifilar turns of no. 14 Formvar insulated wire. Connected as shown, this will provide a 1:4, unbalanced-to-balanced configuration.

Three cores are needed in the high-power balun. Each core is covered with two layers of 3-M type 27 glass-cloth insulating tape. Next, the three cores are stacked, then covered with two more layers of the tape. The winding consists of 15 bifilar turns of either no. 12 or 14 insulated wire. The insulation should have a minimum rating of 1000 volts and can be either Teflon or vinyl-nylon (or any other suitable covering with a minimum voltage rating of 1000 volts).

In making the low-power Transmatch, a roller coil from a junked 40-meter ARC-5 transmitter was salvaged and installed in the unit. Many amateurs know other hams who have old ARC-5 gear, and these units are a good source for the roller coils. However, some hams may not be able to locate used ARC-5 transmitters, so we have included some information on sources of surplus and new roller inductors. There may be surplus outlets in your area worth investigating. Look for a roller coil that has a minimum inductance of 10 μH when used with C1 having a value of 200 pF per section. Such a combination will cover a low frequency of 3500 kHz. In the unit shown, in addition to the ARC-5 roller, we used a value of 100 pF per section for C1 and padded that capacitor with another of 200 pF (single section) in order to provide the required coverage. This added capacitor is shown in Fig. 47 at A. By using this approach, it is sometimes easier to save money then when trying to locate a 200-pF-per-section variable for C1. (Incidentally, you can use a variable at C1 of more than 200 pF per section for good coverage with the roller inductance specified above.)

An even better approach to get the required capacitance for C1, because it is better to maintain the symmetry of the circuit as shown in Fig. 46 at A, would be to gang two 200-pF variables to make up your own split-stator capacitor, with the desired plate spacing. (There may be some around, but we couldn't find any manufactured split-stator with the required plate spacing and capacitance). Still another approach would be to clip fixed transmitting-type mica capacitors across each section of C1 to obtain the required capacitance for use on 160 and 80.

Finding the Parts

As most hams are finding out, it is becoming more and more difficult to buy, or find, components for construction projects. Some searching was done, and the following information is worth passing on. Barry Electronics of New York City has informed us that they will fill any order for any amateur component at the manufacturer's current amateur net price. The parts specified in Fig. 46 are currently manufactured items. Also, Fair Radio Sales in Lima, OH has some surplus roller inductors and counter dials in stock. The roller-inductor catalog number is 5950-199-6469, and the counter dial is listed as RT-45. Also, Millen components can be purchased directly from G. R. Whitehouse, Amherst, NH 03031.

Using the Transmatch

One of the first considerations in using a setup for "coax-to-coax" is exactly how much, or how high an SWR can be tolerated. As has been pointed out, this Transmatch will handle *any* mismatch on the line. Without getting into a lot of details, a few observations about coaxial lines are in order. First, the higher the SWR, the greater the losses in coaxial lines. The amount of losses depends on the line construction and the *frequency* at which the line is used — the lower the frequency, the less will be the losses. For example, RG-8/U has a loss per 100 feet (30.48 m) of line of only 0.33 -dB at 3.5 MHz with an SWR of 1 (a matched condition). At 28 MHz, this same line would have a loss of slightly less than 1 dB. However, as the SWR rises, so do the losses. With an SWR of 10:1, for example, the additional losses at 3.5 MHz would amount to about 0.6 dB, or an overall loss of about 1 dB. For the same SWR at 28 MHz, the losses would be about 2.5 dB, or a total loss of about 3.5 dB. Since a loss of 3 dB would mean half of the ouput power from the rig would be dissipated in 100 feet (30.48 m) of line, one could easily tolerate the condition at 80 meters, but the losses would be prohibitive at 28 MHz. This means that the amateur would be wise to keep the match at the antenna feed point as close to 50 ohms as possible, and thereby keep the SWR low.

With trap or multiple dipoles, the SWR should be less than 5 to 1; the Transmatch would be ideal. Keep in mind that you must provide a load for a transceiver or amplifier that is close to 50 ohms. The Transmatch will provide a means.

In a coax-to-coax system, set both C1 and C2 at maximum capacitance (plates fully meshed), then feed enough power through the Transmatch to get a full-scale forward reading on your SWR indicator. It is always important to use low power when adjusting a Transmatch. Next, switch the SWR bridge to read reflected power, then run the roller inductor slowly through its range. At some point you will notice a sharp dip in the reflected-power reading. Once this point is reached you should adjust C1 and C2, with possibly a slight adjustment of the roller coil, to get a perfect match. Power can then be increased to the desired level. You'll find that several different settings of the Transmatch may provide a perfect match. The one to shoot for is the condition that requires the most capacitance at C1 and C2 for a matched condition.

If a random-length, end-fed antenna is used, merely connect the end of the antenna to terminal J3, Fig. 46B, and go through the adjustment procedures outlined above. It is helpful to have an earth ground connection on the Transmatch. Also, if possible, use an antenna length that comes out to a quarter wavelength, or odd multiple thereof. Such an antenna will be of low impedance, and will reduce the chances of high rf voltages appearing on the Transmatch or associated equipment.

If balanced feeders are used, the feeders should be connected to terminals J4 and J5 with a short jumper connected between terminals J3 and J4. Again, the previously discussed tune-up and adjustment procedures should be followed in setting up the Transmatch.

Some Other Thoughts

Some amateurs might be concerned about the amount of voltage that can be developed in a mismatched coaxial line. In a matched condition, with 1000 watts in a 50-ohm line, the rf voltage would be about 220 volts. With a standing-wave ratio or 20:1 (!), the increase in voltage would be 4-1/2 times, or approximately 990 volts. This however, is well within the rating of the RG-8/U cable.

This Transmatch should satisfy the needs of those hams who desire a multiband unit without switches or plug-in coils. Once the settings for the controls are determined, a chart can be made up for any given istallation. Band changing is then quickly done. This material was originally presented in *QST* by Lewis G. McCoy, W1ICP.

References

[1] "The 50-Ohmer Transmatch," *QST*, July 1961.

[2] [Editor's Note: However, teletype operation would be continuous (to say nothing of those long-winded a-m operators!).]

[3] "In-Line RF Power Metering," *QST*, December 1969. (See chapter 4.)

[4] *Understanding Amateur Radio*, p. 209.

Build a Baby Ultimate

Got a match? Not a classic "match," but one between the antenna and your QRP rig may be what you need. If so, this article is for you.

Nobody needs or wants a 50-pound Transmatch during a QRP junket to a favorite lake, campsite or other distant location. The entire point of QRP operation is negated when the low-power station can be held on the palm of one's hand, but the accessory gear needs to be transported by hand truck to the car, airport or whatever! Operators who prefer to use a random-length wire antenna for field work will require a matching network between the 50-ohm transmitter output and the end of the antenna, whose characteristic impedance can be anything from a few ohms to a couple of thousand. For low-power work (25 watts or less) it doesn't take a big Transmatch to do the job, and some novel ideas can be applied to make the matcher cover 80 through 10 meters without a roller inductor or messy tapped-coil switching arrangement. This article shows some tricks that can be applied to meet that goal.

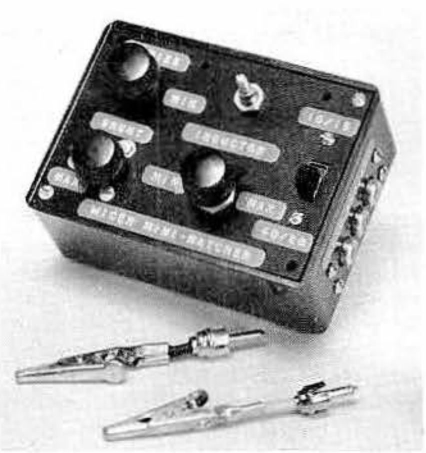

Exterior view of the Baby Ultimate. Dymo tape labels are used to identify the controls.

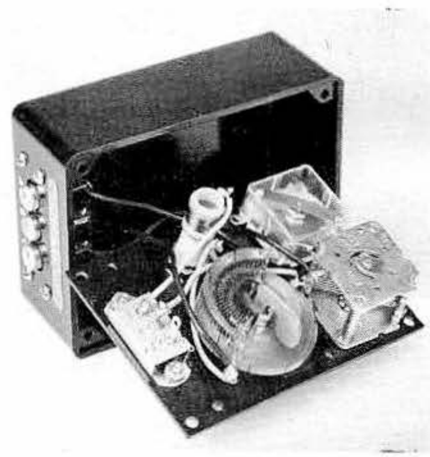

Interior view of the matcher showing the K1KLO variable inductor (lower center).

The heart of the Baby Transmatch is the half-toroid variable inductor. It is the by-product of a few "skull sessions" between Andy Pfieffer, K1KLO, and the writer. Both amateurs are QRP "freaks," and finding the proper mechanical technique for building a miniature panel-operated variable inductor of reasonable inductance range was challenging and productive. The machine-shop skill and impagination of K1KLO can be realized when viewing the accompanying close-up photograph. Early efforts along this line provided a slider type of full-toroid variable inductor (rheostat style), and dismal results were had: the inductor Q was very low, approximately 5, as a result of the shorted-turn syndrome. Finally, a powdered-iron Toroid core of Q1 material, 1-inch (25 mm) diameter, with 3/16 by 3/16-inch (5mm by 5mm) walls, was sawed in half and cemented to a plastic arm. The arm was glued to the shaft of the control so that it would enable the operator to change the coil inductance by moving the semicircular toroid section in and out of the coil.

The coil in this unit was air wound, then cemented to a semicircular piece of plastic which is affixed to a plastic disk of 1-1/2-inch (38 mm) diameter. The overall coil-and-plastic assembly is glued to the 3/8-inch (10 mm) bushing and 1/4-inch (6 mm) diameter control shaft. Although all of the metal work was done from scratch on a lathe, an old volume control or rheostat bushing and shaft can be modified to perform the function required. All that's needed here is some amateur ingenuity! The tuning range of the variable inductor is 3 to 9 μH, and the unloaded Q was measured as 150 at 7.9 MHz.

It is reasonable to conclude that the K1KLO "giz," as he calls it, could be made to cover a greater inductance range by making the coil bigger in ID and cementing both halves of the toroid core together — one atop the other — to provide greater permeability overall. Ferrite material is unsuitable for this component because of the hardness of ferrite. Without special cutting tools the latter will resist all efforts to saw through it. One-half of an Amidon 1-kW balun-kit, powdered-iron toroid should be excellent for larger units of this kind.

Other Circuit Features

As is shown in Fig. 48A, S1 is used to switch an additional variable inductor (L1) in parallel with the K1KLO unit, L2. This provides a lower minimum-inductance amount for operaion on 15 and 10 meters.

Fig. 48B illustrates some variations which will extend the Transmatch range down to 80 meters. The model shown photographically was designed for 40 through 10 meters. In the second example, S2 and L3 have been added to increase the total inductance to permit 80-meter matching. Also, C1 has been changed to a

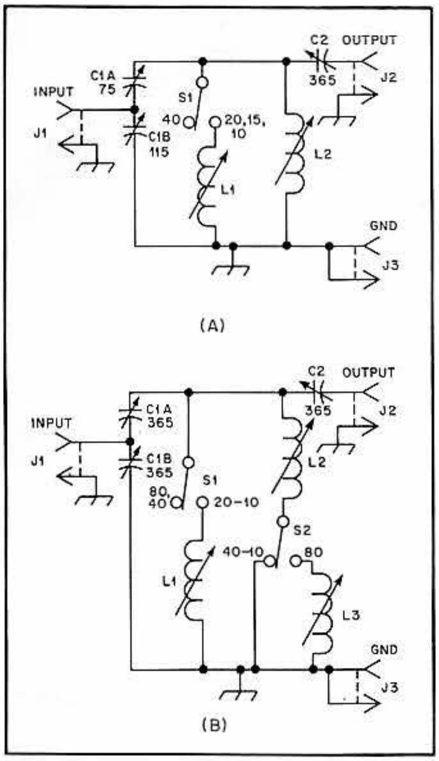

Fig. 48 — The diagram at A is for the 40- through 10-meter Transmatch. At B, a suggested circuit for coverage from 80 through 10 meters.

C1 — Dual-section air variable (Miller 2109, J. W. Miller Co., 19070 Reyes Ave., Compton, CA 90224). See text.
C2 — Calectro or Archer single-section miniature 365-pF variable.
J1-J3, incl. — Phono jack.
L1 — 3.1-to 4.8-μH slug-tuned inductor (Miller 4504 with red core).
L2 — See text. Contains 32 turns of no. 22 enam. wire, air wound, 7/16-inch (11 mm) OD.
L3 — 5.5-to 8.6-μH slug-tuned inductor (Miller 4505 with red core.)
S1, S2 — Spdt slide or toggle switch.

two-section 365-pF, bc-style variable, also for the same reason. A dual 365-pF capacitor can be used for the circuit at A, but the tuning rate will be much sharper than with the unit specified.

Three phono jacks are used for external connections. The first photograph shows a pair of clip leads which have been soldered to two phono plugs. These are used for making connections to a single-wire antenna and ground.

The slug screw of L1 protrudes from the top panel of the small plastic meter case. This feature enables the operator to have additional control of the overall inductance amount during operation on 15 or 10 meters. All internal ground connections are brought to a common point — J3, which has both of its terminals joined.

The "Ultimate" design is based on one which was popularized by W1ICP when he described in *QST* a 1-kW version of the circuit.[1] The network will match a wide range of impedances, but it should be pointed out that this circuit is not capable of providing much (if any) harmonic attenuation. Examination of the circuit will show that the network is basically a high-pass type.

Building the Transmatch

A 1-1/2 × 2-3/4 × 4-inch (38 mm × 70 mm × 102 mm) plastic meter style of case is used to house the Transmatch. The box used by the writer was made by RCA as an enclosure for a 9-volt regulated power-supply kit. Similar boxes are available at Radio Shack and other parts stores, but most have a metal cover. If the latter are used, it will be necessary for the builder to isolate the rotors of C1 and C2 from the metal plate. Adhesive-backed plastic feet are affixed to the bottom of the case. They will keep it from moving about on the operating table.

Using the Transmatch

When matching the 50-ohm transmitter to a given antenna (fed with coaxial line or single wire in nature), an SWR indicator will be necessary between the transmitter and the Transmatch.[2] C1, C2 and L2 are adjusted one at a time for the lowest reflected-power reading on the meter. There will be interaction between the controls, so it will be necessary to go over them several times to effect an SWR of 1.

Some difficulty may be encountered while working with a voltage-fed (high impedance) wire antenna. The symptom is one of hand capacitance affecting the SWR reading. In such instances the tune-and-try method will be required, moving the hands away from the box after each adjustment. For this reason the builder may wish to house the circuit in a metal box and use insulating shaft couplings on C1, C2 and L2. Of course, this will make the unit somewhat larger.

The writer used this Transmatch for two weeks in October 1975 while on a QRP sortie to Barbados (8P6EU). Maximum power used was 20 watts output, and minimum power was 2 watts ouput. The 40-, 20- and 15-meter bands were used, and all manner of antennas (end fed and coaxially fed) were employed. In all cases the SWR could be set for a 1:1 condition. Insertion loss through the Transmatch was measured at 14 MHz while delivering 20 watts to a test dummy load. The loss was approximately 0.1 dB at a matched condition. No heating of the components was noted.

One final word is in order. Always use the maximum possible amount of capacitance at C2 when adjusting the Transmatch for an SWR of 1. There can be several settings of C1, C2 and L2 which will provide a match. Best efficiency will always occur with maximum usable C at C2, and this is true of all variations of the Ultimate Transmatch.

If you're a QRP enthusiast, this matcher should be part of your setup when 50-ohm antennas aren't used. It is lightweight, small of size, and can be tucked away in the XYL's handbag when enroute, if need be! This material was originally presented in *QST* by Doug DeMaw, W1FB.

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[1] McCoy, "The Ultimate Transmatch," *QST*, July 1970. (Included in this chapter.)

[2] DeMaw, "A QRP Man's RF Power Meter," *QST*, June 1973, p. 13.

Simple Broadband Matching Networks

This article gives complete details on constructing broadband matching transformers for ratios of 4:1, 6:1, 9:1 and 16:1.

Are you looking for a physically small DX antenna? To obtain low-angle radiation on 80 and 160 meters, many amateurs use vertical antennas. Horizontal antennas would have to be at elevations of a half-wavelength or greater to be comparable. Suitable supporting structures are beyond the reach of most amateurs at these lower-frequency bands. Quarter-wavelength verticals require some 60 feet (18.29 m) on 80 meters and 120 feet (36.58 m) on 160 meters — still very tall structures! However, short verticals over a good image plane have been shown theoretically[1] and experimentally[2] to perform practically as well as their full-size quarter-wavelength counterparts. The only problems are very low input impedances and narrower bandwidths.

This paper describes broadband matching networks which can efficiently match 50-ohm coaxial cable to verticals as short as 1/25 wavelength. Also included is information on short vertical antenna designs incorporating large top hats in order to improve bandwidth, such as a very short 40-meter vertical and a dual-band 80- and 160-meter short vertical with remote switching. In addition, loading coils using powdered-iron toroidal cores are discussed.

Broadband Matching Transformers

Broadband transformers have been widely used because of their inherent bandwidth ratios (as high as 20,000:1) from a few tens of kilohertz to over a thousand megahertz. This is possible because of the transmission-line nature of the windings. The interwinding capacitance is a component of the characteristic impedance and therefore, unlike the conventional transformer, forms no resonances which seriously limit the bandwidth.[3] At low frequencies, where interwinding capacitances can be neglected, these transformers are similar in operation to the conventional transformer. The main difference (and a very important one from a power standpoint) is that the windings tend to cancel out the induced flux in the core. Thus, high-permeability ferrite cores, which are not only highly nonlinear but also suffer serious damage even at flux levels as low as 200 to 500 gauss, can be used. This greatly extends the low-frequency range of performance. Since higher permeability also permits fewer turns at the lower frequencies, high-frequency performance is also improved since the upper cutoff is determined mainly from transmission-line considerations. At the high-frequency cutoff, the effect of the core is negligible.

Connie, W2FMI's better half, is making use of the shade under Jerry's 40-meter umbrella antenna. It is hoped that Jerry warns her about touching the antenna when he is running high power!

The applications of broadband transformers to antennas and broadband circuits have been covered by a number of authors.[4,5] This paper extends the application of these transformers to include the operation of short ground-mounted vertical antennas with impedances as low as 3 to 4 ohms. Further design considerations illustrate variable matches to vertical antennas having impedances even greater than 35 ohms.

Bifilar matching transformers for ground-mounted verticals lend themselves to unbalanced operation. That is, both input and output terminals can have a common ground connection. This eliminates the third magnetizing winding required in balanced-to-unbalanced (balun) operation. By adding third and fourth windings, as well as tapping windings at appropriate points, various combinations of broadband matching can be obtained. Fig. 49 shows a 4:1 unbalanced-to-balanced configuration. This transformer can be used with verticals of 12.5 or 200 ohms when using 50-ohm cable. No. 14 wire can be used and it will easily handle 1000 watts of power. By tapping at points 1/4, 1/2 and 3/4 of the way along the top winding, ratios of approximately 1.5:1, 2:1, and 3:1 can also be obtained. It should be noted that one of the wires was covered with vinyl electrical tape in order to prevent voltage breakdown between the windings. This was necessary when a step-up ratio was used at high power to match antennas with impedances greater than 50 ohms.

Fig. 50 shows a transformer with four windings, permitting wide-band matching ratios as high as 16:1. A picture shows a four-winding transformer with taps at 4:1, 6:1, 9:1 and 16:1. In tracing the current flow in the windings when using the 16:1 tap, one sees that the top three windings carry the same current. The bottom winding, in order to maintain the proper potentials, sustains a current three times greater. The bottom current cancels out the core flux due to the other three windings. If this transformer is used to match into low impedances, like 3 to 4 ohms, the current in the bottom winding can be as high as 15 amperes if the high side of the transformer is fed with 50-ohm cable handling a kilowatt of power. If one needs a 16:1 match like this at high power, then cascading two 4:1 transformers is recommended. In this case, the transformer at the lowest impedance side only requires each winding to handle 7.5 A. Thus even no. 14 wire would suffice in this application.

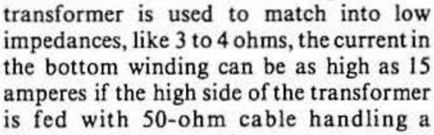
A 4-winding, wideband transformer (with front cover removed) with connections made for matching ratios of 4:1, 6:1, 9:1, and 16:1. The 6:1 ratio is the top coaxial connector and, from left to right, 16:1, 9:1, and 4:1 are the others. There are 10 (quadrifilar) turns of no. 14 enameled wire on a Q1, 2.5 inch (64 mm) ferrite core.

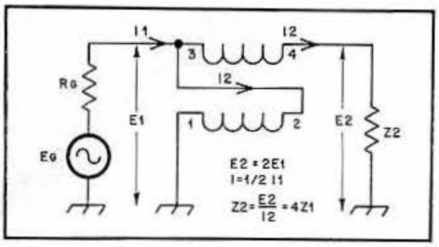

Fig. 49 — Four-to-one broadband bifilar transformer. Upper winding can be tapped at appropriate points to obtain other ratios such as 1.5:1, 2:1 and 3:1.

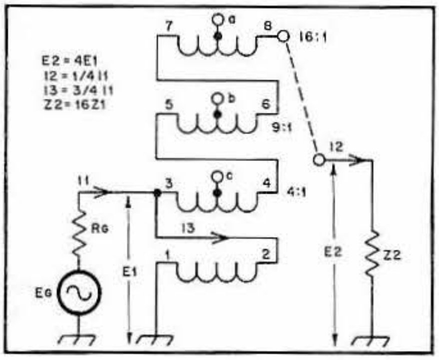

Fig. 50 — Four-winding, broadband, variable impedance transformer. Connections a, b and c can be placed at appropriate points to yield various ratios from 1.5:1 to 16:1.

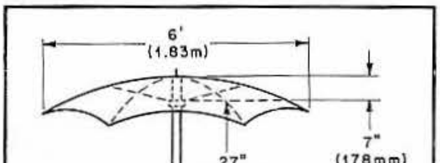

Fig. 51 — Final design and bandwidth characteristic of a short 40-meter vertical having an input impedance of 3.5 ohms and utilizing a commercial beach umbrella. This antenna established its worth as a prototype for the lower frequencies.

The popular cores used in these applications are 2.5 inch (64 mm) OD ferrites[6] of Q1 and Q2 material and powdered iron cores,[7] of 2-inch (51 mm) OD. The permeabilities of these cores, μ, are nominally 125, 40 and 10, respectively. Powdered iron cores of permeabilities 8 and 25 are also available.

In all cases these cores can be made to operate over the 10- to 160-meter bands with full power capability and very low loss. The main difference in their design is that lower permeability cores require more turns at the lower frequencies. For example, Q1 material required 10 turns to cover the 160-meter band, Q2 required 12 turns, and powdered iron ($\mu = 10$) required 14 turns. Since the more common powdered-iron core is generally smaller in diameter and requires more turns because of lower permeability, higher ratios are sometimes difficult to obtain because of physical limitations. Although most of the author's experimentation on these transformers was done on the 40-, 80- and 160-meter bands, the results indicated that they should operate on the higher bands equally well. When working with low impedance levels, unwanted parasitic inductances come into play, particularly on 14 MHz and above. In this case lead lengths should be kept to a minimum.

All the results obtained by the author have shown that the transformers can be used to match a variety of loads and impedance ratios, they can be used over many bands, and that they exhibit negligible loss in operation. More importantly, the core materials are readily available and low in cost.

A Short Vertical Antenna Design

These transformers permit efficient matching to impedances as low as 3 to 4 ohms. This means, with some top-hat loading, antennas could be 4 to 5 feet (1.22 to 1.52 m) tall on 40, 8 to 10 feet (2.44 to 3.05 m) on 80, and 16 to 20 feet (4.88 to 6.10 m) on 160 meters. With the capability of tapping off any portion of the transformer windings, thus providing variable matching, the heights of these antennas can be increased at will depending upon the bandwidth desired.

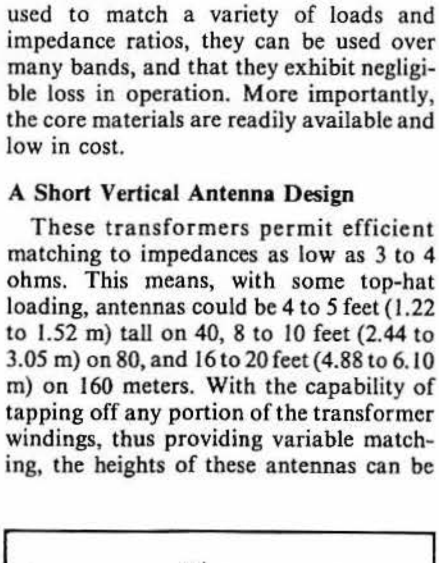

Fig. 52 — The 80- and 160-meter dual-band vertical system. The remotely switched matching network is described in the text. Not shown are three sets of polypropylene guy ropes at heights of about 9, 18 and 26 feet (2.74, 5.49 and 7.92 m).

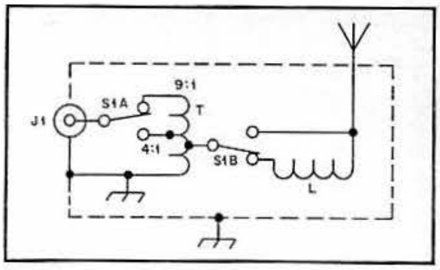

Fig. 53 — The remotely switched matching network for the 80- and 160-meter dual-band vertical antenna. The indicated switch positions are for 160-meter operation.
S1 — Dpdt antenna relay.
J1 — Coaxial connector, chassis type.
L — Load coil for 160 meters, 22-1/2 turns, no. 14 wire on 4 cores of 2-inch (51 mm) OD powdered-iron, permeability of 10 (Amidon T-200-2).
T — Broadband transformer (see text).

The first short vertical designed by the author was brought about by a trip to a local shopping center. The author saw a beach unbrella that had about the right proportions one would use in designing a short 40-meter vertical. The "antenna" was purchased (at a nominal price) and a 14-turn coil, connected across an insulated section about three feet (0.91 m) from the ground, was used to tune the vertical to resonance. The measured input impedance was 3.5 ohms and was matched easily to 50-Ω line with a 16:1 transformer. Fig. 51 shows the final design and the bandwidth characteristic. Several months of operation on 40 meters verified the outstanding capability of this short vertical antenna (with an extensive radial system) and established its worth as a prototype for the lower frequencies. A further study showed that the 6-foot (1.83 m) diameter top-section was about the equivalent of a 4-1/2-foot (1.37 m) diameter solid disk.

A Dual-Band 160- and 80-Meter System

The antenna shown in Fig. 52 is a dual-band design using a remotely switched matching network (see photograph) which not only changed a tap on a broadband transformer from 4:1 to 9:1, but also introduced a powdered-iron base-loading coil for 160-meter operation.

The circuit diagram for the remote matching network is shown in Fig. 53. The loading coil was made with four powdered-iron ($\mu = 10$, 2-inch [51 mm] OD) cores. They were first wrapped individually with several layers of vinyl electrical tape before being combined and wrapped again. The necessary inductance was obtained with 22-1/2 turns. A slight adjustment of the loading coil and the height of the antenna was found necessary in order to put the minimum SWR at 1812 kHz. In general, a 1-foot (0.31 m) change in height of the antenna changes the 80-meter resonance by 60 kHz and the 160-meter resonance by 15 kHz. A change of 1/2 turn on the

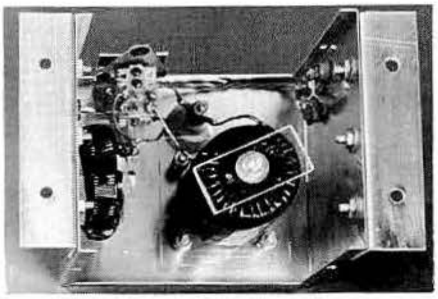

Bottom view of the matching network for the dual-band 80- and 160-meter vertical. The loading coil is on the right and the trifilar 4:1 and 9:1 matching transformer on the left. The dpdt 24-volt antenna relay switches in or out the loading coil and changes the taps on the transformer to the appropriate ratio. The enclosure is the conventional 4 X 5 X 6-inch (102 mm X 127 mm X 152 mm) aluminum Minibox.

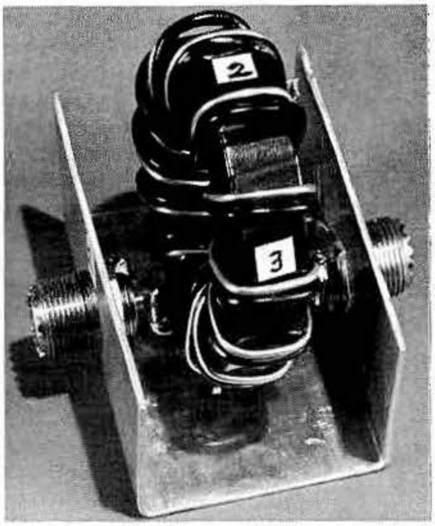

The broadband bifilar transformer shown has 12 bifilar turns, no. 14 wire, on a ferrite (Q1 material, 2.5 inch [64 mm] OD) core. Taps are also placed at 3, 6, and 9 turns, thus yielding ratios of 1.5:1, 2:1, 3:1 and 4:1. This transformer has a connection at the 1.5:1 ratio tap. Extra insulation was provided for the enameled wire in order to prevent voltage breakdown when matching into loads greater than 50 ohms.

powdered-iron core coil changes the 160-meter resonance by about 50 kHz. It should be noted that the windings had extra insulation (about one layer of vinyl tape) added on the inside part of the windings in order to prevent breakdown between them.

Low-permeability ferrite material Q2 (μ = 40, but still four times larger than the powdered iron material) was also investigated for use as a core for a 160-meter loading inductance. It was hoped that with several stacked cores of this material, the flux density would be reduced to a level where nonlinearities and permanent damage could be avoided. Two cores and about 10 turns of wire were used. The result was negative. Large changes in inductance were noted on voice peaks by the sudden large changes in the SWR. Also, small but permanent changes in the SWR were observed, indicating permanent damage. In contrast to ferrite, powdered iron maintains its linearity at high flux densities and suffers no permanent damage. As noted above, four cores of permeability 10, and 22-1/2 turns, provided the proper inductance (approx. 30 μH). The loss in this coil was about equal to the air-wound coil (33 turns, 6 tpi, no. 12 wire, 2-1/2-inch [64 mm] OD). Two stacked powdered-iron cores of permeability 25 were also investigated. This arrangement required about 17 turns, but was rejected because the loss, which was mainly in the two cores, went up to 3 ohms. This is certainly intolerable since it is of the order of magnitude of the radiation resistance of the very short vertical.

Concluding Remarks

The predominant characteristic of the short antenna is probably its very low value of radiation resistance. One must be careful of excessive ground and ohmic losses in coils and matching networks. A good image plane can eliminate the ground-loss factor. The application of a top hat eases the problem somewhat because it increases the effective length and thus the radiation resistance. The radiation resistance can be increased five-fold[8] by resorting to complete top-hat loading of a vertical. Combinations of top-hat and inductive loading can be used depending upon the radiator height and the bandwidth desired. One can also resort to a short folded unipole. With these combinations at his disposal, the designer is left with the problem of efficiently matching his transmission line to various impedance levels. The wide-band transmission-line transformer can provide the answer. It is capable of operating very efficiently over a wide range of impedances and impedance ratios.

The author would like to acknowledge the generosity of the following companies who supplied cores and information for the experiments: Indiana General Corp., Amidon Associates, and the Arnold Engineering Co.

Finally, the author would like to thank his colleague Mort Fagen, WA2EIT, for his encouragement and discussions of the antenna papers the author has written. This material was originally presented in *QST* by Jerry Sevick, W2FMI.

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[4] Turrin, "Application of Broadband Balun Transformers," *QST,* April 1969.

[5] Krauss and Allen, "Designing Toroidal Transformers to Optimize Wideband Performance," *Electronics,* August 16, 1973.

[6] Indiana General Corp., Electronics Div., Keasby, NJ 08832.

[7] Amidon Associates, 12033 Otsego Street, North Hollywood, CA 91607; The Arnold Engineering Co., Marengo, IL.

[8] See reference 2.

An RF-Sensed Antenna Changeover Relay

Flick of the switch, sir? Not with this system — it's automatic!

One subject that can be confusing for the newcomer to Amateur Radio is that of antenna-changeover systems. Several systems have been devised over the years and most can be classified into three or four main categories. Before delving into a discussion on these systems, a brief look at the simplest method of all might be in order, that is, no antenna changeover at all. With this setup two separate antennas are used, one for the transmitter and one for the receiver. This system is impractical for the most part since duplicate antennas would be required for each band of operation. There are instances, however, when separate antennas with different directive patterns can be used to an advantage, as in the case of specialized receiving antennas. Generally speaking, most stations use the same antenna for transmit and receiver purposes, so this is more the exception than the rule.

Several antenna-changeover systems, designed to transfer a single antenna from the receiver to the transmitter, are shown in Fig. 54. At A, a manual switch is used to transfer the antenna connection. This scheme is simple and works well, but is not without several drawbacks. Good-quality, high-power rf switches are often costly and

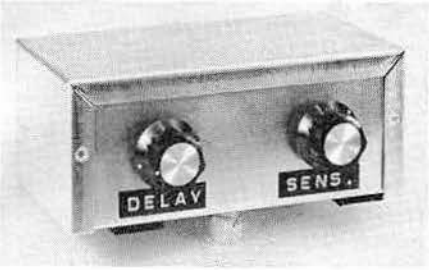

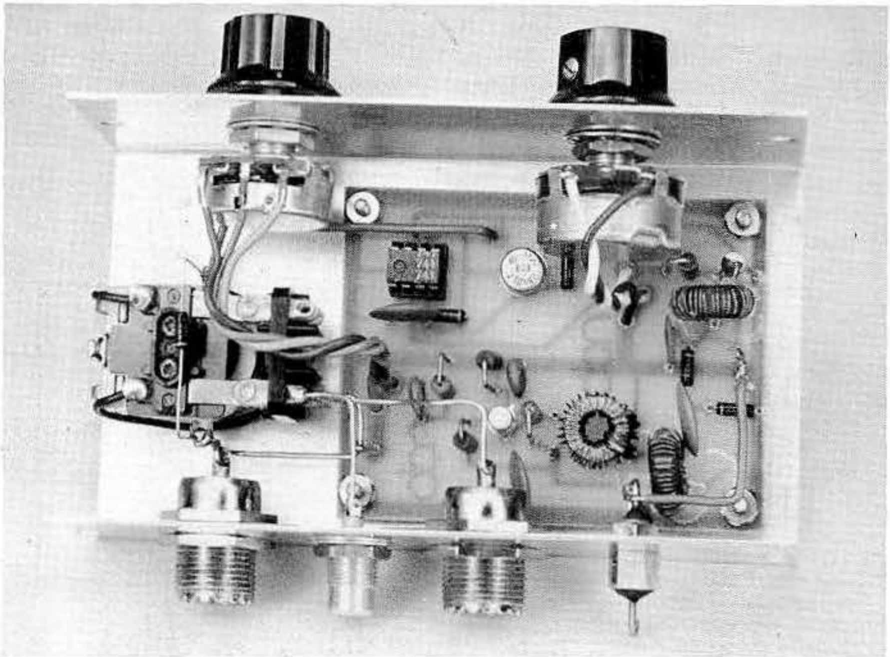

The inner layout of the antenna-changeover relay. Wiring or placement of circuit board and other components is not critical.

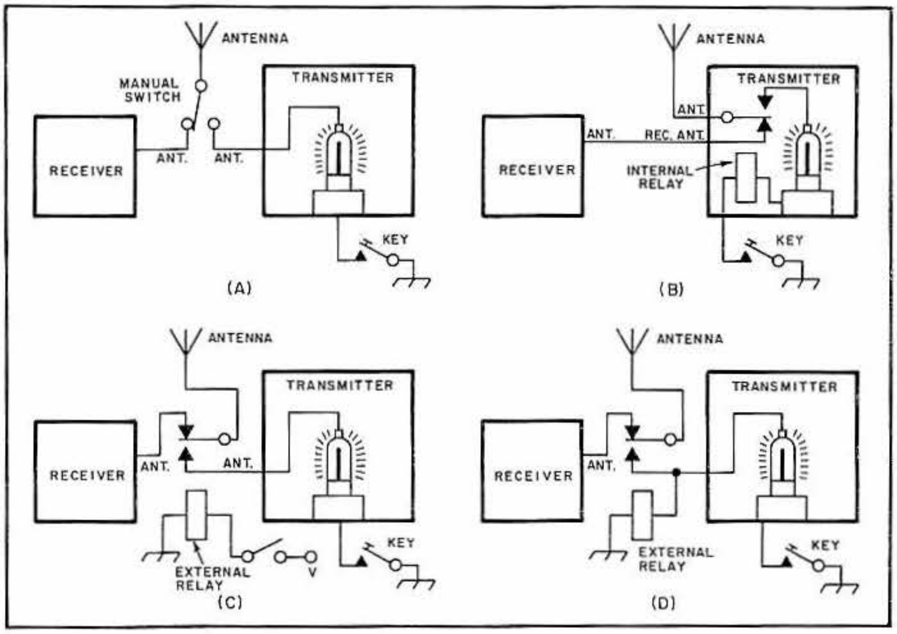

Fig. 54 — Several different antenna-changeover systems in block diagram form.

hard to locate and, of course, the operator is required to switch manually from receive to transmit.

One of these problems was eliminated with the advent of the coaxial relay. These relays were, in most cases, mounted external to the transmitter and receiver with connecting cables running to and from the unit, as shown in Fig. 54B. Many of these relays were rated for a kilowatt a-m signal, and maintained the 50-ohm line impedance. The voltage needed for the relay field was switched on or off with a low-powered toggle or foot switch. Alternatively, the transmit-receive switch might be located on the front panel of the transmitter with control voltage or a normally open or closed circuit available at a socket on the rear apron. Several extra sets of relay contacts were usually furnished with the relay to perform various functions, including that of muting the station receiver during transmit periods. Although this system of antenna transfer represented an improvement over the previous setup, it was still necessary for the operator to switch the antenna manually via the relay-control switch.

It's been said that laziness is the mother of invention and so it seemed natural that a more automatic system be developed. The relatively modern scheme at Fig. 54C has the transfer relay built into the transmitter. This system is quite popular and is used by most commercial manufacturers of amateur equipment that offer a separate transmitter and receiver. When the key is pressed the relay activates automatically and switches the antenna to the transmitter. A variable-length delay is usually included to hold the relay closed, thereby keeping the antenna connected to the transmitter during code characters. After the last group of code characters is sent, the relay will remain closed for a second or two — the amount of time controllable. When the relay deactivates, the antenna is reconnected to the receiver.

Unfortunately, some amateurs who build their own equipment or purchase transmitters and receivers of different manufacture, sometimes resort to switching methods A or B. These setups, of course, do not include the automatic features of system C. The circuit described here and shown in simplified form in Fig. 54D was designed with this in mind. Basically, this system detects the presence of rf at the output of the transmitter and immediately breaks the antenna connection to the receiver. At the same time the antenna connection to the transmitter is made. One of the features of this system is that no modifications to either the transmitter or receiver are required.

Circuit Description

R1 of Fig. 55 serves as an rf-voltage divider to permit the circuit to be used with transmitters of various power-output amounts. Rf energy is routed through C1 to the base of broadband amplifier Q1. The amplified hf-band energy is supplied to a voltage-doubler (D1 and D2) through a broadband toroidal step-down transformer, T1. The rectified rf voltage at the output of D1 and D2 is filtered by means of RFC2, C5 and C6. This prevents unwanted rf from reaching U1 and affecting its performance.

C6, R7 and R6 comprise a timing network (variable) which governs the hold-in time of the relay, K1. The smaller the resistance amount at R6, the shorter will be the time delay.

U1 functions as an inverting amplifier. When the input dc voltage at pin 2 increases, the output dc voltage at pin 6 decreases. The output voltage causes the base of relay driver Q2 to be forward biased negatively when it drops below approximately 1.4 volts. Diodes D5 and D6, by virtue of their combined barrier voltages (0.7 V each), establish the 1.4-V fixed bias level. Without the diodes, Q2 would conduct sufficiently to prevent the relay from dropping out during no-signal periods. D4 is used to suppress transients caused by the field coil of K1. When no rectified rf reaches U1, Q2 is cut off because of the high positive base voltage it receives from U1, and the relay contacts to the transmitter are open.

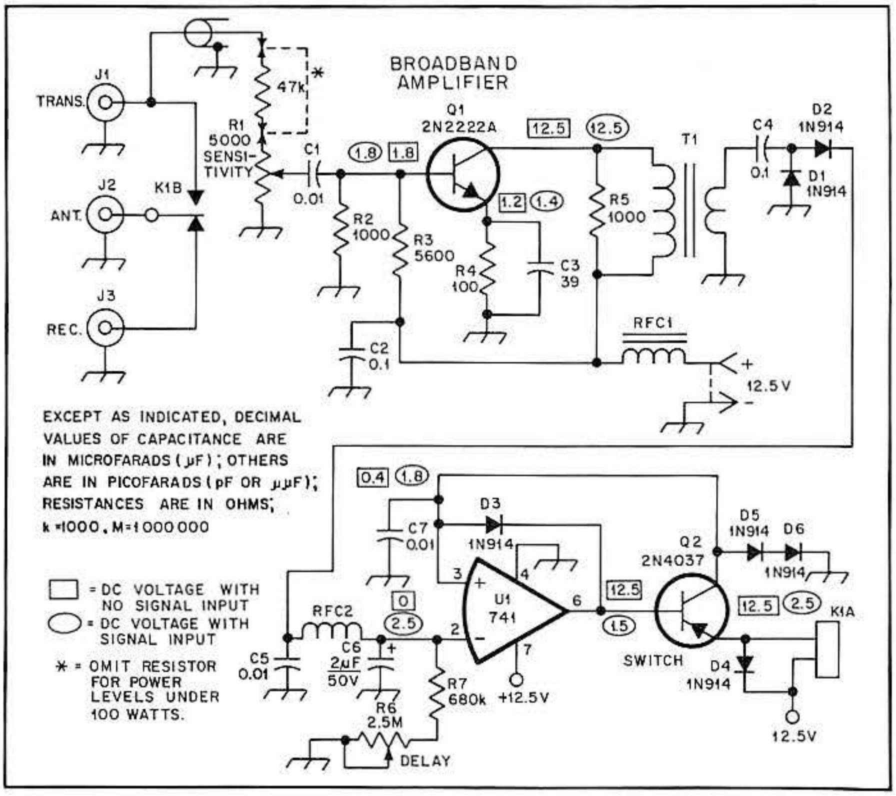

J1
TRANS.
J2
ANT.
K1B
J3
REC.
47k
*
R1
5000
SENSI-TIVITY
C1
0.01
BROADBAND AMPLIFIER
Q1
2N2222A
12.5
12.5
1.8
1.8
1.2
1.4
R2
1000
R3
5600
R4
100
C3
39
R5
1000
T1
C4
0.1
D2
1N914
D1
1N914
RFC1
C2
0.1
+
12.5V
-
EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF); OTHERS ARE IN PICOFARADS (pF OR µµF); RESISTANCES ARE IN OHMS; k=1000, M=1 000 000
☐ = DC VOLTAGE WITH NO SIGNAL INPUT
○ = DC VOLTAGE WITH SIGNAL INPUT
* = OMIT RESISTOR FOR POWER LEVELS UNDER 100 WATTS.
0.4
1.8
C7
0.01
D3
1N914
U1
741
3
4
6
2
7
0
2.5
RFC2
C5
0.01
C6
2µF
50V
R6
2.5M
DELAY
R7
680k
+12.5V
Q2
2N4037
12.5
1.5
SWITCH
D5
1N914
D6
1N914
12.5
2.5
K1A
D4
1N914
12.5V

Fig. 55 — Schematic diagram of the rf-sensed antenna-changeover relay. All resistors are half-watt composition type. Capacitors are disk-ceramic unless noted otherwise. Component numbers not appearing in the parts list are for identification purposes only.

J1, J2 — Connector, SO-239.
J3 — Connector, phono-type.
K1 — Dpdt relay, 5-ampere contacts, 12-volt field.
R1 — Linear potentiometer, 5000 ohms.
R2 — Linear potentiometer, 2.5 megohms.
RFC1, RFC2 — Rf choke, 42 turns no. 28 enam. wire on an Amidon FT-50-43 core.
T1 — Broadband transformer. Primary: 25 turns no. 28 enam. wire on an Amidon FT-50-43 core; secondary: 5 turns no. 28 enam. wire wound over primary winding.
U1 — Op amp, 741.

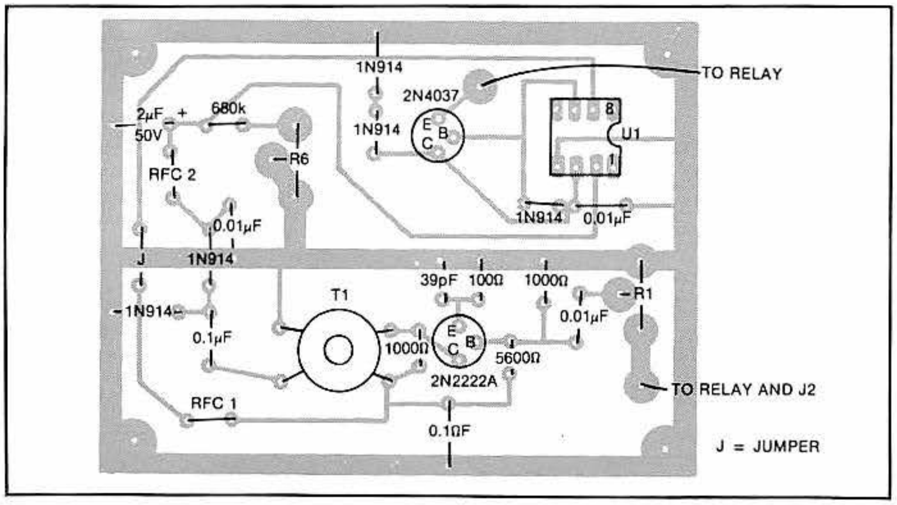

1N914
2N4037
TO RELAY
2µF + 50V
680k
E B C
U1
8
1
R6
RFC 2
0.01µF
1N914
1N914
0.01µF
J
1N914
39pF
100Ω
1000Ω
R1
1N914
T1
0.01µF
0.1µF
1000Ω
E B C
5600Ω
2N2222A
TO RELAY AND J2
RFC 1
0.1ΩF
J = JUMPER

Fig. 56 — Circuit-board etching pattern for the changeover relay. The pattern is shown at actual size from the foil side of the board with gray areas representing copper. Decimal-value numbers alone represent capacitance in microfarads. Whole-number values with no units represent resistances in ohms; k = 1000. J = wire jumper. All components are mounted on the nonfoil side of the board. K indicates the cathode of a diode.

Construction

In Fig. 56 is a suggested printed-circuit board layout showing the foil pattern and parts placement. R1 and R6 may be circuit-board-mounted potentiometers if the builder desires, as the board layout was designed to accommodate such units. Potentiometers of this type are entirely suitable if the builder does not anticipate frequent changes in power levels and length of delay, as these controls must be readjusted for such changes. If the builder is interested in having access to these controls, panel-mounted potentiometers can be used at the front apron, in which case wires will have to be run from the circuit board to the controls.

Our finished model was housed in a 5 × 3 × 2-inch (127 mm × 76 mm × 51 mm) aluminum Minibox. R1 and R6 were mounted on the front panel and Kurz-Kasch knobs were placed on the control shafts to dress up the appearance of the finished product. D4 is attached directly to the relay terminals. The rear panel supports the terminals for the transmitter, antenna, receiver antenna and power supply. SO-239 connectors were used for the transmitter and antenna connections, and a phono connector was employed for the receiver antenna. Any type of connectors may be substituted to match those used in the builder's station. The power-supply lead is brought out through a feedthrough capacitor. This type of feedthrough is not necessary; a simple feedthrough insulator or wire could be used instead. In our case, the capacitor lead served as a convenient tie point during preliminary testing of the unit.

Operation

Connect the antenna, transmitter, receiver antenna lead and the power-supply connections to the appropriate terminals. Set R6, the time-delay control, to its minimum delay position (ccw) and the sensitivity control to its midrotation position. While keying the transmitter, decrease the setting of the sensitivity control to a point just above that where the transmitter no longer makes the relay energize. Once this has been set, it may be left in that position until a moderate change in power level has been made. The delay control should then be adjusted for the length of delay desired. The circuit shown has been tested from 1.8 to 30 MHz and at dc power input levels up to and including 1000 watts. This material was originally presented in *QST* by Doug DeMaw, W1FB, and Jay Rusgrove, W1VD.

Measuring Antenna Gain with Amateur Methods

Beat the cost of expensive test gear. Make your antenna measurements using this unique method! A VU meter, a handful of parts and this simple explanation are all you need.

Several excellent articles have been written about the techniques used at vhf conferences to measure antenna gains. Two such articles in particular, by Clark[1] and Knadle,[2] suggest very good antenna-range procedures. Both describe techniques which, if properly applied, will produce accurate relative antenna-gain data (in decibels) for vhf-uhf antennas.

However, these antenna range-measurement systems require equipment most amateurs lack — ratiometers, precisely calibrated attenuators, or at least specialized detectors and commercial grade audio or VSWR meters. Moreover, setting up a near-field antenna range is a tricky business in itself. One text[3] simply warns amateurs not to expect accurate antenna-gain measurements if they try it! The problem, of course, is that outdoor antenna ranges invite all sorts of error-causing reflections from various objects, not the least of them being the earth itself.

Ground reflections alone can completely invalidate the results on an otherwise good antenna range. At the 1973 West Coast VHF Conference, for instance, the author's 8-element quagi for 432 MHz[4] was measured at precisely the same gain as a well-built 15-element Yagi more than twice its size, despite the fact (established in other tests) that the bigger antenna had 2 to 3 dB more actual gain! The problem was that, even with the sophisticated measuring equipment in use, ground reflections were distorting the results. The best "gain" indication came with both antennas within a few inches of the earth, and the smaller quagi with its lower Q didn't mind the detuning effects of the earth's proximity as much as the bigger and higher Q array.

With results like that, wild claims are sometimes made for one vhf antenna or another. And the claims may be even wilder on the hf bands, where an amateur may well be told his signal is two of three S units louder than another ham's signal when the actual gain difference between the two antennas is insignificant. The ham who "won " the comparison by several S units, of course, is likely to go away thinking his antenna is 12 or 18 dB better than the other guy's, since S meters are supposed to show 6-dB signal difference per S point.

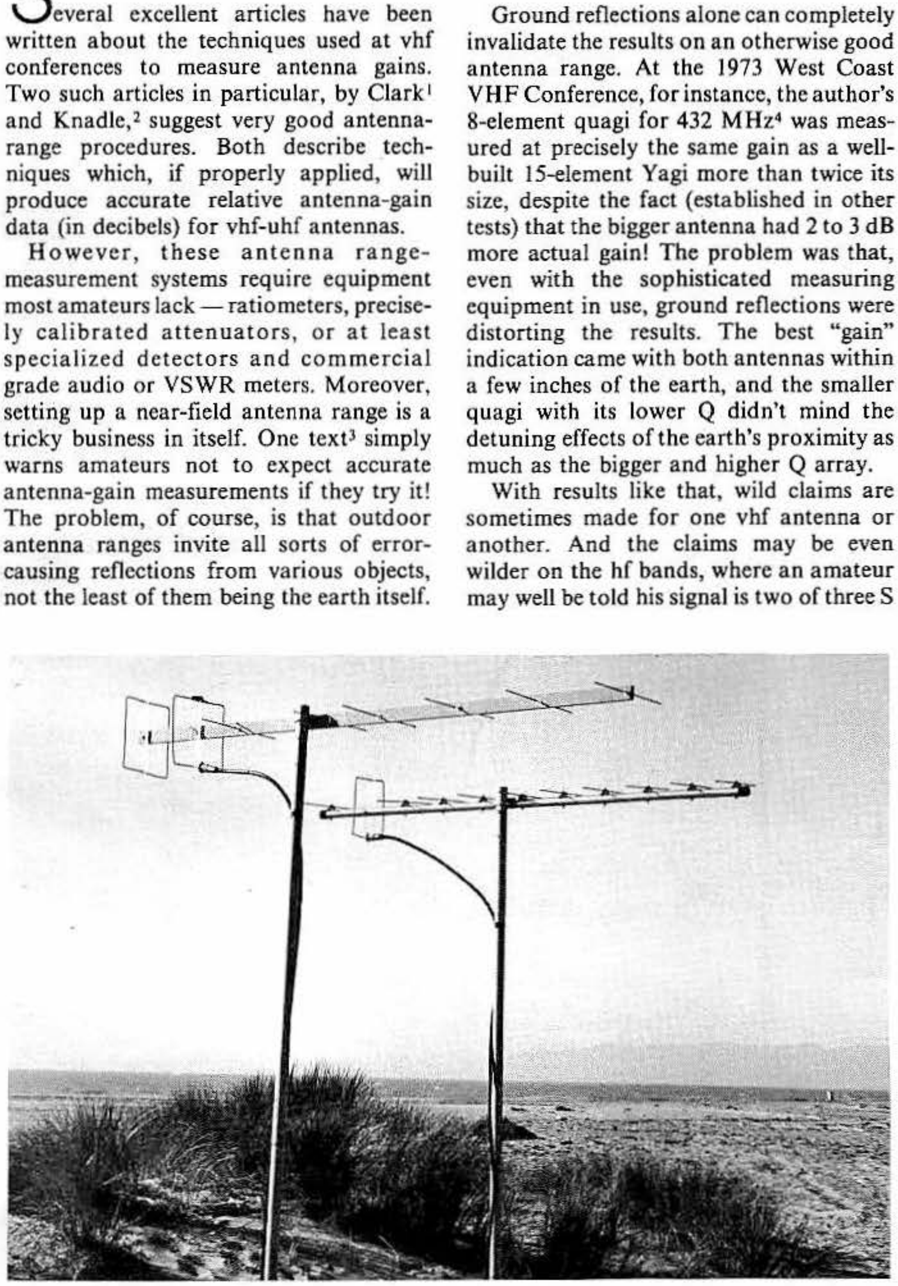

For the antenna gain-measurement technique described here, two identical masts in a clear area (here a southern California beach) are required. With the test and reference antennas at equal heights and fed with identical feed lines, the signal produced by the two antennas is compared by rapid and repeated switching. Here an 8-element quagi is tested against an 11-element Yagi that has been modified for quagi-type drive. The modified Yagi delivers 3 dB more gain than the conventional version, but 2 dB less than the quagi.

A Better Way

This article describes a more reliable and valid way to estimate antenna gain, and without expensive or hard-to-find test equipment. The technique requires only this equipment: a cooperative nearby ham with a transmitter capable of generating a few watts of steady carrier, a receiver whose agc can be turned off, an ordinary audio VU meter, and some antennas to measure.

The technique is nothing more than a more rigorous application of the test procedure radio amateurs have always used when they asked for "comparison" signal reports. It takes advantage of the fact that audio VU meters, unlike S meters, are calibrated directly and fairly accurately in decibels, with easy readout down to fractions of a dB. And with the agc turned off, most receivers will closely reproduce changes in the signal input at the antenna terminals with corresponding changes in audio output until they are badly overloaded.

This means that a nearby amateur's signal transmitted at a reasonably low power level can be used to compare the gain of various antennas by rapidly switching back and forth between them and averaging the results.

The only trick is to use a "test signal" that is coming from a point source — not a signal that is being reflected from surrounding objects. If your test antennas can "see" the signal source a few miles away and are well clear of nearby objects (and clear of the earth itself), valid results should be attainable if the procedures below are followed.

The author has spent many hours working with both local antenna ranges covering a few dozen wavelengths, and on-the-air signals from local stations. It is apparent that ground reflections and other

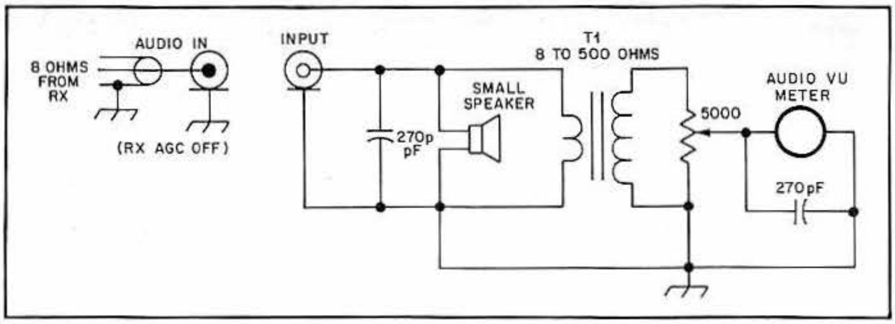

Fig. 57 — The audio VU-meter system for antenna gain measurements.

Fig. 58 — This small box houses all the test equipment required for antenna gain measurements using the technique described here. The front-panel audio VU meter is calibrated directly in decibels, with readout possible to about 0.2 dB in the most expanded part of the scale. Not visible are the meter level potentiometer (on rear), and small speaker which is mounted downward.

such error sources are less serious problems when a steady, on-the-air carrier a few miles away — and not a local signal a few dozen wavelengths away — is the signal source.

Test Procedures

Here's how the procedure works at vhf (at hf, it's a little more complicated because antennas are larger, as we'll see later):

1) Build an audio VU metering circuit like the one shown in the photo and Fig. 57. All parts should be readily available anywhere that consumer electronics parts are sold. The speaker and meter-gain control are handy to have when the receiver itself is located some distance away from the antenna test site, but they aren't absolutely essential.

2) Get a nearby amateur (perhaps one to five miles away) to generate a steady carrier into an antenna of the same polarization as your test antennas. A small beam pointed toward your test site is much better than a dipole or groundplane antenna because it is less likely to invite reflection error. A beam pointed somewhere else is worst of all!

3) Two of the antennas to be tested should be set up side by side, with identical lengths of feed line going to a coaxial relay or well-isolated switch. The two supporting poles should be high enough that the test antennas are at least two wavelengths above ground (13 feet [3.96 m] or more at 2 meters) and clear of nearby obstructions. To minimize interaction between the two antennas, the two masts should also be at least one to two wavelengths apart and standing side by side in relation to the signal source.

4) Make sure you can raise and lower your antennas and move them from side to side by at least a full wavelength or so (81 inches [2.06 m] at 2 meters) without the indicated signal varying more than about 1 dB. If you can't do that, you probably have reflection problems that will have to be solved before you can make valid readings. If this is the case, try different sites until you do achieve nonspotty reception.

5) Check the receiver agc to be sure it is off; then rapidly switch between the two antennas and record the difference in decibels. Do it several times and calculate the average figure (the mean, for statisticians).

6) Next reverse the two antennas. Put antenna no. 1 on mast no. 2 and attach it to feed line no. 2. Move antenna no. 2 over to mast no. 1 and feed line no. 1. Do not eliminate this step and expect valid results.

Now run the test again. If there are more than very slight differences from the previous test, one antenna or the other is seeing some obstruction or reflection source. Your site isn't clear enough for good results; try a different one.

Since this test procedure requires only receiving, there is no reason not to perform it somewhere other than at home — anywhere that is clear of obstructions. Use a receiver or transceiver that runs on battery power, if necessary.

7) If you have followed steps one through six, you now have an accurate indication of the relative gain of your two antennas. Now you can make one of your antennas a "reference" antenna and compare any other antennas you or

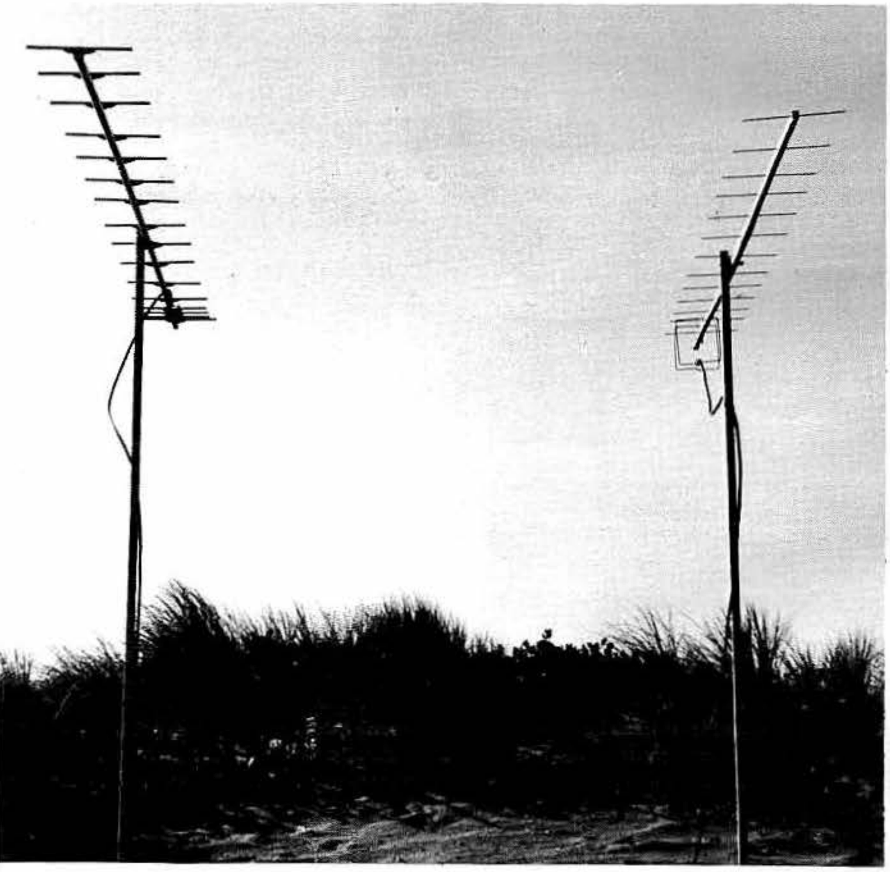

Fig. 59 — Here a 15-element long-boom quagi for 432 MHz is compared to a 16-element log-periodic Yagi, using the test procedure described in this article. The two antennas both deliver 15 dB gain over a dipole, decisively better than any other 432-MHz antenna tested here. The antennas to be tested are set up side by side and fed with identical lengths of coax. The antennas should be at least two wavelengths above ground and clear of nearby obstructions. To minimize interaction between the two antennas, the masts should also be at least one to two wavelengths apart, and standing side by side in relation to the signal source.

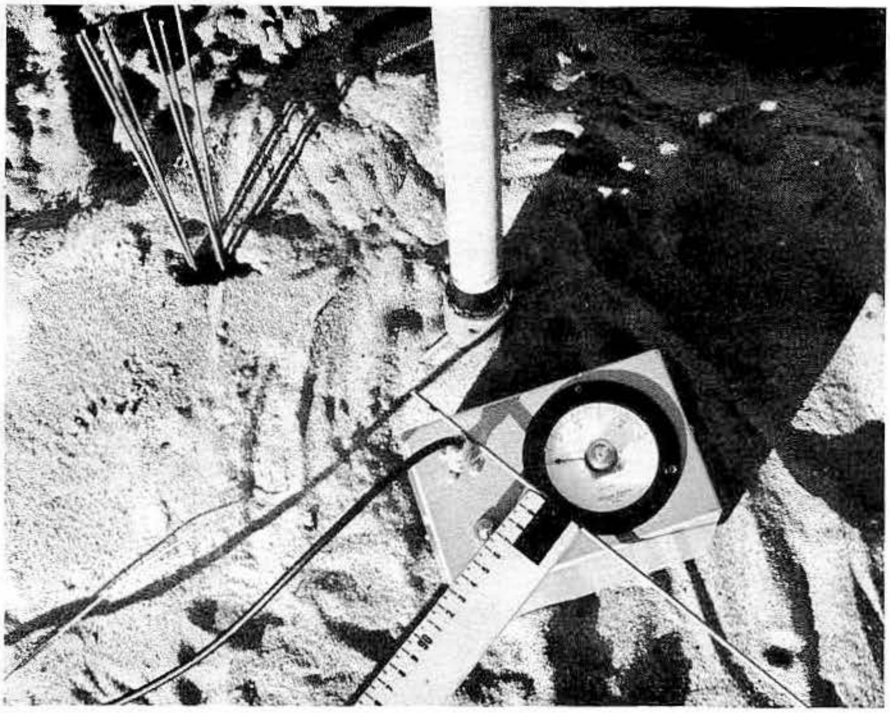

Fig. 60 — An earlier version of the metering system in Fig. 57, with assorted elements of various lengths and the yardstick used to make temporary placements on the boom.

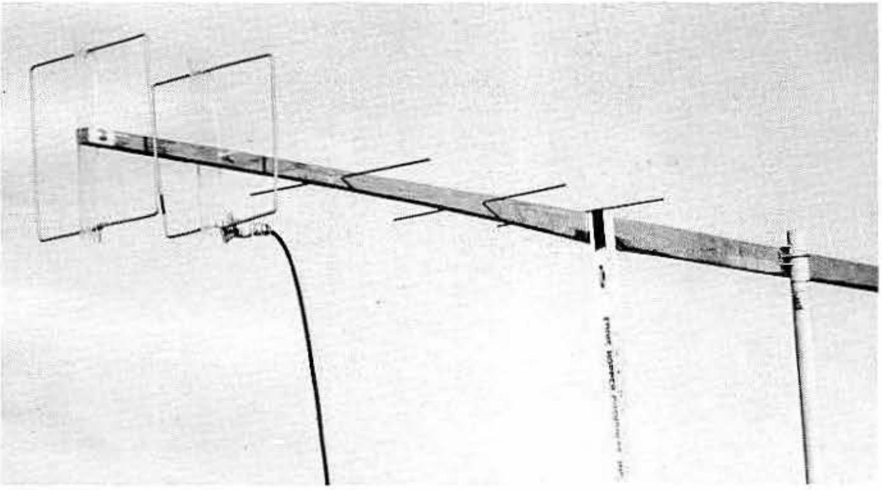

Fig. 61 — The technique used to design a new vhf or uhf antenna experimentally. The boom is shown with the first few elements already in place, and each additional element is adjusted back and forth on the boom until a point of maximum indication of the VU meter is found.

neighboring hams have against this reference.

So how do you determine how much gain your antennas have over a dipole? Some people would say, "Simple, make the reference antenna a dipole." But it may not be that easy, because dipoles are notorious for finding reflections that more directional antennas can't "see." At vhf conference gain-measurement seminars, dipoles have sometimes shown as much as 3 or 4 dB gain over a dipole!

The best reference antenna is probably a small beam of known (or approximately known) gain, assuming you don't have the National Bureau of Standards type of reference antenna that professionals use for this purpose. A 3-element Yagi or a 2-element quad built to handbook dimensions will usually deliver about 6 dB gain over a dipole at 2 meters, if the SWR is okay at the design frequency.

Thus, if you find that a particular 8-element antenna consistently produces 4.5 more dB on the VU meter than your little reference beam, you'll know you have an antenna with about 10.5 dB gain. You won't be exactly correct, but you'll be close to the right figure. Conversely, if your bigger beam doesn't show much gain over the small one, and there are no measurement errors of the sort just described, you'll know for sure that something is wrong with the big antenna.

Once you have established the integrity of your test site, you can even design your own antennas very accurately, using the audio VU-meter technique. To do that, set up your reference antenna and begin designing your new antenna by putting an empty boom on the other pole. Now start with 2 or 3 elements, get a decent SWR and try adding more elements.

As you add elements, you will be able to actually see where each new element "wants to be" on the boom, and you can see your new antenna gain over the reference antenna increase as you go along. Try all sorts of element lengths and spacings as you progress.

Antenna design professionals call this process "perturbation" and they do it with sophisticated mathematics, but you can design antennas that work just as well as theirs on your own antenna range, once you master this technique. Then, if you do go to a vhf conference with your best home-designed antennas, you'll know about how much gain they have before you enter the gain contest. And you'll never come away from such an event with an antenna that has "minus 3 dB gain!" Moreover, you'll know that your measurements, made without any of the sophisticated equipment you saw at the vhf conference, are about as accurate as anybody's. In fact, you may find your own measurements are more valid than the ones at the conference, especially if the antenna-gain figure jumps all over the place when you raise and lower it at the conference antenna range.

HF Antenna Measurements

So far, all of this has been devoted to vhf antenna-gain measurements. Many readers will say, "That's fine, but I want to measure the gain of my 5-element 20-meter beam!" Of course, an audio VU meter and a receiver without agc are a much better way than the notoriously inaccurate S meter to compare two dissimilar hf antennas. The author has seen an S meter show three or four *S units* of signal difference between two antennas that are really only 3 or 4 dB apart in gain.

However, the only accurate way to calculate the gain of an antenna is to compare it to a reference antenna at the same height and then switch the two antennas to opposite masts to validate the data. That may be impractical at hf, but perhaps not as much so as it seems at first. Most amateurs motivated enough to install a 5-element beam on a crankup tower can probably find a way to temporarily set up a smaller beam (not a dipole) on a 20-foot (6.10 m) mast above a roof. Then the two antennas at identical heights can be compared on stable, line-of-sight signals.

The results of this test can be invalidated by obstructions or even by other antennas mounted on the same tower with the test antenna, but at least this will be more valid than a comparison against another ham's readings, when the two locations and rigs may be entirely different.

And if you can switch your test reference hf antennas to opposite masts, you can measure the actual gain of one over the other. One suggestion before you put that giant, long-boom array on the big tower: Put a little beam on the tower and an identical one on the rooftop mast and perform the audio VU-meter tests to see if the two antenna sites do seem to be identical. If they are comparable, then you can put the big antenna on the tower and find out how much gain it has, if any, over the small one on your roof when the two are at the same height.

This may seem cumbersome, and in fact it is! That's why most antenna designers do their research at vhf where antennas are so nice and small, and then scale their best designs up for the hf bands. But if you really want to know your big beam's actual gain, this is probably the easiest way to find out.

Conclusions

The antenna gain-measuring technique described in this article has repeatedly been proved to be reliable and valid. The author has used it to design new antennas that work well enough for all kinds of contest and DX work, including moonbounce. For a dedicated amateur, working DX on a home-designed antenna far surpasses the thrill of working the same DX with an antenna purchased at a store! But remember, whether you're working 20 meters or 23 centimeters, a signal source, a receiver with its agc disabled and an audio VU meter are the only pieces of equipment you need to measure antenna gain with this technique. This material was originally presented in *QST* by Wayne Overbeck, PhD, N6NB.

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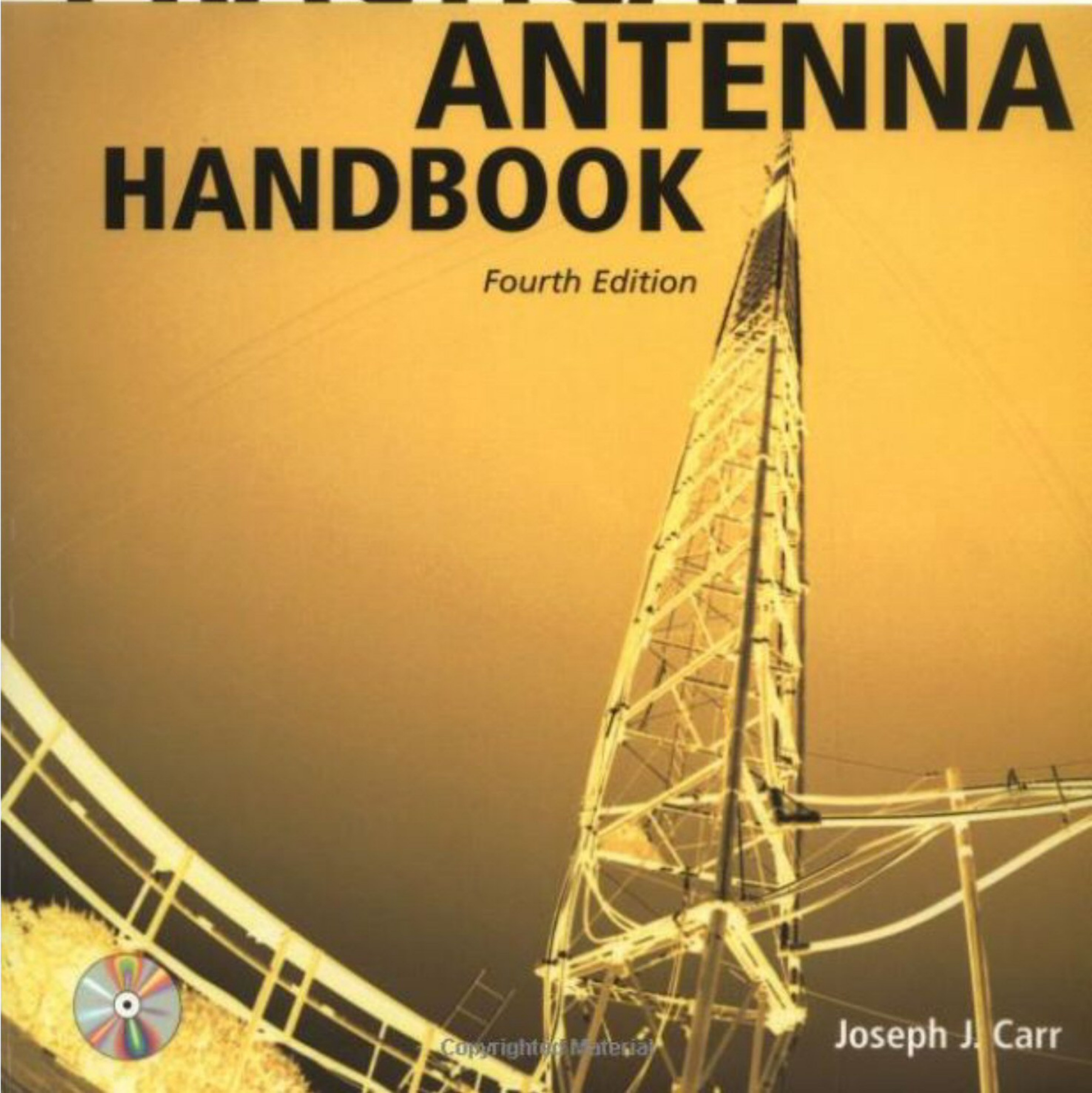

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Dedication

Dedicated in memoriam to Johnnie Harper Thorne, K4NFU:
a friend and colleague for nearly 30 years who is sorely missed.
Johnnie was a genius who knew some real smoke about antennas.
Killed by a drunk driver. . .

From the Publisher

The fourth edition of this book is published in memory of Joe Carr who passed away shortly after completing his manuscript. Joe was a valuable member of the McGraw-Hill family of authors and the electronics community as a whole. He will be missed by us all.

Scott L. Grillo
Editor-in-Chief

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Introduction to the fourth edition

It was with great pleasure that I wrote this fourth edition of *Practical Antenna Handbook*. The original intent when the first edition was planned was to provide the reader with a practical, yet theoretical, book that could be used with only a minimal effort to actually design and install radio antennas. It was assumed that the readership would possess a wide range of levels of antenna sophistication, from the novice “newbie” to the professional engineer. That assumption proved to be correct as I have received letters from a wide variety of people.

The success of the three previous editions of *Practical Antenna Handbook* has been most gratifying. Clerks in radio stores told me that this book was outselling other titles 2:1. They confirmed that the types of people who buy the book meet the profile above. It was with surprise and delight that I noted that clerks in one radio store could cite the McGraw-Hill catalog number from memory, when they could not do that for other antenna books.

While the sales are deeply appreciated (they are an honor), there was one comment that stood out. The salesman at one radio store introduced me to an instructor from a U.S. Government communications school. He typically bought twenty copies of *Practical Antenna Handbook* at a time for use by his students in a training class. He told me that the reason why he selected my book over others was “...it’s the *only book on the market* that people can give to a secretary, or clerk-typist, and expect them to be able to put up a working half-wavelength dipole two hours later.” And, he stated, in his business that could literally happen any time.

Antennas have changed a lot over the years. Figure I-1 shows how antennas were between 1913 and 1940. This facility was the first U.S. Navy radio station (NAA) in Arlington, VA.[1] Those two 600- and 400-ft towers were taken down in 1940 to make room for National Airport (Washington, D.C.). The towers were reassembled in Annapolis, MD, where they lasted until recently.

Antenna technology has changed since 1940. In preparing this fourth edition of *Practical Antenna Handbook* all previous material was reviewed for accuracy and relevance. Additional material was added for the following topics:

- Wire antenna construction methods
- Antenna modeling software (miniNEC, WinNEC, and EZNEC for Windows)
- Antenna noise temperature
- Antennas for radio astronomy
- Antennas for Radio Direction Finding

I hope that you find this fourth edition as useful as the previous three editions. And thank you very much for honoring me by spending your hard-earned money on my book.

Joseph J. Carr, MSEE

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[1] The NAA callsign has since been reassigned to the VLF station at Cutler, ME.

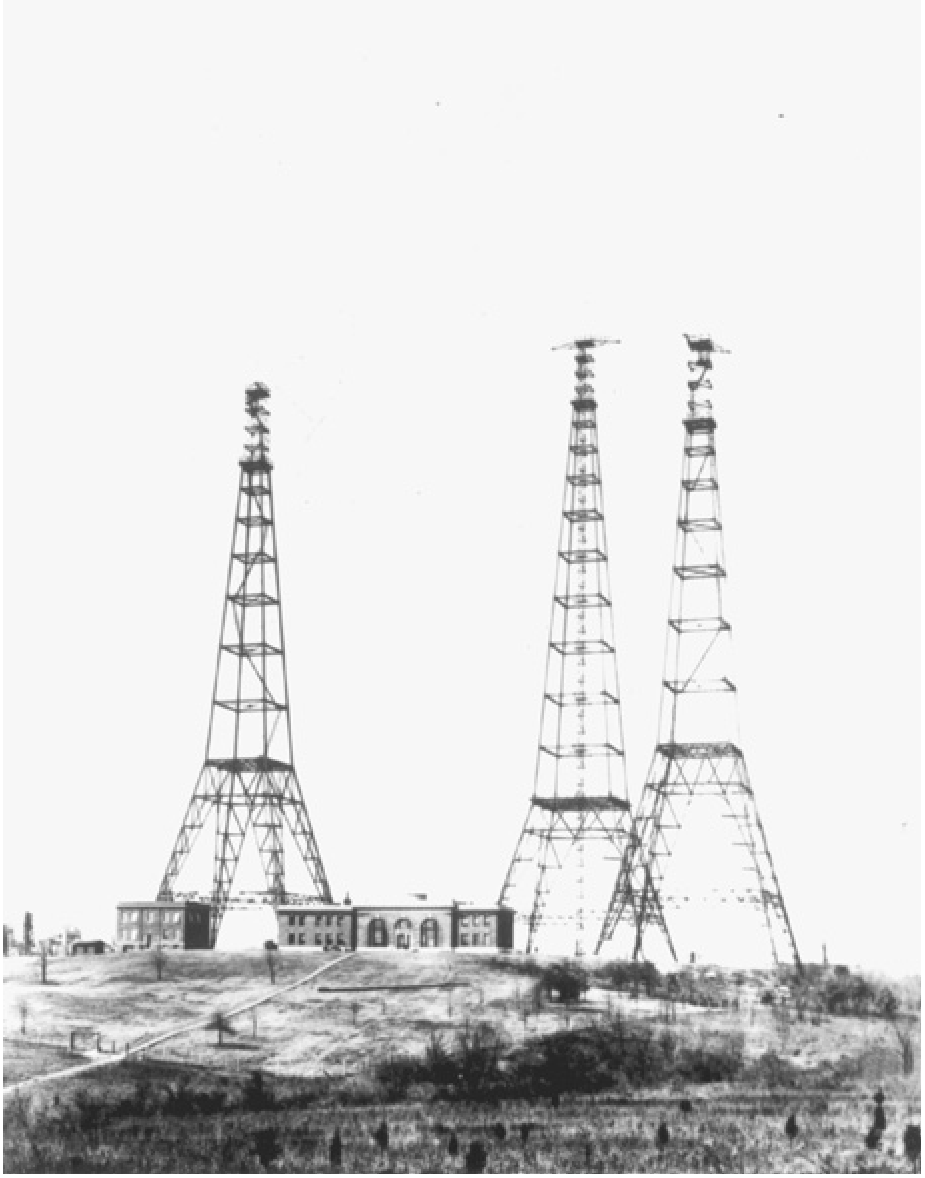

I-1 Massive antenna towers at Navy "Radio Arlington" (1913-1940). (Courtesy of the NAA.)

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1
CHAPTER

Introduction to radio broadcasting and communications

RADIO BROADCASTING AND COMMUNICATIONS SEEMS TO HOLD A STRANGE KIND OF magical allure that attracts a wide variety of people and holds them for years. There is something fascinating about the ability to project yourself over vast intercontinental distances.

Radio communications have been with us now for the entire twentieth century and into the twenty-first. Experiments are on record as early as 1867, and by the turn of the century "wireless telegraphy" (as radio was called then) sparked the imaginations of countless people across the world. Radio communications began in earnest, however, when Guglielmo Marconi successfully demonstrated wireless telegraphy as a commercially viable entity. The "wireless" aspect to radio so radically changed communications that the word is still used to denote radio communications in many countries of the world. Marconi made a big leap to international fame on a cold December day in 1903, when he and a team of colleagues successfully demonstrated transatlantic wireless telegraphy. Until that time, wireless was a neighborhood—or crosstown at best—endeavor that was of limited usefulness. Of course, ships close to shore, or each other, could summon aid in times of emergency, but the ability to communicate over truly long distances was absent. All that changed on that fateful day in Newfoundland when Marconi heard the Morse letter "S" tickle his ears.

Wireless telegraphy was pressed into service by shipping companies because it immediately provided an element of safety that was missing in the prewireless days. Indeed, a ship that sank, leaving its crew and passengers afloat on a forbidding sea, was alone. Any survivors often succumbed to the elements before a chance encounter with a rescue vessel. Some early shipping companies advertised that their ships were safer because of wireless aboard. It was not until 1909, however, that wireless telegraphy proved its usefulness on the high seas. Two ships collided in the foggy Atlantic Ocean and were sinking. All passengers and crew members of both ships were in imminent danger of death in the icy waters. But radio operator Jack

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Binns became the first man in history to send out a maritime distress call. There is some debate over which distress call Binns transmitted, but one thing is certain: It was not "SOS" (today's distress call), because SOS was not adopted until later. Binns probably transmitted either "CQD" or "CQE," both of which were recognized in those days before standardization. Regardless of which call was sent, however, it was received and relayed from ship to ship, allowing another vessel to come to the aid of the stricken pair of ships.

All radio prior to about 1916 was carried on via telegraphy (i.e., the on-off keying of a radio signal in the Morse code). But in 1916 some more magic happened. On a little hill in Arlington, Virginia, on a site that now overlooks the Pentagon and the U.S. Marine Corps base called *Henderson Hall*, there were (and still are) a pair of two-story brick buildings housing the naval radio station NAA (callsign since reassigned to the VLF station at Cutler, ME). On a night in 1916, radio operators and monitors up and down the Atlantic seaboard—from the midwest to the coast and out to sea for hundreds of miles—heard something that must have startled them out of their wits, for crackling out of the "ether," amidst the whining of Alexanderson alternators and "ZZZCHHT" of spark-gap transmitters, came a new sound—a human voice. Engineers and scientists at the Naval Research Laboratory had transmitted the first practical amplitude-modulated (AM) radio signal. Earlier attempts, prior to 1910, had been successful as scientific experiments, but they did not use commercially viable equipment.

Although radio activity in the early years was unregulated and chaotic, today it is quite heavily regulated. Order was brought to the bands (don't laugh, ye who tune the shortwaves) that was lacking before. Internationally radio is regulated by the International Telecommunications Union (ITU) in Geneva, Switzerland through the treaties arising from World Administrative Radio Conferences (WARC) held every 10 to 15 years. In the United States, radio communications are regulated by the Federal Communications Commission (FCC), headquartered in Washington, D.C.

Amateur radio has grown from a few thousand "hams" prior to World War I to more than 900,000 today, about one-third of them in the United States. Amateur operators were ordered off the air during World War I, and almost did not make a comeback after the war. There were, by that time, many powerful commercial interests that greedily coveted the frequencies used by amateurs, and they almost succeeded in keeping postwar amateurs off the air. But the amateurs won the dispute, at least partially. In those days, it was the frequencies with wavelengths longer than 200 m (i.e., 20 to 1500 kHz) that were valuable for communications.

The cynical attitude attributed to the commercial interests regarding amateurs was, "put 'em on 200 meters and below . . . they'll never get out of their backyards there!" But there was a surprise in store for those commercial operators, because the wavelengths shorter than 200 m are in the high-frequency region that we now call "shortwaves." Today, the shortwaves are well-known for their ability to communicate over transcontinental distances, but in 1919 that ability was not suspected.

I once heard an anecdote from an amateur operator "who was there." In the summer of 1921 this man owned a large, beautiful wire "flattop" antenna array for frequencies close to 200 m on his family's farm in southwestern Virginia. Using those frequencies he was used to communicating several hundred miles into eastern Ohio and down to the Carolinas. But, in September 1921 he went to college to study electrical engineering at the University of Virginia in Charlottesville. When he returned home for Thanksgiving he noticed that his younger brother had replaced the long flattop array with a short dipole antenna. He was furious, but managed through great effort to contain the anger until after dinner. Confronting his brother over the incredible sacrilege, he was told that they no longer used 150 to 200 m, but rather were using 40 m instead. Everyone "knew" that 40 m was useless for communications over more than a few blocks, so (undoubtedly fuming) the guy took a turn at the key. He sent out a "CQ" (general call) and was answered by a station with a callsign like "8XX." Thinking that the other station was in the 8th U.S. call district (WV, OH, MI) he asked him to relay a message to a college buddy in Cincinnati, OH. The other station replied in the affirmative, but suggested that ". . . you are in a better position to reach Cincinnati than me, I am *FRENCH* 8XX." (Callsigns in 1921 did not have national prefixes that are used today.) The age of international amateur communications had arrived! And with it came a new problem—the national identifiers in call signs became necessary (which is why American call signs begin with K, W, or N).

During the 1930s, radio communications and broadcasting spread like wildfire as technology and techniques improved. World War II became the first war to be fought with extensive electronics. Immediately prior to the war, the British developed a new weapon called RADAR (radio detection and ranging; now spelled radar). This tool allowed them to see and be forewarned of German aircraft streaming across the English Channel to strike targets in the United Kingdom. The German planes were guided by (then sophisticated) wireless highways in the sky, while British fighters defended the home island by radio vectoring from ground controllers. With night fighters equipped with the first "centimetric" (i.e., microwave) radar, the Royal Air Force was able to strike the invaders accurately—even at night. The first kill occurred one dark, foggy, moonless night when a *Beaufighter* closed on a spot in the sky where the radar in the belly of the plane said an enemy plane was flying. Briefly thinking he saw a form in the fog, the pilot cut loose a burst from his quad mount of 20-mm guns slung in the former bomb bay. Nothing. Thinking that the new toy had failed, the pilot returned to base—only to be told that ground observers had reported that a German *Heinkle* bomber fell from the overcast sky at the exact spot where the pilot had his ghostly encounter.

Radio, television, radar, and a wide variety of services, are available today under the general rubric "radio communications and broadcasting." Homeowners, and other nonprofessionals in radio, can own a receiver system in their backyard that picks up television and radio signals from satellites in geosynchronous orbit 23,000 mi out in space. Amateur operators are able to communicate worldwide on low power, and have even launched their own "OSCAR" satellites.

Some people had written off the HF radio spectrum in recent years, citing satellite technology as the reason. But the no-code license for amateur radio operators, which does not carry HF privileges, has proven to be a stepping stone to higher-class licenses, which do. Also, the shortwave broadcasting market received a tremendous boost during the Gulf War. When the troops of *Operation Desert Shield* and *Desert Storm* were assembling to take back Kuwait from the Iraqis, the sales of shortwave receivers jumped dramatically. And, following January 16, 1991, when the forces started pouring across the border into the actual fight, the sales skyrocketed out of sight. One dealer told me that he couldn't keep receivers in stock, and that he had sold out most models. That interest seems to have matured into long-term interest on the part of a significant number of listeners and new ham operators.

The antenna is arguably one of the most important parts of the receiving and/or transmitting station (Fig. 1-1). That is what this book is all about.

1-1 This AM/FM broadcast antenna tower bristles with two-way antennas.

2
CHAPTER
Radio-wave propagation

THE PROPAGATION OF RADIO SIGNALS IS NOT THE SIMPLE MATTER THAT IT SEEMS AT first glance. Intuitively, radio signal propagation seems similar to light propagation; after all, light and radio signals are both electromagnetic waves. But simple inverse square law predictions, based on the optics of visible light, fall down radically at radio frequencies because other factors come into play. In the microwave region of the spectrum, the differences are more profound because atmospheric pressure and water vapor content become more important than for light. For similar reasons, the properties of microwave propagation differ from lower VHF and HF propagation. In the HF region, solar ionization of the upper reaches of the atmosphere causes the kind of effects that lead to long-distance “skip” communications and intercontinental broadcasting. This chapter examines radio propagation phenomena so that you have a better understanding of what an antenna is used for and what parameters are important to ensure the propagation results that you desire.

Radio waves

Although today it is well recognized that radio signals travel in a wave-like manner, that fact was not always so clear. It was well known in the first half of the nineteenth century that wires carrying electrical currents produced an *induction field* surrounding the wire, which is capable of causing action over short distances. It was also known that this induction field is a magnetic field, and that knowledge formed the basis for electrical motors. In 1887, physicist Heinrich Hertz demonstrated that radio signals were *electromagnetic waves*, like light. Like the induction field, the electromagnetic wave is created by an electrical current moving in a conductor (e.g., a wire). Unlike the induction field, however, the *radiated field* leaves the conductor and propagates through space as an electromagnetic wave.

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The *propagation* of waves is easily seen in the "water analogy." Although not a perfect match to radio waves, it serves to illustrate the point. Figure 2-1 shows a body of water into which a ball is dropped (Fig. 2-1A). When the ball hits the water (Fig. 2-1B), it displaces water at its point of impact, and pushes a leading wall of water away from itself. The ball continues to sink and the wave propagates away from it until the energy is dissipated. Although Fig. 2-1 shows the action in only one dimension (a side view), the actual waves propagate outward in all directions, forming concentric circles when viewed from above.

The wave produced by a dropped ball is not continuous, but rather is *damped* (i.e., it will reduce in amplitude on successive crests until the energy is dissipated and the wave ceases to exist). But to make the analogy to radio waves more realistic, the wave must exist in a continuous fashion. Figure 2-2 shows how this is done: a ball is dipped up and down in a rhythmic, or cyclic manner, successively rein-

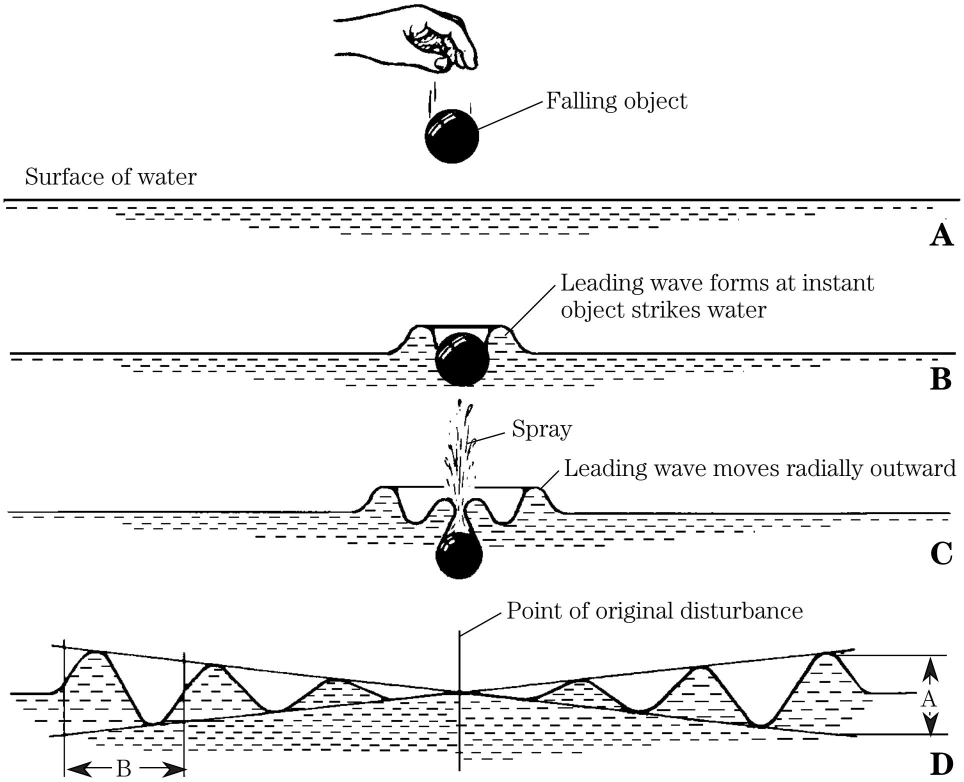
Falling object
Surface of water
A
Leading wave forms at instant object strikes water
B
Spray
Leading wave moves radially outward
C
Point of original disturbance
A
B
D

Notes: A Amplitude of leading wave
B Corresponds to 1 cycle of oscillation

2-1 A ball dropped into water generates a wavefront that spreads out from the point of original disturbances.

forcing new wave crests on each dip. The waves continue to radiate outward as long as the ball continues to oscillate up and down. The result is a *continuous wave train*.

There are two related properties of all waves that are important to radio waves as well: *frequency* (*f*) and *wavelength* (λ). The frequency is the number of oscillations (or cycles) per unit of time. In radio waves, the unit of time is the second, so frequency is an expression of the number of *cycles per second* (*cps*). If the period of time required for the leading wave to travel from point "A" to "B" is one second (1 s), and there are two complete wave cycles in that space, then the frequency of the wave created by the oscillating ball is 2 cps.

At one time, radio frequencies (along with the frequencies of other electrical and acoustical waves) were expressed in cps, but in honor of Heinrich Hertz, the unit was renamed the hertz (Hz) many years ago. Because the units are equal (1 Hz = 1 cps), the wave in Fig. 2-2 has a frequency of 2 Hz.

Because radio frequencies are so high, the frequency is usually expressed in kilohertz (kHz—1000s of Hz) and megahertz (MHz—1,000,000s of Hz). Thus, the frequency of a station operating in the middle of the AM broadcasting band can be properly expressed as 1,000,000 Hz, or 1000 kHz, or 1 MHz, all of which are equivalent to each other. Radio dials in North America are usually calibrated in kHz or MHz. In Europe and the rest of the world, on the other hand, it is not uncommon to find radio dials calibrated in meters, the unit of wavelength, as well as in frequency. In most equations used in radio antenna design, the proper units are hertz, kilohertz, and megahertz.

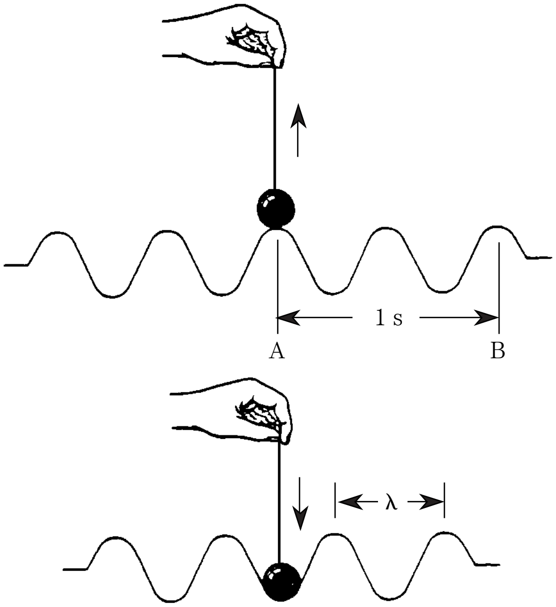

2-2 Bobbing ball on a string demonstrates continuous wave generation action.

The *wavelength* of any wave is the distance between like features on the waveform. In the case of Fig. 2-2, the wavelength (λ) is the distance between successive positive peaks. We could also measure the same distance between successive negative peaks, or between any two similar features on successive waves. In radio work, the wavelength of the signal is expressed in *meters or its subunits*.

The wavelength is proportional to the reciprocal of the frequency. The wavelength of any wave is related to the frequency so that $f\lambda = v$, where f is the frequency in Hz, λ is the wavelength in meters, and v is the *velocity of propagation* in meters per second (m/s). Because radio waves propagate at the speed of light (which is also an electromagnetic wave), approximately 300,000,000 m/s in both free space and the earth's atmosphere, the lowercase letter c is used to represent velocity (rather than v), so you can rewrite this expression in the form

$$f_{\text{Hz}} = \frac{c}{\lambda_{\text{meters}}} = \frac{300{,}000{,}000}{\lambda_{\text{meters}}} \qquad \textbf{[2.1]}$$

These equations are sometimes abbreviated for use with the units kHz and MHz:

$$F_{\text{kHz}} = \frac{300{,}000}{\lambda_{\text{meters}}} \qquad \textbf{[2.2]}$$

$$f_{\text{MHz}} = \frac{300}{\lambda_{\text{meters}}} \qquad \textbf{[2.3]}$$

You can get an idea of the order of length of these waves by solving Eq. 2.3 for several different frequencies: 100 kHz, 1 MHz (in the AM broadcast band), 10 MHz (in the shortwave bands), and 1000 MHz (microwave bands). If you work the equations, then you will find that these wavelengths are 3000 m (100 kHz), 300 m (1 MHz), 30 m (10 MHz), and 0.3 m, or 30 cm (1000 MHz). You can see from these numbers why 1 MHz is in what is called the *medium-wave band*, 10 MHz is in the *short wave band*, and 1,000 MHz is in the *microwave* ("very small" wave) band. At 100 kHz, which is 0.1 MHz, the wavelength is 3000 m, so this frequency is in the *long-wave band*.

The place where the water analogy falls down most profoundly is in the nature of the medium of propagation. Water waves move by moving water molecules; water is said to be the *medium* in which the wave propagates. At one time, scientists could not conceive of the "action at a distance" provided by radio waves, so they invented a hypothetical medium called *ether* (or *aether*) for propagating electromagnetic waves (such as radio waves and light). It was not until the late nineteenth century that American physicists Michaelson and Morley proved that the ether does not exist. Nonetheless, radio enthusiasts still refer to the "stuff" out of which radio waves arrive as the "ether." This terminology is merely an archaic, linguistic echo of the past.

The electromagnetic field: a brief review

A great deal of heavily mathematical material can be presented about electromagnetic waves. Indeed, developing Maxwell's equations is a complete field of study for specialists. In this section, you will not use this rigorous treatment because you can refer to engineering textbooks for that depth of information. The purpose here is to present a descriptive approach that is designed to present you with a basic understanding of the phenomena. The approach here is similar to the learning of a "conversational" foreign language, rather than undertaking a deep study of its grammar, syntax, and context. For those whose professional work routinely involves electromagnetic waves, this treatment is hopelessly simplistic. For that I make no apology, because it serves a greater audience. The goal here is to make you more comfortable when thinking about the propagation of electromagnetic fields in the radio portion of the electromagnetic spectrum.

Radio signals are *transverse electromagnetic* (TEM or EM) *waves* exactly like light, infrared (IR), and ultraviolet (UV), except for frequency. Radio waves have much lower frequencies than light, IR, or UV, hence they have much longer wavelengths. The TEM (EM) wave consists of two mutually perpendicular oscillating fields (see Fig. 2-3) traveling together in phase. One of the fields is an *electric field* and the other is a *magnetic field*.

Radio-wave intensity

The radio wave is *attenuated* (i.e. reduced in apparent power) as it propagates from the transmitter to the receiver. Although at some very high microwave frequencies, there is additional path loss as a result of the oxygen and water vapor content of the air. At other frequencies other losses exist. Radio waves at all frequencies suffer losses due to the *inverse square law*. Let's take a look at that phenomenon.

The electric field vector falls off in direct proportion to the distance traveled. The E field is measured in terms of volts per meter (V/m), or in the subunits millivolts per meter (mV/m) or microvolts per meter (μV/m). That is, if an E field of

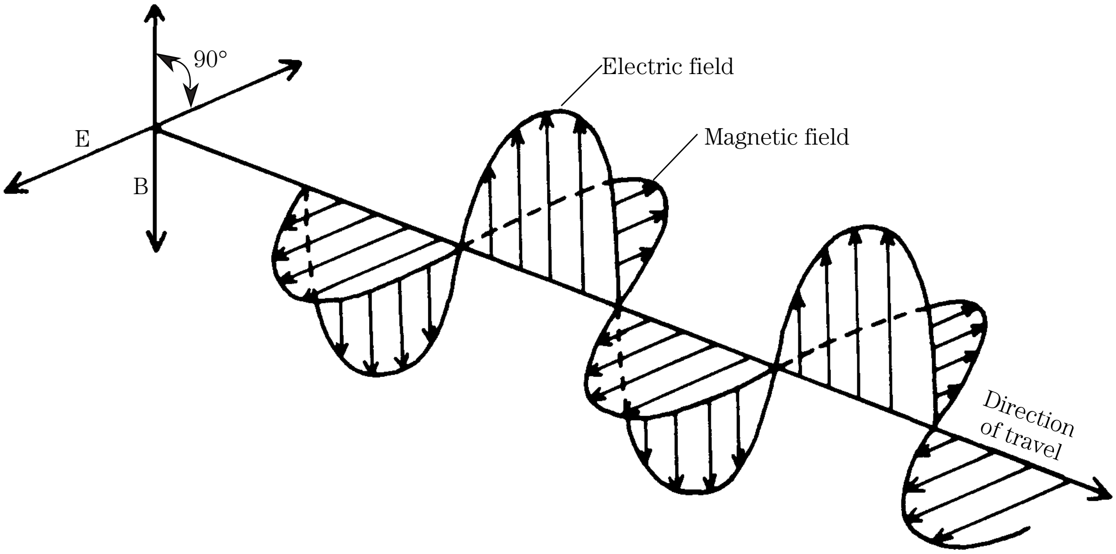

2-3 Electromagnetic wave consists of right angle electric and magnetic fields.

10 V/m crosses your body from head to toe, and you are about 2 m tall, then an electrical voltage is generated of (2 m)×(10 V/m), or 20 V. The reduction of the E field is linearly related to distance (i.e., if the distance doubles the E-field voltage vector halves). Thus, a 100 mV/m E field that is measured 1 mi from the transmitter will be 50 mV/m at 2 mi.

The power in any electrical system is related to the voltage by the relationship

$$P = \frac{E^2}{R} \qquad \textbf{[2.4]}$$

where

P is the power in watts (W)
R is the resistance in ohms (Ω)
E is the electrical potential in volts (V)

In the case of a radio wave, the R term is replaced with the impedance (Z) of free space, which is on the order of 377 Ω. If the E field intensity is, for example, 10 V/m, then the *power density* of the signal is

$$P = \frac{(10\ \text{V/m})^2}{377\ \Omega} = 0.265\ \text{W/m}^2 = 26.5\ \text{mW/m}^2 \qquad \textbf{[2.5]}$$

The power density, measured in watts per square meter (W/m^2), or the subunits (e.g., mW/cm^2), falls off according to the square of the distance. This phenomenon is shown graphically in Fig. 2-4. Here, you can see a lamp emitting a light beam that falls on a surface (A), at distance L, with a given intensity. At another surface (B), that is $2L$ from the source, the same amount of energy is distributed over an area (B) that is twice as large as area A. Thus, the power density falls off according to $1/d^2$, where d is the difference in distance. This is called the *inverse square law*.

Isotropic sources

In dealing with both antenna theory and radio wave propagation, a theoretical construct called an *isotropic source* is sometimes used for the sake of comparison, and for simpler arithmetic. You will see the isotropic model several places in this book. An isotropic source assumes that the radiator (i.e., an "antenna") is a very tiny spherical source that radiates energy equally well in all directions. The radiation pattern is thus a sphere with the isotropic antenna at the center. Because a spherical source is uniform in all directions, and its geometry is easily determined mathematically, the signal intensities at all points can be calculated from basic geometric principles.

For the isotropic case, you can calculate the average power in the extended sphere from

$$P_{\text{av}} = \frac{P_t}{4\pi d^2} \qquad \textbf{[2.6]}$$

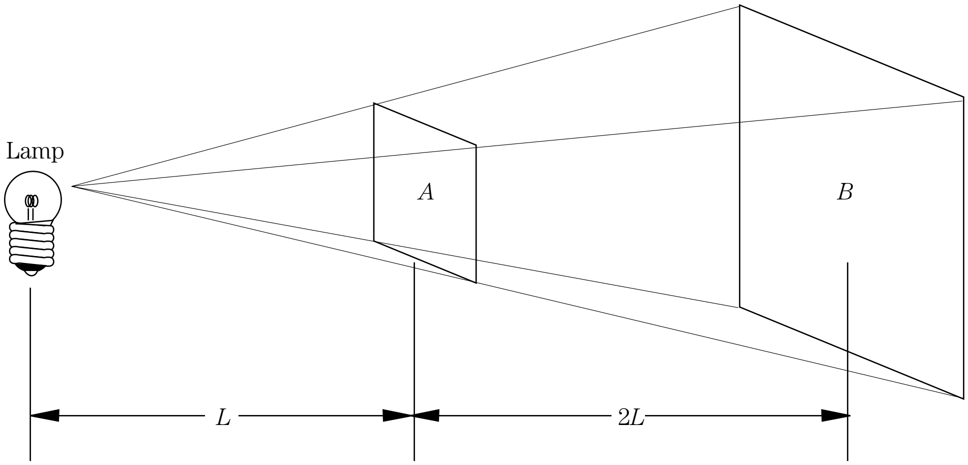

2-4 As a wave propagates, it spreads out according to the inverse square law, i.e., the area of B is 4 times that of A because it is twice as far from the source.

where

P_{av} is the average power per unit area
P_t is the total power
d is the radius of the sphere in meters (i.e., the distance from the radiator to the point in question)

The *effective aperture* (A_e) of the receiving antenna relates to its ability to collect power from the EM wave and deliver it to the load. Although typically smaller than the surface area in real antennas, for the theoretical isotropic case $A_e = \lambda^2/4\pi$. The power delivered to the load is

$$P_L = P_{\text{av}} A_e \tag{2.7}$$

By combining the two previous equations, the power delivered to a load at distance d is given by

$$P_L = \frac{P_t \lambda^2}{(4\pi)^2 d^2} \tag{2.8}$$

where

P_L is the power to the load
λ is the wavelength (c/F) of the signal

From these expressions, there can then be derived an expression for ordinary path losses between an isotropic transmitter antenna and a receiver antenna:

$$L_{\text{dB}} = 10 \log \left(\frac{P_t}{P_L} \right) \tag{2.9}$$

or, by rearranging to account for individual terms:

$$L_{\mathrm{dB}} = [20 \log d] + [20 \log F_{\mathrm{MHz}}] + k \qquad \textbf{[2.10]}$$

where

L_{dB} is the path loss in decibels (dB)
d is the path length
F_{MHz} is frequency in megahertz (MHz)
k is a constant that depends on the units of d as follows:

k = 32.4 if d in kilometers
= 36.58 if d in statute miles
= 37.80 if d in nautical miles
= –37.87 if d in feet
= –27.55 if d in meters

The radiated sphere of energy gets ever larger as the wave propagates away from the isotropic source. If, at a great distance from the center, you take a look at a small slice of the advancing wavefront you can assume that it is essentially a flat plane, as in Fig. 2-5. This situation is analogous to the apparent flatness of the prairie, even though the surface of the earth is nearly spherical. You would be able to "see" the electric and magnetic field vectors at right angles to each other in the flat plane wavefront.

The *polarization* of an EM wave is, by definition, the *direction of the electric field*. Figure 2-6A shows vertical polarization, because the electric field is vertical with respect to the earth. If the fields were exchanged (as in Fig. 2-6B), then the EM wave would be horizontally polarized.

These designations are especially convenient because they also show the type of antenna used: vertical antennas produce vertically polarized signals, while hori-

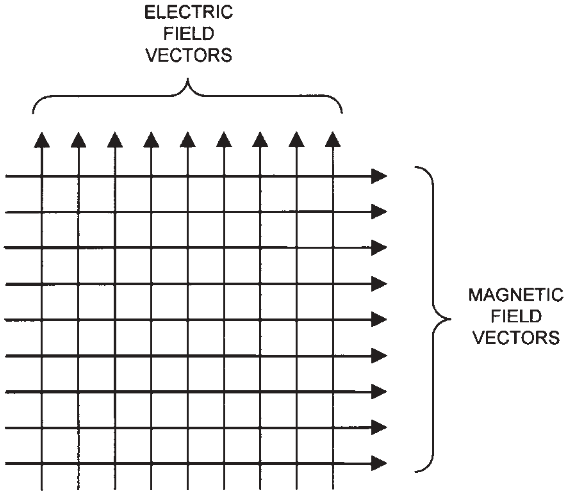

2-5 When viewed as a plane, the fields appear at right angles to each other.

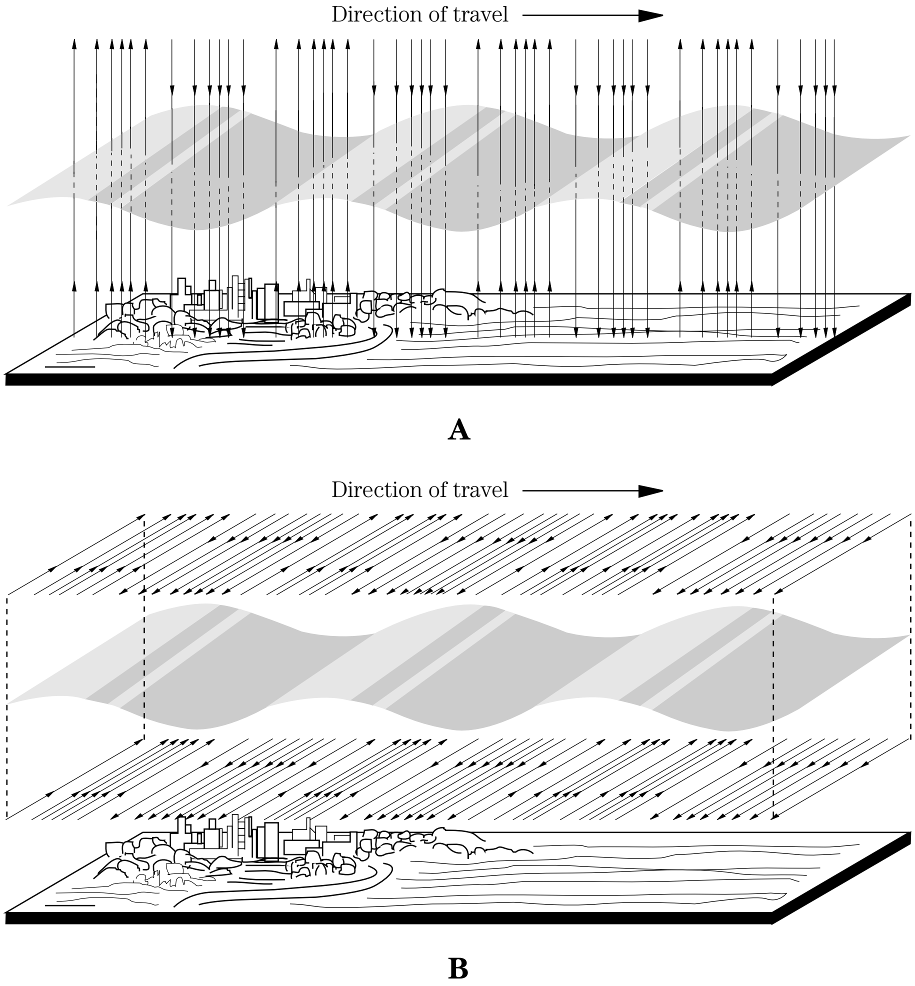

2-6 Wave polarization is determined by the direction of the electric field lines of force: (A) vertical polarized electromagnetic wave; (B) horizontally polarized wave.

zontal antennas produce horizontally polarized signals. At least one text erroneously states that antennas will not pick up signals of the opposite polarity. Such is not the case, especially in the high-frequency (HF) and lower very high-frequency (VHF) regions. At VHF, ultrahigh frequency (UHF), and microwave frequencies a loss of approximately 20 to 30 dB can be observed due to cross-polarization.

An EM wave travels at the speed of light, designated by the letter *c*, which is about 300,000,000 m/s (or 186,000 mi/s). To put this velocity in perspective, a radio signal originating on the sun's surface would reach earth in about 8 minutes. A terrestrial radio signal can travel around the earth seven times in one second. The velocity of the wave slows in dense media, but in air the speed is so close to the "free-space" value of *c*, that the same figures are used for both air and the near vacuum of outer space in practical problems. In pure water, which is much denser than air, the speed of radio signals is about one-ninth that of the free-space speed. This same phenomenon shows up in practical work in the form of the *velocity factor* (*V*) of transmission lines. In foam dielectric coaxial cable, for example, the value of *V* is 0.80, which means that the signal propagates along the line at a speed of 0.80*c*, or 80 percent of the speed of light.

This coverage of radio propagation considers the EM wave as a very narrow "ray" or "pencil beam" that does not diverge as it travels. That is, the ray remains the same width all along its path. This convention makes it easy to use ray tracing diagrams. Keep in mind, however, that the real situation, even when narrow-beamwidth microwave signals are used, is much more complicated. Real signals, after all, are sloppier than textbook examples: they are neither infinitesimally thin, nor nondivergent.

The earth's atmosphere

The electromagnetic waves do not need an atmosphere in order to propagate, as you will undoubtedly realize from the fact that space vehicles can transmit radio signals back to earth in a near vacuum. But when a radio wave does propagate in the earth's atmosphere, it interacts with the atmosphere, and its path of propagation is altered. A number of factors affect the interaction, but it is possible to break the atmosphere into several different categories according to their respective effects on radio signals.

The atmosphere, which consists largely of oxygen (O_2) and nitrogen (N) gases, is broken into three major zones: *troposphere*, *stratosphere*, and *ionosphere* (Fig. 2-7). The boundaries between these regions are not very well defined, and change both diurnally (over the course of a day) and seasonally.

The troposphere occupies the space between the earth's surface and an altitude of 6 to 11 km (4 to 7 mi). The temperature of the air in the troposphere varies with altitude, becoming considerably lower at greater altitude compared with ground temperature. For example, a +10°C surface temperature could reduce to –55°C at the upper edges of the troposphere.

The stratosphere begins at the upper boundary of the troposphere (6 to 11 km), and extends up to the ionosphere (≈50 km). The stratosphere is called an *isothermal region* because the temperature in this region is somewhat constant, despite altitude changes.

The ionosphere begins at an altitude of about 50 km (31 mi) and extends up to approximately 300 km (186 mi). The ionosphere is a region of very thin atmosphere. Cosmic rays, electromagnetic radiation of various types (including ultraviolet light from the sun), and atomic particle radiation from space (most of these from the sun also), have sufficient energy to strip electrons away from the gas molecules of the atmosphere. These freed electrons are called *negative ions*, while the O_2 and N molecules that lost electrons are called *positive ions*. Because the density of the air is so low at those altitudes, the ions can travel long distances before neutralizing each other by recombining. Radio propagation on some bands varies markedly between daytime and nighttime because the sun keeps the level of ionization high during

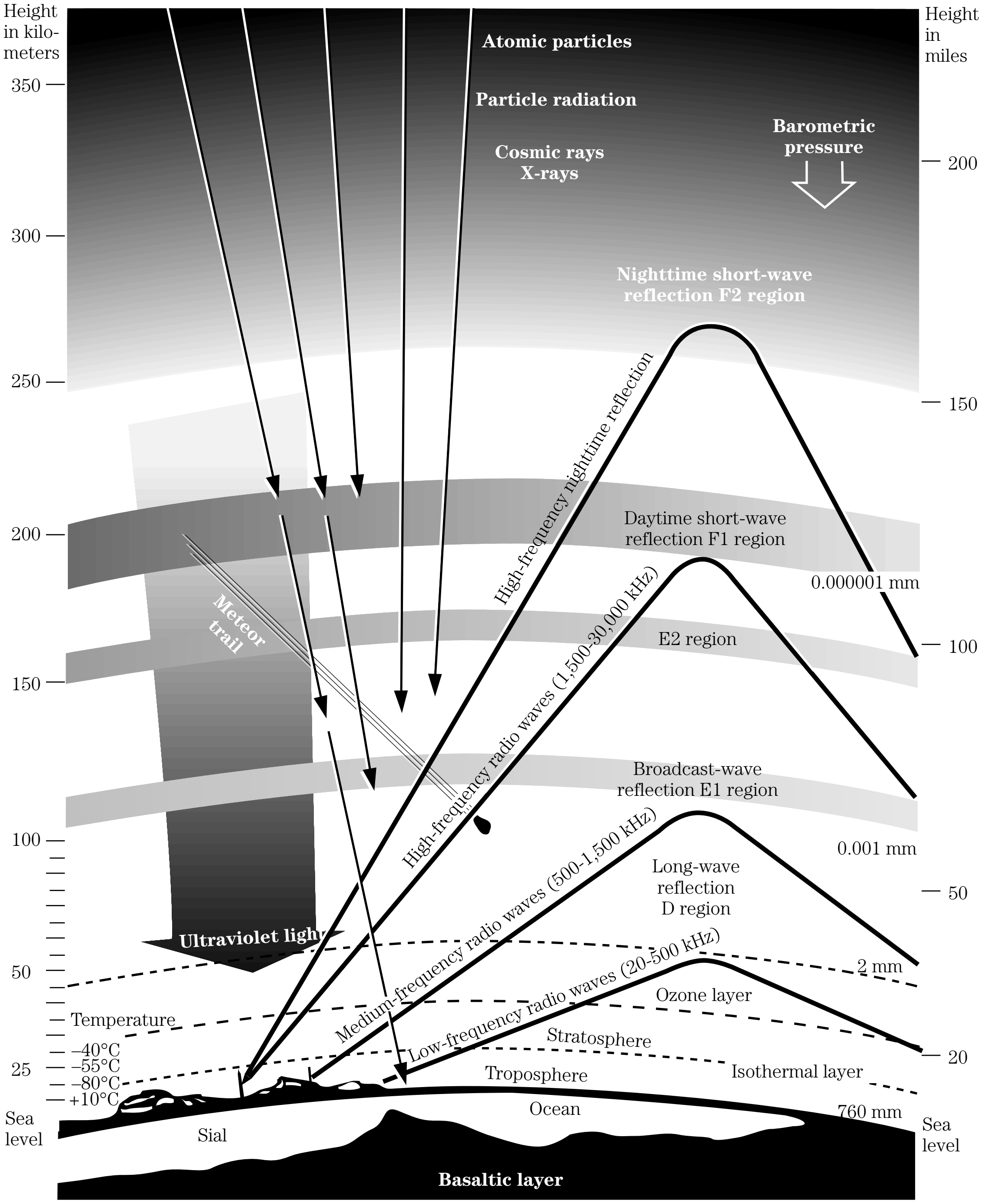
Height in kilometers
350
300
250
200
150
100
50
25
Sea level
Height in miles
200
150
100
50
20
Sea level
Atomic particles
Particle radiation
Cosmic rays
X-rays
Barometric pressure
Nighttime short-wave reflection F2 region
High-frequency nighttime reflection
Daytime short-wave reflection F1 region
0.000001 mm
Meteor trail
E2 region
High-frequency radio waves (1,500-30,000 kHz)
Broadcast-wave reflection E1 region
0.001 mm
Long-wave reflection D region
Ultraviolet light
Medium-frequency radio waves (500-1,500 kHz)
Low-frequency radio waves (20-500 kHz)
2 mm
Ozone layer
Temperature
−40°C
−55°C
−80°C
+10°C
Stratosphere
Isothermal layer
Troposphere
Ocean
760 mm
Sial
Basaltic layer

2-7 Radio propagation in the ionosphere is affected by a number of different physical factors: cosmic rays, atomic particles, solar radiation.

daylight hours, but the ionization begins to fall off rapidly after sunset, altering the radio propagation characteristics after dark. The ionization does not occur at lower altitudes because the air density is such that the positive and negative ions are numerous and close together, so recombination occurs rapidly.

EM wave propagation phenomena

Because EM waves are waves, they behave in a wave-like manner. Figure 2-8 illustrates some of the wave behavior phenomena associated with light and radio waves: *reflection, refraction*, and *diffraction*. All three play roles in radio propagation.

Reflection and refraction are shown in Fig. 2-8A. Reflection occurs when a wave strikes a denser reflective medium, as when a light wave strikes a glass mirror. The incident wave (shown as a single ray) strikes the interface between less dense and more dense mediums at a certain *angle of incidence* (a_i), and is reflected at exactly the same angle (now called the *angle of reflection* (a_r). Because these angles are equal, a reflected radio signal can often be traced back to its origin.

Refraction occurs when the incident wave enters a region of different density, and thereby undergoes both a velocity change and a directional change. The amount and direction of the change are determined by the ratio of the densities between the two media. If Zone B is much different from Zone A, then bending is great. In radio

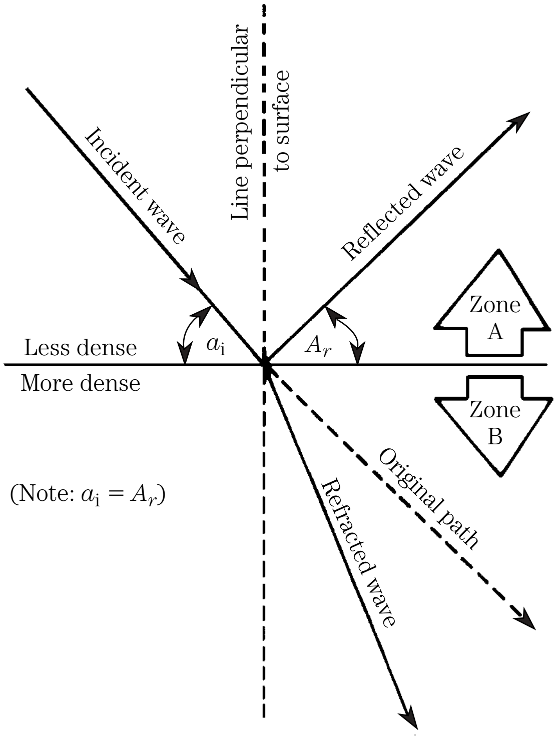

2-8A Reflection and refraction phenomena.

systems, the two media might be different layers of air with different densities. It is possible for both reflection and refraction to occur in the same system. Indeed, more than one form of refraction might be present. These topics will be covered in greater depth shortly.

Diffraction is shown in Fig. 2-8B. In this case, an advancing wavefront encounters an opaque object (e.g., a steel building). The shadow zone behind the building is not simply perpendicular to the wave, but takes on a cone shape as waves bend around the object. The "umbra region" (or diffraction zone) between the shadow zone ("cone of silence") and the direct propagation zone is a region of weak (but not zero) signal strength. In practical situations, signal strength in the cone of silence rarely reaches zero. A certain amount of reflected signals scattered from other sources will fill in the shadow a little bit. The degree of diffraction effect seen in any given case is a function of the wavelength of the signal, the size of the object, and its electromagnetic properties.

Propagation paths

There are four major propagation paths: *surface wave*, *space wave*, *tropospheric,* and *ionospheric*. The ionospheric path is important to medium-wave (MW) and HF propagation, but is not important to VHF, UHF, or microwave propagation. The space wave and surface wave are both *ground waves*, but they behave differently enough to warrant separate consideration. The surface wave travels in direct contact with the earth's surface and it suffers a severe frequency-dependent attenuation caused by absorption into the ground.

The space wave is also a ground-wave phenomenon, but it is radiated from an antenna many wavelengths above the surface. No part of the space wave normally travels in contact with the surface; VHF, UHF, and microwave signals are usually space waves. There are, however, two components of the space wave in many cases: *direct* and *reflected* (see Fig. 2-9).

The tropospheric wave is lumped with the direct space wave in some texts, but it has properties that actually make it different in practical situations. The troposphere

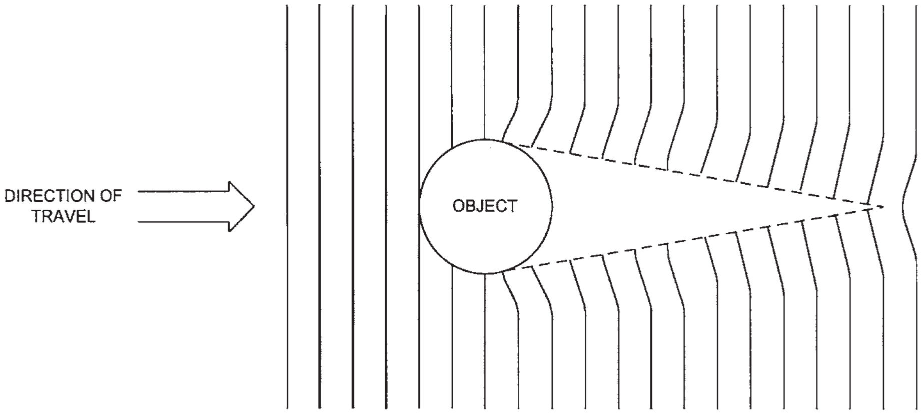

2-8B Diffraction phenomena.

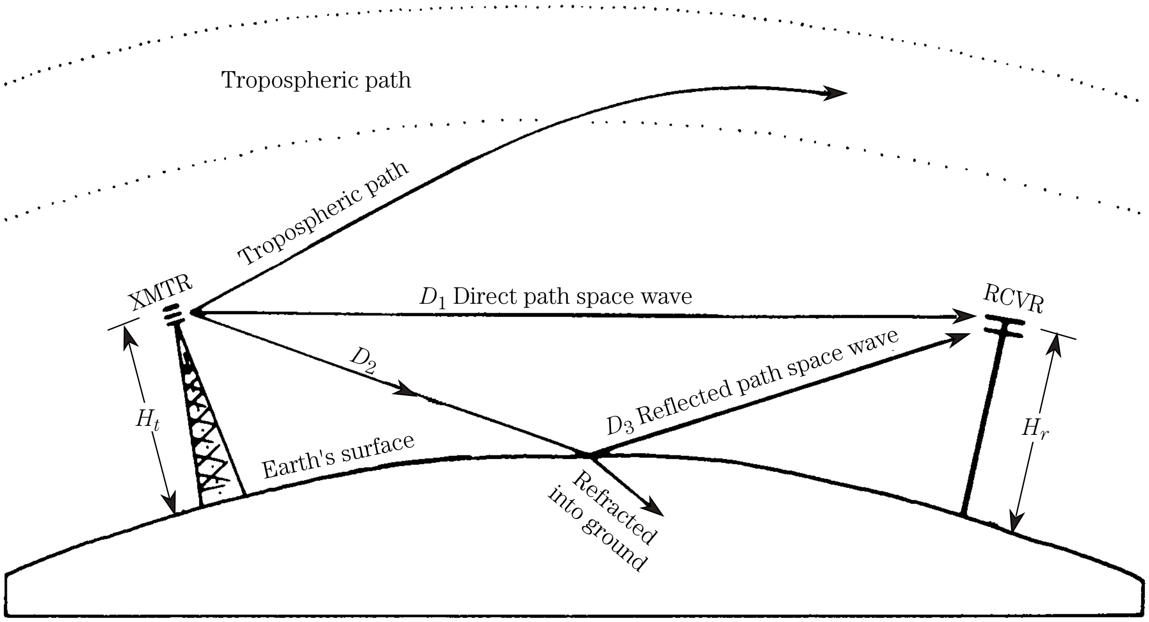

2-9 Space wave propagation.

is the region of earth's atmosphere between the surface and the stratosphere, or about 4 to 7 mi above the surface. Thus, most forms of ground wave propagate in the troposphere. But because certain propagation phenomena (caused mostly by weather conditions) only occur at higher altitudes, tropospheric propagation should be differentiated from other forms of ground wave.

The ionosphere is the region of earth's atmosphere that is above the stratosphere. The peculiar feature of the ionosphere is that molecules of air gas (O_2 and N) can be ionized by stripping away electrons under the influence of solar radiation and certain other sources of energy. In the ionosphere, the air density is so low that ions can travel relatively long distances before recombining with oppositely charged ions to form electrically neutral atoms. As a result, the ionosphere remains ionized for long periods of the day—even after sunset. At lower altitudes, however, air density is greater and recombination thus occurs rapidly. At those altitudes, solar ionization diminishes to nearly zero immediately after sunset, or never achieves any significant levels even at local noon.

Ionization and recombination phenomena in the ionosphere add to the noise level experienced at VHF, UHF, and microwave frequencies. The properties of the ionosphere are important to microwave technology because of the noise contribution. In satellite communications, there are some additional transionospheric effects.

Ground-wave propagation

The *ground wave*, naturally enough, travels along the ground, or at least in close proximity to it. There are three basic forms of ground wave: *space wave*, *surface* *wave*, and *tropospheric wave*. The space wave does not actually touch the ground. As a result, space wave attenuation with distance in clear weather is about the same as in free space (except above about 10 GHz, where H_2O and O_2 absorption increases dramatically). Of course, above the VHF region, weather conditions add attenuation not found in outer space.

The surface wave is subject to the same attenuation factors as the space wave, but in addition it also suffers ground losses. These losses are caused by ohmic resistive losses in the conductive earth. In other words, the signal heats up the ground. Surface wave attenuation is a function of frequency, and it increases rapidly as frequency increases. Both of these forms of ground-wave communications are affected by the following factors: wavelength, height of both the receiving and transmitting antennas, distance between the antennas, and the terrain and weather along the transmission path. Figure 2-10 is a nomograph that can be used to calculate the line of sight distances in miles from a knowledge of the receiver and transmitter antenna heights. Similarly, Figs. 2-11A and 2-11B show power attenuation with frequency and distance (Fig. 2-11A) and power attenuation in terms of field intensity (Fig. 2-11B).

Ground-wave communications also suffer another difficulty, especially at VHF, UHF, and microwave frequencies. The space wave is like a surface wave, but it is radiated many wavelengths above the surface. It is made up of two components (see Fig. 2-9 again): the *direct* and *reflected* waves. If both of these components arrive at the receiving antenna, they will add algebraically to either increase or decrease signal strength. There is always a phase shift between the two components because the two signal paths have different lengths (i.e., D_1 is less than $D_2 + D_3$). In addition, there may possibly be a 180° (π radians) phase reversal at the point of reflection (especially if the incident signal is horizontally polarized), as in Fig. 2-12. The following general rules apply in these situations:

- A phase shift of an odd number of half wavelengths causes the components to add, increasing signal strength (*constructive interference*).
- A phase shift of an even number of half wavelengths causes the components to subtract (Fig. 2-12), thus reducing signal strength (*destructive interference*).
- Phase shifts other than half wavelength add or subtract according to relative polarity and amplitude.

You can characterize the loss of signal over path D_1 with a parametric term n that is defined as follows:

$$n = \frac{S_r}{S_f} \qquad \textbf{[2.11]}$$

where

n is the signal loss coefficient
S_r is the signal level at the receiver in the presence of a ground reflection component
S_f is the free-space signal strength over path D_1 if no reflection took place.

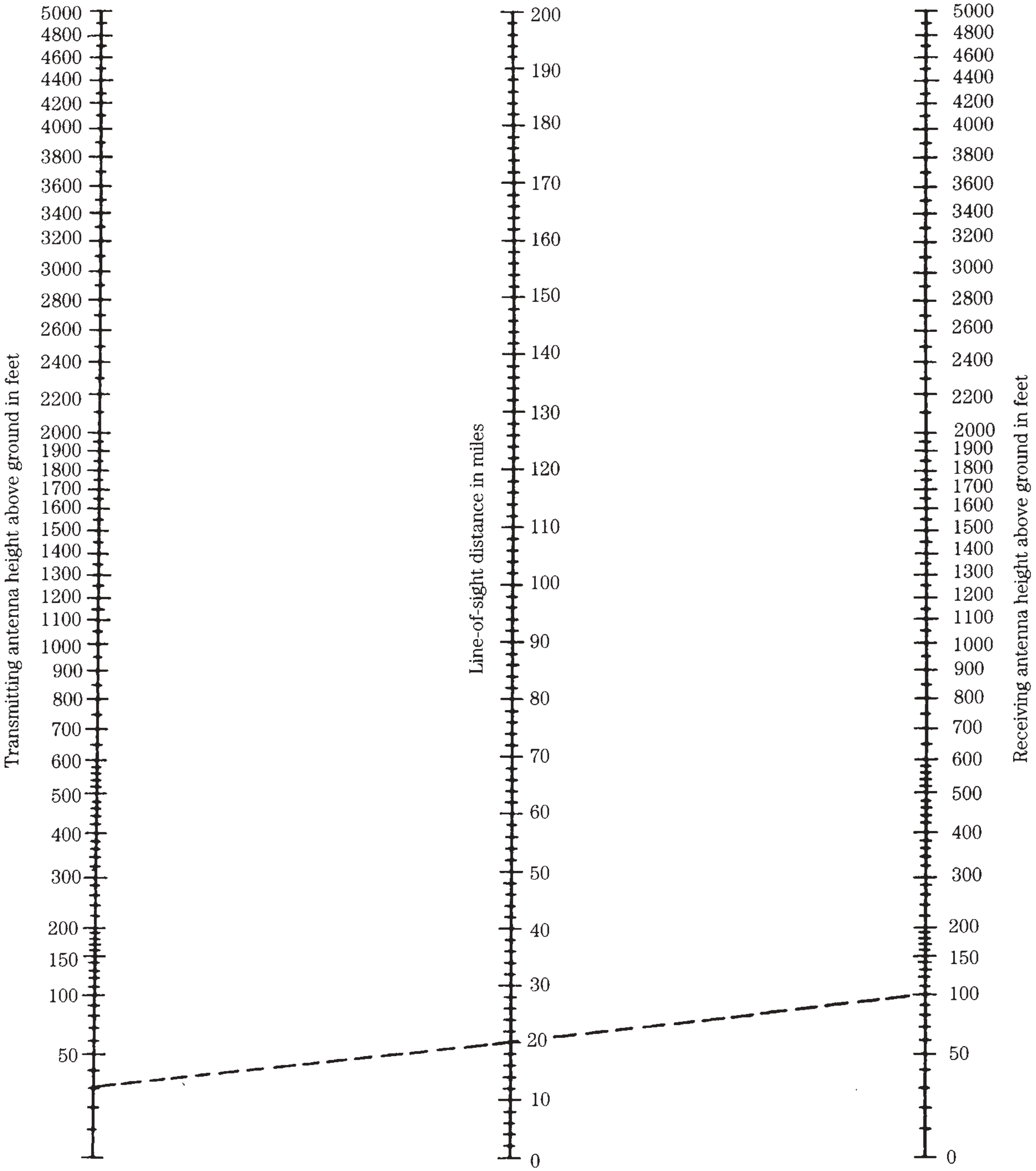

2-10 Nomograph showing the line-of-sight transmission distance as a function of receiving and transmitting antenna heights.

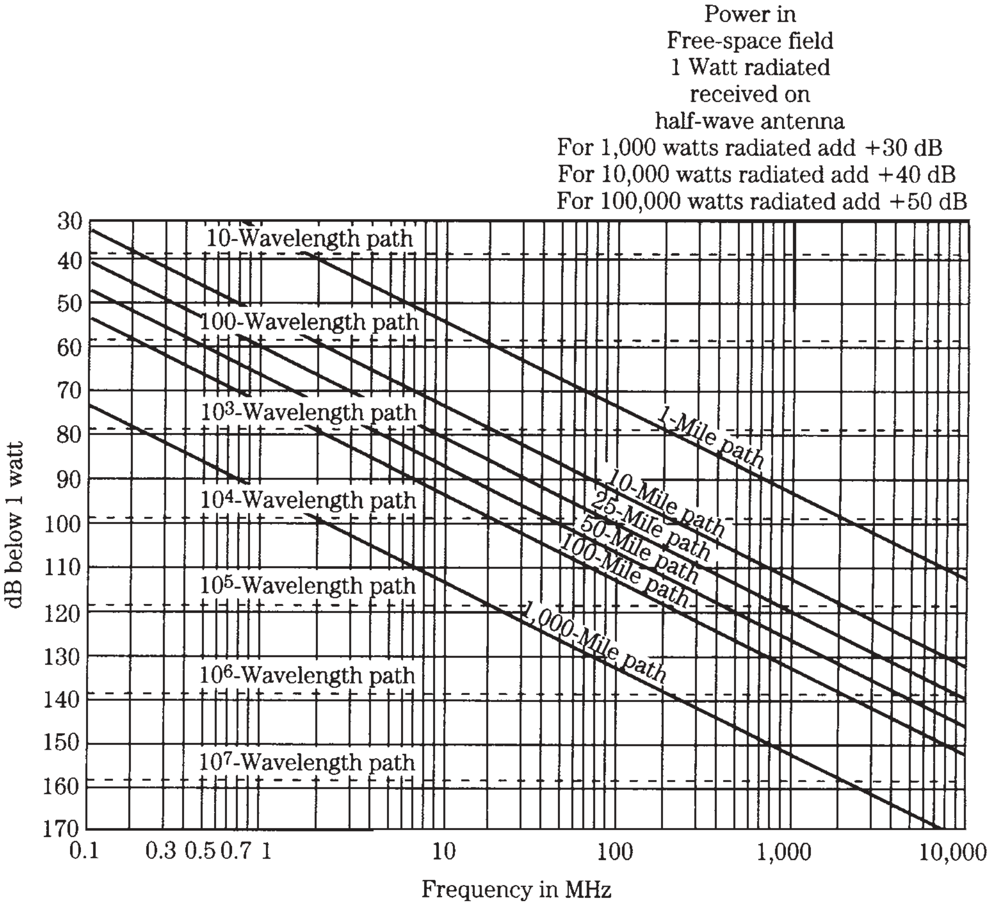

2-11A Power in a free-space field (normalized to 1 W).

You can calculate as follows:

$$n^2 = 4 \sin^2\left(\frac{2\pi h_t h_r}{\lambda D_1}\right) \qquad \textbf{[2.12]}$$

or

$$n = 2 \sin\left(\frac{2\pi h_t h_r}{\lambda D_1}\right) \qquad \textbf{[2.13]}$$

The reflected signal contains both amplitude change and phase change. The phase change is typically π radians (180°). The amplitude change is a function of frequency and the nature of the reflecting surface. The *reflection coefficient* can be characterized as

$$\gamma = pe^{j\phi} \qquad \textbf{[2.14]}$$

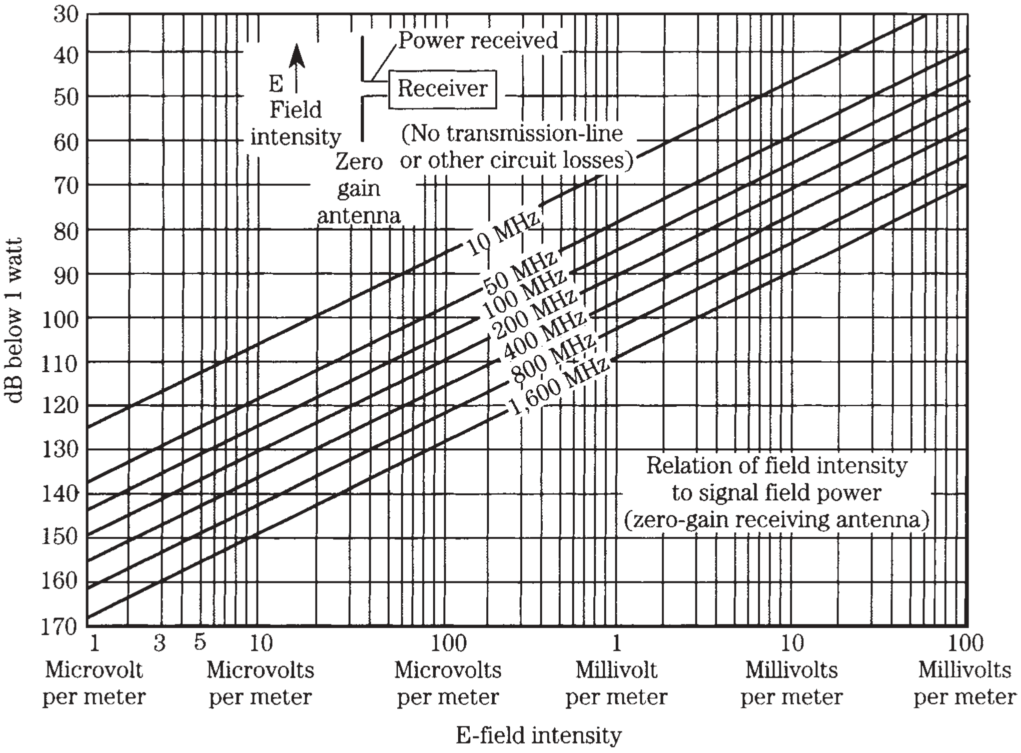

2-11B Relation of field strength to signal field power.

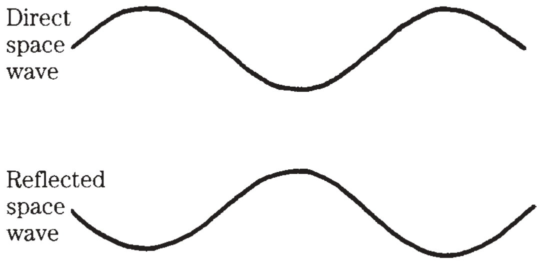

2-12 Out-of-phase waves cancel.

where

γ is the reflection coefficient
p is the amplitude change
ϕ is the phase change
j is the imaginary operator ($\sqrt{-1}$)

For smooth, high-reflectivity surfaces and a horizontally polarized microwave signal that has a shallow angle of incidence, the value of the reflection coefficient is close to –1.

The phase change of the reflected signal at the receiving antenna is at least π radians because of the reflection. Added to this change is an additional phase shift that is a function of the difference in path lengths. This phase shift can be expressed in terms of the two antenna heights and path length.

$$s = \pi + \left(\frac{4\pi h_t h_r}{\lambda D_1}\right) \qquad \textbf{[2.15]}$$

A category of reception problems called *multipath phenomena* exists because of interference between the direct and reflected components of the space wave. The form of multipath phenomena that is, perhaps, most familiar to many readers is ghosting in off-the-air television reception. Some multipath events are transitory in nature (as when an aircraft flies through the transmission path), while others are permanent (as when a large building, or hill, reflects the signal). In mobile communications, multipath phenomena are responsible for reception dead zones and "picket fencing." A *dead zone* exists when destructive interference between direct and reflected (or multiply reflected) waves drastically reduces signal strengths. This problem is most often noticed at VHF and above when the vehicle is stopped; and the solution is to move the antenna one-half wavelength (which at VHF and UHF is a matter of a few inches). *Picket fencing* occurs as a mobile unit moves through successive dead zones and signal enhancement (or normal) zones, and it sounds like a series of short noise bursts.

At VHF, UHF, and microwave frequencies, the space wave is limited to so-called line-of-sight distances. The horizon is theoretically the limit of communications distance, but the radio horizon is actually about 15 percent farther than the optical horizon (Fig. 2-13). This phenomenon is caused by refractive bending in the atmosphere around the curvature of the earth, and it makes the geometry of the situation look as if the earth's radius is $\frac{4}{3}$ the actual radius.

The refraction phenomenon occurs at VHF through microwave frequencies, but not in the visible light spectrum, because water and atmospheric pressure (which relates to the effects of atmospheric gases on microwave signals) become important contributors to the phenomenon. The *K factor* expresses the degree of curvature along any given path, while the *index of refraction n* measures the differential properties between adjacent zones of air.

The *K* factor, also called the *effective earth's radius factor*, is defined according to the relationship of two hypothetical spheres, both centered at the exact center of

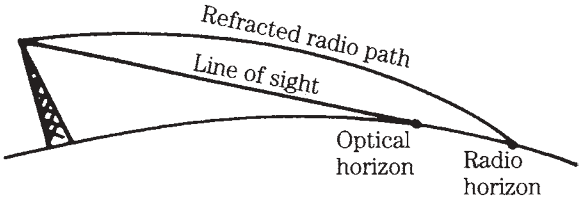

2-13 Phenomenon by which "greater than line of sight" communications occurs.

the earth. The first sphere is the earth's surface, which has a radius r_o (3440 nmi or 6370 km). The second sphere is larger than the first by the curvature of the signal "ray path," and has a radius r. The value of K is approximately

$$K = \frac{r}{r_o} \tag{2.16}$$

A value of $K = 1$ indicates a straight path (Fig. 2-14); a value of $K > 1$ indicates a positively curved path (refraction); and a value of $K < 1$ indicates a negatively curved path (subrefraction). The actual value of K varies with local weather conditions, so one can expect variation not only between locations, but also seasonally. In the arctic regions, K varies approximately over the range 1.2 to 1.34. In the "lower 48" states of the United States, K varies from 1.25 to 1.9 during the summer months (especially in the south and southeast), and from 1.25 to 1.45 in the winter months. The index of refraction n can be defined in two ways, depending on the situation. When a signal passes across boundaries between adjacent regions of distinctly different properties (as occurs in temperature inversions, etc.), the index of refraction is the ratio of the signal velocities in the two regions. In a homogeneous region n can be expressed as the ratio of the free-space velocity c to the actual velocity in the atmosphere V:

$$n = \frac{c}{V} \tag{2.17}$$

At the surface, near sea level, under standard temperature and pressure conditions, the value of n is approximately 1.0003, and in homogeneous atmospheres it will decrease by 4×10^{-8} per mile of altitude. The units of n are a bit cumbersome in equations, so the UHF/microwave communities tend to use a derivative parameter, N, called the *refractivity of the atmosphere*:

$$N = (n - 1) \times 10^6 \tag{2.18}$$

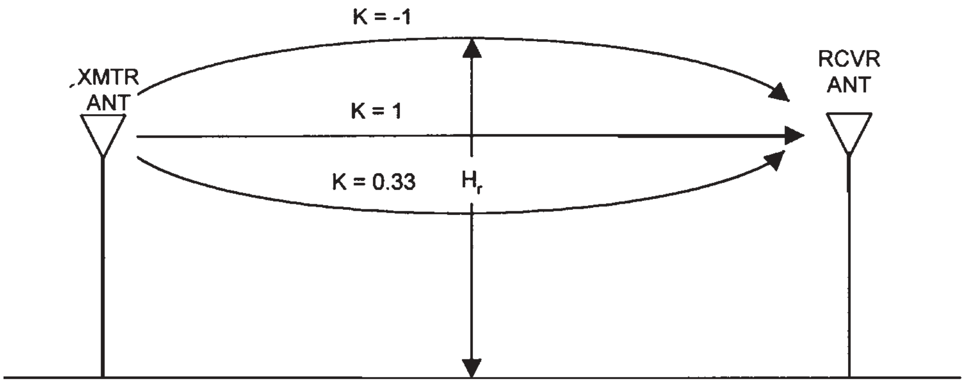

2-14 Refraction changes path length.

The value of N tends to vary from about 280 to 320, and both n and N vary with altitude. In nonhomogeneous atmospheres (the usual case), these parameters will vary approximately linearly for several tenths of a kilometer. All but a few microwave relay systems can assume an approximately linear reduction of n and N with increasing altitude, although airborne radios and radars cannot. There are two methods for calculating N:

$$N = \left(\frac{77.6}{T}\right)\left(P + \frac{4810 e_s H_{\text{rel}}}{T}\right) \tag{2.19}$$

and

$$N = \frac{77.6}{T}\left(\frac{3.73 \times 10^5 e_s}{T^2}\right) \tag{2.20}$$

where

P is the atmospheric pressure in millibars (1 torr = 1.3332 mbar)
T is temperature in kelvins
e_s is saturation vapor pressure of atmospheric water in millibars
H_{rel} is the relative humidity expressed as a decimal fraction (rather than a percentage)

Ray path curvature (K) can be expressed as a function of either n or N, provided that the assumption of a linear gradient d_n/d_h holds true:

$$K = \frac{1}{\left(1 + \frac{r_o d_n}{d_h}\right)} \tag{2.21}$$

or

$$K = \frac{1}{\left(1 + \frac{d_N/d_h}{157}\right)} \tag{2.22}$$

For the near-surface region, where d_n/d_h varies at about 3.9×10^{-8} m, the value of K is 1.33. For most terrestrial microwave paths, this value ($K = 4/3 = 1.33$) is called a *standard refraction*, and is used in calculations *in the absence of additional data*. For regions above the linear zone close to the surface, you can use another expression of refractivity:

$$N_a = N_s e^{-C_e(h_r - h_t)} \tag{2.23}$$

where

N_1 is the refractivity at 1 km altitude
h_r is the height of the receiver antenna
h_t is the height of the transmit antenna

$C_e = L_n(N_s/N_1)$
N_a is the refractivity at altitude
N_s is the refractivity at the earth's surface

For simple models close to the surface, you can use the geometry shown in Fig. 2-15. Distance d is a curved path along the surface of the earth. But because the earth's radius r_o is about 4000 statute miles, and it is thus very much larger than a practical antenna height h, you can simplify the model in Fig. 2-15A to that in Fig. 2-15B. The underlying assumption is that the earth has a radio radius equal to about $4/3$ ($K = 1.33$) of the actual physical radius of its surface.

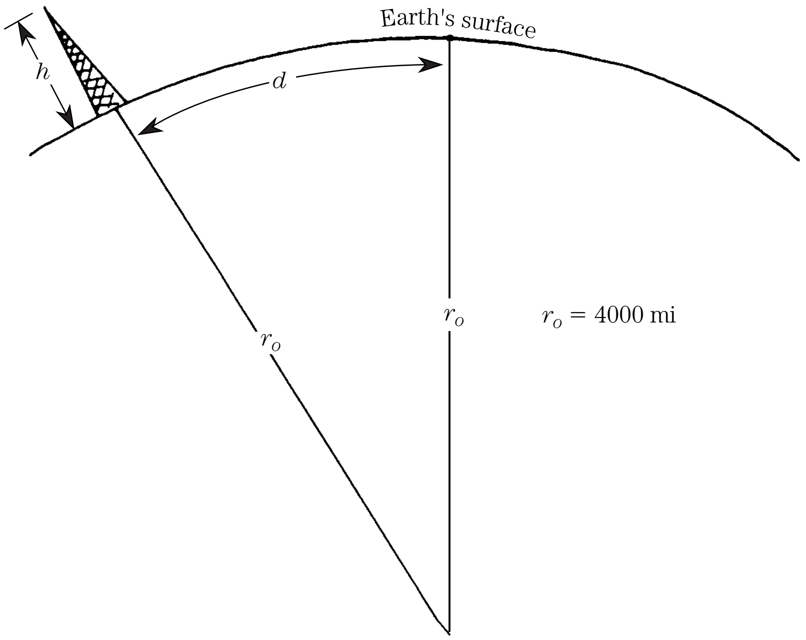

2-15A Geometry for calculating radio distances.

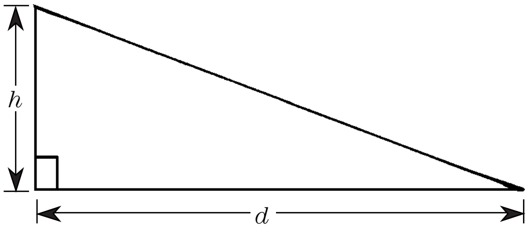

2-15B Simplified geometry.

The value of distance d is found from the expression

$$d = \sqrt{2 r_c h_{\mathrm{ft}}} \tag{2.24}$$

where

d is the distance to the radio horizon in statute miles
r_o is the normalized radius of the earth
h_{ft} is the antenna height in feet

Accounting for all constant factors, the expression reduces to

$$d = 1.414 \sqrt{h_{\mathrm{ft}}} \tag{2.25}$$

all factors being the same as defined above.

Example 2-1 A radio tower has a UHF radio antenna that is mounted 150 feet above the surface of the earth. Calculate the radio horizon (in statute miles) for this system.

Solution:

$$\begin{aligned} d &= 1.414\ (h_t)t \\ &= (1.414)(150\ \mathrm{ft})^{1/2} \\ &= (1.414)(12.25) \\ &= 17.32\ \mathrm{mi} \end{aligned}$$

For other units of measurement:

$$d_{\mathrm{nmi}} = 1.23 \sqrt{h_{\mathrm{ft}}} \quad \mathrm{nmi} \tag{2.26}$$

and

$$d_{\mathrm{km}} = 1.30 \sqrt{h_{\mathrm{ft}}} \quad \mathrm{km} \tag{2.27}$$

Surface-wave communications The surface wave travels in direct contact with the earth's surface, and it suffers a severe frequency-dependent attenuation because of absorption by the ground.

The surface wave extends to considerable heights above the ground level, although its intensity drops off rapidly at the upper end. The surface wave is subject to the same attenuation factors as the space wave, but in addition, it also suffers ground losses. These losses are caused by ohmic resistive losses in the conductive earth, and to the dielectric properties of the earth. In other words, the signal heats up the ground. Horizontally polarized waves are not often used for surface wave communications because the earth tends to short-circuit the E-field component. On vertically polarized waves, however, the earth offers electrical resistance to the E-field and returns currents to following waves (Fig. 2-16). The conductivity of the soil determines how much energy is returned. Table 2-1 shows the typical conductivity values for several different forms of soil.

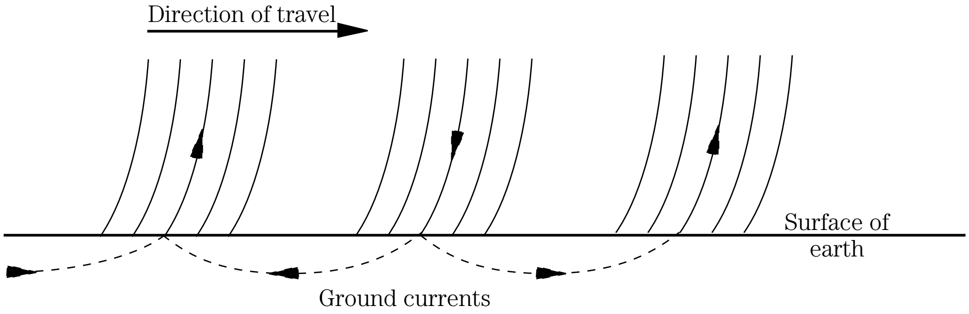

2-16 Distortion of vertically polarized electric field by lossy ground resistance.

Table 2-1. Sample soil conductivity values

Type of soil	Dielectric constant	Conductivity (siemens/meter)	Relative quality
Salt water	81	5	Best
Fresh water	80	0.001	Very poor
Pastoral hills	14–20	0.03–0.01	Very good
Marshy, wooded	12	0.0075	Average/poor
Rocky hills	12–14	10	Poor
Sandy	10	0.002	Poor
Cities	3–5	0.001	Very poor

The wavefront of a surface wave is tilted because of the losses in the ground that tend to retard the wavefront's bottom (also in Fig. 2-16). The tilt angle is a function of the frequency, as shown in Table 2-2.

Table 2-2. Tilt angle as a function of frequency

Frequency (kHz)	Tilt angle ratio	Earth/seawater (degrees)
20	2.07	4.3/2.08
200	104	13.4/0.13
2,000	64	32.3/0.5
20,000	25	35/1.38

Surface-wave attenuation is a function of frequency, and increases rapidly as frequency increases. For both forms of the ground wave, reception is affected by these factors: *wavelength, height* of both the receiving and transmitting antennas, *distance* between antennas, and both *terrain* and *weather* along the transmission path. In addition, the surface wave is affected by the ground losses in Table 2-1. Because of the ground loss effects, the surface wave is attenuated at a much faster rate than the inverse square law.

Ground-wave propagation frequency effects The frequency of a radio signal in large measure determines its surface-wave behavior. In the very low-frequency (VLF) band (<300 kHz), ground losses are small for vertically polarized signals, so medium-distance communications (up to several hundred miles) are possible. In the medium-wave band (300 to 3000 kHz, including the AM broadcast band), distances of 1000 mi are possible with regularity—especially at night. In the high-frequency (HF) band, ground losses are more considerable, so the surface-wave distance reduces drastically. It is possible, in the upper end of the HF band (3000 to 30,000 kHz) for surface-wave signals to die out within a few dozen miles. This phenomenon is often seen in the 15- and 10-m amateur radio bands, as well as the 11-m (27-MHz) Citizen's Band. Stations only 20 mi apart cannot communicate, but both can talk to a third station across the continent via ionospheric skip. Thus, the two stations close together must have a station more than 2000 mi away relay messages between them.

Tropospheric propagation The troposphere is the portion of the atmosphere between the surface of the earth and the stratosphere (or about 4 to 7 mi above the surface). Some older texts group tropospheric propagation with ground-wave propagation, but modern practice requires separate treatment. The older grouping overlooks certain common propagation phenomena that simply don't happen with space or surface waves.

Refraction is the mechanism for most tropospheric propagation phenomena. The dielectric properties of the air, which are set mostly by the moisture content (Fig. 2-17), are a primary factor in tropospheric refraction. Recall that refraction occurs in both light or radio-wave systems when the wave passes between mediums of differing density. Under that situation, the wave path will bend an amount proportional to the difference in density.

Two general situations are typically found—especially at UHF and microwave frequencies. First, because air density normally decreases with altitude, the top of a beam of radio waves typically travels slightly faster than the lower portion of the beam. As a result, those signals refract a small amount. Such propagation provides slightly longer surface distances than are normally expected from calculating the distance to the radio horizon. This phenomenon is called *simple refraction*, and was discussed in a preceding section.

A special case of refraction called *superrefraction* occurs in areas of the world where warmed land air goes out over a cooler sea (Fig. 2-18). Examples of such areas have deserts that are adjacent to a large body of water: the Gulf of Aden, the southern Mediterranean, and the Pacific Ocean off the coast of Baja California are examples. VHF/UHF/microwave communications up to 200 mi are reported in such areas.

The second form of refraction is weather-related. Called *ducting*, this form of propagation (Fig. 2-19) is actually a special case of superrefraction. Evaporation of sea water causes temperature inversion regions to form in the atmosphere—that is, layered air masses in which the air temperature is greater than in the layers below it. (*Note*: air temperature normally decreases with altitude, but at the boundary with an

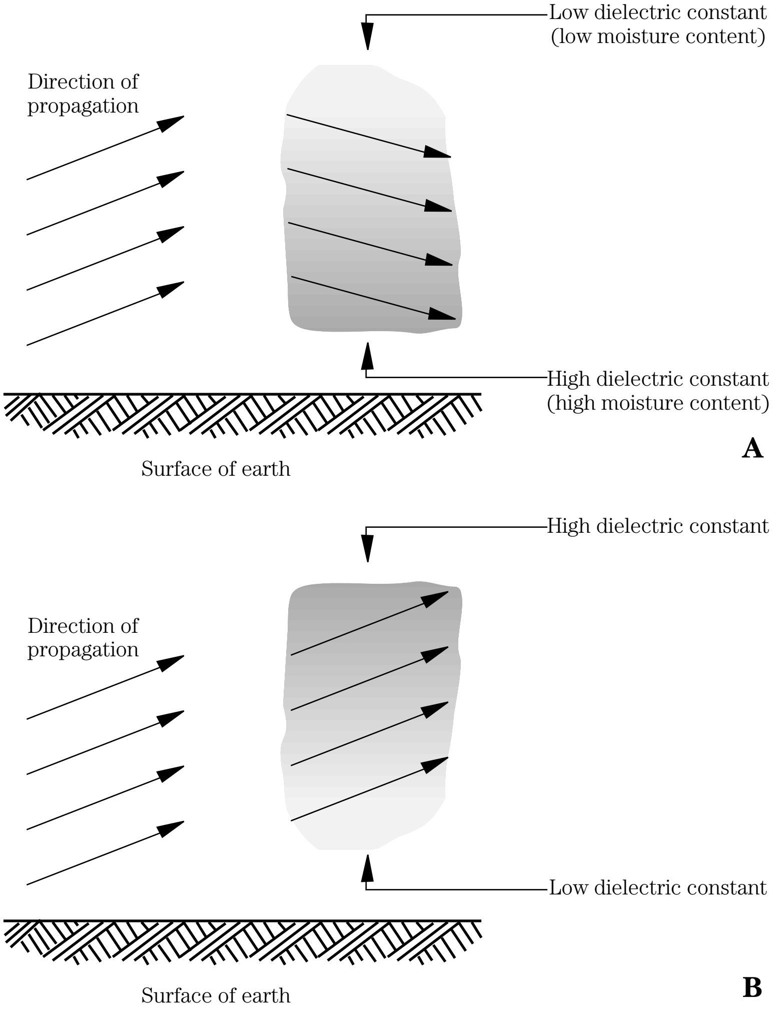
Low dielectric constant
(low moisture content)
Direction of propagation
High dielectric constant
(high moisture content)
Surface of earth
A
High dielectric constant
Direction of propagation
Low dielectric constant
Surface of earth
B

2-17 Refraction in the troposphere.

inversion region, it increases.) The inversion layer forms a "duct" that acts like a waveguide. In Fig. 2-19, the distance D_1 is the normal "radio horizon" distance, and D_2 is the distance over which duct communications can occur.

Ducting allows long-distance communications from lower VHF through microwave frequencies, with 50 MHz being a lower practical limit and 10 GHz being an ill-defined upper limit. Airborne operators of radio, radar, and other electronic equipment can sometimes note ducting at even higher microwave frequencies.

Antenna placement is critical for ducting propagation. Both the receiving and transmitting antennas must be either (1) inside the duct physically (as in airborne cases) or (2) able to propagate at an angle such that the signal gets trapped inside the duct. The latter is a function of antenna radiation angle. Distances up to 2500 mi

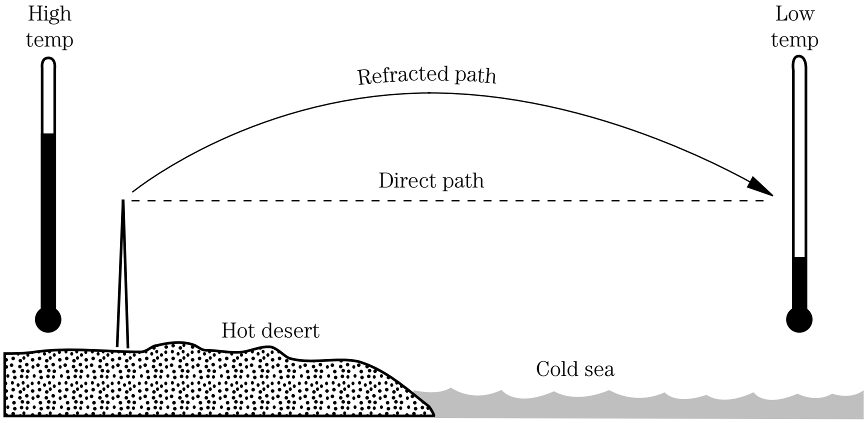
High temp
Low temp
Refracted path
Direct path
Hot desert
Cold sea

2-18 Superrefraction phenomena.

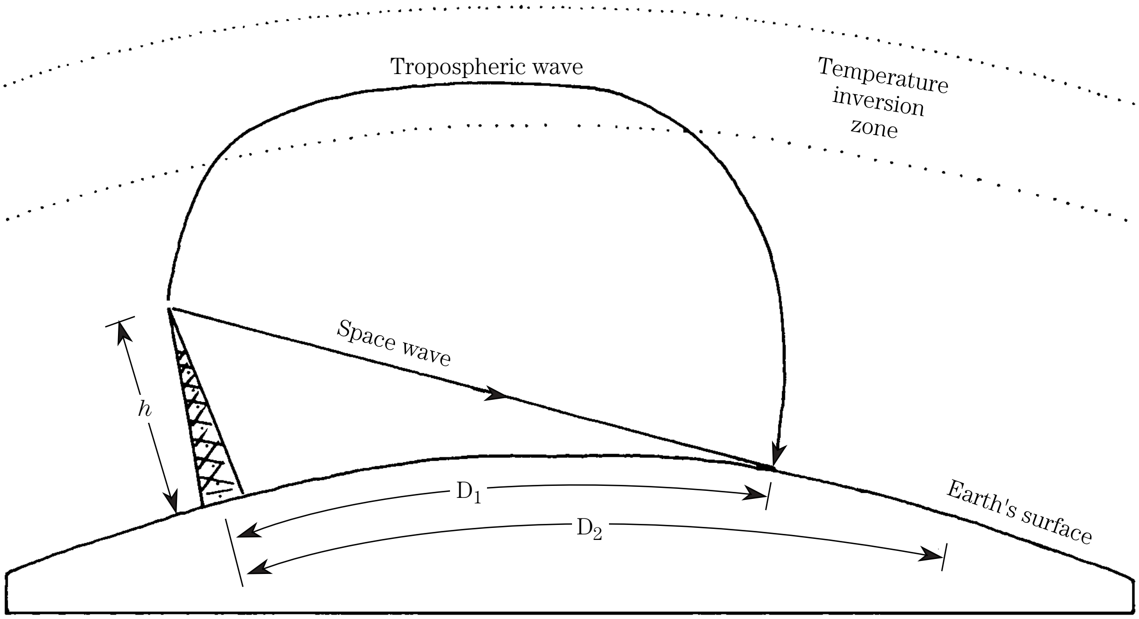
Tropospheric wave
Temperature inversion zone
Space wave
h
D$_1$
D$_2$
Earth's surface

2-19 Ducting phenomenon.

or so are possible through ducting. Certain paths where frequent ducting occurs have been identified: the Great Lakes to the Atlantic seaboard; Newfoundland to the Canary Islands; across the Gulf of Mexico from Florida to Texas; Newfoundland to the Carolinas; California to Hawaii; and Ascension Island to Brazil.

Another condition is noted in the polar regions, where colder air from the land mass flows out over warmer seas (Fig. 2-20). Called *subrefraction*, this phenomena bends EM waves away from the earth's surface—thereby *reducing* the radio horizon by about 30 to 40 percent.

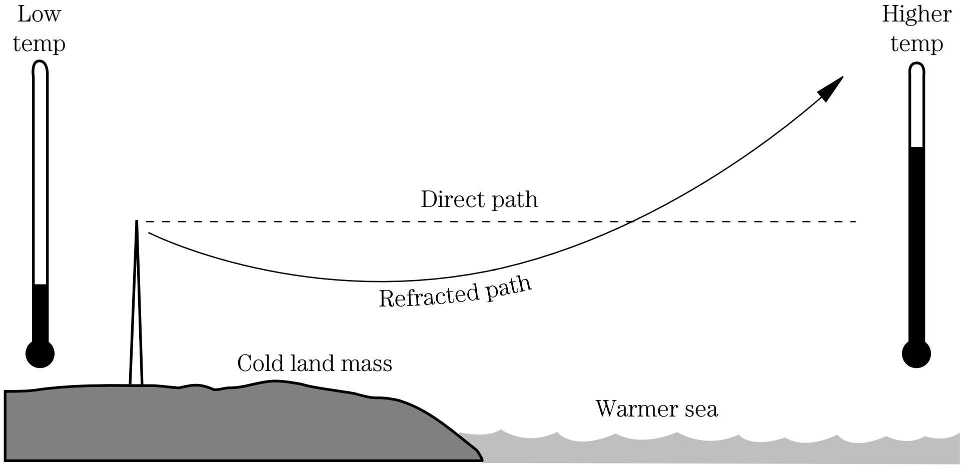

2-20 Subrefraction phenomena.

All tropospheric propagation that depends upon air-mass temperatures and humidity, shows diurnal (i.e., over the course of the day) variation caused by the local rising and setting of the sun. Distant signals may vary 20 dB in strength over a 24-hour period. These tropospheric phenomena explain how TV, FM broadcast, and other VHF signals can propagate great distances, especially along seacoast paths, at some times while being weak or nonexistent at others.

Diffraction phenomena Electromagnetic *waves* diffract when they encounter a radio-opaque object. The degree of diffraction, and the harm it causes, is frequency-related. Above 3 GHz, wavelengths are so small (approximately 10 cm) compared to object sizes that large attenuation of the signal occurs. In addition, beamwidths (a function of antenna size compared with wavelength) tend to be small enough above 3 GHz that blockage of propagation by obstacles is much greater.

Earlier in this chapter, large-scale diffraction around structures (such as buildings) was discussed. The view presented was from above, so it represented the horizontal plane. But there is also a diffraction phenomenon in the vertical plane. Terrain, or man-made objects, intervening in the path between UHF microwave stations (Fig. 2-21A) cause diffraction, and some signal attenuation. There is a minimum clearance required to prevent severe attenuation (up to 20 to 30 dB) from diffraction. Calculation of the required clearance comes from Huygens-Fresnel wave theory.

Consider Fig. 2-21B. A wave source A, which might be a transmitter antenna, transmits a wavefront to a destination C (receiver antenna). At any point along path A-C, you can look at the wavefront as a partial spherical surface (B_1-B_2) on which all wave rays have the same phase. This plane can be called an *isophase plane*. You can assume that the d_n/d_h refraction gradient over the height extent of the wavefront is small enough to be considered negligible.

Using ray tracing we see rays r_a incoming to plane [B_1-B_2], and rays r_b outgoing from plane [B_1-B_2]. The signal seen at C is the algebraic sum of all rays r_b. The signal pattern will have the form of an optical interference pattern with wave cancellation occurring between r_b waves that are a half-wavelength apart on [B_1-B_2]. The ray im-

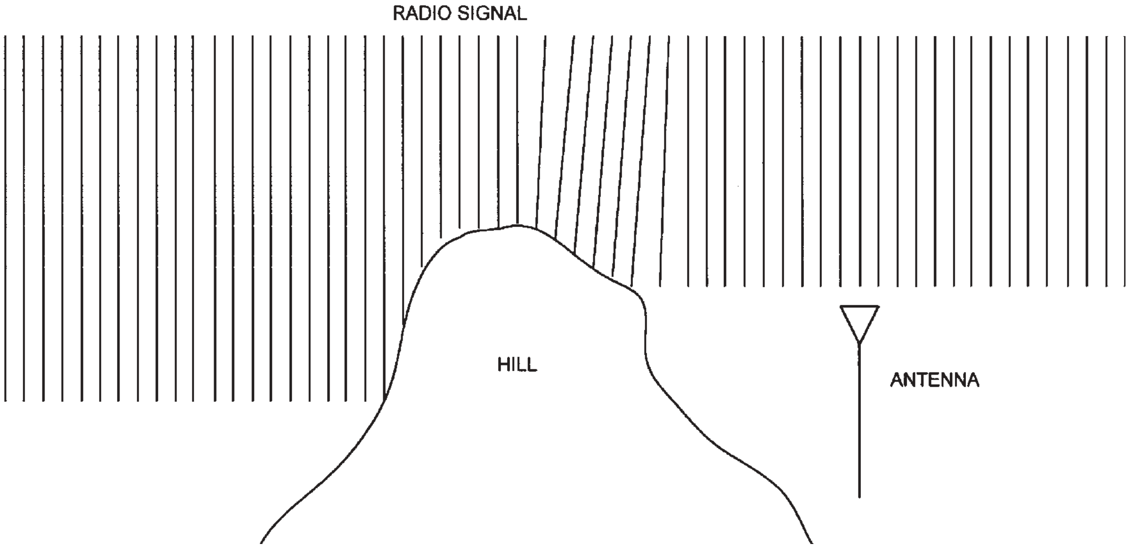

2-21A Terrain masking of VHF and higher-frequency signals.

pact points on plane [B_1-B_2] form radii R_n called *Fresnel zones*. The lengths of the radii are a function of the frequency and the ratio of the distances D_1 and D_2 (see Fig. 2-21B). The general expression is

$$R_n = M\sqrt{\frac{N}{F_{\text{GHz}}}\left(\frac{D_1D_2}{D_1 + D_2}\right)} \qquad \textbf{[2.28]}$$

where

R_m is the radius of the nth Fresnel zone
F_{GHz} is the frequency in GHz
D_1 is the distance from the source to plane B_1-B_2
D_2 is the distance from destination to plane B_1-B_2
N is an integer (1, 2, 3, . . .)
M a constant of proportionality equal to

17.3 if R_m is in meters and D_1, D_2 are in kilometers and

72.1 if R_m is in feet and D_1, D_2 are in statute miles

If you first calculate the radius of the critical first Fresnel zone (R_1), then you can calculate the nth Fresnel zone from

$$R_n = R_1\sqrt{n} \qquad \textbf{[2.29]}$$

Example 2-2 Calculate the radius of the first Fresnel zone for a 2.5-GHz signal at a point that is 12 km from the source and 18 km from the destination.

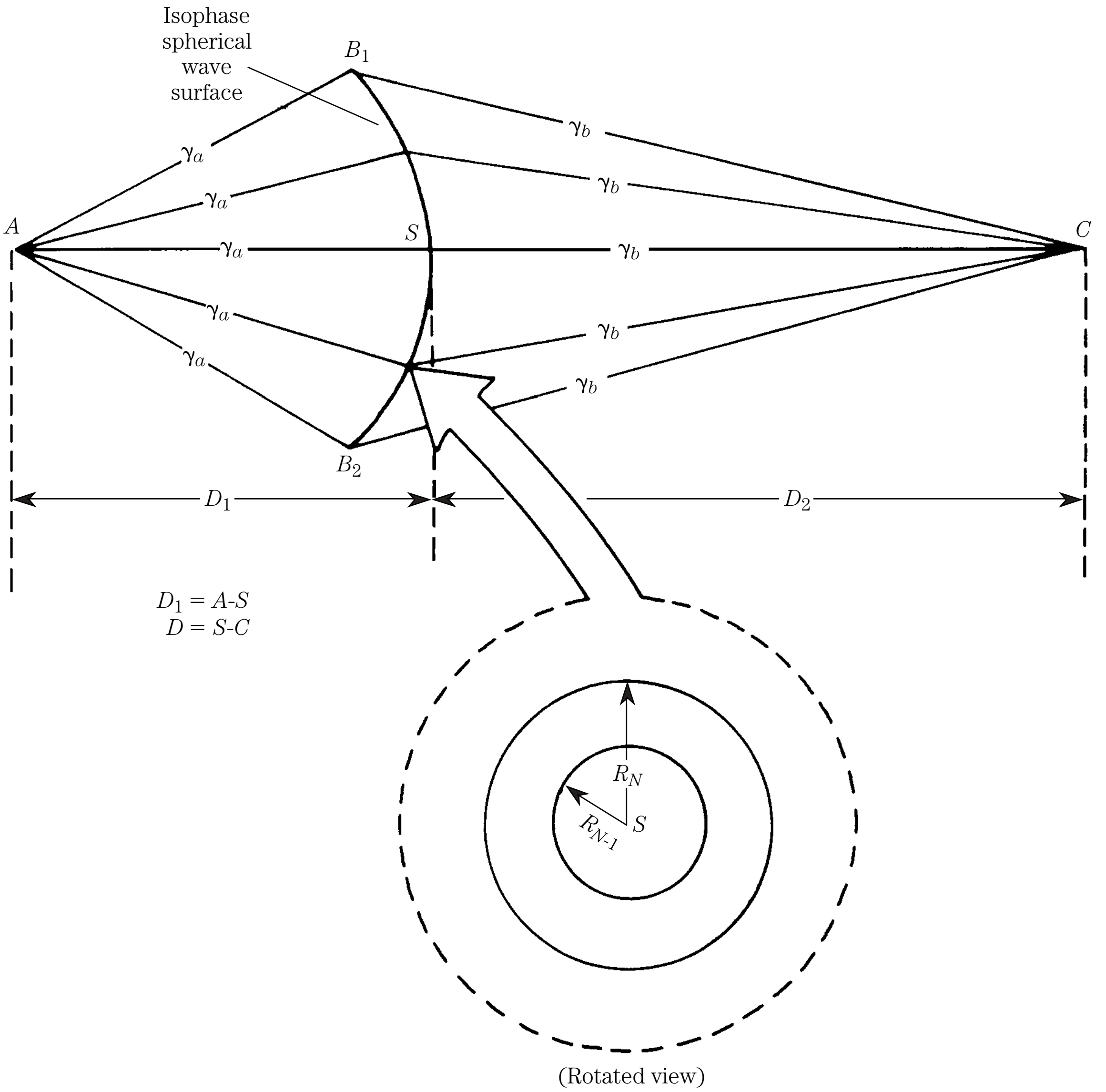
Isophase spherical wave surface
B_1
γ_a
γ_b
A
S
C
B_2
D_1
D_2
$D_1 = A\text{-}S$
$D = S\text{-}C$
R_N
$R_{N\text{-}1}$
S
(Rotated view)

2-21B Fresnel zone geometry.

Solution:

$$R_1 = M\sqrt{\frac{N}{F_{\text{GHz}}}\left(\frac{D_1 D_2}{D_1 + D_2}\right)}$$

$$R_1 = (17.3)\sqrt{\frac{1}{2.5}\left(\frac{12 \times 18}{12 + 18}\right)}$$

$$R_t = (17.3)\sqrt{(0.4)\ (7.2)}$$

$$R_1 = (17.3)\ (2.88) = 29.4\text{ m}$$

For most terrestrial microwave systems an obstacle clearance of $0.6R_1$ is required to prevent diffraction attenuation under most normal conditions. However, there are conditions in which the clearance zone should be more than one Fresnel zone.

Fading mechanisms Fading is defined as a reduction in amplitude caused by reduced received signal power, changes in phase or polarization, wave cancellation, or other related problems that are not caused by a change in the output power level or other parameters associated with either the transmitter or its antenna system. You would not ordinarily think that line-of-sight radio relay links would experience fading, but that is not true. Fading does, in fact, occur, and it can reach levels of 30 dB in some cases (20 dB is relatively common). In addition, fading phenomena in the VHF-and-up range can last several hours, with some periods being reported of several days in duration (although very rare). There are several mechanisms of fading, and these will be dealt with in this section. HF fading caused by ionospheric mechanisms will be covered later.

Any or all of the mechanisms shown in Fig. 2-22 can occur in a given system. In all cases, two or more signals arrive at the receiver antenna (R_x). Ray *A* represents the direct path signal that is, ideally, the only signal to reach the destination. But it is also possible that a signal, in an elevated layer or other atmospheric anomaly, will cause refraction or subrefraction of the wave creating a second component, *B*. If this second signal arrives out of phase with *A*, then fading will occur (signal reinforcement—

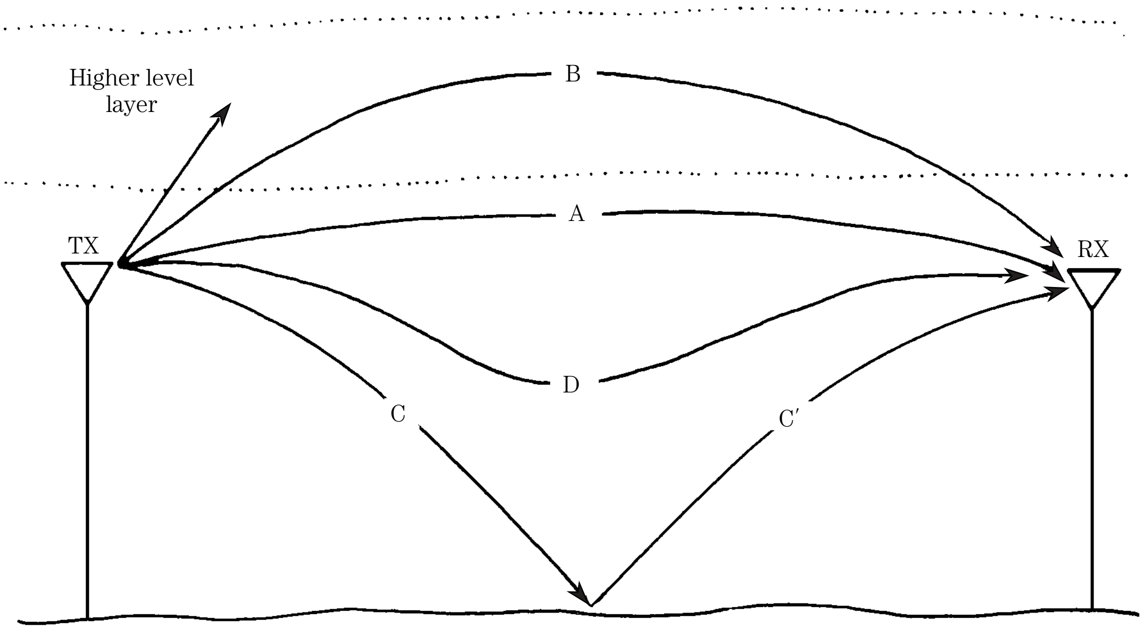

2-22 Multiple paths for signal to take between transmitter and receiver.

in phase—can also occur). It is also possible to see subrefraction fading, as in D. The classical multipath situation represented by ray C and its reflected component C' is also a source of fading.

These mechanisms are frequency-sensitive, so a possible countermeasure is to use *frequency diversity*. Hopping over a 5 percent frequency change will help eliminate fading in many cases. In cases where either system constraints, or local spectrum usage prevents a 5 percent delta (change), then try for at least 2 or 3 percent.

Over ocean areas or other large bodies of water there is a possibility of encountering fair weather surface ducting as a cause of fading. These ducts form in the mid latitudes, starting about 2 to 3 km from shore, up to heights of 10 to 20 mi; wind velocities are found in the 10 to 60 km/h range. The cause of the problem is a combination of power fading, due to the presence of the duct, and surface reflections (see Fig. 2-23). Power fading alone can occur when there is a superrefractive duct elevated above the surface. The duct has a tendency to act as a waveguide and focus the signal (Fig. 2-24). Although the duct shown is superrefractive, it is also possible to have a subrefractive duct.

Attenuation in weather Microwave communications above about 10 GHz suffer an increasingly severe attenuation because of water vapor and oxygen in the atmosphere. Figure 2-25 shows the standard attenuation in dB/km for microwave frequencies. Note that there are several strong peaks in an ever-increasing curve. Setting a system frequency in these regions will cause poor communications or will require a combination of more transmit power, better receiver sensitivity, and better antennas on receiving and transmitting locations. The curves shown in Fig. 2-25 assume certain standardizing conditions. Rain and other weather conditions can severely increase the attenuation of signals. In addition to attenuation, radar exhibits severe clutter problems when signals backscatter from rain cells.

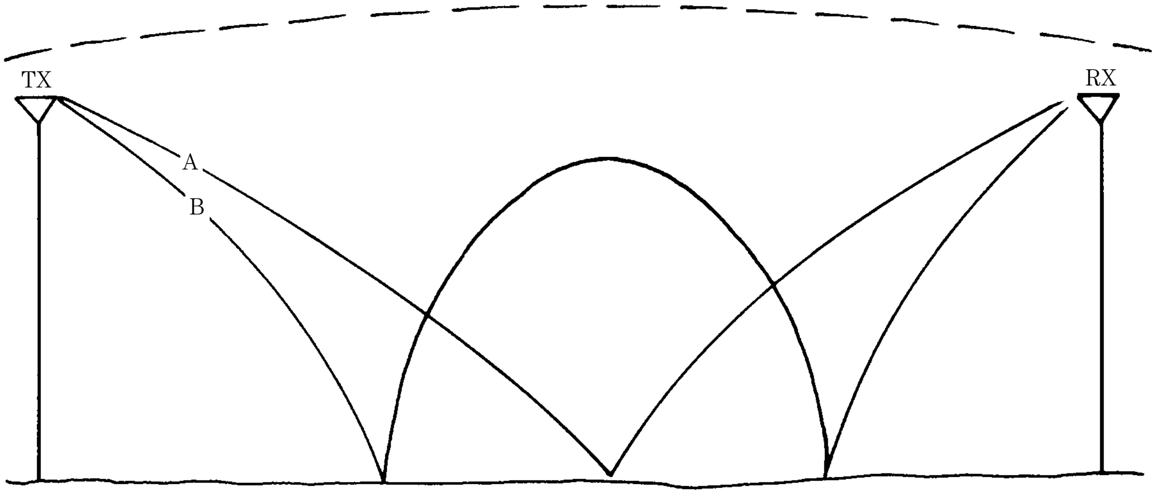

2-23 Multihop interference.

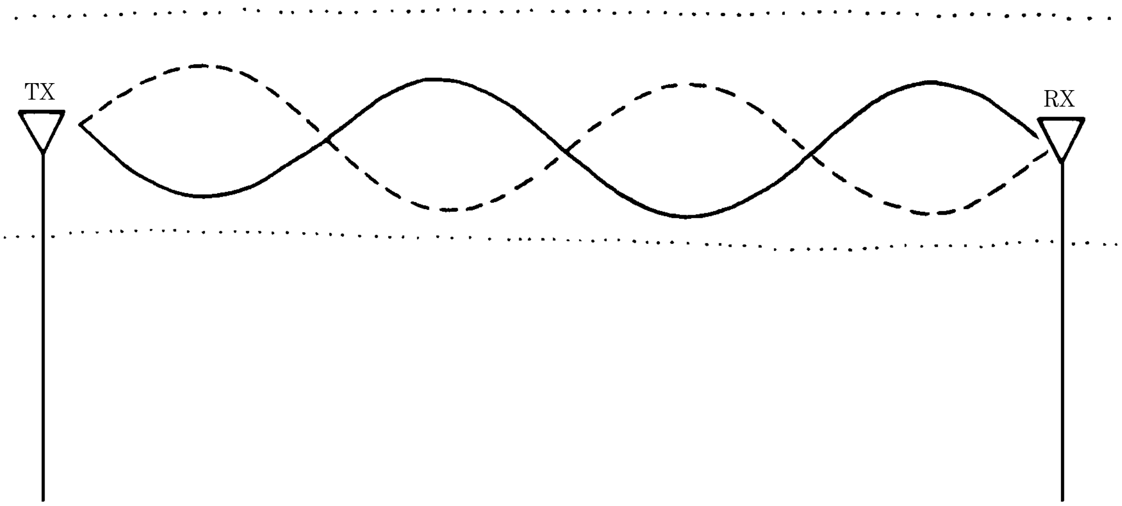

2-24 Wave interference.

Ionospheric propagation

Now let's turn your attention to the phenomenon of skip communications. Ionospheric propagation is responsible for the ability to do intercontinental broadcasting and communications. Long-distance radio transmission is carried out on the high-frequency (HF) bands (3 to 30 MHz), also called the *shortwave* bands. These frequencies are used because of the phenomenon called *skip*. Under this type of propagation, the earth's ionosphere acts as though it is a "radio mirror." Although the actual phenomenon is based on refraction (not reflection, as is frequently believed), the appearance to the casual observer is that shortwave and low-VHF radio signals are reflected from the ionosphere. The actual situation is a little different.

The key lies in the fact that this radio mirror is produced by ionization of the upper atmosphere. The upper portion of the atmosphere is called the *ionosphere* because it tends to be easily ionized by solar and cosmic radiation phenomena. The reason for the ease with which that region (30 to 300 mi above the surface) ionizes, is that the air density is very low. Energy from the sun strips away electrons from the outer shells of oxygen and nitrogen molecules. The electrons become negative ions, while the remaining portion of the atom forms positive ions. Because the air is so rarified at those altitudes, those ions can travel great distances before recombining to form electrically neutral atoms again. As a result, the average ionization level remains high in that region.

Several sources of energy will cause ionization of the upper atomosphere. Cosmic radiation from outer space causes some degree of ionization, but the majority of ionization is caused by solar energy.

The role of cosmic radiation was noticed during World War II, when British radar operators discovered that the distance at which their equipment could detect German aircraft was dependent upon whether or not the Milky Way was above the horizon. Intergalactic radiation raised the background microwave noise level, thereby adversely affecting the signal-to-noise ratio.

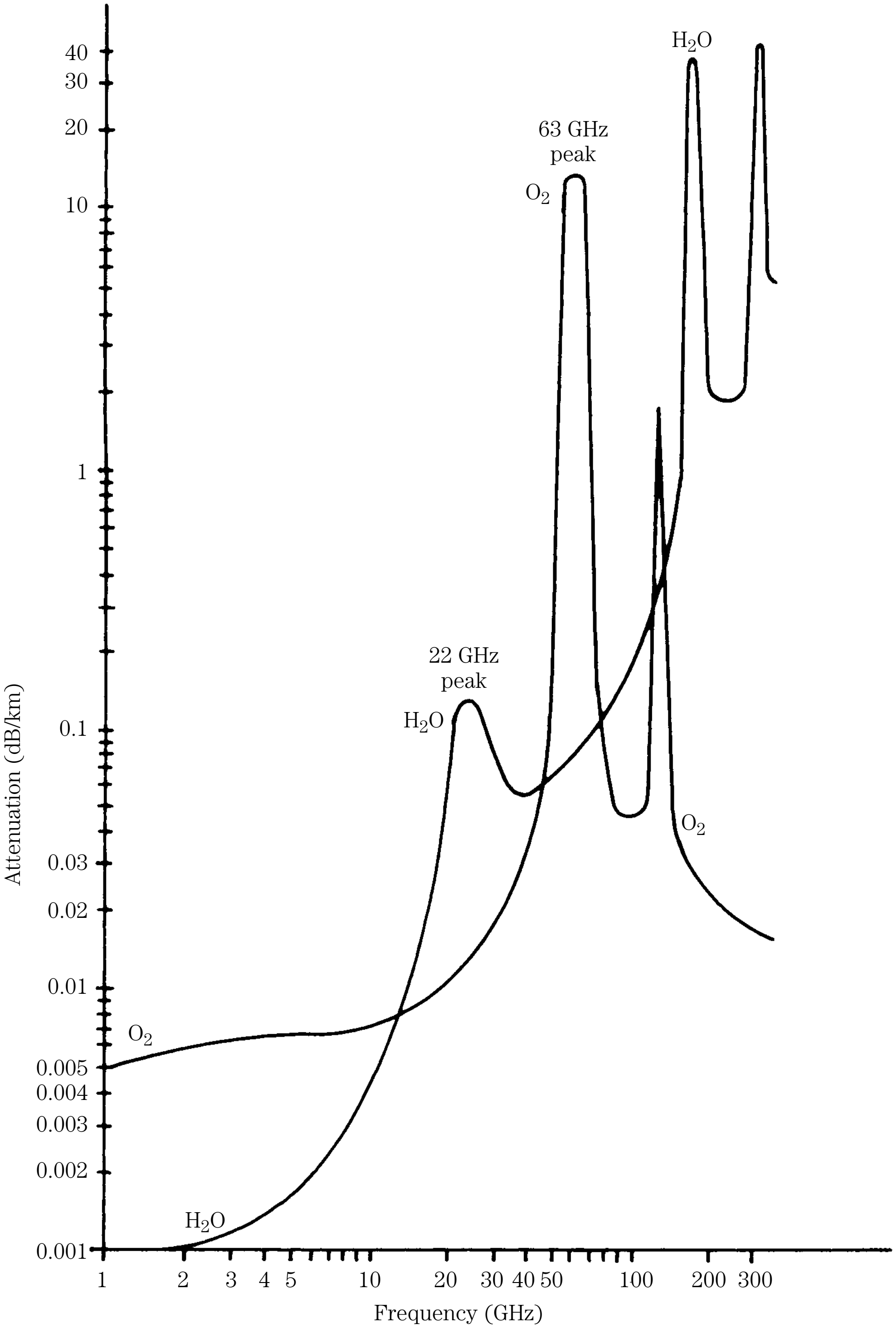

2-25 Atmospheric absorption of radio signals at microwave frequencies.

Events on the surface of the sun sometimes cause the radio mirror to seem to be almost perfect, and this situation makes spectacular propagation possible. At other times, however, solar disturbances (Fig. 2-26A) disrupt radio communications for days at a time.

There are two principal forms of solar energy that affect shortwave communications: *electromagnetic radiation* and *charged solar particles*. Most of the radiation is above the visible spectrum, in the ultraviolet and x-ray/gamma-ray region of the spectrum. Because electromagnetic radiation travels at the speed of light, solar events that release radiation cause changes to the ionosphere about 8 minutes later. Charged particles, on the other hand, having a finite mass must travel at a considerably slower velocity. They require two or three days to reach earth.

Various sources of both radiation and particles exist on the sun. Solar flares can release huge amounts of both radiation and particles. These events are unpredictable and sporadic. Solar radiation also varies over an approximately 27-day period, which is the rotational period of the sun. The same source of radiation will face the earth once every 27 days, and so events tend to be somewhat repetitive.

Solar and galactic noise affect the reception of weak signals. Solar noise can also affect radio propagation and act as a harbinger of changes in propagation patterns. Solar noise can be demonstrated by using an ordinary radio receiver and a directional antenna, preferably operating in the VHF/UHF regions of the spectrum (150 to 152 MHz frequently is used). Aim the antenna at the sun on the horizon at either sunset or sunrise. A dramatic change in background noise will be noted as the sun slides across the horizon.

2-26A Solar event that can affect radio propagation on earth.

Sunspots A principal source of solar radiation, especially the periodic forms, is sunspots (Fig. 2-26B). Sunspots can be as large as 70,000 to 80,000 miles in diameter, and generally occur in clusters. The number of sunspots varies over a period of approximately 11 years, although the actual periods since 1750 (when records were first kept) have varied from 9 to 14 years. The sunspot number is reported daily as the statistically massaged *Zurich Smoothed Sunspot Number*, or *Wolf Number*. The number of sunspots greatly affects radio propagation via the ionosphere. The low was in the range of 60 (in 1907), and the high was about 200 (1958).

Another indicator of ionospheric propagation potential is the *solar flux index* (SFI). This measure is taken in the microwave region (wavelength of 10.2 cm, or 2.8 GHz), at 1700 UTC at Ottawa, Canada. The SFI is reported by the National Institute for Standards and Technology (NIST) radio stations WWV (Fort Collins, CO) and WWVH (Maui, Hawaii).

The ionosphere offers different properties that affect radio propagation at different times. Variations occur not only over the 11 year sunspot cycle, but also diurnally and seasonally. Obviously, if the sun affects propagation in a significant way, then differences between nighttime and daytime, and between summer and winter, must cause variations in the propagation phenomena observed.

The ionosphere is divided, for purposes of radio propagation studies, into various layers that have somewhat different properties. These layers are only well defined

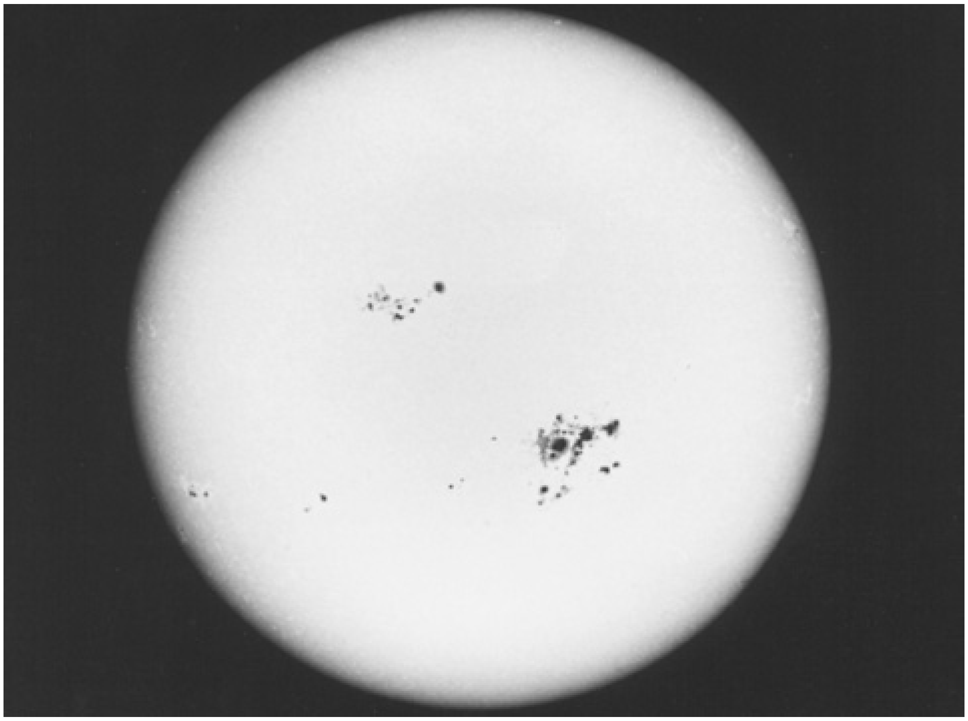

2-26B Sunspots.

in textbooks. However, even there you find a variation in the precise altitudes of the layers above the earth's surface. In addition, the real physical situation is such that layers don't have sharply defined boundaries, but rather fade one into another instead. Thus, the division into layers is somewhat arbitrary. These layers (Fig. 2-27) are designated D, E, and F (with F being further subdivided into F1 and F2 sublayers).

D layer The D layer is the lowest layer in the ionosphere, and exists from approximately 30 to 50 mi above the surface. This layer is not ionized as much as the higher layers, because all forms of solar energy that cause ionization are severely attenuated by the higher layers above the D layer. The reason for this is that the D layer is much more dense than the E and F layers, and that density of air molecules allows ions to recombine to form electroneutral atoms very quickly.

The extent of D layer ionization is proportional to the elevation of the sun, so it will achieve maximum intensity at midday. The D layer exists mostly during the warmer months of the year because of both the greater height of the sun above the horizon and the longer hours of daylight. The D layer almost completely disappears after local sunset. Some observers have reported sporadic incidents of D layer activity for a considerable time past sunset. The D layer exhibits a large amount of absorption of medium-wave and shortwave signals (to such an extent that signals below 4 to 6 MHz are completely absorbed by the D layer).

E layer The E layer exists from approximately 50 to 70 mi above the earth's surface, and it is considered the lowest region of the ionosphere that is important to radio communications. Like the D layer, this region is ionized only during the daylight hours, with ionization levels peaking at midday. The ionization level drops off sharply in the late afternoon, and almost completely disappears after local sunset.

During most of the year, the E layer is absorptive and it will not reflect radio signals. During the summer months, however, E layer propagation does occur. A phenomenon called "short skip" (i.e., less than 100 mi for medium wave and 1000 mi for shortwave signals) occurs in the E layer during the summer months, and in equatorial regions at other times.

A propagation phenomenon associated with the E layer is called *sporadic E propagation*. This phenomenon is caused by scattered zones of intense ionization in the E layer region of the ionosphere. The sporadic E phenomenon varies seasonally, and it is believed to be caused by the bombardment of solar particles. Sporadic E propagation affects the upper HF and lower VHF region. It is observed most frequently in the lower VHF spectrum (50 to 150 MHz), but it is also sometimes observed at higher frequencies. The VHF bands occasionally experience sporadic E propagation. Skip distances on VHF can reach 500 to 1500 miles on one hop—especially in the lower VHF region (including the 6-m band).

F layer The F layer of the ionosphere is the region that is the principal cause of long-distance shortwave communications. This layer is located from about 100 to 300 mi above the earth's surface. Unlike the lower layers, the air density in the F layer is low enough that ionization levels remain high all day, and decay slowly after local sunset. Minimum levels are reached just prior to local sunrise. Propagation in the F layer is capable of skip distances up to 2500 mi on a single hop. During the day there are actually two identifiable and distinct sublayers in the F layer region, and these are designated the Fl and F2 layers. The F1 layer is found approximately

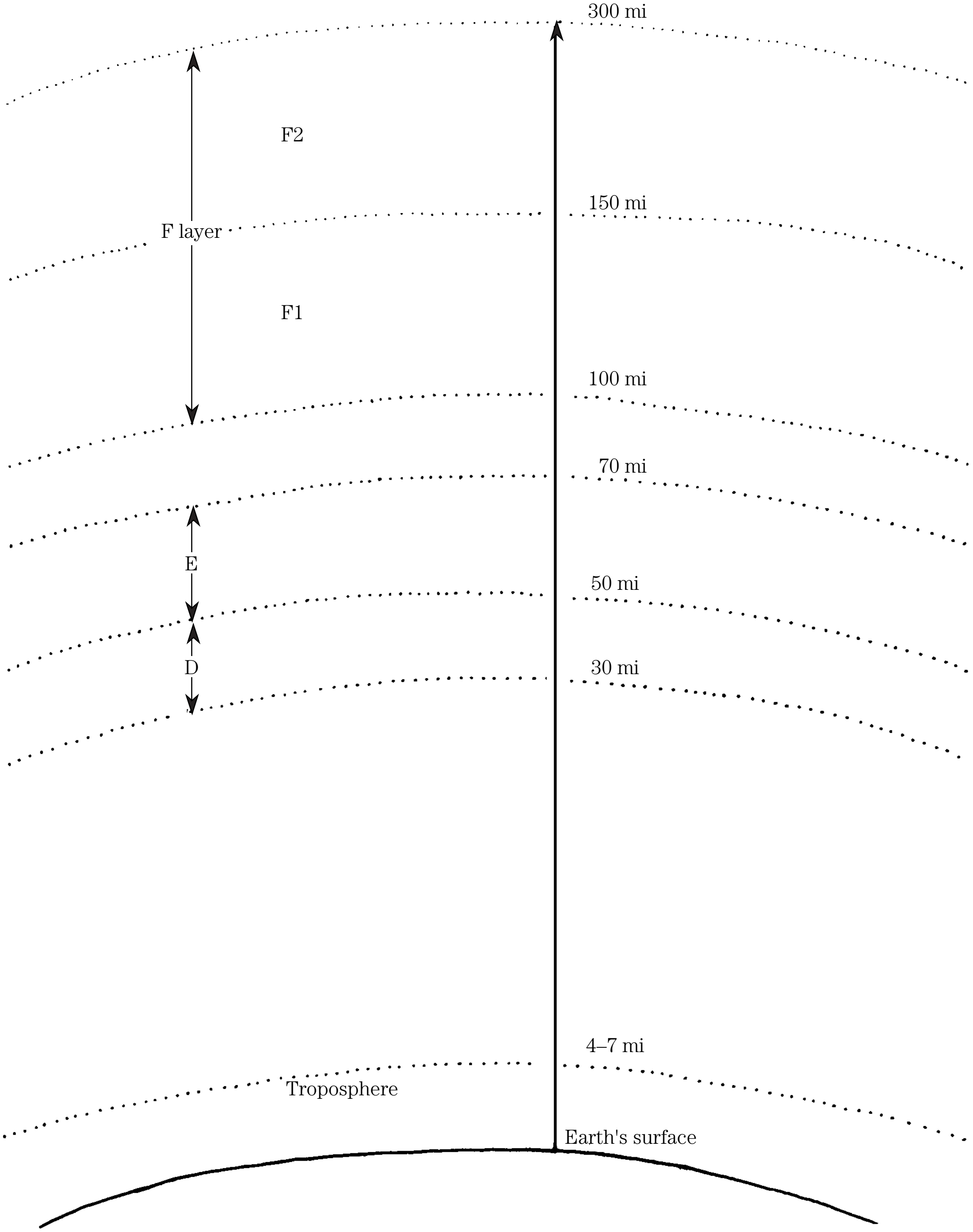
300 mi
F2
150 mi
F layer
F1
100 mi
70 mi
E
50 mi
D
30 mi
4–7 mi
Troposphere
Earth's surface

2-27 Classification of the earth's atmosphere for radio propagation.

100 to 150 miles above the earth's surface, and the F2 layer is above the F1 extending up to the 270- to 300-mi limit. Beginning at local sundown, however, the lower regions of the F1 layer begin to deionize because of recombination of positive and negative ions. At some time after local sunset, the F1 and F2 layers have effectively merged to become a single reduced layer beginning at about 175 mi.

The height and degree of ionization of the F2 layer varies over the course of the day, with the season of the year, and with the 27-day sunspot cycle. The F2 layer begins to form shortly after local sunrise and reaches maximum shortly before noon. During the afternoon, the F2 layer ionization begins to decay in an exponential manner until, for purposes of radio propagation, it disappears sometime after local sunset. There is some evidence that ionization in the F layer does not completely disappear, but its importance to HF radio communication does disappear.

Measures of ionospheric propagation

There are several different measures by which the ionosphere is characterized at any given time. These measures are used in making predictions of radio activity and long-distance propagation.

The *critical frequency* and *maximum usable frequency* (MUF) are indices that tell us something of the state of ionization and communications ability. These frequencies increase rapidly after sunrise and international communications usually begin within 30 minutes.

Critical frequency F_c The *critical frequency*, designated by F_c, is the highest frequency that can be reflected when a signal strikes the ionosphere as a vertical (90° with respect to the surface) incident wave. The critical frequency is determined from an *ionogram*, which is a cathode-ray tube (CRT) oscilloscope display of the height of the ionosphere as a function of frequency. The ionogram is made by firing a pulse vertically (Fig. 2-28) at the ionosphere from the transmitting station. The critical frequency is that frequency that is just sufffficient to be reflected back to the transmitter site. Values of F_c can be as low as 3 MHz during the nighttime hours, and as high as 10 to 15 MHz during the day.

Virtual height Radio waves are refracted in the ionosphere, and those above a certain critical frequency are refracted so much that they return to earth. Such waves appear to have been reflected from an invisible radio "mirror." An observer on the earth's surface could easily assume the existence of such a mirror by noting the return of the "reflected" signal. The height of this apparent "mirror" is called the *virtual height* of the ionosphere. Figure 2-29 shows the refraction phenomenon by which a radio wave is bent sufficiently to return to earth. Virtual height is determined by measuring the time interval required for an ionosonde pulse (similar to that used to measure critical frequency) to travel between the transmitting station and a receiving station (Fig. 2-30). A radio signal travels at a velocity of 300,000,000 m/s (the speed of light). By observing the time between transmitting the pulse and receiving it, you can calculate the virtual height of the ionosphere.

Maximum usable frequency (MUF) The *maximum usable frequency* is the highest frequency at which communications can take place via the ionosphere over a given path. The MUF between a fixed transmitter site and two different, widely separated, receivers need not be the same. Generally, however, the MUF is approximately

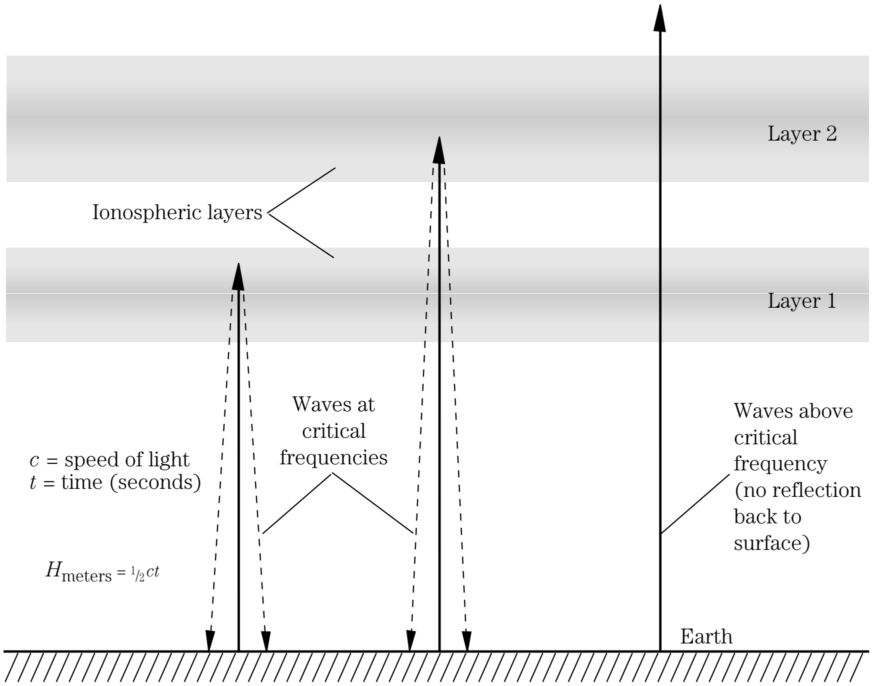
Layer 2
Ionospheric layers
Layer 1
Waves at critical frequencies
c = speed of light
t = time (seconds)
Waves above critical frequency (no reflection back to surface)
$H_{\text{meters}} = \frac{1}{2}ct$
Earth

2-28 Finding critical height of the ionosphere.

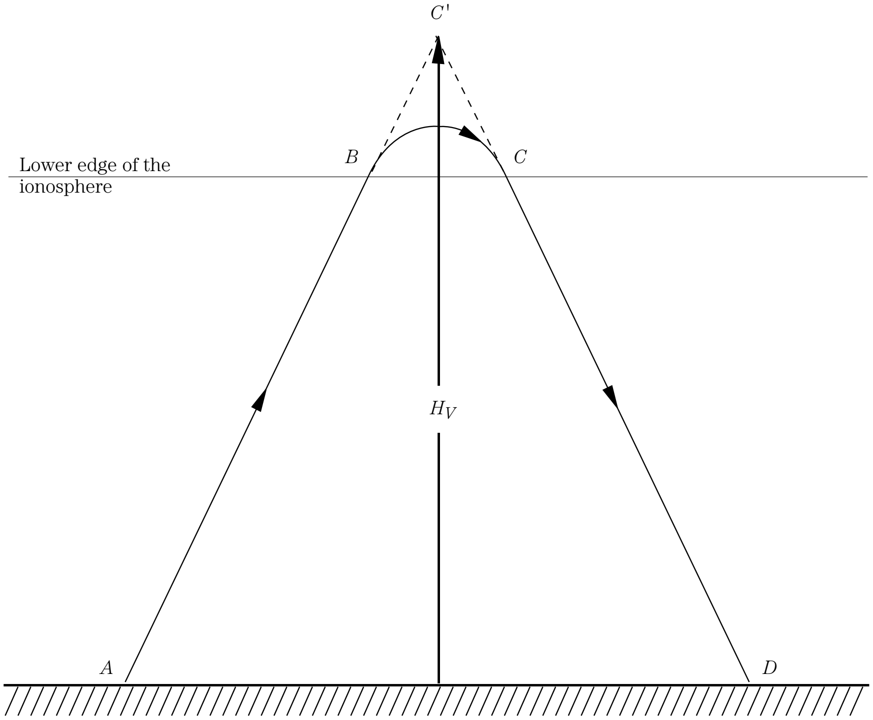
C'
Lower edge of the ionosphere
B
C
H_V
A
D

2-29 Finding virtual height of the ionosphere.

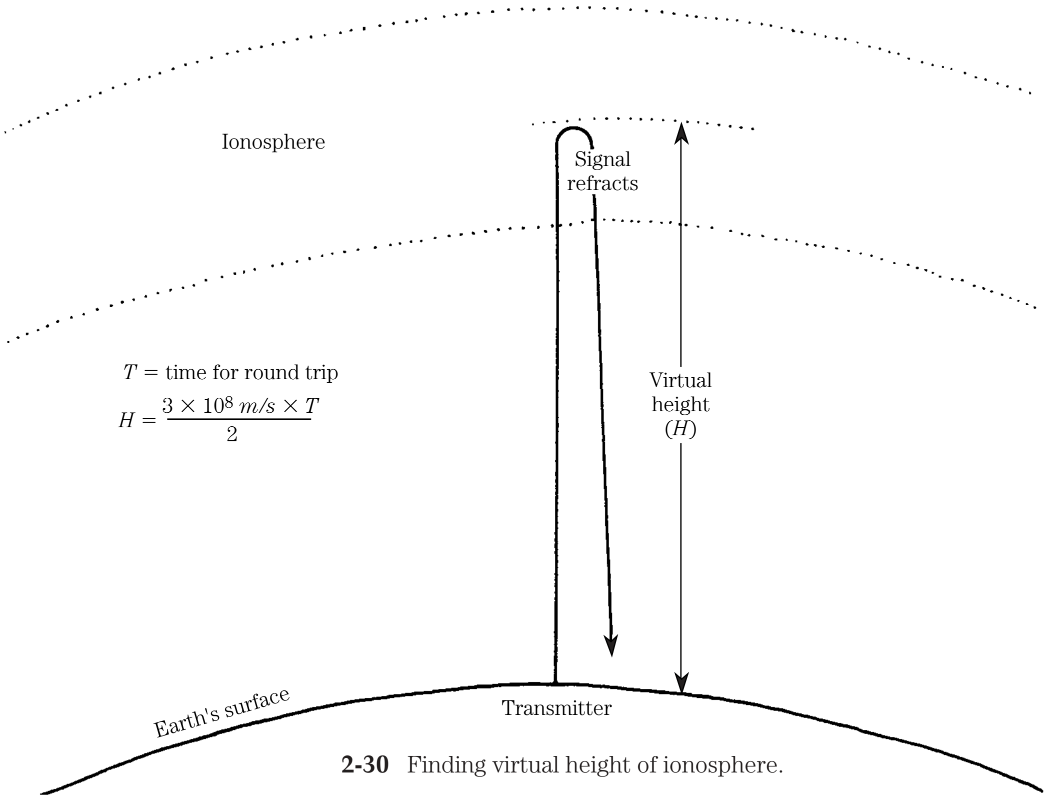

2-30 Finding virtual height of ionosphere.

3 times higher than the critical frequency. Both the MUF and the critical frequency vary geographically, and they become higher at latitudes close to the equator.

It is a general rule that the best propagation occurs at frequencies just below the MUF. In fact, there is a so-called *frequency of optimum traffic* (FOT) that is approximately 85 percent of the MUF. Both noise levels and signal strengths are improved at frequencies near the FOT.

Lowest usable frequency (LUF) At certain low frequencies, the combination of ionospheric absorption, atmospheric noise, miscellaneous static, and/or receiver signal-to-noise ratio requirements conspire to reduce radio communications. The lowest frequency that can be used for communications, despite these factors, is the *lowest usable frequency*.

Unlike the MUF, the LUF is not totally dependent on atmospheric physics. The LUF of a system can be varied by controlling the signal-to-noise ratio (SNR). Although certain factors that contribute to SNR are beyond our control, the effective radiated power (ERP) of the transmitter can be changed; a 2-MHz decrease in LUF is available for every 10-dB increase in the ERP of the transmitter.

Ionospheric variation and disturbances

The ionosphere is an extremely dynamic region of the atmosphere, especially from a radio operator's point of view, because it significantly alters radio propagation. The dynamics of the ionosphere are conveniently divided into two general classes: *regular variation* and *disturbances*. This section covers both types of ionospheric change.

Ionospheric variation There are several different forms of variation seen on a regular basis in the ionosphere: *diurnal*, *27-day* (monthly), *seasonal*, and *11-year cycles*.

Diurnal (daily) variation The sun rises and falls on a 24-hour cycle, and because it is the principal source of iononization of the upper atmosphere, you can expect diurnal variation. During daylight hours the E and D levels exist, but these disappear at night. The height of the F2 layer increases until midday, and then it decreases until evening, when it disappears or merges with other layers. As a result of higher absorption in the E and D layers, lower frequencies are not useful during daylight hours. On the other hand, the F layers reflect higher frequencies during the day. In the 1- to 30-MHz region, the higher frequencies (>11 MHz) are used during daylight hours, and the lower frequencies (<11 MHz) at night.

27-day cycle Approximately monthly, this variation is caused by the rotational period of the sun. Sunspots are localized on the surface of the sun, so they will face the earth only during a portion of the month. As new sunspots are formed, they do not show up on the earthside face until their region of the sun rotates earthside.

Seasonal cycle The earth's tilt varies the exposure of the planet to the sun on a seasonal basis. In addition, the earth's yearly orbit is not circular; it is elliptical. As a result, the intensity of the sun's energy that ionizes the upper atmosphere varies with the seasons of the year. In general, the E, D, and F layers are affected—although the F2 layer is only minimally affected. Ion density in the F2 layer tends to be highest in winter, and less in summer. During the summer, the distinction between F1 and F2 layers is less obvious.

11-year cycle The number of sunspots, statistically averaged, varies on an approximately 11-year cycle. As a result, the ionospheric effects that affect radio propagation also vary on an 11-year cycle. Radio propagation, in the shortwave bands, is best when the average number of sunspots is at its highest.

Disturbances Disturbances in the ionosphere can have a profound effect on radio communications—and most of them (but not all) are bad. This section will briefly examine some of the more common forms.

Sporadic E layer A reflective cloud of ionization sometimes appears in the E layer of the ionosphere; this layer is sometimes called the *E_s layer*. It is believed that the E_s layer forms from the effects of wind shear between masses of air moving in opposite directions. This action appears to redistribute ions into a thin layer that is radio-reflective.

Sporadic E propagation is normally thought of as a VHF phenomenon, with most activity between 30 and 100 MHz, and decreasing activity up to about 200 MHz. However, about 25 to 50 percent of the time, sporadic E propagation is possible on frequencies down to 10 or 15 MHz. Reception over paths of 1400 to 2600 mi are possible in the 50-MHz region when sporadic E is present. In the northern hemisphere, the months of June and July are the most prevalent sporadic E months. On most days when sporadic E is present, it lasts only a few hours.

Sudden ionospheric disturbances (SIDs) The SID, or *Dellinger fade,* mechanism occurs suddenly, and rarely gives any warning. The SID can last from a few minutes to many hours. It is known that SIDs often occur in correlation with solar flares, or "bright solar eruptions," that produce an immense amount of ultraviolet radiation that impinges the upper atmosphere. The SID causes a tremendous increase in D layer ionization, which accounts for the radio propagation effects. The ionization is so intense that all receiver operators on the sunny side of the earth experience profound loss of signal strength above about 3 MHz. It is not uncommon for receiver owners to think their receivers are malfunctioning when this occurs. The sudden loss of signals on sunny side receivers is called *Dellinger fade*. The SID is often accompanied by variations in terrestrial electrical currents and magnetism levels.

Ionospheric storms The *ionospheric storm* appears to be produced by an abnormally large rain of atomic particles in the upper atmosphere, and is often preceded by SIDs 18 to 24 hours earlier. These storms tend to last from several hours, to a week or more, and are often preceded by two days or so by an abnormally large collection of sunspots crossing the solar disk. They occur, most frequently, and with greatest severity, in the higher latitudes, decreasing toward the equator. When the ionospheric storm commences, shortwave radio signals may begin to flutter rapidly and then drop out altogether. The upper ionosphere becomes chaotic; turbulence increases and the normal stratification into layers, or zones, diminishes.

Radio propagation may come and go over the course of the storm, but it is mostly dead. The ionospheric storm, unlike the SID, which affects the sunny side of the earth, is worldwide. It is noted that the MUF and critical frequency tend to reduce rapidly as the storm commences.

An ionospheric disturbance observed in November 1960 was preceded by about 30 minutes of extremely good, but abnormal, propagation. At 1500 hours EST, European stations were noted with S9+ signal strengths in the 7000- to 7300-kHz region of the spectrum, which is an extremely rare occurrence. After about 30 minutes, the bottom dropped out and even AM broadcast band skip (later that evening) was nonexistent. At the time, the National Bureau of Standards* radio station, WWV, was broadcasting a "W2" propagation prediction at 19 and 49 minutes after each hour (which is terrible!). It was difficult to hear even the 5-MHz WWV frequency in the early hours of the disturbance, and it disappeared altogether for the next 48 hours. This signal's fade-out occurred during the weekend of the annual ARRL "Sweepstakes" contest.

Ionospheric sky-wave propagation

Sky-wave propagation occurs because signals in the ionosphere are refracted so much that they are bent back toward the earth's surface. To observers on the surface, it looks like the signal was reflected from a radio mirror at the virtual height of the ionosphere. The *skip distance* is the surface distance between the transmitter point (*A* in Fig. 2-31) and the point where it returns to earth (point *C* in Fig. 2-31). The *ground-wave zone* is the distance from the transmitter site (*A* in Fig. 2-31) to where the ground wave fades to a low level, below usefulness (point *B* in Fig. 2-31). The *skip zone* is the distance from the outer edge of the ground-wave zone to the skip distance, or the distance from *B* to *C* in Fig. 2-31.

It is possible for the sky wave and the ground wave to interfere with each other at some frequencies, under some circumstances. When this happens, the sky wave has a relative phase that depends on its path length (among other

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* Now the National Institute of Standards and Technology.

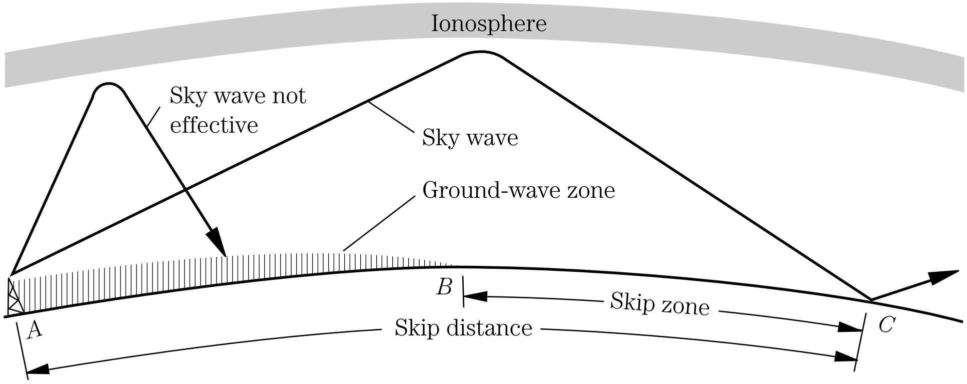

2-31 Relationship between ground wave and different cases of sky wave.

things), so it will arrive at some seemingly random phase relative to the ground wave. Thus, the sky wave can selectively strengthen or cancel the ground wave, giving rise to a type of fading.

Incident angle One of the factors that affects the length of the skip distance is the incident angle of the radio wave. This angle is partially a function of the frequency, and partially a function of the natural radiation angle of the antenna (α_r). The frequency effects are seen as a function of the ionization level and how much a given frequency is refracted.

The antenna radiation angle is the angle of the main vertical lobe with respect to the earth's surface; it is partially a function of its design, and partially of its installation configuration. For example, a ⅝-wavelength vertical antenna tends to have a lower angle of radiation than a ¼-wave vertical antenna. Similarly, the dipole's angle of radiation is a function of its height above ground.

Figure 2-32 shows how the angle of radiation affects skip distance. Low-angle-of-radiation signals tend to travel farther with respect to the earth's surface before refracting, so they produce the longest skip distances. Higher angles of radiation have shorter skip distances because they tend to return to earth more rapidly. In summertime, some high-frequency bands (e.g,. the 11-m—27 MHz—Citizens Band) offer high-angle "short skip" during the summer, and longer skip during the other months. At higher angles of radiation, there will be a *critical angle* wave and *escape angle* waves that are not returned to earth. These waves are not used for terrestrial communications or broadcasting. Figure 2-33 shows the difference between single-hop skip and multihop skip, as a function of incident angle. It is generally true that a multihop transmission is more subject to fading, and is weaker, than a single-hop transmission.

Using the ionosphere

The refraction of high-frequency and some medium-wave radio signals back to earth via the ionosphere gives rise to intercontinental HF radio communications. This phenomenon becomes possible during daylight hours and for a while after sunset when the ionosphere is ionized. Figure 2-34 reiterates the mechanism of long-distance skip communications. The transmitter is located at point *T*, while receiving stations

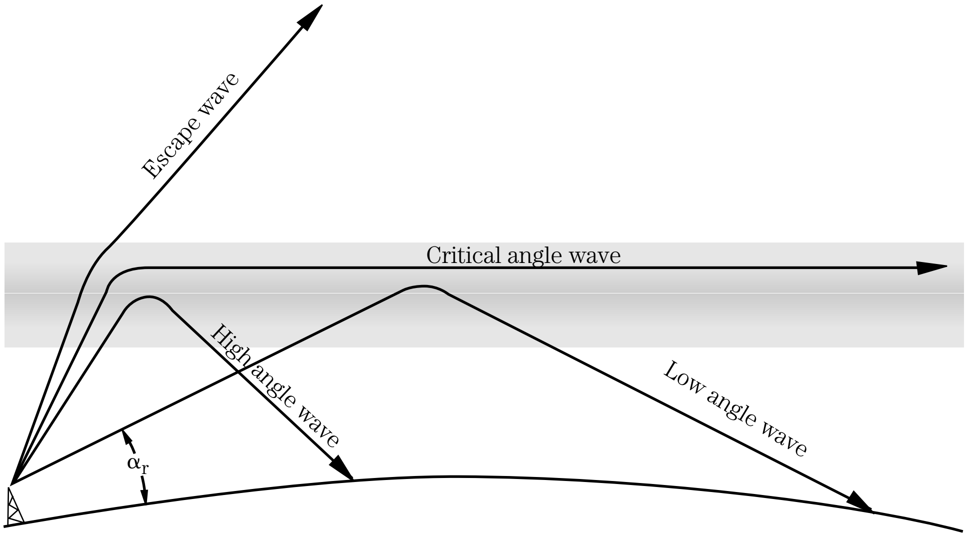
Escape wave
Critical angle wave
High angle wave
Low angle wave
α_r

2-32 Sky-wave propagation as a function of antenna radiation angle.

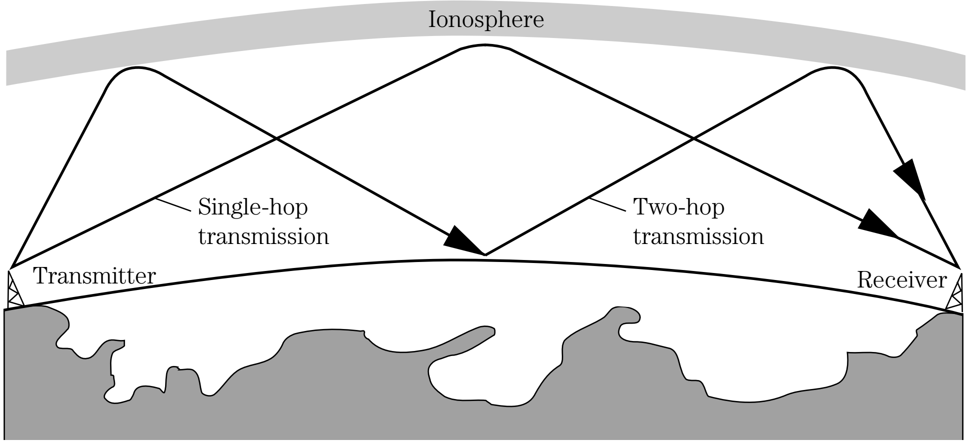
Ionosphere
Single-hop transmission
Two-hop transmission
Transmitter
Receiver

2-33 Single-skip and multihop-skip communications.

are located at sites R_1 and R_2. Signals 1 and 2 are not refracted sufficiently to be refracted back to earth, so they are lost in space. Signal 3, however, is refracted enough to return to earth, so it is heard at station R_1. The skip distance for signal 3 is the distance from T to R_1. At points between T and R_1, signal 3 is inaudible, except within ground-wave distance of the transmitter site (T). This is the reason why two stations 40 mi apart hear each other only weakly, or not at all, while both stations can communicate with a third station 2000 mi away. In amateur radio circles, it is common for South American stations to relay between two U.S. stations only a few miles apart. For an example of this problem, listen to the Inter-American and Halo Missionary

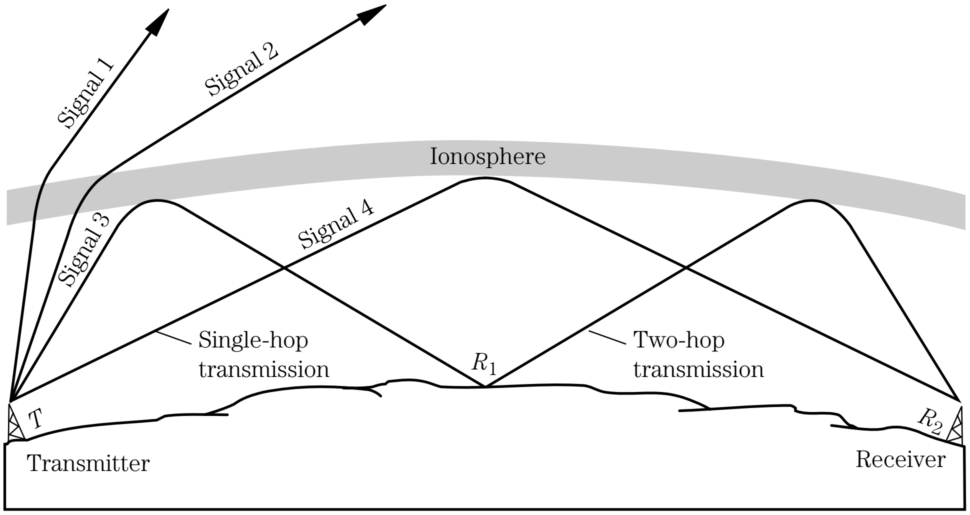

2-34 Effects of radiation angle on distance.

Nets on 21.290 MHz (15 m) daily from about 1700Z to 2100Z (ending time dependent upon traffic).

Multihop skip is responsible for the reception of the signal from transmitter T at site R_3. The signal *reflects* (not refracts) from the surface at R_1, and is retransmitted into the ionosphere, where it is again refracted back to earth.

Figure 2-35 shows a situation where skip signals are received at different distances depending upon the *angle of radiation* of the transmitting antenna. A high angle of radiation causes a shorter skip zone, but a lower angle of radiation results in a longer skip zone. Communication between any particular locations on any given frequency requires adjustment of the antenna radiation angle. Some international shortwave stations have multiple antennas with different radiation angles to ensure that the correct skip distances are available.

Great circle paths A *great circle* is a line between two points on the surface of a sphere, such that it lays on a plane through the earth's center and includes the two points. When translated to "radiospeak," a great circle is the shortest path on the surface of the earth between two points. Navigators and radio operators use the great circle for similar, but different, reasons. The navigator's reason is in order to get from here to there, and the radio operator's is to get a transmission path from here to there.

The heading of a directional antenna is normally aimed at the receiving station along its great circle path. Unfortunately, many people do not understand the concept well enough, for they typically aim the antenna in the wrong direction. For example, I live near Washington, D.C., which is on approximately the same latitude as Lisbon, Portugal. If I catch a lift on Superman's back, and he flies due East, we'll have dinner in Lisbon, right? Wrong. If you head due east from Washington, DC, across the Atlantic, the first landfall would be west Africa, somewhere near Zaire or Angola. Why? Because the great circle bearing 90° takes us far south. The *geometry of spheres*, not flat planes, governs the case.

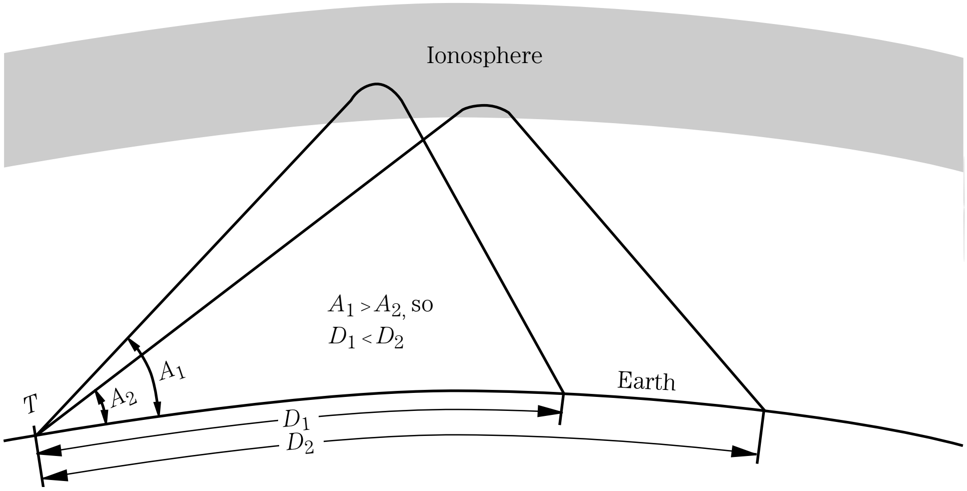

2-35 Skip propagation.

Figure 2-36 shows a great circle map centered on the Washington, D.C. area. These maps, or computer tabulations of the same data, can often be purchased for your own location by supplying your latitude and longitude to the service company that does the job. By drawing a line from your location at the center of the chart to the area you want to hear, and then extending it to the edge of the chart, you will obtain the beam heading required.

Long path versus short path The earth is a sphere (or more precisely, an oblate spheroid), so from any given point to any other point there are two great circle paths: the *long path* (major arc) and the *short path* (minor arc). In general, the best reception occurs along the short path. In addition, short-path propagation is more nearly "textbook," compared with long path reception. However, there are times when long path is better, or is the only path that will deliver a signal to a specific location from the geographic location in question.

Gray line propagation The *gray line* is the twilight zone between the nighttime and daytime halves of the earth. This zone is also called the *planetary terminator* (Fig. 2-37). It varies up to +23° either side of the north-south longitudinal lines, depending on the season of the year (it runs directly north-south only at the vernal and autumnal equinoxes). The D layer of the ionosphere absorbs signals in the HF region. This layer disappears almost completely at night, but it builds up during the day. Along the gray line, the D layer is rapidly decaying west of the line, and has not quite built up east of the line.

Brief periods of abnormal propagation occur along the gray line. Stations on either side of the line can be heard from regions, and at distances, that would otherwise be impossible on any given frequency. For this reason, radio operators often prefer to listen at dawn and dusk for this effect.

Scatter propagation modes

Ionospheric scatter propagation occurs when clouds of ions exist in the atmosphere. These clouds can exist in both the ionosphere and the troposphere, although

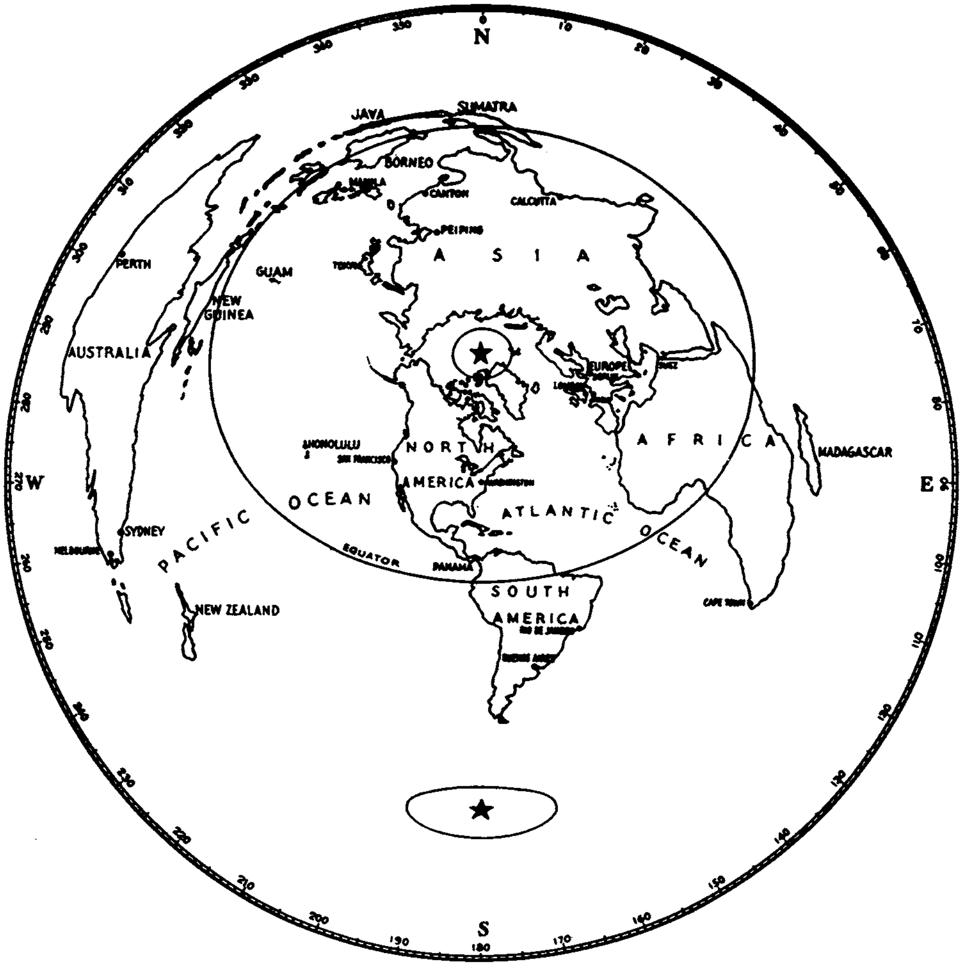
N
E
S
W
JAVA
SUMATRA
BORNEO
MANILA
CANTON
CALCUTTA
PEIPING
A S I A
GUAM
PERTH
NEW GUINEA
AUSTRALIA
EUROPE
SUEZ
LONDON
A F R I C A
MADAGASCAR
HONOLULU
SAN FRANCISCO
N O R T H
AMERICA
WASHINGTON
OCEAN
PACIFIC
ATLANTIC
OCEAN
SYDNEY
MELBOURNE
EQUATOR
PANAMA
SOUTH
AMERICA
RIO DE JANEIRO
BUENOS AIRES
NEW ZEALAND
CAPE TOWN
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350

2-36 Azimuthal map centered on Washington, D.C. (*Courtesy of The ARRL Antenna Book.*)

the tropospheric model is more reliable for communications. Figure 2-38 shows the mechanism for scatter propagation. Radio signals from the transmitter are reflected from the cloud of ions to a receiver location that otherwise might not receive it. Scatter propagation occurs mostly in the VHF region, and it allows communications over extended paths that are not normally available.

There are at least three different modes of scatter from ionized clouds: *backscatter*, *side scatter*, and *forward scatter*. The backscatter mode is a bit like radar, in that the signal is returned back to the transmitter site, or to regions close to the transmitter. Forward scatter occurs when the reflected signal continues in the same azimuthal direction (with respect to the transmitter), but is redirected toward the earth's surface. Side scatter is similar to forward scatter, but the azimuthal direction might change.

Unfortunately, there are often multiple reflections from the ionized cloud, and these are shown as "multiple scatter" in Fig. 2-38. When these reflections are able to

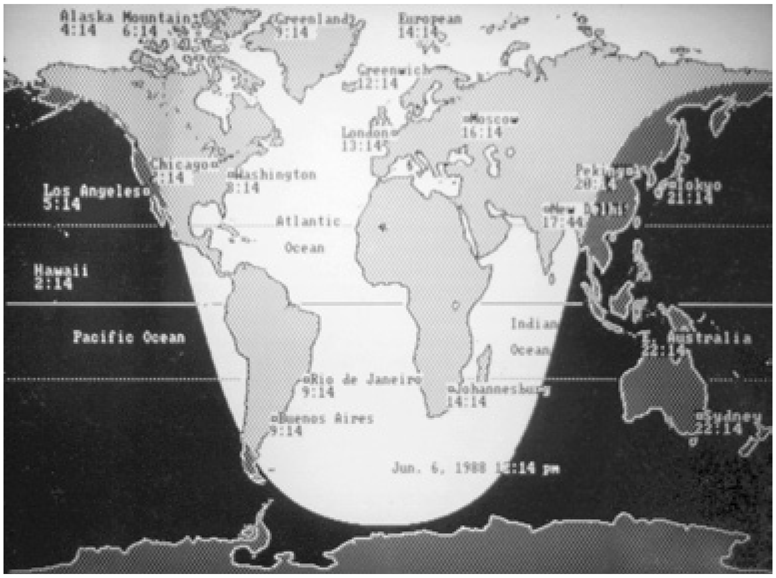
Alaska 4:14
Mountain 6:14
Greenland 9:14
European 14:14
Greenwich 12:14
London 13:14
Moscow 16:14
Chicago 8:14
Washington 9:14
Los Angeles 5:14
Peking 20:14
Tokyo 21:14
New Delhi 17:44
Atlantic Ocean
Hawaii 2:14
Pacific Ocean
Indian Ocean
Australia 22:14
Rio de Janeiro 9:14
Johannesburg 14:14
Buenos Aires 9:14
Sydney 22:14
Jun. 6, 1988 12:14 pm

2-37 The planetary terminator ("gray line") provides some unusual propagation effects. (*Courtesy of MFJ Enterprises.*)

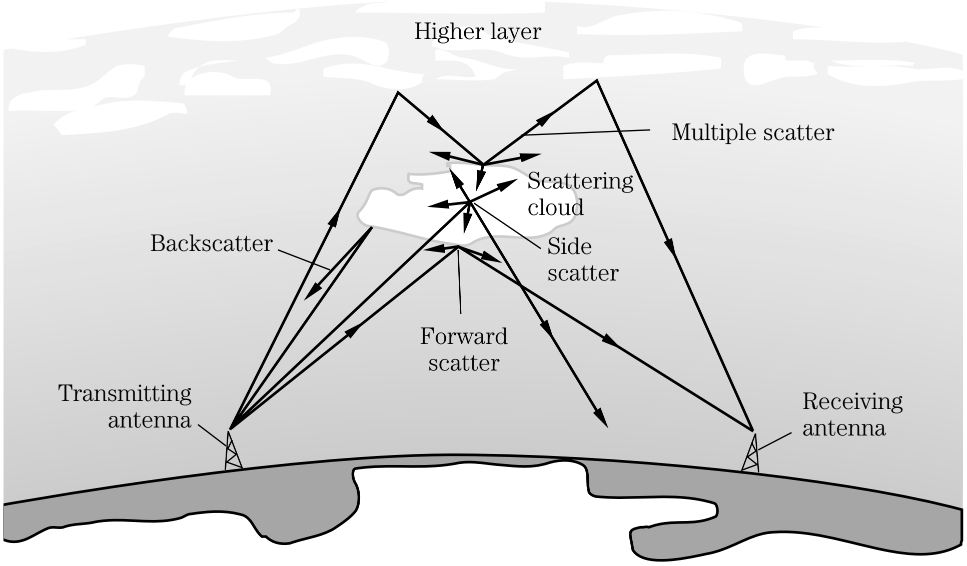
Higher layer
Multiple scatter
Scattering cloud
Backscatter
Side scatter
Forward scatter
Transmitting antenna
Receiving antenna

2-38 Various modes of scatter propagation.

reach the receiving site, the result is a rapid, fluttery fading that can be of quite profound depths.

Auroral propagation

The *auroral effect* produces a luminescence in the upper atmosphere resulting from bursts of particles released from the sun 18 to 48 hours earlier. The light emitted is called the *northern lights* and the *southern lights*. The ionized regions of the atmosphere that create the lights form a radio reflection shield, especially at VHF and above, although 15 to 20 MHz effects are known. Auroral propagation effects are normally seen in the higher latitudes, although listeners in the southern tier of states in the United States are often treated to the reception of signals from the north being reflected from auroral clouds.

Meteor scatter propagation

When meteors enter the earth's atmosphere, they do more than simply heat up to the point of burning. The burning meteor leaves a wide, but very short duration, transient cloud of ionized particles in its path. These ions act as a radio mirror that permits short bursts of reception between sites correctly situated. Meteor scatter reception is not terribly reliable, although at least two companies offer meteor scatter communications services for users in the higher latitudes.

Other propagation anomalies

The ionosphere is a physically complex place, and even the extensive coverage in this chapter is not sufficient to do it justice. Indeed, entire books are available on the subject, and it is a valid engineering subspecialty. It is therefore not surprising that a number of propagation anomalies are known.

Nonreciprocal direction If you listen to an amateur band receiver on the East Coast of the United States, you will sometimes hear European stations—especially in the late afternoon. But when you try to work those stations there is no reply whatsoever. They simply don't hear you! This propagation anomaly causes the radio wave to travel different paths dependent on which direction it travels; i.e., an east→west signal is not necessarily the reciprocal of a west→east signal. This anomaly can occur when a radio signal travels through a heavily ionized medium in the presence of a magnetic field, which is exactly the situation when the signal travels through the ionosphere in the presence of the earth's magnetic field.

Another anomaly seen in the radio literature of the 1930s is the *Radio Luxembourg effect*. It is named after the radio station where it was first noticed. In a nonlinear ionosphere, it is sometimes noted that the modulation of superpower (i.e., > 500,000 W) shortwave broadcasters will be transferred to the carrier of a weaker signal in the same or nearby band. The interchange noted in the 1930s when this phenomenon was first discovered was between Radio Luxembourg and Britain's British Broadcasting Corporation (BBC) overseas outlets.

Propagation predictions

Propagation predictions for the VLF through low VHF bands are published each month in several magazines. Ham radio operators often use those in *QST* magazine (Fig. 2-39), while SWLs and others tend to prefer those published in magazines such as *Monitoring Times*. These charts relate the time of day in Universal Coordinated Time (UTC, formerly, GMT) and the frequency for transmission to different parts of the world.

Fading

Skip communications are not without problems. One phenomenon is fading (i.e., a variation in signal strength as perceived at the receiver site). This problem can sometimes be overcome by using one of several diversity reception systems. Three forms of diversity technique are used: *frequency diversity*, *spatial diversity*, and *polarity diversity*.

In the frequency diversity system (Fig. 2-40), the transmitter will send out two or more frequencies simultaneously with the same modulating information. Because the two frequencies will fade differentially, one will always be strong.

The spatial diversity system (Fig. 2-41) assumes that a single transmitter frequency is used. At the receiving site, two or more receiving antennas are used, spaced one-half wavelength apart. The theory is that the signal will fade at one antenna while it increases at the other. A three-antenna system is often used. Three separate, but identical, receivers, often tuned by the same master local oscillator, are connected to the three antennas. Audio mixing, based on the strongest signal, keeps the audio output constant while the radio-frequency (RF) signal fades.

Polarity diversity reception (Fig. 2-42) uses both vertical and horizontal polarization antennas to receive the signal. As in the space diversity system, the outputs of the vertical and horizontal receivers are combined to produce a constant level output.

Another form of fading, *selective fading*, derives from the fact that fading is a function of frequency. The carrier and upper and lower sidebands of an AM signal have slightly different frequencies, so they arrive out of phase with each other. Although this type of fading is lessened by using single-sideband (SSB) transmission, that does not help AM users. In those systems, some people use a filtering system that eliminates the carrier and one sideband; it then reconstitutes the AM signal with a product detector.

SSB receivers with stable local and product detector oscillators, and a sharp intermediate-frequency (IF) bandpass filter, can be used to reduce the effects of differential fading of AM signals because of the phasing of the lower sideband (LSB), upper sideband (USB), and carrier components. Carefully tune the receiver to only one sideband of the signal, and note when the heterodyne beatnote disappears. The correct point is characterized by the fact that you can then switch among USB, LSB, and continuous-wave (CW) modes without changing the received signal output.

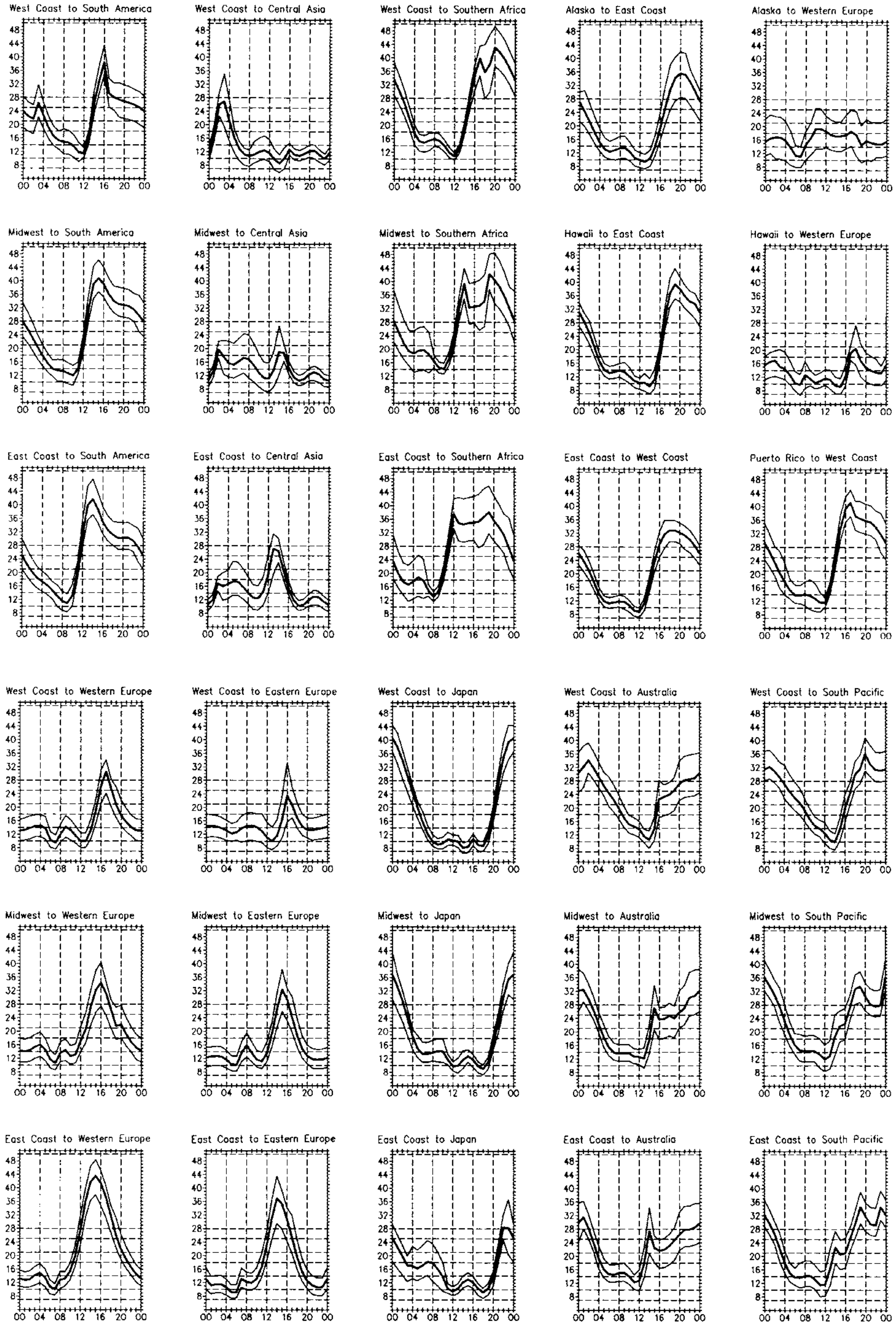

2-39 Propagation prediction charts appear in magazines such as *QST* every month.
(*Courtesy of the American Radio Relay League.*)

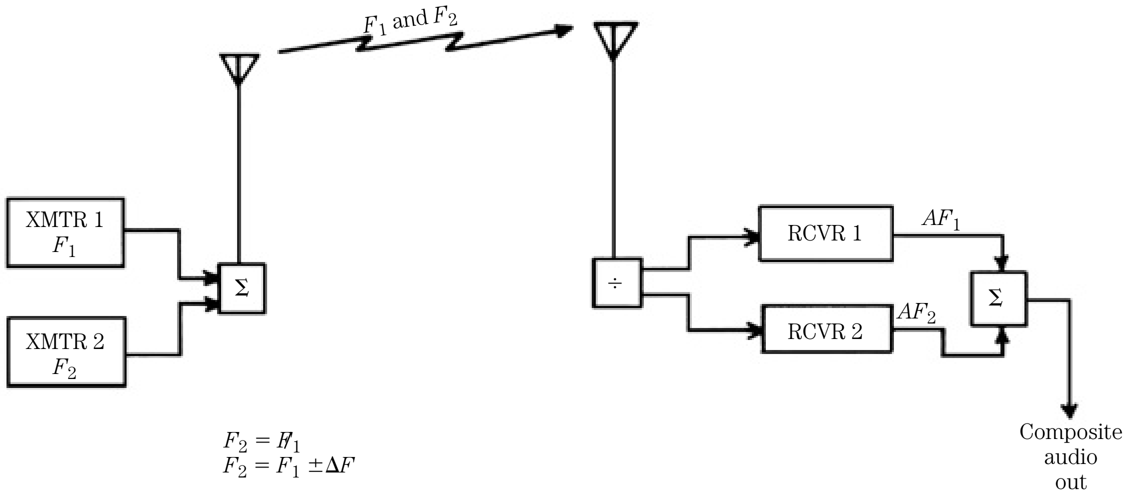
F_1 and F_2
XMTR 1 F_1
XMTR 2 F_2
Σ
÷
RCVR 1
RCVR 2
AF_1
AF_2
Σ
Composite audio out
$F_2 = \not{F}_1$
$F_2 = F_1 \pm \Delta F$

2-40 Frequency diversity reduces fading.

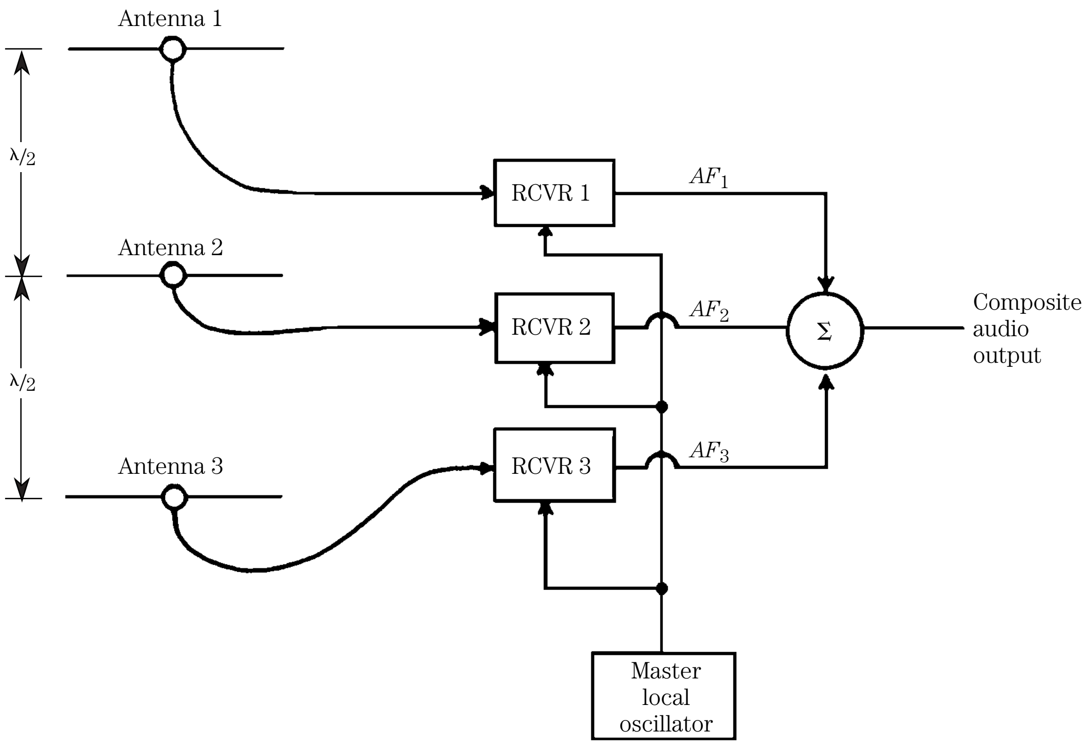
Antenna 1
λ/2
Antenna 2
λ/2
Antenna 3
RCVR 1
RCVR 2
RCVR 3
AF_1
AF_2
AF_3
Σ
Composite audio output
Master local oscillator

2-41 Spatial diversity.

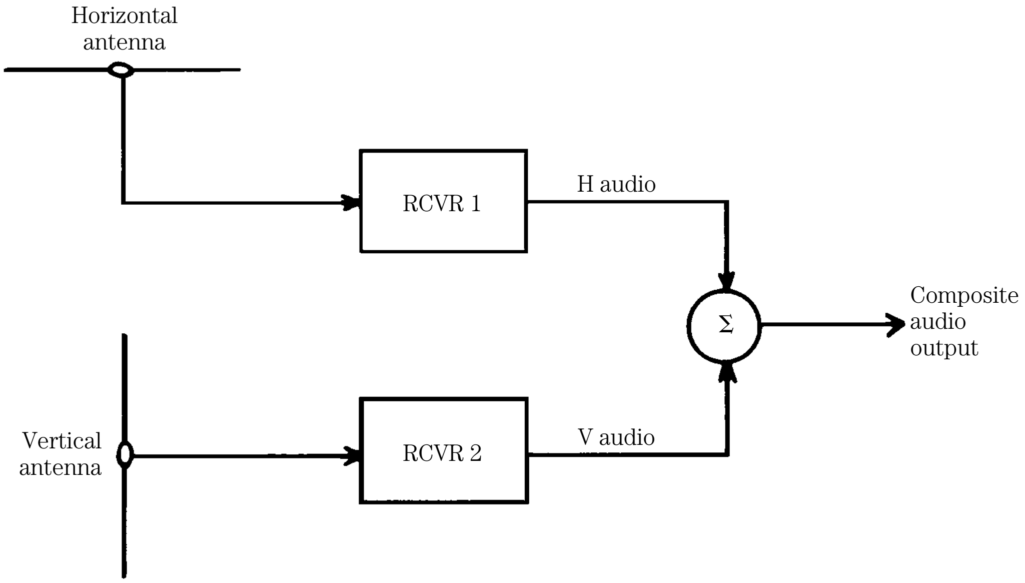
Horizontal antenna
RCVR 1
H audio
Σ
Composite audio output
Vertical antenna
RCVR 2
V audio

2-42 Polarization diversity.

3
CHAPTER
Transmission lines

TRANSMISSION LINES AND *WAVEGUIDES* ARE CONDUITS FOR TRANSPORTING RF SIGNALS between elements of a system. For example, transmission lines are used between an exciter output and transmitter input, and between the transmitter input and its output, and between the transmitter output and the antenna. Although often erroneously characterized as a "length of shielded wire," transmission lines are actually complex networks containing the equivalent of all the three basic electrical components: resistance, capacitance, and inductance. Because of this fact, transmission lines must be analyzed in terms of an *RLC* network.

Parallel and coaxial lines

This chapter will consider several types of transmission lines. Both step-function and sine-wave ac responses will be studied. Because the subject is both conceptual and analytical, both analogy and mathematical approaches to the theory of transmission lines will be used.

Figure 3-1 shows several basic types of transmission line. Perhaps the oldest and simplest form is the *parallel line* shown in Figs. 3-1A through 3-1D. Figure 3-1A shows an end view of the parallel conductor transmission line. The two conductors, of diameter d, are separated by a dielectric (which might be air) by a spacing S. These designations will be used in calculations later. Figure 3-1B shows a type of parallel line called *twin lead*. This is the old-fashioned television antenna transmission line. It consists of a pair of parallel conductors separated by a plastic dielectric. TV-type twin lead has a characteristic impedance of 300 Ω, while certain radio transmitting-antenna twin lead has an impedance of 450 Ω. Another form of twin lead is *open line*, shown in Fig. 3-1C. In this case, the wire conductors are separated by an air dielectric, with support provided by stiff (usually ceramic) insulators. A tie wire (only one shown) is used to fasten each insulator end to the main conductor. Some users of open line prefer the form of insulator or supporter shown in Fig. 3-1D. This

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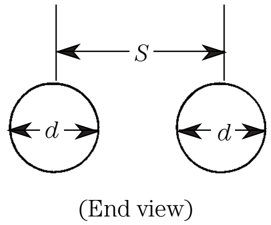
S
d
d
(End view)

3-1A Parallel line transmission line (end view).

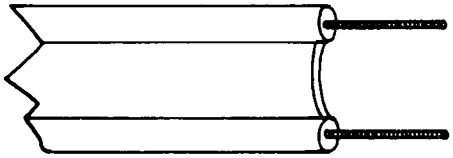

3-1B Twin-lead transmission line.

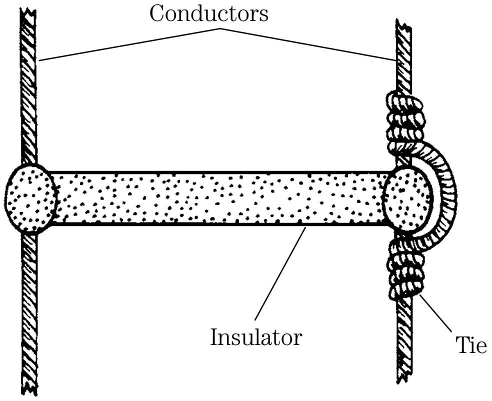
Conductors
Insulator
Tie

3-1C Parallel line construction details.

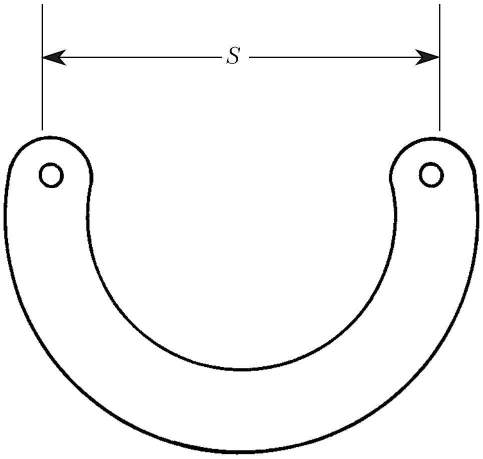

3-1D Horseshoe parallel line spreader.

form of insulator is made of either plastic or ceramic, and is in the form of a U. The purpose of this shape is to reduce losses, especially in rainy weather, by increasing the leakage currents path relative to spacing S.

Parallel lines have been used at VLF, MW, and HF frequencies for decades. Even antennas into the low VHF are often found using parallel lines. The higher impedance of these lines (relative to coaxial cable) yields lower loss in high-power applications. For years, the VHF, UHF, and microwave application of parallel lines was limited to educational laboratories, where they are well suited to performing experiments (to about 2 GHz) with simple, low-cost instruments. Today, however, printed circuit and hybrid semiconductor packaging has given parallel lines a new lease on life, if not an overwhelming market presence.

Figure 3-1E shows a form of parallel line called *shielded twin lead*. This type of line uses the same form of construction as TV-type twin lead, but it also has a braided shielding surrounding it. This feature makes it less susceptible to noise and other problems.

The second form of transmission line, which finds considerable application at microwave frequencies, is *coaxial cable* (Figs. 3-1F through 3-1L). This form of line consists of two cylindrical conductors sharing the same axis (hence “coaxial”), and separated by a dielectric (Fig. 3-1F). For low frequencies (in flexible cables) the dielectric may be polyethylene or polyethylene foam, but at higher frequencies *Teflon* and other materials are used. Also used, in some applications, are dry air and dry nitrogen.

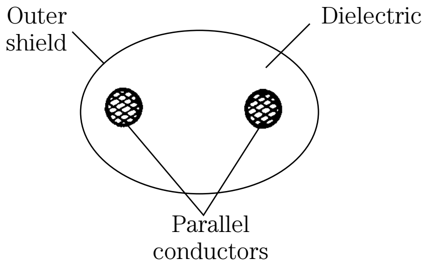

3-1E Shielded twin-lead transmission line.

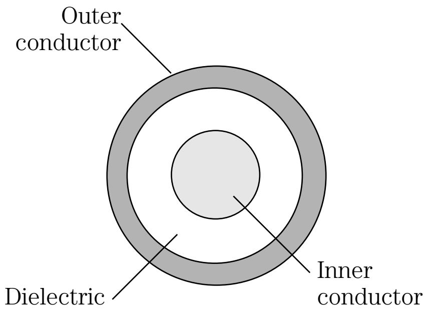

3-1F Coaxial cable (end view).

Several forms of coaxial line are available. Flexible coaxial cable is perhaps the most common form. The outer conductor in such cable is made of either braid or foil (Fig. 3-1G). Television broadcast receiver antennas provide an example of such cable from common experience. Another form of flexible or semiflexible coaxial line is *helical line* (Fig. 3-1H) in which the outer conductor is spiral wound. *Hardline* (Fig. 3-1I) is coaxial cable that uses a thin-wall pipe as the outer conductor. Some hardline coax used at microwave frequencies has a rigid outer conductor and a solid dielectric.

Gas-filled line is a special case of hardline that is hollow (Fig. 3-1J), the center conductor is supported by a series of thin ceramic or Teflon insulators. The dielectric is either anhydrous (i.e., dry) nitrogen or some other inert gas.

Some flexible microwave coaxial cable uses a solid "air-articulated" dielectric (Fig. 3-1K), in which the inner insulator is not continuous around the center conductor, but rather is ridged. Reduced dielectric losses increase the usefulness of the

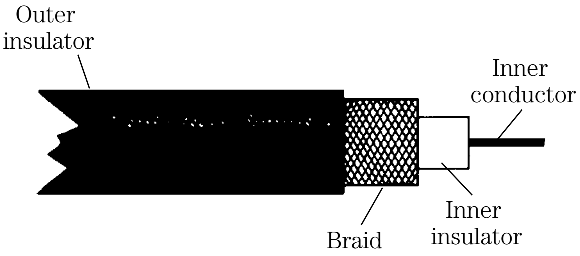
Outer insulator
Inner conductor
Braid
Inner insulator

3-1G Coaxial cable (side view).

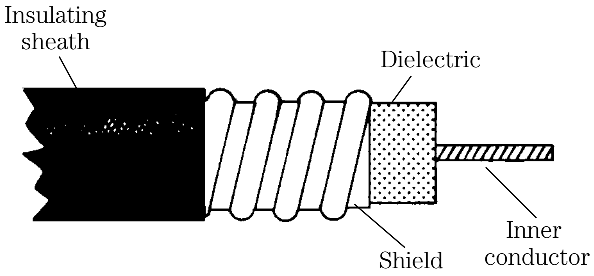
Insulating sheath
Dielectric
Shield
Inner conductor

3-1H Coaxial hardline cable.

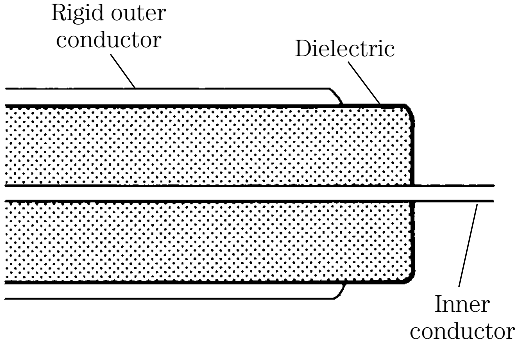
Rigid outer conductor
Dielectric
Inner conductor

3-1I Rigid coaxial line.

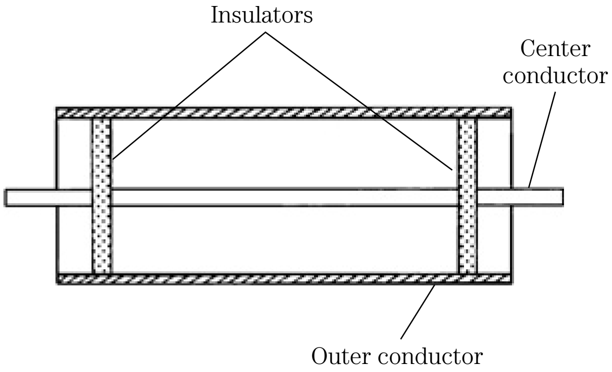
Insulators
Center conductor
Outer conductor

3-1J Gas-filled hollow coaxial line.

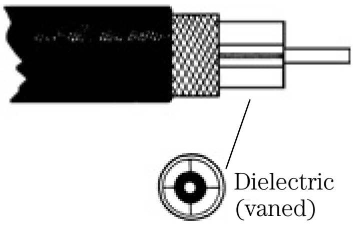
Dielectric (vaned)

3-1K Articulated coaxial line.

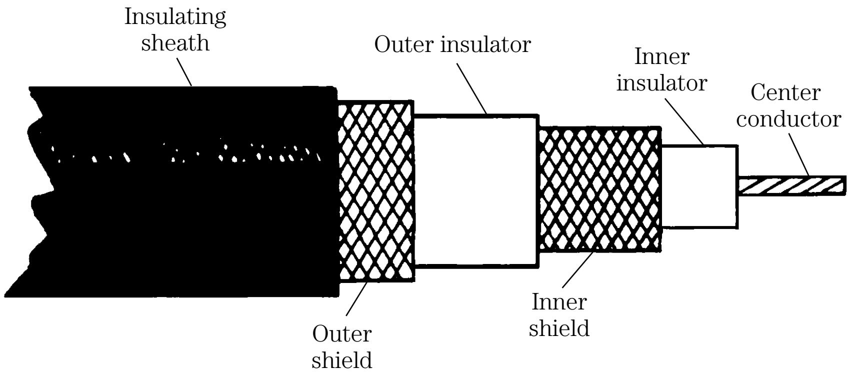
Insulating sheath
Outer insulator
Inner insulator
Center conductor
Outer shield
Inner shield

3-1L Double-shielded coaxial line.

cable at higher frequencies. Double-shielded coaxial cable (Fig. 3-1L) provides an extra measure of protection against radiation from the line, and EMI from outside sources, from getting into the system.

Stripline, also called *microstripline* (Fig. 3-1M), is a form of transmission line used at high UHF and microwave frequencies. The stripline consists of a critically sized conductor over a ground-plane conductor, and separated from it by a dielectric. Some striplines are sandwiched between two groundplanes and are separated from each by a dielectric.

Transmission line characteristic impedance (Z_o)

The transmission line is an *RLC* network (see Fig. 3-2), so it has a *characteristic impedance* Z_o, also sometimes called a *surge impedance*. Network analysis will show that Z_o is a function of the per unit of length parameters *resistance* R, *conductance* G, *inductance* L, and *capacitance* C, and is found from

$$Z_o = \sqrt{\frac{R + j\,\omega L}{G + j\,\omega C}} \qquad \textbf{[3.1]}$$

where

Z_o is the characteristic impedance, in ohms
R is the resistance per unit length, in ohms
G is the conductance per unit length, in mhos
L is the inductance per unit length, in henrys
C is the capacitance per unit length, in farads
ω is the angular frequency in radians per second ($2\pi F$)

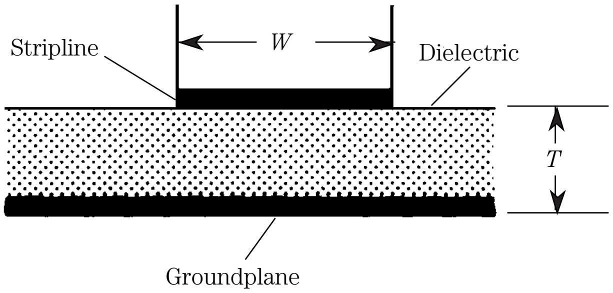

3-1M Stripline transmission line.

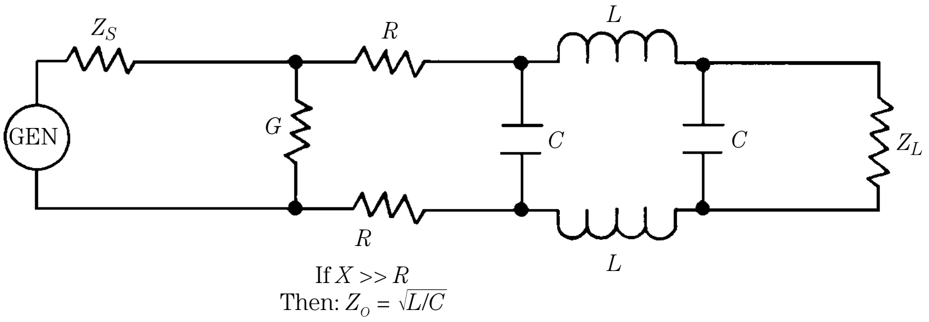

3-2 Equivalent circuit of transmission line.

In microwave systems the resistances are typically very low compared with the reactances, so Eq. 3.1 can be reduced to the simplified form:

$$Z_o = \sqrt{\frac{L}{C}} \qquad \textbf{[3.2]}$$

Example 3-1 A nearly lossless transmission line (R is very small) has a unit length inductance of 3.75 nH and a unit length capacitance of 1.5 pF. Find the characteristic impedance Z_o.

Solution:

$$Z_o = \sqrt{\frac{L}{C}}$$

$$= \sqrt{\frac{\left(3.75\ \text{nH} \times \dfrac{1\ \text{H}}{10^9\ \text{nH}}\right)}{\left(1.5\ \text{pF} \times \dfrac{1\ \text{F}}{10^{12}\ \text{pF}}\right)}}$$

$$= \sqrt{\frac{3.75 \times 10^{-9}\ \text{H}}{1.5 \times 10^{-12}\ \text{F}}}$$

$$= \sqrt{2.5 \times 10^3} = 50\ \Omega$$

The characteristic impedance for a specific type of line is a function of the conductor size, the conductor spacing, the conductor geometry (see again Fig. 3-1), and the dielectric constant of the insulating material used between the conductors. The dielectric constant e is equal to the reciprocal of the velocity (squared) of the wave when a specific medium is used:

$$e = \frac{1}{v^2} \qquad \textbf{[3.3]}$$

where

e is the dielectric constant (for a perfect vacuum $e = 1.000$)
v is the velocity of the wave in the medium

(a) Parallel line

$$Z_o = \frac{276}{\sqrt{e}} \log\left(\frac{2S}{d}\right) \qquad \textbf{[3.4]}$$

where

Z_o is the characteristic impedance, in ohms
e is the dielectric constant
S is the center-to-center spacing of the conductors
d is the diameter of the conductors

(*b*) *Coaxial line*

$$Z_o = \frac{138}{\sqrt{e}} \log \left(\frac{D}{d} \right) \qquad \textbf{[3.5]}$$

where

D is the diameter of the outer conductor
d is the diameter of the inner conductor

(*c*) *Shielded parallel line*

$$Z_o = \frac{276}{\sqrt{e}} \log \left(2A \quad \frac{(1 - B^2)}{(1 + B^2)} \right) \qquad \textbf{[3.6]}$$

where

$A = s/d$
$B = s/D$

(*d*) *Stripline*

$$Z_o = \frac{377}{\sqrt{e_t}} \left(\frac{T}{W} \right) \qquad \textbf{[3.7A]}$$

where

e_t is the relative dielectric constant of the printed wiring board (PWB)
T is the thickness of the printed wiring board
W is the width of the stripline conductor

The relative dielectric constant e_t used above differs from the normal dielectric constant of the material used in the PWB. The relative and normal dielectric constants move closer together for larger values of the ratio W/T.

Example 3-2 A stripline transmission line is built on a 4-mm-thick printed wiring board that has a relative dielectric constant of 5.5. Calculate the characteristic impedance if the width of the strip is 2 mm.

Solution:

$$Z_o = \frac{377}{\sqrt{e_t}} \left(\frac{T}{W} \right)$$

$$= \frac{377}{\sqrt{5.5}}\left(\frac{4\text{ mm}}{2\text{ mm}}\right)$$

$$= \frac{377}{2.35}\,(2) = 321\ \Omega$$

In practical situations, we usually don't need to calculate the characteristic impedance of a stripline, but rather design the line to fit a specific system impedance (e.g., 50 Ω). We can make some choices of printed circuit material (hence dielectric constant) and thickness, but even these are usually limited in practice by the availability of standardized boards. Thus, stripline *width* is the variable parameter. Equation 3.2 can be arranged to the form:

$$W = \frac{377\ T}{Z_o\sqrt{e}} \qquad \textbf{[3.7B]}$$

The impedance of 50 Ω is accepted as standard for RF systems, except in the cable TV industry. The reason for this diversity is that power handling ability and low loss operation don't occur at the same characteristic impedance. For example, the maximum power handling ability for coaxial cables occurs at 30 Ω, while the lowest loss occurs at 77 Ω; 50 Ω is therefore a reasonable tradeoff between the two points. In the cable TV industry, however, the RF power levels are minuscule, but lines are long. The tradeoff for TV is to use 75 Ω as the standard system impedance in order to take advantage of the reduced attenuation factor.

Transmission line characteristics

Velocity factor

In the section preceding this section, we discovered that the velocity of the wave (or signal) in the transmission line is less than the free-space velocity (i.e., less than the speed of light). Further, we discovered in Eq. 3.3 that velocity is related to the dielectric constant of the insulating material that separates the conductors in the transmission line. Velocity factor v is usually specified as a decimal fraction of c, the speed of light (3×10^8 m/s). For example, if the velocity factor of a transmission line is rated at "0.66," then the velocity of the wave is $0.66c$, or $(0.66)\ (3 \times 10^8 \text{ m/s}) = 1.98 \times 10^8$ m/s.

Velocity factor becomes important when designing things like transmission line transformers, or any other device in which the length of the line is important. In most cases, the transmission line length is specified in terms of *electrical length*, which can be either an angular measurement (e.g., 180° or π radians), or a relative measure keyed to wavelength (e.g., one-half wavelength, which is the same as 180°). The *physical length* of the line is longer than the equivalent electrical length. For example, let's consider a 1-GHz half-wavelength transmission line.

A rule of thumb tells us that the length of a wave (in meters) in free space is $0.30/F$, where frequency F is expressed in gigahertz; therefore, a half-wavelength line is $0.15/F$.

At 1 GHz, the line must be 0.15 m/1 GHz = 0.15 m. If the velocity factor is 0.80, then the *physical length* of the transmission line that will achieve the desired *electrical length* is [(0.15 m) (v)]/F = [(0.15 m) (0.80)]/1 GHz = 0.12 m. The derivation of the rule of thumb is "left as an exercise for the student." (*Hint*: It comes from the relationship between wavelength, frequency, and velocity of propagation for any form of wave.)

There are certain practical considerations regarding velocity factor that result from the fact that the physical and electrical lengths are not equal. For example, in a certain type of phased-array antenna design, radiating elements are spaced a half-wavelength apart, and must be fed 180° (half-wave) out of phase with each other. The simplest interconnect is to use a half-wave transmission line between the 0° element and the 180° element. According to the standard wisdom, the transmission line will create the 180° phase delay required for the correct operation of the antenna. Unfortunately, because of the velocity factor, the physical length for a one-half electrical wavelength cable is shorter than the free-space half-wave distance between elements. In other words, the cable will be too short to reach between the radiating elements by the amount of the velocity factor!

Clearly, velocity factor is a topic that must be understood before transmission lines can be used in practical situations. Table 3-1 shows the velocity factors for several types of popular transmission line. Because these are nominal values, the actual velocity factor for any given line should be measured.

Table 3-1. Transmission line characteristics

Type of line	**Z_o (ohms)**	**Velocity factor v**
½-in. TV parallel line (air dielectric)	300	0.95
1-in. TV parallel line (air dielectric)	450	0.95
TV twin lead	300	0.82
UHF TV twin lead	300	0.80
Polyethylene coaxial cable	*	0.66
Polyethylene foam coaxial cable	*	0.79
Air-space polyethylene foam coaxial cable	*	0.86
Teflon	*	0.70

* Various impedances depending upon cable type.

Transmission line noise

Transmission lines are capable of generating noise and spurious voltages that are seen by the system as valid signals. Several such sources exist. One source is the coupling between noise currents flowing in the outer conductor and the inner conductor. Such currents are induced by nearby electromagnetic interference and other sources (e.g., connection to a noisy groundplane). Although coaxial design reduces noise pickup, compared with parallel line, the potential for EMI exists. Selection of high-grade line, with a high degree of shielding, reduces the problem.

Another source of noise is thermal noises in the resistances and conductances. This type of noise is proportional to resistance and temperature.

There is also noise created by mechanical movement of the cable. One species results from the movement of the dielectric against the two conductors. This form of noise is caused by electrostatic discharges in much the same manner as the spark created by rubbing a piece of plastic against woolen cloth.

A second species of mechanically generated noise is *piezoelectricity* in the dielectric. Although more common in cheap cables, one should be aware of it. Mechanical deformation of the dielectric causes electrical potentials to be generated.

Both species of mechanically generated noise can be reduced or eliminated by proper mounting of the cable. Although rarely a problem at lower frequencies, such noise can be significant at microwave frequencies when signals are low.

Coaxial cable capacitance

A coaxial transmission line possesses a certain capacitance per unit of length. This capacitance is defined by

$$C = \frac{24e}{\log\ (D/d)}\ \frac{\text{pF}}{\text{m}} \qquad \textbf{[3.8A]}$$

A long run of coaxial cable can build up a large capacitance. For example, a common type of coax is rated at 65 pF/m. A 150-m roll thus has a capacitance of 65 pF/m × (150 m), or 9750 pF. When charged with a high voltage, as is done in breakdown voltage tests at the factory, the cable *acts like a charged high-voltage capacitor*. Although rarely (if ever) lethal to humans, the stored voltage in new cable can deliver a nasty electrical shock and can irreparably damage electronic components.

Coaxial cable cutoff frequency F_o

The normal mode in which a coaxial cable propagates a signal is as a transverse electromagnetic (TEM) wave, but others are possible—and usually undesirable. There is a maximum frequency above which TEM propagation becomes a problem, and higher modes dominate. Coaxial cable should *not* be used above a frequency of

$$F = \frac{6.75}{(D + d)\sqrt{e}}\ \text{GHz} \qquad \textbf{[3.8B]}$$

where

F is the TEM-mode cutoff frequency
D is the diameter of the outer conductor, in inches
d is the diameter of the inner conductor, in inches
e is the dielectric constant

When maximum operating frequencies for cable are listed, it is the TEM mode that is cited. Beware of attenuation, however, when making selections for microwave frequencies. A particular cable may have a sufficiently high TEM-mode frequency, but still exhibit a high attenuation per unit length at X or Ku bands.

Transmission line responses

In order to understand the operation of transmission lines, we need to consider two cases: *step-function response* and the *steady-state ac response*. The step-function case involves a single event when a voltage at the input of the line snaps from zero (or a steady value) to a new (or nonzero) value, and remains there until all action dies out. This response tells us something of the behavior of pulses in the line, and in fact is used to describe the response to a single-pulse stimulus. The steady-state ac response tells us something of the behavior of the line under stimulation by a sinusoidal RF signal.

Step-function response of a transmission line

Figure 3-3 shows a parallel transmission line with characteristic impedance Z_o connected to a load impedance Z_L. The generator at the input of the line consists of a voltage source V in series with a source impedance Z_s and a switch S_1. Assume for the present that all impedances are pure resistances (i.e., $R + j0$). Also, assume that $Z_s = Z_o$.

When the switch is closed at time T_o (Fig. 3-4A), the voltage at the input of the line (V_{in}) jumps to $V/2$. In Fig. 3-2, you may have noticed that the LC circuit resembles a delay line circuit. As might be expected, therefore, the voltage wavefront propagates along the line at a velocity v of:

$$v = \frac{1}{\sqrt{LC}} \qquad \textbf{[3.9]}$$

where

v is the velocity, in meters per second
L is the inductance, in henrys
C is the capacitance, in farads

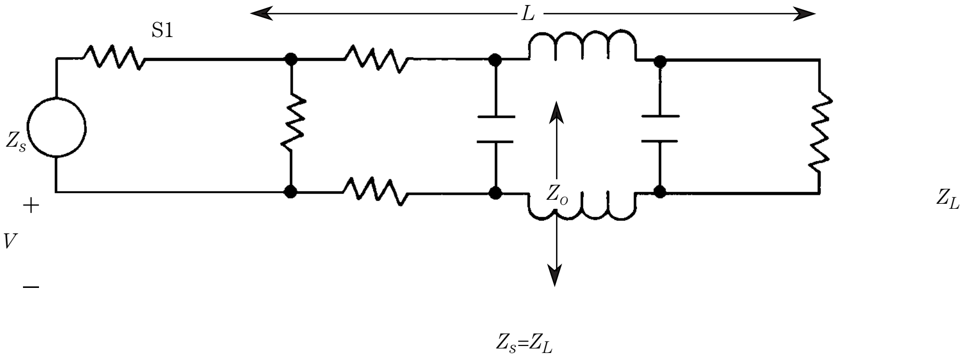

3-3 Schematic example of transmission line.

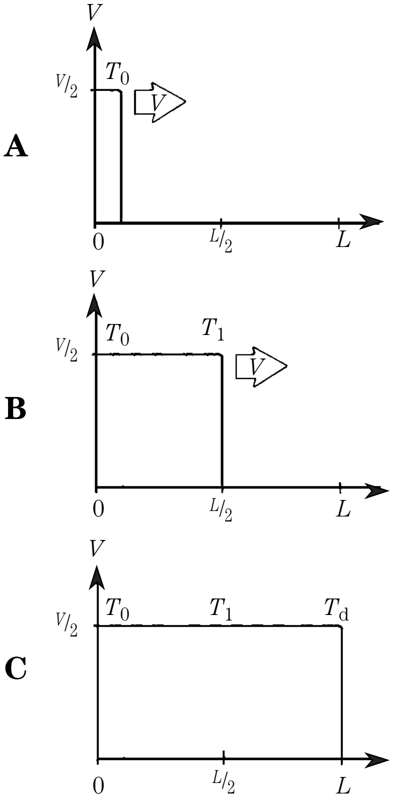

3-4 Step-function propagation along transmission line at three points.

At time T_1 (Fig. 3-4B), the wavefront has propagated one-half the distance L, and by T_d it has propagated the entire length of the cable (Fig. 3-4C).

If the load is perfectly matched (i.e., $Z_L = Z_o$), then the load absorbs the wave and no component is reflected. But in a mismatched system (Z_L is not equal to Z_o), a portion of the wave is reflected back down the line toward the generator.

Figure 3-5 shows the rope analogy for reflected pulses in a transmission line. A taut rope (Fig. 3-5A) is tied to a rigid wall that does not absorb any of the energy in the pulse propagated down the rope. When the free end of the rope is given a vertical displacement (Fig. 3-5B), a wave is propagated down the rope at velocity v (Fig. 3-5C). When the pulse hits the wall (Fig. 3-5D), it is reflected (Fig. 3-5E) and propagates back down the rope toward the free end (Fig. 3-5F).

If a second pulse is propagated down the line before the first pulse dies out, then there will be two pulses on the line at the same time (Fig. 3-6A). When the two pulses interfere, the resultant will be the algebraic sum of the two. In the event that a pulse train is applied to the line, the interference pattern will set up *standing waves*, an example of which is shown in Fig. 3-6B.

Reflection coefficient

The *reflection coefficient* Γ of a circuit containing a transmission line and load impedance is a measure of how well the system is matched. The absolute value of the re-

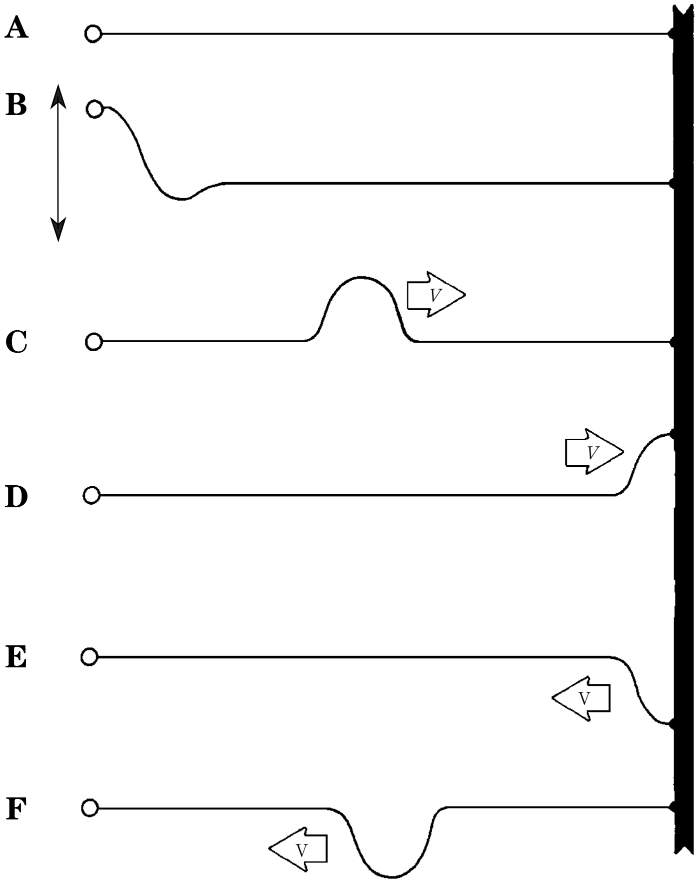
A
B
C
V
D
V
E
V
F
V

3-5 Rope analogy to transmission line.

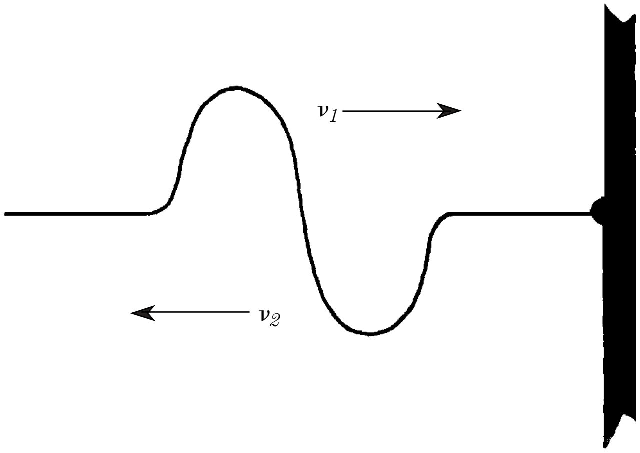

3-6A Interfering opposite waves.

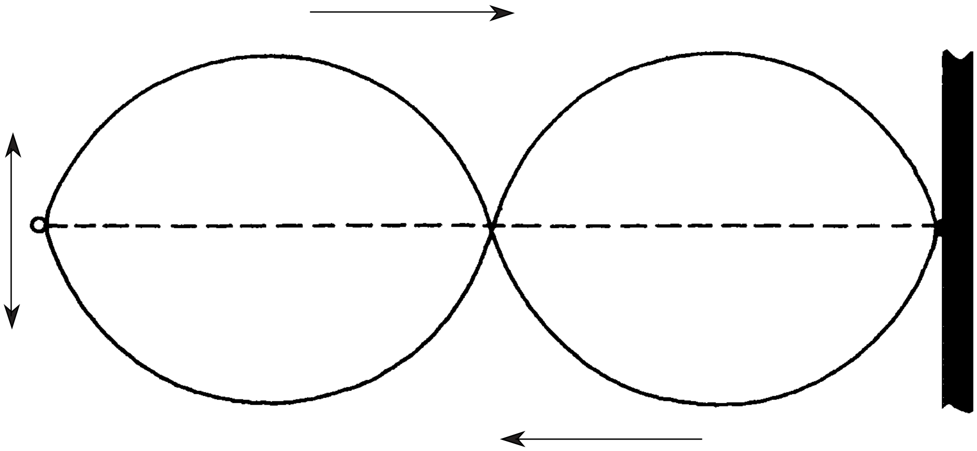

3-6B Standing waves.

flection coefficient varies from –1 to +1, depending upon the magnitude of reflection; $\Gamma = 0$ indicates a perfect match with no reflection, while –1 indicates a short-circuited load, and +1 indicates an open circuit. To understand the reflection coefficient, let's start with a basic definition of the resistive load impedance $Z = R + j0$:

$$Z_L = \frac{V}{I} \tag{3.10}$$

where

Z_L is the load impedance $R + j0$
V is the voltage across the load
I is the current flowing in the load

Because there are both reflected and incident waves, we find that V and I are actually the sum of incident and reflected voltages and currents, respectively. Therefore:

$$Z_L = \frac{V}{I} \tag{3.11A}$$

$$Z_L = \frac{V_{\text{inc}} + V_{\text{ref}}}{I_{\text{inc}} + I_{\text{ref}}} \tag{3.11B}$$

where

V_{inc} is the incident (i.e., forward) voltage
V_{ref} is the reflected voltage
I_{inc} is the incident current
I_{ref} is the reflected current

Because of Ohm's law, you can define the currents in terms of voltage, current, and the characteristic impedance of the line:

$$I_{\text{inc}} = \frac{V_{\text{inc}}}{Z_o} \qquad \textbf{[3.12]}$$

and

$$I_{\text{inc}} = \frac{-V_{\text{ref}}}{Z_o} \qquad \textbf{[3.13]}$$

(The minus sign in Eq. 3.13 indicates that a direction reversal has taken place.)

The two expressions for current (Eqs. 3.12 and 3.13) may be substituted into Eq. 3.11 to yield

$$Z_L = \frac{V_{\text{inc}} + V_{\text{ref}}}{\dfrac{V_{\text{inc}}}{Z_o} - \dfrac{V_{\text{ref}}}{Z_o}} \qquad \textbf{[3.14]}$$

The reflection coefficient Γ is defined as the ratio of reflected voltage to incident voltage:

$$\Gamma = \frac{V_{\text{ref}}}{V_{\text{inc}}} \qquad \textbf{[3.15]}$$

Using this ratio in Eq. 3.14 gives

$$\Gamma = \frac{Z_L - Z_o}{Z_L + Z_o} \qquad \textbf{[3.16]}$$

Example 3-3 A 50-Ω transmission line is connected to a 30-Ω resistive load. Calculate the reflection coefficient Γ.

Solution:

$$\Gamma = \frac{Z_L - Z_o}{Z_L + Z_o}$$

$$= \frac{(50\ \Omega) - (30\ \Omega)}{(50\ \Omega) + (30\ \Omega)}$$

$$= \frac{20}{80} = 0.25$$

Example 3-4 In Example 3-3, the incident voltage is 3 V rms. Calculate the reflected voltage.

Solution:

If

$$\Gamma = \frac{V_{\text{ref}}}{V_{\text{inc}}}$$

then

$$\begin{aligned} V_{\text{ref}} &= \Gamma\, V_{\text{inc}} \\ &= (0.25)\ (3\ \text{V}) = 0.75\ \text{V} \end{aligned}$$

The phase of the reflected signal is determined by the relationship of load impedance and transmission line characteristic impedance. For resistive loads ($Z = R + j0$): if the ratio Z_L/Z_o is 1.0, then there is no reflection; if Z_L/Z_o is less than 1.0, then the reflected signal is 180° out of phase with the incident signal; if the ratio Z_L/Z_o is greater than 1.0 then the reflected signal is in phase with the incident signal. In summary:

Ratio	**Angle of reflection**
$Z_L/Z_o = 1$	No reflection
$Z_L/Z_o < 1$	180°
$Z_L/Z_o > 1$	0°

The step-function (or pulse) response of the transmission line leads to a powerful means of analyzing the line, and its load, on an oscilloscope. Figure 3-7A shows (in schematic form) the test set-up for *time domain reflectometry* (TDR) measurements. An oscilloscope and a pulse (or square-wave) generator are connected in parallel across the input end of the transmission line. Figure 3-7B shows a pulse test jig built by the author for testing lines at HF. The small shielded box contains a TTL square-wave oscillator circuit. Although a crystal oscillator can be used, an *RC* timed circuit running close to 1000 kHz is sufficient. In Fig. 3-7B, you can see the test pulse generator box is connected in parallel with the cable under test and the input of the oscilloscope. A closer look is seen in Fig. 3-7C. A BNC “tee” connector and a double male BNC adapter are used to interconnect the box with the ’scope.

If a periodic waveform is supplied by the generator, then the display on the oscilloscope will represent the sum of reflected and incident pulses. The duration of the pulse (i.e., pulse width), or one-half the period of the square wave, is adjusted so that the returning reflected pulse arrives approximately in the center of the incident pulse.

Figure 3-8 shows a TDR display under several circumstances. Approximately 30 m of coaxial cable, with a velocity factor of 0.66, was used in a test setup similar to Fig. 3-7. The pulse width was approximately 0.9 microseconds (μs). The hori-

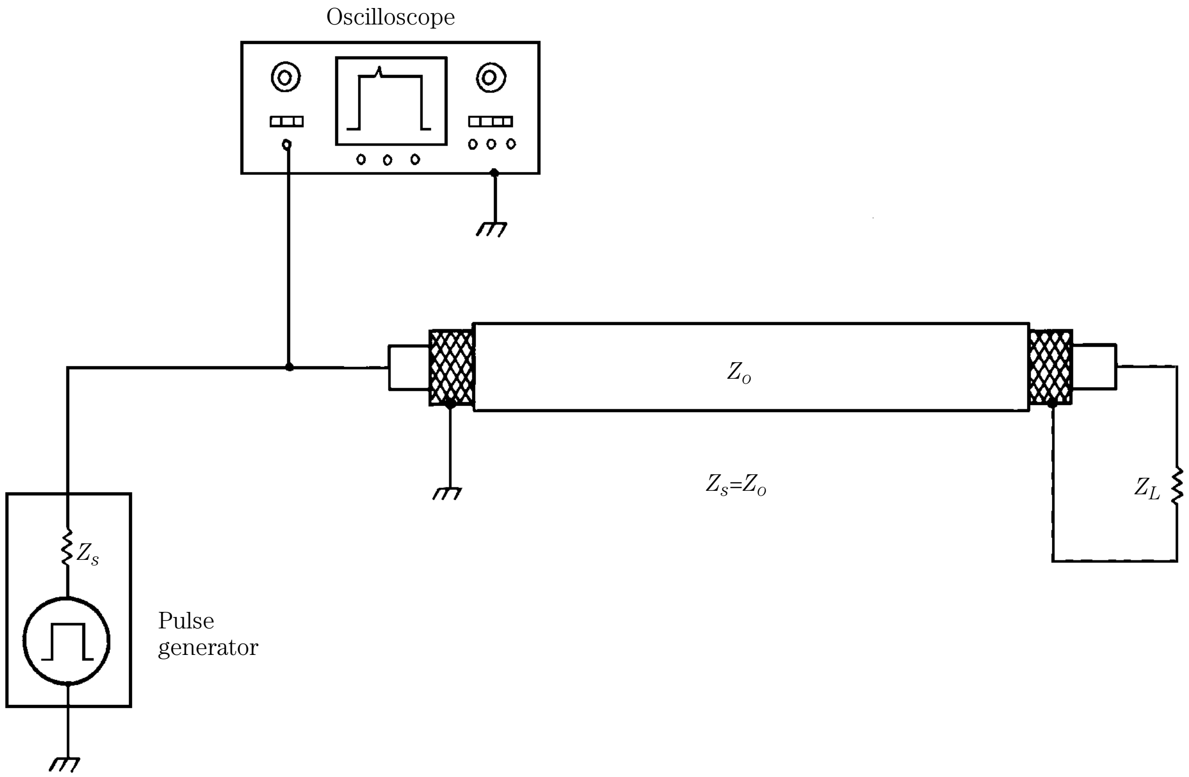
Oscilloscope
Z_o
Z_s=Z_o
Z_L
Z_s
Pulse
generator

3-7A Time domain reflectometry setup.

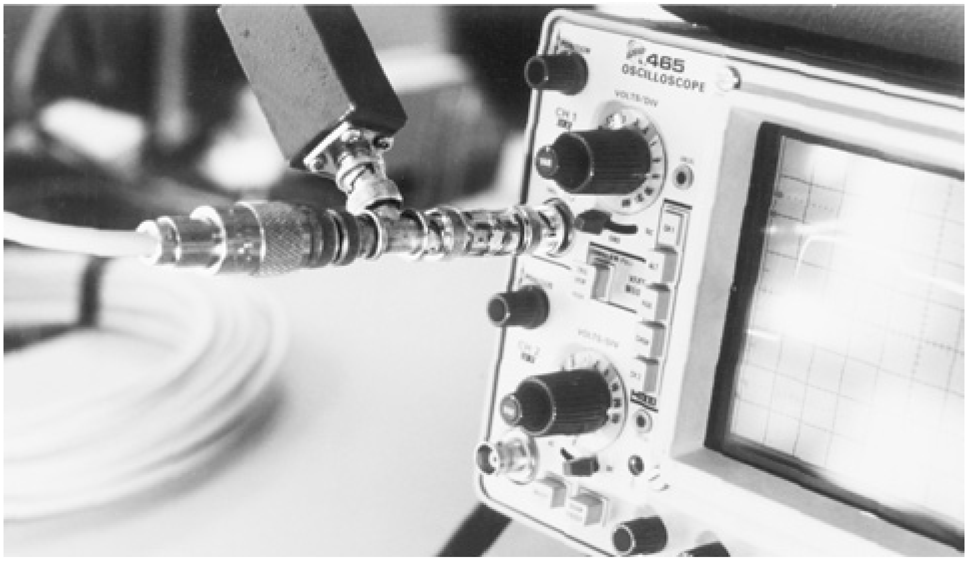
465
OSCILLOSCOPE

3-7B Test setup for impromptu time domain reflectometry.

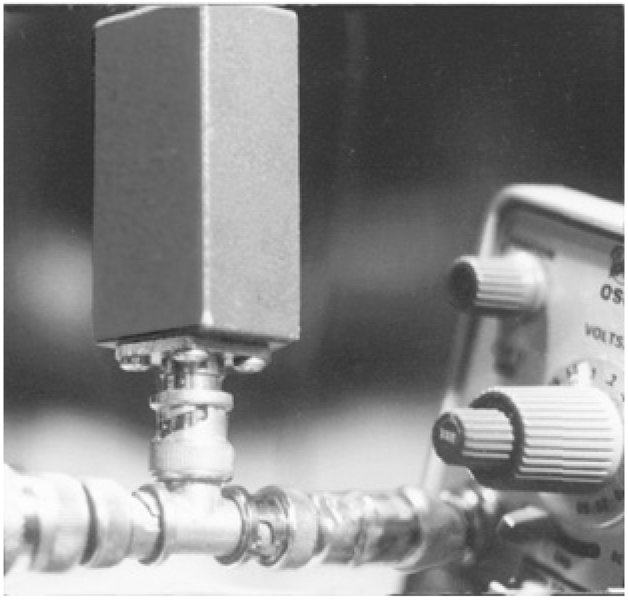

3-7C Close-up of RF connections.

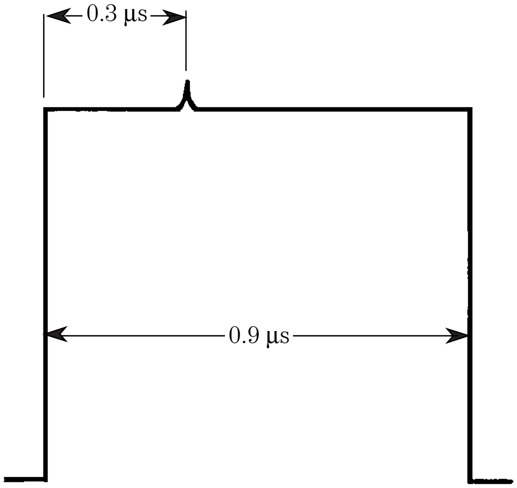

3-8A Idealized TDR pulse. Small "pip" on top is reflected signal interfering with forward pulse.

zontal sweep time on the 'scope was adjusted to show only one pulse—which, in this case, represented one-half of a 550-kHz square wave (Fig. 3-8B).

The displayed trace in Fig. 3-8B shows the pattern when the load is matched to the line ($Z_L = Z_o$). A slight discontinuity exists on the high side of the pulse, and this represents a small reflected wave. Even though the load and line were supposedly matched, the connectors at the end of the line presented a slight impedance discontinuity that shows up on the 'scope as a reflected wave. In general, any discontinuity in the line, any damage to the line, any too-sharp bend, or other anomaly, causes a slight impedance variation, and hence a reflection.

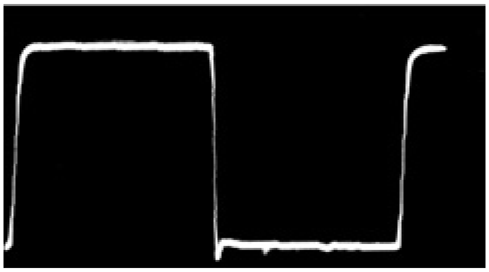

3-8B TDR pulse with no significant reflection.

Notice that the anomaly occurs approximately one-third of the 0.9-μs duration (or 0.3 μs) after the onset of the pulse. This fact tells us that the reflected wave arrives back at the source 0.3 μs after the incident wave leaves. Because this time period represents a round-trip, you can conclude that the wave required 0.3 μs/2, or 0.15 μs to propagate the length of the line. Knowing that the velocity factor is 0.66 for that type of line, you can calculate its approximate length:

$$\text{Length} = cvT \tag{3.17}$$

$$= \frac{(3 \times 10^8 \text{ m/s})}{\text{s}} \times (0.66) \times (1.5 \times 10^{-7} \text{ s})$$

$$= 29.7 \text{ m}$$

which agrees "within experimental accuracy" with the 30 m actual length prepared for the experiment ahead of time. Thus, the TDR setup (or a TDR instrument) can be used to measure the length of a transmission line. A general equation is

$$L_{\text{meters}} = \frac{cvT_d}{2} \tag{3.18}$$

where

L is the length in meters
c is the velocity of light (3×10^8 m/s)
v is the velocity factor of the transmission line
T_d is the round-trip time between the onset of the pulse, and the first reflection

Figures 3-8C through 3-8H show the behavior of the transmission line to the stepfunction when the load impedance is mismatched to the transmission line (Z_L not equal to Z_o). Figure 3-8C shows what happens when the load impedance is less than the line impedance (in this case, $0.5Z_o$). The reflected wave is inverted, and

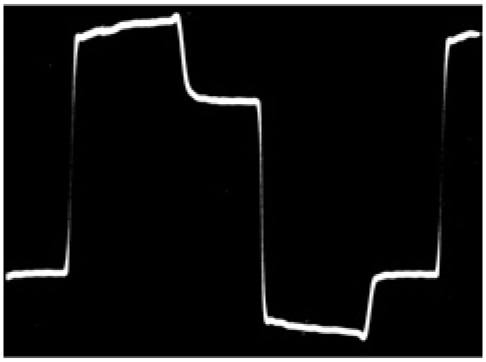

3-8C $Z_L < Z_o$.

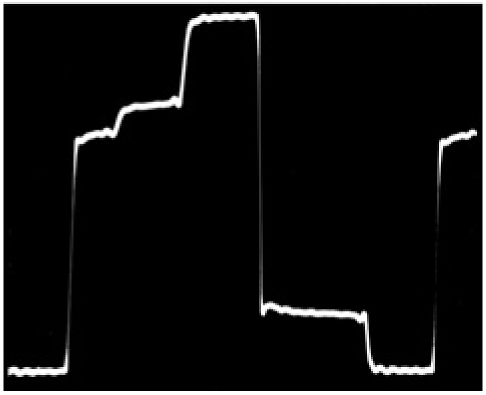

3-8D $Z_L > Z_o$.

sums with the incident wave along the top of the pulse. The reflection coefficient can be determined by examining the relative amplitudes of the two waves.

The opposite situation, in which Z_L is $2Z_o$, is shown in Fig. 3-8D. In this case, the reflected wave is in phase with the incident wave, so it adds to the incident wave as shown. The cases for a short-circuited load and an open-circuited load are shown in Figs. 3-8E and 3-8F, respectively. The cases of reactive loads are shown in Figs. 3-8G and 3-8H. The waveform in Fig. 3-8G resulted from a capacitance in series with a 50-Ω (matched) resistance; the waveform in Fig. 3-8H resulted from a 50-Ω resistance in series with an inductance.

The ac response of the transmission line

When a CW RF signal is applied to a transmission line, the excitation is sinusoidal (Fig. 3-9), so it becomes useful for us to investigate the steady-state ac response of the line. The term *steady-state* implies a sine wave of constant amplitude, phase, and

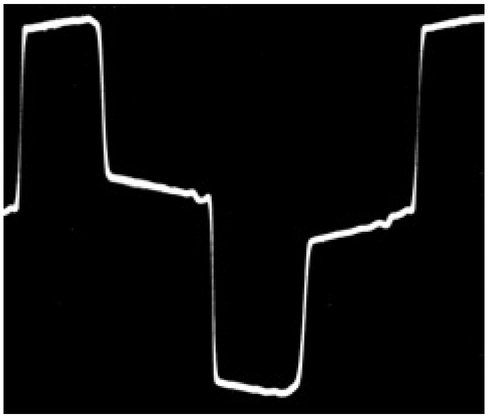

3-8E $Z_L = 0$.

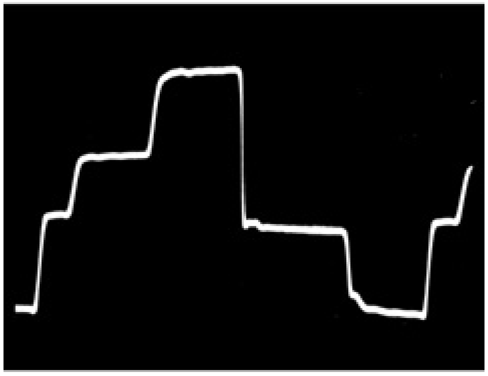

3-8F $Z_L = \infty$.

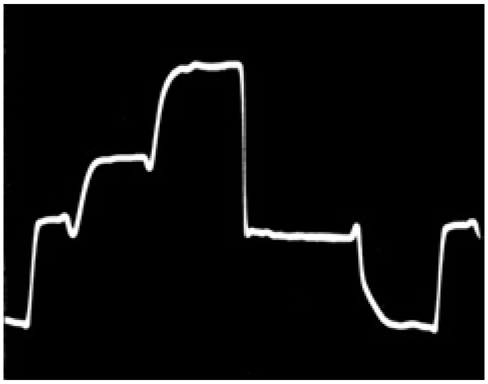

3-8G $Z_L = 50 - jX_C$.

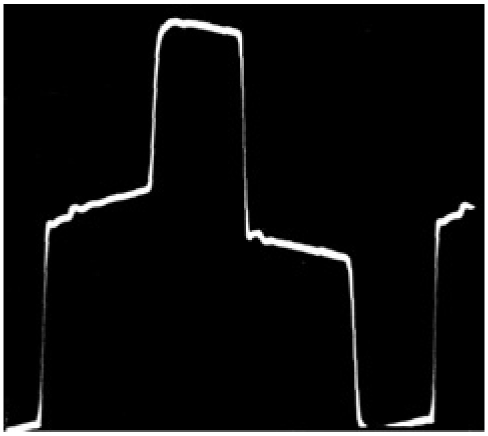

3-8H $Z_L = 50 + jX_L$

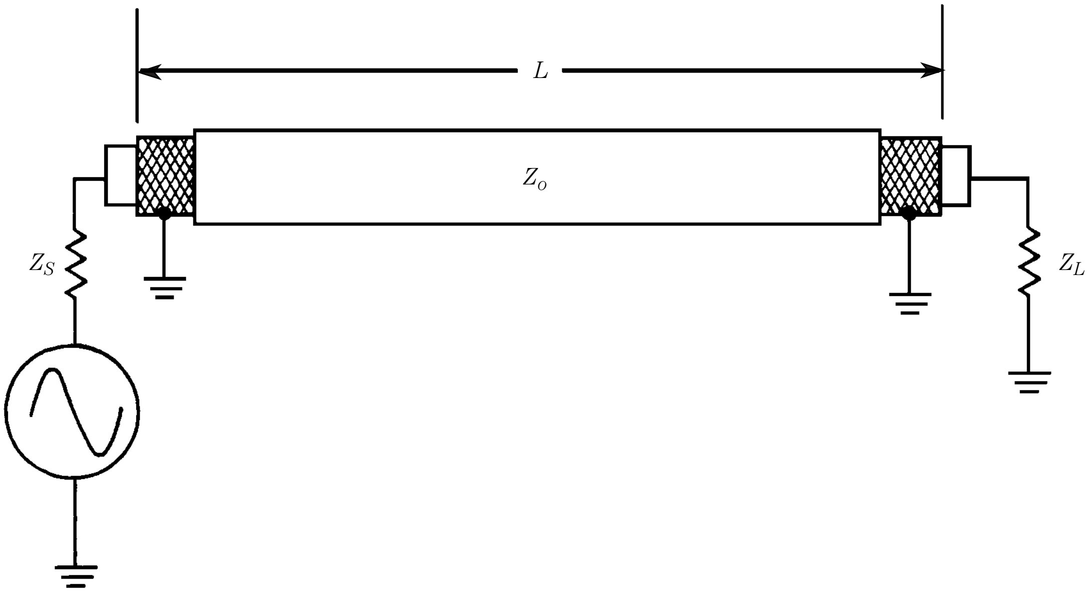

3-9 AC-excited transmission line.

frequency. When ac is applied to the input of the line, it propagates along the line at a given velocity. The ac signal amplitude and phase will decay exponentially:

$$V_R = Ve^{-\gamma l} \qquad \textbf{[3.19]}$$

where

V_R is the voltage received at the far end of the line
V is the applied voltage
l is the length of the line
y is the *propagation constant* of the line

The propagation constant y is defined in various equivalent ways, each of which serves to illustrate its nature. For example, the propagation constant is proportional to the product of impedance and admittance characteristics of the line:

$$y = \sqrt{ZY} \qquad \textbf{[3.20]}$$

or, since $Z = R + j\,\omega\,L$ and $Y = G + j\,\omega\,C$, we may write:

$$y = \sqrt{(R + jwl)\ (G + jwC)} \qquad \textbf{[3.21]}$$

You can also write an expression for the propagation constant in terms of the *line attenuation constant* a and *phase constant* B:

$$y = a + jB \qquad \textbf{[3.22]}$$

If you can assume that susceptance dominates conductance in the admittance term, and reactance dominates resistance in the impedance term (both usually true at microwave frequencies), then we may neglect the R and G terms altogether and write:

$$y = j\omega\sqrt{LC} \qquad \textbf{[3.23]}$$

We may also reduce the phase constant B to

$$B = \omega\sqrt{LC} \qquad \textbf{[3.24]}$$

or

$$B = \omega Z_o C \qquad \text{rad/m} \qquad \textbf{[3.25]}$$

and, of course, the characteristic impedance remains:

$$Z_o = \sqrt{LC} \qquad \textbf{[3.26]}$$

Special cases

The impedance “looking into” a transmission line (Z) is the impedance presented to the source by the combination of load impedance and transmission line characteristic impedance. Below are presented equations that define the looking-in impedance seen by a generator (or source) driving a transmission line.

The case where the load impedance, and line characteristic impedance, are matched is defined by

$$Z_L = R_L + j0 = Z_o$$

In other words, the load impedance is resistive and equal to the characteristic impedance of the transmission line. In this case, the line and load are matched, and the impedance looking in will be a simple $Z = Z_L = Z_o$. In other cases, however, we find different situations where Z_L is not equal to Z_o.

1. Z_L is not equal to Z_o in a random-length lossy line:

$$Z = (Z_o)\left[\frac{Z_L + Z_o \tanh(yl)}{Z_o + Z_L \tanh(yl)}\right] \qquad \textbf{[3.27]}$$

where

Z is the impedance looking in, in ohms
Z_L is the load impedance, in ohms
Z_o is the line characteristic impedance, in ohms
l is the length of the line, in meters
y is the propagation constant

2. Z_L not equal to Z_o in a lossless, or very low loss, random-length line:

$$Z = (Z_o)\left[\frac{Z_L + jZ_o \tan(Bl)}{Z_o + jZ_L \tan(Bl)}\right] \qquad \textbf{[3.28]}$$

Equations 3.27 and 3.28 serve for lines of any random length. For lines that are either integer multiples of a half-wavelength, or odd-integer (i.e., 1, 3, 5, 7, . . ., etc.) multiples of a quarter-wavelength, special solutions for these equations are found—and some of these solutions are very useful in practical situations. For example, consider . . .

3. Half-wavelength lossy lines:

$$Z = (Z_o)\left[\frac{Z_L + Z_o \tanh(al)}{Z_o + Z_L \tanh(al)}\right] \qquad \textbf{[3.29]}$$

Example 3-5 A lossless 50-Ω (Z_o) transmission line is exactly one-half wavelength long and is terminated in a load impedance of $Z = 30 + j0$. Calculate the input impedance looking into the line. (*Note*: in a lossless line $a = 0$.)

Solution:

$$Z = (Z_o)\left[\frac{Z_L + Z_o \tanh(al)}{Z_o + Z_L \tanh(al)}\right]$$

$$
\begin{aligned}
Z &= (50\ \Omega)\left\{\frac{30 + 50 \tanh[(0)(\pi)]}{50 + 30 \tanh[(0)(\pi)]}\right\}\\
&= (50\ \Omega)\left[\frac{30 + 50 \tanh(0)}{50 + 30 \tanh(0)}\right]\\
&= (50\ \Omega)\left(\frac{30 + 0}{50 + 0}\right)\\
&= (50\ \Omega)\ (30/50) = 30\ \Omega
\end{aligned}
$$

In Example 3-5 we discovered that the impedance looking into a lossless (or very low loss) half-wavelength transmission line is the load impedance:

$$Z = Z_L \tag{3.30}$$

The fact that line input impedance equals load impedance, is very useful in certain practical situations. For example, a resistive impedance is not changed by the line length. Therefore, when an impedance is inaccessible for measurement purposes, the impedance can be measured through a transmission line that is an integer multiple of a half wavelength.

Our next special case involves a quarter-wavelength transmission line, and those that are *odd* integer multiples of quarter-wavelengths (of course, *even* integer multiples of a quarter wavelength obey the half-wavelength criteria).

4. Quarter-wavelength lossy lines:

$$Z = (Z_o)\left[\frac{Z_L + Z_o \coth(al)}{Z_o + Z_L \coth(al)}\right] \tag{3.31}$$

and

5. Quarter-wavelength lossless or very low loss lines:

$$Z = \frac{(Z_o)^2}{Z_L} \tag{3.32}$$

From Eq. 3.32, you can discover an interesting property of the quarter-wavelength transmission line. First, divide each side of the equation by Z_o:

$$\frac{Z}{Z_o} = \frac{[Z_o]^2}{Z_L Z_o} \tag{3.33}$$

$$= \frac{Z_o}{Z_L} \tag{3.34}$$

The ratio Z/Z_o shows an inversion of the load impedance ratio Z_L/Z_o, or, stated another way,

$$\frac{Z}{Z_o} = \frac{1}{Z_L/Z_o} \tag{3.35}$$

Again, from Eq. 3.32, you can deduce another truth about quarter-wavelength transmission lines:
If

$$Z = \frac{\sqrt{Z_o}}{Z_L} \tag{3.36}$$

then

$$ZZ_L = \sqrt{Z_o} \tag{3.37}$$

which means

$$Z_o = \sqrt{ZZ_L} \tag{3.38}$$

Equation 3.38 shows that a quarter-wavelength transmission line can be used as an *impedance matching network*. Called a *Q section*, the quarter-wavelength transmission line used for impedance matching requires a characteristic impedance Z_o—if Z is the source impedance and Z_L is the load impedance.

Example 3-6 A 50-Ω source must be matched to a load impedance of 36 Ω. Find the characteristic impedance required of a Q section matching network.

Solution:

$$\begin{aligned} Z &= \sqrt{ZZ_L} \\ &= \sqrt{(50\ \Omega)\ (36\ \Omega)} \\ &= \sqrt{1800\ \Omega^2} = 42\ \Omega \end{aligned}$$

6. Transmission line as a reactance: Reconsider Eq. 3.28, which related impedance looking in to load impedance and line length:

$$Z = (Z_o)\left[\frac{Z_L + jZ_o \tan (Bl)}{Z_o + jZ_L \tan (Bl)}\right] \tag{3.39}$$

Now, for the case of a shorted line (i.e., $Z_L = 0$), the solution is

$$Z = (Z_o)\left[\frac{(0) + jZ_o \tan (B\,l)}{Z_o + j(0) \tan (B\,l)}\right] \tag{3.40}$$

$$Z = (Z_o)\left[\frac{jZ_o \tan (Bl)}{Z_o}\right] \qquad \textbf{[3.41]}$$

$$Z = j\,Z_o \tan (Bl) \qquad \textbf{[3.42]}$$

Recall from Eq. 3.25 that

$$B = WZ_oC \qquad \textbf{[3.43]}$$

Substituting Eq. 3.43 into Eq. 3.42 produces

$$Z = j\,Z_o \tan (\omega Z_oCl) \qquad \textbf{[3.44]}$$

or

$$Z = j\,Z_o \tan (2\pi FZ_oCl) \qquad \textbf{[3.45]}$$

Because the solutions to Eqs. 3.44 and 3.45 are multiplied by the j operator, the impedance is actually a reactance ($Z = 0 + jX$). It is possible to achieve almost any possible reactance (within certain practical limitations) by adjusting the length of the transmission line and shorting the "load" end. This fact leads us to a practical method for impedance matching.

Figure 3-10A shows a circuit in which an unmatched load is connected to a transmission line with characteristic impedance Z_o. The load impedance Z_L is of the form $Z = R \pm jX$, and, in this case, it is equal to $50 - j20$.

A complex impedance load can be matched to its source by interposing the complex conjugate of the impedance. For example, in the case where $Z = 50 - j20$, the matching impedance network will require an impedance of $50 + j20\ \Omega$. The two impedances combine to produce a result of 50 Ω. The situation of Fig. 3-10A shows a matching stub with a reactance equal in magnitude, but opposite in sign, with respect to the reactive component of the load impedance. In this case, the stub has a reactance of $+j20\ \Omega$ to cancel a reactance of $-j20\ \Omega$ in the load.

A *quarter-wavelength shorted stub* is a special case of the stub concept that finds particular application in microwave circuits. *Waveguides* (Chap. 19) are based on the properties of the quarter-wavelength shorted stub. Figure 3-10B shows a quarter-wave stub and its current distribution. The current is maximum across the short, but wave cancellation forces it to zero at the terminals. Because $Z = V/I$, when I goes to zero, the impedance becomes infinite. Thus, a quarter-wavelength stub has an infinite impedance at its resonant frequency, and redundant acts as an insulator. This concept may be hard to swallow, but the stub is a "metal insulator."

Standing wave ratio

The reflection phenomenon was noted earlier during the coverage of the step-function and single-pulse response of a transmission line; the same phenomenon also applies when the transmission line is excited with an ac signal. When a transmission

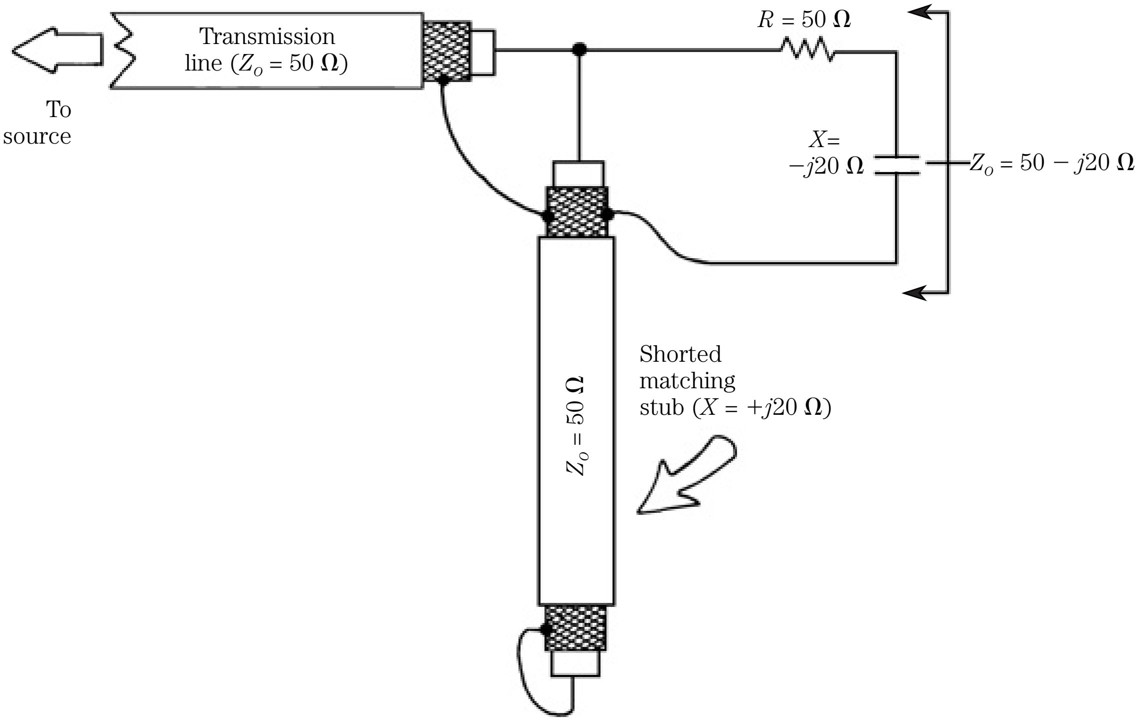
Transmission line (Z_o = 50 Ω)
To source
R = 50 Ω
X= $-j20$ Ω
$Z_o = 50 - j20$ Ω
Z_o = 50 Ω
Shorted matching stub (X = $+j20$ Ω)

3-10A Stub matching system.

line is not matched to its load, some of the energy is absorbed by the load and some is reflected back down the line toward the source. The interference of incident (or "forward") and reflected (or "reverse") waves creates *standing waves* on the transmission line.

If the voltage or current is measured along the line, it will vary, depending on the load, according to Fig. 3-11. Figure 3-11A shows the voltage-versus-length curve for a matched line (i.e., where $Z_L = Z_o$). The line is said to be "flat" because the voltage (and current) is constant all along the line. But now consider Figs. 3-11B and 3-11C.

Figure 3-11B shows the voltage distribution over the length of the line when the load end of the line is *shorted* (i.e., $Z_L = 0$). Of course, at the load end the voltage is zero, which results from zero impedance. The same impedance and voltage situation is repeated every half-wavelength down the line from the load end toward the generator. Voltage *minima* are called *nodes*, and voltage *maxima* are called *antinodes*.

The pattern in Fig. 3-11C results when the line is unterminated (open) (i.e., $Z_L = \infty$). Note that the pattern is the same shape as Fig. 3-11B (shorted line), but the phase is shifted 90°. In both cases, the reflection is 100 percent, but the phase of the reflected wave is opposite.

Figure 3-11D shows the situation in which Z_L is not equal to Z_o, but is neither zero nor infinite. In this case, the nodes represent some finite voltage, V_{min}, rather

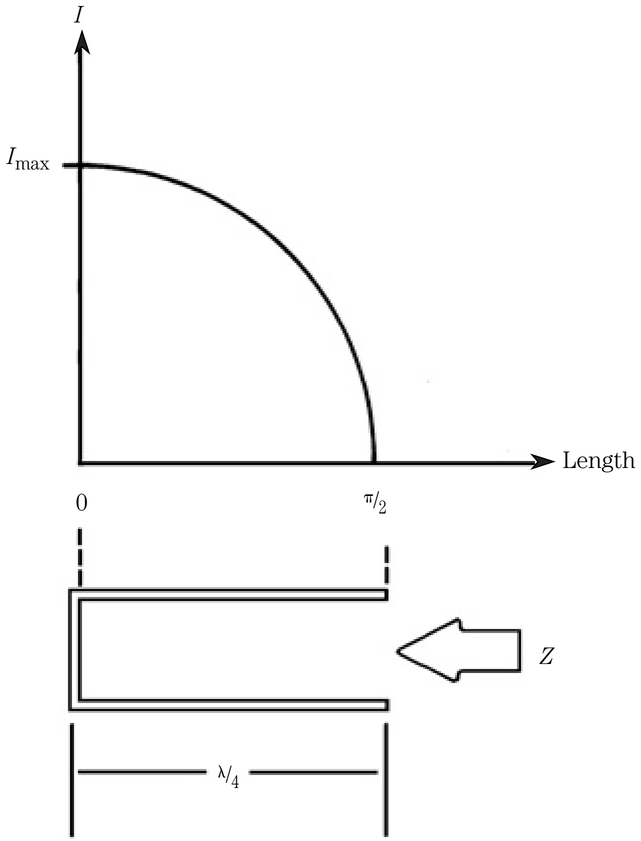

3-10B Quarter-wavelength stub.

than zero. The *standing wave ratio* (SWR) reveals the relationship between load and line.

If the current along the line is measured, the pattern will resemble the patterns of Fig. 3-11. The SWR is then called ISWR, to indicate the fact that it came from a current measurement. Similarly, if the SWR is derived from voltage measurements it is called VSWR. Perhaps because voltage is easier to measure, VSWR is the term most commonly used in most radio work.

VSWR can be specified in any of several equivalent ways:

1. *From incident voltage (V_i) and reflected voltage (V_i):*

$$\mathrm{VSWR} = \frac{V_i + V_r}{V_i - V_r} \qquad \textbf{[3.46]}$$

2. *From transmission line voltage measurements (Fig. 3-11D):*

$$\mathrm{VSWR} = \frac{V_{\max}}{V_{\min}} \qquad \textbf{[3.47]}$$

3. *From load and line characteristic impedances:*

$$(Z_L > Z_o)\ \text{VSWR} = Z_L/Z_o \qquad \textbf{[3.48]}$$

$$(Z_L < Z_o)\ \text{VSWR} = Z_o/Z_L \qquad \textbf{[3.49]}$$

4. *From incident (P_i) and reflected (P_r) power:*

$$\text{VSWR} = \frac{1 + \sqrt{P_r/P_i}}{1 - \sqrt{P_r/P_i}} \qquad \textbf{[3.50]}$$

5. *From reflection coefficient (Γ):*

$$\text{VSWR} = \frac{1 + \Gamma}{1 - \Gamma} \qquad \textbf{[3.51]}$$

It is also possible to determine the reflection coefficient Γ from a knowledge of VSWR:

$$\Gamma = \frac{\text{VSWR} - 1}{\text{VSWR} + 1} \qquad \textbf{[3.52]}$$

The relationship between reflection coefficient Γ and VSWR is shown in Fig. 3-11D.

VSWR is usually expressed as a *ratio*. For example, when Z_L is 100 Ω and Z_o is 50 Ω, the VSWR is Z_L/Z_o = 100 Ω/50 Ω = 2, which is usually expressed as VSWR = 2:1. VSWR can also be expressed in decibel form:

$$\text{VSWR} = 20 \log (\text{VSWR}) \qquad \textbf{[3.53]}$$

Example 3-7 A transmission line is connected to a mismatched load. Calculate both the VSWR and VSWR decibel equivalent if the reflection coefficient Γ is 0.25.

Solution:

$$(a)\ \text{VSWR} = \frac{1 + \Gamma}{1 - \Gamma}$$

$$= \frac{1 + 0.25}{1 - 0.25}$$

$$= \frac{1.25}{0.75} = 1.67{:}1$$

$$(b)\ \text{VSWR}_{\text{dB}} = 20 \log (\text{VSWR})$$

$$= (20)\ (\log 1.67)$$

$$= (20)\ (0.22) = 4.3\ \text{dB}$$

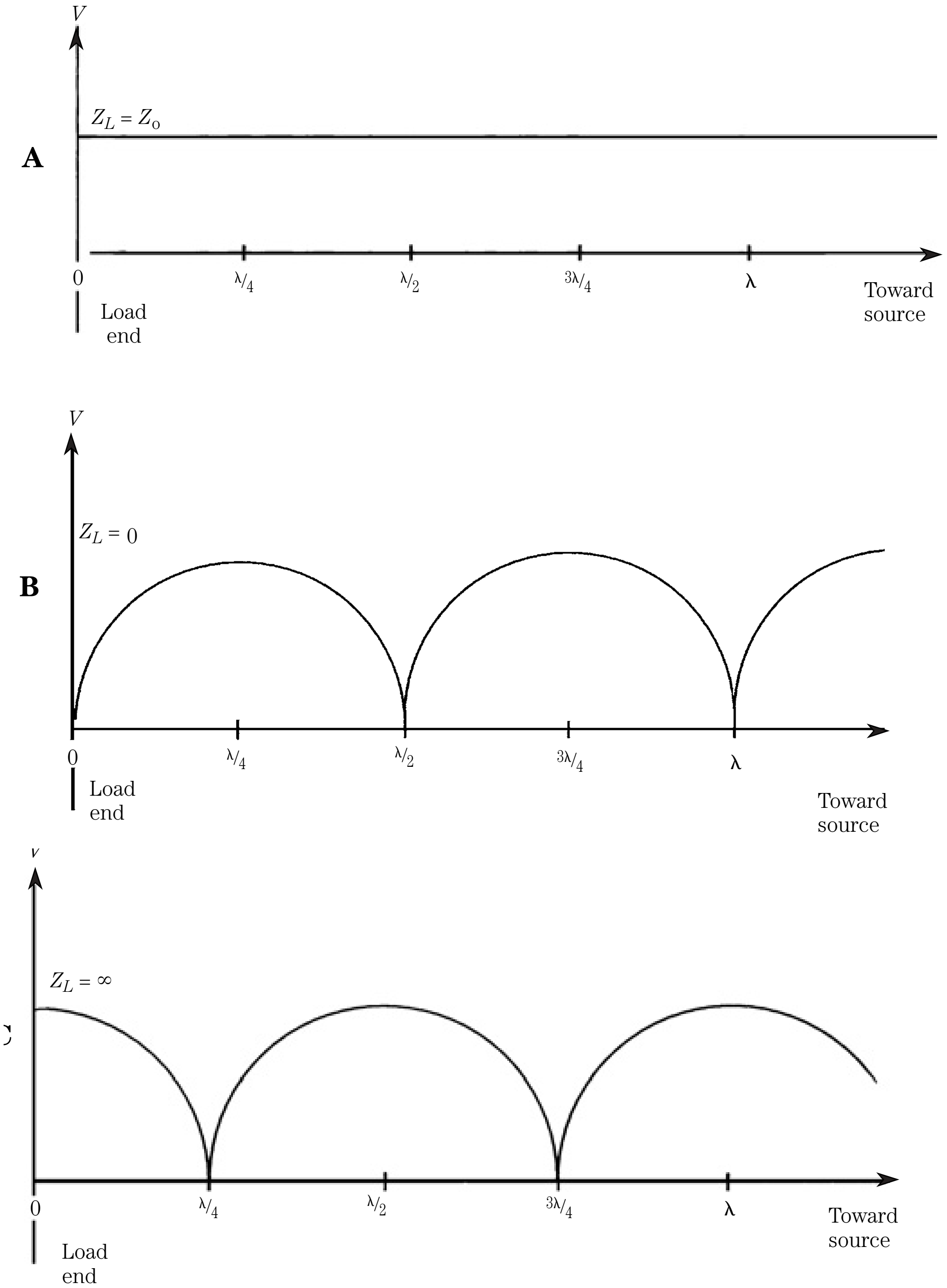

3-11 Voltage versus electrical length: (A) Matched impedances, (B) $Z_L = 0$, (C) Z_L = infinite.

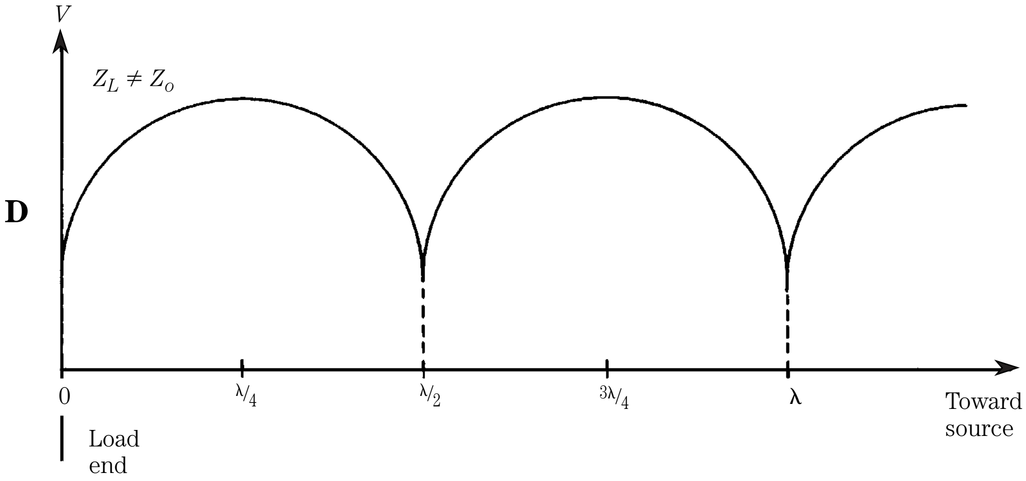

3-11 Continued: (D) Z_L not equal to Z_o.

The SWR is regarded as important in systems for several reasons. The base of these reasons is the fact that the reflected wave represents energy lost to the load. For example, in an antenna system, less power is radiated if some of its input power is reflected back down the transmission line, because the antenna feedpoint impedance does not match the transmission line characteristic impedance. The next section covers the problem of mismatch losses.

Mismatch (VSWR) losses

The power reflected from a mismatched load represents a loss, and will have implications that range from negligible to profound, depending on the situation. For example, one result might be a slight loss of signal strength at a distant point from an antenna. A more serious problem can result in the destruction of the output device in a transmitter. The latter problem so plagued early solid-state transmitters that designers opted to include shutdown circuitry to sense high VSWR, and turn down output power proportionally.

In microwave measurements, VSWR on the transmission lines (that interconnect devices under test, instruments, and signal sources) can cause erroneous readings—and invalid measurements.

Determination of VSWR losses must take into account *two* VSWR situations. Figure 3-9 shows a transmission line of impedance Z_o interconnecting a load impedance Z_L, and a source with an output impedance Z_s. There is a potential for impedance mismatch at *both ends* of the line.

In the case where one end of the line is matched (either Z_s or Z_L), the *mismatch loss* caused by SWR at the mismatched end is

$$\mathrm{ML} = -10 \log \left[1 - \left(\frac{\mathrm{SWR} - 1}{\mathrm{SWR} + 1} \right)^2 \right] \qquad \textbf{[3.54]}$$

which from Eq. 3.52 is

$$\mathrm{ML} = -10 \log (1 - \Gamma^2) \qquad \textbf{[3.55]}$$

Example 3-8 A coaxial transmission line with a characteristic impedance of 50 Ω is connected to the 50-Ω output (Z_o) of a signal generator, and also to a 20-W load impedance Z_L. Calculate the mismatch loss.

Solution:

(*a*) First find the VSWR:

$$\begin{aligned}\mathrm{VSWR} &= Z_o/Z_L \\ &= (50\ \Omega)/(20\ \Omega) = 2.5{:}1\end{aligned}$$

(*b*) Mismatch loss:

$$\begin{aligned}\mathrm{ML} &= -10 \log \left[1 - \left(\frac{\mathrm{SWR} - 1}{\mathrm{SWR} + 1} \right)^2 \right] \\ &= -10 \log \left[1 - \left(\frac{2.5 - 1}{2.5 + 1} \right)^2 \right] \\ &= -10 \log \left[1 - \left(\frac{1.5}{3.5} \right)^2 \right] \\ &= -10 \log [1 - (0.43)^2] \\ &= -10 \log [1 - 0.185] \\ &= -10 \log [0.815] \\ &= (-10)\ (-0.089) = 0.89\end{aligned}$$

When both ends of the line are mismatched, a different equation is required:

$$\mathrm{ML} = 20 \log [1 \pm (\Gamma_1 \times \Gamma_2)] \qquad \textbf{[3.56]}$$

where

Γ_1 is the reflection coefficient at the source end of the line,
$(VSWR_1 - 1)/(VSWR_1 + 1)$
Γ_2 is the reflection coefficient at the load end of the line,
$(VSWR_2 - 1)/(VSWR_2 + 1)$

Note that the solution to Eq. 3.56 has two values: $[1 + (\Gamma_1\Gamma_2)]$ and $[1 - (\Gamma_1\Gamma_2)]$.

The equations reflect the mismatch loss solution for low-loss or “lossless” transmission lines. This is a close approximation in some situations; however, it is insufficient when the line is lossy. Although not very important at low frequencies, loss becomes higher at microwave frequencies. Interference between incident and reflected waves produces increased current at certain antinodes—which increases ohmic losses—and increased voltage at certain antinodes—which increases dielectric losses. It is the latter that increases with frequency. Equation 3.57 relates reflection coefficient and line losses to determine total loss on a given line.

$$\text{Loss} = 10 \log \left(\frac{n^2 - \Gamma^2}{n - n\Gamma^2} \right) \qquad \textbf{[3.57]}$$

where

Loss is the total line loss in decibels
Γ is the reflection coefficient
n is the quantity $10^{(A/10)}$
A is the total attenuation presented by the line, in decibels, when the line is properly matched ($Z_L = Z_o$)

Example 3-9 A 50-Ω transmission line is terminated in a 30-Ω resistive impedance. The line is rated at a loss of 3 dB/100 ft at 1 GHz. Calculate (a) loss in 5 ft of line, (*b*) reflection coefficient, and (*c*) total loss in a 5-ft line mismatched per above.

Solution:

$$(a)\ A = \frac{3 \text{ dB}}{100 \text{ ft}} \times 5 \text{ ft} = 0.15 \text{ dB}$$

$$(b)\ \Gamma = \frac{Z_L - Z_o}{Z_L + Z_o}$$

$$= \frac{50 - 30}{50 + 30}$$

$$= 20/80 = 0.25$$

$$(c)\ n = 10^{(A/10)}$$

$$= 10^{(0.15/10)}$$

$$= 10^{(0.015)} = 1.04$$

$$\text{Loss} = 10 \log \left(\frac{n^2 - \Gamma^2}{n - n\Gamma^2} \right)$$

$$= 10 \log \left[\frac{(1.04)^2 - (0.25)^2}{1.04 - (1.04)\ (0.25)^2} \right]$$

$$= 10 \log \left[\frac{1.082 - 0.063}{1.04 - (1.04)\ (0.063)} \right]$$

$$= 10 \log \left(\frac{1.019}{1.04 - 0.066} \right)$$

$$= 10 \log \left(\frac{1.019}{0.974} \right)$$

$$= 10 \log (1.046)$$

$$= (10)\ (0.02) = 0.2 \text{ dB}$$

Compare the matched line loss ($A = 0.15$ dB) with the total loss (Loss = 0.2 dB), which includes mismatch loss and line loss. The difference (i.e., Loss – A) is only 0.05 dB. If the VSWR was considerably larger, however, the loss would rise.

4
CHAPTER
The Smith chart

THE MATHEMATICS OF TRANSMISSION LINES, AND CERTAIN OTHER DEVICES, BECOMES cumbersome at times, especially in dealing with complex impedances and "nonstandard" situations. In 1939, Phillip H. Smith published a graphical device for solving these problems, and an improved version of the chart followed in 1945. That graphic aid, somewhat modified over time, is still in constant use in microwave electronics, and other fields where complex impedances and transmission line problems are found. The *Smith chart* is indeed a powerful tool for the RF designer.

Smith chart components

The modern Smith chart is shown in Fig. 4-1. It consists of a series of overlapping orthogonal circles (i.e., circles that intersect each other at right angles). This chapter will dissect the Smith chart, so that the origin and use of these circles is apparent. The set of orthogonal circles makes up the basic structure of the Smith chart.

The normalized impedance line

A baseline is highlighted in Fig. 4-2, and bisects the Smith chart outer circle. This line is called the *pure resistance line*, and forms the reference for measurements made on the chart. Recall that a complex impedance contains both resistance and reactance, and is expressed in the mathematical form:

$$Z = R \pm jX \qquad \textbf{[4.1]}$$

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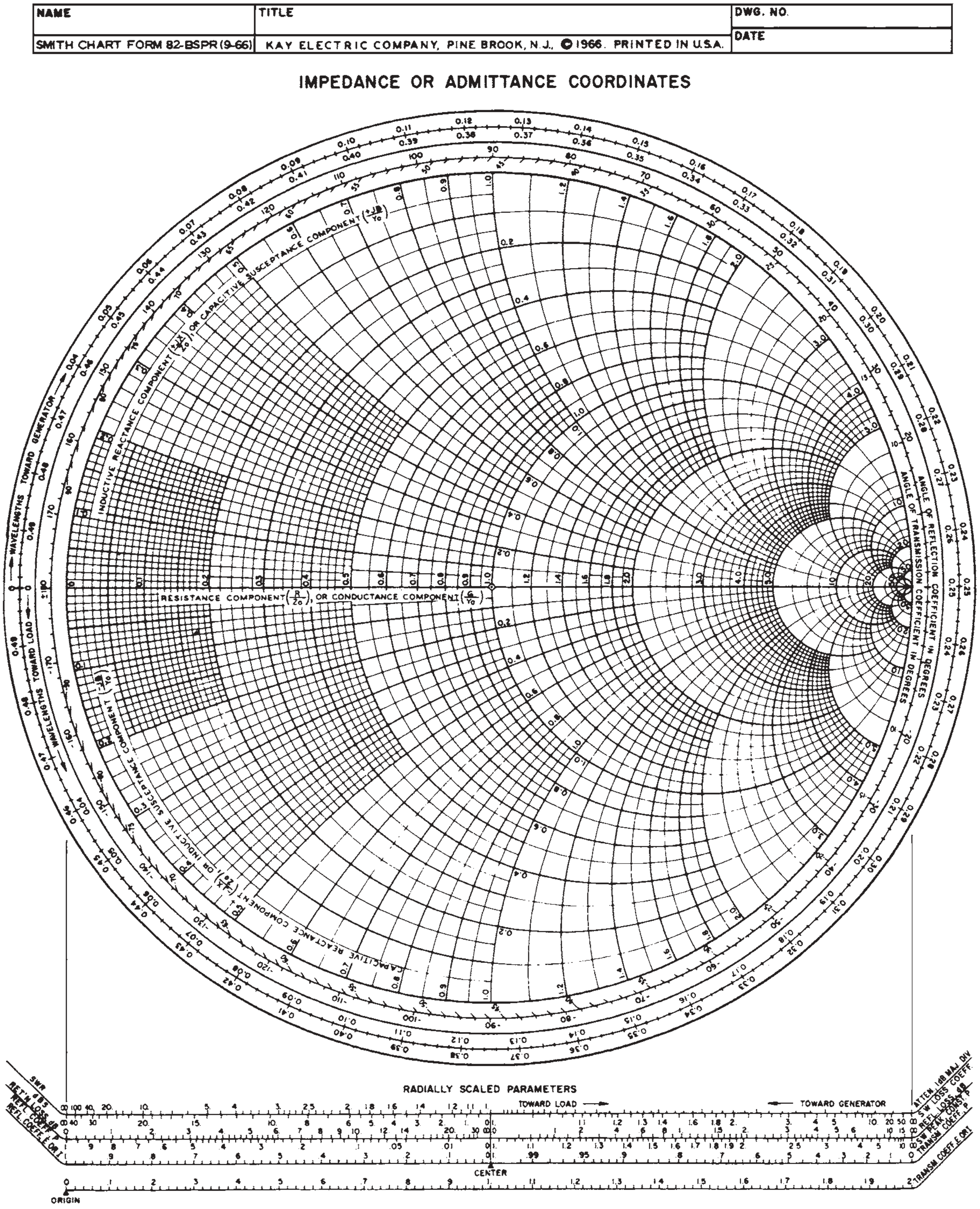
NAME
TITLE
DWG. NO.
SMITH CHART FORM 82-BSPR(9-66)
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DATE
IMPEDANCE OR ADMITTANCE COORDINATES
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo) OR CAPACITIVE SUSCEPTANCE COMPONENT (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo) OR INDUCTIVE SUSCEPTANCE COMPONENT (-jB/Yo)
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS
TOWARD LOAD
TOWARD GENERATOR
SWR
RET'N LOSS dB
REFL. COEFF. P
REFL. COEFF. OR I
ATTEN. 1dB MAJ. DIV.
S.W. LOSS COEFF.
REFL. LOSS dB
S.W. PEAK CONST. P
TRANSM. COEFF. P
TRANSM. COEFF. OR I
CENTER
ORIGIN

4-1 The Smith chart. (*Courtesy of Kay Elementrics*)

where

Z is the complex impedance
R is the resistive component of the impedance
X is the reactive component of the impedance*

The pure resistance line represents the situation where $X = 0$, and the impedance is therefore equal to the resistive component only. In order to make the Smith chart universal, the impedances along the pure resistance line are *normalized* with reference to system impedance (e.g., Z_o in transmission lines); for most microwave RF systems the system impedance is standardized at 50 Ω. In order to normalize the actual impedance, divide it by the system impedance. For example, if the load impedance of a transmission line is Z_L, and the characteristic impedance of the line is Z_o, then $Z = Z_L/Z_o$. In other words,

$$Z = \frac{R \pm jX}{Z_o} \tag{4.2}$$

The pure resistance line is structured such that the system standard impedance is in the center of the chart, and has a normalized value of 1.0 (see point A in Fig. 4-2). This value derives from the fact that $Z_o/Z_o = 1.0$.

To the left of the 1.0 point are decimal fraction values used to denote impedances less than the system impedance. For example, in a 50-Ω transmission line system with a 25-Ω load impedance, the normalized value of impedance is 25 Ω/50 Ω or 0.50 ("B" in Fig. 4-2). Similarly, points to the right of 1.0 are greater than 1 and denote impedances that are higher than the system impedance. For example, in a 50-Ω system connected to a 100-Ω resistive load, the normalized impedance is 100 Ω/50 Ω, or 2.0; this value is shown as point C in Fig. 4-2. By using normalized impedances, you can use the Smith chart for almost any practical combination of system, and load and/or source, impedances, whether resistive, reactive, or complex.

Reconversion of the normalized impedance to actual impedance values is done by multiplying the normalized impedance by the system impedance. For example, if the resistive component of a normalized impedance is 0.45, then the actual impedance is

$$Z = (Z_{\text{normal}})\ (Z_o) \tag{4.3}$$

$$= (0.45)\ (50\ \Omega) \tag{4.4}$$

$$= 22.5\ \Omega \tag{4.5}$$

The constant resistance circles

The *isoresistance circles*, also called the *constant resistance circles*, represent points of equal resistance. Several of these circles are shown highlighted in Fig. 4-3. These circles are all tangent to the point at the righthand extreme of the pure resis-

---

*According to the standard sign convention the inductive reactance (X_L) is positive (+) and the capacitive reactance (X_c) is negative (–). The term X in Eq. 4.1 above is the difference between the two reactances ($X = X_L - X_c$).

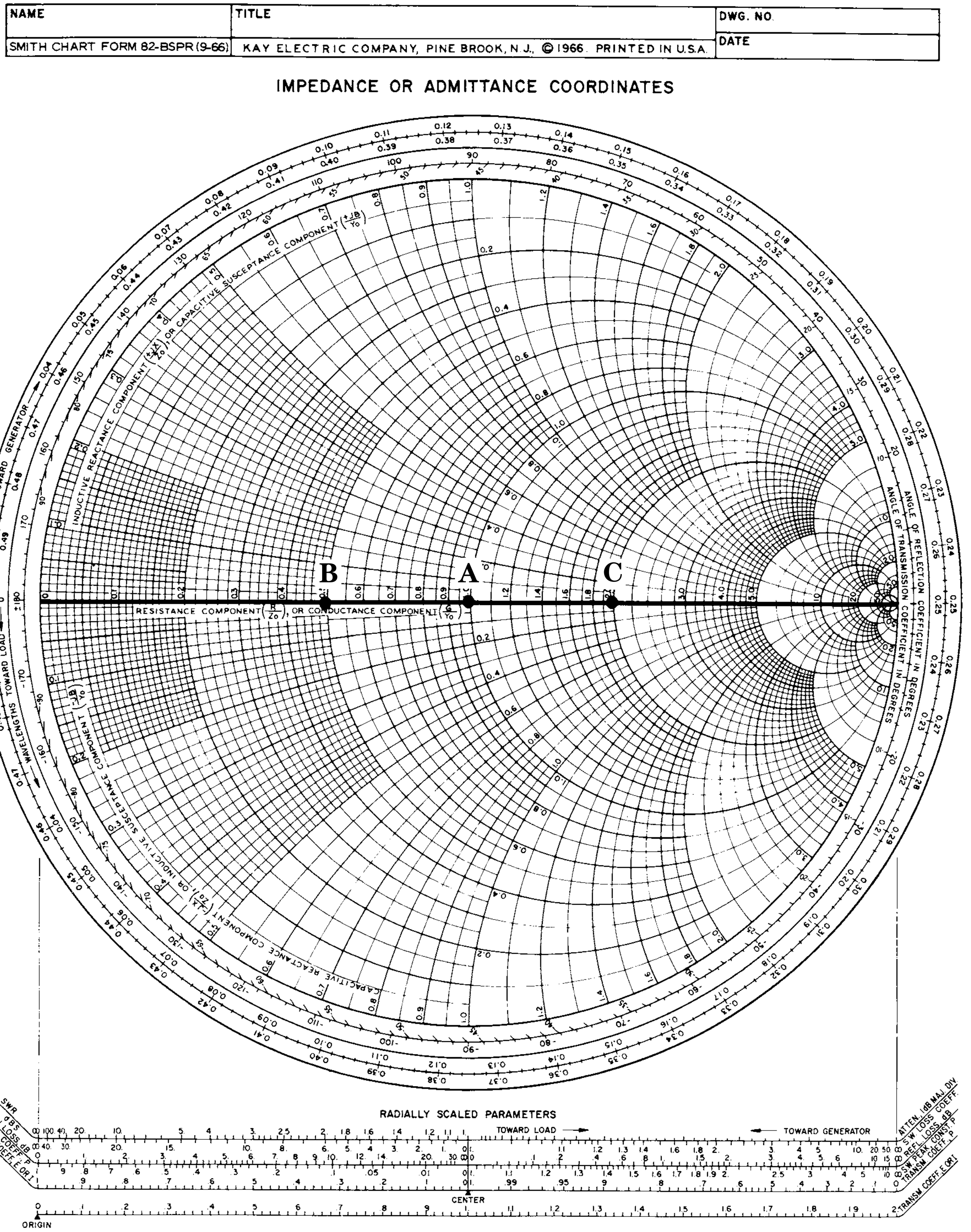
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IMPEDANCE OR ADMITTANCE COORDINATES
B
A
C
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE COMPONENT (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE COMPONENT (-jB/Yo)
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS
TOWARD LOAD
TOWARD GENERATOR
SWR
dBS
ATTEN. 1dB MAJ. DIV.
S.W. LOSS COEFF.
REFL. LOSS dB
S.W. PEAK (CONST. P)
TRANSM. COEFF. P
TRANSM. COEFF. E OR I
CENTER
ORIGIN

4-2 Normalized impedance line. *(Courtesy of Kay Elementrics)*

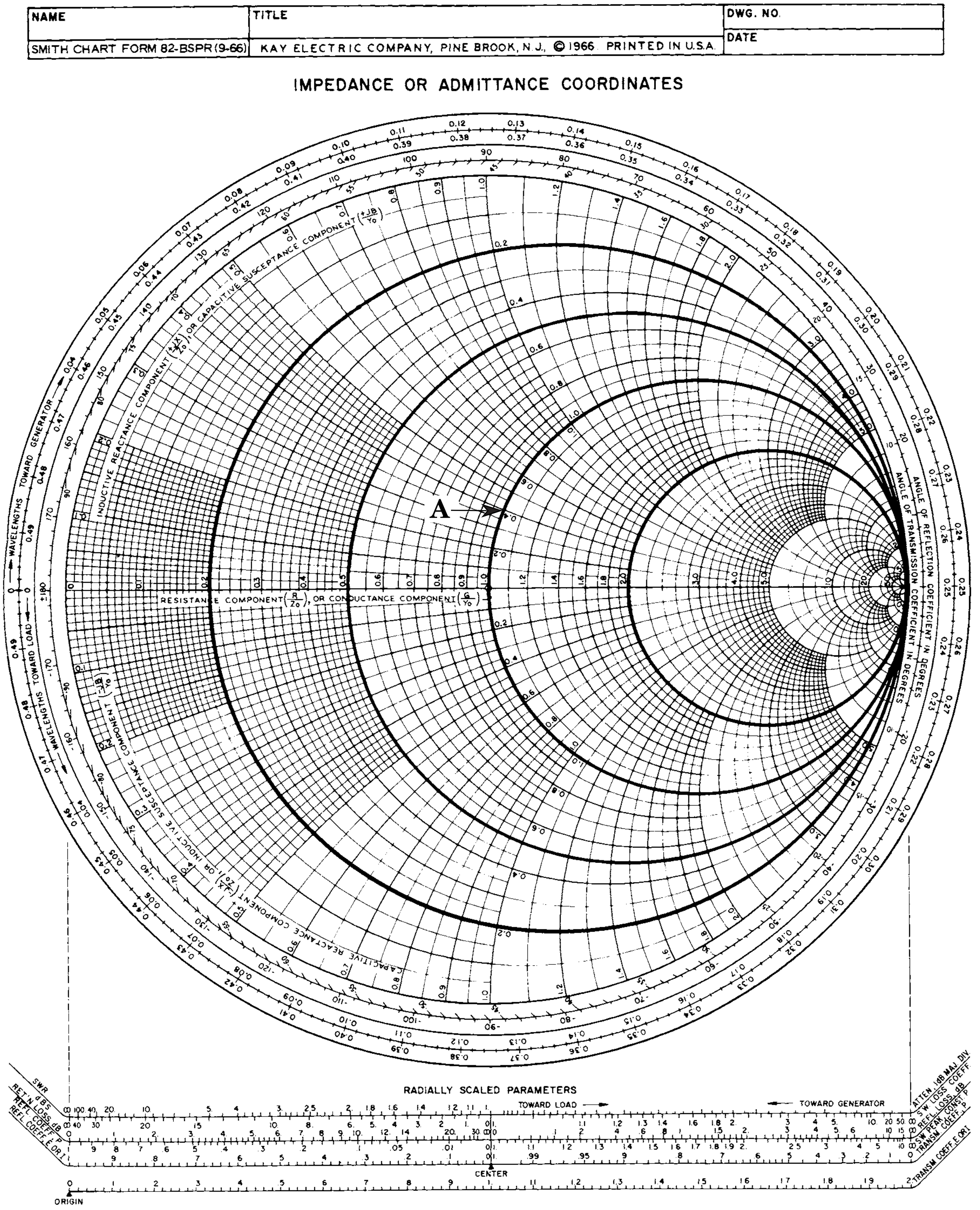
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IMPEDANCE OR ADMITTANCE COORDINATES
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE COMPONENT (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE COMPONENT (-jB/Yo)
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
A
RADIALLY SCALED PARAMETERS
TOWARD LOAD
TOWARD GENERATOR
SWR
dBS
RET'N LOSS, dB
REFL. COEFF, P
REFL. COEFF, E OR I
ATTEN. 1dB MAJ. DIV.
S.W. LOSS COEFF
S.W. PEAK CONST. P
REFL. LOSS, dB
TRANSM. COEFF, P
TRANSM. COEFF, E OR I
CENTER
ORIGIN

4-3 Constant resistance circles. (*Courtesy of Kay Elementrics*) tance line, and are bisected by that line. When you construct complex impedances (for which X = nonzero) on the Smith chart, the points on these circles will all have the same resistive component. Circle *A*, for example, passes through the center of the chart, so it has a normalized constant resistance of 1.0. Note that impedances that are pure resistances (i.e., $Z = R + j0$) will fall at the intersection of a constant resistance circle and the pure resistance line, and complex impedances (i.e., X not equal to zero) will appear at any other points on the circle. In Fig. 4-3, circle *A* passes through the center of the chart, so it represents all points on the chart with a normalized resistance of 1.0. This particular circle is sometimes called the *unity resistance circle*.

The constant reactance circles

Constant reactance circles are highlighted in Fig. 4-4. The circles (or circle segments) *above* the pure resistance line (Fig. 4-4A) represent the *inductive reactance* ($+X$), and those circles (or segments) *below* the pure resistance line (Fig. 4-4B) represent *capacitive reactance* ($-X$). In both cases, circle *A* represents a normalized reactance of 0.80.

One of the outer circles (i.e., circle *A* in Fig. 4-4C) is called the *pure reactance circle*. Points along circle *A* represent reactance only; in other words, an impedance of $Z = 0 \pm jX$ ($R = 0$).

Figure 4-4D shows how to plot impedance and admittance on the Smith chart. Consider an example in which system impedance Z_o is 50 Ω, and the load impedance is $Z_L = 95 + j55\ \Omega$. This load impedance is normalized to

$$Z = \frac{Z_L}{Z_o} \qquad \textbf{[4.6]}$$

$$= \frac{95 + j55\ \Omega}{50\ \Omega} \qquad \textbf{[4.7]}$$

$$= 1.9 + j1.1 \qquad \textbf{[4.8]}$$

An *impedance radius* is constructed by drawing a line from the point represented by the normalized load impedance, $1.9 + j1.1$, to the point represented by the normalized system impedance (1.0) in the center of the chart. A circle is constructed from this radius, and is called the *VSWR circle.*

Admittance is the reciprocal of impedance, so it is found from

$$Y = \frac{1}{Z} \qquad \textbf{[4.9]}$$

Because impedances in transmission lines are rarely pure resistive, but rather contain a reactive component also, impedances are expressed by complex notation:

$$Z = R \pm jX \qquad \textbf{[4.10]}$$

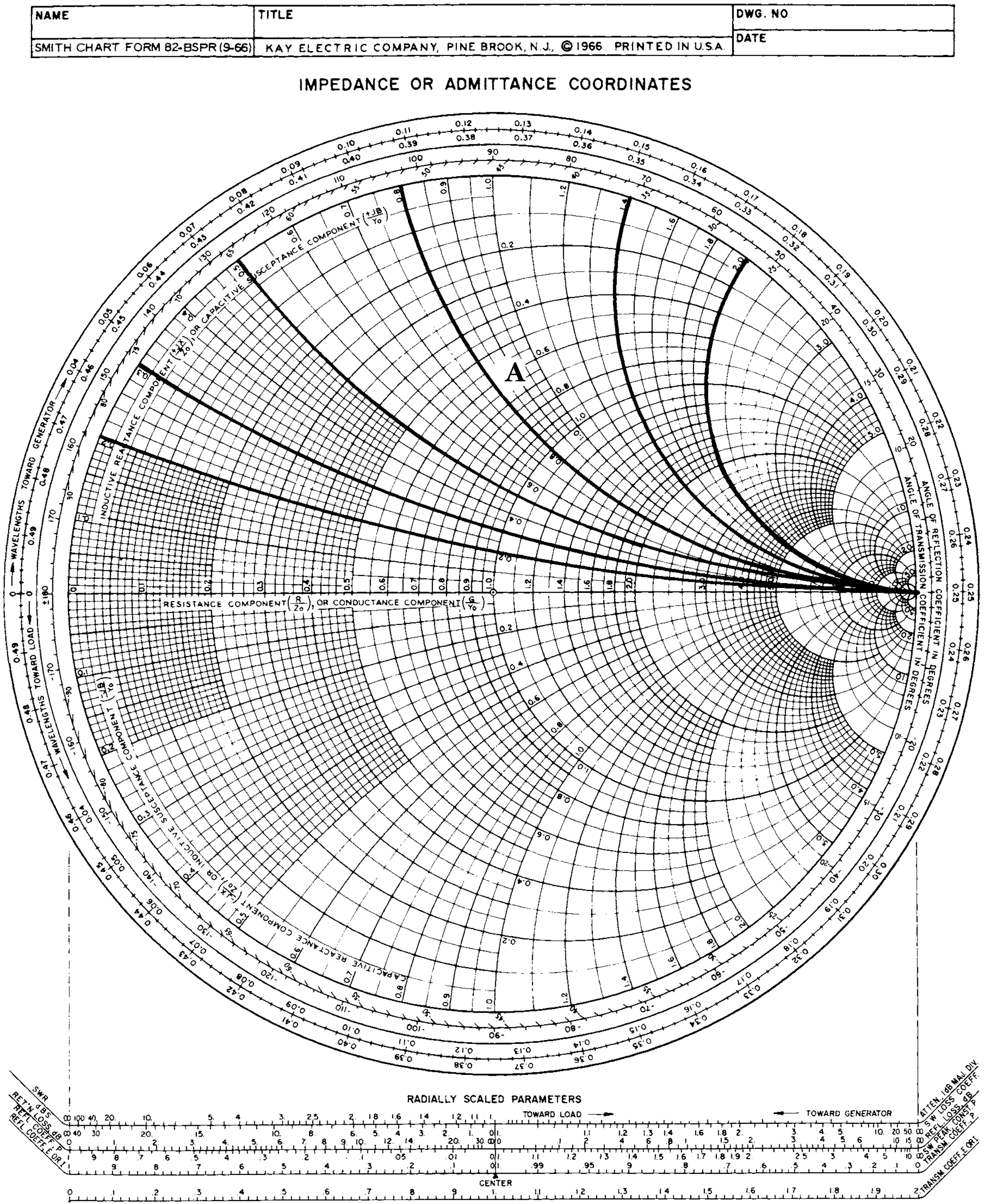
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DATE
IMPEDANCE OR ADMITTANCE COORDINATES
A
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE COMPONENT (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE COMPONENT (-jB/Yo)
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS
TOWARD LOAD
TOWARD GENERATOR
SWR
RET'N dBS
RET'N LOSS dB
REFL COEFF, P
REFL COEFF, E OR I
ATTEN. (dB) MAJ. DIV.
S.W. LOSS COEFF.
S.W. REFL. LOSS dB
S.W. PEAK (CONST. P)
TRANSM. COEFF. P
TRANSM. COEFF. E OR I
CENTER

4-4A Constant inductive reactance lines. (*Courtesy of Kay Elementrics*)

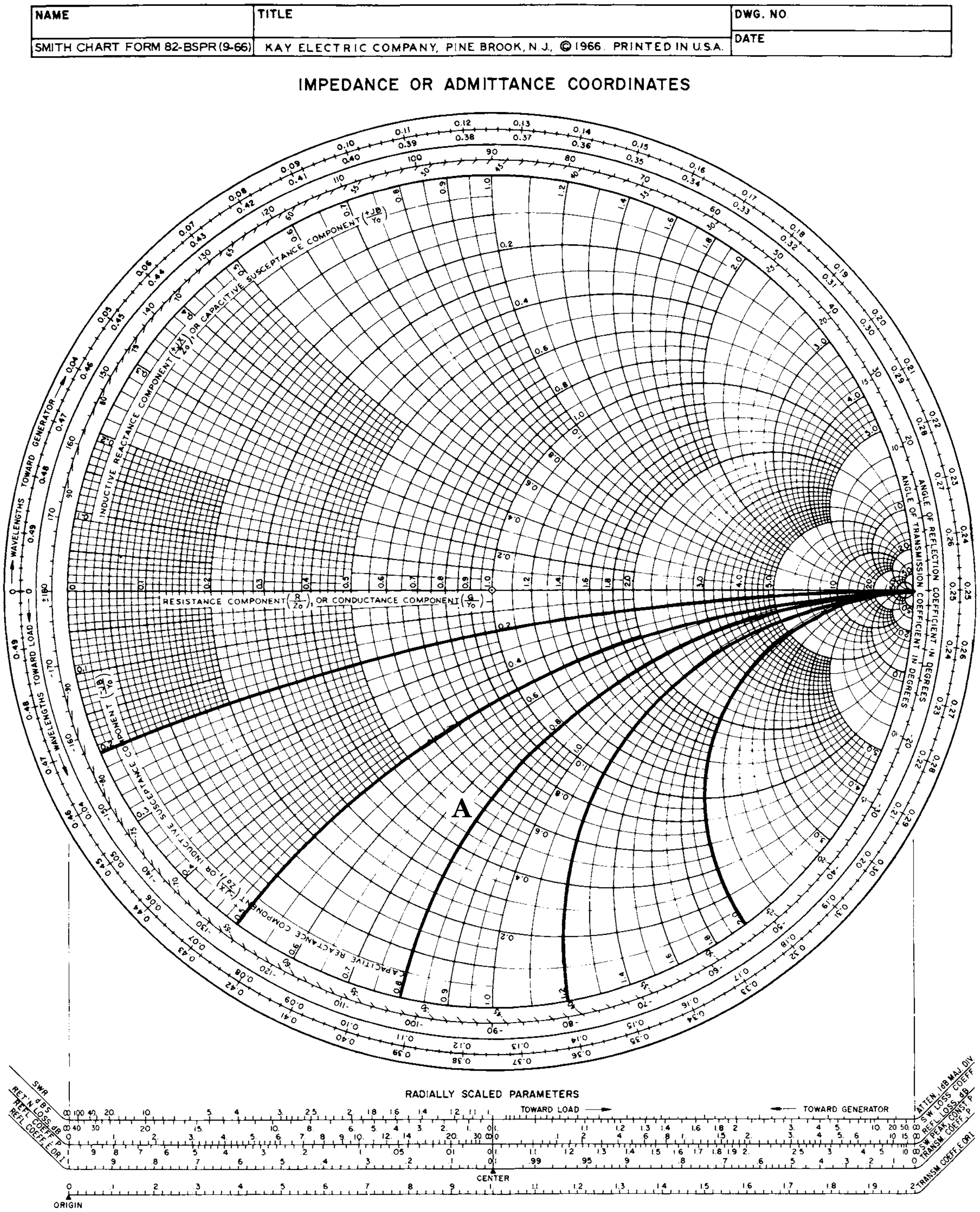

4-4B Constant capacitive reactance lines. (*Courtesy of Kay Elementrics*)

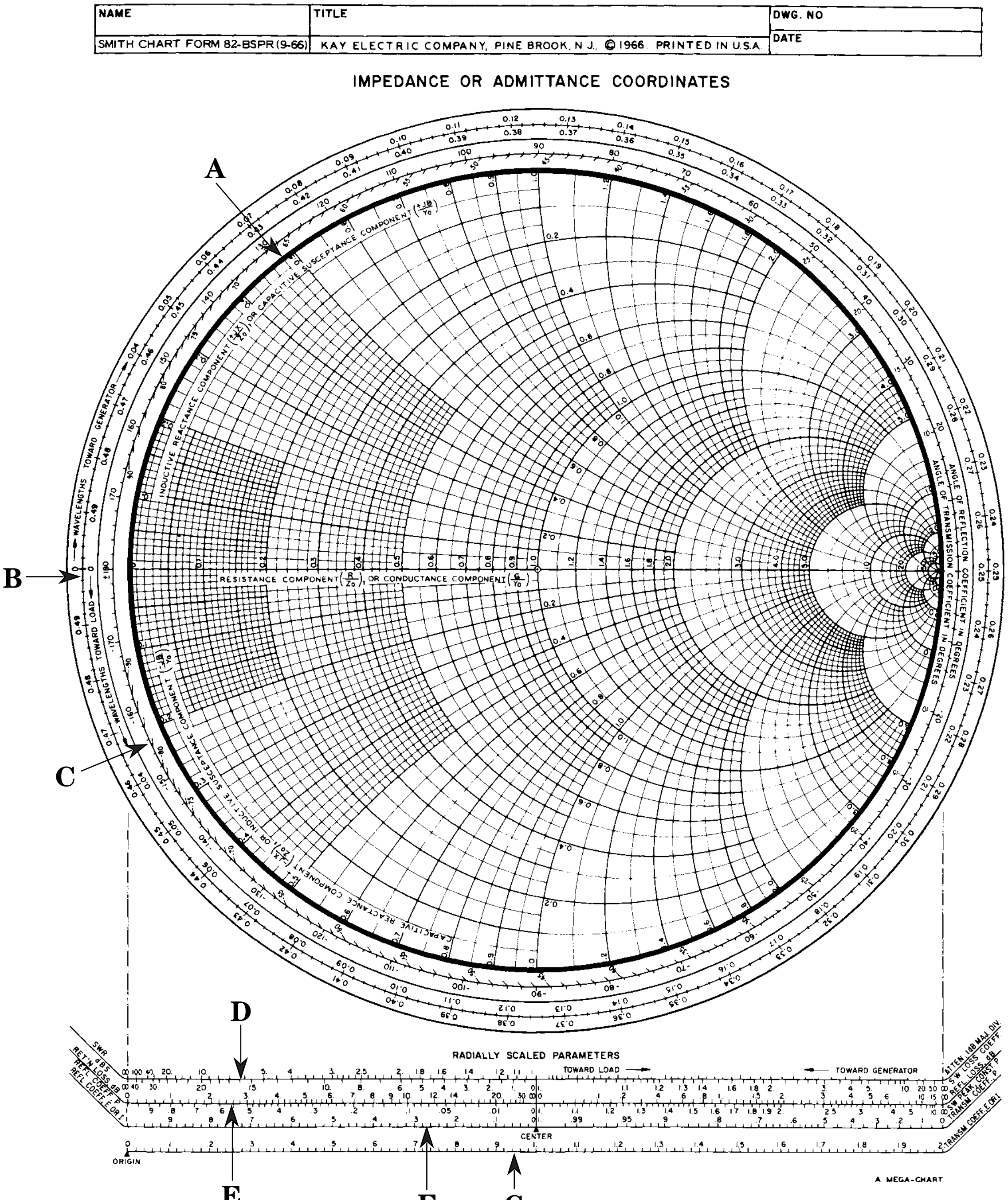
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DATE
IMPEDANCE OR ADMITTANCE COORDINATES
A
B
C
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE COMPONENT (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE COMPONENT (-jB/Yo)
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
D
RADIALLY SCALED PARAMETERS
TOWARD LOAD
TOWARD GENERATOR
SWR
RET'N LOSS, dB
REFL. COEFF. P
REFL. COEFF. E OR I
ATTEN. 1 dB MAJ. DIV.
S.W. LOSS COEFF.
REFL. LOSS, dB
S.W. PEAK CONST. P
TRANSM. COEFF. E OR I
TRANSM. COEFF. P
CENTER
ORIGIN
A MEGA-CHART
E
F
G

4-4C Angle of transmission coefficient circle. (*Courtesy of Kay Elementrics*)

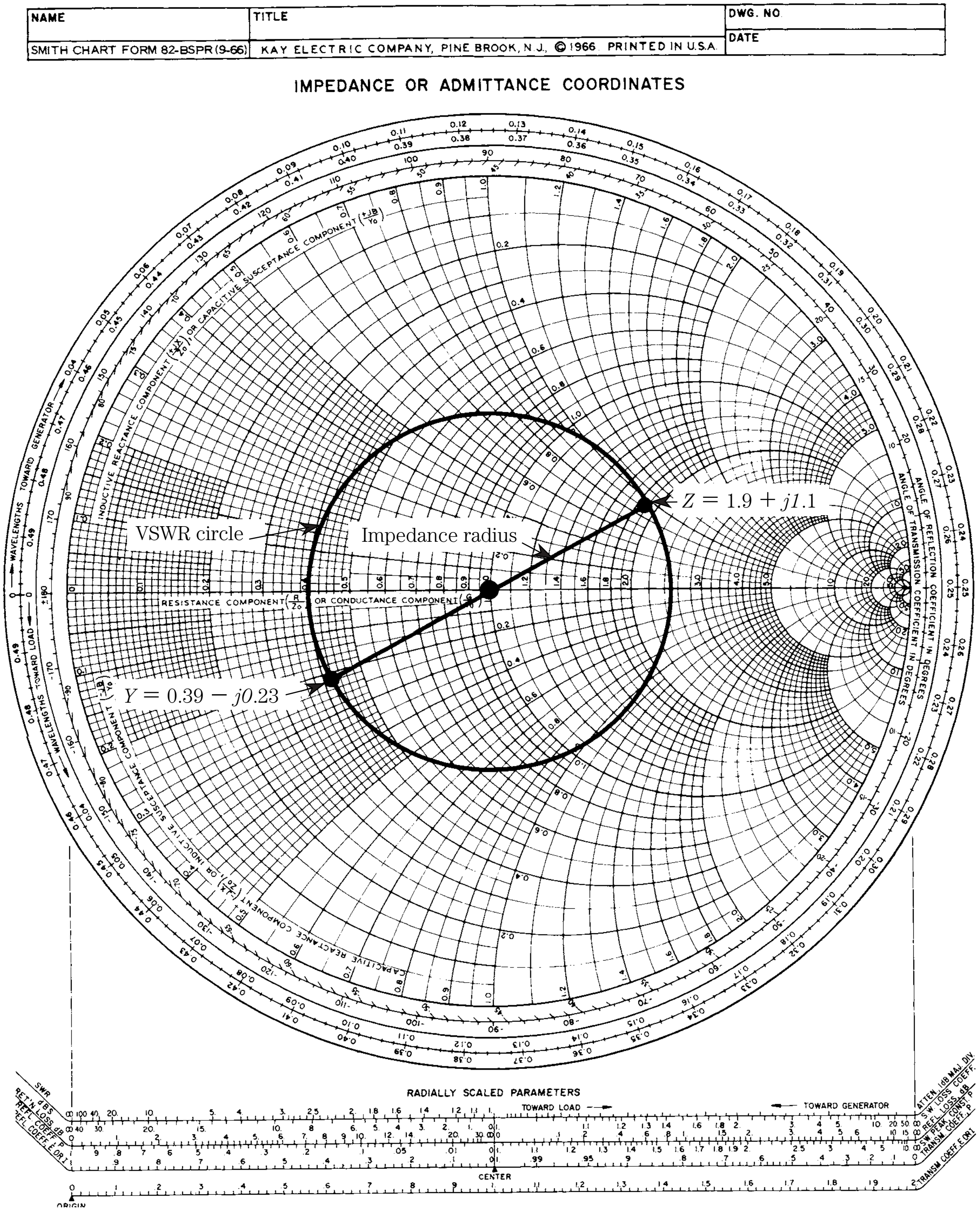
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IMPEDANCE OR ADMITTANCE COORDINATES
VSWR circle
Impedance radius
Z = 1.9 + j1.1
Y = 0.39 − j0.23
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE COMPONENT (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (−jX/Zo), OR INDUCTIVE SUSCEPTANCE COMPONENT (−jB/Yo)
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS
TOWARD LOAD
TOWARD GENERATOR
SWR
RET'N LOSS, dB
REFL. COEFF., P
REFL. COEFF., E OR I
ATTEN. 1dB MAJ. DIV.
S.W. LOSS COEFF.
S.W. PEAK (CONST. P)
TRANSM. COEFF., P
TRANSM. COEFF., E OR I
CENTER
ORIGIN

4-4D VSWR circles. *(Courtesy of Kay Elementrics)*

where

Z is the complex impedance
R is the resistive component
X is the reactive component

In order to find the *complex admittance*, take the reciprocal of the complex impedance by multiplying the simple reciprocal by the complex conjugate of the impedance. For example, when the normalized impedance is $1.9 + j1.1$, the normalized admittance will be:

$$Y = \frac{1}{Z} \quad \textbf{[4.11]}$$

$$= \frac{1}{1.9 + j1.1} \times \frac{1.9 - j1.1}{1.9 - j1.1} \quad \textbf{[4.12]}$$

$$= \frac{1.9 - j1.1}{3.6 + 1.2} \quad \textbf{[4.13]}$$

$$= \frac{1.9 - j1.1}{4.8} = 0.39 - j0.23 \quad \textbf{[4.14]}$$

One of the delights of the Smith chart is that this calculation is reduced to a quick graphical interpretation! Simply extend the impedance radius through the 1.0 center point until it intersects the VSWR circle again. This point of intersection represents the normalized admittance of the load.

Outer circle parameters

The standard Smith chart shown in Fig. 4-4C contains three concentric calibrated circles on the outer perimeter of the chart. Circle *A* has already been covered and it is the pure reactance circle. The other two circles define the wavelength distance (*B*) relative to either the load or generator end of the transmission line, and either the transmission or reflection coefficient angle in degrees (*C*).

There are two scales on the *wavelength* circle (*B* in Fig 4-4C), and both have their zero origin on the left-hand extreme of the pure resistance line. Both scales represent *one-half wavelength for one entire revolution*, and are calibrated from 0 through 0.50 such that these two points are identical with each other on the circle. In other words, starting at the zero point and travelling 360° around the circle brings one back to zero, which represents one-half wavelength, or 0.5 λ.

Although both wavelength scales are of the same magnitude (0 – 0.50), they are opposite in direction. The outer scale is calibrated clockwise and it represents *wavelengths toward the generator*; the inner scale is calibrated counterclockwise and represents *wavelengths toward the load*. These two scales are complementary at all points. Thus, 0.12 on the outer scale corresponds to (0.50 – 0.12) or 0.38 on the inner scale.

The *angle of transmission coefficient* and *angle of reflection coefficient* scales are shown in circle *C* in Fig. 4-4C. These scales are the relative phase angle between reflected and incident waves. Recall from transmission line theory (see Chap. 3), that a short circuit at the load end of the line reflects the signal back toward the generator 180° out of phase with the incident signal; an open line (i.e., infinite impedance) reflects the signal back to the generator in phase (i.e., 0°) with the incident signal. These facts are shown on the Smith chart by the fact that both scales start at 0° on the right-hand end of the pure resistance line, which corresponds to an infinite resistance, and it goes halfway around the circle to 180° at the 0 end of the pure resistance line. Note that the upper half-circle is calibrated 0 to +180°, and the bottom half-circle is calibrated 0 to –180°, reflecting indictive or capacitive reactance situations, respectively.

Radially scaled parameters

There are six scales laid out on five lines (*D* through *G* in Fig. 4-4C and in expanded form in Fig. 4-5) at the bottom of the Smith chart. These scales are called the *radially scaled parameters*—and they are both very important, and often overlooked. With these scales, we can determine such factors as VSWR (both as a ratio and in decibels), return loss in decibels, voltage or current reflection coefficient, and the power reflection coefficient.

The *reflection coefficient* Γ is defined as the *ratio of the reflected signal to the incident signal*. For voltage or current:

$$\Gamma = \frac{E_{\text{ref}}}{E_{\text{inc}}} \qquad \textbf{[4.15]}$$

and

$$\Gamma = \frac{I_{\text{ref}}}{I_{\text{inc}}} \qquad \textbf{[4.16]}$$

Power is proportional to the square of voltage or current, so:

$$P_{\text{pwr}} = \Gamma^2 \qquad \textbf{[4.17]}$$

or

$$\Gamma_{\text{pwr}} = \frac{P_{\text{ref}}}{P_{\text{inc}}} \qquad \textbf{[4.18]}$$

Example 10 W of microwave RF power is applied to a lossless transmission line, of which 2.8 W is reflected from the mismatched load. Calculate the reflection coefficient.

$$\Gamma_{\text{pwr}} = \frac{P_{\text{ref}}}{P_{\text{inc}}} \qquad \textbf{[4.19]}$$

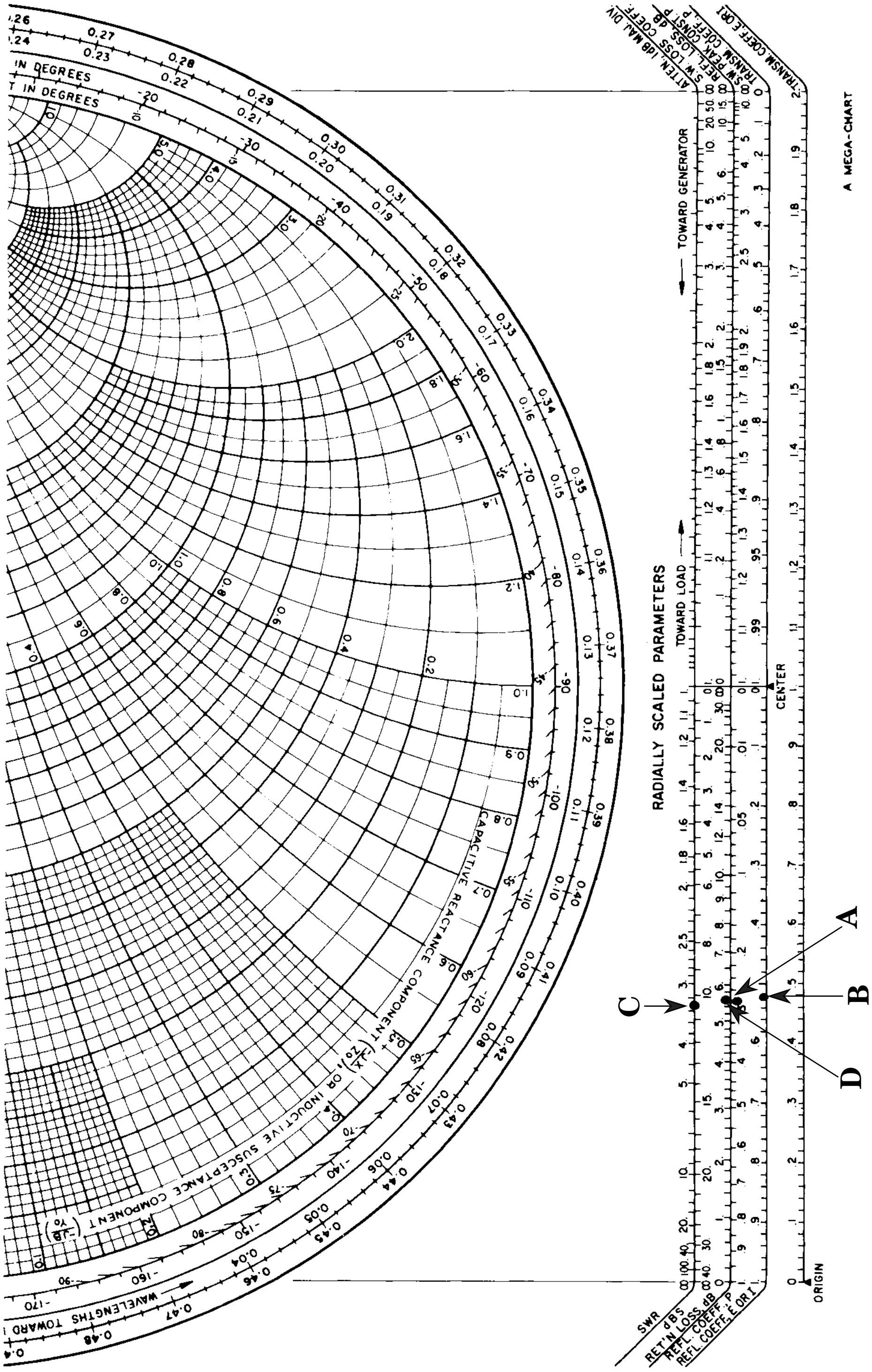
RADIALLY SCALED PARAMETERS
TOWARD GENERATOR
TOWARD LOAD
CENTER
ORIGIN
A MEGA-CHART
SWR
dBS
RET'N LOSS, dB
REFL. COEFF. P
REFL. COEFF. E OR I
ATTEN 1dB MAJ. DIV.
S.W. LOSS COEFF.
S.W. PEAK CONST. P
REFL. LOSS dB
TRANSM. COEFF. P
TRANSM. COEFF. E OR I
CAPACITIVE REACTANCE COMPONENT $\left(\frac{-jX}{Z_o}\right)$, OR INDUCTIVE SUSCEPTANCE COMPONENT $\left(\frac{-jB}{Y_o}\right)$
WAVELENGTHS TOWARD
IN DEGREES
A
B
C
D

4-5 Radially scaled parameters.

$$\Gamma_{\text{pwr}} = \frac{2.8\text{ W}}{10\text{ W}} \qquad \textbf{[4.20]}$$

$$= 0.28 \qquad \textbf{[4.21]}$$

The voltage reflection coefficient Γ is found by taking the square root of the power reflection coefficient, so in this example it is equal to 0.529. These points are plotted at *A* and *B* in Fig. 4-5.

Standing wave ratio (SWR) can be defined in terms of reflection coefficient:

$$\text{VSWR} = \frac{1 + \Gamma}{1 - \Gamma} \qquad \textbf{[4.22]}$$

or

$$\text{VSWR} = \frac{1 + \sqrt{\Gamma_{\text{pwr}}}}{1 - \sqrt{\Gamma_{\text{pwr}}}} \qquad \textbf{[4.23]}$$

or, in our example,

$$\text{VSWR} = \frac{1 + \sqrt{0.28}}{1 - \sqrt{0.28}} \qquad \textbf{[4.24]}$$

$$= \frac{1 + 0.529}{1 - 0.529} \qquad \textbf{[4.25]}$$

$$= \frac{1.529}{0.471} = 3.25{:}1 \qquad \textbf{[4.26]}$$

or, in decibel form,

$$\text{VSWR}_{\text{dB}} = 20 \log (\text{VSWR}) \qquad \textbf{[4.27]}$$

$$= 20 \log (20) \qquad \textbf{[4.28]}$$

$$= (20)\ (0.510) = 10.2\text{ dB} \qquad \textbf{[4.29]}$$

These points are plotted at *C* in Fig. 4-5. Shortly, you will work an example to show how these factors are calculated in a transmission line problem from a known complex load impedance.

Transmission loss is a measure of the one-way loss of power in a transmission line because of reflection from the load. *Return loss* represents the two-way loss, so it is exactly twice the transmission loss. Return loss is found from

$$\text{Loss}_{\text{ret}} = 10 \log (\Gamma_{\text{pwr}}) \qquad \textbf{[4.30]}$$

and, for our example in which $\Gamma_{\text{pwr}} = 0.28$,

$$\text{Loss}_{\text{ret}} = 10 \log (0.28) \qquad \textbf{[4.31]}$$

$$= (10)\ (-0.553) = -5.53\text{ dB} \qquad \textbf{[4.32]}$$

This point is shown as *D* in Fig. 4-5.

The *transmission loss coefficient* can be calculated from

$$\text{TLC} = \frac{1 + \Gamma_{\text{pwr}}}{1 - \Gamma_{\text{pwr}}} \qquad \textbf{[4.33]}$$

or, for our example,

$$\text{TLC} = \frac{1 + (0.28)}{1 - (0.28)} \qquad \textbf{[4.34]}$$

$$= \frac{1.28}{0.72} = 1.78 \qquad \textbf{[4.35]}$$

The TLC is a correction factor that is used to calculate the attenuation caused by mismatched impedance in a lossy, as opposed to the ideal "lossless," line. The TLC is found from laying out the impedance radius on the *loss coefficient* scale on the radially scaled parameters at the bottom of the chart.

Smith chart applications

One of the best ways to demonstrate the usefulness of the Smith chart is by practical example. The following sections look at two general cases: *transmission line problems* and *stub matching systems*.

Transmission line problems

Figure 4-6 shows a 50-Ω transmission line connected to a complex load impedance Z_L of $36 + j40\ \Omega$. The transmission line has a velocity factor v of 0.80, which means that the wave propagates along the line at 8⁄10 the speed of light (c = 300,000,000 m/s). The length of the transmission line is 28 cm. The generator V_{in} is operated at a frequency of 4.5 GHz and produces a power output of 1.5 W. See what you can glean from the Smith chart (Fig. 4-7).

First, normalize the load impedance. This is done by dividing the load impedance by the systems impedance (in this case, $Z_o = 50\ \Omega$):

$$Z = \frac{36 + j40\ \Omega}{50\ \Omega} \qquad \textbf{[4.36]}$$

$$= 0.72 + j0.8 \qquad \textbf{[4.37]}$$

The resistive component of impedance Z is located along the 0.72 pure resistance circle (see Fig. 4-7). Similarly, the reactive component of impedance Z is located by traversing the 0.72 constant resistance circle until the $+j0.8$ constant reactance circle is intersected. This point graphically represents the normalized load impedance $Z = 0.72 + j0.80$. A VSWR circle is constructed with an impedance radius equal to the line between 1.0 (in the center of the chart) and the $0.72 + j0.8$ point.

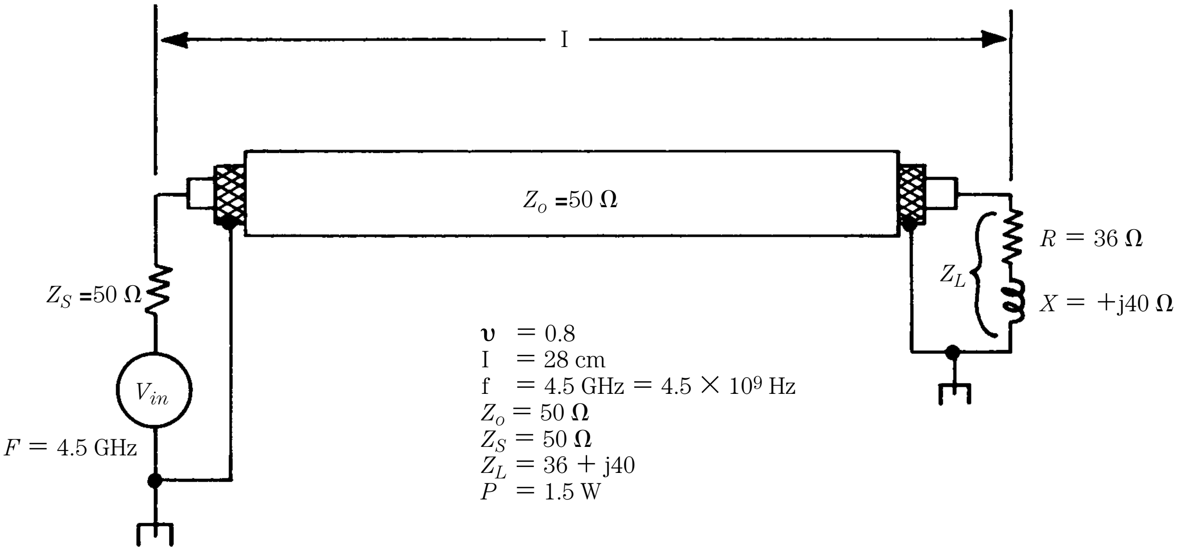

4-6 Transmission line and load circuit.

At a frequency of 4.5 GHz, the length of a wave propagating in the transmission line, assuming a velocity factor of 0.80, is

$$\lambda_{\text{line}} = \frac{c\,v}{F_{\text{Hz}}} \tag{4.38}$$

$$= \frac{(3 \times 10^8 \text{ m/s})\ (0.80)}{4.5 \times 10^9 \text{ Hz}} \tag{4.39}$$

$$= \frac{2.4 \times 10^8 \text{ m/s}}{4.5 \times 10^9 \text{ Hz}} \tag{4.40}$$

$$= 0.053 \text{ m} \times \frac{100 \text{ cm}}{\text{m}} = 5.3 \text{ cm} \tag{4.41}$$

One wavelength is 5.3 cm, so a half-wavelength is 5.3 cm/2, or 2.65 cm. The 28-cm line is 28 cm/5.3 cm, or 5.28 wavelengths long. A line drawn from the center (1.0) to the load impedance is extended to the outer circle, and it intersects the circle at 0.1325. Because one complete revolution around this circle represents one-half wavelength, 5.28 wavelengths from this point represents 10 revolutions plus 0.28 more. The residual 0.28 wavelengths is added to 0.1325 to form a value of (0.1325 + 0.28), or 0.413. The point 0.413 is located on the circle, and is marked. A line is then drawn from 0.413 to the center of the circle, and it intersects the VSWR circle at $0.49 - j0.49$, which represents the input impedance Z_{in} looking into the line.

To find the actual impedance represented by the normalized input impedance, you have to "denormalize" the Smith chart impedance by multiplying the result by Z_o:

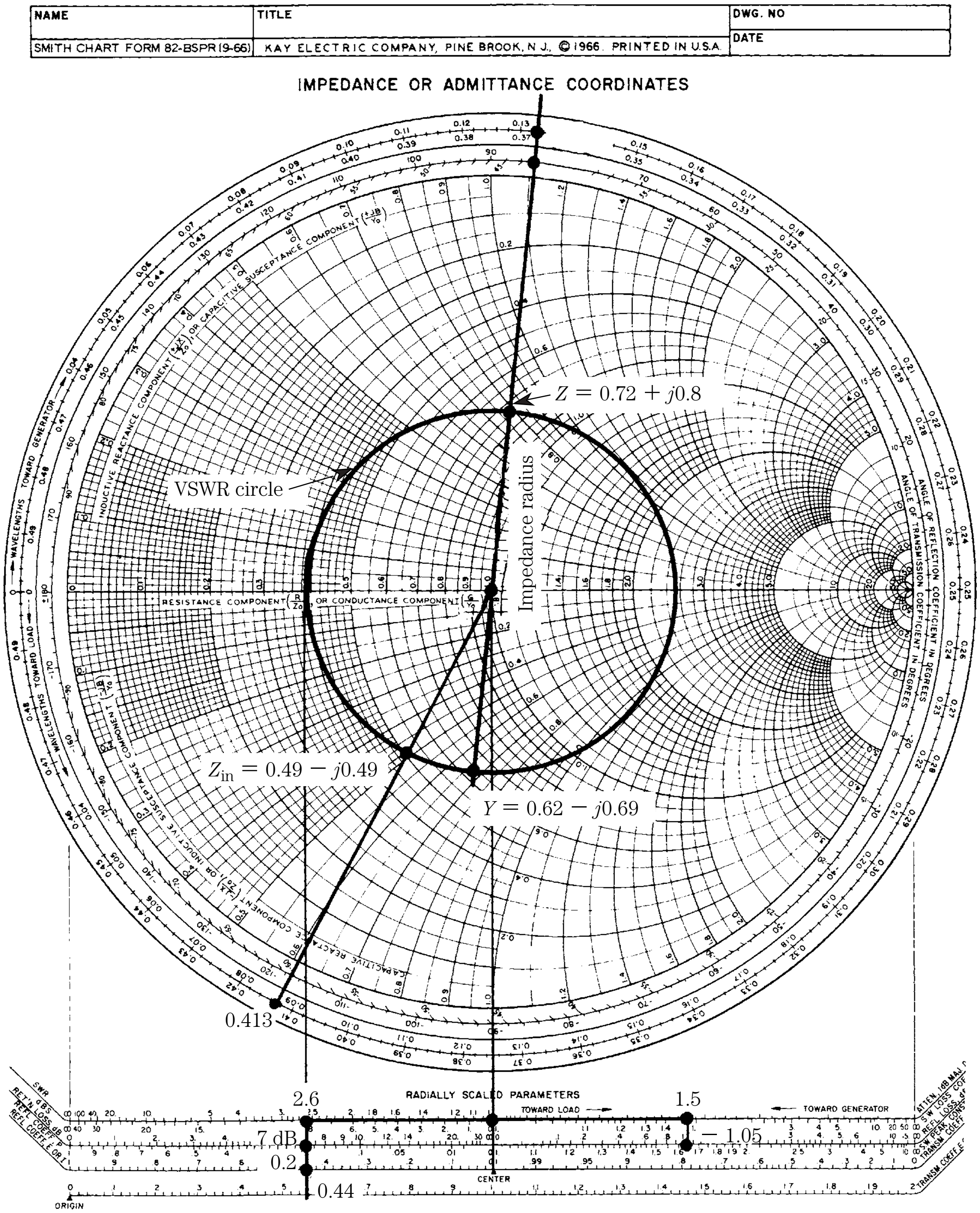
NAME
TITLE
DWG. NO
DATE
SMITH CHART FORM 82-BSPR (9-66)
KAY ELECTRIC COMPANY, PINE BROOK, N.J., © 1966. PRINTED IN U.S.A.
IMPEDANCE OR ADMITTANCE COORDINATES
$Z = 0.72 + j0.8$
VSWR circle
Impedance radius
$Z_{\text{in}} = 0.49 - j0.49$
$Y = 0.62 - j0.69$
0.413
RADIALLY SCALED PARAMETERS
TOWARD LOAD
TOWARD GENERATOR
2.6
1.5
7 dB
1.05
0.2
0.44
CENTER
ORIGIN

4-7 Solution to example. (*Courtesy of Kay Elementrics*)

$$Z_{\text{in}} = (0.49 - j0.49)\ (50\ \Omega) \quad \textbf{[4.42]}$$

$$= 24.5 - j24.5\ \Omega \quad \textbf{[4.43]}$$

It is this impedance that must be matched at the generator by a conjugate matching network.

The admittance represented by the load impedance is the reciprocal of the load impedance, and is found by extending the impedance radius through the center of the VSWR circle until it intersects the circle again. This point is found, and represents the admittance $Y = 0.62 - j0.69$. Confirming the solution mathematically:

$$Y = \frac{1}{Z} \quad \textbf{[4.44]}$$

$$= \frac{1}{0.72 + j0.80} \times \frac{0.72 - j0.80}{0.72 - j0.80} \quad \textbf{[4.45]}$$

$$= \frac{0.72 - j0.80}{1.16} = 0.62 - j0.69 \quad \textbf{[4.46]}$$

The VSWR if found by transferring the "impedance radius" of the VSWR circle to the radial scales below. The radius (0.72 – 0.8) is laid out on the VSWR scale (topmost of the radially scaled parameters) with a pair of dividers from the center mark, and we find that the VSWR is approximately 2.6:1. The decibel form of VSWR is 8.3 dB (next scale down from VSWR), and this is confirmed by

$$\text{VSWR}_{\text{dB}} = 20 \log (\text{VSWR}) \quad \textbf{[4.47]}$$

$$= (20) \log (2.7) \quad \textbf{[4.48]}$$

$$= (20)\ (0.431) = 8.3 \text{ dB} \quad \textbf{[4.49]}$$

The transmission loss coefficient is found in a manner similar to the VSWR, using the radially scaled parameter scales. In practice, once you have found the VSWR you need only drop a perpendicular line from the 2.6:1 VSWR line across the other scales. In this case, the line intersects the voltage reflection coefficient at 0.44. The power reflection coefficient Γ_{pwr} is found from the scale, and is equal to Γ^2. The perpendicular line intersects the power reflection coefficient line at 0.20.

The angle of reflection coefficient is found from the outer circles of the Smith chart. The line from the center to the load impedance ($Z = 0.72 + j0.8$) is extended to the *angle of reflection coefficient in degrees* circle, and intersects it at approximately 84°. The reflection coefficient is therefore 0.44/84°.

The transmission loss coefficient (TLC) is found from the radially scaled parameter scales also. In this case, the impedance radius is laid out on the *loss coefficient* scale, where it is found to be 1.5. This value is confirmed from:

$$\text{TLC} = \frac{1 + \Gamma_{\text{pwr}}}{1 - \Gamma_{\text{pwr}}} \quad \textbf{[4.50]}$$

$$= \frac{1 + (0.20)}{1 - (0.21)} \quad \textbf{[4.51]}$$

$$= \frac{1.20}{0.79} = 1.5 \quad \textbf{[4.52]}$$

The *return loss* is also found by dropping the perpendicular from the VSWR point to the *RET'N LOSS, dB* line, and the value is found to be approximately 7 dB, which is confirmed by

$$\text{Loss}_{\text{ret}} = 10 \log (\Gamma_{\text{pwr}}) \text{ dB} \quad \textbf{[4.53]}$$

$$= 10 \log (0.21) \text{ dB} \quad \textbf{[4.54]}$$

$$= (10)\,(-0.677) \text{ dB} \quad \textbf{[4.55]}$$

$$= 6.77 \text{ dB} = -6.9897 \text{ dB} \quad \textbf{[4.56]}$$

The reflection loss is the amount of RF power reflected back down the transmission line from the load. The difference between incident power supplied by the generator (1.5 W in this example), $P_{\text{inc}} - P_{\text{ref}} = P_{\text{abs}}$ and the reflected power, is the *absorbed power* (P_a); or in the case of an antenna, the radiated power. The reflection loss is found graphically by dropping a perpendicular from the TLC point (or by laying out the impedance radius on the *REFL*. *LOSS*, *dB* scale), and in this example (Fig. 4-7) is –1.05 dB. You can check the calculations:

The return loss is –7 dB, so

$$-7 \text{ dB} = 10 \log \left(\frac{P_{\text{ref}}}{P_{\text{inc}}} \right) \quad \textbf{[4.57]}$$

$$-7 = 10 \log \left(\frac{P_{\text{ref}}}{1.5 \text{ watts}} \right) \quad \textbf{[4.58]}$$

$$\frac{-7}{10} = \log \left(\frac{P_{\text{ref}}}{1.5 \text{ watts}} \right) \quad \textbf{[4.59]}$$

$$10^{(-7/10)} = \frac{P_{\text{ref}}}{1.5 \text{ W}} \quad \textbf{[4.60]}$$

$$0.2 = \frac{P_{\text{ref}}}{1.5 \text{ W}} \quad \textbf{[4.61]}$$

$$(0.2)(1.5 \text{ W}) = P_{\text{ref}} \quad \textbf{[4.62]}$$

$$0.3 \text{ W} = P_{\text{ref}} \quad \textbf{[4.63]}$$

The power absorbed by the load (P_a) is the difference between incident power P_{inc} and reflected power P_{ref}. If 0.3 W is reflected, then that means the absorbed power is (1.5 – 0.3), or 1.2 W.

The reflection loss is –1.05 dB, and can be checked from:

$$-1.05 \text{ dB} = 10 \log\left(\frac{P_a}{P_{\text{inc}}}\right) \qquad \textbf{[4.64]}$$

$$\frac{-1.05}{10} = \log\left(\frac{P_a}{1.5 \text{ W}}\right) \qquad \textbf{[4.65]}$$

$$10^{(-1.05/10)} = \frac{P_a}{1.5 \text{ W}} \qquad \textbf{[4.66]}$$

$$0.785 = \frac{P_a}{1.5 \text{ W}} \qquad \textbf{[4.67]}$$

$$(1.5 \text{ W}) \times (0.785) = P_a \qquad \textbf{[4.68]}$$

$$1.2 \text{ W} = P_a \qquad \textbf{[4.69]}$$

Now check what you have learned from the Smith chart. Recall that 1.5 W of 4.5-GHz microwave RF signal was input to a 50-Ω transmission line that was 28 cm long. The load connected to the transmission line has an impedance of 36 + *j*40. From the Smith chart:

Admittance (load)	0.62 – j0.69
VSWR	2.6:1
VSWR (dB):	8.3 dB
Reflection coefficient (*E*)	0.44
Reflection coefficient (*P*)	0.2
Reflection coefficient angle	84 degrees
Return loss	–7 dB
Reflection loss	–1.05 dB
Transmission loss coefficient	1.5

Note that in all cases the mathematical interpretation corresponds to the graphical interpretation of the problem, within the limits of accuracy of the graphical method.

Stub matching systems

A properly designed matching system will provide a conjugate match to a complex impedance. Some sort of matching system or network is needed any time the load impedance Z_L is not equal to the characteristic impedance Z_o of the transmission line. In a transmission line system, it is possible to use a *shorted stub* connected in parallel with the line, at a critical distance back from the mismatched load, in order to effect a match. The stub is merely a section of transmission line that is shorted at the end not connected to the main transmission line. The reactance (hence also susceptance) of a shorted line can vary from $-\lambda$ to $+\lambda$, depending upon length, so you can use a line of critical length L_2 to cancel the reactive component of the load impedance. Because the stub is connected in parallel with the line it is a bit easier to work with admittance parameters, rather than impedance.

Consider the example of Fig. 4-8, in which the load impedance is $Z = 100 + j60$, which is normalized to $2.0 + j1.2$. This impedance is plotted on the Smith chart in Fig. 4-9, and a VSWR circle is constructed. The admittance is found on the chart at point $Y = 0.37 - j0.22$.

In order to provide a properly designed matching stub, you need to find two lengths. L_1 is the length (relative to wavelength) from the load toward the generator (see L_1 in Fig. 4-8); L_2 is the length of the stub itself.

The first step in finding a solution to the problem is to find the points where the unit conductance line (1.0 at the chart center) intersects the VSWR circle; there are two such points shown in Fig. 4-9: $1.0 + j1.1$ and $1.0 - j1.1$. Select one of these (choose $1.0 + j1.1$) and extend a line from the center 1.0 point through the $1.0 + j1.1$ point to the outer circle (*WAVELENGTHS TOWARD GENERATOR*). Similarly, a line is drawn from the center through the admittance point 0.37 – 0.22 to the outer circle. These two lines intersect the outer circle at the points 0.165 and 0.461. The distance of the stub back toward the generator is found from:

$$L_1 = 0.165 + (0.500 - 0.461)\,\lambda \tag{4.70}$$

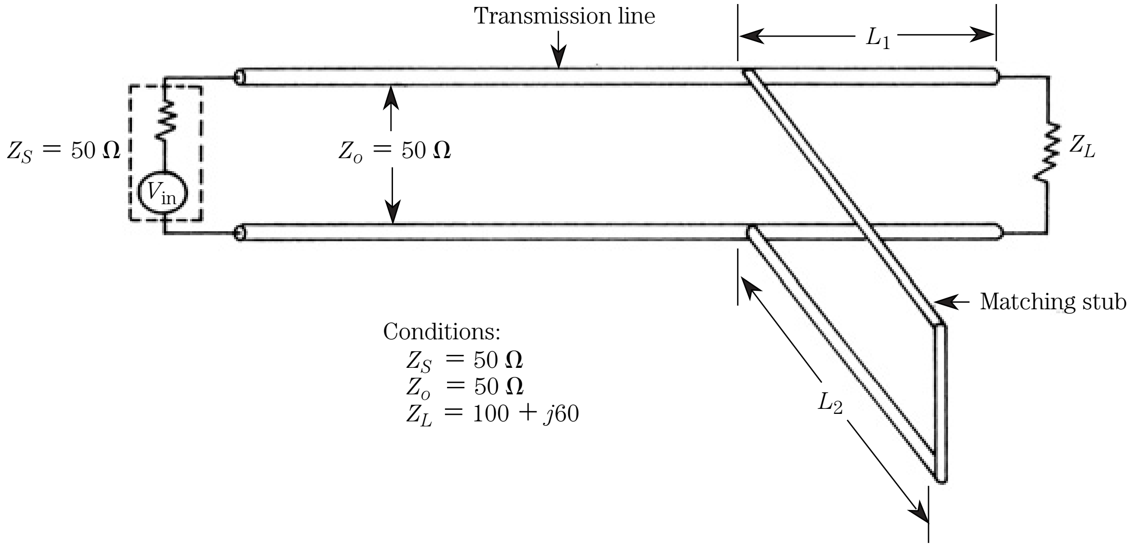

4-8 Matching stub length and position.

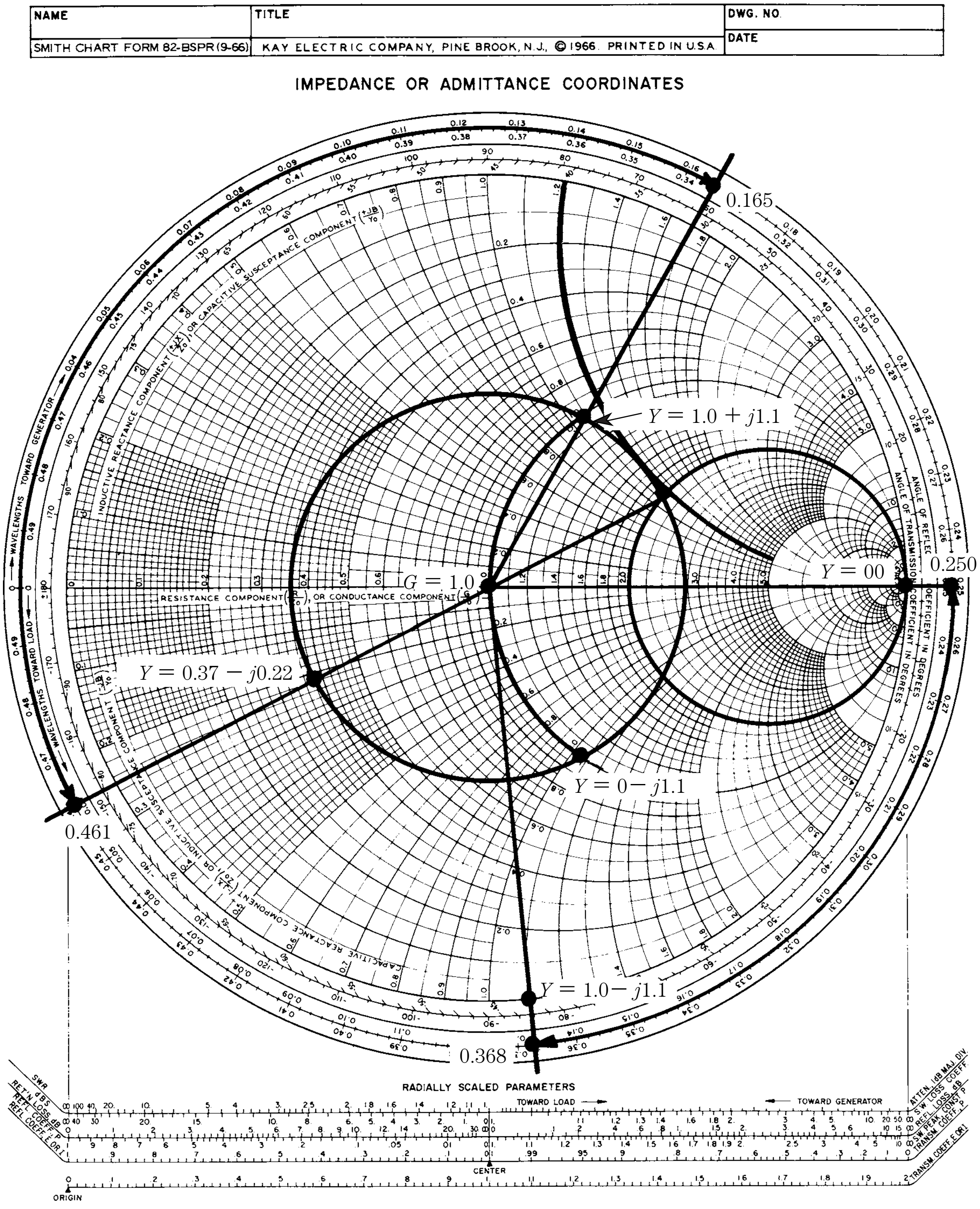
NAME
TITLE
DWG. NO.
DATE
SMITH CHART FORM 82-BSPR(9-66)
KAY ELECTRIC COMPANY, PINE BROOK, N.J., © 1966 PRINTED IN U.S.A.
IMPEDANCE OR ADMITTANCE COORDINATES
0.165
$Y = 1.0 + j1.1$
$Y = 00$
0.250
$G = 1.0$
$Y = 0.37 - j0.22$
$Y = 0 - j1.1$
0.461
$Y = 1.0 - j1.1$
0.368
RESISTANCE COMPONENT $\left(\frac{R}{Z_o}\right)$, OR CONDUCTANCE COMPONENT $\left(\frac{G}{Y_o}\right)$
INDUCTIVE REACTANCE COMPONENT $\left(\frac{+jX}{Z_o}\right)$ OR CAPACITIVE SUSCEPTANCE COMPONENT $\left(\frac{+jB}{Y_o}\right)$
CAPACITIVE REACTANCE COMPONENT $\left(\frac{-jX}{Z_o}\right)$ OR INDUCTIVE SUSCEPTANCE COMPONENT $\left(\frac{-jB}{Y_o}\right)$
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS
TOWARD LOAD
TOWARD GENERATOR
SWR
RET'N LOSS, dB
REFL. COEFF., P
REFL. COEFF. E OR I
ATTEN. 1dB MAJ. DIV.
S.W. LOSS COEFF.
S.W. REFL. LOSS, dB
S.W. PEAK (CONST. P)
TRANSM. COEFF., P
TRANSM. COEFF. E OR I
CENTER
ORIGIN

4-9 Solution to problem. (*Courtesy of Kay Elementrics*)

$$= 0.165 + 0.039\,\lambda \qquad \textbf{[4.71]}$$

$$= 0.204\,\lambda \qquad \textbf{[4.72]}$$

The next step is to find the length of the stub required. This is done by finding two points on the Smith chart. First, locate the point where admittance is infinite (far right side of the pure conductance line); second, locate the point where the admittance is $0 - j1.1$. (Note that the susceptance portion is the same as that found where the unit conductance circle crossed the VSWR circle.) Because the conductance component of this new point is 0, the point will lay on the $-j1.1$ circle at the intersection with the outer circle. Now draw lines from the center of the chart through each of these points to the outer circle. These lines intersect the outer circle at 0.368 and 0.250. The length of the stub is found from

$$L_2 = (0.368 - 0.250)\lambda \qquad \textbf{[4.73]}$$

$$= 0.118\lambda \qquad \textbf{[4.74]}$$

From this analysis you can see that the impedance, $Z = 100 + j60$, can be matched by placing a stub of a length 0.118λ at a distance 0.204λ back from the load.

The Smith chart in lossy circuits

Thus far, you have dealt with situations in which loss is either zero (i.e., ideal transmission lines), or so small as to be negligible. In situations where there is appreciable loss in the circuit or line, however, you see a slightly modified situation. The VSWR circle, in that case, is actually a spiral, rather than a circle.

Figure 4-10 shows a typical situation. Assume that the transmission line is 0.60λ long, and is connected to a normalized load impedance of $Z = 1.2 + j1.2$. An "ideal" VSWR circle is constructed on the impedance radius represented by $1.2 + j1.2$. A line (A) is drawn, from the point where this circle intersects the pure resistance baseline (B), perpendicularly to the *ATTEN, 1 dB/MAJ. DIV.* line on the radially scaled parameters. A distance representing the loss (3 dB) is stepped off on this scale. A second perpendicular line is drawn, from the –3 dB point, back to the pure resistance line (C). The point where line C intersects the pure resistance line becomes the radius for a new circle that contains the actual input impedance of the line. The length of the line is 0.60λ, so you must step back (0.60 – 0.50)λ or 0.1λ. This point is located on the *WAVELENGTHS TOWARD GENERATOR* outer circle. A line is drawn from this point to the 1.0 center point. The point where this new line intersects the new circle is the actual input impedance (Z_{in}).The intersection occurs at $0.76 + j0.4$, which (when denormalized) represents an input impedance of $38 + j20\ \Omega$.

Frequency on the Smith chart

A complex network may contain resistance, inductive reactance, and capacitive reactance components. Because the reactance component of such impedances is a function of frequency, the network or component tends to also be frequency-sensitive.

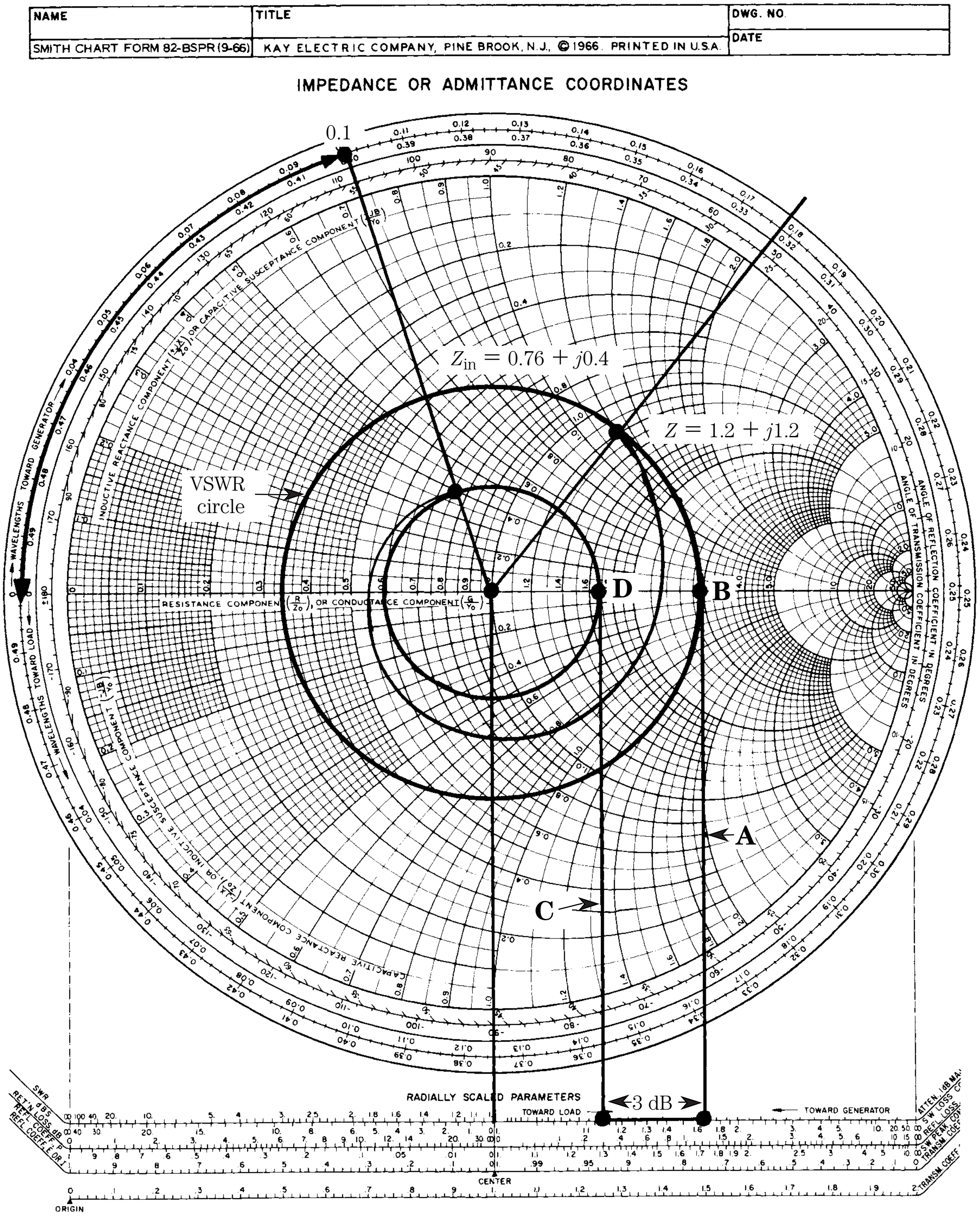
NAME
TITLE
DWG. NO.
DATE
SMITH CHART FORM 82-BSPR(9-66)
KAY ELECTRIC COMPANY, PINE BROOK, N.J., © 1966. PRINTED IN U.S.A.
IMPEDANCE OR ADMITTANCE COORDINATES
0.1
$Z_{\text{in}} = 0.76 + j0.4$
$Z = 1.2 + j1.2$
VSWR circle
D
B
A
C
3 dB
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
RESISTANCE COMPONENT $\left(\frac{R}{Z_0}\right)$, OR CONDUCTANCE COMPONENT $\left(\frac{G}{Y_0}\right)$
INDUCTIVE REACTANCE COMPONENT $\left(\frac{+jX}{Z_0}\right)$, OR CAPACITIVE SUSCEPTANCE COMPONENT $\left(\frac{+jB}{Y_0}\right)$
CAPACITIVE REACTANCE COMPONENT $\left(\frac{-jX}{Z_0}\right)$, OR INDUCTIVE SUSCEPTANCE COMPONENT $\left(\frac{-jB}{Y_0}\right)$
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS
TOWARD LOAD
TOWARD GENERATOR
CENTER
ORIGIN

4-10 Solution. (*Courtesy of Kay Elementrics*)

You can use the Smith chart to plot the performance of such a network with respect to various frequencies. Consider the load impedance connected to a 50-Ω transmission line in Fig. 4-11. In this case, the resistance is in series with a 2.2-pF capacitor, which will exhibit a different reactance at each frequency. The impedance of this network is

$$Z = R - j\left(\frac{1}{\omega C}\right) \qquad \textbf{[4.75]}$$

or

$$Z = 50 - j\left(\frac{1}{2\,\pi\,F\,C}\right) \qquad \textbf{[4.76]}$$

And, in normalized form,

$$Z' = 1.0 - \frac{j}{(2\,\pi\,F\,C) \times 50} \qquad \textbf{[4.77]}$$

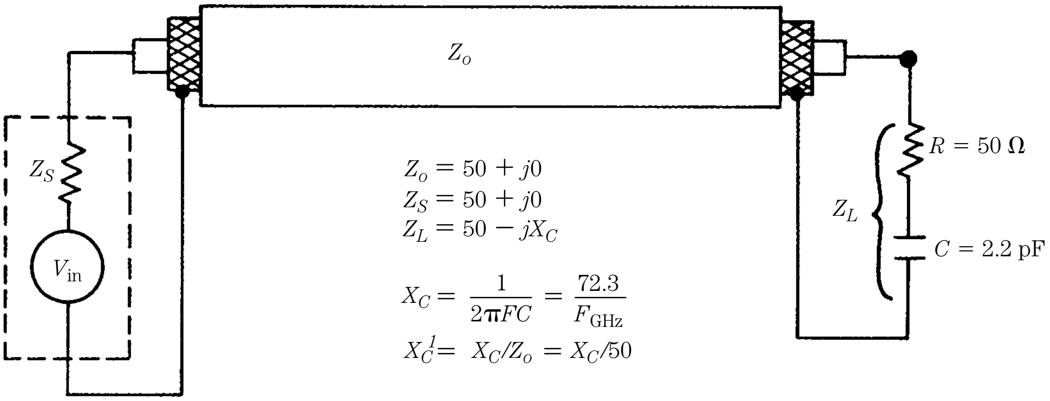
Z_o
Z_S
V_{in}
$R = 50\ \Omega$
Z_L
$C = 2.2$ pF
$Z_o = 50 + j0$
$Z_S = 50 + j0$
$Z_L = 50 - jX_C$
$X_C = \frac{1}{2\pi FC} = \frac{72.3}{F_{GHz}}$
$X_C^1 = X_C/Z_o = X_C/50$

Freq. (GHz)	X_C	
1	$-j72.3$	$-j1.45$
2	$-j36.2$	$-j0.72$
3	$-j24.1$	$-j0.48$
4	$-j18$	$-j0.36$
5	$-j14.5$	$-j0.29$
6	$-j12$	$-j0.24$

4-11 Load and source impedance transmission line circuit.

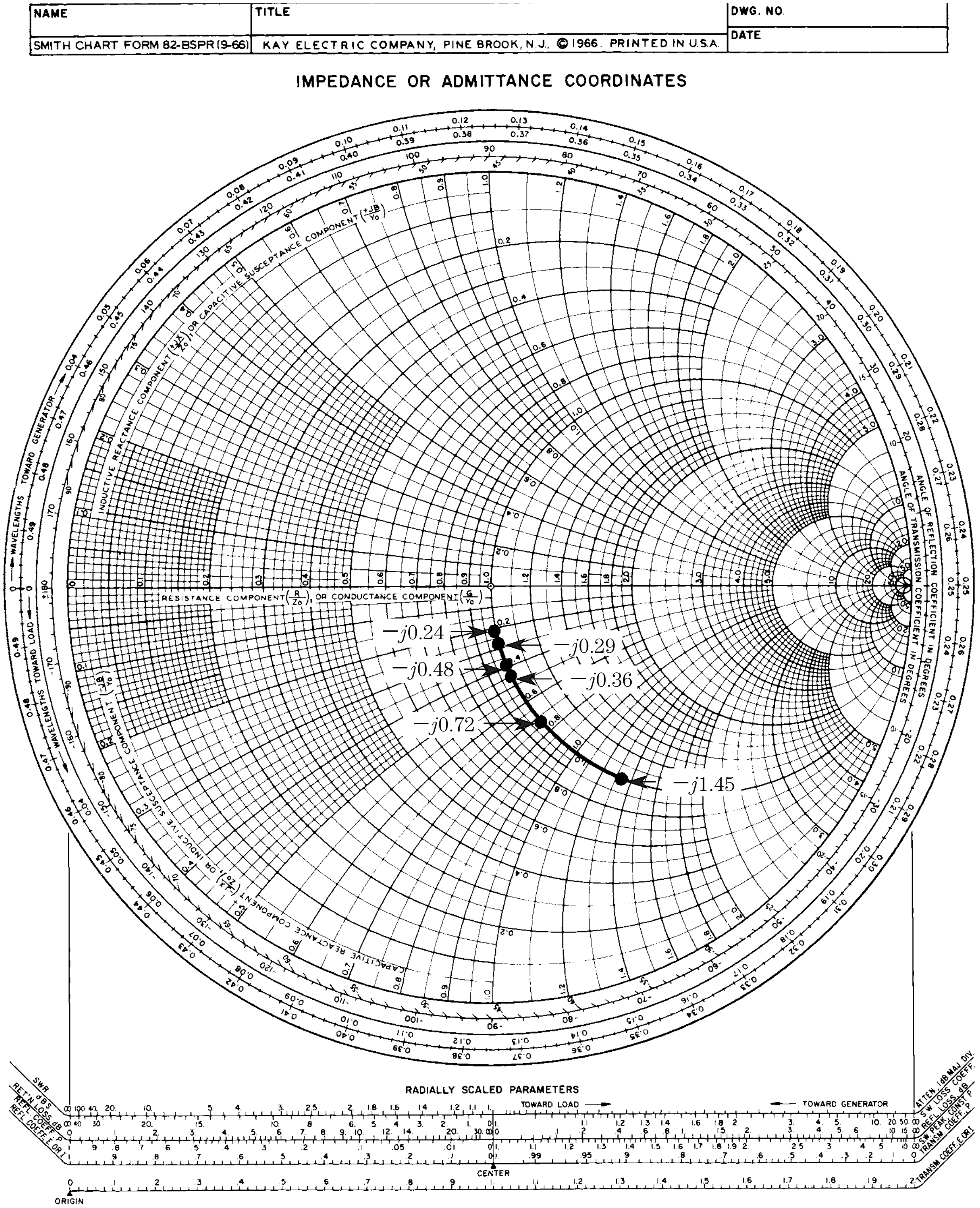

4-12 Solution. (*Courtesy of Kay Elementrics*)

$$= 1.0 - \frac{j}{6.9 \times 10^{-10}\,F} \qquad \textbf{[4.78]}$$

$$= 1.0 - \frac{j \times 7.23 \times 10^{10}}{F} \qquad \textbf{[4.79]}$$

Or, converted to gigahertz,

$$Z' = 1.0 - \frac{j72.3}{F_{\text{GHz}}} \qquad \textbf{[4.80]}$$

The normalized impedances for the sweep of frequencies from 1 to 6 GHz are therefore

$$Z = 1.0 - j1.45 \qquad \textbf{[4.81]}$$

$$Z = 1.0 - j0.72 \qquad \textbf{[4.82]}$$

$$Z = 1.0 - j0.48 \qquad \textbf{[4.83]}$$

$$Z = 1.0 - j0.36 \qquad \textbf{[4.84]}$$

$$Z = 1.0 - j0.29 \qquad \textbf{[4.85]}$$

$$Z = 1.0 - j0.24 \qquad \textbf{[4.86]}$$

These points are plotted on the Smith chart in Fig. 4-12. For complex networks, in which both inductive and capacitive reactance exist, take the difference between the two reactances (i.e., $X = X_L - X_C$).

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5
CHAPTER

Fundamentals of radio antennas

AN UNFORTUNATE OVERSIGHT IN MANY BOOKS ON RADIO ANTENNAS IS A LACK OF coverage on the most basic fundamentals of antenna theory. Most books, including the first draft of this one, start with a discussion of dipoles, but overlook that certain physical mechanisms are at work. An antenna is basically a *transducer* that converts electrical alternating current oscillations at a radio frequency to an electromagnetic wave of the same frequency. This chapter looks at the physics of how that job is accomplished.

The material in this chapter was adapted from a U.S. Army training manual on antennas and radio propagation. Although unfortunately no longer in print, the manual contained the best coverage of basics the author of this book could find. Given that U.S. government publications are not protected by copyright, this information can be brought to you in full.

Antenna fundamentals

The electric and magnetic fields radiated from an antenna form the electromagnetic field, and this field is responsible for the transmission and reception of electromagnetic energy through free space. An antenna, however, is also part of the electrical circuit of a transmitter (or a receiver); because of its distributed constants, it acts as a circuit containing inductance, capacitance, and resistance. Therefore, it can be expected to display definite voltage and current relationships in respect to a given input. A current through it produces a magnetic field, and a charge on it produces an electrostatic field. These two fields taken together form the induction field. To gain a better understanding of antenna theory, a review of the basic electrical concepts of voltage and electric field and of current and magnetic field is necessary.

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Voltage and electric field

When a capacitor is connected across a source of voltage, such as a battery (Fig. 5-1), it is charged some amount, depending on the voltage and the value of capacitance. Because of the emf (electromotive force) of the battery, negative charges flow to the lower plate, leaving the upper plate positively charged. Accompanying the accumulation of charge is the building up of the electric field. The flux lines are directed from the positive to the negative charges and at right angles to the plates.

If the two plates of the capacitor are spread farther apart, the electric field must curve to meet the plates at right angles (Fig. 5-2). The straight lines in A become arcs in B, and approximately semicircles in C, where the plates are in a straight line. Instead of flat metal plates, as in the capacitor, the two elements can take the form of metal rods or wires. The three-dimensional view in Fig. 5-3 depicts the electric field more accurately. In A of Fig. 5-3, the wires are approximately 30° apart, and the flux lines are projected radially from the positively charged wire to the negatively charged wire. In B of Fig. 5-3, the two wires lie in a straight line, and the flux lines form a pattern similar to the lines of longitude around the earth. To bring out the picture more clearly, only the lines in one plane are given.

Assume that the sphere marked *E* in Fig. 5-3B is a transmitter supplying RF energy. The two wires then can serve as the antenna for the transmitter. RF energy is radiated from the antenna and charges move back and forth along the wires, alternately compressing and expanding the flux lines of the electric field. The reversals in polarity of the transmitter signal also reverse the direction of the electric field.

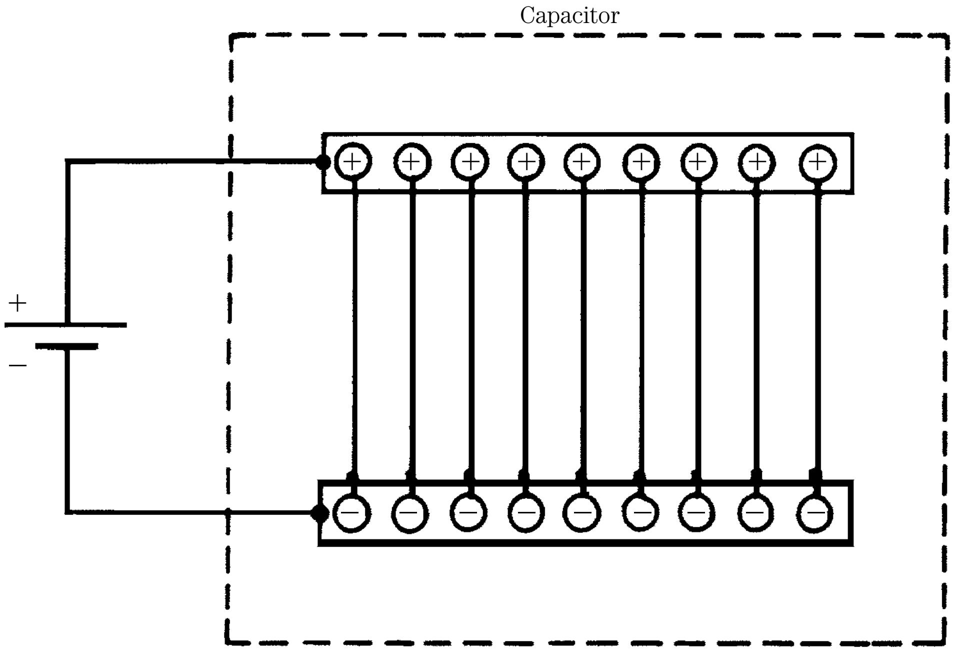

5-1 Charges on plates of a capacitor.

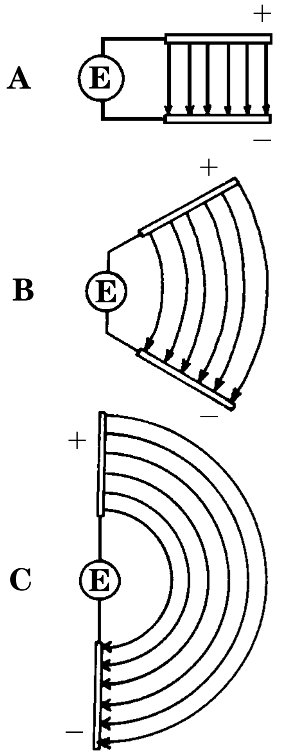

5-2 Electric field between plates at various angles.

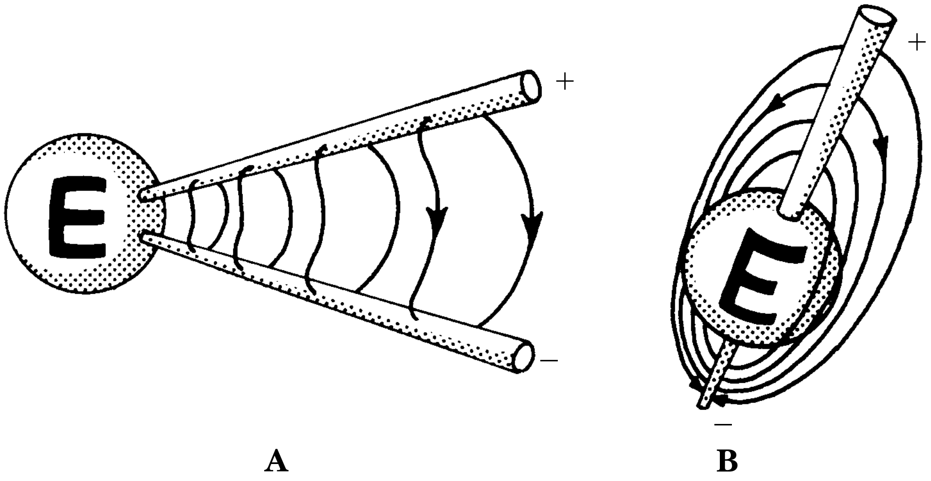

5-3 Electric field between wires at various angles.

When a charge is put on the plates of a capacitor by means of a battery, an electric field is set up between its plates. The flow of charge from source to capacitor ceases when the capacitor is fully charged, and the capacitor is said to be charged to a *voltage* equal, and of opposite polarity, to that of the source. The charged capacitor can be used as a source of emf since it stores energy in the form of an electric field. This is the same as saying that *an electric field indicates voltage*. The presence of an electric field about an antenna also indicates voltage. Since the polarity, and the amount of charge, depend on the nature of the transmitter output, the antenna voltage also depends on the energy source. For example, if a battery constitutes the source, the antenna charges to a voltage equal and opposite to that of the battery. If RF energy is supplied to a half-wave antenna, the voltage across the antenna lags the current by 90°. The half-wave antenna acts as if it was a capacitor, and it can be described as being *capacitive*.

Current and magnetic field

A *moving* charge along a conductor constitutes a current and produces a magnetic field around the conductor. Therefore, the flow of charge along an antenna also will be accompanied by a magnetic field. The intensity of this field is directly proportional to the flow of charge. When the antenna is uncharged, the current flow is maximum, since there is no opposing electric field. Because of this current flow, a charge accumulates on the antenna, and an electric field builds up in increasing opposition to the emf of the source. The current flow decreases and when the antenna is fully charged, the current no longer flows.

The magnetic field in the space around a current-carrying device has a specific configuration, with the magnetic flux lines drawn according to a definite rule (Fig. 5-4). Whereas, in the electric field, the electric lines are drawn from a positive charge to a negative charge, in the magnetic field, the flux lines are drawn according to the *left-hand rule*. The direction of current flow is upward along both halves of the antenna. The lines of magnetic flux form concentric loops that are perpendicular to the direction of current flow. The arrowheads on the loops indicate the direction of the field. If the thumb of the left hand is extended in the direction of current flow and the fingers are clenched, then the rough circles formed by the fingers indicate the direction of the magnetic field. This is the left-hand rule, or convention, which is used to determine the direction of the magnetic field.

Combined electric and magnetic fields

When RF energy from a transmitter is supplied to an antenna, the effects of charge, voltage, current, and the electric and magnetic fields are taking place simultaneously. These effects (Fig. 5-5) have definite time and space relationships to each other. If a half-wave antenna is used, the relations between charge and current flow can be predicted, because of the capacitive nature of this antenna. The voltage will lag the current by 90°, and the electric and magnetic fields will be 90° out of phase. With no electric field present (no charge), the current flow is unimpeded, and the magnetic field is maximum. As charge accumulates on the antenna, the electric field builds up in opposition to current flow and the magnetic field decreases in intensity. When the electric field reaches its maximum strength, the magnetic field has decayed to zero.

A reversal in polarity of the source reverses the direction of current flow as well as the polarity of the magnetic field, and the electric field aids the flow of current by

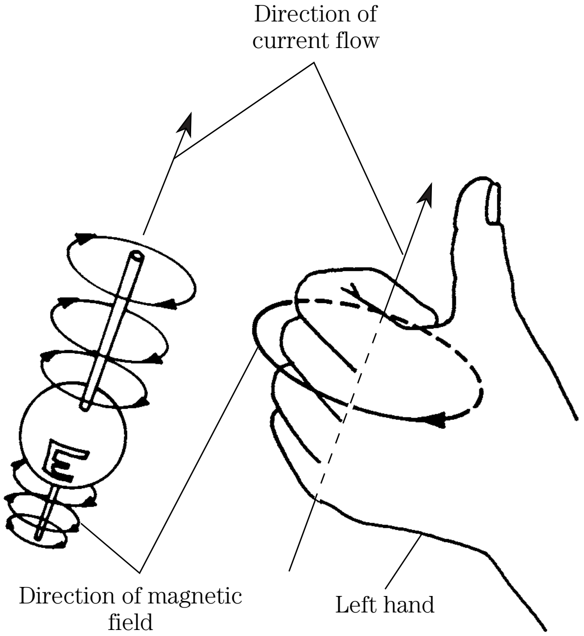

5-4 Magnetic field about a half-wave antenna (left-hand rule).

discharging. The magnetic field builds up to a maximum, and the electric field disappears as the charge is dissipated. The following half-cycle is a repetition of the first half-cycle, but in the reverse direction. This process continues as long as energy is supplied to the antenna. The fluctuating electric and magnetic fields combine to form the induction field, in which the electric and magnetic flux maximum intensities occur 90° apart in time, or in *time quadrature*. Physically, they occur at right angles to each other, or in *space quadrature*. To sum up, the electric and magnetic fields about the antenna are in space and time quadrature.

Standing waves

Assume that it is possible to have a wire conductor with one end extending infinitely, with an RF transmitter connected to this wire. When the transmitter is turned on, an RF current in the form of sine waves of RF energy moves down the wire. These waves of energy are called *traveling waves*. The resistance of the conductor gradually diminishes the amplitude of the waves, but they continue to travel so long as the line does not come to an end.

The antenna, however, has some finite length. Therefore, the traveling waves are halted when they reach the end of the conductor. Assume that the RF transmitter is turned on just long enough to allow one sine wave of energy to get on the line (Fig. 5-6A). This traveling wave is moving down the antenna toward the end. When the wave reaches the end of the conductor, the current path is broken abruptly. With the stoppage of current flow, the magnetic field collapses. A voltage is induced at the end of the conductor that causes current to flow *back toward the source*, as in Fig. 5-6B. The wave is reflected back to the source, and, if a continual succession of

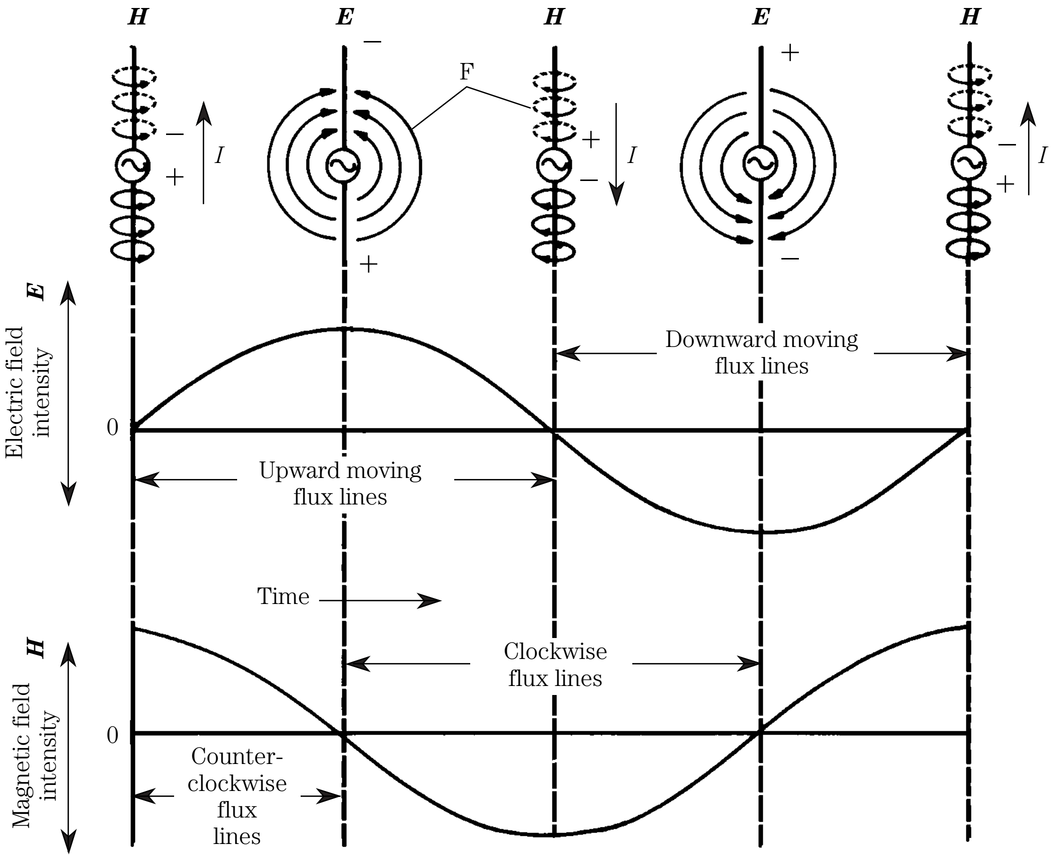
H
E
H
E
H
F
I
I
I
Electric field intensity
E
0
Downward moving flux lines
Upward moving flux lines
Time
Magnetic field intensity
H
0
Clockwise flux lines
Counter-clockwise flux lines

5-5 Electric and magnetic fields 90° out of phase.

waves is sent down the line, waves will be reflected in the same continual pattern. The wave moving from the transmitter toward the end is called the *incident* wave, and its reflection is called the *reflected* wave.

A continuous flow of incident waves results in a continuous flow of reflected waves. Because there is only one conductor, the two waves must pass each other. Electrically, the only current that actually flows is the *resultant* of both of these waves. The waves can reinforce or cancel each other as they move.

When they reinforce, the resultant wave is maximum; when they cancel, the resultant wave is minimum. In a conductor that has a finite length, such as an antenna, the points at which the maxima and minima of the resultant wave occur (Fig. 5-6C) are *stationary*. In other words, the maximum and minimum points stand still, although both the incident and reflected waves are moving. The resultant wave stands still on the line, only its amplitude being subject to change. Because of this effect, the resultant is referred to as a *standing wave*.

The development of the standing wave on an antenna by actual addition of the traveling waves is illustrated in Fig. 5-7. At the instant pictured in A, the incident and reflected waves just coincide. The result is a standing wave having twice the amplitude of either traveling wave. In B, the waves move apart in opposite directions, and

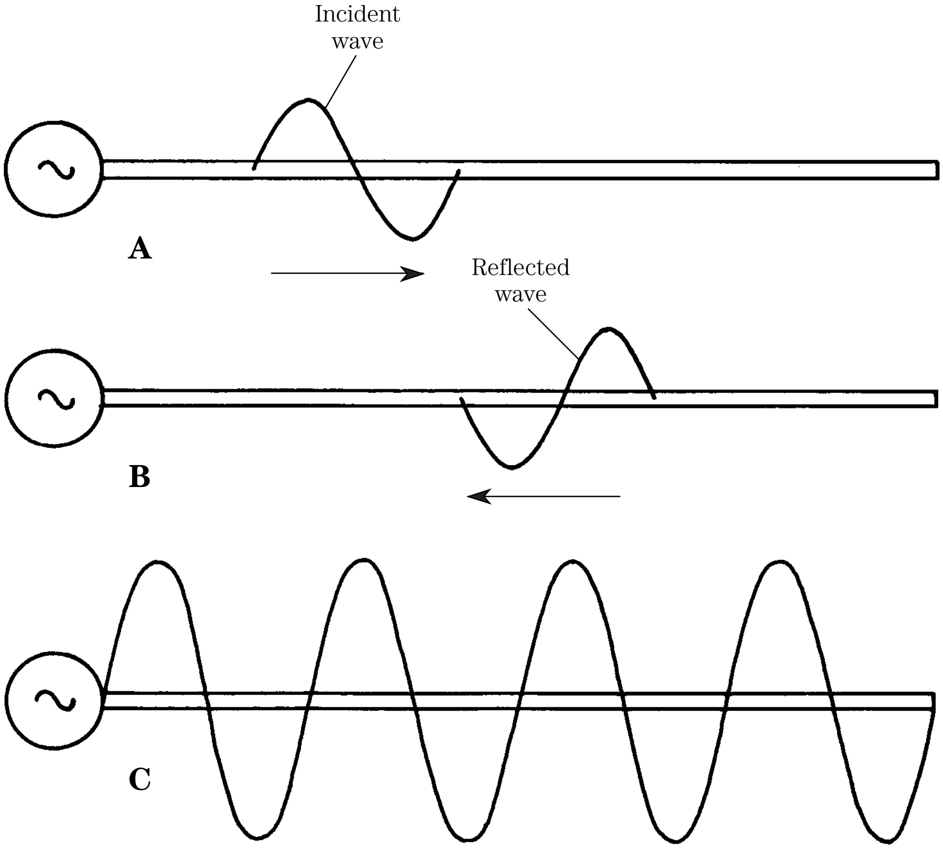

5-6 Traveling waves on an antenna and a typical resultant wave.

the amplitude of the resultant decreases, but the points of maximum and minimum do not move.

When the traveling waves have moved to a position of 180° phase difference, the resultant is zero along the entire length of the antenna, as shown in C. At this instant, there can be no current flow in the antenna. The continuing movement of the traveling waves, shown in D, builds up a resultant in a direction opposite to that in A. The in-phase condition of the traveling waves results in a standing wave, in E, equal in amplitude, but 180° out of phase with the standing wave in A.

If the progressive pictures of the standing wave are assembled on one set of axes, the result is as in Fig. 5-8. The net effect of the incident and reflected waves is apparent. The curves are lettered with reference to Fig. 5-7. As the traveling waves move past each other, the standing wave changes only its amplitude. The fixed minimum points are called *nodes*, and the curves representing the amplitude are called *loops*.

The concept of the standing wave can be applied to the half-wave antenna with reference to either current or voltage distribution at any instant. This application is possible because there are traveling waves of both voltage and current. Because voltage and current are out of phase on the half-wave antenna, the standing waves also are found to be out of phase.

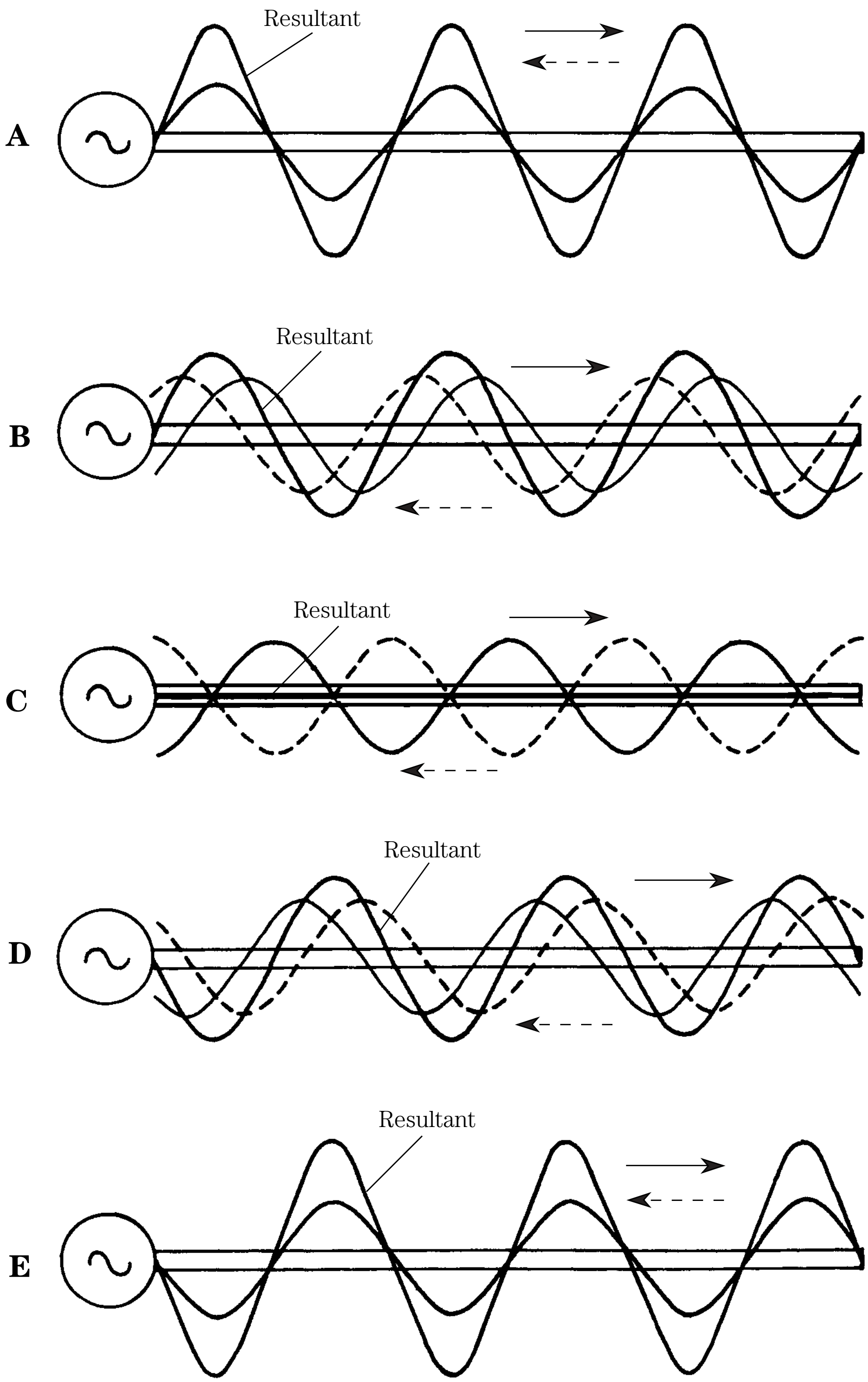
Resultant
A
Resultant
B
Resultant
C
Resultant
D
Resultant
E

5-7 Development of standing wave from traveling wave.

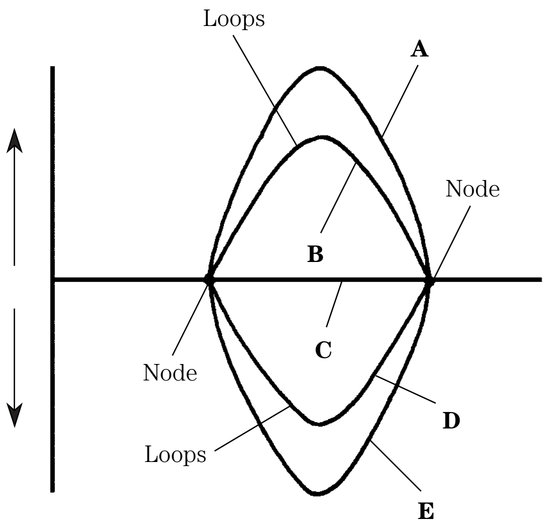

5-8 Standing waves.

Voltage and current distribution on half-wave antenna

When an RF transmitter is feeding a half-wave antenna, positive and negative charges move back and forth along the antenna (Figs. 5-9 and 5-10). The first picture shows the position of the charges at some arbitrary time, T_0. The RF charges being observed are at the ends of the antenna, and there is a maximum difference in potential between the ends, *A* and *B*. The remaining illustrations show the instantaneous positions of the charges at regular intervals of 22.5° throughout a complete cycle.

To the right of each instantaneous position of the charges are curves representing the current and voltage *at that particular time* for any point on the antenna. For example, at time T_0, the positive and negative charges are at points *A* and *B* on the antenna. The voltage between these points represents a maximum difference of potential. The current, being 90° out of phase in respect to the voltage, is everywhere zero. These distribution curves are *standing waves* derived in the same manner as those covered in the previous paragraph.

The next illustration shows the position of the charges at time T_1. The standing wave of current is a relative maximum at the center of the antenna. This current loop has nodes that remain at the ends of the antenna, and it is, therefore, 90° out of phase with the standing wave of voltage.

At T_2 and T_3, the charges move closer together, and the standing wave of voltage slowly decreases in amplitude. Conversely, the current loop increases in magnitude. When the charges meet after 90° of the RF cycle (T_4), the effect is that of having the positive and negative charges cancel. The voltage loop accordingly is zero everywhere on the antenna, and the current loop rises to its maximum value, unimpeded by any charge on the antenna.

At time T_5, the charges have passed each other, each charge having moved past the center point of the antenna. The polarity of the voltage loops is reversed, and they build up in the opposite direction, keeping the node always at the center point of the antenna. The reversal of polarity is shown in the charge positions at T_3, T_4, and

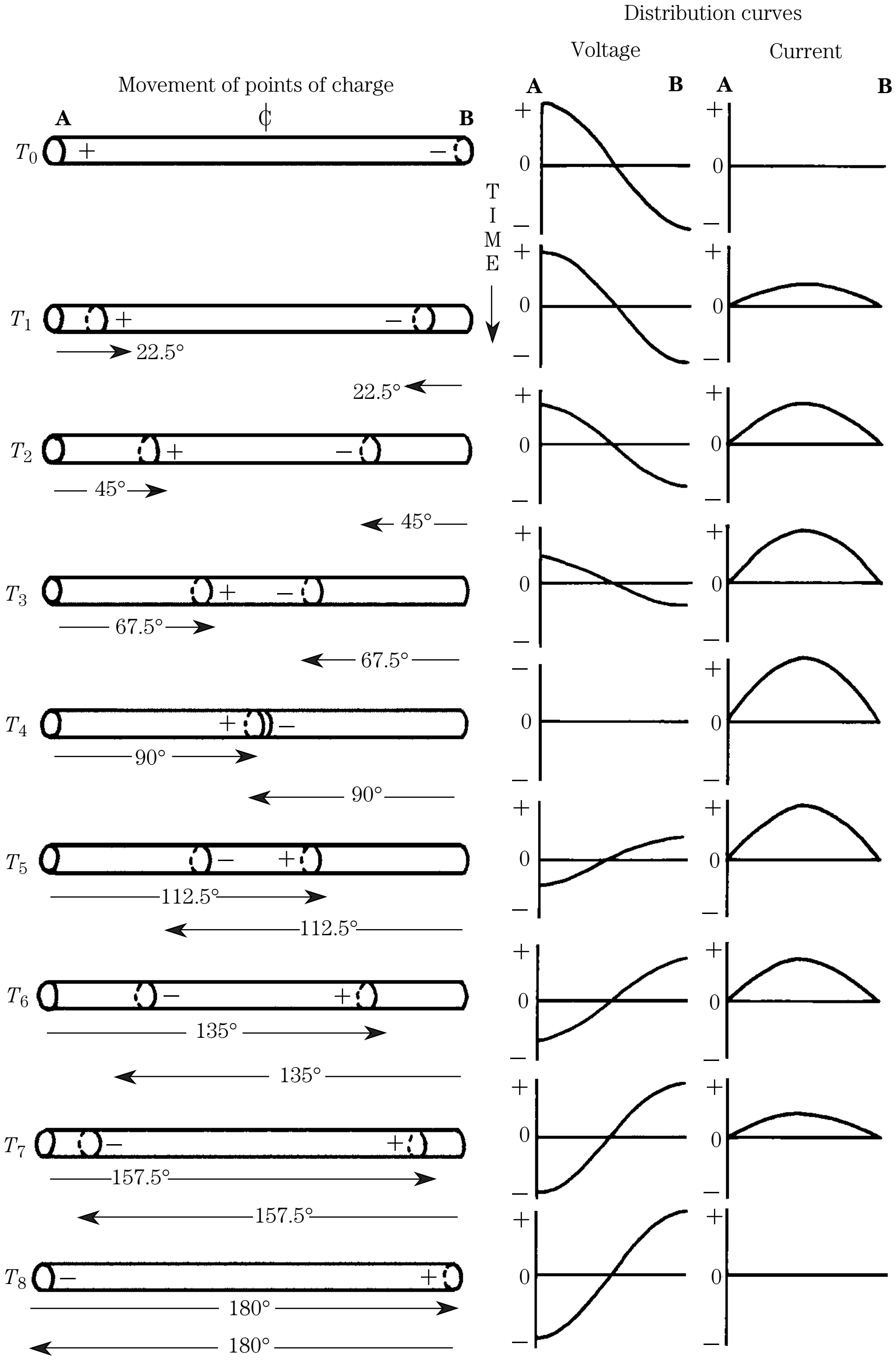
Distribution curves
Voltage
Current
Movement of points of charge
A
B
℄
T_0
T_1
T_2
T_3
T_4
T_5
T_6
T_7
T_8
TIME
22.5°
45°
67.5°
90°
112.5°
135°
157.5°
180°
+
0
–

5-9 Voltage and current distribution in terms of positive and negative charges.

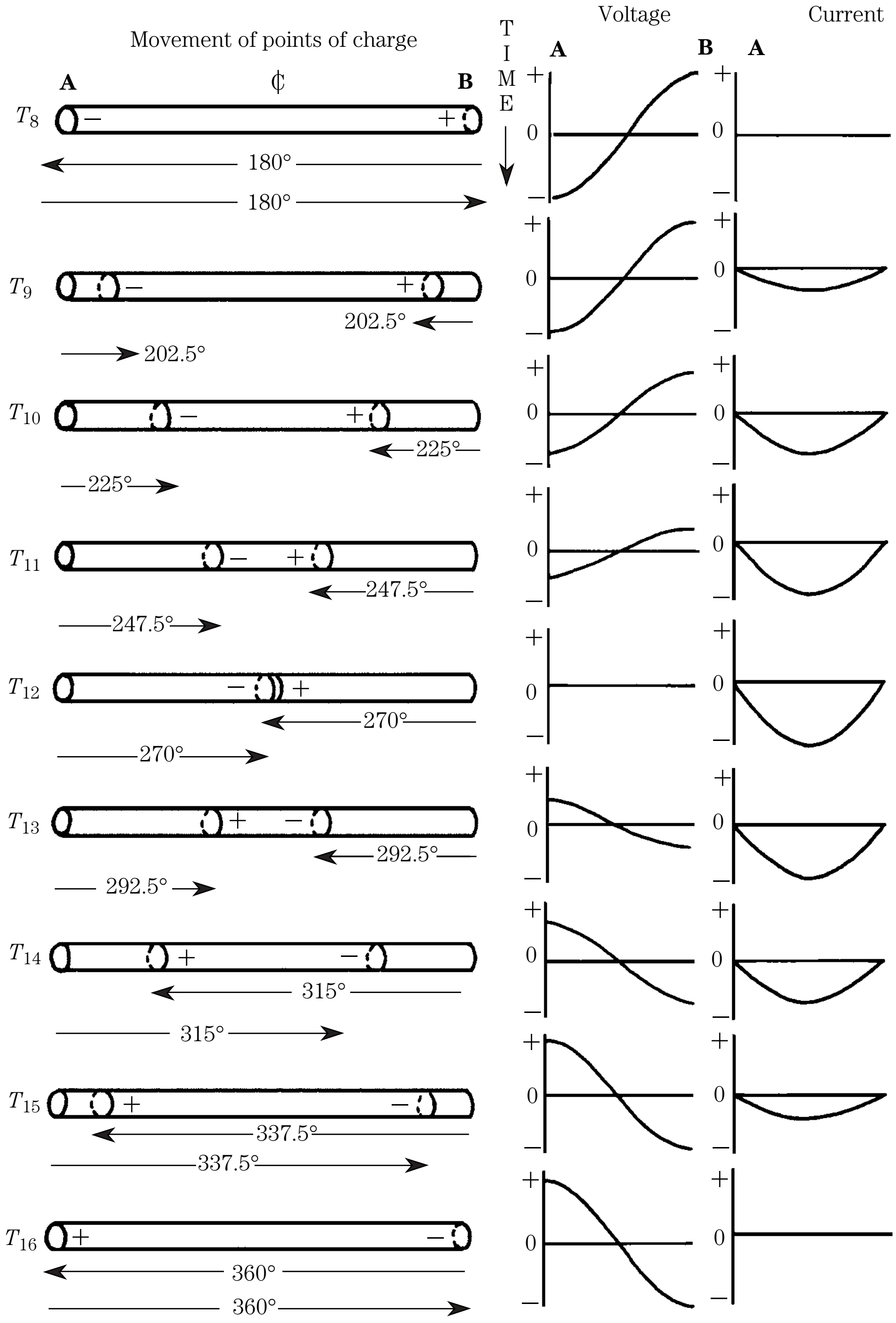
Movement of points of charge
A
₵
B
TIME
Voltage
Current
A
B
A
T8
180°
T9
202.5°
T10
225°
T11
247.5°
T12
270°
T13
292.5°
T14
315°
T15
337.5°
T16
360°
+
0
−

5-10 Voltage and current distribution in terms of positive and negative charges.

T_5. The separation of the charges also is accompanied by a decrease in the amplitude of the current loop.

From T_5 to T_8, the charges move out to the ends of the antenna. During this time, the voltage loops increase and the current loops decrease in amplitude. At time T_8, which occurs 180° after T_0 in the RF cycle, the charges have moved to opposite ends of the antenna. Compare the picture in T_0 to the picture in T_8. It is seen that the negative charge is now at point *A* and the positive charge at point *B*. Because the positions of the charges have been reversed from T_0 to T_8, the voltage loops in T_8 are 180° out of phase, compared with the loops in T_0.

From T_8 to T_{16} in Fig. 5-10, the movement of the charges is shown in the opposite direction, the current loop reaching a maximum at T_{12}. When the entire RF cycle is completed at time T_{16}, the charges have returned to the positions that they occupied at T_0. The distribution curves of voltage and current also are in their original conditions. The entire process then is repeated for each RF cycle.

Standing waves of voltage and current The distribution curves of the current and voltage are standing waves. This means that they are the resultants obtained by adding two traveling waves. The two traveling waves are associated with the positive and negative charges. The wave caused by the negative charge can be called the *incident wave* and the wave caused by the positive charge the *reflected wave*. This, however, is clearer when the concept of negative and positive charges is used.

The positive charge, taken at time T_0 in Fig. 5-9, produces a traveling wave of voltage, shown by the dashed line in Fig. 5-11A. The negative charge at the opposite end of the antenna produces an identical traveling wave (dash-dot curve). These two add together to produce the T_0 voltage distribution curve, which is the resultant wave of Fig. 5-9A. Both of these waveforms are identical, being the *standing wave of voltage* at time T_0. All of the following distribution curves of Fig. 5-11 are produced in the same manner. They are the standing wave resultants caused by the traveling waves accompanying the charges.

In Fig. 5-11B, each of the traveling waves has moved 45°, the positive traveling wave moving to the right and the negative traveling wave moving to the left. This time corresponds to T_2 in Fig. 5-9. The standing wave produced corresponds to the voltage distribution curve at T_2. The standing waves of current are produced in the same manner. The current curves at D, E, and F of Fig. 5-11 correspond to times T_0, T_2, and T_4 of Fig. 5-9.

Standing waves of voltage In Fig. 5-12A, voltage standing waves occurring at different times are brought together on one axis, *AB*, representing a half-wave antenna. Essentially, these are the same curves shown progressively in Figs. 5-9 and 5-10 as voltage distribution curves. They can be used to determine the voltage at any point on the antenna, at any instant of time. For example, if it is desired to know the variations of voltage occurring at point *Y* on the antenna over the RF cycle, the variations are graphed in respect to time, as shown in Fig. 5-12B. At T_0, the voltage at *Y* is maximum. From T_0 through T_3, the voltage decreases, passing through zero at T_4. The voltage builds up to a maximum in the opposite direction at T_8, returning through zero to its original position from T_8 to T_{16}.

Between T_0 and T_{16}, therefore, an entire sine-wave cycle, *Y*, is reproduced. This is also true of any other point on the antenna, with the exception of the node at *X*.

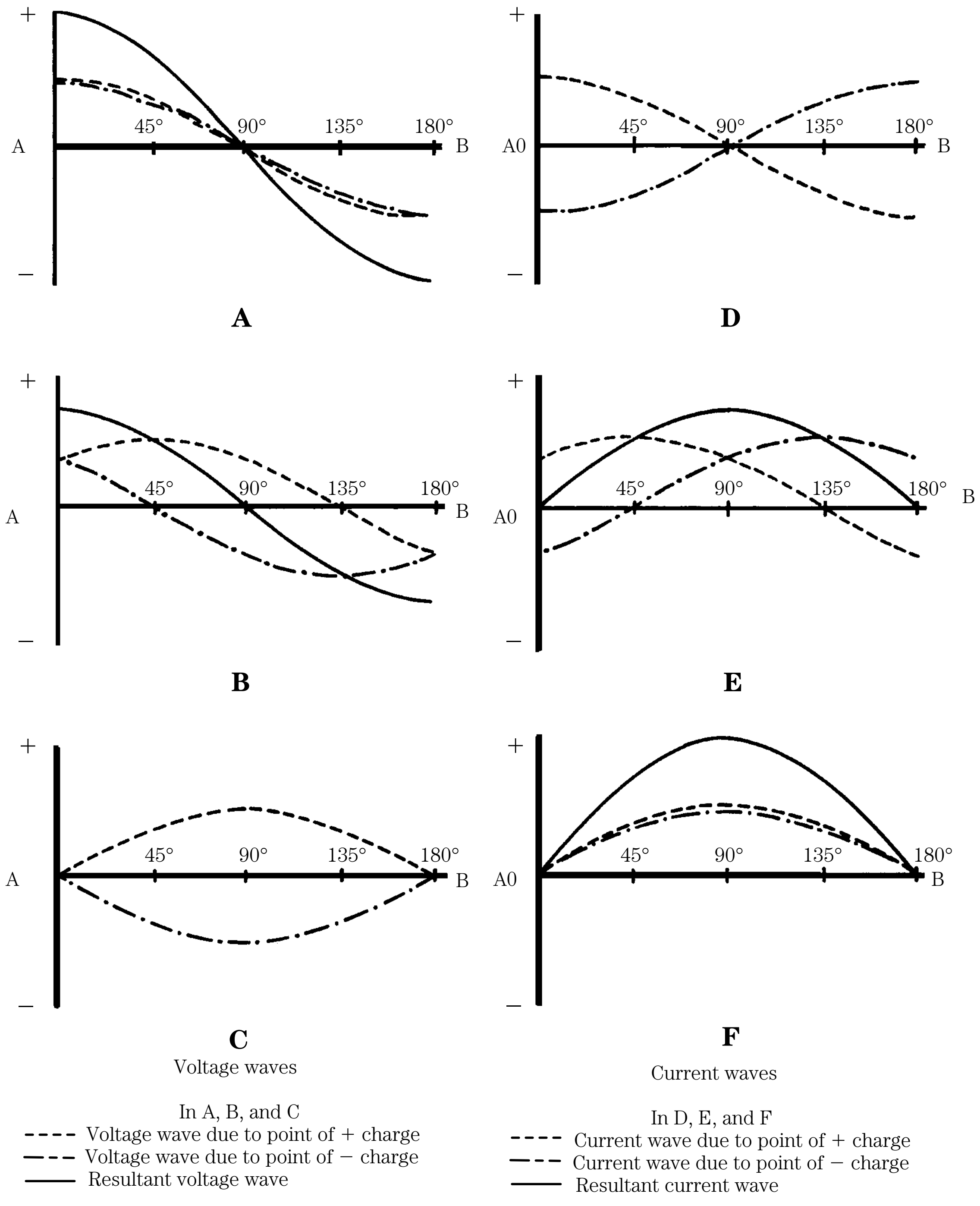

5-11 Standing waves of voltage and current.

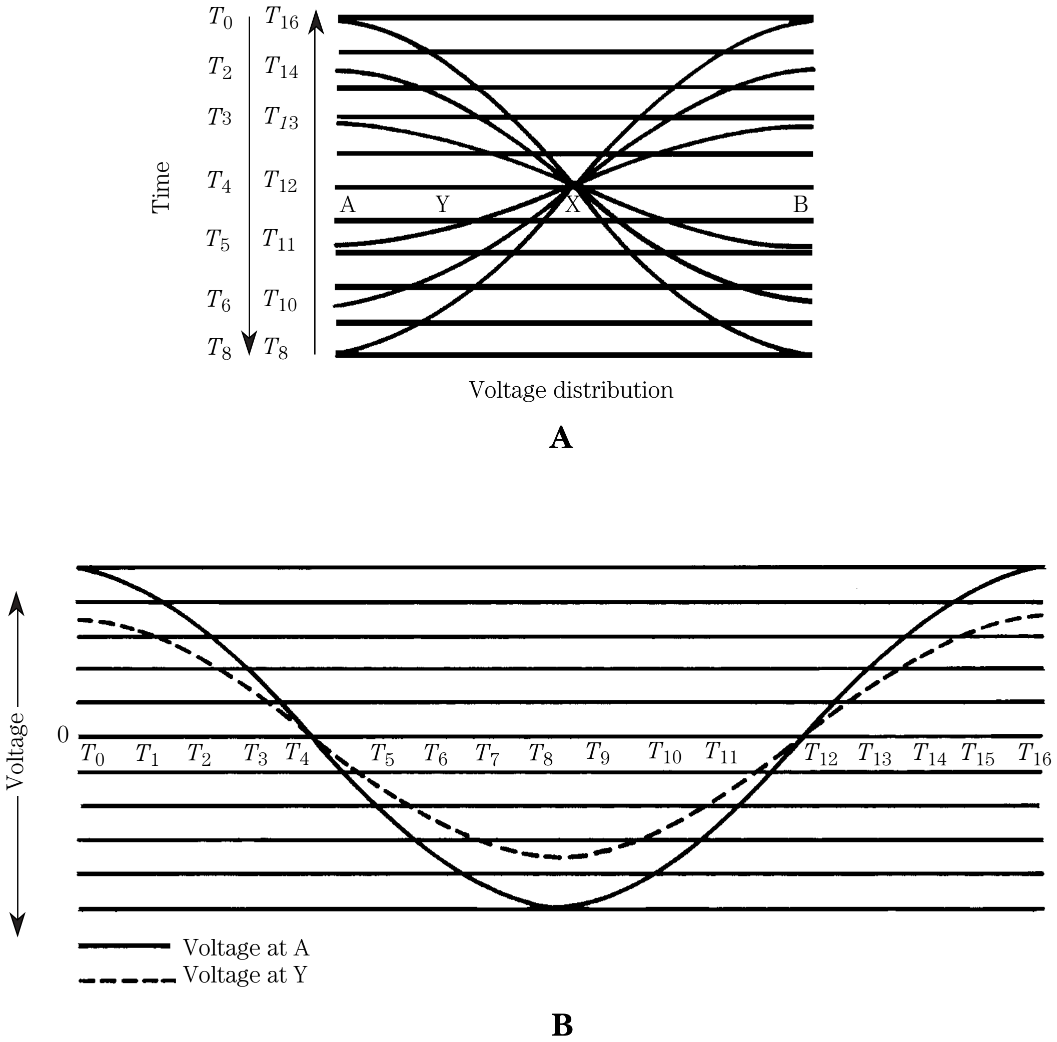
T_0 T_{16}
T_2 T_{14}
T_3 T_{13}
Time
T_4 T_{12}
A
Y
X
B
T_5 T_{11}
T_6 T_{10}
T_8 T_8
Voltage distribution
A
Voltage
0
T_0 T_1 T_2 T_3 T_4 T_5 T_6 T_7 T_8 T_9 T_{10} T_{11} T_{12} T_{13} T_{14} T_{15} T_{16}
Voltage at A
Voltage at Y
B

5-12 Standing waves of voltage at a point on the antenna.

The peak amplitude of the sine wave produced at any point depends on its position on the antenna. The nearer the point is to either end, the greater its peak amplitude.

Standing waves of current The standing waves of current occurring at various times through the RF cycle are assembled on a single axis in Fig. 5-13. This axis, AB, represents the half-wave antenna. If the current variations at point Y from T_0 to T_{16} are graphed in respect to time, the result is the sine wave in Fig. 5-13B. This is true for any point along the antenna with the exception of the nodes at the ends. The current has its greatest swing at *X*, the center of the antenna. Comparison of the voltage variation curve (Fig. 5-12A) with the current variation curve (Fig. 5-13A) shows the voltage curve leading the current curve by 90° at *Y*. This relation can be expected on any half-wave device.

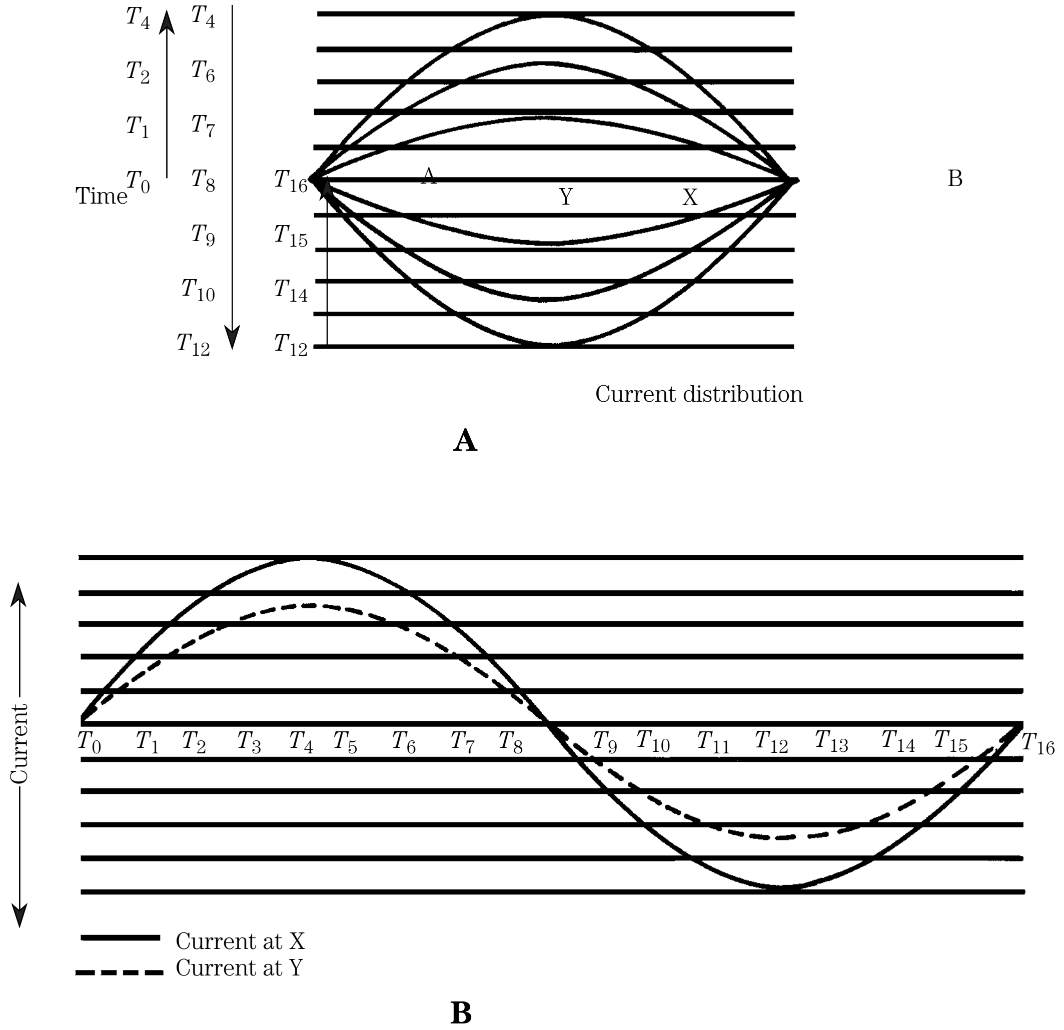
T_4 T_4
T_2 T_6
T_1 T_7
Time T_0 T_8 T_{16}
T_9 T_{15}
T_{10} T_{14}
T_{12} T_{12}
A
Y
X
B
Current distribution
A
Current
T_0 T_1 T_2 T_3 T_4 T_5 T_6 T_7 T_8 T_9 T_{10} T_{11} T_{12} T_{13} T_{14} T_{15} T_{16}
Current at X
Current at Y
B

5-13 Standing waves of current at a point on the antenna.

Measurement of standing waves In Fig. 5-14, the standing waves of voltage *E* and current *I* are indicated along the antenna. There are current nodes at *A* and *B* and a voltage node at *X*. These standing waves are found on any half-wave antenna. A meter that indicates the effective value (0.707 of peak) of the ac signal can be used to measure the standing waves present on the half-wave antenna.

Velocity of propagation and antenna length

In free space, electromagnetic waves travel at a constant velocity of 300,000 km (or approximately 186,000 mi) per second. The RF energy on an antenna, however, moves at a velocity considerably less than that of the radiated energy in free space

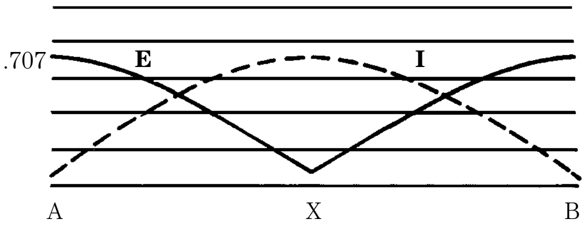

5-14 Standing waves measured with a meter.

because the antenna has a *dielectric constant* greater than that of free space. Because the dielectric constant of free space (air or vacuum) is approximately 1, a dielectric constant greater than 1 retards electromagnetic-wave travel.

Because of the difference in velocity between the wave in free space and the wave on the antenna, the *physical* length of the antenna no longer corresponds to its *electrical* length. The antenna is a half-wavelength electrically, but somewhat shorter than this physically. This is shown in the formula for the velocity of electromagnetic waves,

$$V = f\lambda \tag{5.1}$$

where V is the velocity, f is the frequency, and λ is the wavelength. Since the frequency of the wave remains constant, a decrease in the velocity results in a decrease in the wavelength. Therefore, the wave traveling in an antenna has a shorter wavelength than the same wave traveling in free space, and the physical length of the antenna can be shorter.

The actual difference between the physical length and the electrical length of the antenna depends on several factors. A thin wire antenna, for example, has less effect on wave velocity than an antenna with a large cross section. As the circumference of the antenna increases, the wave velocity is lowered, as compared with its free-space velocity. The effect of antenna circumference on wave velocity is illustrated in the graph of Fig. 5-15.

Other factors are involved that lower wave velocity on the antenna. Stray capacitance, for example, increases the dielectric constant and lowers wave velocity. This capacitance can be caused by the line connecting the antenna to the transmitter, the insulators used to give physical support to the antenna, or nearby objects made of metallic or dielectric materials. The change in velocity resulting from stray capacitance is called *end effect* because the ends of the antenna are made farther apart electrically than they are physically. End effect is counteracted by making the physical length about 5 percent shorter than the electrical length, as expressed in the formula

$$\begin{aligned} L &= 0.95\left(\frac{492}{f}\right) \\ &= \frac{468}{f} \end{aligned} \tag{5.2}$$

where L is the physical length in feet and f is the frequency in megahertz. This formula is accurate for all practical purposes in determining the physical length of a half-wavelength antenna at the operating frequency.

The capacitive end effect also slightly changes the standing waves of voltage and current. When the standing waves are measured, it is found that the nodes have some value and do not reach zero, because some current is necessary to charge the stray capacitance. The standing waves measured in Fig. 5-16 show the results of end effect.

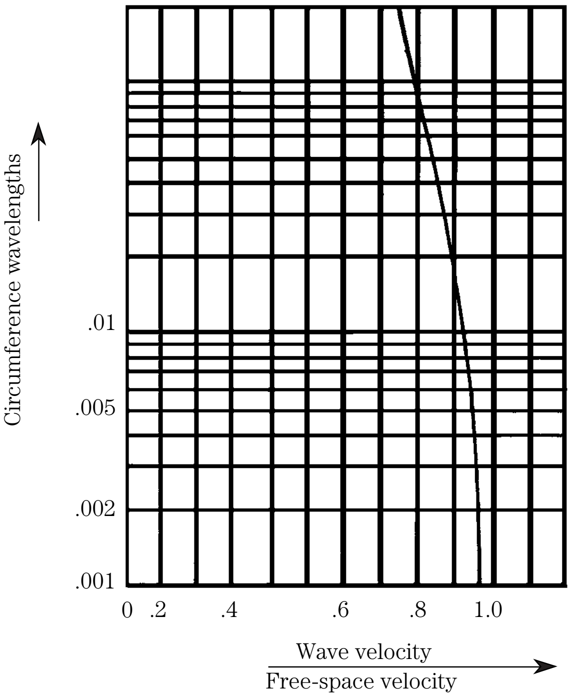

5-15 Effect of antenna circumference on wave velocity.

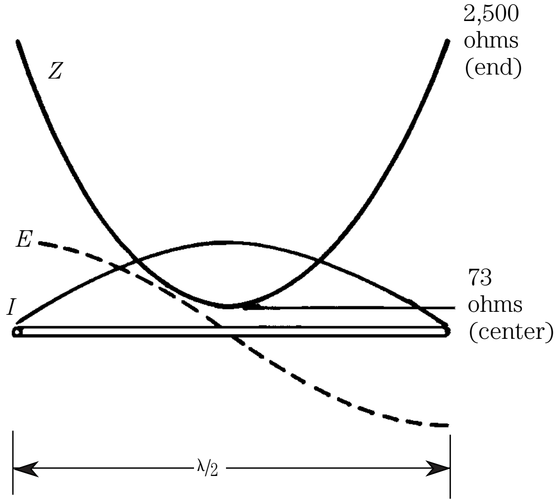

5-16 Impedance along half-wave antenna.

Resonance, resistance, and impedance

The antenna is a circuit element having distributed constants of inductance, capacitance, and resistance, which can be made to form a resonant circuit. The half-wave antenna is the shortest resonant length of antenna. However, antennas which are two or more half-wavelengths can also be resonant. Such antennas are said to operate on *harmonics*. If an antenna is four half-wavelengths at the transmitter frequency, it is being operated at the fourth harmonic of its lowest resonant frequency. In other words, this antenna is a half-wavelength at one-quarter of the frequency of operation. An antenna operating on the third harmonic is shown in Fig. 5-7.

Resistance A current flowing in the antenna must contend with three kinds of resistance. With the antenna considered as a radiator of energy, the power expended in the form of radiation can be thought of as an I^2R_t loss. R_t is called the *radiation resistance*. With the antenna considered as a conductor, a certain amount of energy is dissipated in the form of heat. In this I^2R_0 loss, R_0 is the *ohmic resistance*. There is also an I^2R loss because of the *leakage resistance* of dielectric elements, such as insulators. This R usually is included in the ohmic resistance.

The purpose of the antenna is to dissipate as much energy as possible in the form of radiation. The energy dissipated by the radiation resistance, therefore, is the useful part of the total power dissipated. Because the actual power loss depends on the ohmic resistance, this resistance should be kept as low as possible. In the half-wave antenna, the radiation resistance is large compared to the ohmic resistance, and most of the available energy is radiated. The half-wave antenna is, therefore, a very efficient radiator for most purposes.

For a half-wave antenna fed at the center point, the radiation resistance is equal to 73 Ω. The reference point is the center of the antenna at the time of peak current flow. Ohmic resistance is referred to this point. The total resistance is of importance in matching the antenna to a transmission line.

Impedance Because the half-wave antenna has different conditions of voltage and current at different points, and because impedance is equal to the voltage across a circuit divided by the current through it, the impedance will vary along the length of the antenna. If E is divided by I at each point of the voltage and current curves in Fig. 5-16, the result is the impedance curve, Z. The impedance is about 73 Ω at the center point and rises to a value of about 2500 Ω at the ends.

The impedance of the half-wave antenna usually is considered to be the impedance as *seen* by the transmitter at the input terminals. This impedance consists of both resistance and reactance. If the antenna is cut to a length of exact resonance, the reactance is zero and the impedance is purely resistive. However, if the antenna is longer or shorter than resonance, reactance is present. When the antenna is made shorter, capacitive reactance is present; when the antenna is made longer, inductive reactance is present.

The impedance at the antenna input terminals is important in terms of power efficiency. If the transmitter is feeding a nonresonant antenna, a power loss is caused by the reactive component of the antenna impedance. Conversely, if the frequency of the transmitter is changed, the electrical length of the antenna also changes. If the frequency is made somewhat higher, the electrical length is made greater, and inductive reactance is added to the impedance. If the frequency is lowered, the electrical length is shortened, and capacitive reactance is added to the impedance.

6
CHAPTER

High-frequency dipole and other doublet antennas

A MYTH AROSE IN RADIO COMMUNICATIONS CIRCLES SOME TIME AGO. PEOPLE CAME TO believe (especially in the ham and CB communities) that large antenna arrays are absolutely necessary for effective communications, especially over long distances. Overlooked, almost to the point of disdain, were effective (but simple) antennas that can be erected by inexperienced people and made to work well. The simple *dipole*, or *doublet*, is a case in point. This antenna is also sometimes called the *Hertz*, or *hertzian*, antenna because radio pioneer Heinrich Hertz reportedly used this form in his experiments.

The half-wavelength dipole is a balanced antenna consisting of two radiators (Fig. 6-1) that are each a quarter-wavelength, making a total of a half-wavelength. The antenna is usually installed horizontally with respect to the earth's surface, so it produces a horizontally polarized signal.

In its most common configuration (Fig. 6-1), the dipole is supported at each end by rope and end insulators. The rope supports are tied to trees, buildings, masts, or some combination of such structures.

The length of the antenna is a half-wavelength. Keep in mind that the physical length of the antenna, and the theoretical electrical length, are often different by about 5 percent. A free-space half-wavelength is found from

$$L = \frac{492}{F_{\text{MHz}}}\ \text{ft} \qquad \textbf{[6.1]}$$

In a perfect antenna, that is self-supported many wavelengths away from any object, Eq. 6.1 will yield the physical length. But in real antennas, the length calculated

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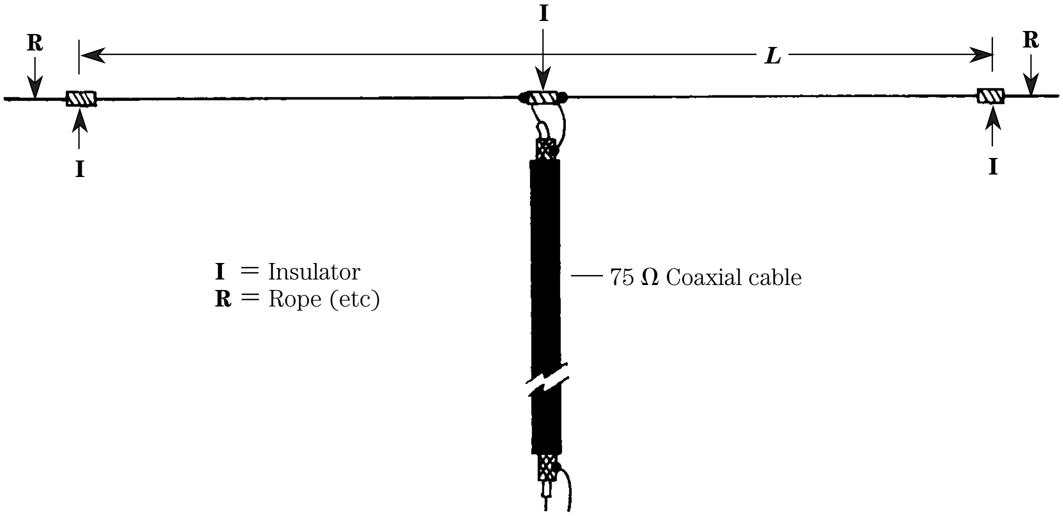

6-1 Simple half-wave dipole antenna.

above is too long. The average physical length is shortened by up to about 5 percent because of the velocity factor of the wire and capacitive effects of the end insulators. A more nearly correct *approximation* (remember that word, it's important) of a half-wavelength antenna is

$$L = \frac{468}{F_{\text{MHz}}} \text{ ft} \qquad \textbf{[6.2]}$$

where

L is the length of a half-wavelength radiator, in feet
F_{MHz} is the operating frequency, in megahertz

Example Calculate the approximate physical length for a half-wavelength dipole operating on a frequency of 7.25 MHz.

Solution:

$$\begin{aligned} L &= \frac{468}{F_{\text{MHz}}} \text{ ft} \\ &= \frac{468}{7.25} \text{ ft} = 64.55 \text{ ft} \end{aligned}$$

or, restated another way:

$$L = 64 \text{ ft } 6.6 \text{ in}$$

It is unfortunate that a lot of people accept Eq. 6.2 as a universal truth, a kind of immutable law of The Universe. Perhaps abetted by books and articles on antennas that fail to reveal the full story, too many people install dipoles without regard for reality. The issue is *resonance*. An antenna is a complex *RLC* network. At some frequency, it will appear like an inductive reactance ($X = +jX_L$), and at others it will appear like a capacitive reactance ($X = -jX_C$). At a specific frequency, the reactances are equal in magnitude, but opposite in sense, so they cancel each other out: $X_L - X_C = 0$. At this frequency, the impedance is purely resistive, and the antenna is said to be resonant.

The goal in erecting a dipole is to make the antenna resonant at a frequency that is inside the band of interest, and preferably in the portion of the band most often used by the particular station. Some of the implications of this goal are covered later on, but for the present, assume that the builder will have to custom-tailor the length of the antenna. Depending on several local factors (among them, nearby objects, the shape of the antenna conductor, and the length/diameter ratio of the conductor) it might prove necessary to add, or trim, the length a small amount to reach resonance.

The dipole feedpoint

The dipole is a half-wavelength antenna fed in the center. Figure 6-2 shows the voltage (V) and current (I) distributions along the length of the half-wavelength radiator element. The feedpoint is at a voltage minimum and a current maximum, so you can assume that the feedpoint is a current antinode.

At resonance, the impedance of the feedpoint is $R_o = V/I$. There are two resistances that make up R_o. The first is the ohmic losses that generate nothing but heat when the transmitter is turned on. These ohmic losses come from the fact that conductors have electrical resistance and electrical connections are not perfect (even when properly soldered). Fortunately, in a well-made dipole these losses are almost negligible. The second contributor is the *radiation resistance* R_r of the antenna. This resistance is a hypothetical concept that accounts for the fact that RF power is radiated by the antenna. The radiation resistance is the fictional resistance that would dissipate the amount of power that is radiated away from the antenna.

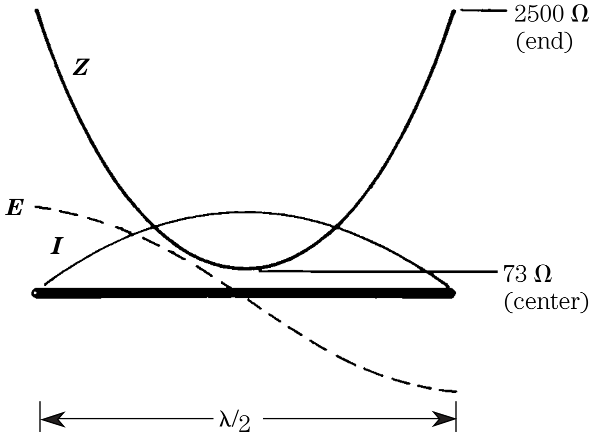

6-2 Graph of current, voltage, and impedance along half-wavelength dipole.

For example, suppose we have a large-diameter conductor used as an antenna, and it has negligible ohmic losses. If 1000 W of RF power is applied to the feedpoint, and a current of 3.7 A is measured, what is the radiation resistance?

$$R_r = \frac{P}{I^2} \tag{6.3}$$

$$= \frac{1000\text{ W}}{(3.7)^2} \tag{6.4}$$

$$= 73\ \Omega \tag{6.5}$$

It is always important to match the feedpoint impedance of an antenna to the transmission-line impedance. Maximum power transfer always occurs (in any system) when the source and load impedances are matched. In addition, if some applied power is not absorbed by the antenna (as happens in a mismatched system), then the unabsorbed portion is reflected back down the transmission line toward the transmitter. This fact gives rise to standing waves, and the so-called standing wave ratio (SWR or VSWR) discussed in Chap. 3. This is a problem to overcome.

Matching antenna feedpoint impedance seems to be simplicity itself because the free-space feedpoint impedance of a simple dipole is about 73 Ω, seemingly a good match to 75-Ω coaxial cable. Unfortunately, the 73-Ω feedpoint impedance is almost a myth. Figure 6-3 shows a plot of approximate radiation resistance (R_r) versus height above ground (as measured in wavelengths). As before, we deal in approximations in Fig. 6-3; in this case, the ambiguity is introduced by ground losses.

Despite the fact that Fig. 6-3 is based on approximations, you can see that radiation resistance varies from less than 10 Ω, to around 100 Ω, as a function of height. At heights of many wavelengths, this oscillation of the curve settles down to the free-space impedance (72 Ω). At the higher frequencies, it might be possible to install a dipole at a height of many wavelengths. In the 2-m amateur radio band (144 to 148 MHz), one wavelength is around 6.5 ft (i.e., 2 m × 3.28 ft/m), so “many wavelengths” is relatively easy to achieve at reasonably attainable heights. In the 80-m band (3.5 to 4.0 MHz), however, one wavelength is on the order of 262 ft, so “many wavelengths” is a practical impossibility.

There are three tactics that can be followed. First, ignore the problem altogether. In many installations, the height above ground will be such that the radiation resistance will be close enough to present only a slight impedance mismatch to a standard coaxial cable. The VSWR is calculated (among other ways) as the ratio:

1. $Z_o > R_r$:

$$\text{VSWR} = \frac{Z_o}{R_r} \tag{6.6}$$

2. $Z_o < R_r$:

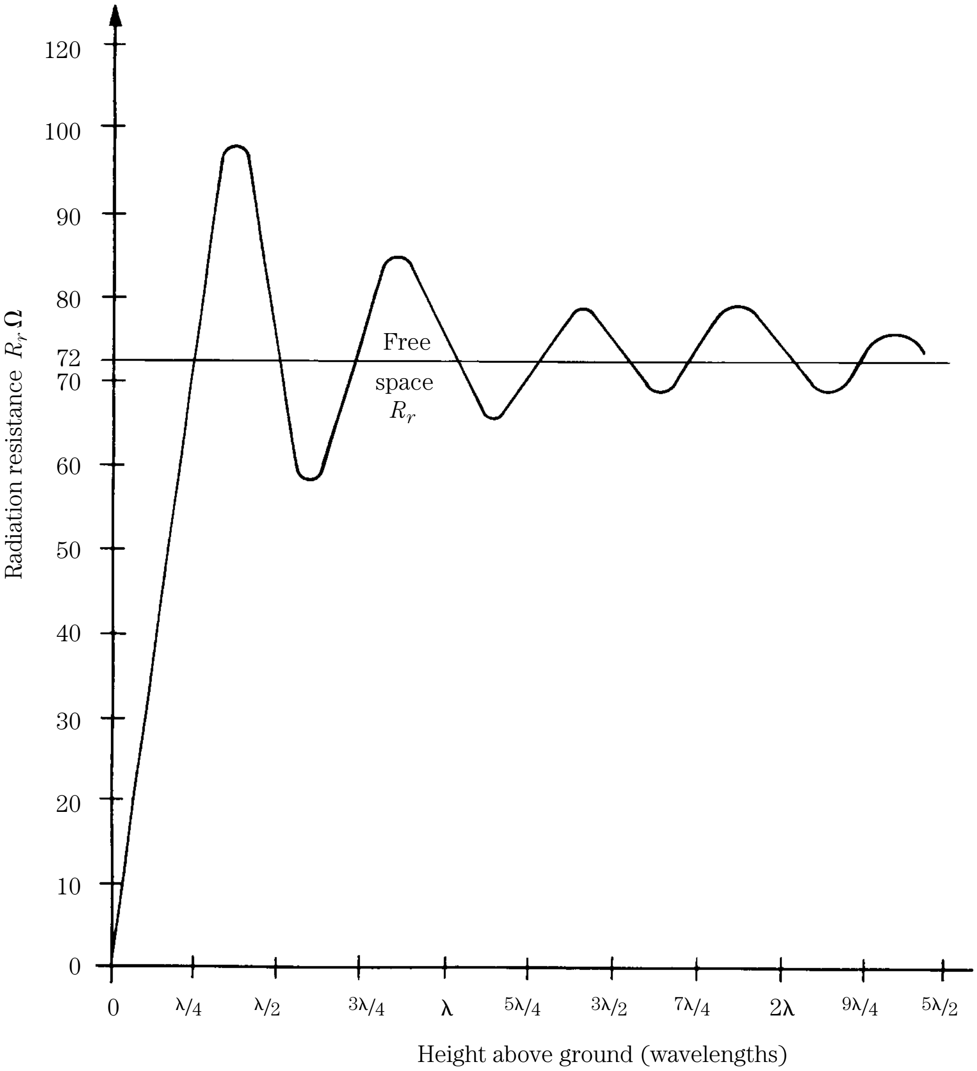

6-3 Radiation resistance versus height above ground.

$$\text{VSWR} = \frac{R_r}{Z_o} \qquad \textbf{[6.7]}$$

where

Z_o is the coaxial-cable characteristic impedance
R_r is the radiation resistance of the antenna

Consider an antenna mounted at a height somewhat less than a quarter-wavelength, such that the radiation resistance is 60 **Ω**. Although not recommended as good engineering practice (there are sometimes practical reasons) it is nonetheless necessary to install a dipole at less than optimum height. So, if that becomes necessary, what are the implications of feeding a 60-Ω antenna with either 52- or 75-Ω standard coaxial cable? Some calculations are revealing:

For 75-Ω coaxial cable:

$$\text{VSWR} = \frac{Z_o}{R_r} \tag*{[6.8]}$$

$$= \frac{75\ \Omega}{60\ \Omega} = 1.25{:}1 \tag*{[6.9]}$$

For 52-Ω coaxial cable:

$$\text{VSWR} = \frac{R_r}{Z_o} \tag*{[6.10]}$$

$$= \frac{60\ \Omega}{52\ \Omega} = 1.15{:}1 \tag*{[6.11]}$$

In neither case is the VSWR created by the mismatch too terribly upsetting.

The second approach is to mount the antenna at a convenient height, and use an impedance matching scheme to reduce the VSWR. In Chap. 23, you will find information on various suitable (relatively) broadbanded impedance matching methods including Q-sections, coaxial impedance transformers, and broadband RF transformers. “Homebrew” and commercially available transformers are available to cover most impedance transformation tasks.

The third approach is to mount the antenna at a height (Fig. 6-3) at which the expected radiation resistance crosses a standard coaxial cable characteristic impedance. The best candidate seems to be a height of a half-wavelength because the radiation resistance is close to the free-space value of 72 Ω, and is thus a good match for 75-Ω coaxial cable (such as RG-11/U or RG-59/U).

The dipole radiation pattern

The radiation patterns of various antennas are covered in this book. Some basic theory of patterns is repeated at each section, not to fill space, but rather to drive home a point and refresh reader memories. We keep harking back to the concepts *directivity* and *gain* (which are actually different expressions of the same thing).

Antenna theory recognizes a point of reference called the *isotropic radiator*. This device is a theoretical construct consisting of a spherical point source of RF radiation in all directions (see Chap. 2). It is truly *omnidirectional* (“all directions”) because it creates an ever-expanding sphere as the RF wavefront propagates outward. Antenna gain is a measure of how the antenna focuses available power away from a spherical wavefront to a limited number of directions (two, in the case of the dipole). Thus are related the concepts *directivity* and *gain*.

Always keep in mind that *directivity and gain are specified in three dimensions*. Too many times, people simplify the topic too much by publishing only part of the radiation pattern (azimuth aspect). In other words, the reader is given a pattern viewed from above that shows the directivity in the horizontal plane. But a signal does not propagate away from an antenna in an infinitely thin sheet, as such presentations seem to imply; rather, it has an elevation extent in addition to the azimuth extent. Thus, proper evaluation of an antenna takes into consideration both horizontal and vertical plane patterns.

Figure 6-4 shows the radiation pattern of a dipole antenna in free space "in the round." In the horizontal plane (6-4A), when viewed from above, the pattern is a "figure

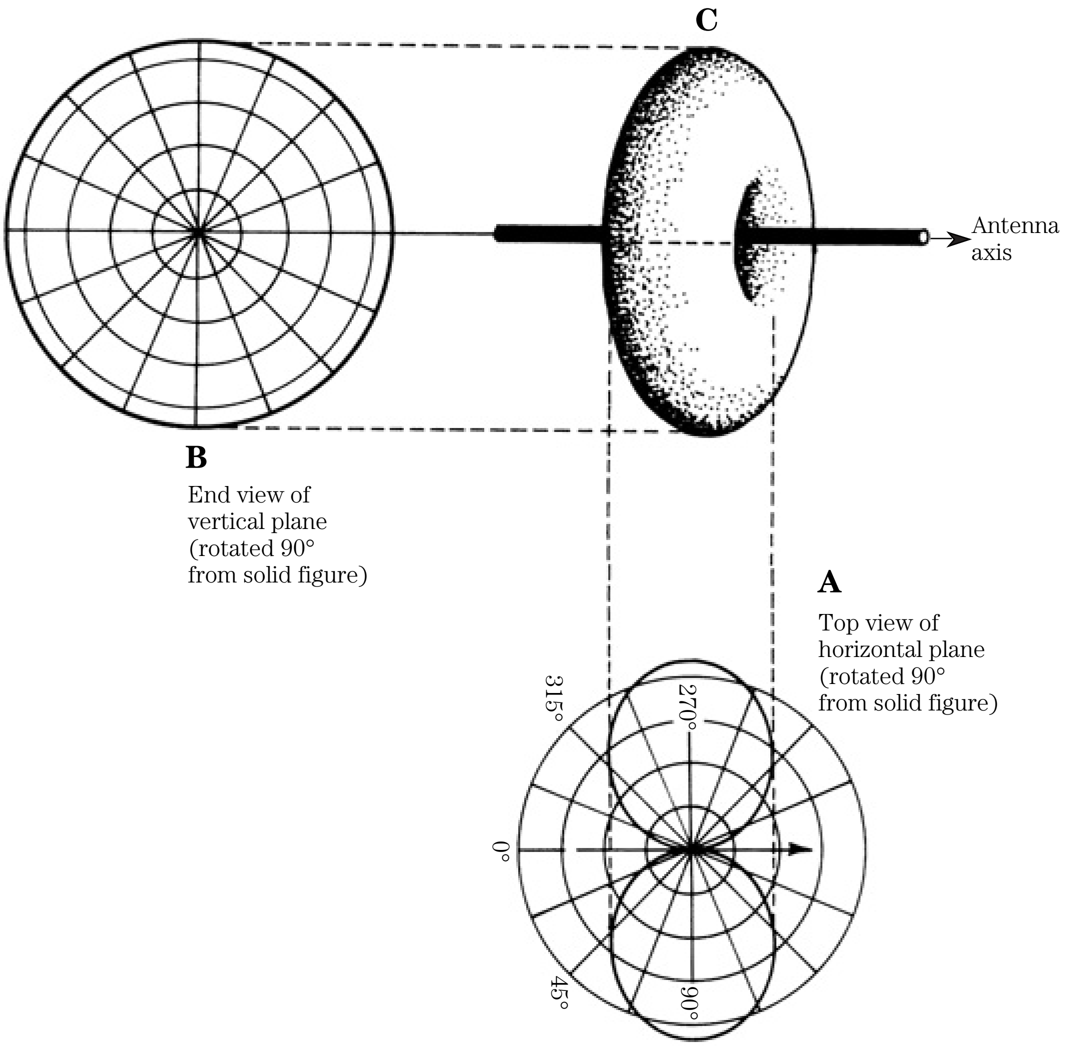
C
Antenna axis
B
End view of vertical plane (rotated 90° from solid figure)
A
Top view of horizontal plane (rotated 90° from solid figure)
315°
270°
0°
45°
90°

6-4 Idealized dipole radiation pattern.

8" that exhibits bidirectional radiation. Two main "lobes" contain the RF power from the transmitter, with sharp nulls of little or no power off the ends of the antenna axis. This pattern is the classical dipole pattern that is published in most antenna books.

Also shown, however, is the vertical plane pattern for a dipole antenna in free space. Note that when sliced in this aspect the radiation pattern is circular (Fig. 6-4B). When the two patterns are combined in the round, you can see the three-dimensional doughnut-shaped pattern (Fig. 6-4C) that most nearly approximates the true pattern of an unobstructed dipole in free space.

When a dipole antenna is installed close to the earth's surface, not in free space, as is the case at most stations, the pattern is distorted from that of Fig. 6-4. Two effects must be taken into consideration. First, and most important, is the fact that the signal from the antenna is reflected from the surface and bounces back into space. This signal will be phase-shifted both by the reflection and by the time required for the transit to occur. At points where the reflected wave combines in phase with the radiated signal, the signal is reinforced; in places where it combines out of phase, the signal is attenuated. Thus, the reflection of the signal from the ground alters the pattern from the antenna. The second factor is that the ground is lossy, so not all of the signal is reflected; some of it heats the ground underneath the antenna. Thus, the signal is attenuated at a greater rate than the inverse square law, so it further alters the expected pattern.

Figure 6-5 shows patterns typical of dipole antennas installed close to the earth's surface. The views in this illustration correspond to Fig. 6-4B, in that they are looking at the vertical plane from a line along the antenna axis. Therefore, the antenna is represented by *R* in each case shown. Figure 6-5A shows the case for a dipole

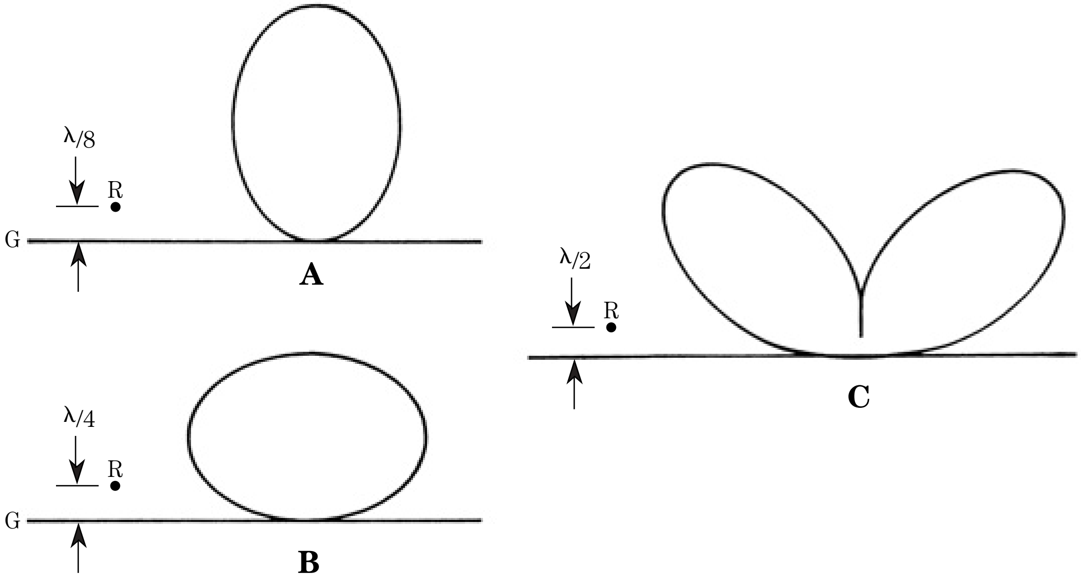

6-5 Vertical extent of dipole antenna at (A) ⅛ wavelength, (B) ¼ wavelength, and (C) ½ wavelength above ground.

installed at 1/8 wavelength above the surface. For this antenna, most of the RF energy is radiated almost straight up (not very useful). This type of antenna is basically limited to ground wave and very short skip (when available). The second case (Fig. 6-5B) shows the pattern when the antenna is a quarter wavelength above the earth's surface. Here the pattern is flattened, but it still shows considerable energy in the vertical direction (where it is useless). Finally, you can see the pattern obtained when the antenna is installed a half-wavelength above the surface. In this case, the pattern is best for long-distance work because energy is redirected away from straight-up into lobes at relatively shallow angles.

Tuning the dipole antenna

There are two issues to address when tuning an antenna (any antenna, not just the dipole): *resonance* and *impedance matching*. Although frequently treated in the literature as the same issue, they are not. This section deals mostly with the process of tuning the antenna to resonance. Although not all forms of antenna are resonant, the dipole *is* an example of a resonant antenna.

There is a lot of misinformation abroad concerning the tuning of antennas. Perhaps much of what is believed comes from the fact that VSWR is used as the indicator of both impedance matching and resonance. Quite a few people honestly, but erroneously, believe that the VSWR can be "tuned out" by adjusting the length of the feedline. That myth probably derives from the fact that voltage or current sensing instruments are used for VSWR measurement, and these are affected by transmission line length. But that fact is caused by a weakness in the instruments, not by radio physics.

There is only one proper way to tune a dipole antenna: *adjust the length of the antenna elements*, not the transmission line. It was in order to make these adjustments that we purposely did not initially tell you to solder the electrical connections at the center insulator.

Resonance The indicator of resonance is the minimum point in the VSWR curve. Figure 6-6 shows a graph of VSWR vs. frequency for several different cases. Curve *A* represents a disaster: a high VSWR all across the band. The actual value of VSWR can be anything from about 3.5:1 to 10:1, or thereabouts, but the cause is nonetheless the same: the antenna is either open or shorted; or it is so far off resonance as to appear to be open or shorted to the VSWR meter.

Curves *B* and *C* represent antennas that are resonant within the band of interest. Curve *B* represents a broadbanded antenna that is relatively flat all across the band and does not exhibit excessive VSWR until the frequency is outside of the band. Curve *C* is also resonant within the band, but this antenna has a much higher *Q* than curve *B.* In the naive sense, the broadbanded antenna is best, but that statement is true only if the broadness is not purchased at the expense of efficiency. Losses tend to broaden the antenna, but also reduce its effectiveness. So, if broad bandedness is purchased at the risk of increased loss, then it is less than desirable.

Curves *D* and *E* are resonant outside the band of interest. The curve marked *D* is resonant at a frequency on the low side of the band, so the dipole is too long. In this case, you need to shorten the antenna a bit to raise the resonant point inside

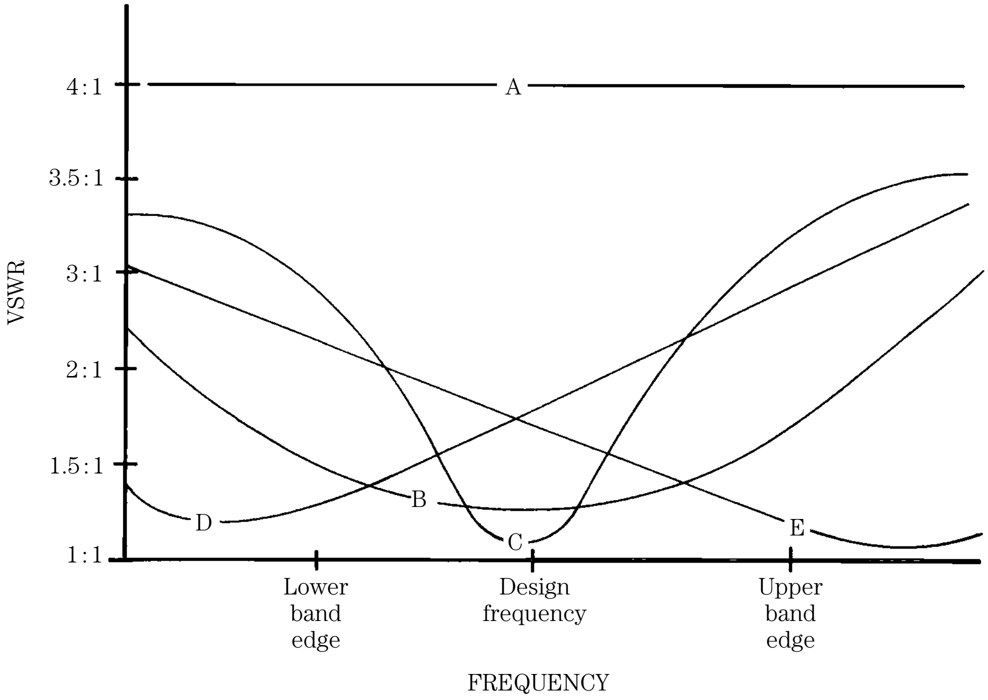

6-6 VSWR versus frequency for several cases.

the band. Curve *E* represents an antenna that is resonant outside the upper limit of the band, so this antenna is too short, and must be lengthened. Because this situation is possible, the antenna elements are typically made longer than needed when they are first cut.

How much to cut? That depends on two factors: how far from the desired frequency the resonant point is found, and which band is being used. The latter requirement comes from the fact that the "frequency per unit length" varies from one band to another. Look at an example of how to calculate this figure. The procedure is simple:

1. Calculate the length required for the upper end of the band.
2. Calculate the length required for the bottom end of the band.
3. Calculate the difference in lengths for the upper and lower ends of the band.
4. Calculate the width of the band in kilohertz by taking the difference between the upper frequency limit and the lower frequency limit.
5. Divide the length difference by the frequency difference; the result is in kilohertz per unit length.

Example 6-1 Calculate the frequency change per unit of length for 80 and for 15 m.

Solution For 80 m (3.5 to 4.0 MHz):

1. $L_{\text{ft}} = \dfrac{468}{4\text{ MHz}} = 117\text{ ft}$
2. $L_{\text{ft}} = \dfrac{468}{3.5\text{ MHz}} = 133.7\text{ ft}$
3. Difference in length: 133.7 ft – 117 ft = 16.7 ft
4. Frequency difference: 4000 kHz – 3500 kHz = 500 kHz
5. Calculate $\dfrac{\text{frequency}}{\text{unit length}} : \dfrac{500\text{ kHz}}{16.7\text{ ft}} = 30\text{ kHz/ft}$

For 15 m (21.0 – 21.45 MHz):

1. $L_{\text{ft}} = \dfrac{468}{21.45} = 21.82\text{ ft}$
2. $L_{\text{ft}} = \dfrac{468}{21} = 22.29\text{ ft}$
3. Difference in length: 22.29 ft – 21.82 ft = 0.47 ft
4. Convert to inches: 0.47 ft × 12 in/ft = 5.64 in
5. Frequency difference: 21,450 kHz – 21,000 kHz = 450 kHz
6. Calculate $\dfrac{\text{frequency}}{\text{unit length}} : \dfrac{450\text{ kHz}}{5.64\text{ in}} = 80\text{ kHz/in}$

At 80 m, the frequency change per foot is small, but at 15 m small changes can result in very large frequency shifts. You can calculate approximately how much to add (or subtract) from an antenna under construction from this kind of calculation. If, for example, you design an antenna for the so-called "net frequency" on 15 m (21,390 kHz), and find the actual resonant point is 21,150 kHz, the frequency shift required is 21,390 – 21,150, or 240 kHz. To determine how much to add or subtract (as a first guess):

1. The factor for 15 m is 80 kHz/in, which is the same as saying 1 in/80 kHz.
2. The required frequency shift is 240 kHz.
3. Therefore:

$$\text{Length change} = 240\text{ kHz} \times \frac{1\text{ in}}{80\text{ kHz}} \tag{6.12}$$

$$= 3\text{ in} \tag{6.13}$$

Each side of the antenna must be changed by half of the length calculated above, or 1.5 in. Because the first resonant frequency is less than the desired frequency, the length should be shortened 1.5 in. Once the length is correct, as proven by the VSWR curve, the connections at the center insulator are soldered and made permanent, and the antenna rehoisted to the operating level.

Impedance matching The difference between resonance and impedance matching is seen in the value of the VSWR minimum. While the minimum indicates the resonant point, its value is a measure of the relationship between the feedpoint impedance of the antenna and the characteristic impedance of the transmission line. Earlier in this chapter you learned that

1. $Z_o > R_r$:

$$\text{VSWR} = \frac{Z_o}{R_r} \qquad \textbf{[6.14]}$$

2. $Z_o < R_r$:

$$\text{VSWR} = \frac{R_r}{Z_o} \qquad \textbf{[6.15]}$$

where

Z_o is the coaxial-cable characteristic impedance
R_r is the radiation resistance of the antenna

Although knowledge of the VSWR will not show which situation is true, you can know that there is a high probability that *one* of them is true, and you can experiment to find which is the case. Of course, if the VSWR is less than about 1.5:1 or 2:1, then forget about it—the improvement is not generally worth the expense and cost. When coupled to a transmitter that is equipped with the tunable output network (most tube-type transmitters or final amplifiers), then it can accommodate a relatively wide range of reflected antenna impedances. But modern solid-state final amplifiers tend to be a little more picky about the load impedance. For these transmitters, a coax-to-coax *antenna tuning unit* (ATU) is needed.

Other dipoles

Thus far, the dipoles covered in this chapter have been the classic form, in which a half-wavelength single-conductor radiator element is connected to a coaxial transmission line. This antenna is typically installed horizontally at a half-wavelength above the earth's surface (or wherever convenient if that is impossible). This section looks at other forms of the dipole. Some of these dipoles are in every way the equal of the horizontal dipole, and others are basically compensation antennas in that they are used when a proper dipole is not practical.

Inverted-vee dipole

The *inverted-vee dipole* is a half-wavelength antenna fed in the center like a dipole. By the rigorous definition, the inverted-vee is merely a variation on the dipole theme. But in this form of antenna (Fig. 6-7), the center is elevated as high as possible from the earth's surface, but the ends droop to very close to the surface. Angle a can be almost anything convenient, provided that $a > 90$ degrees; typically, most inverted-vee antennas use an angle of about 120 degrees. Although essentially a compensation antenna for use when the dipole is not practical, many operators believe that it is essentially a better performer on 40 and 80 m in cases where the dipole cannot be mounted at a half-wavelength (64 ft or so).

By sloping the antenna elements down from the horizontal to an angle (as shown in Fig. 6-7), the resonant frequency is effectively lowered. Thus, the antenna will

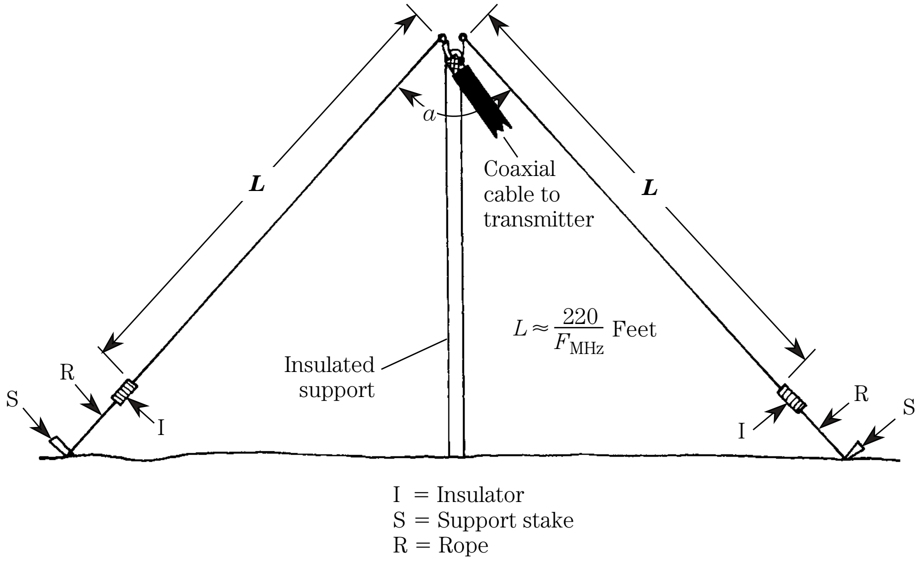

6-7 Inverted-vee dipole.

need to be shorter for any given frequency than a dipole. There is no absolutely rigorous equation for calculation of the overall length of the antenna elements. Although the concept of “absolute” length does not hold for regular dipoles, it is even less viable for the inverted-vee. There is, however, a rule of thumb that can be followed for a starting point: Make the antenna about 6 percent shorter than a dipole for the same frequency. The initial cut of the antenna element lengths (each quarter wavelength) is

$$L = \frac{220}{F_{\text{MHz}}} \text{ ft} \tag{6.16}$$

After this length is determined, the actual length is found from the same cut-and-try method used to tune the dipole in the previous section.

Bending the elements downward also changes the feedpoint impedance of the antenna and narrows its bandwidth. Thus, some adjustment in these departments is in order. You might want to use an impedance matching scheme at the feedpoint, or an antenna tuner at the transmitter.

Sloping dipole (“sloper” or “slipole”)

The *sloping dipole* (Fig. 6-8) is popular with those operators who need a low angle of radiation, and are not overburdened with a large amount of land to install the antenna. This antenna is also called the *sloper* and the *slipole* in various texts. The author prefers the term “slipole,” in order to distinguish this antenna from a sloping vertical of the same name. Whatever it is called, however, it is a half-wavelength dipole that is built with one end at the top of a support, and the other end close to the

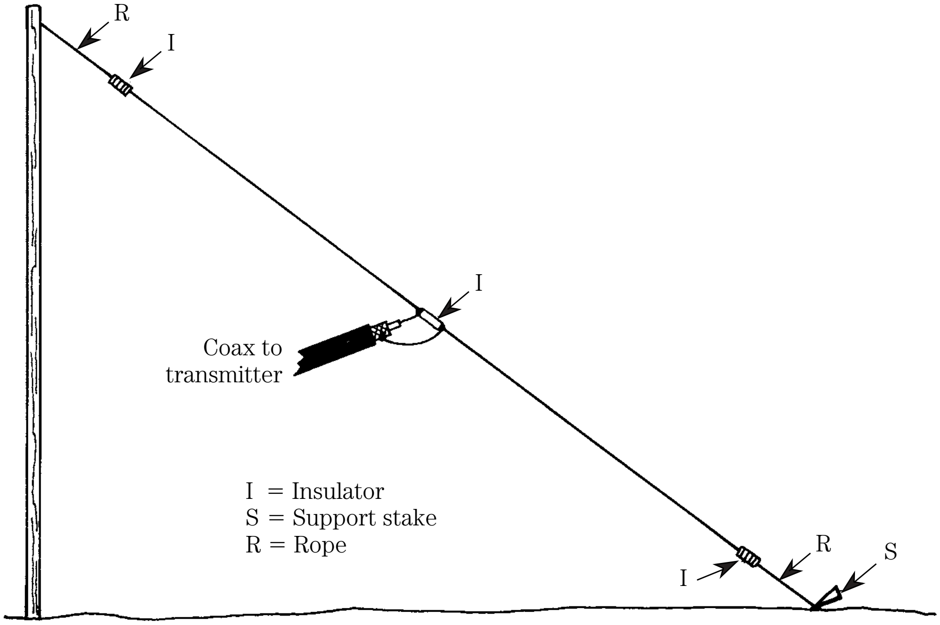

6-8 "Slipole" or "sloper."

ground, and being fed in the center by coaxial cable. Some of the same comments as obtained for the inverted-vee antenna also apply to the sloping dipole, so please see that section also.

Some operators like to arrange four sloping dipoles from the same mast such that they point in different directions around the compass (Fig. 6-9). A single four-position coaxial cable switch will allow switching a directional beam around the compass to favor various places in the world.

Broadbanded dipoles

One of the rarely discussed aspects of antenna construction is that the length/diameter ratio of the conductor used for the antenna element is a factor in determining the bandwidth of the antenna. In general, the rule of thumb states that large cross-sectional area makes the antenna more broadbanded. In some cases, this rule suggests the use of aluminum tubing instead of copper wire for the antenna radiator. On the higher-frequency bands that is a viable solution. Aluminum tubing can be purchased for relatively small amounts of money, and is both lightweight and easily worked with ordinary tools. But, as the frequency decreases, the weight becomes greater because the tubing is both longer and (for structural strength) must be of greater diameter. On 80 m, aluminum tubing is impractical, and at 40 m it is nearly so. Yet, 80 m is a significant problem, especially for older transmitters, because the band is 500 kHz wide, and the transmitters often lack the tuning range for the entire band.

Some other solution is needed. Here are three basic solutions to the problem of wide-bandwidth dipole antennas: *folded dipole*, *bowtie dipole*, and *cage dipole*.

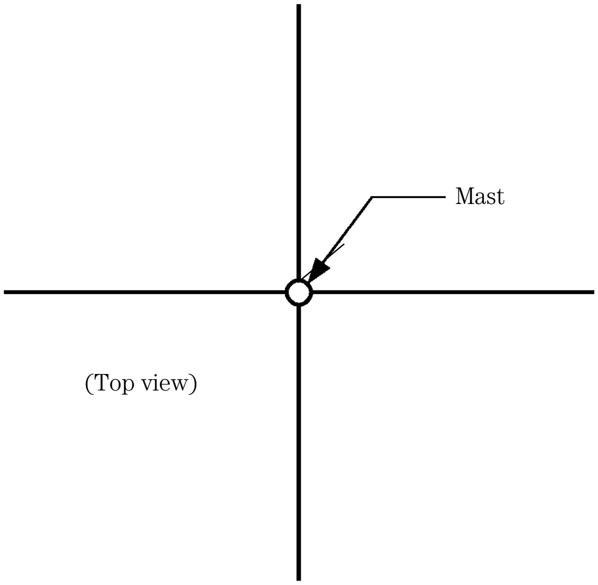

6-9 Directional antenna made of four slopers (top view).

Figure 6-10A shows the *folded dipole* antenna. This antenna basically consists of two half-wavelength conductors shorted together at the ends and fed in the middle of one of them. The folded dipole is most often built from 300-Ω television antenna twin-lead transmission line. Because the feedpoint impedance is nearly 300 Ω, the same type of twin lead can also be used for the transmission line. The folded dipole will exhibit excellent wide-bandwidth properties, especially on the lower bands.

A disadvantage of this form of antenna is that the transmitter has to match the 300-Ω balanced transmission line. Unfortunately, most modern radio transmitters are designed to feed coaxial-cable transmission line. Although an antenna tuner can be placed at the transmitter end of the feedline, it is also possible to use a 4:1 balun transformer at the feedpoint (Fig. 6-10B). This arrangement makes the folded dipole a reasonable match to 52- or 75-Ω coaxial-cable transmission line.

Another method for broadbanding the dipole is to use two identical dipoles fed from the same transmission line, and arranged to form a "bowtie" as shown in Fig. 6-11. The use of two identical dipole elements on each side of the transmission line has the effect of increasing the conductor cross sectional area so that the antenna has a slightly improved length/diameter ratio.

The *bowtie dipole* was popular in the 1930s and 1940s, and became the basis for the earliest television receiver antennas (TV signals are 3 to 5 MHz wide, so they require a broadbanded antenna). It was also popular during the 1950s as the so-called Wonder Bar antenna for 10 m. It still finds use, but it has faded somewhat in popularity.

The *cage diople* (Fig. 6-12) is similar in concept, if not construction, to the bowtie. Again, the idea is to connect several parallel dipoles together from the same transmission line in an effort to increase the apparent cross-sectional area. In the case of the cage dipole, however, spreader disk insulators are constructed to keep the wires separated. The insulators can be built from plexiglass, lucite, or ceramic.

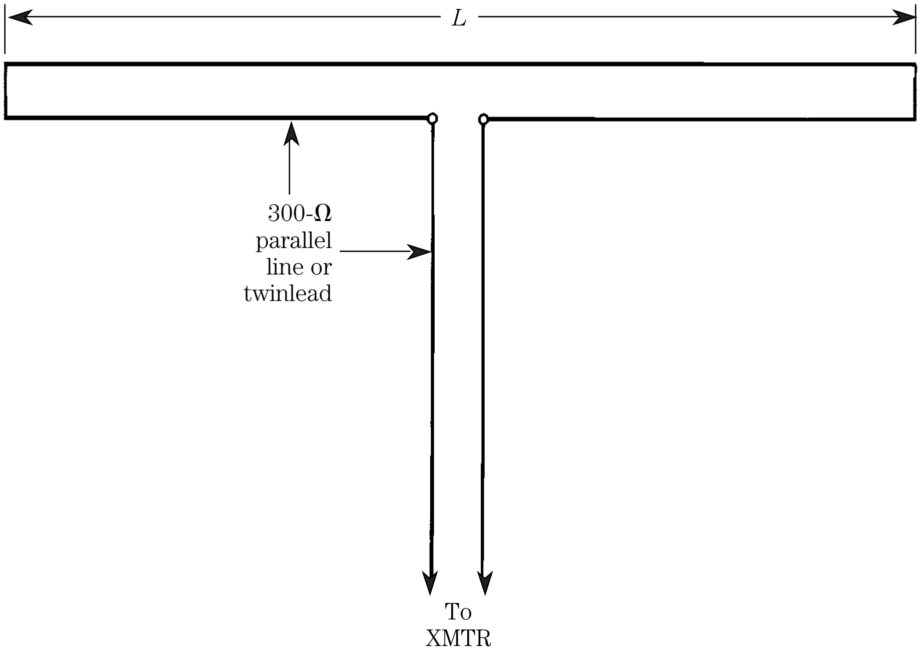
L
300-Ω
parallel
line or
twinlead
To
XMTR

6-10A Folded dipole fed with 300-Ω line.

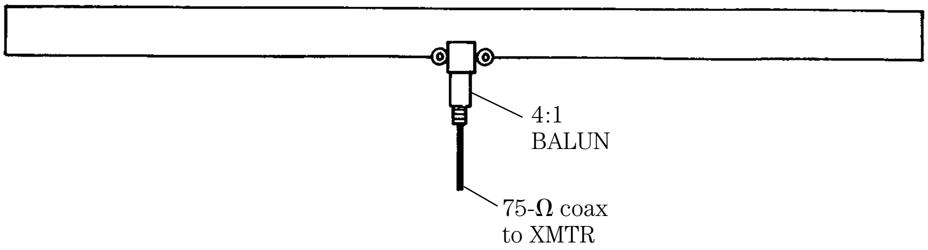
4:1
BALUN
75-Ω coax
to XMTR

6-10B Folded dipole fed with coaxial cable.

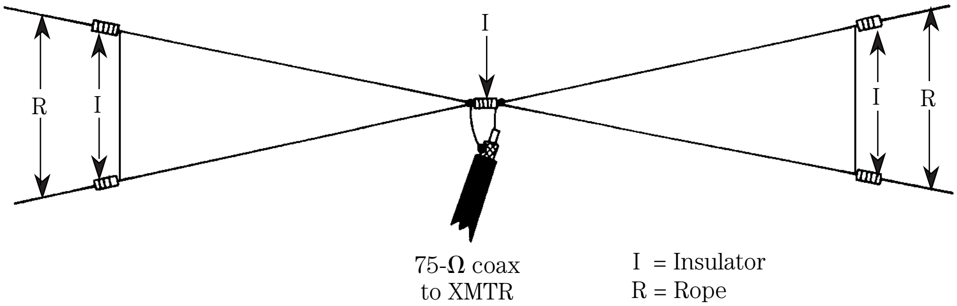
I
R
I
I
R
75-Ω coax
to XMTR
I = Insulator
R = Rope

6-11 Bowtie dipole.

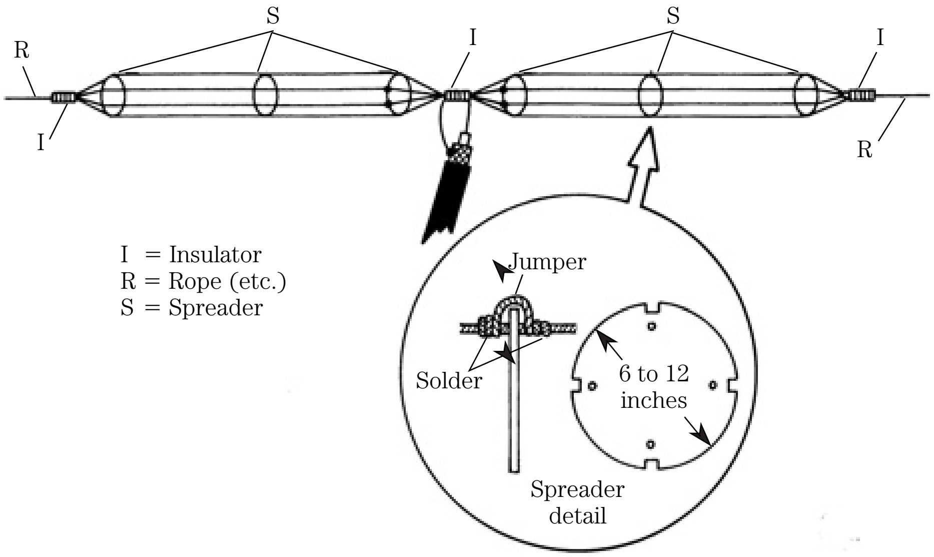

6-12 Cage dipole.

They can also be constructed of materials such as wood, if the wood is properly treated with varnish, polyurethene, or some other material that prevents it from becoming waterlogged. The spreader disks are held in place with wire jumpers (see inset to Fig. 6-12) that are soldered to the main element wires.

A tactic used by some builders of both bowtie and cage dipoles is to make the elements *slightly* different lengths. This “stagger tuning” method forces one dipole to favor the upper end of the band, and the other to favor the lower end of the band. The overall result is a slightly flatter frequency response characteristic across the entire band. On the cage dipole, with four half-wavelength elements, it should be possible to overlap even narrower sections of the band in order to create an even flatter characteristic.

Shortened coil-loaded dipoles

The half-wavelength dipole is too long for some applications where real estate is at a premium. The solution for many operators is to use a coil-loaded shortened dipole such as shown in Fig. 6-13. A shortened dipole (i.e., one which is less than a half-wavelength) is capacitive reactance. There is no reason why the loading coil cannot be any point along the radiator, but in Figs. 6-13A and 6-13B they are placed at 0 percent and 50 percent of the element length, respectively. The reason for this procedure is that it makes the calculation of coil inductances easier, and it also represents the most common practice.

Figure 6-13C shows a table of inductive reactances as a function of the percentage of a half-wavelength, represented by the shortened radiator. It is likely that the percentage figure will be imposed on you by the situation, but the general rule is to pick the largest figure consistent with the available space. For example, sup-

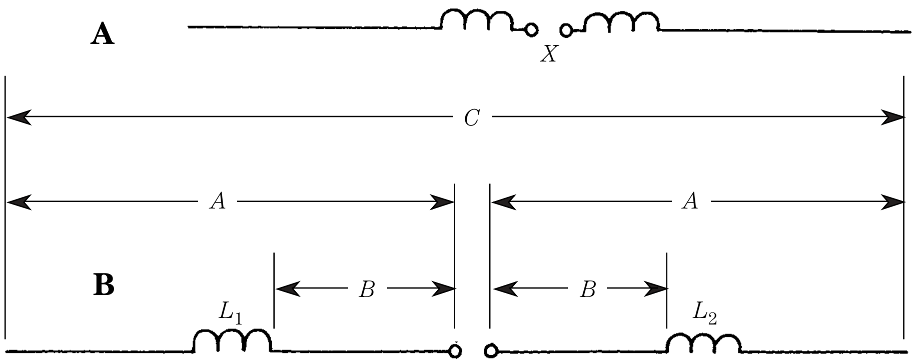

C

$L_1 = L_2 = L$

$C = 2A$

$A = \frac{1}{2}C$

$$C = \frac{468M}{F_{\text{MHz}}}$$

$O \le M \le 1$

Percent of half-wavelength	Coils at feedpoint (Ω)	Coils at middle of radiators (Ω)
20	1800	2800
30	950	1800
40	700	1800
50	500	1300
60	360	950
70	260	700
80	160	500
90	75	160
95	38	80
98	15	30

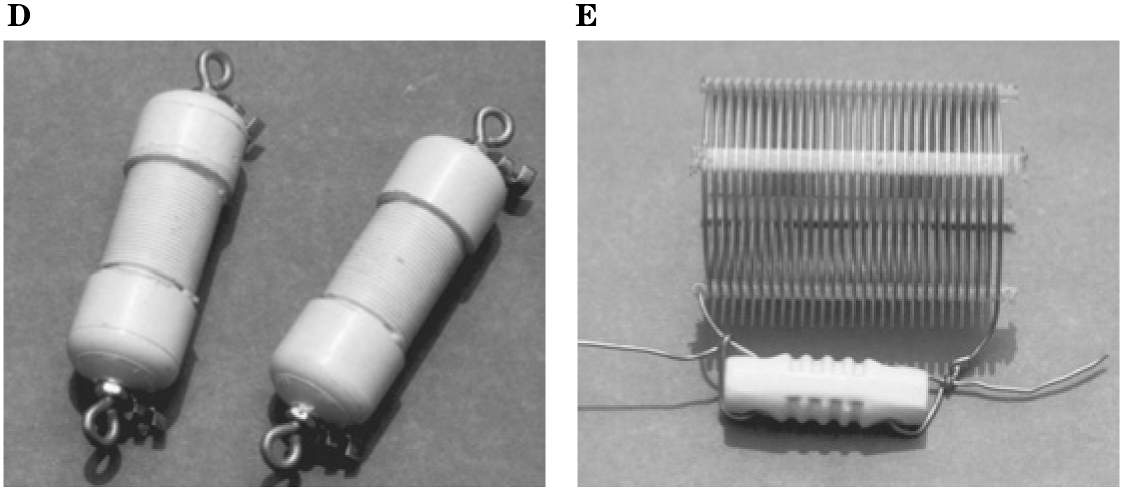

6-13 Shortened or loaded dipole. (A) inductors at feedpoint; (B) inductors midway along elements; (C) chart of reactances for coils; (D) commercially available coils; (E) homemade coil based on commercial coil stock.

pose you have about 40 ft available for a 40-m antenna that normally needs about 65 ft for a half-wavelength. Because 39 ft is 60 percent of 65 ft, you could use this value as the design point for this antenna. Looking on the chart, a 60 percent antenna with the loading coils at the midpoint of each radiator element wants to see an inductive reactance of 700 Ω. You can rearrange the standard inductive reactance equation ($X_L = 6.28\,FL$) to the form

$$L_{\mu\text{H}} = \frac{X_L \times 10^6}{6.28F} \qquad \textbf{[6.17]}$$

where

$L_{\mu\text{H}}$ is the required inductance, in microhenrys
F is the frequency, in hertz (Hz)
X_L is the inductive reactance calculated from the table in Fig. 6-13C.

Example 6-2 Calculate the inductance required for a 60 percent antenna operating on 7.25 MHz. The table requires a reactance of 700 Ω for a loaded dipole with the coils in the center of each element (Fig. 6-15B).

Solution:

$$L_{\mu\text{H}} = \frac{X_L \times 10^6}{6.28F} \qquad \textbf{[6.18]}$$

$$= \frac{(700)\ (10^6)}{(6.28)\ (7{,}250{,}000)} \qquad \textbf{[6.19]}$$

$$= \frac{7 \times 10^8}{4.6 \times 10^7} \qquad \textbf{[6.20]}$$

$$= 15.4\ \mu\text{H} \qquad \textbf{[6.21]}$$

The inductance calculated above is approximate, and it might have to be altered by cut-and-try methods.

The loaded dipole antenna is a very sharply tuned antenna. Because of this fact, you must either confine operation to one segment of the band, or provide an antenna tuner to compensate for the sharpness of the bandwidth characteristic. However, efficiency drops, markedly, far from resonance even with a transmission line tuner. The function of the tuner is to overcome the bad effects on the transmitter, but it does not alter the basic problem. Only a variable inductor in the antenna will do that trick (at least one commercial loaded dipole once used a motor-driven inductor at the center feedpoint).

Figures 6-13D and E show two methods for making a coil-loaded dipole antenna. Figure 6-13D shows a pair of commercially available loading coils especially designed for this purpose. The ones shown here are for 40 m, but other models are also available. The inductor shown in Fig. 6-13E is a section of commercial coil stock connected to a standard end or center insulator. No structural stress is assumed by the coil—all forces are applied to the insulator, which is designed to take it.

Inductance values for other length antennas can be approximated from the graph in Fig. 6-14. This graph contains three curves for coil-loaded, shortened dipoles that are 10, 50, and 90 percent of the normal half-wavelength size. Find the proposed location of the coil, as a percentage of the wire element length, along the horizontal axis. Where the vertical line from that point intersects with one of the three curves, that intersection yields the inductive reactance required (see along vertical axis). Inductances for other overall lengths can be "rough-guessed" by interpolating between the three available curves, and then validated by cut and try.

Tunable dipoles

Dipoles are resonant antennas, so they naturally tend to prefer one frequency over the others. The VSWR will be quite low at the resonant point (assuming no feedline mismatch problems), and will rise at frequencies above and below resonance. If the antenna is a *high-Q* model, then the effect is quite profound, and it might render the antenna nearly useless at frequencies on the other end of the same band (especially where modern transmitters equipped with VSWR shutdown circuitry are used). Figure 6-15 shows a method for overcoming this problem. Here is how it works.

An antenna that is too long for the desired resonant frequency will act inductively (i.e., it will show a feedpoint impedance of the form $Z = R + jX_L$). To counteract the inductive reactance component $+jX_L$ it is necessary to add a bit of capacitive reactance $-jX_c$. This approach is taken in tuning certain antenna forms and it can be used with dipoles to make the antenna tunable over a range of about 15 percent of the frequency.

The tunable dipole of Fig. 5-15 is longer than other dipoles and it has an overall length of

$$L' = \frac{505}{F_{\text{MHz}}} \qquad \textbf{[6.22]}$$

Note that the velocity constant is 505, rather than the 468 that is used with ordinary dipoles.

The required capacitive reactance, which is used to electrically shorten the antenna, is provided by C_1. In one effective design that I've tested, the capacitor was a 500-pF transmitting variable type. When the Heath Company was making kits, they offered an antenna tuner based on this idea. It was a motor-driven 500-pF variable capacitor inside of a weather-resistant metal-shielded case. The Heath tuner can be used on inverted vees and dipoles (if a center support is provided). A low-voltage (which is necessary for safety reasons) dc motor drives the shaft of the capacitor to tune the antenna to resonance.

Stacked dipoles

Figure 6-16 shows a *double dipole* (i.e., two half-wavelength dipole antennas spaced a half-wavelength apart). The transmission lines are connected in parallel at the receiver. This antenna provides about 3-dB gain over a single dipole, and it adds a bit of fade protection because two side-by-side antennas provide a bit of space diversity (see the end of Chap. 2 for information on diversity reception).

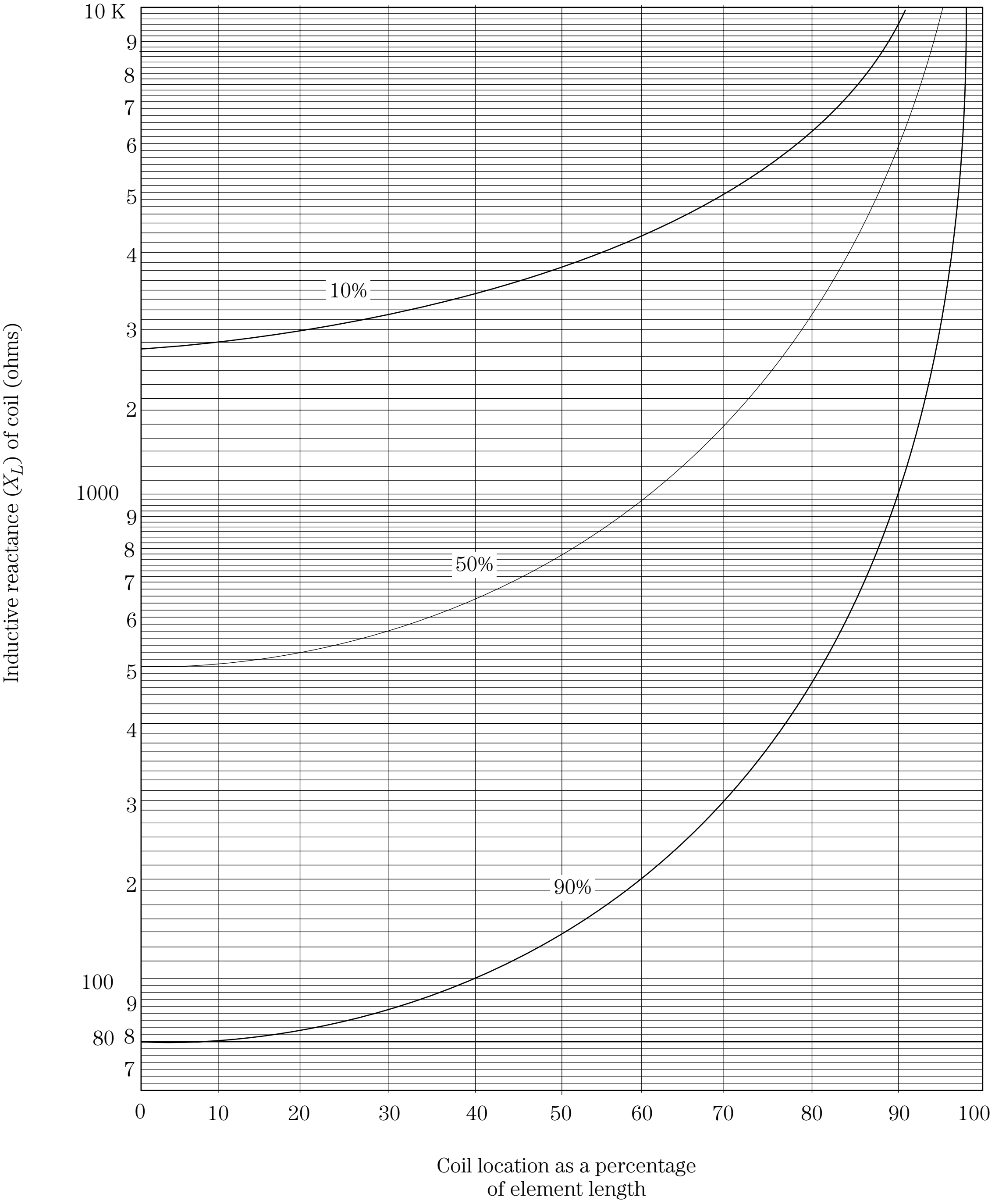

6-14 Inductive reactance versus coil location for shortened inductance-loaded dipole.

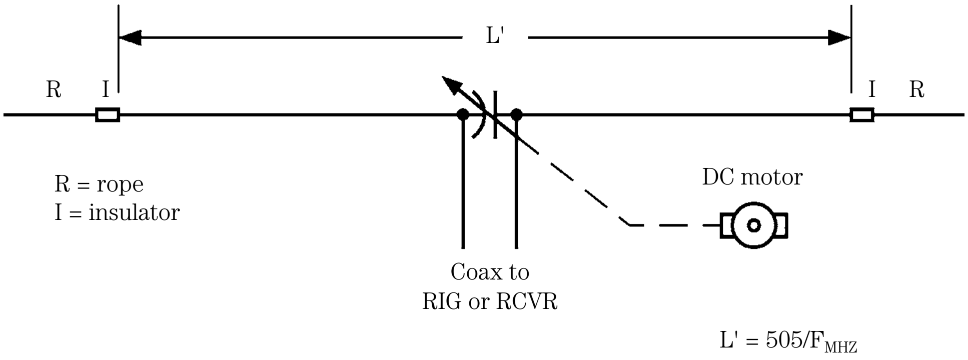
L'
R
I
I
R
R = rope
I = insulator
DC motor
Coax to
RIG or RCVR
L' = 505/F_MHZ

6-15 Electrically reducing the length of a dipole antenna by placing a capacitor at the feedpoint.

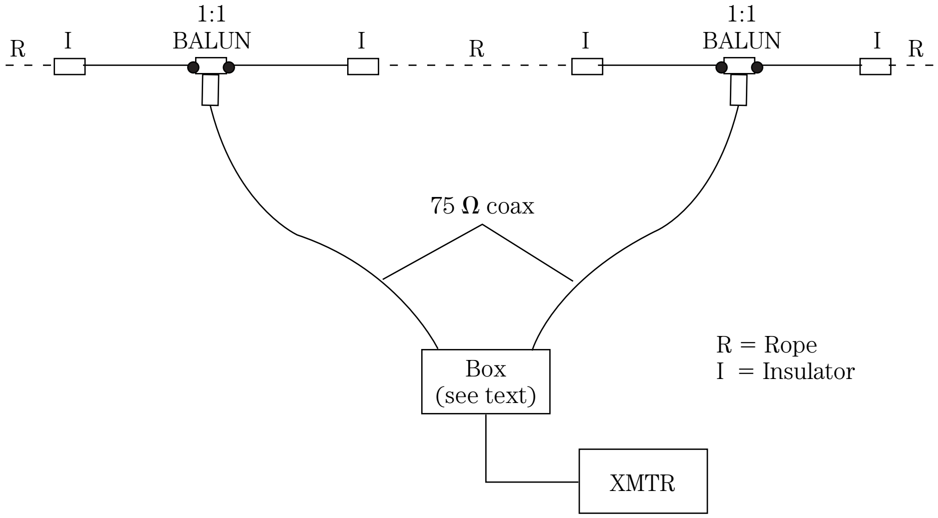
1:1
BALUN
1:1
BALUN
R
I
I
R
I
I
R
75 Ω coax
Box
(see text)
XMTR
R = Rope
I = Insulator

6-16 Phased dipoles provide a 3-dB gain over single dipole.

The two dipoles are supported by a common structure consisting of ropes (R) and end insulators (I) to support masts on the ends. In the center, a half-wavelength space is taken up by a rope so that the structure is maintained. The space is determined by

$$\text{Space}_{\text{feet}} = \frac{492}{F_{\text{MHz}}} \qquad \textbf{[6.23]}$$

and, for the dipoles,

$$\text{Length}_{\text{feet}} = \frac{468}{F_{\text{MHz}}} \qquad \textbf{[6.24]}$$

The stacked dipole gets a bit lengthy on low-frequency bands, but is easily achievable by most people on the upper HF bands.

The feedlines for the two dipoles can be connected directly in parallel and fed from the transmitter, provided that the antenna tuning unit will support one-half the normal expected impedance. Alternatively, a box can be provided that includes a matching transformer for 1:2 ratio. These can be built like a balun transformer on a toroidal core. A trifilar winding is used. Alternatively, a phasing box can be built that will allow altering the directionality of the antenna by 90°. This is done by using the switching circuit to reverse the sense of L_3.

Off-center-fed full-wave doublet (OCFD) antennas

An antenna that superficially resembles the Windom is the off-center-fed doublet (OCFD) antenna of Fig. 6-17. It is a single-band antenna, although at harmonics it will begin to act as a resonant, standing wave, longwire antenna. The overall length is one wavelength long:

$$L_{\text{feet}} = \frac{936}{F_{\text{MHz}}} \qquad \textbf{[6.25]}$$

This antenna works best at heights of at least λ/2 above ground, so practical considerations limit it to frequencies above about 10 MHz (i.e., 30-m band). The feedpoint of the antenna is placed at a distance of λ/4 from one end, and is a good match for 75-Ω coaxial cable. A 1:1 balun transformer at the feedpoint is highly recommended. The pattern of a 1λ antenna is a four-lobe "cloverleaf," with the major lobes being about 53° from the wire. The gain is about 1 dB.

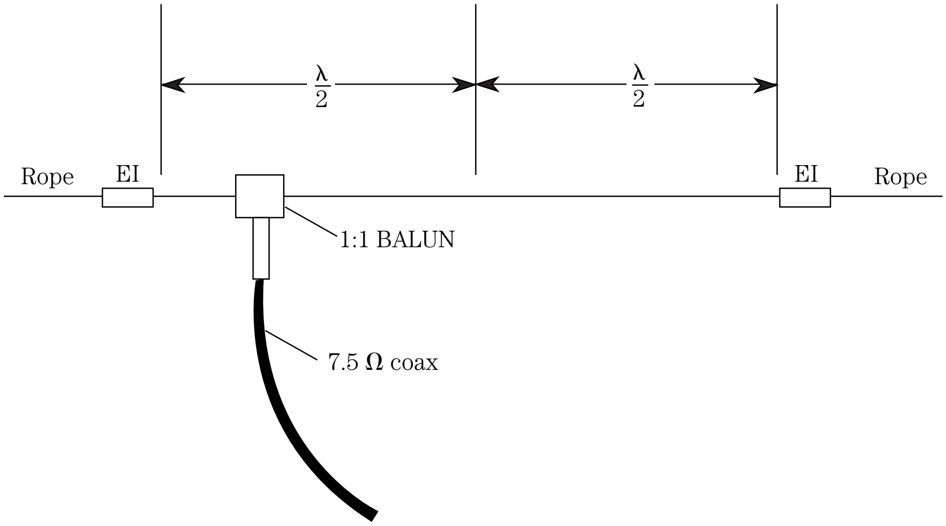

6-17 Off-center-fed 1-wire antenna.

Off-center-fed nonresonant sloper (OCFS)

Perhaps more viable for many people is the *nonresonant off-center-fed sloper* (OCFS) antenna of Fig. 6-18. This antenna consists of a wire radiator that must be longer than 3λ/2 at the lowest frequency of operation. The feedpoint is elevated at least λ/4 above ground at the lowest operating frequency. The antenna is fed with 75-Ω coaxial cable. The shield of the coax is connected to a λ/4 resonant radial (counterpoise ground). There should be at least one radial (more is better) per band of operation.

The far end of the radiator element is sloped to ground, where it is terminated in a 270-Ω noninductive resistor. The resistor should be able to dissipate up to one-third of the power level applied by the transmitter.

Double extended Zepp antenna

The *double extended Zepp* antenna (Fig. 6-19) provides a gain of about 2 dB over a dipole at right angles to the antenna wire plane. It consists of two sections of wire, each one of a length

$$L_{1\text{feet}} = \frac{600}{F_{\text{MHz}}} \qquad \textbf{[6.26]}$$

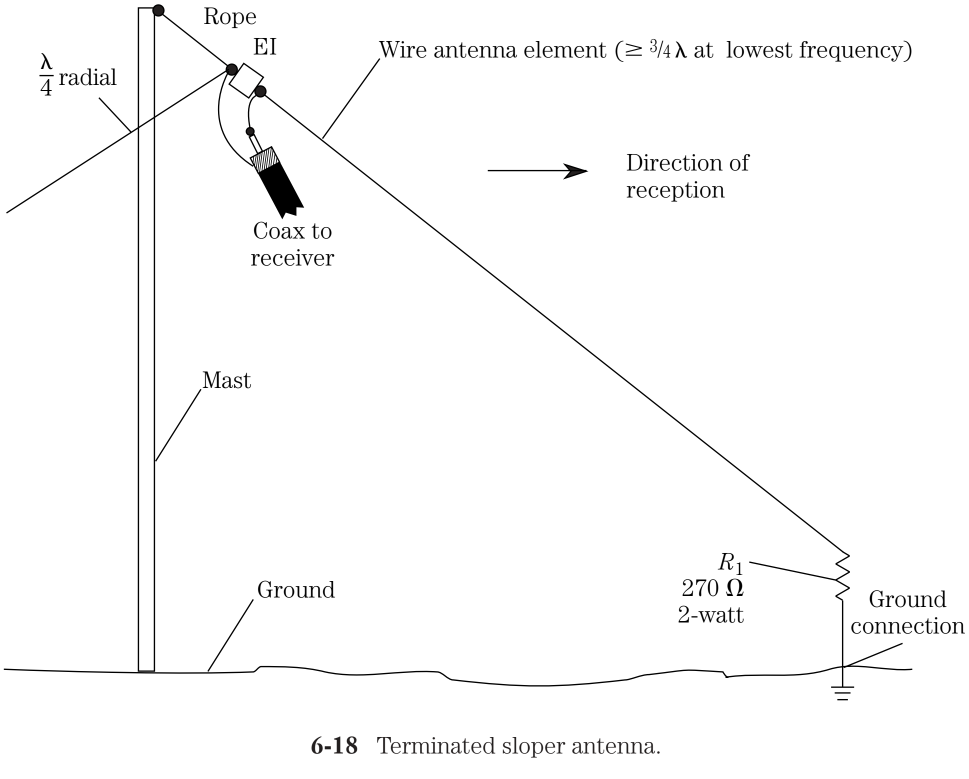
Rope
EI
$\frac{\lambda}{4}$ radial
Wire antenna element (≥ 3/4 λ at lowest frequency)
Direction of reception
Coax to receiver
Mast
Ground
R_1
270 Ω
2-watt
Ground connection

6-18 Terminated sloper antenna.

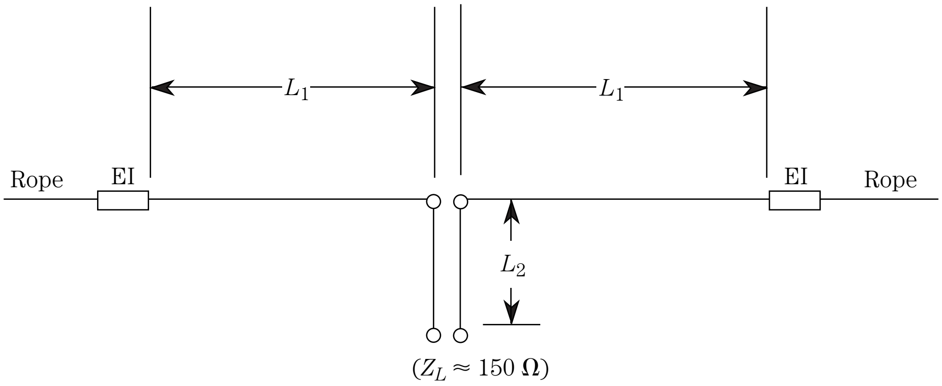

6-19 Double extended Zepp antenna.

Typical lengths are 20.7 ft on the 10-m band, 28 ft on the 15-m band, 42 ft on the 20-m band, and 84 ft on the 40-m band.

The double extended Zepp antenna can be fed directly with 450-Ω twin lead, especially if a balanced antenna tuner is available at the receiver. Alternatively, it can be fed from a quarter-wavelength matching section (made of 450-Ω twin lead, or equivalent open air parallel line), as shown, and a balun if coax is preferred. The length of the matching section should be

$$L_{2\text{feet}} = \frac{103}{F_{\text{MHz}}} \quad \textbf{[6.27]}$$

The double extended Zepp will work on several different bands. For example, a 20-m-band double extended Zepp will work as a Zepp on the design band, a dipole on frequencies below the design band, and as a four-lobed cloverleaf antenna on frequencies above the design band.

Collinear "Franklin" array antenna

Perhaps the cheapest approach to very serious antenna gain is the collinear Franklin array shown in Fig. 6-20. This antenna pushes the dipole and double extended Zepp concepts even farther. It consists of a half-wavelength dipole that is center-fed with a 4:1 balun and 75-Ω coaxial cable. At each end of the dipole, there is a quarter-wavelength *phase reversal stub* that end-feeds another half-wavelength element. Each element is a half-wavelength (λ/2) long, and its length can be calculated from

$$\frac{\lambda}{2} = \frac{492}{F_{\text{MHz}}} \quad \textbf{[6.28]}$$

The phase reversal stubs are a quarter-wavelength long, or one half the length calculated by Eq. 6.28.

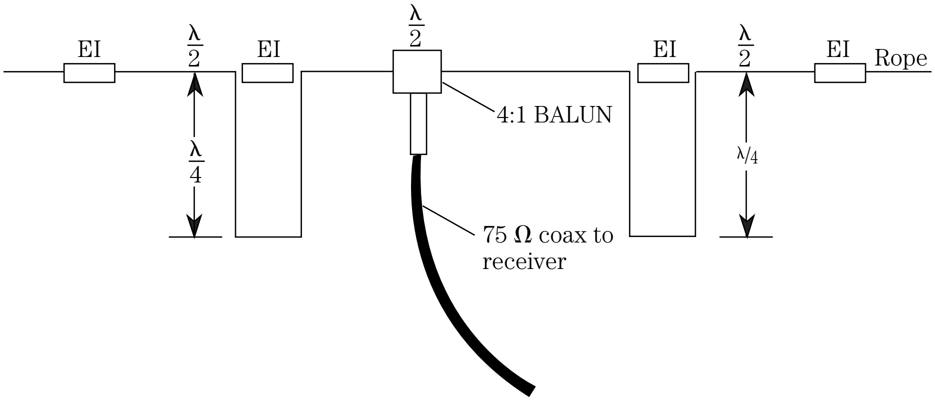

6-20 Wire collinear antenna.

The version of the "Collinear" shown in Fig. 6-20 has a gain of about 3 dB. There is no theoretical reason why you can't extend the design indefinitely, but there is a practical limit set by how much wire can be held by your supports, and how much real estate you own. A 4.5-dB version can be built by adding another half-wavelength section at each end, with an intervening quarter-wavelength phase reversal stub in between each new section, and the preceding section. Once you get longer than five half-wavelengths, which provides the 4.5-dB gain, the physical size becomes a bit of a bother for most folks.

The TCFTFD dipole

The *tilted, center-fed, terminated, folded dipole* (TCFTFD, also called the T^2FD or TTFD) is an answer to both the noise pickup and length problems that sometimes affect other antennas. For example, a random-length wire, even with antenna tuner, will pick up considerable amounts of noise. A dipole for 40 m is 66 ft long.

This antenna was first described publicly in 1949 by Navy Captain C. L. Countryman, although the U.S. Navy tested it for a long period in California during World War II. The TCFTFD can offer claimed gains of 4 to 6 dB over a dipole, depending on the frequency and design, although 1 to 3 dB is probably closer to the mark in practice, and less than 1 dB will be obtained at some frequencies within its range (especially where the resistor has to absorb a substantial portion of the RF power). The main attraction of the TCFTFD is not its gain, but rather its *broad bandedness*.

In addition, the TCFTFD can also be used at higher frequencies than its design frequency. Some sources claim that the TCFTFD can be used over a 5 or 6:1 frequency range, although my own observations are that 4:1 is more likely. Nonetheless, a 40-m antenna will work over a range of 7000 to 25,000 kHz, with at least some decent performance up into the 11-m Citizen's Band (27,000 kHz).

The basic TCFTFD (Fig. 6-21) resembles a folded dipole in that it has two parallel conductors of length L, spaced a distance W apart, and shorted together at the

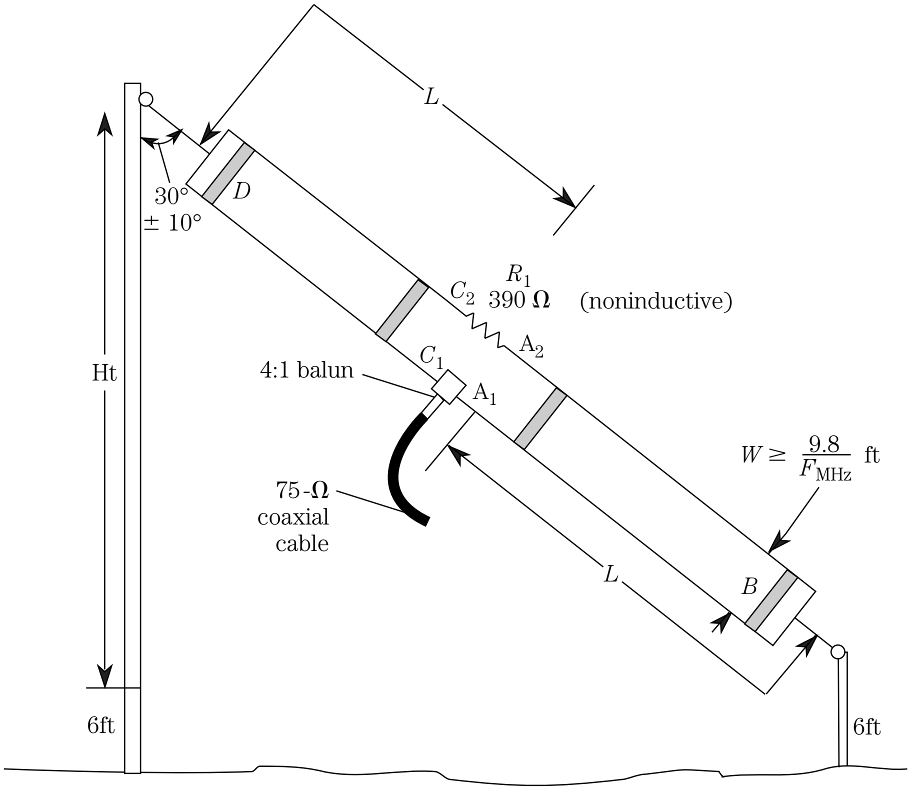

6-21 TTFD antenna.

ends. The feedpoint is the middle of one conductor, where a 4:1 balun coil and 75-Ω coaxial-cable transmission line to the transceiver are used. A noninductive, 390-Ω resistor is placed in the center of the other conductor. This resistor can be a carbon-composition (or metal-film) resistor, but it must not be a wirewound resistor or any other form that has appreciable inductance. The resistor must be able to dissipate about one-third of the applied RF power. The TCFTFD can be built from ordinary no.14 stranded antenna wire.

For a TCFTFD antenna covering 40 through 11 m, the spread between the conductors should be 19½ in, while the length *L* is 27 ft. Note that length *L* includes one-half of the 19-in spread because it is measured from the center of the antenna element to the center of the end supports.

The TCFTFD is a sloping antenna, with the lower support being about 6 ft off the ground. The height of the upper support depends on the overall length of the antenna. For a 40-m design, the height is on the order of 50 ft.

The parallel wires are kept apart by spreaders. At least one commercial TCFTFD antenna uses PVC spreaders, while others use ceramic. You can use wooden dowels of between 1-in and ⅝-in diameter; of course, a coating of varnish (or urethane spray) is recommended for weather protection. Drill two holes, of a size sufficient to pass the wire, that are the dimension *W* apart (19 in for 40 m). Once the spreaders are in place, take about a foot of spare antenna wire and make jumpers to hold the dowels in place. The jumper is wrapped around the antenna wire on either side of the dowel, and then soldered.

The two end supports can be made of 1 × 2 in wood treated with varnish or urethane spray. The wire is passed through screw eyes fastened to the supports. A support rope is passed through two holes on either end of the 1 × 2 and then tied off at an end insulator.

The TCFTFD antenna is noticeably quieter than the random-length wire antenna, and somewhat quieter than the half-wavelength dipole. When the tilt angle is around 30°, the pattern is close to omnidirectional. Although a little harder to build than dipoles, it offers some advantages that ought not to be overlooked. These dimensions will suffice when the "bottom end" frequency is the 40-m band, and it will work well on higher bands.

Vee-sloper antenna

The *vee-sloper antenna* is shown in Fig. 6-22. It is related to the vee beam (covered in Chap. 9), but it is built like a sloper (i.e., with the feed end of the antenna high above ground). The supporting mast height should be about half (to three-fourths) of the length of either antenna leg. The legs are sloped downward to terminating

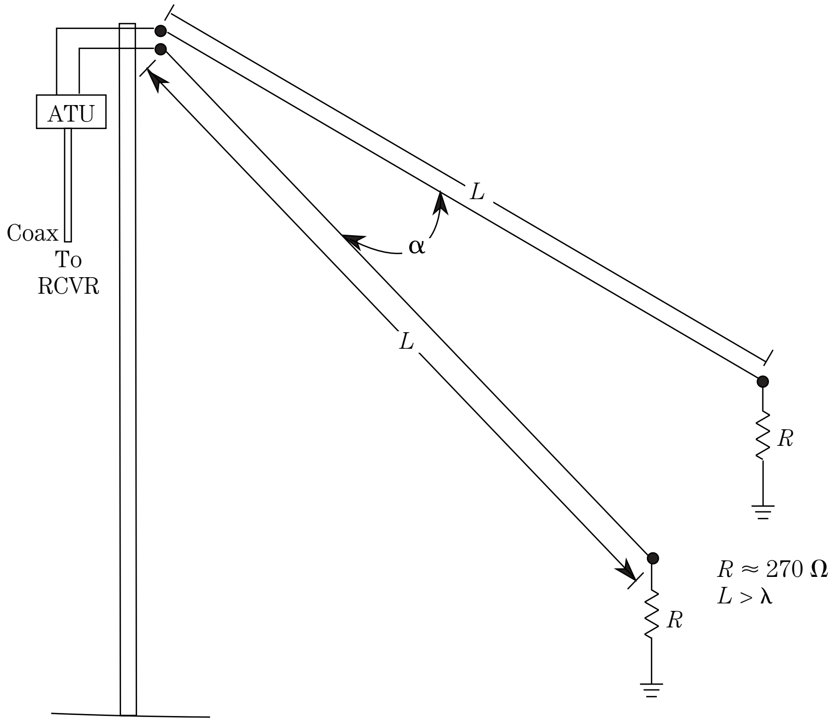

6-22 Vee-sloper antenna.

resistors at ground level. Each wire should be longer than 1λ at the lowest operating frequency. The terminating resistors should be on the order of 270 Ω (about one-half of the characteristic impedance of the antenna), with a power rating capable of dissipating one-third of the transmitter power. Like other terminating resistors, these should be noninductive (carbon composition or metal film).

The advantage of this form of antenna over the vee beam is that it is vertically polarized, and the resistors are close to the earth, so they are easily grounded.

Rhombic inverted-vee antenna

A variation on the theme is the vertically polarized rhombic of Fig. 6-23. Although sometimes called an *inverted vee*—not to be confused with the dipole variant of the same name—this antenna is half a rhombic, with the missing half being "mirrored" in the ground (similar to a vertical). The angle at the top of the mast (Φ) is typically ≥ 90°, and 120 to 145° is more common. Each leg (*A*) should be ≥λ, with the longer lengths being somewhat higher in gain, but harder to install for low frequencies. A requirement for this type of antenna is a very good ground connection. This is often accomplished by routing an underground wire between the terminating resistor ground and the feedpoint ground.

Multiband fan dipole

The basic half-wavelength dipole antenna is a very good performer, especially when cost is a factor. The dipole yields relatively good performance for practically no in-

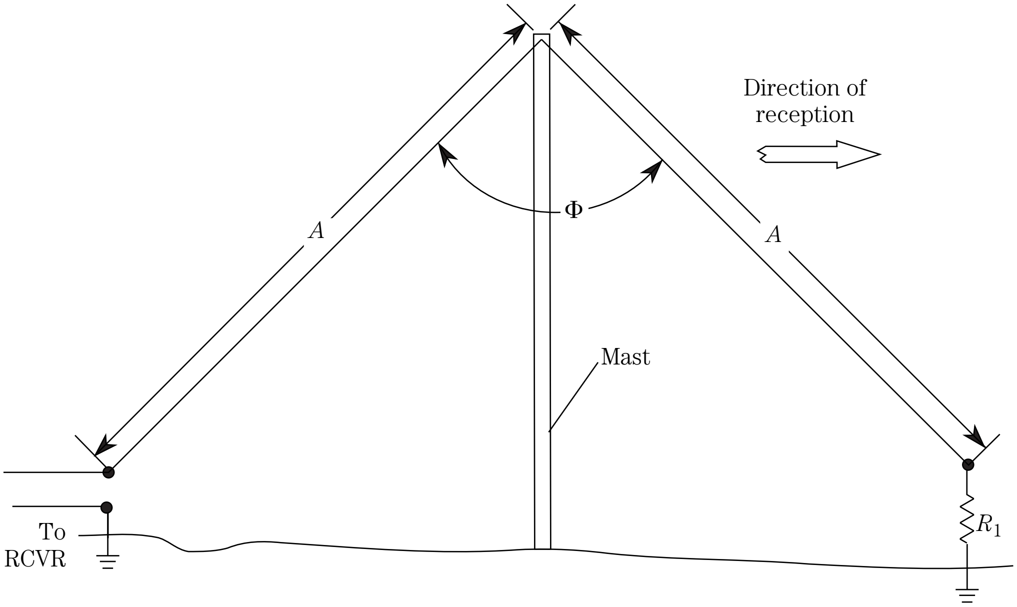

6-23 Inverted-vee antenna.

vestment. A standard half-wavelength dipole offers a bidirectional figure-8 pattern on its basic band (i.e., where the length is a half-wavelength), and a four-lobe cloverleaf pattern at frequencies for which the physical length is 3λ/2. Thus, a 40-m half-wavelength dipole produces a bidirectional pattern on 40 m, and a four-lobe cloverleaf pattern on 15 m.

The dipole is not easily multibanded without resorting to traps (covered in Chap. 8). One can, however, tie several dipoles to the same center insulator or balun transformer. Figure 6-24 shows three dipoles cut for different bands, operating from a common feedline and balun transformer: A1–A2, B1–B2, and C1–C2. Each of these antennas is a half-wavelength (i.e., $L_{\mathrm{feet}} = 468/F_{\mathrm{MHz}}$).

There are two points to keep in mind when building this antenna. First, try to keep the ends spread a bit apart, and second, make sure that none of the antennas is cut as a half-wavelength for a band for which another is 3λ/2. For example, if you make A1–A2 cut for 40 m, then don't cut any of the other three for 15 m. If you do, the feedpoint impedance and the radiation pattern will be affected.

The counterpoise longwire

The *longwire antenna* is an end-fed wire more than 2λ long. It provides considerable gain over a dipole, especially when a very long length can be accommodated. Although 75- to 80-m, or even 40-m longwires are a bit difficult to erect at most locations, they are well within reason at the upper end of the HF spectrum. Low-VHF

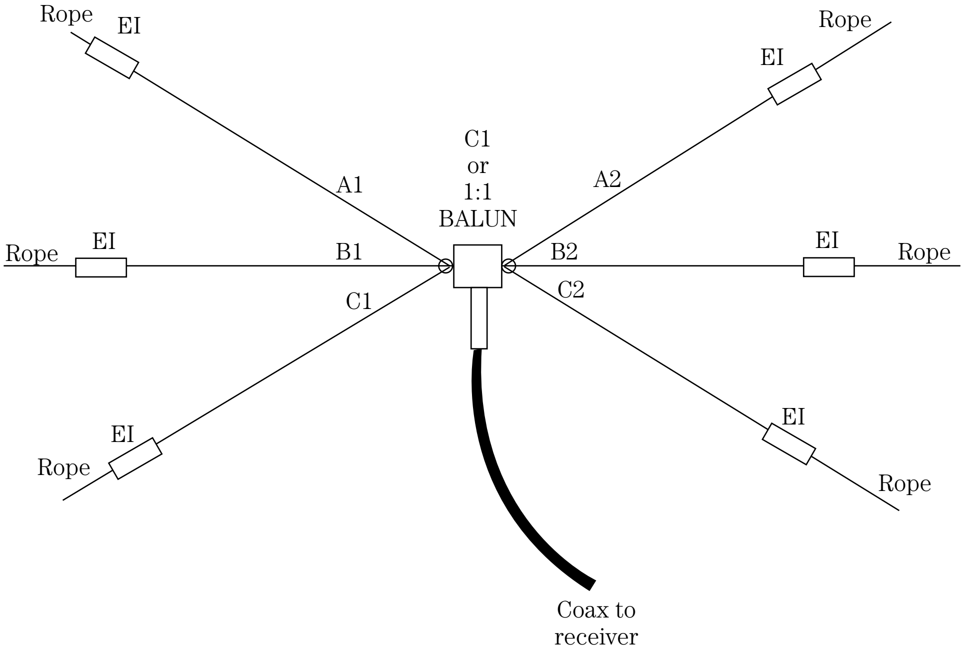

6-24 Multiband dipole antenna.

band operation is also practical. Indeed, I know one fellow who lived in far southwest Virginia as a teenager, and he was able to get his family television reception for very low cost by using a TV longwire (channel 6) on top of his mountain.

There are some problems with longwires that are not often mentioned. Two problems seem to insinuate themselves into the process. First, the Zepp feed is a bit cumbersome (not everyone is enamored of parallel transmission line). Second, how do you go about actually grounding that termination resistor? If it is above ground, then the wire to ground is long, and definitely not at ground potential for RF. If you want to avoid both the straight Zepp feed system employed by most such antennas, as well as the resistor-grounding problem, then you might want to consider the *counterpoise longwire antennas* shown in Fig. 6-25.

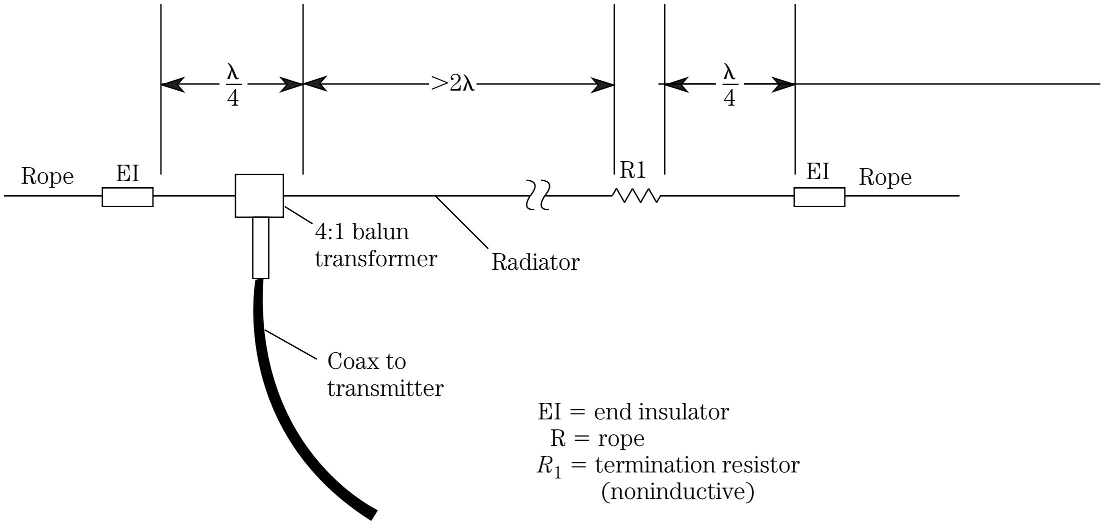
$\frac{\lambda}{4}$
>2λ
$\frac{\lambda}{4}$
Rope
EI
R1
EI
Rope
4:1 balun transformer
Radiator
Coax to transmitter
EI = end insulator
R = rope
R_1 = termination resistor (noninductive)

6-25A Longwire with λ/4 radials used as counterpoise ground at feedpoint and terminating resistor.

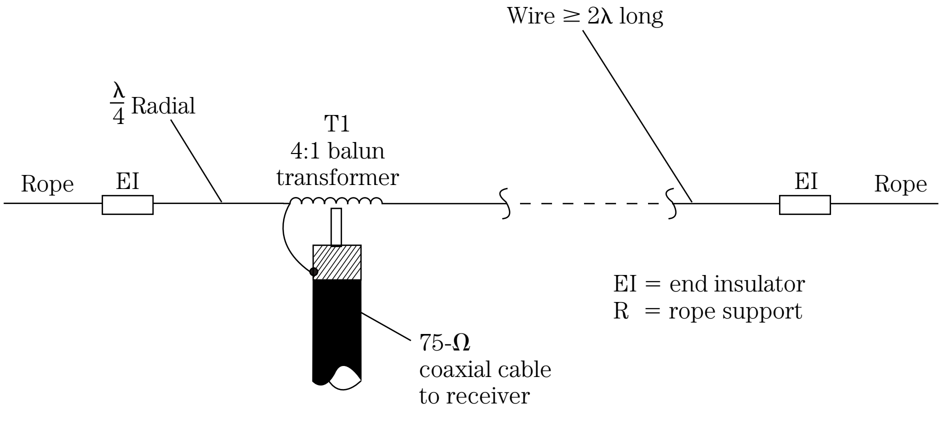
Wire ≥ 2λ long
$\frac{\lambda}{4}$ Radial
T1
4:1 balun
transformer
Rope
EI
EI
Rope
EI = end insulator
R = rope support
75-Ω
coaxial cable
to receiver

6-25B Balun transformer feed for longwire antenna.

A counterpoise ground is a structure that acts like a ground, but is actually electrically floating above real ground (and it is not connected to ground). A groundplane of radials is sometimes used as a counterpoise ground for vertical antennas that are mounted above actual earth ground. In fact, these antennas are often called *ground plane verticals*. In those antennas, the array of four (or more) radials from the shield of the coaxial cable are used as an artificial, or counterpoise, ground system.

In the counterpoise longwire of Fig. 6-25A, there are two counterpoise grounds (although, for one reason or another, you might elect to use either, but not both). One counterpoise is at the feedpoint, where it connects to the "cold" side of the transmission line. The parallel line is then routed to an antenna tuning unit (ATU), and from there to the transmitter. The other counterpoise is from the cold end of the termination resistor to the support insulator. This second counterpoise makes it possible to eliminate the earth ground connection, and all the problems that it might entail, especially in the higher end of the HF spectrum, where the wire to ground is of substantial length compared with 1λ of the operating frequency.

A slightly different scheme used to adapt the antenna to coaxial cable is shown in Fig. 6-25B. In this case, the longwire is a resonant type (nonterminated). Normally, one would expect to find this antenna fed with 450-Ω parallel transmission line. But with a λ/4 radial acting as a counterpoise, a 4:1 balun transformer can be used to effect a reasonable match to 75-Ω coaxial cable. The radial is connected to the side of the balun that is also connected to the coaxial cable shield, and the other side of the balun is connected to the radiator element.

7
CHAPTER

Vertically polarized HF antennas

IN PREVIOUS CHAPTERS, YOU HAVE FOUND THAT THE POLARITY OF AN ANTENNA IS THE direction of the electrical (E) field. Because the transmitted signal is an orthogonal electromagnetic wave, the magnetic field radiated from the antenna is at right angles to the electric field. The direction of the electric field, which sets the polarity of the antenna, is a function of the geometry of the radiator element. If the element is vertical, then the antenna polarity is also vertical. The signal propagates out from the radiator in all directions of azimuth, making this antenna an "omnidirectional" radiator.

Figure 7-1A shows the basic geometry of the vertical antenna: an RF generator (transmitter or transmission line from a transmitter) at the base of a radiator of length L. Although most commonly encountered verticals are quarter-wavelength ($L = \lambda/4$), that length is not the only permissible length. In fact, it may not even be the most desirable length. This chapter covers the standard quarter-wavelength vertical antenna (because it is so popular), and other-length verticals (both greater and less than quarter-wavelength).

The quarter-wavelength vertical antenna is basically half of a dipole placed vertically, with the "other half" of the dipole being the ground. Because of this fact, some texts show the vertical with a double-line ghost radiator, or image antenna, in the earth beneath the main antenna element. Figure 7-1B shows the current and voltage distribution for the quarter-wavelength vertical. Like the dipole, the quarter-wavelength vertical is fed at a current loop, so the feedpoint impedance is at a minimum (typically 2 to 37 Ω, depending upon nearby objects and design). As a result, the current is maximum and the voltage is minimum at the feedpoint. As you will see, however, not all vertical antennas are fed directly at the current loop. As a result, some designs require antenna tuning units to make them match the antenna impedance to the transmitter output impedance.

Figure 7-1C and 7-1D show the two basic configurations for the HF vertical antenna. Figure 7-1C shows the ground-mounted vertical antenna. The radiator

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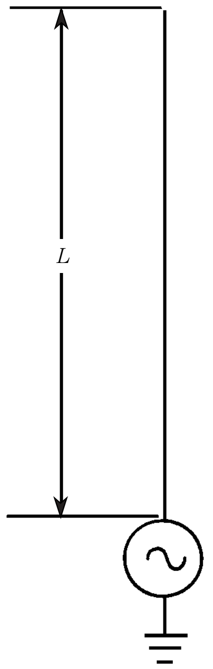

7-1A Basic elements of the vertical antenna.

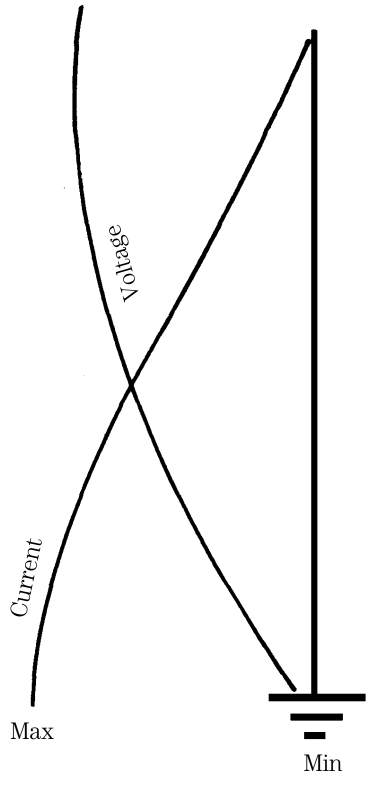
Voltage
Current
Max
Min

7-1B Current and voltage distribution along vertical.

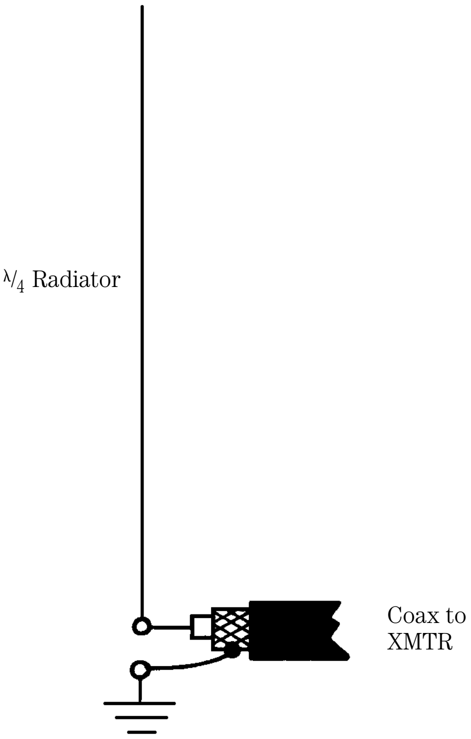

7-1C Simple coaxial-fed vertical antenna. There is a slight mismatch, but it usually is within tolerable limits.

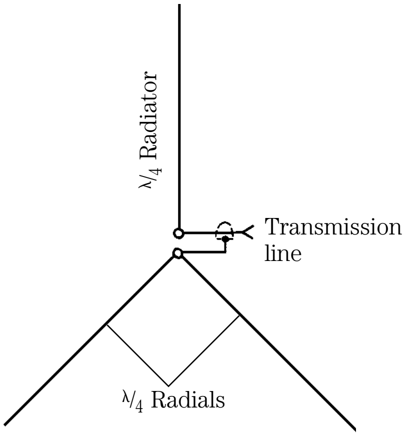

7-1D Mast-mounted vertical uses radials as a counterpoise ground.

element is mounted at ground level, but it is insulated from ground. Because the antenna shown is a quarter-wavelength, it is fed at a current loop with 52-Ω coaxial cable. The inner conductor of the coaxial cable is connected to the radiator element, and the coaxial cable shield is connected to the ground. As you will see shortly, the ground system for the vertical antenna is critical to its performance. Normally, the feedpoint impedance is not 52 Ω, but rather is somewhat lower (37 Ω). As a result, without some matching there will be a slight VSWR, but in most cases, the VSWR is a tolerable tradeoff for simplicity. If the antenna has a feedpoint impedance of 37 Ω, which is the value usually quoted, then the VSWR will be 52 Ω/37 Ω, or 1.41:1.

A vertical mounted above the ground level is shown in Fig. 7-1D. This antenna is equally as popular as the ground mounted. Amateurs and CB operators find it easy to construct this form of antenna because the lightweight vertical can be mounted at reasonable heights (15 to 60 ft) using television antenna slip-up telescoping masts that are reasonably low in cost. A problem with the non-ground-level vertical antenna is that there is no easy way to connect it to ground. The solution to the problem is to create a counterpoise (artificial) ground with a system of quarter-wavelength radials.

In general, at least two radials are required for each band, and even that number is marginal. The standard wisdom holds that the greater the number of radials, the better the performance. Although that statement is true, there are both theoretical and practical limits to the number of radials. The theoretical limit is derived from the fact that more than 120 radials returns practically no increase in operational effectiveness, and at more than 16 radials, the returned added effectiveness per new radial is less than is the case for fewer radials. That is, going from 16 to 32 radials (doubling the number) creates less of an increase in received field strength at a distant point than going from 8 to 16 radials (both represent doubling the density of the radial system). The practical limit is 16 radials.

The radials of the off-ground-level vertical antenna can be at any angle. In Fig. 7-1D, they are “drooping radials” (i.e., the angle is greater than 90° relative to the vertical radiator element). Similarly, Fig. 7-1E shows a vertical antenna that is equipped with radials at exactly 90° (no common antenna has radials less than 90°). Both of these antennas are called *ground plane vertical antennas*.

The angle of the vertical’s radials is said to affect the feedpoint impedance and the angle of radiation of the vertical antenna. Although those statements are undoubtedly true in some sense, there are other factors that also affect those parameters, and they are probably more important in most practical installations. Before digging further into the subject of vertical antennas, take a look at the subjects of angle of radiation and gain in vertical antennas.

Angle of radiation

Long-distance propagation in the HF region depends upon the ionospheric phenomena called “skip.” (See Chap. 2 for a more extensive explanation.) In this type of propagation, the signal leaves the transmitting antenna at some angle a, called the *angle of radiation*, and enters the ionosphere where it is refracted back to earth at a distance D from the transmitting station. The signal in the zone between the outer edge of the antenna’s ground-wave region and the distant skip point is weak or nonexistent.

The distance covered by the signal on each skip is a function of the angle of radiation. Figure 7-2 shows a plot of the angle of radiation of the antenna, and the distance to the first skip zone. The angle referred to along the vertical axis is the angle of radiation away from the antenna relative to the horizon. For example, an angle of

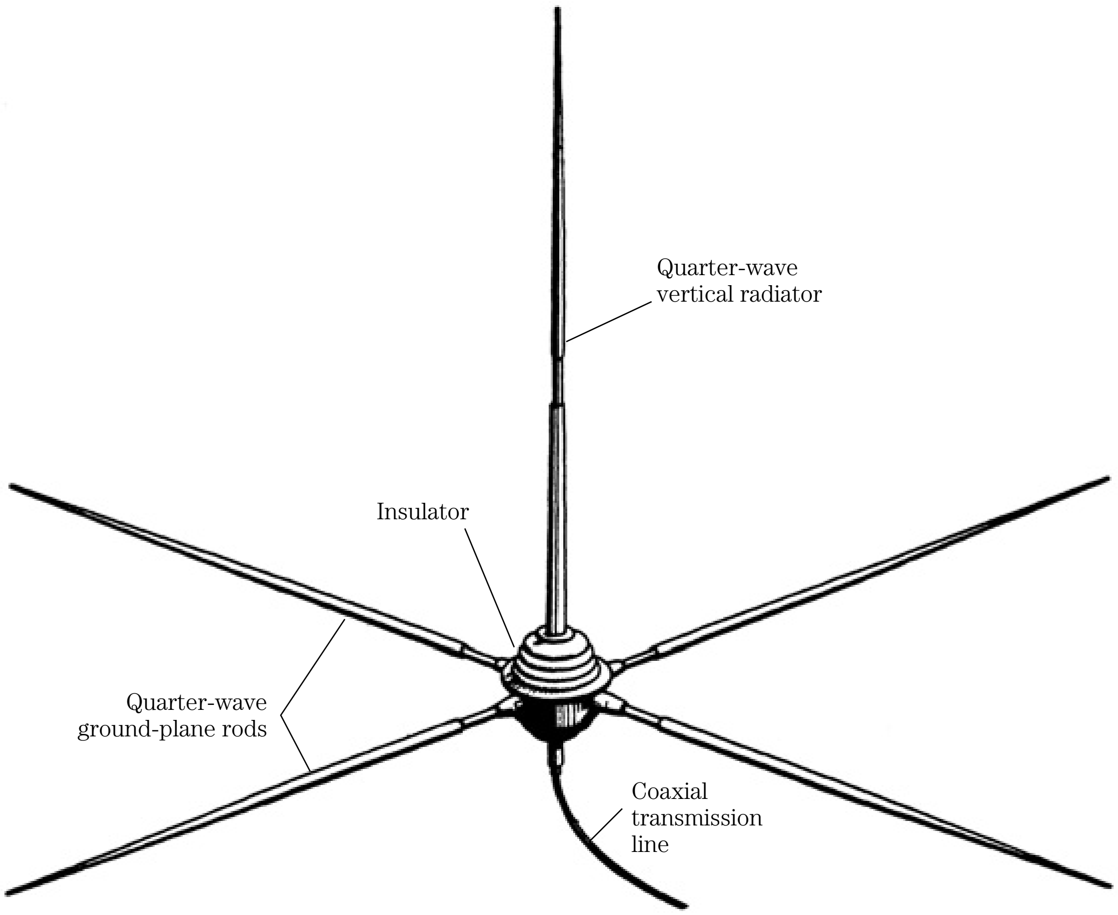
Quarter-wave
vertical radiator
Insulator
Quarter-wave
ground-plane rods
Coaxial
transmission
line

Ground-plane antenna

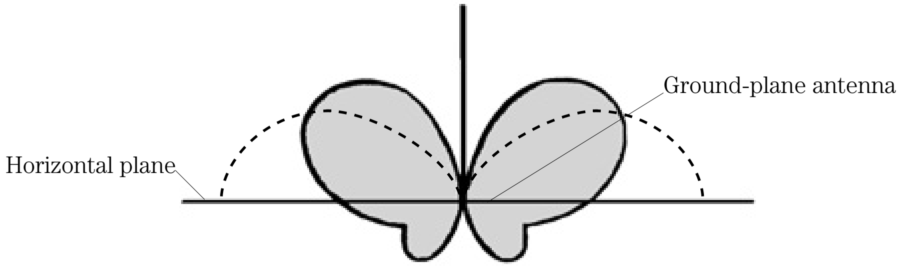
Ground-plane antenna
Horizontal plane

Radiation pattern

7-1E Ground-plane vertical antenna.

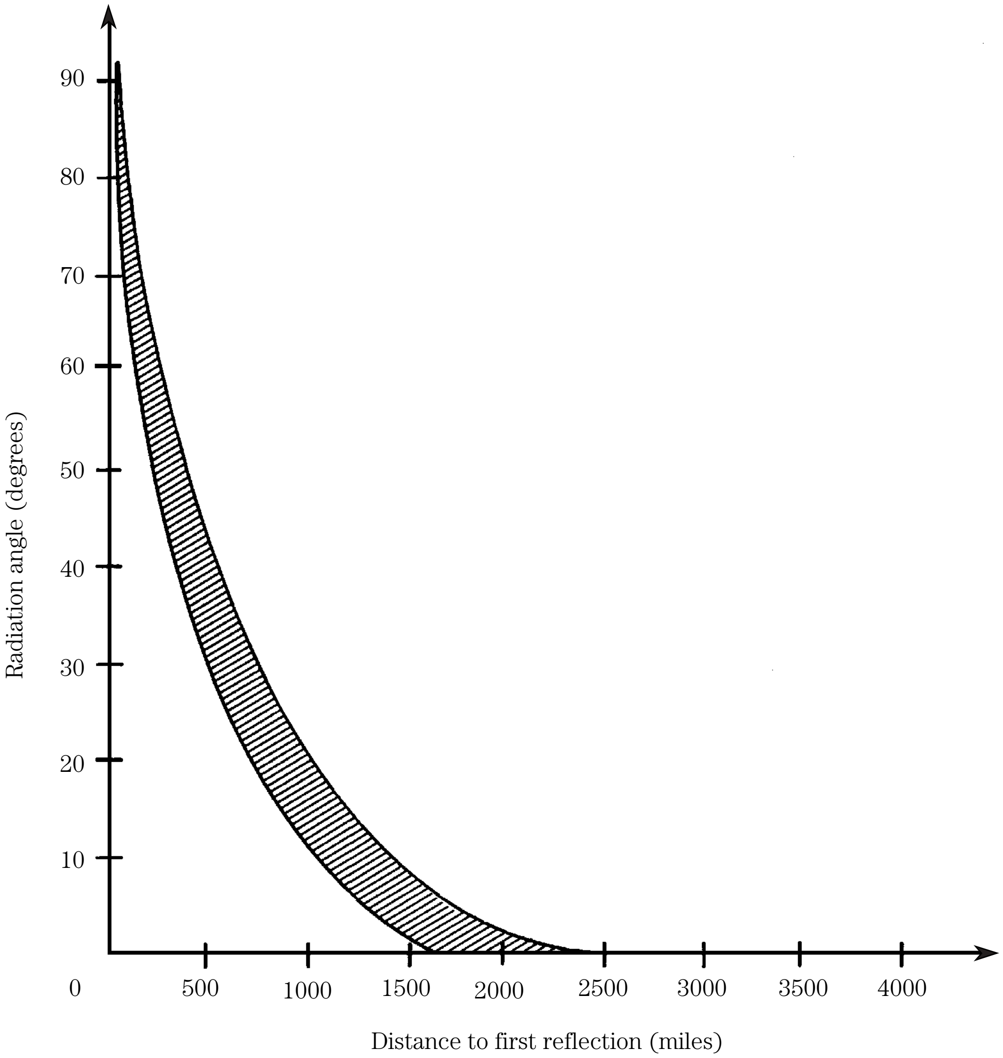

7-2 Effect of radiation angle on skip communications.

10° is elevated 10° above the horizon. Shorter distances are found when the angle of radiation is increased. At an angle of about 30°, for example, the distance per skip is only a few hundred miles.

Although you might expect on first blush to see a single line on the graph, there is actually a zone shown (shaded). This phenomenon exists because the ionosphere is found at different altitudes at different times of the day and different seasons of the year. Generally, however, in the absence of special event phenomena in the ionosphere, you can expect from 1500 to 2500 mi per bounce in the HF bands for low angles of radiation. Note, for example, that for a signal that is only a degree or two above the horizon the skip distance is maximum.

At distances greater than those shown in Fig. 7-2, the signal will make multiple hops. Given a situation where the skip distance is 2500 mi, covering a distance of 7500 mi requires three hops. Unfortunately, there is a signal strength loss on each hop of 3 to 6 dB, so you can expect the distant signal to be attenuated from making multiple hops between the earth's surface and the ionosphere. For maximizing distance, therefore, the angle of radiation needs to be minimized.

So what is the ideal angle of radiation? It is standard—but actually erroneous—wisdom among amateur radio operators (and even commercial operators, it turns out) that the lower the angle of radiation, the better the antenna. That statement is only true if long distance is wanted, so it reflects a strong bias toward the DX community. The correct answer to the question is: "It depends on where you want the signal to go." For example, I live in Virginia. If I want to communicate with stations in the Carolinas or New England, then it would behoove me to select a higher angle of radiation for radio conditions represented in Fig. 7-2 so that the signal will land in those regions. But if I wanted to work stations in Europe or Africa or South America, then a low angle of radiation is required. Because of the difference between performance of high and low angles of radiation, some stations have two antennas for each band: one each for high and low angles of radiation.

Figure 7-3 shows a signal from a hypothetical antenna located at point 0, in order to show what angle is meant by "angle of radiation." The beam from the antenna is elevated above the horizon (represented by the horizontal "tangent to horizon" line). The angle of radiation a is the angle between the tangent line and the center of the beam. This angle is not to be confused with the beamwidth, which is also an angle. In the case of beamwidth, we are talking about the thickness of the main lobe of the signal between points where the field strength is –3 dB down from the maximum signal (which occurs at point P); these points are represented by points X and Y in Fig. 7-3. Thus, angle b is the beamwidth, and angle a is the angle of radiation.

Gain in vertical antennas

Vertical antennas are considered *omnidirectional* because they radiate equally well in all directions. "Gain" in an antenna is not the creation of power, but rather a simple refocusing of energy from all directions to a specific direction; gain therefore infers directivity. According to the convention, then, the vertical antenna cannot have any gain because it radiates in all directions equally . . . gain infers directivity. Right? No, not really. Let's develop the theme more carefully.

Again consider the idea of an isotropic radiator (the word *isotropic* means equal power in all directions). Consider a spherical point source radiator located at point O in Fig. 7-4. Whatever the level of power available from the transmitter, it will be spread equally well over the entire surface of the sphere as it radiates out into space away from point O. If you measure the power distributed over some area A at a distance R from the source, then the power available will be a fraction of the total power:

$$P_{\text{avail}} = \frac{\text{total available power} \times A}{\text{total surface area of sphere}}$$

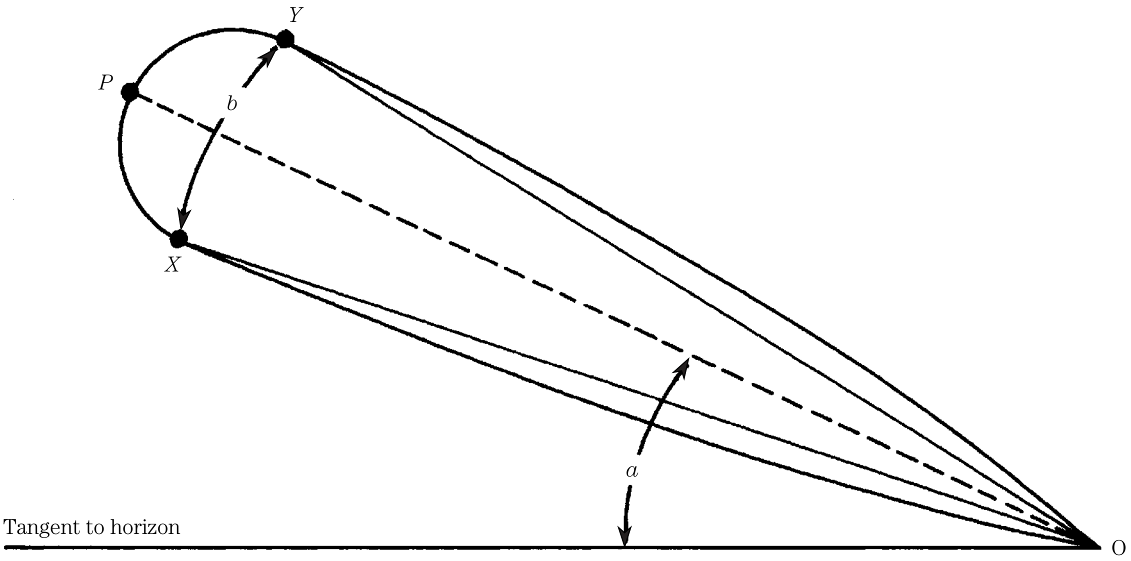

X,Y: −3 dB points
P: center beam
Angle *a*: elevation angle
Angle *b*: 3-dB beam width

7-3 Side view of vertical extent radiation pattern.

or, in math symbols:

$$P_a = \frac{P_s}{4\pi r^2} \qquad \textbf{[7.1]}$$

where

P_a is the power available per solid degree
P_s is the total radiated power, in watts
r is the radius of the sphere (i.e., the distance from O to P).

A practical rule of thumb for this problem is to calculate from the surface area of the sphere. If you perform the right calculations, you will find that there are approximately 41,253 square degrees on the surface of a sphere. By calculating the surface area of the beam front (also in square degrees), you can find the power within that region.

Now for the matter of gain in a vertical antenna. The vertical is not gainless because it does not, in fact, radiate equally well in all directions. In fact, the vertical is quite directional, except in the horizontal (azimuth) plane. Figure 7-5 shows the radiation pattern of the typical free-space vertical radiator. The pattern looks like a giant doughnut in free space (see solid pattern in Fig. 7-5). When sliced like a bagel, the pattern is the familiar circular “omnidirectional” pattern. When examined in the vertical plane, however, the plane looks like a sliced figure-8. The “gain” comes from the fact that energy is not spread over an entire sphere, but rather it is concentrated

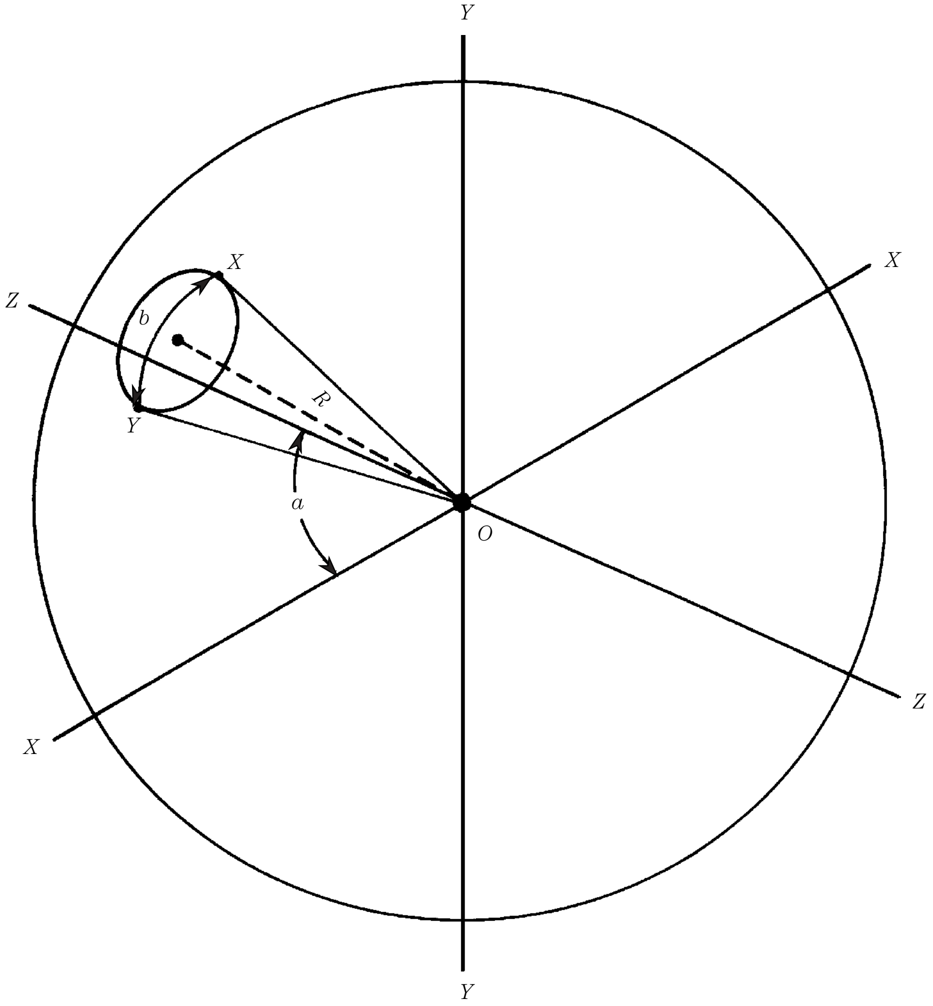

7-4 Spherical or "isotropic" radiation pattern.

to the toroidal doughnut-shaped region shown. Therefore, the power per unit area is greater than for the isotropic (truly omnidirectional) case.

Non-quarter-wavelength verticals

The angle of radiation for a vertical antenna, hence the shape of the hypothetical doughnut radiation pattern, is a function of the length of the antenna. (*Note:* Length in terms of vertical antennas is the same as height, and is sometimes expressed in degrees of wavelength, as well as feet and/or meters.) Figure 7-6A shows the approximate patterns for three different-length vertical antennas: quarter-wavelength, half-wavelength, and ⅝-wavelength. Note that the quarter-wavelength antenna has the highest angle of radiation, as well as the lowest gain of the three cases.

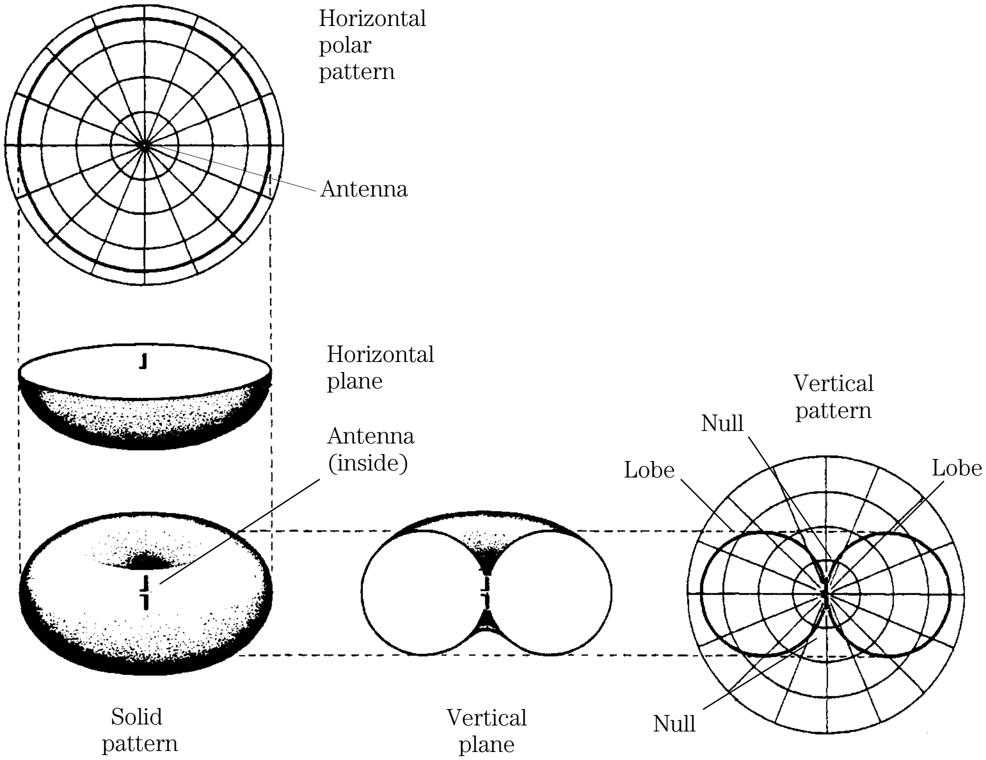
Horizontal polar pattern
Antenna
Horizontal plane
Antenna (inside)
Vertical pattern
Null
Lobe
Lobe
Null
Solid pattern
Vertical plane

7-5 Vertical antenna radiation pattern.

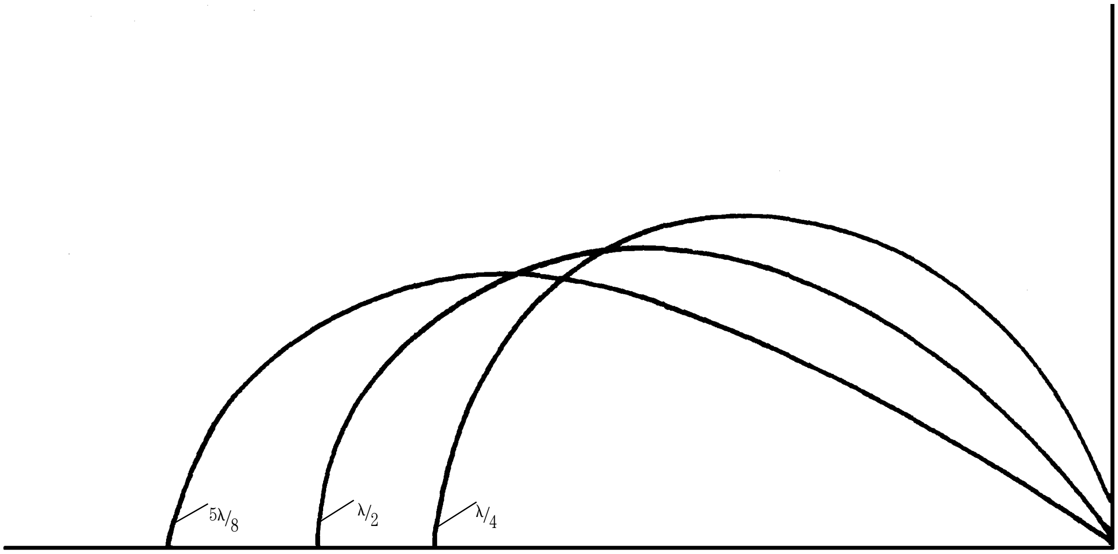

7-6A Vertical radiation pattern as a function of element length: Ideal.

The ⅝-wavelength antenna is both the lowest angle of radiation and the highest gain (compared with isotropic).

The patterns shown in Fig. 7-6A assume a perfectly conducting ground underneath the antenna. However, that is not a possible situation for practical antennas; all real grounds are lossy. The effect of ground losses is to pull in the pattern close to the ground (Fig. 7-6B). Although all of the patterns are elevated from those of Fig. 7-6A, the relationships still remain: the ⅝-wavelength radiator has the lowest angle of radiation and highest gain.

The feedpoint impedance of a vertical antenna is a function of the length of the radiator. For the standard quarter-wavelength antenna, the feedpoint radiation resistance is a maximum of 37 Ω, with only a very small reactance component. Figure 7-7 shows the approximate feedpoint impedances for antennas from nearly zero effective length to 120° of length.

Antenna length expressed in degrees derives from the fact that one wavelength is 360°. Thus, a quarter-wavelength antenna has a length of 360°/4 = 90°. To convert any specific length from degrees to wavelength, divide the length in degrees by 360. Thus, for a 90° antenna: 90°/360° = ¼ wavelength. The graph in Fig. 7-7A shows the antenna feedpoint impedance, both reactance and radiation resistance, for antennas from 60 to 120°; Fig. 7-7B shows the radiation resistance for antennas from near zero to 60°. Note that the radiation resistance for such short antennas is extremely small. For example, an antenna that is 30° long ($^{30}/_{360}$ = 0.083 wavelengths) has a resistance of approximately 3 Ω. It is generally the practice on such antennas to use a broadband impedance-matching transformer to raise the impedance of such antennas to a higher value (Fig. 7-8).

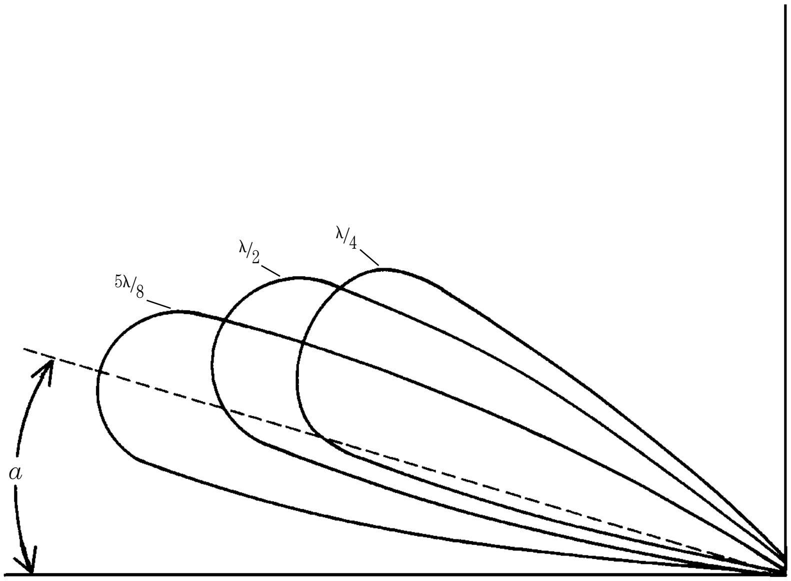

7-6B Accounting for ground losses.

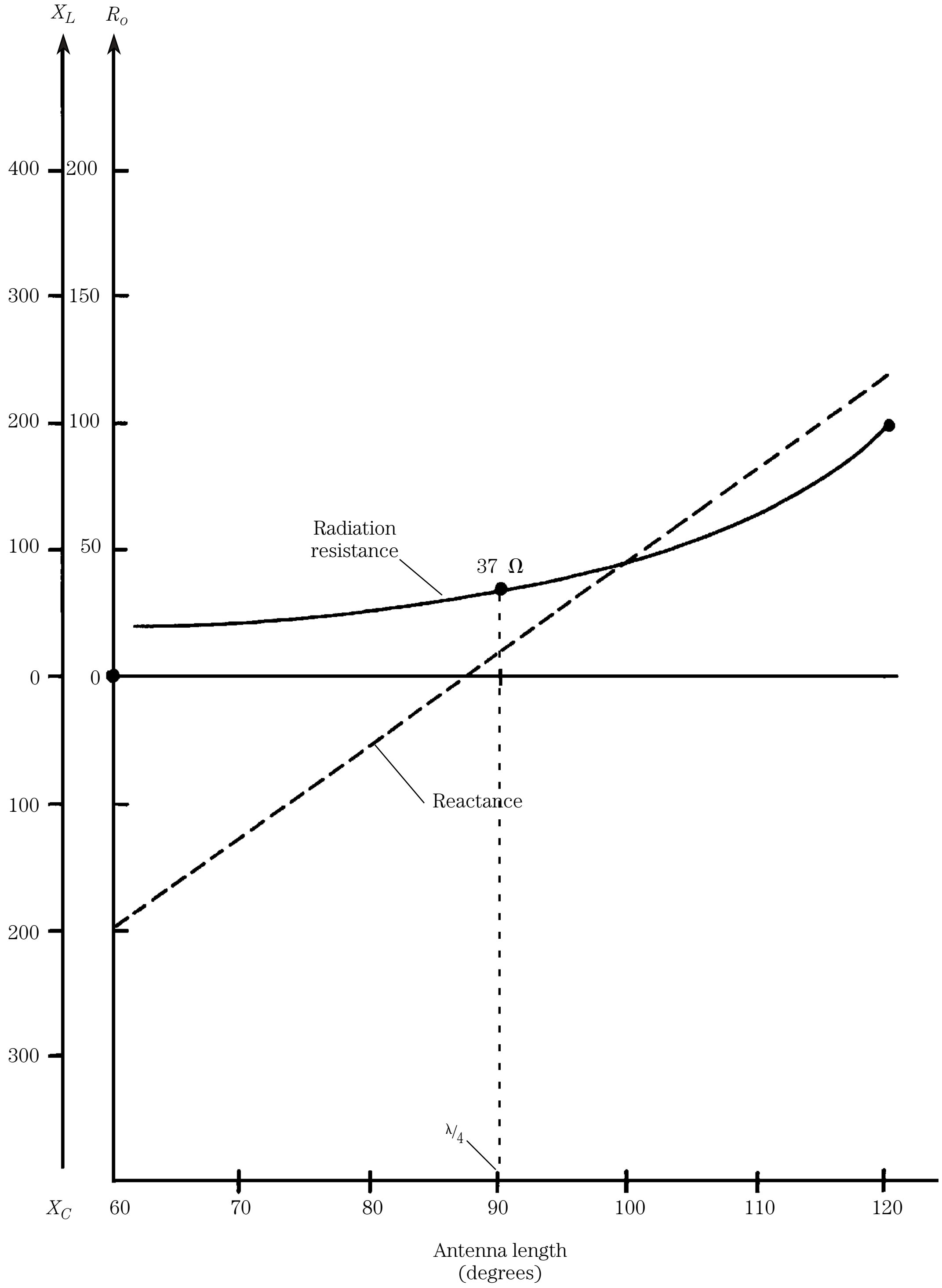

7-7A Antenna impedance as a function of antenna length.

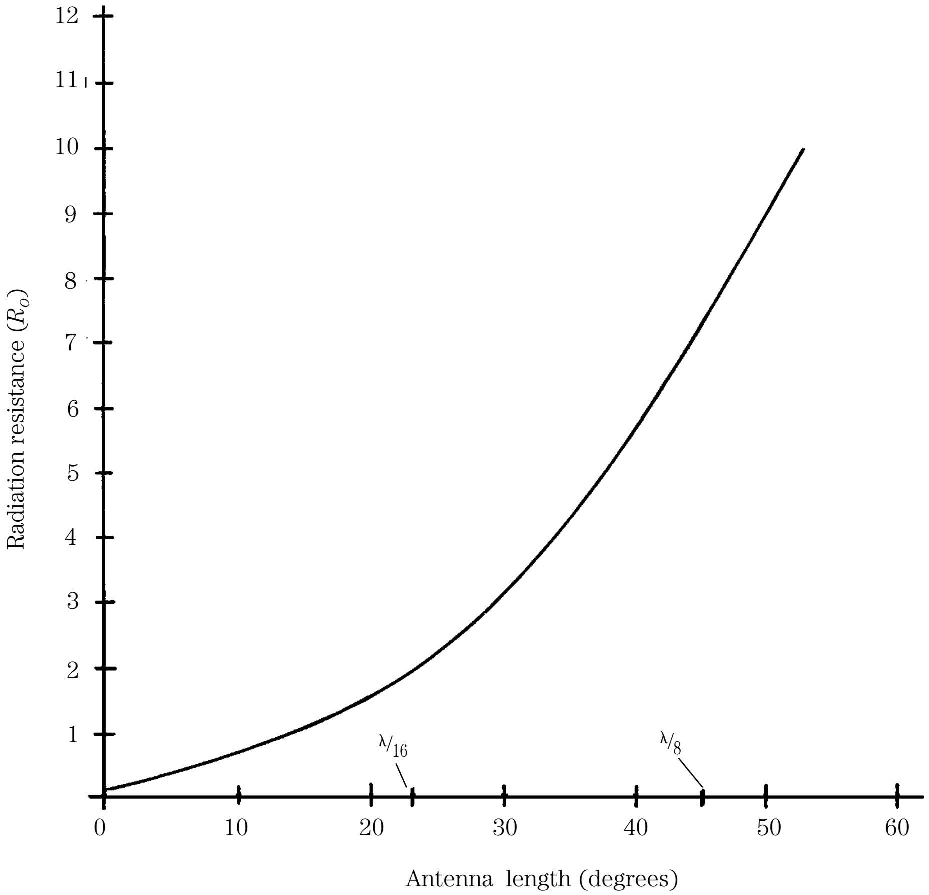

7-7B Radiation resistance as a function of antenna length.

The ground system for the vertical antenna

The vertical antenna works well only when placed over a good ground system. Chapter 28 gives details of proper ground systems for all radio antennas, verticals included, so only certain specifics are included here. The reader should also examine Chap. 28, however, in order to get a firmer grasp of the problem.

The usual way to provide a good ground for a vertical is to use a system of radials such as Fig. 7-9A. This case shows a view (from above) of 16 quarter-wavelength radials arranged to cover the full circle around the antenna. Each radial is a quarterwavelength, so it will have a length (in fact) of $246/F_{\text{MHz}}$. All of the radials are connected together at the base of the antenna, and the ground side of the transmission line is connected to this system. The radials can be placed either on the surface or underground. One friend of the author built an extensive radial system on the bare dirt when his house was built, so when the sod was installed he had a very high-quality underground radial system.

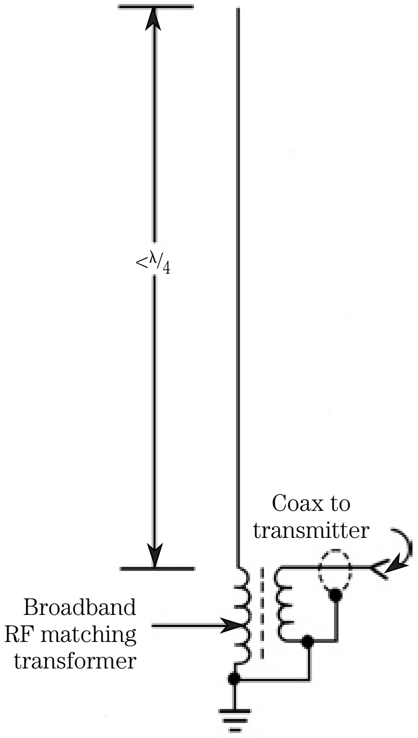

7-8 Impedance matching through broadband transformer.

If you decide to use an aboveground radial system, however, be sure to prevent people from tripping over it. There might be liability implications for people who trip and injure themselves, even when the person is an intruder or trespasser.

Some experts prefer to place a copper wire screen at the center of the radial system. The minimum size of this screen is about 2m square (6 × 6 ft). Connect it to the radials at the points shown using solder. Other experts will drive ground stakes into the ground at these points. Still another method is shown in Fig. 7-9B. This case shows a “spider web” of conductors shorting the radials at points a meter or two from the antenna. Again, some authorities recommend that ground rods be driven into the earth at the indicated points.

The exact number of radials to use depends in part on practical matters (how many can you physically install?). Use at least two radials per band, with four per band preferred for simple, low-cost systems. However, even four is considered a compromise case. The general rule is: *the more the better*. But it’s also true that there is a law of diminishing returns as the number of radials is increased. Figure 7-9C shows the approximate field intensity (mV/m) as a function of the number of radials. Notice that the field intensity does not increase as rapidly with the number of radials above 20 or so. Note that the Federal Communications Commission requires AM band (550 to 1700 kHz) stations to use 120 radials, but that number is not necessary for amateur stations. A practical upper limit of 16 radials is usually accepted for amateur radio work, and four radials work quite well.

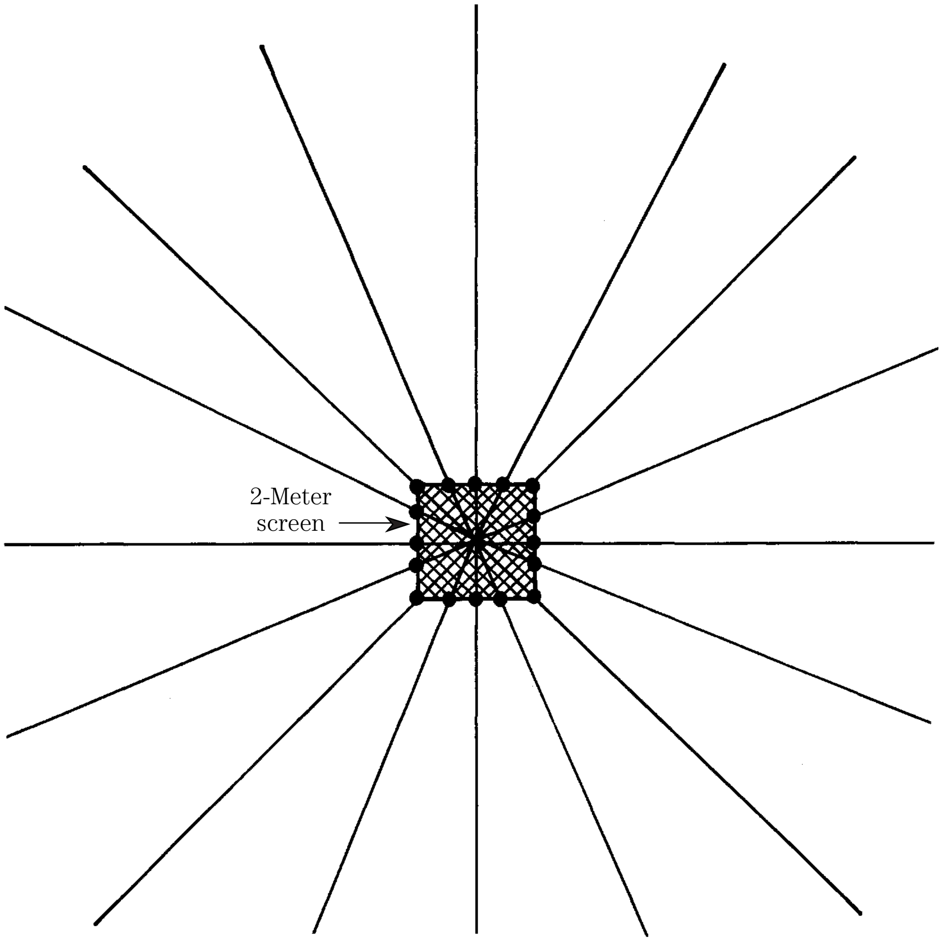

7-9A Comprehensive ground system for vertical antenna.

For vertical antennas mounted above ground, there is an optimum height above ground for the base of the antenna. This height is a quarter-wavelength above the actual ground plane. Unfortunately, that distance might not be the height above the surface. Depending upon ground conductivity and groundwater content, the height can be exactly a quarter-wavelength above the surface or slightly lower. The point is found from experimentation, and will, unfortunately, vary over the year if climatic changes are usual.

Variations on the vertical antenna theme

Thus far, the vertical antennas have been standard quarter- or ⅝-wavelength models. This section looks at several variations on the theme. Consider Fig. 7-10. This antenna is the vertical half-wavelength dipole. The vertical dipole is constructed in exactly the

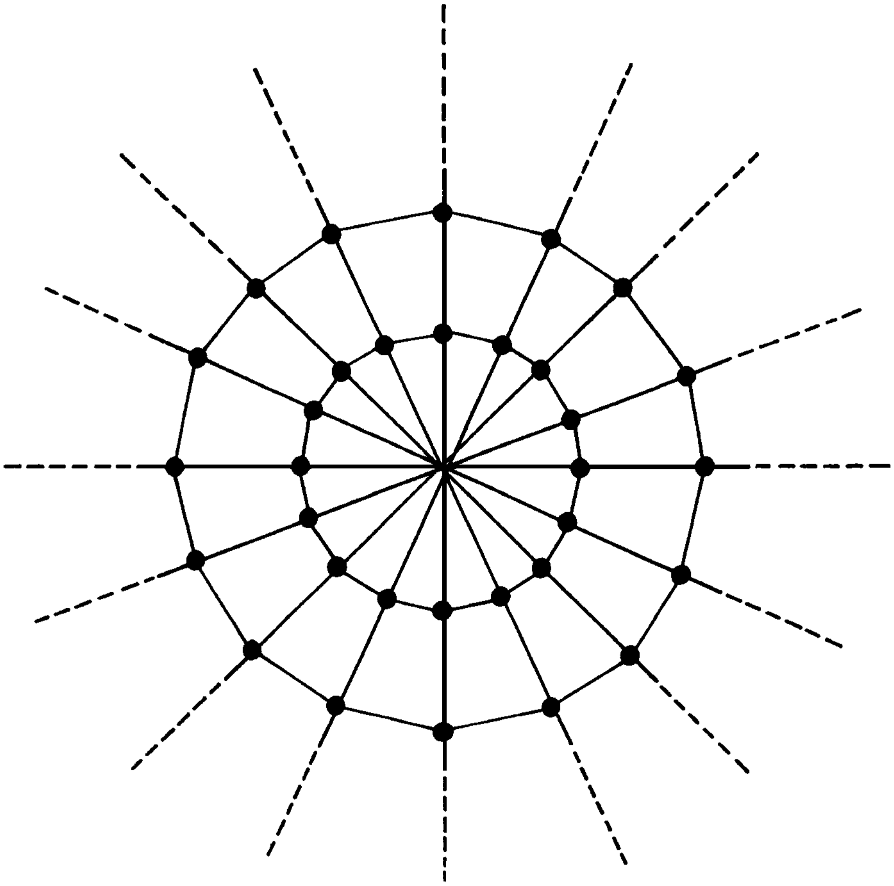

7-9B "Spider web" ground system.

same manner as the horizontal dipole, but is mounted in the vertical plane. In general, the section of the radiator that is closest to the ground should be connected to the shield end of the coaxial cable transmission line.

Like the horizontal dipole, the approximate length of the vertical dipole is calculated from

$$L_{\mathrm{ft}} = \frac{468}{F_{\mathrm{MHz}}} \qquad \textbf{[7.2]}$$

where

L_{ft} is the length, in feet
F_{MHz} is the operating frequency, in megahertz

Example Calculate the length of a half-wavelength vertical dipole for operation on a frequency of 14.250 MHz in the 20-m amateur radio band.

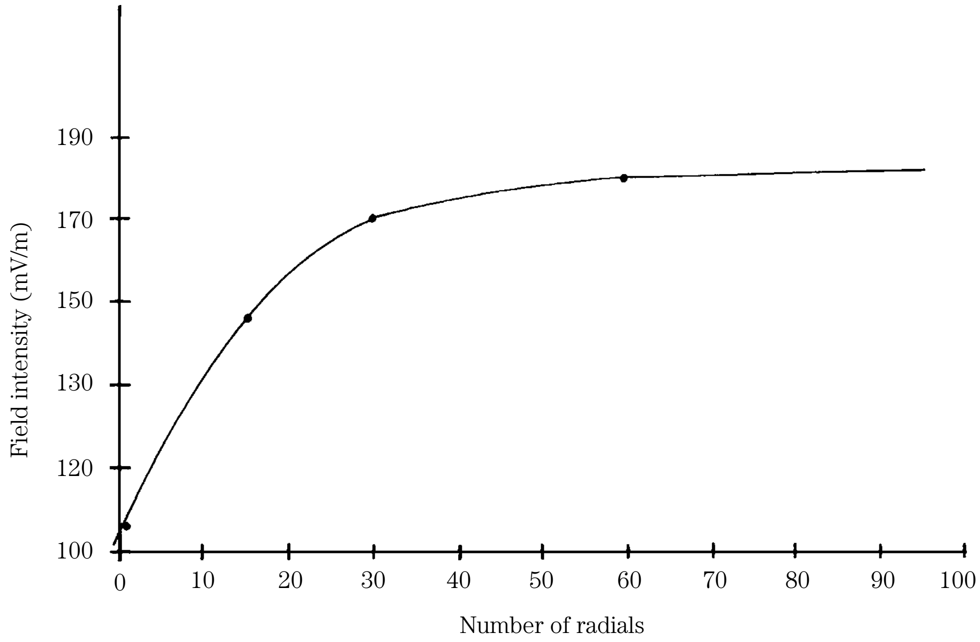

7-9C Effect of increasing the number of radials on field strength.

Solution:

$$L_{\text{ft}} = \frac{468}{F_{\text{MHz}}}$$

$$L_{\text{ft}} = \frac{468}{14.250} = 32.8 \text{ ft}$$

Note: The 0.8 ft part of this calculated length can be converted to inches by multiplying by 12: 0.8 × 12 = 9.6 in.

Each leg of the vertical dipole is one half of the calculated length, or

$$\frac{32.8 \text{ ft}}{2} = 16.4 \text{ ft}$$

The vertical dipole antenna is used in many locations where it is impossible to properly mount a horizontal dipole, or where a roof- or mast-mounted antenna is impossible to install because of logistics, a hostile landlord, and/or a homeowners' association. Some row house and town house dwellers, for example, have been successful with the vertical dipole. In the 1950s and 1960s, the vertical dipole was popular among European amateurs because of space restrictions found in many of those locations.

The construction of the vertical dipole is relatively straightforward. You must find or build a vertical support structure. In the case shown in Fig. 7-10, the support

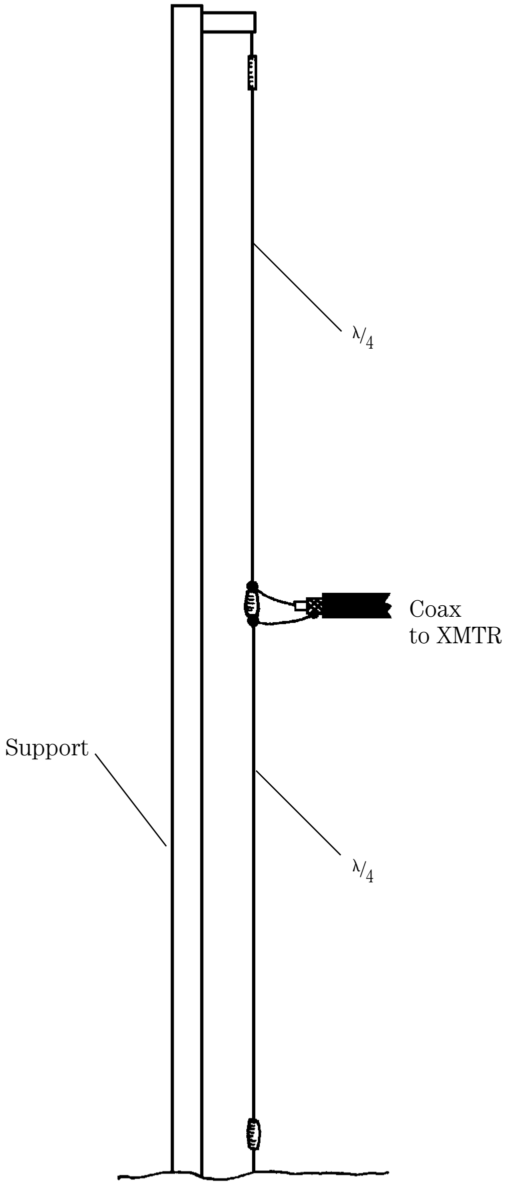

7-10 Vertical half-wavelength dipole antenna.

is a wooden or PVC mast erected for that purpose. Ropes and insulators at either end support the wire elements from the ends and keep the antenna taut. If the neighbors are a problem, then try to find some white PVC pipe that will make a fine flagpole and be patriotic—with a vertical dipole hidden inside of the pipe. In other cases, if your home is not metal-sided, and if it is high enough, then a support from the roof structure (or soffits) will make a proper mount.

One problem with the vertical dipole, and one that liability-conscious people need to consider, is that a high-impedance current node is found at the ends of a half- wavelength dipole. Anyone touching the antenna will likely receive a nasty RF burn (or shock) from this antenna.

A *coaxial vertical* is similar to the vertical dipole (and, in fact, it can be argued that it is a form of vertical dipole) in that it uses a pair of vertical radiator elements. In the case of the coaxial vertical antenna, however, the radiator that is closest to the ground is coaxial with the transmission line and the main radiator element. An example is shown in Fig. 7-11A. An insulator at the feedpoint separates the two halves of the radiator; in most cases, it is of smaller diameter than the coaxial sleeve (also called the *shield pipe* in some publications). The reasons for this arrangement are not entirely electrical, for the most part, but mechanical. The coaxial cable transmission line passes through the sleeve, and is itself coaxial to the sleeve.

The overall length of the coaxial vertical antenna is a half-wavelength, which consists of two quarter-wavelength sections. Both the radiator and the sleeve are quarter-wavelength. The length of each is found (approximately) from

$$L_{\mathrm{ft}} = \frac{234}{F_{\mathrm{MHz}}} \tag{7.3}$$

or

$$L_{\mathrm{meters}} = \frac{72}{F_{\mathrm{MHz}}} \tag{7.4}$$

You should recognize these as similar to the equation used previously to calculate half-wavelength antennas, but reduced by a factor of 2.

The coaxial vertical antenna was once popular with CB operators, and as such was called the *collinear antenna*. In some cases, you can find hardware from these antennas on the hamfest or surplus markets, and the pieces can be modified for amateur radio use. In the situation where a 10-m-band antenna is being built, it is a simple matter to cut the 11-m CB antenna for operation on a slightly higher frequency. In the case of the lower-frequency bands, however, it is a little more difficult and it is likely that only the insulator and mounting assembly are salvageable. Keep in mind, however, the fact that adjacent sizes of aluminum tubing are designed such that the inside diameter (ID) of the larger piece is a slip-fit for the outside diameter (OD) of the smaller piece. You can, therefore, connect adjacent sizes of aluminum tubing together without the need for special couplers, etc. With that in mind, salvaged insulator assemblies can be cut off with just 6 to 10 in of the former radiator and sleeve, and new radiators from “adjacent size” tubing installed.

The configuration shown in Fig. 7-11A is the manner of construction used by commercial antenna manufacturers for VHF and CB collinear vertical dipoles, but is a little difficult for amateurs (unless they happen to own a machine shop) to make the center insulator. For those people, some other method is indicated before this antenna is practical.

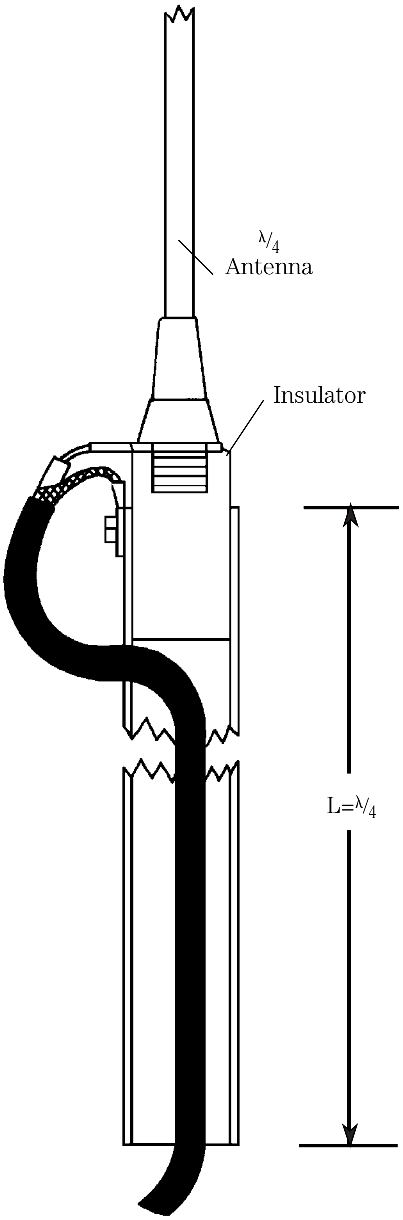

7-11A Construction of the vertical coaxial antenna.

Figure 7-11B shows a construction method that has been used by amateurs with good results. The radiator and shield pipe (sleeve) are joined together in an insulating piece of thick-wall PVC plumbing pipe, Lucite, or plexiglass tubing; 6 to 10 in of tubing are needed.

A gap of about 2 in is left between the bottom end of the radiator pipe and the top end of the shield pipe in order to keep them electrically insulated from each

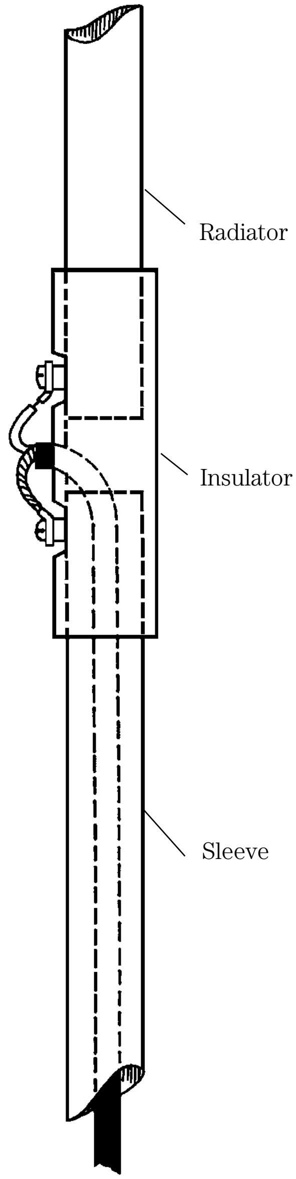

7-11B Vertical dipole made from tubing.

other, and to allow the coaxial cable to be passed through to the outside world. A hole in the insulator pipe is drilled for this purpose.

The aluminum tubing pieces for the radiator and the sleeve are fastened to the insulator with at least two heavy machine screws each. One of the machine screws on each can be used as the electrical connection between the coaxial cable and the pipes, provided that a larger hole is cut in the insulator at that point to admit the washer that provides the electrical pathway between the screw head and the aluminum pipe.

If you depend upon the machine screw touching the pipe at the edges of the hole cut for it, then there will probably be intermittent connection and all of the aggravation that ensues.

Mounting of the homebrew coaxial vertical antenna can be a "pain in the neck." Normally, this antenna is mounted high in the air above ground, so some form of support is needed. Fortunately, you can use small-area metal supports connected to the sleeve for this purpose. Figure 7-11C shows one method for mounting that is popular. A pair of television antenna standoff mounting brackets are used to support the sleeve. Those brackets can be bought in sizes from 6 to 24 in. Note that a 2 × 4 piece of lumber is used between the building wall and the brackets. This wood serves as an

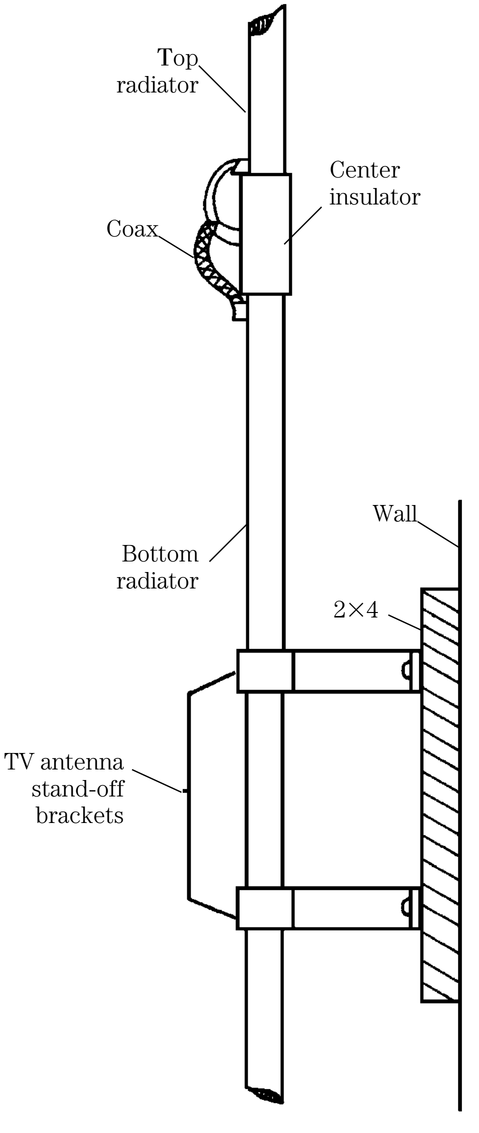

7-11C Mast mounting system for verticals.

insulator, so it should be varnished or painted. It is held to the wall with lag bolts, wing bolts, or some other effective method of anchoring. Keep in mind that the forces on the brackets increase tremendously during wind storms!

It is possible for the two vertical antennas shown previously to become a shock hazard to anyone who touches them. Both of these antennas are half-wavelength radiators and are of the dipole form of construction. The center point is used for feeding the antenna, so it forms the low-impedance point in the antenna. As a result, the ends of the antenna, one of which is close to the ground, are the high-impedance points—hence the voltages at those points within reach of prying hands playing in the yard can be high. It is wise to either mount the antennas so far above the ground that they cannot be reached, or build a small nonconductive fence around the bottom end of the antenna.

Vertical antenna construction

There are two general cases for installing vertical antennas: ground-level-mounted and non-ground-mounted. This section takes a brief look at both forms of mounting. We will concentrate on installation of homebrew verticals rather than commercial, because it is assumed that the vendors of such antennas will provide their own instructions.

The ground-level-mounted vertical is shown in Fig. 7-12. The typical vertical antenna is 8 to 40 ft high. Thus, although the actual weight of the antenna is small, the forces applied to the mounting structure (especially during windstorms) can be quite high. Don't be fooled by the apparent light weight of the antenna in this respect.

The mounting structure for the vertical antenna can be a metal or wooden fence post buried in the ground. At least 2 ft of the fence post should be above ground. In the case of Fig. 7-12, a 4 × 4 wooden fence post is used as the mounting, but the principles are similar for all forms of post. A fence post hole is provided that is at least 2 ft deep. In some cases, it might be possible to use a 1-ft-deep gravel fill topped with back-filled dirt. In other cases, especially where a steel fence post is used, a concrete plug is placed at the bottom of the hole over a 4-in layer of gravel.

The antenna radiator element is installed onto the fence post using standoff insulators. Unfortunately, these insulators are difficult to find, so they might have to be omitted. Given that varnished or painted wood is not a terribly good conductor, it is not unreasonable to bolt the radiator directly to the 4 × 4 fence post. Use $\frac{5}{16}$-in (or larger) bolts, and make them long enough to fit completely through both the antenna element and the 4 × 4 post. Thus, 6-in-, 7-in-, or 8-in-long $\frac{5}{16}$-in bolts are the candidates for this job. Use at least two bolts, one at the bottom of the antenna radiator element, and one near the top of the fence post. A third bolt, halfway between the other two, would not be out of order.

If the antenna is quarter-wavelength, then no matching is generally necessary. Although the feedpoint impedance is not exactly 52 Ω, it is close enough (37 Ω) to form a reasonable match for 52-Ω coaxial cable (with VSWR = 1.4:1). The center conductor of the coaxial cable is connected to the radiator element, while the shield is connected to the ground system. In the example shown in Fig. 7-12, two ground methods are used. First, an 8-ft ground rod is driven into the earth at the base of the

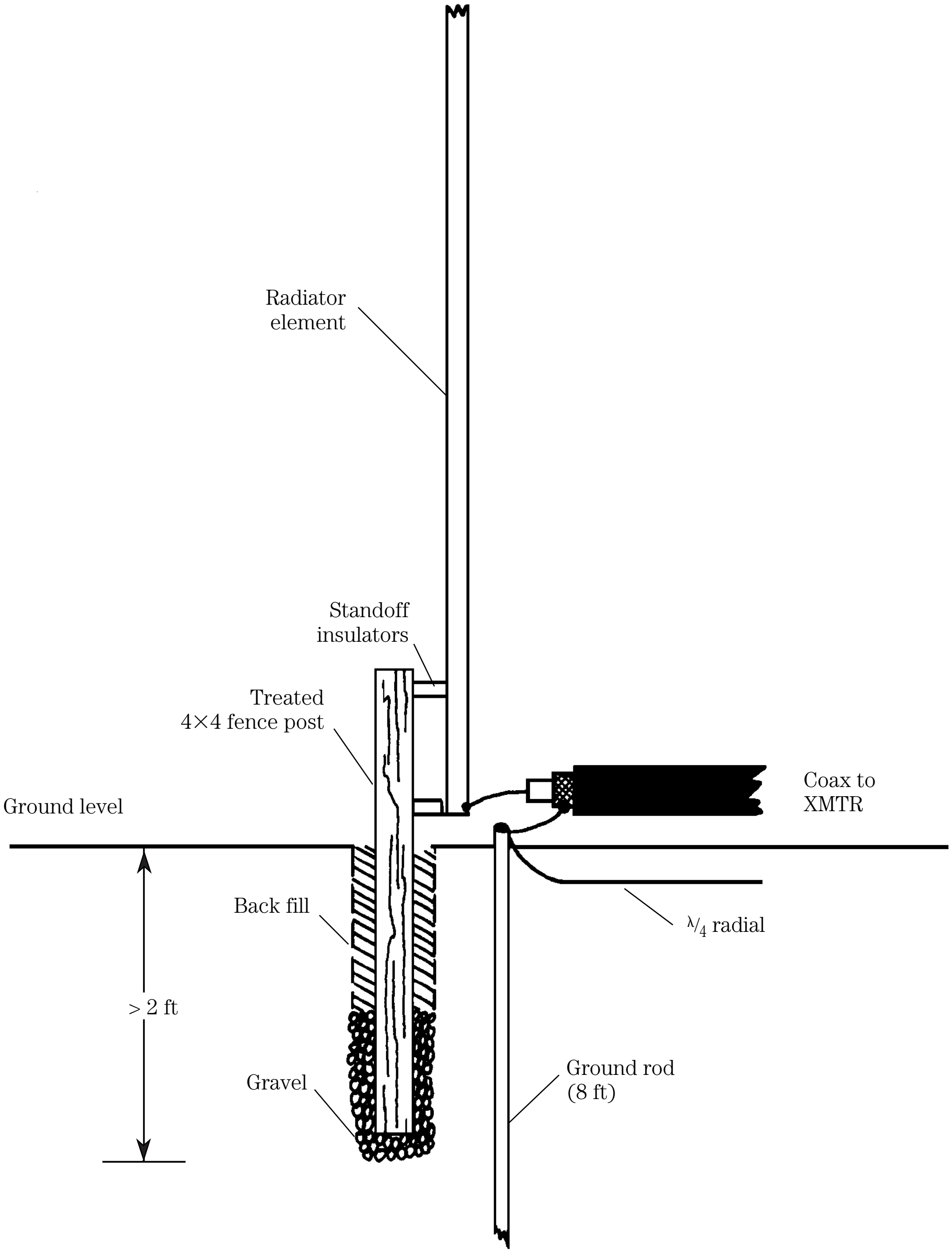
Radiator
element
Standoff
insulators
Treated
4×4 fence post
Coax to
XMTR
Ground level
Back fill
λ/4 radial
> 2 ft
Gravel
Ground rod
(8 ft)

7-12 Ground-mounted vertical.

antenna; second, a system of quarter-wavelength radials is used. Remember that the ground system is absolutely essential.

A method for installing a vertical antenna above ground is shown in Fig. 7-13. In this case, a wooden support (2 × 4 or 4 × 4) is installed in a manner similar to Fig. 7-12, but with a deeper hole to counter the longer length. Alternatively, the wooden support is affixed to the side of a building wall, shed, or other preexisting structure. Once the support is arranged, however, the method of attachment of the radiator element is the same for the previous case, so that will not be repeated here.

Electrical connections to the antenna are also shown in Fig. 7-13. Because the antenna is above ground level, an electrical counterpoise ground consisting of a system of radials is absolutely essential; at least two radials per band must be provided. A small L bracket is used to support the radials and to provide an SO-239 coaxial connector for the coax. This connector is a chassis-mounted type with its center conductor connected to the radiator element. The shield of the connector is connected to the bracket, so it is also connected to the radial system.

In some installations, the antenna support structure will require guy wires to keep the structure stable. Do not use the radials as guy wires. The type of wire that normally works well for radials is too soft, and too easily stretched, for guy wire service. Use regular steel guy line, available where TV antenna supplies are sold, for this antenna. Make the lengths nonresonant, and break the guy lines up with egg insulators, if necessary, to achieve the nonresonance.

⅝-Wavelength verticals

Figure 7-14 shows the configuration for the ⅝-wavelength vertical antenna. Such an antenna generally gives a lower angle of radiation than the more common quarter-wavelength radiator, so presumably it works better for long distance.

The radiator of this antenna is made from 0.5-in to 1.5-in aluminum tubing. Again, remember that adjacent sizes fit together snugly to form longer sections. The physical length of the ⅝-wavelength radiator is found from

$$L_{\text{ft}} = \frac{585}{F_{\text{MHz}}} \qquad \textbf{[7.5]}$$

or, in meters,

$$L_{\text{meters}} = \frac{180}{F_{\text{MHz}}} \qquad \textbf{[7.6]}$$

The radials are the usual quarter-wavelength, and are made of no. 12 or no. 14 copper wire. These lengths are found from:

$$L_{\text{ft}} = \frac{246}{F_{\text{MHz}}} \qquad \textbf{[7.7]}$$

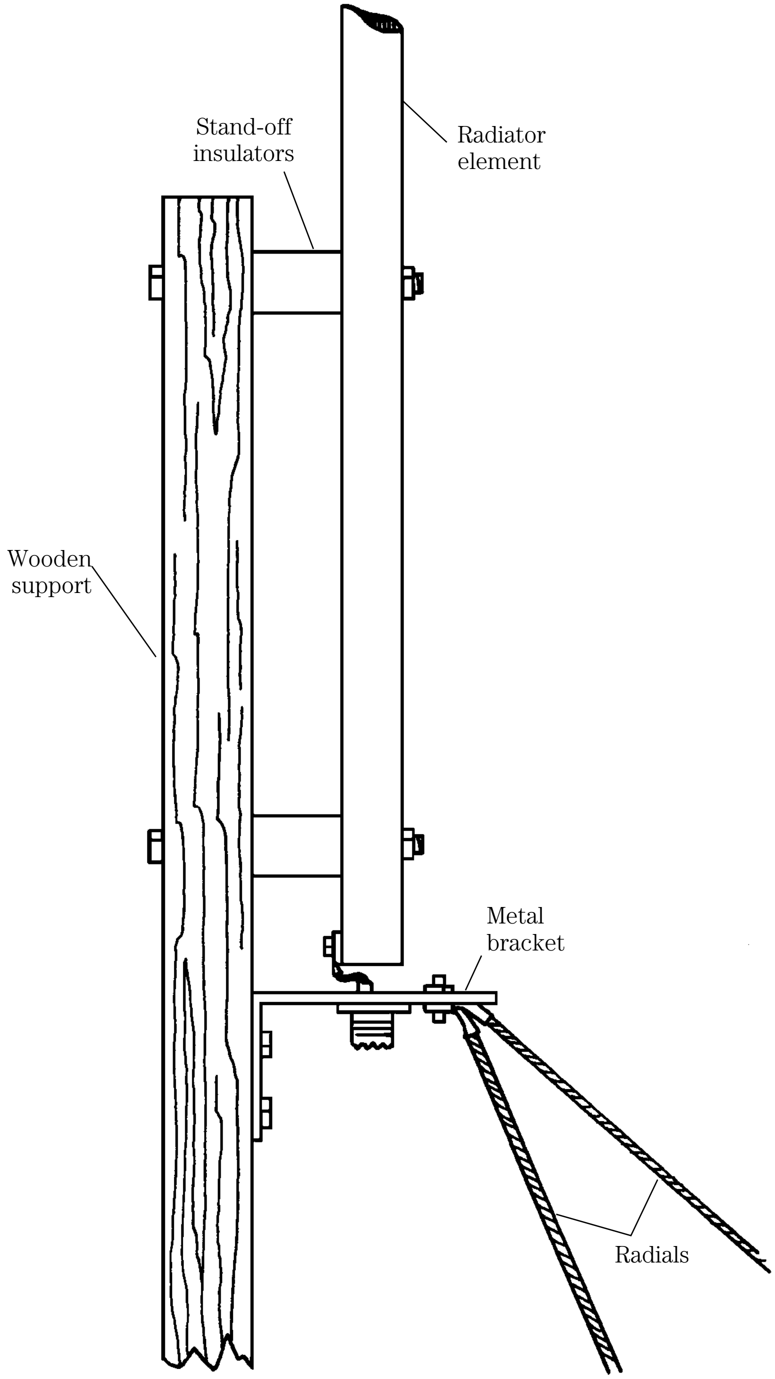
Stand-off insulators
Radiator element
Wooden support
Metal bracket
Radials

7-13 Details of feedpoint circuit on vertical.

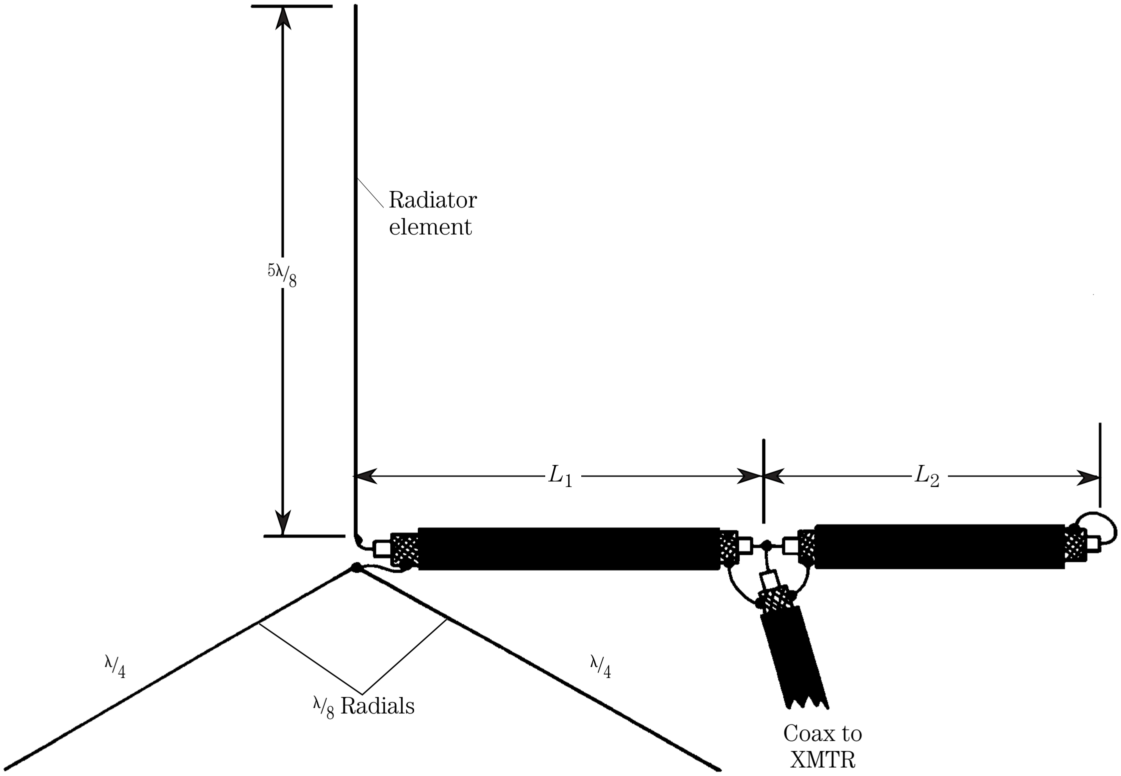

7-14 Using a Q section to match the feedpoint impedance of a vertical antenna.

or, in meters,

$$L_{\text{meters}} = \frac{75}{F_{\text{MHz}}} \tag{7.8}$$

The feedpoint impedance of the ⅝-wavelength antenna is about 1600 **Ω**, not a good match for the ordinary coaxial cables that are routinely available on the amateur market. Some form of impedance matching is needed.

One option is to use a broadbanded RF transformer. These transformers will work throughout the HF spectrum, and match a wide variety of impedances to the 50-**Ω** standard system impedance.

Another option, especially for a single-band antenna, is to use a coaxial cable impedance transformer, such as shown in Fig. 7-14. The transformer consists of two sections of coaxial cable joined together, shown as L_1 and L_2 in Fig. 7-14. The lengths are found from

$$L_1 = \frac{122}{F_{\text{MHz}}}\ \text{ft} \tag{7.9}$$

or

$$L_1 = \frac{38}{F_{\text{MHz}}}\ \text{m} \tag{7.10}$$

and

$$L_2 = \frac{30}{F_{\text{MHz}}}\ \text{ft} \tag{7.11}$$

$$L_2 = \frac{9}{F_{\text{MHz}}}\ \text{m} \tag{7.12}$$

Grounded vertical antennas

The vertical antennas presented thus far in this chapter are called *series-fed verticals*, because the generator is essentially in series with the radiator element. Such an antenna must be insulated from ground. The other class of vertical is the *shunt-fed vertical*, which is grounded at one end (Fig. 7-15). There are three methods of shunt-feeding a grounded vertical antenna: *delta, gamma*, and *omega*. All three matching systems have exactly the same function: to form an impedance transformation between the antenna radiation resistance, at the feedpoint, and the coaxial cable characteristic impedance, as well as cancelling any reactance in the system.

The delta feed system is shown in Fig. 7-15A. In this case, a taut feed wire is connected between a point on the antenna, which represents a specific impedance on

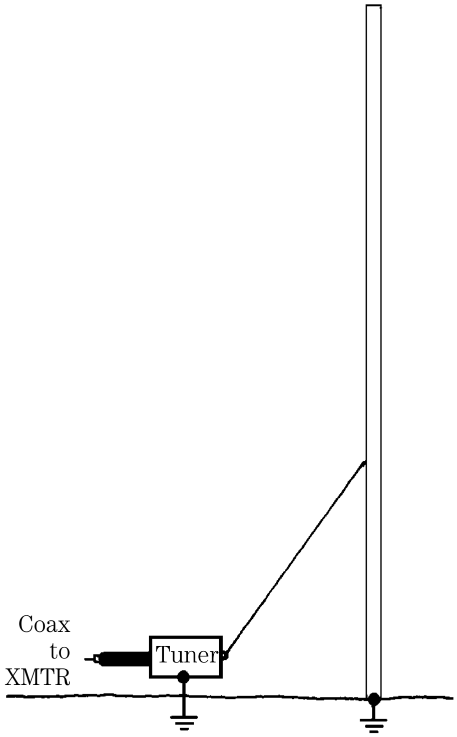

7-15A Delta-fed grounded vertical.

the antenna, and an antenna tuner. This method of feed is common on AM broadcast antennas (which are usually—perhaps always—verticals). Although you would think that the sloping feed wire would distort the pattern, that is not the case. The distortion of the pattern, if any, is minimal, hence it can be neglected.

The gamma feed system is shown in Fig. 7-15B. This method is commonly used by amateurs to feed Yagi beam antennas, so it is quite familiar in the amateur radio world. The feed system consists of a variable capacitor to tune the system, and a matching rod that parallels the antenna radiator element. It is important that the rod not be anywhere near a quarter-wavelength, or it would become a vertical antenna in its own right, and in fact would resemble the so-called *J-pole antenna*. A review of the gamma match is given in Chap. 12. The omega feed (shown in Fig. 7-15C) is similar to the gamma match except that a shunt capacitor is used.

Conclusion

The vertical antenna is a viable alternative for many situations, especially where real estate is at a premium. Contrary to popular opinion, the vertical antenna works well when installed properly and when due consideration has been given to matters such as the grounding and angle of radiation desired.

7-15B Gamma-fed grounded vertical.

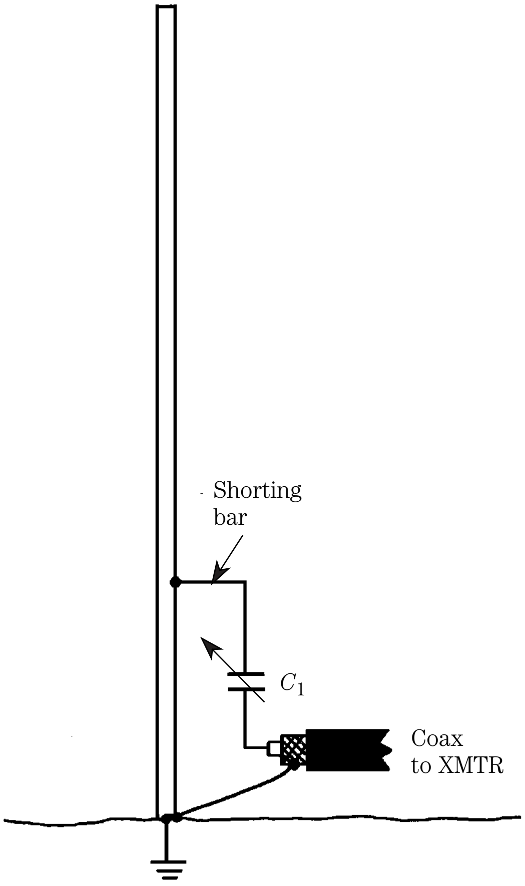

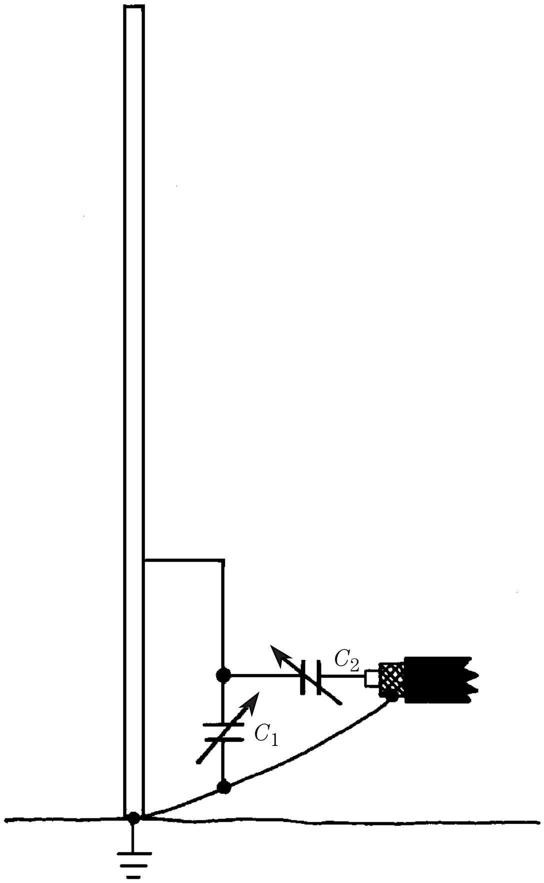

7-15C Omega-fed grounded vertical.

8
CHAPTER
Multiband and tunable-wire antennas

MOST COMMUNICATIONS OPERATORS REQUIRE MORE THAN ONE BAND, AND THAT MAKES the antenna problem exactly that—a problem to be solved. Amateur radio, commercial, and military operators are especially likely to need either multiple antennas for different bands, or a multiband antenna that operates on any number of different bands. This situation is especially likely on the high-frequency (HF) bands from 3.5 to 29.7 MHz.

Another problem regards the tunability of an antenna. Some amateur bands are very wide (several hundred kilohertz), and that causes any antenna to be highly variable from one end of the band to another. It is typical for amateurs to design an antenna for the portion of the band that they use most often, and then tolerate a high VSWR at the other frequencies. Unfortunately, when you see an antenna that seems to offer a low VSWR over such a wide range, it is almost certain that some problem exists that reduces the Q, and the antenna efficiency, to broaden the response. However, it is possible to tune an antenna for a wide band. It is also possible (now that amateurs have new HF bands) to use a single antenna between them, and then tune the difference out. For example, designing a single antenna for 21/24 MHz, 14/18 MHz, or 7/10 MHz should prove possible.

In this chapter we will take a look at both problems: the multiband and the tunable antenna.

Multiband antennas

Although a triband Yagi or quad beam antenna will undoubtedly work better than a wire antenna (when installed correctly!), the low-budget amateur operator need not lament any supposed inability to "get out" on wire antennas. To quote an old saying: "'Better' is the enemy of 'good enough.'" Or, to put it in terms of *Carr's law:* "If it's 'good enough' then don't waste a lot of energy fretting over making it 'better' unless you really want to make it *a lot better*."

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Trap dipoles

Perhaps the most common form of multiband wire antenna is the *trap dipole* shown in Fig. 8-1A. In this type of antenna, one (or more) pairs of parallel resonant traps are placed in series with the quarter-wavelength elements of the dipole. The purpose of the traps is to block their own resonant frequency, while passing all other frequencies.

In the example of Fig. 8-1A, a 10-m trap isolates the first 8 ft or so (quarter-wavelength on 10 m) so that the antenna resonates on that band. A 40-m or 15-m signal, on the other hand, passes through the traps and uses the whole length of the antenna. (*Note*: A half-wavelength 40-m dipole works as a 3/2-wavelength antenna on 15 m.)

The overall length of the trap dipole will be a little less than the natural "non-trap" length for the lowest frequency of operation. At the low frequencies, the traps add a little inductance to the circuit so that the resonant point is lower than the natural resonant frequency. In general, most trap dipoles are just a few percent shorter than nontrap dipoles at the same band. The actual amount of shortening depends upon the values of the components in the traps, so consult the data for each trap purchased. Where more than one pair of traps is used in the antenna, make sure they are of the same brand and are intended to work together.

Another solution to this problem is shown in Fig. 8-1B. This type of antenna actually has two or more half-wavelength dipoles fed from the same transmission line. In this illustration, a total of three dipoles are fed from the same 75-Ω transmission line. There is no theoretical limit to how many dipoles can be accommodated, although there is certainly a practical limit. For one thing, there is a mechanical limit to how many wires are supportable (or desirable) hanging from any given support. There is also an electrical limit, although it is less defined. Having a lot of dipoles increases the possibility of radiating harmonics and other spurious emissions from your transmitter.

The 75-Ω coaxial cable is connected to the center feedpoint of the multidipole either directly or through a 1:1 balun transformer, as shown in Fig. 8-1B. Each an-

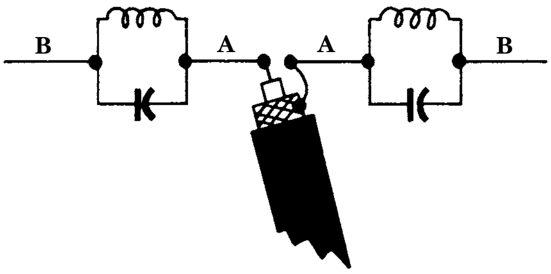

A=10-meter segment
A+B=15-meter/40-meter segment

8-1A Trap dipole for multiband operation. (*Courtesy of Hands-On Electronics and Popular Electronics*)

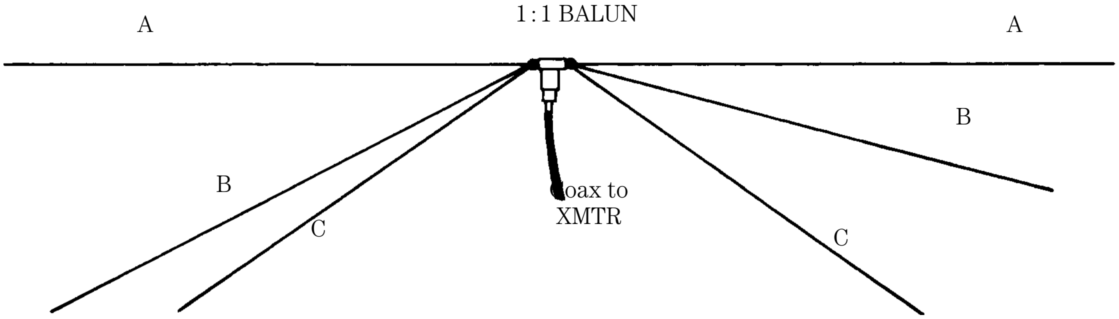

8-1B Multiband dipole consists of several dipoles fed from a common feedline.

tenna (*A-A*, *B-B*, or *C-C*) is a half-wavelength. Therefore, the overall length is found approximately from the standard dipole expressions:

Overall length ($A + A$, $B + B$, or $C + C$):

$$L_{\mathrm{ft}} = \frac{468}{F_{\mathrm{MHz}}} \qquad \textbf{[8.1]}$$

or, for each element alone (*A*, *B*, or *C*):

$$L_{\mathrm{ft}} = \frac{234}{F_{\mathrm{MHz}}} \qquad \textbf{[8.2]}$$

As always, close to the earth's surface, these equations are approximations, and are not to be taken too literally. Some experimentation will probably be necessary to optimize resonance on each band. Also, be aware that the drooping dipoles (*B* and *C* in this case) may act more like an inverted-vee antenna (see Chap. 7) than a straight dipole, so the equation length will be just a few percent too short. In any event, a little spritzing with this antenna will yield results.

Some amateurs build the multiple dipole from four- or five-wire TV rotator lead. That type of wire is used to control antenna rotators, and has either four or five parallel wires in a flat arrangement similar to lamp cord. Cut each wire to the length required for a band, and strip off any unused portions.

Another possibility is the link-tuned dipole shown in Fig. 8-1C. In this situation, a single conductor is used for each half of the dipole, or actually inverted vee. The conductors are broken into segments A, B, and C (or more, if desired). Each segment is separated from the two adjacent sections by inline insulators (standard end insulators are suitable). Segment A is a quarter-wavelength on the highest frequency band of operation, $A + B$ is a quarter-wavelength on the next highest band of operation, and $A + B + C$ is a quarter-wavelength on the lowest frequency band of operation.

The antenna is "tuned" to a specific band by either connecting, or disconnecting, a similar wire (see inset) jumper across the insulator that breaks the connection between the segments. Either a switch or an alligator clip jumper will short out the insulator to effectively lengthen the antenna for a lower band. Some amateurs use single-pole 110-Vac power line switches to jumper the insulator. Although I have not tried this method, it should work.

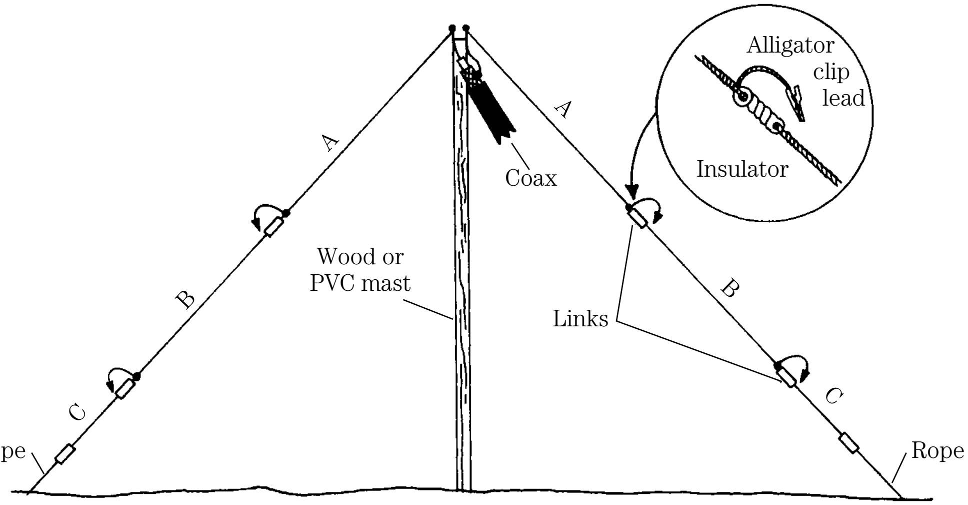

8-1C Multiband inverted vee uses shorting links to change bands.

A big disadvantage to this type of multiband antenna is that you must go out into the yard and manually switch the links to change bands, which probably explains why other antennas are a lot more popular, especially in northern latitudes.

Tuned feeder antennas

Figure 8-2A shows the tuned feeder type of antenna. This antenna can be used from 80 through 10 m, but it requires a special tuner and a length of parallel transmission line. There are two ways to get parallel transmission line: make it or buy it. Using no. 14 or 12 wire, and specially made insulators (also called *spreaders*), you can make 300-, 450-, or 600-Ω parallel transmission line. But that's a pain in the *ptusch* because you can also buy parallel line rather cheaply. I paid $16 for 100 ft of 450-Ω line recently.

One form of parallel line is ordinary TV-type twin lead, which has an impedance of 300 Ω. This line will take up to about 250 W, although some people use it at higher powers (not recommended!). The antenna of Fig. 8-2A uses 450-Ω parallel line. You can buy insulated 450-Ω twin lead (see Fig. 8-2B) that can be handled as easily as TV twin lead—and a lot more easily than open (uninsulated) parallel line.

The G5RV multiband dipole

Figure 8-3 shows the popular G5RV antenna. Although not without some problems, this antenna is very popular. It can be used either as a horizontal dipole, a sloper, or an inverted-vee antenna (which is how I used it). The dipole elements are each 51 ft long. The feedline can be either 300- or 450-Ω twin lead. For 300-Ω cases, use 29 ft of line, and for 450-Ω line, use 34 ft. One end of the parallel transmission line is connected to the antenna, and the other end is connected to a length of 50-Ω coaxial

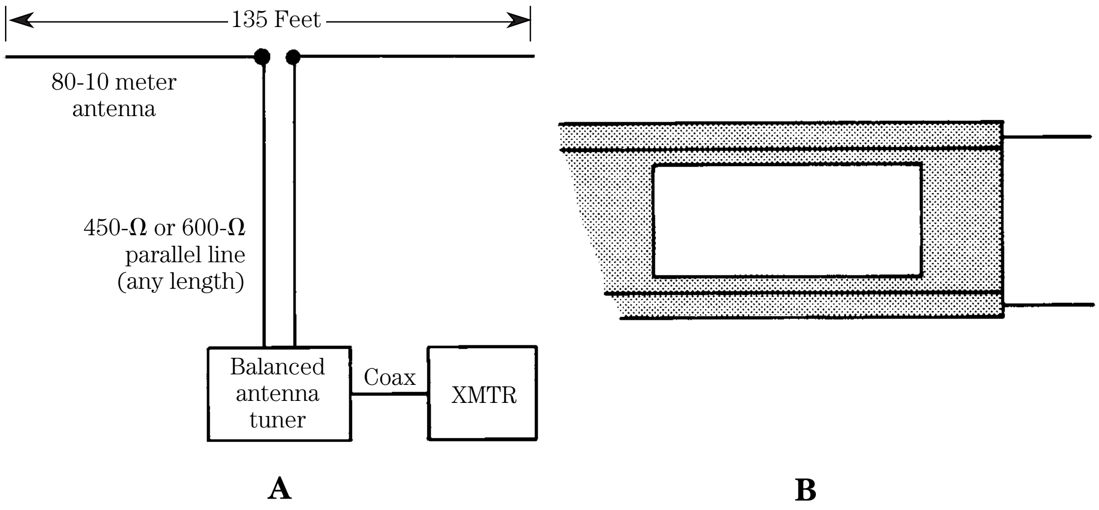
135 Feet
80-10 meter antenna
450-Ω or 600-Ω parallel line (any length)
Balanced antenna tuner
Coax
XMTR
A
B

8-2 Tuned feeder antenna can be used on several bands. (*Courtesy of Hands-On Electronics and Popular Electronics*)

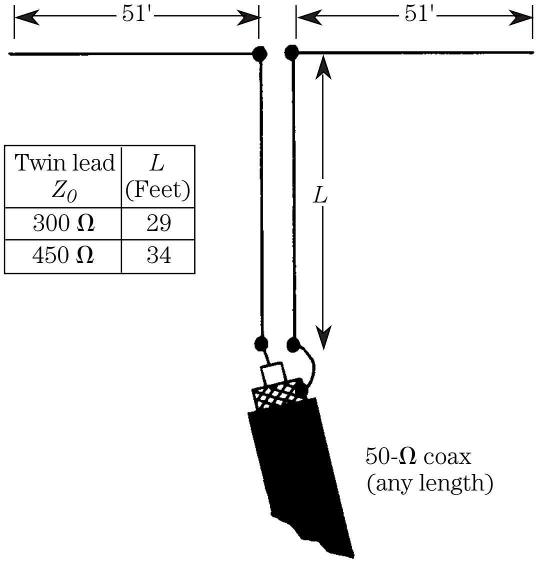
51'
51'
L
50-Ω coax (any length)

Twin lead Z_0	L (Feet)
300 Ω	29
450 Ω	34

8-3 G5RV antenna. (*Courtesy of Hands-On Electronics and Popular Electronics*)

cable. Although most articles on the G5RV claim that any length of 50-Ω line will work, J. M. Haerle (*HF Antenna Systems: The Easy Way*) recommends that the 50-Ω segment should be at least 65 ft long.

Haerle is a little caustic in his comments on the G5RV, but his criticism is well taken. If you don't have a parallel transmatch, then the G5RV will work (especially if your rig can tolerate a 3:1 VSWR on some selected frequencies). Otherwise, use the antenna of Fig. 8-2A (or a transmatch with the G5RV).

Figure 8-4 shows the once-popular end-fed Zepp antenna. This antenna is a "monopole" in that it uses a half-wavelength radiator, but it is fed at a voltage loop rather than a current loop (i.e., the end of the antenna rather than the center). A 450- or 600-Ω parallel transmission line is used to feed the Zepp antenna. Although the line can theoretically be any length, practicality dictates a quarter-wavelength because of the fact that the antenna is fed at a high RF voltage point.

The Zepp (as shown) is a single-band antenna unless the transmission line is fed with a good, widerange transmatch, or other antenna tuner unit. The antenna tuner required is a balanced type, although a standard transmatch with a 4:1 balun transformer at the output will also work well. Using the Zepp on many bands is easy, but keep in mind that it is voltage-fed, and (at frequencies for which the parallel line is not an odd integer multiple of a quarter-wavelength) there will be a high-voltage node at the transmatch. That raises the possibility of "RF in the shack"—"hot" snippets of RF on the grounded chassis of station equipment (including microphones, where it is uncomfortable when touched to the lips).

Feeding parallel transmission line

Parallel transmission line is *balanced* with respect to ground, but coaxial cable is *unbalanced* to ground (i.e., one side of the coax is usually grounded). As a result, the standard amateur transmitter output will not drive parallel (balanced) feedline properly. You need to do one of two things: (1) buy (or build) an antenna tuner that is balanced on the output and unbalanced on the input or (2) convert a standard "coax-to-coax" transmatch or other form of antenna coupler to "coax-to-balanced" configuration. In some cases you can use a 4:1 balun transformer at the output of the coaxial cable tuner. Keep in mind, however, that some tuner manufacturers recommend against this practice. If you use the standard tee-network (or SPC) transmatch

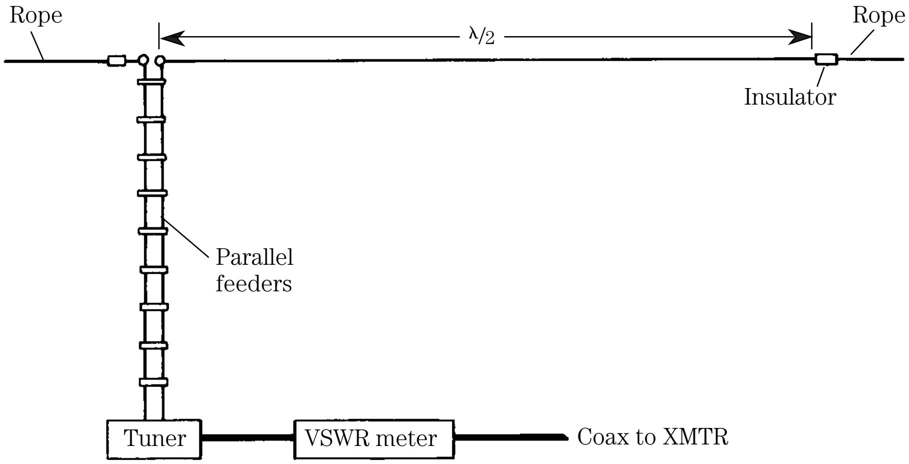

8-4 End-fed Zepp antenna.

then it is possible to make a balun for this purpose from some no.12 formvar- or enamel-covered wire and either a ferrite toroid or a short piece of PVC plumbing pipe. Figure 8-5 shows a balun coil construction project. Use 12 turns of no.12 formvar or enameled wire over a 1-in outside diameter piece of PVC pipe or tubing.

Next, we have the so-called longwire antenna. I use the term *so-called* because not all long wire antennas are truly longwires. A true longwire is longer than two wavelengths at the lowest frequency of operation. In Fig. 8-6 we see a longwire, or "random-length," antenna fed from a tuning unit. If the antenna length L is greater than a quarter-wavelength, then the tuner consists of a single series capacitor (see below); and if it is shorter than a quarter-wavelength, the tuner is a series inductor. The standard tuner for this type of antenna, regardless of length, is a simple L-section coupler (also shown), which can be selected for L-section, series-L or series-C operation.

The Windom antenna (Fig. 8-7) has been popular since the 1920s. Although Loren Windom is credited with the design, there were actually a number of contributors. Coworkers with Windom at the University of Illinois were John Byrne, E. F. Brooke, and W. L. Everett, and they are properly cocredited. The designation of Windom as the inventor was probably due to the publication of the idea (credited to Windom) in the July 1926 issue of *QST* magazine. Additional (later) contributions were rendered by G2BI and GM1IAA (Jim MacIntosh). We will continue the tradition of crediting Loren Windom, with the understanding that others also contributed to this antenna design.

The Windom is a roughly half-wavelength antenna that will also work on even harmonics of the fundamental frequency. The basic premise is that the antenna radiation resistance varies from about 50 Ω to about 5000 Ω, depending upon the

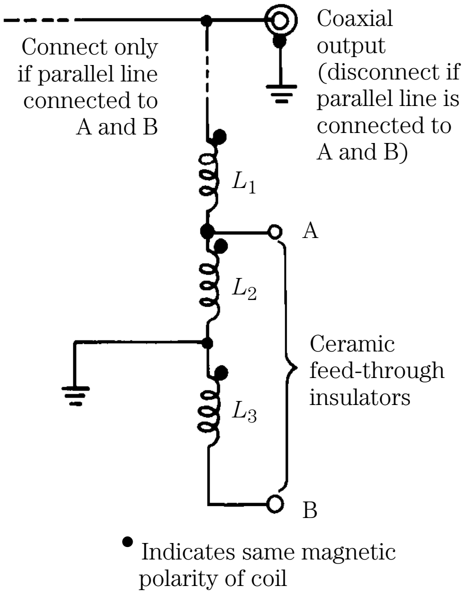
Connect only if parallel line connected to A and B
Coaxial output (disconnect if parallel line is connected to A and B)
L_1
A
L_2
Ceramic feed-through insulators
L_3
B
● Indicates same magnetic polarity of coil

8-5 Balun transformer converts coaxial line to parallel line feed system.

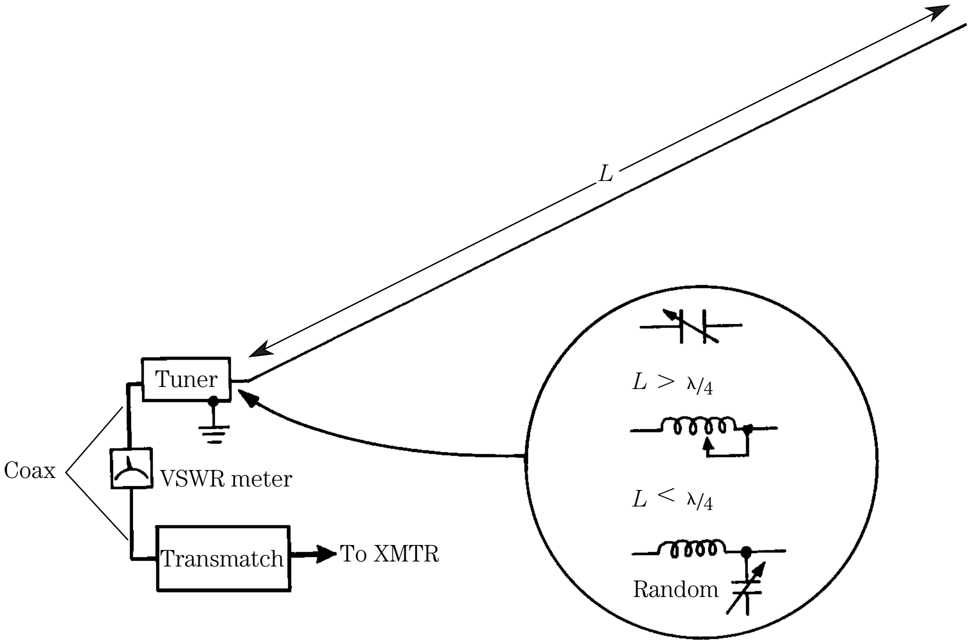

8-6 Random-length (a.k.a., if erroneously, “longwire”) antenna.

selected feedpoint. When fed in the exact center, a current loop, the feedpoint impedance will be 50 Ω; similarly, end feeding the antenna finds a feedpoint impedance of about 5000 Ω. In Fig. 8-7A the feedpoint is tapped away from the center at a point that is about one-third the way from one end, at a point where the impedance is about 600 Ω.

The Windom antenna works well—but with some caveats. For example, the antenna has a tendency to put “RF in the shack” because of the fact that it is voltage-fed. Second, there is some radiation loss from the feedline. Finally, the antenna works poorly on odd harmonics of the fundamental frequency.

The antenna tuning unit can be either a parallel resonant, link-coupled *LC* tank circuit (see inset to Fig. 8-7A); or a reversed pi network. In the case of the Windom, the pi network is turned around backward from the usual configuration: C_1 is at the low-impedance end of the network, so it is larger than C_2. Design a pi network (see programs at end of book) to match 50 Ω on the transmitter end and 600 Ω on the antenna end.

A reasonable compromise Windom that reduces feedline radiation losses is shown in Fig. 8-7B. In this antenna a 4:1 balun transformer is placed at the feed point, and this in turn is connected to 75-Ω coaxial transmission line to the transmitter. A transmatch, or similar antenna tuner, is then connected between the transmitter and the transmission line.

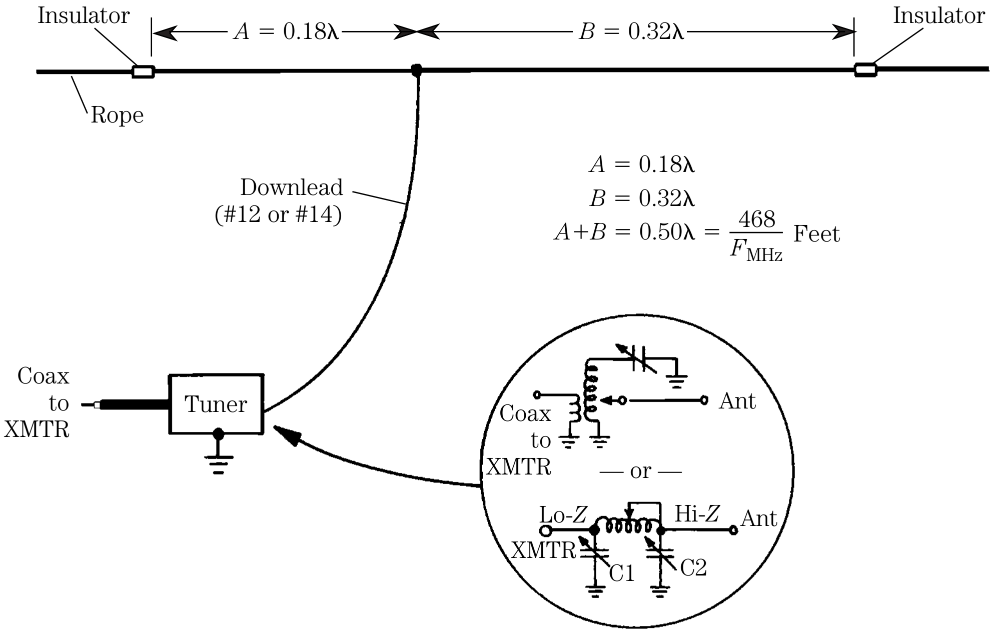
Insulator
A = 0.18λ
B = 0.32λ
Insulator
Rope
Downlead
(#12 or #14)
A = 0.18λ
B = 0.32λ
A+B = 0.50λ = 468/F_MHz Feet
Coax
to
XMTR
Tuner
Coax
to
XMTR
Ant
— or —
Lo-Z
Hi-Z
Ant
XMTR
C1
C2

8-7A Windom antenna.

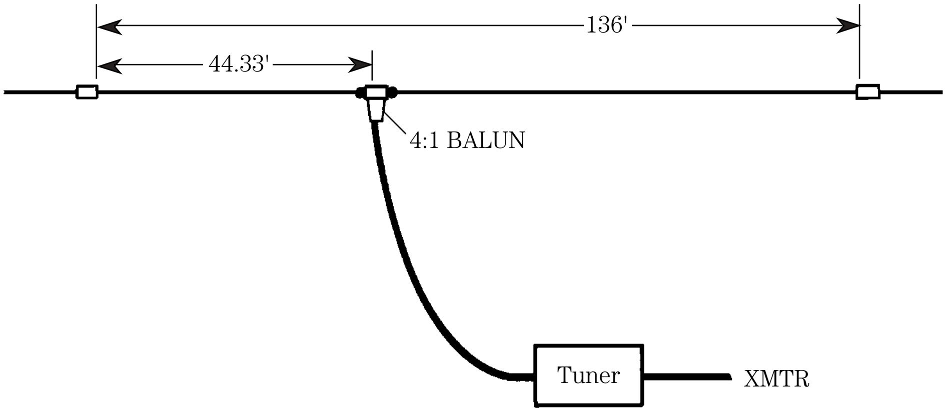
136'
44.33'
4:1 BALUN
Tuner
XMTR

8-7B Coaxial-fed Windom.

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9
CHAPTER
Longwire directional antennas

YOU'VE HEARD IT DOZENS OF TIMES: THE RANDOM-LENGTH LONGWIRE ANTENNA IS THE "perfect" solution to awkward antenna problems. Whether it's a lack of real estate, cranky landlords, or a profound lack of dollars, the random-length longwire will do the job for you. Right? Well, now, that depends on who you ask, and what they did to make it work— or not work. One person says the longwire is not worth a plugged nickel; another is very ho-hum about it because his "kinda works"; still another is enthusiastic because hers is installed correctly and it works better than anything "since sliced pickle and liverwurst sandwiches." Over the years my various living arrangements have forced me to use longwires at many QTHs, as well as on Field Day. Why does the random-length longwire have such a varied reputation? Before we answer that question let's find out (for those who came in late) just what is a longwire antenna.

As an aside, let me point out that random-length wire antennas (less than 2λ) are not true longwire antennas. However, common (if erroneous) usage compels the inclusion of both types.

Longwire antennas

Longwire antennas are any of several types of resonant and nonresonant antennas. Any given longwire antenna may be both resonant and nonresonant, depending upon the operating frequencies used. In the "old days," when I was first starting in amateur radio, most resonant longwires were resonant over all HF bands because those bands were harmonically related to each other. But with the addition of the 10-, 18-, and 24-MHz band segments, that relationship no longer holds true for all cases.

Figure 9-1 shows the classic random length, nonresonant longwire antenna. It consists of a wire radiator that is at least a quarter-wavelength long, but is most often longer than a quarter-wavelength. The specific length is not critical, but it must be *greater than a quarter-wavelength at the lowest frequency of operation anticipated*. If you have a 90-ft wire, it will work on all HF bands above 3.5 MHz. In

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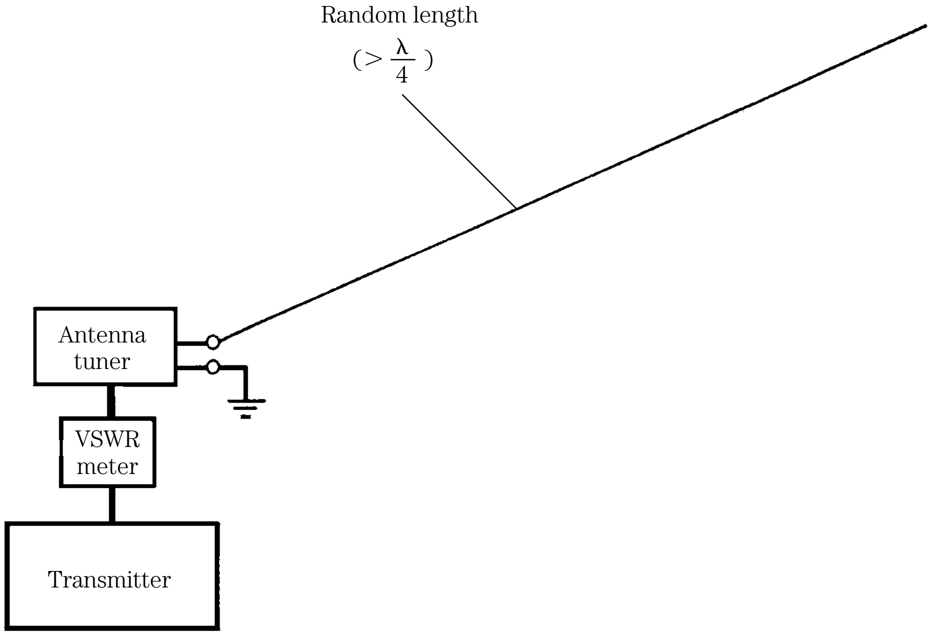

9-1 Random-length antenna.

most installations, the wire is no.12 and no.14 *copperweld*, or hard-drawn copper wire. I have successfully used both no.12 and no.14 house wire, but because it is solid (not stranded) it is not the best material. Stranded wire lasts longer in the wind, because solid wire fatigues and breaks quicker.

The longwire antenna is capable of providing gain over a dipole and a low angle of radiation (which is great for DX operators!). But these advantages are only found when the antenna is several wavelengths long, so it occurs only on typical HF antennas in the 21- through 29-MHz bands.

The longwire is end-fed, and therefore has a high impedance, except in those cases where the radiator happens to be quarter-wavelength. Because of this fact, it is necessary to use an antenna tuner between the low-impedance transmitter output (usually limited to 50- to 75-Ω impedances) and the antenna. You can buy any of several commercial antenna tuners, or make one yourself. Figure 9-2 shows a typical antenna tuner for longwires. It is an L-section coupler consisting of a series inductance and a shunt capacitance, both variable. The inductor can be homemade, or it can be made from a B&W miniductor (3029 is suitable). Alternatively, you can buy a used roller inductor from a hamfest. If you opt for the homemade or miniductor alternatives, then an alligator clip lead (short!) connected to one end of the coil can be used to short out unneeded turns when adjusting the inductance. I prefer the roller inductor method, because it allows the whole “shootin’ match” to be installed inside a shielded cabinet, helping the TVI/BCI (television interference/broadcast interference) situation.

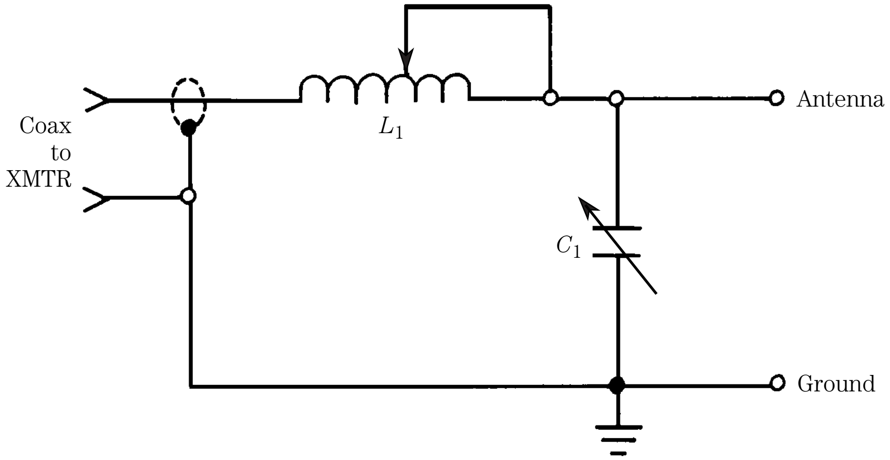

9-2 L-section coupler.

The capacitor (also available from the same sources) should be 150-pF to 250-pF maximum capacitance high-voltage variable. So-called transmitting variables are usually ok if the plate spacing is at least ⅛ in.

Tuning of the longwire is simplicity itself. If the tuner does not have a built-in VSWR meter, then install one in the line between the transmitter output and the tuner input. Adjust both L_1 and C_1 (they are a bit interactive so do it several times) for the lowest VSWR. If you use the alligator clip method, *turn off the darn transmitter before adjusting the clip position—RF burns are nasty!*

So what's the problem?

Ok, so we have decided to install a longwire. How do we make it work? First, make sure that it is long enough. The bare minimum lengths for HF bands are 70 ft for 3.5 MHz and up, 34 ft for 7 MHz and up, and so on. In general, the longer the better. The second problem is a *good ground*. The importance of a good ground cannot be underestimated, and it accounts for about 99 percent of the difference in reported performance of longwires.

A good ground consists of a short wire to either one very long ground rod or multiple ground rods spaced a couple feet apart. An important factor is the length of the ground wire. It must be considerably less than a quarter-wavelength. Use no.10 stranded wire (several parallel lengths) or braid.

When I was in college I lived on the second floor of a whacky student boarding house in Norfolk, VA. The ground was 24 ft away, and that made "short ground wire" a joke—and my longwire nearly inoperative. But I figured out a way around the problem. A quarter-wave radial was dropped out the window (see Fig. 9-3). Use more than one radial if possible. In one case, when the landlord was particularly cranky, I tacked the radial to the baseboard of my room (insulated on standoffs at the far end to protect against the high RF voltages present). It worked well!

A new product also comes to the rescue of those reader-hams who cannot put up a good longwire. The MFJ Enterprises (Box 494, Mississippi State, MS, 39762, 1-800-647-1800) model MFJ-931 artificial RF ground is installed in the ground line (see Fig. 9-4) and is used to tune the ground wire. Adjust the capacitance and inductance controls for maximum ground current as shown on the built-in meter. Be sure to follow the instructions, however, because high RF voltages can appear on a nonresonant ground wire. I wish I'd had one of these when I was in that whacky boarding house; discussing existentialist poetry can't hold a candle to DXing.

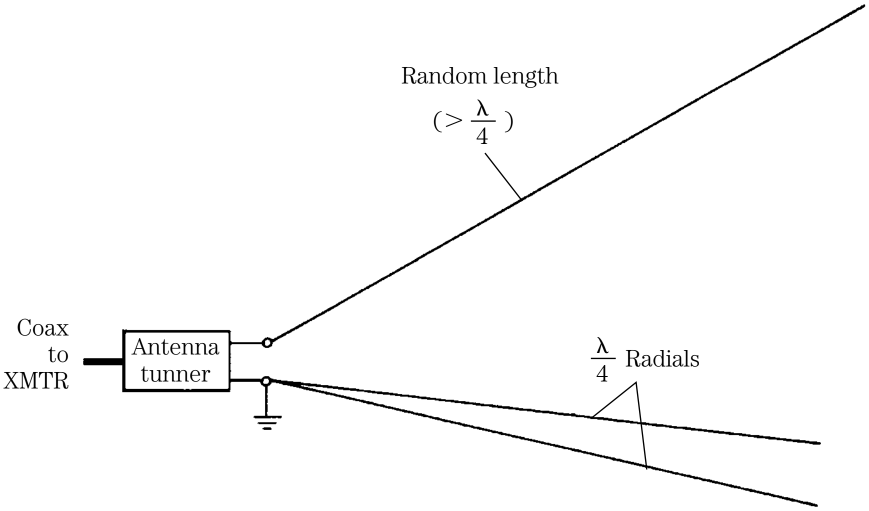
Random length
$(> \frac{\lambda}{4})$
Coax
to
XMTR
Antenna
tunner
$\frac{\lambda}{4}$ Radials

9-3 Radials improve the "ground" of random-length antenna.

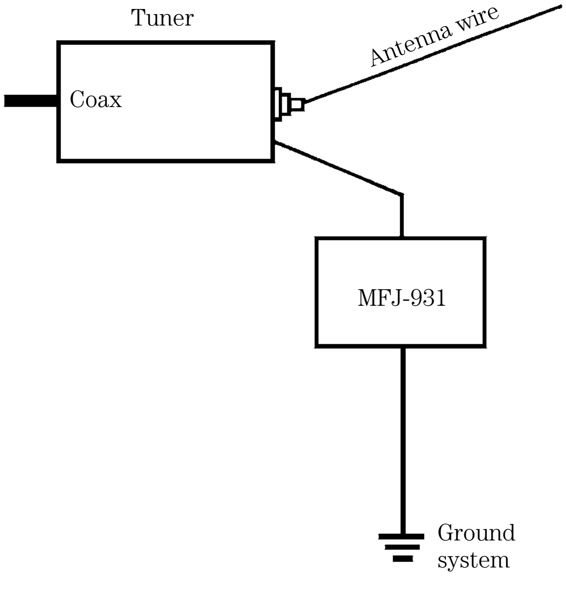
Tuner
Coax
Antenna wire
MFJ-931
Ground
system

9-4 MFJ ground line tuner installation.

When is a long wire a longwire?

For many years, the longwire has been a popular form of antenna. It is cheap, it is easy to construct, and—although reports vary—it has the potential to perform well. Properly constructed, it has a lot of utility. But what is a *real* longwire antenna? In past columns, I have used the term to mean an antenna such as Fig. 9-1. This form of antenna is popularly called a *longwire* if it is more than a quarter-wavelength. I and other authors have used the term longwire to mean this antenna, but that's not rigorously correct. A *true* longwire is an antenna that is many wavelengths long, or to be a little more rigorous, an antenna that is *more than two wavelengths long*. Although I will still use the term *longwire* for both forms of longwire antenna, proper rigor requires Fig. 9-1 to be called a "random-length antenna."

True longwire antennas

Figure 9-5 shows the true resonant longwire antenna. It is a horizontal antenna, and if properly installed, it is not simply attached to a convenient support (as is true with the random length antenna). Rather, the longwire is installed horizontally like a dipole. The ends are supported (dipole-like) from standard end insulators and rope.

The feedpoint of the longwire is one end, so we expect to see a voltage antinode where the feeder is attached. For this reason we do not use coaxial cable, but rather either parallel transmission line (also sometimes called *open-air* line or some such

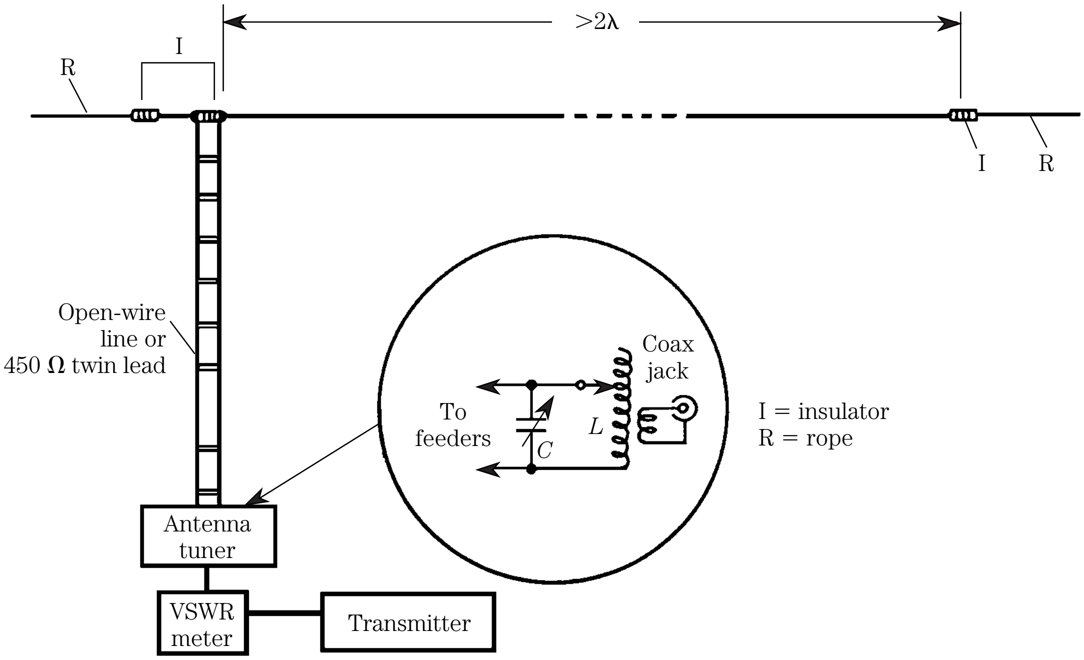

9-5 End-fed longwire with suitable tuner.

name), or 450-Ω twin lead. The transmission line is excited from any of several types of balanced antenna tuning unit (see Fig. 9-5). Alternatively, a standard antenna tuning unit (designed for coaxial cable) can be used if a 4:1 balun transformer is used between the output of the tuner and the input of the feedline.

What does "many wavelengths" mean? That depends upon just what you want the antenna to do. Figure 9-6 shows a fact about the longwire that excites many users of longwires: It has gain! Although a two-wavelength antenna only has a slight gain over a dipole; the longer the antenna, the greater the gain. In fact, it is possible to obtain gain figures greater than a three-element beam using a longwire, but only at nine or ten wavelengths.

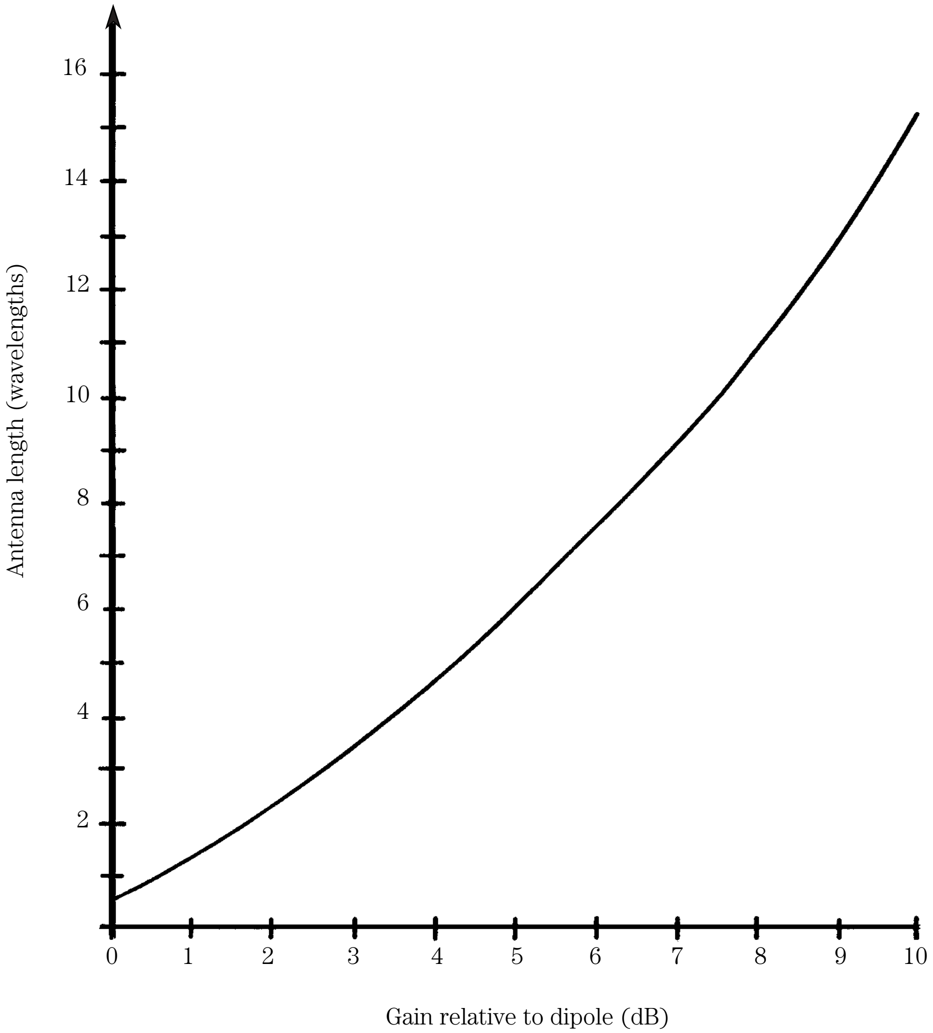

9-6 Antenna length versus gain over dipole.

What does this mean? One wavelength is $984/F_{\mathrm{MHz}}$ ft, so at 10 m (29 MHz) one wavelength is about 34 ft; at 75 m (3.8 MHz) one wavelength is 259 ft long. In order to meet the two-wavelength criterion a 10-m antenna need only be 68 ft long, while a 75-m antenna would be 518 ft long! For a ten-wavelength antenna, therefore, we would need 340 ft for 10 m; and for 75 m, we would need nearly 2,600 ft. Ah me, now you see why the longwire is not more popular. The physical length of a nonterminated resonant longwire is on the order of

$$L_{\mathrm{feet}} = \frac{492(N - 0.025)}{F_{\mathrm{MHz}}} \qquad \textbf{[9.1]}$$

(N is number of half-wavelengths in the radiator elements.)

Of course, there are always people like my buddy (now deceased) John Thorne, K4NFU. He lived near Austin, TX on a multiacre farmette that has a 1400-ft property line along one side. John installed a 1300 ft longwire and found it worked excitingly well. He fed the thing with homebrew 450-Ω parallel (open-air) line and a Matchbox antenna tuner. John's longwire had an extremely low angle of radiation, so he regularly (much to my chagrin on my small suburban lot) worked ZL, VK, and other Southeast Asia and Pacific basin DX, with only 100 W from a Kenwood transceiver.

Oddly enough, John also found a little bitty problem with the longwire that textbooks and articles rarely mention: electrostatic fields build up a high-voltage dc charge on longwire antennas! Thunderstorms as far as 20 mi away produce serious levels of electrostatic fields, and those fields can cause a buildup of electrical charge on the antenna conductor. The electric charge can cause damage to the receiver. John solved the problem by using a resistor at one end to ground. The "resistor" is composed of ten to twenty 10-MΩ resistors at 2 W each. This resistor bleeds off the charge, preventing damage to the receiver.

A common misconception about longwire antennas concerns the normal radiation pattern of these antennas. I have heard amateurs, on the air, claim that the maximum radiation for the longwire is

1. Broadside (i.e., 90°) with respect to the wire run or
2. In line with the wire run

Neither is correct, although ordinary intuition would seem to indicate one or the other. Figure 9-7 shows the approximate radiation pattern of a longwire when viewed from above. There are four main lobes of radiation from the longwire (*A*, *B*, *C*, and *D*). There are also two or more (in some cases many) minor lobes (*E* and *F*) in the antenna pattern. The radiation angle with respect to the wire run (*G*–*H*) is a function of the number of wavelengths found along the wire. Also, the number and extent of the minor lobes is also a function of the length of the wire.

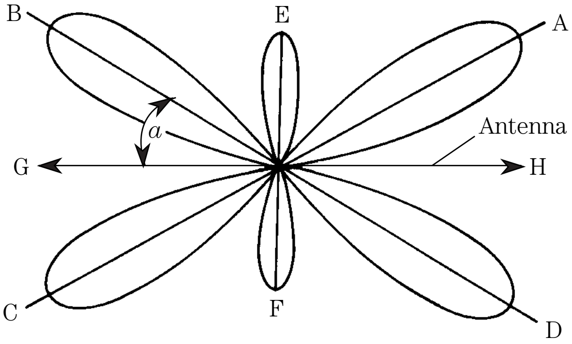

9-7 Radiation pattern of longwire antenna.

Nonresonant single-wire longwire antennas

The resonant longwire antenna is a *standing wave antenna*, because it is unterminated at the far end. A signal propagating from the feedpoint, toward the open end, will be reflected back toward the source when it hits the open end. The interference between the forward and reflected waves sets up stationary standing current and voltage waves along the wire.

A *nonresonant longwire* is terminated at the far end in a resistance equal to its characteristic impedance. Thus, the incident waves are absorbed by the resistor, rather than being reflected. Such an antenna is called a *traveling wave antenna*. Figure 9-8 shows a terminated longwire antenna. The transmitter end is like the feed system for other longwire antennas, but the far end is grounded through a terminating resistor R_1 that has a resistance R equal to the characteristic impedance Z_o of the antenna (i.e., $R = Z_o$). When the wire is 20 to 30 ft above the ground, Z_o is about 500 to 600 Ω.

The radiation pattern for the terminated longwire is a unidirectional version of the multilobed pattern found on the unterminated longwires. The angles of the lobes vary with frequency, even though the pattern remains unidirectional. The directivity of the antenna is partially specified by the angles of the main lobes. It is interesting to note that gain rises almost linearly with $n\lambda$, while the directivity function changes rapidly at shorter lengths (above three or four wavelengths the rate of change diminishes considerably). Thus, when an antenna is cut for a certain low frequency, it will work at higher frequencies, but the directivity characteristic will be different at each end of the spectrum of interest.

A two-wavelength (2λ) pattern is shown in Fig. 9-7. There are four major lobes positioned at angles of ±36° from the longwire. There are also four minor lobes—the strongest of which is –5 dB down from the major lobes—at angles of ±75° from the longwire. Between all of the lobes, there are sharp nulls in which little reception is possible. As the wire length is made longer, the angle of the main lobes pulls in tighter (i.e., toward the wire). As the lobes pull in closer to the wire, the number of minor lobes increases. At 5λ, there are still four main lobes, but they are at angles of ±22° from the wire. Also, the number of minor lobes increases to 16. The minor lobes are located at ±47°, ±62°, ±72°, and ±83° with respect to the wire. The minor lobes tend to be –5 to –10 dB below the major lobes. When the longwire gets very

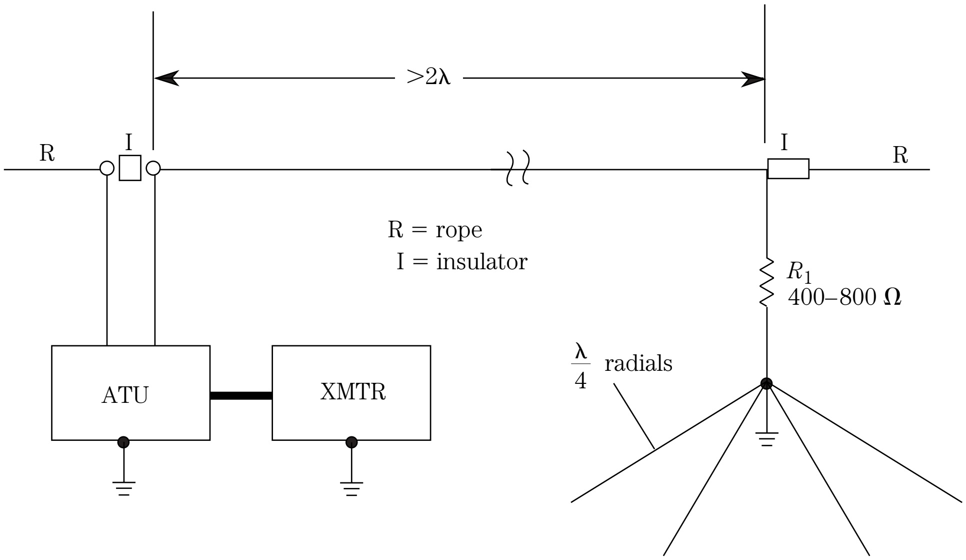

9-8 Longwire (greater than 2λ) antenna is terminated in a resistance (typically 400 to 800 Ω). Radials under the resistor improve the grounding of the antenna.

much longer than 5λ, the four main lobes begin to converge along the length of the wire, and the antenna becomes bidirectional. This effect occurs at physical lengths greater than about 20λ.

In general, the following rules apply to longwire antennas:

- On each side of the antenna, there is at least one lobe, minor or major, for each half-wavelength of the wire element. For the overall element, there is one lobe for every quarter-wavelength.
- If there are an even number of lobes on either side of the antenna wire, then half of the total number of lobes are tilted backward, and half are tilted forward; symmetry is maintained.
- If there are an odd number of lobes on either side of the wire, then one lobe on either side will be perpendicular to the wire, with the other lobes distributed either side of the perpendicular lobe.

Vee beams and rhombic beams

Longwire antennas can be combined in several ways to increase gain and sharpen directivity. Two of the most popular of these are the *vee beam* and the *rhombic* antennas. Both forms can be made in either resonant (unterminated) or nonresonant (terminated) versions.

Vee beams The *vee beam* (Fig. 9-9A) consists of two equal-length longwire elements (wire 1 and wire 2), fed 180° out of phase with each other, and spaced to produce an acute angle between them. The 180° phase difference is inherent in connecting the two wires of the vee to opposite conductors of the same parallel conductor feedline.

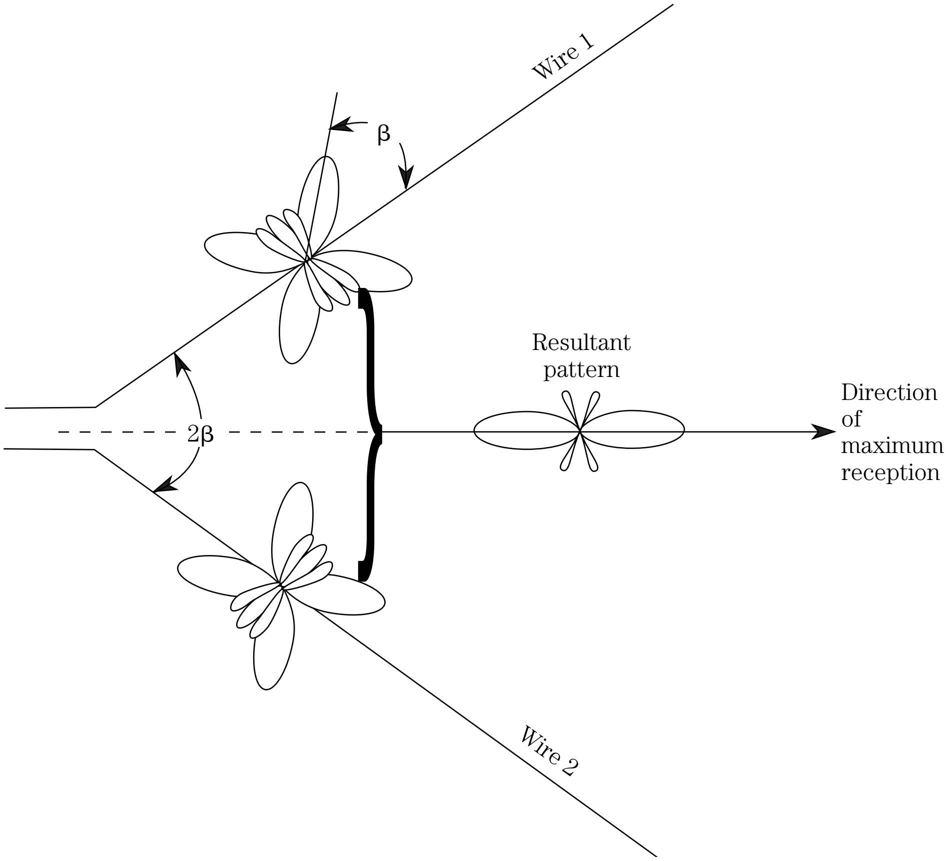

9-9A Radiation pattern of vee beam antenna consists of the algebraic sum of the two longwire patterns that make up the antenna.

The unterminated vee beam (Fig. 9-9A) has a bidirectional pattern that is created by summing together the patterns of the two individual wires. Proper alignment of the main lobes of the two wires requires an included angle, between the wires, of twice the radiation angle of each wire. If the radiation angle of the wire is β, then the appropriate included angle is 2β. To raise the pattern a few degrees, the 2β angle should be slightly less than these values. It is common practice to design a vee beam for a low frequency (e.g., 75-/80- or 40-m bands), and then to use it also on higher frequencies that are harmonics of the minimum design frequency. A typical vee beam works well over a very wide frequency range *only* if the included angle is adjusted to a reasonable compromise. It is common practice to use an included angle that is between 35° and 90°, depending on how many harmonic bands are required.

Vee beam patterns are based on an antenna height that is greater than a half-wavelength from the ground. At low frequencies, such heights will not be practical, and you must expect a certain distortion of the pattern because of ground reflection effects.

Gain on a vee beam antenna is about 3 dB higher than the gain of the single-wire longwire antenna of the same size, and it is considerably higher than the gain of a dipole (see Fig. 9-9B). At three wavelengths, for example, the gain is 7 dB over a dipole. In addition, there may be some extra gain because of mutual impedance effects—which can be about 1 dB at 5λ and 2 dB at 8λ.

Nonresonant vee beams Like the single-wire longwire antennas, the vee beam can be made nonresonant by terminating each wire in a resistance that is equal to the antenna's characteristic impedance (Fig. 9-10). Although the regular vee is a standing wave antenna, the terminated version is a traveling wave antenna and is thus unidirectional. Traveling wave antennas achieve unidirectionality because the terminating resistor absorbs the incident wave after it has propagated to the end of the wire. In a standing-wave antenna, that energy is reflected backwards toward the source, so it can radiate oppositely from the incident wave.

Rhombic beams The *rhombic beam antenna*, also called the *double vee*, consists of two vee beams positioned end-to-end with the tips connected. The unidirectional, nonresonant (terminated) rhombic is shown in Fig. 9-11. The unterminated resonant form gives approximately the same gain and directivity as a vee beam of the same size. The nonresonant rhombic has a gain of about 3 dB over a vee beam of the same size (see Fig. 9-9 again).

Two angles are present on the rhombic antenna. One-half of the included angle of the two legs of one wire is the *tilt angle* (ϕ), while the angle between the two wires is the *apex angle* (θ). A common rhombic design uses a tilt angle of 70°, a length of 6λ for each leg (two legs per side), and a height above the ground of 1.1λ.

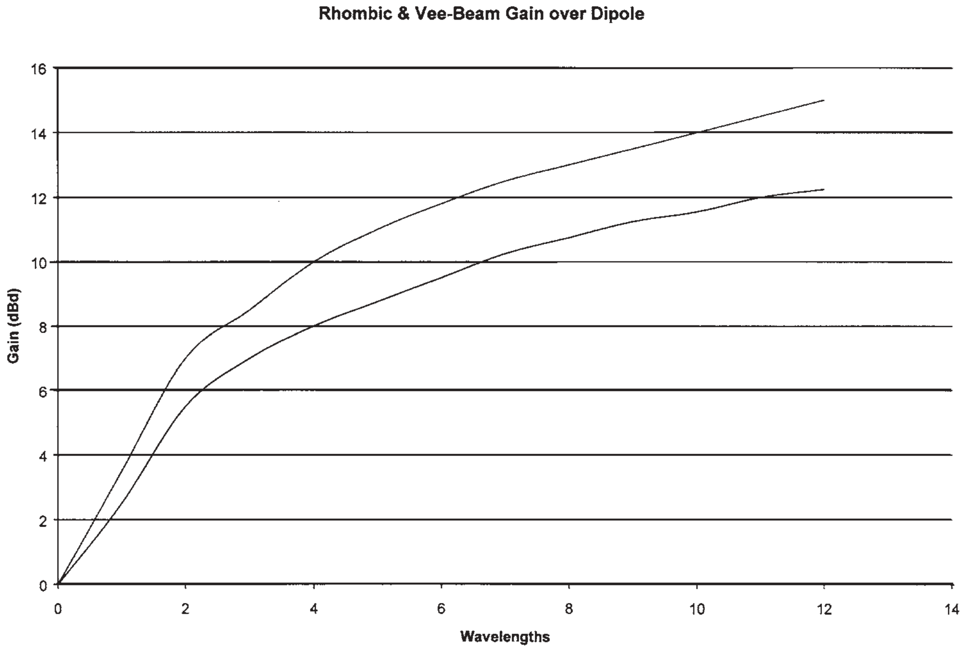

9-9B Gain versus length of vee beam and rhombic beam antennas.

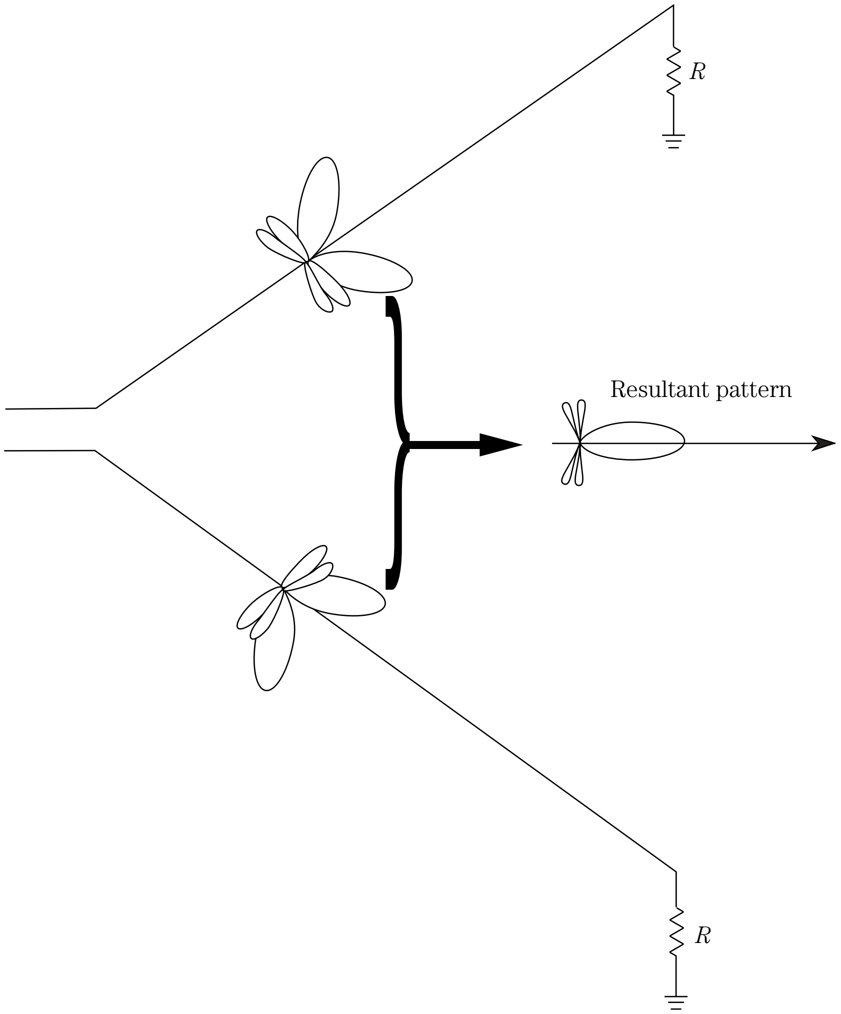

9-10 Nonresonant vee beam antenna.

The termination resistance for the nonresonant rhombic is 600 to 800 **Ω**, and must be noninductive. For transmitting rhombics, the resistor should be capable of dissipating at least one-third of the average power of the transmitter. For receive-only rhombics, the termination resistor can be a 2-W carbon composition or metal-film type. Such an antenna works nicely over an octave (2:1) frequency range.

Beverage or "wave" antennas

The *Beverage* or *wave antenna* is considered by many people to be the best receive antenna available for very low frequency (VLF), AM broadcast band (BCB), medium

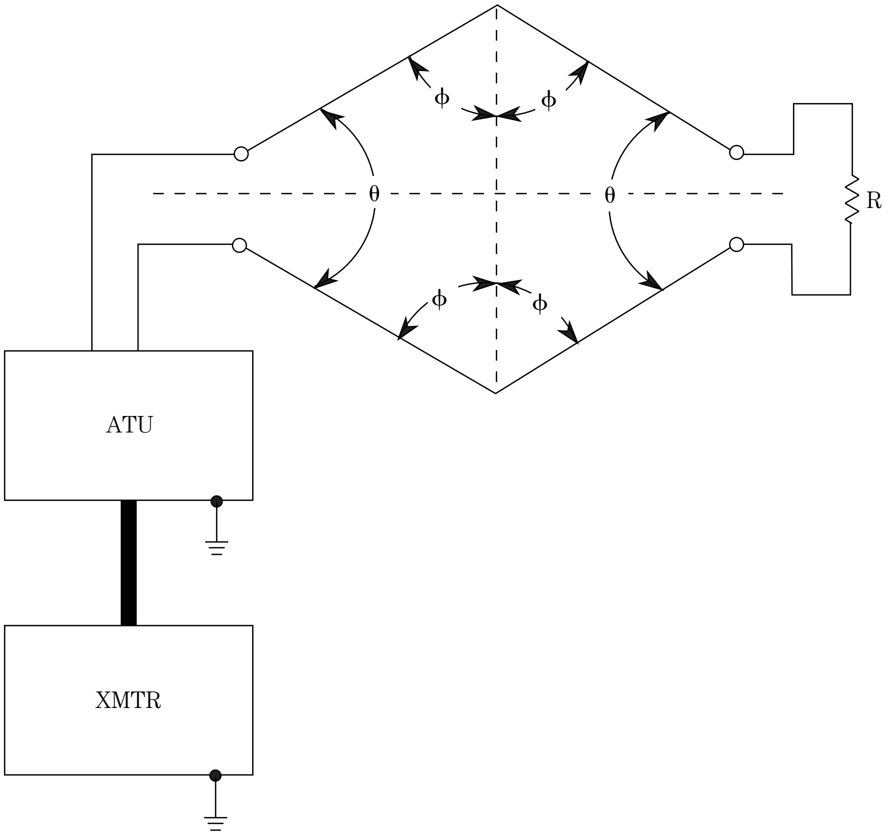

9-11 Terminated rhombic antenna.

wave (MW), or tropical band (low HF region) DXing. The Beverage was used by RCA at its Riverhead, Long Island (NY) station in 1922, and a technical description by Dr. H. H. Beverage (for whom it is named) appeared in *QST* magazine for November 1922, in an article titled "The Wave Antenna for 200-Meter Reception." In 1984, an edited and updated version of the 1922 article appeared in the same magazine. In 1921, Paul Godley, under sponsorship of the American Radio Relay League, journeyed to Scotland to erect a receiving station at Androssan. His mission was to listen for amateur radio signals from North America. As a result of politicking in the post–World War I era, hams were consigned to the supposedly useless shortwave ($\lambda < 200$ m), and it was not clear that reliable international communications were possible. Godley went to Scotland to see if that could happen; he reportedly used a wave antenna for the task (today, called the *Beverage*).

The Beverage antenna is a longwire of special design, more than one wavelength (1λ) long (Fig. 9-12), although some authorities maintain that $>0.5\lambda$ is minimally sufficient. The Beverage provides good directivity and good gain, but is not very efficient.

As a result, it is preferred for receiving, and is less useful for transmitting. This is an example of how different attributes of various antennas make the Law of Reciprocity an unreliable sole guide to antenna selection. Unlike the regular longwire, which is of a different design, the Beverage is intended to be mounted close to the earth's surface (typically $< 0.1\lambda$); heights of 8 to 10 feet is the usual prescription.

Figure 9-12 shows the basic single-wire Beverage antenna. It consists of a single conductor (no.16 to no.8 wire, with no.14 being most common) erected about 8 to 10 ft above ground. Some Beverages are unterminated (and bidirectional), but most of them are terminated at the far end in a resistance R equal to the antenna's characteristic impedance Z_o. The receiver end is also terminated in its characteristic impedance, but generally requires an impedance matching transformer to reduce the antenna impedance to the 50-Ω standard impedance used by most modern transmitters.

The Beverage works best in the low-frequency bands (VLF through MW), although at least some results are reportedly relatively easy to obtain up to 25 m (11.5 MHz). Some questionably successful attempts have been made at making Beverage antennas work as high as the 11-m Citizens Band or the 10-m ham band (29.7 MHz).

The Beverage antenna works on vertically polarized waves arriving at low angles of incidence. These conditions are normal in the AM BCB, where nearly all transmitting antennas are vertically polarized. In addition, the ground- and sky-wave propagations found in these bands (VLF, BCB, and low HF) are relatively consistent. As the frequency increases, however, two factors become increasingly dominant. First, the likelihood of horizontal polarization increases because of the size of a wavelength at those frequencies. The polarization of the received signal not only changes in those bands, but does so constantly when conditions are unsettled. It is the strong dependence of the

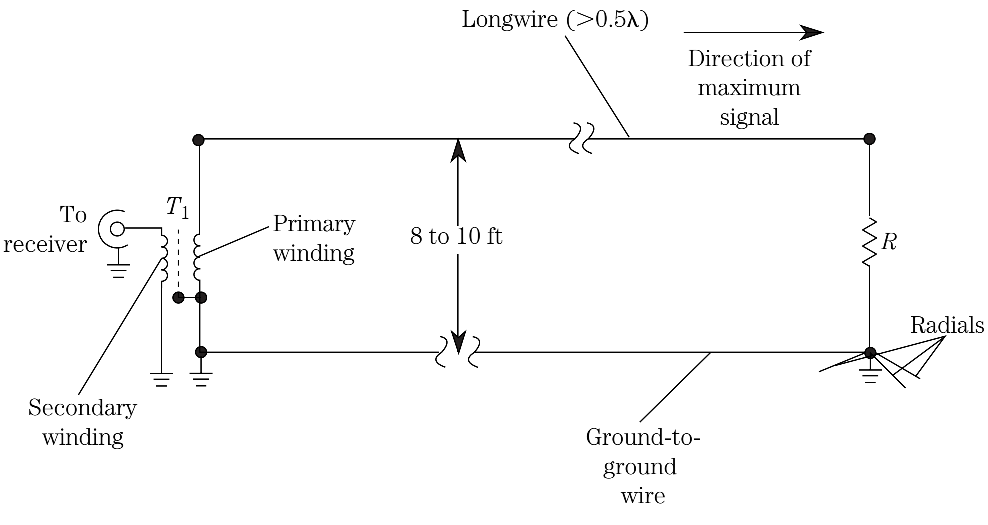

9-12 Beverage antenna.

Beverage on relatively constant vertical polarization that makes me suspect the claims of Beverage-like performance above the 25- or even 31-m bands.

The Beverage depends on being erected over poorly conductive soil, even though the terminating resistor needs a good ground. Thus, one source claimed that sand beaches adjacent to salty marshes make the best Beverage sites (a bit of an overstatement). Figure 9-13 shows why poorly conductive soil is needed. The E-field vectors are launched from the transmitting antenna perpendicular to the earth's surface. Over perfectly conducting soil, the vertical waves would remain vertical. But over imperfectly conducting soil, the field lines tend to bend close to the point of contact with the ground. As shown in the inset of Fig. 9-13, the bending of the wave provides a horizontal component of the E-field vector, and this provides the means of generating an RF current in the conductor wire.

A debate among Beverage antenna fans regards the best length for the antenna. Some sources state that the length can be anything greater than or equal to 0.5λ, yet others say greater than or equal to1λ is the minimum size. One camp says that the length should be as long as possible, while others say it should be close to a factor called the *maximum effective length* (MEL), which is

$$\mathrm{MEL} = \frac{\lambda}{4\left(\frac{100}{K} - 1\right)} \qquad \textbf{[9.2]}$$

where

MEL is the maximum effective length, in meters
λ is the wavelength, in meters
K is the velocity factor, expressed as a percent

Misek, who may well be the leading exponent of the Beverage antenna, uses numbers like 1.6λ to 1.7λ over the 1.8- to 7.3-MHz region, and 0.53λ to 0.56λ on frequencies lower than 1.8 MHz. Doctor Beverage was once quoted as saying that the optimum length is 1λ.

Like the longwire antenna, the Beverage needs a termination resistor that is connected to a good ground. This requirement might be harder to meet on Beverage antennas because they work best over lossy ground, which doesn't make a very good ground connection. As in the longwire case, insulated or bare wires, a quarter-wavelength long, make the best radials. However, a substantial improvement in the ground is possible using just bare wires measuring 15 to 20 ft long (which is much less than λ/4), buried in the soil just below the surface (far enough to prevent erosion from bringing it to the surface). Many articles and books on Beverages show ground rods of 2 or 3 ft long, which borders on the ridiculous. Poor soil requires longer ground rods, on the order of 6 to 8 ft. Copper-clad steel makes the best rods.

In addition to the radials and ground rod, Misek also recommends using a wire connection between the ground connection at the termination resistor, and the

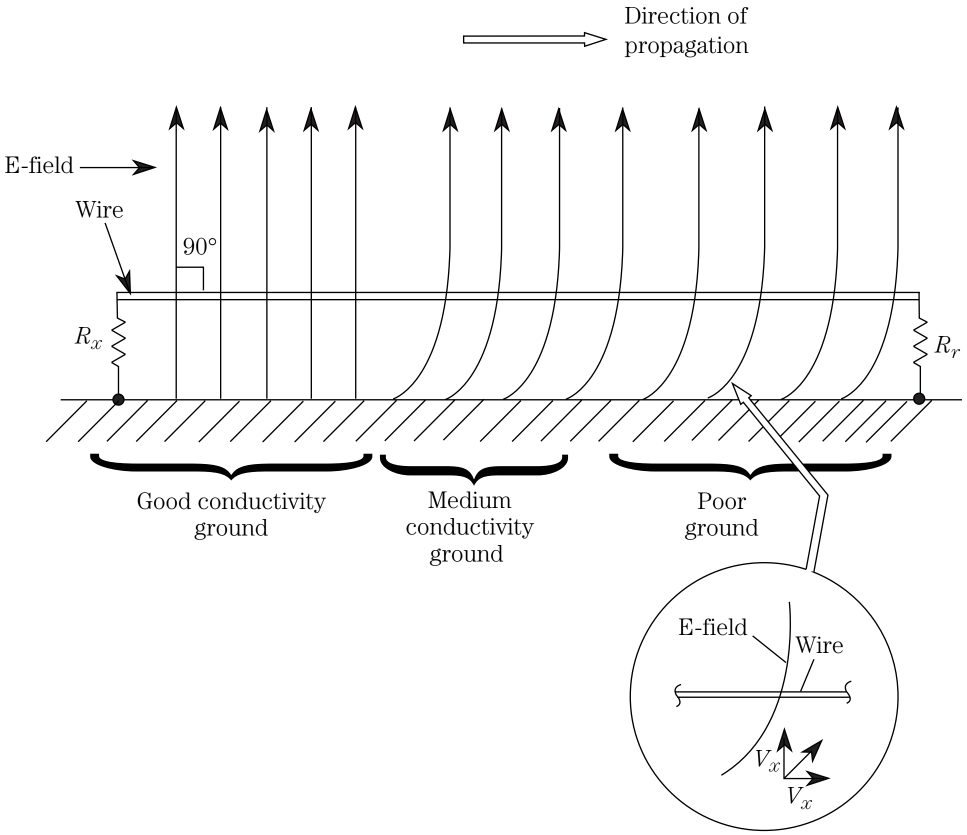

9-13 Performance of Beverage antenna over different values of ground conductance.

ground connection at the receiver transformer (see again Fig. 9-12). According to Misek, this wire helps to stabilize the impedance variations at higher frequencies.

Installation of the Beverage antenna is not overly critical if certain rules are followed. The antenna should be installed at a height of 6 to 10 ft off the ground, and it should be level with the ground over its entire length. If the ground is not flat enough to make a level installation possible, then try to use a height that is 6 to 10 ft above the average terrain elevation along its run. A popular installation method is to erect 16-ft 4 × 4 lumber, such that 3 to 4 ft are buried in a concrete-filled posthole. Use lumber that is treated for outdoor use (i.e., pressure-treated lumber sold for decks and porches. The wire can be fastened to the 4 × 4 posts using either ceramic standoff ("beehive") insulators or electric fence insulators (which some people deem preferable). Try to use one contiguous length of wire for the antenna, if possible, in order to avoid soldered splices and joints.

One of the Beverage installation difficulties shared with the longwire is the need to slope down to a point where a termination resistor can be easily installed close to the ground. While the longwire can be sloped over a large portion of its length, the Beverage should be sloped downward only over the last 60 ft or so.

Steerable notch Beverage antennas

A Beverage erected with two wires—parallel to each other, at the same height, spaced about 12 in apart (Fig. 9-14), with a length that is a multiple of a half-wavelength—is capable of *null steering*. That is, the rear null in the pattern can be steered over a range of 40° to 60°. This feature allows strong, off-axis signals to be reduced in amplitude so that weaker signals in the main lobe of the pattern can be received. There are at least two varieties of the *steerable wave Beverage* (SWB).

If null steering behavior is desired, then a phase control circuit (PCC) will be required—consisting of a potentiometer, an inductance, and a variable capacitor in series with each other. Varying both the "pot" and the capacitor will steer the null. You can select the direction of reception, and the direction of the null, by using a switch to swap the receiver and the PCC between port A and port B.

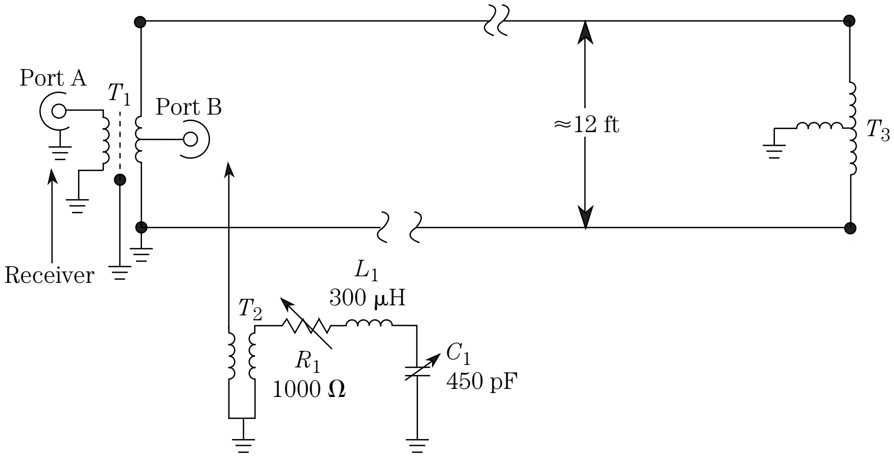

9-14 Beverage antenna with a steerable null.

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10
CHAPTER

Hidden and limited-space antennas

ONE OF THE MOST SIGNIFICANT IMPEDIMENTS TO AMATEUR RADIO OPERATORS, CB operators, and shortwave listeners is the space available for their antennas. In many thousands of other cases, the limitation is less one of space, but of regulators. More and more subdivisions are built with covenants on the deed that prohibit the buyer from installing outdoor antennas. Once limited to townhouse developments, where that breed of contemptible vermin (called the Homeowners Committee) routinely intruded on the affairs of people who mistakenly think they "own" their townhouse (ownership implies right of use, which is limited by the covenants). These onerous covenants are now routinely placed on single-family dwellings as well. In fact, it is the single most serious threat to amateur communications people in the country today. Other homeowners are no longer angered by the restriction on antennas because their television reception is now carried to them via cable systems in most parts of the country. Even where cable is not available, most users can install a moderately sized television antenna in their attic, or use rabbit ears. In other cases, the townhouse community will install a single master TV antenna and then distribute signals to each unit. The result is that the amateur radio operator, CB operator, and shortwave listener are left to fend for themselves without assistance from neighbors.

In this chapter we will examine some of the alternatives available to those readers who have either a limited space situation (such as a small city lot), or are unable to move out of a subdivision where there are stupid rules against outdoor antennas. The suggestions contained in this chapter are not universal, and indeed the author recommends that you adapt, as well as adopt, these recommendations, and come up with some of your own. Creativity within the constraints of the laws of physics governing radio antennas is encouraged.

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Hidden antennas

A hidden antenna is one that is either completely shielded from view or disguised as something else. Alternatively, you could also include in this category antennas that are in semiopen view, but which are not too obvious (except to the trained and diligent eye). Some people have opted for "hidden" longwires made of very fine wire (no. 26 enameled wire is popular). The user will install the wire in the open, high off of the ground (as in an apartment installation), and operate without anyone knowing the difference. One chap used no. 22 wire suspended between two 16-story apartment house buildings that were 100 yards apart. He had one of the best working longwires in town until a windy day when the whole thing came down. No one was injured; but had someone been hurt, there might have been a lawsuit. Hidden antennas must be designed with an eye toward causing others no harm. It is neither ethical nor smart to place others at risk in enjoying our hobbies.

The dipole is a popular antenna with both shortwave listeners and amateur radio operators. Indeed, for the CB operator who wants to get on the air from an apartment or townhouse (or restricted single-family home), the dipole can represent a respectable alternative.

As you learned in Chap. 6, the dipole is a horizontal wire (or pipe) antenna that is a half-wavelength long and fed in the center (ideally) with 75-Ω coaxial cable. In the "townhouse" dipole, it is possible to build the antenna entirely inside the attic of the building. The length of the dipole is given approximately by

$$L_{\text{ft}} = \frac{468}{F_{\text{MHz}}} \tag{10.1}$$

If you do some quick calculations you will find that antennas for the 10-, 13-, 15-, and (possibly) even 18- and 20-m bands, will fit entirely inside the typical townhouse attic. This statement is also true of the 11-m citizen's band antenna: It will fit inside the standard townhouse attic. But what about the lower frequency bands?

Figure 10-1 shows a possible solution to the use of the lower frequencies in the townhouse situation. The two quarter-wavelength arms of the dipole are ideally installed in line with each other, as was shown in the chapter on horizontal antennas. But in a sticky situation we can also install the dipole with the arms bent to accommodate the space available. In this example, only one of many possible methods for accomplishing this job is shown. Here each quarter-wavelength section is composed of two legs, *AB* and *CD*, respectively. Ideally, segments *B* and *C* are the longest dimensions. Also, if possible, make segments *A* and *D* equal lengths. Another method is to reverse the direction of one end leg, say for example *D*, and run it to the other corner of the building over the peak of the roof.

The author is almost hesitant to offer only one drawing, despite space constraints, in the fear that readers will take the offered pattern as the only authorized version, or solution. In reality, you might not be able (for a variety of reasons) to use the exact pattern shown (so ad lib a little bit).

How about performance? Will the constrained dipole of Fig. 10-1 work as well as a regular dipole installed a wavelength or two off the ground and away from objects?

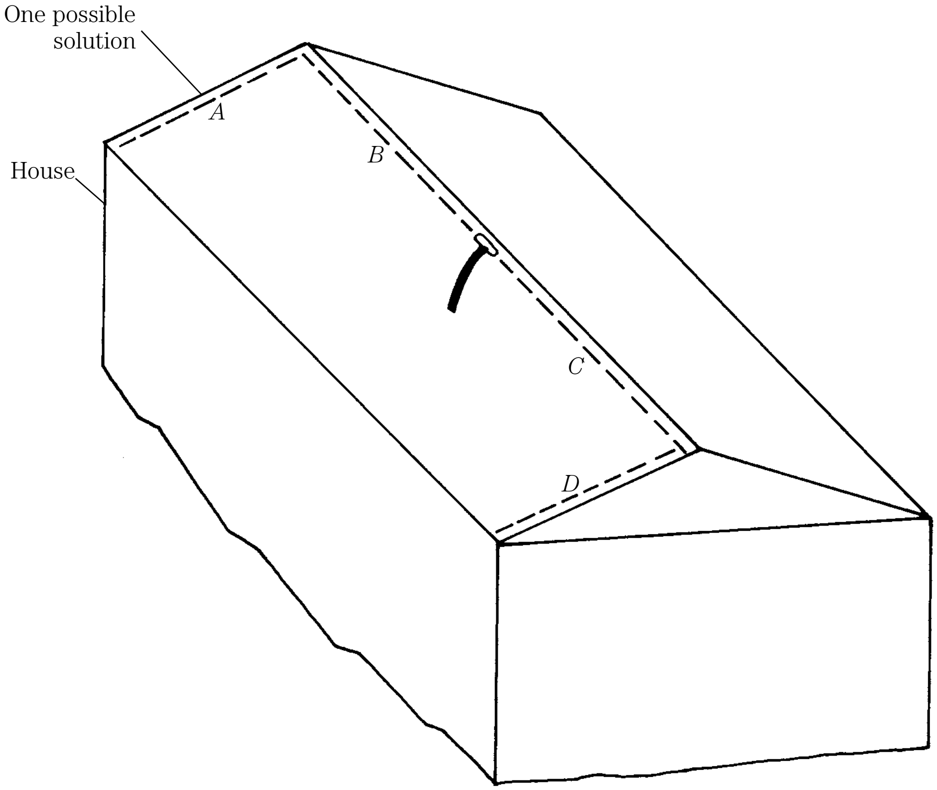

10-1 Installing dipole in attic.

In a word: no. But that is not the problem being solved; getting on the air at all is the present problem. You will find that the pattern of the constrained dipole is distorted compared with that of the regular dipole. In addition, the feedpoint impedance is not going to be 73 Ω (except if by fluke), so you will be required to use an antenna tuner of some kind. You are well advised to read the chapter on antenna instruments and measurements so that you can be prepared to figure out any feed problems that crop up—as well they might.

The wire used in the constrained dipole (or other forms of attic antenna) should be mounted on TV-type screw-in standoff insulators. Almost any outlet that sells TV antennas, or installation parts, will have them. These standoff insulators are also available in many hardware stores, and department stores that sell TV antennas or "Harry and Harriet Homeowner" supplies, in addition to electronics parts suppliers. Do not simply tape the wire to the wooden underside of your roof. The reason is simple: in a poorly tuned antenna, voltages can get high enough at the ends to produce *corona* effects; arcing could be a fire hazard. Also, use insulated wire to avoid accidental contact in the event that someone is in the attic when you are operating. Be aware that the insulation might affect the propagation velocity of signals in the wire, so it will slightly alter the required length.

Another alternative for the attic antenna, and one that avoids some of the problems of corona effects, is the nonresonant loop shown in Fig. 10-2. Although specified as a top view, the loop can be installed in the configuration that best uses the space. In fact, the best performance will be bidirectional when the loop is installed vertically. In this case, a large loop (as large as can be accommodated in the space available) is installed in the attic. Again, use standoff insulators and insulated wire for the installation.

The giant loop is fed with parallel line, and is tuned with a balanced antenna tuning unit. As was true with the constrained dipole, the performance is not to be equated with the performance of more regular antennas; but, with the prospect of not being on the air at all . . . ! Once again we have a compromise antenna for a compromising situation.

Another ploy is the old “flagpole trick” shown in Fig. 10-3. Some developments allow homeowners to vent their patriotism by installing flagpoles—and flagpoles can be disguised antennas. In the most obvious case, you can install a brass or aluminum flagpole and feed it directly from an antenna tuning unit. For single-band operation, especially on the higher frequencies, you can delta-feed the “flagpole” unobtrusively, and call your flagpole a vertical antenna. But that is not always the best solution.

Figure 10-3 shows two methods for creating a flagpole antenna, and both depend on using white PVC plumbing pipe as the pole. The heavier grades of PVC pipe

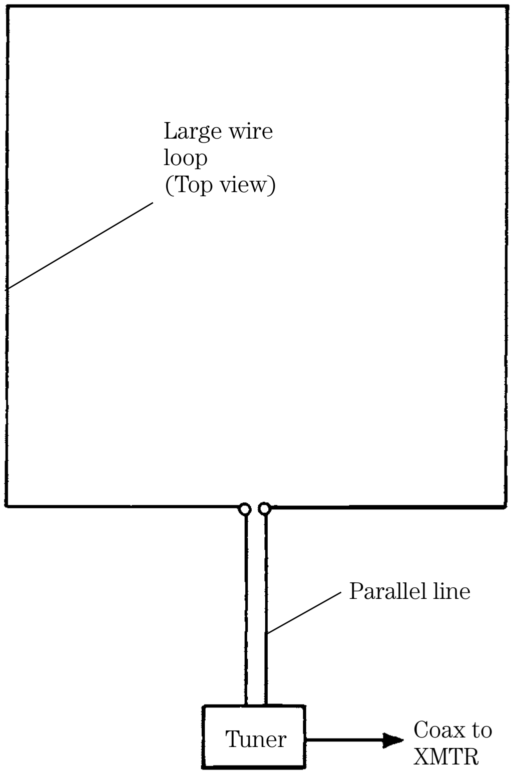

10-2 Large loop antenna.

are self-supporting to heights of 16 to 20 ft, although lighter grades are not self-supporting at all (hence are not usable).

Figure 10-3A shows the use of a PVC flagpole in which a no. 12 (or no. 14) wire is hidden inside. This wire is the antenna radiator. For some frequencies, the wire will be resonant, and for others, it will surely be nonresonant. Because of this problem an antenna tuning unit is used either at the base of the antenna or inside at the transmitter.

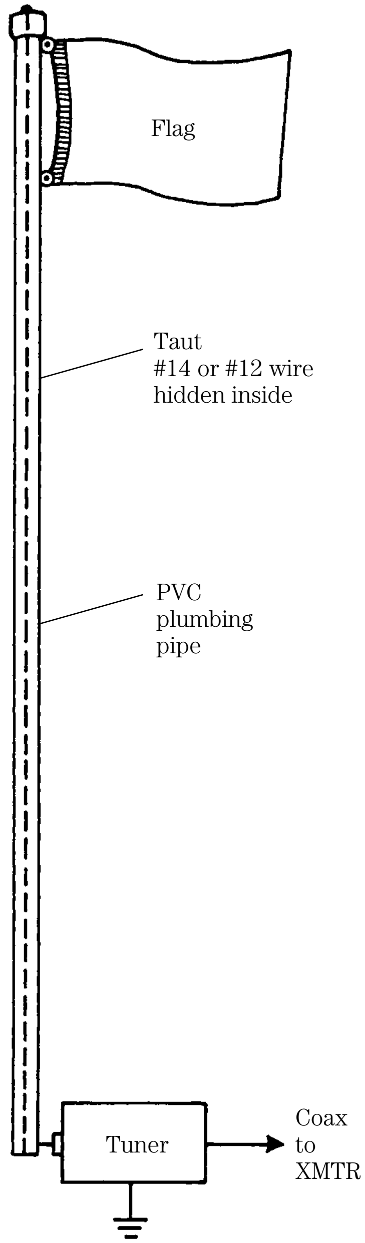
Flag
Taut
#14 or #12 wire
hidden inside
PVC
plumbing
pipe
Tuner
Coax
to
XMTR

10-3A Flagpole antenna made from thick-walled PVC pipe.

If the wire is too long for resonance (as might happen in the higher bands), then place a capacitor in series with the wire. Various settings may be required, so use a multisection transmitting variable that has a total capacitance selectable to more than 1000 pF. Alternatively, use a vacuum variable capacitor of the same range.

In cases where the antenna is too short for resonance, as will occur in the lower bands, insert an inductance in series with the line to "lengthen" it. Another alternative is to use an L-section tuner at the feedpoint.

A good compromise situation is the use of a 16-ft length of "flagpole" pipe with a 16-foot wire embedded inside. The 16-foot wire is resonant at 20 m, so it will perform like a vertical antenna at those frequencies. The tuner will then accommodate frequencies above and below 20 m.

Another alternative is the version shown in Fig. 10-3B. In this case the wire radiator is replaced with a section of aluminum tubing. A wooden or plastic insert is fashioned with a drill and file to support the aluminum tubing inside the PVC tubing. One way to make the support is to use a core bit in an electric drill to cut out a disk that fits snugly inside the PVC tubing. Rat out the center hole, left by the core bit pilot, to the outside diameter of the aluminum tubing. The support can be held in place with screws from the outside, or simply glued in place.

The problem of operating with a hidden antenna is a serious challenge. But with some of these guidelines and a little creativity, you can get on the air and enjoy your amateur radio hobby.

Limited-space antennas

Many people live in situations where it is permissible to install an outdoor antenna, but it is not practical to install a full-size antenna. I once lived in a house that was 16 ft wide and 37 ft long, on a 33 × 100-ft lot. Very few full-sized antennas could be installed on that lot because of the space constraints. Beam antennas were out because county laws required that the antenna not hang over the property line. Although vertical antennas were possible, there was a period of time when I used other antennas that were easier to install. In this chapter, you will examine some of the options open to those with limited space for amateur radio, CB, or SWL antennas.

Once again we return the simple dipole as the basis for our discussion. In Fig. 10-4, you see several alternatives for installing an outdoor antenna in a limited space. In Fig. 10-4A, the slanted dipole (or slipole) antenna uses the standard dipole configuration, but one end is connected to the high point of the building, while the other is anchored near the ground. The coaxial cable is connected to the midpoint of the antenna in the usual manner for regular dipoles. If the end of the dipole is within reach of people on the ground, then they may get a nasty RF burn if the antenna is touched while you are operating. Take precautions to keep people and pets away from this lower end.

Another method is the vee dipole shown in Fig. 10-4B. In a regular dipole installation, the ends of the antenna are along the same axis (in other words, at an angle of 180°). In the example of Fig. 10-4B, however, the angle between the elements is less than 180°, but greater than 90°. In some cases we might want to bend the elements, rather than install them in a vee shape. Figure 10-4C shows an angled dipole with four segments. For the best performance (but not as good as that

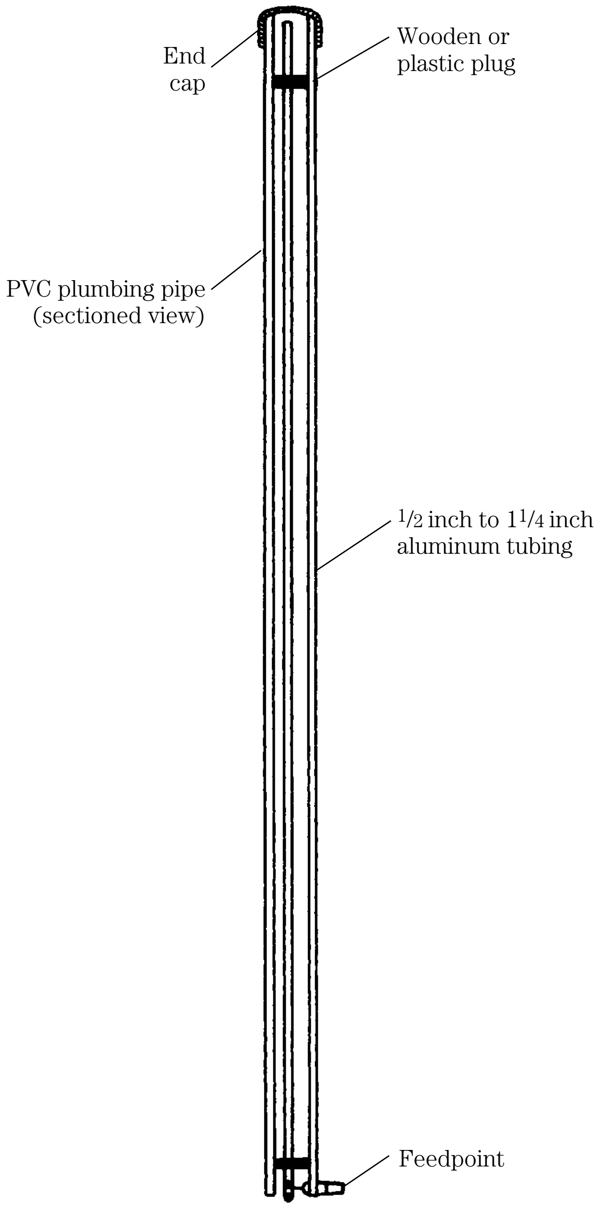
End cap
Wooden or plastic plug
PVC plumbing pipe (sectioned view)
1/2 inch to 1 1/4 inch aluminum tubing
Feedpoint

10-3B PVC flagpole hiding an aluminum tubing vertical.

of a regular dipole), make $A = D$ and $B = C$. In all three examples, Figs. 10-4A through 10-4C, you can expect to find the length needed for resonance varies somewhat from the standard $468/F_{\mathrm{MHz}}$ value, and that the feedpoint impedance is other than 73 Ω. Also, the pattern will be distorted with respect to the regular dipole. Although these antennas do not work as well as a properly installed dipole, the performance is sufficient to allow successful operation.

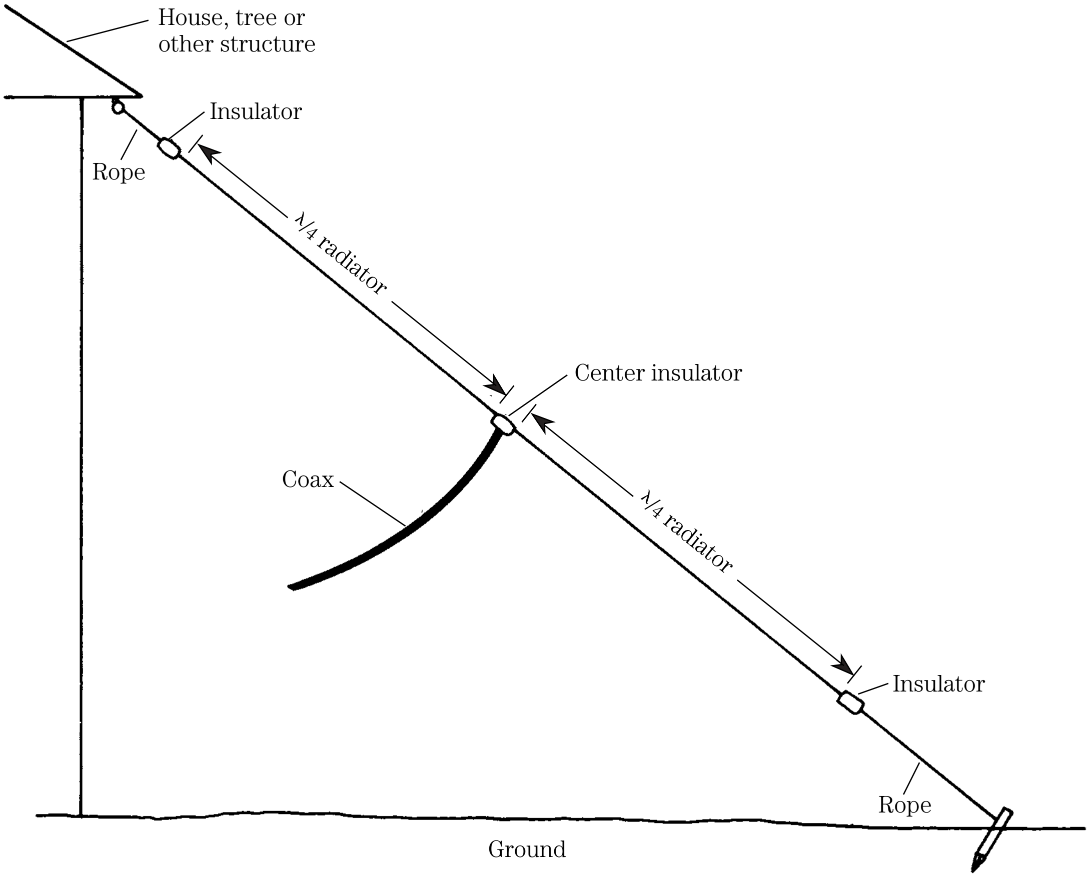

10-4A Sloper dipole.

Another limited-space wire antenna is the (so-called) half-slope shown in Fig. 10-4D. Although single-band versions are often seen, the example in Fig. 10-4D is a multiband version. Resonant traps separate the different band segments. This antenna operates like the vertical, but it is not omnidirectional. Also, the feedpoint impedance will be different from the regular vertical situation. If the impedance varies too much for comfort, insert an antenna tuner, such as the Transmatch, in the coaxial line between the transmitter and the antenna.

Figure 10-5 shows another antenna that's useful for limited-space situations. Although it is easily constructed from low-cost materials, the antenna is also sold by several companies under various rubrics including "cliff-dweller," "apartment house," "townhouse," or "traveler's" antennas. The antenna consists of a 4- to 16-ft section of aluminum or copper tubing. Some of the commercial antennas use a telescoping tubing that can be carried easily in luggage. As was true with the longwire, the window-sill antenna is tuned to resonance with an L-section coupler.

The L-section coupler must be tuned to produce the lowest possible VSWR, so either an RF power meter or a VSWR meter must be installed in the coaxial cable between the transmitter and the tuner. Again, a good ground (or radial system) will

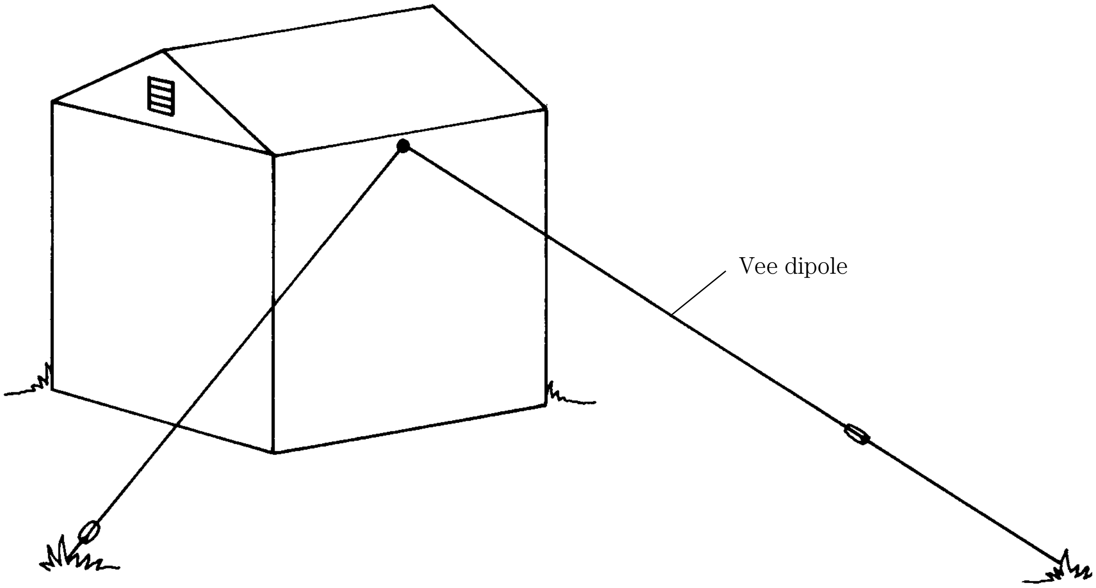

10-4B Vee dipole.

greatly improve the operation of this antenna. The performance should be considerably less than that of a good longwire, but it will work DX for you even on lower frequencies. Once again it is not the best antenna made, but it will get you on the air.

Figure 10-6 shows the use of a mobile antenna for a fixed or portable location. I used this type of antenna at one QTH to good effect. Mount a mobile antenna, such as the Hustler, on the window sill, or other convenient mount (at least one amateur radio operator uses one mounted on the roof of the house). Grounding is essential for this antenna, as was also true for the longwire and window-sill antenna (Fig. 10-5). The operation of this antenna is improved by installing at least two radials per band as a counterpoise ground. My installation worked well, even though only two radials were present.

A directional *rotatable* dipole is shown in Fig. 10-7. This antenna is made from a pair of mobile antennas connected “back-to-back” on a horizontal length of 1 × 2 lumber and fed in the center with a coaxial cable. The end pieces of the mobile antenna set the resonance, and you must recognize that adjusting one requires a countervailing adjustment of the other as well.

Two examples of *helically* wound antennas are shown in Fig. 10-8. In this type of antenna, an insulating mast is wound with a half-wavelength of antenna wire. The overall length of the antenna is considerably less than a half-wavelength, except at the highest frequencies. In order to dissipate the high voltages that tend to build up at the ends of these antennas, a capacitance hat is used. These “hats” are either disks (pie tins work well) or rods of conductor about 16 to 24 in long. The version shown in Fig. 10-8A is a vertical antenna, and like other verticals, it must be installed over either a good ground or a counterpoise ground. The version shown in Fig. 10-8B is horizontally polarized.

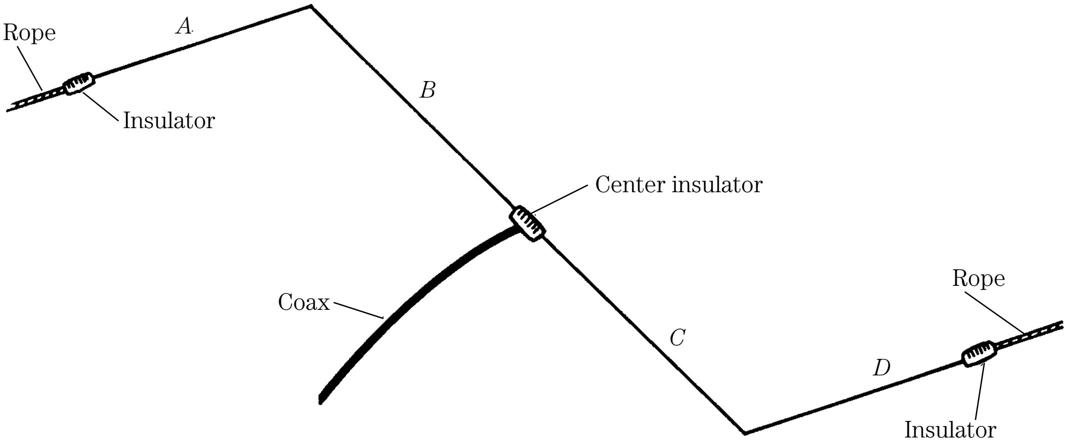
Rope
A
B
Insulator
Center insulator
Coax
Rope
C
D
Insulator

10-4C Bent dipole.

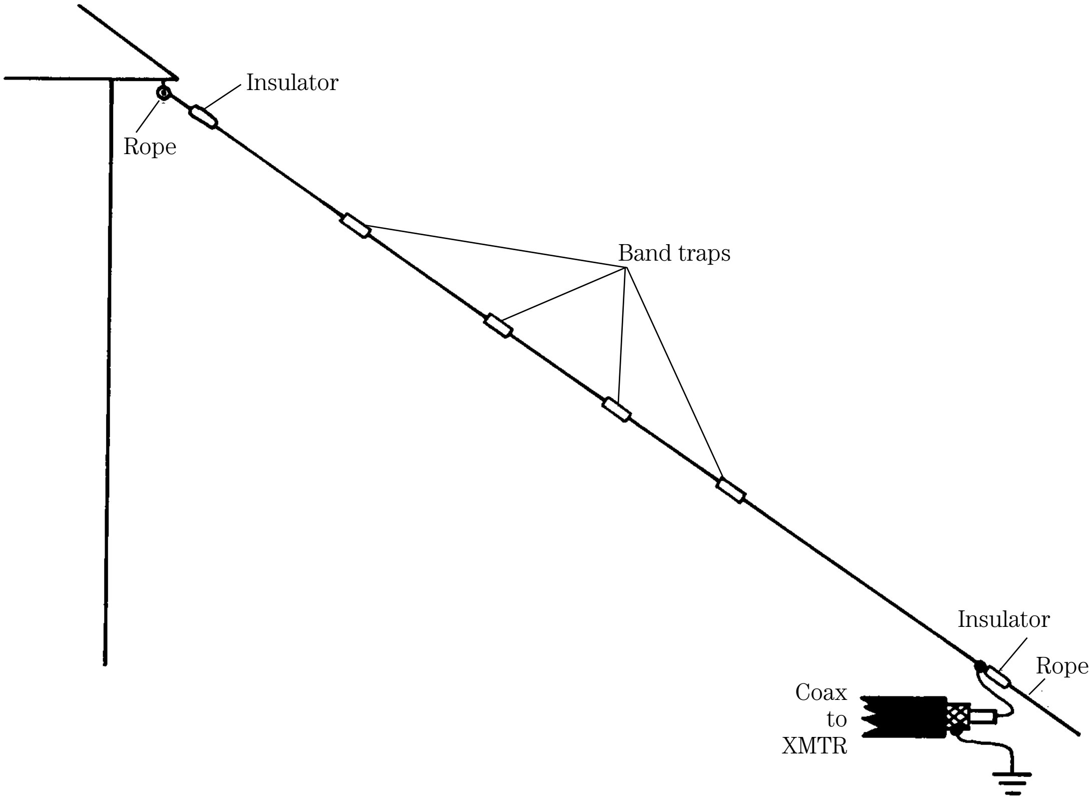
Insulator
Rope
Band traps
Insulator
Rope
Coax
to
XMTR

10-4D Sloper trap vertical.

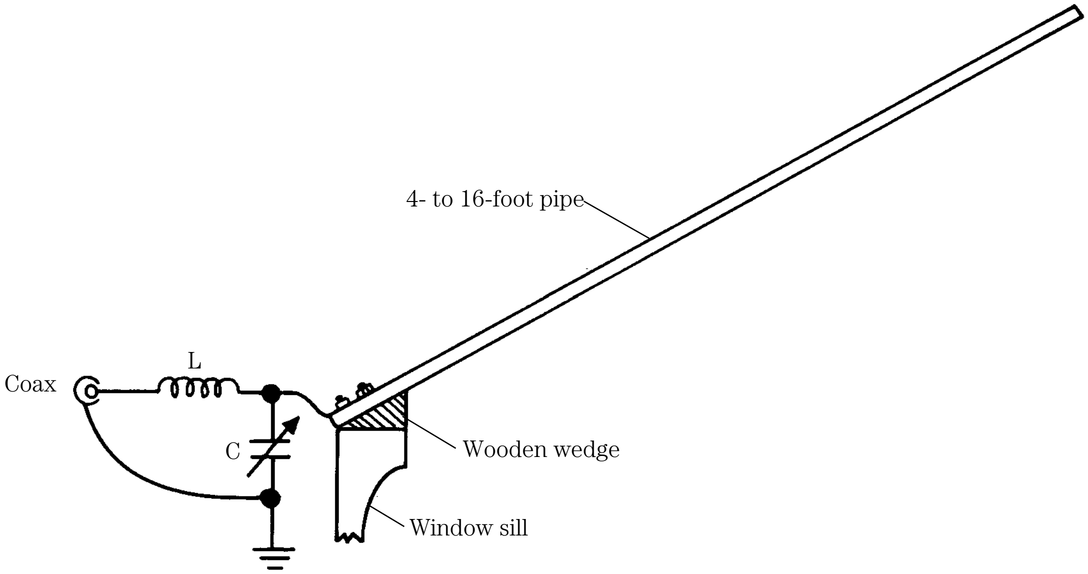
4- to 16-foot pipe
L
Coax
C
Wooden wedge
Window sill

10-5 Window sill antenna.

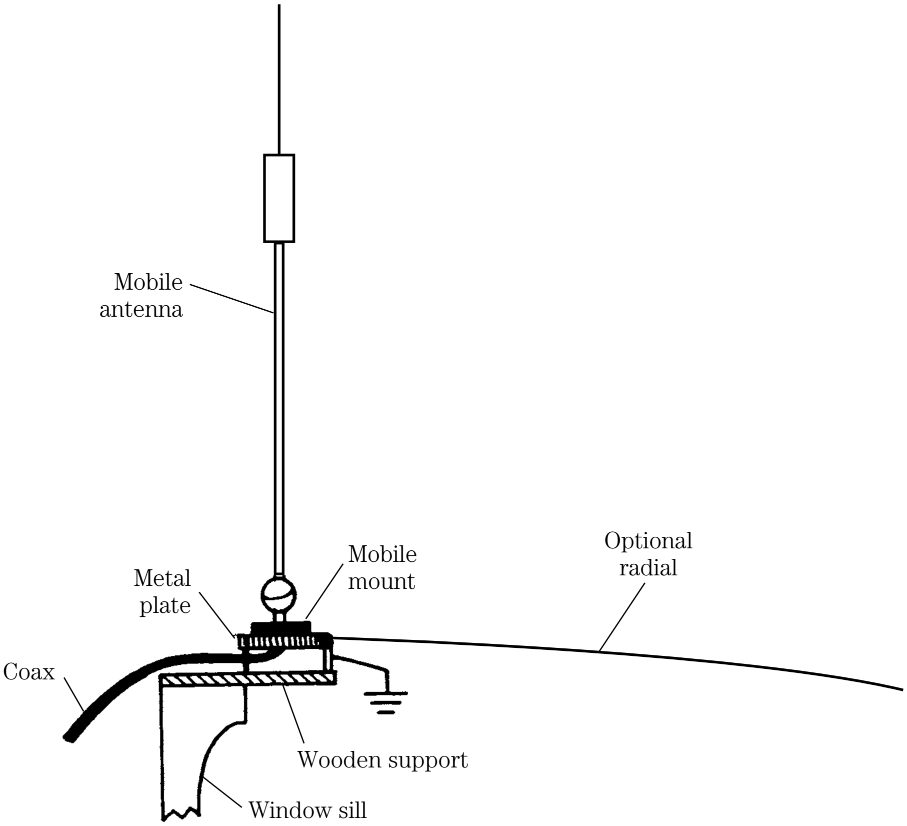
Mobile antenna
Optional radial
Mobile mount
Metal plate
Coax
Wooden support
Window sill

10-6 Use of mobile antenna as a window sill antenna.

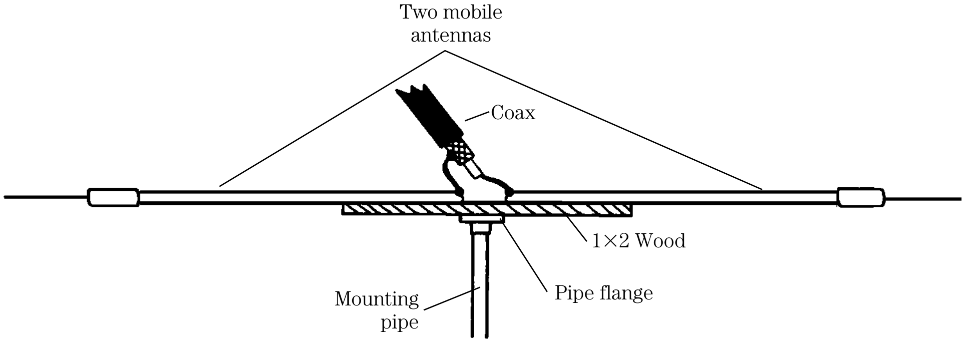
Two mobile antennas
Coax
1×2 Wood
Pipe flange
Mounting pipe

10-7 Use of two mobile antennas as a rotatable dipole.

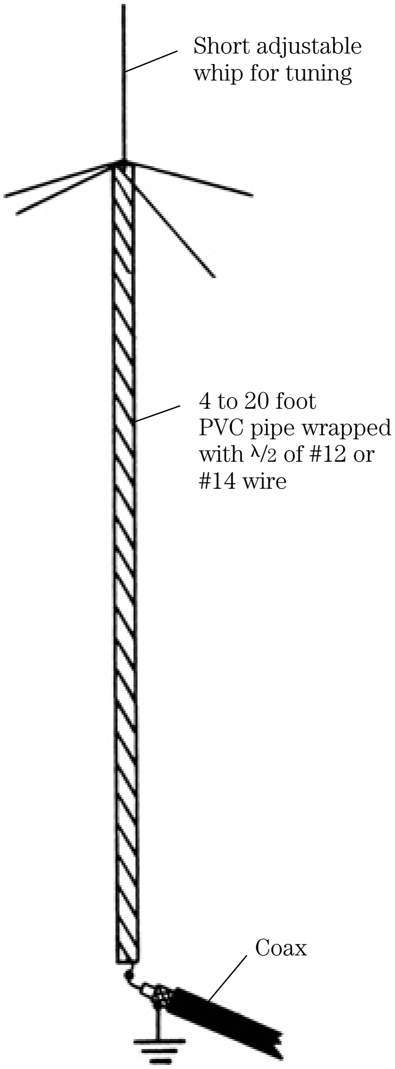
Short adjustable whip for tuning
4 to 20 foot PVC pipe wrapped with λ/2 of #12 or #14 wire
Coax

10-8A Helically vertical antenna.

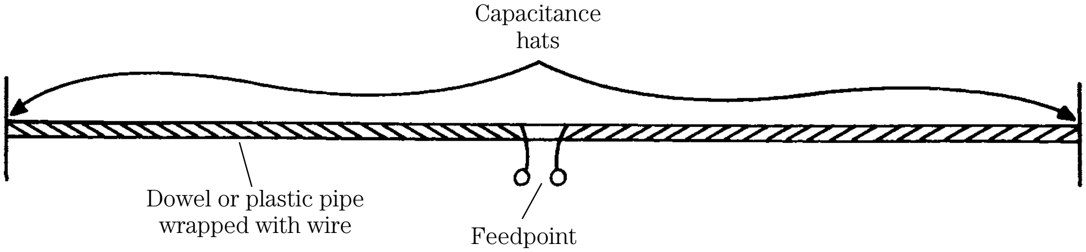
Capacitance hats
Dowel or plastic pipe wrapped with wire
Feedpoint

10-8B Helically wound dipole antenna.

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11
CHAPTER

Directional phased vertical antennas

THE VERTICAL ANTENNA IS A PERENNIAL FAVORITE WITH RADIO COMMUNICATIONS users. The vertical is either praised, or cursed, depending upon the luck of the owner. “DXability” is usually the criterion for judging the antenna’s quality. Some amateurs can’t get out of their backyards with a vertical, and they let everyone within earshot know that such and such a brand is no good. Yet, another person routinely works New Zealand or Australia on 15 m using exactly the same brand of vertical. The proper installation of vertical antennas is dealt with in another chapter, so, for the present, let’s look at another problem attributed to vertical antennas.

That problem is that vertical antennas are *omnidirectional* in the azimuth aspect; that is, they send out and receive equally well from all directions. Some people moan that this pattern dissipates their power, and gives them a weaker signal “out where it counts” (true). However, the main disadvantage of the omnidirectional pattern is noise (QRN and QRM). “QRN” is natural noise from thunderstorms and other sources. “QRM” is man-made noise, and can consist of other stations or the many assorted forms of electrical filth that pollute the airwaves. All forms of noise, however, have one thing in common: they are directional with respect to the station. In other words, if you could null signals coming from the direction of the noise source (or undesired station), you would be able to hear desired stations much better. A directional antenna performs this task, so let’s look at some vertically polarized directional antennas.

Although most amateurs seem to think that the effective radiated power (ERP) increase that the directional antenna gives them is the real reason to own one, the main benefit is actually on receive. Think about it for a moment. With anywhere from 100 to 1500 W available, the increase or decrease in signal strength (due to the directivity of the antenna) results in a minimal difference on the receive end, especially during good DX conditions. If we rotate the directional pattern, to null out interference, then we usually find that the change in our signal strength perceived by the other guy is small; the S meter reading of the desired station is minimally affected; but the amplitude of the interference source is greatly attenuated! The overall effect is an apparent increase

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in the other guy's signal, even though the S meter tells a slightly different story. The improvement of signal-to-noise ratio (SNR) is tremendously improved.

Directivity and phasing

So, how does a vertical antenna owner get the benefit of directivity without the kilobuck investment that a beam or quad costs? The usual solution is to use phased verticals. AM broadcast stations, with more than one tower, are using this type of system (although for different reasons than hams). The idea is to place two or more antennas in close proximity and feed them at specific phase angles to produce a desired radiation pattern. A lot of material is available in the literature on phased vertical antenna systems, and it is far too much to be reproduced here. There are "standard patterns" dating from before World War II that are created with different spacings and different phase angles of feed current. In this chapter, we will consider only one system.

Figure 11-1 shows the patterns for a pair of quarter-wavelength vertical antennas spaced a half-wavelength (180°) apart. Without getting into complex phase shifting networks, there are basically two phasings that are easily obtained: 0° (antennas in phase) and 180° (antennas out of phase with each other).

When the two antennas (*A* and *B*) are fed in phase with equal currents (Fig. 11-1A), the radiation pattern (shown somewhat idealized here) is a bidirectional figure 8 that is directionally perpendicular to the line of centers between the two antennas; this pattern is called a *broadside* pattern. A sharp null exists along the line of centers (*A*-*B*).

When the antennas are fed out of phase with each other by 180° (Fig. 11-1B), the pattern rotates 90° (a quarter way around the compass) and now exhibits directivity along the line of the centers (*A*-*B*); this is the "end fire" pattern. The interference cancelling null is now perpendicular to line *A*-*B*.

It should be apparent that you can select your directivity by selecting the phase angle of the feed currents in the two antennas. Figure 11-2 shows the two feeding

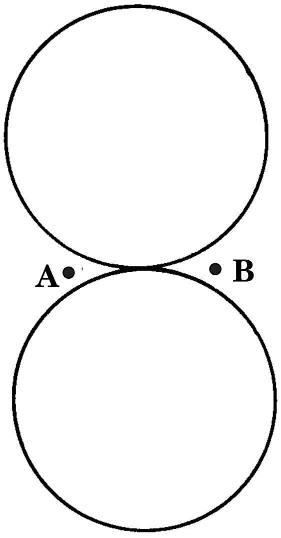

11-1A Pattern of two radiators in-phase, spaced a half-wavelength apart.

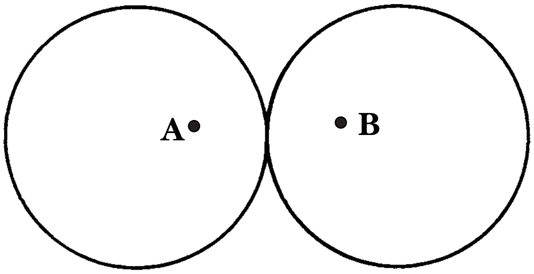

11-1B Pattern of two radiators out of phase, spaced a half-wavelength apart.

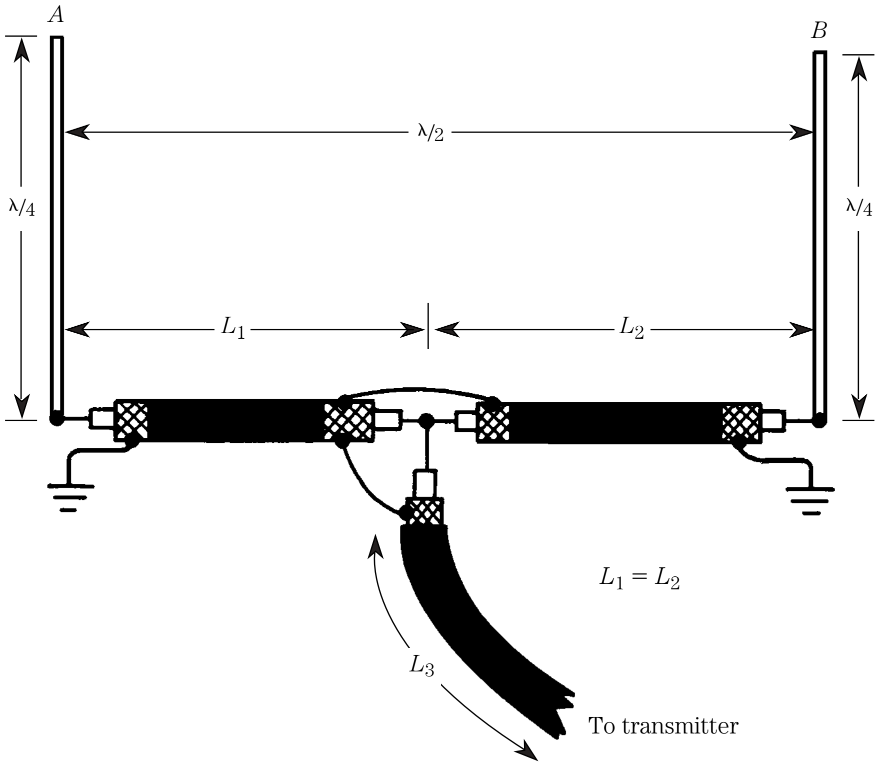

11-2A Feeding a phased array antenna in phase.

systems usually cited for in-phase (Fig. 11-2A) and out-of-phase (Fig. 11-2B) systems. Figure 11-2A shows the coax from the transmitter coming to a coax tee connector. From the connector to the antenna feedpoints are two lengths of coax (L_1 and L_2) that are equal to each other, and identical. Given the variation between coaxial cables, I suspect that it would work better if the two cables were not merely the same length ($L_1 = L_2$), but also that they came from the same roll.

The second variation, shown in Fig. 11-2B, supposedly produces a 180° phase shift between antenna *A* and antenna *B*, when length L_3 is an electrical half-wavelength. According to a much-publicized theory, the system of Fig. 11-2B ought to

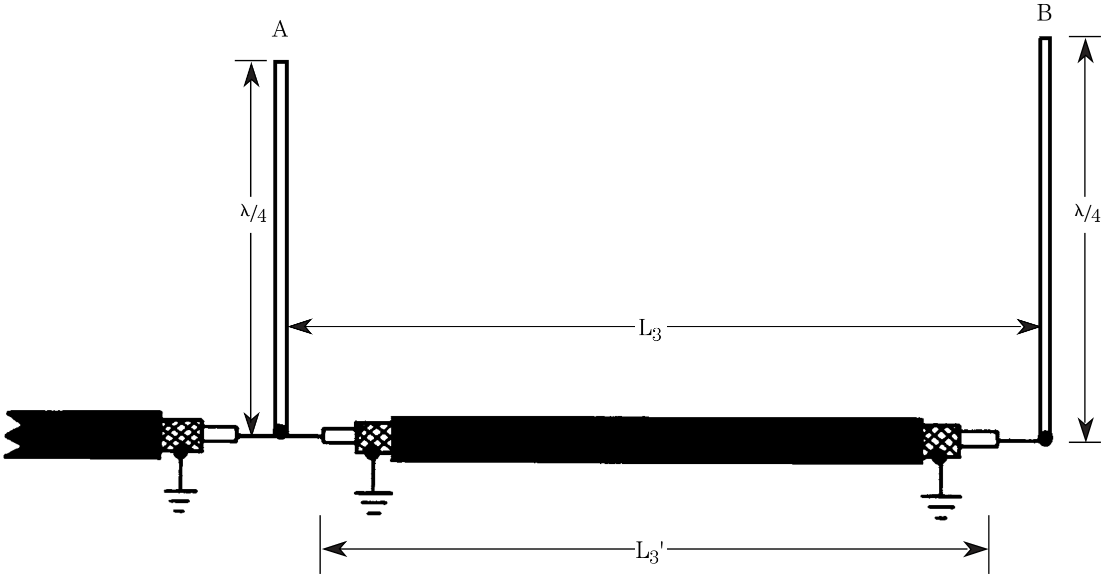

11-2B Feeding a phased array antenna out of phase.

produce the pattern of Fig. 11-1B—yet experience shows this claim is false. It seems that there are several problems with the system in Fig. 11-2B.

First, coax has a property called *velocity factor* (V_F), which is the fraction of the speed of light at which signals in the cable propagate. The V_F is a decimal fraction on the order of 0.66 to 0.90, depending upon the type of coax used. Unfortunately, the physical spacing between *A* and *B* is a real half-wavelength ($L_3 = 492/F$), but the cable length is shorter by the velocity factor [$L_3' = (V_F \times 492)/F$].

Consider an example. A 15-m phased vertical antenna system will have two 11-ft radiators, spaced 22 ft apart (approximately, depending upon exact frequency). If we use foam coax, with $V_F = 0.80$, the cable length is 0.8 × 22 ft, or 17.6 ft. In other words, despite lots of publicity, the cable won't fit between the towers!

Second, the patterns shown in Fig. 11-1 are dependent upon one condition: the *antenna currents are equal*. If both of them are the same impedance, and are fed from the same transmitter, then it is reasonable to assume that the currents are equal—right? No, wrong! What about coax loss? Because of normal coax loss, which increases at higher frequencies, the power available to antenna *B* in Fig. 11-1B is less than the power available to antenna *A*. Thus, the pattern will be somewhat distorted, because the current produced in *B* is less than the current in *A*, when they should be equal.

The first problem is sometimes fixed by using unequal lengths for cables L_1 and L_2 (Fig. 11-2A), and using it for the out-of-phase case. For example, if we make L_1 one-quarter wavelength and L_2 three-quarter wavelength (Fig. 11-2C), antenna *A* is fed with a 90° phase lag (relative to the tee connector signal), while antenna *B* is fed with a 270° phase shift. The result is still a 180° phase difference. Unfortunately, we

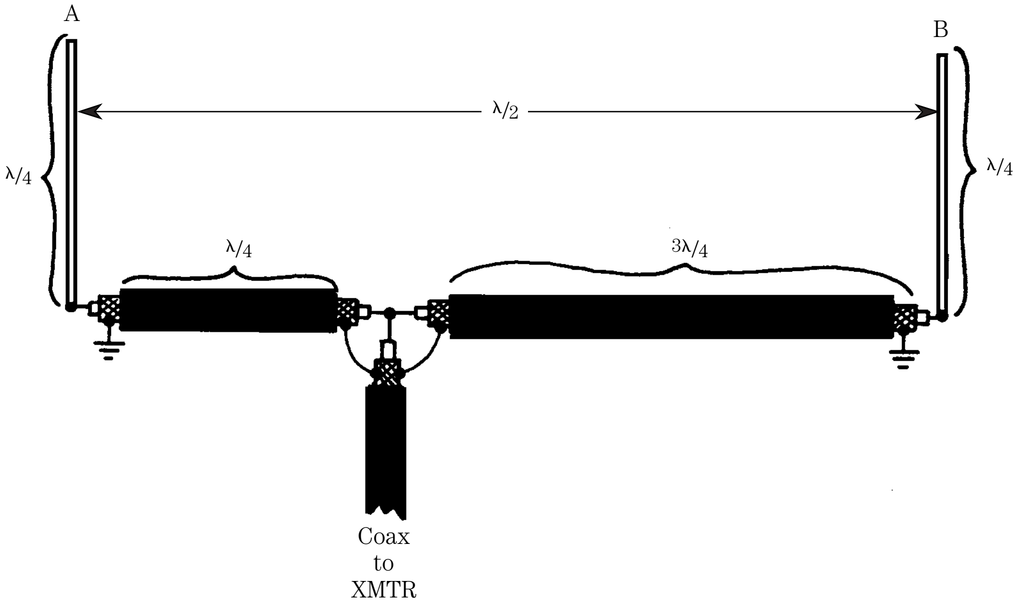

11-2C Corrected feed for a phased array antenna.

have not solved the current level problem, and may have actually made it worse by adding still more lossy cable to the system.

There is still another problem that is generic to the whole class of phased verticals. Once installed, the pattern is fixed. This problem doesn't bother most point-to-point commercial stations, or broadcasters, because they tend to transmit in only one direction. But amateurs are likely to need a rotatable pattern. Neither the antennas in Fig. 11-1A nor that in Fig. 11-1B is rotatable without a lot of effort—like changing the coax feeds, or physically digging up the verticals and repositioning them.

Fortunately, there is a single solution to all three problems. Figure 11-3 shows a two-port phasing transformer made from a toroidal balun kit. Use the kind of kit that makes a 1:1 balun transformer. Although we are not making a balun, we will need enough wire to make three windings, and that is the normal case for 1:1 baluns. Amidon Associates and others make toroidal balun kits.

Wind the three coils in trifilar style, according to the kit instructions. The dots in Fig. 11-3 show the "sense" of the coils, and they are important for correct phasing; call one end the "dot end" and the other end the "plain end" to keep them separate. If the dot end of the first coil is connected to J_3 (and the transmitter), then connect the dot end of the second coil to the 0° output (J_1, which goes to antenna A). The third coil is connected to a DPDT RF relay or switch. In the position shown, S_1 causes the antennas to be 180° out of phase. In the other position, the "sense" of the third coil is reversed, so the antennas are in phase.

Another phasing method is shown in Fig. 11-4. In this scheme, two convenient, but equal, lengths of coaxial cable (L_1 and L_2) are used to carry RF power to the antennas. One segment (L_1) is fed directly from the transmitter's coaxial cable (L_3), while the other is fed from a phasing switch. The phasing switch is used to either by-

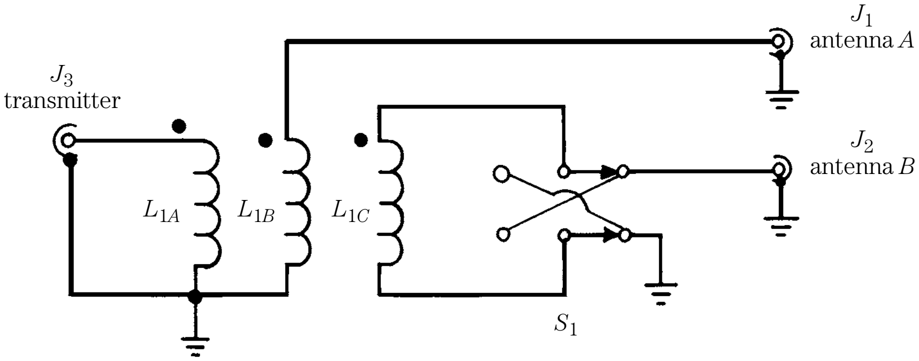

11-3A Phasing transformer circuit.

pass or insert a phase-shifting length of coaxial cable (L_4). For 180° phasing use the following equation to find the length (L_4):

$$L = \frac{492\ V_F}{F_{\text{MHz}}}\ \text{ft} \qquad \textbf{[11.1]}$$

where

L is the length of $L_{4,}$ in feet
V_F is the velocity factor (a decimal fraction)
F_{MHz} is the operating frequency, in megahertz

Some people use a series of switches to select varying amounts of phasing shift from 45° to 270°. Such a switch allows them to select any number of other patterns for special situations.

360° directional array

The phased vertical antenna concept can be used to provide round-the-compass control of the antenna pattern. Figure 11-5A shows how three quarter-wavelength verticals (arranged in a triangle that is a half-wavelength on each side) can be used to provide either end-fire or broadside patterns from any pair (*A*-*B*, *A*-*C*, or *B*-*C*). Any given antenna (*A*, *B*, or *C*) will be grounded, fed at 0°, or fed with 180°. The table in Fig. 11-5B shows the relative phasing for each direction that was labelled in Fig. 11-5A. Either manual phase changing or switch-operated phase changing can be used, although the latter is preferred for convenience. Some international showcase broadcasters use antenna arrays formed into two or more concentric circles of vertical elements, with one element at the center. Selection of elements and phasing determines directivity and gain.

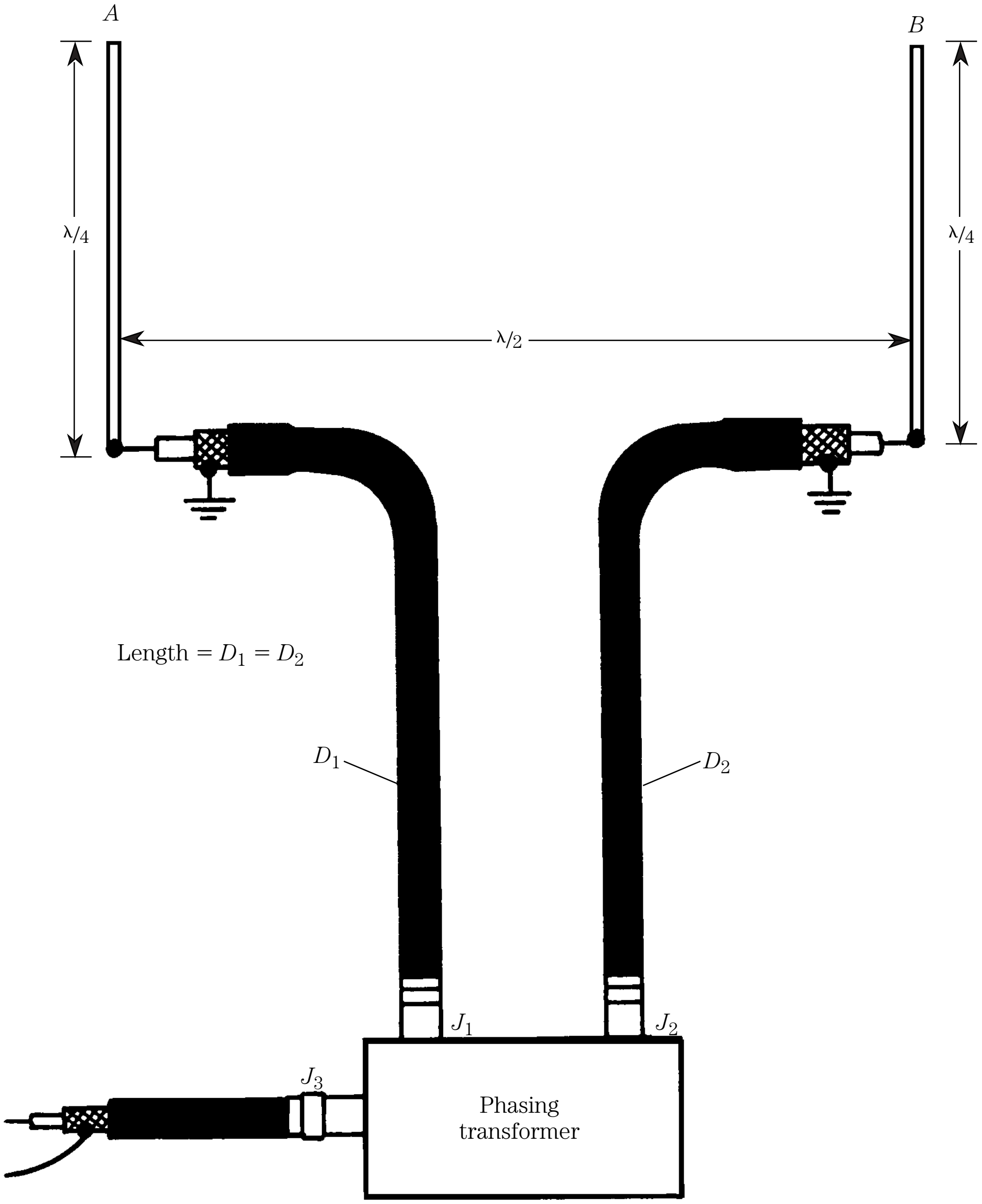
A
B
λ/4
λ/4
λ/2
Length = D_1 = D_2
D_1
D_2
J_1
J_2
J_3
Phasing
transformer

11-3B Connection to antennas.

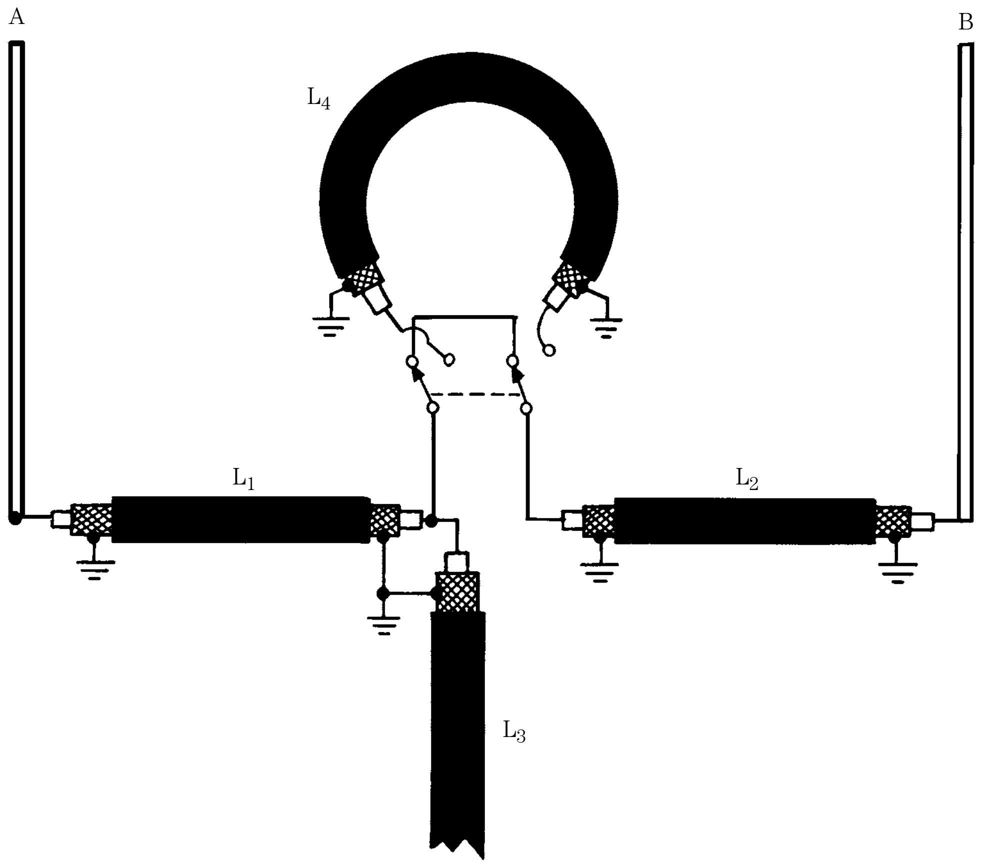

11-4 Phase-shifting antenna circuit.

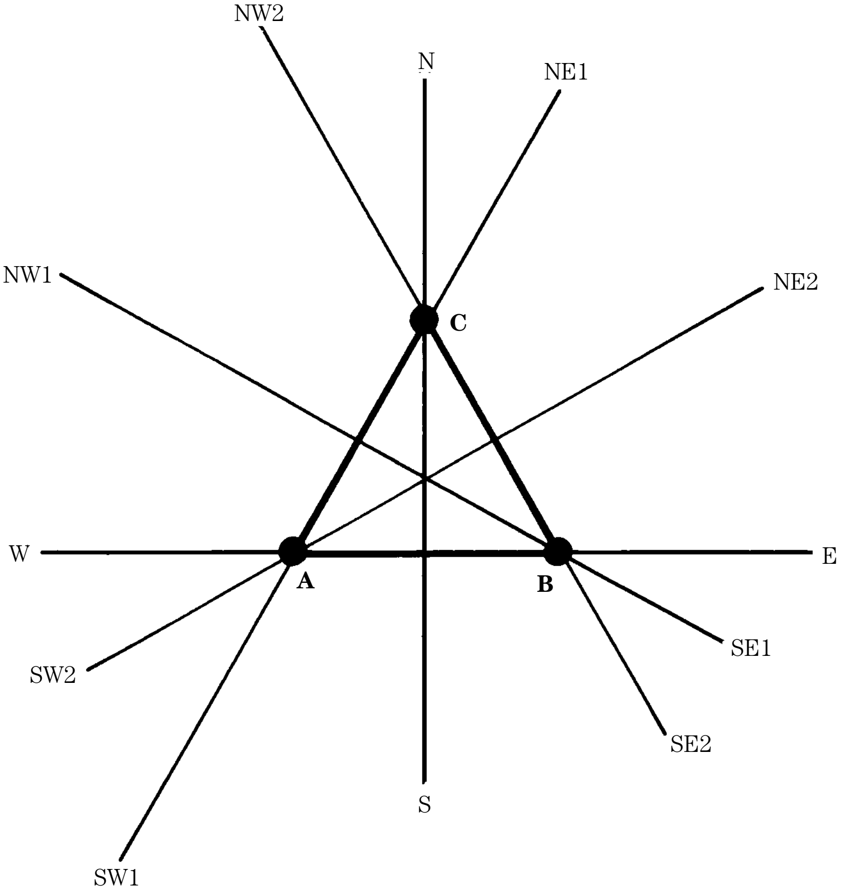
NW2
N
NE1
NW1
NE2
C
W
E
A
B
SW2
SE1
SE2
S
SW1

11-5A Three-element phased array.

Direction	Ant A	Ant B	Ant C
N-S	0°	0°	GND
NE1-SW1	0°	GND	180°
NE2-SW2	GND	0°	0°
E-W	0°	180°	GND
SE1-NW1	0°	GND	0°
SE2-NW2	GND	0°	180°

11-5B Table of feed phasing for the three-element array. Ant = antenna. GND = ground

12
CHAPTER

Directional beam antennas

THE DIRECTIONAL BEAM ANTENNA DOES SEVERAL JOBS. FIRST, IT PROVIDES AN APPARENT increase in radiated power, because it focuses available transmitter power into a single (or at worst limited) direction. For this reason, a bidirectional dipole has a gain of approximately 2 dB over an isotropic radiator. Add one or more additional elements, and the focusing becomes nearly unidirectional, which increases the *effective radiated power* (ERP) even more. Second, the beam increases the received signal available at the inputs of the receiver. Antennas are generally reciprocal, so they will work for receiving as they do for transmitting. Finally, the directivity of the beam antenna allows the operator to null interfering stations. In fact, it is the last attribute of the beam that is most useful on today's crowded bands. All in all, if your funds are too little to provide both increased RF power and a good antenna system, then spend what is available on the antenna—not on the power.

In this chapter we will focus on directional antennas that can be built relatively easily. It is assumed that most readers who want a triband multielement Yagi will prefer to buy a commercial product, rather than build a homebrew model. The material herein concentrates on homebrew projects that are within the reach and capabilities of most readers. The first of these is not a beam antenna at all, but rather a *rotatable dipole.*

Rotatable dipole

The *dipole* is a bidirectional antenna with a figure-8 pattern (when viewed from above). The dipole is a half-wavelength and is usually installed horizontally, although vertical half-wavelength dipoles are known. Although the length of the dipole is too great for rotatability at the lower bands, it is within reason for the higher band. For example, the size of the halfwave dipole is approximately 16 ft on 10 m and 22 ft on 15 m. Even the 33-ft length on 20 m is not unreasonable for amateur constructors. The length of the dipole is found from

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$$L = \frac{468}{F_{\mathrm{MHz}}}\ \mathrm{ft} \qquad \textbf{[12.1]}$$

This length is approximate because of end effects and other phenomena, so some "cut and try" is required.

Example 12-1 Find the length of a dipole antenna for a frequency of 24.930 MHz in the 12-m amateur radio band.

Solution:

:

$$\begin{aligned} L &= \frac{468}{F_{\mathrm{MHz}}}\ \mathrm{ft} \\ &= \frac{468}{24.930\ \mathrm{MHz}} = 18.77\ \mathrm{ft} \end{aligned}$$

The half-wave dipole is fed in the center by coaxial cable. Each element of the dipole is one-half of the overall length (or, in the example given, about 9.4 ft).

Figure 12-1 shows a rotatable dipole that can be designed for use on 15, 12, and 10 m. The radiator elements are made from 10-ft lengths of $\frac{3}{4}$-in aluminum tubing. The tubing is mounted on "beehive" standoff insulators, which in turn are mounted on a 4-ft length of 2 × 2 lumber. The lumber should be varnished against weathering. In a real pinch, the elements can be mounted directly to the lumber without the insulators, but this is not the recommended practice.

The mast is attached to the 2 × 2 lumber through any of several means. The preferred method is the use of a 1-in pipe flange. These devices are available at hardware stores under the names *floor flange* and *right-angle flange.*

The 10-ft lengths of pipe are the standard lengths available in hardware stores, so it was selected as being closest to the required 22 ft for 15 m. A 0.14-µH loading coil is used at the center, between the elements, in order to make up for the short length. The dimensions of the coil are 4 to 5 turns, 0.5-in diameter, 4-in length. For low power levels, the coil can be made of no. 10 (or no. 12) solid wire—and, for higher levels, $\frac{1}{8}$-in copper tubing.

There are two basic ways to feed the antenna, and these are shown in details A and B in Fig. 12-1. The traditional method is to connect the coaxial cable (in parallel) across the inductor. This method is shown in Fig. 12-1, detail A. A second method is to link couple the coil to the line through a one- to three-turn loop (as needed for impedance matching). This is the method that would be used for a toroidal inductor.

Lower frequencies can be accommodated by changing the dimensions of the coil. The coil cannot be scaled, simply because the relative length of the antenna changes as the frequency changes. But it is possible to cut and try by adding turns to the coil, one turn at a time, and remeasuring the resonant frequency. Adding inductance to the coil will make the antenna usable on 17 m and 20 m, as well as on 15 m.

Another method for building a rotatable dipole for lower frequencies is to increase the element lengths. On 17 m, the overall length is approximately 27.4 ft, so each element length is 13.7 ft long. This length can be achieved by either of two methods. First, adjacent sizes of aluminum tubing are designed so that the smaller will be a slip-fit inside of the larger. What constitutes "adjacent sizes" depends on the wall thickness, but for one common brand, the $\frac{7}{8}$-in is adjacent to the $\frac{3}{4}$-in size. You

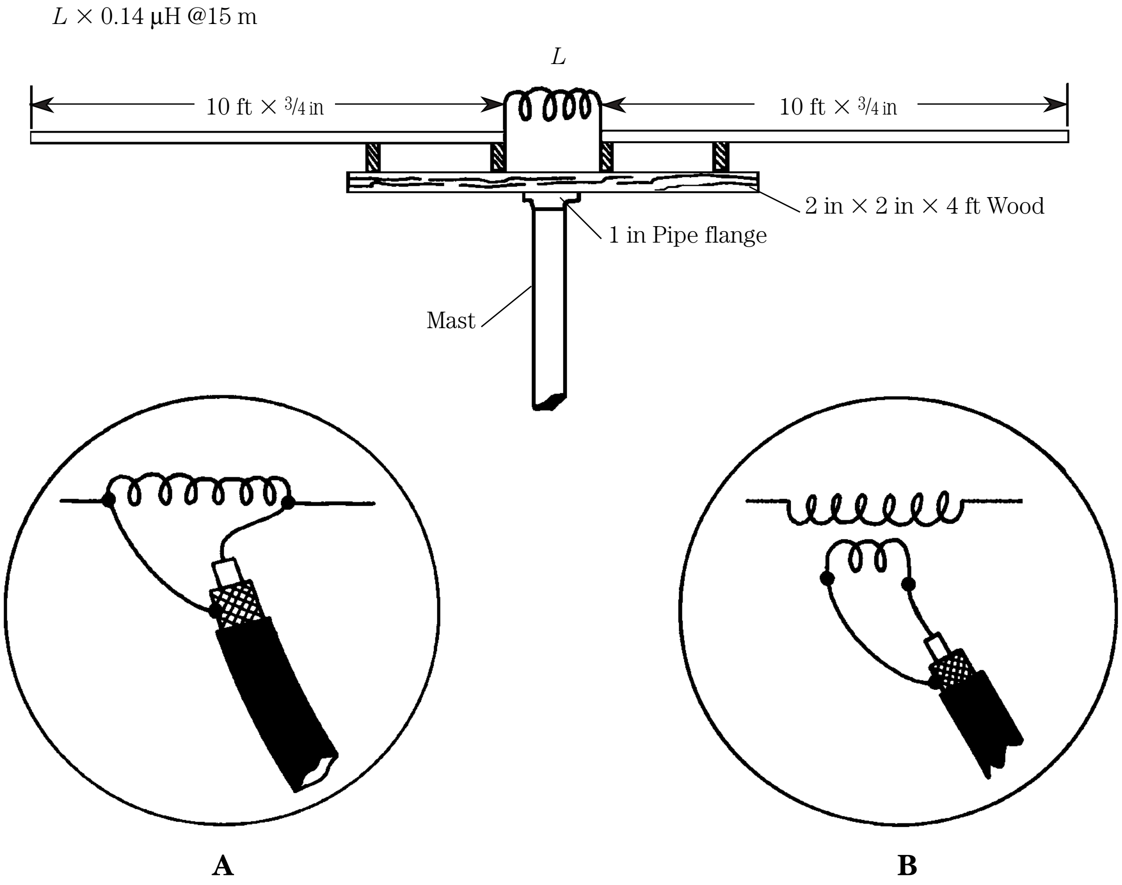

12-1 Rotatable dipole antenna. Inset A shows conventional feed; inset B shows transformer feed.

can use two smaller lengths to make the larger lengths of pipe, and cut it to size. This method is only available to those readers who have a commercial or industrial metals distributor nearby, because the 16-ft lengths are not generally available from hardware stores.

Bands higher than 15 m (i.e., 12 and 10 m) can be accommodated by using the 10-ft lengths of tubing, but without the inductor. The tubing is cut to the desired half-wavelength size and used directly.

Yagi beam antennas

A *Yagi* antenna is one member of a class of directional beam antennas that are popular in the HF bands. Figure 12-2 shows the pattern (viewed from above) typical of the beam antenna. The antenna is located at point P and fires signals in the direction shown by the arrow. The beamwidth of the antenna is the angle a between the points on the main lobe that are -3 dB down from the center point C.

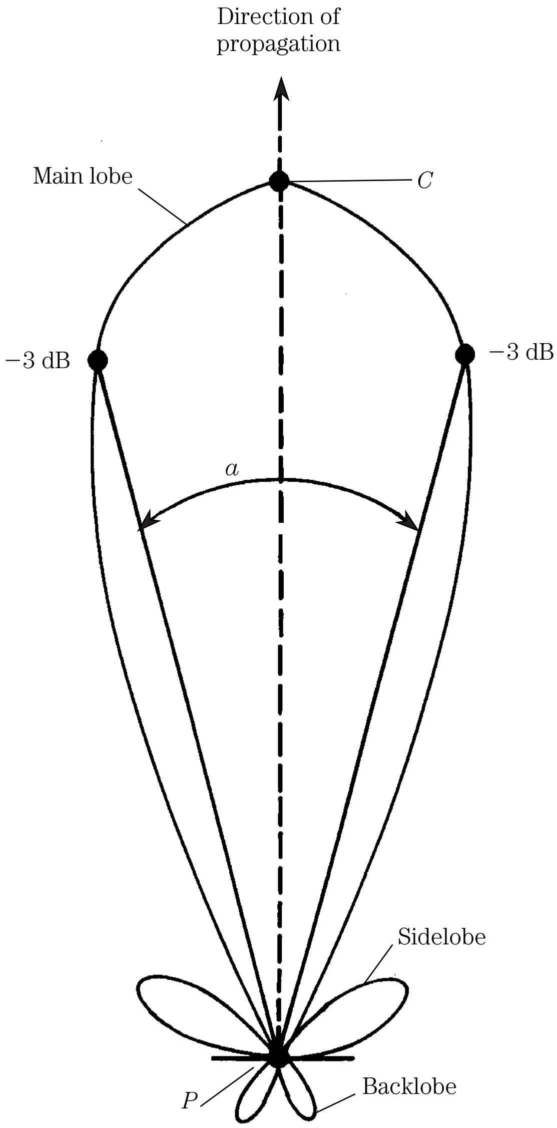

12-2 Pattern of beam antenna.

A perfect beam antenna will have only the main lobe, but that situation occurs only in dreams. All real antennas have both sidelobes and backlobes, also shown in Fig. 12-2. These lobes represent wasted power transmitted in the wrong direction during transmission and interference opportunities while receiving. The goal of the antenna designer is to increase the main lobe while decreasing the sidelobes and backlobes.

Figure 12-3 shows, schematically, the basic *Yagi-Uda* antenna (usually called simply *Yagi*). The driven element is a simple half-wavelength dipole fed in the center. There are two additional elements: *reflectors* and *directors.* These are called *parasitic elements* because they are not directly excited by RF, but rather, they receive energy radiated from the driven element and then reradiate it. The reflector is placed behind the driven element, and is typically about 4 percent longer than the driven element. The director is placed in front of the driven element (relative to the direction of propagation). The director is typically about 4 percent shorter than the driven element. Although there is no fixed rule regarding the number of either reflectors or directors, it is common practice to use a single director and a driven element for two-element beams, and a single reflector and a single director, in addition to the driven element, for three-element beams. Again, additional reflectors can be added for four- and more element beams, but standard practice calls for addition of directors instead.

The length of the elements is given by

$$L = \frac{K}{F_{\mathrm{MHz}}}\ \mathrm{ft} \qquad \textbf{[12.2]}$$

where

L is the length, in feet
F_{MHz} is the frequency, in megahertz
K is a constant

The spacing of the elements is typically from 0.15 to 0.308 wavelengths, although 0.2 and 0.25 are the most common values.

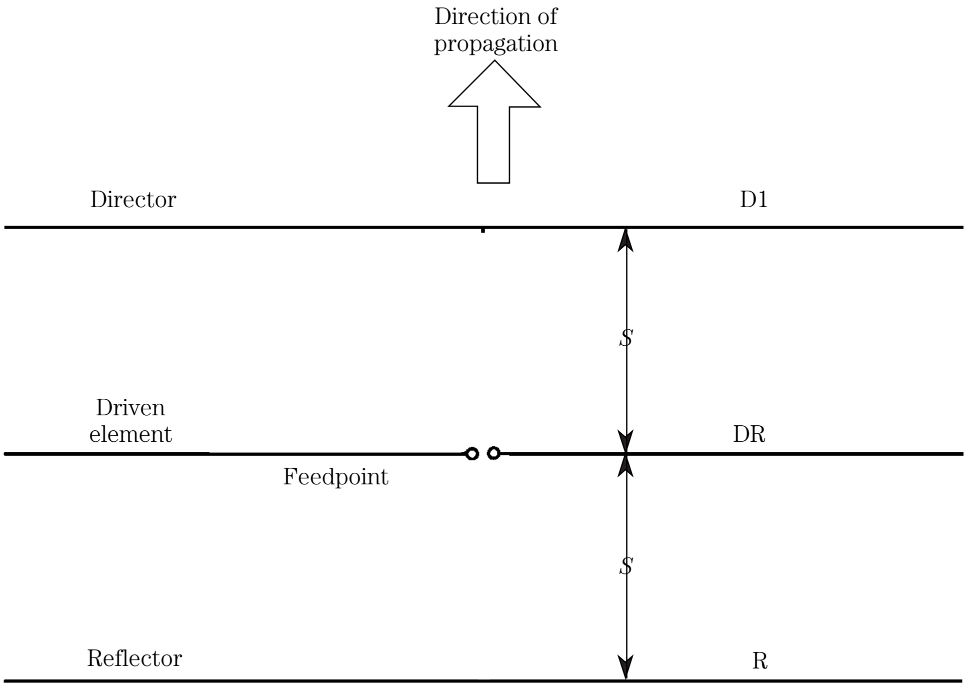

12-3 Basic Yagi-Uda antenna.

Example Calculate the approximate element lengths for a three-element 15-m beam designed to operate on a frequency of 21.39 MHz.

Solution:

1. Driven element ($K = 478$):

$$L = \frac{K}{F_{\text{MHz}}} \text{ ft} = \frac{478}{21.39 \text{ MHz}} \text{ ft} = 22.34 \text{ ft}$$

2. Reflector ($K = 492$):

$$L = \frac{K}{F_{\text{MHz}}} \text{ ft} = \frac{492}{21.39 \text{ MHz}} \text{ ft} = 23 \text{ ft}$$

3. Director ($K = 461.5$):

$$L = \frac{K}{F_{\text{MHz}}} \text{ ft} = \frac{461.5}{21.39 \text{ MHz}} \text{ ft} = 21.58 \text{ ft}$$

4. Element Spacing (K = 142):

$$L = \frac{K}{F_{\text{MHz}}} \text{ ft} = \frac{142}{21.39 \text{ MHz}} \text{ ft} = 6.64 \text{ ft}$$

The elements of a rotatable beam antenna can be built in a manner similar to the rotatable dipole described earlier. In the beam antenna, however, a boom is needed between the elements to support them. The boom can be made of metal or wood. In the case of a metal boom, the driven element must be insulated from the boom, even though the parasitic elements can be mounted directly to it. In general, it is usually better to use wood as a matter of convenience. Metal boom antennas can be obtained from commercial sources. The wood boom is easy to build and maintain, even though a little less durable than a metal boom.

The feedpoint impedance of a dipole is on the order of 72 Ω in free space, although the actual impedance will vary above and below that figure for antennas close to the earth's surface. In addition, adding parasitic elements reduces the impedance even more. The feedpoint impedance of the antenna is too low to be directly fed with coaxial cable, so some means of impedance matching is needed. Some people feed the antenna through an impedance matching balun transformer. Figure 12-4 shows the *gamma match* system. The driven element of the Yagi is not broken in the center, as in the case of the simple dipole. The outer conductor, or shield, of the coaxial cable is connected to the center point of the driven element. The center conductor is connected to the gamma match element. The dimensions of the gamma match are

1. Gamma match length: $L/10$
2. Gamma match director: $D/3$
3. Spacing of gamma match from driven element: $L/70$

where
L is the length of the driven element
D is the diameter of the driven element

The capacitor in series with the center conductor of the coaxial cable has a value of approximately 8 pF per meter of wavelength at the lowest frequency in the band of operation, or approximately,

$$C = \frac{2400}{F_{\mathrm{MHz}}}\ \mathrm{pF} \qquad \textbf{[12.3]}$$

The capacitor must be a high-voltage transmitting variable type. In general, the gamma match capacitors are either air or vacuum variables.

There are three aspects to the adjustment of the Yagi antenna. Resonance is determined by the length of the element. The length is increased or decreased in order to find the resonant point. This point can be determined by the use of a noise bridge, VSWR meter or other means. The capacitor, and the shorting bar/clamp, are adjusted to match the impedance of the antenna to the transmission line impedance. For the dimensions shown, the coaxial cable should be 52 Ω (RG-58 or RG-8).

It is not necessary to use tubing or pipes for the antenna elements in order to obtain the benefits of the Yagi beam antenna. An example of a wire beam is shown in Fig. 12-5. The wire beam is made as if it were two half-wavelength dipoles, installed parallel to and about 0.2 to 0.25 wavelengths apart from each other. Although multielement wire beams are possible, the two-element version is the most common. Perhaps the most frequent

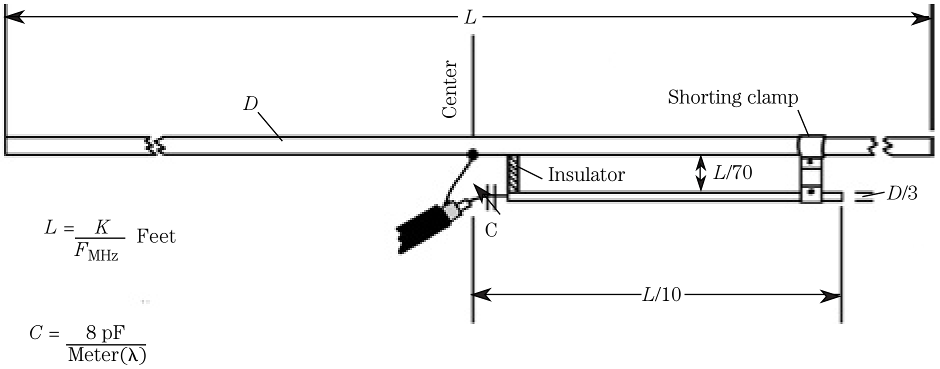
L
D
Center
Shorting clamp
Insulator
L/70
D/3
C
$L = \frac{K}{F_{\mathrm{MHz}}}$ Feet
L/10
$C = \frac{8\ \mathrm{pF}}{\mathrm{Meter}(\lambda)}$

12-4 Gamma feed provides impedance matching.

use of the wire beam antenna is on the lower bands (e.g., 40 m and 75/80 m) where rotatable beams are more difficult to build.

20-m ZL-special beam

The antenna shown in Fig. 12-6 is a close relative of the Yagi beam. It consists of a pair of folded dipoles, mounted approximately 0.12 wavelengths apart. The elements are 30.5 ft in length, and the spacing is 7.1 ft. The elements can be built from aluminum tubing if the antenna is to be rotatable. Alternatively, for a fixed antenna, the elements can be made of 300-Ω television-type twin lead. If the tubing type of construction is selected, then make the size of the tubing, and its spacing, sufficient for 300-Ω parallel transmission lines, according to

$$Z_o = 276 \log \frac{2S}{d} \qquad \textbf{[12.4]}$$

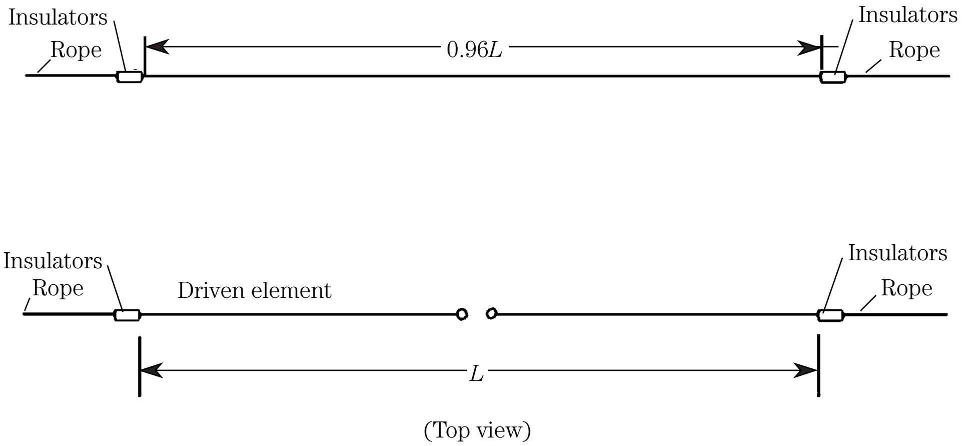
Insulators
Rope
0.96L
Insulators
Rope
Insulators
Rope
Driven element
Insulators
Rope
L
(Top view)

12-5 Wire beam useful for low frequencies.

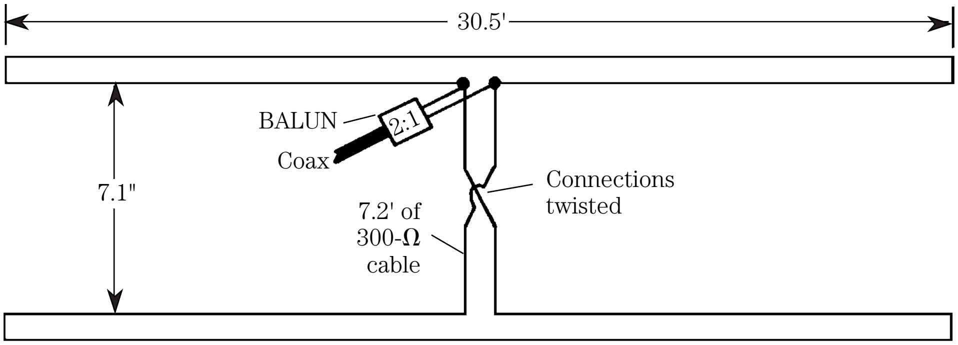
30.5'
BALUN
2:1
Coax
7.1"
7.2' of
300-Ω
cable
Connections
twisted

12-6 ZL-special beam antenna.

where

Z_o is the impedance of the line (300 Ω)
S is the center-to-center spacing of the parallel conductors on the elements
d is the diameter of the conductors

The two half-wavelength elements of the ZL-special are fed 135° out of phase with each other. The feedline is connected to one of the dipoles directly; and then to the other through a length of 300-Ω twin lead that has an electrical length of about 45° (λ/8).

The feedpoint impedance is on the order of 100 to 150 Ω, so it will make a good match to either 52- or 75-Ω coaxial cable if a 2:1 impedance matching transformer is used.

Cubical quad beam antenna

The *cubical quad* antenna is a one-wavelength square wire loop. It was designed in the mid-1940s at radio station HCJB in Quito, Ecuador. HCJB is a Protestant missionary shortwave radio station with worldwide coverage. The location of the station is at a high altitude. This fact makes the Yagi antenna less useful than it is at lower altitudes. According to the story, HCJB originally used Yagi antennas. These antennas are fed in the center at a current loop, so the ends are high-voltage loops. In the thin air of Quito, the high voltage at the ends caused corona arcing, and that arcing periodically destroyed the tips of the Yagi elements. Station engineer Clarence Moore designed the cubical quad antenna (Fig. 12-7) to solve this problem. Because it is a full-wavelength antenna, each side being a quarter wavelength, and fed at a current loop in the center of one side, the voltage loops occur in the middle of the adjacent sides—and that reduces or eliminates the arcing. The elements can be fed in the center of a horizontal side (Figs. 12-7A and 12-8A), in the center of a vertical side (Fig. 12-8B), or at the corner (Fig. 12-8C).

The antenna shown in Fig. 12-7A is actually a quad loop rather than a cubical quad. Two or more quad loops, only one of which needs to be fed by the coax, are used to make a cubical quad antenna. If only this one element is used, then the antenna will have a figure-8 azimuthal radiation pattern (similar to a dipole). The quad loop antenna is preferred by many people over a dipole for two reasons. First, the quad loop has a smaller "footprint" because it is only a quarter-wavelength on each side (*A* in Fig. 12-7A). Second, the loop form makes it somewhat less susceptible to local electromagnetic interference (EMI).

The quad loop antenna (and the elements of a cubical quad beam) is mounted to spreaders connected to a square gusset plate. At one time, carpets were wrapped around bamboo stalks, and those could be used for quad antennas. Those days are gone, however, and today it is necessary to buy fiberglass quad spreaders. A number of kits are advertised in ham radio magazines.

The details for the gusset plate are shown in Fig. 12-7B. The gusset plate is made of a strong insulating material such as fiberglass or $\frac{3}{4}$-in marine-grade plywood. It is mounted to a support mast using two or three large U bolts (stainless steel to prevent corrosion). The spreaders are mounted to the gusset plate using somewhat smaller U bolts (again, use stainless steel U bolts to prevent corrosion damage).

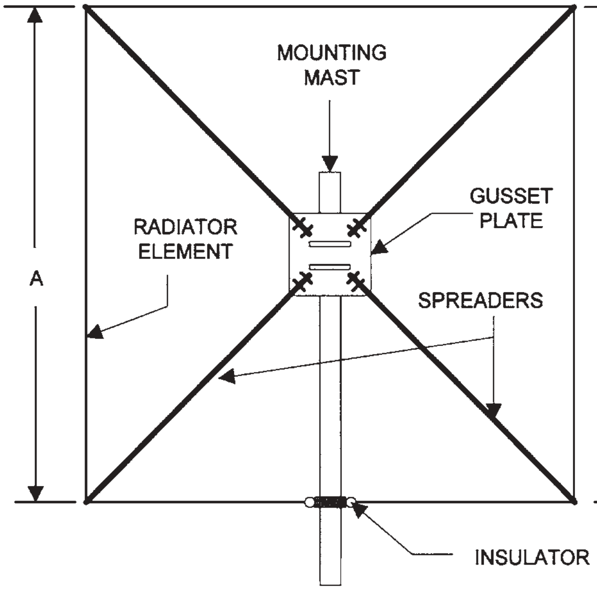
MOUNTING MAST
GUSSET PLATE
RADIATOR ELEMENT
A
A
SPREADERS
INSULATOR

12-7A Quad loop antenna.

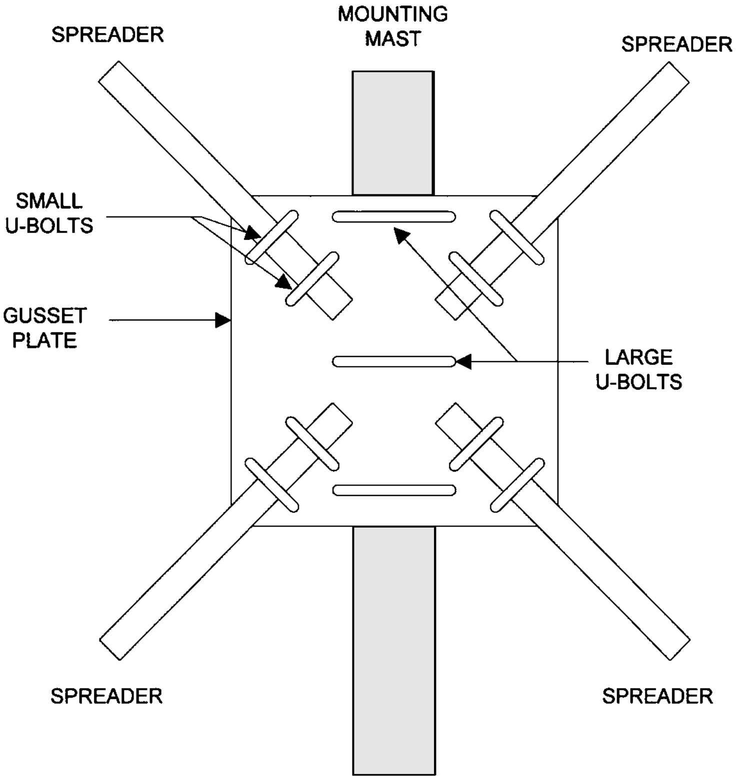
SPREADER
MOUNTING MAST
SPREADER
SMALL U-BOLTS
GUSSET PLATE
LARGE U-BOLTS
SPREADER
SPREADER

12-7B Quad loop antenna.

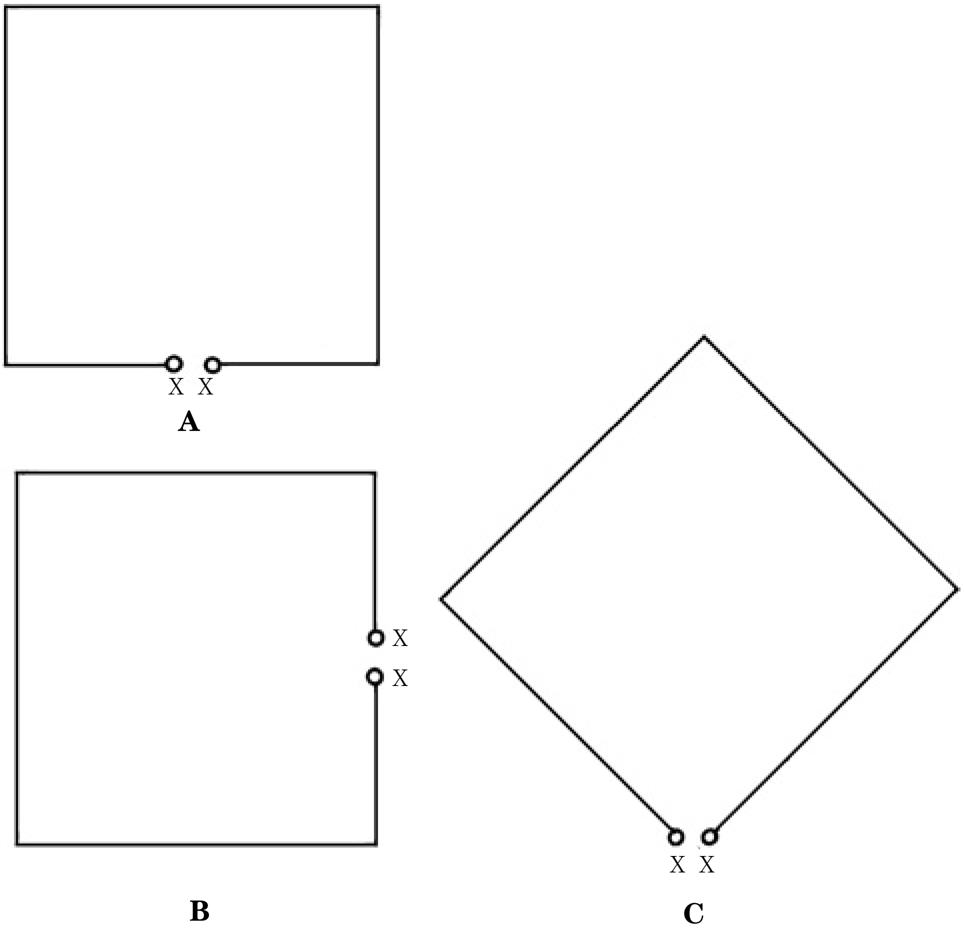

12-8 Feed options for the quad.

There is a running controversy regarding how the antenna compares with other beam antennas, particularly the Yagi. Some experts claim that the cubical quad has a gain of about 1.5 to 2 dB higher than a Yagi (with a comparable boom length between the two elements). In addition, some experts claim that the quad has a lower angle of radiation. Most experts agree that the quad seems to work better at low heights above the earth's surface, but the difference disappears at heights greater than a half-wavelength.

The quad can be used as either a single-element antenna or in the form of a beam. Figure 12-9 shows a pair of elements spaced 0.13 to 0.22 wavelengths apart. One element is the driven element, and it is connected to the coaxial-cable feedline directly. The other element is a reflector, so it is a bit longer than the driven element. A tuning stub is used to adjust the reflector loop to resonance.

Because the wire is arranged into a square loop, one wavelength long, the actual length varies from the naturally resonant length by about 3 percent. The driven

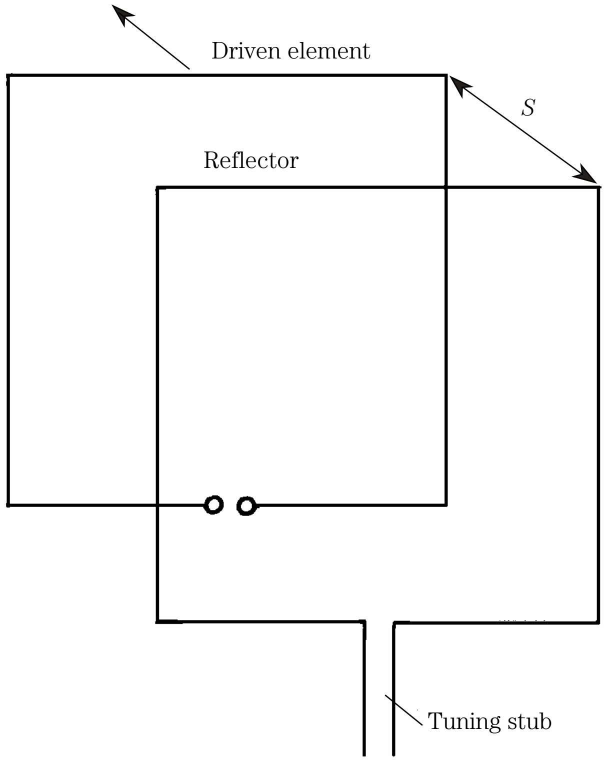

$0.13\lambda \leq S \leq 0.22\lambda$

12-9 Quad beam antenna.

element is about 3 percent longer than the natural resonant point. The overall lengths of the wire elements are

1. Driven element: $$L = \frac{1005}{F_{\mathrm{MHz}}}\ \mathrm{ft} \qquad \textbf{[12.5]}$$

2. Reflector: $$L = \frac{1030}{F_{\mathrm{MHz}}}\ \mathrm{ft} \qquad \textbf{[12.6]}$$

3. Director: $$L = \frac{975}{F_{\mathrm{MHz}}}\ \mathrm{ft} \qquad \textbf{[12.7]}$$

One method for the construction of the quad beam antenna is shown in Fig. 12-10. This particular scheme uses a 12 × 12-in wooden plate at the center, bamboo (or fiberglass) spreaders, and a wooden (or metal) boom. The construction must be heavy-duty in order to survive wind loads. For this reason, it is probably a better solution to buy a quad kit consisting of the spreaders and the center structural element.

More than one band can be installed on a single set of spreaders. The size of the spreaders is set by the lowest band of operation, so higher frequency bands can be accommodated with shorter loops on the same set of spreaders.

This quad antenna is an example of a multielement, large loop antenna. Additional information on large loops, but not in a beam antenna array, is found in Chap. 14.

Inverted bobtail curtain (Thorne array)

The *bobtail curtain* antenna is a fixed array consisting of three individual quarter-wavelength elements spaced a half-wavelength apart, and fed from the top by a

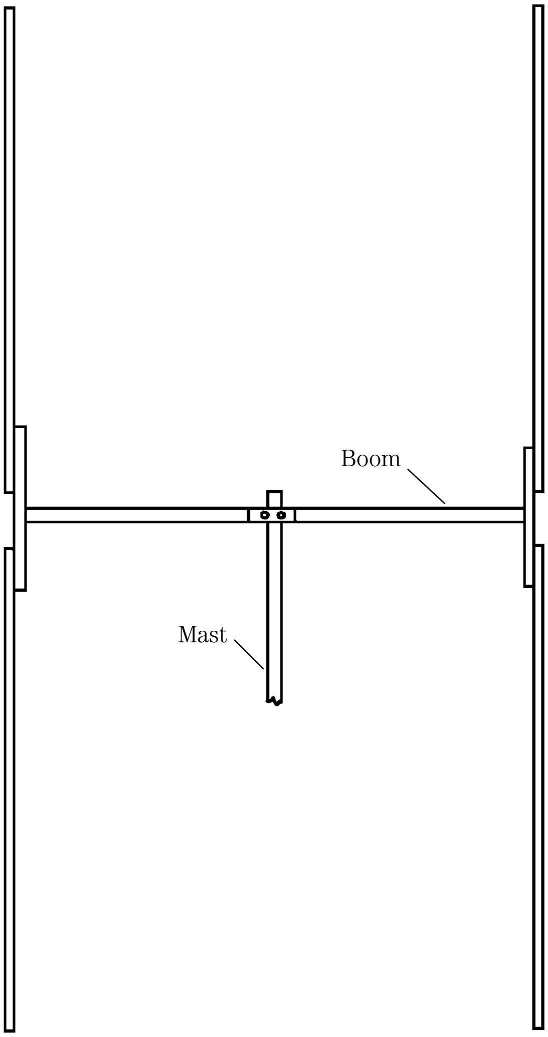

12-10 Quad construction.

shorting element or wire. The *inverted bobtail curtain,* or *Thorne array,* consists of an *upside down* bobtail curtain as shown in Fig. 12-11. The radiator elements are each a quarter-wavelength long. Their lengths are found from

$$L = \frac{246}{F_{\text{MHz}}}\ \text{ft} \qquad \textbf{[12.8]}$$

The lengths of spacing between the elements are exactly twice above the value, or

$$L = \frac{492}{F_{\text{MHz}}}\ \text{ft} \qquad \textbf{[12.9]}$$

The antenna is fed at the base of the center element, through a parallel resonant tuner. The capacitor is a 100- to 200-pF transmitting variable, while the inductor is set to resonate at the band desired (with the capacitor at half to three-quarters full capacitance). A loop or link coupling scheme connects the tuner to the transmission line.

An alternate feed method (Fig. 12-12) worked out by the late J. H. Thorne (K4NFU/5), feeds the end elements from the shield of the coaxial cable, and the center element of the array is fed from the center conductor of the coaxial cable. A coaxial impedance-matching section is used between the cable transmitter and the antenna feedpoint.

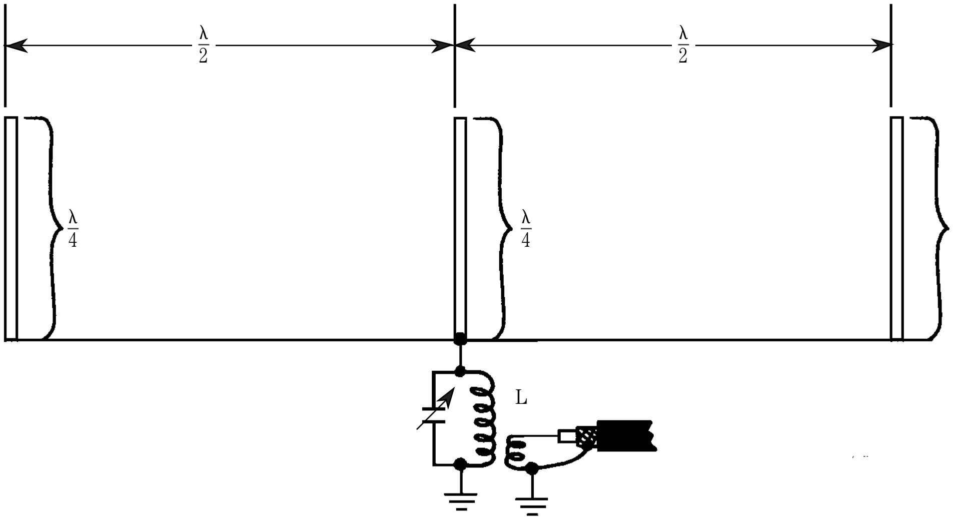

12-11 Inverted bobtail curtain.

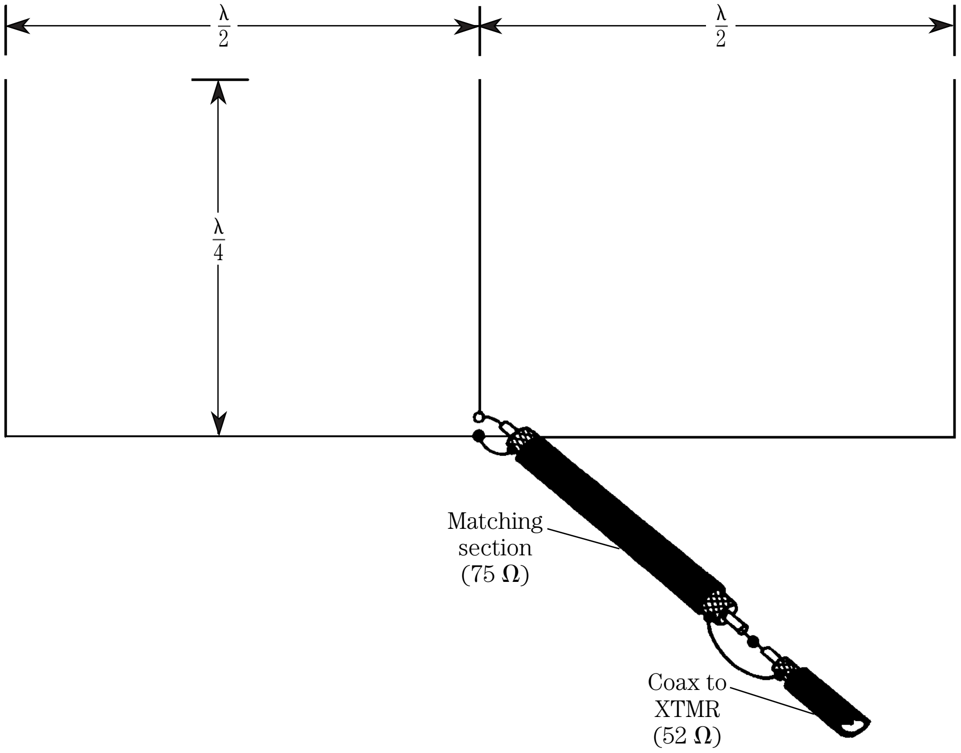
λ/2
λ/2
λ/4
Matching section (75 Ω)
Coax to XTMR (52 Ω)

12-12 Thorne array.

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13
CHAPTER

Antennas for shortwave reception

ALTHOUGH MOST OF THIS BOOK ADDRESSES ANTENNAS FOR TRANSMITTING, THERE IS A certain body of material that pertains purely to receiving antennas. This material also needs to be addressed, and that is the function of this chapter. There are two readers in mind for this chapter. First, and foremost, is the shortwave listener (SWL). Second, however, is the amateur radio operator who wants to either use a separate receiving antenna on the main station receiver or use an ancillary receiver (common among DXers).

The law of reciprocity

Antennas possess a property called *reciprocity.* That is a fancy way of saying that an antenna works on reception the same way it does for transmission. Although articles occasionally appear in the literature claiming an HF or VHF design which violates the *law of reciprocity,* to date all have depended on either variable definitions, false premises, or faulty measurements. There is even a school of thought that falsely argues against antenna reciprocity based on an ionospheric anomaly in which propagation depends on the *direction* traveled (see the end of Chap. 2). The bottom line of reciprocity, for the SWL, is that every antenna described in this book can be also used with equal results on receive. For example, a half-wavelength dipole works equally well as a receiver antenna, or as a transmitter antenna.

Which properties are important?

Selecting a receiver antenna is a function of several factors. Assuming that you want more than a simple longwire (which we will deal with shortly), you will want to home in on the properties desired for your particular monitoring application. Is the antenna to be fixed or rotatable? Do you want omnidirectional or directional reception? In which plane? What about gain?

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What about gain? What is gain, for that matter? The concept of antenna gain derives from the fact that directional antennas focus energy. Two kinds of gain figure are often quoted: gain referenced to a dipole antenna on the same frequency, and gain relative to a theoretical construct called an *isotropic radiator.* In the isotropic case, the reference radiator to which the antenna is compared is a spherical point source that radiates equally well in all directions. The dipole exhibits a figure-8 radiation and reception pattern.

The gain of an antenna is merely the ratio (usually expressed in decibels) of the power radiated in a given direction by two antennas (i.e., the reference antenna and the test antenna). If an antenna gain is listed as "8-dB gain over isotropic," this means that, in the direction specified, the power radiated is 8 dB higher than the same total power applied to an isotropic radiator.

So, of what use is antenna gain? Two answers immediately present themselves. First, by accumulating more signal, the antenna essentially makes your receiver more sensitive. Note that the gain of the antenna does not create a higher powered signal, it merely increases the apparent signal power by focusing energy from a given direction. And, note well that *gain* implies *directivity.* Any antenna that claims to provide gain, but that is truly omnidirectional in all planes, is a fraud. The fundamental assumption is that *gain implies directivity.*

The concept of directivity (hence also of gain) is often taken to mean *horizontal directivity,* which is the case of a dipole antenna. But all forms of antenna radiate in three-dimensional space. Azimuth angle of radiation, and elevation angle of radiation, are both important. Certain 2-m vertical antennas are listed as "gain antennas," yet the pattern in the horizontal direction is 360°—implying omnidirectional behavior. In the vertical plane, however, lost energy is compressed into a smaller range of elevation angles, so gain occurs by refocusing energy that would have been radiated at a higher than useful angle.

The second application of directivity is in suppressing interfering signals. On the regular AM and FM broadcast bands, channelization permits receiver selectivity to overcome adjacent channel interference in most cases. But in the HF amateur radio and international broadcast bands, channelization is either nonexistent, poorly defined, or ignored altogether. In these cases, interfering "adjacent" channel signals can wipe out a weaker, desired station. Similarly, with cochannel interference (i.e., when both stations are on the same frequency), two or more signals compete in a "dog fight" that neither will ever totally win. Consider Fig. 13-1A. Assume that two 9540-kHz signals, S_1 and S_2, arrive at the same omnidirectional vertical antenna. Either both signals will be heard, or the stronger signal will drown out the weaker signal.

Now, consider Fig. 13-1B. Here, a dipole is used as the receiving antenna, so a little directivity is obtained. The main lobes of the dipole are wide enough to provide decent reception of signal S_1, even though the antenna is positioned such that S_1 is not along the maximum line (dotted). But the positioning shown places the interfering cochannel signal (S_2) in the null off the ends of the dipole, so it weakens it considerably. The result will be enhanced reception of S_1. In Fig. 13-1B, the idea is not to exploit the ability of the gain antenna to increase the level of S_1. Indeed, by placing the antenna as shown, we are not getting S_1 levels as high as might otherwise be

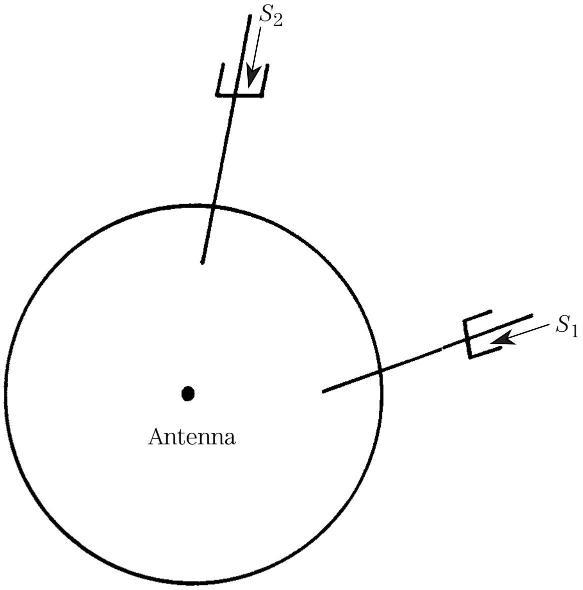

13-1A Omnidirectional antenna picks up cochannel interfering signals equally well.

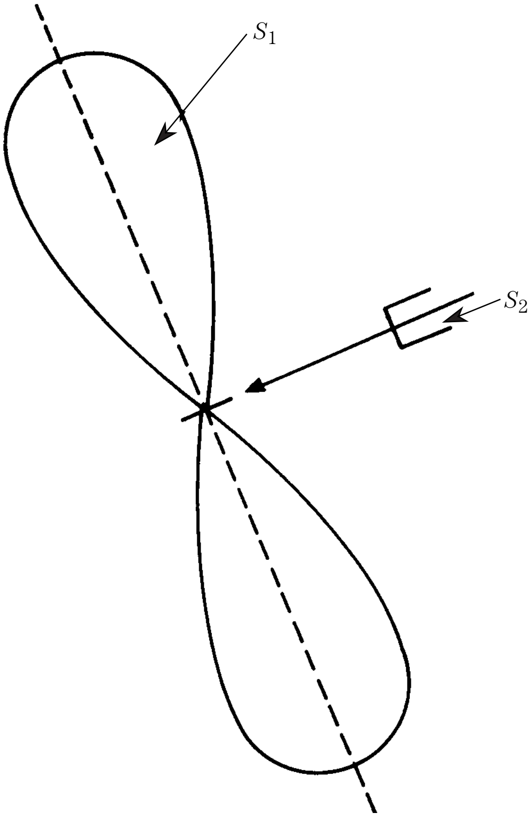

13-1B Directional antenna can discriminate against unwanted signal.

possible. The idea here is to place the unwanted signal (S_2) into the "notch" in order to make it considerably weaker. Note that the notch is sharper than the peak of the main lobe. If the dipole is placed on a mast, with an antenna rotator, this ability is increased even more.

Another antenna parameter, of considerable interest, is *angle of radiation a*, which (by reciprocity) also means angle of reception. Because HF propagation over long distances is created by skip phenomena, the angle at which the signal hits the ionosphere becomes extremely important. Figure 13-2 shows two situations from the same station. Signal S_1 has a high angle of radiation (a_1), so its skip distance (D_1) is relatively short. On signal S_2, however, the angle of radiation (a_2) is low, so the skip distance (D_2) is much longer than D_1.

So which situation do you want in your antenna? The impulsive answer would be the long distance angle of radiation (a_2), but that is often wrong. The correct answer is: "It depends!" The desired angle of radiation is a function of whether you want to receive a station from point A or point B.

The angle of radiation of the antenna is fixed by its design, that is, by antenna physics. The desired angle is a function of the ionospheric properties at the time of interest, and the operating frequency. For this reason, some well-equipped radio hobbyists have several antennas, of differing properties, to enhance their listening.

Connection to the receiver

It's simply too naive to state, I suppose, but let's do it anyway: An antenna must be properly connected to the receiver before it can be effective. If your antenna uses coaxial cable, and the receiver accepts coax, then no discussion is needed: Attach

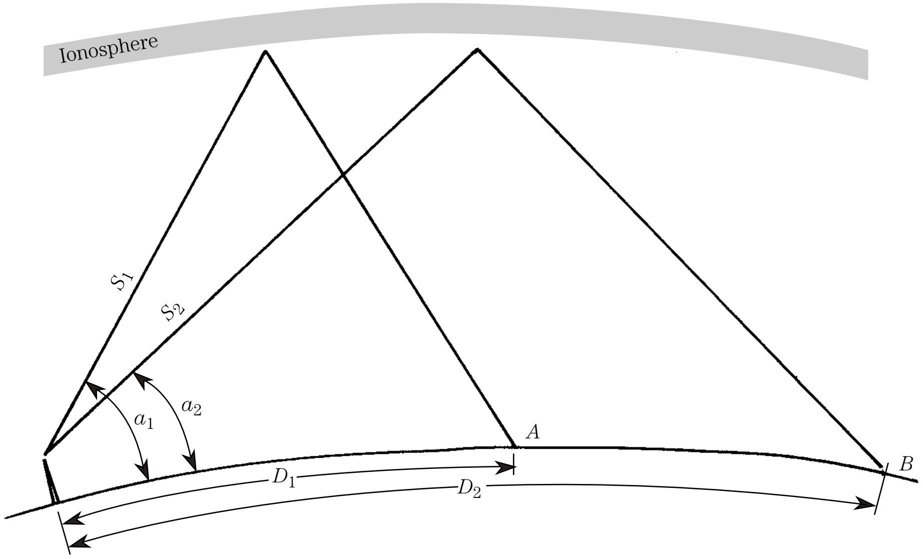

13-2 Skip phenomena dependence on angle of radiation.

the proper coax connector and plug in. But in other cases, non-coaxial-cable antennas are used.

There are two major forms of antenna input connector used on shortwave receivers. One form uses two (or three) screws intended for either wrapped wire leads or spade lugs, while the other is one or more varieties of coaxial connector. This section covers how each type is connected to a single-wire antenna lead-in.

Consider first the screw-type connector (Fig. 13-3A). Depending upon the design, there will be either two or three screws. If only two screws are found, then one is for the antenna wire and the other is for the ground wire. These screws will be marked something like "A/G" or "ANT/GND," or with the schematic symbols for antenna and ground.

Three-screw designs are intended to accommodate balanced transmission lines such as twin lead, or parallel ladder line. Shortwave listeners can sometimes use ordinary ac line cord (called *zipcord*) as an antenna transmission line. Zipcord has an impedance that approximates the 75-Ω impedance of a dipole. When parallel lines of any type are used, connect one lead to A1 and the other to A2. Of course, the ground terminal (G) is connected to the earth ground.

For single-lead antenna lines connect a jumper wire or bar (i.e., a short piece of bare no. 22 solid hookup wire) between A2 and G. This jumper converts the balanced input line to unbalanced. The A2/G terminal is connected to earth ground, while A1 is connected to the single-lead antenna wire.

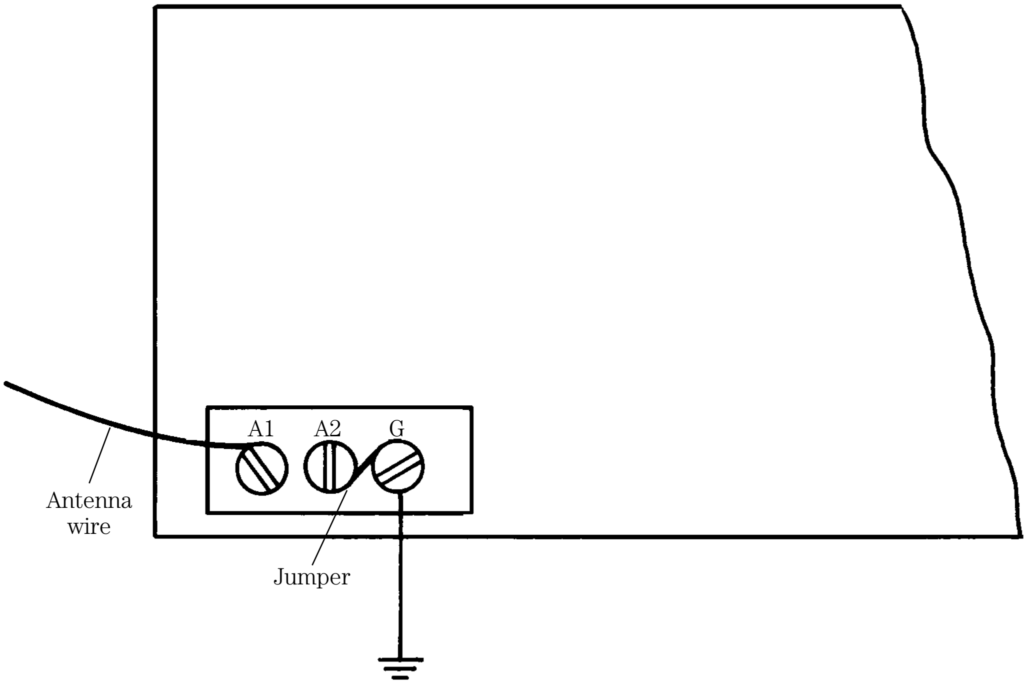

13-3A Connection of wire antenna to balanced antenna terminals on receiver.

On receivers that use an SO-239 coaxial connector, we can use either of two techniques to connect a single-lead wire. First, we can obtain the mating PL-259 plug, and solder the antenna lead to the center conductor pin. The PL-259 connector is then screwed into the mating SO-239 chassis connector. Regardless of the type of coaxial connector, however, the mate can be used for the antenna lead wire. But for SO-239 connectors another alternative is also available. Figure 13-3B shows a "banana plug" attached to the lead wire and inserted into the receptacle of the SO-239.

DANGER!

Certain low-cost receivers, especially older vacuum-tube models, have a so-called ac/dc or transformerless internal dc power supply. On most receivers, the dc common is the chassis, which also serves as the RF signal common. But on ac/dc models the neutral wire of the ac power line serves as the dc common, and it is kept floating as a "counterpoise" ground above the chassis ground used by the RF signals. A capacitor (C_1 in Fig. 13-4) sets the chassis and counterpoise ground at 0-V RF potential, while keeping the counterpoise isolated for dc and 60 Hz ac. A danger exists if either the ac plug is installed backwards or someone plugs the socket in the wall incorrectly (often happens!). Even if C_1 is intact, *a nasty shock can be felt by touching the antenna ground* (G or GND) *terminal.* The capacitive reactance of C_1 is about 2.7 MΩ for 60-Hz ac, so at least a "bite" is going to happen. But if that capacitor is shorted, which is likely on older receivers, then the bite is considerably worse, and might even prove *fatal.* The problem, in that case, is that reversed ac line polarity will set the hot line from the ac socket on the ground lead. The least to expect is massive fireworks and a possible fire hazard; the most to expect is a fire, and your possible electrocution.

The usual advice given to owners of such radios is to make sure that C_1 is intact before using the radio. I prefer a better solution: buy, install, and use a 120:120 Vac isolation transformer to isolate your receiver from the ac power lines. Such a transformer is standard practice in repair shops, and it should also be standard practice in your house.

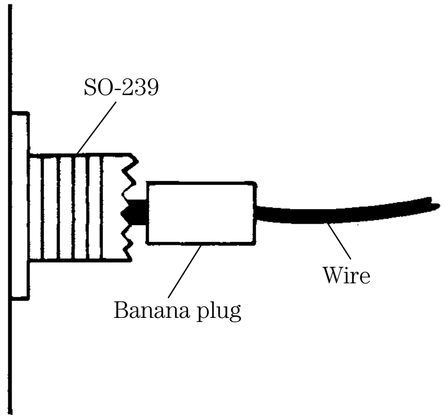

13-3B Connection of wire antenna to coaxial input receiver.

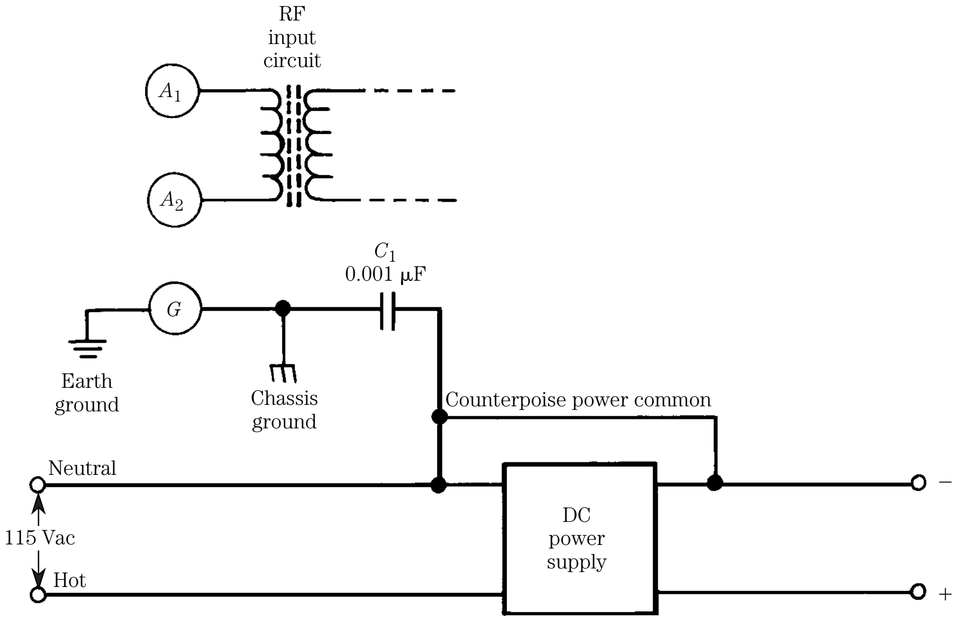

13-4 Dangerous form of antenna/receiver circuitry.

Wire antennas

This section reviews simple wire antennas that are suitable for the reception of shortwave signals, although not necessarily for transmitting. Once again, you are reminded that the law of reciprocity permits you to use any transmitting antenna found in other chapters for receiving also.

Figure 13-5 shows the common receiving longwire. The antenna element should be 30 to 150 ft in length. Although most texts show it horizontal to the ground (and indeed, a case can be made that performance is better that way), it is not strictly necessary. If you must slope the wire, then it is doubtful that you will notice any reception problems.

The far end of the wire is attached to a supporting structure through an insulator and a rope. The support structure can be another building, a tree, or a mast installed especially for this purpose. Chapter 28 deals with antenna construction practices.

Wind will cause motion in the antenna wire and its supporting structure. Over time, the wind movement will fatigue the antenna wire and cause it to break. Also, if a big enough gust of wind (or a sustained storm) comes along, then even a new antenna can either sag badly or break altogether. You can do either of two things to reduce the problem. First, as shown in Fig. 13-5, a door spring can be used to provide a little variable slack in the wire. The spring tension is selected to be only partially expanded under normal conditions, so wind will increase the tension, and stretch the spring. Make sure that the spring is not too strong to be stretched by the action of wind on the antenna, or no good is accomplished.

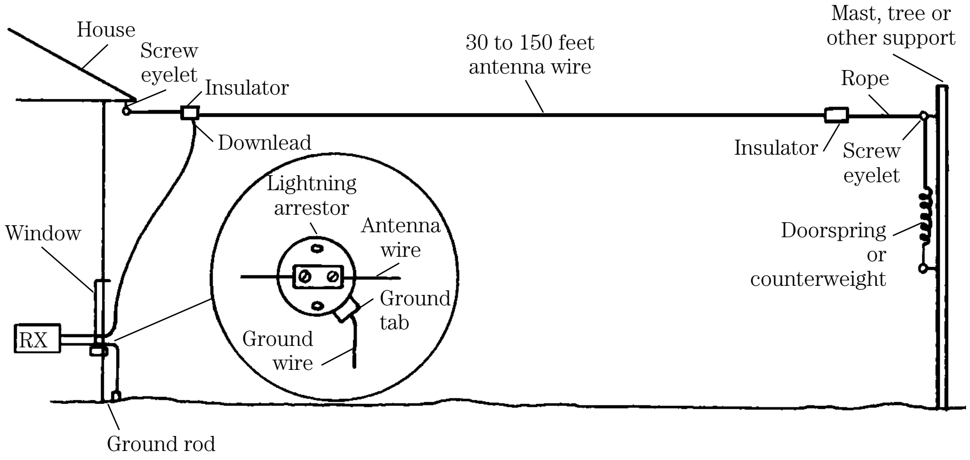
House
Screw eyelet
Insulator
30 to 150 feet antenna wire
Mast, tree or other support
Rope
Downlead
Insulator
Screw eyelet
Lightning arrestor
Antenna wire
Window
Doorspring or counterweight
Ground tab
RX
Ground wire
Ground rod

13-5 Longwire SWL antenna.

Another tactic is to replace the spring with a counterweight that is heavy enough to keep the antenna nearly taut under normal conditions, but not so heavy that it fails to move under wind conditions. In other words, the antenna tension should exactly balance the counterweight under normal conditions, and not be too great that it stretches the antenna wire excessively.

The antenna wire should be either no. 12 or no. 14 hard-drawn copper, or *Copperweld* stranded wire. The latter is actually steel-core wire, but has a copper coating on the outside. Because of skin effect, RF signals flow only in the outer copper coating. Soft-drawn copper wire will stretch and break prematurely, so it should be avoided.

The downlead of the antenna must be insulated, and it should also be stranded wire (which breaks less easily than solid wire). Again, no. 12 or no. 14 wire should be used, although no. 16 would be permissible. The point where the downlead and antenna are joined should be soldered to prevent corrosion of the joint. Mechanical strength is provided by proper splicing technique (see Fig. 13-6). Do not depend on the solder for mechanical strength, for it has none.

There are several ways to bring a downlead into the building. First, if you can tolerate a slight crack in the junction of the sash and sill, then run the wire underneath the sash and close the window. Alternatively, you can buy a flat strap connector to pass under the window. This method is electrically the same as running the lead, but is mechanically nicer. Chapter 28 deals with several methods, and should be consulted.

Grounding

The ground lead should be a heavy conductor, such as heavy wire or braid. The shield stripped from RG-8 or RG-11 coaxial cable is suitable for most applications. For reception purposes only, the ground may be a cold-water pipe inside the house. Do not use the hot-water pipes (which are not well grounded) or gas pipes (which

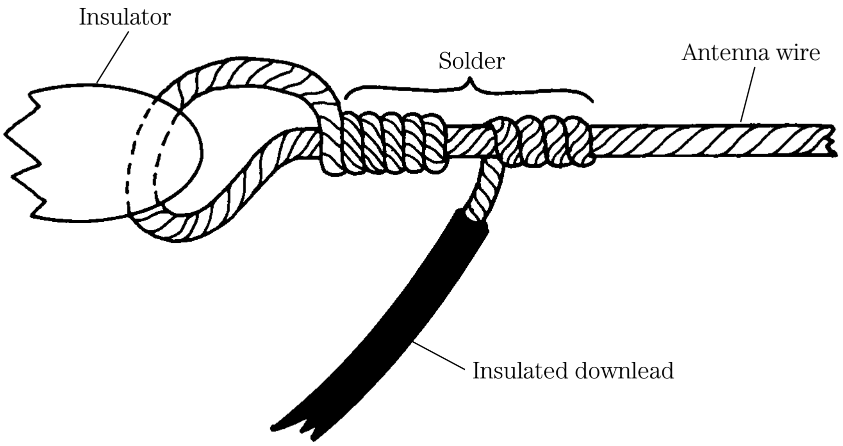

13-6 Construction details.

are dangerous to use). Also, be aware that residential air conditioner liquid lines look like copper cold-water pipes in some cases. Don't use them. Chapter 29 deals with grounding.

The lightning arrester is a safety precaution, and it *must* be used! Its purpose is to supply an alternative path to ground in the event of a lightning strike. Although at least one text calls the arrester optional, it is not. Besides the obvious safety reasons (which are reason enough), there are also legal and economic reasons for using the arrester. Your local government building and/or fire codes might require a lightning arrester for outdoor antennas. Also, your insurance company might not honor your homeowner's policy if the lightning arrester (required by local code) is not used. The antenna lightning arrester is *not optional,* so use it.

WARNING! DO NOT EVER ATTEMPT TO INSTALL AN ANTENNA BY CROSSING A POWER LINE! **EVER!** NO MATTER WHAT YOU BELIEVE OR WHAT YOUR FRIENDS TELL YOU, IT'S NEVER SAFE AND IT COULD KILL YOU.

The rest of this discussion touches on antennas, other than the receiver longwire. Because construction details are similar, we will not repeat them. You are, by the way, encouraged to also read Chap. 28 to glean more details on antenna construction methods.

The flattop antenna

The "flattop" antenna is shown in Fig. 13-7. This antenna is a relative of the longwire, with the exception that the downline is at the approximate center of the antenna section. The flattop should be at least a half-wavelength ($492/F_{\mathrm{MHz}}$) at the lowest frequency of operation. The advantage of the flattop is that it allows the maximum use of space in the configuration shown.

Vertical antennas

It is also possible to build shortwave listener antennas in vertical polarization. Figure 13-8 shows one version of this type of antenna. The support (which could

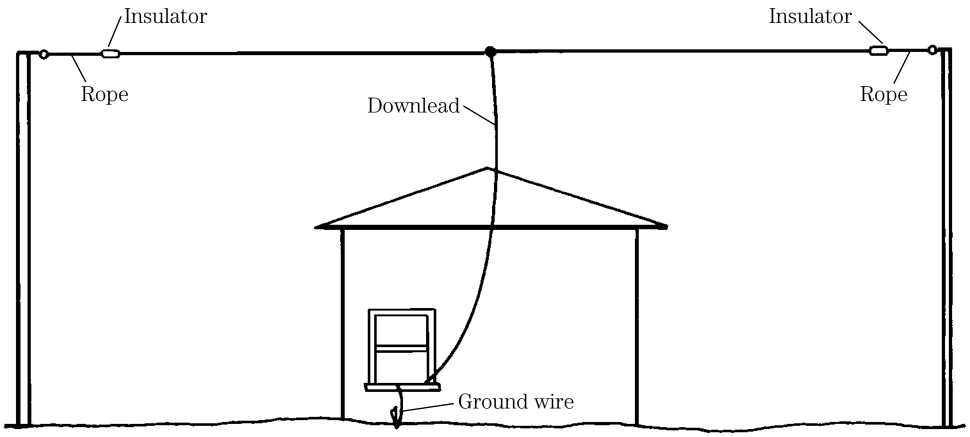
Insulator
Insulator
Rope
Rope
Downlead
Ground wire

13-7 Flattop SWL antenna.

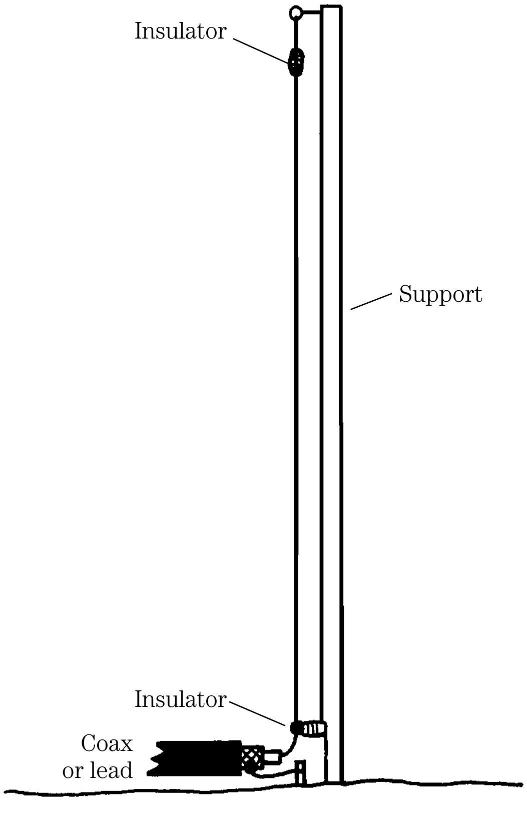
Insulator
Support
Insulator
Coax
or lead

13-8 Wire vertical SWL antenna—works for hams too.

be a tree or building) should have enough height to be at least a quarter-wavelength on the lowest frequency of operation. The antenna is fed at the base with coaxial cable. The center conductor of the coax is connected to the antenna element, and the shield is connected to the ground rod at the base of the structure. You are encouraged to see Chap. 10, which deals with limited space and hidden antennas, for a different version of this antenna. It is possible to install the wire (or multiple wires of different lengths) inside of a length of PVC plumbing pipe. The pipe serves as the support structure, and the conductors are placed inside.

Different lengths of conductor are required for different bands of operation. You can calculate the length (in feet) required for quarter-wavelength vertical antennas from $L_{\mathrm{ft}}=246/F_{\mathrm{MHz}}$. Figure 13-9A shows how several bands are accommodated from the same feedline on the same support structure. In this particular case eight different antenna elements are supported from the same tee bar. Be sure to insulate them from each other, and from the support structure. Again, PVC piping can be used for the support. Another method for accommodating several different bands is to tie the upper ends of the wires to a sloping rope (as in Fig. 13-9B).

Wire directional antenna

A directional antenna has the ability to enhance reception of desired signals, while rejecting undesired signals arriving from slightly different directions. Although directivity normally means a beam antenna, or at least a rotatable dipole, there are certain types of antenna that allow fixed antennas to be both directive and variable. See Chap. 7 for fixed but variable directional antennas and Chap. 11 for fixed and non-variable directive arrays. Those antennas are transmitting antennas, but they work equally well for reception. This section shows a crude, but often effective, directional antenna that allows one to select the direction of reception with pin plugs or switches.

Consider Fig. 13-10. In this case, a number of quarter-wavelength radiators are fanned out from a common feedpoint at various angles from the building. At the near end of each element is a female banana jack. A pair of balanced feedlines from the receiver (300-Ω twin lead, or similar) are brought to the area where the antenna elements terminate. Each wire in the twin lead has a banana plug attached. By selecting which banana jack is plugged into which banana plug, you can select the directional pattern of the antenna. If the receiver is equipped with a balanced antenna input, then simply connect the other end of the twin lead direction to the receiver. Otherwise, use one of the couplers shown in Fig. 13-11.

Figure 13-11A shows a balanced antenna coupler that is tuned to the frequency of reception. The coil is tuned to resonance by the interaction of the inductor and the capacitor. Antenna impedance is matched by selecting the taps on the inductor to which the feedline is attached. A simple RF broadband coupler is shown in Fig. 13-11B. This transformer is wound over a ferrite core, and consists of 12 to 24 turns of no. 26 enameled wire, with more turns being used for lower frequencies, and fewer for higher frequencies. Experiment with the number of turns in order to determine the correct value. Alternatively, use a 1:1 balun transformer instead of Fig. 13-11B; the type intended for amateur radio antennas is overkill powerwise, but it will work nicely.

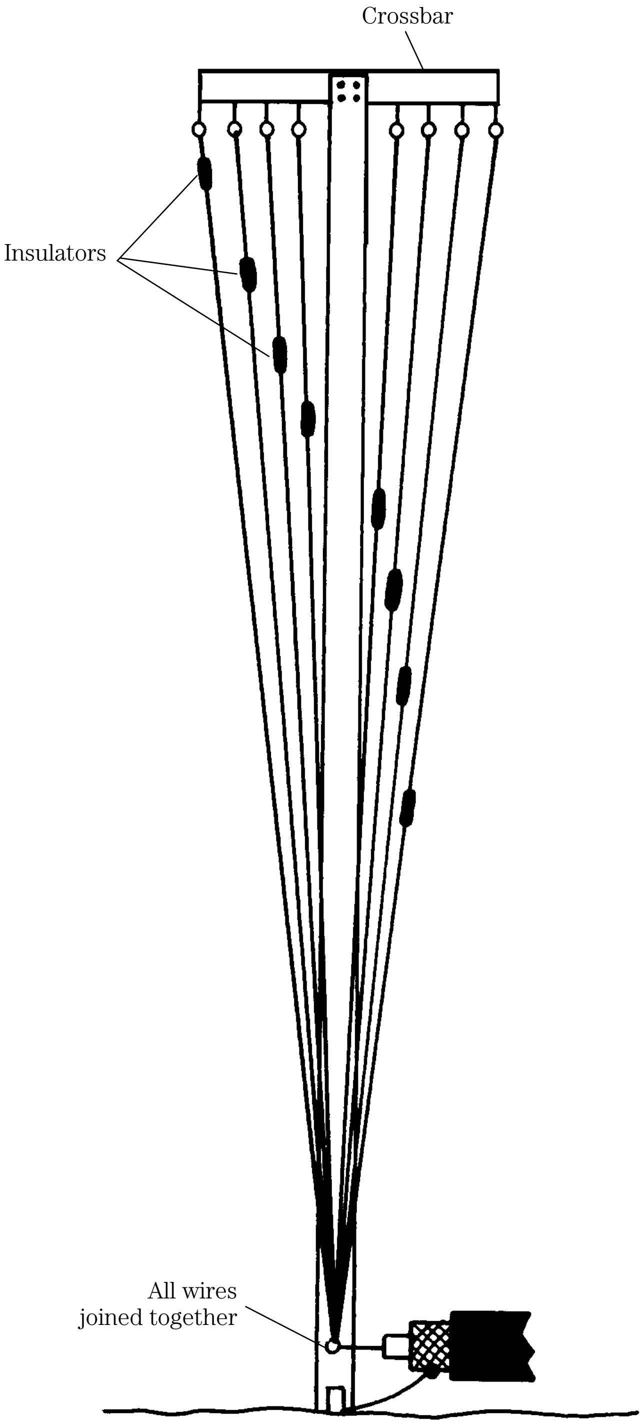
Crossbar
Insulators
All wires
joined together

13-9A Multiband wire vertical SWL antenna: tee bar style.

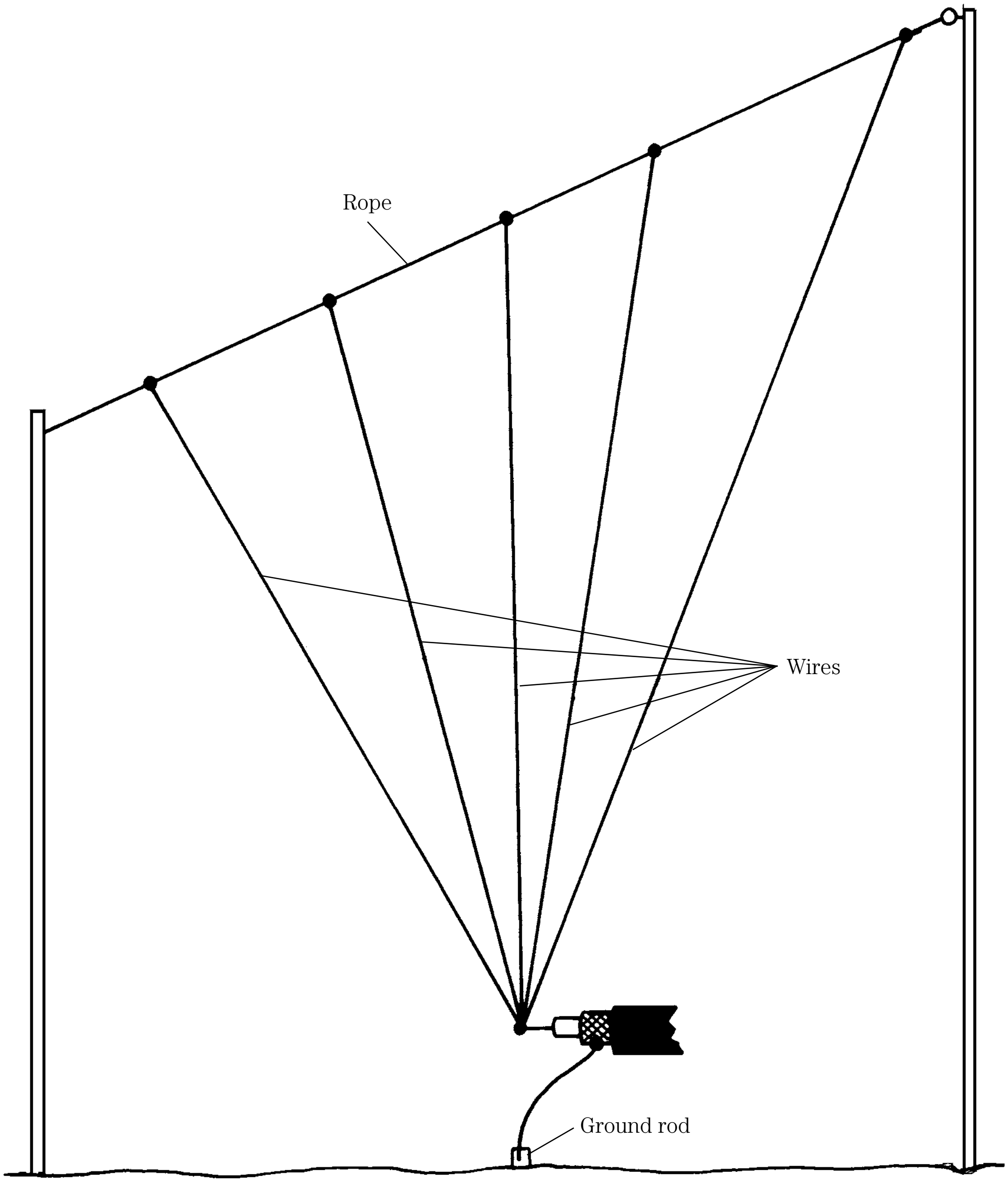
Rope
Wires
Ground rod

13-9B Multiband wire vertical SWL antenna: fan style.

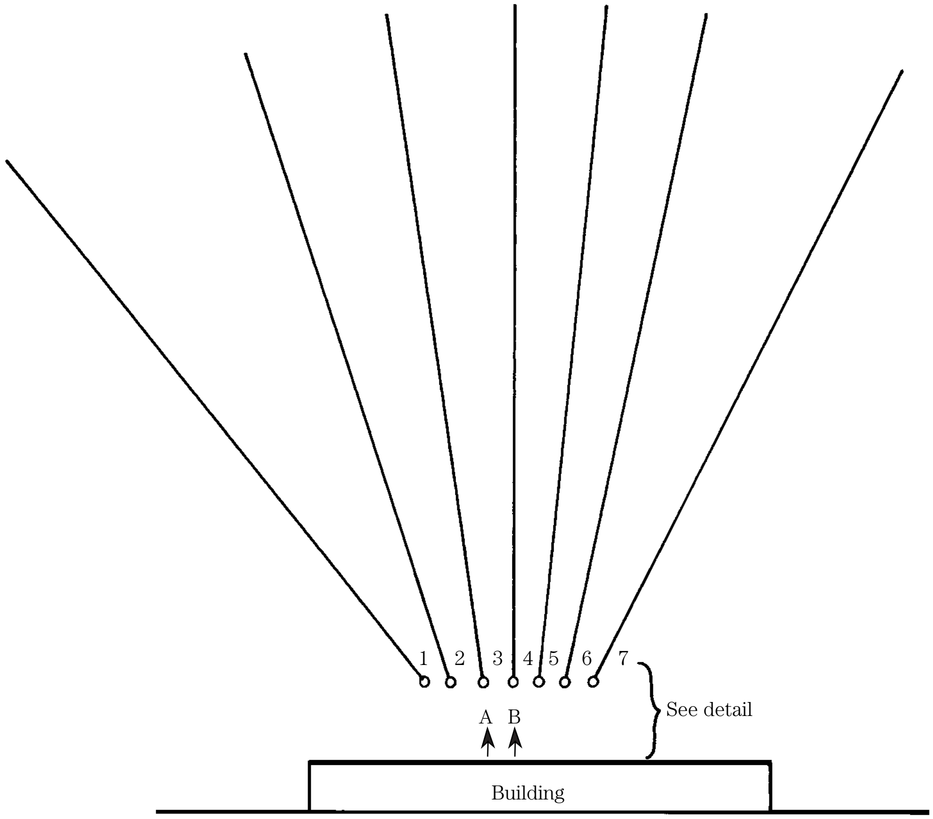

13-10 Directional SWL antenna (view from above).

The antenna of Fig. 13-10 works by phasing the elements so as to null, or enhance (as needed), certain directions. This operation becomes a little more flexible if you build a phasing transformer, as shown in Fig. 13-11C and 13-11D. Windings L_1, L_2, and L_3 are wound “trifilar” style onto a ferrite core. Use 14 turns of no. 26 enameled wire for each winding. The idea in this circuit is to feed one element from coil L_2 in the same way all of the time. This port becomes the 0° phase reference. The other port, B, is fed from a reversible winding, so it can either be in phase or 180° out of phase with port A. Adjust the DPDT switch and the banana plugs of Fig. 13-10 for the best reception.

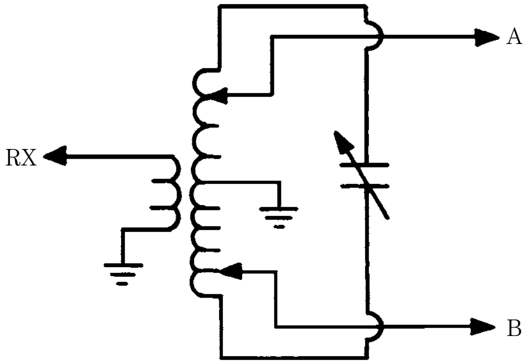

13-11A Antenna matching tuner.

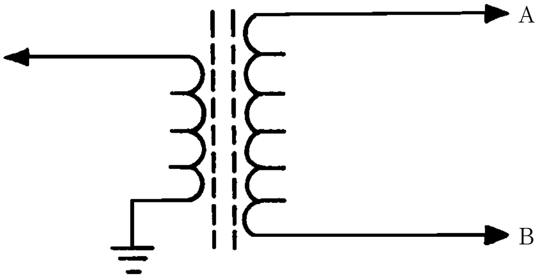

13-11B Antenna matching transformer.

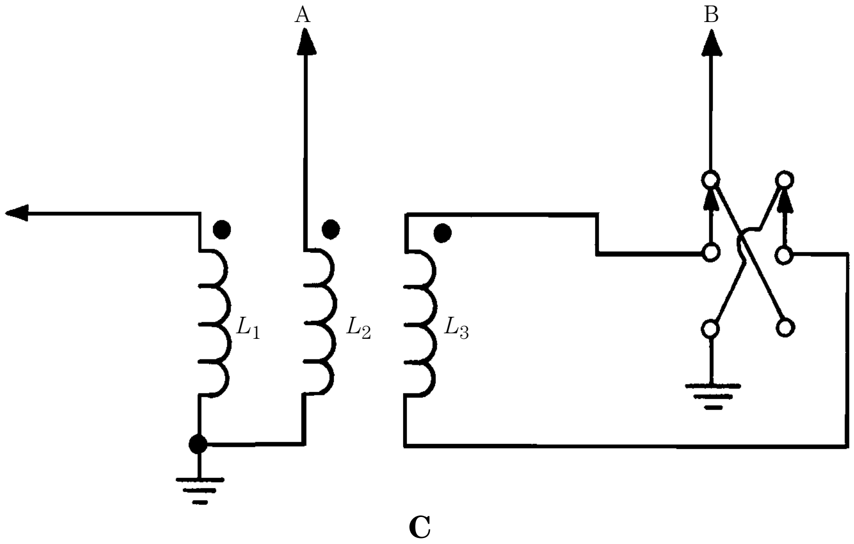

13-11C Phase-switching antenna matcher.

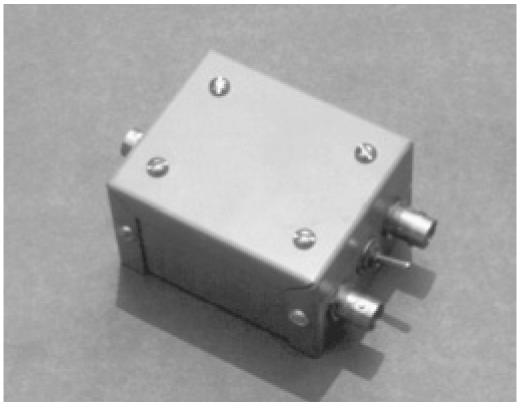

13-11D Phasing box permits phasing antennas 0° to 180°.

14

CHAPTER

Large wire loop antennas

THERE ARE TWO BASIC FORMS OF LOOP ANTENNAS: SMALL AND LARGE. THESE TWO TYPES have different characteristics, work according to different principles, and have different purposes. Small loops are those in which the current flowing in the wire has the same phase and amplitude at every point in the loop (which fact implies a very short wire length, i.e., less than 0.2λ). Such loops respond to the magnetic field component of the electromagnetic radio wave. A large loop antenna has a wire length greater than 0.2λ, with most being either λ/2, 1λ, or 2λ. The current in a large loop varies along the length of the wire in a manner similar to other wire antennas.

λ/2 large loops

The performance of large wire loop antennas depends in part on their size. Figure 14-1 shows a half-wavelength loop (i.e., one in which the four sides are each λ/8 long). There are two basic configurations for this antenna: *continuous* (S_1 closed) and *open* (S_1 open). In both cases, the feedpoint is at the midpoint of the side opposite the switch.

The direction of the main reception, or radiation lobe (i.e., the direction of maximum reception), depends on whether S_1 is open or closed. With S_1 closed, the main lobe is to the right (solid arrow); and with S_1 open, it is to the left (broken arrow). Direction reversal can be achieved by using a switch (or relay) at S_1, although some people opt for unidirectional operation by eliminating S_1, and leaving the loop either open or closed.

The feedpoint impedance is considerably different in the two configurations. In the closed-loop situation (i.e., S_1 closed), the antenna can be modeled as if it were a half-wavelength dipole bent into a square and fed at the ends. The feedpoint ($X_1 - X_2$) impedance is on the order of 3 kΩ because it occurs at a voltage antinode (current node). The current antinode (i.e., I_{max}) is at S_1, on the side opposite the feedpoint. An antenna tuning unit (ATU), or RF impedance transformer, must be used to match the lower impedance of the transmission lines needed to connect to receivers.

The feedpoint impedance of the open-loop configuration (S_1 open) is low because the current antinode occurs at $X_1 - X_2$. Some texts list the impedance as "about 50 Ω," but my own measurements on several test loops were somewhat higher (about 70 Ω). In either case, the open loop is a reasonable match for either 52- or 75-Ω coaxial cable.

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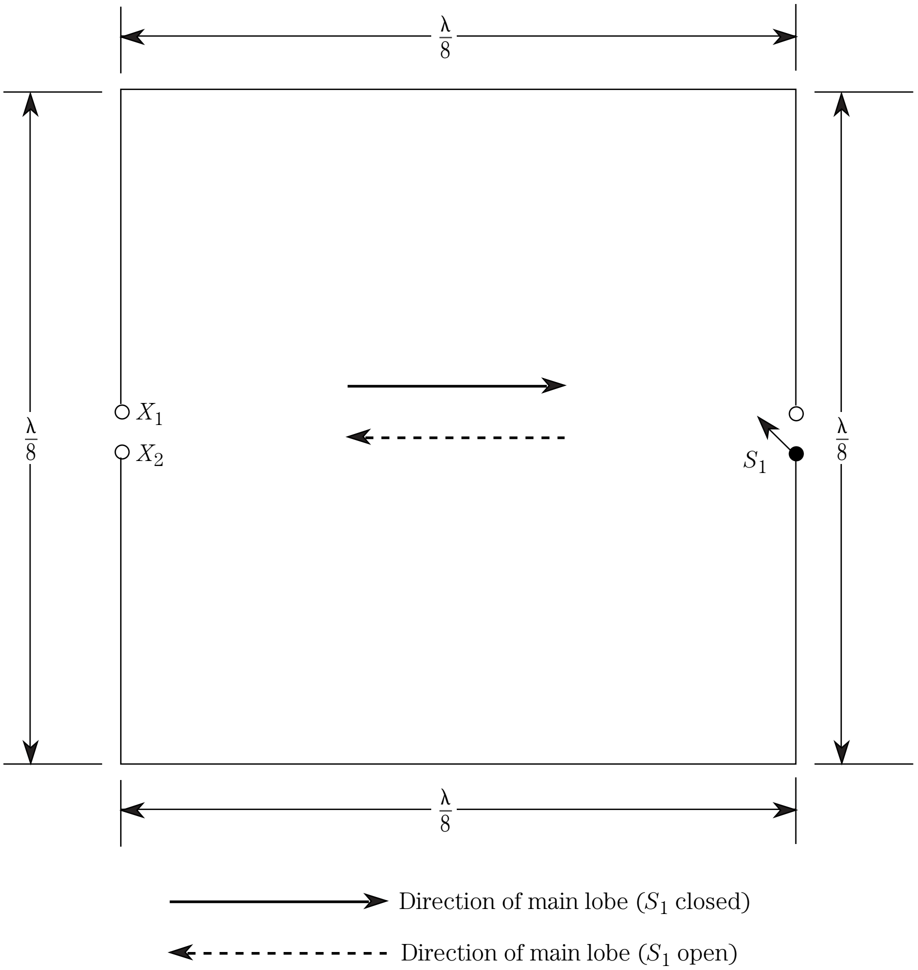
λ/8
λ/8
λ/8
λ/8
X_1
X_2
S_1
Direction of main lobe (S_1 closed)
Direction of main lobe (S_1 open)

14-1 Half-wave square loop antenna with reversal switch.

Neither $\lambda/2$ loop configuration shows gain over a dipole. The figure usually quoted is −1-dB forward gain (i.e., a loss compared with a dipole), and about 6-dB front-to-back ratio (FBR). Such low values of FBR indicate that there is no deep notch ("null") in the pattern.

A lossy antenna with a low FBR seems like a born loser, and in most cases it is. But the $\lambda/2$ loop finds a niche where size must be constrained, for one reason or another. In those cases, the $\lambda/2$ loop can be an alternative. These antennas can be considered limited-space designs, and can be mounted in an attic, or other limited-access place, as appropriate.

A simple trick will change the gain, as well as the direction of radiation, of the closed version of the $\lambda/2$ loop. In Fig. 14-2, a pair of inductors (L_1 and L_2) are inserted into the circuit at the midpoints of the sides adjacent to the side containing the feedpoints. These inductors should have an inductive reactance X_L of about 360 Ω in the center of the band of operation. The inductance of the coil is

$$L_{\mu H} = \frac{3.6 \times 10^8}{2\pi F_{Hz}} \qquad [14.1]$$

where

$L_{\mu H}$ is the coil inductance, in microhenrys (µH)

F_{Hz} is the midband frequency, in hertz (Hz)

Example Find the inductance for the coils in a loaded half-wavelength closed-loop antenna that must operate in a band centered on 10.125 MHz.

Solution:

[*Note:* 10.125 MHz = 10,125,000 Hz]

$$L_{\mu H} = \frac{3.6 \times 10^8}{2\pi\ (10{,}125{,}000\ \text{Hz})} = 5.7\ \mu\text{H}$$

The coils force the current antinodes toward the feedpoint, reversing the direction of the main lobe, and creating a gain of about +1 dB over a half-wavelength dipole.

The currents flowing in the antenna can be quite high, so when making the coils, be sure to use a size that is sufficient for the power and current levels anticipated. The 2- to 3-in B&W Air-Dux style coils are sufficient for most amateur radio use. Smaller coils are available on the market, but their use is limited to low-power situations.

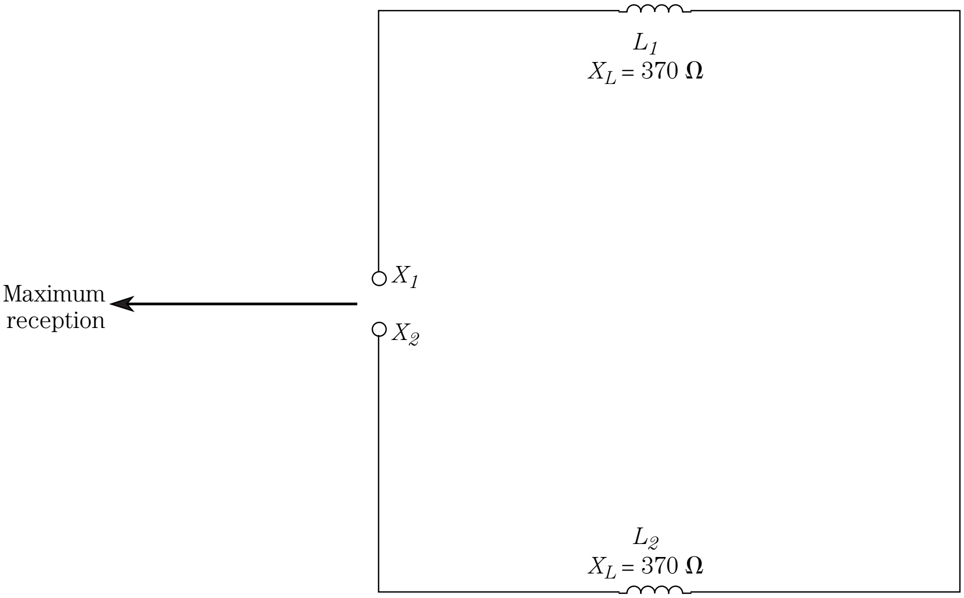

14-2 Use of inductive loading to reduce the size of antenna, and make the pattern more uniform.

1λ large loops

If size is not forcing you to a λ/2 loop, then a 1λ loop might be just the ticket. It produces a gain of about +2 dB over a dipole in the directions that are perpendicular to the plane of the loop. The azimuth patterns formed by these antennas are similar to the figure-8 pattern of the dipole. Three versions are shown: the square loop (Fig. 14-3), the diamond loop (Fig. 14-4), and the delta loop (a.k.a. D-loop and triangle—Fig. 14-5). The square and diamond loops are built with λ/4 on each side, and the delta loop is λ/3 on each side. The overall length of wire needed to build these antennas is

$$L_{\text{feet}} = \frac{1005}{F_{\text{MHz}}} \qquad \textbf{[14.2]}$$

The polarization of the three loop antennas is horizontal, because of the location of the feedpoints. On the square loop, moving the feedpoint to the middle of either vertical side will provide vertical polarization. Similarly, on the diamond loop vertical polarization is realized by moving the feedpoint to either of the two adjacent apexes. On the delta loop, placing the feedpoint at either of the two other apexes produces a diagonal polarization that offers approximately equal vertical and horizontal polarization components.

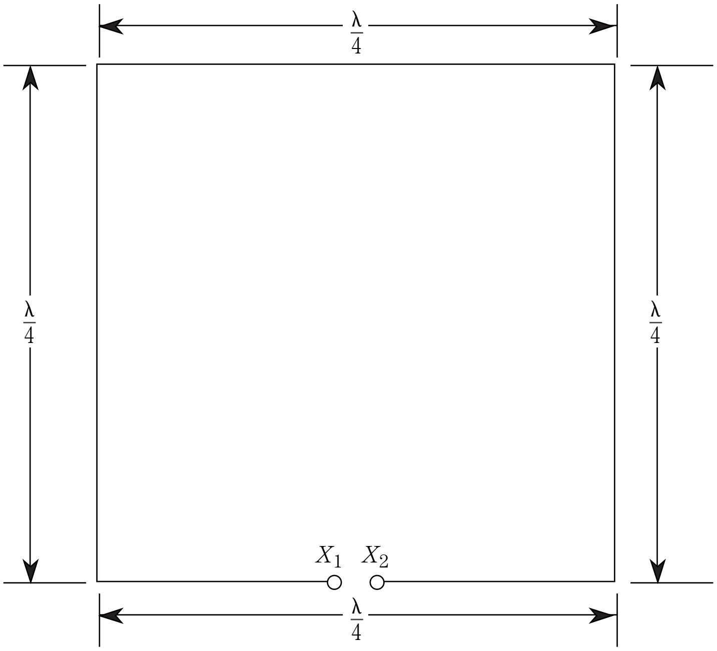

14-3 Quarter-wavelength square loop (single-element quad).

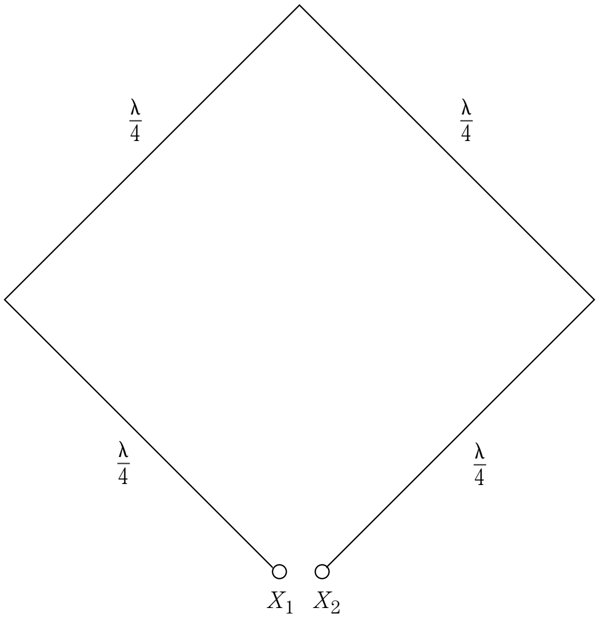
$\frac{\lambda}{4}$
$\frac{\lambda}{4}$
$\frac{\lambda}{4}$
$\frac{\lambda}{4}$
X_1
X_2

14-4 Bottom-fed loop.

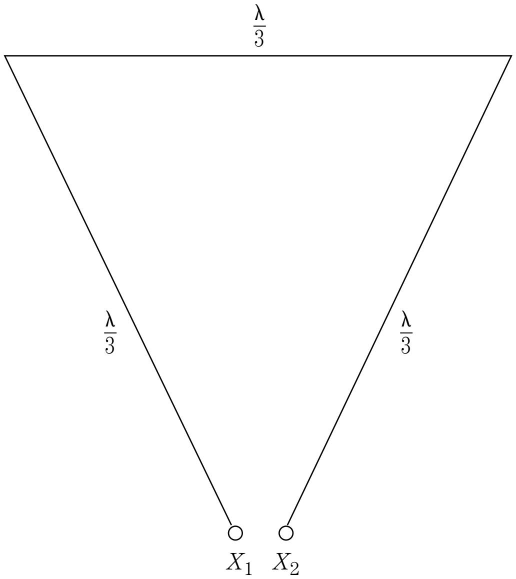
$\frac{\lambda}{3}$
$\frac{\lambda}{3}$
$\frac{\lambda}{3}$
X_1
X_2

14-5 Delta loop antenna.

The feedpoint impedance of the 1λ loop is around 100 Ω, so it provides a slight mismatch to 75-Ω coax and a 2:1 mismatch to 52-Ω coax. A very good match to 52-Ω coax can be produced using the scheme of Fig. 14-6. Here, a quarter-wavelength coaxial cable matching section is made of 75-Ω coaxial cable. The length of this cable should be

$$L_{\text{feet}} = \frac{246V}{F_{\text{MHz}}} \qquad \textbf{[14.3]}$$

where

L_{feet} is the length, in feet (ft)

V is the velocity factor of the coax

F_{MHz} is the frequency, in megahertz (MHz)

The impedance Z_o of the cable used for the matching section should be

$$Z_o = \sqrt{Z_L Z_s} \qquad \textbf{[14.4]}$$

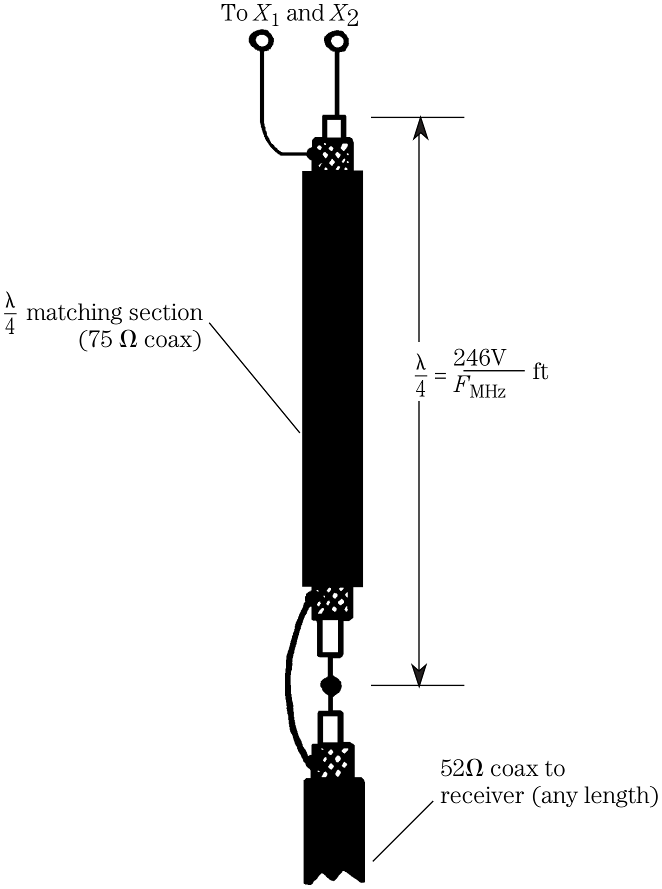
To X_1 and X_2
$\frac{\lambda}{4}$ matching section (75 Ω coax)
$\frac{\lambda}{4} = \frac{246V}{F_{\text{MHz}}}$ ft
52Ω coax to receiver (any length)

14-6 Quarter-wavelength coaxial matching section.

where

Z_o is the characteristic impedance of the coax used in the matching section, in ohms
Z_L is the feedpoint impedance of the antenna, in ohms
Z_s is the source impedance (i.e., the 52-Ω characteristic impedance of the line to the receiver in standard systems)

When Eq. 14.4 is applied to this system, where $Z_s = 52\ \Omega$, $Z_L = 100\ \Omega$:

$$Z_o = \sqrt{(100\ \Omega)(52\ \Omega)} = 72\ \Omega \qquad \textbf{[14.5]}$$

This is a very good match to 75-Ω coaxial cable.

Demiquad loop antenna

The *demiquad* is a single-element 1λ quad antenna. The length of the antenna is, like the cubical quad beam antenna (see Chap. 12), one wavelength. Figure 14-7 shows a type of demi-quad based on the tee-cross type of mast.

The impedance-matching section is a quarter-wavelength piece of 75-Ω coaxial cable (RG-58/U or RF-11/U). The length of the matching section is determined from:

$$L = \frac{246V}{F_{\mathrm{MHz}}} \qquad \textbf{[14.6]}$$

where

L is the overall length, in feet
F_{MHz} is the frequency, in megahertz
V is the velocity factor of the coaxial cable (typically 0.66, 0.70, or 0.80)

Delta loop

The *delta loop antenna,* like the Greek uppercase letter “delta” (Δ) from which it draws its name, is triangle-shaped (Fig. 14-8). The delta loop is a full wavelength, with elements approximately 2 percent longer than the natural wavelength (like the quad). The actual length will be a function of the proximity and nature of the underlying ground, so some experimentation is necessary. The approximate preadjustment lengths of the sides are found from:

$$L_1 = \frac{437}{F_{\mathrm{MHz}}}\ \mathrm{ft} \qquad \textbf{[14.7]}$$

$$L_2 = L_3 = \frac{296}{F_{\mathrm{MHz}}} \qquad \textbf{[14.8]}$$

The delta loop antenna is fed from 52-Ω coaxial cable through a 4:1 balun transformer. The delta loop can be built in a fixed location, and will offer a bidirectional pattern.

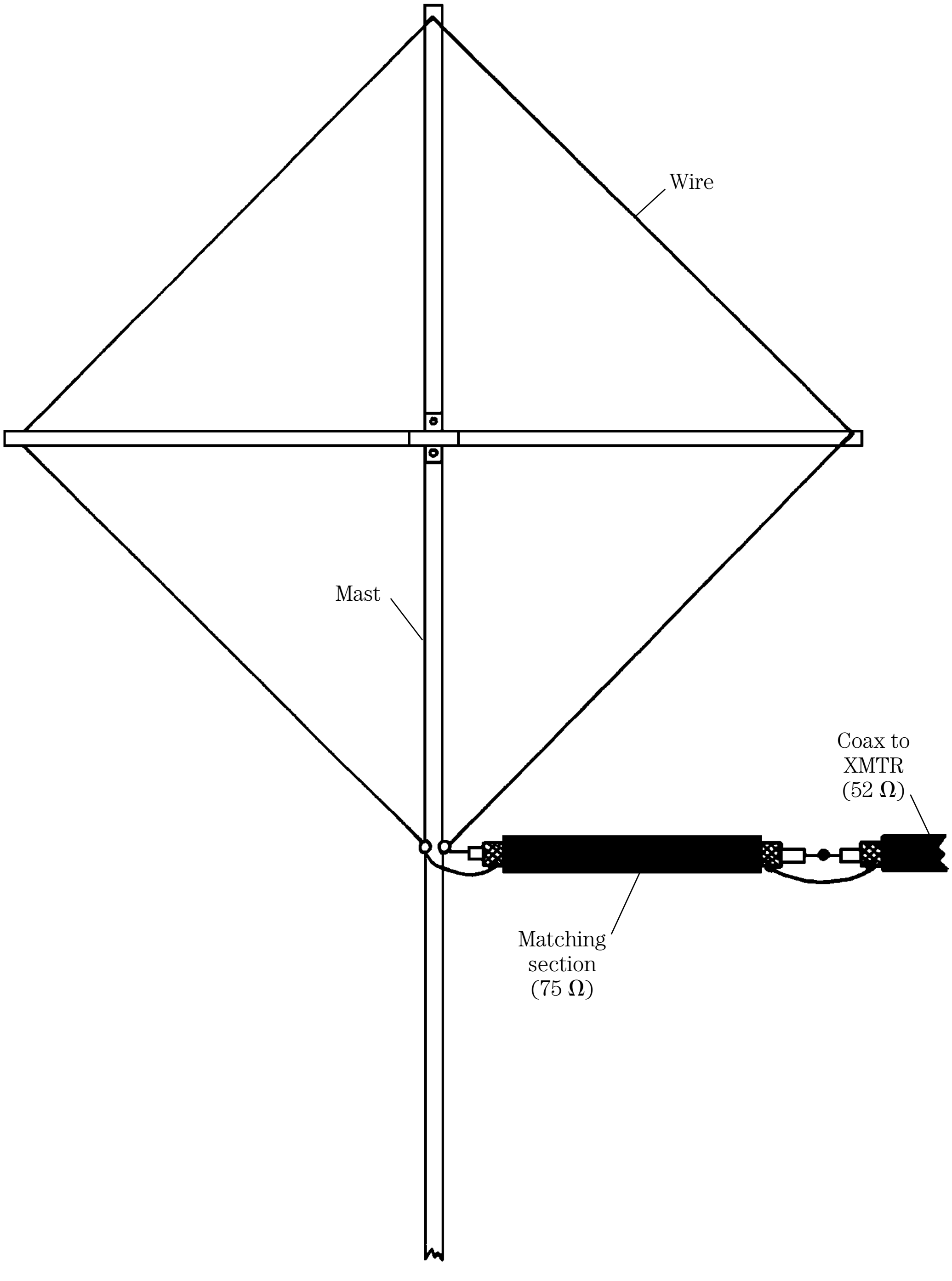
Wire
Mast
Coax to
XMTR
(52 Ω)
Matching
section
(75 Ω)

14-7 Demiquad antenna.

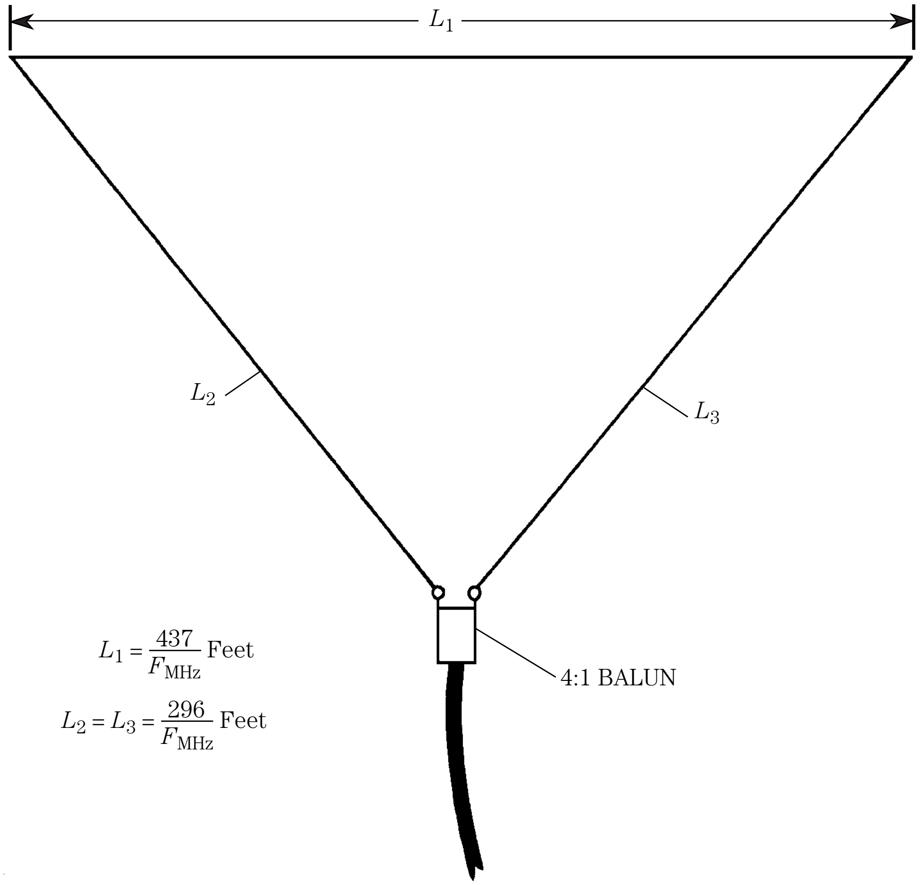
L_1
L_2
L_3
$L_1 = \frac{437}{F_{\text{MHz}}}$ Feet
$L_2 = L_3 = \frac{296}{F_{\text{MHz}}}$ Feet
4:1 BALUN

14-8 Delta loop antenna.

Half-delta sloper (HDS)

The *half-delta sloper* (HDS) antenna (Fig. 14-9) is similar to the full delta loop, except that (like the quarter-wavelength vertical) half of the antenna is in the form of an "image" in the ground. Gains of 1.5 to 2 dB are achievable. The HDS antenna consists of two elements: a $\lambda/3$-wavelength sloping wire and a $\lambda/6$ vertical wire (on an insulated mast), or a $\lambda/6$ metal mast. Because the ground currents are very important, much like the vertical antenna, either an extensive radial system at both ends is needed, or a base ground return wire (buried) must be provided.

The HDS will work on its design frequency, plus harmonics of the design frequency. For a fundamental frequency of 5 MHz, a vertical segment of 33 ft and a sloping section of 66 ft is needed. The lengths for any frequency are found from

$$\frac{\lambda}{3} = \frac{328}{F_{\text{MHz}}} \qquad \textbf{[14.9]}$$

and

$$\frac{\lambda}{6} = \frac{164}{F_{\mathrm{MHz}}} \qquad \textbf{[14.10]}$$

The HDS is fed at one corner, close to the ground. If only the fundamental frequency is desired, then you can feed it with 52-Ω coaxial cable. But at harmonics, the feedpoint impedance changes to as high as 1000 Ω. If harmonic operation is intended, then an antenna tuning unit (ATU) is needed at point *A* to match these impedances.

Bisquare loop antenna

The *bisquare antenna,* shown in Fig. 14-10, is similar to the other large loops, except that it is λ/2 on each side, making a total wire length of two wavelengths. This antenna is built like the diamond loop shown earlier (i.e., it is a large square loop fed at an apex that is set at the bottom of the assembly). In this case, the loop is fed either with an antenna tuning unit (to match a 1000-Ω impedance) or a quarter-wavelength matching section made of 300-Ω or 450-Ω twin-lead transmission line. A 1:1 balun transformer connects the 75-Ω coaxial cable to the matching section.

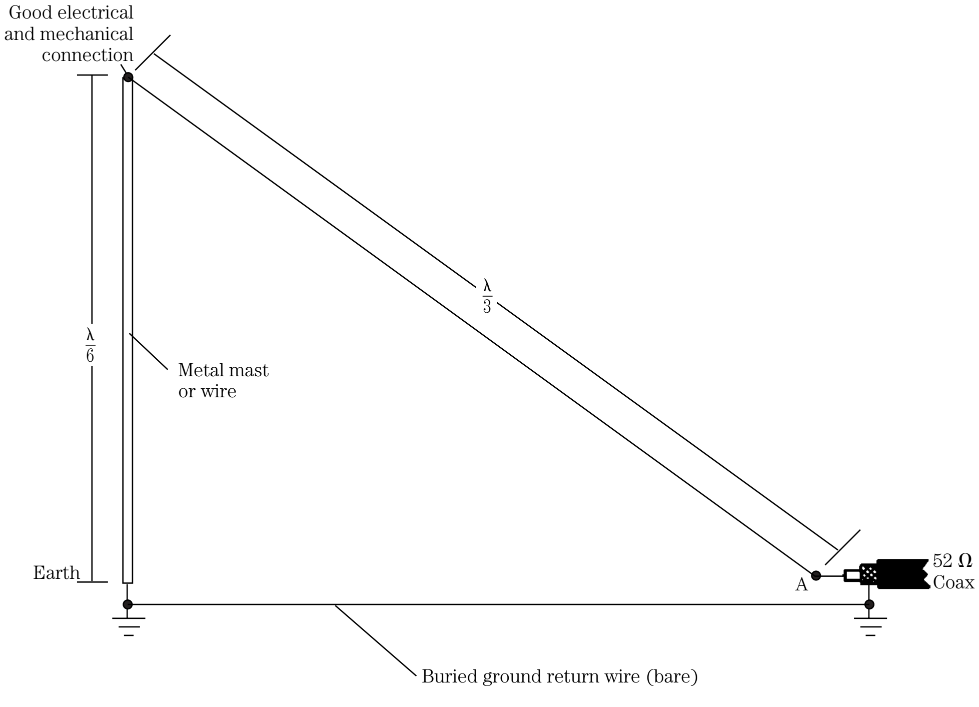
Good electrical
and mechanical
connection
$\frac{\lambda}{3}$
$\frac{\lambda}{6}$
Metal mast
or wire
Earth
A
52 Ω
Coax
Buried ground return wire (bare)

14-9 Half-delta loop antenna.

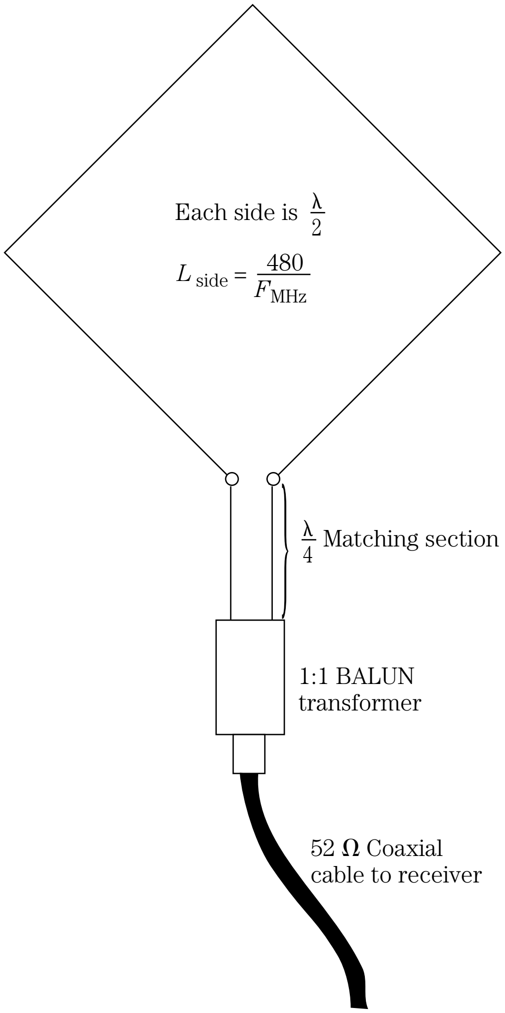
Each side is $\frac{\lambda}{2}$
$L_{\text{side}} = \frac{480}{F_{\text{MHz}}}$
$\frac{\lambda}{4}$ Matching section
1:1 BALUN transformer
52 Ω Coaxial cable to receiver

14-10 Bisquare 2λ square loop antenna.

The bisquare antenna offers as much as 4-dB gain broadside to the plane of the antenna (i.e., in and out of the book page), in a figure-8 pattern, on the design frequency. It is horizontally polarized. When the frequency drops to one-half of the design frequency, the gain drops to about 2 dB, and the antenna works like the diamond loop covered previously.

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15
Chapter

Small loop receiving antennas

Radio direction finders and people who listen to the AM broadcasting bands, VLF, medium-wave, or the so-called low-frequency tropical bands are all candidates for a small loop antenna. These antennas are fundamentally different from large loops and other sorts of antennas used in these bands. Large loop antennas have a length of at least 0.5λ, and most are quite a bit larger than 0.5λ. Small loop antennas, on the other hand, have an overall length that is less than 0.22λ, with most being less than 0.10λ.

The small loop antenna responds to the magnetic field component of the electromagnetic wave instead of the electrical field component. One principal difference between the large loop and the small loop is found when examining the RF currents induced in a loop when a signal intercepts it. In a large loop, the current will vary from one point in the conductor to another, with voltage varying out of phase with the current. In the small loop antenna, the current is the same throughout the entire loop.

The differences between small loops and large loops show up in some interesting ways, but perhaps the most striking is the directions of maximum response—the main lobes—and the directions of the nulls. Both types of loops produce figure-8 patterns but in directions at right angles with respect to each other. The large loop antenna produces main lobes *orthogonal,* at right angles or "broadside," to the plane of the loop. Nulls are off the sides of the loop. The small loop, however, is exactly the opposite: The main lobes are off the sides of the loop (in the direction of the loop plane), and the nulls are broadside to the loop plane (Fig. 15-1A). Do not confuse small loop behavior with the behavior of the loopstick antenna. Loopstick antennas are made of coils of wire wound on a ferrite or powdered-iron rod. The direction of maximum response for the loopstick antenna is broadside to the rod, with deep nulls off the ends (Fig. 15-1B). Both loopsticks and small wire loops are used for radio direction-finding and for shortwave, low-frequency medium-wave, AM broadcast band, and VLF listening.

The nulls of a loop antenna are very sharp and very deep. Small changes of pointing direction can make a profound difference in the response of the antenna. If you point a loop antenna so that its null is aimed at a strong station, the signal strength of

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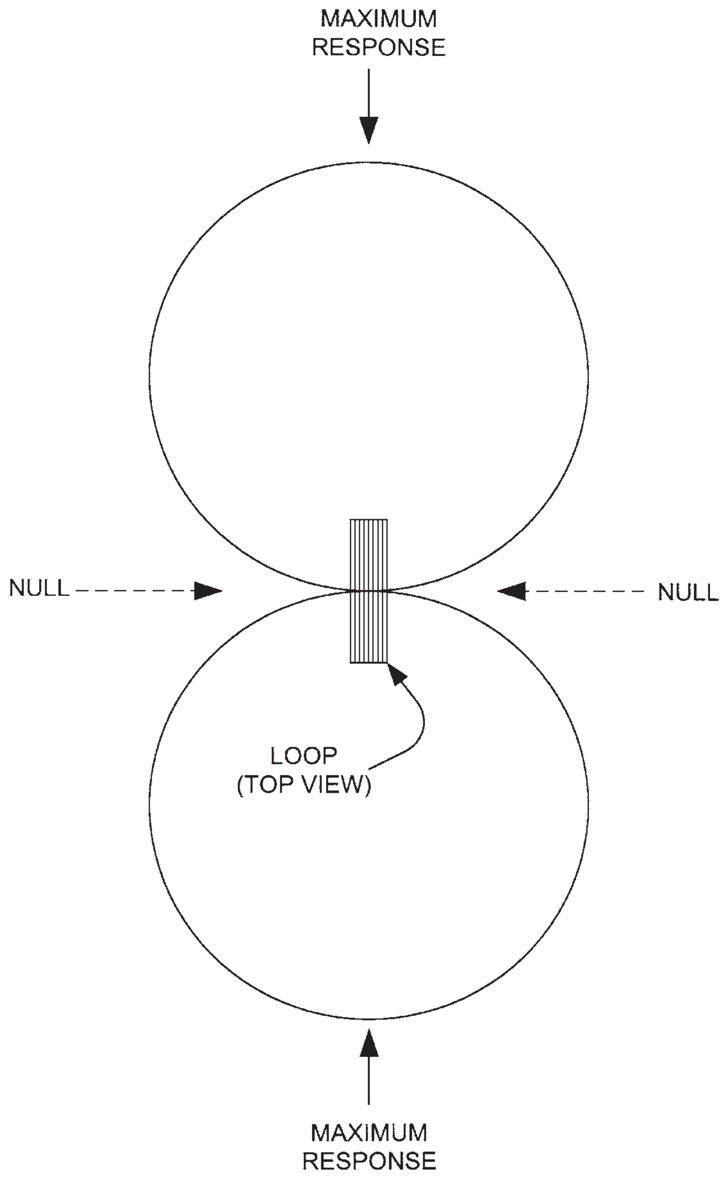

15-1A Large loop antenna.

the station appears to drop dramatically at the center of the notch. Turn the antenna only a few degrees one way or the other, however, and the signal strength increases sharply. The depth of the null can reach 10 to 15 dB on sloppy loops and 30 to 40 dB on well-built loops (30 dB is a very common value). I have seen claims of 60-dB nulls for some commercially available loop antennas. The construction and uniformity of the loop are primary factors in the sharpness and depth of the null.

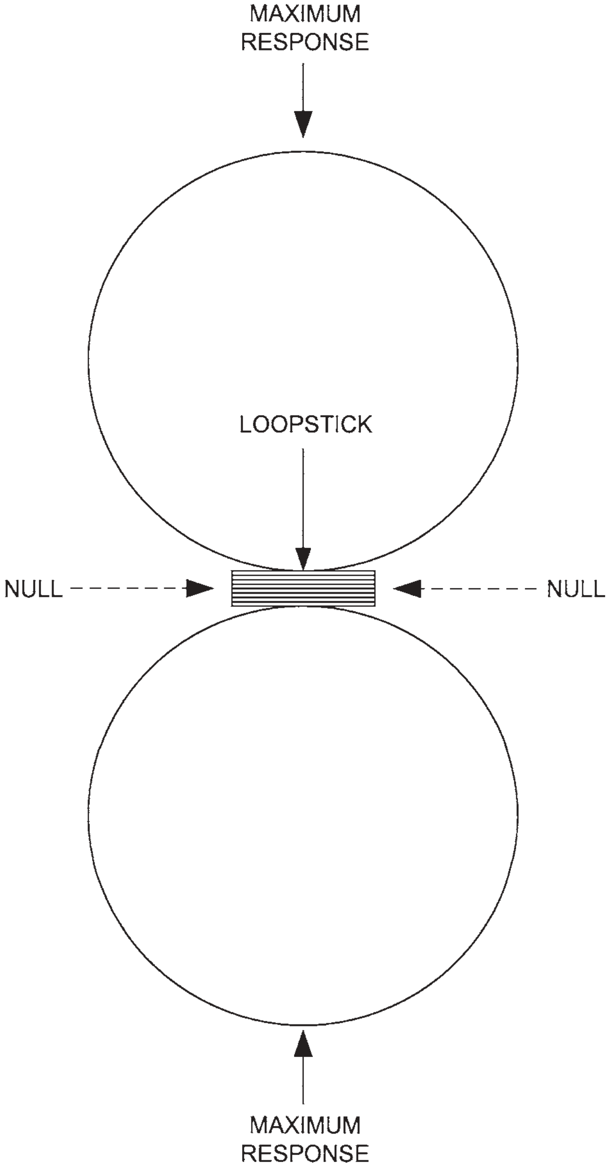

15-1B Loopstick antenna.

At one time, the principal use of the small loop antenna was radio direction-finding, especially in the lower-frequency bands. The RDF loop is mounted with a compass rose to allow the operator to find the direction of minimum response. The null was used, rather than the peak response point, because it is far narrower than the peak. As a result, precise determination of direction is possible. Because the null is bidirectional, ambiguity exists as to which of the two directions is the correct direction. What the direction-finder "finds" is a line along which the station exists. If the line is found from two reasonably separated locations and the lines of direction are plotted on a map, then the two lines will cross in the area of the station. Three or more lines of direction (a process called *triangulation*) yields a pretty precise knowledge of the station's actual location.

Today, these small loops are still used for radio direction-finding, but their use has been extended into the general receiving arena, especially on the low frequencies. One of the characteristics of these bands is the possibility of strong local interference smothering weaker ground-wave and sky-wave stations. As a result, you cannot hear cochannel signals when one of them is very strong and the other is weak. Similarly, if a cochannel station has a signal strength that is an appreciable fraction of the desired signal and is slightly different in frequency, then the two signals will heterodyne together and form a whistling sound in the receiver output. The frequency of the whistle is an audio tone equal to the difference in frequency between the two signals. This is often the case when trying to hear foreign BCB signals on frequencies (called *split frequencies*) between the standard spacing. The directional characteristics of the loop can help if the loop null is placed in the direction of the undesired signal.

Loops are used mainly in the low-frequency bands even though such loops are either physically larger than high-frequency loops or require more turns of wire. Loops have been used as high as VHF and are commonly used in the 10-m ham band for such activities as hidden transmitter hunts. The reason why low frequencies are the general preserve of loops is that these frequencies are more likely to have substantial ground-wave signals. Sky-wave signals lose some of their apparent directivity because of multiple reflections. Similarly, VHF and UHF waves are likely to reflect from buildings and hillsides and so will arrive at angles other than the direction of the transmitter. As a result, the loop is less useful for the purpose of radio direction-finding. If your goal is not RDF but listening to the station, this is hardly a problem. A small loop can be used in the upper shortwave bands to null a strong local ground-wave station in order to hear a weaker sky-wave station. Finally, loops can be useful in rejecting noise from local sources, such as a "leaky" electric power line or a neighbor's outdoor light dimmer.

Let's examine the basic theory of small loop antennas and then take a look at some practical construction methods.

Grover's equation

Grover's equation (Grover, 1946) seems closer to the actual inductance measured in empirical tests than certain other equations that are in use. This equation is

$$L_{\mu\mathrm{H}} = (K_1 N^2 a) \times \left\{ \ln \left[\frac{K_2 a N}{(N+1)\, b} \right] + K_3 + \left[\frac{K_4\,(N+1)\, b}{aN} \right] \right\}$$

where $L_{\mu\mathrm{H}}$ is the inductance, in microhenrys (μH)
a is the length of a loop side, in centimeters (cm)
b is the loop width, in centimeters (cm)

n is the number of turns in the loop
K_1 through K_4 are shape constants and are given in Table 15-1
ln is the natural log of this portion of the equation

Air core frame loops (“box” loops)

A wire loop antenna is made by winding a large coil of wire, consisting of one or more turns, on some sort of frame. The shape of the loop can be circular, square, triangular, hexagonal, or octagonal. For practical reasons, the square loop seems to be most popular. With one exception, the loops considered in this section will be square, so you can easily duplicate them.

The basic form of the simplest loop is shown in Fig. 15-2. This loop is square, with sides the same length A all around. The width of the loop (B) is the distance from the first turn to the last turn in the loop, or the diameter of the wire if only one turn is used. The turns of the loop in Fig. 15-2 are *depth wound,* meaning that each turn of the loop is spaced in a slightly different parallel plane. The turns are spaced evenly across distance B. Alternatively, the loop can be wound such that the turns are in the same plane (this is called *planar winding*). In either case, the sides of the loop (A) should be not less than five times the width (B). There seems to be little difference between depth- and planar-wound loops. The far-field patterns of the different shape loops are nearly the same if the respective cross-sectional areas (πr^2 for circular loops and A^2 for square loops) are less than $\lambda^2/100$.

The reason why a small loop has a null when its broadest aspect is facing the signal is simple, even though it seems counterintuitive at first blush. Take a look at Fig. 15-3. Here, we have two identical small loop antennas at right angles to each other. Antenna A is in line with the advancing radio wave, whereas antenna B is broadside to the wave. Each line in the wave represents a line where the signal strength is the same, i.e., an “isopotential line.” When the loop is in line with the signal (antenna A), there is a difference of potential from one end of the loop to the other, so current can be induced in the wires. When the loop is turned broadside, however, all points on the loop are on the same potential line, so there is no difference of potential between segments of the conductor. Thus little signal is picked up (and the antenna therefore sees a null).

The actual voltage across the output terminals of an untuned loop is a function of the angle of arrival of the signal α (Fig. 15-4), as well as the strength of the signal and the design of the loop. The voltage V_o is given by

Table 15-1. Shape constants

Shape	K_1	K_2	K_3	K_4
Triangle	0.006	1.155	0.655	0.135
Square	0.008	1.414	0.379	0.33
Hexagon	0.012	2.00	0.655	0.135
Octagon	0.016	2.613	0.7514	0.0715

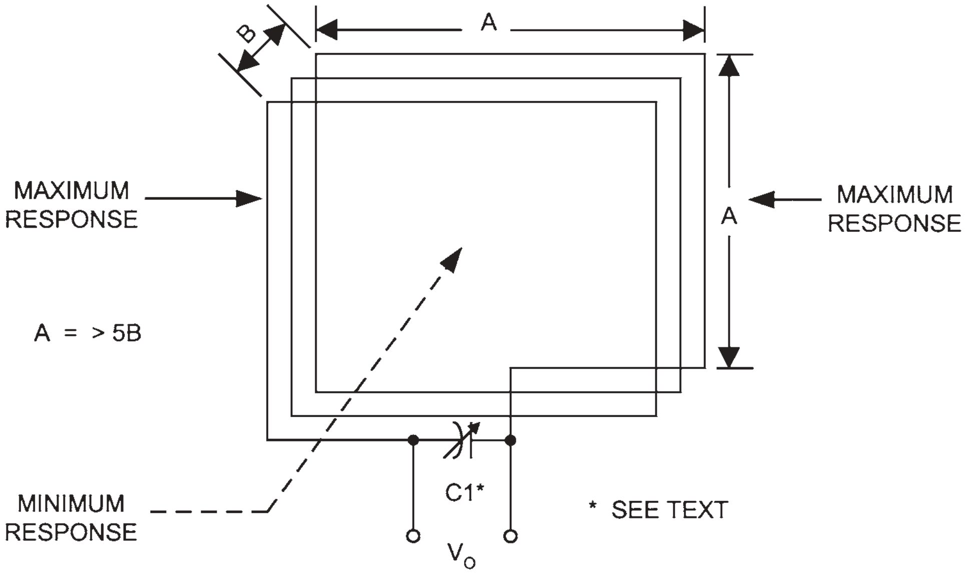

15-2A A simple loop antenna.

$$V_o = \frac{2\pi A N E_f \cos(\alpha)}{\lambda}$$

where V_o is the output voltage of the loop
A is the area of the loop, in square meters (m^2)
N is the number of turns of wire in the loop
E_f is the strength of the signal, in volts per meter (V/m)
a is the angle of arrival of the signal
λ is the wavelength of the arriving signal

Loops are sometimes specified in terms of the *effective height* of the antenna. This number is a theoretical construct that compares the output voltage of a small loop with a vertical piece of the same kind of wire that has a height of

$$H_{eff} = \frac{2\pi N A}{\lambda}$$

If a capacitor (such as C_1 in Fig. 15-2) is used to tune the loop, then the output voltage V_o will rise substantially. The output voltage found using the first equation is multiplied by the loaded Q of the tuned circuit, which can be from 50 to 100:

$$V_o = \frac{2\pi A N E_f Q \cos(\alpha)}{\lambda}$$

Even though the output signal voltage of tuned loops is higher than that of untuned loops, it is nonetheless low compared with other forms of antenna. As a result, a loop preamplifier usually is needed for best performance.

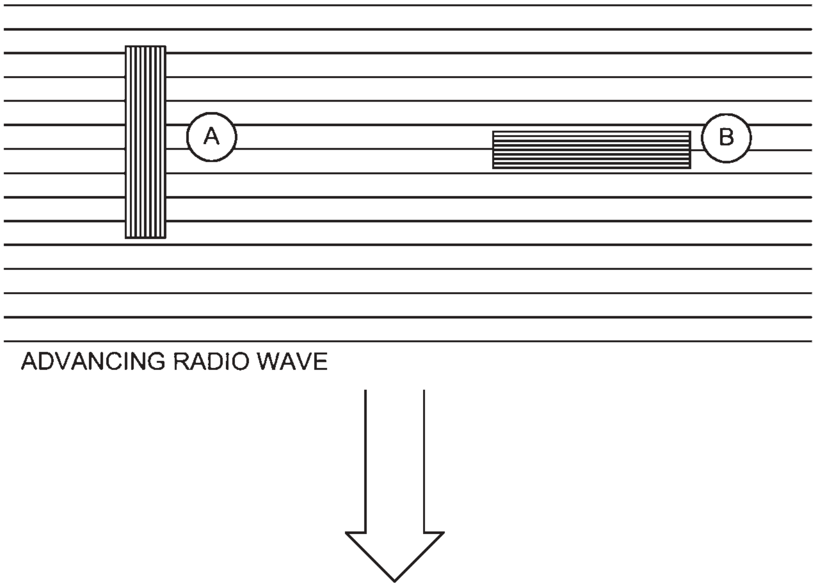
A
B
ADVANCING RADIO WAVE

15-3 Two small loop antennas at right angles to each other.

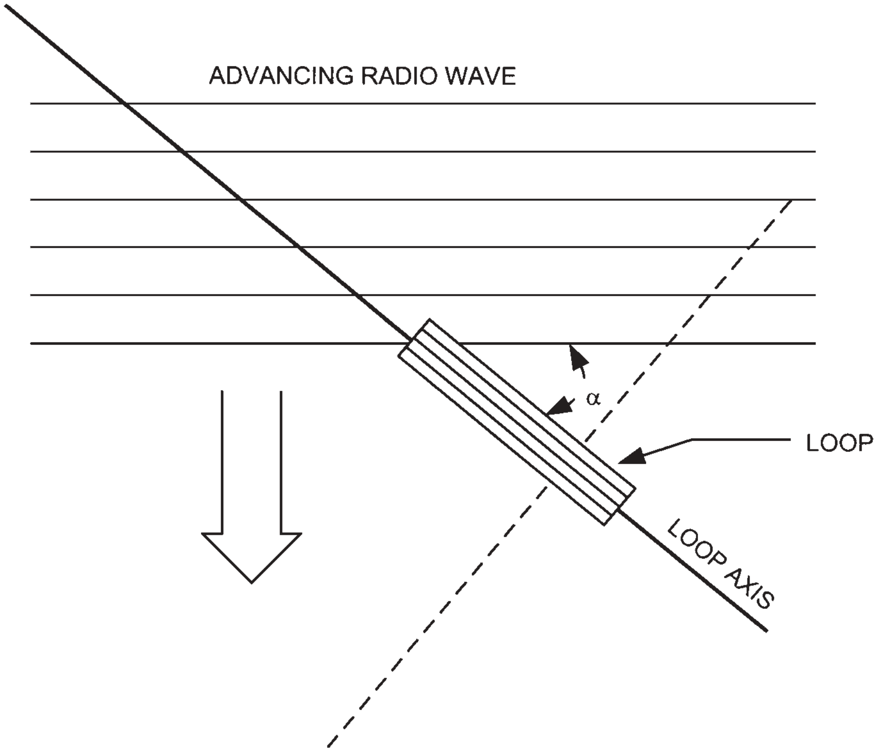
ADVANCING RADIO WAVE
α
LOOP
LOOP AXIS

15-4 An untuned loop antenna.

Transformer loops

It is common practice to make a small loop antenna with two loops rather than just one. Figure 15-5 shows such a transformer loop antenna. The main loop is built exactly as discussed above: several turns of wire on a large frame, with a tuning capacitor to resonate it to the frequency of choice. The other loop is a one- or two-turn *coupling loop.* This loop is installed in very close proximity to the main loop, usually (but not necessarily) on the inside edge not more than a couple of centimeters away. The purpose of this loop is to couple signal induced from the main loop to the receiver at a more reasonable impedance match.

The coupling loop is usually untuned, but in some designs a tuning capacitor (C_2) is placed in series with the coupling loop. Because there are many fewer turns on the coupling loop than on the main loop, its inductance is considerably smaller. As a result, the capacitance to resonate is usually much larger. In several loop antennas constructed for purposes of researching this chapter, I found that a 15-turn main loop resonated in the AM BCB with a standard 365-pF capacitor, but the two-turn

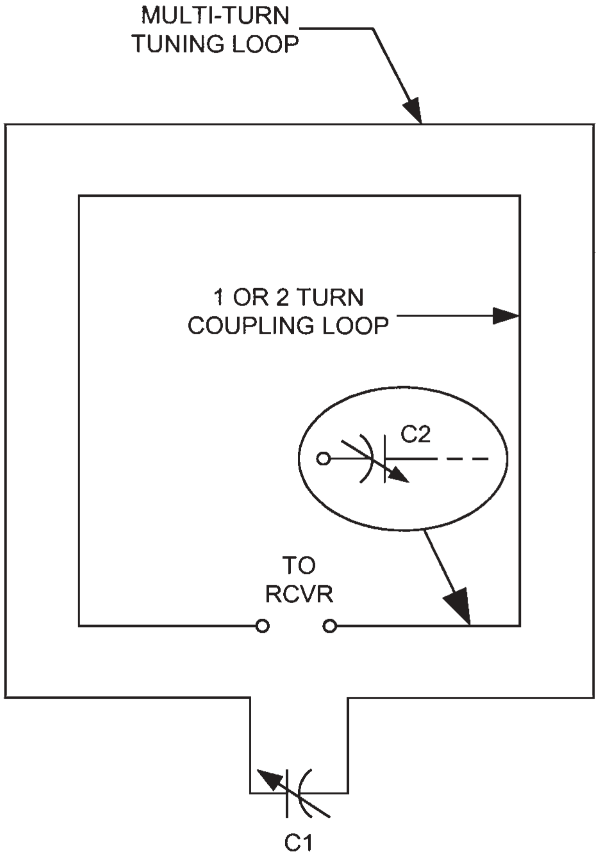

15-5 A transformer loop antenna.

coupling loop required three sections of a ganged 3 × 365-pF capacitor connected in parallel to resonate at the same frequencies.

In several experiments, I used computer ribbon cable to make the loop turns. This type of cable consists of anywhere from 8 to 64 parallel insulated conductors arranged in a flat ribbon shape. Properly interconnected, the conductors of the ribbon cable form a continuous loop. It is no problem to take the outermost one or two conductors on one side of the wire array and use them for a coupling loop.

Tuning schemes for loop antennas

Loop performance is greatly enhanced by tuning the inductance of the loop to the desired frequency. The bandwidth of the loop is reduced, which reduces front-end overload. Tuning also increases the signal level available to the receiver by a factor of 20 to 100 times. Although tuning can be a bother if the loop is installed remotely from the receiver, the benefits are well worth it in most cases.

There are several different schemes available for tuning, and these are detailed in Fig. 15-6. The parallel tuning scheme, which is by far the most popular, is shown in Fig. 15-6A. In this type of circuit, the capacitor (C_1) is connected in parallel with the inductor, which in this case is the loop. Parallel resonant circuits have a very high impedance to signals on their resonant frequency and a very low impedance to other frequencies. As a result, the voltage level of resonant signals is very much larger than the voltage level of off-frequency signals.

The series resonant scheme is shown in Fig. 15-6B. In this circuit, the loop is connected in series with the capacitor. A property of series resonant circuits is that they offer a high impedance to all frequencies except the resonant frequency (exactly the opposite of the case of parallel resonant circuits). As a result, current from the signal will pass through the series resonant circuit at the resonant frequency, but off-frequency signals are blocked by the high impedance.

There is a wide margin for error in the inductance of loop antennas, and even the precise-looking equations to determine the required values of capacitance and inductance for proper tuning are actually only estimations. The exact geometry of the loop "as built" determines the actual inductance in each particular case. As a result, it is often the case that the tuning provided by the capacitor is not as exact as desired, so some form of compensation is needed. In some cases, the capacitance required for resonance is not easily available in a standard variable capacitor, and some means must be provided for changing the capacitance. Figure 15-6C shows how this is done. The main tuning capacitor can be connected in either series or parallel with other capacitors to change the value. If the capacitors are connected in parallel, then the total capacitance is increased (all capacitances are added together). If the extra capacitor is connected in series, however, then the total capacitance is reduced. The extra capacitors can be switched in and out of a circuit to change frequency bands.

Tuning of a remote loop can be a bother if it is done by hand, so some means must be found to do it from the receiver location (unless you enjoy climbing into the attic or onto the roof). Traditional means of tuning called for using a low-rpm dc motor, or stepper motor, to turn the tuning capacitor. A very popular combination was the little 1- to 12-rpm motors used to drive rotating displays in retail store show

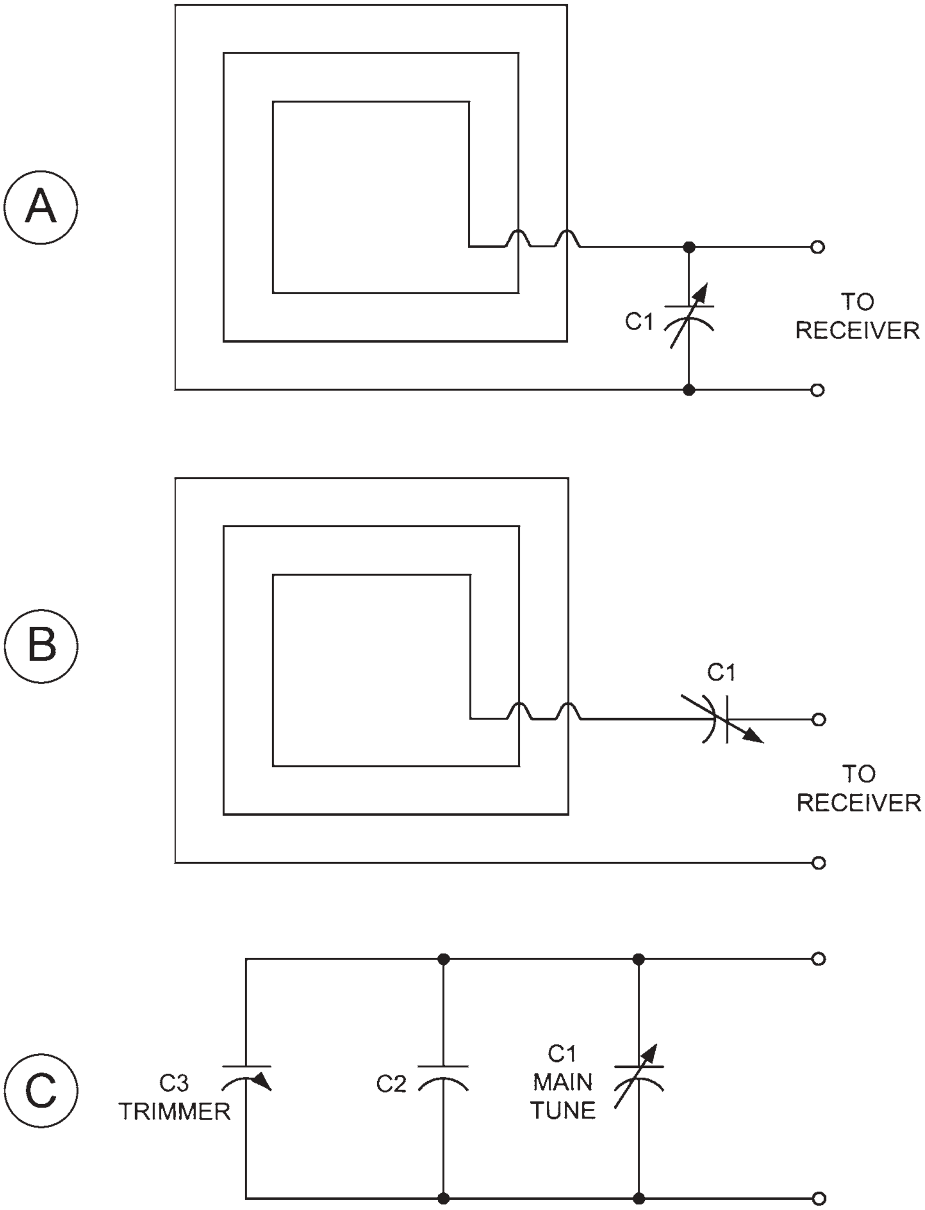
A
C1
TO
RECEIVER
B
C1
TO
RECEIVER
C
C3
TRIMMER
C2
C1
MAIN
TUNE

15-6 Various tuning schemes: (A) parallel, (B) series resonant, (C) series or parallel.

windows. But this approach is not really needed today. We can use varactor voltage-variable capacitance diodes to tune the circuit.

A varactor works because the junction capacitance of the diode is a function of the applied reverse-bias voltage. A high voltage (such as 30 V) drops the capacitance, whereas a low voltage increases it. Varactors are available with maximum capacitances of 22, 33, 60, 100, and 400 pF. The latter are of most interest to us because they have the same range as the tuning capacitors normally used with loops.

Figure 15-7 shows how a remote tuning scheme can work with loop antennas. The tuning capacitor is a combination of a varactor diode and two optional capacitors: a fixed capacitor (C_1) and a trimmer (C_2). The dc tuning voltage (V_t) is provided from the receiver end from a fixed dc power supply (V+). A potentiometer (R_1) is used to set the voltage to the varactor, hence also to tune the loop. A dc blocking capacitor (C_3) keeps the dc tuning voltage from being shorted out by the receiver input circuitry.

The sports fan's loop

OK, sports fans, what do you do when the best game of the week is broadcast only on a low-powered AM station and you live at the outer edge of their service area where the signal strength leaves much to be desired? You use the sports fan's loop antenna, that's what! I first learned of this antenna from a friend of mine, a professional broadcast engineer, who worked at a religious radio station that had a pipsqueek signal but lots of fans. It really works—*one might say it's a miracle.*

The basic idea is to build a 16-turn, 60-cm^2 tuned loop and then place the AM portable radio at the center so that its loopstick is aimed such that its null end is broadside of the loop. When you do so, the nulls of both the loop and the loopstick are in the same direction. The signal will be picked up by the loop and then coupled to the radio's loopstick antenna. Sixteen-conductor ribbon cable can be used for making the loop. For an extra touch of class, place the antenna and radio assembly on a dining room table lazy Susan to make rotation easier. A 365-pF tuning capacitor is used to resonate the loop. If you listen to only one station, then this capacitor can be a trimmer type.

Shielded loop antennas

The loop antennas discussed thus far in this chapter have all been unshielded types. Unshielded loops work well under most circumstances, but in some cases their pattern is distorted by interaction with the ground and nearby structures (trees, buildings, etc.). In my own tests, trips to a nearby field proved necessary to measure the depth of the null because of interaction with the aluminum siding on my house. Figure 15-8 shows two situations. In Fig. 15-8A we see the pattern of the normal "free space" loop, i.e., a perfect figure-8 pattern. When the loop interacts with the nearby environment, however, the pattern distorts. In Fig. 15-8B we see some filling of the notch for a moderately distorted pattern. Some interactions are so severe that the pattern is distorted beyond all recognition.

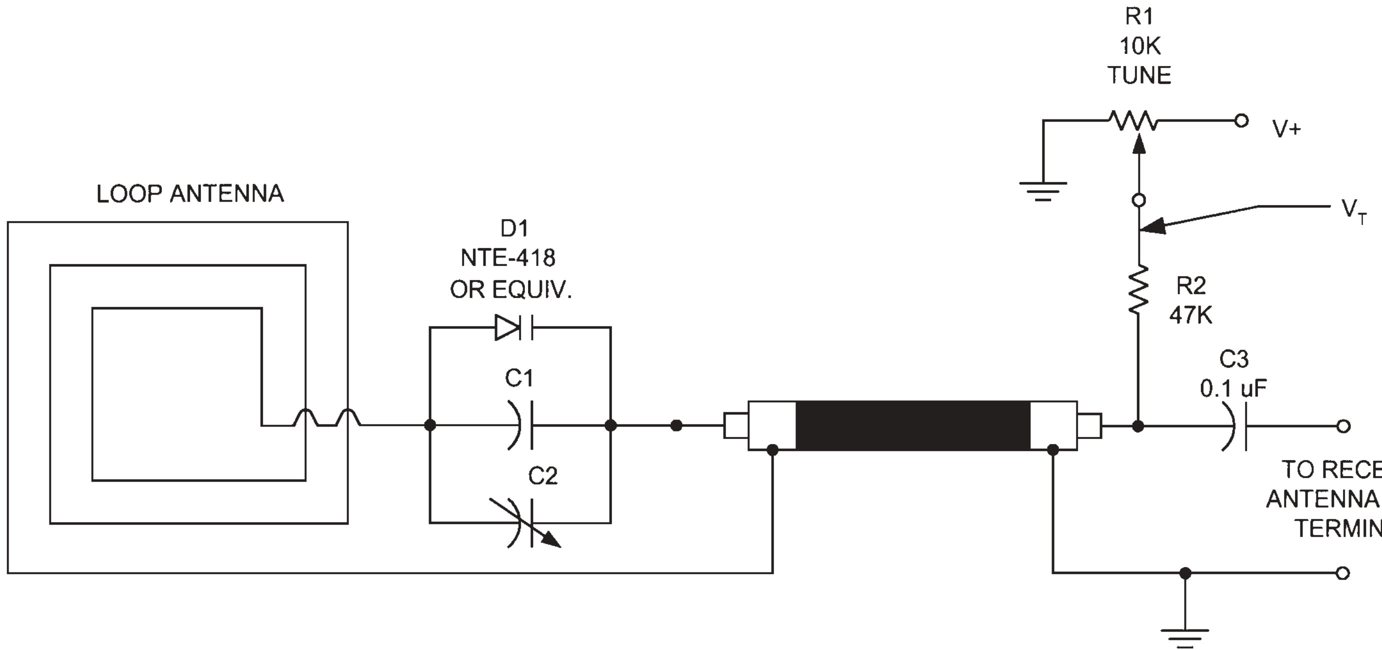
R1
10K
TUNE
V+
V_T
LOOP ANTENNA
D1
NTE-418
OR EQUIV.
C1
C2
R2
47K
C3
0.1 uF
TO RECEIVER
ANTENNA INPUT
TERMINALS

15-7 Remote tuning scheme.

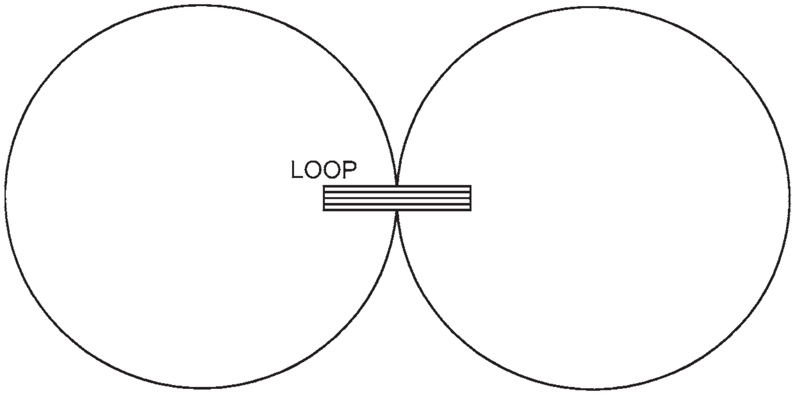

15-8A A normal "free space" loop.

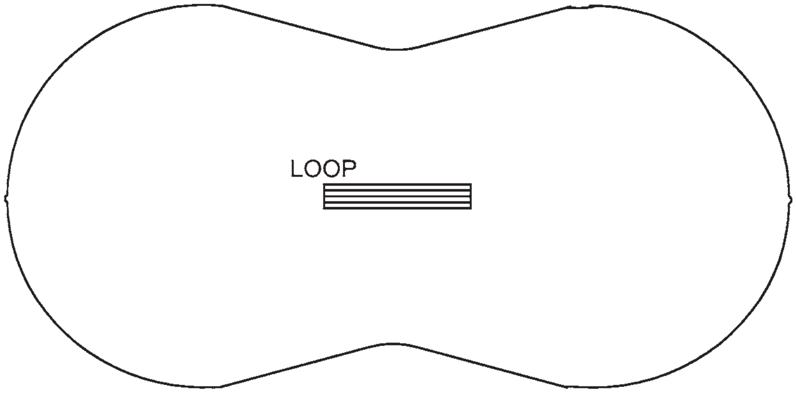

15-8B Filling of the notch.

The solution to the problem is to reduce interaction by shielding the loop, as in Fig. 15-9. Loop antennas operate on the magnetic component of the electromagnetic wave, so the loop can be shielded against voltage signals and electrostatic interactions. In order to prevent harming the ability to pick up the magnetic field, a gap is left in the shield at one point.

There are several ways to shield a loop. You can, for example, wrap the loop in adhesive-backed copper-foil tape. Alternatively, you can wrap the loop in aluminum foil and hold it together with tape. Another method is to insert the loop inside a copper or aluminum tubing frame. Or—the list seems endless.

Using a loop antenna

Most readers will use a loop for DXing rather than hidden transmitter hunting, navigation, or other RDF purposes. For the DXer, there are actually two uses for the

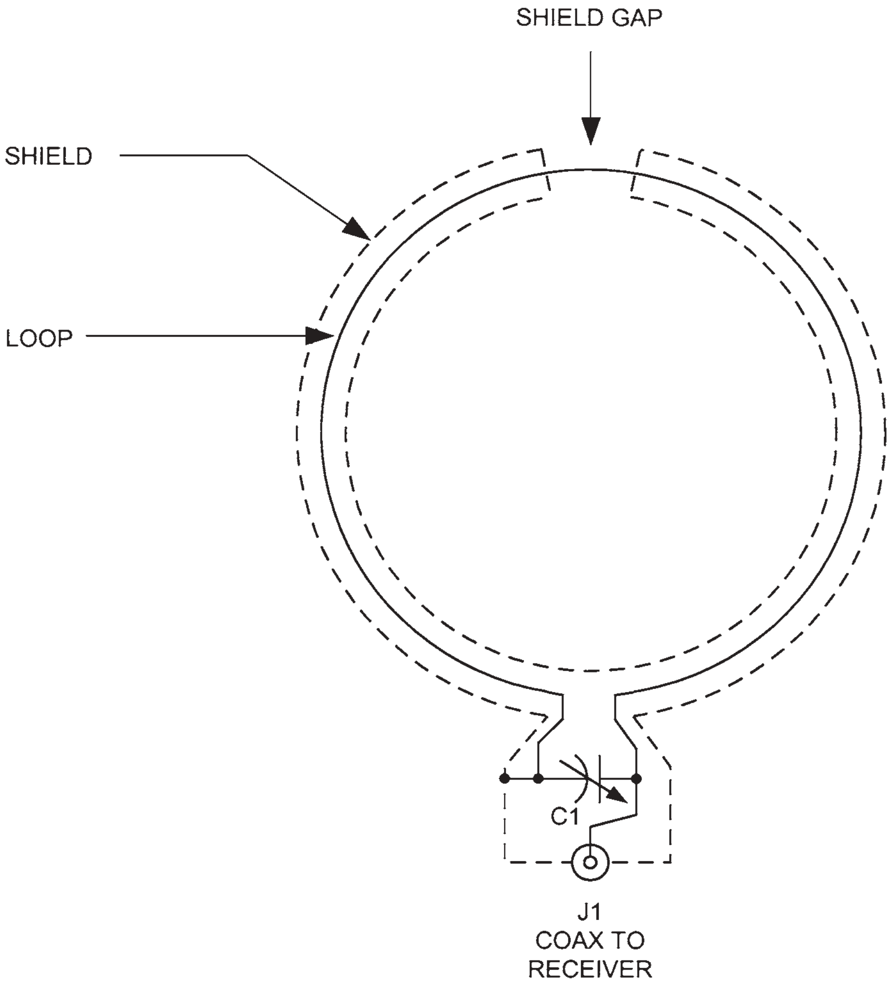

15-9 Shielding the loop.

loop. One is when you are a renter or live in a community that has routine covenants against outdoor antennas. In this situation, the loop will serve as an active antenna for receiving AM BCB and other low-frequency signals without the neighbors or landlord becoming PFJs ("purple-faced jerks").

The other use is illustrated by the case of a friend of mine. He regularly tunes in clear channel WSM (650 kHz, Nashville) in the wee hours between Saturday evening ("Grand Ole Opry" time) and dawn. However, this "clear" channel of WSM is not really so clear, especially without a narrow filter in the receiver. He uses a loop antenna to null out a nearby 630-kHz signal that made listening a bit dicey and can now tape his 1940s–1950s vintage country music.

It is not necessary to place the desired station directly in the main lobes off the ends of the antenna but rather to place the nulls (broadside) in the direction of the offending station that you want to eliminate. So what happens if the offending station and the desired station are in a direct line with each other and your receiving location is in the middle between them? Both nulls and lobes on a loop antenna are bidirectional, so a null on the offending station also will null the desired station in the opposite direction.

One method is to use a sense antenna to spoil the pattern of the loop to a cardioid shape. Another method is to use a spoiler loop to null the undesired signal. The spoiler loop is a large box loop placed 1 to 3 ft (found experimentally) behind the reception loop in the direction of the offending signal. This method was first described by Levintow and is detailed in Fig. 15-10. The small loopstick may be the antenna inside the receiver, whereas the large loop is a box loop such as the sports fan's loop. The large box loop is placed about 33 to 100 cm behind the loopstick and in the direction of the offending station. The angle with respect to the line of centers should be 60° to 90°, which also was found experimentally. It is also possible to use two air core loops to produce an asymmetrical receiving pattern.

Sharpening the loop

Many years ago, the *Q-multiplier* was a popular add-on accessory for a communications receiver. These devices were sold as Heathkits, and many construction projects could be found in magazines and amateur radio books. The Q-multiplier has the effect of seeming to greatly increase the sensitivity of a receiver, as well as greatly reducing the bandwidth of the front end. Thus it allows better reception of some stations because of increased sensitivity and narrowed bandwidth.

A Q-multiplier is an active electronic circuit placed at the antenna input of a receiver. It is essentially an Armstrong oscillator, as shown in Fig. 15-11, that does not quite oscillate. These circuits have a tuned circuit (L_1/C_1) at the input of an amplifier stage and a feedback coupling loop (L_3). The degree of feedback is controlled by the coupling between L_1 and L_3. The coupling is varied by varying both how close the two coils are and their relative orientation with respect to each other. Certain other circuits use a series potentiometer in the L_3 side that controls the amount of feedback.

The Q-multiplier is adjusted to the point that the circuit is just on the verge of oscillating, but not quite. As the feedback is backed away from the threshold of oscillation, but not too far, the narrowing of bandwidth occurs, as does the increase in sensitivity. It takes some skill to operate a Q-multiplier, but it is easy to use once you get the hang of it and is a terrific accessory for any loop antenna.

Loop amplifier

Figure 15-12 shows the circuit for a practical loop amplifier that can be used with either shielded or unshielded loop antennas. It is based on junction field effect transistors (JFET) connected in cascade. The standard common-drain configuration is used for each transistor, so the signals are taken from the source terminals. The drain terminals are connected together and powered from the +12-V dc power

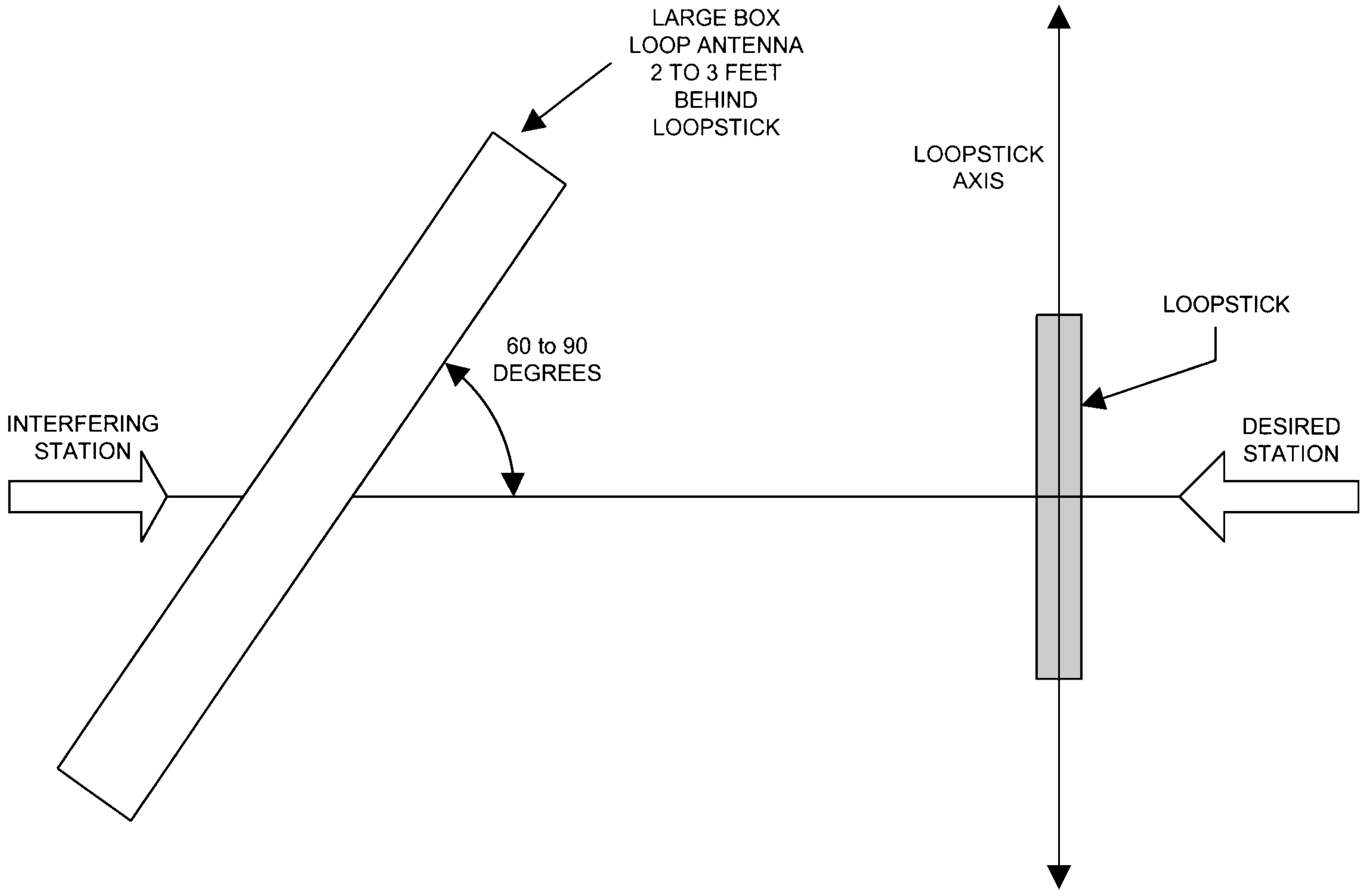
LARGE BOX
LOOP ANTENNA
2 TO 3 FEET
BEHIND
LOOPSTICK
LOOPSTICK
AXIS
LOOPSTICK
60 to 90
DEGREES
INTERFERING
STATION
DESIRED
STATION

15-10 Use of a spoiler loop to null an undesired signal.

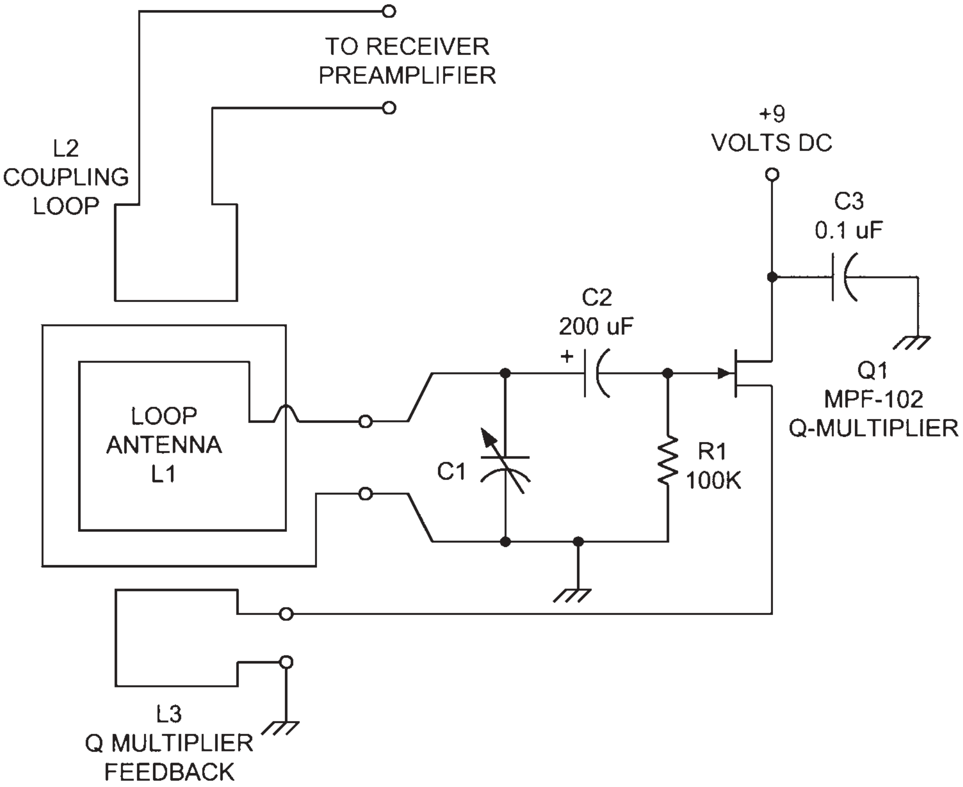
TO RECEIVER
PREAMPLIFIER
L2
COUPLING
LOOP
+9
VOLTS DC
C3
0.1 uF
C2
200 uF
+
Q1
MPF-102
Q-MULTIPLIER
LOOP
ANTENNA
L1
C1
R1
100K
L3
Q MULTIPLIER
FEEDBACK

15-11 A Q-multiplier.

supply. A 2.2-µF bypass capacitor is used to put the drain terminals of Q_1 and Q_2 at ground potential for ac signals while keeping the dc voltage from being shorted out.

The two output signals are applied to the primary of a center-tapped transformer, the center tap of which is grounded. To keep the dc on the source terminals from being shorted through the transformer winding, a pair of blocking capacitors (C_4, C_5) is used.

The input signals are applied to the gate terminals of Q_1 and Q_2 through dc blocking capacitors C_2 and C_3. A pair of diodes (D_1, D_2) is used to keep high-amplitude noise transients from affecting the operation of the amplifier. These diodes are connected back to back in order to snub out both polarities of signal.

Tuning capacitor C_1 is used in lieu of the capacitor in the loop and is used to resonate the loop to a specific frequency. Its value can be found from the equation given earlier.

The transistors used for the push-pull amplifier (Q_1, Q_2) can be nearly any general-purpose JFET device (MPF-102, MPF-104, etc.). A practical approach for many people is to use transistors from service replacement lines, such as the NTE-312 and NTE-316 devices.

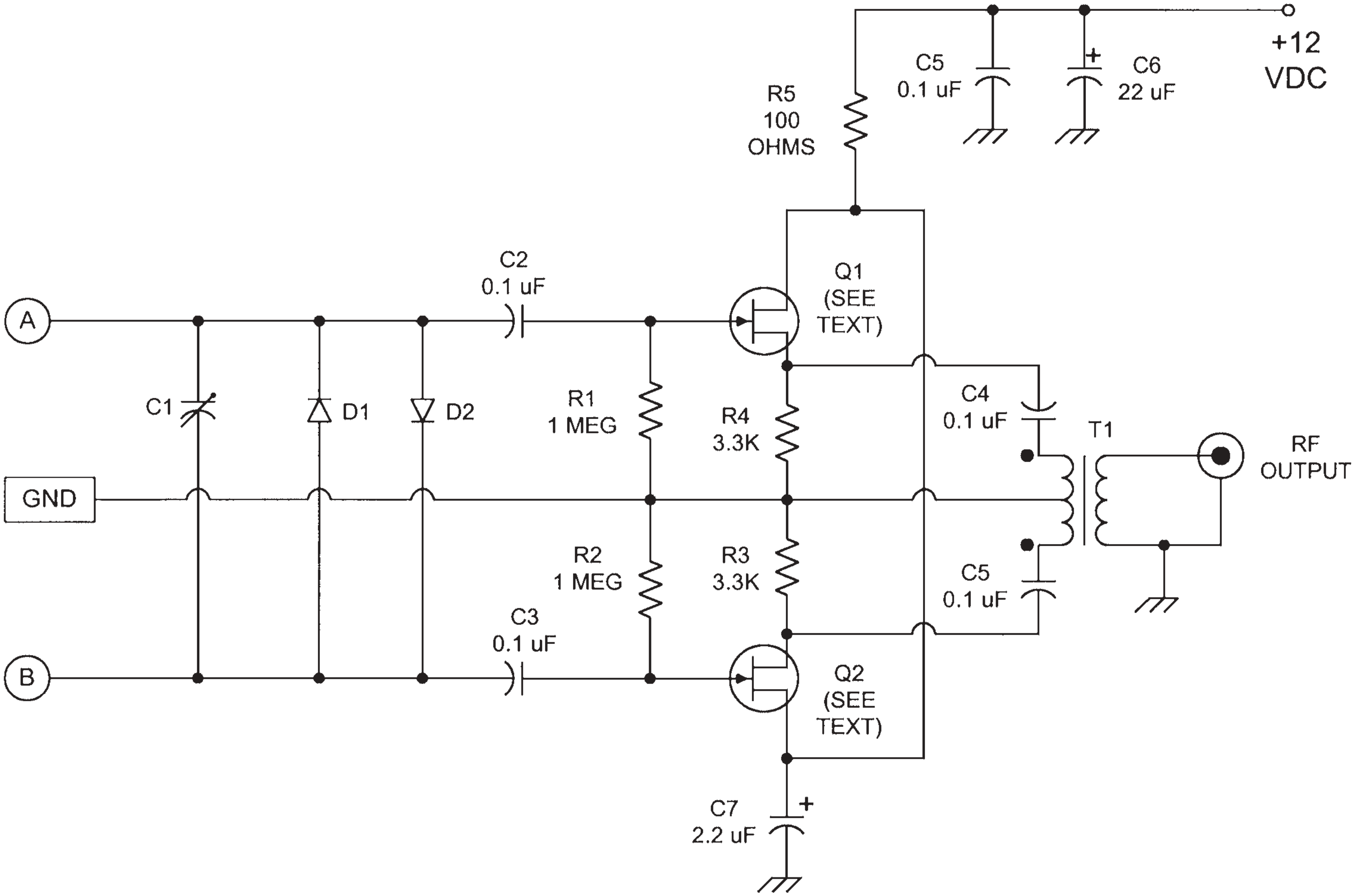
+12
VDC
R5
100
OHMS
C5
0.1 uF
C6
22 uF
C2
0.1 uF
Q1
(SEE
TEXT)
A
C1
D1
D2
R1
1 MEG
R4
3.3K
C4
0.1 uF
T1
RF
OUTPUT
GND
R2
1 MEG
R3
3.3K
C5
0.1 uF
C3
0.1 uF
B
Q2
(SEE
TEXT)
C7
2.2 uF

15-12 A practical loop amplifier.

Special problem for VLF/LF loops

A capacitance is formed whenever two conductors are side by side. A coil produces capacitance as well as inductance because the turns are side by side. Unfortunately, with large multiturn loops, this capacitance can be quite large. The "distributed capacitance" of the loop causes a self-resonance with the inductance. The loop does not work well at frequencies above the self-resonant point, so it is sometimes important to raise the self-resonance to a point where it does not affect operation at the desired frequencies.

Figure 15-13 shows a solution that raises the self-resonant point. The turns are broken into two or more groups and separated by a space. This method reduces the effective capacitance by placing the capacitances of each group of wires in series with the others.

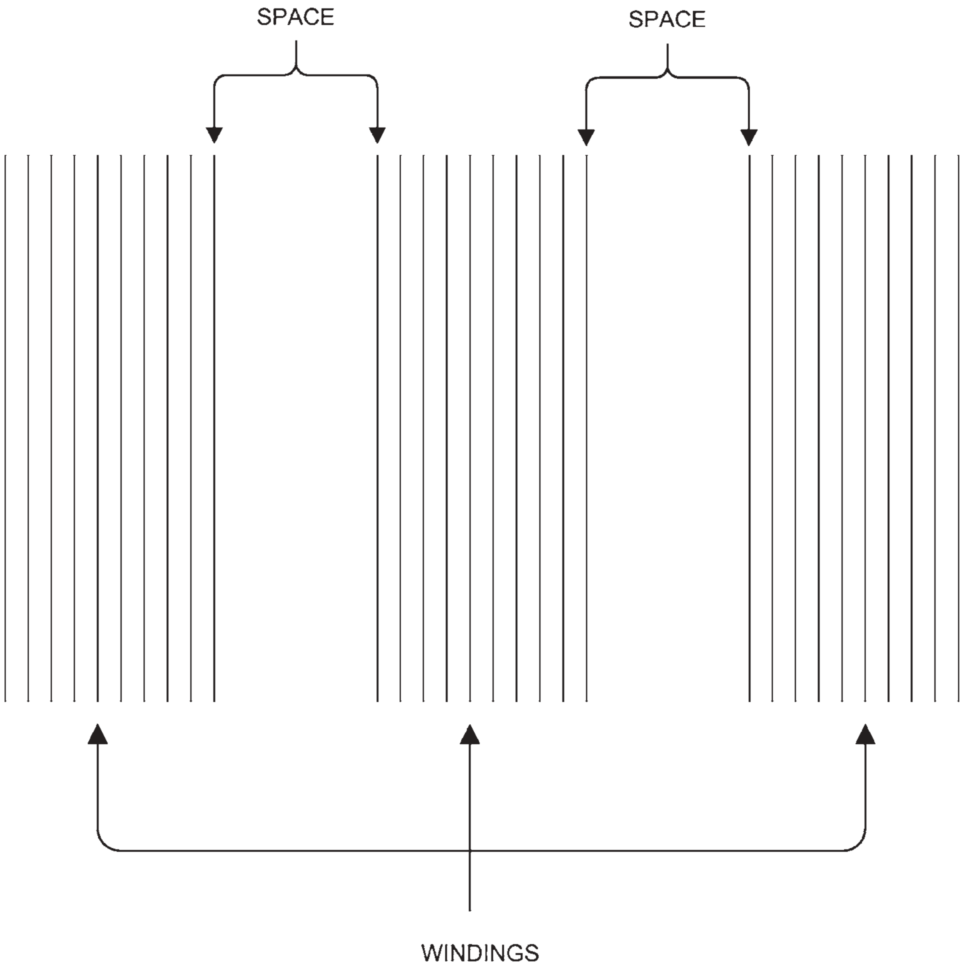

15-13 Raising the self-resonant point.

Coaxial-cable loop antennas

One of the more effective ways to make a shielded loop is to use coaxial cable. Figure 15-14 shows the circuit of such a loop. Although only a single-turn loop is shown, there can be any number of turns. One reader made a 100-kHz LORAN (a navigation system) loop using eight turns of RG-59/U coaxial cable on an 8-ft diameter.

Note the special way that the coaxial cable is connected. This method is called the *Faraday connection* after the fact that the shield of the coax forms a *Faraday shield.* At the output end, the center conductor of the coaxial cable is connected to the center conductor of the coaxial connector. The coax shield is connected to the connector ground/shield terminal. At the other end of the loop, the shield is left floating, but the center conductor is connected to the shield. Note very carefully that the center conductor at the far end is connected to the shield *at the connector,* not at just any convenient point.

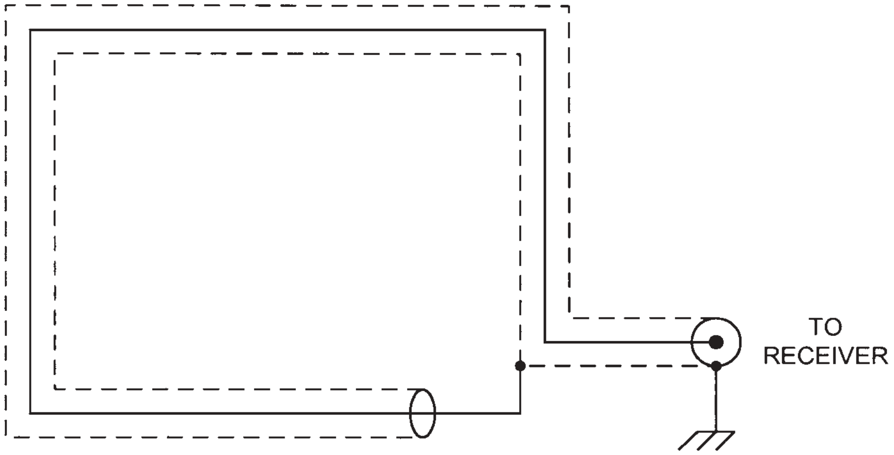

15-14 A coaxial-cable shielded loop.

16
Chapter

Small transmitting loop antennas

Small transmitting loops are those which are less than one-third wavelength (λ/3) according to Hart (1986) or between 0.04λ and 0.10λ according to Belrose (1993). Other sources claim that loops up to about 0.20λ are small. The key characteristic is that the current is equal in all points of the loop rather than varying with loop length the way the current in a large loop (or other antenna) does.

One of the parameters of the small loop antenna is a very low radiation resistance (it is a function of the area of the loop). The radiation resistance of the small loop antenna is less than 1 Ω and often considerably less than this figure (e.g., 0.05 Ω). This means that the copper or aluminum losses of the antenna must be kept very, very low. For such reasons, it is common to assemble the small transmitting loop antenna from 1- to 4-in copper or aluminum pipe. For this reason, the square (Fig. 16-1A) or octagon (Fig. 16-1B) shapes are preferred. The reason this is true is purely mechanical: The square loop can be built with 90° elbow joints, and the octagon can be built with 45° elbow joints. For antennas whose circumference is greater than λ/8, standard $^3/_4$-in copper pipe can be used in construction, but for smaller-sized loops, larger-sized copper piping is used.

The small transmitting loop tends to be highly inductive in its reactance. Values of inductive reactance to 1000 Ω are not unusual, although closer to 100 Ω is the norm. Because of this inductive reactance, the small transmitting loop antenna is tuned by one or more series capacitors.

A sample loop was modeled by Belrose (1993). It was 1 m in diameter and was made of 2.54-cm (1-in) copper pipe. For this loop, the gains were

10 MHz	2.88 dBi
14 MHz	0.22 dBi
21 MHz	1.14 dBi
30 MHz	1.42 dBi

Note that the gains were all less than that of a dipole (12.15 dBi) but in the upper regions of the frequency spectrum were quite decent. Even at 10 MHz, the 1-m

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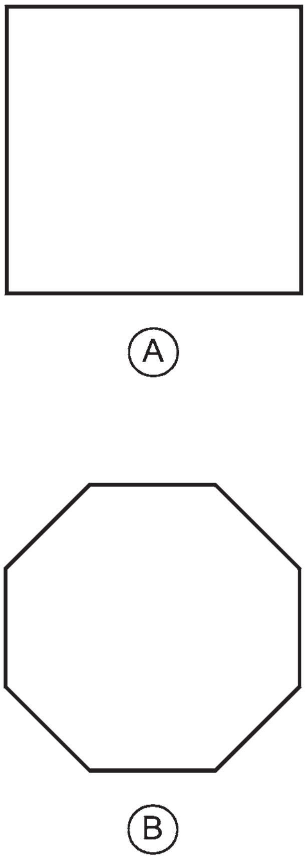

16-1 Small transmitting loop antennas: (A) square, (B) octagon.

small loop antenna was only −5.03 dBi less than the dipole. The loop probably would show similar gains up to the point of self-resonance.

Calculations of the current and voltage within the loop are substantial. The loop impedance at 10 MHz is 0.088 1 *j*161 Ω. This means that a 150-W transmitter, certainly modest for these frequencies, would produce 41 A circulating inside the loop and a voltage across the tuning capacitor of 6600 V. As Belrose (1993) warns: "Don't touch your loop when transmitting!"

The tuning capacitor in Belrose's loop should be rated for at least 10,000 V to guard against anyone using more than 150 W. Keep in mind that a power of 500 W will produce potentials across the capacitor of 30,000 V, so you will need a capacitor with at least $^{1}/_{2}$-in spacing. A 1-in spacing is good for about 75,000 V. It is probably best to use a vacuum-variable capacitor for the tuning capacitor of a small loop antenna if you can afford one. Regardless, the loop power should be kept under control!

The Q of the antenna at any given resonant frequency is very, very high. For the 1-m loop antenna described earlier, the Q at 10 MHz was 1824, which resulted in a bandwidth of 5.5 kHz (although in practice it is twice this amount before VSWR tolerances on the transmitter are exceeded). Regardless, the bandwidth of the resonated loop is tiny, so some means must be provided for retuning the loop as you shift frequency. If you do not shift frequency, then the loop can be tuned and forgotten, but for the rest of the radio fraternity, perhaps a remotely tuned capacitor is in order. Getting a large capacity variable in the voltages that are required for operation with a good power level is a bit tricky.

Design equations

The design equations developed by Hart (1986) are as follows:

Radiation resistance (R_R):

$$R_R = 3.38 \times 10^{-8} (F^2 A)^2 \qquad \textbf{[16.1]}$$

Loss resistance (R_L):

$$R_L = \frac{9.96 \times 10^{-4} S \sqrt{F}}{D} \qquad \textbf{[16.2]}$$

Efficiency (η):

$$\eta = \frac{R_R}{R_R + R_L} \qquad \textbf{[16.3]}$$

Inductance (L):

$$\mathrm{L} = 1.9 \times 10^8 \mathrm{S} \left(7.353 \log_{10} \frac{96S}{\pi D} - 6.386\right) \qquad \textbf{[16.4]}$$

Inductive reactance (X_L):

$$X_L = 2\pi F L \times 10^6 \qquad \textbf{[16.5]}$$

Tuning capacitance (C):

$$C = \frac{1}{2\pi F X_L \times 10^6} \qquad \textbf{[16.6]}$$

Quality factor (Q):

$$Q = \frac{F}{\Delta F} = \frac{X_L}{2\,(R_R + R_L)} \qquad \textbf{[16.7]}$$

Bandwidth (ΔF):

$$\Delta F = \frac{F}{Q} \qquad \textbf{[16.8]}$$

Distributed capacitance (C_D):

$$C_D = 0.82S \qquad \textbf{[16.9]}$$

Capacitor voltage (V_C):

$$V_C = \sqrt{P X_L Q} \qquad \textbf{[16.10]}$$

where

A is the area of the loop, in square feet (ft2)
S is the length of the loop conductor, in feet (ft)
D is the diameter of the conductor, in inches (in)
P is the applied transmitter output power, in watts (W)

Some sample loop antennas

The Patterson (1967) loop antenna is shown in Fig. 16-2. It is made from 1.5-in copper tubing. Segments are cut and are joined together by eight 45° elbow joints, giving the octagon shape. Each segment is 0.5 ft long. The tuning is accomplished by three capacitors, two of which are a split-stator unit (two capacitors on the same shaft). The tuning control is the split-stator capacitor, whereas the loading control is a single capacitor.

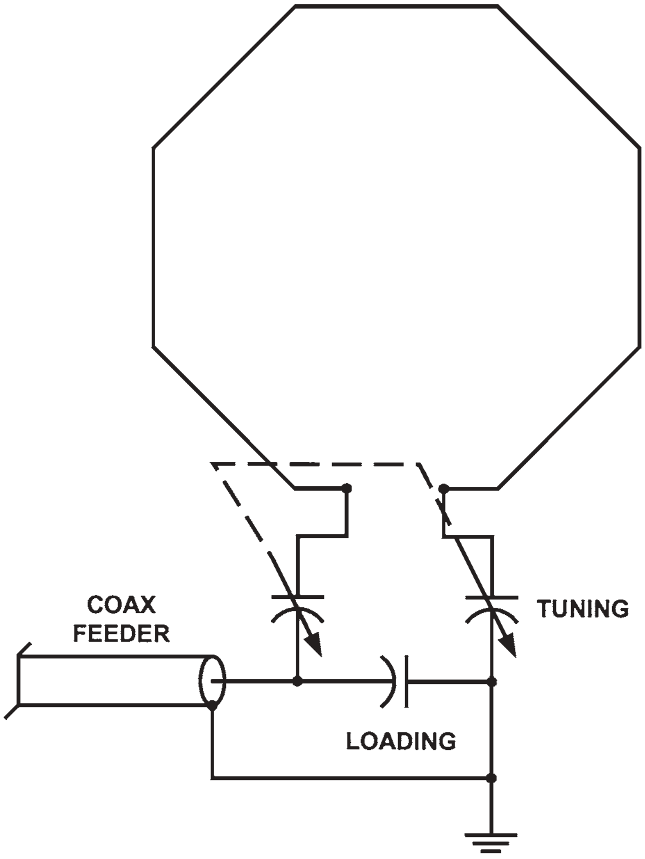

16-2 A Patterson loop antenna.

Another loop antenna is shown in Fig. 16-3. This antenna has a Faraday feed system rather than a capacitor-coupled feed system, as did the Patterson loop. The tuning is accomplished by C_A, the series tuning capacitor. The requirement must be met that $D_1/D_2 = 5$.

Still another loop is shown in Fig. 16-4. This loop relies on magnetic coupling to perform the coupling of the transmitter. In this loop antenna, the coupling is via a small coupling loop and 50-Ω coaxial cable to the transmitter. Capacitor C_1 is used to resonate the loop, whereas capacitors C_2 and C_3 serve the purposes of loading and resonating the coupling loop. According to Mozzochi (1993), the voltages and currents with respect to the capacitors are

$$V_{C1} = 1800\sqrt{P} \tag{16.11}$$

$$V_{C2} = 18\sqrt{\mathrm{P}} \tag{16.12}$$

$$V_{C3} = 17\sqrt{\mathrm{P}} \tag{16.13}$$

$$I_{C1} = 2.2\sqrt{\mathrm{P}} \tag{16.14}$$

$$I_{C2} = 0.21\sqrt{P} \tag{16.15}$$

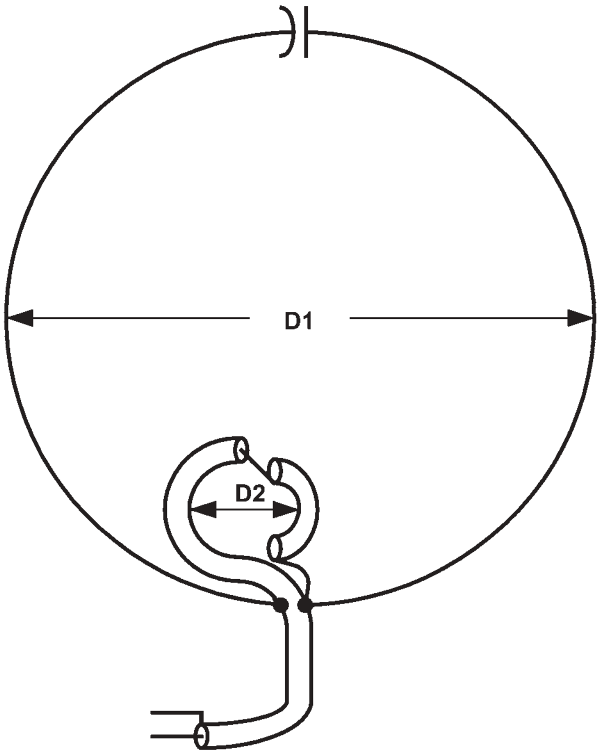

16-3 A loop antenna with a Faraday feed system.

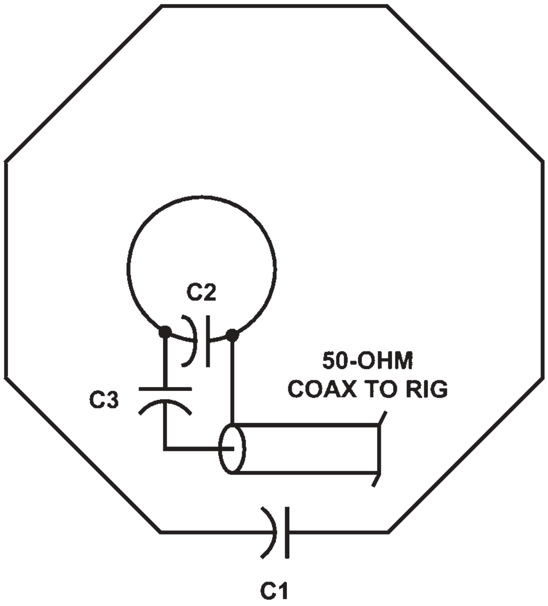

16-4 A loop antenna with magnetic coupling.

$$I_{C3} = 0.15\sqrt{P} \tag{16.16}$$

The radiation patterns for the loop antenna are shown in Fig. 16-5. Note that four elevations are given (0°, 20°, 45°, and 60°).

The bottom line is that small transmitting loop antennas are not very good for those who can afford to put up a better antenna, but for those whose tight quarters permit only a small transmitting loop, they are quite viable.

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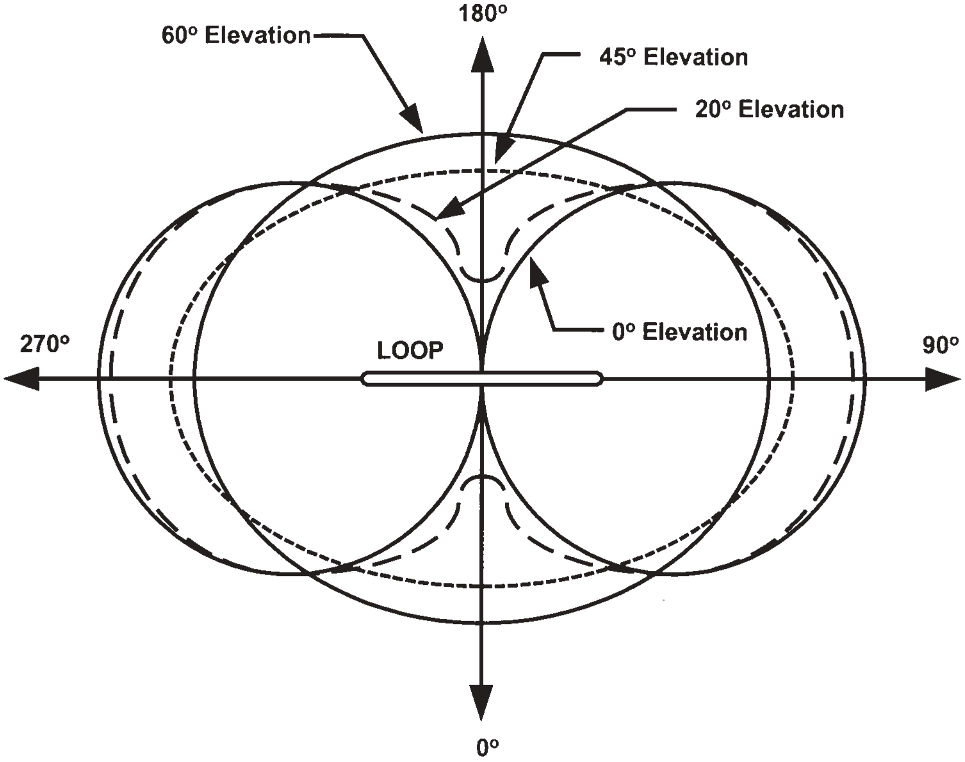

16-5 Radiation patterns.

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17
CHAPTER

Antenna modeling software

One of the significant contributions of computer technology to antenna design is the improvement of modeling and simulation. Modeling and simulation are used in a wide variety of applications, including management, science, and engineering. We can now model just about any process, any device, or any circuit that can be reduced mathematically. The purpose of modeling, at least in engineering, is to do the design cheaply on the computer before "bending metal." The old "cut and try" method works, to be sure, but it is costly in time and money (two things perpetually in short supply). If performance issues and problems can be solved on a computer, then we are time and money ahead of the game. Also, modeling and simulation make it possible to look at more alternatives and to gauge the effect of a change in an antenna design before the change is made.

Modeling is used not just in engineering but also in other processes. Organizations and management consultants use modeling and simulation to study their operations and find the most efficient way of doing things. I saw an example where an inefficient truck terminal and warehouse operation was improved significantly by modeling on a Windows desktop computer. The operators modeled the existing system and several alternative systems, and found that one particular rule (involving bulk deliver trucks such as tankers and dry bulk carriers) was jamming up the normal package deliveries at the warehouse dock. They could have tried different sets of rules over a couple of years, collected lots of data, presented scores of viewgraphs to management committees, and still have overlooked the actual cause of the problem. The model showed the problem in only a few minutes, however.

What is a model?

Models are no big mystery. If you have fingers and can count, then you can make models. In fact, you probably do make models mentally, e.g., when you look at how much cash you have in your pocket when confronted with several different purchase choices but cannot afford all of them. The "model" is the "what if" considerations that lead to your selection.

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Youngsters in the schools are learning that the equations and formulas they learn in algebra and trigonometry are “models.” This designation was not used when I was in school, but it is an apt description in most cases.

One of the earliest modeling methods for the masses was the computer-based spreadsheet program. Software such as Microsoft Excel can be used to test various scenarios by entering different values into the cells. I have seen spreadsheets used for the originally intended business applications, as well as engineering applications (including antenna design).

Antenna modeling software tends to use the “method of moments,” in which each wire in the system is broken into 1 to N segments, and the current in each segment is calculated.

Some common programs

Some years ago an antenna modeling program came on the scene. Developed by the Navy, this program used numerical methods to perform the complex calculations needed to model an antenna. Called the *Numerical Electromagnetic Computation* (NEC) *program,* a smaller version soon became available known as miniNEC (which runs on PCs). You can download miniNEC-3 from several sources in the amateur radio newsgroups in the United States or United Kingdom, or from the Navy Postgraduate School Web site. A miniNEC-4 version is also available, but I understand that it requires a license to use and cannot be exported without a permit from the U.S. government.

There are also a number of private vendors who offer the miniNEC at a price. Some of the better vendors offer their own versions, based on the miniNEC concept, but with some value added to make it worthwhile to buy theirs instead of using the “freebie” version.

The miniNEC programs model wire antennas using the coordinate system shown in Fig. 17-1. This is a standard three-dimensional Cartesian coordinate system in which the y axis is horizontal, the z axis is vertical, and the x axis is orthogonal to both the y and z axes. The idea is to specify the starting and ending points of the wires making up the antenna in terms of the xyz coordinate system. Figure 17-2 shows a single-wire antenna laid out in the x axis. This axis is in the horizontal plane but orthogonal to the y axis. The antenna designer will specify X_1 and X_2, which are the starting and ending points of the wire.

The antenna can consist of a large number of wires, although the larger the number, the longer is the processing time. Each wire is broken into a number of different segments for calculation purposes.

NEC-4

The NEC-4 software is the latest in the NEC series and is proprietary to the University of California, from whom a license must be obtained to use it. Because of national defense considerations, an export license is required to take NEC-4 overseas. The NEC-4 software will produce modeling of underground radials, elements of varying diameter, and carefully constructed close-spaced parallel wires.

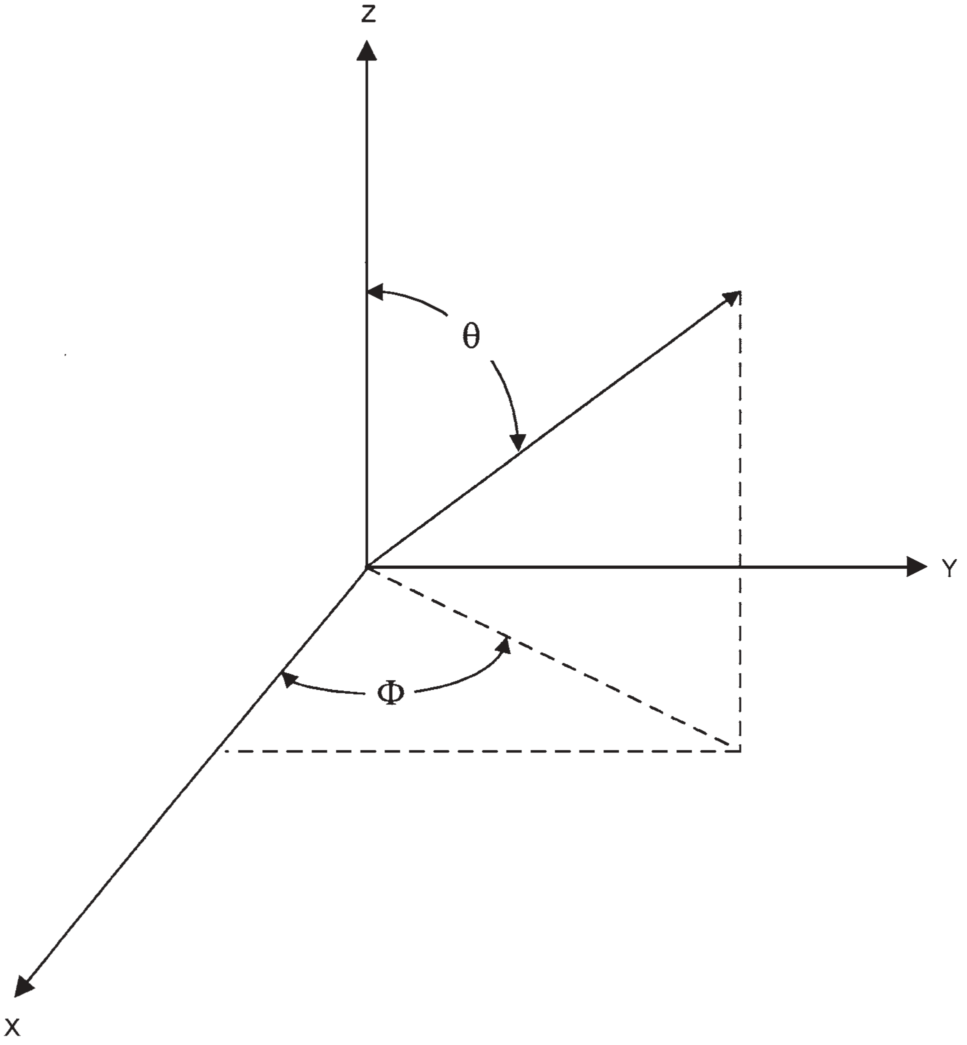

17-1 *XYZ* coordinate system for NecWin modeling software.

EZNEC Professional

Roy Lewallen, W7EL, provides the EZNEC Pro software. This software has an option for NEC-4, provided that the license is obtained from the University of California (again, export restrictions apply).

GNEC

Nittany-Scientific makes a version of NEC-4 known as GNEC. It permits the use of catenary wires, helices, networks, and other possibilities. Outputs include 3-D, polar plots, and rectangular plot graphs, as well as a large array of tabular reports.

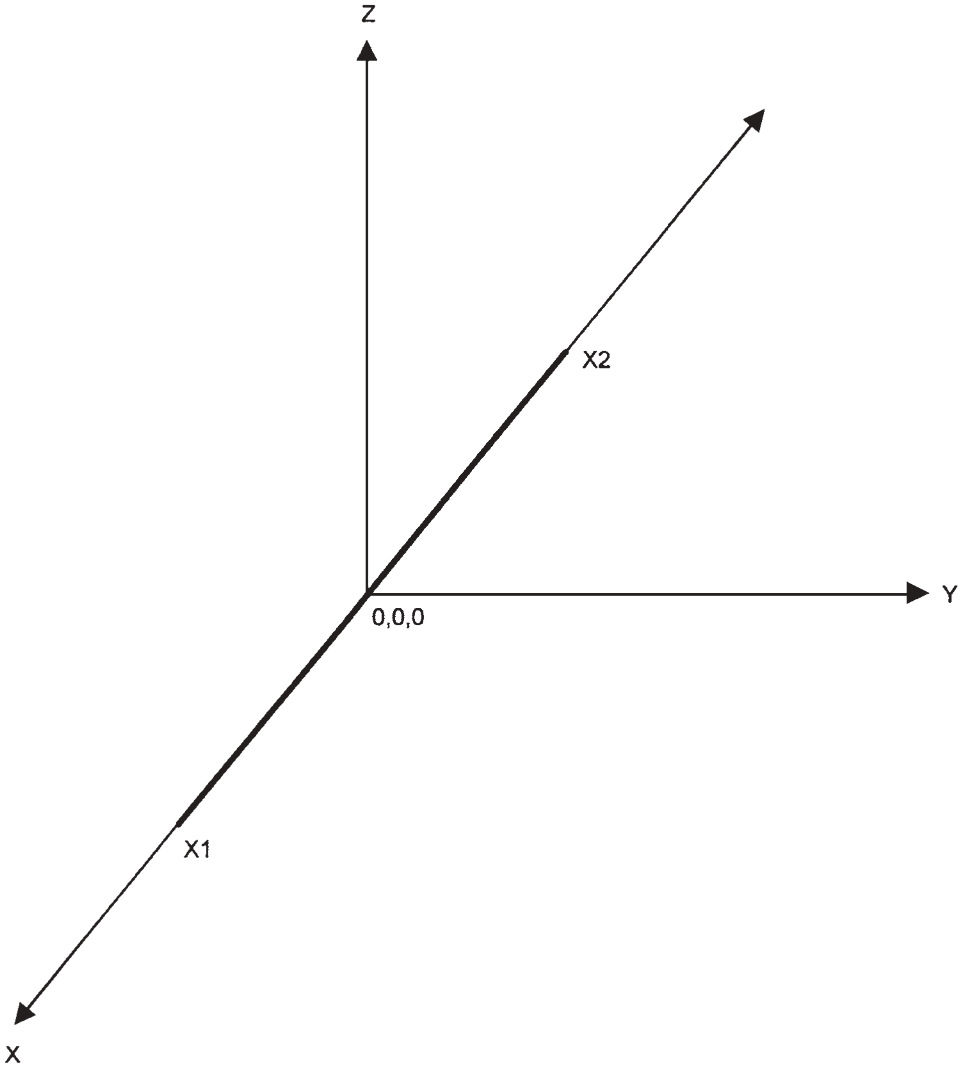

17-2 Example of a single wire laid out on *XYZ* coordinate system.

NEC-2

This is a high-capability version of the NEC software, and it is in the public domain. It is limited to antenna elements of constant diameter, although some software providers who base their wares on NEC-2 provide corrections for multidiameters. It is fitted with the Sommerfield-Norton ground model for modeling horizontal wires close to the earth's surface.

NECWin Plus

This software is provided by Nittany-Scientific. It features true spreadsheet geometry. The software also offers stepped-diameter corrections, a gain-averaging test, a

CAD file (*.dxf), 2-D and 3-D plots, 2-D and 3-D antenna views, and certain graphic outputs. There are two versions, NECWin Pro and NECWin Basic (NECWin Basic is reviewed in this chapter).

EZNEC for Windows

Roy Lewallen's EZNEC for Windows is available in both NEC-2 and NEC-4 versions, although the NEC-4 version requires a license from the University of California to operate. It offers 2-D and 3-D plots, 3-D plots with 2-D slicing, ground-wave output, stepped-diameter correction, and various shortcuts to antenna modeling. The standard EZNEC is limited to 500 segments (the Pro version handles a much larger number of segments).

Expert MiniNEC

This new version of MiniNEC can handle sharp angles in antenna geometry directly and handles antennas close to the ground much more accurately than MiniNEC. Several versions of Expert MiniNEC are available from EM Scientific. These are MiniNEC for Windows and MiniNEC Broadcast Professional.

MiniNEC

MiniNEC Version 3.13 is the latest of the public-domain MiniNEC code. It runs on a PC in the DOS mode. It handles element lengths of changing diameter. Horizontal antennas must be at least 0.2λ above ground for accurate results to occur.

NEC4Win95

Orion (Canada) offers a Windows 95/98 version of MiniNEC known as NEC4Win95. It offers spreadsheet antenna geometry input, pull-down boxes for all other antenna parameters, and a pattern-plotting routine that includes lobe identification and bandwidth.

NECWin Basic

Many amateur and professional users have been increasingly dissatisfied with the commercial miniNEC-based antenna modeling programs on the market (mostly because they only run in the DOS environment and are clumsy to use). A low-cost Windows-based modeling program is NecWin Basic for Windows. This program appears to be a DOS-based NEC engine run with a Windows graphic user interface written in Visual Basic 3.0. The vendor offering NecWin Basic for Windows is Nittany Scientific, Inc. [Airline Highway, Suite 361, Hollister, CA, 95023-5621; phone: (408) 634-0573; Web site: *www.nittany-scientific.com*]. The basic version (which I test drove and now use) costs less than $100, and there is a professional version for a higher price.

NecWin Basic for Windows allows you to specify the geometry of the antenna in the *xyz* coordinate system. This process is made a lot easier by the fact that it uses a "spreadsheet-like" grid (Fig. 17-3). Once the geometry is entered, you can select from several different ground situations (including "none" for free-space calculations), the operating frequency, and units of measure used for the antenna wires (meters is default). You also can customize the calculations using the "Output" button. Once the geometry and parameters are entered, you can visualize the geometry in "stick form" using the "Eye" button on the toolbar. The "Traffic Light" button performs the NEC calculations, whereas the “Polar Coordinates” button creates the elevation and azimuth pattern graphics. When you “Save Screen” in the “File” menu, you will produce a bitmap (*.bmp) file of the pattern.

The particular geometry entered in Fig. 17-3 is for a long-wire antenna (Fig. 17-4) that is two wavelengths long and has a quarter-wavelength radial used as a counterpoise ground. There are no wires in the *y* and *z* planes, so the values of Y_1, Y_2, Z_1, and Z_2 are zero. The antenna is described with the coordinates $X_1 = 0.000$ and $X_2 = 14.56$ m. The operating frequency is set to 25-MHz on another screen. When the NEC calculations are made and the patterns displayed, the azimuth (Fig. 17-5) and elevation (Fig. 17-6) patterns can be printed out.

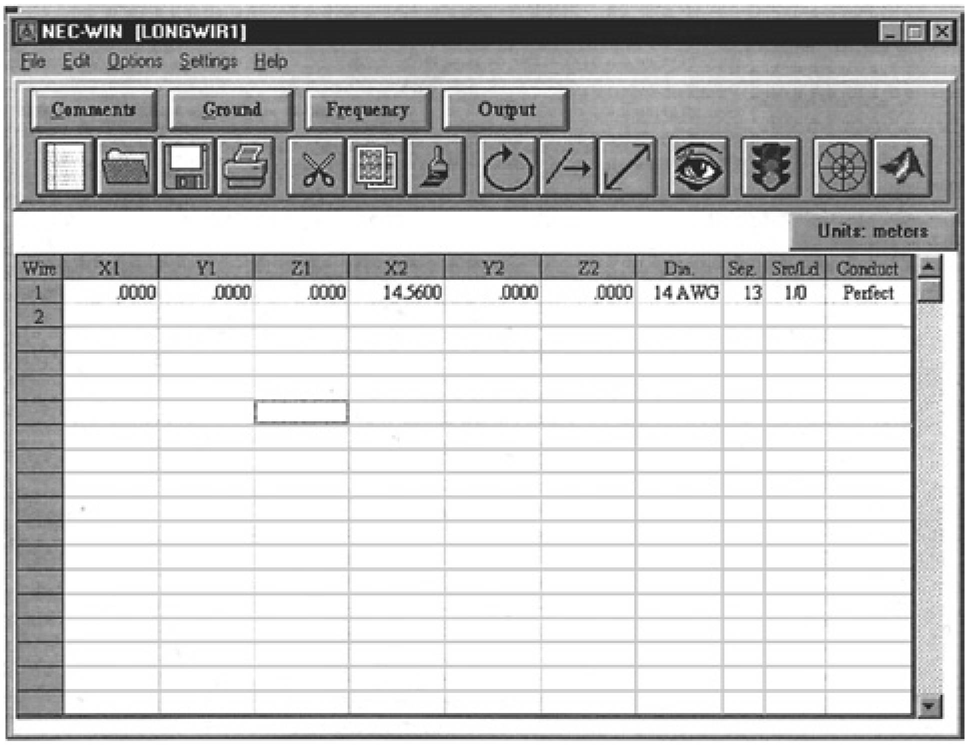
NEC-WIN [LONGWIR1]
File Edit Options Settings Help
Comments
Ground
Frequency
Output
Units: meters

Wire	X1	Y1	Z1	X2	Y2	Z2	Dia.	Seg.	Src/Ld	Conduct
1	.0000	.0000	.0000	14.5600	.0000	.0000	14 AWG	13	1/0	Perfect
2										

17-3 NecWin screen.

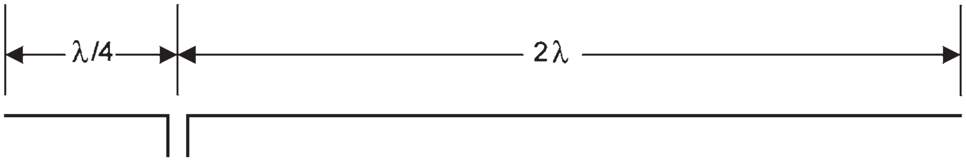

17-4 Off-center fed doublet antenna.

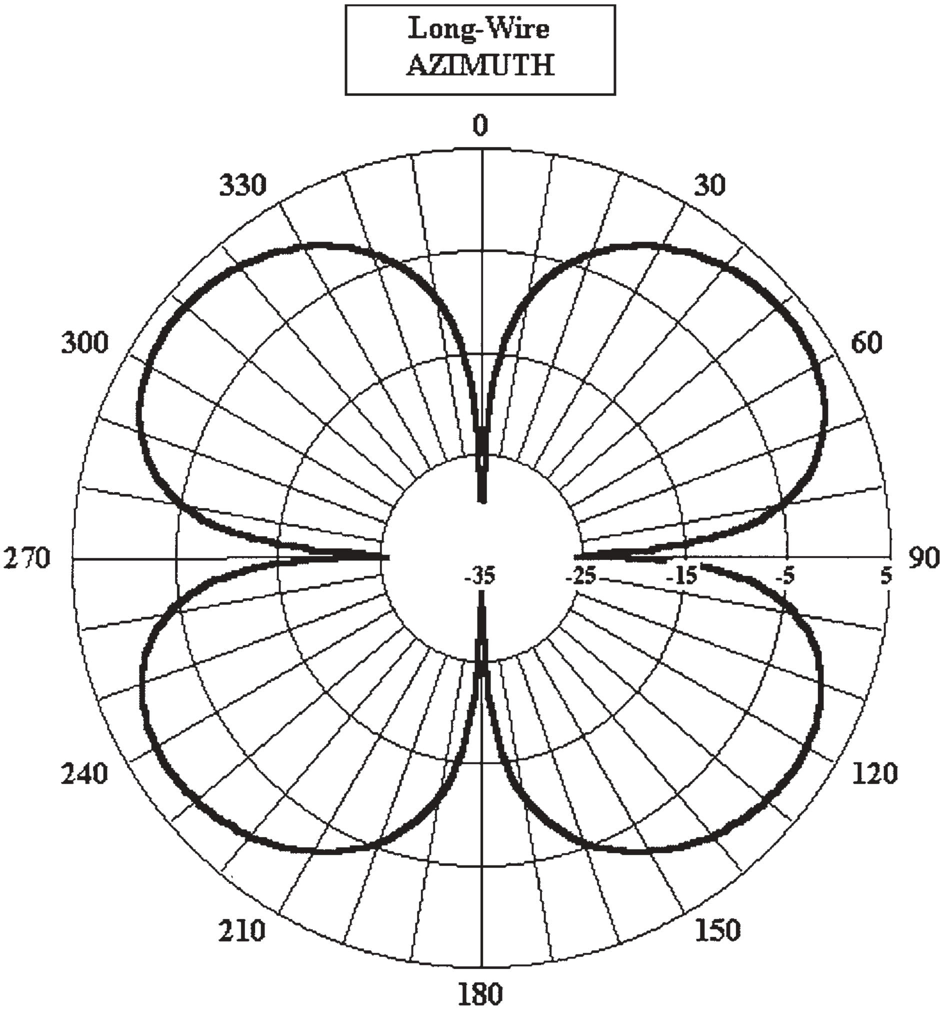

17-5 Modeled horizontal pattern.

NecWin Basic for Windows also will print out a data table of the frequency, wavelength, and VSWR. You can set the starting frequency, number of calculations, and step frequency.

If there is any criticism of the NecWin Basic for Windows program, it is that it does not graph the VSWR versus frequency curve. This is a little harder in Visual Basic 3.0 than in later versions, but users who also have Microsoft Excel on their computers can hand enter the numbers from the NecWin Basic for Windows output report and get a chart similar to Fig. 17-7.

The low price of NecWin Basic for Windows makes it useful to amateur radio operators, shortwave and scanner enthusiasts, and other amateur antenna builders. If

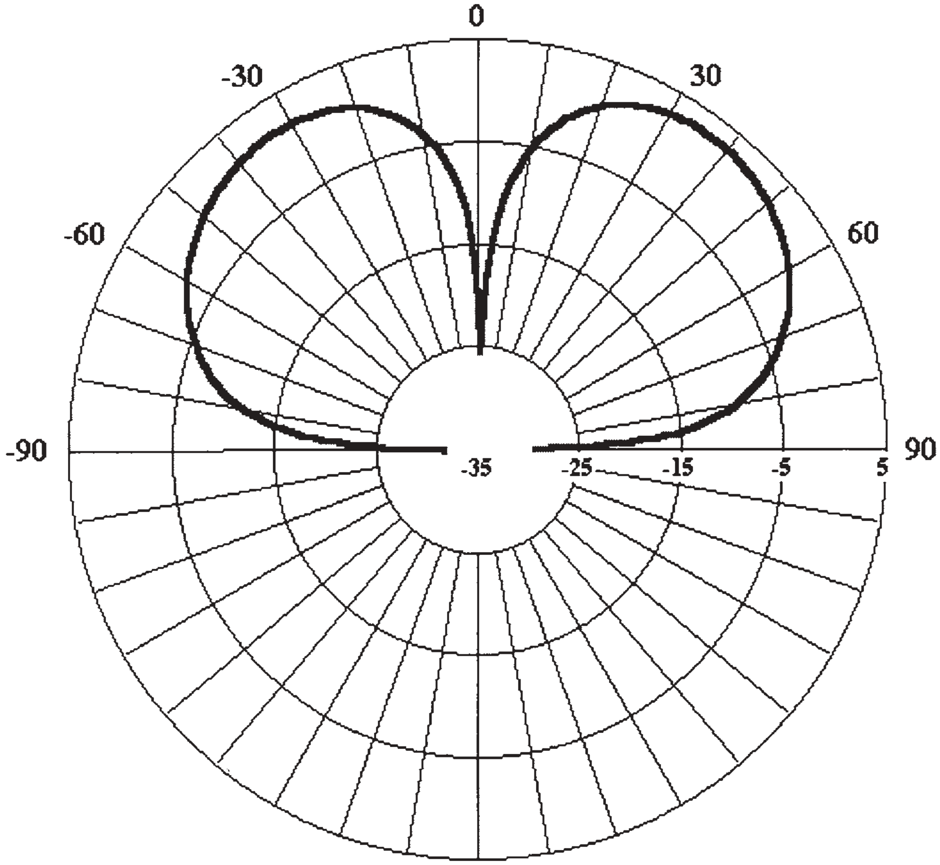

17-6 Modeled vertical pattern.

you are serious about antennas, then you need to obtain this software. It will perform well for many professional users, as well as student users in schools. However, professional users might want to consider buying the higher-priced NecWin Professional for Windows version.

EZNEC for Windows

Roy Lewallen, W7EL, produces the EZNEC for Windows software. The software extends Roy's earlier work on DOS versions of EZNEC but is still based on the NEC-2 engine (a NEC-4 professional version is available for those with the required license from the University of California).

Figure 17-8 shows the basic window that opens when you open an antenna project (in this case, a 10-MHz dipole). Given in the active window are file name, frequency, wavelength (in meters), number of wires and segments, number of sources, number of loads, transmission lines, ground type, wire loss, the units being calculated

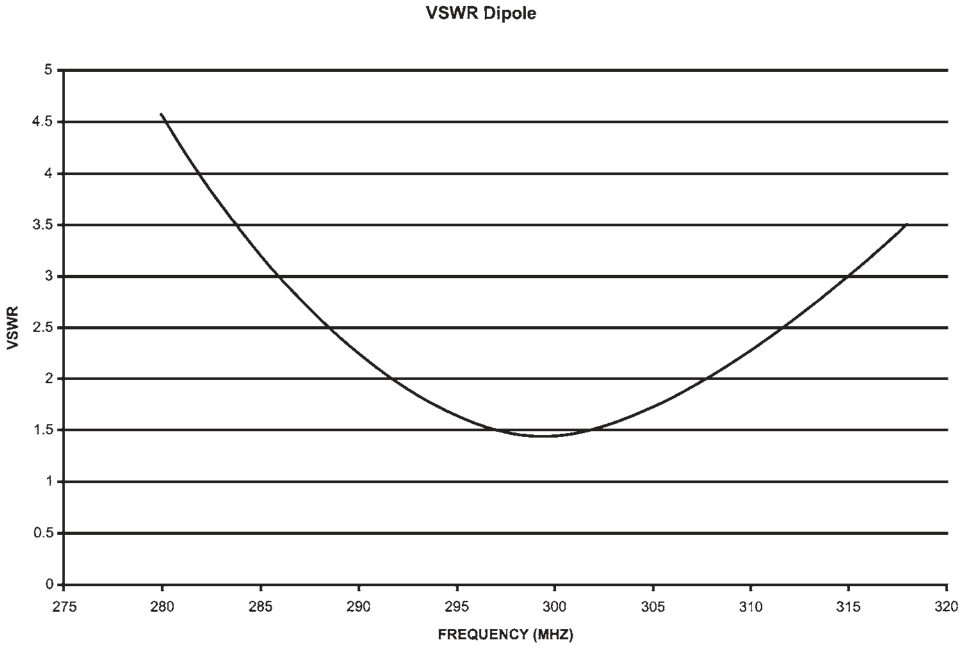

17-7 VSWR curve of the modeled antenna.

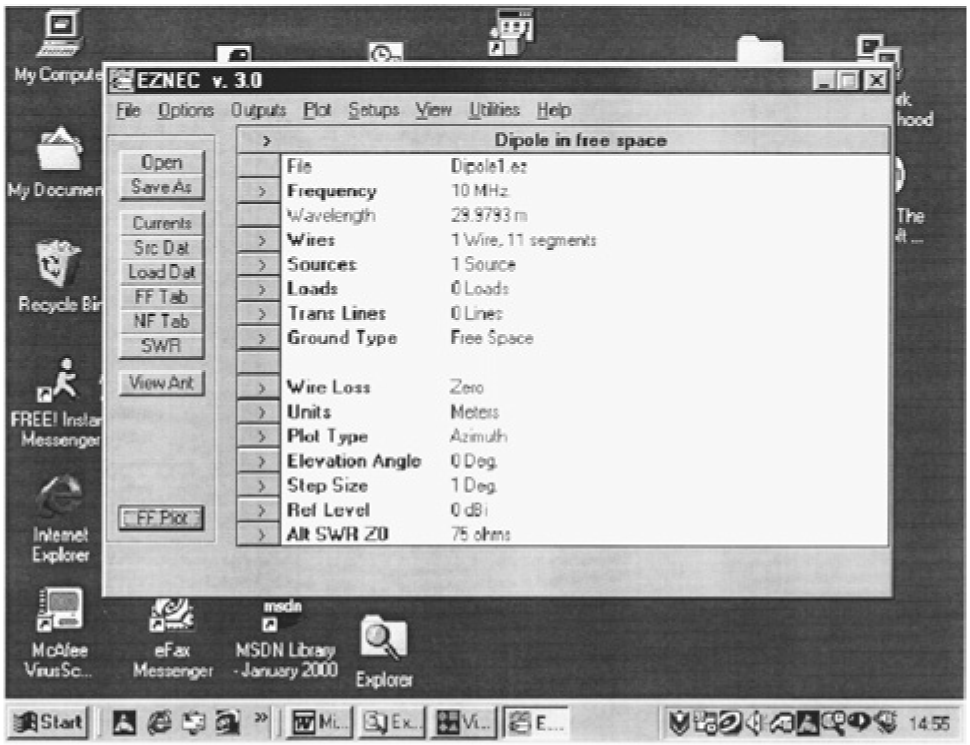
My Computer
My Documents
Recycle Bin
FREE! Instant Messenger
Internet Explorer
McAfee VirusSc...
eFax Messenger
MSDN Library - January 2000
Explorer
EZNEC v. 3.0
File
Options
Outputs
Plot
Setups
View
Utilities
Help
Open
Save As
Currents
Src Dat
Load Dat
FF Tab
NF Tab
SWR
View Ant
FF Plot
Start
14:55

Dipole in free space

File	Dipole1.ez
Frequency	10 MHz
Wavelength	29.9793 m
Wires	1 Wire, 11 segments
Sources	1 Source
Loads	0 Loads
Trans Lines	0 Lines
Ground Type	Free Space
Wire Loss	Zero
Units	Meters
Plot Type	Azimuth
Elevation Angle	0 Deg.
Step Size	1 Deg.
Ref Level	0 dBi
Alt SWR Z0	75 ohms

17-8 Basic window of EZNEC for Windows.

(meters, feet, etc.), plot type (azimuth, elevation), elevation angle, step size, a reference level, and an alternate SWR Z_o.

There are command buttons to the left of the main window. These include Open, Save As, Currents, Sto Dat, Load Dat, FF Tab, NF Tab, SWR, View Antenna, and FF Plot. The "View Antenna" button provides a view of the *xyz* coordinate system along with the wires (Fig. 17-9). The "FF Plot" button plots the far field of the antenna, and the "SWR" button plots the SWR curve based on parameters you give it (starting frequency, stopping frequency, frequency step).

The "View Antenna" window is shown in Fig. 17-9. This antenna view provides the *xyz* coordinate system, along with the wires. There are scroll bars to the left of the main window where the antenna appears that are used to vary the image to better see it. A series of three "Reset" buttons resets the image to the initial setting.

If you wish to plot the radiation pattern (azimuth or elevation) of the antenna, then press "FF Plot" in the main window. The result will be as shown in Fig. 17-10. Some data appears in the lower window on the plot. The data in this case are elevation angle, outer ring gain, slice gain maximum, front-to-side ratio, beamwidth, side-

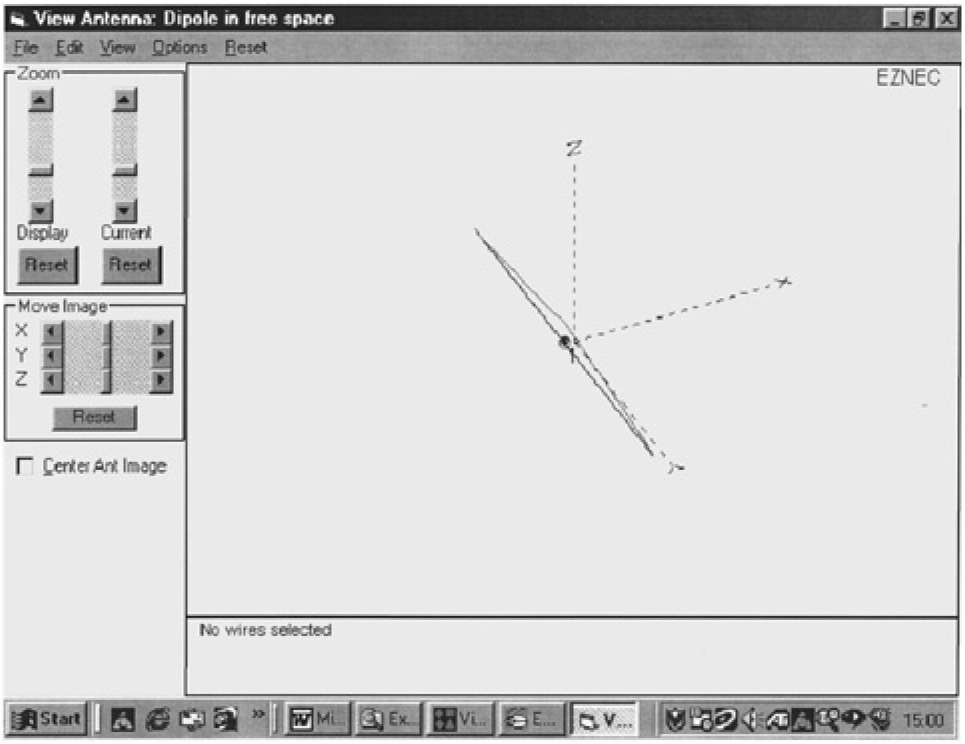
View Antenna: Dipole in free space
File Edit View Options Reset
Zoom
Display
Current
Reset
Reset
Move Image
X
Y
Z
Reset
Center Ant Image
EZNEC
Z
X
Y
Start
Mi...
Ex...
Vi...
E...
V...
15:00

No wires selected

17-9 View Antenna window of EZNEC for Windows.

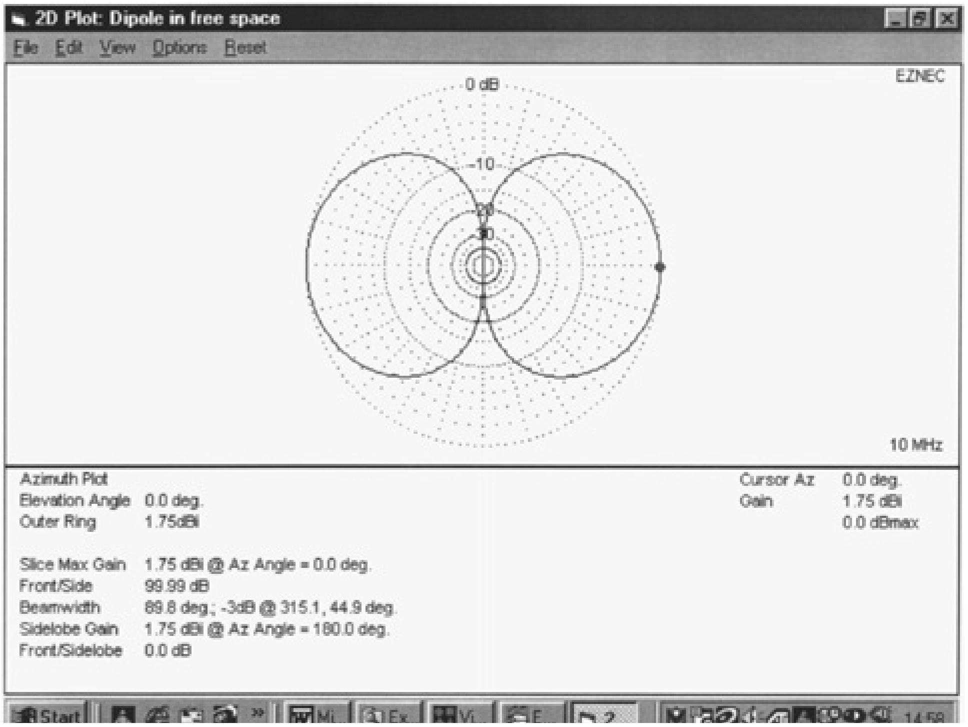

```
Azimuth Plot                                                     Cursor Az   0.0 deg.
Elevation Angle  0.0 deg.                                        Gain        1.75 dBi
Outer Ring       1.75dBi                                                     0.0 dBmax

Slice Max Gain   1.75 dBi @ Az Angle = 0.0 deg.
Front/Side       99.99 dB
Beamwidth        89.8 deg.; -3dB @ 315.1, 44.9 deg.
Sidelobe Gain    1.75 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe   0.0 dB
```

17-10 Result of pressing "FF Plot" button in main window of EZNEC for Windows.

lobe gain, front/sidelobe, cursor azimuth, and gain. You can print out the plot of the radiation pattern with either the data present or the data hidden.

One of the really nice things about EZNEC for Windows is the availability of VSWR plots without going to the professional edition. Figure 17-11 shows the plot for the dipole under consideration. Note that the data given include the starting frequency, the SWR at the starting frequency, the impedance at the starting frequency, the reflection coefficient at the starting frequency, and the source impedance.

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King, R. W. P., *Tables of Antenna Characteristics,* IFI/Plenum Data Corporation, New York, 1971.

Prasad, S., and R. W. P. King, "Experimental Study of L-, T- and Related Transmission Line Antennas," *Journal of Research of the National Bureau of Standards—D Radio Propagation,* Vol. 65D(5): 1961.

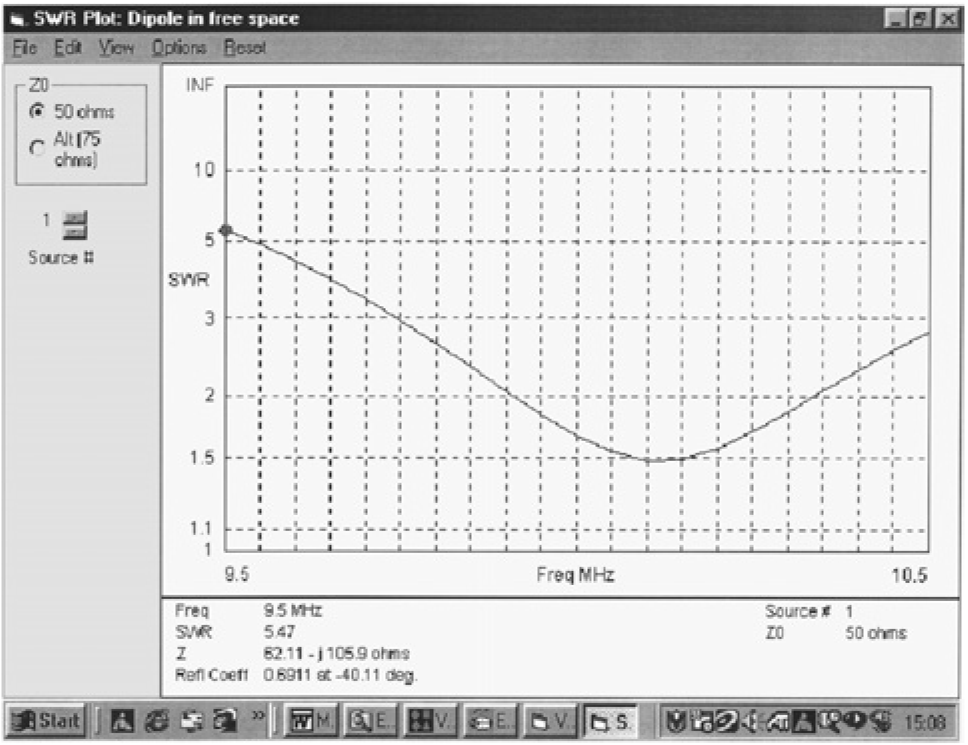
SWR Plot: Dipole in free space
File Edit View Options Reset
Z0
50 ohms
Alt (75 ohms)
1
Source #
INF
10
5
SWR
3
2
1.5
1.1
1
9.5
Freq MHz
10.5
Start
15:08

Z0: ● 50 ohms ○ Alt (75 ohms)

Freq 9.5 MHz
SWR 5.47
Z 62.11 - j 105.9 ohms
Refl Coeff 0.6911 at -40.11 deg.
Source # 1
Z0 50 ohms

17-11 VSWR plot of a dipole with EZNEC for Windows.

Rockway, J. W., and J. C. Logan, MiniNEC Professional for Windows, EM Scientific, Inc., Carson City, NV, 1995.

Rockway, J. W., and J. C. Logan, MiniNEC Broadcast Professional for Windows, EM Scientific, Inc., Carson City, NV, 1996.

Rockway, J. W., and J. C. Logan, "Advances in MiniNEC," *IEEE Antennas and Propagation Magazine,* 37(4): 1995.

18
CHAPTER

VHF/UHF transmitting and receiving antennas

THE VHF/UHF SPECTRUM IS COMMONLY ACCEPTED TO RANGE FROM 30 MHZ TO 900 MHZ, although the upper breakpoint is open to some differences of opinion. The VHF spectrum is 30 MHz to 300 MHz, and the UHF spectrum is 300 MHz to 900 MHz. Above 900 MHz is the microwave spectrum. These bands are used principally for local "line-of-sight" communications, according to the standard wisdom. However, with the advent of OSCAR satellites, the possibility of long-distance direct communications is a reality for VHF/UHF operators. In addition, packet radio is becoming common; this means indirect long-distance possibilities through networking. For the low end of the VHF spectrum (e.g., 6-m amateur band), long-distance communications are a relatively common occurrence.

In many respects, the low-VHF region is much like the 10-m amateur band and 11-m Citizens Band: skip is not an infrequent occurrence. Many years ago, I recall an event where such skip caused many a local police officer to skip a heart beat. In those days, our police department operated on 38.17 MHz, which is between the 6-m and 10-m amateur bands. They received an emergency broadcast concerning a bank robbery at a certain Wilson Boulevard address. After a race to the county line, they discovered that the reported address would be outside of the county, and in fact did not exist even in the neighboring county (a number was skipped). The problem was traced to a police department in a southwest city that also had a Wilson Boulevard, and for them the alarm was real.

The principal difference between the lower frequencies and the VHF/UHF spectrum is that the wavelengths are shorter in the VHF/UHF region. Consider the fact that the wavelengths for these bands range from 10 m to 1 m for the VHF region, and from 1 m to 33 cm for the UHF region. Most antenna designs are based on wavelength, so that fact has some implications for VHF/UHF antenna design. For example, because bandwidth is a function of length/diameter ratio for many classes of antenna, broadbanding an antenna in the VHF/UHF region is relatively easy. If, say, 25-mm (i.e., 1-in) aluminum tubing is used to make a quarter-wavelength vertical, then the approximate *L/D* ratio is 790 in the 8-m band and 20 in the 2-m band. This feature is fortunate, because the VHF/UHF bands tend to be wider than the HF bands.

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Another point to make is that many of the mechanical chores of antenna design and construction become easier for VHF/UHF antennas. One good example is the delta impedance-matching scheme. At 80 m, the delta-match dimensions are approximately 36 × 43 ft, and at 2 m they are 9.5 × 12 *inches.* Clearly, delta matching is a bit more practical for most users at VHF than at HF.

Types of antennas usable for VHF/UHF

The concept "VHF/UHF antenna" is only partially valid because virtually all forms of antenna can be used at HF, MW, and VHF/UHF. The main limitations that distinguish supposedly VHF/UHF designs from others are mechanical: there are some things that are simply much easier to accomplish with small antennas. Besides the delta match mentioned previously, there is the ease of construction for multielement antennas. A 14-element 20-m beam would be a wonderful thing to have in a QRM-laden DX pile-up, but is simply too impractical for all but a few users because of its size. If you look on embassy rooftops around the world you will see many-element Yagi and log periodic HF antennas supported on massive towers…and some of them use a standard Size 25 tower (common for amateur use) as the *antenna boom*! A 14-element 80/75-m Yagi approaches impossibility. But at 2 m, a 14-element Yagi beam antenna can be carried by one person, in one hand, unless the wind is acting up.

Safety note Large array beams, even at VHF/UHF, have a relatively high "windsail area," and even relatively modest winds can apply a lot of force to them. I once witnessed a large, strong technician blown off a ladder by wind acting on a modest, "suburban" sized, TV antenna. *It can happen to you, too. So always install antennas with a helper, and use hoists and other tools to actually handle the array.*

Lower band antennas on VHF/UHF

Between 1958 and 1962, a friend and I had access to a radio club amateur radio station in a Red Cross chapter house in Virginia. The "antenna farm" consisted of a 14-element 2-m beam, a three-element triband HF beam (10, 15, and 20 m), and a five-band (80 to 10 m) trap dipole. All of the coaxial cables came into the station through a wall; they were kept disconnected and shorted out when not in use because of the senior Red Cross official's concern over lightning.

One night, attempting to connect the 2-m beam to the Gonset "gooney box" 2-m AM transceiver, my friend accidentally used the cable from the five-band trap dipole instead. We worked a lot of stations that contest weekend, and scored lots of points. Later, we discovered the error, and asked a more technically competent adult (we were teenagers), "Why the good reports?" He then gave us a lesson in longwire antenna theory. A good longwire is many wavelengths long. Consider that a half-wave antenna on 2 m is 80 m/2 m or 40 wavelengths shorter than an 80-m half-wave antenna. Thus, the 80-m antenna, counting foreshortening of physical lengths because of the traps, was on the order of 35 to 38 wavelengths long on 2 m. We had a highly directional, but multilobed, pattern.

Similarly, 40- to 10-m and 80- to 10-m trap verticals are often usable on VHF/UHF frequencies without any adjustments. Similarly, Citizens Band 11-m antennas, many of which are $\frac{5}{8}$-wavelength (18 ft high), will sometimes work on VHF frequencies. Check the VSWR of an HF antenna on 2 m with a reliable VHF/UHF VSWR meter (or RF wattmeter) to discover the truth about any particular antenna. Always use the low-power setting on the transmitter to limit damage in cases where the specific antenna is not usable on a specific frequency.

The lesson to be learned is that antennas are often usable on frequencies much higher than the design frequency, even though useless on nearby bands. Care must be exercised when initially checking out the antenna, but that is not an inordinate difficulty.

VHF/UHF antenna impedance matching

The VHF/UHF antenna is no more or less immune from the need for impedance matching than lower-frequency antennas. However, some methods are easier (coax baluns, delta match, etc.) and others become either difficult or impossible. An example of the latter case is the tuned *LC* impedance-matching network. At 6 m, and even to some limited extent 2 m, inductor and capacitor *LC* networks can be used. But above 2 m other methods are more reasonable. We can, however, mimic the *LC* tuner by using stripline components, but that approach is not always suited to amateur needs.

The balun transformer makes an impedance transformation between *bal*anced and *un*balanced impedances. Although both 1:1 and 4:1 impedance ratios are possible, the 4:1 ratio is most commonly used for VHF/UHF antenna work. At lower frequencies it is easy to build broadband transformer baluns, but these become more of a problem at VHF and above.

For the VHF/UHF frequencies, a 4:1 impedance ratio coaxial balun (Fig. 18-1A) is normally used. Two sections of identical coaxial cable are needed. One section (*A*) has a convenient length to reach between the antenna and the transmitter. Its characteristic impedance is Z_o. The other section (*B*) is a half-wavelength long at the center of the frequency range of interest. The physical length is found from

$$L = \frac{5904\ V}{F_{\text{MHz}}} \qquad \textbf{[18.1]}$$

where

L is the cable length, in inches
F_{MHz} is the operating frequency, in megahertz
V is the velocity factor of the coaxial cable

The velocity factors of common coaxial cables are shown in the following table.

Coaxial cable velocity factors

Regular polyethylene	0.66
Polyethylene foam	0.80
Teflon	0.72

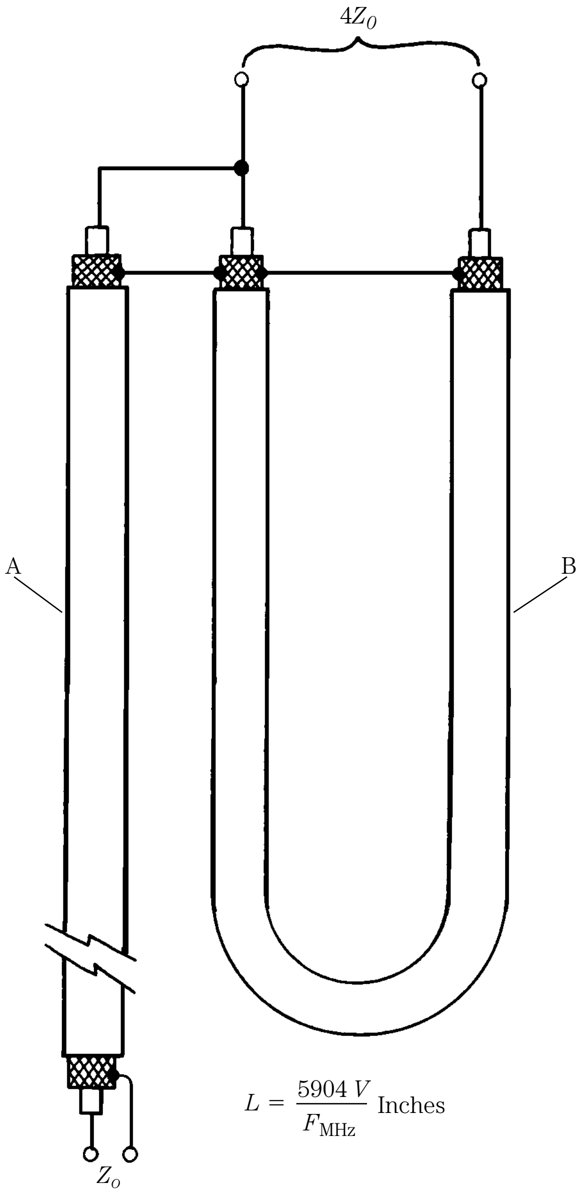
$4Z_0$
A
B
$L = \frac{5904\,V}{F_{\text{MHz}}}$ Inches
Z_o

18-1A Coaxial 4:1 balun transformer.

Example 18-1 Calculate the physical length required of a 146-MHz 4:1 balun made of polyethylene foam coaxial cable.

Solution:

$$L = \frac{5904\,V}{F_{\text{MHz}}}$$

$$= \frac{(5904)\ (0.80)}{146\text{ MHz}}$$

$$= \frac{4723.2}{146\text{ MHz}} = 32.4\text{ in}$$

A mechanical method of joining the coaxial cables is shown in Fig. 18-1B. In this example, three SO-239 coaxial receptacles are mounted on a metal plate. This arrangement has the effect of shorting together the shields of the three ends of coaxial cable. The center conductors are connected in the manner shown. This method is used especially where a mounting bracket is available on the antenna. The lengths of coaxial cable need PL-259 coax connectors installed in order to use this method.

The "delta match" gets its name from the fact that the structure of the matching element has the shape of the Greek letter delta, or a triangle. Figure 18-2A shows the basic delta match scheme. The matching element is attached to the driven element of the antenna (symmetrically, about the center point of the antenna). The width (A) of the delta match is given by

$$L = \frac{1416}{F_{\text{MHz}}}\text{ in} \qquad \textbf{[18.2]}$$

While the height of the match (B) is

$$L = \frac{1776}{F_{\text{MHz}}}\text{ in} \qquad \textbf{[18.3]}$$

The transmission line feeding the delta match is balanced line, such as parallel transmission line or twin lead. The exact impedance is not terribly critical because the dimensions (especially A) can be adjusted to accommodate differences. In general, however, either 450- or 600-Ω line is used, although 300-Ω line can also be used. Figure 18-2B

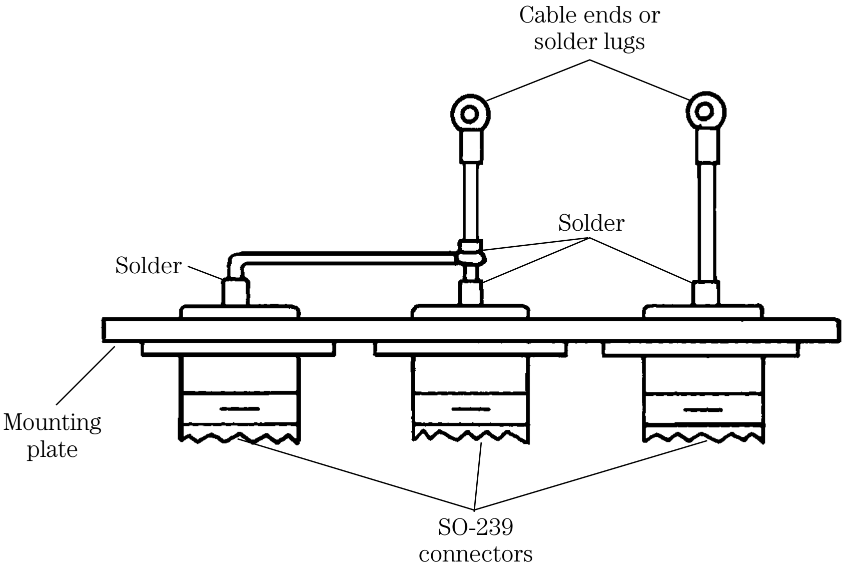

18-1B Practical implementation of 4:1 balun using connectors.

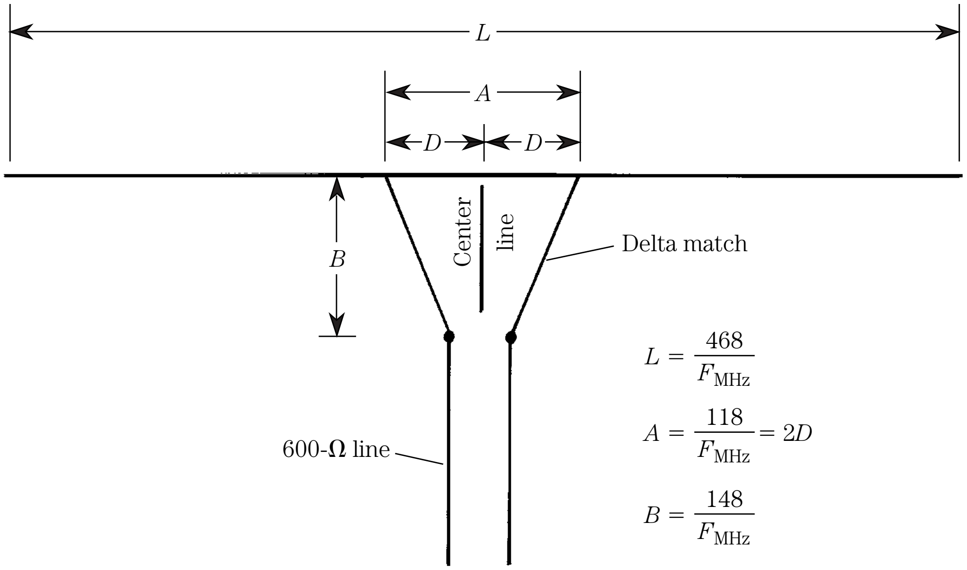
L
A
D
D
B
Center line
Delta match
600-Ω line
$L = \frac{468}{F_{\mathrm{MHz}}}$
$A = \frac{118}{F_{\mathrm{MHz}}} = 2D$
$B = \frac{148}{F_{\mathrm{MHz}}}$

18-2A Delta feed matching system.

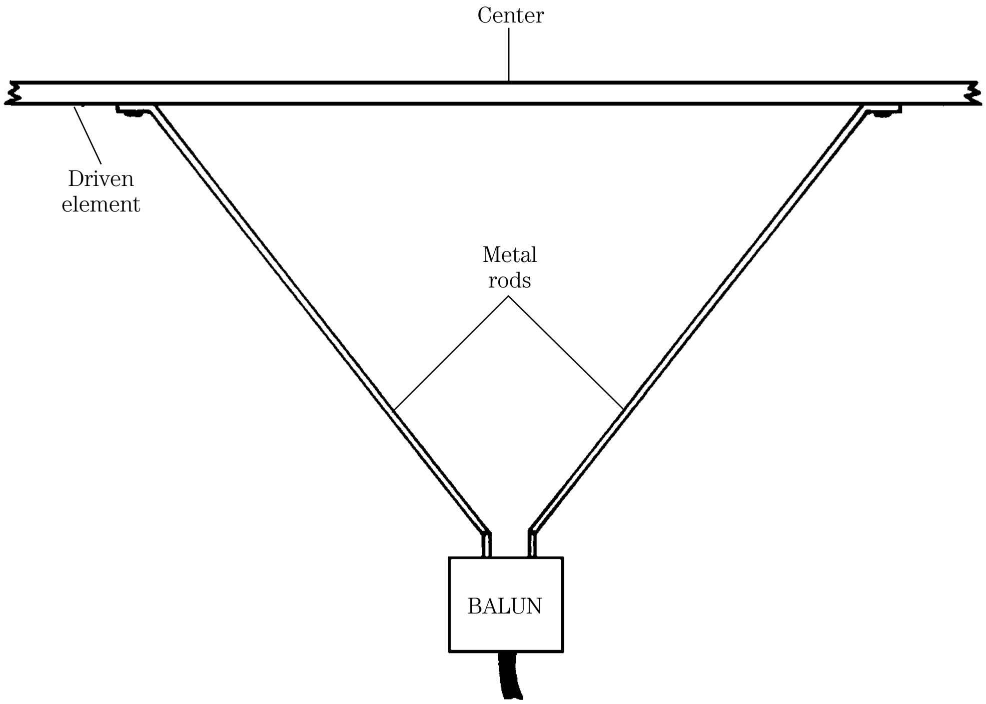
Center
Driven element
Metal rods
BALUN

18-2B Practical VHF delta match.

shows a method for using coaxial cable with the delta match. The impedance is transformed in a 4:1 balun transformer (see Fig. 18-1A). The elements of the delta match can be made from brass, copper, or aluminum tubing, or a bronze brazing rod bolted to the main radiator element.

A stub-matching system is shown in Fig. 18-3. In this case, the impedance transformation is accomplished despite the half-wavelength shorted stub of transmission line. The exact impedance of the line is not very critical, and is found from

$$Z_o = 276 \log_{10} \frac{2S}{d} \qquad \textbf{[18.4]}$$

The matching stub section is made from metal elements such as tubing, wire, or rods (all three are practical at VHF/UHF frequencies). For a $\frac{3}{16}$-in rod, the spacing is approximately 2.56 in to make a 450-Ω transmission line. A sliding short circuit is used to set the electrical length of the half-wave stub. The stub is tapped at a distance

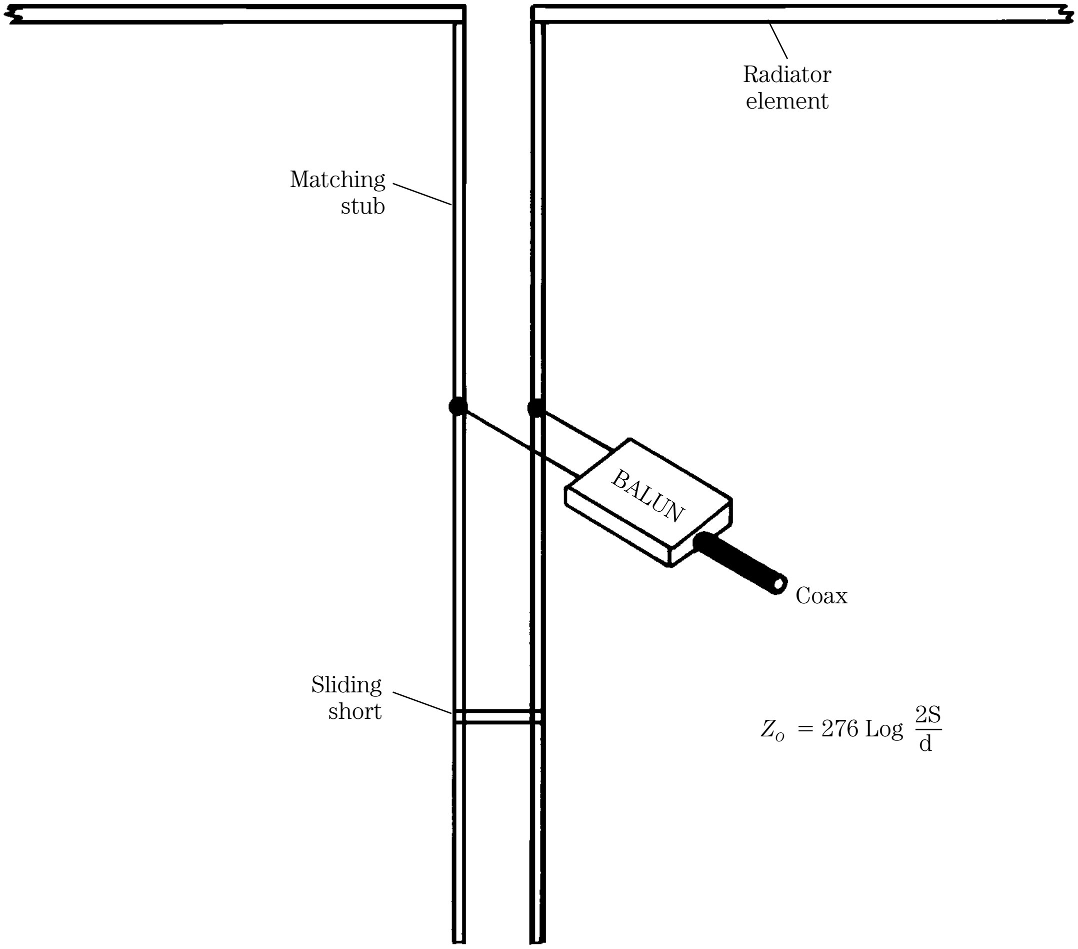

18-3 Stub matching.

from the antenna feedpoint that matches the impedance of the transmission line. In the example shown, the transmission line is coaxial cable, so a 4:1 balun transformer is used between the stub and the transmission line. The two adjustments to make in this system are: (1) the distance of the short from the feedpoint and (2) the distance of the transmission line tap point from the feedpoint. Both are adjusted for minimum VSWR.

The gamma match is basically a half delta match, and operates according to similar principles (Fig. 18-4). The shield (outer conductor) of the coaxial cable is connected to the center point of the radiator element. The center conductor of the coaxial cable series feeds the gamma element through a variable capacitor.

VHF/UHF antenna examples

Although it is probably not necessary to reiterate the point, VHF/UHF antennas are not substantially different from HF antennas, especially those for the higher bands. However, for various practical reasons there are several forms that are specially suited, or at least popular, in the VHF/UHF bands. In this section we will take a look at some of them.

Coaxial vertical

The coaxial vertical is a quarter-wavelength vertically polarized antenna that is popular on VHF/UHF. There are two varieties. In Fig. 18-5A we see the coaxial antenna made with coaxial cable. Although not terribly practical for long-term installation, the coax-coax antenna is very useful for short-term, portable, or emergency applications. For example, a boater found himself adrift, and in dire trouble, after a storm damaged the boat. The mast-top VHF antenna was washed away, leaving only the end of the coaxial cable dangling loose. Fortunately, the boat operator was a two-way radio technician, and he knew how to strip back the coaxial cable to make an impromptu coaxial vertical.

The coax-coax antenna shown in Fig. 18-5A uses a quarter-wavelength radiator and a quarter-wavelength sleeve. The sleeve consists of the coax braid stripped back and folded down the length of the coax cable. The maximum length is found from the equation below (actual length is trimmed from this maximum):

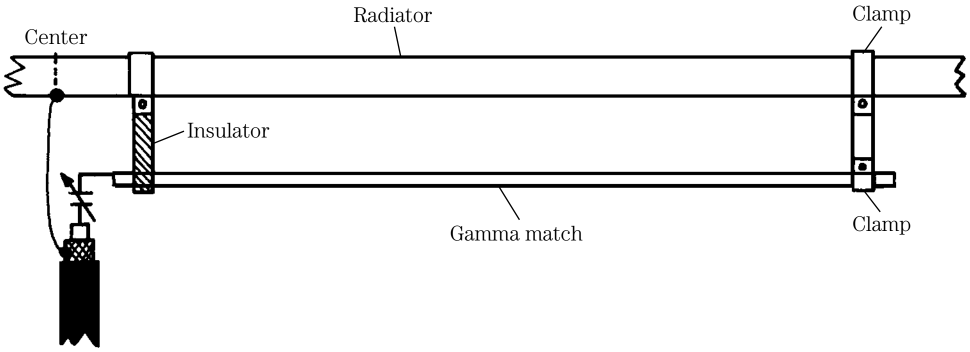

18-4 Gamma matching.

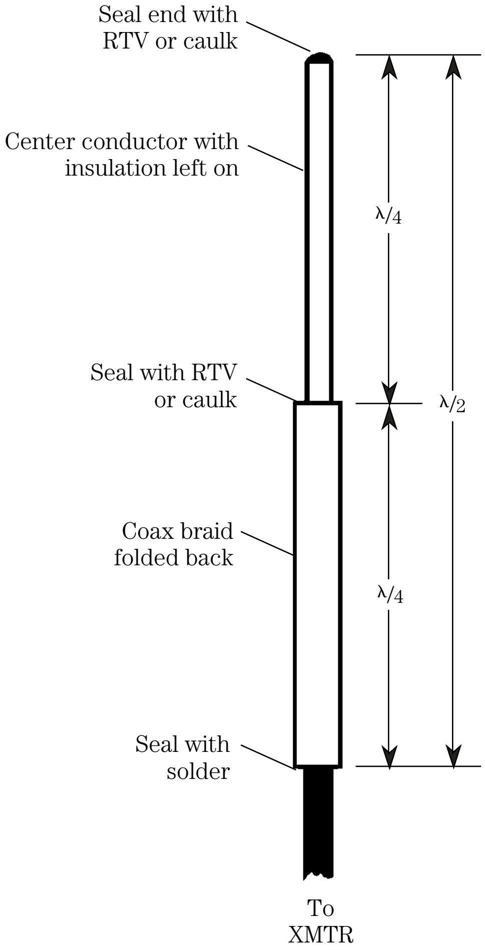
Seal end with RTV or caulk
Center conductor with insulation left on
Seal with RTV or caulk
Coax braid folded back
Seal with solder
To XMTR
λ/4
λ/2
λ/4

18-5A Coaxial vertical based on coaxial cable.

$$L = \frac{2952\ V}{F_{\text{MHz}}}\ \text{in} \qquad \textbf{[18.5]}$$

The antenna is mounted by suspending it from above by a short piece of string, twine, or fishing line. From a practical point of view, the only problem with this form of antenna is that it tends to deteriorate after a few rainstorms. This effect can be reduced by sealing the end, and the break between the sleeve and the radiator, with either silicone *RTV* or bathtub caulk.

A more permanent method of construction is shown in Fig. 18-5B. The sleeve is a piece of copper or brass tubing (pipe) about 1 in in diameter. An end cap is fitted over the end and sweat-soldered into place. The solder is not intended to add mechanical strength, but rather to prevent weathering from destroying the electrical contact between the two pieces. An SO-239 coaxial connector is mounted on the end cap. The coax is connected to the SO-239 inside the pipe, which means making the connection before mounting the end cap.

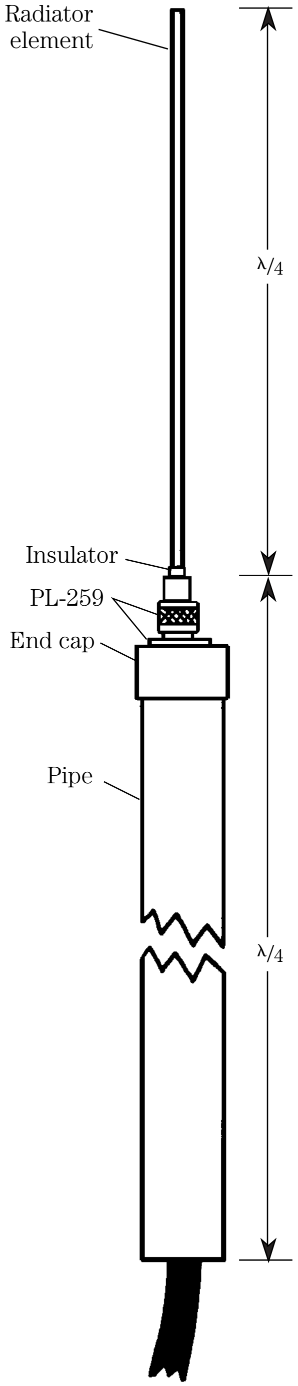
Radiator element
Insulator
PL-259
End cap
Pipe
λ/4
λ/4

18-5B Tubing coaxial vertical.

The radiator element is a small piece of tubing (or brazing rod) soldered to the center conductor of a PL-259 coaxial connector. An insulator is used to prevent the rod from shorting to the outer shell of the PL-259. (Note: an insulator salvaged from the smaller variety of banana plug can be shaved a small amount with a fine file and made to fit inside the PL-259. It allows enough center clearance for $\frac{1}{8}$-inch or $\frac{3}{16}$-inch brass tubing.)

Alternatively, the radiator element can be soldered to a banana plug. The normal-size banana plug happens to fit into the female center conductor of the SO-239.

Collinear vertical

Gain in antennas is provided by *directivity.* In other words, by taking the power radiated by the antenna, and projecting it into a limited direction, we obtain the appearance of higher radiated power. In fact, the *effective radiated power* (ERP) of the antenna is merely its feedpoint power multiplied by its gain. Although most antenna patterns are shown in the horizontal dimension (as viewed from above), it is also possible to obtain gain by compressing the vertical aspect. In this manner it is possible to have a vertical antenna that produces gain. Figure 18-6 shows a collinear gain antenna, with vertical polarization and a horizontally omnidirectional pattern. Incidentally, when mounted horizontally the pattern becomes bidirectional.

The collinear antenna shown in Fig. 18-6 is basically a pair of stacked collinear arrays. Each array consists of a quarter-wavelength section *A* and a half-wavelength section *C* separated by a quarter-wavelength phase reversing stub *B.* The phase reversal stub preserves in-phase excitation for the outer element (referenced to the inner element).

The feedpoint is between the two elements of the array (i.e., between the *A* sections). The coaxial-cable impedance is transformed by a 4:1 balun transformer (see Fig. 18-1A). Alternatively, 300-Ω twin lead can be used for the transmission line. If this alternative is used, then the use of UHF shielded twin lead is highly recommended. If the transmitter lacks the balanced output needed to feed twin lead, then use a balun at the input end of the twin lead (i.e., right at the transmitter).

Yagi antennas

The Yagi beam antenna is a highly directional gain antenna, and is used both in HF and VHF/UHF systems. The antenna is relatively easy to build at VHF/UHF. In fact, it is easier than for HF systems. The basic Yagi was covered in Chap. 12, so we will only show examples of practical VHF devices. A 6-m Yagi antenna is shown in Fig. 18-7. This particular antenna is a four-element model. The reflector and directors can be mounted directly to a metallic boom, because they are merely parasitic. The driven element, however, must be insulated from the metal boom.

The driven element shown in Fig. 18-7 is a folded dipole. While this is common practice at VHF, because it tends to broadband the antenna, it is not strictly necessary. The dimensions of the driven element are found from Eq. 18.4. Set the equation equal to 300 Ω, select the diameter of the tubing from commercially available sources, and then calculate the spacing.

Example 18-2 Calculate the spacing of a 300-Ω folded dipole when $\frac{3}{4}$-in tubing is used in its construction.

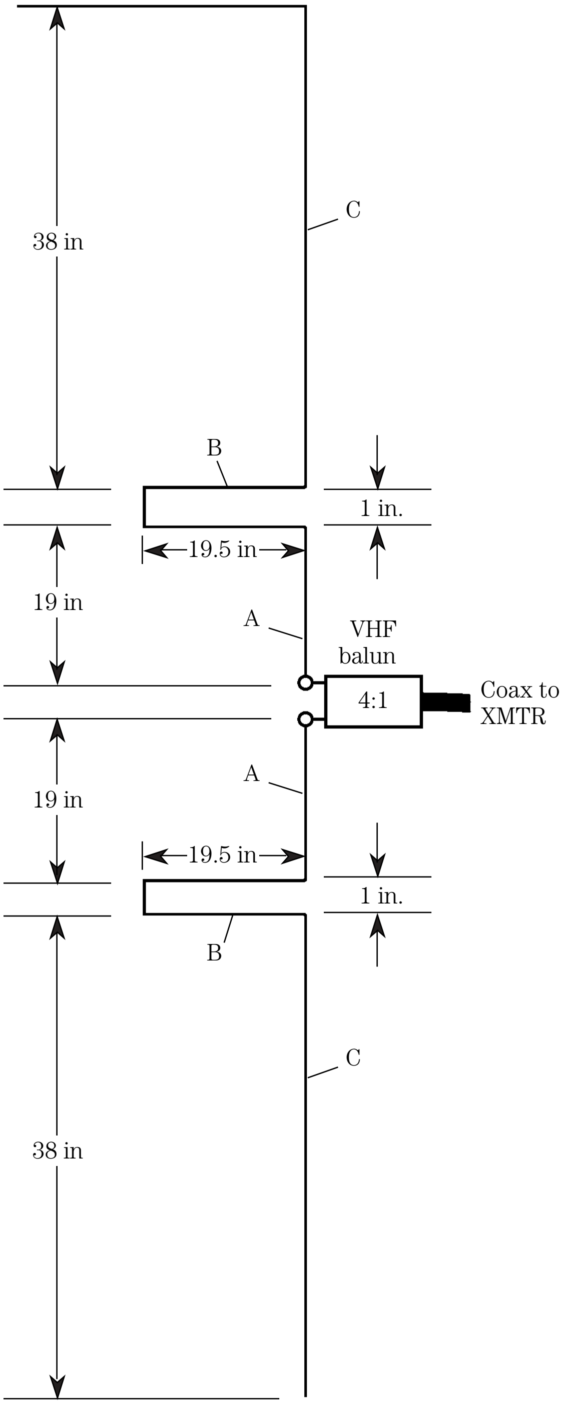
C
38 in
B
1 in.
19.5 in
19 in
A
VHF balun
4:1
Coax to XMTR
A
19 in
19.5 in
1 in.
B
C
38 in

18-6 Vertical collinear antenna.

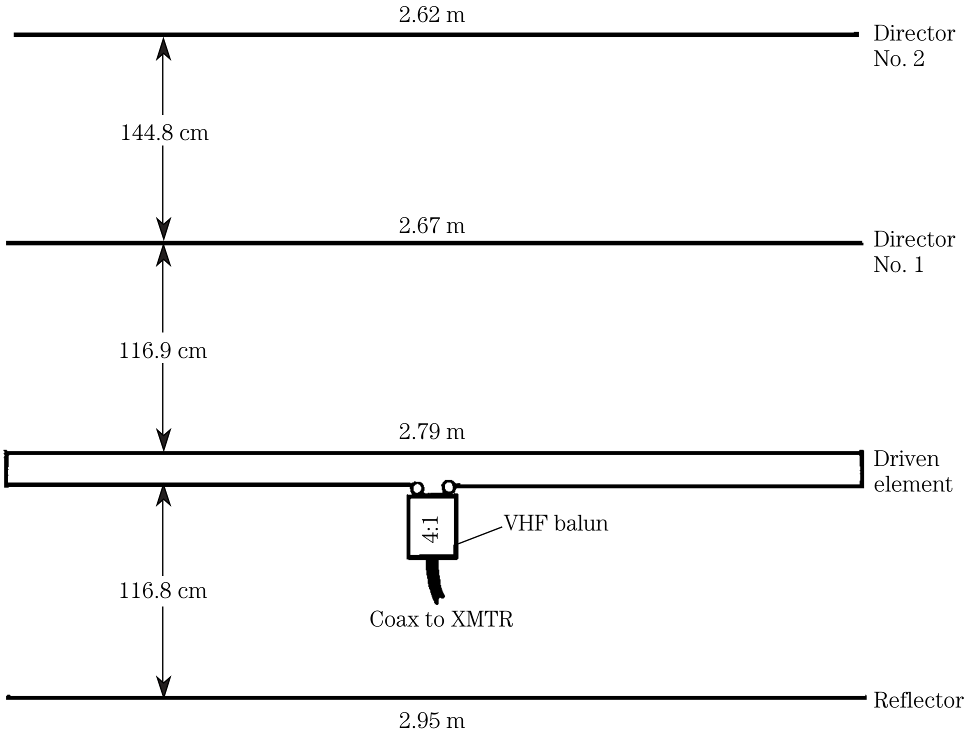
2.62 m
Director No. 2
144.8 cm
2.67 m
Director No. 1
116.9 cm
2.79 m
Driven element
4:1
VHF balun
116.8 cm
Coax to XMTR
Reflector
2.95 m

18-7 Six-meter beam antenna.

Solution:

$$Z_o = 276 \log_{10} \frac{2S}{d}$$

$$300\ \Omega = 276 \log_{10} \frac{2S}{d}$$

$$\frac{300}{276} = \log_{10} \frac{2S}{d}$$

$$1.08 = \log_{10} \frac{2S}{d}$$

$$10^{1.08} = \frac{2S}{d}$$

Using 0.75-in pipe results in

$$10^{1.08} = \frac{2S}{0.75}$$

$$12.02 = 2.67S$$

so

$$S = 4.5 \text{ in}$$

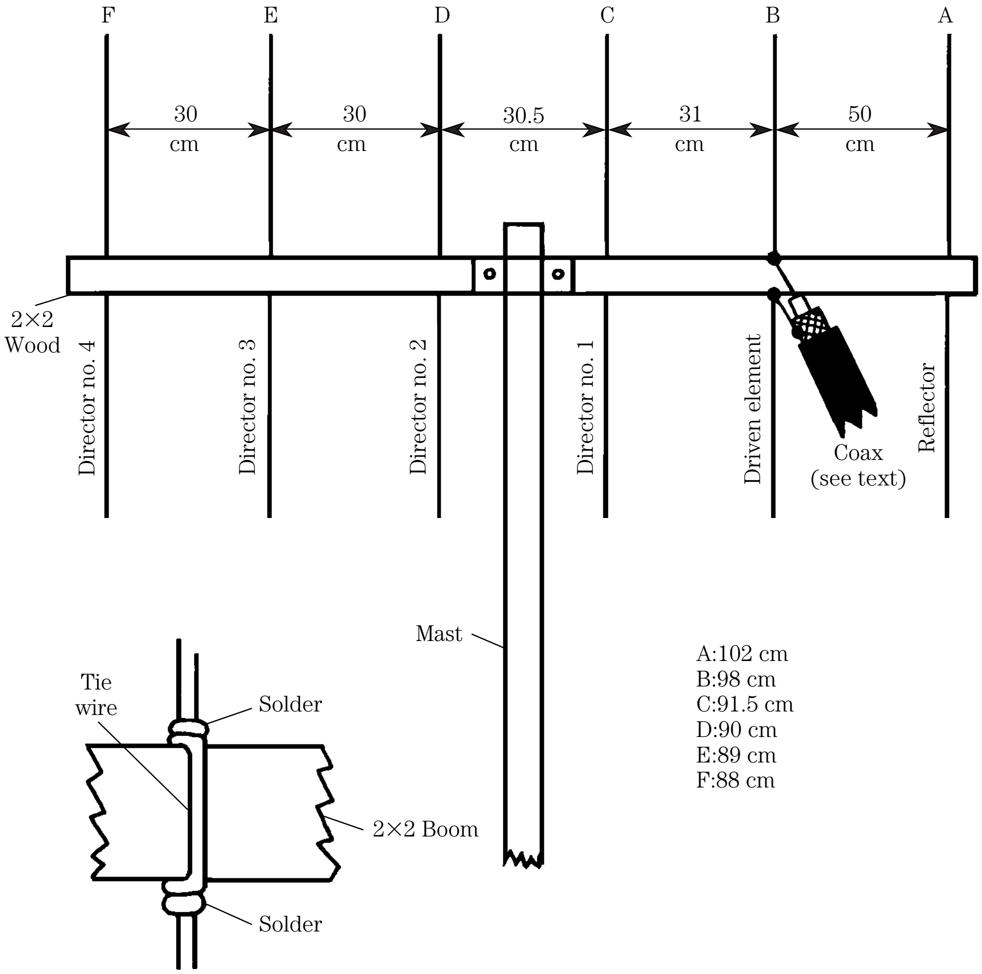
F
E
D
C
B
A
30 cm
30 cm
30.5 cm
31 cm
50 cm
2×2 Wood
Director no. 4
Director no. 3
Director no. 2
Director no. 1
Driven element
Coax (see text)
Reflector
Mast
A:102 cm
B:98 cm
C:91.5 cm
D:90 cm
E:89 cm
F:88 cm
Tie wire
Solder
2×2 Boom
Solder

18-8 Two-meter vertical beam.

Two-meter yagi

Figure 18-8 shows the construction details for a six-element 2-meter Yagi beam antenna. This antenna is built using a 2 × 2-in wooden boom and elements made of either brass or copper rod. Threaded brass rod is particularly useful, but not strictly necessary. The job of securing the elements (other than the driven element) is easier when threaded rod is used, because it allows a pair of hex nuts, one on either side of the 2 × 2-in boom, to be used to secure the element. Nonthreaded elements can be secured with RTV sealing a press-fit. Alternatively, tie wires (see inset to Fig. 18-8) can be used to secure the rods. A hole is drilled through the 2 × 2 to admit the rod or tubing. The element is secured by wrapping a tie wire around the rod on either side of the 2 × 2, and then soldering it in place. The tie wire is no. 14 to no. 10 solid wire.

Mounting of the antenna is accomplished by using a mast secured to the boom with an appropriate clamp. One alternative is to use an end-flange clamp, such as is sometimes used to support pole lamps, etc. The mast should be attached to the boom at the center of gravity, which is also known as the *balance point.* If you try to balance the antenna in one hand unsupported, there is one (and only one) point at which it is balanced (and won't fall). Attach the mast hardware at, or near, this point in order to prevent normal gravitational torques from tearing the mounting apart.

The antenna is fed with coaxial cable at the center of the driven element. Ordinarily, either a matching section of coax, or a gamma match, will be needed because the effect of parasitic elements on the driven element feedpoint impedance is to reduce it.

$\frac{5}{8}$-wavelength 2-m antenna

The $\frac{5}{8}$-wavelength antenna (Fig. 18-9) is popular on 2 m for mobile operation because it is easy to construct, and it provides a small amount of gain relative to a dipole. The radiator element is $\frac{5}{8}$-wavelength, so its physical length is found from:

$$L = \frac{7380}{F_{\text{MHz}}} \text{ in} \qquad \textbf{[18.6]}$$

The $\frac{5}{8}$-wavelength antenna is not a good match to any of the common forms of coaxial cables. Either a matching section of cable, or an inductor match, is normally used. In Fig. 18-9 an inductor match is used. The matching coil consists of 2 to 3 turns of no. 12 wire, wound over a $\frac{1}{2}$-in OD form, $\frac{1}{2}$-in long. The radiator element can be tubing, brazing rod, or a length of heavy "piano wire." Alternatively, for low-power systems, it can be a telescoping antenna that is bought as a replacement for portable radios or televisions. These antennas have the advantage of being adjustable to resonance without the need for cutting.

J-pole antennas

The *J-pole antenna* is another popular form of vertical on the VHF bands. It can be used at almost any frequency, although the example shown in Fig. 18-10 is for 2 m. The antenna radiator is $\frac{3}{4}$-wavelength long, so its dimension is found from

$$L = \frac{8838}{F_{\text{MHz}}} \text{ in} \qquad \textbf{[18.7]}$$

and the quarter-wavelength matching section length from

$$L = \frac{2952}{F_{\text{MHz}}} \text{ in} \qquad \textbf{[18.8]}$$

Taken together the matching section and the radiator form a parallel transmission line with a characteristic impedance that is 4 times the coaxial cable impedance. If 50-Ω coax is used, and the elements are made from 0.5 in OD pipe, then a spacing of 1.5 in will yield an impedance of about 200 Ω. Impedance matching is accomplished by a gamma match consisting of a 25-pF variable capacitor, connected by a clamp to the radiator, about 6 in (experiment with placement) above the base.

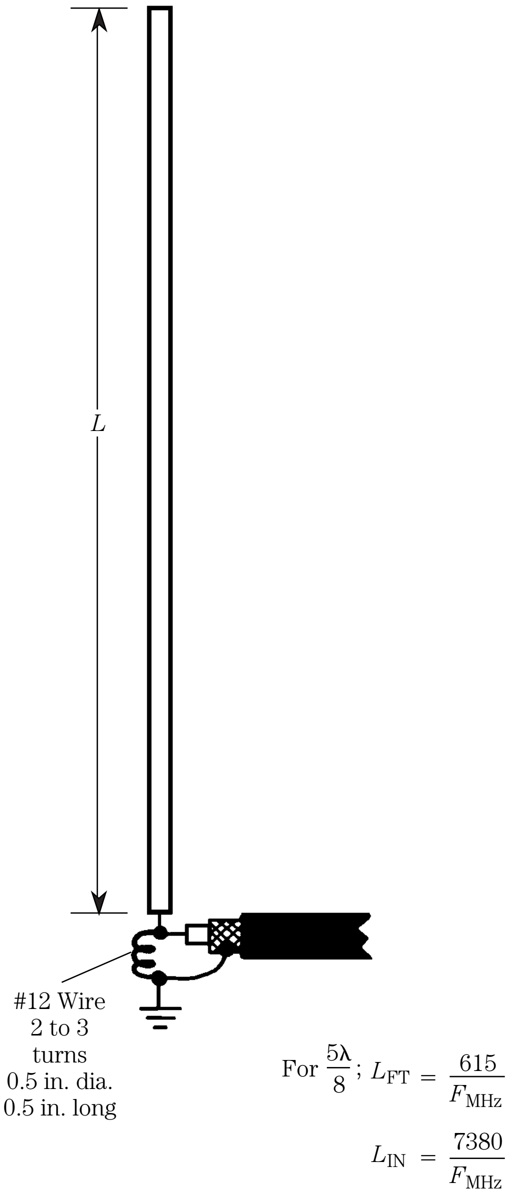
L
#12 Wire
2 to 3
turns
0.5 in. dia.
0.5 in. long
For $\frac{5\lambda}{8}$; $L_{FT} = \frac{615}{F_{MHz}}$
$L_{IN} = \frac{7380}{F_{MHz}}$

18-9 ⅝-wavelength 2-m antenna.

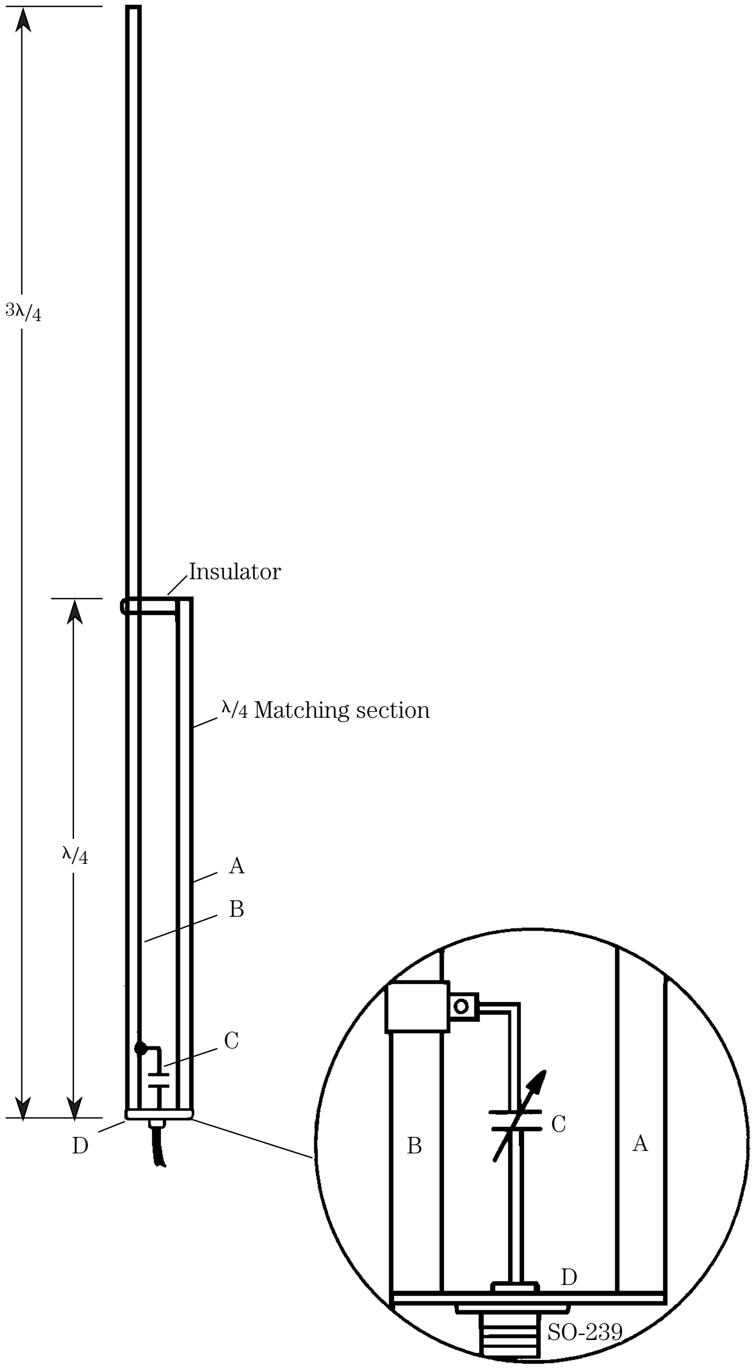
3λ/4
Insulator
λ/4 Matching section
λ/4
A
B
C
D
B
C
A
D
SO-239

18-10 J-pole antenna.

Groundplane

The *groundplane antenna* is a vertical radiator situated above an artificial RF ground consisting of quarter-wavelength radiators. Groundplane antennas can be either $\frac{1}{4}$-wavelength or $\frac{5}{8}$-wavelength (although for the latter case impedance matching is needed—see the previous example).

Figure 18-11 shows how to construct an extremely simple groundplane antenna for 2 m and above. The construction is too lightweight for 6-m antennas (in general), because the element lengths on 6-m antennas are long enough to make their weight too great for this type of construction. The base of the antenna is a single SO-239 chassis-type coaxial connector. Be sure to use the type that requires four small machine screws to hold it to the chassis, and not the single-nut variety.

The radiator element is a piece of $\frac{3}{16}$-in or 4-mm brass tubing. This tubing can be bought at hobby stores that sell airplanes and other models. The sizes quoted just happen to fit over the center pin of an SO-239 with only a slight tap from a lightweight hammer—and I do mean *slight* tap. If the inside of the tubing and the connector pin are pretinned with solder, then sweat soldering the joint will make a good electrical connection that is resistant to weathering. Cover the joint with clear lacquer spray for added protection.

The radials are also made of tubing. Alternatively, rods can also be used for this purpose. At least four radials are needed for a proper antenna (only one is shown in Fig. 18-11). This number is optimum because they are attached to the SO-239 mounting holes, and there are only four holes. Flatten one end of the radial, and drill a small hole in the center of the flattened area. Mount the radial to the SO-239 using small hardware (4-40, etc.).

The SO-239 can be attached to a metal L bracket. While it is easy to fabricate such a bracket, it is also possible to buy suitable brackets in any well-equipped hardware store. While shopping at one do-it-yourself type of store, I found several reasonable candidate brackets. The bracket is attached to a length of 2 × 2-in lumber that serves as the mast.

Halo antennas

One of the more saintly antennas used on the VHF boards is the halo (Fig. 18-12). This antenna basically takes a half-wavelength dipole and bends it into a circle. The ends of the dipole are separated by a capacitor. In some cases, a transmitting-type mica "button" capacitor is used, but in others (and perhaps more commonly), the halo capacitor consists of two 3-in disks separated by a plastic dielectric. While air also serves as a good (and perhaps better) dielectric, the use of plastic allows mechanical rigidity to the system.

Quad beam antennas

The quad antenna was introduced in the chapter on beams. It is, nonetheless, also emerging as a very good VHF/UHF antenna. It should go without saying that the antenna is a lot easier to construct at VHF/UHF frequencies than it is at HF frequencies! Figure 18-13 shows a modest example.

There are several methods for building the quad antenna, and Fig. 18-13 represents only one of them. The radiator element can be any of several materials,

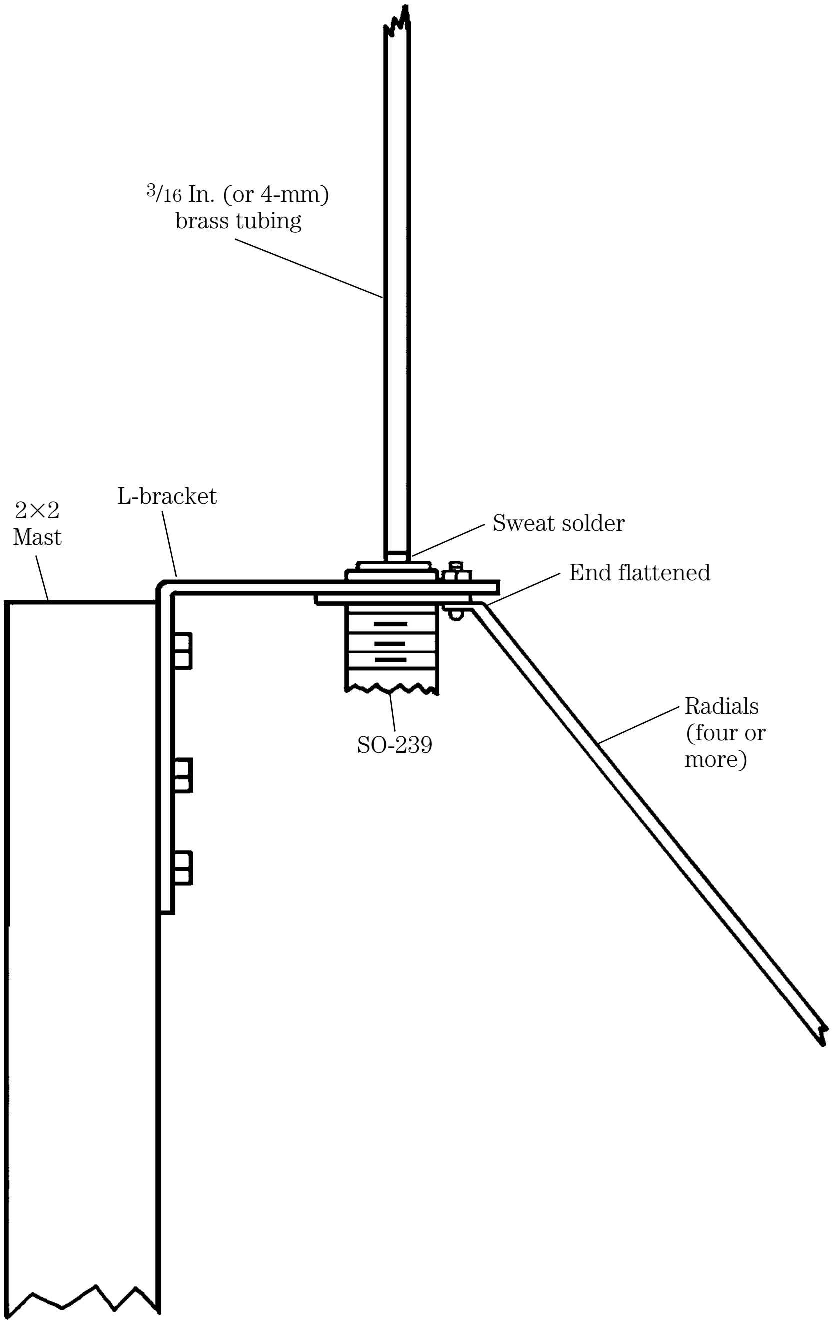
3/16 In. (or 4-mm)
brass tubing
L-bracket
2×2
Mast
Sweat solder
End flattened
SO-239
Radials
(four or
more)

18-11 Small VHF groundplane construction.

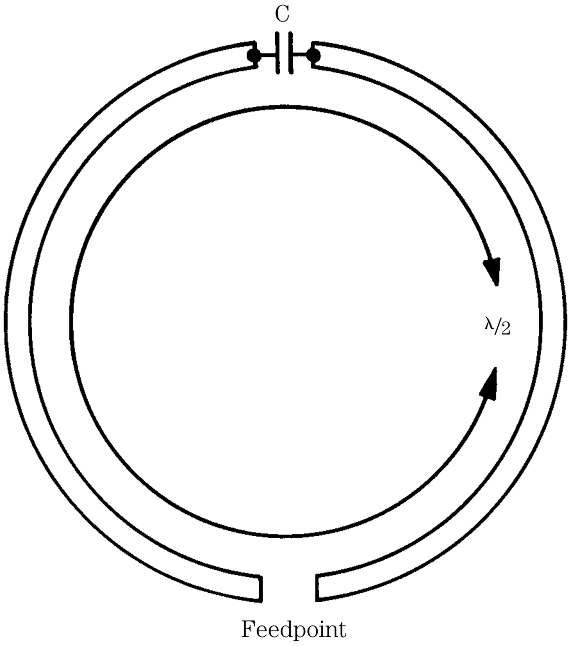

18-12 Halo antenna.

including heavy solid wire (no. 8 to no. 12), tubing, or metal rods. The overall lengths of the elements are given by:

Driven element:

$$L = \frac{11{,}826}{F_{\text{MHz}}} \text{ in} \tag{18.9}$$

Reflector:

$$L = \frac{12{,}562}{F_{\text{MHz}}} \text{ in} \tag{18.10}$$

Director:

$$L = \frac{11{,}248}{F_{\text{MHz}}} \text{ in} \tag{18.11}$$

There are several alternatives for making the supports for the radiator. Because of the lightweight construction, almost any method can be adapted for this purpose. In the case shown in Fig. 18-13, the spreaders are made from either 1-in furring strips, trim strips, or (at above 2 m) even wooden paint stirring sticks. The sticks are cut to length, and then half-notched in the center (Fig. 18-13, detail B). The two spreaders for each element are joined together at right angles and glued (Fig. 18-13, detail C). The spreaders can be fastened to the wooden boom at points *S* in detail C. The usual rules regarding element spacing (0.15 to 0.31 wavelength) are followed. See the information on quad antennas in Chap. 12 for further details. Quads have been successfully built for all amateur bands up to 1296 MHz.

Overall lengths:

$$\text{Reflector: } L = \frac{12{,}562}{F_{\text{MHz}}} \text{ in}$$

$$\text{Director: } L = \frac{11{,}248}{F_{\text{MHz}}} \text{ in}$$

$$\text{Driven element: } L = \frac{11{,}826}{F_{\text{MHz}}} \text{ in}$$

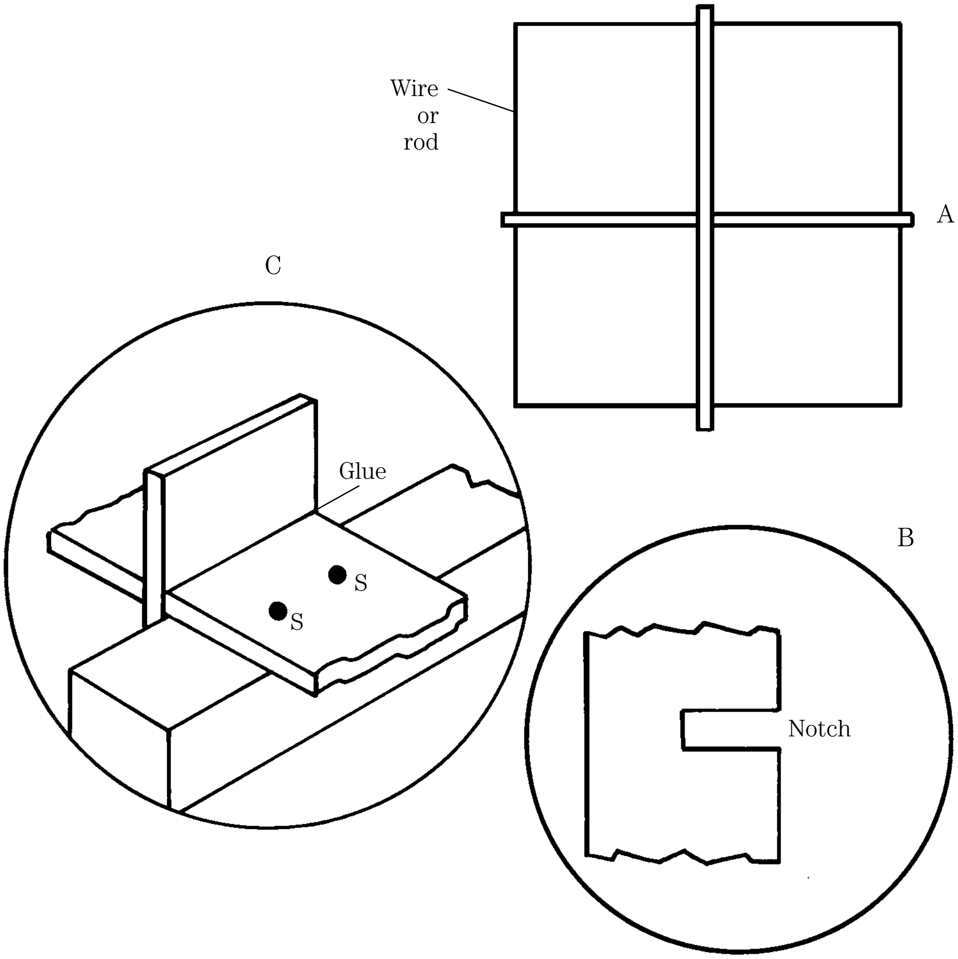

18-13 Quad loop construction on VHF.

VHF/UHF scanner band antennas

The hobby of shortwave listening has always had a subset of adherents who listen exclusively to the VHF/UHF bands. In those bands are found a rich variety of services from commercial two-way radios, police and fire systems, and others. Many of these people are serious DXers, but others have a little of the voyeur in them (they like to listen to what's going on in the community by monitoring the police frequencies). As long as they neither respond to the scene of a police or fire action, nor use the information gained from monitoring in an illegal manner, they are perfectly free to listen in.

A few people have an unusually practical element to their VHF/UHF listening. At least one person known to the author routinely tunes in the local taxicab company's frequency as soon as she orders a cab. She then listens for her own address. She knows from that approximately when to expect the cab.

In the early 1960s, when all VHF monitor receivers were crystal-controlled (and relatively expensive), the listener had a very limited selection of frequencies to choose from. Having worked in various shops that sold those receivers, I can recall that most of our customers tended to be police officers, fire fighters (or volunteers), or journalists covering the local crime news. However, modern scanners operate on both major VHF bands (low and high), plus UHF bands and others.

Scanner-vision antennas

The antennas used by scanner listeners are widely varied, and (in some cases) overpriced. Although it is arguable that a total coverage VHF/UHF antenna is worth the money, and it probably is, there are other possibilities that should be considered.

First, don't overlook the use of television antennas for scanner monitoring! The television bands (about 80 channels from 54 MHz to around 800 MHz) encompass most of the ordinarily used scanner frequencies. Although antenna performance is not optimized for the scanner frequencies, it is also not "zero" on those frequencies. If you already have an "all channel" TV antenna installed, then it is a simple matter to connect the antenna to the scanner receiver. (Note: if the antenna uses 300-Ω twin lead, then install a 4:1 balun transformer that accepts 300 Ω in and produces 75 Ω out. These transformers are usually available at TV shops, video shops—including videotape rental places—and Radio Shack stores.)

The directional characteristic of the TV antenna makes it both an advantage and a disadvantage to the scanner user. If the antenna has a rotator, then there is no problem. Just rotate the antenna to the direction of interest. However, if the antenna is fixed, and the station of interest is elsewhere than where the antenna is pointed, then there is a bit of a problem. Nevertheless, some reception is possible for at least three reasons. One is that the main beam of the antenna is not infinitely thin, so the station of interest might well be within the beam—even if off the point a little bit. Second, there are always sidelobes on an antenna. These are areas outside of the main beam that offer reduced, but nonzero, reception characteristics. Finally, the sidelobes and main lobe of the antenna are optimized for the TV bands, and may not obtain the same directivity on certain scanner frequencies. It is, therefore, possible that a TV antenna will have an unusual lobe in the direction of interest for the scanner channel.

The TV antenna also offers other possibilities. The hardware and electronics, normally found useful on TV antenna systems, are also useful for scanner antennas. The use of the mounting hardware is obvious, but less obvious is the use of components such as multiset couplers, impedance transformers, and wideband amplifiers. For example, Fig. 18-14 shows two scanner antennas joined together into a single

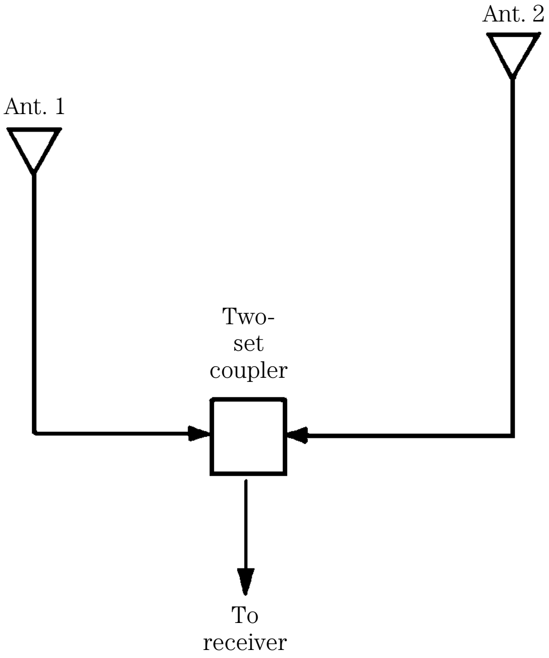

18-14 Combining two antennas with TV hardware.

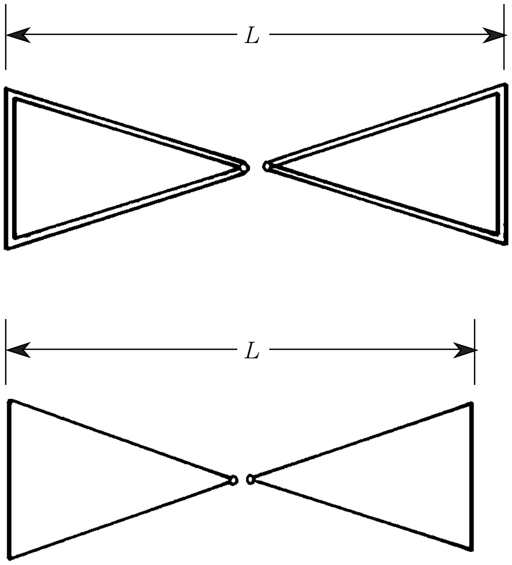

18-15 VHF/UHF "bowtie" dipoles for broadband reception**.**

transmission line using a two-set coupler. Although intended to allow two television sets to receive a signal from the same antenna, the device also works to combine two antennas into a single transmission line. Two popular TV uses include two antennas for different directions and VHF and UHF antennas that share the same downlead. Be sure to buy a weatherproof model if you intend to mount the coupler on the antenna mast (the correct place for it) (Fig. 18-15).

TV antenna amplifiers are used to increase the weak signal from a distant station to a level compatible with the TV receiver. Because these amplifiers are wideband designs, they will also work well for the scanner bands that are inclusive within the 54- to 800-MHz TV bands. Some models are intended to be part of the antenna, while others are mounted indoors, some distance from the antenna. The basic rule of thumb is to place the amplifier as close as possible to the “head end” of the system where the antenna is located. This situation will permit signals to be built up to a level considerably above the noise level before being attenuated in the transmission line losses.

TV/FM receiver folded dipoles made of twin-lead transmission line also work well at other VHF/UHF frequencies. Figures 18-16A and 18-16B show the details of their construction.

Scanner skyhooks

Other antennas not to be overlooked are the CB, or amateur radio, high-frequency (shortwave) antennas. Many amateur radio operators use their 80-m dipole antenna

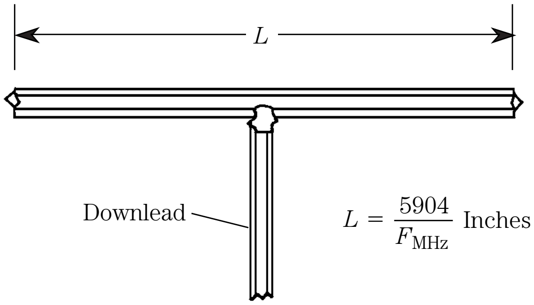

$$L = \frac{5904}{F_{\mathrm{MHz}}} \text{ Inches}$$

18-16A Receiver folded dipole antenna made of 300 Ω twin lead.

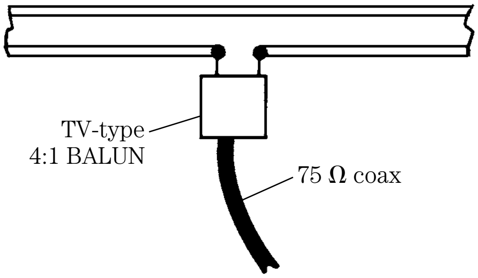

18-16B Poles made of twin-lead transmission VHF frequencies.

on 2 m (144 to 148 MHz) and find that it has the gain and directivity characteristics of a longwire antenna. Similarly, with vertical "ham" and CB antennas, they have apparent gain on some VHF frequencies and will at least perform to some extent on others.

Even the lowly "random length" wire antenna used for your shortwave receiver ought to turn in decent performance as a VHF/UHF longwire antenna. These antennas are simply a 30- to 150-ft length of no. 14 wire attached to a distant support.

Figure 18-17 shows two variants to an antenna that is popular with VHF/UHF receiver operators: the *drooping dipole.* These antennas are similar to the inverted-vee dipole, in that they consist of two quarter-wavelength radiator elements. Unlike the ordinary dipole, the ends of the radiators, in the single-band drooping dipole of Fig. 18-17A, are lowered. The drooping dipole can be made using an SO-239 UHF coaxial connector as the support for either stiff wire, brass hobbyist tubing, or brazing rod elements cut to λ/4 each. The antenna can be made into a multiband, or very wideband, antenna by connecting several pairs of drooping dipoles in parallel, as in Fig. 18-17B.

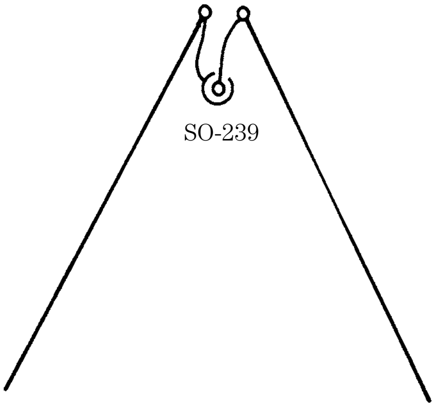

18-17A Drooping dipole.

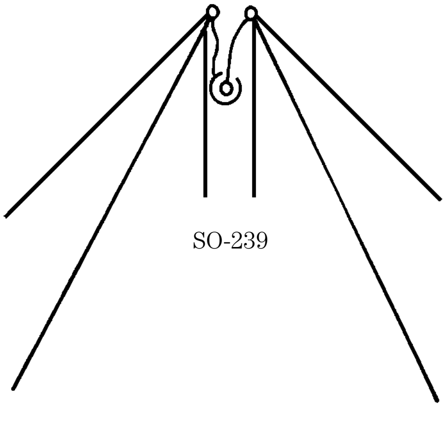

18-17B Multiband drooping dipole.

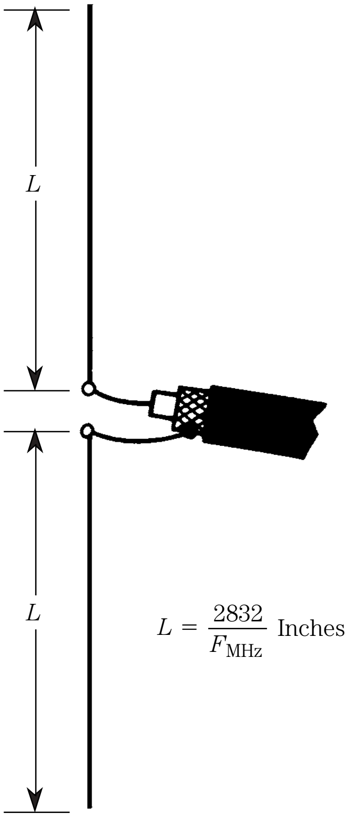

18-18A Vertical dipole.

The vertical dipole (Fig. 18-18A) also finds use in the VHF/UHF region. Each element is λ/4 long, and its physical length can be found from

$$L = \frac{2832}{F_{\mathrm{MHz}}} \text{ in} \qquad \textbf{[18.12]}$$

This antenna can be built with the same types of materials as the drooping dipole. Although several different construction techniques are popular, the method of Fig. 18-18B is probably the most popular with homebrew builders.

A groundplane antenna for VHF/UHF frequencies is shown in Fig. 18-19. The antenna sits on an L bracket mounted to a 2 × 4-in wooden mast or support. The L bracket can be manufactured for the purpose, or purchased at Happy Harry's hardware emporium. The base of the antenna is a chassis-mount SO-239 UHF coaxial connector. A quarter-wave radiator element is made from $\frac{1}{8}$-in brass tubing, or brazing rod, soldered to the center conductor pin of the SO-239. Similarly, radials can be made from the same type of material, but soldered directly to the body of the SO-239 (this action connects it to the coaxial cable shield). The four mounting holes of the SO-239 make reasonable anchors for the radials. Solder them for electrical integrity.

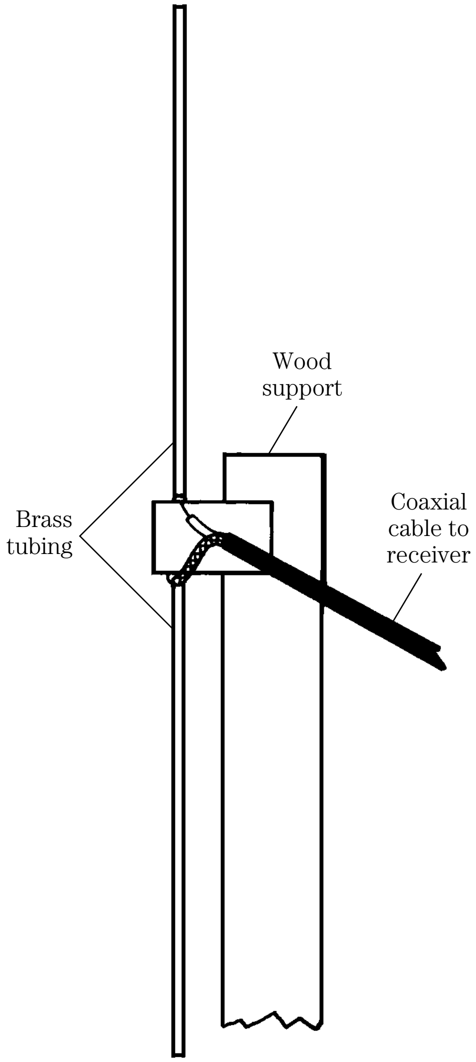

18-18B Construction of VHF vertical dipole.

A coaxial vertical can be made from 1-in brass tubing or copper plumbing pipe, and either brazing rod or brass tubing (Fig. 18-20). The sleeve is fitted with an end cap that has an SO-239 mounted on it (see inset). The radiator element can be made with a mate to the SO-239, namely the PL-259 coaxial plug. The radiator element is soldered to the center conductor, and it is insulated from the shield. You can buy coaxial whips with this type of construction, so you may not have to actually build the radiator element.

Additional gain, about +3 dB, can be achieved by stacking VHF/UHF antennas together. Figure 18-21 shows a typical arrangement in which two half-wavelength dipole antennas are connected together through a quarter-wavelength harness of RG-59/U coaxial cable. This harness is shorter than a quarter wavelength by the velocity factor of the coaxial cable:

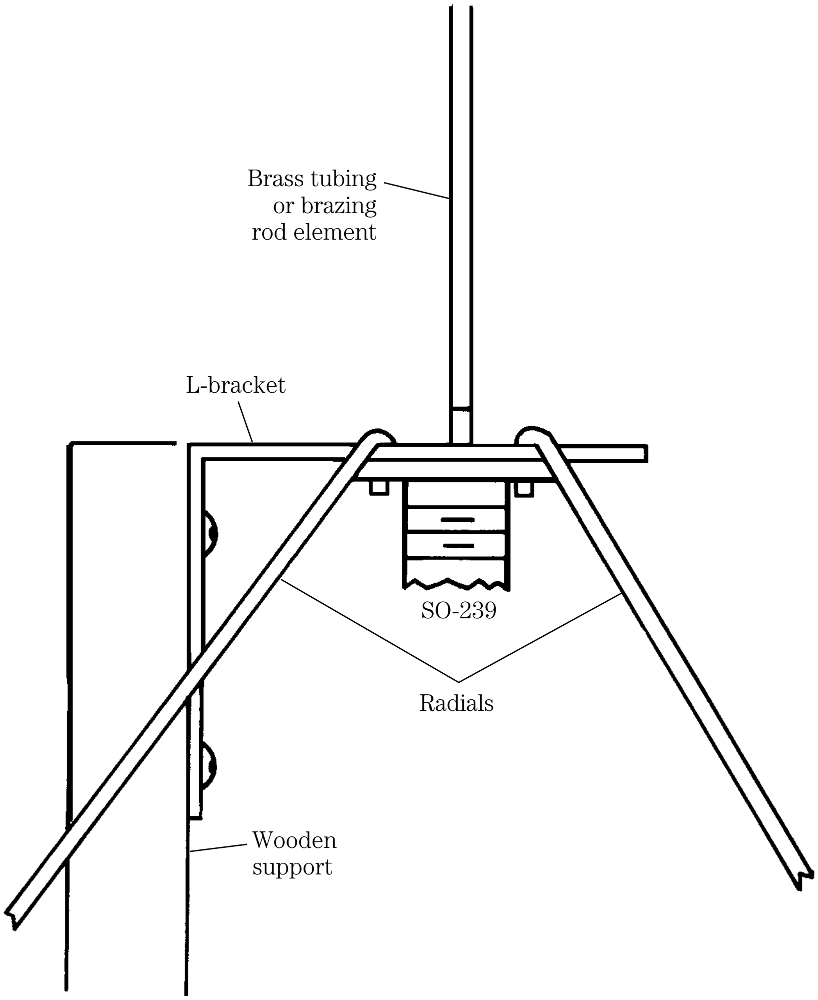
Brass tubing
or brazing
rod element
L-bracket
SO-239
Radials
Wooden
support

18-19 Construction of VHF groundplane for receivers.

$$L = \frac{2832V}{F_{\text{MHz}}} \qquad \textbf{[18.13]}$$

where

L is the length, in inches
V is the velocity factor (typically 0.66 or 0.80 for common coax)
F_{MHz} is the frequency, in megahertz

The antennas can be oriented in the same direction to increase gain, or orthogonally (as shown in Fig. 18-21) to make it more omnidirectional.

Because the impedance of two identical dipoles, fed in parallel, is one-half that of a single dipole, it is necessary to have an impedance-matching section

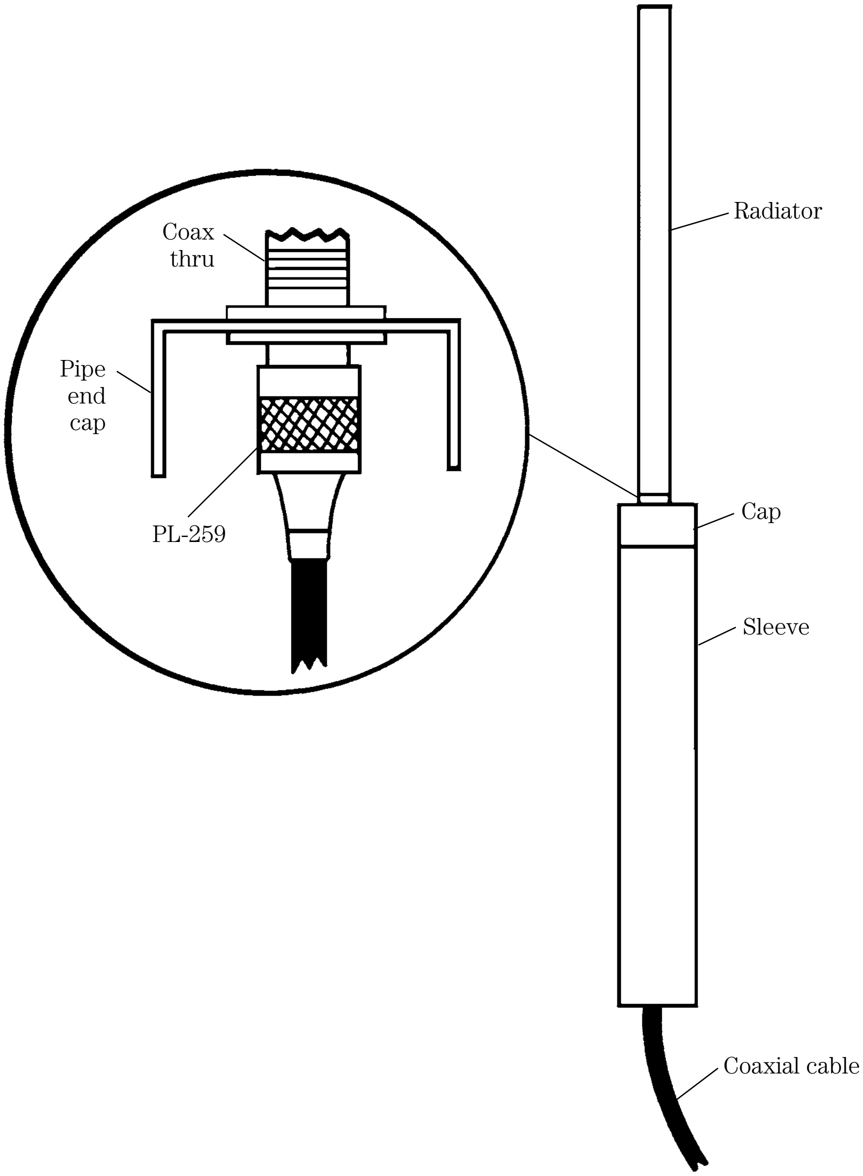
Coax
thru
Pipe
end
cap
PL-259
Radiator
Cap
Sleeve
Coaxial cable

18-20 Coaxial dipole vertical.

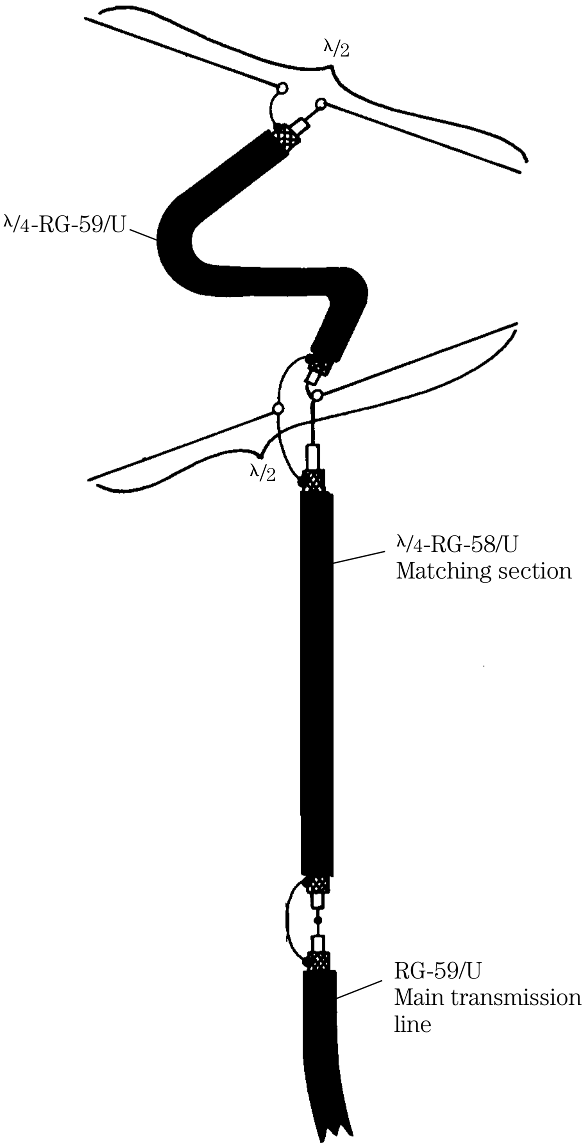
λ/2
λ/4-RG-59/U
λ/2
λ/4-RG-58/U
Matching section
RG-59/U
Main transmission
line

18-21 Stacking VHF antennas.

made of RG-58/U coaxial cable. This cable is then fed with RG-59/U coax from the receiver.

There is nothing magical about scanner receivers that require any form of antenna that is significantly different from other VHF/UHF antennas. Although the designs might be optimized for VHF or UHF, these antennas are basically the same as others shown in this book. As a matter of fact, almost any antennas, from any chapter, can be used by at least some scanner operators.

19
CHAPTER
Microwave waveguides and antennas

THE MICROWAVE PORTION OF THE RADIO SPECTRUM COVERS FREQUENCIES FROM ABOUT 900 MHz to 300 GHz, with wavelengths in free-space ranging from 33 cm down to 1 mm. Transmission lines can be used at frequencies from dc to about 50 or 60 GHz, although, above 5 GHz, only short runs are practical, because attenuation increases dramatically as frequency increases. There are three types of losses in conventional transmission lines: *ohmic, dielectric,* and *radiation.* The ohmic losses are caused by the current flowing in the resistance of the conductors making up the transmission lines. Because of the skin effect, which increases resistance at higher frequencies, these losses tend to increase in the microwave region. Dielectric losses are caused by the electric field acting on the molecules of the insulator and thereby causing heating through molecular agitation. Radiation losses represent loss of energy as an electromagnetic wave propagates away from the surface of the transmission line conductor.

Losses on long runs of coaxial transmission line (the type most commonly used) cause concern even as low as the 400-MHz region. Also, because of the increased losses, power handling capability decreases at high frequencies. Therefore, at higher microwave frequencies, or where long runs make coax attenuation losses unacceptable, or where high power levels would overheat the coax, *waveguides* are used in lieu of transmission lines.

What is a waveguide? Consider the light pipe analogy depicted in Fig. 19-1. A flashlight serves as our "RF source," which (given that light is also an electromagnetic wave) is not altogether unreasonable. In Fig. 19-1A the source radiates into free space and spreads out as a function of distance. The intensity per unit area, at the destination (a wall), falls off as a function of distance (D) according to the *inverse square law* ($1/D^2$).

But now consider the transmission scheme in Fig. 19-1B. The light wave still propagates over distance D, but is now confined to the interior of a mirrored pipe. Almost all of the energy (less small losses) coupled to the input end is delivered to the output end, where the intensity is practically undiminished. Although not

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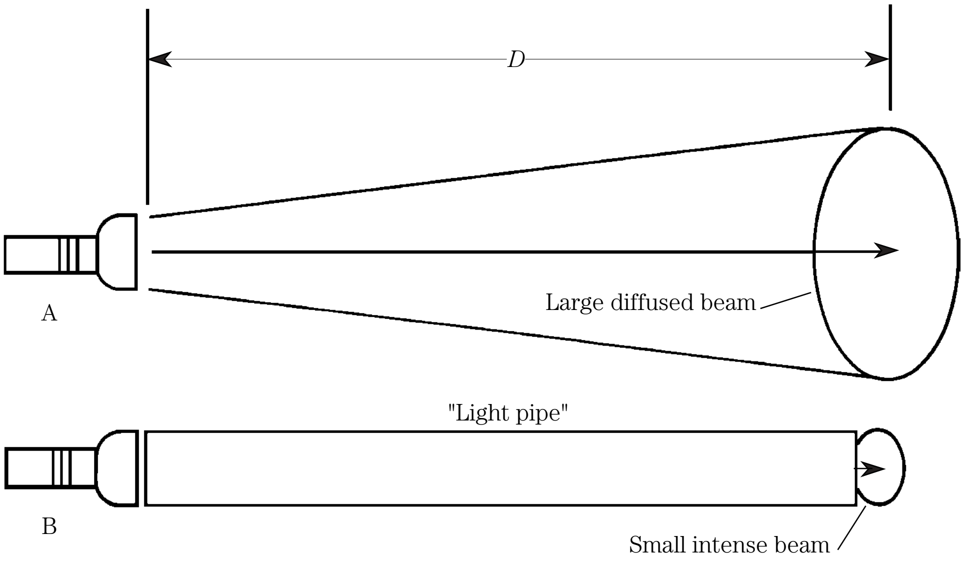

19-1 Waveguide analogy to light pipe.

perfect, the light pipe analogy neatly summarizes, on a simple level, the operation of microwave waveguides.

Thus, we can consider the waveguide as an “RF pipe” without seeming too serenely detached from reality. Similarly, fiber-optic technology is waveguidelike at optical (IR and visible) wavelengths. In fact, the analogy between fiber optics and waveguide can withstand more rigorous comparison than the simplistic light pipe analogy.

The internal walls of the waveguide are not mirrored surfaces, as in our optical analogy, but are, rather, electrical conductors. Most waveguides are made of aluminum, brass, or copper. In order to reduce ohmic losses, some waveguides have their internal surfaces electroplated with either gold or silver, both of which have lower resistivities than the other metals mentioned above.

Waveguides are hollow metal pipes, and can have either circular or rectangular cross sections (although the rectangular are, by far, the most common). Figure 19-2 shows an end view of the rectangular waveguide. The dimension a is the wider dimension, and b is the narrower. These letters are considered the standard form of notation for waveguide dimensions, and will be used in the equations developed in this chapter.

Development of the rectangular waveguide from parallel transmission lines

One way of visualizing how a waveguide works is to develop the theory of waveguides from the theory of elementary parallel transmission lines (see Chap. 3). Figure 19-3A shows the basic parallel transmission line which was introduced in Chap. 3. The line consists of two parallel conductors separated by an air dielectric. Because air won't support the conductors, ceramic or other material insulators are used as supports.

There are several reasons why the parallel transmission line *per se* is not used at microwave frequencies. Skin effect increases ohmic losses to a point that is unacceptable. Also, the insulators supporting the two conductors are significantly more

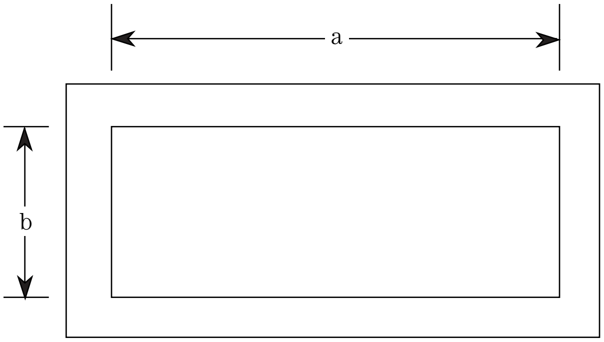

19-2 Rectangular waveguide (end view).

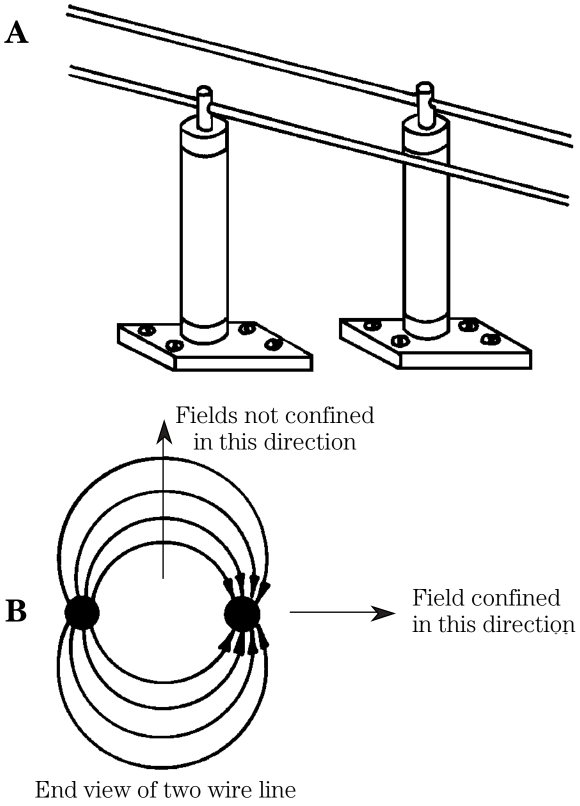
A
B
Fields not confined
in this direction
Field confined
in this direction
End view of two wire line

19-3 Development of waveguide from parallel line.

lossy at microwave frequencies than at lower frequencies. Finally, radiation losses increase dramatically. Figure 19-3B shows the electric fields surrounding the conductors. The fields add algebraically (either constructively or destructively), resulting in pinching of the resultant field along one axis, and bulging along the other. This geometry increases radiation losses at microwave frequencies.

Now let's consider the quarter-wavelength shorted stub. The "looking-in" impedance of such a stub is infinite. When placed in parallel across a transmission line (Fig. 19-4A) the stub acts like an insulator. In other words, at its resonant frequency, the stub is a *metallic insulator,* and can be used to physically support the transmission line.

Again, because the impedance is infinite, we can connect two quarter-wavelength stubs in parallel with each other across the same points on the transmission line (Fig. 19-4B) without loading down the line impedance. This arrangement effectively forms a half-wavelength pair. The impedance is still infinite, so no harm is done. Likewise, we can parallel a large number of center-fed half-wavelength pairs along the line, as might be the case when a long line is supported at multiple points. The waveguide is analogous to an *infinite number of*

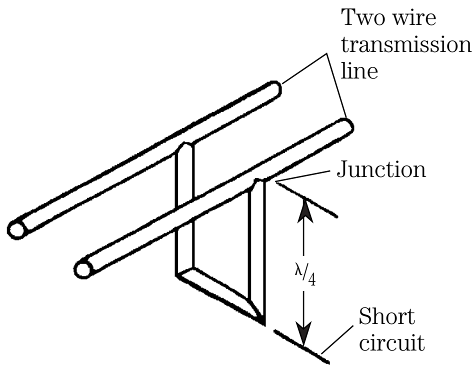

19-4A
Quarter-wave stub analogy.

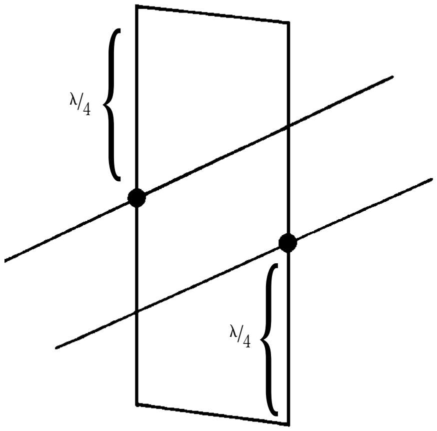

19-4B
Quarter-wave stub analogy extended.

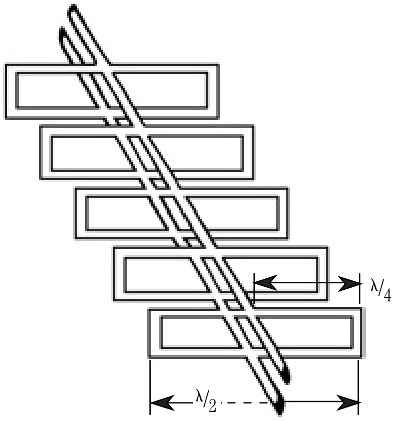

19-4C
Quarter-wave stub analogy extended even further.

center-fed "half-wave pairs" of quarter-wave shorted stubs connected across the line. The result is the continuous metal pipe structure of the common rectangular waveguide (Fig. 19-4C).

On first glance, relating rectangular waveguide to quarter-wavelength shorted stubs seems to fall down, except at the exact resonant frequency. It turns out, however, that the analogy also holds up at other frequencies, so long as the frequency is higher than a certain minimum cutoff frequency. The waveguide thus acts like a high-pass filter. There is also a practical upper frequency limit. In general, waveguides support a bandwidth of 30 to 40 percent of cutoff frequency. As shown in Fig. 19-5, the center line of the waveguide (which represents the points where the conductors are in the parallel line analogy) becomes a "shorting bar" between segments, and that "bar" widens or narrows according to operating frequency. Thus, the active region is still a quarter-wavelength shorted stub.

Below the cutoff frequency, the structure disappears entirely, and the waveguide acts like a parallel transmission line with a low-impedance inductive reactance shorted across the conductors. When modeled as a pair of quarter-wavelength stubs, the a dimension of the waveguide is a half-wavelength long. The cutoff frequency is defined as the frequency at which the a dimension is less than a half-wavelength.

Propagation modes in waveguides

The signal in a microwave waveguide propagates as an electromagnetic wave, not as a current. Even in a transmission line, the signal propagates as a wave because the current in motion down the line gives rise to electric and magnetic fields, which behave as an electromagnetic field. The specific type of field found in transmission lines, however, is a *transverse electromagnetic* (*TEM*) field. The term *transverse* implies things at right angles to each other, so the electric and magnetic fields are perpendicular to the direction of travel. In addition to the word "transverse," these right-angle waves are said to be "normal" or "orthogonal" to the direction of travel—three different ways of saying the same thing: right-angledness.

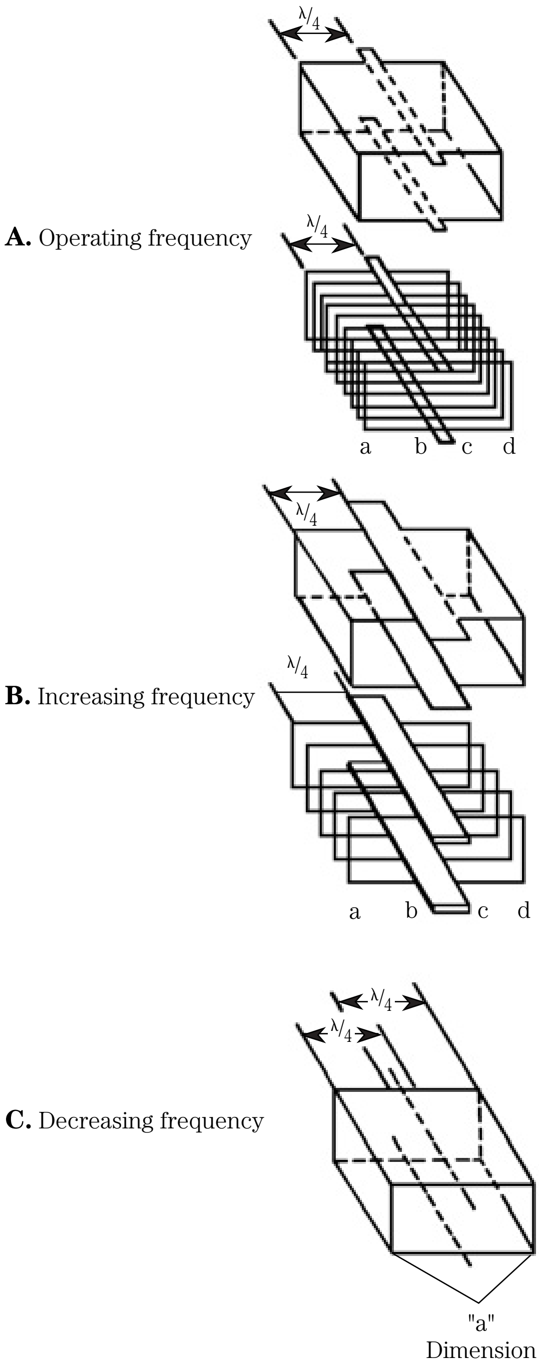
λ/4
λ/4
A. Operating frequency
a
b
c
d
λ/4
λ/4
B. Increasing frequency
a
b
c
d
λ/4
λ/4
C. Decreasing frequency
"a"
Dimension

19-5
Changing frequency does not affect the analogy.

Boundary conditions

The TEM wave will not propagate in a waveguide because certain *boundary conditions* apply. Although the wave in the waveguide propagates through the air (or inert gas dielectric) in a manner similar to free-space propagation, the phenomenon is bounded by the walls of the waveguide, and that implies certain conditions must be met. The boundary conditions for waveguides are

1. The electric field must be orthogonal to the conductor in order to exist at the surface of that conductor.
2. The magnetic field must not be orthogonal to the surface of the waveguide.

In order to satisfy these boundary conditions the waveguide gives rise to two types of propagation modes: *transverse electric mode* (TE mode), and *transverse magnetic mode* (TM mode). The TEM mode violates the boundary conditions because the magnetic field is not parallel to the surface, and so does not occur in waveguides.

The transverse electric field requirement means that the E field must be perpendicular to the conductor wall of the waveguide. This requirement is met by use of a proper coupling scheme at the input end of the waveguide. A vertically polarized coupling radiator will provide the necessary transverse field.

One boundary condition requires that the magnetic (H) field must not be orthogonal to the conductor surface. Because it is at right angles to the E field, it will meet this requirement (see Fig. 19-6). The planes formed by the magnetic field are parallel to both the direction of propagation and the wide dimension surface.

As the wave propagates away from the input radiator, it resolves into two components that are not along the axis of propagation, and are not orthogonal to the walls. The component along the waveguide axis violates the boundary conditions, so it is rapidly attenuated. For the sake of simplicity, only one component is shown in Fig. 19-7. Three cases are shown in Fig. 19-7: high, medium, and low frequency. Note that the angle of incidence with the waveguide wall increases as frequency drops. The angle rises toward 90° as the cutoff frequency is approached from above. Below the cutoff frequency the angle is 90°, so the wave bounces back and forth between the walls without propagating.

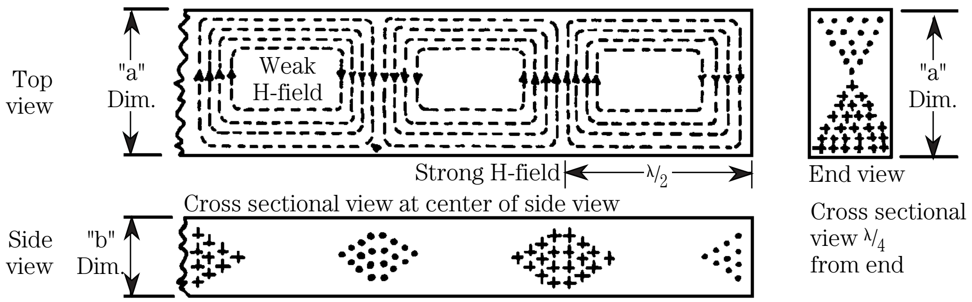

19-6 Magnetic fields in waveguide.

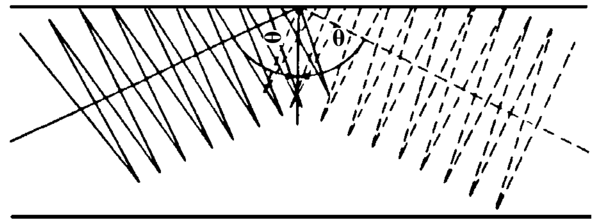

A. High frequency

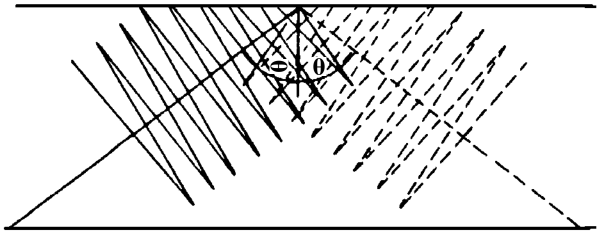

B. Medium frequency

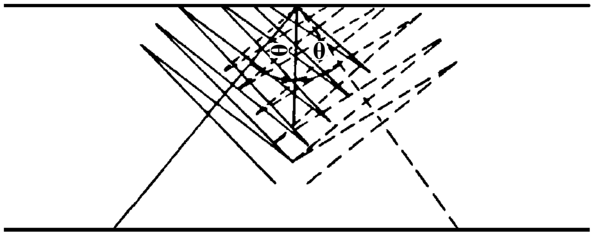

C. Low frequency
(approaching cutoff)

⊖ = ∠ of incidence
θ = ∠ of reflection

19-7
Frequency effect on propagating wave.

Coordinate system and dominant mode in waveguides

Figure 19-8 shows the coordinate system used to denote dimensions and directions in microwave discussions. The a and b dimensions of the waveguide correspond to the x and y axes of a cartesian coordinate system, and the z axis is the direction of wave propagation.

In describing the various modes of propagation, use a shorthand notation as follows:

$$Tx_{m,n}$$

where

x is E for transverse electric mode, and M for transverse magnetic mode
m is the number of half-wavelengths along the x axis (i.e., a dimension)
n is the number of half-wavelengths along the y axis (i.e., b dimension)

The TE_{10} mode is called the *dominant mode, and is the best mode for low attenuation propagation in the z axis*. The nomenclature TE_{10} indicates that there is one half-wavelength in the a dimension and zero half-wavelengths in the b dimension. The dominant mode exists at the lowest frequency at which the waveguide is a half-wavelength.

Velocity and wavelength in waveguides

Figures 19-9A and 19-9B show the geometry for two wave components, simplified for the sake of illustration. There are three different wave velocities to consider with respect to waveguides: *free-space velocity c, group velocity* V_g, and *phase velocity* V_p. The free-space velocity is the velocity of propagation in unbounded free space (i.e., the speed of light $c = 3 \times 10^8$ m/s).

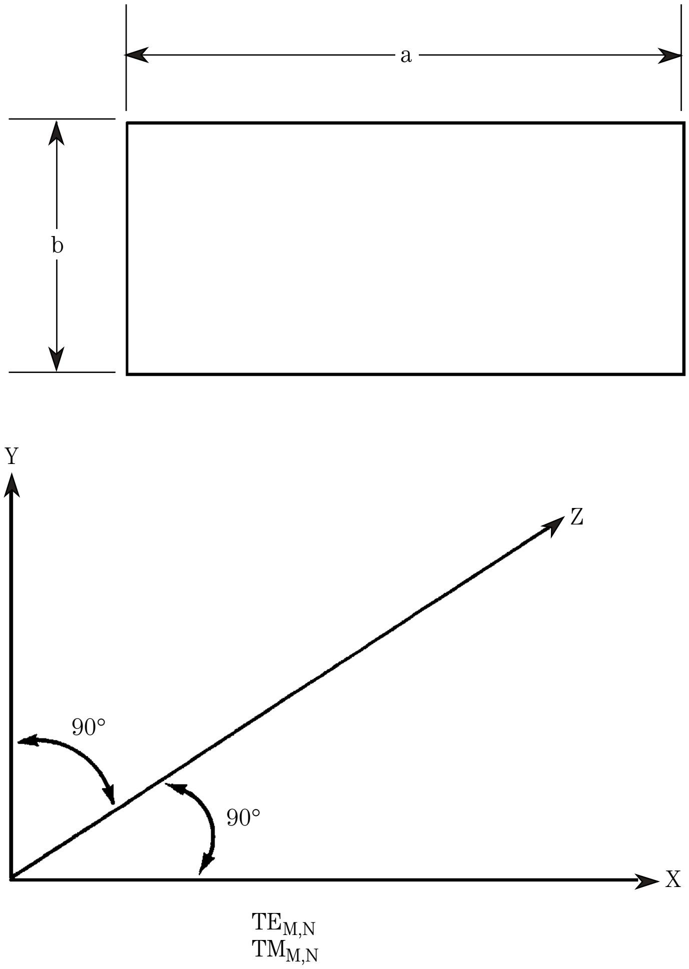

19-8 Rectangular waveguide coordinate system.

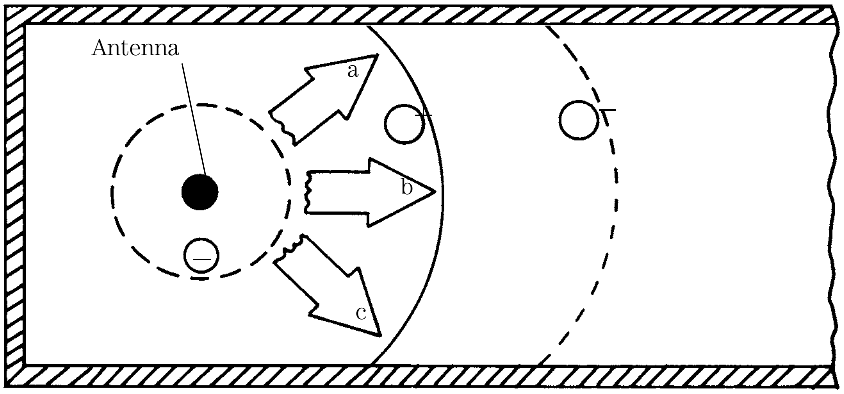

19-9A Antenna radiator in capped waveguide.

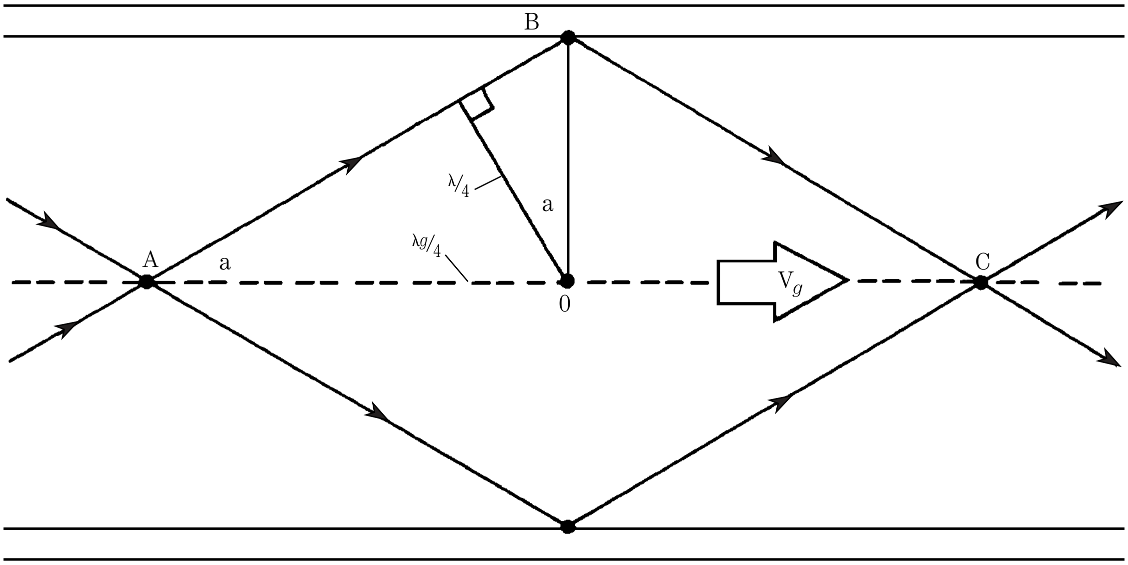

19-9B Wave propagation in waveguide.

The *group velocity* is the straight line velocity of propagation of the wave down the center line *(z* axis) of the waveguides. The value of V_g is always less than c, because the actual path length taken, as the wave bounces back and forth, is longer than the straight line path (i.e., path *ABC* is longer than path *AC*). The relationship between c and V_g is

$$V_g = c \sin a \qquad \textbf{[19.1]}$$

where

V_g is the group velocity, in meters per second
c is the free-space velocity (3×10^8 m/s)
a is the angle of incidence in the waveguide

The *phase velocity* is the velocity of propagation of the spot on the waveguide wall where the wave impinges (e.g., point *B* in Fig. 19-9B). This velocity, depending upon the angle of incidence, can actually be faster than both the group velocity and the speed of light. The relationship between phase and group velocities can be seen in the beach analogy. Consider an ocean beach, on which the waves arrive from offshore at an angle other than 90°. In other words, the arriving wavefronts are not parallel to the shore. The arriving waves have a group velocity V_g. But as a wave hits the shore, it will strike a point down the beach first, and the "point of strike" races up the beach at a much faster phase velocity V_p, that is even faster than the group velocity. In a microwave waveguide, the phase velocity can be greater than *c,* as can be seen from Eq. 19.2:

$$V_p = \frac{c}{\sin a} \qquad \textbf{[19.2]}$$

Example 19-1 Calculate the group and phase velocities for an angle of incidence of 33°.

Solution:

(*a*) *Group velocity*

$$\begin{aligned} V_g &= c \sin a \\ &= (3 \times 10^8)(\sin 33°) \\ &= (3 \times 10^8)(0.5446) = 1.6 \times 10^8 \text{ m/s} \end{aligned}$$

(*b*) *Phase velocity*

$$\begin{aligned} V_p &= c/\sin a \\ &= (3 \times 10^8 \text{ m/s})/\sin 33° \\ &= (3 \times 10^8 \text{ m/s})/(0.5446) \\ &= 5.51 \times 10^8 \text{ m/s} \end{aligned}$$

For this problem the solutions are

$$\begin{aligned} c &= 3 \times 10^8 \text{ m/s} \\ V_p &= 5.51 \times 10^8 \text{ m/s} \\ V_g &= 1.6 \times 10^8 \text{ m/s} \end{aligned}$$

We can also write a relationship between all three velocities by combining Eqs. 19.1 and 19.2, resulting in

$$c = \sqrt{V_p V_g} \qquad \textbf{[19.3]}$$

In any wave phenomenon the product of *frequency* and *wavelength* is the *velocity.* Thus, for a TEM wave in unbounded free space we know that:

$$c = F\lambda_o \qquad \textbf{[19.4]}$$

Because the frequency F is fixed by the generator, only the wavelength can change when the velocity changes. In a microwave waveguide we can relate phase velocity to wavelength as the wave is propagated in the waveguide:

$$V_p = \frac{\lambda \times c}{\lambda_o} \qquad \textbf{[19.5]}$$

where:

V_p is the phase velocity, in meters per second
c is the free-space velocity (3×10^8 m/s)
λ is the wavelength in the waveguide, in meters
λ_o is the wavelength in free space *(c/F)*, in meters (see Eq. 19.4)

Equation 19.5 can be rearranged to find the wavelength in the waveguide:

$$\lambda = \frac{V_p \lambda_o}{c} \qquad \textbf{[19.6]}$$

Example 19-2 A 5.6-GHz microwave signal is propagated in a waveguide. Assume that the internal angle of incidence to the waveguide surfaces is 42 degrees. Calculate (*a*) phase velocity, (*b*) wavelength in unbounded free space, and (*c*) wavelength of the signal in the waveguide.

Solution:

(*a*) *Phase velocity*

$$V_p = \frac{c}{\sin a}$$

$$= \frac{3 \times 10^8 \text{ m/s}}{\sin 42°}$$

$$= \frac{3 \times 10^8 \text{ m/s}}{0.6991} = 4.5 \times 10^8 \text{ m/s}$$

(*b*) *Wavelength in free space*

$$\lambda_o = c/F$$

$$= (3 \times 10^8 \text{ m/s})/(5.6 \times 10^9 \text{ Hz})$$

$$= 0.054 \text{ m}$$

(*c*) *Wavelength in waveguide*

$$\lambda = \frac{V_p \lambda_o}{c}$$

$$= \frac{(4.5 \times 10^8 \text{ m/s})(0.054 \text{ m})}{3 \times 10^8 \text{ m/s}} = 0.08 \text{ m}$$

Comparing, we find that the free-space wavelength is 0.054 m, and the wavelength inside of the waveguide increases to 0.08 m.

Cutoff frequency (F_c)

The propagation of signals in a waveguide depends, in part, upon the operating frequency of the applied signal. As covered earlier, the angle of incidence made by the plane wave to the waveguide wall is a function of frequency. As the frequency drops, the angle of incidence increases toward 90°.

The propagation of waves depends on the angle of incidence and the associated reflection phenomena. Indeed, both phase and group velocities are functions of the angle of incidence. When the frequency drops to a point where the angle of incidence is 90°, then group velocity is meaningless.

We can define a general mode equation based on our system of notation:

$$\frac{1}{(\lambda_c)^2} = \left(\frac{m}{2a}\right)^2 + \left(\frac{n}{2b}\right)^2 \quad \textbf{[19.7]}$$

where

λ_c is the longest wavelength that will propagate
a, b are the waveguide dimensions (see Fig. 19-2)
m, n are integers that define the number of half-wavelengths that will fit in the a and b dimensions, respectively

Evaluating Eq. 19.7 reveals that the longest TE-mode signal that will propagate in the dominant mode (TE_{10}) is given by

$$\lambda_c = 2a \quad \textbf{[19.8]}$$

from which we can write an expression for the cutoff frequency:

$$F_c = \frac{c}{2a} \quad \textbf{[19.9]}$$

where

F_c is the lowest frequency that will propagate, in hertz
c is the speed of light (3×10^8 m/s)
a is the wide waveguide dimension

Example 19-3 A rectangular waveguide has dimensions of 3 × 5 cm. Calculate the TE_{10} mode cutoff frequency.

Solution:

$$F_c = \frac{c}{2a}$$

$$= \frac{(3 \times 108 \text{ m/s}}{(2)\left(5 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}}\right)}$$

$$= \frac{3 \times 10^8 \text{ m/s}}{(2)(0.05 \text{ m})} = 3 \text{ GHz}$$

Equation 19.7 assumes that the dielectric inside the waveguide is air. A more generalized form, which can accommodate other dielectrics, is

$$F_c = \frac{1}{2\sqrt{ue}} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} \qquad \textbf{[19.10]}$$

where

e is the dielectric constant
u is the permeability constant

For air dielectrics, $u = u_o$ and $e = e_o$, from which

$$c = \frac{1}{\sqrt{u_o e_o}} \qquad \textbf{[19.11]}$$

To determine the cutoff wavelength, we can rearrange Eq. 19.10 to the form:

$$\lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}} \qquad \textbf{[19.12]}$$

One further expression for air-filled waveguide calculates the actual wavelength in the waveguide from a knowledge of the free-space wavelength and actual operating frequency:

$$\lambda_g = \frac{\lambda_o}{\sqrt{1 - \left(\frac{F_c}{F}\right)^2}} \qquad \textbf{[19.13]}$$

where

λ_g is the wavelength in the waveguide
λ_o is the wavelength in free space
F_c is the waveguide cutoff frequency
F is the operating frequency

Example 19-4 A waveguide with a 4.5-GHz cutoff frequency is excited with a 6.7-GHz signal. Find (*a*) the wavelength in free space and (*b*) the wavelength in the waveguide.

Solution:

(*a*)

$$\begin{aligned}\lambda_o &= c/F \\ &= \frac{3 \times 10^8 \text{ m/s}}{6.7 \text{ GHz} \times \dfrac{10^9 \text{ Hz}}{1 \text{ GHz}}} \\ &= \frac{3 \times 10^8 \text{ m/s}}{6.7 \times 10^9 \text{ Hz}} = 0.0448 \text{ m}\end{aligned}$$

(*b*)

$$\begin{aligned}\lambda_g &= \frac{\lambda_o}{\sqrt{1-\left(\dfrac{F_c}{F}\right)^2}} \\ &= \frac{0.0448 \text{ m}}{\sqrt{1-\left(\dfrac{4.5 \text{ GHz}}{6.7 \text{ GHz}}\right)^2}} \\ &= \frac{0.0448 \text{ m}}{1 - 0.67} \\ &= \frac{0.0448}{0.33} = 0.136 \text{ m}\end{aligned}$$

Transverse magnetic modes also propagate in waveguides, but the base TM_{10} mode is excluded by the boundary conditions. Thus, the TM_{11} mode is the lowest magnetic mode that will propagate.

Waveguide impedance

All forms of transmission line, including the waveguide, exhibit a characteristic impedance, although in the case of waveguide it is a little difficult to pin down conceptually. This concept was developed for ordinary transmission lines in Chap. 3. For a waveguide, the characteristic impedance is approximately equal to the ratio of the electric and magnetic fields (*E/H*), and converges (as a function of frequency) to the intrinsic impedance of the dielectric (Fig. 19-10). The impedance of the waveguide is a function of waveguide characteristic impedance (Z_o) and the wavelength in the waveguide:

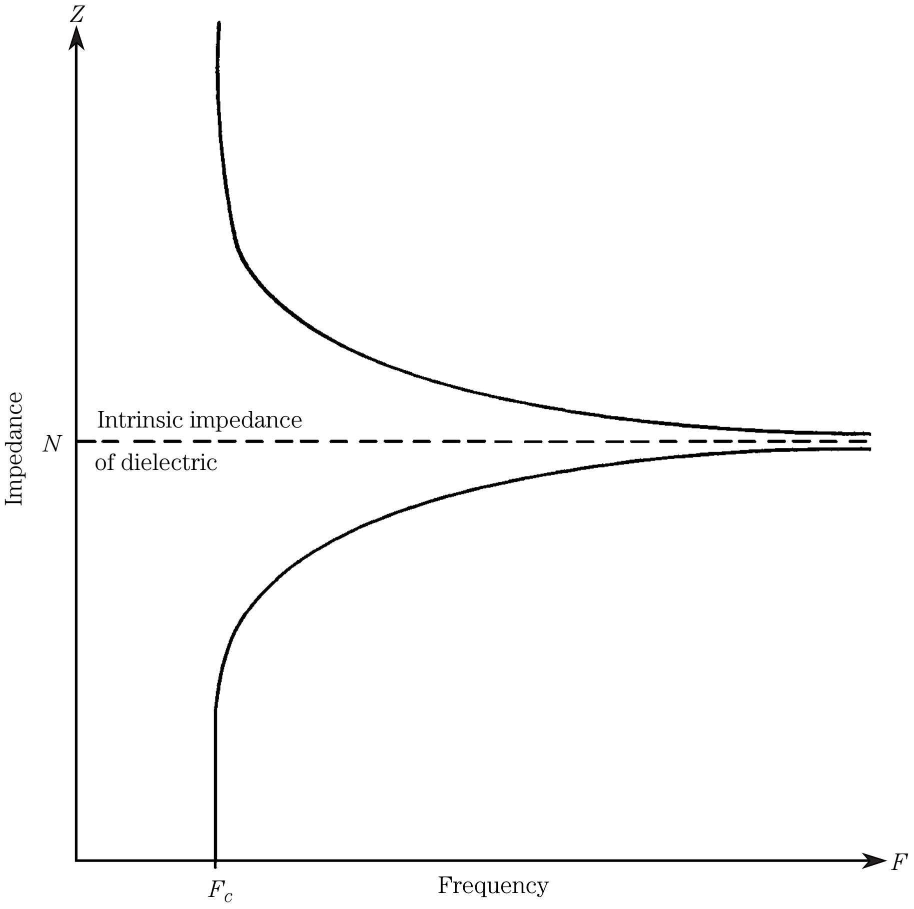

19-10 Impedance versus frequency.

$$Z = \frac{Z_o \lambda_g}{\lambda_o} \qquad \textbf{[19.14]}$$

Or, for rectangular waveguide, with constants taken into consideration:

$$Z = \frac{120\,\pi\,\lambda_g}{\lambda_o} \qquad \textbf{[19.15]}$$

The *propagation constant B* for rectangular waveguide is a function of both cutoff frequency and operating frequency:

$$B = W\sqrt{eu}\,\sqrt{1-\left(\frac{F_c}{F}\right)^2} \qquad \textbf{[19.16]}$$

from which we can express the TE-mode impedance:

$$Z_{\text{TE}} = \frac{\sqrt{ue}}{\sqrt{1-\left(\frac{F_c}{F}\right)^2}} \qquad \textbf{[19.17]}$$

and the TM-mode impedance:

$$Z_{\text{TM}} = 377\sqrt{1-\left(\frac{F_c}{F}\right)^2} \qquad \textbf{[19.18]}$$

Waveguide terminations

When an electromagnetic wave propagates down a waveguide, it must eventually reach the end of the guide. If the end is open, then the wave will propagate into free-space. The horn radiator is an example of an unterminated waveguide. If the waveguide terminates in a metallic wall, then the wave reflects back down the waveguide, from whence it came. The interference between incident and reflected waves forms standing waves (see Chap. 3). Such waves are stationary in space, but vary in the time domain.

In order to prevent standing waves, or more properly, the reflections that give rise to standing waves, the waveguide must be *terminated* in a matching impedance. When a properly designed antenna is used to terminate the waveguide, it forms the matched load required to prevent reflections. Otherwise, a *dummy load* must be provided. Figure 19-11 shows several types of dummy load.

The classic termination is shown in Fig. 19-11A. The “resistor” making up the dummy load is a mixture of sand and graphite. When the fields of the propagated wave enter the load, they cause currents to flow, which in turn cause heating. Thus, the RF power dissipates in the sand-graphite rather than being reflected back down the waveguide.

A second dummy load is shown in Fig. 19-11B. The resistor element is a carbonized rod critically placed at the center of the electric field. The E field causes currents to flow, resulting in I^2R losses that dissipate the power.

Bulk loads, similar to the graphite-sand chamber, are shown in Fig. 19-11C, D, and E. Using bulk material such as graphite or a carbonized synthetic material, these loads are used in much the same way as the sand load (i.e., currents set up, and I^2R losses dissipate the power).

The resistive vane load is shown in Fig. 19-11F. The plane of the element is orthogonal to the magnetic lines of force. When the magnetic lines cut across the vane, currents are induced, which gives rise to the I^2R losses. Very little RF energy reaches the metallic end of the waveguide, so there is little reflected energy and a low VSWR.

There are situations where it isn’t desirable to terminate the waveguide in a dummy load. Several reflective terminations are shown in Fig. 19-12. Perhaps the simplest form is the permanent end plate shown in Fig. 19-12A. The metal cover must be welded or otherwise affixed through a very-low-resistance joint. At the substantial power levels typically handled in transmitter waveguides, even small resistances can be important.

The end plate (shown in Fig. 19-12B) uses a quarter-wavelength cup to reduce the effect of joint resistances. The cup places the contact joint at a point that is a

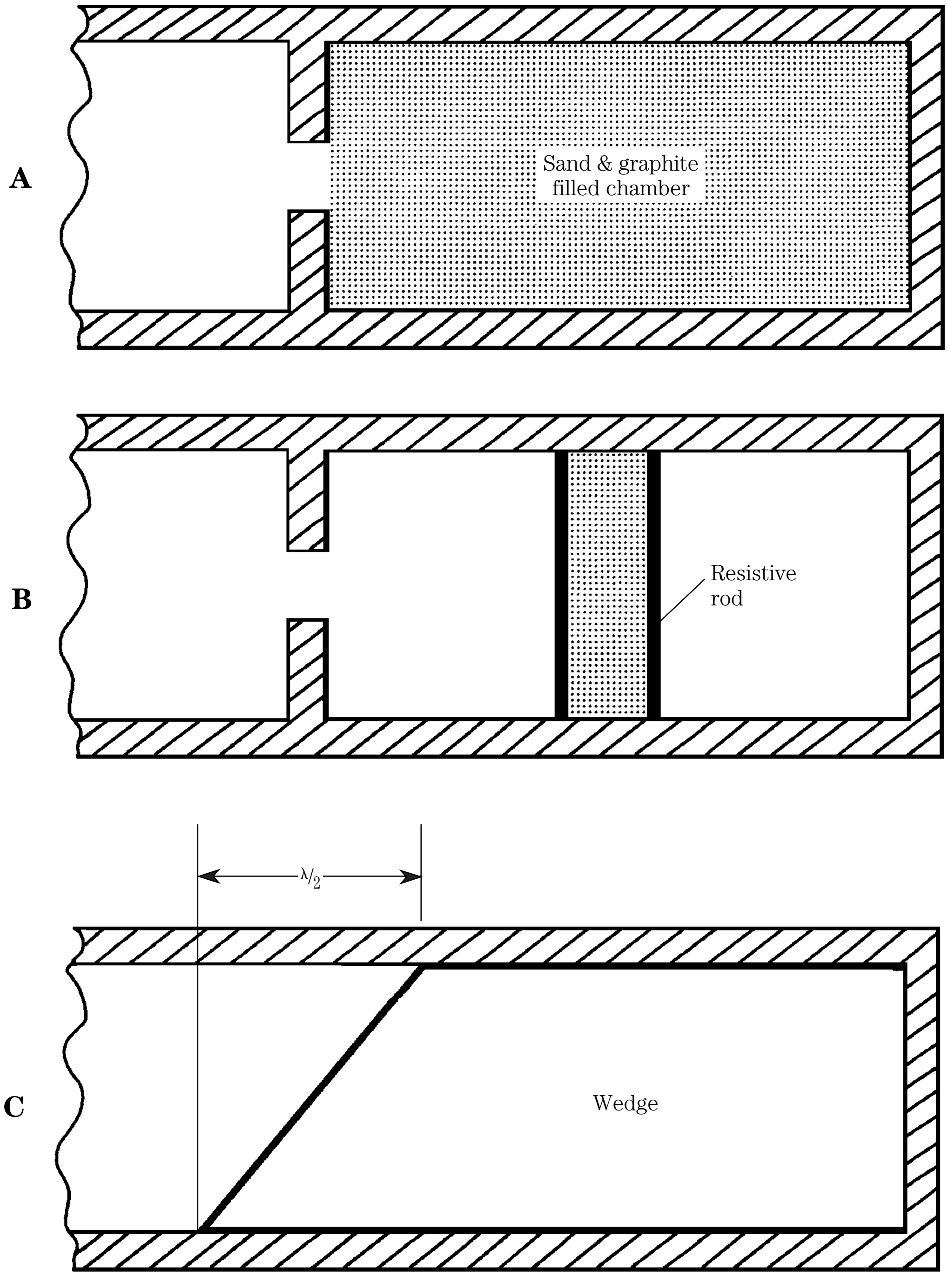
A
Sand & graphite filled chamber
B
Resistive rod
C
$\lambda/2$
Wedge

19-11 Dummy loads: (A) sand-graphite chamber; (B) resistive rod; (C) wedge.

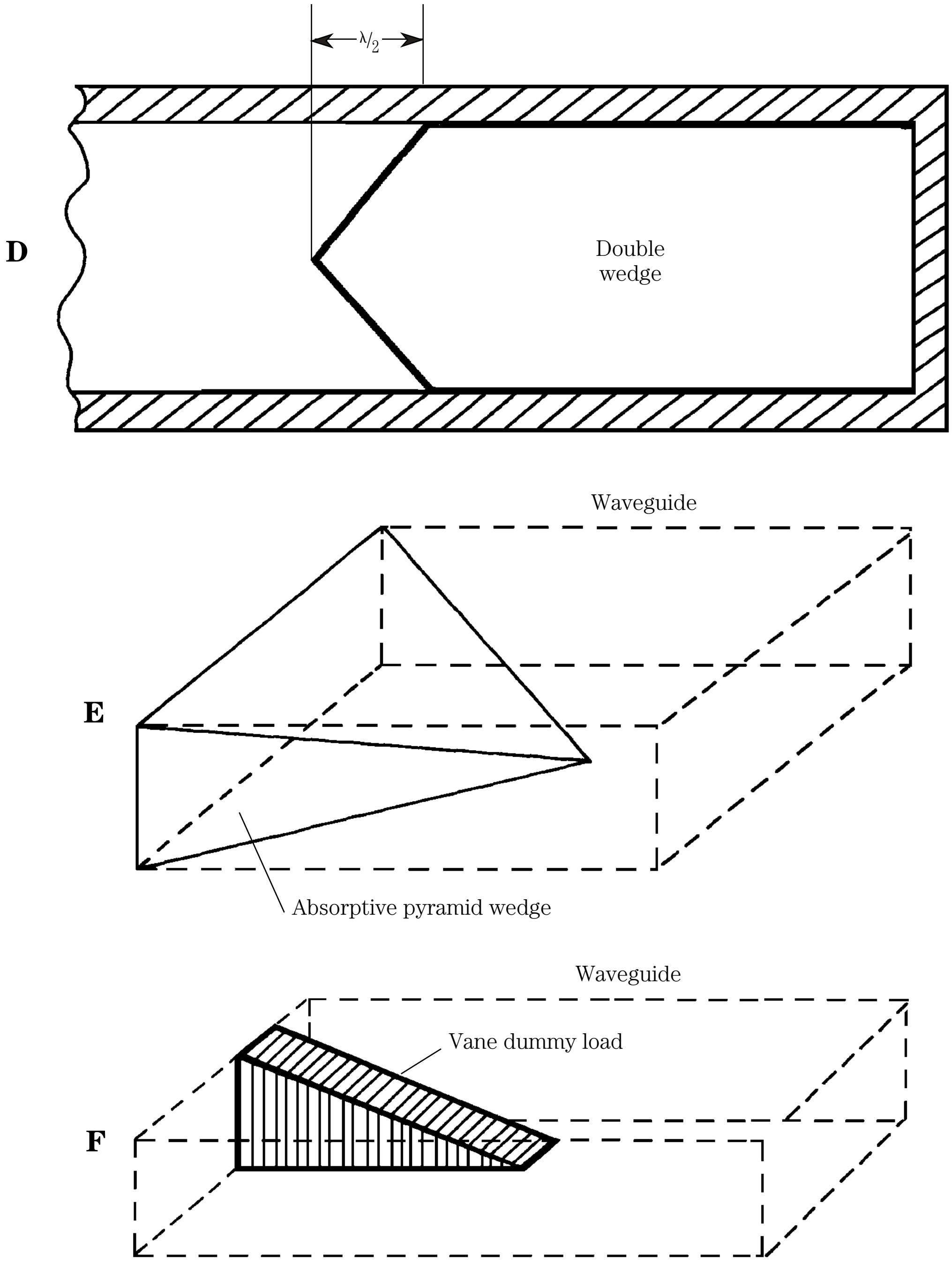
λ/2
D
Double wedge
Waveguide
E
Absorptive pyramid wedge
Waveguide
Vane dummy load
F

19-11 Dummy loads: (D) double wedge; (E) pyramid wedge; (F) vane dummy load.

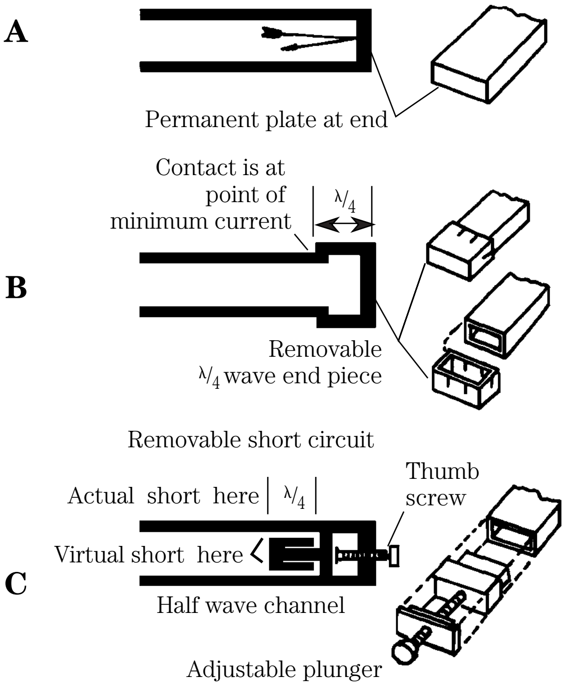
A
Permanent plate at end
Contact is at point of minimum current
λ/4
B
Removable λ/4 wave end piece
Removable short circuit
Actual short here
λ/4
Thumb screw
Virtual short here
C
Half wave channel
Adjustable plunger

19-12
End terminations.

quarter-wavelength from the end. This point is a minimum-current node, so I^2R losses in the contact resistance become less important.

The adjustable short circuit is shown in Fig. 19-12C. The walls of the waveguide and the surface of the plunger form a half-wavelength channel. Because the metallic end of the channel is a short circuit, the impedance reflected back to the front of the plunger is zero ohms, or nearly so. Thus, a virtual short exists at the points shown. By this means, the contact (or joint) resistance problem is overcome.

Waveguide joints and bends

Joints and bends in any form of transmission line or waveguide are seen as impedance discontinuities, and so are points at which disruptions occur. Thus, improperly formed bends and joints are substantial contributors to a poor VSWR. In general, bends, twists, joints, or abrupt changes in waveguide dimension can deteriorate the VSWR by giving rise to reflections.

Extensive runs of waveguide are sometimes difficult to make in a straight line. Although some installations do permit a straight waveguide, many others require directional change. This possibility is especially likely on shipboard installations. Figure 19-13A shows the proper ways to bend a waveguide around a corner. In each case, the radius of the bend must be at least two wavelengths at the lowest frequency that will be propagated in the system.

The “twist” shown in Fig. 19-13B is used to rotate the polarity of the E and H fields by 90°. This type of section is sometimes used in antenna arrays for phasing the elements. As in the case of the bend, the twist must be made over a distance of at least two wavelengths.

When an abrupt 90° transition is needed, it is better to use two successive 45° bends spaced one-quarter wavelength apart (see Fig. 19-13C). The theory (behind this kind of bend) is to cause the interference of the direct reflection of one bend, with the inverted reflection of the other. The resultant relationship between the fields is reconstructed as if no reflections had taken place.

Joints are necessary in practical waveguides because it simply isn't possible to construct a single length of practical size for all situations. Three types of common joints are used: *permanent, semipermanent,* and *rotating.*

To make a permanent joint the two waveguide ends must be machined extremely flat so that they can be butt-fitted together. A welded or brazed seam bonds the two sections together. Because such a surface represents a tremendous discontinuity, reflections and VSWR will result unless the interior surfaces are milled flat and then polished to a mirror-like finish.

A *semipermanent joint* allows the joint to be disassembled for repair and maintenance, as well as allowing easier on-site assembly. The most common example of this class is the *choke joint* shown in Fig. 19-14.

One surface of the choke joint is machined flat and is a simple butt-end planar flange. The other surface is the mate to the planar flange, but it has a quarter-wavelength circular slot cut at a distance of one-quarter wavelength from the waveguide aperture. The two flanges are shown in side view in Fig. 19-14A, and the slotted end view is shown in Fig. 19-14B. The method for fitting the two ends together is shown in the oblique view in Fig. 19-14C.

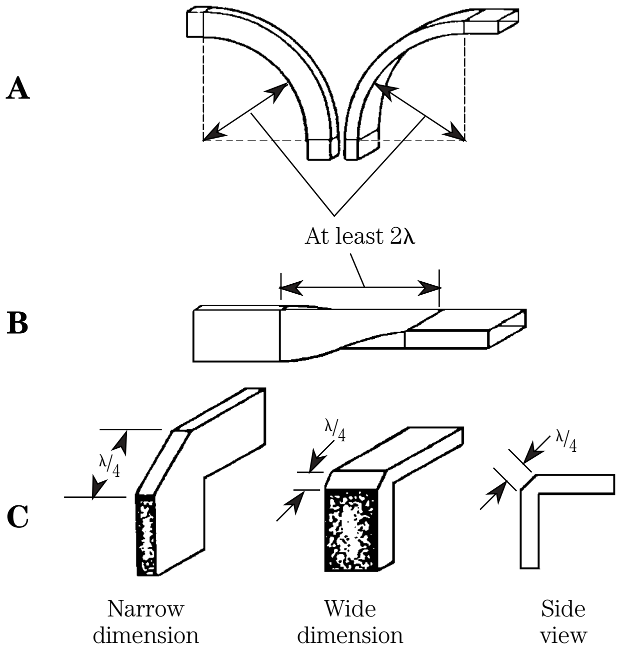

19-13 Bends in waveguide must be gentle.

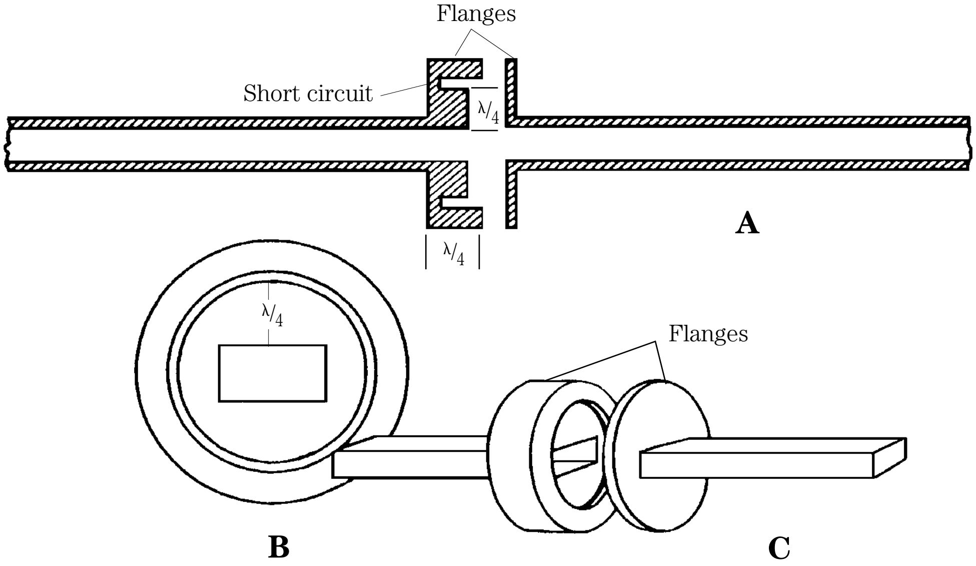

19-14 Choke joint.

Rotating joints are used in cases where the antenna has to point in different directions at different times. Perhaps the most common example of such an application is the radar antenna.

The simplest form of rotating joint is shown in Fig. 19-15. The key to its operation is that the selected mode is symmetrical about the rotating axis. For this reason, a circular waveguide operating in the TM_{01} mode is selected. In this rotating choke joint, the actual waveguide rotates but the internal fields do not (thereby minimizing reflections). Because most waveguide is rectangular, however, a somewhat more complex system is needed. Figure 19-16 shows a rotating joint consisting of two circular waveguide sections inserted between segments of rectangular waveguide. On each end of the joint, there is a rectangular-to-circular transition section.

In Fig. 19-16, the rectangular input waveguide operates in the TE_{10} mode that is most efficient for rectangular waveguide. The E-field lines of force couple with the circular segment, thereby setting up a TM_{01} mode wave. The TM_{01} mode has the required symmetry to permit coupling across the junction, where it meets another transition zone and is reconverted to TE_{10} mode.

Waveguide coupling methods

Except possibly for the case where an oscillator exists inside a waveguide, it is necessary to have some form of input or output coupling in a waveguide system. There are three basic types of coupling used in a microwave waveguide: *capacitive* (or *probe*), *inductive* (or *loop*), and *aperture* (or *slot*).

Capacitive coupling is shown in Fig. 19-17. This type of coupling uses a vertical radiator inserted into one end of the waveguide. Typically, the probe is a quarter-wavelength in a fixed-frequency system. The probe is analogous to the vertical antennas used at lower frequencies. A characteristic of this type of radiator is that the E field is parallel to the waveguide top and bottom surfaces. This arrangement satisfies the first boundary condition for the dominant TE_{10} mode.

The radiator is placed at a point that is a quarter-wavelength from the rear wall (Fig. 19-17B). By traversing the quarter-wave distance (90° phase shift), being reflected from the rear wall (180° phase shift), and then retraversing the

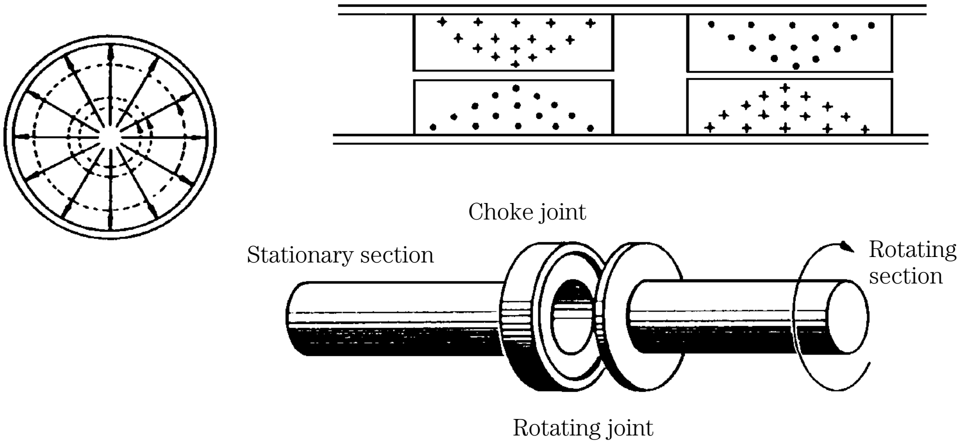
Choke joint
Stationary section
Rotating section
Rotating joint

19-15 Basic rotating joint.

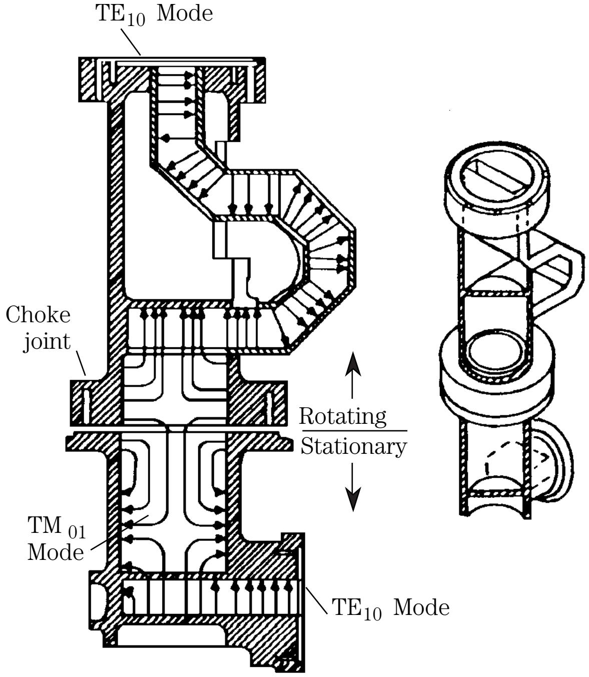
TE$_{10}$ Mode
Choke joint
Rotating
Stationary
TM $_{01}$ Mode
TE$_{10}$ Mode

19-16
Representative practical rotating joint.

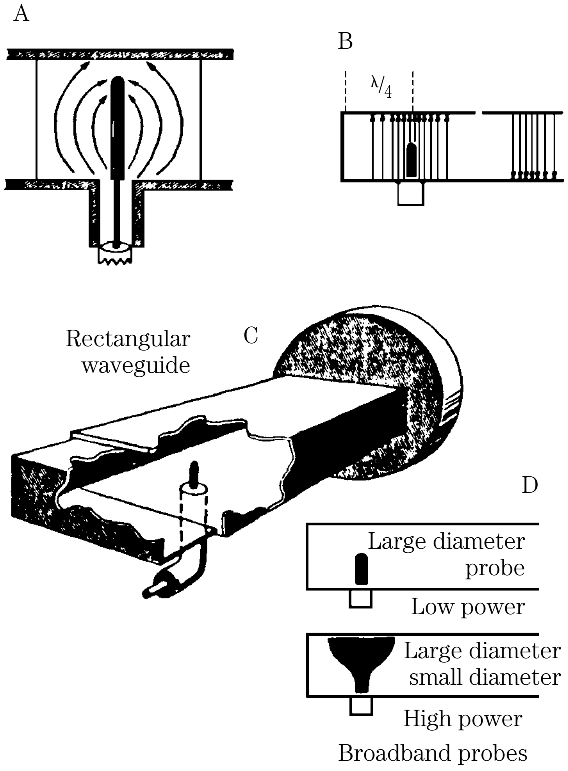

19-17
Probe (capacitive) coupling.

quarter-wavelength distance (another 90° phase shift), the wave undergoes a total phase shift of one complete cycle, or 360°. Thus, the reflected wave arrives back at the radiator in phase to reinforce the outgoing wave. Hence, none of the excitation energy is lost.

Some waveguides have an adjustable end cap (Fig. 19-17C) in order to accommodate multiple frequencies. The end cap position is varied to accommodate the different wavelength signals.

Figure 19-17D shows high- and low-power broadband probes that are typically not a quarter-wavelength except at one particular frequency. Broadbanding is accomplished by attention to the diameter-to-length ratio. The *degree of coupling* can be varied in any of several ways: the *length* of the probe can be varied; the *position* of the probe in the E field can be changed; or *shielding* can be used to partially shade the radiator element.

Inductive, or loop coupling, is shown in Fig. 19-18. A small loop of wire (or other conductor) is placed such that the number of magnetic flux lines is maximized. This form of coupling is popular on microwave receiver antennas, in order to make a waveguide-to-coaxial cable transition. In some cases, the loop is formed by the pigtail lead of a detector diode that, when combined with a local oscillator, downconverts the microwave signal to an IF frequency in the 30- to 300-MHz region.

Aperture, or slot coupling, is shown in Fig. 19-19. This type of coupling is used to couple together two sections of waveguide, as on an antenna feed system. Slots can be designed to couple either electric, magnetic, or electromagnetic fields. In Fig. 19-19, slot *A* is placed at a point where the E field peaks, so it allows electrical field coupling. Similarly, slot *B* is at a point where the H field peaks, so it allows magnetic field coupling. Finally, we see slot *C*, which allows electromagnetic field coupling.

Slots can also be characterized according to whether they are *radiating* or *nonradiating.* A nonradiating slot is cut at a point that does not interrupt the flow of currents in the waveguide walls. The radiating slot, on the other hand, does interrupt currents flowing in the walls. A radiating slot is the basis for several forms of antenna, which are discussed at the end of this chapter.

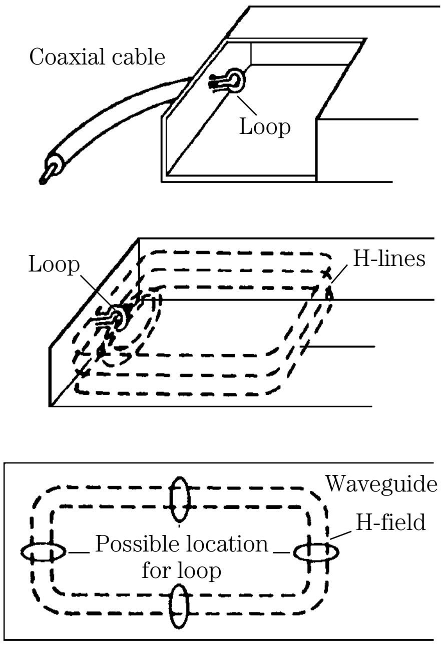

19-18
Loop (inductive) coupling.

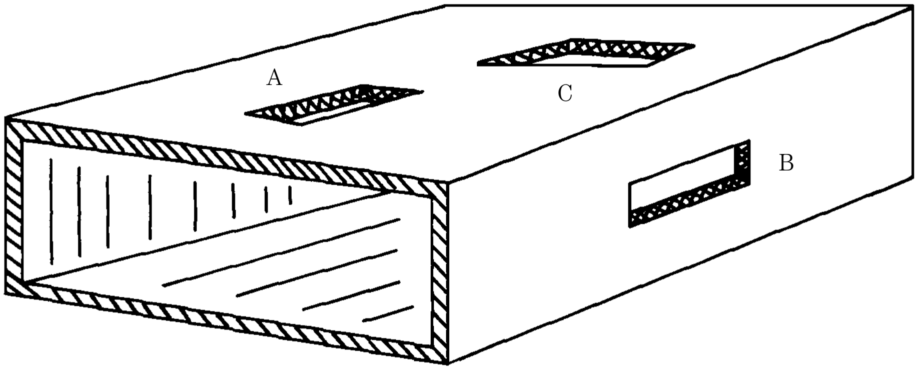

19-19 Slot coupling.

Microwave antennas

Antennas are used in communications and radar systems at frequencies from the very lowest to the very highest. In both theory and practice, antennas are used until frequencies reach infrared and visible light, at which point optics becomes more important. Microwaves are a transition region between ordinary "radio waves" and "optical waves," so (as might be expected) microwave technology makes use of techniques from both worlds. For example, both dipoles and parabolic reflectors are used in microwave systems.

The purpose of an antenna is to act as a *transducer* between either electrical oscillations or propagated "guided waves" (i.e., in transmission lines or waveguides) and a propagating electromagnetic wave in free space. A principal function of the antenna is to act as an *impedance matcher* between the waveguide, or transmission line, impedance and the impedance of free space.

Antennas can be used equally well for both receiving and transmitting signals because they obey the *law of reciprocity.* That is, the same antenna can be used to both receive and transmit with equal success. Although there might be practical or mechanical reasons to prefer specific antennas for one or the other mode, electrically they are the same.

In the transmit mode, the antenna must radiate electromagnetic energy. For this job, the important property is *gain* G. In the receive mode, the job of the antenna is to gather energy from impinging electromagnetic waves in free space. The important property for receiver antennas is the *effective aperture* A_e, which is a function of the antenna's physical area. Because of reciprocity, a large gain usually infers a large effective aperture and vice versa. *Effective aperture* is defined as the area of the impinging radio wavefront that contains the same power as is delivered to a matched resistive load across the feedpoint terminals.

The isotropic "antenna"

Antenna definitions and specifications can become useless unless a means is provided for putting everything on a common footing. Although a variety of systems exist for describing antenna behavior, the most common system compares a specific antenna with a theoretical construct, called the *isotropic radiator.*

An isotropic radiator is a spherical point source that radiates equally well in all directions. By definition, the directivity of the isotropic antenna is unity (1), and all antenna gains are measured against this standard. Because the geometry of the sphere and the physics of radiation are well known, we can calculate field strength and power density at any point. These figures can then be compared with the actual values from an antenna being tested. From spherical geometry, we can calculate isotropic power density at any distance R from the point source:

$$P_d = \frac{P}{4\pi R^2} \qquad \textbf{[19.19]}$$

where

P_d is the power density, in watts per square meter
P is the power in watts input to the isotropic radiator
R is the radius in meters at which point power density is measured

Example 19-5 Calculate the power density at a distance of 1 km (1000 m) from a 1000-W isotropic source.

Solution:

$$P_d = \frac{P}{4\pi R^2}$$

$$= \frac{(1000\text{ W})}{4\pi\,(1000\text{ m})^2}$$

$$= 7.95 \times 10^{-5}\text{ W/m}^2$$

The rest of this chapter covers antenna gains and directivities that are relative to isotropic radiators.

Near field and far field

Antennas are defined in terms of *gain* and *directivity,* both of which are measured by looking at the radiated field of the antenna. There are two fields to consider: *near field* and *far field.* The patterns published for an antenna tend to reflect far-field performance. The far field for most antennas falls off according to the *inverse square law.* That is, the intensity falls off according to the square of the distance ($1/R^2$), as in Eq. 19.19.

The near field of the antenna contains more energy than the far field because of the electric and magnetic fields close to the antenna radiator element. The near field tends to diminish rapidly according to a $1/R^4$ function. The minimum distance to the edge of the near field is a function of both the wavelength of the radiated signals and the antenna dimensions:

$$r_{\min} = \frac{2\,d^2}{\lambda} \qquad \textbf{[19.20]}$$

where

$r_{\min}$ is the near-field distance
d is the largest antenna dimension
λ is the wavelength of the radiated signal (all factors in the same units)

Example 19-6 An antenna with a length of 6 cm radiates a 12-cm wavelength signal. Calculate the near-field distance.

Solution:

$$r_{\min} = \frac{2d^2}{\lambda}$$

$$= \frac{(2)\,(6\text{ cm})^2}{12\text{ cm}}$$

$$= \frac{72}{12} = 6\text{ cm}$$

Antenna impedance

Impedance represents the total opposition to the flow of alternating current (e.g., RF), and includes both resistive and reactive components. The reactive components can be either capacitive or inductive, or a combination of both. Impedance can be expressed in either of two notations:

$$Z = \sqrt{R^2 + (X_L - X_c)^2} \qquad \textbf{[19.21]}$$

or

$$Z = R \pm jX \qquad \textbf{[19.22]}$$

Of these, Eq. 19.22 is perhaps the more commonly used in RF applications. The reactive part of antenna impedance results from the magnetic and electrical fields (close to the radiator) returning energy to the antenna radiator during every cycle. The resistive part of impedance consists of two elements: *ohmic losses* R_o and *radiation resistance* R_r. The ohmic losses are due to heating of the antenna conductor elements by RF current passing through, as when current passes through any conductor.

The radiation resistance relates to the radiated energy. An efficiency factor k compares the loss and radiation resistances:

$$k = \frac{R_r}{R_r + R_o} \qquad \textbf{[19.23]}$$

The goal of the antenna designer is to reduce R_o to a minimum. The value of R_r is set by the antenna design and installation, and is defined as the quotient of the voltage over the current at the feedpoint, less losses.

Dipole antenna elements

The *dipole* is a two-pole antenna (Fig. 19-20) that can be modeled as either a single radiator fed at the center (Fig. 19-20A) or a pair of radiators fed back to back (Fig. 19-20B). RF current from the source oscillates back and forth in the radiator element, causing an electromagnetic wave to propagate in a direction *perpendicular* to the radiator element. The polarity of any electromagnetic field is the direction of the electrical field vector (see Chap. 2). In the dipole, the polarization is parallel to the radiator element: a horizontal element produces a horizontally polarized signal, while a vertical element produces a vertically polarized signal.

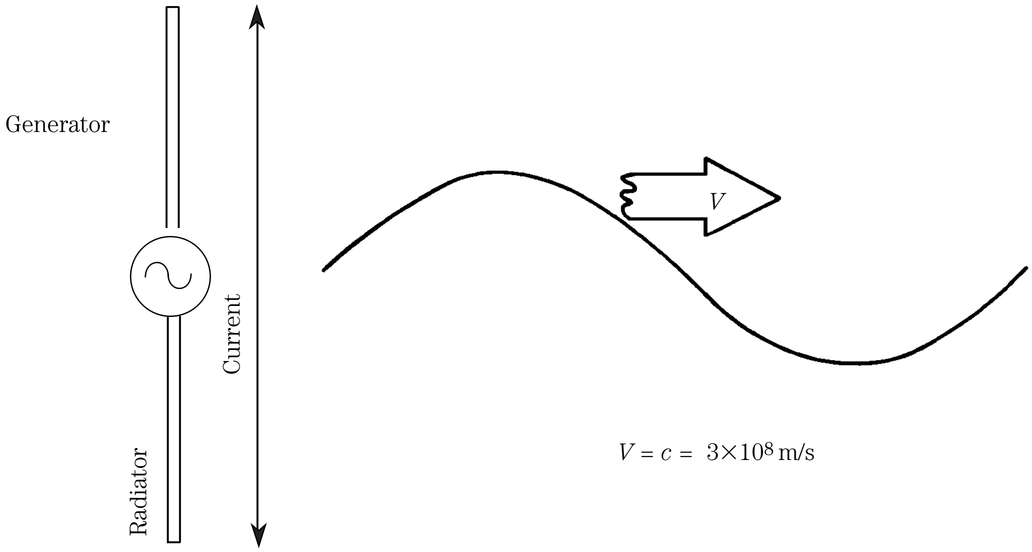

19-20A Basic dipole antenna showing propagation.

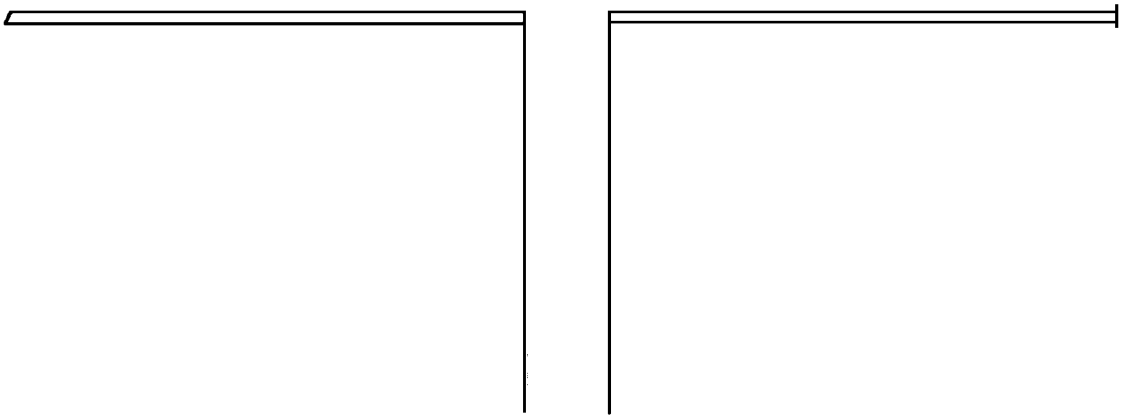

19-20B Basic dipole antenna.

Figure 19-21 shows the radiator patterns for the dipole viewed from two perspectives. Figure 19-21A shows the pattern of a horizontal half-wavelength dipole as viewed from above. This plot shows the *directivity* of the dipole: maximum radiation is found in two lobes perpendicular to the radiator length. The plot in Fig. 19-21B shows the end-on pattern of the dipole. This omnidirectional pattern serves for a vertically polarized dipole viewed from above. The end-on pattern of a horizontal dipole would be similar, except that it is distorted by ground effects unless the antenna is a very large number of wavelengths above the ground.

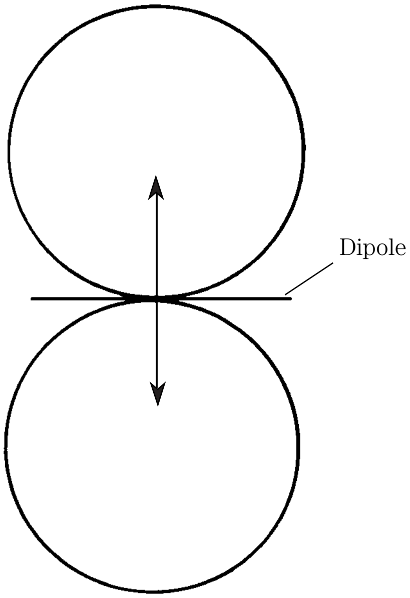

19-21A
Dipole pattern (horizontal).

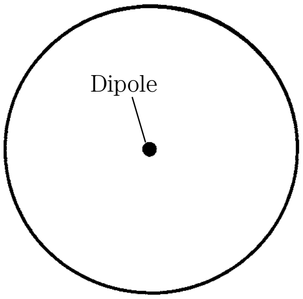

19-21B
Dipole pattern (vertical).

A microwave dipole is shown in Fig. 19-22. The antenna radiator element consists of a short conductor at the end of a section of waveguide. Although most low-frequency dipoles are a half-wavelength, microwave dipoles might be either a half-wavelength, less than a half-wavelength, or greater than a half-wavelength, depending upon application. For example, because most microwave dipoles are used to illuminate a reflector antenna of some sort, the length of the dipole depends upon the exact illumination function required for proper operation of the reflector. Most, however, will be a half-wavelength.

Antenna directivity and gain

The dipole discussed illustrated a fundamental property of the type of antenna generally used at microwave frequencies: *directivity* and *gain.* These two concepts are different but so interrelated that they are usually discussed at the same time. Because of the directivity, the antenna focuses energy in only two directions, which means that all of the energy is found in those directions (Fig. 19-21A), rather than being distributed over a spherical surface. Thus, the dipole has a gain approximately 2.1 dB greater than isotropic. In other words, the measured power density at any point will be 2.1 dB higher than the calculated isotropic power density for the same RF input power to the antenna.

Directivity The directivity of an antenna is a measure of its ability to direct RF energy in a limited direction, rather than in all (spherical) directions equally. As shown in Fig. 19-21A, the horizontal directivity of the dipole forms a bidirectional figure-8 pattern. Two methods for showing unidirectional antenna patterns are shown in Fig. 19-23. The method of Fig. 19-23A is a polar plot viewed from above. The main lobe is centered on 0°. The plot of Fig. 19-23B is a rectangular method for displaying the same information. This pattern follows a (sin x)/x function or, for power, $[(\sin x)/x]^2$.

Directivity D is a measure of relative power densities:

$$D = \frac{P_{\text{max}}}{P_{\text{av}}} \tag{19.24}$$

Or, referenced to isotropic,

$$D = \frac{4\pi}{\Phi} \tag{19.25}$$

where

D is the directivity
P_{max} is the maximum power
P_{av} is the average power
Φ is the solid angle subtended by the main lobe

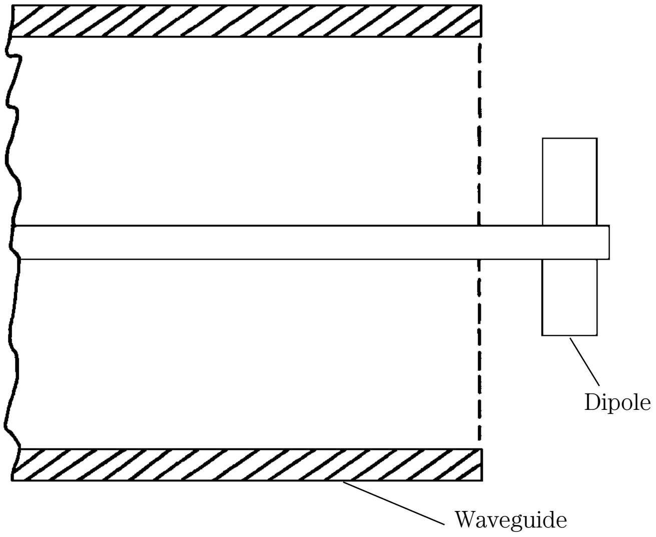

19-22
Microwave dipole radiator.

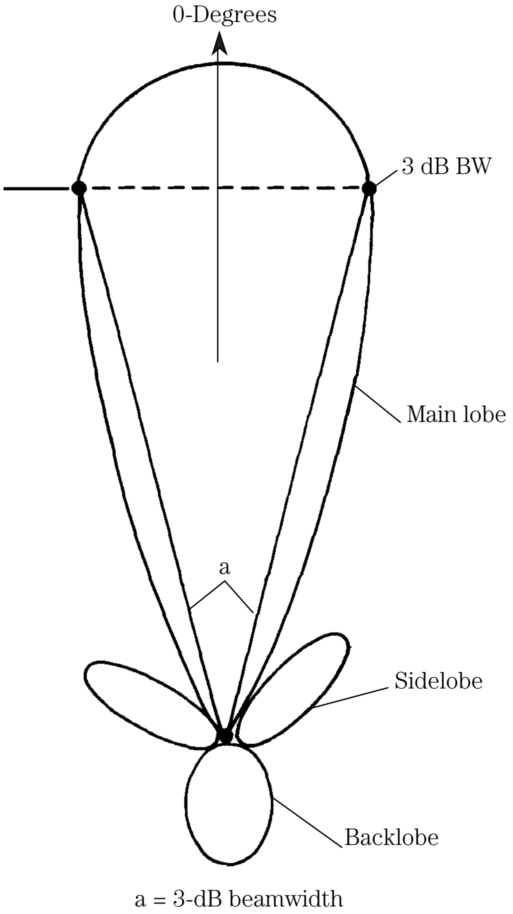

19-23A
Directional antenna pattern (top view).

The term Φ is a solid angle, which emphasizes the fact that antenna patterns must be examined in at least two extents: horizontal and vertical.

A common method for specifying antenna directivity is *beamwidth* (BW). The definition of BW is the angular displacement between points on the main lobe (see Figs. 19-23A and 19-23B), where the power density drops to one-half (−3 dB) of its maximum main lobe power density. This angle is shown in Fig. 19-23A as *a*.

In an ideal antenna system, 100 percent of the radiated power is in the main lobe, and there are no other lobes. But in real antennas certain design and installation anomalies cause additional minor lobes, such as the *sidelobes* and *backlobe* shown in Fig. 19-23A. Several problems derive from the minor lobes. First is the loss of usable power. For a given power density required at a distant receiver site, the transmitter must supply whatever additional power is needed to make up for the minor lobe losses.

The second problem is intersystem interference. A major application of directional antennas is the prevention of mutual interference between nearby cochannel stations. In radar systems, high sidelobes translate to errors in detected targets. If, for example, a sidelobe is large enough to detect a target, then the radar display will show this off-axis target as if it was in the main lobe of the antenna. The result is an azimuth error that could be important in terms of marine and aeronautical navigation.

Gain Antenna gain derives from the fact that energy is squeezed into a limited space instead of being distributed over a spherical surface. The term *gain* implies that the antenna creates a higher power when, in fact, it merely concentrates the power into a single direction that would otherwise be spread out over a larger area. Even so, it is possible to speak of an apparent increase in power. Antenna-transmitter systems are often rated in terms of *effective radiated power* (ERP). The ERP is the product of the transmitter power and the antenna gain. For example, if an antenna has a gain of +3 dB, the ERP will be twice the transmitter output power. In other words, a 100-W output transmitter connected to a +3-dB antenna will produce a power density at a distant receiver equal to a 200-W transmitter feeding an isotropic radiator. There are two interrelated gains to be considered: *directivity gain* G_d *and power gain* G_p.

The directivity gain is defined as the quotient of the maximum radiation intensity over the average radiation intensity (note the similarity to the directivity definition). This measure of gain is based on the shape of the antenna radiation pattern, and can be calculated with respect to an isotropic radiator ($D=1$) from:

$$G_d = \frac{4\pi P_a}{P_r} \qquad \textbf{[19.26]}$$

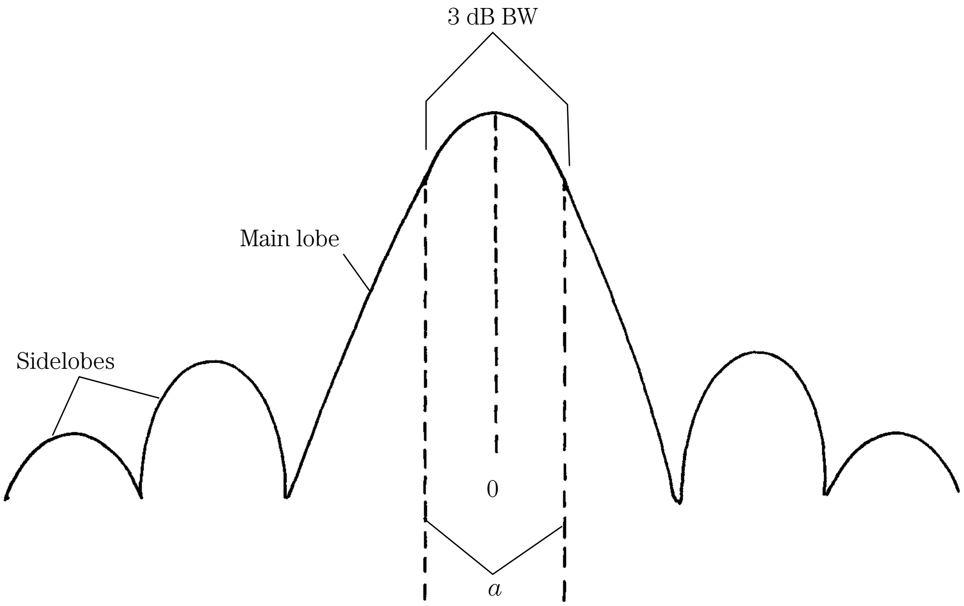

19-23B Graphically presented pattern.

where

G_d is the directivity gain
P_a is the maximum power radiated per unit of solid angle
P_r is the total power radiated by the antenna

The power gain is similar in nature, but slightly different from directivity gain; it includes dissipative losses in the antenna. Not included in the power gain are losses caused by cross-polarization or impedance mismatch between the waveguide (or transmission line) and the antenna. There are two commonly used means for determining power gain:

$$G_p = \frac{4\pi P_a}{P_n} \qquad \textbf{[19.27]}$$

and

$$G_p = \frac{P_{\mathrm{ai}}}{P_i} \qquad \textbf{[19.28]}$$

where

P_a is the maximum radiated per unit solid angle
P_n is the net power accepted by the antenna (i.e., less mismatch losses)
P_{ai} is the average intensity at a distant point
P_i is the intensity at the same point from an isotropic radiator fed the same RF power level as the antenna

(Equations assume equal power to antenna and comparison isotropic source.)

Provided that ohmic losses are kept negligible, the relationship between directivity gain and power gain is given by:

$$G_p = \frac{P_r G_d}{P_n} \qquad \textbf{[19.29]}$$

(All terms as previously defined.)

Relationship of gain and aperture Antennas obey the law of reciprocity, which means that any given antenna will work as well to receive as to transmit. The function of the receiver antenna is to gather energy from the electromagnetic field radiated by the transmitter antenna. The aperture is related to, and often closely approximates, the physical area of the antenna. But in some designs the effective aperture A_e is less than the physical area A, so there is an effectiveness factor n that must be applied. In general, however, a high-gain transmitter antenna also exhibits a high receiving aperture, and the relationship can be expressed as

$$G = \frac{4\,\pi A_e n}{\lambda^2} \qquad \textbf{[19.30]}$$

where

A_e is the effective aperture
n is the aperture effectiveness ($n=1$ for a perfect, lossless antenna)
λ is the wavelength of the signal

Horn antenna radiators

The horn radiator is a tapered termination of a length of waveguide (see Fig. 19-24 (A-C) that provides the impedance transformation between the waveguide impedance and the free-space impedance. Horn radiators are used both as antennas in their own right, and as illuminators for reflector antennas. Horn antennas are not a perfect match to the waveguide, although standing wave ratios of 1.5:1 or less are achievable. The gain of a horn radiator is proportional to the area A of the flared open flange ($A = ab$ in Fig. 19-24B), and inversely proportional to the square of the wavelength:

$$G=\frac{10A}{\lambda^2} \qquad \textbf{[19.31]}$$

where

A is the flange area
λ is the wavelength (both in same units)

The −3-dB beamwidth for vertical and horizontal extents can be approximated from:

Vertical

$$\Phi_v = \frac{51\lambda}{b} \quad \text{degrees} \qquad \textbf{[19.32]}$$

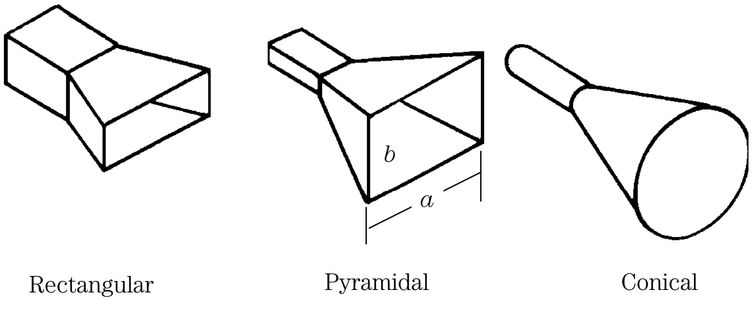

19-24 Horn radiators.

Horizontal

$$\Phi_h = \frac{70\lambda}{a} \qquad \text{degrees} \qquad \textbf{[19.33]}$$

where

Φ_v is the vertical beamwidth, in degrees
Φ_h is the horizontal beamwidth, in degrees
a, b are dimensions of the flared flange
λ is the wavelength

A form of antenna, related to the horn, is the cavity antenna of Fig. 19-25. In this type of antenna, a quarter-wavelength radiating element extends from the waveguide (or transmission line connector) into a resonant cavity. The radiator element is placed a quarter-wavelength into a resonant cavity; and is spaced a quarter-wavelength from the rear wall of the cavity. A tuning disk is used to alter cavity dimensions in order to provide a limited tuning range for the antenna. Gains to about 6 dB are possible with this arrangement.

Reflector antennas

At microwave frequencies, it becomes possible to use *reflector antennas* because of the short wavelengths involved. Reflectors are theoretically possible at lower frequencies, but because of the longer wavelengths, the antennas would be so large that they become impractical. Several forms of reflector are used (Figs. 19-26 and 19-27). In Fig. 19-26 we see the *corner reflector* antenna, which is used primarily in the high-UHF and low-microwave region. A dipole element is placed at the “focal point” of the corner reflector, so it receives (in phase) the reflected wavefronts from the surface. Either solid metallic reflector surfaces or wire mesh may be used. When mesh is used, however, the holes in the mesh must be $\frac{1}{12}$-wavelength or smaller.

Figure 19-27 shows several other forms of reflector surface shape, most of which are used in assorted radar applications.

Parabolic “dish” antennas

The parabolic reflector antenna is one of the most widespread of all the microwave antennas, and is the type that normally comes to mind when thinking of microwave systems. This type of antenna derives its operation from physics similar to optics, and is possible because microwaves are in a transition region between ordinary radio waves and infrared/visible light.

The dish antenna has a paraboloid shape as defined by Fig. 19-28. In this figure, the dish surface is positioned such that the center is at the origin (0,0) of an x-y coordinate system. For purposes of defining the surface, we place a second vertical axis called the *directrix* (y') a distance behind the surface equal to the focal length (u). The paraboloid surface follows the function $y^2 = 4ux$, and has the property that a line from the focal point F to any point on the surface is the same length as a line from that same point to the directrix (in other words, MN = MF).

If a radiator element is placed at the focal point F, then it will illuminate the reflector surface, causing wavefronts to be propagated away from the surface in

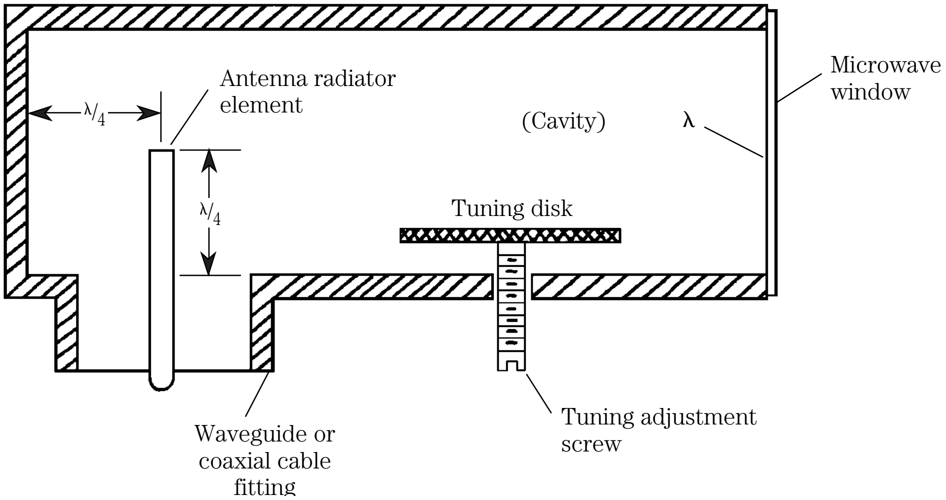
Antenna radiator element
Microwave window
λ/4
(Cavity)
λ
λ/4
Tuning disk
Waveguide or coaxial cable fitting
Tuning adjustment screw

19-25 Cavity antenna.

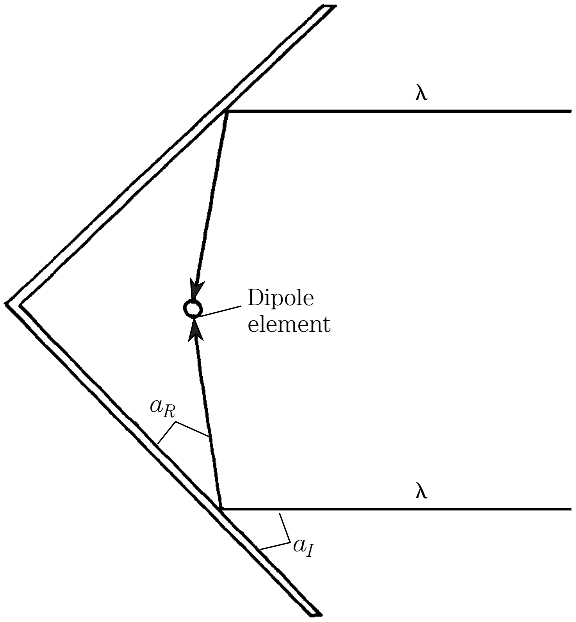
λ
Dipole element
a_R
λ
a_I

19-26 Corner reflector.

phase. Similarly, wavefronts, intercepted by the reflector surface, are reflected to the focal point.

Gain The gain of a parabolic antenna is a function of several factors: dish diameter, feed illumination, and surface accuracy. The dish diameter *D* should be large compared with its depth. Surface accuracy refers to the degree of surface irregularities. For commercial antennas, $\frac{1}{8}$-wavelength surface accuracy is usually sufficient,

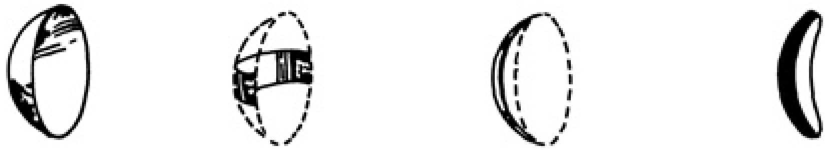

A. Paraboloid

B. Truncated paraboloid (surface search)

C. Truncated paraboloid (height finding)

D. Orange-peel paraboloid

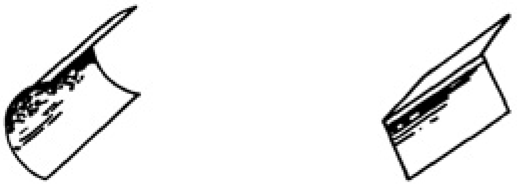

E. Cylindrical paraboloid

F. Corner reflector

19-27 Reflector antennas.

although on certain radar antennas the surface accuracy specification must be tighter.

The feed illumination refers to how evenly the feed element radiates to the reflector surface. For circular parabolic dishes, a circular waveguide feed produces optimum illumination, and rectangular waveguides are less than optimum. The TE_{11} mode is desired. For best performance, the illumination should drop off evenly from the center to the edge, with the edge being 210 dB down from the center. The diameter, length, and beamwidth of the radiator element (or horn) must be optimized for the specific *F/d* ratio of the dish. The cutoff frequency is approximated from

$$f_{\text{cutoff}} = \frac{175{,}698}{d_{\text{mm}}} \qquad \textbf{[19.34]}$$

where

f_{cutoff} is the cutoff frequency
d is the inside diameter of the circular feedhorn

The gain of the parabolic dish antenna is found from

$$G = \frac{k\,(\pi D)^2}{\lambda^2} \qquad \textbf{[19.35]}$$

where

G is the gain over isotropic
D is the diameter
λ is the wavelength (same units as D)
k is the reflection efficiency (0.4 to 0.7, with 0.55 being most common)

The −3-dB beamwidth of the parabolic dish antenna is approximated by

$$\mathrm{BW} = \frac{70\,\lambda}{D} \qquad \textbf{[19.36]}$$

and the focal length by

$$F = \frac{D^2}{16d} \qquad \textbf{[19.37]}$$

For receiving applications, the effective aperture is the relevant specification and is found from

$$A_e = k\pi(D/2)^2 \qquad \textbf{[19.38]}$$

The antenna pattern radiated by the antenna is similar to Fig. 19-23B. With horn illumination, the sidelobes tend to be 23 to 28 dB below the main lobe, or 10 to 15 dB below isotropic. It is found that 50 percent of the energy radiated by the parabolic dish is within the −3-dB beamwidth, and 90 percent is between the first nulls on either side of the main lobe.

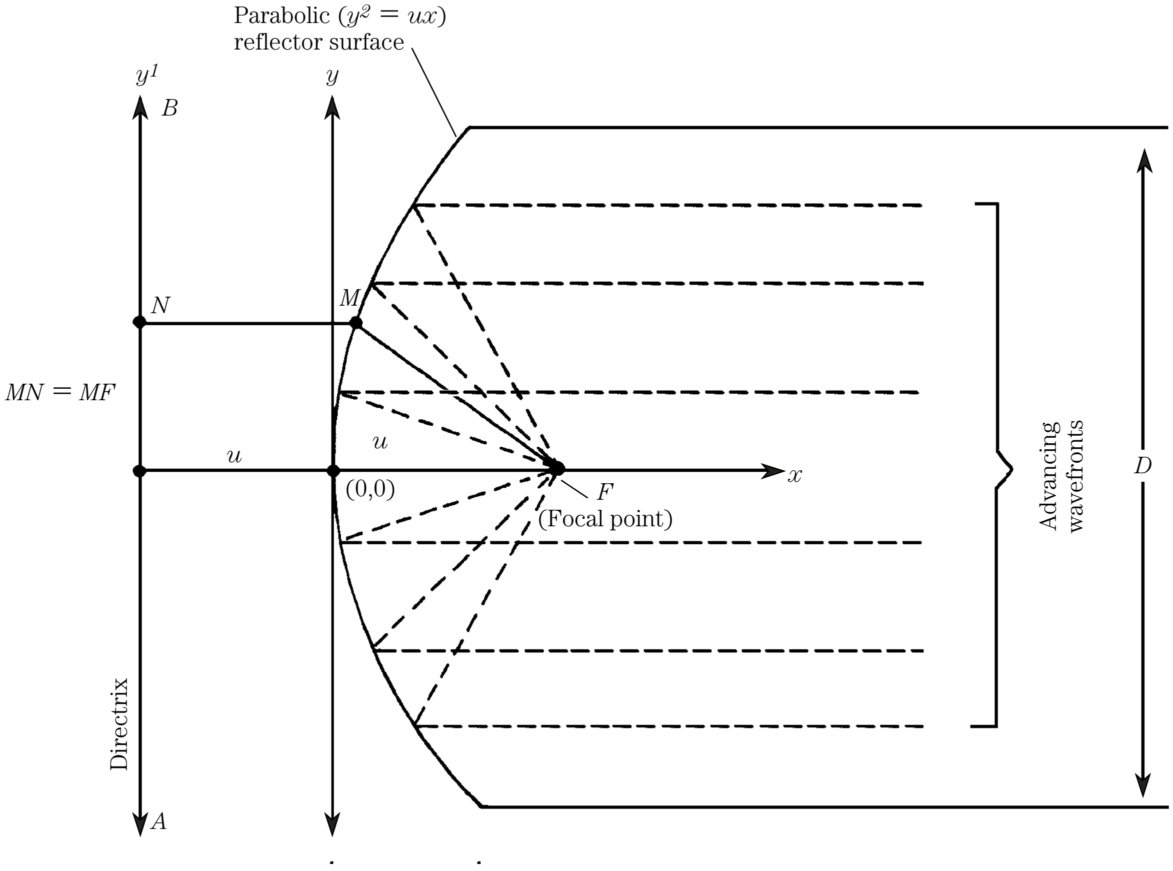
Parabolic ($y^2 = ux$)
reflector surface
y^1
y
B
N
M
$MN = MF$
u
u
(0,0)
F
(Focal point)
x
Directrix
A
Advancing wavefronts
D

19-28 Ray tracing shows operation of parabolic antenna.

If a dipole element is used for the feed device, then a *splash plate* is placed ¼-wavelength behind the dipole in order to improve illumination. The splash plate must be several wavelengths in diameter, and is used to reflect the backlobe back toward the reflector surface. When added to the half-wave phase reversal inherent in the reflection process, the two-way quarter-wavelength adds another half-wavelength and thereby permits the backwave to move out in phase with the front lobe wave.

Parabolic dish feed geometries Figure 19-29 shows two methods for feeding parabolic dish antennas, regardless of which form of radiator (horn, dipole, etc.) is used. In Fig. 19-29A we see the method in which the radiator element is placed at the focal point, and a waveguide (or transmission line) is routed to it. This method is used in low-cost installations such as home satellite TV receive-only (TVRO) antennas.

Figure 19-29B shows the *Cassegrain feed* system. This system is modeled after the Cassegrain optical telescope. The radiator element is placed at an opening at the center of the dish. A hyperbolic subreflector is placed at the focal point, and it is used to reflect the wavefronts to the radiator element. The Cassegrain system results in lower-noise operation because of several factors: less transmission line length, lower sidelobes, and the fact that the open horn sees sky instead of earth

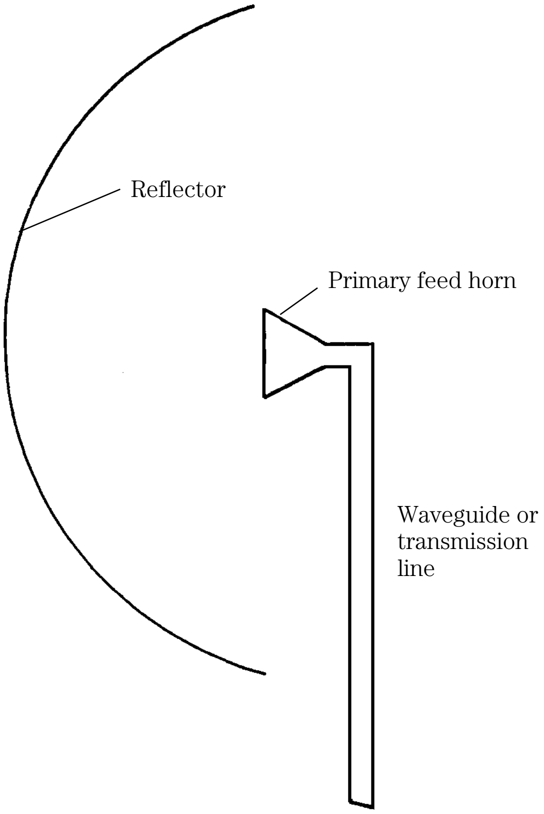

19-29A
Parabolic antenna conventional feed.

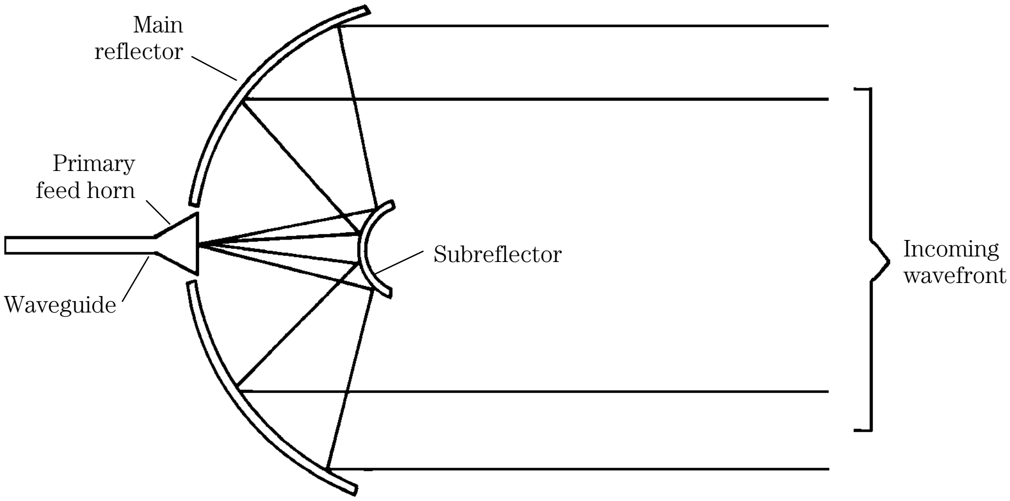

19-29B Parabolic antenna Cassegrain feed.

(which has lower temperature); on the negative side, galactic and solar noise might be slightly higher on a Cassegrain dish.

Figure 19-30A shows the *monopulse* feed geometry. In this system, a pair of radiator elements are placed at the focal point, and fed to a power splitter network that outputs both *sum* and *difference* signals (Fig. 19-30B). When these are combined, the resultant beam shape has improved −3-dB beamwidth as a result of the algebraic summation of the two.

Array antennas

When antenna radiators are arranged in a precision array, an increase in gain occurs. An array might be a series of dipole elements, as in the broadside array of Fig. 19-31 (which is used in the UHF region), or a series of slots, horns, or other radiators. The overall gain of an array antenna is proportional to the number of elements, as well as the details of their spacing. In this, and other antennas, a method of *phase shifting* is needed. In Fig. 19-31, the phase shifting is caused by the crossed feeding of the elements, but in more modern arrays, other forms of phase shifter are used.

Two methods of feeding an array are shown in Fig. 19-32. The *corporate feed* method connects all elements, and their phase shifters, in parallel with the source. The *branch feed* method breaks the waveguide network into two (or more) separate paths.

Solid-state array antennas Some modern radar sets use solid-state array antennas consisting of a large number of elements, each of which is capable of shifting the phase of a microwave input signal. Two forms are known: *passive* (Fig. 19-33A) and *active* (Fig. 19-33B). In the passive type of element, a ferrite (or PIN diode) phase shifter is placed in the transmission path between the RF input and the radiator element (usually a slot). By changing the phase of the RF signal selectively, it is possible to form and steer the beam at will. A 3-bit (i.e., three discrete state) phase

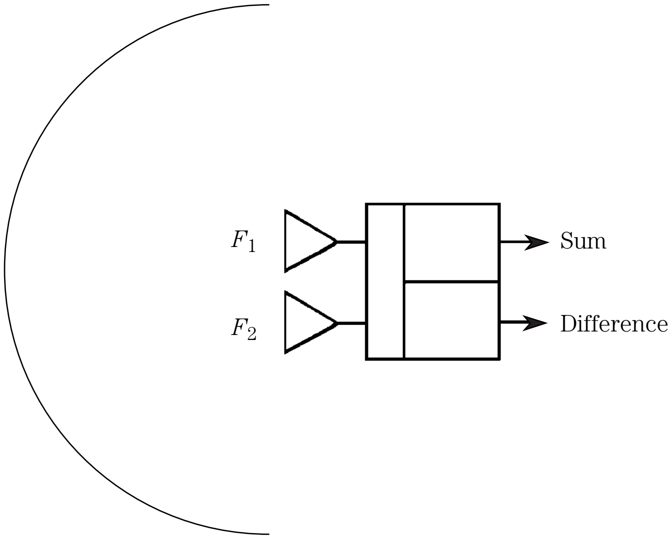
F_1
F_2
Sum
Difference

19-30A
Monopulse feed.

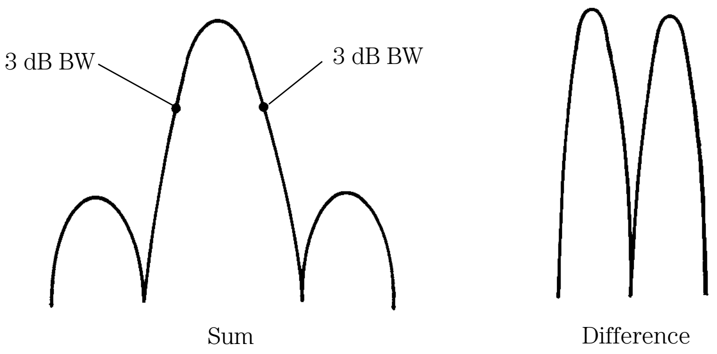

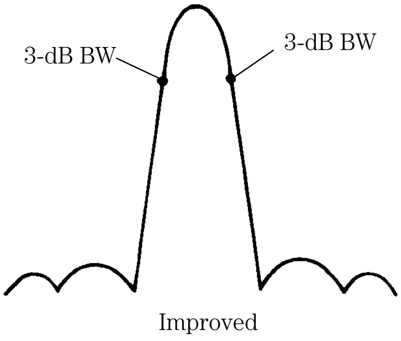

19-30B
Monopulse patterns.

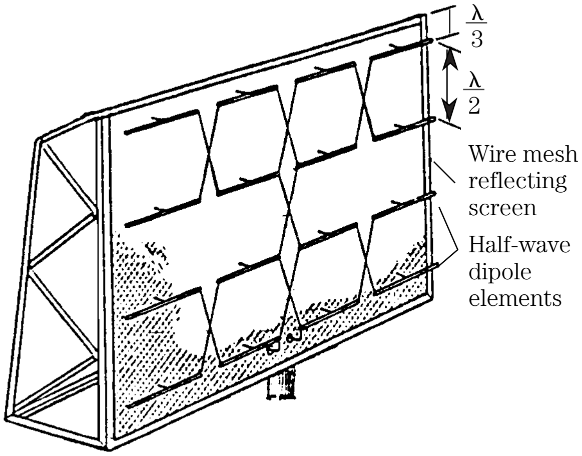

19-31
Reflector array antenna.

shifter allows the phase to shift in 45° increments, while a 4-bit phase shifter allows 22.5° increments of phase shift.

The active element contains, in addition to a phase shifter, a transmit power amplifier (1 or 2 W) and a low-noise amplifier (LNA) for receiving. A pair of transmit/receive (T/R) switches select the path to which the RF signal is directed. The total output power of this antenna is the sum of all output powers from all elements in the array. For example, an array of one thousand 2-W elements makes a 2000-W system.

Slot array antennas

A resonant slot (cut into a wall of a section of waveguide) is somewhat analogous, if not identical, to a dipole. By cutting several slots in the waveguide, we obtain the advantages of an array antenna in which the elements are several slot radiators. Slot array antennas are used for marine navigation radars, telemetry systems, and the reception of microwave television signals in the Multipoint Distribution Service (MDS) on 2.145 GHz.

Figure 19-34 shows a simple slot antenna used in telemetry applications. A slotted section of rectangular waveguide is mounted to a right-angle waveguide flange. An internal wedge (not shown) is placed at the top of the waveguide and serves as a matching-impedance termination to prevent internal reflected waves. Directivity is enhanced by attaching flanges to the slotted section of waveguide parallel to the direction of propagation (see end view of Fig. 19-34).

Figure 19-35 shows two forms of *flatplate array* antennas constructed from slotted waveguide radiator elements (shown as insets). Figure 19-35A shows the rectangular array, and Fig. 19-35B shows the circular array. These flatplate arrays are used extensively in microwave communications and radar applications.

The feed structure for a flatplate array is shown in Fig. 19-35C. The antenna element is the same sort as shown in Figs. 19-35A and 19-35B. A distribution waveguide is physically mated with the element, and a coupling slot is provided between the two waveguides. Energy propagating in the distribution system waveguide is

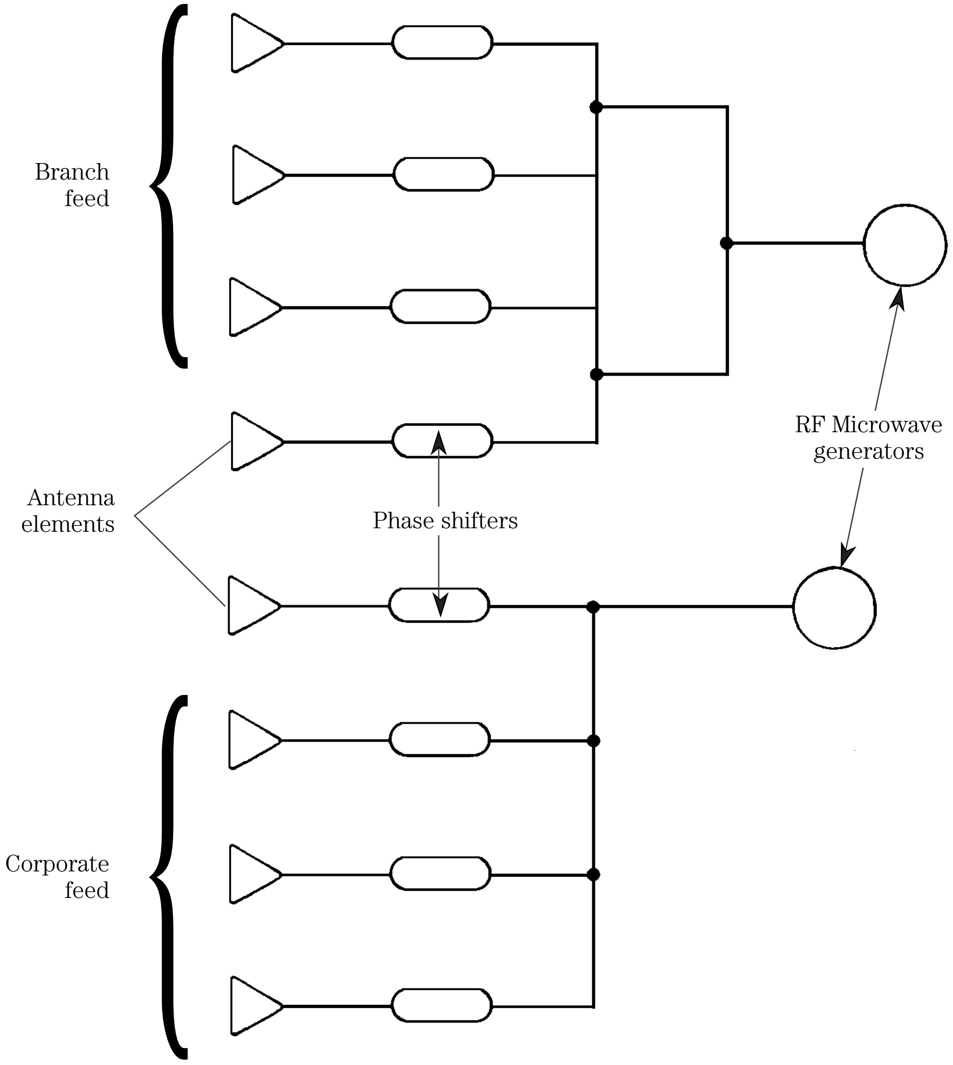
Branch feed
Antenna elements
Phase shifters
RF Microwave generators
Corporate feed

19-32 Branch feed and corporate feed.

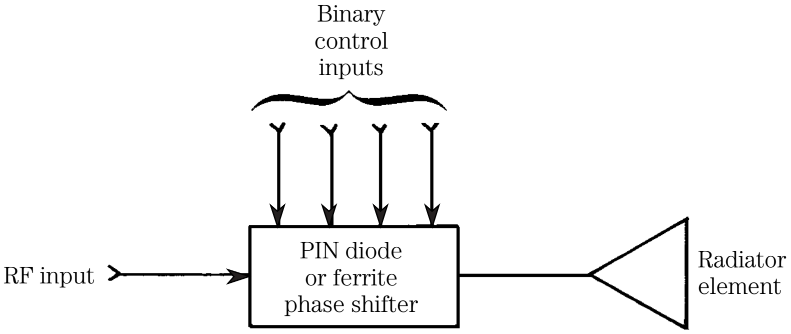
Binary control inputs
RF input
PIN diode or ferrite phase shifter
Radiator element

19-33A Phase shifter.

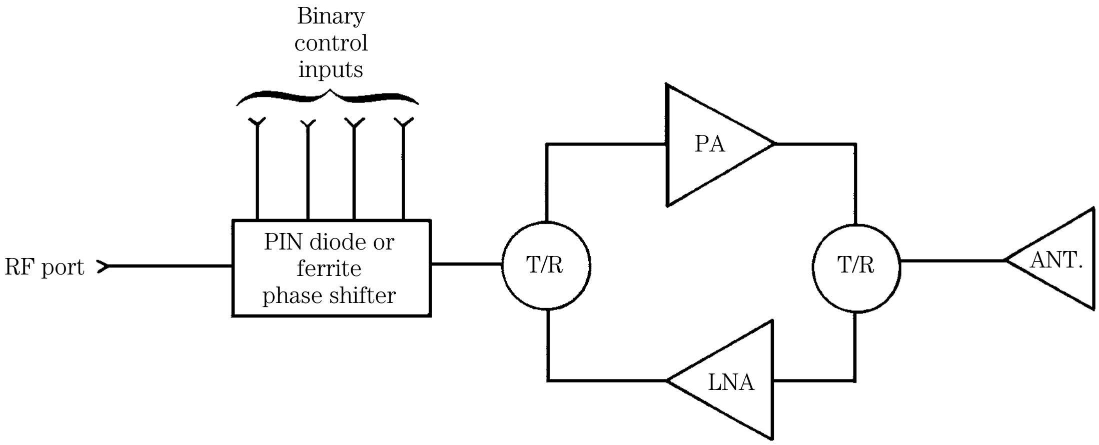
Binary
control
inputs
RF port
PIN diode or
ferrite
phase shifter
T/R
PA
LNA
T/R
ANT.

19-33B Phase-shift T/R element.

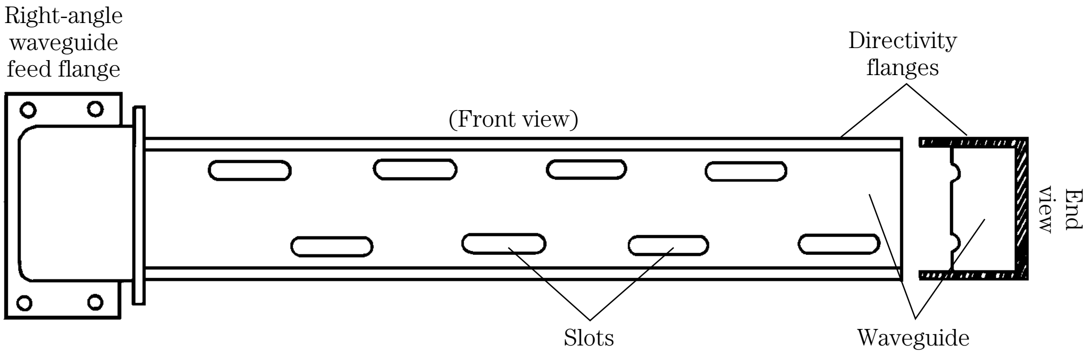
Right-angle
waveguide
feed flange
(Front view)
Directivity
flanges
End
view
Slots
Waveguide

19-34 Slot antenna (front view).

coupled into the antenna radiator element through this slot. In some cases metallic or dielectric phase-shifting stubs are also used in order to fine-tune the antenna radiation pattern.

Microwave antenna safety note

Microwave RF energy is dangerous to your health. Anything that can cook a roast beef can also cook you! The U.S. government sets a safety limit for microwave exposure of 10 mW/cm^2 averaged over 6 minutes; some other countries use a level one-tenth of the U.S. standard. The principal problem is tissue heating, and eyes seem especially sensitive to microwave energy. Some authorities believe that cataracts form from prolonged exposure. Some authorities also believe that genetic damage to offspring is possible as well as other long-term effects as a result of cumulative exposure.

Because of their relatively high gain, microwave antennas can produce hazardous field strengths in close proximity—even at *relatively low RF input power levels.* At

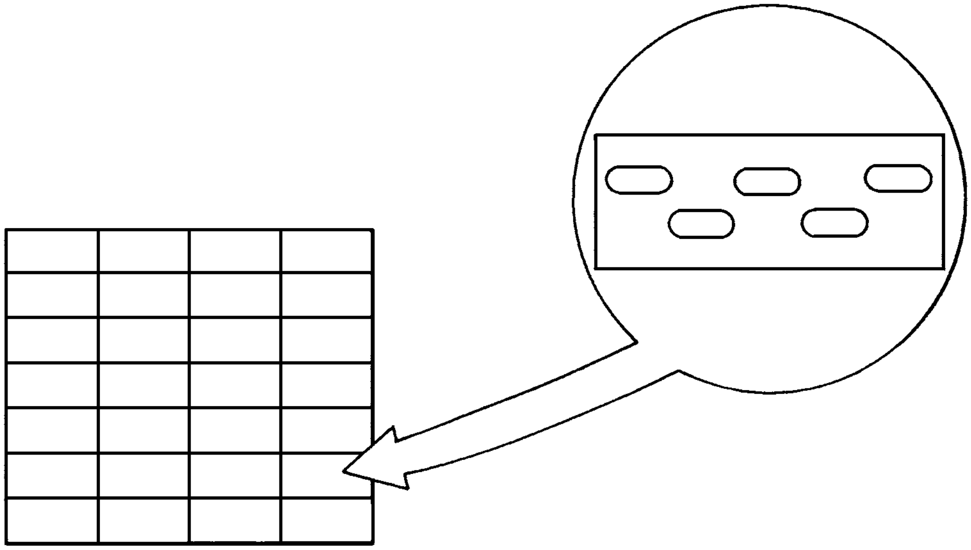

19-35A Flatplate slot array.

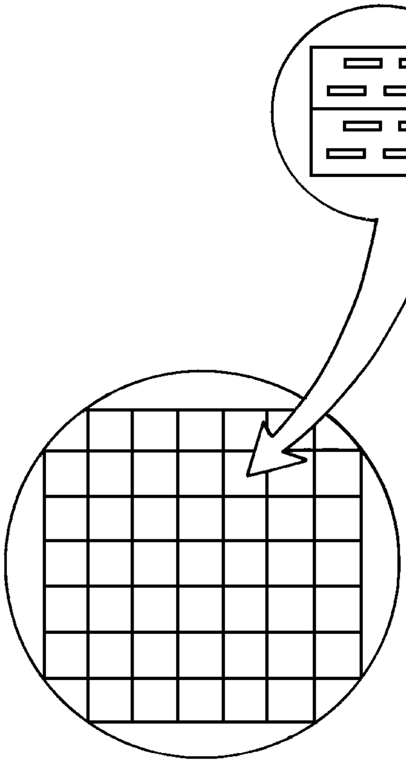

19-35B
Flatplate antenna.

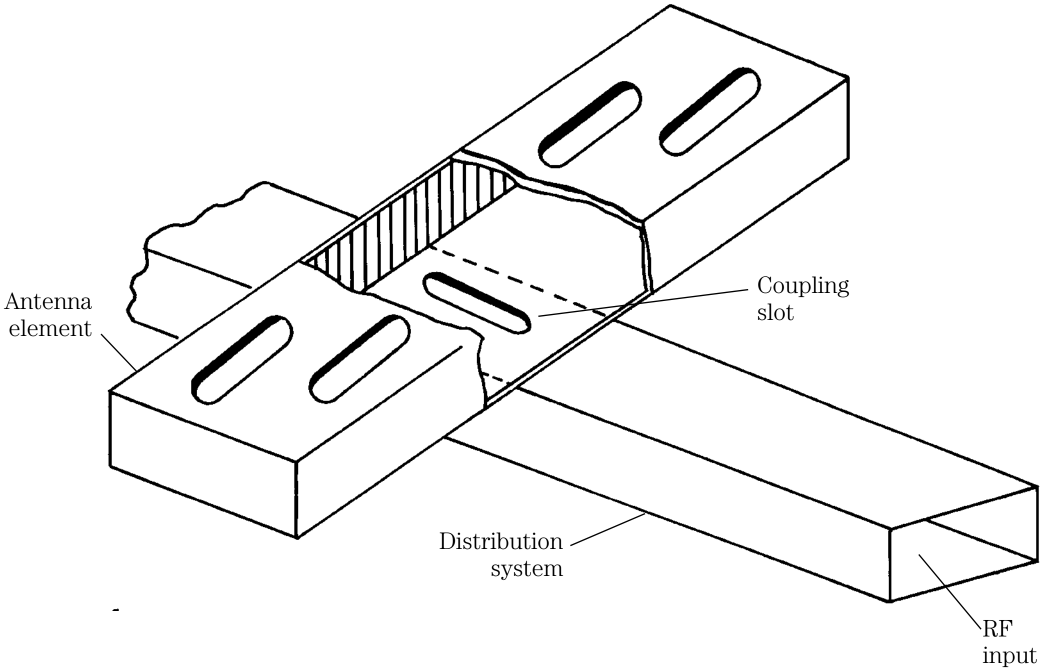

19-35C Flatplate antenna feed coupling.

least one technician in a TV satellite earth station suffered abdominal adhesions, solid matter in the urine, and genital dysfunction after servicing a 45-m-diameter 3.5-GHz antenna with RF power applied.

Be very careful around microwave antennas. Do not service a radiating antenna. When servicing nonradiating antennas, be sure to stow them in a position that prevents the inadvertent exposure of humans, should power accidentally be applied. A *Radiation Hazard* sign should be prominently displayed on the antenna. Good design practice requires an interlock system that prevents radiation in such situations. “Hot” transmitter service should be performed with a shielded dummy load replacing the antenna.

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20
CHAPTER

Antenna noise temperature

RADIO RECEPTION IS ESSENTIALLY A MATTER OF SIGNAL-TO-NOISE RATIO (SNR). SIGNALS must be some amplitude above the noise floor of the system in order to be received properly. All electronic systems (receivers and antennas included) have inherent noise, even if there is no power flowing in them. One of the goals of the antenna designer is to minimize the noise so that weak signals are not obscured. One of the basic forms of noise seen in systems is the *thermal noise.* Even if the amplifiers in the receiver add no additional noise (they will!), there will be thermal noise at the input.

If you replace the antenna with a resistor matched to the system impedance that is totally shielded, there will still be noise present. The noise is produced by the random motion of electrons inside the resistor. At all temperatures above absolute zero (about −273.16°C) the electrons in the resistor material are in random motion. At any given instant there will be a huge number of electrons in motion in all directions. The reason why there is no discernible current flow in one direction is that the motions cancel each other out even over short time periods. The noise power present in a resistor is:

$$P_N = KTBR \qquad \textbf{[20.1]}$$

where

P_N is the noise power, in watts
T is the temperature, in kelvins (K)
K is Boltzmann's constant (1.38×10^{-23} K)
B is the bandwidth, in hertz
R is the resistance, in ohms

Note: By international agreement T is set to 290 K.

Consider a receiver with a 1-MHz bandwidth and an input resistance of 50 Ω. The noise power is $(1.38 \times 10^{-23}\ \text{K}) \times (290\ \text{K}) \times (1{,}000{,}000\ \text{Hz}) \times (50\ \Omega) = 2 \times 10^{-13}$ W. This noise is called *thermal noise, thermal agitation noise,* or *Johnson noise.*

A resonant antenna can be modeled as an impedance consisting solely of a resistor with a value equal to the feedpoint impedance. If an antenna has a 50-Ω feedpoint

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impedance, then it will generate exactly the same amount of thermal noise as a resistor of the same value.

Noise factor, noise figure, and noise temperature

The noise performance of a receiving system can be defined in three different, but related, ways: *noise factor* F_n, *noise figure (NF),* and *equivalent noise temperature* T_e; these properties are definable as a simple ratio, decibel ratio, or kelvin temperature, respectively.

Noise factor (F_n)

For components such as resistors, the noise factor is the ratio of the noise produced by a real resistor to the simple thermal noise of an ideal resistor. The noise factor of a radio receiver (or any system) is the ratio of output noise power P_{no} to input noise power P_{ni}:

$$F_n = \left.\frac{P_{\mathrm{no}}}{P_{\mathrm{ni}}}\right|_{T=290\ \mathrm{K}} \tag{20.2}$$

In order to make comparisons easier, the noise factor is usually measured at the standard temperature (T_o) of 290 K (standardized room temperature), although in some countries 299 K or 300 K is commonly used (the differences are negligible).

It is also possible to define noise factor F_n in terms of output and input signal-to-noise ratios:

$$F_n = \frac{S_{\mathrm{ni}}}{S_{\mathrm{no}}} \tag{20.3}$$

where

S_{ni} is the input signal-to-noise ratio
S_{no} is the output signal-to-noise ratio

Noise figure (NF)

The noise figure is a frequently used measure of a receiver's "goodness," or its departure from "idealness." Thus, it is a *figure of merit.* The noise figure is the noise factor converted to decibel notation:

$$\mathrm{NF} = 10 \log F_n \tag{20.4}$$

where

NF is the noise figure, in decibels
F_n is the noise factor
LOG refers to the system of base 10 logarithms

Noise temperature (T_e)

The noise "temperature" is a means for specifying noise in terms of an equivalent temperature. Evaluating the noise equations shows that the noise power is directly proportional to temperature in kelvins, and also that noise power collapses to zero at the temperature of absolute zero (0 K).

Note that the equivalent noise temperature T_e is *not* the physical temperature of the amplifier, but rather a theoretical construct that is an *equivalent* temperature that produces that amount of noise power. The noise temperature is related to the noise factor by

$$T_e = (F_n - 1)\, T_o \qquad \textbf{[20.5]}$$

and to noise figure by

$$T_e = KT_o \log^{-1}\left(\frac{\mathrm{NF}}{10}\right) - 1 \qquad \textbf{[20.6]}$$

Noise temperature is often specified for receivers and amplifiers in combination with, or in lieu of, the noise figure. The noise temperature concept is also applied to antennas where it is related to the amount of thermal noise generated by the resistive component of the antenna feedpoint impedance.

The antenna-receiver system will be afflicted by three different noise sources external to the receiver. The first is the thermal noise temperature of the feedpoint impedance (T_R). The sky exhibits a noise temperature that depends on where the antenna main lobe is pointed. Similarly, the ground has a noise temperature that consists of components reflected from the sky as well as components of its own caused by whatever thermal agitation exists. In a typical system (Fig. 20-1) the

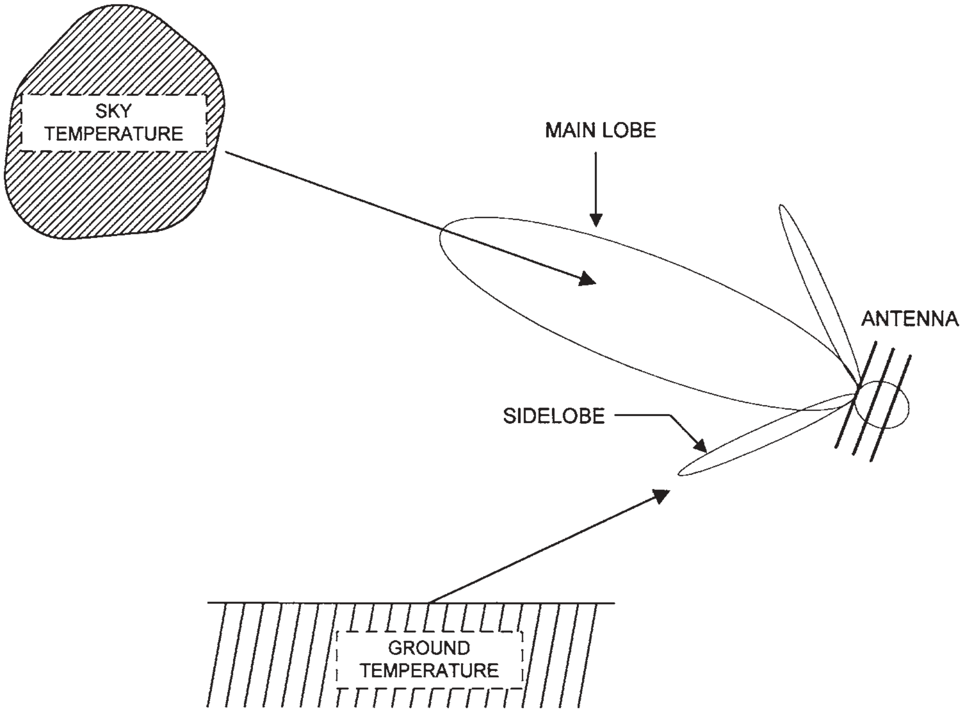

20-1 Contributors to antenna noise temperature.

main lobe will be pointed toward the sky noise source, while the sidelobes will pick up noise from the ground. The total noise temperature of the antenna is

$$T_{\mathrm{ANT}} = (M \times T_{\mathrm{SKY}}) + \xi\,(1 - M)T_{\mathrm{GND}} + T_R \qquad \textbf{[20.7]}$$

where

T_{ANT} is the equivalent noise temperature of the antenna
T_{SKY} is the noise temperature of the sky
T_{GND} is the noise temperature of the ground
T_R is the feedpoint resistance noise temperature
M is the fraction of the total energy that enters the main lobe
ξ is the fraction of sidelobes that are viewing the ground (only one of several sidelobes is shown in Fig. 20-1)

21
CHAPTER

Antennas for radio astronomy

FOR CENTURIES ASTRONOMERS HAVE SCANNED THE HEAVENS WITH OPTICAL TELESCOPES. But today, astronomers have many more tools in their bag, and one of them is *radio* astronomy. The field of radio astronomy emerged in the 1930s and 1940s through the work of Grote Reber and Carl Jansky. Even during World War II, progress was made as many tens of thousands of operators were listening to frequencies from dc to near daylight (well, actually, the low-end microwave bands). British radar operators noted during the Battle of Britain that the distance at which they could detect German aircraft dropped when the Milky Way was above the horizon.

Although there is a lot of amateur radio astronomy being done, most of it requires microwave equipment with low-noise front ends. However, there are several things that almost anyone can do.

The topic of antennas for radio astronomy can include nearly all forms of directional gain antenna. It is common to see Yagis, ring Yagis, cubical quads, and other antennas for lower-frequency use (18 to 1200 MHz). Microwave gain antennas can be used for higher frequencies. Indeed, many amateur radio astronomers appropriate TV receive-only (TVRO) satellite dish antennas for astronomy work. In this chapter we will cover some antennas that are not found in other chapters, at least not in this present context.

Jupiter reception

Jupiter is a strong radio source (next to the sun, it's the strongest in the sky). It produces noiselike signals over the spectrum 5 to 40 MHz, with peaks between 18 and 24 MHz. One source claims that the radio signals come from massive storms on the largest planet's surface, apparently triggered by the transit of the jovian moons through the planet's magnetic field. The signals are plainly audible on the HF band any time Jupiter is above the horizon, day or night. However, in order to eliminate the possibility of both local and terrestrial skip signals from interfering, Jupiter DXers prefer to listen during the hours after 2100 [or whenever the maximum usable frequency (MUF) drops significantly below 18 MHz] and local sunup. Listen to the

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amateur 17- or 15-m bands. If you hear zilch activity, then it's a good bet that the MUF has dropped enough to make listening worthwhile. Even during the day, however, it is possible to hear jovian signals, but differentiating them from other signals or solar noise is difficult.

So what do you need to DX Jupiter? It would help to have a decent radio receiver that works well over the range 18 to 24 MHz. Some cheaper radio receivers are not desirable, but most modern communications receivers are fine. The radio signals are rising and falling "swooshing" noises. The chances of receiving a signal from Jupiter are about 1 in 6, according to several radio astronomers.

The antenna can be a simple dipole cut for the middle of the 18- to 24-MHz band, which happens to be a 15-m amateur radio band antenna. The antenna should be installed in the normal manner for any dipole, except that the wire must run east-west in order to pick up the southerly rising planet.

Figure 21-1 shows a broadband dipole that covers the entire frequency region of interest (18 to 24 MHz) by paralleling three different dipoles: one cut for 18 MHz, one cut for 21 MHz, and one cut for 24 MHz. The dimensions are

A	19.5 ft	24 MHz
B	22.3 ft	21 MHz
C	26 ft	18 MHz

There are several approaches to making this type of antenna. One is to use three-conductor wire, and cut the wires to the lengths indicated above. Another is to use a homemade spacer to spread the wires apart.

Ring antenna

Another popular jovian radio antenna is the ring radiator, two versions of which are shown in Fig. 21-2. This antenna is made of a 5-ft-diameter loop of $\frac{1}{2}$-in-diameter soft-drawn copper plumbing pipe. The single-ended version is shown in Fig. 21-2A. In this antenna the loop is open-ended. The center conductor of the coaxial cable feedline is connected to one end of the ring radiator, while the coax shield is connected to the chicken wire ground plane. The balanced version (Fig. 21-2B) has an RF transformer (T_1) at the feedpoint.

The ring radiator antenna should have a bandpass preamplifier. The preamp is needed because of the low pickup of this kind of antenna, and that preamp should be mounted as close as possible to the antenna. The bandpass characteristic is obtained by filtering. The idea is to get rid of terrestrial signals in the adjacent bands. The typical preamplifier is broadbanded (which is what we want), so will pick up not only the desired signals but others as well (which is what we don't want). Even a 5-W CB transmitter a few blocks away can drive the preamplifier into saturation, so it's wise to eliminate the undesired signals before they get into the preamplifier. In the case of the single-ended amplifier, a single-ended preamplifier is used. But for the balanced version (Fig. 21-2B) a differential preamplifier is used.

The loop (both versions) is mounted about 7 or 8 in above a groundplane made of chicken wire, metal window screen, copper sheeting, or copper foil. The copper sheeting

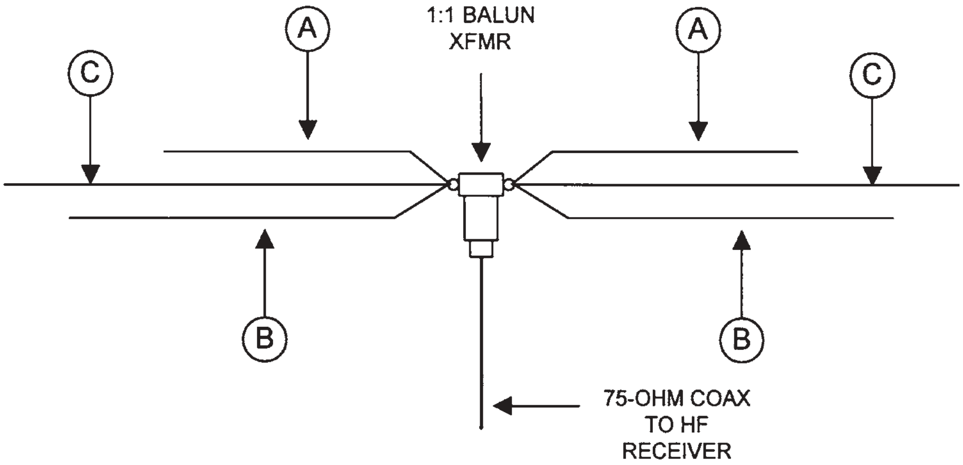
1:1 BALUN
XFMR
A
A
C
C
B
B
75-OHM COAX
TO HF
RECEIVER

21-1 Wideband dipole such as might be used for Jupiter reception.

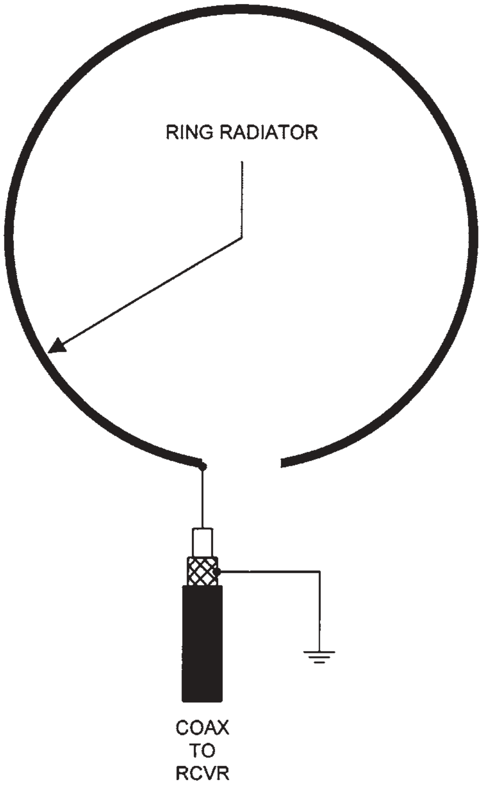
RING RADIATOR
COAX
TO
RCVR

21-2A Ring radiator: single-ended.

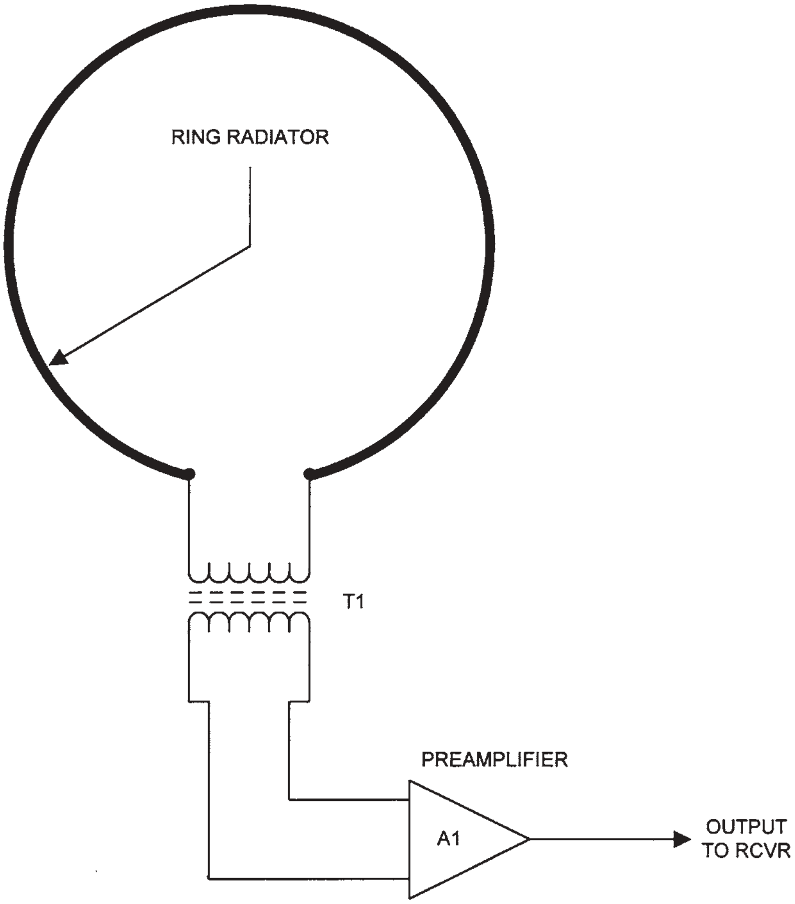

21-2B Ring radiator: balanced.

or foil is best, but costs a lot of money, and turns ugly green after a couple weeks in the elements. If you use screen, make sure that it is a metallic screen. Some window and porch screening material is made of synthetic materials that are insulators.

Figure 21-3A is a mechanical side view of the ring radiator antenna, while Fig. 21-3B is a side view. The antenna is mounted above the screen with insulators. These can be made of wood, plastic, or any other material. The frame holding the groundplane screen (Fig. 21-3B) can be made from 1 × 2-in lumber. Note that the frame has interior crosspieces to support the antenna, as well as the outer perimeter. The larger outer perimeter is needed because the screen groundplane should extend beyond the diameter of the radiator element by about 10 to 15 percent.

DDRR

The directional discontinuity ring radiator (DDRR) antenna is shown in Fig. 21-4A, while a side view showing the mounting scheme is shown in Fig. 21-4B. It is typically

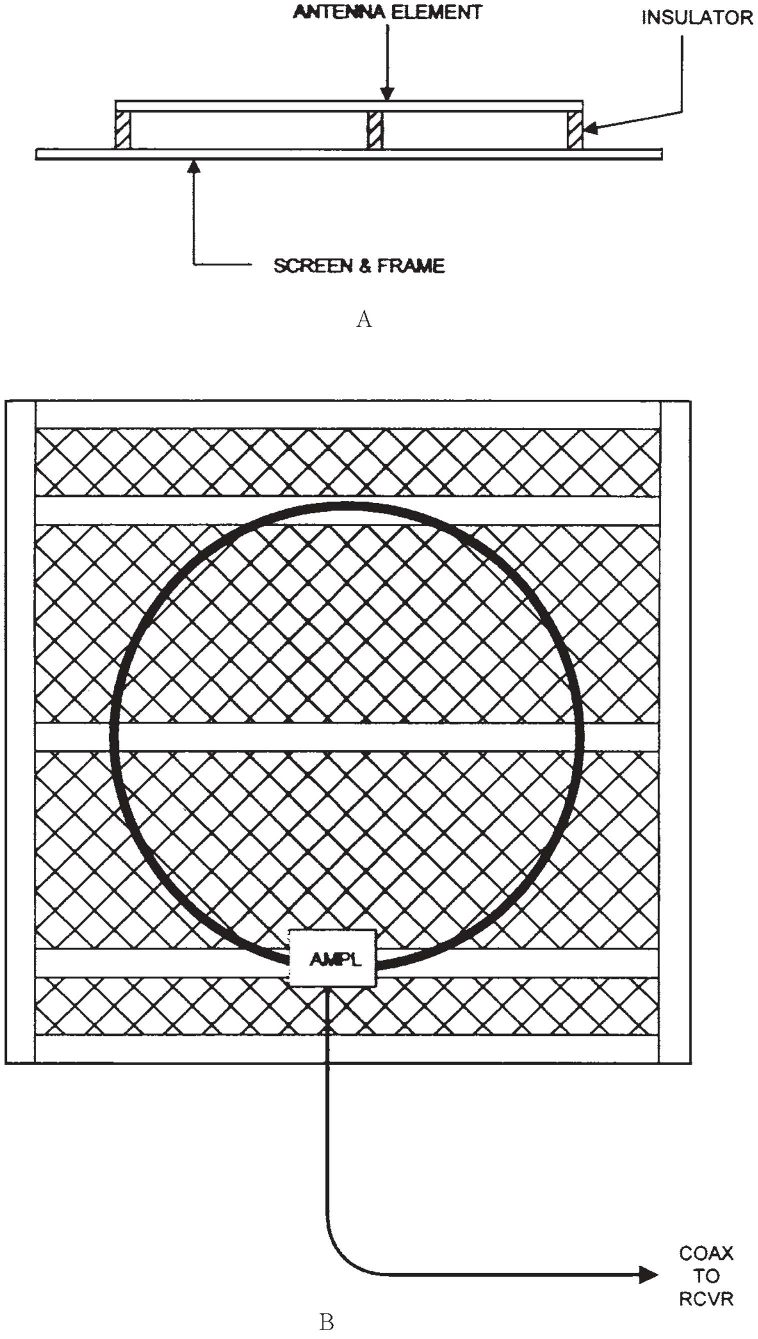
ANTENNA ELEMENT
INSULATOR
SCREEN & FRAME
A
AMPL
COAX
TO
RCVR
B

21-3 Ring radiator mounted over a ground screen.

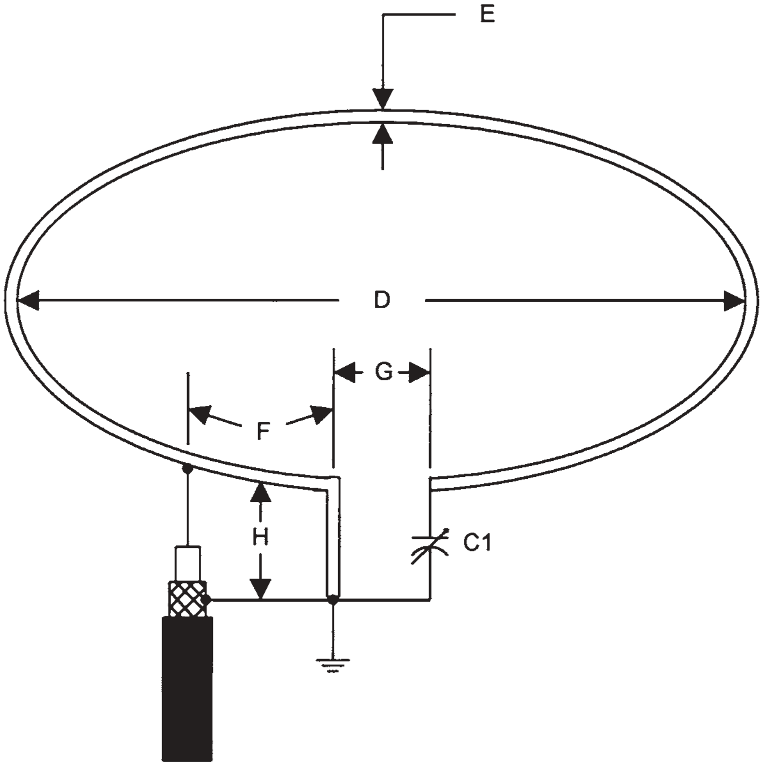

21-4A DDRR antenna.

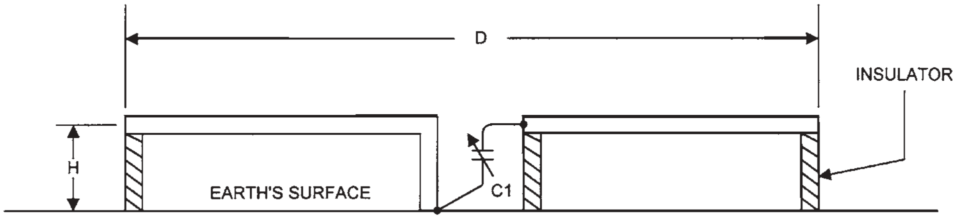

21-4B DDRR antenna: side view.

mounted about 1 ft off the ground ($H = 12$ in). The DDRR consists of two sections, one vertical and one horizontal. The short vertical section has a length equal to the height H of the antenna above the ground. One end of the vertical segment is grounded. The horizontal section is a loop with a diameter D.

The conductor diameter E is at least 0.5 in at 28 MHz, and 4 in at 4 MHz. Because of the loop, some people call this the hula hoop antenna. One author recommends using a 2-in automobile exhaust pipe bent into the correct shape by an auto muffler dealer. The far end of the loop is connected to ground through a small-value tuning capacitor C_1. The actual value of C_1 is found experimentally and is used to resonate the antenna to a particular operating frequency.

The feedline of the DDRR antenna is coaxial cable connected such that the shield is grounded at the bottom end of the vertical section. The center conductor is connected to the ring radiator a distance F from the vertical section. The length F is determined by the impedance that must be matched. The radiation resistance is approximated by

$$R_T = \frac{2620H^2}{\lambda_2} \qquad \textbf{[21.1]}$$

where

R_T is the radiation resistance, in ohms
H is the height of the antenna off the ground
λ is the wavelength

(Both H and λ are in the same units.)

The approximate values for the various dimensions of the DDRR are given below in general terms, with examples in Table 21-1:

D	0.078λ
H	$0.11D$
F	$0.25H$
E	0.5 to 4 in
G	See Table 21-1

Table 21-1. Examples of dimensions for DDRR

	Band (MHz)							
Dimension	**1.8**	**4**	**7.5**	**15**	**22**	**30**	**50**	**150**
G (in)	16	7	5	3	2.5	2	1.5	1
C_1 (pF)	150	100	75	35	15	12	10	6
F (in)	12	6	6	1.5	1.5	1	1	0.5
H (in)	48	24	11	6	4.75	3	1.5	1
D (ft)	36	18	9	4.5	3.33	2.33	1.4	6
E (in)	5	4	2	1	0.75	0.75	0.5	0.25

The construction details of the DDRR are so similar to those of the ring radiator that the same diagram can be used (see Fig. 21-3 again).

The normal attitude of the DDRR for communications is horizontal. However, for Jupiter radio reception, the antenna groundplane screen can be tilted to face Jupiter's point in the sky.

Helical antennas

The helical antenna (Fig. 21-5) provides moderately wide bandwidth and circular polarization. Because of the polarization some people find the helical antenna to be particularly well suited to radio astronomy reception. The antenna (of diameter D) will have a circumference C of 0.75λ to 1.3λ. The pitch of the helix (S) is the axial length of one turn, while the overall length $L=NS$ (where N is the number of turns). The ratio S/C should be 0.22λ to 0.28λ. At least three turns are needed to produce axial-mode main lobe maxima.

The diameter or edge of the groundplane G should be on the order of 0.8λ to 1.1λ if circular and/or square, respectively. The offset between the groundplane and the first turn of the helix is 0.12λ.

The approximate gain of the helical antenna is found from

$$\text{Gain} = 11.8+10 \log (C^2NS) \qquad \text{dBi} \tag{21.2}$$

The pitch angle ϕ and turn length γ for the helical antenna are given by

$$\phi = \tan^{-1}\left(\frac{\pi D}{S}\right) \tag{21.3}$$

and

$$\gamma = \sqrt{(\pi D)^2+S^2} \tag{21.4}$$

The beamwidth of the helical antenna is

$$\Theta = \frac{\mathrm{K}}{\sqrt{\mathrm{NS}}} \tag{21.5}$$

where

Θ is the beamwidth, in degrees
N is the number of turns
S is the pitch, in wavelengths
C is the circumference, in wavelengths
K is 52 for the −3-dB beamwidth and 115 for the beamwidth to the first null in the pattern

The short section between the helix and the groundplane is terminated in a coaxial connector, allowing the antenna to be fed from the rear of the groundplane. The feedpoint impedance is approximately 140 Ω.

Multiple helical antennas

Stacking helical antennas allows a radiation pattern that is much cleaner than the normal one-antenna radiation pattern. It also provides a good way to obtain high gain with only a few turns in each helix. If two helixes are stacked, then the gain will be the same as for an antenna that is twice the length of each element, while for four stacked antennas the gain is the same as for a single antenna 4 times as long. Figure 21-6 shows a side view of the stacked helixes.

The feed system for stacked helixes is a little more complex than for a single helix. Figure 21-7A shows an end view of a set of four stacked helical antennas. Tapered lines (TL) are used to carry signal from each element and the coaxial connector (B). In this case, the coaxial connector is a feed-through "barrel" SO-239 device at the center of the groundplane (B). A side view of the tapered line system

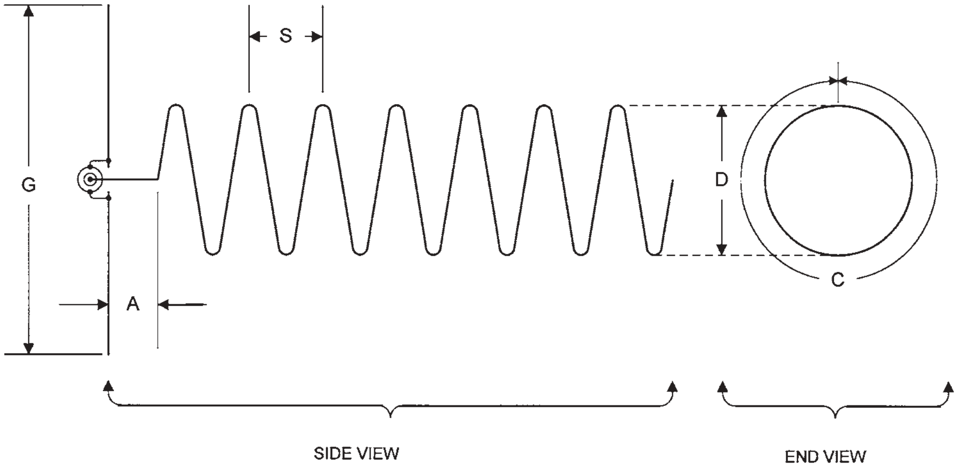
S
G
D
C
A
SIDE VIEW
END VIEW

21-5 Helical antenna.

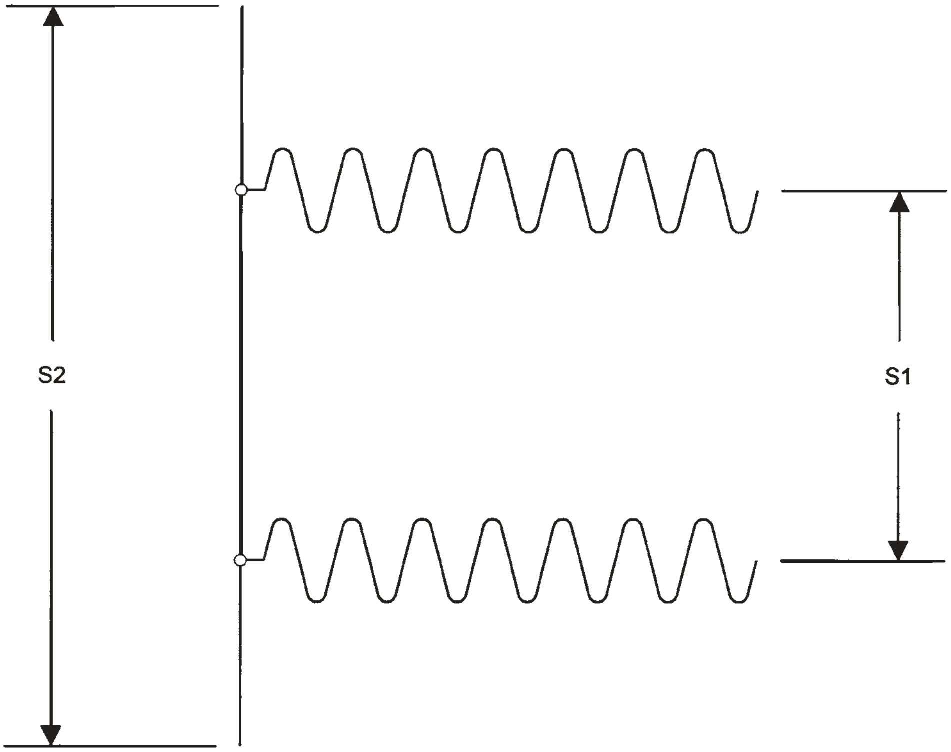

21-6 Dual/quad helical antenna.

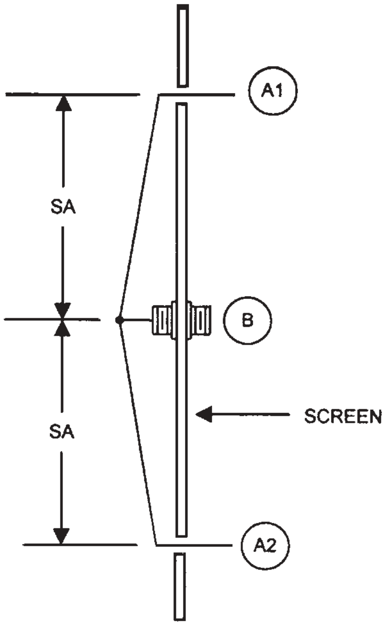
A1
SA
B
SA
SCREEN
A2

B

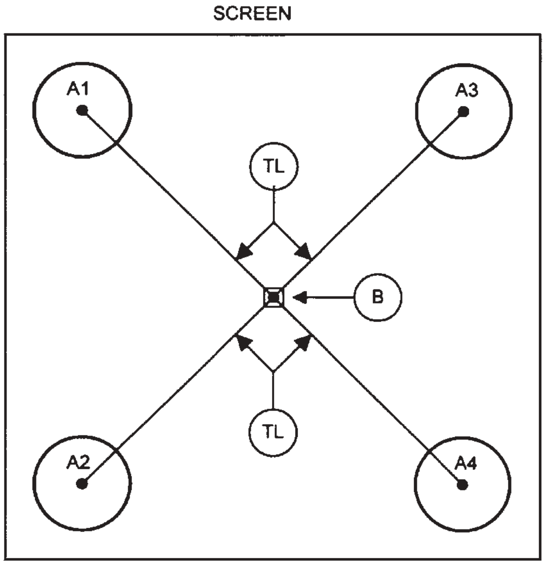
SCREEN
A1
A3
TL
B
TL
A2
A4

A

21-7 Frontal view of quad helical antenna.

is shown in Fig. 21-7B. The length of the tapered lines is 1.06λ, while the center-to-center spacing between the helical elements is 1.5λ. The length of each side of the groundplane is 2.5λ. In the case of Fig. 21-7, the antenna is fed from the front of the groundplane.

Interferometer antennas

The resolution of an antenna is set by its dimensions a relative to the wavelength λ of the received signal. Better resolution can be achieved by increasing the size of the antenna, but that is not always the best solution. Figure 21-8 shows a *summation interferometer array.* Two antennas with aperture a are spaced S wavelengths apart. The radiation pattern is a fringe pattern (Fig. 21-9). This pattern consists of a series of maxima and nulls. The resolution angle ϕ to the first null is

$$\phi = \frac{S+a}{57.3} \qquad \textbf{[21.6]}$$

The interferometer can be improved with additional antennas in the array. Professional radio astronomers use very wide baseline antennas. With modern communications it is possible to link radio telescopes on different continents to make the widest possible baseline.

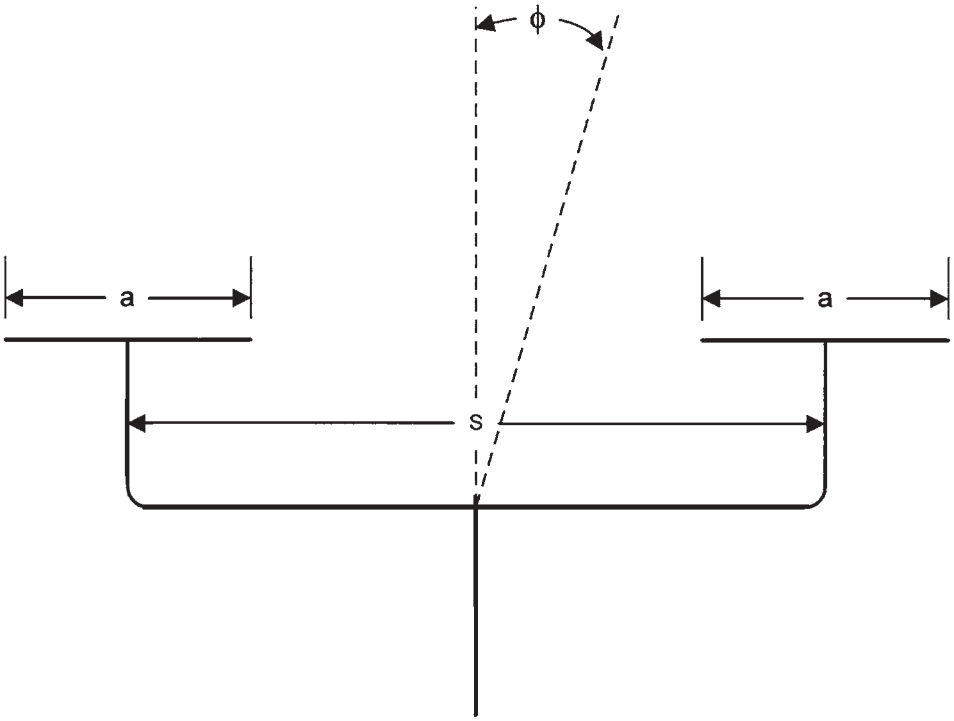

21-8 Interferometer array.

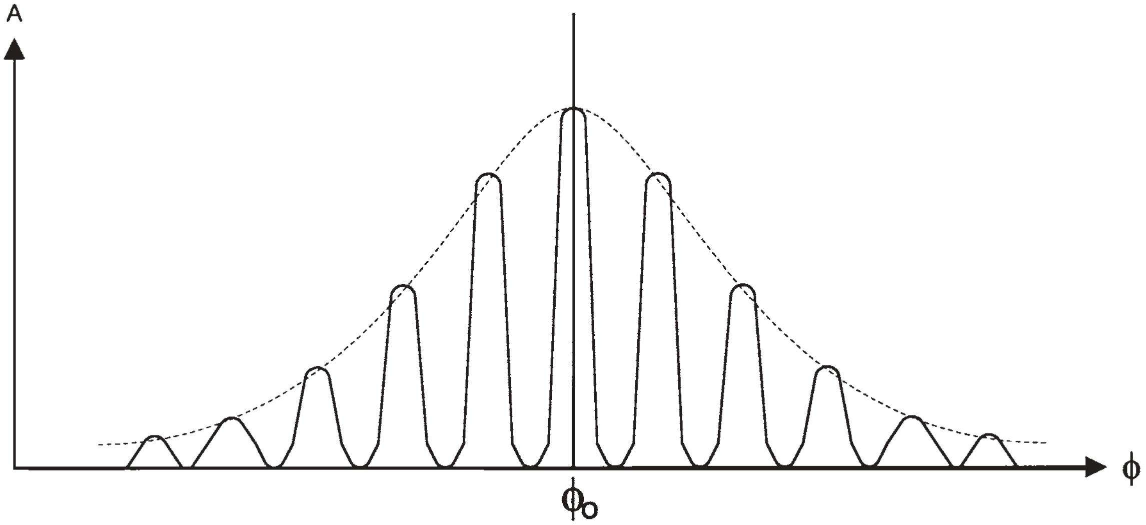

21-9 Interferometer pattern.

22
CHAPTER

Adjusting, installing, and troubleshooting antennas and transmission lines

ANTENNA AND TRANSMISSION LINE MEASUREMENTS SHOULD BE MADE WHEN THE ANTENNA is first installed and periodically thereafter. If some difference in operation is noted, the same measurements should be repeated. Many antenna measurements are difficult to make with any degree of accuracy. There are some things about antennas that can and should be measured, however, regardless of the difficulty. For example, VSWR and the resonant frequency of the antenna are readily accessible. It's also possible to measure the impedance of the antenna feedpoint. You can measure the VSWR either with a special VSWR meter (often built into transmitters or antenna tuning units), or by using an RF wattmeter.

By frequency stepping through the band and testing the VSWR at various frequencies, one can draw a VSWR curve (Fig. 22-1) that shows how the antenna performs across the band. The resonant frequency is the point where the VSWR dips to a minimum (which may or may not be the much sought-after 1:1).

You can use the resonant frequency to figure out whether the antenna is too long (resonant frequency lower than the hoped-for design frequency), or too short (resonant frequency above the design frequency). Figure 22-2 shows all three situations. Curve A represents the desired or ideal curve that is centered on the desired frequency F_D. If the antenna is too long, however, the resonant frequency will be shifted downward towards F_1, and curve B will be observed. Similarly, if the antenna is too short, curve C will be found as the resonant frequency shifts upband to F_2.

But resonant frequency and VSWR curves are not the entire story because they don't tell us anything about the impedance presented by the antenna. One cannot get the VSWR to be 1:1 unless the antenna impedance and transmission line impedance are the same. For example, a dipole has a nominal textbook impedance of 73 Ω,

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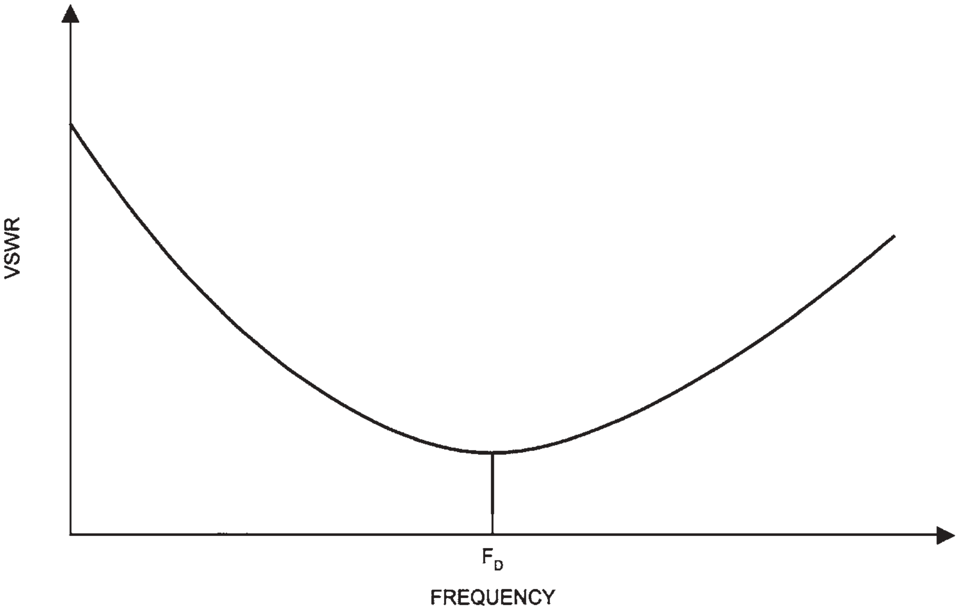

22-1 VSWR-vs-frequency plot.

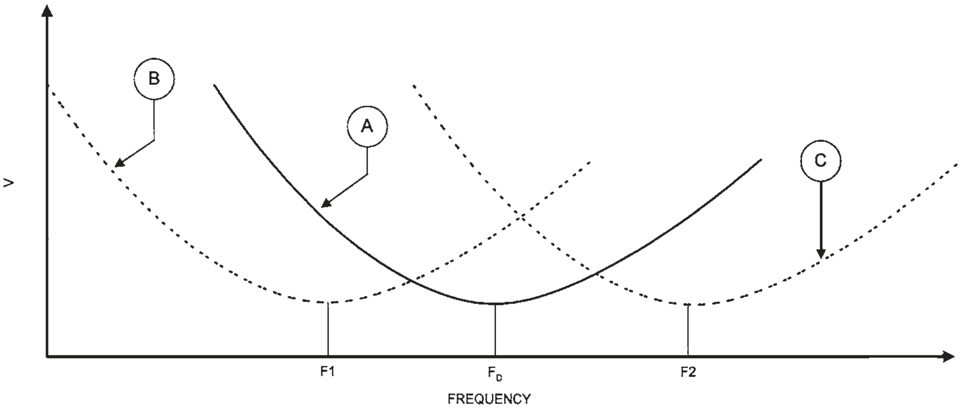

22-2 VSWR-vs-frequency plot for three frequencies.

so it makes a very good match to 75-Ω coaxial cable. But the actual impedance of a real dipole may vary from a few ohms to more than 100 Ω. For example, if your antenna exhibits a feedpoint impedance of (say) 25 Ω, using 75-Ω coaxial cable to feed it produces a VSWR=75/25=3:1. Not too great. Measuring the feedpoint impedance is therefore quite important to making the antenna work properly.

There are any number of instruments on the market that will aid in making antenna measurements. Some of them are quite reasonably priced (or can be built), while others are beyond the reach of all but the most ardent and well-endowed enthusiasts. In this chapter we will look at a newer breed of more universal instrument called the *SWR analyzer.*

VSWR analyzers

One basic premise in this chapter is that the instruments used for measuring VSWR must be accessible to people who don't have a commercial or ham operator's license, as well as those who do (we must remember our SWL and scanner friends). Some of the instruments used by hams meet that requirement, but a relatively new breed of instrument called the SWR analyzer provides a lot of capability to the SWL, scanner operator, and ham radio operator alike. It uses a low-power RF signal generator and some clever circuitry to measure the VSWR of the antenna. One model also measures the feedpoint resistance.

The MFJ-259 VSWR analyzer (MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, MS, 39762) is shown in Fig. 22-3. This instrument combines a VSWR analyzer with a digital frequency counter, and operates over the range 1.8 to 170 MHz. A band switch is set to the desired band, and then the *tune* control is set to the desired frequency. The meter will then read the VSWR at the design frequency. Alternatively, you can adjust the tune control until the minimum VSWR is found. This frequency is the actual, versus the desired, resonant frequency of the antenna. The front panel of the MFJ-259 has two meters, *SWR* and *RESISTANCE.* The SWR meter is calibrated up to 3:1, with a little uncalibrated scale to indicate higher SWRs.

The resistance meter is calibrated from 0 to 500 Ω, which is consistent with the SWR range. Two controls on the front panel are *tune* and *frequency* (a band switch). The MFJ-259 has a digital frequency meter to measure the operating frequency of the internal oscillator. This frequency counter can also be used to measure the frequency of external signal sources. (*Do not* connect the counter to the output of a transmitter; the instrument will be destroyed.) The top end of the MFJ-259 has a number of controls and connectors. An SO-239 UHF-style coaxial connector is provided for the antenna connection. A BNC coaxial connector is provided to apply external signal to the frequency counter, while a push button *input* switch is available to switch the counter from internal to external signal sources. Another push button switch is used to set the gate timing of the counter (a red LED on the front panel blinks every time the gate is triggered). The tuning is from 1.8 MHz to 174 MHz, while the counter will measure up to 200 MHz.

The MFJ-259 will work from an external 12-Vdc source, or from an internal battery pack consisting of eight size-AA standard cells. MFJ recommends that either alkaline or rechargeable batteries, rather than ordinary zinc-carbon cells, be used in order to reduce the possibility of leakage that can damage the instrument (this is good practice in all battery-powered instruments).

Unlike many lesser SWR meters, this instrument is not fooled by antennas that have impedances consisting of both resistance and reactance elements. An example in the manual demonstrates an impedance of $25+j25\ \Omega$ (i.e., R is 25 Ω and reactance X is also 25 Ω). When connected to a 50-Ω load one might be tempted to think the VSWR is 1:1, and some cheaper meters will so indicate. But the actual SWR is 2.6:1, which is what the MFJ-259 will read.

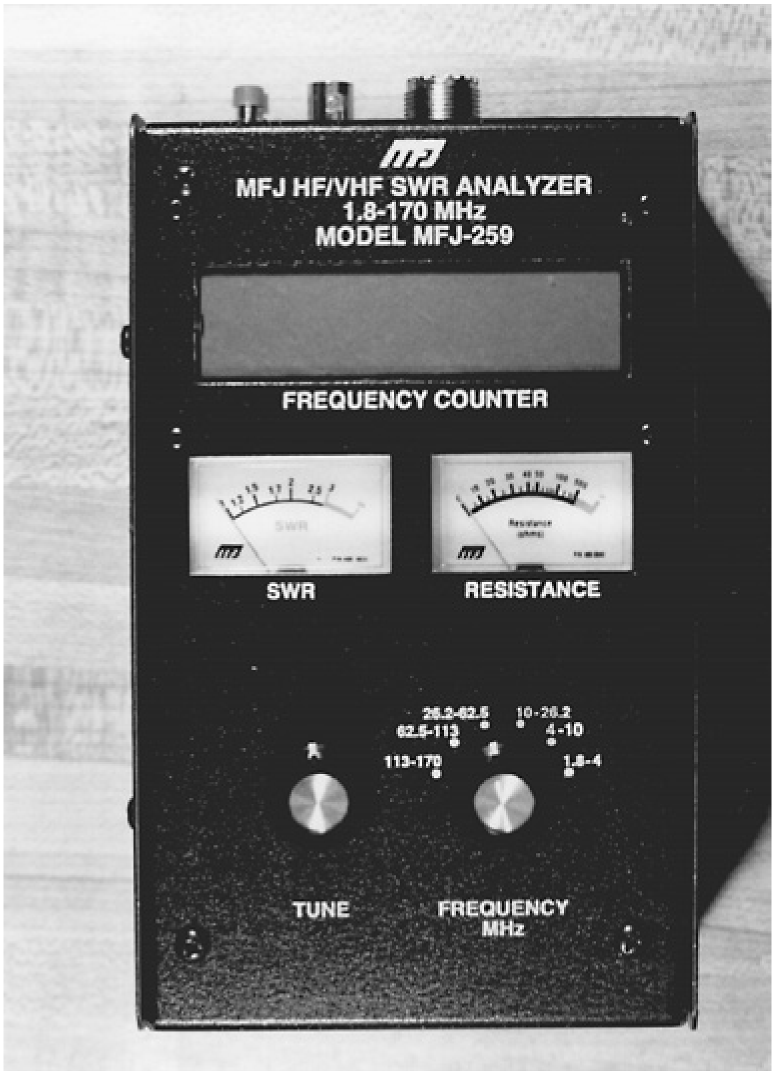
MFJ HF/VHF SWR ANALYZER
1.8-170 MHz
MODEL MFJ-259
FREQUENCY COUNTER
SWR
RESISTANCE
26.2-62.5
10-26.2
62.5-113
4-10
113-170
1.8-4
TUNE
FREQUENCY
MHz

22-3 MFJ-259 VSWR analyzer.

The resistance measurement assumes a resistive load (i.e., the measurement is made at the antenna's resonant frequency), and is referenced to 50 Ω. The VSWR and resistance measurements should be consistent with each other. If the VSWR is 2:1, then the resistance should be either 100 Ω (100/50 = 2:1) or 25 Ω (50/25 = 2:1). If the resistance is not consistent with the VSWR reading, then you should assume that the impedance has a significant reactive component and take steps to tune it out.

In addition to antenna measurements, the MFJ-259 is equipped to measure a wide variety of other things. It will measure the velocity factor of transmission line, help in tuning or adjusting matching stubs or matching networks, measure capacitance or inductance, and determine resonant frequency of *LC* networks.

Doping out coaxial cable

When you install an antenna, or do a bit of preventive maintenance, or find the antenna is not working properly, one thing to check is the transmission line. Two basic measurements are popular. Figure 22-4 shows how to make ohmic checks. The cable consists of an inner conductor and an outer conductor (shield). With terminals A and B open there should not be any resistive path across the input terminals (as shown). If a high resistance is seen, then there might be some contamination in the system, or the insulation has failed, permitting a current path. A low resistance indicates a short circuit. If the cable has been cut, or an object passed through, or the connector is messed up, then a short can result.

If terminals A-B are shorted together, a low resistance should be noted. If not, then it is likely that the center conductor is open. Of course, if connectors are on the line, either the shield or center conductor could be at fault.

The other issue is loss of the transmission line. Cable losses get higher as cables age, so low loss on installation does not guarantee low loss later on. Losses in new cables run from 0.2 dB/100 ft at 4 MHz. At 30 MHz the losses are 0.7 dB/100 ft to 2.6 dB/100 ft. At VHF/UHF frequencies the losses rise considerably.

Figure 22-5 shows a test setup for coaxial cable. It is necessary to know the length of the piece of coax under test. For ease of calculations a 100-ft section

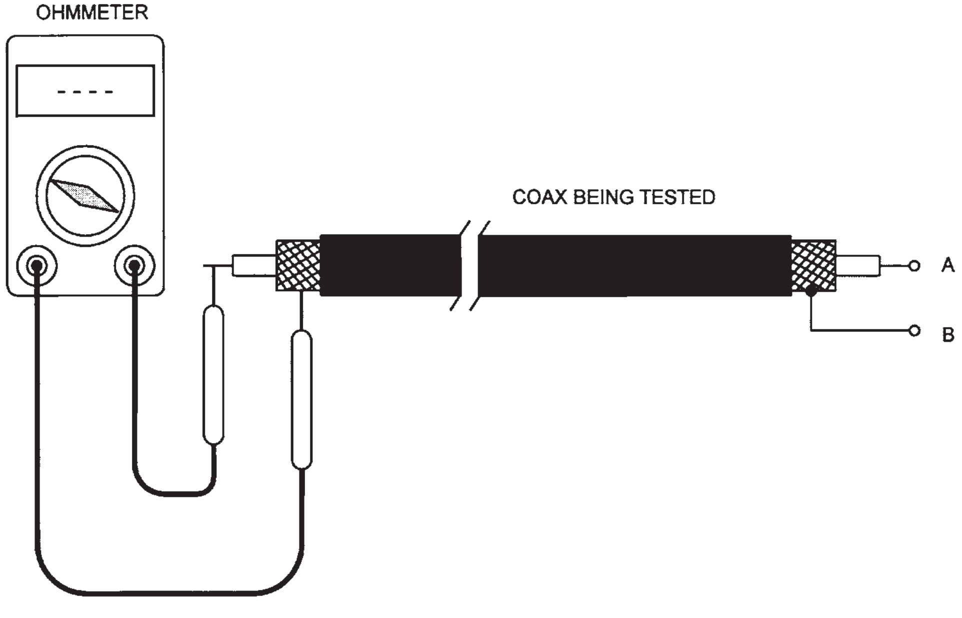

22-4 Ohmmeter used to test coax.

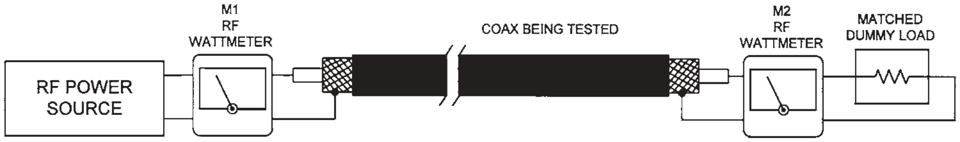
M1
RF
WATTMETER
COAX BEING TESTED
M2
RF
WATTMETER
MATCHED
DUMMY LOAD
RF POWER
SOURCE

22-5 Attenuation test for coax.

should be used. Two RF power meters (M_1 and M_2) are used to measure the input power to the line (M_1) and the delivered power (M_2). The difference in power determines the loss. The loss is

$$\text{Loss}_{\text{dB}} = 10 \log \left(\frac{P_{M2}}{P_{M1}} \right) \qquad \textbf{[22.1]}$$

where

Loss is the loss of the cable, in dB
P_{M1} is the power reading on M_1
P_{M2} is the power reading on M_2

If the cable length is 100 ft, then you already have the loss in dB/100 ft. But if length L is anything other than 100 ft, then you need to make the following calculation:

$$\text{Loss}_{\text{dB/100ft}} = \frac{\text{Loss}_{\text{dB}}}{\text{L}_{\text{ft}}} \times 100 \qquad \textbf{[22.2]}$$

23
CHAPTER

Antennas for radio direction finding (RDF)

RADIO DIRECTION FINDING IS THE ART AND PRACTICE OF EITHER LOCATING YOURSELF OR A radio station by using a directional radio antenna and receiver. When the FCC wants to locate an illegal station that is transmitting, they will use radio direction finders to triangulate the position. If they find the bearing from two stations they will locate the station at the intersection. However, there is a fair degree of ambiguity in the measurement. As a result, radio direction finders typically use three or more (hence "*tri*angulate") sites. Each receiving site that can find the bearing to the station reduces the overall error.

At one time aviators and seafarers relied on radio direction finding. It is said that the Japanese air fleet that attacked Pearl Harbor, Hawaii, on December 7, 1941 homed in on a Honolulu AM radio station. During the 1950s and early 1960s AM radios came with two little circled triangle marks at the 640-kHz and 1040-kHz points on the dial. These were the CONALRAD frequencies that you could tune to in case of a nuclear attack (right before you kissed your butt good-bye, I suspect). All other radio stations were off the air except the CONALRAD stations. The enemy was prevented from using these frequencies for RDF because the system used several stations that transmitted in a rapidly rotating pattern. No one station was on the air long enough to allow a "fix." The result was a wavering sound to the CONALRAD station (which we heard during tests) that would confuse any enemy who tried to DX his way into our cities with nuclear weapons.

Radio direction finders based on the AM broadcast band (BCB) looked a bit like Fig. 23-1. A receiver with an S meter (which measures signal strength) is equipped with a rotatable ferrite loopstick antenna to form the RDF unit. A degree scale around the perimeter of the antenna base could be oriented toward north so that the bearing could be read.

Loopstick antennas have a figure-8 reception pattern (Fig. 23-2A) with the maxima parallel to the loopstick rod and the minima off the ends of the rod. When the antenna is pointed at the signal, maximum reception strength is achieved. Unfortunately, the maxima are so broad that it is virtually impossible to find the true point on the compass dial where the signal peaks. The peak is too shallow for that

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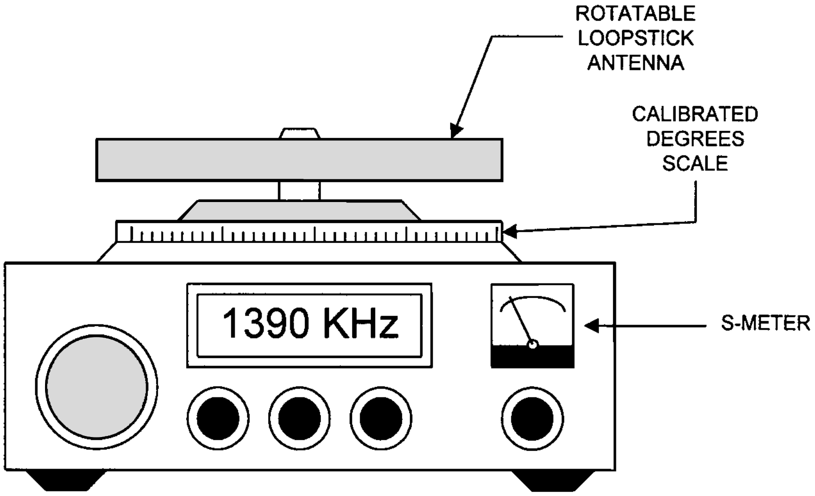
ROTATABLE
LOOPSTICK
ANTENNA
CALIBRATED
DEGREES
SCALE
1390 KHz
S-METER

23-1 Radio direction finding (RDF) receiver using a loopstick antenna.

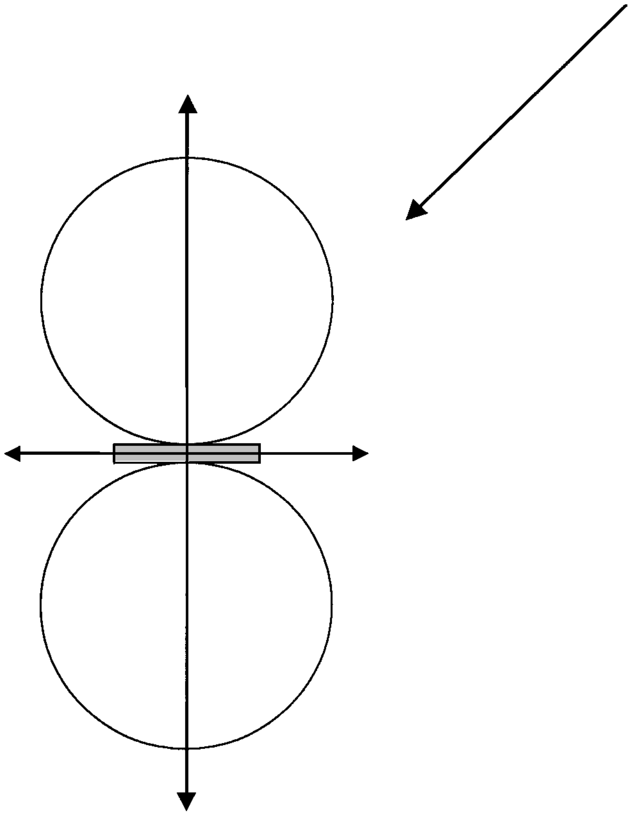

23-2A Pattern of loopstick antenna: not oriented towards signal.

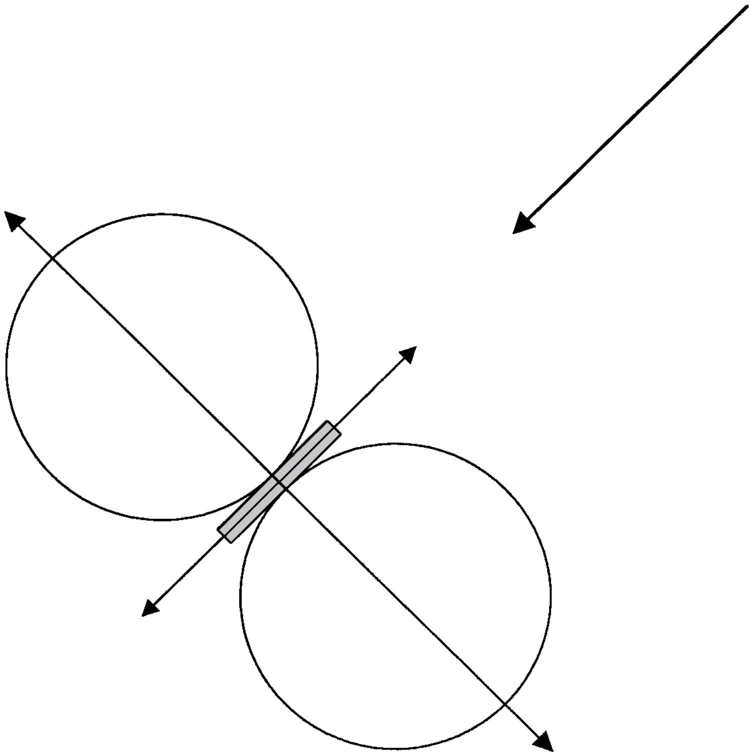

23-2B Pattern of loopstick antenna: oriented towards signal.

purpose. Fortunately, the minima are very sharp. You can get a good fix on the direction of the signal by pointing the minima toward the station. This point is found by rotating the antenna until the audio goes to zip or the S meter dips to a minimum (Fig. 23-2B).

The loopstick is a really neat way to do RDF—except for one little problem: The darn thing is bidirectional. There are two minima because, after all, the pattern is a figure 8. You will get exactly the same response from placing either minima in the direction of the station. As a result, the unassisted loopstick can only show you a line along which the radio station is located, but can't tell you which direction it is. Sometimes this doesn't matter. If you know the station is in a certain city, and that you are generally south of the city, and can distinguish the general direction from other clues, then the line of minima of the loopstick will refine that information. A compass helps, of course. Shortly we will take a look at an impromptu radio direction finder using a portable radio.

The solution to the ambiguity problem is to add a sense antenna to the loopstick (Fig. 23-3). The sense antenna is an omnidirectional vertical whip, and its signal is combined with that of the loopstick in an *RC* phasing circuit. When the two patterns are combined, the resultant pattern will resemble Fig. 23-4. This pattern is called a *cardioid* because of the heart shape it exhibits. This pattern has only one null, so it resolves the ambiguity of the loopstick used alone.

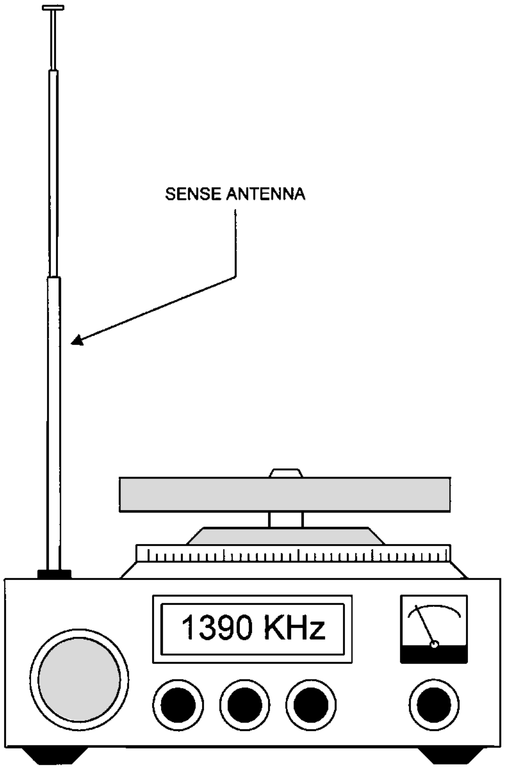

23-3 Addition of sense antenna overcomes directional ambiguity of the loopstick.

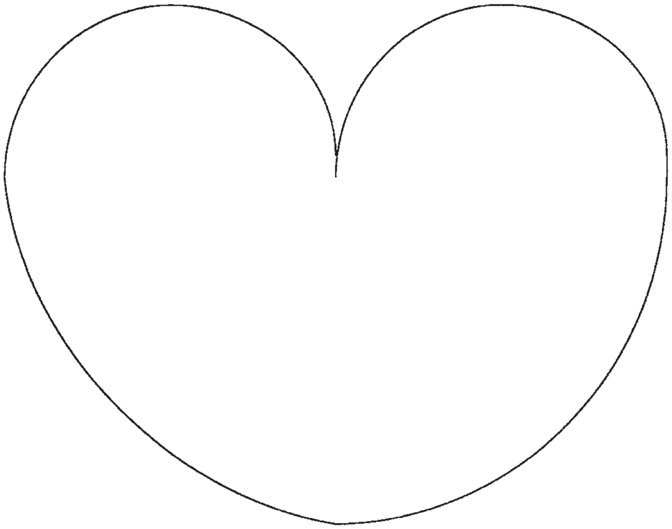

23-4 Cardioid pattern of sense-plus-loopstick antennas.

Field improvisation

Let's suppose you are out in the woods trekking around the habitat of lions, tigers, and bears (plus a rattlesnake or two for good measure). Normally you find your way with a compass, a Geological Survey 7.5-min topological map, and a Global Positioning System (GPS) receiver. Those little GPS marvels can give you real good latitude and longitude indication. But what happens if it breaks or a bear eats it? The answer to your direction finding problem might be the little portable AM BCB radio (Fig. 23-5) that you brought along for company.

Open the back of the radio and find the loopstick antenna. You will need to know which axis it lies along. In the radio shown in Fig. 23-5 the loopstick is along the top of the radio, from left to right. In other radios it is vertical, from top to bottom. Once you know the direction, you can tune in a known AM station and orient the radio until you find a null. Your compass can give you the bearing. If you know the approximate location of the station, then you can reverse the compass direction from it and mark the line on the topo map. Of course, it's still a bidirectional indication, so all you know is the line along which you are lost.

But then you tune into a different station in a different city (or at least wide enough from the line to the other station to make a difference) and take another reading. Your approximate location is where the two lines cross. Take a third, fourth, and fifth reading and you will home in pretty tight. If you were smart enough to plan ahead, you will have selected candidate stations in advance and located their latitude and longitude. Alternatively, you would have bought the topo map that covers their location as well as where you want to hike, and from those maps you can find the latitudes and longitudes of the distant stations.

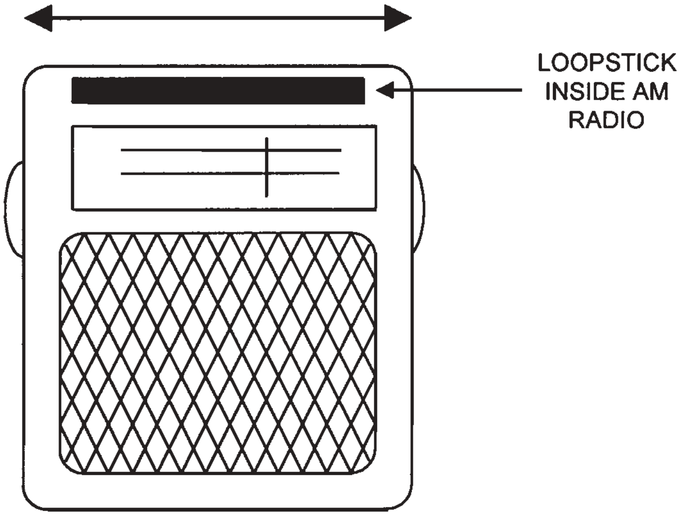

23-5 AM portable radio. Dark bar represents position and direction of internal loopstick.

Regular loop antennas

Regular wire loop antennas (Fig. 23-6) are also used for radio direction finding. In fact, in some cases the regular loop is preferred over the loopstick. The regular loop antenna may be square (as shown), circular, or any other regular "*n*-gon" (e.g., hexagon), although for practical reasons the square is easier to build. The loop has pretty decent inductance even with only a few turns. One loop I built was 24 in square (A in Fig. 23-6) and had, if I recall correctly, about 10 turns of wire spaced over a 1-in width (B in Fig. 23-6). It resonated to the AM BCB with a standard 365-pF "broadcast" variable capacitor.

When you use a regular loop antenna be aware that the antenna has a figure-8 pattern like the loopstick, but it is oriented 90° out of phase with the loopstick antenna. In the regular loop the minima (nulls) are perpendicular to the plane of the loop, while the maxima are off the sides. In Fig. 23-6 the minima are in and out of the page, while the maxima are left and right (or top and bottom).

Fox hunting

An activity popular with ham radio operators in the 1960s was "fox hunting." A fiendishly clever ham (the "fox") would go hide with a mobile or portable transmitter (usually on either 10 or 75 m). The "hunters" would then RDF the fox's brief transmissions and try to locate the transmitter. If you could locate the antenna, you located the station (according to the most common set of rules). Sometimes the hunt got a little wild as hunters raced each other (a no-no) in the final stretch.

One friend of mine had an interesting experience. He drove a 1949 Plymouth that was painted hideous dark green with fire-engine-red hub caps. It looked just plain awful (especially since the paint looked like it was put on with a whisk broom!). He used a Gonset converter linked to the AM BCB receiver installed in the car. The antenna was a wire loop on the end of a broom handle, similar to Fig. 23-7. The antenna was mounted about where you would expect the left-side rear view mirror to be located. He could reach his hand out the window and rotate the antenna while listening for the minima on the receiver. Worked rather well, and he won some fox hunts.

The fox hunts in his area were usually held on Saturday or Sunday morning, and after it was all over the whole crew would get to a restaurant for brunch or beer or something. One morning, however, my buddy with the hideous green car was racing down a residential street to be the first to the transmitter. Others were in the area, and the end game was in motion. Unfortunately, a little old lady called the police complaining about a "…nut racing up and down the street in a strange car waving a cross out the window." Breakfast had to wait that morning, I bet.

Shortwave and AM BCB "skip" RDF

Radio direction finding is most accurate over relatively short distances. If you can use the ground wave, then all the better (which is what you use during daylight hours for nearly all AM BCB stations). Skip rolls in on the AM BCB after local

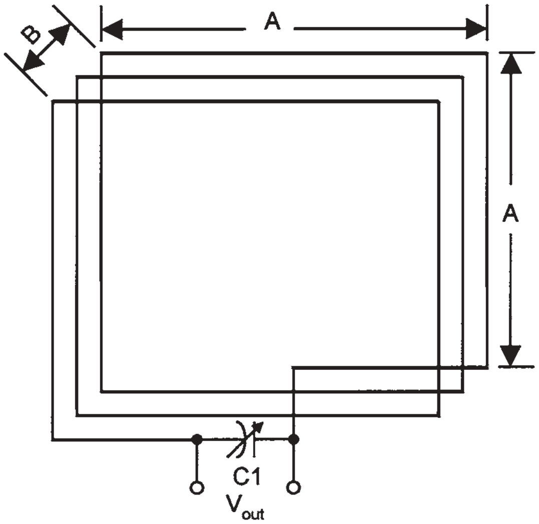

23-6 Wire loop antenna.

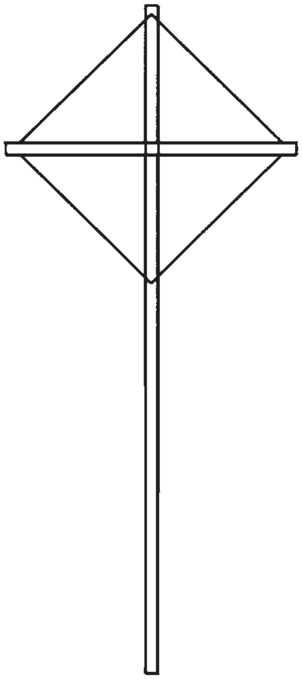

23-7 "…waving a cross out the window" antenna.

sundown, so you can hear all manner of stations all up and down the dial. You can RDF distant stations. Some rather interesting sites have turned up when SWL DXers RDF'ed some of the infamous "numbers stations." Those stations transmit either CW or voice numbers groups, and are believed to be sending messages to spies around the world. RDFing by DXers has located some of these transmitters at, well, "interesting" sites.

Unfortunately, there are some problems with skip RDFing. When we look at propagation drawings of skip in textbooks we usually see a one plane view. The curvature of the earth shows, as does the transmitter and receiver site. A "pencil beam" radio signal travels at some angle up the ionosphere, where it is "reflected" (actually, it's a refraction phenomenon but looks like reflection to an observer on the surface) back to earth. We can tell from the drawing that the angle of incidence equals the angle of reflection, just like they told us in high school science classes. Oops! The real world is not so neat and crisp, however.

In the real world the wave might encounter a different ionization density along its path of travel and therefore be deflected from its original path. It might return to earth at a location offset from the direction it appears. If we look at the true bearing from the receiver site to the transmitter site, and then note the azimuthal angle of arrival of the signal, we note that something is amiss.

Actual reflection also causes some problems, especially when RDFing a station in the high end of the HF band or the VHF/UHF bands. Radio waves will reflect from geological features such as mountains, as well as man-made structures (e.g., buildings). If the reflection is strong enough it might appear to be the real signal, and cause a severe error in RDFing. Be wary of RDF results when the "skip is in."

Sense antenna circuit

Figure 23-8 shows a method for summing together the signals from an RDF antenna (such as a loop) and a sense antenna. The two terminals of the loop are connected to the primary of an RF transformer. This primary (L_{1A}) is center-tapped and the center tap is grounded. The secondary of the transformer (L_{1B}) is resonated by a variable capacitor C_1. The dots on the transformer coils indicate the 90° phase points.

The top of L_{1B} is connected to the sense circuit, and to the receiver antenna input. The phasing control is a potentiometer (R_1). The value of this pot is usually 10 to 100 kΩ, with 25 kΩ being a commonly seen value. Switch S_1 is used to take the sense antenna out of the circuit. The reason for this switch is that the nulls of the loop or loopstick are typically a lot deeper than the null on the cardioid pattern. The null is first located with the switch open. When the switch is closed you can tell by the receiver S meter whether or not the correct null was used. If not, then reverse the direction of the antenna and try again.

Adcock antennas

The Adcock antenna has been around since 1919 when it was patented by F. Adcock. Figure 23-9 shows the basic Adcock RDF array. This antenna consists of two center-fed nonresonant (but identical) vertical radiators. Each side of each element is at least 0.1λ long, but need not be resonant (which means the antenna can be used

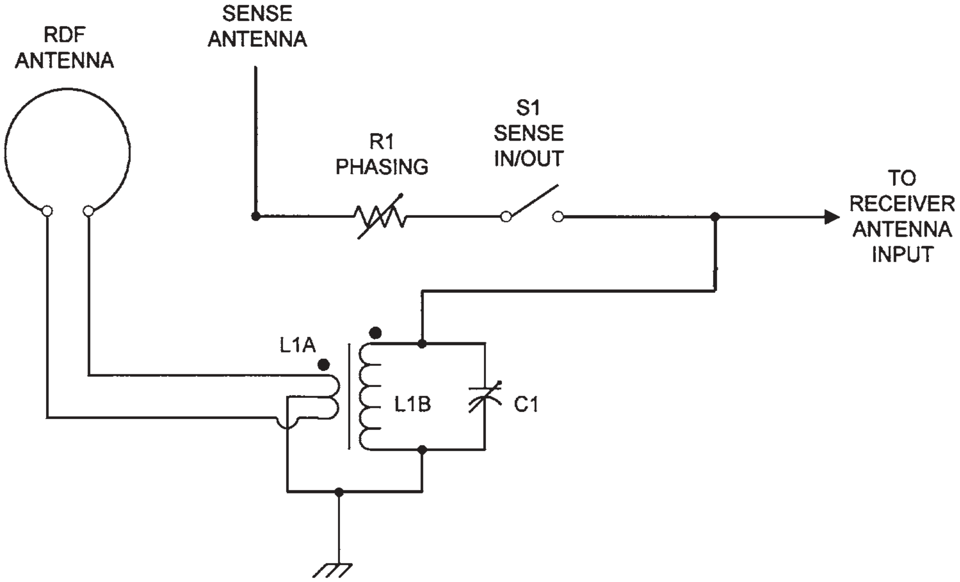

23-8 Sense circuit for a loop/sense antenna RDF.

over a wide band). The elements are spaced from 0.1λ to 0.75λ, although the example shown here is spaced 0.125λ.

The Adcock antenna is vertically polarized, so it will respond to the vertically polarized wave very much like loop or phased array antennas of similar size. The horizontally polarized wave, however, affects all elements the same, so the currents are essentially cancelled, resulting in no pattern. This characteristic makes the Adcock antenna suitable for high-frequency shortwave RDFing.

The pattern for an Adcock antenna is shown in Fig. 23-10. This pattern was generated using the NecWin Basic for Windows program (Chap. 17). The example antenna is a 10-MHz (30-m band) Adcock that uses 1.455-m elements (total 2.91 m on each side), spaced 4 m apart. The pattern is a traditional figure-8 with deep nulls at 0° and 180°. The antenna can be rotated to find a null in the same manner as a loop.

Watson-Watt Adcock array

Figure 23-11 shows the Watson-Watt Adcock RDF array. It consists of two Adcock arrays arranged orthogonally to each other. It is common practice to arrange one Adcock in the east-west direction and the other in the north-south direction. These are fed to identical receivers that are controlled by a common local oscillator (LO). The outputs of the receivers are balanced, and are used to drive the vertical and horizontal plates of a cathode-ray oscilloscope (CRO). Figure 23-12 shows the patterns achieved by signals of various phases arriving at the Watson-Watt array. The patterns of Figs. 23-12A and 23-12B are made from signals 180° out of phase, while the signal of Fig. 23-12C has a 90° phase difference.

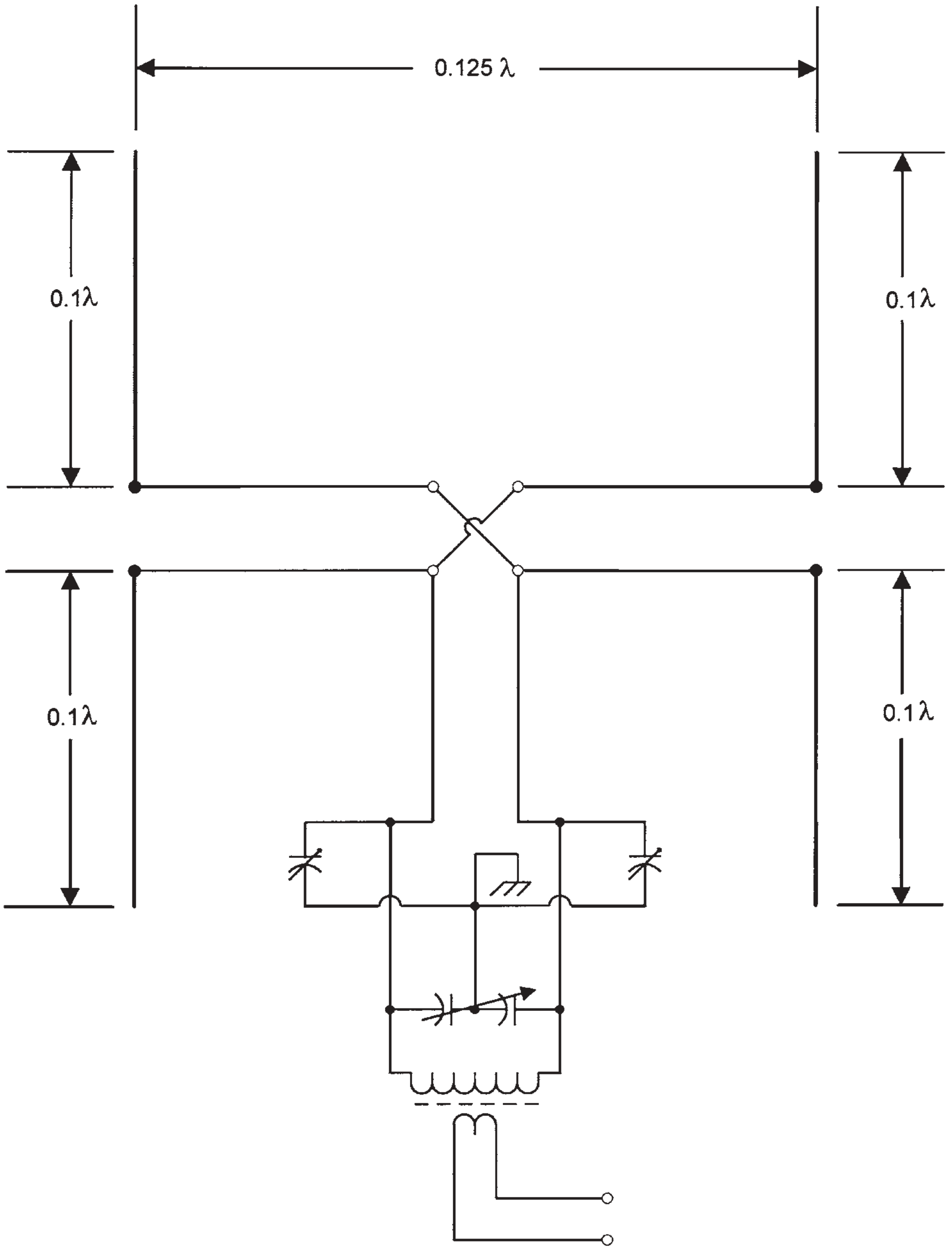
0.125 λ
0.1λ
0.1λ
0.1λ
0.1λ

23-9 Adcock array RDF antenna.

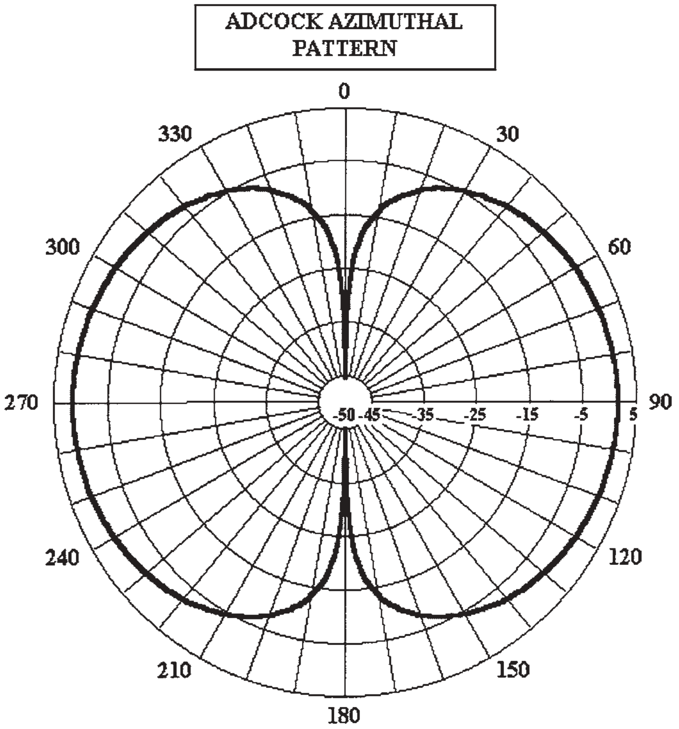

23-10 Adcock pattern.

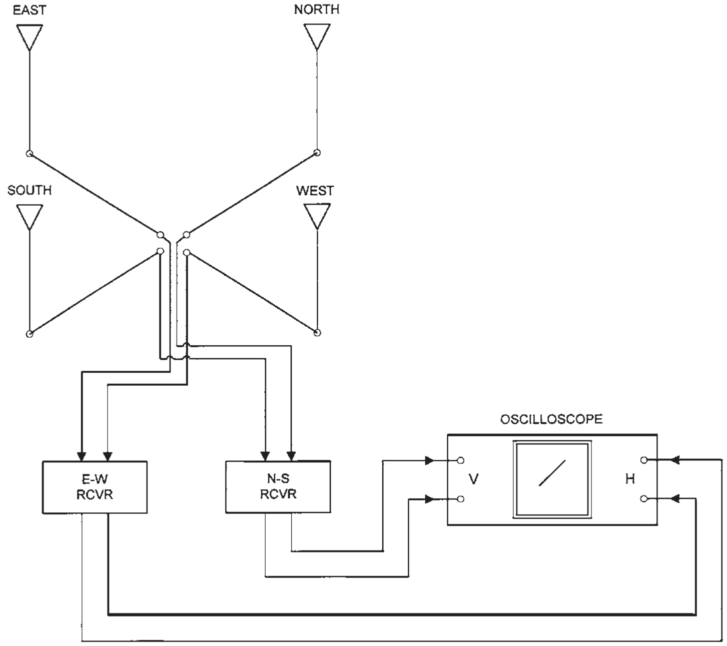
EAST
NORTH
SOUTH
WEST
E-W RCVR
N-S RCVR
OSCILLOSCOPE
V
H

23-11 Watson-Watt Adcock array.

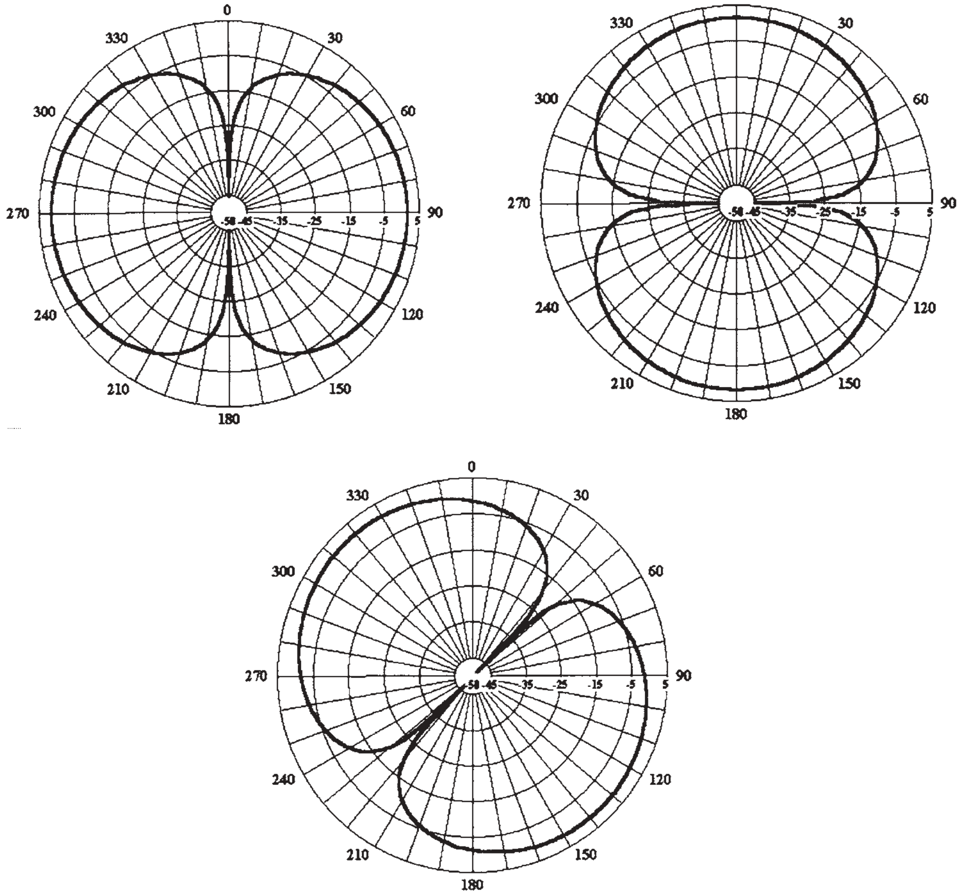

23-12 Patterns for different signals on the Watson-Watt array.

Doppler RDF antennas

Figure 23-13 shows the basic concept of a Doppler RDF antenna. The Doppler effect was discovered in the nineteenth century. A practical example of the Doppler effect is seen when a wailing ambulance siren is approaching you, and then passes you and heads away from you. The wailing pitch will rise as the sound source approaches, and then fall as the sound source recedes in the opposite direction.

In a radio system, when the antenna and signal source move with respect to each other, a Doppler shift is generated. This shift is proportional to the relative speed difference. The Doppler RDF antenna of Fig. 23-13 uses a rotating antenna. The signal approaches from a single direction, so there will be a predictable Doppler shift at any point on the circular path of the antenna. The magnitude of the phase shift is

$$S = \frac{R\omega F_c}{c} \qquad \textbf{[23.1]}$$

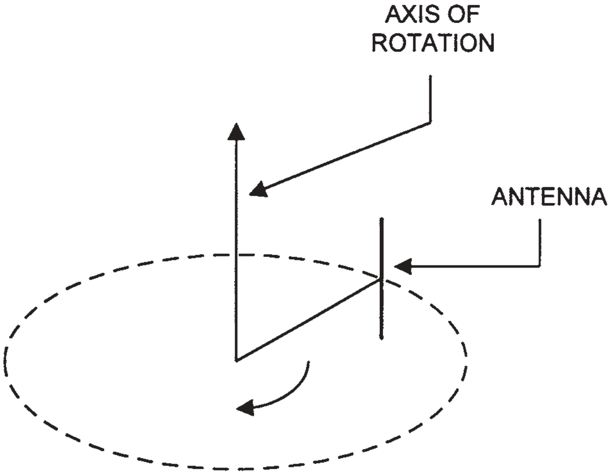

23-13 Doppler antenna.

where

S is the Doppler shift, in hertz
R is the radius of rotation, in meters
ω is the angular velocity of the antenna, in radians per second
F_c is the carrier frequency of the incoming signal, in hertz
c is the velocity of light (3×10^8 m/s)

In theory this antenna works nicely, but in practice there are problems. One of the big problems is getting a large enough Doppler shift to easily measure. Unfortunately, the rotational speed required of the antenna is very high—too high for practical use. However, the effect can be simulated by using a number of antennas, arranged in a circle, that are sequentially scanned. The result is a piecewise approximation of the effect seen when the antenna is rotated at high speed.

Wullenweber array

One of the problems associated with small RDF antennas is that they have such a small aperture that relatively large distortions of their pattern result from even small anomalies. Follow that? What it means is that the pattern is all messed up by small defects. If you build a wide-aperture direction finder (WADF), however, you can average the signals from a large number of antenna elements distributed over a large-circumference circle. The Wullenweber array (Fig. 23-14) is such an antenna. It consists of a circle of vertical elements. In the HF band the circle can be 500 to 2000 ft in diameter.

A goniometer rotor spins inside the ring to produce an output that will indicate the direction of arrival of the signal as a function of the position of the goniometer. The theoretical resolution of the Wullenweber array is on the order of 0.1°, although practical resolutions of about 2.8° are commonly seen.

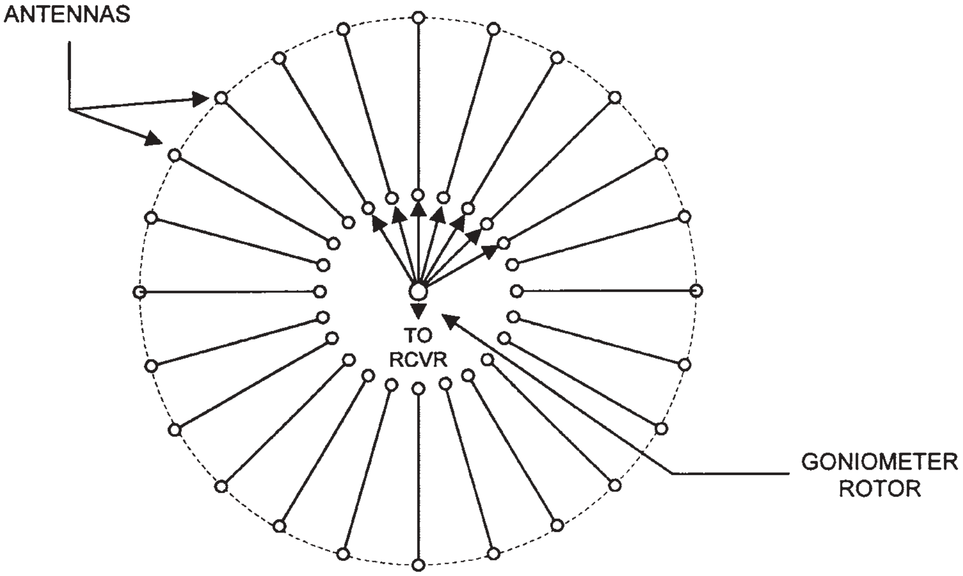

23-14 Wullenweber RDF array.

Time difference of arrival (TDOA) array

If you erect two antennas with distance *d* apart, then arriving signals can be detected by examining the time-of-arrival difference. Figure 23-15A shows an example signal. If the advancing wavefront is parallel to the line between the antennas, then it will arrive at both antennas at the same time. The TDOA is zero in that case. But if the signal arrives at an angle (as in Fig. 23-15A), it will arrive at one antenna first. From the difference between the time of arrival at the two antennas we can discern the direction of arrival.

There is an ambiguity in the basic TDOA array in that the combined output will be the same for conjugate angles, i.e. at the same angle from opposite directions. This problem can be resolved by the system shown in Fig. 23-15B. The signals from ANT1 and ANT2 are designated V_1 and V_2, respectively. These signals are detected by receivers (RCVR1 and RCVR2), and are then threshold detected in order to prevent signal-to-noise problems from interfering with the operation. The outputs of the threshold detectors are used to trigger a sawtooth generator that controls the horizontal sweep on an oscilloscope.

The two signals are then delayed, and one is inverted. The reason for inverting one signal is to allow the operator to distinguish them on the CRT screen. The reason why this is necessary is the ambiguity. If the antennas in Fig. 23-15A are arrayed east to west, then the line perpendicular to the line between them is north to south.

If we designate north as 0°, then the signal shown arrives at an angle of 330°. That means it will arrive at ANT1 before it arrives at ANT2. A signal arriving from a bearing of 30° will produce the same output signal, even though it arrives at ANT2 before ANT1. All signals of bearing $0 \leq x < 180°$ will arrive at ANT2 first, while all

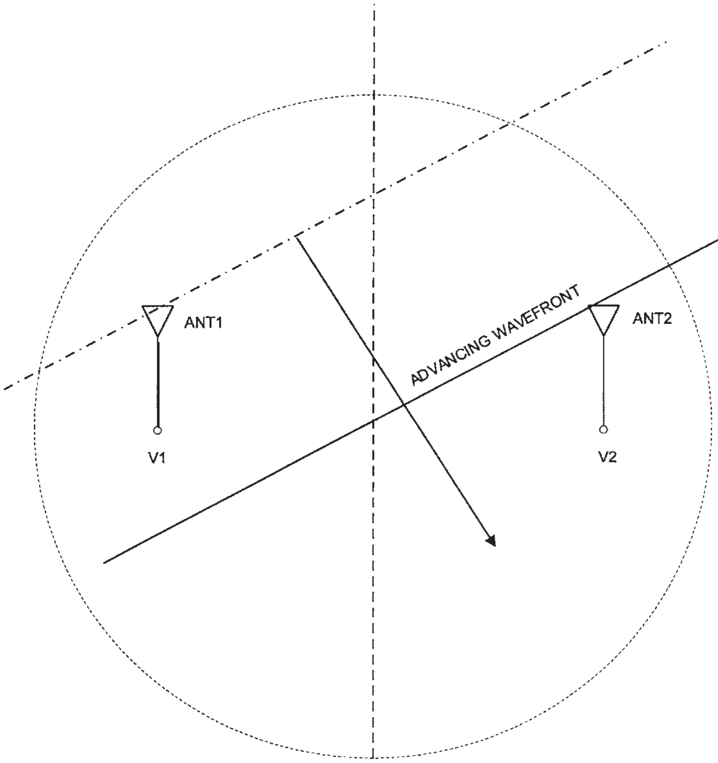
ANT1
ANT2
ADVANCING WAVEFRONT
V1
V2

23-15A Time difference of arrival (TDOA) RDF array.

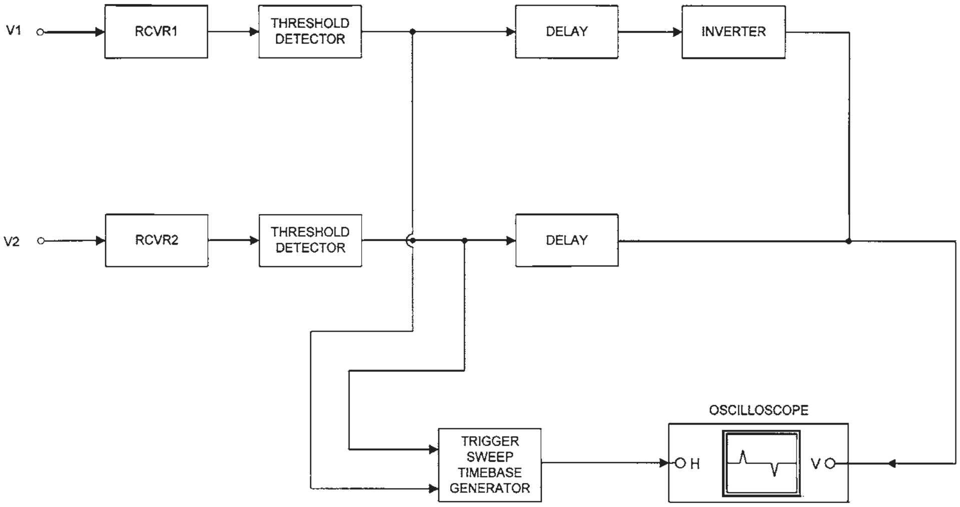
V1
RCVR1
THRESHOLD DETECTOR
DELAY
INVERTER
V2
RCVR2
THRESHOLD DETECTOR
DELAY
TRIGGER SWEEP TIMEBASE GENERATOR
OSCILLOSCOPE
H
V

23-15B Block diagram of typical TDOA circuit.

signals 180 ≤ x < 360° will arrive at ANT1 first. Yet both will produce the same blip on the oscilloscope screen. The solution to discerning which of the two conjugate angles is intended is to invert the ANT1 signal. When this is done, the ANT1 signal falls below the baseline on the CRT screen, while the ANT2 signal is above the baseline. By noting the time difference between the pulses, and their relative position, we can determine the bearing of the arriving signal.

Switched-pattern RDF antennas

Suppose we have a unidirectional pattern such as the cardioid shown in Fig. 23-16. If we can rapidly switch the pattern back and forth between two directions that are 180° apart, then we can not only discern direction, but also we can tell whether an off-axis signal is left or right. This feature is especially useful for mobile and portable direction finding.

In Fig. 23-16 we have three different positions for a signal source. When the signal source is at point *A,* it will affect the pattern to the left more than the pattern to the right, so the meter will read left. If the signal source is at point *B,* on the other hand, the signal affects both pattern positions equally, so the meter reads zero. Finally, if the signal arrives from point *C,* it affects the right-hand pattern more than the left-hand pattern, so the meter reads right.

Figure 23-17 shows how such a system can be constructed. This system has been used by amateur radio operators with “rubber ducky” VHF antennas and a sin-

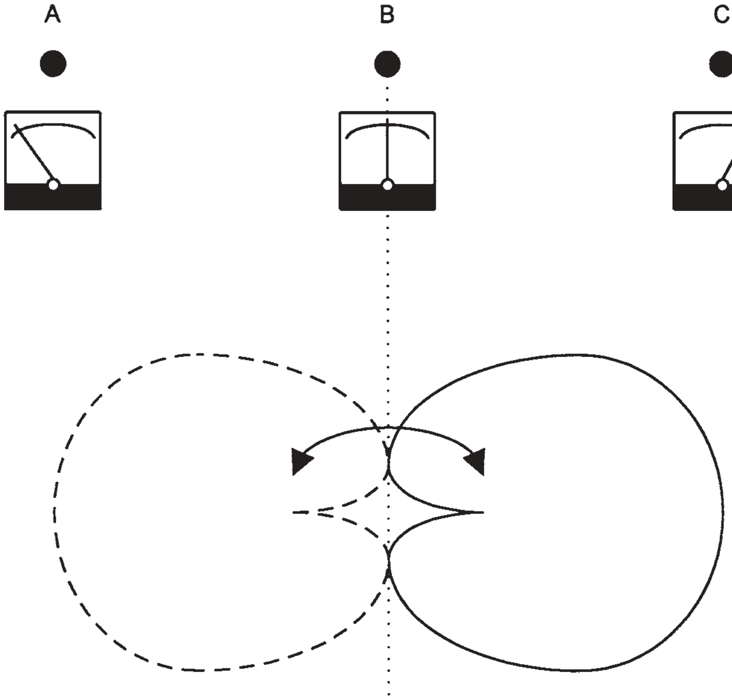

23-16 Switched-pattern RDF system.

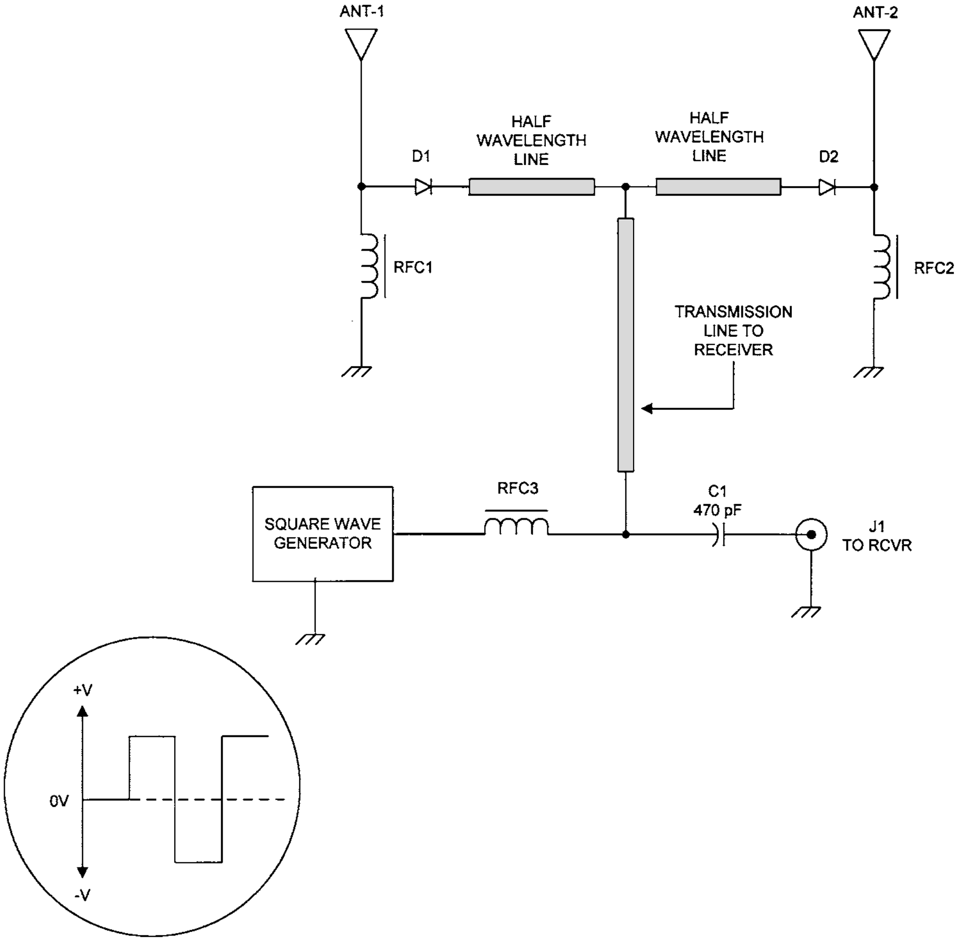
ANT-1
ANT-2
HALF WAVELENGTH LINE
HALF WAVELENGTH LINE
D1
D2
RFC1
RFC2
TRANSMISSION LINE TO RECEIVER
RFC3
C1
470 pF
SQUARE WAVE GENERATOR
J1
TO RCVR
+V
0V
-V

23-17 Double-ducky RDF system based on the switched-pattern system.

gle receiver, where it is commonly called the *double-ducky direction finder* (DDDF). The antennas are spaced from 0.25 λ to 1λ apart over a good groundplane (such as the roof of a car or truck). If no groundplane exists, then a sheet metal groundplane should be provided.

In Fig. 23-17 we see the antennas are fed from a common transmission to the receiver. In order to keep them electrically the same distance apart, a pair of identical half-wavelength sections of transmission line are used to couple to the antennas.

Switching is accomplished by using a bipolar square wave and PIN diodes. The bipolar square wave (see inset to Fig. 23-17) has a positive peak voltage and a negative peak voltage on opposite halves of the cycle. The PIN diodes (D_1 and D_2) are connected in opposite polarity to each other. Diode D_1 will conduct on negative excursions of the square wave, while D_2 conducts on positive excursions. The antenna connected to the conducting diode is the one that is connected to the receiver, while the other one is parasitic. The active antenna therefore switches back and forth between ANT1 and ANT2.

This antenna is coupled to the receiver through a small-value capacitor (C_1) so that the square wave does not enter the receiver. This allows us to use the transmission line for both the RF signal and the switching signal. An RF choke (RFC_3) is used to keep RF from the antenna from entering the square-wave generator.

The DDDF antenna produces a phase modulation of the incoming signal that has the same frequency as the square wave. This signal can be heard in the receiver output. When the signal's direction of arrival is perpendicular to the line between the two antennas, the phase difference is zero, so the audio tone disappears.

The pattern of the DDDF antenna is bidirectional, so there is the same ambiguity problem as exists with loop antennas. The ambiguity can be resolved by either of two methods. First, a reflector can be placed $\lambda/4$ behind the antennas. This is attractive, but it tends to distort the antenna pattern a little bit. The other method is to rotate the antenna through 90° (or walk an L-shaped path).

Conclusion

Radio direction finding can be very useful for locating RF noise sources, illegal stations, and other RF sources. It can also be used to locate yourself if you can get bearings on at least two stations. The lines of bearing will cross at a location approximately where you are standing—try it, you'll like it.

24
CHAPTER

Impedance matching in antenna systems

ONE OF THE FIRST THINGS THAT YOU LEARN IN RADIO COMMUNICATIONS AND broadcasting is that antenna impedance must be matched to the transmission line impedance, and that the transmission line impedance must be matched to the output impedance of the transmitter. The reason for this requirement is that maximum power transfer, between a source and a load, always occurs when the system impedances are matched. In other words, more power is transmitted from the system when the load impedance (the antenna), the transmission line impedance, and the transmitter output impedance are all matched to each other.

Of course, the trivial case is where all three sections of our system have the same impedance. For example, we could have an antenna with a simple 75-Ω resistive feedpoint impedance (typical of a half-wave dipole in free space), and a transmitter with an output impedance that will match 75 Ω. In that case, we need only connect a standard-impedance 75-Ω length of coaxial cable between the transmitter and the antenna. Job done! Or so it seems.

But there are other cases where the job is not so simple. In the case of our "standard" antenna, for example, the feedpoint impedance is rarely what the books say it should be. That ubiquitous dipole, for example, is nominally rated at 73 Ω, but even the simplest antenna books tell us that value is an approximation of the theoretical free-space impedance. At locations closer to the earth's surface, the impedance could vary over the approximate range of 30 to 130 Ω and it might have a substantial reactive component.

But there is a way out of this situation. We can construct an impedance-matching system that will marry the source impedance to the load impedance. This chapter examines several matching systems that might prove useful in a number of antenna situations.

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Impedance-matching approaches

Antenna impedance can contain both reactive and resistive components. In most practical applications, we are searching for a purely resistive impedance ($Z = R$), but that ideal is rarely achieved. A dipole antenna, for example, has a theoretical free-space impedance of 73 Ω at resonance. As the frequency applied to the dipole is varied away from resonance, however, a reactive component appears. When the frequency is greater than resonance, then the antenna tends to look like an inductive reactance, so the impedance is $Z = R + jX$. Similarly, when the frequency is less than the resonance frequency, the antenna looks like a capacitive reactance, so the impedance is $Z = R - jX$. Also, at distances closer to the earth's surface the resistive component may not be exactly 73 Ω, but may vary from about 30 to 130 Ω. Clearly, whatever impedance coaxial cable is selected to feed the dipole, it stands a good chance of being wrong.

The method used for matching a complex load impedance (such as an antenna) to a resistive source (the most frequently encountered situation in practical radio work) is to interpose a matching network between the load and the source (Fig. 24-1). The matching network must have an impedance that is the *complex conjugate* of the complex load impedance. For example, if the load impedance is $R + jX$, then the matching network must have an impedance of $R - jX$; similarly, if the load is $R - jX$ then the matching network must be $R + jX$. The sections to follow look at some of the more popular networks that accomplish this job.

L-section network

The L-section network is one of the most used, or at least the most published, antenna matching networks in existence: it rivals even the pi network. A circuit for the L-section network is shown in Fig. 24-2A. The two resistors represent the source (R_1) and load (R_2) impedances. The elementary assumption of this network is that $R_1 < R_2$. The design equations are

$$R_1 < R_2 \text{ and } 1 < Q < 5 \qquad \textbf{[24.1]}$$

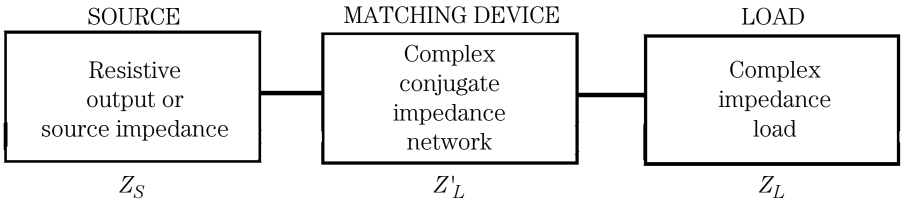
SOURCE
MATCHING DEVICE
LOAD
Resistive output or source impedance
Complex conjugate impedance network
Complex impedance load
Z_S
Z'_L
Z_L

$Z_S = R$

If:

$Z_L = R + jX$, then $Z'_L = R - jX$

$Z_L = R - jX$, then $Z'_L = R + jX$

24-1 Transmitter, matcher, and antenna system.

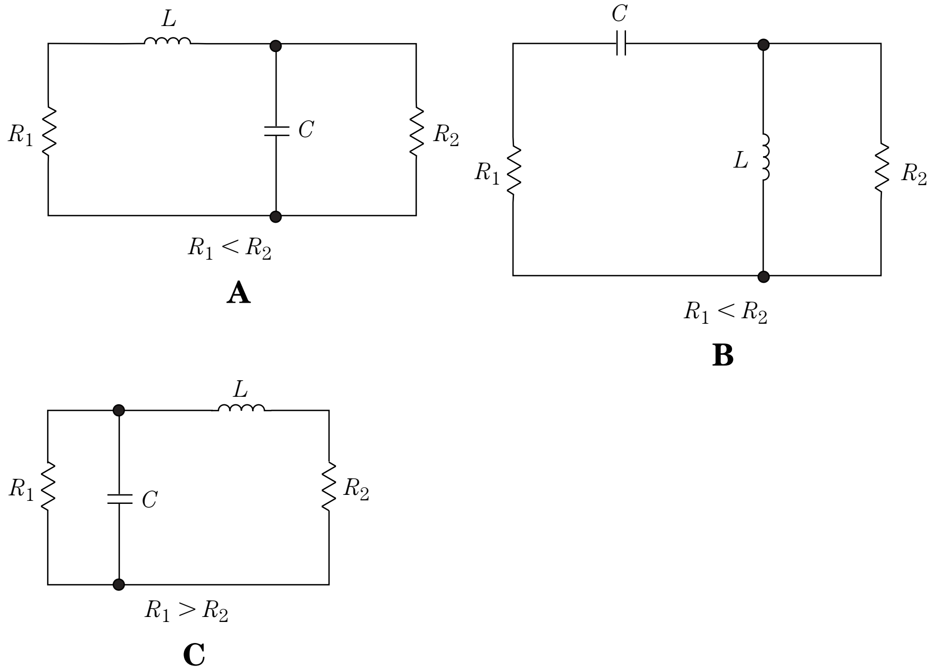

24-2 (A) L-section network; (B) reverse L section; (C) inverted L-section network.

$$X_L = 6.28FL = Q \times R_1 \qquad [24.2]$$

$$X_C = \frac{1}{6.28FC} \qquad [24.3]$$

$$Q = \sqrt{\frac{R_2}{R_1} - 1} \qquad [24.4]$$

also,

$$Q = \frac{X_L}{R_1} = \frac{R_2}{X_C} \qquad [24.5]$$

You will most often see this network published in conjunction with less-than-quarter-wavelength longwire antennas. One common fault of those books and articles is that they typically call for a "good ground" in order to make the antennas work properly. But they don't tell you (1) what a "good ground" is and (2) how you can obtain it. Unfortunately, at most locations a good ground means burying a lot of copper conductor—something that most of us cannot afford. In addition, it is often the case that the person who is forced to use a longwire, instead of a better antenna, cannot construct a "good ground" under any circumstances because of landlords (and/or logistics) problems. The very factors that prompt the use of a longwire antenna in the first place also prohibit any form of practically obtainable "good ground." But there is a way out: *radials*. A good ground can be simulated with a counterpoise ground constructed of quarter-wavelength radials. These radials have a length in feet equal to $246/F_{\text{MHz}}$, and as few as two of them will work wonders. Another form of L-section network is shown in Fig. 24-2B. This circuit differs from the previous circuit in that the roles of the L and C components are reversed. As you might suspect, this role reversal brings about a reversal of the impedance relationships: in this circuit the assumption is that the driving source impedance R_1 is larger than the load impedance R_2 (i.e., $R_1 > R_2$). The equations are shown below:

$$R_2 > R_1 \qquad \textbf{[24.6]}$$

$$X_L = R_2 \sqrt{\frac{R_1}{(R_2 - R_1)}} \qquad \textbf{[24.7]}$$

$$X_C = \frac{(R_1 R_2)}{X_L} \qquad \textbf{[24.8]}$$

Still another form of L-section network is shown in Fig. 24-2C. Again, we are assuming that driving source impedance R_1 is larger than load impedance R_2 (i.e., $R_1 > R_2$). In this circuit, the elements are arranged similar to Fig. 24-2A, with the exception that the capacitor is at the input rather than the output of the network. The equations governing this network are:

$$R_1 > R_2 \text{ and } 1 < Q < 5 \qquad \textbf{[24.9]}$$

$$X_L = 6.28FL = \sqrt{(R_1 R_2) - (R_2)^2} \qquad \textbf{[24.10]}$$

$$X_C = \frac{1}{6.28FC} = \frac{R_1 R_2}{X_L} \qquad \textbf{[24.11]}$$

$$C = \frac{1}{6.28FX_C} \qquad \textbf{[24.12]}$$

$$L = \frac{X_L}{6.28F} \qquad \textbf{[24.13]}$$

Thus far, we have considered only matching networks that are based on inductor and capacitor circuits. But there is also a possibility of using transmission line segments as impedance-matching devices. Two basic forms are available to us: quarter-wave sections and the series matching section.

Pi networks

The pi network shown in Fig. 24-3 is used to match a high source impedance to a low load impedance. These circuits are typically used in vacuum tube RF power amplifiers that need to match low antenna impedances. The name of the circuit comes from its resemblance to the Greek letter pi. The equations for the pi network are:

$$R_1 > R_2 \text{ and } 5 < Q < 15 \qquad \textbf{[24.14]}$$

$$Q > \sqrt{\frac{R_1}{R_2} - 1} \qquad \textbf{[24.15]}$$

$$X_{C2} = \frac{R_2}{\sqrt{\left(\frac{R_2}{R_1}\right)(1 + Q^2) - 1}} \qquad \textbf{[24.16]}$$

$$X_{C1} = \frac{R_1}{Q}$$

$$X_L = \frac{R_1\,\{(Q + (R_2/X_{C2})\}}{Q^2 + 1} \qquad \textbf{[24.17]}$$

Split-capacitor network

The split-capacitor network shown in Fig. 24-4 is used to transform a source impedance that is less than the load impedance. In addition to matching antennas, this circuit is also used for interstage impedance matching inside communications equipment. The equations for design are

$$R_1 < R_2 \qquad \textbf{[24.18]}$$

$$Q > \sqrt{\frac{R_1}{R_2} - 1} \qquad \textbf{[24.19]}$$

$$X_L = \frac{R_2}{Q} \qquad \textbf{[24.20]}$$

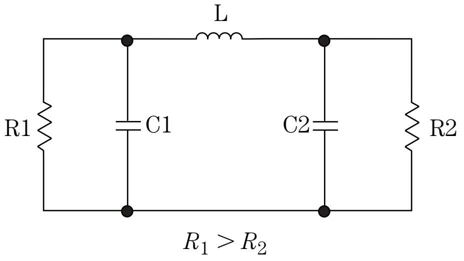

24-3 Pi network.

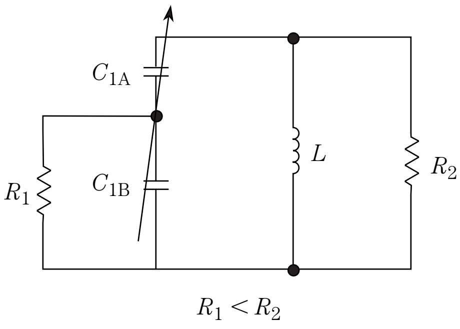

24-4 Split-capacitor network.

$$X_{C1B} = \sqrt{\frac{R_1\,(Q_2 + 1)^2}{R_2}} - 1 \qquad \textbf{[24.21]}$$

$$X_{C1A} = \frac{R_2\,Q}{Q^2 + 1}\left(1 - \frac{R_1}{Q\,X_{C1A}}\right) \qquad \textbf{[24.22]}$$

Transmatch circuit

One version of the *transmatch* is shown in Fig. 24-5. This circuit is basically a combination of the split-capacitor network and an output tuning capacitor (C_2). For the HF bands, the capacitors are on the order of 150 pF per section for C_1, and 250 pF for C_2. The collar inductor should be 28 µH. The transmatch is essentially a coax-to-coax impedance matcher, and is used to trim the mismatch from a line before it affects the transmitter.

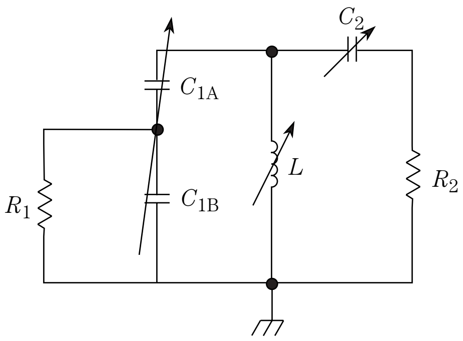

24-5 Split-capacitor transmatch network.

Perhaps the most common form of transmatch circuit is the tee network shown in Fig. 24-6. This network is lower in cost than some of the others, but suffers a problem. Although it does, in fact, match impedance (and thereby, in a naive sense, "tunes out" VSWR on coaxial lines), it also suffers a high pass characteristic. The network, therefore, does not reduce the harmonic output of the transmitter. The simple tee network does not serve one of the main purposes of the antenna tuner: harmonic reduction.

An alternative network, called the *SPC transmatch*, is shown in Fig. 24-7. This version of the circuit offers harmonic attenuation, as well as matching impedance.

Figure 24-8 shows commercially available antenna tuners based on this transmatch design. The unit shown in Fig. 24-8A is manufactured by MFJ Electronics, Inc. It contains the usual three tuning controls, here labeled *transmitter, antenna, and inductor*. Included in this instrument is an antenna selector switch that allows the operator to select a coax antenna through the tuner, to connect input to output (coax) without regard to the tuner, select a balanced antenna, or connect an internal dummy load. The instrument also contains a multifunction meter that can measure 200 W or 2000 W (full scale), in either forward or reverse directions. In addition, the meter operates as a VSWR meter.

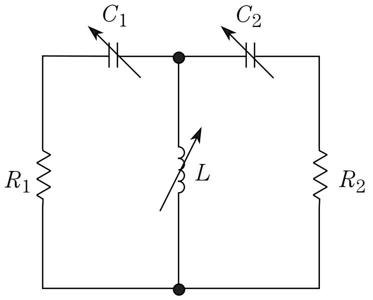

24-6 Tee-network transmatch.

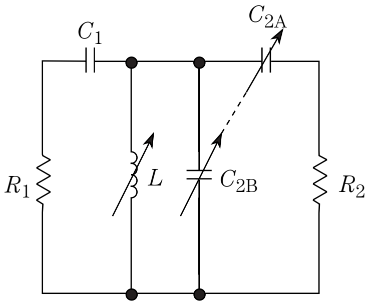

24-7 Improved transmatch offers harmonic attenuation.

Figures 24-8B through 24-8D show an imported tuner from the United Kingdom. This instrument, called the *Nevada* model, is a low-cost model, but contains the three basic controls. For proper operation, an external RF power meter, or VSWR meter, is required. The tuner is shown in Fig. 24-8B; also shown is a Heathkit transmatch antenna tuner. The rear panel of the Nevada instrument is shown in Fig. 24-8C. There are SO-239 coaxial connectors for input and unbalanced output, along with a pair of posts for the parallel line output. A three-post panel is used to select which antenna the RF goes to: unbalanced (coax) or parallel. The internal circuitry of the *Nevada* is shown in Fig. 24-8D. The roller inductor is in the center and allows the user to set the tuner to a wide range of impedances over the entire 3- to 30-MHz HF band.

MFJ VERSA TUNER V
TRANSMITTER
ANTENNA SELECTOR
COAX
ANTENNA
INDUCTOR
DUMMY LOAD
WIRE BAL LINE
COAX DIRECT
SWR SET
METER

24-8A MFJ antenna tuner.

24-8B Author's Heathkit antenna tuner and the Nevada tuner from the United Kingdom.

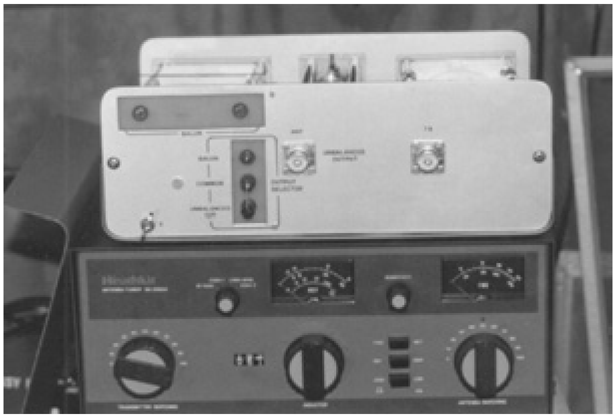

24-8C Rear of Nevada tuner.

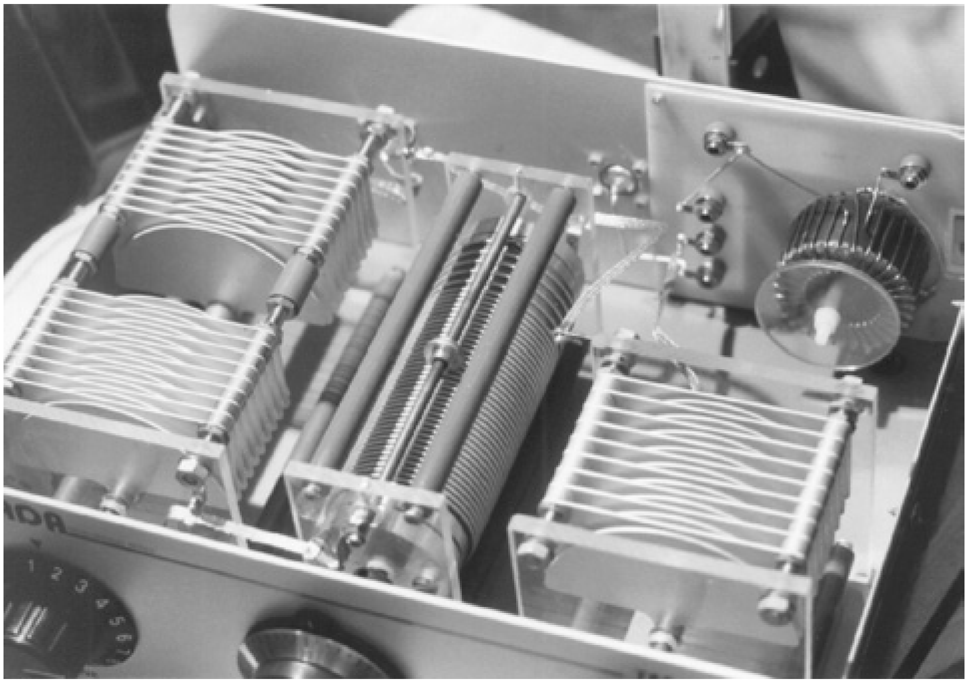

24-8D Inside of Nevada tuner.

Coaxial cable BALUNS

A balun is a transformer that matches an unbalanced resistive source impedance (such as a coaxial cable), to a "balanced" load (such as a dipole antenna). With the circuit of Fig. 24-9, we can make a balun that will transform impedance at a 4:1 ratio, with $R_2 = 4 \times R_1$. The length of the balun section of coaxial cable is

$$L_{\text{ft}} = \frac{492V}{F_{\text{MHz}}} \qquad \textbf{[24.23]}$$

where:

L_{ft} is the length, in feet
V is the velocity factor of the coaxial cable (a decimal fraction)
F_{MHz} is the operating frequency, in megahertz

Matching stubs

A shorted stub can be built to produce almost any value of reactance. This fact can be used to make an impedance-matching device that cancels the reactive portion of a complex impedance. If we have an impedance of $Z = R + j30\ \Omega$ we need to make a stub with a reactance of $-j30\ \Omega$ to match it. Two forms of matching stub are shown in Figs. 24-10A and 24-10B. These stubs are connected exactly at the feedpoint of the complex load impedance, although they are sometimes placed farther back on the line at a (perhaps) more convenient point. In that case, however, the reactance required will be transformed by the transmission line between the load and the stub.

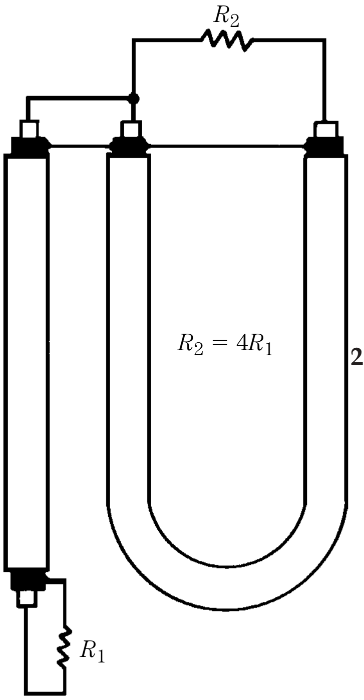

24-9 Coaxial balun transformer.

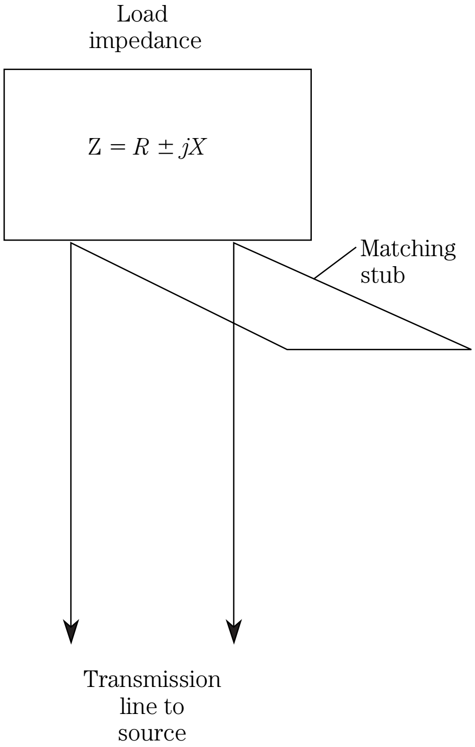
Load impedance
$Z = R \pm jX$
Matching stub
Transmission line to source

24-10A Stub match scheme.

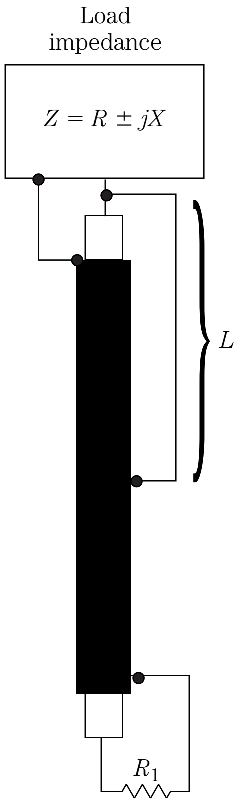

24-10B Coaxial stub matching.

Quarter-wave matching sections

Figure 24-11 shows the elementary quarter-wavelength transformer section connected between the transmission line and the antenna load. This transformer is also sometimes called a *Q section*. When designed correctly, this transmission line transformer is capable of matching the normal feedline impedance Z_s to the antenna feedpoint impedance Z_R. The key factor is to have available a piece of transmission line that has an impedance Z_o of

$$Z_o = \sqrt{Z_s Z_R} \qquad \textbf{[24.24]}$$

Most texts show this circuit for use with coaxial cable. Although it is certainly possible, and even practical in some cases, for the most part there is a serious flaw in using coax for this project. It seems that the normal range of antenna feedpoint impedances, coupled with the rigidly fixed values of coaxial-cable surge impedance available on the market, combines to yield unavailable values of Z_o. Although there are certainly situations that yield to this requirement, many times the quarter-wave section is not usable on coaxial-cable antenna systems having standard impedance values.

On parallel transmission line systems, on the other hand, it is quite easy to achieve the correct impedance for the matching section. We use the equation above to find a value for Z_o, and then calculate the dimensions of the parallel feeders. Be-

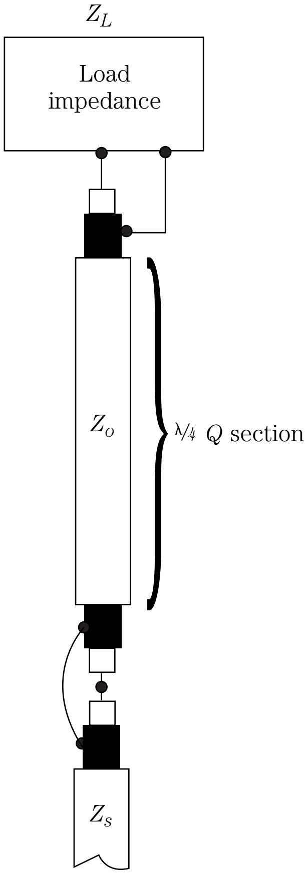

24-11 Quarter-wavelength Q section.

cause we know the impedance, and can more often than not select the conductor diameter from available wire supplies, you can use the equation below to calculate conductor spacing:

$$S = D \times 10^{(Z/276)} \qquad \textbf{[24.25]}$$

where

S is the spacing
D is the conductor diameter
Z is the desired surge impedance.
From there you can calculate the length of the quarter-wave section from the familiar $246/F_{\text{MHz}}$. D *and* S are in the same units.

Series matching section

The quarter-wavelength section, covered in the preceding section, suffers from drawbacks: it must be a quarter-wavelength and it must use a specified (often nonstandard) value of impedance. The series matching section is a generalized case of the same idea, and it permits us to build an impedance transformer that overcomes these faults. According to *The ARRL Antenna Book*, this form of transformer is capable of matching any load resistance between about 5 and 1200 **Ω**. In addition, the transformer section is not located at the antenna feedpoint.

Figure 24-12 shows the basic form of the series matching section. There are three lengths of coaxial cable: L_1, L_2, and the line to the transmitter. Length L_1 and the line to the transmitter (which is any convenient length) have the same characteristic impedance, usually 75 **Ω**. Section L_2 has a different impedance from L_1 and the line to the transmitter. Note that only standard, easily obtainable values of impedance are used here.

The design of this transformer consists of finding the correct lengths for L_1 and L_2. You must know the characteristic impedance of the two lines (50 **Ω** and 75 **Ω** given as examples), and the complex antenna impedance. In the case where the antenna is non resonant, this impedance is of the form $Z = R \pm jX$, where R is the resistive portion, X is the reactive portion (inductive or capacitive), and j is the so-called imaginary operator (i.e., square root of minus one). If the antenna is resonant, then $X = 0$, and the impedance is simply R.

The first chore in designing the transformer is to *normalize* the impedances:

$$N = \frac{Z_{L1}}{Z_o} \qquad \textbf{[24.26]}$$

$$R = \frac{R_L}{Z_o} \qquad \textbf{[24.27]}$$

$$X = \frac{X_L}{Z_o} \qquad \textbf{[24.28]}$$

The lengths are determined in electrical degrees, and from that determination we can find length in feet or meters. If we adopt ARRL notation and define $A = \tan L_1$, and $B = \tan L_2$, then the following equations can be written:

If: $Z_\mathrm{L} = R \pm jX_\mathrm{L}$

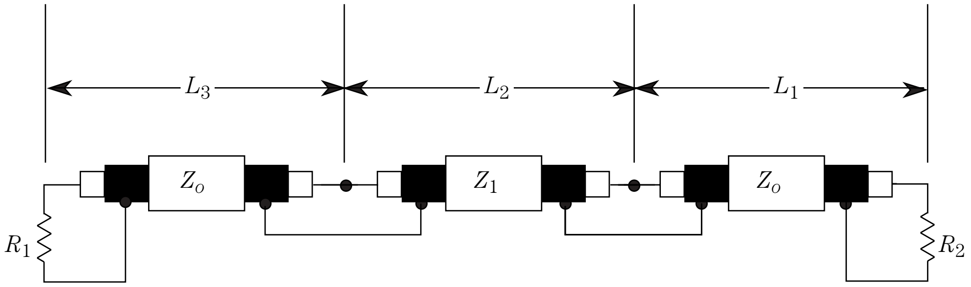

24-12 Series matching section.

$$\tan L_2 = B = \frac{(r-1)^2 + X^2}{r\{N - (1/N)^2\} - (r-1)^2 - X^2} \qquad \textbf{[24.29]}$$

$$\tan L_1 = A = \frac{\{N - (r/R)\} \times B + X}{r + (XNB) - 1} \qquad \textbf{[24.30]}$$

where:

$$N = \frac{Z_1}{Z_o}$$

$$r = \frac{R_L}{Z_o}$$

$$Z = \frac{X_L}{Z_o}$$

Constraints:

$$Z_1 > Z_o \sqrt{\text{VSWR}} \qquad \textbf{[24.31]}$$

$$Z_1 < Z_o \sqrt{\text{VSWR}} \qquad \textbf{[24.32]}$$

If $L_1 < 0$, then add 180°
If $B < 0$, then Z_1 is too close to Z_o
Z_1 not equal to Z_o
$Z_o \sqrt{\text{VSWR}} < Z_1 < Z_o \sqrt{\text{VSWR}}$

Physical length in feet:

$$L_1 = \frac{L_1 \lambda}{360} \qquad \textbf{[24.33]}$$

$$L_2 = \frac{L_2 \lambda}{360} \qquad \textbf{[24.34]}$$

where

$$\lambda = \frac{984 \times \text{velocity factor}}{\text{frequency in megahertz}} \qquad \textbf{[24.35]}$$

The physical length is determined from arctan A and arctan B, divided by 360 and multiplied by the wavelength along the line and the velocity factor.

Although the sign of B can be selected as either – or +, the use of + is preferred because a shorter section is obtained. In the event that the sign of A turns out negative, add 180° to the result.

There are constraints on the design of this transformer. For one thing, the impedance of the two sections L_1 and L_2 cannot be too close together. In general, the following relationships must be observed:

Either

$$Z_{L1} > Z_o \times \text{SWR} \qquad \textbf{[24.36]}$$

or

$$\frac{Z_{L1} < Z_o}{\text{SWR}} \qquad \textbf{[24.37]}$$

Ferrite core inductors

The word *ferrite* refers to any of several examples of a class of materials that behave similarly to powdered iron compounds, and are used in radio equipment in the form of inductors and transformers. Although the original materials were of powdered iron, and indeed the name *ferr*ite still implies iron, many modern materials are composed of other compounds. According to the Amidon Associates literature, ferrites with a permeability u of 800 to 5000 are generally of the manganese-zinc type of material, and cores with permeabilities of 20 to 800 are of nickel-zinc. The latter are useful in the 0.5- to 100-MHz range.

Toroid cores

A *toroid* is a doughnut-shaped object, so one can reasonably expect a toroidal core to be an inductor (or transformer) form, made of a ferrite material, in the general shape of a doughnut. The type of core must be known for application purposes, and is given by the type number. The number will be of the form: FT – *xx* – *nn*, where FT means ferrite toroid and describes the shape, *xx* indicates the size, and *nn* indicates the material type. The F in FT is sometimes deleted in parts lists, and the core defined as a "T-*xx*-*nn*."

A chart is provided by Amidon that gives the dimensions, and a description of the properties of the different types of material, along with a lot of other physical data. Some of these data are also available in the annual ARRL publication *The ARRL Handbook for the Radio Amateur* (the same material has appeared in earlier editions also).

Tables are derived in part from both Amidon and ARRL sources. From these tables, you can see the sizes and properties of various popular toroids. These tables, incidentally, are not exhaustive of either the variety of toroids available, or all of the properties of the toroids mentioned. Using the nomenclature mentioned, a T-50-2 core refers to a core that is useful from 1 to 30 MHz, has a permeability of 10, is painted red, and has the following dimensions: OD = 0.500 in (1.27 cm), ID = 0.281 in (0.714 cm) and a height (i.e., thickness) of 0.188 in (0.448 cm).

Toroidal transformers

A magazine reader once asked a question of this author concerning the winding protocol for toroidal transformers as seen in textbooks and magazine articles. My correspondent included a partial circuit (Fig. 24-13A) as typical of the dilemma. The question was "How do you wind it?" and a couple of alternative methods were proposed. At first I thought it was a silly question because the answer was "obvious,"

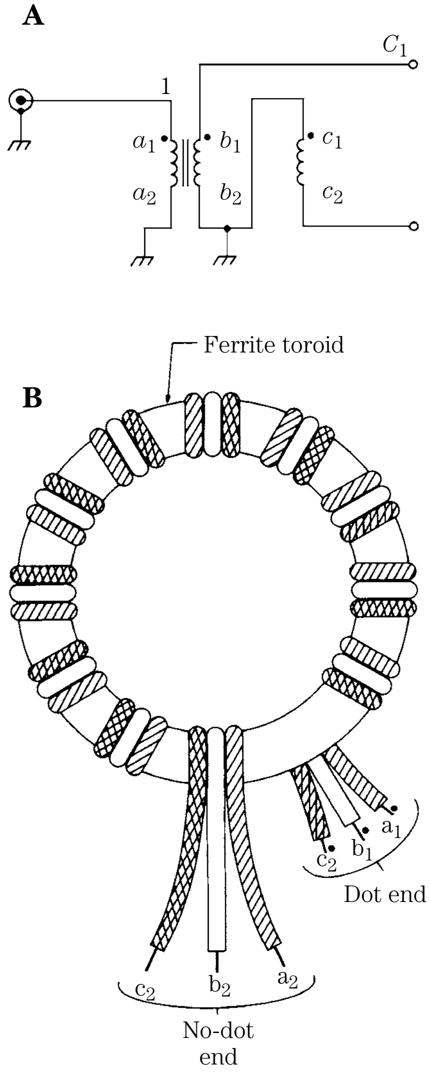

24-13 Broadband RF transformer.

and then I realized that perhaps I was wrong, and to many people the answer was not at all that obvious.

The answer to the question is that all windings are wound together in a "multifilar" manner. Because there are three windings, in this case we are talking about "trifilar" windings. Figure 24-13B shows the trifilar winding method. For the sake of clarity, I have patterned all three wires differently so that you can follow them. This practice is also a good idea for practical situations. Since most small construction projects use no.26, no.28 or no.30 enameled wire to wind coils, I keep three colors of each size on hand, and wind each winding with a different color [Note: for transmitting antenna transformers use no.16, no.14, no.12, or no.10 wire]. Otherwise, label the ends with adhesive labels.

The dots in the schematic, and on the pictorial, are provided to identify one end of the coil windings. Thus, the dot and no-dot ends are different from each other, and it usually makes a difference to circuit operation which way the ends are connected into the circuit (the issue is signal phasing).

Figure 24-14 shows two accepted methods for winding a multifilar coil on a toroidal core. Figure 24-14A is the same method as in Fig. 24-13B, but on an actual toroid instead of a pictorial representation. The wires are laid down parallel to each other as shown previously. The method in Fig. 24-14B uses twisted wires. The three wires are "chucked up" in a drill and twisted together before being wound on the core. With one end of the three wires secured in the drill chuck, anchor the other end of the three wires in something that will hold it taut. Some people use a bench vise for this purpose. Turn on the drill at slow speed and allow the wires to twist together until the desired pitch is achieved.

Be very careful when performing this operation. If you don't have a variable speed electric drill (so that it can be run at very low speed), then use an old-fashioned manual hand drill. If you use an electric drill, then wear eye protection. If the wire breaks, or gets loose from its mooring at the end opposite the drill, it will whip around wildly until the drill stops. That whipping wire will cause painful welts on the skin, and can easily damage eyes permanently.

Of the two methods for winding toroids, the method of Figs. 24-13B and 24-14A is preferred. When winding toroids, at least those of relatively few windings, pass the wire through the "doughnut hole" until the toroid is about in the middle of the length of wire. Then, loop the wire over the outside surface of the toroid, and pass it through the hole again. Repeat this process until the correct number of turns is wound onto the core. Be sure to press the wire against the toroid form, and keep it taut as you wind the coils.

Enameled wire is usually used for toroid transformers and inductors and that type of wire can lead to a problem. The enamel can chip and cause the copper conductor to contact the core. On larger cores, such as those for antenna-matching tranformers (and baluns used at kilowatt power levels), the practical solution is to wrap the bare toroid core in a layer of fiberglass packing tape. Wrap the tape exactly as if it was wire, but overlap the turns slightly to ensure covering the entire circumference of the core.

On some projects, especially those in which the coils and transformers use very fine wire (e.g., no.30), you may experience a tendency for the wire windings to unravel after the winding is completed. This problem is also easily curable. At the ends of the windings, place a tiny dab of rubber cement or RTV silicone sealer.

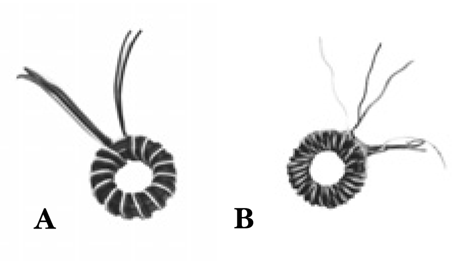

24-14 Winding a toroidal transformer
A) parallel wound,
B) twist wound.

Mounting toroid cores Now that you have a properly wound toroidal inductor or transformer, it is time to actually mount it in a circuit being constructed. There are three easy ways to do this job. First, you might be able to ignore it. If the wire is heavy enough, then just use the wire connections to the circuit board or terminal strip to support the component. But if this is not satisfactory, and in mobile equipment (or wherever else vibration is a factor) it won't be, then try laying the toroid flat on the board and cementing it in place with silicone seal or rubber cement. The third method is to drill a hole in the wiring board and use a screw and nut to secure the toroid. Do not use metallic hardware for mounting the toroid! Metallic fasteners will alter the inductance of the component and possibly render it unusable. Use nylon hardware for mounting the inductor, or transformer.

How many turns? Three factors must be taken into consideration when making toroid transformers or inductors: *toroid size, core material,* and *number of turns of wire.* The toroid size is selected as a function of power-handling capability, or for convenience of handling. The core material is selected according to the frequency range of the circuit. The only thing left to vary is the number of turns. The size and core material yields a figure called the A_L factor. The required value of inductance and the A_L factor are used in the following equation:

$$N = 100\sqrt{\frac{L_{\mu\text{H}}}{A_L}} \tag{24.38}$$

where:

N is the number of turns
$L_{\mu\text{H}}$ is the inductance in microhenrys
A_L is the core factor, in microhenrys per 100 turns

Example Calculate the number of turns required to make a 5-μH inductor on a T-50-6 core. The A_L factor is 40.

Solution:

$$N = 100\sqrt{\frac{L_{\mu\text{H}}}{A_L}}$$

$$= 100\sqrt{\frac{5_{\mu\text{H}}}{40}}$$

$$= 100\ \sqrt{0.125}$$

$$= (100)\ (0.35) = 35$$

Don't take the equation value too seriously, however, because it is my experience that a wide tolerance exists on amateur-grade ferrite cores. Although it isn't too much of a problem when building transformers, it can be critical when making inductors for a tuned circuit. When you find that the tuned circuit takes considerably more (or less) capacitance than called for in the standard equation, and all of the stray capacitance is properly taken into consideration, then it may be that the actual A_L value of your particular core is different from the table value.

Ferrite rods

Another form of ferrite core available on the market is the rod, shown in Fig. 24-15A. This type of core is used to make RF chokes, such as the RFC used in the vacuum tube filament lines of a linear amplifier power tube (Fig. 24-15B). They are also used for baluns by some people. The two windings are wound in a bifilar manner over the ferrite rod. Of course, the wires used must be heavy enough to carry the filament current of the tube. As was true in the toroidal transformer, I use two different wire colors in order to make it easy to identify windings.

Ferrite rods are also used in receiving antennas. Although the amateur use is not extensive, there are places where a ferrite rod antenna (or "loopstick") is used. For example, in radio direction finding antennas, it is common to see the ferrite loop. Also, some amateurs report that they use a loopstick receiving antenna when operating on crowded bands, such as 40 and 75 m. The small loopstick has an extremely directional characteristic, so it is capable of nulling out interfering signals. Of course, you would not want to use the loopstick for transmitting, so some means must be found for transferring the antennas over between the transmit and receive functions.

Mounting ferrite rods Ferrite rods can be mounted in several ways, two of which are analagous to the methods used on toroids. We can, for example, mount the rod using either its own wires for support or by using a dab of cement or silicone sealer to fasten it to the board. Although we cannot use simple nylon screws the way we can on toroids, we can use insulating cable clamps to secure the ends of the rod to the board.

Toroid broadbanded impedance matching transformers

The toroidal transformer forms a broadbanded means for matching antenna impedance to the transmission line, or matching the transmission line to the transmitter. The other matching methods (shown thus far) are frequency-sensitive, and must be readjusted whenever the operating frequency is changed even a small amount. Although this problem is of no great concern to fixed-frequency radio stations, it is of critical importance to stations that operate on a variety of frequencies.

Figure 24-16A shows a trifilar transformer that provides a 1:1 impedance ratio, but it will transform an unbalanced transmission line (e.g., coaxial cable) to a

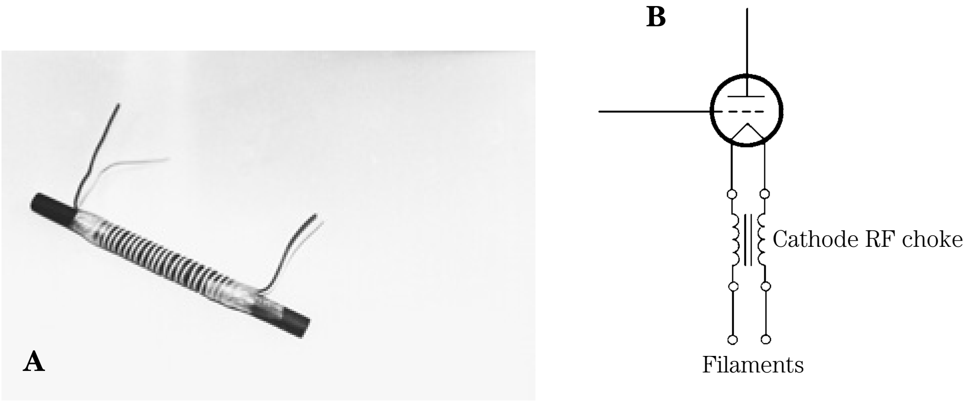

24-15 Ferrite rod inductor (A) construction, (B) use in amplifier.

balanced signal required to feed a dipole antenna. Although it *provides no impedance transformation*, it does tend to balance the feed currents in the two halves of the antenna. This fact makes it possible to obtain a more accurate figure-8 dipole radiation pattern in the horizontal plane. Many station owners make it standard practice to use a balun at the antenna feedpoint.

The balun shown in Fig. 24-16B is designed to provide the unbalanced to balanced transformation, while also providing a 4:1 impedance ratio. Thus, a 300 Ω folded dipole feedpoint impedance will be transformed to 75 Ω unbalanced. This type of balun is often included inside antenna tuners, including all three models shown in Figs. 24-8A and 24-8B. A variable (or at least settable) broadbanded transformer is shown in Fig. 24-16C. In this case the output winding is tapped, and the operator selects the correct tap needed to provide the desired impedance ratio. The usual turns ratio criterion applies.

Another multiple-impedance transformer is shown in Fig. 24-16D. In this case, the operator can select impedance transformation ratios of 1.5:1, 4:1, 9:1 or 16:1. A commercial version of this type of transformer is shown in Fig. 24-16E. It is manufactured by Palomar Engineers, and is intended for vertical antenna feeding in the HF bands. It will, however, work well on antennas other than simple verticals. A top view of the vertical antenna feeding transformer is in Fig. 24-16F.

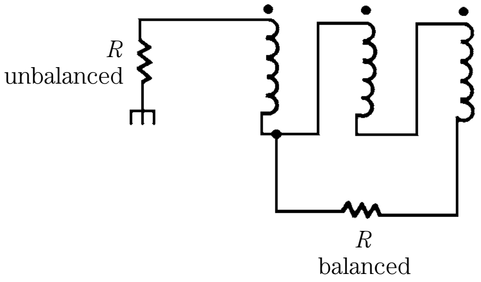

24-16A BALUN 1:1.

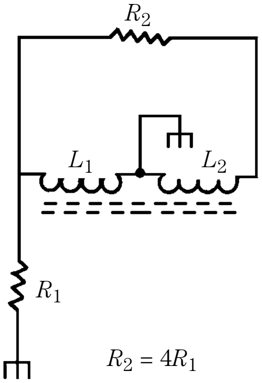

24-16B Balun 1:4.

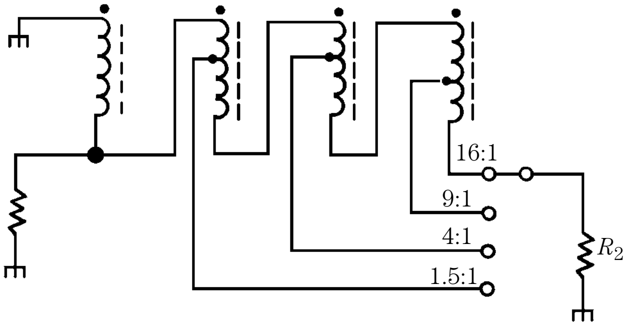
16:1
9:1
4:1
1.5:1
R_1
R_2

24-16C Tapped BALUN.

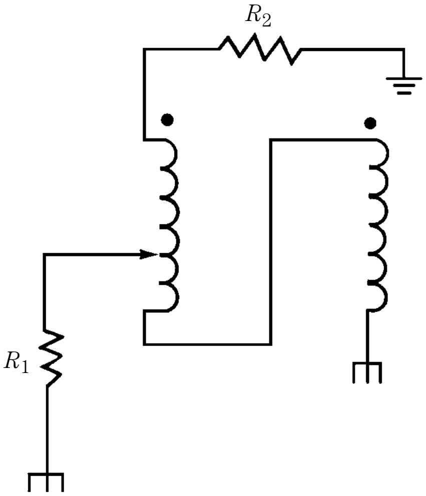

24-16D Multi-impedance BALUN.

24-16E Vertical antenna feeding transformer.

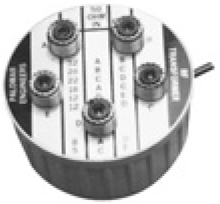

24-16F Top view of Fig. 24-16E.

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25
CHAPTER

Mobile, emergency, portable, and marine antennas

MOBILE OPERATION OF RADIO COMMUNICATIONS EQUIPMENT DATES BACK TO ONLY A little later than “base station” operation. From its earliest times, radio buffs have attempted to place radio communications equipment in vehicles. Unfortunately, two-way radio was not terribly practical until the 1930s, when the earliest applications were amateur radio and police radio (which used frequencies in the 1.7- to 2.0-MHz region). Over the years, the land mobile and amateur radio mobile operation has moved progressively higher in frequency because of certain practical considerations. The higher the frequency, for example, the shorter the wavelength; and, therefore, the shorter a full-size antenna. On the 11-m Citizens Band, for example, a quarter-wavelength whip antenna is 102 in long, and for the 10-m amateur band only 96 in long. At VHF frequencies, antennas become even shorter. As a result, much mobile activity takes place in the VHF and UHF region.

The amateur 144-, 220-, and 440-MHz bands are popular because of several factors, not the least of which is the ease of making ¼- and ⅝-wavelength antennas. Because low-cost commercial antennas are available for these frequencies, however, we will not examine such antennas in this chapter. Rather, we will concentrate on high-frequency antennas.

Mobile HF antennas

High-frequency (HF) mobile operation requires substantially different antennas than VHF or UHF. Quarter-wavelength antennas are feasible only on the 11- and 10-m bands, with some argument in favor of 13 m as well. But by the time the frequency drops to the 21-MHz (15-m) band, the antenna size must be approximately 11 ft long, and that is too long for practical mobile operation. Because of practical considerations,

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you must limit antenna size to 8 or 9 ft; in the amateur radio bands the 8-ft antenna is most popular because it is resonant on 10 m. At all lower frequencies, the 8-ft whip becomes capacitive, and therefore requires an equal inductive reactance to cancel the capacitive reactance of the antenna.

Figure 25-1 shows three basic configurations of coil-loaded HF antennas for frequencies lower than the natural resonant frequency of the antenna. In each case, the antennas are series fed with coaxial cable from the base; point *A* is connected to the coaxial cable center conductor, and point *B* is connected to the shield, and the car body (which serves as ground). The system shown in Fig. 25-1A is base-loaded. Although convenient, there is some evidence that the current distribution is less than optimum. The version shown in Fig. 25-1B is center-loaded, and results in an improved current distribution. This configuration is probably the most common among commercially available HF mobile antennas, although the coil is often located slightly above the center point. Finally, we see the top-loaded coil system in Fig. 25-1B. In all three cases, the point is to use the inductance of the coil to cancel the capacitive reactance of the antenna.

A modified version of the coil-loaded HF mobile antenna is shown in Fig. 25-2A. In this configuration the loading inductance is divided between two individual coils, L_1 and L_2. Coil L_1 is adjustable with respect to the antenna, while L_2 is fixed; coil L_2 is tapped, however, in order to match the impedance of the antenna to the charac-

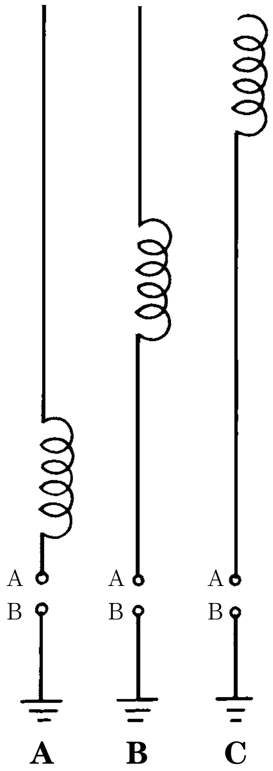

25-1 Loaded mobile antennas.

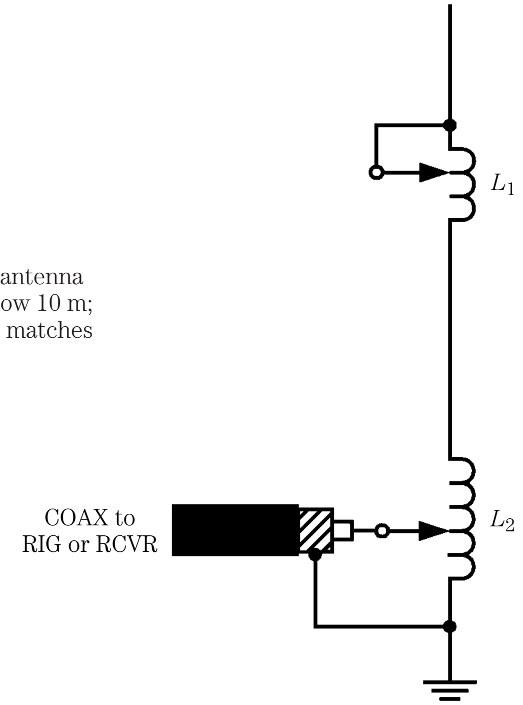

25-2A Practical mobile antenna for HF bands below 10 m; L_1 resonates, L_2 matches impedance.

teristic impedance of the coaxial-cable transmission line. When tuning this antenna, two instruments are needed: a field strength meter and a VSWR meter. The field strength meter gives a relative indication of the amount of power radiated from the antenna, while the VSWR meter helps determine the state of the impedance match. A pair of relative field strength meter projects are discussed later in this chapter.

Variations on the theme are shown in Figs. 25-2B and 25-2C. A helical whip is shown in Fig. 25-2B. In this configuration, the inductor is distributed along the length of a fiberglass antenna rod. The conductor is a wire that is helically wound on the fiberglass shaft. An adjustable tip sets the antenna to resonance. The length of this tip can be set by a local field strength meter. Fixed versions of this type of antenna are very popular on the Citizens Band where they may be as short as 30 in, or as long as 48 in. There are also some amateur radio commercial antennas based on this concept.

The other variant is shown in Fig. 25-2C. In this case, the lower end of the radiator consists of a metal tube topped with a loading coil. An adjustable shaft at the top end is used to tune the antenna to resonance. This form of antenna is popular among commercial makers of HF mobile antennas, such as the Hustler. The fixed shaft tends to be universal for all bands, while the coil and adjustable shaft form a separate "resonator" for each band. Multiband operation of this form of antenna can be accomplished by using a bracket such as shown in Fig. 25-2D. Although early versions of this scheme were homebrewed, several manufacturers currently make factory-built versions. The idea in Fig. 25-2D is to mount two or more resonators to a common fixed shaft.

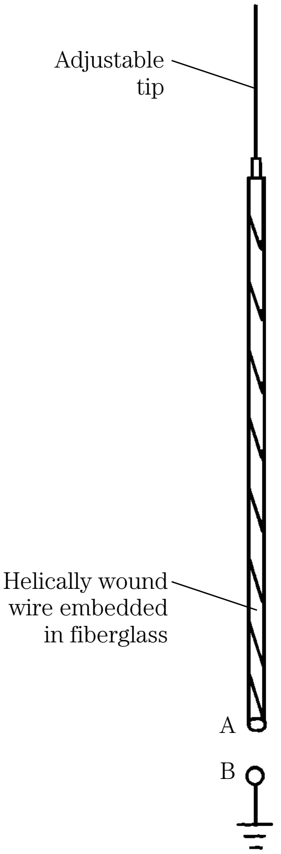
Adjustable tip
Helically wound wire embedded in fiberglass
A
B

25-2B Helically wound mobile antenna.

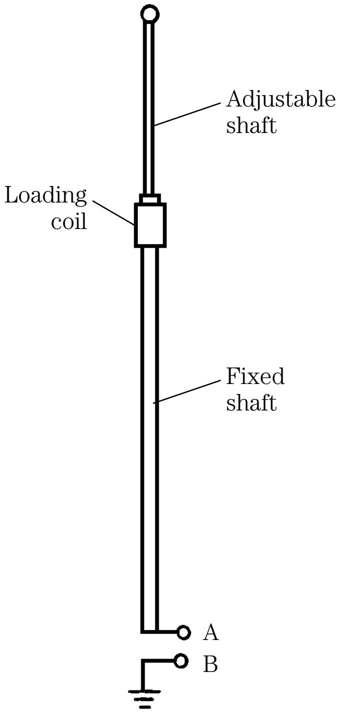
Adjustable shaft
Loading coil
Fixed shaft
A
B

25-2C Top-loaded mobile antenna common in amateur radio.

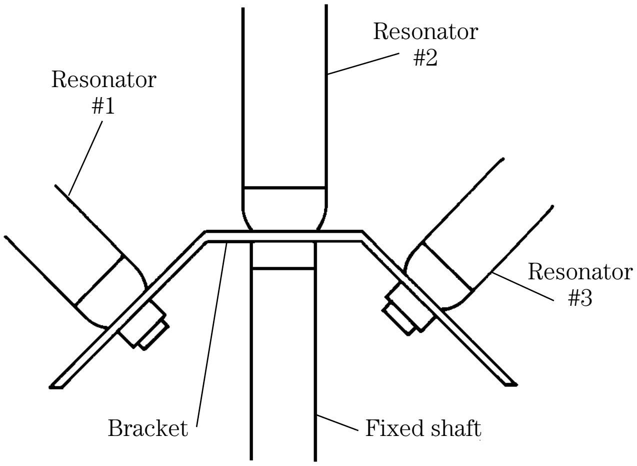
Resonator #2
Resonator #1
Resonator #3
Bracket
Fixed shaft

25-2D Multiband top-loaded antenna.

A common problem with all coil-loaded mobile antennas is that they tend to be very high *Q* antennas. In other words, they are very sharply tuned. The VSWR tends to rise rapidly as the operating frequency departs from the frequency to which the antenna is tuned; as little as 25-kHz change of operating frequency will detune the antenna significantly. Although an antenna tuner at the output of the transmitter will reduce the VSWR to a point that allows the transmitter to operate, that type of tuner is merely a line flattener that does not fully address the problem. The actual problem is that the antenna is not resonant. The efficiency of the antenna drops off rapidly as the frequency changes. The only cure for this problem is to readjust the resonator's adjustable shaft as the band segment is changed (not merely the band, but the *band segment*). Unfortunately, this solution requires tools, and the operator must get out of the vehicle in order to do a good job of retuning. Another solution is to use a motor-driven variable inductor for the loading coil. Several manufacturers offer both base-loaded and center-loaded coils that are either motor-driven or relay-selectable to permit frequency changing from the operator's seat.

Tuning HF mobile antennas

Although the procedures for tuning certain specific antennas might be different from those given below, the basic principles are the same, and can easily be adapted to any given situation. There are two situations to consider. First is the antenna in which there is either a single adjustable (or tap-selectable) loading coil, or a fixed loading coil and an adjustable shaft resonator. Second is the case (Fig. 25-2A) where there is an adjustable or tapped coil in series with a tapped impedance-matching coil at the base.

Case no. 1. In this case, we assume that the antenna has a single adjustment, either a shaft resonator or adjustable coil. In this case we need to use a field strength meter (FSM) to measure the relative field strength of the radiated signal. The antenna resonator is adjusted until the radiated field strength is maximum. Of course, this procedure must be done in steps, keying the transmitter after each adjustment to see what happened. Alternatively, a VSWR meter can be used to set the resonator to a minimum VSWR.

Case no. 2. Here, we have a coil at the base that is fixed with respect to the antenna radiator element, but is tapped with respect to the coaxial cable from the transmitter. A second coil is also used in the antenna (see Fig. 25-2A), which can be either in the center or at the top. This coil is adjustable for setting resonance. Alternatively, this coil may be fixed, and an adjustable resonator shaft may be used to set operating frequency. In this type of antenna the upper coil, or resonator shaft, is adjusted to resonance by using a field strength meter. The lower coil is adjusted for minimum VSWR. Both adjustments are needed to complete the job.

Field strength meters

A *field strength meter* (FSM) is an instrument that measures the radiated field from an antenna. Commercial engineering-grade instruments are calibrated in terms of either watts/square centimeter or volts/meter, and are used for jobs such as broadcast station "proof-of-performance" tests and other professional jobs. For adjusting antennas, however, a considerably different instrument is sufficient. This section describes two simple, passive (which means no dc power is required) field strength meters usable for adjusting HF radio antennas, including both CB and amateur radio antennas.

Two forms are shown in Fig. 25-3; both are basically variations on the old-fashioned "crystal set" theme. Figure 25-3A shows the simplest form of untuned FSM. In this circuit a small whip antenna (used for signal pickup) is connected to one end of a grounded RF choke (RFC). The RF voltage developed across the RFC is applied to a germanium diode detector; either IN34 or IN60 can be used. Silicon diodes are normally preferred in signal applications, but in this case we need the lower contact potential of germanium diodes in order to improve sensitivity (V_g is 0.2 to 0.3 V for Ge and 0.6 to 0.7. V for Si). A potentiometer is used both as the load for the diode and as a sensitivity control to set the meter reading to a convenient level.

The untuned version of the FSM is usable even at low powers, but suffers from a lack of sensitivity. Only a certain amount of signal can be developed across the RFC, so this limits the sensitivity. Also, the RFC does not make a good impedance match to the detector diode D_1. An improvement is possible by adding a tuned circuit and an impedance-matching scheme, as shown in Fig. 25-3B. In this case a variable capacitor C_3 is used as a tune control. The tuning capacitor is parallel resonant with inductor L_1. A tapped capacitive voltage divider (C_1/C_2) is used to provide impedance matching to the diode. Figure 25-3C gives values of capacitance and inductance for various bands.

Operation of the tunable FSM is simple and straightforward. Set the sensitivity control to approximately half-scale, and then key the transmitter; adjust the tuning control (C_3) for maximum deflection of the meter pointer (readjustment of the sensitivity control may be needed). After these adjustments are made, the tunable FSM works just like any other FSM.

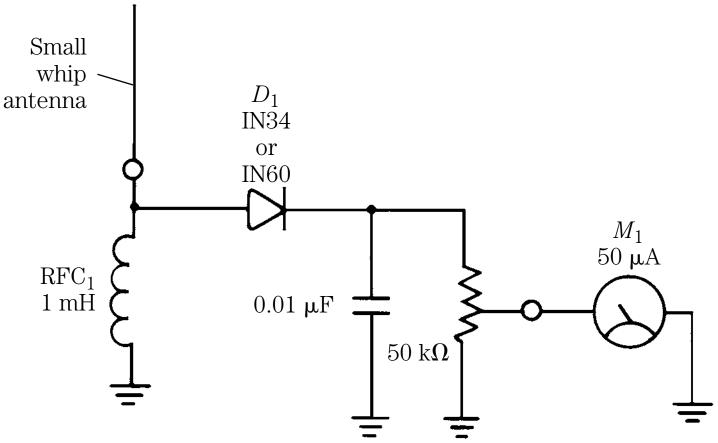

25-3A Simple field strength meter.

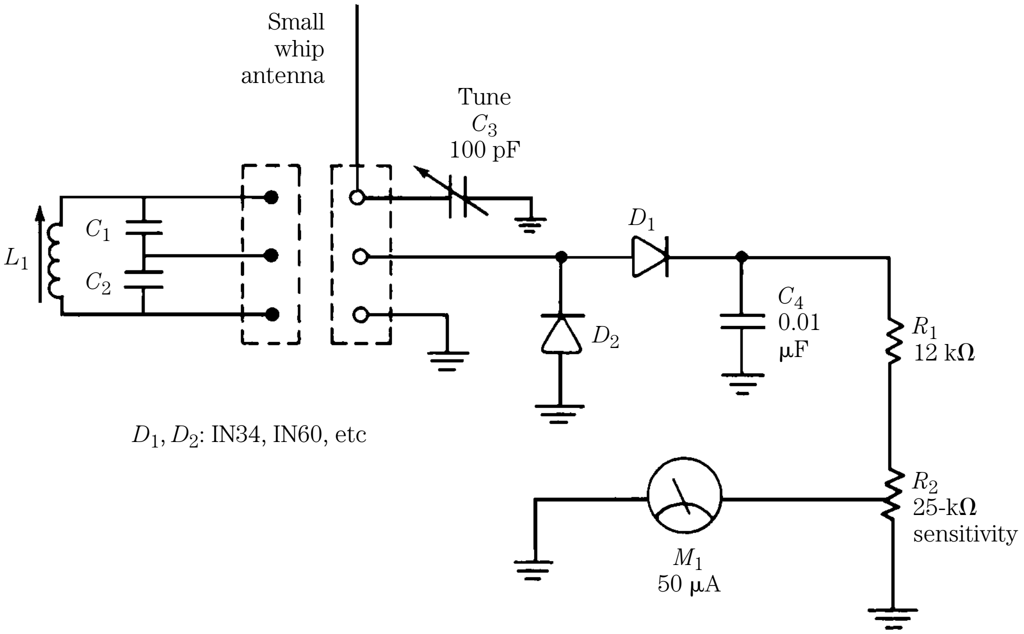

25-3B Tuned field strength meters.

25-3C Values chart for field strength meters.

Band (meters)	L_1 (μH)	C_1 (pF)	C_2 (pF)
75/80	27	25	100
40	10	15	68
30	4.4	15	68
20	2.25	10	68
17	1.7	10	56
15	1.3	10	47
13	0.8	10	39
10	0.5	10	39

Antennas for emergency operations

Some time ago, I met an interesting character at a convention. As a medical doctor, he was a medical missionary working at a relief station in Sudan. Because of his unique business address, he was able to discuss mobile and portable antennas for communications from the boondocks. His *bona fides* for this knowledge includes the fact that he is licensed to operate on both the amateur radio bands, and as a landmobile (or point-to-point) station in the 6.2-MHz band. The desert where he travels is among the worst in the world. The path they euphemistically call a “road” is occasionally littered with camel corpses because of the harsh conditions. The doctor’s organization requires him to check in twice daily on either 6.2 MHz or

3.885 MHz (which some missionary hams in Africa use as an unofficial calling frequency). If he misses two check-ins in a row, then the search and rescue planes are sent up. As a result of his unique "house calls," he does a lot of mobile and portable operating in the lower-HF region of the spectrum. His problem is this: How do you reliably get through the QRM and tropical QRN with only 200 W PEP and a standard loaded mobile antenna?

Another fellow I once met works in Alaska for a government agency. He faces many of the same problems as the doctor in Sudan, but at close to 100° colder. He frequently takes his 100-W mobile rig into the boondocks with him in a four-wheel drive vehicle. Again, with only 100 W into a poor-efficiency loaded mobile antenna, how does one reliably cut through the interference to be heard back at the homestead?

An earthquake, or hurricane, strikes your community. Antenna towers collapse, tribanders become tangled masses of aluminum tubing, dipoles are snarled globs of no.14 Copperweld, and the rig and linear amplifier are smashed under the rubble of one corner of your house. All that remains is the 100-W HF rig in your car. How do you reliably establish communications in "kilowatt alley" with a 100-W mobile driving a 75-W loaded whip? Of course, you always got through one way or another before, but now communications are not for fun—they are deadly serious. Somehow, the distant problems of a Sudanese missionary doctor and a KL7 government forester don't seem too very far away.

For these operators, communications often means life or death for someone, perhaps themselves. Given the inefficiency of the loaded whips typically used as mobile antennas in the low-HF region, the generally low power levels used in available mobile rigs, and the crowded band conditions on the 80-, 75-, and 40-m bands, it becomes a matter of more than academic interest how you might increase the signal strength from your portable (or mobile) emergency station. Anything we can do, easily and cheaply, to improve the signal is like having money in the bank. Fortunately, there are several tricks of the trade that will help us out in a pinch.

Figure 25-4 shows a typical mobile antenna for a low-HF band. Because quarter-wavelength antennas on these frequencies are 30 to 70 ft high, full-size vertical whip antennas are not practical. In fact, at frequencies below 10 m, full-size whips are not generally used. Short antennas exhibit capacitive reactance, so we add a loading coil (inductor L in Fig. 25-4) to the radiator to make up the difference (its inductive reactance cancels the capacitive reactance of the antenna). The inductor in such a loaded antenna can be placed almost anywhere along the radiator, although base-, center-, and top-loaded designs predominate. The actual inductance needed varies somewhat with coil placement, as does antenna performance. The "resonators" used on commercial low-HF mobile antennas are loading coils encapsulated in a weathertight housing.

The mobile configuration is inefficient by its nature, and little can be done to improve matters. Of course, an antenna-matching device or tuner will help in optimizing the power transfer to the antenna, and should always be used in any event (especially with solid-state final amplifiers, which don't tolerate VSWR as easily as do tube finals). In the portable configuration, however, we can both improve the performance of "mobile" antennas and look into antenna options not open to the mobile

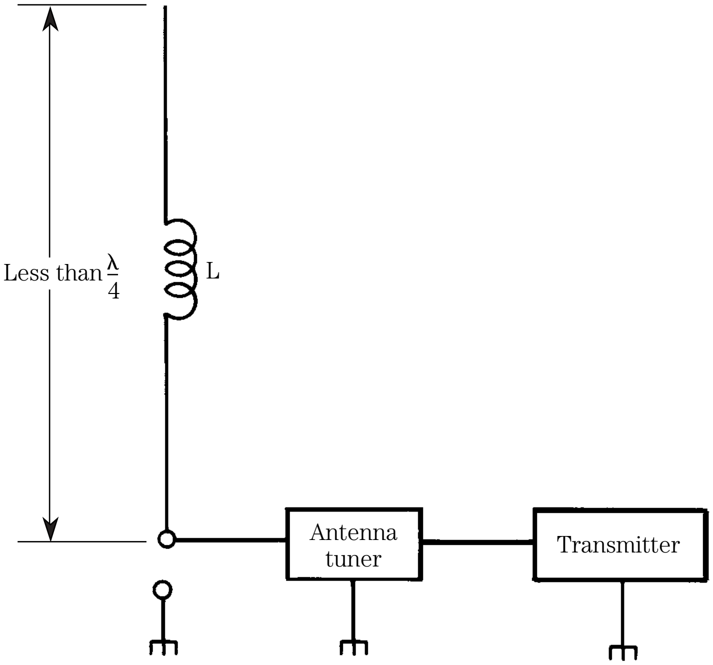

25-4 Basic mobile antenna system often proves unsatisfactory in marginal cases.

operator. We can make a basic assumption for these improvements: The operator needing emergency or urgent communications is not driving down the interstate somewhere, but is stopped in the back country and needs to call out.

In cases of emergencies on most highways, we are in range of some repeater, so we would use a VHF band (probably 2 m) to contact police or other emergency services through a repeater autopatch. In fact, with the wide availability of repeaters around the country it behooves any amateur, backpacking or four-wheeling into remote areas, to be familiar with repeater locations and frequencies. From hilltops, especially, it is often possible to hit repeaters from a surprisingly long distance. I have seen hand-held 2-m rigs trigger mountain top repeaters from the mountains of southwestern Virginia, and presume that other areas of the country are as well off repeaterwise. This chapter deals with HF rigs, especially those operating in the lower end of the HF spectrum, in situations where a temporary antenna must be erected.

Most amateurs, who have low-HF mobile rigs, will testify that getting out is a pain in the mike button. Antenna efficiencies are simply too poor. One factor in this dismal equation is that the vehicle body makes a very poor antenna ground system. One could, I suppose, carry a supply of 6- or 8-ft copper-clad steel ground rods, and a 9-lb sledge hammer to drive them into the earth wherever a portable station is needed. Somehow, that solution doesn't seem too appealing at this point! Besides, have you ever tried to remove an effective 8-ft ground rod from the ground? Forget it, it's too much pain for too little gain. A better solution is to provide a counterpoise groundplane, as shown in Fig. 25-5. In Fig. 25-5A we see the electrical situation and connection, while in Fig. 25-5B we see the mechanical scheme for a specific situation: A groundplane consists of two or more (even *one* helps) quarter-wavelength radials connected to the antenna ground point (i.e., where the coaxial cable shield connects to the vehicle body). The radials are made of no. 14 wire, so are relatively easy to stow.

Figure 25-5B shows a workable system that will improve the performance of a mobile rig in stationary situations. The mobile antenna uses the normal base mount attached to the rear quarter panel of the car adjacent to the trunk lid. An all-metal grounding-type binding post is installed through an extra hole drilled in the base

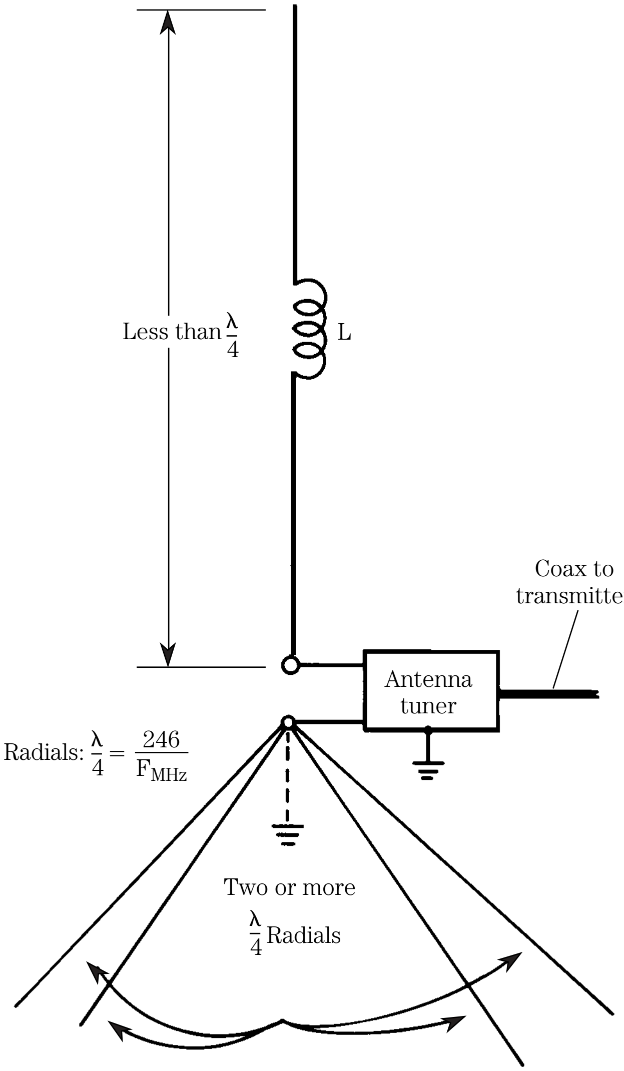
Less than $\frac{\lambda}{4}$
L
Coax to transmitter
Antenna tuner
Radials: $\frac{\lambda}{4} = \frac{246}{F_{MHz}}$
Two or more
$\frac{\lambda}{4}$ Radials

25-5A Two or more radials improve efficiency of mobile antenna used in a portable communications setup.

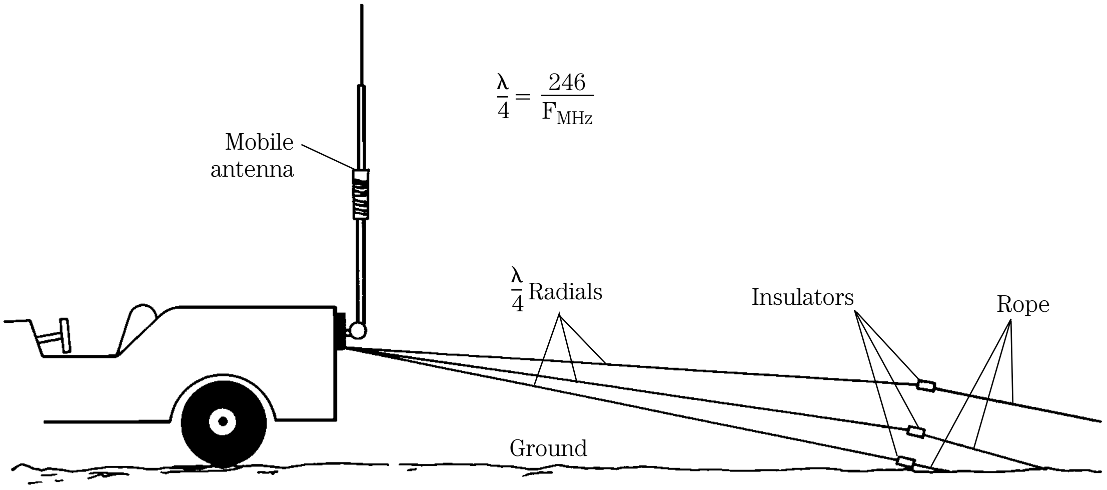
$\frac{\lambda}{4} = \frac{246}{F_{MHz}}$
Mobile antenna
$\frac{\lambda}{4}$ Radials
Insulators
Rope
Ground

25-5B Multiple radials are even better.

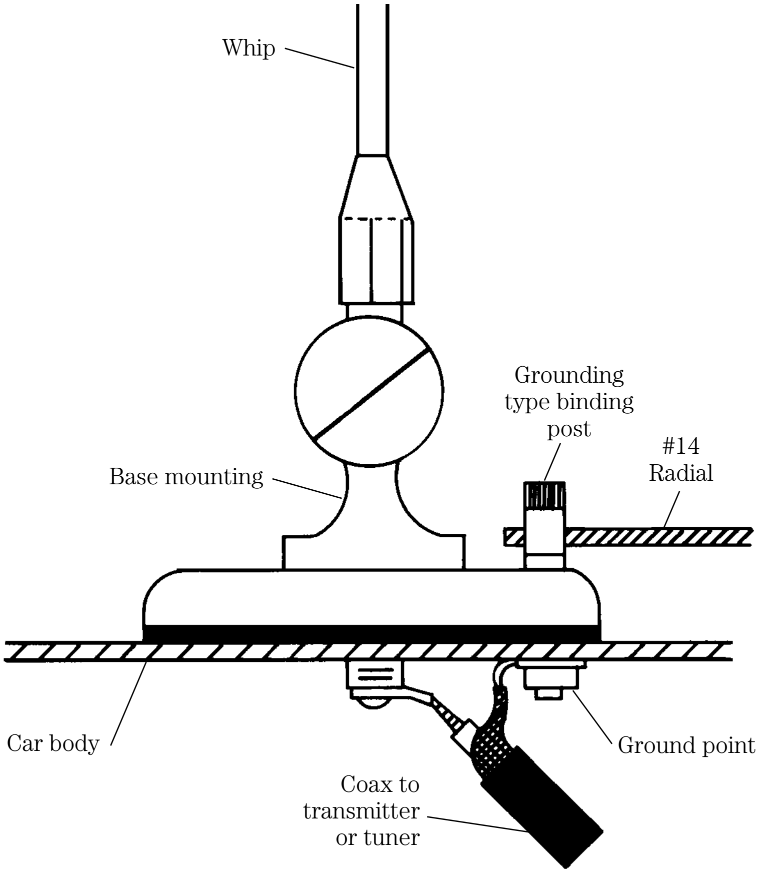
Whip
Grounding type binding post
#14 Radial
Base mounting
Car body
Ground point
Coax to transmitter or tuner

25-5C Connection of radials to mobile antenna.

insulator (see Fig. 25-5C). Radials for portable operation are attached at this point. Although the binding post is small, it easily accommodates two no. 14 radials. The owner used the vehicle for camping, and the radials were used to improve antenna efficiency. I don't believe the dramatic accounts enthusiastically reported by the owner of the car, but my own Field Day experience (and the testimony of the Sudanese missionary doctor) lead me to expect considerable improvement over the unaided loaded whip.

A potential solution to the inefficiency problem is to replace the mobile antenna with a more efficient, but stowable, antenna that can be brought out and erected when needed. One candidate is a surplus military HF whip antenna. Intended for jeeps and communications trucks, these antenna/tuner combinations are collapsible and are as efficient as any on the market. Although my Alaskan friend could use such a surplus find, my Sudanese friend could not. He told me that Americans in the boonies, even (perhaps especially) missionaries, are always suspected by pinheaded local authorities of being agents of the dreaded "Cuban Invasion Authority." Showing up "out there" with obviously military radio equipment serves only to seal that belief!

The common dipole is often looked down upon by the owners of massive array antennas, but those old-fashioned antennas are capable of turning in some impressive results. The dipole is made by connecting two quarter-wavelength pieces of wire to a coaxial-cable transmission line. One length is connected to the center conductor, and the other is connected to the shield of the coax. In a pinch, zip (i.e., lamp) cord and twisted pairs of hookup wire will do for a transmission line. Figure 25-6 shows the common dipole and the normal equation for determining *approximate* length. The actual length is found by trimming length until the VSWR drops to its lowest point, a nicety that might not seem altogether important in an emergency. The ends of the dipole must be supported on trees, masts, or some other elevated structure. Unfortunately, mounting points aren't easily found. My Sudanese friend doesn't see many trees!

Figure 25-7 shows another alternative antenna that works well for portable operation. Based on the dipole, this inverted-vee dipole does not require two end supports but rather a single center support. The length of each leg is 6 percent longer than for a nominal dipole. Because the application is both emergency-related and temporary in nature, we can get away with construction methods that would be unthinkable in more permanent installations.

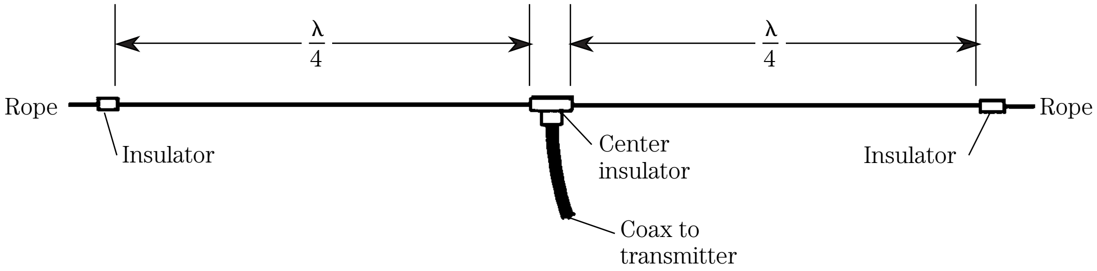

25-6 Basic dipole.

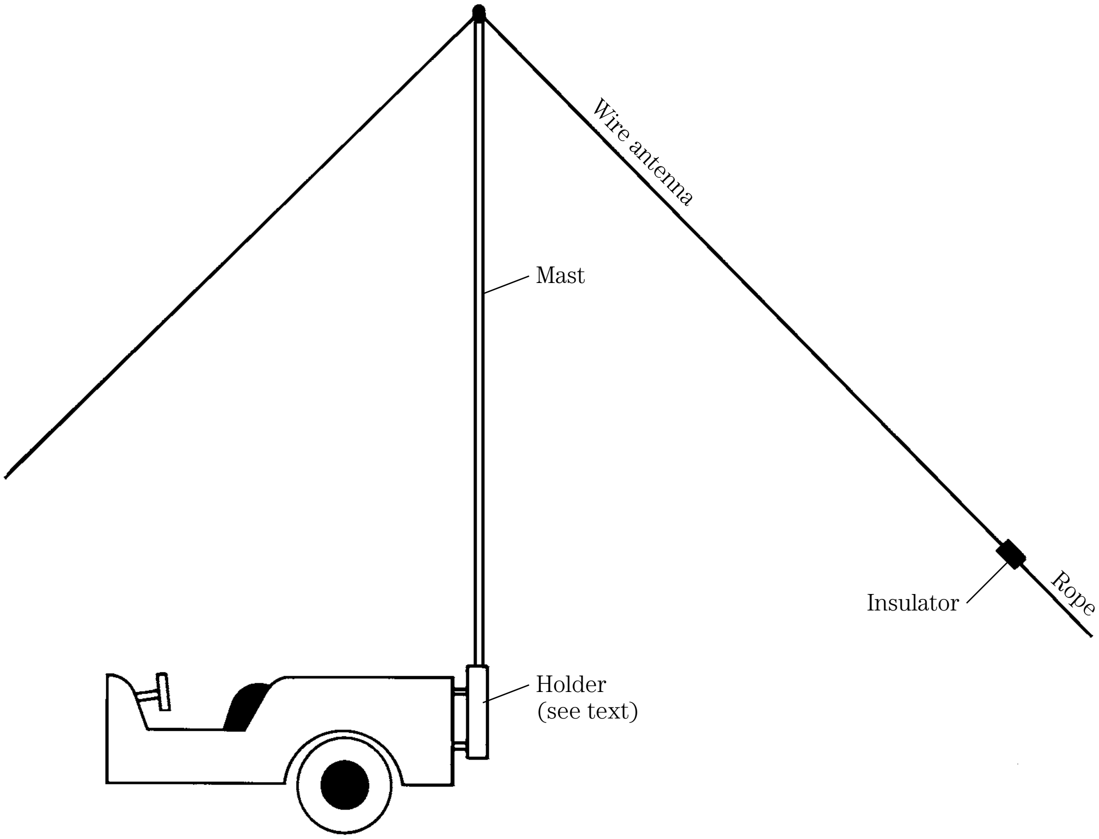

25-7 Portable inverted-vee antenna.

Three problems present themselves. First, the antenna must be portable for backpackers, or stowable in the case of those people who motor into the back country. Size and weight are major constraints in both cases, even though the vehicular case is a lot easier to work with than the backpacker. Second, what materials and means of construction are needed for the mast? Third, how is the mast supported? Because the answer to the third question depends in part on the answer selected for the second, we will deal with it first. The first question is avoided at this point because I have selected the vehicular case.

One alternative is to use a telescoping TV antenna mast to support your antenna. We can either mount a mobile whip and its associated radials at the top, or install an inverted-vee per Fig. 25-7. These masts collapse to 6 or 8 ft in length, but can be slipped up to heights of 18, 25, 30, 40, or 50 ft, depending upon the type selected. Keep in mind, when shopping for these masts, that the larger models are considerably heavier than shorter models, and they require two or more people to install them. Erecting a 40- or 50-ft telescoping mast is not a single-person job, even though you might know someone who has done it. I've done it, and won't do it again! Even the 30-ft models are a bit hairy to install alone.

Another mast that can be used for the inverted vee is made from PVC plastic plumbing pipe. If it can be carried on or in the vehicle, then lengths up to 10 ft are available. Longer lengths are made at the site of erection by joining together 10-ft or shorter sections with couplings (also available at plumbing supply outlets). Be careful of using PVC pipe that is too small, however. PVC pipe is relatively thin walled, and it is therefore flexible. Sizes below 1.5-in diameter will not easily stand alone without guying. While a single 10-ft section might be self-supporting, two or more sections together will not support themselves and the weight of the antenna. Guying can be accomplished with ropes, or on a temporary basis, heavy twine.

Still another alternative is to carry steel TV antenna masts. Available in 5- and 10-ft lengths, these masts are flared on one end and crimped on the other, so that they can be joined together to form longer lengths. In addition, the same sources that sell these masts also sell the guy wire rings that help support the mast when installed. There is also a variety of rooftop mounting devices that aid also in ground mounting the antenna.

I used the TV mast solution on Field Day expeditions for many years. The inverted-vee antenna is, of course, a natural for this solution. Once, however, we used a Hustler mobile antenna mounted at the top of a 20-ft mast, with four radials, and it worked surprisingly well with the 30-W limit for extra points credit then available for Field Day contestants.

There are, then, several alternatives for masts that slip up, snap together, or are otherwise easily unstowed and installed. Let's now turn our attention to base mounting schemes that can be used to support the mast. Of course, in a life or death pinch, you could always just pile rocks around the base, or hold the darn thing up as you transmit. But a little forethought could eliminate those problems easily.

One of the first solutions I'll deal with was seen on the Outer Banks of North Carolina, and was provided to me by a CB operator. Surf fishers on the Outer Banks use four-wheel drive vehicles to get out on the beach (to the surf, where the big sea bass lurk). Welded to either the front or rear bumper attachments are steel tubes (see Fig. 25-7) used for mounting the very, very long surf casting rods they use to catch fish. The CB operator had a 20-ft mast consisting of two 10-ft TV mast sections mounted in one of the rod holders. At the upper end of the mast was his 11-m groundplane antenna. The same method of mounting would also support similar amateur antennas, inverted-vee dipoles, or VHF/UHF antennas.

Given that the antenna installation will be temporary, lasting only a few hours or a couple of days in the worst case, we need not worry about long-term integrity, or the practicality of the installation. Mounting the mast to the back of a four-wheeler or pickup truck with a pair of U bolts is not terribly practical if you must move the vehicle, but works nicely if you plan to camp (or are stranded) for a few days.

For lightweight masts, up to about 25 ft, the base support could be an X-shaped base made of 2 × 4-in lumber (Fig. 25-8A), or even a Christmas tree holder. Alternatively, a TV antenna rooftop tripod mount (Fig. 25-8B) is easily adopted for use on the ground. None of these three alternatives can be depended upon for self-supporting installations, and must be guyed even if used for only a short period. Again, because of the temporary nature of the installation, aluminum or wooden tent pegs can be used to anchor the guy wires. Although they are insufficient for long-term installations, they work fine for the short run.

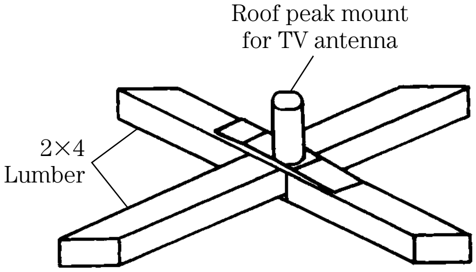

25-8A Wooden antenna stand.

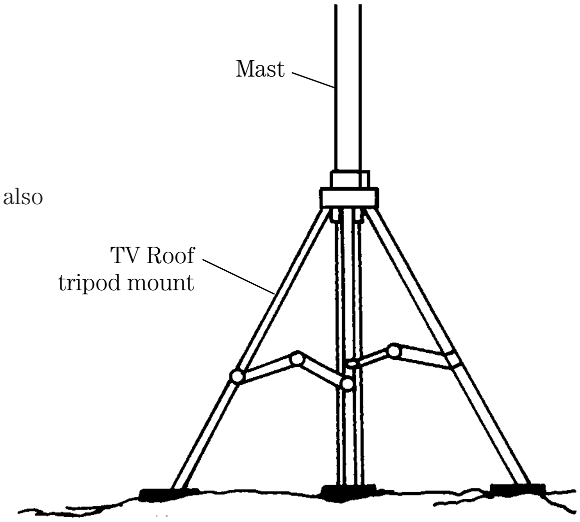

25-8B TV-antenna tripod also works in portable situation for HF antenna masts.

Another problem

Field Day is a reasonably good training ground for people who anticipate operating radio equipment under primitive conditions. If you pay attention to the sometimes humorous foul-ups seen while getting on the air from atop High Peak Mountain in Goose Bump National Park, then you might avoid some of the same mistakes when foul-ups mean more than a quick drive to the nearest town. You will learn, for example, which simple tools are a must for constructing and repairing simple antennas (including the 12-Vdc soldering iron that runs off the vehicle battery). You will also learn a bit about electricity needed to run the rig.

Two alternatives present themselves. First, you could use 12 Vdc from the vehicle electrical system, which makes sense with the current crop of 12 Vdc HF rigs on the market. Or, you could operate from 120 Vac generated by a light plant generator.

When boondocking in a four-wheeler (or other vehicle), it is wise to use a dual battery system such as shown in Fig. 25-9. Two separate 12-Vdc auto batteries (preferably high ampere-hour capacity) are connected essentially in parallel with the alternative charging system. Diodes D_1 and D_2 are rated at 100 A, 50 V peak inverse voltage (PVI), and are used to isolate the two batteries from each other. Diode assemblies such as this can be built, or purchased from van conversion and recreational

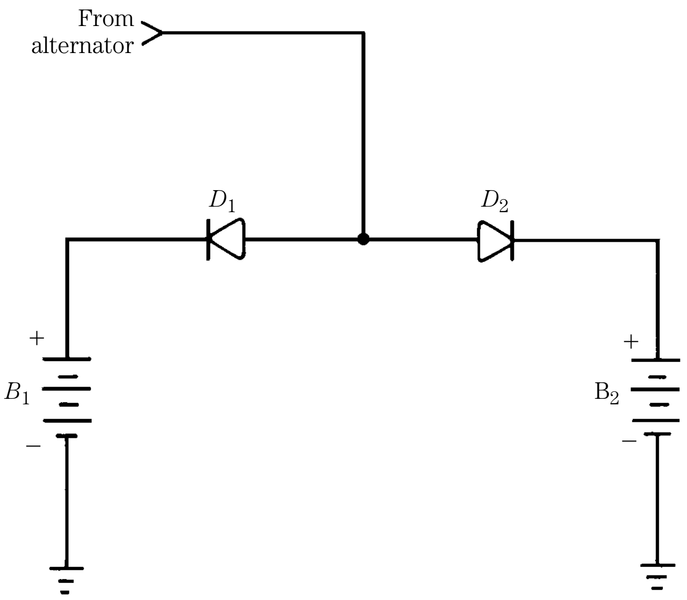

25-9 Diode pack allows charging two batteries from system charger.

vehicle shops. Van and RV owners' use is the same as yours: It's a darn shame to run down the battery needed to start the vehicle just by operating your rig. You not only cannot start the vehicle in such a case, but cannot muster enough power to call for the wilderness equivalent of "Triple A."

One experienced boondocker I met in southern Arizona totes either a 450-W Kawasaki or 500-W Honda mini light plant generator in the back of his Bronco. These models are surprisingly lightweight and quiet operating. One of the generators has a 12-Vdc, 8-A outlet that can be used to charge a dead battery. The other has only the 110-Vac outlet, but can be used for battery charging if a small charger is provided. Simple 10-A battery chargers can usually be bought at auto parts or accessories stores, for about $60.

Operating radio communications equipment successfully under primitive conditions depends upon two major factors: available electrical power and a proper, efficient, antenna system. Although dealing in detail with the means of obtaining power in remote locations is beyond the scope of this book, we have provided some ideas from which you can start planning your own "survival" radio system.

Marine radio antennas

Radio communications considerably lessened the dangers inherent in sea travel. So much so, in fact, that the maritime industry took to the new "wireless telegraphy" earlier than any other segment of society. In the early days of radio, a number of exciting rescues occurred because of wireless. Even the infamous *S.S. Titanic* sinking might have cost less human life if the wireless operator aboard a nearby ship had been on duty. Today, shore stations and ships maintain 24-hour surveillance, and vessels can be equipped with autoalarm devices to wake up those who are not on duty. Even small pleasure boats are now equipped with radio communications, and these are monitored around the clock by the U.S. Coast Guard.

The small shipboard operator can have a selection of either HF single-sideband communications or VHF-FM communications. The general rule is that a station must have the VHF-FM, and can be licensed for the HF SSB mode only if VHF-FM is also aboard. The VHF-FM radio is used in coastal waters, inland waters, and harbors. These radios are equipped with a high/low power switch that permits the use of low power (1 W typically) in the harbor, but higher power when under way. The HF SSB radios are more powerful (100 W typically), and are used for offshore long-distance communications beyond the line-of-radio-sight capability of the VHF-FM band.

The problems of antennas on boats are the same as for shore installations, but are aggravated by certain factors. Space, for one thing, is less on a boat so most HF antennas must be compensation types. Also, grounds are harder to come by on a fiberglass or wooden boat, so external grounds must be provided.

A typical powerboat example is shown in Fig. 25-10. The radio is connected to a whip antenna through a transmission line (and a tuner on HF), while also being grounded to an externally provided groundplate. Over the years, radio grounds have taken a lot of different forms. For example, the ground might be copper or aluminum foil cemented to the boat hull. Alternatively, it might be a bronze plate or hollow bronze tube along the center line of the boat, or along the sides just below the water line. The ground will also be connected to the engine. Careful attention must be paid

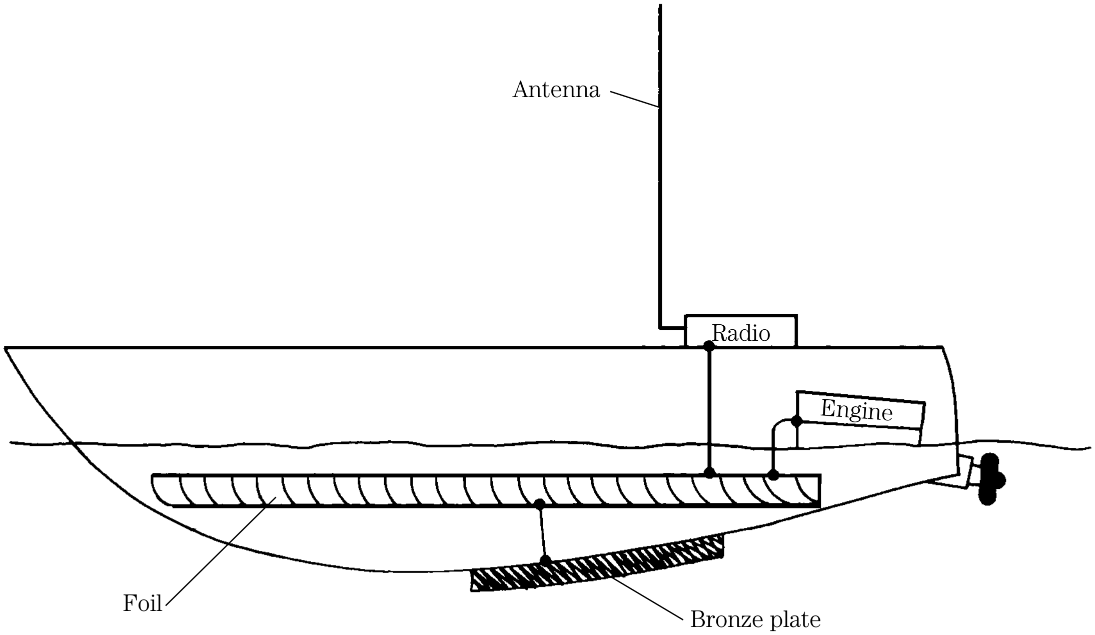

25-10 Motorboat grounding system.

to the electrical system of the boat when creating external grounds to prevent electrolytic corrosion from inadvertent current flows.

On sailboats the whip antenna (especially VHF-FM) might be mast-mounted as shown in Fig. 25-11. The same grounding scheme applies with the addition of a metal keel or metal foil over a nonmetallic keel.

The whips used for boat radios tend to be longer than land mobile antennas for the same frequency. The VHF-FM whip (Fig. 25-12) can be several quarter-wavelengths and take advantage of gain characteristics thereby obtained. Whips for the HF bands tend to be 10 to 30 ft in length, and often look like trolling rods on power boats. You will also see Citizens Band radios on board boats, and the CB antennas are also whips. It is not a good idea to rely solely on CB for boat communications, because it is a lot less

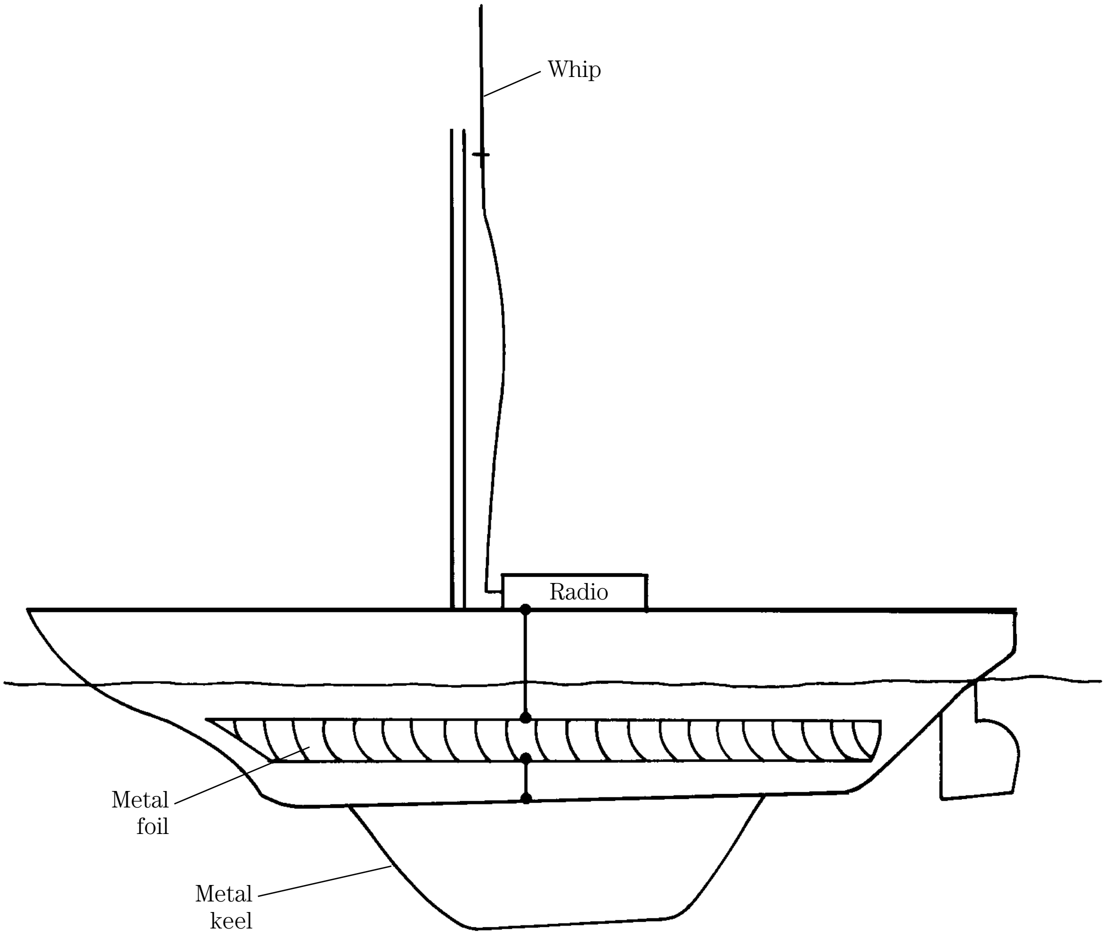

25-11 Sailboat grounding.

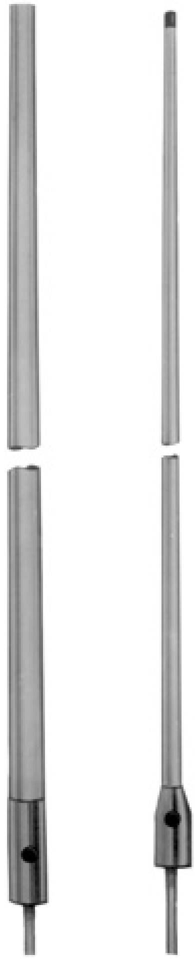

25-12 VHF-FM boat antenna.
Courtesy of Antenna Specialist Company

likely to be useful in emergencies. Also, some boaters use amateur radio sets, often illegally, for emergency communications in lieu of a proper HF-SSB unit.

Longwire antennas also find use in marine service. Figure 25-13 shows two installations. The antenna in Fig. 25-13A shows a wire stretched between the stern and bow by way of the mast. The antenna is end-fed from an antenna tuner or "line flattener." The longwire shown in Fig. 25-13B is similar in concept, but runs from the bottom to the top of the mast. Again, a tuner is needed to match the antenna to the radio transmission line. Notice that the antennas used in this manner are actually not "longwires" in the truly rigorous sense of the term, but rather "random length" antennas.

The format of the tuner can be any of several designs, shown in Fig. 25-14. The reversed L-section coupler shown in Fig. 25-14A is used when the antenna radiator element is less than a quarter-wavelength. Similarly, when the antenna is greater than a quarter-wavelength, the circuit of Fig. 25-14B is the tuner of choice. This circuit is a modified L-section coupler that uses two variable capacitors and the inductor.

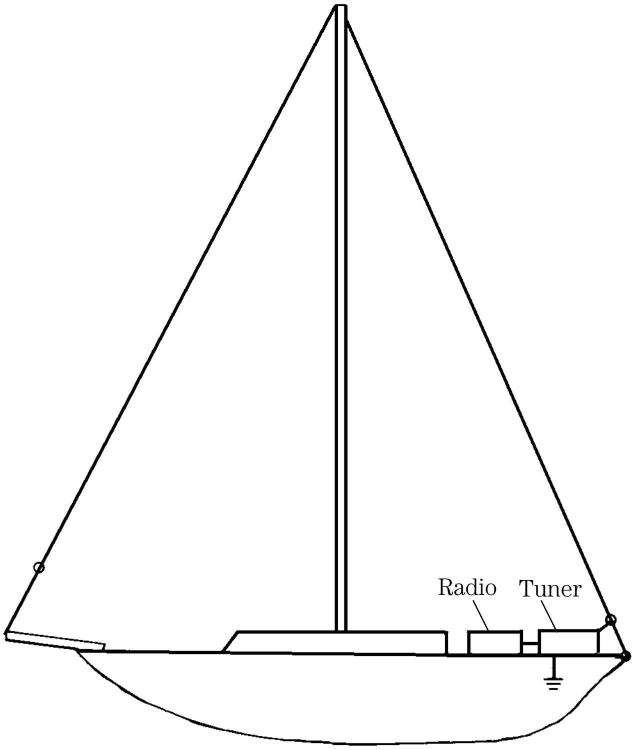
Radio
Tuner

25-13A Sailboat HF antenna.

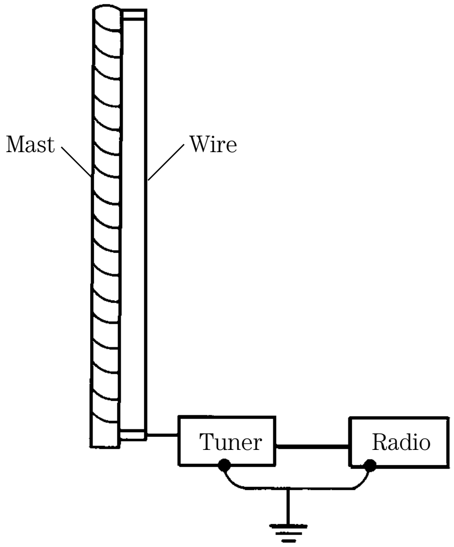
Mast
Wire
Tuner
Radio

25-13B Mast antenna.

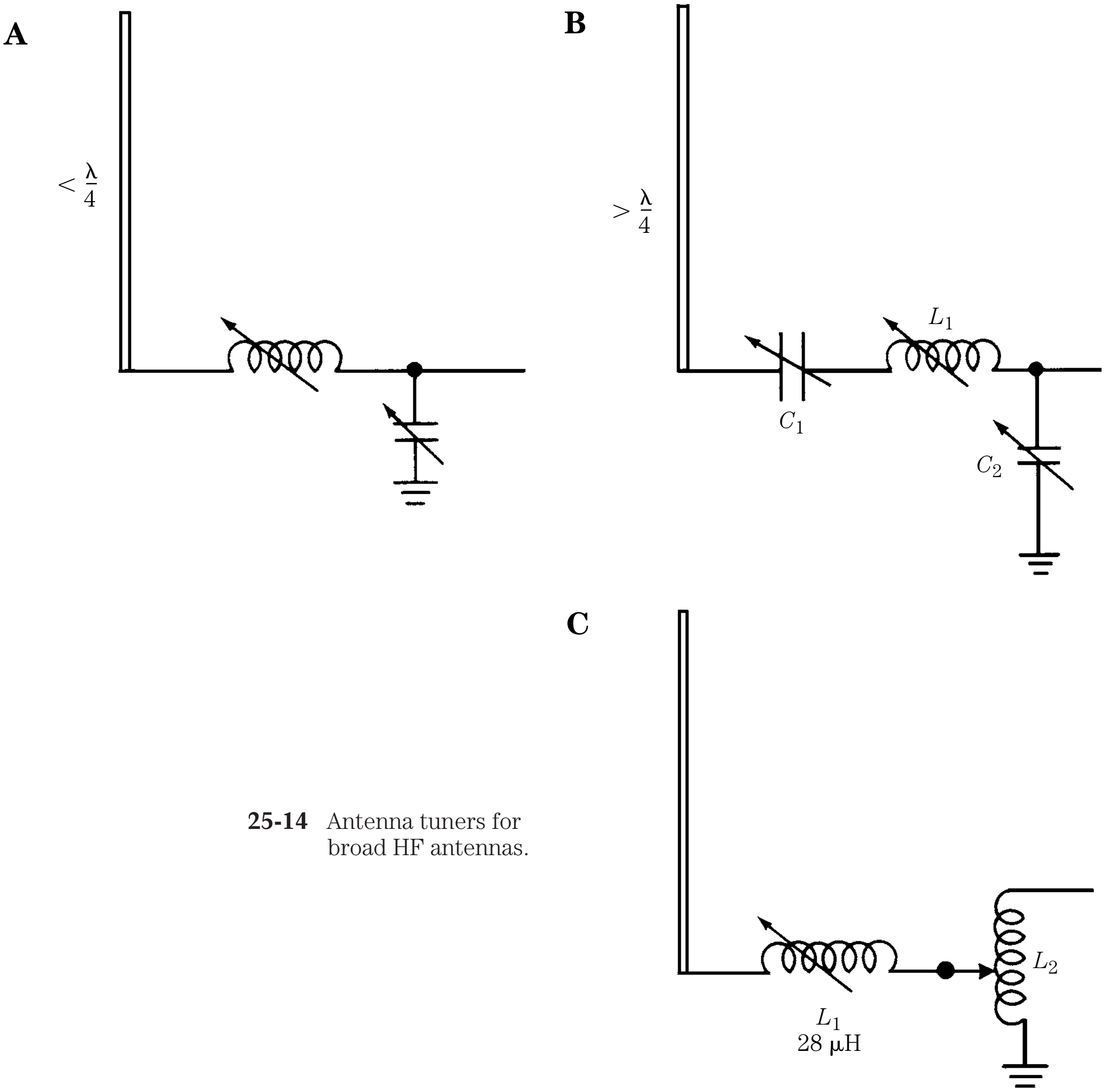

25-14 Antenna tuners for broad HF antennas.

Finally, we see in Fig. 25-14C the coupler used on many radios for random-length antennas. Two variable inductors are used; L_1 is used to resonate the antenna, and L_2 is used to match the impedance looking back to the transmitter to the system impedance. In some designs, the inductors are not actually variable, but rather use switch-selected taps on the coils. The correct coil taps are selected when the operator selects a channel. This approach is less frequently encountered today, when frequency synthesizers give the owner a selection of channels to use. In those cases, either the antenna must be tuned every time the frequency is changed, or an automatic (or motor-driven) preselected tuner is used.

The line flattener (Fig. 25-15) is a standard transmatch antenna tuner that flattens coaxial-cable transmission line for VSWR. This type of tuner is especially useful for transmitters with solid-state finals that are not "happy" with high VSWR. Some of those designs incorporate shutdown circuits that reduce (and then cut off) power as the VSWR increases. The line flattener basically tunes out the VSWR at the transmitter. It does nothing to tune the antenna, but only makes the transmitter operable.

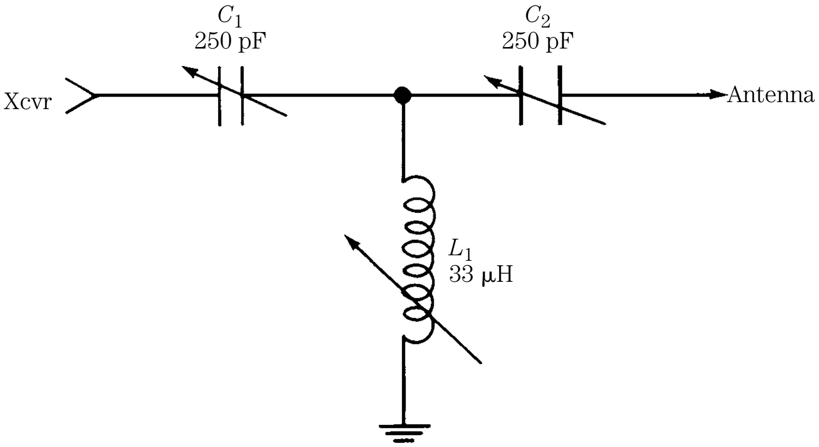

25-15 Line flattener tuner.

26
CHAPTER

Antennas for low-frequency operation

LOW-FREQUENCY OPERATION (E.G., 160- AND 75/80-METER BAND) POSES CERTAIN difficulties for the antenna. Of course, the first thing that springs to mind is the large size of those antennas. A half-wavelength dipole is between 117 and 133 ft long on 75/80 m, and on 160 m it is about twice that length. On my own suburban lot, I cannot erect a half-wave 75/80-m band antenna and stay within the property lines.

A similar situation is seen with vertical antennas. Although a 40-m vertical (33 ft high) is not an unreasonable mechanical job, the 66 ft 75/80-m vertical (never mind the 120-ft 160-m vertical) is a nightmare. In addition, the local authorities might not require any special inspections or permits (check!) on the 33-ft antenna, yet impose rigid and very exacting requirements on the higher structure. On suburban or urban lots, a typical 40-m antenna might well be able to fall over and still not cross the property line—or come in close proximity to power lines. A longer antenna, however, almost inevitably suffers one—or the other—problem when it falls.

Grounding

Still another problem involves grounding. The ground system of a higher-frequency vertical antenna can be installed using $\lambda/4$ radials buried a few inches below the surface. But that same idea becomes problematic when the radials are 66 or 125 ft long. Burying half a dozen 125-ft radials might remind your neighbors of the Galloping Gung-Ho Gopher—and not to their amusement!

There are, however, some solutions to the problem—without having you buy a farm in the flatter regions of the midwest. For example, the length problem can be solved by using one of the bent dipoles covered in Chap. 10. No, they are not

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as effective as an antenna that is correctly installed. But they will serve to get you on the air. Some of them work surprisingly well.

The ground radial problem can be solved by bending the radial system around your property (Fig. 26-1). You will never have to cross your neighbor's line. And, as for the gopher track appearance, it is not necessary to work sloppily, and you can install radials so that nary an eye, practiced or otherwise, can see their location.

Shortened vertical antennas

The biggest problem for most low-frequency DXers, as you have seen, is the excessive size of antennas for those frequencies; it is "not for nothing" that those AM broadcast band (<1.6 MHz) towers are usually hundreds of feet tall. But there are ways to shorten an antenna—not for free, because the TANSTAAFL[*] principle still

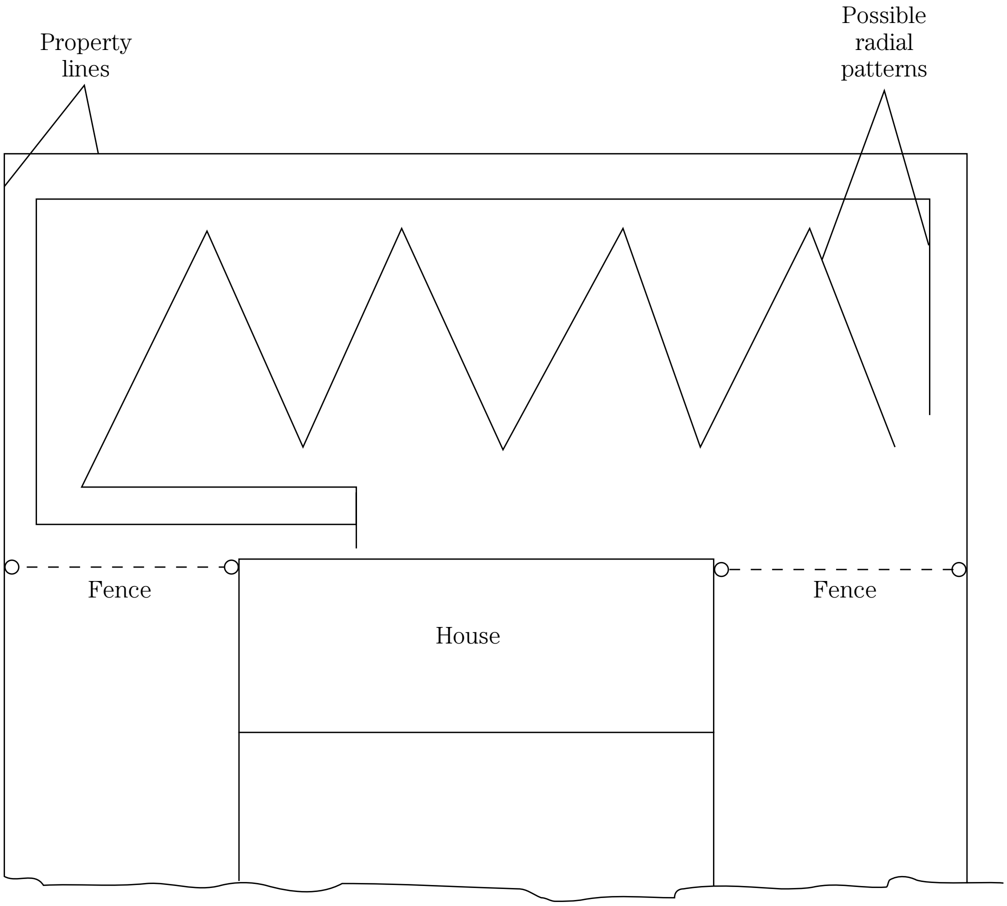

26-1 Methods for laying out low-frequency radials in a cramped space.

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[*] TANSTAAFL = There ain't no such thing as a free lunch!

applies—to a point where it becomes mechanically possible. Let me reiterate once again that these compensation antennas will not work as well as a properly installed full-sized antenna, but they will serve to get you on the air on frequencies where it is otherwise utterly impossible. Several different compensation configurations are popular, and these are shown in Fig. 26-2.

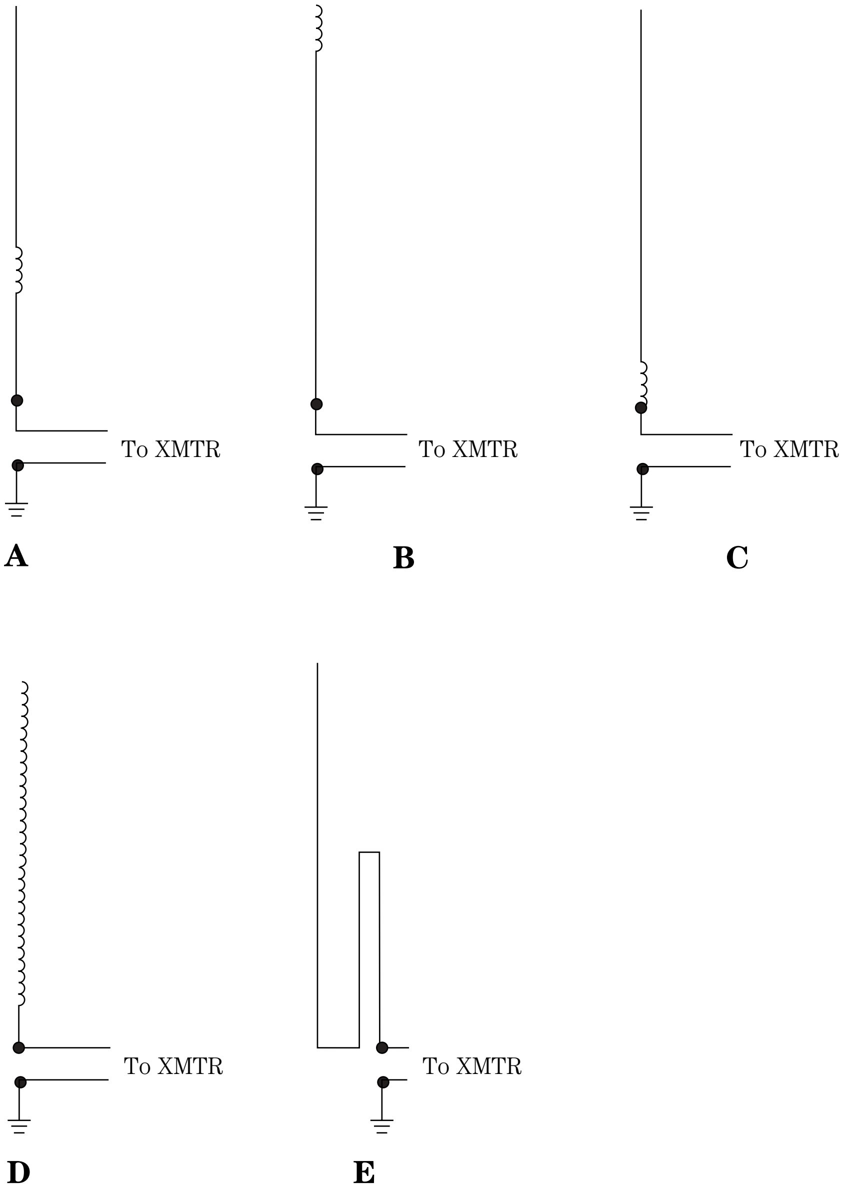

26-2 Inductance loading of vertical antennas: (A) center; (B) top; (C) base; (D) linear or length-loaded; (E) linear hairpin-loaded.

The basic foundation for these antennas is a very short vertical antenna. The "standard" vertical antenna is a quarter-wavelength ($\lambda/4$) (i.e., 90° electrical length), and it is unbalanced with respect to ground.

Recall that a vertical antenna that is too short for its operating frequency (i.e., less than $\lambda/4$) will exhibit capacitive reactance. In order to resonate that antenna, it is necessary to cancel the capacitive reactance with an equivalent inductive reactance, such as $|X_L| = |X_C|$. By placing an inductance in series with the antenna radiator element, therefore, we can effectively "lengthen" it electrically. Of course, what is really happening is that the effects of the lower operating frequency are being accommodated (i.e., "cancelled out") of a too-short antenna.

An antenna that is reactance-compensated for a different frequency is said to be *loaded*, or in the case of a very low frequency antenna, *inductively loaded*. Three basic forms of loading are popular: *discrete loading, continuous loading,* and *linear loading*.

Discrete loading means that there is a discrete, or lumped, inductance in series with the antenna radiator (Figs. 26-2A through 26-2C). These antennas are so constructed that a loading coil is placed at the center (Fig. 26-2A), top (Fig. 26-2B), or bottom (Fig. 26-2C) of the radiator element.

You will recognize these configurations as being the same as those found on mobile antennas. Indeed, low-band mobile antennas can be used in both mobile and fixed installations. Note, however, that although it is convenient to use mobile antennas for fixed locations (because they are easily available in "store bought" form); they are less efficient than other versions of the same concept. The reason is that the mobile antenna, for low frequencies, tends to be based on the standard 96- to 102-in whip antenna used by amateur operators on 10 m or Citizens Band operators on 11 m. In fixed locations, on the other hand, longer radiator elements (which are more efficient) are more easily handled. For example, a 16- to 30-ft high aluminum radiator element can easily be constructed of readily available materials. The 16-ft element can be bought in the form of one or two lengths of 1- to 1.5-in aluminum tubing at do-it-yourself outlets.

A problem seen with these antennas is that they tend to be rather high Q, so the bandwidth is necessarily narrow. An antenna might work in the center of a band, but present a high VSWR at the ends of the band, and thus be unusable. This problem is solved by making the inductor variable so that slightly different inductance values can be selected at different frequencies across the band. For the base-loaded version (Fig. 26-2C), this is particularly easy: a rotary inductor (perhaps motor driven for remote operation) can be used. For the other configurations, a tapped fixed inductor can be used instead. Each tap represents a different inductance value. Either clip connectors, or relay connections, can be used to select which tap is used.

A continuously loaded antenna has the inductance distributed along the entire length of the radiator (Fig. 26-2D). Typical of these antennas is the helically wound verticals in which about a half-wavelength of insulated wire is wound over an insulating form (such as a length of PVC pipe or a wooden dowel); the turns of the coil are spread out over the entire length of the insulated support.

Linear loading (Fig. 26-2E) is an arrangement whereby a section of the antenna is folded back on itself like a stub. Antennas of this sort have been successfully built from the same type of aluminum tubing as regular verticals. For 75/80-m (3.75-MHz) operation a length of 30 ft for the radiator represents 41°, while a normal λ/4 vertical is 90°. The difference between 90° and 41° of electrical length is made up by the "hairpin" structure at the base.

Shortened horizontal antennas

The same strategies that worked for vertical antennas also work for horizontal antennas, although in the horizontal case we are simulating a half wavelength (180°) balanced antenna—rather than a λ/4 unbalanced antenna. Figure 26-3 shows several different shortened, low frequency antennas that are based on the same methods as the verticals shown previously.

Figures 26-3A through 26-3C show discretely loaded dipole antennas. Figures 26-3A and 26-3B are center-loaded versions, and Fig. 26-3C is a center (of each element) -loaded version. In each case, it is assumed that the radiator elements are the same physical length. In the example of Fig. 26-3A, the coil is tapped to provide a match to either 52- or 75-Ω transmission line. In some variants, the shield of the coaxial-cable transmission line is connected directly to the junction of the coil and one radiator element, and the coax center conductor is connected to the tap that best matches the impedance of the line.

The impedance-matching problem is solved a little differently in Fig. 26-3B. In this type of antenna, the coil is used to center-load the dipole, but the transmission line is connected to a link wound on the same form as the loading inductor. The turns ratio between the loading inductor and the coupling link determines the impedance match.

A "hairpin" linear loading scheme is shown in Fig. 26-3D. This design is basically the same as for the vertical case, but it is balanced out of respect for the design of the dipole. This type of design is used for both the driven and parasitic elements on some commercial 40-m beam antennas. In addition, some "add-on" 40-m dipoles (designed for beam antennas that were intended for operation at frequencies in the 20-m and higher bands) use this method. Such antennas are essentially rotatable dipoles.

The continuously loaded dipole of Fig. 26-3E is constructed like the helical vertical (i.e., about a half-wavelength of insulated wire is wound over the entire length of an insulated rod or pipe of some sort). The winding can be either broken at its center point to accommodate the feedline, or link-coupled to the transmitter, or receiver, as shown in Fig. 26-3F. Of the two feed methods, the most popular appears to be the type that breaks the winding into two pieces.

The form of continuously loaded dipole in Fig. 26-3E has a combination of the two methods of feed. The distributed loading coil is broken into two sections, as is often done on continuously loaded dipoles. But in this case, a portion of the overall inductance is made by using a discrete inductor that is part of a toroidal transformer T_1. The length of the wire used for the continuous loading coil is somewhat shorter (find by experimentation) than otherwise would be the case because of the inductance of the transformer secondary. Transformer T_1 can be wound using the same sort of toroidal ferrite or powdered iron core used for Balun transformers.

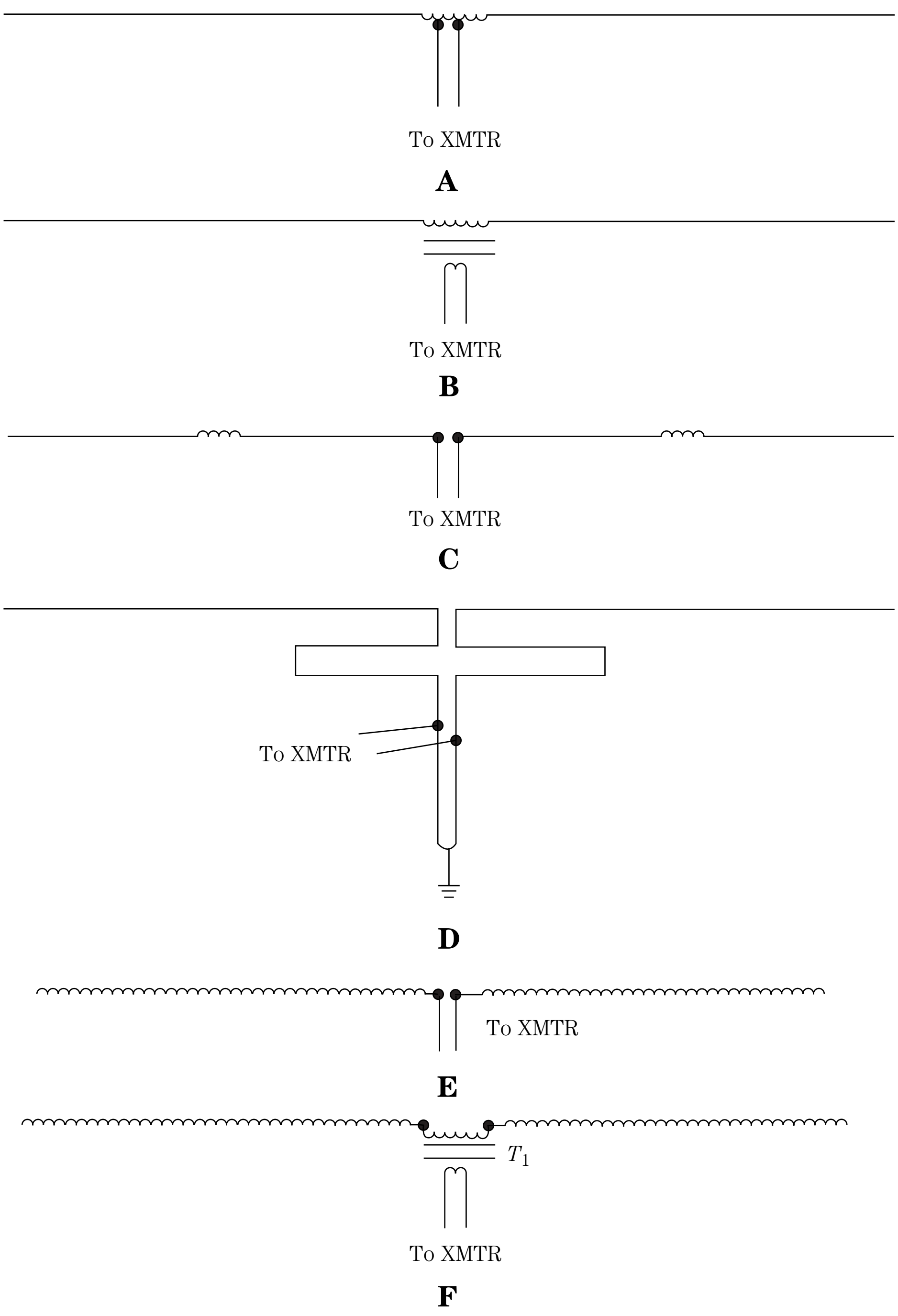
To XMTR
A
To XMTR
B
To XMTR
C
To XMTR
D
To XMTR
E
T_1
To XMTR
F

26-3 Inductance loading of a dipole: (A) center loading with impedance tapped coil; (B) center loading with transformer coupling; (C) loading at center of elements; (D) linear loading (hairpin); (E) linear or length loading; (F) transformer coupling.

Loaded tower designs

Many amateur radio stations and other services use a rotatable beam antenna on top of a tower. Typical towers are from 30 to 120 ft in height. In my locality, towers to 30 ft, or less than 3 ft above the roof line, whichever is taller, can be erected without a permit as long as they are attached to the house and will not fall onto a power line, or across the property line, in a catastrophic failure. Higher towers must be erected under a mechanical permit, and properly inspected by the county. These towers typically support a two-element (or more, three is popular) Yagi /Uda beam antenna, or a quad, or some other highly directional antenna. But they can also be treated as a vertical antenna under the right circumstances.

If the tower is close to 66 ft high (which is a popular height for amateur radio towers), then the tower (already λ/4) can be used as a resonant vertical on 75/80 m. The same tower can also be used on lower frequencies if proper antenna tuning unit (ATU) components are provided.

Figure 26-4 shows a situation in which an 80- to 110-ft tower is insulated from ground, and is considered a random-length vertically polarized Marconi antenna. Like other such antennas, it is fed by a simple L-section, or reverse L-section, ATU. Note the approximate values of the inductors and capacitors in each configuration, and also their relationships. On the 40- and 75/80-m versions, the tower is too long, so a series capacitance and shunt inductance are used for the ATU (i.e., Reverse L-section coupler). On the other hand, the tower is too short for 160 m, so the inductor and capacitor are reversed.

There is only one small problem with the design of Fig. 26-4: Compared with grounded towers, insulated towers are expensive to buy and install. In addition, lightning protection is probably better in the grounded tower. So how do we work a grounded tower? See Fig. 26-5. In this antenna, the tower is grounded at its base. If the tower is mounted to a concrete pedestal (the usual arrangement), then a separate ground rod and ground wire adjacent to the pedestal must be provided. Concrete is not a good insulator, but it is also not a good conductor. A *delta feed* system is used with this antenna. That is, a single wire from the ATU is connected to a point on the antenna where an impedance match can be achieved. It is important that the ATU be spaced away from the tower base (as shown), and the wire must be run straight to the feedpoint on the antenna. This system is an example of several possible *shunt feeding* systems.

Random-length Marconi

One of the old standbys for all bands is the random-length Marconi antenna. Such antennas consist of a length of wire, typically (but not always) less than λ/4, and fed at one end with coaxial cable and an L-section coupler (Fig. 26-6). The antenna radiator element can be angled in any direction as needed, but it works best if the radiator is either as horizontal, or vertical, as possible (for pure polarization). The usual situation, however, is to run the wire at an inclined angle, or with about equal portions horizontal and vertical (see the inverted L) which yields complex polarization.

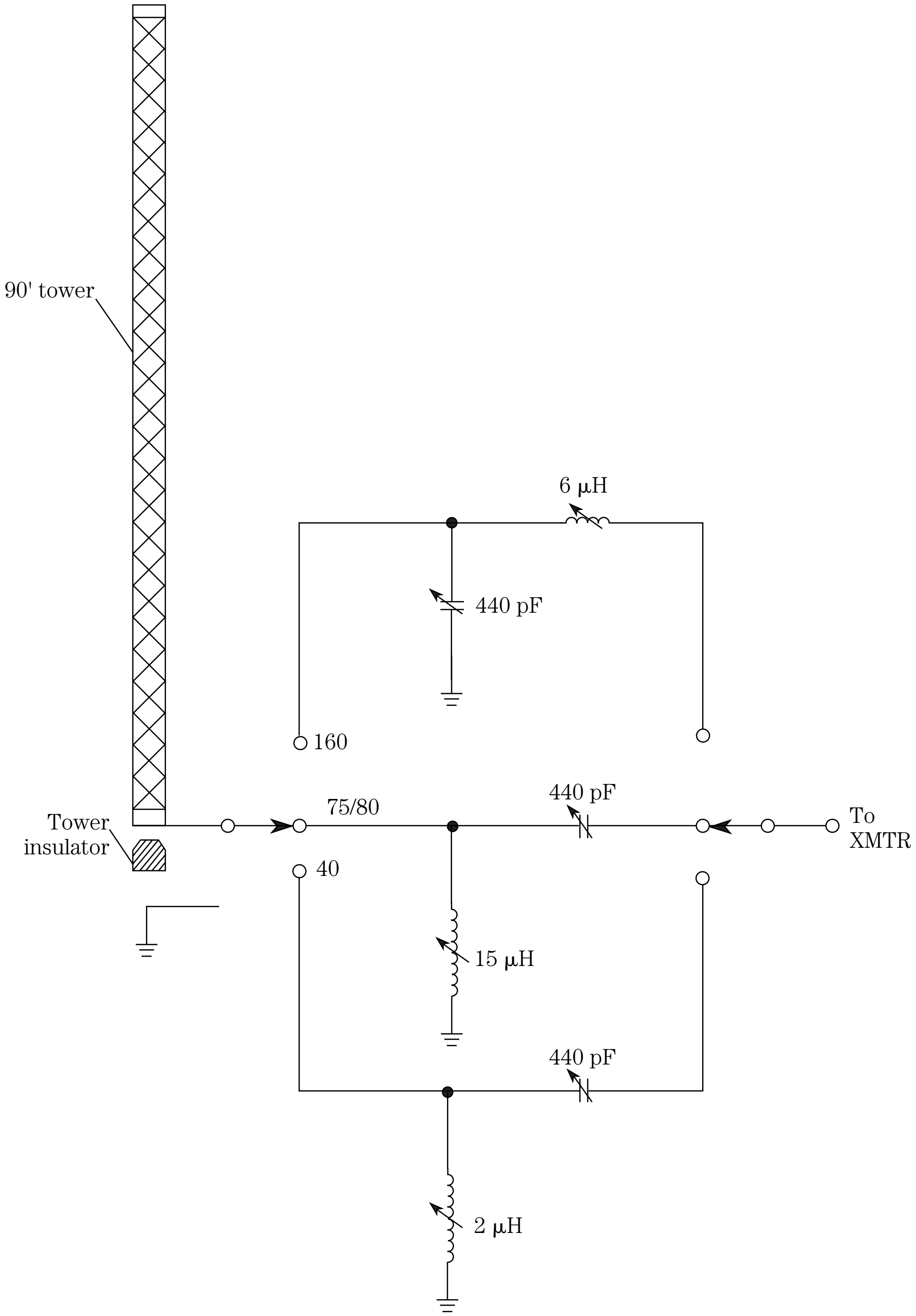
6 μH
440 pF
160
90' tower
75/80
440 pF
Tower
insulator
To
XMTR
40
15 μH
440 pF
2 μH

26-4 Method for impedance matching a tower antenna.

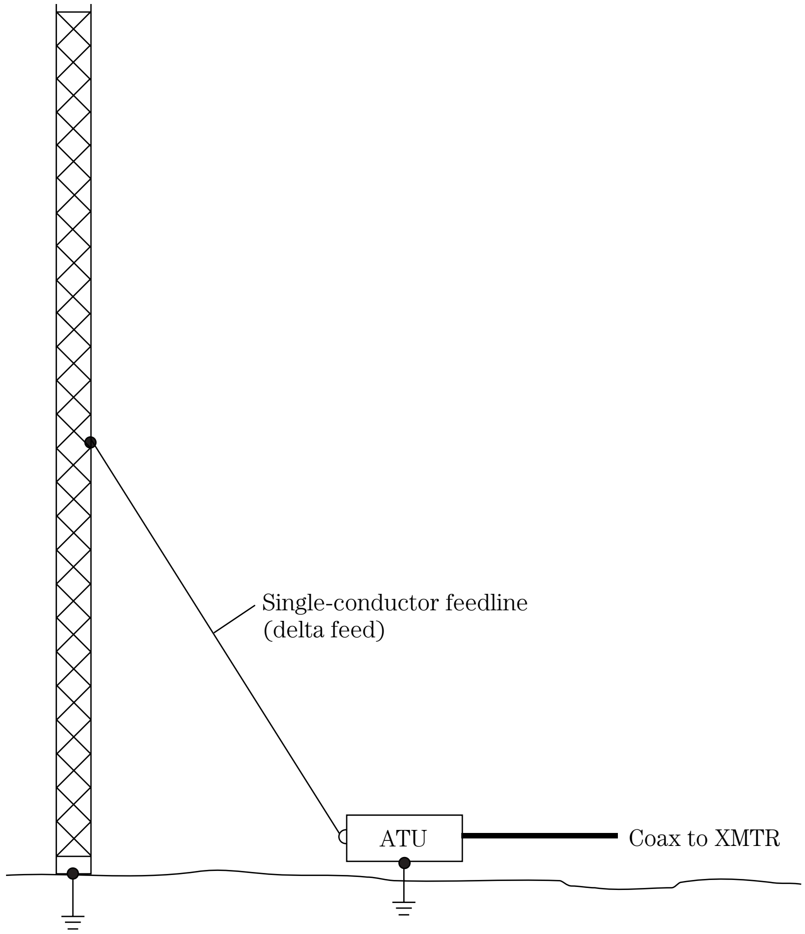
Single-conductor feedline
(delta feed)
ATU
Coax to XMTR

26-5 Delta matching a grounded vertical tower antenna.

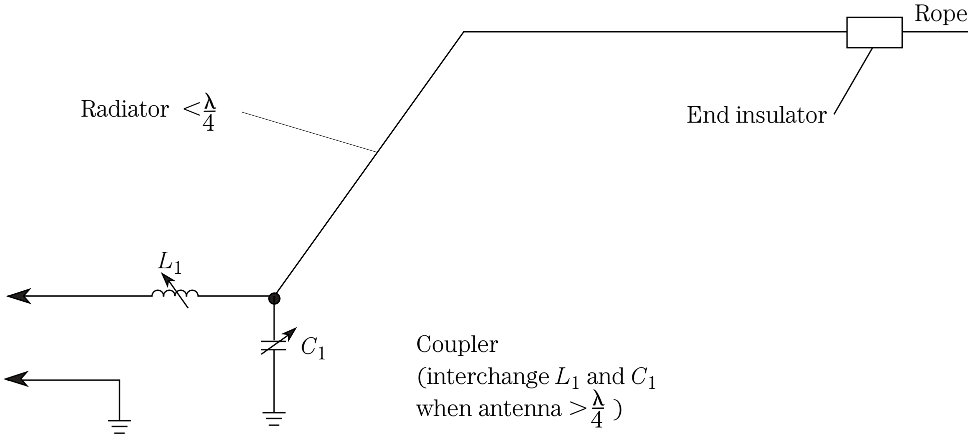
Rope
Radiator $<\frac{\lambda}{4}$
End insulator
L_1
C_1
Coupler
(interchange L_1 and C_1
when antenna $>\frac{\lambda}{4}$)

26-6 Random-length wire antenna.

The L-section coupler shown in Fig. 26-6 is set up for the case where the antenna radiator element is less than λ/4 (i.e., a series inductor and a shunt capacitor). If the antenna is longer than λ/4 on some frequency, then reverse the positions of the capacitor and inductor.

Inverted-L antennas

Another popular antenna for low frequencies is the *λ/4 inverted-L* (Fig. 26-7). In this type of antenna, two sections are erected at a 90° angle with respect to each other; one vertical and the other horizontal. One way to think of this antenna is bent λ/4 vertical, although some people liken it to a top-loaded vertical. The feedline can be 52- or 75-Ω coaxial cable.

It is generally the case that the sections of the inverted-L are equal in length (λ/8 each), but that is not strictly necessary. As the vertical section becomes longer (with overall length remaining at λ/4), the angle of radiation depresses.

One popular method of construction is to use a tower for the vertical section, and a run of wire for the horizontal section. If you already have a 60-ft tower to accommodate the beam antenna used on higher frequencies, then it is relatively easy to build an inverted-L antenna for 160 m.

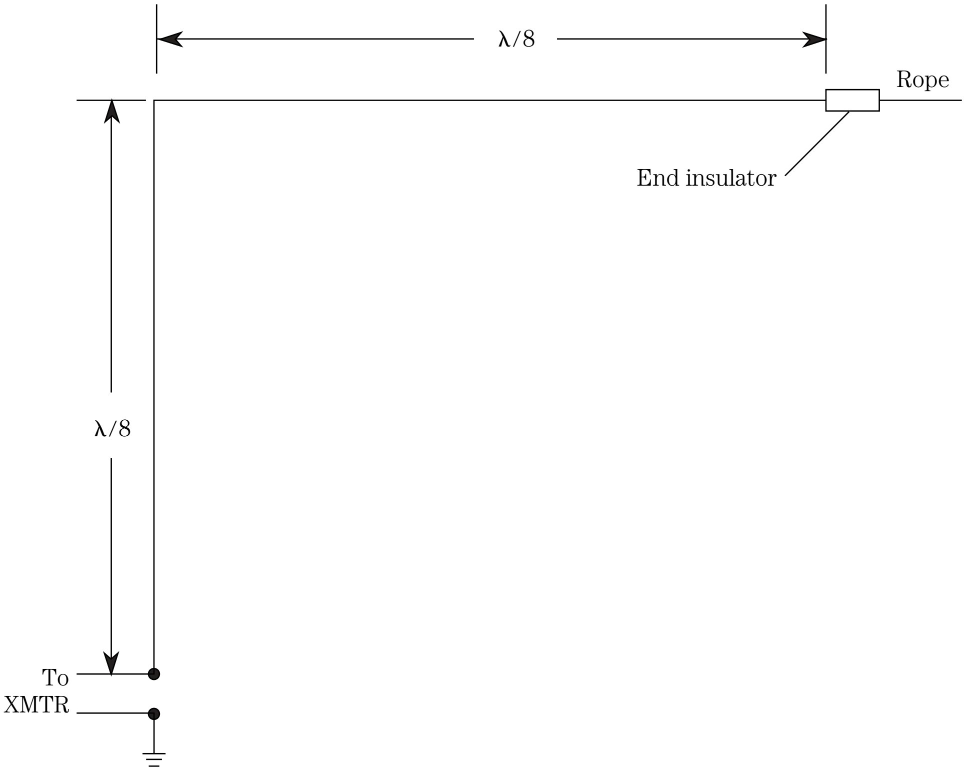

26-7 L-section quarter-wavelength antenna.

The linearly loaded "tee" antenna

A "tee" antenna consists of a horizontal radiator element fed at the center with a single conductor wire (not coax) that is a quarter-wavelength long, and goes away from the radiator at a right angle. Such antennas were popular prior to World War II in the United States, although popularity fell off in the late 1930s as other types (and reasonably priced transmission lines) became available. The tee is possibly one of the oldest forms of radio transmitting antennas. Like other antennas at low frequencies, however, it is far too long for easy use in most locations.

We can, however, linearly load the tee by folding the ends of the radiator back on themselves to form the zigzag pattern of Fig. 26-8. Popular in Europe for some time, this antenna can provide reasonable performance on the lower frequencies without using too much horizontal space.

The radiator element consists of three sections that are each about $\lambda/6$ long ($L_1 = 164/F_{\text{MHz}}$), and spaced 8 to 12 in apart; they are parallel to each other. The quarter-wavelength transmission line is connected to the center point of the middle section of the radiator element.

Figure 26-9 shows how the linearly loaded tee antenna could be built using wire for the radiator elements. Spreaders made of 24-in-long 1 × 2-in lumber (treated against the weather), plastic, or some other synthetic material can be used. Each spreader has three holes drilled in it spaced about 10 in apart. Spreaders A and E are end spreaders, and are identical—except for being upside down with respect to each other. In each case, one of the radiator element conductor sections is terminated, while the other passes through to the back of the spreader to join the center radiator element. The other spreaders are used either for center support, as in C (note the transmission line attachment), or for interim support between the center insulator and the end insulators.

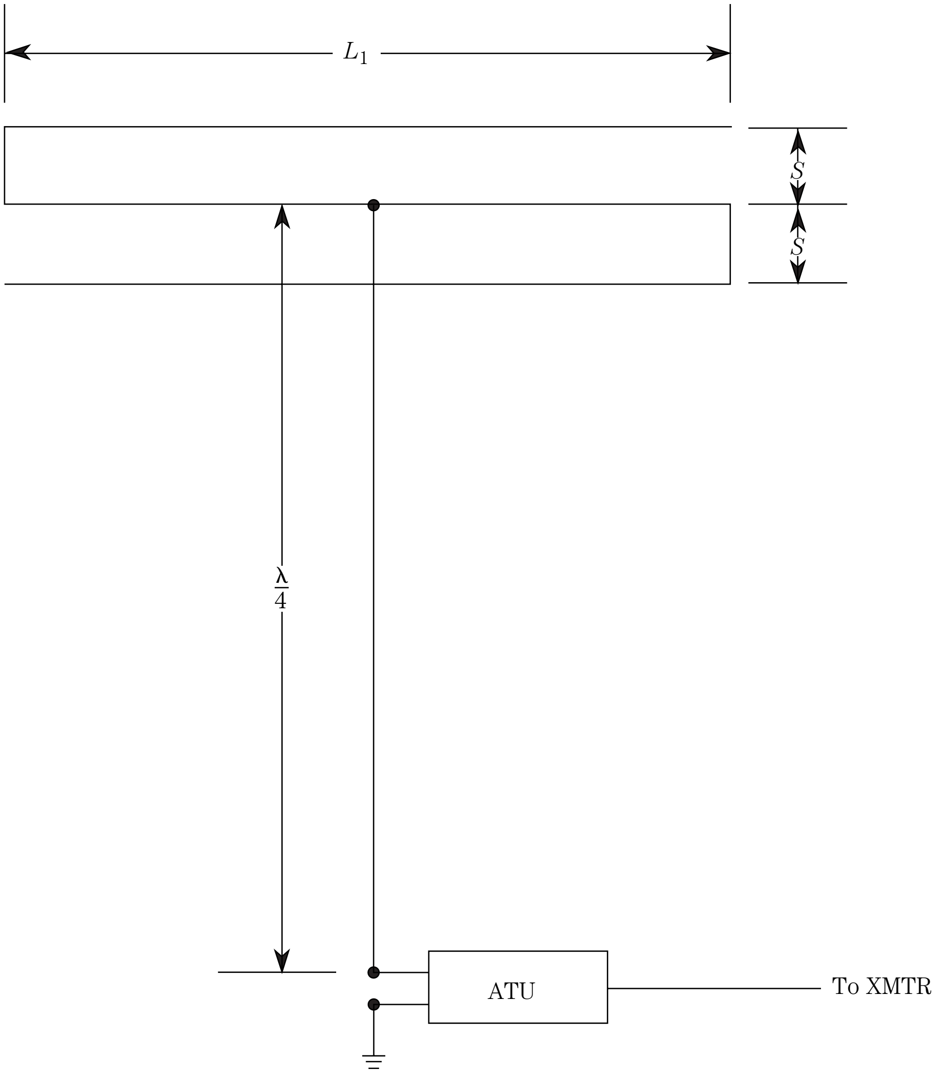
L_1
S
S
$\frac{\lambda}{4}$
ATU
To XMTR

$$L_1 = \frac{164}{F_{\text{MHz}}}$$

$$\frac{\lambda}{4} = \frac{246}{F_{\text{MHz}}}$$

26-8 Tee-loaded antenna.

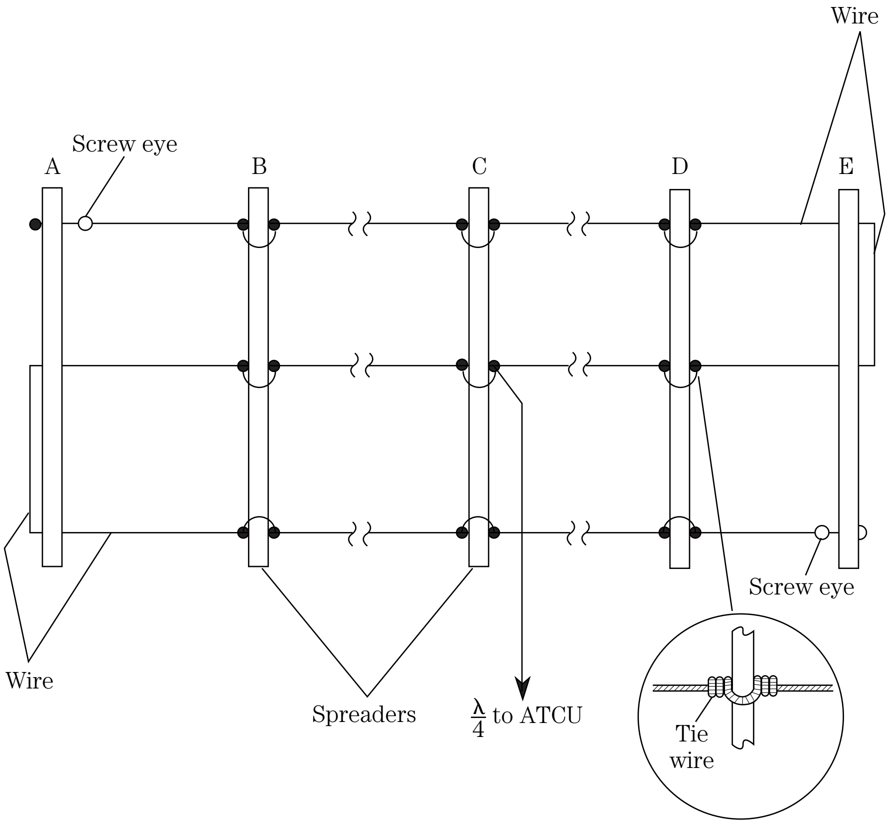
Wire
Screw eye
A
B
C
D
E
Screw eye
Wire
Spreaders
$\frac{\lambda}{4}$ to ATCU
Tie wire

26-9 Shortened tee antenna.

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27
CHAPTER

Measurements and adjustment techniques

THIS CHAPTER EXAMINES SOME OF THE INSTRUMENTS AND TECHNIQUES FOR TESTING antenna systems, whether brand new installations, or in troubleshooting situations on older antenna. The basic radio system is shown in Fig. 27-1. We have several elements in the system: transmitter, low-pass filter, impedance-matching unit, a coaxial relay if the receiver is separate from the transmitter, and the antenna. Connecting these elements are lengths of transmission line. In most modern radio systems below the microwaves, the transmission line is coaxial cable.

The low-pass filter and matching unit may be considered optional by some, but some designers regard them as essentially standard equipment, especially for HF and low-band VHF systems. The low-pass filter has the job of removing harmonics from the output signal that could interfere with other radio systems or radio and TV broadcast reception. It will pass only those frequencies below a certain cutoff point. The impedance matching unit is used to "tune out" impedance mismatches that cause the transmitter to see an excessive VSWR. These units are common in VLF, MW, and HF communications stations, as well as AM broadcasting stations. The matching unit also provides additional attenuation of the harmonics, so it makes the output even cleaner than is possible with the low-pass filter alone.

Another reason to use the matching unit is to allow the radio transmitter to put out the maximum allowable RF power. Modern solid-state final amplifiers are not tolerant of VSWR. In addition, these units use fixed-tuned low-pass filters for each band rather than the wide-range pi networks common on vacuum tube transmitters. Solid-state transmitters usually include a feedback *automatic load control* (ALC) that reduces output power when a high VSWR is sensed. The VSWR cut-in knee begins around 1.5:1 and completely shuts off the transmitter when the VSWR gets high (typically above 2.5:1 or 3:1). The external T/R relay is not used on most modern systems because the receiver and transmitter are typically housed inside of the same box. The coaxial relay was used in days past, when

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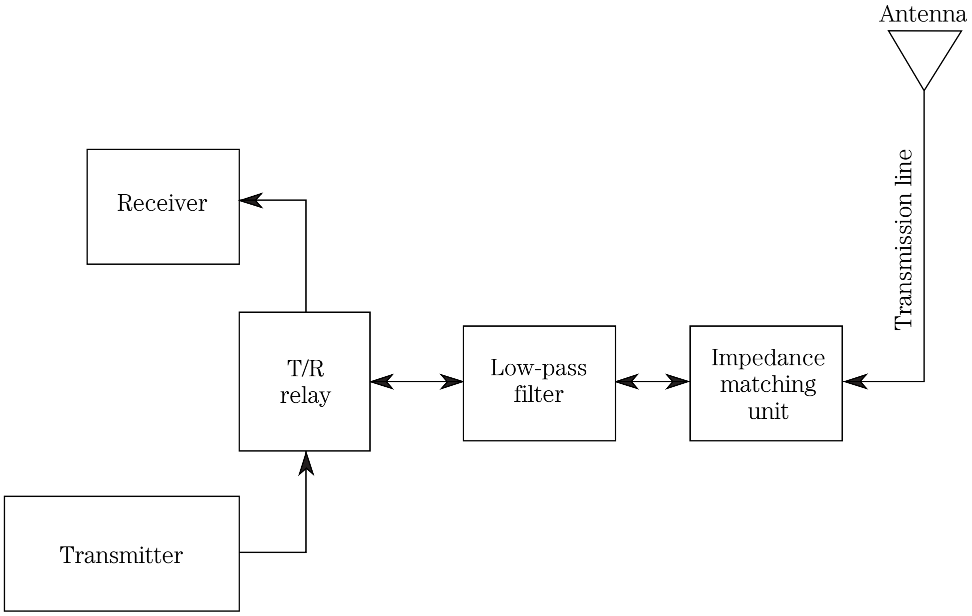

27-1 Basic communications radio station setup.

a separate receiver needed to use the same antenna. In addition, many modern solid-state equipments use PIN diode T/R switching.

Transmission lines

The transmission line is not merely a wire that carries RF power to the antenna. It is actually a complex circuit that simulates an infinite *LC* network. There is a characteristic impedance Z_o, also called *surge impedance*, which describes each transmission line. This impedance is the square root of the ratio of the capacitance and inductance per unit of length. When a load having a "resistive-only" impedance equal to the surge impedance of the transmission line is connected, then we will see maximum transfer of power between the line and the antenna.

We cannot deal extensively with transmission-line theory here, and refer the reader instead to previous chapters. We must, however, have at least some idea of what the circuit looks like. Figure 27-2 shows a model of a transmission line in which Z_o is the surge impedance of the line, R_1 is the load impedance of the antenna, and R_2 is the output impedance of the transmitter. In a properly designed system all three impedances either will be equal ($Z_o = R_1 = R_2$) or a matching network will make them equal.

We must consider the electrical situation along the transmission line in order to understand the readings that we see on our instruments. Figure 27-3 shows several possible situations. These graphs are of the RF voltage along the line, with voltage on the vertical axis and transmission line length (expressed in wavelengths of the RF signal) along the horizontal axis. When the system is matched ($Z_o = R_1$), the voltage

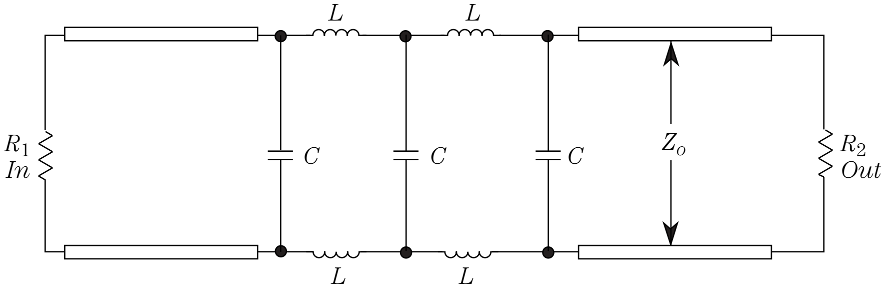

L = Inductance per unit length
C = Capacitance per unit length

27-2 Equivalent circuit of transmission line.

is the same everywhere along the line (Fig. 27-3A). This line is said to be “flat.” But when Z_o and R_2 are not equal, then the voltage varies along the line with wavelength. In mismatched systems, not all of the power is radiated by the antenna, but rather is reflected back to the transmitter. The forward and reflected waves combine algebraically at each point along the line to form standing waves (Fig. 27-3B). We can plot the voltage maxima ($V_{\max}$) and minima ($V_{\min}$). Keep this graph in mind for a few minutes because you will refer again to it when we deal with VSWR.

Two special situations occur in transmission line and antenna systems that yield similar results. The entire forward power is reflected back to the transmitter (none radiated) if the load (i.e., antenna) end of the transmission line is either open or shorted. The voltage plot for an open transmission line (R_2 is infinite) is shown in Fig. 27-3C, and that for the shorted line is shown in Fig. 27-3D. Note that they are very similar to each other except for where the minima ($V_{\min} = 0$) occur. The minima are offset from each other by 90° (i.e., quarter-wavelength).

Calculating standing wave ratio

The VSWR can be calculated from any of several bits of knowledge. Even if you don’t have a VSWR meter, therefore, it is possible to determine VSWR. If the antenna load impedance (R_2) is not equal to Z_o, then we can calculate VSWR from one of the following:

If Z_o is greater than R_2:

$$\text{VSWR} = \frac{Z_o}{R_2} \tag{27.1}$$

If Z_o is less than R_2:

$$\text{VSWR} = \frac{R_2}{Z_o} \tag{27.2}$$

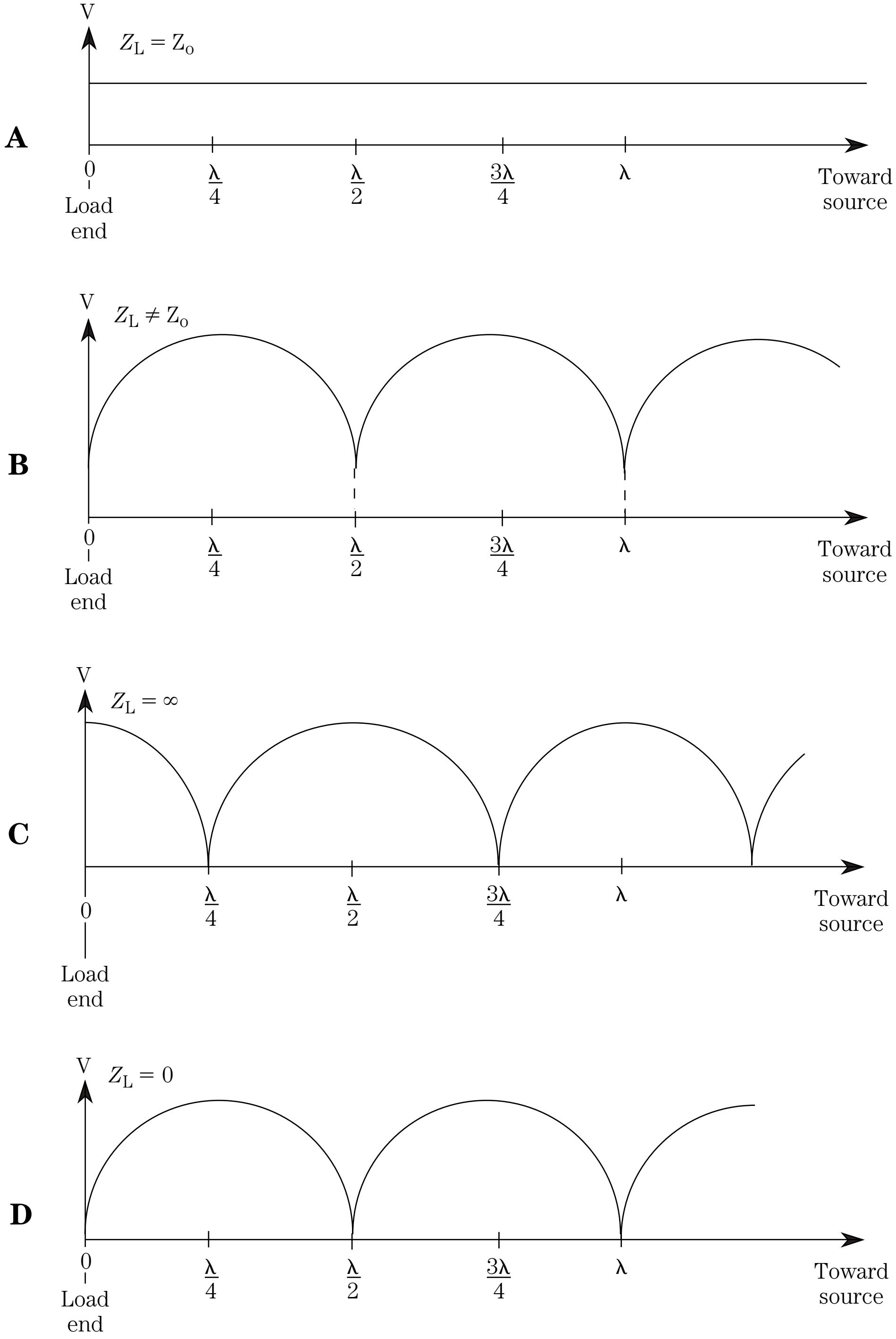

27-3 Voltage along line versus line electrical length: (A) flat line with matched impedance; (B) unequal impedances; (C) open load; (D) shorted load.

We can also measure the forward and reflected power, and calculate the VSWR from those readings:

$$\mathrm{VSWR} = \frac{1 + \sqrt{(P_r/P_f)}}{1 - \sqrt{(P_r/P_f)}} \qquad \textbf{[27.3]}$$

where

VSWR is the voltage standing wave ratio
P_r is the reflected power
P_f is the forward power

If we can measure either the voltage maximum and minimum, or the current maximum and minimum, then we can calculate SWR:

$$\mathrm{VSWR} = \frac{V_{\max}}{V_{\min}} \qquad \textbf{[27.4]}$$

Finally, if the forward and reflected voltage components at any given point on the transmission line can be measured, then we can calculate the VSWR from:

$$\mathrm{VSWR} = \frac{V_f + V_r}{V_f - V_r} \qquad \textbf{[27.5]}$$

where

V_f is the forward voltage component
V_r is the reflected voltage

The last equation, based on the forward and reflected voltages, is the basis for many modern VSWR and RF power meters.

Impedance bridges

We can make antenna impedance measurements using a variant of the old-fashioned Wheatstone bridge. Figure 27-4A shows the basic form of the bridge in its most generalized form. The current flowing in the meter will be zero when $(Z_1/Z_2) = (Z_3/Z_4)$. If one arm of the bridge is the antenna impedance, then we can adjust the others to make the bridge null to make the measurement. A typical example is shown in Fig. 27-4B. The antenna connected to J_2 is one arm of the bridge, while R_2 is a second. The value of R_2 should be 50 Ω or 75 Ω, depending upon the value of the expected antenna impedance. The choice of 68 Ω is a good compromise for meters to operate on both types of antennas. The other two arms of the bridge are the reactances of C_{1A} and C_{1B}, which is a single differential capacitor. Tune C_1 until the meter is nulled, and then read the antenna from the dial. At least one instrument allows the technician to plug in a resistor element equal to system impedance.

Calibrating the instrument is simple. A series of noninductive carbon composition resistors having standard values from 10 to 1000 Ω are connected across J_2. The meter is then nulled, and the value of the load resistor is inscribed on the dial at the point.

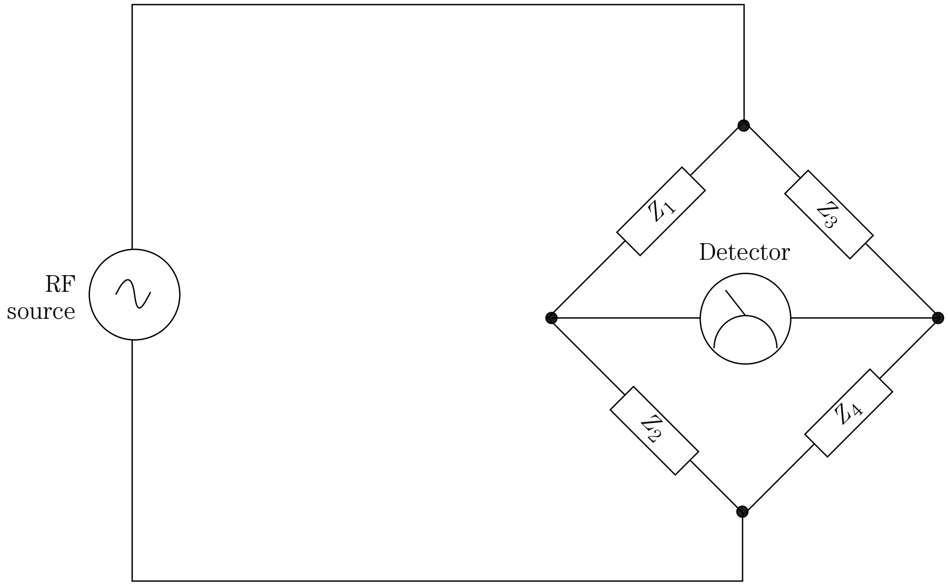
RF
source
Z_1
Z_3
Detector
Z_2
Z_4

27-4A Basic Wheatstone bridge.

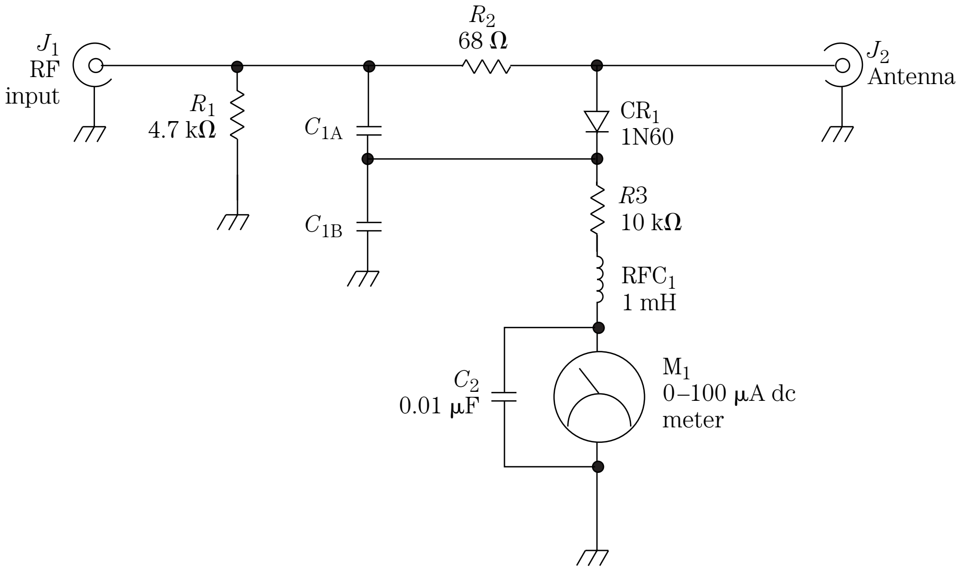
J_1
RF
input
R_1
4.7 kΩ
C_{1A}
C_{1B}
R_2
68 Ω
J_2
Antenna
CR_1
1N60
$R3$
10 kΩ
RFC_1
1 mH
C_2
0.01 μF
M_1
0–100 μA dc
meter

27-4B SWR bridge.

The basic circuit of Fig. 27-4B is useful only to measure the resistive component of impedance. We can modify the circuit as shown in Fig. 27-4C to account for the reactive component. An example of a commercial hand-held radio antenna impedance bridge is shown in Fig. 27-5.

The RF noise bridge

This section explores a device that was once associated only with engineering laboratories, but turns out to have applications in general communications servicing as well: the *RF noise bridge*. It is one of the most useful, low-cost, and often overlooked test instruments in our armamentarium.

Several companies have produced low-cost noise bridges: Omega-T, Palomar Engineers, The Heath Company, and, most recently, MFJ. The Omega-T and the Palomar Engineers models are shown in Fig. 27-5. The Omega-T device is a small cube with minimal dials, and a pair of BNC coax connectors (*antenna* and *receiver*). The dial is calibrated in ohms, and measures only the resistive component of impedance. The Palomar Engineers device is a little less eye appealing, but does everything the Omega-T does; in addition, it allows you to make a rough measurement of the reactive component of impedance. The Heath Company added their Model HD-1422 to the lineup. And the latest entry is the MFJ-204B antenna bridge.

Over the years, some people have found the noise bridge very useful for a variety of test and measurement applications, especially in the HF and low-VHF regions.

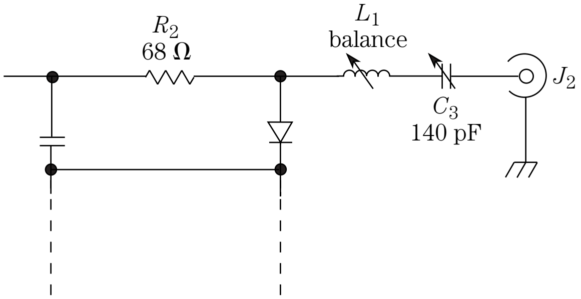

27-4C Circuit with balance control added.

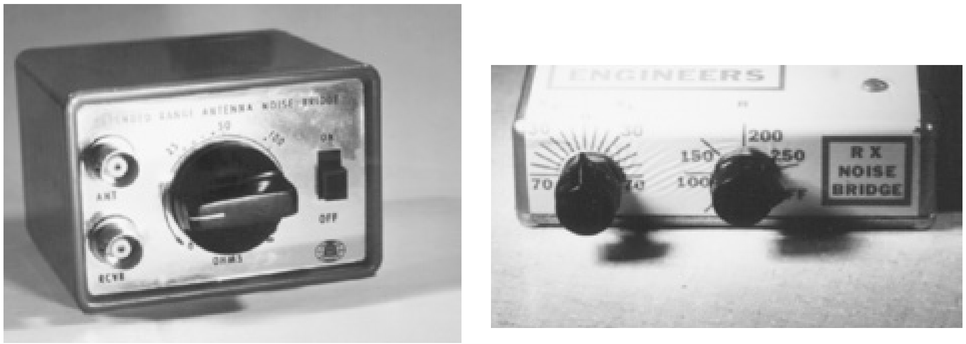

27-5 Commercially available amateur noise bridges.

Those applications are not limited to the testing of antennas (which is the main job of the noise bridge). In fact, although the two-way technician (including CB) or amateur radio operator, will measure antennas, tuned circuits, and resonant cavities with the device, consumer electronics technicians will find other applications.

Figure 27-6 shows the circuit of a noise bridge instrument. The bridge consists of four arms. The inductive arms (L_{1b} and L_{1c}) form a trifilar wound transformer over a ferrite core with L_{1a}, so a signal applied to L_{1a} is injected into the bridge circuit. The measurement consists of a series circuit of a 200-Ω potentiometer and a 120-pF variable capacitor. The potentiometer sets the range (0 to 200 Ω) of the resistive component of measured impedance, while the capacitor sets the reactance component. Capacitor C_2 in the unknown arm of the bridge is used to balance the measurement capacitor. With C_2 in the circuit, the bridge is balanced when C is approximately in the center of its range. This arrangement accommodates both inductive and capacitive reactances, which appear on either side of the "zero" point (i.e., the midrange capacitance of C). When the bridge is in balance, the settings of R and C reveal the impedance across the unknown terminal.

A reverse-biased zener diode (zeners normally operate in the reverse-bias mode) produces a large amount of noise because of the avalanche process inherent in zener operation. Although this noise is a problem in many other applications, in a noise bridge it is highly desirable: the richer the noise spectrum the better the performance. The spec-

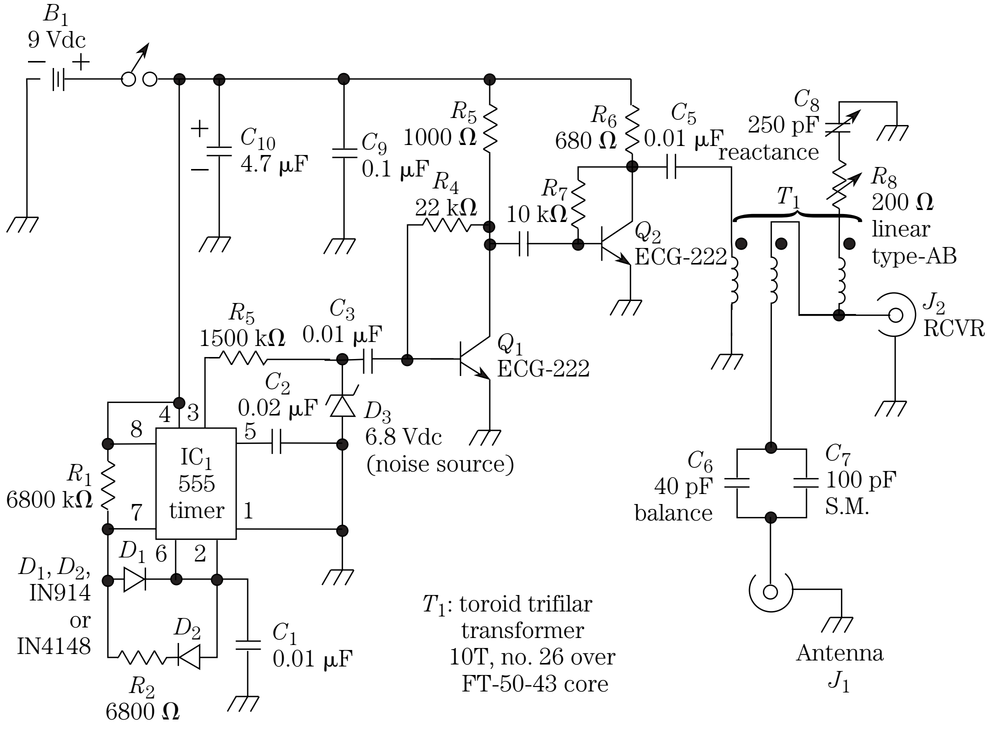
B1
9 Vdc
− +
C10
4.7 µF
C9
0.1 µF
R5
1000 Ω
R4
22 kΩ
R6
680 Ω
C5
0.01 µF
C8
250 pF
reactance
R7
10 kΩ
Q2
ECG-222
T1
R8
200 Ω
linear
type-AB
J2
RCVR
R5
1500 kΩ
C3
0.01 µF
Q1
ECG-222
C2
0.02 µF
D3
6.8 Vdc
(noise source)
IC1
555
timer
8
4
3
5
7
1
6
2
R1
6800 kΩ
D1
D1, D2,
IN914
or
IN4148
D2
R2
6800 Ω
C1
0.01 µF
C6
40 pF
balance
C7
100 pF
S.M.
Antenna
J1
T1: toroid trifilar
transformer
10T, no. 26 over
FT-50-43 core

27-6 Noise bridge circuit.

trum is enhanced because of the 1-kHz square-wave modulator that chops the noise signal. An amplifier boosts the noise signal to the level needed in the bridge circuit.

The detector used in the noise bridge is a tunable receiver covering the frequencies of interest. The preferable receiver uses an AM demodulator, but both CW (morse code) and SSB receivers will do in a pinch. The quality of the receiver depends entirely on the precision with which you need to know the operating frequency of the device under test.

Adjusting antennas

Perhaps the most common use for the antenna noise bridge is finding the impedance and resonant points of an HF antenna. Connect the *receiver* terminal of the bridge to the *antenna* input of the HF receiver through a short length of coaxial cable as shown in Fig. 27-7. The length should be as short as possible, and the characteristic impedance should match that of the antenna feedline. Next, connect the coaxial feedline from the antenna to the *antenna* terminals on the bridge. You are now ready to test the antenna.

Set the noise bridge resistance control to the antenna feedline impedance (usually 50 to 75 Ω for most common antennas). Set the reactance control to midrange (zero). Next, tune the receiver to the *expected* resonant frequency (F_{exp}) of the antenna. Turn the noise bridge *on*, look for a noise signal of about S9 (will vary on different receivers), and if—in the unlikely event that the antenna is resonant on the expected frequency—you will find yourself right in the middle of the null.

Adjust the *resistance* control R on the bridge for a null, i.e., minimum noise as indicated by the S meter. Next, adjust the *resistance* control C for a null. Repeat the adjustments of the R and C controls for the deepest possible null, as indicated by the lowest noise output on the S meter (there is some interaction between the two controls).

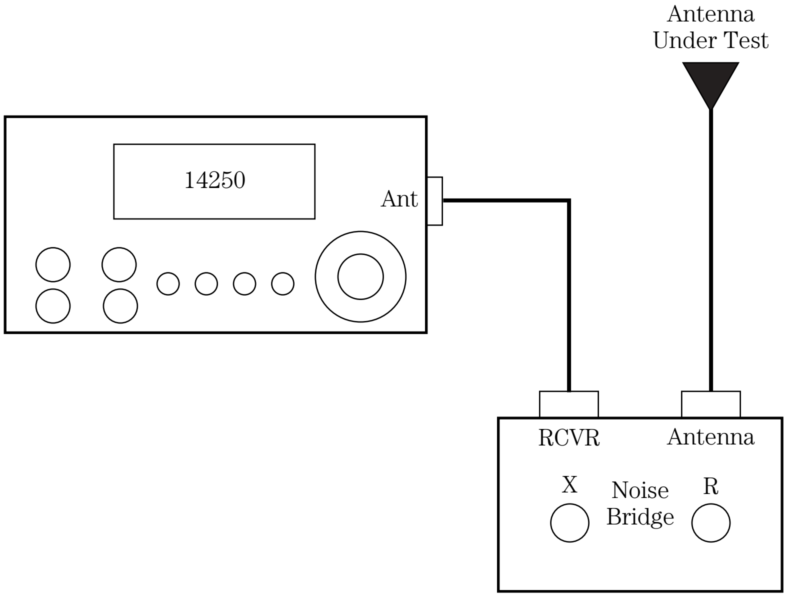

27-7 Connection of noise bridge.

A perfectly resonant antenna will have a reactance reading of zero ohms, and a resistance of 50 to 75 Ω. Real antennas might have some reactance (the less the better), and a resistance that is somewhat different from 50 to 75 Ω. Impedance-matching methods can be used to transform the actual resistive component to the 50- or 75-Ω characteristic impedance of the transmission line. The results to expect:

1. If the resistance is close to zero, then suspect that there is a short circuit on the transmission line. Suspect an open circuit if the resistance is close to 200 Ω.
2. A reactance reading on the X_L side of zero indicates that the antenna is too long, while a reading on the X_C side of zero indicates an antenna that is too short.

An antenna that is too long or too short should be adjusted to the correct length. To determine the correct length, we must find the actual resonant frequency F_r. To do this, reset the *reactance* control to zero, and then *slowly* tune the receiver in the proper direction—downband for too long and upband for too short—until the null is found. On a high-Q antenna, the null is easy to miss if you tune too fast. Don't be surprised if that null is out of band by quite a bit. The percentage of change is given by dividing the expected resonant frequency F_{exp} by the actual resonant frequency F_r, and multiply by 100:

$$\text{Change} = \frac{F_{\text{exp}} \times 100\%}{F_r} \qquad \textbf{[27.6]}$$

Connect the antenna, noise bridge, and receiver in the same manner as above. Set the receiver to the expected resonant frequency (i.e., approximately 468/F for half-wavelength types and 234/F for quarter-wavelength types). Set the resistance control to 50 Ω or 75 Ω, as appropriate for the normal antenna impedance and the transmission line impedance. Set the reactance control to zero. Turn the bridge on and listen for the noise signal.

Slowly rock the reactance control back and forth to find on which side of zero the null appears. Once the direction of the null is determined, set the reactance control to zero, and then tune the receiver toward the null direction (downband if null is on X_L side and upband if it is on the X_C side of zero).

A less-than-ideal antenna will not have exactly 50- or 75-Ω impedance, so some adjustment of R and C to find the deepest null is in order. You will be surprised how far off some dipoles and other forms of antennas can be if they are not in "free space," (i.e., if they are close to the earth's surface).

Nonresonant antenna adjustment

We can operate antennas on frequencies other than their resonant frequency if we know the impedance:

$$X_C = X = \frac{55}{68 - C} - 2340 \qquad \textbf{[27.7]}$$

or

$$X_L = X = 2340 - \frac{159{,}155}{68 + C} \qquad \textbf{[27.8]}$$

Now, plug *"X"* calculated from Eq. 27.7 or 27.8 into $X_f = X/F$ where F is the desired frequency in MHz.

Other jobs

The noise bridge can be used for a variety of jobs. We can find the values of capacitors and inductors, determine the characteristics of series- and parallel-tuned resonant circuits, and adjust transmission lines.

Transmission line measurements Some antennas and non-noise measurements require antenna feedlines that are either a quarter-wavelength or half-wavelength at some specific frequency. In other cases, a piece of coaxial cable of specified length is required for other purposes: for instance, the dummy load used to service depth sounders is nothing but a long piece of shorted coax that returns the echo at a time interval that corresponds to a specific depth. We can use the bridge to find these lengths as follows:

1. Connect a short circuit across the *unknown* terminals and adjust R and X for the best null at the frequency of interest. (*Note*: both will be near zero.)
2. Remove the short circuit.
3. Connect the length of transmission line to the *unknown* terminal—it should be longer than the expected length.
4. For quarter-wavelength lines, shorten the line until the null is very close to the desired frequency. For half-wavelength lines, do the same thing, except that the line must be shorted at the far end for each trial length.

The velocity factor of a transmission line (usually designated by the letter V in equations) is a decimal fraction that tells us how fast the radio wave propagates along the line relative to the speed of light in free space. For example, foam dielectric coaxial cable is said to have a velocity factor of $V = 0.80$. This number means that the signals in the line travel at a speed 0.80 (or 80 percent) of the speed of light.

Because all radio wavelength formulas are based on the velocity of light, you need the V value to calculate the physical length needed to equal any given electrical length. For example, a half-wavelength piece of coax has a physical length of $(492 \times V)/F_{\mathrm{MHz}}$ feet. Unfortunately, the real value of V is often a bit different from the published value. You can use the noise bridge to find the actual value of V for any sample of coaxial cable as follows:

1. Select a convenient length of the coax more than 12 ft in length and install a PL-259 RF connector (or other connector compatible with your instrument) on one end, and short-circuit the other end.
2. Accurately measure the physical length of the coax in feet; convert the "remainder" inches to a decimal fraction of a foot by dividing by 12 (e.g., 32 ft 8 in= 32.67 ft because 8 in/12 in = 0.67). Alternatively, cut off the cable to the nearest foot and reconnect the short circuit.
3. Set the bridge *resistance* and *reactance* controls to zero.
4. Adjust the monitor receiver for deepest null. Use the null frequency to find the velocity factor $V = FL/492$, where V is the velocity factor (a decimal fraction); F is the frequency in megahertz; and L is the cable length in feet.

Tuned circuit measurements An inductor/capacitor (*LC*) tuned "tank" circuit is the circuit equivalent of a resonant antenna, so there is some similarity between the two measurements. You can measure resonant frequency with the noise bridge to within ±20 percent (or better if care is taken). This accuracy might seem poor, but it is better than you can usually get with low-cost signal generators, dip meters, absorption wavemeters, and the like.

A *series tuned circuit* exhibits a low impedance at the resonant frequency and a high impedance at all other frequencies. Start the measurement by connecting the series tuned circuit under test across the *unknown* terminals of the dip meter. Set the *resistance* control to a low resistance value, close to zero ohms. Set the *reactance* control at midscale (zero mark). Next, tune the receiver to the expected null frequency, and then tune for the null. Make sure that the null is at its deepest point by rocking the R and X controls for best null. At this point, the receiver frequency is the resonant frequency of the tank circuit.

A *parallel resonant circuit* exhibits a high impedance at resonance and a low impedance at all other frequencies. The measurement is made in exactly the same manner as for the series resonant circuits, except that the connection is different. Figure 27-8 shows a two-turn link coupling that is needed to inject the noise signal into the parallel resonant tank circuit. If the inductor is the toroidal type, then the link must go through the hole in the doughnut-shaped core and then connect to the *unknown* terminals on the bridge. After this, proceed exactly as you would for the series tuned tank measurement.

Capacitance and inductance measurements The bridge requires a 100-pF silver mica test capacitor and a 4.7-μH test inductor, which are used to measure inductance and capacitance, respectively. The idea is to use the test components to form a series-tuned resonant circuit with an unknown component. If you find a resonant frequency, then you can calculate the unknown value. In both cases, the series tuned circuit is connected across the *unknown* terminals of the dip meter, and the series tuned procedure is followed.

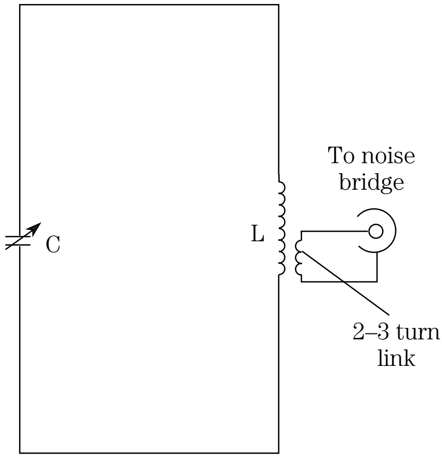

27-8 Noise bridge connection to *LC* tank circuits.

To measure inductance, connect the 100-pF capacitor in series with the unknown coil across the *unknown* terminals of the dip meter. When the null frequency is found, find the inductance from

$$L = \frac{253}{F^2} \qquad \textbf{[27.9]}$$

where

L is the inductance, in microhenries
F is the frequency, in megahertz

Connect the test inductor across the *unknown* terminals in series with the unknown capacitance. Set the *resistance* control to zero, tune the receiver to 2 MHz, and readjust the *reactance* control for null. Without readjusting the noise bridge control, connect the test inductor in series with the unknown capacitance and retune the receiver for a null. Capacitance can now be calculated from:

$$C = \frac{5389}{F^2} \qquad \textbf{[27.10]}$$

where:

C is in picofarads
F is in megahertz

Dip oscillators

One of the most common instruments for determining the resonant frequency of an antenna is the so-called dip oscillator or dip meter. Originally called the *grid dip meter*, the basis for this instrument is the fact that its output energy can be absorbed by a nearby resonant circuit (or antenna, which is an electrically resonant LC tank circuit). When the inductor of the dip oscillator (see Fig. 27-9) is brought into

SOLID STATE
DIP METER

27-9 Dip meter.

close proximity to a resonant tank circuit, and the oscillator is operating on the resonant frequency, then a small amount of energy is transferred. This energy loss shows up on the meter pointer as a slight "dipping" action. The dip is extremely sharp, and is easily missed if the meter frequency dial is tuned too rapidly.

Antennas are resonant circuits, and can be treated in a manner similar to *LC* tank circuits. Figure 27-10A shows one way to couple the dip oscillator to a vertical antenna radiator. The inductor of the dipper is brought into close proximity to the base of the radiator. Figure 27-10B shows the means for coupling the dip oscillator

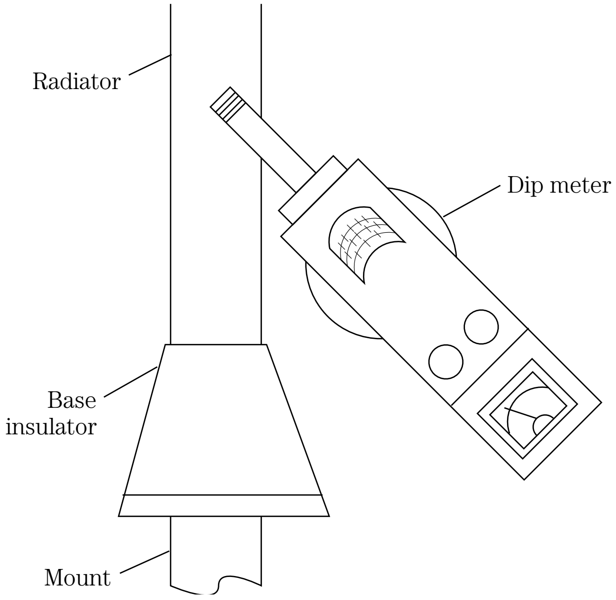
Radiator
Dip meter
Base insulator
Mount

27-10A Direct coupling the dip meter to antenna.

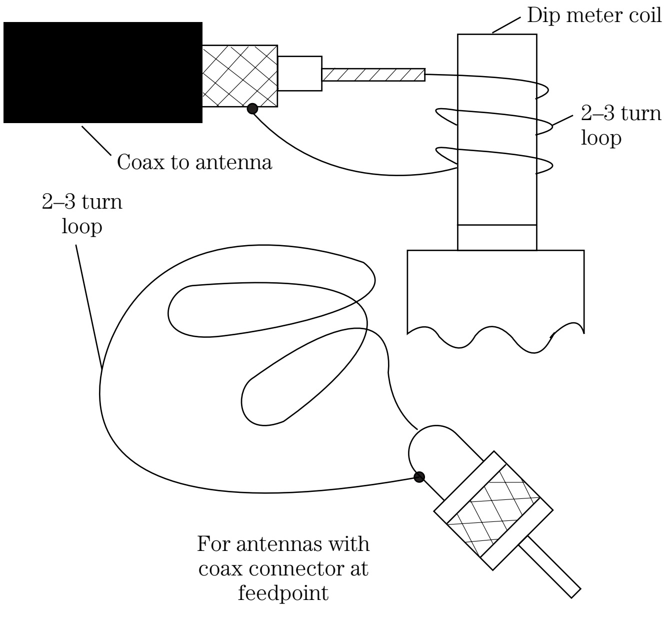
Dip meter coil
2–3 turn loop
Coax to antenna
2–3 turn loop
For antennas with coax connector at feedpoint

27-10B Coupling the dip meter to coaxial cable.

to systems where the radiator is not easily accessed (as when the antenna is still erected). We connect a small two- or three-turn loop to the transmitter end of the transmission line, and then bring the inductor of the dipper close to it. A better way is to connect the loop directly to the antenna feedpoint.

There are two problems with dip meters that must be recognized in order to best use the instrument. First, the dip is very sharp. It is easy to tune past the dip and not even see it. To make matters worse, it is normal for the meter reading to drop off gradually from one end of the tuning range to the other. But if you tune very slowly, then you will notice a very sharp dip when the resonant point is reached.

The second problem is the dial calibration. The dial gradations of inexpensive dip meters are too close together and are often erroneous. It is better to monitor the output of the dip oscillator on a receiver and depend upon the calibration of the receiver for data.

Selecting and using RF wattmeters and antenna VSWR meters

A key instrument required in checking the performance of, or troubleshooting, radio transmitters is the RF power meter (or "wattmeter"). These instruments measure the output power of the transmitter, and display the result in watts, or some related unit. Closely related to RF wattmeters is the antenna VSWR meter. This instrument also examines the output of the transmitter and gives a relative indication of output power. It can be calibrated to display the dimensionless units of *voltage standing wave ratio.* Many modern instruments, a couple of which will be covered as examples in this chapter, combine both RF power and VSWR measurement capabilities.

Measuring RF power

Measuring RF power has traditionally been notoriously difficult, except perhaps in the singular case of continuous-wave (CW) sources that produce nice, well-behaved sine waves. Even in that limited case, however, some measurement methods are distinctly better than others.

The peak voltage of a waveform is 100 V (i.e., peak-to-peak 200 V). Given that the CW waveform is sinusoidal, we know that the root mean square (RMS) voltage is 0.707 V. The output power is related to the RMS voltage across the load by

$$P = \frac{(V_{\text{rms}})^2}{Z_o} \qquad \textbf{[27.11]}$$

where:

P is the power, in watts
V_{rms} is the RMS potential, in volts
Z_o is the load impedance, in ohms

If we assume a load impedance of 50 Ω, then we can state that the power in our hypothetical illustration waveform is 100 W.

We can measure power on unmodulated sinusoidal waveforms by measuring either the RMS or peak values of either voltage or current, assuming that a constant-value resistance load is present. But the problem becomes more complex on modulated signals. The various power readings on a Bird model 4311 peak power meter, the peak (PEP) and average powers, vary markedly with modulation type.

One of the earliest forms of practical RF power measurement was the thermocouple RF ammeter (see Fig. 27-11). This instrument works by dissipating a small amount of power in a small resistance inside the meter, and then measuring the heat generated with a thermocouple. A dc current meter monitors the output of the thermocouple device, and indicates the level of current flowing in the heating element. Because it works on the basis of the power dissipated heating a resistance, *a thermocouple RF ammeter is inherently an RMS-reading device*. Because of this feature it is very useful for making average power measurements. If we know the RMS current and the resistive component of the load impedance, and if the reactive component is zero or very low, then we can determine RF power from the familiar expression:

$$P = I^2 \times R_i \qquad \textbf{[27.12]}$$

There is, however, a significant problem that keeps thermocouple RF ammeters from being universally used in RF power measurement: those instruments are highly frequency-dependent. Even at low frequencies, it is recommended that the meters be mounted on insulating material with at least ⅜-in spacing between the meter and its metal cabinet. Even with that precaution, however, there is a strong frequency dependence that renders the meter less useful at higher frequencies. Some meters are advertised to operate into the low-VHF region, but a note of caution is necessary. That recommendation requires a copy of the calibrated frequency response curve for that specific meter, so that a correction factor can be added (or subtracted) from

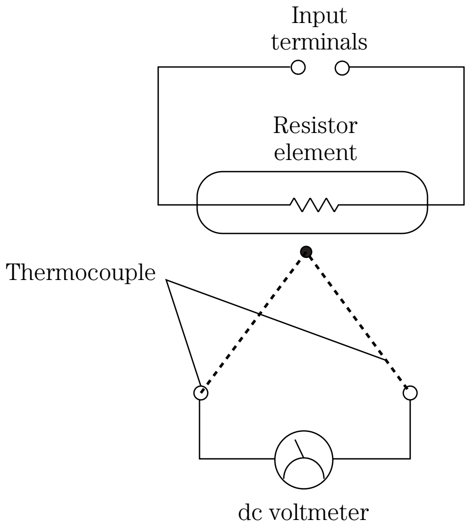

27-11 Circuit for thermocouple RF ammeter.

the reading. At 10 MHz and higher, the readings of the thermocouple RF ammeter must be taken with a certain amount of skepticism unless the original calibration chart is available.

We can also measure RF power by measuring the voltage across the load resistance (see Fig. 27-12). In the circuit of Fig. 27-12, the RF voltage appearing across the load is scaled downward to a level compatible with the voltmeter by the resistor voltage divider (R_2/R_3). The output of this divider is rectified by CR_1 and filtered to dc by the action of capacitor C_2.

The method of measuring the voltage in a simple diode voltmeter is valid only if the RF signal is unmodulated and has a sinusoidal waveshape. While these criteria are met in many transmitters, they are not universal. If the voltmeter circuit is peak reading, as in Fig. 27-12, then the peak power is

$$P = \frac{V_o^2}{R_1} \qquad \textbf{[27.13]}$$

The average power is then found by multiplying the peak power by 0.707. Some meter circuits include voltage dividers that precede the meter and thereby convert the reading to RMS, and thus convert the power to average power. Again, it must be stressed that terms like RMS, average, and peak have meaning only when the input

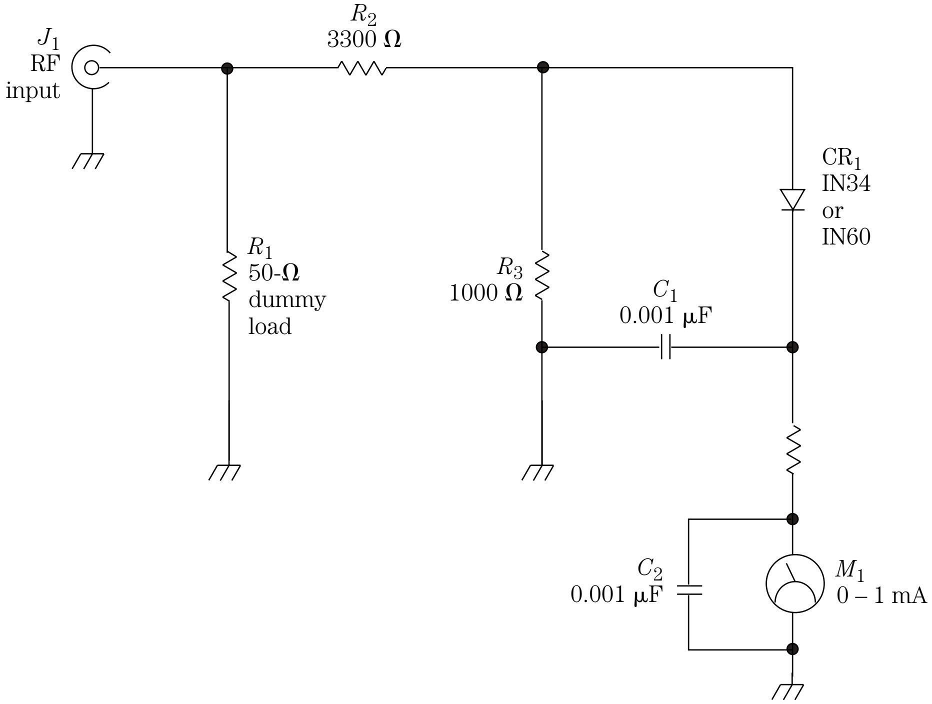

27-12 RF voltmeter "wattmeter."

RF signal is both unmodulated and sinusoidal. Otherwise, the readings are meaningless unless calibrated against some other source.

It is also possible to use various bridge methods for measurement of RF power. Figure 27-13 shows a bridge set up to measure both forward and reverse power. This circuit was once popular for VSWR meters. There are four elements in this quasi-Wheatstone bridge circuit: R_1, R_2, R_3, and the antenna impedance (connected to the bridge at J_2). If R_{ant} is the antenna resistance, then we know that the bridge is in balance (i.e., the null condition) when the ratios R_1/R_2 and R_3/R_{ant} are equal. In an ideal situation, resistor R_3 will have a resistance equal to R_{ant} , but that might overly limit the usefulness of the bridge. In some cases, therefore, the bridge will use a compromise value such as 67 Ω for R_3. Such a resistor will be usable on both 50- and 75-Ω antenna systems with only small errors. Typically, these meters are designed to read relative power level, rather than the actual power.

An advantage of this type of meter is that we can get an accurate measurement of VSWR by proper calibration. With the switch in the *forward* position, and RF power applied to J_1 (XMTR), potentiometer R_6 is adjusted to produce a full-scale deflection on meter M_1. When the switch is then set to the *reverse* position, the meter will read reverse power relative to the VSWR. An appropriate VSWR scale is provided.

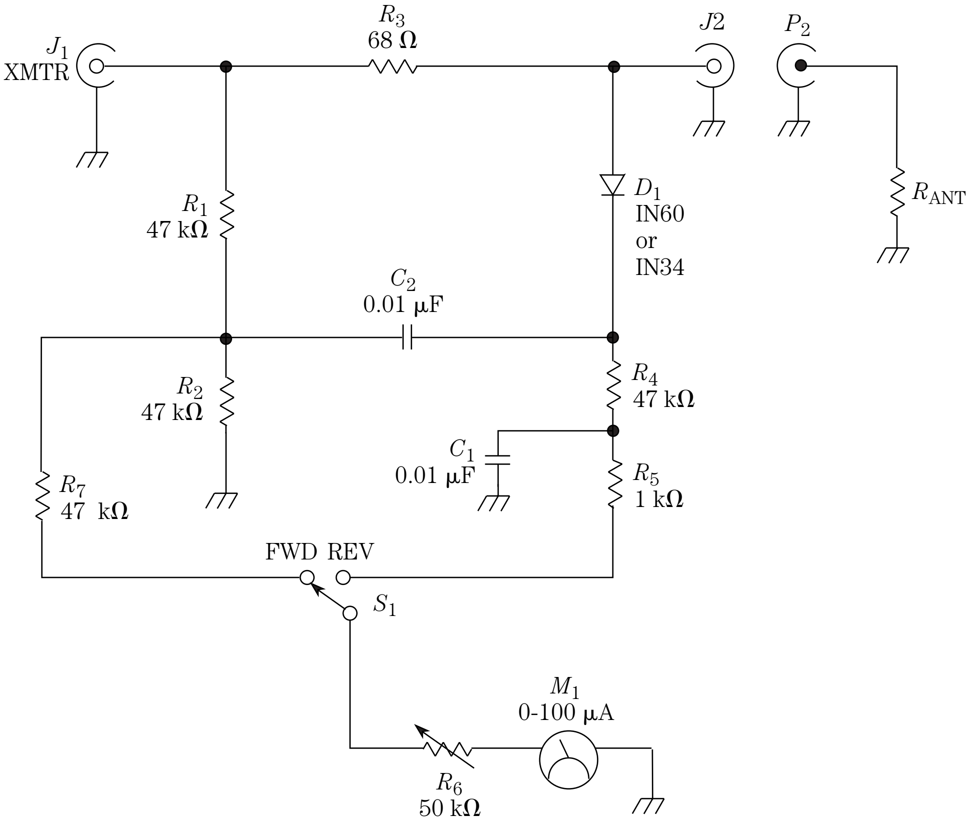

27-13 A bridge arrangement to measure both forward and reverse power.

A significant problem with the bridge of Fig. 27-13 is that it cannot be left in the circuit while transmitting because it dissipates a considerable amount of RF power in the internal resistances. These meters, during the time when they were popular, were provided with switches that bypassed the bridge when transmitting. The bridge was only in the circuit when making a measurement.

An improved bridge circuit is the capacitor/resistor bridge in Fig. 27-14; this circuit is called the micromatch bridge. Immediately, we see that the micromatch is improved over the conventional bridge because it uses only 1 Ω in series with the line (R_i). This resistor dissipates considerably less power than the resistance used in the previous example. Because of this low-value resistance, we can leave the micromatch in the line while transmitting. Recall that the ratios of the bridge arms must be equal for the null condition to occur. In this case, the capacitive reactance ratio of C_1/C_2 must match the resistance ratio R_1/R_{ant}. For a 50-Ω antenna, the ratio is $1/50$, and for 75-Ω antennas it is $1/75$ (or, for the compromise situation, $1/68$). The small-value trimmer capacitor (C_2) must be adjusted for a reactance ratio with C_1 of $1/50$, $1/75$, or $1/68$, depending upon how the bridge is set up.

The sensitivity control can be used to calibrate the meter. In one version of the micromatch, there are three power ranges (10, 100, and 1000 W). Each range has its own sensitivity control, and these are switched in and out of the circuit as needed.

The monomatch bridge circuit in Fig. 27-15 is the instrument of choice for HF and low-VHF applications. In the monomatch design, the transmission line is segment

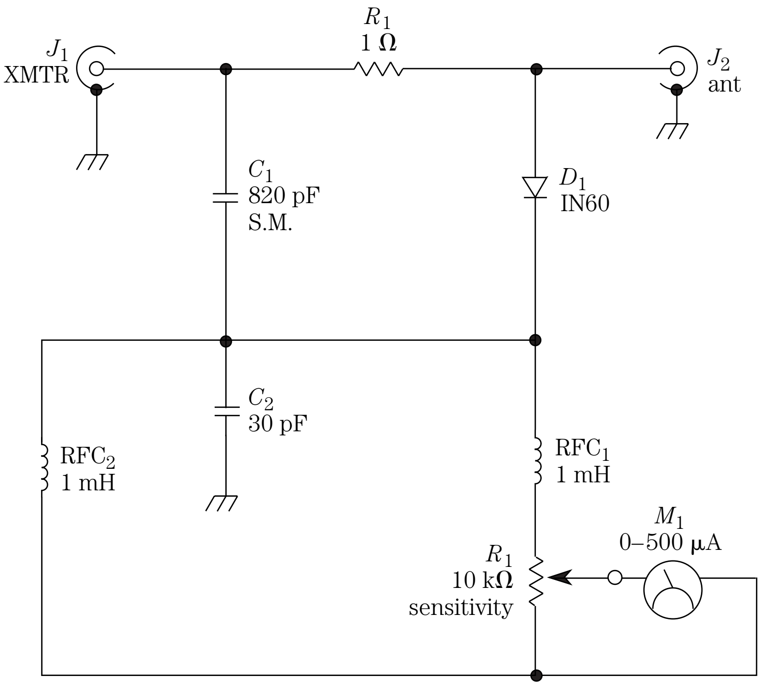

27-14 Micromatch wattmeter.

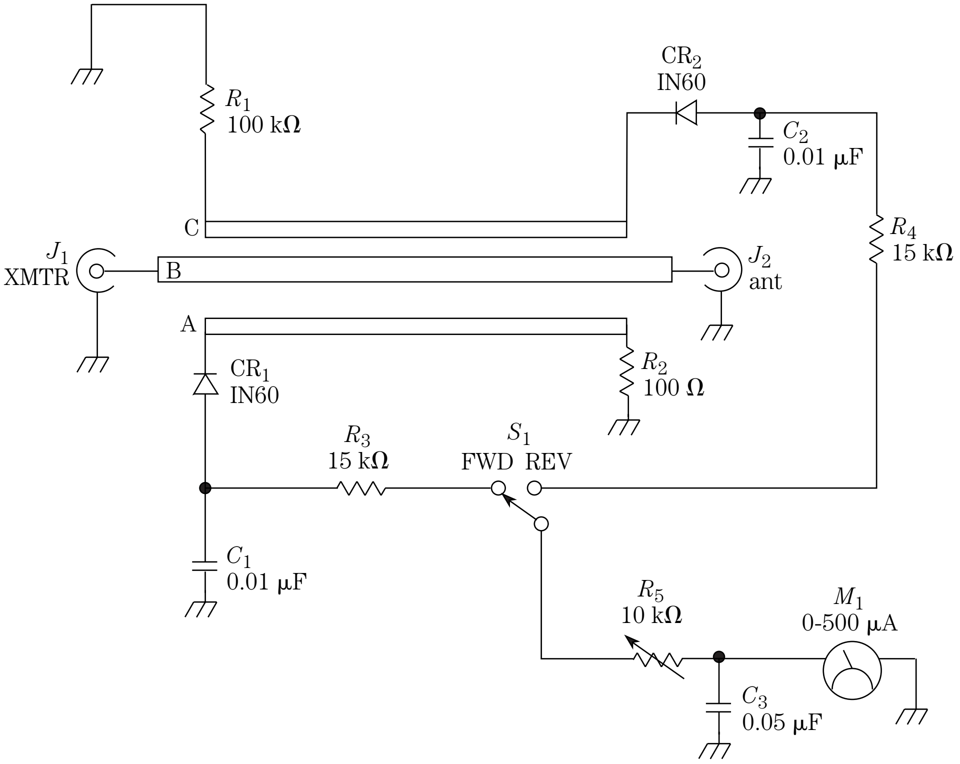

27-15 Monomatch wattmeter.

B, while RF sampling elements are formed by segments A and C. Although the original designs were based on a coaxial-cable sensor, later versions used either printed circuit foil transmission line segments or parallel brass rods for A, B, and C.

The sensor unit is basically a directional coupler with a detector element for both forward and reverse directions. For best accuracy, diodes CR$_1$ and CR$_2$ should be matched, as should R_1 and R_2. The resistance of R_1 and R_2 should match the transmission line surge impedance, although in many instruments a 68-Ω compromise resistance is used.

The particular circuit shown in Fig. 27-15 uses a single dc meter movement to monitor the output power. Many modern designs use two meters (one each for forward and reverse power).

One of the latest designs in VSWR meter sensors is the current transformer assembly shown in Fig. 27-16. In this instrument, a single-turn ferrite toroid transformer is used as the directional sensor. The transmission line passing through the hole in the toroid "doughnut" forms the primary winding of a broadband RF transformer. The secondary, which consists of 10 to 40 turns of small enamel wire, is connected to a measurement bridge circuit ($C_1 + C_2$ + load) with a rectified dc output.

Figures 27-17 and 27-18 show instruments based on the current transformer technique. Shown in Fig. 27-17 is the Heath model HM-102 high-frequency VSWR/power meter. The sensor is a variant on the current transformer method. This

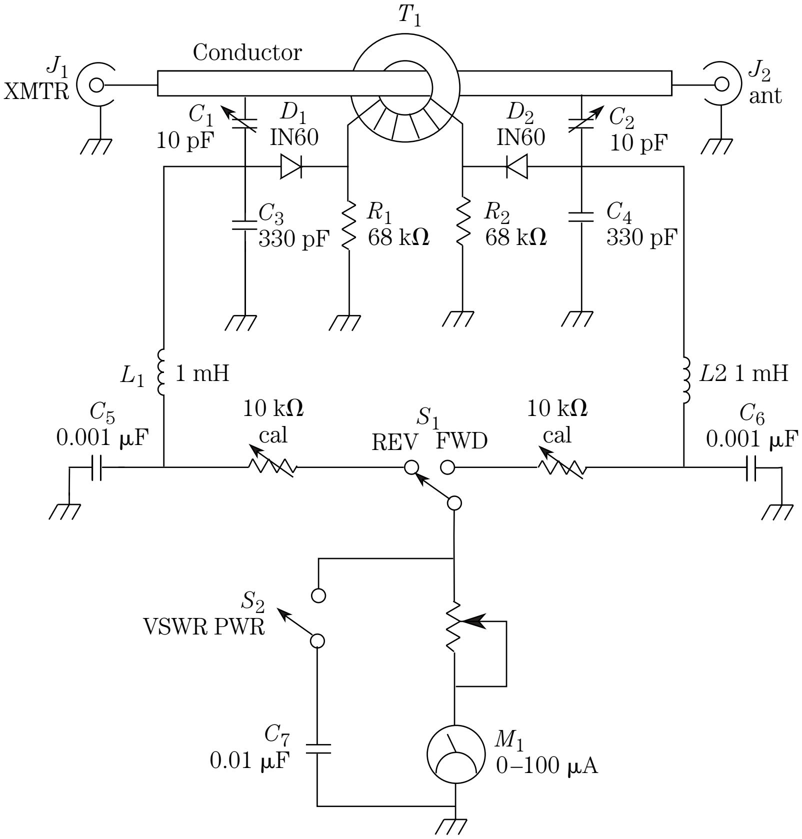
T_1
Conductor
J_1
XMTR
J_2
ant
C_1
10 pF
D_1
IN60
D_2
IN60
C_2
10 pF
C_3
330 pF
R_1
68 kΩ
R_2
68 kΩ
C_4
330 pF
L_1
1 mH
$L2$ 1 mH
C_5
0.001 μF
10 kΩ
cal
S_1
REV
FWD
10 kΩ
cal
C_6
0.001 μF
S_2
VSWR PWR
C_7
0.01 μF
M_1
0–100 μA

27-16 Current transformer wattmeter.

27-17 Amateur radio RF wattmeter.

instrument measures both forward and reflected power, and it can be calibrated to measure VSWR.

The Bird model 43 Thruline RF wattmeter shown in Fig. 27-18 has for years been one of the industry standards in communications service work. Although it is slightly more expensive than lesser instruments, it is also versatile, and it is accurate and rugged. The Thruline meter can be inserted into the transmission line of an

27-18 Bird model 43 RF wattmeter.

antenna system with so little loss that it may be left permanently in the line during normal operations. The Model 43 Thruline is popular with land mobile and marine radio technicians.

The heart of the Thruline meter is the directional coupler transmission line assembly shown in Fig. 27-19A; it is connected in series with the antenna, or dummy load, transmission line. The plug-in directional element can be rotated 180° to measure both forward and reverse power levels. A sampling loop and diode detector are contained within each plug-in element. The main RF barrel is actually a special coaxial line segment with a 50-**Ω** characteristic impedance. The Thruline sensor works due to the mutual inductance between the sample loop and center conductor of the coaxial element. Figure 27-19B shows an equivalent circuit. The output voltage from the sampler (e) is the sum of two voltages, e_r and e_m. Voltage e_r is created by the voltage divider action of R and C on transmission line voltage E. If R is much less then X_C, then we may write the expression for e_r as

$$e_r = \frac{RE}{X_C} = RE(j\omega \mathrm{C}) \qquad \textbf{[27.14]}$$

Voltage e_m, on the other hand, is due to mutual inductance, and is expressed by

$$e_m = I(j\ \omega) \pm M \qquad \textbf{[27.15]}$$

We now have the expression for both factors that contribute to the total voltage e. We know that:

$$e = e_r + e_m \qquad \textbf{[27.16]}$$

so, by substitution,

$$e = j\omega M\left[\left(\frac{E}{Z_o}\right) \pm I\right] \qquad \textbf{[27.17]}$$

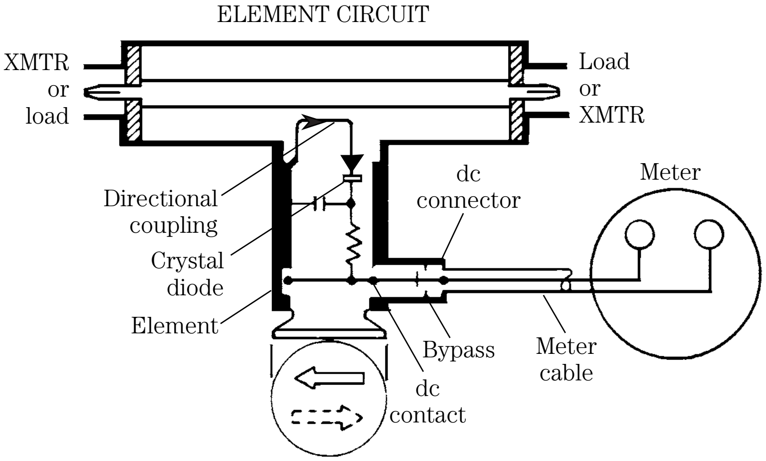
ELEMENT CIRCUIT
XMTR or load
Load or XMTR
Directional coupling
Crystal diode
Element
dc connector
Meter
Bypass
Meter cable
dc contact

27-19A Thruline sensor circuit.

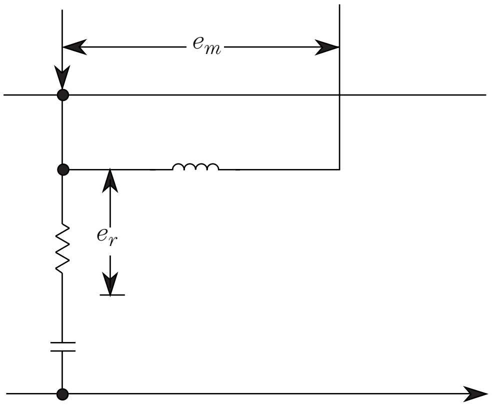

27-19B Circuit of pick-up element in a Model 43 wattmeter.

At any given point in a transmission line, E is the sum of the forward (E_f) and reflected (E_r) voltages, and the line current is equal to

$$I = \frac{E_f}{Z_o} - \frac{E_r}{Z_o} \qquad \textbf{[27.18]}$$

where Z_o is the transmission line impedance.

We may specify e in the forms

$$e = \frac{j\,\omega\,M(2E_f)}{Z_o} \qquad \textbf{[27.19]}$$

and

$$e = \frac{j\,\omega\,M(2E_r)}{Z_o} \qquad \textbf{[27.20]}$$

The output voltage e of the coupler, then, is proportional to the mutual inductance and frequency (by virtue of $j\omega M$). But the manufacturer terminates R in a capacitive reactance, so the frequency dependence is lessened (see Fig. 27-19C). Each element is custom-calibrated, therefore, for a specific frequency and power range. Beyond the specified range for any given element, however, performance is not guaranteed. There are a large number of elements available that cover most commercial applications. The Thruline meter is not a VSWR meter, but rather a power meter. VSWR can be determined from the formula, or by using the nomographs in Fig. 27-20. Some of the Thruline series intended for very high power (Fig. 27-19D) applications use an in-line coaxial cable coupler (for broadcast-style hardline) and a remote indicator.

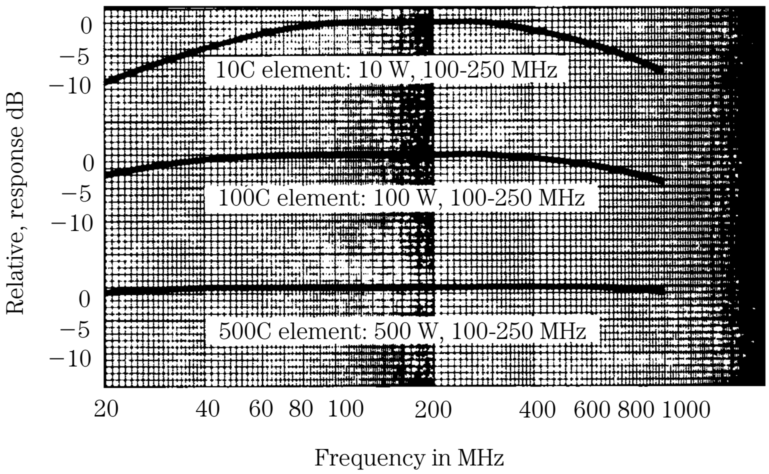

27-19C Power-frequency calibration.

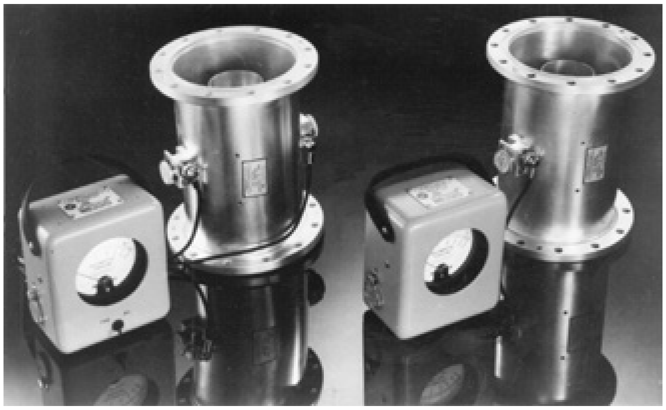

27-19D High-power RF wattmeters.

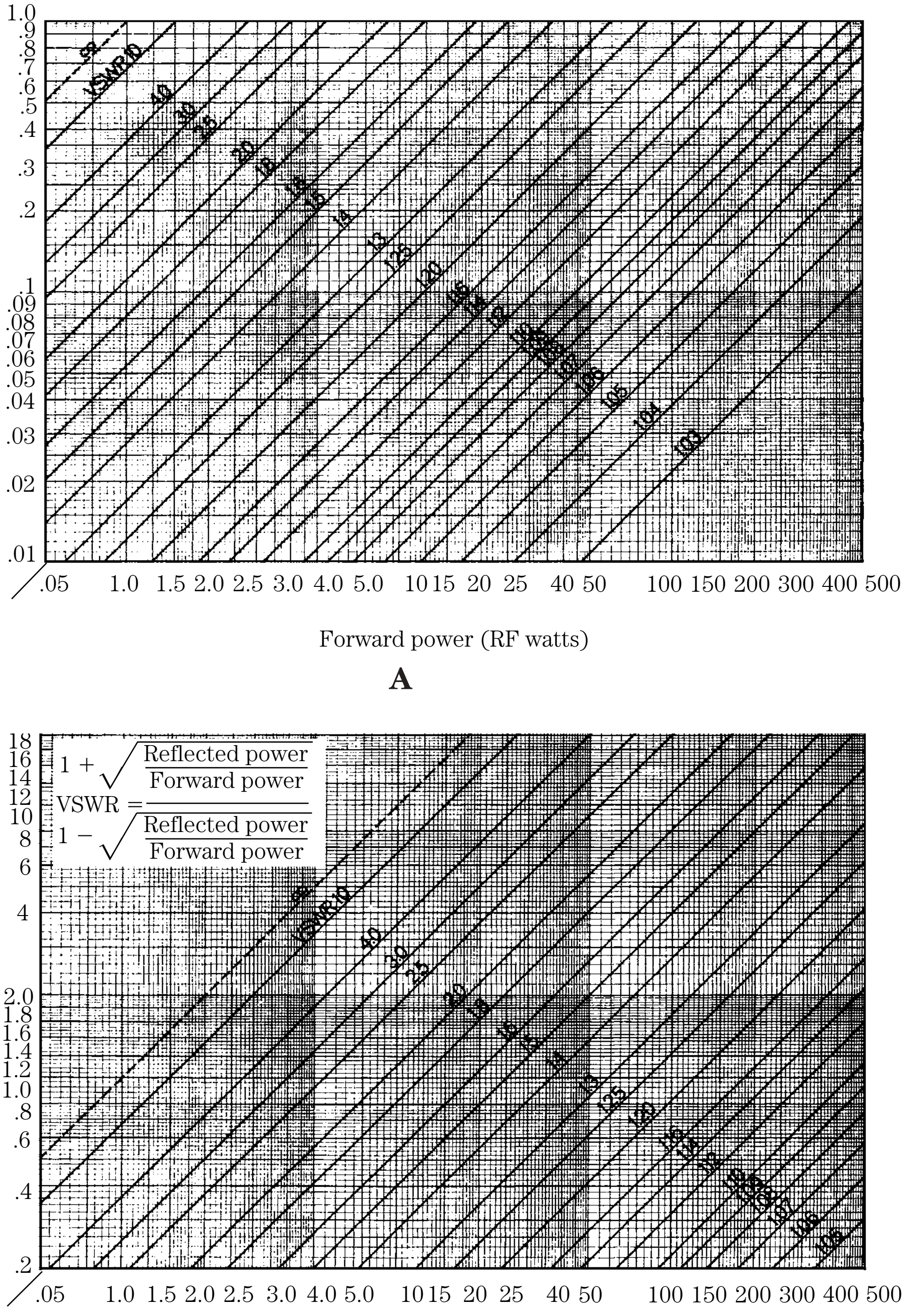

27-20 Forward versus reflected power graphs.

Dummy loads

A *dummy load* is a substitute antenna for making measurements and tests. In fact, British radio engineers often refer to dummy loads as “artificial aerials.” There are several uses for these devices. Radio operators should use dummy loads to tune up on crowded channels and (only then) transfer to the live antenna.

The other use is in troubleshooting antenna systems. Suppose we have a system in which the VSWR is high enough to affect the operation of the transmitter. You can disconnect each successive element and connect the dummy load to its output. If the VSWR goes down to the normal range, then the difficulty is downstream (i.e., toward the antenna). You will eventually find the bad element (which is usually the antenna itself).

Figure 27-21 shows the most elementary form of dummy load, which consists of one or more resistors connected in parallel, series, or series-parallel so that the total resistance is equal to the desired load impedance. The power dissipation is the sum of the individual power dissipations. *It is essential that noninductive resistors be used for this application.* For this reason, carbon-composition or metal-film resistors are used. For very low frequency work, it is permissible to use special counter wound wire low-inductance resistors. These resistors, however, cannot be used over a few hundred kilohertz.

Several commercial dummy loads are shown in Figs. 27-22 through 27-24. The load in Fig. 27-22A is a 5-W model, and is typically used in Citizens Band servicing. The resistor is mounted directly on a PL-259 coaxial connector. These loads typically work to about 300 MHz, although many are not really useful over about 150 MHz. A higher-power version of the same type is shown in Fig. 27-22B. This device works to the low VHF region, and dissipates up to 50 W. I have used this dummy load for servicing high-VHF land mobile rigs, VHF-FM marine rigs, and low-VHF land mobile rigs. Very high power loads are shown in Fig. 27-23. These devices are *Bird Electronics* “coaxial resistors,” and operate to power levels up to 10, 30, and 40 kW. These high-power loads are cooled by flowing water through the body of the resistor and then exhausting the heat in an air-cooled radiator.

Our final dummy load resistor is shown in Fig. 27-24. The actual resistor is shown in Fig. 27-24A, and a schematic view is shown in Fig. 27-24B. The long, high-power noninductive resistor element is rated at 50 **Ω**, and can dissipate 1000 W for

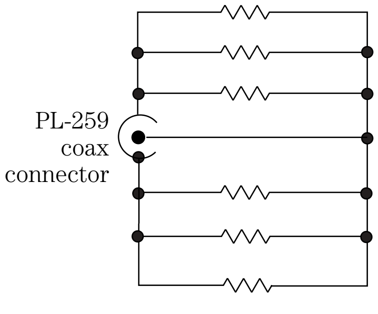

27-21 A very basic dummy load.

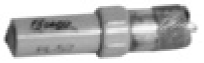

27-22A CB-style 5-W dummy load.

27-22B 15-W dummy load.

WATTS
X1
X10
BLACK SCALE
RED SCALE

27-23 Termaline RF wattmeter.

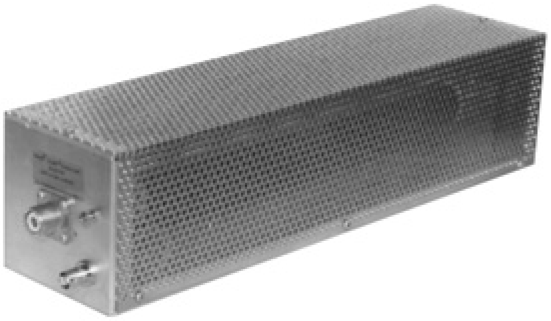

27-24A Drake DL-1000 dummy load.

several minutes. If longer times, or higher powers, are anticipated, then forced air cooling is applied by adding a blower to one end of the cage. The device is modified by adding the BNC sampling jack. This jack is connected internally to either a two-turn loop, made of no.22 insulated hookup wire, or brass rods that are positioned alongside the resistor element. It will therefore pick up a sample of the signal so that it can be viewed on an oscilloscope, or used for other instrumentation purposes.

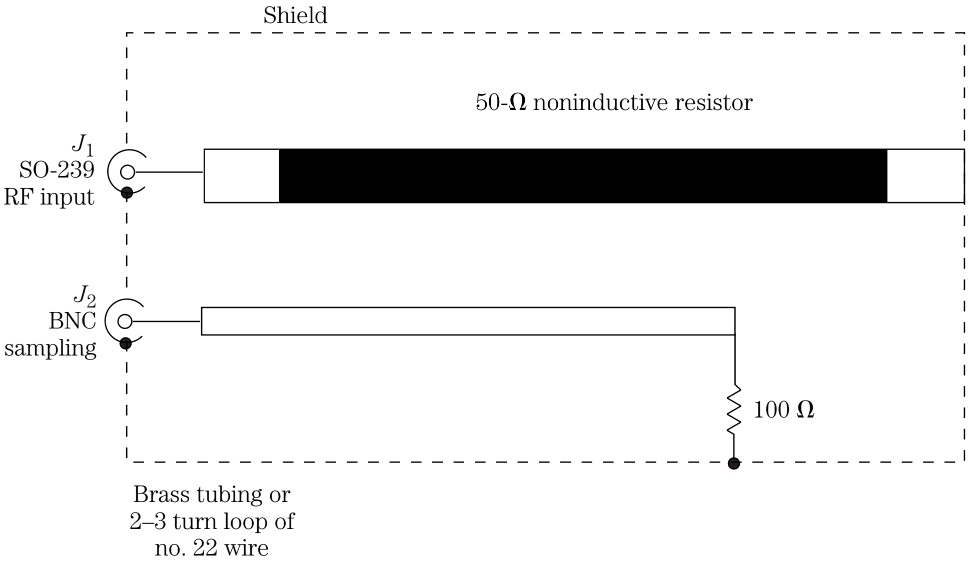
Shield
50-Ω noninductive resistor
J_1
SO-239
RF input
J_2
BNC
sampling
100 Ω
Brass tubing or
2–3 turn loop of
no. 22 wire

27-24B HF dummy load with pickup loop.

28
CHAPTER

General antenna mechanical construction techniques

ANTENNA INSTALLATION CHORES VARY IN COMPLEXITY FROM THE SIMPLE, WHICH A teenager, with no assistance, can execute properly and safely, all the way up to large-scale projects that are best left to professional antenna riggers. If your only antenna installation chore is a dipole handing between the peak of your house roof and a nearby tree, then little need be said besides "Be careful."

The purpose of this chapter is to cover both wire and intermediate installation jobs that can be done by amateurs if instructed properly. Keep in mind when planning an installation, however, that the information given herein is merely informal guidance. Always have your plans reviewed by a professional mechanical or structural engineer licensed to practice in your state. In many locales, there are good insurance reasons for this step. Also, learn and abide by local mechanical, electrical, and building codes. It is simply not worth the pain, and risk, to skirt around local laws.

Antenna erection safety

Before dealing with the radio and performance issues, let's deal first with a few antenna safety matters. You do not want to be hurt either during installation or during the next wind storm. Two problems present themselves: *reliable mechanical installation* and *electrical safety.*

Radio antennas are inherently dangerous to erect if certain precautions are not followed. It is not possible to foresee all the situations you might face in erecting an antenna. I would like to give you all possible warnings, but this is not even possible. You are on your own and must take responsibility for installing your own antenna. I can, however, give you some general safety guidelines. Knowledge of what you face and some hard-nosed, sound judgment, modulated by a little bit of common sense are the best tools on any antenna job.

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One rule that is an absolute is that no antenna should *ever* be erected where the antenna, the feedline, or any part thereof crosses over or under a power line or pole transformer—*ever*! This is a "no kidder"—don't do it. Every year we read sad news in magazines or newspapers about a colleague being electrocuted while installing or working on an antenna. In all these tragic cases, the antenna somehow came into contact with an ac power line. Keep in mind one dictum and make it an absolute:

There is never a time or situation when it is safe to let an antenna contact the electrical power lines!

This advice includes dipoles and other long wire antennas "thrown over" supposedly insulated lines, as well as antennas built from aluminum tubing. The excuse that the power lines are insulated is hogwash. Old insulation crumbles on contact with even a thin wire antenna. *Don't do it*! The operant word is *never*!

Power lines look insulated, but there are often small breaks or weakened spots (especially more than a couple days after installation) that can bring the antenna into contact—lethal contact—with a "hot" power line. Every year or so we hear about an SWL, scanner/monitor buff, or ham operator being *killed* by tossing an antenna wire over a power line. Avoid making yourself into a high-powered resistor—it might blow your "life fuse."

And the same rule applies to situations where the antenna can fall onto a power line if it fails mechanically. You have to examine the situation to see if there is any possible way for that antenna or its support structure to fall onto a power line if it breaks in any way whatsoever. Figure 28-1 is a diagram of my lot in Virginia. A 23-ft mast is erected at the back of the house, and its 23-ft "fall radius" is plotted. It should not intersect either the power lines or the cable TV line, even when it fails and is wind-whipped.

Note that the antenna could fall over the property line onto the next lot to the rear. After consultation with the other landowner and the county mechanical inspector, it was determined that my rear fence is sufficient protection for the other homeowner. Because it is technically on my land, the fence damage is my responsibility. However, should the other homeowner change his mind or a new homeowner buys the place, then my antenna may have to be moved.

Another caution is that you must be physically fit to do the work. While the on-the-ground portion of the work is usually not too strenuous, any climbing at all, even on ladders, can be taxing. Antenna materials are deceptively lightweight on the ground, but when you get up on even a small ladder, they are remarkably difficult to handle. Attempting to manhandle a 22-ft vertical once wiped my back out to the extent that I needed 800-mg of ibuprofen three times a day for about a week—and I consider myself lucky that the pain hit me after I had dismounted the ladder. Besides, if you could see me, you would wonder why a man my size was on any ladder in the first place!

Before using a ladder, learn how to use a ladder. A lot of homeowners, whether putting up antennas or painting the upstairs windows, fall off ladders that were being used incorrectly. There is a right way and a wrong way to use each of the different types of ladder; learn to use them correctly.

If the wind blows even a few kilometers per hour, the danger is magnified considerably. I recall a friend, who is a large, strong "bear of a man," attempting to install

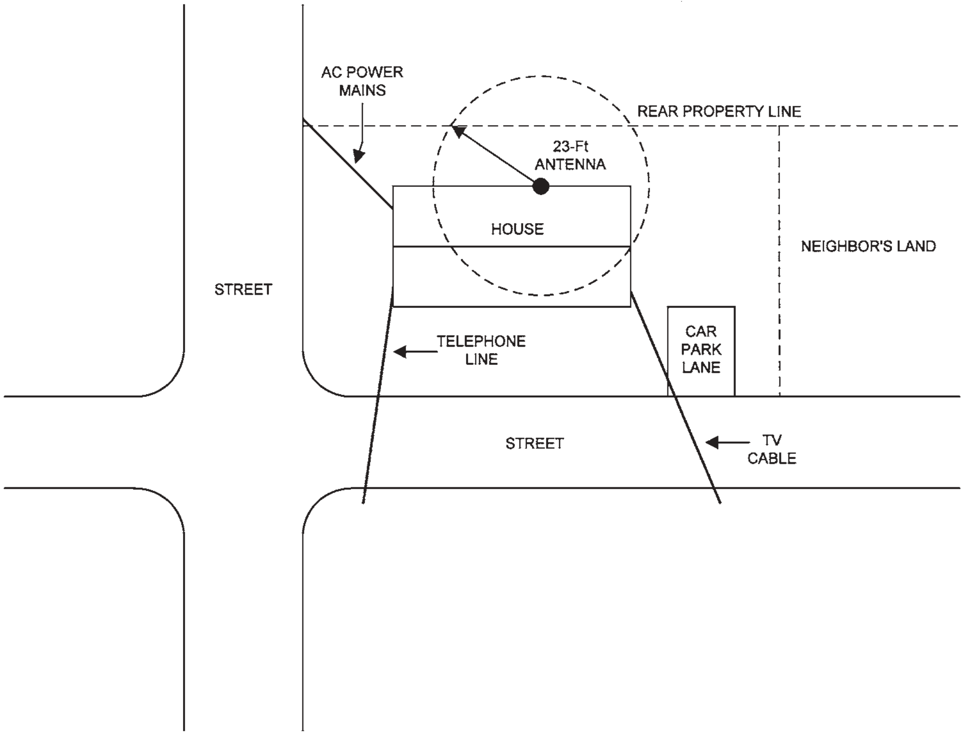

28-1 Antenna installation on suburban lot.

a 26-element television "all channel" rotatable antenna on the roof of his two-story beach house. He wanted to be able to pick up Richmond, VA; Norfolk, VA; Washington, DC; and Baltimore, MD, on television, plus scanner bands, from his beach house on the Chesapeake Bay. The antenna was handled easily with one hand on the ground and with no wind blowing. But up on the roof, it was a different story! "Big Al" was on the peak of the roof when an off-shore gust of wind came up suddenly and caught the antenna. It acted like a hang glider and pulled Al off the roof, plunging him down two stories to the patio below. He fractured his pelvis and busted a leg. Two months of orthopedic casts and a year of physical therapy followed—not to mention lost wages. Expensive TV antenna, I reckon. *Be careful*!

One good rule is to always work under the "buddy system." Ask as many friends as are needed to do the job safely, and always have at least one assistant, even when you think you can do it alone.

Always use quality materials and good work practices. Antennas, being potentially dangerous, always should have the best of both materials and workmanship in order to keep quality high. It is not just the electrical or radio reception workings that are important but also the ability to stay up in the air and be safe.

When planning an antenna job, keep in mind that pedestrian traffic in your yard possibly could affect the antenna system. Wires are difficult to see, and if an antenna wire is low enough to intersect someone's body, then it is possible to cause very serious injuries to passersby. In the United States, even when the person is a trespasser (or even a burglar!), the courts may hold a homeowner liable for injuries caused by an inappropriately designed and installed antenna. Take care for safety not only of yourself but also of others.

Consider a typical scenario involving a four- or five-band trap vertical antenna (Fig. 28-2). It will be 18 to 26 ft tall, judging from the advertisements in magazines, and will be mounted on a roof or mast 12 to 30 ft off the ground. Consider the case of a 25-ft-tall trap vertical installed atop a 15-ft-high telescoping TV antenna mast. The total height above ground will be the sum of the two heights: 15 ft + 25 ft = 40 ft. The tip of the vertical is 40-ft above ground level. You must select a location at which a 40-ft aluminum pole can fit—and fall. This requirement limits the selection of locations for the antenna. If this is done, then a wind storm cannot result in a shorted or downed power line if the antenna falls over.

When installing a vertical antenna, especially one that is not ground-mounted, make sure that you have help. It takes at least two people to safely install a standard HF vertical antenna, and more may be needed for especially large models. If you are alone, then go find some friends to lend an arm or two. Wrenched backs, smashed antennas, crunched house parts, and other calamities simply do not happen as often on a well-organized work party that has sufficient hands to do the job safely.

The second issue pertaining to installing antennas is old-fashioned mechanical integrity. Two problems are often seen. First, you must comply with local building

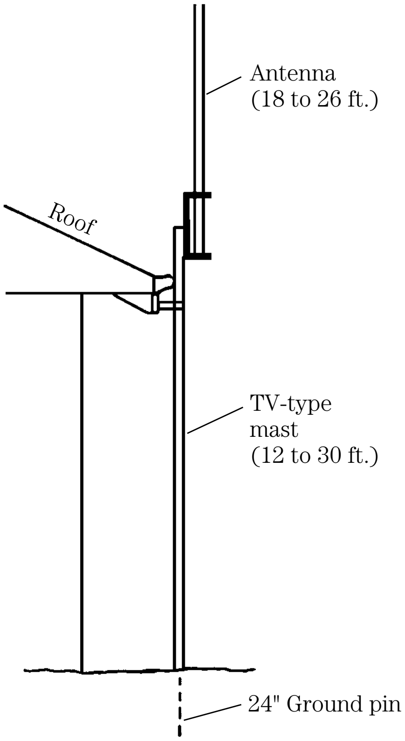

28-2 Mast-mounted vertical antenna.

codes, regulations, and inspections. The local government has a reasonable interest and absolute right to impose reasonable engineering standards on the electrical and mechanical installation of radio antennas. The second issue is that it is in your own best interest to make the installation as good as possible. Consider the local regulations as the minimum acceptable standard, not the maximum.

Both these mechanical integrity issues become extremely important if a problem develops. For example, suppose that a wind or snow storm wrecks the antenna, plus part of your house. Your insurance company may not pay off if your local government requires an inspection and you failed to get one. Make sure that the mechanical and/or electrical inspector (as required by the law) leaves a certificate or receipt proving that the final inspection was done. It could come in handy when disputing the insurance company over damage.

A quality installation starts with the selection of good hardware for the installation. Any radio-TV parts distributor who sells TV antenna hardware will have what you need in most cases. I used Radio Shack standoff brackets, ground pin, and a 19-ft telescoping mast in one installation. Wherever you buy, select the best-quality, strongest materials that you can find. Opt for steel masts and brackets over aluminum, no matter what the salesperson behind the counter tells you. Keep in mind that although salespeople can be knowledgeable and even helpful, you, not they, are responsible for the integrity of the installation.

Local government One necessary reminder is that your local government might have some interesting ideas—legal requirements, actually—concerning your antenna installation. The electrical, mechanical, and zoning codes must be observed. There is a great deal of similarity between local codes because most of them are adaptations (even adoptions) from certain national standards. But there are enough differences that one needs to consult local authorities. Indeed, you may need a license or building permit to install an antenna in the first place.

One problem that SWLs and scanner/monitor buffs face in the United States is that their antennas are not protected by the Federal Communications Commission, as are ham antennas. Local governments have limited rights to regulate ham antennas—only "reasonable" mechanical and electrical standards can be imposed. It may be illegal for you to install any type of antenna.

Save all paperwork regarding your building permit, including the inspection certificates, decals, letters or papers, and the original drawings (with the local building inspector's stamps). If a casualty occurs, then your insurance company may elect not to pay off if you have violated an electrical, mechanical, building, or zoning code. This advice may be overlooked by an enthusiastic antenna builder, but it could prove to be a costly oversight if something bad happens.

In some jurisdictions, there might be another limitation on antenna location. Some local governments have a requirement that the antenna be able to fall over and land entirely on your own property. About 30 years ago, a Maryland county required that antennas be installed double their own length plus 50 ft from the nearest property line—until a local ham radio club sued on grounds that about 99.99 percent of the rooftop TV antennas in the county were noncompliant. In one humorous scene, a group of amateur radio operators went down to the county offices and asked for about 50,000 complaint forms. They filled out several thousand against homeowners with TV antennas before they were stopped by the county officer. Before installing any antenna, check with the local building codes!

Wire antenna construction

Volumes have been written on wire antennas. Indeed, many of my antenna books spend a lot of space on the topic. What seems to be missing in many books is details on the mechanical aspects of wire antenna construction and installation. Although some books cover the mechanical details, much is often missing. Let's take a look at some of the basics.

The basic wire antenna

Wire antennas come in a bewildering variety of forms, but for our purposes, the "standard model" is our old friend the half-wavelength horizontal dipole (Fig. 28-3). The overall length (A) in meters is found from $144/F_{\mathrm{MHz}}$. Each element (B) is one-half the overall length, or $72/F_{\mathrm{MHz}}$. The antenna's nominal feedpoint impedance at resonance is 73 Ω, so it is a good match to standard 75-Ω coaxial cable. It is common practice to use a 1:1 balun transformer at the feedpoint in order to balance currents and keep the pattern according to textbook predictions.

Center insulators

It was once common (but poor) practice to strip a few centimeters of coaxial cable, part the braid and center conductor, and connect them to each side of the dipole. We could then wonder why the darn thing fell down in the next wind storm. Even if you elect to not use the balun transformer, a ready-made center insulator is a must. Figure 28-4A shows a common form of center insulator for use with dipoles and other wire antennas. There is an SO-239 UHF coaxial connector on the bottom to accept the feedline and two eyebolts mounted with solder connectors for the antenna elements on the sidewalls. At the top is a small eyebolt that is used to strain-relieve the system, or to hang it from a center support (as when inverted-V dipoles are built).

A larger form of center insulator is shown in Fig. 28-4B. The enlarged down section indicates that this device contains either a 4:1 or 1:1 impedance ratio balun

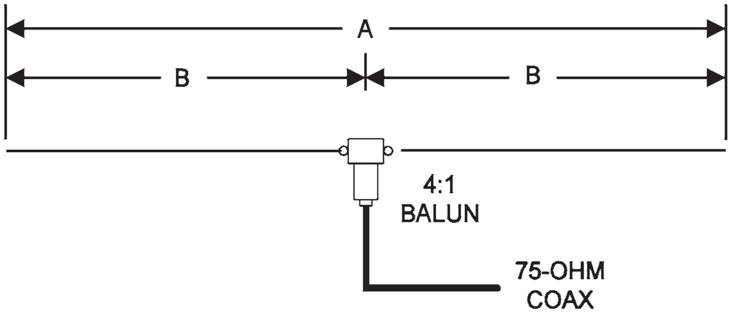

28-3 Dipole antenna.

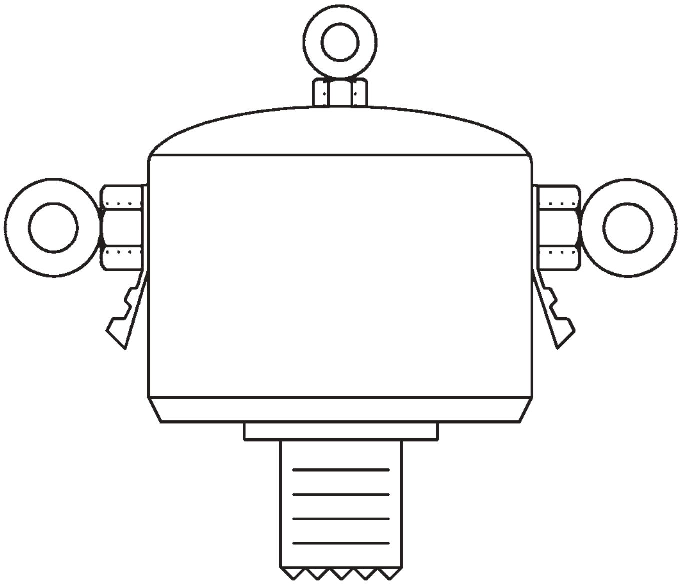

28-4A Center insulator.

transformer. The 1:1 size is recommended for ordinary dipoles, whereas a 4:1 unit is used for folded dipoles and certain other wire antennas.

Connections to the device, whether straight center insulator or balun form, are shown in Fig. 28-5. For simplicity, only one side is shown (the other side is identical). The elements (*B* in Fig. 28-3) typically are made of no. 12 or no. 14 antenna wire. The best wire is stranded and is copper-clad steel core wire (Copperweld).

The end of the antenna wire is passed through the eyebolt and then doubled back and twisted onto itself 7 to 10 times. The remainder of the wire is then soldered to the terminal. Some people prefer to use a separate “pigtail” wire to connect the antenna element to the solder terminal. It is fastened to the antenna element wire between the 7- to 10-turn twist and the eyebolt.

When preparing the center connector/balun, it is good practice to use steel wool or sandpaper on the solder lug to remove oxidation. Oxidation makes it hard to solder and forces you to use too much heat to make a good connection. Also, be sure to have a large pair of pliers to crimp the wings of the solder lugs onto the wire.

Solder assists in making a good connection at the solder lugs, but the crimp should be good enough to do the job. The solder then provides corrosion protection. Also, tin the 7- to 10-turn twist section with solder. This does not increase the strength or provide better electrical connection—it is protection against the corrosion that will occur with copper wires.

Note Use only resin-core solder for antennas! Typical solder is 50/50 or 60/40 lead/tin ratio and may be labeled “radio-TV” or “electronic” or something similar. Plumber’s solder is acid core and will destroy your antenna within a short time after it is erected.

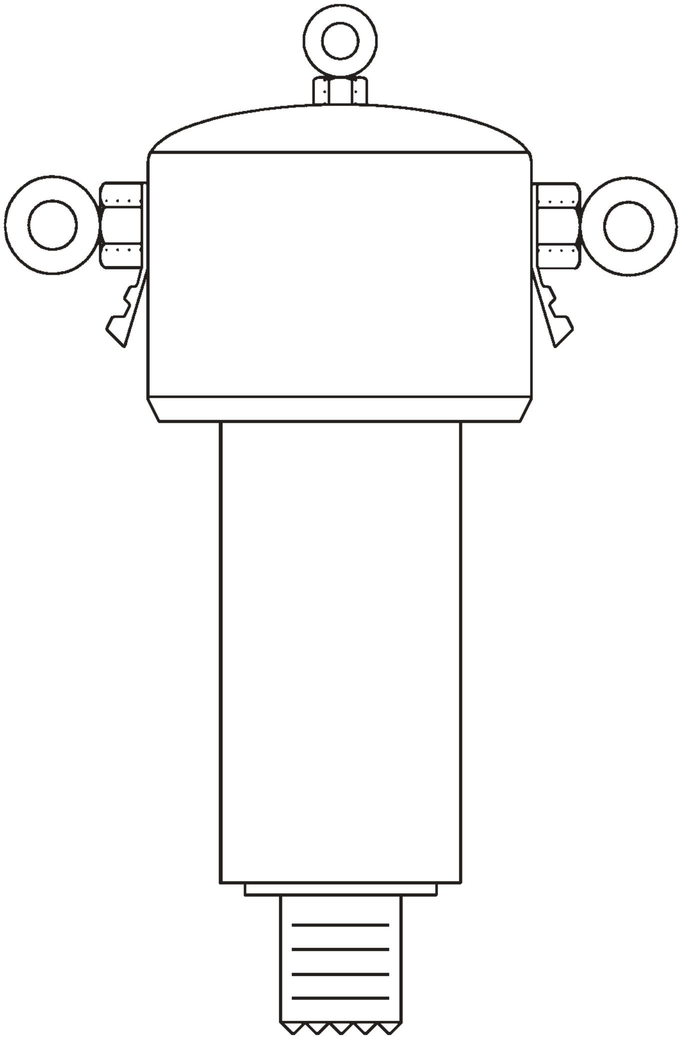

28-4B Balun/center insulator.

Figure 28-6 shows the dipole installed. The ends of the two wire elements are connected to end insulators, which are in turn supported by rope to a vertical support (e.g., mast, tree, roof line of the house, etc.). Although shown nice and straight here, the actual installation will droop a bit in the center due to the weights of the center insulator or balun, the coaxial cable, and the wire itself. Gravity!

Note that the coaxial cable is formed into a 15- to 25-cm loop just below the coaxial connector to the center insulator or balun. This forms a species of RF choke to keep currents from flowing in the outer shield and improves the pattern. The coaxial cable loop is bound together with black electrician's tape or some similar adhesive medium and then fastened to the top eyelet with stout string or fishing line for strain relief.

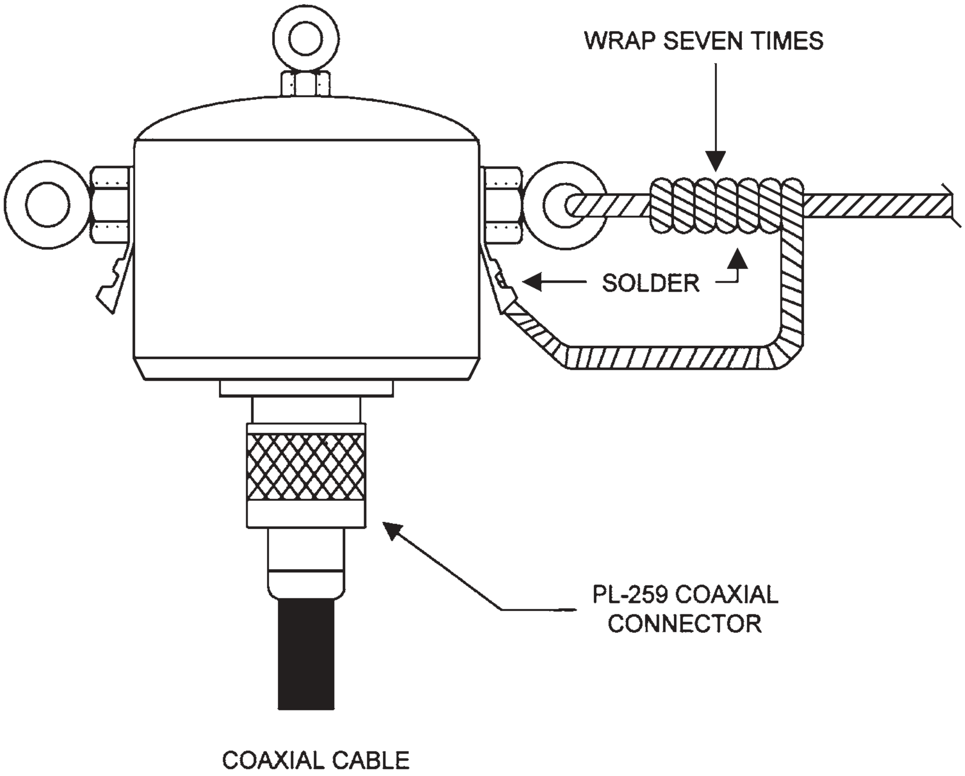

28-5 Center insulator/balun connections.

Support rope

The support rope selected should be large enough to provide support but small enough to fit through the holes of the end insulators. Cotton rope is singularly unsuited to this task because it weathers poorly and will rot through in short order. Nylon rope, sail rope, and parachute rope are perhaps the best types, especially if a particular lot has been tested for high tensile strength. Remember, the wind loading of your antenna, even a short dipole, can be tremendous!

End insulators

End insulators come in a large variety of shapes and sizes (I have even seen one chap use old toothbrushes, suitably drilled, of course). The main categories, however, are represented in Fig. 28-7. The version in Fig. 28-7A is the standard form, whereas that in Fig. 28-7B is an “egg” insulator. The egg insulator has two sets of wire grooves and through-holes that are orthogonal to each other (only one set is shown). Wire passes through one hold and set of grooves, and the supporting rope passes through the other hole/groove set.

The standard form shown in Fig. 28-7A has a number of grooves or ridges cut along the body. These grooves are intended to lengthen the electrical path between

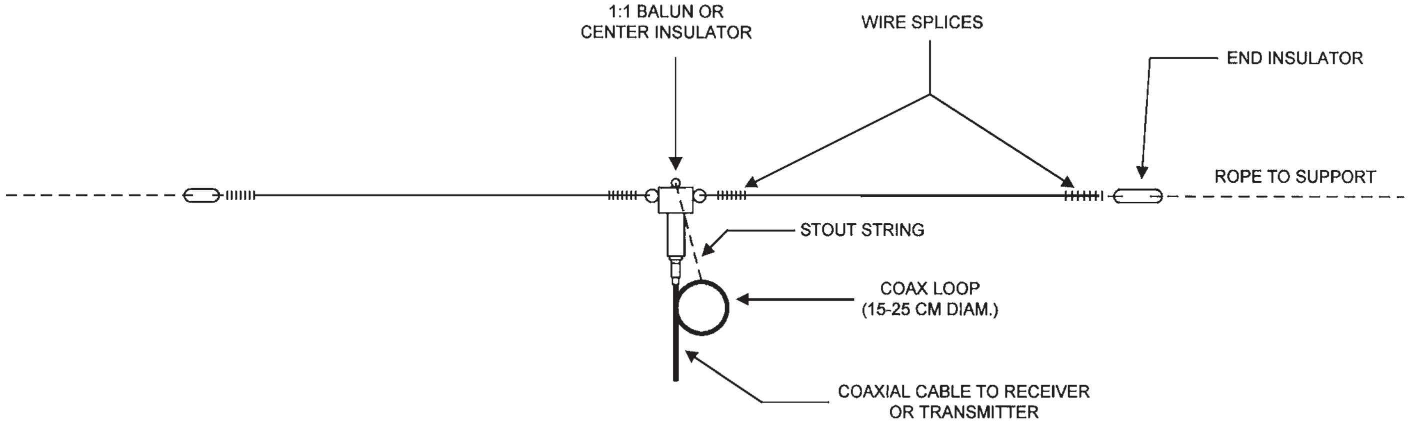
1:1 BALUN OR CENTER INSULATOR
WIRE SPLICES
END INSULATOR
ROPE TO SUPPORT
STOUT STRING
COAX LOOP (15-25 CM DIAM.)
COAXIAL CABLE TO RECEIVER OR TRANSMITTER

28-6 Dipole and wire antenna installation.

ends of the insulator and therefore serve to reduce losses in the insulator. Typical materials used to construct insulators include ceramic, glass, nylon, and plastics.

Figure 28-8 shows the connections to the end insulator. The electrical connections to the antenna wire are the same as for the center insulator. The only proviso here is that for transmitting antennas, it is wise not to leave any sharp points sticking up. The end of the dipole is at high RF voltages, so sharp points tend to cause corona sparking. Cut off any extraneous leads that form sharp points, and then smooth the whole affair down with tinning (i.e., solder).

The rope is treated in a similar manner as the wire, but it must be knotted in some manner that tends to pull together as the rope is pulled into tension. Some people use the "hangman's knot," but this seems a bit excessive.

Strain relief of the antenna

Figure 28-9 shows a method of strain relief for the center insulator or balun. This point is at the highest tension and probably is the weakest because of the number of

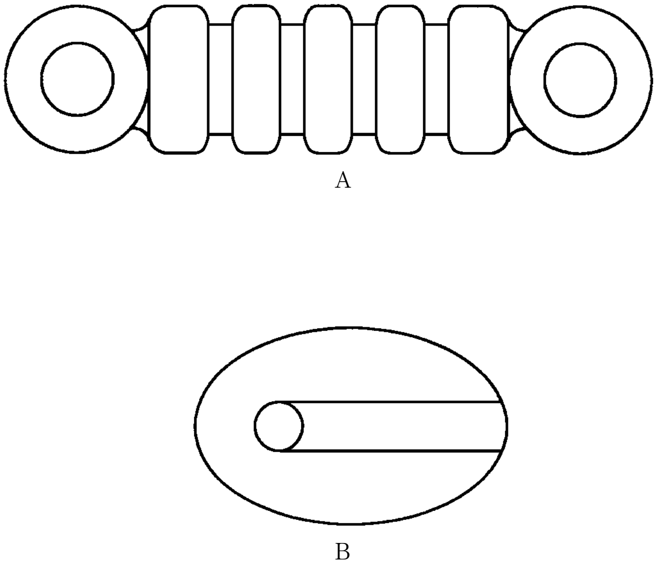

28-7 End insulators.

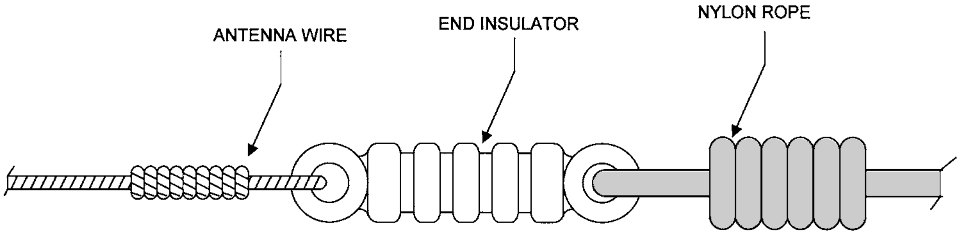

28-8 Connections to end insulators.

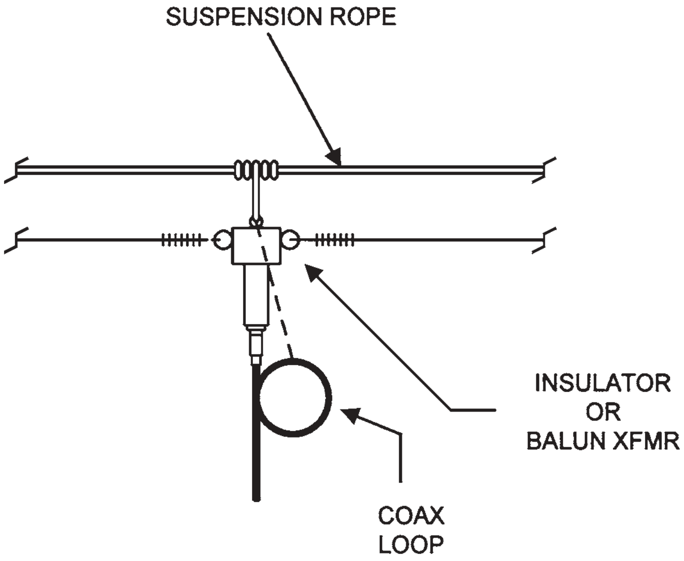

28-9 Strain relieving the center insulator or balun.

connections and things that can break. A suspension rope is run between the antenna's vertical supports, parallel to the antenna wire. It is tied to the top eyelet on the center insulator or balun by a short bit of rope about 15 to 20 cm long.

Special case of the folded dipole

The folded dipole (Fig. 28-10) is a special case of the half-wavelength horizontal dipole. It consists of two close-spaced conductors shorted together on the extreme ends. One of the conductors is split in the center and used as the feedpoint. The feedpoint impedance at resonance is around 280 Ω, so it makes a good match to 300-Ω television antenna twin lead. The usual practice is to build the entire antenna and feedline out of twin lead. An alternative (as shown in Fig. 28-10) is to provide a 4:1 balun transformer at the feedpoint to match 75-Ω coaxial cable. Despite the fact that 300-Ω TV twin lead is disappearing from the market, the folded dipole maintains a certain following among SWLs and hams.

The problem is how to install the antenna such that the terribly weak 300-Ω twin lead wires do not break at the slightest provocation. Figure 28-11 shows a solution used by one fellow (admittedly a fine worker in plastics and other materials). He fashioned a center insulator and the end insulators from a piece of strong Lucite material.

The 300-Ω TV twin lead is prepared as shown in Fig. 28-11A. The antenna element is notched in the center (break along the bottom) for about 1 to 1.5 cm. A hand punch is used to place two or three holes in the center insulation on either side of the break. Either a large-size leather punch or a paper punch can be used to make

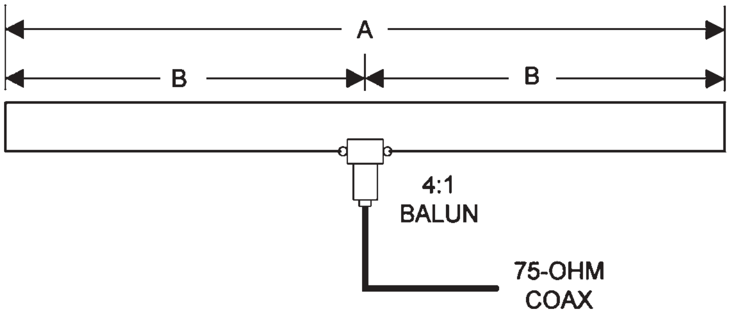
A
B
B
4:1
BALUN
75-OHM
COAX

28-10 Folded dipole.

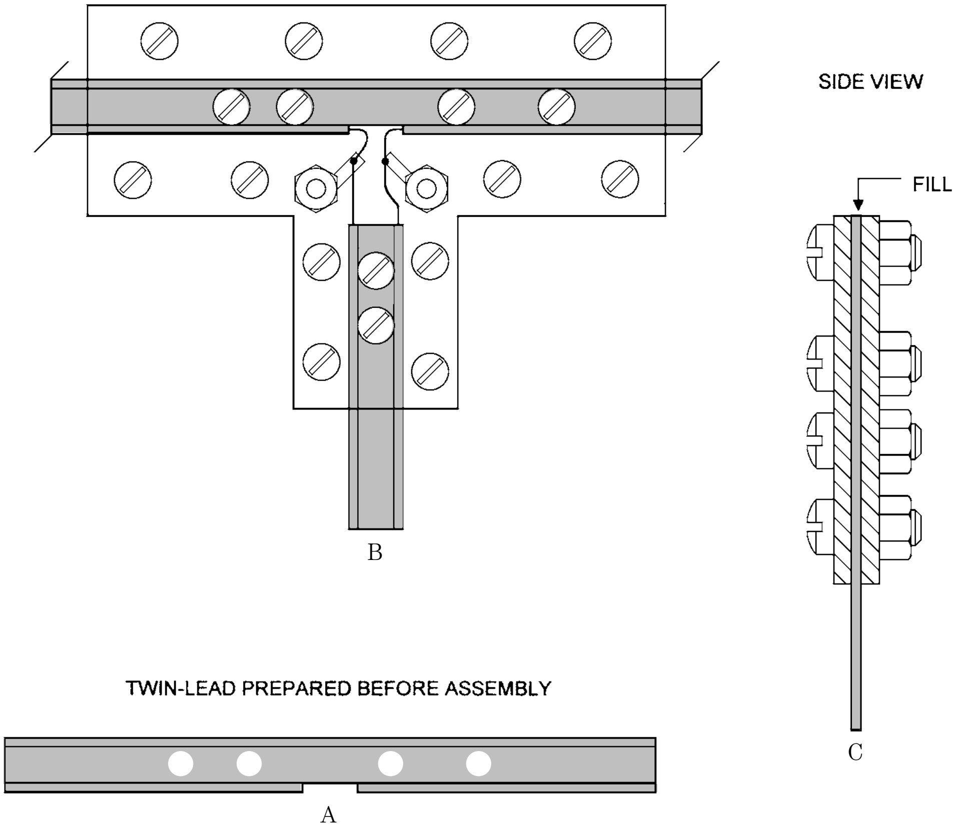
SIDE VIEW
FILL
B
C
TWIN-LEAD PREPARED BEFORE ASSEMBLY
A

28-11 Center insulator for ribbon cable folded dipole: (A) cable preparation, (B) front/back view, (C) edge view.

the holes. In a test, I was able to make the required holes using a hand-operated paper punch, but it required a large force (and turned my hand temporarily purple!).

The center insulator is shown in Fig. 28-11B. It is made from a piece of strong plastic, Lucite, or other insulating material. Two identical sections, front and back, are needed. A number of 5-mm holes are drilled into both pieces at the points shown to clamp the twin lead. A pair of solder lugs is provided to make connections between the antenna element and the transmission line (either twin lead or leads from a balun). The screws and nuts used to fasten the two halves of the insulator are made of nylon to prevent interaction with the antenna.

A side view is shown in Fig. 28-11C. Note that the twin lead causes a gap that can catch water. It also makes it possible to break one or both insulators by overtightening the nuts. In order to prevent this, a gasket of similar material is glued into the space as filler. The gasket material should be about as thick as the twin lead.

If you opt for a balun transformer, then it can be wired to the downleg of the tee insulator using the holes that normally would clamp the twin-lead transmission line.

An end insulator for twin-lead antennas is shown in Fig. 28-12. It is constructed in a similar manner to the center insulator. Two scenarios are possible. The first, and that used in a test antenna, is to make the clamping fixture from metal such as 3- to 6-mm brass or copper stock. The ends of the antenna wires are shorted, so this is not a great problem.

An end insulator is then used with a rope in the normal manner. A chain-link section is used to fasten the clamping fixture and the end insulator. I attempted this with a nylon chain link, about 1.5 × 2.5 in, from a do-it-yourself hardware store. It was only with a bit of difficulty that the ends were pulled apart, slipped into both the end insulator and the clamping fixture, and then reclosed.

The second approach is to make the clamping fixture out of the same material as the center insulator. It then becomes the end insulator, so the other end insulator and that cursed chain link can be ignored. If you opt for this approach, it is a good idea to smooth and polish the rope hole on the clamping fixture to prevent chaffing of the rope.

Masts and other supports for wire antennas

The end supports of the antenna can be anything that provides height: a mast, a tree, or the roof line of a building. Figure 28-13 shows the use of a mast, but either of the other forms of support could be used as well. The support rope is not tied off at the

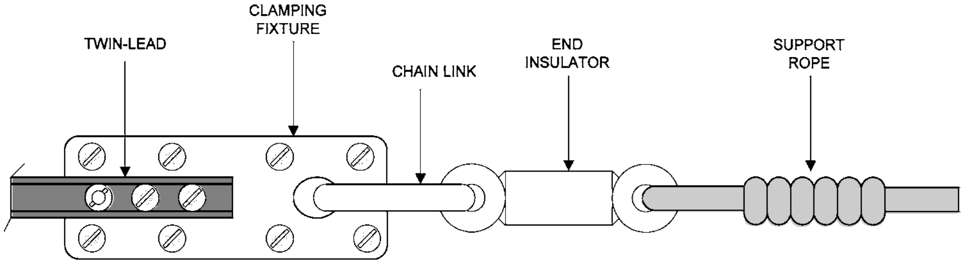

28-12 Folded dipole end insulator.

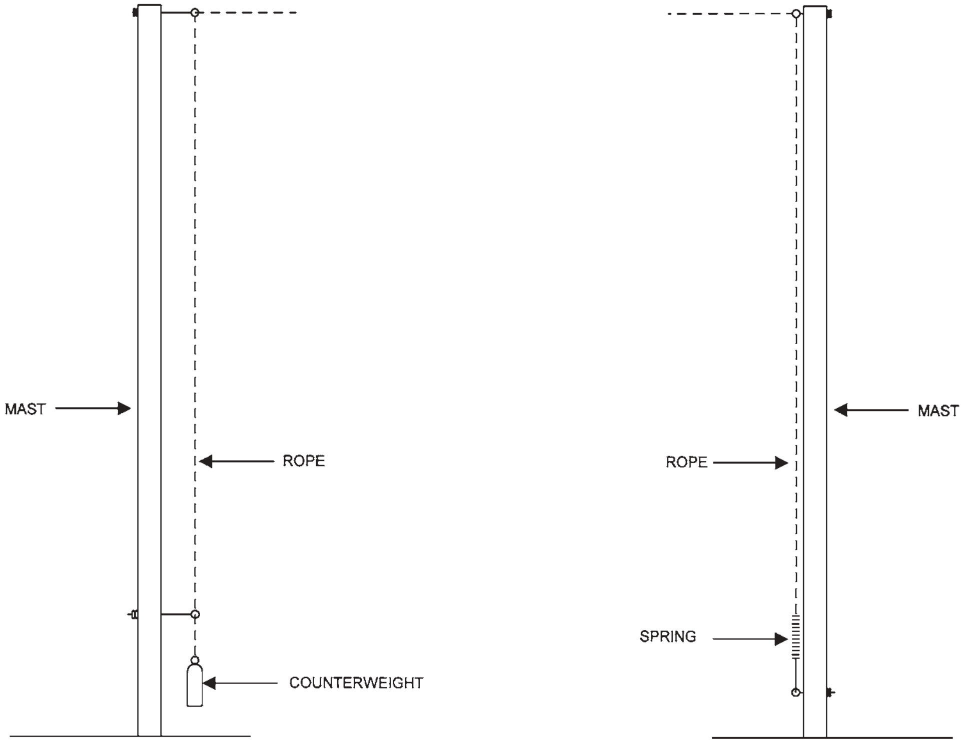

28-13 Mounting mast schemes.

top, as is true in all too many installations, but rather is brought down to ground level. This approach facilitates raising and lowering the antenna for maintenance and tuning. Be sure to provide enough "dead slack" to make lowering the antenna feasible.

The antenna support rope is connected to a spring on one end and a counterweight on the other end. The spring should be stout enough so that it is only slightly extended when the full weight of the antenna places it in tension. I have used door-springs for this task, but only the stoutest varieties.

The counterweight should be just enough to balance the weight of the antenna and keep it not quite taut. As wind moves the antenna up and down, the counterweight raises and lowers, thereby reducing the chances of straining the antenna wires to their limit. Any number of counterweights can be used. I have seen a number of types: drapery cord weights, a small bucket of rocks, a gaggle of fishing weights, and (in one case) a burned-out automobile starter motor (the mounting hole on the front boss of the motor was ideal for accepting the rope).

Figures 28-14A and 28-14B show two methods for making the connections at the top of the mast. Although egg insulators are shown here for the sake of fairness (the alternate form was shown earlier), either form can be used. A pulley is mounted on the top of the mast with a link section and a stout eyebolt that passes through the mount. In the case of a tree, I have used a steel band of the type used to mount TV antennas to house chimneys. By making the down rope a closed loop, you gain the

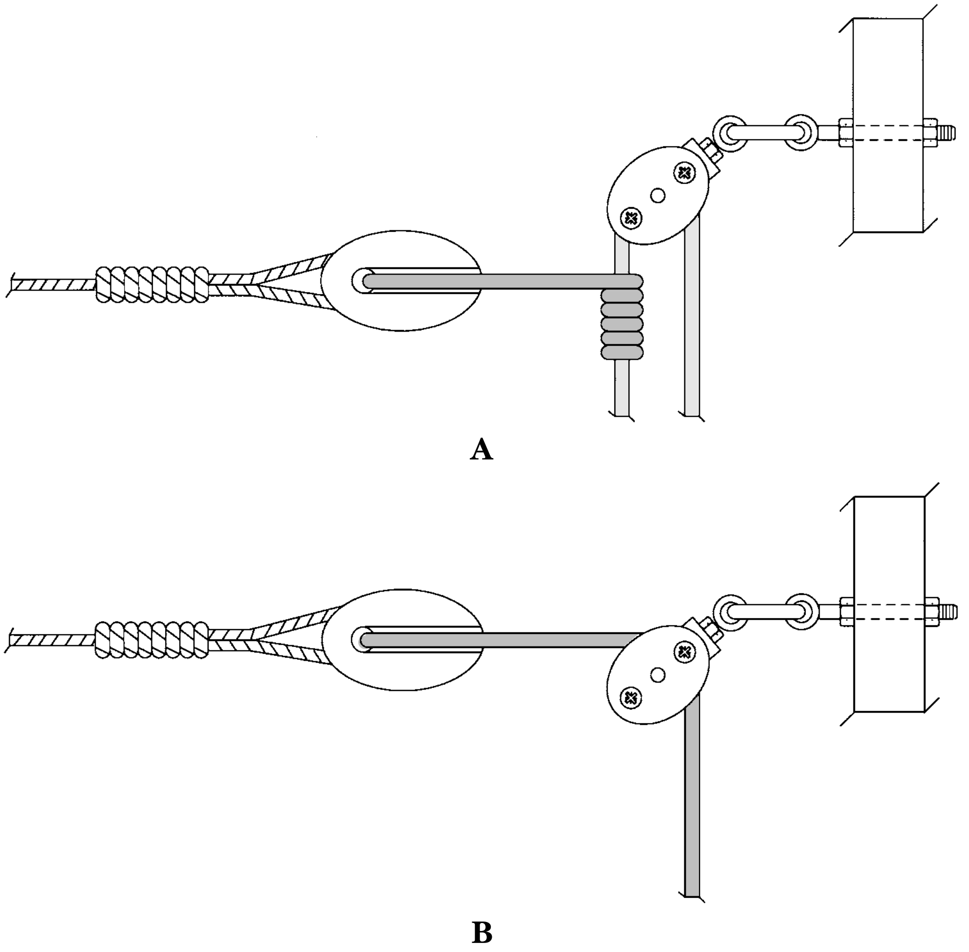

28-14 Two alternate pulley systems for wire antenna mounting.

ability to raise and lower the antenna. But do not let a loose end slip, or you will be chasing the rope up the mast as it slips through the pulley.

Pulleys work nicely, but they are mechanical contraptions that tend to fail occasionally. When they fail, the rope gets stuck. Pulleys also can corrode rather badly, with the same end result. All in all, a pulley is not the best solution for most people.

Figure 28-15 shows a better way. In this approach, a U-bolt is fastened to the top of the support mast. If the U-bolt is made of brass, then all the better, for it will not corrode. The rope can be passed through the U-bolt as in the pulley system but without the mechanical failure problem. Be sure to install the U-bolt all the way up to the threads so that the rope will not chafe against them.

The method shown in Fig. 28-16 can only be used by a horse lover! This method uses a brass stirrup in place of the U-bolt. If you have switched to cars or trucks and no longer need your horse stirrups, then perhaps this is a viable means of attaching the support rope to the top of the mast.

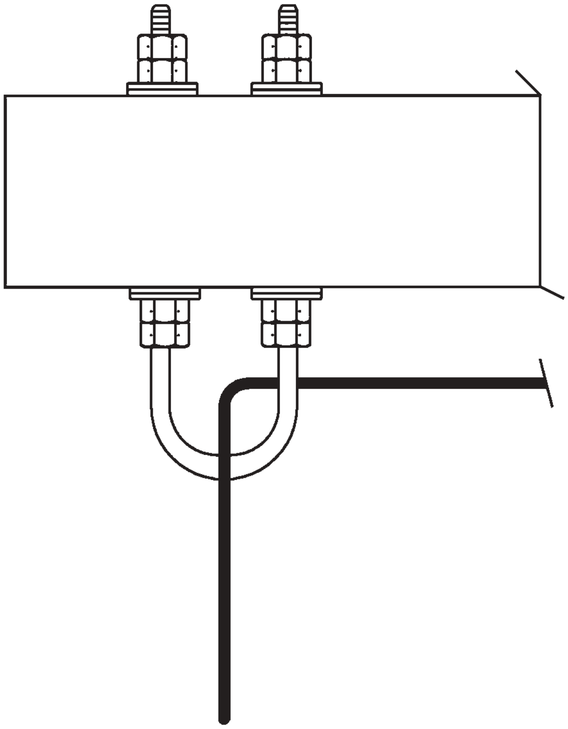

28-15 U-bolt end mounting.

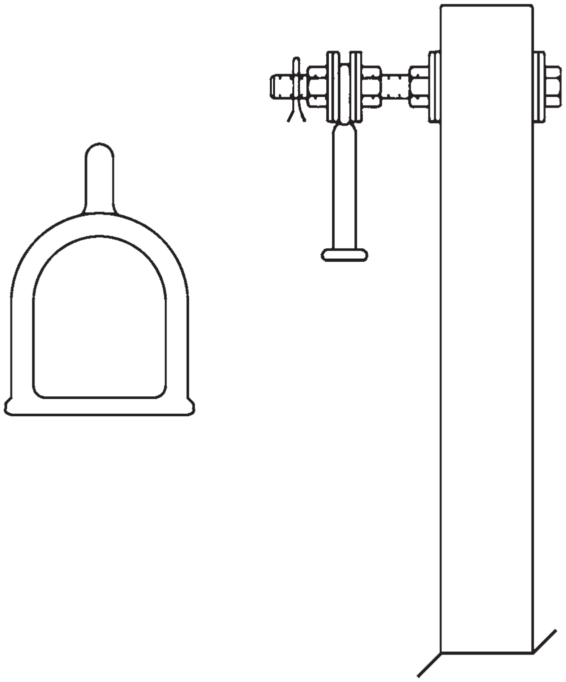

28-16 Stirrup end mounting.

Installing vertical antennas

Despite continuous (and mostly untrue) stories of very poor performance, the four- or five-band commercially manufactured trap vertical antenna remains one of the most popular amateur radio "antlers" in the HF bands. They are economical compared with directional rotating beam antennas, easy to erect, and do not have to occupy a lot of real estate (the "footprint" of the vertical can be very small, especially if you bury the radials). Unfortunately, a misinstalled vertical is both dangerous and a very poor performer. This section covers both problems in order to give you a good chance of success.

Electrical installation

Figure 28-17 shows the usual form of multiband trap vertical antenna. Each trap (*TR1–TR3*) is a parallel resonant LC tank circuit that blocks a certain frequency but passes all others. In Fig. 28-17, *TR1* is the 10-m trap, *TR2* is the 15-m trap, and *TR3* is the 20-m trap. No 40-m trap is needed because the antenna resonates the entire length of the tubing on 40 m. Each section (except perhaps the 10-m section) is actually a little shorter than might be expected from the standard quarter-wavelength formulas. This is because the traps tend to act inductively and so lessen the length required to resonate on any given band.

The vertical antenna manufacturer might give suggested lengths for the various segments between traps. Do not make the mistake of assuming that these are absolute numbers. They are only recommended starting points, even though the literature packed with the antenna may suggest otherwise. Loosely (meaning do not tighten the clamps too much) but safely install the antenna, and then adjust each segment for resonance. Start with the 10-m band, and then work each lower-frequency band in succession: 10-15-20-40, etc. After each lower band is adjusted, recheck the higher bands to make sure that nothing has shifted, because there might be a little interaction between bands. Once the antenna is properly resonant, tighten the clamps, and make the final installation. I know this is a pain in the neck, and means putting the antenna up and taking it down a couple of times, but it pays dividends in the end. I failed to do this once and found that the 15-m band was useless; it resonated at 19.2 MHz.

Radials make or break a vertical antenna; they form the ground plane for the antenna. AM broadcast stations typically use vertical antennas and must have 120 radials for the ground plane. Antenna reference books usually contain a graph plotted to show the effectiveness of radials and demonstrate a decreasing return on investment after about 32 radials. For amateur work, I recommend not less than 2 radials per band, and preferably 4, arranged so that they are equally spaced around the antenna. If you cannot space them correctly, never fear; they will work anyway. On a four-band antenna, this means 16 radials, which really is not a lot. Of course, the general rule is that the more radials, the better is the antenna, at least up to the point where diminishing returns are realized.

The radials are made of no. 14 wire and must be a quarter wavelength ($246/F_{\mathrm{MHz}}$). Figure 28-18 shows how to mount the radials on a mast-mounted (or roof-mounted) installation, and Fig. 28-19 shows radials in a ground-mounted situa-

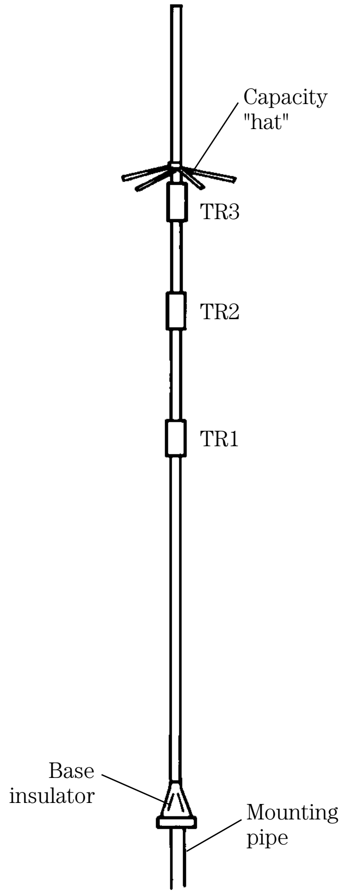

28-17 Mounting commercial trap vertical.

tion. I do not recommend radials on the surface for ground-mounted antennas. It is too easy for a guest or even a trespasser to trip over the radials, and this could land you in court. Wire radials can be buried using a spade tip to cut a 3- to 4-in slit, and they even make for a better ground.

Ground mounting verticals and masts

In the preceding section, the essential assumption was that the antenna is mounted above ground, on a mast or other support. In this section you will take a look at the methods of ground mounting the antenna or its mast. The same mast ideas are also useful for erecting supports for dipoles and other wire antennas.

Figure 28-20 shows a standard chain-link fence post used as a support for either a vertical antenna or a mast (which could be metal, PVC, or wood). The typical fence post is 1.25 to 2.00 in outside diameter and made of thick-wall galvanized steel. Thus such a pipe makes a tough installation. Some authorities believe that the pipe will last longer if painted its entire length (especially the underground portion) with a rust-inhibiting paint such as Rustoleum.

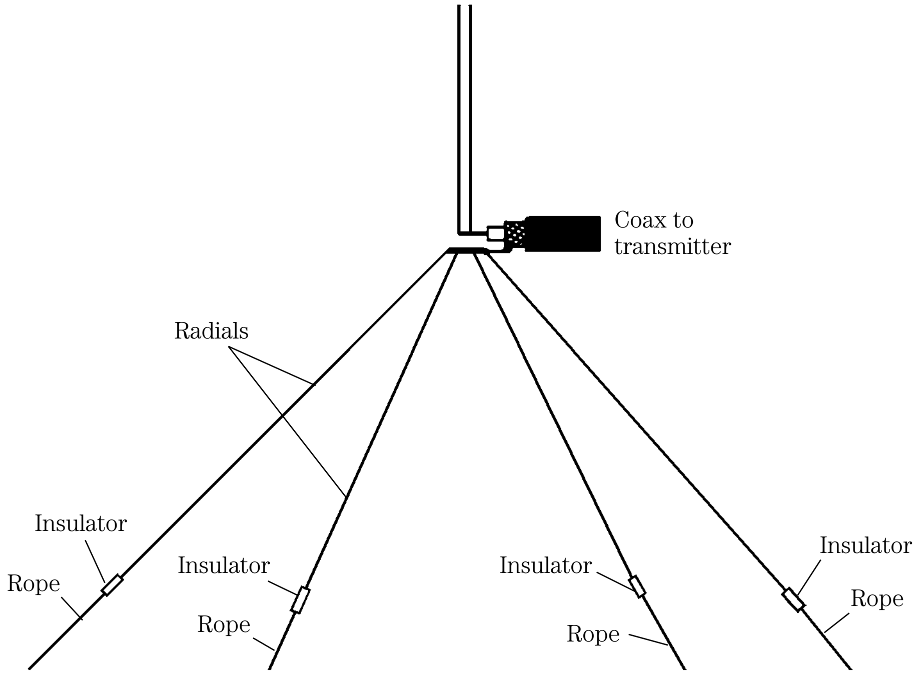
Coax to
transmitter
Radials
Insulator
Rope
Insulator
Rope
Insulator
Rope
Insulator
Rope

28-18 Feeding the mast-mounted vertical antenna.

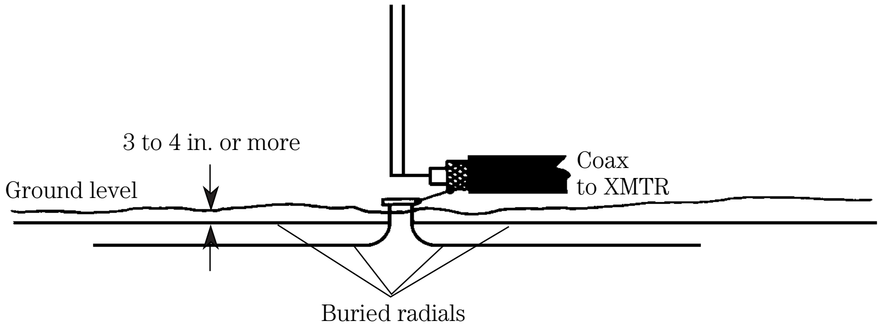
3 to 4 in. or more
Ground level
Coax
to XMTR
Buried radials

28-19 Feeding the ground-mounted vertical antenna.

The beauty of the fence post as an antenna support is that it is relatively easy to install, and supplies are obtained easily from hardware stores. The post is mounted in a concrete plug set at depth *D* in the ground (see again Fig. 28-20). The depth *D* is a function of local climate and local building codes. In the absence of local regulations to the contrary, make the hole at least 24 in deep (or more). The depth is determined by the 100-year depth of the frost line in your area, a figure well familiar to local building experts. Keep in mind, however, that shallower depths may be legal for

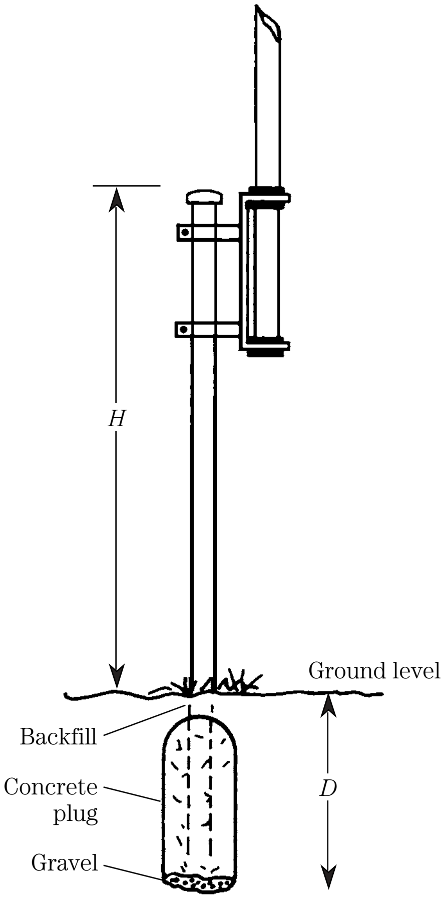

28-20 Fence post mounting.

fence posts, but installation of a vertical antenna (or mast) on top of the fence post changes the mechanical situation considerably.

The hole can be dug with a post-hole digger tool or an earth-auger-bit tool. The latter often can be rented in either gasoline engine, electrical motor, or manual versions from tool rental stores.

Once the hole is dug, place about 4 in (or local requirement) of gravel at the bottom of the hole. This gravel can be bought in bags from hardware stores for small jobs. The post is installed at this point and made plumb (i.e., it is made to sit vertical in the hole). Gravel can be used to force the post to remain upright as the job is finished. On top of the gravel is a concrete plug that fills the hole to at least 4 in below the surface. The rest of the hole is backfilled with dirt, unless you want the plug to extend all the way to the surface. Do not put anything on top of the post for at least 4 days or whatever period of time the concrete manufacturer recommends. Concrete needs time to cure, and 4 to 7 days seems to be the recommended period of time. It is probably a good idea to install the post one weekend and then complete the antenna installation the following weekend.

Chain-link fence posts tend to be about 4 ft high, and this is sufficient for installation of masts for inverted-V and dipole support. However, for vertical installation, make the height *H* of the post about 18 in (otherwise, the antenna tries to act differently from the instructions).

If the antenna is a standard vertical with the usual form of offset base (as shown in Fig. 28-20), then use either the mounting brackets that come with the antenna or U-bolts fastened around the fence post. Never use a single mounting point; always use at least two-point mounting to prevent the antenna from pivoting and shearing off the mounting hardware.

Figure 28-21 shows how to mount a 2 × 4 mast to a fence post. Good-quality 2 × 4 lumber can be purchased in lengths up to 20 ft, although, 8-, 10-, 12-, and 16-ft lengths are the most commonly available (in my area, 16- and 20-ft lengths have to be bought at professional “contractor” lumberyards rather than those which serve homeowners). The 2 × 4 selected should be kiln-dried and pressure-treated. It also should be painted in order to minimize the effects of weathering on the mechanical integrity of the installation. Good-quality 2 × 4 lumber is relatively inexpensive, but

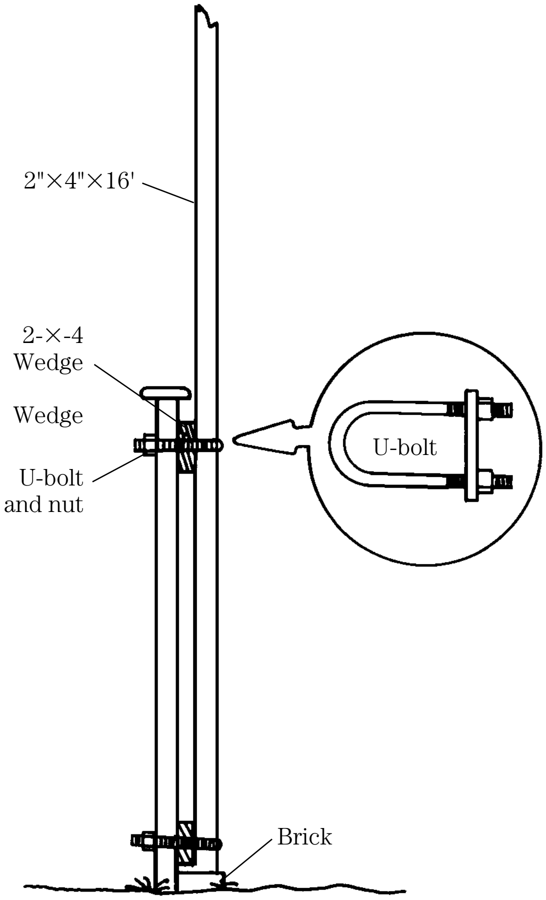

28-21 Making a mast mounted to a fence post.

the less costly material (which is only marginally less costly than the best) will warp and ruin the installation within 1 year.

The 2 × 4 is attached to the fence post using U-bolts. A 2 × 4 scrap is used as a wedge to take up the difference between the post and the mast. In some installations the U-bolt will go around the perimeter of the 2 × 4, whereas in others a pair of holes will be drilled in the 2 × 4 to admit the U-bolt arms. The U-bolt must be at least $^1/_4$-in no. 20 thread, and either a $^5/_{16}$-in bolt or a $^3/_8$-in bolt is highly recommend if the mast supports any significant weight. Some installers like to place a brick at the base of the 2 × 4. This support bears the static and dynamic loads (i.e., gravity and wind) that eventually would cause the mast to list because of the eccentric loading on the footer. The auxiliary purpose is to keep the butt end of the 2 × 4 off the ground and thereby prevent rot. Some additional mechanical stability might be afforded by replacing the brick with a cinder block that is filled with concrete. Another approach is to install a pressure-treated 4 × 4 of the sort used to support decks (Fig. 28-22). Hardware stores and lumber yards sell the specially treated 4 × 4 posts and the concrete for the footers. These footers are dropped onto a gravel bed at the bottom of a hole (see the preceding section for a discussion of how deep the hole must be). A typical deck footer has a plastic or heavy-duty metal mount to support the 4 × 4. After the footer and mount are installed, the hole is backfilled with soil. Some people prefer to backfill, at least to a point above the mount, with builder's gravel (of the same sort as used beneath the concrete footer), or concrete can be used for maximum stability.

Installing towers

Antenna towers are used extensively in amateur and commercial radio communications systems for a very obvious reason: Antennas tend to work better "at altitude" than on the ground. Amateur operators tend to install 30- to 100-ft towers, although the 40- and 50-ft models probably predominate for practical (and in some areas

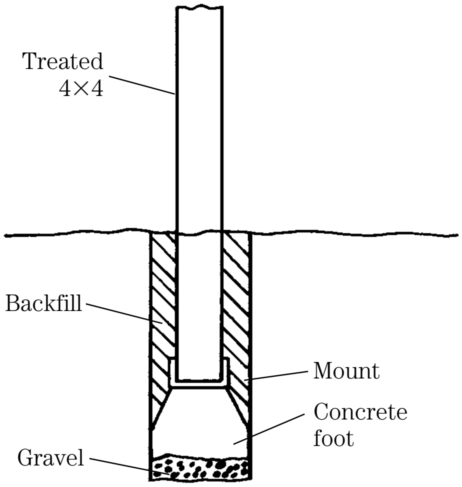

28-22 A 4 × 4 antenna support.

legal) reasons. Local laws vary considerably, from one area to another. Be sure to consult the bureaucracy before erecting a tower.

In my own area, a 30-ft tower that is physically attached to a two-story house does not need a permit or inspection (but must be constructed according to certain regulations), although anything mounted away from the house (or at a height greater than 30 ft, if attached to the house) requires a permit and the usual mechanical inspection. The law requires that an inspection be performed when the hole for the footing is completed and 4 in of gravel is on the bottom. The inspector will take a yardstick and measure both the depth of the hole and the depth of the gravel. A final inspection is performed when the antenna is installed. Prior to all this mess, a permit must be obtained (which means drawings submitted).

Several different types of towers are used by amateurs. Some are square-base designs, and others are triangular-base designs. At least one commercial model is a round pipe that has a rotator at the base. In this model, the entire tower turns when the antenna is rotated. Several tower configurations are seen commonly. Figure 28-23 shows the fixed form of tower. This type of tower costs the least, and a case can be

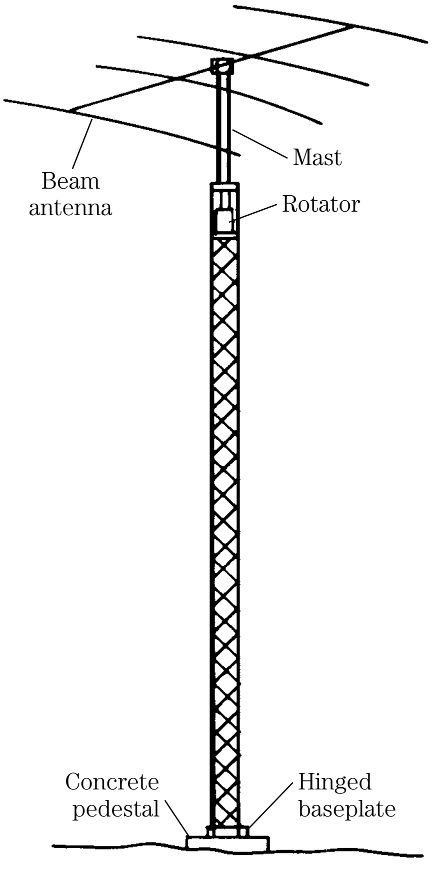

28-23 Antenna tower on hinged baseplate.

made for it also being the most stable. It is made of 10-ft sections and an 8- to 12-ft top section that contains the thrust bearing for the antenna mast and rotator mounting platform. Some fixed towers are self-supporting up to a point, but the use of guy wires is always recommended unless a firm mounting point (against the side of a building, for example) is provided about 18 ft above the surface. The fixed tower can be made to tilt over at the base by using a hinged baseplate on the mounting pedestal.

The tilt-over tower is shown in Fig. 28-24. This type of tower uses the same sort of construction as the fixed model but is hinged at a point between one-third and one-half the total height. A winch at the base drives a steel wire that is used to raise or lower the tower between fully extended and fold-over positions.

Still another configuration is shown in Fig. 28-25. This type of tower is the slip-up variety. A wide base section supports a smaller movable upper section. A winch is used to lift the upper section into its fully extended position. Typical examples will raise from a low position of 20 ft, to a height of 40 ft or so when fully extended (or 20/50 ft). When the tower is fully extended, it is locked into place at the bottom of the upper section with steel bolts. A lot of shear force is applied to these bolts, so it is wise to use several very hard stainless steel bolts for the lockdown.

There is a serious danger inherent in the design of the slip-up tower: the guillotine effect. If the upper section comes loose while you are working on it, it will come plummeting down the shaft formed by the lower section and shear off any arms, legs, or other body parts that get in the way. Whenever you work on this form of tower, use steel fence posts (or similar pieces of metal) as a safety measure (Fig. 28-26); at least two should be used, and both should be attached securely at both ends with

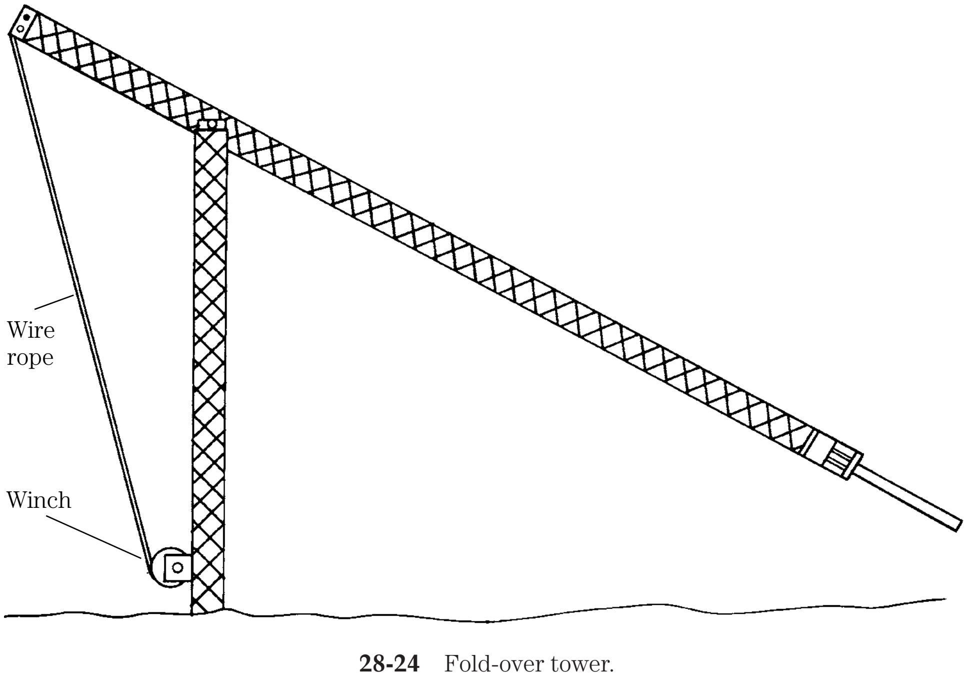

28-24 Fold-over tower.

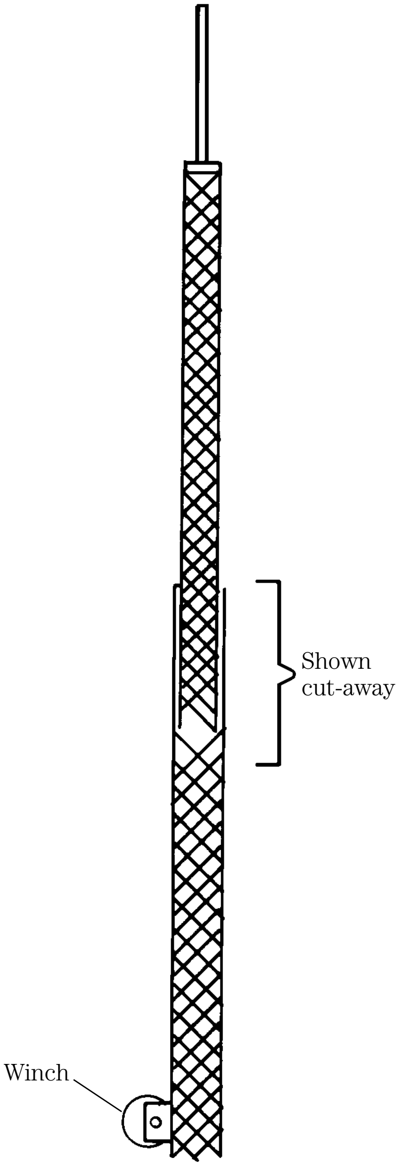

28-25 Slip-up tower.

rope. The purpose of the rope is to prevent the safety pipes from working loose and falling out. These pipes are used in addition to, not instead of, the normal bolt fasteners that keep the antenna tower erect.

The antenna tower, regardless of its configuration, is typically installed on a buried pedestal made of concrete (Fig. 28-27). The construction must follow local laws, but there are some general considerations to keep in mind. The surface area of the pedestal is 242 to 362 in. The top surface is fitted with either a fixed or hinged baseplate (which must be installed before the concrete sets). The depth of the

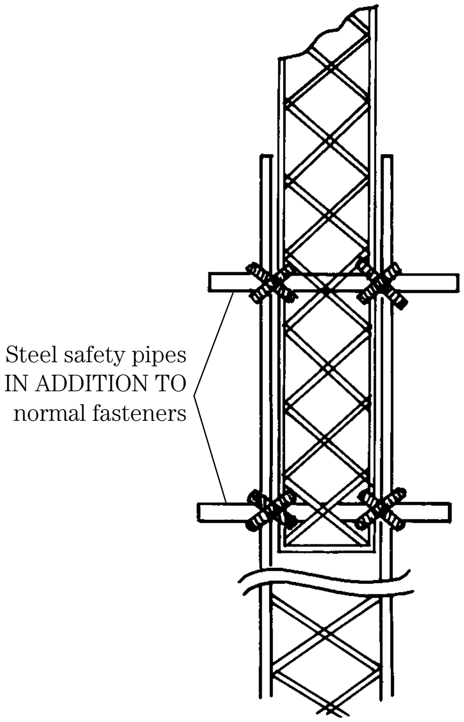
Steel safety pipes
IN ADDITION TO
normal fasteners

28-26 Safety precaution.

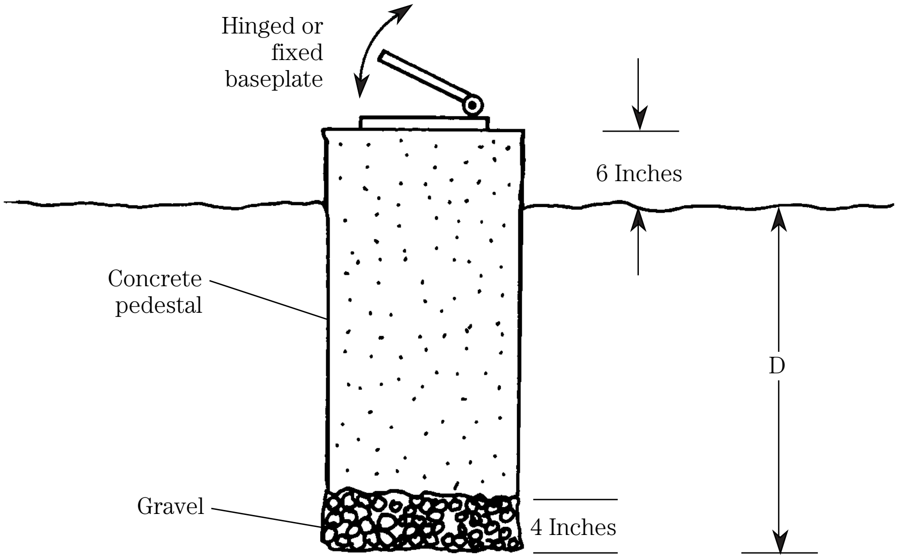
Hinged or
fixed
baseplate
6 Inches
Concrete
pedestal
D
Gravel
4 Inches

28-27 Ground pedestal.

pedestal and the depth of the gravel base tend to reflect the local frost line. Regardless of how general local law is, good advice is to make the pedestal at least 28 in deep—even if local law permits less.

Raising the tower can be accomplished by either of two methods, although, in my opinion, only one of them is safe. Figure 28-28 shows a method by which the tower is laid out on the ground and then raised with a heavy rope over a high support (such as the peak of the house roof). This method is dangerous unless certain precautions are taken. For example, a support must be placed beneath the antenna as it is raised. This requirement means that a constantly increasing height of the tower demands a constantly increasing lower support.

The end-over-end method of raising a tower is shown in Fig. 28-29. A "gin pole" is required for this job. The gin pole is a length of pipe fitted with a pulley at the top and a pair of clamps at the bottom. The gin pole is clamped onto the top end of the highest section so that it can be used to raise the next 10-ft section into place, where it can be bolted down. The gin pole is then raised to the top of the newly installed section, where the operation is repeated again. The end-over-end method is preferred by tower manufacturers and is the method recommended by most of them.

The antenna tower will be most stable if guy wires are installed at appropriate places determined by the tower manufacturer. Although many people are inclined to install towers "free standing" and some towers are advertised as such, it is always good practice to use guy wires attached to at least one point (or more, for tall towers). Use at least four guy wires on a square tower or three on a triangle tower (one in each direction). Figure 28-30 shows two methods for securing the guy wires to the ground. One approach is to bury a heavy concrete or metal "deadman" weight underground. Alternatively, use at least one 4- to 6-ft pipe (1 to 1.5-in in diameter) buried up to a length of 12 to 24 in (18 in is shown in Fig. 28-30).

Note It is absolutely essential to use safety belts when climbing a tower. Use two belts that are completely independent of each other so that no "single-point failure" can eliminate the belt's function. Always keep one belt fastened to the tower; when climbing, unhook one belt and move it up on the tower, and then disconnect the other only when the first is reattached. Be sure to inspect the belts prior to use. Leather and metal wear out and break, and you do not want to find that failure at 50 ft up. Also, do not buy cheap belts.

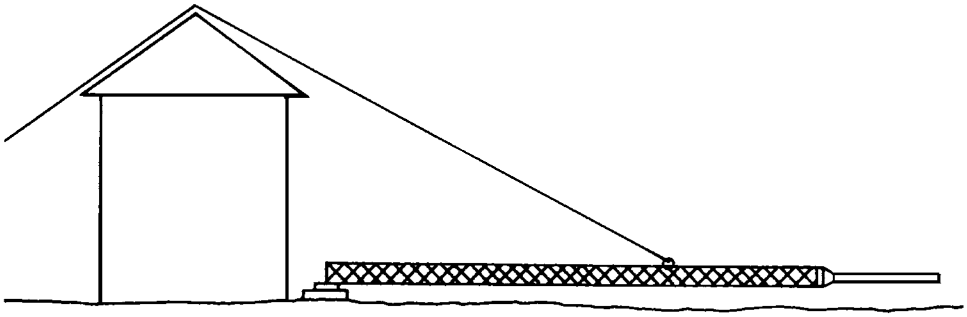

28-28 Dangerous method for erecting tower.

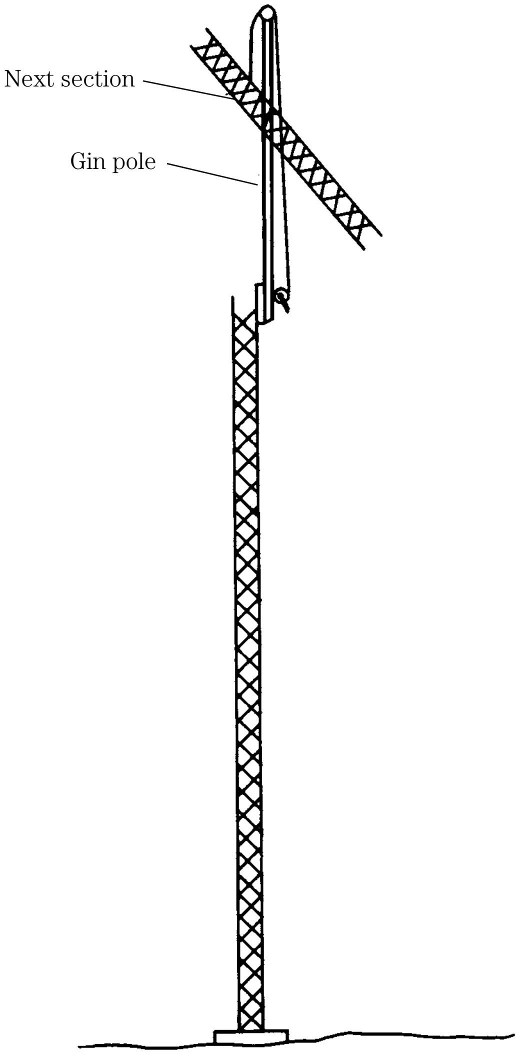
Next section
Gin pole

28-29 Proper tower installation using gin pole.

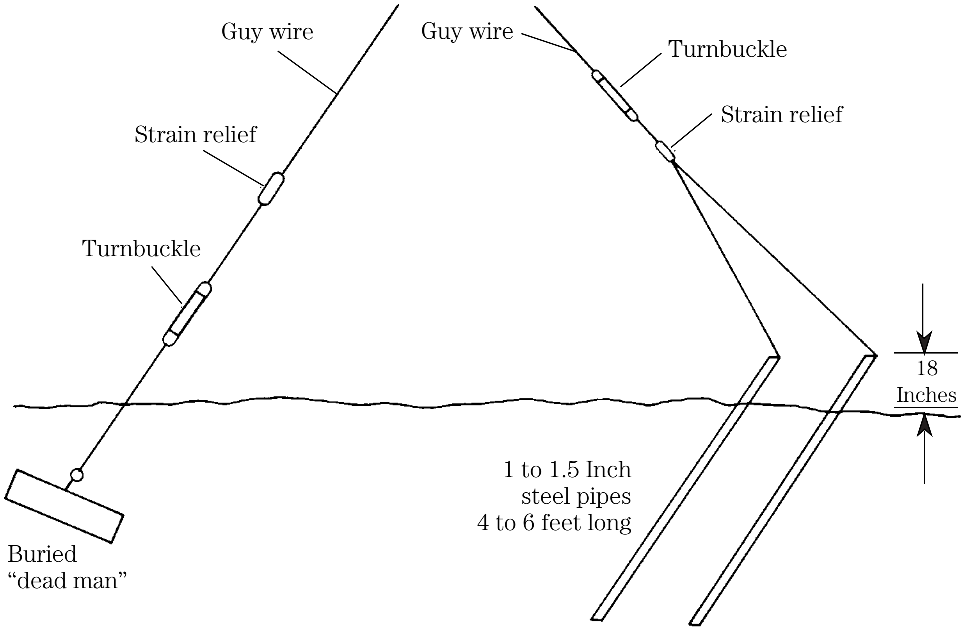
Guy wire
Strain relief
Turnbuckle
Buried
"dead man"
Guy wire
Turnbuckle
Strain relief
18
Inches
1 to 1.5 Inch
steel pipes
4 to 6 feet long

28-30 Ground stakes for guy wires.

29
CHAPTER
Grounding the antenna: What is a good ground?

THE SUCCESS OR FAILURE OF A RADIO ANTENNA SYSTEM OFTEN (PERHAPS USUALLY) hangs on whether or not it has a good RF ground. Poor grounds cause most antennas to operate at less than best efficiency. In fact, it is possible to burn up between 50 and 90 percent of your RF power heating the ground losses under the antenna, instead of propagating into the air. Ground resistances can vary from very low values of 5 Ω, up to more than 100 Ω (5 to 30 Ω is a frequently quoted range). RF power is dissipated in the ground resistance. The factors that affect the ground resistance include the conductivity of the ground, its composition, and the water content. The ideal ground depth is rarely right on the surface, and depending on local water table level might be a couple meters or so below the surface.

It is common practice among some amateur radio operators to use the building electrical ground wiring for the RF antenna ground of their station. Neglecting to install an outdoor ground that will properly do the job, they opt instead for a single connection to the grounded "third wire" in a nearby electrical outlet. Besides being dangerous to work with, unless you know what you are doing, this is also a very poor RF ground. It is too long for even the low RF bands, and radiates RF around the house in large quantity. Stations that use the household electrical wiring as the radio ground tend to cause TV interference, broadcast interference, and other electromagnetic interference both in their own building and in nearby buildings.

Fortunately, there are some fixes that will help your situation. We can reduce the ground resistance by either altering the composition of the earth surrounding the ground point, or by using a large surface area conductor as the ground point.

Figure 29-1 shows the traditional ground rod used on small radio stations, including amateur stations. Use either a copper (or copper-clad steel) rod at least 6 ft long (8 ft preferred). Electrical supply houses, as well as amateur radio and communications equipment suppliers, also sell these ground rods. Do not use the nonclad

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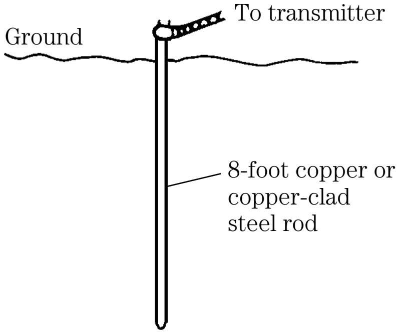

29-1 Single ground rod works—almost.

steel types sold by some electrical supply houses. They are usable by electricians when making a service entrance ground on your home or workplace, but RF applications require the low skin resistance of the copper-clad variety. The rod need not be all copper, because of skin effect forcing the RF current to flow only on the outer surface of the rod. Try to use an 8-ft rod if at all possible, because it will work better than the shorter kind. Do not bother with the small TV-antenna 4-ft ground rods; they are next to useless for HF radio stations. Drive the ground rod into the earth until only 6 in or so remains above the surface. Connect a ground wire from your station to the ground rod.

The ground wire should be as short as possible. Furthermore, it should be a low-inductance conductor. Use either heavy braid (or the outer conductor stripped from RG-8 or RG-11 coaxial cable) or sheet copper. You can buy rolls of sheet copper from metal distributors in widths from 4 in up to about 18 in. Some amateurs prefer to use 7-in-wide foil that is rated at a weight of 1 lb/linear ft. Sweat-solder the ground wire to the rod. You can get away with using mechanical connections like the electricians use, but you will eventually have to service the installation when corrosion takes its toll. I prefer to use soldered connections, and then cover the joint with either petroleum jelly or acrylic spray lacquer.

Another alternative is to use a copper plumbing pipe as the ground rod. The pipe can be purchased in 8-ft through 16-ft lengths from plumbing supply shops or hardware stores. The pipe selected should be ¾ in or larger. Some people report using up to 2-in pipe for this application. The surface area of the hollow pipe is greater than that of a solid rod of the same diameter. Because of certain current flow geometries in the system, however, the ground resistance is not half the resistance of a rod of the same diameter, but is nonetheless lower.

Driving a long pipe into the ground is not easily done. Unlike the copper-clad steel rod, the pipe has no compression strength and will deform when you hit it with a hammer or other driving tool. To overcome this problem (see Fig. 29-2) you can use a garden hose as a water drill. Sweat solder a tee joint on the top end of the pipe, and then sweat-solder a faucet fitting that matches the garden hose end on one end of the tee joint. Cap off the other port of the tee joint. Use the tee

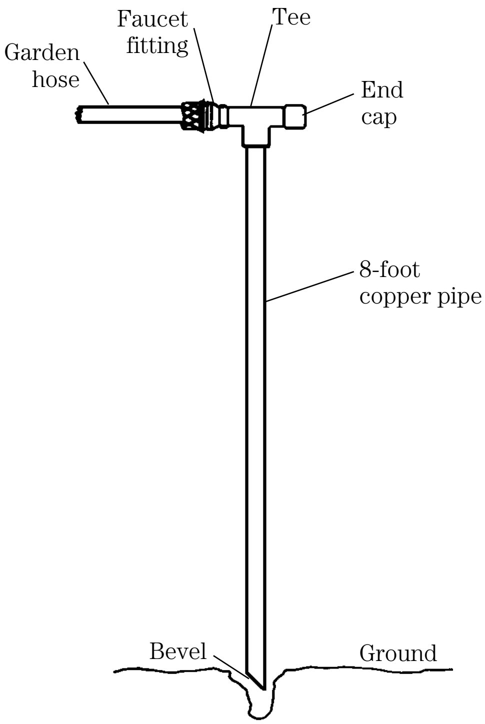

29-2 Hose method of installing ground pipe.

joint as a handle to drive the pipe into the ground. When water pressure is applied, the pipe will sink into the ground as you apply a downward pressure on the tee handle. In some cases, the pipe will slip into the ground easily, requiring only a few minutes. In other cases, where the soil is hard or has a heavy clay content, it will take considerably greater effort and more time. When you finish the task, turn off the water and remove the garden hose. Some people also recommend unsoldering and removing the tee joint.

Altering soil conductivity

The conductivity of the soil determines how well, or how poorly, it conducts electrical current (Table 29-1). Moist soil over a brackish water dome conducts best (southern swamps make better radio station locations), and the sand of the western deserts makes the worst conductor. Figure 29-3 shows a method for reducing the soil electrical resistance by treating with one of two chemicals: copper sulfate or common rock salt. The rock salt is one of several salt materials used for snow and ice melting in snow-prone areas of the country. If you cannot locate rock salt in a hardware store, then look for a store that sells ice-cream-making supplies. Rock salt is a principal ingredient in the process (but not the product).

Table 29-1. Sample soil conductivity values

Type of soil	Dielectric constant	Conductivity (siemens /meter)	Relative quality
Salt water	81	5	Best
Fresh water	80	0.001	Very poor
Pastoral hills	14–20	0.03–0.01	Very good
Marshy, wooded	12	0.0075	Average/poor
Sandy	10	0.002	Poor
Cities	3–5	0.001	Very poor

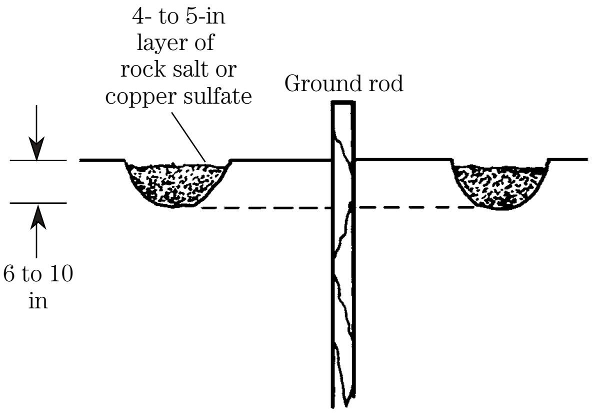

29-3A Ground rod with "improved" ground.

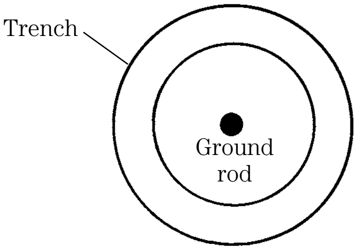

29-3B Trenching pattern.

Figures 29-3A and 29-3B show side and top views (respectively) of a slit trench method of applying the chemical treatment. Dig a 6- to 10-in-deep trench, about 12 to 24 in from the ground rod. Fill that trench with a 4- or 5-in layer of rock salt or copper sulfate. Cover the remaining depth with soil removed when you dug the trench. Water the trench well for about 15 minutes. The treatment will need to be repeated every 12 to 36 months, depending upon local rainfall and soil composition.

Figure 29-3C shows an alternative method: the salt pipe. Use either copper or PVC plumbing pipe, up to 4 in diameter (although 2 to 3 in is easier to work). The overall length of the pipe should be at least 18 to 24 in, although longer is useful.

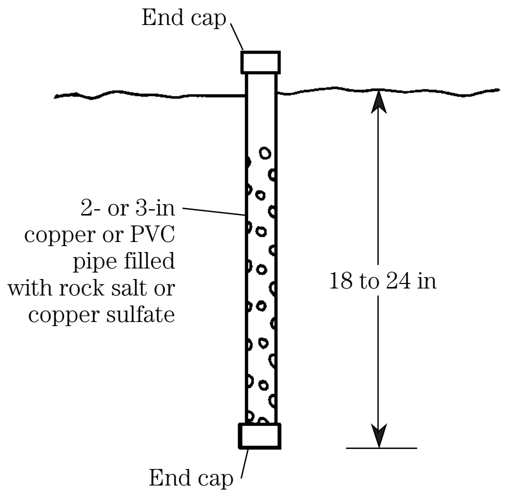
End cap
2- or 3-in copper or PVC pipe filled with rock salt or copper sulfate
18 to 24 in
End cap

29-3C Slow release ground treatment pipe.

Drill a large number of small holes in the pipe (no hole over ⅜ in), sparing only the end that will be above the surface. Fill with rock salt or copper sulfate and cap off both ends.

Install several salt pipes around the ground rod. Installation is best accomplished with a fence posthole digger. Drop the salt pipe into the hole and backfill with water. Remove the top endcap and hose down for about 15 minutes. Refill the pipe occasionally to account for the salt leaching out.

Multiple ground rods

The key to a low-resistance ground is the surface area in contact with soil. One means for gaining surface area, and thereby reducing ground resistance, is to use multiple ground rods. Although multiple 4-ft rods are better than a single 4-ft ground rod, the use of 6- or 8-ft rods is recommended even in cases where multiple rods are used.

Figure 29-4A shows the use of three ground rods in the same system. The 8-ft rods are placed 12 to 18 in apart for low- and medium-power levels, and perhaps 30 in for higher amateur power levels. An electrical connection is made between the rods on the surface using either copper stripping or copper braid. The connections are sweat-soldered in the manner described above, with the feedpoint at the center rod.

Figure 29-4B shows a more complex system with a larger number of rods laid out in an array. The rods are arrayed about 24 in apart. As in the previous case, the rods are electrically connected (by braid or foil) on the surface. Again, connection to the system is made from the rod at the geometric center of the array.

Radials/counterpoise grounds

The effectiveness of the ground system is enhanced substantially by the use of radials either above ground or buried under the surface. Figure 29-5 shows a vertical

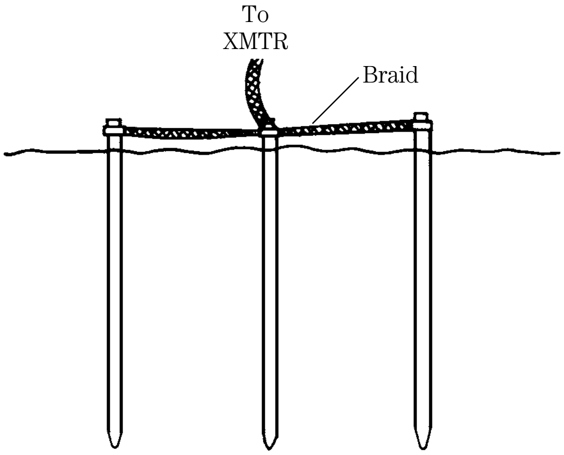

29-4A Multiple ground rod system.

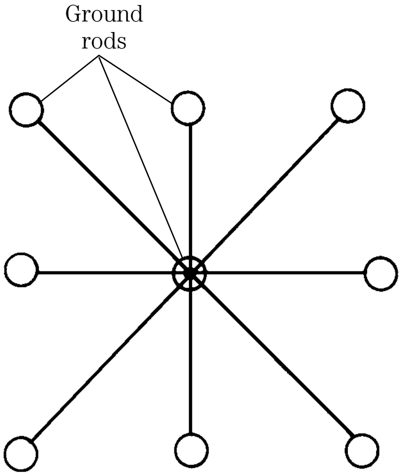

29-4B Connection scheme.

antenna with three different forms of radials: aboveground, subsurface, and ground rod. It is not unreasonable to use both radials and a ground rod. Note (from Chap. 7) that vertical antennas are relatively ineffective unless provided with a good ground system, and for most installations that requirement is best met through a system of ground radials.

An effective system of radials requires a large number of radials. Although as few as two quarter-wavelength resonant radials will provide an improvement, the best performance is to use more. Broadcasters in the AM band (550 to 1640 kHz) are advised to use 120 half-wavelength radials. Installing more than 120 radials is both expensive and time-consuming, but does not provide any substantial improvement. For amateur and small commercial stations, use a minimum of 16 quarter-wavelength radials.

Above ground, the use of insulated wire is recommended, but not required. Below ground, noninsulated wire is preferred. Although some sources claim that any

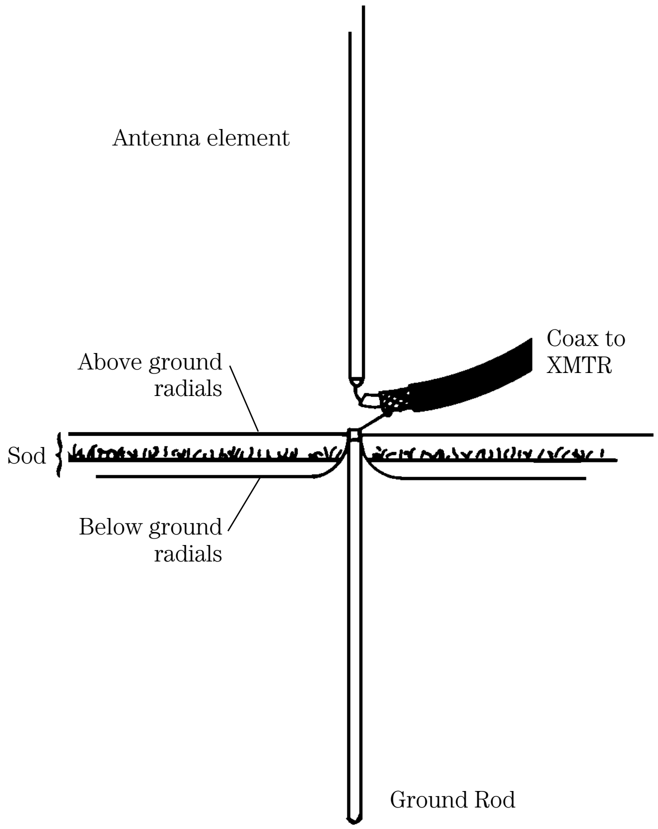

29-5 Combining ground rod and buried radials.

size wire from no. 26 up to no. 10 can be used, it is best to use larger sizes in that range (i.e., no. 14 through no. 10). Either solid or stranded wire can be used.

The layout for a system of radials in a vertical antenna system is depicted in a view from above in Fig. 29-6. Here, the radials are laid out in a uniform pattern around the antenna element. This coverage provides both the lowest resistance and the best radiation pattern for the antenna. Solder all radials together at a common point, which might be the ground or mounting rod used to support the vertical antenna.

Station grounding

It does no good to provide a topflight ground system, such as those shown earlier in this chapter, if the connection between the station equipment and the ground system is substandard. Figure 29-7 shows a method used by the author to good effect. On the back of the operating position is a sheet of copper, 7 in wide, running the length of the equipment platform. This form of copper, in the 1-lb/sq ft weight, is used on older houses for roofing flashing. Each piece of equipment is connected to the ground sheet through a short length of braid harvested from RG-8 or RG-11 coaxial cable shield. RF accessories, such as the low-pass TV interference filter (if used—it should be) are mounted directly to the copper sheet. In one installation, the

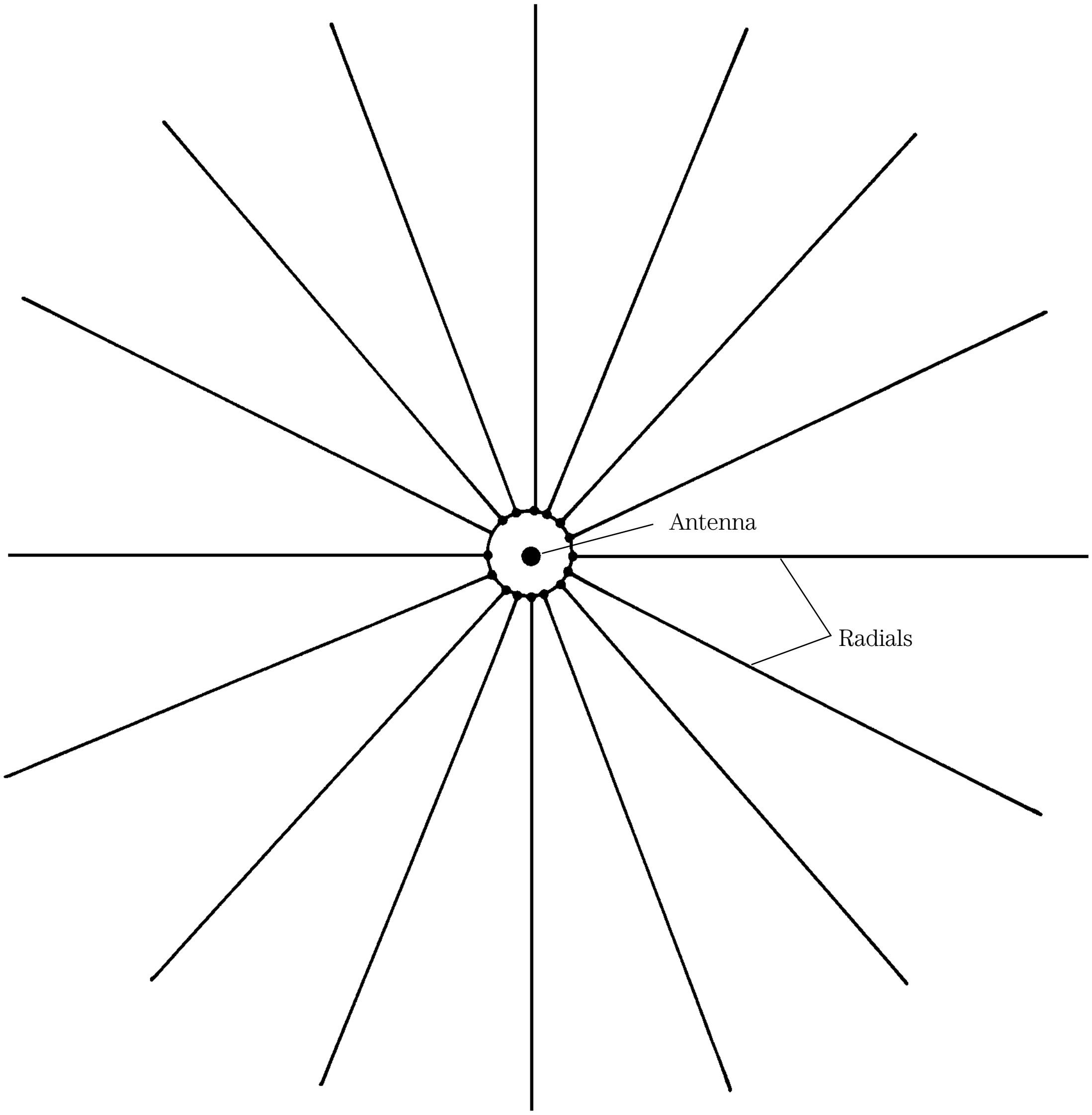

29-6 Radial pattern.

author was able to drop the copper sheet down from the table to connect directly to the ground system outside the building. The run was less than 40 in. But in other cases, a short length of braid wire will be more practical.

Tuning the ground wire

An alternative that some operators use is the ground wire tuner. These instruments insert an inductor or capacitor (or a *LC* network) in series with the ground line. You

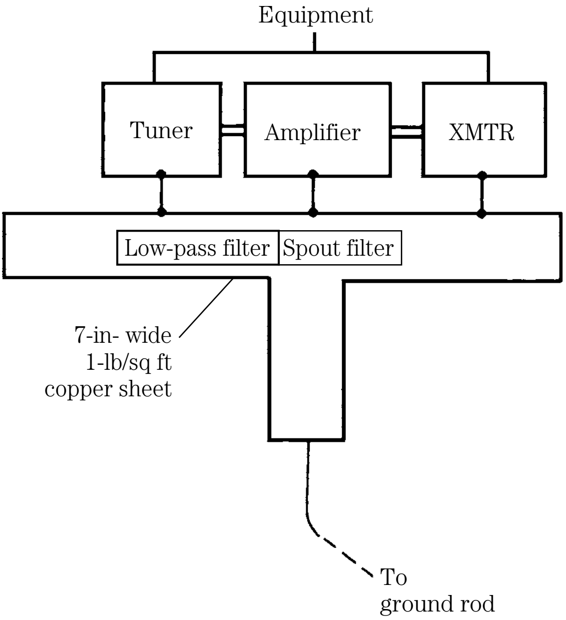
Equipment
Tuner
Amplifier
XMTR
Low-pass filter
Spout filter
7-in- wide
1-lb/sq ft
copper sheet
To
ground rod

29-7 Ground system inside shack.

adjust the ground line tuner for maximum ground current at the operating frequency. MFJ Electronics, Inc., Mississippi State, MS, makes one of these devices.

Conclusion

A high-quality, low-resistance ground might seem costly to install, but in reality it pays rich dividends in the functioning of your antenna. Don't overlook the quality of the ground, or you might be in the position of being penny wise and pound foolish.

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About the Author

Joe Carr was a military electronics technician and author. Along with the best-selling *Practical Antenna Handbook*, his other books with McGraw-Hill include *Secrets of RF Circuit Design*. Carr also contributed a monthly column to *Nuts & Volts* magazine entitled "Open Channel."

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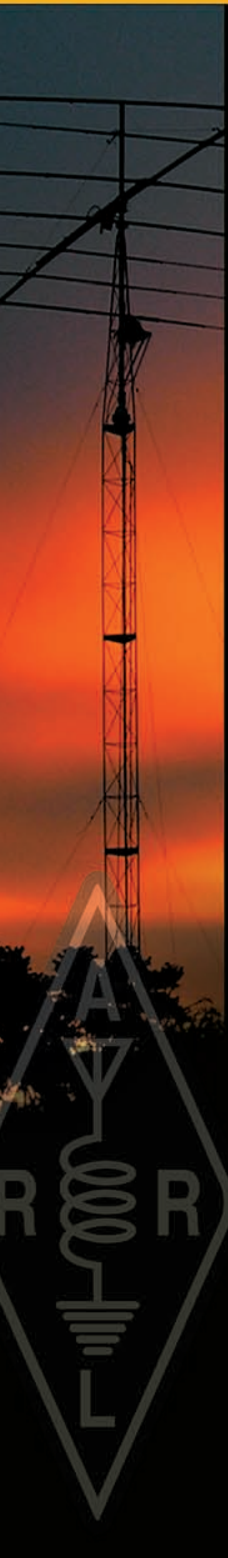

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Center image: Kurt Andress, K7NV, working on 40-meter Yagi at N6RO in Oakley, CA. Photo by Dean Straw, N6BV.

Upper right image: UHF antenna. Photo credit: ShutterStock.com.

Lower right image: Some of the members of the C5Z contest DXpedition near Banjul, The Gambia. Photo by Henryk Kotowski, SM0JHF.

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Foreword

We are pleased to offer the 21st edition of *The ARRL Antenna Book*. Since the first edition in September 1939, each new *Antenna Book* has provided more and better information about the fascinating subject of radio antennas. We've sold more than a million *Antenna Books* over the years to amateurs and professionals alike, making it one of the most successful books in our extensive lineup of publications.

Fundamentals about antennas rarely change from edition to edition, but modern application of these fundamentals can result in more highly optimized or specialized antennas. For example, many of the antennas in this new edition benefit directly from advances in sophisticated computer modeling.

We usually update at least 20% of the material in a new edition, and this book is no exception. There have been major revisions in the following chapters:

- Chapter 2: Updated information the concept of "gain."
- Chapter 6: Further insights into the importance of low elevation angles for the lower frequencies, plus a whole new section on NVIS (Near Vertical Incidence Skywave) operation.
- Chapter 8: Completely new section on feeding of phased arrays by W7EL.
- Chapter 13: Updates on Beverage receiving antennas.
- Chapter 14: New "tape-measure" portable Yagi for fox hunting.
- Chapter 16: New information on mobile "screwdriver" antennas.
- Chapter 23: Expanded section on ionospheric area-coverage maps.
- Chapter 27: New section on S-parameters, as used in Vector Network Analyzers (VNAs)

We are fortunate to have the expertise of some well-known and highly talented authorities, who either wrote or reviewed a number of chapters for technical accuracy:

- Rudy Severns, N6LF, and Roy Lewallen, W7EL—low-frequency antennas.
- LB Cebik, W4RNL—Modeling antennas.
- Dick Jansson, WD4FAB—satellite antennas.
- Dave Hallidy, K2DH—EME arrays.
- Bob Hunsucker, AB7VP, and Carl Luetzelschwab, K9LA—HF propagation.

In addition, some exceptional software writers have contributed programs and data for the *Antenna Book*.

- Roy Lewallen, the author of *EZNEC*, has created a special *EZNEC ARRL* program, just for the *Antenna Book*. *EZNEC ARRL* uses the multitude of specialized modeling files also included on the CD-ROM. These models were used in almost every chapter in the book.
- W7EL has also supplied *Arrayfeed1.exe*, a program to design feed systems for phased-arrays.
- Dr Peter Guth and the US Naval Academy have again graciously allowed ARRL to include the versatile *MicroDEM* mapping program on the CD-ROM. *MicroDEM* can easily and quickly generate customized terrain files for the *HFTA* terrain-assessment program, as well as map terrain all around the country using free US topographic data files from the Internet.
- Jim Tabor, NU5S, wrote *GeoAlert-ARRL*, a wonderful freeware program to track propagation trends and to keep tabs on the latest Internet propagation bulletins.
- Dean Straw, N6BV, editor of *The ARRL Antenna Book* has updated and upgraded his *YW* (Yagi for Windows), *TLW* (Transmission Line for Windows) and *HFTA* (HF Terrain Assessment) programs from the 20th edition. A large number of statistical elevation-angle files for QTHs all around the world are included as well. N6BV has also written a new *Range-Bearing* program that is included on the CD-ROM.
- Also included on the CD-ROM are DOS-based utility programs by several authors that analyze antenna tuners, design mobile antennas and LPDAs, and that scale Yagis for *YW*.
- Are you planning on going on a DXpedition to somewhere you've never been before? The CD-ROM now includes both Simplified and Detailed propagation prediction tables for more than 150 QTHs all around the world. Even if you don't journey to distant lands, these tables will give you plenty of insight on planning contesting or DXing strategies—They can also help you set up that Saturday afternoon schedule with your uncle Harry in Cleveland!

You now have in one place the information you need to design your own complete antenna system scientifically—the elevation angles to aim for from your part of the world and the effects of your own local terrain.

As usual, in a publishing effort of this magnitude, errors creep into the process, despite our best efforts. We appreciate hearing from you, our readers, about errors or about suggestions on how future editions might be made even more useful to you. A form for mailing your comments is included at the back of the book, or you can e-mail us at: **pubsfdbk@arrl.org**.

David Sumner, K1ZZ
Executive Vice President
Newington, Connecticut
February 2007

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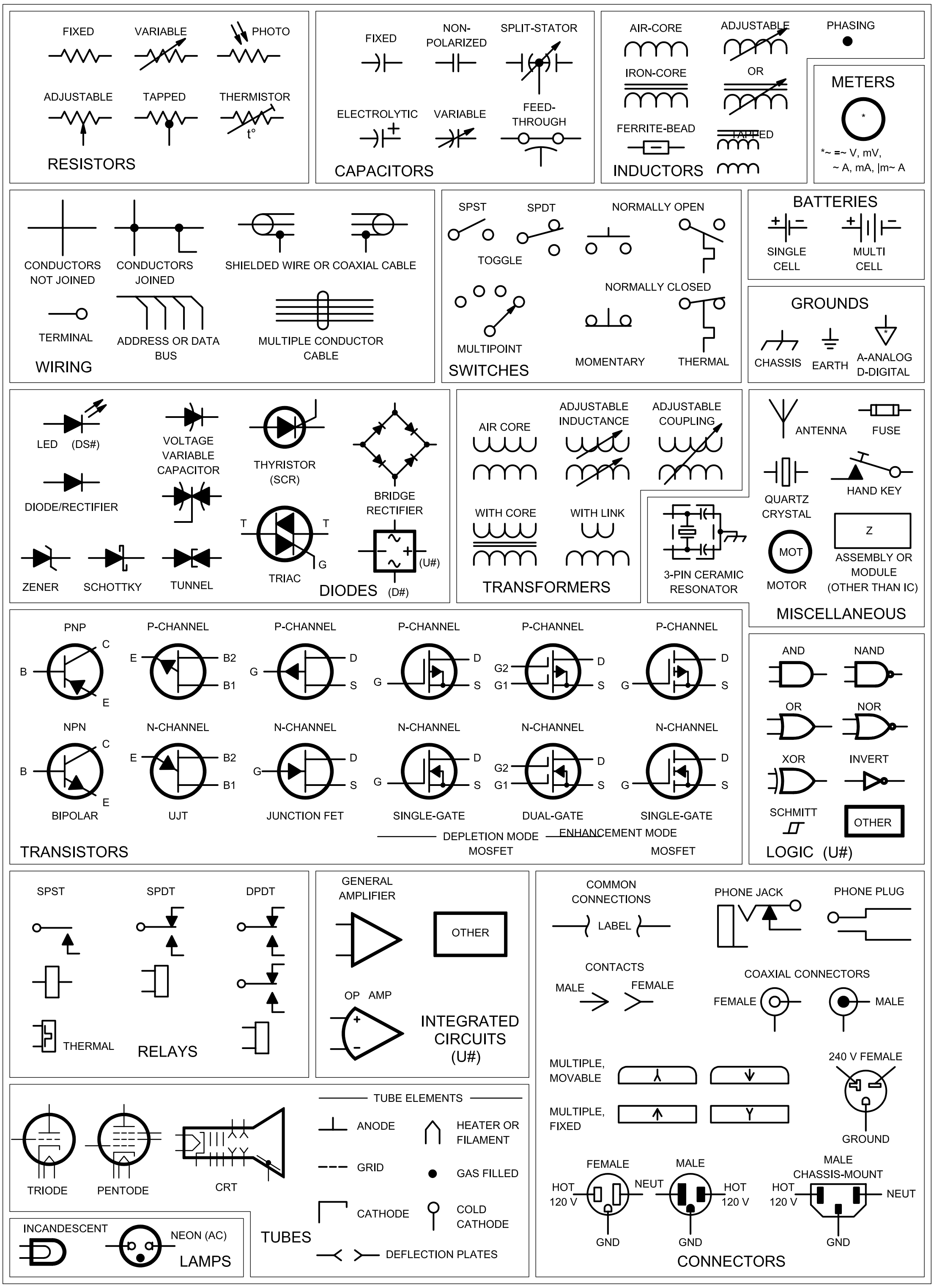
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About the ARRL

The seed for Amateur Radio was planted in the 1890s, when Guglielmo Marconi began his experiments in wireless telegraphy. Soon he was joined by dozens, then hundreds, of others who were enthusiastic about sending and receiving messages through the air—some with a commercial interest, but others solely out of a love for this new communications medium. The United States government began licensing Amateur Radio operators in 1912.

By 1914, there were thousands of Amateur Radio operators—hams—in the United States. Hiram Percy Maxim, a leading Hartford, Connecticut inventor and industrialist, saw the need for an organization to band together this fledgling group of radio experimenters. In May 1914 he founded the American Radio Relay League (ARRL) to meet that need.

Today ARRL, with approximately 150,000 members, is the largest organization of radio amateurs in the United States. The ARRL is a not-for-profit organization that:

- promotes interest in Amateur Radio communications and experimentation
- represents US radio amateurs in legislative matters, and
- maintains fraternalism and a high standard of conduct among Amateur Radio operators.

At ARRL headquarters in the Hartford suburb of Newington, the staff helps serve the needs of members. ARRL is also International Secretariat for the International Amateur Radio Union, which is made up of similar societies in 150 countries around the world.

ARRL publishes the monthly journal *QST*, as well as newsletters and many publications covering all aspects of Amateur Radio. Its headquarters station, W1AW, transmits bulletins of interest to radio amateurs and Morse code practice sessions. The ARRL also coordinates an extensive field organization, which includes volunteers who provide technical information and other support services for radio amateurs as well as communications for public-service activities. In addition, ARRL represents US amateurs with the Federal Communications Commission and other government agencies in the US and abroad.

Membership in ARRL means much more than receiving *QST* each month. In addition to the services already described, ARRL offers membership services on a personal level, such as the ARRL Volunteer Examiner Coordinator Program and a QSL bureau.

Full ARRL membership (available only to licensed radio amateurs) gives you a voice in how the affairs of the organization are governed. ARRL policy is set by a Board of Directors (one from each of 15 Divisions). Each year, one-third of the ARRL Board of Directors stands for election by the full members they represent. The day-to-day operation of ARRL HQ is managed by a Chief Executive Officer.

No matter what aspect of Amateur Radio attracts you, ARRL membership is relevant and important. There would be no Amateur Radio as we know it today were it not for the ARRL. We would be happy to welcome you as a member! (An Amateur Radio license is not required for Associate Membership.) For more information about ARRL and answers to any questions you may have about Amateur Radio, write or call:

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Chapter 1

Safety First

Safety begins with your attitude. If you make it a habit to plan your work carefully and to consider the safety aspects of a project before you begin the work, you will be much safer than "Careless Carl," who just jumps in, proceeding in a haphazard manner. Learn to have a positive attitude about safety. Think about the dangers involved with a job before you begin the work. Don't be the one to say, "I didn't think it could happen to me."

Having a good attitude about safety isn't enough, however. You must be knowledgeable about common safety guidelines and follow them faithfully. Safety guidelines can't possibly cover all the situations you might face, but if you approach a task with a measure of "common sense," you should be able to work safely.

This chapter offers some safety guidelines and protective measures for you and your Amateur Radio station. You should not consider it to be an all-inclusive discussion of safety practices, though. Safety considerations will affect your choice of materials and assembly procedures when building an antenna. Other chapters of this book will offer further suggestions on safe construction practices. For example, Chapter 22 includes some very important advice on a tower installation.

PUTTING UP SIMPLE WIRE ANTENNAS

No matter what type of antenna you choose to erect, you should remember a few key points about safety. If you are using a slingshot or bow and arrow to get a line over a tree, make sure you keep everyone away from the "downrange" area. Hitting one of your helpers with a rock or fishing sinker is considered not nice, and could end up causing a serious injury.

Make sure the ends of the antenna are high enough to be out of reach of passers-by. Even when you are transmitting with low power there may be enough voltage at the ends of your antenna to give someone nasty "RF burns." If you have a vertical antenna with its base at ground level, build a wooden safety fence around it at least 4 feet away from it. Do not use metal fence, as this will interfere with the proper operation of the antenna. Be especially certain that your antenna is not close to any power wires. That is the only way you can be sure it won't come in contact with them!

Antenna work often requires that one person climb up on a tower, into a tree or onto the roof of a house. Never work alone! Work slowly, thinking out each move before you make it. The person on the ladder, tower, tree or rooftop should wear a safety belt, and keep it securely anchored. It is helpful (and safe!) to tie strings or lightweight ropes to all tools. If your tools are tied on, you'll save time getting them back if you drop them, and you'll greatly reduce the risk of injuring a helper on the ground. (There are more safety tips for climbing and working on towers later in this chapter. Those tips apply to any work that you must do above the ground to install even the simplest antenna.)

Tower Safety

Working on towers and antennas is dangerous, and possibly fatal, if you do not know what you are doing. Your tower and antenna can cause serious property damage and personal injury if any part of the installation should fail. Always use the highest quality materials in your system. Follow the manufacturer's specifications, paying close attention to base pier and guying details. Do not overload the tower. If you have any doubts about your ability to work on your tower and antennas safely, contact another amateur with experience in this area or seek professional assistance.

Chapter 22, Antenna Supports, provides more detailed guidelines for constructing a tower base and putting up a tower. It also explains how to properly attach guy wires and install guy anchors in the ground. These are extremely important parts of a tower installation, and you should not take shortcuts or use second-rate materials. Otherwise the strength and safety of your entire antenna system may be compromised.

Any mechanical job is easier if you have the right tools. Tower work is no exception. In addition to a good assortment of wrenches, screwdrivers and pliers, you will need some specialized tools to work safely and efficiently on a tower. You may already own some of these tools. Others may be purchased or borrowed. Don't start a job until you have assembled all of the necessary tools. Shortcuts or improvised tools can be fatal if you gamble and lose at 70 feet in the air. The following sections describe in detail the tools you will need to work safely on a tower.

CLOTHING

The clothing you wear when working on towers and antennas should be selected for maximum comfort and safety. Wear clothing that will keep you warm, yet allow complete freedom of movement. Long denim pants and a long-sleeve shirt will protect you from scrapes and cuts. (A pull-on shirt, like a sweat shirt with no openings or buttons to snag on tower parts, is best.) Wear work shoes with heavy soles, or better yet, with steel shanks (steel inserts in the soles), to give your feet the support they need to stand on a narrow tower rung.

Gloves are necessary for both the tower climber and all ground-crew members. Good quality leather gloves will protect hands from injury and keep them warm. They also offer protection and a better grip when you are handling rope. In cooler weather, a pair of gloves with light insulation will help keep your hands warm. The insulation should not be so bulky as to inhibit movement, however.

Ground-crew members should have hard hats for protection in case something falls from the tower. It is not uncommon for the tower climber to drop tools and hardware. A wrench dropped from 100 feet will bury itself several inches in soft ground; imagine what it might do to an unprotected skull.

SAFETY BELT AND CLIMBING ACCESSORIES

Any amateur with a tower must own a high-quality safety belt, such as the one shown in **Fig 1**. *Do not attempt* to climb a tower, even a short distance, without a belt. The climbing belt is more than just a safety device for the experienced climber. It is a tool to free up both hands for work. The belt allows the climber to lean back away from the tower to reach bolts or connections. It also provides a solid surface to lean against to exert greater force when hoisting antennas into place.

A climber must trust his life to his safety belt. For this reason, nothing less than a professional quality, commercially made, tested and approved safety belt is acceptable. Check the suppliers' list in Chapter 21, Antenna Product Suppliers, and ads in *QST* for suppliers of climbing belts and accessories. Examine your belt for defects before each use. If the belt or lanyard (tower strap) are cracked, frayed or worn in any way, destroy the damaged piece and replace it with a new one. You should never have to wonder if your belt will hold.

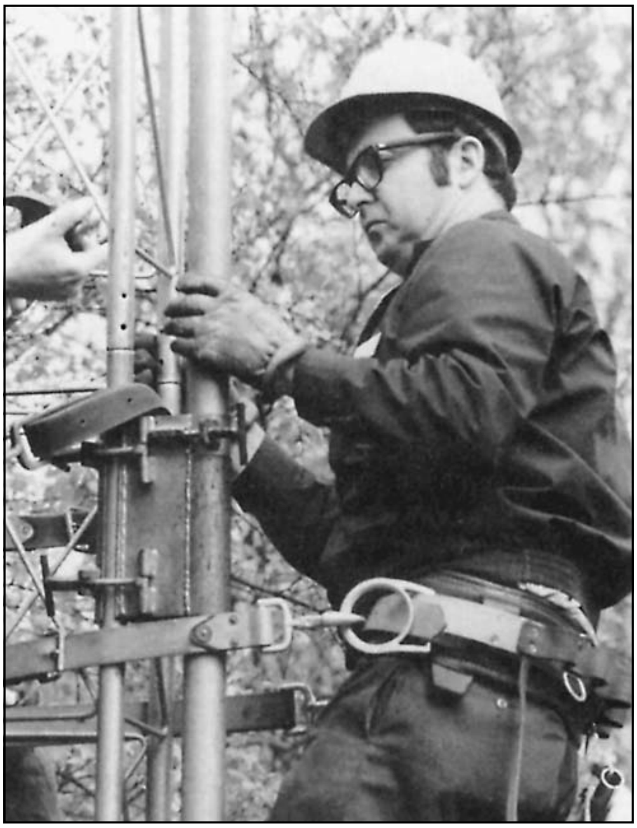

Fig 1—Bill Lowry, W1VV, uses a good quality safety belt, a requirement for working on a tower. The belt should contain large steel loops for the strap snaps. Leather loops at the rear of the belt are handy for holding tools. (*Photo by K1WA*)

Along with your climbing belt, you should seriously consider purchasing some climbing accessories. A canvas bucket is a great help for carrying tools and hardware up the tower. Two buckets, a large one for carrying tools and a smaller one for hardware, make it easier to find things when needed. A few extra snap hooks like those on the ends of your belt lanyard are useful for attaching tool bags and equipment to the tower at convenient spots. These hooks are better than using rope and tying knots because in many cases they can be hooked and unhooked with one hand.

Many hams use climbing belts such as shown in Fig 1. But fully integrated fall-arrest and positioning safety harnesses are preferable. The model ASL-301 in **Fig 2** has a D-ring on the back of the harness to which a safety lanyard is attached. These harnesses are available through Champion Radio Products, Box 572, Woodinville, WA 98072, **www.championradio.com**.

Rope and Pulley

Every amateur who owns a tower should also own a

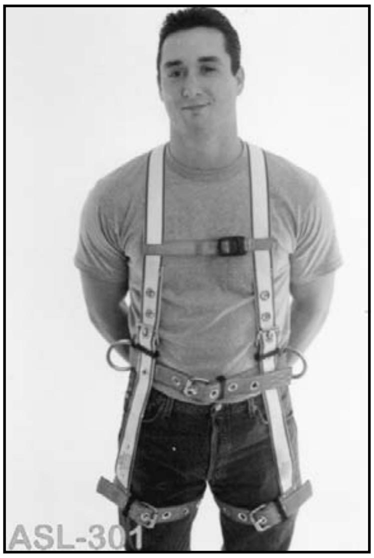

Fig 2—Fall-arrest safety harness integrated with positioning safety belt for tower climbing. *(Courtesy of Champion Radio Products)*

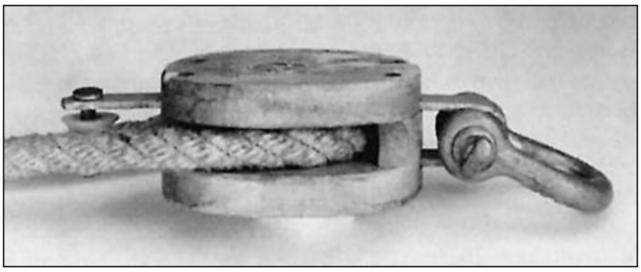

Fig 3—A good quality rope and pulley are essential for anyone working on towers and antennas. This pulley is encased in wood so the rope cannot jump out of the pulley wheel and jam.

good quality rope at least twice as long as the tower height. The rope is essential for safely erecting towers and installing antennas and cables. For most installations, a good quality $^1/_2$-inch diameter manila hemp rope will do the job, although a thicker rope is stronger and may be easier to handle. Some types of polypropylene rope are acceptable also; check the manufacturer's strength ratings. Nylon rope is not recommended because it tends to stretch and cannot be securely knotted without difficulty.

Check your rope before each use for tearing or chafing. Do not attempt to use damaged rope; if it breaks with a tower section or antenna in mid-air, property damage and personal injury are likely results. If your rope should get wet, let it air dry thoroughly before putting it away.

Another very worthwhile purchase is a pulley like the one shown in **Fig 3**. Use the right size pulley for your rope. Be sure that the pulley you purchase will not jam or bind as the rope passes through it.

THE GIN POLE

A gin pole, like the one shown in **Fig 4**, is a handy device for working with tower sections and masts. This gin pole is designed to clamp onto one leg of Rohn No. 25 or 45 tower. The tubing, which is about 12 feet long,

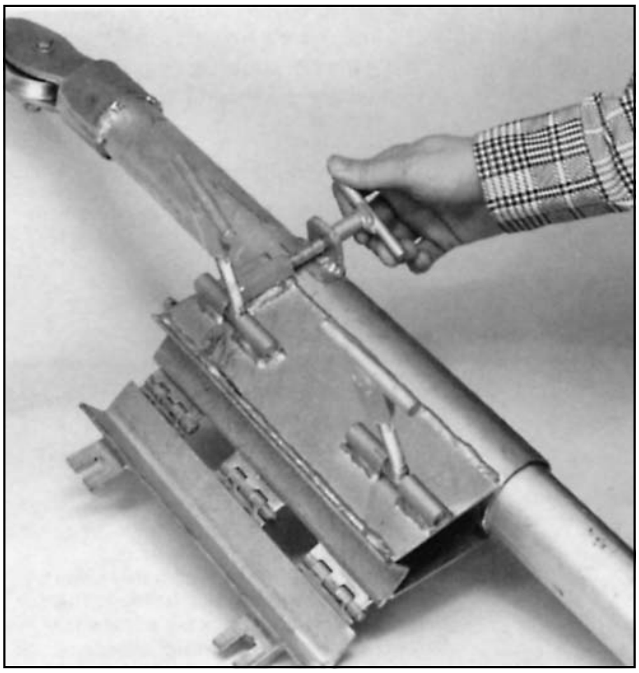

Fig 4—A gin pole is a mechanical device that can be clamped to a tower leg to aid in the assembly of sections as well as the installation of the mast. The aluminum tubing extends through the clamp and may be slipped into position before the tubing clamp is tightened. A rope should be routed through the tubing and over the pulley mounted at the top.

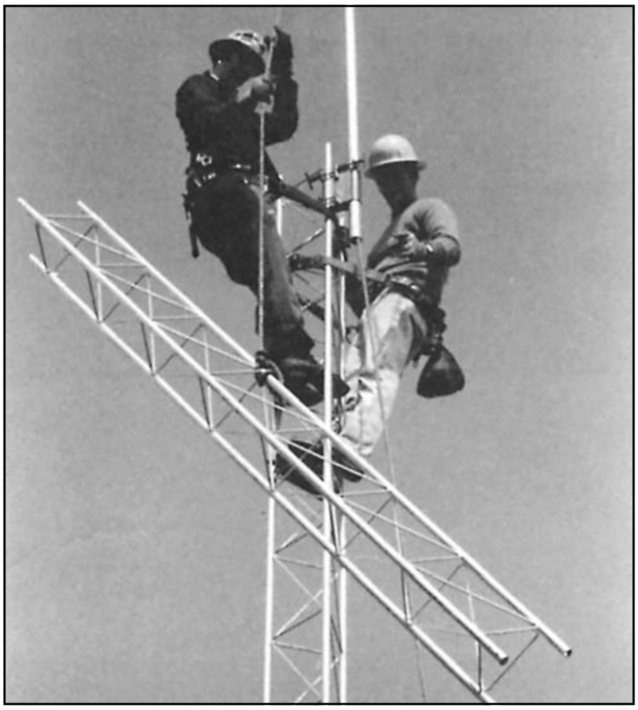

Fig 5—The assembly of tower sections is made simple when a gin pole is used to lift each one into position. Note that the safety belts of both climbers are fastened below the pole, thereby preventing the strap from slipping over the top section. (*Photo by K1WA*)

has a pulley on one end. The rope is routed through the tubing and over the pulley. When the gin pole is attached to the tower and the tubing extended into place, the rope may be used to haul tower sections or the mast into place. **Fig 5** shows the basic process. A gin pole can be expensive for an individual to buy, especially for a one-time tower installation. Some radio clubs own a gin pole for use by their members. Stores that sell tower sections to amateurs and commercial customers frequently will rent a gin pole to erect the tower. If you attempt to make your own gin pole, use materials heavy enough for the job. Provide a means for securely clamping the pole to the tower. There are many cases on record where homemade gin poles have failed, sending tower sections crashing down amidst the ground crew.

When you use a gin pole, make every effort to keep the load as vertical as possible. Although gin poles are strong, you are asking for trouble if you apply too much lateral force.

INSTALLING ANTENNAS ON THE TOWER

All antenna installations are different in some respects. Therefore, thorough planning is the most important first step in installing any antenna. At the beginning, before anyone climbs the tower, the whole process should be thought through. The procedure should be discussed to be sure each crew member understands what is to be done. Plan how to work out all bugs. Consider what tools and parts must be assembled and what items must be taken up the tower. Extra trips up and down the tower can be avoided by using forethought.

Getting ready to raise a beam requires planning. Done properly, the actual work of getting the antenna into position can be accomplished quite easily with only one person at the top of the tower. The trick is to let the ground crew do all the work and leave the person on the tower free to guide the antenna into position.

Before the antenna can be hoisted into position, the tower and the area around it must be prepared. The ground crew should clear the area around the base while someone climbs the tower to remove any wire antennas or other objects that might get in the way. The first person to climb the tower should also rig the rope and pulley that will be used to raise the antenna. The time to prepare the tower is before the antenna leaves the ground, not after it becomes hopelessly entwined with your 3.5-MHz dipole.

SOME TOWER CLIMBING TIPS

The following tower climbing safety tips were compiled by Tom Willeford, N8ETU. The most important safety factor in any kind of hazardous endeavor is the right attitude. Safety is important and worthy of careful consideration and implementation. The right attitude toward safety is a requirement for tower climbers. Lip service won't do, however; safety must be practiced.

The safe ham's safety attitude is simple: *Don't take any unnecessary chances*. There are no exceptions to this plain and simple rule. It is the first rule of safety and, of course, of climbing. The second rule is equally simple: *Don't be afraid to terminate an activity* (climbing, in this case) at any time if things don't seem to be going well.

Take time to plan your climb; this time is never wasted, and it's the first building block of safety. Talk the climb over with friends who will be helping you. Select the date and alternative dates to do the work. Choose someone to be responsible for all activities on the ground and for all communication with the climbers. Study the structure to be climbed and choose the best route to your objective. Plan emergency ascent and descent paths and methods.

Make a list of emergency phone numbers to keep by your phone, even though they may never be used. Develop a plan for rescuing climbers from the structure, should that become necessary.

Give careful thought to how much time you will need to complete the project. Allow enough time to go up, do the work, and then climb down during daylight hours. Include time for resting during the climb and for completing the work in a quality fashion. Remember that the

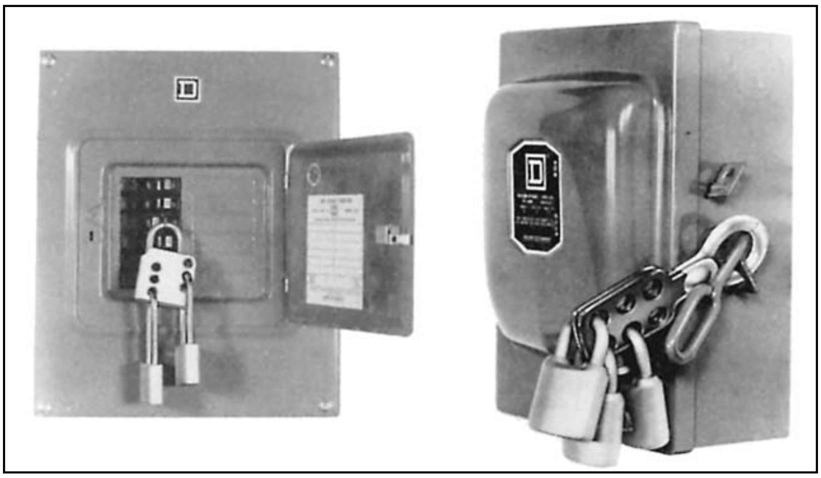

Fig 6—If the switch box feeding power to equipment on your tower is equipped with a lock-out hole, use it. With a lock through the hole on the box, the power cannot be accidentally turned back on. (*Photos courtesy of American ED CO®, at left, and Osborn Mfg Corp, at right.*)

temperature changes fast as the sun goes down. Climbing up or down a tower with cold hands and feet is very difficult—and dangerous.

Give careful consideration to the weather, and climb only in good weather. Investigate wind conditions, the temperature, and the weather forecast. The weather can change quickly, so if you're climbing a really tall tower, it may be a good idea to have a weather alert radio handy during the climb. *Never* climb a wet tower.

The person who is going to do the climbing should be the one to disconnect and tag all sources of power to the structure. All switches or circuit breakers should be labeled clearly with DO NOT TOUCH instructions. Use locks on any switches designed to accept them. (See **Fig 6**.) Only the climber should reconnect power sources.

An important part of the climbing plan is to review notes on the present installation and any previous work. It's a good idea to keep a notebook, listing every bolt and nut size on your tower/antenna installation. Then, when you have to go up to make repairs, you'll be able to take the minimum number of tools with you to do the job. If you take too many tools up the tower, there is a much greater chance of dropping something, risking injury to the ground crew and possibly damaging the tool.

It is also a good idea to review the instruction sheets and take them with you. In other words, plan carefully what you are going to do, and what you'll need to do it efficiently and safely.

It's better to use a rope and pulley to hoist tools. Climbing is hard work and there's no sense making it more difficult by carrying a big load of tools. Always rig the pulley and rope so the ground crew raises and lowers tools and equipment.

Climbing Equipment

Equipment is another important safety consideration. By equipment, we don't just mean tools. We mean safety equipment. Safety equipment should be selected and cared for as if your life depends on it—because it does!

The list of safety equipment essential to a safe climb and safe work on the tower should include:

1) A first class safety belt,
2) Safety glasses,
3) Hard hat,
4) Long-sleeved, pull-over shirt with no buttons or openings to snag (long sleeves are especially important for climbing wooden poles),
5) Long pants without cuffs,
6) Firm, comfortable, steel-shank shoes with no-slip soles and well-defined heels, and
7) Gloves that won't restrict finger movement (insulated gloves if you MUST work in cold weather).

Your safety belt should be approved for use on the structure you are climbing. Different structures may require different types of safety hooks or straps. The belt should be light weight, but strength should not be sacrificed to save weight. It should fit you comfortably. All moving parts, such as snap hooks, should work freely. You should inspect safety belts and harnesses carefully and thoroughly before each climb, paying particular attention to stitching, rivets and weight-bearing mechanical parts.

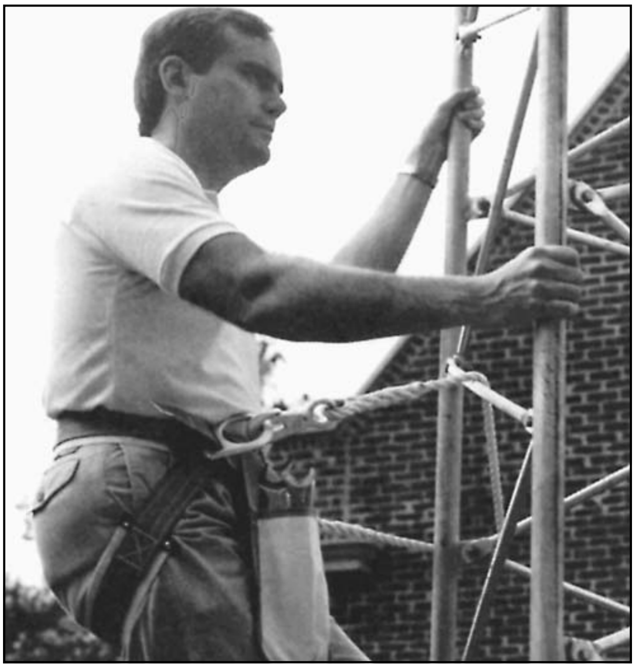

Fig 7—Mark Wilson, K1RO, shows the proper way to attach a safety hook, with the hook opening facing away from the tower. That way the hook can't be accidentally released by pressing it against a tower leg.

Support belt hooks should always be hooked to the D rings in an outward configuration. That is, the opening part of the hook should face away from the tower when engaged in the D rings (see **Fig 7**). Hooks engaged this way are easier to unhook deliberately but won't get squeezed open by a part of the tower or engage and snag a part of the tower while you are climbing. The engagement of these hooks should always be checked visually. A snapping hook makes the same sound whether it's engaged or not. Never check by sound—look to be sure the hook is engaged properly before trusting it.

Remember that the D rings on the safety belt are for support hooks *only*. No tools or lines should be attached to these hooks. Such tools or lines may prevent the proper engagement of support belt hooks, or they may foul the hooks. At best, they could prevent the release of the hooks in an emergency. No one should have to disconnect a support hook to get a tool and then have to reconnect the support hook before beginning to work again. That's foolish.

Equipment you purchase new is best. Homemade belts or home-spliced lines are dangerous. Used belts may have worn or defective stitching, or other faulty components. Be careful of so-called "bargains" that could cost you your life.

Straps, lanyards and lines should be as short as possible. Remember, in general knots reduce the load strength of a line by approximately 50%.

Before actually climbing, check the structure visually. Review the route. Check for obstacles, both natural (like wasp's nests) and man-made. Check the structure supports and add more if necessary. Guy wires can be obstacles to the climb, but it's better to have too many supports than not enough. Check your safety belt, support belts and hooks at the base of the tower. Really test them before you need them. Never leave the ground without a safety belt—even 5 or 10 feet. After all of this, the climb will be a "cake walk" if you are careful.

Climb slowly and surely. Don't overreach or overstep. Patience and watchfulness is rewarded with good hand and foot holds. Take a lesson from rock climbers. Hook on to the tower and rest periodically during the climb. Don't try to rest by wedging an arm or leg in some joint; to rest, hook on. Rests provide an opportunity to review the remainder of the route and to make sure that your safety equipment feels good and is working properly. Rest periods also help you conserve a margin of energy in case of difficulty.

Finally, keep in mind that the most dangerous part of working on a tower occurs when you are actually climbing. Your safety equipment is not hooked up at this time, so be extra careful during the ascent or descent.

You must climb the tower to install or work on an antenna. Nevertheless, any work that can be done on the ground should be done there. If you can do any assembly or make any adjustments on the ground, that's where you should do the work! The less time you have to spend on the tower, the better off you'll be.

When you arrive at the work area, hook on to the tower and review what you have to do. Determine the best position to do the work from, disconnect your safety strap and move to that position. Then reconnect your safety strap at a safe spot, away from joints and other obstacles. If you must move around an obstacle, try to do it while hooked on to the tower. Find a comfortable position and go to work. Don't overreach—move to the work.

Use the right tool for the task. If you don't have it, have the ground crew haul it up. Be patient. Lower tools, don't drop them, when you are finished with them. Dropped tools can bounce and cause injury or damage, or can be broken or lost. It's a good idea to tie a piece of string or light rope to the tools, and to tie the other end to the tower or some other point so if you do drop a tool, it won't fall all the way to the ground. Don't tie tools to the D ring or your safely belt, however!

Beware of situations where an antenna may be off balance. It's hard to obtain the extra leverage needed to handle even a small beam when you are holding it far from the balance point. Leverage can apply to the climber as well as the device being levered. Many slips and skinned knuckles result from such situations. A severely injured hand or finger can be a real problem to a climber.

Before descending, be sure to check all connections and the tightness of all the bolts and nuts that you have worked with. Have the ground crew use the rope and pulley to lower your tools. Lighten your load as much as possible. Remember, you're more tired coming down than going up. While still hooked on, wiggle your toes and move a little to get your senses working again. Check your downward route and begin to descend slowly and even more surely than you went up. Rest is even more important during the descent.

The ground captain is the director of all activities on the ground, and should be the only one to communicate with a person on a tower. Hand-held transceivers can be very helpful for this communication, but no one else should transmit to the workers on the tower. Even minor confusion or misunderstanding about a move to be made could be very dangerous.

"Antenna parties" can be lots of fun, but the joking and fooling around should wait until the job is done and everyone is down safely. Save the celebrating until after the work is completed, even for the ground crew.

These are just a few ideas on tower climbing safety; no list can include everything that you might run into. Check Chapter 22 for additional ideas. *Just remember—you can't be too careful when climbing*. Keep safety in mind while doing antenna work, and help ensure that after you have fallen *for* ham radio, you don't fall *from* ham radio.

THE TOWER SHIELD

A tower can be legally classified as an "attractive nuisance" that could cause injuries. You should take some precautions to ensure that "unauthorized climbers" can't get hurt on your tower. This tower shield was originally described by Baker Springfield, W4HYY, and Richard Ely, WA4VHM, in September 1976 *QST*, and should eliminate the worry.

Generally, the attractive-nuisance doctrine applies to your responsibility to trespassers on your property. (The law is much stricter with regard to your responsibility to an invited guest.) You should expect your tower to attract children, whether they are already technically trespassing

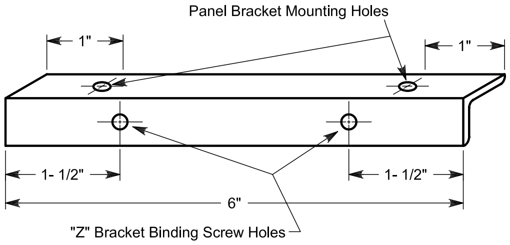

Fig 8—Z-bracket component pieces.

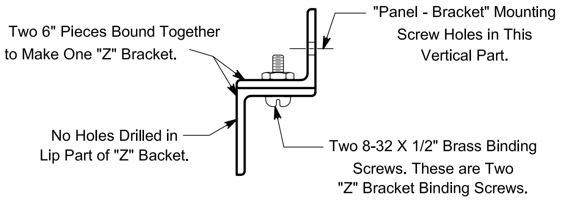
Two 6" Pieces Bound Together
to Make One "Z" Bracket.
"Panel - Bracket" Mounting
Screw Holes in This
Vertical Part.
No Holes Drilled in
Lip Part of "Z" Backet.
Two 8-32 X 1/2" Brass Binding
Screws. These are Two
"Z" Bracket Binding Screws.

Fig 9—Assembly of the Z bracket.

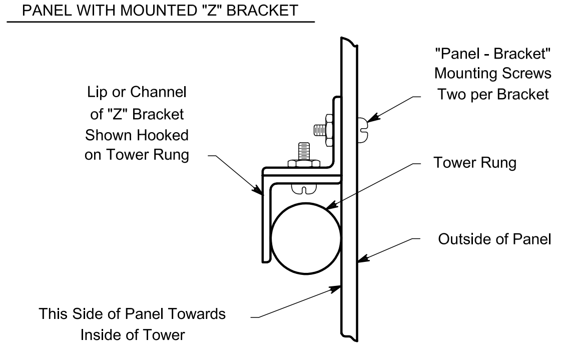
PANEL WITH MOUNTED "Z" BRACKET
"Panel - Bracket"
Mounting Screws
Two per Bracket
Lip or Channel
of "Z" Bracket
Shown Hooked
on Tower Rung
Tower Rung
Outside of Panel
This Side of Panel Towards
Inside of Tower

Fig 10—Installation of the shield on a tower rung.

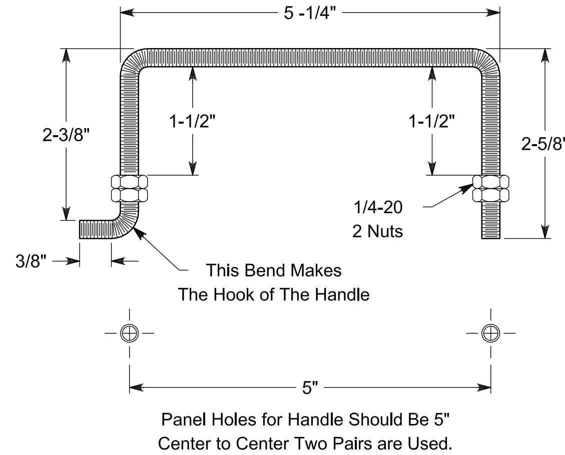
5 -1/4"
2-3/8"
1-1/2"
1-1/2"
2-5/8"
1/4-20
2 Nuts
3/8"
This Bend Makes
The Hook of The Handle
5"
Panel Holes for Handle Should Be 5"
Center to Center Two Pairs are Used.

Notes:

1. Standard Rodstock 1/4"-20 X 36" was Used.
2. Two Pieces were Cut from Rod Stock. Each Approximately 10 7/8".
3. Make The Three Bends of The Rod in Vise.
4. Two Nuts 1/4-20 of The Same Threads as Rods. Jam or Lock Together.This Makes a Handle Stop.

Fig 11—Removable handle construction.

or whether the tower itself lures them onto your property. A tower is dangerous to children, especially because of their inability to appreciate danger. (What child could resist trying to climb a tower once they see one?) Because of this danger, you have a legal duty to exercise reasonable care to eliminate the danger or otherwise protect children against the perils of the attraction.

The tower shield is composed simply of panels that enclose the tower and make climbing practically impossible. These panels are 5 feet in height and are wide enough to fit snugly between the tower legs and flat against the rungs. A height of 5 feet is sufficient in almost every case. The panels are constructed from 18-gauge galvanized sheet metal obtained and cut to proper dimensions from a local sheet-metal shop. A lighter gauge could probably be used, but the extra physical weight of the heavier gauge is an advantage if no additional means of securing the panels to the tower rungs are used. The three types of metals used for the components of the shield are supposedly rust proof and nonreactive. The panels are galvanized sheet steel, the brackets aluminum, and the screws and nuts are brass. For a triangular tower, the shield consists of three panels, one for each of the three sides, supported by two brackets. Construct these brackets from 6-inch pieces of thin aluminum angle stock. Bolt two of the pieces together to form a Z bracket (see **Figs 8**, **9** and **10**). The Z brackets are bolted together with binding head brass machine screws.

Lay the panels flat for measuring, marking and drilling. First measure from the top of the upper mounting rung on the tower to the top of the bottom rung. (Mounting rungs are selected to position the panel on the tower.) Then mark this distance on the panels. Use the same size brass screws and nuts throughout the shield. Bolt the top vertical portion of each Z bracket to the panel. Drill the mounting-screw holes about 1 inch from the end of the Z

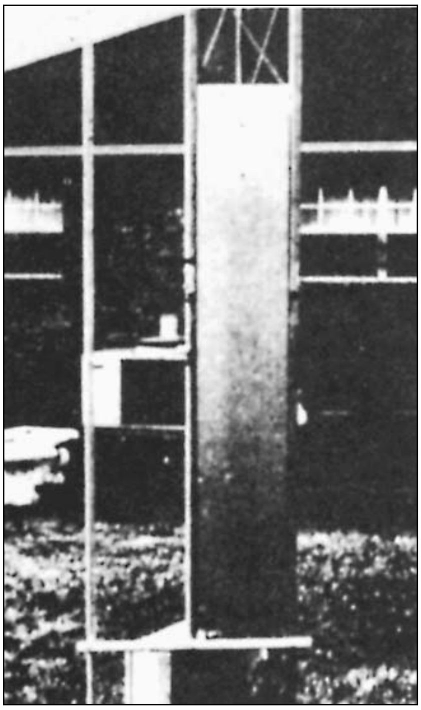

Fig 12—Installed tower shield. Note the holes for using the handles.

brackets so there is an offset clearance between the Z-bracket binding-screw holes and the panel-bracket mounting-screw holes. Drill holes in each panel to match the Z-bracket holes.

The panels are held on the tower by their own weight. They are not easy to grasp because they fit snugly between the tower legs. If you feel a need for added safety against deliberate removal of the panels, this can be accomplished by means of tie wires. Drill a small hole in the panel just above, just below, and in the center of each Z bracket. Run a piece of heavy galvanized wire through the top hole, around the Z bracket, and then back through the hole just below the Z bracket. Twist together the two ends of the wire. One tie wire should be sufficient for each panel, but use two if desired.

The completed panels are rather bulky and difficult to handle. A feature that is useful if the panels have to be removed often for tower climbing or accessibility is a pair of removable handles. The removable handles can be constructed from one threaded rod and eight nuts (see **Fig 11**). Drill two pair of handle holes in the panels a few inches below the top Z bracket and several inches above the bottom Z bracket. For panel placement or removal, you can hook the handles in these panel holes. The hook, on the top of the handle, fits into the top hole of each pair of the handle holes. The handle is optional, but for the effort required it certainly makes removal and replacement much safer and easier.

Fig 12 shows the shield installed on a tower. This relatively simple device could prevent an accident.

Electrical Safety

Although the RF, ac and dc voltages in most amateur stations pose a potentially grave threat to life and limb, common sense and knowledge of safety practices will help you avoid accidents. Building and operating an Amateur Radio station can be, and is for almost all amateurs, a perfectly safe pastime. However, carelessness can lead to severe injury, or even death. The ideas presented here are only guidelines; it would be impossible to cover all safety precautions. Remember, there is no substitute for common sense.

A fire extinguisher is a requirement for the well-equipped amateur station. The fire extinguisher should be of the carbon-dioxide type to be effective in electrical fires. Store it in an easy-to-reach spot and check it at recommended intervals.

Family members should know how to turn the power off in your station. They should also know how to apply artificial respiration. Many community groups offer courses on cardiopulmonary resuscitation (CPR).

AC AND DC SAFETY

The primary wiring for your station should be controlled by one master switch, and other members of your household should know how to kill the power in an emergency. All equipment should be connected to a good ground. All wires carrying power around the station should be of the proper size for the current to be drawn and should be insulated for the voltage level involved. Bare wire, open-chassis construction and exposed connections are an invitation to accidents. Remember that high-current, low-voltage power sources are just as dangerous as high-voltage, low-current sources. Possibly the most-dangerous voltage source in your station is the 120-V primary supply; it is a hazard often overlooked because it is a part of everyday life. Respect even the lowliest power supply in your station.

Whenever possible, kill the power and unplug equipment before working on it. Discharge capacitors with an insulated screwdriver; don't assume the bleeder resistors are 100% reliable. In a power amplifier, always short the tube plate cap to ground just to be sure the supply is discharged. If you must work on live equipment, keep one hand in your pocket. Avoid bodily contact with any grounded object to prevent your body from becoming the return path from a voltage source to ground. Use insulated tools for adjusting or moving any circuitry. Never work alone. Have someone else present; it could save your life in an emergency.

National Electrical Code

The National Electrical Code® is a comprehensive document that details safety requirements for all types of electrical installations. In addition to setting safety standards for house wiring and grounding, the Code also contains a section on Radio and Television Equipment — Article 810. Sections C and D specifically cover Amateur Transmitting and Receiving Stations. Highlights of the section concerning Amateur Radio stations follow. If you are interested in learning more about electrical safety, you may purchase a copy of *The National Electrical Code* or *The National Electrical Code Handbook*, edited by Peter Schram, from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

Antenna installations are covered in some detail in the Code. It specifies minimum conductor sizes for different length wire antennas. For hard-drawn copper wire, the Code specifies #14 wire for open (unsupported) spans less than 150 feet, and #10 for longer spans. Copper-clad steel, bronze or other high-strength conductors may be #14 for spans less than 150 feet and #12 wire for longer runs. Lead-in conductors (for open-wire transmission line) should be at least as large as those specified for antennas.

The Code also says that antenna and lead-in conductors attached to buildings must be firmly mounted at least 3 inches clear of the surface of the building on nonabsorbent insulators. The only exception to this minimum distance is when the lead-in conductors are enclosed in a "permanently and effectively grounded" metallic shield. The exception covers coaxial cable.

According to the Code, lead-in conductors (except those covered by the exception) must enter a building through a rigid, noncombustible, nonabsorbent insulating tube or bushing, through an opening provided for the purpose that provides a clearance of at least 2 inches or through a drilled window pane. All lead-in conductors to transmitting equipment must be arranged so that accidental contact is difficult.

Transmitting stations are required to have a means of draining static charges from the antenna system. An antenna discharge unit (lightning arrester) must be installed on each lead-in conductor (except where the lead-in is protected by a continuous metallic shield that is permanently and effectively grounded, or the antenna is permanently and effectively grounded). An acceptable alternative to lightning arrester installation is a switch that connects the lead-in to ground when the transmitter is not in use.

Grounding conductors are described in detail in the Code. Grounding conductors may be made from copper, aluminum, copper-clad steel, bronze or similar erosion-resistant material. Insulation is not required. The "protective grounding conductor" (main conductor running to the ground rod) must be as large as the antenna lead-in, but not smaller than #10. The "operating grounding conductor" (to bond equipment chassis together) must be at least #14. Grounding conductors must be adequately supported and arranged so they are not easily damaged. They must run in as straight a line as practical between the mast or discharge unit and the ground rod.

The Code also includes some information on safety inside the station. All conductors inside the building must be at least 4 inches away from conductors of any lighting or signaling circuit except when they are separated from other conductors by conduit or a nonconducting material. Transmitters must be enclosed in metal cabinets, and the cabinets must be grounded. All metal handles and controls accessible by the operator must be grounded. Access doors must be fitted with interlocks that will disconnect all potentials above 350 V when the door is opened.

Ground

An effective ground system is necessary for every amateur station. The mission of the ground system is twofold. First, it reduces the possibility of electrical shock if something in a piece of equipment should fail and the chassis or cabinet becomes "hot." If connected properly, three-wire electrical systems ground the chassis, but older amateur equipment may use the ungrounded two-wire system. A ground system to prevent shock hazards is generally referred to as "dc ground."

The second job the ground system must perform is to provide a low-impedance path to ground for any stray RF current inside the station. Stray RF can cause equipment to malfunction and contributes to RFI problems. This low-impedance path is usually called "RF ground." In most stations, dc ground and RF ground are provided by the same system.

The first step in building a ground system is to bond together the chassis of all equipment in your station. Ordinary hookup wire will do for a dc ground, but for a good RF ground you need a low-impedance conductor. Copper strap, sold as "flashing copper," is excellent for this application, but it may be hard to find. Braid from coaxial cable is a popular choice; it is readily available, makes a low-impedance conductor, and is flexible.

Grounding straps can be run from equipment chassis to equipment chassis, but a more convenient approach is illustrated in **Fig 13**. In this installation, a $^1/_2$-inch diameter copper water pipe runs the entire length of the operating bench. A thick braid (from discarded RG-8 cable) runs from each piece of equipment to a clamp on the pipe. Copper water pipe is available at most hardware stores and home centers. Alternatively, a strip of flashing copper may be run along the rear of the operating bench.

After the equipment is bonded to a common ground bus, the ground bus must be wired to a good earth ground. This run should be made with a heavy conductor (braid is a popular choice, again) and should be as short and direct as possible. The earth ground usually takes one of two forms.

In most cases, the best approach is to drive one or more ground rods into the earth at the point where the conductor from the station ground bus leaves the house. The best ground rods to use are those available from an electrical supply house. These rods are 8 to 10 feet long and are made from steel with a heavy copper plating. Do not depend on shorter, thinly plated rods sold by some home electronics suppliers. These rods begin to rust almost immediately after they are driven into the soil, and they become worthless within a short time. Good ground rods, while more expensive initially, offer long-term protection.

If your soil is soft and contains few rocks, an acceptable alternative to "genuine" ground rods is $^1/_2$-inch diameter copper water pipe. A 6- to 8-foot length of this material offers a good ground, but it may bend while being driven into the earth. Some people have recommended that you make a connection to a water line and run water down through the copper pipe so that it forces its own

Fig 13—An effective station ground bonds the chassis of all equipment together with low-impedance conductors and ties into a good earth ground.

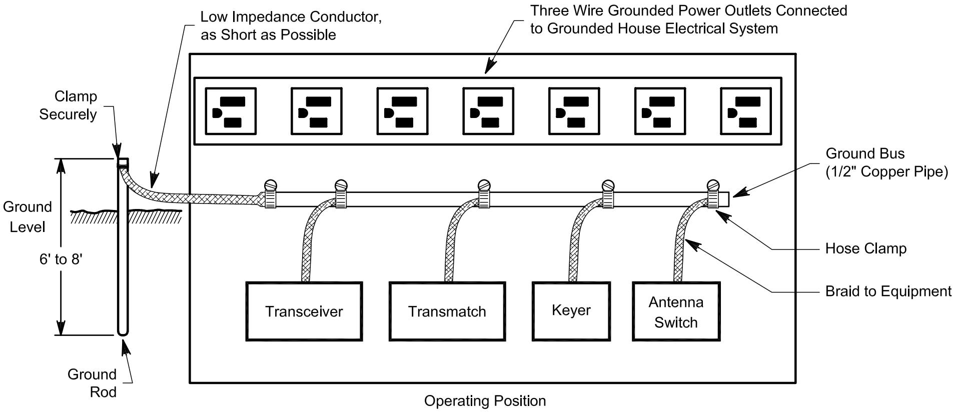
Low Impedance Conductor, as Short as Possible
Three Wire Grounded Power Outlets Connected to Grounded House Electrical System
Clamp Securely
Ground Bus (1/2" Copper Pipe)
Ground Level
6' to 8'
Hose Clamp
Braid to Equipment
Transceiver
Transmatch
Keyer
Antenna Switch
Ground Rod
Operating Position

hole in the ground. There may be a problem with this method, however. When the ground dries, it may shrink away from the pipe and not make proper contact with the ground rod. This would provide a rather poor ground.

Once the ground rod is installed, clamp the conductor from the station ground bus to it with a clamp that can be tightened securely and will not rust. Copper-plated clamps made especially for this purpose are available from electrical supply houses, but a stainless-steel hose clamp will work too. Alternatively, drill several holes through the pipe and bolt the conductor in place.

Another popular station ground is the cold water pipe system in the building. To take advantage of this ready-made ground system, run a low-impedance conductor from the station ground bus to a convenient cold water pipe, preferably somewhere near the point where the main water supply enters the house. Avoid hot water pipes; they do not run directly into the earth. The advent of PVC (plastic) plumbing makes it mandatory to inspect the cold water system from your intended ground connection to the main inlet. PVC is an excellent insulator, so any PVC pipe or fittings rule out your cold water system for use as a station ground.

For some installations, especially those located above the first floor, a conventional ground system such as that just described will make a fine dc ground but will not provide the necessary low-impedance path to ground for RF. The length of the conductor between the ground bus and the ultimate ground point becomes a problem. For example, the ground wire may be about $^1/_4$ λ (or an odd multiple of $^1/_4$ λ) long on some amateur band. A $^1/_4$-λ wire acts as an impedance inverter from one end to the other. Since the grounded end is at a very low impedance, the equipment end will be at a high impedance. The likely result is RF hot spots around the station while the transmitter is operating. A ground system like this may be worse than having no ground at all.

An alternative RF ground system is shown in **Fig 14**. Connect a system of $^1/_4$-λ radials to the station ground bus. Install at least one radial for each band used. You should still be sure to make a connection to earth ground for the ac power wiring. Try this system if you have problems with RF in the shack. It may just solve a number of problems for you. Be careful, however, to prevent contact with the ends of the radials, where there is high-voltage RF for powers greater than QRP level.

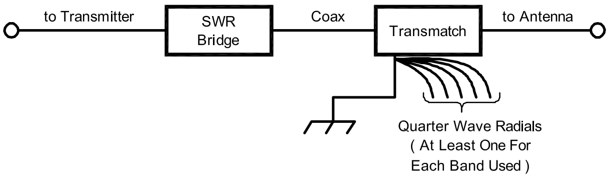
to Transmitter
SWR Bridge
Coax
Transmatch
to Antenna
Quarter Wave Radials (At Least One For Each Band Used)

Fig 14—Here is an alternative to earth ground if the station is located far from the ground point and RF in the station is a problem. Install at least one $^1/_4$-λ radial for each band used.

Ground Noise

Noise in ground systems can affect sensitive radio equipment. It is usually related to one of three problems:

1) Insufficient ground conductor size,
2) Loose ground connections, or
3) Ground loops.

These matters are treated in precise scientific research equipment and some industrial instruments by paying attention to certain rules. The ground conductor should be at least as large as the largest conductor in the primary power circuit. Ground conductors should provide a solid connection to both ground and to the equipment being grounded. Liberal use of lock washers and star washers is highly recommended. A loose ground connection is a tremendous source of noise, particularly in a sensitive receiving system.

Ground loops should be avoided at all costs. A short discussion of what a ground loop is and how to avoid them may lead you down the proper path. A ground loop is formed when more than one ground current is flowing in a single conductor. This commonly occurs when grounds are "daisy-chained" (series linked). The correct way to ground equipment is to bring all ground conductors out radially from a common point to either a good driven earth ground or to a cold water system.

Ground noise can affect transmitted as well as received signals. With the low audio levels required to drive amateur transmitters, and with the ever-increasing sensitivity of our receivers, correct grounding is critical.

Lightning and EMP Protection

The National Fire Protection Association (NFPA) publishes a booklet called *Lightning Protection Code* (NFPA no. 78-1983) that should be of interest to radio amateurs. For information about obtaining a copy of this booklet, write to the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269. Two paragraphs of particular interest to amateurs are presented below:

"3-26 Antennas. Radio and television masts of metal, located on a protected building, shall be bonded to the lightning protection system with a main size conductor and fittings.

"3-27 Lightning arresters, protectors or antenna discharge units shall be installed on electric and telephone service entrances and on radio and television antenna lead-ins."

The best protection from lightning is to disconnect all antennas from equipment and disconnect the equipment from the power lines. Ground antenna feed lines to safely bleed off static buildup. Eliminate the possible paths for lightning strokes. Rotator cables and other control cables from the antenna location should also be disconnected during severe electrical storms.

In some areas, the probability of lightning surges entering homes via the 120/240-V line may be high. Lightning produces both electrical and magnetic fields that vary with distance. These fields can be coupled into power lines and destroy electronic components in equipment that is miles from where the lightning occurred. Radio equipment can be protected from these surges to some extent by using transient-protective devices.

ELECTROMAGMETIC PULSE AND THE RADIO AMATEUR

The following material is based on a 4-part *QST* article by Dennis Bodson, W4PWF, that appeared in the August through November 1986 issues of *QST*. The series was condensed from the National Communications System report NCS TIB 85-10.

An equipment test program demonstrated that most Amateur Radio installations can be protected from lightning and electromagnetic pulse (EMP) transients with a basic protection scheme. Most of the equipment is not susceptible to damage when all external cabling is removed. You can duplicate this stand-alone configuration simply by unplugging the ac power cord from the outlet, disconnecting the antenna feed line at the rear of the radio, and isolating the radio gear from any other long metal conductors. Often it is not practical to completely disconnect the equipment whenever it is not being used. Also, there is the danger that a lightning strike several miles away could induce a large voltage transient on the power lines or antenna while the radio is in use. You can add two transient-protection devices to the interconnected system, however, that will also closely duplicate the safety of the stand-alone configuration.

The ac power line and antenna feed line are the two important points that should be outfitted with transient protection. This is the minimum basic protection scheme recommended for all Amateur Radio installations. (For fixed installations, consideration should also be given to the rotator connections—see **Fig 15**.) Hand-held radios equipped with a "rubber duck" require no protection at the antenna jack. If a larger antenna is used with the hand-held, however, a protection device should be installed.

General Considerations

Because of the unpredictable energy content of a nearby lightning strike or other large transient, it is possible for a metal-oxide varistor (MOV) to be subjected to an energy surge in excess of its rated capabilities. This may result in the destruction of the MOV and explosive rupture of the package. These fragments can cause damage to nearby components or operators and possibly ignite flammable material. Therefore, the MOV should be physically shielded.

A proper ground system is a key factor in achieving protection from lightning and EMP transients. A low-impedance ground system should be installed to eliminate transient paths through radio equipment and to provide a good physical ground for the transient-suppression devices. A single-point ground system is recommended (**Fig 16**) to help prevent lightning from getting into the shack on the shields of antenna feed-line coaxes. Many hams use a well-grounded radio-entrance panel mounted *outside* the shack to ground their coaxes before they enter the house. **Fig 17** shows an entrance panel at K8CH's home in Michigan. All external conductors going to the radio equipment should enter and exit the station through this panel. Install all transient-suppression devices directly on the panel. Use

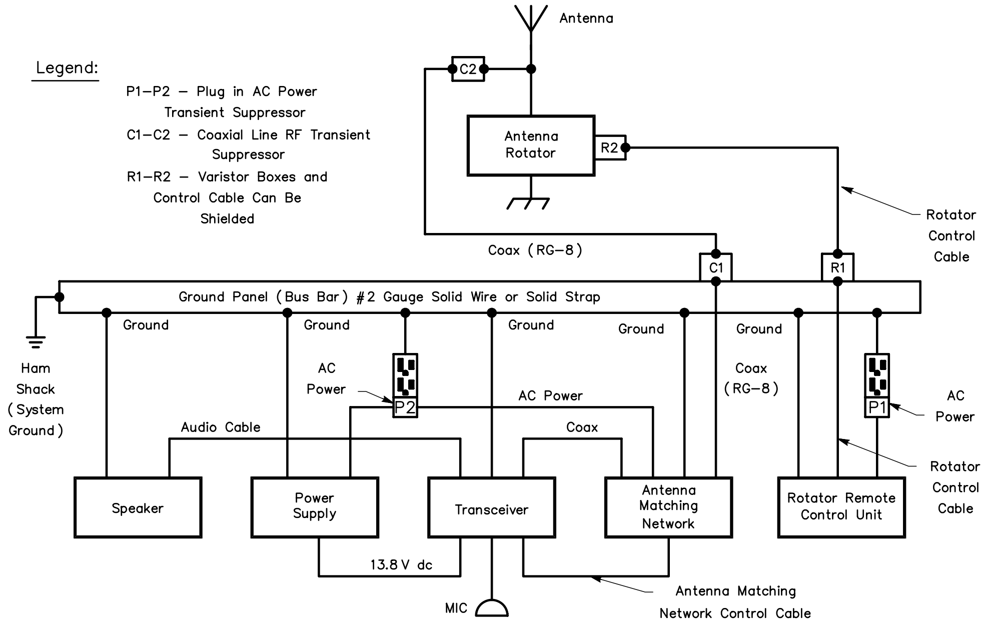
Antenna
Legend:
P1–P2 – Plug in AC Power Transient Suppressor
C1–C2 – Coaxial Line RF Transient Suppressor
R1–R2 – Varistor Boxes and Control Cable Can Be Shielded
C2
Antenna Rotator
R2
Rotator Control Cable
Coax (RG–8)
C1
R1
Ground Panel (Bus Bar) #2 Gauge Solid Wire or Solid Strap
Ground
Ground
Ground
Ground
Ground
Ham Shack (System Ground)
AC Power
P2
AC Power
Coax (RG–8)
P1
AC Power
Audio Cable
Coax
Rotator Control Cable
Speaker
Power Supply
Transceiver
Antenna Matching Network
Rotator Remote Control Unit
13.8 V dc
MIC
Antenna Matching Network Control Cable

Fig 15—Transient suppression techniques applied to an Amateur Radio station.

the shortest length(s) possible of #6 solid wire to connect the radio equipment case(s) to the ground bus.

Ac Power-Line Protection

Tests have indicated that household electrical wiring inherently limits the maximum transient current that it will pass to approximately 120 A. Therefore, if possible, the amateur station should be installed away from the house ac entrance panel and breaker box to take advantage of these limiting effects.

Ac power-line protection can be provided with easy-to-install, plug-in transient protectors. Ten such devices were tested for the article series in 1986. The plug-in-strip units are the best overall choice for a typical amateur installation. They provide the protection needed, they're simple to install and can be easily moved to other operating locations with the equipment.

In their tests, NCS found that the model that provided transient paths to ground from the hot and neutral lines (common mode) as well as the transient path between the hot and neutral lines (normal mode) performed best. The best model used three MOVs and a 3-electrode gas-discharge-tube arrester to provide fast operation and large power dissipation capabilities. This unit was tested repeatedly and operated without failure.

The flood of low-cost computers in the 1990s spawned a host of surge protection devices designed to limit transient voltage spikes coming from the ac line and also through the telephone line into a modem connected to a computer. Many of these devices are well-designed and can be relied upon to provide the protection they claim.

You can, however, easily find a variety of really low-cost bargain strips at flea markets and discount hardware stores. A bargain-brand $6 unit may prove to be a poor bargain indeed if it allows a spike to get through to damage your $2000 computer or $4000 transceiver.

You should be careful to find one that carries a sticker indicating that it meets Underwriters Laboratories safety standard UL 1449. This defines the minimum level of clamping voltage beyond which a surge protector will "fire" to protect the device connected to its output. The UL 1149 limit is 330 V ac. Prices for brand-name units from Tripp Lite, APC or Curtis vary from about $30 to $80, depending on how many ac sockets they have and the number of indicator lights and switched/unswitched sockets. A brand-name device is well worth the small additional cost over the bargain-basement units.

A transient suppressor requires a 3-wire outlet; the outlet should be tested to ensure all wires are properly connected. In older houses, an ac ground may have to be installed by a qualified electrician. The ac ground must be available for the plug-in transient suppressor to function properly. The ac ground of the receptacle should be attached to the station ground bus, and the plug-in receptacle should be installed on the ground panel behind the radio equipment.

Emergency Power Generators

Emergency power generators provide two major transient-protection advantages. First, the station is disconnected from the commercial ac power system. This isolates the radio equipment from a major source of damaging transients. Second, tests have shown that the emergency power generator may not be susceptible to EMP transients.

When the radio equipment is plugged directly into the generator outlets, transient protection may not be

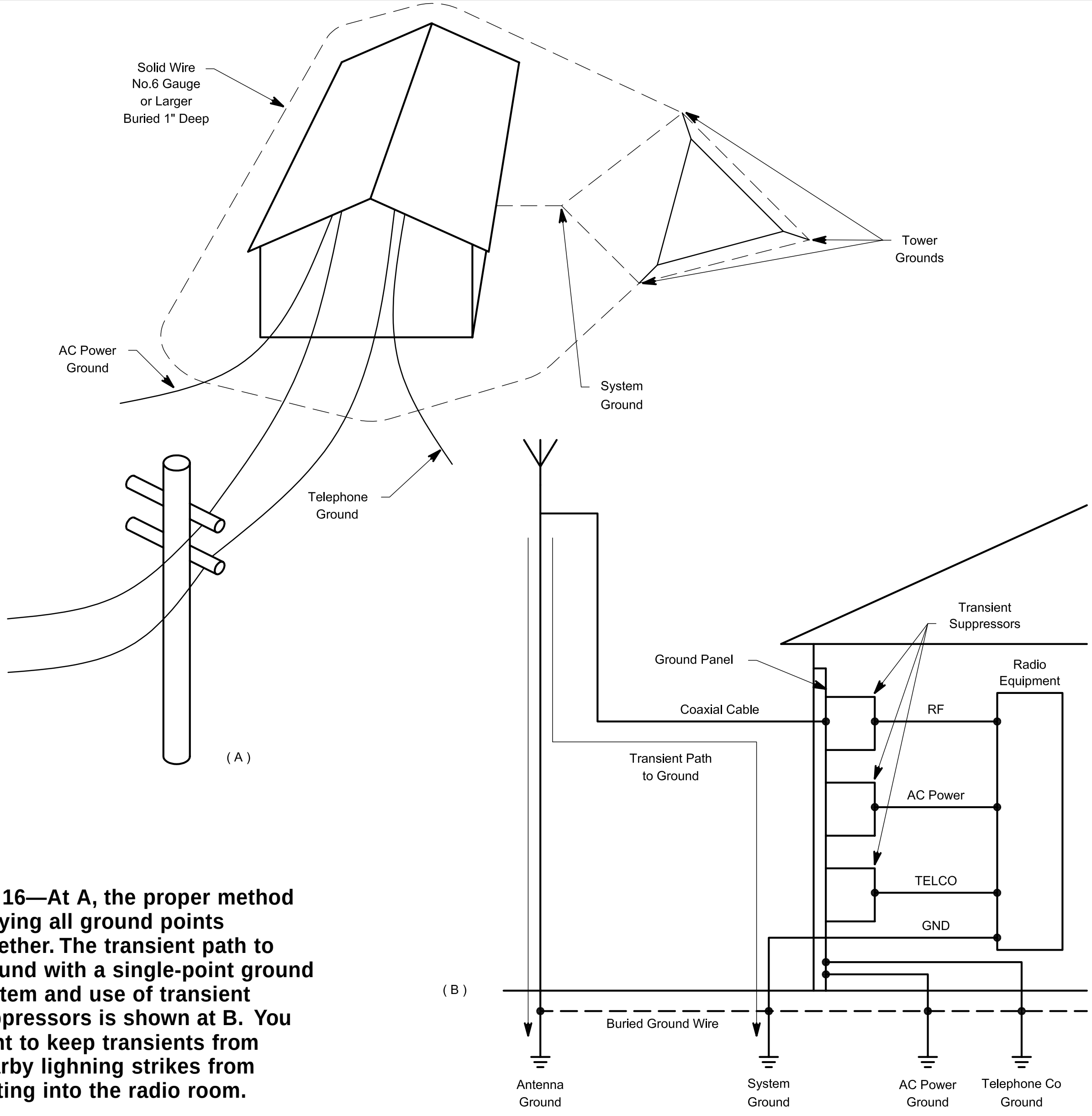
Solid Wire
No.6 Gauge
or Larger
Buried 1" Deep
Tower
Grounds
AC Power
Ground
System
Ground
Telephone
Ground
(A)
Transient
Suppressors
Ground Panel
Radio
Equipment
Coaxial Cable
RF
Transient Path
to Ground
AC Power
TELCO
GND
(B)
Buried Ground Wire
Antenna
Ground
System
Ground
AC Power
Ground
Telephone Co
Ground

Fig 16—At A, the proper method of tying all ground points together. The transient path to ground with a single-point ground system and use of transient suppressors is shown at B. You want to keep transients from nearby lightning strikes from getting into the radio room.

needed. If an extension cord or household wiring is used, transient protection should be employed.

An emergency power generator should be wired into the household circuit only by a qualified electrician. When properly connected, a switch is used to disconnect the commercial ac power source from the house lines before the generator is connected to them. This keeps the generator output from feeding back into the commercial power system. If this is not done, death or injury to unsuspecting linemen can result.

Feed-Line Protection

Coaxial cable is recommended for use as the transmission line because it provides a certain amount of transient surge protection for the equipment to which it is attached. The outer conductor shields the center conductor from the transient field. Also, the cable limits the maximum conducted transient voltage on the center by arcing the differential voltage from the center conductor to the grounded cable shield.

By providing a path to ground ahead of the radio equipment, the gear can be protected from the large currents impressed upon the antenna system by lightning and EMP. A single protection device installed at the radio antenna jack will protect the radio, but not the transmission line. To protect the transmission line, another tran-

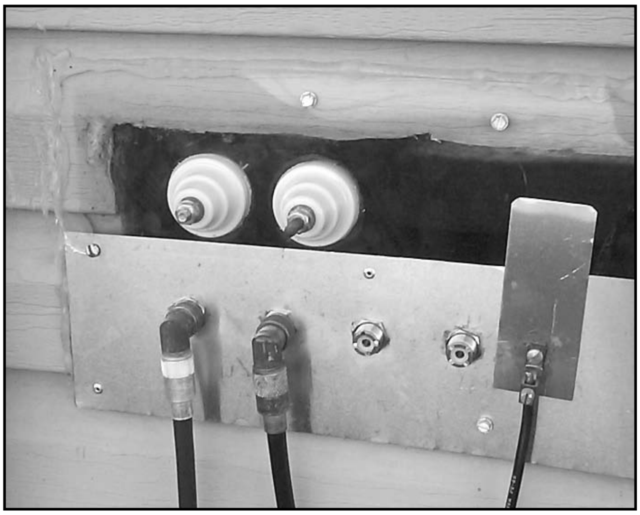

Fig 17—Radio-entrance panel at K8CH. A flat aluminum plate serves as a common grounding point for all coax cables to prevent transients from nearby lightning strikes from getting into the shack on the feed lines. "Spark-gap" protectors to kill transients on the coax inner conductors are located behind the panel. A spark-gap protector is also used on the two open-wire feeder insulators mounted on the Plexiglas sheet behind the aluminum panel.

sient protector must be installed between the antenna and the transmission line. (See Fig 15).

RF transient protection devices from several manufacturers were tested (see **Table 1**) using RG-8 cable equipped with UHF connectors. All of the devices shown can be installed in a coaxial transmission line. Recall that during the tests the RG-8 cable acted like a suppressor; damaging EMP energy arced from the center conductor to the cable shield when the voltage level approached 5.5 kV.

Low price and a low clamping-voltage rating must be considered in the selection of an RF transient-protection device. The lower cost devices have the higher clamping voltages, however, and the higher-cost devices have the lower clamping voltages. Because of this, medium-priced devices manufactured by Fischer Custom Communications were selected for testing. The Fischer Spikeguard Suppressors ($55 price class) for coaxial lines can be made to order to operate at a specific clamping voltage. The Fischer devices satisfactorily suppressed the damaging transient pulses, passed the transmitter RF output power without interfering with the signal, and operated effectively over a wide frequency range.

Polyphaser Corporation devices are also effective in providing the necessary transient protection. The devices available limited the transmitter RF output power to 100 W or less, however. These units cost approximately $83 each.

RF coaxial protectors should be mounted on the station ground bus bar. If the Fischer device is used, it should be attached to a grounded UHF receptacle that will serve as a hold-down bracket. This creates a conductive path between the outer shield of the protector and the bus bar. The Polyphaser device can be mounted directly to the bus bar with the bracket provided.

Attach the transceiver or antenna matching network to the grounded protector with a short (6 foot or less) piece of coaxial cable. Although the cable provides a ground path to the bus bar from the radio equipment, it is not a satisfactory transient-protection ground path for the transceiver. Another ground should be installed between the transceiver case and the ground bus using solid #6 wire. The coaxial cable shield should be grounded to the antenna tower leg at the tower base. Each tower leg should have an earth ground connection and be connected to the single-point ground system as shown in Fig 16.

Table 1
RF Coaxial-Line Protectors

Manufacturer	*Device*	*Approximate Cost (US Dollars)*	*Measured High-Z Clamping Voltage (Volts)*
Fischer	FCC-250-300-UHF	55	393
Fischer	FCC-250-350-UHF	55	260
Fischer	FCC-250-150-UHF	55	220
Fischer	FCC-250-120-UHF	55	240
Fischer	FCC-450-120-UHF	55	120
Polyphaser	IS-NEMP	83	140
Polyphaser	IS-NEMP-1	83	150
Polyphaser	IS-NEMP-2	83	160

Note: The transmitter output power, frequency of operation, and transmission line SWR must be considered when selecting any of these devices.

Antenna Rotators

Antenna rotators can be protected by plugging the control box into a protected ac power source and adding protection to the control lines to the antenna rotator. When the control lines are in a shielded cable, the shield must be grounded at both ends. MOVs of the proper size should be installed at both ends of the control cable. At the station end, terminate the control cable in a small metal box that is connected to the station ground bus. Attach MOVs from each conductor to ground inside the box. At the antenna end of the control cable, place the MOVs inside the rotator case or in a small metal box that is properly grounded.

For example, the Alliance HD73 antenna rotator uses a 6-conductor unshielded control cable with a maximum control voltage of 24.7 V dc. Select an MOV with a clamping voltage level 10% higher (27 V or more) so the MOV won't clamp the control signal to ground. If the control voltage is ac, be sure to convert the RMS voltage value to peak voltage when considering the clamping voltage level.

Mobile Power Supply Protection

The mobile amateur station environment exposes radio equipment to other transient hazards in addition to those of lightning and EMP. Currents as high as 300 A are switched when starting the engine, and this can produce voltage spikes of over 200 V on the vehicle's electrical system. Lightning and EMP are not likely to impact the vehicle's electrical system as much as they would that of a fixed installation because the automobile chassis is not normally grounded. This would not be the case if the vehicle is inadvertently grounded; for example, when the vehicle is parked against a grounded metal conductor. The mobile radio system has two advantages over a fixed installation: Lightning is almost never a problem, and the vehicle battery is a natural surge suppressor.

Mobile radio equipment should be installed in a way that takes advantage of the protection provided by the battery. See **Fig 18**. To do this, connect the positive power lead of the radio directly to the positive battery post, not to intermediate points in the electrical system such as the fuse box or the auxiliary contacts on the ignition switch. To prevent equipment damage or fire, in-line fuses should be installed in the positive lead where they are attached to the battery post.

An MOV should be installed between the two leads of the equipment power cord. A GE MOV (V36ZA80) is recommended for this application. This MOV provides the lowest measured clamping voltage (170 V) and is low in cost.

Mobile Antenna Installation

Although tests indicate that mobile radios can survive an EMP transient without protection for the antenna system, protection from lightning transients is still required. A coaxial-line transient suppressor should be installed on the vehicle chassis between the antenna and the radio's antenna connector.

A Fischer suppressor can be attached to a UHF receptacle that is mounted on, and grounded to, the vehicle chassis. The Polyphaser protector can be mounted on, and grounded to, the vehicle chassis with its flange. Use a short length of coaxial cable between the radio and the transient suppressor.

Clamping Voltage Calculation

When selecting any EMP-protection device to be used at the antenna port of a radio, several items must be considered. These include transmitter RF power output, the SWR, and the operating frequency. The protection device must allow the outgoing RF signal to pass without clamping. A clamping voltage calculation must be made for each amateur installation.

The RF-power input to a transmission line develops a corresponding voltage that becomes important when a voltage-surge arrester is in the line. SWR is important because of its influence on the voltage level. The maximum voltage developed for a given power input is determined by:

$$V = \sqrt{2 \times P \times Z \times SWR} \qquad \text{(Eq 1)}$$

where

P = peak power in W
Z = impedance of the coaxial cable (Ω)
V = peak voltage across the cable

Eq 1 should be used to determine the peak voltage present across the transmission line. Because the RF transient-protection devices use gas-discharge tubes, the voltage level at which they clamp is not fixed; a safety margin must be added to the calculated peak voltage. This is done

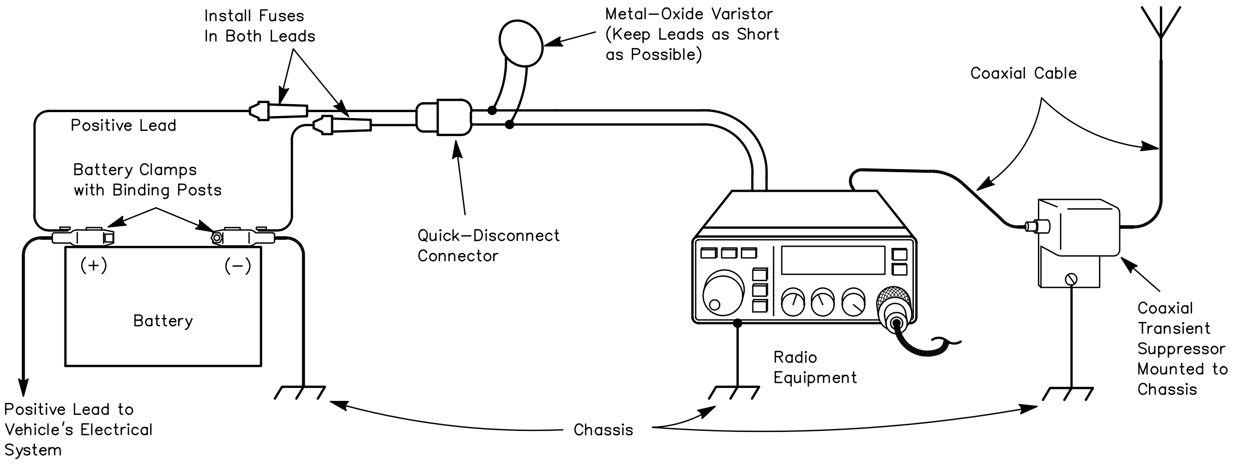
Install Fuses In Both Leads
Metal—Oxide Varistor (Keep Leads as Short as Possible)
Coaxial Cable
Positive Lead
Battery Clamps with Binding Posts
(+)
(−)
Battery
Quick—Disconnect Connector
Radio Equipment
Coaxial Transient Suppressor Mounted to Chassis
Positive Lead to Vehicle's Electrical System
Chassis

Fig 18—Recommended method of connecting mobile radio equipment to the vehicle battery and antenna.

by multiplying the calculated value by a factor of three. This added safety margin is required to ensure that the transmitter's RF output power will pass through the transient suppressor without causing the device to clamp the RF signal to ground. The final clamping voltage obtained is then high enough to allow normal operation of the transmitter while providing the lowest practical clamping voltage for the suppression device. This ensures the maximum possible protection for the radio system.

Here's how to determine the clamping voltage required. Let's assume the SWR is 1.5:1. The power output of the transceiver is 100 W PEP. RG/8 coaxial cable has an impedance of 52 Ω. Therefore:

$P = 100$ W
$Z = 52\ \Omega$
$SWR = 1.5$

Substituting these values into Eq 1:

$$V = \sqrt{2 \times 100 \times 52 \times 1.5} = 124.89 \text{ V peak}$$

Note that the voltage, V, is the peak value at the peak of the RF envelope. The final clamping voltage (FCV) is three times this value, or 374.7 V. Therefore, a coaxial-line transient suppressor that clamps at or above 375 V should be used.

The cost of a two-point basic protection scheme is estimated to be $100 for each fixed amateur station. This includes the cost of a good quality plug-in power-line protector ($45) and one Fischer coaxial-line protector ($55).

Inexpensive Transient-Protection Devices

Here are two low-cost protection devices you can assemble. They performed flawlessly in the tests.

The radio antenna connection can be protected by means of another simple device. As shown in **Fig 19**, two spark gaps (Siemens BI-A350) are installed in series at one end of a coaxial-cable T connector. Use the shortest practical lead length (about 1/4 inch) between the two spark gaps. One lead is bent forward and forced between the split sections of the inner coaxial connector until the spark gaps approach the body of the connector. A short length of insulating material (such as Mylar) is placed between the spark gaps and the connector shell. The other spark-gap lead is folded over the insulator, then conductive (metallic) tape is wrapped around the assembly. This construction method proved durable enough to allow many insertions and removals of the device during testing. Estimated cost of this assembly is $9. Similar devices can be built using components from Joslyn, General Electric, General Semiconductor or Siemens.

Summary

Amateurs should be aware of which components in their radio system are most likely to be damaged by EMP. They should also know how to repair the damaged equipment. Amateurs should know how to reestablish communications after an EMP event, taking into consideration its adverse effects on the earth's atmosphere and radio equipment. One of the first things that would be noticed, providing the radio equipment is operative, is a sudden silence in radio transmissions across all frequencies below approximately 100 MHz. This silence would be caused in part by damage to unprotected radio gear from the EMP transient. Transmissions from one direction, the direction of the nuclear blast, would be completely out. RF signal loss by absorption and attenuation by the nuclear fireball are the reasons for this.

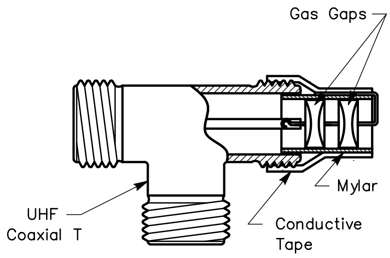

Fig 19—Pictorial diagram of an inexpensive, homemade RF coax transient protector.

After an EMP event, the amateur should be prepared to operate CW. CW gives the most signal power under adverse conditions. It also provides a degree of message security from the general public.

Amateurs should develop the capability and flexibility to operate in more than one frequency band. The lower ground-wave frequencies should be useful for long-distance communications immediately after an EMP event. Line-of-sight VHF would be of value for local communications.

What can be done to increase the survivability of an Amateur Radio station? Here are some suggestions:

1) If you have spare equipment, keep it disconnected; use only the primary station gear. The spare equipment would then be available after an EMP event.
2) Keep equipment turned off and antenna and power lines disconnected when the equipment is not in use.
3) Connect only those external conductors necessary for the current mode of operation.
4) Tie all fixed equipment to a single-point earth ground to prevent closed loops through the ground.
5) Obtain schematic diagrams of your equipment and tools for repair of the equipment.
6) Have spare parts on hand for sensitive components of the radio equipment and antenna system.
7) Learn how to repair or replace the sensitive components of the radio equipment.
8) Use nonmetallic guy lines and antenna structural parts where possible.
9) Obtain an emergency power source and operate from

it during periods of increased world political tension. The power source should be completely isolated from the commercial power lines.

10) Equipment power cords should be disconnected when the gear is idle. Or the circuit breaker for the line feeding the equipment should be kept in the OFF position when the station is off the air.
11) Disconnect the antenna lead-in when the station is off the air. Or use a grounding antenna switch and keep it in the GROUND position when the equipment is not in use.
12) Have a spare antenna and transmission line on hand to replace a damaged antenna system.
13) Install EMP surge arresters and filters on all primary conductors attached to the equipment and antenna.
14) Retain tube type equipment and spare components; keep them in good working order.
15) Do not rely on a microprocessor to control the station after an EMP event. Be able to operate without microprocessor control.

The recommendations contained in this section were developed with low cost in mind; they are not intended to cover all possible combinations of equipment and installation methods found in the amateur community. Amateurs should examine their own requirements and use this report as a guideline in providing protection for the equipment.

RF Radiation and Electromagnetic Field Safety

Amateur Radio is basically a safe activity. In recent years, however, there has been considerable discussion and concern about the possible hazards of electromagnetic radiation (EMR), including both RF energy and power-frequency (50-60 Hz) electromagnetic (EM) fields. FCC regulations set limits on the maximum permissible exposure (MPE) allowed from the operation of radio transmitters. These regulations do not take the place of RF-safety practices, however. This section deals with the topic of RF safety.

This section was prepared by members of the ARRL RF Safety Committee and coordinated by Dr Robert E. Gold, WBØKIZ. It summarizes what is now known and offers safety precautions based on the research to date.

All life on Earth has adapted to survive in an environment of weak, natural, low-frequency electromagnetic fields (in addition to the Earth's static geomagnetic field). Natural low-frequency EM fields come from two main sources: the sun, and thunderstorm activity. But in the last 100 years, man-made fields at much higher intensities and with a very different spectral distribution have altered this natural EM background in ways that are not yet fully understood. Researchers continue to look at the effects of RF exposure over a wide range of frequencies and levels.

Both RF and 60-Hz fields are classified as *nonionizing radiation,* because the frequency is too low for there to be enough photon energy to ionize atoms. (*Ionizing radiation*, such as X-rays, gamma rays and even some ultraviolet radiation has enough energy to knock electrons loose from their atoms. When this happens, positive and negative ions are formed.) Still, at sufficiently high power densities, EMR poses certain health hazards. It has been known since the early days of radio that RF energy can cause injuries by heating body tissue. (Anyone who has ever touched an improperly grounded radio chassis or energized antenna and received an *RF burn* will agree that this type of injury can be quite painful.) In extreme cases, RF-induced heating in the eye can result in cataract formation, and can even cause blindness. Excessive RF heating of the reproductive organs can cause sterility. Other health problems also can result from RF heating. These heat-related health hazards are called *thermal effects.* A microwave oven is a positive application of this thermal effect.

There also have been observations of changes in physiological function in the presence of RF energy levels that are too low to cause heating. These functions return to normal when the field is removed. Although research is ongoing, no harmful health consequences have been linked to these changes.

In addition to the ongoing research, much else has been done to address this issue. For example, FCC regulations set limits on exposure from radio transmitters. The Institute of Electrical and Electronics Engineers, the American National Standards Institute and the National Council for Radiation Protection and Measurement, among others, have recommended voluntary guidelines to limit human exposure to RF energy. The ARRL has established the RF Safety Committee, consisting of concerned medical doctors and scientists, serving voluntarily to monitor scientific research in the fields and to recommend safe practices for radio amateurs.

THERMAL EFFECTS OF RF ENERGY

Body tissues that are subjected to *very high* levels of RF energy may suffer serious heat damage. These effects depend on the frequency of the energy, the power density of the RF field that strikes the body and factors such as the polarization of the wave.

At frequencies near the body's natural resonant frequency, RF energy is absorbed more efficiently, and an increase in heating occurs. In adults, this frequency usually is about 35 MHz if the person is grounded, and about 70 MHz if insulated from the ground. Individual body parts may be resonant at different frequencies. The adult head, for example, is resonant around 400 MHz, while a baby's smaller head resonates near 700 MHz. Body size thus determines the frequency at which most RF energy is absorbed. As the frequency is moved farther from resonance, less RF heating generally occurs. *Specific absorption rate (SAR)* is a term that describes the rate at which RF energy is absorbed in tissue.

Maximum permissible exposure (MPE) limits are based on whole-body SAR values, with additional safety factors included as part of the standards and regulations. This helps explain why these safe exposure limits vary with frequency. The MPE limits define the maximum electric and magnetic field strengths or the plane-wave equivalent power densities associated with these fields, that a person may be exposed to without harmful effect—and with an acceptable safety factor. The regulations assume that a person exposed to a specified (safe) MPE level also will experience a safe SAR.

Nevertheless, thermal effects of RF energy should not be a major concern for most radio amateurs, because of the power levels we normally use and the intermittent nature of most amateur transmissions. Amateurs spend more time listening than transmitting, and many amateur transmissions such as CW and SSB use low-duty-cycle modes. (With FM or RTTY, though, the RF is present continuously at its maximum level during each transmission.) In any event, it is rare for radio amateurs to be subjected to RF fields strong enough to produce thermal effects, unless they are close to an energized antenna or un- shielded power amplifier. Specific suggestions for avoiding excessive exposure are offered later in this chapter.

ATHERMAL EFFECTS OF EMR

Research about possible health effects resulting from exposure to the lower level energy fields, the athermal effects, has been of two basic types: epidemiological research and laboratory research.

Scientists conduct laboratory research into biological mechanisms by which EMR may affect animals including humans. Epidemiologists look at the health patterns of large groups of people using statistical methods. These epidemiological studies have been inconclusive. By their basic design, these studies do not demonstrate cause and effect, nor do they postulate mechanisms of disease. Instead, epidemiologists look for associations between an environmental factor and an observed pattern of illness. For example, in the earliest research on malaria, epidemiologists observed the association between populations with high prevalence of the disease and the proximity of mosquito infested swamplands. It was left to the biological and medical scientists to isolate the organism causing malaria in the blood of those with the disease, and identify the same organisms in the mosquito population.

In the case of athermal effects, some studies have identified a weak association between exposure to EMF at home or at work and various malignant conditions including leukemia and brain cancer. A larger number of equally well designed and performed studies, however, have found no association. A risk ratio of between 1.5 and 2.0 has been observed in positive studies (the number of observed cases of malignancy being 1.5 to 2.0 times the "expected" number in the population). Epidemiologists generally regard a risk ratio of 4.0 or greater to be indicative of a strong association between the cause and effect under study. For example, men who smoke one pack of cigarettes per day increase their risk for lung cancer tenfold compared to nonsmokers, and two packs per day increases the risk to more than 25 times the nonsmokers' risk.

Epidemiological research by itself is rarely conclusive, however. Epidemiology only identifies health patterns in groups—it does not ordinarily determine their cause. And there are often confounding factors: Most of us are exposed to many different environmental hazards that may affect our health in various ways. Moreover, not all studies of persons likely to be exposed to high levels of EMR have yielded the same results.

There also has been considerable laboratory research about the biological effects of EMR in recent years. For example, some separate studies have indicated that even fairly low levels of EMR might alter the human body's circadian rhythms, affect the manner in which T lymphocytes function in the immune system and alter the nature of the electrical and chemical signals communicated through the cell membrane and between cells, among other things. Although these studies are intriguing, they do not demonstrate any effect of these low-level fields on the overall organism.

Much of this research has focused on low-frequency magnetic fields, or on RF fields that are keyed, pulsed or modulated at a low audio frequency (often below 100 Hz). Several studies suggested that humans and animals can adapt to the presence of a steady RF carrier more readily than to an intermittent, keyed or modulated energy source.

The results of studies in this area, plus speculations concerning the effect of various types of modulation, were and have remained somewhat controversial. None of the research to date has demonstrated that low-level EMR causes adverse health effects.

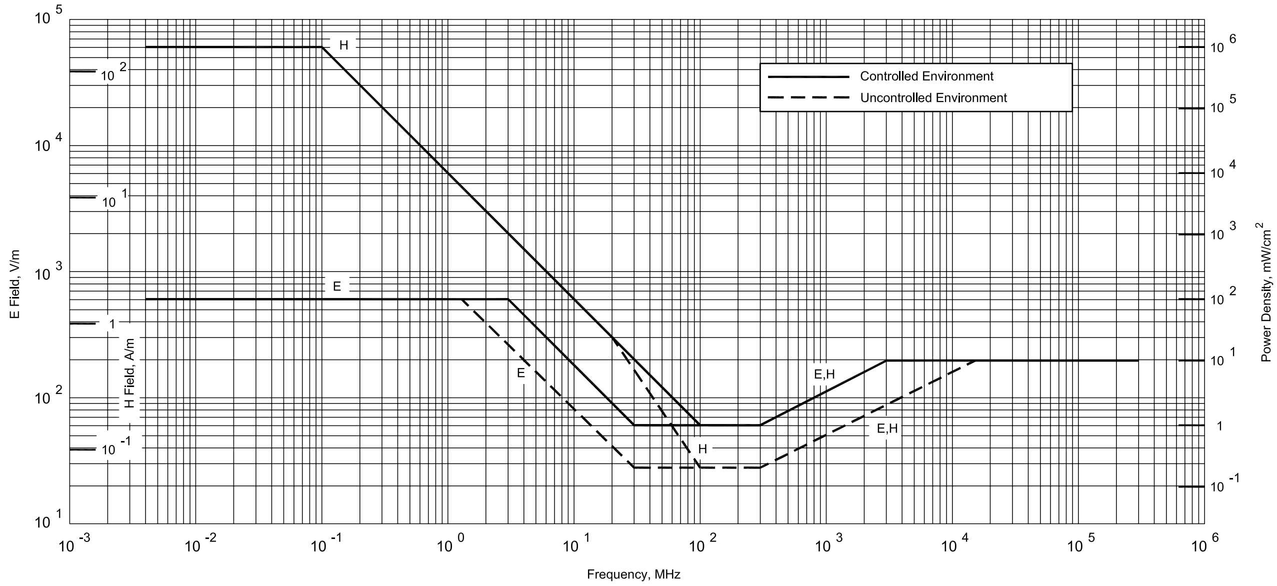

Fig 20—1991 RF protection guidelines for body exposure of humans. It is known officially as the "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz."

Given the fact that there is a great deal of ongoing research to examine the health consequences of exposure to EMF, the American Physical Society (a national group of highly respected scientists) issued a statement in May 1995 based on its review of available data pertaining to the possible connections of cancer to 60-Hz EMF exposure. This report is exhaustive and should be reviewed by anyone with a serious interest in the field. Among its general conclusions were the following:

1. The scientific literature and the reports of reviews by other panels show no consistent, significant link between cancer and power line fields.
2. No plausible biophysical mechanisms for the systematic initiation or promotion of cancer by these extremely weak 60-Hz fields has been identified.
3. While it is impossible to prove that no deleterious health effects occur from exposure to any environmental factor, it is necessary to demonstrate a consistent, significant, and causal relationship before one can conclude that such effects do occur.

In a report dated October 31, 1996, a committee of the National Research Council of the National Academy of Sciences has concluded that no clear, convincing evidence exists to show that residential exposures to electric and magnetic fields (EMFs) are a threat to human health.

A National Cancer Institute epidemiological study of residential exposure to magnetic fields and acute lymphoblastic leukemia in children was published in the *New England Journal of Medicine* in July 1997. The exhaustive, seven-year study concludes that if there is any link at all, it is far too weak to be concerned about.

Readers may want to follow this topic as further studies are reported. Amateurs should be aware that exposure to RF and ELF (60 Hz) electromagnetic fields at all power levels and frequencies has not been fully studied under all circumstances. "Prudent avoidance" of any avoidable EMR is always a good idea. Prudent avoidance doesn't mean that amateurs should be fearful of using their equipment. Most amateur operations are well within the MPE limits. If any risk does exist, it will almost surely fall well down on the list of causes that may be harmful to your health (on the other end of the list from your automobile). It does mean, however, that hams should be aware of the potential for exposure from their stations, and take whatever reasonable steps they can take to minimize their own exposure and the exposure of those around them.

Safe Exposure Levels

How much EM energy is safe? Scientists and regulators have devoted a great deal of effort to deciding upon safe RF-exposure limits. This is a very complex problem, involving difficult public health and economic considerations. The recommended safe levels have been revised downward several times over the years —and not all scientific bodies agree on this question even today. An Institute of Electrical and Electronics Engineers (IEEE) standard for recommended EM exposure limits was published in 1991 (see Bibliography). It replaced a 1982 American National Standards Institute (ANSI) standard. In the new standard, most of the permitted exposure levels were revised downward (made more stringent), to better reflect the current research. The new IEEE stan-

FCC RF-Exposure Regulations

FCC regulations control the amount of RF exposure that can result from your station's operation (§§97.13, 97.503, 1.1307 (b)(c)(d), 1.1310 and 2.1093). The regulations set limits on the maximum permissible exposure (MPE) allowed from operation of transmitters in all radio services. They also require that certain types of stations be evaluated to determine if they are in compliance with the MPEs specified in the rules. The FCC has also required that five questions on RF environmental safety practices be added to Novice, Technician and General license examinations.

These rules went into effect on January 1, 1998 for new stations or stations that file a Form 605 application with the FCC. Other existing stations have until September 1, 2000 to be in compliance with the rules.

The Rules

Maximum Permissible Exposure (MPE)

All radio stations regulated by the FCC must comply with the requirements for MPEs, even QRP stations running only a few watts or less. The MPEs vary with frequency, as shown in **Table A**. MPE limits are specified in maximum electric and magnetic fields for frequencies below 30 MHz, in power density for frequencies above 300 MHz and all three ways for frequencies from 30 to 300 MHz. For compliance purposes, all of these limits must be considered *separately*. If any one is exceeded, the station is not in compliance.

The regulations control human exposure to RF fields, not the strength of RF fields. There is no limit to how strong a field can be as long as no one is being exposed to it, although FCC regulations require that amateurs use the minimum necessary power at all times (§97.311 [a]).

Environments

The FCC has defined two exposure environments — *controlled* and *uncontrolled*. A controlled environment is one in which the people who are being exposed are aware of that exposure and can take steps to minimize that exposure, if appropriate. In an uncontrolled environment, the people being exposed are not normally aware of the exposure. The uncontrolled environment limits are more stringent than the controlled environment limits.

Although the controlled environment is usually intended as an occupational environment, the FCC has determined that it generally applies to amateur operators and members of their immediate households. In most cases, controlled-environment limits can be applied to your home and property to which you can control physical access. The uncontrolled environment is intended for areas that are accessible by the general public, such as your neighbors' properties.

The MPE levels are based on average exposure. An averaging time of 6 minutes is used for controlled exposure; an averaging period of 30 minutes is used for uncontrolled exposure.

Table A—(From §1.1310) Limits for Maximum Permissible Exposure (MPE)

(A) Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	*Electric Field Strength (V/m)*	*Magnetic Field Strength (A/m)*	*Power Density (mW/cm²)*	*Averaging Time (minutes)*
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	$(900/f^2)$*	6
30-300	61.4	0.163	1.0	6
300-1500	—	—	f/300	6
1500-100,000	—	—	5	6

f = frequency in MHz

* = Plane-wave equivalent power density (see Note 1).

(B) Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	*Electric Field Strength (V/m)*	*Magnetic Field Strength (A/m)*	*Power Density (mW/cm²)*	*Averaging Time (minutes)*
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	$(180/f^2)$*	30
30-300	27.5	0.073	0.2	30
300-1500	—	—	f/1500	30
1500-100,000	—	—	1.0	30

f = frequency in MHz

* = Plane-wave equivalent power density (see Note 1).

Note 1: This means the equivalent far-field strength that would have the E or H-field component calculated or measured. It does not apply well in the near field of an antenna. The equivalent far-field power density can be found in the near or far field regions from the relationships: $P_d = |E_{total}|^2 / 3770$ mW/cm^2 or from $P_d = |H_{total}|^2 \times 37.7$ mW/cm^2.

Station Evaluations

The FCC requires that certain amateur stations be evaluated for compliance with the MPEs. Although an amateur can have someone else do the evaluation, it is not difficult for hams to evaluate their own stations. The ARRL book *RF Exposure and You* contains extensive information about the regulations and a large chapter of tables that show compliance distances for specific antennas and power levels. Generally, hams will use these tables to evaluate their stations. Some of these tables have been included in the FCC's information — *OET Bulletin 65* and its *Supplement B*. If hams choose, however, they can do more extensive calculations, use a computer to model their antenna and exposure, or make actual measurements.

Table B—Power Thresholds for Routine Evaluation of Amateur Radio Stations

Wavelength Band	*Evaluation Required if Power* (watts) Exceeds:*
MF	
160 m	500
HF	
80 m	500
75 m	500
40 m	500
30 m	425
20 m	225
17 m	125
15 m	100
12 m	75
10 m	50
VHF (all bands)	50
UHF	
70 cm	70
33 cm	150
23 cm	200
13 cm	250
SHF (all bands)	250
EHF (all bands)	250
Repeater stations (all bands)	*non-building-mounted antennas*: height above ground level to lowest point of antenna < 10 m *and* power > 500 W ERP *building-mounted antennas*: power > 500 W ERP

*Transmitter power = Peak-envelope power input to antenna. For repeater stations ***only,*** power exclusion based on ERP (effective radiated power).

Categorical Exemptions

Some types of amateur stations do not need to be evaluated, but these stations must still comply with the MPE limits. The station licensee remains responsible for ensuring that the station meets these requirements.

The FCC has exempted these stations from the evaluation requirement because their output power, operating mode and frequency are such that they are presumed to be in compliance with the rules.

Stations using power equal to or less than the levels in **Table B** do not have to be evaluated. For the 100-W HF ham station, for example, an evaluation would be required *only* on 12 and 10 meters.

Hand-held radios and vehicle-mounted mobile radios that operate using a push-to-talk (PTT) button are also categorically exempt from performing the routine evaluation. Repeater stations that use less than 500 W ERP or those with antennas not mounted on buildings, if the antenna is at least 10 meters off the ground, also do not need to be evaluated.

Correcting Problems

Most hams are already in compliance with the MPE requirements. Some amateurs, especially those using indoor antennas or high-power, high-duty-cycle modes such as a RTTY bulletin station and specialized stations for moonbounce operations and the like may need to make adjustments to their station or operation to be in compliance.

The FCC permits amateurs considerable flexibility in complying with these regulations. As an example, hams can adjust their operating frequency, mode or power to comply with the MPE limits. They can also adjust their operating habits or control the direction their antenna is pointing.

More Information

This discussion offers only an overview of this topic; additional information can be found in *RF Exposure and You* and on *ARRLWeb* at **www.arrl.org/news/rfsafety/**. *ARRLWeb* has links to the FCC Web site, with *OET Bulletin 65* and *Supplement B* and links to software that hams can use to evaluate their stations.

dard was adopted by ANSI in 1992.

The IEEE standard recommends frequency-dependent and time-dependent maximum permissible exposure levels. Unlike earlier versions of the standard, the 1991 standard recommends different RF exposure limits in controlled environments (that is, where energy levels can be accurately determined and everyone on the premises is aware of the presence of EM fields) and in uncontrolled environments (where energy levels are not known or where people may not be aware of the presence of EM fields). FCC regulations also include controlled/occupational and uncontrolled/general population exposure environments.

The graph in **Fig 20** depicts the 1991 IEEE standard. It is necessarily a complex graph, because the standards differ not only for controlled and uncontrolled environments but also for electric (E) fields and magnetic (H) fields. Basically, the lowest E-field exposure limits occur at frequencies between 30 and 300 MHz. The lowest H-field exposure levels occur at 100-300 MHz. The ANSI standard sets the maximum E-field limits between 30 and 300 MHz at a power density of 1 mW/cm^2 (61.4 V/m) in controlled environments—but at one-fifth that level (0.2 mW/cm^2 or 27.5 V/m) in uncontrolled environments. The H-field limit drops to 1 mW/cm^2 (0.163 A/m) at 100-300 MHz in controlled environments and 0.2 mW/cm^2 (0.0728 A/m) in uncontrolled environments. Higher power densities are permitted at frequencies below 30 MHz (below 100 MHz for H fields) and above 300 MHz, based on the concept that the body will not be resonant at those frequencies and will therefore absorb less energy.

In general, the 1991 IEEE standard requires averaging the power level over time periods ranging from 6 to

30 minutes for power-density calculations, depending on the frequency and other variables. The ANSI exposure limits for uncontrolled environments are lower than those for controlled environments, but to compensate for that the standard allows exposure levels in those environments to be averaged over much longer time periods (generally 30 minutes). This long averaging time means that an intermittently operating RF source (such as an Amateur Radio transmitter) will show a much lower power density than a continuous-duty station—for a given power level and antenna configuration.

Time averaging is based on the concept that the human body can withstand a greater rate of body heating (and thus, a higher level of RF energy) for a short time than for a longer period. Time averaging may not be appropriate, however, when considering nonthermal effects of RF energy.

The IEEE standard excludes any transmitter with an output below 7 W because such low-power transmitters would not be able to produce significant whole-body heating. (Recent studies show that hand-held transceivers often produce power densities in excess of the IEEE standard within the head.)

There is disagreement within the scientific community about these RF exposure guidelines. The IEEE standard is still intended primarily to deal with thermal effects, not exposure to energy at lower levels. A small but significant number of researchers now believe athermal effects also should be taken into consideration. Several European countries and localities in the United States have adopted stricter standards than the recently updated IEEE standard.

Another national body in the United States, the National Council for Radiation Protection and Measurement (NCRP), also has adopted recommended exposure guidelines. NCRP urges a limit of 0.2 mW/cm^2 for non-occupational exposure in the 30-300 MHz range. The NCRP guideline differs from IEEE in two notable ways: It takes into account the effects of modulation on an RF carrier, and it does not exempt transmitters with outputs below 7 W.

The FCC MPE regulations are based on parts of the 1992 IEEE/ANSI standard and recommendations of the National Council for Radiation Protection and Measurement (NCRP). The MPE limits under the regulations are slightly different than the IEEE/ANSI limits. Note that the MPE levels apply to the FCC rules put into effect for radio amateurs on January 1, 1998. These MPE requirements do not reflect and include all the assumptions and exclusions of the IEEE/ANSI standard.

Cardiac Pacemakers and RF Safety

It is a widely held belief that cardiac pacemakers may be adversely affected in their function by exposure to electromagnetic fields. Amateurs with pacemakers may ask whether their operating might endanger themselves or visitors to their shacks who have a pacemaker. Because of this, and similar concerns regarding other sources of electromagnetic fields, pacemaker manufacturers apply design methods that for the most part shield the pacemaker circuitry from even relatively high EM field strengths.

It is recommended that any amateur who has a pacemaker, or is being considered for one, discuss this matter with his or her physician. The physician will probably put the amateur into contact with the technical representative of the pacemaker manufacturer. These representatives are generally excellent resources, and may have data from laboratory or “in the field” studies with specific model pacemakers.

One study examined the function of a modern (dual chamber) pacemaker in and around an Amateur Radio station. The pacemaker generator has circuits that receive and process electrical signals produced by the heart, and also generate electrical signals that stimulate (pace) the heart. In one series of experiments, the pacemaker was connected to a heart simulator. The system was placed on top of the cabinet of a 1-kW HF linear amplifier during SSB and CW operation. In another test, the system was placed in close proximity to several 1 to 5-W 2-meter hand-held transceivers. The test pacemaker was connected to the heart simulator in a third test, and then placed on the ground 9 meters below and 5 meters in front of a three-element Yagi HF antenna. No interference with pacemaker function was observed in these experiments.

Although the possibility of interference cannot be entirely ruled out by these few observations, these tests represent more severe exposure to EM fields than would ordinarily be encountered by an amateur—with an average amount of common sense. Of course, prudence dictates that amateurs with pacemakers, who use hand-held VHF transceivers, keep the antenna as far as possible from the site of the implanted pacemaker generator. They also should use the lowest transmitter output required for adequate communication. For high power HF transmission, the antenna should be as far as possible from the operating position, and all equipment should be properly grounded.

Low-Frequency Fields

Although the FCC doesn’t regulate 60-Hz fields, some recent concern about EMR has focused on low-frequency energy rather than RF. Amateur Radio equipment can be a significant source of low-frequency magnetic fields, although there are many other sources of this kind of energy in the typical home. Magnetic fields can be measured relatively accurately with inexpensive 60-Hz meters that are made by several manufacturers.

Table 2 shows typical magnetic field intensities of Amateur Radio equipment and various household items. Because these fields dissipate rapidly with distance, “prudent avoidance” would mean staying perhaps 12 to 18 inches away from most Amateur Radio equipment (and

24 inches from power supplies with 1-kW RF amplifiers).

Determining RF Power Density

Unfortunately, determining the power density of the RF fields generated by an amateur station is not as simple as measuring low-frequency magnetic fields. Although sophisticated instruments can be used to measure RF power densities quite accurately, they are costly and require frequent recalibration. Most amateurs don't have access to such equipment, and the inexpensive field-

Table 2

Typical 60-Hz Magnetic Fields Near Amateur Radio Equipment and AC-Powered Household Appliances

Values are in milligauss.

Item	*Field*	*Distance*
Electric blanket	30-90	Surface
Microwave oven	10-100	Surface
	1-10	12″
IBM personal computer	5-10	Atop monitor
	0-1	15″ from screen
Electric drill	500-2000	At handle
Hair dryer	200-2000	At handle
HF transceiver	10-100	Atop cabinet
	1-5	15″ from front
1-kW RF amplifier	80-1000	Atop cabinet
	1-25	15″ from front

(Source: measurements made by members of the ARRL RF Safety Committee)

Table 3

Typical RF Field Strengths Near Amateur Radio Antennas

A sampling of values as measured by the Federal Communications Commission and Environmental Protection Agency, 1990

Antenna Type	*Freq (MHz)*	*Power (W)*	*E Field (V/m)*	*Location*
Dipole in attic	14.15	100	7-100	In home
Discone in attic	146.5	250	10-27	In home
Half sloper	21.5	1000	50	1 m from base
Dipole at 7-13 ft	7.14	120	8-150	1-2 m from earth
Vertical	3.8	800	180	0.5 m from base
5-element Yagi at 60 ft	21.2	1000	10-20	In shack
			14	12 m from base
3-element Yagi at 25 ft	28.5	425	8-12	12 m from base
Inverted V at 22-46 ft	7.23	1400	5-27	Below antenna
Vertical on roof	14.11	140	6-9	In house
			35-100	At antenna tuner
Whip on auto roof	146.5	100	22-75	2 m antenna
			15-30	In vehicle
			90	Rear seat
5-element Yagi at 20 ft	50.1	500	37-50	10 m antenna

Table 4

RF Awareness Guidelines

These guidelines were developed by the ARRL RF Safety Committee, based on the FCC/EPA measurements of Table 3 and other data.

- Although antennas on towers (well away from people) pose no exposure problem, make certain that the RF radiation is confined to the antennas' radiating elements themselves. Provide a single, good station ground (earth), and eliminate radiation from transmission lines. Use good coaxial cable or other feed line properly. Avoid serious imbalance in your antenna system and feed line. For high-powered installations, avoid end-fed antennas that come directly into the transmitter area near the operator.
- No person should ever be near any transmitting antenna while it is in use. This is especially true for mobile or ground-mounted vertical antennas. Avoid transmitting with more than 25 W in a VHF mobile installation unless it is possible to first measure the RF fields inside the vehicle. At the 1-kW level, both HF and VHF directional antennas should be at least 35 ft above inhabited areas. Avoid using indoor and attic-mounted antennas if at all possible. If open-wire feeders are used, ensure that it is not possible for people (or animals) to come into accidental contact with the feed line.
- Don't operate high-power amplifiers with the covers removed, especially at VHF/UHF.
- In the UHF/SHF region, never look into the open end of an activated length of waveguide or microwave feed-horn antenna or point it toward anyone. (If you do, you may be exposing your eyes to more than the maximum permissible exposure level of RF radiation.) Never point a high-gain, narrow-bandwidth antenna (a paraboloid, for instance) toward people. Use caution in aiming an EME (moonbounce) array toward the horizon; EME arrays may deliver an effective radiated power of 250,000 W or more.
- With hand-held transceivers, keep the antenna away from your head and use the lowest power possible to maintain communications. Use a separate microphone and hold the rig as far away from you as possible. This will reduce your exposure to the RF energy.
- Don't work on antennas that have RF power applied.
- Don't stand or sit close to a power supply or linear amplifier when the ac power is turned on. Stay at least 24 inches away from power transformers, electrical fans and other sources of high-level 60-Hz magnetic fields.

strength meters that we do have are not suitable for measuring RF power density.

Table 3 shows a sampling of measurements made at Amateur Radio stations by the Federal Communications Commission and the Environmental Protection Agency in 1990. As this table indicates, a good antenna well removed from inhabited areas poses no hazard under any of the IEEE/ANSI guidelines. However, the FCC/EPA survey also indicates that amateurs must be careful about using indoor or attic-mounted antennas, mobile antennas, low directional arrays or any other antenna that is close to inhabited areas, especially when moderate to high power is used.

Ideally, before using any antenna that is in close proximity to an inhabited area, you should measure the RF power density. If that is not feasible, the next best option is make the installation as safe as possible by observing the safety suggestions listed in **Table 4**.

It also is possible, of course, to calculate the probable power density near an antenna using simple equations. Such calculations have many pitfalls. For one, most of the situations where the power density would be high enough to be of concern are in the near field. In the near field, ground interactions and other variables produce power densities that cannot be determined by simple arithmetic. In the far field, conditions become easier to predict with simple calculations.

The boundary between the near field and the far field depends on the wavelength of the transmitted signal and the physical size and configuration of the antenna. The boundary between the near field and the far field of an antenna can be as much as several wavelengths from the antenna.

Computer antenna-modeling programs are another approach you can use. *MININEC* or other codes derived from *NEC* (Numerical Electromagnetics Code) are suitable for estimating RF magnetic and electric fields around amateur antenna systems.

These models have limitations. Ground interactions must be considered in estimating near-field power densities, and the "correct ground" must be modeled. Computer modeling is generally not sophisticated enough to predict "hot spots" in the near field—places where the field intensity may be far higher than would be expected, due to reflections from nearby objects. In addition, "nearby objects" often change or vary with weather or the season, so the model so laboriously crafted may not be representative of the actual situation, by the time it is running on the computer.

Intensely elevated but localized fields often can be detected by professional measuring instruments. These "hot spots" are often found near wiring in the shack, and metal objects such as antenna masts or equipment cabinets. But even with the best instrumentation, these measurements also may be misleading in the near field.

One need not make precise measurements or model the exact antenna system, however, to develop some idea of the relative fields around an antenna. Computer modeling using close approximations of the geometry and power input of the antenna will generally suffice. Those who are familiar with *MININEC* can estimate their power densities by computer modeling, and those who have access to professional power-density meters can make useful measurements.

While our primary concern is ordinarily the intensity of the signal radiated by an antenna, we also should remember that there are other potential energy sources to be considered. You also can be exposed to RF radiation directly from a power amplifier if it is operated without proper shielding. Transmission lines also may radiate a significant amount of energy under some conditions. Poor microwave waveguide joints or improperly assembled connectors are another source of incidental radiation.

Further RF Exposure Suggestions

Potential exposure situations should be taken seriously. Based on the FCC/EPA measurements and other data, the "RF awareness" guidelines of Table 4 were developed by the ARRL RF Safety Committee. A longer version of these guidelines, along with a complete list of references, appeared in a *QST* article by Ivan Shulman, MD, WC2S ("Is Amateur Radio Hazardous to Our Health?" *QST* , Oct 1989, pp 31-34). For more information or background, see the list of RF Safety References in the next section.

In addition, the ARRL has published a book, *RF Exposure and You*, that is helping hams comply with the FCC's RF-exposure regulations. The ARRL also maintains an RF-exposure news page on its Web site. See **www.arrl.org/news/rfsafety**. This site contains reprints of selected *QST* articles on RF exposure and links to the FCC and other useful sites.

Chapter 2

Antenna Fundamentals

Antennas belong to a class of devices called *transducers*. This term is derived from two Latin words, meaning literally "to lead across" or "to transfer." Thus, a transducer is a device that transfers, or converts, energy from one form to another. The purpose of an antenna is to convert radio-frequency electric current to *electromagnetic waves*, which are then *radiated* into space. [For more details on the properties of electromagnetic waves themselves, see Chapter 23, Radio Wave Propagation.]

We cannot directly see or hear, taste or touch electromagnetic waves, so it's not surprising that the process by which they are launched into space from our antennas can be a little mystifying, especially to a newcomer. In everyday life we come across many types of transducers, although we don't always recognize them as such. A comparison with a type of transducer that you can actually see and touch may be useful. You are no doubt familiar with a *loudspeaker*. It converts audio-frequency electric current from the output of your radio or stereo into acoustic pressure waves, also known as *sound waves*. The sound waves are propagated through the air to your ears, where they are converted into what you perceive as sound.

We normally think of a loudspeaker as something that converts electrical energy into sound energy, but we could just as well turn things around and apply sound energy to a loudspeaker, which will then convert it into electrical energy. When used in this manner, the loudspeaker has become a microphone. The loudspeaker/microphone thus exhibits the principle of *reciprocity*, derived from the Latin word meaning to move back and forth.

Now, let's look more closely at that special transducer we call an *antenna*. When fed by a transmitter with RF current (usually through a transmission line), the antenna launches electromagnetic waves, which are propagated through space. This is similar to the way sound waves are propagated through the air by a loudspeaker. In the next town, or perhaps on a distant continent, a similar transducer (that is, a receiving antenna) intercepts some of these electromagnetic waves and converts them into electrical current for a receiver to amplify and detect.

In the same fashion that a loudspeaker can act as a microphone, a radio antenna also follows the principle of reciprocity. In other words, an antenna can transmit as well as receive signals. However, unlike the loudspeaker, an antenna does not require a *medium*, such as air, through which it radiates electromagnetic waves. Electromagnetic waves can be propagated through air, the vacuum of outer space or the near vacuum of the upper ionosphere. This is the miracle of radio—electromagnetic waves can propagate without a physical medium.

Essential Characteristics of Antennas

What other things make an antenna different from an ordinary electronic circuit? In ordinary circuits, the dimensions of coils, capacitors and connections usually are small compared with the wavelength of the frequency in use. Here, we define wavelength as the distance in free space traveled during one complete cycle of a wave. The velocity of a wave in free space is the speed of light, and the wavelength is thus:

$$\lambda_{\text{meters}} = \frac{299.7925 \times 10^6 \text{ meters/sec}}{\text{f hertz}} = \frac{299.7925}{\text{f MHz}} \qquad \text{(Eq 1)}$$

where λ_{meters} , the Greek letter lambda, is the free-space wavelength in meters.

Expressed in feet, Eq 1 becomes:

$$\lambda_{feet} = \frac{983.5712}{f\ MHz} \approx \frac{983.6}{f\ MHz} \qquad \text{(Eq 2)}$$

When circuit dimensions are small compared to λ, most of the electromagnetic energy is confined to the circuit itself, and is used up either performing useful work or is converted into heat. However, when the dimensions of wiring or components become significant compared with the wavelength, some of the energy escapes by radiation in the form of electromagnetic waves.

Antennas come in an enormous, even bewildering, assortment of shapes and sizes. This chapter on fundamentals will deal with the theory of simple forms of antennas, usually in *free space*, away from the influence of ground. Subsequent chapters will concentrate on more exotic or specialized antenna types. Chapter 3 deals with the complicated subject of the effect of ground, including the effect of uneven local terrain. Ground has a profound influence on how an antenna performs in the real world.

No matter what form an antenna takes, simple or complex, its electrical performance can be characterized according to the following important properties:

1. Feed-point Impedance
2. Directivity, Gain and Efficiency
3. Polarization

FEED-POINT IMPEDANCE

The first major characteristic defining an antenna is its *feed-point impedance*. Since we amateurs are free to choose our operating frequencies within assigned bands, we need to consider how the feed-point impedance of a particular antenna varies with frequency, within a particular band, or even in several different bands if we intend to use one antenna on multiple bands.

There are two forms of impedance associated with any antenna: *self impedance* and *mutual impedance*. As you might expect, self impedance is what you measure at the feed-point terminals of an antenna located completely away from the influence of any other conductors.

Mutual, or coupled, impedance is due to the parasitic effect of nearby conductors; that is, conductors located within the antenna's reactive near field. (The subject of fields around an antenna will be discussed in detail later.) This includes the effect of ground, which is a lossy conductor, but a conductor nonetheless. Mutual impedance is defined using Ohm's Law, just like self impedance. However, mutual impedance is the ratio of voltage in one conductor, divided by the current in another (coupled) conductor. Mutually coupled conductors can distort the pattern of a highly directive antenna, as well as change the impedance seen at the feed point.

In this chapter on fundamentals, we won't directly deal with mutual impedance, considering it as a side effect of nearby conductors. Instead, here we'll concentrate on simple antennas in free space, away from ground and any other conductors. Mutual impedance will be considered in detail in Chapter 11, HF Yagi Arrays, where it is essential for proper operation of these beam antennas.

Self Impedance

The current that flows into an antenna's feed point must be supplied at a finite voltage. The self impedance of the antenna is simply equal to the voltage applied to its feed point divided by the current flowing into the feed point. Where the current and voltage are exactly in phase, the impedance is purely resistive, with zero reactive component. For this case the antenna is termed *resonant*. (Amateurs often use the term "resonant" rather loosely, usually meaning "nearly resonant" or "close-to resonant.")

Please recognize that an antenna *need not be resonant* in order to be an effective radiator. There is in fact nothing magic about having a resonant antenna, provided of course that you can devise some efficient means to feed the antenna. Many amateurs use non-resonant (even random-length) antennas fed with open-wire transmission lines and antenna tuners. They radiate signals just as well as those using coaxial cable and resonant antennas, and as a bonus they usually can use these antenna systems on multiple frequency bands. It is important to consider an antenna and its feed line as a *system*, in which all losses should be kept to a minimum. See Chapter 24, Transmission Lines, for details on transmission-line loss as a function of impedance mismatch.

Except at the one frequency where it is truly resonant, the current in an antenna is at a different phase compared to the applied voltage. In other words, the antenna exhibits a feed-point *impedance*, not just a pure resistance. The feed-point impedance is composed of either capacitive or inductive reactance in series with a resistance.

Radiation Resistance

The power supplied to an antenna is dissipated in two ways: radiation of electromagnetic waves, and heat losses in the wire and nearby dielectrics. The radiated power is what we want, the useful part, but it represents a form of "loss" just as much as the power used in heating the wire or nearby dielectrics is a loss. In either case, the dissipated power is equal to I^2R. In the case of heat losses, R is a real resistance. In the case of radiation, however, R is a "virtual" resistance, which, if replaced with an actual resistor of the same value, would dissipate the power actually radiated from the antenna. This resistance is called the *radiation resistance*. The total power in the antenna is therefore equal to $I^2(R_0+R)$, where R_0 is the radiation resistance and R represents the total of all the loss resistances.

In ordinary antennas operated at amateur frequencies, the power lost as heat in the conductor does not exceed a few percent of the total power supplied to the antenna. Expressed in decibels, the loss is less than 0.1 dB. The RF loss resistance of copper wire even as small as #14 is very low compared with the radiation resistance of an antenna that is reasonably clear of surrounding objects and is not too close to the ground. You can therefore assume that the ohmic loss in a reasonably well-located antenna is negligible, and that the total resistance shown by the antenna (the feed-point resistance) is radiation resistance. As a radiator of electromagnetic waves, such an antenna is a highly efficient device.

Impedance of a Center-Fed Dipole

A fundamental type of antenna is the *center-fed half-wave dipole*. Historically, the λ/2 dipole has been the most popular antenna used by amateurs worldwide, largely because it is very simple to construct and because it is an effective performer. It is also a basic building block for many other antenna systems, including beam antennas, such as Yagis.

A center-fed half-wave *dipole* consists of a straight wire, one-half wavelength long as defined in Eq 1, and fed in the center. The term "dipole" derives from Greek words meaning "two poles." See **Fig 1**. A λ/2-long dipole is just one form a dipole can take. Actually, a center-fed dipole can be any length electrically, as long as it is configured in a symmetrical fashion with two equal-length legs. There are also versions of dipoles that are not fed in the center. These are called *off-center-fed dipoles*, sometimes abbreviated as "OCF dipoles."

In free space—with the antenna remote from everything else—the theoretical impedance of a physically half-wave long antenna made of an infinitely thin conductor is 73 + *j* 42.5 Ω. This antenna exhibits both resistance and reactance. The positive sign in the + *j* 42.5-Ω reactive term indicates that the antenna exhibits an inductive reactance at its feed point. The antenna is slightly long electrically, compared to the length necessary for exact resonance, where the reactance is zero.

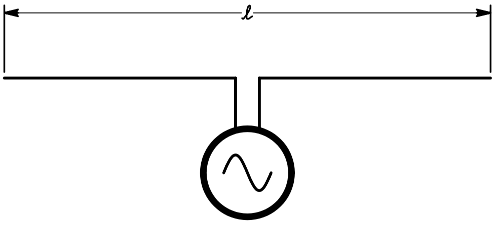

Fig 1—The center-fed dipole antenna. It is assumed that the source of power is directly at the antenna feed point, with no intervening transmission line. Most commonly in amateur applications, the overall length of the dipole is λ/2, but the antenna can in actuality be any length.

The feed-point impedance of any antenna is affected by the wavelength-to-diameter ratio (λ/dia) of the conductors used. Theoreticians like to specify an "infinitely thin" antenna because it is easier to handle mathematically.

What happens if we keep the physical length of an antenna constant, but change the thickness of the wire used in its construction? Further, what happens if we vary the frequency from well below to well above the half-wave resonance and measure the feed-point impedance? **Fig 2** graphs the impedance of a 100-foot long, center-fed dipole in free space, made with extremely thin wire—in this case, wire that is only 0.001 inches in diameter. There is nothing particularly significant about the choice here of 100 feet. This is simply a numerical example.

We could never actually build such a thin antenna (and neither could we install it in free space), but we can model how this antenna works using a very powerful piece of computer software called *NEC-4.1*. See Chapter 4, Antenna Modeling and System Planning, for details on antenna modeling.

The frequency applied to the antenna in Fig 2 is varied from 1 to 30 MHz. The x-axis has a logarithmic scale because of the wide range of feed-point resistance seen over the frequency range. The y-axis has a linear scale representing the reactive portion of the impedance. Inductive reactance is positive and capacitive reactance is negative on the y-axis. The bold figures centered on the spiraling line show the frequency in MHz.

At 1 MHz, the antenna is very short electrically, with a resistive component of about 2 Ω and a series capaci-

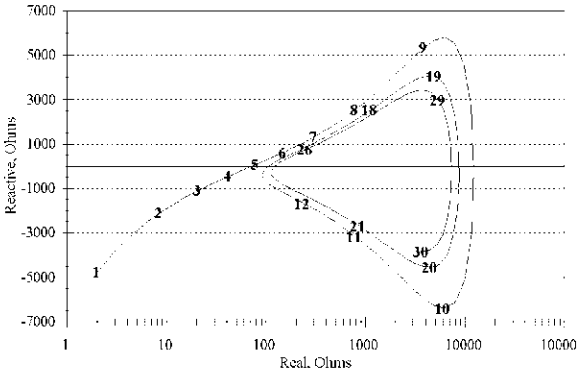

Fig 2—Feed-point impedance versus frequency for a theoretical 100-foot long dipole in free space, fed in the center and made of extremely thin 0.001-inch diameter wire. The y-axis is calibrated in positive (inductive) series reactance up from the zero line, and negative (capacitive) series reactance in the downward direction. The range of reactance goes from –6500 Ω to +6000 Ω. Note that the x-axis is logarithmic because of the wide range of the real, resistive component of the feed-point impedance, from roughly 2 Ω to 10,000 Ω. The numbers placed along the curve show the frequency in MHz.

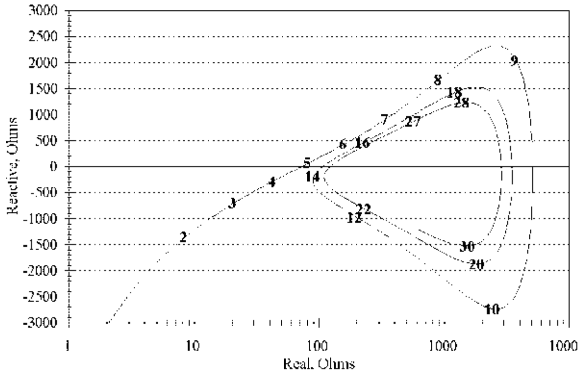

Fig 3—Feed-point impedance versus frequency for a theoretical 100-foot long dipole in free space, fed in the center and made of thin 0.1-inch (#10) diameter wire. Note that the range of change in reactance is less than that shown in Fig 2, ranging from –2700 Ω to +2300 Ω. At about 5,000 Ω, the maximum resistance is also less than that in Fig 2 for the thinner wire, where it is about 10,000 Ω.

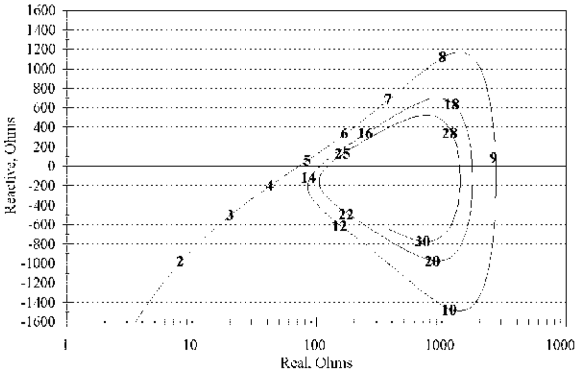

Fig 4—Feed-point impedance versus frequency for a theoretical 100-foot long dipole in free space, fed in the center and made of thick 1.0-inch diameter wire. Once again, the excursion in both reactance and resistance over the frequency range is less with this thick wire dipole than with thinner ones.

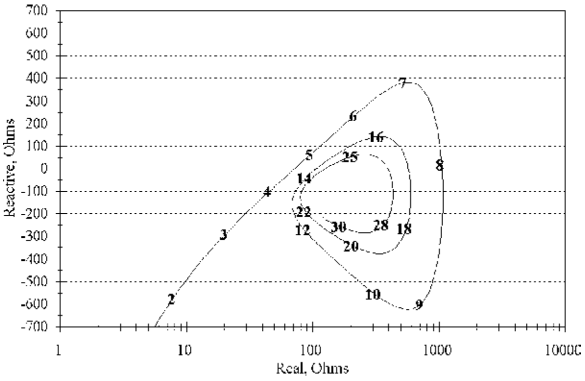

Fig 5—Feed-point impedance versus frequency for a theoretical 100-foot long dipole in free space, fed in the center and made of very thick 10.0-inch diameter wire. This ratio of length to diameter is about the same as a typical rod type of dipole element commonly used at 432 MHz. The maximum resistance is now about 1,000 Ω and the peak reactance range is from about –625 Ω to +380 Ω. This performance is also found in "cage" dipoles, where a number of paralleled wires are used to simulate a fat conductor.

tive reactance about –5000 Ω. Close to 5 MHz, the line crosses the zero-reactance line, meaning that the antenna goes through half-wave resonance there. Between 9 and 10 MHz the antenna exhibits a peak inductive reactance of about 6000 Ω. It goes through full-wave resonance (again crossing the zero-reactance line) between 9.5 and 9.6 MHz. At about 10 MHz, the reactance peaks at about –6500 Ω. Around 14 MHz, the line again crosses the zero-reactance line, meaning that the antenna has now gone through 3/2-wave resonance.

Between 19 and 20 MHz, the antenna goes through 4/2-wave resonance, which is twice the full-wave resonance or four times the half-wave frequency. If you allow your mind's eye to trace out the curve for frequencies beyond 30 MHz, it eventually spirals down to a resistive component somewhere between 200 and 3000 Ω. Thus, we have another way of looking at an antenna—as a sort of *transformer*, one that transforms the free-space impedance into the impedance seen at its feed point.

Now look at **Fig 3**, which shows the same kind of spiral curve, but for a thicker-diameter wire, one that is 0.1 inches in diameter. This diameter is close to #10 wire, a practical size we might actually use to build a real dipole. Note that the y-axis scale in Fig 3 is different from that in Fig 2. The range is from ±3000 Ω in Fig 3, while it was ±7000 Ω in Fig 2. The reactance for the thicker antenna ranges from +2300 to –2700 Ω over the whole frequency range from 1 to 30 MHz. Compare this with the range of +5800 to –6400 Ω for the very thin wire in Fig 2.

Fig 4 shows the impedance for a 100-foot long dipole using really thick, 1.0-inch diameter wire. The reactance varies from +1000 to –1500 Ω, indicating once again that a larger diameter antenna exhibits less of an excursion in the reactive component with frequency. Note that at the half-wave resonance just below 5 MHz, the resistive component of the impedance is still about 70 Ω, just about what it is for a much thinner antenna. Unlike the reactance, the half-wave radiation resistance of an antenna doesn't radically change with wire diameter, although the maximum level of resistance at full-wave resonance is lower for thicker antennas.

Fig 5 shows the results for a very thick, 10-inch diameter wire. Here, the excursion in the reactive component is even less: about +400 to –600 Ω. Note that the full-wave resonant frequency is about 8 MHz for this

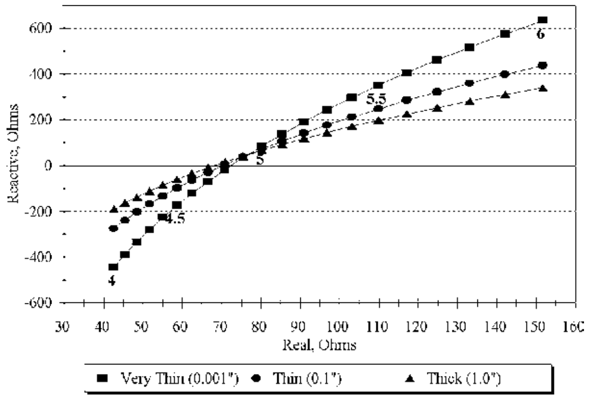

Fig 6—Expansion of frequency range around half-wave resonant point of three center-fed dipoles of three different thicknesses. The frequency is shown along the curves in MHz. The slope of change in series reactance versus series resistance is steeper for the thinner antennas than for the thick 1.0-inch antenna, indicating that the Q of the thinner antennas is higher.

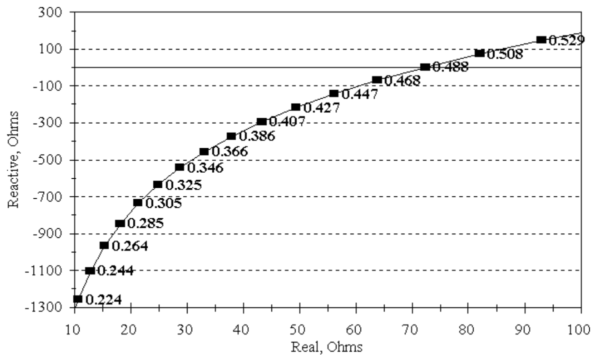

Fig 7—Another way of looking at the data for a 100-foot, center-fed dipole made of #14 wire in free space. The numbers along the curve represent the fractional wavelength, rather than frequency as shown in Fig 6. Note that this antenna goes through its half-wave resonance about 0.488 λ, rather than exactly at a half-wave physical length.

extremely thick antenna, while thinner antennas have full-wave resonances closer to 9 MHz. Note also that the full-wave resistance for this extremely thick antenna is only about 1,000 Ω, compared to the 10,000 Ω shown in Fig 2. All half-wave resonances shown in Figs 2 through 5 remain close to 5 MHz, regardless of the diameter of the antenna wire. Once again, the extremely thick, 10-inch diameter antenna has a resistive component at half-wave resonance close to 70 Ω. And once again, the change in reactance near this frequency is very much less for the extremely thick antenna than for thinner ones.

Now, we grant you that a 100-foot long antenna made with 10-inch diameter wire sounds a little odd! A length of 100 feet and a diameter of 10 inches represent a ratio of 120:1 in length to diameter. However, this is about the same length-to-diameter ratio as a 432-MHz half-wave dipole using 0.25-inch diameter elements, where the ratio is 109:1. In other words, the ratio of length-to-diameter for the 10-inch diameter, 100-foot long dipole is not that far removed from what might actually be used at UHF.

Another way of highlighting the changes in reactance and resistance is shown in **Fig 6**. This shows an expanded portion of the frequency range around the half-wave resonant frequency, from 4 to 6 MHz. In this region, the shape of each spiral curve is almost a straight line. The slope of the curve for the very thin antenna (0.001-inch diameter) is steeper than that for the thicker antennas (0.1 and 1.0-inch diameters). **Fig 7** illustrates another way of looking at the impedance data above and below the half-wave resonance. This is for a 100-foot dipole made of #14 wire. Instead of showing the frequency for each impedance point, the wavelength is shown, making the graph more universal in application.

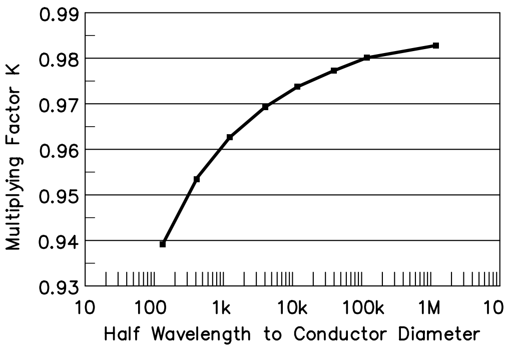

Fig 8—Effect of antenna diameter on length for half-wavelength resonance, shown as a multiplying factor, K, to be applied to the free-space, half-wavelength.

Just to show that there are lots of ways of looking at the same data, **Fig 8** graphs the constant "K" used to multiply the free-space half-wavelength as a function of the ratio between the half-wavelength and the conductor diameter. The curve approaches the value of 1.00 for an infinitely thin conductor, in other words an infinitely large ratio of half-wavelength to diameter.

The behavior of antennas with different λ/diameter ratios corresponds to the behavior of ordinary series-resonant circuits having different values of Q. When the Q of a circuit is low, the reactance is small and changes rather slowly as the applied frequency is varied on either side of resonance. If the Q is high, the converse is true. The response curve of the low-Q circuit is *broad*; that of the high-Q circuit *sharp*. So it is with antennas—the impedance of a thick antenna changes slowly over a comparatively wide band of frequencies, while a thin antenna has a faster change in impedance. Antenna Q is defined

$$Q = \frac{f_0 \Delta X}{2 R_0 \Delta f} \qquad \text{(Eq 3)}$$

where f_0 is the center frequency, ΔX is the change in the reactance for a Δf change in frequency, and R_0 is the resistance the f_0. For the "Very Thin," 0.001-inch diameter dipole in Fig 2, a change of frequency from 5.0 to 5.5 MHz yields a reactance change from 86 to 351 Ω, with an R_0 of 95 Ω. The Q is thus 14.6. For the 1.0-inch-diameter "Thick" dipole in Fig 4, $\Delta X = 131\ \Omega$ and R_0 is still 95 Ω, making Q = 7.2 for the thicker antenna, roughly half that of the thinner antenna.

Let's recap. We have described an antenna first as a transducer, then as a sort of transformer to a range of free-space impedances. Now, we just compared the antenna to a series-tuned circuit. Near its half-wave resonant frequency, a center-fed $\lambda/2$ dipole exhibits much the same characteristics as a conventional series-resonant circuit. Exactly at resonance, the current at the input terminals is in phase with the applied voltage and the feed-point impedance is purely resistive. If the frequency is below resonance, the phase of the current leads the voltage; that is, the reactance of the antenna is capacitive. When the frequency is above resonance, the opposite occurs; the current lags the applied voltage and the antenna exhibits inductive reactance. Just like a conventional series-tuned circuit, the antenna's reactance and resistance determines its Q.

ANTENNA DIRECTIVITY AND GAIN

The Isotropic Radiator

Before we can fully describe practical antennas, we must first introduce a completely theoretical antenna, the *isotropic radiator*. Envision, if you will, an infinitely small antenna, a point located in outer space, completely removed from anything else around it. Then consider an infinitely small transmitter feeding this infinitely small, point antenna. You now have an isotropic radiator.

The uniquely useful property of this theoretical *point-source* antenna is that it radiates equally well in all directions. That is to say, an isotropic antenna favors no direction at the expense of any other—in other words, it has absolutely no *directivity*. The isotropic radiator is useful as a *measuring stick* for comparison with actual antenna systems.

You will find later that real, practical antennas all exhibit some degree of directivity, which is the property of radiating more strongly in some directions than in others. The radiation from a practical antenna never has the same intensity in all directions and may even have zero radiation in some directions. The fact that a practical antenna displays directivity (while an isotropic radiator does not) is not necessarily a bad thing. The directivity of a real antenna is often carefully tailored to emphasize radiation in particular directions. For example, a receiving antenna that favors certain directions can discriminate against interference or noise coming from other directions, thereby increasing the signal-to-noise ratio for desired signals coming from the favored direction.

Directivity and the Radiation Pattern—a Flashlight Analogy

The directivity of an antenna is directly related to the *pattern* of its radiated field intensity in free space. A graph showing the actual or relative field intensity at a fixed distance, as a function of the direction from the antenna system, is called a *radiation pattern*. Since we can't actually see electromagnetic waves making up the radiation pattern of an antenna, we can consider an analogous situation.

Fig 9 represents a flashlight shining in a totally darkened room. To quantify what our eyes are seeing, we might use a sensitive light meter like those used by photographers, with a scale graduated in units from 0 to 10. We place the meter directly in front of the flashlight and adjust the distance so the meter reads 10, exactly full scale. We also carefully note the distance. Then, always keeping the meter the same distance from the flashlight and keeping it at the same height above the floor, we move the light meter around the flashlight, as indicated by the

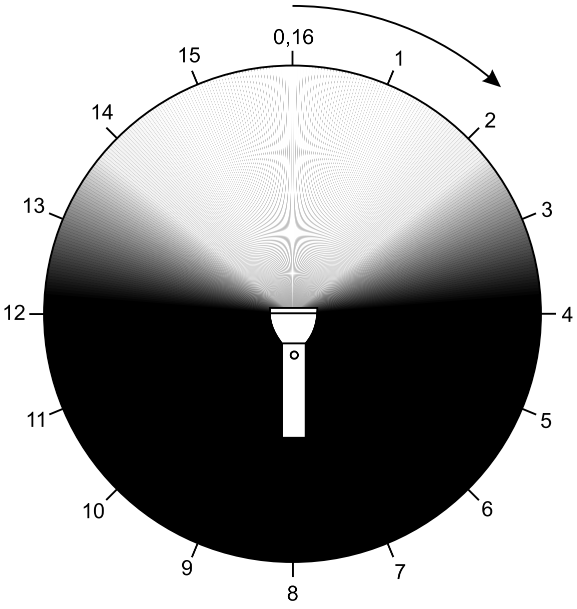

Fig 9—The beam from a flashlight illuminates a totally darkened area as shown here. Readings taken with a photographic light meter at the 16 points around the circle may be used to plot the radiation pattern of the flashlight.

arrow, and take light readings at a number of different positions.

After all the readings have been taken and recorded, we plot those values on a sheet of polar graph paper, like that shown in **Fig 10**. The values read on the meter are plotted at an angular position corresponding to that for which each meter reading was taken. Following this, we connect the plotted points with a smooth curve, also shown in Fig 10. When this is finished, we have completed a radiation pattern for the flashlight.

Antenna Pattern Measurements

Antenna radiation patterns can be constructed in a similar manner. Power is fed to the antenna under test, and a field-strength meter indicates the amount of signal. We might wish to rotate the antenna under test, rather than moving the measuring equipment to numerous positions about the antenna. Or we might make use of antenna reciprocity, since the pattern while receiving is the same as that while transmitting. A source antenna fed by a low-power transmitter illuminates the antenna under test, and the signal intercepted by the antenna under test is fed to a receiver and measuring equipment. Additional information on the mechanics of measuring antenna patterns is contained in Chapter 27, Antennas and Transmission-Line Measurements.

Some precautions must be taken to assure that the measurements are accurate and repeatable. In the case of the flashlight, let's assume that the separation between the light source and the light meter is 2 meters, about 6.5 feet. The wavelength of visible light is about one-half micron, where a micron is one-millionth of a meter.

For the flashlight, a separation of 2 meters between source and detector is $2.0/(0.5\times10^{-6}) = 4$ million λ, a very large number of wavelengths. Measurements of practical HF or even VHF antennas are made at much closer distances, in terms of wavelength. For example, at 3.5 MHz a full wavelength is 85.7 meters, or 281.0 feet. To duplicate the flashlight-to-light-meter spacing in wavelengths at 3.5 MHz, we would have to place the field-strength measuring instrument almost on the surface of the Moon, about a quarter-million miles away!

The Fields Around an Antenna

Why should we be concerned with the separation between the source antenna and the field-strength meter, which has its own receiving antenna? One important reason is that if you place a receiving antenna very close to an antenna whose pattern you wish to measure, mutual coupling between the two antennas may actually alter the pattern you are trying to measure.

This sort of mutual coupling can occur in the region very close to the antenna under test. This region is called the *reactive near-field* region. The term "reactive" refers to the fact that the mutual impedance between the transmitting and receiving antennas can be either capacitive or inductive in nature. The reactive near field is sometimes called the "induction field," meaning that the magnetic field usually is predominant over the electric field in this region. The antenna acts as though it were a rather large, lumped-constant inductor or capacitor, storing energy in the reactive near field rather than propagating it into space.

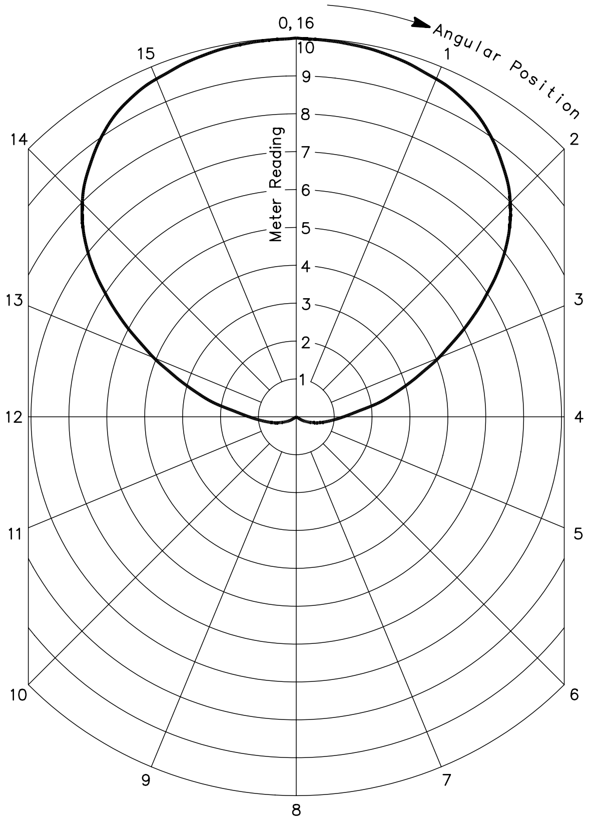

Fig 10—The radiation pattern of the flashlight in Fig 9. The measured values are plotted and connected with a smooth curve.

For simple wire antennas, the reactive near field is considered to be within about a half wavelength from an antenna's radiating center. Later on, in the chapters dealing with Yagi and quad antennas, you will find that mutual coupling between elements can be put to good use to purposely shape the radiated pattern. For making pattern measurements, however, we do not want to be too close to the antenna being measured.

The strength of the reactive near field decreases in a complicated fashion as you increase the distance from the antenna. Beyond the reactive near field, the antenna's radiated field is divided into two other regions: the *radiating near field* and the *radiating far field.* Historically, the terms *Fresnel* and *Fraunhöfer* fields have been used for the radiating near and far fields, but these terms have been largely supplanted by the more descriptive terminology used here. Even inside the reactive near-field

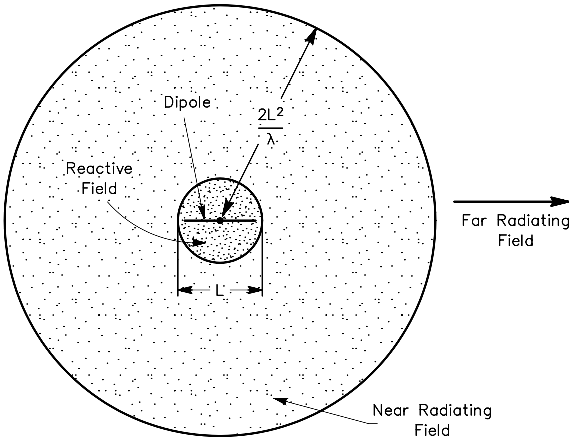

Fig 11—The fields around a radiating antenna. Very close to the antenna, the reactive field dominates. Within this area mutual impedances are observed between antenna and any other antennas used to measure response. Outside of the reactive field, the near radiating field dominates, up to a distance approximately equal to 2L²/λ, where L is the length of the largest dimension of the antenna. Beyond the near/far field boundary lies the far radiating field, where power density varies as the inverse square of radial distance.

region, both radiating and reactive fields coexist, although the reactive field predominates very close to the antenna.

Because the boundary between the fields is rather fuzzy, experts debate where one field begins and another leaves off, but the boundary between the radiating near and far fields is generally accepted as:

$$D \approx \frac{2L^2}{\lambda} \qquad \text{(Eq 4)}$$

where L is the largest dimension of the physical antenna, expressed in the same units of measurement as the wavelength λ. Remember, many specialized antennas do not follow the rule of thumb in Eq 4 exactly. **Fig 11** depicts the three fields in front of a simple wire antenna.

Throughout the rest of this book we will discuss mainly the radiating far-fields, those forming the traveling electromagnetic waves. Far-field radiation is distinguished by the fact that the intensity is inversely proportional to the distance, and that the electric and magnetic components, although perpendicular to each other in the wave front, are in time phase. The total energy is equally divided between the electric and magnetic fields. Beyond several wavelengths from the antenna, these are the only fields we need to consider. For accurate measurement of radiation patterns, we must place our measuring instrumentation at least several wavelengths away from the antenna under test.

Pattern Planes

Patterns obtained above represent the antenna radiation in just one plane. In the example of the flashlight, the plane of measurement was at one height above the floor. Actually, the pattern for any antenna is three dimensional, and therefore cannot be represented in a single-plane drawing. The *solid* radiation pattern of an antenna in free space would be found by measuring the field strength at every point on the surface of an imaginary sphere having the antenna at its center. The information so obtained would then be used to construct a solid figure, where the distance from a fixed point (representing the antenna) to the surface of the figure is proportional to the field strength from the antenna in any given direction. **Fig 12B** shows a three-dimensional wire-grid representation of the radiation pattern of a half-wave dipole.

For amateur work, *relative* values of field strength (rather than absolute) are quite adequate in pattern plotting. In other words, it is not necessary to know how many microvolts per meter a particular antenna will produce at a distance of 1 mile when excited with a specified power level. (This is the kind of specifications that AM broadcast stations must meet to certify their antenna systems to the FCC.)

For whatever data is collected (or calculated from theoretical equations), it is common to normalize the plotted values so the field strength in the direction of maximum radiation coincides with the outer edge of the chart. On a given system of polar coordinate scales, the *shape* of the pattern is not altered by proper normalization, only its size.

E and H-Plane Patterns

The solid 3-D pattern of an antenna in free space cannot adequately be shown with field-strength data on a flat sheet of paper. Cartographers making maps of a round Earth on flat pieces of paper face much the same kind of problem. As we discussed above, cross-sectional or plane diagrams are very useful for this purpose. Two such diagrams, one in the plane containing the straight wire of a dipole and one in the plane perpendicular to the wire, can convey a great deal of information. The pattern in the plane containing the axis of the antenna is called the *E-plane pattern*, and the one in the plane perpendicular to the axis is called the *H-plane pattern*. These designations are used because they represent the planes in which the electric (symbol E), and the magnetic (symbol H) lines of force lie, respectively.

The E lines represent the *polarization* of the antenna. Polarization will be covered in more detail later in this chapter. As an example, the electromagnetic field pictured in Fig 1 of Chapter 23, Radio Wave Propagation, is the field that would be radiated from a vertically polarized antenna; that is, an antenna in which the conductor is mounted perpendicular to the earth.

When a radiation pattern is shown for an antenna mounted over ground rather than in free space, we automatically gain two frames of reference—an *azimuth angle* and an *elevation angle*. The azimuth angle is usually ref-

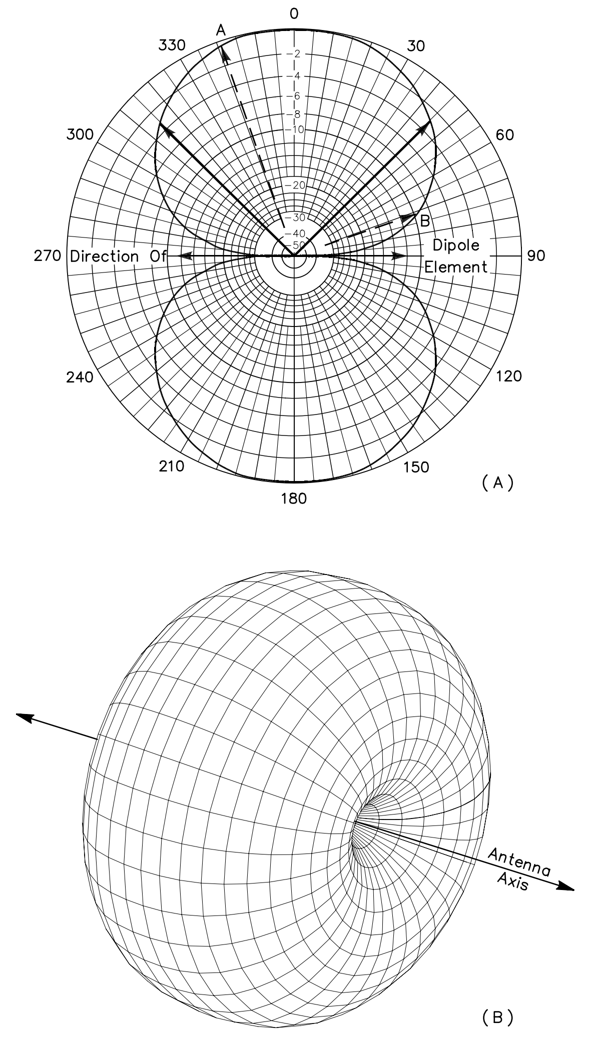

Fig 12—Directive diagram of a free-space dipole. At A, the pattern in the plane containing the wire axis. The length of each dashed-line arrow represents the relative field strength in that direction, referenced to the direction of maximum radiation, which is at right angles to the wire's axis. The arrows at approximately 45° and 315° are the half-power or –3 dB points. At B, a wire grid representation of the solid pattern for the same antenna. These same patterns apply to any center-fed dipole antenna less than a half wavelength long.

Introduction to the Decibel

The power gain of an antenna system is usually expressed in *decibels*. The decibel is a practical unit for measuring power ratios because it is more closely related to the actual effect produced at a distant receiver than the power ratio itself. One decibel represents a just-detectable change in signal strength, regardless of the actual value of the signal voltage. A 20-decibel (20-dB) increase in signal, for example, represents 20 observable steps in increased signal. The power ratio (100 to 1) corresponding to 20 dB gives an entirely exaggerated idea of the improvement in communication to be expected. The number of decibels corresponding to any power ratio is equal to 10 times the common logarithm of the power ratio, or

$$\mathrm{dB} = 10 \log_{10} \frac{P_1}{P_2}$$

If the voltage ratio is given, the number of decibels is equal to 20 times the common logarithm of the ratio. That is,

$$\mathrm{dB} = 20 \log_{10} \frac{V_1}{V_2}$$

When a *voltage* ratio is used, both voltages must be measured across the same value of impedance. Unless this is done the decibel figure is meaningless, because it is fundamentally a measure of a *power* ratio.

The main reason a decibel is used is that successive power gains expressed in decibels may simply be added together. Thus a gain of 3 dB followed by a gain of 6 dB gives a total gain of 9 dB. In ordinary power ratios, the ratios must be multiplied together to find the total gain.

A *reduction* in power is handled simply by subtracting the requisite number of decibels. Thus, reducing the power to ½ is the same as *subtracting* 3 decibels. For example, a power gain of 4 in one part of a system and a reduction to ½ in another part gives a total power gain of 4 × ½ = 2. In decibels, this is 6 – 3 = 3 dB. A power reduction or *loss* is simply indicated by including a negative sign in front of the appropriate number of decibels.

erenced to the maximum radiation lobe of the antenna, where the azimuth angle is defined at 0°, or it could be referenced to the Earth's True North direction for an antenna oriented in a particular compass direction. The E-plane pattern for an antenna over ground is now called the *azimuth pattern*.

The elevation angle is referenced to the horizon at the Earth's surface, where the elevation angle is 0°. Of course, the Earth is round but because its radius is so large, it can in this context be considered to be flat in the area directly under the antenna. An elevation angle of 90° is straight over the antenna, and a 180° elevation is toward the horizon directly behind the antenna.

Professional antenna engineers often describe an antenna's orientation with respect to the point directly overhead—using the *zenith angle*, rather than the elevation angle. The elevation angle is computed by subtracting the zenith angle from 90°.

Referenced to the horizon of the Earth, the H-plane pattern is now called the *elevation pattern*. Unlike the free-space H-plane pattern, the over-ground elevation pattern is drawn as a half-circle, representing only positive elevations above the Earth's surface. The ground reflects or blocks radiation at negative elevation angles, making below-surface radiation plots unnecessary.

After a little practice, and with the exercise of some imagination, the complete solid pattern can be visualized with fair accuracy from inspection of the two planar diagrams, provided of course that the solid pattern of the antenna is *smooth*, a condition that is true for simple antennas like $\lambda/2$ dipoles.

Plane diagrams are plotted on polar coordinate paper, as described earlier. The points on the pattern where the radiation is zero are called *nulls*. The curved section from one null to the next on the plane diagram, or the corresponding section on the solid pattern, is called a *lobe*. The strongest lobe is commonly called the *main lobe*. Fig 12A shows the E-plane pattern for a half-wave dipole. In Fig 12, the dipole is placed in free space. In addition to the labels showing the main lobe and nulls in the pattern, the so-called *half-power* points on the main lobe are shown. These are the points where the power is 3 dB down from the peak value in the main lobe.

Directivity and Gain

Let us now examine directivity more closely. As mentioned previously, all practical antennas, even the simplest types such as dipoles, exhibit directivity. Here's another picture that may help explain the concept of directivity. **Fig 13A** shows a balloon blown into its usual spherical shape. This represents a "reference" isotropic source. Squeezing the balloon in the middle in Fig 13B produces a dipole-like figure-8 pattern whose peak levels at top and bottom are larger than the reference sphere. Compare this with Fig 13C. Next, squeezing the bottom end of the balloon produces a pattern that gives even more "gain" compared to the reference.

Free-space directivity can be expressed quantitatively by comparing the three-dimensional pattern of the antenna under consideration with the perfectly spherical three-dimensional pattern of an isotropic antenna. The field strength (and thus power per unit area, or *power density*) is the same everywhere on the surface of an imaginary sphere having a radius of many wavelengths and having an isotropic antenna at its center. At the surface of the same imaginary sphere around an antenna radiating the same total power, the directive pattern results in greater power density at some points on this sphere and less at others. The ratio of the maximum power density to the average power density taken over the entire sphere (which is the same as from the isotropic antenna under the specified conditions) is the numerical measure of the directivity of the antenna. That is,

$$D = \frac{P}{P_{av}} \quad \text{(Eq 5)}$$

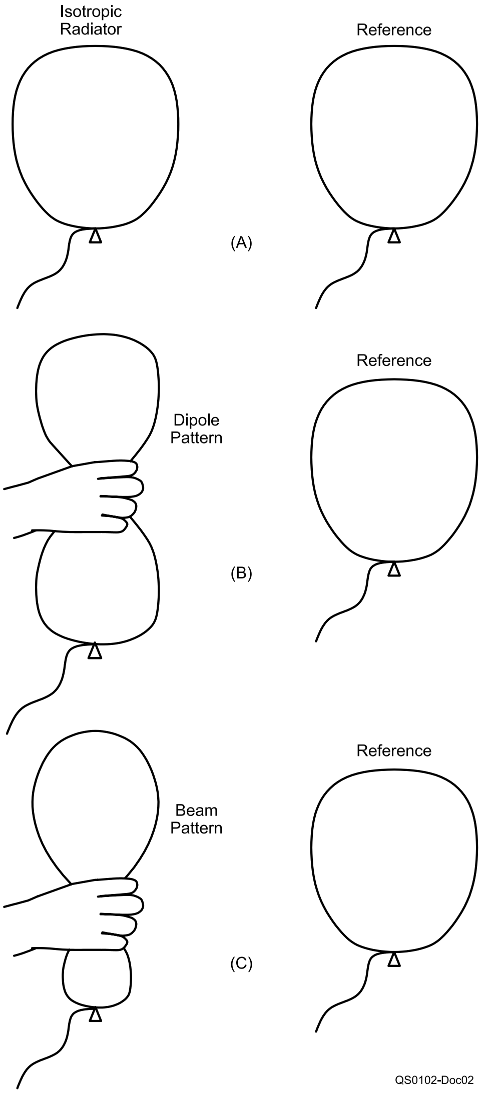

Fig 13—Demonstrating antenna pattern gain with balloons. Take a balloon, blow it up so that it is roughly circular in shape and then declare that this is a radiation pattern from an isotropic radiator. Next, blow up another balloon to the same size and shape and tell the audience that this will be the "reference" antenna (A). Then, squeeze the first balloon in the middle to form a sort of figure-8 shape and declare that this is a dipole and compare the maximum size to that of the reference "antenna" (B). The dipole can be seen to have some "gain" over the reference isotropic. Next, squeeze the end of the first balloon to come up with a sausage-like shape to demonstrate the sort of pattern a beam antenna creates (C).

where

D = directivity

P = power density at its maximum point on the surface of the sphere

P_{av} = average power density

The *gain* of an antenna is closely related to its directivity. Because directivity is based solely on the *shape* of the directive pattern, it does not take into account any power losses that may occur in an actual antenna system. To determine gain, these losses must be subtracted from the power supplied to the antenna. The loss is normally a constant percentage of the power input, so the antenna gain is

$$G = k\frac{P}{P_{av}} = kD \qquad \text{(Eq 6)}$$

where

G = gain (expressed as a power ratio)
D = directivity
k = efficiency (power radiated divided by power input) of the antenna
P and P_{av} are as above

For many of the antenna systems used by amateurs, the efficiency is quite high (the loss amounts to only a few percent of the total). In such cases the gain is essentially equal to the directivity. The more the directive diagram is compressed—or, in common terminology, the *sharper* the lobes—the greater the power gain of the antenna. This is a natural consequence of the fact that as power is taken away from a larger and larger portion of the sphere surrounding the radiator, it is added to the volume represented by the narrow lobes. Power is therefore concentrated in some directions, at the expense of others. In a general way, the smaller the volume of the solid radiation pattern, compared with the volume of a sphere having the same radius as the length of the largest lobe in the actual pattern, the greater the power gain.

As stated above, the gain of an antenna is related to its directivity, and directivity is related to the shape of the directive pattern. A commonly used index of directivity, and therefore the gain of an antenna, is a measure of the width of the major lobe (or lobes) of the plotted pattern. The width is expressed in degrees at the half-power or –3 dB points, and is often called the *beamwidth*.

This information provides only a general idea of relative gain, rather than an exact measure. This is because an absolute measure involves knowing the power density at every point on the surface of a sphere, while a single diagram shows the pattern shape in only one plane of that sphere. It is customary to examine at least the E-plane and the H-plane patterns before making any comparisons between antennas.

A simple approximation for gain over an isotropic radiator can be used, but only if the sidelobes in the antenna's pattern are small compared to the main lobe and if the resistive losses in the antenna are small. When the radiation pattern is complex, numerical integration is employed to give the actual gain.

$$G \approx \frac{41253}{H_{3dB} \times E_{3dB}} \qquad \text{(Eq 7)}$$

where H_{3dB} and E_{3dB} are the half-power points, in degrees, for the H and E-plane patterns.

Radiation Patterns for Center-Fed Dipoles at Different Frequencies

Earlier, we saw how the feed-point impedance of a fixed-length center-fed dipole in free space varies as the frequency is changed. What happens to the radiation pattern of such an antenna as the frequency is changed?

In general, the greater the length of a center-fed antenna, in terms of wavelength, the larger the number of lobes into which the pattern splits. A feature of all such patterns is the fact that the main lobe—the one that gives the largest field strength at a given distance—always is the one that makes the smallest angle with the antenna wire. Furthermore, this angle becomes smaller as the length of the antenna is increased.

Let's examine how the free-space radiation pattern changes for a 100-foot long wire made of #14 wire as the frequency is varied. (Varying the frequency effectively changes the wavelength for a fixed-length wire.) **Fig 14** shows the E-plane pattern at the $\lambda/2$ resonant frequency of 4.8 MHz. This is a classical dipole pattern, with a gain in free space of 2.14 dBi referenced to an isotropic radiator.

Fig 15 shows the free-space E-plane pattern for the same antenna, but now at the full-wave ($2\lambda/2$) resonant frequency of 9.55 MHz. Note how the pattern has been pinched in at the top and bottom of the figure. In other words, the two main lobes have become sharper at this frequency, making the gain 3.73 dBi, higher than at the $\lambda/2$ frequency.

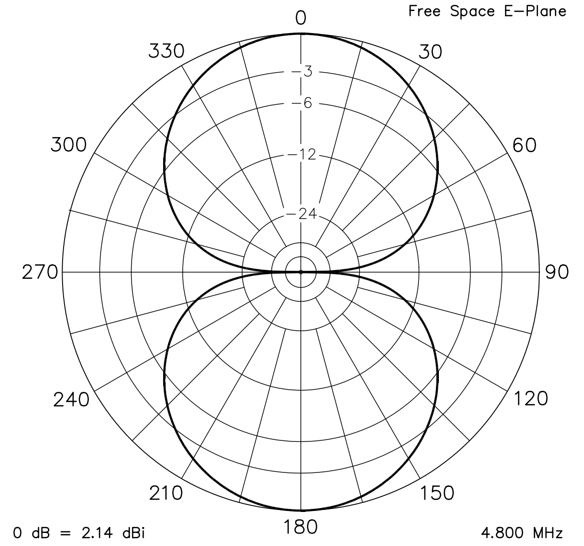

Fig 14—Free-space E-Plane radiation pattern for a 100-foot dipole at its half-wave resonant frequency of 4.80 MHz. This antenna has 2.14 dBi of gain. The dipole is located on the line from 90° to 270°.

Coordinate Scales for Radiation Patterns

A number of different systems of coordinate scales or *grids* are in use for plotting antenna patterns. Antenna patterns published for amateur audiences are sometimes placed on rectangular grids, but more often they are shown using polar coordinate systems. Polar coordinate systems may be divided generally into three classes: linear, logarithmic and modified logarithmic.

A very important point to remember is that the shape of a pattern (its general appearance) is highly dependent on the grid system used for the plotting. This is exemplified in **Fig A**, where the radiation pattern for a beam antenna is presented using three coordinate systems discussed in the paragraphs that follow.

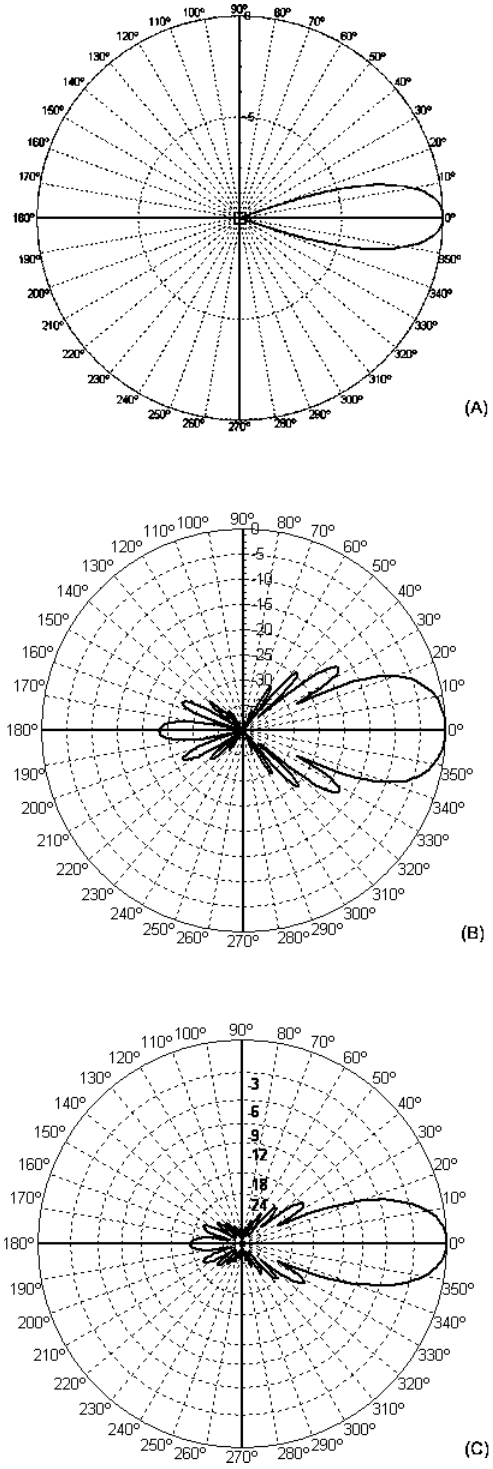

Linear Coordinate Systems

The polar coordinate system for the flashlight radiation pattern, Fig 10, uses linear coordinates. The concentric circles are equally spaced, and are graduated from 0 to 10. Such a grid may be used to prepare a linear plot of the power contained in the signal. For ease of comparison, the equally spaced concentric circles have been replaced with appropriately placed circles representing the decibel response, referenced to 0 dB at the outer edge of the plot. In these plots the minor lobes are suppressed. Lobes with peaks more than 15 dB or so below the main lobe disappear completely because of their small size. This is a good way to show the pattern of an array having high directivity and small minor lobes.

Logarithmic Coordinate System

Another coordinate system used by antenna manufacturers is the logarithmic grid, where the concentric grid lines are spaced according to the logarithm of the voltage in the signal. If the logarithmically spaced concentric circles are replaced with appropriately placed circles representing the decibel response, the decibel circles are graduated linearly. In that sense, the logarithmic grid might be termed a linear-log grid, one having linear divisions calibrated in decibels.

This grid enhances the appearance of the minor lobes. If the intent is to show the radiation pattern of an array supposedly having an omnidirectional response, this grid enhances that appearance. An antenna having a difference of 8 or 10 dB in pattern response around the compass appears to be closer to omnidirectional on this grid than on any of the others. See Fig A-(B).

ARRL Log Coordinate System

The modified logarithmic grid used by the ARRL has a system of concentric grid lines spaced according to the logarithm of 0.89 times the value of the signal voltage. In this grid, minor lobes that are 30 and 40 dB down from the main lobe are distinguishable. Such lobes are of concern in VHF and UHF work. The spacing between plotted points at 0 dB and –3 dB is significantly greater than the spacing between –20 and –23 dB, which in turn is significantly greater than the spacing between –50 and –53 dB.

For example, the scale distance covered by 0 to –3 dB is about $^{1}/_{10}$ of the radius of the chart. The scale distance for the next 3-dB increment (to –6 dB) is slightly less, 89% of the first, to be exact. The scale distance for the next 3-dB increment (to –9 dB) is again 89% of the second. The scale is constructed so that the progression ends with –100 dB at chart center.

The periodicity of spacing thus corresponds generally to the relative significance of such changes in antenna performance. Antenna pattern plots in this publication are made on the modified-log grid similar to that shown in Fig A-(C).

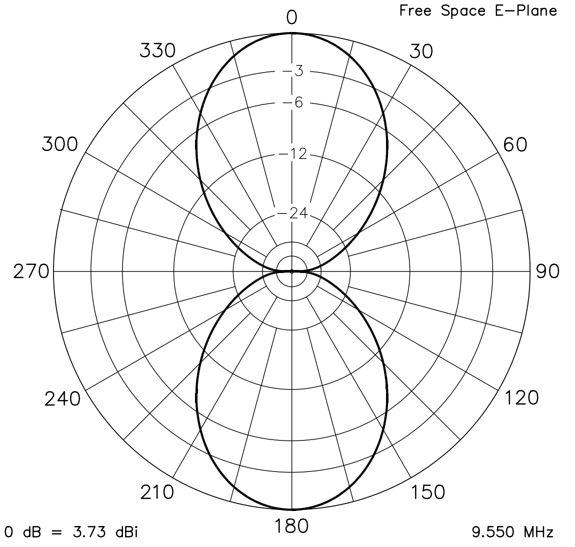

Fig 15—Free-space E-Plane radiation pattern for a 100-foot dipole at its full-wave resonant frequency of 9.55 MHz. The gain has increased to 3.73 dBi, because the main lobes have been focused and sharpened compared to Fig 13.

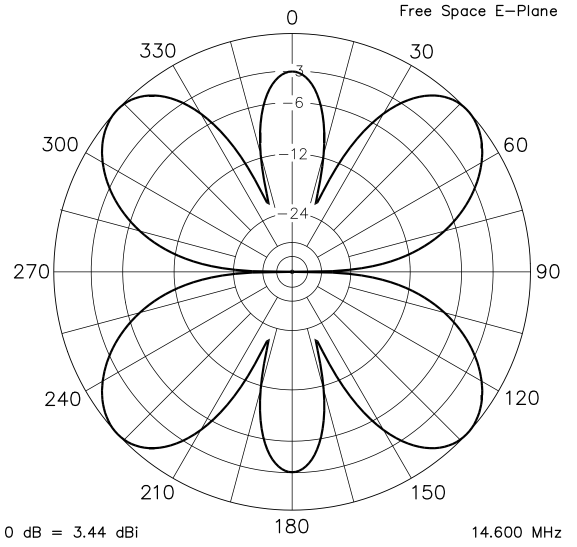

Fig 16—Free-space E-Plane radiation pattern for a 100-foot dipole at its 3/2λ resonant frequency of 14.60 MHz. The pattern has broken up into six lobes, and thus the peak gain has dropped to 3.44 dBi.

Fig 16 shows the pattern at the 3λ/2 frequency of 14.6 MHz. More lobes have developed compared to Fig 14. This means that the power has split up into more lobes and consequently the gain decreases a small amount, down to 3.44 dBi. This is still higher than the dipole at its λ/2 frequency, but lower than at its full-wave frequency. **Fig 17** shows the E-plane response at 19.45 MHz, the 4λ/2, or 2λ, resonant frequency. Now the pattern has reformed itself into only four lobes, and the gain has as a consequence risen to 3.96 dBi.

In **Fig 18** the response has become quite complex at the 5λ/2 resonance point of 24.45 MHz, with ten lobes showing. Despite the presence all these lobes, the main lobes now show a gain of 4.78 dBi. Finally, **Fig 19** shows the pattern at the 3λ (6λ/2) resonance at 29.45 MHz. Despite the fact that there are fewer lobes taking up power than at 24.45 MHz, the peak gain is slightly less at 29.45 MHz, at 4.70 dBi.

Fig A—Radiation pattern plots for a high-gain Yagi antenna on three different grid coordinate systems. At A, the pattern on a linear-power dB grid. Notice how details of sidelobe structure are lost with this grid. At B, the same pattern on a grid with constant 5 dB circles. The sidelobe level is exaggerated when this scale is employed. At B, the same pattern on the modified log grid used by ARRL. The side and rearward lobes are clearly visible on this grid. The concentric circles in all three grids are graduated in decibels referenced to 0 dB at the outer edge of the chart. The patterns look quite different, yet they all represent the same antenna response!

The pattern—and hence the gain—of a fixed-length antenna varies considerably as the frequency is changed. Of course, the pattern and gain change in the same fashion if the frequency is kept constant and the length of the wire is varied. In either case, the wavelength is changing. It is also evident that certain lengths reinforce the pattern to provide more peak gain. If an antenna is not rotated in azimuth when the frequency is changed, the peak gain may occur in a different direction than you might like. In other words, the main lobes change direction as the frequency is varied.

POLARIZATION

We've now examined the first two of the three major properties used to characterize antennas: the radiation pattern and the feed-point impedance. The third general property is *polarization*. An antenna's polarization is defined to be that of its electric field, in the direction where the field strength is maximum.

For example, if a λ/2 dipole is mounted horizontally over the Earth, the electric field is strongest perpendicular to its axis (that is, at right angle to the wire) and parallel to the earth. Thus, since the maximum electric field is horizontal, the polarization in this case is also considered to be *horizontal* with respect to the earth. If the dipole is mounted vertically, its polarization will be *vertical*. See **Fig 20**. Note that if an antenna is mounted in free space, there is no frame of reference and hence its

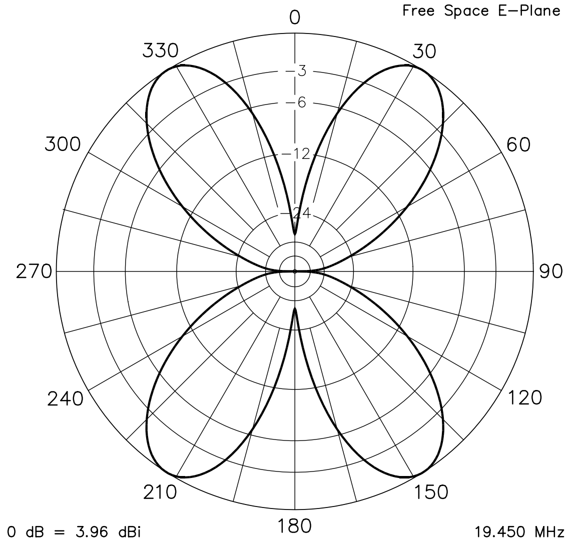

Fig 17—Free-space E-Plane radiation pattern for a 100-foot dipole at twice its full-wave resonant frequency of 19.45 MHz. The pattern has been refocused into four lobes, with a peak gain of 3.96 dBi.

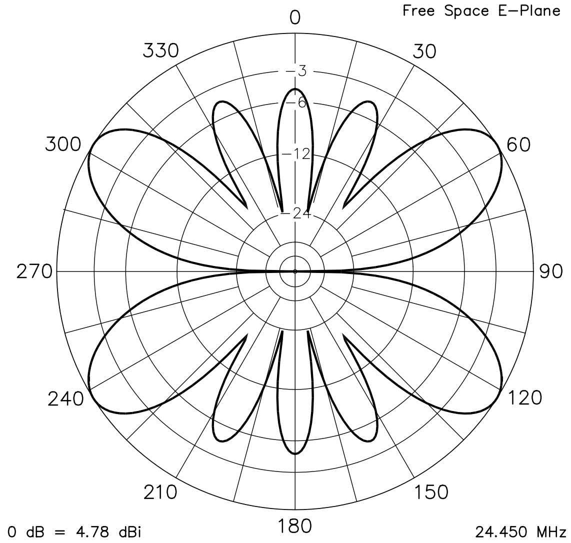

Fig 18—Free-space E-Plane radiation pattern for a 100-foot dipole at its 5/2λ resonant frequency of 24.45 MHz. The pattern has broken down into ten lobes, with a peak gain of 4.78 dBi.

polarization is indeterminate.

Antennas composed of a number of λ/2 elements arranged so that their axes lie in the same or parallel directions have the same polarization as that of any one of the elements. For example, a system composed of a group of horizontal dipoles is horizontally polarized. If both horizontal and vertical elements are used in the same plane and radiate in phase, however, the polarization is the

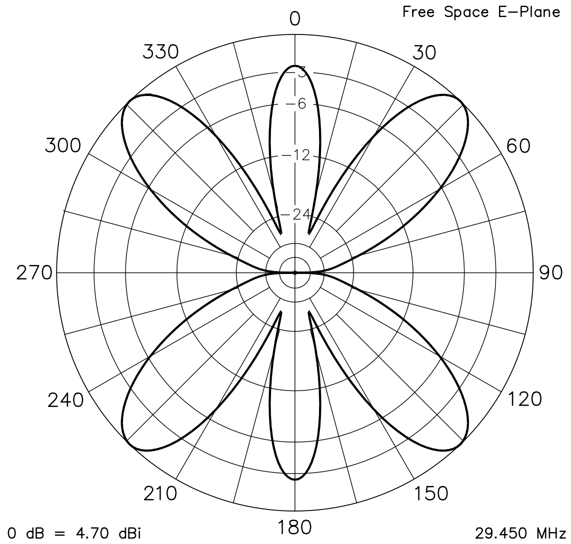

Fig 19—Free-space E-Plane radiation pattern for a 100-foot dipole at three times its full-wave resonant frequency of 29.45 MHz. The pattern has returned to six lobes, with a peak gain of 4.70 dBi.

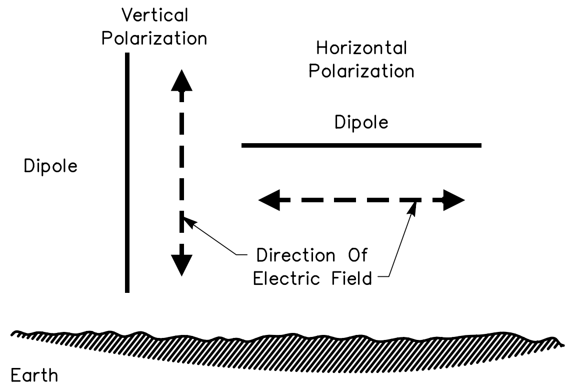

Fig 20—Vertical and horizontal polarization of a dipole above ground. The direction of polarization is the direction of the maximum electric field with respect to the earth.

resultant of the contributions made by each set of elements to the total electromagnetic field at a given point some distance from the antenna. In such a case the resultant polarization is still *linear,* but is tilted between horizontal and vertical.

In directions other than those where the radiation is maximum, the resultant wave even for a simple dipole is a combination of horizontally and vertically polarized components. The radiation off the ends of a horizontal dipole is actually vertically polarized, albeit at a greatly reduced amplitude compared to the broadside horizontally polarized radiation—the sense of polarization changes with compass direction.

Thus it is often helpful to consider the radiation pattern from an antenna in terms of polar coordinates, rather than trying to think in purely linear horizontal or vertical coordinates. See **Fig 21**. The reference axis in a polar system is vertical to the earth under the antenna. The zenith angle is usually referred to as θ (Greek letter theta), and the azimuth angle is referred to as ϕ (Greek letter phi). Instead of zenith angles, most amateurs are more familiar with *elevation angles*, where a zenith angle of 0° is the same as an elevation angle of 90°, straight overhead. Native *NEC* or *MININEC* computer programs use zenith angles rather than elevation angles, although most commercial versions automatically reduce these to elevation angles.

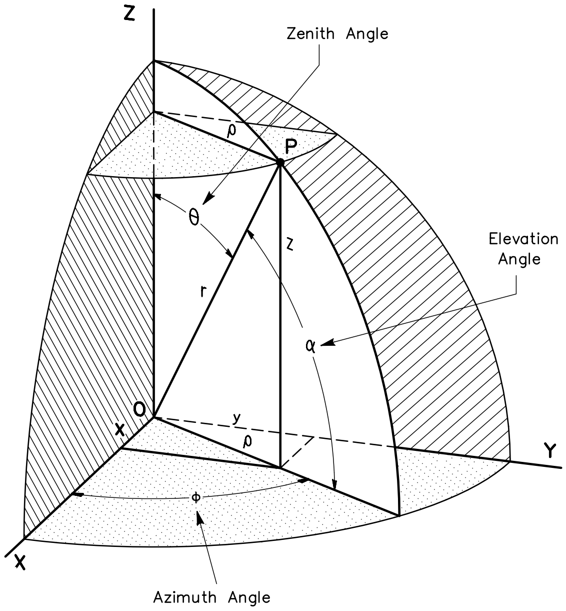

Fig 21—Diagram showing polar representation of a point P lying on an imaginary sphere surround a point-source antenna. The various angles associated with this coordinate system are shown referenced to the x, y and z-axes.

If vertical and horizontal elements in the same plane are fed out of phase (where the beginning of the RF period applied to the feed point of the vertical element is not in time phase with that applied to the horizontal), the resultant polarization is *elliptical*. Circular polarization is a special case of elliptical polarization. The wave front of a circularly polarized signal appears (in passing a fixed observer) to rotate every 90° between vertical and horizontal, making a complete 360° rotation once every period. Field intensities are *equal* at all instantaneous polarizations. Circular polarization is frequently used for space communications, and is discussed further in Chapter 19, Antenna Systems for Space Communications.

Sky-wave transmission usually changes the polarization of traveling waves. (This is discussed in Chapter 23, Radio Wave Propagation.) The polarization of receiving and transmitting antennas in the 3 to 30-MHz range, where almost all communication is by means of sky wave, need not be the same at both ends of a communication circuit (except for distances of a few miles). In this range the choice of polarization for the antenna is usually determined by factors such as the height of available antenna supports, polarization of man-made RF noise from nearby sources, probable energy losses in nearby objects, the likelihood of interfering with neighborhood broadcast or TV reception and general convenience.

Other Antenna Characteristics

Besides the three main characteristics of impedance, pattern (gain) and polarization, there are some other useful properties of antennas.

RECIPROCITY IN RECEIVING AND TRANSMITTING

Many of the properties of a resonant antenna used for reception are the same as its properties in transmission. It has the same directive pattern in both cases, and delivers maximum signal to the receiver when the signal comes from a direction in which the antenna has its best response. The impedance of the antenna is the same, at the same point of measurement, in receiving as in transmitting.

In the receiving case, the antenna is the source of power delivered to the receiver, rather than the load for a source of power (as in transmitting). Maximum possible output from the receiving antenna is obtained when the load to which the antenna is connected is the same as the impedance of the antenna. We say that the antenna is *matched* to its load.

The power gain in receiving is the same as the gain in transmitting, when certain conditions are met. One such condition is that both antennas (usually $\lambda/2$-long antennas) must work into load impedances matched to their own impedances, so that maximum power is transferred in both cases. In addition, the comparison antenna should be oriented so it gives maximum response to the signal used in the test. That is, it should have the same polarization as the incoming signal and should be placed so its direction of maximum gain is toward the signal source.

In long-distance transmission and reception via the ionosphere, the relationship between receiving and transmitting, however, may not be exactly reciprocal. This is because the waves do not always follow exactly the same paths at all times and so may show considerable variation in the time between alternations between transmitting and receiving. Also, when more than one ionospheric layer is involved in the wave travel (see Chapter 23, Radio Wave Propagation), it is sometimes possible for reception to be good in one direction and poor in the other, over the same path.

Wave polarization usually shifts in the ionosphere. The tendency is for the arriving wave to be elliptically polarized, regardless of the polarization of the transmitting antenna. Vertically polarized antennas can be expected to show no more difference between transmission and reception than horizontally polarized antennas. On the average, however, an antenna that transmits well in a certain direction also gives favorable reception from the same direction, despite ionospheric variations.

FREQUENCY SCALING

Any antenna design can be scaled in size for use on another frequency or on another amateur band. The dimensions of the antenna may be scaled with Eq 8 below.

$$D = \frac{f1}{f2} \times d \qquad \text{(Eq 8)}$$

where

D = scaled dimension

d = original design dimension

f1 = original design frequency

f2 = scaled frequency (frequency of intended operation)

From this equation, a published antenna design for, say, 14 MHz can be scaled in size and constructed for operation on 18 MHz, or any other desired band. Similarly, an antenna design could be developed experimentally at VHF or UHF and then scaled for operation in one of the HF bands. For example, from Eq 8, an element of 39.0 inches length at 144 MHz would be scaled to 14 MHz as follows: D = 144/14 × 39 = 401.1 inches, or 33.43 feet.

To scale an antenna properly, *all* physical dimensions must be scaled, including element lengths, element spacings, boom diameters and element diameters. Lengths and spacings may be scaled in a straightforward manner as in the above example, but element diameters are often not as conveniently scaled. For example, assume a 14-MHz antenna is modeled at 144 MHz and perfected with $^3/_8$-inch cylindrical elements. For proper scaling to 14 MHz, the elements should be cylindrical, of 144/14 × $^3/_8$ or 3.86 inches diameter. From a realistic standpoint, a 4-inch diameter might be acceptable, but cylindrical elements of 4-inch diameter in lengths of 33 feet or so would be quite unwieldy (and quite expensive, not to mention heavy). Choosing another, more suitable diameter is the only practical answer.

Diameter Scaling

Simply changing the diameter of dipole type elements during the scaling process is not satisfactory without making a corresponding element-length correction. This is because changing the diameter results in a change in the λ/dia ratio from the original design, and this alters the corresponding resonant frequency of the element. The element length must be corrected to compensate for the effect of the different diameter actually used.

To be more precise, however, the purpose of diameter scaling is not to maintain the same resonant frequency for the element, but to maintain the same ratio of self-resistance to self-reactance at the operating frequency—that is, the Q of the scaled element should be the same as that of the original element. This is not always possible to achieve exactly for elements that use several telescoping sections of tubing.

Tapered Elements

Rotatable beam antennas are usually constructed with elements made of metal tubing. The general practice at HF is to taper the elements with lengths of telescoping tubing. The center section has a large diameter, but the ends are relatively small. This reduces not only the weight, but also the cost of materials for the elements. Tapering of HF Yagi elements is discussed in detail in Chapter 11, HF Yagi Arrays.

Length Correction for Tapered Elements

The effect of tapering an element is to alter its electrical length. That is to say, two elements of the same length, one cylindrical and one tapered but with the same average diameter as the cylindrical element, will not be resonant at the same frequency. The tapered element must be made longer than the cylindrical element for the same resonant frequency.

A procedure for calculating the length for tapered elements has been worked out by Dave Leeson, W6NL (ex-W6QHS), from work done by Schelkunoff at Bell Labs and is presented in Leeson's book, *Physical Design of Yagi Antennas*. In the software accompanying this book is a subroutine called EFFLEN.FOR. It is written in Fortran and is used in the *SCALE* program to compute the effective length of a tapered element. The algorithm uses the W6NL-Schelkunoff algorithm and is commented step-by-step to show what is happening. Calculations are made for only one half of an element, assuming the element is symmetrical about the point of boom attachment.

Also, read the documentation SCALE.PDF for the *SCALE* program, which will automatically do the complex mathematics to scale a Yagi design from one frequency to another, or from one taper schedule to another.

The Vertical Monopole

So far in this discussion on Antenna Fundamentals, we have been using the free-space, center-fed dipole as our main example. Another simple form of antenna derived from a dipole is called a *monopole*. The name suggests that this is one half of a dipole, and so it is. The monopole is always used in conjunction with a *ground plane*, which acts as a sort of electrical mirror. See **Fig 22**, where a λ/2 dipole and a λ/4 monopole are compared. The *image antenna* for the monopole is the dotted line beneath the ground plane. The image forms the missing second half of the antenna, transforming a monopole into the functional equivalent of a dipole. From this explanation you can see where the term *image plane* is sometimes used instead of ground plane.

Although we have been focusing throughout this chapter on antennas in free space, practical monopoles are usually mounted vertically with respect to the surface of the ground. As such, they are called *vertical monopoles*, or simply *verticals*. A practical vertical is supplied power by feeding the radiator against a ground system, usually made up of a series of paralleled wires radiating from and laid out in a circular pattern around the base of the antenna. These wires are termed *radials*.

The term *ground plane* is also used to describe a vertical antenna employing a λ/4-long vertical radiator working against a *counterpoise* system, another name for the ground plane that supplies the missing half of the antenna. The counterpoise for a ground-plane antenna usually consists of four λ/4-long radials elevated well above the earth. See **Fig 23**.

Chapter 3, The Effects of Ground, devotes much attention to the requirements for an efficient grounding system for vertical monopole antennas, and Chapter 6, Low-Frequency Antennas, gives more information on ground-plane verticals.

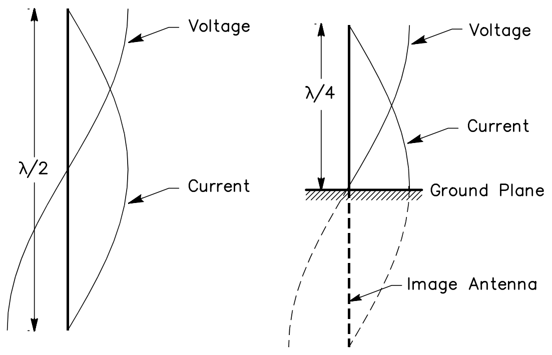

Fig 22—The λ/2 dipole antenna and its λ/4 ground-plane counterpart. The "missing" quarter wavelength is supplied as an image in "perfect" (that is, high-conductivity) ground.

Characteristics of a λ/4 Monopole

The free-space directional characteristics of a λ/4 monopole with its ground plane are very similar to that of a λ/2 antenna in free space. The gain for the λ/4 monopole is slightly less because the H-plane for the λ/2 antenna is compressed compared to the monopole. Like a λ/2 antenna, the λ/4 monopole has an *omnidirectional* radiation pattern in the plane perpendicular to the monopole.

The current in a λ/4 monopole varies practically sinusoidally (as is the case with a λ/2 wire), and is highest at the ground-plane connection. The RF voltage is highest at the open (top) end and minimum at the ground plane. The feed-point resistance close to λ/4 resonance of a vertical monopole over a perfect ground plane is one-half that for a λ/2 dipole at its λ/2 resonance. In this case, a "perfect ground plane" is an infinitely large, lossless conductor.

See **Fig 24**, which shows the feed-point impedance of a vertical antenna made of #14 wire, 50 feet long, located over perfect ground. This is over the whole HF range from 1 to 30 MHz. Again, there is nothing special about the choice of 50 feet for the length of the vertical radiator; it is simply a convenient length for evaluation. **Fig 25** shows an expanded portion of the frequency range above and below the λ/4 resonant point, but now calibrated in terms of wavelength. Note that this particular antenna goes through λ/4 resonance at a length of 0.244 λ, not at exactly 0.25 λ. The exact length for resonance varies with the diameter of the wire used, just as it does for the λ/2 dipole at its λ/2 resonance.

The word *height* is usually used for a vertical monopole antenna whose base is on or near the ground, and in this context, height has the same meaning as *length* when applied to λ/2 dipole antennas. Older texts often refer to heights in electrical degrees, referenced to a free-space wavelength of 360°, but here height is expressed in terms of the free-space wavelength. The range shown in Fig 24 is from 0.132 λ to 0.300 λ, corresponding to a frequency range of 2.0 to 5.9 MHz.

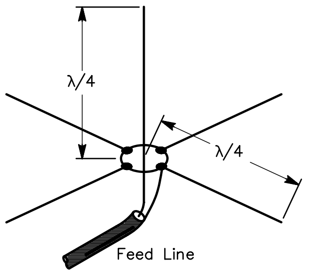

Fig 23—The ground-plane antenna. Power is applied between the base of the vertical radiator and the center of the four ground plane wires.

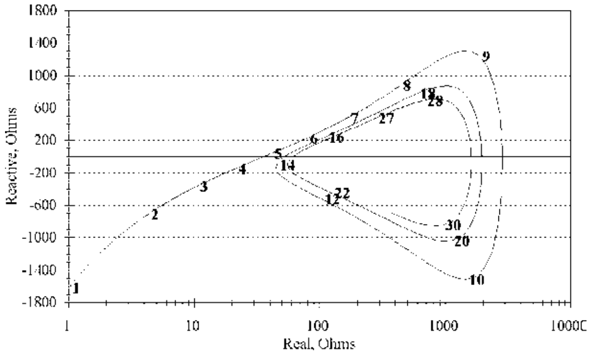

Fig 24—Feed-point impedance versus frequency for a theoretical 50-foot-high grounded vertical monopole made of #14 wire. The numbers along the curve show the frequency in MHz. This was computed using "perfect" ground. Real ground losses will add to the feed-point impedance shown in an actual antenna system.

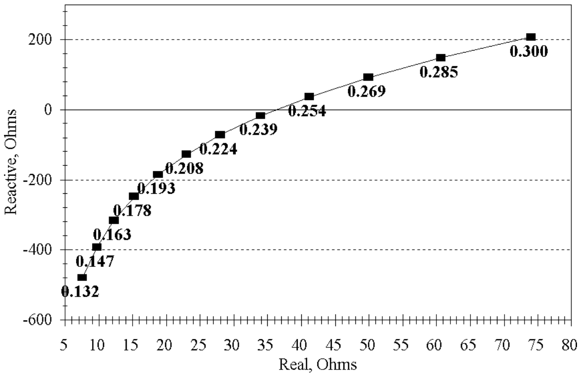

Fig 25—Feed-point impedance for the same antennas as in Fig 21, but calibrated in wavelength rather than frequency, over the range from 0.132 to 0.300λ, above and below the quarter-wave resonance.

The reactive portion of the feed-point impedance depends highly on the length/dia ratio of the conductor, as was discussed previously for a horizontal center-fed dipole. The impedance curve in Figs 24 and 25 is based on a #14 conductor having a length/dia ratio of about 800 to 1. As usual, thicker antennas can be expected to show less reactance at a given height, and thinner antennas will show more.

Efficiency of Vertical Monopoles

This topic of the efficiency of vertical monopole systems will be covered in detail in Chapter 3, The Effects of Ground, but it is worth noting at this point that the efficiency of a real vertical antenna over real earth often suffers dramatically compared with that of a λ/2 antenna. Without a fairly elaborate grounding system, the efficiency is not likely to exceed 50%, and it may be much less, particularly at monopole heights below λ/4.

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Chapter 3

The Effects of Ground

The ground around and under an antenna is part of the environment in which any actual antenna must operate. Chapter 2, Antenna Fundamentals, dealt mainly with theoretical antennas in free space, completely removed from the influence of the ground. This chapter is devoted to exploring the interactions between antennas and the ground.

The interactions can be analyzed depending on where they occur relative to two areas surrounding the antenna: the *reactive near field* and the *radiating far field*. You will recall that the reactive near field only exists very close to the antenna itself. In this region the antenna acts as though it were a large lumped-constant inductor or capacitor, where energy is stored but very little is actually radiated. The interaction with the ground in this area creates mutual impedances between the antenna and its environment and these interactions not only modify the feed-point impedance of an antenna, but also often increase losses.

In the radiating far field, the presence of ground profoundly influences the radiation pattern of a real antenna. The interaction is different, depending on the antenna's polarization with respect to the ground. For horizontally polarized antennas, the *shape* of the radiated pattern in the elevation plane depends primarily on the antenna's height above ground. For vertically polarized antennas, both the *shape* and the *strength* of the radiated pattern in the elevation plane strongly depend on the nature of the ground itself (its dielectric constant and conductivity at the frequency of operation), as well as on the height of the antenna above ground.

The Effects of Ground in the Reactive Near Field

FEED-POINT IMPEDANCE VERSUS HEIGHT ABOVE GROUND

Waves radiated from the antenna directly downward reflect vertically from the ground and, in passing the antenna on their upward journey, induce a voltage in it. The magnitude and phase of the current resulting from this induced voltage depends on the height of the antenna above the reflecting surface.

The total current in the antenna consists of two components. The amplitude of the first is determined by the power supplied by the transmitter and the free-space feed-point resistance of the antenna. The second component is induced in the antenna by the wave reflected from the ground. This second component of current, while considerably smaller than the first at most useful antenna heights, is by no means insignificant. At some heights, the two components will be in phase, so the total current is larger than is indicated by the free-space feed-point resistance. At other heights, the two components are out of phase, and the total current is the difference between the two components.

Changing the height of the antenna above ground will change the amount of current flow, assuming that the power input to the antenna is constant. A higher current at the same power input means that the effective resistance of the antenna is lower, and vice versa. In other words, the feedpoint resistance of the antenna is affected by the height of the antenna above ground because of mutual coupling between the antenna and the ground beneath it.

The electrical characteristics of the ground affect both the amplitude and the phase of reflected signals. For this reason, the electrical characteristics of the ground under the antenna will have some effect on the impedance of that antenna, the reflected wave having been influenced by the ground. Different impedance values may be encountered when an antenna is erected at identical heights but over different types of earth.

Fig 1 shows the way in which the radiation resistance of horizontal and vertical half-wave antennas varies with height above ground (in λ, wavelengths). The height of the vertical half-wave is the distance from the bottom of the antenna to ground. For horizontally polarized half-wave antennas, the differences between the effects of perfect ground and real earth are negligible if the antenna height is greater than 0.2 λ. At lower heights, the feed-point resistance over perfect ground decreases rapidly as the antenna is brought closer to a theoretically perfect ground, but this does not occur so rapidly for actual ground. Over real earth, the resistance actually begins increasing at heights below about 0.08 λ. The reason for the increasing resistance at very low heights is that more and more of the reactive (induction) field of the antenna is absorbed by the lossy ground in close proximity. This results in increased loss that is reflected in the increased value of the feedpoint resistance.

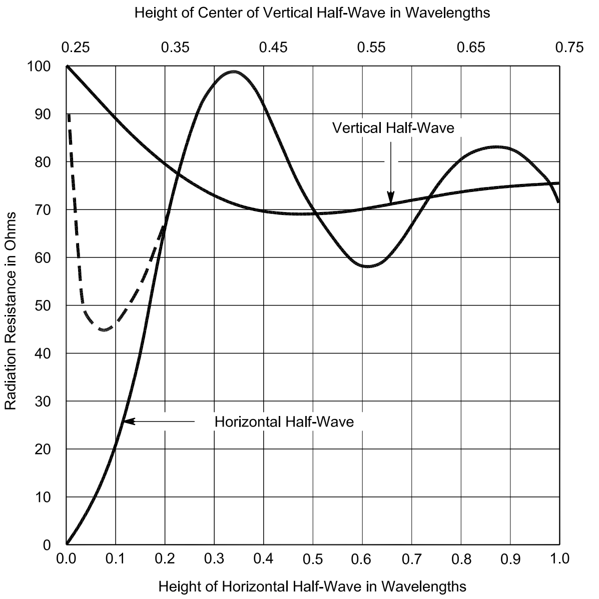

Fig 1—Variation in radiation resistance of vertical and horizontal half-wave antennas at various heights above flat ground. Solid lines are for perfectly conducting ground; the broken line is the radiation resistance of horizontal half-wave antennas at low height over real ground.

For a vertically polarized λ/2-long dipole, differences between the effects of perfect ground and real earth on the feed-point impedance is negligible, as seen in **Fig 1**. The theoretical half-wave antennas on which this chart is based are assumed to have infinitely thin conductors.

GROUND SYSTEMS FOR VERTICAL MONOPOLES

In this section, we'll look at vertical monopoles, which require some sort of ground system in order to make up for the "missing" second half of the antenna and reduce the power lost in the near field. Rudy Severns, N6LF, contributed much of the new material in this chapter.

In Chapter 2, Antenna Fundamentals, and up to this point in this chapter, the discussion about vertical monopoles has mainly been for antennas where *perfect ground* is available. We have also briefly looked at the ground-plane vertical in free space, where the four ground-plane radials form a built-in ground system.

Perfect ground makes a vertical monopole into the functional equivalent of a center-fed dipole, although the feedpoint resistance at resonance is half that of the center-fed dipole. But how can we manage to create that elusive perfect ground, or at least a reasonable approximation, for our real vertical antennas?

Simulating a Perfect Ground in the Reactive Near Field

The effect of a perfectly conducting ground (so far as feed-point resistance and losses are concerned) can be simulated under a real antenna by installing a very large metal screen or mesh, such as poultry netting (chicken wire) or hardware cloth, on or near the surface of the ground. The screen (also called a *counterpoise system*, especially if it is elevated off the ground) should extend at least a half wavelength in every direction from the antenna. The feed-point resistance of a quarter-wave long, thin vertical radiator over such a ground screen will approach the theoretical value of 36.6 Ω. Of course on the lower HF bands such a screen is not practical for most amateurs.

Based on the results of a study published in 1937 by Brown, Lewis and Epstein (see Bibliography), a grounding system consisting of 120 wires, each at least λ/2 long, extending radially from the base of the antenna and spaced equally around a circle, is also the practical equivalent of perfectly conducting ground for reactive-field currents. The wires can either be laid directly on the surface of the ground or buried a few inches below.

Another approach to simulating a perfect ground system is to utilize the ground-plane antenna, with its four ground-plane radials elevated well above lossy earth. Heights (between the bottom of the ground-plane and the surface of the ground) greater than λ/8 have proven to yield excellent results. See Chapter 6, Low-Frequency Antennas, for more details on practical ground-plane verticals.

For a vertical antenna, a large ground screen, either made of wire mesh or a multitude of radials, or an elevated system of ground-plane radials will reduce ground losses near the antenna. This is because the screen conductors are solidly bonded to each other and the resistance is much lower than that of the lossy, low-conductivity earth itself. If the ground screen or elevated ground plane were not present, RF currents would be forced to flow through the lossy, low-conductivity earth to return to the base of the radiator. The ground screen or elevated ground plane in effect shield ground-return currents from the lossy earth.

Less-Than-Ideal Ground Systems

Now, what happens when something less than an ideal ground screen is used as the ground plane for a vertical monopole? Typically this will take the form of an on-ground wire radial system. A great deal of mystery and lack of information seems to surround the vertical antenna ground system. In the case of ground-mounted vertical antennas, many general statements such as “the more radials the better” and “lots of short radials are better than a few long ones” have served as rules of thumb, but many questions as to relative performance differences and optimum number for a given length remain unanswered, as is the justification for the rules of thumb. Most of these questions boil down to one: namely, how many radials, and how long, should be used in a given vertical antenna installation?

A ground system with 120 $\lambda/2$ radials is not very practical for many amateur installations, which often must contend with limited space and funding. Unfortunately the ground resistance, R_g, increases rapidly when the number of radials is reduced. To minimize ground loss where a large, optimum ground system is not possible requires that we understand how ground losses occur and how to optimize the design of a ground system that can fit within the space and budget available.

E and H Fields

E and H fields were introduced in Chapter 2, Antenna Fundamentals, to explain some basic concepts concerning antennas. To understand the reasons for ground loss we need to look at the E and H fields in the near field, but we need to have some feeling for what E and H fields are. The following is a brief description of these fields. It is certainly not a rigorous description but should give at least an intuitive feeling for what is happening.

In 1820 Hans Oerstad discovered that a current flowing in a wire would deflect the needle of a nearby compass. We attribute this effect to a *magnetic* or *H-field*, which at any given location is denoted by the bold-faced letter **H**. **H** is a vector, with an amplitude expressed in A/m (Amperes/meter) and a direction. **Fig 2** shows a typical experimental arrangement. The shape of the magnetic field is roughly shown by the distribution of the iron filings. This field distribution is very similar to that for a vertical antenna.

A compass needle (a small magnet itself) will try to align itself parallel to **H.** As the compass is moved around the conductor, the orientation of the needle changes accordingly. The orientation of the needle gives the direction of **H**. If you attempt to turn the needle away from alignment you will discover a torque trying to restore the needle to its original position. The torque is proportional to the strength of the magnetic field at that point. This is called the *field intensity* or amplitude of **H** at that point. If a larger current flows in the conductor going through the piece of paper holding the iron filings, the amplitude of **H** will be larger. Currents flowing in the conductors of an antenna also generate a magnetic field, one component of the near field.

An antenna will also have an *electric* or *E-field*, which can be visualized using a parallel-plate capacitor, as shown in **Fig 3**. If we connect a battery with a potential V_{dc} across the capacitor plates there will be an electric field **E** established between the plates, as indicated by the lines and directional arrows between the plates. The magnitude of vector **E** is expressed in V/m (volts per meter), so for a potential of V volts and a spacing of d meters, E = V/d V/m. The amplitude of **E** will increase with greater voltage and/or a smaller distance (d). In an antenna, there will be ac potential differences between different parts of the antenna and from the antenna to ground. These ac potential differences establish the electric field associated with the antenna.

Conduction And Displacement Currents

If we replace the dc voltage source in Fig 3 with an ac source, a steady ac current will flow in the circuit. In the

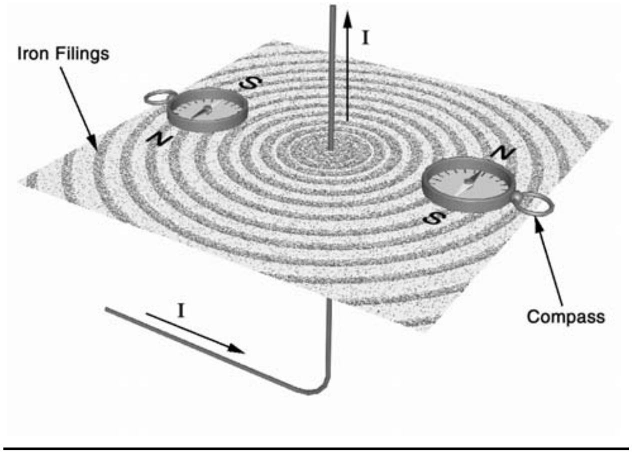

Fig 2—The magnetic lines of force that surround a conductor with an electric current flowing in it are shown by iron filings and small compass needles. The needles point in the direction of the magnetic or H-field. The filings give a general view of the field distribution in the plane perpendicular to the conductor.

conductors between the ac source and the capacitor plates, current (I_c) flows, because of the movement of charge, usually electrons. But in the space between the capacitor plates—particularly in a vacuum—there are no charge carriers available to carry a conduction current. Nonetheless, current still flows in the complete circuit, and we attribute this to a *displacement current* (I_d) flowing between the capacitor plates to account for the continuity of current in the circuit. Displacement and conduction currents are two different phenomena but they both represent current, just two different kinds. Some observers prefer to call conduction currents "currents" and displacement currents "imaginary currents." That terminology is OK, but to account for the current flow in a closed circuit with capacitance you have to keep track of both kinds of current, whatever you call them.

In an antenna over ground, the displacement current represents the current flow from the antenna surface through the air into the ground. The currents flowing in the ground are predominantly conduction currents, but there may also be displacement currents.

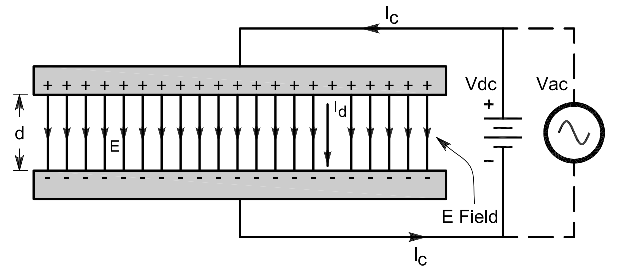

Fig 3—Example of an electric field, E=V$_{dc}$/d. When the dc source is replaced with an ac source there will be a displacement current (I_d) flowing between the capacitor plates.

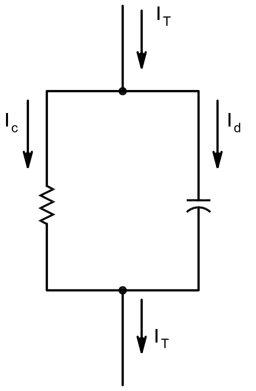

Fig 4—When the capacitor dielectric is less than perfect there will be a conduction current (I_c) in addition to the displacement current (I_d). Soil will typically have both resistive and capacitive components. Power loss in the soil is due to the current flowing through the resistive component.

Where the dielectric material between the capacitor plates is not a perfect insulator, both conduction and displacement currents can flow between the capacitor plates. A good example of this would be a soil dielectric, which has both resistive and capacitive characteristics. Soil can be represented in the circuit of **Fig 4**, where there is a resistor with a conduction current I_c in parallel with a capacitor with a displacement current I_d. The two currents add up (vectorially) as the total current I_T.

A Closer Look at Verticals

A vertical antenna has two field components that induce currents in the ground around the antenna. **Fig 5** shows in a general way the electric-field component (E_z, in V/m) and magnetic-field component (H_ϕ, in A/m) in the region near a vertical. Because the soil near the antenna usually has relatively high resistance, both of these field components will induce currents (I_V and I_H) in the ground, resulting in losses. While the worms may enjoy the heated ground, power dissipated in the ground is subtracted from the radiated power, weakening your signal.

As shown in Fig 5, the tangential component of the H-field (H_ϕ) induces horizontal currents (I_H) flowing radially. The normal component (perpendicular to the ground surface) of the E-field (E_z) induces vertically flowing currents (I_v). Actually, things are more complex than this but we don't need to thrash through that to understand conceptually what's going on.

When modeling an antenna we account for the radiated power (P_r) by assuming there is a resistor we call the *radiation resistance* (R_r) through which the antenna base current (I_o) flows. The radiated power is then $P_r = I_o^2R_r$. Similarly, we can account for the power dissipated in the ground (P_g) by adding a loss resistance (R_g) in series with R_r. The ground loss is then $P_g = I_o^2R_g$. Additional losses due to conductors, loading coils, etc can also be simulated

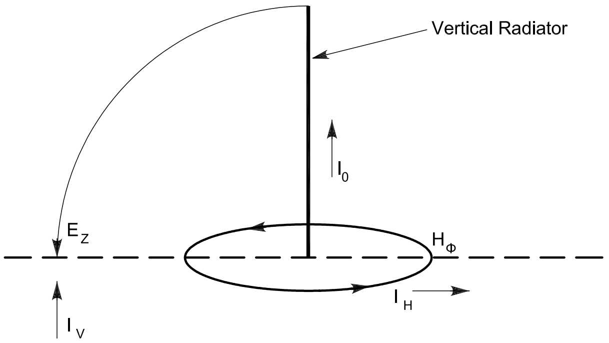

Fig 5—A general view of the fields and ground currents near the base of a vertical antenna. Note that the H-field distribution is equivalent to that shown in Fig 3.

by adding more series loss resistances. Putting aside for the moment these additional losses, the efficiency (η) of a vertical can be expressed as:

$$\eta = \frac{P_r}{P_r + P_g} \qquad \text{(Eq 1)}$$

This can be restated in terms of resistances as:

$$\eta = \frac{R_r}{R_r + R_g} = \frac{1}{1 + \frac{R_g}{R_r}} \qquad \text{(Eq 2)}$$

In essence, efficiency is the ratio of the radiated power to the total input power ($P_T = P_r + P_g$). Another way of saying this is that efficiency depends on the ratio of ground loss resistance (R_g) to radiation resistance (R_r), as Eq 2 shows. The smaller we make R_g the more power will be radiated for a given input power. Reducing R_g is the purpose of the ground system.

A sketch of current flow in the antenna and the surrounding ground (due to H-field), near the base of a vertical, is shown in **Fig 6**. I_z represents the total *zone current* flowing radially through a cylindrical zone at a given radius (r) due to the H field, while I_o is the current at the feed point at the base of the antenna. Technically speaking, the cylinder is infinitely deep, with I_z being the total current integrated over the surface of the cylinder at a given radius.

Fig 7 is a graph of the amplitude of I_z for several antenna heights in wavelengths (h) as we move away from the base of the antenna. Fig 7 shows the zone current that would flow in the ground returning to the base of the antenna, assuming a single ground rod is placed at the feed point for the vertical radiator. The heights indicated are the effective electrical heights. For example, if you use some top loading on the vertical, the effective electrical height will be greater than the physical height.

It is important to recognize that simply adding a top hat to a vertical of a given physical height may reduce ground losses. We can see this from the effect of h on ground current amplitude in Fig 7. Increasing h reduces the ground current. Even something as simple as moving a loading coil from the base up to the center of the antenna may reduce ground losses because it reduces ground current amplitude. But we do have to be careful that the loss introduced by the loading coil does not overcome the reduction in ground loss! Both loading-coil and top-hat schemes also increase the radiation resistance R_r, which further improves efficiency.

The currents in Fig 7 have been adjusted for constant radiated power at the base of the antenna by varying I_o to compensate for the change in R_r as we vary h. To maintain constant radiated power as R_r is falling, you must increase I_o. The base feed-point impedance is a strong function of h. For example, for h = 0.25 λ, R_r will be in the neighborhood of 36 Ω. However, for h = 0.1 λ, R_r will be less than 4 Ω. More information on short antennas can be found in Chapter 16, Mobile and Maritime Antennas.

Fig 7 clearly shows the high currents that flow in the ground near the base of a short antenna due to the antenna's H field. Compared to a 0.25-λ vertical, the 0.1-λ vertical has about three times the base current. As you shorten the antenna further, the zone current increases even more quickly. The ground loss is proportional to the square of the ground current ($P_g = I_g^2 R_g$), so the power loss in the immediate

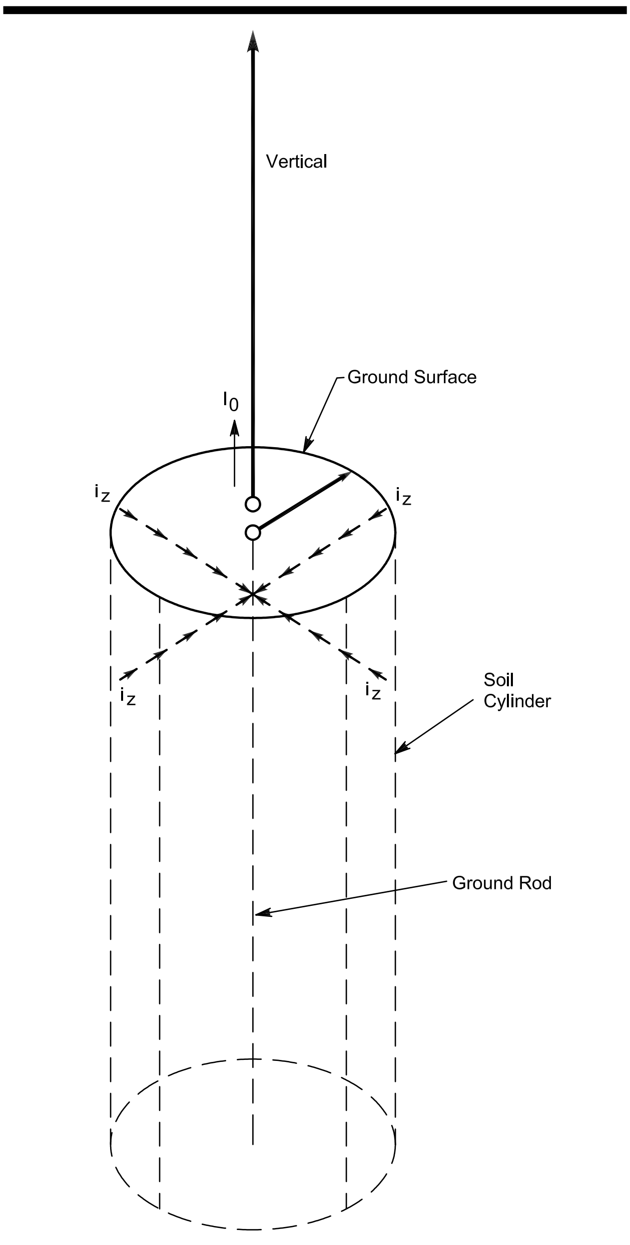

Fig 6—Representation of the zone current near the base of a vertical antenna. Individual i_z components of current flow into a cylinder of soil, with a radius r centered on the base of the vertical. The total current, I_z, thus represents the net current induced in the soil by the H-field for a given radius. (I_z was labeled I_H in Fig 5.)

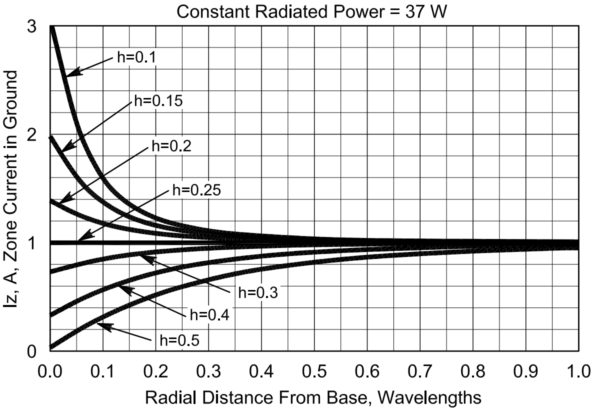

Fig 7—Plot of zone current (I_z) in amperes near the base of a vertical as a function of height (h) and radius (r) in wavelengths. The current in the base of the 0.25-λ antenna is assumed to be 1 A and the current for other values of h is adjusted to maintain the same radiated power ($P_r = I_o^2R_r = 37$ W) as the radiation resistance (R_r) changes with h.

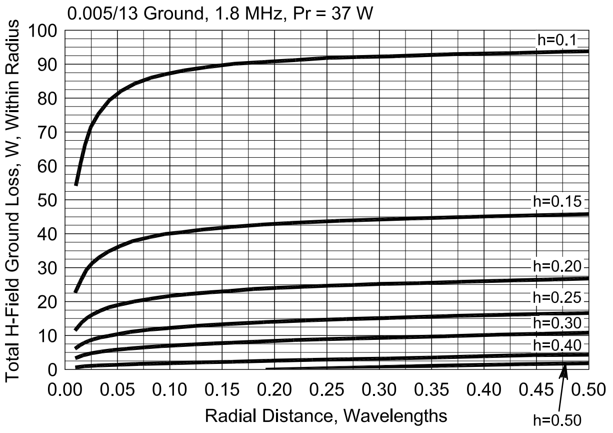

Fig 8—Total H-field induced ground loss within a circle of radius r around the base of a vertical for different values of h and constant $P_r = 37$ W. Note how the total loss increases rapidly near the base of the antenna indicating high loss. Beyond r = 0.15 λ, however, the additional loss is much lower and the curves flatten out. Note also how much higher the loss is for shorter antennas.

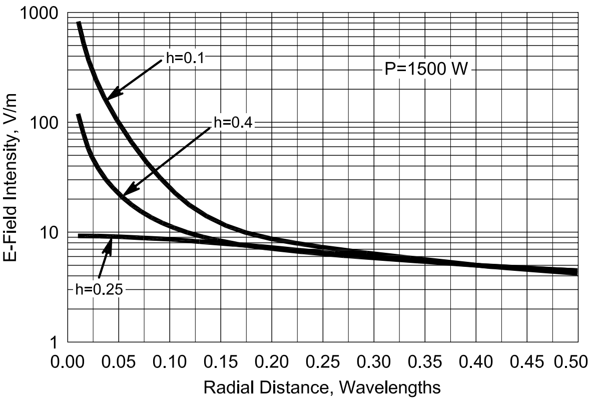

Fig 9—Electric field intensity near the base of a vertical for different values of h. P_r is held constant at 1500 W.

region of the base is much higher for a short antenna operating with the same input power as for a quarter-wave vertical.

We can calculate the losses induced in the soil by either the E- or H-field intensity. **Fig 8** shows an example of the H-field losses for several different antenna heights, given a constant radiated power of 37 W. Note that the total loss within 0.5 λ of the base for h = 0.25 λ is about 16 W (right side of the graph). This gives $\eta = 37/(37 + 16) = 70\%$. However, for h = 0.1 λ, the total loss is about 94 W. Taking into consideration only the H-field losses, $\eta = 37/(37 + 94) = 28\%$. Note that in both cases the majority of the loss is near (< 0.1 λ) the antenna, with the rate of increase of total loss decreasing rapidly as we move farther away from the base, where the lines are almost flat.

Fig 9 is a graph of the E-field intensity around a vertical with 1500 W radiated power, for three values of h. The E-field intensity doesn't depend on the exact type of ground system. (You can see this when you consider that the voltage across a capacitor doesn't depend on the size of the capacitor's plates.) Notice that close to the base, the E-field intensity for the 0.1-λ vertical is almost 100 times that for the 0.25-λ vertical. Because loss is proportional to the square of the voltage, the E-field losses close to the base will be ten thousand times larger in the 0.1-λ vertical! At a 1500-W power level the field intensity near the base of a short vertical is high enough to pose some risk of igniting grass and bushes that grow above any radial system close to the vertical's base. The grass should be kept mowed within 0.1 λ of the base.

Fig 10 shows a computation for the E-field losses, again for a constant radiated power of 37 W and several values of h. For the 0.25-λ vertical, the electric field intensity is quite low and so are the losses associated with it, at only 1.5 W. With any reasonable ground system, the E-field losses for a 0.25-λ vertical will be insignificant.

For shorter or longer verticals, however, the picture is different. This is why we see the very high losses (> 100 W) in Fig 10 for h = 0.1 λ. This loss, when added to the H-field loss, reduces the efficiency of the 0.1-λ vertical to 16% or less without a good ground system. In short antennas the E-field losses cannot be ignored, since they get worse exponentially as the antenna is shortened further.

The presence of a top-loading hat will also increase the E-field intensity in the area below the hat. However, most practical amateur hats will be quite small and the associated E-field loss small. The benefit, however, of reducing I_o because of the addition of the hat—which reduces the field

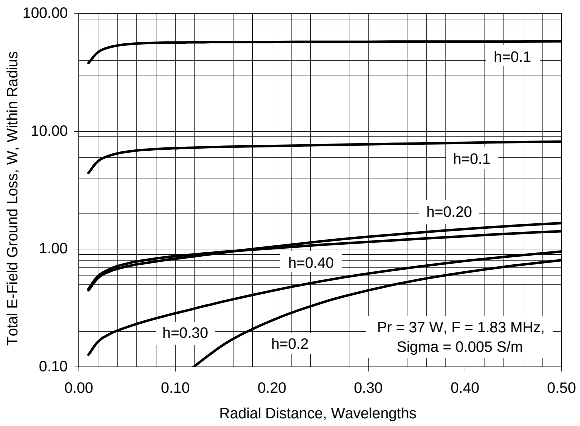

Fig 10—Total E-field induced ground loss within a circle of radius r around the base of a vertical for different values of h and constant P_r = 37 W. Note how the total loss increases rapidly near the base of the antenna, indicating high loss. Beyond r = 0.05 λ, however, the additional loss is much lower and the curves flatten out. Note again how much higher the loss is for shorter antennas. For h = 0.1 λ the E-field loss is greater than the H-field loss.

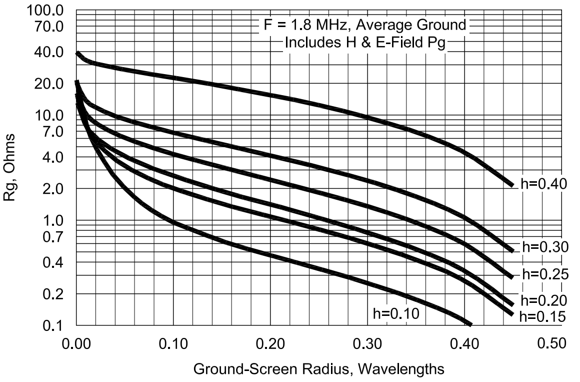

Fig 11—Effective ground resistance (R_g) at the base of the vertical as a function of the radius of a ground screen for several different antenna heights. Note how R_g falls as power dissipation in the soil is eliminated by the highly conducting ground screen.

from the vertical part of the antenna—more than compensates for the small additional E-field loss due to the hat.

Verticals taller than 0.25 λ also display increased E-field intensity, but not nearly so severe as short verticals. In verticals both shorter and longer than a 0.25 λ, the critical loss region is within a radius of about 0.05 λ. We can see this in Fig 10, where the power-loss curves for the shorter antennas flatten out by the time we reach a radius of 0.05 λ.

It's not widely known, but while radial wire systems reduce the H-field losses very effectively, Larsen (see Bibliography) has shown that the E-field losses with the same radial system do not fall in the same fashion as H-field losses. For h > 0.15 λ this doesn't matter much because the E-field loss is so low anyway. However, for short antennas it is very helpful to install either a ground screen or a dense radial system within 0.05 λ of the base.

We can take the data in Figs 8 and 10 and calculate the effective value of the ground resistance R_g. **Fig 11** shows the results of such a computation. Fig 11 assumes a perfect ground screen that varies in radius from 0.001 λ to 0.5 λ. As we would expect, when the ground screen is very small the ground losses are high, meaning R_g is high and the efficiency is low. As we increase the radius of the ground screen, forcing current out of the lossy soil and into the very low-loss screen, R_g drops rapidly and the efficiency increases.

Fig 11 demonstrates why it is desirable to have a good ground system out to at least 0.125 λ, and better yet, even farther. The shorter the antenna, the more important the ground system becomes, especially close to the base. In this example the ground system consists of a highly conductive, bonded ground screen, not always practical for amateur installations. A more typical ground system would consist of a number of individual radial wires. This kind of ground will be inferior to a screen but represents a practical compromise. We'll examine this in more detail shortly.

Note that as we reduce h in Fig 11, R_g actually goes down—even though the ground losses are higher. When h is made smaller the radiation resistance declines rapidly (see Chapter 16, Mobile and Maritime Antennas), so that for a given radiated power I_o must increase. If we measure R_g as we reduce h over a given ground system, we would see that the value for R_g goes down as shown in Fig 11. But because I_o^2 is rising more rapidly than R_g is falling, the power lost in the ground increases and efficiency decreases. The point here is that the value of R_g depends on the ground system, soil characteristics *and* the antenna configuration. You cannot assign an arbitrary value to R_g independent of the antenna system.

Wire Radial Systems

Fig 11 shows R_g for a dense, perfectly conducting ground screen, but what we really need to know is the effect of length and number of individual radials on R_g in a wire radial system. We can calculate the current division between a radial system and the soil and use this to determine R_g. A typical graph of the proportion of the zone current flowing in the radial system, as a function of radius and various numbers of radials (N), is shown in **Fig 12**.

The radial currents decrease as we move away from the base, and the lower the number of radials, the more rapidly the radial current decreases. This means that close to the base of the antenna most of the current is in the radial system, but as we move away from the base the current increasingly flows in the lossy ground. When only a few radials are used, the outer ends of the radials contribute little to reducing ground loss.

Why is this? The problem is that I_z does not go immediately to the nearest radial but may flow for some distance in the soil. This is illustrated in a general way in **Fig 13**. As we move away from the base of the antenna, adjacent radials are further apart from each other and the current must flow further in the soil before it reaches one of the radials. When we use more radials, the distance between radials is less and more of the total current will be in the radials and less in the soil. This reduces ground loss.

When we know the current distribution in the ground we can calculate the power loss and R_g. A typical example for h = 0.25 λ is given in **Fig 14**. We can learn a lot about radial system design from Fig 14 and similar graphs. If we use only a few radials, the radial current drops off very rapidly. Most of the current is flowing in the soil.

Such a ground system is by nature inefficient—that is, R_g is large. We can also see that if we have only 16 radials, R_g falls an ohm or two as we lengthen the radials, but is essentially flat by 0.1 λ. There is no point in making them longer because there is little current in the outer portions and R_g is essentially constant beyond 0.1 λ. As we increase the number of radials, we gather more current further out, making longer radials more useful. The result is cumulative—more radials allow longer radials to be effective and both together reduce ground loss. We can see this in Fig 14, where the initial value of R_g drops as N increases and flattens out at longer radial lengths. For 128 radials, for example, lengths of 0.25 λ or more are useful.

The example in Fig 14 uses #12 wire for the radials. Compared to soil, the resistance of the radial wires is very small, especially if many radials are used, and does not greatly affect overall losses no matter how small the wire. The effect of changing wire size is to slowly change the current division between ground and the radial system. Larger wire results in only a small decrease in R_g. In principle, very small wire could be used for radials but from a mechanical point of view, #18 or #20 wire is about as small as is practical. Any smaller wire breaks too easily to be buried, and also breaks easily when left on the ground surface and is walked on or driven over.

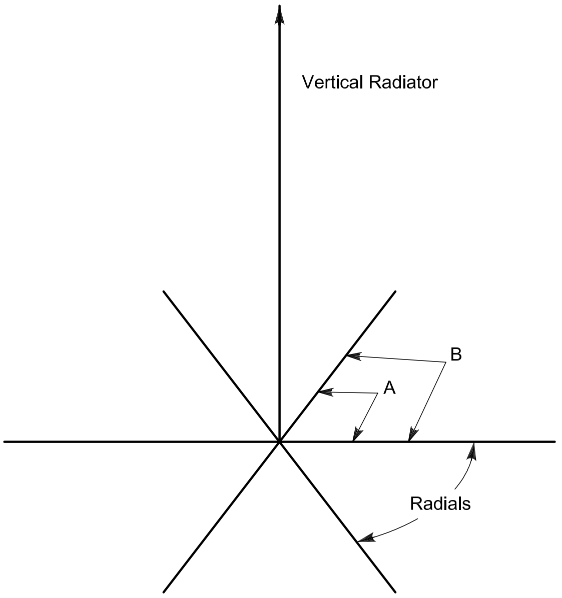

Fig 13—An example of current entering the ground between the radials and flowing for some distance before being picked up by a radial.

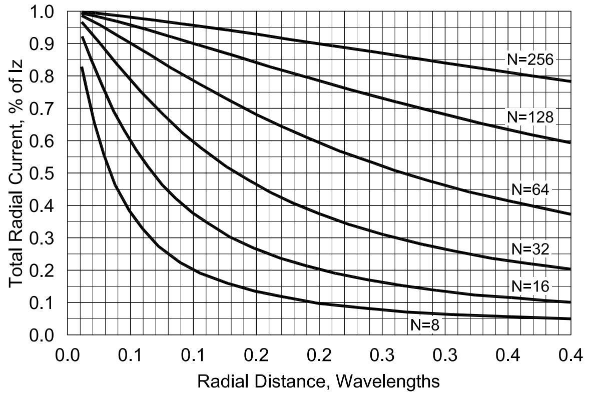

Fig 12—An example of the portion of the zone current flowing in the radial system as you move away from the base of a 0.25 λ vertical for different numbers of radials (N). Note that when more radials are used, more of the zone current flows in the radials and not in the ground, reducing ground loss. The proportion of current in the radial system falls rapidly when only a few radials are used. This leads to high ground loss because most of the zone current is flowing in the ground rather than in the radials.

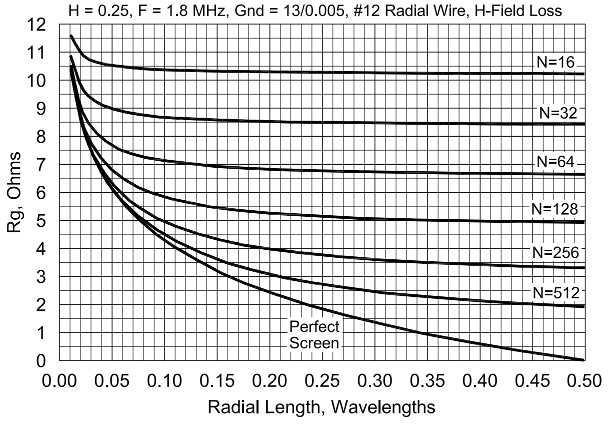

Fig 14—An example of the variation of R_g with radial length and number of radials (N) for h = 0.25 λ. When only a few radials are used there is little point in making them longer than 0.1 λ. Increasing N reduces R_g at a given radius and also makes longer radials useful, further reducing R_g. R_g for other values of h behave similarly.

On the other hand, wire larger than #12 is expensive. Thousands of feet of #8 wire may be affordable for broadcast stations but not for most hams. Increasing the wire size from #20 to #10 would result in only a small reduction in R_g. Of course, if you happen to have a few thousand feet of old RG-8 cable lying around (the diameter is comparable to #0000 wire) then that might indeed help to reduce R_g, as W9QQ has shown (see Bibliography). You are still better off, however, using many radials with small wire than a few radials with large wire. Radial wire size is usually a mechanical and financial issue, not an electrical one.

If the example in Fig 14 were changed for different ground characteristics, then the curves would have a similar shape but would be shifted either up or down. For example, poorer ground will result in higher R_g but the usable length for the radials for a given N would increase somewhat. For better-quality ground, with higher conductivity, R_g will be lower but the usable length of the radials for a given N will be shorter.

For short antennas, the initial drop in R_g will be more rapid and the curves flatten out sooner. This implies that somewhat shorter radials are useful with short antennas. However, given the high losses, it is still a very good idea to use lots of radials with short antennas. As in the above example, increasing N also increases the usable length.

As you go up in frequency from 160 meters, R_g generally rises slowly and then stabilizes around 7 MHz, depending on the ground characteristics. This effect is related to the change in skin depth with frequency, which is discussed in a later section of this chapter. There is also a small shift in current division between the radials and ground as the frequency increases.

A Word Of Caution

In the preceding discussion we presented a number of graphs and the CD-ROM accompanying this book contains some spreadsheets containing the equations from which these graphs were derived. From these graphs we extracted a number of observations on how to design radial systems. Basic to each graph is the assumption that we know the ground characteristics: conductivity and permitivity. In the real world, we amateurs very rarely have more than a rough idea of the ground characteristics under our antennas. Even when careful measurements are made, the characteristics will vary through the year with rainfall or the lack thereof.

Soils are always stratified vertically and can vary by factors or two or more horizontally over distances comparable to radial length, so that even good ground measurements are at best an average. In addition, there will frequently be constraints on the size and shape of the ground system. As a result, we use the calculated information and the previous graphs for general guidance and preliminary design, but when actually installing a ground system we try to measure—or at least estimate—R_g as we go along.

When R_g stops falling, or our patience and/or money run out, we stop adding ground radials. We can measure the feed-point resistance with an impedance bridge to estimate of R_g. The impedance seen at the feed point of the antenna is the sum of the loss and the radiation resistance. To determine R_g you have to estimate R_r (from the antenna height) and other losses due to loading or conductors, and then subtract that from the total measured input resistance. The remainder is R_g, and R_g should fall as we add radials. When R_g stops falling we probably have as many radials of a given length as will be useful. Further reduction in R_g would require more, longer radials.

Practical Suggestions For Vertical Ground Systems

At least 16 radials should be used if at all possible. Experimental measurements and calculations show that with this number, the loss resistance decreases the antenna efficiency by 30% to 50% for a 0.25 λ vertical, depending on soil characteristics. In general, a large number of radials (even though some or all of them must be short) is preferable to a few long radials for a vertical antenna mounted on the ground. The conductor size is relatively unimportant as mentioned before: #12 to #22 copper wire is suitable.

Table 1 summarizes these conclusions. John Stanley, K4ERO, first presented this material in December 1976 *QST*. Another source of information on ground-system design is *Radio Broadcast Ground Systems* (see the Bibliography at the end of this chapter). Most of the data presented in Table 1 is taken from that source, or derived from the interpolation of data contained therein.

Table 1 is based on the number of radials. For each configuration, there is a corresponding optimum radial length. Each configuration also includes the amount of wire used, expressed in wavelengths. Using radials considerably longer than suggested for a given N or using a lot more radials than suggested for a given length, while not adverse to performance, does not yield significant improvement either. That would represent a non-optimum use of wire and construction time. Each suggested configuration represents an optimum relationship between length and number for the given amount of total wire used. Table 1 leads to these conclusions:

- If you install only 16 radials (in configuration A), they need not be very long—0.1 λ is sufficient. The total length of wire will be 1.6 λ, which is about 875 feet at 1.8 MHz.
- If you have the wire, the space and the patience to lay down 120 radials (optimal configuration F), they should be 0.4 λ long. This radial system will gain about 3 dB over the 16-radial case and you'll use 48 λ of wire, or about 26,000 feet at 1.8 MHz.
- If you install 36 radials that are 0.15 λ long, you will lose 1.5 dB compared to optimal configuration F. You will use 5.4 λ of wire, or almost 3,000 feet at 1.8 MHz.

The loss figures in Table 1 assume h = 0.25 λ. A very rough approximation of loss when using shorter antennas can be obtained by doubling the loss in dB each

Table 1
Optimum Ground-System Configurations

	Configuration	*Designation*				
	A	*B*	*C*	*D*	*E*	*F*
Number of radials	16	24	36	60	90	120
Length of each radial in wavelengths	0.1	0.125	0.15	0.2	0.25	0.4
Spacing of radials in degrees	22.5	15	10	6	4	3
Total length of radial wire installed, in wavelengths	1.6	3	5.4	12	22.5	48
Power loss in dB at low angles with a quarter-wave radiating element	3	2	1.5	1	0.5	0*
Feed-point impedance in ohms with a quarter-wave radiating element	52	46	43	40	37	35

Note: Configuration designations are indicated only for text reference.
*Reference: The loss of this configuration is negligible compared to a perfectly conducting ground.

time the antenna height is halved. For taller antennas the losses decrease, approaching 2 dB for configuration A of Table 1 for a half-wave radiator. Even longer antennas yield correspondingly better performance.

Table 1 is based on average ground conductivity. Variation of the loss values shown can be considerable, especially for configurations using fewer radials. Those building antennas over dry, sandy or rocky ground should expect more loss. On the other hand, higher than average soil conductivity and wet soils would make the compromise configurations (those with the fewest radials) even more attractive.

When antennas are combined into arrays, either parasitic or all-driven types, mutual impedances lower the radiation resistance of the elements. This drastically increases the effects of ground loss because I_0 will be higher for the same power level. For instance, an antenna with a 50-Ω feed-point impedance, of which 10 Ω is ground-loss resistance, will have an efficiency of approximately 83%. An array of two similar antennas in a driven array with similar ground losses may have an efficiency of 70% or less.

Special precautions must be taken in such cases to achieve satisfactory operation. Generally speaking, a wide-spaced broadside array presents little problem because R_r is high, but a close-spaced end-fire array should be avoided because R_r is much lower, unless low-loss radial system configurations are used or other precautions taken. Chapter 8, Multielement Arrays, covers the subject of vertical arrays in great detail.

In cases where directivity is desirable or real-estate limitations dictate, longer, more closely spaced radials can be installed in one direction, and shorter, more widely spaced radials in another. Multiband ground systems can be designed using different optimum configurations for different bands. Usually it is most convenient to start at the lowest frequency with fewer radials and add more short radials for better performance on the higher bands.

There is nothing sacred about the exact details of the configurations in Table 1, and small changes in the number of radials and lengths will not cause serious problems. Thus, a configuration with 32 or 40 radials of 0.14 λ or 0.16 λ will work as well as configuration C shown in the table.

If less than 90 radials are contemplated, there is no need to make them a quarter wavelength long. This differs rather dramatically from the case of a ground-plane antenna, where resonant radials are installed above ground. For a ground-mounted antenna, quarter-wave long radials may not be optimum. Because the radials of a ground-mounted vertical are actually on, if not slightly below the surface, they are coupled by capacitance or conduction to the ground, and thus resonance effects are not important. The basic function of radials is to provide a low-loss return path for ground currents.

Radio Broadcast Ground Systems states, "Experiments show that the ground system consisting of only 15 radial wires need not be more than 0.1 wavelength long, while the system consisting of 113 radials is still effective out to 0.5 wavelength." Many graphs in that publication confirm this statement. This is not to say that these two systems will perform equally well; they most certainly will not. However, if 0.1 λ is as long as the radials can be, there is little point in using more than 15 of them unless the vertical radiator's height is also small.

The antenna designer should:

1. Study the cost of various radial configurations versus the gain of each.
2. Compare alternative means of improving transmitted signal and their cost (more power, etc).
3. Consider increasing the physical antenna height (the electrical length) of the vertical radiator, instead of improving the ground system.
4. Use multi-element arrays for directivity and gain, observing the necessary precautions related to mutual impedances discussed in Chapter 8, Multielement Arrays.

The Effect of Ground in the Far Field

The properties of the ground in the far field of an antenna are very important, especially for a vertically polarized antenna, as discussed above. Even if the ground-radial system for a vertical has been optimized to reduce ground-return losses in the reactive near field to an insignificant level, the electrical properties of the ground may still diminish far-field performance to lower levels than "perfect-ground" analyses might lead you to expect. The key is that *ground reflections* from horizontally and vertically polarized waves behave very differently.

Reflections in General

First, let us consider the case of flat ground. Over flat ground, either horizontally or vertically polarized downgoing waves launched from an antenna into the far field strike the surface and are reflected by a process very similar to that by which light waves are reflected from a mirror. As is the case with light waves, the angle of reflection is the same as the angle of incidence, so a wave striking the surface at an angle of, say, 15° is reflected upward from the surface at 15°.

The reflected waves combine with direct waves (those radiated at angles above the horizon) in various ways. Some of the factors that influence this combining process are the height of the antenna, its length, the electrical characteristics of the ground, and as mentioned above, the polarization of the wave. At some elevation angles above the horizon the direct and reflected waves are exactly in phase—that is, the maximum field strengths of both waves are reached at the same time at the same point in space, and the directions of the fields are the same. In such a case, the resultant field strength for that angle is simply the sum of the direct and reflected fields. (This represents a theoretical increase in field strength of 6 dB over the free-space pattern at these angles.)

At other elevation angles the two waves are completely out of phase—that is, the field intensities are equal at the same instant and the directions are opposite. At such angles, the fields cancel each other. At still other angles, the resultant field will have intermediate values. Thus, the effect of the ground is to increase radiation intensity at some elevation angles and to decrease it at others. When you plot the results as an elevation pattern, you will see *lobes* and *nulls*, as described in Chapter 2, Antenna Fundamentals.

The concept of an *image antenna* is often useful to show the effect of reflection. As **Fig 15** shows, the reflected ray has the same path length (AD equals BD) that it would if it originated at a virtual second antenna with the same characteristics as the real antenna, but situated below the ground just as far as the actual antenna is above it.

Now, if we look at the antenna and its image over perfect ground from a remote point on the surface of the ground, we will see that the currents in a horizontally polarized antenna and its image are flowing in opposite directions, or in other words, are 180° out of phase. But the currents in a vertically polarized antenna and its image are flowing in the *same* direction—they are *in* phase. This 180° phase difference between the vertically and horizontally polarized reflections off ground is what makes the combinations with direct waves behave so very differently.

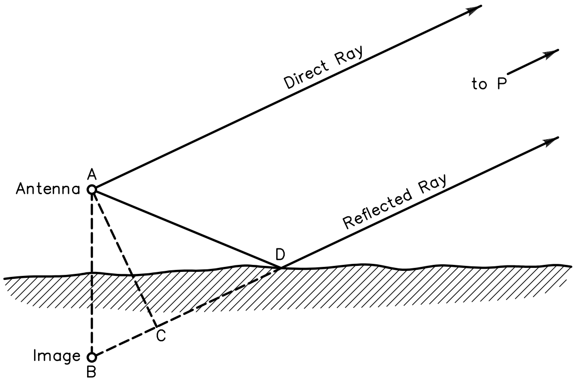

Fig 15—At any distant point, P, the field strength will be the vector sum of the direct ray and the reflected ray. The reflected ray travels farther than the direct ray by the distance BC, where the reflected ray is considered to originate at the *image* antenna.

FAR-FIELD GROUND REFLECTIONS AND THE VERTICAL ANTENNA

A vertical's azimuthal directivity is omnidirectional. A λ/2 vertical over ideal, perfectly conducting earth has the elevation-plane radiation pattern shown by the solid line in **Fig 16**. Over real earth, however, the pattern looks more like the shaded one in the same diagram. In this case, the low-angle radiation that might be hoped for because of perfect-ground performance is not realized in the real world.

Now look at **Fig 17A**, which compares the computed elevation-angle response for two half-wave dipoles at 14 MHz. One is oriented horizontally over ground at a height of λ/2 and the other is oriented vertically, with its center just over λ/2 high (so that the bottom end of the wire doesn't actually touch the ground). The ground is "average" in dielectric constant (13) and conductivity (0.005 S/m). At a 15° elevation angle, the horizontally polarized dipole has almost 7 dB more gain than its vertical brother. Contrast Fig 17A to the comparison in Fig 17B, where the peak gain of a vertically polarized half-wave dipole over seawater, which is virtually perfect for RF reflections, is quite comparable with the horizontal dipole's response at 15°, and exceeds the horizontally polarized antenna dramatically below 15° elevation.

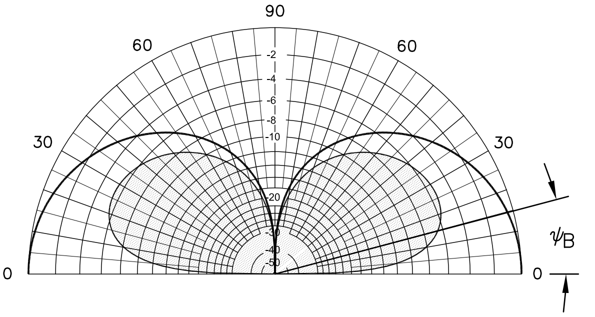

Fig 16—Vertical-plane radiation pattern for a ground-mounted quarter-wave vertical. The solid line is the pattern for perfect earth. The shaded pattern shows how the response is modified over average earth (k = 13, G = 0.005 S/m) at 14 MHz. ψ is the pseudo-Brewster angle (PBA), in this case 14.8°.

To understand in a qualitative fashion why the desired low-angle radiation from a vertical is not delivered when the ground isn't "perfect," examine **Fig 18A**. Radiation from each antenna segment reaches a point P in space by two paths; one directly from the antenna, path AP, and the other by reflection from the earth, path AGP. (Note that P is so far away that the slight difference in angles is insignificant—for practical purposes the waves are parallel to each other at point P.)

If the earth were a perfectly conducting surface, there would be no phase shift of the vertically polarized wave upon reflection at point G. The two waves would add together with some phase difference because of the different path lengths. This difference in path lengths of the two waves is why the free-space radiation pattern differs from the pattern of the same antenna over ground.

Now consider a point P that is close to the horizon, as in Fig 18B. The path lengths AP and AGP are almost the same, so the magnitudes of the two waves add together, producing a maximum at zero angle of radiation. The arrows on the waves point both ways since the process works similarly for transmitting and receiving.

With real earth, however, the reflected wave from a vertically polarized antenna undergoes a change in both *amplitude* and *phase* in the reflection process. Indeed, at a low-enough elevation angle, the phase of the reflected wave will actually change by 180° and its magnitude will then subtract from that of the direct wave. At a zero takeoff angle, it will be almost equal in amplitude, but 180° out of phase with the direct wave.

Note that this is very similar to what happens with horizontally polarized reflected and direct waves at low elevation angles. Virtually complete cancellation will result in a deep null, inhibiting any radiation or reception at 0°. For real-world soils, the vertical loses the theoretical advantage it has at low elevation angles over a horizontal antenna, as Fig 17A so clearly shows.

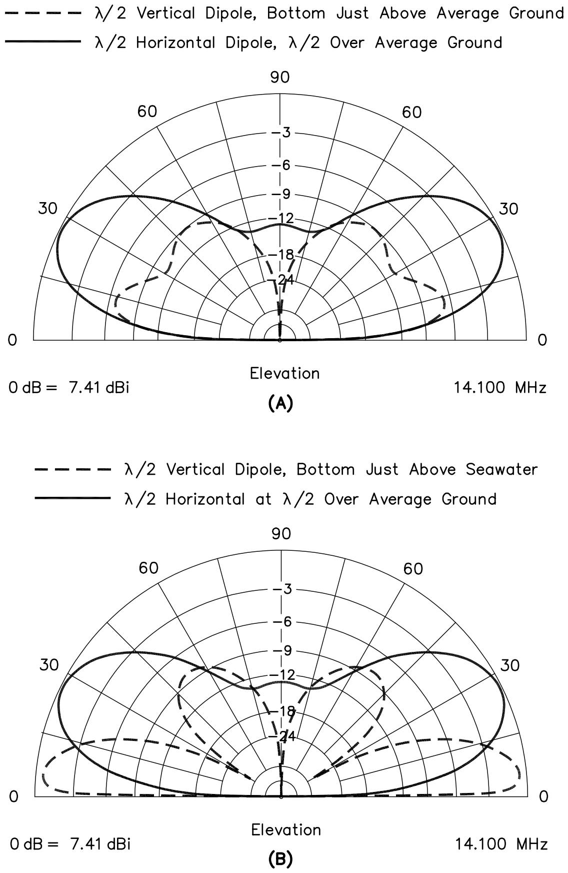

Fig 17—At A, comparison of horizontal and vertical $\lambda/2$ dipoles over average ground. Average ground has conductivity of 5 mS/m and dielectric constant of 13. Horizontal dipole is $\lambda/2$ high; vertical dipole's bottom wire is just above ground. Horizontal antenna is much less affected by far-field ground losses compared with its vertical counterpart. At B, comparison of 20-meter $\lambda/2$ vertical dipole whose bottom wire is just above seawater with $\lambda/2$-high horizontal dipole over average ground. Seawater is great for verticals!

The degree that a vertical works better than a horizontal antenna at low elevation angles is largely dependent on the characteristics of the ground around the vertical, as we'll next examine.

THE PSEUDO-BREWSTER ANGLE AND THE VERTICAL ANTENNA

Much of the material presented here regarding pseudo-Brewster angle was prepared by Charles J. Michaels, W7XC, and first appeared in July 1987 *QST*, with additional information in *The ARRL Antenna Compendium, Vol 3*. (See the Bibliography at the end of this chapter.)

Most fishermen have noticed that when the sun is low, its light is reflected from the water's surface as glare, obscuring the underwater view. When the sun is high, however, the sunlight penetrates the water and it is possible to see objects below the surface of the water. The angle at which this transition takes place is known as the *Brewster angle*,

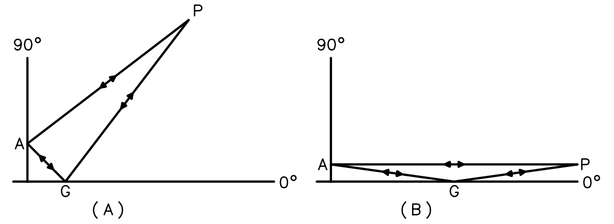

Fig 18—The direct wave and the reflected wave combine at point P to form the pattern (P is very far from the antenna). At A the two paths AP and AGP differ appreciably in length, while at B these two path lengths are nearly equal.

named for the Scottish physicist, Sir David Brewster (1781-1868).

A similar situation exists in the case of vertically polarized antennas; the RF energy behaves as the sunlight in the optical system, and the earth under the antenna acts as the water. The *pseudo-Brewster angle* (PBA) is the angle at which the reflected wave is 90° out of phase with respect to the direct wave. “Pseudo” is used here because the RF effect is similar to the optical effect from which the term gets its name. Below this angle, the reflected wave is between 90° and 180° out of phase with the direct wave, so some degree of cancellation takes place. The largest amount of cancellation occurs near 0°, and steadily less cancellation occurs as the PBA is approached from below.

The factors that determine the PBA for a particular location *are not related to the antenna itself, but to the ground around it*. The first of these factors is earth conductivity, G, which is a measure of the ability of the soil to conduct electricity. Conductivity is the inverse of resistance. The second factor is the dielectric constant, k, which is a unitless quantity that corresponds to the capacitive effect of the earth. For both of these quantities, the higher the number, the better is the ground (for vertical antenna purposes). The third factor determining the PBA for a given location is the frequency of operation. The PBA increases with increasing frequency, all other conditions being equal. **Table 2** gives typical values of conductivity and dielectric constant for different types of soil. The map of **Fig 19** shows the approximate conductivity values for different areas in the continental United States.

As the frequency is increased, the role of the dielectric constant in determining the PBA becomes more significant. **Table 3** shows how the PBA varies with changes in ground conductivity, dielectric constant and frequency. The table shows trends in PBA dependency on ground constants and frequency. The constants chosen are not necessarily typical of any geographical area; they are just examples.

At angles below the PBA, the reflected vertically polarized wave subtracts from the direct wave, causing the radiation intensity to fall off rapidly. Similarly, above the PBA, the reflected wave adds to the direct wave, and the radiated pattern approaches the perfect-earth pattern. Fig 16 shows the PBA, usually labeled ψ_B.

When plotting vertical-antenna radiation patterns over real earth, the reflected wave from an antenna segment is multiplied by a factor called the *vertical reflection coefficient,* and the product is then added vectorially to the direct wave to get the resultant. The reflection coefficient consists of an attenuation factor, A, and a phase angle, ϕ, and is usually expressed as $A\angle\phi$. (ϕ is always a negative angle, because the earth acts as a lossy capacitor in this situation.) The following equation can be used to calculate the reflection coefficient for vertically polarized waves, for earth of given conductivity and dielectric constant at any frequency and elevation angle (also called the wave angle in many texts).

Table 2
Conductivities and Dielectric Constants for Common Types of Earth

Surface Type	*Dielectric Constant*	*Conductivity (S/m)*	*Relative Quality*
Fresh water	80	0.001	
Salt water	81	5.0	
Pastoral, low hills, rich soil, typ Dallas, TX, to Lincoln, NE areas	20	0.0303	Very good
Pastoral, low hills, rich soil typ OH and IL	14	0.01	
Flat country, marshy, densely wooded, typ LA near Mississippi River	12	0.0075	
Pastoral, medium hills and forestation, typ MD, PA, NY, (exclusive of mountains and coastline)	13	0.006	
Pastoral, medium hills and forestation, heavy clay soil, typ central VA	13	0.005	Average
Rocky soil, steep hills, typ mountainous	12-14	0.002	Poor
Sandy, dry, flat, coastal	10	0.002	
Cities, industrial areas	5	0.001	Very Poor
Cities, heavy industrial areas, high buildings	3	0.001	Extremely poor

Table 3
Pseudo-Brewster Angle Variation with Frequency, Dielectric Constant, and Conductivity

Frequency (MHz)	*Dielectric Constant*	*Conductivity (S/m)*	*PBA (degrees)*
7	20	0.0303	6.4
	13	0.005	13.3
	13	0.002	15.0
	5	0.001	23.2
	3	0.001	27.8
14	20	0.0303	8.6
	13	0.005	14.8
	13	0.002	15.4
	5	0.001	23.8
	3	0.001	29.5
21	20	0.0303	10.0
	13	0.005	15.2
	13	0.002	15.4
	5	0.001	24.0
	3	0.001	29.8

$$A_{\text{Vert}} \angle\phi = \frac{k' \sin\psi - \sqrt{k' - \cos^2 \psi}}{k' \sin\psi + \sqrt{k' - \cos^2 \psi}} \qquad \text{(Eq 3)}$$

where

$A_{\text{Vert}} \angle \phi$ = vertical reflection coefficient

ψ = elevation angle

$$k' = k - j \left| \frac{1.8 \times 10^4 \times G}{f} \right|$$

k = dielectric constant of earth (k for air = 1)

G = conductivity of earth in S/m

f = frequency in MHz

j = complex operator ($\sqrt{-1}$)

Solving this equation for several points indicates what effect the earth has on vertically polarized signals at a particular location for a given frequency range. **Fig 20** shows the reflection coefficient as a function of elevation angle at 21 MHz over average earth (G = 0.005 S/m, and k = 13).

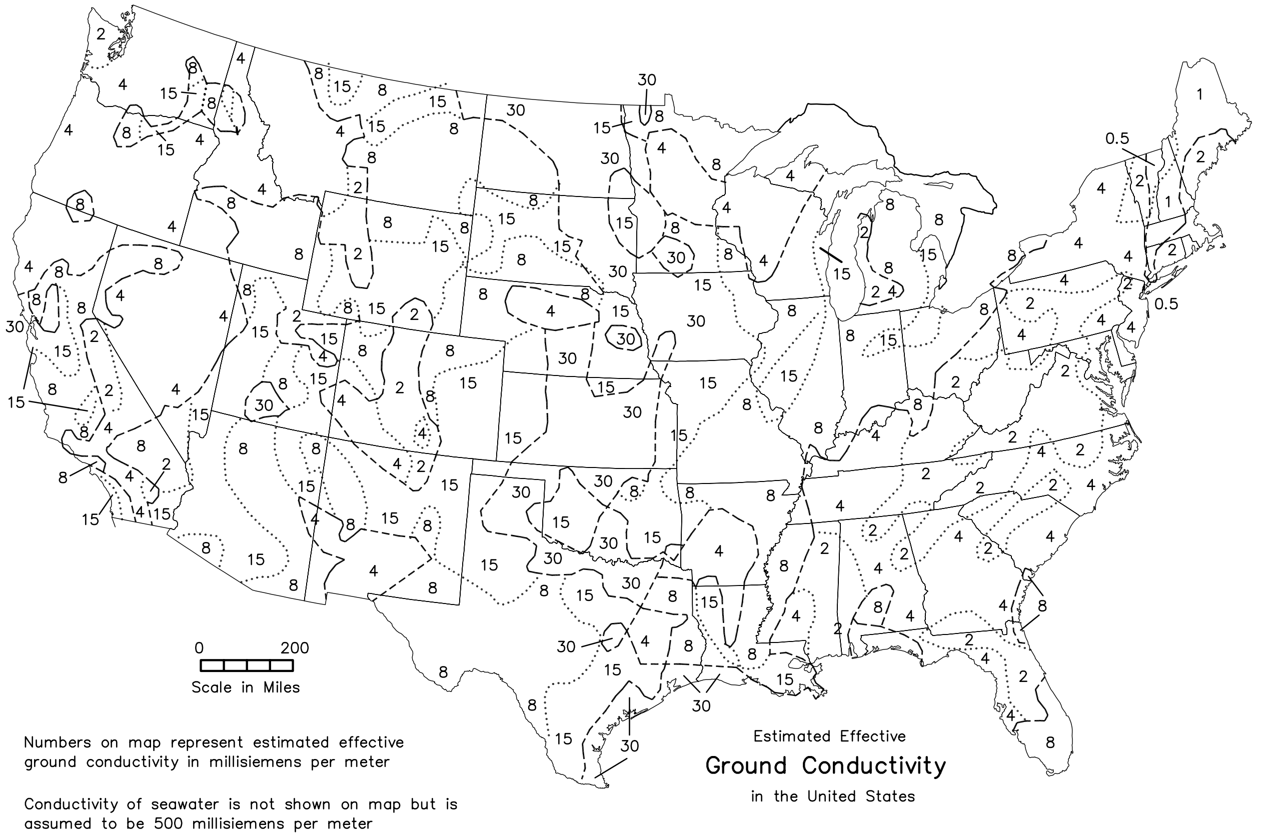

Numbers on map represent estimated effective ground conductivity in millisiemens per meter

Conductivity of seawater is not shown on map but is assumed to be 500 millisiemens per meter

Fig 19—Typical average soil conductivities for the continental United States. Numeric values indicate conductivities in millisiemens per meter (mS/m), where 1.0 mS/m = 0.001 S/m.

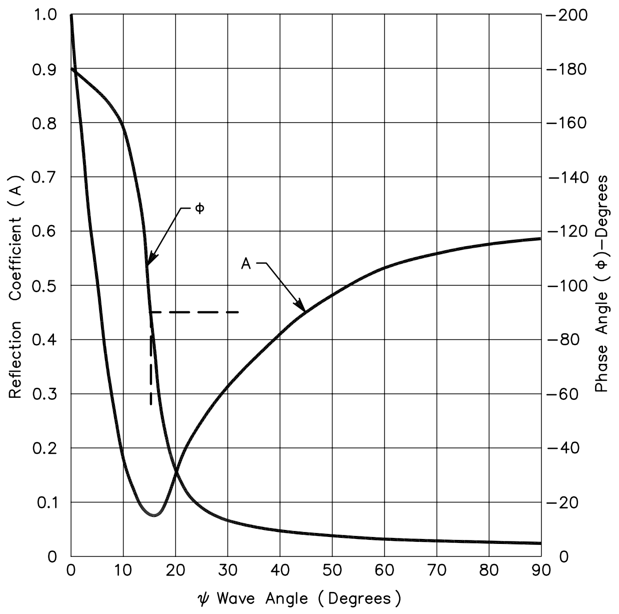

Fig 20—Reflection coefficient for vertically polarized waves. A and ϕ are magnitude and angle for wave angles ψ. This case is for average earth, (k = 13, G = 0.005 S/m), at 21 MHz.

Note that as the phase curve, ψ, passes through 90°, the attenuation curve (A) passes through a minimum at the same wave angle ψ. This is the PBA. At this angle, the reflected wave is not only at a phase angle of 90° with respect to the direct wave, but is so low in amplitude that it does not aid the direct wave by a significant amount. In the case illustrated in Fig 20 this elevation angle is about 15°.

Variations in PBA with Earth Quality

From Eq 3, it is quite a task to search for either the 90° phase point or the attenuation curve minimum for a wide variety of earth conditions. Instead, the PBA can be calculated directly from the following equation.

$$\psi_B = \arcsin\sqrt{\frac{k-1+\sqrt{(x^2+k^2)^2(k-1)^2+x^2[(x^2+k^2)^2-1]}}{(x^2+k^2)^2-1}}$$

(Eq 4)

where k, G and f are as defined for Eq 3, and

$$x = \frac{1.8 \times 10^4 \times G}{f}$$

Fig 21 shows curves calculated using Eq 4 for several different earth conditions, at frequencies between 1.8 and 30 MHz. As expected, poorer earths yield higher PBAs. Unfortunately, at the higher frequencies (where low-angle radiation is most important for DX work), the PBAs are highest. The PBA is the same for both transmitting and receiving.

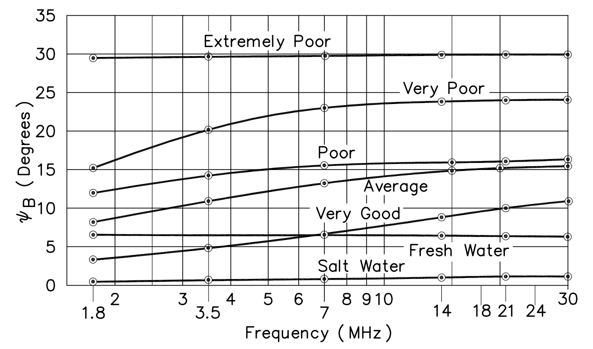

Fig 21—Pseudo-Brewster angle (ψ) for various qualities of earth over the 1.8 to 30-MHz frequency range. Note that the frequency scale is logarithmic. The constants used for each curve are given in Table 2.

Relating PBA to Location and Frequency

Table 2 lists the physical descriptions of various kinds of earth with their respective conductivities and dielectric constants, as mentioned earlier. Note that in general, the dielectric constants and conductivities are higher for better earths. This enables the labeling of the earth characteristics as extremely poor, very poor, poor, average, very good, and so on, without the complications that would result from treating the two parameters independently.

Fresh water and salt water are special cases; in spite of high resistivity, the fresh-water PBA is 6.4°, and is nearly independent of frequency below 30 MHz. Salt water, because of its extremely high conductivity, has a PBA that never exceeds 1° in this frequency range. The extremely low conductivity listed for cities (the last case) in Table 2 results more from the clutter of surrounding buildings and other obstructions than any actual earth characteristic. The PBA at any location can be found for a given frequency from the curves in Fig 21.

FLAT-GROUND REFLECTIONS AND HORIZONTALLY POLARIZED WAVES

The situation for horizontal antennas is different from that of verticals. **Fig 22** shows the reflection coefficient for horizontally polarized waves over average earth at 21 MHz. Note that in this case, the phase-angle departure from 0° never gets very large, and the attenuation factor that causes the most loss for high-angle signals approaches unity for low angles. Attenuation increases with progressively poorer earth types.

In calculating the broadside radiation pattern of a horizontal λ/2 dipole, the perfect-earth image current, equal to the true antenna current but 180° out of phase with it) is multiplied by the horizontal reflection coefficient given by Eq 5 below. The product is then added vectorially to the direct wave to get the resultant at that elevation angle. The reflection coefficient for horizontally polarized waves can be calculated using the following equation.

$$A_{Horiz} \angle \phi = \frac{\sqrt{k' - \cos^2 \psi} - \sin \psi}{\sqrt{k' - \cos^2 \psi} + \sin \psi} \qquad \text{(Eq 5)}$$

where

$A_{Horiz} \angle \phi$ = horizontal reflection coefficient
ψ = elevation angle

$$k' = k - j\left(\frac{1.8 \times 10^4 \times G}{f}\right)$$

k = dielectric constant of earth
G = conductivity of earth in S/m
f = frequency in MHz
j = complex operator ($\sqrt{-1}$)

For a horizontal antenna near the earth, the resultant pattern is a modification of the free-space pattern of the antenna. **Fig 23** shows how this modification takes place for a horizontal λ/2 antenna over a perfectly conducting flat surface. The patterns at the left show the relative radiation when one views the antenna from the side; those at the right show the radiation pattern looking at the end of the antenna. Changing the height above ground from λ/4 to λ/2 makes a significant difference in the high-angle radiation, moving the main lobe down lower.

Note that for an antenna height of λ/2 (Fig 23, bottom), the out-of-phase reflection from a perfectly conducting surface creates a null in the pattern at the zenith (90° elevation angle). Over real earth, however, a *filling in* of this null occurs because of ground losses that prevent perfect reflection of high-angle radiation.

At a 0° elevation angle, horizontally polarized antennas also demonstrate a null, because out-of-phase reflection cancels the direct wave. As the elevation angle departs from 0°, however, there is a slight filling-in effect so that over other-than-perfect earth, radiation at lower angles is enhanced compared to a vertical. A horizontal antenna will often outperform a vertical for low-angle DX work, particularly over lossy types of earth at the higher frequencies.

Reflection coefficients for vertically and horizontally polarized radiation differ considerably at most angles above ground, as can be seen by comparison of Figs 20 and 22. (Both sets of curves were plotted for the same ground constants and at the same frequency, so they may be compared directly.) This is because, as mentioned earlier, the image of a horizontally polarized antenna is out-of-phase with the antenna itself, and the image of a vertical antenna is in-phase with the actual radiator.

The result is that the phase shifts and reflection magnitudes vary greatly at different angles for horizontal and vertical polarization. The magnitude of the reflection coefficient for vertically polarized waves is greatest (near unity) at very low angles, and the phase angle is close to 180°. As mentioned earlier, this cancels nearly all radiation at very low angles. For the same range of angles, the magnitude of the reflection coefficient for horizontally polarized waves is also near unity, but the phase angle is near 0° for the specific conditions shown in Figs 20 and 22. This causes reinforcement of low-angle horizontally polarized waves. At some relatively high angle, the reflection coefficients for

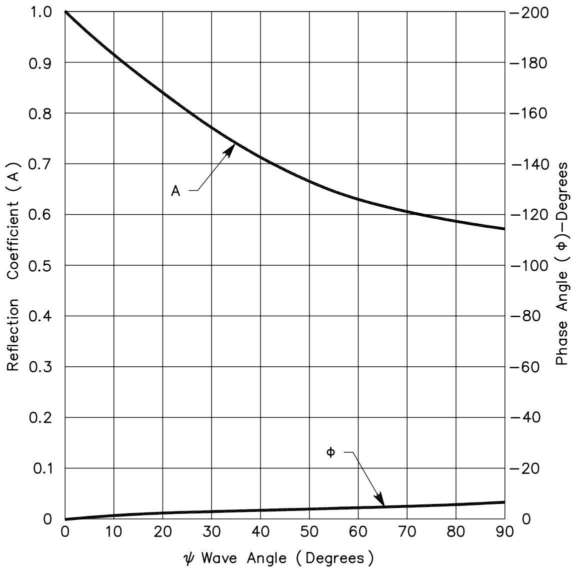

Fig 22—Reflection coefficient for horizontally polarized waves (magnitude A at angle ϕ), at 21 MHz over average earth (k = 13, G = 0.005 S/m).

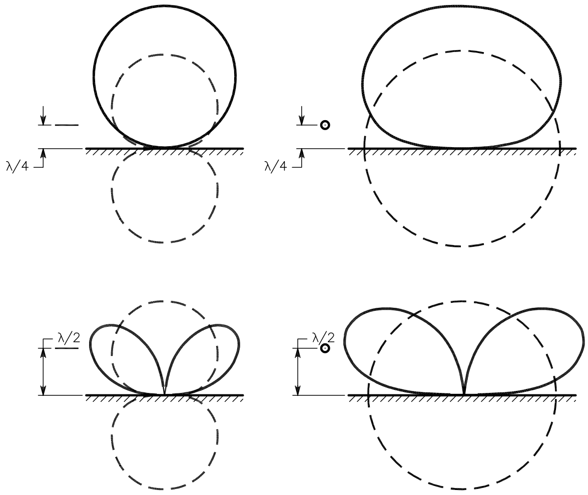

Fig 23—Effect of the ground on the radiation from a horizontal half-wave dipole antenna, for heights of one-fourth and one-half wavelength. Broken lines show what the pattern would be if there were no reflection from the ground (free space).

horizontally and vertically polarized waves are equal in magnitude and phase. At this angle (approximately 81° for the example case), the effect of ground reflection on vertically and horizontally polarized signals will be the same.

DEPTH OF RF CURRENT PENETRATION

When considering earth characteristics, questions about depth of RF current penetration often arise. For instance, if a given location consists of a 6-foot layer of soil overlying a highly resistive rock strata, which material dominates? The answer depends on the frequency, the soil and rock dielectric constants, and their respective conductivities. The following equation can be used to calculate the current density at any depth.

$$e^{-pd} = \frac{\text{Current Density at Depth d}}{\text{Current Density at Surface}} \qquad \text{(Eq 6)}$$

where

d = depth of penetration in cm

e = natural logarithm base (2.718)

$$p = \left(\frac{X \times B}{2} \times \left(\sqrt{1 + \frac{G^2 \times 10^{-4}}{B^2}} - 1 \right) \right)^{1/2}$$

$X = 0.008 \times \pi^2 \times f$

$B = 5.56 \times 10^{-7} \times k \times f$

k = dielectric constant of earth

f = frequency in MHz

G = conductivity of earth in S/m

After some manipulation of this equation, it can be used to calculate the depth at which the current density is some fraction of that at the surface. The depth at which the current density is 37% (1/*e*) of that at the surface (often referred to as *skin depth*) is the depth at which the current density would be zero if it were distributed uniformly instead of exponentially. (This 1/*e* factor appears in many physical situations. For instance, a capacitor charges to within 1/*e* of full charge within one RC time constant.) At this depth, since the power loss is proportional to the square of the current, approximately 91% of the total power loss has occurred, as has most of the phase shift, and current flow below this level is negligible.

Fig 24 shows the solutions to Eq 6 over the 1.8 to 30-MHz frequency range for various types of earth. For example, in very good earth, substantial RF currents flow down to about 3.3 feet at 14 MHz. This depth goes to 13 feet in average earth and as far as 40 feet in very poor earth. Thus, if the overlying soil is rich, moist loam, the underlying rock stratum is of little concern. However, if the soil is only average, the underlying rock may constitute a major consideration in determining the PBA and the depth to which the RF current will penetrate.

The depth in fresh water is about 156 feet and is nearly independent of frequency in the amateur bands below 30 MHz. In salt water, the depth is about seven inches at 1.8 MHz and decreases rather steadily to about two inches at 30 MHz. Dissolved minerals in moist earth increase its conductivity.

The depth-of-penetration curves in Fig 24 illustrate a noteworthy phenomenon. While skin effect confines RF current flow close to the surface of a conductor, the earth is so lossy that RF current penetrates to much greater depths than in most other media. The depth of RF current penetration is a function of frequency as well as earth type. Thus, the only cases in which most of the current flows near the surface are with very highly conductive media (such as salt water), and at frequencies above 30 MHz.

DIRECTIVE PATTERNS OVER REAL GROUND

As explained in Chapter 2, Antenna Fundamentals, because antenna radiation patterns are three-dimensional, it is helpful in understanding their operation to use a form of representation showing the elevation-plane directional characteristic for different heights. It is possible to show selected elevation-plane patterns oriented in various directions with respect to the antenna axis. In the case of the horizontal half-wave dipole, a plane running in a direction along the axis and another broadside to the antenna will give a good deal of information.

The effect of reflection from the ground can be expressed as a separate *pattern factor*, given in decibels. For any given elevation angle, adding this factor algebraically to the value for that angle from the free-space pattern for that antenna gives the resultant radiation value at that

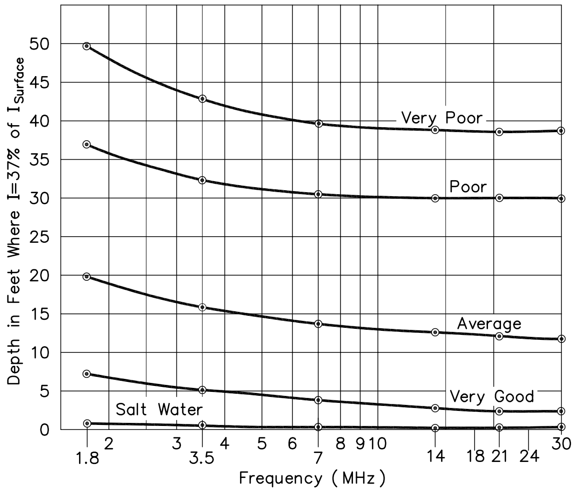

Fig 24—Depths at which the current density is 37% (1/*e*) of that at the surface for different qualities of earth over the 1.8- to 30-MHz frequency range. The depth for fresh water, not plotted, is 156 feet and almost independent of frequency below 30 MHz. See text and Table 2 for ground constants.

angle. The limiting conditions are those represented by the direct ray and the reflected ray being exactly in-phase and exactly out-of-phase, when both (assuming there are no ground losses) have equal amplitudes. Thus, the resultant field strength at a distant point may be either 6 dB greater than the free-space pattern (twice the field strength), or zero, in the limiting cases.

Horizontally Polarized Antennas

The way in which pattern factors vary with height for horizontal antennas over flat earth is shown graphically in the plots of **Fig 25**. The solid-line plots are based on perfectly conducting ground, while the shaded plots are based on typical real-earth conditions. These patterns apply to horizontal antennas of any length. While these graphs are, in fact, radiation patterns of horizontal single-wire antennas (dipoles) as viewed from the axis of the wire, it must be remembered that the plots merely represent pattern factors.

Fig 26 shows vertical-plane radiation patterns in the directions off the ends of a horizontal half-wave dipole for various antenna heights. These patterns are scaled so they may be compared directly to those for the appropriate heights in Fig 25. Note that the perfect-earth patterns in Figs 26A and 25B are the same as those in the upper part of Fig 23. Note also that the perfect-earth patterns of Figs 26B and 25D are the same as those in the lower section of Fig 23. The reduction in field strength off the ends of the wire at the lower angles, as compared with the broadside field strength, is quite apparent. It is also clear from Fig 26 that, at some heights, the high-angle radiation off the ends is nearly as great as the broadside radiation, making the antenna essentially an omnidirectional radiator.

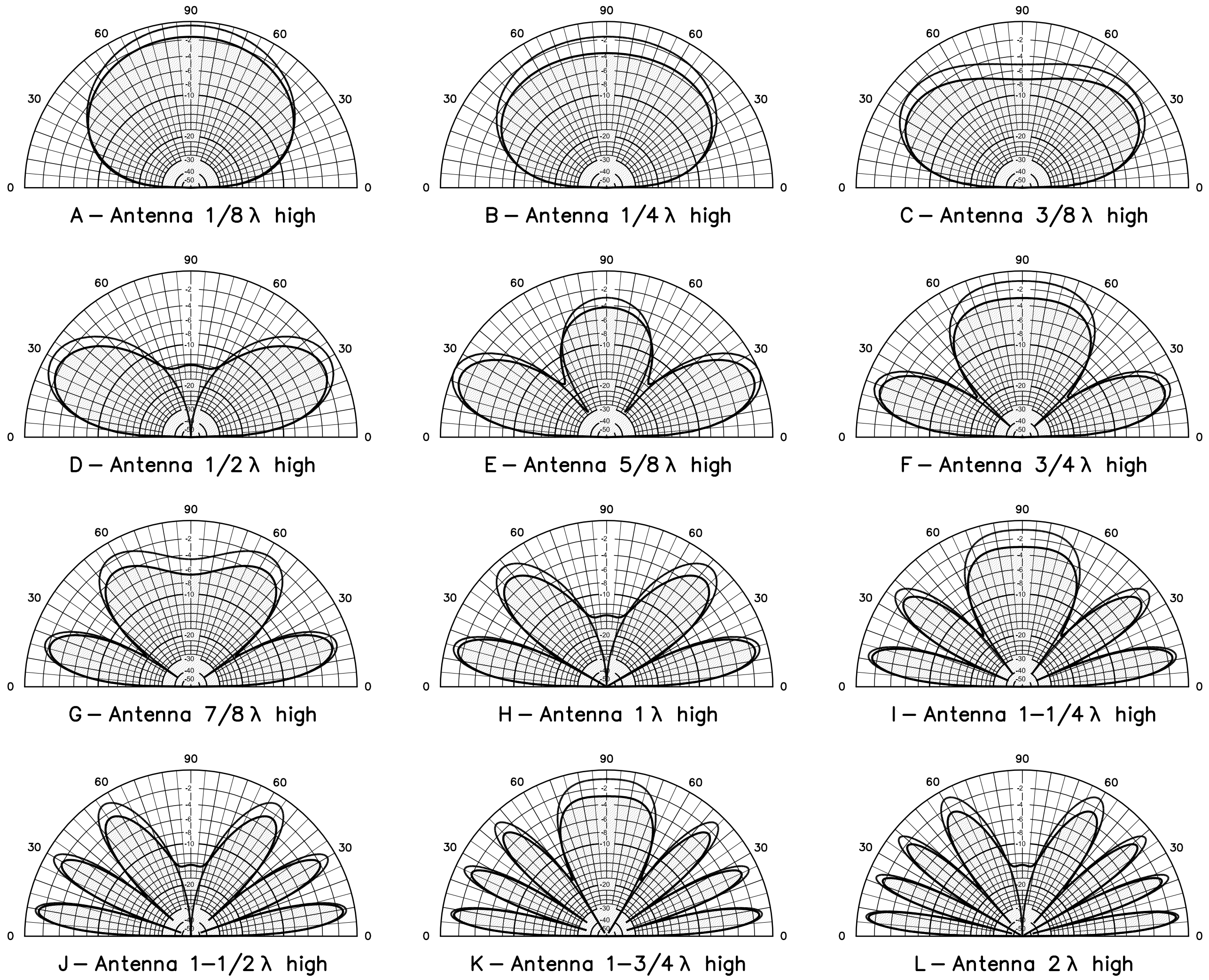

A — Antenna 1/8 λ high

B — Antenna 1/4 λ high

C — Antenna 3/8 λ high

D — Antenna 1/2 λ high

E — Antenna 5/8 λ high

F — Antenna 3/4 λ high

G — Antenna 7/8 λ high

H — Antenna 1 λ high

I — Antenna 1–1/4 λ high

J — Antenna 1–1/2 λ high

K — Antenna 1–3/4 λ high

L — Antenna 2 λ high

Fig 25—Reflection factors for horizontal dipole antennas at various heights above flat ground. The solid-line curves are the perfect-earth patterns (broadside to the antenna wire); the shaded curves represent the effects of average earth (k = 13, G = 0.005 S/m) at 14 MHz. Add 7 dB to values shown for absolute gain in dBd referenced to dipole in free space, or 9.15 dB for gain in dBi. For example, peak gain over perfect earth at 5/8 λ height is 7 dBd (or 9.15 dBi) at 25° elevation.

In vertical planes making some intermediate angle between 0° and 90° with the wire axis, the pattern will have a shape intermediate between the broadside and end-on patterns. By visualizing a smooth transition from the end-on pattern to the broadside pattern as the horizontal angle is varied from 0° to 90°, a fairly good mental picture of the actual solid pattern may be formed. An example is shown in **Fig 27**. At A, the elevation-plane pattern of a half-wave dipole at a height of λ/2 is shown through a plane 45° away from the favored direction of the antenna. At B and C, the pattern of the same antenna is shown at heights of 3λ/4 and 1λ (through the same 45° off-axis plane). These patterns are scaled so they may be compared directly with the broadside and end-on patterns for the same antenna (at the appropriate heights) in Figs 25 and 26.

The curves presented in **Fig 28** are useful for determining heights of horizontal antennas that give either maximum or minimum reinforcement at any desired wave angle. For instance, if you want to place an antenna at a height so that it will have a null at 30°, the antenna should be placed where a broken line crosses the 30° line on the horizontal scale. There are two heights (up to 2 λ) that will yield this null angle: 1 λ and 2 λ.

As a second example, you may want to have the ground reflection give maximum reinforcement of the direct ray from a horizontal antenna at a 20° elevation angle. The antenna height should be 0.75 λ. The same height will give a null at 42° and a second lobe at 90°.

Fig 28 is also useful for visualizing the vertical pattern of a horizontal antenna. For example, if an antenna is erected at 1.25 λ, it will have major lobes (solid-line crossings) at 12° and 37°, as well as at 90° (the zenith). The nulls in this pattern (dashed-line crossings) will appear at 24° and 53°.

The Y-axis in Fig 28 plots the wave angle versus the height in wavelength above flat ground on the X-axis. Fig 28 doesn't show the elevation angles required for actual

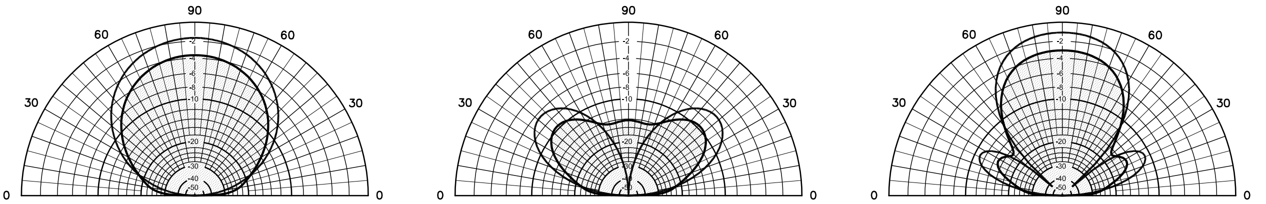

A—Antenna 1/4 λ high

B—Antenna 1/2 λ high

C—Antenna 3/4 λ high

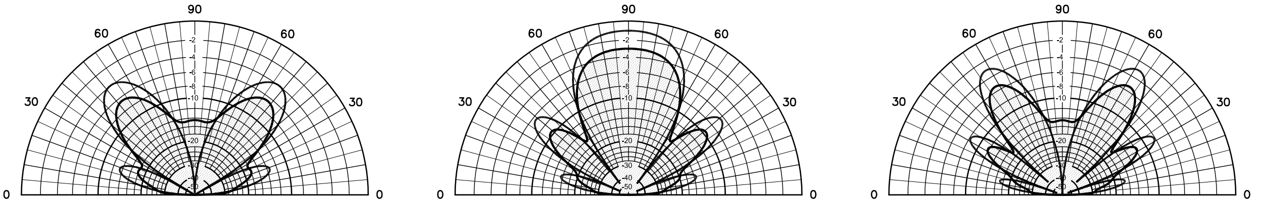

D—Antenna 1 λ high

E—Antenna 1-1/4 λ high

F—Antenna 1-1/2 λ high

Fig 26—Vertical-plane radiation patterns of horizontal half-wave dipole antennas off the ends of the antenna wire. The solid-line curves are the flat, perfect-earth patterns, and the shaded curves represent the effects of average flat earth (k = 13, G = 0.005 S/m) at 14 MHz. The 0-dB reference in each plot corresponds to the peak of the main lobe in the favored direction of the antenna (the maximum gain). Add 7 dB to values shown for absolute gain in dBd referenced to dipole in free space, or 9.15 dB for gain in dBi.

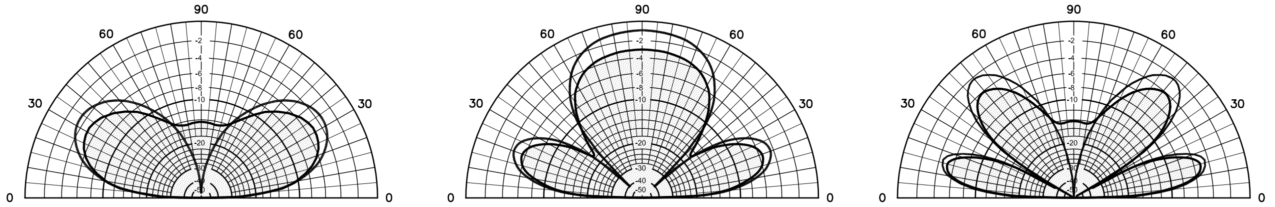

A—Height 1/2 λ

B—Height 3/4 λ

C—Height 1 λ

Fig 27—Vertical-plane radiation patterns of half-wave horizontal dipole antennas at 45° from the antenna wire over flat ground. The solid-line and shaded curves represent the same conditions as in Figs 25 and 26. These patterns are scaled so they may be compared directly with those of Figs 25 and 26.

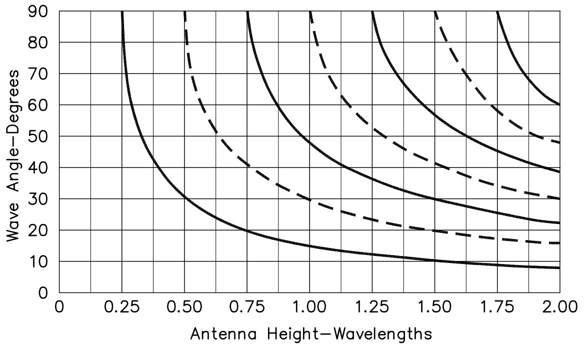

Fig 28—Angles at which nulls and maxima (factor = 6 dB) in the ground-reflection factor appear for antenna heights up to two wavelengths over flat ground. The solid lines are maxima, dashed lines nulls, for all horizontal antennas. See text for examples. Values may also be determined from the trigonometric relationship θ = arc sin (A/4h), where θ is the wave angle and h is the antenna height in wavelengths. For the first maximum, A has a value of 1; for the first null A has a value of 2, for the second maximum 3, for the second null 4, and so on.

communications to various target geographic locations of interest. Chapter 23, Radio Wave Propagation, and the CD-ROM in the back of this book give details about the range of angles required for target locations around the world. It is very useful to overlay plots of these angles together with the elevation pattern for horizontally polarized antennas at various heights above flat ground. This will be demonstrated in detail later in this chapter.

Vertically Polarized Antennas

In the case of a vertical λ/2 dipole or a ground-plane antenna, the horizontal directional pattern is simply a circle at any elevation angle (although the actual field strength will vary, at the different elevation angles, with the height above ground). Hence, one vertical pattern is sufficient to give complete information (for a given antenna height) about the antenna in any direction with respect to the wire. A series of such patterns for various heights is given in **Fig 29**. Rotating the plane pattern about the zenith axis of the graph forms the three-dimensional radiation pattern in each case.

The solid-line curves represent the radiation patterns of the λ/2 vertical dipole at different feed-point heights over perfectly conducting ground. The shaded curves in Fig 29 show the patterns produced by the same antennas at the same heights over average ground (G = 0.005 S/m, k = 13) at 14 MHz. The PBA in this case is 14.8°.

In short, far-field losses for vertically polarized antennas are highly dependent on the conductivity and dielectric constant of the earth around the antenna, extending far beyond the ends of any radials used to complete the ground return for the near field. Putting more radials out around the antenna may well decrease ground-return losses in the reactive near field for a vertical monopole, but will not increase radiation at low elevation launch angles in the far field, unless the radials can extend perhaps 100 wavelengths in all directions! Aside from moving to the fabled “salt water swamp on a high hill,” there is very little that someone can do to change the character of the ground that affects the far-field pattern of a real vertical. Classical texts

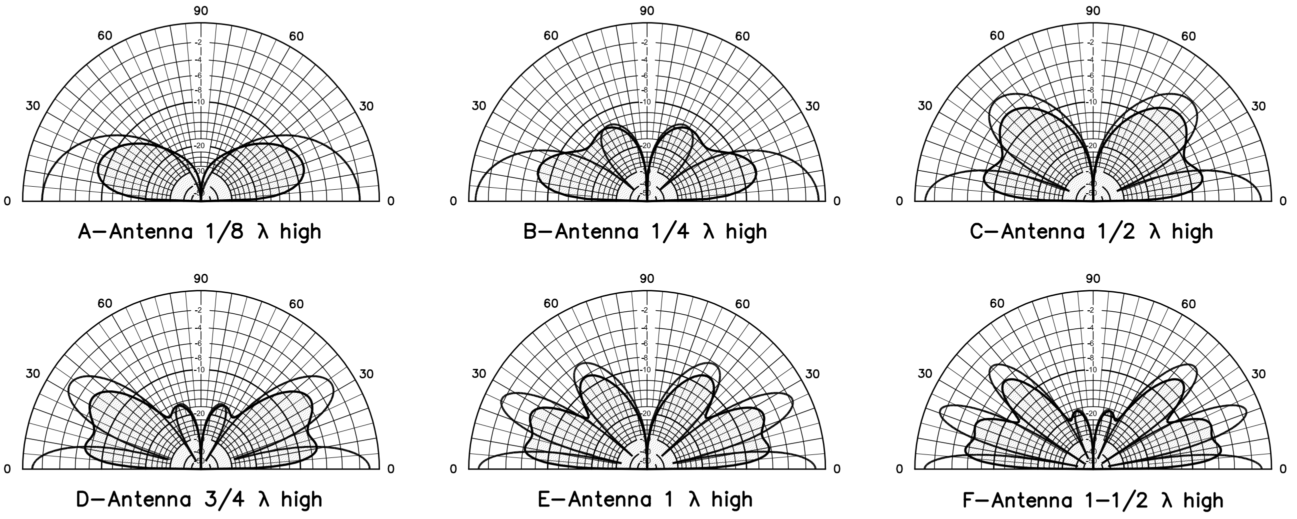

A—Antenna 1/8 λ high

B—Antenna 1/4 λ high

C—Antenna 1/2 λ high

D—Antenna 3/4 λ high

E—Antenna 1 λ high

F—Antenna 1-1/2 λ high

Fig 29—Vertical-plane radiation patterns of a ground-plane antenna above flat ground. The height is that of the ground plane, which consists of four radials in a horizontal plane. Solid lines are perfect-earth patterns; shaded curves show the effects of real earth. The patterns are scaled—that is, they may be directly compared to the solid-line ones for comparison of losses at any wave angle. These patterns were calculated for average ground (k = 13, G = 0.005 S/m) at 14 MHz. The PBA for these conditions is 14.8°. Add 6 dB to values shown for absolute gain in dBd over dipole in free space.

on verticals often show elevation patterns computed over an "infinitely wide, infinitely conducting ground plane." Real ground, with finite conductivity and less than perfect dielectric constant, can severely curtail the low-angle radiation at which verticals are supposed to excel.

While real verticals over real ground are not a surefire method to achieve low-angle radiation, cost versus performance and ease of installation are still attributes that can highly recommend verticals to knowledgeable builders. Practical installations for 160 and 80 meters rarely allow amateurs to put up horizontal antenna high enough to radiate effectively at low elevation angles. After all, a half-wave on 1.8 MHz is 273 feet high, and even at such a lofty height the peak radiation would be at a 30° elevation angle.

The Effects of Irregular Local Terrain in the Far Field

The following material is condensed and updated from an article by R. Dean Straw, N6BV, in July 1995 *QEX* magazine. *HFTA* (HF Terrain Assessment) and supporting data files are included on the CD-ROM at the back of this book. *HFTA* is the latest version of the *YT* program included with earlier editions of *The ARRL Antenna Book.*

Choosing a QTH for DXing

The subject of how to choose a QTH for working DX has fascinated hams since the beginning of amateur operations. No doubt, Marconi probably spent a lot of time wandering around Newfoundland looking for a great radio QTH before making the first transAtlantic transmission. Putting together a high-performance HF station for contesting or DXing has always followed some pretty simple rules. First, you need the perfect QTH, preferably on a rural mountaintop or at least on top of a hill. Even better yet, you need a mountaintop surrounded by seawater! Then, after you have found your dream QTH, you put up the biggest antennas you possibly can, on the highest towers you can afford. Then you work all sorts of DX—sunspots willing, of course.

The only trouble with this straightforward formula for success is that it doesn't always work. Hams fortunate enough to be located on mountain tops with really spectacular drop-offs often find that their highest antennas don't do very well, especially on 15 or 10 meters, but often even on 20 meters. When they compare their signals with nearby locals in the flatlands, they sometimes (but not always) come out on the losing end, especially when sunspot activity is high.

On the other hand, when the sunspots drop into the cellar, the high antennas on the mountaintop are usually the ones crunching the pileups—but again, not always. So, the really ambitious contest aficionados, the guys with lots of resources and infinite enthusiasm, have resorted to putting up antennas at all possible heights, on a multitude of towers.

There is a more scientific way to figure out where and how high to put your antennas to optimize your signal during all parts of the 11-year solar cycle. We advocate a *system approach* to HF station design, in which you need to know the following:

1. The range of elevation angles necessary to get from point A to point B
2. The elevation patterns for various types and configurations of antennas
3. The effect of local terrain on elevation patterns for horizontally polarized antennas.

WHAT IS THE RANGE OF ELEVATION ANGLES NEEDED?

Up until 1994, *The ARRL Antenna Book* contained only a limited amount of information about the elevation angles needed for communication throughout the world. In the 1974 edition, Table 1-1 in the Wave Propagation chapter was captioned: "Measured vertical angles of arrival of signals from England at receiving location in New Jersey."

What the caption didn't say was that Table 1-1 was derived from measurements made during 1934 by Bell Labs. The highest frequency data seemed pretty shaky, considering that 1934 was the low point of Cycle 17. Neither was this data applicable to any other path, other than the one from New Jersey to England. Nonetheless, many amateurs located throughout the US tried to use the sparse information in Table 1-1 as the only rational data they had for determining how high to mount their antennas. (If they lived on hills, they made estimates of the effect of the terrain, assuming that the hill was adequately represented by a long, unbroken slope. More on this later.)

In 1993 ARRL HQ embarked on a major project to tabulate the range of elevation angles from all regions of the US to important DX QTHs around the world. This was accomplished by running many thousands of computations using the *IONCAP* computer program. *IONCAP* has been under development for more than 25 years by various agencies of the US government and is considered the standard of comparison for propagation programs by many agencies, including the Voice of America, Radio Free Europe, and more than 100 foreign governments throughout the world. *IONCAP* is a real pain in the neck to use, but it is the standard of comparison.

The calculations were done for all levels of solar activity, for all months of the year, and for all 24 hours of the day. The results were gathered into some very large databases, from which special custom-written software extracted detailed statistics. The results appeared in summary form in Tables 4 through 13 printed in Chapter 23, Radio Wave Propagation, of the 17th Edition and in more detail on the diskette included with that book. (This book, the 20th Edition, contains even more statistical data, for more areas of the world, on the accompanying CD-ROM.)

Fig 30 shows the full range of elevation angles (represented as vertical bars) for the 20-meter path from New England (centered on Newington, Connecticut) to all of Europe. This is for all openings, in all months, over the entire 11-year solar cycle. The most likely elevation angle occurs at 5° for about 13% of the times when the 20-meter band is open to Europe from New England. From 4° to 6° the band is open a total of about 34% of the times the band is open. There is a secondary peak between 10° to 12°, occurring for a total of about 25% of the times the band is open.

Overlaid on Fig 30 along with the elevation-angle statistics are the elevation-plane responses for three different horizontally polarized Yagi beams, all over flat ground. The first is mounted 140 feet high, 2 λ in terms of wavelength. The second Yagi is mounted 70 feet high (at 1 λ) and the third is 35 feet (0.5 λ). The 140-foot high antenna has a deep null at 15°, but it also has the highest response (13.4 dBi) of the three at the statistical peak elevation angle of 5°. However, at 12°—where the band is open some 9% of the time—the 140-foot high Yagi is down 4 dB compared to the 70-foot antenna.

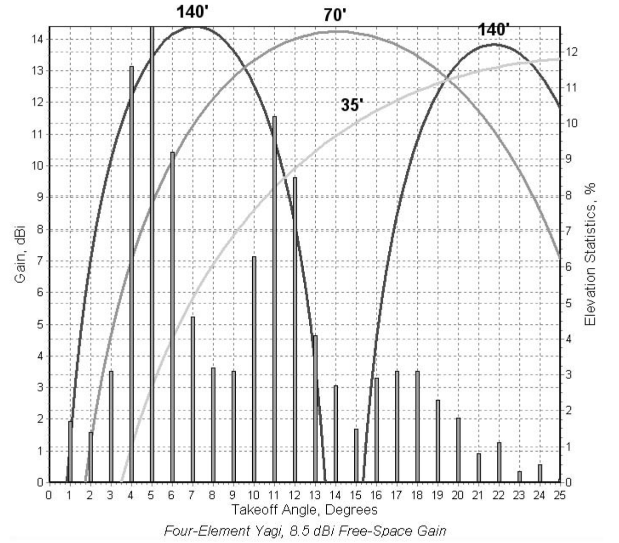

Fig 30—Graph showing 20-meter percentage of all openings from New England to Europe versus elevation angles, together with overlay of elevation patterns over flat ground for three 20-meter antenna systems. The most statistically likely angle at which the band will be open is 5°, although at any particular hour, day, month and year, the actual angle will likely be different. Note the deep null exhibited by the 140-foot high antenna centered at 14°.

The 70-foot high Yagi arguably covers the overall range best, since it has no disastrous nulls in the 1° to 25° range, where most of the action is occurring on 20 meters. At 5°, however, its response is only 8.8 dBi, 4.6 dB down from the 140-foot high antenna at that angle. The 35-foot antenna peaks above 26° in elevation angle, and is down some 10.4 dB compared to the 140-foot antenna at 5°. Obviously, no single antenna covers the complete range of elevation angles needed.

Note that the highest Yagi has a strong *second lobe* peaking at 22°. Let's say that you could select between two antennas, one at 140 and one at 70 feet, and that the incoming angle for a particular distant station is 22°. You might be fooled into thinking that the incoming angle is around 6°, favoring the first peak of the higher antenna, when in truth the angle is relatively high. The 70-foot antenna's response would be lower at 22° than the higher one, but only because the 140-foot antenna is operating on its second lobe. (What would clinch a determination of the correct incoming angle—6° or 22°—would be the response of the 35-foot high Yagi, which would be close to its peak at 22°, while it would be very far down at 6°.)

Now, we must emphasize that these elevation angles are *statistical entities*— in other words, just because 5° is the "statistically most likely angle" for the 20-meter path from New England to Europe doesn't mean that the band will be open at 11° at any particular hour, on a particular day, in a particular month, in any particular year. In fact, however, experience agrees with the *IONCAP* computations: the 20-meter path to Europe usually opens at a low angle in the New England morning hours, rising to about 11° during the afternoon, when the signals remain strongest throughout the afternoon until the evening in New England.

What would happen if we were to feed all three Yagi at 140, 70 and 35 feet in-phase as a stack? **Fig 31** shows this situation, along with a more highly optimized stack at 120, 80 and 40 feet that better covers the overall range of elevation angles from Connecticut to Europe.

Now see **Fig 32**, which uses the same 120/80/40-foot stack of 20-meter antennas as in Fig 31, but this time from Seattle, Washington, to Europe. For comparison, the response of a single 4-element Yagi at 100 feet over flat ground is also shown in Fig 32. Just because 5º is the statistically most prevalent angle (occurring some 13% of the time) from Seattle to Europe on 20 meters, this doesn't mean that the actual angle *at any particular moment in time* might not be 10º, or even 2º. The statistics for W7 to Europe say that 5º is the most likely angle, but 20-meter signals from Europe arrive at angles ranging from 1º to 18º. Note that this range of angles is quite a bit less than from W1 to Europe, which is much closer geographically to Europe than is the Pacific Northwest coast of the US. If you design an antenna system to cover all possible angles needed to talk to Europe from Seattle (or from Seattle to Europe) on 20 meters, you would need to cover the full range from 1º to 18º equally well.

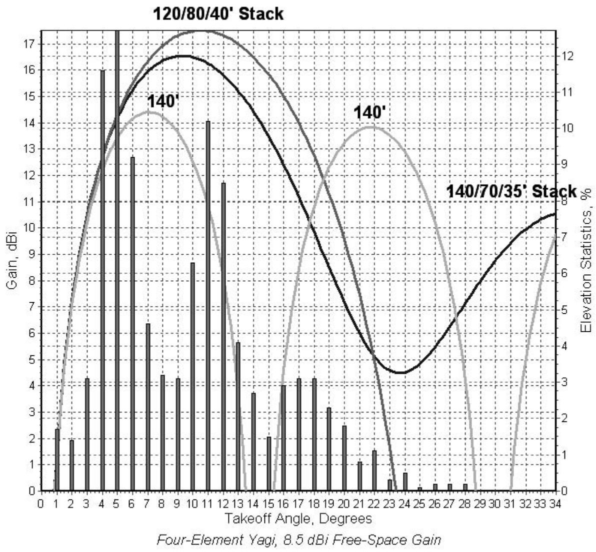

Fig 31—Graph showing results of stacking antennas at different heights on the same tower to cover a wider range of elevation angles, in this case for the path from Connecticut (W1) to all of Europe on 20 meters. The optimized stack at 120/80/40 feet covers the needed range of elevation angles better than the stack at 140/70/35 feet or the single Yagi at 140 feet.

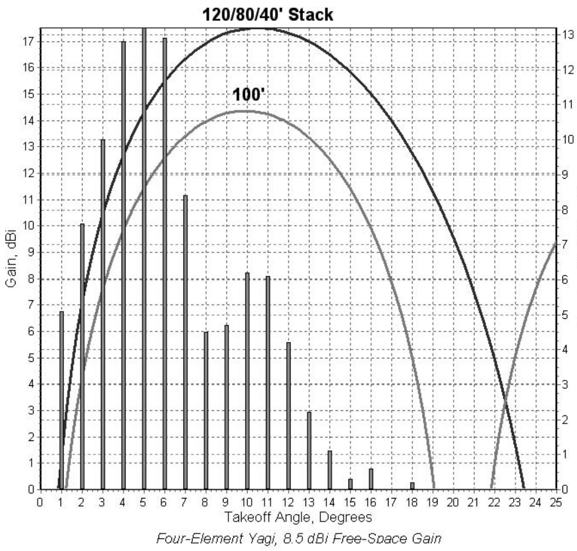

Fig 32—Graph showing 20-meter percentage of all openings, this time from Seattle, WA, to Europe, together with an overlay of elevation patterns over flat ground for two 20-meter antenna systems. The statistically most likely angle on this path is 5°, occurring about 13% of the time when the band is actually open. Higher antennas predominate on this low-angle path.

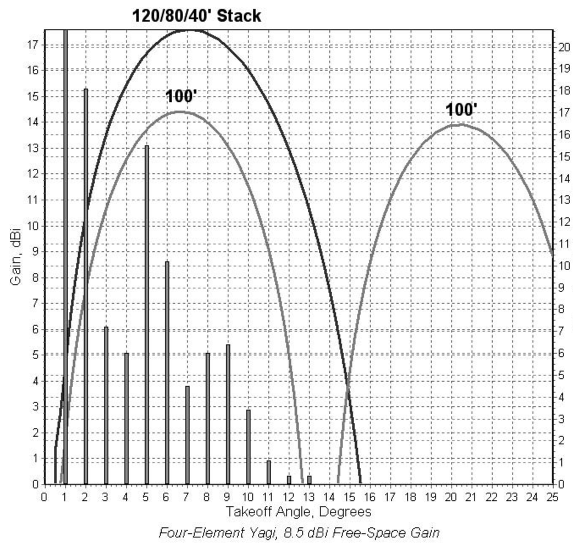

Fig 33—Graph showing 15-meter percentage of all openings from Chicago to Southern Africa, together with overlay of elevation patterns over flat ground for two 15-meter antenna systems. On this long-distance, low-angle path, higher antennas are again most effective.

Similarly, if you wish to cover the full range of elevation angles from Chicago to Southern Africa on 15 meters, you would need to cover 1º to 13º, even though the most statistically likely signals arrive at 1º, for 21% of the time when that the band is open for that path. See **Fig 33**.

It is important to recognize that Figs 30 through 33 are for flat ground. When the antennas are mounted over irregular local terrain, things get much more complicated. First, however, we'll discuss general-purpose antenna modeling programs as they try to model real terrain.

DRAWBACKS OF COMPUTER MODELS FOR ANTENNAS OVER REAL TERRAIN

Modern general-purpose antenna modeling programs such as *NEC* or *MININEC* (or their commercially upgraded equivalents, such as *NEC-Win Plus*, *EZNEC* and *EZNEC ARRL*) can accurately model almost any type of antenna commonly used by radio amateurs. In addition, there are specialized programs specifically designed to model Yagis efficiently, such as *YO* or *YW* (Yagi for Windows, bundled on the CD-ROM with this book) or *YagiMax*. These programs however are all unable to model antennas accurately over anything other than *purely flat ground*.

While both *NEC* and *MININEC* can simulate irregular ground terrain, they do so in a decidedly crude manner, employing step-like concentric rings of height around an antenna. The documentation for *NEC* and *MININEC* both clearly state that diffraction off these steps is not modeled.

Common experience among serious modelers is that the warnings in the manuals are worth heeding.

Although you can analyze and even optimize antenna designs using free-space or flat-earth ground models, it is *diffraction* that makes the real world a very, very complicated place. This should be clarified—diffraction is hard, even tortuous, to analyze properly, but it makes analysis of real world results far more believable than a flat-world reflection model does.

RAY-TRACING OVER UNEVEN LOCAL TERRAIN

The Raytracing Technique

First, let's look at a simple raytracing procedure involving only horizontally polarized reflections, with no diffractions. From a specified height on the tower, an antenna shoots "rays" (just as though they were bullets) in 0.25° increments from +35° above the horizon to –35° below the horizon. Each ray is traced over the foreground terrain to see if it hits the ground at any point on its travels in the direction of interest. If it does hit the ground, the ray is reflected following the classical *law of reflection*. That is, the outgoing angle equals the incoming angle, reflected through the normal to the slope of the surface. Once the rays exit into the ionosphere, the individual contributions are vector-summed to create the overall far-field elevation pattern.

The next step in terrain modeling involves adding *diffractions* as well as reflections. At the Dayton antenna forum in 1994, Jim Breakall, WA3FET, gave a fascinating and tantalizing lecture on the effect of foreground terrain. Later Breakall, Dick Adler, K3CXZ, Joel Young and a group of other researchers published an extremely interesting paper entitled "The Modeling and Measurement of HF Antenna Skywave Radiation Patterns in Irregular Terrain" in July 1994 *IEEE Transactions on Antennas and Propagation*. They described in rather general terms the modifications they made to the *NEC-BSC* program. They showed how the addition of a ray-tracing reflection and diffraction model to the simplistic stair-stepped reflection model in regular *NEC* gave far more realistic results. For validation, they compared actual pattern measurements made on a site in Utah (with an overflying helicopter) to computed patterns made using the modified *NEC* software. However, because the US Navy funded this work the software remained for a long time a military secret.

Thumbnail History of the Uniform Theory of Diffraction

It is instructive to look briefly at the history of how *Geometric Optics* (GO) evolved (and still continues to evolve) into the *Uniform Theory of Diffraction* (UTD). The following is summarized from the historical overview in one book found to be particularly useful and comprehensive on the subject of UTD: *Introduction to the Uniform Geometrical Theory of Diffraction*, by McNamara, Pistorius, and Malherbe.

Many years before the time of Christ, the ancient Greeks studied optics. Euclid is credited with deriving the law of reflection about 300 BC. Other Greeks, such as Ptolemy, were also fascinated with optical phenomena. In the 1600s, a Dutchman named Snell finally figured out the law of refraction, resulting in *Snell's law*. By the early 1800s, the basic world of classical optics was pretty well described from a mathematic point of view, based on the work of a number of individuals.

As its name implies, classical geometric optical theory deals strictly with geometric shapes. Of course, the importance of geometry in optics shouldn't be minimized—after all, we wouldn't have eyeglasses without geometric optics. Mathematical analysis of shapes utilizes a methodology that traces the paths of straight-line *rays* of light. (Note that the paths of rays can also be likened to the straight-line paths of particles.) In classical geometric optics, however, there is no mention of three important quantities: phase, intensity and polarization. Indeed, without phase, intensity or polarization, there is no way to deal properly with the phenomenon of *interference*, or its cousin, *diffraction*. These phenomena require theories that deal with *waves* rather than rays.

Wave theory has also been around for a long time, although not as long as geometry. Workers like Hooke and Grimaldi had recorded their observations of interference and diffraction in the mid 1600s. Huygens had used elements of wave theory in the late 1600s to help explain refraction. By the late 1800s, the work of Lord Rayleigh, Sommerfeld, Fresnel, Maxwell and many others led to the full mathematic characterization of all electromagnetic phenomena, light included.

Unfortunately, ray theory doesn't work for many problems, at least ray theory in the classical optical form. The real world is a lot more jagged, pointy and fuzzy in shape than can be described in a totally rigorous mathematic fashion. Some properties of the real world are most easily explained on the micro level using electrons and protons as conceptual objects, while other macro phenomena (like resonance, for example) are more easily explained in terms of waves. To get a handle on a typical real-world physical situation, a combination of classical ray theory and wave theory was needed.

The breakthrough in the combination of classical geometric optics and wave concepts came from J. B. Keller of Bell Labs in 1953, although he published his work in the early 1960s. In the very simplest of terms, Keller introduced the notion that shooting a ray at a diffraction *wedge* causes wave interference at the tip, with an infinite number of diffracted waves emanating from the diffraction point. Each diffracted wave can be considered to be a point source radiator at the place of generation, the diffraction point. Thereafter, the paths of individual waves can be traced as though they were individual classical optic rays again. What Keller came up with was a reasonable mathematical description of what happens at the tip of the diffraction wedge.

Fig 34 is a picture of a simple diffraction wedge, with an incoming ray launched at an angle of α_r, referenced to the horizon, impinging on it. The diffraction wedge here is considered to be perfectly conducting, and hence impenetrable by the ray. The wedge generates an infinite number of diffracted waves, going in all directions not blocked by the wedge itself. The amplitudes and phases of the diffracted waves are determined by the interaction at the wedge tip, and this in turn is governed by the various angles associated with the wedge. Shown in Fig 34 are the included angle a of the wedge, the angle ϕ' of the incoming ray (referenced to the incoming surface of the wedge), and the observed angle ϕ of one of the outgoing diffracted waves, also referenced to the wedge surface.

The so-called *shadow boundaries* are also shown in Fig 34. The Reflection-Shadow Boundary (RSB) is the angle beyond which no further reflections can take place for a given incoming angle. The Incident-Shadow Boundary (ISB) is that angle beyond which the wedge's face blocks any incident rays from illuminating the observation point.

Keller derived the amplitude and phase terms by comparing the classical Geometric Optics (GO) solution with the exact mathematical solution calculated by Sommerfeld for a particular case where the boundary conditions were well known—an infinitely long, perfectly conducting wedge illuminated by a plane wave. Simply speaking, whatever was left over had to be diffraction terms. Keller combined these diffraction terms with GO terms to yield the total field everywhere.

Keller's new theory became known as the *Geometric Theory of Diffraction* (abbreviated henceforth as GTD). The beauty of GTD was that in the regions where classical GO predicted zero fields, the GTD "filled in the blanks," so to speak. For example, see **Fig 35**, showing the terrain for a hypothetical case, where a 60-foot high 4-element 15-meter Yagi illuminates a wide, perfectly flat piece of ground. A 10-foot high rock has been placed 400 feet away from the tower base in the direction of outgoing rays. **Fig 36** shows the elevation pattern predicted using reflection-only GO techniques. Due to blockage of the direct wave (A) trying to shoot past the 10-foot high rock, and due to blockage of (B) reflections from the flat ground in front of the rock by the rock, there is a *hole* in the smooth elevation pattern.

Now, doesn't it defy common sense to imagine that a single 10-foot high rock will really have such an effect on a 15-meter signal? Keller's GTD took diffraction effects into account to show that waves do indeed sneak past and over the rock to fill in the pattern. The whole GTD scheme is very clever indeed.

However, GTD wasn't perfect. Keller's GTD predicts some big spikes in the pattern, even though the overall shape of the elevation pattern is much closer to reality than a simple GO reflection analysis would indicate. The region right at the RSB and ISB shadow boundaries is where problems are found. The GO terms go to zero at these points because of blockage by the wedge, while Keller's diffraction terms tend to go to infinity at these very spots. In mathematical terms this is referred to as a *caustic problem*. Nevertheless, despite these nasty problems at the ISB and RSB, the GTD provided a remarkably better solution to diffraction problems than did classical GO.

In the early 1970s, a group at Ohio State University under R. G. Kouyoumjian and P. H. Pathak did some pivotal work to resolve this caustic problem, introducing what amounts to a clever *fudge factor* to compensate for the tendency of the diffraction terms at the shadow boundaries to go to infinity. They introduced what is known as a *transition function*, using a form of Fresnel integral. Most importantly, the Ohio State researchers also created several FORTRAN computer programs to compute the amplitude and phase of diffraction components. Now computer hackers could get to work!

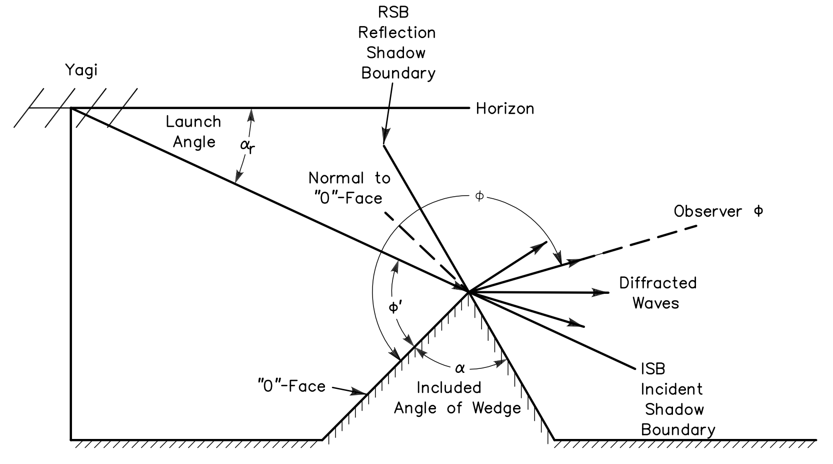

Fig 34—Diagram showing diffraction mechanism of ray launched at angle α_r below the horizon at a diffraction wedge, whose included angle is α. Referenced to the incident face (the *o-face* as it is called in UTD terminology), the incoming angle is ϕ' (phi prime). The wedge creates an infinite number of diffracted waves. Shown is one whose angle referenced to the o-face is ϕ, the so-called *observation angle* in UTD terminology.

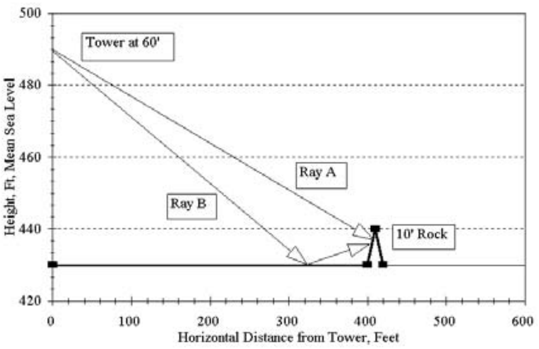

Fig 35—Hypothetical terrain exhibiting so-called "10-foot rock effect." The terrain is flat from the tower base out to 400 feet, where a 10-foot high rock is placed. Note that this forms a diffraction wedge, but that it also blocks direct waves trying to shoot through it to the flat surface beyond, as shown by Ray A. Ray B reflects off the flat surface before it reaches the 10-foot rock, but it is blocked by the rock from proceeding further. A simple Geometric Optics (GO) analysis of this terrain without taking diffraction into account will result in the elevation response shown in Fig 36.

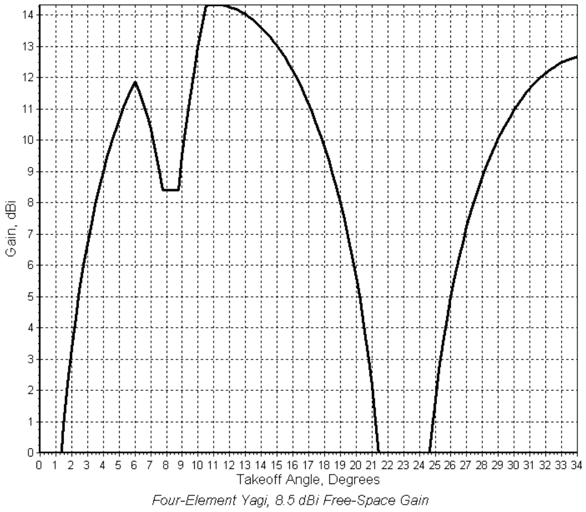

Fig 36—Elevation response for rays launched at terrain in Fig 35 from a height of 60 feet using a 4-element Yagi. This was computed using a simple Geometrical Optics (GO) reflection-only analysis. Note the *hole* in the response between 6° to 10° in elevation. It is not reasonable for a 10-foot high rock to create such a disturbance at 21 MHz!

The program that finally resulted is called *HFTA*, standing for "HF Terrain Assessment." (The DOS version of *HFTA* was known as *YT*, standing for "Yagi Terrain.") As the name suggests, *HFTA* analyzes the effect of local terrain on HF propagation through the ionosphere. It is designed for horizontally polarized Yagis, although it will model the effects of a simple flattop dipole also. The accurate appraisal of the effect of terrain on vertically polarized signals is a far more complex problem than for horizontally polarized waves, and *HFTA* doesn't do verticals.

SIMULATION OF REALITY—SOME SIMPLE EXAMPLES FIRST

We want to focus first on some simple results, to show that the computations do make some sense by presenting some simulations over simple terrains. We've already described the "10-foot rock at 400 feet" situation, and showed where a simple GO reflection analysis is inadequate to the task without taking diffraction effects into account.

Now look at the simple case shown in **Fig 37**, where a very long, continuous downslope from the tower base is shown. Note that the scales used for the X and Y axes are different: the Y-axis changes 300 feet in height (from 800 to 1100 feet), while the X-axis goes from 0 to 3000 feet. This exaggerates the apparent steepness of the downwards slope, which is actually a rather gentle slope, at $\tan^{-1}$ (1000 – 850) / (3000 – 0) = –2.86°. In other words, the terrain falls 150 feet in height over a range of 3000 feet from the base of the tower.

Fig 38 shows the computed elevation response for this terrain profile, for a 4-element horizontally polarized Yagi on a 60-foot tower. The response is compared to that of an identical Yagi placed 60 feet above flat ground. Compared to the "flatland" antenna, the hilltop antenna has an elevation response shifted over by almost 3° towards the lower elevation angles. In fact, this shift is directly due to the –2.86° slope of the hill. Reflections off the slope are tilted by the slope. In this situation there is a single diffraction at the bottom of the gentle slope at 3000 feet, where the program assumes that the terrain becomes flat.

Look at **Fig 39**, which shows another simple terrain profile, called a "Hill-Valley" scenario. Here, the 60-foot high tower stands on the edge of a gentle hill overlooking a long valley. Once again the slope of the hill is exaggerated by the different X and Y-axes. **Fig 40** shows the computed elevation response at 21.2 MHz for a 4-element Yagi on a 60-foot high tower at the edge of the slope.

Once again, the pattern is overlaid with that of an identical 60-foot-high Yagi over flat ground. Compared to the flatland antenna, the hilltop antenna's response above 9° in elevation is shifted by almost 3° towards the lower elevation angles. Again, this is due to reflections off the downward slope. From 1° to 9°, the hilltop pattern is enhanced even more compared to the flatland antenna, this time by diffraction occurring at the bottom of the hill.

Now let's see what happens when there is a hill ahead in the direction of interest. **Fig 41** depicts such a situation, labeled "Hill-Ahead." Here, at a height of 400 feet above mean sea level, the land is flat in front of the tower, out to a distance 500 feet, where the hill begins. The hill then rises 100 feet over the range 500 to 1000 feet away

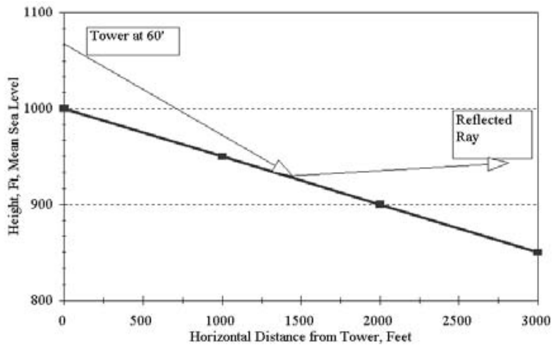

Fig 37—A long, gentle downwards-sloping terrain. This terrain has no explicit diffraction points and can be analyzed using simple GO reflection techniques.

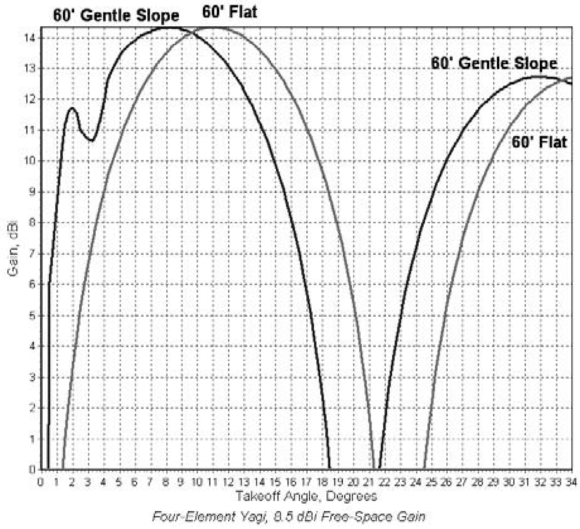

Fig 38—Elevation response for terrain shown in Fig 37, using a 4-element 15-meter Yagi, 60-foot high. Note that the shape of the response is essentially shifted towards the left, towards lower elevation angles, by the angle of the sloping ground. For reference, the response for an identical Yagi placed over flat ground is also shown.

from the tower base. After that, the terrain is a plateau, at a constant 500 feet elevation.

Fig 42 shows the computed elevation pattern for a 4-element 21-MHz Yagi 60-feet high on the tower, compared again with an overlay for an identical 60-foot high antenna over flat ground. The hill blocks low-angle waves directly radiated from the antenna from 0° to 2.3°. In addition, waves that would normally be reflected from the ground, and that would normally add in phase from about 2.3° to 12°, are blocked by the hill also. Thus the signal at 8° is down almost 5 dB from the signal over flat ground, all due to the effect of the hill. Diffracted waves start kicking in once the direct wave rises enough above the horizon to illuminate the top edge of the hill. These diffracted waves tend to augment elevation angles above about 12°, which reflected waves can't reach.

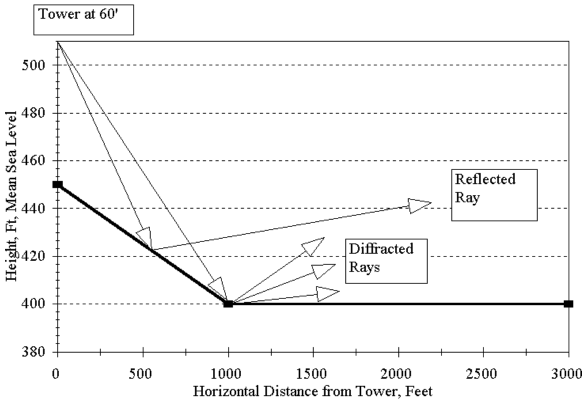

Fig 39—"Hill-Valley" terrain, with reflected and diffracted rays.

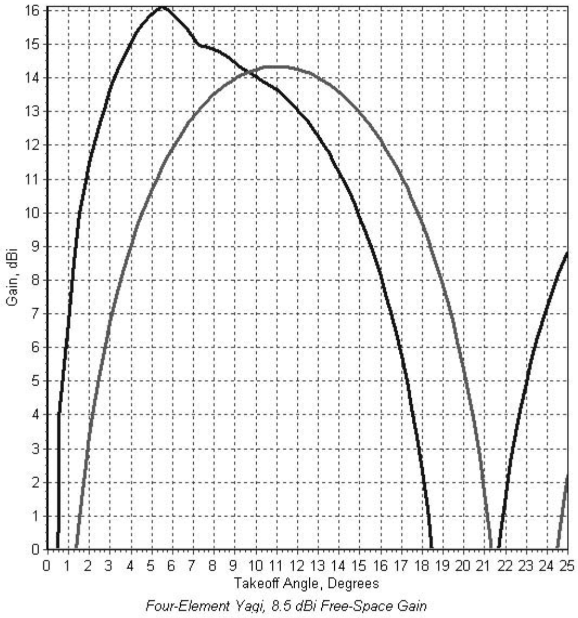

Fig 40—Elevation response computed by *HFTA* program for single 4-element 15-meter Yagi at 60 feet above "Hill-Valley" terrain shown in Fig 39. Note that the slope has caused the response in general to be shifted towards lower elevation angles. At 5° elevation, the diffraction components add up to increase the gain slightly above the amount a GO-only analysis would indicate.

Is there is any hope for someone in such a lousy QTH for DXing? **Fig 43** shows the elevation response for a truly heroic solution. This involves a stack of four 4element Yagis, mounted at 120, 90, 60 and 30 feet on the tower. Now, the total gain at low angles is just about comparable to that from a single 4-element Yagi mounted over flat ground. Where there's a ham, there is a way!

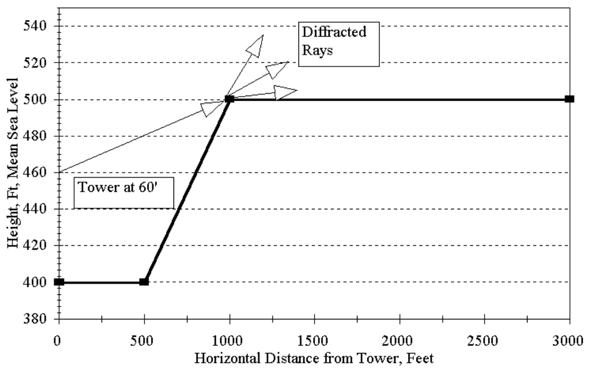

Fig 41—"Hill-Ahead" terrain, shown with diffracted rays created by illumination of the edge of the plateau at the top of the hill.

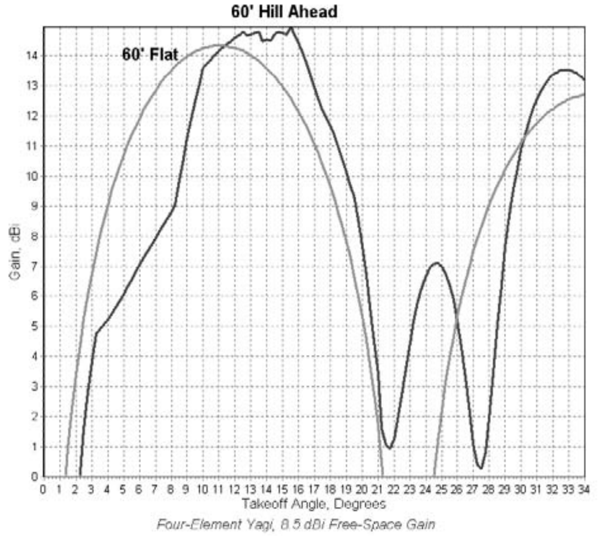

Fig 42—Elevation response computed by *HFTA* for "Hill-Ahead" terrain shown in Fig 41. Now the hill blocks direct rays and also precludes possibility of any constructive reflections. Above 10°, diffraction components add up together with direct rays to create the response shown.

At 5° elevation, four diffraction components add up (there are zero reflection components) to achieve the far-field pattern. This seems reasonable, because each of the four antennas is illuminating the diffraction point separately and we know that none of the four antennas can *see over* the hill directly to produce a reflection at a low launch angle.

At an elevation angle of 5°, 15-meter signals arrive from Europe from New England about 13% of the total time when the band is actually open. We can look at this another way. For about two-thirds of the times when the band is open on this path, the incoming angle is between 3° to 12°. For about one-third of the time, signals arrive above 10°, where the "heroic" four-stack is really beginning to come into its own.

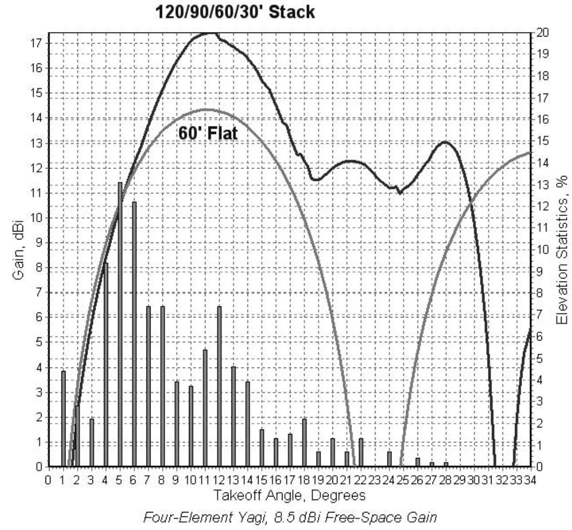

Fig 43—Elevation response of "heroic effort" to surmount the difficulties imposed by hill in Fig 41. This effort involves a stack of four 4-element Yagis in a stack starting at 120 feet and spaced at 30-foot increments on the tower. The response is roughly equivalent to a single 4-element Yagi at 60 feet above flat ground, hence the characterization as being a "heroic effort." The elevation-angle statistics from New England to Europe are overlaid on the graph for reference.

A More Complex Terrain

The results for simple terrains look reasonable; let's try a more complicated real-world situation. **Fig 44** shows the terrain from the New Hampshire N6BV/1 QTH towards Japan. The terrain was complex, with 52 different points *HFTA* identifies as diffraction points. **Fig 45** shows a labeled *HFTA* output for three different types of antennas on 20 meters: a stack at 120 and 60 feet, the 120-foot antenna by itself, and then a 120/60-foot stack over flat ground, for reference. The elevation-angle statistics for New England to Japan are overlaid on the graph also, making for a very complicated looking picture—it is a *lot* easier to decipher the lines on the color CRT, by the way than on a black-and-white printer.

Comparison of the same 120/60-foot stacks over irregular terrain and flat ground is useful to show where the terrain itself is affecting the elevation response. The flatland stack has more gain in the region of 3° to 7° than the same stack over the N6BV/1 local terrain towards Japan. On the other hand, the N6BV/1 local terrain boosts signals in the range of 8° to about 12°. This demonstrates the conservation of energy—you may gain a stronger signal at certain elevation angles, but you will lose gain at others. In this case, the N6BV/1 station always felt "weak" towards Japan on 20 meters, because the dominant angles are low.

Examination of the detailed data output from *HFTA* shows that at an elevation angle of 5°, there are 6159

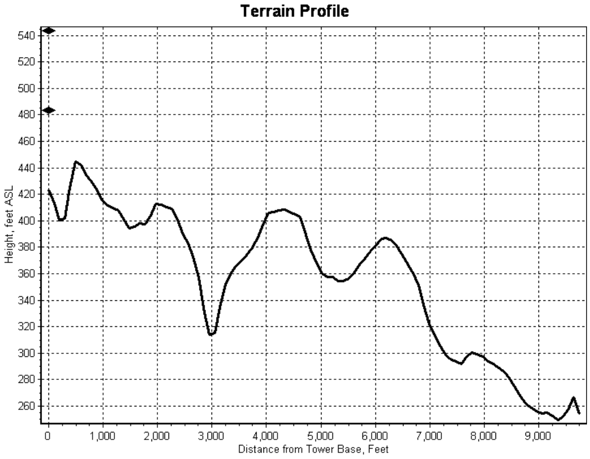

Fig 44—Terrain of N6BV in Windham, NH, towards Japan. *HFTA* identifies 52 different points where diffraction can occur.

diffraction components. There are many, many signals bouncing around off the terrain on their trip to Japan! Note that because of blockage of some parts of the terrain, the 60-foot high Yagi cannot illuminate all the diffraction points, while the higher 120-foot Yagi is able to see these diffraction points.

It is fascinating to reflect on the thought that received signals coming down from the ionosphere to the receiver are having encounters with the terrain, but from the opposite direction. It's not surprising, given these kinds of interactions, that transmitting and receiving might not be totally reciprocal.

The 120/60-foot stack in Fig 45 achieves its peak gain of 17.3 dBi at 11° elevation, where it is about 3 dB stronger than the single Yagi at 120 feet. It maintains this 3-dB advantage over most of the range of incoming signals from Japan. This difference in performance between the stack and each antenna by itself was observed many times on the air. Much of the time when comparisons are being made, however, the small differences in signal are difficult to measure meaningfully, especially when the QSB varies signals by 20 dB or so during a typical QSO. It should be noted that the stack usually exhibited less fading compared to each antenna by itself.

USING *HFTA*

Manually Generating a Terrain Profile

The *HFTA* program uses two distinct algorithms to generate the far-field elevation pattern. The first is a simple reflection-only Geometric Optics (GO) algorithm. The second is the diffraction algorithm using the Uniform Theory of Diffraction (UTD). These algorithms work with a digitized representation of the terrain profile for a single azimuthal direction—for example, towards Japan or towards Europe.

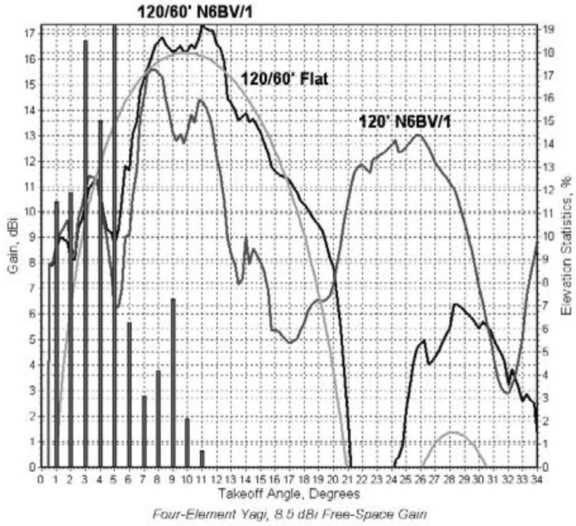

Fig 45—Elevation responses computed by *HFTA* for N6BV/1 terrain shown in Fig 44, for a stack of two 4-element 20-meter Yagis at 120 and 60 feet, together with the response for a single Yagi at 120 feet and a 120/60-foot stack over flat ground for reference. The response due to many diffraction and reflection components is quite complicated!

You can generate a terrain file manually using a topographic map and a ruler or a pair of dividers. The HFTA.PDF file (accessed by clicking on the **Help** button) and on the accompanying CD-ROM gives complete instructions on how to create a terrain file manually (or automatically). The manual process is simple enough in concept. Mark on your US Geological Survey 7.5-minute map the exact location of your tower. You will find 7.5-minute maps available from some local sources, such as large hardware stores, but the main contact point is the U.S. Geological Survey, Denver, CO 80225 or Reston, VA 22092. Call 1-800-MAPS-USA. Ask for the folder describing the topographic maps available for your geographic area. Many countries outside the USA have topographic charts also. Most are calibrated in meters. To use these with *HFTA*, you will have to convert meters to feet by multiplying meters by 3.28 or else inserting a single line at the very beginning of the disk file, saying "meters" for *HFTA* to recognize meters automatically.

Mark off a pencil line from the tower base, in the azimuthal direction of interest, perhaps 45° from New England to Europe, or 335° to Japan. Then measure the distance from the tower base to each height contour crossed by the pencil line. Enter the data at each distance/height into an ASCII computer file, whose filename extension is "PRO," standing for *profile*.

Fig 46 shows a portion of the USGS paper map for the N6BV QTH in Windham, NH, along with lines scribed in several directions towards various parts of Europe and the Far East. Note that the elevation heights of the intermediate contour lines are labeled manually in pencil in order to make sense of things. It is very easy to get confused unless you do this!

The terrain model used by *HFTA* assumes that the terrain is represented by flat *plates* connecting the elevation points in the *.PRO file with straight lines. The model is two dimensional, meaning that range and elevation are the only data for a particular azimuth. In effect, *HFTA* assumes that the width of a terrain plate is wide relative to its length. Obviously, the world is three-dimensional. If your shot in a particular direction involves aiming your Yagi down a canyon with steep walls, then it's pretty likely that your actual elevation pattern will be different than what *HFTA* tells you. The signals must careen horizontally from wall to wall, in addition to being affected by the height changes of the terrain. *HFTA* isn't designed to do canyons.

To get a true 3-D picture of the full effects of terrain, a terrain model would have to show azimuth, along with range and elevation, point-by-point for about two miles in every direction around the base of the tower. After you go through the pain of creating a profile for a single azimuth, you'll appreciate the immensity of the process if you were you try to create a full 360° 3D profile manually.

Terrain Data from the Internet

At one time digitized terrain data commonly available from the Internet didn't have sufficient resolution to be accurate enough for *HFTA*. Nowadays, the complete, accurate set of USGS topographic 7.5-minute maps are available at no cost on the Internet. You can use a program called *MicroDEM*, written by Professor Peter Guth at the US Naval Academy, to quickly and easily produce terrain data files suitable for *HFTA* from topographic data files. Dr Guth and the US Naval Academy have graciously allowed ARRL to include the *MicroDEM* program on the CD-ROM accompanying this book. It should be noted that besides automatically creating terrain profiles for *HFTA*, *MicroDEM* is a full-featured mapping program on its own.

Instructions for using *MicroDEM* are in the Help file for *HFTA* (HFTA.PDF), which you can access from the *HFTA* main window by clicking on the **Help** button. **Fig 47** shows a screen capture of the *MicroDEM* program for the N6BV/1 location in New Hampshire for an azimuth of 45° into Europe. The black/white rendering of the screen capture doesn't do justice to the same information in color. The computed terrain profile is plotted in the window at the right of Fig 47 and the data file is shown in the inset window at the top right.

Using *MicroDEM* and on-line USGS topographic map data, you can also automatically create up to 360 terrain profiles with 1° spacing of azimuths in a few seconds. (Specifying a 1° spacing is really overkill; most operator choose to create 72 profiles with 5° spacing.) On a topographic DEM (digital elevation model) map that covers the geographic

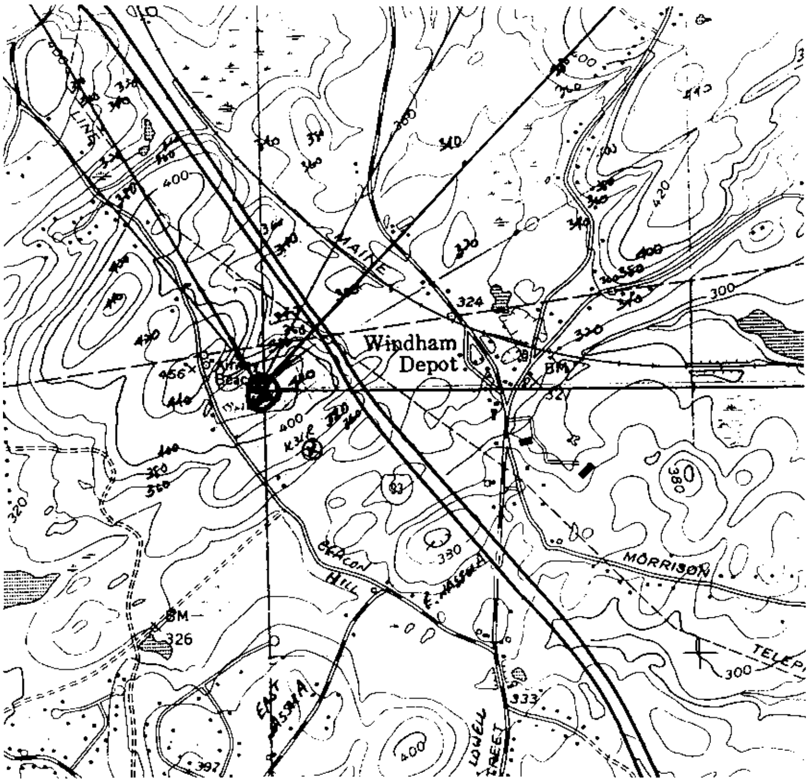

Fig 46—A portion of USGS 7.5 minute topographic map, showing N6BV/1 QTH, together with marks in direction of Europe and Japan from tower base. Note that the elevations contours were marked by hand to help eliminate confusion. This required a magnifying glass and a steady hand!

area of interest, you simply specify the latitude and longitude of a tower's location—found using a GPS receiver—and then ask *MicroDEM* for a **Viewshed**. See the *HFTA* **Help** file for the details.

Compare this automated several-second *MicroDEM* process to creating manual profiles on a paper topographic map—It can take up to an hour of meticulous measurements to manually create a single terrain profile!

Algorithm for Ray-Tracing the Terrain

Once a terrain profile is created, there are a number of mechanisms that *HFTA* takes into account as a ray travels over that terrain:

1. Classical ray reflection, with Fresnel ground coefficients.
2. Direct diffraction, where a diffraction point is illuminated directly by an antenna, with no intervening terrain features blocking the direct illumination.
3. When a diffracted ray is subsequently reflected off the terrain.
4. When a reflected ray encounters a diffraction point and causes another series of diffracted rays to be generated.
5. When a diffracted ray hits another diffraction point, generating another whole series of diffractions.

Certain unusual, bowl-shaped terrain profiles, with sheer vertical faces, can conceivably cause signals to reflect or diffract in a backwards direction, only to be reflected back again in the forward direction by the sheer-walled terrain to the rear. *HFTA* does not accommodate these interactions, mainly because to do so would increase the computation time too much. It only evaluates terrain in the forward direction along one azimuth of interest.

Fig 48 shows a portion of an *HFTA* screen capture in the direction towards Europe from the N6BV/1 location in New Hampshire on 21.2 MHz. It compares the results for a 90/60/30-foot stack of TH7DX tribanders to the same stack over flat land, and to a single antenna at 70 feet over flat ground. The 70-foot single antenna represents a pretty typical station on 15 meters. The terrain produces excellent gain at lower elevation angles compared to the same stack over flat ground. The stack is very close to or superior to the single 70-foot high Yagi at all useful elevation angles. Terrain can indeed exhibit a profound effect on the launch of signals into the ionosphere—for good or for bad.

HFTA's Internal Antenna Model

The operator selects the antenna used inside *HFTA* to be anything from a dipole to an 8-element Yagi. The default assumes a simple cosine-squared mathematic response, equivalent to a 4-element Yagi in free space. *HFTA* traces rays only in the forward direction from the tower along the azimuth of interest. This keeps the algorithms reasonably simple and saves computing time.

HFTA considers each antenna in a stack as a separate *point source*. The simulation begins to fall apart if a traveling wave type of antenna like a rhombic is used, particularly if the terrain changes under the antenna—that is, the ground is not flat under the entire antenna. For a typical Yagi, even a long-boom one, the point-source assumption is reasonable. The internal antenna model also assumes that the Yagi is horizontally polarized. *HFTA* does not do vertically polarized antennas, as discussed previously. The documentation for *HFTA* also cautions the user to work with practical spacings between stacked Yagis—0.5 λ or more

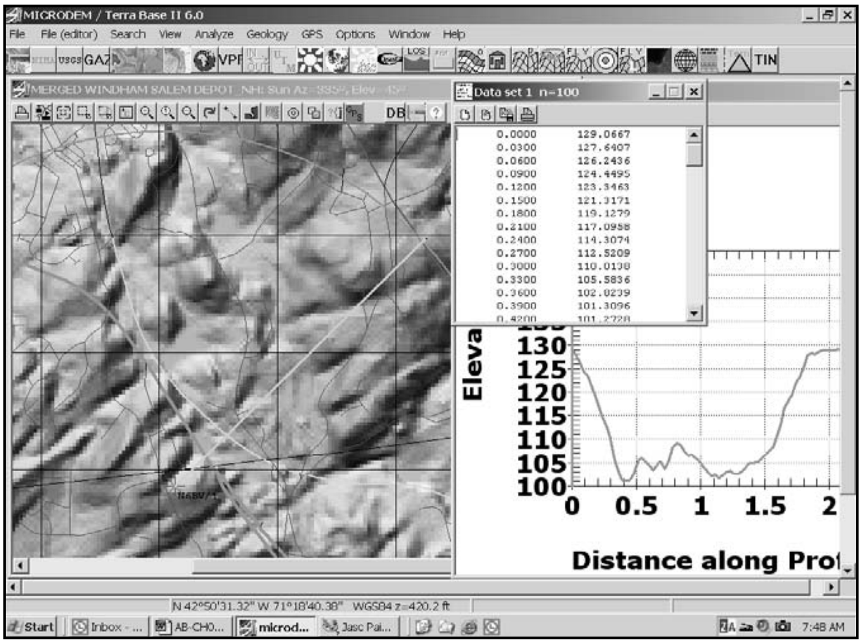

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      0.0000      129.0667
      0.0300      127.6407
      0.0600      126.2436
      0.0900      124.4495
      0.1200      123.3463
      0.1500      121.3171
      0.1800      119.1279
      0.2100      117.0958
      0.2400      114.3074
      0.2700      112.5209
      0.3000      110.0138
      0.3300      105.5836
      0.3600      102.0239
      0.3900      101.3096
      0.4200      101.2728
```

N 42°50'31.32" W 71°18'40.38"   WGS84 z=420.2 ft

Fig 47—A screen-capture of the *MicroDEM* program, showing the topographic map for the same terrain shown in Fig 46, together with the computed terrain profile along an azimuth of 45° on the path towards Europe from the N6BV/1 location in Windham, NH.

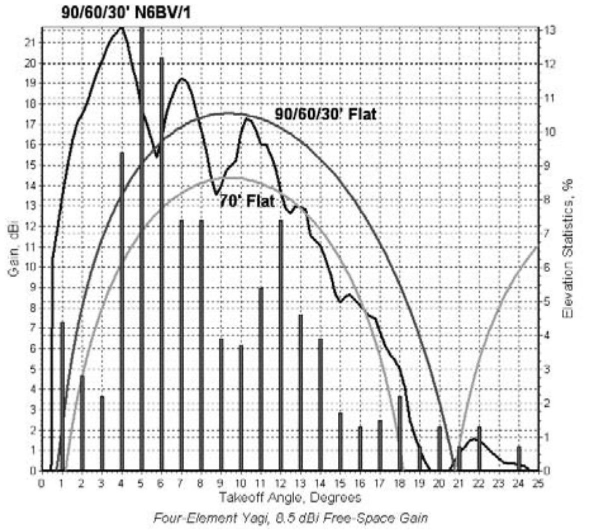

Fig 48—The 21-MHz elevation response for a stack of three TH7DX Yagis mounted on a single tower at 90/60/30 feet, at the N6BV/1 QTH for a 45° azimuth towards Europe. The terrain focuses the energy at low elevation angles compared to the same stack over flat ground. This illustrates once again the conservation of energy—Energy squeezed down into low elevation angles is stolen from other, higher, angles.

because *HFTA* doesn't explicitly model mutual coupling between Yagis in a stack.

HFTA compares well with the measurements for the horizontal antennas described earlier by Jim Breakall, WA3FET, using a helicopter in Utah. Breakall's measurements were done with a 15-foot high horizontal dipole.

More Details About *HFTA*

Frequency Coverage

HFTA can be used on frequencies higher than the HF bands, although the graphical resolution is only 0.25°. The patterns above about 100 MHz thus look rather grainy. The UTD is a *high-frequency-asymptotic* solution, so in theory the results become more realistic as the frequency is raised. Keep in mind too that *HFTA* is designed to model launch angles for skywave propagation modes, including E- and F-layer, and even Sporadic-E. Since by definition the ionospheric launch angles include only those above the horizon, direct line-of-sight UHF modes involving negative launch angles are not considered in *HFTA*.

See the HFTA.PDF documentation file for further details on the operation of *HFTA*. This file, as well as sample terrain profiles for some *big-gun* stations, is located on the CD-ROM accompanying this book.

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The last major study that appeared in the Amateur literature on the subject of local terrain as it affects DX appeared in four *QST* "How's DX" columns, by Clarke Greene, K1JX, from October 1980 to January 1981. Greene's work was an update of a landmark Sep 1966 *QST* article entitled "Station Design for DX," by Paul Rockwell, W3AFM. The long-range profiles of several prominent, indeed legendary, stations in Rockwell's article are fascinating: W3CRA, W4KFC and W6AM.

Chapter 4

Antenna Modeling & System Planning

OVERVIEW: ANTENNA ANALYSIS BY COMPUTER

As pointed out in Chapter 3, The Effects of Ground, irregular local terrain can have a profound effect on the launch of HF signals into the ionosphere. A *system approach* is needed to create a scientifically planned station. We pointed out in Chapter 3 that antenna modeling programs do not generally take into account the effects of irregular terrain, and by "irregular" we mean any sort of ground that is not flat. Most modeling programs based on *NEC-2* or *MININEC* do model reflections, but they do not model diffractions.

On the other hand, while a ray-tracing program like *HFTA* (HF Terrain Assessment) does take into account diffraction, it doesn't explicitly factor in the mutual impedance between an antenna and the ground. Instead, *HFTA* makes the basic assumption that the antenna is mounted sufficiently high above ground so that the mutual impedance between an antenna and the ground is minimal.

In this chapter we'll look at modeling the antennas themselves on the PC. We'll evaluate some typical antennas over flat ground and also in free space. Once characterized—or even optimized for certain characteristics—these antennas can then be analyzed over real terrain using *HFTA* and the other tools discussed in Chapter 3.

A Short History of Antenna Modeling

With the proliferation of personal computers since the early 1980s, amateurs and professionals alike have made significant strides in computerized antenna system analysis. It is now possible for the amateur with a relatively inexpensive computer to evaluate even complicated antenna systems. Amateurs can obtain a keener grasp of the operation of antenna systems—a subject that has been a great mystery to many in the past. We might add that modern computing tools allow hams to debunk overblown claims made about certain antennas.

The most commonly encountered programs for antenna analysis are those derived from a program developed at US government laboratories called *NEC*, short for "Numerical Electromagnetics Code." *NEC* uses a so-called *Method of Moments* algorithm. This intriguing name derives from a mathematical convention dealing with how "momentous" the accumulated error becomes when certain simplifying assumptions are made about the current distribution along an antenna wire. If you want to delve into details about the method of moments, John Kraus, W8JK, has an excellent chapter in his book *Antennas*, 2nd edition. See also the article "Programs for Antenna Analysis by the Method of Moments," by Bob Haviland, W4MB, in *The ARRL Antenna Compendium, Vol 4*.

The mathematics behind the method-of-moments algorithm are pretty formidable, but the basic principle is simple. An antenna is broken down into a number of straight-line wire *segments*, and the field resulting from the RF current in each segment is evaluated by itself and also with respect to other mutually coupled segments. Finally, the field from each contributing segment is vector-summed to yield the total field, which can be computed for any elevation or azimuth angle desired. The effects of flat-earth ground reflections, including the effect of ground conductivity and dielectric constant, may be evaluated as well.

In the early 1980s, *MININEC* was written in BASIC for use on personal computers. Because of limitations in memory and speed typical of personal computers of the time, several simplifying assumptions were necessary in *MININEC* and these limited potential accuracy. Perhaps the most significant limitation was that perfect ground was assumed to be directly under the antenna, even though the radiation pattern in the far field did take into account real ground parameters. This meant that antennas modeled closer than approximately 0.2 λ over ground sometimes gave erroneous impedances and inflated gains, especially for horizontal polarization. Despite some limitations, *MININEC* represented a remarkable leap forward in analytical capability. See Roy Lewallen's (W7EL) "*MININEC*—the Other Edge of the Sword" in Feb 1991 *QST* for an excellent treatment on pitfalls when using *MININEC*.

Because source code was made available when *MININEC* was released to the public, a number of programmers produced some very capable commercial versions for the amateur market, many incorporating exciting graphics showing antenna patterns in 2D or 3D. These programs also simplify the creation of models for popular antenna types, and several come with libraries of sample antennas.

By the end of the 1980s, the speed and capabilities

Commercial Implementations of *MININEC* and *NEC-2* Programs

Ever since the source code for *NEC-2* and *MININEC* came into in the public domain, enterprising programmers have been upgrading, extending and improving these programs. There are a number of "freeware" versions available nowadays, and there are also a variety of commercial implementations.

This sidebar deals only with the most popular commercial versions, programs that many hams use. You should keep in mind that whatever program you choose will require an investment in learning time, if not in dollars. Your time is valuable, of course, and so is the ability to swap modeling files you create with other modelers. Other peoples' modeling files, particularly when you are just starting out, are a great way to learn how the "experts" do their modeling. For example, there are archives of *EZNEC/ELNEC* files available on the Internet, since this popular modeling program has been around for a number of years. (*ELNEC* is the DOS-only, *MININEC*-core predecessor of EZNEC.)

The following table summarizes the main features and the pricing as of 2006 for some popular commercial antenna modeling programs. The programs that use the *NEC-4* core require separate licenses from Lawrence Livermore National Laboratories.

Commercial Implementations of *MININEC* and *NEC 2* programs

Name	***EZNEC 4.0 (+ ver.)***	***EZNEC-M Pro***	***EZNEC/4***	***NEC-Win Plus +***	***NEC-Win Pro***	***GNEC***	***Antenna Model***
Manufacturer	Roy Lewallen	Roy Lewallen	Roy Lewallen	Nittany Scientific	Nittany Scientific	Nittany Scientific	Teri Software
Core	*NEC-2*	*NEC-2*	*NEC-4*	*NEC-2*	*NEC-2*	*NEC-2/NEC-4*	*MININEC*
Operating System	Windows 32-bit	Windows 32-bit	Windows 32-bit	Windows 32-bit	Windows 32-bit	Windows 32-bit	Windows 32-bit
Number Segments	500 (1500, + ver.)	20,000	20,000	10,000	10,000	80,000	Limited by memory
NEC-Card Inputs	No	Yes	Yes	Yes	Yes	Yes	No
Other Input	ASCII (NEC, + ver.)	ASCII, NEC	ASCII, NEC	CAD *.DXF	CAD *.DXF	CAD *.DXF	No
Wires by Equation	No	No	No	Yes	Yes	Yes	Yes
Source Setting	By %	By %	By %	By %	By %	By %	By %
Source Type	Current/ Voltage/Split	Current/ Voltage/Split	Current /Voltage/Split	Current/ Voltage/Split	All types	All types	Current/Voltage
R + *j* X Loads	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RLC Loads	Series, Parallel, Trap	Series, Parallel, Trap	Series, Parallel, Trap	Series, Parallel	Series, Parallel	Series, Parallel	Series, Parallel
True Trap Loads	Yes	Yes	Yes	No	No	No	No
Laplace Loads	Yes	Yes	Yes	Yes	Yes	Yes	No
Conductivity Table	Yes *	Yes *	Yes *	Yes	Yes	Yes	Yes
Average Gain Test	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Transmission Lines	Yes	Yes	Yes	Yes	Yes	Yes	No
View Geometry	Excellent	Excellent	Excellent	Good	Good	Good	Very Good
Geometry Checking	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Easy Height Change	Yes	Yes	Yes	No	No	No	No
Polar Plots	ARRL, linear-dB Az/El, Circ. (+ ver.)	ARRL, linear-dB Az/El, Circ.	ARRL, linear-dB Az/El, Circ.	ARRL, linear-dB Az/El Patterns	ARRL, linear-dB Az/El Patterns	ARRL, linear-dB Az/El Patterns	ARRL, Linear -dB Az/El Patterns
Rectangular Plots	SWR	SWR	SWR	SWR, Zin	SWR, Zin, Az/El, Near/Far Plots, Currents	SWR, Zin, Az/El, Near/Far Plots, Currents	Gain, SWR, F/B, F/R, Rin, Xin
Operating Speed	Fast	Fast	Fast	Very Fast	Very Fast	Very Fast	Slow
Smith Chart	Data for Ext. Smith program	Data for Ext. Smith program	Data for Ext. Smithprogram	No	Yes	Yes	Yes
Near/Far Field Tables	Both	Both	Both	Far	Both	Both	Both
Ground Wave Analysis	No	Yes	Yes	No	Yes	Yes	No
Pricing	$89 Web; $99 CD-ROM, $139 (+ ver.)	$450	$600; must have *NEC-4* license	$150	$425	$795	$85

* Wire conductivity is the same for all wires.

Excellent, Very Good, Good ratings done by *Antenna Book* editor.

of personal computers had advanced to the point where PC versions of *NEC* became practical, and several versions are now available to amateurs. The most recent public-domain version is *NEC-2* and this is the computational core that we'll use as an example throughout this chapter.

Like *MININEC*, *NEC-2* is a general-purpose modeling package and it can be difficult to use and relatively slow in operation for certain specialized antenna forms. Thus, custom commercial software has been created for more user-friendly and speedier analysis of specific antenna varieties, mainly Yagi arrays. See Chapter 11, HF Yagi Arrays. Also see the sidebar, "Commercial Implementations of *MININEC* and *NEC-2* Programs."

For this edition of *The ARRL Antenna Book*, Roy Lewallen, W7EL, has graciously provided a special version of his *EZNEC 3.0* program, called *EZNEC-ARRL*. This version works with the specific antenna models also bundled on the CD-ROM. Please note that this ARRL-specific version of *EZNEC* is limited to a maximum of 20 segments (we'll explain segments later) for all models except for the special ones included on this CD-ROM. You can find information on how to purchase the full-fledged version of *EZNEC* in the **Help** section of the *EZNEC-ARRL* program.

The following material on antenna modeling is by necessity a summary, since entire books have been written on this subject. Serious modelers would be well-advised to enroll in the online Antenna Modeling course, part of the ARRL Certification and Continuing Education series. L. B. Cebik, W4RNL created the ARRL Antenna Modeling course and it contains a great deal of information, tips and techniques concerning modeling by computer. See: **http://www.arrl.org/news/stories/2002/02/06/2/** for more information. We also strongly recommend that you read the Help files in *EZNEC-ARRL*. There is a wealth of practical information on the finer points of antenna modeling there.

THE BASICS OF ANTENNA MODELING

This chapter will discuss the following antenna-modeling topics for an *NEC-2*-based modeling software, using *EZNEC-ARRL* as an example:

- Program outputs
- Wire geometry
- Segmentation, warnings and limitations
- Source (feed point) placement
- Environment, including ground types and frequency
- Loads and transmission lines
- Testing the adequacy of a model

PROGRAM OUTPUTS

Instruction manuals for software programs traditionally start out describing in detail the input data needed by the program. They then demonstrate the output data the program can generate. We feel it is instructive, however, to turn things around and start out with a brief overview of the output from a typical antenna-modeling program.

We'll look at the output from public-domain *NEC-2*. Next, we'll look at the output information available from commercial adaptations of *NEC-2*, using *EZNEC-ARRL* provided by W7EL. After this brief overview of the output data, we'll look in detail at the input data needed to make a modeling program work. In the following discussions it will be very instructive if you to bring up *EZNEC-ARRL* on your computer and open the specific modeling files used in each example. [From now on in this chapter we'll refer merely to *EZNEC* rather than *EZNEC 3.0*, the official name or *EZNEC-ARRL*, a specialized subset of *EZNEC 3.0*. Where there are specific differences between *EZNEC 3.0* and the limited-edition *EZNEC-ARRL* we'll identify them.]

Native *NEC-2*

The native *NEC-2* program produces pages and pages of output formatted for a mainframe "line printer." You may be old enough to remember the stacks of green-and-white, tractor-feed, 132-column computer paper that such a line printer produced. Corporate MIS departments stored untold number of boxes of that paper.

Native *NEC-2* was written in the Fortran language, which stands for *Formula Translation*. Programmers used punched cards to enter the program itself and its accompanying input data into huge mainframe computers. To say that the paper output from *NEC-2* is massive, even intimidating, is putting it mildly. There is a strong distinction between "useful information" and "raw data" and the raw output from native *NEC-2* bombards the user with raw data.

Commercial versions that use the *NEC-2* computational core shield the user from the ugliness of raw line-printer output, as well as punched-card input (or disk surrogates for punched cards). Commercial versions like *EZNEC* do produce output numerical tables where this is useful. These tables show parameters such as the source impedance and SWR at a single frequency, or the characteristics of a load or a transmission line. But as the old saying goes, "One picture is worth a thousand words." This is as true for modeling programs as it is for other endeavors dealing with reams of numbers. Thus, most commercial modeling software packages create *graphs* for the user. *EZNEC* produces the following types of graphs:

- Polar (linear-dB or ARRL-style) graphs of the far-field elevation and azimuth responses.
- 3-D wire-frame graph of the total far-field response.
- Graph of the SWR across a frequency band.
- Graphical display of the RF currents on various conductors in a model.
- Rotatable, zoomable 3-D views of the wires used to make a model.
- Output to programs capable of generating Smith charts.

Fig 1A and 1B shows the computed far-field 2-D elevation and azimuth patterns for a 135-foot long horizontal dipole, mounted in a flattop configuration 50 feet above flat ground. These figures were generated using *EZNEC* at 3.75 MHz. Fig 1C shows a 3-D wire-frame picture of the far-field response, but this time at 14.2 MHz. For comparison, **Table 1** shows a short portion of the line-printer output for the azimuth pattern at 3.75 MHz. The actual printout is many pages long. One picture can indeed replace thousands of numbers!

Fig 2 shows the computed SWR curve over the frequency range 3.0 to 4.0 MHz for this dipole, fed with lossless 50-Ω transmission line. *EZNEC* generated this plot using the "SWR" button. Figs 1 and 2 are typical of the kind of graphical outputs that commercial implementations of the *NEC-2* computing core can produce.

Now, let's get into the details of what kind of input data is required to run a typical method-of-moments antenna-modeling program.

PROGRAM INPUTS: WIRE GEOMETRY

Coordinates in an X, Y and Z World

The most difficult part of using a *NEC*-type of modeling program is setting up the antenna's geometry—you must condition yourself to think in three-dimensional, Cartesian coordinates. Each end point of a wire is represented by three numbers: an x, y and z coordinate. These coordinates represent the distance from the origin (x-axis), the width of an antenna (y-axis), and the height (z-axis).

An example should help sort things out. **Fig 3** shows a simple model of a 135-foot center-fed dipole, made of #14 copper wire placed 50 feet above flat ground. The common term for this antenna is *flattop dipole*. For convenience, the ground is located at the *origin* of the coordinate system, at (0, 0, 0) feet, directly under the center of the dipole. **Fig 4** shows the *EZNEC* spreadsheet-like input data for this antenna. (Use model file: **Ch4-Flattop Dipole.EZ**.) *EZNEC* allows you to specify the type of conductor material from its main window, using the **Wire Loss** button to open a new window. We will click on the **Copper** button for this dipole.

Above the origin, at a height of 50 feet on the z-axis, is the dipole's *feed point*, called a *source* in *NEC* terminology. The width of the dipole goes toward the left (that is, in the "negative-y" direction) one-half the overall length of 135 feet, or –67.5 feet. Toward the right, our dipole's other end is at +67.5 feet. The x-axis dimension of our dipole is zero, meaning that the dipole wire is parallel to and directly above the x-axis. The dipole's ends are thus represented by two points, whose coordinates are (0, –67.5, 50) and (0, 67.5, 50) feet. The use of parentheses with a sequential listing of (x, y, z) coordinates is a common practice among antenna modelers to describe a wire end point.

Fig 3B includes some other useful information about this antenna beyond the wire geometry. Fig 3B overlays the wire geometry, the current distribution along the wire and the far-field azimuth response, in this case at an elevation angle of 30°.

Although not shown specifically in Fig 3, the thickness of the antenna is the diameter of the wire, #14 gauge. Note that native *NEC* programs specify the *radius* of the

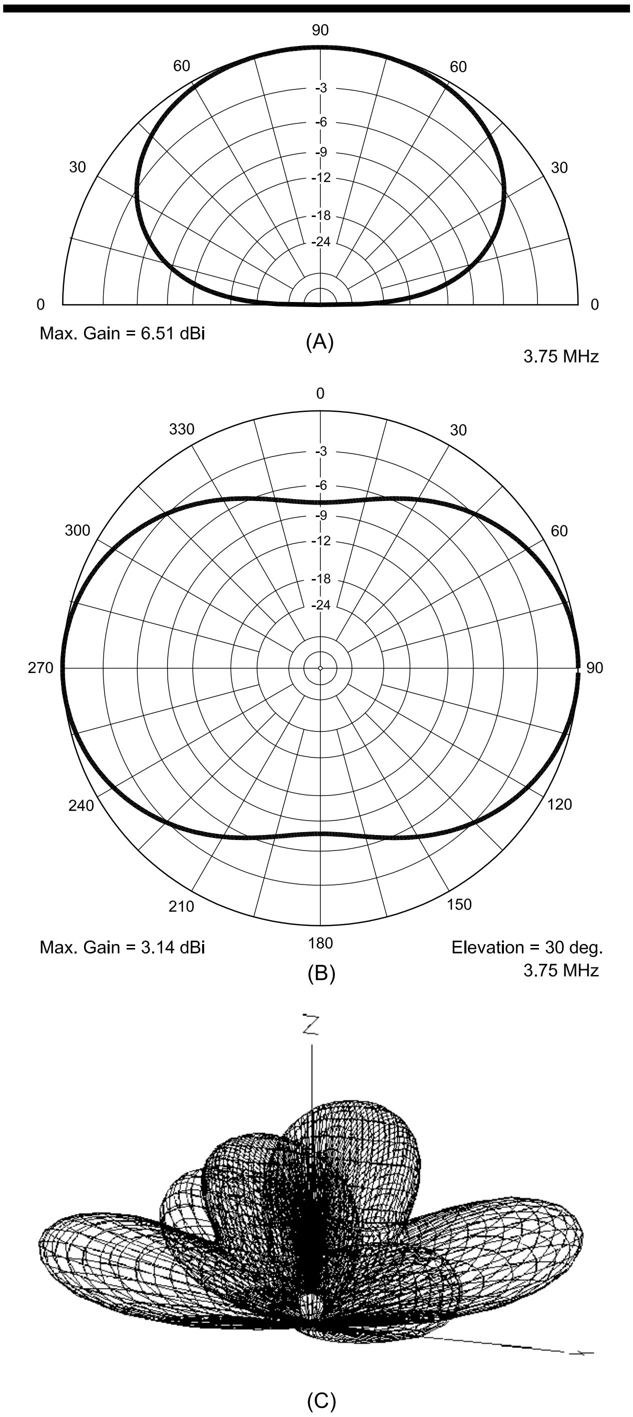

Fig 1—At A, far-field elevation-plane pattern for a 135-foot-long horizontal dipole, 50 feet above flat ground, at 3.5 MHz. At B, the far-field azimuth-plane pattern at an elevation angle of 30°.

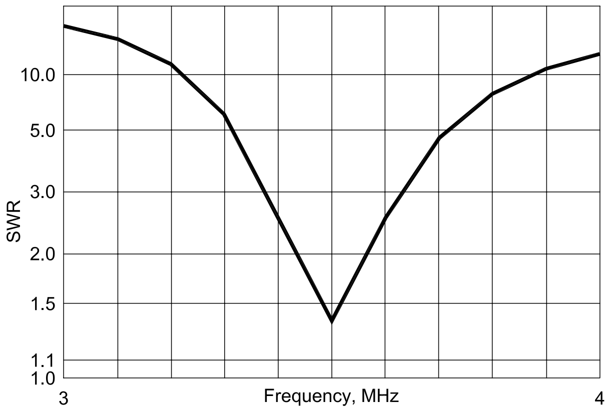

Fig 2—SWR curve for 135-foot flattop dipole over the frequency range 3.0 to 4.0 MHz for a 50-Ω feed line. This antenna is an example and is not optimized for the amateur band.

wire, rather than the diameter, but programs like *EZNEC* use the more intuitive diameter of a wire rather than the radius. *EZNEC* (and other commercial programs) also allows the user to specify the wire as an AWG gauge, such as #14 or #22, for example.

We've represented our simple dipole in Fig 3 using a single, straight wire. In fact, all antenna models created for method-of-moment programs are made of combinations of straight wires. This includes even complex antennas, such as helical antennas or round loops. (The mathematical basis for modeling complex antennas is that they can be simulated using straight-wire *polygons*. A circular loop, for example, can be modeled using an octagon.)

Segmentation and Specifying a Source Segment

We've specified the physical geometry of this simple one-wire dipole. Now several more modeling details surface—you must specify the number of *segments* into which the dipole is divided for the method-of-moment analysis and you must somehow feed the antenna. The *NEC-2* guideline for setting the number of segments is to use at least 10 segments per half-wavelength. This is a general rule of thumb, however, and in many models more dense segmentation is mandatory for good accuracy.

In Fig 3, we've specified that the dipole be divided into 11 segments for operation on the 80-meter band. This follows the rule of thumb above, since the 135-foot dipole is about a half-wavelength long at 3.5 MHz.

Setting the Source Segment

The use of 11 segments, an odd rather than an even number such as 10, places the dipole's feed point (the

Table 1
Portion of line-printer output from *NEC-2* for 135-foot dipole.

- - - RADIATION PATTERNS - - -

- - ANGLES - -		*- POWER GAINS -*			*- - - POLARIZATION - - -*			*- - - E(THETA) - - -*		*- - - E(PHI) - - -*	
Theta Degrees	*Phi Degrees*	*Vert dB*	*Hor dB*	*Total dB*	*Axial Ratio*	*Tilt Degrees*	*Sense*	*Magnitude Volts*	*Phase Degrees*	*Magnitude Volts*	*Phase Degrees*
60.00	0.00	–999.99	3.14	3.14	0.00000	90.00	LINEAR	0.00000E+00	0.00	6.62073E-01	–66.87
60.00	1.00	–37.87	3.13	3.14	0.00301	89.52	LEFT	5.89772E-03	–86.64	6.61933E-01	–66.87
60.00	2.00	–31.85	3.13	3.13	0.00603	89.04	LEFT	1.17915E-02	–86.64	6.61512E-01	–66.87
60.00	3.00	–28.33	3.12	3.12	0.00904	88.56	LEFT	1.76776E-02	–86.64	6.60812E-01	–66.87
60.00	4.00	–25.84	3.11	3.11	0.01206	88.08	LEFT	2.35520E-02	–86.64	6.59834E-01	–66.87
60.00	5.00	–23.91	3.09	3.10	0.01508	87.59	LEFT	2.94109E-02	–86.64	6.58577E-01	–66.87
60.00	6.00	–22.34	3.07	3.08	0.01810	87.11	LEFT	3.52504E-02	–86.64	6.57045E-01	–66.87
60.00	7.00	–21.01	3.05	3.06	0.02112	86.62	LEFT	4.10669E-02	–86.63	6.55237E-01	–66.87
60.00	8.00	–19.87	3.02	3.04	0.02415	86.14	LEFT	4.68565E-02	–86.63	6.53158E-01	–66.87
60.00	9.00	–18.86	2.99	3.02	0.02718	85.65	LEFT	5.26156E-02	–86.63	6.50808E-01	–66.87
60.00	10.00	–17.96	2.95	2.99	0.03022	85.15	LEFT	5.83405E-02	–86.63	6.48190E-01	–66.87
60.00	11.00	–17.15	2.91	2.96	0.03327	84.66	LEFT	6.40278E-02	–86.63	6.45308E-01	–66.86
60.00	12.00	–16.42	2.87	2.92	0.03631	84.16	LEFT	6.96739E-02	–86.63	6.42165E-01	–66.86
60.00	13.00	–15.75	2.83	2.89	0.03937	83.66	LEFT	7.52755E-02	–86.63	6.38764E-01	–66.86
60.00	14.00	–15.13	2.78	2.85	0.04243	83.16	LEFT	8.08291E-02	–86.63	6.35108E-01	–66.86
60.00	15.00	–14.56	2.72	2.80	0.04550	82.65	LEFT	8.63317E-02	–86.62	6.31203E-01	–66.86
60.00	16.00	–14.03	2.66	2.76	0.04858	82.14	LEFT	9.17800E-02	–86.62	6.27051E-01	–66.86
60.00	17.00	–13.53	2.60	2.71	0.05166	81.62	LEFT	9.71711E-02	–86.62	6.22657E-01	–66.85
60.00	18.00	–13.07	2.54	2.66	0.05475	81.10	LEFT	1.02502E-01	–86.62	6.18027E-01	–66.85

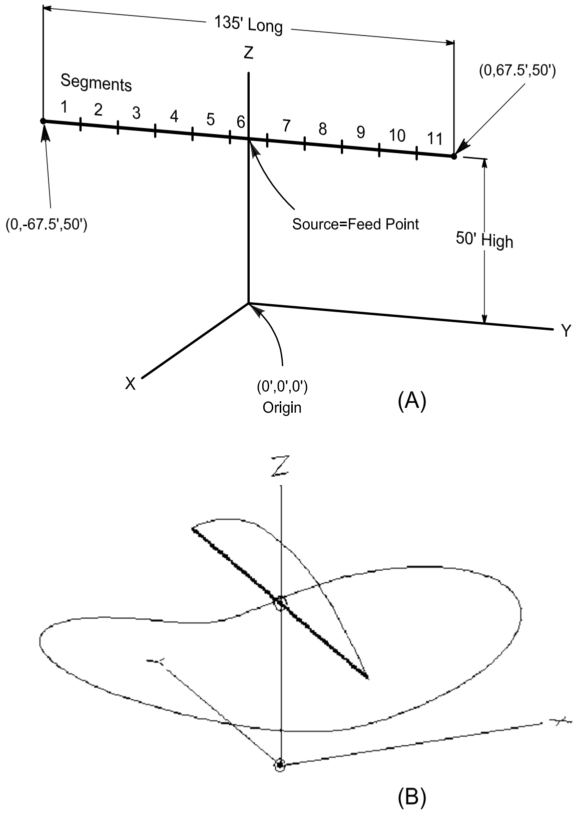

Fig 3—At A, simple model for a 135-foot long horizontal dipole, 50 feet above the ground. The dipole is over the y-axis. The wire has been segmented into 11 segments, with the center of segment number 6 as the feed point. The left-hand end of the antenna is -67.5 feet from the center feed point and that the right-hand end is at 67.5 feet from the center. At B, *EZNEC* "View Antenna" drawing, showing geometry of wire and the x, y and z axes. Overlaid on the wire geometry drawing are the current distribution along the wire and the far-field azimuthal response at an elevation angle of 30°.

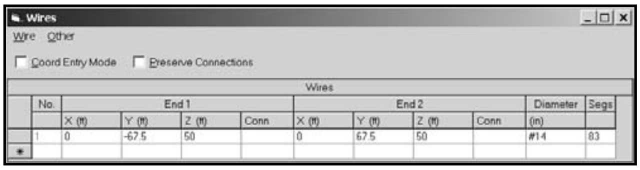

☐ Coord Entry Mode ☐ Preserve Connections

Wires

	No.	End 1				End 2				Diameter	Segs
		X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
	1	0	-67.5	50		0	67.5	50		#14	83
*											

Fig 4—*EZNEC* "Wires" spreadsheet for simple flattop dipole in Fig 3. The numbers shown are in feet, except for the wire diameter, which *EZNEC* allows you to specify as an AWG gauge, in this case #14. Note that 83 segments have been specified for this antenna for analysis over the range from 3.5 to 29.7 MHz.

source in *NEC*-speak, a word choice that can befuddle beginners) right at the antenna's center, at the center of segment number six. In concert with the "EZ" in its name, *EZNEC* makes choosing the source segment easy by allowing the user to specify a percentage along the wire, in this case 50% for center feeding.

At this point you may very well be wondering why no center insulator is shown in the middle of our center-fed dipole. After all, a real dipole would have a center insulator. However, method-of-moment programs assume that a source generator is placed across an infinitely small gap in the antenna wire. While this is convenient from a mathematical point of view, the unstated use of such an infinitely small gap often confuses newcomers to the world of antenna modeling. We'll get into more details, caveats and limitations in source placement later in this chapter. For now, just trust us that the model we've just described with 11 segments, fed at segment 6, will work well over the full amateur band from 3.5 to 4.0 MHz.

Now, let's consider what would happen if we want to use our 135-foot long dipole on all HF amateur bands from 3.5 to 29.7 MHz, rather than just from 3.5 to 4.0 MHz. Instead of feeding such an antenna with coax cable, we would feed it with open-wire line and use an antenna tuner in the shack to create a 50-Ω load for the transmitter. To comply with the segmentation rule above, the number of segments used in the model should vary with frequency—or at least be segmented at or above the minimum recommended level at the highest frequency used. This is because a half wavelength at 29.7 MHz is 16.6 feet, while a half wavelength at 3.5 MHz is 140.6 feet. So the number of segments for proper operation on 29.7 MHz should be 10 × 135/16.6 = 81. We'll be a little more conservative than the minimum requirement and specify 83 segments. **Fig 4** shows the *EZNEC* input spreadsheet for this model. (Use model file: **Ch4-Multiband Dipole.EZ**.)

The penalty for using more segments in a program like *NEC* is that the program slows down roughly as the square of the segments—double the number of segments and the speed drops to a fourth. If we try to use too few segments, we'll introduce inaccuracies, particularly in computing the feed-point impedance. We'll delve into this area of segmentation density in more detail later when we discuss testing the adequacy of a model.

Segment Length-to-Wire-Diameter Ratio

Even if you're willing to live with the slowdown in computing speed for situations involving a large number of wire segments, you should make sure the ratio between the segment length and the diameter of any wire is greater than 1:1. This is to say that the length of each segment is longer than the diameter of the wire. Doing so stays away from internal limitations in the *NEC* program.

For the #14 wire specified in this simple 135-foot long dipole, it's pretty unlikely that you'll bump up against this limitation for any reasonable level of segmentation. After all, #14 wire has a diameter of 0.064 inches and 135 feet is 1620 inches. To keep above a segment length of 0.064 inches, the maximum number of segments is 1620/

0.064 = 25,312. This is a *very* large number of segments and it would take a very long time to compute, assuming that your program can handle that many segments.

Keeping above a 1:1 ratio in segment length to wire diameter can be more challenging at VHF/UHF frequencies, however. This is particularly true for fairly large "wires" made of aluminum tubing. Incidentally, this is another point where newcomers to antenna modeling can be led astray by the terminology. In a *NEC*-type program, all conductors in a model are considered to be *wires*, even if they consist of hollow aluminum or copper tubes. Surface effect keeps the RF current in any conductor confined to the outer surface of that conductor, and thus it doesn't matter whether the conductor is hollow or solid, or even made using a number of stranded wires twisted together.

Let's look at a half-wave dipole at 420 MHz. This would be about 14.1 inches long. If you use $^1/_4$-inch diameter tubing for this dipole, the maximum segment length meeting the 1:1 diameter-to-length ratio requirement is also $^1/_4$ inches long. The maximum number of segments then would be 14.1/0.25 = 56.4, rounded down to 56. From this discussion you should now understand why method-of-moment programs are known for using a "thin-wire approximation." Really fat conductors can get you into trouble, particularly at VHF/UHF.

Some Caveats and Limitations Concerning Geometry

Example: Inverted-V Dipole

Now, let's get a little more complicated and specify another 135-foot-long dipole, but this time configured as an *inverted V*. As shown in **Fig 5**, you must now specify two wires. The two wires join at the top, at (0, 0, 50) feet. (Again, the program doesn't use a center insulator in the model.)

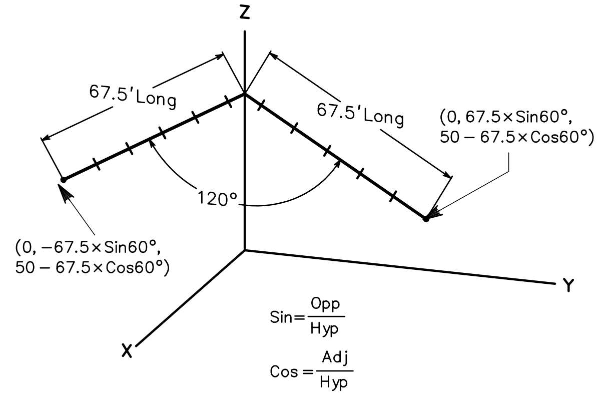

Fig 5—Model for an inverted-V dipole, with an included angle between the two legs of 120°. Sine and cosine functions are used to describe the heights of the end points for the sloping arms of the antenna.

If you are using a native version of *NEC*, you may have to go back to your high-school trigonometry book to figure out how to specify the end points of our "droopy" dipole, with its 120° included angle. Fig 5 shows the details, along with the trigonometric equations needed. *EZNEC* is indeed more "easy" here, since it allows you to tilt the ends of each wire downwards an appropriate number of degrees (in this case –30° at each end of the dipole) to automatically create an inverted-V configuration. **Fig 6A** shows the *EZNEC* spreadsheet describing this inverted-V dipole with a 120° included angle between the two wires.

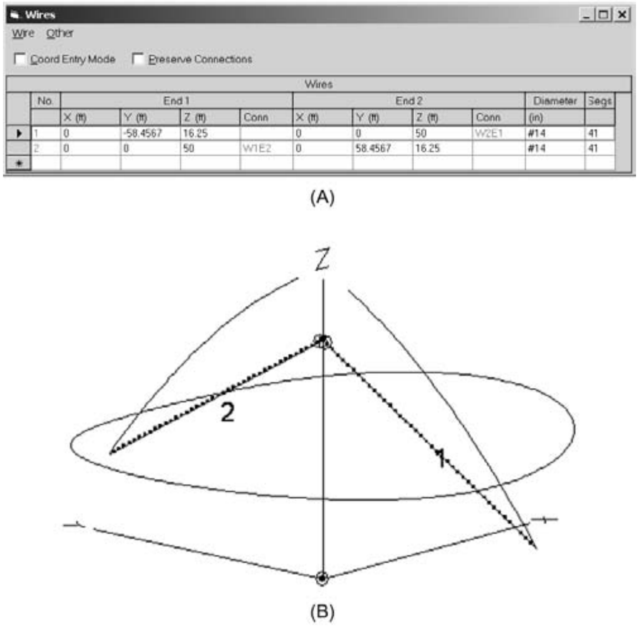

☐ Coord Entry Mode ☐ Preserve Connections

Wires

	No.	End 1				End 2				Diameter	Segs
		X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
▶	1	0	-58.4567	16.25		0	0	50	W2E1	#14	41
	2	0	0	50	W1E2	0	58.4567	16.25		#14	41
*											

(A)

(B)

Fig 6—At A, *EZNEC* spreadsheet for inverted-V dipole in Fig 5. Now the ends of the inverted-V dipole are 16.25 feet above ground, instead of 50 feet for the flattop dipole. At B, *EZNEC* "View Antenna" drawing, with overlay of geometry, current distribution and azimuth plot.

See the *EZNEC* **Help** section under "Wire Coordinate Shortcuts" for specific instructions on how to use the "elevation rotate end" shortcut "RE–30" to create the sloping wires easily by rotating the end of the wire down 30°. Now the specification of the source becomes a bit more complicated. The easiest way is to specify two sources, one on each end segment at the junction of the two wires. *EZNEC* does this automatically if you specify a so-called *split-source* feed. Fig 6B shows the two sources as two open circles at the top ends of the two wires making up the inverted-V dipole. What *EZNEC* is doing is creating two sources, each on the closest segments on either side of the junction of the two wires. *EZNEC* sums up the two source impedances to provide a single readout.

Navigating in the View Antenna Window

At this point it's worthwhile to explore some of the ways you can see what the wire geometry looks like using the *EZNEC* **View Ant** button on the main window. Bring up the file **Ch4-Inverted V Dipole.EZ** in *EZNEC*, and click on the **View Ant** button. You will see a small inverted-V dipole raised over the (0, 0, 0) origin on the ground directly under the feed point of the inverted-V dipole. First, "rotate" the dipole by holding down the left-mouse button and moving the mouse. You can orient the picture any way you wish.

Let's take a closer look at the junction of the two wires at the feed point. Click the **Center Ant Image** checkbox toward the bottom of the window to anchor the center of the image at the center of the window, and then move the **Zoom** slider upwards to zoom in on the image. At some point the junction of the two slanted wires will move up off the edge of the window, so you will need to click on the left-hand side of the **Z Move Image** slider to bring the junction back into view. Now you should be able to see a zoomed view of the junction, along with the two open circles that represent the location of the split sources in the middle of the segments adjacent to the wire junction.

Now put the mouse cursor over one of the slanted wires and double click the left-mouse button. *EZNEC* will now identify that wire and show its length, as well as the length of each segment on that wire. Pretty slick, isn't it?

Short, Fat Wires and the Acute-Angle Junction

Another possible complication can arise for wires with short, fat segments, particularly ones that have only a small included angle between them. These wire segments can end up inter-penetrating within each other's volumes, leading to problems in a model. Once you think of each wire segment as a thick cylinder, you can appreciate the difficulty in connecting two wires together at their ends. The two wires always inter-penetrate each other's volume to some extent. **Fig 7** depicts this problem graphically for two short, fat wires joined at their ends at an acute angle. A rule of thumb is to avoid creating junctions where more than $^1/_3$ of the wire volumes inter-penetrate. You can achieve this by using longer segment lengths or thinner wire diameters.

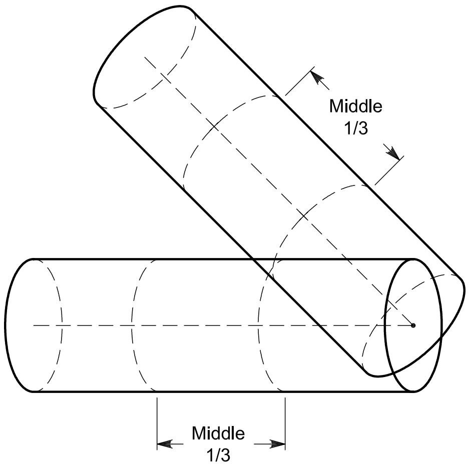

Fig 7—A junction of two short, fat wire segments at an acute angle. This results in inter-penetration of the two wire volumes beyond the middle-1/3 recommended limit.

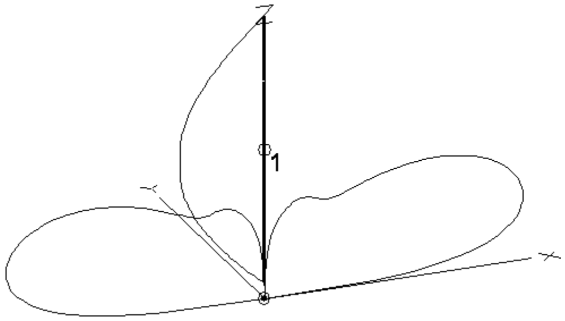

Fig 8—A vertical half-wave dipole, created by turning the dipole in Fig 3 on its end, with a minimum height at the lower end of 8 feet to keep the antenna away from people and animals. The current distribution and the elevation pattern for this antenna are also shown overlaid on the wire geometry.

Some Other Practical Antenna Geometries

A Vertical Half-Wave Dipole

If you turn the 135-foot-long horizontal dipole in Fig 1 on its end you will create a vertical half-wave dipole that is above the origin of the x, y and z axes. See **Fig 8**, where the bottom end of the dipole is placed 8 feet off the ground to keep it away from humans and animals for safety, at (0, 0, 8) feet. The top end is thus at 8 + 135 = 143 feet off the ground at (0, 0, 143). Fig 8 also shows the current distribution and the elevation pattern for this antenna. (Use *EZNEC* model file: **Ch4-Vertical Dipole.EZ**.)

A Ground-Plane Antenna

The ground-plane model is more complicated than previous ones because a total of five wires are now needed: one for the vertical radiator and four for the radials. **Fig 9** shows the *EZNEC* view for a 20-meter ground plane mounted 15 feet off the ground (perhaps on a garage roof), with the overlay of both the current distribution and the elevation-plane plot. (Use *EZNEC* model file: **Ch4-GP.EZ**.) Note that the source has been placed at the

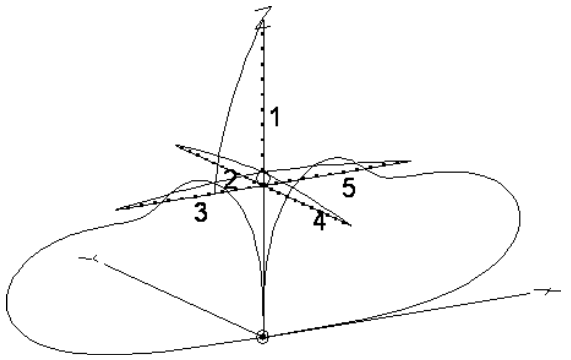

Fig 9—A vertical ground-plane antenna. The radials and the bottom of the vertical radiator are located 15 feet off the ground in this model. The current distribution along each wire and the far-field elevation-plane pattern are overlaid on the antenna geometry.

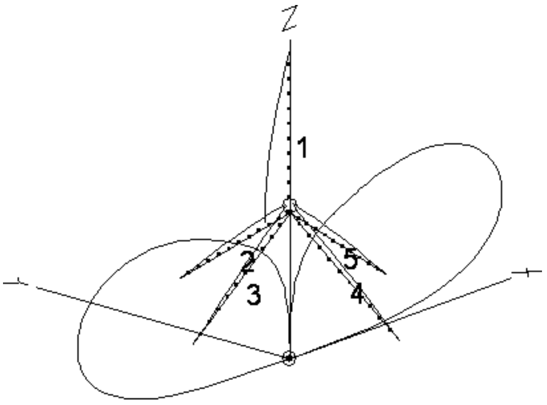

Fig 10—*EZNEC* View Antenna for the ground-plane antenna with its four radials tilted downwards by 40° to improve the SWR at the feed point.

bottom segment of the vertical radiator. Once again, the program needs no bottom insulator, since all five wires are connected together at a common point. *EZNEC* reports that this antenna has a resonant feed-point impedance of about 22 Ω, which would show an SWR of 2.3:1 for a 50-Ω coax feed line if no matching system is used, such as a gamma or hairpin match.

Fig 10 shows the same antenna, except that the radials have now been tilted downwards by 35° to facilitate an almost perfect 50-Ω match (SWR = 1.08:1). In addition, the length of the radiator in this model was shortened by 6 inches to re-resonate the antenna. (Use *EZNEC* model file: **Ch4-Modified GP.EZ**.) The trick of tilting the radials downwards for a ground-plane antenna is an old one, and the modeling programs validates what hams have been doing for years.

A 5-Element Horizontal Yagi

This is a little more challenging modeling exercise. Let's use a 5-element design on a 40-foot boom, but rather than using telescoping aluminum tubing for the elements, we'll use #14 wire. The *SCALE* program included with this book on the CD-ROM converted the aluminum-tubing 520-40.YW to a design using #14 copper wire. **Table 2** shows the element lineup for this antenna. (Later in this chapter we'll see what happens when telescoping aluminum tubing is used in a real-world Yagi design.)

Some explanations of what Table 3 means are in order. First, only one half of each element is shown. The *YW* program (Yagi for Windows), also included on the CD-ROM, computes the other half of the Yagi automatically, essentially mirroring the other half on the opposite side of the boom. Having to enter the dimensions for only half of a real-world Yagi element that uses telescoping aluminum tubing is much easier this way.

Second, the placement of the elements along the boom starts at 0.0 inches for the reflector. The distance between adjacent elements defined in this particular file is the spacing between the element itself and the element just before it. For example, the spacing between the driven element and the reflector is 72 inches, and the spacing between the first director and the driven element is also 72 inches. The spacing between the second director and the first director is 139 inches.

Fig 11A shows the wire geometry for this Yagi array when it is mounted 720 inches (60 feet) above flat ground and Fig 11B shows the *EZNEC* Wires spreadsheet that describes the coordinates. (Use *EZNEC* model file: **Ch4-520-40W.EZ**.) You can see that the x-axis coordinates for the elements have been automatically moved by the *SCALE* program so that the center of the boom is located directly above the origin. This makes it easier to evaluate the effects of stacking different monoband Yagis on a rotating mast in a "Christmas Tree" arrangement. A typical Christmas Tree stack might include 20, 15 and 10-meter monobanders on a single rotating mast sticking out of the top of the tower.

Fig 12 shows the computed azimuth pattern for this Yagi at 14.175 MHz, at an elevation angle of 15°, the angle where the peak of the forward lobe occurs at this

Table 2

```
520-40W.YW, using #14 wire from 520-40H.YW
14.000  14.174  14.350 MHz
5 elements,    inches
Spacing           .064
0.000          210.923
72.000         200.941
72.000         199.600
139.000        197.502
191.000        190.536
```

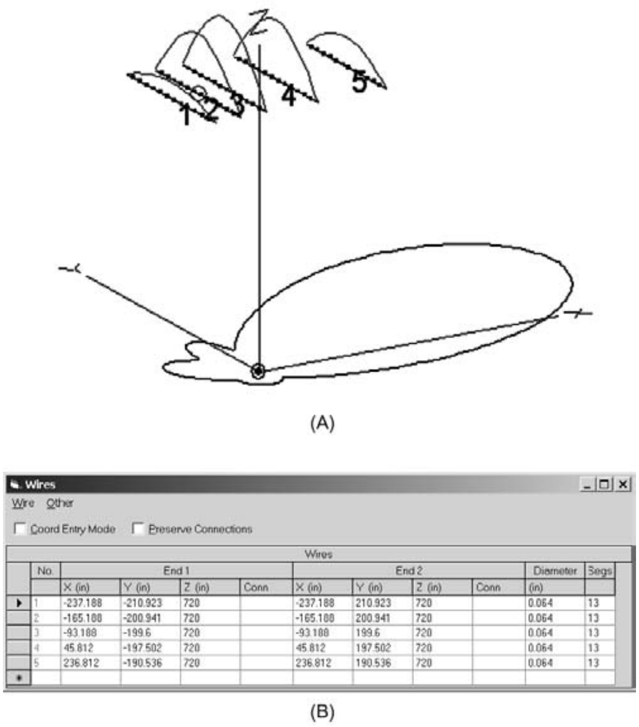

☐ Coord Entry Mode ☐ Preserve Connections

Wires

	No.	End 1				End 2				Diameter	Segs
		X (in)	Y (in)	Z (in)	Conn	X (in)	Y (in)	Z (in)	Conn	(in)	
▸	1	-237.188	-210.923	720		-237.188	210.923	720		0.064	13
	2	-165.188	-200.941	720		-165.188	200.941	720		0.064	13
	3	-93.188	-199.6	720		-93.188	199.6	720		0.064	13
	4	45.812	-197.502	720		45.812	197.502	720		0.064	13
	5	236.812	-190.536	720		236.812	190.536	720		0.064	13
*											

Fig 11—At A, geometry for 5-element Yagi on a 40-foot boom, mounted 720 inches (60 feet) above flat ground, with an overlay of current and the azimuth pattern. At B, *EZNEC* Wires spreadsheet for this antenna. This design uses #14 wire for simplicity.

height above flat ground. The antenna exhibits excellent gain at 13.1 dBi, as well as a clean pattern behind the main lobe. The worst-case front-to-rear ratio at any point from 90° to 270° in azimuth is better than 23 dB. *EZNEC* says the feed-point impedance is 25 – *j* 23 Ω, just the right impedance suited for a simple hairpin or gamma match.

A Monoband 2-Element Cubical Quad

Unlike a Yagi, with its elements existing only in the x-y plane, a quad type of beam is a three-dimensional sort of antenna. A quad loop has height in the z-axis, as well as width and length in the x-y plane. Each individual loop for a monoband quad consists of four wires, joined together at the corners. **Fig 13** shows the coordinates for a 2-element 15-meter quad, consisting of a reflector and a driven element on a 10-foot boom.

You can see that the axis of symmetry, the x-axis, runs down the center of this model, meaning that the origin of this particular x, y and z-coordinate scheme is in the center of the reflector. The (0, 0, 0) origin is placed this way for convenience in assigning corner coordinates for each element. For actual placement of the antenna at a particular height above real ground, the heights of all z-axis coordinates are changed accordingly. *EZNEC* has a convenient built-in function to change the height of all wires at a single stroke.

Fig 14 shows the input *EZNEC* spreadsheet for this quad in free space, clearly showing the symmetrical nature of the corner coordinates. (Use *EZNEC* model file: **Ch4-Quad.EZ**.) This is a good place to emphasize that you should enter the wire coordinates in a logical

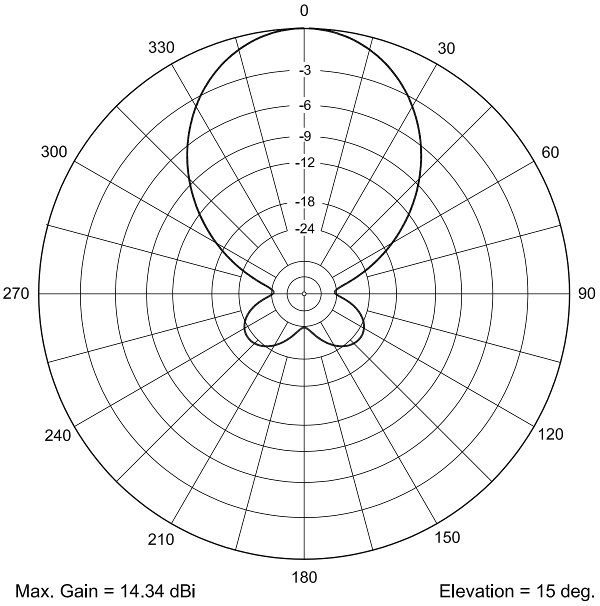

Fig 12—*EZNEC* azimuth-plane pattern at an elevation angle of 15° for #14 wire Yagi described in Fig 11.

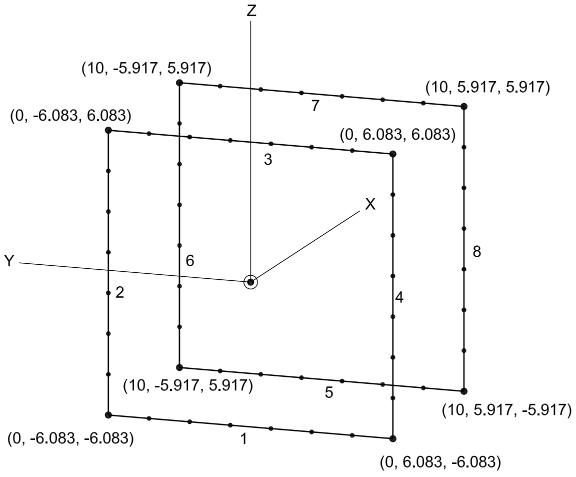

Fig 13—Wire geometry for a 2-element cubical quad, with a reflector and driven element. The x-axis is the axis of symmetry for this free-space model.

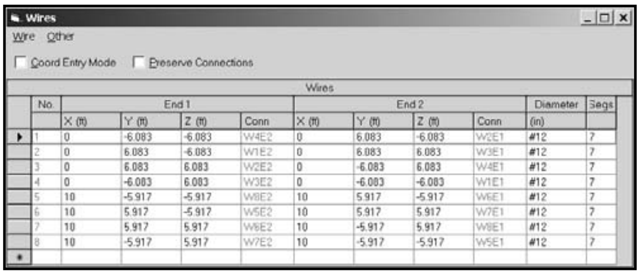

No.	End 1				End 2				Diameter	Segs
	X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
1	0	-6.083	-6.083	W4E2	0	6.083	-6.083	W2E1	#12	7
2	0	6.083	-6.083	W1E2	0	6.083	6.083	W3E1	#12	7
3	0	6.083	6.083	W2E2	0	-6.083	6.083	W4E1	#12	7
4	0	-6.083	6.083	W3E2	0	-6.083	-6.083	W1E1	#12	7
5	10	-5.917	-5.917	W8E2	10	5.917	-5.917	W6E1	#12	7
6	10	5.917	-5.917	W5E2	10	5.917	5.917	W7E1	#12	7
7	10	5.917	5.917	W6E2	10	-5.917	5.917	W8E1	#12	7
8	10	-5.917	5.917	W7E2	10	-5.917	-5.917	W5E1	#12	7

Fig 14—*EZNEC* Wires spreadsheet showing the coordinates used for the quad in Fig 13. Note how the x-axis describes the position of an element on the 10-foot boom and also is the axis of symmetry for each element. The values for the z-axis and y-axis vary above and below the axis of symmetry.

sequence. The most obvious example in this particular model is that you should group all the wires associated with a particular element together—for example, the four wires associated with the reflector should be in one place. In Fig 14 you can see that all four wires with an x-coordinate of zero represent the reflector.

It's best to follow a convention in entering wires in a loop structure in a logical fashion. The idea to connect the end point of one wire to the starting point of the next wire. For example, in Fig 13 you can see that the left-hand end of Wire 1 is connected to the bottom of Wire 2, and that the top of Wire 2 connects to the left-hand end of Wire 3. In turn, Wire 3 connects to the top of Wire 4, whose bottom end connects to the right-hand end of Wire 1. The pattern is known as "going around the horn" meaning that the connections proceed smoothly in one direction, in this case in a clockwise direction.

You can see that the entry for the wires making up the elements in the 5-element Yagi in Fig 11B also proceeded in an orderly fashion by starting with the reflector, then the driven element, then director 1, then director 2 and finally director 3. This doesn't mean that you couldn't mix things up, say by specifying the driven element first, followed by director 3, and then the reflector, or whatever. But it's a pretty good bet that doing so in this quasi-random fashion will result in some confusion later on when you revisit a model, or when you let another person see your model.

THE MODELING ENVIRONMENT

The Ground

Above, when considering the 135-foot dipole mounted 50 feet above flat earth, we briefly mentioned the most important environmental item in an antenna model—the ground beneath it. Let's examine some of the options available in the *NEC-2* environment in *EZNEC*:

- Free space
- Perfect ground
- *MININEC* type ground
- "Fast" type ground
- Sommerfeld-Norton ground.

The free space environment option is pretty self-explanatory—the antenna model is placed in free space away from the influence of any type of ground. This option is useful when you wish to optimize certain characteristics of a particular antenna design. For example, you might wish to optimize the front-to-rear ratio of a Yagi over an entire amateur band and this might entail many calculation runs. The free-space ground will run the fastest among all the ground options.

Perfect ground is useful as a reference case, especially for vertically polarized antennas over real ground. Antenna evaluations over perfect ground are shown in most classical antenna textbooks, so it is useful to compare models for simple antennas over perfect ground to those textbook cases.

MININEC type ground is useful when modeling vertical wires, or horizontal wires that are higher than 0.2 λ above ground. A *MININEC* type ground will compute faster than either a "Fast" ground or a Sommerfeld-Norton type of ground because it assumes that the ground under the antenna is perfect, while still taking into account the far-field reflections for ground using user-specified values of ground conductivity and dielectric constant. The fact that the ground under the antenna is perfect allows the *NEC-2* user of a *MININEC* type ground to specify wires that touch (but don't go below) the ground surface, something that only users of the advanced *NEC-4* program can do with the more accurate Sommerfeld-Norton type of ground described below. (*NEC-4* is presently not in the public domain and is strictly restricted and licensed by the US government.) The ability to model grounded wires is useful with vertical antennas. The modeler must be wary of the feed-point source impedances reported for either horizontally or vertically polarized wires because of the perfect-ground assumption inherent in a *MININEC*-type ground.

The "fast" type of ground is a hybrid type of ground that makes certain simplifying assumptions that allow it to be used provided that horizontal wires are higher than about 0.1 λ above ground. With today's fast computers the Sommerfeld-Norton model is preferred.

The Sommerfeld-Norton ground (referred to in *EZNEC* as the "high accuracy" ground) is preferable to the other ground types because it has essentially no practical limitations for wire height. It has the disadvantage that it can run about four times slower than a *MININEC* type of ground, but today's fast computers make that almost a non-issue. Again, *NEC-2*-based programs cannot model wires that penetrate into the ground (although there are work-arounds described below).

As mentioned above, for any type of ground other than perfect ground or free space, the user must specify the conductivity and dielectric constant of the soil. *EZNEC* allows the entry by several user-friendly categories, where σ is conductivity in Siemens/meter and ε is dielectric constant:

- Extremely poor: cities, high buildings (σ = 0.001, ε = 3)
- Very Poor: cities, industrial (σ = 0.001, ε = 5)
- Sandy, dry (σ = 0.002, ε = 10)
- Poor: rocky, mountainous (σ = 0.002, ε = 13)
- Average: pastoral, heavy clay (σ = 0.005, ε = 13)
- Pastoral: medium hills and forestation (σ = 0.006, ε = 13)
- Flat, marshy, densely wooded (σ = 0.0075, ε = 12)
- Pastoral, rich soil, US Midwest (σ = 0.010, ε = 14)
- Very Good: pastoral, rich, central US (σ = 0.0303, ε = 20)
- Fresh water (σ = 0.001, ε = 80)
- Saltwater (σ = 5, ε = 80)

Let's use *EZNEC*'s ability to overlay one or more plots together on one graph to compare the response of the vertical ground plane antenna in Fig 9 for two different types of ground: Saltwater and Poor. Open the **Ch4-GP.EZ** file in *EZNEC*. Click the **Ground Descrip** button and then right-click anywhere in the Media window that opens up. Choose first the "Poor: rocky, mountainous" option button, click **OK** and then **FF Plot**. When the elevation plot appears, click the **File** menu at the top of the main window, and then **Save As**. Choose an appropriate name for the trace, perhaps "Poor Gnd.PF."

Go back and select saltwater as your **Ground Descrip** and follow the same procedure to compute the far-field plot for saltwater ground. Now, add the Poor Gnd.PF trace, by clicking menu selection **File**, **Add Trace**. **Fig 15** shows this comparison, which greatly favors the saltwater environment, particularly at low elevation angles. At 5° the ground plane mounted over saltwater has about a 10 dB advantage compared to its landlocked cousin.

You might be wondering what happens if we move the ground-plane antenna down closer to the ground. The lower limit to how far the radials can approach the lossy earth is 0.001 λ or twice the diameter of the radial wire. A distance of 0.001 λ at 1.8 MHz is about 6 inches, while it is 0.4 inches at 30 MHz. While *NEC-2*-based programs cannot model wires that penetrate the ground, radial systems just above the ground with more than about eight radial wires can provide a work-around to simulate a direct-ground connection.

Modeling Environment: Frequency

It's always a good idea to evaluate an antenna over a *range of frequencies*, rather than simply at a single spot frequency. Trends that become quite apparent on a frequency sweep are frequently lost when looking simply at a single frequency. Native *NEC-2* has built-in frequency sweep capabilities, but once again the commercial programs make the process easier to use and understand. You saw in the SWR curve in Fig 2 the result of one such frequency sweep using *EZNEC*. **Fig 16** shows a frequency sweep of the azimuth response for the 5-element Yagi in Fig 11 across the 20-meter band, using steps of 117 kHz so there are four evaluation frequencies. At 14.0 MHz this Yagi's gain is down a small amount compared to the gain at 14.351 MHz but the rearward pattern is noticeably degraded, dropping to a front-to-back ratio of just under 20 dB.

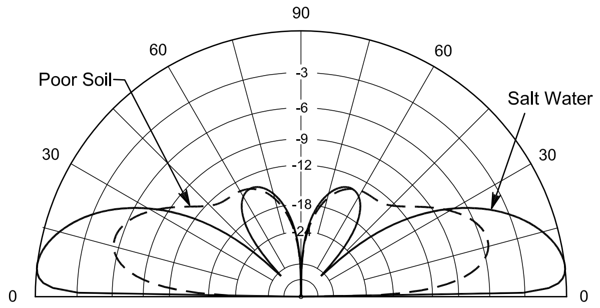

Fig 15—A comparison of the elevation response for the vertical ground plane in Fig 9 over saltwater and over "poor: rocky, mountainous" soil. Saltwater works wonders for verticals, providing excellent low-angle signals.

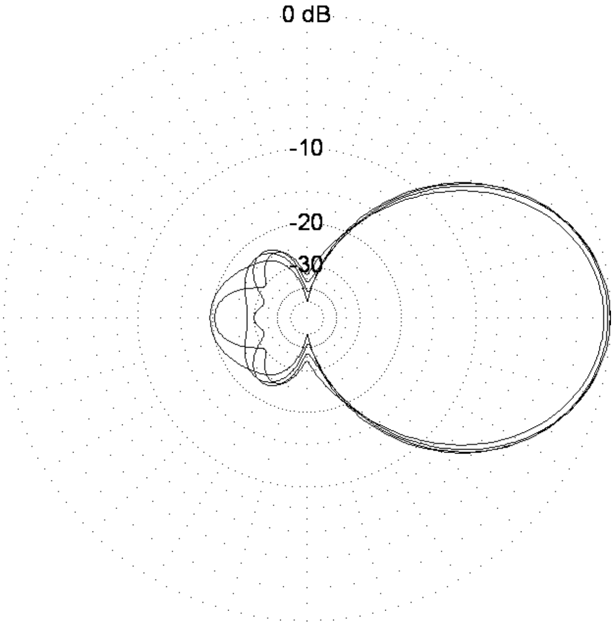

Fig 16—Frequency sweep of 5-element Yagi described in Fig 11, showing how the azimuth pattern changes with frequency.

EZNEC can save to a series of output plot files a frequency sweep of elevation (or azimuth) patterns. In essence, this automates the process described above for saving a plot to disk and then overlaying it on another plot. *EZNEC* can save to a text file for later analysis (or perhaps importation into a spreadsheet) the following parameters, chosen by the user:

- Source data
- Load data
- Pattern data
- Current data
- MicroSmith numeric data
- Pattern analysis summary.

Frequency Scaling

EZNEC has a very useful feature that allows you to create new models *scaled* to a new frequency. You invoke the algorithm used to scale a model from one frequency to another by checking the **Rescale** box after you've clicked the **Frequency** button. *EZNEC* will scale all model dimensions (wire length, height and diameter) except for one specific situation—the wire diameter will stay the same at the new frequency if you originally specified wire size by AWG gauge. For example, #14 copper wire for a half-wave 80-meter dipole will stay #14 copper wire for a 20-meter half-wave dipole. If, however, you specified diameter as a floating point number originally, the diameter will be scaled by the ratio of new to old frequency, along with wire length and height.

Start up *EZNEC* and open up the file **Ch4-520-40W.EZ** for the 5-element 20-meter Yagi on a 40-foot boom. Click the **Frequency** box and then check the **Rescale** check box. Now, type in the frequency of 28.4 MHz and click **OK**. You have quickly and easily created a new 5-element 10-meter Yagi, that is mounted 29.9949 feet high, the exact ratio of 28.4 MHz to 14.1739 MHz, the original design frequency on 20 meters. Click the **FF Plot** button to plot the azimuth pattern for this new Yagi. You will see that it closely duplicates the performance of its 20-meter brother. Click **Src Dat** to see that the source impedance is 25.38 – *j* 22.19 Ω, again very close to the source data for the 20-meter version.

REVISITING SOURCE SPECIFICATION

Sensitivity to Source Placement

Earlier, we briefly described how to specify a source on a particular segment using *EZNEC*. The sources for the relatively simple dipole, Yagi and quad models investigated so far have been in the center of an easy-to-visualize wire. The placement for the source on the vertical ground plane was at the bottom of the vertical radiator, an eminently logical place. In the other cases we specified the position of the source at 50% of the distance along a wire, given that the wire being fed had an odd number of segments. Please note that in each case so far, the feed point (source) has been placed at a relatively low-impedance point, where the current changes relatively slowly from segment to segment.

Now we're going to examine some subtler source-placement problems. *NEC-2* is well-known as being very sensitive to source placement. Significant errors can result from a haphazard choice of the source segment and the segments surrounding it.

Let's return to the inverted-V dipole in Fig 5. The first time we evaluated this antenna (**Ch4-Inverted V Dipole.EZ**) we specified a split source in *EZNEC*. This function uses two sources, one on each of the segments immediately adjacent to the junction of the two downward slanting wires.

Another common method to create a source at the junction of two wires that meet at an angle is to separate these two slanted wires by a short distance and bridge that gap with a short straight wire, which is fed at its center. **Fig 17** shows a close-up of this scheme. In Fig 17 the length of the segments surrounding the short middle wire are purposely made equal to the length of the middle wire. The segmentation for the short middle wire is set to one. **Table 3** lists the source impedance and the maximum gain the *EZNEC* computes for three different models:

1. **Ch4-Inverted V Dipole.EZ** (the original model)
2. **Ch4-Inverted V Dipole Triple Segmentation.EZ**
3. **Ch4-Modified Inverted V Dipole.EZ** (as shown in Fig 17, for the middle wire set to be 2 feet long)
4. **Ch4-Mod Inverted V Poor Segmentation.EZ** (where the number of segments on the two slanted wires have been increased to 200)

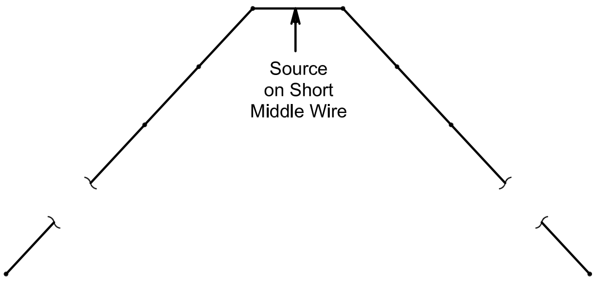

Fig 17—Model of inverted-V dipole using a short center wire on which the source is placed.

Table 3
135-Foot Inverted-V Dipole at 3.75 MHz

Case	*Segments*	*Source Impedance Ω*	*Max. Gain dBi*
1	82	72.64 + *j* 128.2	4.82
2	246	73.19 + *j* 128.9	4.82
3	67	73.06 + *j* 129.1	4.85
4	401	76.21 + *j* 135.2	4.67

Case 2 shows the effect of tripling the number of segments in Case 1. This is a check on the segmentation, to see that the results are stable at a lower level compared to a higher level of segmentation (which theoretically is better, although slower in computation). We purposely set up Case 4 so that the lengths of the segments on either side of the single-segment middle wire are significantly different (0.33 feet) compared to the 2-foot length of the middle wire.

The feed-point and gain figures for the first three models are close to each other. But you can see that the figures for the fourth model are beginning to diverge from the first three, with about a 5% overall change in the reactance and resistance compared to the average values, and about a 3% change in the maximum gain. This illustrates that it is best to keep the segments surrounding the source equal or at least close to equal in length. We'll soon examine a figure of merit called the *Average Gain* test, but it bears mentioning here that the average gain test is very close for the first three models and begins to diverge for the fourth model.

Things get more interesting if the source is placed at a high-impedance point on an antenna—for example, in the center of a full-wave dipole—the value computed for the source impedance will be high, and things will be quite sensitive to the segment lengths. We'll repeat the computations for the same inverted-V models, but this time at twice the operating frequency, at 7.5 MHz.

Table 4 summarizes the results. The impedance is high, as expected. Note that the resistance term varies quite a bit for all four models, a range of about 23% around the average value. Interestingly, the poorly segmented model's resistance falls in between the other three. The reactive terms are closer for all four models but still cover a range of 4% around the average value. The maximum gain shows the same tendancy to be somewhat lower in the fourth model compared to the first three and thus looks as potentially untrustworthy at 7.5 MHz as it does at 3.75 MHz.

This is, of course, but a small sampling of segmentation schemes, and caution dictates that you shouldn't take these results as being representative of all possibilities. Nevertheless, the lesson to be learned here is that the feed-point (source) impedance can vary significantly at a point where the current is changing rapidly, as it does where a high impedance feed is involved. Another general conclusion that can be drawn from Table 5 is that more segments, particularly if they surround the source segment improperly, is not necessarily better.

Table 4
135-Foot Inverted-V Dipole at 7.5 MHz

Case	*Segments*	*Source Impedance Ω*	*Max. Gain dBi*
1	82	2297 – *j* 2668	5.67
2	246	1822 – *j* 2553	5.66
3	67	1960 – *j* 2583	5.66
4	401	2031 – *j* 2688	5.48

Voltage and Current Sources

Before we leave the topic of sources, you should be aware that programs like *EZNEC* and others have the ability to simulate both voltage sources and current sources. Although native *NEC-2* has several source types, voltage sources are the most commonly used by hams. Native *NEC-2* doesn't have a current source, but a current source is nothing more than a voltage source delivering current through a high impedance. Basic network theory says that every Thevenin voltage source has a Norton current source equivalent. Various commercial implementations of *NEC-2* approach the creation of a current source in slightly different fashions. Some use a high value of inductive reactance as a series impedance, while others use a high value of series resistance.

Why would we want to use a current source instead of a voltage source in a model? The general-purpose answer is that models containing a single source at a single feed point can use a voltage source with no problems. Models that employ multiple sources, usually with different amplitudes and different phase shifts, do best with current sources.

For example, *phased arrays* feed RF currents at different amplitudes and phase shifts into two or more elements. The impedances seen at each element may be very different—some impedances might even have negative values of resistance, indicating that power is flowing out of that element into the feed system due to mutual coupling to other elements. Having the ability to specify the amplitude and phase of the current, rather than a feed voltage, at a feed point in a program like *EZNEC* is a valuable tool.

Next, we examine one more important aspect of building a model, setting up loads. After that, we'll look into two tests for the potential accuracy of a model. These tests can help identify source placement, as well as other problems.

LOADS

Many ham antennas, in particular electrically short ones, employ some sort of *loading* to resonate the system. Sometimes loading takes the form of *capacitance hats*, but these can and should be modeled as wires connected to the top of a vertical radiator. A capacitance hat is not the type of loading we'll explore in this section.

Here, the term *loads* refers to discrete inductances, capacitances and resistances that are placed at some point (or points) in an antenna system to achieve certain effects. One fairly common form of a load is a *loading coil* used to resonate an electrically short antenna. Another form of load often seen in ham antennas is a *trap*. *EZNEC* has a special built-in function to evaluate parallel-resonant traps, even at different frequencies beyond their main parallel resonance.

Just for reference, a more subtle type of load is a *distributed* material load. We encountered just such a load in our first model antenna, the 135-foot long flattop dipole—although we didn't identify it specifically as a load at that time. Instead, it was identified as a "wire loss" associated with copper.

The *NEC-2* core program has the capability of simulating a number of built-in loads, including distributed material and discrete loads. *EZNEC* implements the following discrete loads:

- Series R ± *j* X loads.
- Series R-L-C loads, specified in Ω of resistance, µH of inductance and pF of capacitance.
- Parallel R-L-C loads, specified in Ω of resistance, µH of inductance and pF of capacitance.
- Trap loads, specified in Ω of resistance in series with µH of inductance, shunted by pF of capacitance, at a specific frequency.
- Laplace loads, specified as mathematical Laplace coefficients (sometimes used in older modeling programs and left in *EZNEC* for backwards compatibility).

It is important to recognize that the discrete loads in an antenna modeling program *do not radiate* and they have zero size. The *NEC-2* discrete loads are described by L. B. Cebik in his antenna modeling course as being *mathematical loads*. The fact that *NEC-2* loads do not radiate means that the popular mobile antennas that use helical loading coils wound over a length of fiberglass whip cannot be modeled with *NEC-2*, because such coils do radiate.

Let's say that we want to put a air-wound loading coil with an unloaded Q of 400 at the center of a 40-foot long, 50-foot high, flattop dipole so that it is resonant at 7.1 MHz. The schematic of this antenna is shown in **Fig 18**. Examine the modeling file **Ch4-Loaded Dipole.EZ** to see how a discrete series RL load is used to resonate this short dipole at 7.1 MHz, with a feed-point (source) impedance of 25.3 Ω. This requires a series resistance of 1.854 Ω and an inductive reactance of +741.5 Ω. Note that we again used a single wire to model this antenna, and that we placed the load at a point 50% along the length of the wire.

This load represents a 16.62 µH coil with an unloaded Q of 741.5/1.854 = 400, just what we wanted. Let's assume for now that we use a perfect transformer to transform the 25.3-Ω source impedance to 50 Ω. If we now attempt to run a frequency sweep over the whole 40-meter band from 7.0 to 7.3 MHz, the load reactance and resistance will not change, since we specified fixed values for reactance and resistance. Hence, the source impedance will be correct only at the frequency where the reactance and resistance are specified, since the reactance changes with frequency.

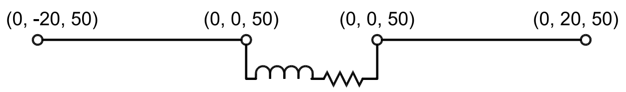

Fig 18—Schematic diagram of a 40-foot long flattop dipole with a loading coil placed at the center. This coil has an unloaded Q of 400 at 7.1 MHz.

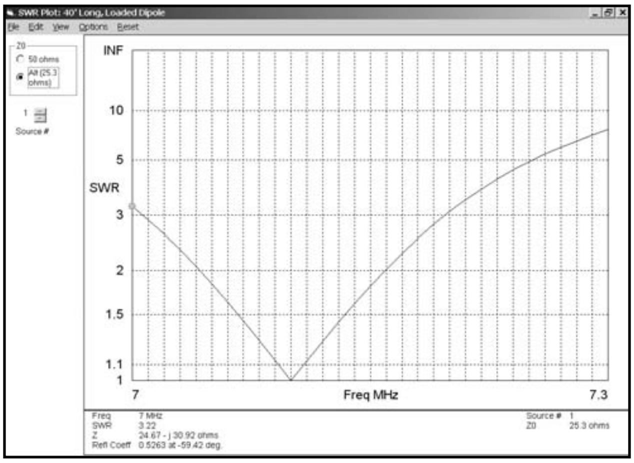

```
Freq       7 MHz                                  Source #   1
SWR        3.22                                   Z0         25.3 ohms
Z          24.67 - j 30.92 ohms
Refl Coeff 0.5263 at -59.42 deg.
```

Fig 19—SWR graph of the loaded 40-foot long flattop dipole shown in Fig 18.

So let's use another load capability and substitute a 16.62 µH coil with a series 1.854-Ω resistance at 7.1 MHz. We'll let *EZNEC* take care of the details of computing both the reactance and the changing series resistance at various frequencies. The degree that both reactance and series loss resistance of the coil change with frequency may be viewed using the **Load Dat** button from the main *EZNEC* window.

Fig 19 shows the computed SWR curve for a 25.3-Ω **Alt SWR Z0** reference resistance. The 2:1 SWR bandwidth is about 120 kHz. As could be expected, the antenna has a rather narrow bandwidth because it is electrically short.

ACCURACY TESTS

There are two tests that can help identify accuracy problems in a model:

- The Convergence test.
- The Average Gain test.

Convergence Test

The idea behind the *Convergence* test is simple: If you increase the segmentation in a particular model and the results changes more than you'd like, then you increase the segmentation until the computations converge to a level that is suitable to you. This process has the potential for being subjective, but simple antenna models do converge quickly. In this section, we'll review several more of the antennas discussed previously to see how they converge.

Let's go back to the simple dipole in Fig 3. The original segmentation was 11 segments, but we'll start with a very low value of segmentation of three, well below the minimum recommended level. **Table 5** shows how the source impedance and gain change with increase in segmentation at 3.75 MHz. For this simple antenna, the gain levels off at 6.50 dBi by the time the segmentation has reached 11 segments. Going to ten times the minimum-recommended level (to 111 segments) results in an increase of only 0.01 dBi in the gain.

Arguably, the impedance has also stabilized by the time we reach a segmentation level of 11 segments, although purists may opt for 23 segments. The tradeoff is a slowdown in computational speed.

Let's see how the 5-element Yagi model converges with changes in segmentation level. **Table 6** shows how the source impedance, gain, 180° front-to-back ratio and worst-case front-to-rear ratio change with segmentation density. By the time the segmentation has reached 11 segments per wire, the impedance and gain have stabilized quite nicely, as has the F/R. The 180° F/B is still increasing with segmentation level until about 25 segments, but a relatively small shift in frequency will change the maximum F/B level greatly. For example, with 11 segments per wire, shifting the frequency to 14.1 MHz—a shift of only 0.5%— will change the maximum 180° F/B from almost 50 dB down to 27 dB. For this reason the F/R is considered a more reliable indicator of the adequacy of the segmentation level than is F/B.

Average Gain Test

The theory behind the *Average Gain* test is a little more involved. Basically, if you remove all intentional losses in a model, and if you place the antenna either in free space or over perfect ground, then all the power fed to the antenna should be radiated by it. Internally, the program runs a full 3-D analysis, adding up the power in all directions and then dividing that sum by the total power fed to the antenna. Since *NEC-2* is very sensitive about source placement, as mentioned before, the Average Gain test is a good indicator that something is wrong with the specification of the source.

Various commercial versions of *NEC-2* handle the Average Gain test in different ways. *EZNEC* requires the operator to turn off all distributed losses in wires or set to zero any discrete resistive losses in loads. Next you set the ground environment to free space (or perfect ground) and request a 3-D pattern plot. *EZNEC* will then report the average gain, which will be 1.000 if the model has no problems. The average gain can be lower or higher than 1.000, but if it falls within the range 0.95 to 1.05 it is usually considered adequate.

Table 5

135-Foot Flattop Dipole at 3.75 MHz

Segments	*Source Impedance Ω*	*Max. Gain dBi*
3	85.9 + *j* 128.0	6.34
5	86.3 + *j* 128.3	6.45
7	86.8 + *j* 128.8	6.48
11	87.9 + *j* 129.5	6.50
23	88.5 + *j* 130.3	6.51
45	89.0 + *j* 130.8	6.51
101	89.4 + *j* 131.1	6.51

Table 6

5-element Wire Yagi at 14.1739 MHz

Segments	*Source Impedance Ω*	*Max. Gain dBi*	*180° F/B dB*	*F/R dB*
3	28.5 – *j* 30.6	12.79	23.2	22.4
5	26.3 – *j* 25.6	13.02	30.5	23.1
7	25.6 – *j* 24.0	13.07	34.8	23.1
11	25.1 – *j* 22.9	13.09	39.9	23.1
25	24.9 – *j* 22.0	13.10	43.7	23.1
99	24.7 – *j* 21.5	13.10	44.2	23.1

As L. B. Cebik, W4RNL, stated in his ARRL Certification and Continuing Education Course on antenna modeling: "Like the convergence test, the average gain test is a necessary but not a sufficient condition of model reliability." Pass both tests, however, and you can be pretty well sure that your model represents reality. Pass only one test, and you have reason to worry about how well your model represents reality.

Once again, open the model file **Ch4-Mod Inverted V Poor Segmentation.EZ** and set **Wire Loss** to zero, **Ground Type** to Free Space and **Plot Type** to 3-Dimensional. Click on the **FF Plot** button. *EZNEC* will report that the Average Gain is 0.955 = –0.2 dB. This is very close to the lower limit of 0.95 considered valid for excellent accuracy. This is a direct result of forcing the segment lengths adjacent to the source segment to be considerably shorter than the source segment's length. The gain reported using this test would be approximately –0.2 dB from what it should be—just what Table 4 alludes to also.

Now, let's revisit the basic model **Ch4-Inverted V Dipole.EZ** and look at Case 2 in Table 4. Case 2 amounts to a Convergence test for the basic inverted-V model. Since the impedance and gain changes were small comparing the basic model to the one using three times the number of segments, the model passed the Convergence test. The Average Gain test for the basic model yields a value of 0.991, well within the limits for good accuracy. This model has thus passed both tests and can be considered accurate.

Running the Average Gain test for the 5-element Yagi (using 11 segments per wire and whose convergence we examined in Table 6) yields a value of 0.996, again well within the bounds indicating a good model. And the simple flattop dipole with 11 segments at 3.75 MHz yields an Average Gain result of 0.997, again indicating a very accurate model.

OTHER POSSIBLE MODEL LIMITATIONS

Programs based on the *NEC-2* core computational code have several well-documented limitations that you should know about. Some limitations have been removed in the restricted-access *NEC-4* core (which is not generally available to users), but other limitations still exist, even in *NEC-4*.

Closely Spaced Wires

If wires are spaced too close to each other, the *NEC-2* core can run into problems. If the segments are not carefully aligned, there also can be problems with accuracy. The worst-case situation is where two wires are so close together that their volumes actually merge into each other. This can happen where wires are thick, parallel to each other and close together. You should keep parallel wires separated by at least several diameters.

For example, #14 wire is 0.064 inches in diameter. The rule then is to keep parallel #14 wires separated by more than 2 × 0.064 = 0.128 inches. And you should run the Convergence test to assure yourself that the solution is indeed converging when you have closely spaced wires, especially if the two wires have different diameters. To model antennas containing closely spaced wires, very often you will need many more segments than usual and you must also carefully ensure that the segments line up with each other.

Things can get a little more tricky when wires cross over or under each other, simply because such crossings are sometimes difficult to visualize. Again, the rule is to keep crossing wires separated by more than two diameters from each other. And if you intend to join two wires together, make sure you do so at the ends of the two wires, using identical end coordinates. When any or all of these rules are violated, the Convergence and Average Gain tests will usually warn you of potential inaccuracies.

Parallel-Wire Transmission Lines and LPDAs

A common example of problems with closely spaced wires is when someone attempts to model a parallel-wire transmission line. *NEC-2*-based programs usually do not work as well in such situations as do *MININEC*-based programs. The problems are compounded if the diameters are different for the two wires simulating a parallel-wire transmission line. In *NEC-2* programs, it is usually better to use the built-in "perfect transmission line" function than to try to model closely spaced parallel wires as a transmission line.

For example, a Log Periodic Dipole Array (LPDA) is composed of a series of elements fed using a transmission line that reverses the phase 180° at each element. In other words, the elements are connected to a transmission line that reverses connections left-to-right at each element. It is cumbersome to do so, but you could model such a transmission line using separate wires in *EZNEC*, but it is a potentially confusing and a definitely painstaking process. Further, the accuracy of the resulting model is usually suspect, as shown by the Average Gain test.

It is far easier to use the **Trans Lines** function from the *EZNEC* main window to accurately model an LPDA. See **Fig 20**, which shows the **Trans Lines** window for the **9302A.EZ** 16-element LPDA. There are 15 transmission lines connecting the 16 elements, placed at the 50% point on each element, with a 200-Ω characteristic impedance and with Reversed connections.

Fat Wires Connected to Skinny Wires

Another inherent limitation in the *NEC-2* computational core shows up when modeling several popular ham-radio antennas: many Yagis and some quads.

Tapered Elements

As mentioned before, many Yagis are built using telescoping aluminum tubing. This technique saves weight and makes for a more flexible and usually stronger element, one that can survive wind and ice loading better than a "monotaper" element design. Many vertical antennas are also constructed using telescoping aluminum tubing.

Unfortunately, native *NEC-2* doesn't model accurately such *tapered elements*, as they are commonly called. There is, however, a sophisticated and accurate work-around for such elements, called the *Leeson corrections*. The Leeson corrections, derived by Dave Leeson, W6NL, from pioneering work by Schelkunoff at Bell Labs, compute the diameter and length of an element that is electrically equivalent to a tapered element. This monotaper element is much easier to use in a pro-

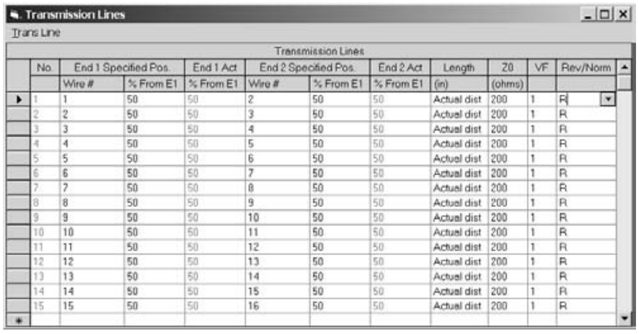

Transmission Lines

No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(in)	(ohms)		
1	1	50	50	2	50	50	Actual dist	200	1	R
2	2	50	50	3	50	50	Actual dist	200	1	R
3	3	50	50	4	50	50	Actual dist	200	1	R
4	4	50	50	5	50	50	Actual dist	200	1	R
5	5	50	50	6	50	50	Actual dist	200	1	R
6	6	50	50	7	50	50	Actual dist	200	1	R
7	7	50	50	8	50	50	Actual dist	200	1	R
8	8	50	50	9	50	50	Actual dist	200	1	R
9	9	50	50	10	50	50	Actual dist	200	1	R
10	10	50	50	11	50	50	Actual dist	200	1	R
11	11	50	50	12	50	50	Actual dist	200	1	R
12	12	50	50	13	50	50	Actual dist	200	1	R
13	13	50	50	14	50	50	Actual dist	200	1	R
14	14	50	50	15	50	50	Actual dist	200	1	R
15	15	50	50	16	50	50	Actual dist	200	1	R

Fig 20—Transmission-line window for the 9302A.EZ 16-element LPDA. Note that the transmission lines going between elements are "reversed," meaning that they are 180° out-of-phase at each element, a requirement for properly feeding an LPDA.

Table 7

5-element Yagi at 14.1739 MHz with Telescoping Aluminum Elements

	With Leeson Corrections			Without Leeson Corrections		
Freq. MHz	*Source Impedance Ω*	*Gain dBi*	*F/R dB*	*Source Impedance Ω*	*Gain dBi*	*F/R dB*
14.0	23.2 – *j* 26.5	14.82	23.3	22.4 – *j* 12.7	14.92	23.1
14.1	22.7 – *j* 20.5	14.87	22.8	18.6 – *j* 12.5	14.70	21.6
14.2	22.8 – *j* 14.8	14.87	22.7	6.6 – *j* 4.6	14.01	16.2
14.3	22.5 – *j* 11.9	14.76	21.5	1.9 + *j* 10.6	10.61	3.1
14.4	14.5 – *j* 10.5	14.45	19.9	1.6 + *j* 23.7	11.15	–11.4

gram like *NEC-2*. See Chapter 2, Antenna Fundamentals, for more information on the Leeson corrections.

EZNEC and other *NEC-2* programs can automatically invoke the Leeson corrections, providing that some basic conditions are met—and happily, these conditions are true for the telescoping aluminum-tubing elements commonly used as Yagi elements. *EZNEC* gives you the ability to disable or enable Leeson corrections, under the **Option** menu, under **Stepped Diameter Correction**, *EZNEC*'s name for the Leeson corrections. Open the modeling file **520-40H.EZ**, which contains tapered aluminum tubing elements and compare the results using and without using the Leeson corrections.

Table 7 lists the differences over the 20-meter band, with the 5-element Yagi at a height of 70 feet above flat ground. You can see that the non-Leeson corrected figures are very different from the corrected ones. At 14.3 MHz, the pattern for the non-corrected Yagi has degenerated to a F/R of 3.1 db, while at 14.4 MHz, just outside the top of the Amateur band, the pattern for the non-corrected antenna actually has reversed. Even at 14.2 MHz, the non-corrected antenna shows a low source impedance, while the corrected version exhibits smooth variations in gain, F/R and impedance across the whole band, just as the actual antenna exhibits.

Some Quads

Some types of cubical quads are made using a combination of aluminum tubing and wire elements, particularly in Europe where the "Swiss" quad has a wide following. Again, *NEC-2*-based programs don't handle such tubing/wire elements well. It is best to avoid modeling this type of antenna, although there are some ways to attempt to get around the limitations, ways that are beyond the scope of this chapter.

NEAR-FIELD OUTPUTS

FCC regulations set limits on the maximum permissible exposure (MPE) allowed from the operation of radio transmitters. These limits are expressed in terms of the electric (V/m) and magnetic fields (A/m) close to an antenna. *NEC-2*-based programs can compute the electric and magnetic *near fields* and the FCC accepts such computations to demonstrate that an installation meets their regulatory requirements. See Chapter 1, Safety, in this book.

Table 8

E- and H-Field Intensities for 1500 W into 5-Element Yagi at 70 Feet on 14.2 MHz

Height Feet	*H-Field (A/m)*	*E-Field (V/m)*
0	0.04	4.1
10	0.03	13.8
20	0.04	20.6
30	0.06	22.6
40	0.08	25.8
50	0.10	33.8
60	0.12	41.5
70	0.12	44.3

We'll continue to use the 5-element Yagi at 70 feet to demonstrate a near-field computation. Open **Ch4-520-40H.EZ** in *EZNEC* and choose **Setups** and then **Near Field** from the menu at the top of the main window. Let's calculate the E-field and H-field intensity for a power level of 1500 W (chosen using the **Options**, **Power Level** choices from the main menu) in the main beam at a fixed distance, say 50 feet, from the tower base. We'll do this at various heights, using 10-foot increments of height, in order to see the lobe structure of the Yagi at 70 feet height.

Table 8 summarizes the total H- and E-field intensities as a function of height. As you might expect, the fields are strongest directly in line with the antenna at a height of 70 feet. At ground level, the total fields are well within the FCC limits for rf exposure for both fields. In fact, the fields are within the FCC limits if someone were to stand at the tower base, directly under the antenna.

ANTENNA MODELING SUMMARY

This section on antenna modeling is by necessity only a brief introduction to the science of antenna modeling. The subject is partly art as well as science because there are usually several ways of creating a model for a particular antenna or antennas.

Indeed, the presence of other wires surrounding a particular antenna can affect the performance of that antenna. Finally, there are the practical aspects of putting a actual antenna up in the real world. We'll explore this next.

Practical Aspects, Designing Your Antenna System

The most important time spent in putting together an antenna system is the time spent in planning. In Chapter 3, The Effects of Ground, we outlined the steps needed to evaluate how your local terrain can affect HF communications. There we emphasized that you need to compare the patterns resulting from your own terrain to the statistically relevant elevation angles needed for coverage of various geographic areas. (The elevation-angle statistics were developed in Chapter 23, Radio Wave Propagation and are located on the CD-ROM included with this book, as is the terrain-assessment program *HFTA*.)

The implicit assumptions in Chapter 3 are (1) that you know where you want to talk to, and (2) that you'd like the most effective system possible. At the start of such a theoretical analysis, cost is no object. Practical matters, like cost or the desires of your spouse, can come later! After all, you're just checking out all the possibilities. If nothing else, you will use the methodology in Chapter 3 to evaluate any property you are considering buying so that you can build your "dream station."

Next, in the first part of this chapter we described modeling tools used to evaluate different types of antennas. These modeling tools can help you evaluate what type of antenna might be suitable to your own particular style of operating. Do you want a Yagi with a lot of rejection of received signals from the rear? Let's say that terrain analysis shows that you need an antenna at least 50 feet high. Do you really need a steel tower, or would a simple dipole in the trees serve your communication needs just fine? How about a vertical in your backyard? Would that be inconspicuous enough to suit your neighbors and your own family, yet still get you on the air?

In short, using the techniques and tools we've presented in Chapters 3, 23 and here in Chapter 4, you can scientifically plan an antenna *system* that will be best suited for your own particular conditions. Now, however, you have to get practical. Thinking through and planning the installation can save a lot of time, money and frustration. While no one can tell you the exact steps you should take in developing your own master plan, this section, prepared originally by Chuck Hutchinson, K8CH, should help you with some ideas.

WHAT DO YOU REALLY WANT?

Begin planning by spelling out your communications *desires*. What bands are you interested in? Who (or where) do you want to talk to? When do you operate? How much time and money are you willing to spend on an antenna system? What physical limitations affect your master plan?

From the answers to the above questions, begin to formulate *goals*—short, intermediate and long range. Be realistic about those goals. Remember that there are three station effectiveness factors that are under your control. These are: operator skill, equipment in the shack, and the antenna system. There is no substitute for developing operating skills. Some tradeoffs are possible between shack equipment and antennas. For example, a high-power amplifier can compensate for a less than optimum antenna. By contrast, a better antenna has advantages for receiving as well as for transmitting.

Consider your *limitations*. Are there regulatory restrictions on antennas in your community? Are there any deed restrictions or covenants that apply to your property? Do other factors (finances, family considerations, other interests, and so forth) limit the type or height of antennas that you can erect? All of these factors must be investigated because they play a major role determining the type of antennas you erect.

Chances are that you won't be able to immediately do all you desire. Think about how you can budget your resources over a period of time. Your resources are your money, your time available to work, materials you may have on hand, friends that are willing to help, etc. One way to budget is to concentrate your initial efforts on a given band or two. If your major interest is in chasing DX, you might want to start with a very good antenna for the 14-MHz band. A simple multiband antenna could initially serve for other frequencies. Later you can add better antennas for those other bands.

SITE PLANNING

A map of your property or proposed antenna site can be of great help as you begin to consider alternative antennas. You'll need to know the size and location of buildings, trees and other major objects in the area. Be sure to note compass directions on your map. Graph or quadrille paper (or a simple CAD program) can be very useful for this purpose. See **Fig 21** for an example. It's a good idea to make a few photocopies of your *site map* so you can mark on the copies as you work on your plans.

Use your map to plan antenna layouts and locations of any supporting towers or masts. If your plan calls for more than one tower or mast, think about using them as supports for wire antennas. As you work on a layout, be sure to think in three dimensions even though the map shows only two.

Be sensitive to your neighbors. A 70-foot guyed tower in the front yard of a house in a residential neighborhood is not a good idea (and probably won't comply with local ordinances!). You probably will want to locate that tower in the back yard.

ANALYSIS

Use the information earlier in this chapter and in Chapters 3 and 23 to analyze antenna patterns in both

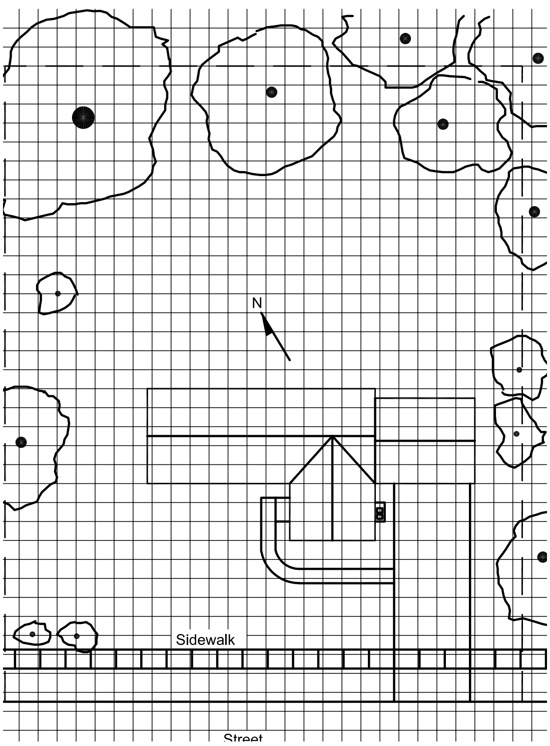

Fig 21—A site map such this one is a useful tool for planning your antenna installation.

horizontal and vertical planes towards geographic areas of interest. If you want to work DX, you'll want antennas that radiate energy at low as well as intermediate angles. An antenna pattern is greatly affected by the presence of ground and by the local topography of the ground. Therefore, be sure to consider what effect ground will have on the antenna pattern at the height you are considering. A 70-foot high antenna is approximately $^1/_2$, 1, 1$^1/_2$ and 2 wavelengths (λ) high on 7, 14, 21 and 28 MHz respectively. Those heights are useful for long-distance communications. The same 70-foot height represents only $\lambda/4$ at 3.5 MHz, however. Most of the radiated energy from a dipole at that height would be concentrated straight up. This condition is not great for long-distance communication, but can still be useful for some DX work and excellent for short-range communications.

Lower heights can be useful for communications. However, it is generally true that "the higher, the better" as far as communications effectiveness is concerned. This general rule of thumb, of course, should be tempered by an exact analysis of your local terrain. Being located at the top of a steep hill can mean that you can use lower tower heights to achieve good coverage.

There may be cases where it is not possible to install low-frequency dipoles at $\lambda/4$ or more above the ground. A vertical antenna with many radials is a good choice for long-distance communications. You may want to install both a dipole and a vertical for the 3.5- or 7-MHz bands. On the 1.8-MHz band, unless extremely tall supports are available, a vertical antenna is likely to be the most useful for DXing. You can then choose the antenna that performs best for a given set of conditions. A low dipole will generally work better for shorter-range communications, while the vertical will generally be the better performer over longer distances.

Consider the azimuthal pattern of fixed antennas. You'll want to orient any fixed antennas to favor the directions of greatest interest to you.

BUILDING THE SYSTEM

When the planning is completed, it is time to begin construction of the antenna system. Chances are that you can divide that construction into a series of *phases* or steps. Say, for example, that you have lots of room and that your long-range plan calls for a pair of towers, one 100-feet high, and the other 70-feet high, to support monoband Yagi antennas. The towers will also support a horizontal 3.5-MHz dipole, for DX work. On your map you've located them so the 80-meter dipole will be broadside to Europe. You decide to build the 70-foot tower with a "triband" beam and 80- and 40-meter inverted-V dipoles to begin the project.

In your master plan you design the guys, anchors and all hardware for the 70-foot tower to support the load of stacked 4-element 10- and 15-meter monobanders Yagis. So you make sure you buy a heavy-duty rotator and the stout mast needed for the monoband antennas later. Thus you avoid having to buy, and then sell, a medium-duty rotator and lighter weight tower equipment later on when you upgrade the station. You could have saved money in the long run by putting up a monoband beam for your favorite band, but you decided that for now it is more important to have a beam on 14, 21 and 28 MHz, so you choose a commercial triband Yagi.

The second step of your plan calls for installing the second tower and stacking a 2-element 40-meter and a 4-element 20-meter monoband Yagi on it. You also plan to replace the tribander on the 70-foot tower with stacked 4-element 10- and 15-meter monoband Yagis. Although this is still a "dream system" you can now apply some of the modeling techniques discussed earlier in this chapter to determine the overall system performance.

Modeling Interactions at Your Dream Station

In this analysis we're going to assume that you have sufficient real estate to separate the 70- and 100-foot towers by 150 feet so that you can easily support an 80-meter dipole between them. We'll also assume that you want the 80-meter dipole to have its maximum response at a heading of 45° into Europe from your location in Newington, Connecticut. The dipole will also have a lobe

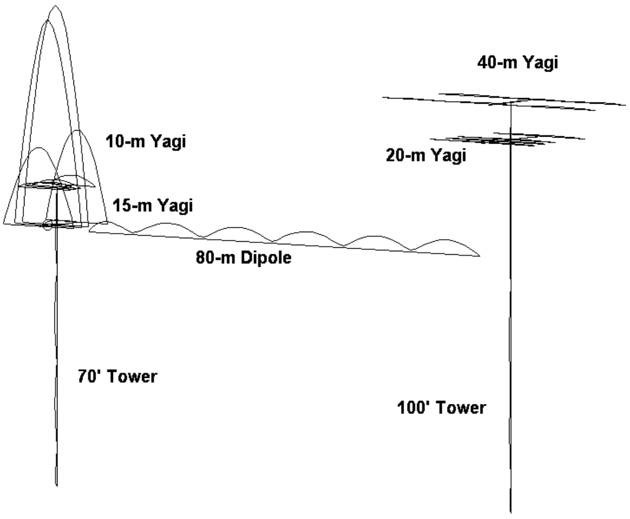

Fig 22—Layout for two-tower antenna system, at 70 and 100 feet high and 150 feet apart. The 70-foot tower has a 4-element 10-meter Yagi at 80 feet on a 10-foot rotating mast and a 4-element 15-meter Yagi at 70 feet. An 80-meter dipole goes from the 70-foot tower to the 100-foot tower, which holds a 2-element 40-meter Yagi at 110 feet and a 4-element 20-meter Yagi at 100 feet. In this figure all the rotatable Yagis are facing the direction of Europe and the currents on the 15-meter Yagi are shown. Note the significant amount of current re-radiated by the nearby 80-meter dipole.

facing 225° towards the USA and New Zealand, making it a good antenna for both domestic contacts and DX work.

Let's examine the interactions that occur between the rotatable Yagis for 10, 15, 20 and 40 meters. See **Fig 22**, which purposely exaggerates the magnitude of the currents on the 4-element 15-meter Yagi mounted at 70 feet. Here, both sets of Yagis have been rotated so that they are pointing into Europe. There is a small amount of current radiated onto the 10-meter antenna but virtually no current is radiated onto the 40- and 20-meter Yagis. This is good.

However, significant current is radiated onto, and then re-radiated, by the 80-meter dipole. This undesired current affects the radiation pattern of the 15-meter antenna, as shown in **Fig 23**, which overlays the pattern of the 4-element 15-meter Yagi by itself with that of the Yagi interacting with the other antennas. You can see "ripples" in the azimuthal response of the 15-meter Yagi due to the effects of the 80-meter dipole's re-radiation. The magnitude of the ripples is about 1 dB at worst, so they don't seriously affect the forward pattern (into Europe), but the rearward lobes are degraded somewhat, to just below 20 dB.

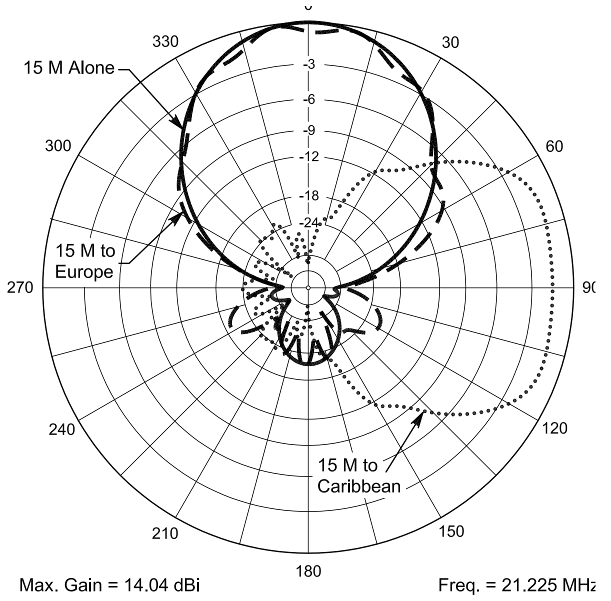

Fig 23—An overlay of azimuth patterns. The solid line is the radiation pattern for the 15-meter Yagi all by itself. The dashed line is the pattern for the 15-meter Yagi, as affected by all the other antennas. The dotted line is the pattern for the 15-meter Yagi when it is pointed toward the Caribbean, with the Yagis on the 100-foot tower pointed toward the 70-foot tower. The peak response of the 15-meter Yagi has dropped by about 1.5 dB.

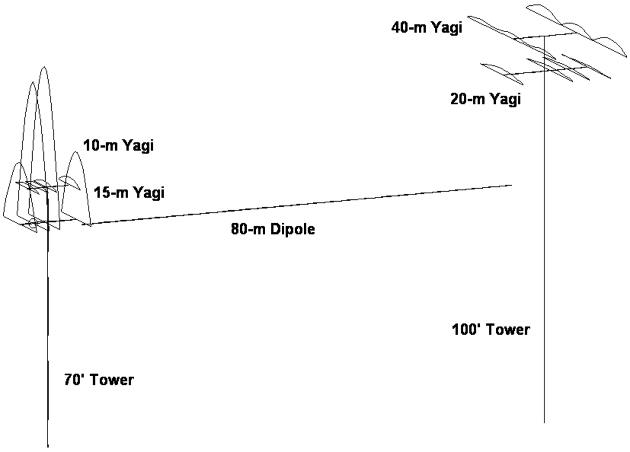

Fig 24—The layout and 15-meter currents when the Yagis on the 100-foot tower are pointed toward the 70-foot tower. The 15-meter Yagi has been rotated to face the direction of the 100-foot tower (toward the Caribbean).

Fig 23 also shows the worst-case situation for the 15-meter Yagi. Here, the 15- and 10-meter stack has been turned clockwise 90°, facing the Caribbean, while the 40- and 20-meter Yagis on the 100-foot tower have been turned counter-clockwise 90° (in the direction of Japan) to face the 70-foot tower holding the 10/15-meter Yagis. You can see the layout and the currents in **Fig 24**. Now the 40- and 20-meter Yagis re-radiate some 15-meter

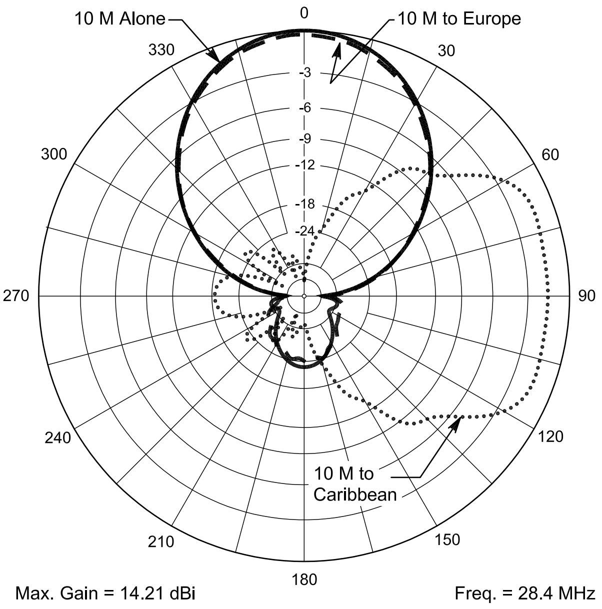

Fig 25—The radiation patterns for the 10-meter Yagi. The solid line is the 10-meter Yagi by itself. The dashed line is for the same Yagi, with all other antenna interactions. The dotted line shows the worst-case pattern, with the stacked Yagis on the 100-foot tower facing the 70-foot tower and the 10-meter Yagi pointed toward the Caribbean. Again, the peak response of the 10-meter Yagi has dropped about 1.5 dB in the worst-case situation.

energy and reduce the maximum gain by about 1.5 dB. Note that in this direction the 80-meter dipole no longer has 15-meter energy radiated onto it by the 15-meter Yagi.

The shape of the patterns will change depending on whether you specify "current" or "voltage" sources in the models for the other antennas, since this effectively opens up or shorts the feed points at the other antennas so far as 15-meter energy is concerned. In practice, this means that the interaction between antennas will vary somewhat depending on the length of the feed lines going to each antenna and whether each feed line is open-circuited or short-circuited when it is not in use.

You can now see that interactions between various antennas pointing in different directions can be significant in a real-world antenna system. In general, higher-frequency antennas are affected by re-radiation from lower-frequency antennas, rather than the other way around. Thus the presence of a 10- or 15-meter stack does not affect the 20-meter Yagi at all.

Modeling can also help determine the minimum stacking distance required between monoband Yagis on the same rotating mast. In this case, stacking the 10- and 15-meter monobanders 10 feet apart holds down interaction between them so that the pattern and gain of the 10-meter Yagi is not impacted adversely. **Fig 25** demonstrates this in the European direction, where the patterns for the 10-meter beam by itself looks very clean compared to the same Yagi separated by 10 feet from the 15-meter Yagi below it. The worst-case situation is pointing towards the Caribbean, when the 40- and 20-meter stack is facing the 70-foot tower. This drops the 10-meter gain down about 1.5 dB from maximum, indicating significant interaction is occurring.

In this situation you might find it best to place the 70-foot tower in the direction closest to the Caribbean if this direction is very important to you. Doing so will, however, cause the pattern in the direction of the Far East to be affected on 10 and 15 meters. You have the modeling tools necessary to evaluate various configurations to achieve whatever is most important to you.

COMPROMISES

Because of limitations, most amateurs are never able to build their dream antenna system. This means that some compromises must be made. Do not, under any circumstances, compromise the *safety* of an antenna installation. Follow the manufacturer's recommendations for tower assembly, installation and accessories. Make sure that all hardware is being used within its ratings.

Guyed towers are frequently used by radio amateurs because they cost less than more complicated unguyed or freestanding towers with similar ratings. Guyed towers are fine for those who can climb, or those with a friend who is willing to climb. But you may want to consider an antenna tower that folds over, or one that cranks up (and down). Some towers crank up (and down) and fold over too. See **Fig 26**. That makes for convenient access to antennas for adjustments and maintenance without climbing. Crank-up towers also offer another advantage. They allow antennas to be lowered during periods of no operation, such as for aesthetic reasons or during periods of high winds.

A well-designed monoband Yagi should outperform a multiband Yagi. In a monoband design the best adjustments can be made for gain, front-to-rear ratio (F/R) and matching, *but only for a single band*. In a multiband design, there are always tradeoffs in these properties for the ability to operate on more than one band. Nevertheless, a multiband antenna has many advantages over two or more single band antennas. A multiband antenna requires less heavy-duty hardware, requires only one feed line, takes up less space and it costs less.

Apartment dwellers face much greater limitations in their choice of antennas. For most, the possibility of a tower is only a dream. (One enterprising ham made arrangements to purchase a top-floor condominium from a developer. The arrangements were made before construction began, and the plans were altered to include a roof-top tower installation.) For apartment and condominium dwellers, the situation is still far from hopeless. A later section presents ideas for consideration.

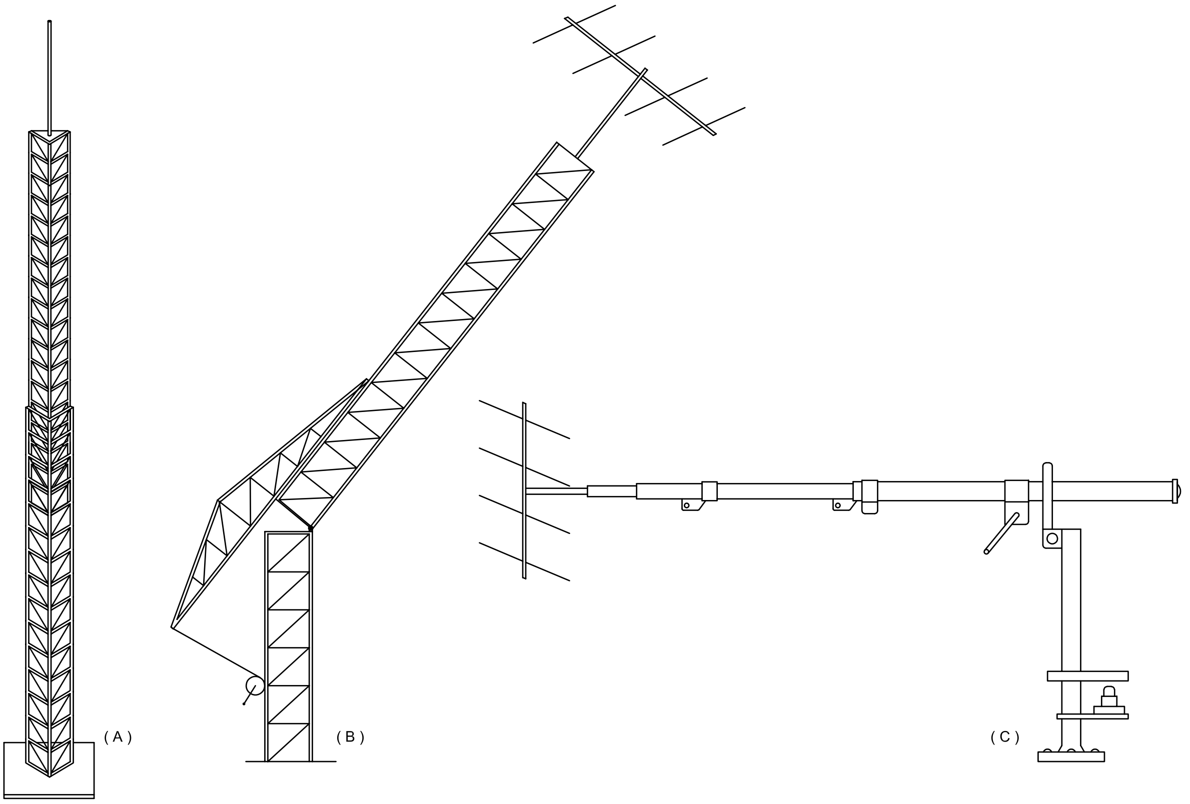

Fig 26—Alternatives to a guyed tower are shown here. At A, the crank-up tower permits working on antennas at reduced height. It also allows antennas to be lowered during periods of no operation. Motor-driven versions are available. The fold-over tower at B and the combination at C permit working on antennas at ground level.

EXAMPLES

You can follow the procedure previously outlined to put together modest or very large antenna systems. What might a ham put together for antennas when he or she wants to try a little of everything, and has a modest budget? Let's suppose that the goals are (1) low cost, (2) no tower, (3) coverage of all HF bands and the repeater portion of one VHF band, and (4) the possibility of working some DX.

After studying the pages of this book, the station owner decides to first put up a 135-foot center-fed antenna. High trees in the back yard will serve as supports to about 50 feet. This antenna will cover all the HF bands by using a balanced feeder and an antenna tuner. It should be good for DX contacts on 10 MHz and above, and will probably work okay for DX contacts on the lower bands. However, her plan calls for a vertical for 3.5 and 7 MHz to enhance the DX possibilities on those bands. For VHF, a chimney-mounted vertical is included.

ANOTHER EXAMPLE

A licensed couple has bigger ambitions. Goals for their station are (1) a good setup for DX on 14, 21 and 28 MHz, (2) moderate cost, (3) one tower, (4) ability to work some DX on 1.8, 3.5 and 7 MHz, and (5) no need to cover the CW portion of the bands.

After considering the options, the couple decides to install a 65-foot guyed tower. A large commercial triband Yagi will be mounted on top of the tower. The center of a trap dipole tuned for the phone portion of the 3.5- and 7-MHz bands will be supported by a wooden yardarm installed at the 60-foot level of the tower, with ends drooping down to form an inverted V. An inverted L for 1.8 MHz starts near ground level and goes up to a similar yardarm on the opposite side of the tower. The horizontal portion of the inverted L runs away from the tower at right angles to the trap dipole. Later, the husband will experiment with sloping antennas for 3.5 MHz. If those experiments are not successful, a $\lambda/4$ vertical will be used on that band.

Apartment Possibilities

A complete and accurate assessment of antenna types, antenna placement and feed-line placement is very important for the apartment dweller. Among the many possibilities for types are balcony antennas, *invisible* ones (made of fine wire), vertical antennas disguised as flag poles or as masts with a TV antenna on top, and indoor antennas.

A number of amateurs have been successful negotiating with the apartment owner or manager for permission to install a short mast on the roof of the building. Coaxial lines and rotator control cables might be routed through conduit troughs or through ductwork. If you live in one of the upper stories of the building, routing the cables over the edge of the roof and in through a window might be the way to go. There is a story about one amateur who owns a triband beam mounted on a 10-foot mast. But even with such a short mast, he is the envy of all his amateur friends because of his superb antenna height. His mast stands on top of a 22-story apartment building.

Usually the challenge is to find ways to install antennas that are unobtrusive. That means searching out antenna locations such as balconies, eaves, nearby trees, etc. For example, a simple but effective balcony antenna is a dangling vertical. Attach a thin wire to the tip of a mobile whip or a length of metal rod or tubing. Then mount the rigid part of the antenna horizontally on the balcony rail, dangling the wire over the edge. The antenna is operated against the balcony railing or other metallic framework. A matching network is usually required at the antenna feed point. Metal in the building will likely give a directivity effect, but this may be of little consequence and perhaps even an advantage. The antenna may be removed and stored when not in use.

Frequently, the task of finding an inconspicuous route for a feed line is more difficult than the antenna installation itself. When Al Francisco, K7NHV, lived in an apartment, he used a tree-mounted vertical antenna. The coax feeder exited his apartment through a window and ran down the wall to the ground. Al buried the section of line that went from under the window to a nearby tree. At the tree, a section of enameled wire was connected to the coax center conductor. He ran the wire up the side of the tree away from foot traffic. A few short radials completed the installation. The antenna worked fine, and was never noticed by the neighbors.

See Chapters 6, Low-Frequency Antennas, and Chapter 15, Portable Antennas, for ideas about low-frequency and portable antennas that might fit into your available space. Your options are limited as much by your imagination and ingenuity as by your pocketbook. Another option for apartment dwellers is to operate away from home. Some hams concentrate on mobile operation as an alternative to a fixed station. It is possible to make a lot of contacts on HF mobile. Some have worked DXCC that way.

Suppose that you like VHF contests. Because of other activities, you are not particularly interested in operating VHF outside the contests. Why not take your equipment and antennas to a hilltop for the contests? Many hams combine a love for camping or hiking with their interest in radio.

Antennas for Limited Space

It is not always practical to erect full-size antennas for the HF bands. Those who live in apartment buildings may be restricted to the use of minuscule radiators because of house rules, or simply because the required space for full-size antennas is unavailable. Other amateurs may desire small antennas for aesthetic reasons, perhaps to keep peace with neighbors who do not share their enthusiasm about high towers and big antennas. There are many reasons why some amateurs prefer to use physically-shortened antennas. This section discusses proven designs and various ways of building and using them effectively. You will find that modeling antennas by computer, even compromised "stealth antennas," can help you determine the most practical system possible for your particular circumstances—before you go through the effort of stringing up wires.

Few compromise antennas are capable of delivering the performance you can expect from the full-size variety. But the patient and skillful operator can often do as well as some who are equipped with high power and full-size antennas. Someone with a reduced-size antenna may not be able to "bore a hole" in the bands as often and with the commanding dispatch enjoyed by those who are better equipped, but DX can be worked successfully when band conditions are suitable.

INVISIBLE ANTENNAS

We amateurs don't regard our antennas as eyesores; in fact, we almost always regard them as works of art! But there are occasions when having an outdoor or visible antenna can present problems.

When we are confronted with restrictions—self-imposed or otherwise—we can take advantage of a number of options toward getting on the air and radiating at least a moderately effective signal. In this context, a poor antenna is certainly better than no antenna at all! This section describes a number of techniques that enable us to use indoor antennas or "invisible" antennas outdoors.

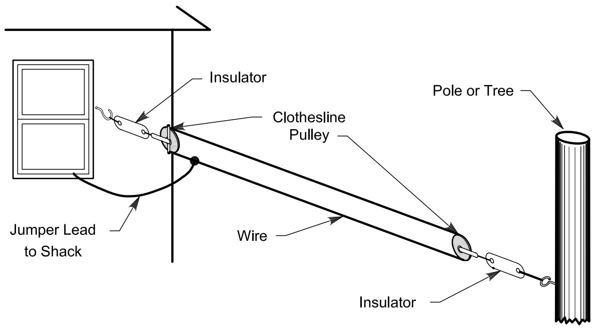

Fig 27—The clothesline antenna is more than it appears to be.

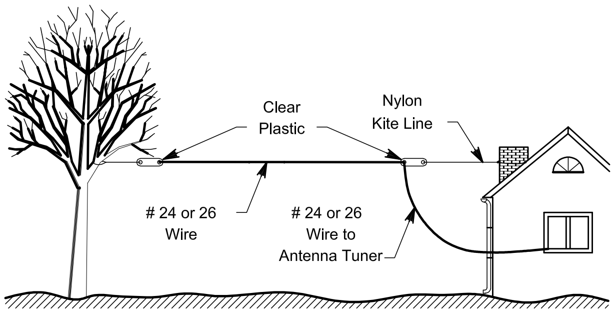

Fig 28—The "invisible" end-fed antenna.

Many of these systems will yield good-to-excellent results for local and DX contacts, depending on band conditions at any given time. *The most important consideration is that of not erecting any antenna that can present a hazard (physical or electrical) to humans, animals and buildings. Safety first!*

Clothesline Antenna

Clotheslines are sometimes attached to pulleys (**Fig 27**) so that the user can load the line and retrieve the laundry from a back porch. Laundry lines of this variety are accepted parts of the neighborhood "scenery," and can be used handily as amateur antennas by simply insulating the pulleys from their support points. This calls for the use of a conducting type of clothesline, such as heavy gauge stranded electrical wire with Teflon or vinyl insulation. A high quality, flexible steel cable (stranded) is suitable as a substitute if you don't mind cleaning it before clothing is hung on it.

A jumper wire can be brought from one end of the line to the ham shack when the station is being operated. If a good electrical connection exists between the wire clothesline and the pulley, a permanent connection can be made by connecting the lead-in wire between the pulley and its insulator. An antenna tuner can be used to match the "invisible" random-length wire to the transmitter and receiver.

Invisible Long Wire

A wire antenna is not actually a "long wire" unless it is one wavelength or greater in length. Yet many amateurs refer to (relatively) long physical spans of conductor as *long wires*. For the purpose of this discussion we will assume we have a fairly long span of wire, and refer to it as an *end-fed* wire antenna.

If we use small-diameter enameled wire for our end-fed antenna, chances are that it will be very difficult to see against the sky and neighborhood scenery. The smaller the wire, the more invisible the antenna will be. The limiting factor with small wire is fragility. A good compromise is #24 or #26 magnet wire for spans up to 130 feet; lighter-gauge wire can be used for shorter spans, such as 30 or 60 feet. The major threat to the longevity of fine wire is icing. Also, birds may fly into the wire and break it. Therefore, this style of antenna may require frequent service or replacement.

Fig 28 illustrates how you might install an invisible end-fed wire. It is important that the insulators also be lacking in prominence. Tiny Plexiglas blocks perform this function well. Small-diameter clear plastic medical vials are suitable also. Some amateurs simply use rubber bands for end insulators, but they will deteriorate rapidly from sun and air pollutants. They are entirely adequate for short-term operation with an invisible antenna, however.

Rain Gutter and TV Antennas

A great number of amateurs have taken advantage of standard house fixtures when contriving inconspicuous antennas. A very old technique is the use of the gutter and downspout system on the building. This is shown in **Fig 29**, where a lead wire is routed to the operating room

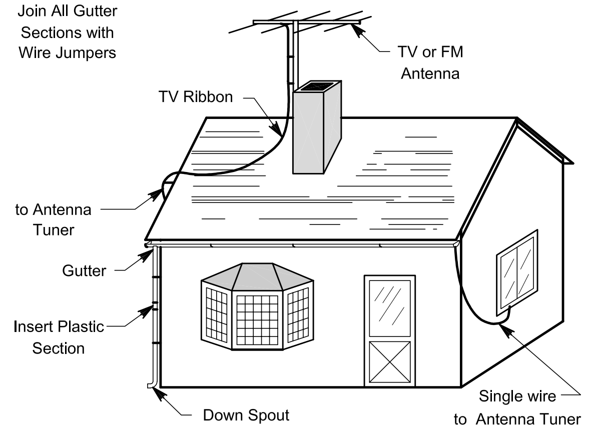

Fig 29—Rain gutters and TV antenna installations can be used as inconspicuous Amateur Radio antennas.

from one end of the gutter trough. We must assume that the wood to which the gutter is affixed is dry and of good quality to provide reasonable electrical insulation. The rain gutter antenna may perform quite poorly during wet weather or when there is ice and snow on it and the house roof.

All joints between gutter and downspout sections must be bonded electrically with straps of braid or flashing copper to provide good continuity in the system. Poor joints can permit rectification of RF and subsequently cause TVI and other harmonic interference. Also, it is prudent to insert a section of plastic downspout about 8 feet above ground to prevent RF shocks or burns to passersby while the antenna is being used. Improved performance may result if you join the front and back gutters of the house with a jumper wire to increase the area of the antenna.

Fig 29 also shows a TV or FM antenna that can be employed as an invisible amateur antenna. Many of these antennas can be modified easily to accommodate the 144- or 222-MHz bands, thereby permitting the use of the 300-Ω line as a feeder system. Some FM antennas can be used on 6 meters by adding #10 bus wire extensions to the ends of the elements, and adjusting the match for an SWR of 1:1. If 300-Ω line is used it will require a balun or antenna tuner to interface the line with the station equipment.

For operation in the HF bands, the TV or FM antenna feeders can be tied together at the transmitter end of the span and the system treated as a random length wire. If this is done, the 300-Ω line will have to be on TV standoff insulators and spaced well away from phone and power company service entrance lines. Naturally, the TV or FM radio must be disconnected from the system when it is used for amateur work! Similarly, masthead amplifiers and splitters must be removed from the line if the system is to be used for amateur operation. If the system is mostly vertical, a good RF ground system with many radials around the base of the house should be used to improve performance.

A very nice top-loaded vertical can be made from a length of TV mast with a large TV antenna on the top. Radials can be placed on the roof or at ground level with the TV "feed line" acting as part of the vertical. There is an extensive discussion of loaded verticals and radial systems in Chapter 6, Low-Frequency Antennas.

Flagpole Antennas

We can exhibit our patriotism and have an invisible amateur antenna at the same time by disguising our antenna as shown in **Fig 30**. The vertical antenna is a wire that has been placed inside a plastic or fiberglass pole.

The flagpole antenna shown is structured for a single amateur band, and it is assumed that the height of the pole corresponds to a quarter wavelength for the chosen band. The radials and feed line can be buried in the ground as shown. In a practical installation, the sealed end of the coax cable would protrude slightly into the lower end of the plastic pole.

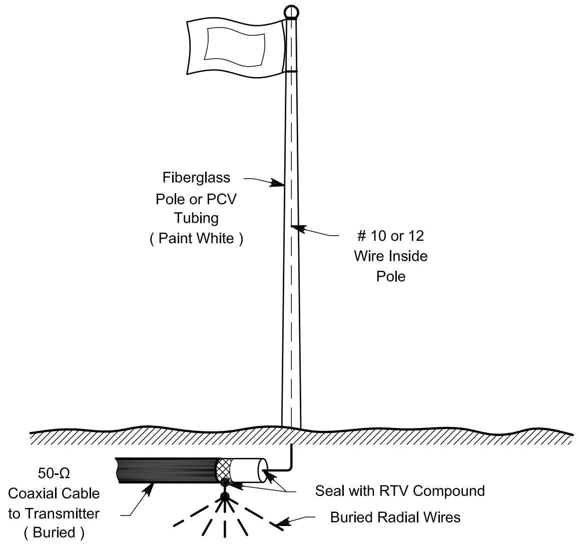

Fig 30—A flagpole antenna.

If a large-diameter fiberglass pole were available, a multiband trap vertical may be concealed inside it. Or you might use a metal pole and bury a water-tight box at its base, containing fixed-tuned matching networks for the bands of interest. The networks could then be selected remotely by means of relays inside the box. A 30-foot flagpole would provide good results in this kind of system, provided it was used in conjunction with a buried radial system.

Still another technique is one that employs a wooden flagpole. A small diameter wire can be stapled to the pole and routed to the coax feeder or matching network. The halyard could by itself constitute the antenna wire if it were made from heavy-duty insulated hookup wire. There are countless variations for this type of antenna, and they are limited only by the imagination of the amateur.

Other Invisible Antennas

Some amateurs have used the metal fence on apartment verandas as antennas, and have had good results on the upper HF bands (14, 21 and 28 MHz). We must presume that the fences were not connected to the steel framework of the building, but rather were insulated by the concrete floor to which they were affixed. These verandah fences have also been used effectively as ground systems (counterpoises) for HF-band vertical antennas put in place temporarily after dark.

One amateur in New York City uses the fire escape on his apartment building as a 7-MHz antenna, and he reports good success working DX stations with it. Another apartment dweller makes use of the aluminum frame on his living room picture window as an antenna for 21 and 28 MHz. He works it against the metal conductors of the baseboard heater in the same room.

Many jokes have been told over the years about *bedspring antennas*. The idea is by no means absurd. Bedsprings and metal end boards have been used to advantage as antennas by many apartment dwellers as 14, 21 and 28 MHz radiators. A counterpoise ground can be routed along the baseboard of the room and used in combination with the bedspring. It is important to remember that any independent (insulated) metal object of reasonable size can serve as an antenna if the transmitter can be matched to it. An amateur in Detroit once used his Shopsmith craft machine (about 5 feet tall) as a 28 MHz antenna. He worked a number of DX stations with it when band conditions were good.

A number of operators have used metal curtain rods and window screens for VHF work, and found them to be acceptable for local communications. Best results with any of these makeshift antennas will be had when the "antennas" are kept well away from house wiring and other conductive objects.

INDOOR ANTENNAS

Without question, the best place for your antenna is outdoors, and as high and in the clear as possible. Some of us, however, for legal, social, neighborhood, family or landlord reasons, are restricted to indoor antennas. Having to settle for an indoor antenna is certainly a handicap for the amateur seeking effective radio communication, but that is not enough reason to abandon all operation in despair.

First, we should be aware of the reasons why indoor antennas do not work well. Principal faults are:

- Low height above ground—the antenna cannot be placed higher than the highest peak of the roof, a point usually low in terms of wavelength at HF
- The antenna must function in a lossy RF environment involving close coupling to electrical wiring, guttering, plumbing and other parasitic conductors, besides dielectric losses in such nonconductors as wood, plaster and masonry
- Sometimes the antenna must be made small in terms of a wavelength
- Usually it cannot be rotated.

These are appreciable handicaps. Nevertheless, global communication with an indoor antenna is still possible, although you must be sure that you are not exposing anyone in your family or nearby neighbors to excessive radiation. See Chapter 1, Safety, in this book.

Some practical points in favor of the indoor antenna include:

- Freedom from weathering effects and damage caused by wind, ice, rain and sunlight (the SWR of an attic antenna, however, can be affected somewhat by a wet or snow-covered roof).
- Indoor antennas can be made from materials that would be altogether impractical outdoors, such as aluminum foil and thread (the antenna need support only its own weight).
- The supporting structure is already in place, eliminating the need for antenna masts.
- The antenna is readily accessible in all weather conditions, simplifying pruning or tuning, which can be accomplished without climbing or tilting over a tower.

Empiricism

A typical house or apartment presents such a complex electromagnetic environment that it is impossible to predict theoretically which location or orientation of the indoor antenna will work best. This is where good old fashioned cut-and-try, use-what-works-best *empiricism* pays off. But to properly determine what really is most suitable requires an understanding of some antenna measuring fundamentals.

Unfortunately, many amateurs do not know how to evaluate performance scientifically or compare one antenna with another. Typically, they will put up one antenna and try it out on the air to see how it "gets out" in comparison with a previous antenna. This is obviously a very poor evaluation method because there is no way to know if the better or worse reports are caused by changing band conditions, different S-meter characteristics or any of several other factors that could influence the reports received.

Many times the difference between two antennas or between two different locations for identical antennas amounts to only a few decibels, a difference that is hard to discern unless instantaneous switching between the two is possible. Those few decibels are not important under strong signal conditions, of course, but when the going gets rough, as is often the case with an indoor antenna, a few dB can make the difference between solid copy and no possibility of real communication.

Very little in the way of test equipment is needed for casual antenna evaluation, other than a communications receiver. You can even do a qualitative comparison by ear, if you can switch antennas instantaneously. Differences of less than 2 dB, however, are still hard to discern. The same is true of S-meters. Signal strength differences of less than a decibel are usually difficult to see. If you want to measure that last fraction of a decibel, you should use a good ac voltmeter at the receiver audio output (with the AGC turned off).

In order to compare two antennas, switching the coaxial transmission line from one to the other is necessary. No elaborate coaxial switch is needed; even a simple double-throw toggle or slide switch will provide more than 40 dB of isolation at HF. See **Fig 31**. Switching by means of manually connecting and disconnecting coaxial lines is not recommended because that takes too long.

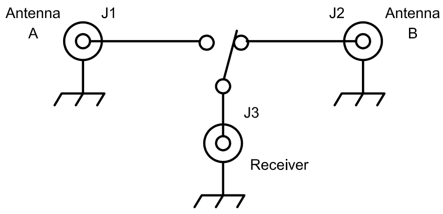

Fig 31—When antennas are compared on fading signals, the time delay involved in disconnecting and reconnecting coaxial cables is too long for accurate measurements. A simple slide switch will do well for switching coaxial lines at HF. The four components can be mounted in a tin can or any small metal box. Leads should be short and direct. J1 through J3 are coaxial connectors.

Fading can cause signal-strength changes during the changeover interval.

Whatever difference shows up in the strength of the received signal will be the difference in performance between the two antennas in the direction of that signal. For this test to be valid, both antennas must have nearly the same feed-point impedance, a condition that is reasonably well met if the SWR is below 2:1 on both antennas.

On ionospheric propagated signals (sky wave) there will be constant fading, and for a valid comparison it will be necessary to take an average of the difference between the two antennas. Occasionally, the inferior antenna will deliver a stronger signal to the receiver, but in the long run the law of averages will put the better antenna ahead.

Of course with a ground-wave signal, such as that from a station across town, there will be no fading problems. A ground-wave signal will enable the operator to properly evaluate the antenna under test in the direction of the source. The results will be valid for ionospheric-propagated signals at low elevation angles in that direction. On 28 MHz, all sky-wave signals arrive and leave at low angles. But on the lower bands, particularly 3.5 and 7 MHz, we often use signals propagated at high elevation angles, almost up to the zenith. For these angles a ground-wave test between local stations may not provide a proper evaluation of the antenna, and use of sky wave signals becomes necessary.

Dipoles

At HF the most practical indoor antenna is usually the dipole. Attempts to get more gain with parasitic elements will usually fail because of close proximity to the ground or coupling to house wiring. Beam antenna dimensions determined outdoors will not usually be valid for an attic antenna because the roof structure will cause dielectric loading of the parasitic elements. It is usually more worthwhile to spend time optimizing the location and performance of a dipole than to try to improve results with parasitic elements.

Most attics are not long enough to accommodate half-wave dipoles for 7 MHz and below. If this is the case, some folding of the dipole will be necessary. The final shape of the antenna will depend on the dimensions and configuration of the attic. Remember that the center of the dipole carries the most current and therefore does most of the radiating. This part should be as high and unfolded as possible. Because the dipole ends radiate less energy than the center, their orientation is not as important. They do carry the maximum voltage, nevertheless, so care should be taken to position the ends far enough from other conductors to avoid arcing.

The dipole may end up being L-shaped, Z-shaped, U-shaped or some indescribable corkscrew shape, depending on what space is available, but reasonable performance can often be had even with such a non-straight arrangement. **Fig 32** shows some possible configurations. Multiband operation is possible with the use of open-wire feeders and an antenna tuner.

One alternative not shown here is the aluminum-foil dipole, which was conceived by Rudy Stork, KA5FSB. He suggests mounting the dipole behind wallpaper or in the attic, with portability, ease of construction and adjustment, and economy in design among its desirable features. This antenna should also display reasonably good bandwidth resulting from the large area of its conductor material. If coaxial feed is used, some pruning of an attic antenna to establish minimum SWR at the band center will be required. Tuning the antenna outdoors and then installing it inside is usually not feasible since the behavior of the antenna will not be the same when placed in the attic. Resonance will be affected somewhat if the antenna is bent.

Even if the antenna is placed in a straight line, parasitic conductors and dielectric loading by nearby wood structures can affect the impedance. Trap and loaded dipoles are shorter than the full-sized versions, but are comparable performers. Trap dipoles are discussed in Chapter 7, Multiband Antennas, and loaded dipoles in Chapter 6, Low-Frequency Antennas.

Dipole Orientation

Theoretically a vertical dipole is most effective at low radiation angles, but practical experience shows that the horizontal dipole is usually a better indoor antenna. A high horizontal dipole does exhibit directional effects at low radiation angles, but you will not be likely to see much, if any, directivity with an attic-mounted dipole. Some operators place two dipoles at right angles to each other with provisions at the operating position for switching between the two. Their reasoning is the radiation patterns will inevitably be distorted in an unpredictable manner by nearby parasitic conductors. There will be little coupling between the dipoles if they are oriented a right

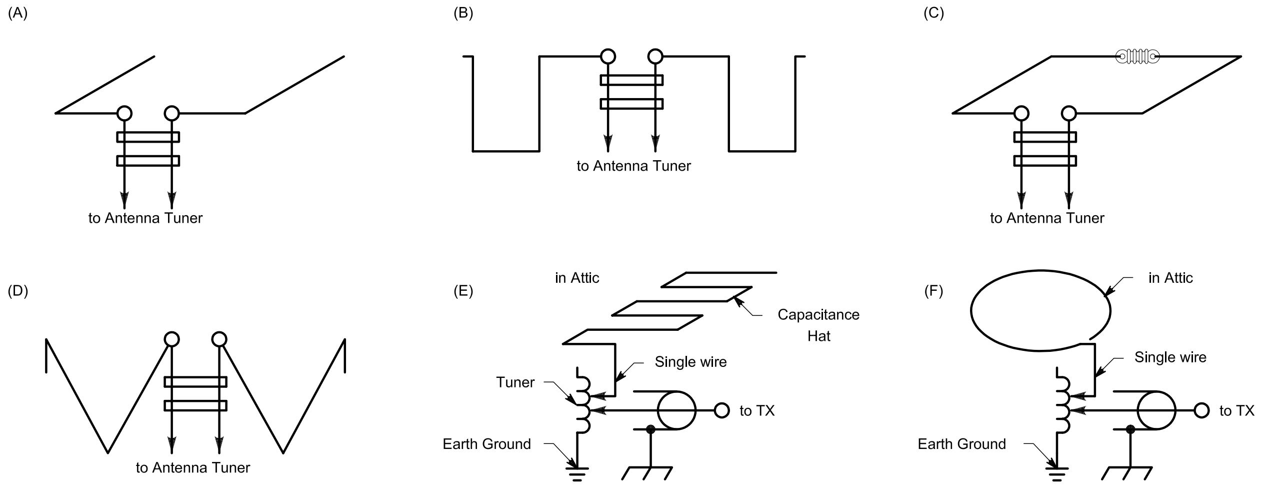
(A)
to Antenna Tuner
(B)
to Antenna Tuner
(C)
to Antenna Tuner
(D)
to Antenna Tuner
(E)
in Attic
Capacitance Hat
Single wire
Tuner
to TX
Earth Ground
(F)
in Attic
Single wire
to TX
Earth Ground

Fig 32—Various configurations for small indoor antennas. See text for discussion.

angles to each other as shown in **Figs 33A** and 33B. There will be some coupling with the arrangement shown in Fig 33C, but even this orientation is preferable to a single dipole.

With two antennas mounted 90° apart, you may find that one dipole is consistently better in nearly all directions, in which case you will want to remove the inferior dipole, perhaps placing it someplace else. In this manner the best spots in the house or attic can be determined experimentally.

Parasitic Conductors

Inevitably, any conductor in your house near a quarter wave in length or longer at the operating frequency will be parasitically coupled to your antenna. The word *parasitic* is particularly appropriate in this case because these conductors usually introduce losses and leave less energy for radiation into space. Unlike the parasitic elements in a beam antenna, conductors such as house wiring and plumbing are usually connected to lossy objects such as earth, electrical appliances, masonry or other objects that dissipate energy. Even where this energy is reradiated, it is not likely to be in the right phase in the desired direction; it is, in fact, likely to be a source of RFI.

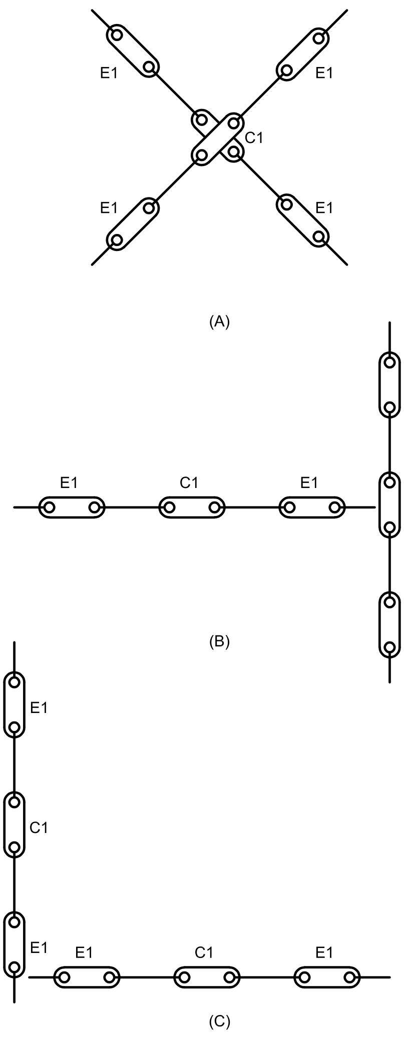
E1
E1
C1
E1
E1
(A)
E1
E1
C1
E1
C1
E1
(B)
E1
C1
E1
E1
C1
E1
(C)

Fig 33—Ways to orient a pair of perpendicular dipoles. The orientation at A and B will result in no mutual coupling between the two dipoles, but there will be some coupling in the configuration shown at C. End (EI) and center (CI) insulators are shown.

There are, however, some things that can be done about parasitic conductors. The most obvious is to reroute them at right angles to the antenna or close to the ground, or even underground—procedures that are usually not feasible in a finished home. Where these conductors cannot be rerouted, other measures can be taken. Electrical wiring can be broken up with RF chokes to prevent the flow of radio-frequency currents while permitting 60-Hz current (or audio, in the case of telephone wires) to flow unimpeded. A typical RF choke for a power line can be 100 turns of #10 insulated wire close wound on a length of 1-inch diameter plastic pipe. Of course one choke will be needed for each conductor. A three-wire line calls for three chokes. The chokes can be simplified by winding them bifilar or trifilar on a single coil form.

THE RESONANT BREAKER

Obviously, RF chokes cannot be used on conductors such as metal conduit or water pipes. But it is still possible, surprising as it may seem, to obstruct RF currents on such conductors without breaking the metal. The resonant breaker was first described by Fred Brown, W6HPH, in Oct 1979 *QST*.

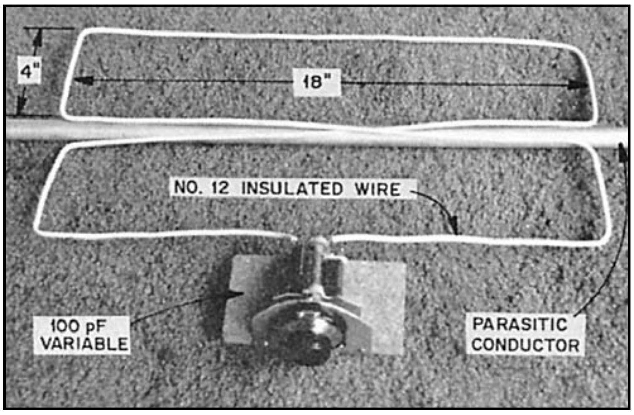

Fig 34—A "resonant breaker" such as shown here can be used to obstruct radio-frequency currents in a conductor without the need to break the conductor physically. A vernier dial is recommended for use with the variable capacitor because tuning is quite sharp. The 100-pF capacitor is in series with the loop. This resonant breaker tunes from 14 through 29.7 MHz. Larger models may be constructed for the lower frequency bands.

Fig 34 shows a method of accomplishing this. A figure-eight loop is inductively coupled to the parasitic conductor and is resonated to the desired frequency with a variable capacitor. The result is a very high impedance induced in series with the pipe, conduit or wire. This impedance will block the flow of radio-frequency currents. The figure-eight coil can be thought of as two turns of an air-core toroid and since the parasitic conductor threads through the hole of this core, there will be tight coupling between the two. Inasmuch as the figure-eight coil is parallel resonated, transformer action will reflect a high impedance in series with the linear conductor.

Before you bother with a *resonant breaker* of this type, be sure that there is a significant amount of RF current flowing in the parasitic conductor, and that you will therefore benefit from installing one. The relative magnitude of this current can be determined with an RF current probe of the type described in Chapter 27, Antenna and Transmission-Line Measurements. According to the rule of thumb regarding parasitic conductor current, if it measures less than $^1/_{10}$ of that measured near the center of the dipole, the parasitic current is generally not large enough to be of concern.

The current probe is also needed for resonating the breaker after it is installed. Normally, the resonant breaker will be placed on the parasitic conductor near the point of maximum current. When it is tuned through resonance, there will be a sharp dip in RF current, as indicated by the current probe. Of course, the resonant breaker will be effective only on one band. You will need one for each band where there is significant current indicated by the probe.

Power-Handling Capability

So far, our discussion have not considered the full power-handling capability of an indoor antenna. Any tendency to flash over must be determined by running full power or, preferably, somewhat more than the peak power you intend to use in regular operation. The antenna should be carefully checked for arcing or RF heating before you do any operating. Bear in mind that attics are indeed vulnerable to fire hazards. A potential of several hundred volts exists at the ends of a dipole fed by the typical Amateur Radio transmitter. If a power amplifier is used, there could be a few thousand volts at the ends of the dipole. Keep your antenna elements well away from other objects. *Safety first*!

Construction Details and Practical Considerations

Ultimately the success of an antenna project depends on the details of how the antenna is fabricated. A great deal of construction information is given in other chapters of this book. For example the construction of HF Yagis is discussed in Chapter 11, Quad arrays in Chapter 12, VHF antennas in Chapter 18, and in Chapter 20 there is an excellent discussion of antenna materials, particularly wire and tubing for elements. Here is still more helpful antenna construction information.

END EFFECT

If the standard expression $\lambda/2 \approx 491.8/f$ (MHz) is used for the length of a $\lambda/2$ wire antenna, the antenna will resonate at a somewhat lower frequency than is desired. The reason is that in addition to the effect of the conductor diameter and ground effects (Chapter 3, The Effects of Ground) an additional "loading" effect is caused by the insulators used at the ends of the wires to support the antenna. The insulators and the wire loops that tie the insulators to the antenna add a small amount of capacitance to the system. This capacitance helps to tune the antenna to a slightly lower frequency, in much the same way that additional capacitance in any tuned circuit lowers the resonant frequency. In an antenna this is called *end effect*. The current at the ends of the antenna does not quite reach zero because of the end effect, as there is some current flowing into the end capacitance. Note that the computations used to create Figs 2 through 7 in Chapter 2, Antenna Fundamentals, did not take into account any end effect.

End effect increases with frequency and varies slightly with different installations. However, at frequencies up to 30 MHz (the frequency range over which wire antennas are most commonly used), experience shows that the length of a practical $\lambda/2$ antenna, including the effect of diameter and end effect, is on the order of 5% less than the length of a half wave in space. As an average, then, the physical length of a resonant $\lambda/2$ wire antenna can be found from:

$$\lambda = \frac{491.8 \times 0.95}{f\ (\text{MHz})} \approx \frac{468}{f\ (\text{MHz})} \qquad \text{(Eq 1)}$$

Eq 1 is reasonably accurate for finding the physical length of a $\lambda/2$ antenna for a given frequency, but does not apply to antennas longer than a half wave in length. In the practical case, if the antenna length must be adjusted to exact frequency (not all antenna systems require it) the length should be "pruned" to resonance. Note that the use of plastic-insulated wire will typically lower the resonant frequency of a half-wave dipole about 3%.

INSULATORS

Wire antennas must be insulated at the ends. Commercially available insulators are made from ceramic, glass or plastic. Insulators are available from many Amateur Radio dealers. RadioShack and local hardware stores are other possible sources. Acceptable homemade insulators may be fashioned from a variety of material including (but not limited to) acrylic sheet or rod, PVC tubing, wood, fiberglass rod or even stiff plastic from a discarded container. **Fig 35** shows some homemade insulators. Ceramic or glass insulators will usually outlast the wire, so they are highly recommended for a safe, reliable, permanent installation. Other materials may tear under stress or break down in the presence of sunlight. Many types of plastic do not weather well.

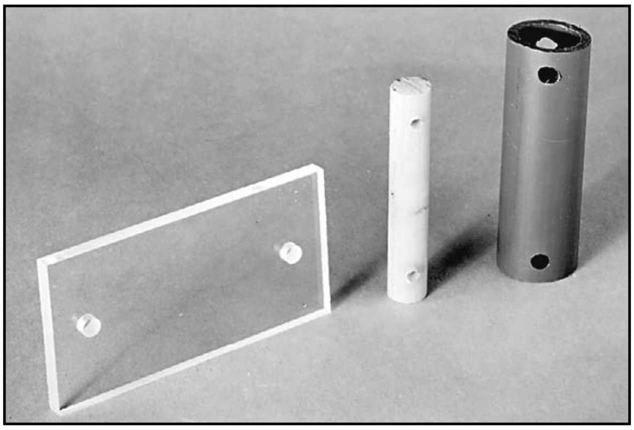

Fig 35—Some ideas for homemade antenna insulators.

INSTALLING TRANSMISSION LINES

Many wire antennas require an insulator at the feed point. Although there are many ways to connect the feed line, there are a few things to keep in mind. If you feed your antenna with coaxial cable, you have two choices. You can install an SO-239 connector on the center insu-

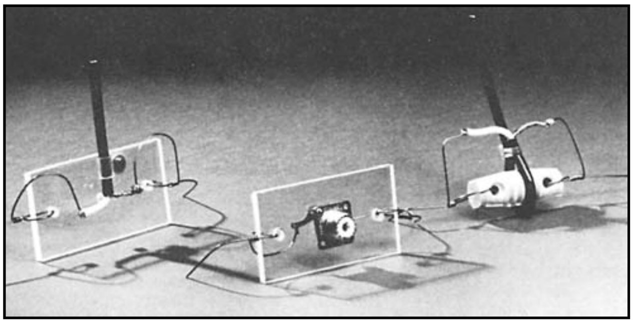

Fig 36—Some homemade dipole center insulators. The one in the center includes a built-in SO-239 connector. Others are designed for direct connection to the feed line.

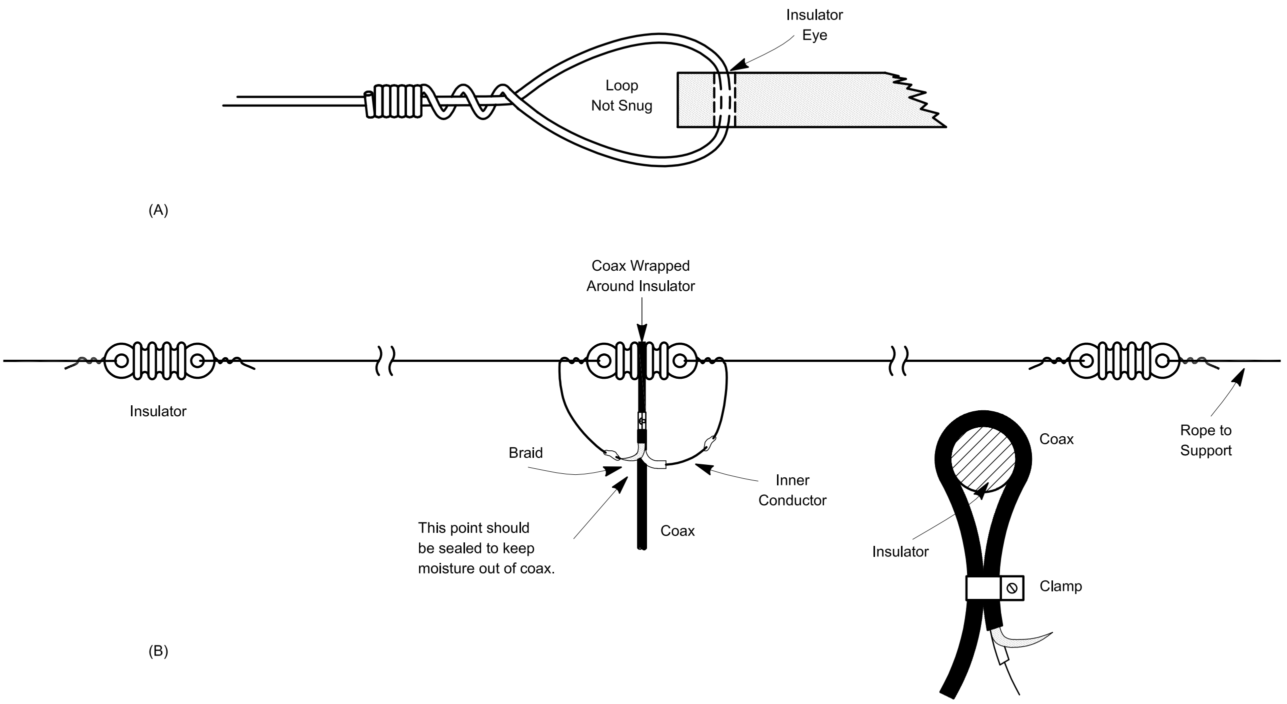
Insulator
Eye
Loop
Not Snug
(A)
Coax Wrapped
Around Insulator
Insulator
Braid
Inner
Conductor
This point should
be sealed to keep
moisture out of coax.
Coax
Coax
Rope to
Support
Insulator
Clamp
(B)

Fig 37—Details of dipole antenna construction. At A, the end insulator connection is shown. At B, the completed antenna is shown. A balun (not shown) is often used at the feed point, since this is a balanced antenna.

lator, as shown by the center example in **Fig 36,** and use a PL-259 on the end of your coax, or you can separate the center conductor from the braid and connect the feed line directly to the antenna wire as shown in the other two examples in Fig 36 and the example in **Fig 37**. Although it costs less to connect direct, the use of connectors offers several advantages. Coaxial cable braid soaks up water like a sponge unless it is very well waterproofed. If you do not adequately seal the antenna end of the feed line, water will find its way into the braid. Water in the feed line will lead to contamination, rendering the coax useless long before its normal lifetime is up. Many hams waterproof the coax, first with vinyl electrical tape, and then using a paint-on material called “PlastiDip,” which is sold by RadioShack (part number 910-5166 for the white variety).

It is not uncommon for water to drip from the end of the coax inside the shack after a year or so of service if the antenna connection is not properly waterproofed. Use of a PL-259/SO-239 combination (or connector of your choice) makes the task of waterproofing connections much easier. Another advantage to using the PL-259/SO-239 combination is that feed-line replacement is much easier, should that become necessary.

Whether you use coaxial cable, ladder line, or twin lead to feed your antenna, an often overlooked consideration is the mechanical strength of the connection. Wire antennas and feed lines tend to move a lot in the breeze, and

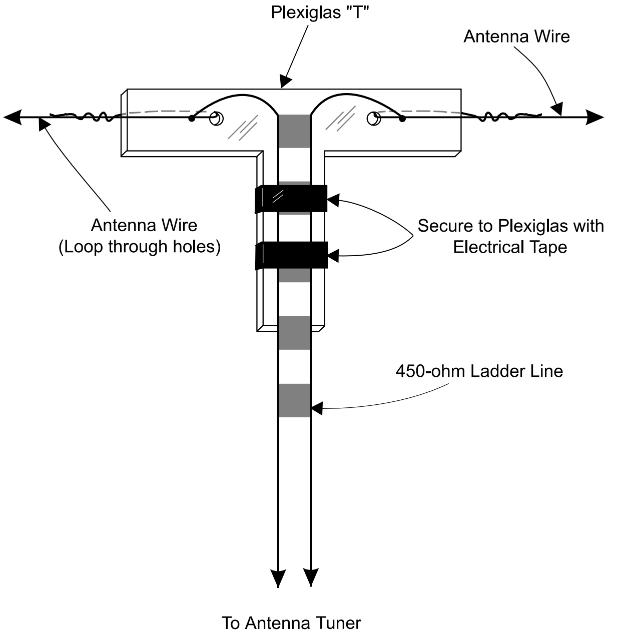
Plexiglas "T"
Antenna Wire
Antenna Wire
(Loop through holes)
Secure to Plexiglas with
Electrical Tape
450-ohm Ladder Line
To Antenna Tuner

Fig 38—A piece of cut Plexiglas can be used as a center insulator and to support a ladder-line feeder. The Plexiglas acts to reduce the flexing of the wires where they connect to the antenna. Use thick Plexiglas in areas subject to high winds.

unless the feed line is attached securely, the connection will weaken with time. The resulting failure can range from a frustrating intermittent electrical connection to a complete separation of feed line and antenna. Fig 37 and **Fig 38** illustrate different ways of attaching either coax or ladder line to the antenna securely.

When open-wire feed line is used, the conductors of the line should be anchored to the insulator by threading them through the eyes of the insulator two or three times, and twisting the wire back on itself before soldering. A slack tie wire should then be used between the feeder conductor and the antenna, as shown in Fig 38. (The tie wires may be extensions of the line conductors themselves.) When window-type line is suspended from an antenna in a manner such as that shown in Fig 38, the line should be twisted—at several twists per foot—to prevent stress hardening of the wire because of constant flexing in the wind.

When using plastic-insulated open-wire line, the tendency of the line to twist and short out close to the antenna can be counteracted by making the center insulator of the antenna longer than the spacing of the line, as shown in Fig 38. In severe wind areas, it may be necessary to use ¼-inch thick Plexiglas for the center insulator rather than thinner material.

RUNNING THE FEED LINE FROM THE ANTENNA TO THE STATION

Chapter 24, Transmission Lines, contains some general guidelines for installing feed lines. More detailed information is contained in this section. Whenever possible, the transmission line should be lead away from the antenna at a 90° angle to minimize coupling from the antenna to the transmission line. This coupling can cause unequal currents on the transmission line, which will then radiate and it can detune the antenna.

Except for the portion of the line in close proximity to the antenna, coaxial cable requires no particular care in running from the antenna to the station entrance, other than protection from mechanical damage. If the antenna is not supported at the center, the line should be fastened to a post more than head high located under the center of the antenna, allowing enough slack between the post and the antenna to take care of any movement of the antenna in the wind. If the antenna feed point is supported by a tower or mast, the cable can be taped to the mast at intervals or to one leg of the tower.

Coaxial cable rated for direct burial can be buried a few inches in the ground to make the run from the antenna to the station. A deep slit can be cut by pushing a square-end spade full depth into the ground and moving the handle back and forth to widen the slit before removing the spade. After the cable has been pushed into the slit with a piece of 1-inch board 3 or 4 inches wide, the slit can be tamped closed. Many hams run coax cables through PVC pipe buried in the ground deeper than the frost line and slanted downwards slightly so that water will drain, rather than pooling inside the length of the pipe.

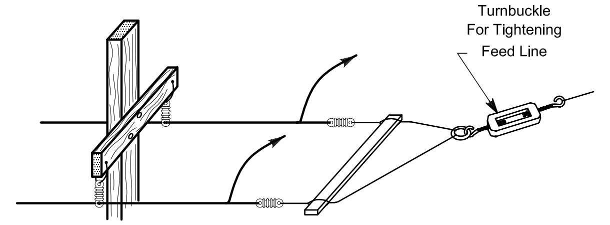

Fig 39—A support for open-wire line. The support at the antenna end of the line must be sufficiently rigid to stand the tension of the line.

Solid ribbon or the newer *window* types of line should be kept reasonably well spaced from other conductors running parallel to it for more than a few feet. TV-type standoff insulators with strap clamp mountings can be used for running this type of line down a mast or tower leg. Similar insulators of the screw-in type can be used in supporting the line on wooden poles for a long run.

Open-wire lines with bare conductors require frequent supports to keep the lines from twisting and shorting out, as well as to relieve the mechanical strain. One method of supporting a long horizontal run of heavy open-wire line is shown in **Fig 39**. The line must be anchored securely at a point under the feed point of the antenna. Window-type line can be supported similarly with wire links fastened to the insulators or with black cable ties (ones not affected by UV radiation from the sun).

To keep the line clear of pedestrians and vehicles, it is usually desirable to anchor the feed line at the eaves or rafter line of the station building (see **Fig 40**), and then drop it vertically to the point of entrance. The points of anchorage and entrance should be chosen to permit the vertical drop without crossing windows for aesthetic reasons.

If the station is located in a room on the ground floor, one way of bringing coax transmission line into the house is to go through the outside wall below floor level, feed it through the basement or crawl space and then up to the station through a hole in the floor. When making the entrance hole in the side of the building, suitable measurements should be made in advance to be sure the hole will go through the sill 2 or 3 inches above the foundation line (and between joists if the bore is parallel to the joists). The line should be allowed to sag below the entrance hole level outside the building to allow rain water to drip off.

Open-wire line can be fed in a similar manner, although it will require a separate hole for each conductor. Each hole should be insulated with a length of polystyrene or Lucite tubing. If available, ceramic tubes salvaged from old-fashioned *knob and tube* electrical

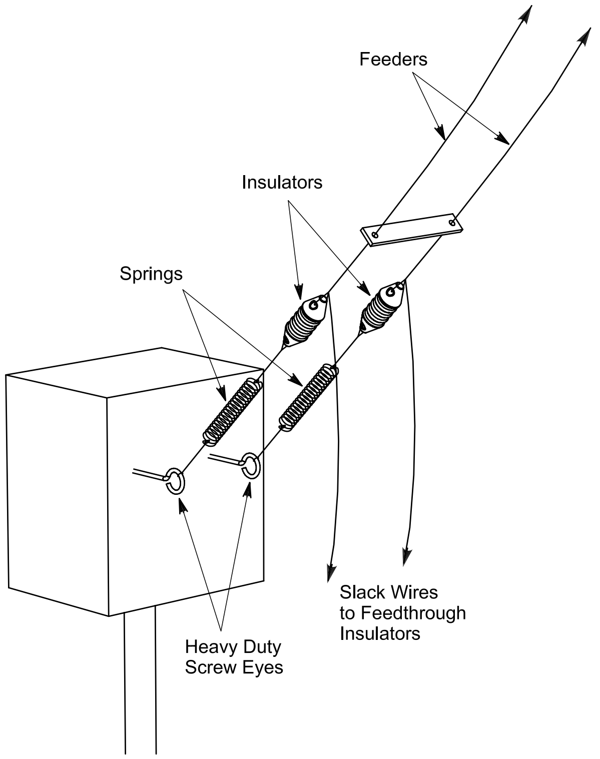

Fig 40—Anchoring open-wire line at the station end. The springs are especially desirable if the line is not supported between the antenna and the anchoring point.

installations, work very well for this purpose. Drill the holes with a slight downward slant toward the outside of the building to prevent rain seepage. With window ladder line, it will be necessary to remove a few of the spreader insulators, cut the line before passing through the holes (allowing enough length to reach the inside) and splice the remainder on the inside.

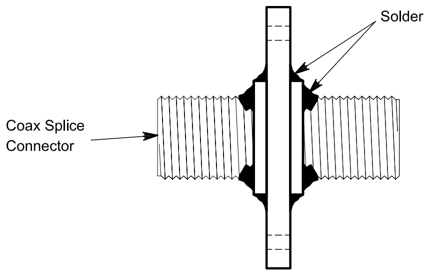

Fig 42—Feedthrough connector for coax line. An Amphenol 83-1J (PL-258) connector, the type used to splice sections of coax line together, is soldered into a hole cut in a brass mounting flange. An Amphenol bulkhead adapter 83-1F may be used instead.

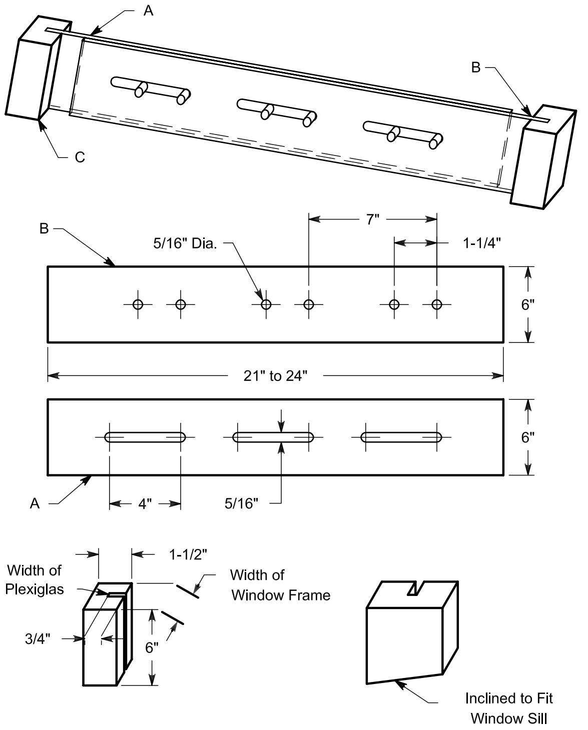

Fig 41—An adjustable window lead-in panel made up of two sheets of Lucite or Plexiglas. A feedthrough connector for coax line can be made as shown in Fig 28. Ceramic feedthrough insulators are suitable for open-wire line. (W1RVE)

If the station is located above ground level, or if there is other objection to the procedure described above, entrance can be made at a window, using the arrangement shown in **Fig 41**. An Amphenol type 83-1F (UG-363) connector can be used as shown in **Fig 42**; ceramic feedthrough insulators can be used for open-wire line. Ribbon line can be run through clearance holes in the panel, and secured by a winding of tape on either side of the panel, or by cutting the retaining rings and insulators from a pair of TV standoff insulators and clamping one on each side of the panel.

LIGHTNING PROTECTION

Two or three types of lightning arresters for coaxial cable are available on the market. If the antenna feed point is at the top of a well-grounded tower, the arrester can be fastened securely to the top of the tower for grounding purposes. A short length of cable, terminated in a coaxial plug, is then run from the antenna feed point to one receptacle of the arrester, while the transmission line is run from the other arrester receptacle to the station. Such arresters may also be placed at the entrance point to the station, if a suitable ground connection is available at that point (or arresters may be placed at both points for added insurance).

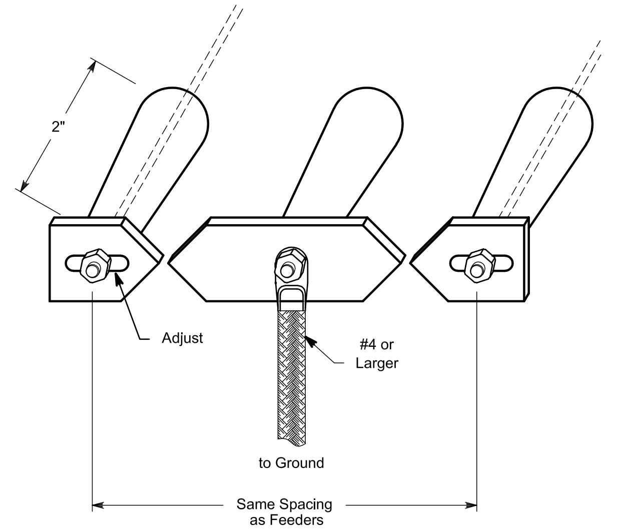

Fig 43—A simple lightning arrester for open-wire line made from three standoff or feedthrough insulators and sections of 1/8 × 1/2-inch brass or copper strap. It should be installed in the line at the point where the line enters the station. The heavy ground lead should be as short and as direct as possible. The gap setting should be adjusted to the minimum width that will prohibit arcing when the transmitter is operated.

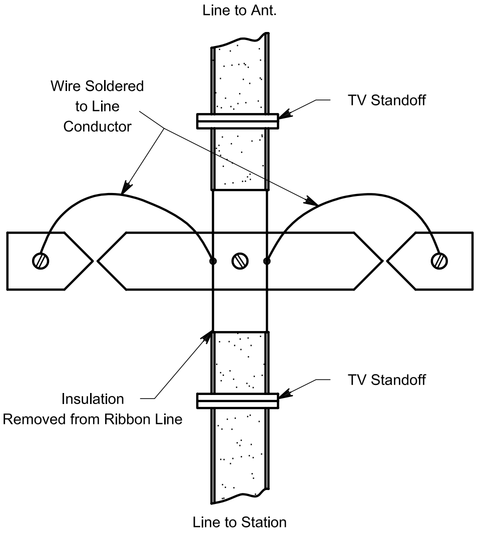
Line to Ant.
Wire Soldered to Line Conductor
TV Standoff
TV Standoff
Insulation Removed from Ribbon Line
Line to Station

Fig 44—The lightning arrester of Fig 39 may be used with 300-Ω ribbon line in the manner shown here. The TV standoffs support the line an inch or so away from the grounded center member of the arrester

The construction of a homemade arrester for open-wire line is shown in **Fig 43**. This type of arrester can be adapted to ribbon line an inch or so away from the center member of the arrester, as shown in **Fig 44**. Sufficient insulation should be removed from the line where it crosses the arrester to permit soldering the arrester connecting leads.

Lightning Grounds

Lightning-ground connecting leads should be of conductor size equivalent to at least #10 wire. The #8 aluminum wire used for TV-antenna grounds is satisfactory. Copper braid 3/4-inch wide (Belden 8662-10) is also suitable. The conductor should run in a straight line to the grounding point. The ground connection may be made to a water pipe system (if the pipe is not plastic), the grounded metal frame of a building, or to one or more 5/8-inch ground rods driven to a depth of at least 8 feet. More detailed information on lightning protection is contained in Chapter 1, Safety.

A central grounding panel for coax cables coming into the house is highly recommended. See **Fig 45** for a photo of the homemade grounding panel installed by Chuck Hutchinson, K8CH, at his Michigan home. The coax cables screwed into dual-female feed-through UHF connectors. K8CH installed this aluminum panel under the outside grill for a duct that provided combustion air to an unused fireplace. He used ground strap to connect to ground rods located under the panel. See the ARRL book *Simple and Fun Antennas* for more information about ground panels.

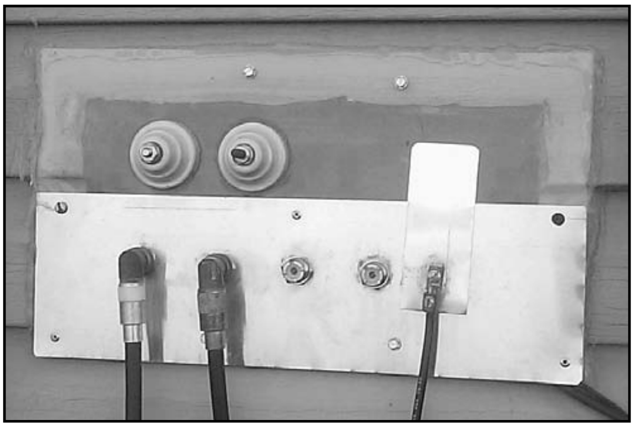

Fig 45—K8CH's coax entry panel mounted on exterior wall (later covered by grill that provides combustion to an unused fireplace). The ground braid goes to a ground rod located beneath the panel. (Photo courtesy: *Simple and Fun Antennas for Hams*)

Before a lightning storm approaches, a prudent ham will disconnect all feed lines, rotor lines and control lines inside the shack to prevent damage to sensitive electronics. When lightning is crashing about outside, you certainly don't want that lightning inside your shack!

Chapter 5

Loop Antennas

A loop antenna is a closed-circuit antenna—that is, one in which a conductor is formed into one or more turns so its two ends are close together. Loops can be divided into two general classes, those in which both the total conductor length and the maximum linear dimension of a turn are very small compared with the wavelength, and those in which both the conductor length and the loop dimensions begin to be comparable with the wavelength.

A "small" loop can be considered to be simply a rather large coil, and the current distribution in such a loop is the same as in a coil. That is, the current has the same phase and the same amplitude in every part of the loop. To meet this condition, the total length of conductor in the loop must not exceed about 0.1 λ. Small loops are discussed later in this chapter, and further in Chapter 14, Direction Finding Antennas.

A "large" loop is one in which the current is not the same either in amplitude or phase in every part of the loop. This change in current distribution gives rise to entirely different properties compared with a small loop.

Half-Wave Loops

The smallest size of "large" loop generally used is one having a conductor length of $^1/_2$ λ. The conductor is usually formed into a square, as shown in **Fig 1**, making each side $^1/_8$ λ long. When fed at the center of one side, the current flows in a closed loop as shown in Fig 1A. The current distribution is approximately the same as on a $^1/_2$ λ wire, and so is maximum at the center of the side opposite the terminals X-Y, and minimum at the terminals themselves. This current distribution causes the field strength to be maximum in the plane of the loop and in the direction looking from the low-current side to the high-current side. If the side opposite the terminals is opened at the center as shown in Fig 1B (strictly speaking, it is then no longer a loop because it is no longer a closed circuit), the direction of current flow remains unchanged but the maximum current flow occurs at the terminals. This reverses the direction of maximum radiation.

The radiation resistance at a current antinode (which is also the resistance at X-Y in Fig 1B) is on the order of 50 Ω. The impedance at the terminals in Fig 1A is a few thousand ohms. This can be reduced by using two identical loops side by side with a few inches spacing between them and applying power between terminal X on one loop and terminal Y on the other.

Unlike a $^1/_2$ λ dipole or a small loop, there is no direction in which the radiation from a loop of the type shown in Fig 1 is zero. There is appreciable radiation in the direction perpendicular to the plane of the loop, as well as to the "rear"—the opposite direction to the arrows shown. The front-to-back (F/B) ratio is approximately 4 to 6 dB. The small size and the shape of the directive pattern result in a loss of about 1 dB when the field strength in the optimum direction from such a

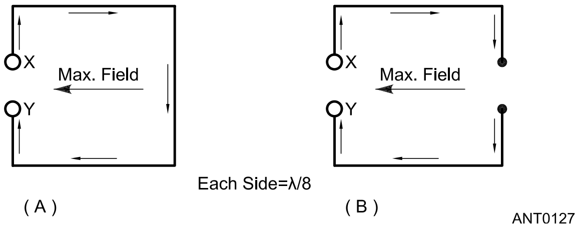

Fig 1—Half-wave loops, consisting of a single turn having a total length of $^1/_2$ λ.

loop is compared with the field from a $^1/_2$ λ dipole in its optimum direction.

The ratio of the forward radiation to the backward radiation can be increased, and the field strength likewise increased at the same time to give a gain of about 1 dB over a dipole, by using inductive reactances to “load” the sides joining the front and back of the loop. This is shown in **Fig 2**. The reactances, which should have a value of approximately 360 Ω, decrease the current in the sides in which they are inserted and increase it in the side having terminals. This increases the directivity and thus increases the efficiency of the loop as a radiator. Lossy coils can reduce this advantage greatly.

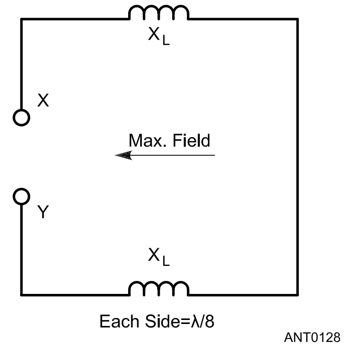

Fig 2—Inductive loading in the sides of a $^1/_2$-λ loop to increase the directivity and gain. Maximum radiation or response is in the plane of the loop, in the direction shown by the arrow.

One-Wavelength Loops

Loops in which the conductor length is 1 λ have different characteristics than $^1/_2$-λ loops. Three forms of 1 λ loops are shown in **Fig 3**. At A and B the sides of the squares are equal to $^1/_4$ λ, the difference being in the point at which the terminals are inserted. At C the sides of the triangle are equal to $^1/_3$ λ. The relative direction of current flow is as shown in the drawings. This direction reverses halfway around the perimeter of the loop, as such reversals always occur at the junction of each $^1/_2$-λ section of wire.

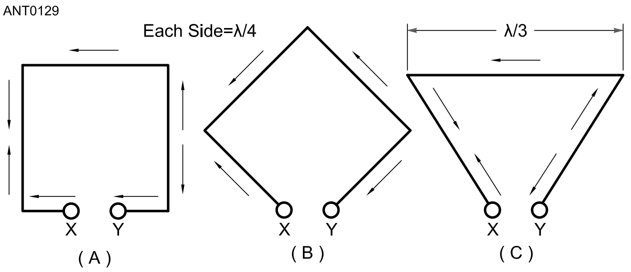

Fig 3—At A and B, loops having sides $^1/_4$ λ long, and at C having sides $^1/_3$ λ long (total conductor length 1 λ). The polarization depends on the orientation of the loop and on the position of the feed point (terminals X-Y) around the perimeter of the loop.

The directional characteristics of loops of this type are opposite in sense to those of a small loop. That is, the radiation is maximum perpendicular to the plane of the loop and is minimum in either direction in the plane containing the loop. If the three loops shown in Fig 3 are mounted in a vertical plane with the terminals at the bottom, the radiation is horizontally polarized. When the terminals are moved to the center of one vertical side in Fig 3A, or to a side corner in B, the radiation is vertically polarized. If the terminals are moved to a side corner in C, the polarization will be diagonal, containing both vertical and horizontal components.

In contrast to straight-wire antennas, the electrical length of the circumference of a 1-λ loop is shorter than the actual length. For a loop made of bare #18 wire and operating at a frequency of 14 MHz, where the ratio of conductor length to wire diameter is large, the loop will be close to resonance when

$$\text{Length}_{\text{feet}} = \frac{1032}{f_{\text{MHz}}}$$

The radiation resistance of a resonant 1 λ loop is approximately 120 Ω, under these conditions. Since the loop dimensions are larger than those of a $^1/_2$-λ dipole, the radiation efficiency is high.

In the direction of maximum radiation (that is, broadside to the plane of the loop, regardless of the point at which it is fed) the 1-λ loop will show a small gain over a $^1/_2$-λ dipole. Theoretically, this gain is about 1 dB, and measurements have confirmed that it is of this order.

The 1-λ loop is more frequently used as an element of a directive antenna array (the quad and delta-loop antennas described in Chapter 12, Quad Arrays) than singly, although there is no reason why it cannot be used alone. In the quad and delta loop, it is nearly always driven so that the polarization is horizontal.

Small Loop Antennas

The electrically small loop antenna has existed in various forms for many years. Probably the most familiar form of this antenna is the ferrite *loopstick* found in portable AM broadcast-band receivers. Amateur applications of the small loop include direction finding, low-noise directional receiving antennas for 1.8 and 3.5 MHz, and small transmitting antennas. Because the design of transmitting and receiving loops requires some different considerations, the two situations are examined separately in this section. This information was written by Domenic M. Mallozzi, N1DM.

The Basic Loop

What is and what is not a small loop antenna? By definition, the loop is considered to be electrically small when its total conductor length is less than 0.1 λ—0.085 is the number used in this section. This size is based on the fact that the current around the perimeter of the loop must be in phase. When the winding conductor is more than about 0.085 λ long, this is no longer true. This constraint results in a very predictable figure-eight radiation pattern, shown in **Fig 4**.

The simplest loop is a 1-turn untuned loop with a load connected to a pair of terminals located in the center of one of the sides, as shown in **Fig 5**. How its pattern is developed is easily pictured if we look at some "snapshots" of the antenna relative to a signal source. **Fig 6** represents a loop from above, and shows the instantaneous radiated voltage wave. Note that points A and B of the loop are receiving the same instantaneous voltage. This means that no current will flow through the loop, because there is no current flow between points of equal potential. A similar analysis of **Fig 7**, with the loop turned 90° from the position represented in Fig 6, shows that this position of the loop provides maximum response. Of course, the voltage derived from the passing wave is small because of the small physical size of the loop. Fig 4 shows the ideal radiation pattern for a small loop.

The voltage across the loop terminals is given by

$$V = \frac{2\pi A N E \cos\theta}{\lambda} \qquad \text{(Eq 1)}$$

where

V = voltage across the loop terminals
A = area of loop in square meters
N = number of turns in the loop
E = RF field strength in volts per meter
θ = angle between the plane of the loop and the signal source (transmitting station)
λ = wavelength of operation in meters

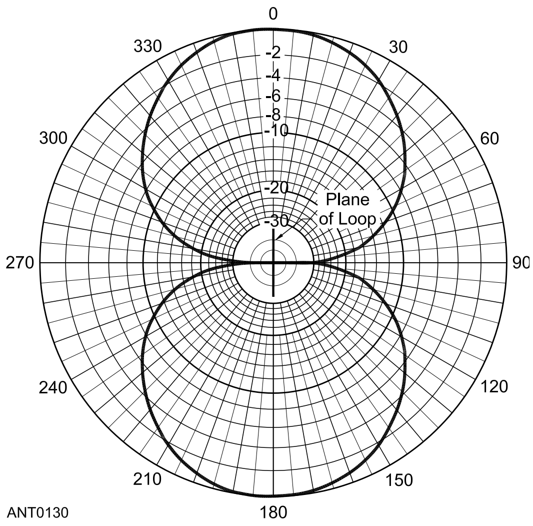

Fig 4—Calculated small loop antenna radiation pattern.

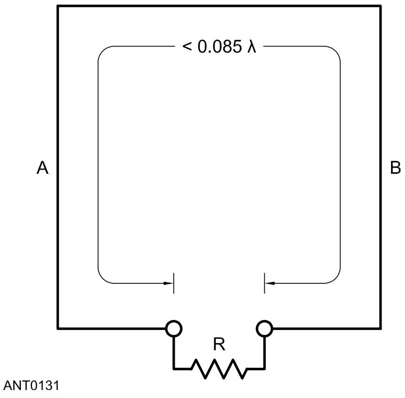

Fig 5—Simple untuned small loop antenna.

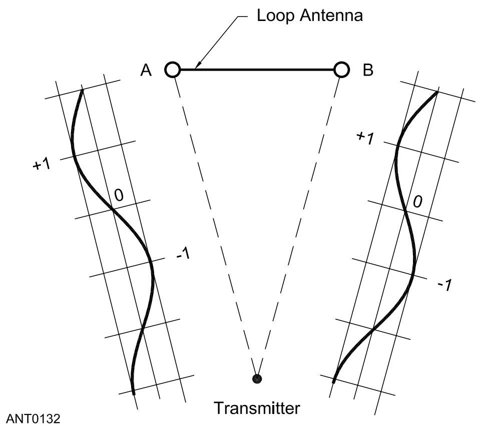

Fig 6—Example of orientation of loop antenna that does not respond to a signal source (null in pattern).

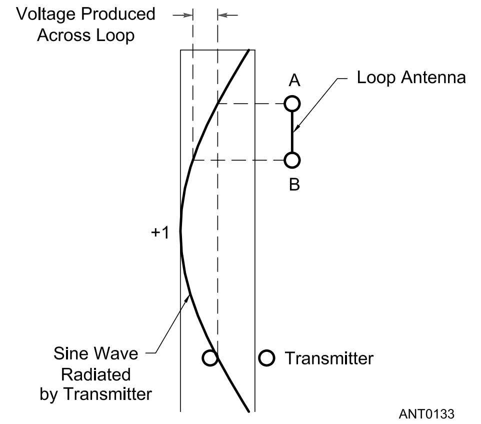

Fig 7—Example of orientation of loop antenna for maximum response.

This equation comes from a term called *effective height*. The effective height refers to the height (length) of a vertical piece of wire above ground that would deliver the same voltage to the receiver. The equation for effective height is

$$h = \frac{2\pi N A}{\lambda} \qquad \text{(Eq 2)}$$

where h is in meters and the other terms are as for Eq 1.

A few minutes with a calculator will show that, with the constraints previously stated, the loop antenna will have a very small effective height. This means it will deliver a relatively small voltage to the receiver, even with a large transmitted signal.

TUNED LOOPS

We can tune the loop by placing a capacitor across the antenna terminals. This causes a larger voltage to appear across the loop terminals because of the Q of the parallel resonant circuit that is formed.

The voltage across the loop terminals is now given by

$$V = \frac{2\pi A N E Q \cos\theta}{\lambda} \qquad \text{(Eq 3)}$$

where Q is the loaded Q of the tuned circuit, and the other terms are as defined above.

Most amateur loops are of the tuned variety. For this reason, all comments that follow are based on tuned-loop antennas, consisting of one or more turns. The tuned-loop antenna has some particular advantages. For example, it puts high selectivity up at the "front" of a receiving system, where it can significantly help factors such as dynamic range. Loaded Q values of 100 or greater are easy to obtain with careful loop construction.

Consider a situation where the inherent selectivity of the loop is helpful. Assume we have a loop with a Q of 100 at 1.805 MHz. We are working a DX station on 1.805 MHz and are suffering strong interference from a local station 10 kHz away. Switching from a dipole to a small loop will reduce the strength of the off-frequency signal by 6 dB (approximately one S unit). This, in effect, increases the dynamic range of the receiver. In fact, if the off-frequency station were further off frequency, the attenuation would be greater.

Another way the loop can help is by using the nulls in its pattern to null out on-frequency (or slightly off-frequency) interference. For example, say we are working a DX station to the north, and just 1 kHz away is another local station engaged in a contact. The local station is to our west. We can simply rotate our loop to put its null to the west, and now the DX station should be readable while the local will be knocked down by 60 or more dB. This obviously is quite a noticeable difference. Loop nulls are very sharp and are generally noticeable only on ground-wave signals (more on this later).

Of course, this method of nulling will be effective only if the interfering station and the station being worked are not in the same direction (or in exact opposite directions) from our location. If the two stations were on the same line from our location, both the station being worked and the undesired station would be nulled out. Luckily the nulls are very sharp, so as long as the stations are at least 10° off axis from each other, the loop null will be usable.

A similar use of the nulling capability is to eliminate local noise interference, such as that from a light dimmer in a neighbor's house. Just put the null on the offending light dimmer, and the noise should disappear.

Now that we have seen some possible uses of the small loop, let us look at a bit of detail about its design. First, the loop forms an inductor having a very small ratio of winding length to diameter. The equations for finding inductance given in most radio handbooks assume that the inductor coil is longer than its diameter. However, F. W. Grover of the US National Bureau of Standards has provided equations for inductors of common cross-sectional shapes and small length-to-diameter ratios. (See the Bibliography at the end of this chapter.) Grover's equations are shown in **Table 1**. Their use will yield relatively accurate numbers; results are easily worked out with a scientific calculator or home computer.

The value of a tuning capacitor for a loop is easy to calculate from the standard resonance equations. The only matter to consider before calculating this is the value of distributed capacitance of the loop winding. This capacitance shows up between adjacent turns of the coil because of their slight difference in potential. This causes each turn to appear as a charge plate. As with all other capacitances, the value of the distributed capacitance is based on the physical dimensions of the coil. An exact mathematical analysis of its value is a complex problem. A simple approximation is given by Medhurst (see Bibliography) as:

$$C = HD \qquad \text{(Eq 4)}$$

where

C = distributed capacitance in pF
H = a constant related to the length-to-diameter ratio of the coil (**Table 2** gives H values for length-to-diameter ratios used in loop antenna work.)
D = diameter of the winding in cm

Medhurst's work was with coils of round cross section. For loops of square cross section the distributed capacitance is given by Bramslev (see Bibliography) as

$$C = 60S \qquad \text{(Eq 5)}$$

where

C = the distributed capacitance in pF
S = the length of the side in meters

If you convert the length in this equation to centimeters, you will find Bramslev's equation gives results in the same order of magnitude as Medhurst's equation.

This distributed capacitance appears as if it were a capacitor across the loop terminals. Therefore, when determining the value of the tuning capacitor, the distributed capacitance must be subtracted from the total capacitance required to resonate the loop. The distributed capacitance also determines the highest frequency at which a particular loop can be used, because it is the minimum capacitance obtainable.

Electrostatically Shielded Loops

Over the years, many loop antennas have incorporated an electrostatic shield. This shield generally takes the form of a tube around the winding, made of a conductive but non-magnetic material (such as copper or aluminum). Its purpose is to maintain loop balance with respect to ground, by forcing the capacitance between all portions of the loop and ground to be identical. This is illustrated in **Fig 8**. It is necessary to maintain electrical loop balance to eliminate what is referred to as the *antenna effect*. When the antenna becomes unbalanced it appears to act partially as a small vertical antenna. This vertical pattern gets superimposed on the ideal figure-eight pattern, distorting the pattern and filling in the nulls. The type of pattern that results is shown in **Fig 9**.

Adding the shield has the effect of somewhat reducing the pickup of the loop, but this loss is generally offset by the increase in null depth of the loops. Proper balance of the loop antenna requires that the load on the loop also be balanced. This is usually accomplished by use of a balun transformer or a balanced input preamplifier. One important point regarding the shield is that it cannot form a continuous electrical path around the loop perimeter, or it will appear as a shorted coil turn. Usually the insulated break is located opposite the feed point to maintain symmetry. Another point to be considered is that the shield should be of a much larger diameter than the loop winding, or it will lower the Q of the loop.

Various construction techniques have been used in

Table 1
Inductance Equations for Short Coils (Loop Antennas)

Triangle:

$$L\left(\mu H\right) = 0.006N^2\, s \left[\ln\left(\frac{1.1547\, sN}{\left(N+1\right)\ell}\right) + 0.65533 + \frac{0.1348\left(N+1\right)\ell}{sN}\right]$$

Square:

$$L\left(\mu H\right) = 0.008N^2\, s \left[\ln\left(\frac{1.4142sN}{\left(N+1\right)\ell}\right) + 0.37942 + \frac{0.3333\left(N+1\right)\ell}{sN}\right]$$

Hexagon:

$$L\left(\mu H\right) = 0.012N^2\, s \left[\ln\left(\frac{2sN}{\left(N+1\right)\ell}\right) + 0.65533 + \frac{0.1348\left(N+1\right)\ell}{sN}\right]$$

Octagon:

$$L\left(\mu H\right) = 0.016N^2 \left[\ln\left(\frac{2.613sN}{\left(N+1\right)\ell}\right) + 0.75143 + \frac{0.07153\left(N+1\right)\ell}{sN}\right]$$

where

N = number of turns
s = side length in cm
ℓ = coil length in cm

Note: In the case of single-turn coils, the diameter of the conductor should be used for ℓ.

Table 2
Values of the Constant H for Distributed Capacitance

Length to Diameter Ratio	*H*
0.10	0.96
0.15	0.79
0.20	0.78
0.25	0.64
0.30	0.60
0.35	0.57
0.40	0.54
0.50	0.50
1.00	0.46

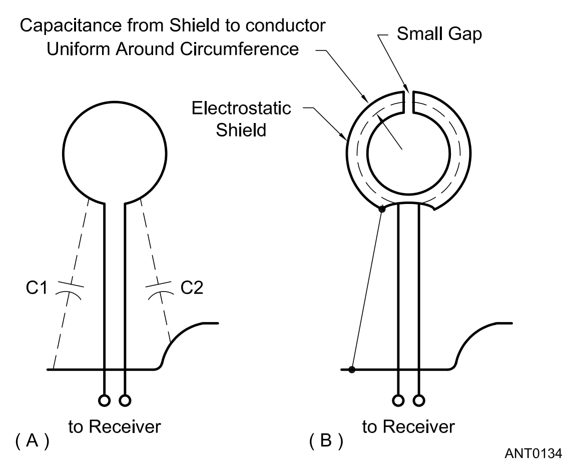

Fig 8—At A, the loop is unbalanced by capacitance to its surroundings. At B, the use of an electrostatic shield overcomes this effect.

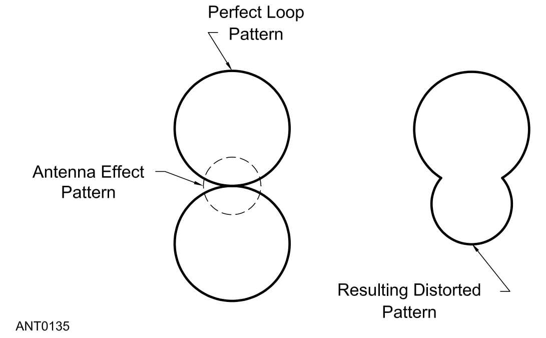

Fig 9—Distortion in loop pattern resulting from antenna effect.

making shielded loops. Genaille located his loop winding inside aluminum conduit, while True constructed an aluminum shield can around his winding. Others have used pieces of Hardline to form a loop, using the outer conductor as a shield. DeMaw used flexible coax with the shield broken at the center of the loop conductor in a multiturn loop for 1.8 MHz. Goldman uses another shielding method for broadcast receiver loops. His shield is in the form of a barrel made of hardware cloth, with the loop in its center. (See Bibliography for above references.) All these methods provide sufficient shielding to maintain the balance. It is possible, as Nelson shows, to construct an unshielded loop with good nulls (60 dB or better) by paying great care to symmetry.

LOOP Q

As previously mentioned, Q is an important consideration in loop performance because it determines both the loop bandwidth and its terminal voltage for a given field strength. The loaded Q of a loop is based on four major factors. These are (1) the intrinsic Q of the loop winding, (2) the effect of the load, (3) the effect of the electrostatic shield, and (4) the Q of the tuning capacitor.

The major factor is the Q of the winding of the loop itself. The ac resistance of the conductor caused by skin effect is the major consideration. The ac resistance for copper conductors may be determined from

$$R = \frac{0.996 \times 10^{-6}\sqrt{f}}{d} \qquad \text{(Eq 6)}$$

where

R = resistance in ohms per foot
f = frequency, Hz
d = conductor diameter, inches

The Q of the inductor is then easily determined by taking the reactance of the inductor and dividing it by the ac resistance. If you are using a multiturn loop and are a perfectionist, you might also want to include the loss from conductor proximity effect. This effect is described in detail later in this chapter, in the section on transmitting loops.

Improvement in Q can be obtained in some cases by the use of Litz wire (short for *Litzendraht*). Litz wire consists of strands of individual insulated wires that are woven into bundles in such a manner that each conductor occupies each location in the bundle with equal frequency. Litz wire results in improved Q over solid or stranded wire of equivalent size, up to about 3 MHz.

Also, the Q of the tuned circuit of the loop antenna is determined by the Q of the capacitors used to resonate it. In the case of air variables or dipped micas this is not usually a problem. But if variable-capacitance diodes are used to remotely tune the loop, pay particular attention to the manufacturer's specification for Q of the diode at the frequency of operation. The tuning diodes can have a significant effect on circuit Q.

Now we consider the effect of load impedance on loop Q. In the case of a directly coupled loop (as in Fig 5), the load is connected directly across the loop terminals, causing it to be treated as a parallel resistance in a parallel-tuned RLC circuit. Obviously, if the load is of a low value, the Q of the loop will be low. A simple way to correct this is to use a transformer to step up the load impedance that appears across the loop terminals. In fact, if we make this transformer a balun, it also allows us to use our unbalanced receivers with the loop and maintain loop symmetry. Another solution is to use what is referred to as an inductively coupled loop, such as DeMaw's four turn electrostatically shielded loop. A one-turn link is connected to the receiver. This turn is wound with the four-turn loop. In effect, this builds the transformer into the antenna.

Another solution to the problem of load impedance on loop Q is to use an active preamplifier with a high impedance balanced input and unbalanced output. This method also has the advantage of amplifying the low-level output voltage of the loop to where it can be used with a receiver of even mediocre sensitivity. In fact, the Q of the loop when used with a balanced preamplifier having high input impedance may be so high as to be unusable in certain applications. An example of this situation would occur where a loop is being used to receive a 5 kHz wide AM signal at a frequency where the bandwidth of the loop is only 1.5 kHz. In this case the detected audio might be very distorted. The solution to this is to put a Q-degrading resistor across the loop terminals.

FERRITE-CORE LOOP ANTENNAS

The ferrite-core loop antenna is a special case of the air-core receiving loops considered up to now. Because of its use in every AM broadcast-band portable radio, the ferrite-core loop is, by quantity, the most popular form of the loop antenna. But broadcast-band reception is far from its only use; it is commonly found in radio-direction-finding equipment and low-frequency-receiving systems (below 500 kHz) for time and frequency standard systems. In recent years, design information on these types of antennas has been a bit sparse in the amateur literature, so the next few paragraphs are devoted to providing some details.

Ferrite-loop antennas are characteristically very small compared to the frequency of use. For example, a 3.5-MHz version may be in the range of 15 to 30 cm long and about 1.25 cm in diameter. Earlier in this chapter, effective height was introduced as a measure of loop sensitivity. The effective height of an air-core loop antenna is given by Eq 2.

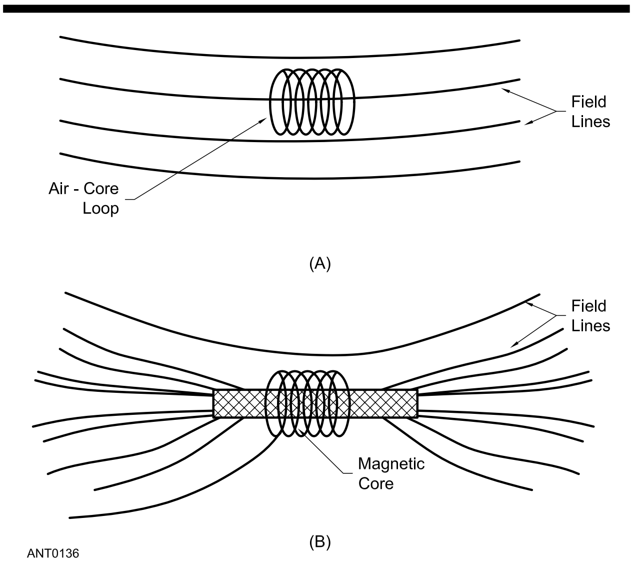

Fig 10—At A, an air-core loop has no effect on nearby field lines. B illustrates the effect of a ferrite core on nearby field lines. The field is altered by the reluctance of the ferrite material.

If an air-core loop is placed in a field, in essence it cuts the lines of flux without disturbing them (**Fig 10A**). On the other hand, when a ferrite (magnetic) core is placed in the field, the nearby field lines are redirected into the loop (Fig 10B). This is because the reluctance of the ferrite material is less than that of the surrounding air, so the nearby flux lines tend to flow through the loop rather than passing it by. (Reluctance is the magnetic analogy of resistance, while flux is analogous to current.) The reluctance is inversely proportional to the permeability of the rod core, μ_{rod}. (In some texts the rod permeability is referred to as effective permeability, μ_{eff}). This effect modifies the equation for effective height of a ferrite-core loop to

$$h = \frac{2\pi N A \mu_{rod}}{\lambda} \qquad \text{(Eq 7)}$$

where

h = effective height (length) in meters
N = number of turns in the loop
A = area of loop in square meters
μ_{rod} = permeability of the ferrite rod
λ = wavelength of operation in meters

This obviously is a large increase in "collected" signal. If the rod permeability were 90, this would be the same as making the loop area 90 times larger with the same number of turns. For example, a 1.25-cm diameter ferrite-core loop would have an effective height equal to an air-core loop 22.5 cm in diameter (with the same number of turns).

By now you might have noticed we have been very careful to refer to rod permeability. There is a very important reason for this. The permeability that a rod of ferrite exhibits is a combination of the material permeability or μ, the shape of the rod, and the dimensions of the rod. In ferrite rods, μ is sometimes referred to as initial permeability, μ_i, or toroidal permeability, μ_{tor}. Because most amateur ferrite loops are in the form of rods, we will discuss only this shape.

The reason that μ_{rod} is different from μ is a very complex physics problem that is well beyond the scope of this book. For those interested in the details, books by Polydoroff and by Snelling cover this subject in considerable detail. (See Bibliography.) For our purposes a simple explanation will suffice. The rod is in fact not a perfect director of flux, as is illustrated in **Fig 11**. Note that some lines impinge on the sides of the core and also exit from the sides. These lines therefore would not pass through all the turns of the coil if it were wound from one end of the core to the other. These flux lines are referred to as *leakage flux*, or sometimes as flux leakage.

Leakage flux causes the flux density in the core to be nonuniform along its length. From Fig 11 it can be seen that the flux has a maximum at the geometric center of the length of the core, and decreases as the ends of the core are approached. This causes some noticeable effects. As a short coil is placed at different locations along a long core, its inductance will change. The maximum inductance exists when the coil is centered on the rod. The Q of a short coil on a long rod is greatest at the center. On the other hand, if you require a higher Q than this, it is recommended that you spread the coil turns along the whole length of the core, even though this will result in a lower value of inductance. (The inductance can be increased to the original value by adding turns.) **Fig 12** gives the relationship of rod permeability to material permeability for a variety of values.

The change in μ over the length of the rod results in an adjustment in the term μ_{rod} for its so called “free ends” (those not covered by the winding). This adjustment factor is given by

$$\mu' = \mu_{rod} \sqrt[3]{\frac{a}{b}} \qquad \text{(Eq 8)}$$

where

μ' = the corrected permeability
a = the length of the core
b = the length of the coil

This value of μ' should be used in place of μ_{rod} in Eq 7 to obtain the most accurate value of effective height.

All these variables make the calculation of ferrite loop antenna inductance somewhat less accurate than for the air-core version. The inductance of a ferrite loop is given by

$$L = \frac{4\pi N^2 A \mu_{rod} \times 10^{-4}}{\ell} \qquad \text{(Eq 9)}$$

where

L = inductance in μH
N = number of turns
A = cross-sectional area of the core in square mm
ℓ = magnetic length of core in mm

Experiments indicate that the winding diameter should be as close to that of the rod diameter as practical in order to maximize both inductance value and Q. By using all this information, we may determine the voltage at the loop terminals and its signal-to-noise ratio (SNR). The voltage may be determined from

$$V = \frac{2\pi A N \mu' Q E}{\lambda} \qquad \text{(Eq 10)}$$

where

V = output voltage across the loop terminals
A = loop area in square meters
N = number of turns in the loop winding
μ' = corrected rod permeability
Q = loaded Q of the loop
E = RF field strength in volts per meter
λ = wavelength of operation in meters

Lankford’s equation for the sensitivity of the loop for a 10 dB SNR is

$$E = \frac{1.09 \times 10^{-10} \lambda \sqrt{f\ L\ b}}{A N \mu' \sqrt{Q}} \qquad \text{(Eq 11)}$$

where

f = operating frequency in Hz
L = loop inductance in henrys
b = receiver bandwidth in Hz

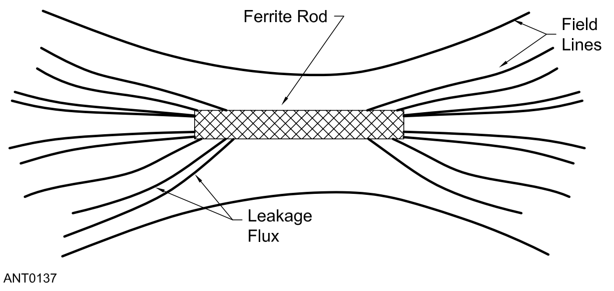

Fig 11—Example of magnetic field lines near a practical ferrite rod, showing leakage flux.

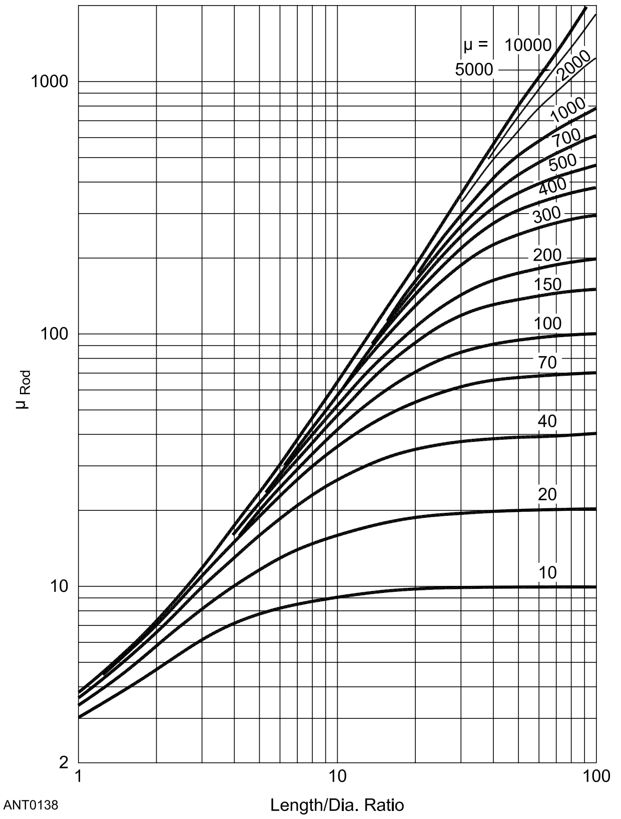

Fig 12—Rod permeability, μ_{rod}, versus material permeability, μ, for different rod length-to-diameter ratios.

Similarly, Belrose gives the SNR of a tuned loop antenna as

$$\mathrm{SNR} = \frac{66.3\,N\,A\,\mu_{\mathrm{rod}}\,E}{\sqrt{b}}\sqrt{\frac{Q\,f}{L}} \qquad \text{(Eq 12)}$$

From this, if the field strength E, μ_{rod}, b, and A are fixed, then Q or N must increase (or L decrease) to yield a better SNR. Higher sensitivity can also be obtained (especially at frequencies below 500 kHz) by bunching ferrite cores together to increase the loop area over that which would be possible with a single rod. High sensitivity is important because loop antennas are not the most efficient collectors of signals, but they do offer improvement over other receiving antennas in terms of SNR. For this reason, you should attempt to maximize the SNR when using a small loop receiving antenna. In some cases there may be physical constraints that limit how large you can make a ferrite-core loop.

After working through Eq 11 or 12, you might find you still require some increase in antenna system gain to effectively use your loop. In these cases the addition of a low noise preamplifier may be quite valuable even on the lower frequency bands where they are not commonly used. Chapter 14 contains information on such preamplifiers.

The electrostatic shield discussed earlier with reference to air-core loops can be used effectively with ferrite-core loops. (Construction examples are presented in Chapter 14.) As in the air-core loop, a shield will reduce electrical noise and improve loop balance.

PROPAGATION EFFECTS ON NULL DEPTH

After building a balanced loop you may find it does not approach the theoretical performance in the null depth. This problem may result from propagation effects. Tilting the loop away from a vertical plane may improve performance under some propagation conditions, to account for the vertical angle of arrival. Basically, the loop performs as described above only when the signal is arriving perpendicular to the axis of rotation of the loop. At incidence angles other than perpendicular, the position and depth of the nulls deteriorate.

The problem can be even further influenced by the fact that if the loop is situated over less than perfectly conductive ground, the wave front will appear to tilt or bend. (This bending is not always detrimental; in the case of Beverage antennas, sites are chosen to take advantage of this effect.)

Another cause of apparent poor performance in the null depth can be from polarization error. If the polarization of the signal is not completely linear, the nulls will not be sharp. In fact, for circularly polarized signals, the loop might appear to have almost no nulls. Propagation effects are discussed further in Chapter 14.

SITING EFFECTS ON THE LOOP

The location of the loop has an influence on its performance that at times may become quite noticeable. For ideal performance the loop should be located outdoors and clear of any large conductors, such as metallic downspouts and towers. A VLF loop, when mounted this way, will show good sharp nulls spaced 180° apart if the loop is well balanced. This is because the major propagation mode at VLF is by ground wave. At frequencies in the HF region, a significant portion of the signals is propagated by sky wave, and nulls are often only partial.

Most hams locate their loop antennas near their operating position. If you choose to locate a small loop indoors, its performance may show nulls of less than the expected depth, and some skewing of the pattern. For precision direction finding there may be some errors associated with wiring, plumbing, and other metallic construction members in the building. Also, a strong local signal may be reradiated from the surrounding conductors so that it cannot be nulled with any positioning of the loop. There appears to be no known method of curing this type of problem. All this should not discourage you from locating a loop indoors; this information is presented here only to give you an idea of some pitfalls. Many hams have reported excellent results with indoor mounted loops, in spite of some of the problems.

Locating a receiving loop in the field of a transmitting antenna may cause a large voltage to appear at the receiver antenna terminals. This may be sufficient to destroy sensitive RF amplifier transistors or front-end protection diodes. This can be solved by disconnecting your loop from the receiver during transmit periods. This can obviously be done automatically with a relay that opens when the transmitter is activated.

LOOP ANTENNA ARRAYS

Arrays of loop antennas, both in combination with each other and with other antenna types, have been used for many years. The arrays are generally used to cure some “deficiency” in the basic loop for a particular application, such as a 180° ambiguity in the null direction, low sensitivity, and so forth.

A Sensing Element

For direction-finding applications the single loop suffers the problem of having two nulls that are 180° apart. This leads to an ambiguity of 180° when trying to find the direction to a transmitting station from a given location. A sensing element (often called a *sense antenna*) may be added to the loop, causing the overall antenna to have a cardioid pattern and only one null. The sensing element is a small vertical antenna whose height is equal to or greater than the loop effective height. This vertical is physically close to the loop, and when its omnidirectional pattern is adjusted so that its amplitude and phase are equal to one of the loop lobes, the patterns combine to form a cardioid. This antenna can be made quite compact by use of a ferrite loop to form a portable DF antenna for HF direction finding. Chapter 14 contains additional information and construction projects using sensing elements.

Arrays of Loops

A more advanced array that can develop more diverse patterns consists of two or more loops. Their outputs are combined through appropriate phasing lines and combiners to form a phased array. Two loops can also be formed into an array that can be rotated without physically turning the loops themselves. This method was developed by Bellini and Tosi in 1907 and performs this apparently contradictory feat by use of a special transformer called a *goniometer*. The goniometer is described in Chapter 14.

Aperiodic Arrays

The aperiodic loop array is a wide-band antenna. This type of array is useful over at least a decade of frequency, such as 2 to 20 MHz. Unlike most of the loops discussed up to now, the loop elements in an aperiodic array are untuned. Such arrays have been used commercially for many years. One loop used in such an array is shown in **Fig 13**. This loop is quite different from all the loops discussed so far in this chapter because its pattern is not the familiar figure eight. Rather, it is omnidirectional.

The antenna is omnidirectional because it is purposely unbalanced, and also because the isolating resistor causes the antenna to appear as two closely spaced short monopoles. The loop maintains the omnidirectional characteristics over a frequency range of at least four or five to one. These loops, when combined into end-fire or broadside phased arrays, can provide quite impressive performance. A commercially made end-fire array of this type consisting of four loops equally spaced along a 25-meter baseline can provide gains in excess of 5 dBi over a range of 2 to 30 MHz. Over a considerable portion of this frequency range, the array can maintain F/B ratios of 10 dB. Even though the commercial version is very expensive, an amateur version can be constructed using the information provided by Lambert. One interesting feature of this type of array is that, with the proper combination of hybrids and combiners, the antenna can simultaneously feed two receivers with signals from different directions, as shown in **Fig 14**. This antenna may be especially interesting to one wanting a directional receiving array for two or more adjacent amateur bands.

SMALL TRANSMITTING LOOP ANTENNAS

The electrically small transmitting-loop antenna involves some different design considerations compared to receiving loops. Unlike receiving loops, the size limitations of the antenna are not as clearly defined. For most purposes, any transmitting loop whose physical circumference is less than ¼ λ can be considered "small." In most cases, as a consequence of their relatively large size (when compared to a receiving loop), transmitting loops have a nonuniform current distribution along their circumference. This leads to some performance changes from a receiving loop.

The transmitting loop is a parallel-tuned circuit with a large inductor acting as the radiator. As with the receiving

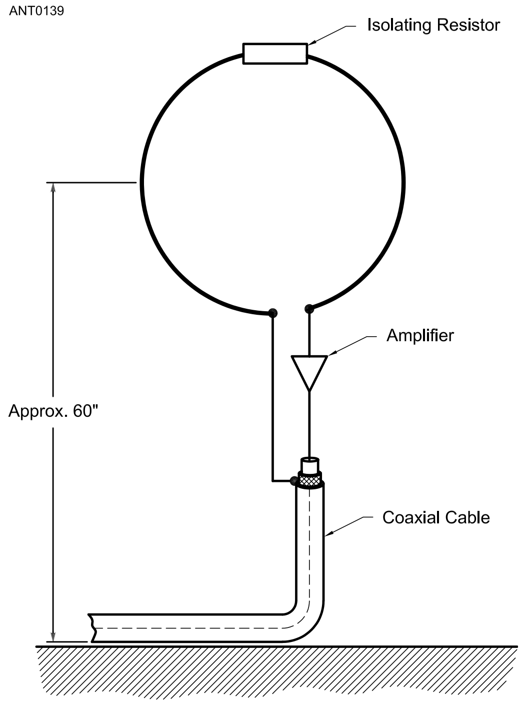

Fig 13—A single wide-band loop antenna used in an aperiodic array.

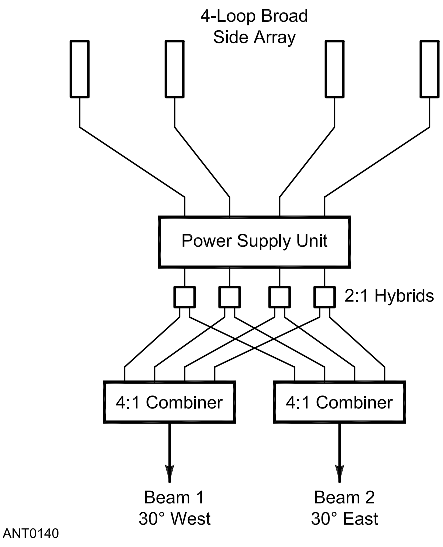

Fig 14—Block diagram of a four-loop broadside array with dual beams separated by 60° in azimuth.

Table 3
Transmitting Loop Equations

$$X_L = 2\pi f L \text{ ohms}$$

$$Q = \frac{f}{\Delta f} = \frac{X_L}{2\left(R_R + R_L\right)}$$

$$R_R = 3.12 \times 10^4 \left[\frac{NA}{\lambda^2}\right]^2 \text{ ohms}$$

$$V_C = \sqrt{P X_L Q}$$

$$I_L = \sqrt{\frac{PQ}{X_L}}$$

where

X_L = inductive reactance, ohms
f = frequency, Hz
Δf = bandwidth, Hz
R_R = radiation resistance, ohms
R_L = loss resistance, ohms (see text)
N = number of turns
A = area enclosed by loop, square meters
λ = wavelength at operating frequency, meters
V_C = voltage across capacitor
P = power, watts
I_L = resonant circulating current in loop

loop, the calculation of the transmitting-loop inductance may be carried out with the equations in Table 1. Avoid equations for long solenoids found in most texts. Other fundamental equations for transmitting loops are given in **Table 3**.

In the March 1968 *QST*, Lew McCoy, W1ICP, introduced the so-called "Army Loop" to radio amateurs. This was an amateur version of a loop designed for portable use in Southeast Asia by Patterson of the US Army and described in 1967. The Army Loop is diagrammed in **Fig 15A**, showing that this is a parallel tuned circuit fed by a tapped-capacitance impedance-matching network.

The Hart "high-efficiency" loop was introduced in the June 1986 *QST* by Ted Hart, W5QJR. It is shown schematically in Fig 15B and has the series-tuning capacitor separate from the matching network. The Hart matching network is basically a form of gamma match. Other designs have used a smaller loop connected to the transmission line to couple into the larger transmitting loop.

The approximate radiation resistance of a loop in ohms is given by

$$R_R = 3.12 \times 10^4 \left(\frac{NA}{\lambda^2}\right)^2 \qquad \text{(Eq 13)}$$

where

N = number of turns
A = area of loop in square meters
λ = wavelength of operation in meters

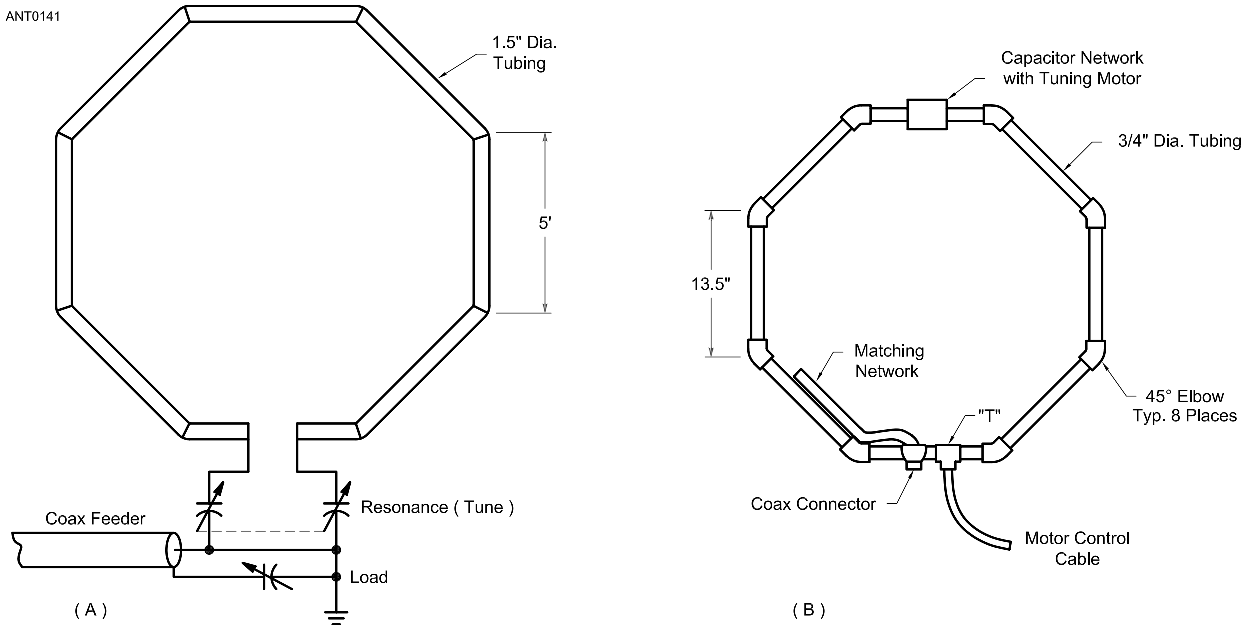

Fig 15—At A, a simplified diagram of the Army Loop. At B, the W5QJR loop, which is described in more detail later in this chapter.

The radiation resistance of a small transmitting loop is usually very small. For example, a 1-meter diameter, single-turn circular loop has a radius of 0.5 meters and an enclosed area of $\pi \times 0.5^2 = 0.785$ m^2. Operated at 14.0 MHz, the free-space wavelength is 21.4 meters and this leads to a computed radiation resistance of only $3.12 \times 10^{-4} (0.785/21.4^2)^2 = 0.092\ \Omega$.

Unfortunately the loop also has losses, both ohmic and from skin effect. By using this information, the radiation efficiency of a loop can be calculated from

$$\eta = \frac{R_R}{R_R + R_L} \qquad \text{(Eq 14)}$$

where

η = antenna efficiency, %

R_R = radiation resistance, Ω

R_L = loss resistance, Ω, which includes the loop's conductor loss plus the loss in the series-tuning capacitor.

A simple ratio of R_R versus R_L shows the effects on the efficiency, as can be seen from **Fig 16**. The loss resistance is primarily the ac resistance of the conductor. This can be calculated from Eq 6. A transmitting loop generally requires the use of copper conductors of at least ¾ inch in diameter in order to obtain reasonable efficiency. Tubing is as useful as a solid conductor because high-frequency currents flow only along a very small depth of the surface of the conductor; the center of the conductor has almost no effect on current flow.

Note that the R_L term above also includes the effect of the tuning capacitor's loss. Normally, the unloaded Q of a capacitor can be considered to be so high that any loss in the tuning capacitor can be neglected. For example, a very high-quality tuning capacitor with no mechanical wiping contacts, such as a vacuum-variable or a transmitting butterfly capacitor, might have an unloaded Q of about 5000. This implies a series loss resistance of less than about 0.02 Ω for a capacitive reactance of 100 Ω. This relatively tiny loss resistance can become significant, however, when the radiation resistance of the loop is only on the order of 0.1 Ω! Practical details for curbing capacitor losses are covered later in this chapter.

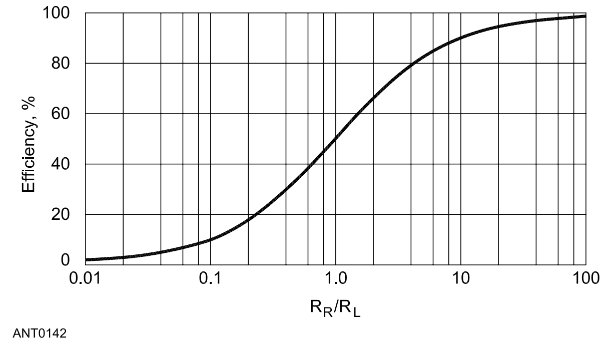

Fig 16—Effect of ratio of R_R/R_L on loop efficiency.

In the case of multiturn loops there is an additional loss related to a term called *proximity effect*. The proximity effect occurs in cases where the turns are closely spaced (such as being spaced one wire diameter apart). As these current-carrying conductors are brought close to each other, the current density around the circumference of each conductor gets redistributed. The result is that more current per square meter is flowing at the surfaces adjacent to other conductors. This means that the loss is higher than a simple skin-effect analysis would indicate, because the current is bunched so it flows through a smaller cross section of the conductor than if the other turns were not present.

As the efficiency of a loop approaches 90%, the proximity effect is less serious. But unfortunately, the less efficient the loop, the worse the effect. For example, an 8-turn transmitting loop with an efficiency of 10% (calculated by the skin-effect method) actually only has an efficiency of 3% because of the additional losses introduced by the proximity effect. If you are contemplating construction of a multiturn transmitting loop, you might want to consider spreading the conductors apart to reduce this effect. G. S. Smith includes graphs that detail this effect in his 1972 IEEE paper.

The components in a resonated transmitting loop are subject to both high currents and voltages as a result of the large circulating currents found in the high-Q tuned circuit formed by the antenna. This makes it important that any fixed capacitors have a high RF current rating, such as transmitting micas or the Centralab 850 series. Be aware that even a 100-W transmitter can develop currents in the tens of amperes, and voltages across the tuning capacitor in excess of 10,000 V. This consideration also applies to any conductors used to connect the loop to the capacitors. A piece of #14 wire may have more resistance than the rest of the loop conductor!

It is therefore best to use copper strips or the braid from a piece of large coax cable to make any connections. Make the best electrical connection possible, using soldered or welded joints. Using nuts and bolts should be avoided, because at RF these joints generally have high resistance, especially after being subjected to weathering.

An unfortunate consequence of having a small but high-efficiency transmitting loop is high loaded Q, and therefore limited bandwidth. This type of antenna may require retuning for frequency changes as little as 5 kHz. If you are using any wide-band mode such as AM or FM, this might cause fidelity problems and you might wish to sacrifice a little efficiency to obtain the required bandwidth.

A special case of the transmitting loop is that of the ferrite-loaded loop. This is a logical extension of the transmitting loop if we consider the improvement that a ferrite core makes in receiving loops. The use of ferrites in a transmitting loop is still under development. (See the Bibliography reference for DeVore and Bohley.)

PRACTICAL COMPACT TRANSMITTING LOOPS

The ideal small transmitting antenna would have performance equal to a large antenna. A small loop antenna can approach that performance except for a reduction in bandwidth, but that effect can be overcome by retuning. This section is adapted and updated from material written by Robert T. (Ted) Hart, W5QJR.

As pointed out above, small antennas are characterized by low radiation resistance. For a typical small antenna, such as a short dipole, loading coils are often added to achieve resonance. However, the loss inherent in the coils can result in an antenna with low efficiency. If instead of coils a large, low-loss capacitor is added to a low-loss conductor to achieve resonance, and if the antenna conductor is bent to connect the ends to the capacitor, a loop is formed.

Based on this concept, the small loop is capable of relatively high efficiency, compared to its coil-loaded cousin. In addition, the small loop, when mounted vertically, can radiate efficiently over the wide range of elevation angles required on the lower frequency bands. This is because it has both high-angle and low-angle response. See **Fig 17**, which shows the elevation response for a compact transmitting loop only 16.2 inches wide at 14.2 MHz. This loop is vertically polarized and its bottom is 8 feet above average ground, which has a conductivity of 5 mS/m and a dielectric constant of 13. For comparison, Fig 17 also shows the responses of three other reference antennas—the same small loop flipped sideways at a height of 30 feet to produce horizontal radiation, a full-sized ¼-λ ground plane antenna mounted 8 feet above average ground using two tuned radials, and finally a simple ½ λ flattop dipole mounted 30 feet above flat ground. The considerably smaller transmitting loop comes to within 3 dB of the larger ¼-λ vertical at a 10° elevation angle, and it is far stronger for high elevation angles because it does not have the null at high elevation angles that the ground plane has. Of course, this characteristic does make it more susceptible to strong signals received at high elevation angles. Incidentally, just in case you were wondering, adding more radials to the λ/4 ground plane doesn't materially improve its performance when mounted at an 8-foot height on 20 meters.

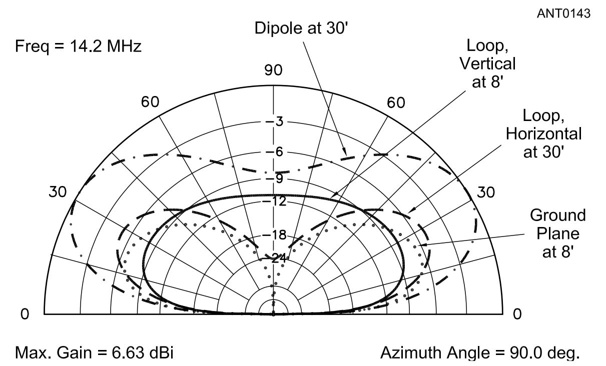

Fig 17—Elevation-plane plot at 14.2 MHz, showing response of an 8.5-foot circumference octagonal copper loop (width of 16.2 inches), compared to a full-sized λ/4 ground-plane vertical with two elevated λ/4 radials, the same small loop flipped horizontally at a height of 30 feet, and lastly, a λ/2 flattop dipole also at a height of 30 feet. Both the λ/4 ground-plane vertical and the vertically polarized loop are elevated 8 feet above typical ground, with σ = 5 mS/m and ε = 13. The low vertically polarized loop is surprisingly competitive, only down about 2.5 dB compared to the far larger ground plane at low elevation angles. Note that the vertical loop has both high-angle as well as low-angle radiation, and hence would be better at working close-in local stations than the ground-plane vertical, with its deep nulls at higher angles. The simple flattop dipole, however, is better than either vertical because of the poor ground reflection for a vertically polarized compared to a horizontally polarized signal.

The simple horizontal dipole in Fig 17 would be the clear winner in any shootout because its horizontally polarized radiation does not suffer as much attenuation at reflection from ground as does a vertically polarized wave. The case is not quite so clear-cut, however, for the small loop mounted horizontally at 30 feet. While it does have increased gain at medium elevation angles, it may not be worth the effort needed to mount it on a mast, considering the slight loss at low angles compared to its twin mounted vertically only 8 feet above ground.

A physically small antenna like the 16.2-inch-wide vertically polarized loop does put out an impressive signal compared to far larger competing antennas. Though somewhat ungainly, it is a substantially better performer than most mobile whips, for example. The main deficiency in a compact transmitting loop is its narrow bandwidth—it must be accurately tuned to the operating frequency. The use of a remote motor drive allows the loop to be tuned over a wide frequency range.

For example, for fixed-station use, two loops could be constructed to provide continuous frequency coverage from 3.5 to 30 MHz. A loop with an 8.5 foot circumference, 16 inches wide, could cover 10 through 30 MHz and a loop with a 20-foot circumference, 72 inches wide, could cover 3.5 to 10.1 MHz.

Table 4 presents summary data for various size loop antennas for the HF amateur bands. Through computer analysis, the optimum size conductor was determined to be 3/4-inch rigid copper water pipe, considering both performance and cost. Performance will be compromised, but only slightly, if 5/8-inch flexible copper tubing is used. This tubing can easily be bent to any desired shape, even a circle. The rigid 3/4-inch copper pipe is best used with 45° elbows to make an octagon.

The loop circumference should be between 1/4 and 1/8 λ at the operating frequency. It will become self-resonant above 1/4 λ, and efficiency drops rapidly below 1/8 λ. In the frequency ranges shown in Table 4, the high fre-

Table 4

Design Data for Loops

Loop Circumference = 8.5' (Width = 32.4"), Vertically Polarized

Frequency, MHz	10.1	14.2	21.2	29.0
Max Gain, dBi	–4.47	–1.42	+1.34	+2.97
Max Elevation Angle	40°	30°	22°	90°
Gain, dBi @10°	–8.40	–4.61	–0.87	+0.40
Total Capacitance, pF	145	70	29	13
Peak Capacitor kV	23	27	30	30

Loop Circumference = 8.5' (Width = 32.4"), Horizontally Polarized, @30'

Frequency, MHz	10.1	14.2	21.2	29.0
Max Gain, dBi	–3.06	+1.71	+5.43	+6.60
Max Elevation Angle	34°	28°	20°	16°
Gain, dBi @10°	–9.25	–3.11	+2.61	+5.34
Total Capacitance, pF	145	70	29	13
Peak Capacitor kV	23	27	30	30

Loop Circumference = 20' (Width = 6'), Vertically Polarized

Frequency, MHz	3.5	4.0	7.2	10.1
Max Gain, dBi	–7.40	–6.07	–1.69	–0.34
Max Elevation Angle	68°	60°	38°	30°
Gain, dBi @10°	–11.46	–10.12	–5.27	–3.33
Capacitance, pF	379	286	85	38
Peak Capacitor kV	22	24	26	30

Loop Circumference = 20' (Width = 6'), Horizontally Polarized, @30'

Frequency, MHz	3.5	4.0	7.2	10.1
Max Gain, dBi	–13.32	–10.60	–0.20	+3.20
Max Elevation Angle	42°	42°	38°	34°
Gain, dBi @10°	–21.62	–18.79	–7.51	–3.22
Capacitance, pF	379	286	85	38
Peak Capacitor kV	22	24	26	30

Loop Circumference = 38' (Width = 11.5'), Vertically Polarized

Frequency, MHz	3.5	4.0	7.2
Max Gain, dBi	–2.93	–2.20	–0.05
Max Elevation Angle	46°	42°	28°
Gain, dBi @10°	–6.48	–5.69	–2.80
Capacitance, pF	165	123	29
Peak Capacitor kV	26	27	33

Notes: These loops are octagonal in shape, constructed with ¾-inch copper water pipe and soldered 45° copper elbows. The gain figures assume a capacitor unloaded $Q_C = 5000$, typical for vacuum-variable type of tuning capacitor. The bottom of the loop is assumed to be 8 feet high for safety and the ground constants are "typical" at conductivity = 5 mS/m and dielectric constant = 13. Transmitter power is 1500 W. The voltage across the tuning capacitor for lower powers goes down with a multiplier of $\sqrt{\frac{P}{1500}}$. For example, at 100 W using the 38-foot-circumference loop at 7.2 MHz, the peak voltage would be $33\text{ kV} \times \sqrt{\frac{100}{1500}} = 8.5\text{ kV}$.

quency is tuned with a minimum capacitance of about 29 pF—including stray capacitance.

The low frequency listed in Table 4 is that where the loop response is down about 10 dB from that of a full-sized elevated ground plane at low elevation angles suitable for DX work. **Fig 18** shows an overlay at 3.5 MHz of the elevation responses for two loops: one with an 8.5-foot circumference and one with a 20-foot circumference, together with the response for a full-sized 80-meter ground plane elevated 8 feet off average ground with 2 tuned radials. The 20-foot circumference loop holds its own well compared to the full-sized ground plane.

Controlling Losses

Contrary to earlier reports, adding quarter-wave ground radials underneath a vertically polarized transmitting loop doesn't materially increase loop efficiency. The size of the conductor used for a transmitting loop, however, does directly affect several interrelated aspects of loop performance.

Data for Table 4 was computed for ¾-inch copper water pipe (nominal OD of 0.9 inch). Note that the efficiency is higher and the Q is lower for loops having a circumference near $\frac{1}{4}\ \lambda$. Larger pipe size will reduce the loss resistance, but the Q increases. Therefore the bandwidth decreases, and the voltage across the tuning capacitor increases. The voltage across the tuning capacitor for high-power operation can become very impressive, as shown in Table 4. Rigid ¾-inch copper water pipe is a good electrical compromise and can also help make a small-diameter loop mechanically sturdy.

The equivalent electrical circuit for the loop is a parallel resonant circuit with a very high Q, and therefore a narrow bandwidth. The efficiency is a function of radiation resistance divided by the sum of the radiation plus loss resistances. The radiation resistance is much less than 1 Ω, so it is necessary to minimize the loss resistance, which is largely the skin-effect loss of the conductor, assuming that the tuning capacitor has very low loss. Poor construction techniques must be avoided. All joints in the loop must be brazed or soldered.

However, if the system loss is too low, for example by using even larger diameter tubing, the Q may become excessive and the bandwidth may become too narrow for practical use. These reasons dictate the need for a complete analysis to be performed before proceeding with the construction of a loop.

There is another source of additional loss in a completed loop antenna besides the conductor and capacitor losses. If the loop is mounted near lossy metallic conductors, the large magnetic field produced will induce currents into those conductors and be reflected as losses in the loop. Therefore the loop should be as far from other conductors as possible. If you use the loop inside a building constructed with large amounts of iron or near ferrous materials, you will simply have to live with the loss if the loop cannot otherwise be relocated.

The Tuning Capacitor

Fig 19 demonstrates the selection of loop size versus tuning capacitance for any desired operating frequency range for the HF amateur bands. This is for octagonal-shaped loops using ¾-inch copper water pipe with 45° copper elbows. For example, a capacitor that varies from 5 to 50 pF, used with a loop 10 feet in circumference, tunes from 13 to 27 MHz (represented by the left dark vertical bar). A 25 to 150-pF capacitor with a 13.5-foot loop circumference covers the 7 to 14.4-MHz range, represented by the right vertical bar.

Fig 20 illustrates how the 29-MHz elevation pattern becomes distorted and rather bulbous-looking for the 10-foot circumference loop, although the response at low elevation angles is still better than that of a full-sized ground-plane antenna.

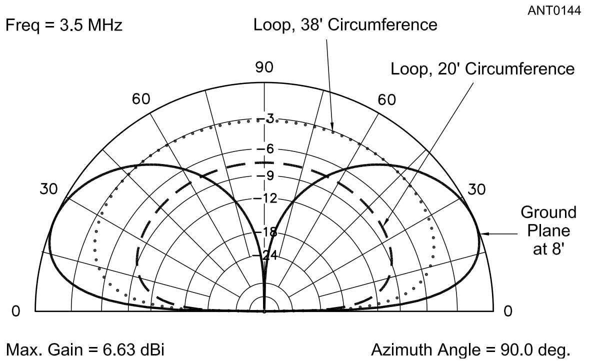

Fig 18—Elevation-plane response of three antennas at 3.5 MHz—a 20-foot circumference octagonal copper loop, a 38-foot circumference copper loop and a full-sized λ/4 ground plane with two elevated radials. The bottom of each antenna is mounted 8 feet above ground for safety. The 38-foot circumference loop (which has a "wingspan" of 11.5 feet) is fairly competitive with the much large ground-plane, being down only about 4 dB at low elevation angles. The 20-foot circumference loop is much more lossy, but with its top only about 14 feet off the ground is very much of a "stealth" antenna.

Air Variable Capacitors

Special care must be taken with the tuning capacitor if an air-variable type is used. The use of a split-stator capacitor eliminates the resistance of wiper contacts, resistance that is inherent in a single-section capacitor. The ends of the loop are connected to the stators, and the rotor forms the variable coupling path between the stators. With this arrangement the value of capacitance is divided by two, but the voltage rating is doubled.

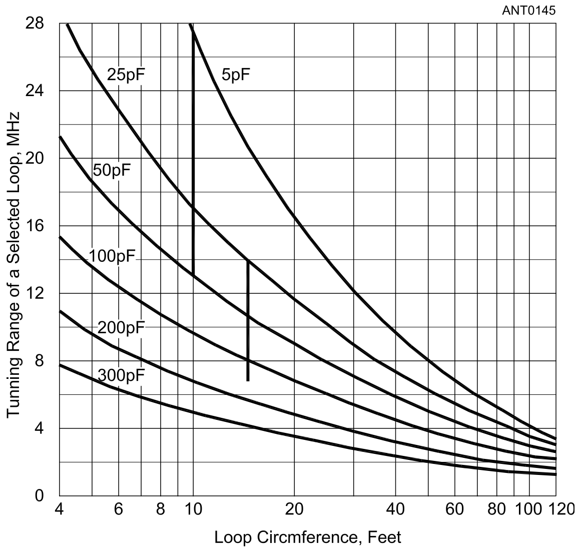

Fig 19—Frequency tuning range of an octagon-shaped loop using $^{3}/_{4}$-inch copper water pipe, for various values of tuning capacitance and loop circumference.

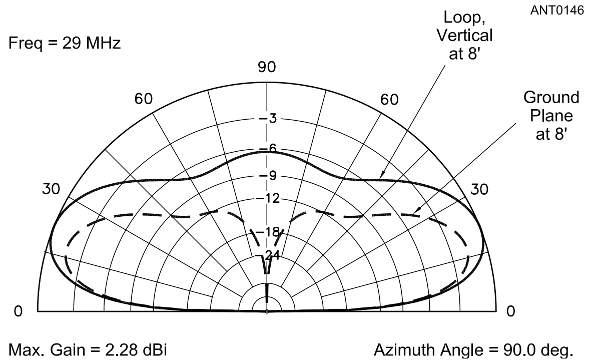

Fig 20—Elevation-plane plot for a 16.2-inch wingspan octagonal copper loop at 29 MHz, compared to a λ/4 ground-plane antenna with two resonant elevated radials. The gains at low angles are almost identical, but the loop exhibits more gain at medium and high elevation angles. Again, the bottom of each antenna is located 8 feet above ground for safety.

You must carefully select a variable capacitor for transmitting-loop application—that is, all contacts must be welded, and no mechanical wiping contacts are allowed. For example, if the spacers between plates are not welded to the plates, there will be loss at each joint, and thus degraded loop efficiency. (Earlier transmitting loops exhibited poor efficiency because capacitors with wiping contacts were used.)

There are several suitable types of capacitors for this application. A vacuum variable is an excellent choice, provided one is selected with an adequate voltage rating. Unfortunately, those capacitors are very expensive.

W5QJR used a specially modified air-variable capacitor in his designs. This had up to 340 pF maximum per section, with 1/4-inch spacing, resulting in 170 pF when both sections were in series as a butterfly capacitor. Another alternative is to obtain a large air variable, remove the aluminum plates, and replace them with copper or double-sided PC board material to reduce losses. Connect all plates together on the rotor and on the stators. Solder copper straps to the capacitor for soldering to the loop itself.

The spacing between plates in an air-variable capacitor determines the voltage-handling capability, rated at 75,000 V per inch. For other power ratings, multiply the spacing (and voltage) by the square root of the ratio of your power to 1000 W. For example, for 100 W, the ratio would be = 0.316.

Table 5
KD7S Loop-Tuning Capacitor Parts List for Nominal 50-pF Capacitor

Qty	*Description*
2	10-inch length of ¾-inch-ID type M copper water pipe
2	10-inch length of ½-inch-ID type M copper water pipe
1	3-inch length of ½-inch-ID type M copper water pipe
2	½-inch, 90° copper elbows
2	¾-inch, 90° copper elbows
2	10 × 22-inch piece of 0.005-inch-thick Teflon sheet plastic
1	12-inch length of #8-32 threaded brass rod
1	#8-32 brass shoulder nut
2	22 × 5½ × ¼-inch ABS plastic sheet (top and bottom covers)
3	1 × 5½ × ¼-inch ABS plastic sheet (end pieces and center) brace/guide
2	1 × 22 × ¼-inch ABS plastic sheet (side rails)
1	50 to 200-rpm gear-head dc motor
1	DPDT center-off toggle switch (up/down control)
2	SPDT microswitches (limit switches)
50 feet	3-conductor control cable
1	Enclosure for control switch

A Teflon-Insulated Trombone Variable Capacitor

Another type of variable capacitor discussed in the amateur literature for use with a compact transmitting loop is the so-called "trombone" type of capacitor. **Fig 21** shows a practical trombone capacitor created by Bill Jones, KD7S, for Nov 1994 *QST*. This capacitor uses downward pointing extensions of the two 3/4-inch OD main conductor copper pipes, with a Teflon-insulated trombone section made of 1/2-inch ID copper pipe. The trombone telescopes into the main pipes, driven by a lead screw and a 180-rpm gear-head motor. Like the butterfly air variable capacitor, the trombone works without lossy wiper contacts. Jones' capacitor varied from 12 pF (including strays) to almost 60 pF, making it suitable to tune his 3-foot circumference loop from 14 to 30 MHz at the 100-W level.

KD7S used 5-mil (0.005 inch) thick Teflon sheet as an insulator. Since Teflon is conservatively rated at more than 1 kV per mil of thickness, the voltage breakdown capability of this capacitor is well in excess of 5 kV. The parts list is given in **Table 5**.

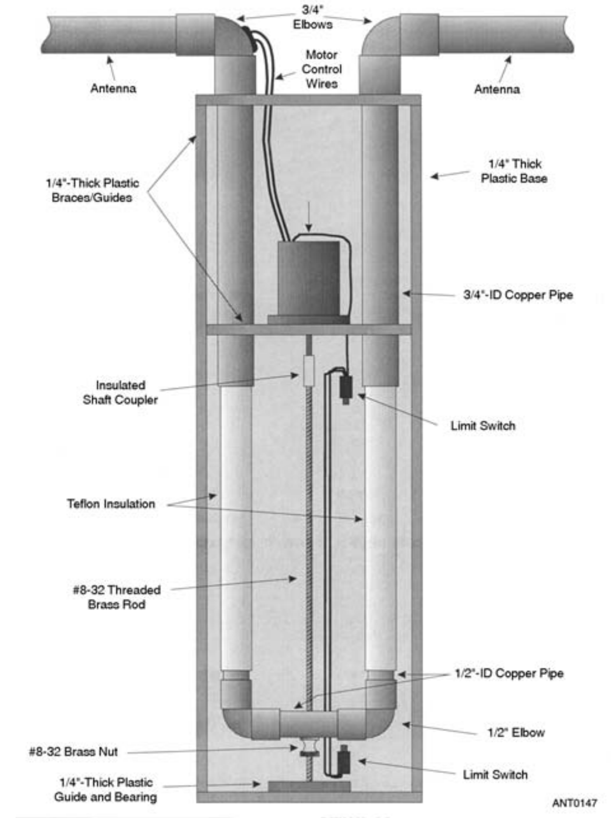

Fig 21—A practical trombone capacitor designed by Bill Jones, KD7S, for his compact transmitting loop. This capacitor has a tuning range from 12 to almost 60 pF, and can withstand at least 5 kV peak. The 10-inch ½-inch ID tubes are covered with Teflon-sheet insulation and slide into the ¾-inch ID copper pipes.

A short length of plastic tubing connects the threaded brass rod to the motor. The tubing acts as an insulator and a flexible coupling to smooth out minor shaft-alignment errors. The other end of the rod is threaded into a brass nut soldered to the crossbar holding the 1/2-inch pipes together. Jones used a 12-V motor rated at 180 rpm, but it has sufficient torque to work with as little as 4 V applied. Instead of a sophisticated variable duty-cycle speed control circuit, he used an LM327 adjustable voltage regulator to vary the motor-control voltage from 4 to 12 V. Tuning speeds ranged from 11 seconds per inch at 12 V to 40 seconds per inch at 4 V. The higher speed is necessary to jump from band to band in a reasonable length of time. The lower speed makes it easy to fine-tune the capacitor to any desired frequency within a band.

When building the capacitor, keep in mind that the smaller tubes must telescope in and out of the larger tubes with silky smoothness. Any binding will cause erratic tuning. For the same reason, the #8-32 brass threaded rod must be straight and properly aligned with the brass nut. *Take your time with this part of the project*.

Perhaps the easiest way to form the insulator is to precut a length of Teflon sheet to the proper size. Place a lengthwise strip of double-sided tape on the tube to secure one end of the Teflon sheet. Begin wrapping the Teflon around the tube while keeping it as tight as possible. *Don't allow wrinkles or ridges to form*. Secure the other end with another piece of tape. Once both tubes are covered, ensure they are just short of being a snug fit inside the larger tubes. Confirm that the insulation completely overlaps the open end of the small tubes. If not, the capacitor is certain to arc internally with more than a few watts of power applied to it.

Route the motor wiring inside the antenna pipes to minimize the amount of metal within the field of the antenna. Bring the wires out next to the coaxial connector. A three-wire system allows the use of limit switches to restrict the movement of the trombone section. Be sure to solder together all metal parts of the capacitor. Use a small propane torch, a good quality flux and 50/50 solid solder. Do not use acid-core solder! Clean all parts to be joined with steel wool prior to coating them with flux.

A Cookie-Sheet and Picture-Frame-Glass Variable Capacitor

In Vol 2 of *The ARRL Antenna Compendium* series, Richard Plasencia, WØRPV, described a clever high-voltage variable capacitor he constructed using readily available materials. See **Fig 22**, which shows Plasencia's homebrew high-voltage variable capacitor, along with the coil and other parts used in his homemade antenna coupler. This capacitor could be varied from 16 to 542 pF and tested at a breakdown of 12,000 V.

The capacitor sits on four PVC pillars and consists of two 4 1/2 × 4 1/2-inch aluminum plates separated by a piece of window glass that is 8 1/2 × 5 1/2 inches in size. The lower plate is epoxied to the glass. The upper plate is free to move in a wooden track epoxied to the upper surface of the glass. The motor is reversible and moves the upper capacitor plate by rotating a threaded rod in a wing nut pinned to a tab on the capacitor plate. The four pillars are cut from PVC pipe to insulate the capacitor from the chassis and to elevate it into alignment with the motor shaft.

WØRPV used a piece of 0.063-inch thick single-weight glass that exhibited a dielectric constant of 8. He removed the glass from a dime-store picture frame. In time-honored ham fashion, he improvised his wooden tracks for the upper capacitor plate from a single wooden paint stirrer, and for the capacitor plates, he used aluminum cookie sheets.

The wooden track for the upper plate is made by splitting the wooden paint stirrer with a knife into one narrow and one wide strip. The narrow strip is cemented on top and overhangs the movable plate, creating a slotted track. Since the wood is supported by the glass plate, its insulating qualities are of no importance.

The principle of operation is simple. The reversible motor turns a threaded 1/4-inch rod with a pitch of 20 threads to the inch. This rod engages a wing nut attached to the movable capacitor plate. Although WØRPV grounded his capacitor's movable plate with a braid, an insulator similar to that used in the trombone capacitor above should be used to isolate the lead-screw mechanism. Several pieces of braid made from RG-8 coax shield should be used to connect to the ends of the compact transmitting loop conductors to form low-loss connections.

WØRPV used a 90-rpm motor from a surplus vending machine. It moved his variable capacitor plate 4 1/2 inches, taking about a minute to travel from one end to the other. Since he wished to eliminate the complexity and dubious reliability of limit switches when used outdoors, he monitored the motor's dc current through two 3 Ω, 2W resistors

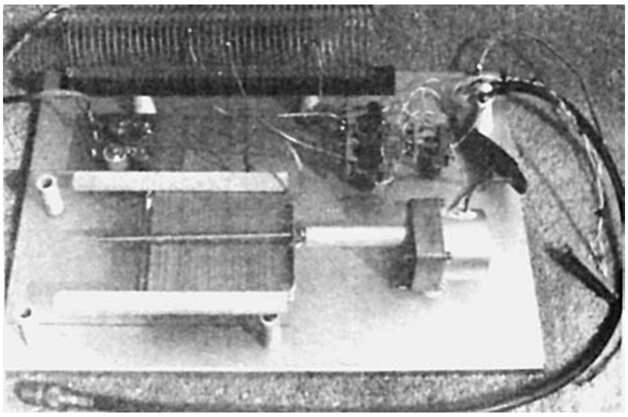

Fig 22—The picture-frame-glass variable capacitor design of Richard Plasencia, WØRPV. Two aluminum plates separated by a piece of glass scavenged from a picture frame create a variable capacitor that can withstand 12,000 V, with a variable range from 16 to 542 pF.

placed in series with each lead of the motor and shunted by red LEDs at the control box. When the motor stalled by jamming up against the PVC limit stop or against the inside of the plastic mounting box, the increased motor current caused one or the other of the LEDs to light up.

TYPICAL LOOP CONSTRUCTION

After you select the electrical design for your loop application, you must consider how to mount it and how to feed it. If you wish to cover only the upper HF bands of 20 through 10 meters, you will probably choose a loop that has a circumference of about 8.5 feet. You can make a reasonably sturdy loop using 1-inch diameter PVC pipe and $^5/_8$-inch flexible copper tubing bent into the shape of a circle. Robert Capon, WA3ULH, did this for a QRP-level transmitting loop described in May 1994 *QST*. **Fig 23** shows a picture of his loop, with PVC H-frame stand.

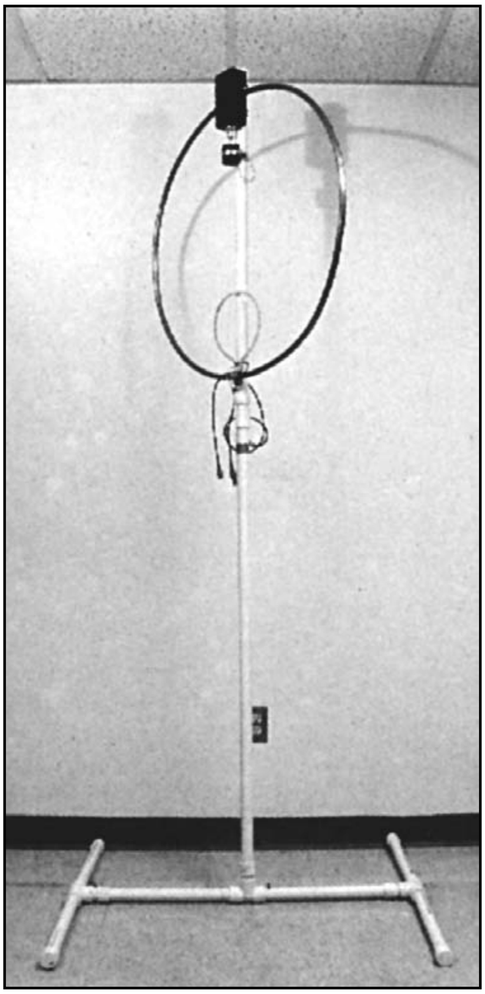

Fig 23—Photo of compact transmitting loop designed by Robert Capon, WA3ULH. This uses a 1-inch PVC H-frame to support the loop made of flexible $^5/_8$-inch copper tubing. The small coupling loop made of RG-8 coax braid couples the loop to the coax feed line. The tuning capacitor and drive motor are at the top of the loop, shown here in the ARRL Laboratory during testing.

This loop design used a 20-inch long coupling loop made of RG-8 coax to magnetically couple into the transmitting loop rather than the gamma-match arrangement used by W5QJR in his loop designs. The coupling loop was fastened to the PVC pipe frame using 2-inch long #8 bolts that also held the main loop to the mast.

A more rugged loop can be constructed using rigid $^3/_4$-inch copper water pipe, as shown in the W5QJR design in **Fig 24**. While a round loop is theoretically a bit more efficient, an octagonal shape is much easier to construct. The values presented in Table 4 are for octagons.

For a given loop circumference, divide the circumference by 8 and cut eight equal-length pieces of $^3/_4$ inch copper water pipe. Join the pieces with 45° elbows to form the octagon. With the loop lying on the ground on scraps of 2 × 4 lumber, braze or solder all joints.

W5QJR made a box from clear plastic to house his air-variable capacitor and drive motor at the top of the loop. The side of the box that mounts to the loop and the capacitor should be at least ¼-inch thick, preferably $^3/_8$-inch. The remainder of the box can be $^1/_8$-inch plastic sheet. He mounted the loop to the plastic using $^1/_4$-inch bolts (two on either side of center) after cutting out a section of pipe 2 inches wide in the center. On the motor side of the capacitor, he cut the pipe and installed a copper T for the motor wiring.

W5QJR's next step was to solder copper straps to the loop ends and to the capacitor stators, then he remounted the loop to the plastic. If you insert wood dowels, the pipe will remain round when you tighten the bolts. Next he installed the motor drive cable through the loop and connected it to the motor. Antenna rotator cable is a good choice for this cable. He completed the plastic box using short pieces of aluminum angle and small sheet-metal screws to join the pieces.

The loop was then ready to raise to the vertical position. Remember, no metal is allowed near the loop. W5QJR made a pole of 2 × 4-inch lumber with 1 × 4-inch boards on either side to form an I section. He held the boards together with $^1/_4$-inch bolts, 2 feet apart and tied rope guys to the top. This made an excellent mast up to 50 feet high. The pole height should be one foot greater than the loop diameter, to allow room for cutting grass or weeds at the bottom of the loop. W5QJR installed a pulley at the top so that his loop could be raised, supported by rope. He supported the bottom of the loop by tying it to the pole and tied guy ropes to the sides of the loop to keep it from rotating in the wind. By moving the anchor points, he could rotate his loop in the azimuth plane.

W5QJR used a gamma-matching arrangement made of flexible $^1/_4$-inch copper tubing to couple the loop to the transmission line. In the center of one leg, he cut the pipe and installed a copper T. Adjacent to the T, he installed a mount for the coax connector. He made the mount from copper strap, which can be obtained by splitting a short piece of pipe and hammering it flat.

While the loop was in the vertical position he cut a piece of $^1/_4$-inch flexible copper tubing the length of one

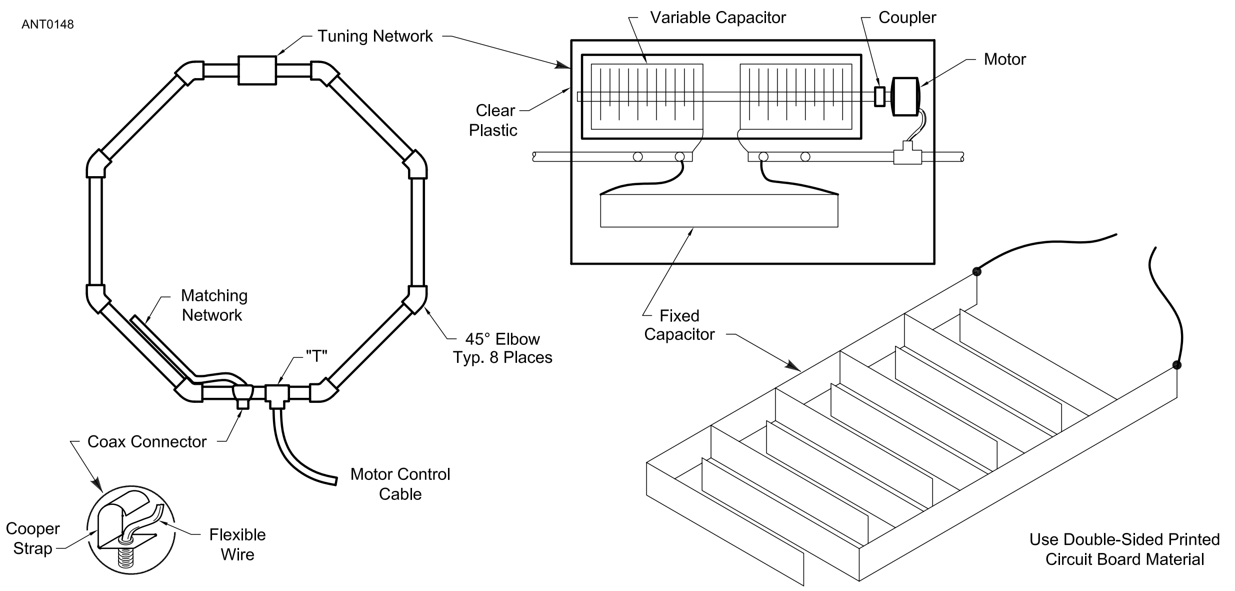

Fig 24—Octagonal loop construction details. Table 4 gives loop design data for various frequency ranges.

of the straight sides of the loop. He then flattened one end and soldered a piece of flexible wire to the other. He wrapped the tubing with electrical tape for insulation and connected the flexible wire to the coax connector. He then installed the tubing against the inside of the loop, held temporarily in place with tape. He soldered the flat part to the loop, ending up with a form of gamma match, but without reactive components. This simple feed provided better than 1.7:1 SWR over a 2:1 frequency range. For safety, he installed a good ground rod under the loop and connected it to the strap for the coax connector, using large flexible wire.

TUNE-UP PROCEDURE

The resonant frequency of the loop can be readily found by setting the receiver to a desired frequency and rotating the capacitor (by remote control) until signals peak. The peak will be very sharp because of the high Q of the loop.

Turn on the transmitter in the tune mode and adjust either the transmitter frequency or the loop capacitor for maximum signal on a field-strength meter, or for maximum forward signal on an SWR bridge. Adjust the matching network for minimum SWR by bending the matching line. Normally a small hump in the $^{1}/_{4}$-inch tubing line, as shown in Fig 24, will give the desired results. For a loop that covers two or more bands, adjust the feed to give equally low SWR at each end of the tubing range. The SWR will be very low in the center of the tuning range but will rise at each end.

If there is metal near the loop, the additional loss will reduce the Q and therefore the impedance of the loop. In those cases it will be necessary to increase the length of the matching line and tap higher up on the loop to obtain a 50-Ω match.

PERFORMANCE COMPARISON

As previously indicated, a compact transmitting loop can provide performance approaching full-size dipoles and verticals. To illustrate one case, a loop 100 feet in circumference would be 30 feet high for 1.8 MHz. However, a good dipole would be 240 feet ($^{1}/_{2}$ λ) in length and at least 120 feet high ($^{1}/_{4}$ λ). A $^{1}/_{4}$-λ vertical would be 120 feet tall with a large number of radials on the ground, each 120 feet in length. The smaller loop could replace both of those antennas with only a moderate degradation in performance and a requirement for a high-voltage variable capacitor.

On the higher frequencies, the same ratios apply, but full-size antennas are less dramatic. However, very few city dwellers can erect good verticals even on 7 MHz with a full-size counterpoise. Even on 14 MHz a loop about 3 feet high can work the world.

Other than trading small size for narrow bandwidth and a high-voltage capacitor, the compact transmitting loop is an excellent antenna and should find use where large antennas are not practical.

The Loop Skywire

Are you looking for a multiband HF antenna that is easy to construct, costs nearly nothing and yet works well? You might want to try this one. The *Loop Skywire* antenna is a full-sized horizontal loop. Early proponents suggested that the antenna could be fed with coaxial cable with little concern for losses, but later analysis proved that this was a bit of wishful thinking—the relatively low values for SWR across multiple bands indicate that cable losses were part and parcel of performance. The best way to feed this versatile antenna is with open-wire ladder line, with an antenna tuner in the shack to present the transmitter with a low value of SWR.

THE DESIGN

The Loop Skywire is shown in **Fig 25**. The antenna has one wavelength of wire in its perimeter at the design or fundamental frequency. If you choose to calculate L_{total} in feet, the following equation should be used:

$$L_{total} = \frac{1005}{f}$$

where f equals the frequency in MHz.

Given any length of wire, the maximum possible area the antenna can enclose is with the wire in the shape of a circle. Since it takes an infinite number of supports to hang a circular loop, the square loop (four supports) is the most practical. Further reducing the area enclosed by the wire loop (fewer supports) brings the antenna closer to the properties of the folded dipole, and both harmonic-impedance and feed-line voltage problems can result. Loop geometries other than a square are thus possible, but remember the two fundamental requirements for the Loop Skywire—its horizontal position and maximum enclosed area.

There is another great advantage to this antenna system. It can be operated as a vertical antenna with top-hat loading on other bands as well. This is accomplished by simply keeping the feed line run from the antenna to the shack as vertical as possible and clear of objects. Both feed-line conductors are then tied together, and the antenna is fed against a good ground.

CONSTRUCTION

Antenna construction is simple. Although the loop can be made for any band or frequency of operation, the following two Loop Skywires are good performers. The 10-MHz band can also be operated on both.

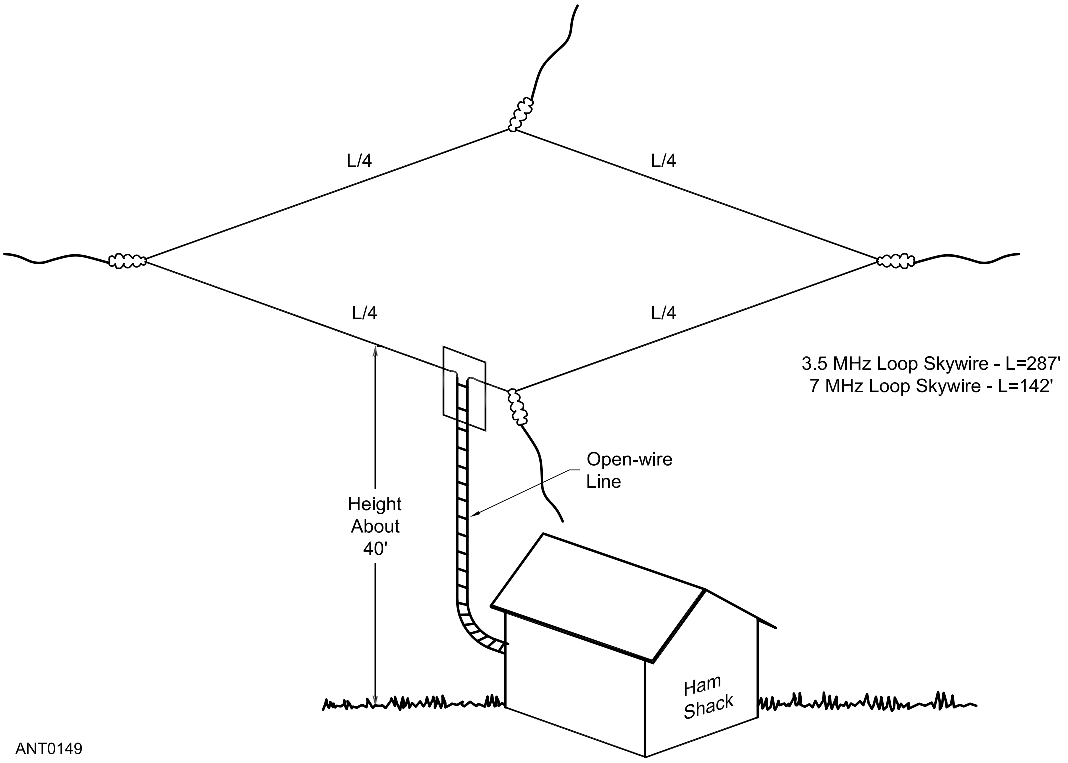

Fig 25—A complete view of the Loop Skywire. The square loop is erected horizontal to the earth.

3.5-MHz Loop Skywire
(3.5-28 MHz loop and 1.8-MHz vertical)
Total loop perimeter: 272 feet
Square side length: 68 feet

7-MHz Loop Skywire
(7-28 MHz loop and 3.5-MHz vertical)
Total loop perimeter: 142 feet
Square side length: 35.5 feet

The actual total length can vary from the above by a few feet, as the length is not at all critical. Do not worry about tuning and pruning the loop to resonance. No signal difference will be detected on the other end when that method is used.

Bare #14 copper wire is used in the loop. **Fig 26** shows the placement of the insulators at the loop corners. Two common methods are used to attach the insulators. Either lock or tie the insulator in place with a loop wire tie, as shown in Fig 26A, or leave the insulator free to "float" or slide along the wire, Fig 26B. Most loop users float at least two insulators. This allows pulling the slack out of the loop once it is in the air, and eliminates the need to have all the supports exactly placed for proper tension in each leg. Floating two opposite corners is recommended.

Fig 27A shows the azimuth-plane performance on 7.2 MHz of a 142-foot long, 7-MHz Loop Skywire, 40 feet high at an elevation angle of 10º, compared to a regular flattop $^1/_2$-λ dipole at a height of 30 feet. The loop comes into its own at higher frequencies. Fig 27B shows the response at 14.2 MHz, compared again to a $^1/_2$–λ 14.2-MHz

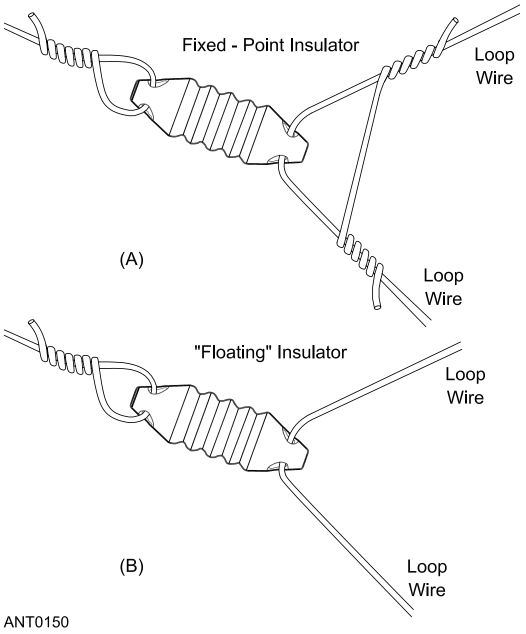

Fig 26—Two methods of installing the insulators at the loop corners.

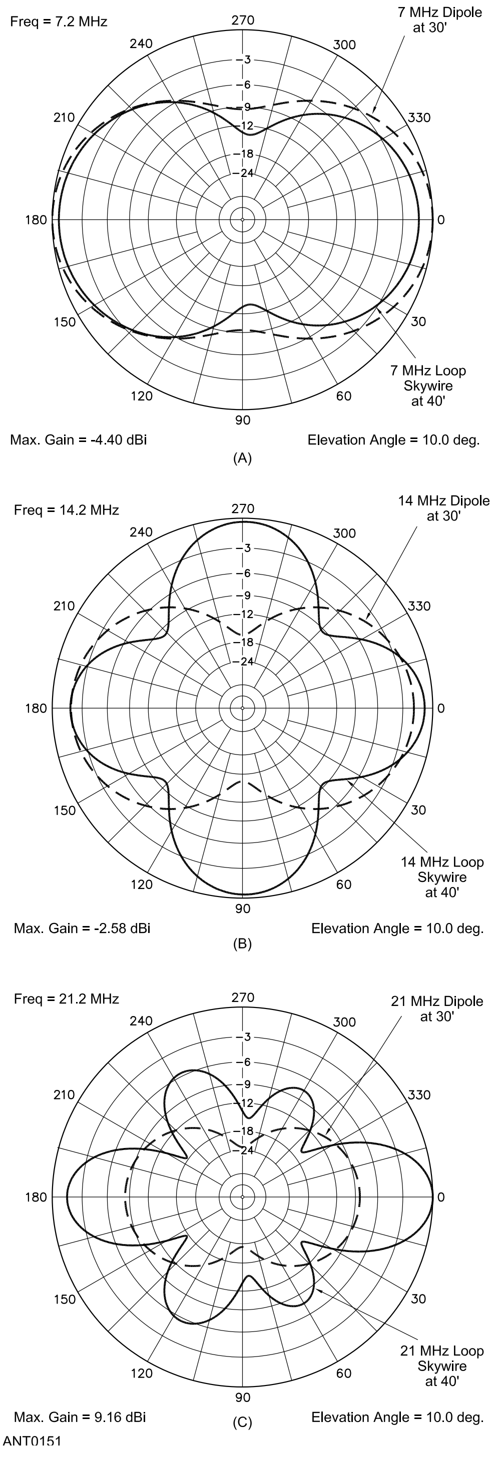

Fig 27—At A, azimuth-plane response of 142-foot long, 7-MHz Loop Skywire, 40 feet in the air at 7.2 MHz, compared with ½-λ dipole 30 feet in the air. At B, response of same Loop Skywire at 14.2 MHz, compared with ½-λ 14.2-MHz dipole 30 feet in the air. Now the loop has some advantage in certain directions. At C, response of the same Loop Skywire at 21.2 MHz compared to a 21.2-MHz dipole at 30 feet. Here, the Loop Skywire has more gain in almost all directions than the simple dipole. All azimuth-plane patterns were made at 10° elevation.

dipole at a height of 30 feet. Now the loop has several lobes that are stronger than the dipole. Fig 27C shows the response at 21.2 MHz, compared to a dipole. Now the loop has superior gain compared to the $^1/_2$-λ dipole at almost any azimuth. In its favored direction on 21.2 MHz, the loop is 8 dB stronger than the dipole.

The feed point can be positioned anywhere along the loop that you wish. However, most users feed the Skywire at a corner. **Fig 28** depicts a method of doing this, using a piece of plexiglass to provide insulation as well as strain relief for the open-wire ladder line. It is advantageous to keep the feed-point mechanicals away from the corner support. Feeding a foot or so from one corner allows the feed line to exit more freely. This method keeps the feed line free from the loop support.

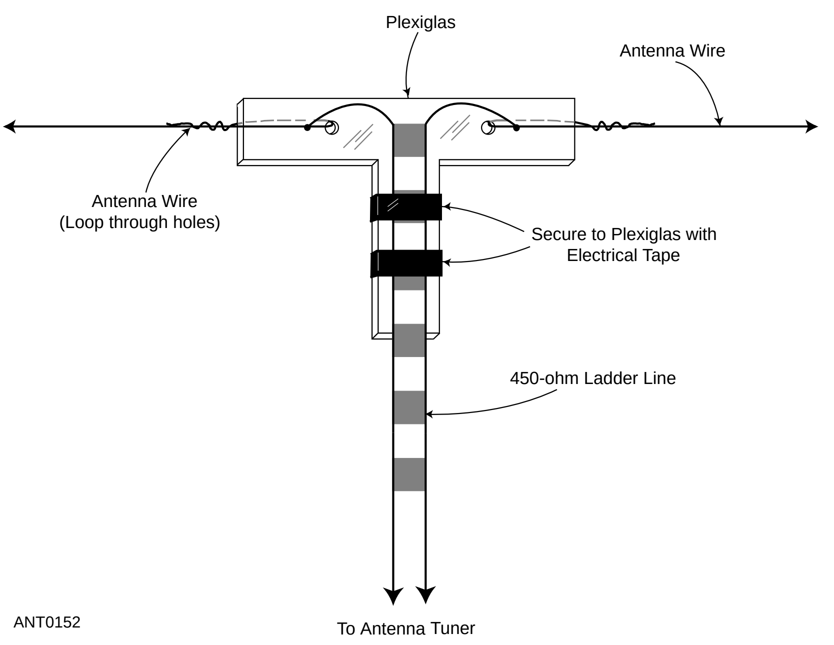

Fig 28—Most users feed the Skywire at a corner. A high-impedance weather-resistant insulator should be used for the feed-point insulator.

Generally a minimum of four supports is required. If trees are used for supports, then at least two of the ropes or guys used to support the insulators should be counterweighted and allowed to move freely. The feedline corner is almost always tied down, however. Very little tension is needed to support the loop (far less than that for a dipole). Thus, counterweights are light. Several such loops have been constructed with bungie cords tied to three of the four insulators. This eliminates the need for counterweighting.

Recommended height for the antenna is 40 feet or more. The higher the better, especially if you wish to use the loop in the vertical mode. However, successful local and DX operation has been reported in several cases with the antenna at 20 feet. **Fig 29** shows the feed arrangement for using the Loop Skywire as a top-loaded vertical fed against ground on the lower bands.

Because the loop is high in the air and has considerable electrical exposure to the elements, proper methods should be employed to eliminate the chance of induced or direct lightning hazard to the shack and operator. Some users simply completely disconnect the antenna from the antenna tuner and rig and shack during periods of possible lightning activity.

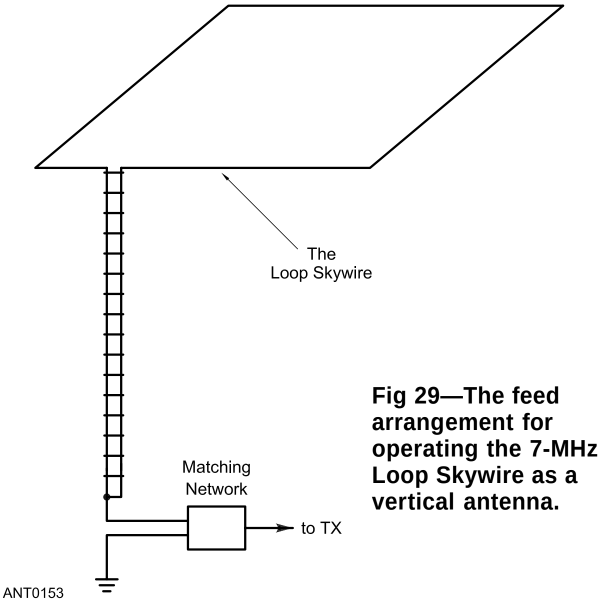

Fig 29—The feed arrangement for operating the 7-MHz Loop Skywire as a vertical antenna.

7-MHz Loop

An effective but simple 7MHz antenna that has a theoretical gain of approximately 1 dB over a dipole is a full-wave, closed vertical loop. Such a loop need not be square, as illustrated in **Fig 30A**. It can be trapezoidal, rectangular, circular, or some distorted configuration in between those shapes. For best results, however, you should attempt to make the loop as square as possible. The more rectangular the shape, the greater the cancellation of energy in the system, and the less effective it will be. In the limiting case, the antenna loses its identity as a loop and becomes a folded dipole.

You can feed the loop in the center of one of the vertical sides if you want vertical polarization. For horizontal polarization, you feed either of the horizontal sides at the center. Since optimum directivity occurs at right angles to the plane of the loop (or in more simple terms, broadside to the loop), you should hang the loop to radiate the maximum amount in some favored direction.

Fig 31A shows the azimuthal response at a takeoff angle of 15°, a typical angle for 40-meter DX, for vertical and horizontal feed systems over ground with "average" conductivity and dielectric constant. Fig 31A includes, for reference, the response of a flattop dipole 50 feet high. For DX work on 40 meters, the vertically polarized loop can perform as well as or substantially better than either a horizontally polarized loop or a flattop dipole, particularly in the azimuthal nulls of the dipole.

For the low elevation angles that favor DX work, the optimal feed point is at the center of one of the vertical wires. Feeding the loop at one of the corners at the bottom gives a

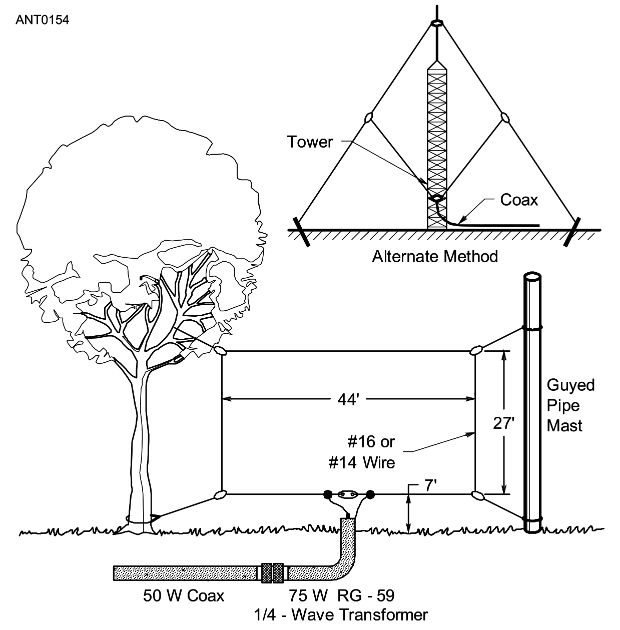

Fig 30—At A, details of the rectangular full-wave loop. The dimensions given are for operation at 7.05 MHz. The height above ground was 7 feet in this instance, although improved performance should result if the builder can install the loop higher above ground without sacrificing length on the vertical sides. At B, illustration how a single supporting structure can be used to hold the loop in a diamond-shaped configuration. Feeding the diamond at the lower tip provides radiation in the horizontal plane. Feeding the system at either side will result in vertical polarization of the radiated signal.

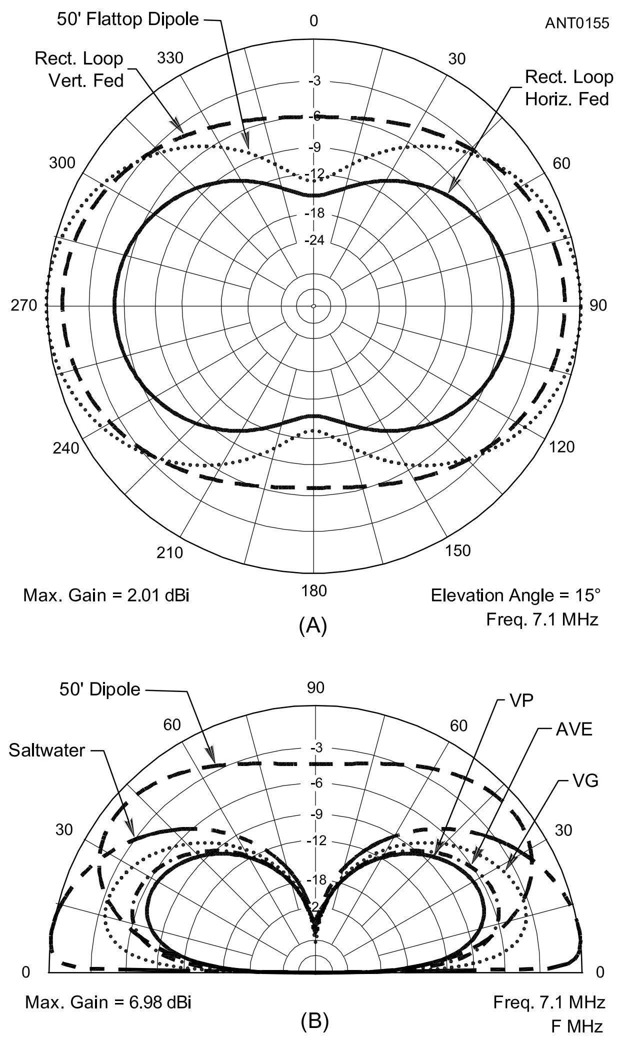

Fig 31—At A, azimuthal plane responses for the vertically and horizontally polarized 7-MHz loop, compared to a flattop 50-foot high dipole, all at a takeoff angle of 15° for DX work. The solid line is for feeding the loop horizontally at the bottom; the dashed line is for feeding the loop vertically at a side, and the dotted line is for a simple flattop horizontal dipole at 50 feet in height. For DX work, the vertically polarized loop is an excellent performer.

compromise result for both local and DX work. The actual impedance is roughly the same at each point: bottom horizontal center, corner or vertical side center.

Fig 31B demonstrates how the gain for vertical polarization changes over different type of grounds: saltwater, very poor ground (conductivity = 1 mS/m, dielectric constant = 5) very good (conductivity = 30 mS/m, dielectric constant = 20) and average ground (conductivity = 5 mS/m, dielectric constant = 13). Again, for reference a 50-foot high flattop dipole's elevation response is included. As has been mentioned previously in other chapters, a seaside location is a wonderful environment for verticals!

Just how you erect such a loop will depend on what is available in your backyard. Trees are always handy for supporting loop antennas. A disadvantage to the rectangular loop shown in Fig 30A is that two 34-foot high supports are needed, although in many instances your house may be high enough to serve as one of these supports. If you have a tower higher than about 50 feet, Fig 30B demonstrates how you can use it to support a diamond-shaped loop for 40 meters. The elevation and azimuthal responses are almost the same for either loop configuration, rectangular- or diamond-shaped.

The overall length of the wire used in a loop is determined in feet from the formula 1005/f (MHz). Hence, for operation at 7.125 MHz the overall wire length will be 141 feet. The matching transformer, an electrical $^1/_4$ λ of 75Ω coax cable, can be computed by dividing 246 by the operating frequency in MHz, then multiplying that number by the velocity factor of the cable being used. Thus, for operation at 7.125 MHz, 246/7.125 MHz = 34.53 feet. If coax with solid polyethylene insulation is used, a velocity factor of 0.66 must be employed. Foam-polyethylene coax has a velocity factor of 0.80. Assuming RG-59 is used, the length of the matching transformer becomes 34.53 (feet) × 0.66 = 22.79 feet, or 22 feet, $9^1/_2$ inches.

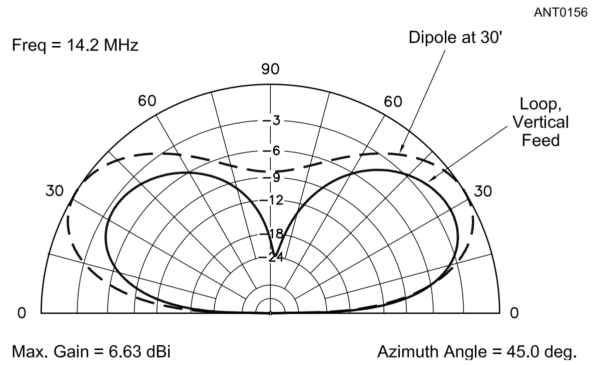

Fig 32—Elevation-plane response of 7-MHz loop used on 14.2 MHz. This is for a feed point at the center of one of the two vertical wires. The dashed line is the response of a flattop 20-meter dipole at 30 feet in height for comparison.

This same loop antenna in Fig 30A fed vertically may be used on the 14 and 21MHz bands, although its pattern will not be as good as that on its fundamental frequency and you will have to use an open-wire transmission line to feed the loop for multiband use. **Fig 32** shows the response at the peak lobe of the loop, at a 45° angle to the plane of the loop, compared to the peak response for a simple halfwave 20-meter dipole, 30 feet high. The gain from a simple flattop dipole, mounted at 30 feet, will be superior to the loop operated on a harmonic frequency.

A Receiving Loop for 1.8 MHz

You can use a small shielded-loop antenna to improve reception under certain conditions, especially at the lower amateur frequencies. This is particularly true when high levels of man-made noise are prevalent, when the second-harmonic energy from a nearby broadcast station falls in the 1.8MHz band, or when interference exists from some other amateur station in the immediate area. A properly constructed and tuned small loop will exhibit approximately 30 dB of front-to-side response, the minimum response being at right angles to the plane of the loop. Therefore, noise and interference can be reduced significantly or completely nulled out, by rotating the loop so that it is sideways to the interference-causing source.

Generally speaking, small shielded loops are far less responsive to man-made noise than are the larger antennas used for transmitting and receiving. But a trade-off in performance must be accepted when using the loop, for the strength of received signals will be 10 or 15 dB less than when using a full-size resonant antenna. This condition is not a handicap on 1.8 or 3.5 MHz, provided the station receiver has normal sensitivity and overall gain. Because a front-to-side ratio of 30 dB may be expected, a shielded loop can be used to eliminate a variety of receiving problems if made rotatable, as shown in **Fig 33**.

To obtain the sharp bidirectional pattern of a small loop, the overall length of the conductor must not exceed 0.1 λ. The loop of **Fig 34** has a conductor length of 20 feet. At 1.81 MHz, 20 feet is 0.037 λ. With this style of loop, 0.037 λ is about the maximum practical dimension if you want to tune the element to resonance. This limitation results from the distributed capacitance between the shield and inner conductor of the loop. RG-59 was used for the loop element in this example. The capacitance per foot for this cable is 21 pF, resulting in a total distributed

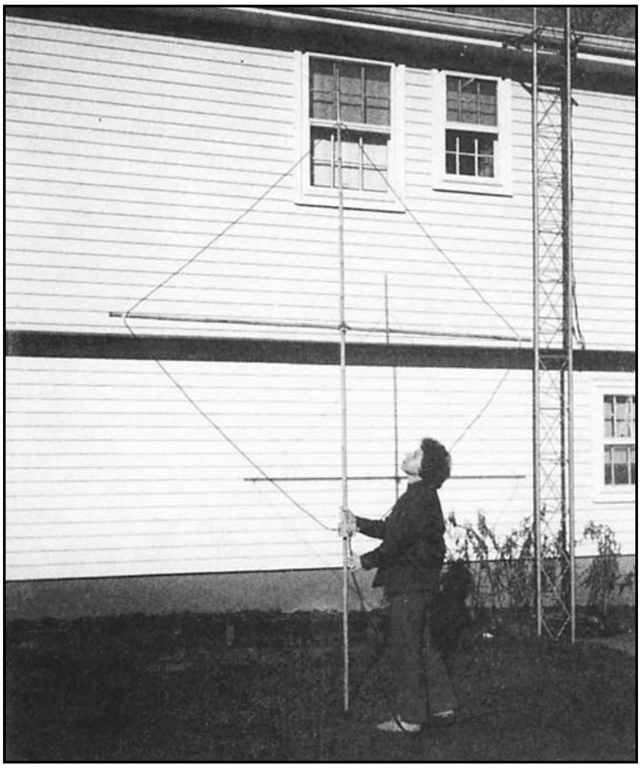

Fig 33—Jean DeMaw, W1CKK, tests the 1.8-MHz shielded loop. Bamboo cross arms are used to support the antenna.

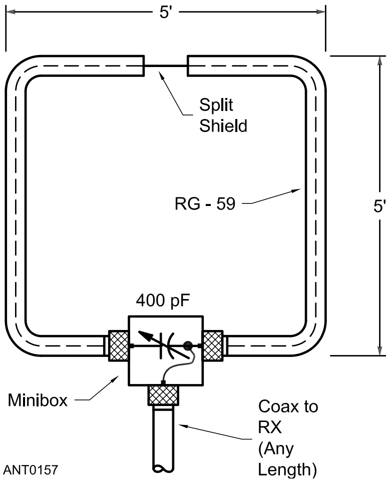

Fig 34—Schematic diagram of the loop antenna. The dimensions are not critical provided overall length of the loop element does not exceed approximately 0.1 λ. Small loops which are one half or less the size of this one will prove useful where limited space is a consideration.

capacitance of 420 pF. An additional 100 pF was needed to resonate the loop at 1.810 MHz.

Therefore, the approximate inductance of the loop is 15 µH. The effect of the capacitance becomes less pronounced at the higher end of the HF spectrum, provided the same percentage of a wavelength is used in computing the conductor length. The ratio between the distributed capacitance and the lumped capacitance used at the feed point becomes greater at resonance. These facts should be contemplated when scaling the loop to those bands above 1.8 MHz.

There will not be a major difference in the construction requirements of the loop if coaxial cables other than RG-59 are used. The line impedance is not significant with respect to the loop element. Various types of coaxial line exhibit different amounts of capacitance per foot, however, thereby requiring more or less capacitance across the feed point to establish resonance.

Shielded loops are not affected noticeably by nearby objects, and therefore they can be installed indoors or out after being tuned to resonance. Moving them from one place to another does not significantly affect the tuning.

You can see in the model shown in Fig 33 that a supporting structure was fashioned from bamboo poles. The X frame is held together at the center with two U bolts. The loop element is taped to the cross-arms to form a square. You could likely use metal cross arms without seriously degrading the antenna performance. Alternatively, wood can be used for the supporting frame.

A Minibox was used at the feed point of the loop to hold the resonating variable capacitor. In this model a 50 to 400-pF compression trimmer was used to establish resonance. You must weatherproof the box for outdoor installations.

Remove the shield braid of the loop coax for one inch directly opposite the feed point. You should treat the exposed areas with a sealing compound once this is done.

In operation this receiving loop has proven very effective for nulling out second-harmonic energy from local broadcast stations. During DX and contest operations on 1.8 MHz it helped prevent receiver overloading from nearby 1.8-MHz stations that share the band. The marked reduction in response to noise has made the loop a valuable station accessory when receiving weak signals. It is not used all of the time, but is available when needed by connecting it to the receiver through an antenna selector switch. Reception of European stations with the loop has been possible from New England at times when other antennas were totally ineffective because of noise.

It was also discovered that the effects of approaching storms (with attendant atmospheric noise) could be nullified considerably by rotating the loop away from the storm front. It should be said that the loop does not exhibit meaningful directivity when receiving sky-wave signals. The directivity characteristics relate primarily to ground-wave signals. This is a bonus feature in disguise, for when nulling out local noise or interference, one is still able to copy sky-wave signals from all compass points!

For receiving applications it is not necessary to match the feed line to the loop, though doing so may enhance the performance somewhat. If no attempt is made to obtain an SWR of 1, the builder can use 50 or 75-Ω coax for a feeder, and no difference in performance will be observed. The Q of this loop is sufficiently low to allow the operator to peak it for resonance at 1.9 MHz and use it across the entire 1.8MHz band. The degradation in performance at 1.8 and 2 MHz will be so slight that it will be difficult to discern.

An Indoor Stealth Loop

Ted Phelps, W8TP, wrote an article in *The ARRL Antenna Compendium, Vol 7* describing his attic-mounted wire loop antenna, fed with an automatic antenna tuner. Here is a shortened version of that article.

If you drive down my street in Whitechapel Village in Newark, DE, trying to find my ham location by looking for my antenna, you wouldn't find it. Even if you pulled up in front of my condo, you wouldn't notice any telltale signs, because my multiband antenna is completely hidden. It's in the attic of my two-bedroom condominium in a small retirement community completed in 1999.

Before the move, I had given considerable thought to what type of antenna I might use, if any. I already knew that permanent outdoor types were out of the question, due to restrictive real estate and condo association rules. So I planned a clause for any sales contract I might sign, specifically mentioning amateur radio and my desire to set up a station in my new living quarters. I decided I would not move where my lifelong hobby would be severely restricted or prohibited.

That meant that to be reasonably sure I could continue enjoying Amateur Radio as before, I would have to install an indoor antenna that could perform as well as a typical outdoor system. What kind? In Ohio, I had tried a horizontally polarized attic dipole made with #14 wire. It didn't work very well—it was just too low to the ground.

I learned about a high-tech method of remote antenna tuning using an antenna coupler which contains a microprocessor. I found this kind of automatic tuner available from two American manufacturers and within a reasonable price range. Although our move was still a few months ahead, I purchased a model SG-230 antenna coupler made by SGC Inc, Bellevue, WA, for use in Delaware.

Fig 35 shows the final dimensions of my hidden loop, which is a single-turn rectangular loop, erected in a north-south vertical plane and made from nearly 78 feet of #6 stranded, aircraft primary wire in a PVC jacket, held taut at the lower corners and supported by a pulley and guy rope at each upper corner. Because it's vertically polarized, it supports low-angle radiation reasonably well. By the way, if you're wondering why I used such a relatively large-gauge wire as #6 for the loop antenna, it was readily available from my son-in-law!

Fig 36 shows my completed condo unit. Note the doghouse dormer on the roof about 12 feet above ground at the attic floor. This is the level of my hidden loop's base leg.

In constructing my system I had to overcome RFI problems on my own premises. Each condo unit has its own electronic security panel on an upper shelf in a closet. As soon as I applied moderate power to my radio and loop, the Fire Alarm sounded and firefighters came to my door! The burglar/intrusion signal was triggered a couple of times, too. Working with a security installation technician, I found that *there was no ground wire connected to my security panel.* "We don't bother with that," said the tech, and then, reacting to my surprise, connected a #14 ground between the security panel and the house water-pipe ground. I then installed a ferrite bead on each lead entering the security panel. I also placed ferrite beads on keyer-paddle leads, GFCI electrical outlets, etc. Those

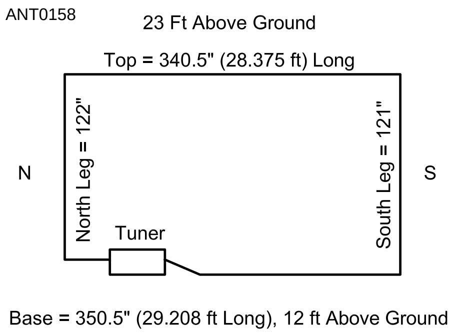
ANT0158
23 Ft Above Ground
Top = 340.5" (28.375 ft) Long
N
North Leg = 122"
South Leg = 121"
S
Tuner
Base = 350.5" (29.208 ft Long), 12 ft Above Ground

Fig 35—Diagram showing layout of W8TP's indoor hidden loop antenna.

Fig 36—Can you see W8TP's antenna in this photograph? Of course you can't—it's hidden from view inside his attic!

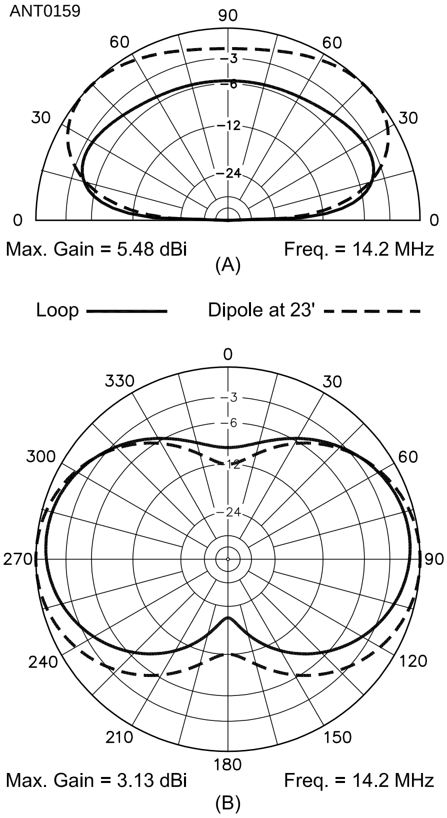

Fig 37—At A, computed elevation pattern at 14.2 MHz for W8TP's hidden loop (solid line), compared to a 20-meter dipole (dashed line) at a height of 23 feet. At B, a comparison of the azimuth patterns at a 20°-elevation angle for W8TP's loop (solid line) and the same 20-meter dipole (dashed line). The loop has a slightly asymmetrical response because it is fed at a corner, but its performance is competitive to an outdoor dipole. In fact, it has superior low-angle performance, typical of a vertically polarized antenna compared to a low horizontal antenna.

measures seem to have eliminated my RFI problems.

When we moved into our condo, I took the obvious precaution of not using a linear amplifier. I took extra care to establish a single-point ground for my station equipment by connecting all equipment grounds to the cover plate of the dedicated metallic outlet box behind the operating position, and thence to a separate ground rod in our front yard. I use a 1-kW RL Drake low-pass filter in the transceiver-antenna feed line.

Is this indoor antenna system safe? I believe so. In the attic it is not at all close to our living space. It is fixed firmly in place and unlike most amateur antennas it is *out of the weather*! I therefore do not use a quick-grounding system for times when a thunderstorm approaches.

Fig 37 shows the computed elevation and azimuth patterns on 20 meters. The tuner is able to hold the SWR down low enough so that my JRC-245 transceiver can operate through its internal antenna tuner.

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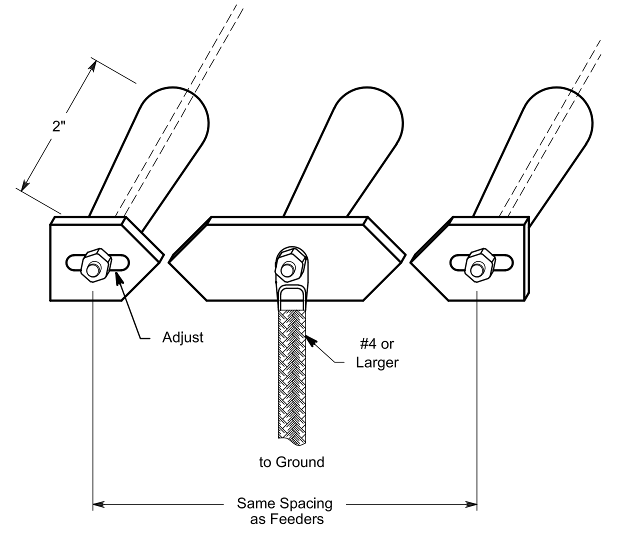

Fig 43—A simple lightning arrester for open-wire line made from three standoff or feedthrough insulators and sections of 1/8 × 1/2-inch brass or copper strap. It should be installed in the line at the point where the line enters the station. The heavy ground lead should be as short and as direct as possible. The gap setting should be adjusted to the minimum width that will prohibit arcing when the transmitter is operated.

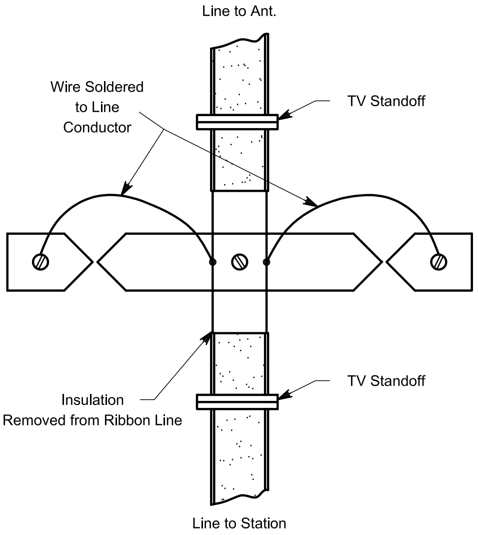
Line to Ant.
Wire Soldered to Line Conductor
TV Standoff
TV Standoff
Insulation Removed from Ribbon Line
Line to Station

Fig 44—The lightning arrester of Fig 39 may be used with 300-Ω ribbon line in the manner shown here. The TV standoffs support the line an inch or so away from the grounded center member of the arrester

The construction of a homemade arrester for open-wire line is shown in **Fig 43**. This type of arrester can be adapted to ribbon line an inch or so away from the center member of the arrester, as shown in **Fig 44**. Sufficient insulation should be removed from the line where it crosses the arrester to permit soldering the arrester connecting leads.

Lightning Grounds

Lightning-ground connecting leads should be of conductor size equivalent to at least #10 wire. The #8 aluminum wire used for TV-antenna grounds is satisfactory. Copper braid 3/4-inch wide (Belden 8662-10) is also suitable. The conductor should run in a straight line to the grounding point. The ground connection may be made to a water pipe system (if the pipe is not plastic), the grounded metal frame of a building, or to one or more 5/8-inch ground rods driven to a depth of at least 8 feet. More detailed information on lightning protection is contained in Chapter 1, Safety.

A central grounding panel for coax cables coming into the house is highly recommended. See **Fig 45** for a photo of the homemade grounding panel installed by Chuck Hutchinson, K8CH, at his Michigan home. The coax cables screwed into dual-female feed-through UHF connectors. K8CH installed this aluminum panel under the outside grill for a duct that provided combustion air to an unused fireplace. He used ground strap to connect to ground rods located under the panel. See the ARRL book *Simple and Fun Antennas* for more information about ground panels.

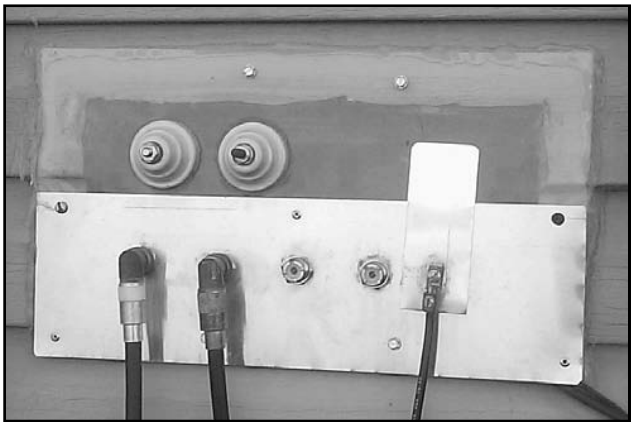

Fig 45—K8CH's coax entry panel mounted on exterior wall (later covered by grill that provides combustion to an unused fireplace). The ground braid goes to a ground rod located beneath the panel. (Photo courtesy: *Simple and Fun Antennas for Hams*)

Before a lightning storm approaches, a prudent ham will disconnect all feed lines, rotor lines and control lines inside the shack to prevent damage to sensitive electronics. When lightning is crashing about outside, you certainly don't want that lightning inside your shack!

Chapter 6

Low-Frequency Antennas

In theory there is no difference between antennas at 10 MHz and up and those for lower frequencies. In reality however, there are often important differences. It is the size of the antennas, which increases as frequency is decreased, that creates practical limits on what can be realized physically at reasonable cost.

At 7.3 MHz, 1λ = 133 feet and by the time we get to 1.8 MHz, 1 λ = 547 feet. Even a λ/2 dipole is very long on 160 meters. The result is that the average antenna for these bands is quite different from the higher bands, where Yagis and other relatively complex antennas dominate. In addition, vertical antennas can be more useful at low frequencies than they are on 20 meters and above because of the low heights (in wavelengths) usually available for horizontal antennas on the low bands. Much of the effort on the low bands is focused on how to build simple but effective antennas with limited resources. This section is devoted to antennas for use on amateur bands between 1.8 to 7 MHz.

The Importance of Low Angles for Low-Band DXing

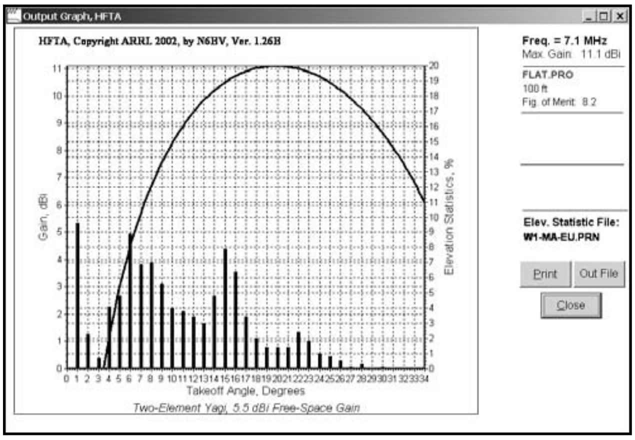

Freq. = 7.1 MHz
Max. Gain: 11.1 dBi
FLAT.PRO
100 ft
Fig. of Merit: 8.2
Elev. Statistic File:
W1-MA-EU.PRN

Fig 1—Screen capture from *HFTA* (HF Terrain Assessment) program showing elevation response for 100-foot high dipole over flat ground on 7.1 MHz, with bar-graph overlay of the statistical elevation angles needed over the whole 11-year solar cycle from New England (Boston) to all of Europe. Even a 100-foot high antenna cannot cover all the necessary angles.

In Chapter 3, The Effects of Ground, we emphasized the importance of matching the elevation response of your antennas as closely as possible to the range of elevation angles needed for communication with desired geographic areas. **Fig 1** shows the statistical 40-meter elevation angles needed over the entire 11-year solar cycle to cover the path from Boston, Massachusetts, to all of Europe. These angles range from 1° (at 9.6% of the time when the 40-meter band is open to Europe) to 28° (at 0.3% of the time).

Fig 1 also overlays the elevation pattern response of a 100-foot high flattop dipole on the elevation-angle statistics, illustrating that even at this height the coverage is hardly optimum to cover all the necessary elevation angles. While Fig 1 is dramatic in its own right, the data can be viewed in another way that emphasizes even more the importance of low elevation angles. **Fig 2** plots the the *cumulative distribution function*, the total percentage of time 40 meters is open from Boston to Europe, at or below each elevation angle. For example, Fig 2 says that 40 meters is open to Europe from Boston 50% of the time at an elevation angle of 9° or less. The band is open 90%

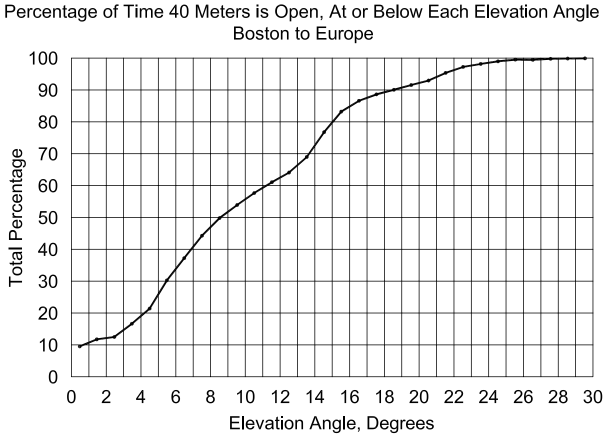

Fig 2—Another way of looking at the elevation statistics from Fig 1. This shows the percentage of time the 40-meter band is open, at or below each elevation angle, on the path from Boston to Europe. For example, the band is open 50% of the time at an angle of 9° or lower. It is open 90% of the time at an angle of 19° or lower.

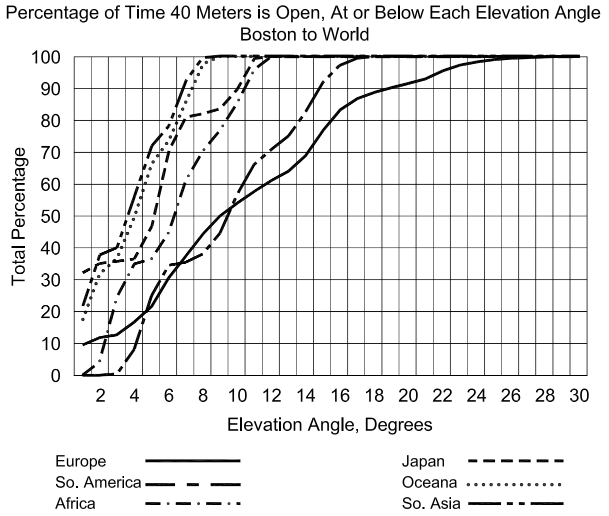

Fig 3—The percentage of time the 40-meter band is open, at or below each elevation angle, for various DX paths from Boston: to Europe, South America, southern Africa, Japan, Oceania and south Asias. The angles are predominantly quite low. For example, on the path from Boston to Japan, 90% of the time when the 40-meter band is open, it is open at elevation angles less than or equal to 10°. Achieving good performance at these low takeoff angles requires very high horizontally polarized antennas, or efficient vertically polarized antennas.

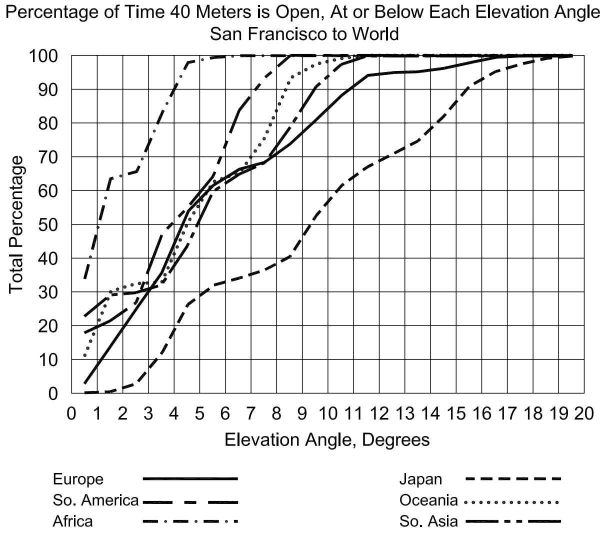

Fig 4—The 40-meter statistics from the West Coast: from San Francisco to the rest of the DX world. Here, 90% of the time the path to Europe is open, it is at takeoff angles less than or equal to 11°. No wonder the hams living on mountain tops do best into Europe from the West Coast.

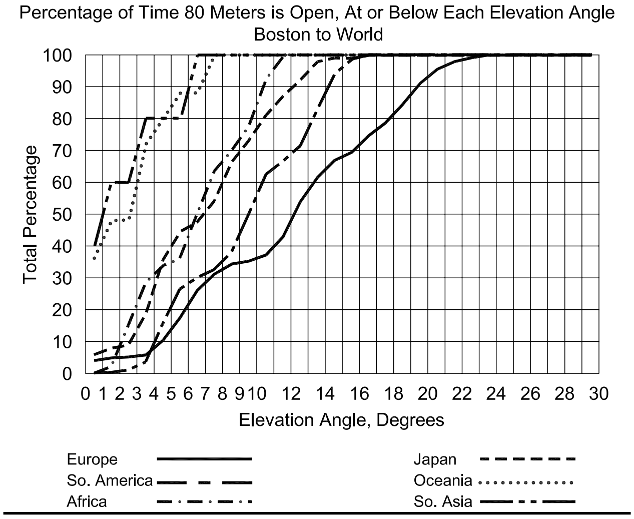

Fig 5—The situation on 80 meters from Boston to the rest of the DX world. Into Europe, 90% of the time the elevation angle is less than or equal to 20°. Into Japan from Boston, 90% of the time the angle is less than or equal to 12°.

of the time at an elevation angle of 19° or less.

Fig 3 plots the 40-meter elevation-angle data for six major geographic areas around the world from Boston. In general, the overall range of elevation angles for far-distant locations is smaller, and the angles are lower than for closer-in areas. For example, from Boston to southern Asia (India), 50% of the time the takeoff angles are 4° or less. On the path to Japan from Boston, the takeoff angles is less than or equal to 6° about 70% of the time. These are low angles indeed.

Fig 4 shows similar data for the 40-meter band from San Francisco, California, to the rest of the world. The path to southern Africa from the US West Coast is a very long-distance path, open some 65% of the time it is open at angles of 2° or less! The 40-meter path to Japan involves takeoff angles of 10° or less more than 50% of the time. If you are

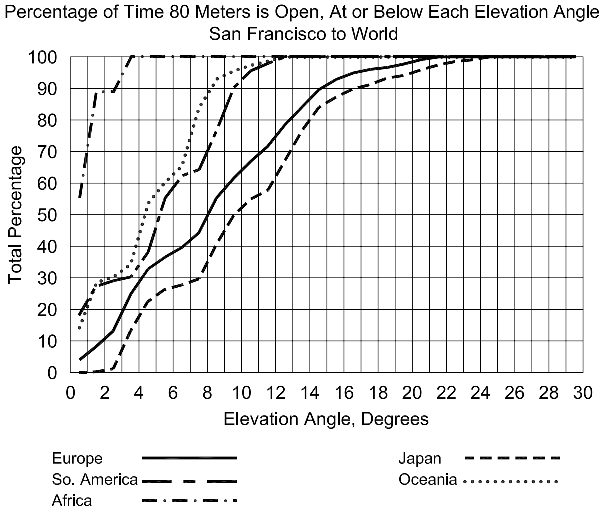

Fig 6—From San Francisco to the rest of the world on 80 meters: 90% of the time on the path to Japan, the takeoff angle is less than or equal to 17°; 50% of the time the angle is less than or equal to 10°; 25% of the time the angle is less than or equal to 6°. A horizontally polarized antenna would have to be 600 feet above flat ground to be optimum at 6°!

fortunate enough to have a 100-foot high flattop dipole for 40 meters, at a takeoff angle of 10° the response would be down about 3 dB from its peak level at 20°. At an elevation angle of 5° the response would be about 8 dB down from peak. You can see why the California stations located on mountain tops do best on 40 meters for DXing.

Fig 5 shows the same percentage-of-time data for the 80-meter band from Boston to the world. Into Europe from Boston, the 80-meter elevation angle is 13° or less more than 50% of the time. Into Japan from Boston, 90% of the time the band is open is at a takeoff angle of 13° or less. (Note that these elevation statistics are computed for "undisturbed" ionospheric conditions. There are times when the incoming angles are affected by geomagnetic storms, and generally speaking the elevation angles rise under these conditions.)

Fig 6 shows the 80-meter data from San Francisco to the world. Low elevation angles dominate in this graph and high horizontal antennas would be necessary to optimal coverage. In fact, 50% of the time for all paths, the elevation angle is less than 10°.

In the rest of this chapter, we'll often compare horizontally polarized antennas at practical heights with vertically polarized antennas, usually at takeoff angles of 5° or 10°, angles useful for DX work. But first, let us look at situations where *high* takeoff angles are most useful.

Short/Medium-Range Communications

Not all hams are interested in working stations thousands of miles from them. Traffic handlers and rag chewers may, in fact, only be interested in *nearby* communications—perhaps out to 600 miles from their location.

For example, a ham in Boston may want to talk with his brother-in-law in Cleveland, OH, a path that is just over 550 miles away. Or an operator in Buffalo, NY, may be the net control station (NCS) for a regional net involving the states of New York and New Jersey. She needs to cover distances up to about 300 miles away.

Depending on the time of day, the most appropriate ham frequencies needed for nearby communications are the 40 and 80/75-meter bands, with 160 meters also a possibility during the night hours, particularly during low portions of the sunspot cycle. The elevation angles involved in such nearby distances are usually high, even almost directly overhead for distances beyond ground-wave coverage (which may be as short as a few miles on 40 meters). For example, the distance between the Massachusetts cities of Boston and Worchester is about 40 miles. On 40 meters, 40 miles is beyond ground-wave coverage. So you will need sky-wave signals that use the ionosphere to communicate between these two cities, where the elevation angle is 83°—very nearly straight up.

Hams using vertical antennas for communications with nearby stations may well find that their signals will be below the noise level typical on the lower bands, especially if they aren't running maximum legal power. Such relatively short-range paths involve so-called *NVIS*, "Near Vertical Incidence Skywave," a fancy name for HF communication systems covering nearby geographic areas. The US military discusses NVIS out to about 500 miles, encompassing the territory a brigade might cover. Elevation angles needed to cover distances from 0 to 500 miles range from about 40º to 90º. This also covers the circumstances involved in amateur communications, particularly in emergency situations.

The following section is adopted from the article "What's the Deal About NVIS?" that appeared in December 2005 *QST*. This article used an example of a hypothetical earthquake in San Francisco to analyze HF emergency communication requirements.

HAM RADIO RESPONSE IN NATURAL DISASTERS

One of San Francisco's somewhat less endearing nicknames is "the city that waits to die." When the *Big Earthquake* does come, you can be assured that all the cell phones and the land-line telephones will be totally jammed, making calling in or out of the San Francisco Bay Area virtually impossible. The same thing occurred in Manhattan on September 11, 2001. The Internet will also be severely affected throughout northern California because of its trunking via the facilities of the telephone network. Commercial electricity will be out in wide areas because power lines will be down. It's virtually certain that water mains will be out of commission too.

If the repeaters on the hills around the San Francisco Bay Area haven't been damaged by the shaking itself, there will be some ham VHF/UHF voice coverage in the intermediate area, at least until the backup batteries run down. But connecting to the dysfunctional telephone system will be difficult at best through amateur repeaters.

With little or no telephone coverage, an obvious need for ham radio communications to aid disaster relief would be from San Francisco to Sacramento, the state capital. Sacramento is 75 miles northeast of the Bay Area, well outside VHF/UHF coverage, so amateur HF will be required on this radio circuit. On-the-ground communications directly between emergency personnel (including the armed-forces personnel who will be brought into the rescue and rebuilding effort) will often be difficult on VHF/UHF since San Francisco is a hilly place. So HF will probably be needed even for short distance, operator-to-operator or operator-to-communications center work. Throughout the city, portable HF stations will have to be quickly set up and staffed to provide such communications.

Hams used to half jokingly call short range HF communications on 40 and 80 meters "cloud warming." This is an apt description, because the takeoff angles needed to launch HF signals up into the ionosphere and then down again to a nearby station are almost directly upwards. **Table 1** lists the distance and takeoff angles from San Francisco to various cities around the western part of the USA. The distance between San Francisco and Sacramento is about 75 miles, and the optimum takeoff angle is about 78°. Launching such a high-angle signal is best done using horizontally polarized antennas mounted relatively close to the ground.

GEOGRAPHIC COVERAGE FOR NVIS

Figure 7A shows the geographic area coverage around San Francisco for a 100-W, 7.2-MHz station using an inverted V dipole. The center of this antenna is 20 feet above flat

Table 1
Average Elevation Angles for Target Destinations from San Francisco

Location	*Distance Miles*	*Average Elevation Angle, Degrees*
San Jose, CA	43	80
Sacramento, CA	75	78
Fresno, CA	160	63
Reno, NV	185	60
Los Angeles	350	44
San Diego	450	42
Portland, OR	530	30
Denver, CO	950	18
Dallas, TX	1500	8

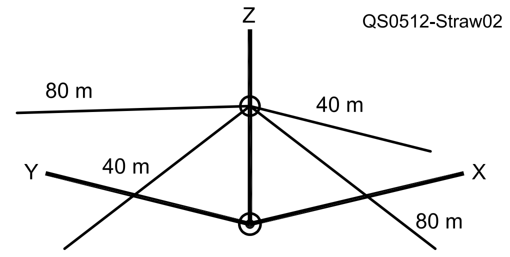

Fig 8—Layout for two band inverted V dipoles for 40 and 80 meters. The two dipoles are fed together at the center and are laid out at right angles to each other to minimize interaction between them. Each end of both dipoles is kept 8 feet above ground for personnel safety.

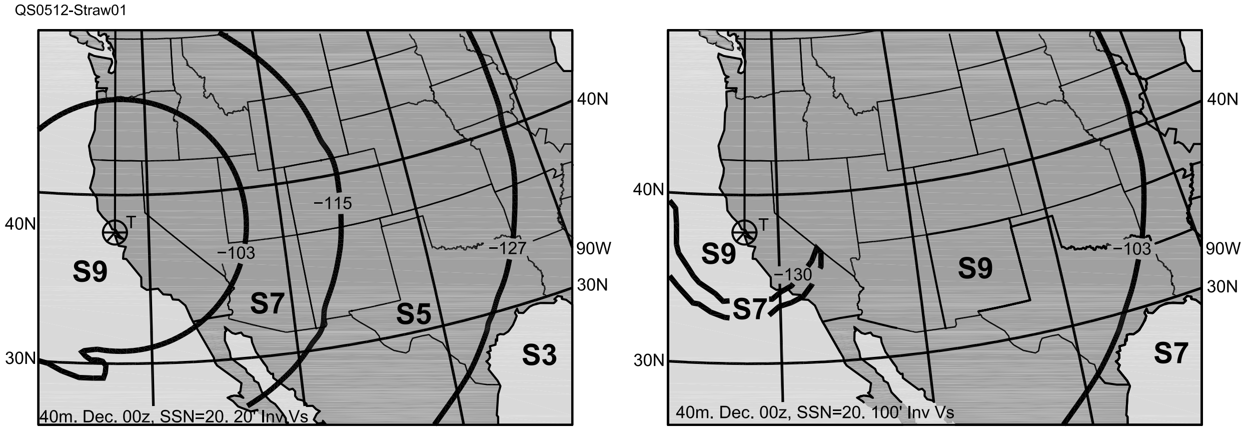

(A)

(B)

Fig 7—At A, Predicted 40 meter geographic coverage plot for a 100 W transmitter in December at 0000 UTC (near sunset), for a SSN (Smoothed Sunspot Number) of 20. The antennas used are 20 foot-high inverted V dipoles. At B, 40 meter coverage for same date and time, but for 100 foot-high flattop dipoles. Most of California is well covered with S9 signals in both cases, but there is more susceptibility in the higher dipole case to thunderstorm crashes coming from outside California, for example from Arizona or even Texas. Such noise can interfere with communications inside California.

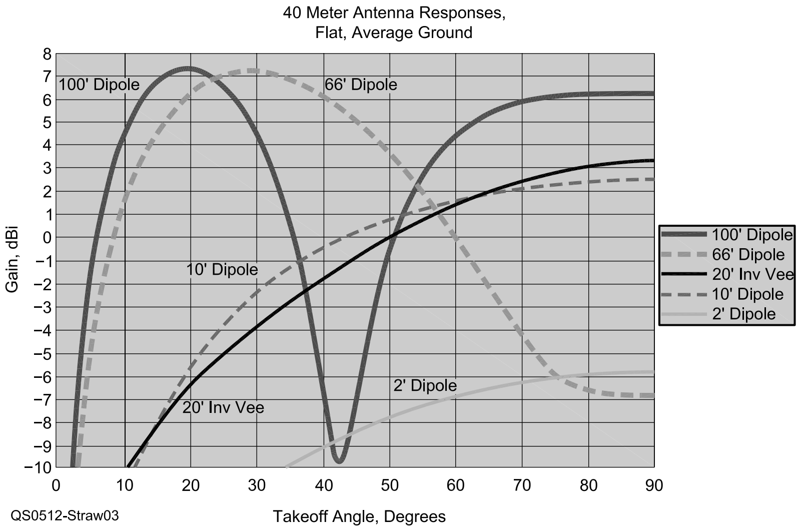

Fig 9—Elevation plots for different 40 meter antennas above flat ground with average ground characteristics (5 mS/m conductivity and dielectric constant of 13). The 10 foot-high flattop dipole and the 20 foot-high inverted V dipoles both have close to the same characteristics. Note that there is a null in the response of the 100 foot-high flattop dipole at a 42° elevation angle. The gain there is roughly that of a 2 foot-high dipole!

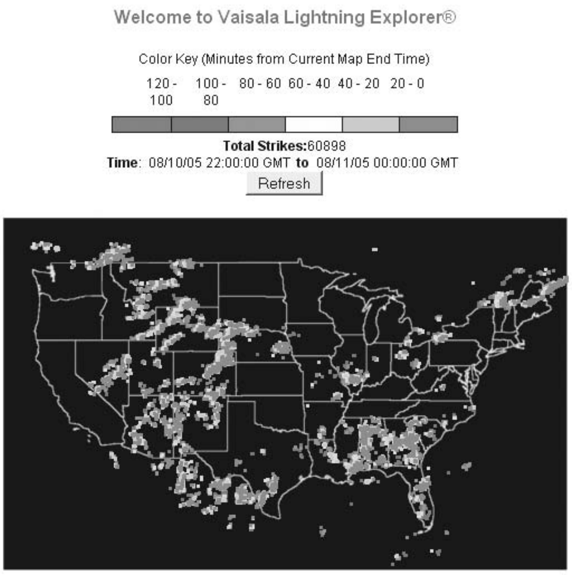

Welcome to Vaisala Lightning Explorer®

Color Key (Minutes from Current Map End Time)

120 - 100 | 100 - 80 | 80 - 60 | 60 - 40 | 40 - 20 | 20 - 0

Total Strikes:60898

Time: 08/10/05 22:00:00 GMT **to** 08/11/05 00:00:00 GMT

Fig 10—The distribution of lightning strikes across the USA for August 10, 2005 from 2200 to 0000 UTC, in the afternoon California time. There are lots of lightning strikes in the US during the summer—60,898 of them in this two-hour period! (*Courtesy Vaisala Lightning Explorer.*)

ground and the ends are 8 feet high. An actual implementation of such an antenna could be as an 80-meter inverted V, fed in parallel with a 40-meter inverted V dipole at a 90° angle. See **Fig 8**. The 8-foot height puts the ends high enough to prevent RF burns to humans (or most animals). The low height of the antenna above ground means that the azimuthal pattern is omnidirectional for high elevation angles.

Fig 7 was generated using the *VOAAREA* program, part of the *VOACAP* propagation-prediction suite, for the month of December. This was for 0000 UTC, close to sundown, for a low period of solar activity (Smoothed Sunspot Number, SSN of 20). The receiving stations were also assumed to be using identical inverted-V dipoles.

You can see that almost the whole state of California is covered with S9 signals, minus only a thin slice of land near the Mexican border in the southeast portion of the state, where the signal drops to S7. Signals from Texas are predicted to be only S5 or less in strength. Signals (or thunderstorm static) coming from, say, Louisiana would be several S units weaker than signals from central Texas.

Now take a look at Fig 7B. Here, the date, time and solar conditions remain the same, but now the antennas are 100-foot high flattop dipoles. California is still blanketed with S9 signals, save for an interesting crescent-shaped slice near Los Angeles, where the signal drops down to S7. Close investigation of this intriguing drop in signal strength reveals that the necessary elevation angle, 44°, from San Francisco to this part of southern California falls in the first null of the 100-foot high antenna's elevation pattern. See **Fig 9**, which shows the elevation patterns for five 40-meter antennas at different heights. In the null at a 44° takeoff angle, the 100-foot high dipole is just about equal to a 2-foot high dipole. We'll discuss 2-foot high dipoles in more detail later.

For most of California, the problem with 100-foot high 40-meter antennas is that interfering signals from Texas, Colorado or Washington State will *also* be S9 in San Francisco. So will static crashes coming from thunderstorms all over the West and much of the Gulf Coast. (Ed Farmer, AA6ZM, joked once that the Army doesn't have any problem with interfering signals—they just call in an airstrike. We hams don't generally have this ability, although we occasionally call in the FCC.) See **Fig 10**, which shows a typical distribution of thunderstorms across the US in the late afternoon, California time, in mid-August. There certainly are a lot of thunderstorms raging around the country in the summer.

The signal-to-noise and signal-to-interference ratios for a 20-foot high inverted V dipole will be superior for medium-

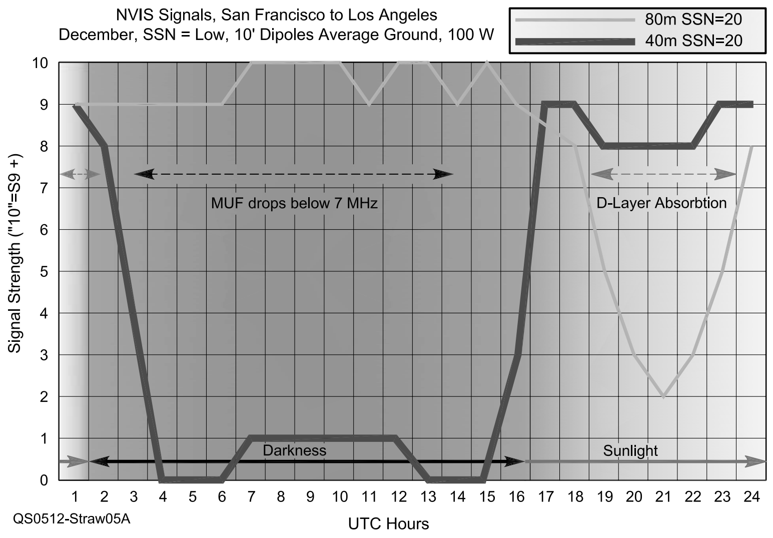

Fig 11—VOACAP calculations for a 350 mile path from San Francisco to Los Angeles, using 10 foot-high flattop dipoles. This plot shows the signal strength in S Units ("S10" = S9+10) for a worst-case month/SSN combination—winter solstice, in December, for a low level of solar activity (SSN = 20). The 40-meter signal drops to a very low level during the night because the MUF drops well below 7.2 MHz. The 80-meter signal drops in the afternoon because of D-layer absorption. For 24-hour communications on this path, the rule of thumb is to select 40 meters during the day and 80 meters during the night.

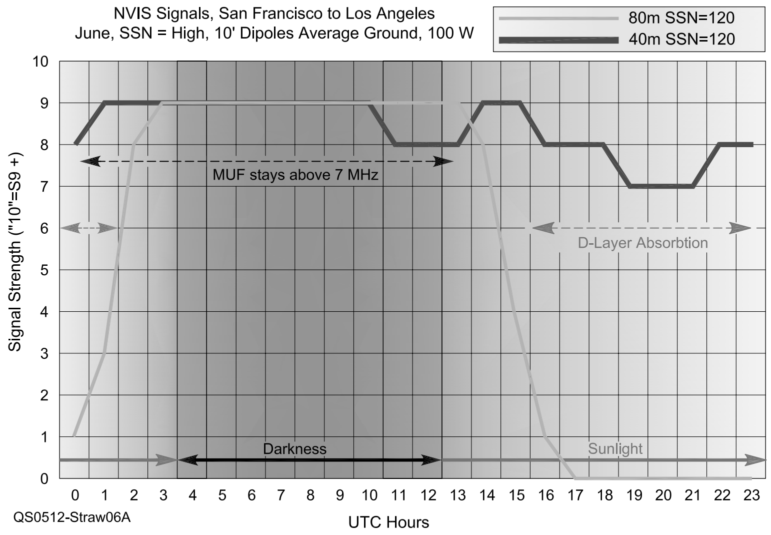

Fig 12—Signal strengths for the San Francisco to Los Angeles path for a worst-case month/SSN combination—summer solstice, in June, for a high level of solar activity (SSN = 120). Now 80 meters drops out more dramatically during the daylight hours, due to increased D-layer absorption. At this high level of solar activity, 40 meters remains open 24 hours with reasonable signal levels. However, the NVIS rule-of-thumb still holds: Use 40 meters during the day; 80 meters at night.

range distances, say out to 500 miles from the center, compared to a 100-foot high antenna. The 20-foot high antenna can discriminate against medium-angle thunderstorm noise in the late afternoon coming from the Arizona desert, although it wouldn't help much for thunderstorms in the Sierra Nevada in central Nevada, which are arriving in San Francisco at high angles, along with the desired NVIS signals.

This is the essence of what NVIS means. NVIS exploits the difference in elevation pattern responses of low horizontally polarized antennas compared to higher horizontal antennas, or even verticals. Over the years, many hams have been lead to believe that higher is always better. This is not quite so true for consistent coverage of medium or short distance signals!

If NVIS only involved putting up a low horizontally polarized antenna on 40 meters the story would end here. However, real cloud warming is more complicated. It also involves the intelligent choice of more than just one operating frequency to achieve reliable all day, all-night communications coverage.

Fig 11 shows the signal strength predicted using *VOACAP* for the 350-mile path from San Francisco to Los Angeles for the month of December for a period of low solar activity (SSN of 20). The antennas used in this case are 10-foot high dipoles, just for some variety. These act almost like 20-foot high Inverted V dipoles. December at a low SSN was chosen as a worst-case scenario because the *winter solstice* occurs on December 21. This is the day that has the fewest hours of daylight in the year. (Contrast this with the *summer solstice*, on June 21, which has the most hours of daylight in the year.) Note that the upper signal limit in Fig 11 is "S10"—a fictitious quantity that allows easier graphing.

S10 is equivalent to S9+, or at least S9+10 dB.

The 40-meter curve in Fig 11 shows that the MUF (maximum usable frequency) actually drops below the 7.2 MHz amateur band after sunset. The signal becomes quite weak for about 14 hours during the night, from about 0300 to 1700 UTC. In a period of low solar activity the 40-meter band thus becomes strictly a *daytime band* on this medium-distance path.

The 80-meter curve in Fig 11 shows strong signals after dusk, through the night and up until about an hour after sunrise. After sunrise, 80 meters starts to suffer absorption in the D layer of the ionosphere and hence the signal strength drops. Here, 80 meters is a true *nighttime band*.

Let's see what happens from San Francisco to Los Angeles during a period of high solar activity (SSN of 120) during the summer solstice in June. **Fig 12** shows that 40 meters now stays open all hours of the day due to the greater number of hours of sunlight in June and because the ionosphere becomes more highly ionized by higher solar activity. Meanwhile, 80 meters still remains a nighttime band during these conditions on this path.

Now, let's look at a shorter-distance path—our 75-mile emergency communications path from San Francisco to Sacramento. We'll again use June during the summer solstice, at a high level of solar activity (SSN of 120) because this represents another worst-case scenario. **Fig 13** shows that 40 meters remains open on this path all day, dropping to a lower signal level just before sunrise. At sunrise, the MUF drops close to 7.2 MHz. 80 meters is still mainly a nighttime band to Sacramento, even though it does yield workable signal levels even during the daylight hours. However, 40 meters is better from 1200 to 0400 UTC, so 40 would be still the right daytime band for this path during the day.

CHOOSING THE RIGHT NVIS FREQUENCY

You can see that a pattern is developing here for efficient NVIS short/medium-distance communications out to 500 miles:

- You should pick a frequency on 40 meters during the day.
- You should pick a frequency on 80 meters during the night.
- You should choose an antenna that emphasizes moderate to high elevation angles, from 40° to almost directly overhead at 90°.

"What about 60 meters?" you might ask. The characteristics on 60 meters fall in-between 40 and 80 meters, although it resembles 40 meters more closely. With characteristics close to that of 40, but with only five channels available and a 50-W power limit, the 60-meter band is of low utility for serious NVIS use.

What about 160 meters? For 100-W level radios, even at the worst-case month or during low solar activity, the critical frequency doesn't fall below 3.8 MHz often enough to destroy the ability to communicate, even for short distances. That is a relief, considering that installing a 160-meter half-wave dipole involves a 255-foot wingspan, and it would need to be elevated at least 30 feet in the center. A short loaded vertical such as a 160-meter mobile whip would have poor response at the high elevation angles needed for NVIS. You could probably put a monster 160-meter horizontal dipole up at a permanent location, but hauling such a thing around in the field would not be an easy task.

SOME OTHER OBSERVATIONS ABOUT NVIS—STRATEGY

You could pose the question about whether NVIS is an operating *mode* or whether it is actually an operating *strategy*. We maintain that NVIS is a strategy. It involves choosing both appropriate frequencies and then appropriate antennas for those frequencies. Fig 13 does show that on short-distance

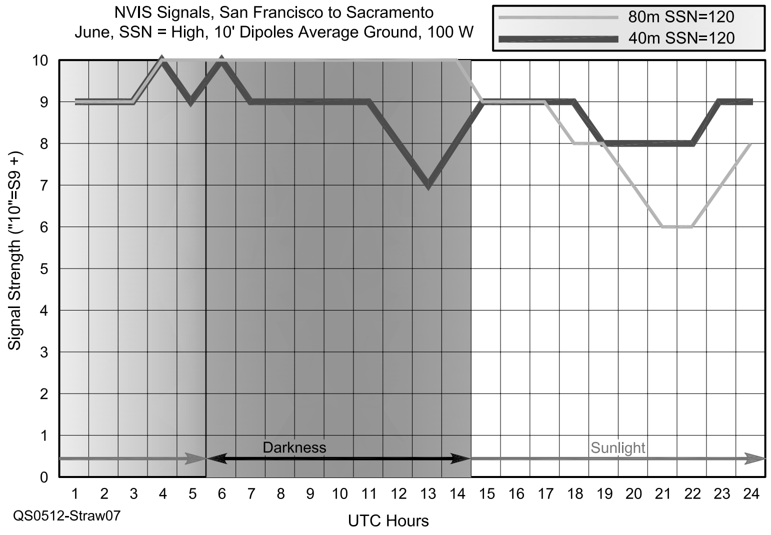

Fig 13—Signal strengths for a 75 mile path—San Francisco to Sacramento. This is for June and SSN = 120. Either band could be used successfully over the full 24-hour period because signal levels are always higher than S6. But the simple NVIS rule-of-thumb still holds: Use 40 meters during the day; 80 meters at night. This simplifies giving instructions to operators unaccustomed to the use of HF.

paths, such as between San Francisco and Sacramento, you could stay on 80 meters all day and night. But if you have to give a single rule-of-thumb to operators who are not very experienced at operating HF, we would tell them to operate on the higher frequency band during the day and on the lower frequency band at night.

SOME OTHER OBSERVATIONS ABOUT NVIS—ANTENNA HEIGHT

Some NVIS aficionados have advocated placing dipoles only a few feet over ground, something akin to saying, “If low is good for NVIS, then lower must be even better.” Now we are not claiming that a very low antenna *won’t* work in specific instances—for example, covering a small state such as Rhode Island or even just the San Francisco Bay Area.

It certainly is convenient to mount a 40-meter dipole on some 2-foot high red traffic cones! You should be very skeptical, however, about the ability of such antennas to cover all of a large state, such as California or Texas, especially on 80 meters. **Fig 14** shows the computed elevation responses for a number of 80-meter antennas, including a 2-foot-high dipole.

Fig 15B shows the 80 meter geographic coverage plot for 2-foot-high flattop dipoles, compared with the plot in Fig 15A for 20-foot-high inverted V dipoles on both ends of the path. The 2-foot-high dipoles produce about two S-units less signal across all of California than the 20-foot-high inverted V dipoles, at 0300 UTC in December, with an SSN of 20. The reason is that a low dipole will suffer more losses in the ground under it.

The differential between California signals and possible interfering signals from, say, New Mexico, is predicted to be four S-units, the same as it is for the higher inverted V dipole

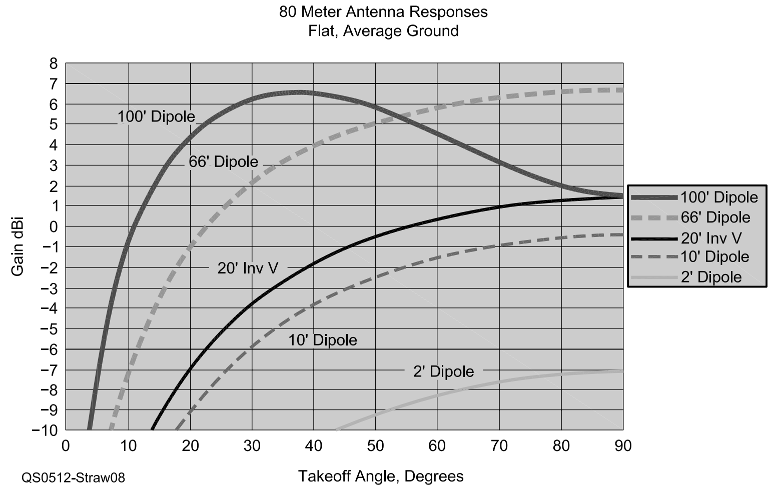

Fig 14—Elevation response patterns for 80 meter antennas over average soil. The shapes track each other rather well, remaining parallel for heights from 2 to 66 feet over flat ground. The 2 foot dipole is substantially down, about 9 dB, from the 20 foot inverted V dipole at all angles.

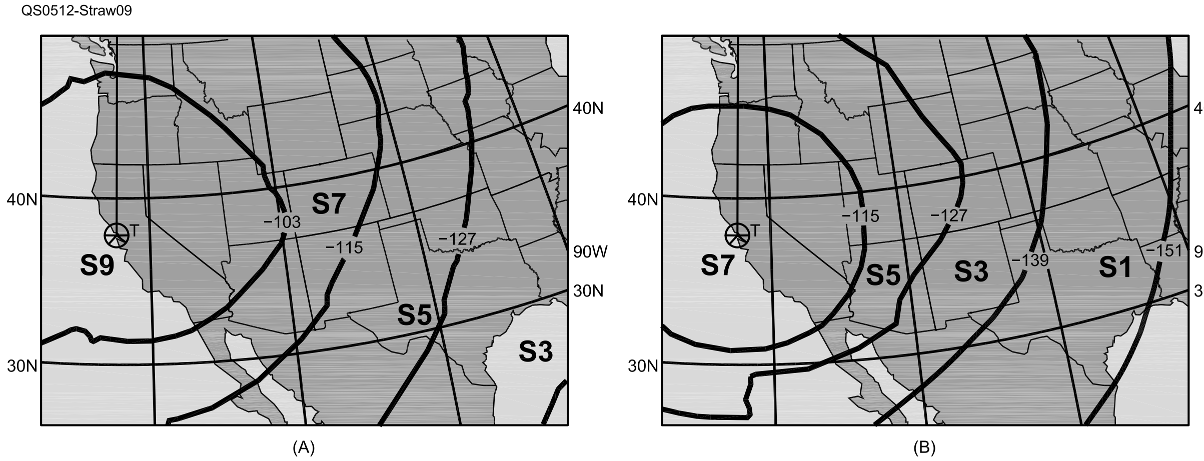

Fig 15—Geographic coverage plots for December, SSN = 20, 0300 UTC. At A, antennas are 20 foot-high inverted V dipoles over Average soil. At B, antennas are 2-foot-high flattop dipoles over Average soil. The response for the 2-foot-high antennas is down about 2 S Units, 8 to 12 dB for a typical communications receiver.

at 20 feet. Thus there is no real advantage in terms of signal-to-interference ratio or signal-to-noise ratio (for thunderstorm static crashes) for either height. This is because the shape of all the response curves in Fig 14 below 20 feet essentially track each other in parallel.

However, the lower the antenna, the lower the transmitted signal strength. Physics remain physics. And if you are in an emergency situation operating on batteries, you could reduce power from 100 W to 10 W with a 20-foot high inverted-V antenna and still maintain the same signal strength as a 2-foot high dipole at 100W.

LOW NVIS ANTENNAS AND LOCAL POWERLINE NOISE

Some advocates of really low antennas have stated that the received noise is much lower than that received from higher antennas, and this therefore leads to better signal-to-noise ratios (SNR). How much this is true depends on the source of the noise. If the noise comes from distant thunderstorms, then the SNR advantage going to a 2-foot antenna from a 20-foot-high one is insignificant, as Fig 15 indicates.

If noise is from an arcing insulator on a HV power line half a mile away, that noise will arrive at the antenna as a ground-wave signal. We calculate that the 2-foot antenna receives 4.4 dB less noise by groundwave than a 20-foot-high inverted V dipole. However, at an incoming elevation angle of 45º—suitable for a signal going from Los Angeles to San Francisco—the signal would be down 7.1 dB on the low dipole compared to the higher antenna. The net loss in SNR for the 2-foot-high dipole is thus 7.1– 4.4 or 2.7 dB. Close, but no cigar. Summarizing about really low NVIS antennas:

- A 2-foot-high dipole yields weaker signals, but without an SNR advantage compared to its more elevated brethren.
- A 2-foot-high dipole is a lot easier to trip over at night. We would call this a "knee biter" (or maybe an "ankle biter" if you're really tall).
- You (and your dog) can easily get RF burns from an antenna that is only 2 feet off the ground.

This is not a winning strategy to make friends or QSOs, it seems. But still, a really low dipole may serve your short-range communication needs just fine. But remember, that just as "higher is better" isn't universally true for NVIS (or even longer range) applications, "lower is better" isn't a panacea either.

ELEVATION ANGLES FOR MODERATE DISTANCES ON 75/80 METERS

Fig 16 shows the elevation angles statistics for a 75-meter, 550-mile path from Boston to Cleveland, together with overlays of the elevation patterns for several different types of antennas. These elevation statistics cover all parts of the 11-year solar cycle for this path. The responses for the popular G5RV antenna (described later in this chapter) are shown for two different heights above flat ground: 50 and 100 feet. An 80-meter half-wave sloper ("full sloper") and an 80-meter ground-plane antenna are also shown. All antenna patterns are for "average ground" constants of 5 mS/m conductivity and a dielectric constant of 13.

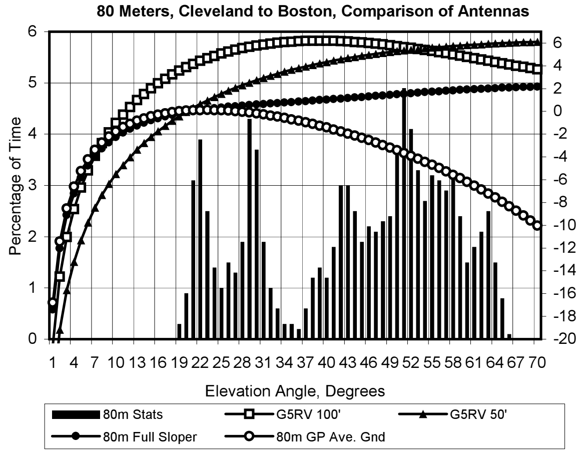

Fig 16—80/75-meter elevation statistics for all portions of the 11-year solar cycle for the path from Cleveland, Ohio, to Boston, Massachusetts, together with the elevation responses for four different multiband antennas. The 100-foot high horizontally polarized G5RV performs well over the entire range of necessary takeoff elevation angles.

At the statistically most significant takeoff angles around 50°, the two horizontally polarized G5RV antennas are about equal. At the second-highest elevation peak near 30°, the 100-foot G5RV has about a 4-dB advantage over its lower counterpart. The full sloper has comparable performance to the 100-foot high G5RV from 1° to about 20° and then gradually rises to its peak at angles higher than 70°. The full sloper is superior to the 50-foot horizontal G5RV at low takeoff elevation angles. The 80-meter ground plane has a deep null directly overhead. At an elevation angle of 70° it is down some 16 dB compared to the 50-foot high horizontal G5RV.

The advantage of antennas suitable for high-angle radiation was vividly demonstrated during a 75-meter QSO one fall evening between N6BV/1 in southern New Hampshire and W1WEF in central Connecticut. This involved a distance of about 100 miles and W1WEF was using his Four Square vertical array. Although W1WEF's signal was S9 on the Four Square, N6BV/1 suggested an experiment. Instead of connecting the so-called "dump power" connector on his Comtek ACB-4 hybrid phasing coupler to a 50-Ω dummy load (the normal configuration), W1WEF switched the dump power to his 100-foot high 80-meter horizontal dipole. W1WEF's signal came up more than 20 dB! The approximately 100-W of power that would otherwise be "wasted" in the dummy load was converted to useful signal.

ELEVATION ANGLES FOR MODERATE DISTANCES ON 40 METERS

Fig 17 shows the situation for the 40-meter band, from Boston to Cleveland, together with the same antennas used for 80 meters in Fig 16. Note that the 100-foot high horizontally

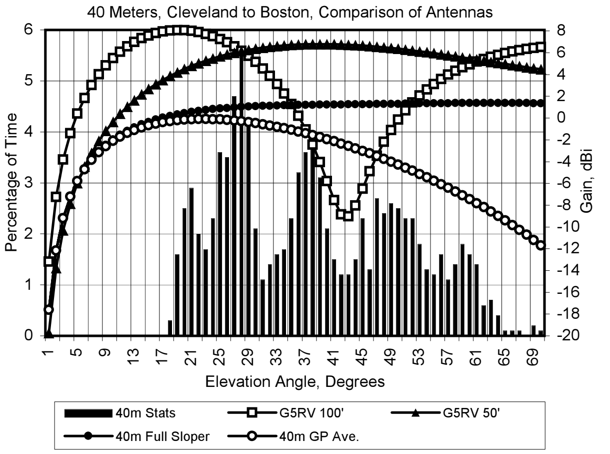

Fig 17—40-meter elevation statistics for the Cleveland to Boston path, together with elevation patterns for four antennas. Here, the 100-foot high horizontally polarized G5RV would have a null in the middle of the range of elevation angles needed for consistent performance on this path. For multiband use on this path to relatively nearby stations, the 50-foot high horizontal antenna would be a better choice than the 100-foot high antenna.

polarized G5RV has about a 16-dB null at an elevation angle of 43°. This doesn't affect things for low elevation angles, but it certainly has a profound effect on signals arriving between about 30° to 60°, especially when compared to the 50-foot high horizontal G5RV. The 40-meter full sloper beats out the high horizontal antenna from about 35° to 50°. And the ground plane is obviously not the antenna of choice for this moderate-range path from Boston to Cleveland, although it is still a good performer on longer-distance paths, with their low takeoff angles.

A 100-foot high multiband dipole is about ⅜-λ high on 75/80 meters. It is an excellent antenna for general-purpose local and DXing operation. But the same dipole used on 40 meters becomes ¾-λ high. At that height, the nulls in its elevation pattern give large holes in coverage for nearby 40-meter contacts. Many operators have found that a 40- to 50-foot high dipole on 40 meters gives them far superior performance for close-in QSOs, when compared to a high dipole, or even a high 2-element 40-meter Yagi.

NVIS SUMMARY

The use of NVIS strategies to cover close-in and intermediate distance communications within about 600 miles involves the intelligent choice of low HF frequencies. As a rule-of-thumb for ham band NVIS, 40 meters is recommended for use during the day; 80 meters during the night.

NVIS involves the choice of antennas suitable for this strategy. Horizontally polarized dual-band 80 and 40-meter flattop dipoles that are mounted higher than about 10 feet high will work adequately for portable operations. Dual-band 80 and 40-meter inverted V dipoles supported 20 feet above the ground at the center can also work well in portable operations.

Single-band 40-meter flattop antennas about 30 feet high and 80-meter flattop antennas about 60 feet high can do a good job for fixed locations.

Horizontal Antennas for the Low Bands

As shown in Chapter 3, The Effects of Ground, and here, radiation angles from horizontal antennas are a very strong function of the height above ground in wavelengths. Typically for DX work heights of λ/2 to 1 λ are considered to be a minimum. As we go down in frequency these heights become harder to realize. For example, a 160-meter dipole at 70 feet is only 0.14 λ high. This antenna will be very effective for local and short distance QSOs but not very good for DX work. Despite this limitation, horizontal antennas are very popular on the lower bands because the low frequencies are often used for short range communications, local nets and rag chewing. Also horizontal antennas do not require extensive ground systems to be efficient.

DIPOLE ANTENNAS

Half-wave dipoles and variations of these can be a very good choice for a low band antenna. A variety of possibilities are shown in **Fig 18**. An untuned or "flat" feed line is a logical choice on any band because the losses are low, but this generally limits the use of the antenna to one band. Where only single-band operation is wanted, the λ/2 antenna fed with open-wire line is one of the most popular systems on the 3.5 and 7-MHz bands.

If the antenna is a single-wire affair, its impedance is in the vicinity of 60 Ω, depending on the height and the ground characteristics. The most common way to feed the antenna is with 50- or 75-Ω coaxial line. Heavy coaxial lines present support problems because they are a concentrated weight at the center of the antenna, tending to pull the center of the antenna down. This can be overcome by using an auxiliary pole to take at least some of the weight of the line. The line should come away from the antenna at right angles, and it can be of any length.

Folded Dipoles

A folded dipole (Fig 18B and C) has an impedance of about 300 Ω, and can be fed directly with any length of 300-Ω line. The folded dipole can be made of ordinary wire spaced by lightweight wooden or plastic spacers, 4 or 6 inches long, or a piece of 300 or 450-Ω twin-lead or ladder line.

A folded dipole can be fed with a 600-Ω open wire line with only a 2:1 SWR, but a nearly perfect match can be ob-

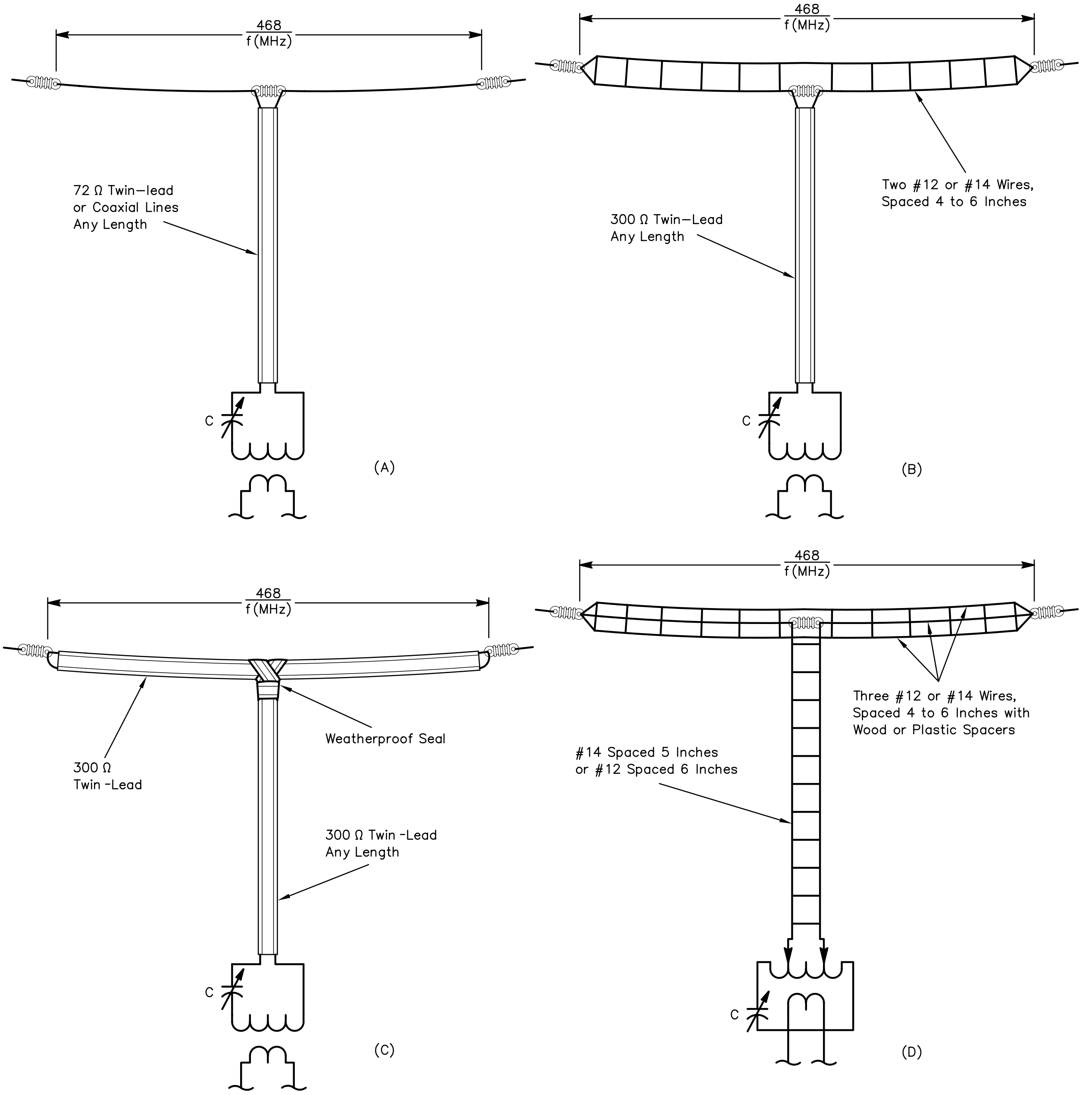
468
f (MHz)
72 Ω Twin—lead
or Coaxial Lines
Any Length
C
(A)
468
f (MHz)
Two #12 or #14 Wires,
Spaced 4 to 6 Inches
300 Ω Twin—Lead
Any Length
C
(B)
468
f (MHz)
300 Ω
Twin -Lead
Weatherproof Seal
300 Ω Twin -Lead
Any Length
C
(C)
468
f (MHz)
Three #12 or #14 Wires,
Spaced 4 to 6 Inches with
Wood or Plastic Spacers
#14 Spaced 5 Inches
or #12 Spaced 6 Inches
C
(D)

Fig 18—Half-wavelength antennas for single band operation. The multiwire types shown in B, C and D offer a better match to the feeder over a somewhat wider range of frequencies but otherwise the performances are identical. The feeder should run away from the antenna at a right angle for as great a distance as possible. In the coupling circuits shown, tuned circuits should resonate to the operating frequency. In the series-tuned circuits of A, B, and C, high L and low C are recommended, and in D the inductance and capacitance should be similar to the output-amplifier tank, with the feeders tapped across at least ½ the coil. The tapped-coil matching circuit shown in Chapter 25 can be substituted in each case.

tained with a three-wire dipole fed with either 450-Ω ladder line or 600-Ω open wire line. One advantage of the two- and three-wire antennas over the single wire is that they offer a better match over a wider band. This is particularly important if full coverage of the 3.5-MHz band is contemplated.

Inverted-V Dipole

The halves of a dipole may be sloped to form an inverted V, as shown in **Fig 19**. This has the advantages of requiring only a single high support and less horizontal space. There will be some difference in performance between a normal horizontal dipole and the inverted V as shown by the radiation patterns in **Fig 20**. There is small loss in peak gain and the pattern is less directional.

Sloping of the wires results in a raising of the resonant frequency and a decrease in feed-point impedance and

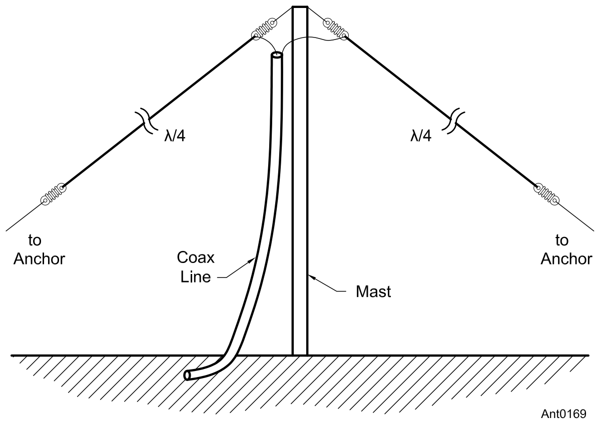

Fig 19—The inverted-V dipole. The length and apex angle should be adjusted as described in the text.

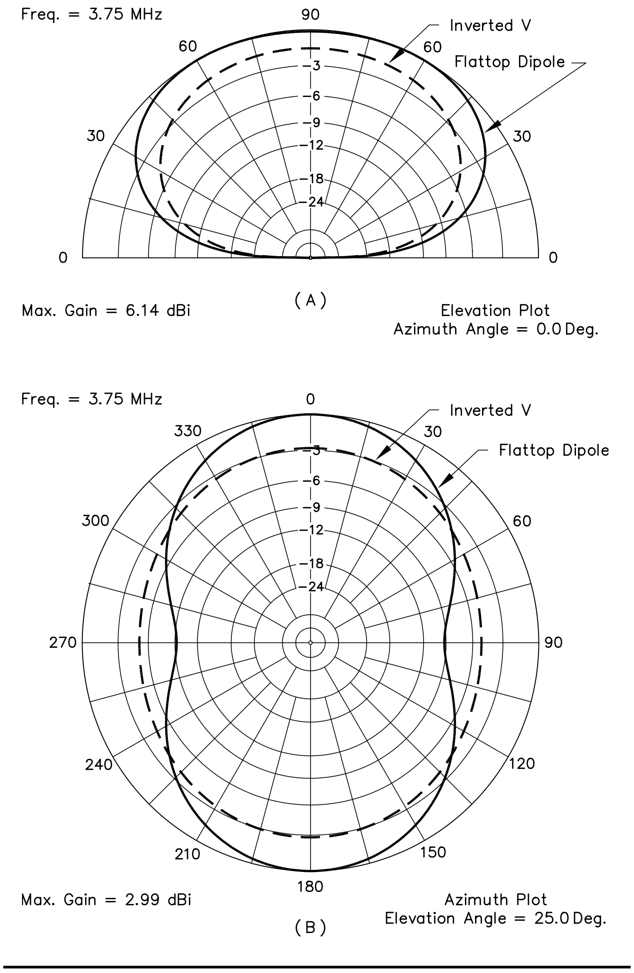

Fig 20—At A, elevation and at B, azimuthal radiation patterns comparing a normal 80-meter dipole and an inverted-V dipole. The center of both dipoles is at 65 feet and the ends of the inverted V are at 20 feet. The frequency is 3.750 MHz.

bandwidth. Thus, for the same frequency, the length of the dipole must be increased somewhat. The angle at the apex is not critical, although it should probably be made no smaller than 90°. Because of the lower impedance, a 50-Ω line should be used. For those who are dissatisfied with anything but a perfect match, the usual procedure is to adjust the angle for lowest SWR while keeping the dipole resonant by adjustment of length. Bandwidth may be increased by using multiconductor elements, such as a cage configuration.

PHASED HORIZONTAL ARRAYS

Phased arrays with horizontal elements, which provide some directional gain, can be used to advantage at 7 MHz, if they can be placed at least 40 feet above ground. At 3.5 MHz heights of 70 feet or more are needed for any real advantage.

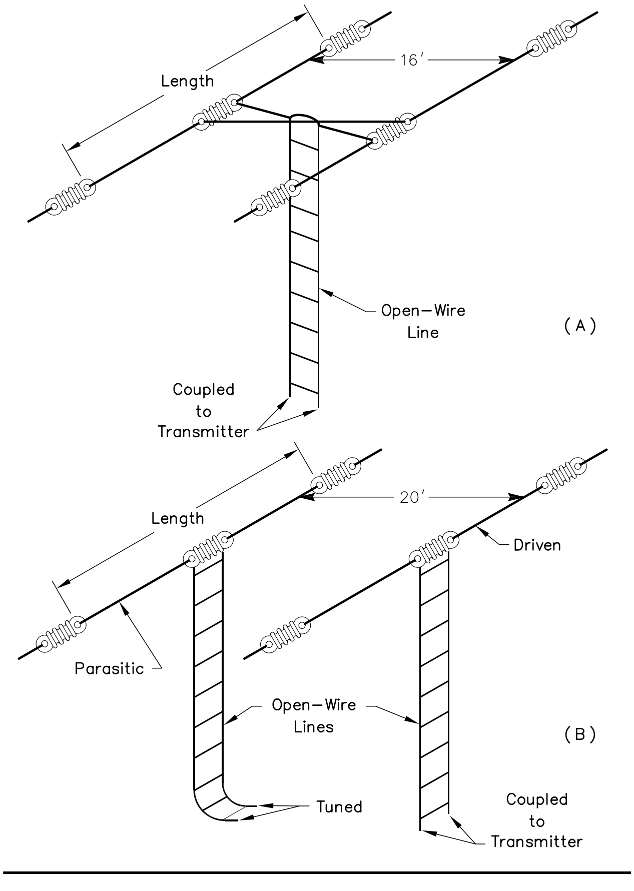

Fig 21—Directional antennas for 7 MHz. To realize any advantage from these antennas, they should be at least 40 feet high. At A, system is bidirectional. At B, system is unidirectional in a direction depending upon the tuning conditions of the parasitic element. The length of the elements in either antenna should be exactly the same, but any length from 60 to 150 feet can be used. If the length of the antenna at A is between 60 and 80 feet, the antenna will be bidirectional along the same line on both 7 and 14 MHz. The system at B can be made to work on 7 and 14 MHz in the same way, by keeping the length between 60 and 80 feet.

Many of the driven arrays discussed in Chapter 8 and even some of the Yagis discussed in Chapter 11 can be used as fixed directional antennas. If a bidirectional characteristic is desired, the W8JK array, shown in **Fig 21A**, is a good one. If a unidirectional characteristic is required, two elements can be mounted about 20 feet apart and provision included for tuning one of the elements as either a director or reflector, as shown in Fig 21B.

The parasitic element is tuned at the end of its feed line with a series or parallel-tuned circuit (whichever would normally be required to couple power into the line), and the proper tuning condition can be found by using the system for receiving and listening to distant stations along the line to the rear of the antenna. Tuning the feeder to the parasitic element can minimize the received signals from the back of the antenna. This is in effect adjusting the antenna for maximum front-to-back ratio. Maximum front-to-back does not occur at the same point as maximum forward gain but the loss in forward gain is very small. Adjusting the antenna for maximum forward gain (peaking received signals in the forward direction) may increase the forward gain slightly but will almost certainly result in relatively poor front-to-back ratio.

A MODIFIED EXTENDED DOUBLE ZEPP

If the distance between the available supports is greater than λ/2 then a very simple form of a single wire collinear array can be used to achieve significant gain. The *extended double Zepp* antenna has long been used by amateurs and is discussed in Chapter 8, Multielement Arrays. A simple variation of this antenna with substantially improved bandwidth can be very useful on 3.5 and 7.0 MHz. The following material has been taken from an article by Rudy Severns, N6LF, in *The ARRL Antenna Compendium Vol 4*.

The key to improving the characteristics of a standard double-extended Zepp is to modify the current distribution. One of the simplest ways to do this is to insert a reactance(s) in series with the wire. This could either be an inductor(s) or a capacitor(s). In general, a series capacitor will have a higher Q and therefore less loss. With either choice it is desirable to use as few components as possible.

As an initial trial at 7 MHz, only two capacitors, one on each side of the antenna, were used. The value and position of the capacitors was varied to see what would happen. It quickly became clear that the reactance at the feed point could be tuned out by adjusting the capacitor value, making the antenna look essentially like a resistor over the entire band. The value of the feed-point resistance could be varied from less than 150 Ω to over 1500 Ω by changing the location of the capacitors and adjusting their values to resonate the antenna.

A number of interesting combinations were created. The one ultimately selected is shown in **Fig 22**. The antenna is 170 feet in length. Two 9.1 pF capacitors are located 25 feet out each side of the center. The antenna is fed with 450-Ω transmission line and a 9:1 three-core Guanella balun used at the transmitter to convert to 50 Ω. The transmission line can be any convenient length and it operates with a very low SWR.

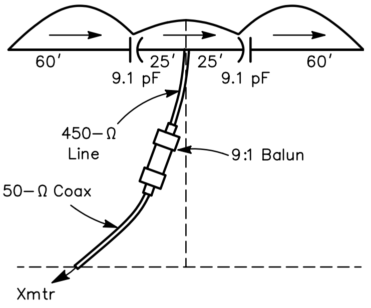

Fig 22—Schematic for modified N6LF Double Extended Zepp. Overall length is 170 feet, with 9.1 pF capacitors placed 25 feet each side of center.

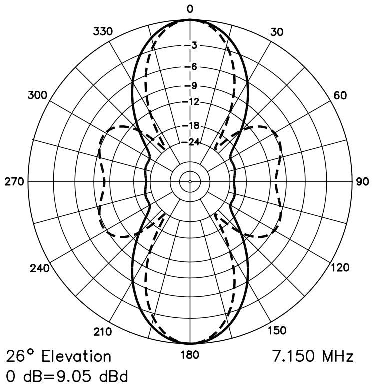

Fig 23—Azimuth pattern for N6LF Double Extended Zepp (solid line), compared to classic Double Extended Zepp (dashed line). The main lobe for the modified antenna is slightly broader than that of the classic model, and the sidelobes are suppressed better.

That's all there is to it. The radiation pattern, overlaid with that for a standard DEZepp for comparison, is shown in **Fig 23**. The sidelobes are now reduced to below 20 dB. The main lobe is now 43° wide at the 3-dB points, as opposed to 35° for the original DEZepp. The antenna has gain over a dipole for > 50° now and the gain of the main lobe has dropped only 0.2 dB below the original DEZepp.

Experimental Results

The antenna was made from #14 wire and the capacitors were made from 3.5-inch sections of RG-213, shown in **Fig 24A**. Note that great care should be taken to seal out moisture in these capacitors. The voltage across the capacitor for 1.5 kW will be about 2000 V so any corona will quickly destroy the capacitor.

A silicon sealant was used and then both ends covered

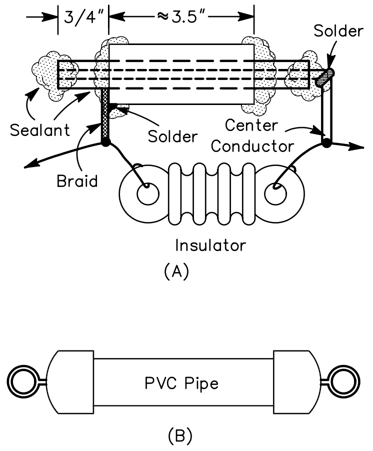

Fig 24—Construction details for series capacitor made from RG-213 coaxial cable. At A, the method used by N6LF is illustrated. At B, a suggested method to seal capacitor better against weather is shown, using a section of PVC pipe with end caps.

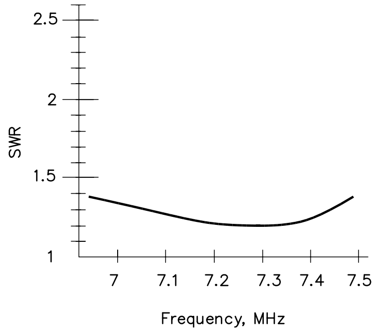

Fig 25—Measured SWR curve across 40-meter band for N6LF DEZepp.

with coax seal, finally wrapping it with plastic tape. The solder balls indicated on the drawing are to prevent wicking of moisture through the braid and the stranded center conductor. This is a small but important point if long service out in the weather is expected. An even better way to protect the capacitor would be to enclose it in a short piece of PVC pipe with end caps, as shown in Fig 24B.

Note that all RG-8 type cables do not have exactly the same capacitance per foot and there will also be some end effect adding to the capacitance. If possible the capacitor should be trimmed with a capacitance meter. It isn't necessary to be too exact—the effect of varying the capacitance ±10% was checked and the antenna still worked fine.

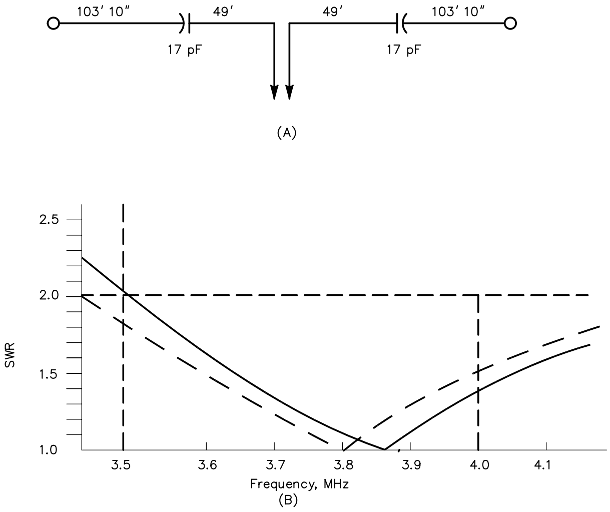

Fig 26—75/80-meter modified Double Extended Zepp, designed using *NEC Wires*. At A, a schematic is shown for antenna. At B, SWR curve is shown across 75/80-meter band. Solid line shows measured curve for W7ISV antenna, which was pruned to place SWR minimum higher in the band. The dashed curve shows the computed response when SWR minimum is set to 3.8 MHz.

The results proved to be close to those predicted by the computer model. **Fig 25** shows the measured value for SWR across the band. These measurements were made with a Bird directional wattmeter. The worst SWR is 1.35:1 at the low end of the band.

Dick Ives, W7ISV, erected an 80-meter version of the antenna, shown in **Fig 26A**. The series capacitors are 17 pF. Since he isn't interested in CW, Dick adjusted the length for the lowest SWR at the high end of the band, as shown in the SWR curve (Fig 26B). The antenna could have been tuned somewhat lower in frequency and would then provide an SWR < 2:1 over the entire band, as indicated by the dashed line.

This antenna provides wide bandwidth and moderate gain over the entire 75/80-meter band. Not many antennas will give you that with a simple wire structure.

Vertical Antennas

On the low bands quarter-wave high vertical antennas become increasingly attractive, especially for DX work, because they provide a means for lowering the radiation angle. This is especially true where practical heights for horizontally polarized antennas are too low. In addition, verticals can be very simple and unobtrusive structures. For example, it is very easy to disguise a vertical as a flagpole. In fact an actual flagpole may be used as a vertical. Performance of a vertical is determined by several factors:

- Height of the vertical portion of the radiator
- The ground or counterpoise system efficiency, if one is used
- Ground characteristics in the near- and far-field regions
- The efficiency of loading elements and matching networks

THE HALF-WAVE VERTICAL DIPOLE (HVD)

The simplest form of vertical is that of a half-wave vertical dipole, an HVD. This is a horizontal dipole turned 90º so that it is perpendicular to the ground under it. Of course, the top end of such an antenna must be at least a half wave above the ground or else it would be touching the ground. This poses quite a construction challenge if the builder wants a free-standing low-frequency antenna. Hams fortunate enough to have tall trees on their property can suspend wire HVDs from these trees. Similarly, hams with two tall towers can run rope catenaries between them to hold up an HVD.

A vertical half-wave dipole has some operational advantages compared to a more-commonly used vertical configuration—the quarter-wave vertical used with some sort of above-ground counterpoise or an on-ground radial system. See **Fig 27** and 27B, which shows the two configurations discussed here. In each case, the lowest part of each antenna is 8 feet above ground, to prevent passersby from being able to touch any live wire. Each antenna is assumed to be made of #14 wire resonant on 80 meters.

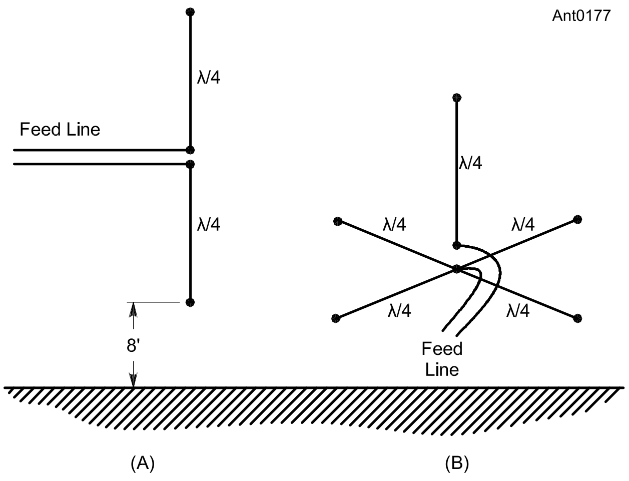

Fig 27—At A, a 80-meter half-wave vertical dipole elevated 8 feet above the ground. The feed line is run perpendicularly away from the dipole. At B, a "ground plane" type of quarter-wave vertical, with four elevated resonant radials. Both antennas are mounted 8 feet above the ground to keep them away from passersby.

Feeding a Half-Wave Vertical Dipole

Fig 28 compares elevation patterns for the two antennas for "average ground." You can see that the half-wave vertical dipole has about 1.5 dB higher peak gain, since it compresses the vertical elevation pattern down somewhat closer to the horizon than does the quarter-wave ground plane. Another advantage to using a half-wave radiator besides higher gain is that less horizontal "real estate" is needed compared to a quarter-wave vertical with its horizontal radials.

The obvious disadvantage to an HVD is that it is taller than a quarter-wave ground plane. This requires a higher support (such as a taller tree) if you make it from wire, or a longer element if you make it from telescoping aluminum tubing.

Another problem is that theory says you must dress the feed line so that it is perpendicular to the half-wave radiator. This means you must support the coax feed line above ground for some distance before bringing the coax down to ground level. A question immediately arises: How far must you go out horizontally with the feed line before going to ground level to eliminate common-mode currents that are radiated onto the coax shield? Such common-mode currents will affect the feed-point impedance as well as the radiation pattern for the antenna system. Quite a bit of distortion in the azimuthal pattern can be created if common-mode currents aren't suppressed, usually by using a common-mode choke, also known as a current balun.

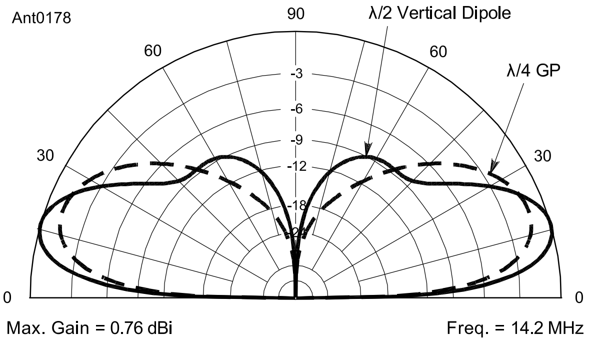

Fig 28—A comparison of the elevation patterns for the two antennas in Fig 27. The peak gain of the HVD is about 1.5 dB higher than that for the quarter-wave ground-plane radiator with radials.

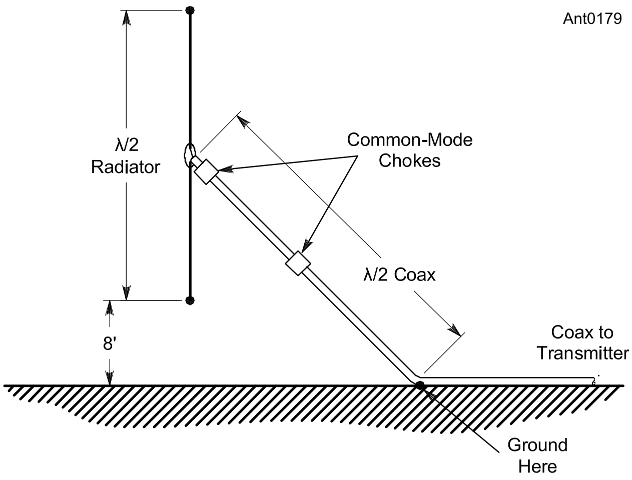

Fig 29—A 20-meter HVD whose bottom is 8 feet above ground. This is fed with a λ/2 of RG-213 coax. This system uses a common-mode choke at the feed point and another λ/4 down the line. The resulting azimuthal radiation pattern is within 0.4 dB of being perfectly circular. The "wingspan" of this antenna system is 27 feet from the radiator to the point where the coax comes to ground level.

Constructing such a common-mode choke is very simple: Three large ferrite beads are slipped over the coax (before the connectors are soldered on or else they won't fit!) and taped in place. The only problem with this scheme is that an additional support (some sort of "skyhook") is required to support the coax horizontally. Let's try to simplify the installation, by slanting the feed-line coax down to ground from the feed point at a fairly steep angle of about 30º from vertical. See **Fig 29**.

Note that the bottom end of the coax in Fig 29 is grounded to a ground rod. This serves several purposes—this serves as a mechanical connection to hold the coax in place and it provides some protection against lightning strikes. Now, as a purely practical matter, just how picky are we being here? What if we skip the second common-mode choke and just use one at the feed point? The computer models predicts that there will be some distortion in the azimuthal pattern—about 1.1 dB worth. Whether this is serious is up to you. However, you may find other problems with common-mode currents on the coax shield—problems such as RF in the shack or variable SWR readings depending on the way coax is routed in the shack. The addition of three extra ferrite beads to suppress the common-mode currents is cheap insurance.

Later in this chapter we'll discuss shortened vertical antennas, ones arranged both as vertical dipoles and as vertical monopoles with radial systems.

MONOPOLE VERTICALS WITH GROUND PLANE RADIALS

For best performance the vertical portion of a ground-plane type of antenna should be λ/4 or more, but this is not an absolute requirement. With proper design, antennas as short as 0.1 λ or even less can be efficient and effective. Antennas shorter than λ/4 will be reactive and some form of loading and perhaps a matching network will be required.

If the radiator is made of wire supported by nonconducting material, the approximate length for λ/4 resonance can be found from:

$$\ell_{\text{feet}} = \frac{234}{f_{\text{MHz}}} \qquad \text{(Eq 1)}$$

For tubing, the length for resonance must be shorter than given by the above equation, as the length-to-diameter ratio is lower than for wire (see Chapter 2, Antenna Fundamentals). For a tower, the resonant length will be shorter still. In any case, after installation the antenna length (height) can be adjusted for resonance at the desired frequency.

The effect of ground characteristics on losses and elevation pattern is discussed in detail in Chapter 3, The Effects of Ground. The most important points made in that discussion are the effect of ground characteristics on the radiation pattern and the means for achieving low ground-loss resistance in a buried ground system. As ground conductivity increases, low-angle radiation improves. This makes a vertical very attractive to those who live in areas with good ground conductivity. If your QTH is on a saltwater beach, then a vertical would be very effective, even when compared to horizontal antennas at great height.

When a buried-radial ground system is used, the efficiency of the antenna will be limited by the loss resistance of the ground system. The ground can be a number of radial wires extending out from the base of the antenna for about λ/4. Driven ground rods, while satisfactory for electrical safety and for lightning protection, are of little value as an RF ground for a vertical antenna, except perhaps in marshy or beach areas. As pointed out in Chapter 3, many long radials are desirable. In general, however, a large number of short radials are preferable to only a few long radials, although the best system would have 60 or more radials longer than λ/4. An elevated system of radials or a ground screen (*counterpoise*) may be used instead of buried radials, and can result in an efficient antenna.

ELEVATED RADIALS AND COUNTERPOISES

Elevated radials, isolated from ground, can be used in place of an extensive buried radial system. Work by Al Christman, K3LC (ex-KB8I), has shown that 4 to 8 elevated radials can provide performance comparable to a 120 λ/4-long buried wires. This is especially important for the low bands, where such a buried ground system is very large and impractical for most amateurs. An elevated ground system is sometimes referred to as a *ground plane* or *counterpoise*. **Fig 30** compares buried and elevated ground systems, showing the difference in current flow in the two systems.

An elevated ground can take several forms. A number of wires arranged with radial symmetry around the base of the antenna is shown in Fig 30B. Four radials are normally

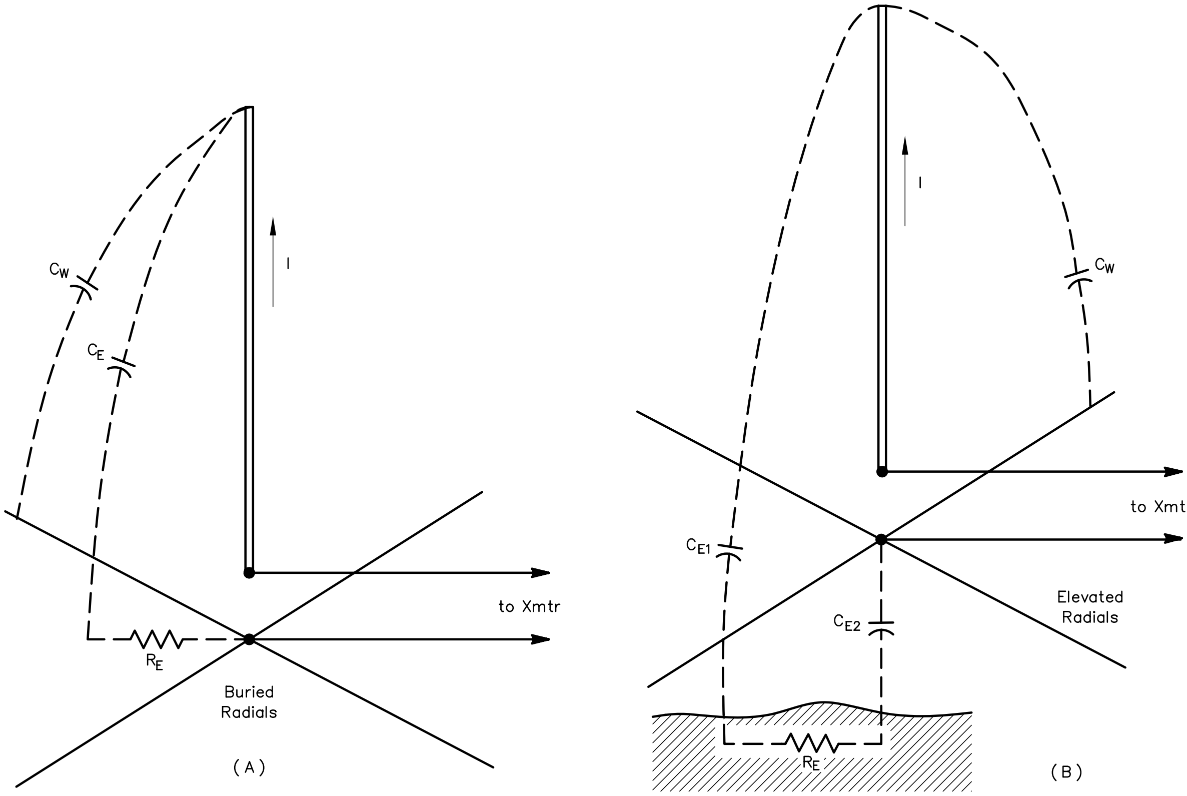

Fig 30—How earth currents affect the losses in a short vertical antenna system. At A, the current through the combination of C_E and R_E may be appreciable if C_E is much greater than C_W, the capacitance of the vertical to the ground wires. This ratio can be improved (up to a point) by using more radials. By raising the entire antenna system off the ground, C_E (which consists of the series combination of C_{E1} and C_{E2}) is decreased while C_W stays the same. The radial system shown at B is sometimes called a *counterpoise*.

used, but as few as two, or as many as eight, can be used. For a given height of vertical, the length of the radials can be adjusted to resonate the antenna. For a λ/4 vertical, the radials are normally λ/4 long.

In the case of a multiband vertical, two or more sets of radials, with different lengths, may be interleaved. The radials associated with each band are adjusted for resonance on their associated band.

A counterpoise is most commonly a system of elevated radials, where the radial wires are interconnected with jumpers, as shown in **Fig 31**. As illustrated in Fig 30, the purpose of the elevated-ground system is to provide a return path for the displacement currents flowing in the vicinity of the antenna. The idea is to minimize the current flowing through the ground itself, which is usually very lossy. By raising the radials above ground most of the current will flow in the radials, which are good conductors. This allows a simple radial system to provide a very efficient ground. However, there is a price to be paid for this.

The ground system now has a direct effect on the feed-point impedance, introducing reactance as well as resistance, and is relatively narrow band. For a given vertical height, the

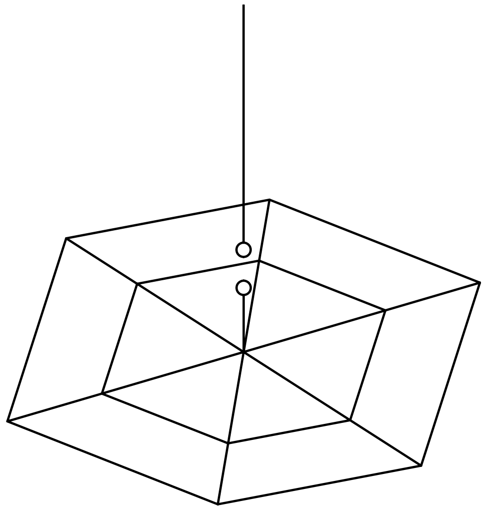

Fig 31—Counterpoise, showing the radial wires connected together by cross wires. The length of the perimeter of the individual meshes should be < λ/4 to prevent undesired resonances. Sometimes the center portion of the counterpoise is made from wire mesh.

Table 2

Illustration of the effect of variable vertical height (L_1) on elevated radial length (L2) and R_R.
#12 wire, elevated 5 feet over average ground at 3.525 MHz.

L_1 (λ)	L_1 (feet)	L_2 (feet)	R_R (Ω)
0.225	62.8	94	28.8
0.25	69.8	67	38.4
0.27	75.0	45	51.0
0.3	83.7	24	75.9

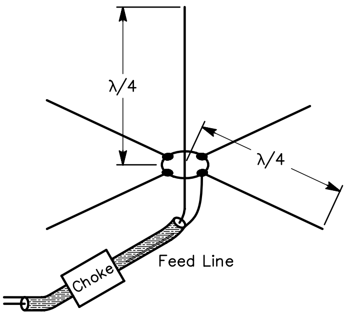

Fig 32—The ground-plane antenna. Power is applied between the base of the vertical radiator and the center of the ground plane, as indicated in the drawing. Decoupling from the transmission line and any conductive support structure is highly desirable.

radial length must be adjusted to resonate the antenna. The length of the radials must be readjusted for each band if a multiband vertical is used. As pointed out above, this usually means the installation of a set of radials for each band. To minimize current flowing in the ground, the antenna, ground plane and feed line must be isolated from ground for RF. More on this later.

The height of the vertical does not have to be exactly $\lambda/4$. Other lengths may be used and the antenna may be resonated by adjusting the length of the radials. **Table 2** gives a comparison between three different vertical lengths in an antenna using four elevated radials at 3.525 MHz.

An important feature of Table 2 is the dramatic reduction in radial length (L_2) with even a small increase in vertical height (L_1). For example, increasing the height by 5 feet reduces the radial length by 22 feet on 80 meters. On the other hand even a small decrease in L_1 can cause a substantial increase in L_2. This would be very undesirable, since the area required by the radials is already considerable. Notice also that the small increase in height raises R_R to 51 Ω. This trick of increasing the height slightly to reduce the size of the elevated ground system and to increase the input resistance can be very useful. In a following section the use of *top loading* for short antennas will be discussed. Top loading can also be used on a $\lambda/4$ vertical to achieve the same effect as increasing the height—the ability to use shorter radials and a better match.

GROUND-PLANE ANTENNAS

The ground-plane antenna is a $\lambda/4$ vertical with four radials, as shown in **Fig 32**. The entire antenna is elevated above ground. A practical example of a 7-MHz ground-plane antenna is given in **Fig 33**. As explained earlier, elevating the antenna reduces the ground loss and lowers the radiation angle somewhat. The radials are sloped downward to make the feed-point impedance closer to 50 Ω.

The feed-point impedance of the antenna varies with the height above ground, and to a lesser extent varies with the ground characteristics. **Fig 34** is a graph of feed-point resistance (R_R) for a ground-plane antenna with the radials parallel to the ground. R_R is plotted as a function of height above ground. Notice that the difference between perfect ground and average ground (ε=13 and σ = 0.005 S/m) is small, except when quite close to ground. Near ground R_R is between 36 and 40 Ω. This is a reasonable match for 50-Ω feed line but as the antenna is raised above ground R_R drops to approximately 22 Ω, which is not a very good match. The feed-point resistance can be increased by sloping the radials downward, away from the vertical section.

The effect of sloping the radials is shown in **Fig 35**. The

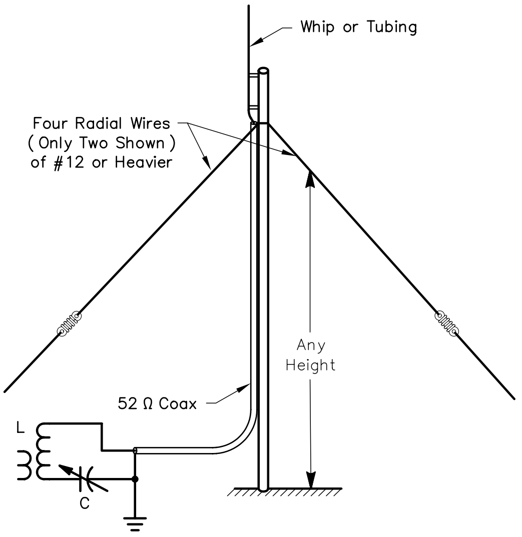

Fig 33—A ground-plane antenna is effective for DX work on 7 MHz. Although its base can be any height above ground, losses in the ground underneath will be reduced by keeping the bottom of the antenna and the ground plane as high above ground as possible. Feeding the antenna directly with 50-Ω coaxial cable will result in a low SWR. The vertical radiator and the radials are all λ/4 long electrically. Contrary to popular myth, the radials need not necessarily be 5% longer than the radiator. Their physical length will depend on their length-to-diameter ratios, the height over ground and the length of the vertical radiator, as discussed in text.

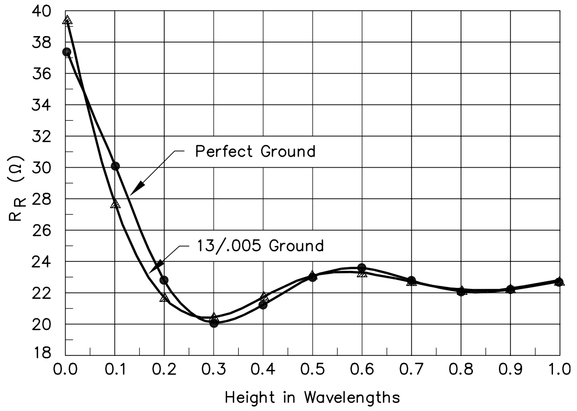

Fig 34—Radiation resistance of a 4-radial ground-plane antenna as a function of height over ground. Perfect and average ground are shown. Frequency is 3.525 MHz. Radial angle (θ) is 0°.

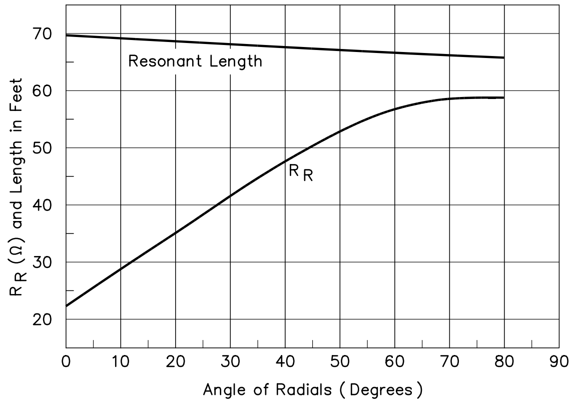

Fig 35—Radiation resistance and resonant length for a 4-radial ground-plane antenna > 0.3 λ above ground as a function of radial droop angle (θ).

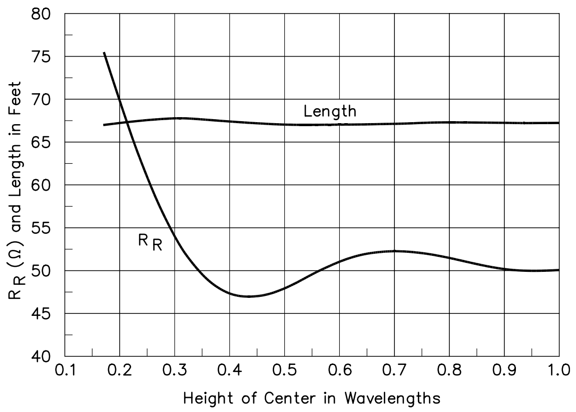

Fig 36—Radiation resistance and resonant length for a 4-radial ground-plane antenna for various heights above average ground for radial droop angle θ = 45°.

graph is for an antenna well above ground (> 0.3 λ). Notice that R_R = 50 Ω when the radials are sloped downward at an angle of 45°, a convenient value. The resonant length of the antenna will vary slightly with the angle. In addition, the resonant length will vary a small amount with height above the ground. It is for these reasons, as well as the effect of conductor diameter, that some adjustment of the radial lengths is usually required. When the ground-plane antenna is used on the higher HF bands and at VHF, the height above ground is usually such that a radial sloping angle of 45° will give a good match to 50-Ω feed line.

The effect of height on R_R with a radial angle of 45° is shown in **Fig 36**. At 7 MHz and lower, it is seldom possible to elevate the antenna a significant portion of a wavelength and the radial angle required to match to 50-Ω line is usually of the order of 10° to 20°. To make the vertical portion of the antenna

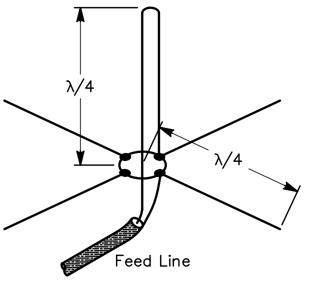

Fig 37—The folded monopole antenna. Shown here is a ground plane of four λ/4 radials. The folded element may be operated over an extensive counterpoise system or mounted on the ground and worked against buried radials and the earth. As with the folded dipole antenna, the feed-point impedance depends on the ratios of the radiator conductor sizes and their spacing.

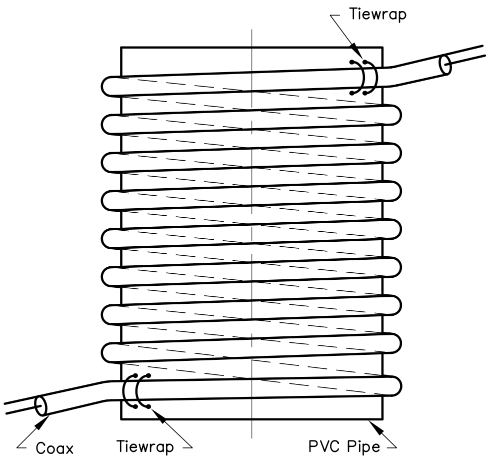

Fig 38—A choke balun with sufficient impedance to isolate the antenna properly can be made by winding coaxial cable around a section of plastic pipe. Suitable dimensions are given in the text.

as long as possible, it may be better to accept a slightly poorer match and keep the radials parallel to ground.

The principles of the folded dipole (Fig 18) can also be applied to the ground-plane antenna, as shown in **Fig 37**. This is the *folded monopole* antenna. The feed-point resistance can be controlled by the number of parallel vertical conductors and the ratios of their diameters.

As mentioned earlier, it is important in most installations to isolate the antenna from the feed line and any conductive supporting structure. This is done to minimize the return current conducted through the ground. A return current on the feed line itself or the support structure can drastically alter the radiation pattern, usually for the worse. For these reasons, a balun (see Chapter 26, Coupling the Line to the Antenna) or other isolation scheme must be used. 1:1 baluns are effective for the higher bands but at 3.5 and 1.8 MHz commercial baluns often have too low a shunt inductance to provide adequate isolation. It is very easy to recognize when the isolation is inadequate. When the antenna is being adjusted while watching an isolated impedance or SWR meter, adjustments may be sensitive to your touching the instrument. After adjustment and after the feed line is attached, the SWR may be drastically different. When the feed line is inadequately isolated, the apparent resonant frequency or the length of the radials required for resonance may also be significantly different from what you expect.

In general, an isolation choke inductance of 50 to 100 µH will be needed for 3.5 and 1.8-MHz ground-plane antennas. One of the easiest ways to make the required isolation choke is to wind a length of coaxial cable into a coil as shown in **Fig 38**. For 1.8 MHz, 30 turns of RG-213 wound on a 14-inch length of 8-inch diameter PVC pipe, will make a very good isolation choke that can handle full legal power continuously. A smaller choke could be wound on 4-inch diameter plastic drain pipe using RG-8X or a Teflon insulated cable. The important point here is to isolate or decouple the antenna from the feed line and support structure.

A full-size ground-plane antenna is often a little impractical for 3.5-MHz and quite impractical for 1.8 MHz, but it can be used at 7 MHz to good advantage, particularly for DX work. Smaller versions can be very useful on 3.5 and 1.8 MHz.

EXAMPLES OF VERTICALS

There are many possible ways to build a vertical antenna—the limits are set by your ingenuity. The primary problem is creating the vertical portion of the antenna with sufficient height. Some of the more common means are:

- A dedicated tower
- Using an existing tower with an HF Yagi on top
- A wire suspended from a tree limb or the side of a building
- A vertical wire supported by a line between two trees or other supports
- A tall pole supporting a conductor
- Flagpoles
- Light standards
- Irrigation pipe
- TV masts

If you have the space and the resources, the most straightforward means is to erect a dedicated tower for a vertical. While this is certainly an effective approach, many amateurs do not have the space or the funds to do this, especially if they already have a tower with an HF antenna on the top. The existing tower can be used as a top-loaded vertical, using shunt feed and a ground radial system. A system like this is shown in **Fig 39B**.

For those who live in an area with tall trees, it may be possible to install a support rope between two trees, or between a tree and an existing tower. (Under no circumstances should you use an active utility pole!) The vertical portion of the antenna can be a wire suspended from the support line to ground, as shown in Fig 39C. If top loading is needed, some or all of the support line can be made part of the antenna.

Your local utility company will periodically have older power poles that they no longer wish to keep in service. These are sometimes available at little or no expense. If you see a power line under reconstruction or repair in your area you might stop and speak with the crew foreman. Sometimes they will have removed older poles they will not use again and will have to haul them back to their shop for disposal. Your offer for local “disposal” may well be accepted. Such a pole can be used in conjunction with a tubing or whip extension such as that shown in Fig 39A. Power poles are not your only option. In some areas of the US, such as the southeast or northwest, tall poles made directly from small conifers are available.

Freestanding (unguyed) flagpoles and roadway illumination standards are available in heights exceeding 100 feet. These are made of fiberglass, aluminum or galvanized steel. All of these are candidates for verticals. Flagpole suppliers are listed under “Flags and Banners” in your Yellow Pages. For lighting standards (lamp posts), you can contact a local electrical hardware distributor. Like a wooden pole, a fiberglass flagpole does not require a base insulator, but metal poles do. Guy wires will be needed.

One option to avoid the use of guys and a base insulator is to mount the pole directly into the ground as originally intended and then use shunt feed. If you want to keep the pole grounded but would like to use elevated radials, you can attach a cage of wires (four to six) at the top as shown in Fig 39D. The cage surrounds the pole and allows the pole (or tower for that matter) to be grounded while allowing elevated radials to be used. The use of a cage of wires surrounding the pole or tower is a very good way to increase the effective diameter. This reduces the Q of the antenna, thereby increasing the bandwidth. It can also reduce the conductor loss, especially if the pole is galvanized steel, which is not a very good RF conductor.

Aluminum irrigation tubing, which comes in diameters of 3 and 4 inches and in lengths of 20 to 40 feet, is widely available in rural areas. One or two lengths of tubing con-

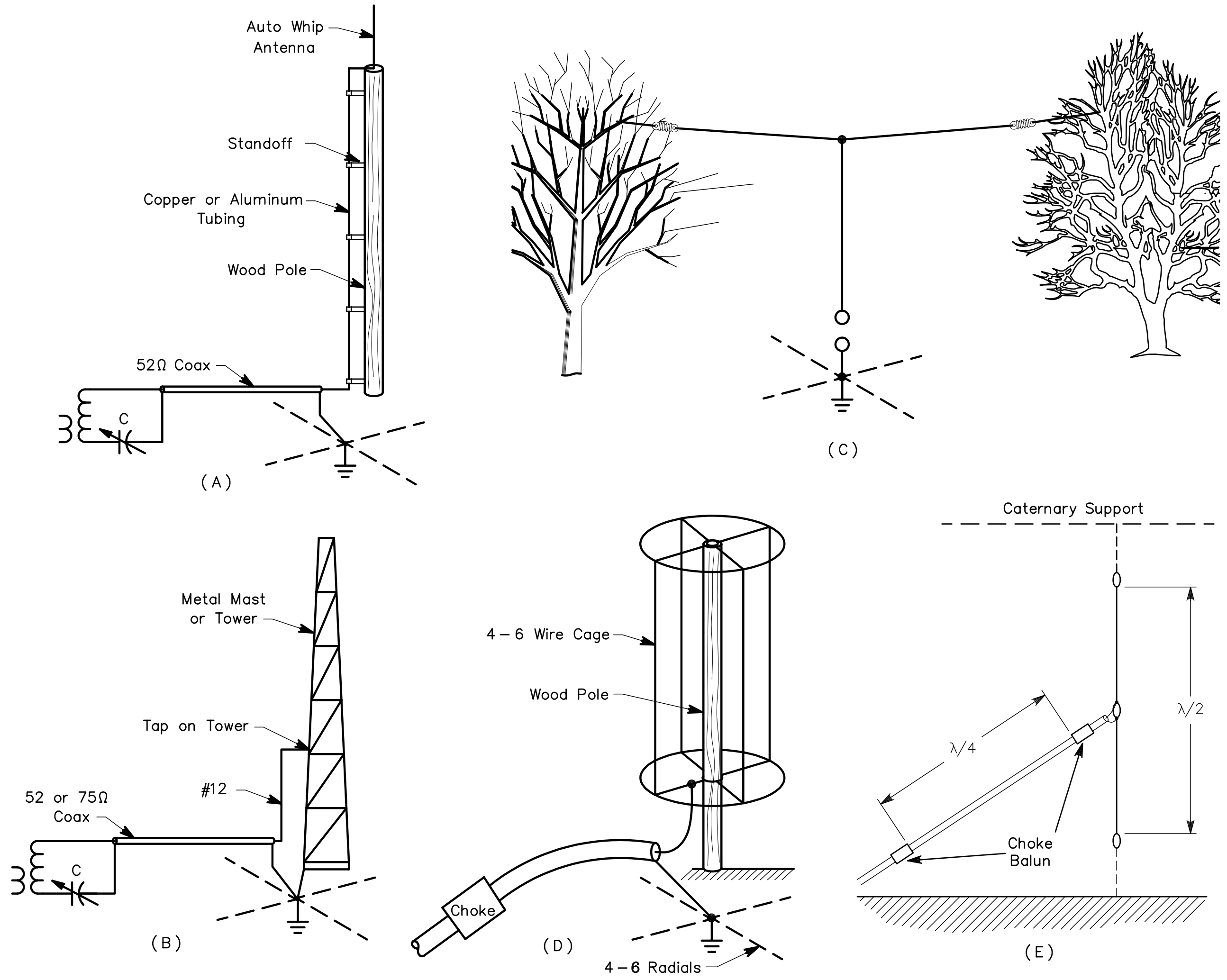

Fig 39—Vertical antennas are effective for 3.5- or 7-MHz work. The λ/4 antenna shown at A is fed directly with 50-Ω coaxial line, and the resulting SWR is usually less than 1.5 to 1, depending on the ground resistance. If a grounded antenna is used as at B, the antenna can be shunt fed with either 50- or 75-Ω coaxial line. The tap for best match and the value of C will have to be found by experiment. The line running up the side of the antenna should be spaced 6 to 12 inches from the antenna. If tall trees are available the antenna can be supported from a line suspended between the trees, as shown in C. If the vertical section is not long enough then the horizontal support section can be made of wire and act as top loading. A pole or even a grounded tower can be used with elevated radials if a cage of four to six wires is provided as shown in D. The cage surrounds the pole which may be wood or a grounded conductor.

nected together can make a very good vertical when guyed with non-conducting line. It is also very lightweight and relatively easy to erect. A variety of TV masts are available which can also be used for verticals.

1.8 TO 3.5-MHz VERTICAL USING AN EXISTING TOWER

A tower can be used as a vertical antenna, provided that a good ground system is available. The shunt-fed tower is at its best on 1.8 MHz, where a full λ/4 vertical antenna is rarely possible. Almost any tower height can be used. If the beam structure provides some top loading, so much the better, but anything can be made to radiate—if it is fed properly. W5RTQ (now K6SE) uses a self-supporting, aluminum, crank-up, tilt-over tower, with a TH6DXX tribander mounted at 70 feet. Measurements showed that the entire structure has about the same properties as a 125-foot vertical. It thus works quite well as an antenna on 1.8 and 3.5 MHz for DX work requiring low-angle radiation.

Preparing the Structure

Usually some work on the tower system must be done before shunt-feeding is tried. If present, metallic guys should be broken up with insulators. They can be made to simulate top loading, if needed, by judicious placement of the first insulators. Don't overdo it; there is no need to "tune the radiator to resonance" in this way since a shunt feed is employed. If the tower is fastened to a house at a point more than about one-fourth of the height of the tower, it may be desirable to insulate the tower from the building. Plexiglas sheet, ¼-inch or more thick, can be bent to any desired shape for this purpose, if it is heated in an oven and bent while hot.

All cables should be taped tightly to the tower, on the inside, and run down to the ground level. It is not necessary to bond shielded cables to the tower electrically, but there should be no exceptions to the down-to-the-ground rule.

A good system of buried radials is very desirable. The ideal would be 120 radials, each 250 feet long, but fewer and shorter ones must often suffice. You can lay them around corners of houses, along fences or sidewalks, wherever they can be put a few inches under the surface, or even on the earth's surface. Aluminum clothesline wire may be used extensively in areas where it will not be subject to corrosion. Neoprene-covered aluminum wire will be better in highly acid soils. Contact with the soil is not important. Deep-driven ground rods and connection to underground copper water pipes may be helpful, if available, especially to provide some protection from lightning.

Installing the Shunt Feed

Principal details of the shunt-fed tower for 1.8 and 3.5 MHz are shown in **Fig 40**. Rigid rod or tubing can be used for the feed portion, but heavy gauge aluminum or copper wire is easier to work with. Flexible stranded #8 copper wire is used at W5RTQ (now K6SE) for the 1.8-MHz feed, because when the tower is cranked down, the feed wire must come down with it. Connection is made at the top, 68 feet, through a 4-foot length of aluminum tubing clamped to the top of the tower, horizontally. The wire is clamped to the tubing at the outer end, and runs down vertically through standoff insulators. These are made by fitting 12-inch lengths of PVC plastic water pipe over 3-foot lengths of aluminum tubing. These are clamped to the tower at 15- to 20-foot intervals, with the bottom clamp about 3 feet above ground. These lengths allow for adjustment of the tower-to-wire spacing over a range of about 12 to 36 inches, for impedance matching.

The gamma-match capacitor for 1.8 MHz is a 250-pF variable with about ⅙-inch plate spacing. This is adequate for power levels up to about 200 W. A large transmitting or a vacuum-variable capacitor should be used for high-power applications.

Tuning Procedure

The 1.8-MHz feed wire should be connected to the top of the structure if it is 75 feet tall or less. Mount the standoff insulators so as to have a spacing of about 24 inches between wire and tower. Pull the wire taut and clamp it in place at the bottom insulator. Leave a little slack below to permit adjustment of the wire spacing, if necessary.

Adjust the series capacitor in the 1.8-MHz line for minimum reflected power, as indicated on an SWR meter connected between the coax and the connector on the capacitor housing. Make this adjustment at a frequency near the middle of your expected operating range. If a high SWR is indicated, try moving the wire closer to the tower. Just the

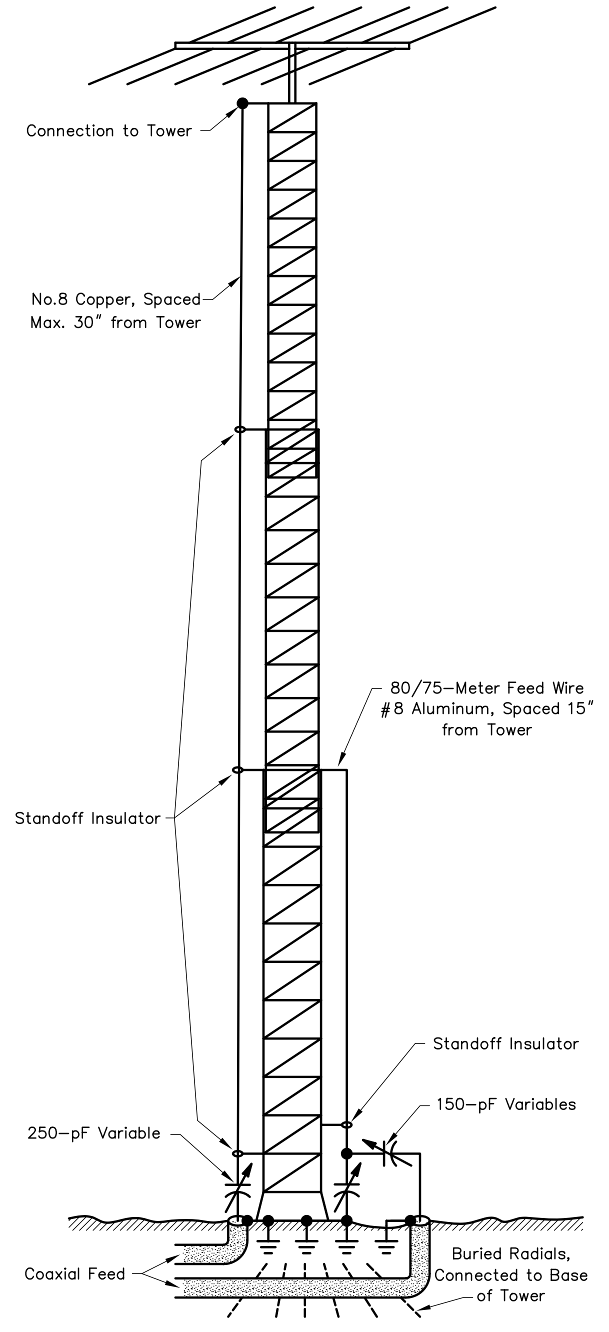
Connection to Tower
No.8 Copper, Spaced Max. 30" from Tower
80/75–Meter Feed Wire #8 Aluminum, Spaced 15" from Tower
Standoff Insulator
Standoff Insulator
150–pF Variables
250–pF Variable
Coaxial Feed
Buried Radials, Connected to Base of Tower

Fig 40—Principal details of the shunt-fed tower at W5RTQ (now K6SE). The 1.8-MHz feed, left side, connects to the top of the tower through a horizontal arm of 1-inch diameter aluminum tubing. The other arms have standoff insulators at their outer ends, made of 1-foot lengths of plastic water pipe. The connection for 3.5-4 MHz, right, is made similarly, at 28 feet, but two variable capacitors are used to permit adjustment of matching with large changes in frequency.

lower part of the wire need be moved for an indication as to whether reduced spacing is needed. If the SWR drops, move all insulators closer to the tower, and try again.

If the SWR goes up, increase the spacing. There will be a practical range of about 12 to 36 inches. If going down to 12 inches does not give a low SWR, try connecting the top a bit farther down the tower. If wide spacing does not make it, the omega match shown for 3.5-MHz work should be tried. No adjustment of spacing is needed with the latter arrangement, which may be necessary with short towers or installations having little or no top loading.

The two-capacitor arrangement in the omega match is also useful for working in more than one 25-kHz segment of the 1.8-MHz band. Tune up on the highest frequency, say 1990 kHz, using the single capacitor, making the settings of wire spacing and connection point permanent for this frequency. To move to the lower frequency, say 1810 kHz, connect the second capacitor into the circuit and adjust it for the new frequency. Switching the second capacitor in and out then allows changing from one segment to the other, with no more than a slight retuning of the first capacitor.

SIMPLE, EFFECTIVE, ELEVATED GROUND-PLANE ANTENNAS

This section describes a simple and effective means of using a grounded tower, with or without top-mounted antennas, as an elevated ground-plane antenna for 80 and 160 meters. It first appeared in a June 1994 *QST* article by Thomas Russell, N4KG.

From Sloper to Vertical

Recall the quarter-wavelength sloper, also known as the *half sloper*. [The half sloper is covered later in this chapter in more detail.—*Ed.*] It consists of an isolated quarter wavelength of wire, sloping from an elevated feed point on a grounded tower. Best results are usually obtained when the feed point is somewhere below a top-mounted Yagi antenna. You feed a sloper by attaching the center conductor of a coaxial cable to the wire and the braid of the cable to the tower leg. Now, imagine four (or more) slopers, but instead of feeding each individually, connect them together to the center conductor of a single feed line. Voilà! Instant elevated ground plane.

Now, all you need to do is determine how to tune the antenna to resonance. With no antennas on the top of the tower, the tower can be thought of as a fat conductor and should be approximately 4% shorter than a quarter wavelength in free space. Calculate this length and attach four insulated quarter-wavelength radials at this distance from the top of the tower. For 80 meters, a feed point 65 feet below the top of an unloaded tower is called for. The tower guys must be broken up with insulators for all such installations. For 160 meters, 130 feet of tower above the feed point is needed.

What can be done with a typical grounded-tower-and-Yagi installation? A top-mounted Yagi acts as a large capacitance hat, top loading the tower. Fortunately, top loading is the most efficient means of loading a vertical antenna.

The examples in **Table 3** should give us an idea of how much top loading might be expected from typical amateur antennas. The values listed in the *Equivalent Loading* column tell us the approximate vertical height replaced by the antennas listed in a top-loaded vertical antenna. To arrive at the remaining amount of tower needed for resonance, subtract these numbers from the non-loaded tower height needed for resonance. Note that for all but the 10-meter antennas, the equivalent loading equals or exceeds a quarter wavelength on 40 meters. For typical HF Yagis, this method is best used only on 80 and 160 meters.

Construction Examples

Consider this example: A TH7 triband Yagi mounted on a 40-foot tower. The TH7 has approximately the same overall dimensions as a full-sized 3-element 20-meter beam, but has more interlaced elements. Its equivalent loading is estimated to be 40 feet. At 3.6 MHz, 65 feet of tower is needed without loading. Subtracting 40 feet of equivalent loading, the feed point should be 25 feet below the TH7 antenna.

Ten quarter-wavelength (65-foot) radials were run from a nylon rope tied between tower legs at the 15-foot level, to various supports 10 feet high. Nylon cord was tied to the insulated, stranded, #18 wire, without using insulators. The radials are all connected together and to the center of an exact half wavelength (at 3.6 MHz) of RG-213 coax, which will repeat the antenna feed impedance at the other end. **Fig 41** is a drawing of the installation. The author used a Hewlett-Packard low-frequency impedance analyzer to measure the input impedance across the 80-meter band. An exact resonance (zero reactance) was seen at 3.6 MHz, just as predicted. The radiation resistance was found to be 17 Ω. The next question is, how to feed and match the antenna.

One good approach to 80-meter antennas is to tune them to the low end of the band, use a low-loss transmission line, and switch an antenna tuner in line for operation in the higher portions of the band. With a 50-Ω line, the 17-Ω radiation resistance represents a 3:1 SWR, meaning that an antenna tuner should be in-line for all frequencies. For short runs, it

Table 3
Effective Loading of Common Yagi Antennas

Antenna	*Boom Length (feet)*	*S (area, ft^2)*	*Equivalent Loading (feet)*
3L 20	24	768	39
5L 15	26	624	35
4L 15	20	480	31
3L 15	16	384	28
5L 10	24	384	28
4L 10	18	288	24
3L 10	12	192	20
TH7	24	—	40 (estimated)
TH3	14	—	27 (estimated)

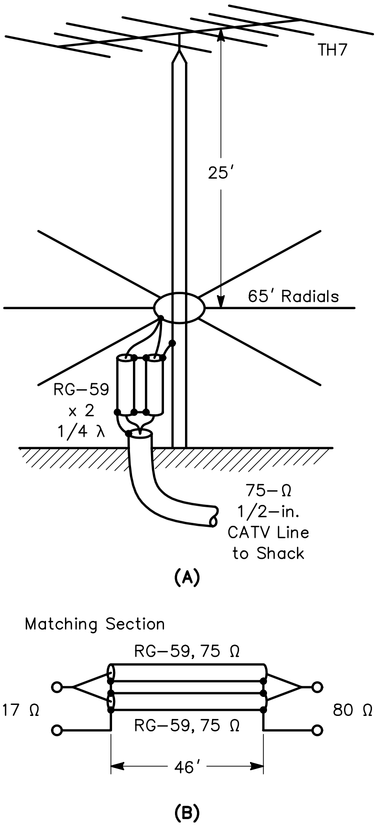

Fig 41—At A, an 80-meter top-loaded, reverse-fed elevated ground plane, using a 40-foot tower carrying a TH7 triband Yagi antenna. At B, dimensions of the 3.6-MHz matching network, made from RG-59.

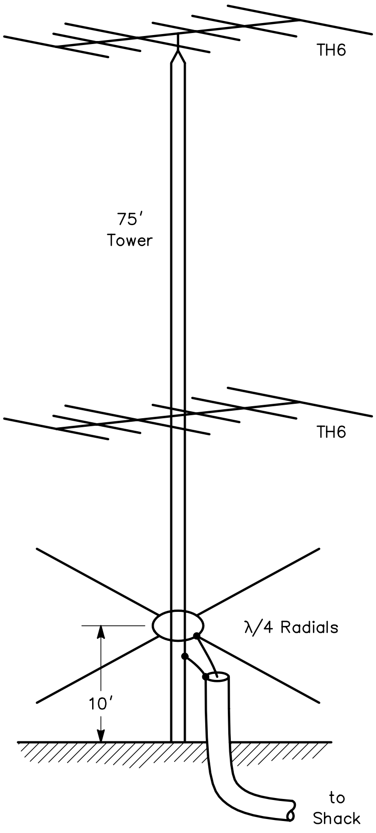

Fig 42—A 160-meter antenna using a 75-foot tower carrying stacked triband Yagis.

would be permissible to use RG-8 or RG-213 directly to the tuner. If you have a plentiful supply of low-loss 75-Ω CATV rigid coax, you can take another approach.

Make a quarter-wave (70 feet × 0.66 velocity factor = 46 feet) 37-Ω matching line by paralleling two pieces of RG-59 and connecting them between the feed point and a run of the rigid coax to the transmitter. The magic of quarter-wave matching transformers is that the input impedance (R_i) and output impedance (R_o) are related by:

$$Z_0^2 = R_i \times R_o \qquad \text{(Eq 2)}$$

For $R_i = 17\ \Omega$ and $Z_0 = 37\ \Omega$, $R_o = 80\ \Omega$, an almost perfect match for the 75-Ω CATV coax. The resulting 1.6:1 SWR at the transmitter is good enough for CW operation without a tuner.

160-Meter Operation

On the 160-meter band, a resonant quarter-wavelength requires 130 feet of tower above the radials. That's a pretty tall order. Subtracting 40 feet of top loading for a 3-element 20-meter or TH7 antenna brings us to a more reasonable 90 feet above the radials. Additional top loading in the form of more antennas will reduce that even more.

Another installation, using stacked TH6s on a 75-foot tower, is shown in **Fig 42**. The radials are 10 feet off the ground.

PHASED VERTICALS

Two or more vertical antennas spaced apart can be operated as a single antenna system to obtain additional gain and a directional pattern. There is an extensive discussion of phased arrays in Chapter 8, Multielement Arrays. Much of the material in Chapter 8 is useful for low-band antennas.

The Half-Square Antenna

The *half-square* antenna is a very simple form of vertical two-element phased array that can be very effective on the low bands. The following section was originally presented in *The ARRL Antenna Compendium Vol 5*, by Rudy Severns, N6LF.

A simple modification to a standard dipole is to add two λ/4 vertical wires, one at each end, as shown in **Fig 43**. This makes a *half-square antenna*. The antenna can be fed at one corner (low-impedance, current fed) or at the lower end of one of the vertical wires (high-impedance, voltage fed).

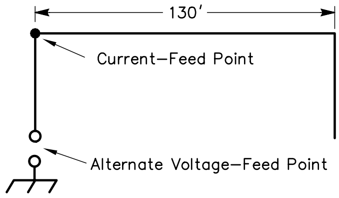

Fig 43—Typical 80-meter half-square, with λ/4-high vertical legs and a λ/2-long horizontal leg. The antenna may be fed at the bottom or at a corner. When fed at a corner, the feed point is a low-impedance, current-feed. When fed at the bottom of one of the wires against a small ground counterpoise, the feed point is a high-impedance, voltage-feed.

Other feed arrangements are also possible.

The “classical” dimensions for this antenna are λ/2 (131 feet at 3.75 MHz) for the top wire and λ/4 (65.5 feet) for the vertical wires. However, there is nothing sacred about these dimensions! They can vary over a wide range and still obtain nearly the same performance.

This antenna is two λ/4 verticals, spaced λ/2, fed in-phase by the top wire. The current maximums are at the top corners. The theoretical gain over a single vertical is 3.8 dB. An important advantage of this antenna is that it does not require the extensive ground system and feed arrangements that a conventional pair of phased λ/4 verticals would.

Comparison to a Dipole

In the past, one of the things that has turned off potential users of the half-square on 80 and 160 meters is the perceived need for λ/4 vertical sections. This forces the height to be > 65 feet on 80 meters and > 130 feet on 160 meters. That’s not really a problem. If you don’t have the height there are several things you can do. For example, just fold the ends in, as shown in **Fig 44**. This compromises the performance surprisingly little.

It is helpful to compare the examples given in Figs 43 and 44 to dipoles at the same height. Two heights, 40 and 80 feet, and average, very good and sea water grounds, were used for this comparison. It is also assumed that the lower end of the vertical wires had to be a minimum of 5 feet above ground.

At 40 feet the half-square is really mangled, with only 35-foot long (≈ λ/8) vertical sections. The elevation-plane comparison between this antenna and a dipole of the same height is shown in **Fig 45**. Over average ground the half-square is superior below 32° and at 15° is almost 5 dB better. That is a worthwhile improvement. If you have very good soil conductivity, like parts of the lower Midwest and South, then the half-square will be superior below 38° and at 15° will be nearly 8 dB better. For those fortunate few with saltwater frontal property the advantage at 15° is 11 dB! Notice also that above 35°, the response drops off rapidly. This is great for DX but is not good for local work.

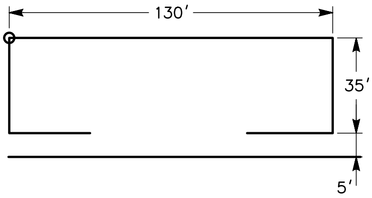

Fig 44—An 80-meter half-square configured for 40-foot high supports. The ends have been bent inward to reresonate the antenna. The performance is compromised surprisingly little.

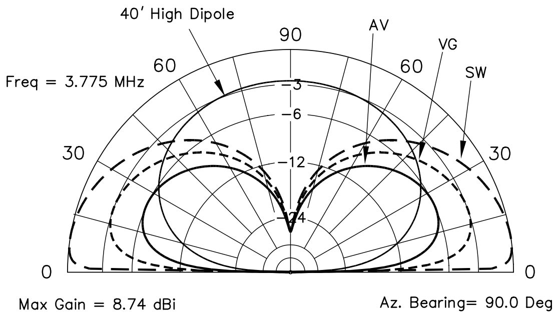

Fig 45—Comparison of 80-meter elevation response of 40-foot high, horizontally polarized dipole over average ground and a 40-foot high, vertically polarized half-square, over three types of ground: average (conductivity σ = 5 mS/m, dielectric constant ε = 13), very good (σ = 30 mS/m, ε = 20) and salt water (σ = 5000 mS/m, ε = 80). The quality of the ground clearly has a profound effect on the low-angle performance of the half-square. Even over average ground, the half-square outperforms the low dipole below about 32°.

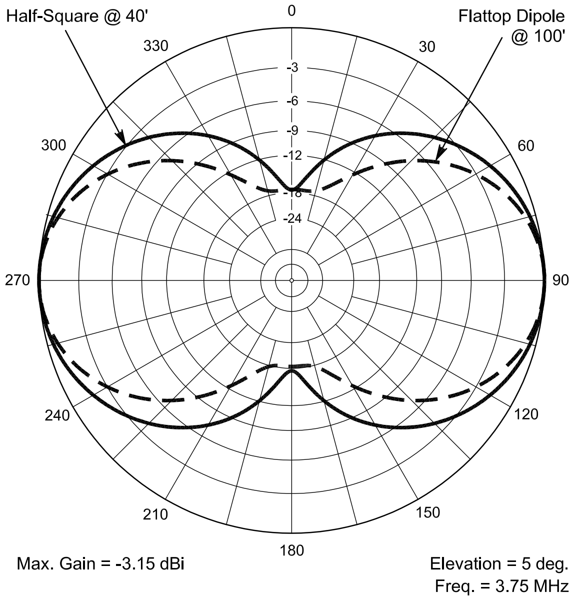

Fig 46—80-meter azimuth patterns for shortened half-square antenna (solid line) shown in Fig 44, compared with flattop dipole (dashed line) at 100 feet height. Average ground is assumed for these cases.

Fig 46 shows the azimuthal-plane pattern for the 80-meter half-square antenna in Fig 44, but this time compared with the response of a flattop horizontal dipole that is 100 feet high. These comparisons are for average ground and are for an elevation angle of 5°. The message here is that the lower your dipole and the better your ground, the more you have to gain by switching from a dipole to a half-square. The half-square antenna looks like a good bet for DXing.

Changing the Shape of the Half Square

Just how flexible is the shape? There are several common distortions of practical importance. Some have very little effect but a few are fatal to the gain. Suppose you have either more height and less width than called for in the standard version or more width and less height, as shown in **Fig 47A**.

The effect on gain from this type of dimensional variation is given in **Table 4**. For a top length (L_T) varying between 110 and 150 feet, where the vertical wire lengths (L_V) readjusted to resonate the antenna, the gain changes only by 0.6 dB. For a 1-dB change the range of L_T is 100 to 155 feet, a pretty wide range.

Another variation results if we vary the length of the horizontal top wire and readjust the vertical wires for resonance, while keeping the top at a constant height. See Fig 47B. **Table 5** shows the effect of this variation on the peak gain. For a range of L_T = 110 to 145 feet, the gain changes only 0.65 dB.

The effect of bending the ends into a V shape, as shown in Fig 47C, is given in **Table 6**. The bottom of the antenna is kept at a height of 5 feet and the top height (H) is either 40 or 60 feet. Even this gross deformation has only a relatively small effect on the gain. Sloping the ends outward as shown in Fig 47D and varying the top length also has only a small effect on the gain. While this is good news because it allows you dimension the antenna to fit different QTHs, not all distortions are so benign.

Table 4

Variation in Gain with Change in Horizontal Length, with Vertical Height Readjusted for Resonance (see Fig 47A)

L_T (feet)	L_V (feet)	Gain (dBi)
100	85.4	2.65
110	79.5	3.15
120	73.7	3.55
130	67.8	3.75
140	61.8	3.65
150	56	3.05
155	53	2.65

Table 5

Variation in Gain with Change in Horizontal Length, with Vertical Length Readjusted for Resonance, but Horizontal Wire Kept at Constant Height (see Fig 47B)

L_T (feet)	L_V (feet)	Gain (dBi)
110	78.7	3.15
120	73.9	3.55
130	68	3.75
140	63	3.35
145	60.7	3.05

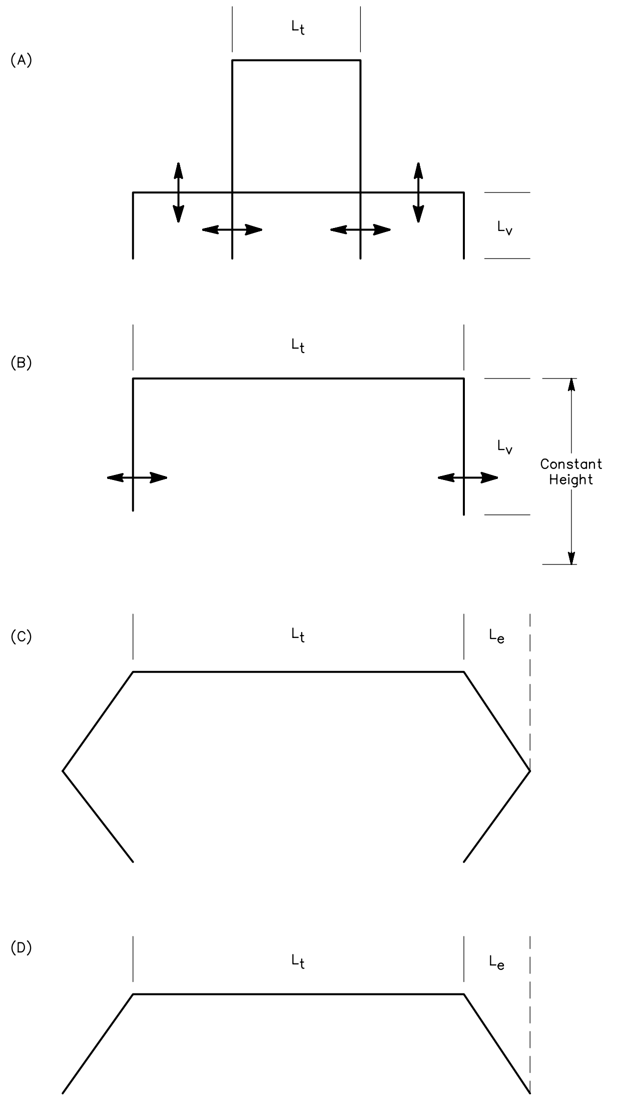

Fig 47—Varying the horizontal and vertical lengths of a half-square. At A, both the horizontal and vertical legs are varied, while keeping the antenna resonant. At B, the height of the horizontal wire is kept constant, while its length and that of the vertical legs is varied to keep the antenna resonant. At C, the length of the horizontal wire is varied and the legs are bent inwards in the shape of "vees." At D, the ends are sloped outward and the length of the flattop portion is varied. All these symmetrical forms of distortion of the basic half-square shape result in small performance losses. At E, a "halfwave vertical dipole" (HVD) with the feed coax isolated with common-mode choke baluns to keep RF current off the coax shield.

Table 6

Gain for Half-Square Antenna, Where Ends Are Bent Into V-Shape (see Fig 47 C)

Height ⇒	*H=40 feet*	*H=40 feet*	*H=60 feet*	*H=60 feet*
L_T (feet)	*L_e (feet)*	*Gain (dBi)*	*L_e (feet)*	*Gain (dBi)*
40	57.6	3.25	52.0	2.75
60	51.4	3.75	45.4	3.35
80	45.2	3.95	76.4	3.65
100	38.6	3.75	61.4	3.85
120	31.7	3.05	44.4	3.65
140	—	—	23	3.05

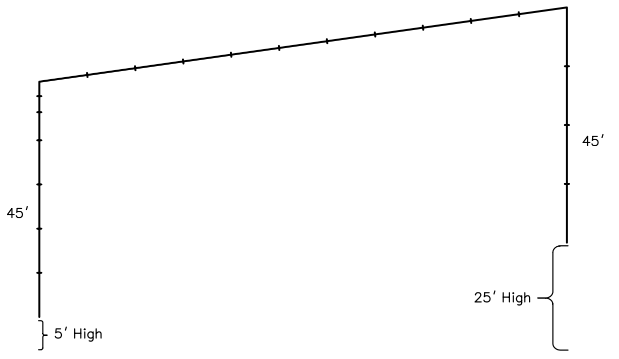

Fig 48—An asymmetrical distortion of the half-square antenna, where the bottom of one leg is purposely made 20 feet higher than the other. This type of distortion does affect the pattern!

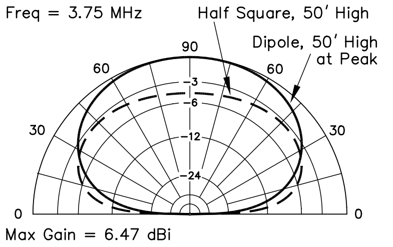

Fig 49—Elevation pattern for the asymmetrical half-square shown in Fig 48, compared with pattern for a 50-foot high dipole. This is over average ground, with a conductivity of 5 mS/m and a dielectric constant of 13. Note that the zenith-angle null has filled in and the peak gain is lower compared to conventional half-square shown in Fig 43 over the same kind of ground.

Suppose the two ends are not of the same height, as illustrated in **Fig 48**, where one end of the half-square is 20 feet higher than the other. The elevation-plane radiation pattern for this antenna is shown in **Fig 49** compared to a dipole at 50 feet. This type of distortion does affect the pattern. The gain drops somewhat and the zenith null goes away. The nulls off the end of the antenna also go away, so that there is some end-fire radiation. In this example the difference in height is fairly extreme at 20 feet. Small differences of 1 to 5 feet do not affect the pattern seriously.

If the top height is the same at both ends but the length of the vertical wires is not the same, then a similar pattern distortion can occur. The antenna is very tolerant of symmetrical distortions but it is much less accepting of asymmetrical distortion.

What if the length of the wires is such that the antenna is not resonant? Depending on the feed arrangement, that may or may not matter. We will look at that issue later on, in the section on patterns versus frequency. The half-square antenna, like the dipole, is very flexible in its proportions.

Half-Square Feed-Point Impedance

There are many different ways to feed the half-square. Traditionally the antenna has been fed either at the end of one of the vertical sections, against ground, or at one of the upper corners as shown in Fig 43.

For voltage feed at the bottom against ground, the impedance is very high, on the order of several thousand ohms. For current feed at a corner, the impedance is much lower and is usually close to 50 Ω. This is very convenient for direct feed with coax.

The half-square is a relatively high-Q antenna (Q ≈ 17). **Fig 50** shows the SWR variation with frequency for this feed arrangement. An 80-meter dipole is not particularly wideband either, but a dipole will have less extreme variation in SWR than the half-square.

Patterns Versus Frequency

Impedance is not the only issue when defining the bandwidth of an antenna. The effect on the radiation pattern of changing frequency is also a concern. For a voltage-fed half-square, the current distribution changes with frequency. For an antenna resonant near 3.75 MHz, the current distribution is nearly symmetrical. However, above and below resonance the current distribution increasingly becomes asymmetrical. In effect, the open end of the antenna is constrained to be a voltage maximum but the feed point can behave less as a voltage point and more like a current maxima. This allows the current distribution to become asymmetrical.

The effect is to reduce the gain by –0.4 dB at 3.5 MHz and by –0.6 dB at 4 MHz. The depth of the zenith null is reduced from –20 dB to –10 dB. The side nulls are also reduced. Note that this is exactly what happened when the antenna was made physically asymmetrical. Whether the asymmetry is due to current distribution or mechanical arrangements, the antenna pattern will suffer.

When current-feed at a corner is used, the asymmetry introduced by off-resonance operation is much less, since both ends of the antenna are open circuits and constrained to be voltage maximums. The resulting gain reduction is only –0.1 dB. It is interesting that the sensitivity of the pattern to changing frequency depends on the feed scheme used.

Of more concern for corner feed is the effect of the transmission line. The usual instruction is to simply feed

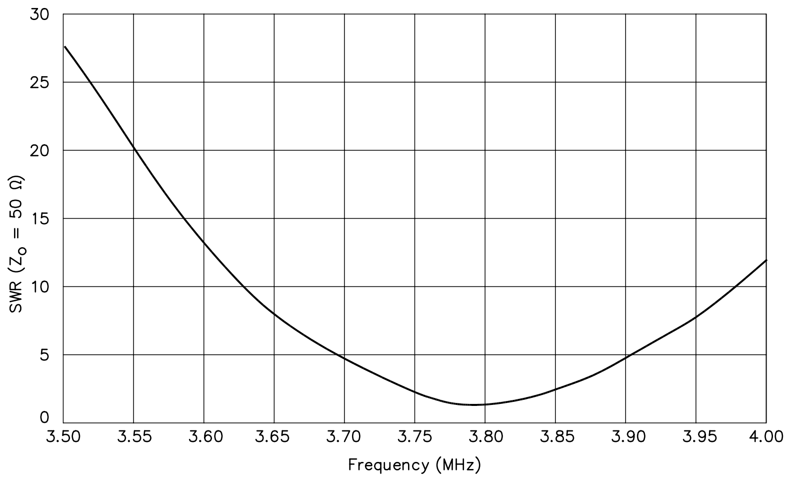

Fig 50—Variation of SWR with frequency for current-fed half-square antenna. The SWR bandwidth is quite narrow.

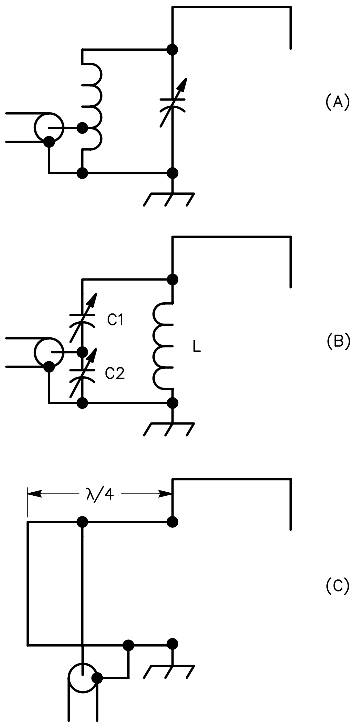

Fig 51—Typical matching networks used for voltage-feeding a half-square antenna.

the antenna using coax, with the shield connected to vertical wire and the center conductor to the top wire. Since the shield of the coax is a conductor, more or less parallel with the radiator, and is in the immediate field of the antenna, you might expect the pattern to be seriously distorted by this practice. This arrangement seems to have very little effect on the pattern. The greatest effect is when the feed line length was near a multiple of λ/2. Such lengths should be avoided.

Of course, you may use a choke balun at the feed point if you desire. This might reduce the coupling to the feed line even further but it doesn't appear to be worth the trouble. In fact, if you use an antenna tuner in the shack to operate away from resonance with a very high SWR on the transmission line, a balun at the feed point would take a beating.

Voltage-Feed at One End of Antenna: Matching Schemes

Several straightforward means are available for narrow-band matching. However, broadband matching over the full 80-meter band is much more challenging. Voltage feed with a parallel-resonant circuit and a modest local ground, as shown in **Fig 51**, is the traditional matching scheme for this antenna. Matching is achieved by resonating the circuit at the desired frequency and tapping down on the inductor in Fig 51A or using a capacitive divider (Fig 51B). It is also possible to use a λ/4 transmission-line matching scheme, as shown in Fig 51C.

If the matching network shown in Fig 51B is used, typical values for the components would be: L = 15 µH, C1 = 125 pF and C2 = 855 pF. At any single point the SWR can be made very close to 1:1 but the bandwidth for SWR < 2:1 will be very narrow at <100 kHz. Altering the L-C ratio doesn't make very much difference. The half-square antenna has a well-earned reputation for being narrow-band.

Short Vertical Antennas

On the lower frequencies it becomes increasingly difficult to accommodate a full λ/4 vertical height and full-sized λ/4 radials, or even worse, a full-sized half-wave vertical dipole (HVD). In fact, it is not absolutely necessary to make the antenna full size, whether it is an HVD, a grounded monopole antenna or a ground-plane type of monopole antenna. The size of the antenna can be reduced by half or even more and still retain high efficiency and the desired radiation pattern. This requires careful design, however. And if high efficiency is maintained, the operating bandwidth of the shortened antenna will be reduced because the shortened antenna will have a higher Q.

This translates into a more rapid increase of reactance away from resonance. The effect can be mitigated to some extent by using larger-diameter conductors. Even doing this however, bandwidth will be a problem, particularly on the 3.5 to 4-MHz band, which is very wide in proportion to the center frequency.

If we take a vertical monopole with a diameter of 2 inches and a frequency of 3.525 MHz and progressively shorten it from λ/4 in length, the feed-point impedance and efficiency (using an inductor at the base to tune out the capacitive reactance) will vary as shown in **Table 7**. In this example perfect ground and conductor are assumed. Real ground will not make a great difference in the impedance but will introduce ground loss, which will reduce the efficiency further. Conductor loss will also reduce efficiency. In general, higher R_R will result in better efficiency.

The important point of Table 7 is the drastic reduction in radiation resistance R_R as the antenna gets shorter. This combined with the increasing loss resistance of the inductor (R_L) used to tune out the increasing base reactance (X_C) reduces the efficiency.

BASE LOADING A SHORT VERTICAL ANTENNA

The base of the antenna is a convenient point at which to add a loading inductor, but it is usually not the lowest loss point at which an inductor, of a given Q, could be placed. There is an extensive discussion of the optimum location of the loading in a short vertical as a function of ground loss and inductor Q in Chapter 16 for mobile antennas, which by necessity are electrically and physically short. This information should be reviewed before using inductive loading.

On the accompanying CD-ROM is a copy of the program *MOBILE.EXE*. This is an excellent tool for designing short, inductively loaded antennas. In most cases, where top loading (discussed below) is not used, the optimum point is near or a little above the middle of the vertical section. Moving the loading coil from the base to the middle of the vertical antenna can make an important difference, increasing R_R and reducing the inductor loss. For example, in an antenna operating at 3.525 MHz, if we make L_1 = 34.9 feet (0.125 λ) the amount of loading inductor placed at the center is 25.2 µH. This resonates the antenna. In this configuration R_R will increase from 6.8 Ω (base loading) to 13.5 Ω (center loading). This substantially increases the efficiency of the antenna, depending on the ground loss and conductor resistances.

Instead of a lumped inductance being inserted at some point in the antenna, it is also possible to use "continuous loading," where the entire radiator is wound as a small diameter coil. The effect is to distribute the inductive loading all along the radiator. In this version of inductive loading the coil is the radiator. An example of a short vertical using this principle is given later in this chapter.

OTHER WAYS OF LOADING A SHORT ANTENNA FOR RESONANCE

Inductive loading is not the only, or even the best, way to compensate for reduced antenna height. *Capacitive top loading* can also be used as indicated in **Fig 52** to bring a vertical monopole to resonance. **Table 8** gives information on a shortened 3.525-MHz vertical using top loading. The vertical portion (L_1) is made from 2-inch tubing. The top loading is also 2-inch tubing extending across the top like a T. The length of the top loading T (±L_2) is adjusted to resonate the

Table 7

Effect of Shortening a Vertical Radiator Below λ/4 Using Inductive Base Loading.

Frequency is 3.525 MHz and for the Inductor Q_L = 200. Ground and conductor losses are omitted.

Length (feet)	*Length (λ)*	*R_R (Ω)*	*X_C (Ω)*	*R_L (Ω)*	*Efficiency (%)*	*Loss (dB)*
14	0.050	0.96	–761	3.8	20	–7.0
20.9	0.075	2.2	–533	2.7	45	–3.5
27.9	0.100	4.2	–395	2.0	68	–1.7
34.9	0.125	6.8	–298	1.5	82	–0.86
41.9	0.150	10.4	–220	1.1	90	–0.44
48.9	0.175	15.1	–153	0.77	95	–0.22
55.8	0.200	21.4	–92	0.46	98	–0.09
62.8	0.225	29.7	–34	0.17	99	–0.02

Table 8

Effect of Shortening a Vertical Using Top Loading

L_1 (feet)	*L_2 (feet)*	*Length (λ)*	*R_R (Ω)*
14.0	48.8	0.050	4.0
20.9	38.6	0.075	8.5
27.9	30.1	0.100	14.0
34.9	22.8	0.125	19.9
41.9	17.3	0.150	25.5
48.9	11.9	0.175	30.4
55.8	7.0	0.200	33.9
62.8	2.4	0.225	35.7

antenna. Again, the ground and the conductors are assumed to be perfect in Table 8.

For a given vertical height, resonating the antenna with top loading results in much higher radiation resistance R_R—2 to 4 times. In addition, the loss associated with the loading element will be smaller. The result is a more efficient antenna for low heights. A comparison of R_R for both capacitive top loading and inductive base loading is given in **Fig 53**. For heights below 0.15 λ the length of the top-loading elements becomes impractical but there are other, potentially more useful, top-loading schemes.

A multiwire system such as the one shown in **Fig 54** has more capacitance than the single-conductor arrangement, and thus does not need to be as long to resonate at a given frequency. This design does, however, require extra supports for the additional wires. Ideally, an arrangement of this sort should be in the form of a cross, but parallel wires separated by several feet give a considerable increase in capacitance

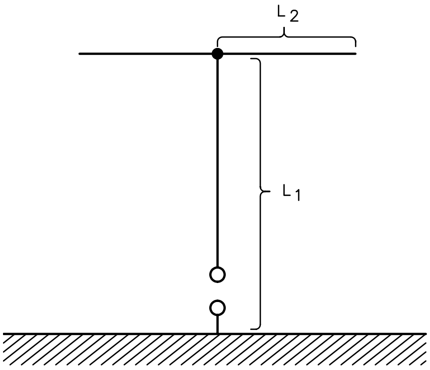

Fig 52—Horizontal wire used to top load a short vertical.

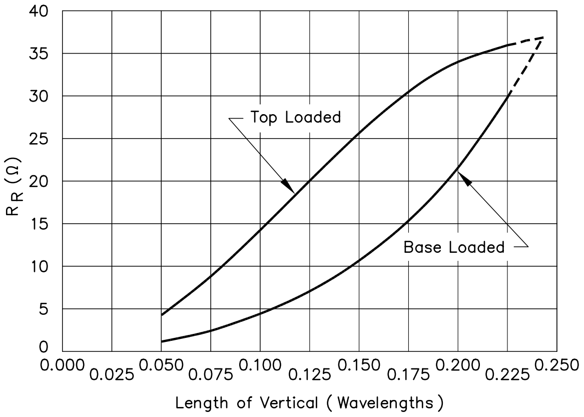

Fig 53—Comparison of top (capacitive) and base (inductive) loading for short verticals. Sufficient loading is used to resonate the antenna.

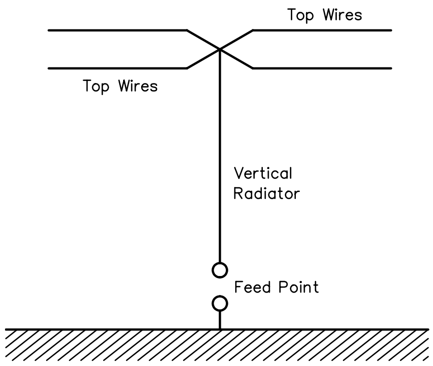

Fig 54—Multiple top wires can increase the effective capacitance substantially. This allows the use of shorter top wires to achieve resonance.

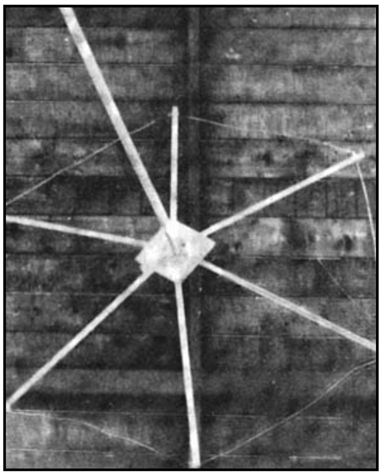

Fig 55—A close-up view of the capacitance hat for a 7-MHz vertical antenna. The ½-in. diameter radial arms terminate in a loop of copper wire.

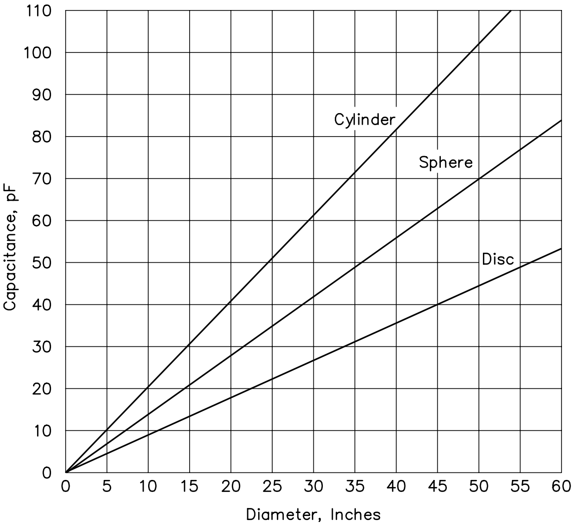

Fig 56—Capacitance of sphere, disc and cylinder as a function of their diameters. The cylinder length is assumed equal to its diameter.

over a single wire.

The top loading can be supplied by a variety of metallic structures large enough to have the necessary self-capacitance. For example, as shown in **Fig 55**, a multi-spoked structure with the ends connected together can be used. One simple way to make a capacitance hat is to take four to six 8-foot fiberglass CB mobile whips, arrange them like spokes in a wagon wheel and connect the ends with a peripheral wire. This arrangement will produce a 16-foot diameter hat that is economical and very durable, even when loaded with ice. Practically any sufficiently large metallic structure can be used for this purpose, but simple geometric forms such as the sphere, cylinder and disc are preferred because of the relative ease with which their capacitance can be calculated.

The capacitance of three geometric forms can be estimated from the curves of **Fig 56** as a function of their size. For the cylinder, the length is specified equal to the diameter. The sphere, disc and cylinder can be constructed from sheet metal, if such construction is feasible, but the capacitance will be practically the same in each if a "skeleton" type of construction with screening or networks of wire or tubing are used.

Finding Capacitance Hat Size

The required size of a capacitance hat may be determined from the following procedure. The information in this section is based on a September 1978 *QST* article by Walter Schulz, K3OQF. The physical length of a shortened antenna can be found from:

$$h_{inches} = \frac{11808}{F_{MHz}} \qquad \text{(Eq 3)}$$

where h = length in inches.

Thus, using an example of 7 MHz and a shortened length of 0.167 λ, h = 11808/7 × 0.167 = 282 inches, equivalent to 23.48 feet.

Consider the vertical radiator as an open-ended transmission line, so the impedance and top loading may be determined. The characteristic impedance of a vertical antenna can be found from

$$Z_0 = 60 \left(\ln\left(\frac{4h}{d}\right) - 1 \right) \qquad \text{(Eq 4)}$$

where

ln = natural logarithm

h = length (height) of vertical radiator in inches (as above)

d = diameter of radiator in inches

The vertical radiator for this example has a diameter of 1 inch. Thus, for this example,

$$Z_0 = 60 \left(\ln\left(\frac{4 \times 281}{1}\right) - 1 \right) = 361\ \Omega$$

The capacitive reactance required for the amount of top loading can be found from

$$Z_0 = 60\ \ln\left(\frac{4 \times 281}{1}\right) - 1 = 361\ \Omega \qquad \text{(Eq 5)}$$

where

X = capacitive reactance, ohms

Z_0 = characteristic impedance of antenna (from Eq 4)

θ = amount of electrical loading, degrees.

This value for a 30° hat is 361/tan 30° = 625 Ω. This capacitive reactance may be converted to capacitance with the following equation,

$$C = \frac{10^6}{2\pi f X_C} \qquad \text{(Eq 6)}$$

where

C = capacitance in pF

f = frequency, MHz

X_C = capacitive reactance, ohms (from above).

For this example, the required C = $10^6/(2\ \pi \times 7 \times 625)$ = 36.4 pF, which may be rounded to 36 pF. A disc capacitor is used in this example. The appropriate diameter for 36 pF of hat capacitance can be found from Fig 56. The disc diameter that yields 36 pF of capacitance is 40 inches.

The skeleton disc shown in Fig 55 is fashioned into a wagonwheel configuration. Six 20-inch lengths of ½-inch OD aluminum tubing are used as spokes. Each is connected to the hub at equidistant intervals. The outer ends of the spokes terminate in a loop made of #14 copper wire. Note that the loop increases the hat capacitance slightly, making a better approximation of a solid disc. The addition of this hat at the top of a 23.4-foot radiator makes it quarter-wave resonant at 7 MHz.

After construction, some slight adjustment in the radiator length or the hat size may be required if resonance at a specific frequency is desired. From Fig 53, the radiation resistance of a 0.167-λ high radiator is seen to be about 13 Ω without top loading. With top loading Rr ≈ 25 Ω or almost double.

THE COMPACT VERTICAL DIPOLE

A variation on the HVD (half-wave vertical dipole) theme is the *compact vertical dipole*, or CVD. The CVD uses capacitance-hat loading on each end of a shortened vertical radiator, as shown in **Fig 57C**. Some call this "top hat" and "bottom hat" loading. Les Moxon, G6XN, called this method of loading a shortened antenna simply "end loading." The vertical wire for his 40-meter CVD is 25 feet high, with 15-foot long horizontal loading wires on each side, top and bottom.

K8CH Compact Vertical Dipole

The top loading wires needn't be perpendicular to the vertical radiator, although that is convenient if you construct the antenna from aluminum tubing. K8CH described a wire 30-meter CVD in the 2006 Edition of *The ARRL Handbook.* This used #14 wire throughout, with sloping top loading wires. It was designed to be suspended from a tree at least

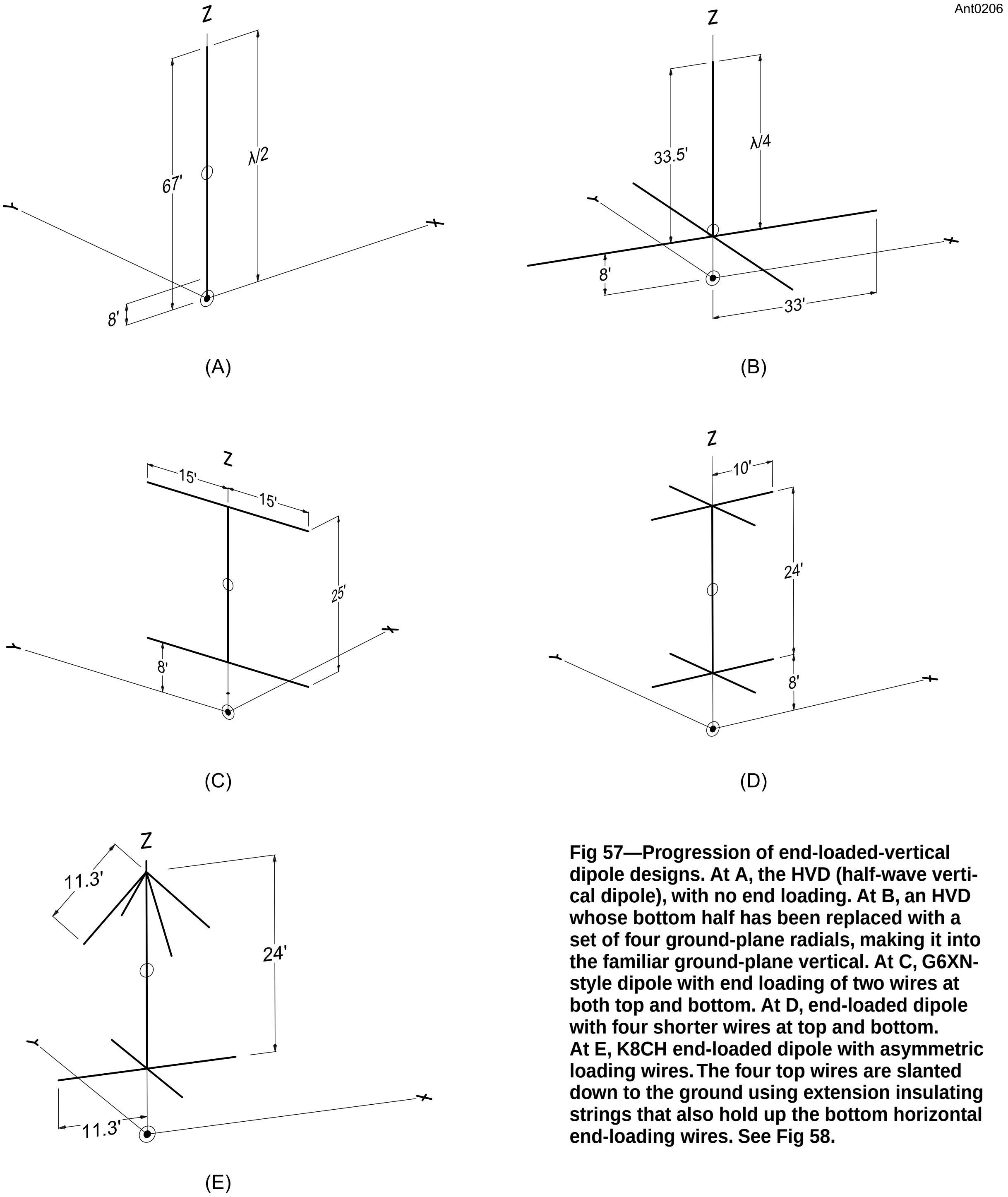

Fig 57—Progression of end-loaded-vertical dipole designs. At A, the HVD (half-wave vertical dipole), with no end loading. At B, an HVD whose bottom half has been replaced with a set of four ground-plane radials, making it into the familiar ground-plane vertical. At C, G6XN-style dipole with end loading of two wires at both top and bottom. At D, end-loaded dipole with four shorter wires at top and bottom.
At E, K8CH end-loaded dipole with asymmetric loading wires. The four top wires are slanted down to the ground using extension insulating strings that also hold up the bottom horizontal end-loading wires. See Fig 58.

32 feet high to keep all wires 8 feet or more above humans and animals. The vertical radiating wire is 24 feet long, and the eight top and bottom end-loading wires are all 5 feet 9 inches long. See Fig 57E and **Table 9**, CVD 1.

The top loading wires slant at an angle of 45º down to the ground, using insulating strings that also support the ends of the bottom loading wires, holding them out so that they are horizontal. See **Fig 58**. There is a small loss of gain because of the “umbrella” shape of the top loading wires, and the 2:1 SWR bandwidth is diminished slightly from the horizontal case. This isn’t a problem on a narrow band like 30 meters.

A 40-meter version of this antenna, CVD 6, also uses a 24-foot long vertical radiator, 8 feet high at its bottom. It uses 11.3-foot long radial wires made of #14 wire, again with the top four slanted down at 45º. This CVD has a 2:1

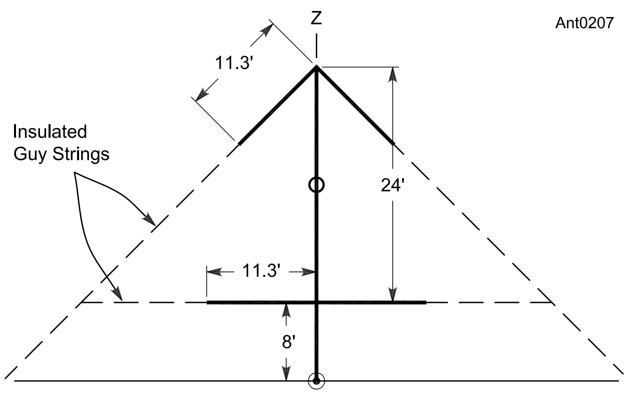

Fig 58—Layout of CVD made using #14 wire suspended from a tree branch.

SWR bandwidth of 250 kHz. It is directly fed with 50-Ω coax with ferrite-core common-mode choke baluns in the middle of the vertical radiator. An additional choke balun is used where the coax reaches ground level in order to knock down common-mode currents that might otherwise radiate onto the coax shield.

You should note the comparison of 40-meter ground-plane vertical antennas in Table 9. GP 1 is for horizontal radials that are 8 feet off the ground, while GP 2 has its radials only 2 feet high. There is some loss in gain because of the proximity of the lossy ground. The 40-meter CVD 1 and CVD 2 cases illustrate the same effect of being close to the lossy ground.

Some of the cases in Table 9 require Center Load coils to bring the antenna to resonance. Where the loading coil inductance is equal to the "Hairpin Coil" inductance, the loading coil also serves as a hairpin matching coil. Where the amount of Hairpin Coil inductance is less than the Load Coil inductance, a match is achieved by tapping the Center Load Coil symmetrically out from the center.

80-Meter CVD

The size of a CVD becomes a real challenge on 80 meters, requiring either very tall support structures or multiple loading methods to keep the vertical radiator to a reasonable length. The CVD 2 design in Table 9 shows a K8CH-style CVD wire antenna whose vertical radiator is 46.5 feet long. It requires a 54.5-foot high tree to keep the bottom end of the vertical radiator 8 feet above ground for safety. Compare this to an HVD that requires a 143-foot support of some sort to keep it 8 feet off the ground at the bottom. The CVD 2 sacrifices some 0.7 dB in gain for this difference in size, and about 75 kHz in 2:1 SWR bandwidth.

The CVD 2 would require retuning when going from

Table 9
Variations on a Vertical Center-Fed Dipole

Name	*Style Fig 57*	*Vertical Length feet*	*Spoke Length feet*	*Min. Ht feet*	*Max. Gain dBi*	*2:1 SWR kHz*	*Hairpin Coil µH*	*Center Load µH*
20 Meters								
GP	B	17.53	16.53	8	0.29	400	—	—
CVD 1	C	13	7.57	8	0.12	625	—	—
CVD 2	D	12	5.1	8	0.00	550	0.68	0.68
CVD 3	E	12.15	5.6	8	–0.01	450	0.5	0.5
30 Meters								
GP	B	24.54	23.14	8	0.04	400	—	—
CVD 1	E	24	5.33	8	–0.2	500	—	—
CVD 2	E	17	7.60	8	–0.36	400	0.82	0.82
40 Meters								
HVD	A	66	—	8	0.13	450	—	—
GP 1	B	35	33	8	–0.12	325	—	—
GP 2	B	34.5	33	2	–0.37	400	—	—
CVD 1	C	25	15	8	–0.42	450	—	—
CVD 2	C	24	15	2	–1.09	400	—	—
CVD 3	D	24	10	8	–0.55	425	—	0.25
CVD 4	D	24	5	8	–0.85	225	—	8.7
CVD 5	D	16	8	8	–1.18	175	0.94	6.8
CVD 6	E	24	11.3	8	–0.59	250	—	—
80 Meters								
HVD	A	135	—	8	0.19	225	—	—
GP	B	65.5	61	8	0.11	200	—	—
CVD 1	C	48.3	30	8	–0.27	200	—	—
CVD 2	E	46.5	21.9	8	–0.50	150	—	—

CW to phone, probably by changing the length of the four bottom horizontal wires equally.

LINEAR LOADING

Another alternative to inductive loading is *linear loading*. This little-understood method of shortening radiators can be applied to almost any antenna configuration—including parasitic arrays. Although commercial antenna manufacturers make use of linear loading in their HF antennas, relatively few hams have used it in their own designs. Linear loading can be used to advantage in many antennas because it introduces relatively little loss, does not degrade directivity patterns, and has low enough Q to allow reasonably good bandwidth. Some examples of linear-loaded antennas are shown in **Fig 59**.

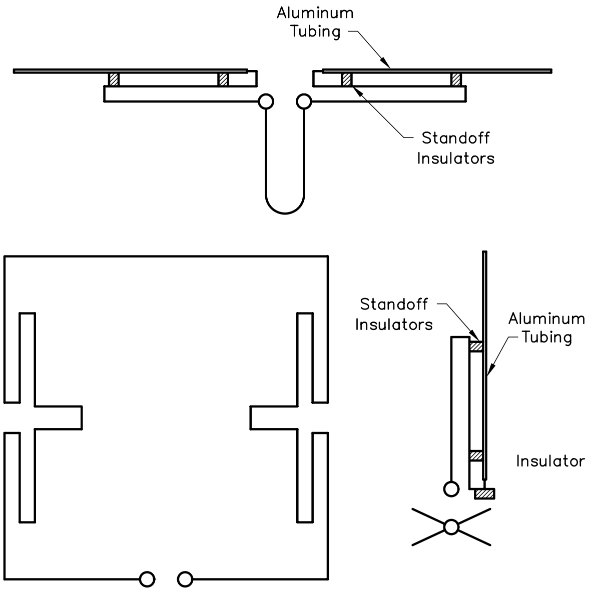

Fig 59—Some examples of linear loading. The small circles indicate the feed points of the antennas.

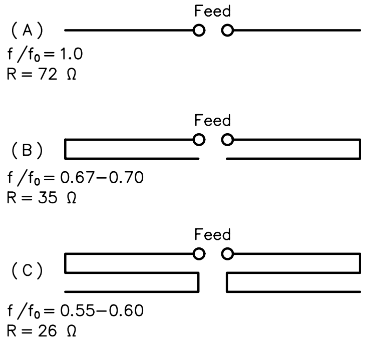

Fig 60—Wire dipole antennas. The ratio f/f$_0$ is the measured resonant frequency divided by frequency f$_0$ of a standard dipole of same length. R is radiation resistance in ohms. At A, standard single-wire dipole. At B, two-wire linear-loaded dipole, similar to folded dipole except that side opposite feed line is open. At C, three-wire linear-loaded dipole.

Since the dimensions and spacing of linear-loading devices vary greatly from one antenna installation to another, the best way to employ this technique is to try a length of conductor 10% to 20% longer than the difference between the shortened antenna and the full-size dimension for the linear-loading device. Then use the "cut-and-try" method, varying both the spacing and length of the loading device to optimize the match. A hairpin at the feed point can be useful in achieving a 1:1 SWR at resonance.

Linear-Loaded Short Wire Antennas

More detail on linear loading is provided in this section, which was originally presented in *The ARRL Antenna Compendium Vol 5* by John Stanford, NNØF. Linear loading can significantly reduce the required length for resonant antennas. For example, it is easy to make a resonant antenna that is as much as 30 to 40% shorter than an ordinary dipole for a given band. The shorter overall lengths come from bending back some of the wire. The increased self-coupling lowers the resonant frequency. These ideas are applicable to short antennas for restricted space or portable use.

Experiments

The results of the measurements are shown in **Fig 60** and are also consistent with values given by Rashed and Tai from an earlier paper. This shows several simple wire antenna configurations, with resonant frequencies and impedance (radiation resistance). The reference dipole has a resonant frequency f$_0$ and resistance R = 72 Ω. The f/f$_0$ values give the effective reduced frequency obtained with the linear loading in each case. For example, the two-wire linear-loaded dipole has its resonant frequency lowered to about 0.67 to 0.70 that of the simple reference dipole of the same length.

The three-wire linear-loaded dipole has its frequency reduced to 0.55 to 0.60 of the simple dipole of the same length. As you will see later, these values will vary with conductor diameter and spacing.

The two-wire linear-loaded dipole (Fig 60B) looks almost like a folded dipole but, unlike a folded dipole, it is open in the middle of the side opposite where the feed line is attached. Measurements show that this antenna structure has a resonant frequency lowered to about two-thirds that of the reference dipole, and R equal to about 35 Ω. A three-wire linear-loaded dipole (Fig 60C) has even lower resonant frequency and R about 25 to 30 Ω.

Linear-loaded monopoles (one half of the dipoles in Fig 60) working against a radial ground plane have similar resonant frequencies, but with only half the radiation resistance shown for the dipoles.

A Ladder-Line Linear-Loaded Dipole

Based on these results, NNØF next constructed a linear loaded dipole as in Fig 60B, using 24 feet of 1-inch ladder line (the black, 450-Ω plastic kind widely available) for the dipole length. He hung the system from a tree using nylon fishing line, about 4 feet from the tree at the top, and about 8 feet from the ground on the bottom end. It was slanted at about a 60° angle to the ground. This antenna resonated at 12.8 MHz and had a measured resistance of about 35 Ω. After the resonance measurements, he fed it with 1-inch ladder open-wire line (a total of about 100 feet to the shack).

For brevity, this is called a vertical *LLSD* (linear-loaded short dipole). A tuner resonated the system nicely on 20 and 30 meters. On these bands the performance of the vertical LLSD seemed comparable to his 120-foot long, horizontal center-fed Zepp, 30 feet above ground. In some directions where the horizontal, all-band Zepp has nulls, such as toward Siberia, the vertical LLSD was definitely superior. This system also resonates on 17 and 40 meters. However, from listening to various signals, NN0F had the impression that this length LLSD is not as good on 17 and 40 meters as the horizontal 120-foot antenna.

Using Capacitance End Hats

He also experimented with an even shorter resonant length by trying an LLSD with capacitance end-hats. The hats, as expected, increased the radiation resistance and lowered the resonant frequency. Six-foot long, single-wire hats were used on each end of the previous 24-foot LLSD, as shown in **Fig 61**. The antenna was supported in the same way as the previous vertical dipole, but the bottom-end hat wire was only inches from the grass. This system resonated at 10.6 MHz with a measured resistance of 50 Ω.

If the dipole section were lengthened slightly, by a foot or so, to about 25 feet, it should hit the 10.1-MHz band and be a good match for 50-Ω coax. It would be suitable for a restricted space, shortened 30-meter antenna. Note that this antenna is only about half the length of a conventional 30-meter dipole, needs no tuner, and has no losses due to traps. It does have the loss of the extra wire, but this is essentially negligible.

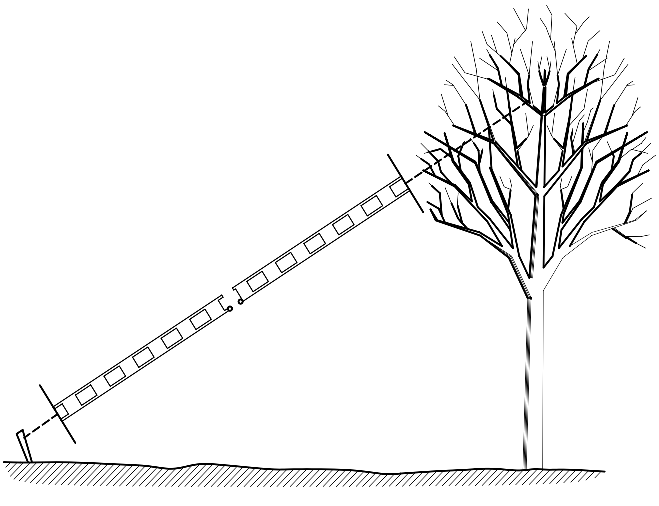

Fig 61—Two-wire linear-loaded dipole with capacitance end hats. Main dipole length was constructed from 24 feet of "windowed" ladder line. The end-hat elements were stiff wires 6 feet long. The antenna was strung at about a 60° angle from a tree limb using monofilament fishing line. Measured resonant frequency and radiation resistance were 10.6 MHz and 50 Ω.

Any of the linear-loaded dipole antennas can be mounted either horizontally or vertically. The vertical version can be used for longer skip contacts—beyond 600 miles or so—unless you have rather tall supports for horizontal antennas to give a low elevation angle. Using different diameter conductors in linear-loaded antenna configurations yields different results, depending on whether the larger or small diameter conductor is fed. NN0F experimented with a vertical ground-plane antenna using a 10-foot piece of electrical conduit pipe (⅝ inch OD) and #12 copper house wire.

Fig 62 shows the configuration. The radial ground system was buried a couple of inches under the soil and is not shown. Note that this is not a folded monopole, which would have either A or B grounded.

The two conductors were separated by 2 inches, using plastic spreaders held onto the pipe by stainless-steel hose clamps obtained from the local hardware store. Hose clamps intertwined at right angles were also used to clamp the pipe on electric fence stand-off insulators on a short 2×4 post set vertically in the ground.

The two different diameter conductors make the antenna characteristics change, depending on how they are configured. With the antenna bridge connected to the larger diameter conductor (point A in Fig 62), and point B unconnected, the system resonated at 16.8 MHz and had R = 35 Ω. With the bridge at B (the smaller conductor), and point A left unconnected, the resonance lowered to 12.4 MHz and R was found to be about 24 Ω.

The resonant frequency of the system in Fig 62 can be adjusted by changing the overall height, or for increasing the frequency, by reducing the length of the wire. Note that a 3.8-MHz resonant ground plane can be made with height only about half that of the usual 67 feet required, if the smaller conductor is fed (point B in Fig 62). In this case, the pipe would be left unconnected electrically. The lengths given above can be scaled to determine a first-try attempt for your favorite band. Resonant lengths will, however, depend on the conductor diameters and spacing.

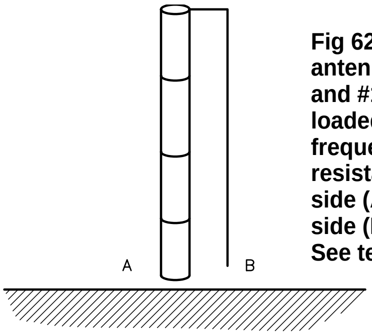

Fig 62—Vertical ground-plane antenna with a 10-foot pipe and #12 wire as the linear-loaded element. Resonant frequency and radiation resistance depend on which side (A or B) is fed. The other side (B or A) is *not* grounded. See text for details.

The same ideas hold for a dipole, except that the lengths should be doubled from those of the ground plane in Fig 62. The resistance will be twice that of the ground plane. Say, how about a shortened 40-meter horizontal beam to enhance your signal?!

COMBINED LOADING

As an antenna is shortened further the size of the top loading device will become larger and at some point will be impractical. In this situation inductive loading, usually placed directly between the capacitance "hat" and the top of the antenna, can be added to resonate the antenna. An alternative would be to use linear loading in place of inductive loading. The previous section contained an example of end loading combined with linear loading.

SHORTENING THE RADIALS

Very often the space required by full-length radials is simply not available. Like the vertical portion of the antenna, the radials can also be shortened and loaded in very much the same way. An example of end loaded radials is given in **Fig 63A**. Radials half the usual length can be used with little reduction in efficiency but, as in the case of top loading, the antenna Q will be higher and the bandwidth reduced. As shown in Fig 63B**,** inductive loading can also be used. As long as they are not made too short (down to 0.1λ) loaded radials can be efficient—with careful design.

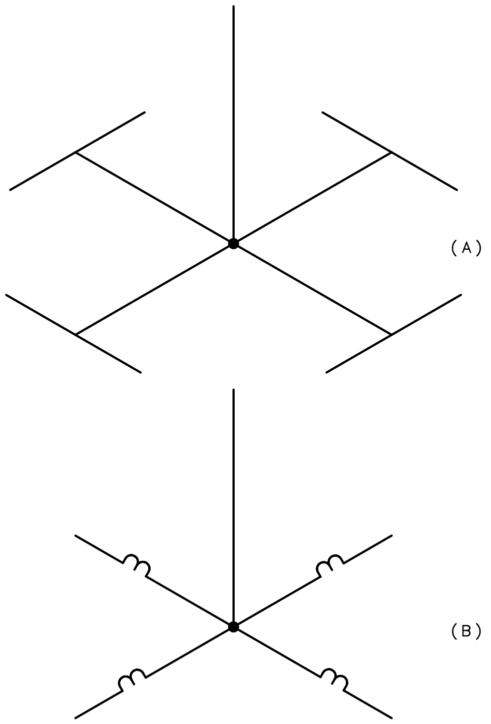

Fig 63—Radials may be shortened by using either capacitive (A) or inductive (B) loading. In extreme cases both may be used but the operating bandwidth will be limited.

GENERAL RULES

The steps in designing an efficient short vertical antenna system are:

- Make the vertical section as long as possible.
- Make the diameter of the vertical section as large as possible. Tubing or a cage of smaller wires will work well.
- Provide as much top and/or bottom loading as possible.
- If the top/bottom loading is insufficient, resonate the antenna with a high-Q inductor placed between the hat and the top of the antenna.
- For buried-ground systems, use as many radials (> 0.2 λ) as possible. 40 or more is best.
- If an elevated ground plane is used, use 4 to 8 radials, 5 or more feet above ground.
- If shortened radials must be used then capacitive loading is preferable to inductive loading.

EXAMPLES OF SHORT VERTICALS

A 6-Foot-High 7-MHz Vertical Antenna

Figs 64 through 67 give details for building short, effective vertical quarter-wavelength radiators. This information was originally presented by Jerry Sevick, W2FMI.

A short vertical antenna, properly designed and installed, approaches the efficiency of a full-size resonant quarter-wave antenna. Even a 6-foot vertical on 7 MHz can produce an exceptional signal. Theory tells us that this should be possible, but the practical achievement of such a result requires an understanding of the problems of ground losses, loading, and impedance matching.

The key to success with shortened vertical antennas lies in the efficiency of the ground system with which the antenna is used. A system of at least 60 radial wires is rec-

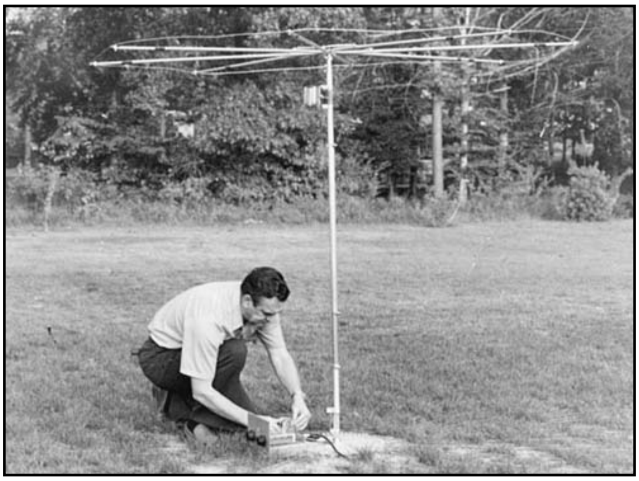

Fig 64—Jerry Sevick, W2FMI, adjusts the 6-foot high, 40-meter vertical.

ommended for best results, although the builder may elect to reduce the number at the expense of some performance. The radials can be tensioned and pinned at the far ends to permit on-the-ground installation, which will enable the amateur to mow the lawn without the wires becoming entangled in the mower blades. Alternatively, the wires can be buried in the ground, where they will not be visible. There is nothing critical about the wire size for the radials. Radials made of 28, 22, or even 16-gauge wire, will provide the same results. The radials should be at least 0.2 λ long (27 feet or greater on 7 MHz).

A top hat is formed as illustrated in **Fig 65**. The diameter is 7 feet, and a continuous length of wire is connected to the spokes around the outer circumference of the wheel. A loading coil consisting of 14 turns of B&W 3029 Miniductor stock (2½-inch dia, 6 TPI, #12 wire) is installed 6 inches below the top hat (see Fig 65). This antenna exhibits a feed-point impedance of 3.5 Ω at 7.21 MHz. For operation above or below this frequency, the number of coil turns must be decreased or increased, respectively. Matching is accomplished by increasing the feed-point impedance to 14 Ω through addition of a 4:1-transformer, then matching 14 Ω to 50 Ω (feeder impedance) by means of a pi network. The 2:1 SWR bandwidth for this antenna is approximately 100 kHz.

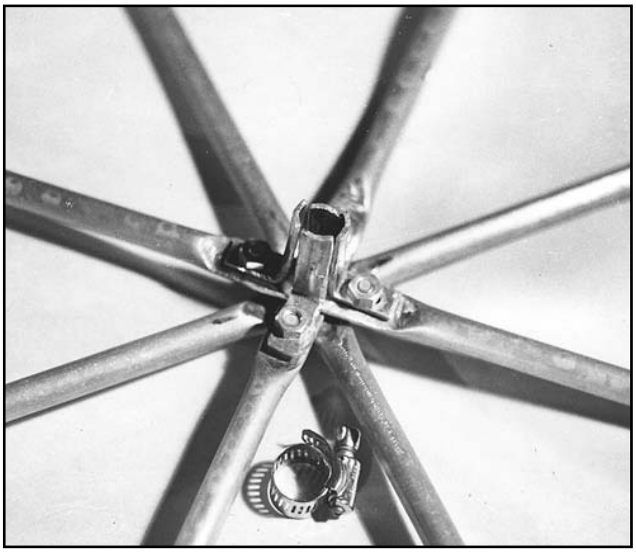

Fig 65—Construction details for the top hat. For a diameter of 7 feet, ½-in. aluminum tubing is used. The hose clamp is made of stainless steel and is available at Sears. The rest of the hardware is aluminum.

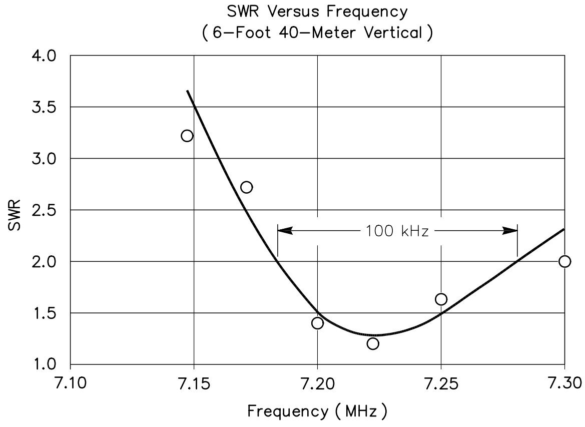

Fig 66—Standing-wave ratio of the 6-foot vertical using a 7-foot top hat and 14 turns of loading 6 inches below the top hat.

More than 200 contacts with the 6-foot antenna have indicated the efficiency and capability of a short vertical. Invariably at distances greater than 500 or 600 miles, the short vertical yields excellent signals. Similar antennas can be scaled and constructed for bands other than 7 MHz. The 7-foot-diameter-top hat was tried on a 3.5-MHz vertical, with an antenna height of 22 feet. The loading coil had 24 turns and was placed 2 feet below the top hat. On-the-air results duplicated those on 40-meters. The bandwidth was 65 kHz.

Short verticals such as these have the ability to radiate and receive almost as well as a full-size quarter-wave. Trade-offs are in lowered input impedances and bandwidths. However, with a good radial system and a proper design, these trade-offs can be made entirely acceptable.

Short Continuously Loaded Verticals

While there is the option of using lumped inductance to achieve resonance in a short antenna, the antenna can also be helically wound to provide the required inductance. This is shown in **Fig 68**. Shortened quarter-wavelength vertical antennas can be made by forming a helix on a long cylindrical insulator. The diameter of the helix must be small in terms of λ to prevent the antenna from radiating in the axial mode.

Acceptable form diameters for HF-band operation are from 1 inch to 10 inches when the practical aspects of antenna construction are considered. Insulating poles of fiberglass, PVC tubing, treated bamboo or wood, or phenolic are suitable for use in building helically wound radiators. If wood or bamboo is used the builder should treat the material with at least two coats of exterior spar varnish prior to winding the antenna element. The completed structure should be given two more coats of varnish, regardless of the material used for the coil form. Application of the varnish will help weatherproof the antenna and prevent the coil turns from changing position.

No strict rule has been established concerning how short a helically wound vertical can be before a significant drop in performance is experienced. Generally, one should use the greatest amount of length consistent with available space. A guideline might be to maintain an element length of 0.05 wavelength or more for antennas which are electrically a quarter wavelength long. Thus, use 13 feet or more of stock for an 80-meter antenna, 7 feet for 40 meters, and so on.

A quarter-wavelength helically wound vertical can be used in the same manner as a full-size vertical. That is, it can be worked against an above-ground wire radial system (four or more radials), or it can be ground-mounted with

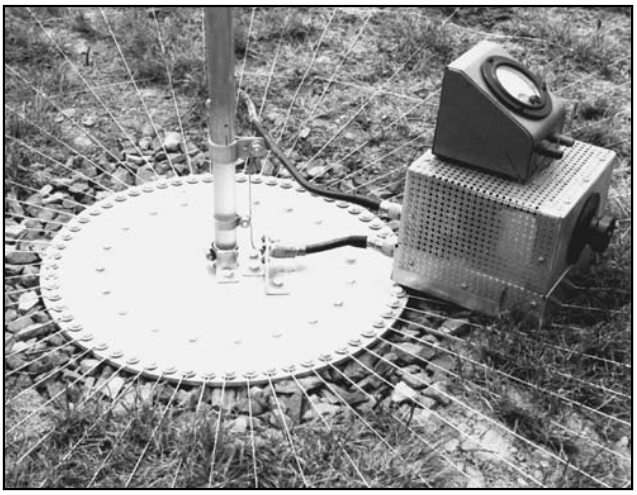

Fig 67—Base of the vertical antenna showing the 60 radial wires. The aluminum disc is 15 inches in diameter and ¼ inches thick. Sixty tapped holes for ¼-20 aluminum hex-head bolts form the outer ring and 20 form the inner ring. The inner bolts were used for performance comparisons with more than 60 radials. The insulator is polystyrene material (phenolic or Plexiglas suitable) with a 1-inch diameter. Also shown is the impedance bridge used for measuring input resistance.

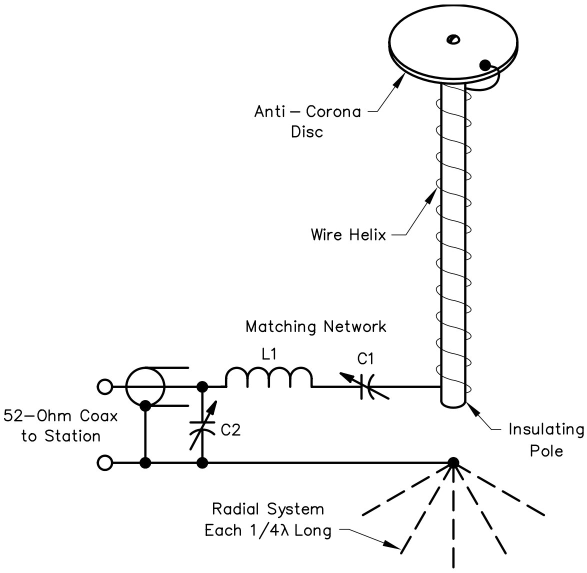

Fig 68—Helically wound ground-plane vertical. Performance from this type of antenna is comparable to that of many full-size λ/4 vertical antennas. The major design trade-off is usable bandwidth. All shortened antennas of this variety are narrow-band devices. At 7 MHz, in the example illustrated here, the bandwidth between the 2:1 SWR points will be on the order of 50 kHz, half that amount on 80 meters, and twice that amount on 20 meters. Therefore, the antenna should be adjusted for operation in the center of the frequency band of interest.

radials buried or lying on the ground. Some operators have reported good results when using antennas of this kind with four helically wound radials cut for resonance at the operating frequency. The latter technique should capture the attention of those persons who must use indoor antennas.

Winding Information

There is no hard-and-fast formula for determining the amount of wire needed to establish resonance in a helical antenna. The relationship between the length of wire needed for resonance and a full quarter wave at the desired frequency depends on several factors. Some of these are wire size, diameter of the turns, and the dielectric properties of the form material, to name a few. Experience has indicated that a section of wire approximately one half wavelength long, wound on an insulating form with a linear pitch (equal spacing between turns) will come close to yielding a resonant quarter wavelength. Therefore, an antenna for use on 160 meters would require approximately 260 feet of wire, spirally wound on the support.

No specific rule exists concerning the size or type of wire one should use in making a helix. Larger wire sizes are, of course, preferable in the interest of minimizing I^2R losses in the system. For power levels up to 1000 W it is wise to use a wire size of #16 or larger. Aluminum clothesline wire is suitable for use in systems where the spacing between turns is greater than the wire diameter. Antennas requiring close-spaced turns can be made from enameled magnet wire or #14 vinyl jacketed, single-conductor house wiring stock. Every effort should be made to keep the turn spacing as large as is practical to maximize efficiency.

A short rod or metal disc should be made for the top or high-impedance end of the vertical. This is a necessary part of the installation to assure reduction in antenna Q. This broadens the bandwidth of the system and helps prevent extremely high amounts of RF voltage from being developed at the top of the radiator. (Some helical antennas act like Tesla coils when used with high-power transmitters, and can actually catch fire at the high-impedance end when a stub or disc is not used.) Since the Q-lowering device exhibits some additional capacitance in the system, it must be in place before the antenna is tuned.

Tuning and Matching

Once the element is wound it should be mounted where it will be used, with the ground system installed. The feed end of the radiator can be connected temporarily to the ground system. Use a dip meter to check the antenna for resonance by coupling the dipper to the last few turns near the ground end of the radiator. Add or remove turns until the vertical is resonant at the desired operating frequency.

It is impossible to predict the absolute value of feed impedance for a helically wound vertical. The value will depend upon the length and diameter of the element, the ground system used with the antenna, and the size of the disc or stub atop the radiator. Generally speaking, the radiation resistance will be very low—approximately 3 to 10 Ω. An L network of the kind shown in Fig 68 can be used to increase the impedance to 50 Ω. The Q_L (loaded Q) of the network inductors is low to provide reasonable bandwidth, consistent with the bandwidth of the antenna. Network values for other operating bands and frequencies can be determined by using the reactance values listed below. The design center for the network is based on a radiation resistance of 5 Ω. If the exact feed impedance is known, the following equations can be used to determine precise component values for the matching network. (See Chapter 25, Coupling the Transmitter to the Line, for additional information on L-network matching.)

XA QRL (Eq 7)

$$X_{C2} = 50\sqrt{\frac{R_L}{50 - R_L}} \quad \text{(Eq 8)}$$

$$X_{L1} = X_{C1} + \frac{R_L\, 50}{X_{C2}} \quad \text{(Eq 9)}$$

where

X_{C1} = capacitive reactance of C1
X_{C2} = capacitive reactance of C2
X_{L1} = inductive reactance of L1
Q = loaded Q of network
R_L = radiation resistance of antenna

Example: Find the network constants for a helical antenna with a feed impedance of 5 Ω at 7 MHz, Q = 3:

$$X_{C1} = 3 \times 5 = 15$$

$$X_{C2} = \sqrt{\frac{5}{50 - 5}} = 16.666$$

$$X_{L1} = 15 + \frac{250}{16.666} = 30$$

Therefore, C1 = 1500 pF, C2 = 1350 pF, and L1 = 0.7 µH. The capacitors can be made from parallel or series combinations of transmitting micas. L_1 can be a few turns of large Miniductor stock. At RF power levels of 100 W or less, large compression trimmers can be used at C1 and C2 because the maximum RMS voltage at 100 W (across 50 Ω) will be 50 V. At, say, 800 W there will be approximately 220 V RMS developed across 50 Ω. This suggests the use of small transmitting variables at C1 and C2, possibly connected in parallel with fixed values of capacitance to constitute the required amount of capacitance for the network.

By making some part of the network variable, it will be possible to adjust the circuit for an SWR of 1:1 without knowing precisely what the antenna feed impedance is. Actually, C1 is not required as part of the matching network. It is included here to bring the necessary value for L1 into a practical range.

Fig 68 illustrates the practical form a typical helically wound ground-plane vertical might take. Performance from this type antenna is comparable to that of many full-size quarter-wavelength vertical antennas. The major design trade-off is in usable bandwidth. All shortened antennas of this variety are narrow-band devices. At 7 MHz, in the example illustrated here, the bandwidth between the 2:1 SWR points will be on the order of 50 kHz, half that amount on 80 meters, and twice that amount on 20 meters. Therefore, the antenna should be adjusted for operation in the center of the frequency spread of interest.

SHORTENED DIPOLES

As shown in preceding sections, there are a number of ways to load antennas so they may be reduced in size without severe reductions in effectiveness. Loading is always a compromise; the best method is determined by the amount of space available and the band(s) to be worked.

The simplest way to shorten a dipole is shown in **Fig 69**. If you do not have sufficient length between the supports, simply hang as much of the center of the antenna as possible between the supports and let the ends hang down. The ends can be straight down or may be at an angle as indicated but in either case should be secured so that they do not move in the wind. As long as the center portion between the supports is at least ¼, the radiation pattern will be very nearly the same

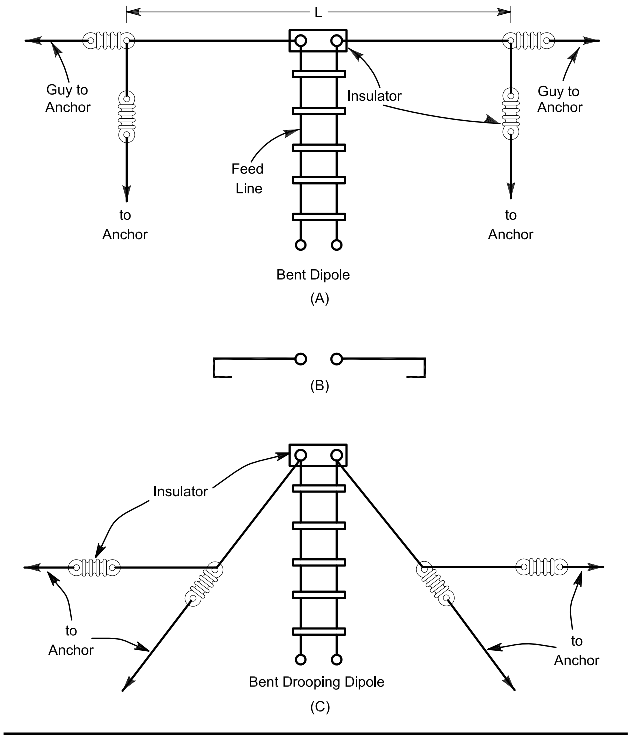

Fig 69—When space is limited, the ends may be bent downward as shown at A, or back on the radiator as shown at B. The bent dipole ends may come straight down or be led off at an angle away from the center of the antenna. An inverted V at C can be erected with the ends bent parallel to the ground when the support structure is not high enough.

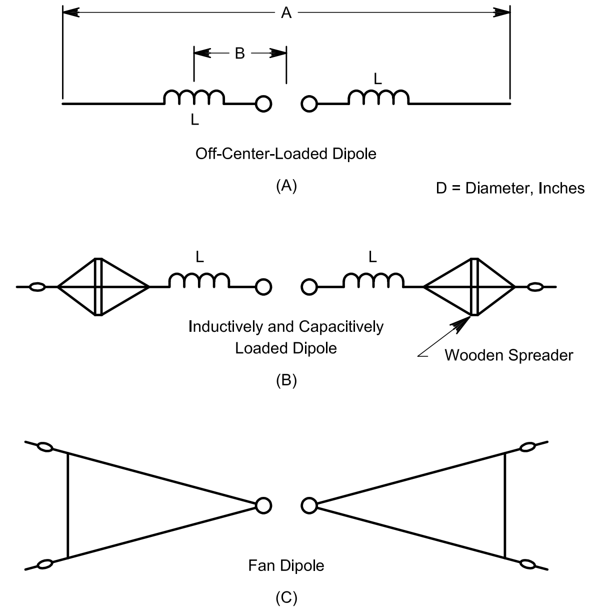

Fig 70—At A is a dipole antenna lengthened electrically with off-center loading coils. For a fixed dimension A, greater efficiency will be realized with greater distance B, but as B is increased, L must be larger in value to maintain resonance. If the two coils are placed at the ends of the antenna, in theory they must be infinite in size to maintain resonance. At B, capacitive loading of the ends, either through proximity of the antenna to other objects or through the addition of capacitance hats, will reduce the required value of the coils. At C, a fan dipole provides some electrical lengthening as well as broadbanding.

as a full-length dipole.

The resonant length of the wire will be somewhat shorter than a full-length dipole and can best be determined by experimentally adjusting the length of ends, which may be conveniently near ground. Keep in mind that there can be very high potentials at the ends of the wires and for safety the ends should be kept out of reach. Letting the ends hang down as shown is a form of capacitive end loading. While it is efficient, it will also reduce the matching bandwidth—as does any form of loading.

The most serious drawback associated with inductive loading is high loss in the coils themselves. It is important that you use inductors made from reasonably large wire or tubing to minimize this problem. Close winding of turns should also be avoided if possible. A good compromise is to use some off-center inductive loading in combination with capacitive end loading, keeping the inductor losses small and the efficiency as high as possible.

Some examples of off-center coil loading and capacitive-end loading are shown in **Fig 70**. This technique was described by Jerry Hall, K1TD in Sep 1974 *QST*. In the equation below, the diameter D is that of the wire used for the antenna, in inches. The frequency f is expressed in MHz.

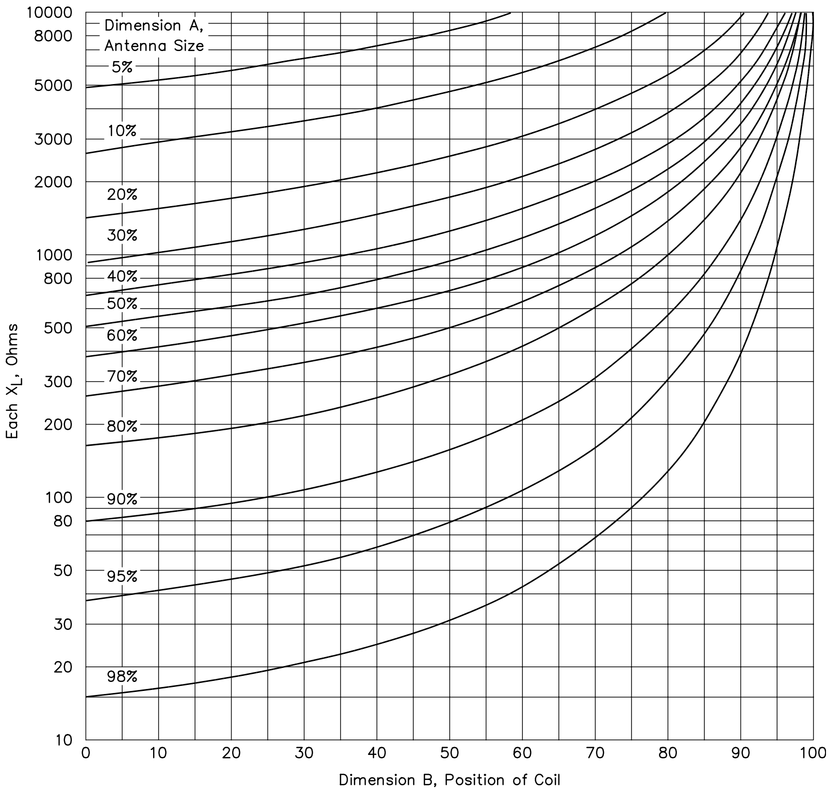

Fig 71—Chart for determining approximate inductance values for off-center-loaded dipoles. See Fig 70A. At the intersection of the appropriate curve from the body of the chart for dimension A and proper value for the coil position from the horizontal scale at the bottom of the chart, read the required inductive reactance for resonance from the scale at the left. Dimension A is expressed as percent length of the shortened antenna with respect to the length of a half-wave dipole of the same conductor material. Dimension B is expressed as the percentage of coil distance from the feed point to the end of the antenna. For example, a shortened antenna, which is 50% or half the size of a half-wave dipole (one-quarter wavelength overall) with loading coils positioned midway between the feed point and each end (50% out), would require coils having an inductive reactance of approximately 950 Ω at the operating frequency for antenna resonance.

Fig 72—The WØSVM "Shorty Forty" center-loaded antenna. Dimensions given are for 7.0 MHz. The loading coil is 5 inches long and 2½ inches diameter. It has a total of 30 turns of #12 wire wound at 6 turns per inch (Miniductor 3029 stock).

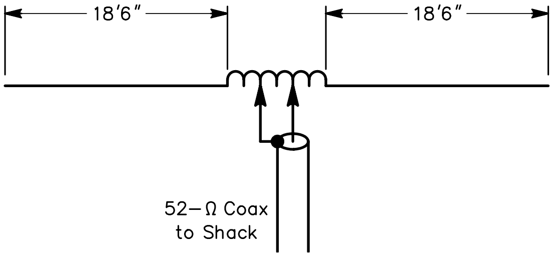

For the antennas shown, the longer the overall length (dimension A, Fig 70A, in feet) and the farther the loading coils are from the center of the antenna (dimension B, also in feet), the greater the efficiency of the antenna. As dimension B is increased, however, the inductance required to resonate the antenna at the desired frequency increases.

Approximate inductive reactances for single-band resonance (for the antenna in Fig 70A only) may be determined with the aid of **Fig 71** or from Eq 10 below. The final values will depend on the proximity of surrounding objects in individual installations and must be determined experimentally. The use of high-Q low-loss coils is important for maximum efficiency.

A dip meter or SWR indicator is recommended for use during adjustment of the system. Note that the minimum inductance required is for a center-loaded dipole. If the inductive reactance is read from Fig 66 for a dimension B of zero, one coil having approximately twice this reactance can be used near the center of the dipole. **Fig 72** illustrates this idea. This antenna was conceived by Jack Sobel, WØSVM, who dubbed the 7-MHz version the "Shorty Forty."

$$X_L = \frac{10^6}{34\pi f}\left(\frac{\left(\ln\frac{24\left(\frac{234}{f}\right)-B}{D}-1\right)\left(\left(1-\frac{fB}{234}\right)^2-1\right)}{\frac{234}{f}-B} - \frac{\left(\ln\frac{24\left(\frac{A}{2}-B\right)}{D}-1\right)\left(\left(\frac{\frac{fA}{2}-fB}{234}\right)^2-1\right)}{\frac{A}{2}-B} \right) \quad \text{(Eq 10)}$$

Inverted-L Antennas

The antenna shown in **Fig 73** is called an *inverted-L* antenna. It is simple and easy to construct and is a good antenna for the beginner or the experienced 1.8-MHz DXer. Because the overall electrical length is made somewhat greater than λ/4, the feed-point resistance is on the order of 50 Ω, with an inductive reactance. That reactance is canceled by a series capacitor as indicated in the figure. For a vertical section length of 60 feet and a horizontal section length of 115 feet, the input impedance is ≈ 40 + *j* 300 Ω. Longer vertical or horizontal sections would increase the input impedance. The azimuthal radiation pattern is slightly asymmetrical with ≈1 to 2-dB increase in the direction opposite to the horizontal wire. This antenna requires a good buried ground system or elevated radials and will have a 2:1 SWR bandwidth of about 50 kHz.

This antenna is a form of top-loaded vertical, where the top loading is asymmetrical. This results in both vertical and horizontal polarization because the currents in the top wire do not cancel like they would in a symmetrical-T vertical. This is not necessarily a bad thing because it eliminates the zenith null present in a true vertical. This allows for good communication at short ranges as well as for DX.

A yardarm attached to a tower or a tree limb can be used to support the vertical section. As with any vertical, for best results the vertical section should be as long as possible. A good ground system is necessary for good results—the better the ground, the better the results.

If you don't have the space for the inverted L shown in Fig 73 (with its 115-foot horizontal section) and if you don't have a second tall supporting structure to make the top

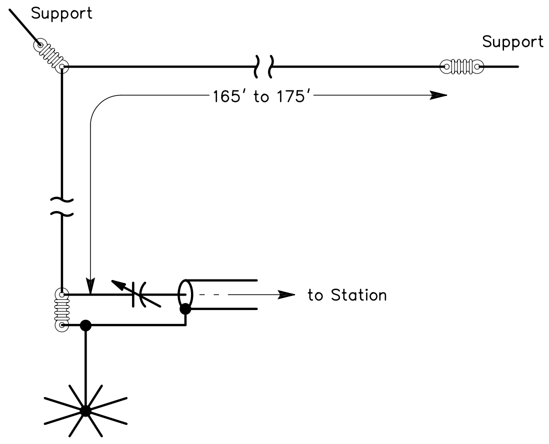

Fig 73—The 1.8-MHz inverted L. Overall wire length is 165 to 175 feet. The variable capacitor has a capacitance range from 100 to 800 pF, at 3 kV or more. Adjust antenna length and variable capacitor for lowest SWR.

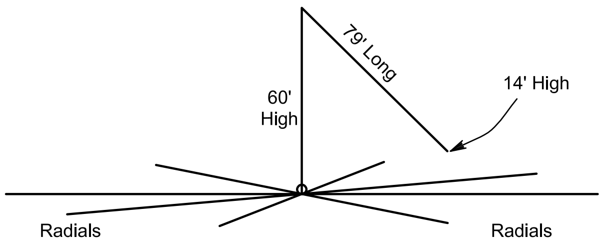

Fig 74—Sketch showing a modified 160-meter inverted L, with a single supporting 60-foot high tower and a 79-foot long slanted top-loading wire. The feed-point impedance is about 12 Ω in this system, requiring a quarter-wave matching transformer made of paralleled 50-Ω coaxes.

wire horizontal, consider sloping the top wire down towards ground. **Fig 74** illustrates such a setup, with a 60-foot high vertical section and a 79-foot sloping wire. As always, you will have to adjust the length of the sloping wire to fine-tune the resonant frequency. For a good ground radial system, the feed-point impedance is about 12 Ω, which may be transformed to 50 Ω with a 25-Ω quarter-wave transformer consisting of two paralleled 50-Ω quarter-wave coaxes. The peak gain will decrease about 1 dB compared to the inverted L shown in Fig 73. **Fig 75** overlays the elevation responses for average ground conditions. The 2:1 SWR bandwidth will be about 30 kHz, narrower than the larger system in Fig 73.

If the ground system suggested for Figs 73 and 74 is not practical, you can use a single elevated radial as shown in **Fig 76**. For the dimensions shown in the figure $Z_i = 50 + j\,498\ \Omega$, requiring a 175-pF series resonating capacitor. The azimuthal radiation pattern is shown in **Fig 77** compared to

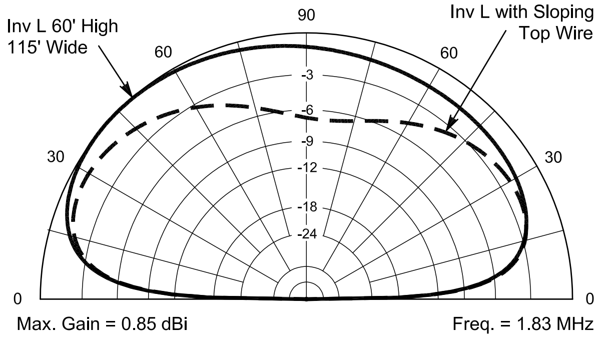

Fig 75—Overlay of the elevation responses for the inverted-L antennas in Fig 73 (solid line) and Fig 74 (dashed line). The gains are very close for these two setups, provided that the ground radial system for the antenna in Fig 74 is extensive enough to keep ground losses low.

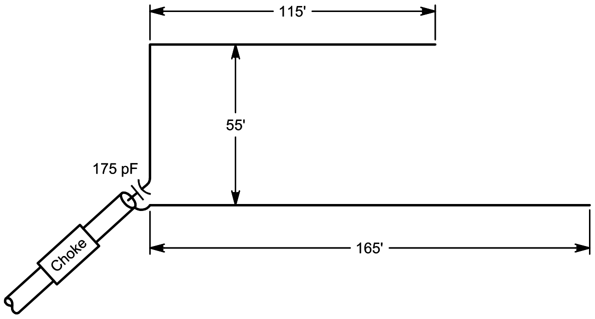

Fig 76—A single elevated radial can be used for the inverted-L. This changes the directivity slightly. The series tuning capacitor is approximately 175 pF for this system.

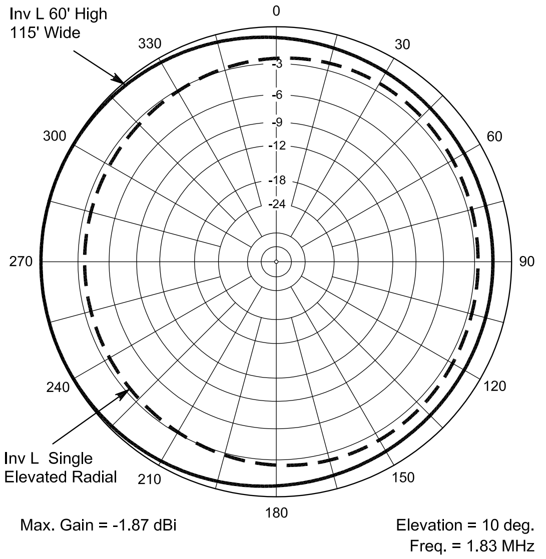

Fig 77—Azimuthal pattern comparison for inverted-L antennas shown in Fig 73 (solid line) and the compromise, single-radial system in Fig 76 (dashed line). This is for a takeoff angle of 10°.

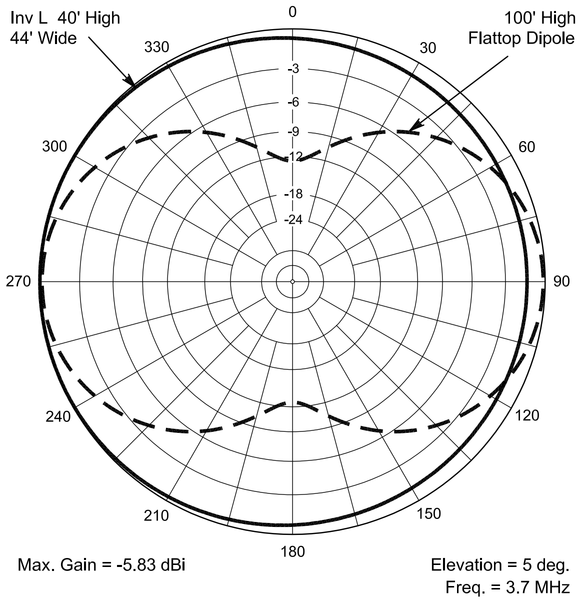

Fig 78—Azimuthal pattern at a takeoff angle of 5° for an 80-meter version of the inverted L (solid line) in Fig 73, compared to the response for a 100-foot high flattop dipole (dashed line).

the inverted L in Fig 68. Note that the 1 to 2-dB asymmetry is now in the direction of the horizontal wires, just the opposite of that for a symmetrical ground system. The 2:1 SWR bandwidth is about 40 kHz, assuming that the series capacitor is adjusted at 1.83 MHz for minimum SWR.

Fig 78 shows the azimuthal response at a 5° elevation angle for an 80-meter version of the inverted L in Fig 73. The peak response occurs at an azimuth directly behind the direction in which the horizontal portion of the inverted L points. For comparison, the response for a 100-foot high flattop dipole is also shown. The top wire of this antenna is only 40 feet high and the 2:1 SWR bandwidth is about 150 kHz wide with a good, low-loss ground-radial system.

Fig 78 illustrates that the azimuth response of an inverted L is nearly omnidirectional. This gives such an antenna an advantage in certain directions compared to a flattop dipole, which is constrained by its supporting mounts (such as trees or towers) to favor fixed directions. For example, the flattop dipole in Fig 78 is at its weakest at azimuths of 90° and 270°, where it is down about 12 dB compared to the inverted L. Hams who are fortunate enough to have high rotary dipoles or rotatable low-band Yagis have found them to be very effective antennas indeed.

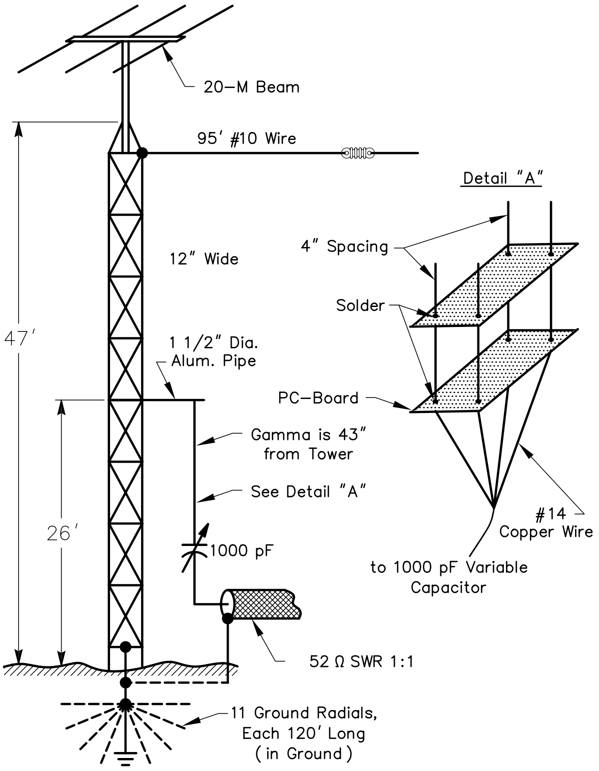

Fig 79—Details and dimensions for gamma-match feeding a 50-foot tower as a 1.8-MHz vertical antenna. The rotator cable and coaxial feed line for the 14-MHz beam is taped to the tower legs and run into the shack from ground level. No decoupling networks are necessary.

A DIFFERENT APPROACH

Fig 79 shows the method used by Doug DeMaw, W1FB, to gamma match his self-supporting 50-foot tower operating as an inverted L. A wire cage simulates a gamma rod of the proper diameter. The tuning capacitor is fashioned from telescoping sections of 1½ and 1½-inch aluminum tubing with polyethylene tubing serving as the dielectric. This capacitor is more than adequate for power levels of 100 W. The horizontal wire connected to the top of the tower provides the additional top loading.

Sloper Antennas

Sloping dipoles and λ/2 dipoles can be very useful antennas on the low bands. These antennas can have one end attached to a tower, tree or other structure and the other end near ground level, elevated high enough so that passersby can't contact them, of course. The following section gives a number of examples of these types of antennas.

THE HALF-WAVE SLOPING DIPOLE

If you have a sufficiently high support, you can install a halfwave dipole sloping downwards toward ground to provide vertical as well as horizontal polarization. This antenna is popularly known as a *sloper* or a *halfwave sloper*. The amount of slope from horizontal can vary from 0°, where the dipole is in a flattop configuration, all the way to 90°, where the dipole becomes fully vertical. The latter configuration is sometimes called a *Halfwave Vertical Dipole* (HVD).

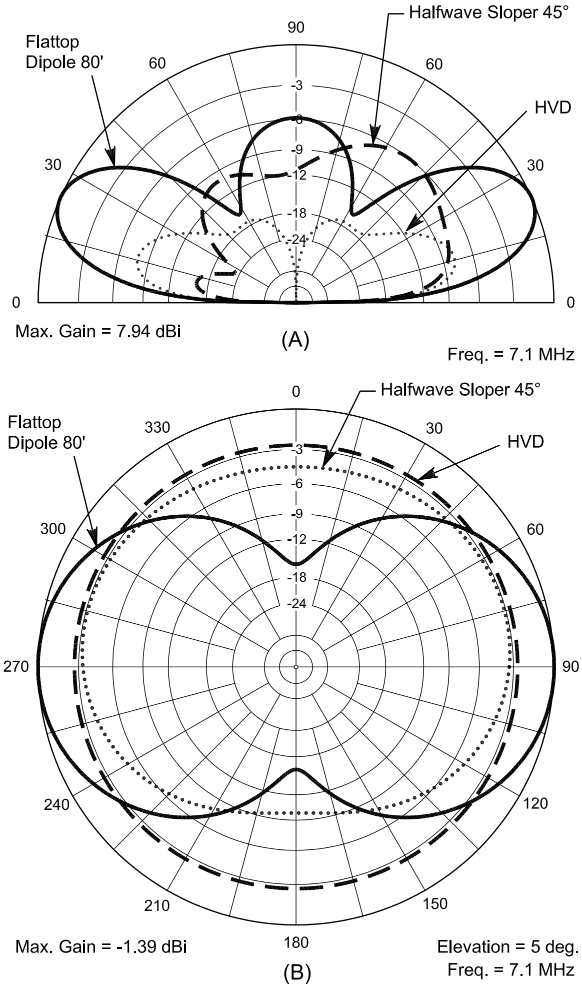

Fig 80—At A, the azimuthal responses for a flattop dipole (solid line), a dipole whose end has been tilted down 45° (dashed line), and a HVD (halfwave vertical dipole, dotted line). All these were modeled over average ground, with a conductivity of 5 mS/m and a dielectric constant of 13. Note that the tilted dipole exhibits about 5 dB front-to-back ratio, although its maximum gain is less than either the HVD or flattop dipole. At B, the elevation-plane patterns for the same antennas. Note that the tilted halfwave dipole (dashed line) has more energy at higher elevation angles than either the flattop dipole or HVD.

The question arises when contemplating a vertical half-wave dipole or a halfwave sloping dipole about how to treat the feed line to make sure it doesn't accidentally become part of the radiating system. The ideal situation would be to bring the feed line out perpendicular to the vertical or sloping wire for an infinite distance. Obviously, that isn't very practical because the feed line eventually has to be connected to a transmitter located near the ground. An intensive modeling study on feeding an HVD was done for the book *Simple and Fun Antennas for Hams*. This study indicated that a slant angle down to the ground of as little as 30° from a vertical radiator can work with only minor interaction, provided that common-mode decoupling chokes were employed at the feed point and a quarter-wavelength down the line from the feed point. These common-mode chokes can consist of either discrete ferrite beads placed over the outer jacket of the coaxial line or multiple turns of the coax itself to form a choke.

Fig 80A compares the 40-meter azimuthal patterns at a DX takeoff angle of 5° for three configurations: a flattop dipole, a dipole tilted down 45° and an HVD (halfwave vertical dipole). These are computed for ground with average conductivity and dielectric constant, and for a maximum height of 80 feet in each configuration. The sloping halfwave dipole exhibits about 5 dB of front-to-back ratio, although even at its most favored direction it doesn't quite have the same maximum gain as the HVD or the flattop dipole.

The reason why the maximum gain for the sloper is less than the other two configurations, even while still exhibiting some front-to-back pattern, is shown in Fig 80A, which shows the elevation-plane patterns for the same antennas, each at the azimuth of maximum gain. The halfwave sloper distributes much of its energy higher in elevation than the HVD, lowering the peak-gain potential of the sloper.

You can also see from Fig 80B that the 80-foot high horizontal dipole would perform much better than either the HVD or halfwave sloper for close-in local contacts, which occur at high elevation angles. On the other hand, except for the greater gain exhibited in the flattop dipole's most favored directions, the HVD has more gain than the other antennas at low elevation angles. While the HVD's omnidirectional pattern is a plus for transmitting, it may be a problem for receiving, where local noise may be coming from specific directions (such as power lines) and may also be predominantly vertically polarized. In such cases, a horizontally polarized flattop dipole may be a considerably better receiving antenna than a vertically polarized antenna of any sort. We've already mentioned the fact that a rotary flattop dipole high in the air can be a very effective antenna on the low bands.

THE QUARTER-WAVELENGTH “HALF SLOPER”

Perhaps one of the easiest antennas to install is the λ/4 sloper shown in **Fig 81**. As pointed out above, a sloping λ/2 dipole is known among radio amateurs as a *sloper* or sometimes as a *full sloper*. If only one half of it is used, it becomes a *half sloper*. The performance of the two types of sloping antennas is similar—They exhibit some directivity in the direction of the slope and radiate vertically polarized energy at low angles respective to the horizon. The amount of directivity will range from 3 to 6 dB, depending upon the individual installation, and will be observed in the slope direction.

The main advantage of the half sloper over the full half-wave-long sloping dipole is that its supporting tower needn’t be as high. Both the half sloper and the full sloper place the feed point (the point of maximum current) high above lossy ground. But the half-sloper only needs half as much wire to build the antenna for a given amateur band. The disadvantage of the half sloper is that it is sometimes difficult or even impossible to obtain a low SWR when using coaxial-cable feed, especially without a good isolating choke balun. (See the section above on isolating ground-plane antennas.)

Other factors that affect the feed impedance are tower height, height of the attachment point, enclosed angle between the sloper and the tower, and what is mounted atop the tower (HF or VHF beams). Further, the quality of the ground under the tower (ground conductivity, radials, etc) has a marked effect on the antenna performance. The final SWR can vary (after optimization) from 1:1 to as high as 6:1. Generally speaking, the closer the low end of the slope wire is to ground, the more difficult it will be to obtain a good match.

Basic Recommendations for a Half Sloper

The half sloper can be an excellent DX type of antenna. Hams usually install theirs on a metal supporting structure such as a mast or tower. The support needs to be grounded at the lower end, preferably to a buried or on-ground radial system. If a nonconductive support is used, the outside of the coax braid becomes the return circuit and should be grounded at the base of the support. As a starting point you can attach the sloper so the feed point is approximately λ/4 above ground. If the tower is not high enough to permit this, the antenna should be fastened as high on the supporting structure as possible. Start with an enclosed angle of approximately 45°, as indicated in Fig 81. Cut the wire to the length determined from

$$\ell = \frac{260}{f_{MHz}} \tag{Eq 11}$$

This will allow sufficient extra length for pruning the wire for the lowest SWR. A metal tower or mast becomes an operating part of the half sloper system. In effect, it and the slope wire function somewhat like an inverted-V dipole antenna. In other words, the tower operates as the missing half of the dipole. Hence its height and the top loading (beams) play a significant role.

Detailed modeling indicates that a sufficiently large

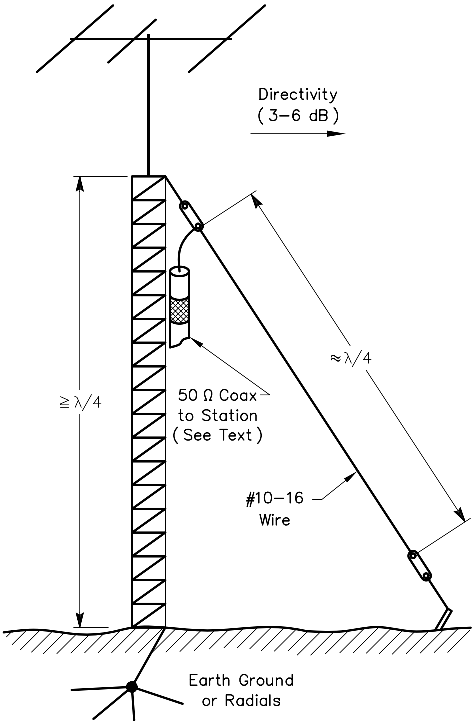

Fig 81—The λ/4 “half sloper” antenna.

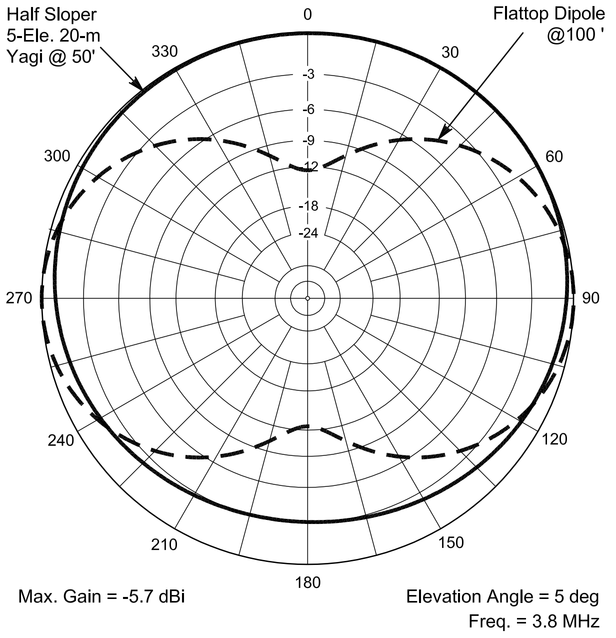

Fig 82—Radiation pattern for a typical half sloper (solid line) mounted on a 50-foot high tower with a large 5-element 20-meter beam on the top compared to that for a flattop dipole (dashed line) at 100 feet. At a 5° takeoff angle typical for DX work on 80 meters, the two antennas are pretty comparable in the directions favored by the high dipole. In other directions, the half sloper has an advantage of more than 10 dB.

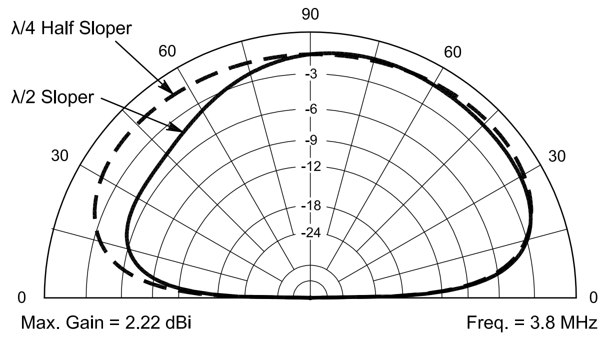

Fig 83—Comparison of elevation patterns for a full-sized halfwave sloper (solid line) on a 100-foot tower and a half sloper (dashed line) on a 50-foot tower with a 5-element 20-meter Yagi acting as a top counterpoise. The performance is quite comparable for these two systems.

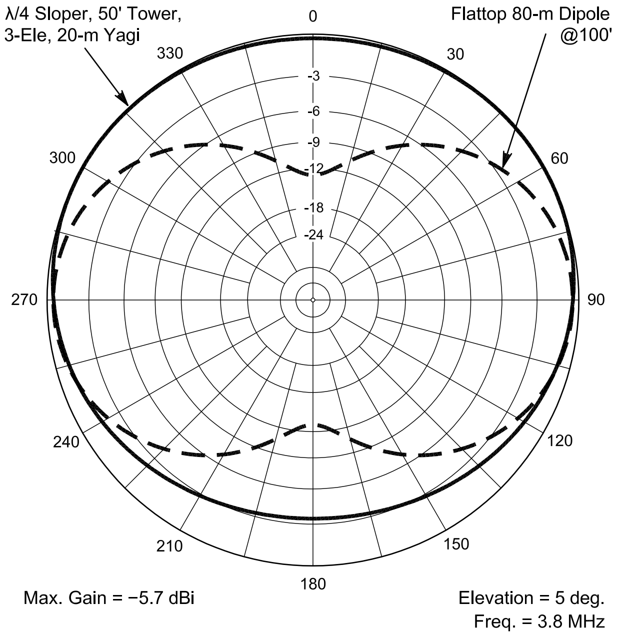

Fig 84—Comparing the azimuthal response of a half sloper (solid line) on a 50-foot tower with a 3-element 20-meter Yagi on top to that of a flattop dipole (dashed line) at 100 feet. The two are again quite comparable at a 5° takeoff angle.

mass of metal (that is, a large, "Plumber's Delight" Yagi) connected to the top of the tower acts like enough of a "top counterpoise" that the tower may be removed from the model with little change in the essential characteristics of the half-sloper system. Consider an installation using a freestanding 50-foot tower with a large 5-element 20-meter Yagi on top. This Yagi is assumed to have a 40-foot boom oriented 90° to the direction of the slanted 80-meter half-sloper wire. The best SWR that could be reached by changing the length and slant angle for this sloper is 1.67:1, representing a feed-point impedance of 30.1 – *j* 2.7 Ω. The peak gain at 3.8 MHz is 0.97 dBi at an elevation angle of 70°. **Fig 82** shows the azimuth-plane pattern for this half sloper, compared to a 100-foot high flattop dipole for reference, at an elevation angle of 5°.

Removing the tower from the model resulted in a feed-point impedance of 30.1 – *j* 1.5 Ω and a peak gain of 1.17 dBi. The tower is obviously not contributing much in this setup, since the mass of the large 20-meter Yagi is acting like an elevated counterpoise all by itself. It's interesting to rotate the boom of the model Yagi and observe the change in SWR that occurs on the half-sloper antenna. With the boom turned 90°, the SWR falls to 1.38:1. This level of SWR change could be measured with amateur-type instrumentation.

On the other hand, substituting a smaller 3-element 20-meter Yagi with an 18-foot boom in the model does result in significant change in feed-point impedance and gain when the tower is removed from the model, indicating that the "counterpoise effect" of the smaller beam is insufficient by itself. Interestingly enough, the best SWR for the half sloper/tower and the 3-element Yagi (with its boom inline with the half sloper is 1.33:1), changing to 1.27:1 with the boom turned 90°. Such a small change in SWR would be difficult to measure using typical amateur instrumentation.

In any case, the 50-Ω transmission line feeding a half sloper should be taped to the tower leg at frequent intervals to make it secure. The best method is to bring it to earth level, then route it to the operating position along the surface of the ground if it can't be buried. This will ensure adequate RF decoupling, which will help prevent RF energy from affecting the equipment in the station. Rotator cable and other feed lines on the tower or mast should be treated in a similar manner.

Adjustment of the half sloper is done with an SWR indicator in the 50-Ω transmission line. A compromise can usually be found between the enclosed angle and wire length, providing the lowest SWR attainable in the center of the chosen part of an amateur band. If the SWR "bottoms out" at 2:1 or lower, the system will work fine without using an antenna tuner, provided the transmitter can work into the load. Typical optimum values of SWR for 3.5 or 7-MHz half slopers are between 1.3:1 and 2:1. A 100-kHz bandwidth is normal on 3.5 MHz, with 200 kHz being typical at 7 MHz.

If the lowest SWR possible is greater than 2:1, the attachment point can be raised or lowered to improve the match. Readjustment of the wire length and enclosed angle may be necessary when the feed-point height is changed. If the tower is guyed, the guy wires will need to be insulated from the tower and broken up with additional insulators to prevent resonance.

At this point you may be curious about which antenna is better—a full sloper or a half sloper. The peak gain for each antenna is very nearly identical. **Fig 83** overlays the elevation-plane pattern for the full-sized halfwave sloper on a 100-foot tower and for the half sloper shown in Fig 81 on a 50-foot tower with a 5-element 20-meter Yagi on top. The

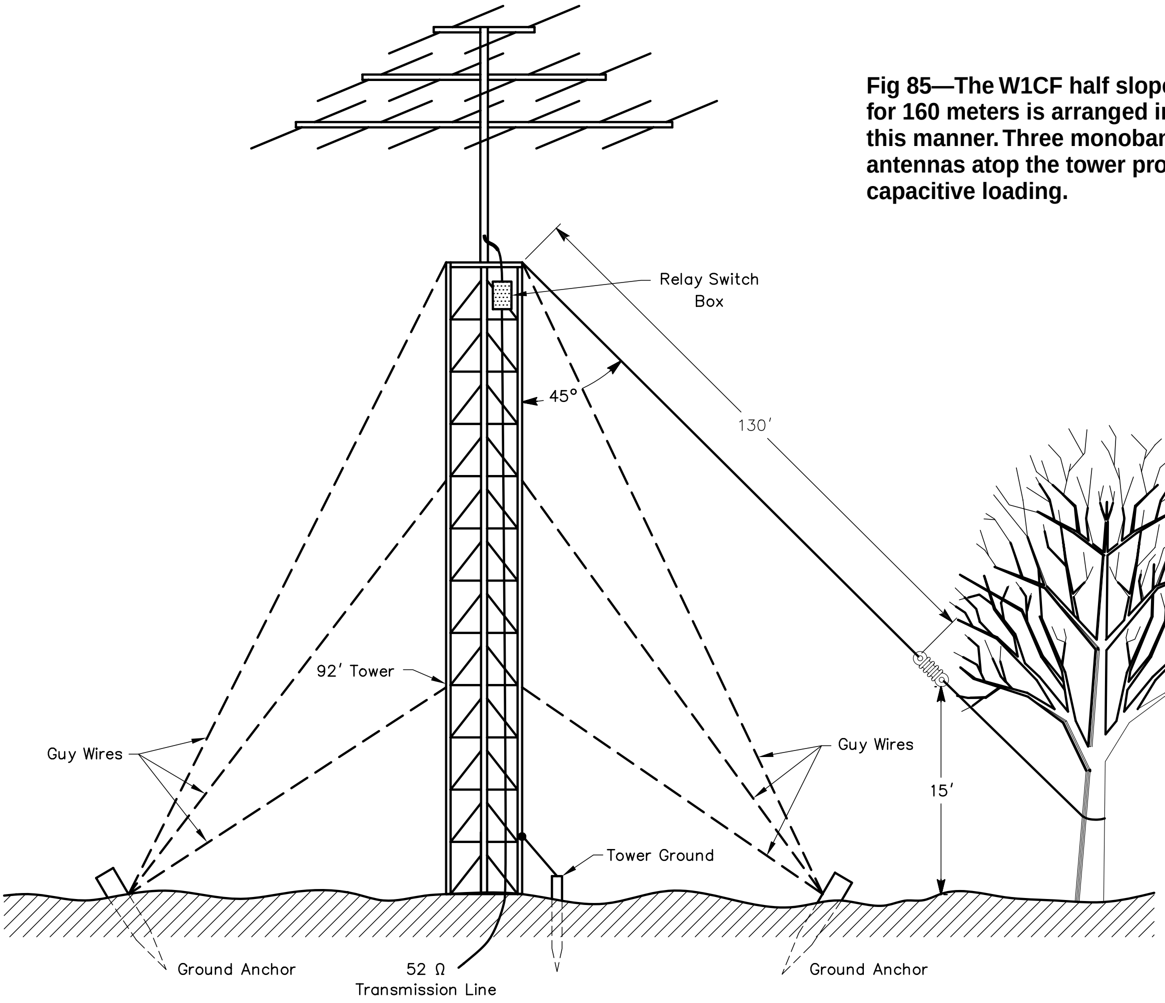
Relay Switch Box
45°
130′
92′ Tower
Guy Wires
Guy Wires
15′
Tower Ground
Ground Anchor
52 Ω Transmission Line
Ground Anchor

Fig 85—The W1CF half sloper for 160 meters is arranged in this manner. Three monoband antennas atop the tower provide capacitive loading.

full-sized halfwave sloper has more front-to-back ratio, but it is only a few dB more than the half sloper. **Fig 84** compares the azimuthal patterns at a 5° takeoff angle for a 100-foot high flattop dipole and a half-sloper system on a 50-foot tower with a 3-element 20-meter Yagi on top.

Despite the frustration some have experienced trying to achieve a low SWR with some half-sloper installations, many operators have found the half sloper to be an effective and low-cost antenna for DX work.

1.8-MHz ANTENNA SYSTEMS USING TOWERS

The half sloper discussed above for 80 or 40-meter operation will also perform well on 1.8 MHz where vertically polarized radiators can achieve the low takeoff angles needed on Topband. Prominent 1.8-MHz operators who have had success with the half sloper antenna suggest a minimum tower height of 50 feet. Dana Atchley, W1CF (SK), used the configuration sketched in **Fig 85**. He reported that the uninsulated guy wires act as an effective counterpoise for the sloping wire. In **Fig 86** is the feed system used by Doug

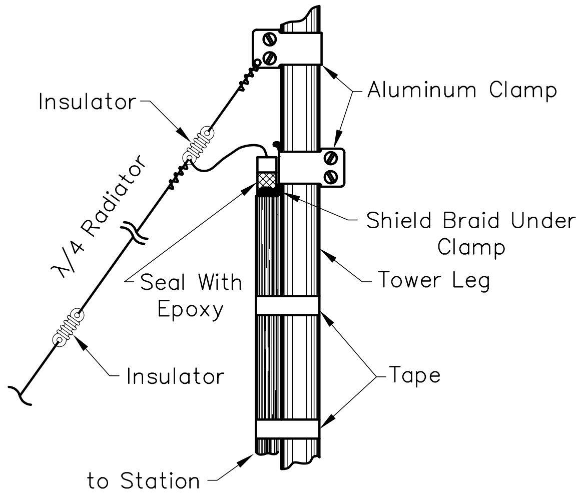
Insulator
Aluminum Clamp
λ/4 Radiator
Shield Braid Under Clamp
Seal With Epoxy
Tower Leg
Insulator
Tape
to Station

Fig 86—Feed system used by W1FB for 1.8 MHz half sloper on a 50-foot self-supporting tower.

DeMaw, W1FB (SK), on a 50-foot self-supporting tower. The ground for the W1FB system is provided by buried radials connected to the tower base.

As described previously, a tower can also be used as a true vertical antenna, provided a good ground system is used. The shunt-fed tower is at its best on 1.8 MHz, where a full λ/4 vertical antenna is rarely possible. Almost any tower height can be used. An HF beam at the top provides some top loading.

THE K1WA 7-MHz "SLOPER SYSTEM"

One of the more popular antennas for 3.5 and 7 MHz is the half-wave long sloping dipole described previously. David Pietraszewski, K1WA, made an extensive study of sloping dipoles at different heights with reflectors at the 3-GHz frequency range. From his experiments, he developed the novel 7-MHz antenna system described here. With several sloping dipoles supported by a single mast and a switching network, an antenna with directional characteristics and forward gain can be simply constructed. This 7-MHz system uses several "slopers" equally spaced around a common center support. Each dipole is cut to λ/2 and fed at the center with 50-Ω coax. The length of each feed line is 36 feet.

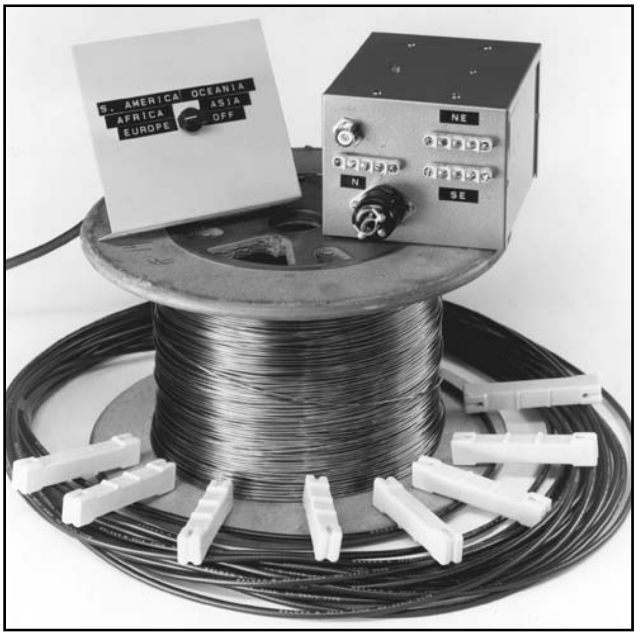

Fig 88—The basic materials required for the sloper system. The control box appears at the left, and the relay box at the right.

All of the feed lines go to a common point on the support (tower) where the switching takes place. The line length of 36 feet is just over 3λ/8, which provides a useful quality. At 7 MHz, the coax looks inductive to the antenna when the end at the switching box is open circuited. This has the effect of adding inductance at the center of the sloping dipole element, which electrically lengthens the element. The 36-foot length of feed line serves to increase the length of the element about 5%. This makes any unused element appear to be a reflector.

The array is simple and effective. By selecting one of the slopers through a relay box located at the tower, the system becomes a parasitic array that can be electrically rotated. All but the driven element of the array become reflectors.

The physical layout is shown in **Fig 87**, and the basic materials required for the sloper system are shown in **Fig 88**. The height of the support point should be about 70 feet, but can be less and still give reasonable results. The upper portion of the sloper is 5 feet from the tower, suspended by rope. The wire makes an angle of 60° with the ground.

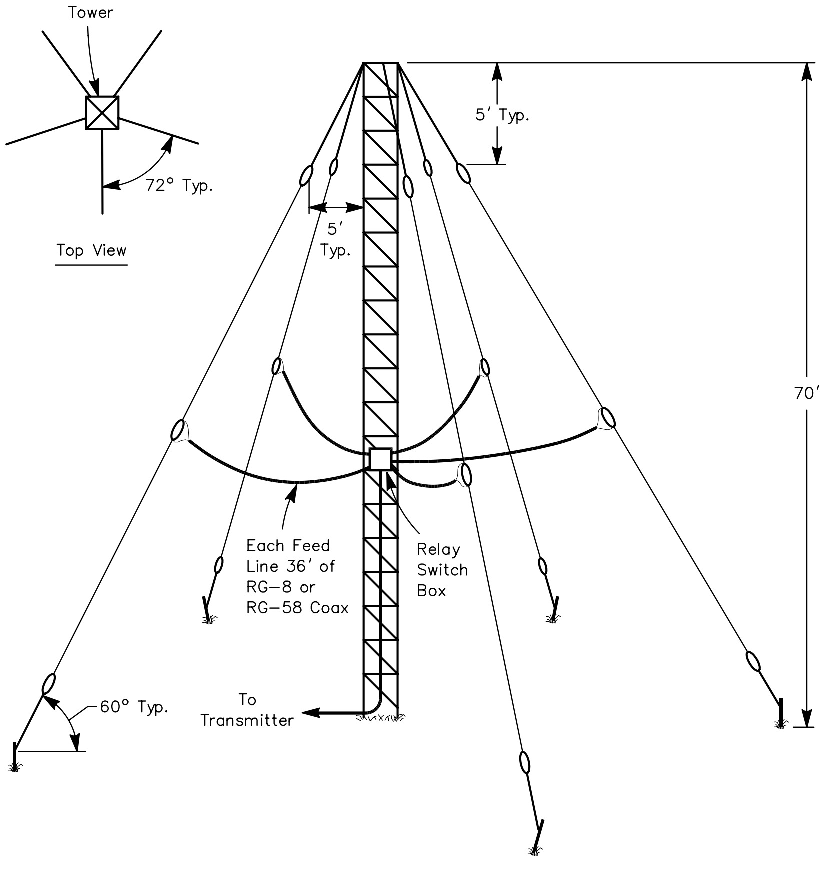

Fig 87—Five sloping dipoles suspended from one support. Directivity and forward gain can be obtained from this simple array. The top view shows how the elements should be spaced around the support.

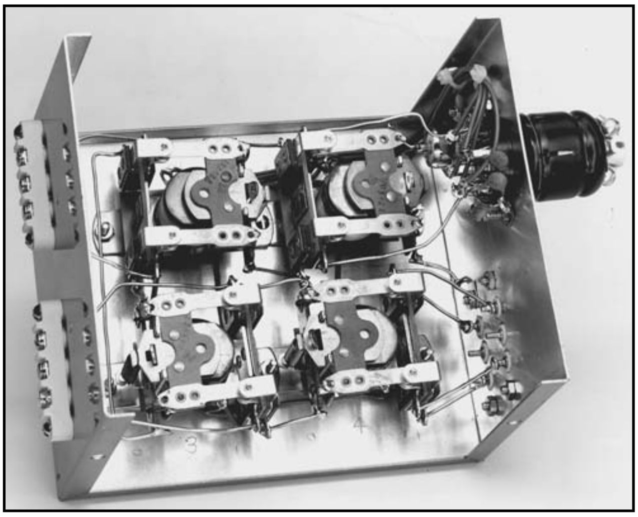

Fig 89—Inside view of relay box. Four relays provide control over five antennas. See text. The relays pictured here are Potter and Brumfeld type MR11D.

In **Fig 89**, the switch box is shown containing all the necessary relays to select the proper feed line for the desired direction. One feed line is selected at a time and the feed lines of those remaining are opened, **Fig 90**. In this way the array is electrically rotated. These relays are controlled from inside the shack with an appropriate power supply and rotary switch. For safety reasons and simplicity, 12-volt dc relays are used. The control line consists of a five conductor cable, one wire used as a common connection; the others go to the four relays. By using diodes in series with the relays and a dual-polarity power supply, the number of control wires can be reduced, as shown in Fig 90B.

Measurements indicate that this sloper array provides up to 20 dB front-to-back ratio and forward gain of about 4 dB over a single half-wave sloper. **Fig 91** shows the azimuthal pattern (at a 5° takeoff angle) for the K1WA array, compared to a 100-foot high flattop dipole and a full sloper suspended from a 50-foot tower. These patterns were calculated for average ground conditions. Just for fun, look at

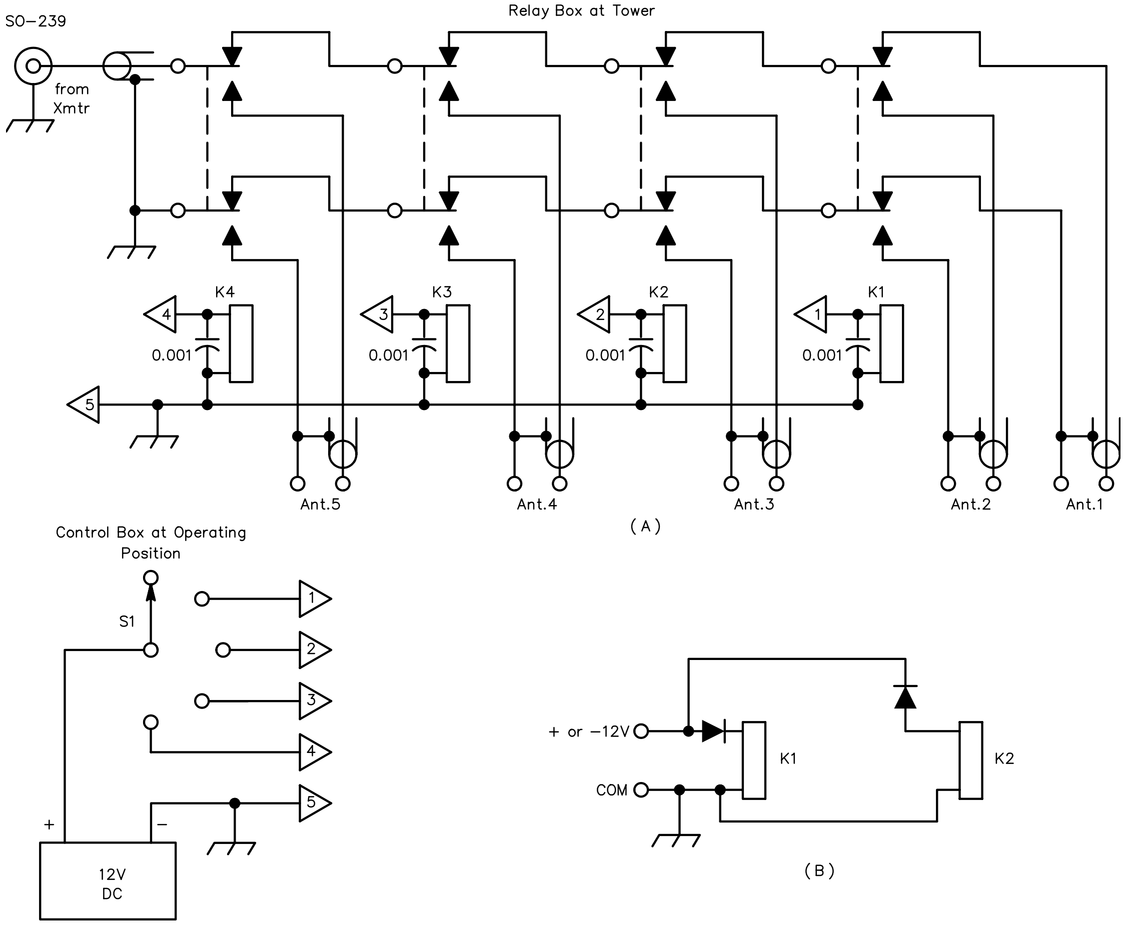

Fig 90—Schematic diagram for sloper control system. All relays are 12-volt dc, DPDT, with 8-A contact ratings. At A, the basic layout, excluding control cable and antennas. Note that the braid of the coax is also open-circuited when not in use. Each relay is bypassed with 0.001-µF capacitors. The power supply is a low current type. At B, diodes are used to reduce the number of control wires when using dc relays. See text.

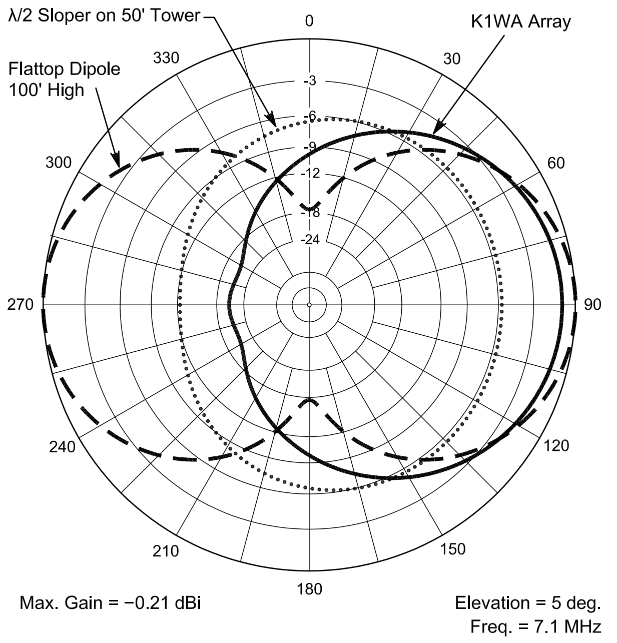

Fig 91—Azimuth pattern for K1WA 40-meter sloper array (solid line), compared to a flattop dipole (dashed line) at 100 feet and a halfwave full sloper on a 50-foot tower (dotted line). The K1WA array has an excellent front-to-back ratio and almost as much gain as the high flattop dipole. These patterns are for average ground.

Fig 92, which shows a comparison between a 100-foot high flattop dipole and a K1WA array placed over saltwater. Now that's a real barnburner at low takeoff angles! Such a seaside system would be very competitive with a rotatable 2-element "shorty-40" type of Yagi.

If one direction is the only concern, the switching system can be eliminated and the reflectors should be cut 5% longer than the resonant frequency. The feature worth noting is the good F/B ratio. By arranging the system properly, a null can be placed in an unwanted direction, thus making it an effective receiving antenna. In the tests conducted with this antenna, the number of reflectors used were as few as one and as many as five. The optimum combination appeared to occur with four reflectors and one driven element. No tests were conducted with more than five reflectors. This same array can be scaled to 3.5 MHz for similar results.

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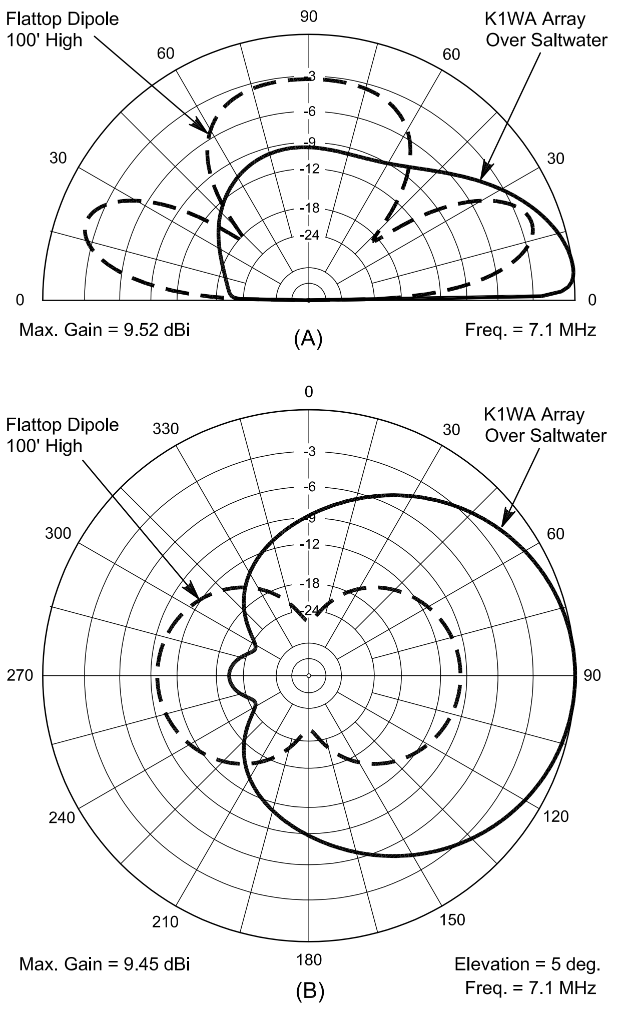

Fig 92—The K1WA 40-meter sloper array over saltwater, compared to a 100-foot high flattop dipole. At A, azimuth patterns. At B, elevation patterns. Now the sloper array really comes into its own!

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Chapter 7

Multiband Antennas

For operation in a number of bands, such as those between 3.5 and 30 MHz, it would be impractical for most amateurs to put up a separate antenna for each band. But this is not necessary—a dipole, cut for the lowest frequency band to be used, can be operated readily on higher frequencies. To do so, one must be willing to accept the fact that such harmonic-type operation leads to a change in the directional pattern of the antenna, both in the azimuth and the elevation planes (see Chapter 2, Antenna Fundamentals, and Chapter 3, The Effects of Ground).

You can see from discussions in Chapter 6, Low-Frequency Antennas, that you should carefully plan the height at which you install a multiband horizontally polarized antenna. This is one aspect of multiband antennas. Another important thing to consider is that you should be willing to use so-called *tuned feeders*. A center-fed single-wire antenna can be made to accept power and radiate it with high efficiency on any frequency higher than its fundamental resonant frequency and, with a reduction in efficiency and bandwidth, on frequencies as low as one half the fundamental.

In fact, it is not necessary for an antenna to be a full half-wavelength long at the lowest frequency. An antenna can be considerably shorter than ½ λ, even as short as ¼ λ, and still be a very efficient radiator. The use of such short antennas results in stresses, however, on other parts of the system, for example the antenna tuner and the transmission line. This will be discussed in some detail in this chapter.

Methods have been devised for making a single antenna structure operate on a number of bands while still offering a good match to a transmission line, usually of the coaxial type. It should be understood, however, that a multiband antenna is not *necessarily* one that will match a given line on all bands on which you intend to use it. Even a relatively short whip type of antenna can be operated as a multiband antenna with suitable loading for each band. Such loading may be in the form of a coil at the base of the antenna on those frequencies where loading is needed, or it may be incorporated in the tuned feeders running from the transmitter to the base of the antenna.

This chapter describes a number of systems that can be used on two or more bands. Beam antennas, such as Yagis or quads, are treated separately in later chapters.

Simple Wire Antennas

The simplest multiband antenna is a random length of #12 or #14 wire. Power can be fed to the wire on practically any frequency using one or the other of the methods shown in **Fig 1**. If the wire is made either 67 or 135 feet long, it can also be fed through a tuned circuit, as in **Fig 2**. It is advantageous to use an SWR bridge or other indicator in the coax line at the point marked “X.”

If you have installed a 28- or 50-MHz rotary beam, in many cases it may be possible to use the beam’s feed line as an antenna on the lower frequencies. Connecting the two wires of the feeder together at the station end will give a random-length wire that can be conveniently coupled to the transmitter as in Fig 1. The rotary system at the far end will serve only to *end-load* the wire and will not have much other effect.

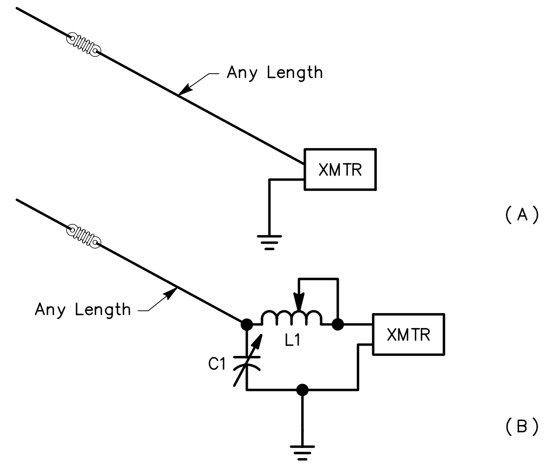

Fig 1—At A, a random-length wire driven directly from the pi-network output of a transmitter. At B, an L network for use in cases where sufficient loading cannot be obtained with the arrangement at A. C1 should have about the same plate spacing as the final tank capacitor in a vacuum-tube type of transmitter; a maximum capacitance of 100 pF is sufficient if L1 is 20 to 25 μH. A suitable coil would consist of 30 turns of #12 wire, 2½ inches diameter, 6 turns per inch. Bare wire should be used so the tap can be placed as required for loading the transmitter.

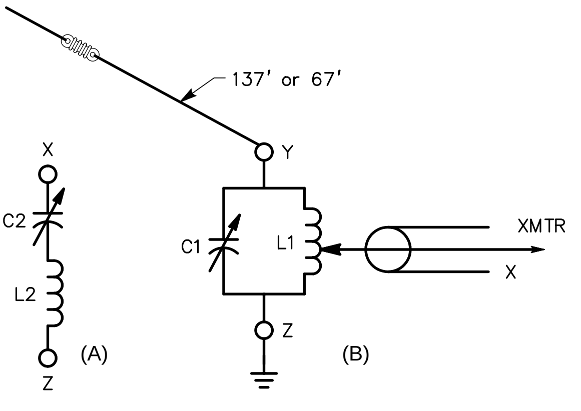

Fig 2—If the antenna length is 137 feet, a parallel-tuned coupling circuit can be used on each amateur band from 3.5 through 30 MHz, with the possible exception of the WARC 10-, 18- and 24-MHz bands. C1 should duplicate the final tank tuning capacitor and L1 should have the same dimensions as the final tank inductor on the band being used. If the wire is 67 feet long, series tuning can be used on 3.5 MHz as shown at the left; parallel tuning will be required on 7 MHz and higher frequency bands. C2 and L2 will in general duplicate the final tank tuning capacitor and inductor, the same as with parallel tuning. The L network shown in Fig 1B is also suitable for these antenna lengths.

One disadvantage of all such directly fed systems is that part of the antenna is practically within the station, and there is a good chance that you will have some trouble with RF feedback. RF within the station can often be minimized by choosing a length of wire so that the low feed-point impedance at a current loop occurs at or near the transmitter. This means using a wire length of $\lambda/4$ (65 feet at 3.6 MHz, 33 feet at 7.1 MHz), or an odd multiple of $\lambda/4$ (¾-λ is 195 feet at 3.6 MHz, 100 feet at 7.1 MHz). Obviously, this can be done for only one band in the case of even harmonically related bands, since the wire length that presents a current loop at the transmitter will present a voltage loop at two (or four) times that frequency.

When you operate with a random-length wire antenna, as in Figs 1 and 2, you should try different types of grounds on the various bands, to see what gives you the best results. In many cases it will be satisfactory to return to the transmitter chassis for the ground, or directly to a convenient metallic water pipe. If neither of these works well (or the metallic water pipe is not available), a length of #12 or #14 wire (approximately $\lambda/4$ long) can often be used to good advantage. Connect the wire at the point in the circuit that is shown grounded, and run it out and down the side of the house, or support it a few feet above the ground if the station is on the first floor or in the basement. It should not be connected to actual ground at any point.

END-FED ANTENNAS

When a straight-wire antenna is fed at one end with a two-wire transmission line, the length of the antenna portion becomes critical if radiation from the line is to be held to a minimum. Such an antenna system for multiband operation is the *end-fed Zepp* or *Zepp-fed* antenna shown in **Fig 3**. The antenna length is made $\lambda/2$ long at the lowest operating frequency. (This name came about because the first documented use of this sort of antennas was on the *Zeppelin* airships.) The feeder length can be anything that is convenient, but feeder lengths that are multiples of $\lambda/4$ generally give trouble with parallel currents and radiation from the feeder portion of the system. The feeder can be an open-wire line of #14 solid

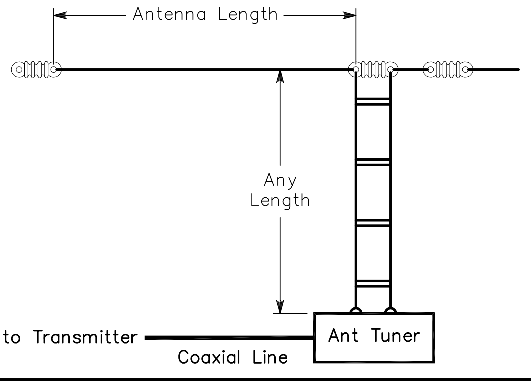

Fig 3—An end-fed Zepp antenna for multiband use.

copper wire spaced 4 or 6 inches with ceramic or plastic spacers. Open-wire TV line (not the type with a solid web of dielectric) is a convenient type to use. This type of line is available in approximately 300- and 450-Ω characteristic impedances.

If you have room for only a 67-foot flat top and yet want to operate in the 3.5-MHz band, the two feeder wires can be tied together at the transmitter end and the entire system treated as a random-length wire fed directly, as in Fig 1. The simplest precaution against parallel currents that could cause feed-line radiation is to use a feeder length that is not a multiple of λ/4. An antenna tuner can be used to provide multiband coverage with an end-fed antenna with any length of open-wire feed line, as shown in Fig 3.

CENTER-FED ANTENNAS

The simplest and most flexible (and also least expensive) all-band antennas are those using open-wire parallel-conductor feeders to the center of the antenna, as in **Fig 4**. Because each half of the flat top is the same length, the feeder currents will be balanced at all frequencies unless, of course, unbalance is introduced by one half of the antenna being closer to ground (or a grounded object) than the other. For best results and to maintain feed-current balance, the feeder should run away at right angles to the antenna, preferably for at least λ/4.

Center feed is not only more desirable than end feed because of inherently better balance, but generally also results in a lower standing wave ratio on the transmission line, provided a parallel-conductor line having a characteristic impedance of 450 to 600 Ω is used. TV-type open-wire line is satisfactory for all but possibly high power installations (over 500 W), where heavier wire and wider spacing is desirable to handle the larger currents and voltages.

The length of the antenna is not critical, nor is the length of the line. As mentioned earlier, the length of the antenna can be considerably less than λ/2 and still be very effective. If the overall length is at least λ/4 at the lowest frequency, a quite usable system will result. The only difficulty that may exist with this type of system is the matter of coupling the antenna-system load to the transmitter. Most modern transmitters are designed to work into a 50-Ω coaxial load. With this type of antenna system a coupling network (an antenna tuner) is required.

Feed-Line Radiation

The preceding sections have pointed out means of reducing or eliminating feed-line radiation. However, it should be emphasized that any radiation from a transmission line is not “lost” energy and is not necessarily harmful. Whether or not feed-line radiation is important depends entirely on the antenna system being used. For example, feed-line radiation is not desirable when a directive array is being used. Such feed-line radiation can distort the desired pattern of such an array, producing responses in unwanted directions. In other words, you want radiation only from the directive array, rather than from the directive array and the feed line. See Chapter 26, Coupling the Line to the Antenna, for a detailed discussion of this topic.

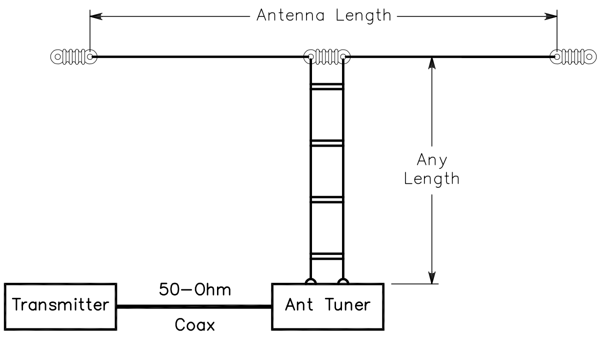

Fig 4—A center-fed antenna system for multiband use.

On the other hand, in the case of a multiband dipole where general coverage is desired, if the feed line happens to radiate, such energy could actually have a desirable effect. Antenna purists may dispute such a premise, but from a practical standpoint where you are not concerned with a directive pattern, much time and labor can be saved by ignoring possible transmission-line radiation.

THE 135-FOOT, 80 TO 10-METER DIPOLE

As mentioned previously, one of the most versatile antennas around is a simple dipole, center-fed with open-wire transmission line and used with an antenna tuner in the shack. A 135-foot long dipole hung horizontally between two trees or towers at a height of 50 feet or higher works very well on 80 through 10 meters. Such an antenna system has significant gain at the higher frequencies.

Flattop or Inverted-V Configuration?

There is no denying that the inverted-V mounting configuration (sometimes called a *drooping dipole*) is very convenient, since it requires only a single support. The flattop configuration, however, where the dipole is mounted horizontally, gives more gain at the higher frequencies. **Fig 5** shows the 80-meter azimuth and elevation patterns for two 135-foot long dipoles. The first is mounted as a flattop at a height of 50 feet over flat ground with a conductivity of 5 mS/m and a dielectric constant of 13, typical for average soil. The second dipole uses the same length of wire, with the center apex at 50 feet and the ends drooped down to be suspended 10 feet off the ground. This height is sufficient so that there is no danger to passersby from RF burns.

At 3.8 MHz, the flattop dipole about 4 dB more peak gain than its drooping cousin. On the other hand, the inverted-V configuration gives a pattern that is more omnidirectional than the flattop dipole, which has nulls off the ends of the wire. Omnidirectional coverage may be more important to net operators, for example, than maximum gain.

Fig 6 shows the azimuth and elevation patterns for the same two antenna configurations, but this time at 14.2 MHz. The flattop dipole has developed four distinct lobes at a 10° elevation angle, an angle typical for 20-meter skywave communication. The peak elevation angle gain of 9.4 dBi occurs at about 17° for a height of 50 feet above flat ground for the flattop dipole. The inverted-V configuration is again nominally more omnidirectional, but the peak gain is down some 6 dB from the flattop.

The situation gets even worse in terms of peak gain at 28.4 MHz for the inverted-V configuration. Here the peak gain is down about 8 dB from that produced by the flattop dipole, which exhibits eight lobes at this frequency with a maximum gain of 10.5 dBi at about 7° elevation. See the comparisons in **Fig 7**.

Whatever configuration you choose to mount the 135-foot dipole, you will want to feed it with some sort of low-loss open-wire transmission line. So-called *window* 450-Ω ladder line is popular for this application. Be sure to twist the line about three or four turns per foot to keep it from twisting excessively in the wind. Make sure also that you provide some mechanical support for the line at the junction with the dipole

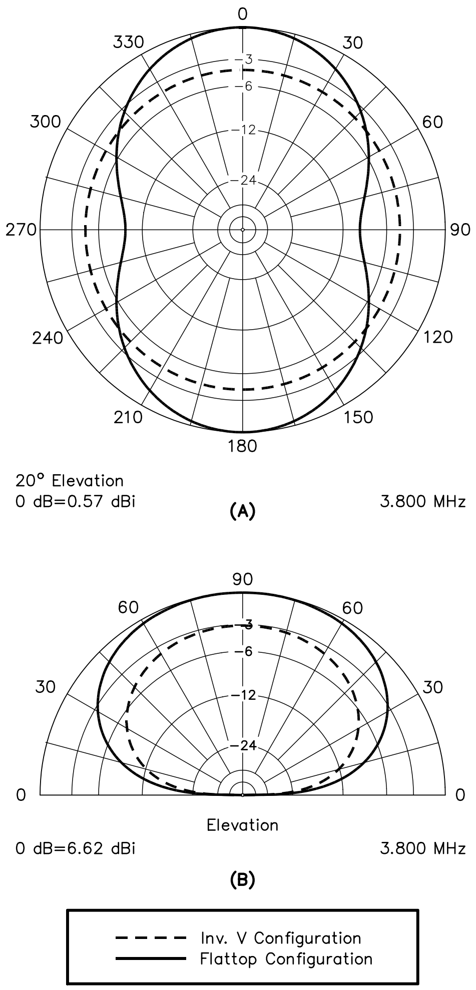

Fig 5—Patterns on 80 meters for 135-foot, center-fed dipole erected as a horizontal flattop dipole at 50 feet, compared with the same dipole installed as an inverted V with the apex at 50 feet and the ends at 10 feet. The azimuth pattern is shown at A, where the dipole wire lies in the 90° to 270° plane. At B, the elevation pattern, the dipole wire comes out of the paper at a right angle. On 80 meters, the patterns are not markedly different for either flattop or inverted-V configuration.

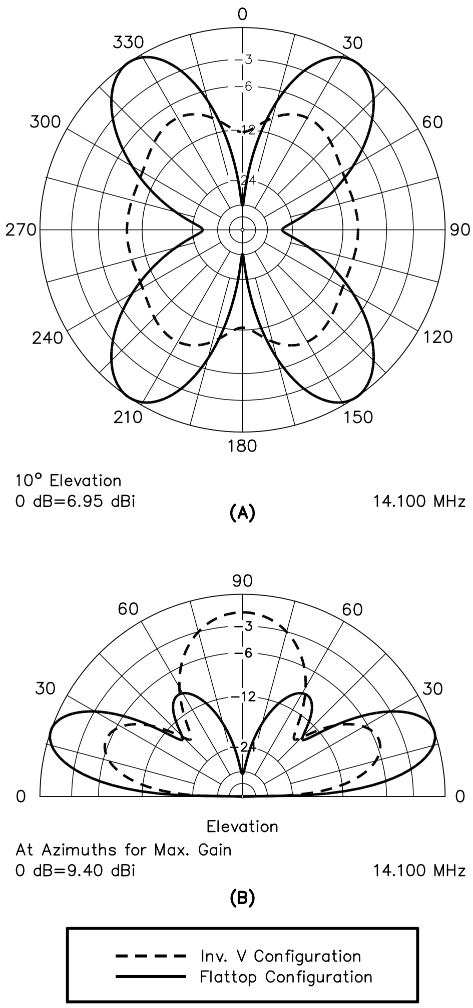

Fig 6—Patterns on 20 meters for two 135-foot dipoles. One is mounted horizontally as a flattop and the other as an inverted V with 120° included angle between the legs. The azimuth pattern is shown in A and the elevation pattern is shown in B. The inverted V has about 6 dB less gain at the peak azimuths, but has a more uniform, almost omnidirectional, azimuthal pattern. In the elevation plane, the inverted V has a fat lobe overhead, making it a somewhat better antenna for local communication, but not quite so good for DX contacts at low elevation angles.

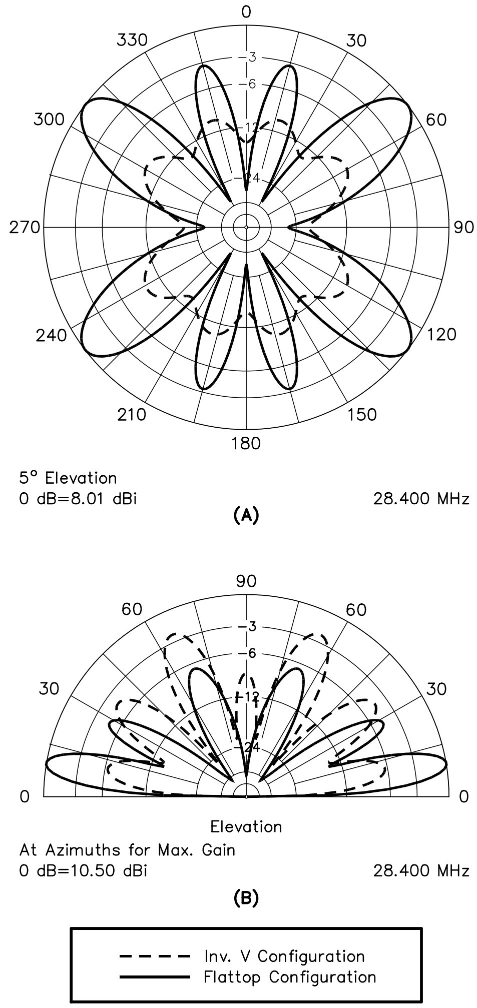

Fig 7—Patterns on 10 meters for same antenna configurations as in Figs 7 and 8. Once again, the inverted-V configuration yields a more omnidirectional pattern, but at the expense of almost 8 dB less gain than the flattop configuration at its strongest lobes.

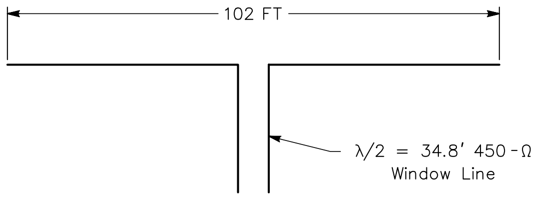

Fig 8—The G5RV multiband antenna covers 3.5 through 30 MHz. Although many amateurs claim it may be fed directly with 50-Ω coax on several amateur bands, Louis Varney, its originator, recommends the use of a matching network on bands other than 14 MHz.

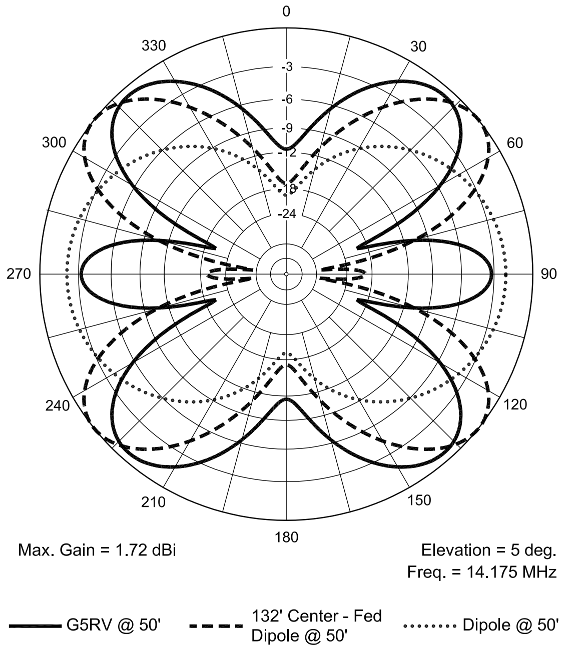

Fig 9—Azimuth pattern at a 5° takeoff angle for a 102-foot long, 50-foot high G5RV dipole (solid line). For comparison, the response for a 132-foot long, center-fed dipole at 50 feet height (dashed line) and a 33-foot long half wave 20-meter dipole at 50 feet (dotted line) are also shown. The longest antenna exhibits about 0.5 dB more gain than the G5RV, although the response is more omnidirectional for the G5RV—an advantage for a wire antenna that is not usually rotatable.

wires. This will prevent flexing of the transmission-line wire, since excessive flexing will result in breakage.

THE G5RV MULTIBAND ANTENNA

A multiband antenna that does not require a lot of space, is simple to construct, and is low in cost is the G5RV. Designed in England by Louis Varney (G5RV) some years ago, it has become quite popular in the US. The G5RV design is shown in **Fig 8**. The antenna may be used from 3.5 through 30 MHz. Although some amateurs claim it may be fed directly with 50-Ω coax on several amateur bands with a low SWR, Varney himself recommended the use of an antenna tuner on bands other than 14 MHz (see Bibliography). In fact, an analysis of the G5RV feed-point impedance shows there is *no* length of balanced line of *any* characteristic impedance that will transform the terminal impedance to the 50 to 75-Ω range on all bands. (Low SWR indication with coax feed and no matching network on bands other than 14 MHz may indicate excessive losses in the coaxial line.)

Fig 9 shows the 20-meter azimuthal pattern for a G5RV at a height of 50 feet over flat ground, at an elevation angle of 5° that is suitable for DX work. For comparison, the response for two other antennas is also shown in Fig 9—a standard half wave 20-meter dipole at 50 feet and a 132-foot long center-fed dipole at 50 feet. The G5RV on 20 meters is, of course, longer than a standard half wave dipole and it exhibits about 2 dB more gain compared to that dipole. With four lobes making it look rather like a four-leaf clover, the azimuth pattern is more omnidirectional than the two-lobed dipole. The 132-foot center-fed dipole is longer than the G5RV and it has about 0.5 dB more gain than the G5RV, also exhibiting four major lobes, along with two strong minor lobes in the plane of the wire. Overall, the azimuthal response for the G5RV is more omnidirectional than the comparison antennas.

The G5RV patterns for other frequencies are similar to those shown for the 135-foot dipole previously for other frequencies. Incidentally, you may be wondering why a 132-foot dipole is shown in Fig 9, rather than the 135-foot dipole described earlier. The 132-foot overall length describes another antenna that we'll discus in the next section on Windom antennas.

The portion of the G5RV antenna shown as horizontal in Fig 8 may also be installed in an inverted-V dipole arrangement, subject to the same loss of peak gain mentioned above for the 135-foot dipole. Or instead, up to ⅙ of the total length of the antenna at each end may be dropped vertically, semi-vertically, or bent at a convenient angle to the main axis of the antenna, to cut down on the requirements for real estate.

THE WINDOM ANTENNA

An antenna that enjoyed popularity in the 1930s and into the 1940s was what we now call the *Windom*. It was known at the time as a "single-feeder Hertz" antenna, after being described in Sep 1929 *QST* by Loren G. Windom, W8GZ (see Bibliography).

The Windom antenna, shown in **Fig 10**, is fed with a single wire, attached approximately 14% off center. In theory, this location provides a match for the single-wire transmission line, which is worked against an earth ground. Because the single-wire feed line is not inherently well balanced and because it is brought to the operating position, "RF in the shack" and a potential radiation hazard may be experienced with this antenna.

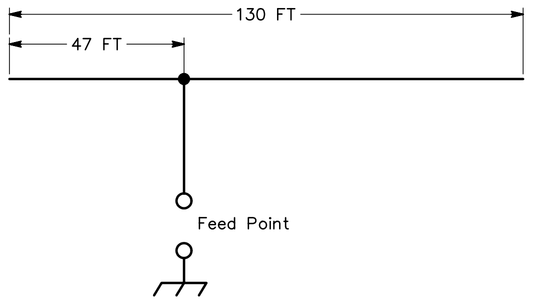

Fig 10—The Windom antenna, cut for a fundamental frequency of 3.75 MHz. The single-wire feeder, connected 14% off center, is brought into the station and the system is fed against ground. The antenna is also effective on its harmonics.

Later variations of the off-center fed Windom moved the attachment point slightly to accommodate balanced 300-Ω ribbon line. One relatively recent variation is called the "Carolina Windom," apparently because two of the designers, Edgar Lambert, WA4LVB, and Joe Wright, W4UEB, lived in coastal North Carolina (the third, Jim Wilkie, WY4R, lived

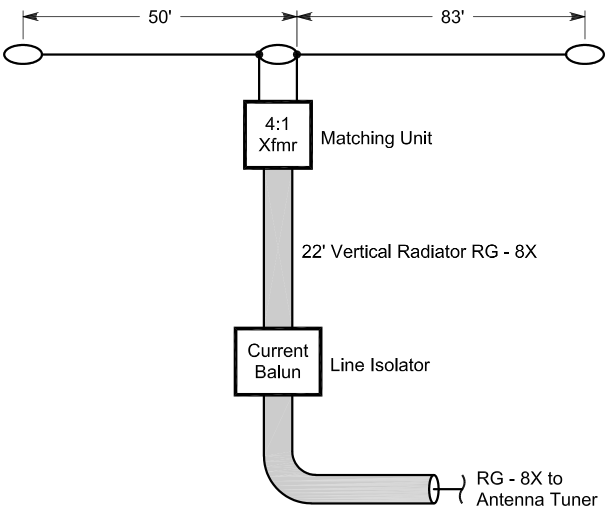

Fig 11—Layout for flattop "Carolina Windom" antenna.

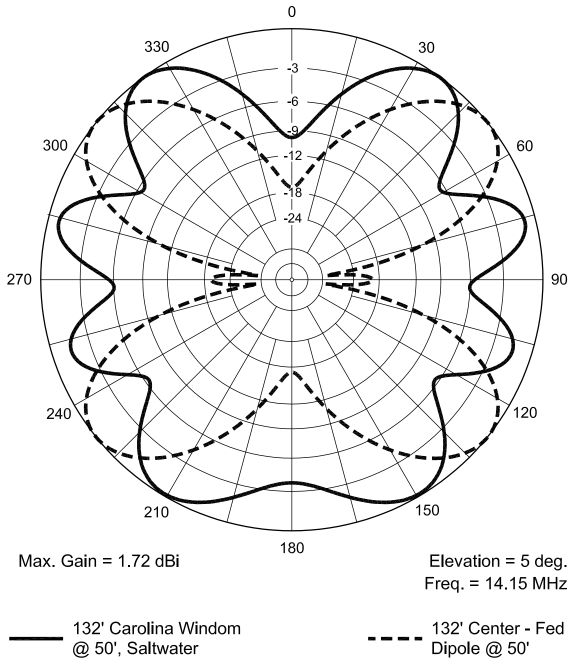

Fig 12—20-meter azimuth patterns for a 132-foot long off-center fed Carolina Windom and a 132-foot long center-fed flattop dipole on 20 meters, both at a height of 50 feet above saltwater. The response for the Carolina Windom is more omnidirectional because the vertically polarized radiation from the 22-foot long vertical RG-8X coax fills in the deep nulls.

in nearby Norfolk, Virginia). One of the interesting parts about the Carolina Windom is that it turns a potential disadvantage—feed line radiation—into a potential advantage.

Fig 11 is a diagram of a flattop Carolina Windom, which uses a 50-foot wire joined with an 83-foot wire at the feedpoint insulator. This resembles the layout shown in Fig 10 for the original W8GZ Windom. The "Vertical Radiator" for the Carolina Windom is a 22-foot piece of RG-8X coax, with a "Line Isolator" (current-type choke balun) at the bottom end and a 4:1 "Matching Unit" at the top. The system takes advantage of the asymmetry of the horizontal wires to induce current onto the braid of the vertical coax section. Note that the matching unit is a voltage-type balun transformer, which purposely does not act like a common-mode current choking balun. You must use an antenna tuner with this system to present a 1:1 SWR to the transmitter on the amateur bands from 80 through 10 meters.

The radiation resulting from current induced onto the 22-foot vertical coax section tends to fill in the deep nulls that would be present if the 132-feet of horizontal wire were symmetrically center fed. Over saltwater, the vertical radiator can give significant gain at the low elevation angles needed for DX work. Indeed, field reports for the Carolina Windom are most impressive for stations located near or on saltwater. Over average soil the advantage of the additional vertically polarized component is not quite so evident. **Fig 12** compares a 50-foot high Carolina Windom on 14 MHz over saltwater to a 50-foot high, 132-foot long, flattop center-fed dipole. The Carolina Windom has a more omnidirectional azimuthal pattern, a desirable characteristic in a 132-foot long wire antenna that is not normally rotated to favor different directions.

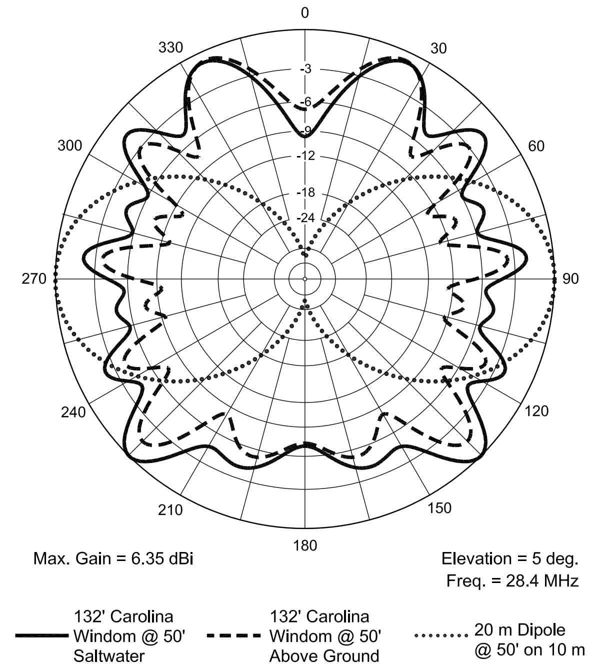

Fig 13—10-meter azimuthal responses for a 132-foot long, 50-foot high Carolina Windom over saltwater (solid line) and over average ground (dashed line), compared to that for a 20-meter half-wave dipole at 50 feet (dotted line).

Another advantage of the Carolina Windom over a traditional Windom is that the coax feed line hanging below the common-mode current choke does not radiate, meaning that there will be less "RF in the shack." Since the feed line is not always operating at a low SWR on various ham bands, use the minimum length of feed coax possible to hold down losses in the coax.

Fig 13 shows the azimuth responses for a 50-foot long flattop Carolina Windom on 28.4 MHz over saltwater and over average soil. The pattern for a 50-foot high, flattop 20-meter dipole operated on 28.4 MHz is also shown, since this 20-meter dipole can also be used as a multiband antenna, when fed with open-wire transmission line rather than with coax. Again, the Carolina Windom exhibits a more omnidirectional pattern, even if the pattern is somewhat lopsided at the bottom.

MULTIPLE-DIPOLE ANTENNAS

The antenna system shown in **Fig 14** consists of a group of center-fed dipoles, all connected in parallel at the point where the transmission line joins them. The dipole elements are *stagger-tuned*. That is, they are individually cut to be λ/2 at different frequencies. Chapter 9, Broadband Antenna Matching, discusses stagger tuning of dipole antennas to attain a low SWR across a broad range of frequencies. An extension of the stagger tuning idea is to construct multiwire dipoles cut for different bands.

In theory, the 4-wire antenna of Fig 14 can be used with a coaxial feeder on five bands. The four wires are prepared as parallel-fed dipoles for 3.5, 7, 14, and 28 MHz. The 7-MHz dipole can be operated on its 3rd harmonic for 21-MHz operation to cover a fifth band. However, in practice it has been found difficult to get a good match to coaxial line

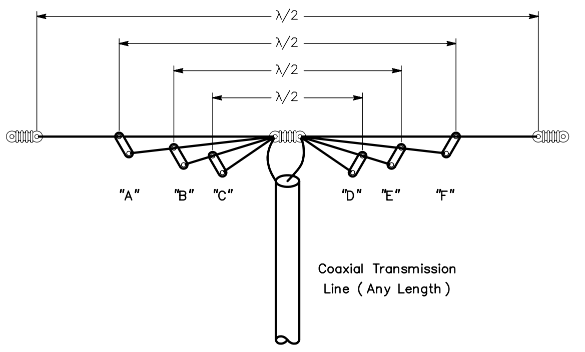

Fig 14—Multiband antenna using paralleled dipoles all connected to a common low-impedance transmission line. The half-wave dimensions may be either for the centers of the various bands or selected to fit favorite frequencies in each band. The length of a half wave in feet is 468/frequency in MHz, but because of interaction among the various elements, some pruning for resonance may be needed on each band.

on all bands. The λ/2 resonant length of any one dipole in the presence of the others is not the same as for a dipole by itself due to interaction, and attempts to optimize all four lengths can become a frustrating procedure. The problem is compounded because the optimum tuning changes in a different antenna environment, so what works for one amateur may not work for another. Even so, many amateurs with limited antenna space are willing to accept the mismatch on some bands just so they can operate on those frequencies using a single coax feed line.

Since this antenna system is balanced, it is desirable to use a balanced transmission line to feed it. The most desirable type of line is 75-Ω transmitting twin-lead. However, either 52-Ω or 75-Ω coaxial line can be used. Coax line introduces some unbalance, but this is tolerable on the lower frequencies. An alternative is to use a balun at the feed point, fed with coaxial cable.

The separation between the dipoles for the various frequencies does not seem to be especially critical. One set of wires can be suspended from the next larger set, using insulating spreaders (of the type used for feeder spreaders) to give a separation of a few inches. Users of this antenna often run some of the dipoles at right angles to each other to help reduce interaction. Some operators use inverted-V-mounted dipoles as guy wires for the mast that supports the antenna system.

An interesting method of construction used successfully by Louis Richard, ON4UF, is shown in **Fig 15**. The antenna has four dipoles (for 7, 14, 21 and 28 MHz) constructed from 300-Ω ribbon transmission line. A single length of ribbon makes two dipoles. Thus, two lengths, as shown in the sketch, serve to make dipoles for four bands. Ribbon with copper-clad steel conductors (Amphenol type 14-022) should be used because all of the weight, including that of the feed line, must be supported by the uppermost wire.

Two pieces of ribbon are first cut to a length suitable for the two halves of the longest dipole. Then one of the conductors in each piece is cut to proper length for the next band higher in frequency. The excess wire and insulation is stripped away. A second pair of lengths is prepared in the same manner, except that the lengths are appropriate for the next two higher frequency bands.

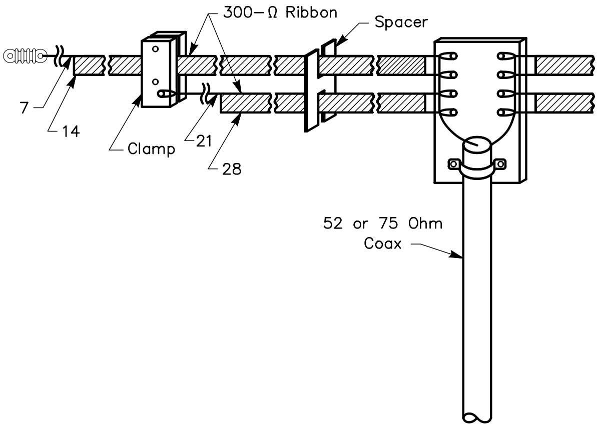

Fig 15—Sketch showing how the twin-lead multiple-dipole antenna system is assembled. The excess wire and insulation are stripped away.

A piece of thick polystyrene sheet drilled with holes for anchoring each wire serves as the central insulator. The shorter pair of dipoles is suspended the width of the ribbon below the longer pair by clamps also made of poly sheet. Intermediate spacers are made by sawing slots in pieces of poly sheet so they will fit the ribbon snugly.

The multiple-dipole principle can also be applied to vertical antennas. Parallel or fanned λ/4 elements of wire or tubing can be worked against ground or tuned radials from a common feed point.

OFF-CENTER-FED DIPOLES

Fig 16 shows an off-center-fed or *OCF* dipole. Because it is similar in appearance to the Windom of Fig 12, this antenna is often mistakenly called a “Windom,” or sometimes a “coax-fed Windom.” The two antennas are not the same, since the Windom is worked against its image in the ground, while one leg is worked against the other in the OCF dipole.

It is not necessary to feed a dipole antenna at its center, although doing so will allow it to be operated with a relatively low feed-point impedance on its fundamental and *odd* harmonics. (For example, a 7-MHz center-fed half-wave dipole can also be used for 21-MHz operation.) By contrast, the OCF dipole of Fig 16, fed ⅓ of its length from one end, may be used on its fundamental and *even* harmonics. Its free-space antenna-terminal impedance at 3.5, 7 and 14 MHz is on the order of 150 to 200 Ω. A 1:4 step-up transformer at the feed point should offer a reasonably good match to 50- or 75-Ω line, although some commercially made OCF dipoles use a 1:6 transformer.

At the 6th harmonic, 21 MHz, the antenna is three wavelengths long and fed at a voltage loop (maximum), instead of a current loop. The feed-point impedance at this frequency

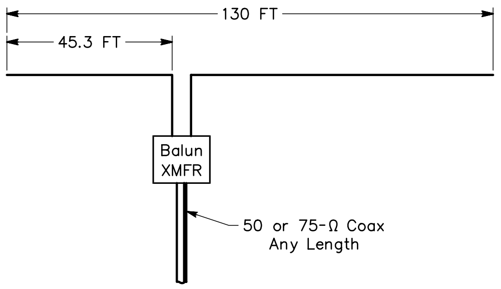

Fig 16—The off-center-fed (OCF) dipole for 3.5, 7 and 14 MHz. A 1:4 or 1:6 step-up current balun is used at the feed point.

is high, a few thousand ohms, so the antenna is unsuitable for use on this band.

Balun Requirements

Because the OCF dipole is not fed at the center of the radiator, the RF impedance paths of the two wires at the feed point are unequal. If the antenna is fed directly with coax (or a balanced line), or if a voltage step-up transformer is used, then voltages of equal magnitude (but opposite polarity) are applied to the wires at the feed point. Because of unequal impedances, the resulting antenna currents flowing in the two wires will not be equal. This also means that antenna current can flow on the feeder—on the *outside* of a coaxial line. (You may recall that this is how the Carolina Windom works, actually inducing current onto a carefully chosen length of coax, choked at its bottom end, so that it acts as a vertical radiator.)

How much current flows on the coax shield depends on the impedance of the RF current path down the outside of the feed line. In general, this is not a desirable situation. To prevent radiation, equal *currents* are required at the feed point, with the same current flowing in and out of the short leg as in and out of the long leg of the radiator. A *current* or *choke* type of balun provides just such operation. (Current baluns are discussed in detail in Chapter 26, Coupling the Line to the Antenna.)

Trap Antennas

By using tuned circuits of appropriate design strategically placed in a dipole, the antenna can be made to show what is essentially fundamental resonance at a number of different frequencies. The general principle is illustrated by **Fig 17**.

Even though a trap-antenna arrangement is a simple one, an explanation of how a trap antenna works can be elusive. For some designs, traps are resonated in our amateur bands, and for others (especially commercially made antennas) the traps are resonant far outside any amateur band.

A trap in an antenna system can perform either of two functions, depending on whether or not it is resonant at the operating frequency. A familiar case is where the trap is parallel-resonant in an amateur band. For the moment, let us assume that dimension A in Fig 17 is 32 feet and that each L/C combination is resonant in the 7-MHz band. Because of its parallel resonance, the trap presents a high impedance at that point in the antenna system. The electrical effect at 7 MHz is that the trap behaves as an insulator. It serves to divorce the outside ends, the B sections, from the antenna. The result is easy to visualize—we have an antenna system that is resonant in the 7-MHz band. Each 33-foot section (labeled A in the drawing) represents λ/4, and the trap behaves as an insulator. We therefore have a full-size 7-MHz antenna.

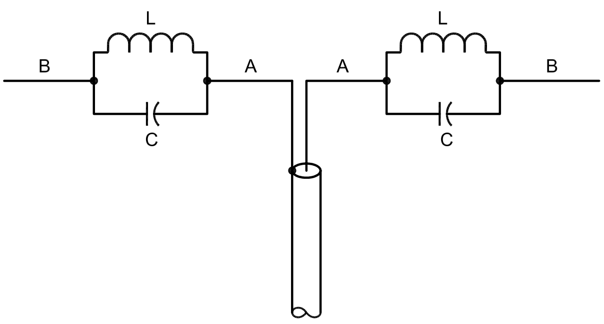

Fig 17—A trap dipole antenna. This antenna may be fed with 50-Ω coaxial line. Depending on the L/C ratio of the trap elements and the lengths chosen for dimensions A and B, the traps may be resonant either in an amateur band or at a frequency far removed from an amateur band for proper two-band antenna operation.

The second function of a trap, obtained when the frequency of operation is *not* the resonant frequency of the trap, is one of electrical loading. If the operating frequency is below that of trap resonance, the trap behaves as an inductor; if above, as a capacitor. Inductive loading will electrically lengthen the antenna, and capacitive loading will electrically shorten the antenna.

Let's carry our assumption a bit further and try using the antenna we just considered at 3.5 MHz. With the traps resonant in the 7-MHz band, they will behave as inductors when operation takes place at 3.5 MHz, electrically lengthening the antenna. This means that the total length of sections A and B (plus the length of the inductor) may be something less than a physical λ/4 for resonance at 3.5 MHz. Thus, we have a two-band antenna that is shorter than full size on the lower frequency band. But with the electrical loading provided by the traps, the overall electrical length is λ/2. The total antenna length needed for resonance in the 3.5-MHz band will depend on the L/C ratio of the trap elements.

The key to trap operation off resonance is its L/C ratio, the ratio of the value of L to the value of C. At resonance, however, within practical limitations the L/C ratio is immaterial as far as electrical operation goes. For example, in the antenna we've been discussing, it would make no difference for 7-MHz operation whether the inductor were 1 μH and the capacitor were 500 pF (the reactances would be just below 45 Ω at 7.1 MHz), or whether the inductor were 5 μH and the capacitor 100 pF (reactances of approximately 224 Ω at 7.1 MHz). But the choice of these values will make a significant difference in the antenna size for resonance at 3.5 MHz. In the first case, where the L/C ratio is 2000, the necessary length of section B of the antenna for resonance at 3.75 MHz would be approximately 28.25 feet. In the second case, where the L/C ratio is 50,000, this length need be only 24.0 feet, a difference of more than 15%.

The above example concerns a two-band antenna with trap resonance at one of the two frequencies of operation. On each of the two bands, each half of the dipole operates as an electrical λ/4. However, the same band coverage can be obtained with a trap resonant at, say, 5 MHz, a frequency quite removed from either amateur band. With proper selection of the L/C ratio and the dimensions for A and B, the trap will act to shorten the antenna electrically at 7 MHz and lengthen it electrically at 3.5 MHz. Thus, an antenna that is intermediate in physical length between being full size on 3.5 MHz and full size on 7 MHz can cover both bands, even though the trap is not resonant at either frequency. Again, the antenna operates with electrical λ/4 sections. Note that such non-resonant traps have less RF current flowing in the trap components, and hence trap losses are less than for resonant traps.

Additional traps may be added in an antenna section to cover three or more bands. Or a judicious choice of dimensions and the L/C ratio may permit operation on three or more bands with just a pair of identical traps in the dipole.

An important point to remember about traps is this. If the operating frequency is below that of trap resonance, the trap behaves as an inductor; if above, as a capacitor. The above discussion is based on dipoles that operate electrically as λ/2 antennas. This is not a requirement, however. Elements may be operated as electrical 3/2 λ, or even 5/2 λ, and still present a reasonable impedance to a coaxial feeder. In trap antennas covering several HF bands, using electrical lengths that are odd multiples of λ/2 is often done at the higher frequencies.

To further aid in understanding trap operation, let's now choose trap L and C components that each have a reactance of 20 Ω at 7 MHz. Inductive reactance is directly proportional to frequency, and capacitive reactance is inversely proportional. When we shift operation to the 3.5-MHz band, the inductive reactance becomes 10 Ω, and the capacitive reactance becomes 40 Ω. At first thought, it may seem that the trap would become capacitive at 3.5 MHz with a higher capacitive reactance, and that the extra capacitive reactance would make the antenna electrically shorter yet. Fortunately, this is not the case. The inductor and the capacitor are connected in parallel with each other.

$$Z = \frac{-jX_L X_C}{X_L + X_C} \qquad \text{(Eq 1)}$$

where *j* indicates a reactive impedance component, rather than resistive. A positive result indicates inductive reactance, and a negative result indicates capacitive. In this 3.5-MHz case, with 40 Ω of capacitive reactance and 10 Ω of inductive, the equivalent series reactance is 13.3 Ω inductive. This inductive loading lengthens the antenna to an electrical λ/2 overall at 3.5 MHz, assuming the B end sections in Fig 17 are of the proper length.

With the above reactance values providing resonance at 7-MHz, X_L equals X_C, and the theoretical series equivalent is infinity. This provides the insulator effect, divorcing the ends.

At 14 MHz, where X_L = 40 Ω and X_C = 10 Ω, the resultant series equivalent trap reactance is 13.3 Ω capacitive. If the total physical antenna length is slightly longer than 3/2 λ at 14 MHz, this trap reactance at 14 MHz can be used to shorten the antenna to an electrical 3/2 λ. In this way, 3-band operation is obtained for 3.5, 7 and 14 MHz with just one pair of identical traps. The design of such a system is not straightforward, however, for any chosen L/C ratio for a given total length affects the resonant frequency of the antenna on both the 3.5 and 14-MHz bands.

Trap Losses

Since the tuned circuits have some inherent losses, the efficiency of a trap system depends on the unloaded Q values of the tuned circuits. Low-loss (high-Q) coils should be used, and the capacitor losses likewise should be kept as low as possible. With tuned circuits that are good in this respect—comparable with the low-loss components used in transmitter tank circuits, for example—the reduction in efficiency compared with the efficiency of a simple dipole is small, but tuned circuits of low unloaded Q can lose an appreciable portion of the power supplied to the antenna.

The commentary above applies to traps assembled from conventional components. The important function of a trap that is resonant in an amateur band is to provide a high isolating impedance, and this impedance is directly proportional to Q. Unfortunately, high Q restricts the antenna bandwidth, because the traps provide maximum isolation only at trap resonance.

FIVE-BAND W3DZZ TRAP ANTENNA

C. L. Buchanan, W3DZZ, created one of the first trap antennas for the five pre-1979 WARC amateur bands from 3.5 to 30 MHz. Dimensions are given in **Fig 18**. Only one set of traps is used, resonant at 7 MHz to isolate the inner (7-MHz) dipole from the outer sections. This causes the overall system to be resonant in the 3.5-MHz band. On 14, 21 and 28 MHz the antenna works on the capacitive-reactance principle just outlined. With a 75-Ω twin-lead feeder, the SWR with this antenna is under 2:1 throughout the three highest frequency

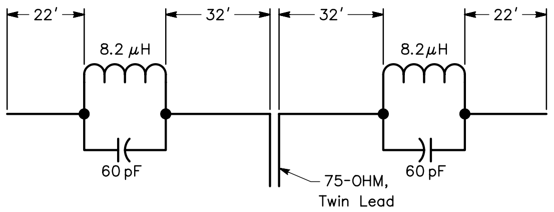

Fig 18—Five-band (3.5, 7, 14, 21 and 28 MHz) trap dipole for operation with 75-Ω feeder at low SWR (C. L. Buchanan, W3DZZ). The balanced (parallel-conductor) line indicated is desirable, but 75-Ω coax can be substituted with some sacrifice of symmetry in the system. Dimensions given are for resonance (lowest SWR) at 3.75, 7.2, 14.15 and 29.5 MHz. Resonance is very broad on the 21-MHz band, with SWR less than 2:1 throughout the band.

bands, and the SWR is comparable with that obtained with similarly fed simple dipoles on 3.5 and 7 MHz.

Trap Construction

Traps frequently are built with coaxial aluminum tubes (usually with polystyrene tubing in-between them for insulation) for the capacitor, with the coil either self-supporting or wound on a form of larger diameter than the tubular capacitor. The coil is then mounted coaxially with the capacitor to form a unit assembly that can be supported at each end by the antenna wires. In another type of trap devised by William J. Lattin, W4JRW (see Bibliography at the end of this chapter), the coil is supported inside an aluminum tube and the trap capacitor is obtained in the form of capacitance between the coil and the outer tube. This type of trap is inherently weatherproof.

A simpler type of trap, easily assembled from readily available components, is shown in **Fig 19**. A small transmitting-type ceramic "doorknob" capacitor is used, together with a length of commercially available coil material, these being supported by an ordinary antenna strain insulator. The circuit constants and antenna dimensions differ slightly from those of Fig 18, in order to bring the antenna resonance points closer to the centers of the various phone bands. Construction data are given in **Fig 20**. If a 10-turn length of inductor is used, a half turn from each end may be used to slip through the anchor holes in the insulator to act as leads.

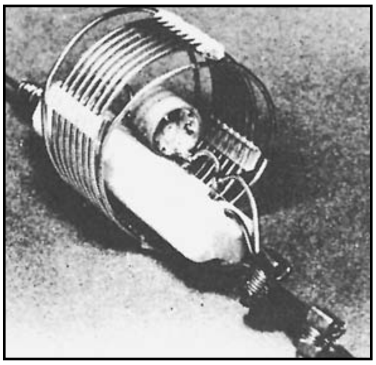

Fig 19—Easily constructed trap for wire antennas (A. Greenburg, W2LH). The ceramic insulator is 4¼ inches long (Birnback 688). The clamps are small service connectors available from electrical supply and hardware stores (Burndy KS90 servits).

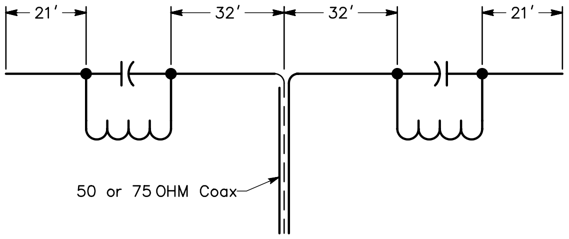

Fig 20—Layout of multiband antenna using traps constructed as shown in Fig 21. The capacitors are 100 pF each, transmitting type, 5000-volt dc rating (Centralab 850SL-100N). Coils are 9 turns of #12 wire, 2½ inches diameter, 6 turns per inch (B&W 3029) with end turns spread as necessary to resonate the traps to 7.2 MHz. These traps, with the wire dimensions shown, resonate the antenna at approximately the following frequencies on each band: 3.9, 7.25, 14.1, 21.5 and 29.9 MHz (based on measurements by W9YJH).

The components used in these traps are sufficiently weatherproof in themselves so that no additional weatherproofing has been found necessary. However, if it is desired to protect them from the accumulation of snow or ice, a plastic cover can be made by cutting two discs of polystyrene slightly larger in diameter than the coil, drilling at the center to pass the antenna wires, and cementing a plastic cylinder on the edges of the discs. The cylinder can be made by wrapping two turns or so of 0.02-inch poly or Lucite sheet around the discs, if no suitable ready-made tubing is available. Plastic drinking glasses and 2-liter soft-drink plastic bottles are easily adaptable for use as impromptu trap covers.

TWO W8NX MULTIBAND, COAX-TRAP DIPOLES

Over the last 60 or 70 years, amateurs have used many kinds of multiband antennas to cover the traditional HF bands. The availability of the 30, 17 and 12-meter bands has expanded our need for multiband antenna coverage.

Two different antennas are described here. The first covers the traditional 80, 40, 20, 15 and 10-meter bands, and the second covers 80, 40, 17 and 12 meters. Each uses the same type of W8NX trap—connected for different modes of operation—and a pair of short capacitive stubs to enhance coverage. The W8NX coaxial-cable traps have two different modes: a high- and a low-impedance mode. The inner-conductor windings and shield windings of the traps are connected in series for both modes. However, either the low- or high-impedance point can be used as the trap's output terminal. For low-impedance trap operation, only the center conductor turns of the trap windings are used. For high-impedance operation, all turns are used, in the conventional manner for a trap. The short stubs on each antenna are strategically sized and located to permit more flexibility in adjusting thc resonant frequencies of the antenna.

80, 40, 20, 15 and 10-Meter Dipole

Fig 21 shows the configuration of the 80, 40, 20, 15 and 10-meter antenna. The radiating elements are made of #14

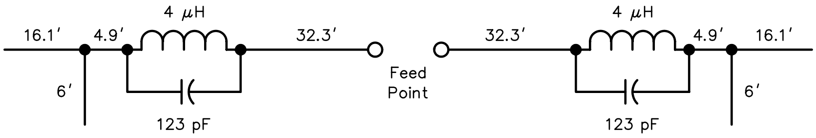

Fig 21—A W8NX multiband dipole for 80, 40, 20, 15 and 10 meters. The values shown (123 pF and 4 µH) for the coaxial-cable traps are for parallel resonance at 7.15 MHz. The low-impedance output of each trap is used for this antenna.

stranded copper wire. The element lengths are the wire span lengths in feet. These lengths do not include the lengths of the pigtails at the balun, traps and insulators. The 32.3-foot-long inner 40-meter segments are measured from the eyelet of the input balun to the tension-relief hole in the trap coil form. The 4.9-foot segment length is measured from the tension-relief hole in the trap to the 6-foot stub. The 16.l-foot outer-segment span is measured from the stub to the eyelet of the end insulator.

The coaxial-cable traps are wound on PVC pipe coil forms and use the low-impedance output connection. The stubs are 6-foot lengths of ⅛-inch stiffened aluminum or copper rod hanging perpendicular to the radiating elements. The first inch of their length is bent 90° to permit attachment to the radiating elements by large-diameter copper crimp connectors. Ordinary #14 wire may be used for the stubs, but it has a tendency to curl up and may tangle unless weighed down at the end. You should feed the antenna with 75-Ω coax cable using a good 1:1 balun.

This antenna may be thought of as a modified W3DZZ antenna due to the addition of the capacitive stubs. The length and location of the stub give the antenna designer two extra degrees of freedom to place the resonant frequencies within the amateur bands. This additional flexibility is particularly helpful to bring the 15 and 10-meter resonant frequencies to more desirable locations in these bands. The actual 10-meter resonant frequency of the original W3DZZ antenna is somewhat above 30 MHz, pretty remote from the more desirable low frequency end of 10 meters.

80, 40, 17 and 12-Meter Dipole

Fig 22 shows the configuration of the 80, 40, 17 and 12-meter antenna. Notice that the capacitive stubs are attached immediately outboard after the traps and are 6.5 feet long, ½ foot longer than those used in the other antenna. The traps are the same as those of the other antenna, but are connected for the high-impedance parallel-resonant output mode. Since only four bands are covered by this antenna, it is easier to fine tune it to precisely the desired frequency on all bands. The 12.4-foot tips can he pruned to a particular 17-meter frequency with little effect on the 12-meter frequency. The stub lengths can be pruned to a particular 12-meter frequency with little effect on the 17-meter frequency. Both such pruning adjustments slightly alter the 80-meter resonant frequency. However, the bandwidths of the antennas are so broad on 17 and 12 meters that little need for such pruning exists. The 40-meter frequency is nearly independent of adjustments to the capacitive stubs and outer radiating tip elements. Like the first antennas, this dipole is fed with a 75-Ω balun and feed line.

Fig 23 shows the schematic diagram of the traps. It explains the difference between the low and high-impedance modes of the traps. Notice that the high-impedance terminal is the output configuration used in most conventional trap applications. The low-impedance connection is made across only the inner conductor turns, corresponding to one-half of the total turns of the trap. This mode steps the trap's impedance down to approximately one-fourth of that of the high-impedance level. This is what allows a single trap design to be used for two different multiband antennas.

Fig 24 is a drawing of a cross-section of the coax trap shown through the long axis of the trap. Notice that the traps are conventional coaxial-cable traps, except for the added low-impedance output terminal. The traps are 8¾ close-spaced turns of RG-59 (Belden 8241) on a 2⅜-inch-OD PVC pipe (schedule 40 pipe with a 2-inch ID) coil form. The forms are 4⅛ inches long. Trap resonant frequency is very sensitive to the outer diameter of the coil form, so check it carefully. Unfortunately, not all PVC pipe is made with the same wall thickness. The trap frequencies should be checked with a dip meter and general-coverage receiver and adjusted to within 50 kHz of the 7150 kHz resonant frequency before installation. One inch is left over at each end of the coil forms to allow for the coax feed-through holes and holes for tension-relief attachment of the antenna radiating elements to the traps. Be sure to seal the ends of the trap coax cable with RTV sealant to prevent moisture from entering the coaxial cable.

Also, be sure that you connect the 32.3-foot wire element at the start of the inner conductor winding of the trap. This avoids detuning the antenna by the stray capacitance of the coaxial-cable shield. The trap output terminal (which has the shield stray capacitance) should be at the outboard side of

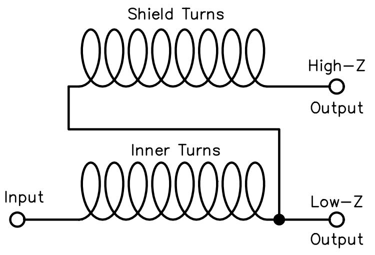

Fig 23—Schematic for the W8NX coaxial-cable trap. RG-59 is wound on a 2⅜-inch OD PVC pipe.

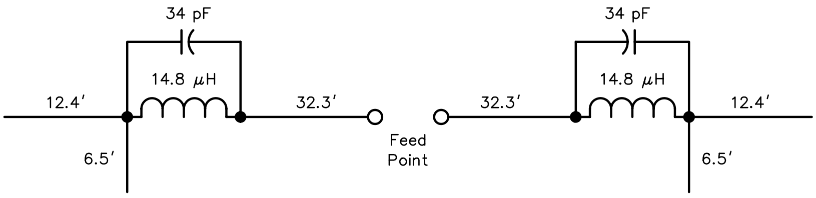

Fig 22—A W8NX multiband dipole for 80, 40, 17 and 12 meters. For this antenna, the high-impedance output is used on each trap. The resonant frequency of the traps is 7.15 MHz.

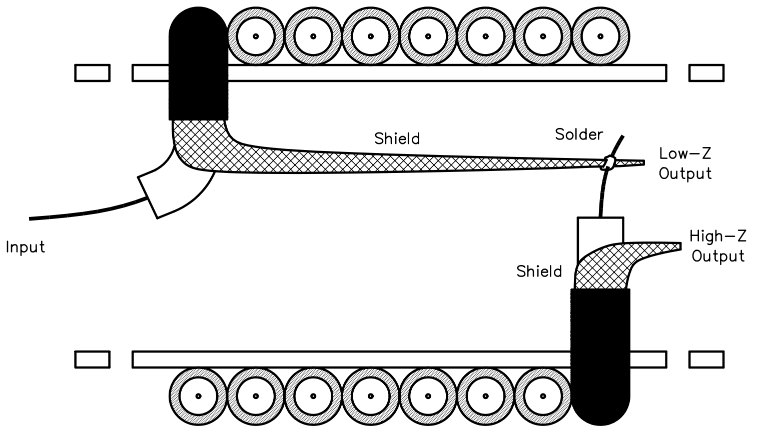

Fig 24—Construction details of the W8NX coaxial-cable trap.

the trap. Reversing the input and output terminals of the trap will lower the 40-meter frequency by approximately 50 kHz, but there will be negligible effect on the other bands.

Fig 25 shows a coaxial-cable trap. Further details of the trap installation are shown in **Fig 26**. This drawing applies specifically to the 80, 40, 20, 15 and l0-meter antenna, which uses the low-impedance trap connections. Notice the lengths of the trap pigtails: 3 to 4 inches at each terminal of the trap. If you use a different arrangement, you must modify the span lengths accordingly. All connections can be made using crimp connectors rather than by soldering. Access to the trap's interior is attained more easily with a crimping tool than with a soldering iron.

Performance

The performance of both antennas has been very satisfactory. W8NX uses the 80, 40, 17 and 12-meter version because it covers 17 and 12 meters. (He has a tribander for 20, 15 and 10 meters.) The radiation pattern on 17 meters is that of a 3/2-wave dipole. On 12 meters, the pattern is that of a 5/2-wave dipole. At his location in Akron, Ohio, the antenna runs essentially east and west. It is installed as an inverted V, 40 feet high at the center, with a 120° included angle between the legs. Since the stubs are very short, they radiate little power and make only minor contributions to the radiation patterns. In theory, the pattern has four major lobes on 17 meters, with maxima to the northeast, southeast, southwest and northwest. These provide low-angle radiation into Europe, Africa, South Pacific, Japan and Alaska. A narrow pair of minor broadside lobes provides north and south coverage into Central America, South America and the polar regions.

There are four major lobes on 12 meters, giving nearly end-fire radiation and good low-angle east and west coverage. There are also three pairs of very narrow, nearly broadside, minor lobes on 12 meters, down about 6 dB from the major end-fire lobes. On 80 and 40 meters, the antenna has the usual figure-8 patterns of a half-wave-length dipole.

Both antennas function as electrical half-wave dipoles on 80 and 40 meters with a low SWR. They both function as odd-harmonic current-fed dipoles on their other operating frequencies, with higher, but still acceptable, SWR. The presence of the stubs can either raise or lower the input impedance of the antenna from those of the usual third and fifth harmonic dipoles. Again W8NX recommends that 75-Ω,

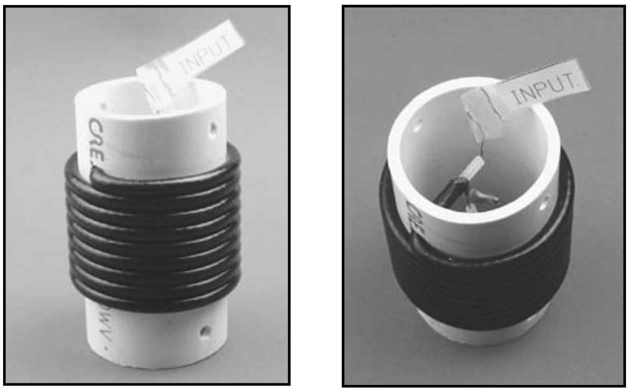

Fig 25—Other views of a W8NX coax-cable trap.

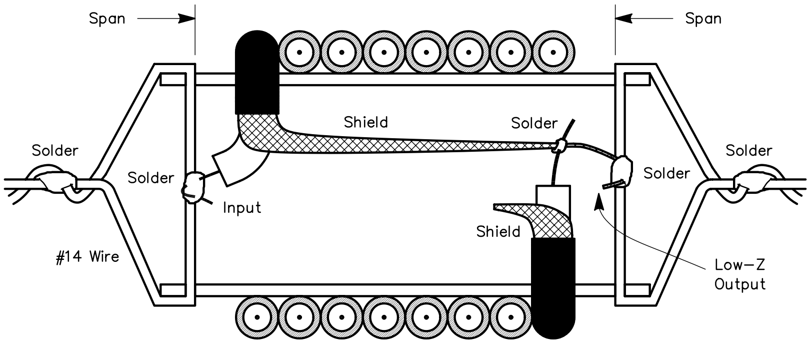

Fig 26—Additional construction details for the W8NX coaxial-cable trap.

rather than 50-Ω, feed line be used because of the generally higher input impedances at the harmonic operating frequencies of the antennas.

The SWR curves of both antennas were carefully measured using a 75 to 50-Ω transformer from Palomar Engineers inserted at the junction of the 75-Ω coax feed line and a 50-Ω SWR bridge. The transformer is required for accurate SWR measurement if a 50-Ω SWR bridge is used with a 75-Ω line. Most 50-Ω rigs operate satisfactorily with a 75-Ω line, although this requires different tuning and load settings in the final output stage of the rig or antenna tuner. The author uses the 75 to 50-Ω transformer only when making SWR measurements and at low power levels. The transformer is rated for 100 W, and when he runs his 1-kW PEP linear amplifier the transformer is taken out of the line.

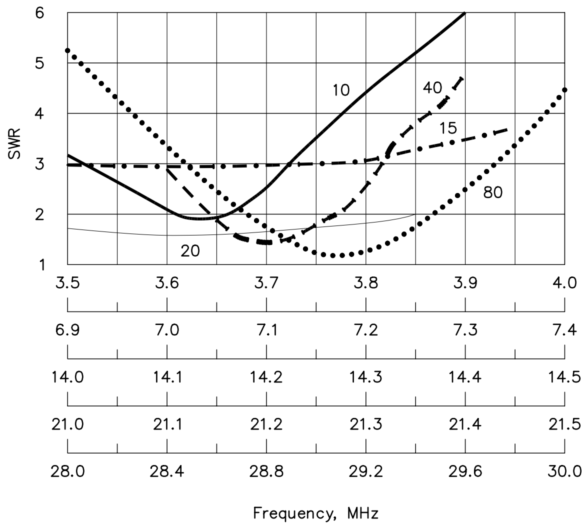

Fig 27—Measured SWR curves for an 80, 40, 20, 15 and 10-meter antenna, installed as an inverted-V with 40-ft apex and 120° included angle between legs.

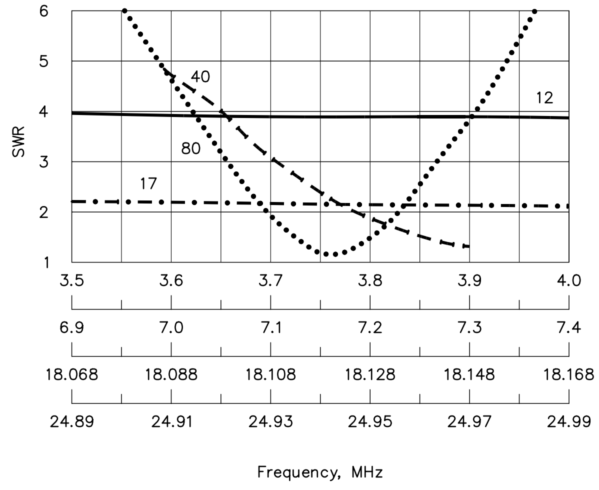

Fig 28—Measured SWR curves for an 80, 40, 17 and 12-meter antenna, installed as an inverted-V with 40-ft apex and 120° included angle between legs.

Fig 27 gives the SWR curves of the 80, 40, 20, 15 and 10-meter antenna. Minimum SWR is nearly 1:1 on 80 meters, 1.5:1 on 40 meters, 1.6:1 on 20 meters, and 1.5:1 on 10 meters. The minimum SWR is slightly below 3:1 on 15 meters. On 15 meters, the stub capacitive reactance combines with the inductive reactance of the outer segment of the antenna to produce a resonant rise that raises the antenna input resistance to about 220 Ω, higher than that of the usual 3/2-wavelength dipole. An antenna tuner may be required on this band to keep a solid-state final output stage happy under these load conditions.

Fig 28 shows the SWR curves of the 80, 40, 17 and 12-meter antenna. Notice the excellent 80-meter performance with a nearly unity minimum SWR in the middle of the band. The performance approaches that of a full-size 80-meter wire dipole. The short stubs and the low-inductance traps shorten the antenna somewhat on 80 meters. Also observe the good 17-meter performance, with the SWR being only a little above 2:1 across the band.

But notice the 12-meter SWR curve of this antenna, which shows 4:1 SWR across the band. The antenna input resistance approaches 300 Ω on this band because the capacitive reactance of the stubs combines with the inductive reactance of the outer antenna segments to give resonant rises in impedance. These are reflected back to the input terminals. These stub-induced resonant impedance rises are similar to those on the other antenna on 15 meters, but are even more pronounced.

Too much concern must not be given to SWR on the feed line. Even if the SWR is as high as 9:1 *no destructively high voltages will exist on the transmission line.* Recall that transmission-line voltages increase as the square root of the SWR in the line. Thus, 1 kW of RF power in 75-Ω line corresponds to 274 V line voltage for a 1:1 SWR. Raising the SWR to 9:1 merely triples the maximum voltage that the line must withstand to 822 V. This voltage is well below the 3700-V rating of RG-11, or the 1700-V rating of RG-59, the two most popular 75-Ω coax lines. Voltage breakdown in the traps is also very unlikely. As will be pointed out later, the operating power levels of these antennas are limited by RF power dissipation in the traps, not trap voltage breakdown or feed-line SWR.

Trap Losses and Power Rating

Table 1 presents the results of trap Q measurements and extrapolation by a two-frequency method to higher frequencies above resonance. W8NX employed an old, but recently calibrated, Boonton Q meter for the measurements. Extrapolation to higher-frequency bands assumes that trap resistance losses rise with skin effect according to the square root of frequency, and that trap dielectric loses rise directly with frequency. Systematic measurement errors are not increased by frequency extrapolation. However, random measurement

Table 1
Trap Q

Frequency (MHz)	*3.8*	*7.15*	*14.18*	*18.1*	*21.3*	*24.9*	*28.6*
High Z out (Ω)	101	124	139	165	73	179	186
Low Z out (Ω)	83	103	125	137	44	149	155

Table 2
Trap Loss Analysis: 80, 40, 20, 15, 10-Meter Antenna

Frequency (MHz)	*3.8*	*7.15*	*14.18*	*21.3*	*28.6*
Radiation Efficiency (%)	96.4	70.8	99.4	99.9	100.0
Trap Losses (dB)	0.16	1.5	0.02	0.01	0.003

Table 3
Trap Loss Analysis: 80, 40, 17, 12-Meter Antenna

Frequency (MHz)	*3.8*	*7.15*	*18.1*	*24.9*
Radiation Efficiency (%)	89.5	90.5	99.3	99.8
Trap Losses (dB)	0.5	0.4	0.03	0.006

errors increase in magnitude with upward frequency extrapolation. Results are believed to be accurate within 4% on 80 and 40 meters, but only within l0 to 15% at 10 meters. Trap Q is shown at both the high- and low-impedance trap terminals. The Q at the low-impedance output terminals is 15 to 20% lower than the Q at the high-impedance output terminals.

W8NX computer-analyzed trap losses for both antennas in free space. Antenna-input resistances at resonance were first calculated, assuming lossless, infinite-Q traps. They were again calculated using the Q values in Table 1. The radiation efficiencies were also converted into equivalent trap losses in decibels. **Table 2** summarizes the trap-loss analysis for the 80, 40, 20, 15 and 10-meter antenna and **Table 3** for the 80, 40,17 and 12-meter antenna.

The loss analysis shows radiation efficiencies of 90% or more for both antennas on all bands except for the 80, 40, 20, 15 and 10-meter antenna when used on 40 meters. Here, the radiation efficiency falls to 70.8%. A 1-kW power level at 90% radiation efficiency corresponds to 50-W dissipation per trap. In W8NX's experience, this is the trap's survival limit for extended key-down operation. SSB power levels of 1 kW PEP would dissipate 25 W or less in each trap. This is well within the dissipation capability of the traps.

When the 80, 40, 20, 15 and 10-meter antenna is operated on 40 meters, the radiation efficiency of 70.8% corresponds to a dissipation of 146 W in each trap when 1 kW is delivered to the antenna. This is sure to burn out the traps—even if sustained for only a short time. Thus, the power should be limited to leas than 300 W when this antenna is operated on 40 meters under prolonged key-down conditions. A 50% CW duty cycle would correspond to a 600-W power limit for normal 40-meter CW operation. Likewise, a 50% duty cycle for 40-meter SSB corresponds to a 600-W PEP power limit for the antenna.

The author knows of no analysis where the burnout wattage rating of traps has been rigorously determined. Operating experience seems to be the best way to determine trap burnout ratings. In his own experience with these antennas, he's had no traps burn out, even though he operated the 80, 40, 20, 15 and 10-meter antenna on the critical 40-meter band using his AL-80A linear amplifier at the 600-W PEP output level. He did not make a continuous, key-down, CW operating test at full power purposely trying to destroy the traps!

Some hams may suggest using a different type of coaxial cable for the traps. The dc resistance of 40.7 Ω per 1000 feet of RG-59 coax seems rather high. However, W8NX has found no coax other than RG-59 that has the necessary inductance-to-capacitance ratio to create the trap characteristic reactance required for the 80, 40, 20, 15 and 10-meter antenna. Conventional traps with wide-spaced, open-air inductors and appropriate fixed-value capacitors could be substituted for the coax traps, but the convenience, weatherproof configuration and ease of fabrication of coaxial-cable traps is hard to beat.

Multiband Vertical Antennas

There are two basic types of vertical antennas; either type can be used in multiband configurations. The first is the ground-mounted vertical and the second, the ground plane. These antennas are described in detail in Chapter 6, Low-Frequency Antennas.

The efficiency of any ground-mounted vertical depends a great deal on near-field earth losses. As pointed out in Chapter 3, The Effects of Ground, these near-field losses can be reduced or eliminated with an adequate radial system. Considerable experimentation has been conducted on this subject by Jerry Sevick, W2FMI, and several important results were obtained. It was determined that a radial system consisting of 40 to 50 radials, 0.2 λ long, would reduce the earth losses to about 2 Ω when a λ/4 radiator was being used. These radials should be on the earth's surface, or if buried, placed not more than an inch or so below ground. Otherwise, the RF current would have to travel through the lossy earth before reaching the radials. In a multiband vertical system, the radials should be 0.2 λ long for the lowest band, that is, 55 feet long for 3.5-MHz operation. Any wire size may be used for the radials. The radials should fan out in a circle, radiating from the base of the antenna. A metal plate, such as a piece of sheet copper, can be used at the center connection.

The other common type of vertical is the ground-plane antenna. Normally, this antenna is mounted above ground with the radials fanning out from the base of the antenna. The vertical portion of the antenna is usually an electrical λ/4, as is each of the radials. In this type of antenna, the system of radials acts somewhat like an RF choke, to prevent RF currents from flowing in the supporting structure, so the number of radials is not as important a factor as it is with a ground- mounted vertical system. From a practical standpoint, the customary number of radials is four or five. In a multiband configuration, λ/4 radials are required for each band of operation with the ground-plane antenna.

This is not so with the ground-mounted vertical antenna, where the ground plane is relied upon to provide an image of the radiating section. Note that even quarter-wave-long radials are greatly detuned by their proximity to ground—radial resonance is not necessary or even possible. In the ground-mounted case, so long as the ground-screen radials are approximately 0.2 λ long at the lowest frequency, the length will be more than adequate for the higher frequency bands.

Short Vertical Antennas

A short vertical antenna can be operated on several bands by loading it at the base, the general arrangement being similar to Figs 1 and 2. That is, for multiband work the vertical can be handled by the same methods that are used for random-length wires.

A vertical antenna should not be longer than about ¾ λ at the highest frequency to be used, however, if low-angle radiation is wanted. If the antenna is to be used on 28 MHz and lower frequencies, therefore, it should not be more than approximately 25 feet high, and the shortest possible ground lead should be used.

Another method of feeding is shown in **Fig 29**. L1 is a loading coil, tapped to resonate the antenna on the desired band. A second tap permits using the coil as a transformer for matching a coax line to the transmitter. C1 is not strictly necessary, but may be helpful on the lower frequencies, 3.5 and 7 MHz, if the antenna is quite short. In that case C1 makes it possible to tune the system to resonance with a coil of reasonable dimensions at L1. C1 may also be useful on other bands as well, if the system cannot be matched to the feed line with a coil alone.

The coil and capacitor should preferably be installed at the base of the antenna, but if this cannot be done a wire can be run from the antenna base to the nearest convenient location for mounting L1 and C1. The extra wire will of course be a part of the antenna, and since it may have to run through unfavorable surroundings it is best to avoid using it if at all possible.

This system is best adjusted with the help of an SWR indicator. Connect the coax line across a few turns of L1 and take trial positions of the shorting tap until the SWR reaches its lowest value. Then vary the line tap similarly; this should bring the SWR down to a low value. Small adjustments of both taps then should reduce the SWR to close to 1:1. If not, try adding C1 and go through the same procedure, varying C1 each time a tap position is changed.

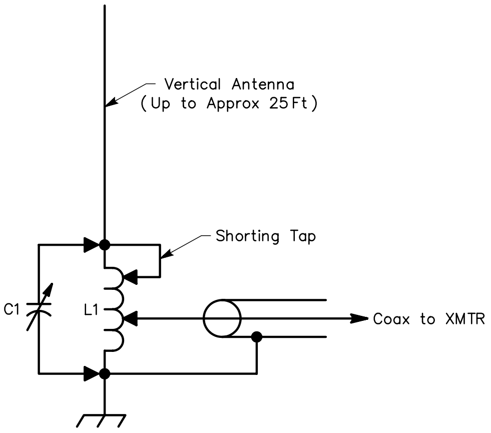

Fig 29—Multiband vertical antenna system using base loading for resonating on 3.5 to 28 MHz. L1 should be wound with bare wire so it can be tapped at every turn, using #12 wire. A convenient size is 2½ inches diameter, 6 turns per inch (such as B&W 3029). Number of turns required depends on antenna and ground lead length, more turns being required as the antenna and ground lead are made shorter. For a 25-foot antenna and a ground lead of the order of 5 feet, L1 should have about 30 turns. The use of C1 is explained in the text. The smallest capacitance that will permit matching the coax cable should be used; a maximum capacitance of 100 to 150 pF will be sufficient in any case.

Trap Verticals

The trap principle described in Fig 17 for center-fed dipoles also can be used for vertical antennas. There are two principal differences. Only one half of the dipole is used, the ground connection taking the place of the missing half, and the feed-point impedance is one half the feed-point impedance of a dipole. Thus it is in the vicinity of 30 Ω (plus the ground-connection resistance), so 52-Ω cable should be used since it is the commonly available type that comes closest to matching.

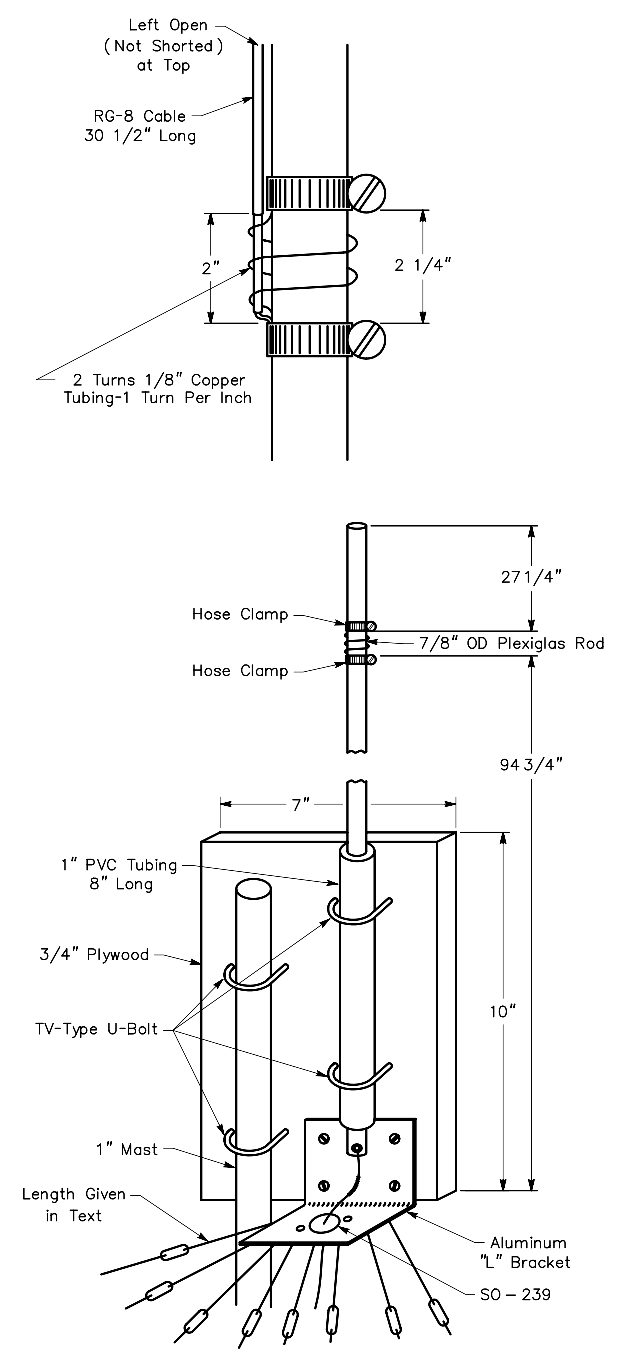
Left Open
(Not Shorted)
at Top
RG-8 Cable
30 1/2" Long
2"
2 1/4"
2 Turns 1/8" Copper
Tubing-1 Turn Per Inch
27 1/4"
Hose Clamp
7/8" OD Plexiglas Rod
Hose Clamp
94 3/4"
7"
1" PVC Tubing
8" Long
3/4" Plywood
TV-Type U-Bolt
10"
1" Mast
Length Given
in Text
Aluminum
"L" Bracket
SO – 239

Fig 30—Constructional details of the 21- and 28-MHz dual-band antenna system.

A TRAP VERTICAL FOR 21 AND 28 MHZ

Simple antennas covering the upper HF bands can be quite compact and inexpensive. The two-band vertical ground plane described here is highly effective for long-distance communication when installed in the clear.

Figs 30, **31** and **32** show the important assembly details. The vertical section of the antenna is mounted on a ¾-inch thick piece of plywood board that measures 7 × 10 inches. Several coats of exterior varnish or similar material will help protect the wood from inclement weather. Both the mast and the radiator are mounted on the piece of wood by means of TV U-bolt hardware. The vertical is electrically isolated from the wood with a piece of 1-inch diameter PVC tubing. A piece approximately 8 inches long is required, and it is of the schedule-80 variety. To prepare the tubing, you must slit it along the entire length on one side. A hacksaw will work quite well. The PVC fits rather snugly on the aluminum tubing and

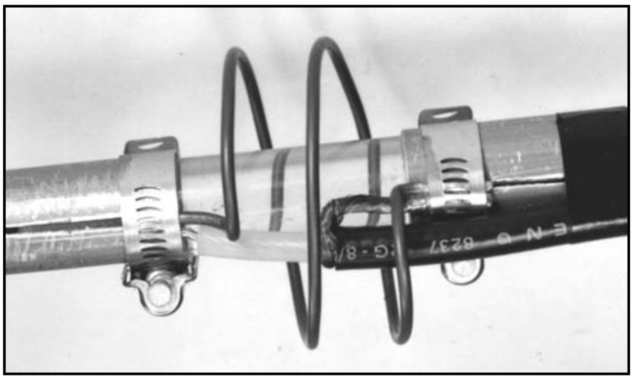

Fig 31—A close-up view of a trap. The coil is 3 inches in diameter. The leads from the coaxial-cable capacitor should be soldered directly to the pigtails of the coil. These connections should be coated with varnish after they have been secured under the hose clamps.

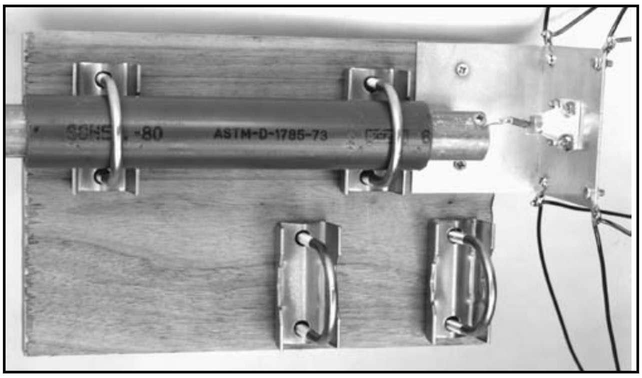
ASTM-D-1785-73

Fig 32—The base assembly of the 21- and 28-MHz vertical. The SO-239 coaxial connector and hood can be seen in the center of the aluminum L bracket. The U bolts are TV-type antenna hardware. The plywood should be coated with varnish or similar material.

will have to be "persuaded" with the aid of a hammer. Mount the mast directly on the wood with no insulation.

Use an SO-239 coaxial connector and four solder lugs on an L-shaped bracket made from a piece of aluminum sheet. Solder a short length of test probe wire, or inner conductor of RG-58 cable, to the inner terminal of the connector. A UG-106 connector hood is then slid over the wire and onto the coaxial connector. Then bolt the hood and connector to the aluminum bracket. Two wood screws are used to secure the aluminum bracket to the plywood, as shown in the drawing and photograph. Solder the free end of the wire coming from the connector to a lug mounted on the bottom of the vertical radiator. Fill any space between the wire and where it passes through the hood with GE silicone sealant or similar material to keep moisture out. The eight radials, four for each band, are soldered to the four lugs on the aluminum bracket. Separate the two sections of the vertical member with a piece of clear acrylic rod. Approximately 8 inches of ⅞-inch OD material is required. You must slit the aluminum tubing lengthwise for several inches so the acrylic rod may be inserted. The two pieces of aluminum tubing are separated by 2¼ inches.

The trap capacitor is made from RG-8 coaxial cable and is 30.5 inches long. RG-8 cable has 29.5 pF of capacitance per foot and RG-58 has 28.5 pF per foot. RG-8 cable is recommended over RG-58 because of its higher breakdown-voltage capability. The braid should be pulled back 2 inches on one end of the cable, and the center conductor soldered to one end of the coil. Solder the braid to the other end of the coil. Compression type hose clamps are placed over the capacitor/coil leads and put in position at the edges of the aluminum tubing. When tightened securely, the clamps serve a two-fold purpose—they keep the trap in contact with the vertical members and prevent the aluminum tubing from slipping off the acrylic rod. The coaxial-cable capacitor runs upward along the top section of the antenna. This is the side of the antenna to which the braid of the capacitor is connected. Place a cork or plastic cap in the very top of the antenna to keep moisture out.

Installation and Operation

The antenna may be mounted in position using a TV-type tripod, chimney, wall or vent mount. Alternatively, a telescoping mast or ordinary steel TV mast may be used, in which case the radials may be used as guys for the structure. The 28-MHz radials are 8 feet 5 inches long, and the 21-MHz radials are 11 feet 7 inches.

Any length of 50-Ω cable may be used to feed the antenna. The SWR at resonance should be on the order of 1.2:1 to 1.5:1 on both bands. The reason the SWR is not 1:1 is that the feed-point resistance is something other than 50 Ω —closer to 35 or 40 Ω.

The Open-Sleeve Antenna

Although only recently adapted for the HF and VHF amateur bands, the open-sleeve antenna has been around since 1946. The antenna was invented by Dr J. T. Bolljahn, of Stanford Research Institute. This section on sleeve antennas was written by Roger A. Cox, WB0DGF.

The basic form of the open-sleeve monopole is shown in **Fig 33**. The open-sleeve monopole consists of a base-fed central monopole with two parallel closely spaced parasitics, one on each side of the central element, and grounded at each base. The lengths of the parasitics are roughly one half that of the central monopole.

Impedance

The operation of the open sleeve can be divided into two modes, an antenna-mode and a transmission-line mode. This is shown in **Fig 34**.

The antenna-mode impedance, Z_A, is determined by the length and diameter of the central monopole. For sleeve lengths less than that of the monopole, this impedance is essentially independent of the sleeve dimensions.

The transmission-line mode impedance, Z_T, is determined by the characteristic impedance, end impedance, and length of the 3- wire transmission line formed by the central monopole and the two sleeve elements. The characteristic impedance, Z_c, can be determined by the element diameters and spacing if all element diameters are equal, and is found from

$$Z_c = 207 \log 1.59 (D/d) \qquad \text{(Eq 2)}$$

where

D = spacing between the center of each sleeve element and the center of the driven element

d = diameter of each element

This is shown graphically in **Fig 35**. However, since the end impedance is usually unknown, there is little need to know the characteristic impedance. The transmission-line mode impedance, Z_T, is usually determined by an educated guess and experimentation.

As an example, let us consider the case where the central monopole is λ/4 at 14 MHz. It would have an antenna mode impedance, Z_A, of approximately 52 Ω, depending upon the ground conductivity and number of radials. If two sleeve elements were added on either side of the central monopole, with each approximately half the height of the monopole and at a distance equal to their height, there would be very little

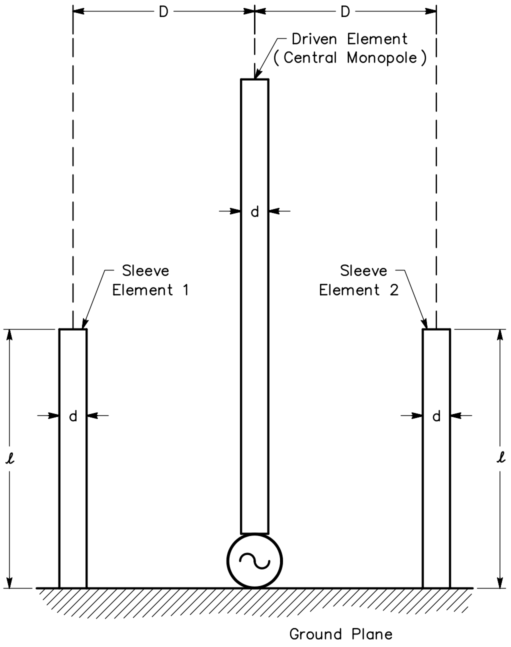

Fig 33—Diagram of an open-sleeve monopole.

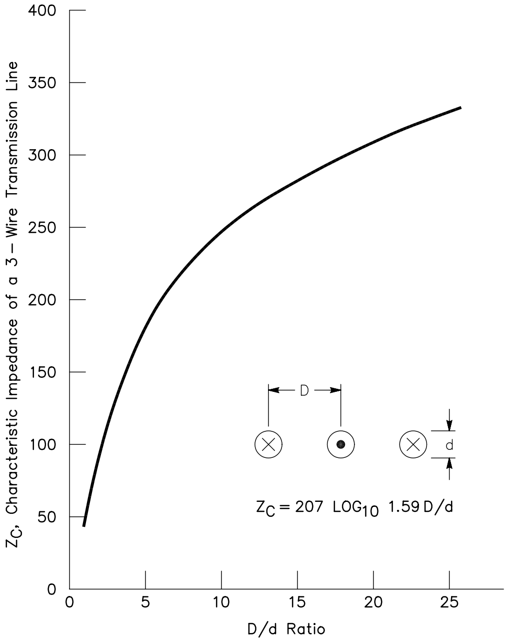

Fig 35—Characteristic impedance of transmission-line mode in an open-sleeve antenna.

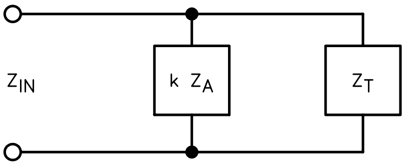

Fig 34—Equivalent circuit of an open-sleeve antenna.

effect on the antenna mode impedance, Z_A, at 14 MHz.

Also, Z_T at 14 MHz would be the end impedance transformed through a $\lambda/8$ section of a very high characteristic impedance transmission line. Therefore, Z_T would be on the order of 500-2000 Ω resistive plus a large capacitive reactance component. This high impedance in parallel with 52 Ω would still give a resultant impedance close to 52 Ω.

At a frequency of 28 MHz, however, Z_A is that of an end-fed half-wave antenna, and is on the order of 1000-5000 Ω resistive. Also, Z_T at 28 MHz would be on the order of 1000 to 5000 Ω resistive, since it is the end impedance of the sleeve elements transformed through a quarter-wave section of a very high characteristic impedance 3-wire transmission line. Therefore, the parallel combination of Z_A and Z_T would still be on the order of 500 to 2500 Ω resistive.

If the sleeve elements were brought closer to the central monopole such that the ratio of the spacing to element diameter was less than 10:1, then the characteristic impedance of the 3-wire transmission line would drop to less than 250 Ω. At 28 MHz, Z_A remains essentially unchanged, while Z_T begins to edge closer to 52 Ω as the spacing is reduced. At some particular spacing the characteristic impedance, as determined by the D/d ratio, is just right to transform the end impedance to exactly 52 Ω at some frequency. Also, as the spacing is decreased, the frequency where the impedance is purely resistive gradually increases.

The actual impedance plots of a 14/28-MHz open-sleeve monopole appear in **Figs 36** and **37**. The length of the central monopole is 195.5 inches, and of the sleeve elements 89.5 inches. The element diameters range from 1.25 inches at the bases to 0.875 inch at each tip. The measured impedance of the 14-MHz monopole alone, curve A of Fig 36, is quite high. This is probably because of a very poor ground plane under the antenna. The addition of the sleeve elements raises this impedance slightly, curves B, C and D.

As curves A and B in Fig 37 show, an 8-inch sleeve spacing gives a resonance near 27.8 MHz at 70 Ω, while a 6-inch spacing gives a resonance near 28.5 MHz at 42 Ω. Closer spacings give lower impedances and higher resonances. The optimum spacing for this particular antenna would be somewhere between 6 and 8 inches. Once the spacing is found, the lengths of the sleeve elements can be tweaked slightly for a choice of resonant frequency.

In other frequency combinations such as 10/21, 10/24, 14/21 and 14/24-MHz, spacings in the 6 to 10-inch range work very well with element diameters in the 0.5 to 1.25-inch range.

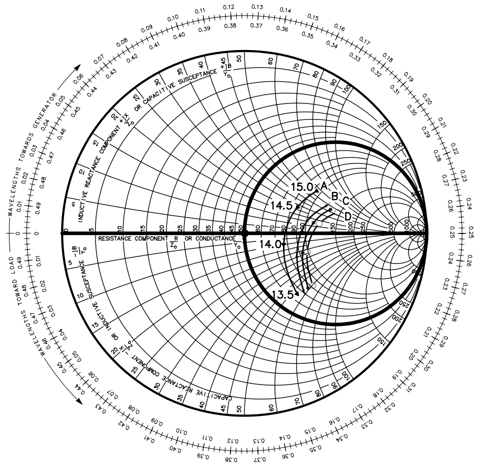

Fig 36—Impedance of an open-sleeve monopole for the frequency range 13.5-15 MHz. Curve A is for a 14 MHz monopole alone. For curves B, C and D, the respective spacings from the central monopole to the sleeve elements are 8, 6 and 4 inches. See text for other dimensions.

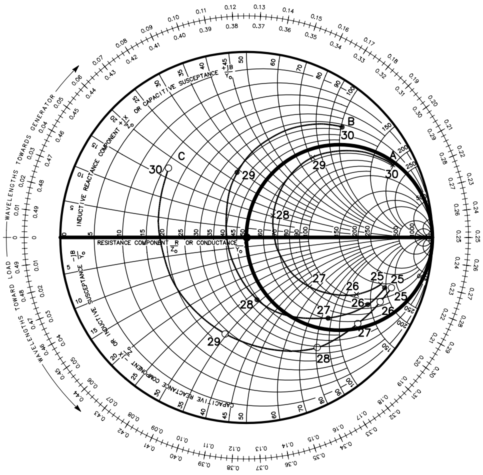

Fig 37—Impedance of the open-sleeve monopole for the range 25-30 MHz. For curves A, B and C the spacings from the central monopole to the sleeve elements are 8, 6 and 4 inches, respectively.

Bandwidth

The open-sleeve antenna, when used as a multiband antenna, does not exhibit broad SWR bandwidths unless, of course, the two bands are very close together. For example, **Fig 38** shows the return loss and SWR of a single 10-MHz vertical antenna. Its 2:1 SWR bandwidth is 1.5 MHz, from 9.8 to 11.3 MHz. Return loss and SWR are related as given by the following equation.

$$\mathrm{SWR} = \frac{1+k}{1-k} \qquad \text{(Eq 3)}$$

where

$$k = 10^{\frac{R_L}{20}}$$

RL = return loss, dB

When sleeve elements are added for a resonance near 22 MHz, the 2:1 SWR bandwidth at 10 MHz is still nearly 1.5 MHz, as shown in **Fig 39**. The total amount of spectrum under 2:1 SWR increases, of course, because of the additional band, but the individual bandwidths of each resonance are virtually unaffected.

The open-sleeve antenna, however, can be used as a broadband structure, if the resonances are close enough to overlap. With the proper choices of resonant frequencies, sleeve and driven element diameters and sleeve spacing, the SWR "hump" between resonances can be reduced to a value less than 3:1. This is shown in **Fig 40**.

Current Distribution

According to H. B. Barkley (see Bibliography at the end of this chapter), the total current flowing into the base of the open-sleeve antenna may be broken down into two components, that contributed by the antenna mode, I_A, and that contributed by the transmission-line mode, I_T. Assuming that the sleeves are approximately half the height of the central monopole, the impedance of the antenna mode, Z_A, is very low at the resonant frequency of the central monopole, and

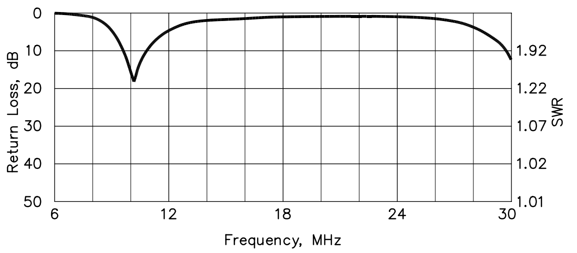

Fig 38—Return loss and SWR of a 10 MHz vertical antenna. A return loss of 0 dB represents an SWR of infinity. The text contains an equation for converting return loss to an SWR value.

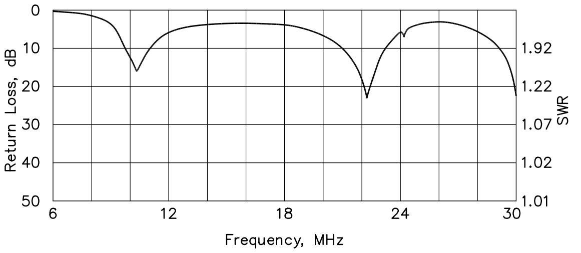

Fig 39—Return loss and SWR of a 10/22 MHz open-sleeve vertical antenna.

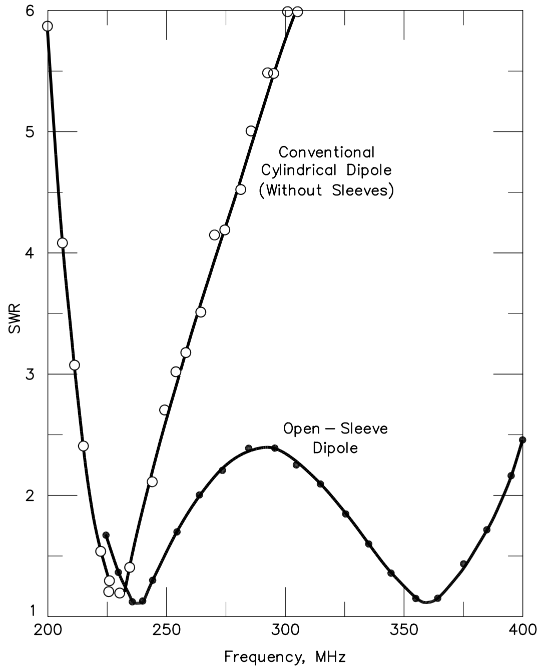

Fig 40—SWR response of an open-sleeve dipole and a conventional dipole.

the impedance of the transmission-line mode, Z_T, is very high. This allows almost all of the current to flow in the antenna mode, and I_A is very much greater than I_T. Therefore, the current on the central λ/4 monopole assumes the standard sinusoidal variation, and the radiation and gain characteristics are much like those of a normal λ/4 vertical antenna.

However, at the resonant frequency of the sleeves, the impedance of the central monopole is that of an end fed half-wave monopole and is very high. Therefore I_A is small. If proper element diameters and spacings have been used to match the transmission line mode impedance, Z_T, to 52 Ω, then I_T, the transmission line mode current, is high compared to I_A.

This means that very little current flows in the central monopole above the tops of the sleeve elements, and the radiation is mostly from the transmission-line mode current, I_T, in all three elements below the tops of the sleeve elements. The resulting current distribution is shown in **Figs 41** and **42** for this case.

Radiation Pattern and Gain

The current distribution of the open-sleeve antenna where all three elements are nearly equal in length is nearly that of a single monopole antenna. If, at a particular frequency, the elements are approximately λ/4 long, the current distribution is sinusoidal.

If, for this and other length ratios, the chosen diameters and spacings are such that the two sleeve elements approach an interelement spacing of λ/8, the azimuthal pattern will show directivity typical of two in-phase vertical radiators, approximately λ/8 apart. If a bi-directional pattern is needed, then this is one way to achieve it.

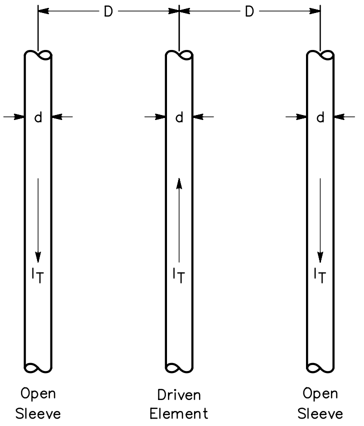

Fig 41—Current distribution in the transmission-line mode. The amplitude of the current induced in each sleeve element equals that of the current in the central element but the phases are opposite, as shown.

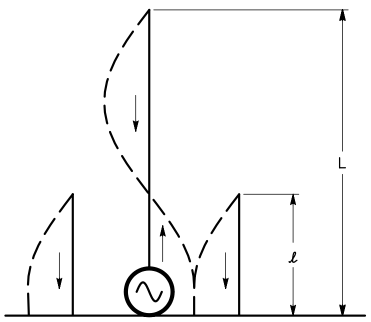

Fig 42—Total current distribution with λ= L/2.

Spacings closer than this will produce nearly circular azimuthal radiation patterns. Practical designs in the 10 to 30 MHz range using 0.5 to 1.5-inch diameter elements will produce azimuthal patterns that vary less than ±1 dB.

If the ratio of the length of the central monopole to the length of the sleeves approaches 2:1, then the elevation pattern of the open-sleeve vertical antenna at the resonant frequency of the sleeves becomes slightly compressed. This is because of the in-phase contribution of radiation from the λ/2 central monopole.

As shown in **Fig 43**, the 10/21-Mhz open-sleeve vertical antenna produces a lower angle of radiation at 21.2 MHz with a corresponding increase in gain of 0.66 dB over that of the 10-MHz vertical alone. At length ratios approaching 3:1, the

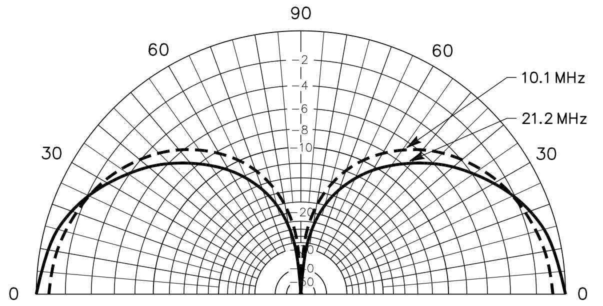

Fig 43—Vertical-plane radiation patterns of a 10/21-MHz open-sleeve vertical antenna on a perfect ground plane. At 10.1 MHz the maximum gain is 5.09 dBi, and 5.75 dBi at 21.2 MHz.

antenna mode and transmission-line mode impedance become nearly equal again, and the central monopole again carries a significant portion of the antenna current. The radiation from the top λ/2 combines constructively with the radiation from the λ/4 sleeve elements to produce gains of up to 3 dB more than just a quarter-wave vertical element alone.

Length ratios in excess of 3.2:1 produce higher level sidelobes and less gain on the horizon, except for narrow spots near the even ratios of 4:1, 6:1, 8:1, etc. These are where the central monopole is an even multiple of a half-wave, and the antenna-mode impedance is too high to allow much antenna-mode current.

Up to this point, it has been assumed that only λ/4 resonance could be used on the sleeve elements. The third, fifth, and seventh-order resonances of the sleeve elements and the central monopole element can be used, but their radiation patterns normally consist of high-elevation lobes, and the gain on the horizon is less than that of a λ/4 vertical.

Practical Construction and Evaluation

The open-sleeve antenna lends itself very easily to home construction. For the open-sleeve vertical antenna, only a feed-point insulator and a good supply of aluminum tubing are needed. No special traps or matching networks are required. The open-sleeve vertical can produce up to 3 dB more gain than a conventional λ/4 vertical. Further, there is no reduction in bandwidth, because there are no loading coils.

The open-sleeve design can also be adapted to horizontal dipole and beam antennas for HF, VHF and UHF. A good example of this is Telex/Hy-Gain's Explorer 14 triband beam which utilizes an open sleeve for the 10/15-meter driven element. The open-sleeve antenna is also very easy to model in computer programs such as *NEC* and *MININEC*, because of the open tubular construction and lack of traps or other intricate structures.

In conclusion, the open-sleeve antenna is an antenna experimenters delight. It is not difficult to match or construct, and it makes an ideal broadband or multiband antenna.

The Coupled-Resonator Dipole

A variation of the open-sleeve system above is the coupled-resonator system described by Gary Breed, K9AY, in an article in *The ARRL Antenna Compendium, Vol 5*, entitled “The Coupled-Resonator Principle: A Flexible Method for Multiband Antennas.” The following is condensed from that article.

In 1995, *QST* published two antenna designs that use an interesting technique to get multiband coverage in one antenna. Rudy Severns, N6LF, described a wideband 80 and 75-meter dipole using this technique, and Robert Wilson, AL7KK, showed us how to make a three-band vertical. Both of these antennas achieve multi-frequency operation by placing resonant conductors very close to a driven dipole or vertical—with no physical connection.

The Coupled-Resonator Principle

As we all know, nearby conductors can interact with an antenna. Our dipoles, verticals and beams can be affected by nearby power lines, rain gutters, guy wires and other metallic materials. The antennas designed by Severns and Wilson use this interaction intentionally, to combine the resonances of several conductors at a single feed point. While other names have been used, I call the behavior that makes these antennas work the *coupled-resonator* (C-R) principle.

Take a look at **Fig 44**, which illustrates the general idea. Each figure shows the SWR at the feed point of a dipole, over a range of frequencies. When this dipole is all alone, it will have a very low SWR at its half-wave resonant frequency (Fig 44A). Next, if we take another wire or tubing conductor and start bringing it close to the dipole, we will see a “bump” in the dipole’s SWR at the resonant frequency of this new wire. See Fig 44B. We are beginning to the see the effects of interaction between the two conductors. As we bring this new conductor closer, we reach a point where the SWR “bump” has grown to a very deep dip—a low SWR. We now have a good match at both the original dipole’s resonant frequency and the frequency of the new conductor, as illustrated in Fig 44C.

We can repeat this process for several more conductors at other frequencies to get a dipole with three, four, five, six, or more resonant frequencies. The principle also applies to verticals, so any reference to a dipole can be considered to be valid for a vertical, as well.

We can write a definition of the C-R principle this

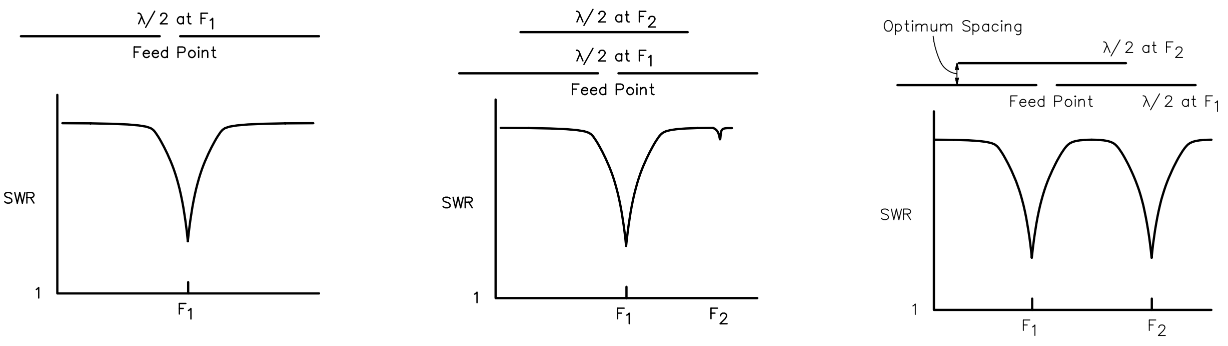

Fig 44—At A, the SWR of a dipole over a wide frequency range. At B, a nearby conductor is just close enough to interact with the dipole. At C, when the second conductor is at the optimum spacing, the combination is matched at both frequencies.

way: *Given a dipole (or vertical) at one frequency and an additional conductor resonant at another frequency, there is an optimum distance between them that results in the resonance of the additional conductor being imposed upon the original dipole, resulting in a low SWR at both resonant frequencies.*

Some History

In the late 1940s, the *coaxial sleeve* antenna was developed (**Fig 45A**), covering two frequencies by surrounding a dipole or monopole with a cylindrical tube resonant at the higher of the desired frequencies. In the 1950s, Gonset briefly marketed a two-band antenna based on this design. Other experimenters soon determined that two conductors at the second frequency, placed on either side of the main dipole or monopole, would make a skeleton representation of a cylinder (Fig 45B). This is called the *open-sleeve* antenna. The Hy-Gain Explorer tribander uses this method in its driven element to obtain resonance in the 10-meter band. Later on, a few antenna developers finally figured out that these extra conductors did not need to be added in pairs, and that a single conductor at each frequency could add the extra resonances (Fig 45C). This is the method used by Force 12 in some of their multiband antennas.

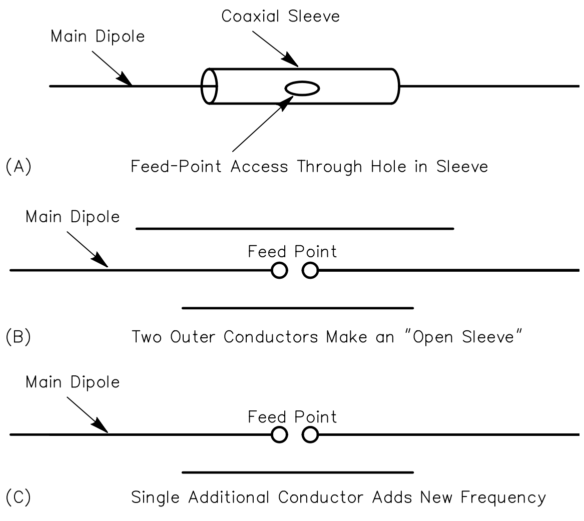
Coaxial Sleeve
Main Dipole
(A)
Feed-Point Access Through Hole in Sleeve
Main Dipole
Feed Point
(B)
Two Outer Conductors Make an "Open Sleeve"
Main Dipole
Feed Point
(C)
Single Additional Conductor Adds New Frequency

Fig 45—Evolution of coupled-resonator antennas: At A, the *coaxial-sleeve* dipole; at B, the *open-sleeve* dipole; and at C, a *coupled-resonator* dipole, the most universal configuration.

This is a perfect example of how science works. A specific idea is discovered, with later developments leading to an underlying general principle. The original coaxial-sleeve configuration is the most specific, being limited to two frequencies and requiring a particular construction method. The open-sleeve antenna is an intermediate step, showing that the sleeve idea is not limited to one configuration.

Finally, we have the coupled-resonator concept, which is the general principle, applicable in many different antenna configurations, for many different frequency combinations. Severns' antenna uses it with a folded dipole, and Wilson uses it with a main vertical that is off-center fed. The author K9AY used it with conventional dipoles and quarter-wave verticals. Other designers have used the principle more subtly, like putting the first director in a Yagi very close to the driven element, broadening the SWR bandwidth the same way Severns' design does with a dipole.

In the past, most antennas built with this single-conductor technique have also been called *open-sleeve* (or *multiple-open-sleeve*) antennas, a term taken from the history of their development. However, the term *sleeve* implies that one conductor must surround another. This is not really a physical or electrical description of the antenna's operation, therefore, K9AY suggests using the term *coupled-resonator,* which is the most accurate description of the general principle.

A Little Math

The interaction that makes the C-R principle work is not random. It behaves in a predictable, regular manner. K9AY derived an equation that shows the relationship between the driven element and the additional resonators for ordinary dipoles and verticals:

$$\frac{\log_{10} d}{\log_{10}(D/4)} = 0.54 \qquad \text{(Eq 4)}$$

where

d = distance between conductors, measured in wavelengths at the frequency of the chosen additional resonator

D = the diameter of the conductors, also in wavelengths at the frequency of the additional resonator.

Eq 4 assumes they are both the same diameter and that the feed point impedance at both frequencies is the same as a dipole in free space (72 Ω) or a quarter-wave monopole over perfect ground (36 Ω).

The equation only describes the impedance due to the additional resonator. The main dipole element is always part of the antenna, and it may have a fairly low impedance at the additional frequency. This is the case when the frequencies are close together, or when the main element is operating at its third harmonic. At these frequencies, the spacing distance must be adjusted so that the parallel combination of dipole and resonator results in the desired feed-point impedance.

K9AY worked out two correction factors, one to cover a range of impedances and another for frequencies close together. These can be included in the basic equation, which is rearranged below to solve for the distance between the conductors:

$$d = 10^{0.54\log_{10}(D/4)} \times \frac{Z_0 + 35.5}{109} \times [1 + e^{-[((F_2/F_1)-1.1)\times 11.3)+0.1)]}] \qquad \text{(Eq 5)}$$

where

d and D are the same as above.

Z_0 = the desired feed point impedance at the frequency of the additional resonator (between 20 and 120 Ω). For a vertical, multiply the desired impedance by two to get Z_0. If you want a 50-Ω feed, use 100 Ω for Z_0.

F_1 = the resonant frequency of the main dipole or vertical.

F_2 = the resonant frequency of the additional conductor. The ratio F_2/F_1 is more than 1.1.

e = 2.7183, the base of natural logarithms.

Eq 5 does not directly allow for conductors of unequal diameters, but it can be used as a starting point if you use the diameter of the driven dipole or vertical element for D in the equation.

Characteristics of C-R Antennas

Here's the important stuff—what's different about C-R antennas, what are they good for and what are their drawbacks? The key points are:

- Multiband operation without traps, stubs or tuners

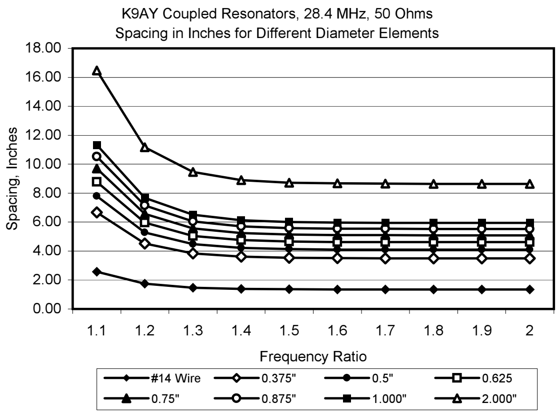

Fig A—Graph of the spacing versus frequency ratio for two Coupled-Resonator elements at 28.4 MHz, for 50-Ω feed-point impedance.

K9AY's Eq 5 above does indeed yield a good "first-cut" value for the spacing between coupled-resonator elements. **Fig A** shows the spacing, in inches, plotted against the ratio of frequencies, for two coupled resonator elements with different diameters, again expressed in inches. This is for an upper frequency of 28.4 MHz. Beyond a frequency ratio of about 1.5:1 (28.4:18.1 MHz), the spacing flattens out to a fixed distance between elements for each element diameter. For example, if $^1/_2$-inch elements are used at 28.4 and 18.1 MHz, the spacing between the elements is about 3.75 inches.

EZNEC verifies Eq 5's computations. Note that a large number of segments are necessary for each element when they are closely spaced from each other, and the segments on the elements must be closely aligned with each other. Be sure to run the Average Gain test, as well as Segmentation tests. The modeler should also be aware that if mutually coupled resonators are placed along a horizontal boom (as they would be on multiband Yagis using coupled resonators), the higher-frequency elements will act like retrograde directors, producing some gain (or lack of gain, depending on the azimuth being investigated).

For example, in the *EZNEC* file **K9AY C-R 28-21-14 MHz 1 In.EZ**, using 1-inch diameter elements spaced 6 inches apart, if the 28-MHz element is placed 6 inches behind the 14-MHz driven element (with the 21-MHz element placed 6 inches ahead), on 28 MHz the system will have a F/B of 2.6 dB, favoring the rearward direction. On 21 MHz, the system will exhibit a F/B of 1.6 dB, favoring the forward direction. Of course, there are systems where gain and F/B due to the C-R configuration may be put to good use, such as the multiband Yagis mentioned above. However, if the elements are spaced above/below the 14-MHz driven element there is no distortion of the dipole patterns.

- Flexible impedance matching at each frequency
- Independent fine-tuning at each frequency (little interaction)
- Easily modeled using *MININEC* or *NEC*-based programs
- Pruning process same as a simple dipole
- Can accommodate many frequencies (seven or more)
- Virtually lossless coupling (high efficiency)
- Requires a separate wire or tubing conductor at each frequency
- Mechanical assembly requires a number of insulated supports
- Narrower bandwidth than equivalent dipole
- Capacitance requires slight lengthening of conductors

To begin with, the most obvious characteristic is that this principle can be used to add multiple resonant frequencies to an ordinary dipole or vertical, using additional conductors that are not physically connected. This gives us three variable factors: (1) the diameter of the conductor, (2) its length, and (3) its position relative to the main element.

Having the freedom to control these factors gives us the advantage of *flexibility*; we have a wide range of control over the impedance at each added frequency. Another advantage is that the behavior at each frequency is quite *independent*, once the basic design is in place. In other words, making fine-tuning adjustments at one frequency doesn't change the resonance or impedance at the other frequencies. A final advantage is *efficiency.* With conductors close together, and with a resonant target conductor, coupling is very efficient. Traps, stubs, and compensating networks found on other multiband antennas all introduce lossy reactive components.

There are two main disadvantages of C-R antennas. The first is the relative *complexity* of construction. Several conductors are needed, installed with some type of insulating spacers. Other multiband antennas have their complexities as well (such as traps that need to be mounted and tuned), but C-R antennas will usually be bulkier. The larger size generally means greater windload, which is a disadvantage to some hams.

The other significant disadvantage is *narrower bandwidth,* particularly at the highest of the operating frequencies. We can partially overcome this problem with large conductors that are naturally broad in bandwidth, and in some cases we might even use an extra conductor to put two resonances in one band. It is interesting to note that the pattern is opposite that of trapped antennas. The C-R antenna gets narrower at the highest frequencies of operation, while trap antennas generally have narrowest bandwidth at their lowest frequencies.

There are two special situations that should be noted. First, when the antenna has a resonance near the frequency where the driven dipole is 3/2 λ long (3/4 λ for a vertical), the dipole has a fairly low impedance. The spacing of the C-R element needs to be increased to raise its impedance so that the parallel combination of the main element and C-R element equals the desired impedance (usually 50 Ω). There is also significant antenna current in the part of the main dipole extending beyond the C-R section, contributing to the total radiation pattern. As a result, this particular arrangement radiates as three λ/2 sections in phase, and has about 3 dB gain and a narrower directional pattern compared to a dipole (**Fig 46**). This might be an advantage for antennas covering bands with a frequency ratio of about three, such as 3.5 and 10.1 MHz, 7 and 21 MHz, or 144 and 430 MHz.

The other special situation is when we want to add a new frequency very close to the resonant frequency of the main dipole. An antenna for 80 and 75 meters would be an example of this. Again, the driven dipole has a fairly low impedance at the new frequency. Add the fact that coupling is very strong between these similar conductors and we find that a wide spacing is required to make the antenna work. A dipole resonant at 3.5 MHz and another wire resonant at 3.8 MHz will need to be 3 or 4 feet apart, while a 3.5 MHz and 7 MHz combination might only need to be spaced 4 or 5 inches.

Another useful characteristic of C-R antennas is that they are easily and accurately modeled by computer programs based on either *MININEC* or *NEC*, as long as you stay within each program's limitations. For example, Severns points out that *MININEC* does not handle folded dipoles very well, and *NEC* modeling is required. With ease of computer modeling, a precise answer isn't needed for the design equation given above. An approximate solution will provide a starting point that can quickly be adjusted for optimum dimensions.

The added resonators have an effect on the lengths of all conductors, due to the capacitance between the conductors. Capacitance causes antennas to look electrically shorter, so

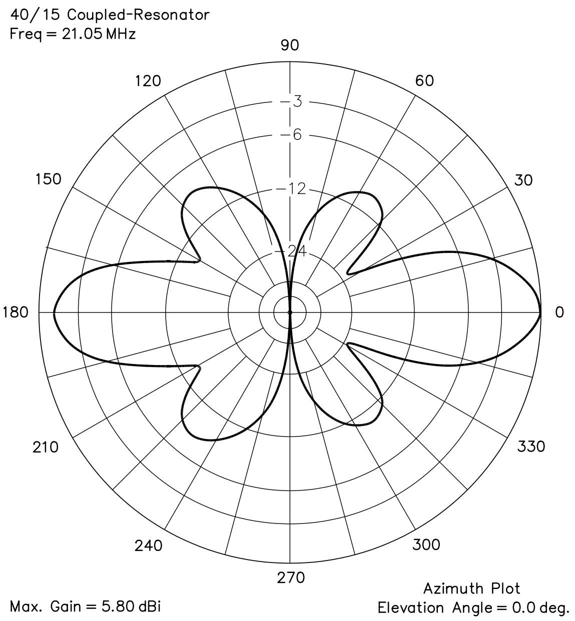

Fig 46—Radiation pattern for the special case of a C-R antenna with the additional frequency at the third harmonic of the main dipole resonant frequency.

each element needs to be about 1% or 2% longer than a simple dipole at the same frequency. As a rule of thumb, use 477/f (in feet) instead of the usual 468/f when calculating dipole length, and 239/f instead of 234/f for a λ/4 vertical.

A 30/17/12-Meter Dipole

To show how a C-R antenna is designed, let's build a dipole to cover all three WARC bands. We'll use #12 wire, which has a diameter of 0.08 inches, and the main dipole will be cut for the 10.1 MHz band. From the equation above, the spacing between the main dipole and the 18-MHz resonator should be 2.4 inches for 72 Ω, or 1.875 inches for 50 Ω. At 24.9 MHz, the spacing to the resonator for that band should be 2.0 inches for 72 Ω, or 1.62 inches for 50 Ω. Of course, this antenna will be installed over real ground, not in free space, so these spacing distances may not be exact. Plugging these numbers into your favorite antenna-modeling program will let you optimize the dimensions for installation at the height you choose.

For those of you who like to work with real antennas, not computer-generated ones, the predicted spacing is accurate enough to build an antenna with minimum trial-and-error. You should use a nice round number just larger than the calculated spacing for 50 Ω. For this antenna, K9AY decided that the right spacing for the desired height would be 2 inches for the 18 MHz resonator and 1.8 inches for the 24.9 MHz resonator. For simplicity of construction, he just used 2 inches for both, figuring that the worst he would get is a 1.2:1 SWR if the numbers were a little bit off. Like all dipoles, the impedance varies with height above ground, but the 2-inch spacing results in an excellent match on the two additional bands, at heights of more than 25 feet.

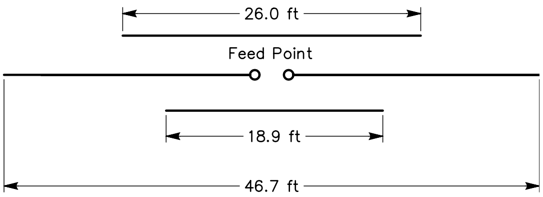

Fig 47—Dimensions of a C-R dipole for the 30, 17 and 12-meter bands.

The final dimensions of the dipole for 10.1, 18.068 and 24.89 MHz are shown in **Fig 47**. These are the final pruned lengths for a straight dipole installed at a height of about 40 feet. If you put up the antenna as an inverted V, you will need each wire to be a bit longer. Pruning this type of antenna is just like a dipole—if it's resonant too low in frequency, it's too long and the appropriate wire needs to be shortened. So, you can cut the wires just a little long to start with and easily prune them to resonance.

A final note: if you want to duplicate this antenna design, remember that the 2-inch spacing is just for #12 wire! The required spacing for a C-R antenna is related to the conductor diameter. This same antenna built with #14 wire needs under 1½-inch spacing, while a 1-inch aluminum-tubing version requires about 7-inch spacing.

Summary

The coupled-resonator principle is one more weapon in the antenna designer's arsenal. It's not the perfect method for all multiband antennas, but what the C-R principle offers is an alternative to traps and tuners, in exchange for using more wire or aluminum. Although a C-R antenna requires more complicated construction, its main attraction is in making a multiband antenna that can be built with no compromise in matching or efficiency.

HF Discone Antennas

The material in this section is adapted from an article by Daniel A. Krupp, W8NWF, in *The ARRL Antenna Compendium, Vol 5*. The name *discone* is a contraction of the words disc and cone. Although people often describe a discone by its design-center frequency (for example, a "20-meter discone"), it works very well over a wide frequency range, as much as several octaves. **Fig 48** shows a typical discone, constructed of sheet metal for UHF use. On lower frequencies, the sheet metal may be replaced with closely spaced wires and/or aluminum tubing.

The dimensions of a discone are determined by the lowest frequency of use. The antenna produces a vertically polarized signal at a low-elevation angle and it presents a good match for 50-Ω coax over its operating range. One advantage of the discone is that its maximum current area is near the top of the antenna, where it can radiate away from ground clutter. The cone-like skirt of the discone radiates the signal—radiation from the disc on top is minimal. This is because the currents flowing in the skirt wires essentially all go in the same direction, while the currents in the disc elements oppose each other and cancel out. The discone's omnidirectional characteristics make it ideal for roundtable QSOs or for a Net Control station.

Electrical operation of this antenna is very stable, with no changes due to rain or accumulated ice. It is a self-contained antenna—unlike a traditional ground-mounted vertical radiator, the discone does not rely on a ground-radial system for efficient operation. However, just like any other vertical

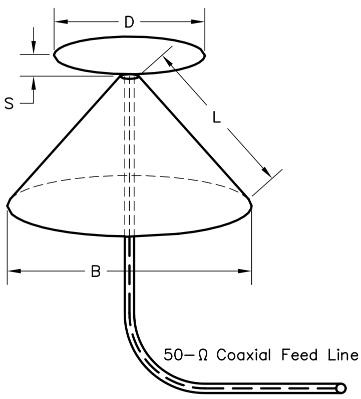

Fig 48—Diagram of VHF/UHF discone, using a sheet-metal disc and cone. It is fed directly with 50-Ω coax line. The dimensions L and D, together with the spacing S between the disc and cone, determine the frequency characteristics of the antenna. L = 246 / f_{MHz} for the lowest frequency to be used. Diameter D should be from 0.67 to 0.70 of dimension L. The diameter at the bottom of the cone B is equal to L. The space S between disc and cone can be 2 to 12 inches, with the wider spacing appropriate for larger antennas.

antenna, the quality of the ground in the Fresnel area will affect the discone's far-field pattern.

Both the disc and cone are inherently balanced for wind loading, so torque caused by the wind is minimal. The entire cone and metal mast or tower can be connected directly to ground for lightning protection.

Unlike a trap vertical or a triband beam, discone antennas are not adjusted to resonate at a particular frequency in a ham band or a group of ham bands. Instead, a discone functions as a sort of high-pass filter, efficiently radiating RF all the way from the low-frequency design cutoff to the high-frequency limits imposed by the physical design.

While VHF discones have been available out-of-the-box for many years, HF discones are rare indeed. Some articles have dealt with HF discones, where the number of disc elements and cone wires was minimized to cut costs or to simplify construction. While the minimalist approach is fine if the sought-after results really are obtained, W8NWF believes in building his discones without compromise.

History of the Discone

The July 1949 and July 1950 issues of *CQ* magazine both contained excellent articles on discones. The first article, by Joseph M. Boyer, W6UYH, said that the discone was developed and used by the military during World War II. (See Bibliography.) The exact configuration of the top disc and cone was the brainchild of Armig G. Kandonian. Boyer described three VHF models, plus information on how to build them, radiation patterns, and most importantly, a detailed description of how they work. He referred to the discone as a type of "coaxial taper transformer."

The July 1950 article was by Mack Seybold, W2RYI. He described an 11-MHz version he built on his garage roof. The mast actually fit through the roof to allow lowering the antenna for service. Seybold stated that his 11-MHz discone would load up on 2 meters but that performance was down 10 dB compared to his 100-MHz Birdcage discone. He commented that this was caused by the relatively large spacing between the disc and cone. Actually, the performance degradation he found was caused by the wave angle lifting upward at high frequencies. The cone wires were electrically long, causing them to act like long wire antennas. See **Fig 49**.

W8NWF's First Discone: the A-Frame Discone

The first discone was one designed to cover 20 through 10 meters without requiring an antenna tuner. The cone assembly uses 18-foot long wires, with a 60° included apex angle and a 12-foot diameter disc assembly. See **Fig 50** and **Fig 51**. The whole thing was assembled on the ground, with the feed coax and all guys attached. Then with the aid of some friends, it was pulled up into position.

The author used a 40-foot tall wooden "A-frame" mast, made of three 22-foot-long 2 × 4s. He primed the mast with sealer and then gave it two coats of red barn paint to make it look nice and last a long time. The disc hub was a 12-inch length of 3-inch schedule-40 PVC plumbing pipe. The PVC is very tough, slightly ductile, and easy to drill and cut. PVC is well suited for RF power at the feed point of the antenna.

Three 12-foot by 0.375-inch OD pieces of 6061 aluminum, with 0.058-inch wall thickness, were used for the 12-foot diameter top disc. These were cut in half to make the center portions of the six telescoping spreaders. Four twelve foot by 0.250-inch OD (0.035-inch wall thickness) tubes were cut into 12 pieces, each 40 inches long. This gave extension tips for each end of the six spreaders.

See **Fig 52** for details on the disc hub assembly. W8NWF started by drilling six holes straight through the PVC for the six spreaders, accurately and squarely, starting

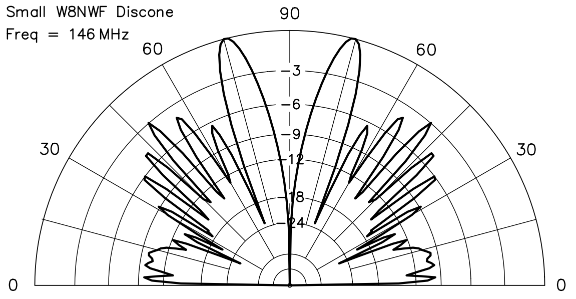

Fig49—Computed elevation plot over average ground for W8NWF's small discone at 146 MHz, ten times its design frequency range. The cone wires are acting as long-wire antennas, distorting severely the low-elevation angle response, even though the feed-point impedance is close to 50 Ω.

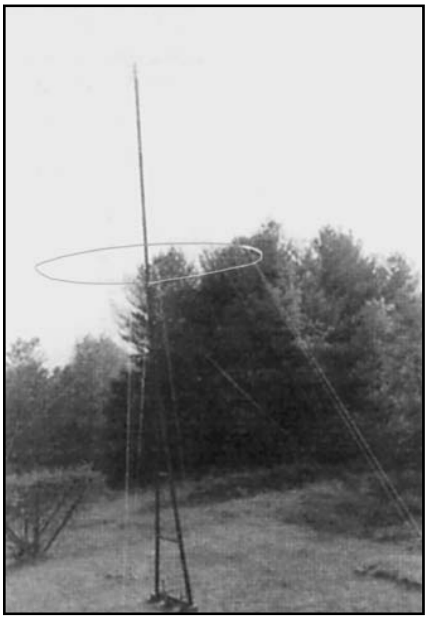

Fig 50—Photo of W8NWF's original A-frame mounted HF discone.

about two inches down from the top and spaced radially every 30°. Each hole is 0.375 inches below the plane of the previous one. Take great care in drilling—a poor job now will look bad from the ground up for a long time! It's a good idea to make up a paper template beforehand. Tape this to the PVC hub and then drill the holes, which should make for a close fit with the elements. If you goof, start over with a new piece of PVC—it's cheap.

Each six-foot spreader tube was secured exactly in the center to clear a 6-32 threaded brass rod that secured the elements mechanically and electrically. A two-foot long by ¼-inch OD wooden dowel was inserted into the middle of each six-foot length of tubing. The dowel added strength and also prevented crushing the element when the nuts on the threaded rod were tightened.

Insert the 40-inch long extensions four inches into each end of the six-foot spreaders. Mark and drill holes to pin the telescoping tips, plus holes big enough to clear #18 soft-drawn copper wire. This was for the inner circumferential wire for the disc. Drill a single hole for #18 wire about ¼ inch from each extension element tip, through which passes the outer circumferential wire. Finally, insert all 6-foot elements into the PVC hub and line up the holes in the center so the brass rod could be inserted through the middle to secure the elements.

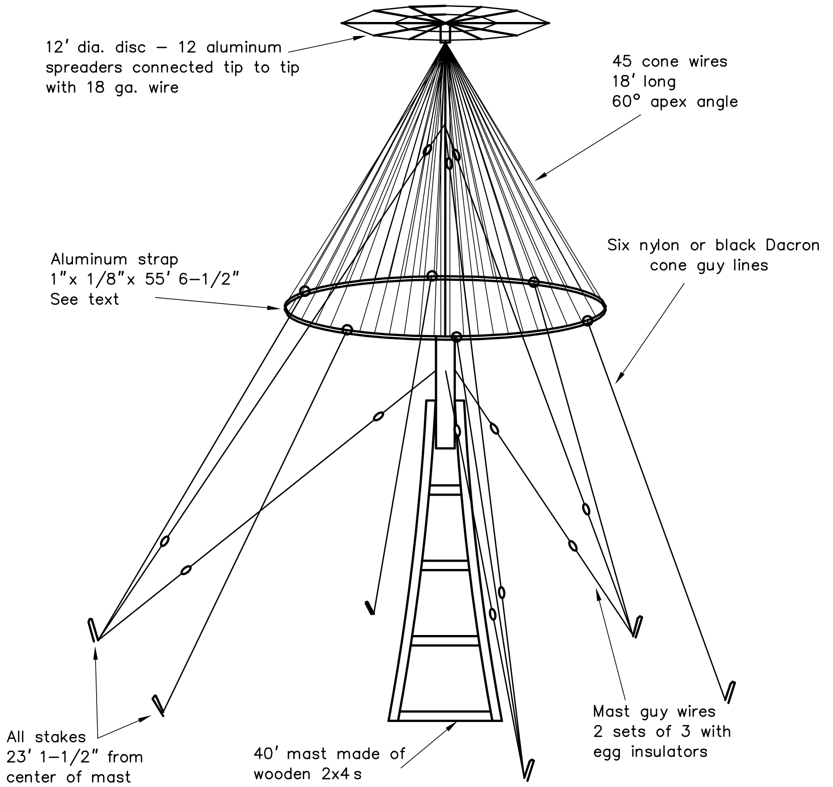
12′ dia. disc — 12 aluminum spreaders connected tip to tip with 18 ga. wire
45 cone wires 18′ long 60° apex angle
Aluminum strap 1″x 1/8″x 55′ 6-1/2″ See text
Six nylon or black Dacron cone guy lines
All stakes 23′ 1-1/2″ from center of mast
40′ mast made of wooden 2x4 s
Mast guy wires 2 sets of 3 with egg insulators

Fig 51—Detailed drawing of the A-frame discone for 14 to 30 MHz. The disc assembly at the top of the A-frame is 12 feet in diameter. There are 45 cone wires, each 18 feet long, making a 60° included angle of the cone. This antenna works very well over the design frequency range.

The next step is to "chisel to fit" the top of my wooden mast to allow the PVC to slide down on it about six or seven inches. For convenience, place the whole mast assembly in a horizontal position on top of two clothesline poles and one stepladder.

Place the disc head assembly over the top of the mast, but don't secure it yet. This allows for rotation while adding the disc spreader extensions. A tip for safety: tie white pieces of cloth to the ends of elements near eye level. Just remember to remove them before raising the antenna.

For a long-lasting installation, use an anti-corrosion compound, such as Penetrox, when assembling the aluminum antenna elements. As the extensions are added, secure them in the innermost of the two holes with a short piece of #18 wire. Then run a wire through the remaining holes looping each element as you go. This gives added support laterally to the elements. Next add a #18 wire to the tips of the extensions in the same fashion. This provides even more

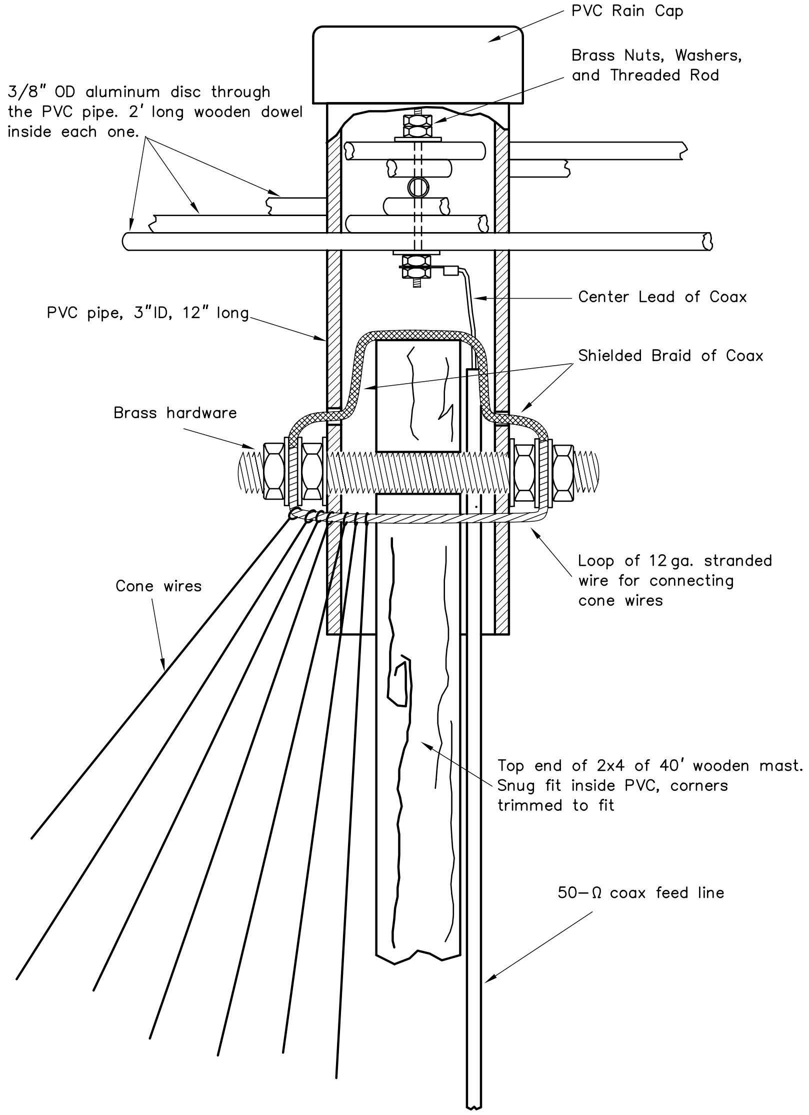
PVC Rain Cap
Brass Nuts, Washers, and Threaded Rod
3/8" OD aluminum disc through the PVC pipe. 2' long wooden dowel inside each one.
Center Lead of Coax
PVC pipe, 3"ID, 12" long
Shielded Braid of Coax
Brass hardware
Loop of 12 ga. stranded wire for connecting cone wires
Cone wires
Top end of 2x4 of 40' wooden mast. Snug fit inside PVC, corners trimmed to fit
50-Ω coax feed line

Fig 52—Details of the top hub for the A-frame discone. The three-inch PVC pipe was drilled to hold the six spreaders making up the top disc. Connections for the shield of the feed coax were made to the disc. The coax center conductor was connected to the cone-wire assembly by means of a loop of #12 stranded wire encircling the outside of the PVC hub.

physical stability as well as making electrical connections.

Next, pin the PVC disk hub to the wooden mast with a ⅜-inch threaded rod. This is also the point where the cone wires are attached, using a loop of #12 stranded copper wire around the PVC. Solder each cone wire to this loop, together with the coax shield braid. Make sure the loop of #12 wire is large enough to make soldering possible without burning the PVC with the soldering iron.

Connect the coax center conductor to the disc assembly by securing it with the same 6-32 threaded rod that ties all the disc elements together. Make sure to use coax-seal compound to keep moisture out of the coax. The coax is then fed down the mast and secured in a few places to provide strain relief and to keep it out of the way of the cone wires.

Use two sets of three guy wires. Break these up with egg insulators, just to be sure there won't be any interaction with the antenna. Use 45 wires of #18 soft-drawn copper wire for the cone, 18 feet long each. Cut them a little long so they can be soldered to the connecting loop.

A difficult task is now at hand—keeping all the cone wires from getting tangled! Solder each of the 45 cone wires to the loop of #12 wire, spacing each wire about ¼ inch from the last one for an even distribution all the way around.

The cone base is 18 feet in diameter to provide a 60° included angle. At the base of the cone, use five 12-foot long aluminum straps, 1 inche wide by ⅛ inch thick, overlapping 8¼ inches and fastened together with aluminum rivets. Drill holes along the strap every 15 inches to secure the cone wires.

Make sure to handle the aluminum strap carefully while fastening the cone wire ends; too sharp of a bend could possibly break it. Fasten six small-diameter nylon lines to the cone-base aluminum strap to stabilize the cone. These cone-guys share the same guy stakes as the mast guy lines.

After cutting the nylon lines, heat the frayed ends of each with a small flame to prevent unraveling. Apply several coats of clear protective spray to the disk head assembly, after checking that all hardware is tight. A rain cap at the top of the PVC disc hub completes construction.

Putting It All Up

You are going to need a lot of help now to raise this antenna. Have the whole process fully thought out before trying to raise it. You should have the spot selected for the base of the mast and some pipes driven into the ground to prevent the mast from slipping sideways as it is being pulled up. The three guy stakes should be in place, 23 feet, 1½ inches from mast center. Of course, the guys should have been cut to the correct length, with some extra. Be sure the coax transmission line will come off the mast where it should. A long length of rope to an upper and lower guy line is used to pull up the whole works.

The author used an old trick of standing an extension ladder vertically near the antenna base with the pull lines looped over the top rung to get a good lift angle. The weight added to the mast from the antenna disc assembly and cone wires is about 26 pounds, most of it from the cone assembly. Use two strong people to pull up the antenna slowly so that the other helpers on the guy wires and cone guy lines have time to move about as required. As the antenna rises to the vertical position, if there are no snafus, the guy lines can be secured. Then tie the six cone lines to stakes.

A Really Big Discone

When an opportunity arose to buy a 64-foot self-supporting TV tower, the author jumped at the chance to implement a full 7 to 30-MHz discone. His new tower had eight sections, each eight feet long. Counting the overlap between sections, the cone wires would come off the tower at about the 61.5-foot mark.

W8NWF took some liberties with the design of this larger discone compared to the first one, which he had done strictly “by the book.” The first change was to make the cone wires 70 feet long, even though the formula said they should be 38 feet long. Further, the cone wires would not be connected together at the bottom. With the longer cone wires, he felt that 75 and 80-meter operation might be a possibility.

The second major change was to widen the apex angle out from 60° to about 78°. Modeling said this should produce a flatter SWR over the frequency spectrum and would also give a better guy system for the tower.

The topside disc assembly would be 27 feet in diameter and have 16 radial spreaders, using telescoping aluminum tubing tapering from ⅝ to ½ to ⅜ inches OD. All spreaders were made from 0.058-inch wall thickness 6063-T832 aluminum tubing, available from Texas Towers. A section of 10-inch PVC plumbing pipe would be used as the hub for construction of the disc assembly.

Construction Details for the Large Discone.

While installing the tower, the author had left the top section on the ground. This allowed him to fit the disc head assembly precisely to it. **Fig 53** shows the overall plan for the large discone. The 10-inch diameter PVC hub was designed to slip over the tower top section, but was a little too large. So a set of shims was installed on the three legs at the top of the tower for a just-right fit. Drilling the PVC pipe for the eight ⅝-inch OD elements was started about an inch down from the top. W8NWF purposely staggered the drilled holes in the same fashion as the hub for the smaller antenna. See **Fig 54**.

Again, three-foot sections of ½-inch wooden dowel were used to strengthen the ⅝-inch center portion of each spreader. Instead of using a loop of #12 wire for connecting the cone wires, as had been done on the smaller discone, he drilled 36 holes in the PVC hub. These holes are small enough so

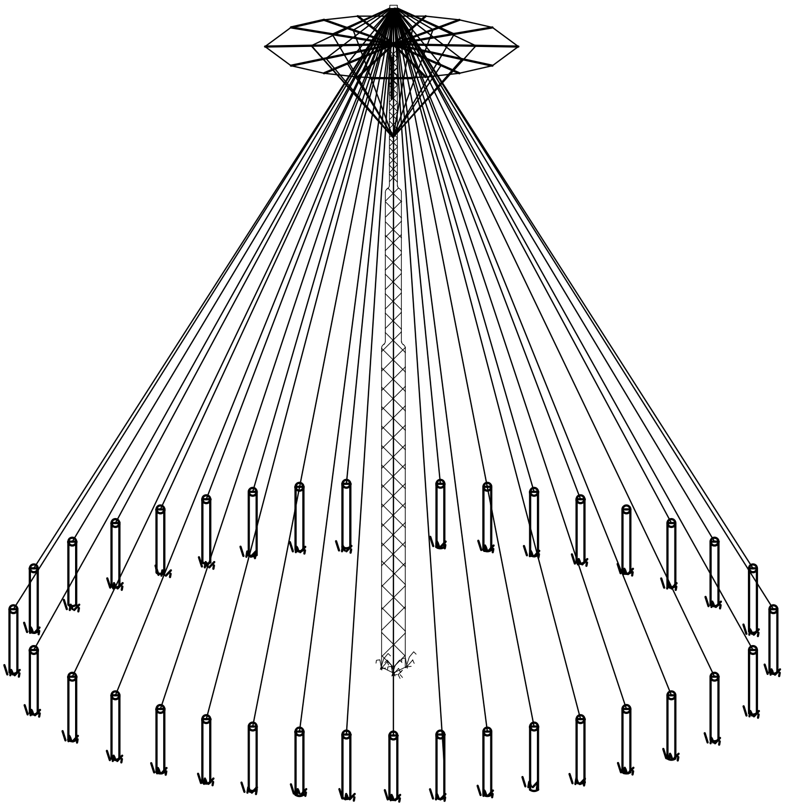

Fig 53—The large W8NWF discone, designed for operation from 7 to 14 MHz, but useable with a tuning network in the shack for 3.8 MHz.

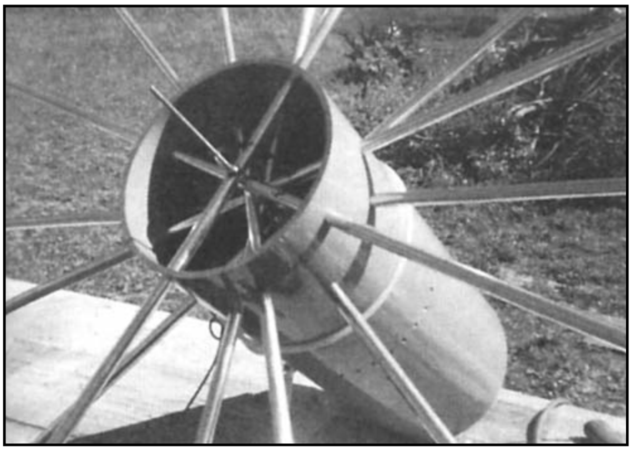

Fig 54—Photo showing details of the hub assembly for the large discone, including the threaded brass rod that connects the radial spreaders together. The 10-inch PVC pipe is drilled to accommodate the radial spreaders. Each spreader is reinforced with a three-foot long wooden dowel inside for crush resistance. Note the row of holes drilled below the lowest spreader. Each of the 36 cone wire passes through one of these holes.

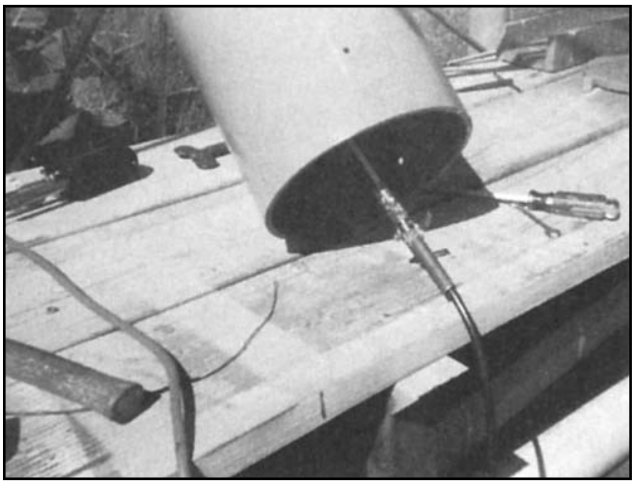

Fig 55—Details of the copper pipe slipped over the feed coax. The coax shield has been folded back over the copper pipe and secured with two stainless-steel hose clamps. The cone wires are also laid against the copper pipe and secured with additional hose clamps.

that the PVC hub would not be weakened appreciably. He drilled the circles of holes for the cone wires about 6 inches below the disc spreaders.

He prepared a three-foot long piece of RG-213 coax, permanently fastened on one end to the antenna, with a female type-N connector at the other end. Type-N fittings were used because of their superior waterproofing abilities. The coax center lead was connected with a terminal lug under a nut on the brass threaded rod securing the disc spreaders. The coax shield braid was folded back over a six-inch long copper pipe and clamped to it with a stainless-steel hose clamp. See **Fig 55** for details.

The plan was that after the top disc assembly had been hoisted up and attached at the top of the tower, individual cone wires would be fed, one at a time, through the small holes drilled in the PVC. They were to be laid against the copper pipe and secured with stainless-steel hose clamps.

The ½ and ⅜-inch OD spreader extension tips were secured in place with two aluminum pop-rivets at each joint. Again, the author used anti-oxidant compound on all spreader junctions. He drilled a hole horizontally near the tip of each ⅜-inch tip all around the perimeter to allow a #8 aluminum wire to circle the entire disc. A small stainless-steel sheet-metal screw was threaded into the end of each element to secure the wire.

In parallel with the aluminum wire, a length of small-diameter black Dacron line was run, securing it in a couple of places between each set of spreaders with UV-resistant plastic tie-wraps. The reason for doing this was to hold the aluminum wire in position and to prevent it from dangling, in case it should break some years in the future. Two coats of clear protective spray were applied for protection.

A truss system helps prevent the disc from sagging due to its own weight. See **Fig 56** for details. This shows the completed disk assembly mounted on the

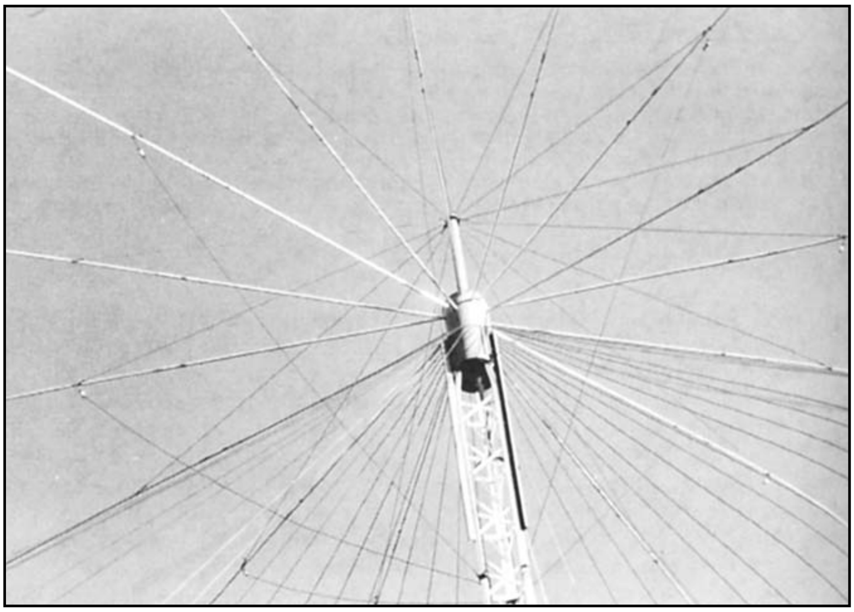

Fig 56—Photo of the spreader hub assembly, showing the truss ropes above and below the radial spreaders. This is a very rugged assembly!

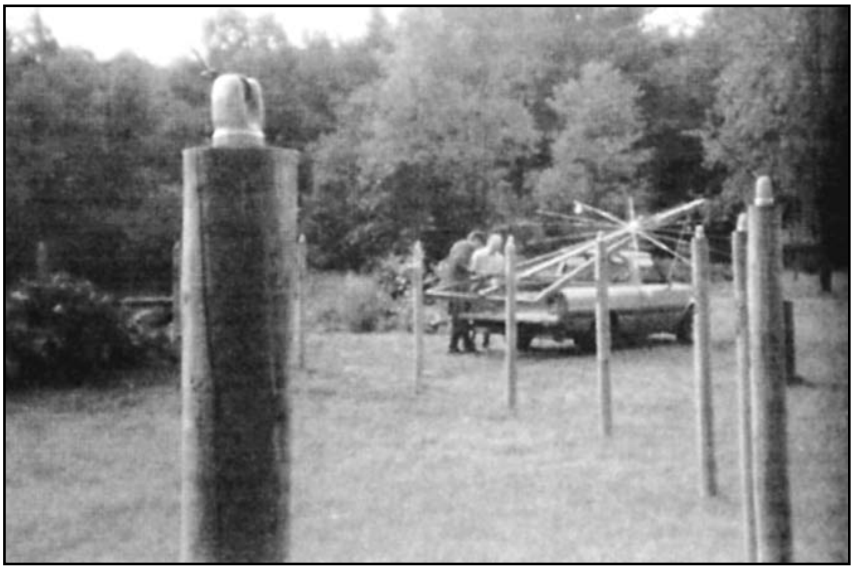

Fig 57—Photo showing some of the fence posts used to hold individual cone wires to keep them off the ground and out of harm's way. The truck in the background is carting away the A-frame discone for installation at KA8UNO's QTH.

top of the tower. A 3-foot length of 2-inch PVC pipe was used for a truss mast above the disc assembly, notching the bottom of the pipe so that it would form a saddle over the top couple of spreaders. This gave a good foothold. He cut a circle of thin sheet aluminum to fit over the 10-inch PVC to serve as a rain cap. The cap has a hole in the center for the two-inch PVC truss mast to pass through, thereby holding it down tight. The author sprayed a few light coats of paint over the PVC for protection from ultraviolet radiation from the sun.

Sixteen small-diameter black Dacron ropes were connected at the top of the truss support mast, with the other ends fastened to the disc spreaders, halfway out. Another rain cap was added to the top of the two-inch PVC truss mast. Eight lengths of the same small diameter Dacron rope were added halfway out the length of every other spreader. These ropes are meant to be tied back to the tower, to prevent updrafts from blowing the disc assembly upwards. Small egg insulators were used near the spot where the eight bottom trusses were tied to the disc spreaders, just to be sure there would be no RF leakage in rainy weather.

Hoisting the completed disc assembly to the top of the tower can be done easily, with the assistance of at least two others. The trickiest part is to get the disc assembly from its position sitting flat on the ground to the vertical position needed for hoisting it up the tower without damaging it. The disc assembly weighs about 35 pounds. Someone at the top of the tower will receive the disc as it is hoisted up by gin pole, and can mount it on the tower top.

You should prepare three 6-foot long metal braces going over the outside of the PVC to fasten to the tower legs. They really beef things up.

In plastic irrigation pipe buried between the house and tower base, the author ran 100 feet of 9086 low-loss coax to the shack. For cone wires, he was able to obtain some #18 copperclad steel wire, with heavy black insulation that looked a lot like neoprene. The cone system takes a lot of wire: 36 × 70 feet = 2520 feet, plus some extra at each end for termination. You'd be well advised to look around at hamfests to save money.

As each cone wire was connected at the top of the tower, a helper should place the other end at its proper spot below. The lower end of each cone wire is secured to an insulator screwed into a fencepost. See **Fig 57**. There are 36 treated-pine fenceposts, each standing about 5½ feet tall, 45 feet from the tower base to hold the lower end of the cone wires. This makes mowing the grass easier and the cone wires are less likely to be tripped over too.

On the final trip down the tower, the eight Dacron downward-truss lines were tied back to the tower about 6 feet below the disc assembly. The author's tower has three ground rods driven near the base, connected with heavy copper wire to the three tower legs.

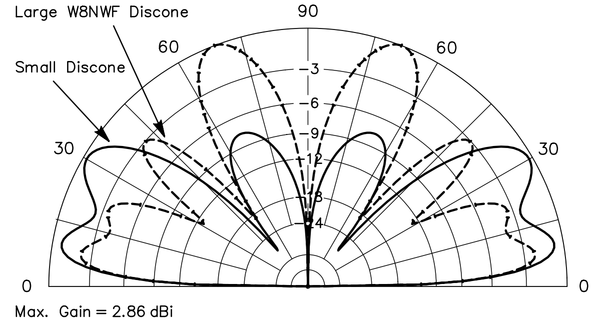

Fig 58—Computed patterns showing elevation response of small discone at 28.5 MHz compared to that of the larger discone at 28.5 MHz. The cone wires are clearly too long for efficient operation on 10 meters, producing unwanted high-angle lobes that rob power from the desirable low-elevation angles.

Performance Tests

On the air tests proved to be very satisfying. Loading up on 40 meters was easy—the SWR was 1:1 across the entire band. W8NWF can work all directions very well and receives excellent signal reports from DX stations. When he switches to his long (333 foot) center-fed dipole for comparison, he finds the dipole is much noisier and that received signals are weaker. During the daytime, nearby stations (less than about 300 to 500 miles) can be louder with the dipole, but the discone can work them just fine also.

The author happily reports that this antenna even works well on 75 meters. As you might expect, it doesn't present a 1:1 match. However, the SWR is between 3.5:1 and 5.5:1 across the band. W8NWF uses an antenna tuner to operate the discone on 75. It seems to get out as well on 75 as it does on 40 meters.

The SWR on 30 meters is about 1.1:1. On 20 meters the SWR runs from 1.05:1 at 14.0 MHz to 1.4:1 at 14.3 MHz. The SWR on the 17, 15, 12 and 10-meter bands varies, going up to a high of 3.5:1 on 12 meters.

Radiation Patterns for the Discones

From modeling using *NEC/Wires* by K6STI, W8NWF verified that the low-angle performance for the bigger antenna is worse than that for the smaller discone on the upper frequencies. See **Fig 58** for an elevation-pattern comparison on 10 meters for both antennas, with average ground constants. The azimuth patterns are simply circles. Radiation patterns produced by antenna modeling programs are very helpful to determine what to expect from an antenna.

The smaller discone, which was built by the book, displays good, low-angle lobes on 20 through 10 meters. The frequency range of 14 through 28 MHz is an octave's worth of coverage. It met his expectations in every way by covering this frequency span with low SWR and a low angle of radiation.

The bigger discone, with a modified cone suitable for use on 75 meters, presents a little different story. The low-angle lobe on 40 meters works well, and 75-meter performance also is good, although an antenna tuner is necessary on this band. The 30-meter band has a good low-angle lobe but secondary high-angle lobes are starting to hurt performance. Note that 30 meters is roughly three times the design frequency of the cone. On 20 and 17 meters there still are good low-angle lobes but more and more power is wasted in high-angle lobes.

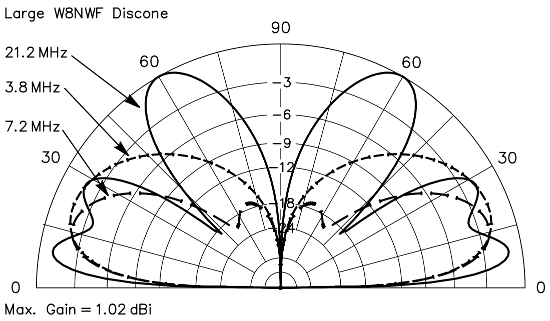

Fig 59—Computed elevation-response patterns for the larger W8NWF discone for 3.8, 7.2 and 21.2 MHz operation. Again, as in Fig 58, the pattern degrades at 21.2 MHz, although it is still reasonably efficient, if not optimal.

The operation on 15, 12, and 10 meters continues to worsen for the larger discone. The message here is that although a discone may have a decent SWR as high as 10 times the design frequency, its radiation pattern is not necessarily good for low-angle communications. See **Fig 59** for a comparison of elevation patterns for 3.8, 7.2 and 21.2 MHz on the larger discone.

A discone antenna built according to formula will work predictably and without any adjustments. One can modify the antenna's cone length and apex angle without fear of rendering it useless. The broadband feature of the discone makes it attractive to use on the HF bands. The low angle of radiation makes DX a real possibility, and the discone is also much less noisy on receive than a dipole.

Probably the biggest drawback to an HF discone is its bulky size. There is no disguising this antenna! However, if you live in the countryside you should be able to put up a nice one.

Harmonic Radiation from Multiband Antennas

Since a multiband antenna is intentionally designed for operation on a number of different frequencies, any harmonics or spurious frequencies that happen to coincide with one of the antenna resonant frequencies will be radiated with very little, if any, attenuation. Particular care should be exercised, therefore, to prevent such harmonics from reaching the antenna.

Multiband antennas using tuned feeders have a certain inherent amount of built-in protection against such radiation, since it is nearly always necessary to use a tuned coupling circuit (antenna tuner) between the transmitter and the feeder. This adds considerable selectivity to the system and helps to discriminate against frequencies other than the desired one.

Multiple dipoles and trap antennas do not have this feature, since the objective in design is to make the antenna show as nearly as possible the same resistive impedance in all the amateur bands the antenna is intended to cover. It is advisable to conduct tests with other amateur stations to determine whether harmonics of the transmitting frequency can be heard at a distance of, say, a mile or so. If they can, more selectivity should be added to the system since a harmonic that is heard locally, even if weak, may be quite strong at a distance because of propagation conditions.

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Chapter 8

Multielement Arrays

The gain and directivity offered by an array of elements represents a worthwhile improvement both in transmitting and receiving. *Power gain* in an antenna is the same as an equivalent increase in the transmitter power. But unlike increasing the power of your own transmitter, antenna gain works equally well on signals received from the favored direction. In addition, the directivity reduces the strength of signals coming from the directions not favored, and so helps discriminate against interference.

One common method of obtaining gain and directivity is to combine the radiation from a group of $\lambda/2$ dipoles to concentrate it in a desired direction. A few words of explanation may help make it clear how power gain is obtained.

In **Fig 1**, imagine that the four circles, A, B, C and D, represent four dipoles so far separated from each other that the coupling between them is negligible. Also imagine that point P is so far away from the dipoles that the distance from P to each one is exactly the same (obviously P would have to be much farther away than it is shown in this drawing). Under these conditions the fields from all the dipoles will add up at P if all four are fed RF currents in the same phase.

Let us say that a certain current, I, in dipole A will produce a certain value of field strength, E, at the distant point P. The same current in any of the other dipoles will produce the same field at P. Thus, if only dipoles A and B are operating, each with a current I, the field at P will be 2E. With A, B and C operating, the field will be 3E, and with all four operating with the same I, the field will be 4E. Since the power received at P is proportional to the square of the field strength, the relative power received at P is 1, 4, 9 or 16, depending on whether one, two, three or four dipoles are operating.

Now, since all four dipoles are alike and there is no coupling between them, the same power must be put into each in order to cause the current I to flow. For two dipoles the relative power input is 2, for three dipoles it is 3, for four dipoles 4, and so on. The actual gain in each case is the relative received (or output) power divided by the relative input power. Thus we have the results shown in **Table 1**. The power ratio is directly proportional to the number of elements used.

It is well to have clearly in mind the conditions under which this relationship is true:

1) The fields from the separate antenna elements must be in-phase at the receiving point.

2) The elements are identical, with equal currents in all elements.

3) The elements must be separated in such a way that the current induced in one by another is negligible; that is, the radiation resistance of each element must be the same as it would be if the other elements were not there.

Very few antenna arrays meet all these conditions exactly. However, the power gain of a directive array using dipole elements with optimum values of element spacing is approximately proportional to the number of elements.

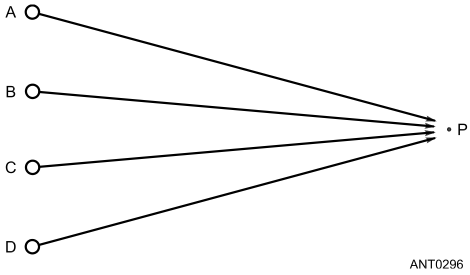

Fig 1—Fields from separate antennas combine at a distant point, P, to produce a field strength that exceeds the field produced by the same power in a single antenna.

Table 1
Comparison of Dipoles with Negligible Coupling (See Fig 1)

Dipoles	*Relative Output Power*	*Relative Input Power*	*Power Gain*	*Gain in dB*
A only	1	1	1	0
A and B	4	2	2	3
A, B and C	9	3	3	4.8
A, B, C and D	16	4	4	6

Another way to say this is that a gain of approximately 3 dB will be obtained each time the number of elements is doubled, assuming the proper element spacing is maintained. It is possible, though, for an estimate based on this rule to be in error by a ratio factor of two or more (gain error of 3 dB or more), especially if mutual coupling is *not* negligible.

DEFINITIONS

An *element* in a multi-element directive array is usually a λ/2 radiator or a λ/4 vertical element above ground. The length is not always an exact electrical half or quarter wavelength, because in some types of arrays it is desirable that the element show either inductive or capacitive reactance. However, the departure in length from resonance is ordinarily small (not more than 5% in the usual case) and so has no appreciable effect on the radiating properties of the element.

Antenna elements in multi-element arrays of the type considered in this chapter are always either *parallel*, as in **Fig 2A** , or *collinear* (end-to-end), as in Fig 2B. Fig 2C shows an array combining both parallel and collinear elements. The elements can be either horizontal or vertical, depending on whether horizontal or vertical polarization is desired. Except for space communications, there is seldom any reason for mixing polarization, so arrays are customarily constructed with all elements similarly polarized.

A *driven element* is one supplied power from the transmitter, usually through a transmission line. A *parasitic element* is one that obtains power solely through coupling to another element in the array because of its proximity to such an element.

A *driven array* is one in which all the elements are driven elements. A *parasitic array* is one in which one or more of the elements are parasitic elements. At least one element must be a driven element, since you must somehow introduce power into the array.

A *broadside array* is one in which the principal direction of radiation is perpendicular to the axis of the array and to the plane containing the elements, as shown in **Fig 3**. The elements of a broadside array may be collinear, as in Fig 3A, or parallel (two views in Fig 3B).

An *end-fire array* is one in which the principal direction of radiation coincides with the direction of the array axis. This definition is illustrated in **Fig 4**. An end-fire array must consist of parallel elements. They cannot be collinear, as λ/2 elements do not radiate straight off their ends. A Yagi is a familiar form of an end-fire array.

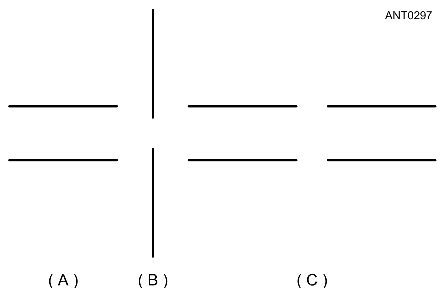

Fig 2—At A, parallel and at B, collinear antenna elements. The array shown at C combines both parallel and collinear elements.

A *bidirectional array* is one that radiates equally well in either direction along the line of maximum radiation. A bidirectional pattern is shown in **Fig 5A**. A *unidirectional array* is one that has only one principal direction of radiation, as the pattern in Fig 5B shows.

The *major lobes* of the directive pattern are those in which the radiation is maximum. Lobes of lesser radiation intensity are called *minor lobes*. The *beamwidth* of a directive antenna is the width, in degrees, of the major lobe between the two directions at which the relative radiated power is equal to one half its value at the peak of the lobe. At these *half-power points* the field intensity is equal to 0.707 times its maximum value, or in other words, is down 3 dB from the maximum. **Fig 6** shows a lobe having a beamwidth of 30°.

Unless specified otherwise, the term *gain* as used in this

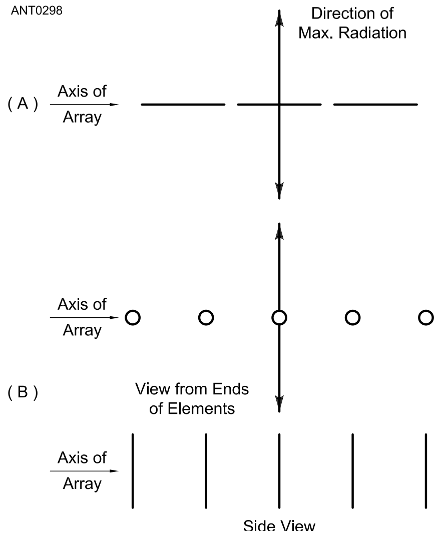

Fig 3—Representative broadside arrays. At A, collinear elements, with parallel elements at B.

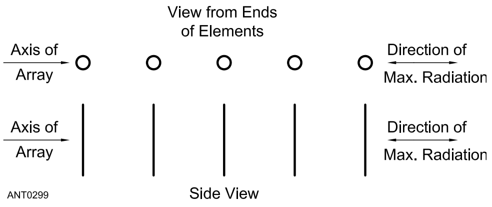

Fig 4—An end-fire array. Practical arrays may combine both broadside directivity (Fig 3) and end-fire directivity, including both parallel and collinear elements.

section is the power gain over an isotropic radiator in free space. The gain can also be compared with a λ/2 dipole of the same orientation and height as the array under discussion and having the same power input. Gain may either be measured experimentally or determined by calculation. Experimental measurement is difficult and often subject to considerable error, for two reasons. First, errors normally occur in measurement because the accuracy of simple RF measuring equipment is relatively poor—even high-quality instruments suffer in accuracy compared with their low-frequency and dc counterparts. And second, the accuracy depends considerably on conditions—the antenna site, including height, terrain characteristics, and surroundings—under which the measurements are made.

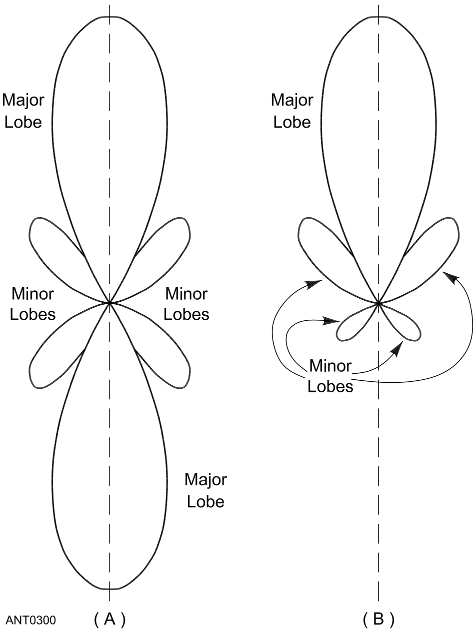

Fig 5—At A, typical bidirectional pattern and at B, unidirectional directive pattern. These drawings also illustrate the application of the terms *major* and *minor* to the pattern lobes.

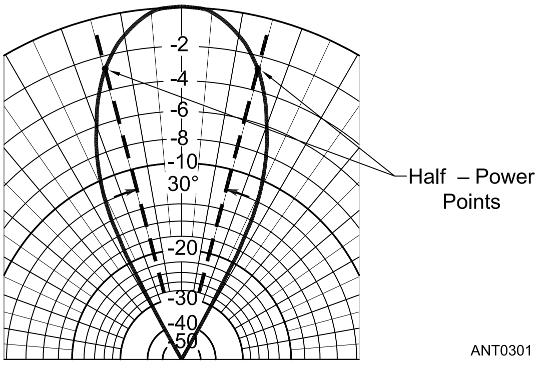

Fig 6—The width of a beam is the angular distance between the directions at which the received or transmitted power is half the maximum power (–3 dB). Each angular division of the pattern grid is 5°.

Calculations are frequently based on the measured or theoretical directive patterns of the antenna (see Chapter 2). The theoretical gain of an array may be determined approximately from:

$$G = 10 \log \frac{41{,}253}{\theta_H \ \theta_V} \qquad \text{(Eq 1)}$$

where

G = decibel gain over a dipole in its favored direction
θ_H = horizontal half-power beamwidth in degrees
θ_V = vertical half-power beamwidth in degrees.

This equation, strictly speaking, applies only to lossless antennas having approximately equal and narrow E- and H-plane beam widths—up to about 20°—and no large minor lobes. The E and H planes are discussed in Chapter 2. The error may be considerable when the formula is applied to simple directive antennas having relatively large beam widths. The error is in the direction of making the calculated gain larger than the actual gain.

Front-to-back ratio (F/B) is the ratio of the power radiated in the favored direction to the power radiated in the opposite direction. See Chapter 11 for a discussion of front-to-back ratio, and its close cousin, *worst-case front-to-rear ratio*.

Phase

The term *phase* has the same meaning when used in connection with the currents flowing in antenna elements as it does in ordinary circuit work. For example, two currents are in-phase when they reach their maximum values, flowing in the same direction, at the same instant. The direction of current flow depends on the way in which power is applied to the element.

This is illustrated in **Fig 7**. Assume that by some means an identical voltage is applied to each of the elements at the ends marked A. Assume also that the coupling between the elements is negligible, and that the instantaneous polarity of the voltage is such that the current is flowing away from the point at which the voltage is applied. The arrows show the assumed current directions. Then the currents in elements 1 and 2 are in-phase, since they are flowing in the same direction in space and are caused by the same voltage. However, the current in element 3 is flowing in the *opposite* direction in space because the voltage is applied to the opposite end of the element. The current in element 3 is therefore 180° out-of-phase with the currents in elements 1 and 2.

The phasing of driven elements depends on the direction of the element, the phase of the applied voltage, and the point at which the voltage is applied. In many systems used by amateurs, the voltages applied to the elements are exactly

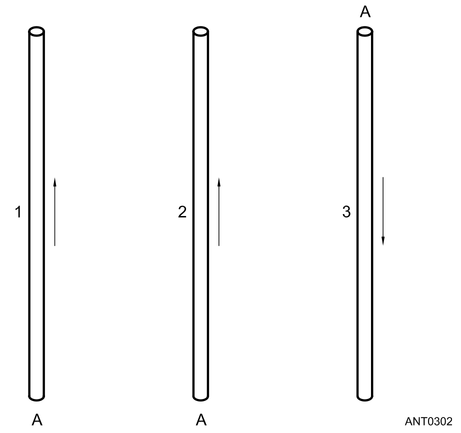

Fig 7—This drawing illustrates the phase of currents in antenna elements, represented by the arrows. The currents in elements 1 and 2 are in phase, while that in element 3 is 180° out of phase with 1 and 2.

in or exactly out-of-phase with each other. Also, the axes of the elements are nearly always in the same direction, since parallel or collinear elements are invariably used. The currents in driven elements in such systems therefore are usually either exactly in or exactly out-of-phase with the currents in other elements.

It is possible to use phase differences of less than 180° in driven arrays. One important case is where the current in one set of elements differs by 90° from the current in another set. However, making provision for proper phasing in such systems is considerably more complex than in the case of simple 0° or 180° phasing, as described in a later section of this chapter.

In parasitic arrays the phase of the currents in the parasitic elements depends on the spacing and tuning, as described later.

Ground Effects

The effect of the ground is the same with a directive antenna as it is with a simple dipole antenna. The reflection factors discussed in Chapter 3 may therefore be applied to the vertical pattern of an array, subject to the same modifications mentioned in that chapter. In cases where the array elements are not all at the same height, the reflection factor for the mean height of the array may be used for a close approximation. The mean height is the average of the heights measured from the ground to the centers of the lowest and highest elements.

MUTUAL IMPEDANCE

Consider two $\lambda/2$ elements that are fairly close to each other. Assume that power is applied to only one element, causing current to flow. This creates an electromagnetic field, which induces a voltage in the second element and causes current to flow in it as well. The current flowing in element 2 will in turn induce a voltage in element 1, causing additional current to flow there. The total current in 1 is then the sum (taking phase into account) of the original current and the induced current.

With element 2 present, the amplitude and phase of the resulting current in element 1 will be different than if element 2 were not there. This indicates that the presence of the second element has changed the impedance of the first. This effect is called *mutual coupling*. Mutual coupling results in a *mutual impedance* between the two elements. The mutual impedance has both resistive and reactive components. The actual impedance of an antenna element is the sum of its self-impedance (the impedance with no other antennas present) and its mutual impedances with all other antennas in the vicinity.

The magnitude and nature of the feed-point impedance of the first antenna depends on the amplitude of the current induced in it by the second, and on the phase relationship between the original and induced currents. The amplitude and phase of the induced current depend on the spacing between the antennas and whether or not the second antenna is tuned to resonance.

In the discussion of the several preceding paragraphs, power is applied to only one of the two elements. Do not interpret this to mean that mutual coupling exists only in parasitic arrays! It is important to remember that mutual coupling exists between any two conductors that are located near one another.

Amplitude of Induced Current

The induced current will be largest when the two antennas are close together and are parallel. Under these conditions the voltage induced in the second antenna by the first, and in the first by the second, has its greatest value and causes the largest current flow. The coupling decreases as the parallel antennas are moved farther apart.

The coupling between collinear antennas is comparatively small, and so the mutual impedance between such antennas is likewise small. It is not negligible, however.

Phase Relationships

When the separation between two antennas is an appreciable fraction of a wavelength, a measurable period of time elapses before the field from antenna 1 reaches antenna 2. There is a similar time lapse before the field set up by the current in number 2 gets back to induce a current in number 1. Hence the current induced in antenna 1 by antenna 2 will have a phase relationship with the original current in antenna 1 that depends on the spacing between the two antennas.

The induced current can range all the way from being completely in-phase with the original current to being completely out-of-phase with it. If the currents are in-phase, the total current is larger than the original current and the antenna feed-point impedance is reduced. If the currents are out-of-phase, the total current is smaller and the impedance is increased. At intermediate phase relationships the impedance will be lowered or raised depending on whether the induced current is mostly in or mostly out-of-phase with the original current.

Except in the special cases when the induced current is exactly in or out-of-phase with the original current, the induced current causes the phase of the total current to shift with respect to the applied voltage. Consequently, the presence of a second antenna nearby may cause the impedance of an antenna to be reactive—that is, the antenna will be detuned from resonance—even though its self-impedance is entirely resistive. The amount of detuning depends on the magnitude and phase of the induced current.

Tuning Conditions

A third factor that affects the impedance of antenna 1 when antenna 2 is present is the tuning of number 2. If antenna 2 is not exactly resonant, the current that flows in it as a result of the induced voltage will either lead or lag the phase it would have if the antenna were resonant. This causes an additional phase advance or delay that affects the phase of the current induced back in antenna 1. Such a phase lag has an effect similar to a change in the spacing between self-resonant antennas. However, a change in tuning is not exactly equivalent to a change in spacing because the two methods do not have the same effect on the amplitude of the induced current.

MUTUAL IMPEDANCE AND GAIN

The mutual coupling between antennas is important because it can have a significant effect on the amount of current that will flow for a given amount of power supplied. And it is the amount of *current* flowing that determines the field strength from the antenna. Other things being equal, if the mutual coupling between two antennas is such that the currents are greater for the same total power than would be the case if the two antennas were not coupled, the power gain will be greater than that shown in Table 1.

On the other hand, if the mutual coupling is such as to reduce the current, the gain will be less than if the antennas were not coupled. The term *mutual coupling*, as used in this paragraph, assumes that the mutual impedance between elements is taken into account, along with the added effects of propagation delay because of element spacing and element tuning or phasing.

The calculation of mutual impedance between antennas is a complex problem. Data for two simple but important cases are graphed in Figs 8 and 9. These graphs do not show the mutual impedance, but instead show a more useful quantity—the feed-point resistance measured at the center of an antenna as it is affected by the spacing between two antennas.

As shown by the solid curve in **Fig 8**, the feed-point resistance at the center of either antenna, when the two are self-resonant, parallel, and operated in-phase, decreases as the spacing between them is increased until the spacing is about 0.7 λ. This is a broadside array. The maximum gain is achieved from a pair of such elements when the spacing is in this region, because the current is larger for the same power and the fields from the two arrive in-phase at a distant point placed on a line perpendicular to the line joining the two antennas.

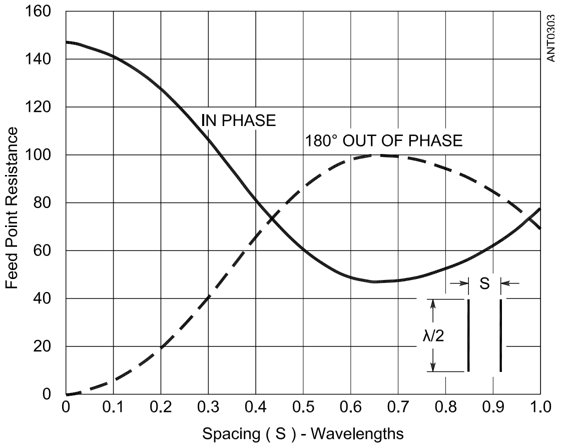

Fig 8—Feed-point resistance measured at the center of one element as a function of the spacing between two parallel ½-λ self-resonant antenna elements. For ground-mounted ¼-λ vertical elements, divide these resistances by two.

The dashed line in Fig 8, representing two antennas operated 180° out-of-phase (end-fire), cannot be interpreted quite so simply. The feed-point resistance decreases with spacing decreasing less than about 0.6 λ in this case. However, for the range of spacings considered, only when the spacing is 0.5 λ do the fields from the two antennas add up exactly in phase at a distant point in the favored direction. At smaller spacings the fields become increasingly out-of-phase, so the total field is less than the simple sum of the two. Smaller spacings thus decrease the gain at the same time that

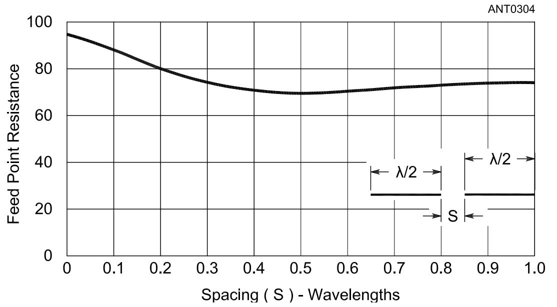

Fig 9—Feed-point resistance measured at the center of one element as a function of the spacing between the ends of two collinear self-resonant ½-λ antenna elements operated in phase.

the reduction in feed-point resistance is increasing it. For a lossless antenna, the gain goes through a maximum when the spacing is in the region of ⅛ λ.

The feed-point resistance curve for two collinear elements in-phase, **Fig 9**, shows that the feed-point resistance decreases and goes through a broad minimum in the region of 0.4 to 0.6-λ spacing between the adjacent ends of the antennas. As the minimum is not significantly less than the feed-point resistance of an isolated antenna, the gain will not exceed the gain calculated on the basis of uncoupled antennas. That is, the best that two collinear elements will give, even with optimum spacing, is a power gain of about 2 (3 dB). When the separation between the ends is very small—the usual method of operation—the gain is reduced.

GAIN AND ARRAY DIMENSIONS

The gain of an array is principally determined by the dimensions of the array, so long as there are a minimum number of elements. A good example of this is the relationship between boom length, gain and number of elements for an array such as a Yagi. **Fig 10** compares the gain versus boom length for Yagis with different numbers of elements. For given number of elements, notice that the gain increases as the boom length increases, up to a maximum. Beyond this point, longer boom lengths result in less gain for a given number of elements. This observation does not mean that it is always desirable to use only the minimum number of elements. Other considerations of array performance, such as front-to-back ratio, minor lobe amplitudes or operating bandwidth, may make it advantageous to use more than the minimum number of elements for a given array length. A specific example of this is presented in a later section in a comparison between a half-square, a bobtail curtain and a Bruce array.

In a broadside array the gain is a function of both the length and width of the array. The gain can be increased by adding more elements (with additional spacing) or by using longer elements (>λ/2), although the use of longer elements requires proper attention to current phase in the elements. In general, in a broadside array the element spacing that gives maximum gain for a minimum number of elements, is in the range of 0.5 to 0.7 λ. Broadside arrays with elements spaced for maximum gain will frequently have significant side lobes and associated narrowing of the main lobe beamwidth. Side lobes can be reduced by using more than the minimum number of elements, spaced closer than the maximum gain distance.

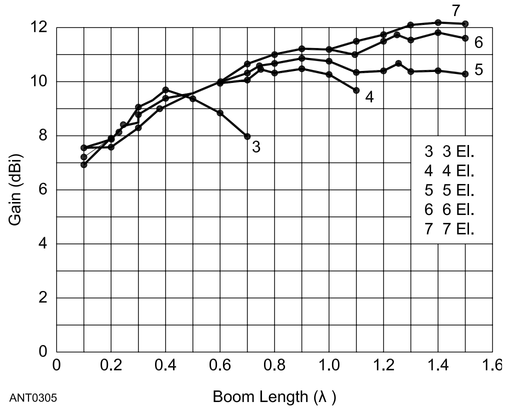

Fig 10—Yagi gain for 3, 4, 5, 6 and 7-element beams as a function of boom length. (From *Yagi Antenna Design*, J. Lawson, W2PV.)

Additional gain can be obtained by expanding the array into a third dimension. An example of this is the stacking of endfire arrays in a broadside configuration. In the case of stacked short endfire arrays, maximum gain occurs with spacings in the region of 0.5 to 0.7 λ. However, for longer higher-gain end-fire arrays, larger spacing is required to achieve maximum gain. This is important in VHF and UHF arrays, which often use long-boom Yagis.

PARASITIC ARRAYS

The foregoing applies to multi-element arrays of both types, driven and parasitic. However, there are special considerations for driven arrays that do not necessarily apply to parasitic arrays, and vice versa. Such considerations for Yagi and quad parasitic arrays are presented in Chapters 11 and 12. The remainder of this chapter is devoted to driven arrays.

Driven Arrays

Driven arrays in general are either broadside or end-fire, and may consist of collinear elements, parallel elements, or a combination of both. From a practical standpoint, the maximum number of usable elements depends on the frequency and the space available for the antenna. Fairly elaborate arrays, using as many as 16 or even 32 elements, can be installed in a rather small space when the operating frequency is in the VHF range, and more at UHF. At lower frequencies the construction of antennas with a large number of elements is impractical for most amateurs.

Of course the simplest of driven arrays is one with just two elements. If the elements are collinear, they are always fed in-phase. The effects of mutual coupling are not great, as illustrated in Fig 9. Therefore, feeding power to each element in the presence of the other presents no significant problems. This may not be the case when the elements are parallel to each other. However, because the combination of spacing and phasing arrangements for parallel elements is infinite, the number of possible radiation patterns is endless.

This is illustrated in **Fig 11**. When the elements are fed in-phase, a broadside pattern always results. At spacings of less than ⅝ λ with the elements fed 180° out-of-phase, an end-fire pattern always results. With intermediate amounts of phase difference, the results cannot be so simply stated. Patterns evolve that are not symmetrical in all four quadrants.

Because of the effects of mutual coupling between the two driven elements, for a given power input greater or lesser currents will flow in each element with changes in spacing and phasing, as described earlier. This, in turn, affects the gain of the array in a way that cannot be shown merely by plotting the *shapes* of the patterns, as has been done in Fig 11. Therefore, supplemental gain information is also shown in Fig 11, adjacent to the pattern plot for each combination of spacing and phasing. The gain figures shown are referenced to a single element. For example, a pair of elements fed 90° apart at a spacing of λ/4 will have a gain in the direction of maximum radiation of 3.1 dB over a single element.

Current Distribution in Phased Arrays

In the plots of Fig 11, the two elements are assumed to be identical and self-resonant. In addition, currents of equal amplitude are assumed to be flowing at the feed point of each element, a condition that most often will not exist in practice without devoting special consideration to the feeder system. Such considerations are discussed in the next section of this chapter.

Most literature for radio amateurs concerning phased arrays is based on the assumption that if all elements in the array are identical, the *current distribution* in all the elements will be identical. This distribution is presumed to be that of a single, isolated element, or nearly sinusoidal. However, information published in the professional literature as early as the 1940s indicates the existence of dissimilar current distributions among the elements of phased arrays. (See Harrison and King references in the Bibliography.) Lewallen, in July 1990 *QST*, pointed out the causes and effects of dissimilar current distributions.

In essence, even though the two elements in a phased array may be identical and have exactly equal currents of the desired phase flowing *at the feed point*, the amplitude and phase relationships degenerate with departure from the feed point. This happens any time the phase relationship is not 0° or 180°. Thus, the field strengths produced at a distant point by the individual elements may differ. This is because the field from each element is determined by the *distribution* of the current, as well as its magnitude and phase.

The effects are minimal with shortened elements—verticals less than λ/4 or dipoles less than λ/2 long. The effects on radiation patterns begin to show at the above resonant lengths, and become profound with longer elements—λ/2 or longer verticals and 1 λ or longer center-fed elements. These effects are less pronounced with thin elements. The amplitude and phase degeneration takes place because the currents in the array elements are not sinusoidal. Even in two-element arrays with phasing of 0° or 180°, the currents are not sinusoidal, but in these two special cases they do remain identical.

The pattern plots of Fig 11 take element current distributions into account. The visible results of dissimilar distributions are incomplete nulls in some patterns and the development of very small minor lobes in others. For example, the pattern for a phased array with 90° spacing and 90° phasing has traditionally been published in amateur literature as a cardioid with a perfect null in the rear direction. Fig 11, calculated for 7.15-MHz self-resonant dipoles of #12 wire in free space, shows a minor lobe at the rear and only a 33-dB front-to-back ratio.

It is characteristic of broadside arrays that the power gain is proportional to the length of the array but is substantially independent of the number of elements used, provided the optimum element spacing is not exceeded. This means, for example, that a five-element array and a six-element array will have the same gain, provided the elements in both are spaced so the overall array length is the same. Although this principle is seldom used for the purpose of reducing the number of elements because of complications introduced in feeding power to each element in the proper phase, it does illustrate the fact that there is nothing to be gained, in terms of more gain, by increasing the number of elements if the space occupied by the antenna is not increased proportionally.

Generally speaking, the maximum gain in the smallest linear dimensions will result when the antenna combines both broadside and end-fire directivity and uses both parallel and collinear elements. In this way the antenna is spread over a greater volume of space, which has the same effect as extending its length to a much greater extent in one linear direction.

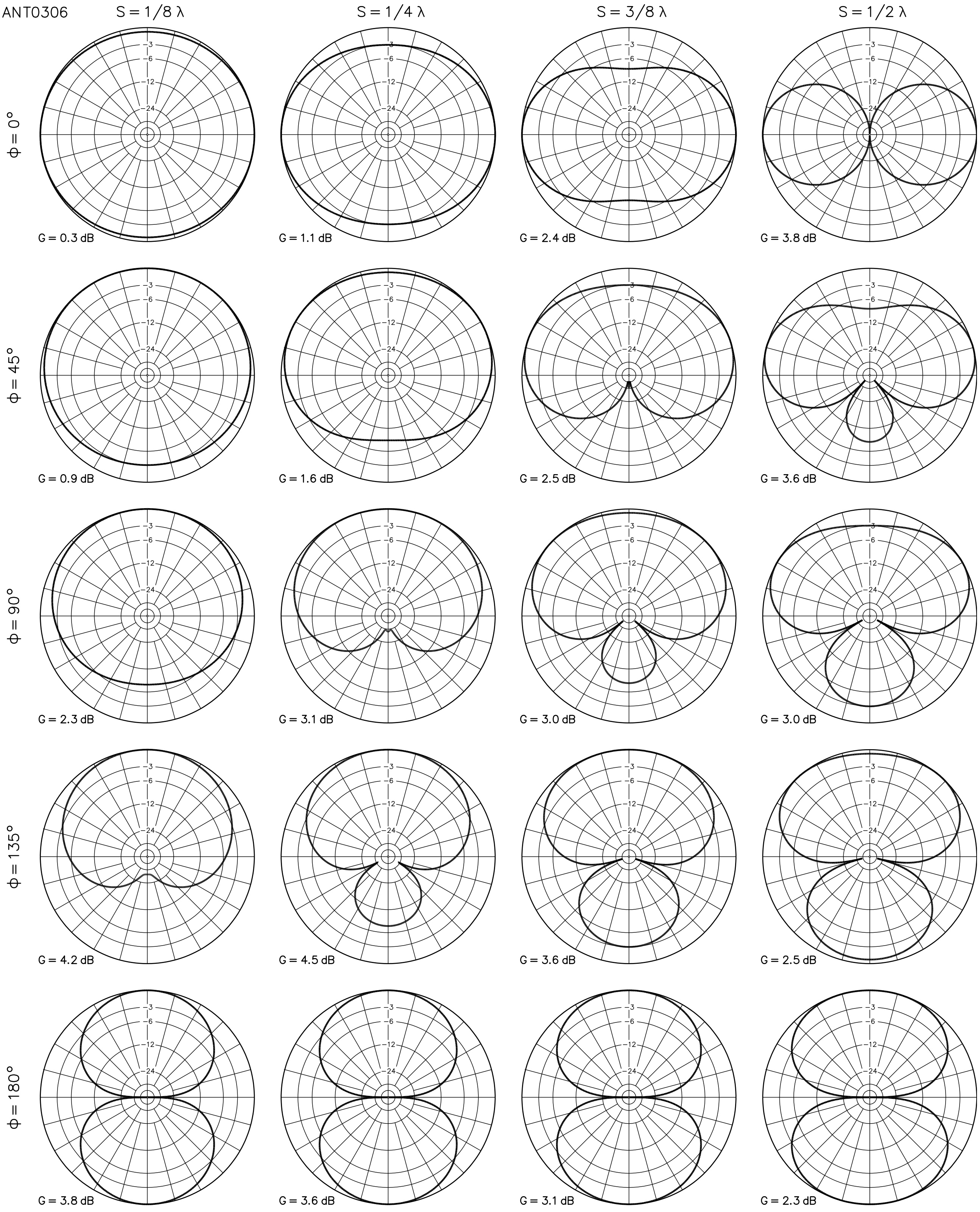

Fig 11—H-plane patterns of two identical parallel driven elements, spaced and phased as indicated (S = spacing, φ = phasing). The elements are aligned with the vertical (0°-180°) axis, and the element nearer the 0° direction (top of page) is of lagging phase at angles other than 0°. The two elements are assumed to be thin and self-resonant, with equal-amplitude currents flowing at the feed point. See text regarding current distributions. The gain figure associated with

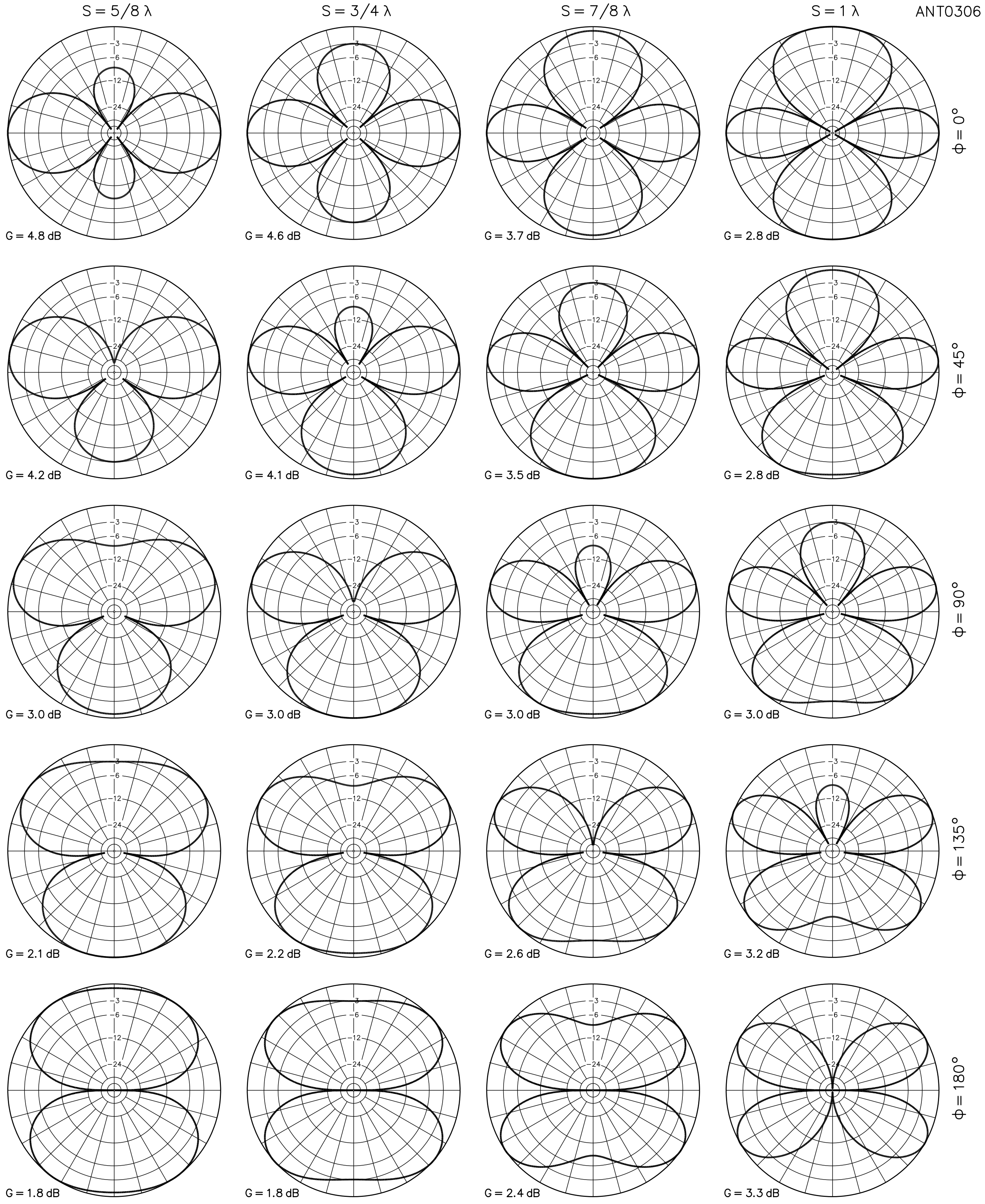

each pattern indicates that of the array over a single element. The plots represent the horizontal or azimuth pattern at a 0° elevation angle of two ¼-λ vertical elements over a perfect conductor, or the free-space vertical or elevation pattern of two horizontal ½-λ elements when viewed on end, with one element above the other. (Patterns computed with *ELNEC*—see Bibliography.)

Phased Array Techniques

Phased antenna arrays have become increasingly popular for amateur use, particularly on the lower frequency bands, where they provide one of the few practical methods to obtain substantial gain and directivity. This section on phased-array techniques was written by Roy Lewallen, W7EL.

The operation and limitations of phased arrays, how to design feed systems to make them work properly and how to make necessary tests and adjustments are discussed in the pages that follow. The examples deal primarily with vertical HF arrays, but the principles apply to VHF/UHF arrays and arrays made from other element types as well.

OVERVIEW

Much of this chapter is devoted to techniques for feeding phased arrays. Many people who have a limited acquaintance with phased array techniques believe this is a simple problem, consisting only of connecting array elements through "phasing lines" consisting of transmission lines of the desired electrical lengths. Unfortunately, except for a very few special cases, this approach won't achieve the desired array pattern.

Other proposed universal solutions, such as hybrid couplers or Wilkinson or other power dividers, also usually fail to achieve the necessary phasing. These approaches sometimes produce—often more by accident than design—results good enough to mislead the user into believing that the simple approach is working as planned. Confusion can result when an approach fails to work in different circumstances. This section will explain why the simple solutions don't work as often thought, and how to design feed systems that do consistently produce the desired results.

Very briefly, the reason why the simple phasing-line approach fails is that the delay of current or voltage in a transmission line equals the line's electrical length only if the line is terminated in its characteristic impedance. And in phased arrays, element feed-point impedances are profoundly affected by mutual coupling.

Consequently, even if each element has the correct impedance when isolated, it won't when all elements are excited. Furthermore, transmission lines that are not terminated in their characteristic impedance will transform both the voltage and current magnitude. The net result is that the array elements will have neither the correct magnitudes nor phases of current necessary for proper operation except in a few special cases. This isn't a minor effect of concern only to perfectionists, but often a major one that causes significant pattern distortion and poor or mislocated nulls. The problem is examined in greater depth later.

Power dividers and hybrid couplers also fail to achieve the desired result for different reasons, which will be discussed below, although in one common application hybrid couplers fortuitously provide results that are acceptable to many users. This chapter will show how to design array feed systems that *will* produce predicted element currents and array patterns.

Various *EZNEC* models are provided to illustrate concepts presented in this chapter. They can all be viewed with the *EZNEC-ARRL* software furnished on the CD included with this book. Step-by-step instructions for the examples are given in **Appendix A**.

FUNDAMENTALS OF PHASED ARRAYS

The performance of a phased array is determined by several factors. Most significant among these are the characteristics of a single element, reinforcement or cancellation of the fields from the elements and the effects of mutual coupling. To understand the operation of phased arrays, it is first necessary to understand the operation of a single antenna element.

Of primary importance is the strength of the field produced by the element. The field radiated from a linear (straight) element, such as a dipole or vertical monopole, is proportional to the sum of the elementary currents flowing in each part of the antenna element. For this discussion it is important to understand what determines the current in a single element.

The amount of current flowing at the base of a ground mounted vertical or ground-plane antenna is given by the familiar formula

$$I = \sqrt{\frac{P}{R}} \qquad \text{(Eq 2)}$$

where

P is the power supplied to the antenna

R is the feed-point resistance.

R consists of two parts, the loss resistance and the radiation resistance. The loss resistance, R_L, includes losses in the conductor, in the matching and loading components and dominantly (in the case of ground-mounted verticals) in ground losses. The power "dissipated" in the radiation resistance, R_R, is actually the power that is radiated, so maximizing the power dissipated by the radiation resistance is desirable. However, the power dissipated in the loss resistance truly is lost as heat, so resistive losses should be made as small as possible.

The radiation resistance of an element can be derived from electromagnetic field theory, being a function of antenna length, diameter and geometry. Graphs of radiation resistance versus antenna length are given in Chapter 2. The radiation resistance of a thin resonant λ/4 ground-mounted vertical is about 36 Ω. A resonant λ/2 dipole in free space has a radiation resistance of twice this amount, about 73 Ω. Reducing the antenna lengths by one half drops the radiation resistances to approximately 7 and 14 Ω, respectively.

The radiation resistance of a large variety of antennas can easily be determined by using *EZNEC-ARRL*, which is included on the CD in the back of this book. The radiation

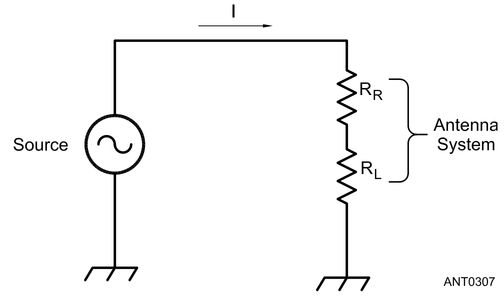

Fig 12—Simplified equivalent circuit for a single-element resonant antenna. R_R represents the radiation resistance, and R_L the ohmic losses in the total antenna system.

resistance is simply the feed-point resistance (the resistive part of the feed-point impedance) when all losses have been set to zero.

Radiation Efficiency

To generate a stronger field from a given radiator, it is necessary to increase the power P (the brute-force solution), decrease the loss resistance R_L (by putting in a more elaborate ground system for a vertical, for instance) or to somehow decrease the radiation resistance R_R so more current will flow with a given power input. This can be seen by expanding the formula for base current as

$$I = \sqrt{\frac{P}{R_R + R_L}} \quad \text{(Eq 3)}$$

Splitting the feed-point resistance into components R_R and R_L easily leads to an understanding of element efficiency. The efficiency of an element is the proportion of the total power that is actually radiated. The roles of R_R and R_L in determining efficiency can be seen by analyzing a simple equivalent circuit, shown in **Fig 12**.

The power dissipated in R_R (the radiated power) equals I^2R_R. The total power supplied to the antenna system is

$$P = I^2 (R_R + R_L) \quad \text{(Eq 4)}$$

so the efficiency (the fraction of supplied power that is actually radiated) is

$$\text{Eff} = \frac{I^2 R_R}{I^2 (R_R + R_L)} = \frac{R_R}{R_R + R_L} \quad \text{(Eq 5)}$$

Efficiency is frequently expressed in percent, but expressing it in decibels relative to a 100%-efficient radiator gives a better idea of what to expect in the way of signal strength. The field strength of an element relative to a lossless but otherwise identical element, in dB, is

$$\text{FSG} = 10 \log \frac{R_R}{R_R + R_L} \quad \text{(Eq 6)}$$

where FSG = field strength gain, dB.

For example, information presented by Sevick in March 1973 *QST* shows that a λ/4 ground-mounted vertical antenna with four 0.2-λ radials has a feed-point resistance of about 65 Ω (see the Bibliography at the end of this chapter). The efficiency of such a system is 36/65 = 55.4%. It is rather disheartening to think that, of 100 W fed to the antenna, only 55 W is being radiated, with the remainder literally warming up the ground. Yet the signal will be only 10 log (36/65) = –2.57 dB relative to the same vertical with a perfect ground system. In view of this information, trading a small reduction in signal strength for lower cost and greater simplicity may become an attractive consideration.

So far, only the current at the base of a resonant antenna has been discussed, but the field is proportional to the sum of currents in each tiny part of the antenna. The field is a function of not only the magnitude of current flowing at the feed point, but also the distribution of current along the radiator and the length of the radiator. Nothing can be done at the feed point to change the current distribution, so for a given element the field strength is proportional to the feed point current. However, changing the radiator length or loading it at some point other than the feed point will change the current distribution.

More information on shortened or loaded radiators may be found in Chapters 2 and 6 and in the Bibliography references of this chapter. The current distribution is also changed by mutual coupling to other array elements, although for most arrays this has only a minor effect on the pattern. This is discussed later in more detail. A few other important facts follow.

1) If there is no loss, the field from even an infinitesimally short radiator is less than ½ dB weaker than the field from a half-wave dipole or quarter-wave vertical. Without loss, all the supplied power is radiated regardless of the antenna length, so the only factor influencing gain is the slight difference in the patterns of very short and λ/2 antennas. The small pattern difference arises from different current distributions. A short antenna has a very low radiation resistance, resulting in a heavy current flow over its short length. In the absence of loss, this generates a field strength comparable to that of a longer antenna. Where loss is present—that is, in practical antennas—shorter radiators usually don't do so well, since the low radiation resistance leads to lower efficiency for a given loss resistance. If care is taken, reasonably short antennas can achieve good efficiency.

2) Care has to be taken in calculating the efficiency of folded antennas. (See Chapter 6.) Folding transforms both the radiation resistance and loss resistance by the same factor, so their ratio and therefore the efficiency remains the same. It's easy to show that in a ground-mounted vertical array, folding reduces the current flowing from the feed line to the ground system by a factor of two due to the impedance transformation. However, the folded antenna has an additional connection to ground, which also carries half the original ground current. The result is that the same amount of current flows

into the ground system, whether unfolded or folded, resulting in the same ground system loss. Analyses purporting to show otherwise invariably transform the radiation resistance but neglect to also transform the loss resistance and reach an incorrect conclusion.

3) The current flowing in an element with a given power input can be increased or decreased by mutual coupling to other elements. The effect is equivalent to changing the element radiation resistance. Mutual coupling is sometimes thought of as a minor effect, but often it is not minor!

Field Reinforcement and Cancellation

The mechanism by which phased arrays produce gain, and the role of mutual coupling in determining gain, were covered earlier in this chapter. One important point that can't be emphasized enough is that all antennas must abide by the law of *conservation of energy*. No antenna can radiate more power than supplied to it. The total amount of power it radiates is the amount it's supplied, less the amount lost as heat. This is true of all antennas, from the smallest "rubber ducky" to the most gigantic array.

Gain

Gain is strictly a relative measure, so the term is completely meaningless unless accompanied by a statement of just what it is relative to. One useful measure for phased array gain is *gain relative to a single similar element*. This is the increase in signal strength that would be obtained by replacing a single element by an array made from elements just like it. In some instances, such as investigating what happens to array performance when *all* elements become more lossy, it's useful to state gain relative to a more absolute, although unattainable standard: a lossless element.

And the most universal reference for gain is another unattainable standard, the *isotropic radiator*. This fictional antenna radiates absolutely equally in all directions. It's very useful because the field strength resulting from any power input is readily calculated, so if the gain relative to this standard is known, the field strength is also known for any radiated power. Gain relative to this reference is referred to as dBi, and it's the standard used by most modeling programs including *EZNEC-ARRL*. To find the gain of an array relative to a single element or other reference antenna such as a dipole, model both the array and the single element or other reference antenna in the same environment and subtract their dBi gains. Don't rely on some assumption about the gain of a single element—many people assume values that can be very wrong.

Nulls

Pattern nulls are very often more important to users of phased arrays than gain because of their importance in reducing both man-made and natural interference when receiving. Consequently, a good deal of emphasis is, and should be, placed on achieving good pattern nulls. Unfortunately, good nulls are much more difficult to achieve than gain and they are much more sensitive to array and feed-system imperfections.

As an illustration, consider two elements that each produce a field strength of, say, exactly 1 millivolt per meter (mV/m) at some distance many wavelengths from the array. In the direction in which the fields from the elements are in-phase, a total field of 2 mV/m results. In the direction in which they're out-of-phase, zero field results. The ratio of maximum to minimum field strength of this array is 2/0, or infinity.

Now suppose, instead, that one field is 10% high and the other 10% low—1.1 and 0.9 mV/m, respectively. In the forward direction, the field strength is still 2 mV/m, but in the canceling direction, the field will be 0.2 mV/m. The front-to-back ratio has dropped from infinity to 2/0.2, or 20 dB. (Actually, slightly more power is required to redistribute the field strengths this way, so the forward gain is reduced—but by only a small amount, less than 0.1 dB.) For most arrays, unequal fields from the elements have a minor effect on forward gain, but a major effect on pattern nulls. This is illustrated by ***EZNEC* Example: Nulls** in Appendix A.

Even with perfect current balance, deep nulls aren't assured. **Fig 13** shows the minimum spacing required for total field reinforcement or cancellation. If the element spacing isn't adequate, there may be no direction in which the fields are completely out-of-phase (see curve B of Fig 13). Slight physical and environmental differences between elements will invariably affect null depths, and null depths will also vary with elevation angle.

However, a properly designed and fed array can produce very impressive nulls. The key to producing good nulls, like producing gain, is controlling the strengths and phases of the fields from the elements. Just how to accomplish that is the subject of most of the remainder of this section. But be sure to keep in mind that producing good nulls is generally a much more difficult task than producing approximately the predicted gain.

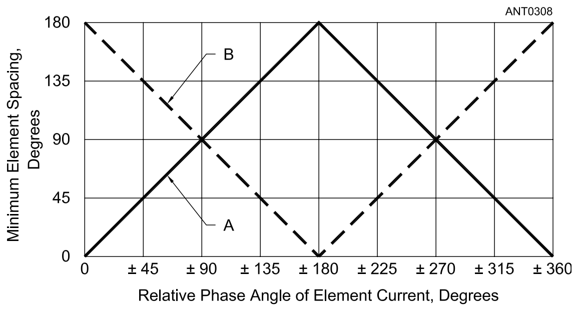

Fig 13—Minimum element spacing required for total field reinforcement, curve A, or total field cancellation, curve B. Total cancellation results in pattern nulls in one or more directions. Total reinforcement does not necessarily mean there is gain over a single element, as the effects of loss and mutual coupling must also be considered.

Mutual Coupling

Mutual coupling was discussed briefly earlier in this chapter. Because it has an important and profound effect on both the performance and feed system design of phased arrays, it will be covered in greater depth here.

Mutual coupling refers to the effects which the elements in an array have on each other. Mutual coupling can occur intentionally or entirely unintentionally. People with multiple antennas on a small lot (or car top) often discover that a better description of their system is a single antenna with multiple feed points. Current is induced in conductors in various antennas by mutual coupling, causing them to act like parasitic elements, which re-radiate and distort the antenna's pattern. The effects of mutual coupling are present whether or not the elements are driven.

Suppose that two driven elements are many wavelengths from each other. Each has some voltage and current at its feed point. For each element, the ratio of this voltage to current is the element self-impedance. If the elements are brought close to each other, the current in each element will change in magnitude and phase because of coupling with the field from the other element. The field from the first element changes the current in the second. This changes the field from the second, which alters the current in the first, and so forth until an equilibrium condition is reached in which the currents in all elements (hence, their fields) are totally interdependent.

The feed-point impedances of all elements also are changed from their values when far apart, and all are dependent on each other. In a driven array, the changes in feed-point impedances can cause additional changes in element currents, because the operation of many feed systems depends on the element feed-point impedances. Significant mutual coupling occurs at spacings as great as a wavelength or more.

Connecting the elements to a feed system to form a driven array does not eliminate the effects of mutual coupling. In fact, in many driven arrays the mutual coupling has a greater effect on antenna operation than the feed system does. All feed-system designs must account for the impedance changes caused by mutual coupling if the desired current balance and phasing are to be achieved.

Several general statements can be made regarding the effects of mutual coupling on phased-array systems.

1) The resistances and reactances of all elements of an array generally will be substantially different from the values when the elements are isolated (that is, very distant from other elements).

2) If the elements of a two-element array are identical and have equal currents that are in-phase or 180° out-of-phase, the feed-point impedances of the two elements will be equal. But they will be different than for an isolated element. If the two elements are part of a larger array, their impedances can be very different from each other.

3) If the elements of a two-element array have currents that are neither in-phase (0°) nor out-of-phase (180°), their feed-point impedances will not be equal. The difference will be considerable in typical amateur arrays.

4) The feed-point resistances of the elements in a closely spaced, 180° out-of-phase array will be very low, resulting in poor efficiency due to ohmic losses unless care is taken to minimize loss. This is also true for any other closely spaced array with significant predicted gain.

It's essential to realize that this is *not* a minor effect and one that can be overlooked or ignored. See ***EZNEC* Example—Mutual Coupling** in Appendix A for an illustration of these phenomena.

Loss Resistance, Mutual Coupling and Antenna Gain

Loss reduces the effects of mutual coupling because the feed-point impedance change resulting from mutual coupling is effectively in series with loss resistance. If the loss is great enough, two important results occur. First, the feed-point impedance becomes independent of the presence of nearby current-carrying elements. This greatly simplifies feed system design—the simple "phasing-line" or hybrid-coupler feed system described below is adequate *provided that all elements are physically identical and the feed point of each element is matched to the* Z_0 *of the feed line and, if used, the hybrid coupler.*

The impedance matching restrictions are necessary to insure that the phasing line or hybrid coupler performs as expected. Identical elements are needed so that equal element currents will result in equal fields from the elements.

In the absence of mutual coupling effects, the maximum gain of an array of identical elements relative to a single (similarly lossy) element is simply 10 log(N), where N is the number of elements—providing that spacing is adequate for the fields to fully reinforce in some direction. If spacing is less, maximum gain will also be less. Of course, the array gain relative to a single *lossless* element will be very low, most likely a sizeable negative number when expressed in dB. So intentionally introducing loss isn't a wise idea for a transmitting array. It is sometimes an advantageous thing to do for a receiving array, however, as explained in the following section.

High-gain close-spaced arrays, such as the W8JK phased array (see *EZNEC-ARRL* example file **ARRL_W8JK.EZ** and accompanying Antenna Notes file), and most parasitic arrays depend heavily on mutual coupling to achieve their gain. Introduction of any loss to these arrays, which reduces the mutual coupling effects, has a profound effect on the gain. Consequently, parasitic or close-spaced driven arrays often produce disappointing results when made from grounded vertical elements unless each has a fairly elaborate (and therefore very low-loss) ground system.

If you place two low-loss elements very close together and feed them in-phase, mutual coupling reduces the array gain to essentially that of a single element, so there's no advantage to this configuration over a single element. However, if you have a single lossy element, for example a short vertical having a relatively poor ground system, you can improve the gain by up to 3 dB by adding a second, close spaced, element and ground system and feeding the two in-phase. Another way to look at this technique is that you're putting two equal ground system resistances in parallel, which effectively cuts the loss in half. The gain you can realize in practice depends on such things as the ground system overlap, but it might be a practical way to improve transmitting array performance in some situations.

FEEDING PHASED ARRAYS

The previous section explains why the fields from the elements must be very close to the ratios required by the array design. Since the field strengths are proportional to the currents in the elements, controlling the fields requires controlling the element currents. Since the desired current ratio is 1:1 for virtually all two-element and for most (but not all) larger amateur arrays, special attention is paid to methods of assuring equal element currents. But we will examine other current ratios also.

The Role of Element Currents

The field from a conductor is proportional to the current flowing on it. So if we're to control the relative strengths and phases of the fields from the elements, we have to control their currents. We usually do this by controlling the currents at the element feed points. But because the field from an element depends on the current everywhere along the element, elements having identical feed-point currents will produce different fields if they have different current distributions—that is, if the way the current varies along the lengths of the elements is different.

A previous section explained that mutual coupling alters the current distribution, so in many arrays the current distributions will be different on the elements and consequently the relationship between the overall fields won't be the same as that between the feed-point currents. Fortunately, this effect is relatively minor in thin, λ/4 monopole or λ/2 dipole elements. The most common arrays are made from elements in this category, so we can generally get very nearly the desired ratio of fields by effecting the same ratio of feed point currents. Exceptions are detailed immediately below.

Feed-point vs Element Current

For most antennas, environmental factors are likely to cause greater performance anomalies than current distribution differences, and both can be corrected with minor feed system adjustments. The difference between field and feed-point current ratios can become very significant, however, if the elements are very fat and/or close to λ/2 (monopole) or 1 λ (dipole) long. In those cases, most of the feed systems described here won't produce the desired field ratios without major adjustment or modification, except in the special cases of 2-element arrays with identical elements having feed point currents in-phase or 180° out-of-phase. In those special cases, the element current distributions are the same for the same reason the feed-point impedances are equal. This is explained later in the feed system sections.

To get an idea of just how large an element must be to disturb the pattern of an array with correct feed-point currents, a two-element cardioid array of quarter wave vertical elements was modeled at 10 MHz. With thin, 0.1-inch diameter elements, the front/back ratio was 35 dB, the very small reverse lobe caused by slightly unequal element current distributions. Increasing the element diameter to 20 inches decreased the front/back ratio to 20 dB. Returning the front/back ratio of the array of 20-inch elements to >35 dB required changing the feed-point current ratio from the nominal value of 1.0 at an angle of 90° to 0.88 at 83°.

The same array was first modeled with 0.1 inch diameter elements, where it has a front/back ratio of 35 dB, then the elements were lengthened. The front/back ratio dropped to 20 dB at an element length of 36 feet, or about 0.37 λ. In that case, adjustment of the feed-point current ratio to about 0.9 at about 83° restored a good front/back ratio.

In the discussion and development which follow, the assumption is made that the fields will be very nearly proportional to the feed-point currents. If the elements are fat or long enough to make this assumption untrue, some adjustment of feed-point current ratio will be necessary to achieve the desired pattern, particularly nulls. Most feed systems can be designed for any current ratio. Modeling will reveal the ratio required for the desired pattern, and then the feed system can be designed accordingly.

COMMON PHASED-ARRAY FEED SYSTEMS

This section will first describe several popular approaches to feeding phased arrays that often don't produce the desired results. It will describe why they don't work as well as hoped. It also briefly discusses systems that could be used, but that often aren't appropriate or optimum for amateur arrays.

This will be followed in the next section by detailed descriptions of array feed systems that *do* produce the predicted element current ratios and array patterns.

The "Phasing-Line" Approach

For an array to produce the desired pattern, the element currents must have the required magnitude and the required phase relationship. As explained above, this can generally be achieved well enough by causing the feed point currents to have that same relationship.

On the surface, this sounds easy—just make sure that the difference in electrical lengths of the feed lines to the elements equals the desired phase angle. Unfortunately, this approach doesn't necessarily achieve the desired result. The first problem is that the phase shift through the line is not equal to its electrical length. The current (or, for that matter, voltage) delay in a transmission line is equal to its electrical length in only a few special cases—cases which don't exist in most amateur arrays! The impedance of an element in an array is frequently very different from the impedance of an isolated element and the impedances of all the elements in an array can be different from each other.

See the ***EZNEC* Example—Mutual Coupling** in Appendix A for a graphic illustration of the effect of mutual coupling on feed-point impedance. Also look at the Four-Square array example in the **Phased Array Design Examples** section. The array in that example has one element with a *negative* feed-point resistance, if ground loss is low. Without mutual coupling, the resistance of that same element would be about 36 Ω plus ground loss.

Because of mutual coupling, the elements seldom provide a matched load for the element feed lines. The effect of mismatch on phase shift can be seen in **Fig 14**. Observe what happens to the phase of the current and voltage on a line terminated by a purely resistive impedance that is lower than the characteristic impedance of the line (Fig 14A). At a point 45° from the load the current has advanced less than 45°, and the voltage more than 45°. At 90° from the load both are advanced 90°. At 135° the current has advanced more and the voltage less than 135°. This apparent slowing down and speeding up of the current and voltage waves is caused by interference between the forward and reflected waves. It occurs on any line that is not terminated with a pure resistance equal to its characteristic impedance. If the load resistance is greater than the characteristic impedance of the line, as shown in Fig 14B, the voltage and current exchange angles. Adding reactance to the load causes additional phase shift. The *only cases in which the current (or voltage) delay is equal to the electrical length of the line are*

1) When the line is flat; that is, terminated in a purely resistive load equal to its characteristic impedance;

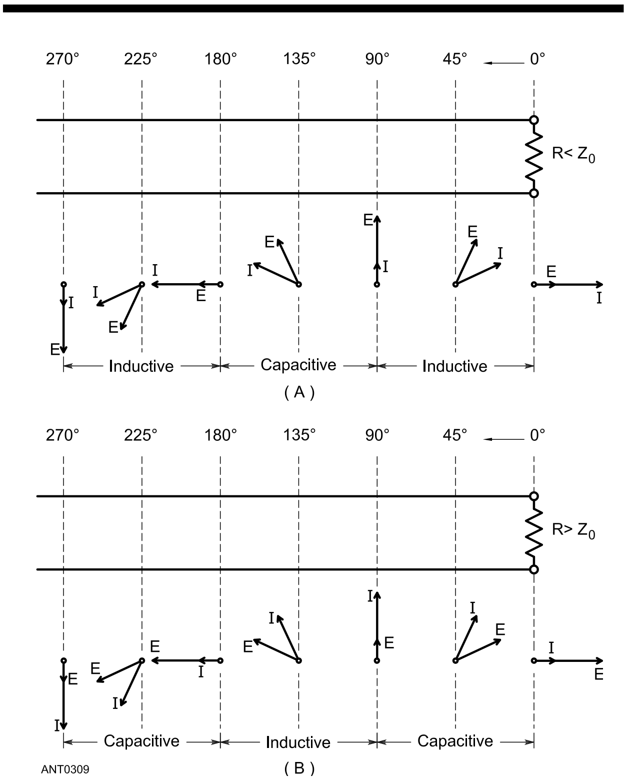

Fig 14—Resultant voltages and currents along a mismatched line. At A, R less than Z_0, and at B, R greater than Z_0.

2) When the line length is an integral number of half wavelengths;

3) When the line length is an odd number of quarter wavelengths and the load is purely resistive; and

4) When other specific lengths are used for specific load impedances.

Just how much phase error can be expected if two feed lines are simply hooked up to form an array? There is no simple answer. Some casually designed feed systems might deliver satisfactory results, but most will not. See the ***EZNEC* Example—"Phasing-Line" Feed** in Appendix A for the typical consequences of using this sort of feed system.

A second problem with simply connecting feed lines of different lengths to the elements is that the lines will change the *magnitudes* of the currents. The magnitude of the current (or voltage) out of a line does not equal the magnitude into that line, except in cases 1, 2 and 4 above. The feed systems presented later in this chapter assure currents that are correct in both magnitude and phase.

The elementary phasing-line approach *will* work in three very special but common situations. If the array consists of only two identical elements and those elements are fed in-phase, mutual coupling will modify the element impedances, but both will be modified exactly the same amount. Consequently, if the two elements are fed through equal-length transmission lines, the lines will transform and delay the currents by the same amount and result in equal, in-phase currents at the element feed points.

Similarly, an array of two identical elements fed 180º out-of-phase will have the same feed-point impedances and can be fed with two lines of any length so long as one line is an electrical half wavelength longer than the other. But this can't be extended to any two elements in a larger array, since mutual coupling to the other elements can result in different feed-point impedances. Methods will be described later which do assure a correct current ratio in this situation.

The third application in which the phasing-line approach works is in receiving arrays where the elements are very short in terms of wavelength and/or very lossy. In either of these cases, mutual coupling between elements is much less than an element's self-impedance. This allows the elements to be individually matched to the feed lines, with no significant change taking place when the elements are formed into an array. Under those conditions, the transmission lines can be matched and the lines used as simple delay lines with easily predictable phase shift and with no transformation of current or voltage magnitude other than cable loss. This is discussed in the later section on receiving antennas.

Many arrays *can* be correctly fed with a feed system consisting of only transmission lines, but the technique requires knowledge of the element feed-point impedances in a correctly fed array. Line lengths can then be computed that provide the correct ratio of currents into those particular load impedances. The line lengths generally differ by amount that's considerably different from the element phase angle difference, and appropriate line lengths can't always be found for all arrays. This technique is described more fully in the **"The Simplest Phased Array Feed System—That Works"** section later in the chapter and illustrated in the examples in **Phased Array Design Examples**.

The Wilkinson Divider

The *Wilkinson divider*, sometimes called the *Wilkinson power divider*, was once heavily promoted as a means to distribute power among the elements of a phased array. While it's a very useful device for other purposes, it won't produce the desired current ratios in antenna elements. In most phased arrays, element feed-point resistances are different and therefore require different amounts of power to achieve the desired equal magnitude currents. (See the section on mutual coupling above.) A Wilkinson divider is intended to deliver equal powers, not currents, to multiple loads. And it won't even do that when the load impedances are different.

The Hybrid Coupler

Hybrid couplers are promoted as solving the problem of achieving equal magnitude currents with a 90º phase difference between elements. Unfortunately, they provide equal magnitude, quadrature (90° phased) currents only when the load impedances are equal and correct. And this simply isn't true of arrays with quadrature-fed elements, except for arrays consisting of short and/or lossy elements, usually suitable only for receiving. In those arrays, the hybrid coupler can be useful for the same reasons as the phasing-line approach, discussed in an earlier section.

At the time of this writing, hybrid couplers are being used in a popular commercial product for phasing at least one type of array. Reports are that it works satisfactorily. However, this shouldn't be taken as proof that the hybrid coupler forces equal magnitude 90º phased currents in loads of arbitrary impedances. No passive network, including the hybrid coupler, is capable of doing that. See **The "Magic Bullet"** below for more information.

Large Array Feed Systems

The author once worked on a radar system where the transmit array consisted of over 5,000 separate dipole elements and the receive array over 4,000 pairs of crossed dipoles, all over a metal reflecting plane, which was the sloping side of a 140 foot high building. In such large arrays, each element is in essentially the same environment as every other element except near the array edges, so almost all elements have very nearly the same feed-point impedance. While producing the phase shifts and magnitude tapers is a considerable mathematical challenge, the problem of unequal element feed-point impedances can largely be ignored. Consequently, feed methods for these large arrays are generally not suitable for typical amateur arrays of a few elements.

The Broadcast Approach

Networks can be designed to transform the element base impedances from their values in an excited array to, say, 50 Ω resistive. Then another network can be inserted at the junction of the feed lines to properly divide the power among the elements (not necessarily equally!). And finally, additional networks must be added to correct for the phase shifts and magnitude transformations of the other networks. This general approach is used by the broadcast industry, in installations that are typically adjusted only once for a particular frequency and pattern.

Although this technique can be used to correctly feed any type of array, design is difficult and adjustment is tedious, since all adjustments interact. When the relative currents and phasings are adjusted, the feed-point impedances change, which in turn affect the element currents and phasings, and so on. A further disadvantage of using this method is that switching the array direction is generally impossible. Information on applying this technique to amateur arrays can be found in Paul Lee's book, listed in the Bibliography.

The "Magic Bullet"

For about 15 years prior to this writing, this *Antenna Book* section has contained a specification for a hypothetical passive circuit that would provide equal-magnitude, 90° phased currents into two loads without respect to the load impedances. This would be a circuit to which we could connect any two elements and guarantee that they'd have exactly the correct currents.

Along with the specifcation was a request that any person knowing of such a circuit would contact the author (Roy Lewallen, W7EL) or the book editors. During this time, only a single response was received, in 1996. It was from Kevin Schmidt, W9CF, who has formulated a mathematical proof that such a circuit—in fact, one resulting in any relative phase other than 0º or 180º—*cannot exist* if restricted to reciprocal elements. (That is, it can't exist unless directional components such as ferrite circulators are used.) This means that, in order to design a network to feed elements at any other phase angle other than 0 or 180º, we *must* know the impedance of at least one element, and correct feed system operation depends on that impedance. There's no way around this requirement. At the time of this writing, Schmidt's proof can be found at **fermi.la.asu.edu/w9cf/articles/magic/index.html**.

RECOMMENDED FEED METHODS FOR AMATEUR ARRAYS

The following feed methods are able to produce element feed-point currents having a desired magnitude and phase relationship, resulting in desirable and predictable patterns. Most methods require knowing the feed-point impedance of one or more array elements *when the array element currents are the correct values*. This isn't possible to measure directly, because if the element currents were correct, the feed system would already be working properly and no further design would be necessary.

By far the easiest way to get this information, if possible, is by computer modeling. Modeling programs such as *EZNEC-ARRL* (included on the CD in the back of this book) allow you to construct an ideal array with perfect element currents, then look at the resulting feed-point impedances. Because of its simplicity and versatility, this approach is highly recommended and it's the one used for the array design examples in this chapter.

Some feed systems allow adjustment, so even an approximate result provides an adequate starting point on which to base the feed-system design. There are several other alternatives to computer modeling. One is to first eliminate the effects of coupling of the element to be measured from all other elements, usually by open circuiting the feed points of the other elements. Then the feed-point impedance of the element is measured. Next, the impedance change due to mutual coupling from all other elements has to be calculated, based on the intended currents in the other elements, their lengths and their distances from the element being measured. Mutual impedance (which is not the same as the impedance *change* due to mutual coupling) between each pair of elements must be known for this calculation and it can be determined by measurement, calculation or from a graph.

The latter two methods are possible only for the simplest element types and measurement is very difficult to do accurately because it involves resolving very small differences between two relatively large values. Accuracy of a calculated result will be reduced if any elements are relatively fat (that is, they have a large diameter, because this impacts the current distribution) or they aren't perfectly straight and parallel.

So the only situations where you're likely to get good results from approaches other than modeling are the very easiest ones to model! And modeling allows determination of the feed-point impedances of many antennas that areimpossible to calculate by manual or graphical methods. Therefore, the manual approach isn't discussed or used here. Appendix B, on the CD, contains equations and manual techniques from previous editions of *The ARRL Antenna Book,* for those who are interested. You can also find a great deal of additional information in many of the texts listed in the Bibliography, particularly Jasik and Johnson.

Current Forcing with λ/4 Lines—Elements In-Phase or 180° Out-of-Phase

The feed method introduced here has been used in its simplest form to feed television receiving antennas and other arrays, as presented by Jasik, pages 2-12 and 24-10 or Johnson, on his page 2-14. However, until first presented in *The ARRL Antenna Book*, this feed method was not widely applied to amateur arrays.

The method takes advantage of an interesting property of λ/4 transmission lines. (All references to lengths of lines are electrical length and lines are assumed to have negligible loss.) See **Fig 15**. The magnitude of the *current out* of a λ/4 transmission line is equal to the *input voltage* divided by the characteristic impedance of the line. This is independent of the load impedance. In addition, the phase of the output current lags the phase of the input voltage by 90°, also independent of the load impedance. These properties can be used to advantage in feeding arrays with certain phase angles between elements.

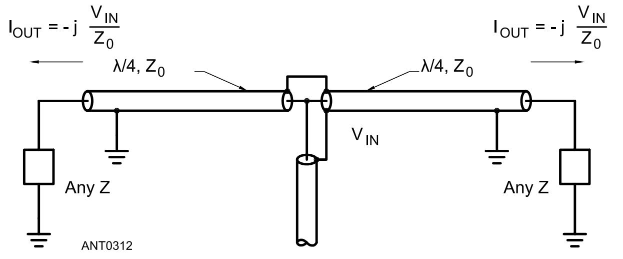
$I_{OUT} = -j \frac{V_{IN}}{Z_0}$
λ/4, Z_0
λ/4, Z_0
$I_{OUT} = -j \frac{V_{IN}}{Z_0}$
V_{IN}
Any Z
Any Z
ANT0312

Fig 15—A useful property of λ/4 transmission lines; see text. This property is utilized in the "current-forcing" method of feeding an array of coupled elements.

If any number of loads are connected to a common driving point through λ/4 lines of equal impedance, the currents in the loads will be *forced* to be equal and in-phase, regardless of the load impedances. So any number of in-phase elements can be correctly fed using this method, regardless of how their impedances might have been changed by mutual coupling. Arrays that require unequal currents can be fed through λ/4 lines of unequal impedances to achieve other current ratios.

The properties of λ/2 lines also are useful. Since the current out of a λ/2 line equals the input current shifted 180°, regardless of the load impedance, any number of half wavelengths of line may be added to the basic λ/4, and the current and phase forcing property will be preserved. For example, if one element is fed through a λ/4 line and another element is fed from the same point through a 3λ/4 line of the same characteristic impedance, the currents in the two elements will be forced to be equal in magnitude and 180° out-of-phase, regardless of the feed-point impedances of the elements.

If an array of two, and only two, identical elements is fed in-phase or 180° out-of-phase with equal magnitude currents, both elements have the same feed-point impedance. The reason is that each element sees exactly the same thing when looking at the other. In an in-phase array, each sees another element with an identical current; in an out-of-phase array, each sees another element with an equal magnitude current that's 180° out-of-phase, the same distance away in both cases. This isn't true in something like a 90° fed array, where one element sees another with a current leading its current by 90°, while the other sees another element with a lagging current.

With arrays fed in-phase or 180° out-of-phase, feeding the elements through equal lengths of feed line (in-phase) or lengths differing by 180° (out-of-phase) will lead to the correct current magnitude ratio and phase difference, regardless of the line length and regardless of how much the element feed-point impedances depart from the lines' Z_0.

Unless the feed-point impedances equal the line Z_0 or the lines are an integral number of half wavelengths long, the magnitudes of the currents out of the lines will not be equal to the input magnitudes, and the phase will not be shifted an amount equal to the electrical lengths of the lines. But both lines will produce the same transformation and phase shift because their load impedances are equal, resulting in a properly fed array. In practice, however, feed-point impedances of elements frequently are different even in these arrays, because of such things as different ground systems (for ground mounted vertical elements), proximity to buildings or other antennas, or different heights above ground (for horizontal or elevated vertical elements).

In many larger arrays, two or more elements must be fed either in-phase or out-of-phase with equal currents, but coupling to other elements can cause their impedances to change unequally—sometimes extremely so. Using the current-forcing method allows the feed system designer to ignore all these effects, while guaranteeing equal and correctly phased currents in any combination and number of 0° and 180° fed elements.

This method is used to develop feed systems for the Four Square and 4-element rectangular arrays in the **Practical Array Design** section. The front and rear elements of a Four-Square antenna provide a good example of elements having very different feed-point impedances that are forced to have equal out-of-phase currents.

"The Simplest Phased Array Feed System—That Works"

This is the title of an article in *The ARRL Antenna Compendium, Vol 2*, which describes how arrays can be fed with a feed system consisting of only transmission lines. (The article is available for viewing at **eznec.com/Amateur/Articles/Simpfeed.pdf** and is also on the CD included in the back of this book, along with the program *Arrayfeed1*, which solves the equations presented in the article.)

As explained earlier in the Phasing Line section, this method requires knowing what the element feed-point impedances will be in a correctly fed array. Feed-line lengths can then be computed, for most but not all arrays. These lengths will produce the desired current ratio in array elements that do present those feed-point impedances. If you know the load impedances connected to transmission lines whose inputs are connected to a common source, it's simple to calculate the resulting load currents for any transmission line lengths. However, the reverse problem is much more difficult; that is, given the load impedances and desired currents to calculate the required cable lengths.

One way to solve the problem is to choose some feed-line lengths, solve for the currents, examine the answer, adjust the feed-line lengths, and try again until the desired currents are obtained. The author used this iterative approach, using first a programmable calculator and later a computer, for some time before developing a direct way of solving for the transmission-line lengths. The direct solution method is described briefly in the *Compendium* article.

Fig 16 shows the basic so-called "simplest" system applied to a two element array. Although it resembles an elementary phasing-line system as described earlier, the critical difference is that the lengths of Lines 1 and 2 are calculated to provide the correct current relative magnitude transformation and phase shift when terminated with the actual feed-point impedances.

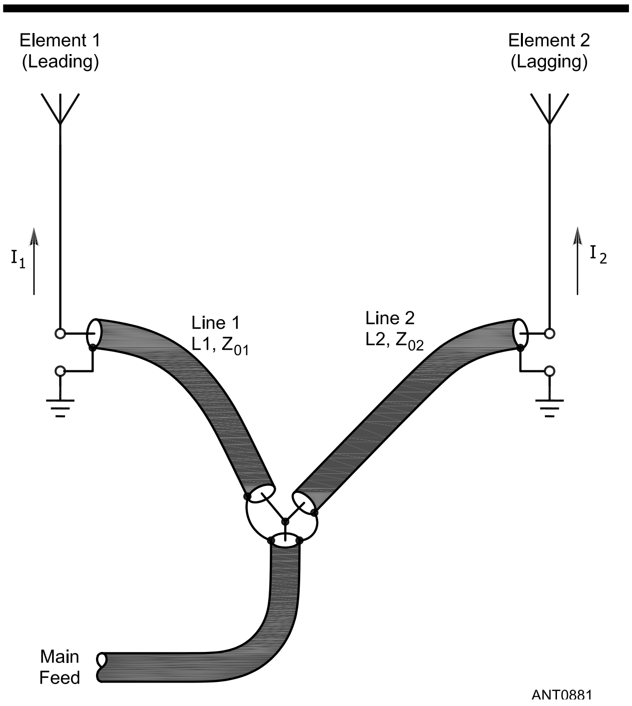

Fig 16—"Simplest" feed system for 2-element array. No matching or phasing network is used here, only transmission lines.

The advantage to using this "simplest" feed system is indeed its simplicity. It's no more complicated than the elementary phasing-line approach but actually works as planned. The disadvantage over some other methods is that there's no convenient adjustment to compensate for environment factors, array imperfections or inaccurately known feed-point impedances.

Also, while unusual, it's possible that no suitable feedline lengths can be found for some arrays, or at least none with practical feed-line characteristic impedances. The difference in electrical feed-line lengths almost never equals the difference in phase angles between element currents. This is because of the different line delays resulting from different feed-point impedances.

Program *Arrayfeed1*, included on the CD included with this book, can do the calculations for any two elements (alone or in a larger array), a Four-Square array or a rectangular array in which two in-phase elements are driven at any current magnitude and phase relative to the other two in-phase elements. These possibilities cover a large number of common arrays.

Arrayfeed1 can also be applied to other types of arrays using the method described in the **Feeding Larger Arrays** section in Appendix B (on the CD). The required knowledge of element feed-point impedances in a correctly fed array can be obtained using *EZNEC-ARRL*, also included on the CD. Examples of the design of a "simplest" feed system for several different arrays using *EZNEC-ARRL* and *Arrayfeed1* can be found in the **Phased Array Design Examples** section.

When a solution is possible for a given choice of line characteristic impedances, a second solution with different lengths is always available. See the comments in the introductory part of the **Phased Arrray Design Examples** section about choosing the solution to use.

An Adjustable L-Network Feed System

Adjustment of the current ratio of any two elements requires varying two independent quantities; for example the magnitude and phase of the current ratio. Two degrees of freedom—adjustments that are at least partially independent—are required. The "simplest" all-transmission line feed system described earlier adjusts the lengths of the two transmission lines to achieve the correct ratio.

But if the antenna characteristics aren't well known—for example, if the ground resistance isn't known even approximately—then the initial "simplest" design won't be optimum and adjustment can be difficult and tedious. The current-forcing method produces correct currents independently of the element characteristics, so it doesn't require adjustment as long as the elements are identical. But it's suitable only for feeding elements in-phase or 180° out-of-phase and a few fixed current-magnitude ratios.

The addition of a simple network as shown in **Fig 17** allows you to easily adjust feeding of element pairs at other relative phase angles and/or magnitude ratios. Any desired current ratio (magnitude and phase) can be obtained with two elements fed with any lengths of wire, equal or unequal, by adding a network.

However, calculations for the general case are complex. The problem becomes much simpler if the transmission lines are restricted to lengths of odd multiples of λ/4, forming a modified "forcing" system that includes an added network. There are at least three additional advantages of this scheme. One is that a λ/4 line is easy to measure, even if the velocity factor isn't known. This is described in the **Practical Aspects of Phased Array Design** section.

Second is that the feed system becomes completely insensitive to the feed-point impedance of one of the two elements. And the third is that the transmission lines of "forcing" systems feeding groups of elements in larger arrays can be used in place of the normal λ/4 lines. This greatly simplifies both the design of feed systems for larger arrays and the feed systems themselves. Note that both lines can be changed to 3λ/4 if necessary to span the physical distance between elements, but *both* lines must be the same 3λ/4 length.

This basic feed method can be used for any pair of elements, or for two groups of elements having forced equal currents. (See **Feeding Four Element and Larger Arrays** below.) Many networks can accomplish the desired function, but a simple L network is adequate for most feed systems. The network can be designed to produce a phase lead or phase lag. The basic two-element L-network feed system is shown in Fig 17. Many variations of this general method can be used, but the equations, program, and method to be discussed here apply only to the feed system shown.

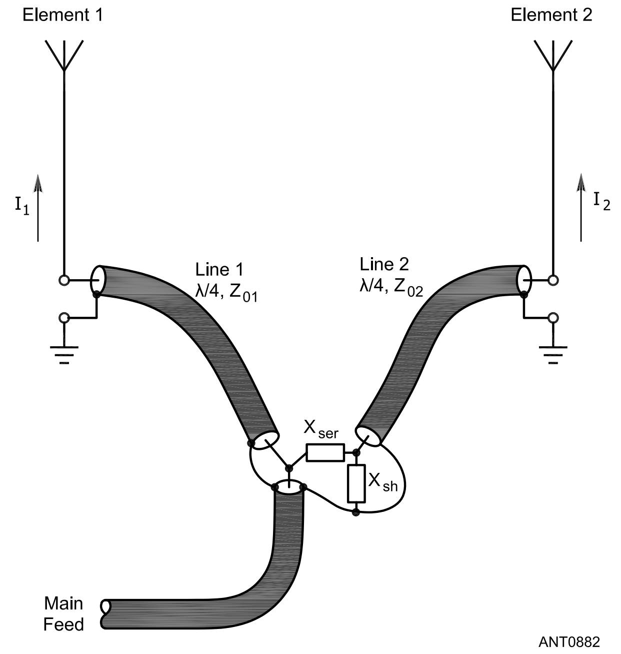

Fig 17—The addition of a simple L-network to Fig 16 allows you to easily adjust feeding of element pairs at other relative phase angles and/or magnitude ratios.

If the phase angle of I_2/I_1 is negative (element 2 is lagging element 1), the L network will usually resemble a low-pass network (X_{ser} is an inductor and X_{sh} is a capacitor). But if the phase angle is positive (element 2 lagging element 1), the L network will resemble a high-pass network (X_{ser} is a capacitor and X_{sh} is an inductor). However, some current ratios and feed-point impedances could result in both components being inductors or both being capacitors.

If it's desired to maintain symmetry in the feed system, X_{ser} can be divided into two components, each being inserted in series with a transmission line conductor. If X_{ser} is an inductor, the new components will each have half the value of the original X_{ser}, as shown in **Fig 18**. If X_{ser} is a capacitor, each of the new components will be twice the original value of X_{ser}.

Because of the current-forcing properties of λ/4 lines, we need to make the ratio of *voltages* at the inputs of the lines equal to the desired ratio of *currents* at the output ends of the lines; that is, at the element feed points. The job of the L network is to provide the desired voltage transformation. If the output-to-input voltage ratio of the network is, say, 2.0 at an angle of –60°, then the ratio of element currents (I_2/I_1)

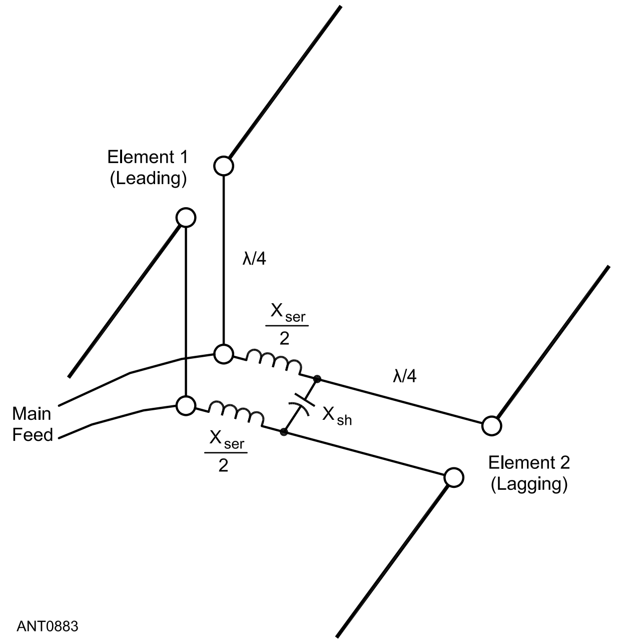

Fig 18—Symmetrical feed system similar to Fig 17, where feed network is split into two symmetrical parts.

will be 2.0 at an angle of –60°. The voltage transformation of the network is affected by the impedance of element 2, but not by the impedance of element 1. So only the impedance of element 2 must be known to design the feed system.

Equations for designing the L network are given in Appendix B, but the program *Arrayfeed1* is included on the CD to make it unnecessary to solve them. The feed-point impedance of the lagging element or group of elements must be known in order to design the network. This can best be determined by modeling the array with *EZNEC-ARRL*. The impedance can be manually calculated for some simple element and array types by using the equations in Appendix B, but those same types of element and array are simple to model.

Examples of the design of L-network feed systems for several different arrays using *EZNEC-ARRL* and *Arrayfeed1* can be found in the **Phased Array Design Examples** section. A similar application of this feed system and a spreadsheet program for calculation was developed by Robye Lahlum, W1MK, and described in *Low-Band DXing* (see the Bibliography). *Arrayfeed1* can be used for the applications of the feed system described in that book if desired.

Additional Considerations

Feeding 4-Element and Larger Arrays

Both the simplest and L-network feed systems described above can be extended to feeding larger arrays having two groups of elements in which all the elements in a group are in-phase or 180° out-of-phase with each other—basically, any group that can be fed with the current-forcing method. The elements in each group are connected to a common point with $\lambda/4$ or $3\lambda/4$ lines to force the currents to be in the correct ratio within the group. Then the "simplest" or L-network feed system can be used to produce the correct phasing between the two groups, just as it does between two individual elements.

Two common arrays that fit this description are the Four Square and the 4-element rectangular array. But more elaborate arrays could be constructed and fed using this method, such as a pair of binomial arrays. (A single binomial array is described in the **Phased Array Design Example** section below.) The *Arrayfeed1* program incorporates additional calculations necessary for designing Four Square and 4-element rectangular arrays. The general procedure for adapting the feed methods to other larger arrays can be found in Appendix B.

What If the Elements Aren't Identical?

Getting the desired pattern requires getting the correct relative magnitude and phase of the *fields* from the elements. If the elements are identical, which we've generally assumed up to this point, then producing currents of the desired magnitude and phase will create the desired fields (neglecting mutual coupling current distribution effects, discussed elsewhere).

But what if the elements aren't identical? Fortunately, the feed systems described here can still be used for any 2-element array and some more complex arrays, provided that the system can be accurately modeled. But a slightly different approach is required than for identical elements.

The first step is to model the array with a current source at the feed point of each element. Next, the magnitudes and phases of the model source currents are varied until the desired pattern is achieved. Then the ratio of feed-point (source) currents is calculated and this value, along with the feed-point impedances reported by the model, are used for the feed system design. The feed system will produce the same ratio of currents as the model, resulting in the same pattern.

In general, this approach won't work with shunt fed towers or gamma-fed elements because of the difficulty of accurately modeling those structures. See **Shunt and Gamma Fed Towers and Elements** for more information.

Shunt and Gamma Fed Towers and Elements

In a shunt, gamma, or similarly fed tower or element, the feed-point current isn't the same as the main current flowing in the element. The ratio between the feed-point current and element current isn't a constant, but depends on a number of factors. The ratio of currents in shunt or gamma fed elements are typically different—often vastly different—from the currents at the feed points. This complicates the design of feed systems for arrays of these elements.

An even more limiting problem is that the feed-point impedances are difficult to determine. The feed-point impedances of one or more elements in a properly fed array must be known in order to design a feed system for anything but

2-element in-phase or 180° out-of-phase arrays.

The only practical way to get this information for a shunt or gamma fed array is by modeling an array having the desired element currents. But Cebik has pointed out ("Two Limitations of NEC-4"—see the Bibliography) that many common antenna analysis programs, including *EZNEC-ARRL*, have difficulty accurately modeling folded dipoles with unequal diameter wires. The same problem applies to shunt and gamma-fed elements when the element diameter is significantly different from the diameter of the shunt or gamma feed wire. Without accurate feed-point impedances, feed systems can't be designed to work without adjustment. It might be possible to get reasonably accurate results from a *MININEC*-based modeling program, but there are a number of issues which must be given great care when using one. (See Lewallen, "*MININEC*—The Other Edge of the Sword," listed in the Bibliography.)

If such a *MININEC* program is available, you would have to model the complete array including feed system, with sources at the normal feed points in the shunt or gamma wires. Next, you would have to adjust the magnitudes and phases of the sources to produce the desired pattern. The reported source impedances and currents would be the ones you would use to design the feed system. It's likely that some adjustment would be necessary, so an adjustable system such as the L-network feed system described later would be best.

Loading, Matching and Other Networks

Adding a component such as a loading inductor in series with an element or element feed point won't change the ratio of element current to feed-point current. As a result, a feed system designed to produce a particular ratio of element currents will still function properly if the elements contain series components. The extra feed-point impedance introduced by the loading component(s) must be considered when designing the feed system, however. Similarly, end or top loading won't alter the relationship between feed-point and element current, provided that the current distribution in the elements is essentially the same. (See **Feed-point vs Element Current** in a previous section.)

However, insertion of any *shunt* component, or a network containing a shunt component, *will* alter the relationship between feed-point and element current because it will divert part of the feed-line current that would otherwise flow into the antenna. As a result, a feed system designed to deliver correct currents at the feed points will produce incorrect element currents and therefore an incorrect pattern. Therefore, any components or networks other than a series loading component should be avoided at any place in the feed system on the antenna side of the point at which the feed system splits to go to the various elements.

There are a few exceptions to this rule. If the feed-point impedances of the elements when in the excited array are equal, then identical networks with or without shunt components can be put at the feed points of the elements and the proper element current ratio maintained—so long as the feed system is designed to deliver the proper feed-point current ratio with the networks in place. Equal element impedances occur in arrays having only two identical elements fed in-phase or 180º out-of-phase, or arrays of any number of elements where the elements are electrically short and/or very lossy.

Baluns in Phased Arrays

For purposes of achieving the correct array pattern, baluns aren't usually required when feeding grounded vertical elements with coaxial cable feed lines. However, a balun might be desirable if current induced onto the outside of the feed line by mutual coupling to the elements is causing RF in the shack. And with arrays of dipole or other elevated elements, baluns can be important to achieve the proper element current ratio, as explained below.

First, however, the general rules for using baluns in phased arrays will be stated. Here, "main feed line" means the feedline going from the transmitter or receiver to the common point where the system splits to feed the various elements. "Phasing-system lines" means any transmission lines between that common point and any element. The rules:

- **Rule 1:** A balun or baluns (more specifically, a current, sometimes called a choke balun) should be used as necessary to suppress unbalanced current on the main feed line. This usually isn't required when feeding grounded elements with coaxial feed line from an unbalanced rig or tuner. Unbalanced current can occur on either coax or parallel-conductor line.

"Baluns: What They Do and How They Do It", listed in the Bibliography, describes conducted-imbalance (common-mode) currents. Imbalance can also be caused by mutual coupling to the array elements. Common-mode currents have at least two undesirable effects on array performance. First, the imbalance current can flow from the main feed line to the phasing system lines, not necessarily splitting in the right proportion to maintain the correct element current ratio. This can affect the array pattern. In practice, however, this effect is likely to be small unless the common-mode current is unusually large. Even a small common-mode current, however, results in main feed-line radiation, and even a small amount of radiation can significantly degrade array pattern nulls. Any type of current balun can be used on the main feed line, at any place along the line, without any effect on the array pattern except to the extent that it reduces common mode current.

- **Rule 2:** No balun or any other component or network should be inserted in any phasing system line that will alter the line length or characteristic impedance. This means that baluns in phasing system lines must be of a type made from the phasing line itself. Options are the W2DU type balun, consisting of ferrite cores placed along the outside of the feed line; an air-core balun made by winding part of the line into an approximately self-resonant or otherwise high-impedance coil; or winding part of the line onto a ferrite core or rod to make a several-turn winding. When coaxial cable is used, the feed system characteristics are dictated by the inside of the cable. Any cores or winding of the outside prevents common-mode current on the outside, but otherwise have no effect on the phasing performance. This rule applies equally to parallel wire line, where the balun affects only common-mode current (equivalent to current on the outside of coax) while the phasing performance depends on differential mode current (equivalent to the current on the inside of coax).

Baluns are important when feeding dipole or other elevated arrays, unless a fully balanced tuner is used. This is because common-mode current represents a diversion of some of the current that should be going to the array elements. The presence of common-mode current means that the element currents are being altered from the desired ratio and therefore the pattern won't as intended. A balun should be placed wherever a path for current exists other than along a parallel-line conductor or on the inside of a coaxial line. Such a path exists, for example, where a coaxial cable connects to a dipole, as shown in Fig 1 of the balun article referenced above. Or a path can exist where a parallel-conductor transmission line connects to an unbalanced tuner or to a coaxial line, as shown in Fig 2 of that article. In both those cases, a path exists for a common-mode current to flow on the outside of the coax cable. A balun creates a high impedance to this current, thereby reducing its magnitude. But remember that all baluns must conform to the rules above.

Fig19 shows recommended balun locations for a coax-fed dipole array using an L-network feed system.

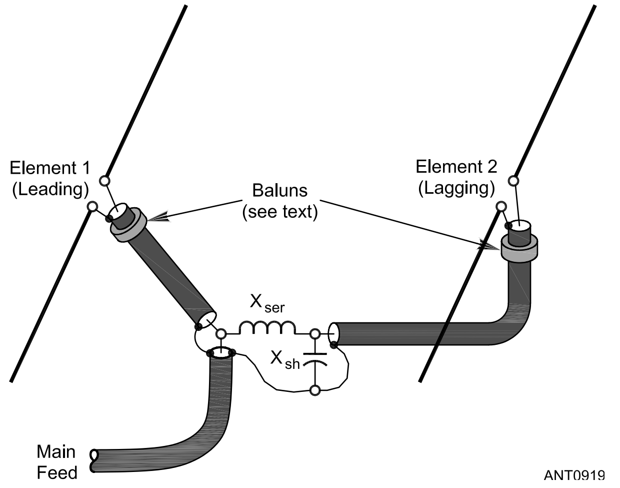

Fig 19—Adding choke baluns to a two-dipole feed system to get rid of common-mode currents radiated onto the coax shields.

Receiving Arrays

While it might not be entirely intuitive, an array designed for a particular gain and pattern for transmitting that considers mutual coupling, element currents, field reinforcement and cancellation, and so forth, will perform exactly the same when receiving. So a receiving array can be designed by approaching the problem as though the array were to be used for transmitting.

However, at HF and below, the system requirements for transmitting and receiving antennas are different, so receiving-only arrays can be designed that aren't suitable for transmitting but are perfectly adequate for receiving in that frequency range. The reason, described in more detail in Chapter 13 of this book, is that at HF and below atmospheric noise is typically much greater than a receiver's internally generated noise. Lowering a receiving antenna's gain and efficiency reduces the signal and atmospheric noise both by the same factor. Because the overall noise is for practical purposes all atmospheric noise, the signal/noise ratio isn't affected by antenna efficiency.

Of course, a point can be reached where the atmospheric noise is so reduced by inefficiency that the receiver itself becomes the dominant source of noise, but this typically doesn't happen until the antenna is extremely inefficient. When transmitting, reduced efficiency lowers the transmitted signal, but it has no effect on the receiving station's noise. So reduced efficiency of a transmitting antenna results in a reduced signal/noise ratio at the receiving end, and consequently should be avoided.

Mutual coupling effects can be minimized by increasing the loss (and therefore reducing the efficiency) of the elements, or by reducing the element sizes to a small fraction of a wavelength. Doing the second without the first isn't usually a good idea because the feed-point impedance tends to change rapidly with frequency for very small elements, making an antenna that works well over only a narrow bandwidth. But increasing loss broadens the bandwidth, even for small elements, as well as reducing mutual coupling effects. So this approach is often taken for designing a receiving-only array. With mutual coupling effects minimized because of loss, feed-system design becomes relatively simple, provided a few simple rules are followed. See **Loss Resistance, Mutual Coupling, and Antenna Gain**, above.

Phased Array Design Examples

This section, also written by Roy Lewallen, W7EL, presents examples of feed-system design for several kinds of array using the design principles given in previous sections. All but the last example array are assumed to be made of λ/4 vertical elements. The last example is for a halfwave-dipole array, which illustrates that exactly the same method can be used for arrays of any shape of elements, including dipole, square (quad) and triangular. Likewise, the methods shown here apply equally well to VHF and UHF arrays. The first example includes more detail than the remaining ones, so you should read it before the others.

General Array Design Considerations

If either the "simplest" feed system (Fig 16) or L-network feed system (Fig 17) is used, the feed-point impedance of one or more elements—*when the array elements all have the correct currents*—must be known. By far the best way to determine this is by modeling. If accurate modeling isn't practical for some reason, an estimation should be made from an approximate model, and you should expect to have to adjust the feed system after building and installing it.

Manual calculation methods for some simple configurations are given in Appendix B (on the CD), but calculation is tedious and, as stated earlier, the configurations for which this method works are the very ones which are easiest to model. *EZNEC-ARRL* (also included on the CD) is used in the following examples to determine feed-point impedance. Space doesn't permit detailed instructions here on creating the models, so they are included in complete form. They should provide a convenient starting point for any variations you might like to try. See the *EZNEC-ARRL* manual (accessed by clicking **Help/Contents** in the main *EZNEC-ARRL* window) for help in using this program.

In the following examples, vertical elements are close to λ/4 high and dipole elements close to λ/2, and their lengths have been adjusted for resonance when all other elements are absent or open circuited. There's actually no need in practice to make the elements self-resonant—it's simply used as a convenient reference point for these examples. You'll also find it interesting to see how much reactance is present at the feed points of the elements when in the arrays, knowing that it's very nearly zero when only one element is present.

In any real grounded vertical array, there is ground loss associated with each element. The amount of loss depends on the length and number of ground radials, and on the type and wetness of the ground under and around the antenna. This resistance becomes part of the feed-point resistance, so it must be included in the model used to determine feed-point impedance. The 90° Fed, 90° Spaced Array example below discusses how this is done. **Fig 20** gives resistance values for typical ground systems, based on measurements by Sevick (July 1971 and March 1973 *QST*). The values of feed system components based on Fig 20 will be reasonably close to correct, even if the ground characteristics are somewhat different than Sevick's.

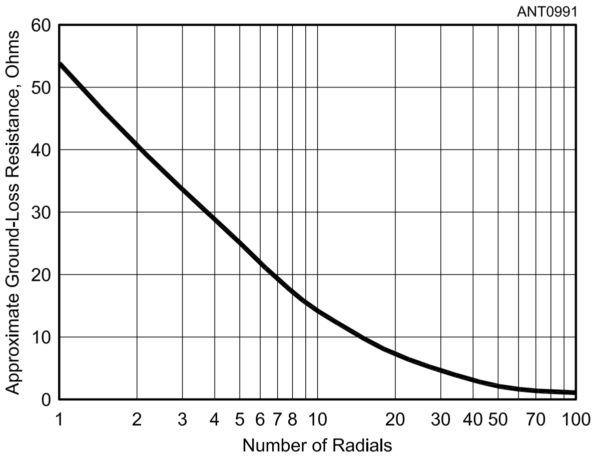

Fig 20—Approximate ground system loss resistance of a resonant λ/4 ground-mounted vertical element versus the number of radials, based on measurements by Jerry Sevick, W2FMI. Moderate length radials (0.2 to 0.4 λ) were used for the measurements. The exact resistance, especially for only a few radials, will depend on the nature of the soil under the antenna. Add 36 Ω for the approximate feed-point resistance of a thin resonant λ/4 vertical.

Feed systems for the design example arrays to follow are based on the resistance values given below.

Number of Radials	*Loss Resistance, Ω*
4	29
8	18
16	9
Infinite	0

Elevated radial systems also have some ground loss, although it can be considerably less than a system with the same number of buried radials. This loss will be automatically included in the feed-point impedance of a model which includes the elevated radials, so no further estimation is required. Be sure to use Perfect, High-Accuracy ground type when modeling an elevated radial system with *EZNEC-ARRL*. In other *NEC-2* based programs, this might be referred to as Sommerfeld type ground. More information can be found in the *EZNEC-ARRL* manual.

The matter of matching the array for the best SWR on the feed line to the station is not dealt with here, since it's a separate problem from that of the main topic, which is designing feed systems to produce a desired pattern. Some of the simpler arrays provide a match that is close to 50 or 75 Ω, so no further matching is required. However, as shown by program *Arrayfeed1*, many larger arrays present a less favorable impedance for direct connection and will require matching if a low SWR on the main feedline is required. If matching is necessary, the appropriate network should be placed in the single feed line running to the station. Attempts to improve the match by adjustment of the phasing L network, individual element lengths, matching at the element feed points or individual element feeder lengths will usually ruin the current balance of the array. Program *TLW*, included on the CD, can be used for designing an appropriate matching network. Additional information on impedance matching may be found in Chapters 25 and 26 of this book.

Choosing Arrayfeed1 Solutions

When designing a feed system for a two element array, *Arrayfeed1* program allows you to choose the characteristic impedances of the two transmission lines going to the elements, which don't have to be equal, so you have your choice of more than one solution. However, directional array switching is much more difficult if the lines have different impedances, so in general you should use the same characteristic impedances.

For larger arrays, *Arrayfeed1* requires the feed lines to all elements to have the same impedance. In choosing the transmission line impedance values, usually you can simply use convenient impedances. But in general, you should avoid solutions where component reactance (X) values are vastly different (say, more than three times or less than one third as large) as the line characteristic impedances. Such networks will become more critical to adjust, and both the impedance and pattern will change more rapidly with changes in frequency. You can usually avoid this situation by choosing feed-line impedances that are in the same ballpark as the element feed-point impedances. The last example in the Practical Array Design section illustrates this problem and its solution.

When designing a "simplest" feed system, the most broadbanded and least critical system is usually one where the difference in electrical feed-line lengths is closest to the relative element phase angle. Here, "broadbanded" means that the pattern changes less with frequency, not necessarily that the SWR changes less. However, an array that's broadbanded in the pattern sense is usually also relatively broadbanded with respect to SWR.

Arrayfeed1 reports the impedance seen at the main array feed point. While it might be tempting to choose the solution producing the lowest SWR on the main feedline, you'll end up with a less critical and more broadbanded system if you base your choice on the criteria given above, and provide separate impedance matching at the array's main feed point when necessary.

90° Fed, 90° Spaced Vertical Array

This example illustrates the design of both "simplest" and L-network feed systems for a 2-element, 90° spaced and fed vertical array. The first task when using either feed system is to determine the feed-point impedances of the elements when placed in an array having the desired element currents. The "simplest" feed system method requires knowledge of both element impedances, while the L-network system requires you to know only one. Actually, it's equally easy to determine both as it is to find just one, using *EZNEC-ARRL*. (Appendix B contains equations for those interested in manual methods or for more insight as to how the impedances come about.) The first step is to specify the antenna we want. For this example, we'll specify:

- Frequency: 7.15 MHz.
- Two identical, one inch (2.54 cm) diameter, 33 feet (10.06 meter) long elements spaced 90 electrical degrees, with element currents equal in magnitude and 90° apart in-phase.
- 8 buried radial wires, 0.3 λ long, under each element.

A model of this antenna has been created and furnished with *EZNEC-ARRL*. So the next step is to start *EZNEC-ARRL*, click the **Open** button, enter **ARRL_Cardioid_Example** in the text box (or double-click it in the file list) to open example file **ARRL_Cardioid_Example.EZ**.

This *EZNEC* example model uses a *MININEC*-type ground, which is the same as perfect ground when calculating antenna currents and impedances. A real antenna would have some additional resistive loss due to the finite conductivity of the ground system. The only way to model a buried radial ground system with an *NEC-2* based program like *EZNEC* is to create radial wires just above the ground (using the Real, High-Accuracy ground type), because *NEC-2* can't handle buried conductors.

This provides only a moderate approximation of a buried system. Another way to estimate ground-system resistance is to measure the feed-point impedance of a single element, then subtract from that the resistance reported for a model of that element over perfect (or *MININEC*-type) ground. For most uses, however, an adequate approximation can be made by simply referring to the graph of Fig 20. As stated previously, the feed system design depends on the feed-point impedances of the elements, which in turn depend on the ground system resistance. So the ground system resistance must be known, approximately anyway, before designing the feed system. At the end of this example we'll investigate the effect of changes in the ground system or errors in estimating the resistance on the pattern.

For 8 radials, Fig 20 shows the ground system resistance to be about 18 Ω. This is included in the example model as a simple resistive load at the feed point of each element. Click the **Src Dat** button to see the feed-point impedances of the two elements. In this model, Source 1 is at the base of Wire 1 (element 1), and Source 2 is at the base of Wire 2 (element 2). Notice in the **Source Data** display that the Source 1 current has been specified at 1 amp at 0°, and Source 2 is 1 amp at –90°. So the Source 2 element is the lagging element. You should see impedances of 37.53 – *j*19.1 Ω for element 1 and 68.97 + *j*18.5 Ω for element 2. These are the feed-point impedances resulting when the array is ideally fed, with equal magnitude and 90° phased currents. Record these values for use in *Arrayfeed1*.

Click the **FF Plot** button to generate a plot of the azimuth pattern at an elevation angle of 10°. In the 2D Plot Window, open the **File** menu and select **Save Trace As**. Enter **Cardioid_Ideal Feed** in the **File Name** box, then click **Save**. This saves the cardioid pattern plot so you can compare it later to the pattern you get with the transmission line feed system.

Now it's time to design the feed system. Refer to the appropriate subheading below for the design of each of the two kinds of feed systems. Both systems use program *Arrayfeed1* program.

"Simplest" (Transmission Line Only) Feed System

Start *Arrayfeed1*. In the **Array Type** frame, select **Two Element**. In Feed System Type, select **"Simplest."** In the **Inputs** frame, enter the following values:

Frequency MHz = 7.15; Feed-point impedances – Leading Element: R ohms = 37.53, X ohms = –19.1; Lagging Element: R ohms = 68.97, X ohms = 18.5 (these are the element R and X values from *EZNEC-ARRL*). We'll be discussing the array input impedance, so check the **Calc Zin** box near the lower left corner of the main window if it's not already checked.

We're free to choose any transmission-line characteristic impedances we want, so long as we can get cables with those impedances. And the two cables don't have to have the same characteristic impedances. Each choice will lead to a different set of solutions. But sometimes a solution isn't possible, which then requires choosing different line impedances. Let's try 50 Ω for both lines. Enter **50** in both **Z0** boxes.

Finally, enter **1** for the lagging:leading **I Mag**, and **–90** for the **Phase**. Click **Find Solutions**. The result is no solution! So enter **75** into both the line impedance boxes and click **Find Solutions** again. You should now see two sets of results in the **Solutions** frame, electrical lengths of 68.80° and 156.03° for the first solution and 131.69° and 185.00° for the second. (Notice that the difference in length between the two lines isn't 90° for either solution, although the first solution is quite close. It's normal for the feed-line length difference to be different than the phase difference, due to the unequal element feed-point impedances caused by mutual coupling.)

The solution with a line length difference closest to the element phase difference is usually preferable. Also, all else being equal, the solution with shortest lines is better providing that the lines will physically reach the elements. This is because the current magnitude and phase will change less with frequency than for a longer-length solution. However, there might be some cases where the change with frequency luckily compensates for the changing electrical distance between elements, so it's not a bad idea to model both solutions unless you plan on using the antenna over only a narrow frequency range.

In this case, the first solution looks best in all respects. The sum of the two lines in the first solution is about 225 electrical degrees. Assuming the lines have a velocity factor of 0.66, the total length of the lines will be more than 148 physical degrees. Since our two elements are spaced 90 physical degrees apart, the lines will comfortably reach. If they didn't, we could either use the second solution's lengths, use cable with a higher velocity factor or add a half wavelength to both the line lengths in the first solution.

The impedance **Zin** shown by *Arrayfeed1* is the impedance at the input to the feed system, so it's the impedance that will be seen by the main feed line. The second solution provides nearly a perfect match for a 50-Ω transmission line. But the first solution is good for nearly all applications. Also a 50-Ω line connected to the first solution's feed system would have an SWR of only 1.65:1, which wouldn't require any matching under most circumstances. Normal line loss would reduce the SWR even more at the transmitter end of the feed coax.

To find the required physical line lengths, enter the cable velocity factor and make your choice of units in the **Physical Lengths** frame. The design is now complete; all you have to do is cut two lines to the specified lengths and connect one from a common feed point to each element as shown in Fig 16, or the screen capture from *Arrayfeed1* shown in **Fig 21**.

Next, we'll design an L-network feed system for the same array.

L Network Feed System

In *Arrayfeed1*, select **L Network** in the **Feed System Type** frame. The program doesn't need to know the leading element impedance to calculate the L-network values, but it does need it to calculate the array input impedance. If you want to know the impedance, check the **Zin** box at the lower left corner of the main window, otherwise you can uncheck it and the input box for the leading element Z will disappear. The values from the "Simplest" analysis should still be present in the appropriate boxes; if not, refer to the "Simplest" feed system design above and re-enter the values. Again, we'll use 75 Ω for the line impedances, since that gave us a

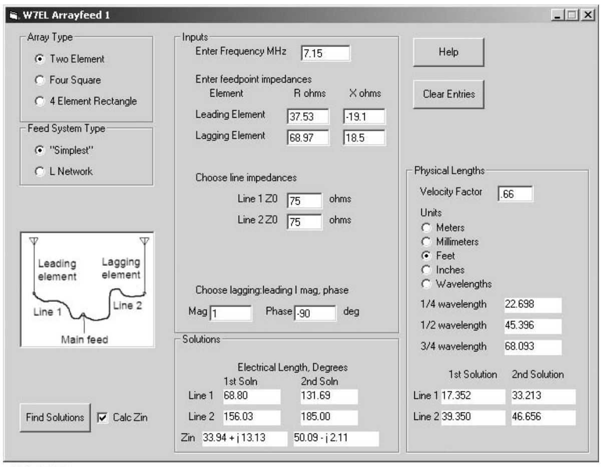

W7EL Arrayfeed 1

Array Type
● Two Element
○ Four Square
○ 4 Element Rectangle

Feed System Type
● "Simplest"
○ L Network

Inputs
Enter Frequency MHz 7.15
Enter feedpoint impedances

Element	R ohms	X ohms
Leading Element	37.53	-19.1
Lagging Element	68.97	18.5

Choose line impedances
Line 1 Z0 75 ohms
Line 2 Z0 75 ohms

Choose lagging:leading I mag, phase
Mag 1 Phase -90 deg

Solutions
Electrical Length, Degrees

	1st Soln	2nd Soln
Line 1	68.80	131.69
Line 2	156.03	185.00
Zin	33.94 + j 13.13	50.09 - j 2.11

☑ Calc Zin

Physical Lengths
Velocity Factor .66
Units
○ Meters
○ Millimeters
● Feet
○ Inches
○ Wavelengths
1/4 wavelength 22.698
1/2 wavelength 45.396
3/4 wavelength 68.093

	1st Solution	2nd Solution
Line 1	17.352	33.213
Line 2	39.350	46.656

ANT0992

Fig 21—Screen capture from *Arrayfeed1* program for "Simplest" 2-element phased array shown in Fig 16 and whose feed-point impedances are modeled by *EZNEC-ARRL*.

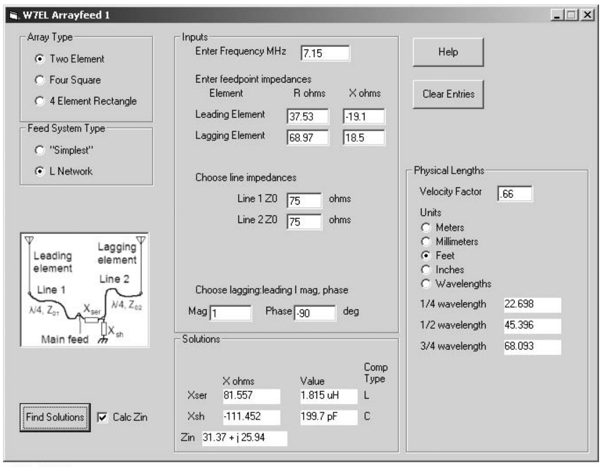

W7EL Arrayfeed 1

Array Type
● Two Element
○ Four Square
○ 4 Element Rectangle

Feed System Type
○ "Simplest"
● L Network

Inputs
Enter Frequency MHz 7.15
Enter feedpoint impedances

Element	R ohms	X ohms
Leading Element	37.53	-19.1
Lagging Element	68.97	18.5

Choose line impedances
Line 1 Z0 75 ohms
Line 2 Z0 75 ohms

Choose lagging:leading I mag, phase
Mag 1 Phase -90 deg

Solutions

	X ohms	Value	Comp Type
Xser	81.557	1.815 uH	L
Xsh	-111.452	199.7 pF	C

Zin 31.37 + j 25.94

☑ Calc Zin

Physical Lengths
Velocity Factor .66
Units
○ Meters
○ Millimeters
● Feet
○ Inches
○ Wavelengths
1/4 wavelength 22.698
1/2 wavelength 45.396
3/4 wavelength 68.093

ANT0993

Fig 22—Screen capture from *Arrayfeed1* program for L-network feed system using "current-forcing" properties of λ/4 feed lines.

solution for the "Simplest" feed system. This feed system is more versatile, though, so we could use 50-Ω lines with this feed system if desired.

Click **Find Solution** and see the results in the **Solution** frame. See screen capture in **Fig 22**. With 75-Ω lines, the L network consists of a series inductor of 1.815 µH and a shunt capacitor of 199.7 pF, connected as shown in the diagram in the left part of the program window. To find the physical length of the λ/4 lines, enter the velocity factor and choice of units in the **Physical Lengths** frame.

The main feed-point impedance of 31.37 + *j* 25.94 Ω would result in about a 2.2:1 SWR on a 50-Ω feed line, which would be acceptable for many applications. It could easily be reduced to 1.6:1 by the simple addition of a series capacitor of 25.94 Ω reactance (858 pF) at the main feed point or, of course, reduced to 1:1 with a simple L network or other matching system designed with the *TLW* program.

Pattern Verification and Effect of Loss Resistance—"Simplest" System

EZNEC-ARRL doesn't have the capability to model an L-network, so *EZNEC-ARRL* verification of the pattern and the effect of various modifications can be done only for the "simplest" feed system.

EZNEC model **ARRL_Cardioid_TL_Example.EZ** has been created to model the "simplest" feed system just designed. Open it with *EZNEC-ARRL*. In the View Antenna Display, you can see the transmission lines connecting to the source midway between the antennas. In *EZNEC*, the physical locations of the ends of transmission line models don't have to be the same as the physical locations, so the view isn't a precise representation of what the actual setup would look like. (You can find more about this in **ARRL_Cardioid_TL_Example.txt**, the Antenna Notes file that accompanies example file **ARRL_Cardioid_TL_Example.EZ.**)

Click **FF Plot** to generate a 2D pattern of the antenna. In the 2D Plot Window, open the **File** menu and select **Add Trace**. Select **Cardioid—Ideal Feed** (which you saved earlier) and click **Open**. The added plot overlays perfectly, indicating that the pattern using this feed system is identical to the pattern we got with perfect current sources at each feed point.

To check the feed-point currents, click the **Currents** button. In the resulting table, you can see that **Wire 1 Segment 1** current is 0.56467 A at a phase of –56.73° and **Wire 2 Segment 1** current is 0.56467 A at –146.7°. (If you get the correct phase angles but wrong magnitudes, open the main window **Options** menu, select **Power level**, and make sure the **Absolute V, I sources** box is checked.) The ratio is 1.0000 at an angle of –89.97°, which is within normal error bounds for the desired 1 at –90°.

As a check on *Arrayfeed1*, click the **Src Dat** button to find the impedance seen by the source. This would be the impedance at the main feedline connection in the real array. *EZNEC-ARRL* reports 33.96 + *j*13.11 Ω, very close to the 33.94 + *j*13.13 Ω given by *Arrayfeed1* in Fig 21. Small differences of this order are normal and to be expected. This provides a further check that the *EZNEC-ARRL* model is correctly analyzing the *Arrayfeed1* feed system.

This *EZNEC-ARRL* model uses lossless transmission lines of a fixed physical length rather than a fixed electrical length (number of degrees), so they'll behave like real lines as the frequency is changed. By changing the *EZNEC* frequency and re-running the 2D plot, you can see that the front-to-back ratio degrades at 7.0 and 7.3 MHz. A slight adjustment of one or more line lengths, or a new *Arrayfeed1* solution at a slightly different frequency might produce a better compromise for some uses.

Other things you can try are to evaluate the second *Arrayfeed1* solution, or to try using different line impedances. (Keep the two line impedances equal if you anticipate doing array direction switching.) The effect of varying ground system resistance can also be evaluated by clicking the **Loads** line in the main window and changing the load resistance values. For example, if the ground system resistance were 9 Ω instead of the 18 Ω we have assumed, the front/back ratio would drop from about 32 to about 20 dB. Note that changing the *EZNEC* ground conductivity in this model has no effect on the feed-point current ratio. With a *MININEC* type ground, it's used only for pattern calculation—the ground is assumed perfect during impedance and current calculations, and the only ground system loss resistance in the model is what we've specifically put in as loads.

Not surprisingly, the forward gain is affected very little by changes in frequency or ground system loss. To find the gain relative to a single element, compare the reported dBi gain of **ARRL_Cardioid_Example** with the same model with one of the elements deleted. You'll find it's very close to 3.0 dB. The 90° fed, 90° spaced array is a special case of array where the effects of mutual coupling on the two elements are opposite and cancel, resulting in the same gain as if mutual coupling didn't exist. But mutual coupling most certainly does exist!

The second solution presented a more favorable main feed-point impedance, so it would be tempting to use that one instead of the first solution. Replacing the feed-line lengths with the second solution lengths to model the second solution shows that the front/back ratio deteriorates more at the band edges when the second solution is used. This might be tolerable if restricted frequency use is anticipated. But it does illustrate that the solution with shorter lines is generally more broadbanded and that the choice of solution shouldn't in general be based on the one giving the most favorable impedance.

A Three-Element Binomial Broadside Array

An array of three in-line elements spaced λ/2 apart and fed in-phase gives a pattern that is generally bidirectional. If the element currents are equal, the resulting pattern has a forward gain of 5.7 dB (for lossless elements) compared to a single element, but it has substantial side lobes. If the currents are tapered in a binomial coefficient 1:2:1 ratio (twice the current in the center element as in the two end elements), the gain drops slightly to just under 5.3 dB, the main lobes widen and the side lobes disappear.

The array is shown in **Fig 23**, and an *EZNEC-ARRL* model of the antenna over perfect ground to show the ideal pattern is provided as **ARRL_Binomial_Example.EZ**. To obtain a 1:2:1 current ratio in the elements, each end element is fed through a 3λ/4 line of impedance Z_0. Line lengths of 3λ/4 are chosen because λ/4 lines will not physically reach. The center element is fed from the same point through two parallel 3λ/4 lines of the same characteristic impedance. This is equivalent to feeding it through a line of impedance $Z_0/2$. The currents are thus forced to be in-phase and to have the correct ratio. **ARRL_Binomial_TL_Example.EZ** is an *EZNEC-ARRL* model that shows this feed system with lossless transmission lines. The reader is encouraged to experiment with this model to see the effect of changes in frequency, the addition of loss resistance (as resistive loads at the element feed points) and other alterations on the array pattern and gain. You should also replace the perfect ground with *MININEC* type of ground to show how radiation patterns over real ground differ from the theoretical perfect-ground pattern.

A "Four Square" Array

Several types of feed system are used for feeding this popular array, and most share a common problem—they don't provide the correct element current ratio—although a number of them produce a workable approximation. The feed systems described here are capable of producing exactly the correct current ratio. The only significant variable is the element feed-point impedances, so the quality of the result depends on your ability to model the feed-point impedances of a correctly fed array. As in the examples above, *EZNEC-ARRL* will be used for that purpose and *Arrayfeed1* for the design of the feed system itself.

In this array (see **Fig 24**), four elements are placed in a square with λ/4 sides. (A variation of the Four Square uses wider spacing.) The rear and front elements (1 and 4) are 180° out-of-phase with each other. The side elements (2 and 3) are in phase with each other and 90° delayed from the front ele-

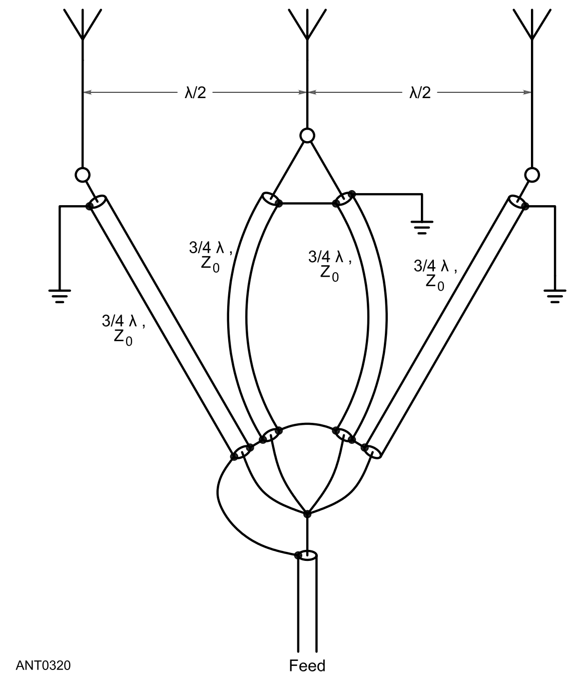

Fig 23—Feed system for the three element 1:2:1 binomial array. All feed lines are ¾ electrical wavelength long and have the same characteristic impedance.

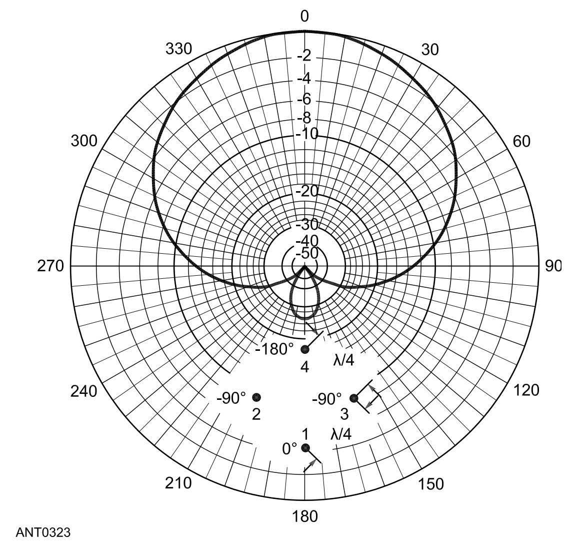

Fig 24—Pattern and layout of the four-element Four-Square array. Gain is referenced to a single similar element; add 5.5 dB to the scale values shown.

ment. The magnitudes of the currents in all four elements are equal. The front and rear elements can be forced to be 180° out-of-phase and to have equal currents by using the current-forcing method described earlier. One element is connected to a line that is either λ/4 or 3λ/4 long, the other to a line that is λ/2 longer, and the two lines to a common point.

Likewise, the two side element currents are forced to be equal by connecting them to a common point via λ/4 or 3λ/4 lines. **Fig 25** shows the basic current-forcing system.

If the pattern is to be electrically rotated, it is necessary to bring lines from all four elements to a common location. If solid-polyethylene dielectric coaxial cable, which has a dielectric constant of 0.66, is used, λ/4 lines won't reach the center of the array. So 3λ/4 lines must be used. Alternatively, you can use λ/4 lines with foam or other dielectric having a velocity factor of more than about 0.71 (plus a little extra margin). These will reach to the center. Whatever your choice, three of the lines must be the same length and the fourth must be λ/2 longer.

In this array, the side elements (2 and 3) have equal impedances, but the rear and front (1 and 4) are different from each other, and both are different from the side elements. We have to know the feed-point impedances of the front, rear and side elements in order to design the "simplest" feed system, but only the side element impedances are needed to design the L-network system. Knowledge of all feed-point impedances is necessary if the array main feedpoint impedance **Zin** is to be calculated. *EZNEC-ARRL* model **4Square_Example.EZ** shows a 40-meter Four Square array with 18 Ω of loss resistance at each element, to approximate an 8-radial per element ground system. (See the cardioid array example above for more information about modeling ground system loss.) Opening the file in *EZNEC-ARRL* and clicking the **Src Dat** button gives the following impedances:

Source 1: 16.4 – *j*15.85 Ω
Sources 2 and 3: 57.47 – *j*19.44 Ω
Source 4: 77.81 + *j*54.8 Ω

It's interesting to note that the resistive part of source 1 is less than the 18 Ω of loss resistance we intentionally added to simulate ground system loss. That means that the element 1 feed-point resistance would be negative if the ground resistance were less than about an ohm and a half. This isn't uncommon in phased arrays and simply means that the element is feeding power *into* the feed system. This power is coming via mutual coupling from the other elements.

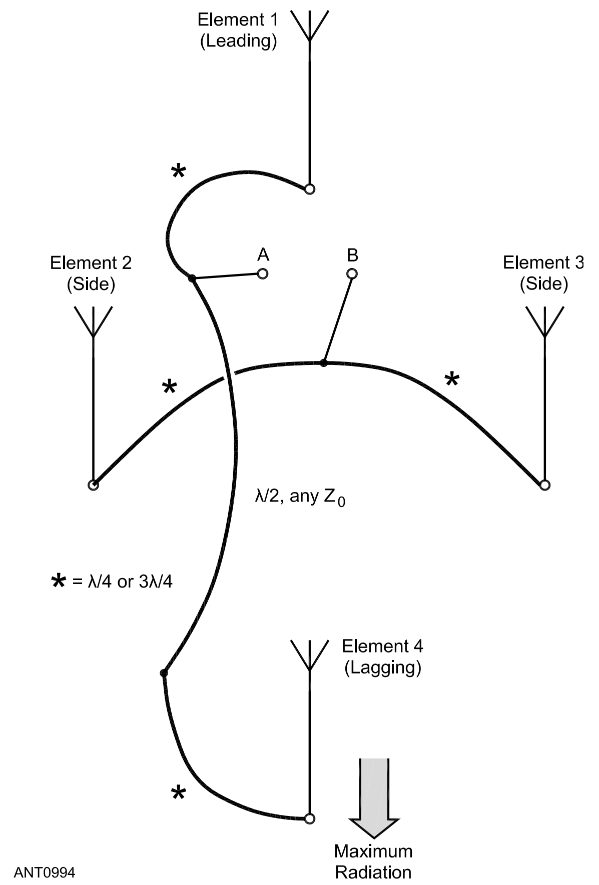

Fig 25—"Simplest" feed system for the Four-Square array in Fig 24. Grounds and cable shields have been omitted for clarity.

"Simplest" (Transmission Line Only) Feed System

To design a "simplest" feed system, start *Arrayfeed1*. In the **Array Type** frame, select **4 Square**, and select **"Simplest"** in the **Feed System Type** frame. In the **Inputs** frame, enter the frequency and the impedances from *EZNEC-ARRL*:

Frequency = 7.15 MHz
Leading Element: R = 16.4, X = –15.85
Side elements: R = 57.47, X = –19.44
Lagging Element: R = 77.81, X = 54.8

We'll try using 50 Ω for all lines, so enter **50** into the next three boxes.

Enter **1** for the lagging:leading I magnitude and **–90** for the phase.

Click **Find Solutions**.

The result is shown in the **Solutions** frame, shown in **Fig 26**. As always when any solution exists, there are two to choose from. The one with the shortest lines is generally preferable, so we'll choose it. For this example, we'll use λ/4 lines with velocity factor of 0.82. So enter **0.82** in the **Velocity Factor** box in the **Physical Lengths** frame, and read the physical lengths from the bottom of that frame. The λ/4 lines (marked in the *Arrayfeed1* diagram with an asterisk) are 28.2 feet, line 1 is 7.483 feet and line 2 is 51.668 feet. The "simplest" feed system is shown in Fig 26, and the complete feed system consists of this connected to the array of Fig 25.

EZNEC-ARRL model **ARRL_4Square_TL_Example.EZ** is simulates the array fed with this system. Comparison of the pattern plot to one from ideal-current model **ARRL_4Square_Example.EZ** and examination of

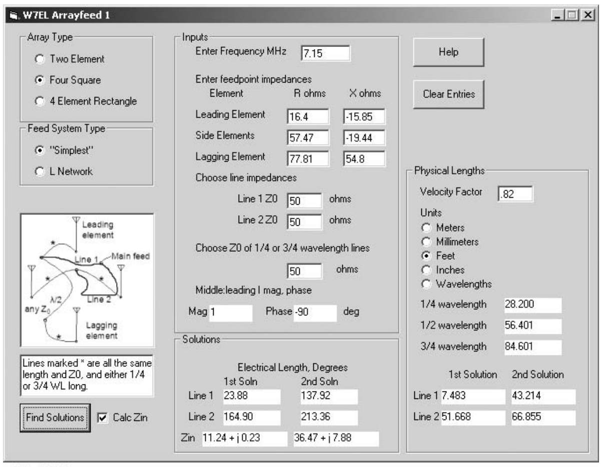

W7EL Arrayfeed 1

Array Type
○ Two Element
● Four Square
○ 4 Element Rectangle

Feed System Type
● "Simplest"
○ L Network

Lines marked * are all the same length and Z0, and either 1/4 or 3/4 WL long.

☑ Calc Zin

Inputs
Enter Frequency MHz 7.15
Enter feedpoint impedances

Element	R ohms	X ohms
Leading Element	16.4	-15.85
Side Elements	57.47	-19.44
Lagging Element	77.81	54.8

Choose line impedances
Line 1 Z0 50 ohms
Line 2 Z0 50 ohms
Choose Z0 of 1/4 or 3/4 wavelength lines
50 ohms
Middle:leading I mag, phase
Mag 1 Phase -90 deg

Solutions
Electrical Length, Degrees

	1st Soln	2nd Soln
Line 1	23.88	137.92
Line 2	164.90	213.36
Zin	11.24 + j 0.23	36.47 + j 7.88

Physical Lengths
Velocity Factor .82
Units
○ Meters
○ Millimeters
● Feet
○ Inches
○ Wavelengths
1/4 wavelength 28.200
1/2 wavelength 56.401
3/4 wavelength 84.601

	1st Solution	2nd Solution
Line 1	7.483	43.214
Line 2	51.668	66.855

Fig 26—Screen capture from *Arrayfeed1* for "Simplest" feed system for Four Square feed system shown in Fig 25.

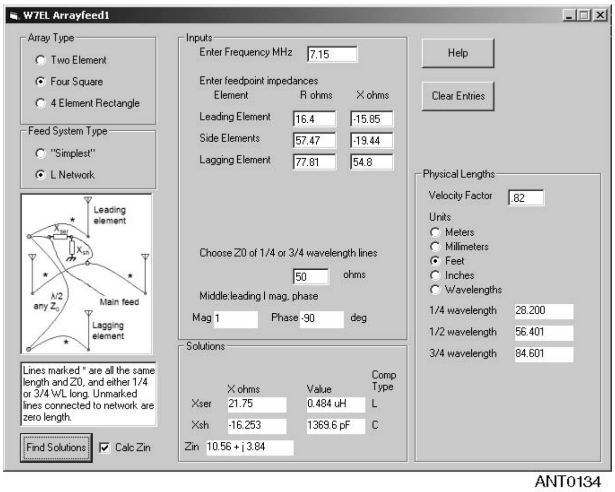

W7EL Arrayfeed1

Array Type
○ Two Element
● Four Square
○ 4 Element Rectangle

Feed System Type
○ "Simplest"
● L Network

Lines marked * are all the same length and Z0, and either 1/4 or 3/4 WL long. Unmarked lines connected to network are zero length.

☑ Calc Zin

Inputs
Enter Frequency MHz 7.15
Enter feedpoint impedances

Element	R ohms	X ohms
Leading Element	16.4	-15.85
Side Elements	57.47	-19.44
Lagging Element	77.81	54.8

Choose Z0 of 1/4 or 3/4 wavelength lines
50 ohms
Middle:leading I mag, phase
Mag 1 Phase -90 deg

Solutions

	X ohms	Value	Comp Type
Xser	21.75	0.484 uH	L
Xsh	-16.253	1369.6 pF	C

Zin 10.56 + j 3.84

Physical Lengths
Velocity Factor .82
Units
○ Meters
○ Millimeters
● Feet
○ Inches
○ Wavelengths
1/4 wavelength 28.200
1/2 wavelength 56.401
3/4 wavelength 84.601

Fig 27—L-network setup for Four-Square array in Fig 25, fed with λ/4 (or 3λ/4) current-forcing feed system.

the element currents verify that the feed system is producing the desired pattern and element currents. You can use **ARRL_4Square_Example.EZ** to investigate the effect of frequency change, ground loss and other changes on the array gain and pattern.

L-Network Feed System

To design the L-network feed system, simply change the **Feed System Type** to **L Network** and click **Find Solutions**. The results you should see are a 0.484 µH inductor for the series component X_{ser}, and a 1369.6 pF capacitor for the shunt component X_{sh}. The L-network feed system is shown in **Fig 27**, and the complete feed system consists of this L network connected to the array of Fig 25.

EZNEC-ARRL doesn't have the ability to directly model the L network, so it's unable to model the complete system. However, the system has been modeled using the network capability of *EZNEC v.5* and found to work as designed. Arrays have also been built using this feed system and the element currents measured, with exactly the expected results.

This array is more sensitive to adjustment than the 2-element 90° fed, 90° spaced array. Adjustment procedures and a method of remotely switching the direction of this array are described in the **Practical Aspects of Phased Array Design** section that follows.

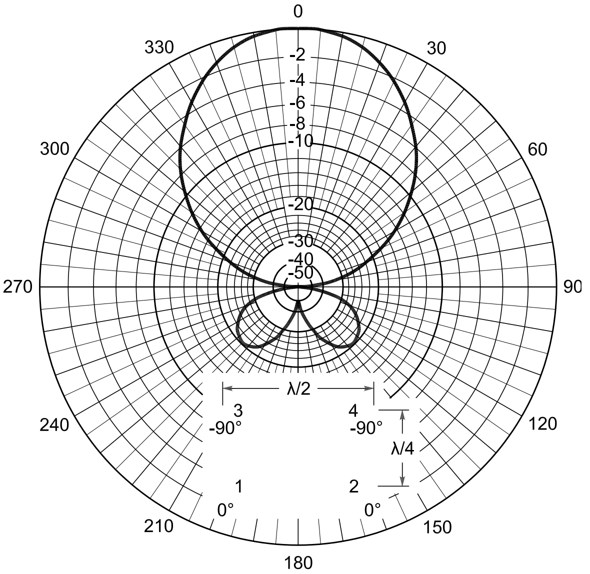

Fig 28—Pattern and layout of the four-element rectangular array. Gain is referenced to a single similar element; add 6.8 dB to the scale values shown.

A 4-Element Rectangular Array

The 4-element rectangule array shown with its pattern in **Fig 28** has appeared numerous times in amateur publications. However, many of the accompanying feed systems fail to deliver currents in the proper amounts and phases to the various elements. The array can be correctly fed using the principles discussed in this chapter and the design methods that follow.

Elements 1 and 2 can be forced to be in-phase and to have equal currents by feeding them through 3λ/4 lines. (As in the binomial and Four Square array examples, 3λ/4 lines are chosen because λ/4 lines won't physically reach.) The currents in elements 3 and 4 can similarly be forced to be equal and in-phase. **Fig 29** shows the "current-forcing" feed system. Elements 3 and 4 are made to have currents of equal magnitude but of 90° phase difference from elements 1 and 2 by use of either a "simplest" all-transmission line feed system or an L-network feed system. Both will be designed in this example.

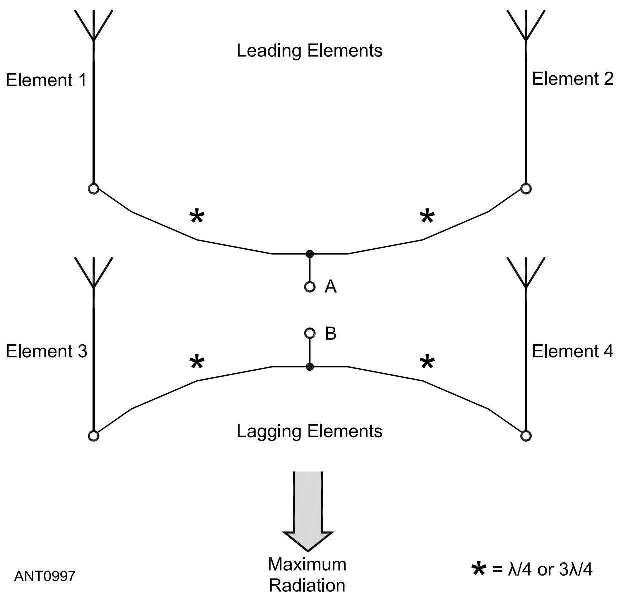

Fig 29—"Simplest" feed system for four-element rectangular array, using four equal-length λ/4 (or 3λ/4) cables.

For this array, we have to know the feed-point impedances of two elements (one of each pair) in order to design either type of feed system. *EZNEC-ARRL* model **Rectangular_Example.EZ** shows a 20-meter rectangular array with 18 Ω of loss resistance at each element, again to approximate an 8-radial per element ground system. (See the cardioid array example above for more information about modeling ground system loss.) Open the file in *EZNEC-ARRL* and click the **Src Dat** button to find the following feed-point impedances:

Sources 1 and 2: $21.44 - j21.29$ Ω
Sources 3 and 4: $70.81 - j5.232$ Ω

"Simplest" (Transmission- Line Only) Feed System

To design a "simplest" feed system, start program *Arrayfeed1*. In the **Array Type** frame, select **4 Element Rectangle**, and select **"Simplest"** in the **Feed System Type** frame. In the **Inputs** frame, enter the frequency and the impedances from *EZNEC-ARRL*:

Frequency = 14.15 MHz
Leading Elements R = 21.44, X = –21.29
Lagging Elements R = 70.81, X = –5.232

We'll use 50 Ω for all lines, so enter **50** into the next three boxes.

Enter **1** for the lagging:leading I magnitude and **–90** for the phase.

Click Find Solutions.

The result is "No Solution"—This combination of line impedances can't be used. Several other combinations also produce this result, but making lines 1 and 2 each 75 Ω and the 3λ/4 lines 50 Ω does produce a solution. Enter **75** into the **Line 1 Z0** and **Line 2 Z0** boxes, and leave **50** in the **Choose Z0 of ¼ or ¾ wavelength lines** box, then click the Find Solutions button. There won't be any problem making lines 1 and 2 reach, so we'll choose the first solution because the lines are shorter. The physical lengths of all the lines are shown in the **Physical Lengths** frame when the velocity factor is entered in the appropriate box. Assuming that we use coax with a velocity factor of 0.66 (and the example frequency of 14.15 MHz), the lengths are:

Line 1: 4.982 feet
Line 2: 20.153 feet
3λ/4 lines (marked with an asterisk in the *Arrayfeed1* diagram): 34.408 feet

The lines are connected following the diagram in the upper left part of the *Arrayfeed1* window. This completes the "simplest" feed system design. *EZNEC-ARRL* model **Rectangular_TL_Example.EZ** simulates an array fed with this system.

Comparison of the pattern plot to one from ideal-current **Rectangular_Example.EZ**, and examination of the element currents verify that the feed system is producing the desired pattern and element currents.

L-Network Feed System

To design the L-network feed system using *Arrayfeed1*, change the **Feed System Type** to **L Network** and click **Find Solutions**. The resulting L-network values are a 0.484 µH inductor for the series component X_{ser} and a 1369.6 pF capacitor for the shunt component X_{sh}.

120° Fed, 60° Spaced Dipole Array

This example shows the design of "simplest" and L network feed systems for a 2-element 20- meter dipole array, rather than a vertical array. No special accommodation is required for the array made from dipoles rather than vertical elements—the same methods can be used regardless of element shape. This example also shows that both the "simplest" and L-network feed systems can readily be applied to elements that use phase angles other than 90°.

Any 2-element array made with identical elements spaced λ/2 or closer and having equal magnitude currents with a relative phase angle of 180° minus the spacing will produce a unidirectional pattern with a good null to the rear. In practice, very close spacings lead to very low feed-point resistances, with consequent losses and very narrowband characteristics. But this 60° spaced array is well within the range of practical realization. File **ARRL_Dipole_Array_Example.EZ** is a model created for this array, with ideal element currents. Open this file in *EZNEC-ARRL* and click **FF Plot** to show the pattern at an elevation angle of 10°. You can save this pattern for later comparison to the pattern with a "simplest" feed system by opening the **File** menu in the **2D Plot** window, selecting **Save Trace As**, entering a name for the trace file and clicking **Save**.

Following the same procedure as in the previous examples, we begin the array design by finding the element feed-point impedances in the ideally fed array using *EZNEC-ARRL* numbers. Having already opened **ARRL_Dipole_Array_Example.EZ**, all that's needed is to click **Src Dat.** The results are:

Leading element (source 1) : 36.16 – j46.05 Ω
Lagging element (source 2) : 49.56 + j51.47 Ω

"Simplest" (Transmission Line Only) Feed System

Select **Two Element** for the **Array Type** in *Arrayfeed1* and **"Simplest"** for the **Feed System Type**. Enter the frequency of 14.15 MHz and enter the element feed-point impedances from *EZNEC-ARRL* into the appropriate boxes in the **Inputs** frame. For line impedances, the section describing the "simplest" feed system recommends against choosing one which is very different from the element feed-point impedances, but for fun let's try 300 Ω for the two lines and see what happens. Enter **300** in the **Line 1 Z0** and **Line 2 Z0** boxes. Finally, enter the **lagging:leading I mag, phase** of **1** for **Mag** and **–120** for **Phase**.

Click **Find Solutions**. For this example we'll assume that TV type twinlead with a velocity factor of 0.8 is being used. So enter **0.8** for the **Velocity Factor** and read the physical line lengths in the **Physical Lengths** frame. A model of the array using the first solution has been created as **ARRL_Dipole_Array_TL_Example.EZ**. Open this file in *EZNEC-ARRL* and click **FF Tab**. You should see that the plot is virtually identical to the one saved earlier from the ideal-current model. Note the gain and front/back ratio or 8.79 dBi and 31.01 dB respectively reported in the data box below the 2D plot.

Don't subtract 2.15 dB to find the gain relative to a single element! This isn't a free-space model, and the gain of a single dipole over ground is much greater than 2.15 dBi. Instead, delete one of the elements in **ARRL_Dipole_Array_Example.EZ** to find the gain of a single element and subtract that value from the array gain. You can use the undo feature or re-open the file to restore the array.

Now, go back to the model with the "simplest" feed system in *EZNEC-ARRL* and change the Frequency to **14.0** MHz. Click **FF Tab** again. The gain has decreased a little, to 8.54 dBi and the front/back ratio has also decreased, to 21.8 dB. At 14.3 MHz, the gain is slightly higher, 9.04 dBi, but the front/back is again worse, down to 18.64 dB. But this isn't bad overall.

Let's take a look at the second solution. Click the **Trans Lines** line in the main *EZNEC-ARRL* window to open the Transmission Lines Window. Change the length of the first line to **26.856** feet, the second to **28.356** feet, and press the **Enter** key to complete the change. Change the **Frequency** back to **14.15** MHz and click **FF Tab**. You should see exactly the same pattern as for both the first solution and for the ideal current model. But now change the **Frequency** to **14.0** MHz, click FF Tab, and look at the pattern.

What happened? The gain has dropped to 5.95 dBi and the front/back to only 3.1 dB. The array is now nearly bi-directional! It's almost as bad at 14.3 MHz. So we've created a terribly touchy system. The chance of its working correctly even at the design frequency is slim, because there are inevitably some differences between the model and real antenna.

We did have a clue this might happen. As stated in the section describing the "simplest" feed system, the best choices for line Z_0 and for the resulting solution give a difference in electrical line lengths about equal to the desired phase delay of the current. The difference in electrical line lengths for the first solution was about 152°—not as close to the 120° current phase difference as we'd like, but much better than the mere 9.7° difference of the lines for the second solution. While the 300-Ω line Z_0 is quite different from the element feed-point impedances, the first solution result is quite good. If desired, you can try other line impedance values into *Arrayfeed1* and evaluate the results with *EZNEC-ARRL*.

Please see the information about baluns in the **Baluns in Phased Arrays** section. Baluns are placed the same as in Fig 19, which shows the L-network feed system.

L-Network Feed System

To design an L network feed system, change the *Arrayfeed1* **Feed System Type** to **L Network** and click **Find Solutions**. The results aren't good ones to use. The component reactance magnitudes of about 1573 and 2619 Ω are more than five times the 300-Ω Z_0 of the feed lines. As explained in the section describing the L-network feed system, it's undesirable to have such a large ratio of component reactance to line Z_0. Among other problems, the inductor and capacitor values are quite extreme and capacitor stray inductance and inductor capacitance would have a significant impact on performance.

The problem occurs because the feed-line impedance we chose is much larger than the element feed-point impedances, so the $\lambda/4$ lines transform the feed-point impedances to much higher values at the L network and main feed point. This feed system would be extremely critical, narrowbanded and difficult to adjust. We can do better by choosing feed-line impedances that aren't too drastically different than the element feed-point impedances. In this case, 50 or 75 Ω would be a much better choice than 300. Let's try 75.

In *Arrayfeed1*, change the **Line 1 Z0** and **Line 2 Z0** impedances from **300** to **75** and click **Find Solutions**. L-network component reactance magnitudes are now about 98 and 164 Ω, much better than before. This will be a relatively uncritical and broadbanded feed system.

Again, be sure to read the information about baluns in the **Baluns in Phased Arrays** section. Fig 19 shows the completed feed system including baluns.

PRACTICAL ASPECTS OF PHASED ARRAY DESIGN

With almost any type of antenna system, there is much that can be learned from experimenting with, testing and using various array configurations. In this section, Roy Lewallen, W7EL, shares the benefit of years of his experience from actually building, adjusting and using phased arrays. There is much more work to be done in most of the areas covered here, and Roy encourages the reader to build on this work.

Adjusting Phased Array Feed Systems

If a phased array is constructed only to achieve forward gain, adjusting it is seldom worthwhile. This is because the forward gain of most arrays is quite insensitive to either the magnitude or phase of the relative currents flowing in the elements. If, however, good rejection of unwanted signals is desired, adjustment may be required. And achieving very deep nulls will almost surely require some adjustment.

The in-phase and 180° out-of-phase current-forcing method supplies very well-balanced and well-phased currents to elements without adjustment. If the pattern of an array fed using this method is unsatisfactory, it's generally the result of environmental differences—where the elements, even though furnished with correct currents, aren't generating the correct fields. Such an array can be optimized in a single direction, but a more general approach than the current-forcing method must be taken. Some possibilities are described by Paul Lee and Forrest Gehrke (see Bibliography).

Unlike the current-forcing method, the "simplest" and L-network feed systems described earlier in this chapter are dependent on the self and mutual impedance of one or more elements. The required transmission-line lengths or L-network component values can be computed to a high level of precision, but the results are only as good as the knowledge of the relevant feed-point impedances.

While the simplest feed system doesn't readily lend itself to adjustment, the components of an L network can easily be made adjustable or can be experimentally changed in increments. A practical approach is to model the array as accurately as possible, design and build the feed system based on the model results and then adjust the network for the best performance.

Simple arrays such as the two-element 90° fed and spaced array can be adjusted as follows. Place a low-power signal source at a distance from the array (preferably several wavelengths), in the direction a null should be. While listening to the signal on a receiver connected to the array, alternately adjust the two L-network components for the best rejection of the signal.

This has proved to be a very good way to adjust 2-element arrays. However, variable results were obtained when a Four-Square array was adjusted using this technique. The probable reason is that more than one combination of current balance and phasing can produce a null in a given direction but each produces a different overall pattern. So a different method must be used for adjusting more complex arrays. This involves actually measuring the element currents in some way, and adjusting the network until the currents are correct. After adjusting the currents, small adjustments can be made to deepen the null(s) if desired.

Measuring Element Currents

You can measure the element currents two ways. One way is to measure them directly at the element feed points, as shown in **Fig 30**. A dual-channel oscilloscope is required to monitor the currents. This method is the most accurate and it provides a direct indication of the actual relative magnitudes and phases of the element currents. The current probe is shown in **Fig 31**.

Instead of measuring the element currents directly, you could measure them indirectly by measuring the voltages on the feed lines an electrical λ/4 or 3λ/4 distance from the array. The voltages at these points are directly proportional to the element currents. This introduces additional variables that can reduce the accuracy of the result, but the method generally produces adequate performance. The 2-element arrays fed with the L-network system and all the four element arrays presented earlier have λ/4 or 3λ/4 lines from all elements to a common location, making this second measurement method convenient. The voltages can be observed with a dual-channel oscilloscope, or, to adjust for equal-magnitude currents and 90° phasing, you can use the test circuit shown in **Fig 32**.

The test circuit is connected to the feed lines of two elements that are to be adjusted for 90° phasing (such as elements 1 and 2, or 2 and 4 of the Four-Square array of Figs 24 and 25). Adjust the L-network components alternately until both meters read zero. Proper operation of the test circuit can be verified by disconnecting one of the inputs. The *phase* output

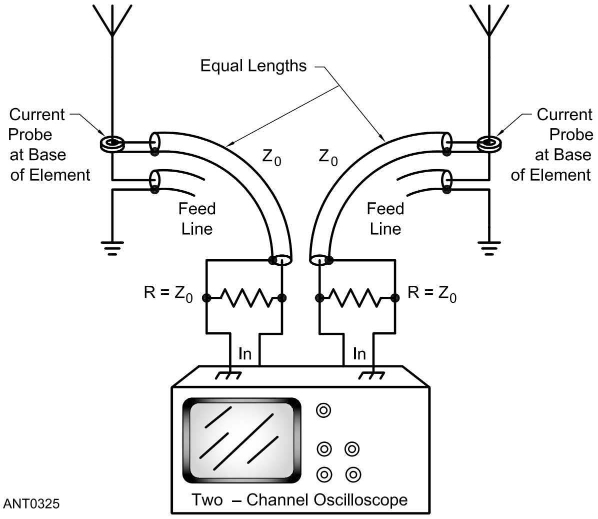
Equal Lengths
Current Probe at Base of Element
Current Probe at Base of Element
Z_0
Z_0
Feed Line
Feed Line
$R = Z_0$
$R = Z_0$
In
In
Two – Channel Oscilloscope
ANT0325

Fig 30—One method of measuring element currents in a phased array. Details of the current probe are given in Fig 31. Caution: Do not run high power to the antenna system for this measurement, or damage to the test equipment may result.

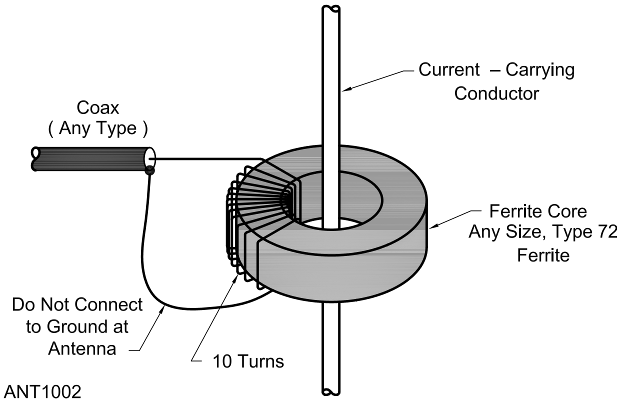
Current – Carrying Conductor
Coax (Any Type)
Ferrite Core Any Size, Type 72 Ferrite
Do Not Connect to Ground at Antenna
10 Turns
ANT1002

Fig 31—The current probe for use in the test setup of Fig 30. The ferrite core is of type 72 material, and may be any size. The coax line must be terminated at the opposite end with a resistor equal to its characteristic impedance. You should build this probe in a plastic or metal box to provide mechanical ruggedness.

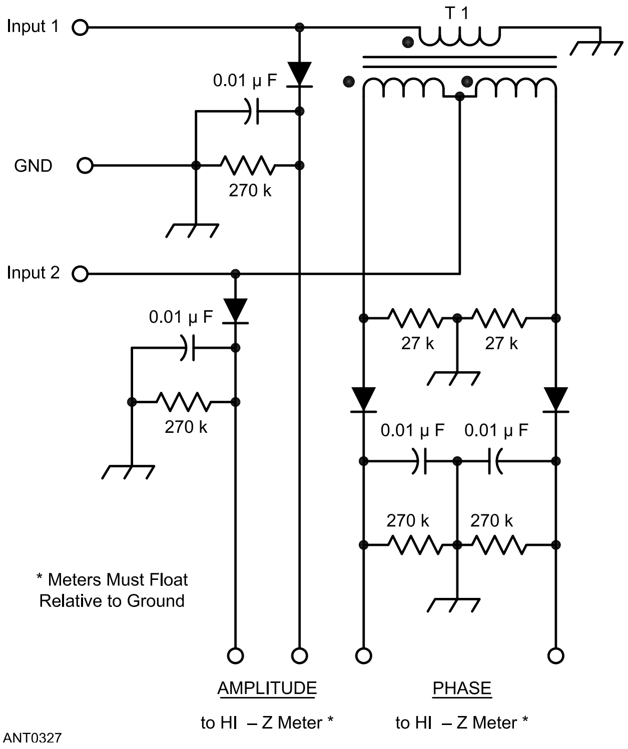

Fig 32—Quadrature test circuit. All diodes are germanium, such as 1N34A, 1N270, or equiv. Hot carrier or silicon diodes can be used at higher power levels. All resistors are ¼ or ½ W, 5% tolerance. Capacitors are ceramic. Alligator clips are convenient for making the input and ground connections to the array.

T1—7 trifilar turns on an Amidon FT-37-43, -75, -77, or equivalent ferrite toroid core.

should remain close to zero. If not, there is an undesirable imbalance in the circuit, which must be corrected. Another means of verification is to first adjust the L network so the tester indicates correct phasing (zero volts at the *phase* output). Then reverse the tester input connections to the elements. The *phase* output should remain close to zero.

Directional Switching of Arrays

One ideal directional-switching method would take the entire feed system, including the lines to the elements and physically rotate it. The smallest possible increment of rotation would depend on the symmetry of the array—the feed system would need to rotate until the array again *looks* the same to it. For example, any 2-element array can be rotated 180° (although that wouldn't accomplish anything if the array is bidirectional to begin with). The 4-element rectangular array of Figs 28 and 29 can also be reversed, and the Four-Square array of Figs 24 and 25 can be switched in 90° increments.

Smaller switching increments can be accomplished only by reconfiguring the feed system, including any network if used, effectively creating a different kind of array. Switching in smaller increments than dictated by symmetry will create a different pattern in some directions than in others, and must be thoughtfully done to maintain equal and properly phased element currents. The methods illustrated here will deal only with switching in increments related to the array symmetry, except for one: a 2-element broadside/end-fire array.

In all arrays, the success of directional switching depends on the elements and ground systems being identical so that equal element currents result in equal fields. It's even more important in arrays fed with any method other than current forcing, because the effectiveness of those methods depends on the element feed-point impedances. Few of us can afford the luxury of having an array many wavelengths away from all other conductors, so an array will nearly always perform somewhat differently in each direction. The array should be adjusted when steered in the direction requiring the most signal rejection in the nulls. Forward gain will, for all practical purposes, be equal in all the switched directions, since gain is much more tolerant of error than are nulls.

Basic Switching Methods

Following is a discussion of basic switching methods, how to power relays through the main feed line and other practical considerations. In diagrams, grounds are frequently omitted to aid clarity, but connections of the ground conductors must be carefully made. In fact, it is recommended that the ground conductors be switched just as the center conductors are, as explained in more detail in **Improving Array Switching Systems** below. In all cases, interconnecting lines must be very short.

A pair of elements spaced λ/2 apart can readily be switched between broadside and end-fire bidirectional pat-

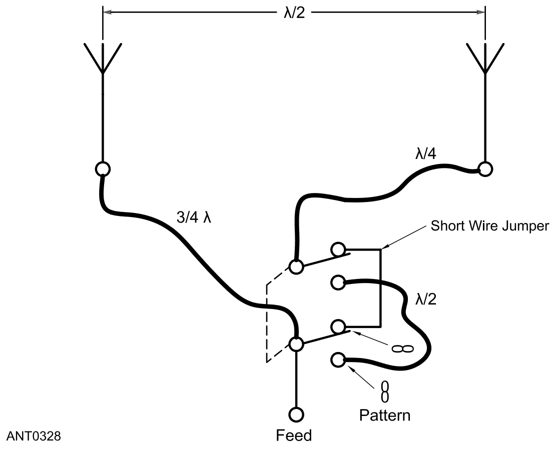

Fig 33—Two-element broadside/end-fire switching. All lines must have the same characteristic impedance. Grounds and cable shields have been omitted for clarity.

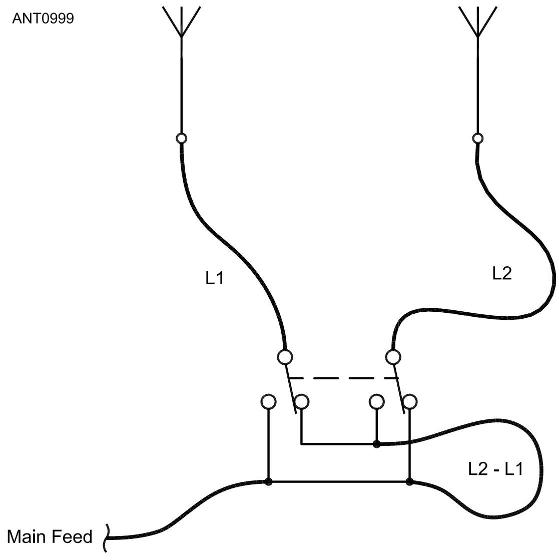

Fig 34—Directional switching for 90°, 90° spaced 2-element array fed with a "simplest" feed system.

terns, using the current-forcing properties of λ/4 lines. The method is shown in **Fig 33**. The switching device can be a relay powered via a separate cable or by dc sent along the main feed line.

Fig 34 shows directional switching of a 90° fed, 90° spaced array fed with a "simplest" feed system, where L1 and L2 are the required lengths of the two feed lines. **Fig 35** shows how to switch the same array when fed with an L-network, current-forcing system.

The rectangular array of Fig 28 can be switched in a similar manner, as shown in **Fig 36**. To switch a "simplest" fed rectangular array, use the switching circuit of Fig 34, but connect the two equal length lines to points A and B of Fig 29 in place of the two elements shown in Fig 34.

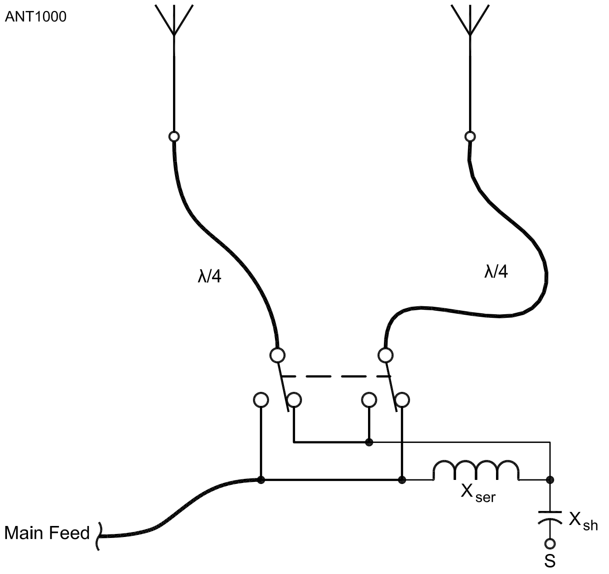

Fig 35—Directional switching for 90°, 90° spaced 2-element array fed with an L-network, current-forcing feed system.

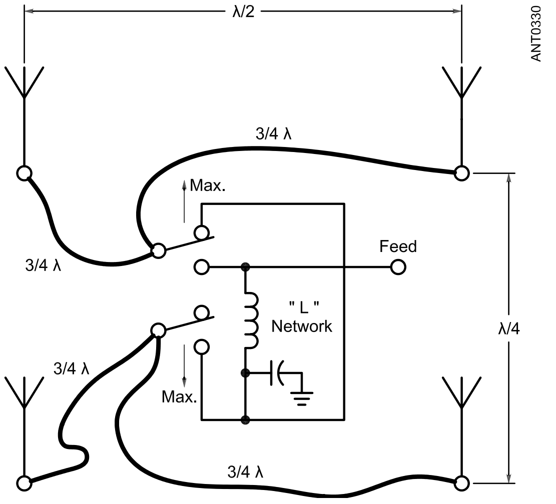

Fig 36—Directional switching of a four-element rectangular array. All interconnections must be very short. As usual, grounds and cable shields have been omitted for clarity.

Switching the direction of an array in increments of 90°, when permitted by symmetry, requires at least two relays. A method of 90° switching of the Four-Square array with L-network feed is shown in **Fig 37**.

Powering Relays Through Feed Lines

All of the above switching methods can be implemented without additional wires to the switch box. A single-relay system is shown in **Fig 38A**, and a two-relay system in

Fig 38B. Small 12 or 24-V dc power relays can be used in either system at power levels up to at least a few hundred watts. Do not attempt to change directions while transmitting, however. Blocking capacitors C1 and C2 should be good quality ceramic or transmitting mica units of 0.01 to 0.1 µF. No problems have been encountered using 0.1 µF, 300-V monolithic ceramic units at RF output levels up to 300 W. C2 may be omitted if the antenna system is an open circuit at dc. C3 and C4 should be ceramic, 0.001 µF or larger.

In Fig 38B, capacitors C5 through C8 should be selected with the ratings of their counterparts in Fig 38A, as given above. Electrolytic capacitors across the relay coils, C9 and C10 in Fig 38B, should be large enough to prevent the relays from buzzing, but not so large as to make relay operation too slow. Final values for most relays will be in the range from 10 to 100 µF. They should have a voltage rating of at least double the relay coil voltage. Some relays do not require this capacitor. All diodes are 1N4001 or similar. A rotary switch may be used in place of the two toggle switches in the two-relay system to switch the relays in the desired sequence.

Improving Array-Switching Systems

The extra circuitry involved in switching arrays can degrade array performance by altering the relative currents fed to each element. One common cause is current sharing in common ground conductors, even when connections are kept very short. The author has seen a 30° phase shift in voltage along a 4-inch piece of #12 wire in a 40-meter array feed system.

When the two conductors of a feedline are physically separated from each other, the impedance increases. This is especially true when the main lines are coaxial cables. If currents from two elements share the ground conductor of a split line, a relatively large voltage drop results. Voltage changes λ/4 from the elements translate to current changes at the elements. Although keeping all leads extremely short is sometimes adequate, the best way to reduce current sharing problems is to keep the two conductors of each transmission line as close together as possible, and switch both conductors of each line rather than just a single or "hot" conductor.

An example of a carefully designed switching system is shown in **Fig 39**. It avoids the problem of shared ground conductor currents, as well as another common problem, namely that effective line lengths are often different along different switching paths. Notice how the path from the main feed point travels through a single line to each element with no common ground connections to other lines except at the

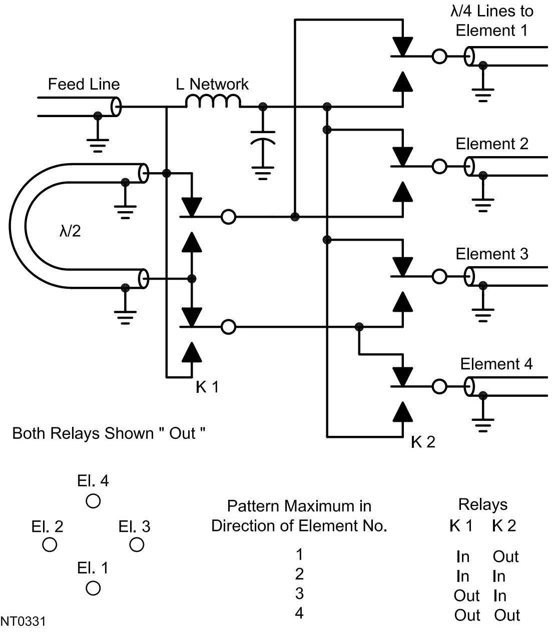

Pattern Maximum in Direction of Element No.	Relays K 1	K 2
1	In	Out
2	In	In
3	Out	In
4	Out	Out

Fig 37—Directional switching of the four-square array. All interconnections must be very short.

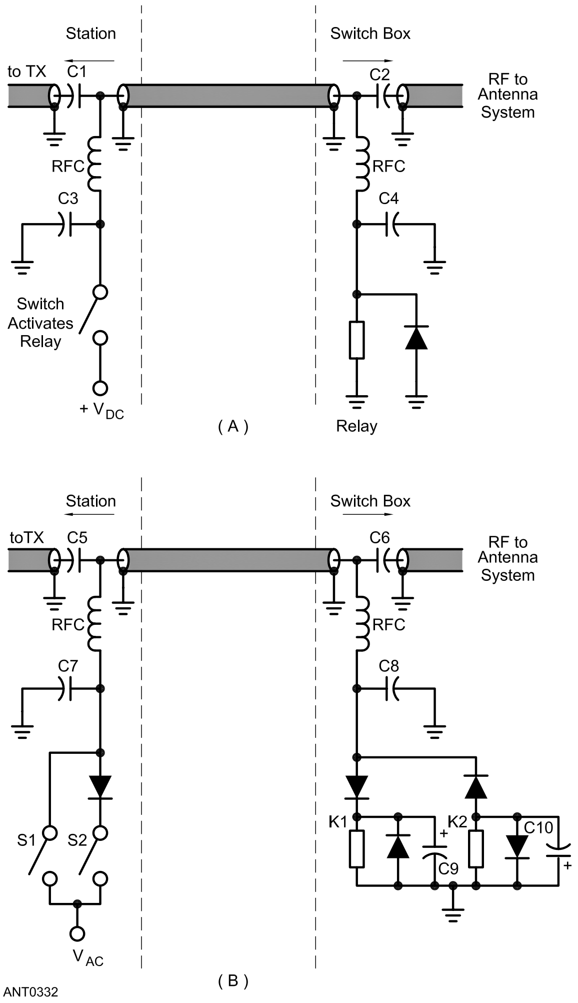

Fig 38—Remote switching of relays. See text for component information. A one-relay system is shown at A, and a two-relay system at B. In B, S1 activates K1, and S2 activates K2.

main feed point. Notice also that the distance doesn't change as the direction is switched. The λ/4 lines going to the two elements must be shortened by the length ℓ of the lines on the feed side of the relays, so that the total line length from the main feed point to each element is λ/4 (or 3λ/4).

You can see that in either relay position, there's an open ended stub of length ℓ connected at the main feed point and another at the output end of the L network. These will add capacitance at those points. Extra C at the main feed point will alter the overall impedance seen by a transmitter, but won't otherwise have any effect on the array or its performance. The one at the output of the L network will, however, change the transformation and phase shift properties of the network. But it's easy to compensate—the value of the shunt capacitor element is simply reduced by the amount of the C added by the stub. The amount of C for any kind of transmission line can be calculated from:

$$C(\mathrm{pf/ft}) = \frac{1017}{Z_0 \mathrm{VF}}$$

or

$$C(\mathrm{pf/m}) = \frac{3336}{Z_0 \mathrm{VF}}$$

where Z_0 = the characteristic impedance of the line and VF = the velocity factor. This works out to 31 pF/foot or 101 pF/meter for 50-Ω solid polyethylene insulated coax, which has a velocity factor of 0.66.

The general principles illustrated in Fig 39 can be extended to other switching systems. If switching the ground conductors as described above isn't practical, use of a metal box for the switching circuitry is recommended, so that the relatively large surface area of the box can be used for the common ground conductors, minimizing their inductance. Always keep leads extremely short.

Measuring the Electrical Length of Feed Lines

When using the feed methods described earlier the feed lines must be very close to the correct length. For best results, they should be correct within 1% or so. This means that a line that is intended to be, say, λ/4 at 7 MHz, should actually be λ/4 at some frequency within 70 kHz of 7 MHz. A simple but accurate method to determine at what frequency a line is λ/4 or λ/2 is shown in **Fig 40A**. The far end of the line is short circuited with a very short connection. A signal is applied to the input and the frequency is swept until the impedance at the input is a minimum. This is the frequency at which the

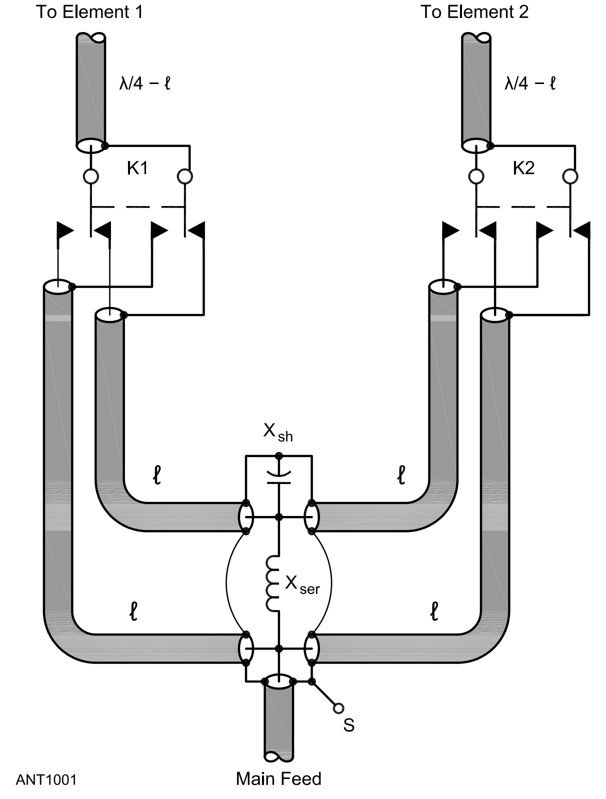

Fig 39—A carefully designed L-network, current-forcing switching system that switches both hot and shield conductors in feed coaxes.

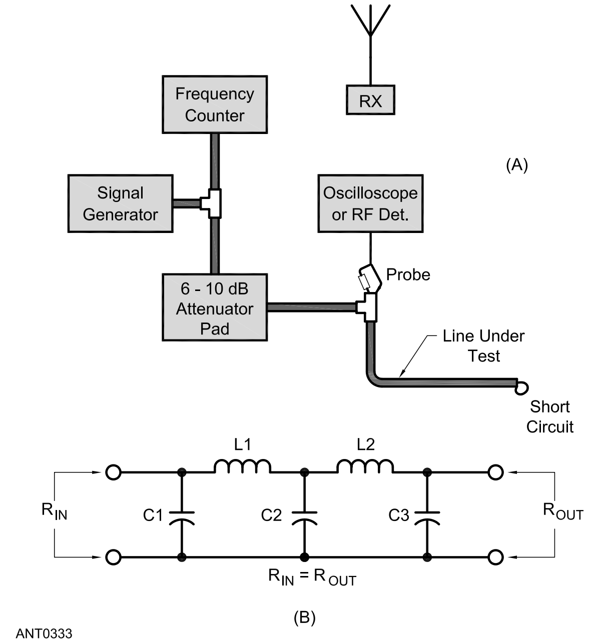

Fig 40—At A, the setup for measurement of the electrical length of a transmission line. The receiver may be used in place of the frequency counter to determine the frequency of the signal generator. The signal generator output must be free of harmonics; the half-wave harmonic filter at B may be used outboard if there is any doubt. It must be constructed for the frequency band of operation. Connect the filter between the signal generator and the attenuator pad.

C1, C3—Value to have a capacitive reactance = R_{IN}.
C2—Value to have a capacitive reactance = ½ R_{IN}.
L1, L2—Value to have an inductive reactance = R_{IN}.

line is λ/2. Either the frequency counter or the receiver may be used to determine this frequency. The line is, of course, λ/4 at one half the measured frequency.

The detector can be a simple diode detector or an oscilloscope may be used if available. A 6 to 10 dB attenuator pad is included to prevent the signal generator from looking into a short circuit at the measurement frequency. The signal generator output must be free of harmonics. If there is any doubt, an outboard low-pass filter, such as a half-wave harmonic filter, should be used. The half-wave filter circuit is shown in Fig 40B, and must be constructed for the frequency band of operation.

Another satisfactory method is to use a noise or resistance bridge or antenna analyzer at the input of the line, again looking for a low impedance at the input while the output is short circuited. Simple resistance bridges are described in Chapter 27.

Dip oscillators have been found to be unsatisfactory. The required coupling loop has too great an effect on measurements.

Measuring Element Self and Mutual Impedances

The need for measuring element self and mutual impedances has been made largely unnecessary with the ready availability of modeling software. Few amateurs appreciate the considerable difficulty of making accurate impedance measurements and accurate mutual impedance measurements are very difficult even with professional test equipment and skills. Despite the limitations of computer modeling, results very often are better than measured values because of the multiple factors affecting measurement accuracy.

Those who are interested in measuring self and mutual impedances can find more detailed information about doing so in Appendix B. The information there is from earlier editions of *The ARRL Antenna Book*.

Broadside Arrays

Broadside arrays can be made up of collinear or parallel elements or combinations of the two. This section was contributed by Rudy Severns, N6LF.

COLLINEAR ARRAYS

Collinear arrays are always operated with the elements in-phase. (If alternate elements in such an array are out-of-phase, the system simply becomes a harmonic type of antenna.) A collinear array is a broadside radiator, the direction of maximum radiation being at right angles to the line of the antenna.

POWER GAIN

Because of the nature of the mutual impedance between collinear elements, the feed-point resistance (compared to a single element, which is ≈73 Ω) is increased as shown earlier in this chapter (Fig 9). For this reason the power gain does not increase in direct proportion to the number of elements. The gain with two elements, as the spacing between them is varied, is shown by **Fig 41**. Although the gain is greatest when the end-to-end spacing is in the region of 0.4 to 0.6 λ, the use of spacings of this order is inconvenient constructionally and introduces problems in feeding the two elements. As a result, collinear elements are almost always operated with their ends

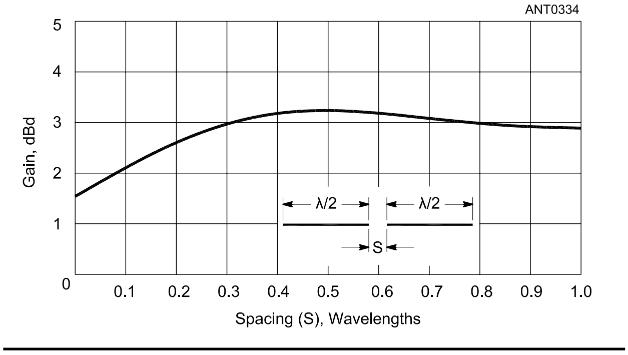

Fig 41—Gain of two collinear λ/2 elements as a function of spacing between the adjacent ends.

quite close together—in wire antennas, usually with just a strain insulator between.

With very small spacing between the ends of adjacent elements the theoretical power gain of collinear arrays, assuming the use of #12 copper wire, is approximately as follows over a dipole in free space:

2 collinear elements—1.6 dB
3 collinear elements—3.1 dB
4 collinear elements—3.9 dB

More than four elements are rarely used.

DIRECTIVITY

The directivity of a collinear array, in a plane containing the axis of the array, increases with its length. Small secondary lobes appear in the pattern when more than two elements are used, but the amplitudes of these lobes are low enough so that they are usually not important. In a plane at right angles to the array the directive diagram is a circle, no matter what the number of elements. Collinear operation, therefore, affects only E-plane directivity, the plane containing the antenna.

When a collinear array is mounted with the elements vertical, the antenna radiates equally well in all geographical directions. An array of such *stacked* collinear elements tends to confine the radiation to low vertical angles.

If a collinear array is mounted horizontally, the directive pattern in the vertical plane at right angles to the array is the same as the vertical pattern of a simple λ/2 antenna at the same height (Chapter 3).

TWO-ELEMENT ARRAYS

The simplest and most popular collinear array is one using two elements, as shown in **Fig 42**. This system is commonly known as *two half-waves in phase*. The directive pattern in a plane containing the wire axis is shown in **Fig 43**, which shows superimposed patterns for a dipole and 2, 3 and 4-element collinear arrays. Depending on the conductor size, height, and similar factors, the impedance at the feed point can be expected to be in the range of 4 to 6 kΩ, for wire antennas. If the elements are made of tubing having a low λ/dia (wavelength to diameter) ratio, values as low as 1 kΩ are representative. The system can be fed through an open-wire tuned line with negligible loss for ordinary line lengths, or a matching section may be used if desired.

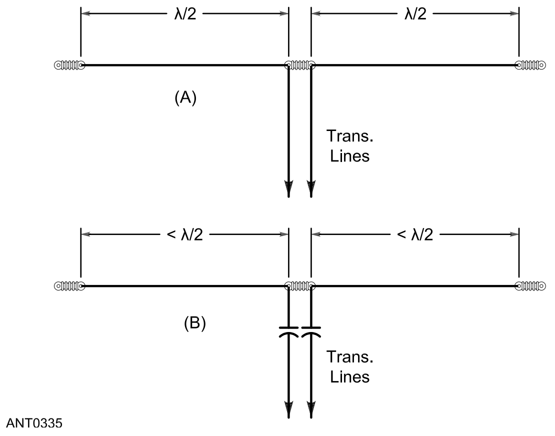

Fig 42—At A, two-element collinear array (two half-waves in phase). The transmission line shown would operate as a tuned line. A matching section can be substituted and a nonresonant line used if desired, as shown at B, where the matching section is two series capacitors.

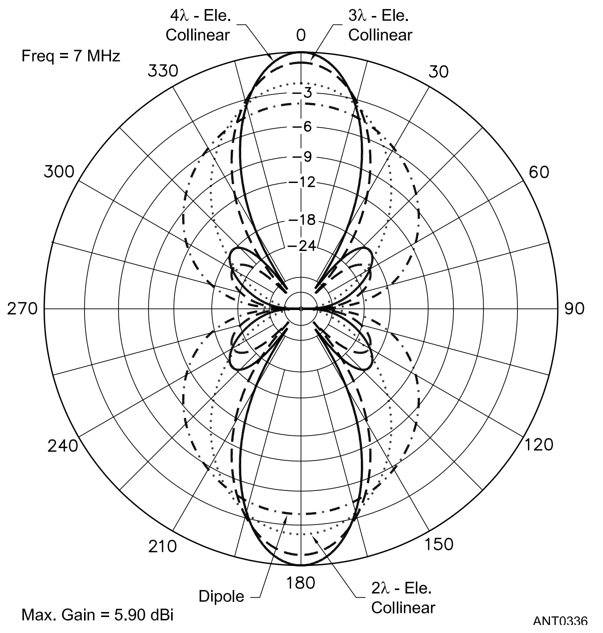

Fig 43—Free-space E-plane directive diagram for dipole, 2, 3 and 4-element collinear arrays. The solid line is a 4-element collinear; the dashed line is for a 3-element collinear; the dotted line is for a 2-element collinear and the dashed-dotted line is for a λ/2 dipole.

A number of arrangements for matching the feed line to this antenna are described in Chapter 26. If elements somewhat shorter than λ/2 are used, then additional matching schemes can be employed at the expense of a slight reduction in gain. When the elements are shortened two things happen—the impedance at the feed-point drops and the impedance has inductive reactance that can be tuned out with simple series capacitors, as shown in Fig 42B.

Note that these capacitors must be suitable for the power level. Small *doorknob* capacitors such as those frequently used in power amplifiers, are suitable. By way of an example, if each side of a 40-meter 2-element array is shortened from 67 to 58 feet, the feed-point impedance drops from nearly 6000 Ω to about 1012 Ω with an inductive reactance of 1800 Ω. The reactance can be tuned out by inserting 25 pF capacitors at the feed-point. The 1012 Ω resistance can be transformed to 200 Ω using a λ/4 matching section made of 450-Ω ladder line and then transformed to 50 Ω with a 4:1 balun. Shortening the array as suggested reduces the gain by about 0.5 dB.

Another scheme that preserves the gain is to use a 450-Ω

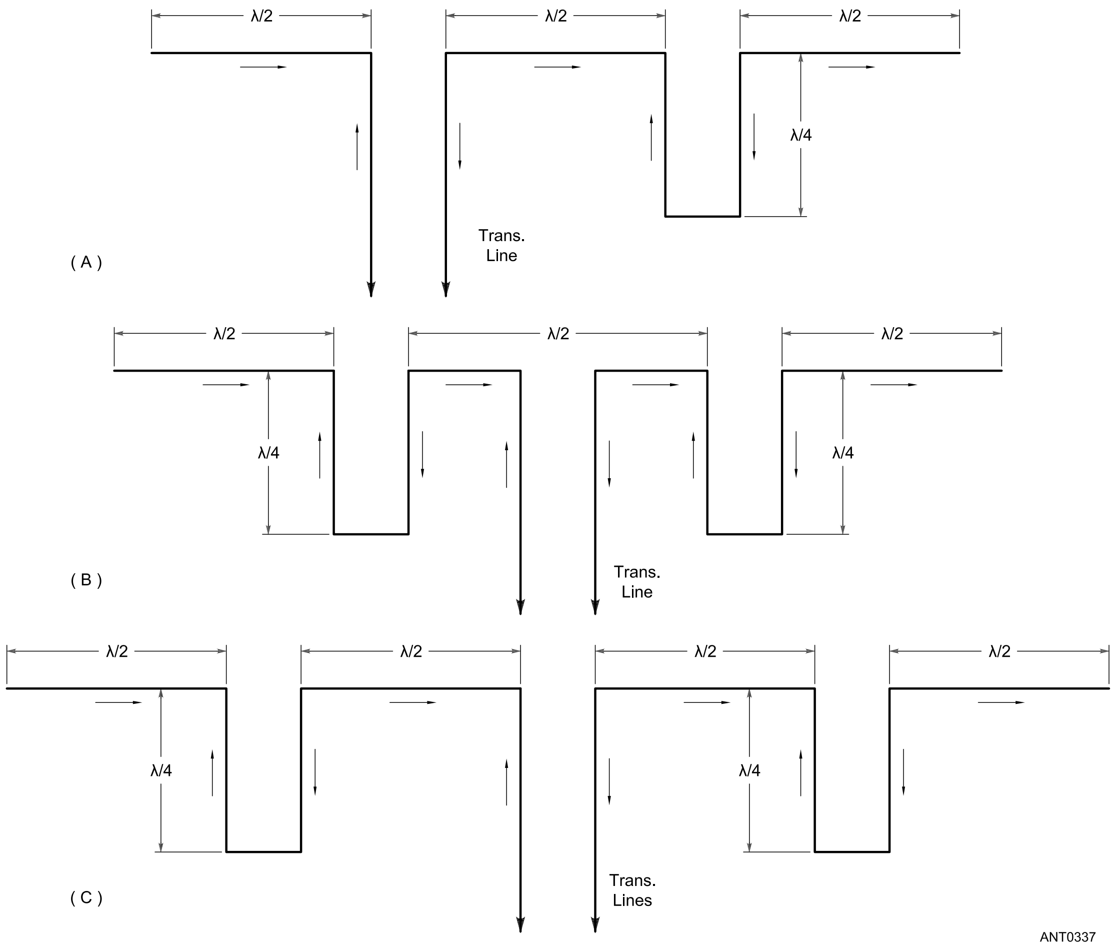

Fig 44—Layouts for 3- and 4-element collinear arrays. Alternative methods of feeding a 3-element array are shown at A and B. These drawings also show the current distribution on the antenna elements and phasing stubs. A matched transmission line can be substituted for the tuned line by using a suitable matching section.

λ/4 matching section and shorten the antenna only slightly to have a resistance of 4 kΩ. The impedance at the input of the matching section is then near 50 Ω and a simple 1:1 balun can be used. Many other schemes are possible. The free-space E-plane response for a 2-element collinear array is shown in Fig 43, compared with the responses for more elaborate collinear arrays described below.

THREE- AND FOUR-ELEMENT ARRAYS

In a long wire the direction of current flow reverses in each λ/2 section. Consequently, collinear elements cannot simply be connected end to end; there must be some means for making the current flow in the same direction in all elements. When more than two collinear elements are used it is necessary to connect *phasing* stubs between adjacent elements in order to bring the currents in all elements in-phase. In **Fig 44A** the direction of current flow is correct in the two left-hand elements because the shorted λ/4 transmission line (*stub*) is connected between them. This stub may be looked upon simply as the alternate λ/2 section of a long-wire antenna folded back on itself to cancel its radiation. In Fig 44A the part to the right of the transmission line has a total length of three half wavelengths, the center half wave being folded back to form a λ/4 phase-reversing stub. No data are available on the impedance at the feed point in this arrangement, but various considerations indicate that it should be over 1 kΩ.

An alternative method of feeding three collinear elements is shown in Fig 44B. In this case power is applied at the center of the middle element and phase-reversing stubs are used between this element and both of the outer elements. The impedance at the feed point in this case is somewhat over 300 Ω and provides a close match to 300 Ω line. The SWR will be less than 2:1 when 600-Ω line is used. Center feed of this type is somewhat preferable to the arrangement in Fig 44A because the system as a whole is balanced. This assures more uniform power distribution among the elements. In Fig 44A, the right-hand element is likely to receive somewhat less power than the other two because a portion of the input power is radiated by the middle element before it can reach the element located at the extreme right.

A four-element array is shown in Fig 44C. The system is symmetrical when fed between the two center elements as shown. As in the three-element case, no data are available on the impedance at the feed point. However, the SWR with a 600 Ω line should not be much over 2:1.

Fig 43 compares the directive patterns of 2, 3 and 4-element arrays. Collinear arrays can be extended to more than four elements. However, the simple 2-element collinear array is the type most frequently used, as it lends itself well to multi-band operation. More than two collinear elements are seldom used because more gain can be obtained from other types of arrays.

ADJUSTMENT

In any of the collinear systems described, the lengths of the radiating elements in feet can be found from the formula $468/f_{MHz}$. The lengths of the phasing stubs can be found from the equations given in Chapter 26 for the type of line used. If the stub is open-wire line (500 to 600 Ω impedance) you may assume a velocity factor of 0.975 in the formula for a λ/4 line. On-site adjustment is, in general, an unnecessary refinement. If desired, however, the following procedure may be used when the system has more than two elements.

Disconnect all stubs and all elements except those directly connected to the transmission line (in the case of feed such as is shown in Fig 44B leave only the center element connected to the line). Adjust the elements to resonance, using the still-connected element. When the proper length is determined, cut all other elements to the same length. Make the phasing stubs slightly long and use a shorting bar to adjust their length. Connect the elements to the stubs and adjust the stubs to resonance, as indicated by maximum current in the shorting bars or by the SWR on the transmission line. If more than three or four elements are used it is best to add elements two at a time (one at each end of the array), resonating the system each time before a new pair is added.

THE EXTENDED DOUBLE ZEPP

One method to obtain higher gain that goes with wider spacing in a simple system of two collinear elements is to make the elements somewhat longer than λ/2. As shown in **Fig 45**, this increases the spacing between the two in-phase λ/2 sections at the ends of the wires. The section in the center carries a current of opposite phase, but if this section is short the current will be small; it represents only the outer ends of a λ/2 antenna section. Because of the small current and short length, the radiation from the center is small. The optimum length for each element is 0.64 λ. At greater lengths the system tends to act as a long-wire antenna, and the gain decreases.

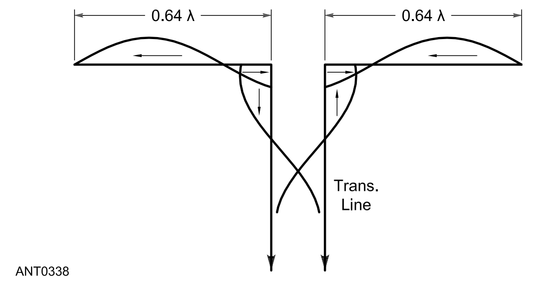

Fig 45—The extended double Zepp. This system gives somewhat more gain than two λ-sized collinear elements.

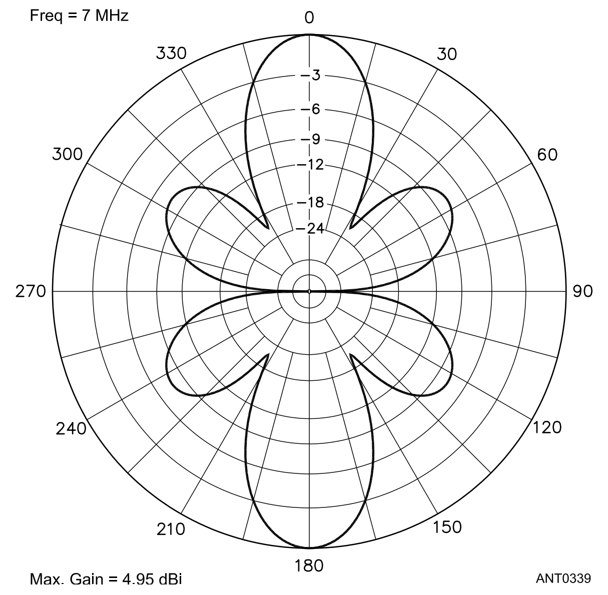

Fig 46—E-plane pattern for the extended double Zepp of Fig 45. This is also the horizontal directional pattern when the elements are horizontal. The axis of the elements lies along the 90°-270° line. The free-space array gain is approximately 4.95 dBi.

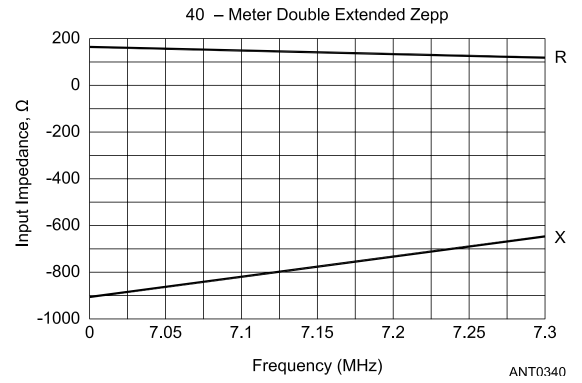

Fig 47—Resistive and reactive feed-point impedance of a 40-meter extended double Zepp in free space.

This system is known as the *extended double Zepp*. The gain over a λ/2 dipole is approximately 3 dB, as compared with about 1.6 dB for two collinear λ/2 dipoles. The directional pattern in the plane containing the axis of the antenna is shown in **Fig 46**. As in the case of all other collinear arrays, the free-space pattern in the plane at right angles to the antenna elements is the same as that of a λ/2 antenna—circular.

This antenna is not resonant at the operating frequency so that the feed-point impedance is complex (R ± *j* X). A typical example of the variation of the feed-point impedance over the band for a 40-meter double-extended Zepp is shown in **Fig 47**. This antenna is normally fed with open-wire transmission line to an antenna tuner. Other matching arrangements are, of course, possible. A method for transforming the feed-point impedance to 450 Ω and eliminating the minor lobes is given in Chapter 6.

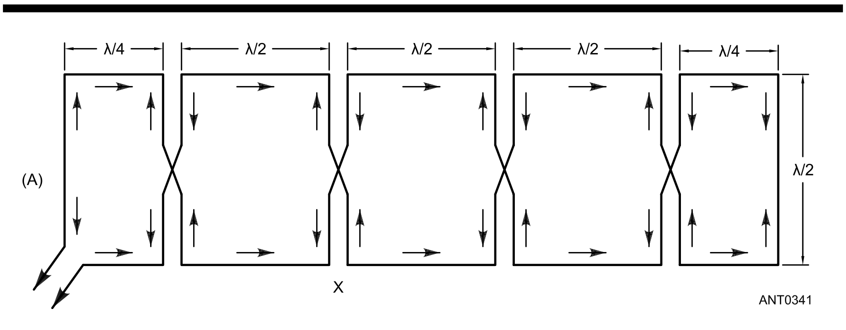

Fig 48—Typical Sterba array, an 8-element version.

THE STERBA ARRAY

Two collinear arrays can be combined to form the *Sterba array*, often called the *Sterba curtain*. An 8-element example of a Sterba array is shown in **Fig 48**. The four λ/4 elements joined on the ends are equivalent to two λ/2 elements. The two collinear arrays are spaced λ/2 and the λ/4 phasing lines connected together to provide λ/2 phasing lines. This arrangement has the advantage of increasing the gain for a given length and also increasing the E-plane directivity, which is no longer circular. An additional advantage of this array is that the wire forms a closed loop. For installations where icing is a problem a low voltage dc or low frequency (50 or 60 Hz) ac current can be passed through the wire to heat it for deicing. The heating current is isolated from RF by decoupling chokes. This is standard practice in commercial installations.

The number of sections in a Sterba array can be extended as far as desired but more than four or five are rarely used because of the slow increase in gain with extra elements, the narrow H-plane directivity and the appearance of multiple sidelobes. When fed at the point indicated the impedance is about 600 Ω. The antenna can also be fed at the point marked X. The impedance at this point will be about 1 kΩ. The gain of the 8-element array in Fig 48 will be between 7 to 8 dB over a single element.

Parallel Broadside Arrays

To obtain broadside directivity with parallel elements the currents in the elements must all be in-phase. At a distant point lying on a line perpendicular to the axis of the array and also perpendicular to the plane containing the elements, the fields from all elements add up in phase. The situation is like that pictured in Fig 1 in this chapter, where four parallel λ/2 dipoles were fed together a broadside array.

Broadside arrays of this type theoretically can have any number of elements. However, practical limitations of construction and available space usually limit the number of broadside parallel elements.

POWER GAIN

The power gain of a parallel-element broadside array depends on the spacing between elements as well as on the number of elements. The way in which the gain of a two-element array varies with spacing is shown in **Fig 49**. The greatest gain is obtained when the spacing is in the vicinity of 0.67 λ.

The theoretical gains of broadside arrays having more than two elements are approximately as follows:

No. of Parallel Elements	*dB Gain with λ/2 Spacing*	*dB Gain with 3λ/4 Spacing*
3	5.7	7.2
4	7.1	8.5
5	8.1	9.4
6	8.9	10.4

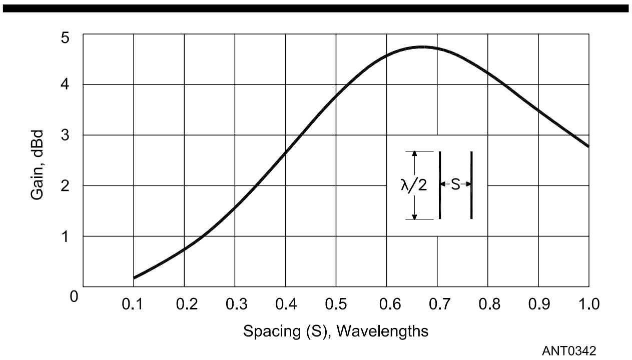

Fig 49—Gain as a function of the spacing between two parallel elements operated in-phase (broadside).

The elements must, of course, all lie in the same plane and all must be fed in-phase.

DIRECTIVITY

The sharpness of the directive pattern depends on spacing between elements and number of elements. Larger element spacing will sharpen the main lobe, for a given number of elements, up to a point as was shown in Fig 41. The two-element array has no minor lobes when the spacing is λ/2, but small minor lobes appear at greater spacings. When three or more elements are used the pattern always has minor lobes.

Other Forms Of Broadside Arrays

For those who have the available room, multi-element arrays based on the broadside concept have something to offer. The antennas are large but of simple design and noncritical dimensions; they are also very economical in terms of gain per unit of cost.

Large arrays can often be fed at several different points. However, the pattern symmetry may be sensitive to the choice of feed point within the array. Non-symmetrical feed points will result in small asymmetries in the pattern but these are not usually of great concern.

Arrays of three and four elements are shown in **Fig 50**. In the 3-element array with λ/2 spacing at A, the array is fed at the center. This is the most desirable point in that it tends to keep the power distribution among the elements uniform. However, the transmission line could alternatively be connected at either point B or C of Fig 50A, with only slight skewing of the radiation pattern.

When the spacing is greater than λ/2, the phasing lines must be 1 λ long and are not transposed between elements. This is shown Fig 50B. With this arrangement, any element spacing up to 1 λ can be used, if the phasing lines can be folded as suggested in the drawing.

The 2-element array at C is fed at the center of the system to make the power distribution among elements as uniform as possible. However, the transmission line could be connected at either point B, C, D or E. In this case the section of phasing line between B and D must be transposed to make the currents flow in the same direction in all elements. The 4-element array at C and the 3-element array at B have approximately the same gain when the element spacing in the array at B is 3λ/4.

An alternative feeding method is shown in Fig 50D. This system can also be applied to the 3-element arrays, and will result in better symmetry in any case. It is necessary only to move the phasing line to the center of each element, making connection to both sides of the line instead of one only.

The free-space pattern for a 4-element array with λ/2 spacing is shown in **Fig 51**. This is also approximately the pattern for a 3-element array with 3λ/4 spacing.

Larger arrays can be designed and constructed by following the phasing principles shown in the drawings. No accurate figures are available for the impedances at the various feed points indicated in Fig 50. You can estimate it to be in the vicinity of 1 kΩ when the feed point is at a junction between the phasing line and a λ/2 element, becoming smaller as the number of elements in the array is increased. When the feed point is midway between end-fed elements as in Fig 50C, the feed-point impedance of a 4-element array is in the vicinity of 200 to 300 Ω, with 600-Ω open-wire phasing lines. The impedance at the feed point with the antenna shown at D should be about 1.5 kΩ.

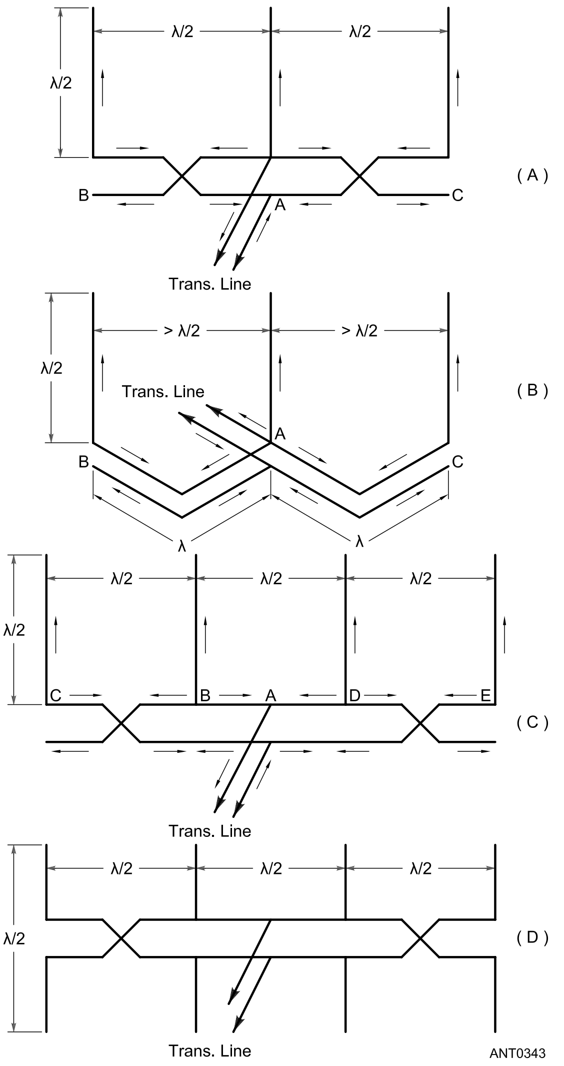

Fig 50—Methods of feeding 3- and 4-element broadside arrays with parallel elements.

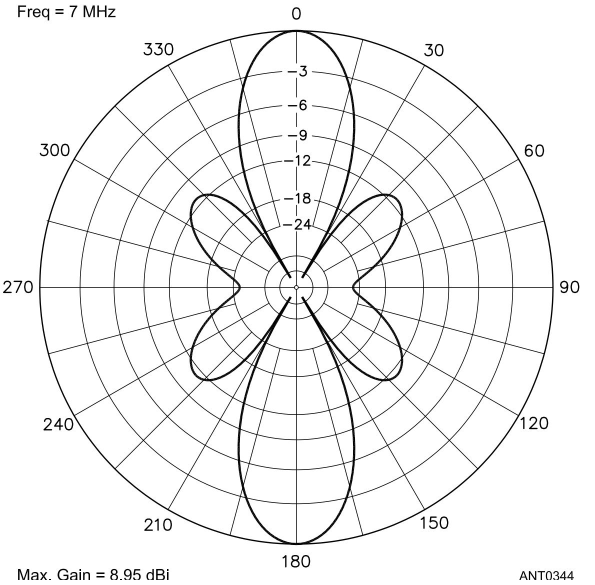

Fig 51—Free-space E-plane pattern of a 4-element broadside array using parallel elements (Fig 50). This corresponds to the horizontal directive pattern at low wave angles for a vertically polarized array over ground. The axis of the elements lies along the 90°-270° line.

NON-UNIFORM ELEMENT CURRENTS

The pattern for a 4-element broadside array shown in Fig 51 has substantial side lobes. This is typical for arrays more than λ/2 wide when equal currents flow in each element. Sidelobe amplitude can be reduced by using non-uniform current distribution among the elements. Many possible current amplitude distributions have been suggested. All of them have reduced current in the outer elements and greater current in the inner elements. This reduces the gain somewhat but can produce a more desirable pattern. One of the common current distributions is called *binomial current grading*. In this scheme the ratio of element currents is set equal to the coefficients of a polynomial. For example:

$$\begin{aligned} &1\,x+1, \quad \Rightarrow\ 1,1 \\ &(x+1)^2 = 1x^2+2x+1, \quad \Rightarrow\ 1, 2, 1 \\ &(x+1)^3 = 1x^3+3x^2+3x+1, \quad \Rightarrow\ 1, 3, 3, 1 \\ &(x+1)^4 = 1x^4+4x^3+6x^2+6x+1, \quad \Rightarrow\ 1, 4, 6, 4, 1 \end{aligned} \qquad \text{(Eq 7)}$$

In a 2-element array the currents are equal, in a 3-element array the current in the center element is twice that in the outer elements, and so on.

HALF-SQUARE ANTENNA

On the low-frequency bands (40, 80 and 160 meters) it becomes increasingly difficult to use λ/2 elements because of their size. The half-square antenna is a 2-element broadside array with λ/4-high vertical elements and λ/2 horizontal spacing. See **Fig 52**. The free-space H-plane pattern for this array is shown in **Fig 53**. The antenna gives modest (4.2 dBi) but useful gain and has the advantage of only λ/4 height. Like all vertically polarized antennas, real-world performance depends directly on the characteristics of the ground surrounding it.

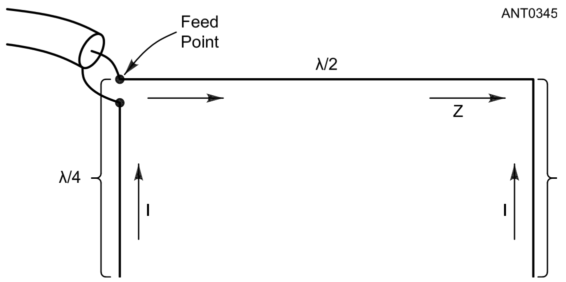

Fig 52—Layout for the half-square antenna.

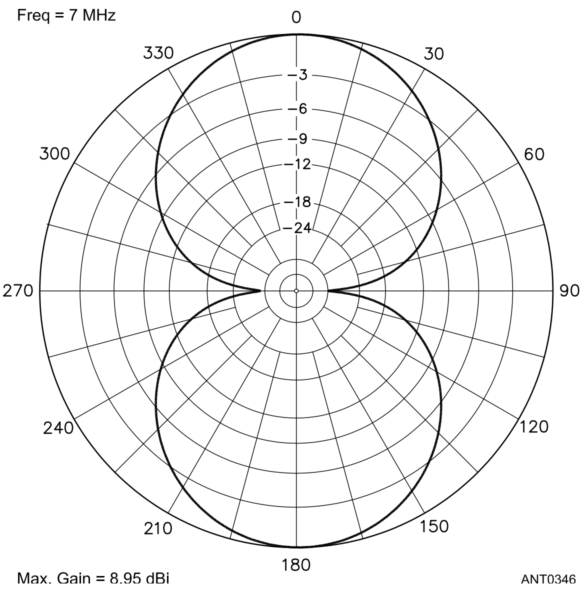

Fig 53—Free-space E-plane directive pattern for the half-square antenna.

The half-square can be fed either at the point indicated or at the bottom end of one of the vertical elements using a voltage-feed scheme, such as that shown in **Fig 54** for the bobtail curtain. The feed-point impedance is in the region of 50 Ω when fed at a corner as shown in Fig 52. A typical SWR plot is shown in **Fig 55**. Chapter 6 has a detailed discussion of the half-square antenna with several variations, together with practical considerations.

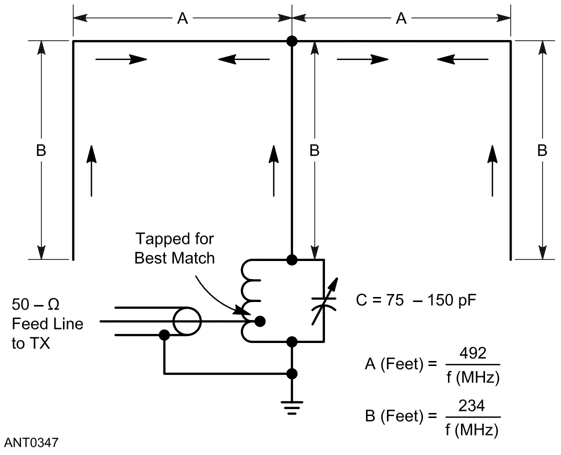

Fig 54—The bobtail curtain is an excellent low-angle radiator having broadside bidirectional characteristics. Current distribution is represented by the arrows. Dimensions A and B (in feet, for wire antennas) can be determined from the equations.

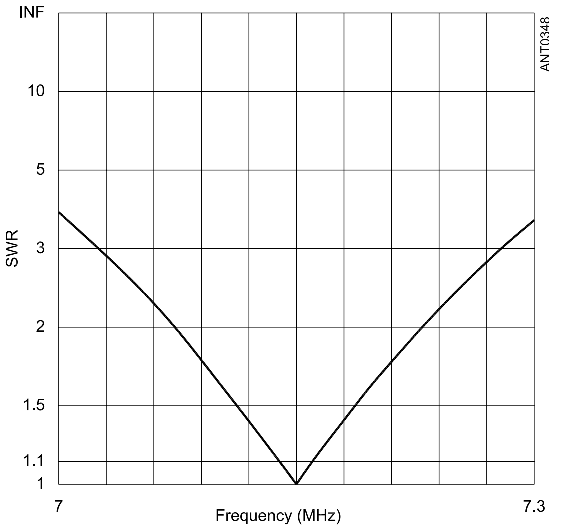

Fig 55—Typical SWR plot for a 40-meter half-square antenna fed at one corner. Antenna in free space.

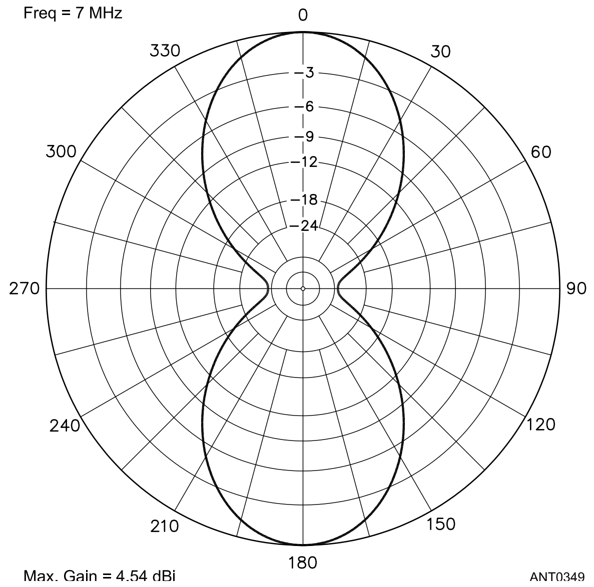

Fig 56—Calculated free-space E-plane directive diagram of the bobtail curtain shown in Fig 54. The array lies along the 90°-270° axis.

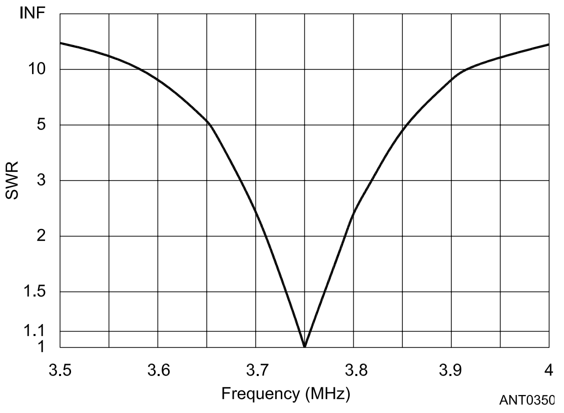

Fig 57—Typical SWR plot for an 80-meter bobtail curtain in free space. This is a narrow-band antenna.

BOBTAIL CURTAIN

The antenna system in Fig 54 uses the principles of co-phased verticals to produce a broadside, bidirectional pattern providing approximately 5.1 dB of gain over a single $\lambda/4$ element. The antenna performs as three in-phase, top-fed vertical radiators approximately $\lambda/4$ in height and spaced approximately $\lambda/2$. It is most effective for low-angle signals and makes an excellent long-distance antenna for 1.8, 3.5 or 7 MHz.

The three vertical sections are the actual radiating components, but only the center element is fed directly. The two horizontal parts, A, act as phasing lines and contribute very little to the radiation pattern. Because the current in the center element must be divided between the end sections, the current distribution approaches a binomial 1:2:1 ratio. The radiation pattern is shown in **Fig 56**.

The vertical elements should be as vertical as possible. The height for the horizontal portion should be slightly greater than B, as shown in Fig 54. The tuning network is resonant at the operating frequency. The L/C ratio should be fairly low to provide good loading characteristics. As a starting point, a maximum capacitor value of 75 to 150 pF is recommended, and the inductor value is determined by C and the operating frequency. The network is first tuned to resonance and then the tap point is adjusted for the best match. A slight readjustment of C may be necessary. A link coil consisting of a few turns can also be used to feed the antenna.

A feeling for the matching bandwidth of this antenna can be obtained by looking at a feed point located at the top end of the center element. The impedance at this point will be approximately $32\ \Omega$. An SWR plot (for $Z_0 = 32\ \Omega$) for an 80-meter bobtail curtain at this feed-point is shown in **Fig 57**. However, it is not advisable to actually connect a feed line at this point since it would detune the array and alter the pattern. This antenna is relatively narrow band. When fed at the bottom of the center element as shown in Fig 54, the SWR can be adjusted to be 1:1 at one frequency but the operating bandwidth for SWR < 2:1 may be even narrower than Fig 57 shows. For 80-meters, where operation is often desired in the CW DX window (3.510 MHz) and in the phone DX window (3.790 MHz), it will be necessary to retune the matching network as you change frequency. This can be done by switching a capacitor in or out, manually or remotely with a relay.

While the match bandwidth is quite narrow, the radiation pattern changes more slowly with frequency. **Fig 58** shows the variation in the pattern over the entire band (3.5 to 4.0 MHz). As would be expected, the gain increases with frequency because the antenna is larger in terms of wavelengths. The general shape of the pattern, however, is quite stable.

THE BRUCE ARRAY

Four variations of the Bruce array are shown in **Fig 59**. The Bruce is simply a wire folded so that the vertical sections carry large in-phase currents, while the horizontal sections carry small currents flowing in opposite directions with respect to the center of a section (indicated by dots). The radiation is vertically polarized. The gain is proportional to the length of the array but is somewhat smaller than you can obtain from a broadside array of $\lambda/2$ elements of the same length. This is because the radiating portion of the elements is only $\lambda/4$.

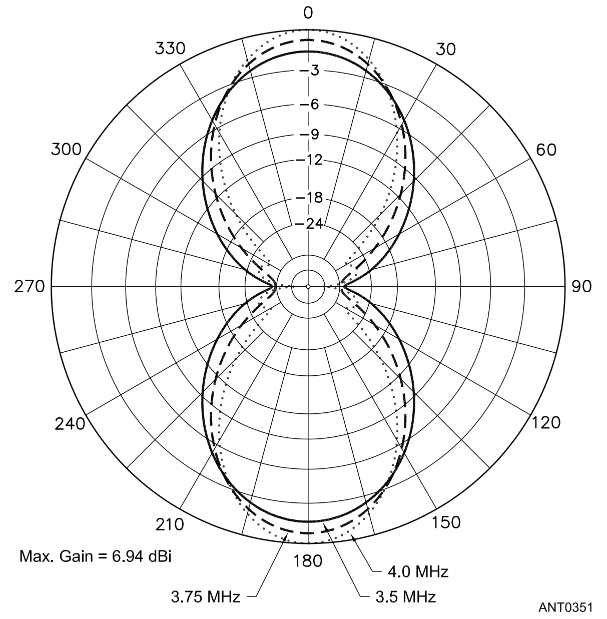

Fig 58—80-meter bobtail curtain's free-space E-plane pattern variation over the 80-meter band.

The Bruce array has a number of advantages:

1) The array is only $\lambda/4$ high. This is especially helpful on 80 and 160 meters, where the height of $\lambda/2$ supports becomes impractical for most amateurs.

2) The array is very simple. It is just a single piece of wire folded to form the array.

3) The dimensions of the array are very flexible. Depending on the available distance between supports, any number of elements can be used. The longer the array, the greater the gain.

4) The shape of the array does not have to be exactly 1.05 $\lambda/4$ squares. If the available height is short but the array can be made longer, then shorter vertical sections and longer horizontal sections can be used to maintain gain and resonance. Conversely, if more height is available but width is restricted then longer vertical sections can be used with shorter horizontal sections.

5) The array can be fed at other points more convenient for a particular installation.

6) The antenna is relatively low Q, so that the feed-point impedance changes slowly with frequency. This is very helpful on 80 meters, for example, where the antenna can be relatively broadband.

7) The radiation pattern and gain is stable over the width of an amateur band.

Note that the nominal dimensions of the array in Fig 59 call for section lengths = 1.05 $\lambda/4$. The need to use slightly longer elements to achieve resonance is common in large wire arrays. A quad loop behaves in the same manner. This is quite different from wire dipoles, which are typically *shortened* by 2-5% to achieve resonance.

Fig 60 shows the variations in gain and pattern for 2 to 5-element 80-meter Bruce arrays. **Table 2** lists the gain over a vertical $\lambda/2$ dipole, a 4-radial ground-plane vertical and the size of the array. The gain and impedance parameters listed are for free space. Over real ground the patterns and gain will depend on the height above ground and the ground characteristics. Copper loss using #12 conductors in included.

Worthwhile gain can be obtained from these arrays, especially on 80 and 160 meters, where any gain is hard to come by. The feed-point impedance is for the center of a vertical section. From the patterns in Fig 60 you can see that sidelobes start to appear as the length of the array is increased beyond $3\lambda/4$. This is typical for arrays using equal currents in the elements.

It is interesting to compare the bobtail curtain (Fig 54) with a 4-element Bruce array. **Fig 61** compares the radiation patterns for these two antennas. Even though the Bruce is shorter ($3\lambda/4$) than the bobtail ($1\ \lambda$), it has slightly more

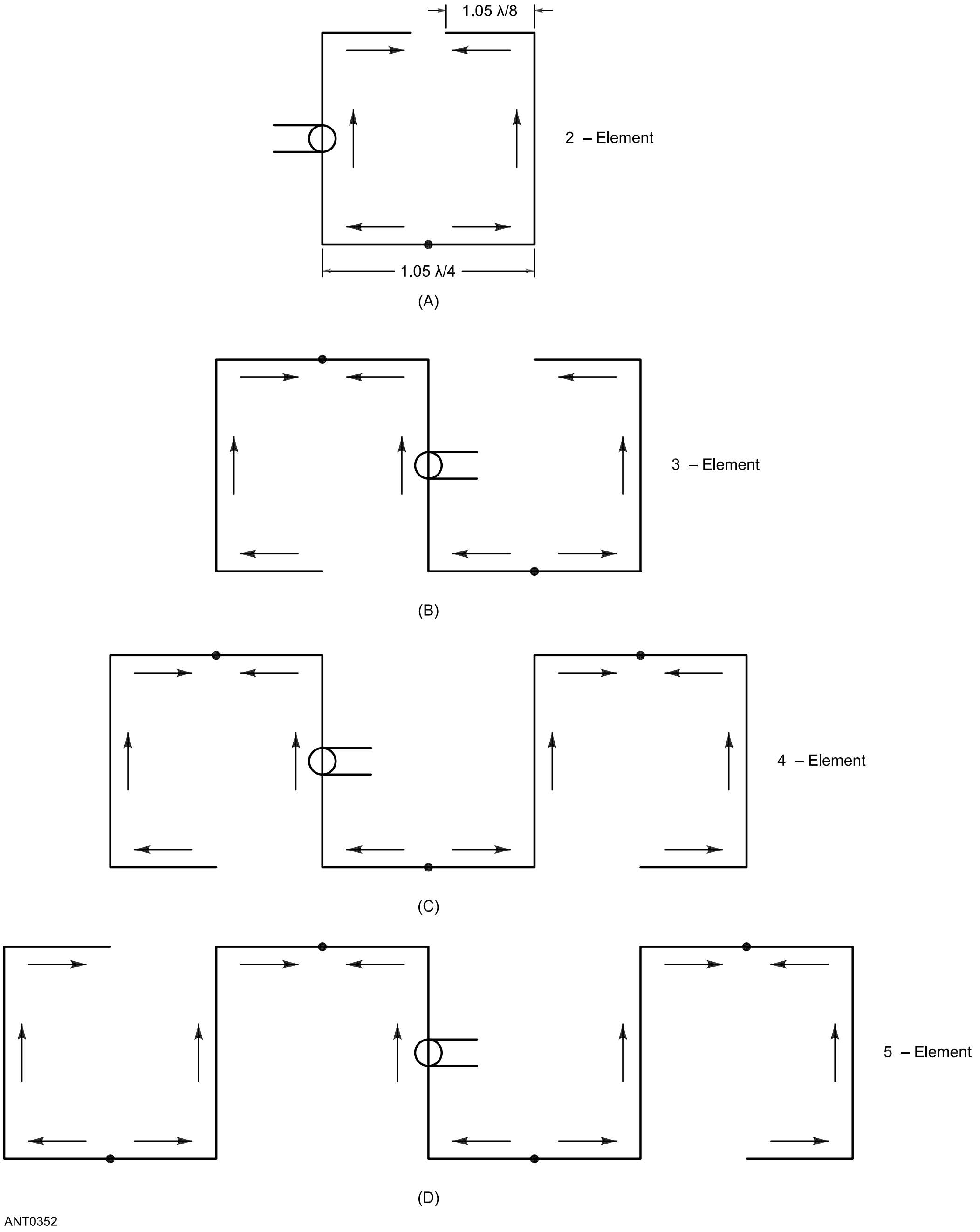
1.05 λ/8
2 – Element
1.05 λ/4
(A)
3 – Element
(B)
4 – Element
(C)
5 – Element
(D)
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Fig 59—Various Bruce arrays: 2, 3, 4 and 5-element versions.

Table 2

Bruce array length, impedance and gain as a function of number of elements

Number Elements	*Gain Over λ/2 Vertical Dipole*	*Gain over λ/4 Ground-Plane*	*Array Length Wavelengths*	*Approx. Feed Z, Ω*
2	1.2 dB	1.9 dB	¼	130
3	2.8 dB	3.6 dB	½	200
4	4.3 dB	5.1 dB	¾	250
5	5.3 dB	6.1 dB	1	300

gain. The matching bandwidth is illustrated by the SWR curve in **Fig 62**. The 4-element Bruce has over twice the match bandwidth (200 kHz) than does the bobtail (75 kHz in Fig 57). Part of the gain difference is due to the binomial current distribution—the center element has twice the current as the outer elements in the bobtail. This reduces the gain slightly so that the 4-element Bruce becomes competitive. This is a good example of using more than the minimum number of elements to improve performance or to reduce size. On 160 meters the 4-element Bruce will be 140 feet shorter than the bobtail, a significant reduction. If additional space is available for the bobtail (1 λ) then a 5-element Bruce could

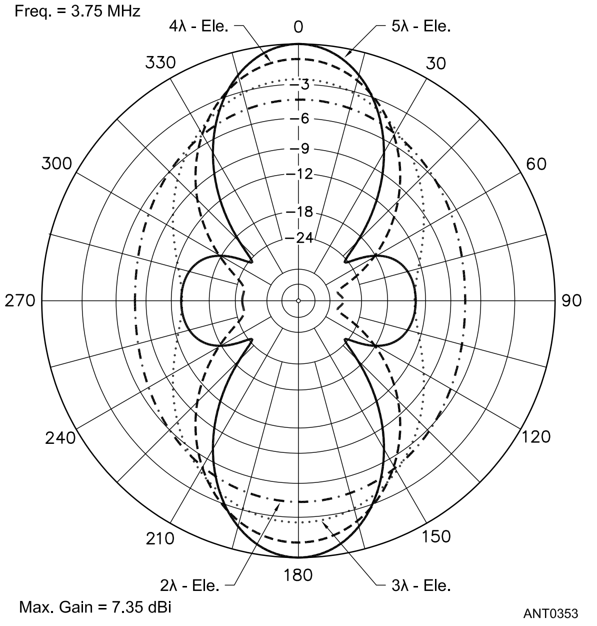

Fig 60—80-meter free-space E-plane directive patterns for the Bruce arrays shown in Fig 59. The 5-element's pattern is a solid line; the 4-element is a dashed line; the 3-element is a dotted line, and the 2-element version is a dashed-dotted line.

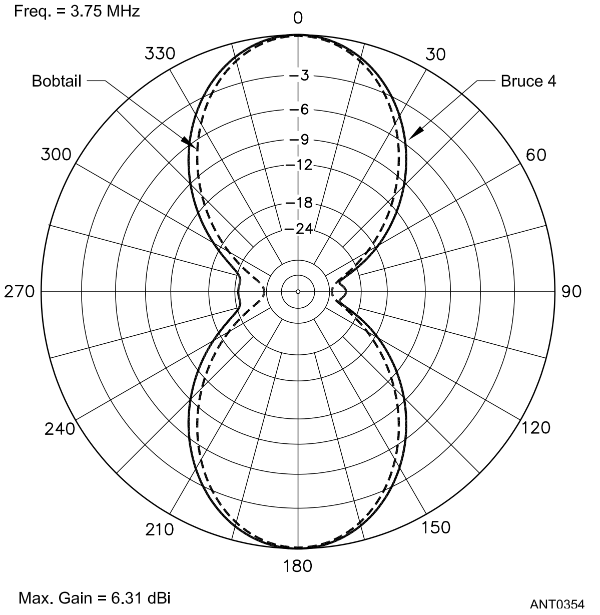

Fig 61—Comparison of free space patterns of a 4-element Bruce array (solid line) and a 3-element bobtail curtain (dashed line).

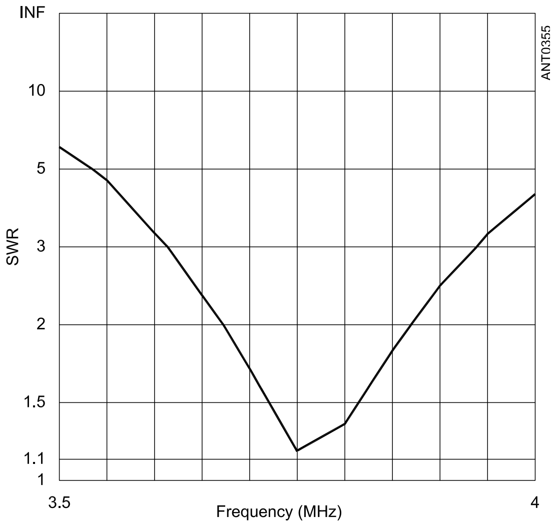

Fig 62—Typical SWR curve for a 4-element 80-meter Bruce array.

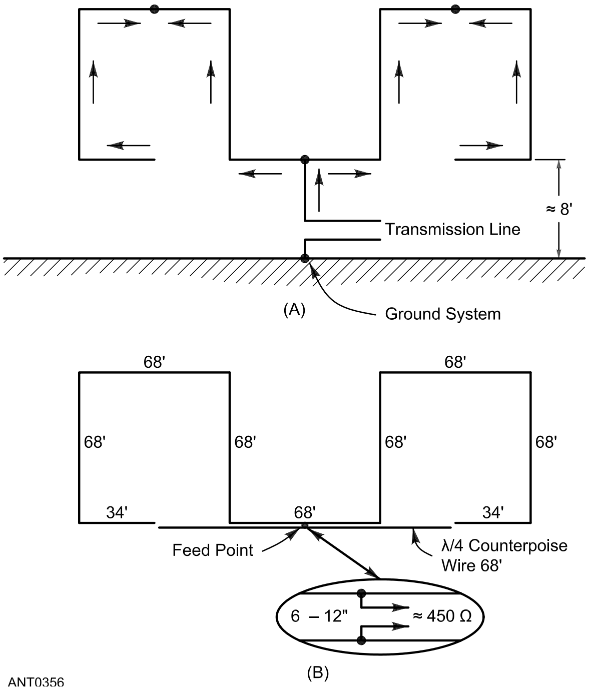

Fig 63—Alternate feed arrangements for the Bruce array. At A, the antenna is driven against a ground system and at B, it uses a two-wire counterpoise.

be used, with a small increase in gain but also introducing some sidelobes.

The 2-element Bruce and the half-square antennas are both 2-element arrays. However, since the spacing between radiators is greater in the half-square (λ/2) the gain of the half-square is about 1 dB greater. If space is available, the half-square would be a better choice. If there is not room for a half-square then the Bruce, which is only half as long (λ/4), may be a good alternative. The 3-element Bruce, which has the same length (λ/2) as the half-square, has about 0.6 dB more gain than the half-square and will have a wider match bandwidth.

The Bruce antenna can be fed at many different points and in different ways. In addition to the feed points indicated in Fig 59, you may connect the feed line at the center of any of the vertical sections. In longer Bruce arrays, feeding at one end will result in some current imbalance among the elements but the resulting pattern distortion is small. Actually, the feed-point can be anywhere along a vertical section. One very convenient point is at an outside corner. The feed-point impedance will be higher (about 600 Ω). A good match for 450-Ω ladder-line can usually be found somewhere on the vertical section. It is important to recognize that feeding the antenna at a voltage node (dots in Fig 59) by breaking the wire and inserting an insulator, completely changes the current distribution. This will be discussed in the section on endfire arrays.

A Bruce can be fed unbalanced against ground or against a counterpoise as shown in **Fig 63**. Because it is a vertically polarized antenna, the better the ground system, the better the performance. As few as two elevated radials can be used as shown in Fig 63B, but more radials can also be used to improve the performance, depending on local ground constants. The original development of the Bruce array in the late 1920s used this feed arrangement.

FOUR-ELEMENT BROADSIDE ARRAY

The 4-element array shown in **Fig 64** is commonly known as the *lazy H*. It consists of a set of two collinear elements and a set of two parallel elements, all operated in-phase to give broadside directivity. The gain and directivity will depend on the spacing, as in the case of a simple parallel-element broadside array. The spacing may be chosen between the limits shown on the drawing, but spacings below 3λ/8 are not worthwhile because the gain is small. Estimated gains compared to a single element are:

3λ/8 spacing—4.2 dB
λ/2 spacing—5.8 dB
5λ/8 spacing—6.7 dB
3λ/4 spacing—6.3 dB

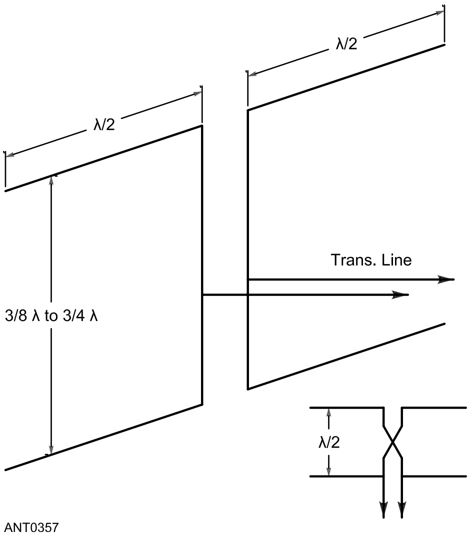

Fig 64—Four-element broadside array ("lazy H") using collinear and parallel elements.

Half-wave spacing is generally used. Directive patterns for this spacing are given in **Figs 65** and **66**. With λ/2 spacing between parallel elements, the impedance at the junction of the phasing line and transmission line is resistive and in the vicinity of 100 Ω. With larger or smaller spacing the impedance at this junction will be reactive as well as resistive. Matching stubs are recommended in cases where a non-resonant line is to be used. They may be calculated and adjusted as described in Chapter 26.

The system shown in Fig 64 may be used on two bands having a 2-to-1 frequency relationship. It should be designed for the higher of the two frequencies, using 3λ/4 spacing between parallel elements. It will then operate on the lower frequency as a simple broadside array with 3λ/8 spacing.

An alternative method of feeding is shown in the small diagram in Fig 64. In this case the elements and the phasing line must be adjusted exactly to an electrical half wavelength. The impedance at the feed point will be resistive and on the order of 2 kΩ.

THE BI-SQUARE ANTENNA

A development of the lazy H, known as the *bi-square antenna*, is shown in **Fig 67**. The gain of the bi-square is somewhat less than that of the lazy-H, but this array is attractive because it can be supported from a single pole. It has a circumference of 2 λ at the operating frequency, and is horizontally polarized.

The bi-square antenna consists of two 1 λ radiators, fed 180° out-of-phase at the bottom of the array. The radiation resistance is 300 Ω, so it can be fed with either 300- or 600-Ω line. The free space gain of the antenna is about 5.8 dBi, which is 3.7 dB more than a single dipole element. Gain may be increased by adding a parasitic reflector or director. Two bi-square arrays can be mounted at right angles and switched to provide omnidirectional coverage. In this way, the antenna wires may be used as part of the guying system for the pole.

Although it resembles a loop antenna, the bi-square is not a true loop because the ends opposite the feed point

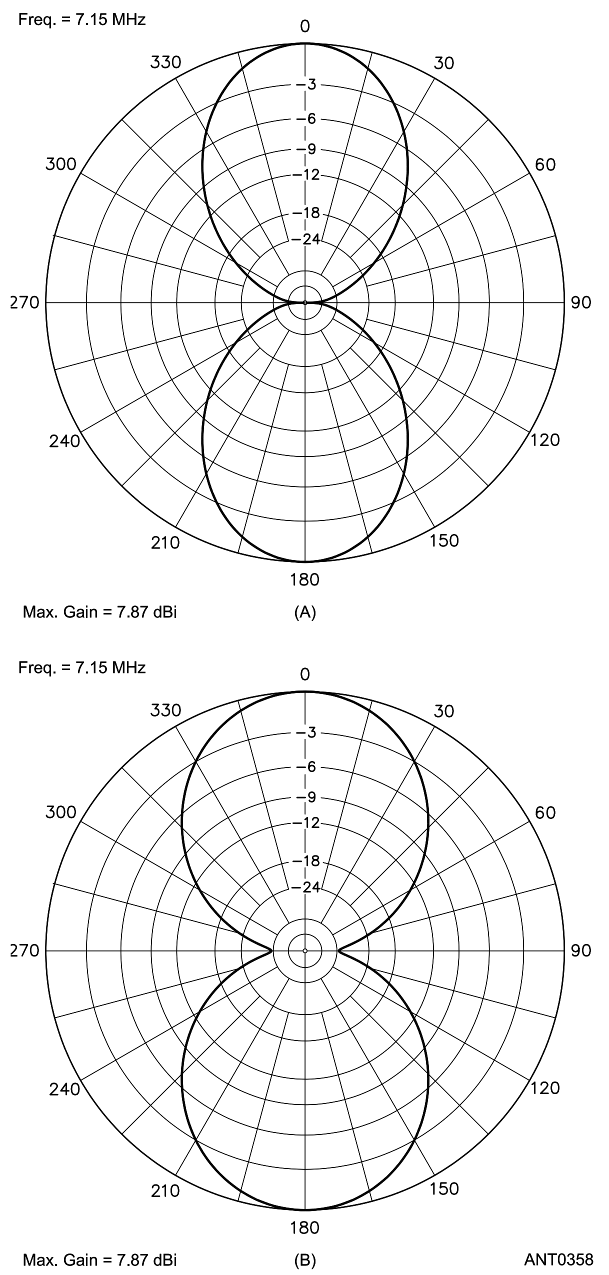

Fig 65—Free-space directive diagrams of the 4-element antenna shown in Fig 64. At A is the E-plane pattern. The axis of the elements lies along the 90°-270° line. At B is the free-space H-plane pattern, viewed as if one set of elements is above the other from the ends of the elements.

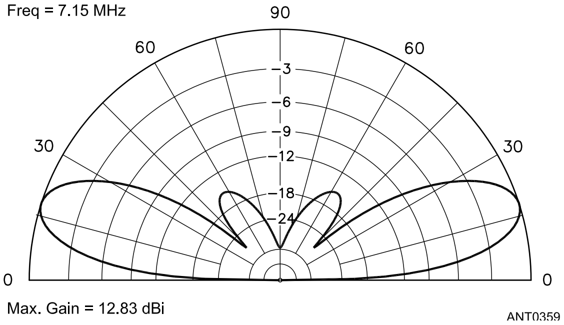

Fig 66—Vertical pattern of the 4-element broadside antenna of Fig 64, when mounted with the elements horizontal and the lower set λ/4 above flat ground. Stacked arrays of this type give best results when the lowest elements are at least λ/2 high. The gain is reduced and the wave angle raised if the lowest elements are too close to ground.

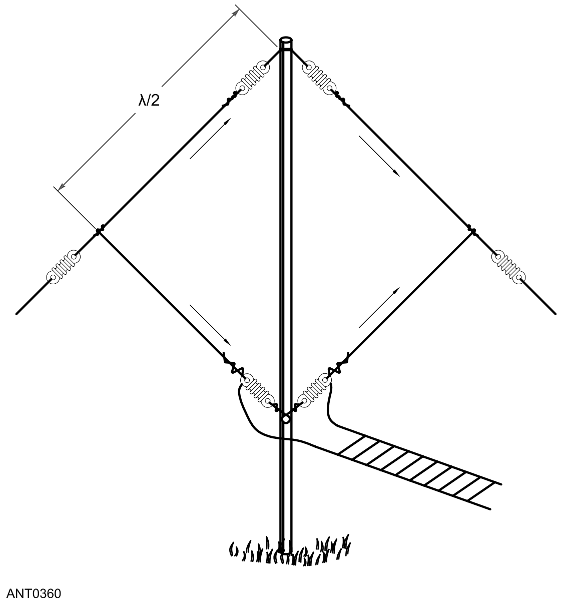

Fig 67—The bi-square array. It has the appearance of a loop, but is not a true loop because the conductor is open at the top. The length of each side, in feet, is 480/f (MHz).

are open. However, identical construction techniques can be used for the two antenna types. Indeed, with a means of remotely closing the connection at the top for lower frequency operation, the antenna can be operated on two harmonically related bands. As an example, an array with 17 feet per side can be operated as a bi-square at 28 MHz and as a full-wave loop at 14 MHz. For two-band operation in this manner, the side length should favor the higher frequency. The length of a closed loop is not as critical.

End-Fire Arrays

The term *end-fire* covers a number of different methods of operation, all having in common the fact that the maximum radiation takes place along the array axis, and that the array consists of a number of parallel elements in one plane. End-fire arrays can be either bidirectional or unidirectional. In the bidirectional type commonly used by amateurs there are only two elements, and these are operated with currents 180° out-of-phase. Even though adjustment tends to be complicated, unidirectional end-fire driven arrays have also seen amateur use, primarily as a pair of phased, ground-mounted λ/4 vertical elements. Extensive discussion of this array is contained in earlier sections of this chapter.

Horizontally polarized unidirectional end-fire arrays see little amateur use except in log-periodic arrays (described in Chapter 10). Instead, horizontally polarized unidirectional arrays usually have parasitic elements (described in Chapter 11) and are called Yagis.

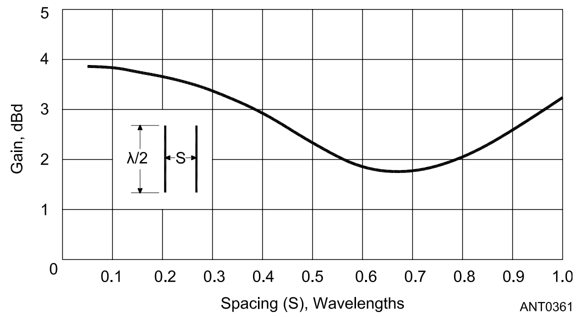

Fig 68—Gain of an end-fire array consisting of two elements fed 180° out-of-phase, as a function of the spacing between elements. Maximum radiation is in the plane of the elements and at right angles to them at spacings up to λ/2, but the direction changes at greater spacings.

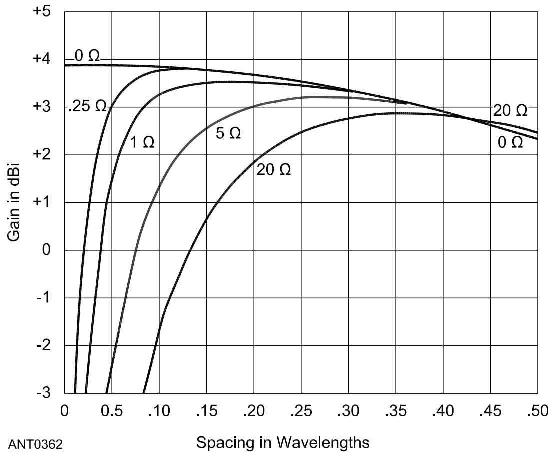

Fig 69—Gain over a single element of two out-of-phase elements in free space as a function of spacing for various loss resistances.

TWO-ELEMENT END-FIRE ARRAY

In a 2-element array with equal currents out-of-phase, the gain varies with the spacing between elements as shown in **Fig 68**. The maximum gain occurs in the neighborhood of 0.1 λ spacing. Below that the gain drops rapidly due to conductor loss resistance.

The feed-point resistance for either element is very low at the spacings giving greatest gain, as shown in Fig 8 earlier in this chapter. The spacings most frequently used are λ/8 and λ/4, at which the resistances of center-fed λ/2 elements are about 9 and 32 Ω, respectively.

The effect of conductor resistance on gain for various spacings is shown in **Fig 69**. Because current along the element is not constant (it is approximately sinusoidal), the resistance shown is the equivalent resistance (R_{eq}) inserted at the center of the element to account for the loss distributed along the element.

The equivalent resistance of a λ/2 element is one half the ac resistance (R_{ac}) of the complete element. R_{ac} is usually >> R_{dc} due to skin effect. For example, a 1.84 MHz dipole using #12 copper wire will have the following R_{eq}:

Wire length = 267 feet
Rdc = 0.00159 [/foot] × 267 [feet] = 0.42
Fr = Rac/Rdc = 10.8
Req =(Rdc/2) × Fr = 2.29

For a 3.75 MHz dipole made with #12 wire, Req = 1.59 Ω. In Fig 69, it is clear that end-fire antennas made with #12 or smaller wire will limit the attainable gain because of losses. There is no point in using spacings much less than λ/4 if you use wire elements. If instead you use elements made of aluminum tubing then smaller spacings can be used to increase gain. However, as the spacing is reduced below λ/4 the increase in gain is quite small even with good conductors. Closer spacings give little gain increase but can drastically reduce the operating bandwidth due to the rapidly increasing Q of the array.

Unidirectional End-Fire Arrays

Two parallel elements spaced λ/4 apart and fed equal currents 90° out-of-phase will have a directional pattern in the plane at right angles to the plane of the array. See **Fig 70**. The maximum radiation is in the direction of the element in which the current lags. In the opposite direction the fields from the two elements cancel.

When the currents in the elements are neither in-phase nor 180° out-of-phase, the feed-point resistances of the elements are not equal. This complicates the problem of feeding equal currents to the elements, as discussed in earlier sections.

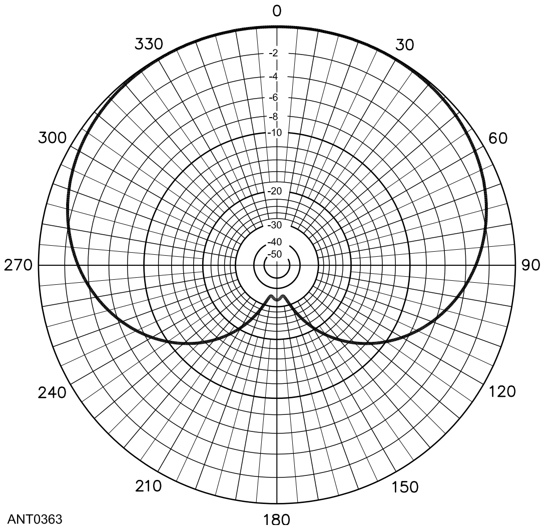

Fig 70—Representative H-plane pattern for a 2-element end-fire array with 90° spacing and phasing. The elements lie along the vertical axis, with the uppermost element the one of lagging phase. Dissimilar current distributions are taken into account. (Pattern computed with *ELNEC*.)

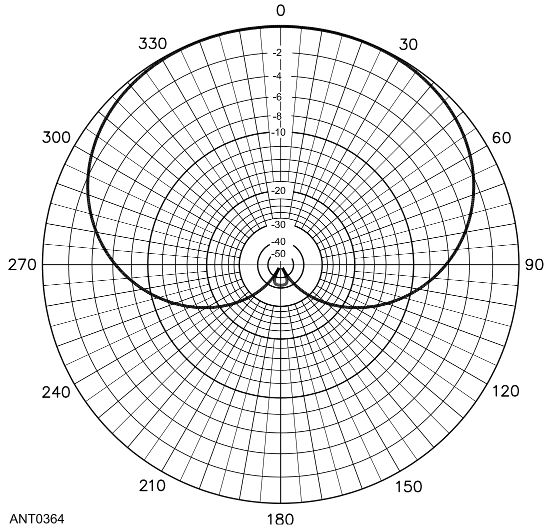

Fig 71—H-plane pattern for a 3-element end-fire array with binomial current distribution (the current in the center element is twice that in each end element). The elements are spaced λ/4 apart along the 0°-180° axis. The center element lags the lower element by 90°, while the upper element lags the lower element by 180° in phase. Dissimilar current distributions are taken into account. (Pattern computed with *ELNEC*.)

More than two elements can be used in a unidirectional end-fire array. The requirement for unidirectivity is that there must be a progressive phase shift in the element currents equal to the spacing, in electrical degrees, between the elements. The amplitudes of the currents in the various elements also must be properly related. This requires binomial current distribution. In the case of three elements, this requires that the current in the center element be twice that in the two outside elements, for 90° (λ/4) spacing and element current phasing. This antenna has an overall length of λ/2. The directive diagram is shown in **Fig 71**. The pattern is similar to that of Fig 70, but the 3-element binomial array has greater directivity, evidenced by the narrower half-power beamwidth (146° versus 176°). Its gain is 1.0 dB greater.

THE W8JK ARRAY

As pointed out earlier, John Kraus, W8JK, described his bidirectional flat-top W8JK beam antenna in 1940. See **Fig 72**. Two λ/2 elements are spaced λ/8 to λ/4 and driven 180° out-of-phase. The free-space radiation pattern for this antenna, using #12 copper wire, is given in **Fig 73**. The pattern is representative of spacings between λ/8 and λ/4 where the gain varies less than 0.5 dB. The gain over a dipole is about 3.3 dB (5.4 dBi referenced to an isotropic radiator), a worthwhile improvement. The feed-point impedance (including wire resistance) of *each* element is about 11 Ω for λ/8 spacing and 33 Ω for λ/4 spacing. The feed-point impedance at the center connection will depend on the length and Z_0 of the connecting transmission line.

Kraus gave a number of other variations for end-fire arrays, some of which are shown in **Fig 74**. The ones fed at the center (A, C and E) are usually horizontally polarized flat-top beams. The end-fed versions (B, D & F) are usually vertically polarized, where the feed point can be conveniently near ground.

A practical variation of Fig 74B is given in **Fig 75**. In this example, the height is limited to λ/4 so the ends can be bent over as shown, producing a 2-element Bruce array. This reduces the gain somewhat but allows much shorter supports, an important consideration on the low bands. If additional height is available, then you can achieve some additional gain. The upper ends can be bent over to fit the available height. The feed-point impedance will greater than 1 kΩ.

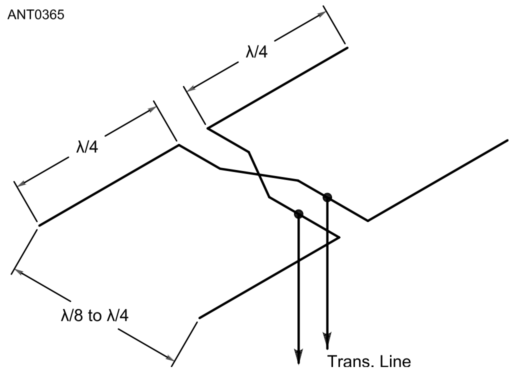

Fig 72—A 2-element W8JK array.

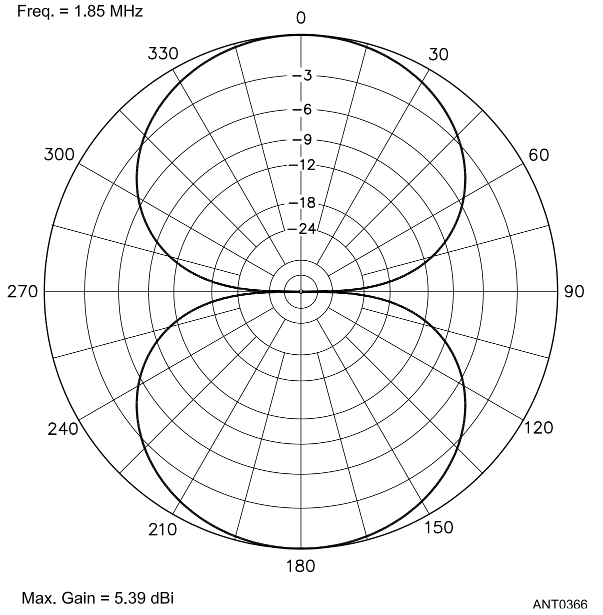

Fig 73—Free-space E-plane pattern for the 2-element W8JK array

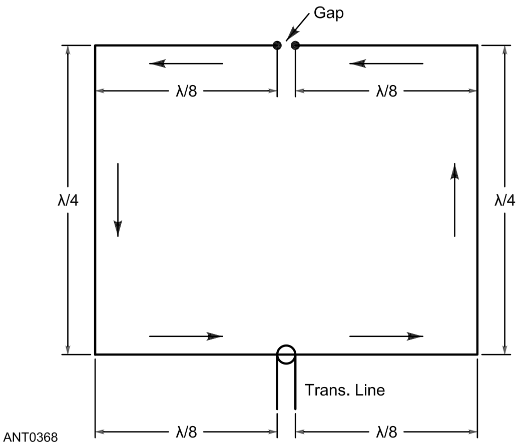
Gap
λ/8
λ/8
λ/4
λ/4
Trans. Line
λ/8
λ/8
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Fig 75—A 2-element end-fire array with reduced height.

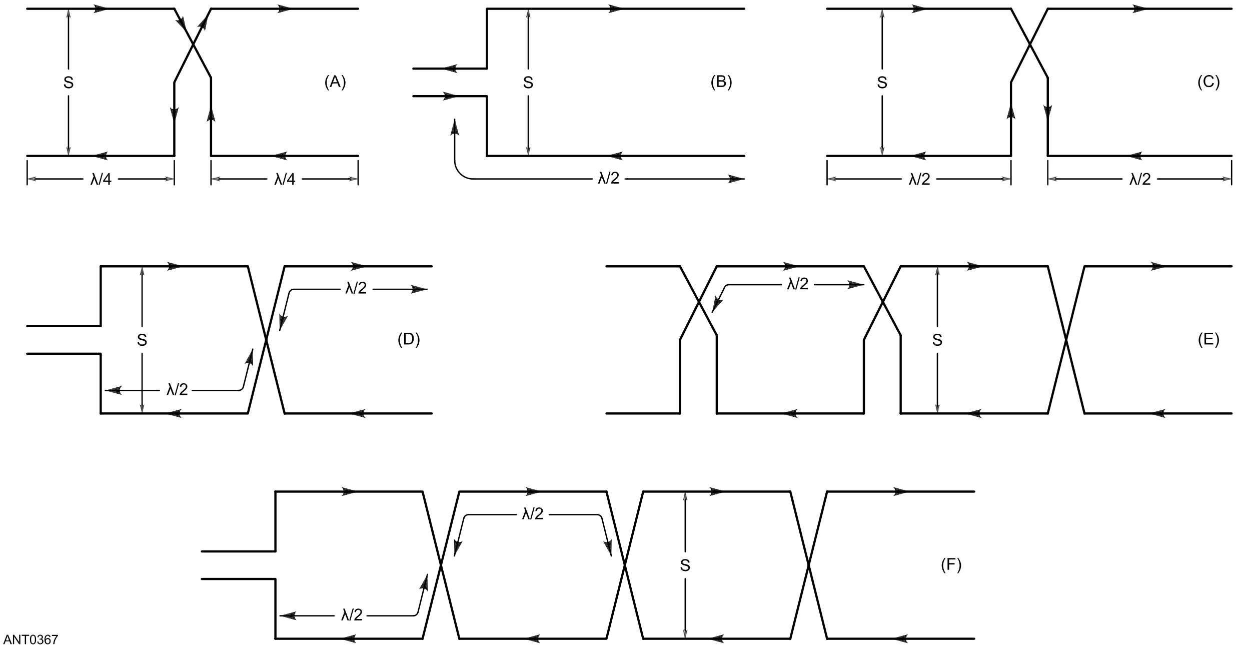
S
(A)
λ/4
λ/4
S
(B)
λ/2
S
(C)
λ/2
λ/2
λ/2
S
(D)
λ/2
λ/2
S
(E)
λ/2
λ/2
S
(F)
λ/2
ANT0367

Fig 74—Six other variations of W8JK “flat-top beam” antennas.

FOUR-ELEMENT END-FIRE AND COLLINEAR ARRAYS

The array shown in **Fig 76** combines collinear in-phase elements with parallel out-of-phase elements to give both broadside and end-fire directivity. It is a *two-section W8JK*. The approximate free-space gain using #12 copper wire is 4.9 dBi with $\lambda/8$ spacing and 5.4 dBi with $\lambda/4$ spacing. Directive patterns are given in **Figs 77** for free space, and in **Fig 78** for heights of 1 λ and $\lambda/2$ above flat ground.

The impedance between elements at the point where the phasing line is connected is of the order of several thousand ohms. The SWR with an unmatched line consequently is quite high, and this system should be constructed with open-wire line (500 or 600 Ω) if the line is to be resonant. With $\lambda/4$ element spacing the SWR on a 600 Ω line is estimated to be in the vicinity of 3 or 4:1.

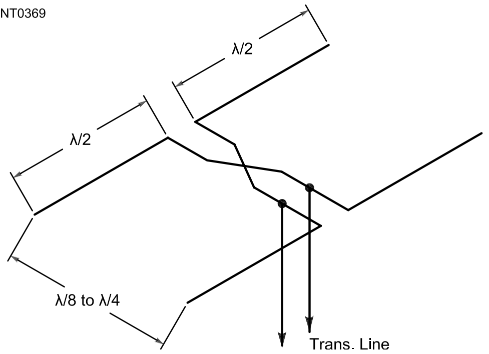

Fig 76—A 4-element array combining collinear broadside elements and parallel end-fire elements, popularly known as a two-section W8JK array.

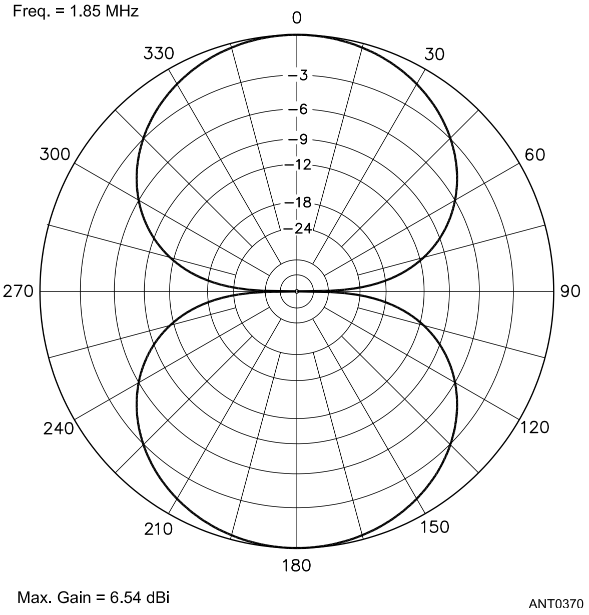

Fig 77—Free-space E-plane pattern for the antenna shown in Fig 76, with $\lambda/8$ spacing. The elements are parallel to the 90°-270° line in this diagram. Less than a 1° change in half-power beamwidth results when the spacing is changed from $\lambda/8$ to $\lambda/4$.

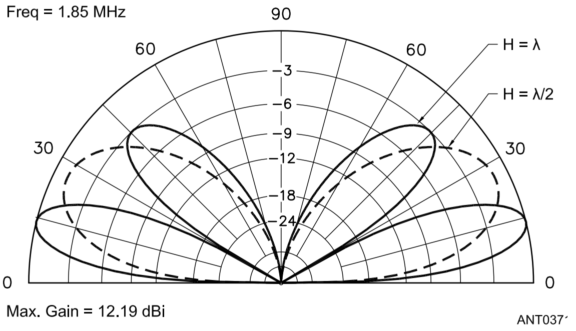

Fig 78—Elevation-plane pattern for the 4-element antenna of Fig 76 when mounted horizontally at two heights over flat ground. Solid line = 1 λ high; dashed line = $\lambda/2$ high.

To use a matched line, you could connect a closed stub $3\lambda/16$ long at the transmission-line junction shown in Fig 76. The transmission line itself can then be tapped on this matching section at the point resulting in the lowest line SWR. This point can be determined by trial.

This type of antenna can be operated on two bands having a frequency ratio of 2 to 1, if a resonant feed line is used. For example, if you design for 28 MHz with $\lambda/4$ spacing between elements, you can also operate on 14 MHz as a simple 2-element end-fire array having $\lambda/8$ spacing.

Combination Driven Arrays

You can readily combine broadside, end-fire and collinear elements to increase gain and directivity, and this is in fact usually done when more than two elements are used in an array. Combinations of this type give more gain, in a given amount of space, than plain arrays of the types just described. Since the combinations that can be worked out are almost endless, this section describes only a few of the simpler types.

The accurate calculation of the power gain of a multi-element array requires a knowledge of the mutual impedances between all elements, as discussed in earlier sections. For approximate purposes it is sufficient to assume that each set (collinear, broadside, end-fire) will have the gains as given earlier, and then simply add up the gains for the combination. This neglects the effects of cross-coupling between sets of elements. However, the array configurations are such that the mutual impedances from cross-coupling should be relatively small, particularly when the spacings are $\lambda/4$ or more, so the estimated gain should be reasonably close to the actual gain. Alternatively, an antenna modeling program, such as *EZNEC*, can give good estimates of all parameters for a real-world antenna, providing that you take care to model all applicable parameters.

FOUR-ELEMENT DRIVEN ARRAYS

The array shown in **Fig 79** combines parallel elements with broadside and end-fire directivity. The smallest array (physically)—3λ/8 spacing between broadside and λ/8 spacing between end-fire elements—has an estimated gain of 6.5 dBi and the largest—3λ/4 and λ/4 spacing, respectively—about 8.4 dBi. Typical directive patterns for a λ/4 × λ/2 array are given in **Figs 80** and **81**.

The impedance at the feed point will not be purely resistive unless the element lengths are correct and the phasing lines are exactly λ/2 long. (This requires somewhat less than λ/2 spacing between broadside elements.) In this case the impedance at the junction is estimated to be over 10 kΩ. With other element spacings the impedance at the junction will be reactive as well as resistive, but in any event the SWR will be quite large. An open-wire line can be used as a resonant line, or a matching section may be used for non-resonant operation.

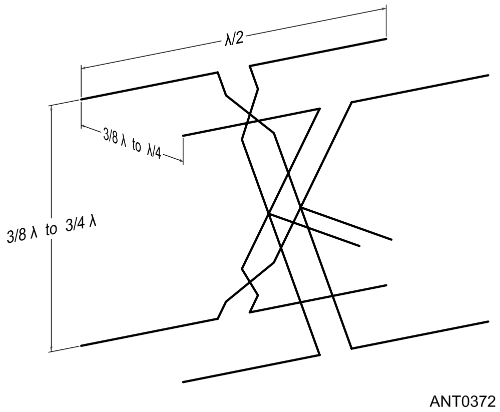

Fig 79—Four-element array combining both broadside and end-fire elements.

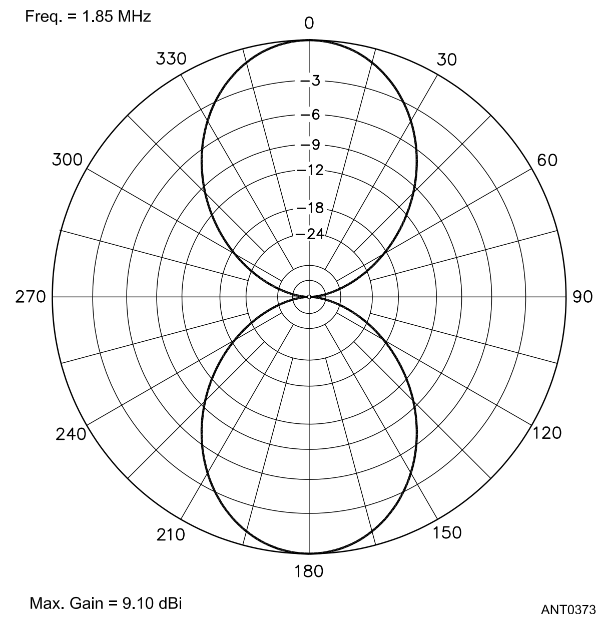

Fig 80—Free-space H-plane pattern of the 4-element antenna shown in Fig 79.

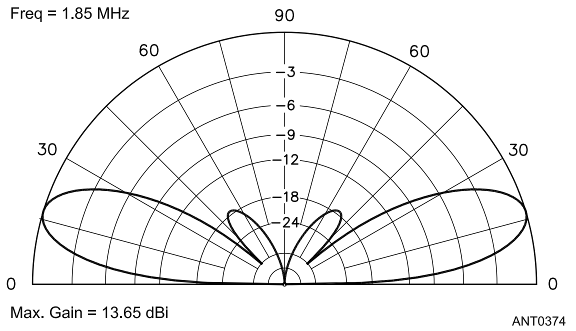

Fig 81—Vertical pattern of the antenna shown in Fig 79 at a mean height of 3λ/4 (lowest elements λ/2 above flat ground) when the antenna is horizontally polarized. For optimum gain and low wave angle the mean height should

EIGHT-ELEMENT DRIVEN ARRAYS

The array shown in **Fig 82** is a combination of collinear and parallel elements in broadside and end-fire directivity. Common practice in a wire antenna is to use λ/2 spacing for the parallel broadside elements and λ/4 spacing for the end-fire elements. This gives a free-space gain of about 9.1 dBi. Directive patterns for an array using these spacings are similar to those of Figs 80 and 81, but are somewhat sharper.

The SWR with this arrangement will be high. Matching stubs are recommended for making the lines non-resonant. Their position and length can be determined as described in Chapter 26.

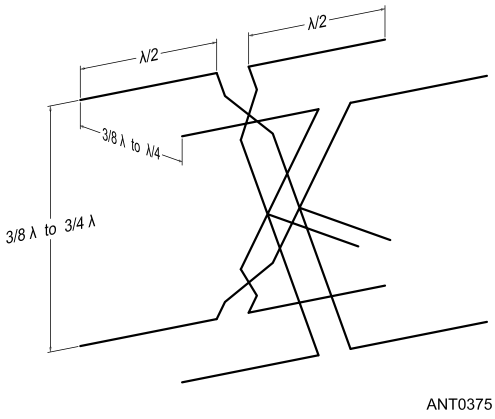

Fig 82—Eight-element driven array combining collinear and parallel elements for broadside and end-fire directivity.

This system can be used on two bands related in frequency by a 2-to-1 ratio, providing it is designed for the higher of the two, with 3λ/4 spacing between the parallel broadside elements and λ/4 spacing between the end-fire elements. On the lower frequency it will then operate as a 4-element antenna of the type shown in Fig 79, with 3λ/8 broadside spacing and λ/8 end-fire spacing. For two-band operation a resonant transmission line must be used.

PHASING ARROWS IN ARRAY ELEMENTS

In the antenna diagrams of preceding sections, the relative direction of current flow in the various antenna elements and connecting lines was shown by arrows. In laying out any antenna system it is necessary to know that the phasing lines are properly connected; otherwise the antenna may have entirely different characteristics than anticipated. The phasing may be checked either on the basis of current direction or polarity of voltages. There are two rules to remember:

1) In every λ/2 section of wire, starting from an open end, the current directions reverse. In terms of voltage, the polarity reverses at each λ/2 point, starting from an open end.
2) Currents in transmission lines always must flow in opposite directions in adjacent wires. In terms of voltage, polarities always must be opposite.

Examples of the use of current direction and voltage polarity are given at A and B, respectively, in **Fig 83**. The λ/2 points in the system are marked by small circles. When current in one section flows toward a circle, the current in the next section must also flow toward it, and vice versa. In the 4-element antenna shown at A, the current in the upper right-hand element cannot flow toward the transmission line because then the current in the right-hand section of the phasing line would have to flow upward and thus would be flowing in the same direction as the current in the left-hand wire. The phasing line would simply act like two wires in parallel in such a case. Of course, all arrows in the drawing could be reversed, and the net effect would be unchanged.

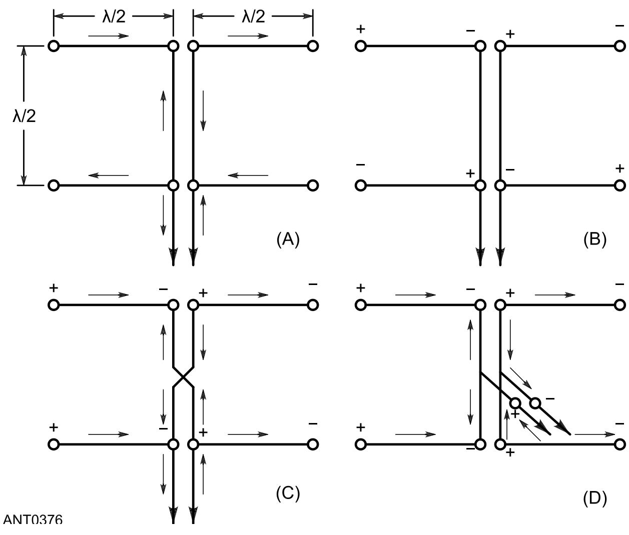

Fig 83—Methods of checking the phase of currents in elements and phasing lines.

C shows the effect of transposing the phasing line. This transposition reverses the direction of current flow in the lower pair of elements, as compared with A, and thus changes the array from a combination collinear and end-fire arrangement into a collinear-broadside array.

The drawing at D shows what happens when the transmission line is connected at the center of a section of phasing line. Viewed from the main transmission line, the two parts of the phasing line are simply in parallel, so the half wavelength is measured from the antenna element along the upper section of phasing line and thence along the transmission line. The distance from the lower elements is measured in the same way. Obviously, the two sections of phasing line should be the same length. If they are not, the current distribution becomes quite complicated; the element currents are neither in-phase nor 180° out-of-phase, and the elements at opposite ends of the lines do not receive the same current. To change the element current phasing at D into the phasing at A, simply transpose the wires in one section of the phasing line. This reverses the direction of current flow in the antenna elements connected to that section of phasing line.

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Appendix A—*EZNEC-ARRL* Examples

This appendix contains step-by-step procedures using *EZNEC-ARRL* (included on the *Antenna Book* CD) to illustrate various topics discussed in the main chapter. A standard *EZNEC* program type of v. 4.0 or later may also be used. Different versions, program types and calculating engines may give results that are slightly different from those shown in the examples. However, any differences should be insignificantly small.

EZNEC Example—Mutual Coupling

Illustrates the effect of mutual coupling on feed-point impedance. Open the **ARRL_Cardioid.EZ** file, which is mounted over "perfect" ground. Click the **View Ant** button to see a diagram of the antenna, a 2-element array of vertical elements. Click on the **Wires** line in the main window to open the Wires Window. Click the button at the left of the Wire 2 line, and then press the **Delete** key on your keyboard to delete wire #2. After clicking **Ok**, note that one of the verticals has disappeared from the View Antenna display, leaving a single element. Click **Src Dat** and note that the feed-point impedance of this single vertical is about 37 + *j* 1 Ω--it's very nearly resonant.

Next, in the Wires Window, open the **Edit** menu at the top and click **Undo delete wire(s)** to restore the second element. Click **Src Dat** again and notice that the feed-point impedance of wire #1 is now about 21 – *j* 19 Ω. The feed-point impedance of the second element, which is identical to the first, is about 52 + *j* 21 Ω. This difference, and the change from the self-impedance of 37 + *j* 1 Ω, is due to mutual coupling. As you see, it's not at all a minor effect.

As an additional exercise, change the magnitude or phase angle of the source at the base of wire #2 (click **Sources** in the main window), and see how this changes the feed-point impedances of both elements. You should be able to confirm each of the four points enumerated in the **MUTUAL COUPLING** section.

EZNEC Example—Nulls

Illustrates the effect of current magnitude on nulls and gain. Again, open the **ARRL_Cardioid.EZ** file. Click the **FF Plot** button to generate the azimuth pattern of an ideal array. Save the plot for future reference as follows: In the plot window, open the **File** menu and select **Save Trace As**. Enter the name **Cardioid** and click **Save**. Now, in the main window click on the **Sources** line to open the Sources Window. Change the magnitude of source 1 from 1 to 1.1, and of source 2 from 1 to 0.9 and press **Enter** on your keyboard so that *EZNEC-ARRL* will accept the last change.

Click **FF Plot** to generate a pattern with the new currents. In the plot window, open the File menu and select **Add**

Trace. Enter the name **Cardioid** and click Open. You should now see the original plot and new plot overlaid. Notice that the null is much less deep with the altered currents, but the forward patterns are nearly identical. By clicking on the names of the traces, **Primary** and **Cardioid**, you can see in turn the gain and front-to-back ratio of each of the traces. The original, **Cardioid**, has a front-to-back ratio of about 32 dB, while Primary, the new plot, has a ratio of about 22.5 dB. The forward gain, however, differs by only 0.02 dB, a completely insignificant amount.

EZNEC **Example—"Phasing-Line" Feed**

Illustrates the effect of using a "phasing-line" feed. Open the **ARRL_CardTL.EZ** file. This is a model of an array fed with transmission lines whose lengths were designed using the *Arrayfeed1* program to take into account the actual load impedances of elements in a phased array. This model is mounted over "perfect" ground.

Click the **View Ant** button to show the array. Note that the lengths of the lines from the source (circle) to the elements don't represent the actual physical lengths of the lines. In the main window, click on the **Trans Lines** line to open the Transmission Lines window. In it you can see that the lengths of the feed lines, both of which are connected to the same source, are about 81° and 155°, a difference of 74° rather than 90°.

In the main window, click the **Currents** button and take a look at the current shown for segment 1 of wires 1 and 2. These are the currents at the element feed points. The ratio of the magnitude of currents is 4.577/4.561 = 1.003, and the phase difference is –56.3°–(–147.5°) = 91.2°. (A more accurate determination of feed-line lengths with program *Arrayfeed1* gives lengths of 80.61° and 153.70°, resulting in a current ratio of 1.000 at a phase of 90.02°. But the resulting pattern is very nearly the same.) But let's see what happens when we make the lines exactly 90° different in length.

First, click the **FF Plot** button to generate the azimuth pattern of the original model. Save the plot for future reference as follows: In the plot window, open the **File** menu and select **Save Trace As**. Enter the name **CardTL** and click **Save**. Now in the Transmission Lines Window, change the length of line number 1 from 80.56° to 90°. *Important:* In the line 1 Length box, enter **90d** to make the line 90° long. If you omit the **d**, it will become 90 meters long! Similarly, change the length of line 2 to 180° by entering **180d** in the line 2 Length box, then press **Enter** on your keyboard so that *EZNEC* will accept the last change.

Click **FF Plot** to generate a pattern with the new line lengths. In the plot window, open the **File** menu and select **Add Trace**. Enter the name **CardTL** and click **Open**. You should now see the original plot and new plot overlaid together. Notice that the gain of the modified model is about 1 dB greater than the original, but the front-to-back ratio has deteriorated to about 10 dB.

Experiment with different combinations of line lengths that differ by 90°--for example, 45° and 135° (don't forget the '**d**'!), or change the impedance of one or both lines and you'll see that you can get a wide variety of patterns. None, however, are likely to be as close to the ideal cardioid pattern as the original.

Chapter 9

Broadband Antenna Matching

Antenna systems that provide a good impedance match to the transmitter over a wide frequency range have been a topic of interest to hams for many years. Most emphasis has been focused on the 80-meter band since a conventional half-wave dipole will provide better than 2:1 SWR over only about one-third of the 3.5 to 4.0 MHz band. The advantage of a broadband match is obvious—fewer adjustments during tune-up and an antenna tuner may not be required.

This chapter was written by Frank Witt, AI1H, who has written numerous articles in *QST* and in *The ARRL Antenna Compendium* series on this subject. See the Bibliography for details.

The term *broadband antennas* has frequently been used to describe antenna systems that provide a wideband impedance match to the transmitter. This is something of a misnomer, since most antennas are good radiators over a wide range of frequencies and are therefore "broadband antennas" by definition. The problem is getting the energy to the antenna so it can be radiated. Antenna tuners solve this problem in some cases, although losses in transmission lines, baluns and the antenna tuner itself can be excessive. Also worthy of mention is that antenna directional properties are usually frequency dependent. In this chapter, we discuss broadbanding the impedance match to the transmitter only.

GENERAL CONCEPTS

The Objective

Fig 1 shows a simplified system: the transmitter, an SWR meter and the transmitter load impedance. Modern transceivers are designed to operate properly into a 50-Ω load and they will deliver full power into the load impedance, at their rated level of distortion, when the SWR is less than about 1.5:1. Loads beyond this limit may cause the transceiver to protect itself by lowering the output power.

Many transceivers have built-in automatic antenna tuners that permit operation for loads outside the 1.5:1 SWR range, but the matching range is often limited, particularly on the lower-frequency bands. In practice, barefoot operation is simplified if the load SWR is held to less than 2:1.

For high-power amplifiers, it is also best to keep the load SWR to less than about 2:1, since output tuning components are commonly rated to handle such loads. You can see that the primary function of the SWR meter in Fig 1 is to measure the suitability of the load impedance so far as the transmitter is concerned. Henceforth, we will use the term *load SWR* as a description of the transmitter's load.

The SWR meter is actually reading a circuit condition at a single point in the system. In fact, the meter really measures magnitude of the reflection coefficient, but is calibrated in SWR. The relationships between the complex load impedance, Z_L, the magnitude of the reflection coefficient, $|\rho|$, and the load SWR are as follows:

$$|\rho| = \left| \frac{Z_L - 50}{Z_L + 50} \right| \qquad \text{(Eq 1)}$$

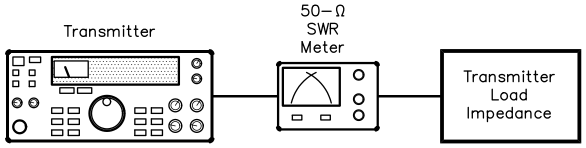

Fig 1—Basic antenna system elements at the output of a transmitter.

$$\mathrm{SWR} = \frac{1+|\rho|}{1-|\rho|} \qquad \text{(Eq 2)}$$

where 50 Ω is used as the reference impedance, since the design load impedance for the transmitter is assumed to be 50 Ω.

An important point is that you need not know the output impedance of the transmitter to design a broadband matching network. The issue of the actual value of the output impedance of typical RF power amplifiers is a matter of continuing controversy in amateur circles. Fortunately, this issue is not important for the design of broadband matching networks, since the load SWR is independent of the output impedance of the transmitter. Our objective is to design the matching network so that the load SWR (with a 50-Ω reference resistance) is less than some value, say 2:1, over as wide a band as possible.

Resonant Antennas

The broadband matching techniques described here apply to antennas operating near resonance. Typical resonant antennas include half-wave dipoles, quarter-wave verticals over a ground plane and full-wave loops. To design a broadband matching network, you must know the antenna feed-point impedance near resonance. **Fig 2** shows the antenna-impedance equivalent circuit near resonance. Although the series RLC circuit is an approximation, it is good enough to allow us to design matching networks that significantly increase the band over which a good match to the transmitter is achieved.

Note that the impedance is defined by F_0, the resonant frequency, R_A, the antenna resistance at resonance, and Q_A, the antenna Q. R_A is actually the sum of the radiation resistance and any loss resistance, including conductor losses and losses induced by surrounding objects, such as the ground below the antenna. R_A is frequency dependent, but it is sufficient to assume it is fixed during the matching network design process. Minor adjustments to the matching network will correct for the frequency dependence of R_A.

The antenna resistance and Q depend on the physical properties of the antenna itself, the properties of ground and the height above ground. Consider as an example an 80-meter horizontal half-wave dipole made from #12 wire located over average ground (dielectric constant = 13 and conductivity = 5 mS/m). **Figs 3** and **4** show how feed-point resistance and Q vary with height. It is clear from these figures that there are wide gyrations in antenna parameters. The better these parameters are known, the more successful we will be at designing the broadband matching network. For horizontal dipoles, Figs 3 and 4 may be used to get a good idea of antenna resistance and Q, so long as the height is scaled in proportion to wavelength. For example, a 160-meter dipole at a height of 100 feet would have about the same resistance and Q as an 80-meter dipole at 50 feet.

For optimum results, the resistance and Q can be

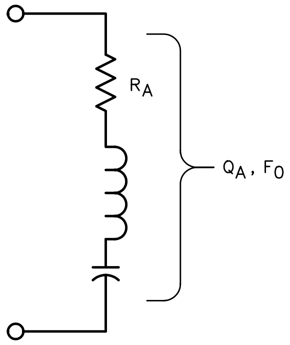

Fig 2—The equivalent circuit of a resonant antenna. The simple series RLC approximation applies to many resonant antenna types, such as dipoles, monopoles, and loops. R_A, Q_A and F_0 are properties of the entire antenna, as discussed in the text.

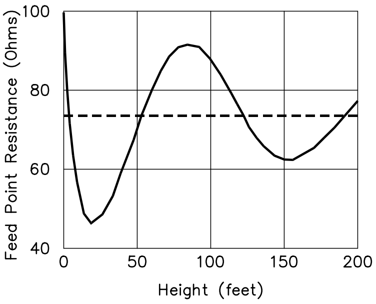

Fig 3—Feed-point resistance (solid line) for 80-meter horizontal dipole at resonance versus height over ground. The free-space value is shown as a dashed line.

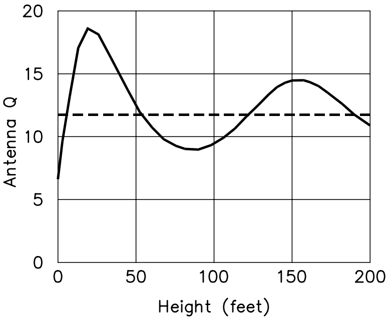

Fig 4—Antenna Q for 80-meter horizontal dipole (solid line) versus height. The free-space value is shown as a dashed line.

determined from computer simulation (using a program like *EZNEC,* for example) or measurement (using a low power SWR/Z meter such as the MFJ-259B or the Autek Research VA1 or RF-1). R_A can be computed using SWR measurements at resonance. **Fig 5** shows the typical bowl-shaped SWR curve as a function of frequency for a resonant antenna. S_0 is the SWR at resonance. You must take into account the loss of the feed line if the measurement must be made at the end of a long 50-Ω transmission line. If the line loss is low or if the measurement is made at the antenna terminals, the formulas given below apply.

For $R_A > 50\ \Omega$

$$R_A = S_0 \times 50 \qquad \text{(Eq 3)}$$

For $R_A < 50\ \Omega$

$$R_A = \frac{50}{S_0} \qquad \text{(Eq 4)}$$

There is an ambiguity, since we do not know if R_A is greater than or less than 50 Ω. A simple way of resolving this ambiguity is to take the same SWR measurement at resonance with a 10-Ω non-inductive resistor added in series with the antenna impedance. If the SWR goes up, $R_A > 45\ \Omega$. If the SWR goes down, $R_A < 45\ \Omega$. This will resolve the ambiguity.

Q_A may be determined by measuring the SWR bandwidth. Define BW_2 as the bandwidth over which the resonant antenna SWR is less than 2:1 (in the same units as F_0). See Fig 5.

For $R_A > 50\ \Omega$

$$Q_A = \frac{F_0}{BW_2}\sqrt{2.5\,S_0 - S_0^{\,2} - 1} \qquad \text{(Eq 5)}$$

For $R_A < 50\ \Omega$

$$Q_A = \frac{F_0}{BW_2 \times S_0}\sqrt{2.5\,S_0 - S_0^{\,2} - 1} \qquad \text{(Eq 6)}$$

Again, you must take into account the loss of the feed line if you make the measurement at the end of a long 50-Ω transmission line.

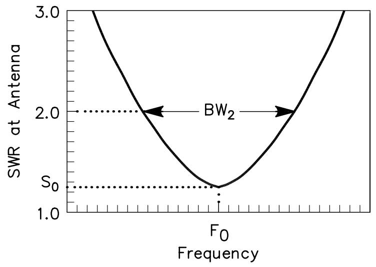

Fig 5—SWR at the antenna versus frequency in the vicinity of resonance.

For horizontal and inverted-V half-wave dipoles, a very good approximation for the antenna Q when R_A is known is given by:

$$Q_A = \frac{93.9\left[\ln\dfrac{8110}{D\,F_0} - 1\right]}{R_A} \qquad \text{(Eq 7)}$$

where D = the diameter of wire, in inches.

Loss

When you build a resonant antenna with some matching scheme designed to increase the bandwidth, you might overlook the loss introduced by the broadband matching components. Loss in dB is calculated from:

$$\text{Loss} = -10\log\frac{\text{Power radiated by antenna}}{\text{Total power from transmitter}} \qquad \text{(Eq 8)}$$

or, alternatively, define efficiency in % as

$$\text{Efficiency} = \frac{100 \times \text{Power radiated by antenna}}{\text{Total power from transmitter}} \qquad \text{(Eq 9)}$$

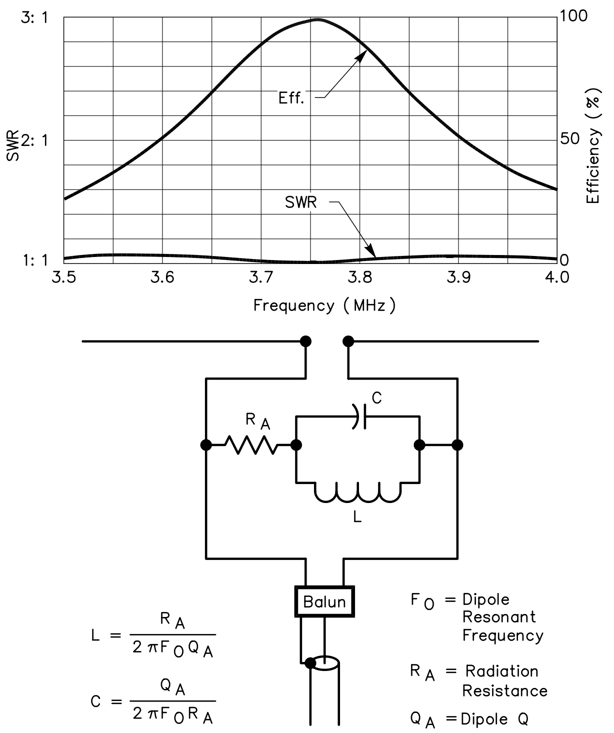
3: 1
2: 1
1: 1
SWR
100
50
0
Efficiency (%)
Eff.
SWR
3.5
3.6
3.7
3.8
3.9
4.0
Frequency (MHz)
C
R_A
L
Balun
$L = \frac{R_A}{2\pi F_0 Q_A}$
$C = \frac{Q_A}{2\pi F_0 R_A}$
F_0 = Dipole Resonant Frequency
R_A = Radiation Resistance
Q_A = Dipole Q

Fig 6—Matching the dipole with a complementary RLC network greatly improves the SWR characteristics, nearly 1:1 across the 3.5-MHz band. However, the relative loss at the band edges is greater than 5 dB.

An extreme degree of bandwidth broadening of an 80-meter dipole is illustrated in **Fig 6**. This approach is not recommended, but it is offered here to make a point. The broadening is accomplished by adding resistive losses. From network theory we obtain the RLC (resistor, inductor, capacitor) matching network shown. The network provides the complement of the antenna impedance. Note that the SWR is virtually 1:1 over the entire band (and beyond), but the efficiency falls off dramatically away from resonance.

The band-edge efficiency of 25 to 30% shown in Fig 6 means that the antenna has about 5 to 6 dB of loss relative to an ideal dipole. At the band edges, 70 to 75% of the power delivered down the transmission line from the transmitter is heating up the matching-network resistor. For a 1-kW output level, the resistor must have a power rating of at least 750 W! Use of an RLC complementary network for broadbanding is not recommended, but it does illustrate how resistance (or losses) in the matching network can significantly increase the apparent antenna SWR bandwidth.

The loss introduced by any broadband matching approach must be taken into consideration. Lossy matching networks will usually provide more match bandwidth improvement than less lossy ones.

SIMPLE BROADBAND MATCHING TECHNIQUES

The Cage Dipole

You can increase the match bandwidth of a single-wire dipole by using a thick radiator, one with a large diameter. The gain and radiation pattern are essentially the same as that of a thin-wire dipole. The radiator does not necessarily have to be solid; open construction such as shown in **Fig 7** may be used.

The theoretical SWR response of an 80-meter cage dipole having a 6-inch diameter is shown in **Fig 8**. BW_2 for this antenna fed with 50-Ω line is 287 kHz, and the Q is approximately 8. Its 2:1-SWR frequency range is 1.79 times broader than a dipole with a Q of 13, typical for thin-wire dipoles.

There are other means of creating a thick radiator, thereby gaining greater match bandwidth. The bow-tie and the fan dipole make use of the same Q-lowering principle as the cage for increased match bandwidth. The broadbanding techniques described below are usually more practical than the unwieldy cage dipole.

Stagger-Tuned Dipoles

A single-wire dipole exhibits a relatively narrow bandwidth in terms of coverage for the 3.5 to 4.0-MHz band. A technique that has been used for years to cover the entire band is to use two dipoles, one cut for the CW portion and one for the phone portion. The dipoles are connected in parallel at the feed point and use a single feeder. This technique is known as *stagger tuning*.

Fig 9 shows the theoretical SWR response of a pair of stagger-tuned dipoles fed with 50-Ω line. No mutual coupling between the wires is assumed, a condition

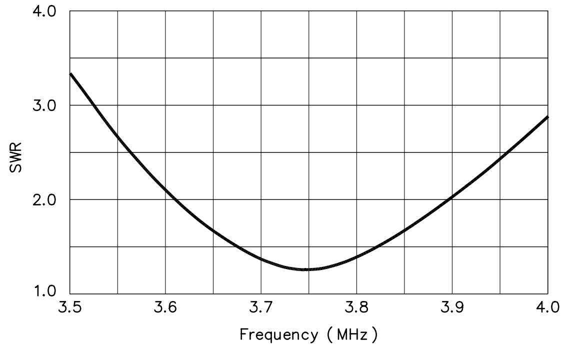

Fig 8—Theoretical SWR versus frequency response for a cage dipole of length 122 feet 6 inches and a spreader diameter of 6 inches, fed with 50-Ω line. The 2:1-SWR bandwidth frequencies are 3.610 and 3.897 MHz, with a resulting BW_2 of 287 kHz.

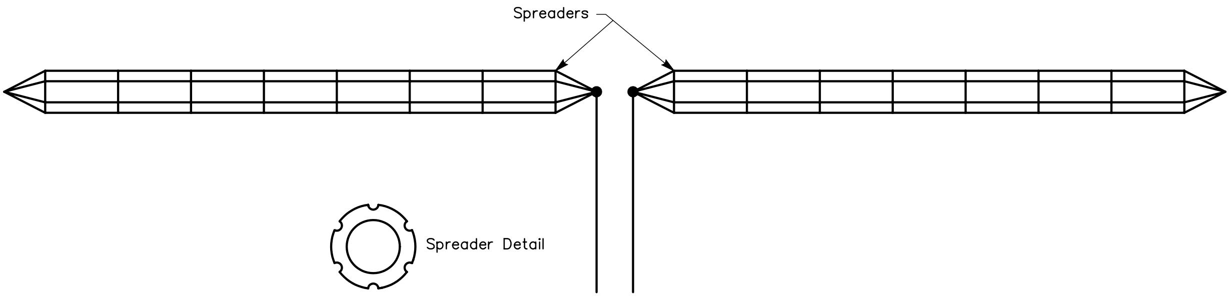

Fig 7—Construction of a cage dipole, which has some resemblance to a round birdcage. The spreaders need not be of conductive material, and should be lightweight. Between adjacent conductors, the spacing should be 0.02 λ or less. The number of spreaders and their spacing should be sufficient to maintain a relatively constant separation
of the radiator wires.

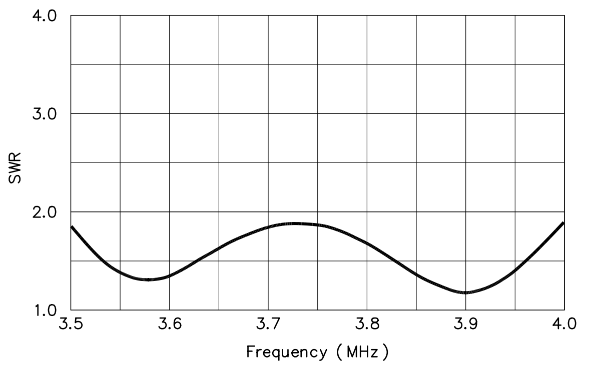

Fig 9—Theoretical SWR response of two stagger-tuned dipoles. They are connected in parallel at the feed point and fed with 50-Ω line. The dipoles are of wire such as #12 or #14, with total lengths of 119 and 132 feet.

that would exist if the two antennas were mounted at right angles to one another. As Fig 9 shows, the SWR response is less than 1.9:1 across the entire band.

A difficulty with such crossed dipoles is that four supports are required for horizontal antennas. A more common arrangement is to use inverted V dipoles with a single support, at the apex of each element. The radiator wires can also act as guy lines for the supporting mast.

When the dipoles are mounted at something other than a right angle, mutual coupling between them comes into play. This causes interaction between the two elements—tuning of one by length adjustment will affect the tuning of the other. The interaction becomes most critical when the two dipoles are run parallel to each other, suspended by the same supports, and the wires are close together. Finding the optimum length for each dipole for total band coverage can become a tedious and frustrating process.

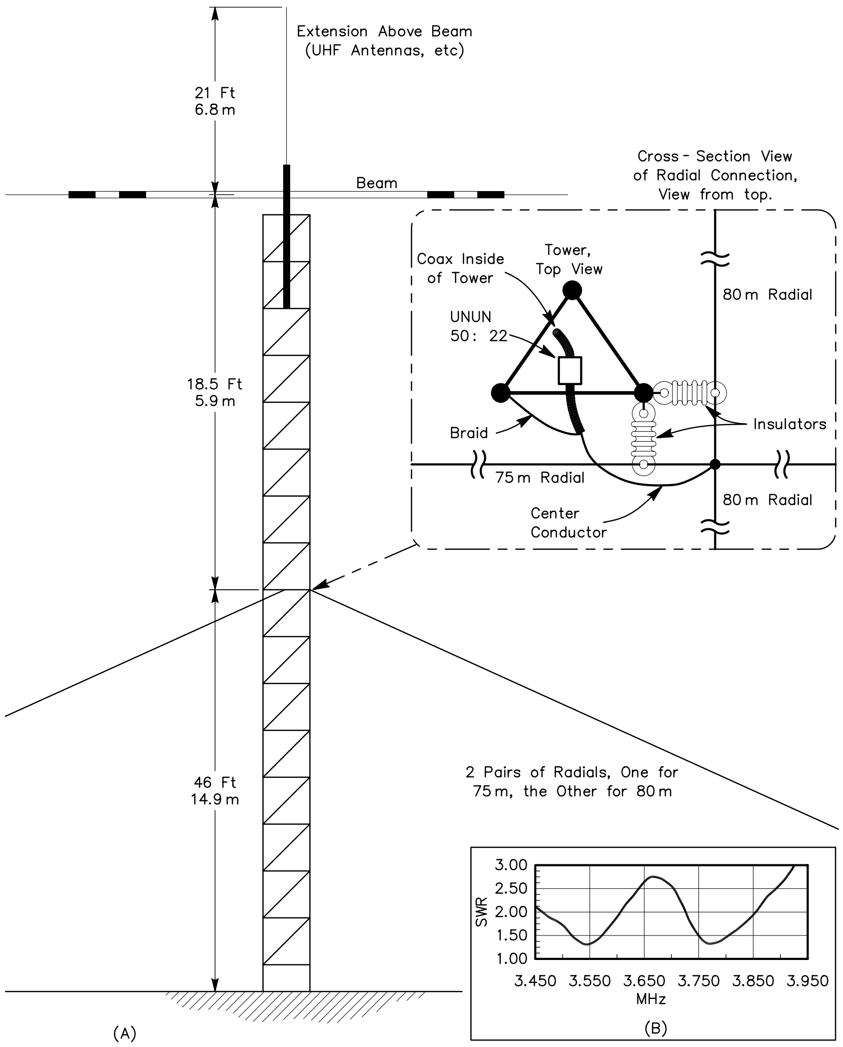
Extension Above Beam
(UHF Antennas, etc)
21 Ft
6.8 m
Beam
18.5 Ft
5.9 m
46 Ft
14.9 m
Cross - Section View
of Radial Connection,
View from top.
Coax Inside
of Tower
Tower,
Top View
UNUN
50: 22
80 m Radial
Insulators
Braid
75 m Radial
80 m Radial
Center
Conductor
2 Pairs of Radials, One for
75 m, the Other for 80 m
3.00
2.50
SWR
2.00
1.50
1.00
3.450
3.550
3.650
3.750
3.850
3.950
MHz
(A)
(B)

Fig 10—At A, details of the inverse-fed ground-plane at W4PK. The inset shows the feed-point details. Keep the two sets of radials as close to 90· as possible. Don't try to resonate the antenna by adjusting radial lengths. At B, SWR curve of the inverse-fed ground plane antenna with stagger-tuned radials. The objective is to have a low SWR for both the CW and SSB 80/75-meter DX windows.

Stagger-Tuned Radials

A variation of the use of stagger tuning has been applied by Sam Leslie, W4PK. See his article entitled “Broadbanding the Elevated, Inverse-Fed Ground Plane Antenna” in *The ARRL Antenna Compendium, Vol 6*. An existing tower with a large beam and VHF/UHF antennas on top is used as an 80-meter monopole. See **Fig 10A**. The feed point is part way up the tower, at a point where the metal above it makes up an electrical quarter wavelength. Four elevated quarter-wave radials are used as a ground plane. The radials droop away from the tower. They are joined together at the tower but not connected to the tower. The antenna is fed with 50-Ω coax and an impedance step-down autotransformer (50:22 Ω unun) located at the tower. The shield of the coax is carried through the transformer and connected to the tower. The coax “hot side” is connected to the junction of the radials. A Q-section made from two paralleled RG-59 coax cables (Z_0 = 75/2 = 37.5 Ω) may be used instead of the autotransformer.

The broadband match is achieved by cutting two opposing radials for one end of the desired match range (75 meters) and cutting the other two for the other end of the range (80 meters). See Fig 10B for the resultant SWR versus frequency characteristic.

FEED-LINE IMPEDANCE MISMATCHING

The simplest broadband matching network is a transformer at the junction of the transmission line and the antenna. See Frank Witt’s article entitled “Match Bandwidth of Resonant Antenna Systems” in October 1991 *QST*. Observe that the impedance of the series RLC resonant antenna model of Fig 2 increases at frequencies away from resonance. The result is that more bandwidth is achieved when SWR at resonance is not exactly 1:1. For example, if the antenna is fed with a low-loss 50-Ω transmission line, the maximum SWR bandwidth is obtained if the effective R_A = 50/1.25 = 40 Ω. The improvement in BW_2, the 2:1 SWR bandwidth, over a perfect match at resonance is only 6%, however. This condition of R_A = 40 Ω can be achieved by installing a transformer at the junction of the feed line and the antenna.

If the line loss is larger, you can gain more benefit in terms of bandwidth by deliberately mismatching at the antenna. If the matched-line loss is 2 dB, the improvement rises to 18%. To achieve this requires an R_A = 28.2 Ω. Again, the improvement over a perfect match at resonance is modest.

It is interesting to compare the 2:1 SWR bandwidth (at the transmitter end of the line) for the case of a lossless line versus the case of 2-dB matched-line loss. BW_2 for the lossy line case is 1.95 times that of the lossless line case, so substantial match bandwidth improvement occurs, but at the cost of considerable loss. The band edge loss for the lossy-line case is 3 dB!

This example is provided mostly as a reference for comparison with the more desirable broadbanding techniques below. It also explains why some installations with long feed lines show large match bandwidths.

PARALLEL-TUNED CIRCUITS AT THE ANTENNA TERMINALS

As mentioned previously, a resonant antenna has an equivalent circuit that may be represented as a series RLC circuit. We can cancel out some of the antenna reactance away from resonance with a parallel-tuned circuit connected across the antenna terminals. The impedance level of the parallel-tuned circuit must be low enough to be effective and must have the same resonant frequency as the antenna. You can use a parallel-tuned circuit made with lumped LC components or with transmission-line segments. A quarter-wave transmission line with a short at the far end, or a half-wave line with an open at the far end, each behave like a parallel-tuned LC circuit.

The Double Bazooka

The response of the controversial *double bazooka* antenna is shown in **Fig 11**. This antenna actually consists of a dipole with two quarter-wave coaxial resonator stubs connected in series. The stubs are connected across the antenna terminals.

Not much bandwidth enhancement is provided by this resonator connection because the impedance of the matching network is too high. The antenna offers a 2:1-SWR bandwidth frequency range that is only 1.14 times that of a simple dipole with the same feeder. And the bandwidth enhancement is partially due to the “fat” antenna wires composed mostly of the coax shield. No

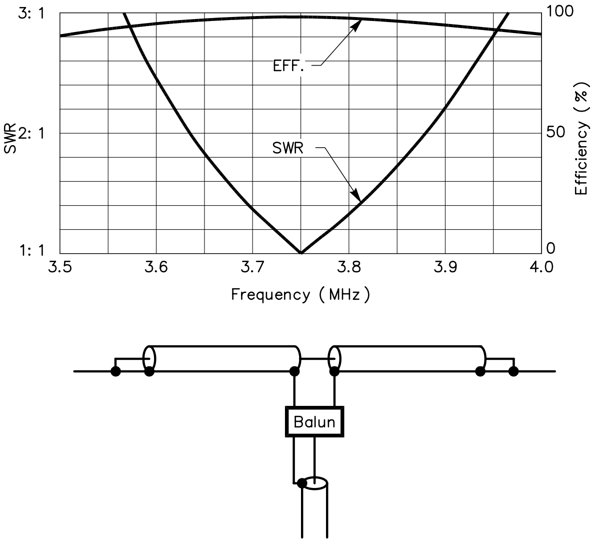

Fig 11—The double bazooka, sometimes called a coaxial dipole. The antenna is self-resonant at 3.75 MHz. The resonator stubs are 43.23-foot lengths of RG-58A coax.

improvement in antenna gain or pattern over a thin-wire dipole can be expected from this antenna.

The Crossed Double Bazooka

A modified version of the double-bazooka antenna is shown in **Fig 12**. In this case, the impedance of the matching network is reduced to one-fourth of the impedance of the standard double-bazooka network. The lower impedance provides more reactance correction, and hence increases the bandwidth frequency range noticeably, to 1.55 times that of a simple dipole. Notice, however, that the efficiency of the antenna drops to about 80% at the 2:1-SWR points. This amounts to a loss of approximately 1 dB. The broadbanding, in part, is caused by the losses in the coaxial resonator stubs (made of RG-58A coax), which have a remarkably low Q (only 20).

MATCHING NETWORK DESIGN

Optimum Matching

You can improve the match bandwidth by using a transformer or a parallel-tuned circuit at the antenna terminals. A combination of these two techniques can yield a very effective match bandwidth enhancement. Again, you can make the impedance transformation and implement the tuned circuit using lumped-circuit elements (transformers, inductors and capacitors) or with distributed-circuit elements (transmission lines).

In 1950, an article by R. M. Fano presented the theory of broadband matching of arbitrary impedances. This classic work was limited to lossless matching networks. Unfortunately, matching networks realized with transmission lines have enough loss to render the Fano results useful as only a starting point in the design process. A theory of optimum matching with lossy matching networks was presented in an article by Frank Witt entitled "Optimum Lossy Broadband Matching Networks for Resonant Antennas" that appeared in April 1990 *RF Design* and was summarized and extended in "Broadband Matching with the Transmission Line Resonator," in *The ARRL Antenna Compendium Vol 4*.

Using a matching network, the 2:1 SWR bandwidth can be increased by a factor of about 2.5. Instead of the familiar bowl-shaped SWR versus frequency characteristic seen in Fig 5, the addition of the matching network yields the W-shaped characteristic of **Fig 13**. The maximum SWR over the band is S_M. The band edges are F_L and F_H. Thus the bandwidth, BW, and the center frequency, F_0, are

$$BW = F_H - F_L \qquad \text{(Eq 10)}$$

$$F_0 = \sqrt{F_H \times F_L} \qquad \text{(Eq 11)}$$

Fig 14 shows the pertinent equivalent circuit for a typical broadband antenna system. The parallel LC matching network is defined by its resonant frequency, F_0 (which is the same as the resonant frequency of the antenna), its Q and its impedance level. The impedance level is the reactance of either the matching network inductance or capacitance at F_0. The optimum transmitter load resistance,

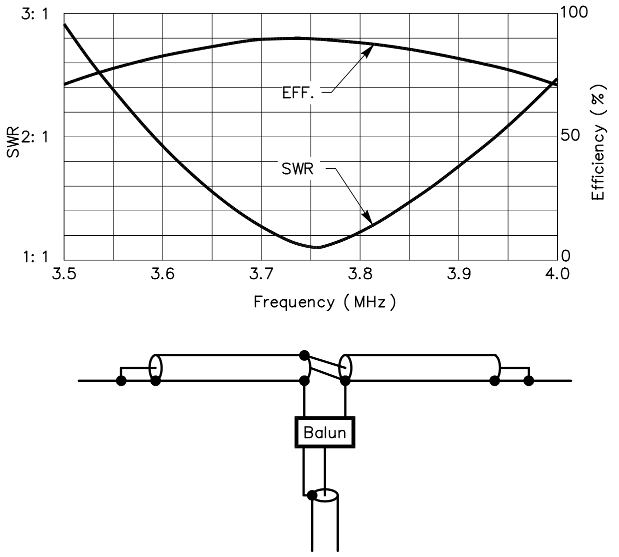

Fig 12—The crossed double bazooka yields bandwidth improvement by using two quarter-wave resonators, parallel connected, as a matching network. As with the double bazooka, the resonator stubs are 43.23-foot lengths of RG-58A coax.

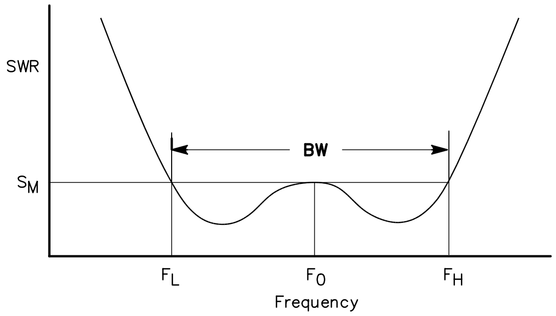

Fig 13—W-shaped SWR versus frequency characteristic that results when a transformer and parallel LC matching network are used.

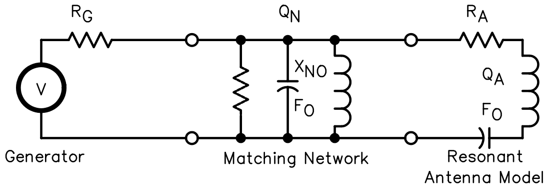

Fig 14—Assumed equivalent circuit for the broadband matching system. The antenna and the matching network have the same resonant frequency.

R_G, is achieved using an impedance transformer between the transmitter and the input to the parallel-tuned circuit. Thus for a transmitter whose optimum load resistance is 50 Ω, the required impedance transformer would have an impedance transformation ratio of 50:R_G.

The goal is to keep the SWR over the band as low as possible. There is a best or minimum value of S_M that may be achieved over the entire band. It depends on the desired match bandwidth and the Q's of the antenna and matching network and is given by the following formula:

$$S_{M\,min} = \frac{\sqrt{B_N{}^2 + 1} + \sqrt{B_N{}^2 + 1 + \frac{2Q_A}{Q_N}\left(1 + \frac{Q_A}{2Q_N}\right)}}{2\left(1 + \frac{Q_A}{2Q_N}\right)} \qquad \text{(Eq 12)}$$

where $B_N = \frac{BW}{F_0}$ and

Q_A = antenna Q

Q_N = matching network Q.

The reactance at resonance of the parallel tuned LC matching network is given by:

$$X_{N0} = \frac{R_A}{Q_A}\left[\left(1 + \frac{Q_A}{2Q_N}\right) S_{M\,min}{}^2 - \frac{Q_A}{2Q_N}\right] \qquad \text{(Eq 13)}$$

where R_A = antenna resistance in Ω.

The transmitter load resistance is calculated from:

$$R_G = \frac{S_{M\,min}\, R_A\, Q_N\, X_{N0}}{R_A + Q_N\, X_{N0}} \qquad \text{(Eq 14)}$$

The loss of the matching network is always greatest at the edges of the band. This loss, L_{MNE}, in dB, is given by:

$$L_{MNE} = 10 \log\left[1 + \frac{R_A}{Q_N\, X_{N0}}\left(B_N{}^2 + 1\right)\right] \qquad \text{(Eq 15)}$$

Now you have all the information needed to design an optimal broadband matching network. An 80-meter dipole will serve as an example to illustrate the procedure. The following parameters are assumed:

F_L = 3.5 MHz
F_H = 4.0 MHz
R_A = 57.2 Ω
Q_A = 13
Q_N = 40.65

The values of R_A and Q_A are reasonable values for an 80-meter inverted V with an apex 60 feet above ground. Q_N = 40.65 is the calculated value of the Q of a resonator made from RG-213 or similar cable in the middle of the 80-meter band. The results are:

BW = 0.5 MHz	(from Eq 10)
F_0 = 3.742 MHz	(from Eq 11)
S_{Mmin} = 1.8	(from Eq 12)
X_{N0} = 15.9 Ω	(from Eq 13)
R_G = 94.8 Ω	(from Eq 14)
L_{MNE} = 1.32 dB	(from Eq 15)

Shown in **Fig 15** is the plot of SWR and matching-network loss versus frequency for this example. The reference resistance for the SWR calculation is R_G or 94.8 Ω. Since the desired load resistance for the transmitter is 50 Ω, we need some means to transform from 94.8 Ω to 50 Ω. The examples given in the rest of this chapter will show a variety of ways of achieving the necessary impedance transformation.

The meaning of X_{N0} = 15.9 Ω is that the inductor and the capacitor in the matching network would each have a reactance of 15.9 Ω at 3.742 MHz. Methods for obtaining a particular value of X_{N0} are shown in the fol-

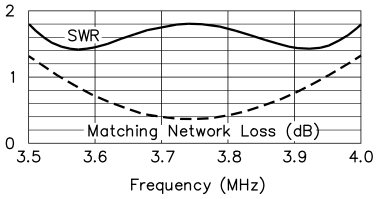

Fig 15—SWR and matching-network loss for example. Note that S_M is exactly 1.8 and the band-edge loss is exactly 1.32 dB, as calculated.

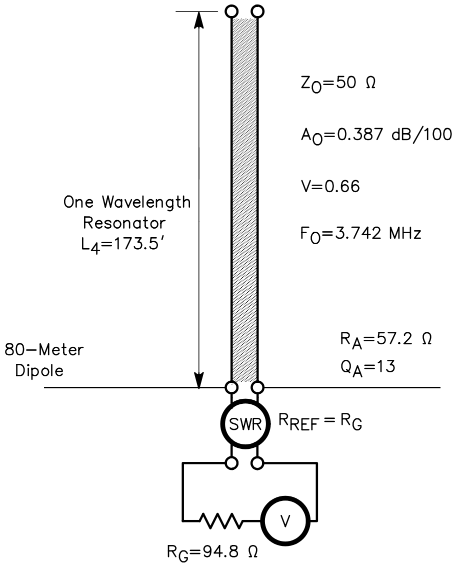

Fig 16—80-meter dipole example with a 1-λ resonator as the matching network.

lowing examples as well. The particular value of X_{N0} of this example may be obtained with a one-wavelength resonator (open-circuited at the far end) made from RG-213. The system described in this example is shown in **Fig 16**.

The broadband antenna system shown in Fig 16 has a desirable SWR characteristic, but the feed line to the transmitter is not yet present. Fortunately, the same cable segment that makes up the resonator may be used as the feed line. A property of a feed line whose length is a multiple of λ/2 (an even multiple of λ/4) is that its input impedance is a near replica of the impedance at the far end. This is exactly true for lossless lines at the frequencies where the λ/2 condition is true. Fortunately, practical lines have low-enough loss that the property mentioned above is true at the resonant frequency. Off resonance, the desired reactance cancellation we are looking for from the resonant line takes place. The very same design equations apply.

In **Fig 17**, the antenna shown in Fig 16 is moved to the far end of the 1λ resonator. The SWR and loss for this case are shown in **Fig 18**, which should be compared with Fig 15. The SWR is only slightly degraded, but the loss is about the same at the band edges. We have picked up a feed line that is 1λ long (173.5 feet) *and* broadband matching. You can make the SWR curve virtually the same as that of Fig 15 if the transmitter load resistance is increased from 94.8 Ω to 102 Ω. From a practical point of view, this degree of design refinement is unnecessary, but is instructive to know how the SWR characteristic may be controlled. You may apply the same approach when the resonator is an odd multiple of a wavelength, but in that case the transmitter or antenna must be connected λ/4 from the shorted end.

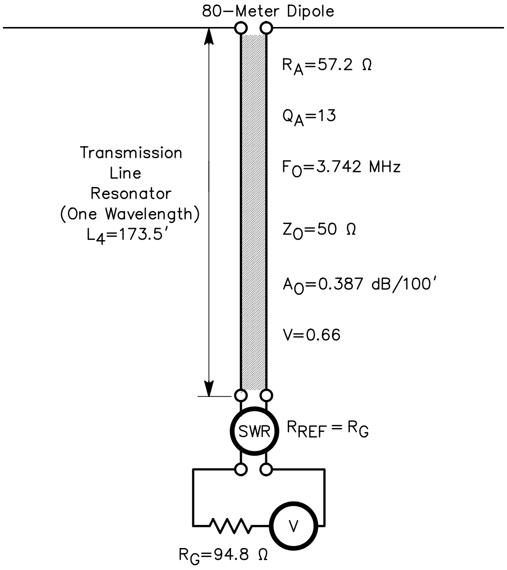

Fig 17—The antenna is at the far end of the 1-λ line. The line does double duty—broadband matching and signal transport.

Chebyshev Matching

Although it is not as efficient from the standpoint of bandwidth improvement and loss, Chebyshev matching is useful for some purposes. This arrangement yields a transmitter load impedance of 50 + *j* 0 Ω at two frequencies in the band. The matching network circuit is the same as the optimum matching case, but the parameters are different. In this case, we assume that the antenna parameters, F_0, R_A and Q_A, the network Q and the maximum SWR over the band are specified. The bandwidth, impedance level and generator resistance are given by:

$$BW = \frac{F_0}{Q_A Q_N} \left\{ \frac{(Q_A + Q_N)\left[(Q_A + 2Q_N)S_M - Q_A\right](S_M - 1)}{S_M} \right\}^{\frac{1}{2}} \qquad \text{(Eq 16)}$$

$$X_{N0} = \frac{R_A}{Q_A}\left[S_M + \frac{Q_A}{Q_N}(S_M - 1)\right] \qquad \text{(Eq 17)}$$

$$R_G = R_A\left(S_M - \frac{Q_A}{Q_A + Q_N}\right) \qquad \text{(Eq 18)}$$

The loss at the band edges is given by Eq 15. The frequencies where the transmitter load is 50 + *j* 0 Ω, F_L and F_H, are given by:

$$F_L = \sqrt{F_0^{\,2} + F_M^{\,2}} - F_M \qquad \text{(Eq 19)}$$

where

$$F_M = \frac{F_0}{2Q_A}\left[(S_M - 1)\left(1 + \frac{Q_A}{Q_N}\right)\right]^{\frac{1}{2}} \qquad \text{(Eq 20)}$$

$$F_H = \frac{F_0^{\,2}}{F_L} \qquad \text{(Eq 21)}$$

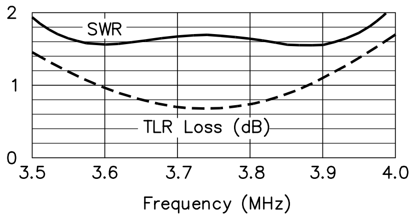

Fig 18—SWR and loss for a 1-λ 50-Ω feed line. The antenna system model is the one shown in Fig 17.

LC-MATCHING NETWORKS

Before the theory of optimal matching above was developed, Frank Witt, AI1H, described in his article “Broadband Dipoles—Some New Insights” in October 1986 *QST* the basic principle and some applications of LC matching networks. **Fig 19** shows an LC matching network that is a modified version of one originally proposed by Alan Bloom, N1AL. Note that the basic ingredients are present: the parallel-tuned circuit for reactance cancellation and a transformer.

The network also functions as a voltage balun by connecting the shield of the coaxial feed line to the center tap of the inductor. The capacitor is connected across the entire coil to obtain practical element values. The SWR response and efficiency offered by a network of lumped components is shown in **Fig 20**. The 2:1-SWR bandwidth with 50-Ω line is 460 kHz. The design is a Chebyshev match, where SWR = 1:1 is achieved at two frequencies. For the same configuration, more match bandwidth and less loss could have been realized if the optimal-match theory had been applied.

The efficiency at the band edges for the antenna system shown in Fig 20 is 90% (Loss = 0.5 dB). This low loss is due to the high Q of the LC matching network ($Q_N \approx 200$). The very low-impedance level required (X_{N0} = 12.4 Ω) cannot be easily realized with practical inductor-capacitor values. It is for this reason that the coil is tapped and serves as an autotransformer with multiple taps. The required impedance transformation ratio of 1:2.8 is easily achieved with this arrangement.

80-Meter DXer’s Delight

A version of an antenna system with an LC broadbanding network is dubbed the *80-meter DXer’s Delight*. This antenna has SWR minima near 3.5 and 3.8 MHz. A single antenna permits operation with a transmitter load impedance of about 50 Ω in the DX portions of the band, both CW and phone. The efficiency and SWR characteristic are shown in **Fig 21**.

Fig 22 shows the method of construction. The selection of a capacitor for this application must be made carefully, especially if high power is to be used. For the capacitor described in the caption of Fig 22, the allowable peak power (limited by the breakdown voltage) is 2450 W. However, the allowable average power (limited by the RF current rating of 4 A) is only 88 W! These limits apply at the 1.8:1 SWR points.

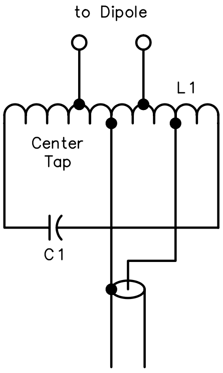

Fig 19—A practical LC matching network that provides reactance compensation, impedance transformation and balun action.

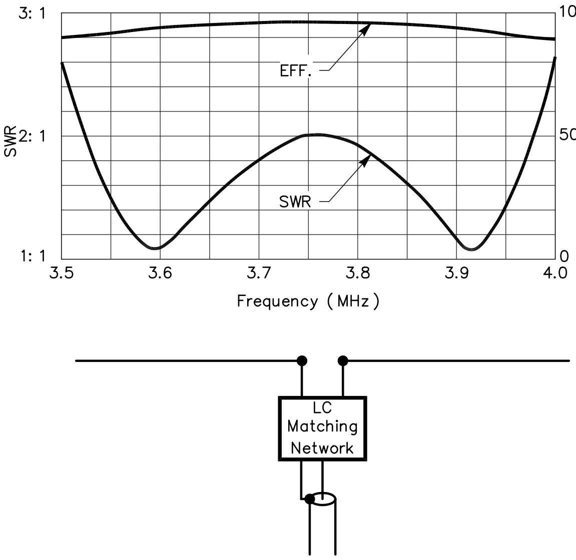

Fig 20—Efficient broadband matching with a lumped element LC network. The antenna in this example has a resistance of 72 Ω and a Q of 12. The matching network has an impedance level of 12.4 Ω, and a Q of 200. The feed line is 50-Ω coax, and the matching network provides an impedance step-up ratio of 2.8:1.

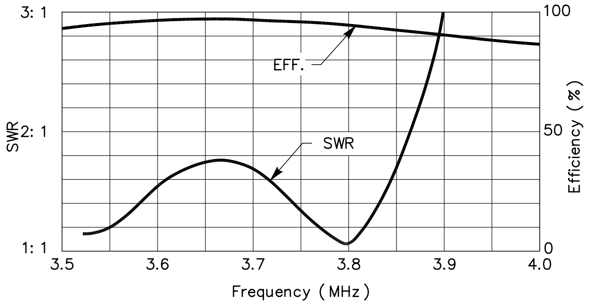

Fig 21—The 80-meter DXer’s Delight permits operation with a 50-Ω transmitter load in the DX portions of the band, both CW and phone. This network was designed to provide a broadband match for an inverted V with F_0 = 3.67 MHz, an antenna resistance of 60 Ω and a Q of 13. The matching network has an impedance level of 9 Ω, and a Q of 220. The feed line is 50-Ω coax, and the matching network provides an impedance step-up ratio of 2.0:1.

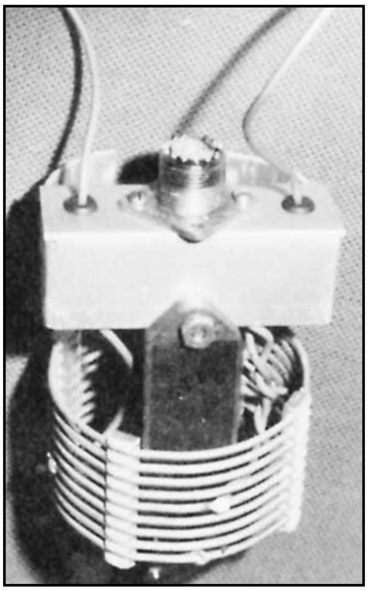

Fig 22—A method of constructing the LC broadband matching network. Components must be chosen for high Q and must have adequate voltage and current ratings. The network is designed for use at the antenna feed point, and should be housed in a weather-resistant package. The component values are as follows:

C1—400 pF transmitting mica rated at 3000 V, 4 A (RF)

L1—4.7 µH, 8½ turns of B&W coil stock, type 3029 (6 turns per in., 2½-in. dia, #12 wire). The LC circuit is brought to midband resonance by adjusting an end tap on the inductor. The primary and secondary portions of the coil have 1¾ and 2½ turns, respectively.

PROPERTIES OF TRANSMISSION-LINE RESONATORS

One way around the power limitations of LC broadband matching networks is to use a transmission line as the resonator. Transmission line resonators, TLRs, typically have higher power-handling capability because the losses, though higher, are distributed over the length of the line instead of being concentrated in the lumped-LC components. Transmission-line resonators must be multiples of a quarter wavelength. For a parallel-tuned circuit, the odd-multiple λ/4 lines must be shorted at the far end and the even-multiple λ/4 lines must be open circuited.

The length of the matching network resonator is n electrical quarter wavelengths. The impedance level, Q, and line length are given by:

$$X_{N0} = \frac{4 Z_0}{n \pi}$$

or, solving for Z_0,

$$Z_0 = \frac{n \pi X_{N0}}{4} \qquad \text{(Eq 22)}$$

$$Q_N = \frac{2.774 F_0}{A_0 V} \qquad \text{(Eq 23)}$$

$$L_N = \frac{245.9 n V}{F_0} \qquad \text{(Eq 24)}$$

where

Z_0 = line characteristic impedance in Ω

A_0 = matched line loss in dB per 100 feet

V = velocity factor, and

L_N = line length in feet.

These equations may be used to find the properties of the transmission line resonator in the systems shown in Figs 16 and 17. The line is RG-213 with the following properties:

Z_0 = 50 Ω

V = 0.66

A_0 = 0.4 dB/100 feet at 4 MHz

We need the matched loss at 3.742 MHz. Since the line loss is approximately proportional to $\sqrt{\text{frequency}}$,

$$A_{0F2} = A_{0F1} \sqrt{\frac{F_2}{F_1}} \qquad \text{(Eq 25)}$$

where A_{0F1} and A_{0F2} are the matched line losses at frequencies F_1 and F_2, respectively. Hence,

A_0 = 0.387 dB/100 feet at 3.742 MHz

Q_N = 40.65 (from Eq 23)

This is the Q of any resonator made from RG-213 for a frequency of 3.742 MHz. It does not matter how many quarter wavelengths (n) make up the cable segment. Earlier we calculated that the required impedance level, X_{N0}, is 15.9 Ω. Therefore, the required impedance level is:

$$Z_0 = \frac{n \pi \times 15.9}{4} = 12.5 n \Omega \qquad \text{(from Eq 22)}$$

This means that you could use a quarter-wavelength segment with a short at the far end if Z_0 = 12.5 Ω, or a half-wavelength segment with a open at the far end if Z_0 = 25 Ω. Our example used an open-circuited full-wavelength resonator (n = 4) with a Z_0 of 50 Ω. This example was crafted to make this happen (so that it fits RG-213 properties), but it illustrates that some juggling is required to obtain the right resonator properties when it is made from a transmission line, since we are stuck with the cable's characteristic impedance.

The TLR Transformer

A way around the limitation created by available characteristic impedance values is to use the *transmission-line resonator transformer*. The basic idea is to make the connection to the TLR at an intermediate point along the line instead of at the end of the line. It is analogous to using taps on a parallel-tuned LC resonant circuit to achieve transformer action (See Fig 19). The nature of the transformer action is seen in **Fig 23**, where the ends of the transformer are designated 1-1 and 2-2. The impedance ratio of the transformer, N_Z, is approximated by

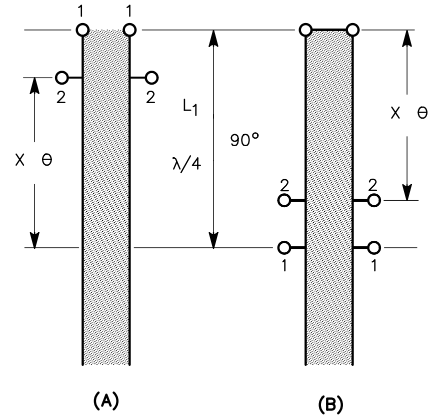

Fig 23—Transformer action in the TLR. The definition of transformer terminals depends on whether the TLR end is open- or short-circuited. θ is the distance between the minimum of the voltage standing wave (at resonance) and the connection point, expressed as an electrical angle. The distance x is that same distance expressed in feet.

$$N_Z = \sin^2 \theta \qquad \text{(Eq 26)}$$

The distance in feet, x, is given by

$$x = \frac{\theta}{90} \times \frac{\lambda}{4} = \frac{\theta}{90} \times \frac{245.9\ V}{F_0} \qquad \text{(Eq 27)}$$

This approach may be used for the connection of the TLR to the transmitter or to the antenna or both. An example will help make the power of the TLR transformer clear. We want to broadband match an 80-meter dipole (where F_0 is 3.742 MHz, R_A is 65 Ω and Q_A is 13). The feed line is RG-213 50-Ω cable, and the total distance between the antenna and transmitter is less than 100 feet.

Since we know that Z_0 = 50 Ω, we will design a prototype system with a 3/4 λ TLR (n=3). Since n is odd, the TLR must be shorted at one end, and we will place the short at the transmitter end of the line. The intermediate step of using a prototype system will enable us to design a system with the final TLR, but without transformer action. Then we'll calculate the proper connection points along the TLR. **Fig 24** shows the prototype system and the system with built-in transformers.

Note that the prototype antenna is connected to the open end of the TLR. The prototype generator (transmitter) is connected at a multiple of λ/2 from the antenna. Here, at resonance, an approximate replica of the antenna will appear. We will use primed variables to indicate prototype antenna system elements. The prototype antenna differs from the actual antenna in impedance level, so only R_A will change. F_0 and Q_A remain the same.

Starting with the 3/4 λ TLR, we have:

X_{N0} = 21.2 Ω (from Eq 22)

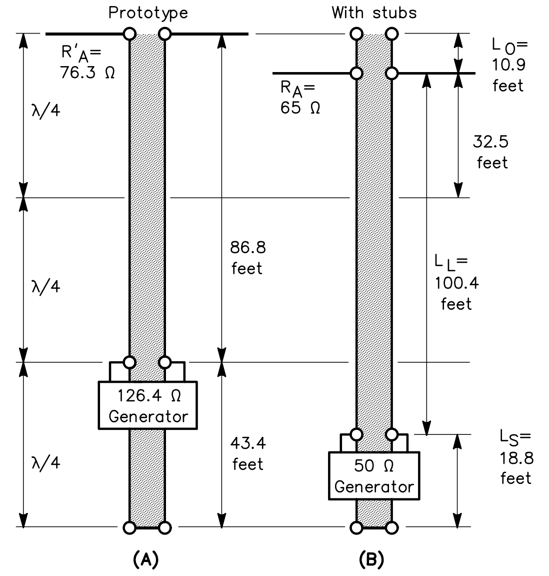

Fig 24—An optimized antenna system with a 3/4 λ TLR made from RG-213 coaxial cable. The prototype system at A is a convenient intermediate step in the design process. At B is the configuration with TLR transformers. It has an open stub, L_O, a link, L_L (which serves as the feed line), and a shorted stub, L_S.

The prototype antenna resistance at resonance, R'_A, is calculated by rearranging Eq 13.

$$R'_G = \frac{X_{N0}\, Q_A}{\left(1 + \dfrac{Q_A}{2Q_N}\right) S_{M\,min}{}^2 - \dfrac{Q_A}{2\,Q_N}} \qquad \text{(Eq 28)}$$

Earlier we calculated that Q_N = 40.65 and S_{Mmin} = 1.8. Now we find

R'_A = 76.3 Ω (from Eq 28)
R'_G = 126.4 Ω (from Eq 14)

The electrical angles (in degrees) and connection locations (in feet) are given by

$$\theta_A = \sin^{-1} \sqrt{\frac{R_A}{R'_A}} \qquad \text{(Eq 29)}$$

$$\theta_G = \sin^{-1} \sqrt{\frac{R_G}{R'_G}} \qquad \text{(Eq 30)}$$

$$X_A = \frac{\theta_A}{90} L_1 \qquad \text{(Eq 31)}$$

$$X_G = \frac{\theta_G}{90} L_1 \qquad \text{(Eq 32)}$$

where

$$L_1 = \frac{\lambda}{4} = \frac{245.9\ V}{F_0}$$

The lengths of the stubs and link of Fig 24 are given by

$$L_O = L_1 = x_A \qquad \text{(Eq 33)}$$

$$L_S = x_G \qquad \text{(Eq 34)}$$

$$L_L = 3L_1 - L_O - L_S \qquad \text{(Eq 35)}$$

Since L_1 = 43.4 feet,

$\theta_A = 67.4°$ (from Eq 29)

$\theta_G = 39.0°$ (from Eq 30)

L_O = 10.9 feet (from Eq 33)

L_S = 18.8 feet (from Eq 34)

L_L = 100.4 feet (from Eq 35)

These dimensions are summarized in Fig 24. If required, additional 50-Ω cable may be added between the transmitter and the junction of the shorted stub and the link. A remarkable aspect of the TLR transformer, as demonstrated in this example, is that it is a transformer with multiple taps distributed over a great distance, in this case over 100 feet.

The calculated SWR and loss of the antenna system with the TLR transformer are shown in **Fig 25A**. We mentioned earlier that the stub calculations are an approximation. Fig 25 bears this out, but the changes necessary to achieve the optimized results are relatively small. By changing the lengths and dipole resonant frequency slightly, the target optimized SWR characteristic of Fig 25B results. See **Table 1** for a summary of the changes required.

To demonstrate the significant improvement in match bandwidth that the TLR transformer provides, the SWR and loss of the same dipole fed with 100.4 feet of RG-213 cable is shown in Fig 25C. The loss added by the two stubs used to obtain match bandwidth enhancement is negligible (0.2 to 0.5 dB).

A TLR transformer may be used by itself to achieve a low-loss narrow-band impedance transformation, functioning like a λ/4 Q-section. It is different in nature from a Q-section, in that it is a true impedance transformer, while a Q section is an *impedance inverter*. The TLR transformer may be designed into the antenna system and is a useful tool when a narrow-band impedance transformation is needed.

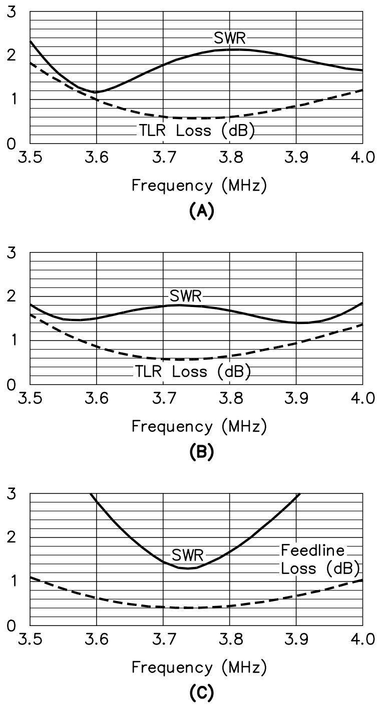

Fig 25—The SWR and loss of the TLR transformer antenna system. At A, the results are shown with the calculated line lengths. At B, the improvement after the lengths were optimized is shown in Table 1. At C, for comparison, SWR and loss for the same setup as at A, but with the stubs removed.

Table 1
Calculated and Optimized Parameters Using TLR Transformers

	Calculated	*Optimized*
Dipole resonant frequency (F_0)	3.742 MHz	3.710 MHz
Open stub (L_O)	10.9 feet	13.1 feet
Shorted stub (L_S)	18.8 feet	20.1 feet
Link (L_L)	100.4 feet	101.0 feet

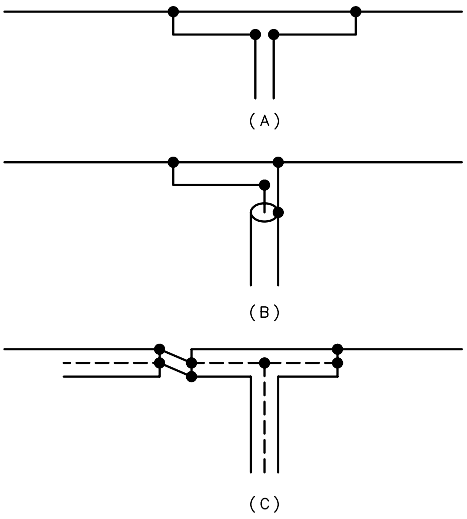

Fig 26—Dipole matching methods. At A, the T match; at B, the gamma match; at C, the coaxial resonator match.

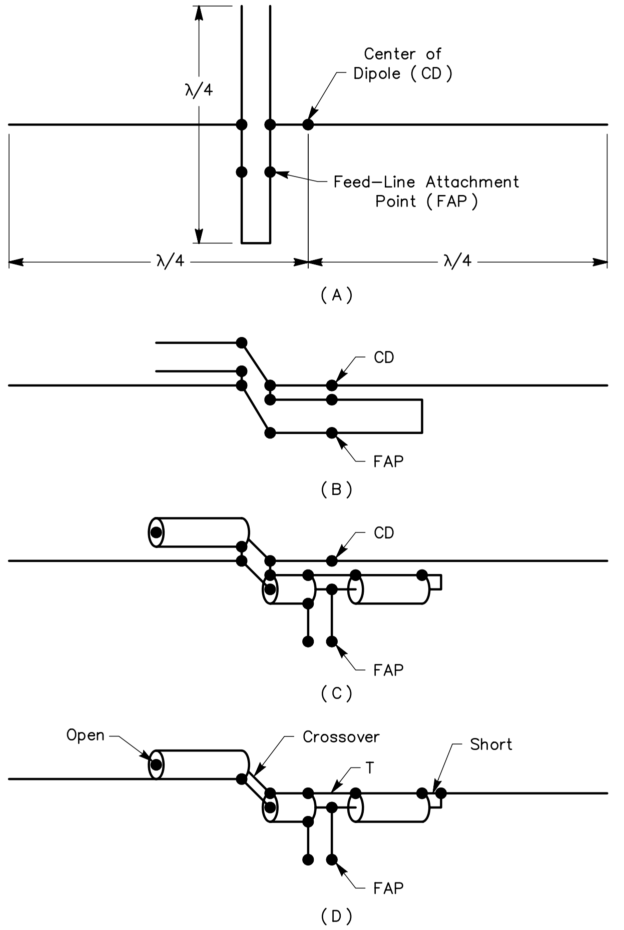

Fig 27—Evolution of the coaxial-resonator-match broadband dipole. At A, a TLR transformer is used to match the feed line to the off-center-fed dipole. The match and dipole are made collinear at B. At C, the balanced transmission-line TLR transformer of A and B is replaced by a coaxial version. Because the shield of the coax can serve as a part of the dipole radiator, the wire adjacent to the coax match may be eliminated, D.

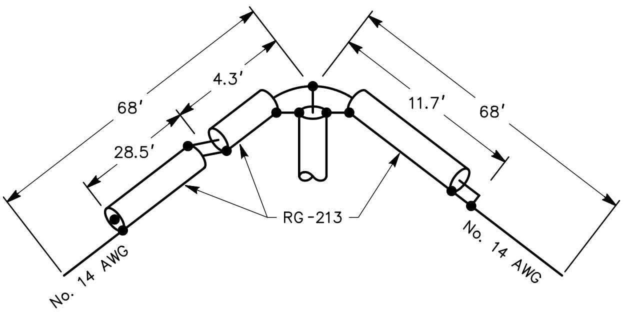

Fig 28—Dimensions for the 80-Meter MHz DX Special, an antenna optimized for the phone and CW DX portions of the 3.5-MHz band. The coax segment lengths total to one quarter-wavelength. The overall length is the same as that of a conventional inverted V dipole.

TRANSMISSION-LINE RESONATORS AS PART OF THE ANTENNA

The Coaxial-Resonator Match

This material is condensed from articles that appeared in April 1989 *QST* and *The ARRL Antenna Compendium, Vol 2*. The coaxial-resonator match, a concept based on the TLR transformer, performs the same function as the T match and the gamma match, that is, matching a transmission line to a resonant dipole. These familiar matching devices as well as the coaxial resonator match are shown in **Fig 26**. The coaxial resonator match has some similarity to the gamma match in that it allows connection of the shield of the coaxial feed line to the center of the dipole, and it feeds the dipole off center. The coaxial resonator match has a further advantage: It can be used to broadband the antenna system while providing an impedance match.

The coaxial resonator match is a resonant transformer made from a quarter-wave long piece of coaxial cable. **Fig 27** shows the evolution of the coaxial-resonator match. Now it becomes clear why coaxial cable is used for the quarter-wave TLR transformer—interaction between the dipole and the matching network is minimized. The effective dipole feed point is located at the crossover, which is an off-center feed point. In effect, the match is physically located "inside" the dipole. Currents flowing on the inside of the shield of the coax are associated with the resonator; currents flowing on the outside of the shield of the coax are the usual dipole currents. Skin effect provides a degree of isolation and allows the coax to perform its dual function. The wire extensions at each end make up the remainder of the dipole, making the overall length equal to one half-wavelength.

A useful feature of an antenna using the coaxial-resonator match is that the entire antenna is at the same dc potential as the feed-line potential, thereby avoiding charge buildup on the antenna. Hence, noise and the potential of lightning damage are reduced.

Fig 28 shows the detailed dimensions of an 80-meter inverted-V dipole using a coaxial-resonator match. This design provides a load SWR better than 1.6:1 from 3.5 to 3.825 MHz and has been named the *80-Meter DX Special*. The coax is an electrical quarter wavelength, has a short at one end, an open at the other end, a strategically placed crossover, and is fed at a tee junction. (The crossover is made by connecting the shield of one coax segment to the center conductor of the adjacent segment and by connecting the remaining center conductor and shield in a similar way.) The antenna is constructed as an inverted-V dipole with a 110° included angle and an apex at 60 feet. The measured SWR versus frequency is shown in **Fig 29**. Also in Fig 29

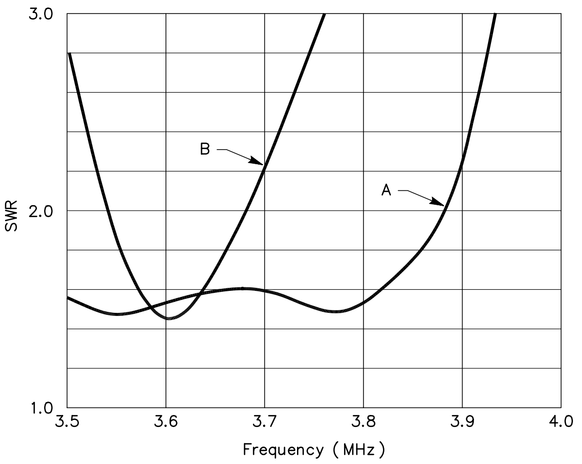

Fig 29—Measured SWR performance of the 80-Meter DX Special, curve A. Note the substantial broadbanding relative to a conventional uncompensated dipole, curve B.

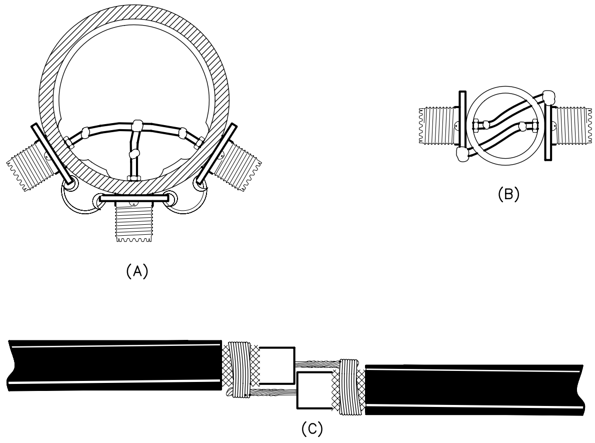

Fig 30—T and crossover construction. At A, a 2-inch PVC pipe coupling can be used for the T, and at B, a 1-inch coupling for the crossover. These sizes are the nominal inside diameters of the PVC pipe that is normally used with the couplings. The T could be made from standard UHF hardware (an M-358 T and a PL-258 coupler). An alternative construction for the crossover is shown at C, where a direct solder connection is made.

is the SWR characteristic for an uncompensated inverted-V dipole made from the same materials and positioned exactly like the broadband version.

The 80-Meter DX Special is made from RG-213 coaxial cable and #14 AWG wire, and is fed with 50-Ω coax. The coax forming the antenna should be cut so that the stub lengths of Fig 28 are within $^{1}/_{2}$ inch of the specified values. PVC plastic-pipe couplings and SO-239 UHF chassis connectors can be used to make the T and crossover connections, as shown in **Fig 30A** and 30B. Alternatively, a standard UHF T connector and coupler can be used for the T, and the crossover may be a soldered connection (Fig 30C). RG-213 is used because of its ready availability, physical strength, power handling capability, and moderate loss.

Cut the wire ends of the dipole about three feet longer than the lengths given in Fig 28. If there is a tilt in the SWR-frequency curve when the antenna is first built, it may be flattened to look like the shape given in Fig 29 by increasing or decreasing the wire length. Each end should be lengthened or shortened by the same amount.

A word of caution: If the coaxial cable chosen is not RG-213 or equivalent, the dimensions will have to be modified. The following cable types have about the same characteristic impedance, loss and velocity factor as RG-213 and could be substituted: RG-8, RG-8A, RG-10, RG-10A and RG-215. If the Q of the dipole is particularly high or the radiation resistance is unusually low because of different ground characteristics, antenna height, surrounding objects and so on, then different segment lengths will be required.

What is the performance of this broadband antenna relative to that of a conventional inverted-V dipole? Aside from the slight loss (about 0.75 dB at band edges, less elsewhere) because of the non-ideal matching network, the broadband version will behave essentially the same as a dipole cut for the frequency of interest. That is, the radiation patterns for the two cases will be virtually the same.

The Snyder Dipole

A commercially manufactured antenna utilizing the principles described in the Matching Network Design section is the Snyder dipole. Patented by Richard D. Snyder in late 1984 (see Bibliography), it immediately received much public attention through an article that Snyder published. Snyder's claimed performance for the antenna is a 2:1 SWR bandwidth of 20% with high efficiency.

The configuration of the Snyder antenna is like that of the crossed-double bazooka of Fig 12, with 25-Ω line used for the cross-connected resonators. In addition, the antenna is fed through a 2:1 balun, and exhibits a W-shaped SWR characteristic like that of Fig 13. The SWR at band center, based on information in the patent document, is 1.7 to 1. There is some controversy in professional circles regarding the claims for the Snyder antenna.

The Improved Crossed-Double Bazooka

The following has been condensed from an article by Reed Fisher, W2CQH, that appeared in *The ARRL Antenna Compendium Volume 2*. The antenna is shown in **Fig 31**. Note that the half-wave flat-top is constructed of sections of RG-58 coaxial cable. These sections of coaxial cable serve as quarter-wave shunt stubs that are essentially connected *in parallel* at the feed point in the crossed double-bazooka fashion. At an electrical quarter

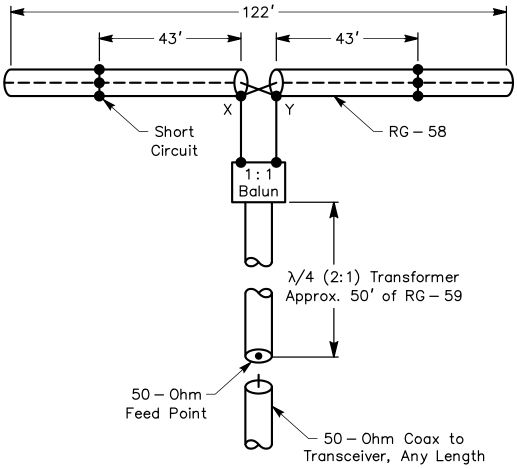
122'
43'
43'
X
Y
Short Circuit
RG – 58
1 : 1 Balun
λ/4 (2:1) Transformer
Approx. 50' of RG – 59
50 – Ohm Feed Point
50 – Ohm Coax to Transceiver, Any Length

Fig 31—Details of the W2CQH broadband-matched 80-meter dipole.

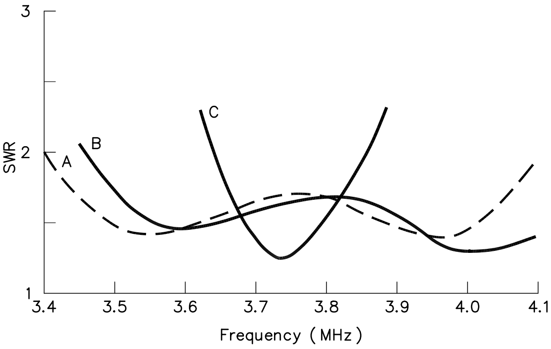

Fig 32—SWR curves for the improved double bazooka. Curve A, the theoretical curve with 50-Ω stubs and a λ/4, 75-Ω matching transformer. Curve B, measured response of the same antenna, built with RG-58 stubs and an RG- 59 transformer. Curve C, measurements from a dipole without broadbanding. Measurements were made at W2CQH with the dipole horizontal at 30 feet.

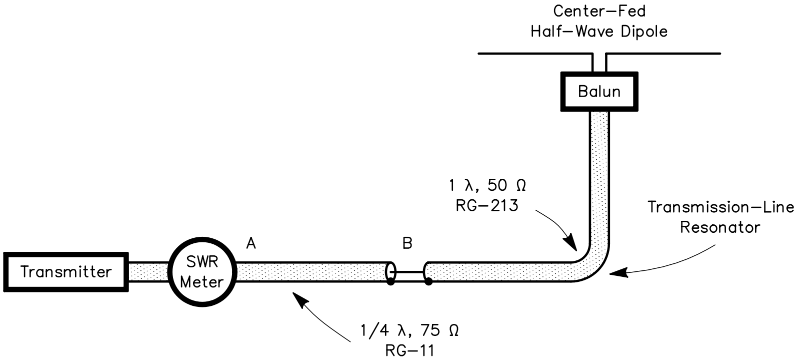
Center–Fed Half–Wave Dipole
Balun
1 λ, 50 Ω RG–213
Transmission–Line Resonator
Transmitter
SWR Meter
A
B
1/4 λ, 75 Ω RG–11

Fig 33—This simple broadband antenna system resembles a conventional 80-meter dipole except for the λ/4-wavelength 75-Ω segment. The lengths of the Q-section, TLR (including balun) and dipole are 43.3 feet, 170.5 feet, and 122.7 feet, respectively.

wavelength (43 feet) from each side of the feed point X-Y, the center conductor is shorted to the braid of the coaxial cable.

The parallel stubs provide reactance compensation. The necessary impedance transformation at the antenna feed point is provided by the quarter-wave Q-section constructed of a 50-foot section of 75-Ω coaxial cable (RG-59). A W2DU 1:1 current balun is used at the feed point. See **Fig 32** for the SWR versus frequency for this antenna with and without the broadband matching network.

This antenna is essentially that of the crossed double bazooka antenna shown in Fig 12, with the addition of the 75-Ω Q-section. The improvement in match bandwidth is substantial. The antenna at W2CQH is straight and nearly horizontal with an average height of about 30 feet.

TRANSMISSION-LINE RESONATORS AS PART OF THE FEED LINE

A Simple Broadband Dipole for 80 Meters

This system was described in an article in September 1993 *QST*. It has the advantage that the radiator is the same as that of a conventional half-wave wire dipole. Thus the antenna is light weight, easy to support and has small wind and ice loading. The broadband matching network is integrated into the feed line.

The system is shown in **Fig 33**. It is a variation of the example shown in the Matching Network Design section of this chapter as shown in Fig 17. The TLR is a 1λ length of RG-213 50-Ω coax and the impedance transformation is accomplished with a 75-Ω Q-section

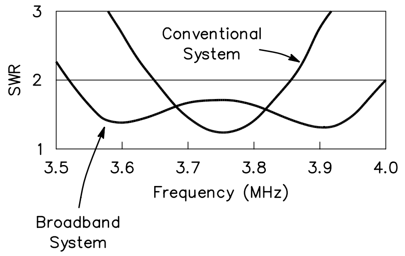

Fig 34—Measured SWR versus frequency for the broadband and conventional antenna systems.

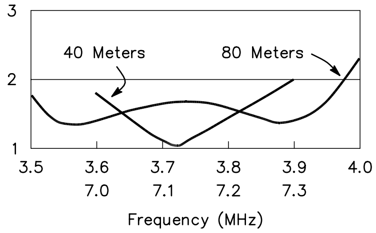

Fig 35—Measured SWR for the 80- and 40-meter multiband antenna system.

made of RG-11. The antenna is an inverted-V with a 140° included angle and an apex height of 60 feet. The wire size is #14, but is not critical. The balun is a W2DU 1:1 current type. It easily handles the legal power limit over the entire 80-meter band. The measured SWR is shown in **Fig 34**.

A unique advantage of this antenna is that by paralleling a 40-meter dipole at the feed point and sharing the feed line, operation on both 80 and 40 meters is possible. The reason for this is that the lengths of the Q-section and the TLR are multiples of a half-wavelength on 40 meters. To minimize the interaction, the two dipoles should be spaced from each other away from the feed point. First tune the 80-meter antenna and then the 40-meter one. **Fig 35** shows the result of adding a 40-meter dipole to the system shown in Fig 33. Each 40-meter dipole leg is 34.4 feet long. Note that the SWR on 80 meters changes very little compared to Fig 34. No change was made to the 80-meter dipole or to the transmission line.

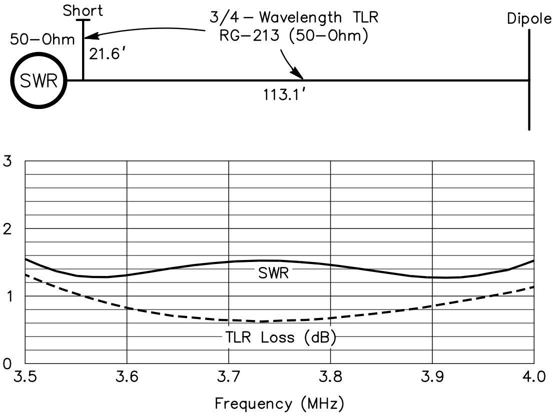

Fig 36—Broadbanding with the TLR transformer. The dimensions shown apply for an 80-meter horizontal dipole 80 feet above average ground.

80-Meter Dipole with the TLR Transformer

The total length of the feed line in the system just described above in Fig 33 is quite long, about 214 feet. For installations with shorter runs, the TLR transformer concept may be employed to advantage. An example provided in “Optimizing the 80-Meter Dipole” in *The ARRL Antenna Compendium, Vol 4* is shown in **Fig 36**. Here the TLR is $^3/_4$ λ long overall and is made from RG-213 50-Ω cable. The design applies for an 80-meter horizontal dipole, 80 feet above average ground, with an assumed antenna F_0, R_A, and Q_A of 3.72 MHz, 92 Ω and 9, respectively. (See Figs 3 and 4). The lengths must be revised for other dipole parameters.

For this design, the feed line is 113.1 feet long and the shorted stub at the transmitter end is 21.6 feet long. You can add any length of 50-Ω cable between the transmitter and the junction of the shorted stub and the feed line. The shorted stub gives a dc path to ground for both sides of the dipole, preventing charge buildup and some lightning protection. For multiband operation with an antenna tuner, the stub should be removed.

The general application of the TLR transformer concept has a tap at both the transmitter end and a tap at the antenna end. (See Fig 24.) In this case, the concept was applied only at the transmitter end, since very little impedance transformation was required at the antenna end. The location of the TLR transformer is not obvious. Consider a $^3/_4$ λ TLR with a short at one end, and an open at the other end where the antenna is connected. The generator for no impedance transformation would be located λ/4 (43.6 feet @ 3.72 MHz) from the short. By connecting the transmitter 21.6 feet from the short, the required impedance transformation for a transmitter optimized for 50-Ω loads is achieved.

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Chapter 10

Log Periodic Arrays

This chapter was contributed by L. B. Cebik, W4RNL. The *Log Periodic Dipole Array* (*LPDA*) is one of a family of frequency-independent antennas. Alone, an LPDA forms a directional antenna with relatively constant characteristics across a wide frequency range. It may also be used with parasitic elements to achieve specific characteristic within a narrow frequency range. Common names for such hybrid arrays are the *log-cell Yagi* or the *Log-Yag*. We shall look at the essential characteristics of both types of arrays in this chapter.

The LPDA is the most popular form of log-periodic systems, which also include zig-zag, planar, trapezoidal, slot, and V forms. The appeal of the LPDA version of the log periodic antenna owes much to its structural similarity to the Yagi-Uda parasitic array. This permits the construction of directional LPDAs that can be rotated—at least within the upper HF and higher frequency ranges. Nevertheless, the LPDA has special structural as well as design considerations that distinguish it from the Yagi. A number of different construction techniques for both wire and tubular elements are illustrated later in this chapter.

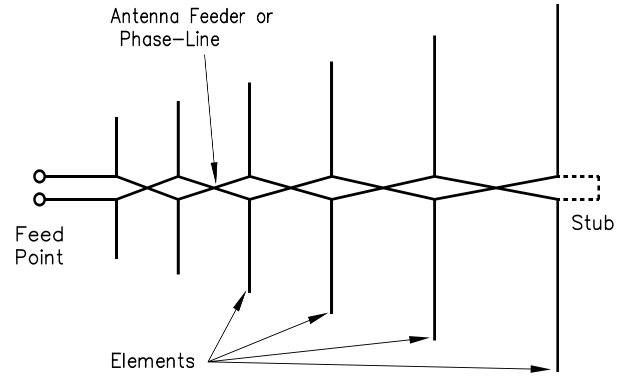

Fig 1—The basic components of a log periodic dipole array (LPDA). The forward direction is to the left in this sketch. Many variations of the basic design are possible.

The LPDA in its present form derives from the pioneering work of D. E. Isbell at the University of Illinois in the late 1950s. Although you may design LPDAs for large frequency ranges—for example, from 3 to 30 MHz or a little over 3 octaves—the most common LPDA designs that radio amateurs use are limited to a one-octave range, usually from 14 to 30 MHz. Amateur designs for this range tend to consist of linear elements. However, experimental designs for lower frequencies have used elements shaped like inverted Vs, and some versions use vertically oriented $^1/_4$ λ elements over a ground system.

Fig 1 shows the parts of a typical LPDA. The structure consists of a number of linear elements, the longest of which is approximately $^1/_2$ λ long at the lowest design frequency. The shortest element is usually about $^1/_2$ λ long at a frequency well above the highest operating frequency. The antenna feeder, also informally called the *phase-line*, connects the center points of each element in the series, with a phase reversal or *cross-over* between each element. A stub consisting of a shorted length of parallel feed line is often added at the back of an LPDA.

The arrangement of elements and the method of feed yield an array with relatively constant gain and front-to-back ratio across the designed operating range. In addition, the LPDA exhibits a relatively constant feed-point impedance, simplifying matching to a transmission line.

BASIC DESIGN CONSIDERATIONS

For the amateur designer, the most fundamental facets of the LPDA revolve around three interrelated design variables: α (alpha), τ (tau), and σ (sigma). Any one of the three variables may be defined by reference to the other two.

Fig 2 shows the basic components of an LPDA. The angle α defines the outline of an LPDA and permits every dimension to be treated as a radius or the consequence of a radius (R) of a circle. The most basic structural dimensions are the element lengths (L), the distance (R) of each element from the apex of angle α, and the distance between elements (D). A single design constant, τ, defines all of these relationships in the following manner:

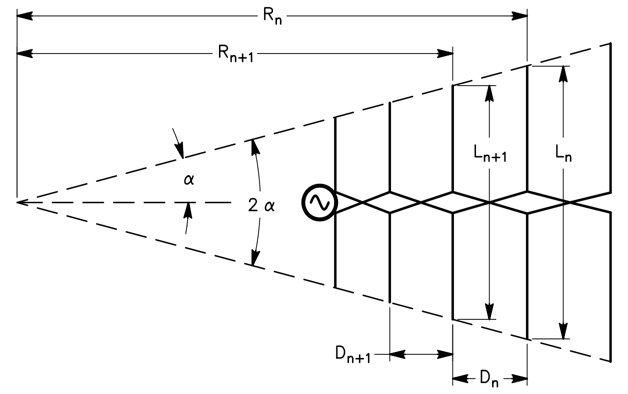

Fig 2—Some fundamental relationships that define an array as an LPDA. See the text for the defining equations.

$$\tau = \frac{R_{n+1}}{R_n} = \frac{D_{n+1}}{D_n} = \frac{L_{n+1}}{L_n} \tag{Eq 1}$$

where element n and n+1 are successive elements in the array working toward the apex of angle α. The value of τ is always less than 1.0, although effective LPDA design requires values as close to 1.0 as may be feasible.

The variable τ defines the relationship between successive element spacings but it does not itself determine the initial spacing between the longest and next longest elements upon which to apply τ successively. The initial spacing also defines the angle α for the array. Hence, we have two ways to determine the value of σ, the relative spacing constant:

$$\sigma = \frac{1 - \tau}{4 \tan \alpha} = \frac{D_n}{2L_n} \tag{Eq 2}$$

where D_n is the distance between any two elements of the array and L_n is the length of the longer of the two elements. From the first of the two methods of determining the value of σ, we may also find a means of determining α when we know both τ and σ.

For any value of τ, we may determine the optimal value of σ:

$$\sigma_{opt} = 0.243\tau - 0.051 \tag{Eq 3}$$

The combination of a value for τ and its corresponding optimal value of σ yields the highest performance of which an LPDA is capable. For values of τ from 0.80 through 0.98, the value of optimal σ varies from 0.143 to 0.187, in increments of 0.00243 for each 0.01 change in τ. However, using the optimal value of σ usually yields a total array length that is beyond ham construction or tower/mast support capabilities. Consequently, amateur LPDAs usually employ compromise values of τ and σ that yield lesser but acceptable performance.

For a given frequency range, increasing the value of τ increases both the gain and the number of required elements. Increasing the value of σ increases both the gain and the overall boom length. A τ of 0.96—which approaches the upper maximum recommended value for τ—yields an optimal σ of about 0.18, and the resulting array grows to over 100 feet long for the 14 to 30 MHz range. The maximum free space gain is about 11 dBi, with a front-to-back ratio that approaches 40 dB. Normal amateur practice, however, uses values of τ from about 0.88 to 0.95 and values of σ from about 0.03 to 0.06.

Standard design procedures usually set the length of the rear element for a frequency about 7% lower than the lowest design frequency and use the common dipole formula ($L_{feet} = 468/f_{MHz}$) to determine its length (5% lower than a free-space half wavelength, where $L_{feet} = 493.56/f_{MHz}$). The upper frequency limit of the design is ordinarily set at about 1.3 times the highest design frequency. Since τ and σ set the increment between successive element lengths, the number of elements becomes a function of when the shortest element reaches the dipole length for the adjusted upper frequency.

The adjusted upper frequency limit results from the behavior of LPDAs with respect to the number of active elements. See **Fig 3**, which shows an edge view of a 10-element LPDA for 20 through 10 meters. The vertical lines represent the peak relative current magnitude for each element at the specified frequency. At 14 MHz, virtually every element of the array shows a significant cur-

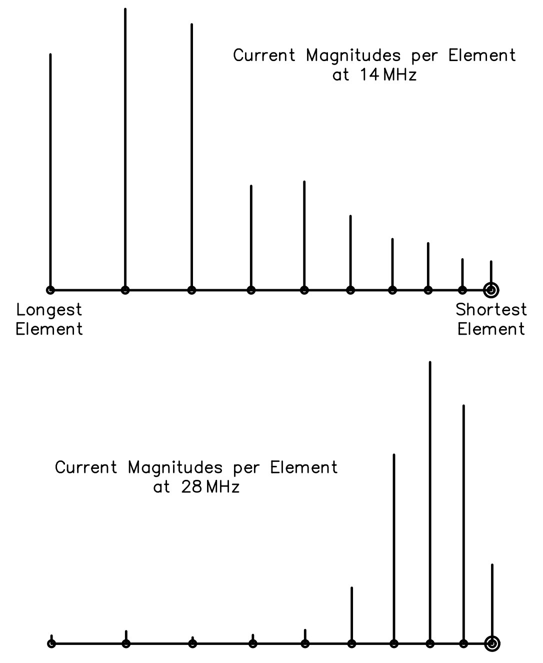

Fig 3—The relative current magnitude on the elements of an LPDA at the lowest and highest operating frequencies for a given design. Compare the number of "active" elements, that is, those with current levels at least 1/10 of the highest level.

rent magnitude. However, at 28 MHz, only the forward 5 elements carry significant current. Without the extended design range to nearly 40 MHz, the number of elements with significant current levels would be severely reduced, along with upper frequency performance.

The need to extend the design equations below the lowest proposed operating frequency varies with the value of τ. In **Fig 4**, we can compare the current on the rear elements of two LPDAs, both with a σ value of 0.04. The upper design uses a τ of 0.89, while the lower design uses a value of 0.93. The most significant current-bearing element moves forward with increases in τ, reducing (but not wholly eliminating) the need for elements whose lengths are longer than a dipole for the lowest operating frequency.

LPDA Design and Computers

Originally, LPDA design proceeded through a series of design equations intended to yield the complete specifications for an array. More recent techniques available to radio amateurs include basic LPDA design software and antenna modeling software. One good example of LPDA design software is *LPCAD28* by Roger Cox, WB0DGF. A copy of this freeware program is on the CD-ROM that accompanies this volume. The user begins by specifying the lowest and highest frequencies in the design. He then enters either his selected values for τ and σ or his choices for the number of elements and the total length of the array. With this and other input data, the program provides a table of element lengths and spacings, using the adjusted upper and lower frequency limits described earlier.

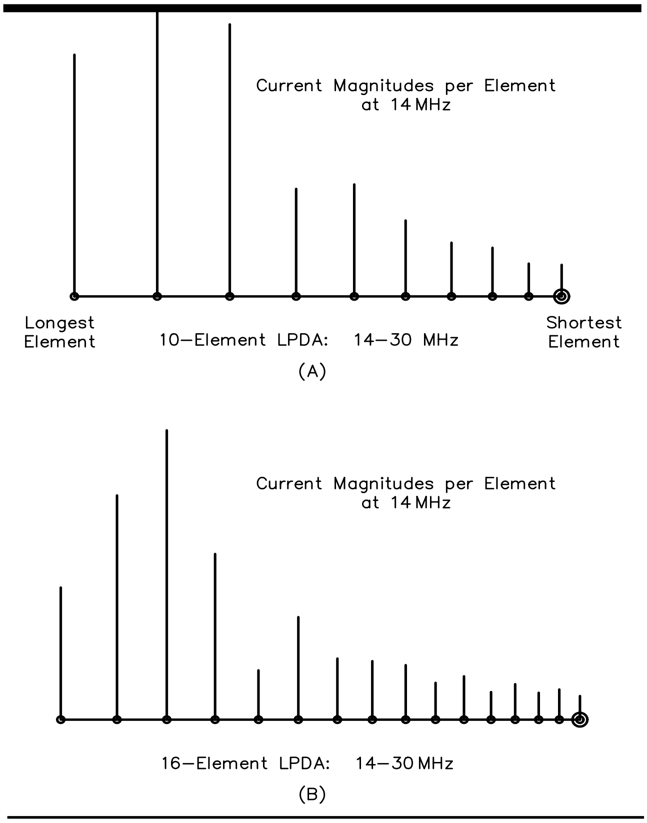

Fig 4—Patterns of current magnitude at the lowest operating frequency of two different LPDA designs: a 10-element low-τ design and a 16-element higher-τ design.

The program also requests the diameters of the longest and shortest elements in the array, as well as the diameter of average element. From this data, the program calculates a recommended value for the phase-line connecting the elements and the approximate resistive value of the input impedance. Among the additional data that *LPCAD28* makes available is the spacing of conductors to achieve the desired characteristic impedance of the phase-line. These conductors may be round—as we would use for a wire phase-line—or square—as we might use for double-boom construction.

An additional vital output from *LPCAD28* is the conversion of the design into antenna modeling input files of several formats, including versions for *AO* and *NEC4WIN* (both *MININEC*-based programs), and a version in the standard *.NEC format usable by many implementations of *NEC-2* and *NEC-4*, including *NECWin Plus*, *GNEC*, and *EZNEC Pro*. Every proposed LPDA design should be verified and optimized by means of antenna modeling, since basic design calculations rarely provide arrays that require no further work before construction. A one-octave LPDA represents a segment of an arc defined by α that is cut off at both the upper and the lower frequency limits. Moreover, some of the design equations are based upon approximations and do not completely predict LPDA behavior. Despite these limitations, most of the sample LPDA designs shown later in this chapter are based directly upon the fundamental calculations. Therefore, the procedure will be outlined in detail before turning to hybrid log-cell Yagi concepts.

Modeling LPDA designs is most easily done on a version of *NEC*. The transmission line (TL) facility built into *NEC-2* and *NEC-4* alleviates the problem of modeling the phase-line as a set of physical wires, each section of which has a set of constraints in *MININEC* at the right-angle junctions with the elements. Although the *NEC* TL facility does not account for losses in the lines, the losses are ordinarily low enough to neglect.

NEC models do require some careful construction to obtain the most accurate results. Foremost among the cautions is the need for careful segmentation, since each element has a different length. The shortest element should have about 9 or 11 segments, so that it has sufficient segments at the highest modeling frequency for the design. Each element behind the shortest one should have a greater number of segments than the preceding element by the inverse of the value of τ. However, there is a further limitation. Since the transmission line is at the center of each element, *NEC* elements should have an odd number of segments to hold the phase-line centered. Hence, each segmentation value calculated from the inverse of τ must be rounded up to the nearest odd integer.

Initial modeling of LPDAs in *NEC-2* should be done with uniform-diameter elements, with any provision for stepped-diameter element correction turned off. Since these correction factors apply only to elements within about 15% of dipole resonance at the test frequency, models with stepped-diameter elements will correct for only a few elements at any test frequency. The resulting combination of corrected and uncorrected elements will not yield a model with assured reliability.

Once one has achieved a satisfactory model with uniform-diameter elements, the modeling program can be used to calculate stepped-diameter substitutes. Each uniform-diameter element, when extracted from the larger array, will have a resonant frequency. Once this frequency is determined, the stepped-diameter element to be used in final construction can be resonated to the same frequency. Although *NEC-4* handles stepped diameter elements with much greater accuracy than *NEC-2*, the process just described is also applicable to *NEC-4* models for the greatest precision.

LPDA Behavior

Although LPDA behavior is remarkably uniform over a wide frequency range compared to narrow-band designs, such as the Yagi-Uda array, it nevertheless exhibits very significant variations within the design range. **Fig 5** shows several facets of these behaviors. Fig 5 shows the free-space gain for three LPDA designs using 0.5-inch diameter aluminum elements. The designations for each model list the values of τ (0.93, 0.89, and 0.85) and of σ (0.02, 0.04, and 0.06) used to design each array. The resultant array lengths are listed with each designator. The total number of elements varies from 16 for "9302" to 10 for "8904" to 7 for "8504."

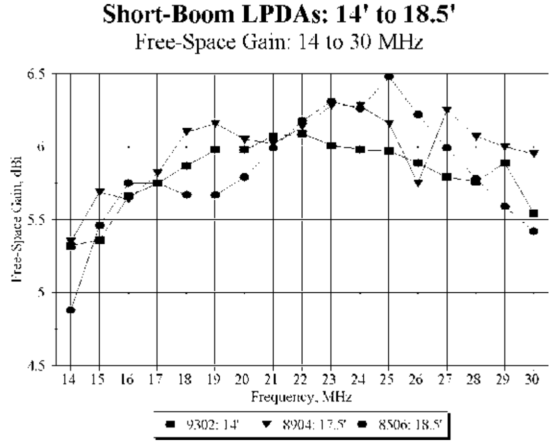

Fig 5—The modeled free-space gain of 3 relatively small LPDAs of different design. Note the relationship of the values of τ and of σ for these arrays with quite similar performance across the 14-30 MHz span.

First, the gain is never uniform across the entire frequency span. The gain tapers off at both the low and high ends of the design spectrum. Moreover, the amount of gain undulates across the spectrum, with the number of peaks dependent upon the selected value of τ and the resultant number of elements. The front-to-back ratio tends to follow the gain level. In general, it ranges from less than 10 dB when the free-space gain is below 5 dBi to over 20 dB as the gain approaches 7 dBi. The front-to-back ratio may reach the high 30s when the free-space array gain exceeds 8.5 dBi. Well-designed arrays, especially those with high values of τ and σ, tended to have well-controlled rear patterns that result in only small differences between the 180° front-to-back ratio and the averaged front-to-rear ratio.

Since array gain is a mutual function of both τ and σ, average gain becomes a function of array length for any given frequency range. Although the gain curves in Fig 5 interweave, there is little to choose among them in terms of average gain for the 14 to 18-foot range of array lengths. Well-designed 20- to 10-meter arrays in the 30-foot array length region are capable of about 7 dBi free-space gain, while 40-foot arrays for the same frequency range can achieve about 8 dBi free-space gain.

Exceeding an average gain of 8.5 dBi requires at least a 50-foot array length for this frequency range. Long arrays with high values of τ and σ also tend to show smaller excursions of gain and of front-to-back ratio in the overall curves. In addition, high-τ designs tend to show higher gain at the low frequency end of the design spectrum.

The frequency sweeps shown in Fig 5 are widely spaced at 1 MHz intervals. The evaluation of a specific design for the 14 to 30-MHz range should decrease the interval between check points to no greater than 0.25 MHz in order to detect frequencies at which the array may show a *performance weakness*. Weaknesses are frequency regions in the overall design spectrum at which the array shows unexpectedly lower values of gain and front-to-back ratio. In Fig 5 note the unexpected decrease in gain of model "8904" at 26 MHz. The other designs also have weak points, but they fall between the frequencies sampled.

In large arrays, these regions may be quite small and may occur in more than one frequency region. The weakness results from the harmonic operation of longer elements to the rear of those expected to have high current levels. Consider a 7-element LPDA about 12.25-foot long for 14 to 30 MHz using 0.5-inch aluminum elements. At 28 MHz, the rear elements operate in a harmonic mode, as shown by the high relative current magnitude curves in **Fig 6**. The result is a radical decrease in gain, as shown in the "No Stub" curve of **Fig 7**. The front-to-back ratio also drops as a result of strong radiation from the long

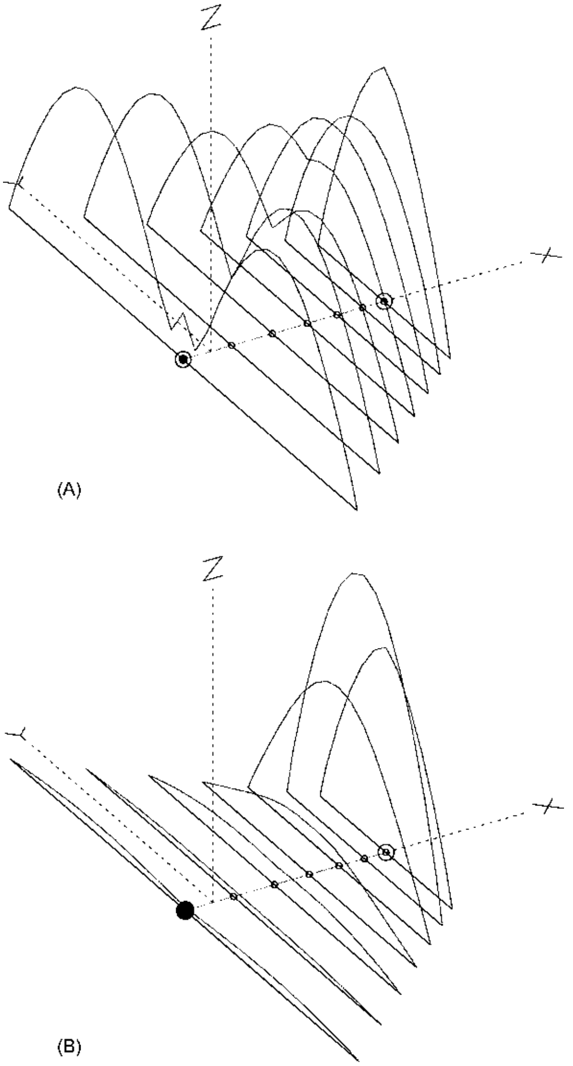

Fig 6—The relative current magnitude on the elements of model "8504" at 28 MHz without and with a stub. Note the harmonic operation of the rear elements before a stub is added to suppress such operation.

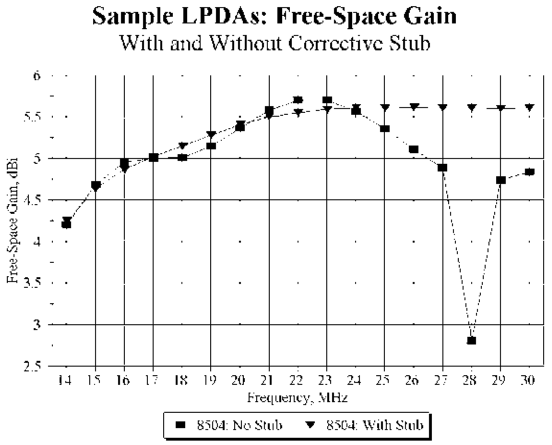

Fig 7—A graph of the gain of model "8504" showing the frequency region in which a "weakness" occurs and its absence once a suitable stub is added to the array.

elements to the rear of the array.

Early designs of LPDAs called for terminating transmission-line stubs as standard practice to help eliminate such weak spots in frequency coverage. In contemporary designs, their use tends to be more specific for eliminating or moving frequencies that show gain and front-to-back weakness. (Stubs have the added function of keeping both sides of each element at the same level of static charge or discharge.) The model dubbed "8504" was fitted (by trial and error) with an 18-inch shorted stub of 600-Ω transmission line. As Fig 6B shows, the harmonic operation of the rear elements is attenuated. The "stub" curve of Fig 7 shows the smoothing of the gain curve for the array throughout the upper half of its design spectrum. In some arrays showing multiple weaknesses, a single stub may not eliminate all of them. However, it may move the weaknesses to unused frequency regions. Where full-spectrum operation of an LPDA is necessary, additional stubs located at specific elements may be needed.

Most LPDA designs benefit (with respect to gain and front-to-back ratio) from the use of larger-diameter elements. Elements with an average diameter of at least 0.5-inch are desirable in the 14 to 30 MHz range. However, standard designs usually presume a constant element length-to-diameter ratio. In the case of *LPCAD28*, this ratio is about 125:1, which assumes an even larger diameter. To achieve a relatively constant length-to-diameter ratio in the computer models, you can set the diameter of the shortest element in a given array design and then increase the element diameter by the inverse of τ for each succeeding longer element. This procedure is often likely to result in unreasonably large element diameters for the longest elements, relative to standard amateur construction practices.

Since most amateur designs using aluminum tubing for elements employ stepped-diameter (tapered) elements, roughly uniform element diameters will result unless the LPDA mechanical design tries to lighten the elements at the forward end of the array. This practice may not be advisable, however. Larger elements at the high end of the design spectrum often counteract (at least partially) the natural decrease in high-frequency gain and show improved performance compared to smaller diameter elements.

An alternative construction method for LPDAs uses wire throughout. At every frequency, single-wire elements reduce gain relative to larger-diameter tubular elements. An alternative to tubular elements appears in **Fig 8**. For each element of a tubular design, there is a roughly equivalent 2-wire element that may be substituted. The

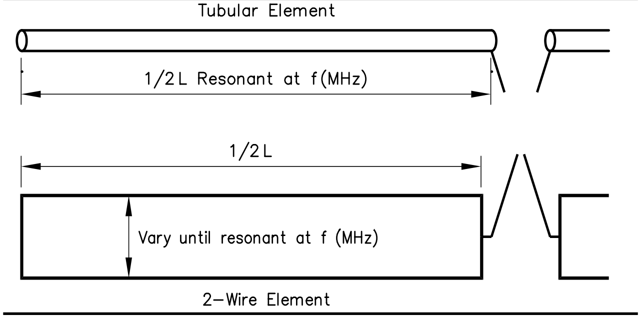
Tubular Element
1/2 L Resonant at f (MHz)
1/2 L
Vary until resonant at f (MHz)
2–Wire Element

Fig 8—A substitute for a large-diameter tubular element composed of two wires shorted at both the outer ends and at the center junction with the phase-line.

spacing between the wire is determined by taking one of the modeled tubular elements and finding its resonant frequency. A two-wire element of the same length is then constructed with shorts at the far ends and at the junctions with the phase-line. The separation of the two wires is adjusted until the wire element is resonant at the same frequency as the original tubular element. The required separation will vary with the wire chosen for the element. Models used to develop these substitutes must pay close attention to segmentation rules for *NEC* due to the short length of segments in the end and center shorts, and to the need to keep segment junctions as exactly parallel as possible with close-spaced wires.

Feeding and Constructing the LPDA

Original design procedures for LPDAs used a single, ordinarily fairly high, characteristic impedance for the phase-line (antenna feeder). Over time, designers realized that other values of impedance for the phase line offered both mechanical and performance advantages for LPDA performance. Consequently, for the contemporary designer, phase-line choice and construction techniques are almost inseparable considerations.

High-impedance phase lines (roughly 200 Ω and higher) are amenable to wire construction similar to that used with ordinary parallel-wire transmission lines. They require careful placement relative to a metal boom used to support individual elements (which themselves must be insulated from the support boom). Connections also require care. If the phase-line is given a half-twist between each element, the construction of the line must ensure constant spacing and relative isolation from metal supports to maintain a constant impedance and to prevent shorts.

Along with the standard parallel-wire line, shown in **Fig 9A**, there are a number of possible LPDA structures using booms. The booms serve both to support the elements and to create relatively low-impedance (under 200 Ω) phase-lines. Fig 9B shows the basics of a twin circular tubing boom with the elements cross-supported by insulated rods. Fig 9C shows the use of square tubing with the elements attached directly to each tube by through-bolts. Fig 9D illustrates the use of L-stock, which may be practical at VHF frequencies. Each of these sketches is incomplete, however, since it omits the necessary stress analyses that determine the mechanical feasibility of a structure for a given LPDA project.

The use of square boom material requires some adjustment when calculating the characteristic impedance of the phase-line. For conductors with a circular cross-section,

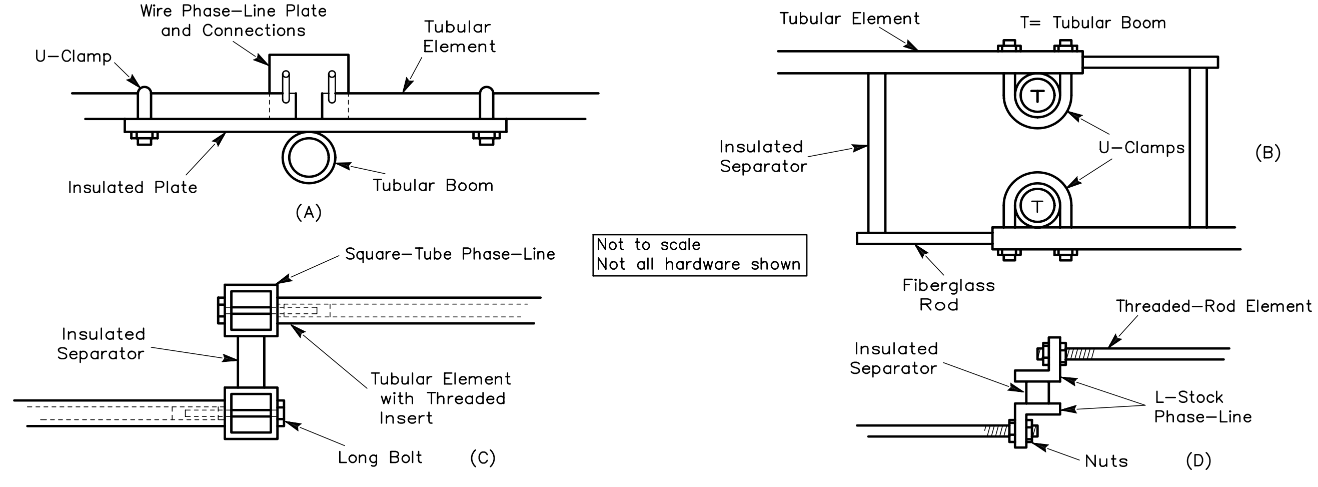
Wire Phase–Line Plate and Connections
U–Clamp
Tubular Element
Insulated Plate
Tubular Boom
(A)
Tubular Element
T= Tubular Boom
Insulated Separator
U–Clamps
(B)
Fiberglass Rod
Not to scale
Not all hardware shown
Square–Tube Phase–Line
Insulated Separator
Tubular Element with Threaded Insert
Long Bolt
(C)
Threaded–Rod Element
Insulated Separator
L–Stock Phase–Line
Nuts
(D)

Fig 9—Four (of many) possible construction techniques, shown from the array end. In A, an insulated plate supports and separates the wires of the phase-line, suitable with wire or tubular elements. A dual circular boom phase-line also supports the elements, which are cross-supported for boom stability. Square tubing is used in C, with the elements joined to the boom/phase-line with through-bolts and an insert in each half element. The L-stock shown in D is useful for lighter VHF and UHF arrays.

$$Z_0 = 120 \cosh^{-1} \frac{D}{d} \qquad \text{(Eq 4)}$$

where D is the center-to-center spacing of the conductors and d is the outside diameter of each conductor, both expressed in the same units of measurement. Since we are dealing with closely spaced conductors, relative to their diameters, the use of this version of the equation for calculating the characteristic impedance (Z_0) is recommended. For a square conductor,

$$d \approx 1.18\ w \qquad \text{(Eq 5)}$$

where d is the approximate equivalent diameter of the square tubing and w is the width of the tubing across one side. Thus, for a given spacing, a square tube permits you to achieve a lower characteristic impedance than round conductors. However, square tubing requires special attention to matters of strength, relative to comparable round tubing.

Electrically, the characteristic impedance of the LPDA phase-line tends to influence other performance parameters of the array. Decreasing the phase-line Z_0 also decreases the feed-point impedance of the array. For small designs with few elements, the decrease is not fully matched by a decrease in the excursions of reactance. Consequently, using a low impedance phase-line may make it more difficult to achieve a 2:1 or less SWR for the entire frequency range. However, higher-impedance phase-lines may result in a feed-point impedance that requires the use of an impedance-matching balun.

Decreasing the phase-line Z_0 also tends to increase LPDA gain and front-to-back ratio. There is a price to be paid for this performance improvement—weaknesses at specific frequency regions become much more pronounced with reductions in the phase-line Z_0. For a specific array you must weigh carefully the gains and losses, while employing one or more transmission line stubs to get around performance weaknesses at specific frequencies.

Depending upon the specific values of τ and σ selected for a design, you can sometimes select a phase-line Z_0 that provides either a 50-Ω or a 75-Ω feed-point impedance, holding the SWR under 2:1 for the entire design range of the LPDA. The higher the values of τ and σ for the design, the lower the reactance and resistance excursions around a central value. Designs using optimal values of σ with high values of τ show a very slight capacitive reactance throughout the frequency range. Lower design values obscure this phenomenon due to the wide range of values taken by both resistance and reactance as the frequency is changed.

At the upper end of the frequency range, the source resistance value decreases more rapidly than elsewhere in the design spectrum. In larger arrays, this can be overcome by using a variable Z_0 phase-line for approximately the first 20% of the array length. This technique is, however, difficult to implement with anything other than wire phase-lines. Begin with a line impedance about half of the final value and increase the wire spacing evenly until it reaches its final and fixed spacing. This technique can sometimes produce smoother impedance performance across the entire frequency span and improved high-frequency SWR performance.

Designing an LPDA requires as much attention to designing the phase-line as to element design. It is always useful to run models of the proposed design through several iterations of possible phase-line Z_0 values before freezing the structure for construction.

Special Design Corrections

The curve for the sample 8504 LPDA in Fig 7 revealed several deficiencies in standard LPDA designs. The weakness in the overall curve was corrected by the use of a stub to eliminate or move the frequency at which rearward elements operated in a harmonic mode. In the course of describing the characteristics of the array, we have noted several other means to improve performance. Fattening elements (either uniformly or by increasing their diameter in step with τ) and reducing the characteristic impedance of the phase-line are capable of small improvements in performance. However, they cannot wholly correct the tendency of the array gain and front-to-back ratio to fall off at the upper and lower limits of the LPDA frequency range.

One technique sometimes used to improve performances near the frequency limits is to design the LPDA for upper and lower frequency limits much higher and lower than the frequencies of use. This technique unnecessarily increases the overall size of the array and does not eliminate the downward performance curves. Increasing the values of τ and σ will usually improve perfor-

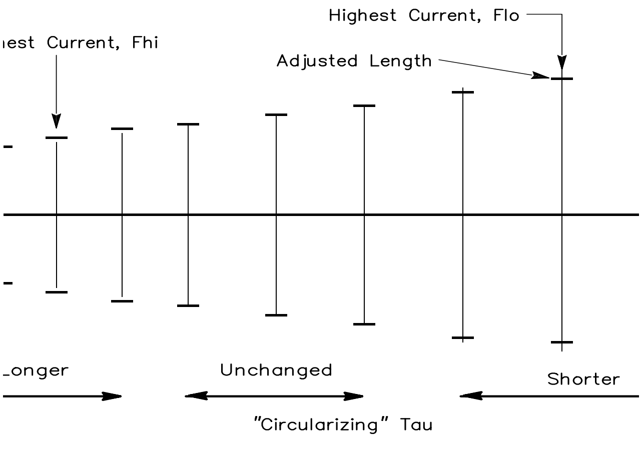

Fig 10—A before and after sketch of an LPDA, showing the original lengths of the elements and their adjustments from diminishing the value of τ at both ends of the array. See the text for the amount of change applicable to each element.

mance at no greater cost in size than extending the frequency range. Increasing the value of τ is especially effective in improving the low frequency performance of an LPDA.

Working within the overall size limits of a standard design, one may employ a technique of *circularizing* the value of τ for the rear-most and forward-most elements. See **Fig 10**, which is not to-scale relative to overall array length and width. Locate (using an antenna-modeling program) the element with the highest current at the lowest operating frequency, and the element with the highest current at the highest operating frequency. The adjustments to element lengths may begin with these elements or—at most—one element further toward the array center. For the first element (counting from the center) to be modified, reduce the value of τ by about 0.5%. For a rearward element, use the inverse of the adjusted value of τ to calculate the new length of the element relative to the unchanged element just forward of the change. For a forward element, use the new value of τ to calculate the new length of the element relative to the unchanged element immediately to the rear of it.

For succeeding elements outward, calculate new values of τ from the adjusted values, increasing the increment of decrease with each step. Second adjusted elements may use values of τ about 0.75% to 1.0% lower than the values just calculated. Third adjusted elements may use an increment of 1.0% to 1.5% relative to the preceding value.

Not all designs require extensive treatment. As the values of τ and σ increase, fewer elements may require adjustment to obtain the highest possible gain at the frequency limits, and these will always be the most outward elements in the array. A second caution is to check the feed-point impedance of the array after each change to ensure that it remains within design limits.

Fig 11 shows the free-space gain curves from 14 to 30 MHz for a 10-element LPDA with an initial τ of 0.89 and a σ of 0.04. The design uses a 200-Ω phase-line, 0.5-inch aluminum elements, and a 3-inch 600-Ω stub. The lowest curve shows the modeled performance across the design frequency range with only the stub. Performance at the frequency limits is visibly lower than within the peak performance region. The middle curve shows the effects of circularizing τ. Average performance levels have improved noticeably at both ends of the spectrum.

In lieu of, or in addition to, the adjustment of element lengths, you may also add a parasitic director to an LPDA, as shown in **Fig 12**. The director is cut roughly for the highest operating frequency. It may be spaced between 0.1 λ and 0.15 λ from the forward-most element of the LPDA. The exact length and spacing should be determined experimentally (or from models) with two factors in mind. First, the element should not adversely effect the feed-point impedance at the highest operating frequencies. Close spacing of the director has the greatest effect on this impedance. Second, the exact spacing and element length should be set to have the most desired effect on the overall performance curve of the array. The mechanical impact of adding a director is to increase overall array length by the spacing selected for the element.

The upper curve in Fig 11 shows the effect of adding a director to the circularized array already equipped with a stub. The effect of the director is cumulative, increasing the upper range gain still further. Note that the added parasitic director is not just effective at the highest

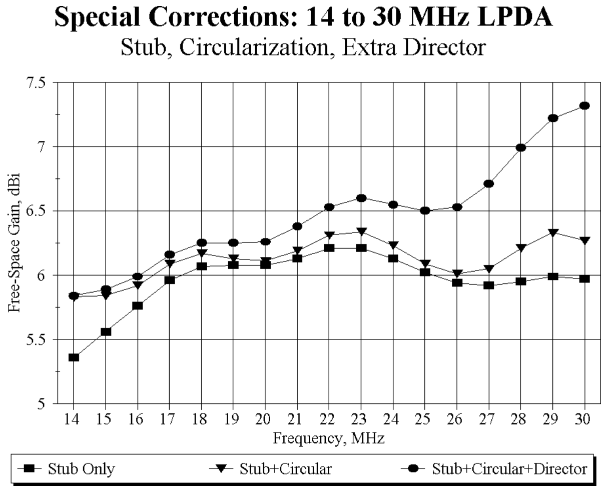

Fig 11—The modeled free space gain from 14 to 30 MHz of an LPDA with τ of 0.89 and σ of 0.04. Squares: just a stub to eliminate a weakness; Triangles: with a stub and circularized elements, and Circles: with a stub, circularized elements and a parasitic director.

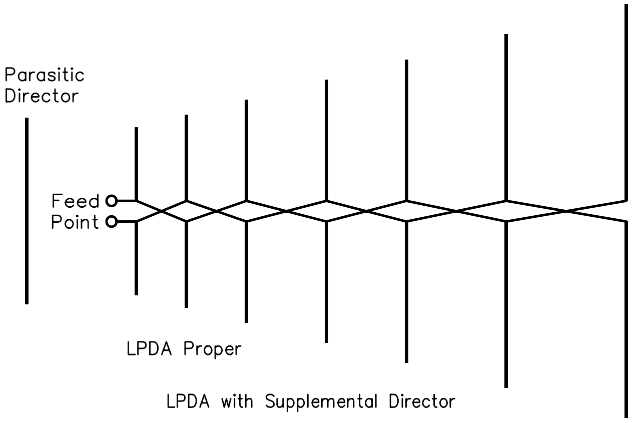

Fig 12—A generalized sketch of an LPDA with the addition of a parasitic director to improve performance at the higher frequencies within the design range.

frequencies within the LPDA design range. It has a perceptible effect almost all the way across the frequency span of the array, although the effect is smallest at the low-frequency end of the range.

The addition of a director can be used to enhance upper frequency performance of an LPDA, as in the illustration, or simply to equalize upper frequency performance with mid-range performance. High-τ designs, with good low-frequency performance, may need only a director to compensate for high-frequency gain decrease. One potential challenge to adding a director to an LPDA is sustaining a high front-to-back ratio at the upper frequency range.

Throughout the discussion of LPDAs, the performance curves of sample designs have been treated at all frequencies alike, seeking maximum performance across the entire design frequency span. Special compensations are also possible for ham-band-only LPDA designs. They include the insertion of parasitic elements within the array as well as outside the initial design boundaries. In addition, stubs may be employed not so much to eliminate weaknesses, but only to move them to frequencies outside the range of amateur interests.

A DESIGN PROCEDURE FOR AN LPDA

The following presents a systematic step-by-step design procedure for an LPDA with any desired bandwidth. The procedure requires some mathematical calculations, but a common calculator with square-root, logarithmic, and trigonometric functions is completely adequate. The notation used in this section may vary slightly from that used earlier in this chapter.

1) Decide on an operating bandwidth B between f_1, lowest frequency and f_n, highest frequency:

$$B = \frac{f_n}{f_1} \qquad \text{(Eq 6)}$$

2) Choose τ and σ to give the desired estimated average gain.

$$0.8 \le \tau \le 0.98 \text{ and } 0.03 \le \sigma \le \sigma_{opt} \qquad \text{(Eq 7)}$$

where σ_{opt} is calculated as noted earlier in this chapter.

3)Determine the value for the cotangent of the apex half-angle α from

$$\cot \alpha = \frac{4\sigma}{1-\tau} \qquad \text{(Eq 8)}$$

Although α is not directly used in the calculations, cot α is used extensively.

4) Determine the bandwidth of the active region B_{ar} from

$$B_{ar} = 1.1 + 7.7\left(1-\tau\right)^2 \cot \alpha \qquad \text{(Eq 9)}$$

5) Determine the structure (array) bandwidth B_s from

$$B_S = B \times B_{ar} \qquad \text{(Eq 10)}$$

6) Determine the boom length L, number of elements N, and longest element length ℓ_1.

$$L_n = \left(1 - \frac{1}{B_S}\right) \cot \alpha \times \frac{\lambda_{max}}{4} \qquad \text{(Eq 11)}$$

$$\lambda_{max} = \frac{984}{f_1} \qquad \text{(Eq 12)}$$

$$N = 1 + \frac{\log B_s}{\log \frac{1}{\tau}} = 1 + \frac{\ln B_S}{\ln \frac{1}{\tau}} \qquad \text{(Eq 13)}$$

$$\lambda_{1ft} = \frac{492}{f_1} \qquad \text{(Eq 14)}$$

Usually the calculated value for N will not be an integral number of elements. If the fractional value is more than about 0.3, increase the value of N to the next higher integer. Increasing the value of N will also increase the actual value of L over that obtained from the sequence of calculations just performed.

Examine L, N and l_1 to determine whether or not the array size is acceptable for your needs. If the array is too large, increase f_1 or decrease σ or τ and repeat steps 2 through 6. Increasing f_1 will decrease all dimensions. Decreasing σ will decrease the boom length. Decreasing τ will decrease both the boom length and the number of elements.

7) Determine the terminating stub Z_t. (Note: For many HF arrays, you may omit the stub, short out the longest element with a 6-inch jumper, or design a stub to overcome a specific performance weakness.) For VHF and UHF arrays calculate the stub length from

$$Z_t = \frac{\lambda_{max}}{8} \qquad \text{(Eq 15)}$$

8) Solve for the remaining element lengths from

$$\ell_n = \tau \ell_{n-1} \qquad \text{(Eq 16)}$$

9) Determine the element spacing $d_{1\text{-}2}$ from

$$d_{1-2} = \frac{\left(\ell_1 - \ell_2\right) \cot \alpha}{2} \qquad \text{(Eq 17)}$$

where ℓ_1 and ℓ_2 are the lengths of the rearmost elements, and d_{1-2} is the distance between the elements with the lengths ℓ_1 and ℓ_2. Determine the remaining element-to-element spacings from

$$d_{(n-1)-n} = \tau d_{(n-2)-(n-1)} \qquad \text{(Eq 18)}$$

10) Choose R_0, the desired feed-point resistance, to give the lowest SWR for the intended balun ratio and feed-line impedance. R_0, the mean radiation resistance level of the LPDA input impedance, is approximated by:

$$R_0 = \frac{Z_0}{\sqrt{1 + \frac{Z_0}{4\sigma' Z_{AV}}}} \qquad \text{(Eq 19)}$$

where the component terms are defined and/or calculated in the following way.

From the following equations, determine the necessary antenna feeder (phase-line) impedance, Z_0:

$$Z_0 = \frac{{R_0}^2}{8\sigma' Z_{AV}} + R_0 \sqrt{\left(\frac{R_0}{8\sigma' Z_{AV}}\right)^2 + 1} \qquad \text{(Eq 20)}$$

σ' is the mean spacing factor and is given by

$$\sigma' = \frac{\sigma}{\sqrt{\tau}} \qquad \text{(Eq 21)}$$

Z_{AV} is the average characteristic impedance of a dipole and is given by

$$Z_{AV} = 120\left[\mathrm{1n}\left(\frac{\ell_n}{\mathrm{diam}_n}\right) - 2.25\right] \qquad \text{(Eq 22)}$$

The ratio, l_n/diam_n is the length-to-diameter ratio of the element n.

11) Once Z_0 has been determined, select a combination of conductor size and spacing to achieve that impedance, using the appropriate equation for the shape of the conductors. If an impractical spacing results for the antenna feeder, select a different conductor diameter and repeat step 11. In severe cases it may be necessary to select a different R_0 and repeat steps 10 and 11. Once a satisfactory feeder arrangement is found, the LPDA design is complete.

A number of the LPDA design examples at the end of this chapter make use of this calculation method. However, the resultant design should be subjected to extensive modeling tests to determine whether there are performance deficiencies or weaknesses that require modification of the design before actual construction.

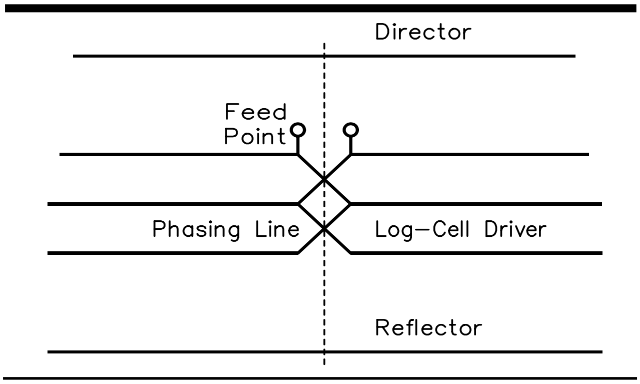

Fig 13—A sketch of a typical monoband log-cell Yagi. The reflector is, in principle, optional. The log-cell may have from 2 to 5 (or more elements). There may be one or more directors.

Log-Cell Yagis

Fig 12 showed an LPDA with an added parasitic director. Technically, this converts the original design into a hybrid Log-Yag. However, the term *Log-Yag* (or more generally the *log-cell Yagi*) is normally reserved for monoband designs that employ two or more elements in a single-band LPDA arrangement, together with (usually) a reflector and one or more directors. The aim is to produce a monoband directive array with superior directional qualities over a wider bandwidth than can be obtained from many Yagi-Uda designs. Log-cells have also been successfully used as wide-band driver sections for multiband Yagi beams.

Fig 13 illustrates the general outline of a typical log-cell Yagi. The driver section consists of a log periodic array designed for the confines of a single amateur band or other narrow range of frequencies. The parasitic reflector is usually spaced about 0.085 λ behind the rear element of the log cell, while the parasitic director is normally placed between 0.13 and 0.15 λ ahead of the log cell.

Early log-cell Yagis tended to be casually designed. Most of these designs have inferior performance compared with present-day computer-optimized Yagis of the same boom length. Some were designed by adding one or more parasitic directors to simple phased pairs of elements. Although good performance is possible, the operating bandwidth of these designs is small, suitable only for the so-called WARC bands. However, when the log-cell is designed as a narrowly spaced monoband log periodic array, the operating bandwidth increases dramatically. Operating bandwidth here refers not just to the SWR bandwidth, but also to the gain and front-to-back bandwidth.

The widest operating bandwidths require log cells of 3 to 4 elements for HF bands like 20 meters, and 4 to 5 elements for bands as wide as 10 meters. (The bandwidth of the 20-meter band is approximately 2.4% of the center frequency, while the bandwidth of the 10-meter band approaches 9.4% of the center frequency.) A practical limit to σ for log cells used within parasitic arrays is about 0.05. Slightly higher gain may be obtained from higher values of σ, but at the cost of a much longer log cell. The limiting figure for σ results in a practical value for τ between 0.94 and 0.95 to achieve a cell with the desired bandwidth characteristics.

An array designed according to these principles has an overall length that varies with the size of the log cell. A typical array with a 4-element log-cell and single parasitic elements fore and aft is a bit over 0.35 λ long, while a 5-element log-cell Yagi will be between 0.4 and 0.45 λ long. Spacing the reflector more widely (for example, up

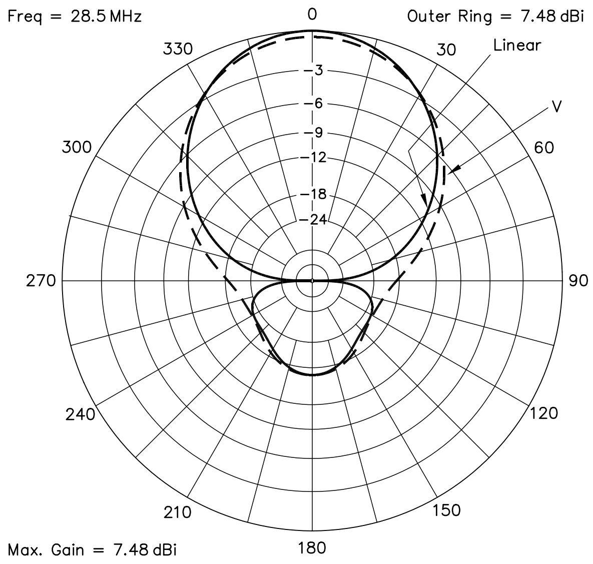

Fig 14—Overlaid free-space azimuth patterns for virtually identical 5-element log-cell Yagis (with 3-element log-cells), one having the elements V'd forward at 40° from linear (dashed), the other with linear elements (solid).

to 0.25 λ) has little effect on either gain or front-to-back ratio. Wider spacing of the director will also have only a small effect on gain, since the arrangement is already close to the boom-length limit recommended for director-driver-reflector arrays. Further lengthening of the boom should be accompanied by the addition of one or more directors to the array, if additional gain is desired from the design.

Compared to a modern-day Yagi of the same boom length, the log-cell Yagi is considerably heavier and exhibits a higher wind load due to the requirements of the log-cell driver. Yagis with 3- and 4-elements within the boom lengths just given are capable of peak free-space gain values of 8.2 to 8.5 dBi, while sustaining a high front-to-back ratio. Peak front-to-back ratios are typically in the vicinity of 25 dB. However, Yagi gain tends to decrease below the design frequency (and increase above it), while the front-to-back ratio tends to taper off as one moves away from the design frequency. For the largest log-cell sizes, log-cell Yagis of the indicated boom lengths are capable of sustaining at least 8.2 dBi free-space gain over the entire band, with front-to-back ratios of over 30 dB across the operating bandwidth.

The feed-point impedance of a log-cell Yagi is a function of both the cell design and the influence of the parasitic elements. However, for most cell designs and common phase-line designs, you can achieve a very low variation of resistance and reactance across a desired band. In many cases, the feed impedance will form a direct match for the standard 50-Ω coaxial cable used by most amateur installations. (In contrast, the high-gain, high-front-to-back Yagis used for comparison here have feed-point impedances ranging from 20 to 25 Ω.)

A common design technique used in some LPDA and log-cell Yagi designs is to bend the elements forward to form a series of Vs. A forward angle on each side of the array centerline of about 40° relative to a linear element has been popular. In some instances, the mechanical design of the array may dictate this element formation. However, this arrangement has no special benefits and possibly may degrade performance.

Fig 14 shows the free-space azimuth patterns of a single 5-element log-cell Yagi in two versions: with the elements linear and with the elements bent forward 40°. The V-array loses about $^1/_2$ dB gain, but more significantly, it loses considerable signal rejection from the sides. Similar comparisons can be obtained from pure LPDA designs and from Yagi-Uda designs when using elements in the vicinity of $^1/_2$ λ. Unless mechanical considerations call for arranging the elements in a V, the technique is not recommended.

Ultimately, the decision to build and use a log-cell Yagi involves balancing the additional weight and wind-load requirements of this design against the improvements in operating bandwidth for all of the major operating parameters, especially with respect to the front-to-back ratio and the feed-point impedance.

Wire Log-Periodic Dipole Arrays for 3.5 or 7 MHz

These wire log-periodic dipole arrays for the lower HF bands are simple in design and easy to build. They are designed to have reasonable gain, be inexpensive and lightweight, and may be assembled with stock items found in large hardware stores. They are also strong—they can withstand a hurricane! These antennas were first described by John J. Uhl, KV5E, in *QST* for August, 1986. **Fig 15** shows one method of installation. You can use the information here as a guide and point of reference for building similar LPDAs.

If space is available, the antennas can be rotated or repositioned in azimuth after they are completed. A 75-foot tower and a clear turning radius of 120 feet around the base of the tower are needed. The task is simplified

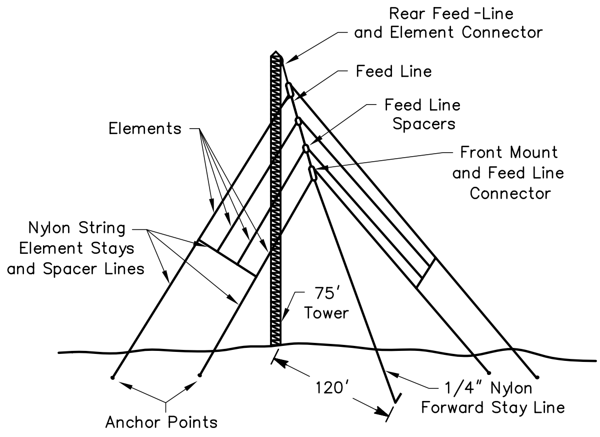

Fig 15—Typical lower-HF wire 4-element log periodic dipole array erected on a tower.

if you use only three anchor points, instead of the five shown in Fig 15. Omit the two anchor points on the forward element, and extend the two nylon strings used for element stays all the way to the forward stay line.

DESIGN OF THE LOG-PERIODIC DIPOLE ARRAYS

Design constants for the two arrays are listed in **Tables 1** and **2**. The preceding sections of this chapter contain the design procedure for arriving at the dimensions and other parameters of these arrays. The primary differences between these designs and one-octave upper HF arrays are the narrower frequency ranges and the use of wire, rather than tubing, for the elements. As design examples for the LPDA, you may wish to work through the step-by-step procedure and check your results against the values in Tables 1 and 2. You may also wish to compare these results with the output of an LPDA design software package such as *LPCAD28*.

From the design procedure, the feeder wire spacings for the two arrays are slightly different, 0.58 inch for the 3.5-MHz array and 0.66 inch for the 7-MHz version. As a compromise toward the use of common spacers for both bands, a spacing of $^5/_8$ inch is quite satisfactory. Surprisingly, the feeder spacing is not at all critical here from a matching standpoint, as may be verified from Z_0 = 276 log (2S/diam) and from Eq 4. Increasing the spacing to as much as $^3/_4$ inch results in an R_0 SWR of less than 1.1:1 on both bands.

Constructing the Arrays

Construction techniques are the same for both the 3.5 and the 7-MHz versions of the array. Once the designs are completed, the next step is to fabricate the fittings; see **Fig 16** for details. Cut the wire elements and feed lines to the proper sizes and mark them for identification. After the wires are cut and placed aside, it will be difficult to remember which is which unless they are marked. When you have finished fabricating the connectors and cutting all of the wires, the antenna can be assembled. Use your ingenuity when building one of these antennas; it isn't necessary to duplicate these LPDAs precisely.

The elements are made of standard #14 stranded cop-

Table 1

Design Parameters for the 3.5-MHz Single-Band LPDA

f1 = 3.3 MHz
f_n = 4.1 MHz
B = 1.2424
τ = 0.845
σ = 0.06
Gain = 5.9 dBi = 3.8 dBd
cot α = 1.5484
B_{ar} = 1.3864
B_s = 1.7225
L = 48.42 feet
N = 4.23 elements (decrease to 4)
Zt = 6-inch short jumper
R_0 = 208 Ω
Z_{AV} = 897.8 Ω
σ′ = 0.06527
Z_0 = 319.8 Ω
Antenna feeder:
#12 wire spaced 0.58 inches
Balun: 4:1
Feed line: 52-Ω coax

Element lengths:
ℓ1 = 149.091 feet
ℓ2 = 125.982 feet
ℓ3 = 106.455 feet
ℓ4 = 89.954 feet
Element spacings:
d_{12}=17.891 feet
d_{23} = 15.118 feet
d_{34} = 12.775 feet
Element diameters
All = 0.0641 inches
ℓ/diameter ratios:
ℓ/$diam_4$ = 16840
ℓ/$diam_3$ = 19929
ℓ/$diam_2$ = 23585
ℓ/$diam_1$ = 27911

Table 2

Design Parameters for the 7-MHz Single-Band LPDA

f1 = 6.9 MHz
f_n = 7.5 MHz
B = 1.0870
τ = 0.845
σ = 0.06
Gain = 5.9 dBi = 3.8 dBd
cot α = 1.5484
B_{ar} = 1.3864
B_s = 1.5070
L = 18.57 feet
N = 3.44 elements (increase to 4)
Z_t = 6-inch short jumper
R_0 = 208 Ω
Z_{AV} = 809.3 Ω
σ′ = 0.06527
Z_0 = 334.2 Ω
Antenna feeder:
#12 wire spaced 0.66 inches
Balun: 4:1
Feed line: 52-Ω coax

Element lengths:
ℓ1 = 71.304 feet
ℓ2 = 60.252 feet
ℓ3 = 50.913 feet
ℓ4 = 43.022 feet
Element spacings:
d_{12} = 8.557 feet
d_{23} = 7.230 feet
d_{34} = 6.110 feet
Element diameters:
All = 0.0641 inches
ℓ/diameter ratios:
ℓ4/$diam_4$ = 8054
ℓ3/$diam_3$ = 9531
ℓ2/$diam_2$ = 11280
ℓ1/$diam_1$ = 13349

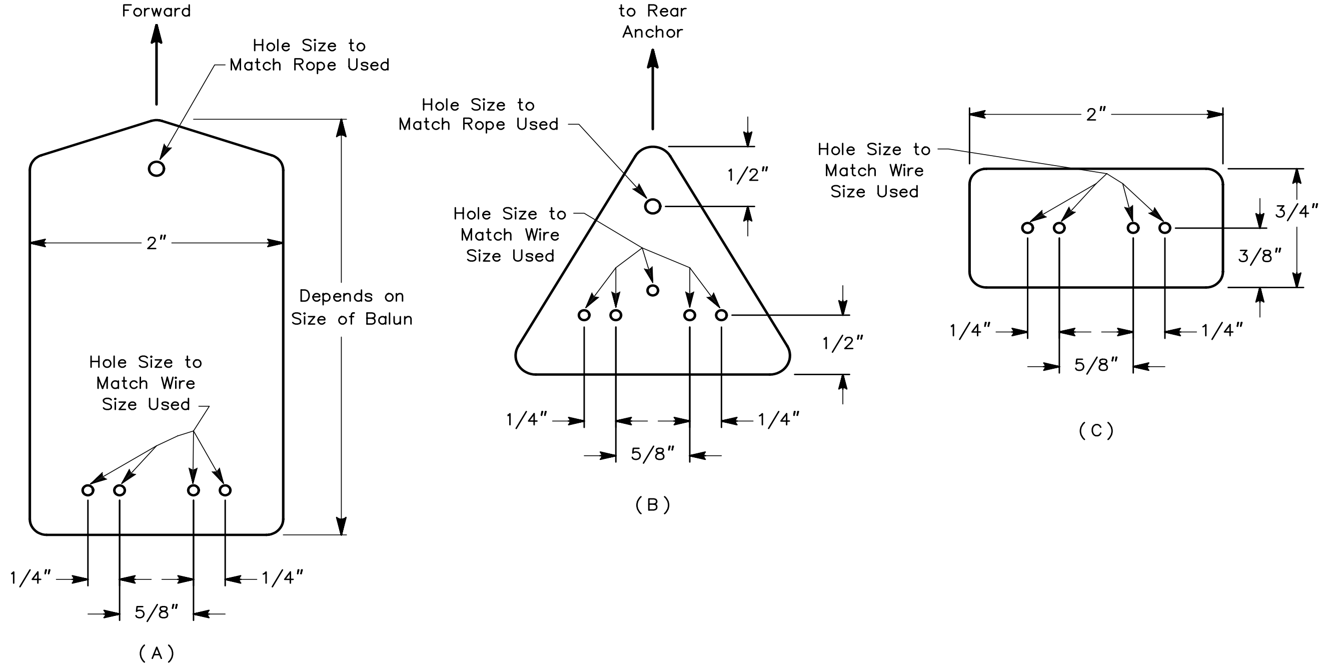
Forward
Hole Size to Match Rope Used
2"
Depends on Size of Balun
Hole Size to Match Wire Size Used
1/4"
1/4"
5/8"
(A)
to Rear Anchor
Hole Size to Match Rope Used
1/2"
Hole Size to Match Wire Size Used
1/2"
1/4"
1/4"
5/8"
(B)
2"
Hole Size to Match Wire Size Used
3/4"
3/8"
1/4"
1/4"
5/8"
(C)

Fig 16—Pieces for the LPDA that require fabrication. At A is the forward connector, made from $^1/_2$-inch Lexan (polycarbonate). At B is the rear connector, also made from $^1/_2$-inch Lexan. At C is the pattern for the phase-line spacers, made from $^1/_4$-inch Plexiglas. Two spacers are required for the array.

per wire. The two parallel feed lines are made of #12 solid copper-coated steel wire, such as Copperweld. Copperweld will not stretch when placed under tension. The front and rear connectors are cut from $^1/_2$-inch thick Lexan sheeting, and the feed-line spacers from $^1/_4$-inch Plexiglas sheeting.

Study the drawings carefully and be familiar with the way the wire elements are connected to the two feed lines, through the front, rear and spacer connectors. Details are sketched in **Figs 17** and **18**. Connections made in the way shown in the drawings prevent the wire from breaking. All of the rope, string, and connectors must be made of materials that can withstand the effects of tension and weathering. Use nylon rope and strings, the type that yachtsmen use. Fig 15 shows the front stay rope coming down to ground level at a point 120 feet from the base of a 75-foot tower. Space may not be available for this arrangement in all cases. An alternative installation technique is to put a pulley 40 feet up in a tree and run the front stay rope through the pulley and down to ground level at the base of the tree. The front stay rope will have to be tightened with a block and tackle at ground level.

Putting an LPDA together is not difficult if it is assembled in an orderly manner. It is easier to connect the elements to the feeder lines when the feed-line

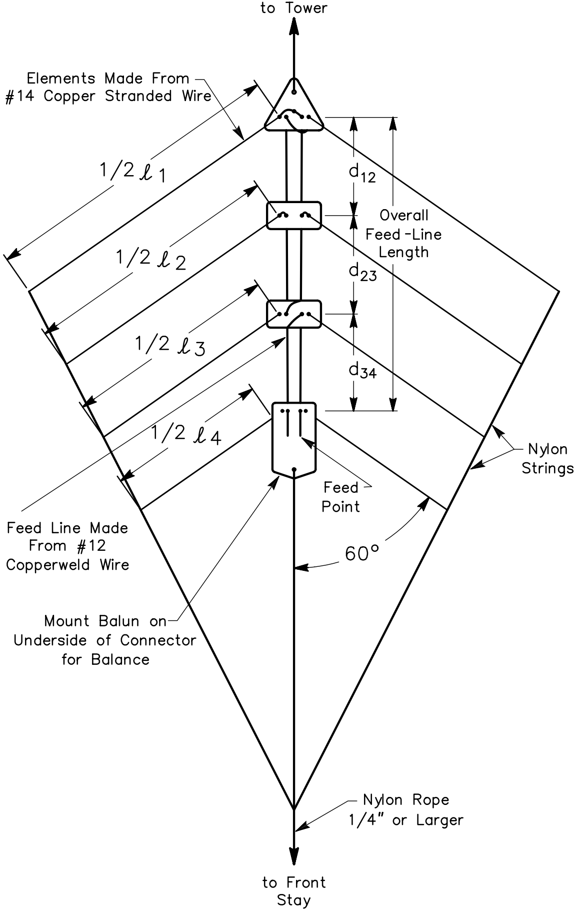
to Tower
Elements Made From #14 Copper Stranded Wire
1/2 ℓ 1
1/2 ℓ 2
1/2 ℓ 3
1/2 ℓ 4
d12
d23
d34
Overall Feed-Line Length
Nylon Strings
Feed Point
60°
Feed Line Made From #12 Copperweld Wire
Mount Balun on Underside of Connector for Balance
Nylon Rope 1/4" or Larger
to Front Stay

Fig 17—The generic layout for the lower HF wire LPDA. Use a 4:1 balun on the forward connector. See Tables 1 and 2 for dimensions.

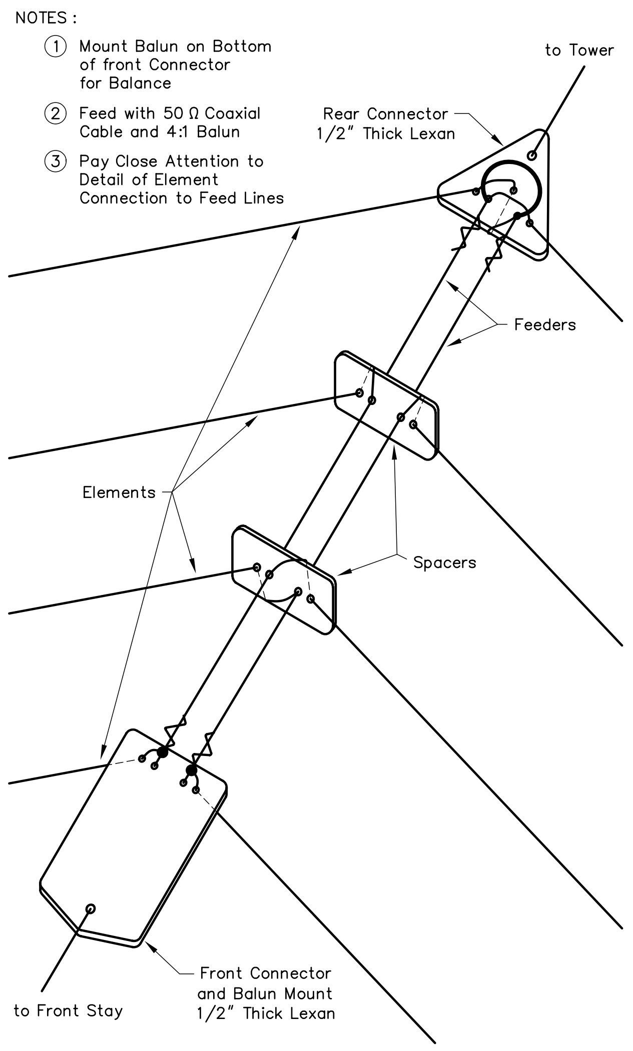
NOTES :
① Mount Balun on Bottom of front Connector for Balance
② Feed with 50 Ω Coaxial Cable and 4:1 Balun
③ Pay Close Attention to Detail of Element Connection to Feed Lines
to Tower
Rear Connector 1/2" Thick Lexan
Feeders
Elements
Spacers
to Front Stay
Front Connector and Balun Mount 1/2" Thick Lexan

Fig 18—Details of the electrical and mechanical connections of the elements to the phase-line. Knots in the nylon rope stay line are not shown.

assembly is stretched between two points. Use the tower and a block and tackle. Attaching the rear connector to the tower and assembling the LPDA at the base of the tower makes raising the antenna into place a much simpler task. Tie the rear connector securely to the base of the tower and attach the two feeder lines to it. Then thread the two feed-line spacers onto the feed line. The spacers will be loose at this time, but will be positioned properly when the elements are connected. Now connect the front connector to the feed lines. A word of caution: Measure accurately and carefully! Double-check all measurements before you make permanent connections.

Connect the elements to the feeder lines through their respective plastic connectors, beginning with element 1, then element 2, and so on. Keep all of the element wires securely coiled. If they unravel, you will have a tangled mess of kinked wire. Recheck the element-to-feeder connections to ensure proper and secure junctions. (See Figs 17 and 18.) Once you have completed all of the element connections, attach the 4:1 balun to the underside of the front connector. Connect the feeder lines and the coaxial cable to the balun.

You will need a separate piece of rope and a pulley to raise the completed LPDA into position. First secure the eight element ends with nylon string, referring to Figs 15 and 17. The string must be long enough to reach the tie-down points. Connect the front stay rope to the front connector, and the completed LPDA is now ready to be raised into position. While raising the antenna, uncoil the element wires to prevent their getting away and tangling up into a mess. Use care! Raise the rear connector to the proper height and attach it securely to the tower, then pull the front stay rope tight and secure it. Move the elements so they form a 60° angle with the feed lines, in the direction of the front, and space them properly relative to one another. By adjusting the end positions of the elements as you walk back and forth, you will be able to align all the elements properly. Now it is time to hook your rig to the system and make some contacts.

Performance

The reports received from these LPDAs were compared with an inverted-V dipole. All of the antennas are fixed; the LPDAs radiate to the northeast, and the dipole to the northeast and southwest. The apex of the dipole is at 70 feet, and the 40- and 80-meter LPDAs are at 60 and 50 feet, respectively. Basic array gain was apparent from many of the reports received. During pileups, it was possible to break in with a few tries on the LPDAs, yet it was impossible to break in the same pileups using the dipole. The gain of the LPDAs is several dB over the dipole. For additional gain, experimenters may wish to try a parasitic director about $^1/_8\ \lambda$ ahead of the array. Director length and spacing from the forward LPDA element should be field-adjusted for maximum performance while maintaining the impedance match across each of the bands.

Wire LPDA systems offer many possibilities. They are easy to design and to construct: real advantages in countries where commercially built antennas and parts are not available at reasonable cost. The wire needed can be obtained in all parts of the world, and cost of construction is low. If damaged, the LPDAs can be repaired easily with pliers and solder. For those who travel on DXpeditions where space and weight are large considerations, LPDAs are lightweight but sturdy, and they perform well.

5-Band Log Periodic Dipole Array

A rotatable log periodic array designed to cover the frequency range from 13 to 30 MHz is pictured in **Fig 19**. This is a large array having a free-space gain that varies from 6.6 to over 6.9 dBi, depending upon the operating portion of the design spectrum. This antenna system was originally described by Peter D. Rhodes, WA4JVE, in Nov 1973 *QST*. A measured radiation pattern for the array appears in **Fig 20**.

The characteristics of this array are:

1) Half-power beamwidth, 43° (14 MHz)
2) Design parameter $\tau = 0.9$
3) Relative element spacing constant $\sigma = 0.05$
4) Boom length, L = 26 feet
5) Longest element $\lambda 1$ = 37 feet 10 inches. (A tabulation

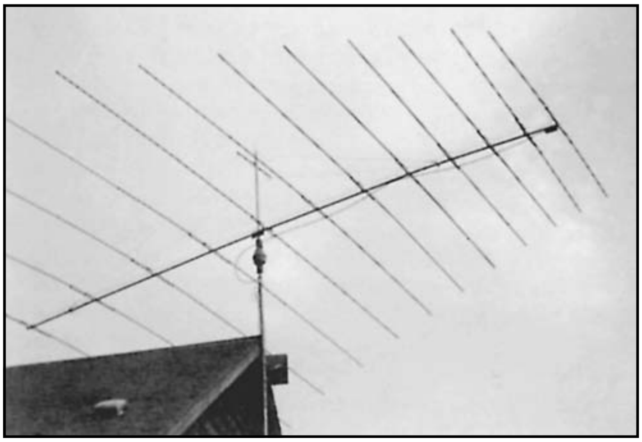

Fig 19—The 13-30 MHz log periodic dipole array.

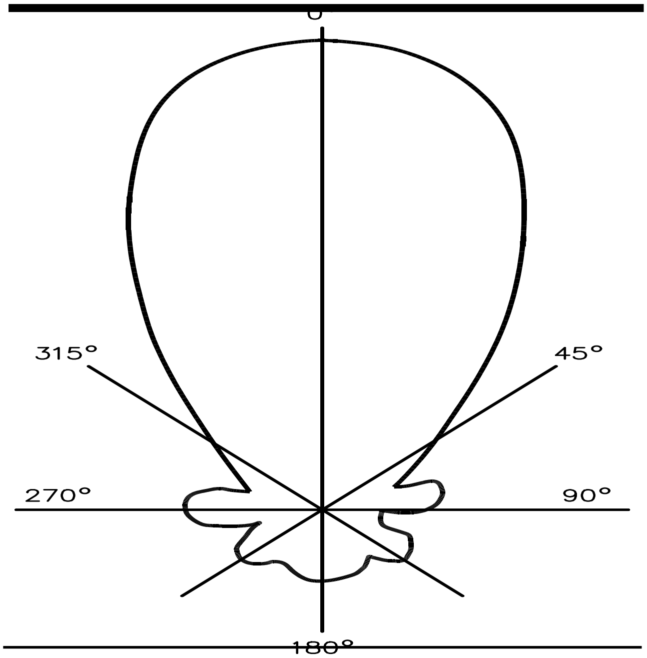

Fig 20—Measured radiation pattern of the 13-30 MHz LPDA. The front-to-back ratio is about 14 dB at 14 MHz and increases to 21 dB at 28 MHz.

Table 3
13-30 MHz LPDA Dimensions, feet

Ele. No.	*Length*	$d_{n-1,n}$ *(spacing)*	*Nearest Resonant*
1	37′ 10.2″	—	
2	34′ 0.7″	3′ 9.4″ = d_{12}	14 MHz
3	30′ 7.9″	3′ 4.9″ = d_{23}	
4	27′ 7.1″	3′ 0.8″ = d_{34}	
5	24′ 10.0″	2′ 9.1″ = d_{45}	18 MHz
6	22′ 4.2″	2′ 5.8″ = d_{56}	21 MHz
7	20′ 1.4″	2′ 2.8″ = d_{67}	
8	18′ 1.2″	2′ 0.1″ = d_{78}	24.9 MHz
9	16′ 3.5″	1′ 9.7″ = d_{89}	28 MHz
10	14′ 7.9″	1′ 7.5″ = $d_{9,10}$	
11	13′ 2.4″	1′ 5.6″ = $d_{10,11}$	
12	11′ 10.5″	1′ 3.8″ = $d_{11,12}$	

Table 4
Materials list: 13-30 MHz LPDA

Material Description	*Quantity*
1) Aluminum tubing—0.047″ wall thickness	
1″—12′ or 6′ lengths	126 lineal feet
7/8″—12′ lengths	96 lineal feet
7/8″—6′ or 12′ lengths	66 lineal feet
3/4″—8′ lengths	16 lineal feet
2) Stainless-steel hose clamps—2″ max	48 ea
3) Stainless-steel hose clamps—1 1/4″ max	26 ea
4) TV type U bolts	14 ea
5) U bolts, galv. type	
5/16″ × 1 1/2″	4 ea
1/4″ × 1″	2 ea
6) 1″ ID polyethylene water-service pipe 160 lb/in.^{2} test, approx. 1 1/4″ OD	20 lineal feet
A) 1 1/4″ × 1 1/4 × 1/8″ aluminum Angle—6' lengths	30 lineal feet
B) 1″ × 1/4″ aluminum bar—6′ lengths	12 lineal feet
7) 1 1/4″ top rail of chain-link fence	26 lineal feet
8) 1:1 toroid balun	1 ea
9) 6-32 × 1″ stainless steel screws	24 ea
6-32 stainless steel nuts	48 ea
#6 solder lugs	24 ea
10) #12 copper feeder wire	60 lineal feet
11A) 12″ × 8″ × 1/4″ aluminum plate	1 ea
B) 6″ × 4″ × 1/4″ aluminum plate	1 ea
12A) 3/4″ galv. Pipe	3 lineal feet
B) 1″ galv. pipe-mast	5 lineal feet
13) Galv. guy wire	50 lineal feet
14) 1/4″ × 2″ turnbuckles	4 ea
15) 1/4″ × 1 1/2″ eye bolts	2 ea
16) TV guy clamps and eye bolts	2 ea

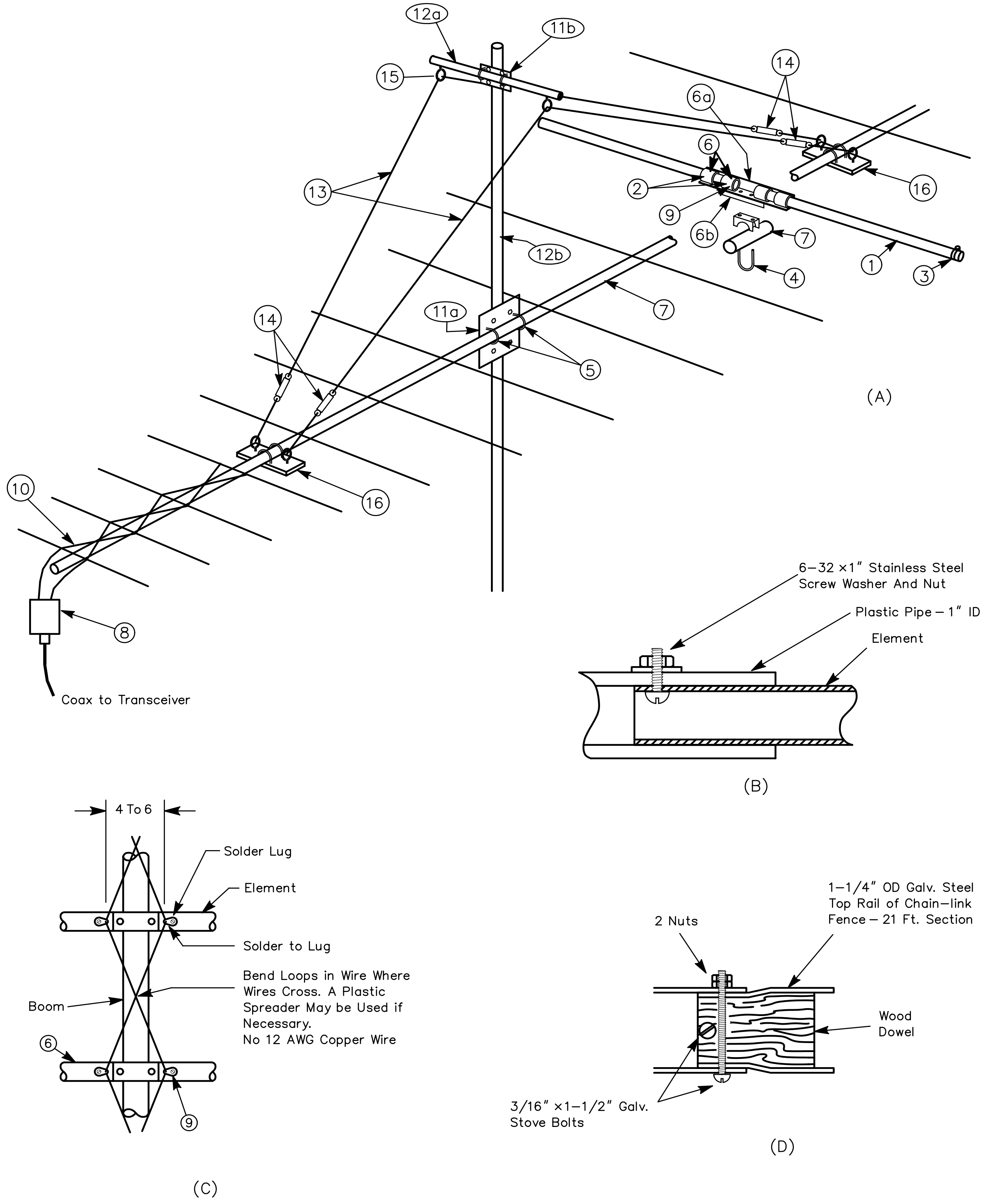
12a
11b
15
14
6a
6
16
2
13
9
6b
7
12b
4
1
3
11a
7
14
5
(A)
16
10
8
Coax to Transceiver
6–32 ×1″ Stainless Steel
Screw Washer And Nut
Plastic Pipe – 1″ ID
Element
(B)
4 To 6
Solder Lug
Element
Solder to Lug
Bend Loops in Wire Where
Wires Cross. A Plastic
Spreader May be Used if
Necessary.
No 12 AWG Copper Wire
Boom
6
9
(C)
1–1/4″ OD Galv. Steel
Top Rail of Chain–link
Fence – 21 Ft. Section
2 Nuts
Wood
Dowel
3/16″ ×1–1/2″ Galv.
Stove Bolts
(D)

Fig 21—Construction diagrams of the 13-30 MHz LPDA. B and C show the method of making electrical connection between the phase-line and each half-element. D shows how the boom sections are joined.

Table 5
Element Material Requirements: 13-30 MHz LPDA

Ele. No.	***1″ Tubing***		***⅞″ Tubing***		***¾″ Tubing***		***1¼″ Angle***	***1″ Bar***
	Len.	*Qty*	*Len.*	*Qty*	*Len.*	*Qty*	*Len.*	*Len.*
1	6′	2	6′	2	8′	2	3′	1′
2	6′	2	12′	2	—	—	3′	1′
3	6′	2	12′	2	—	—	3′	1′
4	6′	2	8.5′	2	—	—	3′	1′
5	6′	2	7′	2	—	—	3′	1′
6	6′	2	6′	2	—	—	3′	1′
7	6′	2	5′	2	—	—	2′	1′
8	6′	2	3.5′	2	—	—	2′	1′
9	6′	2	2.5′	2	—	—	2′	1′
10	3′	2	5′	2	—	—	2′	1′
11	3′	2	4′	2	—	—	2′	1′
12	3′	2	4′	2	—	—	2′	1′

of element lengths and spacings appears in **Table 3**.)

6) Total weight, 116 pounds
7) Wind-load area, 10.7 square feet
8) Required input impedance (mean resistance), R_0 = 72 Ω, Z_t = 6-inch jumper #18 wire
9) Average characteristic dipole impedance, Z_{AV}: 337.8 Ω
10) Impedance of the feeder, Z_0: 117.1 Ω
11) Feeder: #12 wire, close spaced
12) With a 1:1 toroid balun at the input terminals and a 72-Ω coax feed line, the maximum SWR is 1.4:1.

The mechanical assembly uses materials readily available from most local hardware stores or aluminum supply houses. The materials needed are given in **Table 4**. In the construction diagram, **Fig 21**, the materials are referenced by their respective material list numbers. The photograph shows the overall construction, and the drawings show the details. **Table 5** gives the required tubing lengths to construct the elements.

Experimenters may wish to improve the performance of the array at both the upper and lower frequency ends of the design spectrum so that it more closely approaches the performance in the middle of the design frequency range. The most apt general technique for raising both the gain and the front-to-back ratio at the frequency extremes would be to circularize τ as described earlier in this chapter. However, other techniques may also be applied.

The Telerana

The Telerana (Spanish for *spider web*) is a rotatable log periodic antenna that is lightweight, easy to construct and relatively inexpensive to build. Designed to cover 12.1 to 30 MHz, it was co-designed by George Smith, W4AEO, and Ansyl Eckols, YV5DLT, and first described by Eckols in *QST* for Jul 1981. Some of the design parameters are as follow.

1) $\tau = 0.9$
2) $\sigma = 0.05$
3) Gain = 4.5 to 5.5 dBi (free-space) depending upon frequency
4) Feed arrangement: 400-Ω feeder line with 4:1 balun, fed with 52-Ω coax. The SWR is 1.5:1 or less in all amateur bands.

The array consists of 13 dipole elements, properly spaced and transposed, along an open wire feeder having an impedance of approximately 400 Ω. See **Figs 22** and **23**. The array is fed at the forward (smallest) end with a 4:1 balun and RG-8 cable placed inside the front arm and leading to the transmitter. An alternative feed method is to use open wire or ordinary TV ribbon and a tuner, eliminating the balun.

The frame that supports the array (**Fig 24**) consists of four 15-foot fiberglass vaulting poles slipped over short nipples at the hub, appearing like wheel spokes (**Fig 25**). Instead of being mounted directly into the fiberglass, the hub mounts into short metal tubing sleeves that are inserted into the ends of each arm to prevent crushing and splitting the fiberglass. The necessary holes are drilled to receive the wires and nylon.

A shopping list is provided in **Table 6**. The center hub is made from a 1¼-inch galvanized four-outlet cross or X and four 8-inch nipples (Fig 25). A 1-inch diameter X may be used alternatively, depending on the diameter of the fiberglass. A hole is drilled in the bottom of the hub to allow the cable to be passed through after welding the hub to the rotator mounting stub.

All four arms of the array must be 15 feet long. They should be strong and springy to maintain the tautness of the array. If vaulting poles are used, try to obtain all of them with identical strength ratings.

The forward spreader should be approximately 14.8 feet long. It can be much lighter than the four main arms, but must be strong enough to keep the lines rigid.

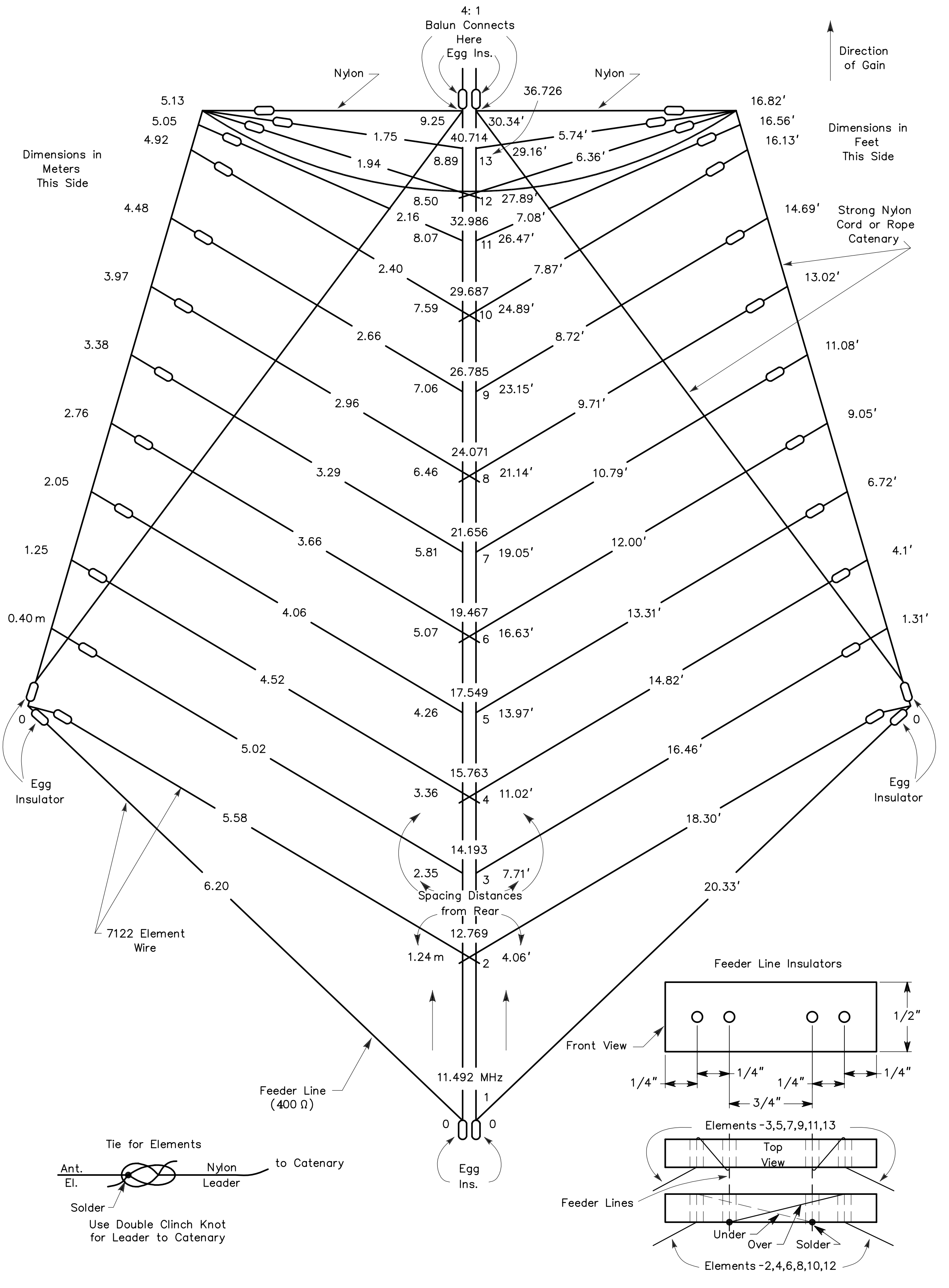
4: 1
Balun Connects
Here
Egg Ins.
Direction
of Gain
Nylon
Nylon
36.726
5.13
5.05
4.92
9.25
30.34′
16.82′
16.56′
16.13′
1.75
40.714
5.74′
1.94
8.89
13
29.16′
6.36′
Dimensions in
Meters
This Side
Dimensions in
Feet
This Side
4.48
8.50
12
27.89′
2.16
32.986
7.08′
14.69′
8.07
11
26.47′
Strong Nylon
Cord or Rope
Catenary
3.97
2.40
7.87′
13.02′
29.687
7.59
10
24.89′
3.38
2.66
8.72′
11.08′
26.785
7.06
9
23.15′
2.76
2.96
9.71′
9.05′
24.071
6.46
8
21.14′
2.05
3.29
10.79′
6.72′
21.656
5.81
7
19.05′
1.25
3.66
12.00′
4.1′
19.467
0.40 m
4.06
13.31′
1.31′
5.07
6
16.63′
17.549
4.52
14.82′
4.26
5
13.97′
0
0
15.763
5.02
16.46′
3.36
4
11.02′
Egg
Insulator
Egg
Insulator
5.58
18.30′
14.193
2.35
3
7.71′
6.20
Spacing Distances
from Rear
20.33′
12.769
7122 Element
Wire
1.24 m
2
4.06′
Feeder Line Insulators
1/2″
Front View
11.492 MHz
1/4″
1/4″
1/4″
1/4″
3/4″
Feeder Line
(400 Ω)
1
0
0
Elements -3,5,7,9,11,13
Tie for Elements
Top
View
Ant.
El.
Nylon
Leader
to Catenary
Egg
Ins.
Feeder Lines
Solder
Use Double Clinch Knot
for Leader to Catenary
Under
Over
Solder
Elements -2,4,6,8,10,12

Fig 22—The overall configuration of the spider web antenna. Nylon monofilament line is used from the ends of the elements to the nylon cords. Use nylon line to tie every point where lines cross. The forward fiberglass feeder lies on the feeder line and is tied to it. Both metric and English measurements are shown, except for the illustration of the feed-line insulator. Use soft-drawn copper or stranded wire for elements 2 through 12. Element 1 should use 7/22 flexible wire or #14 AWG Copperweld.

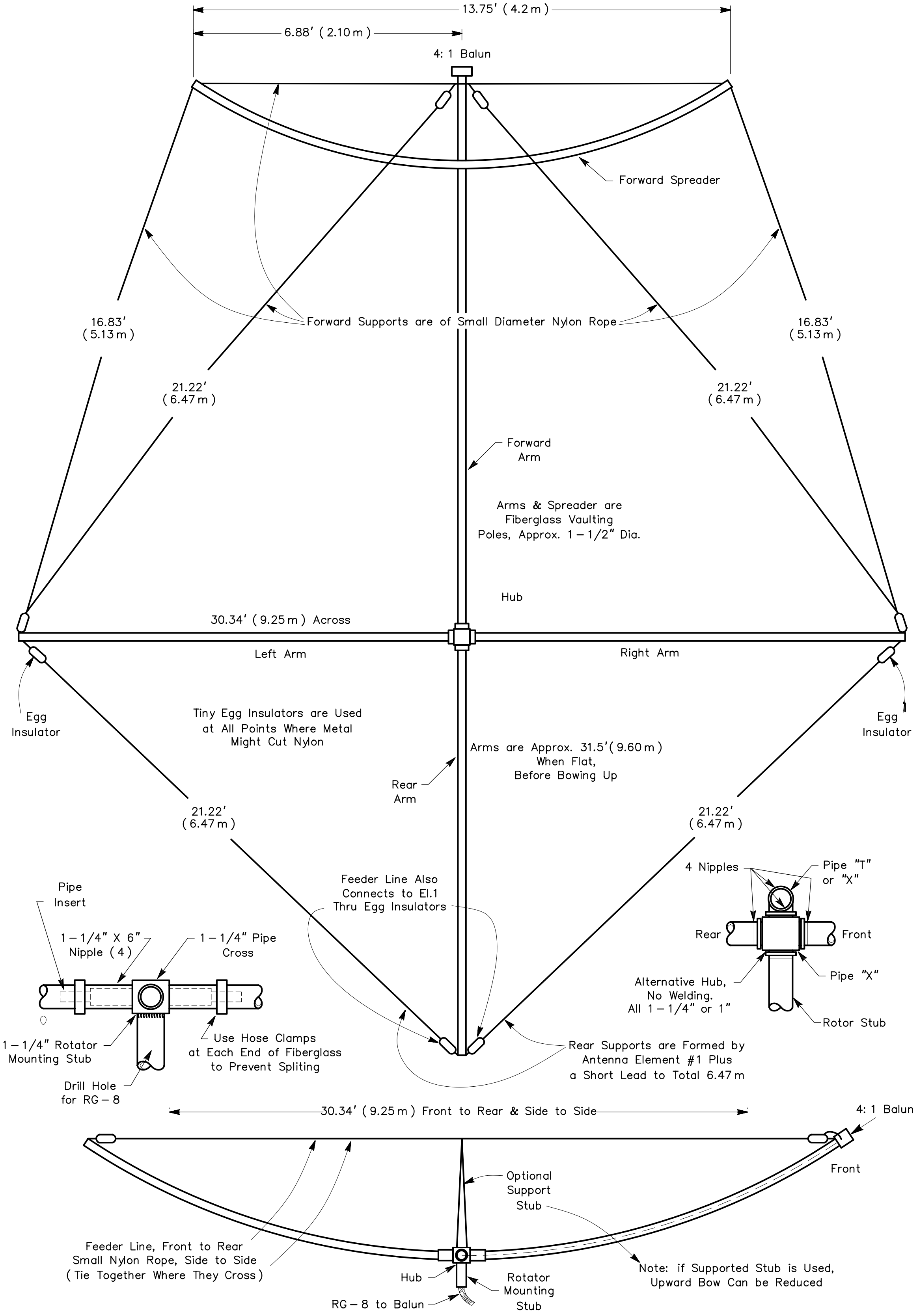
13.75′ (4.2 m)
6.88′ (2.10 m)
4: 1 Balun
Forward Spreader
Forward Supports are of Small Diameter Nylon Rope
16.83′ (5.13 m)
16.83′ (5.13 m)
21.22′ (6.47 m)
21.22′ (6.47 m)
Forward Arm
Arms & Spreader are Fiberglass Vaulting Poles, Approx. 1 – 1/2″ Dia.
Hub
30.34′ (9.25 m) Across
Left Arm
Right Arm
Egg Insulator
Egg Insulator
Tiny Egg Insulators are Used at All Points Where Metal Might Cut Nylon
Arms are Approx. 31.5′(9.60 m) When Flat, Before Bowing Up
Rear Arm
21.22′ (6.47 m)
21.22′ (6.47 m)
Feeder Line Also Connects to El.1 Thru Egg Insulators
4 Nipples
Pipe "T" or "X"
Rear
Front
Alternative Hub, No Welding. All 1 – 1/4″ or 1″
Pipe "X"
Rotor Stub
Pipe Insert
1 – 1/4″ X 6″ Nipple (4)
1 – 1/4″ Pipe Cross
1 – 1/4″ Rotator Mounting Stub
Use Hose Clamps at Each End of Fiberglass to Prevent Spliting
Drill Hole for RG – 8
Rear Supports are Formed by Antenna Element #1 Plus a Short Lead to Total 6.47 m
30.34′ (9.25 m) Front to Rear & Side to Side
4: 1 Balun
Front
Optional Support Stub
Feeder Line, Front to Rear Small Nylon Rope, Side to Side (Tie Together Where They Cross)
Hub
Rotator Mounting Stub
RG – 8 to Balun
Note: if Supported Stub is Used, Upward Bow Can be Reduced

Fig 23—The frame construction of the spider web antenna. Two different hub arrangements are illustrated.

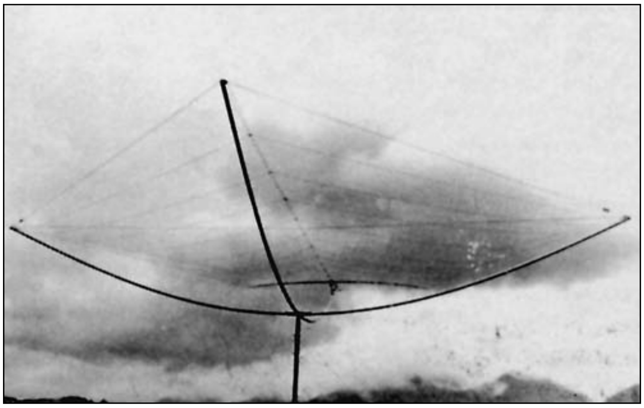

Fig 24—Although the spider web antenna resembles a rotatable clothes line, it is much larger, as indicated by Figs 22 and 23. However, the antenna can be lifted by hand.

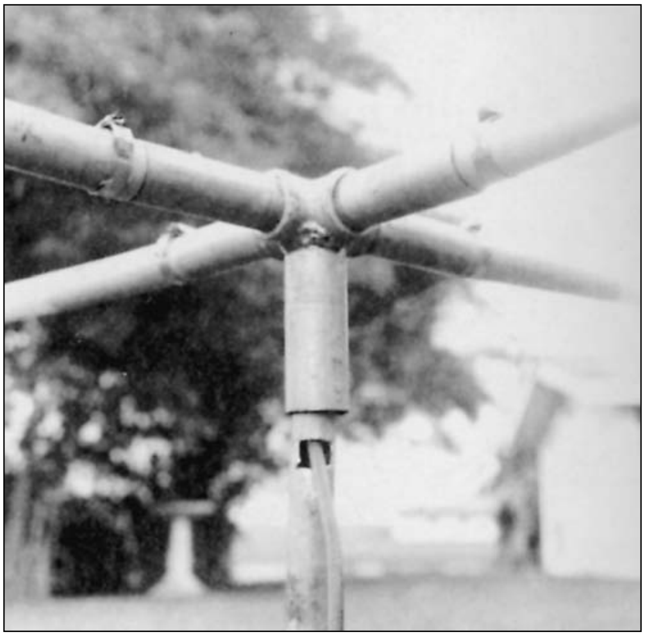

Fig 25—The simple arrangement of the spider web antenna hub. See Fig 23 and the text for details.

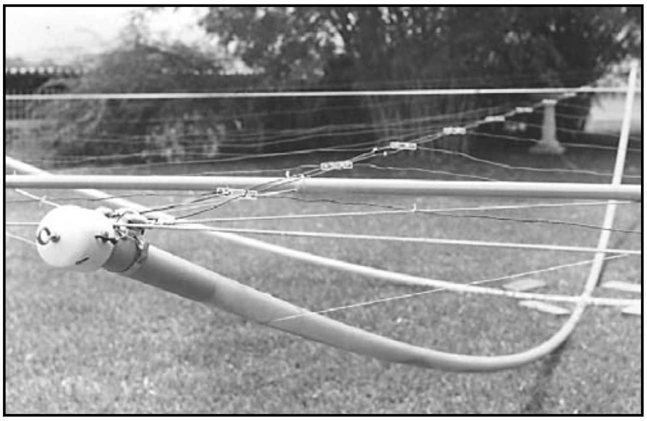

Fig 26—The elements, balun, transmission line and main bow of the spider web antenna.

Table 6

Shopping List for the Telerana

1—1$^1/_4$-inch galvanized, 4-outlet cross or X.
4—8-inch nipples.
4—15-foot long arms. Vaulting poles suggested. These must be strong and all of the same strength (150 lb) or better.
1—Spreader, 14.8 foot long (must not be metal).
1—4:1 balun unless open-wire or TV cable is used.
12—Feed-line insulators made from Plexiglas or fiberglass.
36—Small egg insulators.
328 feet copper wire for elements; flexible 7/22 is suggested.
65.6 feet (20 m) #14 Copperweld wire for interelement feed line.
164 feet (50 m) strong $^1/_8$-inch dia cord.
1—Roll of nylon monofilament fishing line, 50 lb test or better.
4—Metal tubing inserts go into the ends of the fiberglass arms.
2—Fiberglass fishing-rod blanks.
4—Hose clamps.

If tapered, the spreader should have the same measurements from the center to each end. *Do not use metal for this spreader*.

Building the frame for the array is the first construction step. Once the frame is prepared, then everything else can be built onto it. Begin by assembling the hub and the four arms, letting them lie flat on the ground with the rotator stub inserted in a hole in the ground. The tip-to-tip length should be about 31.5 feet each way. A hose clamp is used at each end of the arms to prevent splitting. Place the metal inserts in the outer ends of the arms, with 1 inch protruding. The mounting holes should have been drilled at this point. If the egg insulators and nylon cords are mounted to these tube inserts, the whole antenna can be disassembled simply by bending up the arms and pulling out the inserts with everything still attached.

Choose the arm to be at the front end. Mount two egg insulators at the front and rear to accommodate the inter-element feeder. These insulators should be as close as possible to the ends.

At each end of the cross-arm on top, install a small pulley and string nylon cord across and back. Tighten the cord until the upward bow reaches 3 feet above the hub. All cords will require retightening after the first few days because of stretching. The cross-arm can be laid on its side while preparing the feeder line. For the front-to-rear bowstring it is important to use a wire that will not stretch, such as #14 Copperweld. This bowstring is actually the inter-element transmission line. See **Fig 26**.

Secure the rear ends of the feeder to the two rear insulators, soldering the wrap. Before securing the fronts, slip the 12 insulators onto the two feed lines. A rope can be used temporarily to form the bow and to aid in mounting the feeder line. The end-to-end length of the feeder

Improving the Telerana

In *The ARRL Antenna Compendium, Vol 4*, Markus Hansen, VE7CA, described how he modified the Telerana to improve the front-to-back ratio on 20 and 15 meters. In addition, he added a trapped 30/40-meter dipole that functions as a top truss system to stabilize the modified Telerana in strong uprising winds that otherwise could turn the antenna into an "inside-out umbrella."

Fig A shows the layout for the modified Telerana, and Table A lists the lengths and spacings for the #14 wire elements. Note that VE7CA used tuning stubs to tweak the 15 and 20-meter reflector wires for best rearward pattern. The construction techniques used by VE7CA are the same as for the original Telerana. Fig B shows a side view of the additional 40/30-meter-dipole truss sytem.

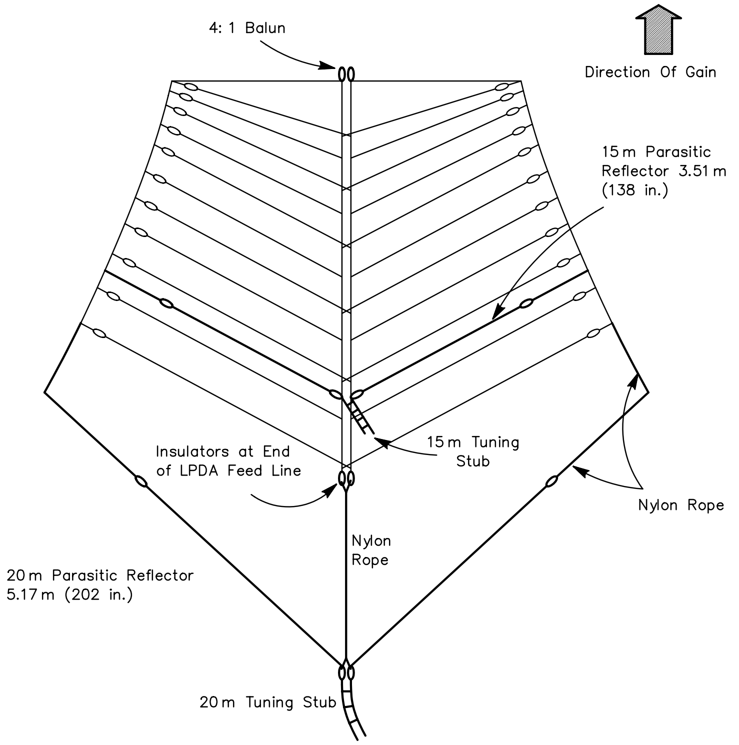
4: 1 Balun
Direction Of Gain
15 m Parasitic Reflector 3.51 m (138 in.)
Insulators at End of LPDA Feed Line
15 m Tuning Stub
Nylon Rope
Nylon Rope
20 m Parasitic Reflector 5.17 m (202 in.)
20 m Tuning Stub

Table A

Element Lengths and Spacings, in Inches

Element Number	*1/2 Element Length (inches)*	*Total Distance (inches)*
R1	202.0	0.0
L1	210.1	102.0
L2	191.2	140.7
R2	138.0	158.3
L3	174.0	175.9
L4	158.3	207.9
L5	144.1	237.0
L6	131.1	261.5
L7	119.3	285.6
L8	108.6	307.6
L9	98.8	327.6
L10	89.9	345.8
L11	82.4	364.5

Note: the reflector lengths do not include the length of the tuning stubs.

Fig A—Physical layout of modified Telerana with 20 and 15-meter reflectors added (in place of first two elements in original Telerana). Note the tuning stubs for the added reflectors.

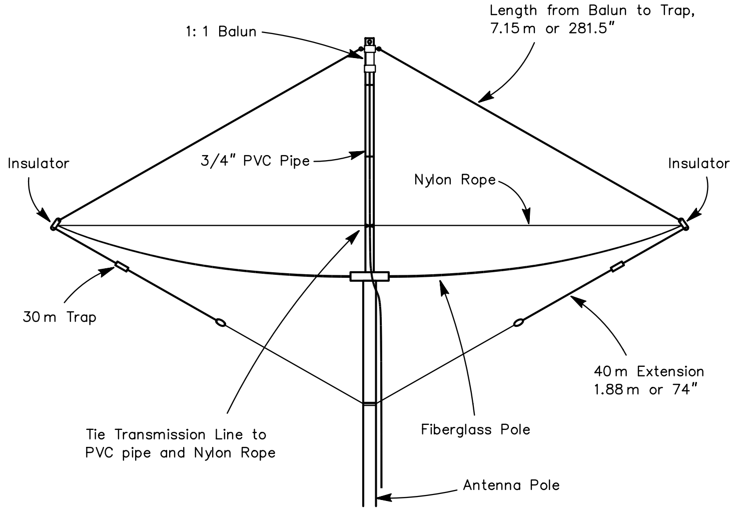
1: 1 Balun
Length from Balun to Trap, 7.15 m or 281.5″
Insulator
3/4″ PVC Pipe
Nylon Rope
Insulator
30 m Trap
40 m Extension 1.88 m or 74″
Tie Transmission Line to PVC pipe and Nylon Rope
Fiberglass Pole
Antenna Pole

Fig B—Side view of 30/40-meter addition to the modified Telerana, using 3/4-inch PVC pipe as a vertical stabilizer and support for the 30/40-meter trapped dipole.

should be 30.24 feet.

Now lift both bows to their upright position and tie the feeder line and the cross-arm bowstring together where they cross, directly over and approximately 3 feet above the hub.

The next step is to install the number 1 rear element from the rear egg insulators to the right and left cross-arms using other egg insulators to provide the proper element length. Be sure to solder the element halves to the transmission line. Complete this portion of the construction by installing the nylon cord catenaries from the front arm to the cross-arm tips. Use egg insulators where needed to prevent cutting the nylon cords.

When preparing the fiberglass forward spreader, keep in mind that it should be 14.75 feet long before bowing and is approximately 13.75 feet across when bowed. Secure the center of the bowstring to the end of the front arm. Lay the spreader on top of the feed line, then tie the feeder to the spreader with nylon fish line. String the catenary from the spreader tips to the cross-arm tips.

At this point of assembly, prepare antenna elements 2 through 13. There will be two segments for each element. At the outer tip make a small loop and solder the wrap. The loop will be for the nylon leader. Measure the length plus 0.4 inch for wrapping and soldering the element segment to the feeder. Seven-strand #22 antenna wire is suggested for the element wires. Slide the feed-line insulators to their proper position and secure them temporarily.

The drawings show the necessary transposition scheme. Each element half of elements 1, 3, 5, 7, 9, 11 and 13 is connected to its own side of the feeder, while elements 2, 4, 6, 8, 10 and 12 cross over to the opposite side of the transmission line.

There are four holes in each of the transmission-line insulators (see Fig 22). The inner holes are for the transmission line, and the outer ones are for the elements. Since the array elements are slanted forward, they should pass through the insulator from front to back, then back over the insulator to the front side and be soldered to the transmission line. The small drawings of Fig 22 show the details of the element transpositions.

Everywhere that lines cross, tie them together with nylon line, including all copper-nylon and nylon-nylon junctions. Careful tying makes the array much more rigid. However, all elements should be mounted loosely before you try to align the whole thing. Tightening any line or element affects all the others. There will be plenty of walking back and forth before the array is aligned properly. Expect the array to be firm but not extremely taut.

The Pounder: A Single-Band 144-MHz LPDA

The 4-element Pounder LPDA pictured in **Fig 27** was developed by Jerry Hall, K1TD, for the 144-148 MHz band. Because it started as an experimental antenna, it utilizes some unusual construction techniques. However, it gives a very good account of itself, exhibiting a theoretical free-space gain of about 7.2 dBi and a front-to-back ratio of 20 dB or better. The Pounder is small and light. It weighs just 1 pound, and hence its name. In addition, as may be seen in **Fig 28**, it can be disassembled and reassembled quickly, making it an excellent antenna for portable use. This array also serves well as a fixed-station antenna, and may be changed easily to either vertical or horizontal polarization.

The antenna feeder consists of two lengths of $^1/_2 \times {}^1/_2 \times {}^1/_{16}$-inch angle aluminum. The use of two facing flat surfaces permits the builder to obtain a lower characteristic impedance than can be obtained from round conductors with the same spacing. The feeder also serves as the boom for the Pounder. In the first experimental model, the array contained only two elements with a spacing of 1 foot, so a boom length of 1 foot was the primary design requirement for the 4-element version. **Table 7** gives the calculated design data for the 4-element array.

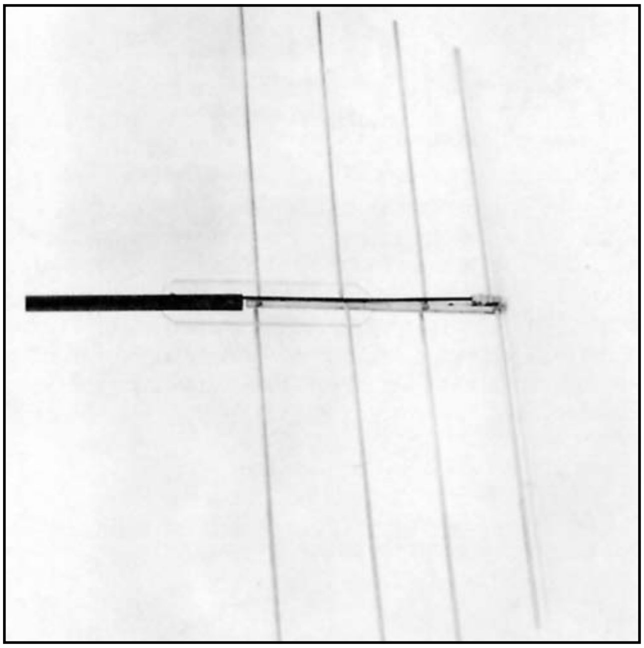

Fig 27—The 144 MHz Pounder. The boom extension at the left of the photo is a 40-inch length of slotted PVC tubing, $^7/_8$-inch outer diameter. The tubing may be clamped to the side of a tower or attached to a mast with a small boom-to-mast plate. Rotating the tubing at the clamp will provide for either vertical or horizontal polarization.

Construction

You can see the general construction approach for

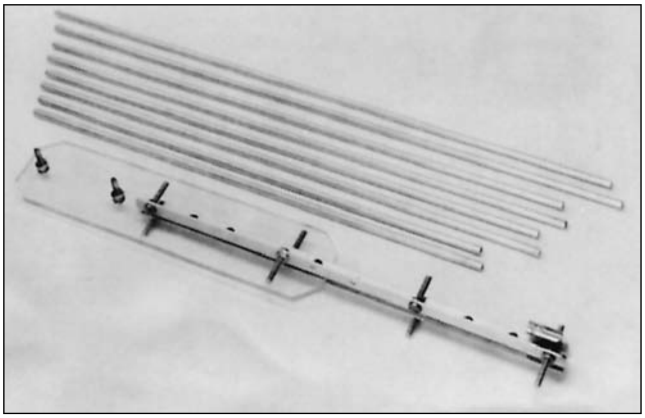

Fig 28—One end of each half element is tapped to fasten onto boom-mounted screws. Disassembly of the array consists of merely unscrewing 8 half elements from the boom. The entire disassembled array creates a small bundle only 21 inches long.

Table 7

Design Parameters for the 144-MHz Pounder

f1 = 143 MHz
f_n = 148 MHz
B = 1.0350
τ = 0.92
σ = 0.053
Gain = 7.2 dBi = 5.1 dBd
cot α = 2.6500
B_{ar} = 1.2306
B_s = 1.2736
L = 0.98 feet
N = 3.90 elements (increase to 4)
Zt = none
R_0 = 52 Ω
Z_{AV} = 312.8 Ω
σ' = 0.05526
Z_0 = 75.1 Ω

Element lengths:
ℓ1 = 3.441 feet
ℓ2 = 3.165 feet
ℓ3 = 2.912 feet
ℓ4 = 2.679 feet
Element spacings:
d_{12} = 0.365 feet
d_{23} = 0.336 feet
d_{34} = 0.309 feet
Element diameters:
All = 0.25 inches
ℓ/diameter ratios:
$\ell 4/\text{diam}_4$ = 128.6
$\ell 3/\text{diam}_3$ = 139.8
$\ell 2/\text{diam}_2$ = 151.9
$\ell 1/\text{diam}_1$ = 165.1

Antenna feeder: 1/2 × 1/2 × 1/16″ angle aluminum spaced 1/4″
Balun: 1:1 (see text)
Feed line: 52-Ω coax (see text)

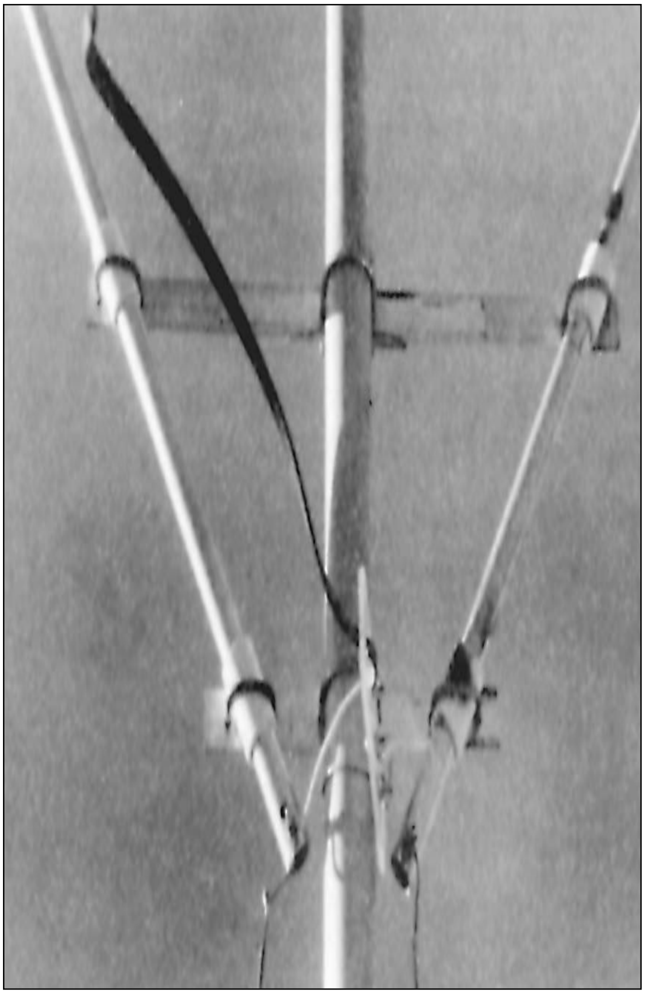

Fig 29—A close-up view of the boom, showing an alternative mounting scheme. This photo shows an earlier 2-element array, but the boom construction is the same for 2 or 4 elements. See the text for details.

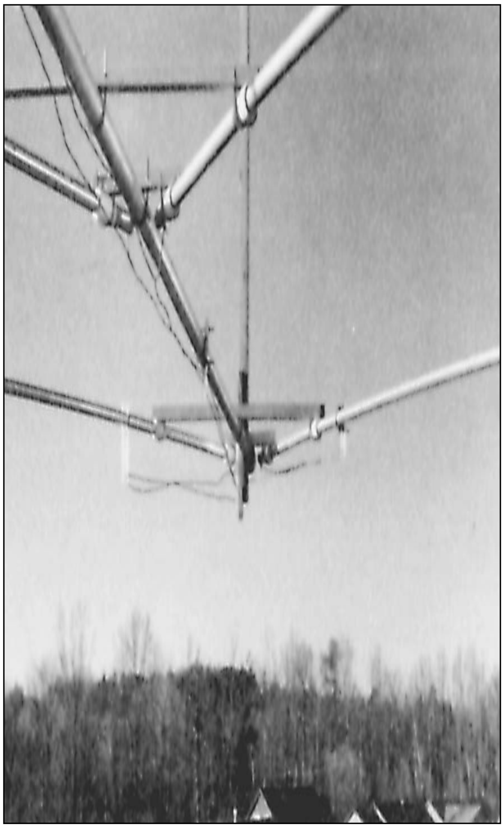

Fig 30—The feed arrangement, using a right-angle chassis-mounted BNC connector, modified by removing a portion of the flange. A short length of bus wire connects the center pin to the opposite feeder conductor.

the Pounder in the photographs. Drilled and tapped pieces of Plexiglas sheet, 1/4-inch thick, serve as insulating spacers for the angle aluminum feeder. Two spacers are used, one near the front and one near the rear of the array. Four #6-32 × 1/4-inch pan head screws secure each aluminum angle section to the Plexiglas spacers, as shown in **Figs 29** and **30**. Use flat washers with each screw to prevent it from touching the angle stock on the opposite side of the spacer. Be sure the screws are not so long as to short out the feeder! A clearance of about 1/16 inch is sufficient. If you have doubts about the screw lengths, check the assembled boom for a short with your ohmmeter on a Megohm range.

Either of two mounting techniques may be used for the Pounder. As shown in Figs 27 and 28, the rear spacer measures 10 × 2 1/2 inches, with 45º corners to avoid sharp points. This spacer also accommodates a boom extension of PVC tubing, which is attached with two #10-32 × 1-inch screws. This tubing provides for side mounting the Pounder away from a mast or tower.

An alternative support arrangement is shown in Fig 29. Two 1/2 × 3-inch Plexiglas spacers are used at the front and rear of the array. Each spacer has four holes drilled 5/8 inch apart and tapped with #6-32 threads. Two screws enter each spacer from either side to make a tight aluminum-Plexiglas-aluminum sandwich. At the center of the boom, secured with only two screws, is a 2 × 18-inch strip of 1/4-inch Plexiglas. This strip is slotted about 2 inches from each end to accept hose clamps for mounting the Pounder atop a mast. As shown, the strip is attached for vertical polarization. Alternate mounting holes, visible on the now-horizontal lip of the angle stock, provide for horizontal polarization. Although sufficient, this mounting arrangement is not as sturdy as that shown in Fig 27.

The elements are lengths of thick-wall aluminum tubing, 1/4-inch OD. The inside wall conveniently accepts a #10-32 tap. The threads should penetrate the tubing to a depth of at least 1 inch. Eight #10-32 × 1-inch screws are attached to the boom at the proper element spacings and held in place with #10-32 nuts, as shown in Fig 28. For assembly, the elements are then simply screwed into place.

Note that with this construction arrangement, the two halves of any individual element are not precisely collinear; their axes are offset by about 3/4 inch. This offset does not seem to affect performance.

The Feed Arrangement

Use care initially in mounting and cutting the elements to length. To obtain the 180° crossover feed arrangement, the element halves from a single section of the feeder/boom must alternate directions. That is, for half-elements attached to one of the two pieces of angle stock, elements 1 and 3 will point to one side, and elements 2 and 4 to the other. This arrangement may be seen by observing the element-mounting screws in Fig 28. Because of this mounting scheme, the length of tubing for an element “half” is not simply half of the length given in Table 7. After final assembly, halves for elements 2 and 4 will have a slight overlap, while elements 1 and 3 are extended somewhat by the boom thickness. The best procedure is to cut each assembled element to its final length by measuring from tip to tip.

The Pounder may be fed with RG-58 or RG-59 coax and a BNC connector. A modified right-angle chassis-mount BNC connector is attached to one side of the feeder/boom assembly for cable connection, Fig 30. The modification consists of cutting away part of the mounting flange that would otherwise protrude from the boom assembly. This leaves only two mounting-flange holes, but these are sufficient for a secure mount. A short length of small bus wire connects the center pin to the opposite side of the feeder, where it is secured under the mounting-screw nut for the shortest element.

For operation, you may secure the coax to the PVC boom extension or to the mast with electrical tape. You should use a balun, especially if the Pounder is operated with vertical elements. A choke type of balun is satisfactory, formed by taping 6 turns of the coax into a coil of 3 inches diameter, but a bead balun is preferred (see Chapter 26). The balun should be placed at the point where the coax is brought away from the boom. If the mounting arrangement of Fig 29 is used with vertical polarization, a second balun should be located approximately 1/4 wavelength down the coax line from the first. This will place it at about the level of the lower tips of the elements. For long runs of coax to the transmitter, a transition from RG-58 to RG-8 or from RG-59 to RG-9 is suggested, to reduce line losses. Make this transition at some convenient point near the array.

No shorting feeder termination is used with the array described here. The antenna feeder (phase-line) Z_0 of this array is in the neighborhood of 120 Ω, and with a resulting feed-point impedance of about 72 Ω. The theoretical mean SWR with 52 Ω line is 72/52 or 1.4 to 1. Upon array completion, the measured SWR (52-Ω line) was found to be relatively constant across the band, with a value of about 1.7 to 1. The Pounder offers a better match to 72-Ω coax.

Being an all-driven array, the Pounder is more immune to changes in feed-point impedance caused by nearby objects than is a parasitic array. This became obvious during portable use when the array was operated near trees and other objects… the SWR did not change noticeably with antenna rotation toward and away from those objects. Consequently, the Pounder should behave well in a restricted environment, such as an attic. Weighing just one pound, this array indeed does give a good account of itself.

Log Periodic-Yagi Arrays

Several possibilities exist for constructing high-gain arrays that use the log periodic dipole array concept. One technique is to add parasitic elements to the LPDA to increase both the gain and the front-to-back ratio for a specific frequency within the passband of the LPDA. The LPDA-Yagi combination is simple in concept. It utilizes an LPDA group of driven elements, along with parasitic elements at normal Yagi spacings from the active elements of the LPDA.

The LPDA-Yagi combinations are endless. An example of a single-band high-gain design is a 2- or 3-element LPDA for 21.0 to 21.45 MHz with the addition of two or three parasitic directors and one parasitic reflector. The name Log-Yag (log-cell Yagi) array has been coined for these hybrid antennas. The LPDA portion of the array is of the usual design to cover the desired bandwidth, and standard Yagi design procedures are used for the parasitic elements. Information in this section is based on a Dec 1976, *QST* article by P. D. Rhodes, K4EWG, and J. R. Painter, W4BBP, "The Log-Yag Array."

THE LOG-YAG ARRAY

The Log-Yag array, with its added parasitic elements, provides higher gain and greater directivity than would be realized with the LPDA alone. Yagi arrays require a long boom and wide element spacing for wide bandwidth and high gain, because the Q of the Yagi system increases as the number of elements is increased or as the spacing between adjacent elements is decreased. An increase in the Q of the Yagi array means that the total operating bandwidth of the array is decreased, and the gain and front-to-back ratio specified in the design are obtainable only over small portions of the band. [Older Yagi designs did indeed exhibit the limitations mentioned here. But modern, computer-aided design has resulted in wideband Yagis, provided that sufficient elements are used on the boom to allow stagger tuning for wide-band coverage. See Chapter 11.—*Ed.*]

The Log-Yag system overcomes this difficulty by using a multiple driven element cell designed in accordance with the principles of the log periodic dipole array. Since this log cell exhibits both gain and directivity by itself, it is a more effective wide-band radiator than a simple dipole driven element. The front-to-back ratio and gain of the log cell can then be improved with the addition of a parasitic reflector and director.

It is not necessary for the parasitic element spacings to be large with respect to wavelength, since the log cell is the determining factor in the array bandwidth. As well, the element spacings within the log cell may be small with respect to a wavelength without appreciable deterioration of the cell gain. For example, decreasing the relative spacing constant (σ) from 0.1 to 0.05 will decrease the array gain by less than 1 dB.

A Practical Example

The photographs and figures show a Log-Yag array for the 14-MHz amateur band. The array design takes the form of a 4-element log cell, a parasitic reflector spaced at 0.085 λ_{max}, and a parasitic director spaced at 0.15 λ_{max} (where λ_{max} is the longest free-space wavelength within the array passband). Array gain is almost unaffected with reflector spacings from 0.08 λ to 0.25 λ, and the increase in boom length is not justified. The function of the reflector is to improve the front-to-back ratio of the log cell, while the director sharpens the forward lobe and decreases the half-power beamwidth. As the spacing between the parasitic elements and the log cell decreases, the parasitic elements must increase in length.

The log cell is designed to meet upper and lower band limits with $\sigma = 0.05$. The design parameter τ is dependent on the structure bandwidth, B_s. When the log periodic design parameters have been found, the element length and spacings can be determined.

Array layout and construction details can be seen in Figs 31 through 34. Characteristics of the array are given in **Table 8**.

The method of feeding the antenna is identical to that of feeding the log periodic dipole array without the parasitic elements. As shown in **Fig 31**, a balanced feeder is required for each log-cell element, and all adjacent elements are fed with a 180° phase shift by alternating connections. Since the Log-Yag array will be covering a relatively small bandwidth, the radiation resistance of the narrow-band log cell will vary from 80 to 90 Ω (tubing

Table 8
Log-Yag Array Characteristics

1) Frequency range	14 to 14.35 MHz
2) Operating bandwidth	B = 1.025
3) Design parameter	$\tau = 0.946657$
4) Apex half angle	$\alpha = 14.921°$; $\cot \alpha = 3.753$
5) Half-power beamwidth	42° (14 to 14.35 MHz)
6) Bandwidth of structure	Bs = 1.17875
7) Free-space wavelength	λ_{max} = 70.28 feet
8) Log cell boom length	L = 10.0 feet
9) Longest log element	$\ell 1$ = 35.14 feet (a tabulation of element lengths and spacings is given in Table 9)
10) Forward gain (free space)	8.2 dBi
11) Front-to-back ratio	32 dB (theoretical)
12) Front-to-side ratio	45 dB (theoretical)
13) Input impedance	Z_0 = 37 Ω
14) SWR	1.3 to 1 (14 to 14.35 MHz)
15) Total weight	96 pounds
16) Wind-load area	8.5 sq feet
17) Reflector length	36.4 feet at 6.0 foot spacing
18) Director length	32.2 feet at 10.5 foot spacing
19) Total boom length	26.5 feet

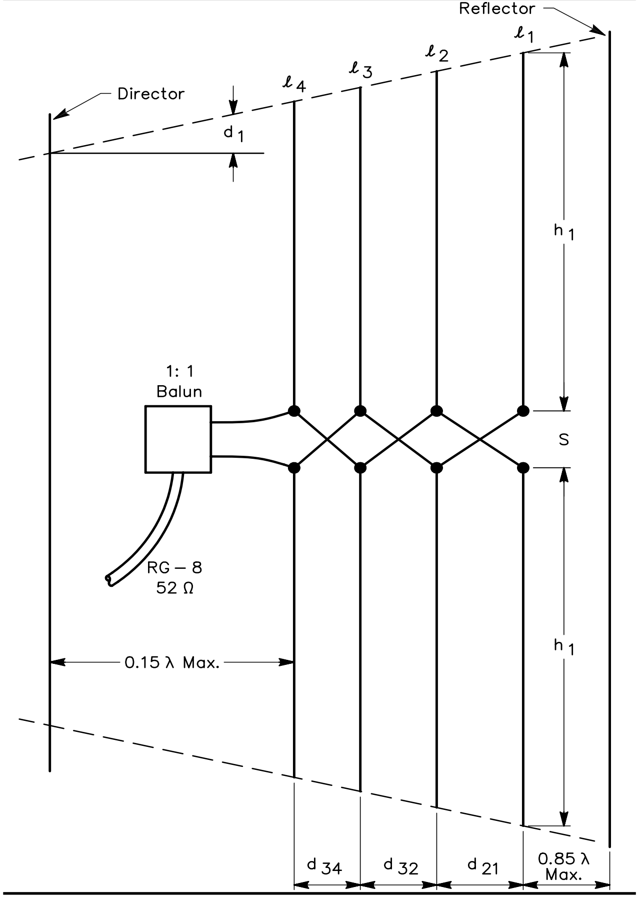
Reflector
ℓ1
ℓ2
ℓ3
ℓ4
Director
d1
h1
1: 1
Balun
s
RG – 8
52 Ω
h1
0.15 λ Max.
d34
d32
d21
0.85 λ
Max.

Fig 31—Layout of the Log-Yag array.

Table 9

Log-Yag Array Dimensions

Element	*Length Feet*	*Spacing Feet*
Reflector	36.40	6.00 (Ref. to ℓ1)
ℓ1	35.14	3.51 (d_{12})
ℓ2	33.27	3.32 (d_{23})
ℓ3	31.49	3.14 (d_{34})
ℓ4	29.81	10.57 (ℓ4 to dir.)
Director	32.20	

elements) depending on the operating bandwidth. The addition of parasitic elements lowers the log-cell radiation resistance. Hence, it is recommended that a 1:1 balun be connected at the log-cell input terminals and 50-Ω coaxial cable be used for the feed line.

The measured radiation resistance of the 14-MHz Log-Yag is 37 Ω over the frequency range from 14.0 to 14.35 MHz. It is assumed that tubing elements will be used. However, if a wire array is used, then the radiation resistance R_0 and antenna-feeder input impedance Z_0 must be calculated so that the proper balun and coax may be used. The procedure is outlined in detail in an earlier part of this chapter. However, programs such as *LPCAD28* are also suitable to automate the calculations.

Table 9 has array dimensions. **Tables 10** and **11** contain lists of the materials necessary to build the Log-Yag array.

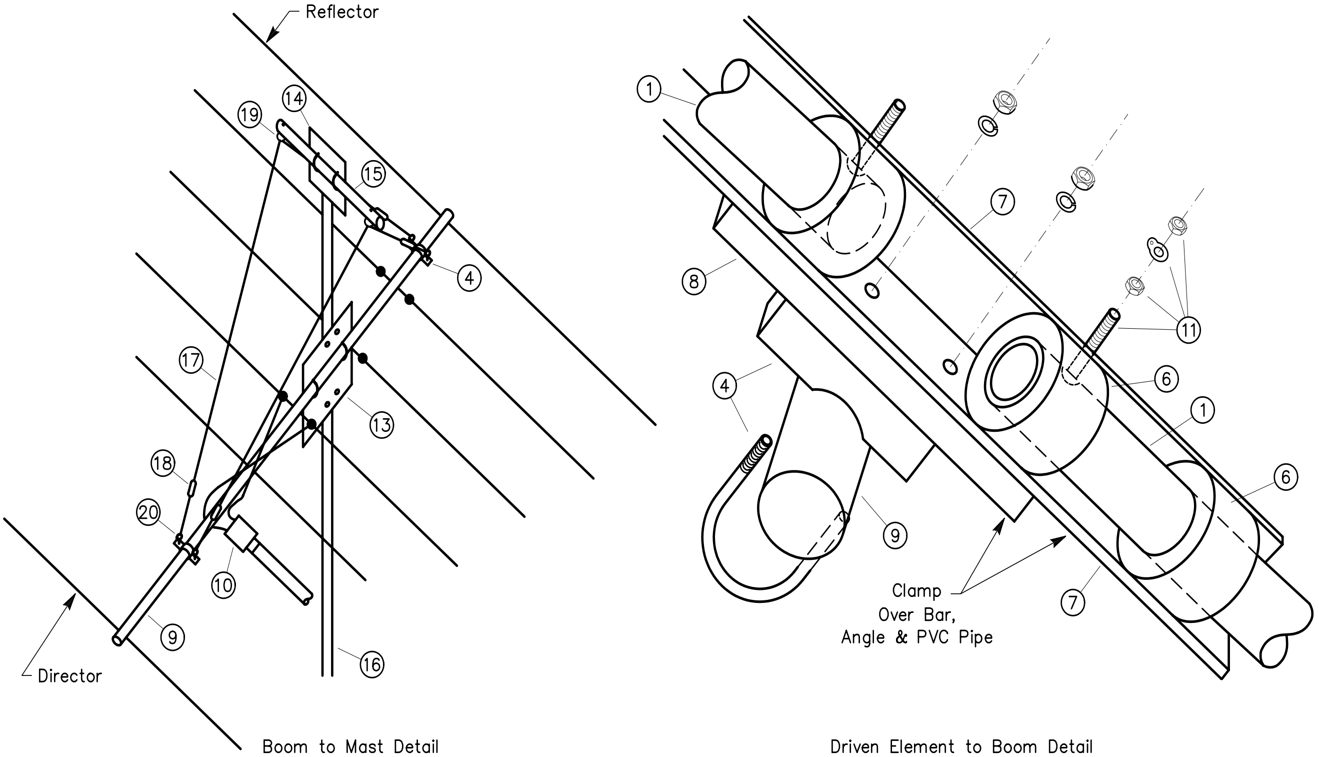
Reflector
19
14
15
4
17
13
18
20
10
9
16
Director
1
7
8
11
6
4
1
6
9
7
Clamp
Over Bar,
Angle & PVC Pipe

Boom to Mast Detail

Driven Element to Boom Detail

Fig 32—Assembly details. The numbered components refer to Table 11.

Table 10
Element Material Requirements: Log-Yag Array

	1-in. Tubing		***⅞-in. Tubing***		***¾-in. Tubing***		***1¼-in. Angle***	***1¼-in. Bar***
	Len. Feet	*Qty*	*Len. Feet*	*Qty*	*Len. Feet*	*Qty*	*Len. Feet*	*Len. Feet*
Reflector	12	1	6	2	8	2	None	None
ℓ1	6	2	6	2	8	2	3	1
ℓ2	6	2	6	2	8	2	3	1
ℓ3	6	2	6	2	6	2	3	1
ℓ4	6	2	6	2	6	2	3	1
Director	12	1	6	2	6	2	None	None

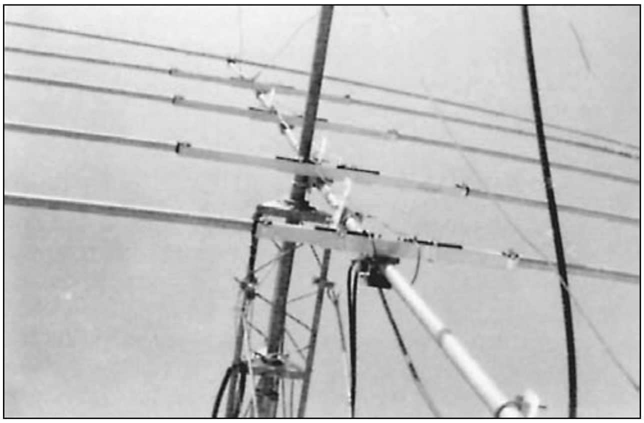

Fig 33—The attachment of the elements to the boom.

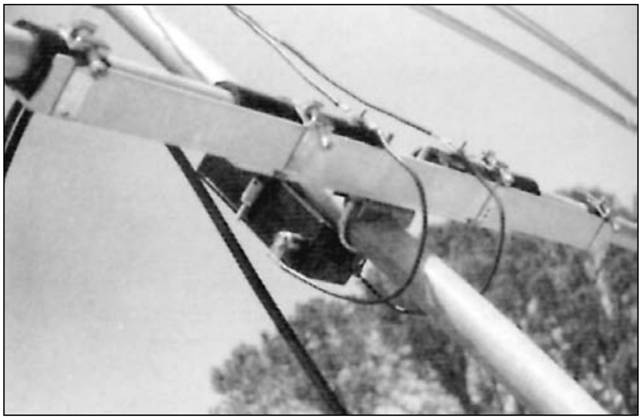

Fig 34—Looking from the front to the back of the Log-Yag array. A truss provides lateral and vertical support.

Table 11
Materials List, Log-Yag Array

1) Aluminum tubing—0.047 in. wall thickness
   1 in.—12 ft lenths, 24 lin. ft
   1 in.—12 ft or 6 ft lengths, 48 lin. ft
   ⅞ in.—12 ft or 6 ft lengths, 72 lin. ft
   ¾ in.—8 ft lengths, 48 lin. ft
   ¾ in.—6 ft lengths, 36 lin. ft
2) Stainless steel hose clamps—2 in. max, 8 ea
3) Stainless steel hose clamps—1¼ in. max, 24 ea
4) TV-type U bolts—1½ in., 6 ea
5) U bolts, galv. type: 5/16 in. × 1½ in., 6 ea
5A) U bolts, galv. type: ¼ in. × 1 in., 2 ea
6) 1 in. ID water-service polyethylene pipe 160 lb/in.^{2} test, approx. 1⅜ in. OD, 7 lin. ft
7) 1¼ in. × 1¼ in. × ⅛ in. aluminum angle—6 ft lengths, 12 lin. ft
8) 1 in. × ¼ in. × ¼ in. aluminum angle—6 ft lengths, 6 lin. ft
9) 1¼ in. top rail of chain-link fence, 26.5 lin. ft
10) 1:1 toroid balun, 1 ea
11) No. 6-32 × 1 in. stainless steel screws, 8 ea
    No. 6-32 stainless steel nuts, 16 ea
    No. 6 solder lugs, 8 ea
12) #12 copper feed wire, 22 lin. ft
13) 12 in. × 6 in. × ¼ in. aluminum plate, 1 ea
14) 6 in. × 4 in. × ¼ in. aluminum plate, 1 ea
15) ¾ in. galv. pipe, 3 lin. ft
16) 1 in. galv. pipe—mast, 5 lin. ft
17) Galv. guy wire, 50 lin. ft
18) ¼ in. × 2 in. turnbuckles, 4 ea
19) ¼ in. × 1½ in. eye bolts, 2 ea
20) TV guy clamps and eyebolts, 2 ea

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Chapter 11

HF Yagi Arrays

Along with the dipole and the quarter-wave vertical, radio amateurs throughout the world make extensive use of the Yagi array. Hidetsugu Yagi and Shintaro Uda, two Japanese university professors, invented the Yagi in the 1920s. Uda did much of the developmental work, while Yagi introduced the array to the world outside Japan through his writings in English. Although the antenna should properly be called a *Yagi-Uda* array, it is commonly referred to simply as a *Yagi*.

The Yagi is a type of endfire multielement array. At the minimum, it consists of a single driven element and a single parasitic element. These elements are placed parallel to each other, on a supporting boom spacing them apart. This arrangement is known as a 2-element Yagi. The parasitic element is termed a *reflector* when it is placed behind the driven element, opposite to the direction of maximum radiation, and is called a *director* when it is placed ahead of the driven element. See **Fig 1**. In the VHF and UHF spectrum, Yagis employing 30 or more elements are not uncommon, with a single reflector and multiple directors. See Chapter 18, VHF and UHF Antenna Systems, for details on VHF and UHF Yagis. Large HF arrays may employ 10 or more elements, and will be covered in this chapter.

The gain and directional pattern of a Yagi array is determined by the relative amplitudes and phases of the currents induced into all the parasitic elements. Unlike the directly driven multielement arrays considered in Chapter 8, Multielement Arrays, where the designer must compensate for mutual coupling between elements, proper Yagi operation *relies on* mutual coupling. The current in each parasitic element is determined by its spacing from both the driven element and other parasitic elements, and by the tuning of the element itself. Both length and diameter affect element tuning.

For about 50 years amateurs and professionals created Yagi array designs largely by "cut and try" experimental techniques. In the early 1980s, Jim Lawson, W2PV, described in detail for the amateur audience the fundamental mathematics involved in modeling Yagis. His book *Yagi Antenna Design* is highly recommended for serious antenna designers. The advent of powerful microcomputers and sophisticated computer antenna modeling software in the mid 1980s revolutionized the field of Yagi design for the radio amateur. In a matter of minutes, a computer can

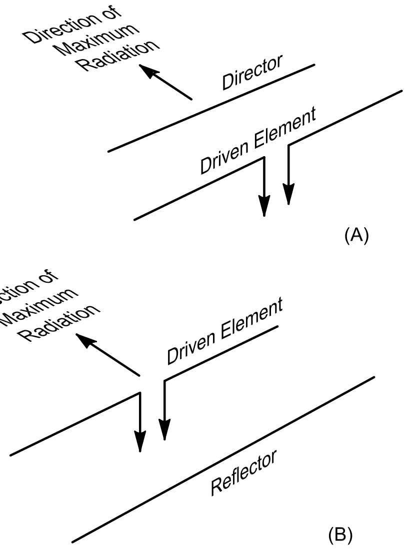
Direction of Maximum Radiation
Director
Driven Element
(A)
Direction of Maximum Radiation
Driven Element
Reflector
(B)

Fig 1—Two-element Yagi systems using a single parasitic element. At A the parasitic element acts as a director, and at B as a reflector. The arrows show the direction in which maximum radiation takes place.

try 100,000 or more different combinations of element lengths and spacings to create a Yagi design tailored to meet a particular set of high-performance parameters. To explore this number of combinations experimentally, a human experimenter would take an unimaginable amount of time and dedication, and the process would no doubt suffer from considerable measurement errors. With the computer tools available today, an antenna can be designed, constructed and then put up in the air, with little or no tuning or pruning required.

Yagi Performance Parameters

There are three main parameters used to characterize the performance of a particular Yagi—*forward gain*, *pattern* and *drive impedance/SWR*. Another important consideration is *mechanical strength*. It is very important to recognize that each of the three electrical parameters should be characterized over the frequency band of interest in order to be meaningful. Neither the gain, SWR nor the pattern measured at a single frequency gives very much insight into the overall performance of a particular Yagi.

Poor designs have been known to reverse their directionality over a frequency band, while other designs have excessively narrow SWR bandwidths, or overly "peaky" gain response. Finally, an antenna's ability to survive the wind and ice conditions expected in one's geographical location is an important consideration in any design. Much of this chapter will be devoted to describing detailed Yagi designs that are optimized for a good balance between gain, pattern and SWR over various amateur bands, and that are designed to survive strong winds and icing.

YAGI GAIN

Like any other antenna, the gain of a Yagi must be stated in comparison to some standard of reference. Designers of phased vertical arrays often state gain referenced to a single, isolated vertical element. See the section on "Phased Array Techniques" in Chapter 8, Multielement Arrays.

Many antenna designers prefer to compare gain to that of an *isotropic radiator in free space*. This is a theoretical antenna that radiates equally well in all directions, and by definition, it has a gain of 0 *dBi* (dB isotropic). Many radio amateurs, however, are comfortable using a dipole as a standard reference antenna, mainly because it is *not* a theoretical antenna.

In free space, a dipole does not radiate equally well in all directions—it has a figure-eight azimuth pattern, with deep nulls off the ends of the wire. In its favored directions, a free-space dipole has 2.15 dB gain compared to the isotropic radiator. You may see the term *dBd* in amateur literature, meaning gain referenced to a dipole in free space. Subtract 2.15 dB from gain in dBi to convert to gain in dBd.

Assume for a moment that we take a dipole out of "free space," and place it one wavelength over the ocean, whose saltwater makes an almost perfect ground. At an elevation angle of 15°, where sea water-reflected radiation adds in phase with direct radiation, the dipole has a gain of about 6 dB, compared to its gain when it was in free space, isolated from any reflections. See Chapter 3, The Effects of the Earth.

It is perfectly legitimate to say that this dipole has a gain of 6 dBd, although the term "dBd" (meaning "dB dipole") makes it sound as though the dipole somehow has gain over itself! Always remember that gain expressed in dBd (or dBi) refers to the *counterpart antenna in free space*. The gain of the dipole over saltwater in this example can be rated at either 6 dBd (over a dipole in free space), or as 8.15 dBi (over an isotropic radiator in free space). Each frame of reference is valid, as long as it is used consistently and clearly. In this chapter we will often switch between Yagis in free space and Yagis over ground. To prevent any confusion, gains will be stated in dBi.

Yagi free-space gain ranges from about 5 dBi for a small 2-element design to about 20 dBi for a 31-element long-boom UHF design. The length of the boom is the main factor determining the gain a Yagi can deliver. Gain as a function of boom length will be discussed in detail after the sections below defining antenna response patterns and SWR characteristics.

RESPONSE PATTERNS—FRONT-TO-REAR RATIO

As discussed in Chapter 2, Antenna Fundamentals, for an antenna to have gain, it must concentrate energy radiated in a particular direction, at the expense of energy radiated in other directions. Gain is thus closely related to an antenna's directivity pattern, and also to the losses in the antenna. **Fig 2** shows the *E-plane* (also called *E-field*, for electric field) and *H-plane* (also called *H-field*, for magnetic field) pattern of a 3-element Yagi in free space, compared to a dipole, and an isotropic radiator. These patterns were generated using the computer program *NEC-2*, which is highly regarded by antenna professionals for its accuracy and flexibility.

In free space there is no Earth reference to determine whether the antenna polarization is horizontal or vertical, and so its response patterns are labeled as E-field (electric) or H-field (magnetic). For a Yagi mounted over ground rather than in free space, if the

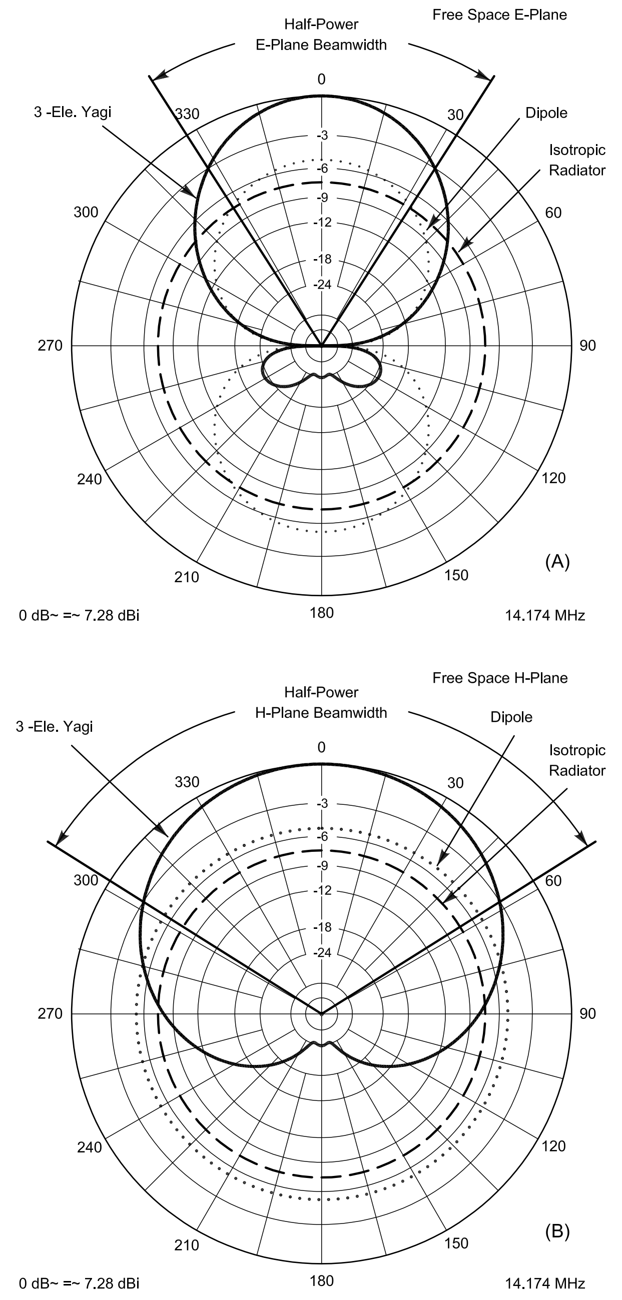

Fig 2—E-Plane (electric field) and H-Plane (magnetic field) response patterns for 3-element 20-meter Yagi in free space. At A the E-Plane pattern for a typical 3-element Yagi is compared with a dipole and an isotropic radiator. At B the H-Plane patterns are compared for the same antennas. The Yagi has an E-Plane half-power beamwidth of 66°, and an H-Plane half-power beamwidth of about 120°. The Yagi has 7.28 dBi (5.13 dBd) of gain. The front-to-back ratio, which compares the response at 0° and at 180°, is about 35 dB for this Yagi. The front-to-rear ratio, which compares the response at 0° to the largest lobe in the rearward 180° arc behind the antenna, is 24 dB, due to the lobes at 120° and 240°.

E-field is parallel to the earth (that is, the elements are parallel to the earth) then the antenna polarization is horizontal, and its E-field response is then usually referred to as its *azimuth* pattern. Its H-field response is then referred to as its *elevation* pattern.

Fig 2A demonstrates how this 3-element Yagi in free space exhibits 7.28 dBi of gain (referenced to isotropic), and has 5.13 dB gain over a free-space dipole. The gain is in the forward direction on the graph at 0° azimuth, and the forward part of the lobe is called the *main lobe*. For this particular antenna, the angular width of the E-plane main lobe at the half power, or 3 dB points compared to the peak, is about 66°. This performance characteristic is called the antenna’s azimuthal *half-power beamwidth*.

Again as seen in Fig 2A, this antenna’s response in the reverse direction at 180° azimuth is 34 dB less than in the forward direction. This characteristic is called the antenna’s *front-to-back ratio,* and it describes the ability of an antenna to discriminate, for example, against interfering signals coming directly from the rear, when the antenna is being used for reception. In Fig 2A there are two sidelobes, at 120° and at 240° azimuth, which are about 24 dB down from the peak response at 0°. Since interference can come from any direction, not only directly off the back of an antenna, these kinds of sidelobes limit the ability to discriminate against rearward signals. The term *worst-case front-to-rear ratio* is used to describe the worst-case rearward lobe in the 180°-wide sector behind the antenna’s main lobe. In this case, the worst-case front-to-rear ratio is 24 dB.

In the rest of this chapter the worst-case front-to-rear ratio will be used as a performance parameter, and will be abbreviated as “F/R.” For a dipole or an isotropic radiator, Fig 2A demonstrates that F/R is 0 dB. Fig 2B depicts the H-field response for the same 3-element Yagi in free space, again compared to a dipole and an isotropic radiator in free space. Unlike the E-field pattern, the H-field pattern for a Yagi does not have a null at 90°, directly over the top of the Yagi. For this 3-element design, the H-field half-power beamwidth is approximately 120°.

Fig 3 compares the azimuth and elevation patterns for a horizontally polarized 6-element 14-MHz Yagi, with a 60-foot boom mounted one wavelength over ground, to a dipole at the same height. As with any horizontally polarized antenna, the height above ground is the main factor determining the peaks and nulls in the elevation pattern of each antenna. Fig 3A shows the E-field pattern, which has now been labeled as the Azimuth pattern. This antenna has a half-power azimuthal beamwidth of about 50°, and at an elevation angle of 12° it exhibits a forward gain of 16.02 dBi, including about 5 dB of ground reflection gain over relatively poor ground, with a dielectric constant of 13 and conductivity of 5 mS/m. In free space this Yagi has a gain of 10.97 dBi.

The H-field elevation response of the 6-element Yagi has a half-power beamwidth of about 60° in free space,

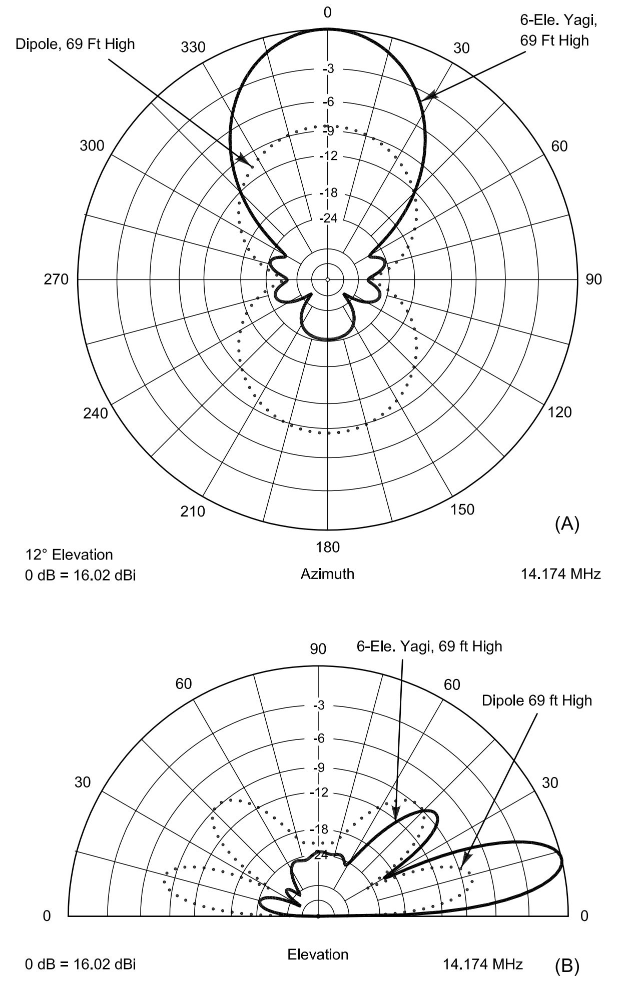

Fig 3—Azimuth pattern for 6-element 20-meter Yagi on 60-foot long boom, mounted 60 feet over ground. At A, the azimuth pattern at 12° elevation angle is shown, compared to a dipole at the same height. Peak gain of the Yagi is 16.04 dBi, or just over 8 dB compared to the dipole. At B, the elevation pattern for the same two antennas is shown. Note that the peak elevation pattern of the Yagi is compressed slightly lower compared to the dipole, even though they are both at the same height over ground. This is most noticeable for the Yagi's second lobe, which peaks at about 40°, while the dipole's second lobe peaks at about 48°. This is due to the greater free-space directionality of the Yagi at higher angles.

but as shown in Fig 3B, the first lobe (centered at 12° in elevation) has a half-power beamwidth of only 13° when the antenna is mounted one wavelength over ground. The dipole at the same height has a very slightly larger first-lobe half-power elevation beamwidth of 14°, since its free-space H-field response is omnidirectional.

Note that the free-space H-field directivity of the Yagi suppresses its second lobe over ground (at an elevation angle of about 40°) to 8 dBi, while the dipole's response at its second lobe peak (at about 48°) is at a level of 9 dBi.

The shape of the azimuthal pattern for a Yagi operated over real ground will change slightly as the Yagi is placed closer and closer to earth. Generally, however, the azimuth pattern doesn't depart significantly from the free-space pattern until the antenna is less than 0.5 λ high. This is just over 17 feet high at 28.4 MHz, and just under 35 feet at 14.2 MHz, heights that are not difficult to achieve for most amateurs. Some advanced computer programs can optimize Yagis at the exact installation height.

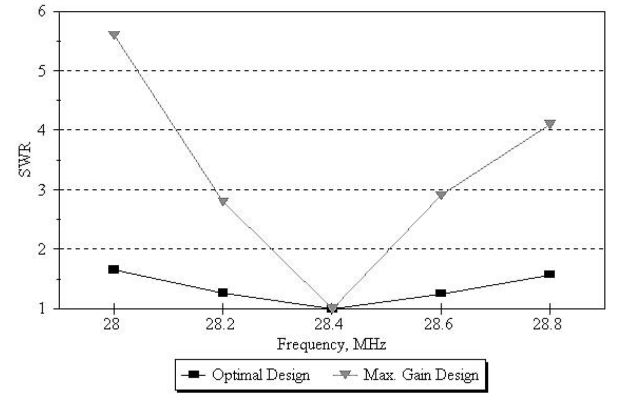

Fig 4—SWR over the 28.0 to 28.8 MHz portion of the 10-meter band for two different 3-element Yagi designs. One is designed strictly for maximum gain, while the second is optimized for F/R pattern and SWR over the frequency band. A Yagi designed only for maximum gain usually suffers from a very narrow SWR bandwidth.

DRIVE IMPEDANCE AND SWR

The impedance at the driven element in a Yagi is affected not only by the tuning of the driven element itself, but also by the spacing and tuning of nearby parasitic elements, and to a lesser extent by the presence of ground. In some designs that have been tuned solely for maximum gain, the driven-element impedance can fall to very low levels, sometimes less than 5 Ω. This can lead to excessive losses due to conductor resistance, especially at VHF and UHF. In a Yagi that has been optimized solely for gain, conductor losses are usually compounded by large excursions in impedance levels with relatively small changes in frequency. The SWR can thus change dramatically over a band and can create additional losses in the feed cable. **Fig 4** illustrates the SWR over the 28 to 28.8 MHz portion of the 10-meter amateur band for a 5-element Yagi on a 24-foot boom, which has been tuned for maximum forward gain at a spot frequency of 28.4 MHz. Its SWR curve is contrasted to that of a Yagi designed for a good compromise of gain, SWR and F/R.

Even professional antenna designers have difficulty accurately measuring forward gain. On the other hand, SWR can easily be measured by professional and amateur alike. Few manufacturers would probably want to advertise an antenna with the narrow-band SWR curve shown in Fig 4!

Monoband Yagi Performance Optimization

DESIGN GOALS

The previous section discussing driven-element impedance and SWR hinted at possible design trade-offs among gain, pattern and SWR, especially when each parameter is considered over a frequency band rather than at a spot frequency. Trade-offs in Yagi design parameters can be a matter of personal taste and operating style. For example, one operator might exclusively operate the CW portions of the HF bands, while another might only be interested in the Phone portions. Another operator may want a good pattern in order to discriminate against signals coming from a particular direction; someone else may want the most forward gain possible, and may not care about responses in other directions.

Extensive computer modeling of Yagis indicates that the parameter that must be compromised most to achieve wide bandwidths for front-to-rear ratio and SWR is forward gain. However, not much gain must be sacrificed for good F/R and SWR coverage, especially on long-boom Yagis. Although 10 and 7-MHz Yagis are not rare, the HF bands from 14 to 30 MHz are where Yagis are most often found, mainly due to the mechanical difficulties involved with making sturdy antennas for lower frequencies. The highest HF band, 28.0 to 29.7 MHz, represents the largest percentage bandwidth of the upper HF bands, at almost 6%. It is difficult to try to optimize in one design the main performance parameters of gain, worst-case F/R ratio and SWR over this large a band. Many commercial designs thus split up their 10-meter designs into antennas covering one of two bands: 28.0 to 28.8 MHz, and 28.8 to 29.7 MHz. For the amateur bands below 10 meters, optimal designs that cover the entire band are more easily achieved.

DESIGN VARIABLES

There are only a few variables available when one is designing a Yagi to meet certain design goals. The variables are:

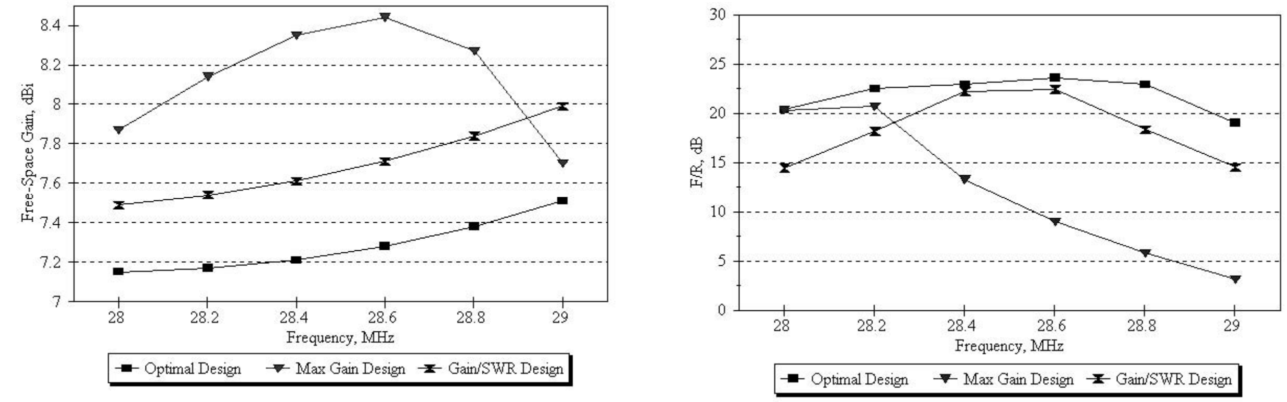

(A)

(B)

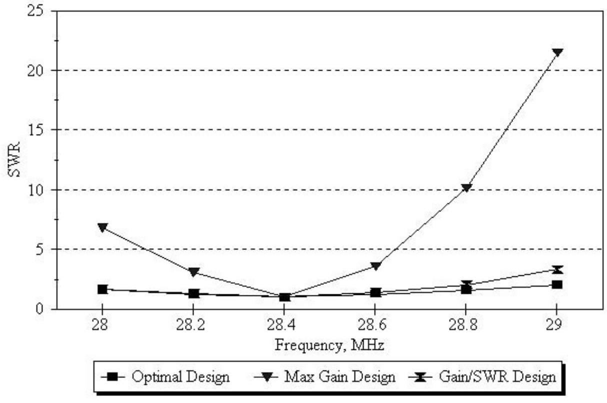

(C)

Fig 5—Comparisons of three different 3-element 10-meter Yagi designs using 8-foot booms. At A, gain comparisons are shown. The Yagi designed for the best compromise of gain and SWR sacrifices an average of about 0.5 dB compared to the antenna designed for maximum gain. The Yagi designed for optimal F/R, gain and SWR sacrifices an average of 1.0 dB compared to the maximum-gain case, and about 0.4 dB compared to the compromise gain and SWR case. At B, the front-to-rear ratio is shown for the three different designs. The antenna designed for optimal combination of gain, F/R and SWR maintains a F/R higher than 20 dB across the entire frequency range, while the antenna designed strictly for gain has a F/R of 3 dB at the high end of the band. At C, the three antenna designs are compared for SWR bandwidth. At the high end of the band, the antenna designed strictly for gain has a very high SWR.

1. The physical length of the boom
2. The number of elements on the boom
3. The spacing of each element along the boom
4. The tuning of each element
5. The type of matching network used to feed the array.

GAIN AND BOOM LENGTH

As pointed out earlier, the gain of a Yagi is largely a function of the length of the boom. As the boom is made longer, the maximum gain potential rises. For a given boom length, the number of elements populating that boom can be varied, while still maintaining the antenna's gain, provided of course that the elements are tuned properly. In general, putting more elements on a boom gives the designer added flexibility to achieve desired design goals, especially to spread the response out over a frequency band.

Fig 5A is an example illustrating gain versus frequency for three different types of 3-element Yagis on 8-foot booms. The three antennas were designed for the lower end of the 10-meter band, 28.0 to 28.8 MHz, based on the following different design goals:

Antenna 1: Maximum mid-band gain, regardless of F/R or SWR across the band
Antenna 2: SWR less than 2:1 over the frequency band; best compromise gain, with no special consideration for F/R over the band.
Antenna 3: "Optimal" case: F/R greater than 20 dB, SWR less than 2:1 over the frequency band; best compromise gain.

Fig 5B shows the F/R over the frequency band for these three designs, and Fig 5C shows the SWR curves over the frequency band. Antenna 1, the design that strives strictly for maximum gain, has a poor SWR response over the band, as might be expected after the previous section discussing SWR. The SWR is 10:1 at 28.8 MHz and rises to 22:1 at 29 MHz. At 28 MHz, at the low end of the band, the SWR of the maximum-gain design is more than 6:1. Clearly, designing for maximum gain alone produces an unacceptable design in terms of SWR bandwidth. The F/R for Antenna 1 reaches a high point of about 20 dB at the low-frequency end of the band, but falls to only 3 dB at the high-frequency end.

Antenna 2, designed for the best compromise of gain while the SWR across the band is held to less than 2:1, achieves this goal, but at an average gain sacrifice of 0.7 dB compared to the maximum gain case. The F/R for this design is just under 15 dB over the band. This design is fairly typical of many amateur Yagi designs before the advent of computer modeling and optimization programs. SWR can easily be measured, and experimental optimization for forward gain is a fairly straightforward procedure. By contrast, overall pattern optimization is not a trivial thing to achieve experimentally, particularly for antennas with more than four or five elements.

Antenna 3, designed for an optimum combination of F/R, SWR and gain, compromises forward gain an average of 1.0 dB compared to the maximum gain case, and about 0.4 dB compared to the compromise gain/SWR case. It achieves its design objectives of more than 20 dB F/R over the 28.0 to 28.8 MHz portion of the band, with an SWR less than 2:1 over that range.

Fig 6A shows the free-space gain versus frequency for the same three types of designs, but for a bigger 5-element 10-meter Yagi on a 20-foot boom. Fig 6B shows the variation in F/R, and Fig 6C shows the SWR curves versus frequency. Once again, the design that concentrates solely on maximum gain has a poor SWR curve over the band, reaching just over 6:1 toward the high end of the band. The difference in gain between the maximum gain case and the optimum design case has narrowed for this size of boom to an average of under 0.5 dB. This comes about because the designer has access to more variables in a 5-element design than he does in a 3-element design, and he can stagger-tune the various elements to spread the response out over the whole band.

Fig 7A, **B** and **C** show the same three types of designs, but for a 6-element Yagi on a 36-foot boom. The SWR bandwidth of the antenna designed for maximum gain has improved compared to the previous two shorter-boom examples, but the SWR still rises to more than 4:1 at 28.8 MHz, while the F/R ratio is pretty constant over the band, at a mediocre 11 dB average level. While the antenna designed for gain and SWR does hold the SWR below 2:1 over the band, it also has the same mediocre level of F/R performance as does the maximum-gain design.

The optimized 36-foot boom antenna achieves an excellent F/R of more than 22 dB over the whole 28.0 to 28.8 MHz band. Again, the availability of more elements and more space on the 36-foot long boom gives the designer more flexibility in broadbanding the response over the whole band, while sacrificing only 0.3 dB of gain compared to the maximum-gain design.

Fig 8A, **B**, and **C** show the same three types of 10-meter designs, but now for a 60-foot boom, populated with eight elements. With eight elements and a very long boom on which to space them out, the antenna designed solely for maximum gain can achieve a much better SWR response across the band, although the SWR does rise to more than 7:1 at the very high end of the band. The SWR remains less than 2:1 from 28.0 to 28.7 MHz, much better than for shorter-boom, maximum-gain designs. The worst-case F/R ratio is never better than 19 dB, however, and remains around 10 dB over much of the band. The antenna designed for the best compromise gain and SWR loses only about 0.1 dB of gain compared to the maximum-gain design, but does little better in terms of F/R across the band.

Contrasted to these two designs, the antenna optimized for F/R, SWR and gain has an outstanding pattern, exhibiting an F/R of more than 24 dB across the entire

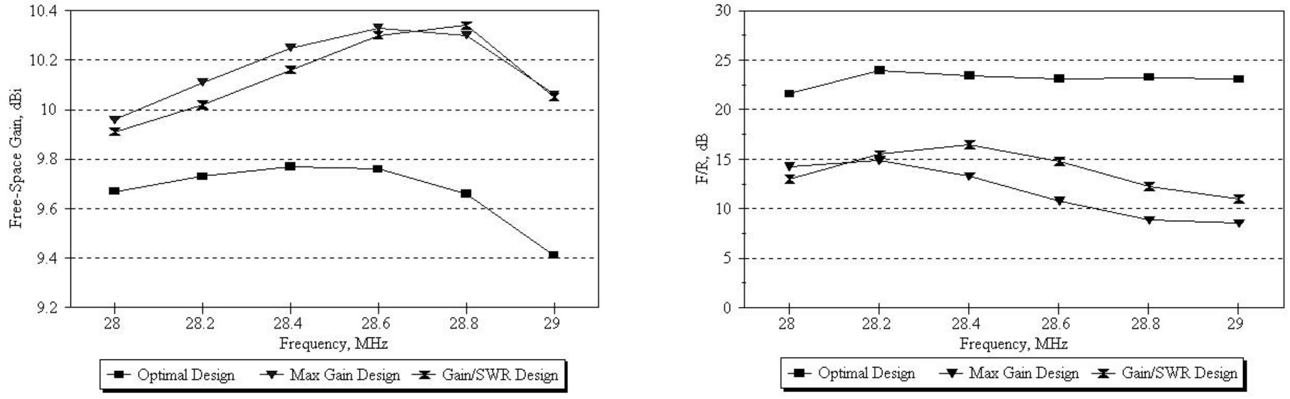

(A)

(B)

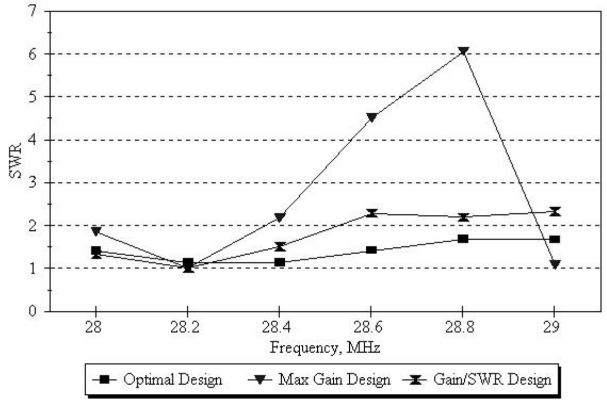

(C)

Fig 6—Comparisons of three different designs for 5-element 10-meter Yagis on 20-foot booms. At A, the gain of three different 5-element 10-meter Yagi designs are graphed. The difference in gain between the three antennas narrows because the elements can be stagger-tuned to spread the response out better over the desired frequency band. The average gain reduction for the fully optimized antenna design is about 0.5 dB. At B, the optimal antenna displays better than 22 dB F/R over the band, while the Yagi designed for gain and SWR displays on average 10 dB less F/R throughout the band. At C, the SWR bandwidth is compared for the three Yagis. The antenna designed strictly for forward gain has a poor SWR bandwidth and a high peak SWR of 6:1 at 28.8 MHz.

band, while keeping the SWR below 2:1 from 28.0 to 28.9 MHz. It must sacrifice an average of only 0.4 dB compared to the maximum gain design at the low end of the band, and actually has more gain than the maximum gain and gain/SWR designs at the high-frequency end of the band.

The conclusion drawn from these and many other detailed comparisons is that designing strictly for maximum mid-band gain yields an inferior design when the antenna is examined over an entire frequency band, especially in terms of SWR. Designing a Yagi for both gain and SWR will yield antennas that have mediocre rearward patterns, but that lose relatively little gain compared to the maximum gain case, at least for designs with more than three elements.

However, designing a Yagi for an optimal combination of F/R, SWR and gain results in a loss of gain less than 0.5 dB compared to designs designed only for gain and SWR. **Fig 9** summarizes the forward gain achieved for the three different design types versus boom length, as expressed in wavelength.

Except for the 2-element designs, the Yagis described in the rest of this chapter have the following design goals over a desired frequency band:

1. Front-to-rear ratio over the frequency band of more than 20 dB
2. SWR over the frequency band less than 2:1
3. Maximum gain consistent with points 1 and 2 above

Just for fun, **Fig 10** shows the gain versus boom length for theoretical 20-meter Yagis that have been designed to meet the three design goals above. The 31-element design for 14 MHz would be wondrous to behold. Sadly, it is unlikely that anyone will build one, considering that the boom would be 724 feet long! However, such a design *does* become practical when scaled to 432 MHz. In fact, a K1FO 22-element and a K1FO 31-element Yagi are the prototypes for the theoretical 14-MHz long-boom designs. See Chapter 18, VHF and UHF Antenna Systems.

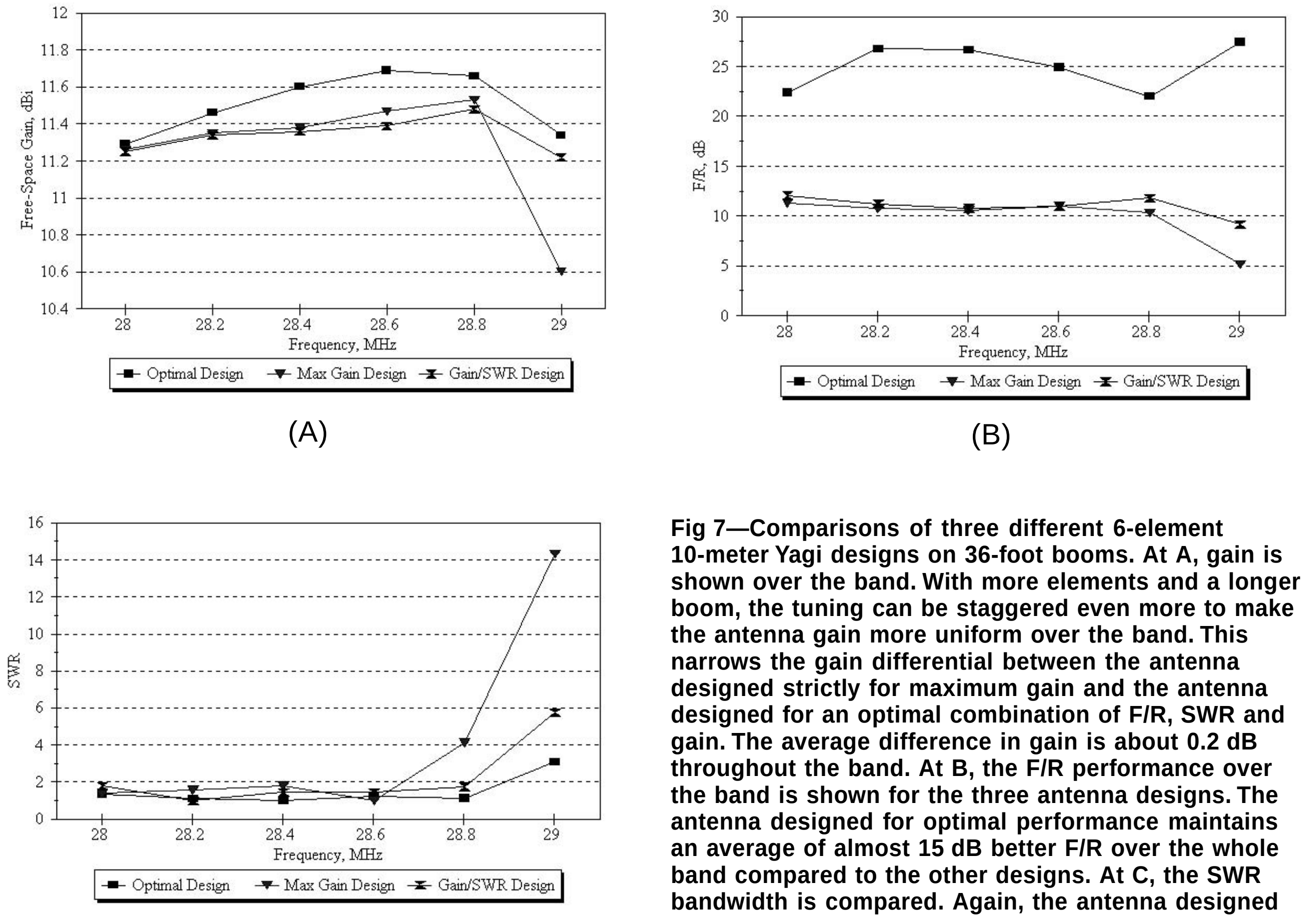

Fig 7—Comparisons of three different 6-element 10-meter Yagi designs on 36-foot booms. At A, gain is shown over the band. With more elements and a longer boom, the tuning can be staggered even more to make the antenna gain more uniform over the band. This narrows the gain differential between the antenna designed strictly for maximum gain and the antenna designed for an optimal combination of F/R, SWR and gain. The average difference in gain is about 0.2 dB throughout the band. At B, the F/R performance over the band is shown for the three antenna designs. The antenna designed for optimal performance maintains an average of almost 15 dB better F/R over the whole band compared to the other designs. At C, the SWR bandwidth is compared. Again, the antenna designed strictly for maximum gain exhibits a high SWR of 4:1 at 28.8 MHz, and rises to more than 14:1 at 29.0 MHz.

OPTIMUM DESIGNS AND ELEMENT SPACING

Two-Element Yagis

Many hams consider a 2-element Yagi to give “the most bang for the buck” among various Yagi designs, particularly for portable operations such as Field Day. A 2-element Yagi has about 4 dB of gain over a simple dipole (sometimes jokingly called a “one-element Yagi”) and gives a modest F/R of about 10 dB to help with rejection of interference on receive. By comparison, going from a 2-element to a 3-element Yagi increases the boom length by about 50% and adds another element, a 50% increase in the number of elements—for a gain increase of about 1 dB and another 10 dB in F/R.

Element Spacing in Larger Yagis

One of the more interesting results of computer modeling and optimization of high-performance Yagis with four or more elements is that a distinct pattern in the element spacings along the boom shows up consistently. This pattern is relatively independent of boom length, once the boom is longer than about 0.3 λ.

The reflector, driven element and first director of these optimal designs are typically bunched rather closely together, occupying together only about 0.15 to 0.20 λ of the boom. This pattern contrasts sharply with older designs, where the amount of boom taken up by the reflector, driven element and first director was typically more than 0.3 λ. **Fig 11** shows the element spacings for an optimized 6-element, 36-foot boom, 10-meter design, compared to a W2PV 6-element design with constant spacing of 0.15 λ between all elements.

A problem arises with such a bunching of elements toward the reflector end of the boom—the wind loading of the antenna is not equal along the boom. Unless properly compensated, such new-generation Yagis will act like windvanes, punishing, and often breaking, the rotators trying to turn, or hold, them in the wind. One successful solution to windvaning has been to employ “dummy elements” made of PVC piping. These nonconducting elements are placed on the boom close to the last director so

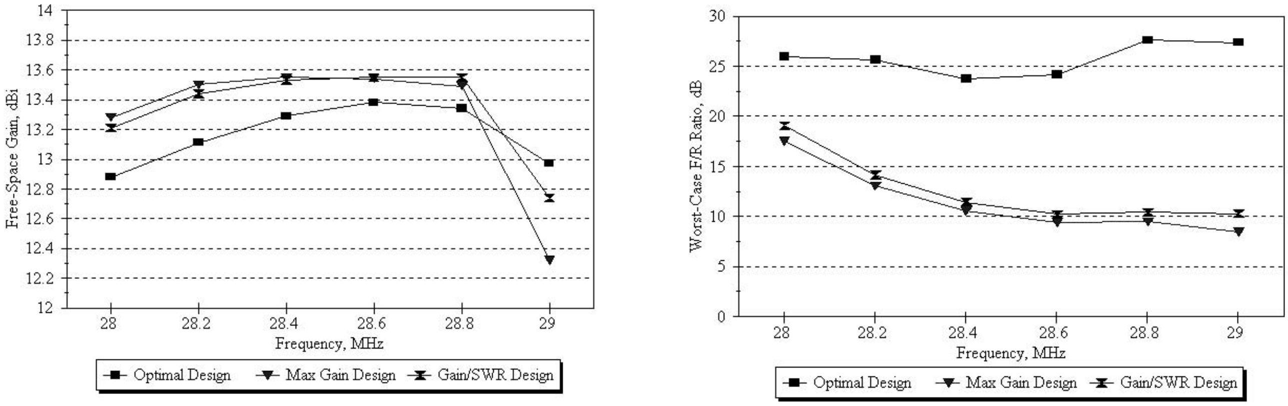

(A)

(B)

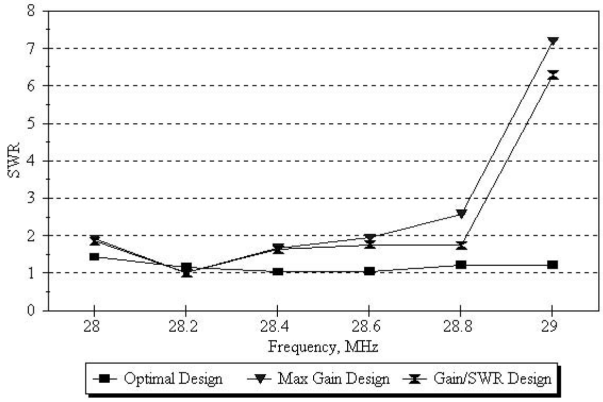

(C)

Fig 8—Comparisons of three different 8-element 10-meter Yagi designs using 60-foot booms. At A, gain is shown over the frequency band. With even more freedom to stagger-tune elements and a very long boom on which to place them, the average antenna gain differential over the band is now less than 0.2 dB between the three design cases. At B, an excellent 24 dB F/R for the optimal design is maintained over the whole band, compared to the average of about 12 dB for the other two designs. At C, the SWR differential over the band is narrowed between the three designs, again because there are more variables available to broaden the bandwidth.

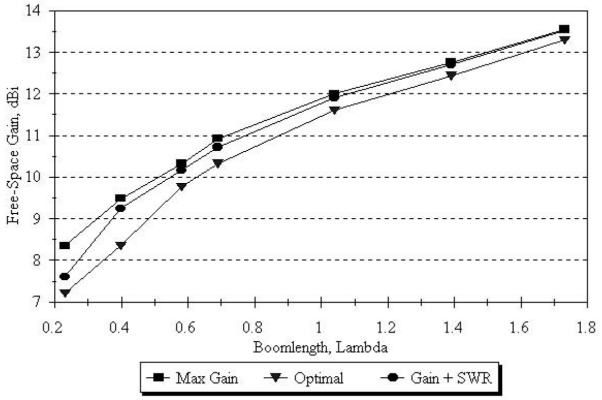

Fig 9—Gain versus boom length for three different 10-meter design goals. The goals are: (1) designed for maximum gain across band, (2) designed for a compromise of gain and SWR, and (3) designed for optimal F/R, SWR and gain across 28.0 to 28.8 MHz portion of 10-meter band. The gain difference is less than 0.5 dB for booms longer than approximately 0.5 λ.

the windload is equalized at the mast-to-boom bracket. In addition, it may be necessary to insert a small amount of lead weight at one end of the boom in order to balance the antenna weight.

Despite the relatively close spacing of the reflector, driven element and first director, modern optimal Yagi designs are not overly sensitive to small changes in either element length or spacing. In fact, these antennas can be constructed from design tables without excessive concern about close dimensional tolerances. In the HF range up to 30 MHz, building the antennas to the nearest $^1/_8$-inch results in performance remarkably consistent with the computations, without any “tweaking” or fine-tuning when the Yagi is on the tower.

ELEMENT TUNING

Element tuning (or *self-impedance*) is a complex function of the effective electrical length of each element and the effective diameter of the element. In turn, the effective length and diameter of each element is related to

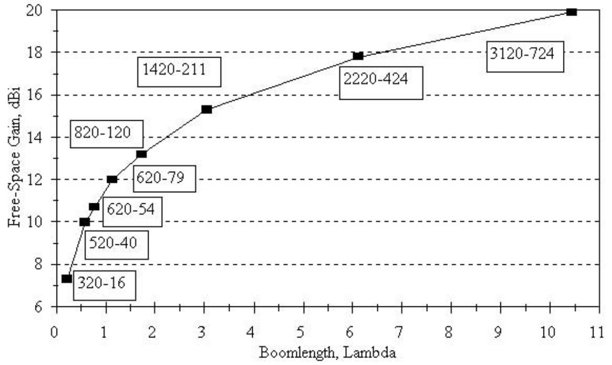

Fig 10—Theoretical gain versus boom length for 20-meter Yagis designed for optimal combination of F/R, SWR and gain across the entire 14.0 to 14.35 MHz band. The theoretical gain approaches 20 dBi for a gigantic 724-foot boom, populated with 31 elements. Such a design on 20 meters is not too practical, of course, but can readily be achieved on a 24-foot boom on 432 MHz.

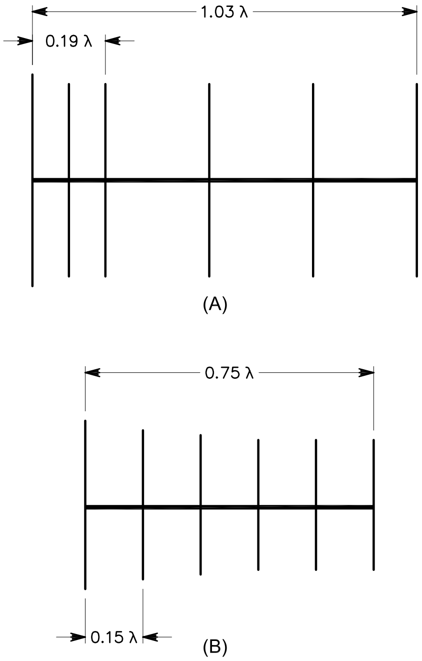

Fig 11—Tapering spacing versus constant element spacing. At A, illustration of how the spacing of the reflector, driven element and first director (over the first 0.19 λ of the boom) of an optimally designed Yagi is bunched together compared to the Yagi at B, which uses constant 0.15 λ spacing between all elements. The optimally designed antenna has more than 22 dB F/R and an SWR less than 1.5:1 over the frequency band 28.0 to 28.8 MHz.

the taper schedule (if telescoping aluminum tubing is used, the most common method of construction), the length of each telescoping section, the type and size of mounting bracket used to secure the element to or through the boom, and the size of the Yagi boom itself. See the section entitled "Antenna Frequency Scaling," and "Tapered Elements" in Chapter 2, Antenna Fundamentals, of this book for details about element tuning as a function of tapering and element diameter. Note especially that Yagis constructed using wire elements will perform very differently compared to the same antenna constructed with elements made of telescoping aluminum tubing.

The process by which a modern Yagi is designed usually starts out with the selection of the longest boom possible for a given installation. A suitable number of elements of a given taper schedule are then placed on this boom, and the gain, pattern and SWR are calculated over the entire frequency band of interest to the operator. Once an electrical design is chosen, the designer must then ensure the mechanical integrity of the antenna design. This involves verifying the integrity of the boom and each element in the face of the wind and ice loading expected for a particular location. The section entitled "Construction with Aluminum Tubing" in Chapter 20, Antenna Materials and Accessories, of this book shows details of tapered telescoping aluminum elements for the upper HF bands. In addition, the ARRL book *Physical Design of Yagi Antennas*, by Dave Leeson, W6NL (ex-W6QHS), describes the mechanical design process for all portions of a Yagi antenna very thoroughly, and is highly recommended for serious Yagi builders.

Specific Monoband Yagi Designs

The detailed Yagi design tables that follow are for two taper schedules for HF Yagis covering the 14 through 30-MHz amateur bands. The heavy-duty elements are designed to survive at least 120-mph winds without icing, or 85-mph winds with 1/4-inch radial ice. The medium-duty elements are designed to survive winds greater than 80 mph, or 60-mph winds with 1/4-inch radial ice.

For 10.1 MHz, the elements shown are capable of surviving 105-mph winds, or 93-mph winds with 1/4-inch radial ice. For 7.1 MHz the elements shown can survive 93-mph winds, or 69-mph winds with 1/4-inch radial ice. For these two lower frequency bands, the elements and the booms needed are very large and heavy. Mounting, turning and keeping such antennas in the air is not a trivial task.

Each element is mounted above the boom with a heavy rectangular aluminum plate, by means of U-bolts with saddles, as shown in Fig 35 in Chapter 18, VHF and UHF Antenna Systems for a 6-meter Yagi. This method of element mounting is rugged and stable, and because the element is mounted away from the boom, the amount of element detuning due to the presence of the boom is minimal. The element dimensions given in each table already take into account any element detuning due to the boom-to-element mounting plate. For each element, the length of the tip determines the tuning, since the inner tubes are fixed in diameter and length.

Half Elements

Each design shows the dimensions for *one-half* of each element, mounted on *one side* of the boom. The other half of each element is symmetrical, mounted on the other side of the boom. The use of a tubing sleeve inside the center portion of the element is recommended, so that the element is not crushed by the mounting U-bolts. Unless otherwise noted, each section of tubing is made of 6061-T6 aluminum tubing, with a 0.058-inch wall thickness. This wall thickness ensures that the next standard size of tubing can telescope with it. Each telescoping section is inserted 3 inches into the larger tubing, and is secured by one of the methods shown in Fig 11 in Chapter 20, Antenna Materials and Accessories.

Matching System

Each antenna is designed with a driven-element length appropriate for a hairpin type of matching network. The driven-element's length may require slight readjustment for best match, particularly if a different matching network is used. *Do not change* either the lengths or the telescoping tubing schedule of the parasitic elements—they have been optimized for best performance and will not be affected by tuning of the driven element!

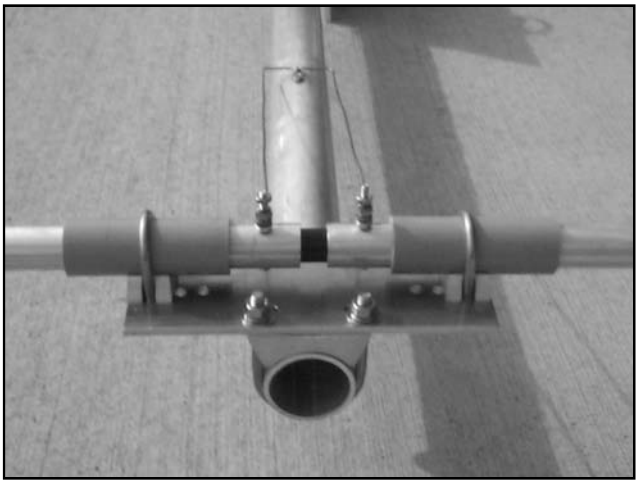

Fig 12—Typical construction techniques for an HF Yagi. This photo shows a hairpin match on a driven element that uses a fiberglass insulator (wrapped in black vinyl tape for protection against UV). Muffler clamps and saddles mount the element to the boom, while U-bolts and saddles mount the element to the boom-to-element plate. The gray PVC sleeves insulate the element from the plate. The feed coax is connected to the two bolts that also connect to the hairpin wire. Note that the hairpin is grounded at its opposite end to dissipate static charges that might otherwise build up.

Fig 12 is a photograph of the driven element for a 2-element 17-meter Yagi built by Chuck Hutchinson, K8CH, for the ARRL book *Simple and Fun Antennas for Hams*. The aluminum tubing on each side of the boom was 1-inch OD, and the two pieces were mechanically joined together with a 3/4-inch OD fiberglass insulator. Chuck wound electrical tape over the insulator to protect the fiberglass from the sun's UV.

Chuck used 3-inch lengths of 1-inch sunlight-resistant PVC conduit, split lengthwise, to make the grey outer insulators for the driven element. The aluminum plates came from DX Engineering, as did the stainless-steel U-bolts and saddle clamps. These saddles ensured that the elements don't rotate on the 2-inch OD boom in the heavy winds in his part of rural Michigan.

You can see the bolts used to pin the center fiberglass insulator to the aluminum tubing, while also providing an electrical connection for the #12 hairpin wire and for the feed-line coax, which uses ferrite beads over the coax's outer vinyl jacket to make a common-mode current-type of balun (not shown in Fig 12). Note that the center of the hairpin is connected to the boom using a grounding lug for some measure of protection from static buildup.

10-METER YAGIS

Fig 13 describes the electrical performance of eight optimized 10-meter Yagis with boom lengths between 6 to 60 feet. The end of each boom includes 3 inches of space for the reflector and last-director (or driven element for the 2-element designs) mounting plates. Fig 13A shows the free-space gain versus frequency for each antenna; 13B shows the front-to-rear ratio, and 13C shows the SWR versus frequency. Each antenna with three or more elements was designed to cover the lower half of the 10-meter band from 28.0 to 28.8 MHz, with SWR less than 2:1 and F/R better than 20 dB over that range.

Fig 13D shows the taper schedule for two types of 10-meter elements. The heavy-duty design can survive 125-mph winds with no icing, and 88-mph winds with $^{1}/_{4}$-inch of radial ice. The medium-duty design can handle 96-mph winds with no icing, and 68-mph winds with $^{1}/_{4}$-inch of radial ice. The element-to-boom mounting plate for these Yagis is a 0.250-inch thick flat aluminum plate, 4 inches wide by 4 inches long. Each element except for the insulated driven element, is centered on the plate, held by two stainless-steel U-bolts with saddles. Another set

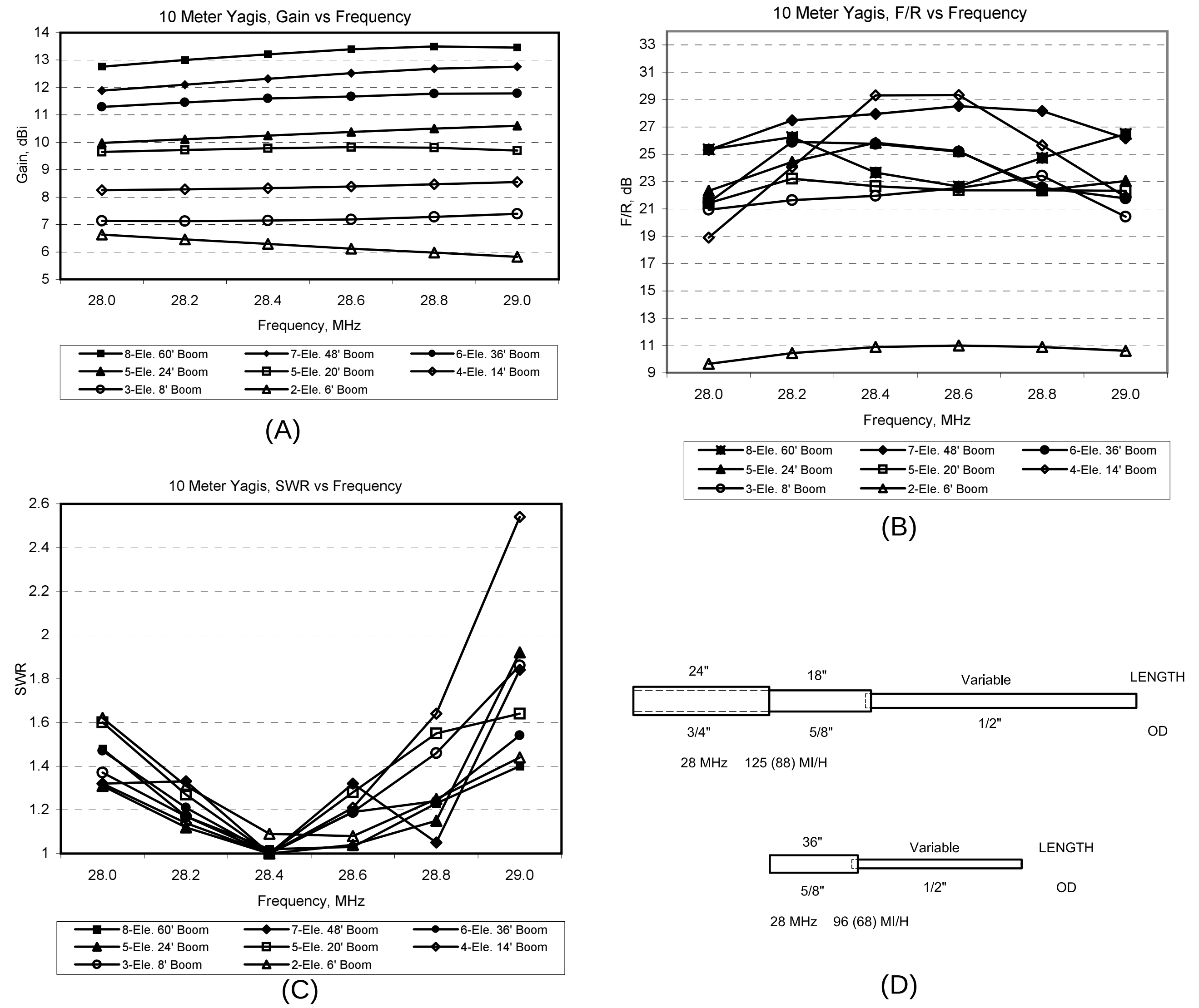

Fig 13—Gain, F/R and SWR performance versus frequency for optimized 10-meter Yagis. At A, gain is shown versus frequency for eight 10-meter Yagis whose booms range from 6 feet to 60 feet long. Except for the 2-element design, these Yagis have been optimized for better than 20 dB F/R and less than 2:1 SWR over the frequency range 28.0 to 28.8 MHz. At B, front-to-rear ratio for these antennas is shown versus frequency, and at C, SWR is shown over the frequency range. At D, the taper schedule is shown for heavy-duty and for medium-duty 10-meter elements. The heavy-duty elements can withstand 125-mph winds without icing, and 88-mph winds with $^{1}/_{4}$-inch radial ice. The medium-duty elements can survive 96-mph winds without icing, and 68-mph winds with $^{1}/_{4}$-inch radial ice. The wall thickness for each telescoping section of 6061-T6 aluminum tubing is 0.058 inches, and the overlap at each telescoping junction is 3 inches.

Table 1

Optimized 10-Meter Yagi Designs

Two-element 10-meter Yagi, 6 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		210-06H.YW	210-06M.YW
Reflector	0.000"	66.000"	71.500"
Driven Element	66.000"	57.625"	63.000"

Three-element 10-meter Yagi, 8 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		310-08H.YW	310-08M.YW
Reflector	0.000"	66.750"	71.875"
Driven Element	36.000"	57.625"	62.875"
Director 1	54.000"	53.125"	58.500"
Compensator	12" behind Dir. 1	19.000"	18.125"

Four-element 10-meter Yagi, 14 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		410-14H.YW	410-14M.YW
Reflector	0.000"	66.000"	72.000"
Driven Element	36.000"	58.625"	63.875"
Director 1	36.000"	57.000"	62.250"
Director 2	90.000"	47.750"	53.125"
Compensator	12" behind Dir. 2	22.000"	20.500"

Five-element 10-meter Yagi, 24 foot boom

Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		510-24H.YW	510-24M.YW
Reflector	0.000"	65.625"	70.750"
Driven Element	36.000"	58.000"	63.250"
Director 1	36.000"	57.125"	62.375"
Director 2	99.000"	55.000"	60.250"
Director 3	111.000"	50.750"	56.125"
Compensator	12" behind Dir. 3	28.750"	26.750"

Six-element 10-meter Yagi, 36 foot boom

Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		610-36H.YW	610-36M.YW
Reflector	0.000"	66.500"	71.500"
Driven Element	37.000"	58.500"	64.000"
Director 1	43.000"	57.125"	62.375"
Director 2	98.000"	54.875"	60.125"
Director 3	127.000"	53.875"	59.250"
Director 4	121.000"	49.875"	55.250"
Compensator	12" behind Dir. 4	32.000"	29.750"

Seven-element 10-meter Yagi, 48 foot boom

Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		710-48H.YW	710-48M.YW
Reflector	0.000"	65.375"	70.500"
Driven Element	37.000"	59.000"	64.250"
Director 1	37.000"	57.500"	62.750"
Director 2	96.000"	54.875"	60.125"
Director 3	130.000"	52.250"	57.625"
Director 4	154.000"	52.625"	58.000"
Director 5	116.000"	49.875"	55.250"
Compensator	12" behind Dir. 5	35.750"	33.750"

Eight-element 10-meter Yagi, 60 foot boom

Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		810-60H.YW	810-60M.YW
Reflector	0.000"	65.000"	70.125"
Driven Element	42.000"	58.000"	63.500"
Director 1	37.000"	57.125"	62.375"
Director 2	87.000"	55.375"	60.625"
Director 3	126.000"	53.250"	58.625"
Director 4	141.000"	51.875"	57.250"
Director 5	157.000"	52.500"	57.875"
Director 6	121.000"	50.125"	55.500"
Compensator	12" behind Dir. 6	59.375"	55.125"

These 10-meter Yagi designs are optimized for > 20 dB F/R, and SWR < 2:1 over frequency range from 28.000 to 28.800 MHz, for heavy-duty elements (125 mph wind survival) and for medium-duty (96 mph wind survival). For coverage from 28.8 to 29.7 MHz, subtract 2.000 inches from end of each element, but leave element spacings the same as shown here. Only element tip dimensions are shown, and all dimensions are inches. See Fig 13D for element telescoping tubing schedule. Torque compensator element is made of 2.5" OD PVC water pipe placed 12 inches behind last director. Dimensions shown for compensators is one-half of total length, centered on boom.

of U-bolts with saddles is used to secure the mounting plate to the boom.

Electrically each mounting plate is equivalent to a cylinder, with an effective diameter of 2.405 inches for the heavy-duty element, and 2.310 inches for the medium-duty element. The equivalent length on each side of the boom is 2 inches. These dimensions are incorporated in the files for the *YW* (Yagi for Windows) computer modeling program on the CD-ROM accompanying this book to simulate the effect of the mounting plate.

The second column in **Table 1** shows the spacing of each element relative to the next element in line on the boom, starting at the reflector, which itself is defined as being at the 0.000-inch reference point on the boom. The boom for antennas less than 30 feet long can be constructed of 2-inch OD tubing with 0.065-inch wall thickness. Designs larger than 30 feet long should use 3-inch OD heavy-wall tubing for the boom. Because each boom has extra space at each end, the reflector is actually placed 3 inches from the end of the boom. For example, in the 310-08H.YW design (3 elements on an 8-foot boom), the driven element is placed 36 inches ahead of the reflector, and the director is placed 54 inches ahead of the driven element.

The next columns give the lengths for the variable tips for the heavy-duty and then the medium-duty elements. In the example above for the 310-08H.YW Yagi, the heavy-duty reflector tip, made out of $^{1}/_{2}$-inch OD tubing, sticks out 66.750 inches from the $^{5}/_{8}$-inch OD tubing. Note that each telescoping piece of tubing overlaps 3 inches inside the piece into which it fits, so the overall length of $^{1}/_{8}$-inch OD tubing is 69.750 inches long for the reflector. The medium-duty reflector tip has 71.875 inches protruding from the $^{5}/_{8}$-inch OD tube, and is 74.875 inches long overall. As previously stated, the dimensions are not extremely critical, although measurement accu-

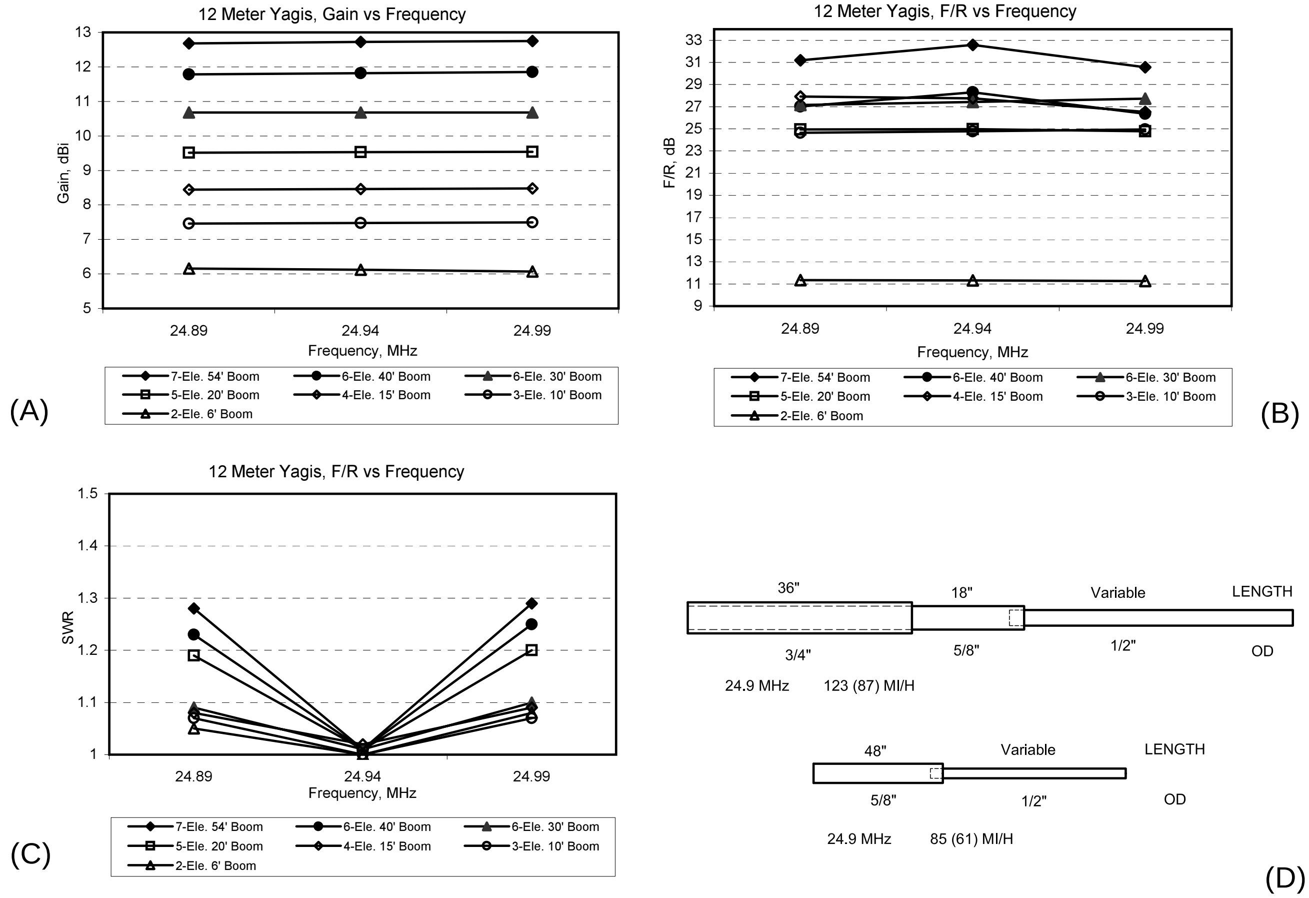

Fig 14—Gain, F/R and SWR performance versus frequency for optimized 12-meter Yagis. At A, gain is shown versus frequency for seven 12-meter Yagis whose booms range from 6 feet to 54 feet long. Except for the 2-element design, these Yagis have been optimized for better than 20 dB F/R and less than 2:1 SWR over the narrow 12-meter band 24.89 to 24.99 MHz. At B, front-to-rear ratio for these antennas is shown versus frequency, and at C, SWR over the frequency range is shown. At D, the taper schedule for heavy-duty and for medium-duty 12-meter elements is shown. The heavy-duty elements can withstand 123-mph winds without icing, and 87-mph winds with $^{1}/_{4}$-inch radial ice. The medium-duty elements can survive 85-mph winds without icing, and 61-mph winds with $^{1}/_{4}$-inch radial ice. The wall thickness for each telescoping section of 6061-T6 aluminum tubing is 0.058 inches, and the overlap at each telescoping junction is 3 inches.

Table 2
Optimized 12-Meter Yagi Designs

Two-element 12-meter Yagi, 6 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		212-06H.YW	212-06M.YW
Reflector	0.000"	67.500"	72.500"
Driven Element	66.000"	59.500"	65.000"

Three-element 12-meter Yagi, 10 foot boom

Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		312-10H.YW	312-10M.YW
Reflector	0.000"	69.000"	73.875"
Driven Element	40.000"	60.250"	65.250"
Director 1	74.000"	54.000"	59.125"
Compensator	12" behind Dir. 1	13.625"	12.000"

Four-element 12-meter Yagi, 15 foot boom

Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		412-15H.YW	412-15M.YW
Reflector	0.000"	66.875"	71.875"
Driven Element	46.000"	61.000"	66.000"
Director 1	46.000"	58.625"	63.750"
Director 2	82.000"	50.875"	56.125"
Compensator	12" behind Dir. 2	16.375"	14.500"

Five-element 12-meter Yagi, 20 foot boom

Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		512-20H.YW	512-20M.YW
Reflector	0.000"	69.750"	74.625"
Driven Element	46.000"	62.250"	67.000"
Director 1	46.000"	60.500"	65.500"
Director 2	48.000"	55.500"	60.625"
Director 3	94.000"	54.625"	59.750"
Compensator	12" behind Dir. 3	22.125"	19.625"

Six-element 12-meter Yagi, 30 foot boom

Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		612-30H.YW	612-30M.YW
Reflector	0.000"	68.125"	73.000"
Driven Element	46.000"	61.750"	66.750"
Director 1	46.000"	60.250"	65.250"
Director 2	73.000"	52.375"	57.625"
Director 3	75.000"	57.625"	62.750"
Director 4	114.000"	53.625"	58.750"
Compensator	12" behind Dir. 4	30.000"	26.250"

Six-element 12-meter Yagi, 40 foot boom

Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		612-40H.YW	612-40M.YW
Reflector	0.000"	67.000"	71.875"
Driven Element	46.000"	60.125"	65.500"
Director 1	46.000"	57.375"	62.500"
Director 2	91.000"	57.375"	62.500"
Director 3	157.000"	57.000"	62.125"
Director 4	134.000"	54.375"	59.500"
Compensator	12" behind Dir. 4	36.500"	31.625"

Seven-element 12-meter Yagi, 54 foot boom

Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		712-54H.YW	712-54M.YW
Reflector	0.000"	68.000"	73.000"
Driven Element	46.000"	60.500"	65.500"
Director 1	46.000"	56.750"	61.875"
Director 2	75.000"	58.000"	63.125"
Director 3	161.000"	55.625"	60.750"
Director 4	174.000"	56.000"	61.125"
Director 5	140.000"	53.125"	58.375"
Compensator	12" behind Dir. 5	43.125"	37.500"

These 12-meter Yagi designs were optimized for > 20 dB F/R, and SWR < 2:1 over frequency range from 24.890 to 24.990 MHz, for heavy-duty elements (123 mph wind survival) and for medium-duty (85 mph wind survival). Only element tip dimensions are shown, and all dimensions are inches. See Fig 14D for element telescoping tubing schedule. Torque compensator element is made of 2.5" OD PVC water pipe placed 12" behind last director. Dimensions shown for compensators is one-half of total length, centered on boom.

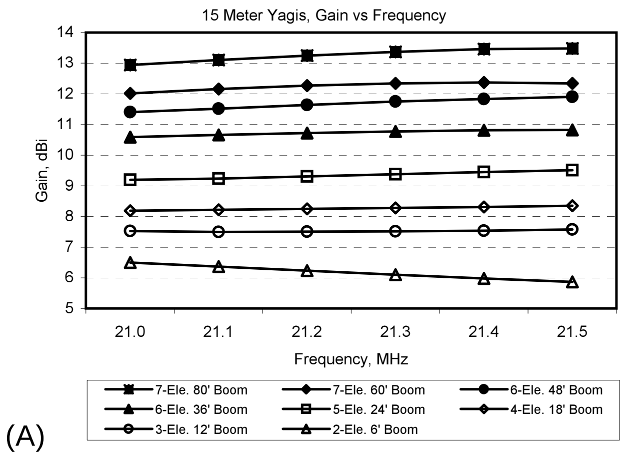

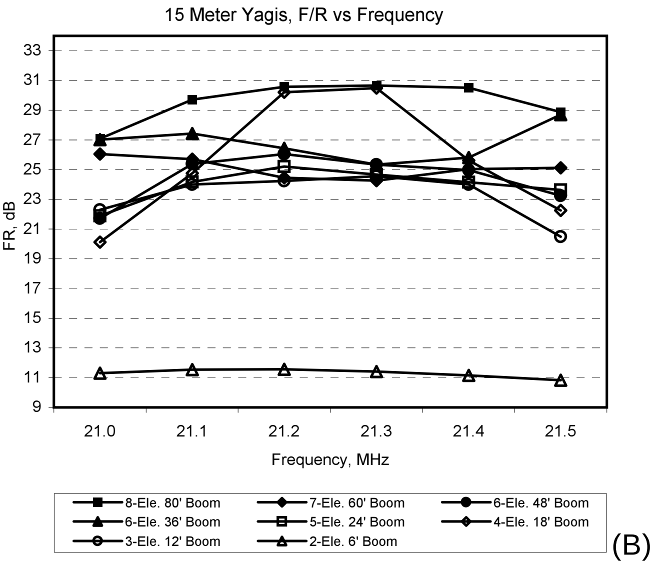

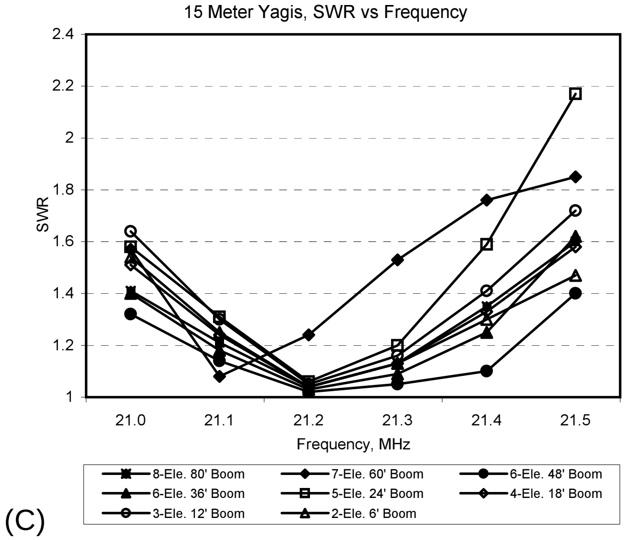

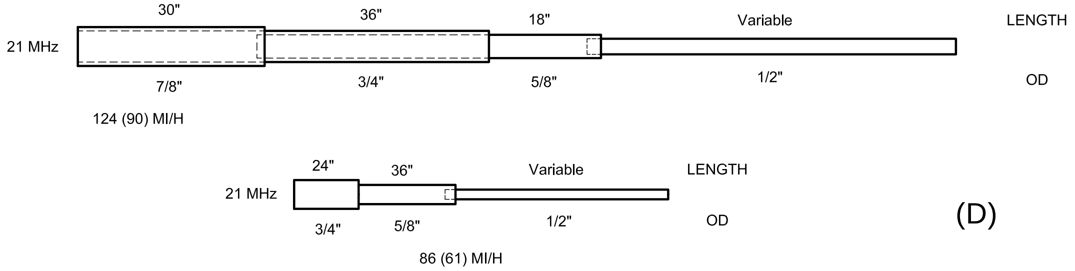

Fig 15—Gain, F/R and SWR performance versus frequency for optimized 15-meter Yagis. At A, gain versus frequency is shown for eight 15-meter Yagis whose booms range from 6 feet to 80 feet long. Except for the 2-element design, these Yagis have been optimized for better than 20 dB F/R and less than 2:1 SWR over the frequency range 21.0 to 21.45 MHz. At B, front-to-rear ratio for these antennas is shown versus frequency, and at C, SWR over the frequency range is shown. At D, the taper schedule for heavy-duty and for medium-duty 15-meter elements is shown. The heavy-duty elements can withstand 124-mph winds without icing, and 90-mph winds with $^1/_4$-inch radial ice. The medium-duty elements can survive 86-mph winds without icing, and 61-mph winds with $^1/_4$-inch radial ice. The wall thickness for each telescoping section of 6061-T6 aluminum tubing is 0.058 inches, and the overlap at each telescoping junction is 3 inches.

racy to $^1/_8$ inch is desirable.

The last row in each variable tip column shows the length of one-half of the "dummy element" torque compensator used to correct for uneven wind loading along the boom. This compensator is made from 2.5 inches OD PVC water pipe mounted to an element-to-boom plate like those used for each element. The compensator is mounted 12 inches behind the last director, the first director in the case of the 3-element 310-08H.YW antenna. Note that the heavy-duty elements require a correspondingly longer torque compensator than do the medium-duty elements.

12-METER YAGIS

Fig 14 describes the electrical performance of seven optimized 12-meter Yagis with boom lengths between 6 to 54 feet. The end of each boom includes 3 inches of space for the reflector and last director (or driven element) mounting plates. The narrow frequency width of the 12-meter band allows the performance to be optimized easily. Fig 14A shows the free-space gain versus frequency for each antenna; 14B shows the front-to-rear ratio, and 14C shows the SWR versus frequency. Each antenna with three or more elements was designed to

Table 3
Optimized 15-Meter Yagi Designs

Two-element 15-meter Yagi, 6 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		215-06H.YW	215-06M.YW
Reflector	0.000"	62.000"	85.000"
Driven Element	66.000"	51.000"	74.000"

Three-element 15-meter Yagi, 12 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		315-12H.YW	315-12M.YW
Reflector	0.000"	62.000"	84.250"
Driven Element	48.000"	51.000"	73.750"
Director 1	92.000"	43.500"	66.750"
Compensator	12" behind Dir. 1	34.750"	37.625"

Four-element 15-meter Yagi, 18 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		415-18H.YW	415-18M.YW
Reflector	0.000"	61.000"	83.500"
Driven Element	56.000"	51.500"	74.500"
Director 1	56.000"	48.000"	71.125"
Director 2	98.000"	36.625"	60.250"
Compensator	12" behind Dir. 2	20.875"	18.625"

Five-element 15-meter Yagi, 24 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		515-24H.YW	515-24M.YW
Reflector	0.000"	62.000"	84.375"
Driven Element	48.000"	52.375"	75.250"
Director 1	48.000"	47.875"	71.000"
Director 2	52.000"	47.000"	70.125"
Director 3	134.000"	41.000"	64.375"
Compensator	12" behind Dir. 3	40.250"	35.125"

Six-element 15-meter Yagi, 36 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		615-36H.YW	615-36M.YW
Reflector	0.000"	61.000"	83.375"
Driven Element	53.000"	52.000"	75.000"
Director 1	56.000"	49.125"	72.125"
Director 2	59.000"	45.125"	68.375"
Director 3	116.000"	47.875"	71.000"
Director 4	142.000"	42.000"	65.375"
Compensator	12" behind Dir. 4	45.500"	39.750"

Seven-element 15-meter Yagi, 48 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		615-48H.YW	615-48M.YW
Reflector	0.000"	62.000"	84.000"
Driven Element	48.000"	52.000"	75.000"
Director 1	48.000"	51.250"	74.125"
Director 2	125.000"	48.000"	71.125"
Director 3	190.000"	45.500"	68.750"
Director 4	161.000"	42.000"	65.375"
Compensator	12" behind Dir. 4	51.500"	45.375"

Seven-element 15-meter Yagi, 60 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		715-60H.YW	715-60M.YW
Reflector	0.000"	59.750"	82.250"
Driven Element	48.000"	52.000"	75.000"
Director 1	48.000"	52.000"	74.875"
Director 2	93.000"	49.500"	72.500"
Director 3	173.000"	44.125"	67.375"
Director 4	197.000"	45.500"	68.750"
Director 5	155.000"	41.750"	65.125"
Compensator	12" behind Dir. 5	58.500"	51.000"

Eight-element 15-meter Yagi, 80 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		815-80H.YW	815-80M.YW
Reflector	0.000"	62.000"	84.000"
Driven Element	56.000"	52.500"	75.500"
Director 1	48.000"	51.500"	74.375"
Director 2	115.000"	48.375"	71.500"
Director 3	164.000"	45.750"	69.000"
Director 4	202.000"	43.125"	66.500"
Director 5	206.000"	44.750"	68.000"
Director 6	163.000"	40.875"	64.250"
Compensator	12" behind Dir. 6	95.000"	83.375"

These 15-meter Yagi designs are optimized for > 20 dB F/R, and SWR < 2:1 over entire frequency range from 21.000 to 21.450 MHz, for heavy-duty elements (124 mph wind survival) and for medium-duty (86 mph wind survival). Only element tip dimensions are shown. See Fig 15D for element telescoping tubing schedule. All dimensions are in inches. Torque compensator element is made of 2.5" OD PVC water pipe placed 12" behind last director, and dimensions shown for compensators is one-half of total length, centered on boom.

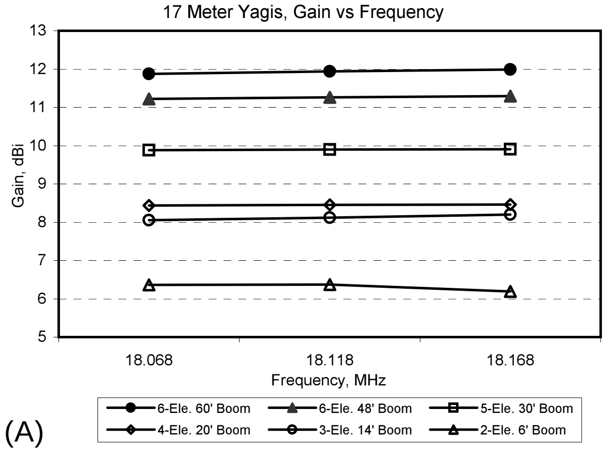

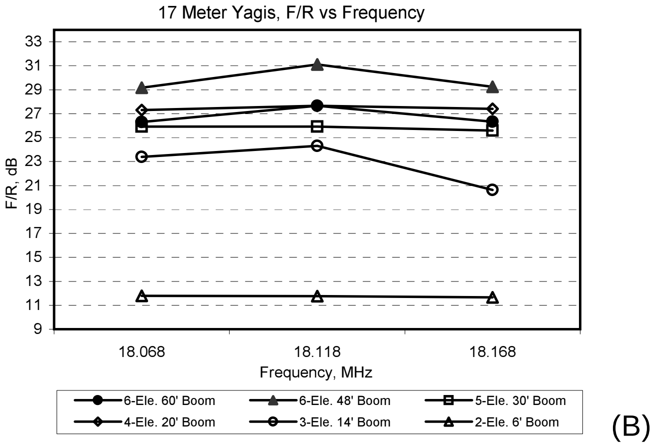

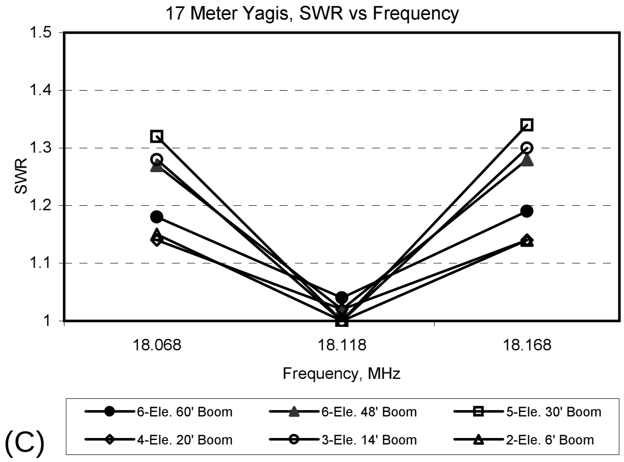

Fig 16—Gain, F/R and SWR performance versus frequency for optimized 17-meter Yagis. At A, gain versus frequency is shown for six 17-meter Yagis whose booms range from 6 feet to 60 feet long. Except for the 2-element design, these Yagis have been optimized for better than 20 dB F/R and less than 2:1 SWR over the narrow 17-meter band 18.068 to 18.168 MHz. At B, front-to-rear ratio for these antennas is shown versus frequency, and at C, SWR over the frequency range is shown. At D, the taper schedule for heavy-duty and for medium-duty 10-meter elements is shown. The heavy-duty elements can withstand 123-mph winds without icing, and 89-mph winds with $^1/_4$-inch radial ice. The medium-duty elements can survive 83-mph winds without icing, and 59-mph winds with $^1/_4$-inch radial ice. The wall thickness for each telescoping section of 6061-T6 aluminum tubing is 0.058 inches, and the overlap at each telescoping junction is 3 inches.

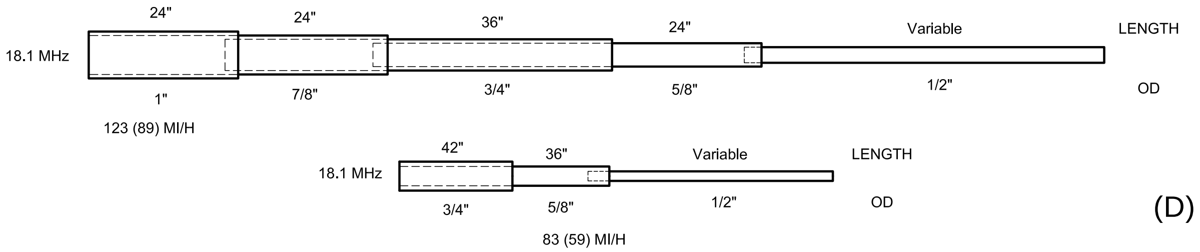

cover the narrow 12-meter band from 24.89 to 24.99 MHz, with SWR less than 2:1 and F/R better than 20 dB over that range.

Fig 14D shows the taper schedule for two types of 12-meter elements. The heavy-duty design can survive 123-mph winds with no icing, and 87-mph winds with $^1/_4$ inch of radial ice. The medium-duty design can handle 85-mph winds with no icing, and 61-mph winds with $^1/_4$ inch of radial ice. The element-to-boom mounting plate for these Yagis is a 0.375 inch thick flat aluminum plate, 5 inches wide by 6 inches long.

Electrically, each mounting plate is equivalent to a cylinder, with an effective diameter of 2.945 inches for the heavy-duty element, and 2.857 inches for the medium-duty element. The equivalent length on each side of the boom is 3 inches. As usual, the torque compensator is mounted 12 inches behind the last director.

15-METER YAGIS

Fig 15 describes the electrical performance of eight optimized 15-meter Yagis with boom lengths between 6 feet to a spectacular 80 feet. The end of each boom includes 3 inches of space for the reflector and last-director (or driven element) mounting plates. Fig 15A shows the free-space gain versus frequency for each antenna; 15B shows the worst-case front-to-rear ratio, and 15C shows the SWR versus frequency. Each antenna with three or more elements was designed to cover the full 15-meter band from

Table 4

Optimized 17-meter Yagi Designs

Two-element 17-meter Yagi, 6 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		217-06H.YW	217-06M.YW
Reflector	0.000"	61.000"	89.000"
Driven Element	66.000"	48.000"	76.250"

Three-element 17-meter Yagi, 14 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		317-14H.YW	317-14M.YW
Reflector	0.000"	61.500"	91.500"
Driven Element	65.000"	52.000"	79.500"
Director 1	97.000"	46.000"	73.000"
	12" behind Dir. 1	12.625"	10.750"

Four-element 17-meter Yagi, 20 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		417-20H.YW	417-20M.YW
Reflector	0.000"	61.500"	89.500"
Driven Element	48.000"	54.250"	82.625"
Director 1	48.000"	52.625"	81.125"
Director 2	138.000"	40.500"	69.625"
Compensator	12" behind Dir. 2	42.500"	36.250"

Five-element 17-meter Yagi, 30 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		517-30H.YW	517-30M.YW
Reflector	0.000"	61.875"	89.875"
Driven Element	48.000"	52.250"	80.500"
Director 1	52.000"	49.625"	78.250"
Director 2	93.000"	49.875"	78.500"
Director 3	161.000"	43.500"	72.500"
Compensator	12" behind Dir. 3	54.375"	45.875"

Six-element 17-meter Yagi, 48 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		617-48H.YW	617-48M.YW
Reflector	0.000"	63.000"	90.250"
Driven Element	52.000"	52.500"	80.500"
Director 1	51.000"	45.500"	74.375"
Director 2	87.000"	47.875"	76.625"
Director 3	204.000"	47.000"	75.875"
Director 4	176.000"	42.000"	71.125"
Compensator	12" behind Dir. 4	68.250"	57.500"

Six-element 17-meter Yagi, 60 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		617-60H.YW	617-60M.YW
Reflector	0.000"	61.250"	89.250"
Driven Element	54.000"	54.750"	83.125"
Director 1	54.000"	52.250"	80.750"
Director 2	180.000"	46.000"	74.875"
Director 3	235.000"	44.625"	73.625"
Director 4	191.000"	41.500"	70.625"
Compensator	12" behind Dir. 4	62.875"	53.000"

These 17-m Yagi designs are optimized for > 20 dB F/R, and SWR < 2:1 over entire frequency range from18.068 to 18.168 MHz, for heavy-duty elements (123 mph wind survival) and for medium-duty (83 mph wind survival). Only element tip dimensions are shown. All dimensions are in inches. Torque compensator element is made of 2.5" OD PVC water pipe placed 12" behind last director, and dimensions shown for compensators is one-half of total length, centered on boom.

21.000 to 21.450 MHz, with SWR less than 2:1 and F/R ratio better than 20 dB over that range.

Fig 15D shows the taper schedule for two types of 15-meter elements. The heavy-duty design can survive 124-mph winds with no icing, and 90-mph winds with $^{1}/_{4}$ inch of radial ice. The medium-duty design can handle 86-mph winds with no icing, and 61-mph winds with $^{1}/_{4}$ inch of radial ice. The element-to-boom mounting plate for these Yagis is a 0.375-inch thick flat aluminum plate, 5 inches wide by 6 inches long.

Electrically, each mounting plate is equivalent to a cylinder, with an effective diameter of 3.0362 inches for

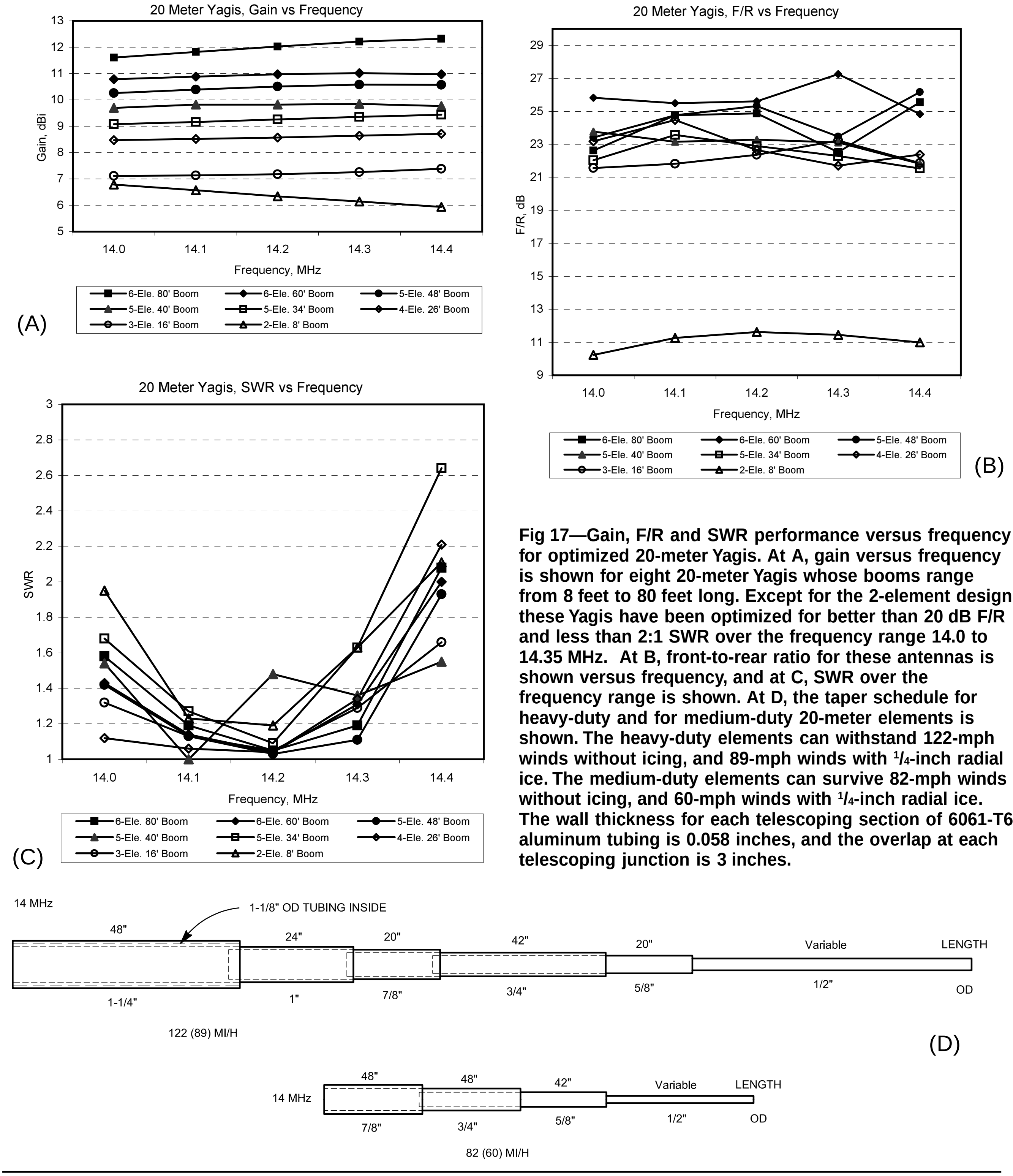

Fig 17—Gain, F/R and SWR performance versus frequency for optimized 20-meter Yagis. At A, gain versus frequency is shown for eight 20-meter Yagis whose booms range from 8 feet to 80 feet long. Except for the 2-element design, these Yagis have been optimized for better than 20 dB F/R and less than 2:1 SWR over the frequency range 14.0 to 14.35 MHz. At B, front-to-rear ratio for these antennas is shown versus frequency, and at C, SWR over the frequency range is shown. At D, the taper schedule for heavy-duty and for medium-duty 20-meter elements is shown. The heavy-duty elements can withstand 122-mph winds without icing, and 89-mph winds with $^1/_4$-inch radial ice. The medium-duty elements can survive 82-mph winds without icing, and 60-mph winds with $^1/_4$-inch radial ice. The wall thickness for each telescoping section of 6061-T6 aluminum tubing is 0.058 inches, and the overlap at each telescoping junction is 3 inches.

the heavy-duty element, and 2.9447 inches for the medium-duty element. The equivalent length on each side of the boom is 3 inches. As usual, the torque compensator is mounted 12 inches behind the last director.

17-METER YAGIS

Fig 16 describes the electrical performance of six optimized 17-meter Yagis with boom lengths between 6 to a heroic 60 feet. As usual, the end of each boom includes 3 inches of space for the reflector and last director (or driven element) mounting plates. Fig 16A shows the free-space gain versus frequency for each an-

Table 5

Optimized 20-Meter Yagi Designs

Two-element 20-meter Yagi, 8 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		220-08H.YW	220-08M.YW
Reflector	0.000"	66.000"	80.000"
Driven Element	90.000"	46.000"	59.000"

Three-element 20-meter Yagi, 16 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		320-16H.YW	320-16M.YW
Reflector	0.000"	69.625"	81.625"
Driven Element	80.000"	51.250"	64.500"
Director 1	106.000"	42.625"	56.375"
Compensator	12" behind Dir. 1	33.375"	38.250"

Four-element 20-meter Yagi, 26 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		420-26H.YW	420-26M.YW
Reflector	0.000"	65.625"	78.000"
Driven Element	72.000"	53.375"	65.375"
Director 1	60.000"	51.750"	63.875"
Director 2	174.000"	38.625"	51.500"
Compensator	12" behind Dir. 2	54.250"	44.250"

Five-element 20-meter Yagi, 34 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		520-34H.YW	520-34M.YW
Reflector	0.000"	68.625"	80.750"
Driven Element	72.000"	52.250"	65.500"
Director 1	71.000"	45.875"	59.375"
Director 2	68.000"	45.875"	59.375"
Director 3	191.000"	37.000"	51.000"
Compensator	12" behind Dir. 3	69.250"	56.250"

Five-element 20-meter Yagi, 40 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		520-40H.YW	520-40M.YW
Reflector	0.000"	68.375"	80.500"
Driven Element	72.000"	53.500"	66.625"
Director 1	72.000"	51.500"	64.625"
Director 2	139.000"	48.375"	61.750"
Director 3	191.000"	38.000"	52.000"
Compensator	12" behind Dir. 3	69.750"	56.750"

Five-element 20-meter Yagi, 48 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		520-48H.YW	520-48M.YW
Reflector	0.000"	66.250"	78.500"
Driven Element	72.000"	53.000"	66.000"
Director 1	88.000"	50.500"	63.750"
Director 2	199.000"	47.375"	60.875"
Director 3	211.000"	39.750"	53.625"
Compensator	12" behind Dir. 3	70.325"	57.325"

Six-element 20-meter Yagi, 60 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		620-60H.YW	620-60M.YW
Reflector	0.000"	67.000"	79.250"
Driven Element	84.000"	51.500"	65.000"
Director 1	91.000"	45.125"	58.750"
Director 2	130.000"	41.375"	55.125"
Director 3	210.000"	46.875"	60.375"
Director 4	199.000"	39.125"	53.000"
Compensator	12" behind Dir. 4	72.875"	59.250"

Six-element 20-meter Yagi, 80 foot boom

Element	*Spacing*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		620-80H.YW	620-80M.YW
Reflector	0.000"	66.125"	78.375"
Driven Element	72.000"	52.375"	65.500"
Director 1	122.000"	49.125"	62.500"
Director 2	229.000"	44.500"	58.125"
Director 3	291.000"	42.625"	56.375"
Director 4	240.000"	38.750"	52.625"
Compensator	12" behind Dir. 4	78.750"	64.125"

These 20-meter Yagi designs are optimized for > 20 dB F/R, and SWR < 2:1 over entire frequency range from 14.000 to 14.350 MHz, for heavy-duty elements (122 mph wind survival) and for medium-duty (82 mph wind survival). Only element tip dimensions are shown. See Fig 17 for element telescoping tubing schedule. All dimensions are in inches. Torque compensator element is made of 2.5" OD PVC water pipe placed 12" behind last director, and dimensions shown for compensators is one-half of total length, centered on boom.

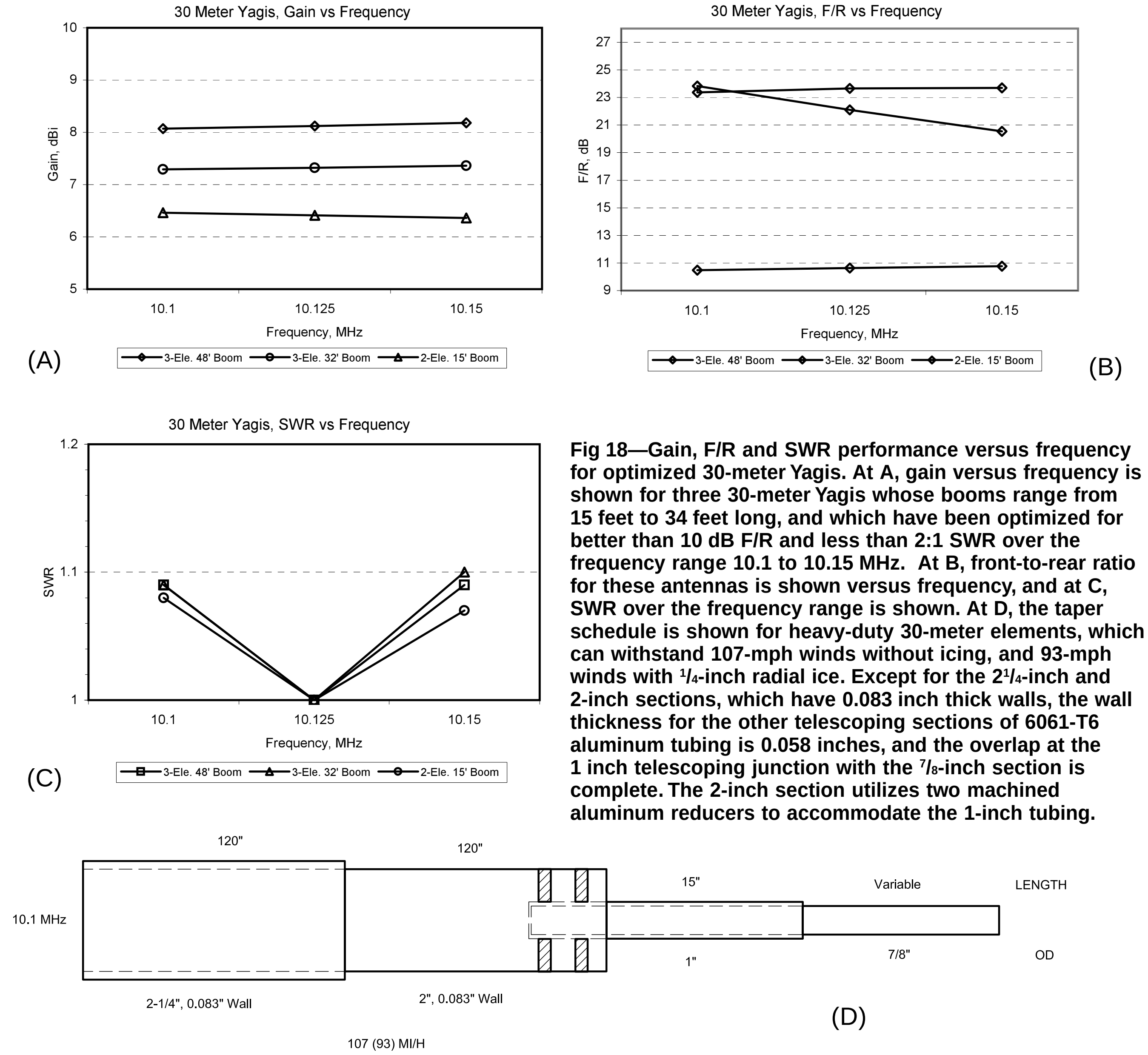

Fig 18—Gain, F/R and SWR performance versus frequency for optimized 30-meter Yagis. At A, gain versus frequency is shown for three 30-meter Yagis whose booms range from 15 feet to 34 feet long, and which have been optimized for better than 10 dB F/R and less than 2:1 SWR over the frequency range 10.1 to 10.15 MHz. At B, front-to-rear ratio for these antennas is shown versus frequency, and at C, SWR over the frequency range is shown. At D, the taper schedule is shown for heavy-duty 30-meter elements, which can withstand 107-mph winds without icing, and 93-mph winds with 1/4-inch radial ice. Except for the 21/4-inch and 2-inch sections, which have 0.083 inch thick walls, the wall thickness for the other telescoping sections of 6061-T6 aluminum tubing is 0.058 inches, and the overlap at the 1 inch telescoping junction with the 7/8-inch section is complete. The 2-inch section utilizes two machined aluminum reducers to accommodate the 1-inch tubing.

tenna; 16B shows the worst-case front-to-rear ratio, and 16C shows the SWR versus frequency. Each antenna with three or more elements was designed to cover the narrow 17-meter band from 18.068 to 18.168 MHz, with SWR less than 2:1 and F/R ratio better than 20 dB over that range.

Fig 16D shows the taper schedule for two types of 17-meter elements. The heavy-duty design can survive 123-mph winds with no icing, and 83-mph winds with 1/4-inch of radial ice. The medium-duty design can handle 83-mph winds with no icing, and 59-mph winds with ¼ inch of radial ice.

The element-to-boom mounting plate for these Yagis is a 0.375-inch thick flat aluminum plate, 6 inches wide by 8 inches long. Electrically, each mounting plate is equivalent to a cylinder, with an effective diameter of 3.5122 inches for the heavy-duty element, and 3.3299 inches for the medium-duty element. The equivalent length on each side of the boom is 4 inches. As usual, the torque compensator is mounted 12 inches behind the last director.

20-METER YAGIS

Fig 17 describes the electrical performance of eight optimized 20-meter Yagis with boom lengths between 8 to a giant 80 feet. As usual, the end of each boom includes 3 inches of space for the reflector and last director (driven element) mounting plates. Fig 17A shows the free-space gain versus frequency for each antenna; 17B shows the front-to-rear ratio, and 17C shows the SWR versus frequency. Each antenna with three or more ele-

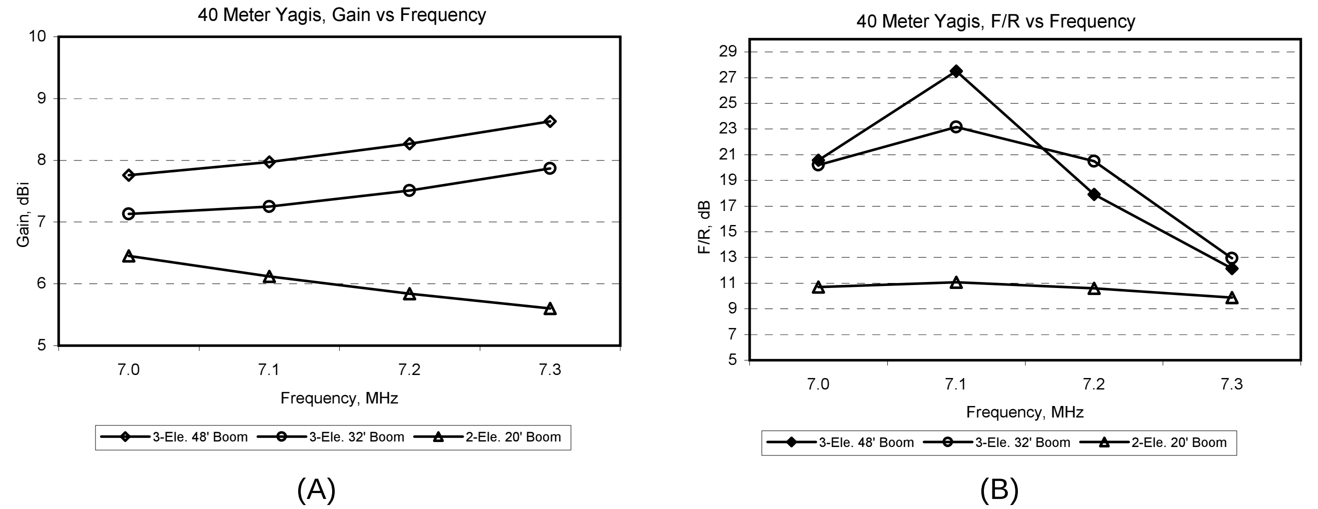

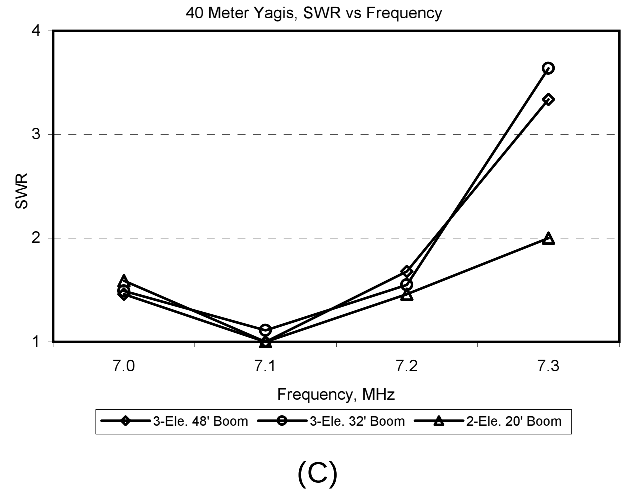

Fig 19—Gain, F/R and SWR performance versus frequency for optimized 40-meter Yagis. At A, gain versus frequency is shown for three 40-meter Yagis whose booms range from 20 feet to 48 feet long, and which have been optimized for better than 10 dB F/R and less than 2:1 SWR over the frequency range 7.0 to 7.2 MHz. At B, front-to-rear ratio for these antennas is shown versus frequency, and at C, SWR over the frequency range is shown. At D, the taper schedule is shown for heavy-duty 40-meter elements, which can withstand 107-mph winds without icing, and 93-mph winds with $^{1}/_{4}$-inch radial ice. Except for the $2^{1}/_{4}$-inch and 2-inch sections, which have 0.083 inch thick walls, the wall thickness for the other telescoping sections of 6061-T6 aluminum tubing is 0.058 inches, and the overlap at the end telescoping junction is 3 inches. The 2-inch section utilizes two machined aluminum reducers to accommodate the 1-inch tubing.

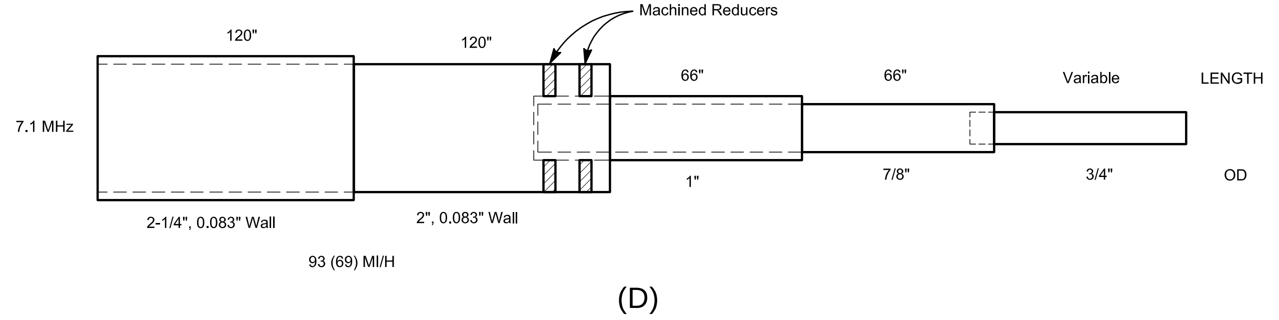

ments was designed to cover the complete 20-meter band from 14.000 to 14.350 MHz, with SWR less than 2:1 and F/R ratio better than 20 dB over that range.

Fig 17D shows the taper schedule for two types of 20-meter elements. The heavy-duty design can survive 122-mph winds with no icing, and 89-mph winds with $^{1}/_{4}$ inch of radial ice. The medium-duty design can handle 82-mph winds with no icing, and 60-mph winds with $^{1}/_{4}$ inch of radial ice. The element-to-boom mounting plate for these Yagis is a 0.375-inch thick flat aluminum plate, 6 inches wide by 8 inches long. Electrically, each mounting plate is equivalent to a cylinder, with an effective diameter of 3.7063 inches for the heavy-duty element, and 3.4194 inches for the medium-duty element. The equivalent length on each side of the boom is 4 inches. As usual, the torque compensator is mounted 12 inches behind the last director.

30-METER YAGIS

Fig 18 describes the electrical performance of three

Table 6

Optimized 30-Meter Yagi Designs

Two-element 30-meter Yagi, 15 foot boom

Element	*Spacing*	*Heavy-Duty Tip*
File Name		230-15H.YW
Reflector	0.000"	50.250"
Driven Element	174.000"	14.875"

3-element 30-meter Yagi, 22 foot boom

Element	*Spacing*	*Heavy-Duty Tip*
File Name		330-22H.YW
Reflector	0.000	59.375
Driven Element	135.000	35.000
Director 1	123.000	19.625

Three-element 30-meter Yagi, 34 foot boom

Element	*Spacing*	*Heavy-Duty Tip*
File Name		330-34H.YW
Reflector	0.000"	53.750"
Driven Element	212"	29.000"
Director 1	190"	14.500"

These 30-m Yagi designs are optimized for > 10 dB F/R, and SWR < 2:1 over entire frequency range from 10.100 to 10.150 MHz for heavy-duty elements (105 mph wind survival). Only element tip dimensions are shown. See Fig 18D for element telescoping tubing schedule. All dimensions are in inches. No torque compensator element is required.

Table 7

Optimized 40-Meter Yagi Designs

Two-element 40-meter Yagi, 20 foot boom

Element	*Spacing*	*Heavy-Duty Tip*
File Name		240-20H.YW
Reflector	0.000"	85.000"
Driven Element	234.000"	35.000"

Three-element 40-meter Yagi, 32 foot boom

Element	*Spacing*	*Heavy-Duty Tip*
File Name		340-32H.YW
Reflector	0.000"	90.750"
Driven Element	196.000"	55.875"
Director 1	182.000"	33.875"

Three-element 40-meter Yagi, 48 foot boom

Element	*Spacing*	*Heavy-Duty Tip*
File Name		340-48H.YW
Reflector	0.000"	81.000"
Driven Element	300.000"	45.000"
Director 1	270.000"	21.000"

These 40-m Yagi designs are optimized for > 10 dB F/R, and SWR < 2:1 over low-end of frequency range from 7.000 to 7.200 MHz, for heavy-duty elements (95 mph wind survival). Only element tip dimensions are shown. See Fig 19D for element telescoping tubing schedule. All dimensions are in inches. No wind torque compensator is required.

optimized 30-meter Yagis with boom lengths between 15 to 34 feet. Because of the size and weight of the elements alone for Yagis on this band, only 2-element and 3-element designs are described. The front-to-rear ratio requirement for the 2-element antenna is relaxed to be greater than 10 dB over the band from 10.100 to 10.150 MHz, while that for the 3-element designs is kept at greater than 20 dB over that frequency range.

As usual, the end of each boom includes 3 inches of space for the reflector and last director mounting plates. Fig 18A shows the free-space gain versus frequency for each antenna; 18B shows the worst-case front-to-rear ratio, and 18C shows the SWR versus frequency.

Fig 18D shows the taper schedule for the 30-meter elements. Note that the wall thickness of the first two sections of tubing is 0.083 inches, rather than 0.058 inches. This heavy-duty element design can survive 107-mph winds with no icing, and 93-mph winds with $^{1}/_{4}$ inch of radial ice. The element-to-boom mounting plate for these Yagis is a 0.500-inch thick flat aluminum plate, 6 inches wide by 24 inches long. Electrically, each mounting plate is equivalent to a cylinder, with an effective diameter of 4.684 inches. The equivalent length on each side of the boom is 12 inches. These designs require no torque compensator.

40-METER YAGIS

Fig 19 describes the electrical performance of three optimized 40-meter Yagis with boom lengths between 20 to 48 feet. Like the 30-meter antennas, because of the size and weight of the elements for a 40-meter Yagi, only 2-element and 3-element designs are described. The front-to-rear ratio requirement for the 2-element antenna is relaxed to be greater than 10 dB over the band from 7.000 to 7.300 MHz, while the goal for the 3-element designs is 20 dB over the frequency range of 7.000 to 7.200 MHz. It is exceedingly difficult to hold the F/R greater than 20 dB over the entire 40-meter band without sacrificing excessive gain with a 3-element design.

As usual, the end of each boom includes 3 inches of space for the reflector and last director mounting plates. Fig 19A shows the free-space gain versus frequency for each antenna; 19B shows the front-to- rear ratio, and 19C shows the SWR versus frequency.

Fig 19D shows the taper schedule for the 40-meter elements. Note that the wall thickness of the first two sections of tubing is 0.083 inches, rather than 0.058 inches. This element design can survive 93-mph winds with no icing, and 69-mph winds with $^{1}/_{4}$ inch of radial ice. The element-to-boom mounting plate for these Yagis is a 0.500-inch thick flat aluminum plate, 6 inches wide by 24 inches long. Electrically each mounting plate is equivalent to a cylinder, with an effective diameter of 4.684 inches. The equivalent length on each side of the boom is 12 inches. These designs require no torque compensator.

Modifying Monoband Hy-Gain Yagis

Enterprising amateurs have long used the Telex Communications Hy-Gain "Long John" series of HF monobanders as a source of top-quality aluminum and hardware for customized Yagis. Often-modified older models include the 105BA for 10 meters, the 155BA for 15 meters, and the 204BA and 205BA for 20 meters. Newer Hy-Gain designs, the 105CA, 155CA and 205CA, have been redesigned by computer for better performance.

Hy-Gain antennas have historically had an excellent reputation for superior mechanical design, and Hy-Gain proudly points out that many of their monobanders are still working after more than 30 years. In the older designs the elements were purposely spaced along the boom to achieve good weight balance at the mast-to-boom bracket, with electrical performance as a secondary goal. Thus, the electrical performance was not necessarily optimum, particularly over an entire amateur band. Newer Hy-Gain designs are electrically superior to the older ones, but because of their strong concern for weight-balance are still not optimal by the definitions used in this chapter.

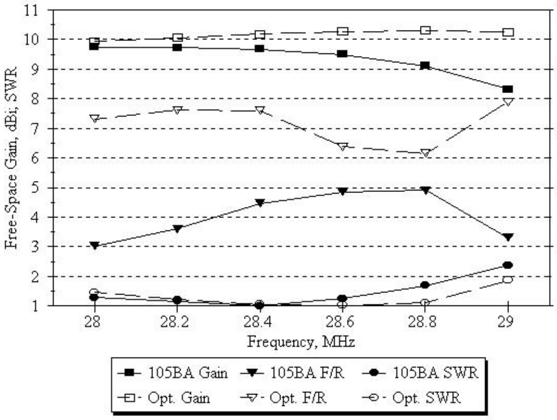

Fig 20—Gain, F/R and SWR over the 28.0 to 28.8 MHz range for original and optimized Yagis using Hy-Gain hardware. Original 105BA design provided excellent weight balance at boom-to-mast bracket, but compromised the electrical performance somewhat because of non-optimum spacing of elements. Optimized design requires wind torque-balancing compensator element, and compensating weight at director end of boom to rebalance weight. The F/R ratio over the frequency range for the optimized design is more than 23 dB. Each element uses the original Hy-Gain taper schedule and element-to-boom clamp, but the length of the tip is changed per Table 8.

Table 8
Optimized Hy-Gain 20-Meter Yagi Designs

Optimized 204BA, Four-element 20-meter Yagi, 26 foot boom

Element	*Spacing*	*Element Tip*
File Name		BV204CA.YW
Reflector	0.000"	56.000"
Driven Element	85.000"	52.000"
Director 1	72.000"	61.500"
Director 2	149.000"	50.125"

Optimized 205CA, Five-element 20-meter Yagi, 34 foot boom

Element	*Spacing*	*Element Tip*
File Name		BV205CA.YW
Reflector	0.000"	62.625"
Driven Element	72.000"	53.500"
Director 1	72.000"	63.875"
Director 2	74.000"	61.625"
Director 3	190.000"	55.000"

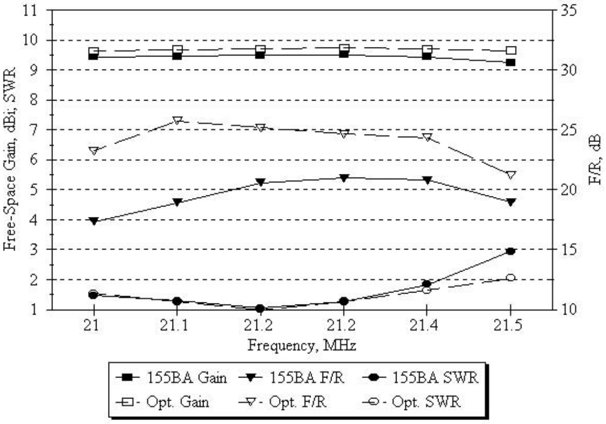

Fig 21—Gain, F/R and SWR over the 21.0 to 21.45 MHz band for original and optimized Yagis using Hy-Gain hardware. Original 155BA design provided excellent weight balance at boom-to-mast bracket, but compromised the electrical performance somewhat because of non-optimum spacing of elements. Optimized design requires wind torque-balancing compensator element, and compensating weight at director end of boom to rebalance weight. The F/R ratio over the frequency range for the optimized design is more than 22 dB. Each element uses the original Hy-Gain taper schedule and element-to-boom clamp, but the length of the tip is changed per Table 9.

Table 9
Optimized Hy-Gain 15-Meter Yagi Designs

Optimized 155BA, Five-element 15-meter Yagi, 24 foot boom

Element	*Spacing*	*Element Tip*
File Name		BV155CA.YW
Reflector	0.000"	64.000"
Driven Element	48.000"	65.500"
Director 1	48.000"	63.875"
Director 2	82.750"	61.625"
Director 3	127.250"	55.000"

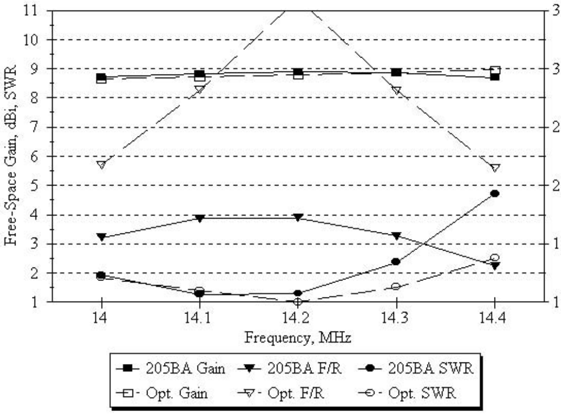

Fig 22—Gain, F/R and SWR over the 14.0 to 14.35 MHz band for original and optimized Yagis using Hy-Gain hardware. Original 205BA design provided good weight balance at boom-to-mast bracket, but compromised the electrical performance because of non-optimum spacing of elements. Optimized design requires wind torque-balancing compensator element, and compensating weight at director end of boom to rebalance weight. The F/R ratio over the frequency range for the optimized design is more than 23 dB, while the original design never went beyond 17 dB of F/R. Each element uses the original Hy-Gain taper schedule and element-to-boom clamp, but the length of the tip is changed per Table 10.

Table 10
Optimized Hy-Gain 10-Meter Yagi Designs

Optimized 105BA, Five-element 10-meter Yagi, 24 foot boom

Element	*Spacing, inches*	*Element Tip*
File Name		BV105CA.YW
Reflector	0.000"	44.250"
Driven Element	40.000"	53.625"
Director 1	40.000"	52.500"
Director 2	89.500"	50.500"
Director 3	112.250"	44.750"

With the addition of wind torque-compensation dummy elements, and with extra lead weights, where necessary, at the director end of the boom for weight-balance, the electrical performance can be enhanced, using the same proven mechanical parts.

Fig 20 shows the computed gain, F/R ratio and SWR for a 24-foot boom, 10-meter optimized Yagi (modified 105BA) using Hy-Gain hardware. **Fig 21** shows the same for a 26-foot boom 15-meter Yagi (modified 155BA), and **Fig 22** shows the same for a 34-foot boom (modified 205BA) 20-meter Yagi. **Tables 8** through **10** show dimensions for these designs. The original Hy-Gain taper schedule is used for each element. Only the length of the end tip (and the spacing along the boom) is changed for each element.

Multiband Yagis

So far, this chapter has discussed monoband Yagis—that is, Yagis designed for a single Amateur-Radio frequency band. Because hams have operating privileges on more than one band, multiband coverage has always been very desirable.

INTERLACING ELEMENTS

In the late 1940s, some experimenters tried interlacing Yagi elements for different frequencies on a single boom, mainly to cover the 10 and 20-meter bands (at that time the 15-meter band wasn't yet available to hams). The experimenters discovered, to their considerable chagrin, that the mutual interactions between different elements tuned to different frequencies are very difficult to handle.

Adjusting a lower-frequency element usually results in interaction with higher-frequency elements near it. In effect, the lower-frequency element acts like a retrograde reflector, throwing off the effectiveness of the higher-frequency directors nearby. Element lengths and the spacing between elements can be changed to improve performance of the higher-frequency Yagi, but the resulting compromise is rarely equal to that of an optimized monoband Yagi. A reasonable compromise for portable operation may be found in Chapter 15, Portable Antennas, by VE7CA.

TRAPPED MULTIBANDERS

Multiband Yagis using a single boom can also be made using traps. Traps allow an element to have multiple resonances. See Chapter 7, Multiband Antennas, for details on trap designs. Commercial vendors have sold trapped antennas to hams since the 1950s and surveys show that after simple wire dipoles and multiband verticals, trapped triband Yagis are the most popular antennas in the Amateur Radio service.

The originator of the trapped tribander was Chester Buchanan, W3DZZ, in his Mar 1955 *QST* article, "The Multimatch Antenna System." On 10 meters this rather unusual tribander used two reflectors (one dedicated and one with traps) and two directors (one dedicated and one with traps). On 20 and 15 meters three of the five elements were active using traps. The W3DZZ tribander employed 12 traps overall, made with heavy wire and concentric tubular capacitors to hold down losses in the traps. Each trap was individually fine tuned after construction before mounting it on an element.

Another example of a homemade tribander was the 26-foot boom 7-element 20/15/10-meter design described by Bob Myers, W1XT (ex-W1FBY) in Dec 1970 *QST*. The W1FBY tribander used only two sets of traps in the driven element, with dedicated reflectors and directors for each frequency band. Again, the traps were quite robust in this design to minimize trap losses, using $^7/_{16}$-inch aluminum tubing for the coils and short pieces of RG-8 coax as high-voltage tuning capacitors.

Only a relatively few hams actually built tribanders for themselves, mainly because of the mechanical complexity and the close tolerances required for such antennas. The traps themselves must be constructed quite accurately for reproducible results, and they must be carefully weatherproofed for long life in rain, snow, and often polluted or corrosive atmospheres.

Christmas Tree Stacks

Another possible method for achieving multiband coverage using monoband Yagis is to stack them in a "Christmas tree" arrangement. See **Fig 23**. For an installation covering 20, 15 and 10 meters, you could mount on the rotating mast just at the top of the tower the 20-meter monobander. Then perhaps 9 feet above that you would mount the 15-meter monobander, followed by the 10-meter monoband Yagi 7 feet further up on the mast. Another configuration would be to place the 10-meter Yagi in between the lower 20-meter and upper 15-meter Yagis. Whatever the arrangement, the antenna in the middle of such a Christmas-tree always suffers the most interaction from the lowest-frequency Yagi.

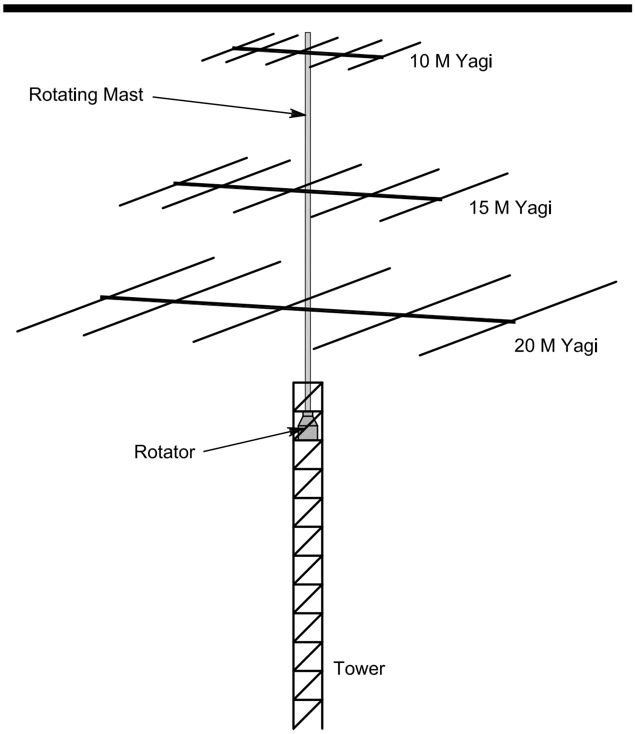

Fig 23—"Christmas Tree" stack of 20/15/10-meter Yagis spaced vertically on a single rotating mast.

Dave Leeson, W6NL (ex-W6QHS), mentions that the 10-meter Yagi in his closely stacked Christmas Tree (15 meters at the top, 10 meters in the middle, and 20 meters at the bottom of the rotating mast) loses "substantial gain" because of serious interaction with the 20-meter antenna. (N6BV and K1VR calculated that the free-space gain in the W6NL stack drops to 5 dBi, compared to about 9 dBi with no surrounding antennas.) Monobanders are *definitely not* universally superior to tribanders in multiband installations. In private conversations, W6NL has indicated that he would not repeat this kind of short Christmas Tree installation again.

Forward Staggering

Some hams have built multiband Yagis on a common boom, using a technique called *forward staggering*. This means that that most (or all) of the higher-frequency elements are placed in front of any lower-frequency elements—in other words, most of the elements are not interlaced. Richard Fenwick, K5RR, described his triband Yagi design in Sep 1996 *QEX* magazine. This uses forward-stagger and open-sleeve design techniques and was optimized using several sophisticated modeling programs.

Fenwick's tribander used a 57-foot, 3-inch OD boom to hold 4 elements on 20 meters, 4 elements on 15 meters and 5 elements on 10 meters. **Fig 24** shows the element placement for the K5RR tribander. Most hams, of course, don't have the real-estate or the large rotator needed to turn such a large, but elegant solution to the interaction problem!

Force 12 C3 "Multi-Monoband" Triband Yagi

Antenna manufacturer Force 12 also uses forward-stagger layouts and patented combinations of open- and closed-sleeve drive techniques extensively in their product line of multiband antennas, which they call "multi-monoband Yagis." **Fig 25** shows the layout for the popular Force 12 C3 triband Yagi. The C3 uses no traps, thereby avoiding any losses due to traps. The C3 consists of three 2-element Yagis on an 18-foot boom, using full-sized elements designed to withstand high winds.

The C3 feed system employs open-sleeves, where the 20-meter driver element is fed with coax through a common-mode current balun and parasitically couples to the closely spaced 15-meter driver and the two 10-meter drivers to yield a feed-point impedances close to 50 Ω on all three bands. See the section on open-sleeve dipoles in Chapter 7, Multiband Antennas.

Note the use of the forward-stagger technique in the C3, especially on 10 meters. To reduce interaction with

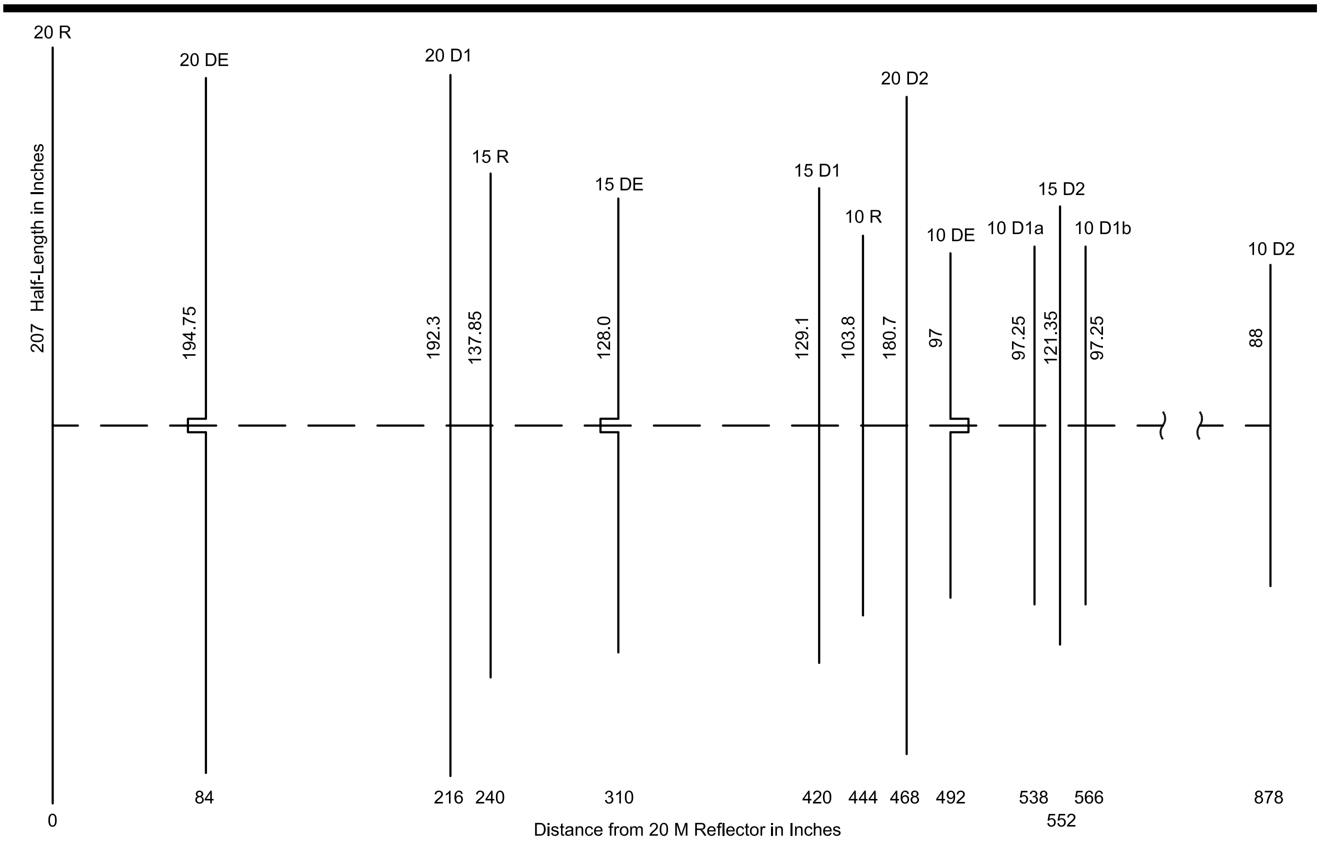
20 R
20 DE
20 D1
20 D2
15 R
15 DE
15 D1
10 R
10 DE
10 D1a
15 D2
10 D1b
10 D2
207 Half-Length in Inches
194.75
192.3
137.85
128.0
129.1
103.8
180.7
97
97.25
121.35
97.25
88
0
84
216
240
310
420
444
468
492
538
552
566
878
Distance from 20 M Reflector in Inches

Fig 24—Dimensions of K5RR's trapless tribander using "forward stagger" and open-sleeve techniques to manage interaction between elements for different frequencies.

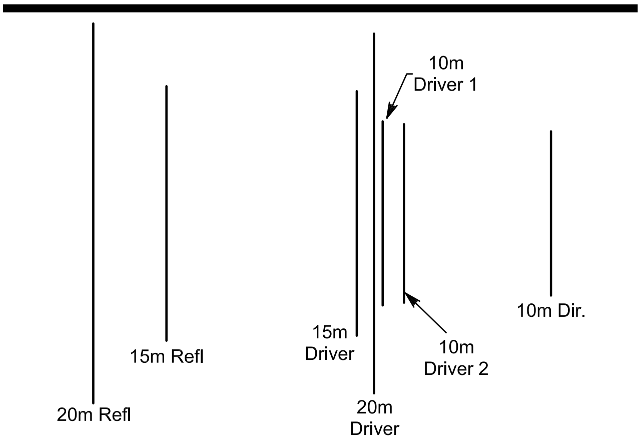
10m
Driver 1
10m Dir.
15m Refl
15m
Driver
10m
Driver 2
20m Refl
20m
Driver

Fig 25—Layout of Force 12 C3 multiband Yagi. Note that the 10-meter (driver/director) portion of the antenna is "forward staggered" ahead of the 15-meter (reflector/driver) portion, which in turn is placed ahead of the 20-meter (reflector/driver) portion. The antenna is fed at the 20-meter driver, which couples parasitically to the 15-meter driver and the two 10-meter drivers.

the lower-frequency elements behind it, the 10-meter portion of the C3 is mounted on the boom ahead of all the lower-frequency elements, with the main 10-meter parasitic element (#7) acting as a director. The lower-frequency elements behind the 10-meter section act as retrograde reflectors, gaining some improvement of the gain and pattern compared to a monoband 2-element Yagi. A simplified *EZNEC* model of the C3 is included on the CD-ROM accompanying this book.

On 15 meters, the main parasitic element (#2) is a dedicated reflector, but the other elements ahead on the boom act like retrograde directors to improve the gain and pattern somewhat over a typical 2-element Yagi with a reflector. On 20 meters, the C3 is a 2-element Yagi with a dedicated reflector (#1) at the back end of the boom.

The exact implementation of any Yagi, of course, depends on the way the elements are constructed using telescoping aluminum tubing. The C3 type of design is no exception.

Stacked Yagis

Monoband parasitic arrays are commonly stacked either in broadside or collinear fashion to produce additional directivity and gain. In HF amateur work, the most common broadside stack is a vertical stack of identical Yagis on a single tower. This arrangement is commonly called a *vertical stack*. At VHF and UHF, amateurs often employ collinear stacks, where identical Yagis are stacked side-by-side at the same height. This arrangement is called a *horizontal stack*, and is not usually found at HF, because of the severe mechanical difficulties involved with large, rotatable side-by-side arrays.

Fig 26 illustrates the two different stacking arrangements. In either case, the individual Yagis making up the stack are generally fed in phase. There are times, however, when individual antennas in a stacked array are purposely fed out of phase in order to emphasize a particular elevation pattern. See Chapter 17, Repeater Antenna Systems, for such a case where elevation pattern steering is implemented for a repeater station.

Let's look at the reasons hams stack Yagis:

- For more gain
- For a wider elevation footprint in a target geographical area
- For azimuthal diversity—two or more directions at once
- For less fading
- For less precipitation static

STACKS AND GAIN

Fig 27 compares the elevation responses for three antenna systems of 4-element 15-meter Yagis. The response for the single Yagi at a height of 120 feet peaks at an elevation of about 5°, with a second peak at 17° and a third at 29°. When operated by itself, the 60-foot high Yagi has its first peak at about 11° and its second peak beyond 34°.

The basic principle of a vertically stacked HF array is that it takes energy from higher-angle lobes and concentrates that energy into the main elevation lobe. The main lobe of the 120/60-foot stack peaks about 7° and is about 2 dB stronger than either the 60- or 120-foot antenna by itself. The shape of the left-hand side of the stack's main lobe is determined mainly by the 120-foot antenna's response. The right-hand side of the stack's main lobe is "stretched" rightwards (toward higher angles) mainly by the 60-foot Yagi, while the shape follows the curve of the 120-foot Yagi.

Look at the second and third lobes of the stack, which appear about 18° and 27°. These are about 14 dB down from the stack's peak gain, showing that energy has indeed been extracted from them. By contrast, look at the levels of the second and third lobes for the individual Yagis at 60 and 120 feet. These higher-angle lobes are almost as strong as the first lobes.

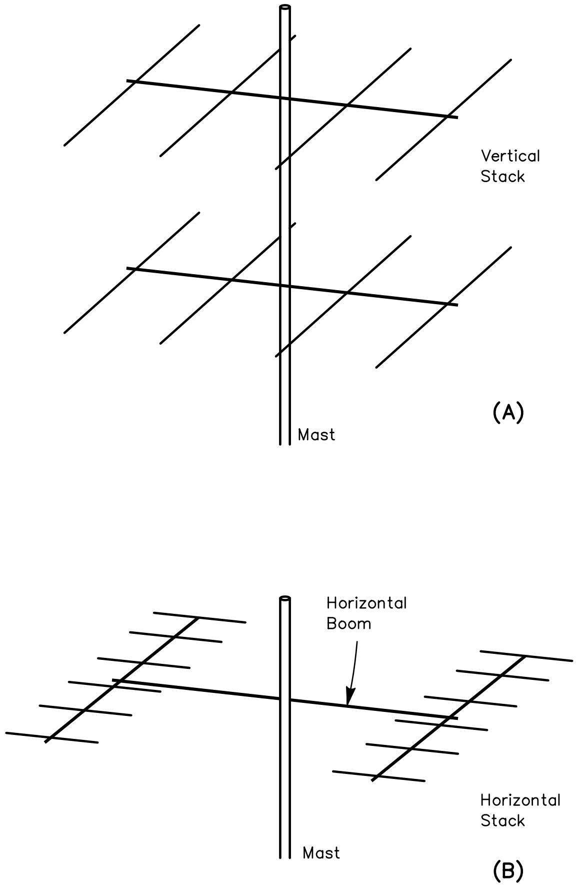

Fig 26—Stacking arrangements. At A, two Yagis are stacked vertically (broadside) on the same mast. At B, two Yagis are stacked horizontally (collinear) side-by-side. At HF the vertical stack is more common because of mechanical difficulties involved with large HF antennas stacked side-by-side, whereas at VHF and UHF the horizontal stack is common.

The stack squeezes higher-angle energy into its main elevation lobe, while maintaining the frontal lobe azimuth pattern of a single Yagi. This is the reason why many state-of-the-art contest stations are stacking arrays of relatively short-boom antennas, rather than stacking long-boom, higher-gain Yagis. A long-boom HF Yagi narrows the azimuthal pattern (and the elevation pattern too), making pointing the antenna more critical and making it more difficult to spread a signal over a wide azimuthal area, such as all of Europe and Asiatic Russia at one time.

STACKS AND WIDE ELEVATION FOOTPRINTS

Detailed studies using sophisticated computer models of the ionosphere have revealed that coverage

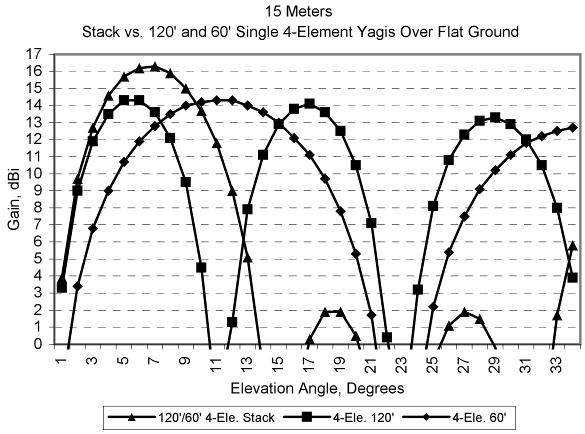

Fig 27—Comparison of elevation patterns on 15 meters for a stack of 4-element Yagis at 120 and 60 feet and individual Yagis at those two heights. The shape of the stack's response is determined mainly by that of the top antenna.

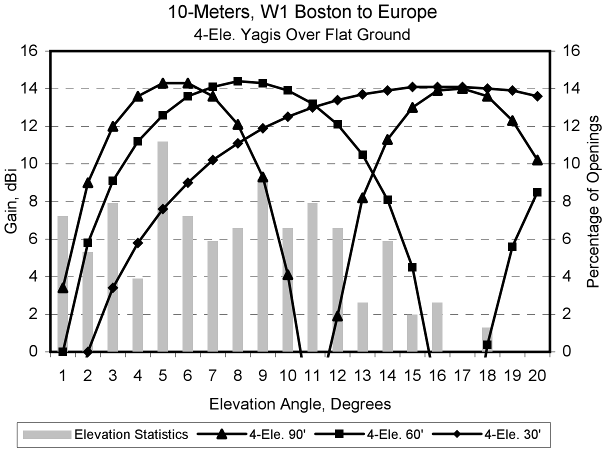

Fig 28—Comparison of elevation patterns and elevation-angle statistics for individual 10-meter TH7DX tribanders mounted over flat ground aiming from New England to Europe. No single antenna can cover the wide range of angles needed—from 1° to 18°.

of a wide range of elevation angles is necessary to ensure consistent DX or contest coverage on the HF bands. These studies have been conducted over all phases of the 11-year solar cycle, and for numerous transmitting and receiving QTHs throughout the world.

Chapter 23, Radio Wave Propagation, covers these studies in more detail, and the CD-ROM accompanying this book contains a huge number of elevation-angle statistical tables for locations all around the world. The *HFTA* (HF Terrain Assessment) program on the CD-ROM can not only compute antenna elevation patterns over irregular local terrain, but it can compare them directly to the elevation-angle statistics for a particular target geographic area.

A 10-Meter Example

Fig 28 shows the 10-meter elevation-angle statistics for the New England path from Boston, Massachusetts, to all of the continent of Europe. The statistics are overlaid with the computed elevation response for three individual 4-element Yagis, at three heights: 90, 60 and 30 feet above flat ground. In terms of wavelength, these heights are 2.60 λ, 1.73 λ and 0.86 λ high.

You can see that the 90-foot high Yagi covers the lower elevation angles best, but it has a large null in its response centered at about 11°. This null puts a big hole in the coverage for some 22% of all the times the 10-meter band is open to Europe. At those angles where the 90-foot Yagi exhibits a null, the 60-foot Yagi would be effective, and so would the 30-foot Yagi. If that is the only antenna you have, the 90-foot high Yagi would be too high for good coverage of Europe from New England.

The peak statistical elevation angle into Europe is 5°, and this occurs about 11% of all the times the 10-meter band is open to Europe from Boston. At an elevation of 5° the 30-foot high Yagi would be down almost 7 dB compared to the 90-foot high Yagi, but at 11° the 90-foot Yagi would be more than 22 dB down from the 30-foot Yagi. There is no single height at which one Yagi can optimally cover all the necessary elevation angles, especially to a large geographic area such as Europe—although the 60-foot high antenna is arguably the best compromise for a single height. To cover all the possibilities to Europe, however, you need a 10-meter antenna system that can cover equally well the entire range of elevation angles from 1° to 18°.

Fig 29 compares elevation-angle statistics for two 10-meter paths from New England to Europe and to Japan. The elevation angles needed for communications with the Far East are very low. Overlaid on Fig 29 for comparison are the elevation responses over flat ground for three different antenna systems, using identical 4-element Yagis:

- Three Yagis, stacked at 90, 60 and 30 feet
- Two Yagis, stacked at 70 and 40 feet
- One Yagi at 90 feet.

The best coverage of all the necessary angles on 10 meters to Europe is with the stack of three Yagis at 90/60/30 feet. The two-Yagi stack at 70 and 40 feet comes in a close second to Europe, and for elevation angles higher than about 9° the 70/40-foot stack is actually superior to the 90/60/30-foot stack.

Both of the stacks illustrated here give a wider *elevation footprint* than any single antenna, so that all the angles can be covered automatically without having to switch from higher to lower antennas manually. This is perhaps the major benefit of using stacks, but not the only

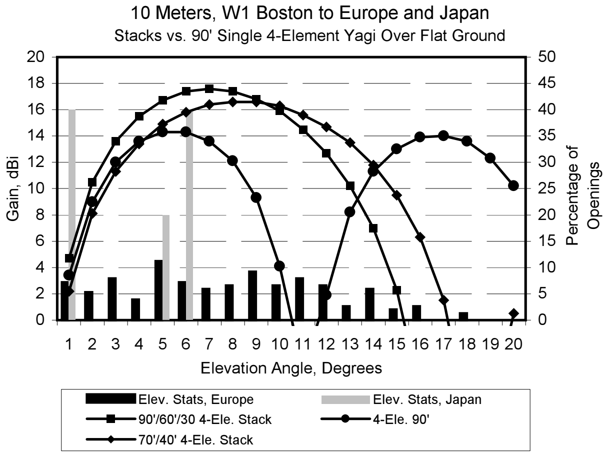

Fig 29—Combinations of 4-element Yagis over flat ground. The elevation-angle statistics into Japan from New England (Boston) are represented by the black vertical bars, while the grey vertical bars represent the elevation-angle statistics to Europe. The 90/60/30-foot stack has the best *elevation footprint* into Japan, although the 70/40-foot stack performs well also.

one, as we'll see.

To Japan, the necessary range of elevation angles is considerably smaller than that needed to a larger geographic target area like Europe. The 90/60/30-foot stack is still best on the basis of having higher gain at low angles, although the two-Yagi stack at 70 and 40 feet is a good choice too. Note that the single 90-foot high Yagi's performance is very close to the 70/40-foot stack of two Yagis at low angles, but the two-Yagi stack is superior to the single 90-foot antenna for angles higher than about 5° on 10 meters.

A 15-Meter Example

The situation is similar on 15 meters from New England to Europe. On 15 meters, the range of angles needed to fully cover Europe is 1° to 28°. This large range of angles makes covering all the angles even more challenging. Ken Wolff, K1EA, a devoted contest operator and the author of the famous *CT* contest logging program, put it very clearly when he wrote in the bulletin for the Yankee Clipper Contest Club:

"Suppose you have 15-meter Yagis at 120 feet and 60 feet, but can feed only one at a time. A 15-meter beam at 120 feet has its first maximum at roughly 5° and the first minimum at 10°. The Yagi at 60 feet has a maximum at 10° and a minimum at 2°. At daybreak, the band is just opening, signals are arriving at 3° or less and the high Yagi outperforms the low one by 5-10 dB. Late in the morning, western Europeans are arriving at angles of 10° or more, while UA6 is still arriving at 4-5°. Western Europe can be 20-30 dB louder on the low antenna than the high! What to do? Stack em!"

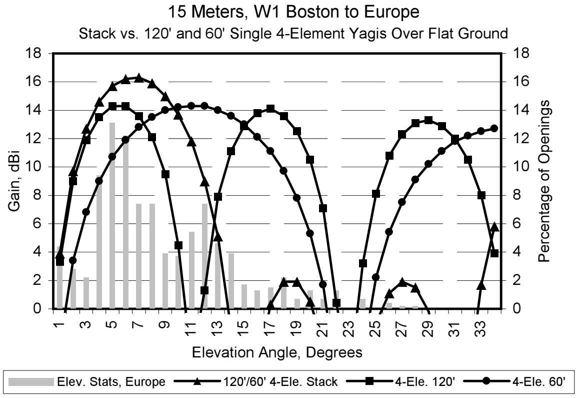

Fig 30—Comparison of elevation patterns for K1EA's illustration about 15-meter Yagis mounted over flat ground, with elevation-angle statistics to Europe added. The stack at 120 and 60 feet yields a better footprint over the range of 3° to 11° at its half-power points, better than either antenna by itself.

Fig 30 illustrates K1EA's scenario, showing the elevation statistics to Europe from Massachusetts and the elevation responses for a 120- and a 60-foot high, 4-element Yagi, both over flat ground, together with the response for both antennas operated as vertical stack. The half-power beamwidth of the stack's main lobe is 6.9°, while that for the 120-foot antenna by itself is 5.5° and that for the 60-foot antenna by itself is 11.1°. The half-power beamwidth numbers by themselves can be deceiving, mainly because the stack starts out with a higher gain. A more meaningful observation is that the stack has equal to or more gain than either of the two individual antennas from 1° to about 10°.

Is such a stack of 15-meter Yagis at 120 and 60 feet optimal for the New England to Europe path? No, it isn't, as we'll explore later, but the stack is clearly better than either antenna by itself for the scenario K1EA outlined above.

A 20-Meter Example

Take a look now at **Fig 31**, which overlays elevation-angle statistics for Europe (gray vertical bars) and Japan (black vertical bars) from Boston on 20 meters, plus the elevation responses for four different sets of antennas mounted over flat ground. Just for emphasis, the highest antenna is a 200-foot high 4-Element Yagi. It is clearly too high for complete coverage of all the needed angles into Europe. A number of New England operators have verified that this is true—a really high Yagi will open the 20-meter band to Europe in the morning and may shut it down in the afternoon, but during the middle of the day the high antenna gets soundly beaten by lower antennas.

To Japan, however, from New England the range of angles needed narrows considerably on 20 meters,

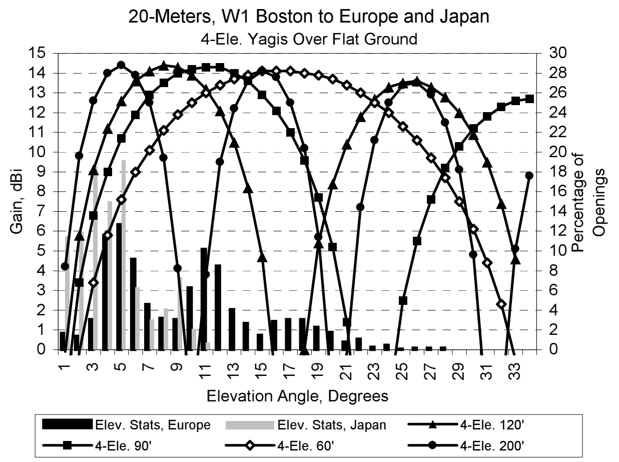

Fig 31—Comparison of elevation patterns for individual 20-meter Yagis over flat ground, compared with the range of elevation angles needed on this band from New England to Europe (gray bars) and to Japan (black bars). For fun, the response of a 200-foot high Yagi is included—this antenna is far too high to cover the needed range of angles to Europe because of its deep nulls at critical angles, like 10°. But the 200 footer is great into Japan!

from 1° to only 11°. For these angles, the 200-foot Yagi is the best antenna to work Japan from New England on 20 meters.

This is true provided that the antenna is aiming out over flat ground. The actual, generally irregular, terrain in various directions can profoundly modify the takeoff angles favored by an antenna system, particularly on steep hills. There will be more discussion on this important topic later on.

SPARE ME THE NULLS!

Now, let's look closely at some other 20-meter antennas in Fig 28, the ones at 120 and 60 feet. At an elevation angle of 8° the difference in elevation response between the 60- and 120-foot high Yagis is just over 3 dB. Can you really notice a change of 3 dB on the air? Signals on the HF bands often rise and fall quickly due to fading, so differences of 2 or 3 dB are difficult to discern. Consequently, the difference between a Yagi at 120 feet and one at 60 feet may be difficult to detect at elevation angles covered well by both antennas. But a *deep null* in the elevation response is very noticeable.

Back in 1990, when editor Dean Straw, N6BV, put up his 120-foot tower in Windham, New Hampshire, his first operational antenna was a 5-element triband Yagi, with 3 elements on 40 and 4 elements on both 20 and 15 meters. Just as the sun was going down on a late August day Straw finished connecting the feed line in the shack. The antenna seemed to be playing like it should, with a good SWR curve and a good pattern when it was rotated. So N6BV/1 called a nearby friend, John Dorr, K1AR, on the telephone and asked him to get on the air to make some signal comparisons on 20 meters into Europe.

Straw was shocked that every European they worked that evening said his signal was several S units weaker than K1AR's. Dorr was using a 4-element 20-meter monobander at 90 feet, which at first glance should have been comparable to Straw's 4-element antenna at 120 feet. But N6BV really shouldn't have been so shocked—in New England, the elevation angles from Europe late in the day on 20 meters are almost always higher than 11°, and that is true for the entire solar cycle.

The N6BV/1 station was located on a small hill, while K1AR was located on flat terrain towards Europe. The elevation response for N6BV/1's 120-foot high Yagi fell right into a deep null at 11°. This was later confirmed many times in the following eight years that the N6BV/1 station was operational. During the early morning opening on 20 meters into Europe, the top antenna was always very close to or equal to the stack of three TH7DX tribanders at 90/60/30 feet on the same tower. But in the afternoon the top antenna was *always* decidedly worse than the stack, so much so that Straw often wondered whether something had gone wrong with the top antenna!

So what's the moral to this short tale? It's simple: *The gain you can achieve, while useful, is not so important as the deep nulls you can avoid by using a stack.*

STACKING DISTANCES BETWEEN YAGIS

So far, we've examined stacks as a means of achieving more gain over an individual Yagi, while also matching the antenna system's response to the range of elevation angles needed for particular propagation paths. Most importantly, we seek to avoid nulls in the elevation response. Earlier we asked whether a 120/60-foot stack was optimal for the path from New England to Europe on 15 meters. Let's examine how the stacking distance between individual antennas affects the performance of a stack.

Fig 32 shows overlays of various combinations of 15-meter Yagis. Just for reference, a plot for a single 60-foot high Yagi is also included. Let's start by looking at the most widely spaced stack in the group: the 120/30-foot stack. Here, the spacing is obviously too large, since the second lobe is actually stronger than the first lobe. In terms of wavelength, the 90-foot spacing between antennas in this stack is 1.94 λ, a large spacing indeed.

There is a great deal of folklore and superstition among amateurs about stacking distances for HF arrays. For years, high-performance stacked Yagi arrays have been used for weak-signal DXing on the VHF and UHF bands. The most extreme example of weak-signal work is EME work (Earth-Moon-Earth, also called *moonbounce*) because of the huge path losses incurred on the way to and from the Moon. The most successful arrays used for

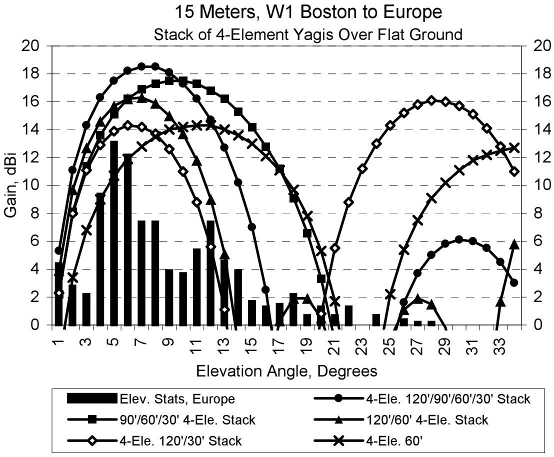

Fig 32—Various stacks towards Europe from New England for 15-meters. The stack at 120 and 30 feet is clearly suboptimal, since the second lobe is higher than the first lobe. The 120/60-foot stack is better in this regard, but is still not as good a performer as the 90/60/30-foot stack. It's debatable whether going to four Yagis in the 120/90/60/30-foot stack is a good idea because it drops below the performance of the 90/60/30-foot stack at about 10° in elevation. The exact distance between practical HF Yagis is not critical to obtain the benefits of stacking. For a stack of tribanders at 90, 60 and 30 feet, the distance in wavelengths between individual antennas is 0.87 λ at 28.5 MHz, 0.65 λ at 21.2 MHz, and 0.43 λ at 14.2 MHz.

moonbounce have low sidelobe levels and very narrow frontal lobes that give huge amounts of gain. The low sidelobes help minimize received noise, since the receive levels for signals that do manage to bounce off the Moon and return to Earth are exceedingly weak.

But HF work is different from moonbounce in that rigorously trying to minimize high-angle lobes is far less crucial at HF, where we've already shown that the main goal is to achieve gain over a wide elevation-plane footprint without any disastrous nulls in the pattern. The gain gradually increases as spacing in terms of wavelength is increased between individual Yagis in a stack, and then decreases slowly once the spacing is greater than about 1.0 λ. The difference in gain between spacings of 0.5 λ to 1.0 λ for a stack of typical HF Yagis amounts to only a fraction of a decibel. Stacking distances on the order of 0.6 λ to 0.75 λ give best gain commensurate with good patterns.

While the stack at 120/60 feet in Fig 32 doesn't have the second-lobe-stronger problem the 120/30-foot stack has, 60 feet between antennas is 1.29 λ, again outside the normal range of HF stack spacings. As a consequence, the 120/60-foot stack doesn't cover the range of elevation angles as well as it could, and is inferior to both the 90/60/30-foot stack and the 120/90/60/30-foot stack. The 120/60-foot two-Yagi stack needs at least one more antenna placed in-between to spread out the elevation-range coverage and to provide more gain.

It could be debated, but the 90/60/30-foot stack seems optimal for coverage of all the angles into Europe from New England on 15 meters. Note that the 30-foot spacing between Yagis is 0.65 λ on 21.2 MHz, right in the middle of the range of typical stack spacings.

Switching Out Yagis in the Stack

Still, the extra gain that is available at low elevation angles from a 120/90/60/30-foot high, four-Yagi stack in Fig 32 is alluring. For those statistically possible, but less likely, occasions when the elevation angle is higher than about 12°, it would be advantageous to switch out the top 120-foot Yagi and operate with only the lower three Yagis in a stack. (This also allows the top antenna to be rotated in another direction, an aspect we'll explore later.) There are even times when the incoming angles are really high and when the top two antennas might be switched out to create a 60/30-foot stack. Later in this chapter we'll explore flexible circuitry for such stack switching.

Stacking Distance and Lobes at HF

Let's look a little more closely at how a stack achieves gain and a wide elevation footprint. **Fig 33** shows a rectangular X-Y graph of the elevation response from 0° to 180° for two 3-element 15-meter Yagis (with 12-foot booms) spaced 30 feet apart (0.65 λ at 21.2 MHz), but mounted at two different heights: 95/65 and 85/55 feet. The rectangular plot gives more resolution than is possible on a polar plot. Note that the heights shown represent typical stacking heights on 15 meters—there's nothing magic about these choices. The free-space H-Plane pattern for the 30-foot spaced stack is also shown for reference.

The worst-case overhead elevation lobe, which ranges from about 60° to 120° in elevation (±30° from straight overhead at 90°), is about 14.7 dB down for the 95/65-foot stack. The overhead lobe peaks broadly at an elevation angle of about 82°. The overhead lobe for the lower 85/55-foot stack occurs at an elevation of about 64°, where it is 19 dB down.

The F/B for both 3-element sets of heights is about 15 dB, well down from the excellent 32 dB F/B for each Yagi by itself. The degradation of F/B is mainly due to mutual coupling to its neighbor in the stack.

The ground-reflection pattern in effect "modulates" the free-space pattern of the individual Yagi, but in a complex and not always intuitive manner. This is quite evident for the 85/55-foot stack at near-overhead angles. In this region things become complicated indeed, because the fourth and fifth lobes due to ground reflections are interacting with the free-space pattern of the stack.

Because the spacing remains constant at 30 feet for

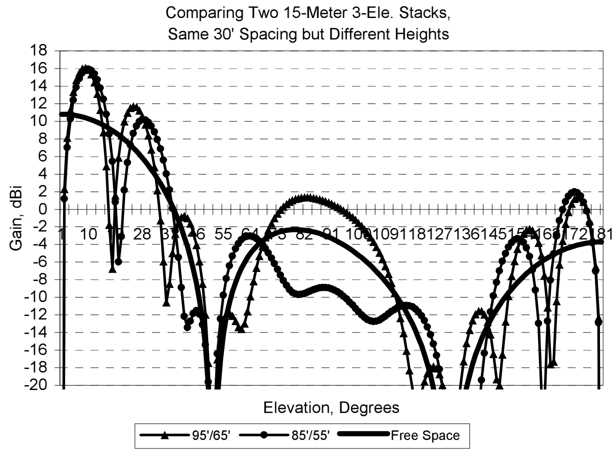

Fig 33—Rectangular plot comparing two 15-meter stacks of 3-element Yagis—each antenna is spaced 30 feet from its partner, but at different heights. The lobes are a complicated function of the antenna height, not the spacing, since that remains constant.

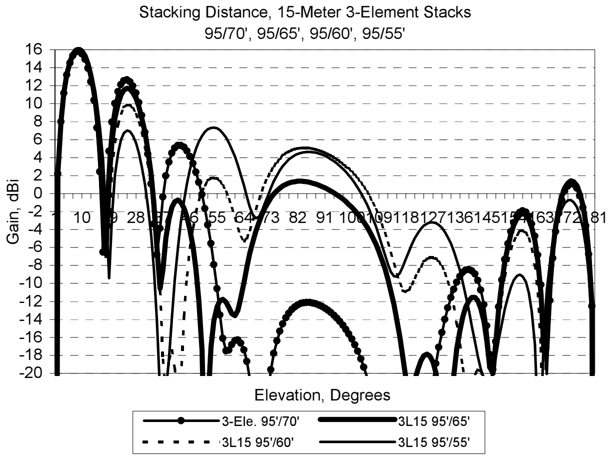

Fig 34—Four spacing scenarios for two 3-element 15-meter Yagis. Things get very complicated. The optimal spacing in terms of stacking gain is 30 feet, which is 0.65 λ. The near-overhead lobes turn out to be ugly looking, but unimportant for skywave propagation.

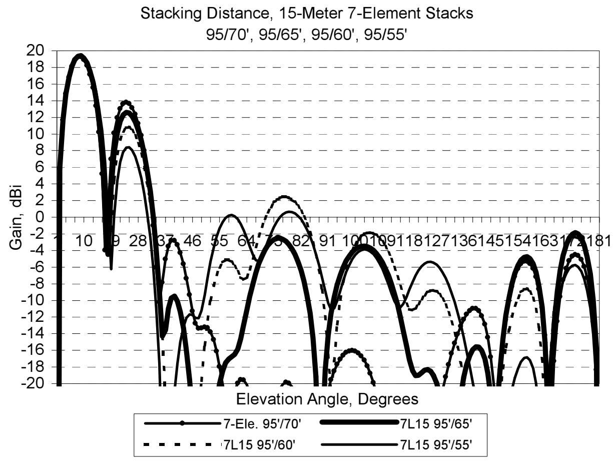

Fig 35—Four spacing scenarios for two large 7-element 15-meter Yagis (on 64-foot booms). Again, a 0.65 λ spacing (30 feet) provides the most stacking gain.

these pairs of antennas, however, the main determinant for the upper-elevation angle lobes is the distance of the horizontally polarized antennas above the ground, not the spacing between them.

Changing the Stack Spacing

Fig 34 demonstrates just how complicated things get for four different spacing scenarios. Here, the lower Yagi in the stack is moved down in 5-foot increments from the 95/70 feet level, to 95/65, 95/60 and 95/55 feet. The closest spacing, 25 feet in the 95/70-foot stack, yields nominally the "cleanest" pattern in the overhead region from 60° to 120°. The worst-case overhead lobe for the 95/70-foot stack is down 28 dB from peak. The F/B is again about 15 dB.

The worst case overhead lobe for the widest spacing, 40 feet in the 95/55-foot stack, is about 11 dB down from peak. The F/B has increased marginally, but is still only about 16 dB. It is difficult to pinpoint directly whether the spacing or the height above ground is the major determinant for the various lobe amplitudes for the 3-element stack. We'll soon look closely at whether the overhead lobe is important or not for HF work.

Longer Boom Length and Stack Spacing

Fig 35 shows the same type overlay of elevation plots, but this time for two 7-element 15-meter Yagis on gigantic 64-foot booms. These Yagis are also spaced 30 feet apart (0.65 λ at 21.2 MHz), mounted at the same four sets of heights in Fig 34. As you'd expect, the free-space elevation pattern for a stacked pair of 7-element Yagis on 64-foot booms is narrower than that for a stacked pair of 3-element Yagis on 12-foot booms. The intrinsic F/B of the longer Yagi is also better than the F/B of the shorter antenna. As a result, all lobes beyond the main lobe of the stacked 7-element pair are lower for both sets of heights than their 3-element counterparts. The worst-case overhead lobe for the 7-element 95/65-foot pair is about 22 dB down at 76° and the F/B at 172° is greater than 21 dB for all four sets of heights.

Table 11 summarizes the main performance characteristics for four sets of stacked Yagis. The first entry for each boom length is for the Yagi by itself at a height of 95 feet. Stacked configurations are next listed in order of gain. The column labeled "Worst lobe, dB re Peak" is the

Table 11
Example, Spacing Between 15–Meter Yagis

Antenna	*Peak Gain dBi*	*Worst Lobe dB re Peak*	*Worst Lobe Angle,°*	*F/B dB*	*Overhead Lobe dB re Peak*
3–Ele., 12' boom					
By itself 95'	13.2	–0.9	21	28.8	–17.5
95'/65' (Δ 30')	16.08	–4.5	25	14.9	–14.7
95'/60' (Δ 35')	16.01	–6.2	24	15.1	–10.9
95'/70' (Δ 25')	15.81	–3.2	24	14.8	–28
95'/55' (Δ 40')	15.71	–8.7	24	16.4	–11
95'/75' (Δ 20')	15.34	–2.3	23	16.3	–17.2
4–Ele., 18' boom					
By itself 95'	13.92	–1	21	28.3	–20.4
95'/65' (Δ 30')	16.63	–4.5	23	18.5	–17.3
95'/60' (Δ 35')	16.6	–6.2	24	18.2	–13.1
95'/55' (Δ 40')	16.36	–8.7	24	19.8	–13.2
95'/70' (Δ 25')	16.36	–3.3	24	20.4	–31.8
95'/75' (Δ 20')	15.92	–2.5	23	25.9	–19
5–Ele., 23' boom					
By itself 95'	14.26	–1.1	21	27.9	–22.3
95'/65' (Δ 30')	16.86	–4.6	24	20.8	–19
95'/60' (Δ 35')	16.86	–6.3	24	20.7	–14.4
95'/55' (Δ 40')	16.67	–8.8	24	23.5	–14.4
95'/70' (Δ 25')	16.59	–3.4	24	24.9	–34.4
95'/75' (Δ 20')	16.18	–2.6	23	34.3	–20.2
7–Ele., 64' boom					
By itself 95'	17.93	–2.2	21	28.9	–17.1
95'/65' (Δ 30')	19.39	–6.9	24.3	21.4	–21.9
95'/60' (Δ 35')	19.38	–8.6	24	21.4	–16.9
95'/55' (Δ 40')	19.29	–10.9	24	25.0	–18.6
95'/70' (Δ 25')	19.26	–5.5	23	24	–35.3
95'/75' (Δ 20')	19.08	–4.6	23	27	–23.4

amplitude of the second lobe due to ground reflections, and the elevation angle of that second lobe is listed as well.

Besides the 3- and 7-element designs discussed above, we've also added 4- and 5-element designs in Table 11. Over the range of stacking distances between 20 and 40 feet on 15 meters (0.43 λ to 0.86 λ), the peak gain for the 3-element stacks changes less than 0.75 dB, with the 30-foot spacing exhibiting the highest gain. The differences between peak gains versus stacking distance become smaller as the boom length increases. For example, for the 64-foot boom Yagi, the gain varies 19.39 – 19.08 = 0.31 dB for stack spacings from 20 to 40 feet.

In other words, changing the spacing from 20 to 40 feet (0.43 λ to 0.86 λ) doesn't change the gain significantly for boom lengths from 12 to 64 feet (0.26 λ to 1.38 λ). From the point of view of gain, the vertical spacing between individual antennas in an HF stack is not critical.

The worst-case lobes (generally speaking, the second lobe due to ground reflections) are highest for a Yagi operated by itself. After all, a single Yagi doesn't benefit from the redistribution of energy from higher-angle lobes into the main lobe that a stack gives. Thus, the 3-element, 12-foot boom Yagi by itself at 95 feet would have a second lobe at 21° that is only 0.9 dB down from the main lobe, while the stack of two such antennas at a 30-foot (0.65 λ) spacing at 95/65 feet would have a second lobe down 4.5 dB. As the spacing between antennas in a vertical stack increases, the second lobe is suppressed more, up to 8.7 dB at a 40-foot (0.86 λ) spacing.

Since the free-space elevation pattern for a 3-element Yagi is wider than that for a 7-element Yagi, the second lobe due to ground reflection will be somewhat reduced. This is true for all longer-boom antennas operating by themselves over ground. Used in stacks, the second lobe's amplitude will vary depending on spacing between antennas, but they range only about 6 dB.

The front-to-back ratio will also tend to increase with longer boom lengths on a properly designed Yagi. Table 11 shows that the F/B is somewhat better for closer spacings between antennas in a stack, a rather non-intuitive result, considering that the mutual coupling should be greater for closer antennas. For example, the 5-element Yagi stack with a 20-foot spacing has a exceptional F/B of 34.3 dB, compared to a F/B of 21.4 dB with the 30-foot spacing distance that gives nominally the most gain. High values of F/B, however, rarely hold over a wide frequency range because of the very critical phasing relationships necessary to get a deep null, so the difference between 34.3 and 21.4 dB would rarely be noticeable in practice.

The near-overhead lobe structure (between 60º to 120º in elevation) tends also to be lower for smaller stack spacings—for all boom lengths—peaking in this example at a spacing of 25 feet for the boom lengths considered here. Since the peak gain actually occurs with smaller spacing between Yagis in this 7-element stack, even relatively large and messy looking overhead lobes are not subtracting from the stacking gain. In the next section we'll now examine whether this overhead lobe is important or not.

Are Higher-Angle Lobes Important?

We've already shown that the exact spacing between HF Yagis is not critical for stacking gain. Further, the heights (and hence spacing) of the individual Yagis in a stack interact in a complicated fashion to determine higher-angle lobes.

Let's examine the relevance of such higher-angle lobes for stacked HF Yagis, this time in terms of interference reduction on receive. As Chapter 23, Radio Wave Propagation, points out, few DX signals arrive at elevation angles greater than about 30°. In fact, DX signals only propagate at elevation angles in the range from 1° to 30° on all the bands where operators might reasonably expect to stack Yagis—nominally from 7 to 29.7 MHz.

You should remember that the definition of the *critical frequency* for HF propagation is the highest frequency for which a wave launched directly overhead at 90° elevation is reflected back down to Earth, rather than being lost into outer space. The maximum critical frequency for extremely high levels of solar flux is about 15 MHz. In other words, high overhead angles do not propagate signals on the upper HF bands.

However, some domestic signals do arrive at relatively high elevation angles. Let's look at some scenarios where higher angles might be encountered and how the elevation patterns of typical HF stacks affect these signals. Let's examine a situation where a medium-range interfering station is on the same heading as a more distant target station.

We'll examine a typical scenario involving stations in Atlanta, Boston and Paris. The heading from Atlanta to Paris is 49º, the same heading as Atlanta to Boston. In other words, the Atlanta station would have to transmit over (and listen through) a Boston station for communication with Paris. The distance between Atlanta and Boston is about 940 miles, while the distance from Atlanta to Paris is about 4350 miles. Ground wave signals obviously cannot travel either of these distances at 21 MHz (ground wave coverage is less than about 10 miles at this frequency), and so the propagation between Atlanta to Boston and Atlanta to Paris will be entirely by means of the ionosphere.

Let's evaluate the situation on 15 meters in the month of October. We'll assume a smoothed sunspot number (SSN) of 100 and that each station puts 1500 W of power into theoretical isotropic antennas that have +10 dBi of gain at all elevation and azimuth angles. [We use such theoretical isotropic antennas because they make it easier to work in *VOACAP*. We will factor in real-world stacks later.] *VOACAP* predicts that the signal from Boston will be S9 + 8 dB in Atlanta at 1400 UTC, arriving at an elevation angle of 21.3º on a single F_2 hop. This elevation angle is higher than commonly encountered angles for DX signals, but it is still far away from near-overhead angles.

The signal from Paris into Atlanta is predicted to be about S6 for the same theoretical isotropic antennas, at an incoming elevation angle of 6.4º on three F_2 hops. The S6 level validates the rule-of-thumb that each extra hop loses approximately 10 dB of signal strength, assuming that each S unit is about 4 dB, typical for modern receivers.

Now look at **Fig 36**, which shows the response for a stack of 3-element Yagis at 90/60/30 feet over flat ground, along with the response for a similar stack of 7-element Yagis. Again, we'll assume that all three stations are using such 3-element 90/60/30-foot stacks. The stations in Atlanta and Boston point their stacks into Europe and the Parisian station points his stack towards the USA. The gain of the Atlanta array at 6.4º into Paris will be about 16 dBi, or 6 dB more than the isotropic array with its +10 dBi of gain selected for use in *VOACAP*. Similarly, the French station's transmitted signal will enjoy a 6 dB gain advantage over the isotropic array used in the *VOACAP* calculation, and thus the French signal into Atlanta will now be S6 + 12 dB, or about S9.

By comparison, the interfering signal from Boston into Atlanta will be reduced by the rearward pattern of his array, which will launch a signal at 180º – 21.3º = 158.7º in elevation at the single F_2 mode from Boston to Atlanta. From Fig 33, the Boston station's gain at this rearward elevation is going to drop from the isotropic's +10 dBi of gain down to –11 dBi, a drop of 21 dB. The signal into the Atlanta receiver will also be reduced by the pattern of the Atlanta array on receive, which has a gain of about 0 dBi at 21.3º, compared to the isotropic's +10 dBi gain at 6.4º, a net drop of 10 dB.

Thus, the Boston station's signal will drop by about 21 + 10 = 31 dB, bringing the interfering signal from Boston, which would be S9 + 8 dB for isotropic antennas, down to about S3 due to the combined effects of the arrays. This is a very significant reduction in interference. But you will note that the reduction has nothing to

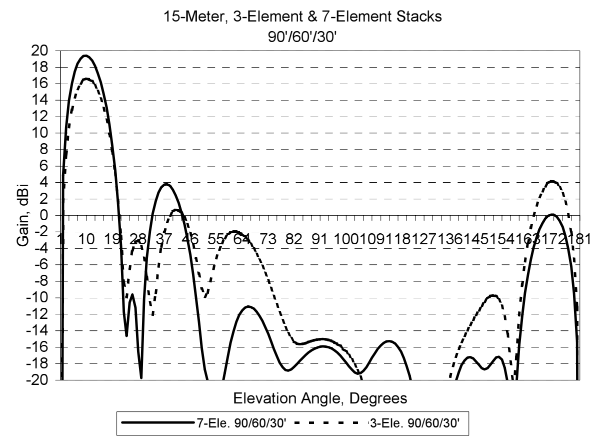

Fig 36—Stacks of three 3-element and 7-element Yagis on 15 meters at 90/60/30 feet heights. The F/B for the 7-element stack is superior to the 3-element stack mainly because the F/B is intrinsically better for the long-boom design.

do with the near-overhead lobes, dealing as it does with the trailing edge of the main lobe and the F/B lobe.

Even Higher Elevation Angles

Now let's evaluate a station that is even closer to Boston, say a station in Philadelphia. The heading from Philadelphia to Paris is 53º and the distance is 3220 miles. On the same day in October as above, *VOACAP* predicts a signal strength of S8 from Paris to Philadelphia, at a 2.7º elevation angle on two F_2 hops. Again, the *VOACAP* computations assume isotropic antennas with +10 dBi gain at all three stations. The gain of the 3-element stacks at both ends of the circuit at 2.7º is also about +10 dBi, so the signal level from Paris to Philadelphia would be S8 with the 3-element stacks.

Now *VOACAP* computes the elevation angle from Philadelphia to Boston as 56.3º, on one F_2 hop launched at an azimuth of 53º, well within the azimuthal beamwidth of the stack. *VOACAP* says the predicted signal strength for isotropic antennas with +10 dBi of gain is less than S1!

What's happening here? Boston and Philadelphia are within the "skip" region on 21 MHz and signals are skipping right over Boston from Philadelphia (and vice versa). Actual signals would be much weaker than they would be with theoretical isotropic antennas because of the actual patterns of the transmitting and receiving stacks. At an elevation angle of 56.3º the receiving stack would have a gain of –10 dBi, while at an elevation of 180º – 56.3º = 123.7º the transmitting stack would be down to –10 dBi as well. The net reduction for the stacks compared to isotropics with +10 dBi gain each would be 40 dB, putting the interfering signal well into the receiver noise.

You can safely say that near-overhead angles don't enter into the picture, simply because signals at intermediate distances are in the ionospheric skip zone and interfering signals are very weak in that zone already.

Even in situations where having a poor front-to-back ratio might be beneficial—because it alerts stations tuning across your signal that you are occupying that frequency—the ionosphere doesn't cooperate for intermediate-distance signals that are in the skip zone. Often two stations may be on the same frequency without either knowing that the other is there.

Ground Wave?

What happens, you might wonder, for ground-wave signals? Let's look at a situation where the interfering station is in the same direction as the desired target, but is only 5 miles away. Unfortunately, his signal is S9 + 50 dB. Even reducing the level by 30 dB, a huge number, is still going to make his signal 20 dB stronger than signals from your desired target location! There is not much you can do about ground-wave signals and fretting about optimizing stack heights to discriminate against local signals is generally futile.

Stacking Distances for Multiband Yagis

By definition, a stack of multiband Yagis (such as a "tribander" covering 20/15/10 meters) has a constant vertical spacing between antennas in terms of feet or meters, but not in terms of wavelength. Tribanders are no different than monobanders in terms of optimal spacing between individual antennas. Again, the difference in gain between spacings of 0.5 λ and 1.0 λ for a stack of triband Yagis amounts to only a fraction of a decibel. Furthermore, the main practical constraint that limits choice of stacking distances between any kind of Yagis, multiband or monoband, is the spacing between guy wire sets on the tower itself.

Summary, Stacking Distances

In short, let us summarize that there is nothing magical about stacking distances for practical HF Yagis—a good rule-of-thumb is a stacking distance of 0.65 λ. This is 23 feet on 10 meters, 30 feet on 15 meters and 45 feet on 20 meters for monoband stacks. Practically speaking, however, you've only got limited places where you can mount antennas on the tower—mainly where guy wires allow you to place them. This is especially applicable if you wish to rotate lower antennas on the tower, where you must clear the guys from up above.

STACKS AND FADING

The following is derived from an article by Fred Hopengarten, K1VR, and Dean Straw, N6BV, in a Feb 1994 *QST* article. Using stacked Hy-Gain TH7DXs or TH6DXXs at their respective stations, they have solicited a number of reports from stations, mainly in Europe, to compare various combinations of antennas in stacks and as single antennas. The peak gain of the stack is usually just a little bit higher than that for the best of the single antennas, which is not surprising. Even a large stack has no more than about 6 dB of gain over a single Yagi at a height favoring the prevailing elevation angle. Fading on the European path can easily be 20 dB or more, so it is very confusing to try to make definitive comparisons. They have noticed over many tests that the stacks are much less susceptible to fading compared to single Yagis. Even within the confines of a typical SSB bandwidth, frequency-selective fading occasionally causes the tonal quality of a voice to change on both receive and transmit, often dramatically becoming fuller on the stacks, and tinnier on the single antennas. This doesn't happen all the time, but is often seen. They have also observed often that the depth of a fade is less, and the period of fading is longer, on the stacks compared to single antennas.

Exactly *why* stacks exhibit less fading is a fascinating subject, for which there exist a number of speculative ideas, but little hard evidence. Some maintain that stacks outperform single antennas because they can afford *space diversity* effects, where by virtue of the difference in physical placement one antenna will randomly pick up signals that another one in another physical location might not hear.

This is difficult to argue with, and equally difficult to prove scientifically. A more plausible explanation about why stacked Yagis exhibit superior fading performance is that their narrower frontal elevation lobes can discriminate against undesired propagation modes. Even when band conditions favor, for example, a very low 3° elevation angle on 10 or 15 meters from New England to Western Europe, there are signals, albeit weaker ones, that arrive at higher elevation angles. These higher-angle signals have traveled longer distances on their journey through the ionosphere, and thus their signal levels and their phase angles are different from the signals traversing the primary propagation mode. When combined with the dominant mode, the net effect is that there is both destructive and constructive fading. If the elevation response of a stacked antenna can discriminate against signals arriving at higher elevation angles, then in theory the fading will be reduced. Suffice it to say: In practice, stacks do reduce fading.

STACKS AND PRECIPITATION STATIC

The top antenna in a stack is often much more affected by rain or snow precipitation static than is the lower antenna. N6BV and K1VR have observed this phenomenon, where signals on the lower antenna by itself are perfectly readable, while S9+ rain static is rendering reception impossible on the higher antenna or on the stack. This means that the ability to select individual antennas in a stack can sometimes be extremely important.

STACKS AND AZIMUTHAL DIVERSITY

Azimuthal diversity is a term coined to describe the situation where one of the antennas in a stack is purposely pointed in a direction different from the main direction of the stack. During most of the time in a DX contest from the East Coast, the lower antennas in a stack are pointed into Europe, while the top antenna is often rotated toward the Caribbean or Japan. In a stack of three identical Yagis, the first-order effect of pointing one antenna in a different direction is that one-third of the transmitter power is diverted from the main target area. This means that the peak gain is reduced by 1.8 dB, not a very large amount considering that signals are often 10 to 20 dB over S9 anyway when the band is open from New England to Europe.

Fig 37 shows the 3D pattern of a pair of 4-element Yagis fed in-phase at 95 and 65 feet, but where the lower antenna has been rotated 180° to fire in the –X direction. The backwards lobe peaks at a higher elevation angle because the antenna doing the radiating in this direction is lower on the tower. The forward lobe peaks at a lower angle because its main radiator is higher.

THE N6BV/1 ANTENNA SYSTEM—BRUTE FORCE FEEDING

The N6BV/1 system in Windham, New Hampshire, was located on the crest of a small hill about 40 miles from Boston, and could be characterized as a good, but not dominant, contesting station. A number of top-10 contest results were achieved from that station in the 1990s before N6BV returned to California.

There was a single 120-foot high Rohn 45 tower, guyed at 30-foot intervals, with a 100-foot horizontal spread from tower base to each guy point so there was sufficient room for rotation of individual Yagis on the tower. Each set of guy wires employed heavy-duty insulators at 57-foot intervals, to avoid resonances in the 80 through 10-meter amateur bands. There were five Yagis on the tower. A heavy-duty 12-foot long steel mast with 0.25-inch walls was at the top of the tower, turned by an Orion 2800 rotator. Two thrust bearings were used above the rotator, one at the top plate of the tower itself, and the other about 2 feet down in the tower on a modified rotator shelf plate. The two thrust bearings allowed the rotator to be removed for service.

At the top of the mast, 130 feet high, was a 5-element, computer-optimized 10-meter Yagi, which was a modified Create design on a 24-foot boom. The element tuning was modified from the stock antenna in order to achieve higher gain and a better pattern over the band. At the top of the tower (120-foot level) was mounted a Create 714X-3 triband Yagi. This was a large tribander, with a 32-foot boom and five elements. Three elements were active on 40 meters, four were active on 20 meters and four were active on 15 meters. The 40-meter elements were loaded with coils, traps and

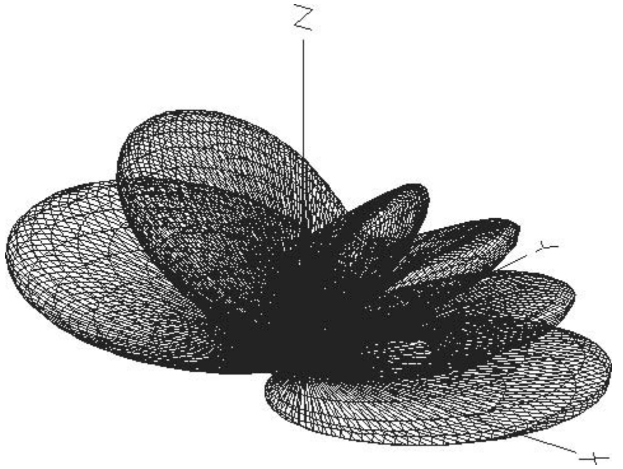

Fig 37—3D representation of the pattern for two 4-element 15-meter Yagis, with the top antenna at 95 and the bottom at 65 feet, but pointed in the opposite direction.

capacitance hats, and were approximately 46 feet long. A triband 20/15/10-meter Hy-Gain TH7DX tribander was fixed into Europe at the 90-foot level on the tower, just above the third set of guys.

At the 60-foot level on the tower, just above the second set of guys, there was a "swinging-gate" side-mount bracket, made by DX Engineering of Oregon. A Hy-Gain *Tailtwister* rotator turned a TH7DX on this side mount. (Note that both the side mount and the element spacings of the TH7DX itself prevented full rotation around the tower—about 280° of rotation was achieved with this system.) At the 30-foot level, just above the first set of guys, was located the third TH7DX, also fixed on Europe.

All five Yagis were fed with equal lengths of Belden 9913 low-loss coaxial cable, each measured with a noise bridge to ensure equal electrical characteristics. At each feed point a ferrite-bead choke balun (using seven large beads) was placed on the coax. All five coaxial cables went to a relay switch box mounted at the 85-foot level on the tower. **Fig 38** shows the schematic for the switch box, which was fed with 250 feet of 75-Ω, 0.75-inch OD Hardline coaxial cable.

The stock DX Engineering remote switch box was modified by adding relay K6, so that either the 130-foot or the 120-foot rotating antenna could be selected through a second length of 0.75-inch Hardline going to the shack. This created a *Multiplier* antenna, independent of the *Main* antennas. A second band could be monitored in this fashion while calling CQ using the main antennas on another band. Band-pass filters were required at the multiplier receiver to prevent overload from the main transmitter.

The 0.75-inch Hardline had very low losses, even when presented with a significant amount of SWR at the switch-box end. This was important, because unlike K1VR's system, no attempt was made at N6BV to maintain a constant SWR when relays K1 through K5 were switched in or out. This seemingly cavalier attitude came about because of several factors. First, there were many

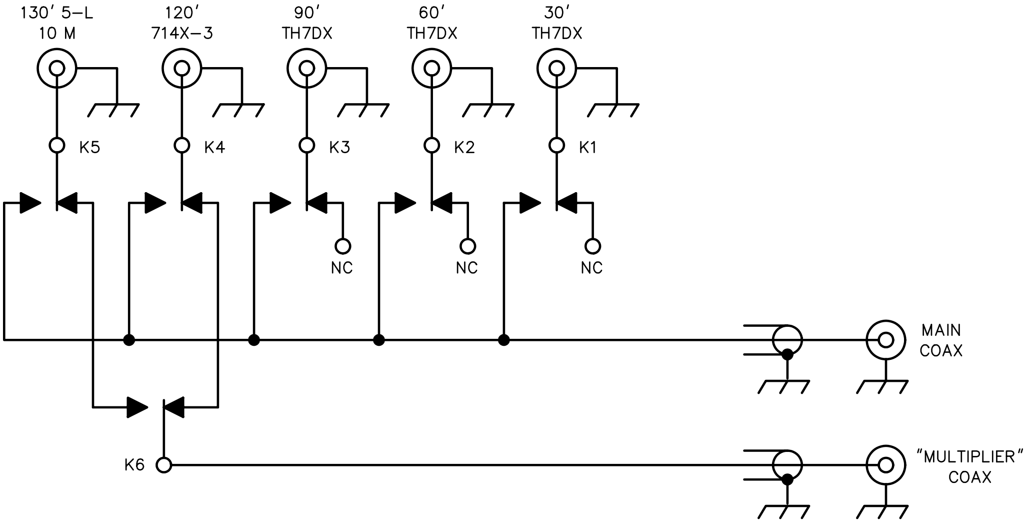

Fig 38—N6BV/1 switch box system. This uses a modified DX Engineering remote switch box, with relay K6 added to allow selection of either of the two top antennas (5-element 10-meter Yagi or 40/20/15-meter triband 714X-3) as a "multiplier" antenna. There is no special provision for SWR equalization when any or all of the Yagis are connected in parallel as a stack fed by the Main coaxial cable. Each of the five Yagis is fed with equal lengths of flexible Belden 9913 coax, so phasing can be maintained on any band. The Main and "Multiplier" coaxes going to the shack are 0.75" OD 75-Ω Hardline cables.

different combinations of antennas that could be used together in this system. Each relay coil was independently controlled by a toggle switch in the shack. N6BV was unable to devise a matching system that did not become incredibly complex because of the numerous impedance combinations used over all the five bands.

Second, the worst-case additional transmission line loss due to a 4:1 SWR mismatch when four antennas were connected in parallel on 10 meters was only 0.5 dB. It was true that the linear amplifier had to be retuned slightly when combinations of antennas were switched in and out, but this was a small penalty to pay for the reduced complexity of the switching and matching networks. The 90/60/30-foot stack into Europe was used for about 95% of the time during DX contests, so the small amount of amplifier retuning for other antenna combinations was considered only a minor irritation.

WHY TRIBANDERS?

Without a doubt, the most common question K1VR and N6BV have been asked is: "Why did you pick *tribanders* for your stacks?" Triband antennas were chosen with full recognition that they are compromise antennas. Other enterprising amateurs have built stacked tribander arrays. Bob Mitchell, N5RM, is a prominent example, with his so-called *TH28DX* array of four TH7DX tribanders on a 145-foot-high rotating tower. Mitchell employed a rather complex system of relay-selected tuned networks to choose either the upper stacked pair, the lower stacked pair or all four antennas in stack. Others in Texas have also had good results with their tribander stacks. Contester Danny Eskenazi, K7SS, has very successfully used a pair of stacked KT-34XA tribanders for years.

A major reason why tribanders were used is that over the years both authors have had good results using TH6DXX or TH7DX antennas. They are ruggedly built, mechanically and electrically. They are able to withstand New England winters without a whimper, and their 24-foot long booms are long enough to produce significant gain, despite trap-loss compromises. Amateurs speculating about trap losses in tribanders freely bandy about numbers between 0.5 and 2 dB. Both N6BV and K1VR are comfortable with the lower figure, as are the Hy-Gain engineers.

Consider this: If 1500 W of transmitter power is going into an antenna, a loss of 0.5 dB amounts to 163 W. This would create a significant amount of heat in the six traps that are on average in use on a TH6DXX, amounting to 27 W per trap. If the loss were as high as 1 dB, this would be 300 W total, or 50 W per trap. Common sense says that if the overall loss were greater than about 0.5 dB, the traps would act more like big *firecrackers* than resonant circuits! A long-boom tribander like the TH6DXX or TH7DX also has enough space to employ elements dedicated to different bands, so the compromises in element spacing usually found on short-boom 3 or 4-element tribanders can be avoided.

Another factor in the conscious choice of tribanders was first-hand frustration with the serious interaction that can result from stacking monoband antennas closely together on one mast in a Christmas Tree configuration. N6BV's worst experience was with the ambitious 10 through 40-meter Christmas Tree at W6OWQ in the early 1980s. This installation used a Tri-Ex SkyNeedle tubular crankup tower with a rotating 10-foot-long heavy-wall mast. The antenna suffering the greatest degradation was the 5-element 15-meter Yagi, sandwiched 5 feet below the 5-element 10-meter Yagi at the top of the mast, and 5 feet above the full-sized 3-element 40-meter Yagi, which also had five 20-meter elements interlaced on its 50-foot boom.

The front-to-back ratio on 15 meters was at best about 12 dB, down from the 25+ dB measured with the bottom 40/20-meter Yagi removed. No amount of fiddling with element spacing, element tuning or even orientation of the 15-meter boom with respect to the other booms (at 90° or 180°, for example) improved its performance. Further, the 20-meter elements had to be lengthened by almost a foot *on each end of each element* in order to compensate for the effect of the interlaced 40-meter elements. It was a lucky thing that the tower was a motorized crankup, because it went up and down hundreds of times as various experiments were attempted!

Interaction due to close proximity to other antennas in a short Christmas Tree can definitely destroy carefully optimized patterns of individual Yagis. Nowadays, such interaction can be modeled using a computer program such as *EZNEC* or *NEC*. A gain reduction of as much as 2 to 3 dB can easily result due to close vertical spacing of monobanders, compared to the gain of a single monoband antenna mounted in the clear. Curiously enough, at times such a reduction in gain can be found even when the front-to-back ratio is not drastically degraded, or when the front-to-back occasionally is actually *improved*.

If you plan on stacking monoband Yagis—for example, putting only 15-meters Yagis on a single tower, with your other monoband stacks on other towers—do make sure you model the system to see if any interactions occur. You may be quite surprised.

Finally, in the N6BV/1 installation, triband antennas were chosen because the system was meant to be as simple as possible, given a certain desired level of performance, of course. Triband antennas make for less mechanical complexity than do an equivalent number of monobanders. There were five Yagis on the N6BV/1 tower, yielding gain from 40 to 10 meters, as opposed to using 12 or 13 monobanders on the tower.

THE K1VR ARRAY: A MORE ELEGANT APPROACH TO MATCHING

The K1VR stacked array is on a 100-foot high Rohn

25 tower, with sets of guy wires at 30, 60 and 90 feet, made of nonconducting Phillystran. Phillystran is a nonmetallic Kevlar rope covered by black polyethylene to protect against the harmful effects of the sun's ultraviolet rays. A caution about Phillystran: Don't allow tree branches to rub against it. It is designed to work in tension, but unlike steel guy wire, it does not tolerate abrasion well.

Both antennas are Hy-Gain TH6DXX tribanders, with the top one at 97 feet and the bottom one at 61 feet. The lower antenna is rotated by a Telex Ham-M rotator on a homemade swinging-gate side mount, which allows it to be rotated 300° around the tower without hitting any guy wires or having an element swing into the tower. At the 90-foot point on the tower, a 2-element 40-meter Cushcraft Yagi has been mounted on a RingRotor so it can be rotated 360° around the tower.

After several fruitless attempts trying to match the TH6DXX antennas so that either could be used by itself or together in a stack, K1VR settled on using a relay-selected broadband toroidal matching transformer. When both triband antennas are fed together in parallel as a stack, it transforms the resulting 25-Ω impedance to 50 Ω. The transformer is wound on a T-200A powdered-iron core, available from Amidon, Palomar Engineering or Ocean State Electronics. Two lengths of twin RG-59 coax (sometimes called Siamese or WangNet), four turns each, are wound on the core. Two separate RG-59 cables could be used, but the Siamese-twin cable makes the assembly look much more tidy. The shields of the RG-59 cables are connected in series, and the center conductors are connected in parallel. See **Fig 39** for details.

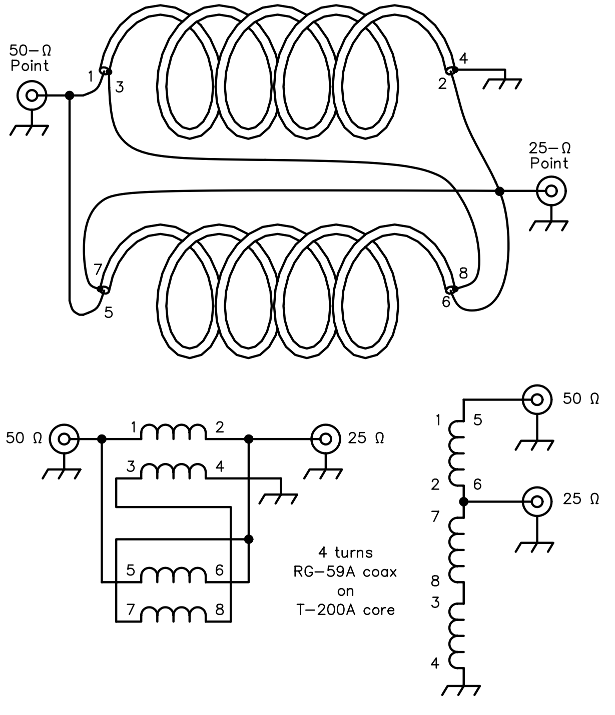
50-Ω Point
1
3
4
2
25-Ω Point
7
8
5
6
50 Ω
1
2
25 Ω
3
4
5
6
7
8
4 turns RG-59A coax on T-200A core
1
5
50 Ω
2
6
25 Ω
7
8
3
4

Fig 39—Diagram for matching transformer for K1VR stacked tribander system. The core is powdered iron-core T-200A, with four turns of two RG-59A or "Siamese" coax cables. Center conductors are connected in parallel and shields are connected in series to yield 0.667:1 turns ratio, close to desired 25-Ω to 50-Ω transformation.

Fig 40 shows the schematic of the K1VR switch box, which is located in the shack. Equal electrical lengths of 50-Ω Hardline are brought from the antennas into the shack and then to the switch box. Inside the box, the relay contacts were soldered directly to the SO-239 chassis connectors to keep the wire lengths down to the absolute minimum. K1VR used a metal box that was larger than

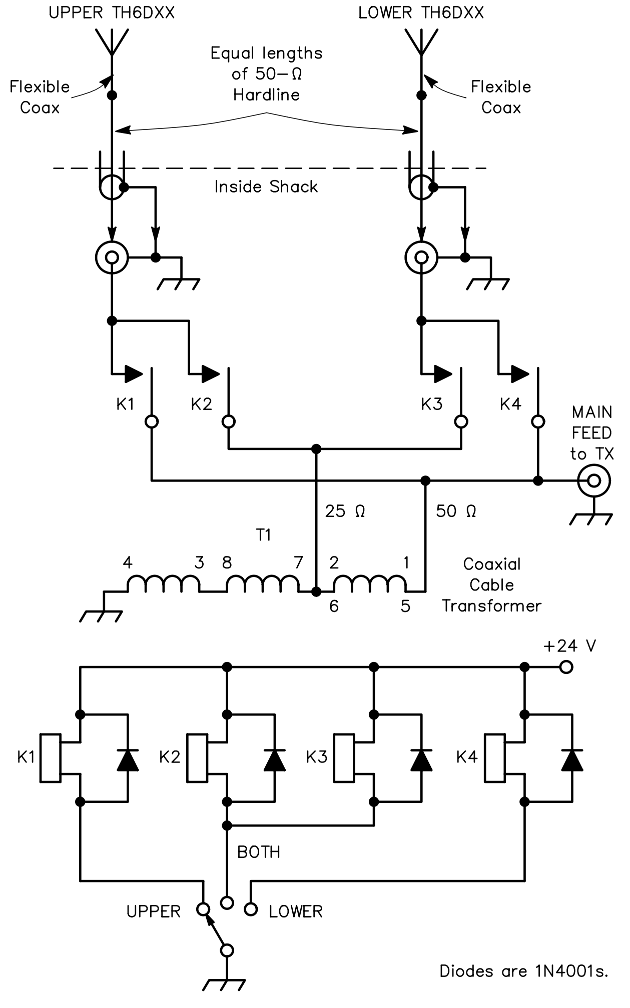
UPPER TH6DXX
LOWER TH6DXX
Equal lengths of 50-Ω Hardline
Flexible Coax
Flexible Coax
Inside Shack
K1
K2
K3
K4
MAIN FEED to TX
25 Ω
50 Ω
T1
4
3
8
7
2
1
6
5
Coaxial Cable Transformer
+24 V
K1
K2
K3
K4
BOTH
UPPER
LOWER
Diodes are 1N4001s.

Fig 40—Relay switch box for K1VR stacked tribander system. Equal lengths of 50-Ω Hardline (with equal lengths of flexible 50-Ω cable at each antenna to allow rotation) go to the switch box in the shack. The SWR on all three bands for Upper, Lower or Both switch positions is very close to constant.

might appear necessary because he wanted to mount the toroidal transformer with plenty of clearance between it and the box walls. The toroid is held in place with a piece of insulation foam board. Before placing the switch box in service, the system was tested using two 50-Ω dummy loads, with equal lengths of cable connected in parallel to yield 25 Ω. The maximum SWR measured was 1.25:1 at 14 MHz, 1.3:1 at 21 MHz and 1.15:1 at 28 MHz, and the core remained cold with 80 W of continuous output power.

One key to the system performance is that K1VR made the electrical lengths of the two hardlines the same (within 1 inch) by using a borrowed TDR (time domain reflectometer). Almost as good as Hardline, K1VR points out, would be to cut exactly the same length of cable from the same 500-foot roll of RG-213. This eliminates manufacturing tolerances between different rolls of cable.

K1VR's experience over the last 10 years has been that at the beginning of the 10 or 15-meter morning opening to Europe the upper antenna is better. Once the band is wide open, both antennas are fed in phase to cast a bigger shadow, or footprint, on Europe. By mid-morning, the lower antenna is better for most Europeans, although he continues to use the stack in case someone is hearing him over a really long distance path throughout Europe. He reports that it is always very pleasant to be called by a 4S7 or HS0 or VU2 when he is working Europeans at a fast clip!

SOME SUGGESTIONS FOR STACKING TRIBANDERS

It is unlikely that many amateurs will try to duplicate exactly K1VR's or N6BV's contest setups. However, many hams already have a tribander on top of a moderately tall tower, typically at a height of about 70 feet. It is not terribly difficult to add another, identical tribander at about the 40-foot level on such a tower. The second tribander can be pointed in a fixed direction of particular interest (such as Europe or Japan), or it can be rotated around the tower on a side mount or a Ring Rotor. If guy wires get in the way of rotation, the antenna can usually be arranged so that it is fixed in a single direction.

Insulate the guy wires at intervals to ensure that they don't shroud the lower antenna electrically. A simple feed system consists of equal-length runs of surplus 0.5-inch 75-Ω Hardline (or more expensive 50-Ω Hardline, if you are really obsessed by SWR) from the shack up the tower to each antenna. Each tribander is connected to its respective Hardline feeder by means of an equal length of flexible coaxial cable, with a ferrite choke balun, so that the antenna can be rotated.

Down in the shack, the two hardlines can simply be switched in and out of parallel to select the upper antenna only, the lower antenna only, or the two antennas as a stack. See **Fig 41**. Any impedance differences can be handled as stated previously, simply by retuning the linear amplifier, or by means of the internal antenna tuner (included in most modern transceivers) when the transceiver is run barefoot. The extra performance experienced in such a system will be far greater than the extra decibel or two that modeling calculates.

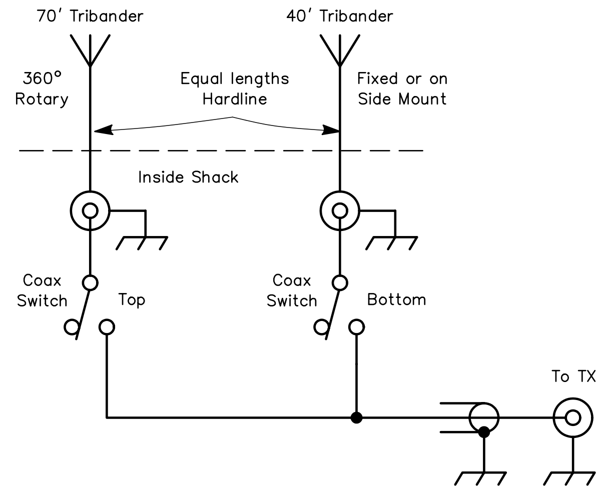

Fig 41—Simple feed system for 70/40-foot stack of tribanders. Each tribander is fed with equal lengths of 0.5-inch 75-Ω Hardline cables (with equal lengths of flexible coax at the antenna to allow rotation), and can be selected singly or in parallel at the operator's position in the shack. Again, no special provision is made in this system to equal SWR for any of the combinations.

THE WX0B APPROACH TO STACK MATCHING AND FEEDING

Earlier we mentioned how useful it would be to switch various antennas in or out of a stack, depending on the elevation angles that need to be emphasized at that moment. Jay Terleski, WX0B, of Array Solutions has designed switchable matching systems, called *StackMatches*, for stacks of monoband or multiband Yagis.

The StackMatch uses a 50-Ω to 22.25-Ω broadband transmission-line transformer to match combinations of up to three Yagis in a stack. See **Fig 42** for a schematic of the StackMatch. For selection of any 50-Ω Yagi by itself, no matching transformer is needed and Relay IN routes RF directly to the common bus going to Relay 1, 2 and 3. For selection of two Yagis together the parallel impedance is 50/2 = 25 Ω and Relay IN routes RF to the matching transformer. The SWR is 25/22.25 = 1.1:1. For three Yagis used together, the parallel impedance is 50/3 = 16.67 Ω, and the SWR is 22.25/16.67 = 1.3:1.

The broadband transformer consists of four trifilar turns of #12 enamel-insulated wire wound on a Ferrite Corporation FT-240 2.4-inch OD core made of #61

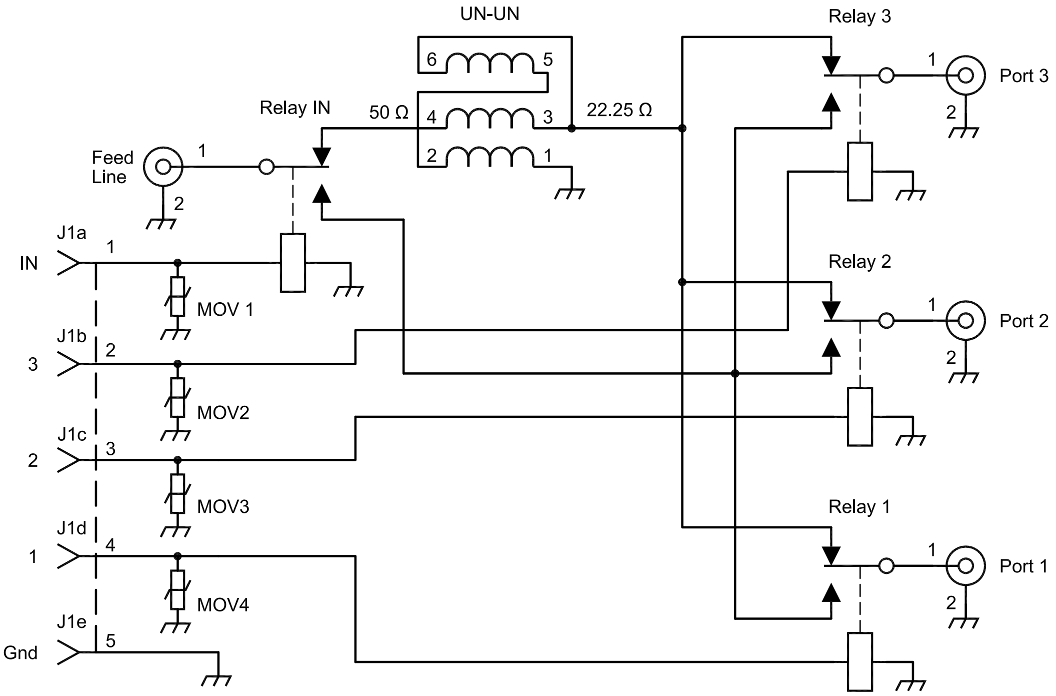

Fig 42—Schematic of WX0B's StackMatch 2000 switchbox, which uses a broadband transmission line transformer using trifilar #12 enamel-insulated wires. (*Courtesy Array Solutions.*)

material ($\mu = 125$). WX0B uses 10-A relays enclosed in plastic cases to do the RF switching, selected by a control box at the operating position. (10-A relays can theoretically handle $10\ A^2 \times 50\ \Omega = 5000$ W.) **Fig 43** shows a photo of the transmission-line transformer and StackMaster PCB.

The control/indicator box uses a diode matrix to switch various combinations of antennas in/out of the stack. Three LEDs lined up vertically on the front panel indicate which antennas in a stack are selected.

"BIP/BOP" OPERATION

The contraction "BIP" means "both in-phase," while "BOP" means "both out-of-phase." BIP/BOP refer to stacks containing two Yagis, although the term is commonly used for stacks containing more than two Yagis. In theory, feeding a stack with the antennas out-of-phase will shift the elevation response higher than in-phase feeding.

Fig 44 shows a rectangular plot comparing BIP/BOP operation of two 3-element 15-meter Yagis at heights of 2 λ and 1 λ (93 and 46 feet) over flat ground. The BOP pattern is the higher-angle lobe and the two lobes cross over about 14°. The maximum amplitude of the BOP stack's gain is about ½ dB less than the BIP pair. For reference, the pattern of a single 46-foot high Yagi is overlaid on the pattern for the stacks.

The most common method for feeding one Yagi 180° out-of-phase is to include an extra electrical half wavelength of feed-line coax going to one of the antennas. This method obviously works on a single frequency band and thus is not applicable to stacks of multiband Yagis, such as tribanders. For such multiband stacks, feeding only the lower antenna(s)—by switching out higher antenna(s) in the stack—is a practical method for achieving better coverage at medium or high elevation angles.

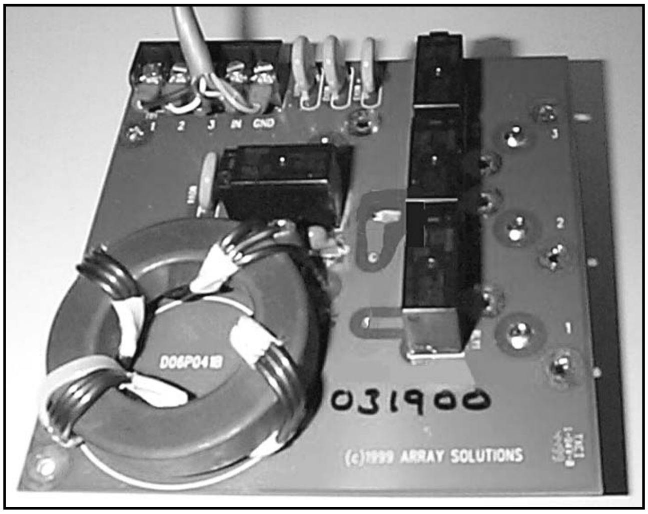

Fig 43—Inside view of StackMatch. (*Photo courtesy Array Solutions.*)

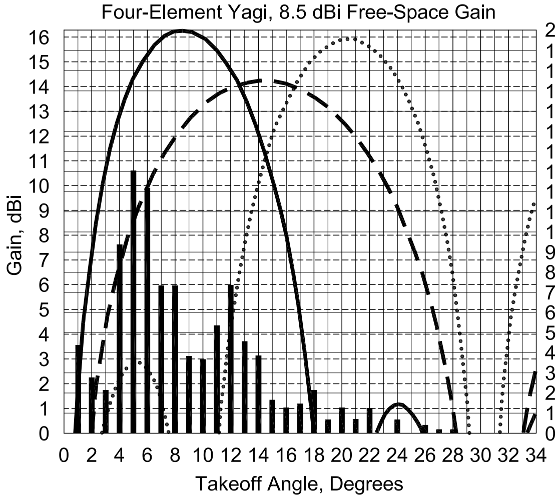

Fig 44—*HFTA* screen shot of "BIP/BOP" operation of two 4-element 15-meter Yagis at 93 and 46 feet above flat ground. The elevation response in BOP (both out-of-phase) operation is shifted higher, peaking at about 21°, compared to the BIP (both in-phase) operation where the peak is at 8°. The dashed line is response of single Yagi at 46 feet.

STACKING DISIMILAR YAGIS

So far we have been discussing vertical stacks of identical Yagis. Less commonly, hams have successfully stacked dissimilar Yagis. For example, consider a case where two 5-element 10-meter Yagis are placed 46 and 25 feet above flat ground, with a 7-element 10-meter Yagi at 68 feet on the same tower. See **Fig 45**, which is a schematic of the layout for this stack. Note that the driven element for the top 7-element Yagi is well behind the vertical plane of the driven elements for the two 5-element Yagis. This offset distance must be compensated for with a phase shift in the drive system for the top Yagi.

Fig 46 shows the elevation-pattern responses for uncompensated (equal-length feed lines) and the compensated (additional 150° of phase shift to top Yagi) stacks. These patterns were computed using *EZNEC ARRL*, which is included with this book. Not only is about 1.7 dB of maximum gain lost, but the peak elevation angle is shifted upwards by 11° from the optimal takeoff angle of 8°—where some 10 dB of gain is also lost. Without compensation, this is a severe distortion of the stack's elevation pattern.

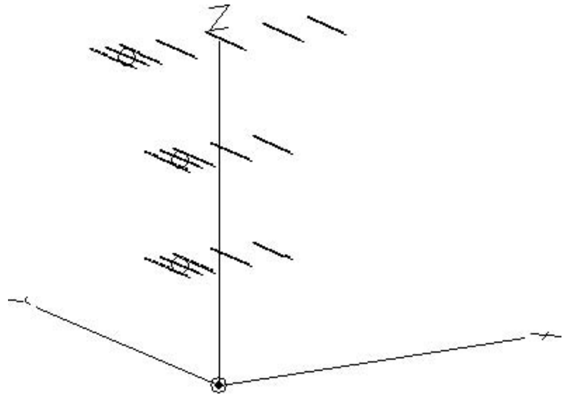

Fig 45—Stacking dissimilar Yagis. In this case a 7-element 10-meter Yagi is stacked over two 5-element Yagis. Note the displacement of the 7-element Yagi's driven element compared to the position of the two 5-element Yagis. This leads to an undesired phase shift for the higher antenna.

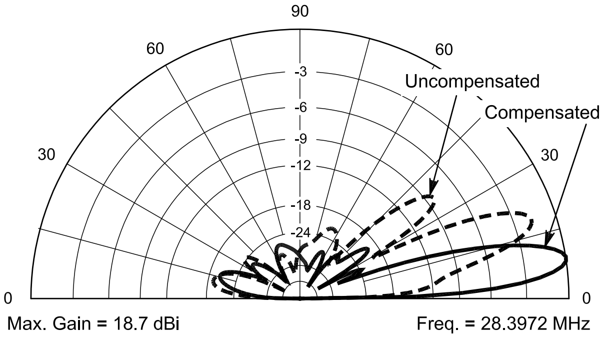

Fig 46—Comparison of elevation responses for 7/5/5-element 10-meter stacks, with and without compensation for driven-element offset.

For RG-213 coax, the extra length needed to provide an additional 150° of phase shift = 150°/360° λ = 0.417 λ = 9.53 feet at 28.4 MHz. This was computed using the program *TLW* (Transmission Line for Windows) included on the CD-ROM accompanying this book.

It is not always possible to compensate for dissimilar Yagis in a stack with a simple length of extra coax, so you should be sure to model such combinations to make sure that they work properly. A safe alternative, of course, is to stack only identical Yagis, feeding all of them with equal lengths of coax to ensure in-phase operation.

Real-World Terrain and Stacks

So far, the stacking examples shown have been for flat ground. Things can become a lot more complicated when you deal with real-world irregular terrains! See Chapter 3, The Effects of Ground, for a description of the *HFTA* (High Frequency Terrain Assessment) program that is included with this book.

Fig 47 shows the *HFTA*-computed 20-meter elevation responses towards Europe (at an azimuth of 45°) for three antennas at the N6BV/1 location in Windham, New Hampshire. Overlaid as a bar graph are the elevation-angle statistics for the path to all of Europe from New England (Massachusetts). The stack at 90/60/30 feet clearly covers all the angles needed best at 14 MHz. The N6BV 120-foot Yagi has a severe null in the region from about 7° to about 20°, with the deepest part of that null occurring at about 13° and is roughly comparable to the 90/60/30-foot stack between 2° to 7°.

In practice, the 120-foot Yagi was indeed comparable to the stack during morning openings to Europe on 20 meters, when the elevation angles are typically about 5°. In the New England afternoon, when the elevation angles typically rise to about 11°, the 120-foot Yagi was always distinctly inferior to the stack.

For reference, the response of a single 120-foot high Yagi over flat ground is also shown. Note that the N6BV 120-foot high Yagi has about 3 dB more gain at a 5° takeoff angle than does its flatland counterpart. This additional gain is due to the focusing effects of the local terrain, which had about a 3° downwards slope towards Europe.

Fig 48 shows the *HFTA*-computed 15-meter elevation responses towards Europe for the 90/60/30-foot stack at 90/60/30 feet at N6BV/1, compared to the same 120-foot high Yagi and a 90/60/30-foot stack, but this time over flat ground. Again, the N6BV/1 terrain towards Europe has a significant effect on the gain of the stack compared to that of an identical stack over flat ground. In fact, the peak gain of 20.1 dBi at a 4° elevation angle is close to moon-bounce levels.

OPTIMIZING OVER LOCAL TERRAIN

There are only a small number of possibilities to optimize an installation over local terrain:

- Change the antenna height(s) above ground.
- Stack two (or more) Yagis.
- Change the spacing between stacked Yagis.
- Move the tower back from a cliff (or a hill).
- BIP/BOP (Both In Phase/Both Out of Phase).

The *HFTA* program on the CD-ROM accompanying this book can be used, together with Digital Elevation Model (DEM) topographic data available on the Internet, to evaluate all these options.

SO NEAR, YET SO FAR

It is sometimes very surprising to compare elevation responses for different towers located at various points on the same property, particularly when that prop-

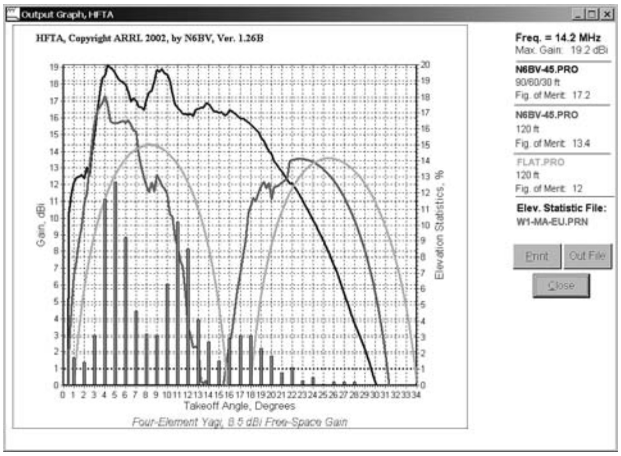

Output Graph, HFTA
HFTA, Copyright ARRL 2002, by N6BV, Ver. 1.26B
Gain, dBi
Elevation Statistics, %
Takeoff Angle, Degrees
Four-Element Yagi, 8.5 dBi Free-Space Gain
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Print
Out File
Close

Freq. = 14.2 MHz
Max. Gain: 19.2 dBi
N6BV-45.PRO
90/60/30 ft
Fig. of Merit: 17.2
N6BV-45.PRO
120 ft
Fig. of Merit: 13.4
FLAT.PRO
120 ft
Fig. of Merit: 12
Elev. Statistic File:
W1-MA-EU.PRN

Fig 47—*HFTA* screen shot showing how complicated things become when real-world irregular terrain is analyzed. This is the 20-meter elevation pattern for the N6BV/1 station location in Windham, NH, for the 90/60/30-foot stack of triband TH7DX Yagis and a 4-element Yagi at 120 feet on the same tower. For comparison, the response of a 120-foot Yagi over flat ground is also included.

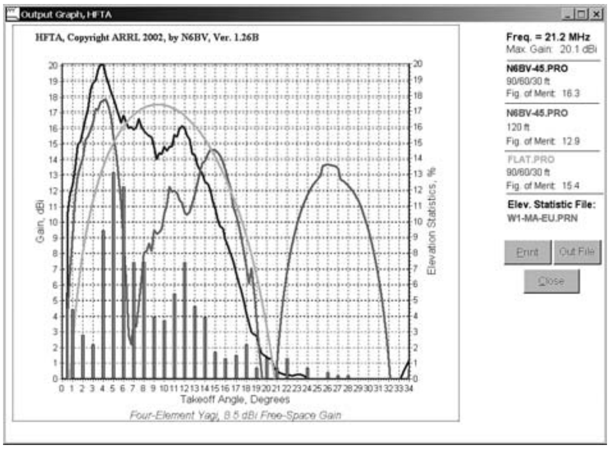

Output Graph, HFTA
HFTA, Copyright ARRL 2002, by N6BV, Ver. 1.26B
Gain, dBi
Elevation Statistics, %
Takeoff Angle, Degrees
Four-Element Yagi, 8.5 dBi Free-Space Gain
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Print
Out File
Close

Freq. = 21.2 MHz
Max. Gain: 20.1 dBi
N6BV-45.PRO
90/60/30 ft
Fig. of Merit: 16.3
N6BV-45.PRO
120 ft
Fig. of Merit: 12.9
FLAT.PRO
90/60/30 ft
Fig. of Merit: 15.4
Elev. Statistic File:
W1-MA-EU.PRN

Fig 48—*HFTA* screen shot showing the 15-meter elevation pattern for the N6BV/1 station location in Windham, NH, for the 90/60/30-foot stack of triband TH7DX Yagis and a 4-element Yagi at 120 feet on the same tower. For comparison, the response of a 120-foot Yagi over flat ground is also included.

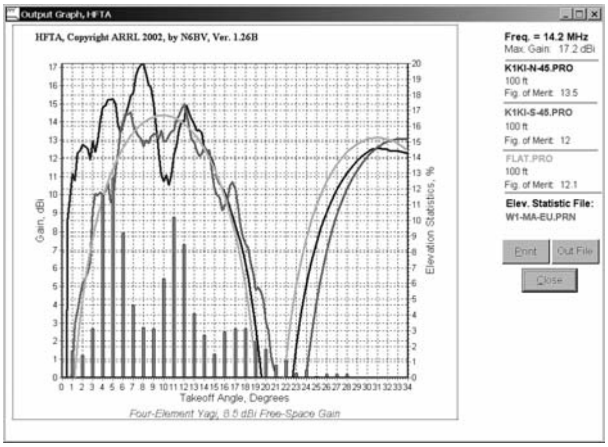
Output Graph, HFTA
HFTA, Copyright ARRL 2002, by N6BV, Ver. 1.26B
Gain, dBi
Elevation Statistics, %
Takeoff Angle, Degrees
Four-Element Yagi, 8.5 dBi Free-Space Gain
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
Print
Out File
Close

Freq. = 14.2 MHz
Max Gain: 17.2 dBi

K1KI-N-45.PRO
100 ft
Fig. of Merit: 13.5

K1KI-S-45.PRO
100 ft
Fig. of Merit: 12

FLAT.PRO
100 ft
Fig. of Merit: 12.1

Elev. Statistic File:
W1-MA-EU.PRN

Fig 49—*HFTA* screen shot showing the 20-meter elevation pattern for K1KI's North and South towers, with 100-foot high 4-element Yagis pointing into Europe at an azimuth of 45°. The responses are surprisingly different for two towers separated by only 600 feet.

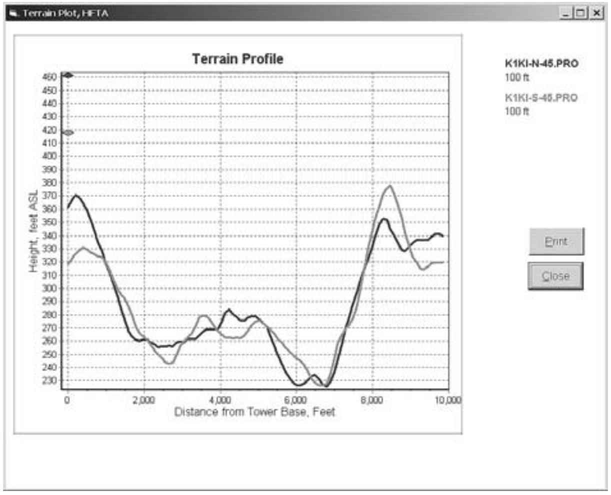
Terrain Plot, HFTA
Terrain Profile
Height, feet ASL
230
240
250
260
270
280
290
300
310
320
330
340
350
360
370
380
390
400
410
420
430
440
450
460
0
2,000
4,000
6,000
8,000
10,000
Distance from Tower Base, Feet
Print
Close

K1KI-N-45.PRO
100 ft
K1KI-S-45.PRO
100 ft

Fig 50—K1KI's terrain profiles for the North and South towers at an azimuth of 45° into Europe.

erty is located in the mountains. **Fig 49** shows the computed elevation responses for three 100-foot high 14-MHz Yagis over three terrains towards Europe: from the North tower at K1KI's location in West Suffield, Connecticut, from the South tower at K1KI, and over flat ground. The elevation response from the South tower follows that over flat ground well, while the response from the North tower is quite a bit stronger at low elevation angles—about 1.5 dB on average, as the Figure of Merit shows from *HFTA*.

Fig 50 shows the reason why this happens—the terrain from the North tower slopes down quickly towards Europe, while the terrain from the South tower goes out almost 900 feet before starting to fall off. These two towers are about 600 feet apart.

Moxon Rectangle Beams

LB Cebik, W4RNL, has written extensively about the *Moxon rectangle*, an antenna invented by Les Moxon, G6XN, derived from a design by VK2ABQ. The Moxon rectangle beam takes less space horizontally than a conventional 2-element Yagi design, yet it offers nearly the same amount of gain and a superior front-to-back ratio. And as an additional benefit, the drive-point impedance is close to 50 Ω, so that it doesn't need a matching section.

For example, rather than a "wingspan" of 17 feet for the reflector in a conventional 2-element 10-meter Yagi, the Moxon rectangle is 13 feet wide, a saving of almost 25%. The Moxon rectangle W4RNL created for *The ARRL Antenna Compendium, Vol 6*, had an SWR less than 2:1 from 28.0 to 29.7 MHz, with a gain over ground of 11 dBi. It had a F/B of 15 dB at 28.0 MHz, more than 20 dB at 28.4 MHz, and 12 dB at 29.7 MHz.

The Moxon rectangle relies on controlling the spacing (hence controlling the coupling) between the ends of the driven element tips and the ends of the reflector tips, which are both bent toward each other. See **Fig 51**, which shows the general outline for W4RNL's 10-meter aluminum Moxon rectangle. The tips of the elements are kept a fixed distance from each other by PVC spacers. The closed rectangular mechanical assembly gives some rigidity to the design, keeping it stable in the wind. W4RNL described other Moxon rectangle designs using wire elements in June 2000 *QST*.

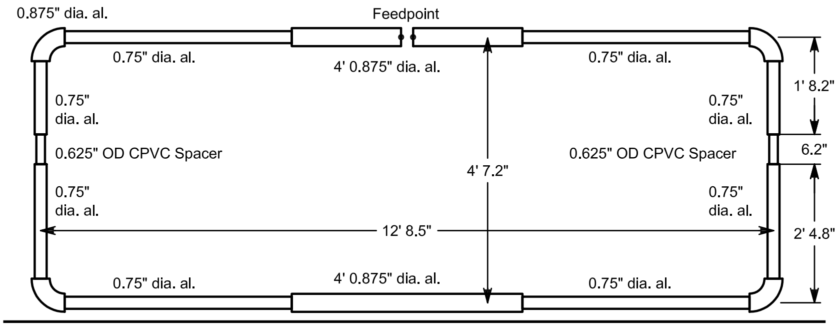
Radius corners
0.875" dia. al.
Feedpoint
0.75" dia. al.
4' 0.875" dia. al.
0.75" dia. al.
1' 8.2"
0.75"
dia. al.
0.75"
dia. al.
0.625" OD CPVC Spacer
0.625" OD CPVC Spacer
6.2"
4' 7.2"
0.75"
dia. al.
0.75"
dia. al.
12' 8.5"
2' 4.8"
0.75" dia. al.
4' 0.875" dia. al.
0.75" dia. al.

Fig 51—General outline of the 10-meter aluminum Moxon rectangle, showing tubing dimensions.

Chapter 12

Quad Arrays

Chapter 11, HF Yagi Arrays, discussed Yagi arrays as systems of approximately half-wave dipole elements that are coupled together mutually. You can also employ other kinds of elements using the same basic principles of analysis. For example, loops of various types may be combined into directive arrays. A popular type of parasitic array using loops is the *quad antenna*, in which loops having a perimeter of about one wavelength are used in much the same way as half-wave dipole elements in the Yagi antenna.

Clarence Moore, W9LZX, created the quad antenna in the early 1940s while he was at the Missionary Radio Station HCJB in Quito, Ecuador. He developed the quad to combat the effects of corona discharge at high altitudes. The problem at HCJB was that their large Yagi was literally destroying itself by melting its own element tips. This occurred due to the huge balls of corona it generated in the thin atmosphere of the high Andes mountains. Moore reasoned correctly that closed loop elements would generate less high voltage—and hence less corona—than would the high impedances at the ends of a half-wave dipole element.

Fig 1 shows the original version of the two-element quad, with a driven element and a parasitic reflector. The square loops may be mounted either with the corners lying on horizontal and vertical lines, as shown at the left, or with two sides horizontal and two vertical (right). The feed points shown for these two cases will result in horizontal polarization, which is commonly used.

Since its inception, there has been controversy whether the quad is a better performer than a Yagi. Chapter 11 showed that the three main electrical performance parameters of a Yagi are gain, response patterns (front-to-rear ratio, F/R) and drive impedance/SWR. Proper analysis of a quad also involves checking all these parameters across the entire frequency range over which you intend to use it. Both a quad and a Yagi are classified as "parasitic, end-fire arrays." Modern antenna modeling by computer shows that monoband Yagis and quads with the same boom lengths and optimized for the same performance parameters have gains within about 1 dB of each other, with the quad slightly ahead of the Yagi.

Fig 2 plots the three parameters of gain, front-to-

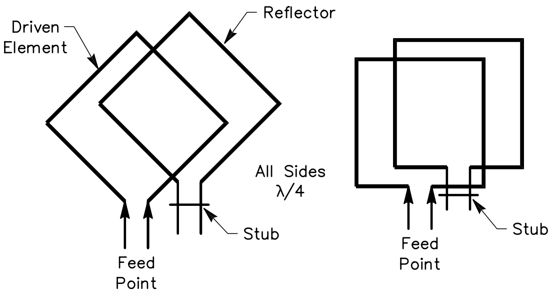

Fig 1—The basic two-element quad antenna, with driven-element loop and reflector loop. The driven loops are electrically one wavelength in circumference ($^1/_4$ wavelength on a side); the reflectors are slightly longer. Both configurations shown give horizontal polarization. For vertical polarization, the driven element should be fed at one of the side corners in the arrangement at the left, or at the center of a vertical side in the "square" quad at the right.

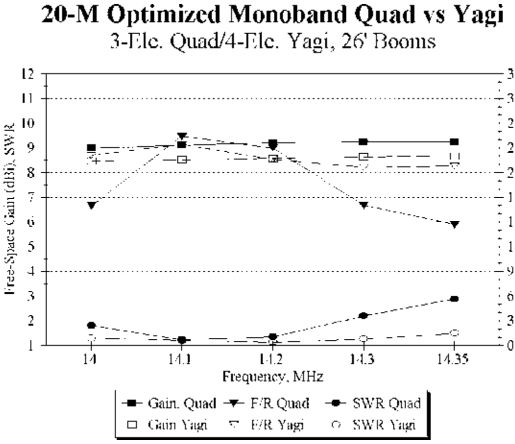

Fig 2—Comparison of gain, F/R and SWR over the 14.0 to 14.35-MHz range for an optimized three-element quad and an optimized three-element Yagi, both on 26-foot booms. The quad exhibits almost 0.5 dB more gain for the same boom length, but doesn't have as good a rearward pattern over the whole frequency range compared to the Yagi. This is evidenced by the F/R curve. The quad's SWR curve is also not quite as flat as the Yagi. The quad's design emphasizes gain more than the other two parameters.

rear ratio (F/R) and SWR over the 14.0 to 14.35-MHz band for two representative antennas—a monoband three-element quad and a monoband four-element Yagi. Both of these have 26-foot booms and both are optimized for the best compromise of gain, F/R and SWR across the whole band.

While the quad in Fig 2 consistently exhibits about 0.5 dB more gain over the whole band, its F/R pattern toward the rear isn't quite as good as the Yagi's over that span of frequencies. This quad attains a maximum F/R of 25 dB at 14.1 MHz, but it falls to 17 dB at the bottom end of the band and 15 dB at the top. On the other hand, the Yagi's F/R stays consistently above 21 dB across the whole 20-meter band. The quad's SWR rises to just under 3:1 at the top end of the band, but stays below 2:1 from 14.0 to almost 14.3 MHz. The Yagi's SWR remains lower than 1.5:1 over the whole band.

The reason the Yagi in Fig 2 has more consistent responses for gain, F/R and SWR across the whole 20-meter band is that it has an additional parasitic element, giving two additional variables to play with—that is, the length of that additional element and the spacing of that element from the others on the boom.

Yagi advocates point out that it is easier to add extra elements to a Yagi, given the mechanical complexities of adding another element to a quad. Extra parasitic elements give a designer more flexibility to tailor all performance parameters over a wide frequency range. Quad designers have historically opted to optimize strictly for gain and, as stated before, they can achieve as much as 1 dB more gain than a Yagi with the same length boom. But in so doing, a quad designer typically has to settle for front-to-rear patterns that are peaked over more narrow frequency ranges. The 20-meter quad plots in Fig 2 actually represent an even-handed approach, where the gain is compromised slightly to obtain a more consistent pattern and SWR across the whole band.

Fig 3 plots gain, F/R and SWR for two 10-meter monoband designs: a five-element quad and a five-element Yagi, both placed on 26-foot booms. The quad now has the same degrees of freedom as the Yagi, and as a consequence the pattern and SWR are more consistent across the range from 28.0 to 28.8 MHz. The quad's F/R remains above about 18.5 dB from 28.0 to 28.8 MHz. Meanwhile, the Yagi maintains an F/R of greater than 22 dB over the same range, but has almost 0.8 dB less gain compared to the quad at the low end of the band, eventually catching up at the high end of the band. The SWR for the quad is just over 2:1 at the bottom of the band, but remains less than 2:1 up to 28.8 MHz. The SWR on the Yagi remains less than 1.6:1 over the whole band.

Fig 4 shows the performance parameters for two 15-meter monoband designs: a five-element quad and a five-element Yagi, both on 26-foot booms. The quad is still the leader in gain, but has a less optimal rearward pattern and a somewhat less flat SWR curve than the Yagi. One thing should be noted in Figs 2 through 4. The F/R pattern on the Yagi is largely determined by the response at the 180° point, directly in back of the frontal lobe. This point is usually referred to when discussing the "front-to-back ratio."

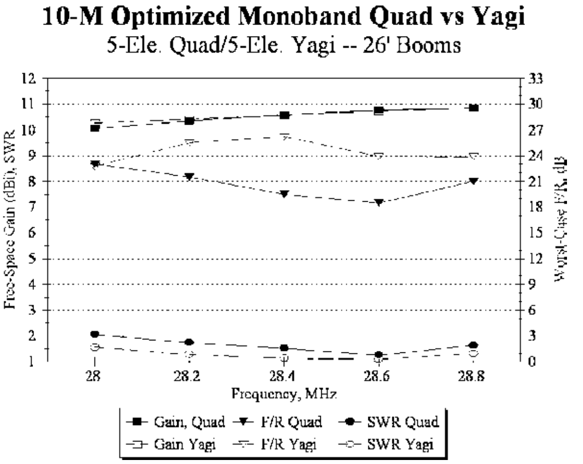

Fig 3—Comparison of gain, F/R and SWR over the 28.0 to 28.8-MHz range for an optimized five-element quad and an optimized five-element Yagi, both on 26-foot booms. The gain advantage of the quad is about 0.25 dB at the low end of the band. The F/R is more peaked in frequency for the quad, however, than the Yagi.

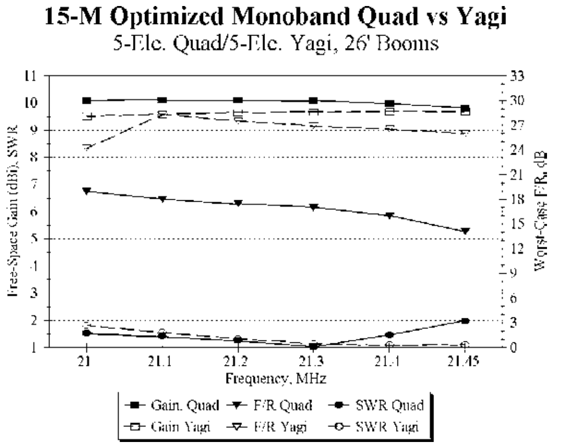

Fig 4—Comparison of gain, F/R and SWR over the 21.0 to 21.45-MHz range for an optimized 5-element quad and optimized 5-element Yagi, both on 26-foot booms. The quad enjoys a gain advantage of about 0.5 dB over most of the band. Its rearward pattern is not as good as the Yagi, which remains higher than 24 dB across the whole range, compared to the quad, which remains in the 16-dB average range.

The quad on the other hand has what a sailor might term "quartering lobes" (referring to the direction back towards the "quarterdeck" at the stern of a sailing vessel) in the rearward pattern. These quartering lobes are often

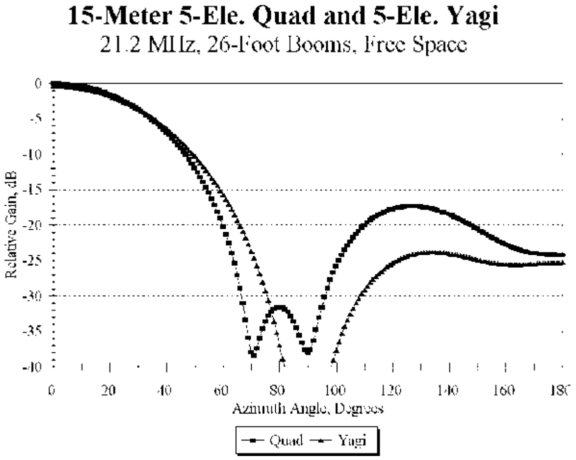

Fig 5—Comparing the pattern of the 15-meter quad and Yagi shown in Fig 4. The quad has a slightly narrower frontal beamwidth (it has 0.5 dB more gain than the Yagi), but has higher "rear quartering" sidelobes at about 125° (with a twin sidelobe, not shown, at 235°). These sidelobes limit the worst-case front-to-rear (F/R) to about 17 dB, while the F/B (at 180°, directly at the back of the quad) is more than 24 dB for each antenna.

Table 1
Dimensions for Optimized Monoband Quads in Figs 2, 3 and 4, on 26-Foot Booms

	14.2 MHz	*21.2 MHz*	*28.4 MHz*
Reflector	73′ 9"	49′ 6"	37′ 3"
R-DE Spacing	17′ 8"	7′	6′ 4"
Driven Element	71′ 8"	47′ 6"	35′ 9"
DE-D1 Spacing	8′ 3"	5′	5′ 6"
Director 1	68′ 7"	46′ 8"	34′ 8"
D1-D2 Spacing	—	6′ 8"	6′ 9"
Director 2	—	46′ 10"	35′ 2"
D2-D3 Spacing	—	7′ 4"	7′ 5"
Director 3	—	45′ 8"	34′ 2"
Feed method	Direct 50 Ω	Direct 50 Ω	Direct 50 Ω

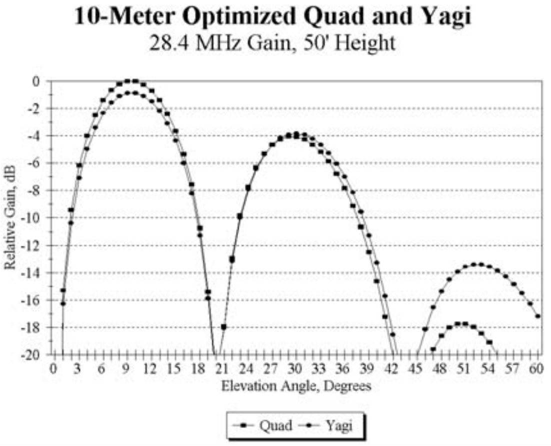

Fig 6—A comparison on 10 meters between an optimized five-element quad and an optimized five-element Yagi, both mounted 50 feet high over flat ground and both employing 26-foot booms. There is no appreciable difference in the peak elevation angle for either antenna. In other words, a quad does not have an appreciable elevation-angle advantage over a Yagi mounted at the same boom height. Note that the quad achieves its slightly higher gain by taking energy from higher-angle lobes and concentrating that energy in the main elevation lobe. This is a process that is similar to what happens with stacked Yagis.

worse than the response at 180°, directly in back of the main beam. **Fig 5** overlays the free-space E-Field responses of the 15-meter quad and Yagi together. At 21.2 MHz, the quad actually has a front-to-back ratio (F/B) of about 24 dB, excellent in anyone's book. The Yagi at 180° has a F/B of about 25 dB, again excellent.

However, at an azimuth angle of about 125° (and at 235° azimuth on the other side of the main lobe) the quad's "quartering lobe" is down only some 17 dB, setting the worst-case F/R at 17 dB also. As explained in Chapter 11, the reason F/R is more important than just the F/B is that on receive signals can come from any direction, not just from directly behind the main beam.

Table 1 lists the dimensions for the three computer-optimized monoband quads shown in Figs 2, 3 and 4.

Is a Quad Better at Low Heights than a Yagi?

Another belief held by some quads enthusiasts is that they need not be mounted very high off the ground to give excellent DX performance. Quads are somehow supposed to be greatly superior to a Yagi at the same height above ground. Unfortunately, this is mainly wishful thinking.

Fig 6 compares the same two 10-meter antennas as in Fig 3, but this time with each one mounted on a 50-foot tower over flat ground, rather than in theoretical free space. The quad does indeed have slightly more gain than a Yagi with the same boom length, as it has in free space. This is evidenced by the very slight compression of the quad's main lobe, but is more obvious when you look at the third lobe, which peaks at about 53° elevation. In effect, the quad squeezes some energy out of its second and third lobes and adds that to the first lobe. However, the difference in gain compared to the Yagi is only 0.8 dB for this particular quad design at a 9° elevation angle. And while it's true that every dB counts, you can also be certain that on the air you wouldn't be able to tell the difference between the two antennas. After all, a 10- to 20-dB variation in the level of signals is pretty common because of fading at HF.

Multiband Quads

On the other hand, one of the valid reasons quads have remained popular over the years is that antenna homebrewers can build multiband quads far more easily than they can construct multiband Yagis. In effect, all you have to do with a quad is add more wire to the existing support arms. It's not quite as simple as that, of course, but the idea of ready expandability for other bands is very appealing to experimenters.

Like the Yagi, the quad does suffer from interactions between wires of different frequencies, but the degree of interaction between bands is usually less for a quad. The higher-frequency bands are the ones that often suffer most from any interaction, for both Yagis and quads. For example, the 10- and 15-meter bands are usually the ones affected most by nearby 20-meter wires in a triband quad, while the 20-meter elements are not affected by the 10- or 15-meter elements.

Modern computer modeling software can help you counteract at least some of the interaction by allowing you to do virtual "retuning" of the quad on the computer screen — rather than clinging precariously to your tower fiddling with wires. However, the programs (such as *NEC-2* or *EZNEC*) that can model three-dimensional wire antennas such as quads typically run far more slowly than those designed for monoband Yagis (such as *YW* included with this book). This makes optimizing rather tedious, but you use the same considerations for tradeoffs between gain, pattern (F/R) and SWR over the operating bandwidth as you do with monoband Yagis.

CONSTRUCTING A QUAD

The parasitic element shown in Fig 1 is tuned in much the same way as the parasitic element in a Yagi antenna. That is, the parasitic loop is tuned to a lower frequency than the driven element when the parasitic is to act as a reflector, and to a higher frequency when it is to act as a director. Fig 1 shows the parasitic element with an adjustable tuning stub, a convenient method of tuning since the resonant frequency can be changed simply by changing the position of the shorting bar on the stub. In practice, it has been found that the length around the loop should be approximately 3.5% greater than the self-resonant length if the element is a reflector, and about 3.0% shorter than the self-resonant length if the parasitic element is a director. Approximate formulas for the loop lengths in feet are:

$$\text{Driven Element} = \frac{1008}{f_{\text{MHz}}}$$

$$\text{Reflector} = \frac{1045}{f_{\text{MHz}}}$$

$$\text{Director} = \frac{977}{f_{\text{MHz}}}$$

These are valid for quad antennas intended for operation below 30 MHz and using uninsulated #14 stranded copper wire. At VHF, where the ratio of loop circumference to conductor diameter is usually relatively small, the circumference must be increased in comparison to the wavelength. For example, a one-wavelength loop constructed of $^1/_4$-inch tubing for 144 MHz should have a circumference about 2% greater than in the above equation for the driven element.

Element spacings on the order of 0.14 to 0.2 free-space wavelengths are generally used. You would employ the smaller spacings for antennas with more than two elements, where the structural support for elements with larger spacings tends to become challenging. The feed-point impedances of antennas having element spacings on this order have been found to be in the 40- to 60-Ω range, so the driven element can be fed directly with coaxial cable with only a small mismatch.

For spacings on the order of 0.25 wavelength (physically feasible for two elements, or for several elements at 28 MHz) the impedance more closely approximates the impedance of a driven loop alone—that is, 80 to 100 Ω. The feed methods described in Chapter 26 can be used, just as in the case of the Yagi.

Making It Sturdy

The physical sturdiness of a quad is directly proportional to the quality of the material used and the care with which it is constructed. The size and type of wire selected for use with a quad antenna is important because it will determine the capability of the spreaders to withstand high winds and ice. One of the more common problems confronting the quad owner is that of broken wires. A solid conductor is more apt to break than stranded wire under constant flexing conditions. For this reason, stranded copper wire is recommended. For 14-, 21- or 28-MHz operation, #14 or #12 stranded wire is a good choice. Soldering of the stranded wire at points where flexing is likely to occur should be avoided.

You may connect the wires to the spreader arms in many ways. The simplest method is to drill holes through the fiberglass at the appropriate points on the arms and route the wires through the holes. Soldering a wire loop across the spreader, as shown later, is recommended. However, you should take care to prevent solder from flowing to the corner point where flexing could break it.

While a boom diameter of 2 inches is sufficient for smaller quads using two or even three elements for 14, 21 and 28 MHz, when the boom length reaches 20 feet or longer a 3-inch diameter boom is highly recommended. Wind creates two forces on the boom, vertical and horizontal. The vertical load on the boom can be reduced with a guy-wire truss cable. The horizontal forces on the boom are more difficult to relieve, so 3-inch diameter tubing is desirable.

Generally speaking, three grades of material can be used for quad spreaders. The least expensive material is bamboo. Bamboo, however, is also the weakest material normally used for quad construction. It has a short life, typically only three or four years, and will not withstand a harsh climate very well. Also, bamboo is heavy in contrast to fiberglass, which weighs only about a pound per 13-foot length. Fiberglass is the most popular type of spreader material, and will withstand normal winter climates. One step beyond the conventional fiberglass arm is the pole-vaulting arm. For quads designed to be used on 7 MHz, surplus "rejected" pole-vaulting poles are highly recommended. Their ability to withstand large amounts of bending is very desirable. The cost of these poles is high, and they are difficult to obtain. See Chapter 21 for dealers and manufacturers of spreaders.

Diamond or Square?

The question of how to orient the spreader arms has been raised many times over the years. Should you mount the loops in a diamond or a square configuration? Should one set of spreaders be horizontal to the earth as shown in Fig 1 (right), or should the wire itself be horizontal to the ground (spreaders mounted in the fashion of an X) as shown in Fig 1 (left)? From the electrical point of view, there is not enough difference in performance to worry about.

From the mechanical point of view there is no question which version is better. The diamond quad, with the associated horizontal and vertical spreader arms, is capable of holding an ice load much better than a system where no vertical support exists to hold the wire loops upright. Put another way, the vertical poles of a diamond array, if sufficiently strong, will hold the rest of the system erect. When water droplets are accumulating and forming into ice, it is very reassuring to see water running down the wires to a corner and dripping off, rather than just sitting there on the wires and freezing. The wires of a loop (or several loops, in the case of a multiband antenna) help support the horizontal spreaders under a load of ice. A square quad will droop severely under heavy ice conditions because there is nothing to hold it up straight.

Of course, in climates where icing is not a problem, many amateurs point out that they like the aesthetics of the square configuration. There are thousands of square-configuration quads in temperate areas around the world.

Another consideration will enter into your choice of orientation for a quad. You must mount a diamond quad somewhat higher on the mast or tower than for an equivalent square array, just to keep the bottom spreader away from the tower guys when you rotate the antenna.

Two Multiband Quads

This section describes two multiband quad designs. The first is a large triband 20/15/10-meter quad built on a 26-foot boom made of 3-inch irrigation tubing. This antenna has three elements on 20 meters, four elements on 15 meters, and five elements on 10 meters. **Fig 7** shows a photograph of the five-element triband quad.

The second project is a compact two-element triband quad on an 8-foot boom that covers 20, 17, 15, 12 and 10 meters. We call this a "pentaband" quad since it covers five bands. This antenna uses five concentric wire loops mounted on each of the two sets of spreaders. Either antenna may be constructed in a diamond or square configuration.

While the same basic construction techniques are employed for both multiband quads, the scale of the larger triband antenna makes it a far more ambitious undertaking! The large quad requires a strong tower and a rugged rotator. It also requires a fair amount of real estate in order to raise the quad to the top of the tower without entangling trees or other antennas.

A FIVE-ELEMENT, 26-FOOT BOOM TRIBAND QUAD

Five sets of element spreaders are used to support the three elements used on 14 MHz, four elements on 21 MHz and five elements on 28-MHz. We chose to use four elements on 15 meters in this design (rather than the five we could have been employed on this length of boom) because the difference in optimized performance wasn't great enough to warrant the extra complexity of using five elements. The dimensions are listed in **Table 2**, and are designed for center frequencies of 14.175, 21.2 and 28.4 MHz.

The spacing between elements has been chosen to provide good compromises in performance consistent with boom length and mechanical construction. You can see that the element spacings for 20 meters are quite different from those for the optimized monoband design. This is because the same set of spreaders is used for all

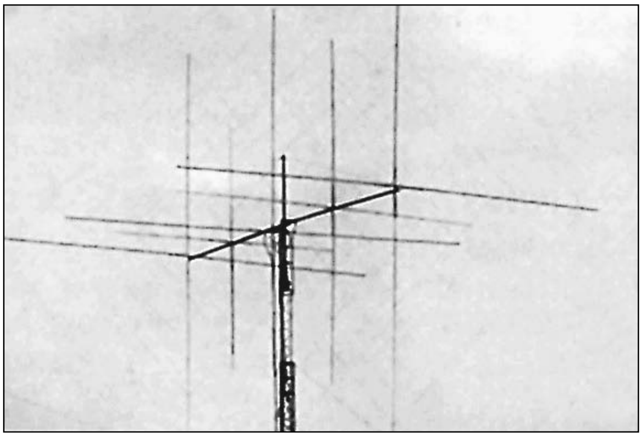

Fig 7—Photo of the three-band, five-element quad antenna.

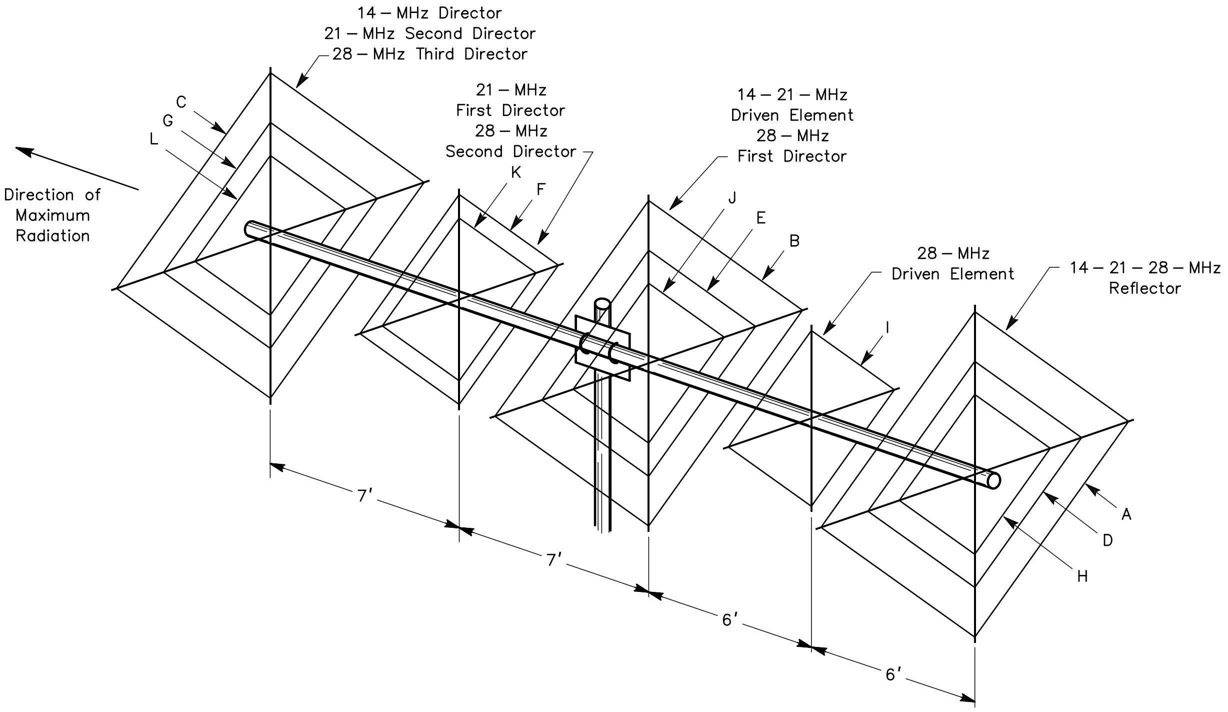
14 – MHz Director
21 – MHz Second Director
28 – MHz Third Director
C
G
L
Direction of Maximum Radiation
21 – MHz First Director
28 – MHz Second Director
K
F
14 – 21 – MHz Driven Element
28 – MHz First Director
J
E
B
28 – MHz Driven Element
I
14 – 21 – 28 – MHz Reflector
A
D
H
7′
7′
6′
6′

Fig 8—Layout for the three-band, five-element quad, not drawn to scale. See Table 2 for dimensions.

three bands on three out of the five elements, and the higher-frequency bands dictate the spacing because they are more critical.

Each of the parasitic loops is closed (ends soldered together) and requires no tuning. **Fig 8** shows the physical layout of the triband quad. **Fig 9** plots the computed free-space gain, front-to-rear ratio and SWR response across the 20-meter band. With only a few degrees of freedom in tuning and spacing of the three elements, it is impossible to spread the response out to cover the entire 20-meter band. The compromise design results in a rearward pattern that varies from a worst-case of just under 10 dB at the high end of the band, to a peak F/R of just under 19 dB at 14.2 MHz, in the phone portion of the band. The F/R is about 11 dB at the low end of the band.

The SWR remains under 3:1 for the entire 20-meter band, rising to 2.8:1 at the high end. The feed system for this triband quad consists of three separate 50-Ω coax

Table 2
Three-Band Five-Element Quad on 26-Foot Boom

	14.15 MHz	*21.2 MHz*	*28.4 MHz*
Reflector	72′ 6"	49′ 4"	36′ 8"
R-DE Spacing	12′	12′	6′
Driven Element	71′	47′ 6"	35′ 4"
DE-D1 Spacing	14′	7′	6′
Director 1	68′ 6"	46′ 8"	34′ 8"
D1-D2 Spacing	—	14′	7′
Director 2	—	46′ 5"	34′ 8"
D2-D3 Spacing	—	—	7′
Director 3	—	—	34′
Feed method	Direct 50 Ω	Direct 50 Ω	Direct 50 Ω

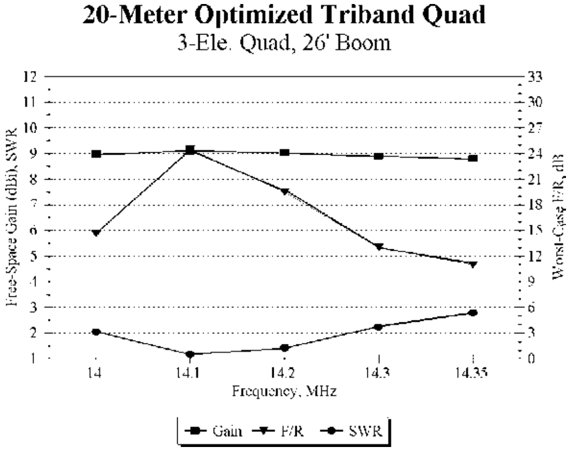

Fig 9—Computed performance of the triband, five-element quad over the 20-meter band. The direct 50-Ω feed system holds the SWR below 2.8: 1 across the whole band. This could be improved with a gamma-match system tuned to 14.1 MHz if the builder really desires a low SWR. The F/R peaks at 14.1 MHz and remains above 10 dB across the whole band.

lines, one per driven element, together with a relay switchbox mounted to the boom so that a single coax can be used back to the operating position. Each feed line uses a ferrite-bead balun to control common-mode currents and preserve the radiation pattern and each coax going to the switchbox is cut to be an electrical three-quarter wavelength on 15 meters. This presents a short at the unused driven elements since modeling indicated that the 15-meter band is adversely affected by the presence of the 20-meter driven element if it is left open-circuited. If you use RG-213 coax, the $^3/_4$-λ electrical length of each feed line is 23 feet long at 21.2 MHz. This is sufficient physical length to reach each driven element from the switchbox.

Fig 10 shows the free-space response for the 15-meter band. The rearward response is roughly 15 dB across the band. This is a result of the residual interaction between the 20-meter elements on 15 meters, and no further tuning could improve the F/R. Note how flat the SWR curve is. This SWR characteristic is what gives the quad the reputation of being "wideband." A flat SWR curve, however, is not necessarily a good indicator of optimal performance for directional antennas like quads or Yagis, particularly multiband designs where compromises must be made by physical necessity.

Fig 11 shows the characteristics of the 10-meter portion of the two-element triband quad. The response favors the low-phone band, with the F/R falling to about 12 dB at the low end of the frequency range and rising to just about 23 dB at 28.4 MHz. The SWR curve is once again relatively flat across the major portion of the band up to 28.8 MHz.

Construction

The most obvious problem related to quad antennas is the ability to build a structurally sound system. If high winds or heavy ice are a normal part of the environment, special precautions are necessary if the antenna is to survive a winter season. Another stumbling block for would-be quad builders is the installation of a three-dimensional system (assuming a Yagi has only two important dimensions) on top of a tower—especially if the tower needs guy wires for support. With proper planning, however, many of these obstacles can be overcome. For example, a tram system may be used.

Both multiband quad arrays use fiberglass spreaders (see Chapter 21 for suppliers). Bamboo is a suitable substitute (if economy is of great importance). However, the additional weight of the bamboo spreaders over fiberglass is an important consideration. A typical 12-foot bamboo pole weighs about 2 pounds; the fiberglass type weighs less than a pound. By multiplying the difference times 8 for a two-element array, times 12 for a three-element antenna, and so on, it quickly becomes apparent that fiberglass is worth the investment if weight is an important factor. Properly treated, bamboo has a useful life of three or four years, while fiberglass life is probably 10 times longer.

Spreader supports (sometimes called *spiders*) are available from many different manufacturers. If the builder is keeping the cost at a minimum, he should consider building his own. The expense is about half that of a commercially manufactured equivalent and, according to some authorities, the homemade arm supports described below are less likely to rotate on the boom as a result of wind pressure.

A 3-foot length of steel angle stock, 1 inch per side, is used to interconnect the pairs of spreader arms. The steel is drilled at the center to accept a muffler clamp of sufficient size to clamp the assembly to the boom. The fiberglass is clamped to the steel angle stock with auto-

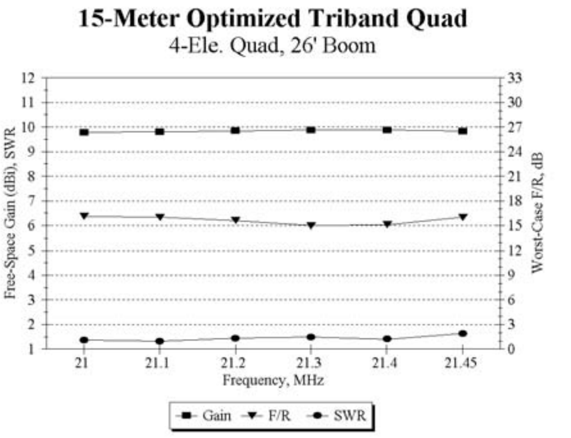

Fig 10—Computed performance of the triband, five-element quad over the 15-meter band. There is some degree of interaction with the 20-meter elements, limiting the worst-case F/R to about 15 dB. The gain and SWR curves are relatively flat across the band.

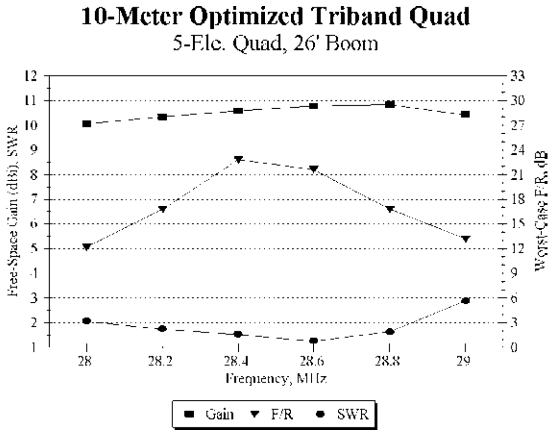

Fig 11—Computed performance of the triband, five-element quad over the 10-meter band. The F/R is higher than 12 dB across the band from 28.0 to 29.0 MHz, but the SWR rises at the top end of the band beyond 2:1. The free-space gain is higher than 10 dBi across the band.

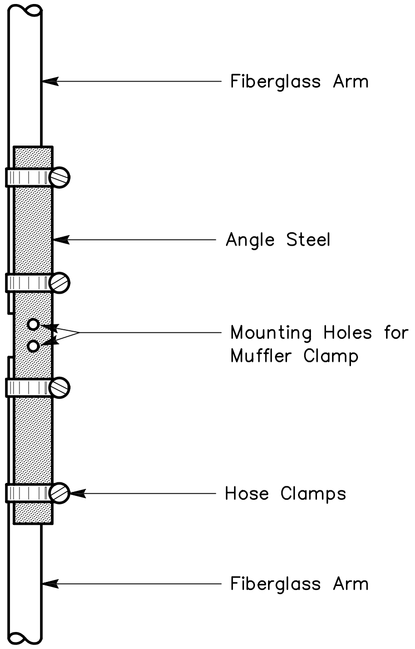
Fiberglass Arm
Angle Steel
Mounting Holes for Muffler Clamp
Hose Clamps
Fiberglass Arm

Fig 12—Details of one of two assemblies for a spreader frame. The two assemblies are joined back-to-back to form an X with a muffler clamp mounted at the position shown.

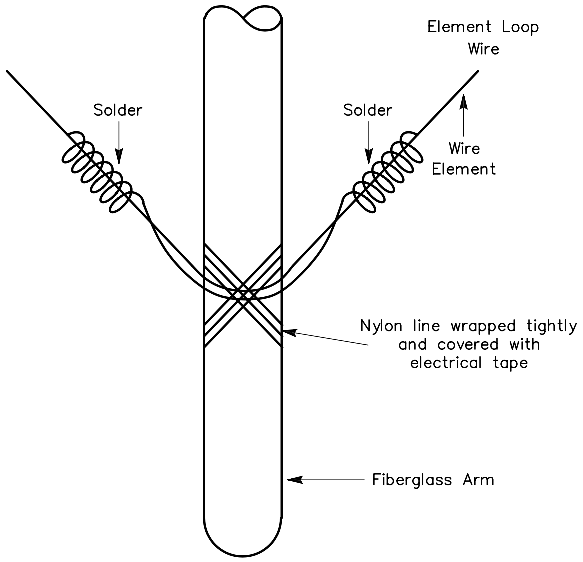
Element Loop Wire
Solder
Solder
Wire Element
Nylon line wrapped tightly and covered with electrical tape
Fiberglass Arm

Fig 14—An alternative method of assembling the wire of a quad loop to the spreader arm.

motive hose clamps, two per pole. Each quad-loop spreader frame consists of two assemblies of the type shown in **Fig 12**.

Connecting the wires to the fiberglass can be done in a number of different ways. Holes can be drilled at the proper places on the spreader arms and the wires run through them. A separate wrap wire should be included at the entry/exit point to prevent the loop from slipping. Details are presented in **Fig 13**. Some amateurs have experienced cracking of the fiberglass, which might be a result of drilling holes through the material. However, this seems to be the exception rather than the rule. The model described here has no holes in the spreader arms; the wires are attached to each arm with a few layers of

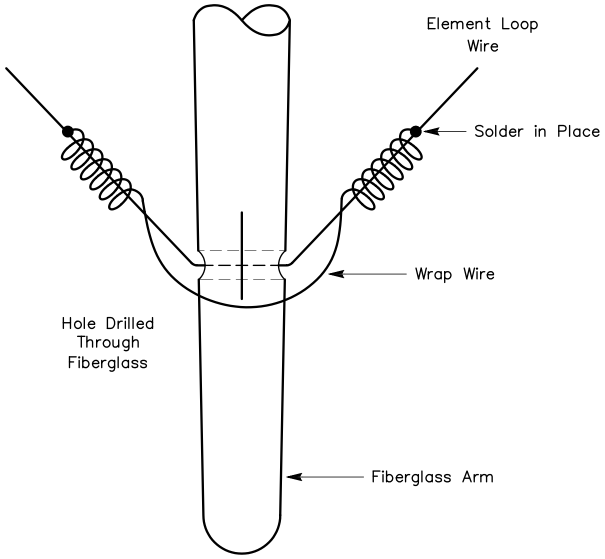
Element Loop Wire
Solder in Place
Wrap Wire
Hole Drilled Through Fiberglass
Fiberglass Arm

Fig 13—A method of assembling a corner of the wire loop of a quad element to the spreader arm.

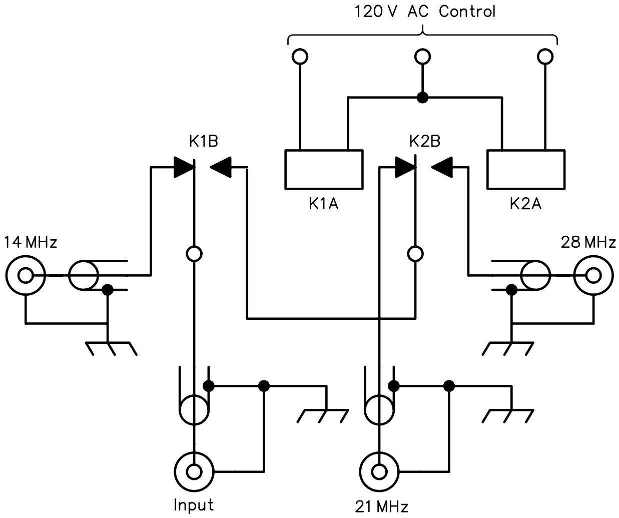
120 V AC Control
K1B
K2B
K1A
K2A
14 MHz
28 MHz
Input
21 MHz

Fig 15—Suitable circuit for relay switching of bands for the three-band quad. A three-wire control cable is required. K1, K2—any type of relay suitable for RF switching, coaxial type not required (Potter and Brumfeld MR11A acceptable; although this type has double-pole contacts, mechanical arrangements of most single-pole relays make them unacceptable for switching of RF).

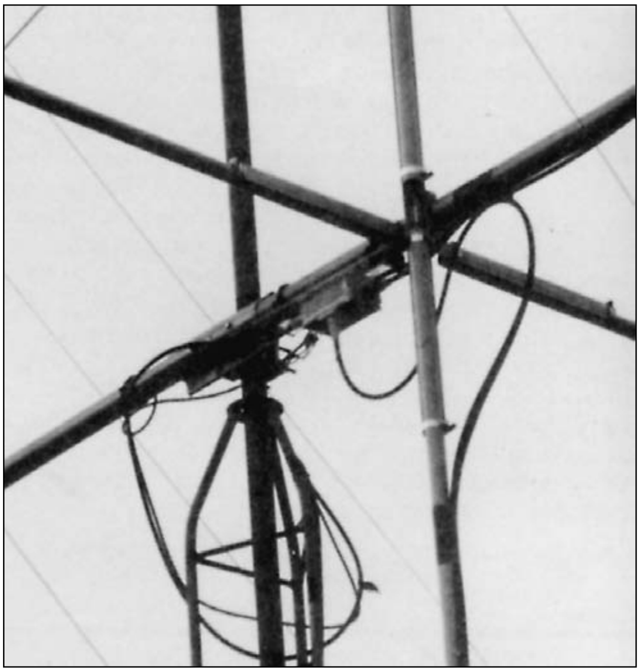

Fig 16—The relay box is mounted on the boom near the center. Each of the spreader-arm fiberglass poles is attached to steel angle stock with hose clamps.

plastic electrical tape and then wrapped approximately 20 times in a crisscross fashion with ⅛-inch diameter nylon string, followed by more electrical tape for UV protection, as shown in **Fig 14**.

The wire loops are left open at the bottom of each driven element where the feed-line coaxes are attached. All of the parasitic elements are continuous loops of wire; the solder joint is at the base of the diamond.

Although you could run three separate coax cables down to the shack, we suggest that you install a relay box at the center of the boom. A three-wire control system may be used to apply power to the proper relay for changing bands. The circuit diagram of a typical configuration is presented in **Fig 15** and its installation is shown in **Fig 16**.

Every effort must be placed upon proper construction if you want to have freedom from mechanical problems. Hardware must be secure or vibration created by the wind may cause separation of assemblies. Solder joints should be clamped in place to keep them from flexing, which might fracture a connection point.

A TWO-ELEMENT, 8-FOOT BOOM PENTABAND QUAD

This two-element pentaband (20/17/15/12/10-meter) quad uses the same construction techniques as its big brother above. Since only two elements are used, the boom can be less robust for this antenna, at 2 inches diameter rather than 3 inches. Those who like really rugged antennas can still use the 3-inch diameter boom, of course.

Table 3 lists the element dimensions for the pentaband quad. The following plots show the performance for each of the five bands covered. The feed system for the pentaband quad uses five, direct 50-Ω coaxes, one to each driven element. These five coaxes are cut to be ¾-λ electrically on 10 meters (17 feet, 2 inches for RG-213 at 28.4 MHz). In this design the 10-meter band is the one most affected by the presence of the other driven elements if they are left unshorted. The ¾-λ lines open-circuited at the switchbox are long enough physically to reach all elements from a centrally mounted switchbox. This length assumes that the switchbox open-circuits the unused coaxes. If the switchbox short-circuits unused coaxes (as several commercial switchboxes do), then use ½-λ long lines to feed all five driven elements (11 feet,

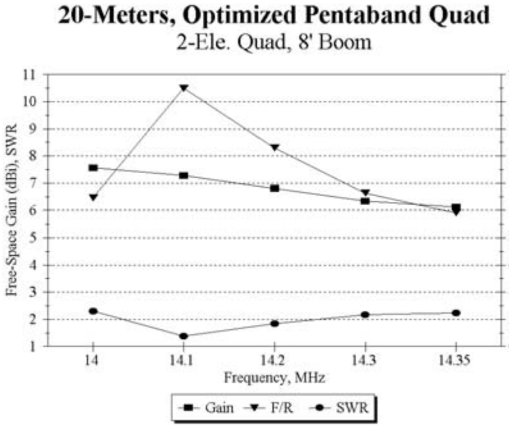

Fig 17—Computed performance of the pentaband two-element quad on 20 meters. With the simple direct-feed system, the SWR rises to about 2.3:1 at the low end of the band. A gamma match can bring the SWR down to 1:1 at 14.1 MHz, if desired.

Table 3
Five-Band Two-Element Quad on 8-Foot Boom

	14.2 MHz	*18.1 MHz*	*21 MHz*	*24.9 MHz*	*28.4 MHz*
Reflector	72′ 4"	56′ 4"	48′ 6"	40′ 11¼"	37′ 5½"
R-DE Spacing	8′	8′	8′	8′	8′
Driven Element	69′ 10½"	54′ 10½"	46′ 7"	39′ 10½"	34′ 6"

5 inches for RG-213 at 28.4 MHz).

The SWR curves do not necessarily go down to 1:1 because of this simple, direct feed system. If anyone is bothered by this, of course they can always implement individual matching systems, such as gamma matches. Most amateurs would agree that such a degree of complexity is not warranted. The worst-case SWR is less than 2.3:1 on each band, even with direct feed on 20 meters. With typical lengths of coaxial feed line from the shack to the switchbox at the antenna, say 100 feet of RG-213, the SWR at the transmitter would be less than 2.0:1 on all bands due to losses in the feed line.

Fig 17 shows the computed responses for the pentaband quad over the 20-meter band. With only two degrees of freedom (spacing and element tuning) there is not much that can be done to spread the response out over the entire 20-meter band. Nonetheless, the performance over the band is still pretty reasonable for an antenna this small. The F/R pattern peaks at 19 dB at 14.1 MHz and falls to about 10 dB at either end of the band. The free-space gain varies from about 7.5 dBi to just above 6 dBi, comparable to a short-boom three-element Yagi. The SWR curve remains below 2.3:1 across the band. If you were to employ a gamma match tuned at 14.1 MHz, you could limit the peak SWR to less than 2.0:1, and this would still occur at 14.0 MHz.

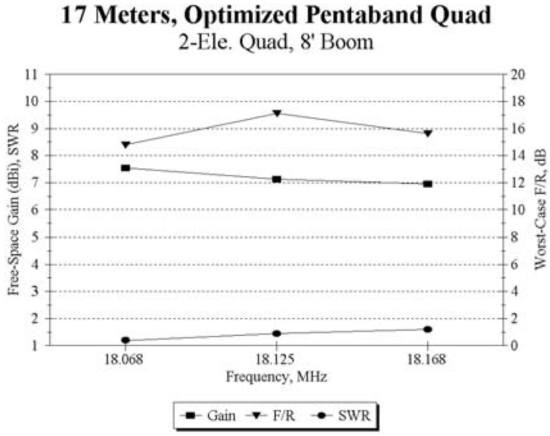

Fig 18—Computed performance of the pentaband two-element quad on 17 meters. There is some interaction with the other elements, but overall the performance is satisfactory on this band.

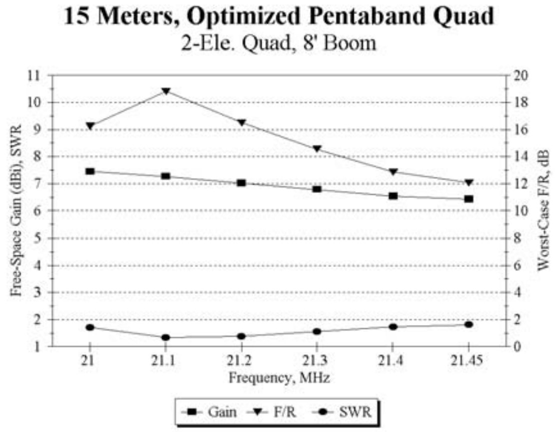

Fig 19—Computed performance of the pentaband two-element quad on 15 meters. The performance is acceptable across the whole band.

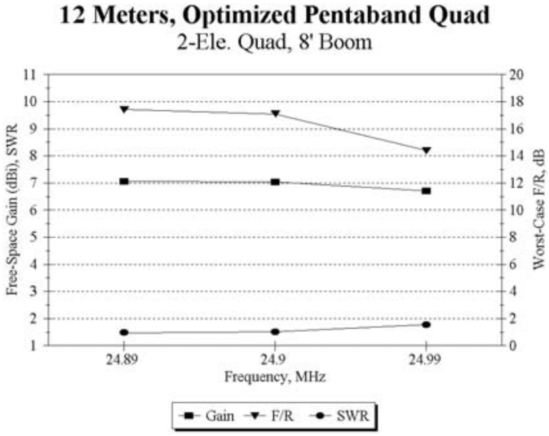

Fig 20—Computed performance of the pentaband two-element quad on 12 meters.

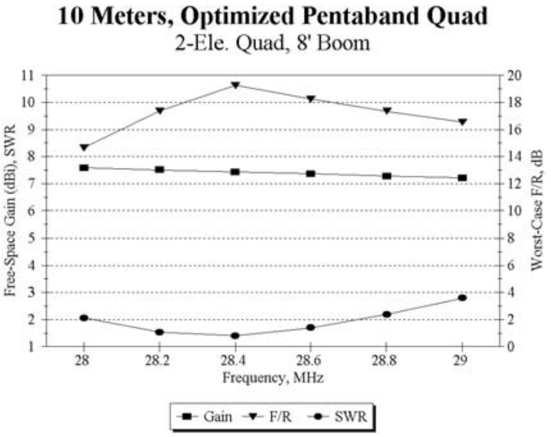

Fig 21—Computed performance of the pentaband two-element quad on 10 meters. The SWR curve is slightly above the target 2:1 at the low end of the band and rises to about 2.2:1 at 28.8 MHz. This unlikely to be a problem, even with rigs with automatic power-reduction due to SWR, since the SWR at the input of a typical coax feed line will be lower than that at the antenna due to losses in the line.

On 17 meters, **Fig 18** shows that the other elements are affecting 18 MHz, even with element-length optimization. Careful examination of the current induced on the other elements shows that the 20-meter driven element is interacting on 18 MHz, deteriorating the pattern and gain slightly. Even still, the performance on 17 meters is reasonable, especially for a five-band quad on an 8-foot boom.

On 15 meters, the interactions seems to have been contained, as **Fig 19** demonstrates. The F/R peaks at 21.1 MHz, at 19 dB and remains better than 12 dB past the top of the band. The SWR curve is low across the whole band.

On 12 meters, the interaction between bands is minor, leading to the good results shown in **Fig 20**. The SWR change across this band is quite flat, which isn't surprising given the narrow bandwidth of the 12-meter band.

On 10 meters, the interaction seems to have been tamed well by computer-tuning of the elements. The F/R remains higher than about 14 dB from 28 to 29 MHz. The SWR remains below 2.2:1 up to about 28.8 MHz, while the gain is relatively flat across the band at more than 7.2 dBi in free space. See **Fig 21**.

Overall, this pentaband quad is physically compact and yet it provides good performance across all five bands. It is competitive with commercial Log Periodic Dipole Array (LPDA) designs and triband Yagi designs that employ longer booms.

BIBLIOGRAPHY

Source material and more extended discussions of the topics covered in this chapter can be found in the references given below and in the textbooks listed at the end of Chapter 2.

P. S. Carter, C. W. Hansell and N. E. Lindenblad, "Development of Directive Transmitting Antennas by R.C.A. Communications," *Proc. IRE*, Oct 1931.

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Chapter 13

Long-Wire and Traveling-Wave Antennas

The power gain and directive characteristics of electrically long wires (that is, wires that are long in terms of wavelength), as described in Chapter 2, make them useful for long-distance transmission and reception on the higher frequencies. Long wires can be combined to form antennas of various shapes that increase the gain and directivity over a single wire. The term *long wire*, as used in this chapter, means any such configuration, not just a straight-wire antenna.

Long Wires Versus Multielement Arrays

In general, the gain obtained with long-wire antennas is not as great, when the space available for the antenna is limited, as you can obtain from the multielement phased arrays in Chapter 8 or from a parasitic array such as a Yagi or quad (Chapters 11 or 12). However, the long-wire antenna has advantages of its own that tend to compensate for this deficiency. The construction of long-wire antennas is simple both electrically and mechanically, and there are no especially critical dimensions or adjustments. The long-wire antenna will work well and give satisfactory gain and directivity over a 2-to-1 frequency range. In addition, it will accept power and radiate well on any frequency for which its overall length is not less than about a half wavelength. Since a wire is not electrically long, even at 28 MHz, unless its physical length is equal to at least a half wavelength on 3.5 MHz, any long-wire can be used on all amateur bands that are useful for long-distance communication.

Between two directive antennas having the same theoretical gain, one a multielement array and the other a long-wire antenna, many amateurs have found that the long-wire antenna seems more effective in reception. One possible explanation is that there is a *diversity effect* with a long-wire antenna because it is spread out over a large distance, rather than being concentrated in a small space, as would be the case with a Yagi, for example. This may raise the average level of received energy for ionospheric-propagated signals. Another factor is that long-wire antennas have directive patterns that can be extremely sharp in the horizontal (azimuthal) plane. This is an advantage that other types of multielement arrays do not have, but it can be a double-edged sword too. We'll discuss this aspect in some detail in this chapter.

General Characteristics of Long-Wire Antennas

Whether the long-wire antenna is a single wire running in one direction or is formed into a V-beam, rhombic, or some other configuration, there are certain general principles that apply and some performance features that are common to all types. The first of these is that the power gain of a long-wire antenna as compared with a half-wave dipole is not considerable until the antenna is really long (its length measured in wavelengths rather than in a specific number of feet). The reason for this is that the fields radiated by elementary lengths of wire along the antenna do not combine, at a distance, in as simple a fashion as the fields from half-wave dipoles used in other types of directive arrays.

There is no point in space, for example, where the distant fields from all points along the wire are exactly in phase (as they are, in the optimum direction, in the case of two or more collinear or broadside dipoles when fed with in-phase currents). Consequently, the field strength at a distance is always less than would be obtained if the same length of wire were cut up into properly phased and separately driven dipoles. As the wire is made longer, the fields combine to form increasingly intense main lobes, but these lobes do not develop appreciably until the wire is several wavelengths long. See **Fig 1**.

The longer the antenna, the sharper the lobes become, and since it is really a hollow cone of radiation about the wire in free space, it becomes sharper in both planes. Also, the greater the length, the smaller the angle with the wire at which the maximum radiation lobes occur. There are four main lobes to the directive patterns of long-wire antennas; each makes the same angle with respect to the wire.

Fig 2A shows the azimuthal radiation pattern of a 1-λ long-wire antenna, compared with a $^1/_2$-λ dipole. Both antennas are mounted at the same height of 1 λ above flat ground (70 feet high at 14 MHz, with a wire length of 70 feet) and both patterns are for an elevation angle of 10°, an angle suitable for long-distance communication on 20 meters. The long-wire in Fig 2A is oriented in the 270° to 90° direction, while the dipole is aligned at right angles so that its characteristic figure-8 pattern goes left-to-right. The 1-λ long-wire has about 0.6 dB more gain than the dipole, with four main lobes as compared to the two lobes from the dipole.

You can see that the two lobes on the left side of Fig 2A are about 1 dB down compared to the two lobes on the right side. This is because the long-wire here is fed at the left-hand end in the computer model. Energy is radiated as a wave travels down the wire and some energy is also lost to ohmic resistance in the wire and the ground. The forward-going wave then reflects from the open-circuit at the right-hand end of the wire and reverses direction, traveling toward the left end, still radiating as it

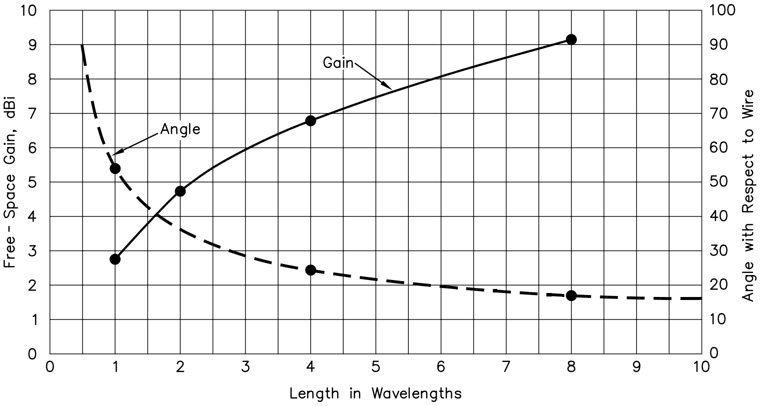

Fig 1—Theoretical gain of a long-wire antenna, in dBi, as a function of wire length. The angle, with respect to the wire, at which the radiation intensity is maximum also is shown.

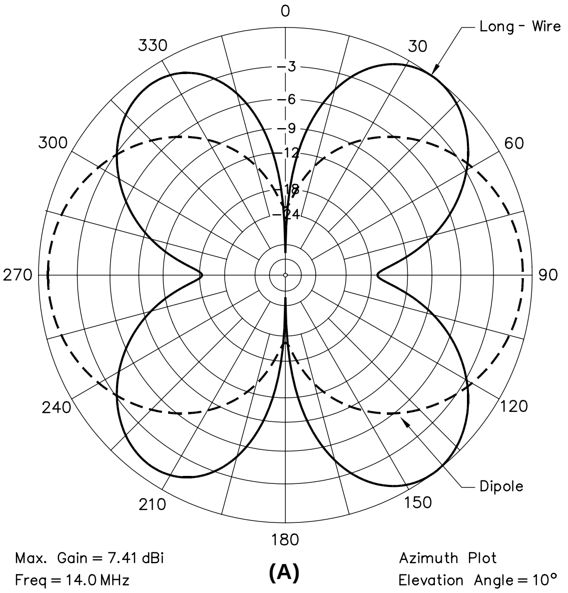

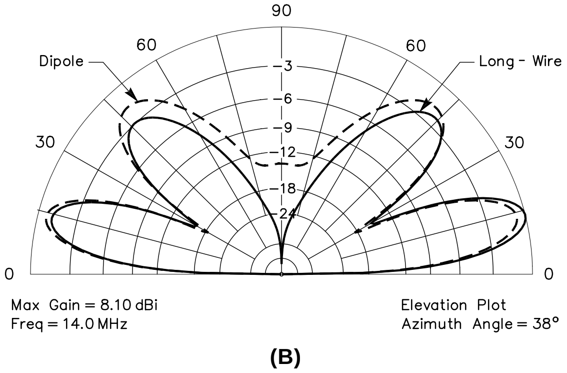

Fig 2—At A, comparison of azimuthal patterns for a 1-λ long-wire antenna (solid line) and a ½-λ dipole (dashed line) at an elevation angle of 10°. Each antenna is located 1 λ (70 feet) over flat ground at 14 MHz. At B, the elevation-plane patterns at peak azimuth angles for each antenna. The long-wire has about 0.6 dB more gain than the dipole.

travels. An antenna operating in this way has much the same characteristics as a transmission line that is terminated in an open circuit—that is, it has standing waves on it. Unterminated long-wire antennas are often referred to as *standing wave antennas*. As the length of a long-wire antenna is increased, a moderate front-to-back ratio results, about 3 dB for very long antennas.

Fig 2B shows the elevation-plane pattern for the long-wire and for the dipole. In each case the elevation pattern is at the azimuth of maximum gain—at an angle of 38° with respect to the wire-axis for the long-wire and at 90° for the dipole. The peak elevation for the long-wire is very slightly lower than that for the dipole at the same height above ground, but not by much. In other words, the height above ground is the main determining factor for the shape of the main lobe of a long-wire's elevation pattern, as it is for most horizontally polarized antennas.

The shape of the azimuth and elevation patterns in Fig 2 might lead you to believe that the radiation pattern is simple. **Fig 3** is a 3-D representation of the pattern from a 1-λ long-wire that is 1 λ high over flat ground. Besides the main low-angle lobes, there are strong lobes at higher angles. Things get even more complicated when the length of the long-wire increases.

Directivity

Because many points along a long wire are carrying currents in different phases (with different current amplitudes as well), the field pattern at a distance becomes more complex as the wire is made longer. This complexity is manifested in a series of minor lobes, the number of which increases with the wire length. The intensity of radiation from the minor lobes is frequently as great as, and sometimes greater than, the radiation from a half-wave dipole. The energy radiated in the minor lobes is not available to improve the gain in the major lobes, which is another reason why a long-wire antenna must be long to give appreciable gain in the desired directions.

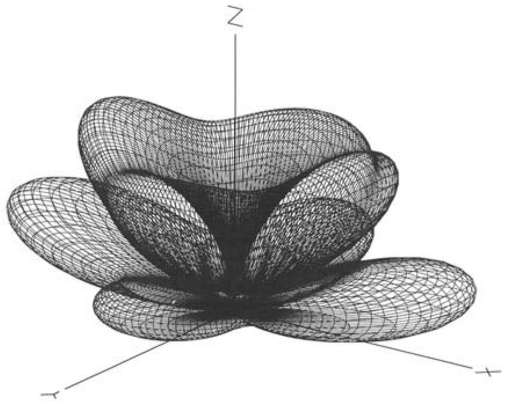

Fig 3—A 3-D representation of the radiation pattern for the 1-λ long-wire shown in Fig 2. The pattern is obviously rather complex. It gets even more complicated for wires longer than 1 λ.

Fig 4 shows an azimuthal-plane comparison between a 3-λ (209 feet long) long-wire and the comparison $^1/_2$-λ dipole. The long-wire now has 8 minor lobes besides the four main lobes. Note that the angle the main lobes make with respect to the axis of the long-wire (also left-to-right in Fig 4) becomes smaller as the length of the long-wire increases. For the 3-λ long-wire, the main lobes occur 28° off the axis of the wire itself.

Other types of simple driven and parasitic arrays do not have minor lobes of any great consequence. For that reason they frequently seem to have much better directivity than long-wire antennas, because their responses in undesired directions are well down from their response in the desired direction. This is the case even if a multielement array and a long-wire antenna have the same peak gain in the favored direction. **Fig 5** compares the same 3-λ long-wire with a 4-element Yagi and a ½-λ dipole, again both at the same height as the long-wire. Note that the Yagi has only a single backlobe, down about 21 dB from its broad main lobe, which has a 3-dB beamwidth of 63°. The 3-dB beamwidth of the long-wire's main lobes (at a 28° angle from the wire axis) is far more narrow, at only 23°.

For amateur work, particularly with directive antennas that cannot be rotated, the minor lobes of a long-wire antenna have some advantages. Although the nulls in the

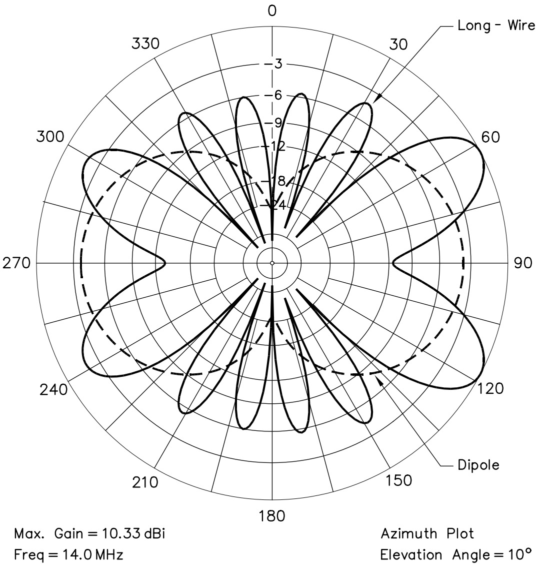

Fig 4—An azimuthal-plane comparison between a 3-λ (209 feet long) long-wire (solid line) and the comparison ½-λ dipole (dashed line) at 70 feet high (1 λ) at 14 MHz.

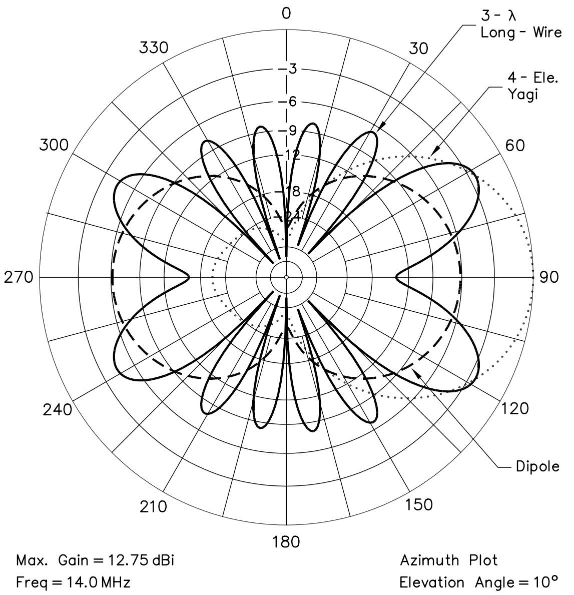

Fig 5—A comparison between the 3-λ long-wire (solid line) in Fig 4, a 4-element 20-meter Yagi on a 26-foot boom (dotted line), and a ½-λ dipole (dashed line), again at a height of 70 feet. The main lobes of the long-wire are very narrow compared to the wide frontal lobe of the Yagi. The long-wire exhibits an azimuthal pattern that is more omnidirectional in nature than a Yagi, particularly when the narrow, deep nulls in the long-wire's pattern are filled-in due to irregularities in the terrain under its long span of wire.

computer model in Fig 5 are deeper than 30 dB, they are not so dramatic in actual practice. This is due to irregularities in the terrain that inevitably occur under the span of a long wire. In most directions the long-wire antenna will be as good as a half-wave dipole, and in addition will give high gain in the most favored directions, even though that is over narrow azimuths.

Fig 6A compares the azimuth responses for a 5-λ long-wire (350 feet long at 14 MHz) to the same 4-element Yagi and dipole. The long-wire now exhibits 16 minor lobes in addition to its four main lobes. The peaks of these sidelobes are down about 8 dB from the main lobes and they are stronger than the dipole, making this long-wire antenna effectively omnidirectional. Fig 6B shows the elevation pattern of the 5-λ long-wire at its most effective azimuth compared to a dipole. Again, the shape of the main lobe is mainly determined by the long-wire's height above ground, since the peak angle is only just a bit lower than the peak angle for the dipole. The long-wire's elevation response breaks up into numerous lobes above the main lobes, just as it does in the azimuth plane.

For the really ambitious, **Fig 7** compares the performance for an 8-λ (571 feet) long-wire antenna with a 4-element Yagi and the 1/2-λ dipole. Again, in actual practice, the nulls would tend to be filled in by terrain irregularities, so a very long antenna like this would be a pretty potent performer.

Calculating Length

In this chapter, lengths are discussed in terms of wave-

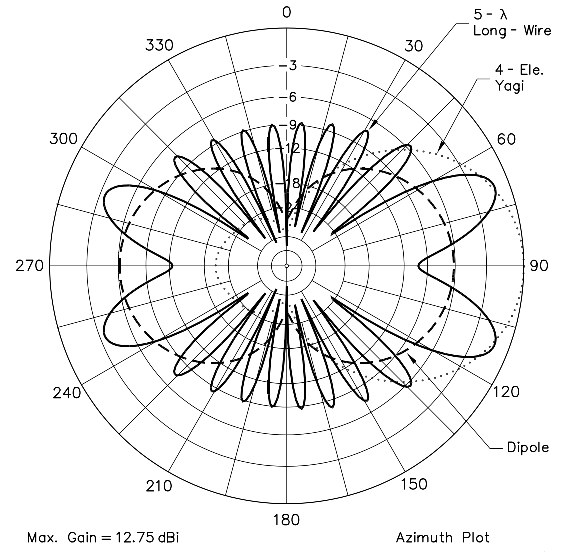

(A)

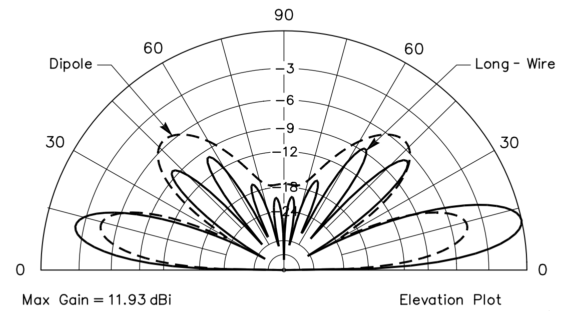

(B)

Fig 6—At A, the azimuth responses for a 5-λ long-wire (350 feet long at 14 MHz—solid line) to the same 4-element Yagi (dotted line) and dipole (dashed line) as in Fig 5. At B, the elevation-plane responses for the long-wire (solid line) and the dipole (dashed line) by themselves. Note that the elevation angle giving peak gain for each antenna is just about the same. The long-wire achieves gain by compressing mainly the azimuthal response, squeezing the gain into narrow lobes; not so much by squeezing the elevation pattern for gain.

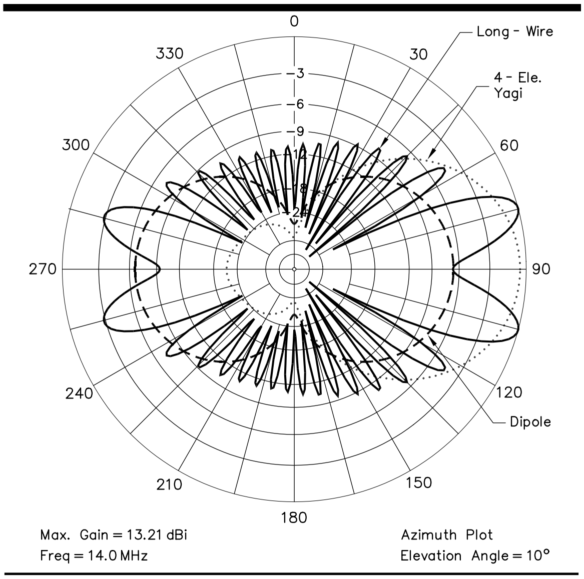

Fig 7—The azimuthal-plane performance for an 8-λ (571 feet) long-wire antenna (solid line), compared with a 4-element Yagi (dotted line) and a ½-λ dipole (dashed line).

lengths. Throughout the preceding discussion the frequency in the models was held at 14 MHz. Remember that a long-wire that is 4 λ long at 14 MHz is 8 λ long at 28 MHz.

There is nothing very critical about wire lengths in an antenna system that will work over a frequency range including several amateur bands. The antenna characteristics change very slowly with length, except when the wires are short (around one wavelength, for instance). There is no need to try to establish exact resonance at a particular frequency for proper antenna operation.

The formula for determining the lengths for harmonic wires is:

$$\text{Length}\left(\text{feet}\right)=\frac{984\left(\text{N}-0.025\right)}{\text{f}\left(\text{MHz}\right)} \qquad \text{(Eq 1)}$$

where N is the antenna length in wavelengths. In cases where precise resonance is desired for some reason (for obtaining a resistive load for a transmission line at a particular frequency, for example) it is best established by trimming the wire length until the standing-wave ratio on the line is minimum.

Tilted Wires

In theory, it is possible to maximize gain from a long-wire antenna by tilting it to favor a desired elevation take-off angle. Unfortunately, the effect of real ground under the antenna negates the possible advantages of tilting, just as it does when a Yagi or other type of parasitic array is tilted from horizontal. You would do better keeping a long-wire antenna horizontal, but raising it higher above ground, to achieve more gain at low takeoff angles.

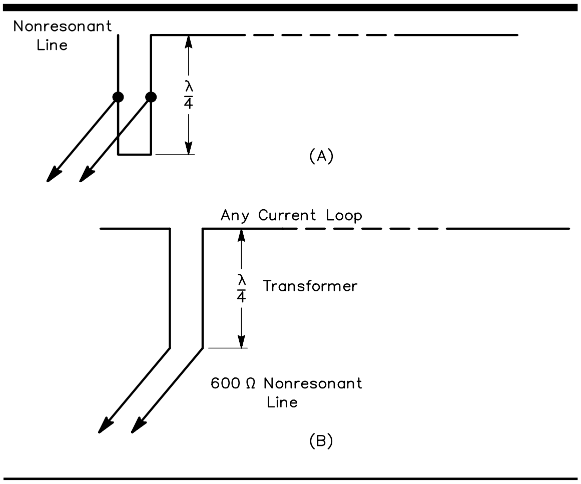

Fig 8—Methods for feeding long single-wire antennas.

Feeding Long Wires

A long-wire antenna is normally fed at the end or at a current loop. Since a current loop changes to a node when the antenna is operated at any even multiple of the frequency for which it is designed, a long-wire antenna will operate as a true long wire on all bands only when it is fed at the end.

A common method of feeding a long-wire is to use a resonant open-wire line. This system will work on all bands down to the one, if any, at which the antenna is only a half wave long. Any convenient line length can be used if you match the transmitter to the line's input impedance using an antenna tuner, as described in Chapter 25.

Two arrangements for using nonresonant lines are given in **Fig 8**. The one at A is useful for one band only since the matching section must be a quarter wave long, approximately, unless a different matching section is used for each band. In B, the λ/4 transformer (Q-section) impedance can be designed to match the antenna to the line, as described in Chapter 26. You can determine the value of radiation resistance using a modern modeling program or you can actually measure the feed-point impedance. Although it will work as designed on only one band, the antenna can be used on other bands by treating the line and matching transformer as a resonant line. In this case, as mentioned earlier, the antenna will not radiate as a true long wire on even multiples of the frequency for which the matching system is designed.

The end-fed arrangement, although the most convenient when tuned feeders are used, suffers the disadvantage that there is likely to be a considerable antenna current on the line. In addition, the antenna reactance changes rapidly with frequency. Consequently, when the wire is several wavelengths long, a relatively small change in frequency—a fraction of the width of a band—may require major changes in the adjustment of the antenna tuner. Also, the line becomes unbalanced at all frequencies between those at which the antenna is resonant. This leads to a considerable amount of radiation from the line. The unbalance can be overcome by using multiple long wires in a V or rhombic shape, as described below.

COMBINATIONS OF LONG WIRES

The directivity and gain of long wires may be increased by using two wires placed in relation to each other such that the fields from both combine to produce the greatest possible field strength at a distant point. The principle is similar to that used in designing the multi-element arrays described in Chapter 8.

Parallel Wires

One possible method of using two (or more) long wires is to place them in parallel, with a spacing of $^1/_2$ λ or so, and feed the two in phase. In the direction of the wires the fields will add in phase. However, the takeoff angle is high directly in the orientation of the wire, and this method will result in rather high-angle radiation even if the wires are several wavelengths long. With a parallel arrangement of this sort the gain should be about 3 dB over a single wire of the same length, at spacings in the vicinity of $^1/_2$ wavelength.

The V-Beam Antenna

Instead of using two long wires parallel to each other, they may be placed in the form of a horizontal V, with the included angle between the wires equal to twice the angle made by the main lobes referenced to the wire axis for a single wire of the same physical length. For example, for a leg length of 5 λ, the angle between the legs of a V should be about 42°, twice the angle of 21° of the main lobe referenced to the long-wire's axis. See Fig 6A.

The plane directive patterns of the individual wires combine along a line in the plane of the antenna and bisecting the V, where the fields from the individual wires reinforce each other. The sidelobes in the azimuthal pattern are suppressed by about 10 dB, so the pattern becomes essentially bidirectional. See **Fig 9**.

The included angle between the legs is not particularly critical. This is fortunate, especially if the same antenna is used on multiple bands, where the electrical length varies directly with frequency. This would normally require different included angles for each band. For multi-band V-antennas, a compromise angle is usually chosen to equalize performance. **Fig 10** shows the azimuthal pattern for a V-beam with 1-λ legs, with an included angle of 75° between the legs, mounted 1 λ above flat ground. This is for a 10° elevation angle. At 14 MHz the antenna has two 70-foot high, 68.5-foot long legs, separated at their far ends by 83.4 feet. For comparison the azimuthal patterns for the same 4-element Yagi and ½-λ dipole used previously for the long-wires are overlaid on the same plot. The V has about 2 dB more gain than the dipole but is down some 4 dB compared to the Yagi, as expected for relatively short legs.

Fig 11 shows the azimuthal pattern for the same antenna in Fig 10, but at 28 MHz and at an elevation angle of 6°. Because the legs are twice as long electrically at 28 MHz, the V-beam has compressed the main lobe into a narrow beam that now has a peak gain equal to the Yagi, but with a 3-dB beamwidth of only 18.8°. Note that you could obtain about 0.7 dB more gain at 14 MHz, with a 1.7-dB degradation of gain at 28 MHz, if you increase the included angle to 90° rather than 75°.

Fig 12 shows the azimuthal pattern for a V-beam with 2-λ legs (137 feet at 14 MHz), with an included angle of 60° between them. As usual, the assumed height is 70 feet, or 1 λ at 14 MHz. The peak gain for the V-beam is just about equal to that of the 4-element Yagi, although the 3-dB

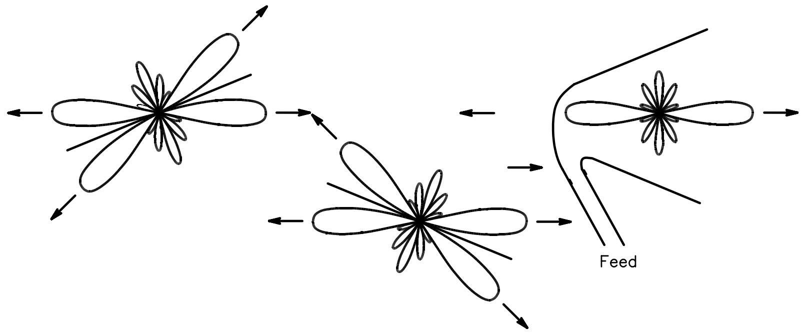

Fig 9—Two long wires and their respective patterns are shown at the left. If these two wires are combined to form a V with an angle that is twice that of the major lobes of the wires and with the wires excited out of phase, the radiation along the bisector of the V adds and the radiation in the other directions tends to cancel.

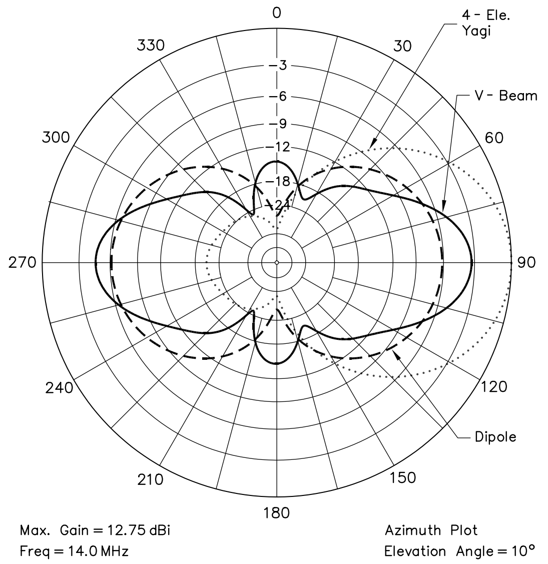

Fig 10— Azimuthal-plane pattern at 10° elevation angle for a 14-MHz V-beam (solid line) with 1-λ legs (68.5 feet long), using an included angle of 75° between the legs. The V-beam is mounted 1 λ above flat ground, and is compared with a ½-λ dipole (dashed line) and a 4-element 20-meter Yagi on a 26-foot boom (dotted line).

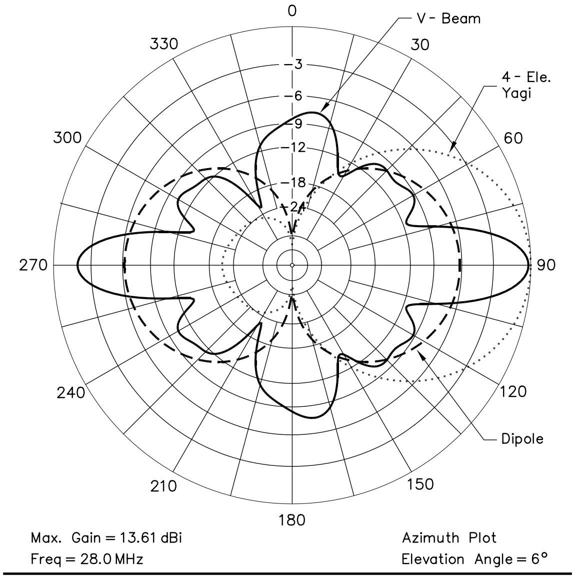

Fig 11—The same V-beam as in Fig 10 at 28 MHz (solid line), at an elevation angle of 6°, compared to a 4-element Yagi (dotted line) and a dipole (dashed line). The V-beam's pattern is very narrow, at 18.8° at the 3-dB points, requiring accurate placement of the supports poles to aim the antenna at the desired geographic target.

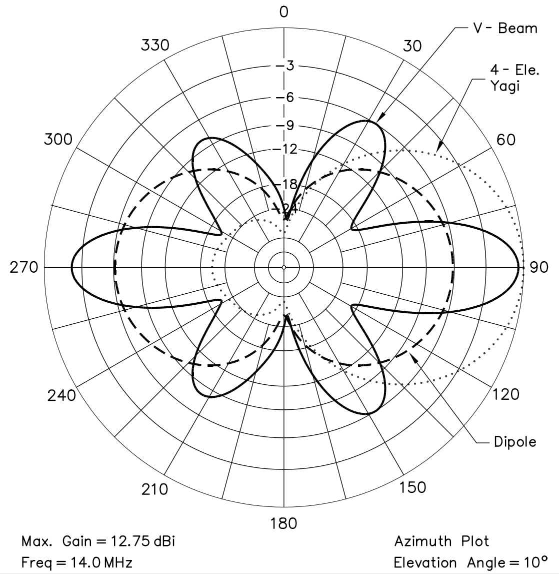

Fig 12—Azimuthal pattern for a V-beam (solid line) with 2-λ legs (137 feet at 14 MHz), with an included angle of 60° between them. The height is 70 feet, or 1 λ, over flat ground. For comparison, the response for a 4-element Yagi (dotted line) and a dipole (dashed line) are shown. The 3-dB beamwidth has decreased to 23.0°.

nose beamwidth is narrow, at 23°. This makes setting up the geometry critical if you want to maximize gain into a particular geographic area. While you might be able to get away with using convenient trees to support such an antenna, it's far more likely that you'll have to use carefully located towers to make sure the beam is aimed where you expect it to be pointed.

For example, in order to cover all of Europe from San Francisco, an antenna must cover from about 11° (to Moscow) to about 46° (to Portugal). This is a range of 35° and signals from the V-beam in Fig 12 would be down some 7 dB over this range of angles, assuming the center of the beam is pointed exactly at a heading of 28.5°. The 4-element Yagi on the other hand would cover this range of azimuths more consistently, since its 3-dB beamwidth is 63°.

Fig 13 shows the same V-beam as in Fig 12, but this time at 28 MHz. The peak gain of the main lobe is now about 1 dB stronger than the 4-element Yagi used as a reference, and the main lobe has two nearby sidelobes that tend to broaden out the azimuthal response. At this frequency the V-beam would cover all of Europe better from San Francisco.

Fig 14 shows a V-beam with 3-λ (209 feet at 14 MHz) legs with an included angle of 50° between them. The peak gain is now greater than that of a 4-element Yagi, but the 3-dB beamwidth has been reduced to 17.8°, making aim-

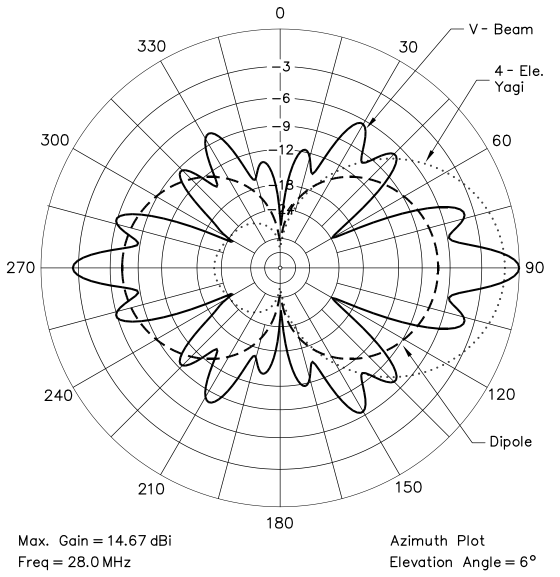

Fig 13—The same 2-λ per leg V-beam (solid line) as in Fig 12, but at 28 MHz and at a 6° takeoff elevation angle. Two sidelobes have appeared flanking the main lobe, making the effective azimuthal pattern wider at this frequency.

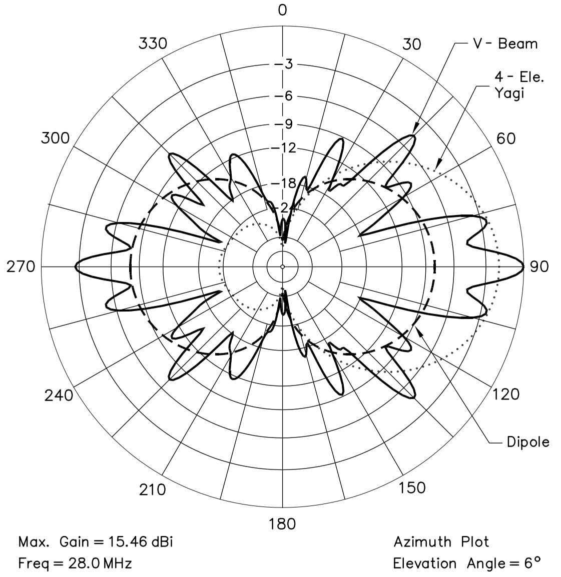

Fig 15—The same 209-foot/leg V-beam as Fig 14, but at 28 MHz. Again, the two close-in sidelobes tend to spread out the response some at 28 MHz.

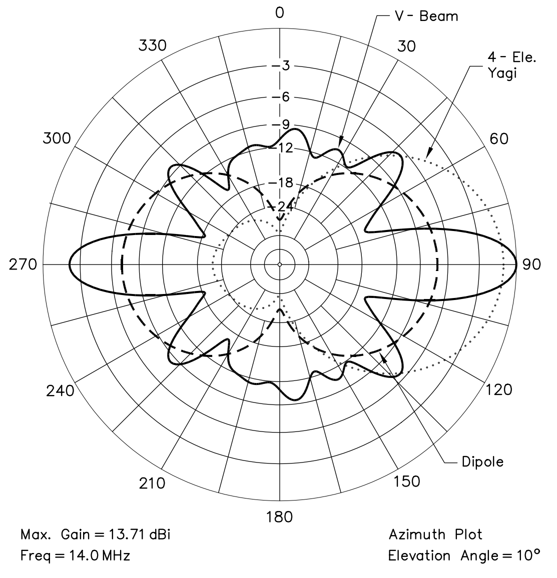

Fig 14—A V-beam (solid line) with 3-λ (209 feet at 14 MHz) legs using an included angle of 50° between them, compared to a 4-element Yagi (dotted line) and a dipole (dashed line). The 3-dB beamwidth has now decreased to 17.8°.

ing the antenna even more critical. **Fig 15** shows the same V-beam at 28 MHz. Here again, the main lobe has nearby sidelobes that broaden the effective azimuth to cover a wider area.

Fig 16 shows the elevation-plane response for the same 209-foot leg V-beam at 28 MHz (3-λ at 14 MHz), compared to a dipole at the same height of 70 feet. The higher-gain V-beam suppresses higher-angle lobes, essentially stealing energy from them and concentrating it in the main beam at 6° elevation.

The same antenna can be used at 3.5 and 7 MHz. The gain will not be large, however, because the legs are not very long at these frequencies. **Fig 17** compares the V-beam versus a horizontal ½-λ 40-meter dipole at 70 feet. At low elevation angles there is about 2 dB of advantage on 40 meters. **Fig 18** shows the same type of comparison for 80 meters, where the 80-meter dipole is superior at all angles.

Other V Combinations

A gain increase of about 3 dB can be had by stacking two V-beams one above the other, a half wavelength apart, and feeding them with in-phase currents. This will result in a lowered angle of radiation. The bottom V should be at least a quarter wavelength above the ground, and preferably a half wavelength. This arrangement will narrow the

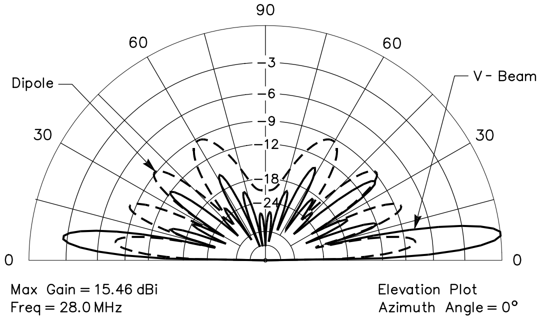

Fig 16—The elevation-plane of the 209-foot/leg V-beam (solid line) compared to the dipole (dashed line). Again, the elevation angle for peak gain corresponds well to that of the simple dipole at the same height.

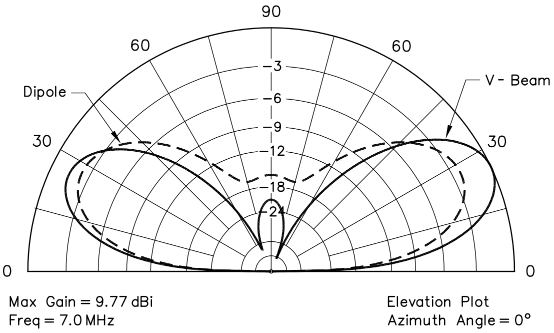

Fig 17—Elevation pattern for the same 209-foot-per-leg V-beam (solid line), at 7 MHz, compared to a 40-meter dipole (dashed line) at the same height of 70 feet.

elevation pattern and it will also have a narrow azimuthal pattern.

The V antenna can be made unidirectional by using a second V placed an odd multiple of a quarter wavelength in back of the first and exciting the two with a phase difference of 90º. The system will be unidirectional in the direction of the antenna with the lagging current. However, the V reflector is not normally employed by amateurs at low frequencies because it restricts the use to one band and requires a fairly elaborate supporting structure. Stacked Vs with driven reflectors could, however, be built for the 200- to 500-MHz region without much difficulty.

Feeding the V Beam

The V-beam antenna is most conveniently fed with tuned open-wire feeders with an antenna tuner, since this permits multiband operation. Although the length of the wires in a V-beam is not at all critical, it is important that both wires be the same electrical length. If a single band matching solution is desired, probably the most appropriate matching system is that using a stub or quarter-wave matching section. The adjustment of such a system is described in Chapter 26.

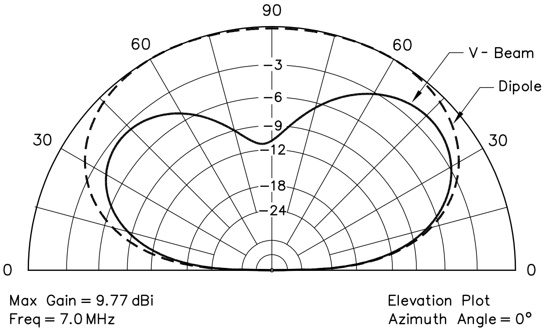

Fig 18—Elevation pattern for the same 209-foot-per-leg V-beam (solid line), at 3.5 MHz, compared to an 80-meter dipole at 70 feet (dashed line).

THE RESONANT RHOMBIC ANTENNA

The diamond-shaped or rhombic antenna shown in **Fig 19** can be looked upon as two acute-angle V-beams placed end-to-end. This arrangement is called a *resonant rhombic*. The leg lengths of the resonant rhombic must be an integral number of half wavelengths to avoid reactance at its feed point.

The resonant rhombic has two advantages over the simple V-beam. For the same total wire length it gives somewhat greater gain than the V-beam. A rhombic with 3 λ on a leg, for example, has about 1 dB gain over a V antenna with 6 wavelengths on a leg. **Fig 20** compares the azimuthal pattern at a 10° elevation for a resonant rhombic with 3 λ legs on 14 MHz, compared to a V-beam with 6 λ legs at the same height of 70 feet. The 3-dB nose beamwidth of the resonant rhombic is only 12.4° wide, but the gain is very high at 16.26 dBi.

The directional pattern of the rhombic is less frequency sensitive than the V when the antenna is used over a wide frequency range. This is because a change in frequency causes the major lobe from one leg to shift in one direction while the lobe from the opposite leg shifts the other way. This automatic compensation keeps the direction the same over a considerable frequency range. The disadvantage of the rhombic as compared with the V-beam is that an additional support is required.

The same factors that govern the design of the V-beam apply in the case of the resonant rhombic. The optimal apex angle A in Fig 19 is the same as that for a V having an equal leg length. The diamond-shaped antenna also can be operated as a terminated antenna, as described later in this chapter, and much of the discus-

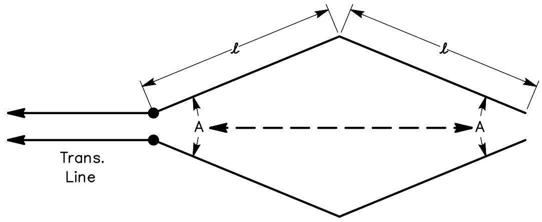

Fig 19—The resonant rhombic or diamond-shaped antenna. All legs are the same length, and opposite angles of the diamond are equal. Length ℓ is an integral number of half wavelengths for resonance.

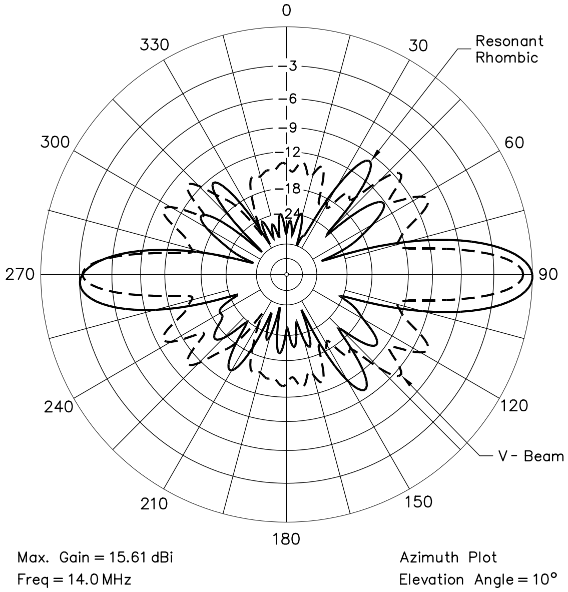

Fig 20—Azimuthal-plane pattern of resonant (unterminated) rhombic (solid line) with 3-λ legs on 14 MHz, at a height of 70 feet above flat ground, compared with a 6-λ per leg V-beam (dashed line) at the same height. Both azimuthal patterns are at a takeoff angle of 10°. The sidelobes for the resonant rhombic are suppressed to a greater degree than those for the V-beam.

sion in that section applies to the resonant rhombic as well.

The resonant rhombic has a bidirectional pattern, with minor lobes in other directions, their number and intensity depending on the leg length. In general, these sidelobes are suppressed better with a resonant rhombic than with a V-beam. When used at frequencies below the VHF region, the rhombic antenna is always mounted with the plane containing the wires horizontal. The polarization in this plane, and also in the perpendicular plane that bisects the rhombic, is horizontal. At 144 MHz and above, the dimensions are such that the antenna can be mounted with the plane containing the wires vertical if vertical polarization is desired.

When the rhombic antenna is to be used on several HF amateur bands, it is advisable to choose the apex angle, A, on the basis of the leg length in wavelengths at 14 MHz. Although the gain on higher frequency bands will not be quite as favorable as if the antenna had been designed for the higher frequencies, the system will still work well at the low angles that are necessary at such frequencies.

The resonant rhombic has lots of gain, but you must not forget that this gain comes from a radiation pattern that is very narrow. This requires careful placement of the supports for the resonant rhombic to cover desired geographic areas. This is definitely not an antenna that allows you to use just any convenient trees as supports!

The resonant rhombic antenna can be fed in the same way as the V-beam. Resonant feeders are necessary if the antenna is to be used in several amateur bands.

TERMINATED LONG-WIRE ANTENNAS

All the antenna systems considered so far in this chapter have been based on operation with standing waves of current and voltage along the wire. Although most hams use antenna designs based on using resonant wires, resonance is by no means a necessary condition for the wire to radiate and intercept electromagnetic waves efficiently, as discussed in Chapter 2. The result of using nonresonant wires is reactance at the feed point, unless the antenna is terminated with a resistive load.

In **Fig 21**, suppose that the wire is parallel with the ground (horizontal) and is terminated by a load Z equal to its characteristic impedance, Z_{ANT}. The wire and its image in the ground create a transmission line. The load Z can represent a receiver matched to the line. The *terminating resistor* R is also equal to the Z_{ANT} of the wire. A wave coming from direction X will strike the wire first at its far end and sweep across the wire at some angle until it reaches the end at which Z is connected. In so doing, it will induce voltages in the antenna, and currents will flow as a result. The current flowing toward Z is the useful output of the antenna, while the current flowing backwards toward R will be absorbed in R. The same thing is true of a wave coming from the direction X'. In such an antenna there are no standing waves, because all received power is absorbed at either end.

The greatest possible power will be delivered to the load Z when the individual currents induced as the wave sweeps across the wire all combine properly on reaching the load. The currents will reach Z in optimum phase when the time required for a current to flow from the far end of the antenna to Z is exactly one-half cycle longer than the time taken by the wave to sweep over the antenna. A half cycle is equivalent to a half wavelength greater than the distance traversed by the wave from the instant it strikes

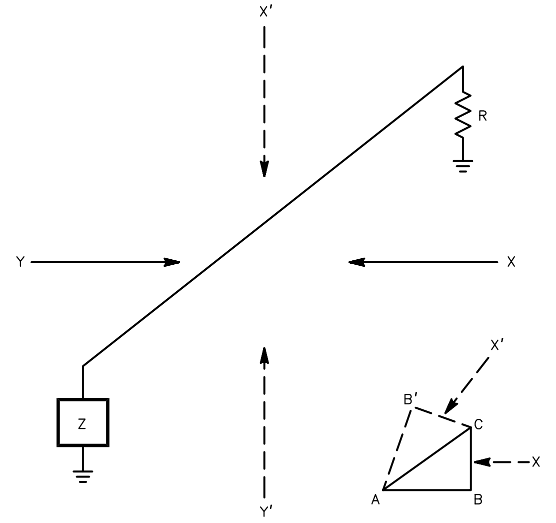

Fig 21—Layout for a terminated long-wire antenna.

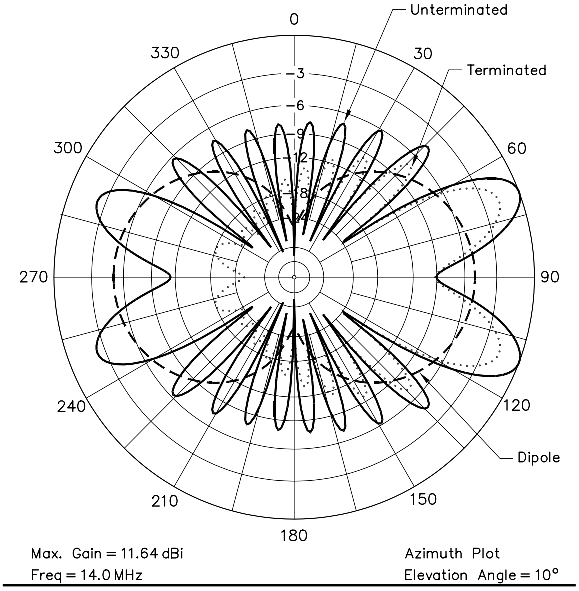

Fig 22—Azimuthal-plane pattern for 5-λ long-wire antenna at 14 MHz and 70 feet above flat ground. The solid line shows the long-wire terminated with 600-Ω to ground, while the dashed line is for the same antenna unterminated. For comparison, the response for a ½-λ dipole is overlaid with the two other patterns. You can see that the terminated long-wire has a good front-to-back pattern, but it loses about 2 dB in forward gain compared to the unterminated long-wire.

the far end of the antenna to the instant that it reaches the near end. This is shown by the small drawing, where AC represents the antenna, BC is a line perpendicular to the wave direction, and AB is the distance traveled by the wave in sweeping past AC. AB must be one-half wavelength shorter than AC. Similarly, AB' must be the same length as AB for a wave arriving from X'.

A wave arriving at the antenna from the opposite direction Y (or Y'), will similarly result in the largest possible current at the far end. However, since the far end is terminated in R, which is equal to Z, all the power delivered to R by the wave arriving from Y will be absorbed in R. The current traveling to Z will produce a signal in Z in proportion to its amplitude. If the antenna length is such that all the individual currents arrive at Z in such phase as to add up to zero, there will be no current through Z. At other lengths the resultant current may reach appreciable values. The lengths that give zero amplitude are those which are odd multiples of $^1/_4$ λ, beginning at $^3/_4$ λ. The response from the Y direction is greatest when the antenna is any even multiple of $^1/_2$ λ long; the higher the multiple, the smaller the response.

Directional Characteristics

Fig 22 compares the azimuthal pattern for a 5-λ long 14-MHz long-wire antenna, 70 feet high over flat ground, when it is terminated and when it is unterminated. The rearward pattern when the wire is terminated with a 600 Ω resistor is reduced about 15 dB, with a reduction in gain in the forward direction of about 2 dB.

For a shorter leg length in a terminated long-wire antenna, the reduction in forward gain is larger—more energy is radiated by a longer wire before the forward wave is absorbed in the terminating resistor. The azimuthal patterns for terminated and unterminated V-beams with 2-λ legs are overlaid for comparison in **Fig 23**. With these relatively short legs the reduction in forward gain is about 3.5 dB due to the terminations, although the front-to-rear ratio approaches 20 dB for the terminated V-beam. Each leg of this terminated V-beam use a 600-Ω non-inductive resistor to ground. Each resistor would have to dissipate about one-quarter of the transmitter power. For average conductor diameters and heights above ground, the Z_{ANT} of the antenna is of the order of 500 to 600 Ω.

THE TERMINATED RHOMBIC ANTENNA

The highest development of the long-wire antenna is the *terminated rhombic*, shown schematically in **Fig 24**. It consists of four conductors joined to form a diamond, or *rhombus*. All sides of the antenna have the same length and the opposite corner angles are equal. The antenna can be considered as being made up of two V antennas placed end to end and terminated by a noninductive resistor to produce a unidirectional pattern. The terminating resistor is connected between the far ends of the two sides, and is made approximately equal to the characteristic impedance of the antenna as a unit. The rhombic may be constructed either horizontally or vertically, but is practically always constructed horizontally at frequencies below 54 MHz,

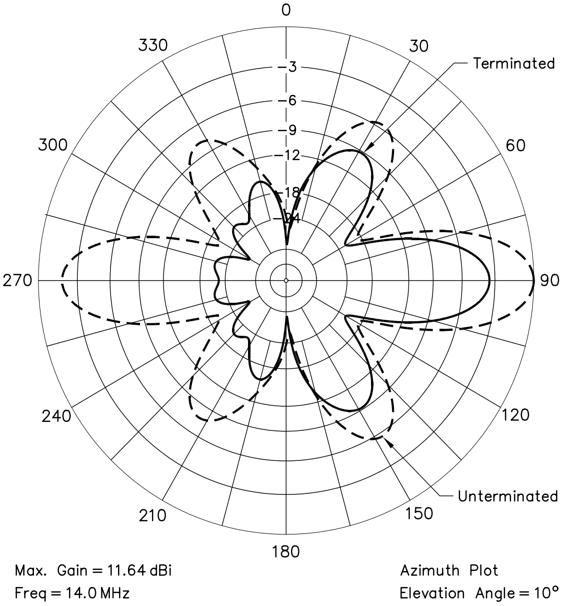

Fig 23—The azimuthal patterns for a shorter-leg V-beam (2-λ legs) when it is terminated (solid line) and unterminated (dashed line). With shorter legs, the terminated V-beam loses about 3.5 dB in forward gain compared to the unterminated version, while suppressing the rearward lobes as much as 20 dB.

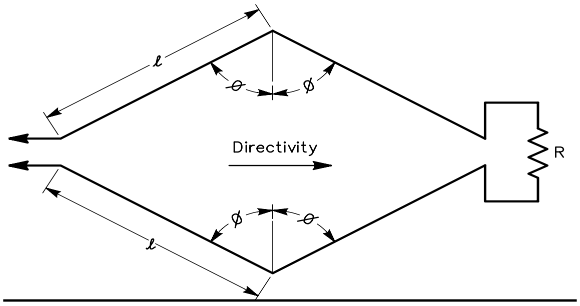

Fig 24—The layout for a terminated rhombic antenna.

since the pole height required is considerably less. Also, horizontal polarization is equally, if not more, satisfactory at these frequencies over most types of soil.

The basic principle of combining lobes of maximum radiation from the four individual wires constituting the rhombus or diamond is the same in either the terminated type or the resonant type described earlier in this chapter.

Tilt Angle

In dealing with the terminated rhombic, it is a matter of custom to talk about the *tilt angle* (ϕ in Fig 24), rather than the angle of maximum radiation with respect to an individual wire. **Fig 25** shows the tilt angle as a function of the antenna leg length. The curve marked "0°" is used for a takeoff elevation angle of 0°; that is, maximum radiation in the plane of the antenna. The other curves show the proper tilt angles to use when aligning the major lobe with a desired takeoff angle. For a 5° takeoff angle, the difference in tilt angle is less than 1° for the range of lengths shown.

The broken curve marked "optimum length" shows the leg length at which maximum gain is obtained at any given takeoff angle. Increasing the leg length beyond the optimum will result in less gain, and for that reason the curves do not extend beyond the optimum length. Note that the optimum length becomes greater as the desired takeoff angle decreases. Leg lengths over 6 λ are not recommended because the directive pattern becomes so sharp that the antenna performance is highly variable with small changes in the angle, both horizontal and vertical, at which an incoming wave reaches the antenna. Since these angles vary to some extent in ionospheric propagation, it does not pay to attempt to try for too great a degree of directivity.

Multiband Design

When a rhombic antenna is to be used over a considerable frequency range, a compromise must be made in the tilt angle. **Fig 26** gives the design dimensions of a suitable compromise for a rhombic that covers the 14 to 30 MHz range well. **Fig 27** shows the azimuth and elevation patterns for this antenna at 14 MHz, at a height of 70 feet over flat ground. The comparison antenna in this case is a 4-element Yagi on a 26-foot boom, also 70 feet above flat ground. The rhombic has about 2.2 dB more gain, but its azimuthal pattern is 17.2° wide at the 3 dB points, and only 26° at the –20 dB points! On the other hand, the Yagi has a 3-dB beamwidth of 63°, making it far easier to aim at a distant geographic location. Fig 27B shows the elevation-plane patterns for the same antennas above. As usual, the peak angle for either horizontally polarized antenna is determined mainly by the height above ground.

The peak gain of a terminated rhombic is less than that of an unterminated resonant rhombic. For the rhombic of Fig 26, the reduction in peak gain is about 1.5 dB. **Fig 28** compares the azimuthal patterns for this rhombic with and without an 800-Ω termination.

Fig 29 shows the azimuth and elevation patterns for the terminated rhombic of Fig 26 when it is operated at 28 MHz. The main lobe becomes very narrow, at 6.9° at the 3-dB points. However, this is partially compensated for by the appearance of two sidelobes each side of the main beam. These tend to spread out the main pattern some. Again, a 4-element Yagi at the same height is used for comparison.

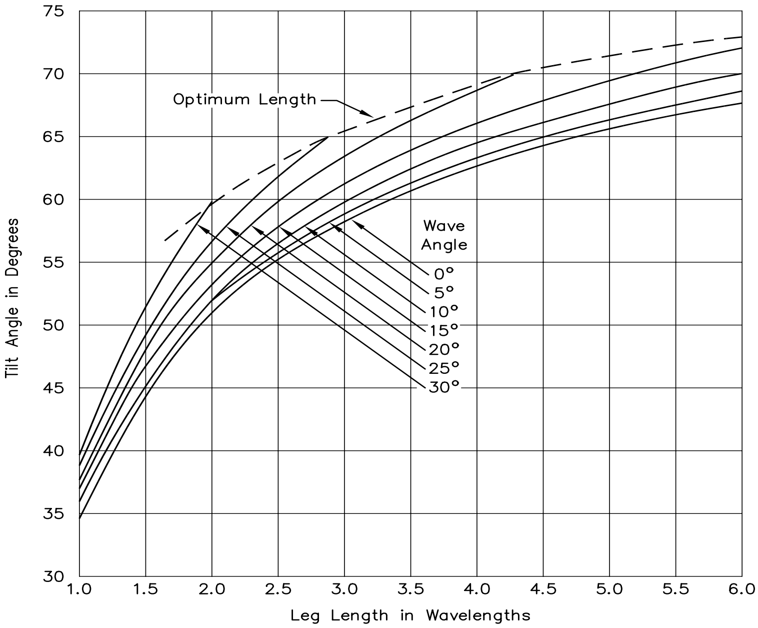

Fig 25—Rhombic-antenna design chart. For any given leg length, the curves show the proper tilt angle to give maximum radiation at the selected takeoff angle. The broken curve marked "optimum length" shows the leg length that gives the maximum possible output at the selected takeoff angle. The optimum length as given by the curves should be multiplied by 0.74 to obtain the leg length for which the takeoff angle and main lobe are aligned.

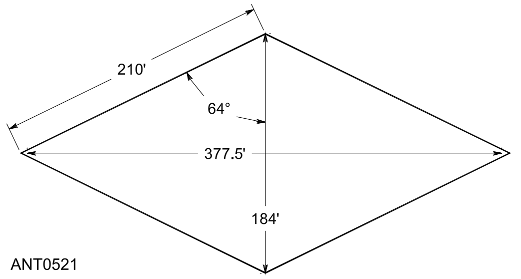

Fig 26—Rhombic antenna dimensions for a compromise design between 14- and 28-MHz requirements, as discussed in the text. The leg length is 6 λ at 28 MHz, 3 λ at 14 MHz.

Termination

Although the difference in the gain is relatively small with terminated or unterminated rhombics of comparable design, the terminated antenna has the advantage that over a wide frequency range it presents an essentially resistive and constant load to the transmitter. In a sense, the power dissipated in the terminating resistor can be considered power that would have been radiated in the other direction had the resistor not been there. Therefore, the fact that some of the power (about one-third) is used up in heating the resistor does not mean that much actual loss in the desired direction.

The characteristic impedance of an ordinary rhombic antenna, looking into the input end, is in the order of 700 to 800 Ω when properly terminated in a resistance at the far end. The terminating resistance required to bring about the matching condition usually is slightly higher than the input impedance because of the loss of energy through radiation by the time the far end is reached. The correct value usually will be found to be of the order of 800 Ω, and should be determined experimentally if the flattest possible antenna is desired. However, for average work a noninductive resistance of 800 Ω can be used with the assurance that the operation will not be far from optimum.

The terminating resistor must be practically a pure resistance at the operating frequencies; that is, its inductance and capacitance should be negligible. Ordinary wire-wound resistors are not suitable because they have far too much inductance and distributed capacitance. Small carbon resistors have satisfactory electrical characteristics but will not dissipate more than a few watts and so cannot be used, except when the transmitter power does not exceed 10 or 20 watts or when the antenna is to be used for reception only. The special resistors designed either for use as dummy antennas or for terminating rhombic antennas should be used in other cases. To allow a factor of safety, the total rated power dissipation of the resistor or resistors should be equal to half the power output of the transmitter.

To reduce the effects of stray capacitance it is desirable to use several units, say three, in series even when one alone will safely dissipate the power. The two end units should be identical and each should have one fourth to one third the total resistance, with the center unit making up the difference. The units should be installed in a weather-

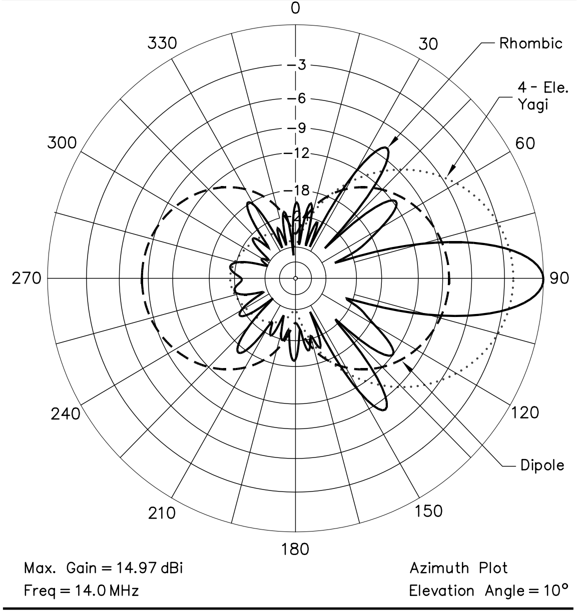

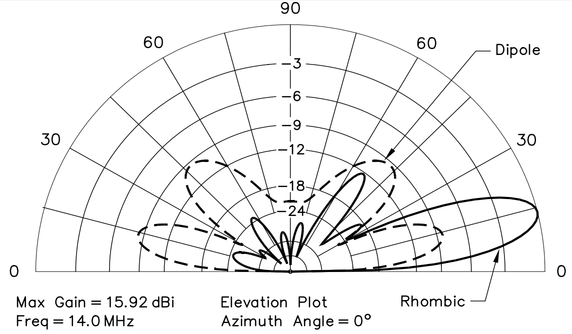

Fig 27—At left, azimuthal pattern for 3-λ (at 14 MHz) terminated rhombic (solid line) shown in Fig 26, compared with 4-element 20-meter Yagi (dotted line) on a 26-foot boom and a 20-meter dipole (dashed line). All antennas are mounted 70 feet (1 λ) above flat ground. The rearward pattern of the terminated rhombic is good and the forward gain exceeds that of the Yagi, but the frontal lobe is very narrow. Above, elevation-plane pattern of terminated rhombic compared to that of a simple dipole at the same height.

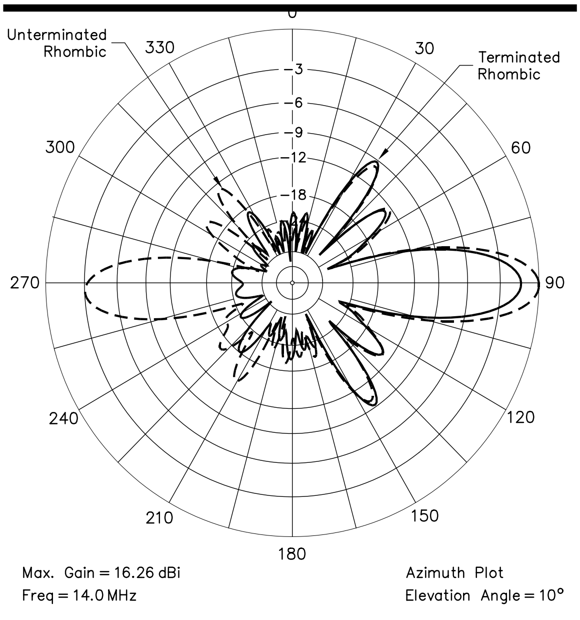

Fig 28—Comparison of azimuthal patterns for terminated (solid line) and unterminated (dashed line) rhombic antennas, using same dimensions as Fig 26 at a frequency of 14 MHz. The gain tradeoff is about 1.5 dB in return for the superior rearward pattern of the terminated antenna.

proof housing at the end of the antenna to protect them and to permit mounting without mechanical strain. The connecting leads should be short so that little extraneous inductance is introduced.

Alternatively, the terminating resistance may be placed at the end of an 800-Ω line connected to the end of the antenna. This will permit placing the resistors and their housing at a point convenient for adjustment rather than at the top of the pole. Resistance wire may be used for this line, so that a portion of the power will be dissipated before it reaches the resistive termination, thus permitting the use of lower wattage lumped resistors.

Multiwire Rhombics

The input impedance of a rhombic antenna constructed as in Fig 26 is not quite constant as the frequency is varied. This is because the varying separation between the wires causes the characteristic impedance of the antenna to vary along its length. The variation in Z_{ANT} can be minimized by a conductor arrangement that increases the capacitance per unit length in proportion to the separation between the wires.

The method of accomplishing this is shown in **Fig 30**. Three conductors are used, joined together at the ends but with increasing separation as the junction between legs is approached. For HF work the spacing between the wires at the center is 3 to 4 feet, which is similar to that used in commercial installations using legs several wavelengths long. Since all three wires should have the same length, the top and bottom wires should be slightly farther from the support than the middle wire. Using three wires in this way reduces the Z_{ANT} of the antenna to approximately 600 Ω, thus providing a better match for practical open-wire line, in addition to smoothing out the impedance variation over the frequency range.

A similar effect (although not quite as favorable) is obtained by using two wires instead of three. The 3-wire system has been found to increase the gain of the

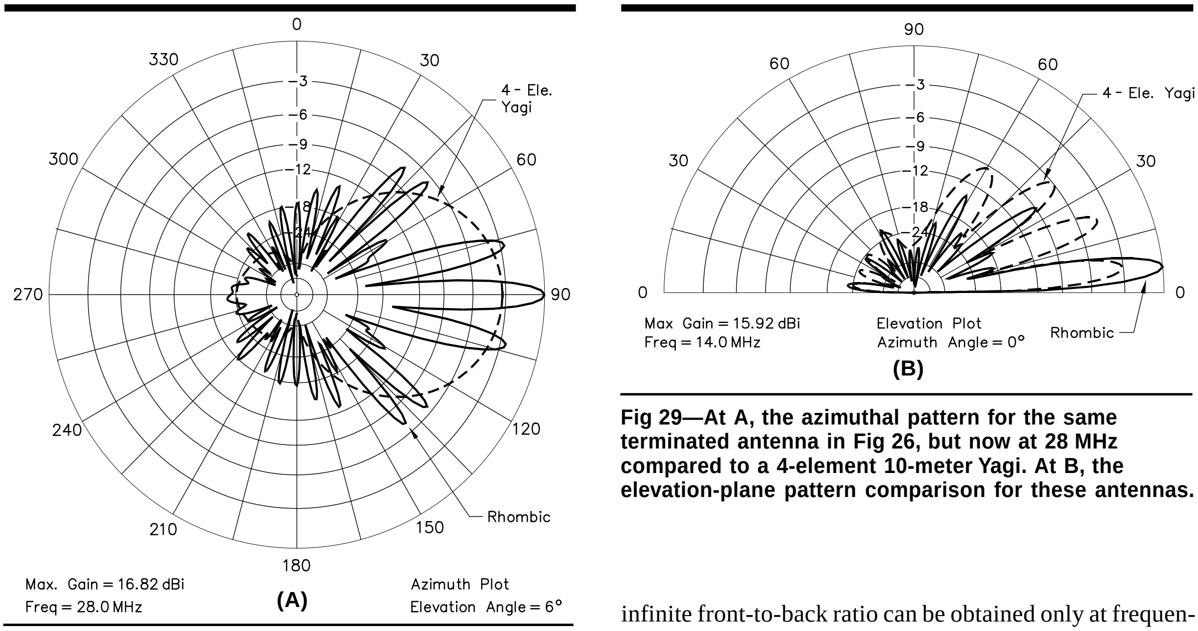

Fig 29—At A, the azimuthal pattern for the same terminated antenna in Fig 26, but now at 28 MHz compared to a 4-element 10-meter Yagi. At B, the elevation-plane pattern comparison for these antennas.

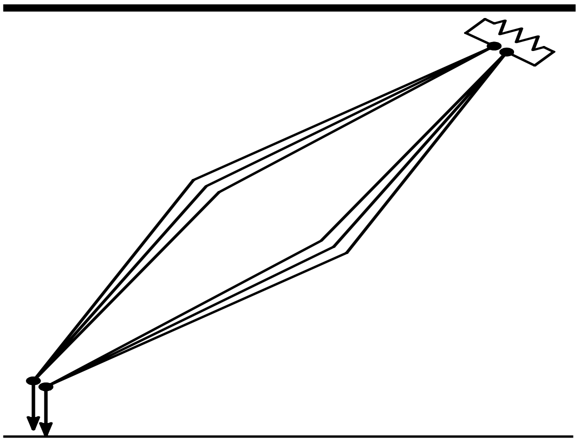

Fig 30—Three-wire rhombic antenna. Use of multiple wires improves the impedance characteristic of a terminated rhombic and increases the gain somewhat.

antenna by about 1 dB over that of a single-conductor version.

Front-to-Back Ratio

It is theoretically possible to obtain an infinite front-to-back ratio with a terminated rhombic antenna, and in practice very large values can be had. However, when the antenna is terminated in its characteristic impedance, the infinite front-to-back ratio can be obtained only at frequencies for which the leg length is an odd multiple of a quarter wavelength. The front-to-back ratio is smallest at frequencies for which the leg length is a multiple of a half wavelength.

When the leg length is not an odd multiple of a quarter wave at the frequency under consideration, the front-to-back ratio can be made very high by decreasing the value of terminating resistance slightly. This permits a small reflection from the far end of the antenna, which cancels out the residual response at the input end. With large antennas, the front-to-back ratio may be made very large over the whole frequency range by experimental adjustment of the terminating resistance. Modification of the terminating resistance can result in a splitting of the back null into two nulls, one on either side of a small lobe in the back direction. Changes in the value of terminating resistance thus permit steering the back null over a small horizontal range so that signals coming from a particular spot not exactly to the rear of the antenna may be minimized.

Methods of Feed

If the broad frequency characteristic of the terminated rhombic antenna is to be utilized fully, the feeder system must be similarly broadbanded. Open-wire transmission line of the same characteristic impedance as that shown at the antenna input terminals (approximately 700 to 800 Ω) may be used. Data for the construction of such lines is given in Chapter 24. While the usual matching stub can be used to provide an impedance transformation to more satisfactory line impedances, this limits the operation of the antenna to a comparatively narrow range of frequencies centering about that for which the stub is adjusted. Probably a more satisfactory arrangement would be to use a coaxial transmission line and a broadband transformer balun at the antenna feed point.

Receiving Wave Antennas

Perhaps the best known type of wave antenna is the *Beverage*. Many 160-meter enthusiasts have used Beverage antennas to enhance the signal-to-noise ratio while attempting to extract weak signals from the often high levels of atmospheric noise and interference on the low bands. Alternative antenna systems have been developed and used over the years, such as loops and long spans of unterminated wire on or slightly above the ground, but the Beverage antenna seems to be the best for 160-meter weak-signal reception. The information in this section was prepared originally by Rus Healy, K2UA (ex-NJ2L).

THE BEVERAGE ANTENNA

A Beverage is simply a directional wire antenna, at least one wavelength long, supported along its length at a fairly low height and terminated at the far end in its characteristic impedance. This antenna is shown in **Fig 31A**. It takes its name from its inventor, Harold Beverage, W2BML.

Many amateurs choose to use a single-wire Beverage because they are easy to install and they work well. The drawback is that Beverages are physically long and they do require that you have the necessary amount of real estate to install them. Sometimes, a neighbor will allow you to put up a temporary Beverage for a particular contest or DXpedition on his land, particularly during the winter months.

Beverage antennas can be useful into the HF range, but they are most effective at lower frequencies, mainly on 160 through 40 meters. The antenna is responsive mostly to low-angle incoming waves that maintain a constant (vertical) polarization. These conditions are nearly always satisfied on 160 meters, and most of the time on 80 meters. As the frequency is increased, however, the polarization and arrival angles are less and less constant and favorable, making Beverages less effective at these frequencies. Many amateurs have, however, reported excellent performance from Beverage antennas at frequencies as high as 14 MHz, especially when rain or snow (precipitation) static prevents good reception on the Yagi or dipole transmitting antennas used on the higher frequencies.

Beverage Theory

The Beverage antenna acts like a long transmission line with one lossy conductor (the earth), and one good conductor (the wire). Beverages have excellent directivity if erected properly, but they are quite inefficient because they are mounted close to the ground. This is in contrast with the terminated long-wire antennas described earlier, which are typically mounted high off the ground. Beverage antennas are not suitable for use as transmitting antennas.

Because the Beverage is a traveling wave, terminated antenna, it has no standing waves resulting from radio signals. As a wave strikes the end of the Beverage from the desired direction, the wave induces voltages along the antenna and continues traveling in space as well. Fig 31B shows part of a wave on the antenna resulting from a desired signal. This diagram also shows the tilt of the wave. The signal induces equal voltages in both directions. The resulting currents are equal and travel in both directions; the component traveling toward the termination end moves *against* the wave and thus builds down to a very low level at the termination end. Any residual signal resulting from this direction of current flow will be absorbed in the termination (if the termination is equal to the antenna impedance). The component of the signal flowing in the other direction, as we will see, becomes a key part of the received signal.

As the wave travels along the wire, the wave in space travels at approximately the same velocity. (There is some phase delay in the wire, as we shall see.) At any given point in time, the wave traveling along in space induces a voltage in the wire in addition to the wave already travel-

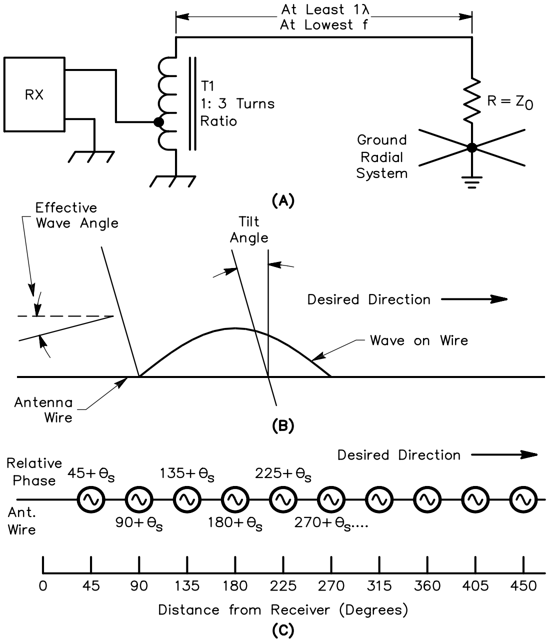

Fig 31—At A, a simple one-wire Beverage antenna with a variable termination impedance and a matching 9:1 autotransformer for the receiver impedance. At B, a portion of a wave from the desired direction is shown traveling down the antenna wire. Its tilt angle and effective takeoff angle are also shown. At C, a situation analogous to the action of a Beverage on an incoming wave is shown. See text for discussion.

ing on the wire (voltages already induced by the wave). Because these two waves are nearly in phase, the voltages add and build toward a maximum at the receiver end of the antenna.

This process can be likened to a series of signal generators lined up on the wire, with phase differences corresponding to their respective spacings on the wire (Fig 31C). At the receiver end, a maximum voltage is produced by these voltages adding in phase. For example, the wave component induced at the receiver end of the antenna will be in phase (at the receiver end) with a component of the same wave induced, say, 270° (or any other distance) down the antenna, after it travels to the receiver end.

In practice, there is some phase shift of the wave on the wire with respect to the wave in space. This phase shift results from the velocity factor of the antenna. (As with any transmission line, the signal velocity on the Beverage is somewhat less than in free space.) Velocity of propagation on a Beverage is typically between 85 and 98% of that in free space. As antenna height is increased to a certain optimum height (which is about 10 feet for 160 meters), the velocity factor increases. Beyond this height, only minimal improvement is afforded, as shown in **Fig 32**. These curves are the result of experimental work done in 1922 by RCA, and reported in a *QST* article (November 1922) entitled "The Wave Antenna for 200-Meter Reception," by H. H. Beverage. The curve for 160 meters was extrapolated from the other curves.

Phase shift (per wavelength) is shown as a function of velocity factor in **Fig 33**, and is given by:

$$\theta = 360\left(\frac{100}{k} - 1\right) \qquad \text{(Eq 2)}$$

where k = velocity factor of the antenna in percent.

The signals present on and around a Beverage antenna are shown graphically in A through D of **Fig 34**. These curves show relative voltage levels over a number of periods of the wave in space and their relative effects in terms of the total signal at the receiver end of the antenna.

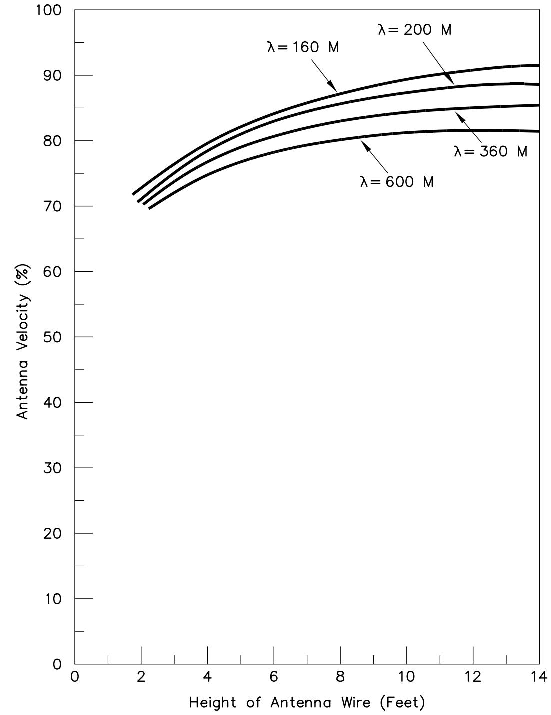

Fig 32—Signal velocity on a Beverage increases with height above ground, and reaches a practical maximum at about 10 feet. Improvement is minimal above this height. (The velocity of light is 100%.)

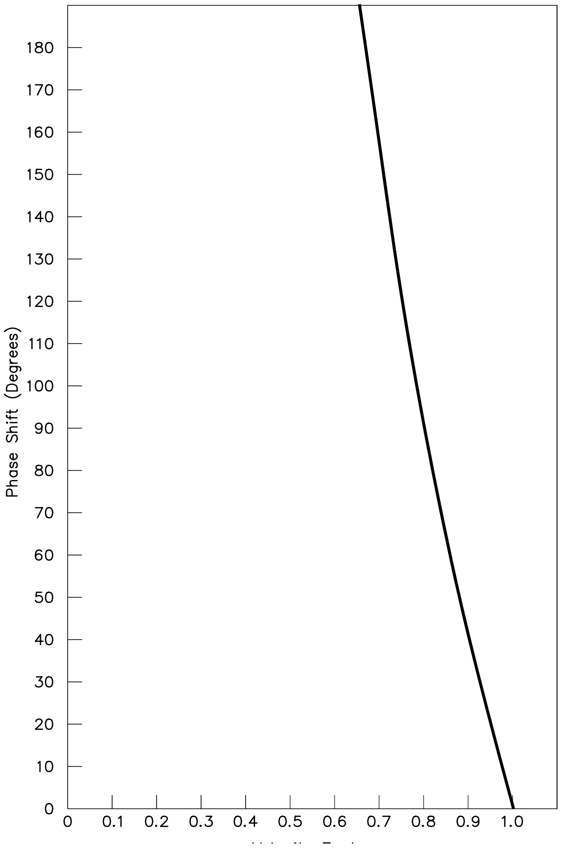

Fig 33—This curve shows phase shift (per wavelength) as a function of velocity factor on a Beverage antenna. Once the phase shift for the antenna goes beyond 90°, the gain drops off from its peak value, and any increase in antenna length will decrease gain.

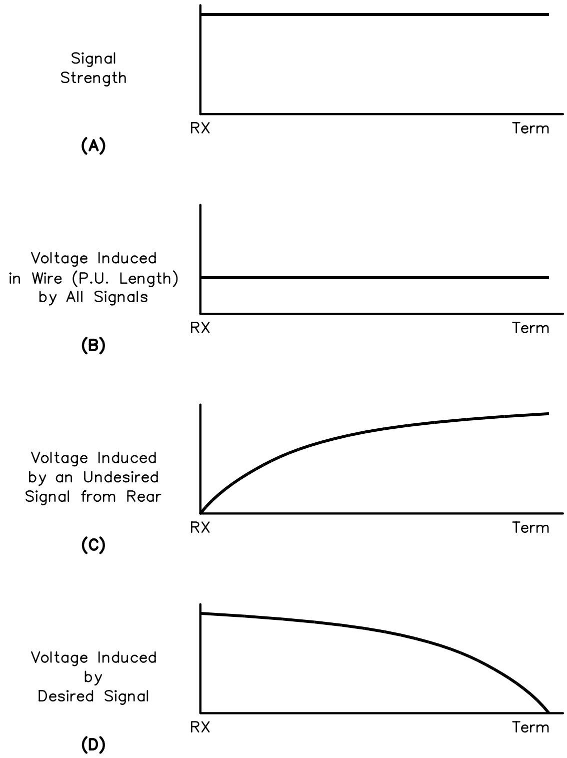

Fig 34—These curves show the voltages that appear in a Beverage antenna over a period of several cycles of the wave. Signal strength (at A) is constant over the length of the antenna during this period, as is voltage induced per unit length in the wire (at B). (The voltage induced in any section of the antenna is the same as the voltage induced in any other section of the same size, over the same period of time.) At C, the voltages induced by an undesired signal from the rearward direction add in phase and build to a maximum at the termination end, where they are dissipated in the termination (if $Z_{term} = Z_0$). The voltages resulting from a desired signal are shown at D. The wave on the wire travels closely with the wave in space, and the voltages resulting add in phase to a maximum at the receiver end of the antenna.

Performance in Other Directions

The performance of a Beverage antenna in directions other than the favored one is quite different than previously discussed. Take, for instance, the case of a signal arriving perpendicular to the wire (90° either side of the favored direction). In this case, the wave induces voltages along the wire that are essentially *in phase*, so that they arrive at the receiver end more or less out of phase, and thus cancel. (This can be likened to a series of signal generators lined up along the antenna as before, but having no progressive phase differences.)

As a result of this cancellation, Beverages exhibit deep nulls off the sides. Some minor sidelobes will exist, as with other long-wire antennas, and will increase in number with the length of the antenna.

In the case of a signal arriving from the rear of the antenna, the behavior of the antenna is very similar to its performance in the favored direction. The major difference is that the signal from the rear adds in phase at the termination end and is absorbed by the termination impedance. **Fig 35** compares the azimuth and elevation patterns for a 2-λ (1062 foot) and a 1-λ (531 foot) Beverage at 1.83 MHz. The wire is mounted 8 feet above flat ground (to keep it above deer antlers and away from humans too) and is terminated with a 500-Ω resistor in each case, although the exact value of the terminating resistance is not very critical. The ground constants assumed in this computer model are conductivity of 5 mS/m and a dielectric constant of 13. Beverage dielectric performance tends to decrease as the ground becomes better. Beverages operated over saltwater do not work as well as they do over poor ground.

For most effective operation, the Beverage should be terminated in an impedance equal to the characteristic impedance Z_{ANT} of the antenna. For maximum signal transfer to the receiver you should also match the receiver's input impedance to the antenna. If the termination impedance is not equal to the characteristic impedance of the antenna, some part of the signal from the rear will be reflected back toward the receiver end of the antenna.

If the termination impedance is merely an open circuit (no terminating resistor), total reflection will result and the antenna will exhibit a bidirectional pattern (still with very deep nulls off the sides). An unterminated Beverage will not have the same response to signals in the rearward direction as it exhibits to signals in the forward direction because of attenuation and reradiation of part of the reflected wave as it travels back toward the receiver end. **Fig 36** compares the response from two 2-λ Beverages, one terminated and the other unterminated. Just like a terminated long-wire transmitting antenna (which is mounted higher off the ground than a Beverage, which is meant only for receiving), the terminated Beverage has a reduced forward lobe compared to its unterminated sibling. The unterminated Beverage exhibits about a 5 dB front-to-back ratio for this length because of the radiation and wire and ground losses that occur before the forward wave gets to the end of the wire.

If the termination is between the extremes (open circuit and perfect termination in Z_{ANT}), the peak direction and intensity of signals off the rear of the Beverage will change. As a result, an adjustable reactive termination can be employed to *steer* the nulls to the rear of the antenna (see **Fig 37**). This can be of great help in eliminating a local interfering signal from a rearward direction (typically 30° to 40° either side of the back direction). Such a scheme doesn't help much for interfering skywave signals because of variations encountered in the ionosphere that constantly shift polarity, amplitude, phase and

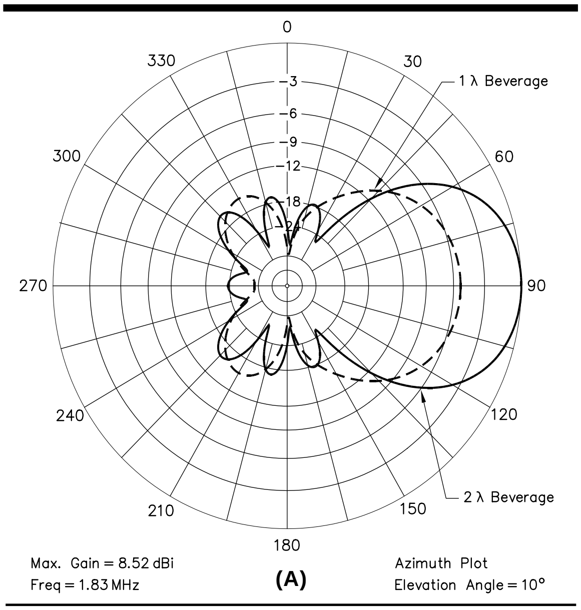

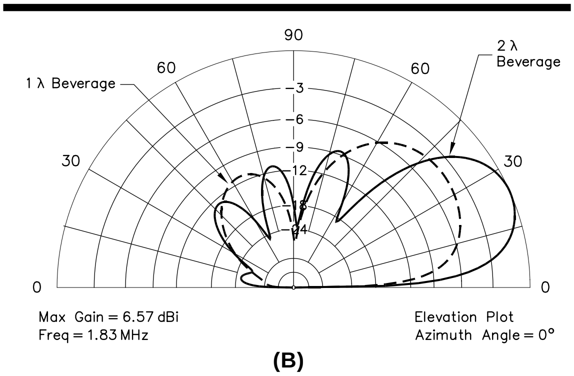

Fig 35—At A, azimuthal patterns of a 2-λ (solid line) and a 1-λ (dashed line) Beverage antenna, terminated with 550-Ω resistor at 1.83 MHz, at an elevation angle of 10°. The rearward pattern around 180° is more than 20 dB down from the front lobe for each antenna. At B, the elevation-plane patterns. Note the rejection of very high-angle signals near 90°.

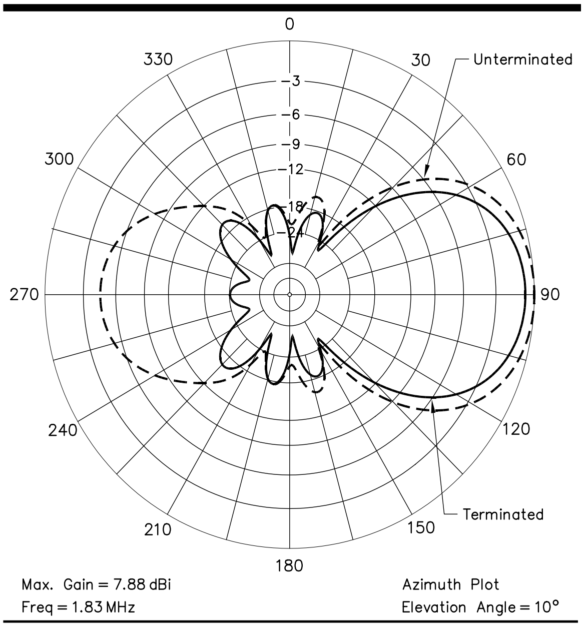

Fig 36—Comparing the azimuthal patterns for a 2-λ Beverage, terminated (solid line) and unterminated (dashed line).

incoming elevation angles.

To determine the appropriate value for a terminating resistor, you need to know the characteristic impedance (surge impedance), Z_{ANT}, of the Beverage. It is interesting to note that Z_{ANT} is not a function of the length, just like a transmission line.

$$Z_{ANT} = 138 \times \log \left(\frac{4h}{d} \right) \qquad \text{(Eq 3)}$$

where

Z_{ANT} = characteristic impedance of the Beverage = terminating resistance needed
h = wire height above ground
d = wire diameter (in the same units as h)

Another aspect of terminating the Beverage is the quality of the RF ground used for the termination. For most types of soil a ground rod is sufficient, since the optimum value for the termination resistance is in the range of 400 to 600 Ω for typical Beverages and the ground-loss resistance is in series with this. Even if the ground-loss resistance at the termination point is as high as 40 or 50 Ω, it still is not an appreciable fraction of the overall terminating resistance. For soil with very poor conductivity, however, (such as sand or rock) you can achieve a better ground termination by laying radial wires on the ground at both the receiver and termination ends. These wires need not be resonant quarter-wave in length, since the ground detunes them anyway. Like the ground counterpoise for a vertical antenna, a number of short radials is better than a few long ones. Some amateurs use chicken-wire ground screens for their ground terminations.

As with many other antennas, improved directivity and gain can be achieved by lengthening the antenna and by arranging several antennas into an array. One item that must be kept in mind is that by virtue of the velocity factor of the antenna, there is some phase shift of the wave on the antenna with respect to the wave in space. Because of this phase shift, although the directivity will continue to sharpen with increased length, there will be some optimum length at which the gain of the antenna will peak. Beyond this

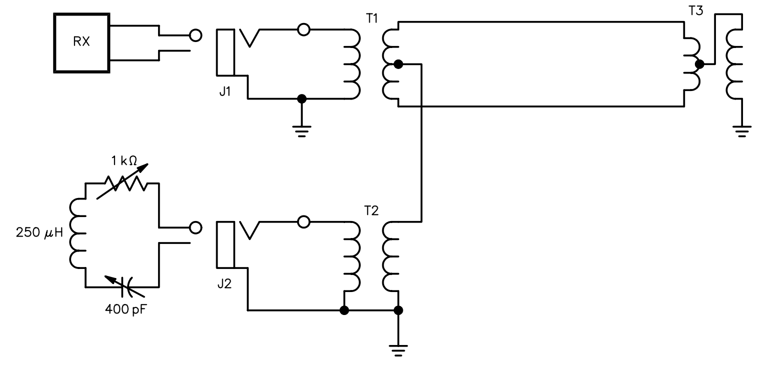

Fig 37—A two-wire Beverage antenna that has provisions for direction switching and null steering in the rear quadrant. Performance improves with height to a point, and is optimum for 1.8-MHz operation at about 10 to 12 feet. Parts identifications are for text reference.

length, the current increments arriving at the receiver end of the antenna will no longer be in phase, and will not add to produce a maximum signal at the receiver end. This optimum length is a function of velocity factor and frequency, and is given by:

$$L = \frac{\lambda}{4\left(\frac{100}{k} - 1\right)} \qquad \text{(Eq 4)}$$

where
L = maximum effective length
λ = signal wavelength in free space (same units as L)
k = velocity factor of the antenna in percent

Because velocity factor increases with height (to a point, as mentioned earlier), optimum length is somewhat longer if the antenna height is increased. The maximum effective length also increases with the number of wires in the antenna system. For example, for a two-wire Beverage like the bidirectional version shown in Fig 37, the maximum effective length is about 20% longer than the single-wire version. A typical length for a single-wire 1.8-MHz Beverage (made of #16 wire and erected 10 feet above ground) is about 1200 feet.

Feed-Point Transformers for Single-Wire Beverages

Matching transformer T1 in Fig 31 is easily constructed. Small toroidal ferrite cores are best for this application, with those of high permeability (μ_i = 125 to 5000) being the easiest to wind (requiring fewest turns) and having the best high-frequency response (because few turns are used). Trifilar-wound autotransformers are most convenient.

Most users are not concerned with a small amount of SWR on the transmission line feeding their Beverages. For example, let us assume that the Z_{ANT} of a particular Beverage is 525 Ω and the terminating resistance is made equal to that value. If a standard 3:1 turns-ratio autotransformer is used at the input end of the antenna, the nominal impedance transformation $50\ \Omega \times 3^2 = 450\ \Omega$. This leads to the terminology often used for this transformer as a *9:1 transformer*, referring to its impedance transformation. The resulting SWR on the feed line going back to the receiver would be 525/450 = 1.27:1, not enough to be concerned about. For a Z_{ANT} of 600 Ω, the SWR is 600/450 = 1.33:1, again not a matter of concern.

Hence, most Beverage users use standard 9:1 (450:50 Ω) autotransformers. You can make a matching transformer suitable for use from 160 to 40 meters using eight trifilar turns of #24 enameled wire wound over a stack of two Amidon FT-50-75 or two MN8-CX cores. See **Fig 38**.

Make your own trifilar cable bundle by placing three 3-foot lengths of the #24 wire side-by-side and twisting them in a hand drill so that there is a uniform twist about one twist-per-inch. This holds the three wires together in a bundle that can be passed through the two stacked cores, rather like threading a needle. Remember that each time you put the bundle through the center of the cores counts as one turn.

After you finish winding, cut the individual wires to leave about 3/4-inch leads, sand off the enamel insulation and tin the wires with a soldering iron. Identify the individual wires with an ohmmeter and then connect them together following Fig 38. Coat the transformer with Q-dope (liquid polystyrene) to finalize the transformer. White glue will work also. See Chapters 25 and 26 and *The ARRL Handbook* for more information on winding toroidal transformers or see Chapter 7 (Special Receiving Antennas) of *ON4UN's Low-Band DXing* book.

The Two-Wire Beverage

The two-wire antenna shown in Fig 37 has the major advantage of having signals from both directions available at the receiver at the flip of a switch between J1 and J2. Also, because there are two wires in the system (equal amounts of signal voltage are induced in both wires), greater signal voltages will be produced.

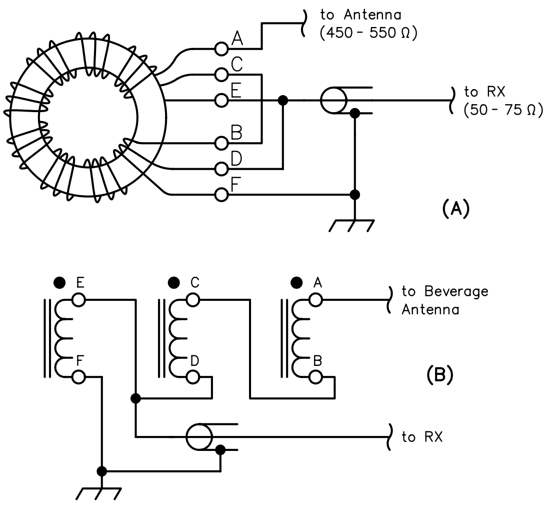

Fig 38—Constructing the feed-point transformer for a single-wire Beverage. See text for details.

A signal from the left direction in Fig 37 induces equal voltages in both wires, and equal in-phase currents flow as a result. The *reflection transformer* (T3 at the right-hand end of the antenna) then inverts the phase of these signals and reflects them back down the antenna toward the receiver, using the antenna wires as a balanced open-wire transmission line. This signal is then transformed by T1 down to the input impedance of the receiver (50 Ω) at J1.

Signals traveling from right to left also induce equal voltages in each wire, and they travel in phase toward the receiver end, through T1, and into T2. Signals from this direction are available at J2.

T1 and T2 are standard 9:1 wideband transformers capable of operating from 1.8 to at least 10 MHz. Like any two parallel wires making up a transmission line, the two-wire Beverage has a certain characteristic impedance—we'll call it Z_1 here—depending on the spacing between the two wires and the insulation between them. T3 transforms the terminating resistance needed at the end of the line to Z_1. Keep in mind that this terminating resistance is equal to the characteristic impedance Z_{ANT} of the Beverage—that is, the impedance of the parallel wires over their images in the ground below. For example, if Z_1 of the Beverage wire is 300 Ω (that is, you used TV twin-lead for the two Beverage wires), T3 must transform the balanced 300 Ω to the unbalanced 500 Ω Z_{ANT} impedance used to terminate the Beverage.

The design and construction of the reflection transformer used in a two-wire Beverage is more demanding than that for the straightforward matching transformer T1 because the exact value of terminating impedance is more critical for good F/B. See Chapter 7 (Special Receiving Antennas) in *ON4UN's Low-Band DXing* for details on winding the reflection transformers for a two-wire Beverage.

Another convenient feature of the two-wire Beverage is the ability to steer the nulls off either end of the antenna while receiving in the opposite direction. For instance, if the series RLC network shown at J2 is adjusted while the receiver is connected to J1, signals can be received from the left direction while interference coming from the right can be partially or completely nulled. The nulls can be steered over a 60° (or more) area off the right-hand end of the antenna. The same null-steering capability exists in the opposite direction with the receiver connected at J2 and the termination connected at J1.

The two-wire Beverage is typically erected at the same height as a single-wire version. The two wires are at the same height and are spaced uniformly—typically 12 to 18 inches apart for discrete wires. Some amateurs construct two-wire Beverages using "window" ladder-line, twisting the line about three twists per foot for mechanical and electrical stability in the wind.

The characteristic impedance Z_{ANT} of a Beverage made using two discrete wires with air insulation between them depends on the wire size, spacing and height and is given by:

$$Z_{ANT} = \frac{69}{\sqrt{\varepsilon}} \times \log\left[\frac{4h}{d}\sqrt{1+\left(\frac{2h}{S}\right)^2}\right] \qquad \text{(Eq 5)}$$

where

Z_{ANT} = Beverage impedance = desired terminating resistance
S = wire spacing
h = height above ground
d = wire diameter (in same units as S and h)
ε = 2.71828

Beverages in Echelon

The pattern of a Beverage receiving antenna is dependent on the terminating resistance used for a particular antenna, as was demonstrated at the extremes by Fig 36. This compared the patterns for a terminated and an unterminated Beverage. The pattern of even a poorly terminated Beverage can be significantly improved by the addition of a second Beverage. The additional Beverage is installed so that it is operated *in echelon*, a word deriving from the fact that the two wires look like the parallel rungs on a ladder. For a practial 160- and 80-meter setup the second Beverage wire is parallel to the first Beverage, spaced from it by about 5 meters, and also staggered 30 meters ahead. See **Fig 38**.

The forward Beverage is fed with a phase difference of +125° such that the total phase, including that due to the forward staggering, is 180°. This forms the equivalent of an end-fire array fed out-of-phase, but it takes advantage of the natural directivity of each Beverage. **Fig 39** compares the pattern of a single 1-λ 160-meter Beverage that is sloppily terminated with two Beverages fed in echelon. The

Beverages in echelon gives a modest additional gain of almost 2 dB. But where the two Beverages in echelon really shine is how they cleans up the rearward pattern—from an average about 15 dB for the single Beverage to more than 25 dB for the two Beverages.

Even at a spacing of 5 meters, there is very little mutual coupling between the two Beverage wires because of their inherently small radiation resistance when they are mounted low above lossy ground. If you adjust for a low SWR (using proper transformers to match the feed-line coaxes), the phase difference will depend solely on the difference in length of the two coaxes feeding the Beverage wires. **Fig 40** shows a wideband feed system designed by Tom Rauch, W8JI, as a "cross-fire" feed system. The 180° wideband phase-inverting transformer allows the system to work on two bands, say 160 and 80 meters. See Chapter 7, Receiving Antennas, in *ON4UN's Low-Band DXing* book, 4th Edition for transformer details.

Practical Considerations

Even though Beverage antennas have excellent directive patterns if terminated properly, gain never exceeds about −3 dBi in most practical installations. However, the directivity that the Beverage provides results in a much higher signal-to-noise ratio for signals in the desired direction than almost any other real-world antenna used at low frequencies.

A typical situation might be a station located in the US Northeast (W1), trying to receive Topband signals from Europe to the northeast, while thunderstorms behind him in the US Southeast (W4) are creating huge static crashes. Instead of listening to an S7 signal with 10-dB over S9 noise and interference on a vertical, the directivity of a Beverage will typically allow you to copy the same signal at perhaps S5 with only S3 (or lower) noise and interference. This is certainly a worthwhile improvement. However, if you are in the middle of a thunderstorm, or if there is a thunderstorm in the direction from which you are trying to receive a signal, no Beverage is going to help you!

There are a few basic principles that must be kept in mind when erecting Beverage antennas if optimum performance is to be realized.

1) Plan the installation thoroughly, including choosing an antenna length consistent with the optimum length values discussed earlier.
2) Keep the antenna as straight and as nearly level as possible over its entire run. Avoid following the terrain under the antenna too closely—keep the antenna level with the average terrain.
3) Minimize the lengths of vertical downleads at the ends of the antenna. Their effect is detrimental to the directive pattern of the antenna. It is best to slope the antenna wire from ground level to its final height (over a distance of 50 feet or so) at the feed-point end. Similar action should be taken at the termination end. Be sure to seal the transformers against weather.

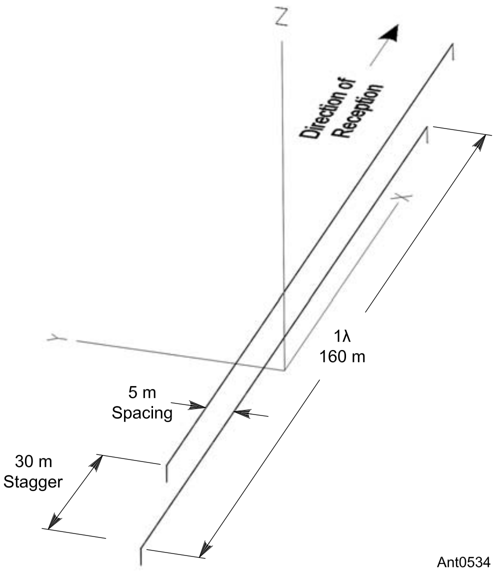

Fig 39—Layout of two 160-meter 1-λ long Beverages in echelon, spaced 5 meters apart, with 30 meter forward stagger. The upper antenna has a 125° phase shift in its feed system.

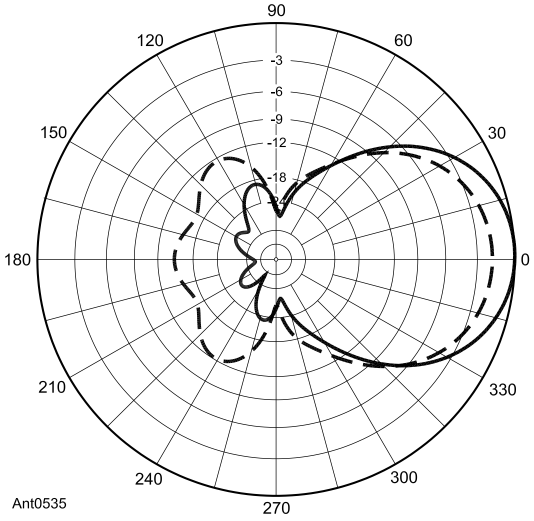

Fig 40—Azimuth pattern at 10° takeoff angle for single Beverage (dashed line) and two Beverages in an echelon end-fire array. The rearward pattern is considerably cleaner on the echelon. Thus, two closely spaced, short Beverages can give considerable improvement over a single short Beverage.

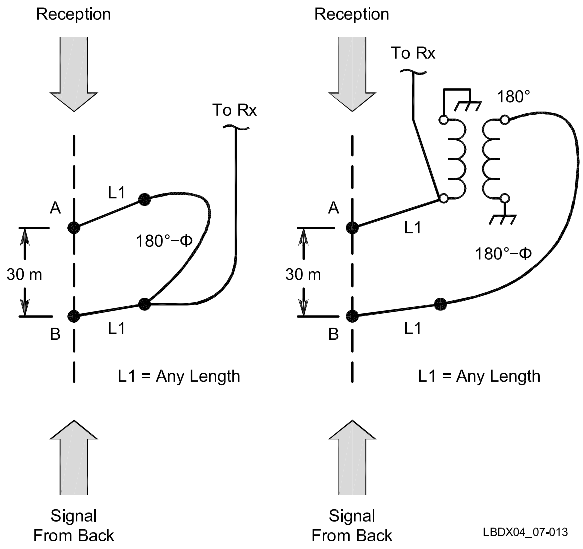

Fig 41—Two ways of feeding the two-Beverage echelon array in Fig 39. On the left, a feed system good for one frequency; on the right, a "cross-fire" feed system good for 1.8 and 3.6 MHz. For this system we want a phase shift due to the coax length of +116° at the back Beverage A. The angle ϕ is thus 180°–116° = 64° long on 160 meters. In the system on the right, a 64° length on 160 meters becomes 128° long on 80 meters. So with the phase-inverting transformer the net phase shift becomes 53° on 80 meters, a reasonable compromise. (*Courtesy W8JI and ON4UN.*)

4) Use a noninductive resistor for terminating a single-wire Beverage. If you live in an area where lightning storms are common, use 2-W terminating resistors, which can survive surges due to nearby lightning strikes.
5) Use high-quality insulators for the Beverage wire where it comes into contact with the supports. Plastic insulators designed for electric fences are inexpensive and effective.
6) Keep the Beverage away from parallel conductors such as electric power and telephone lines for a distance of at least 200 feet. Perpendicular conductors, even other Beverages, may be crossed with relatively little interaction, but do not cross any conductors that may pose a safety hazard.
7) Run the coaxial feed line to the Beverage so that it is not directly under the span of the wire. This prevents common-mode currents from appearing on the shield of the coax. It may be necessary to use a ferrite-bead choke on the feed line if you find that the feed line itself picks up signals when it is temporarily disconnected from the Beverage. See Chapter 26 for details on common-mode chokes.
8) If you use elevated radials in your transmitting antenna system, keep your Beverage feed lines well away from them to avoid stray pickup that will ruin the Beverage's directivity.

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Chapter 14

Direction Finding Antennas

The use of radio for direction-finding purposes (RDF) is almost as old as its application for communications. Radio amateurs have learned RDF techniques and found much satisfaction by participating in hidden-transmitter hunts. Other hams have discovered RDF through an interest in boating or aviation, where radio direction finding is used for navigation and emergency location systems.

In many countries of the world, the hunting of hidden amateur transmitters takes on the atmosphere of a sport, as participants wearing jogging togs or track suits dash toward the area where they believe the transmitter is located. The sport is variously known as *fox hunting*, *bunny hunting*, ARDF (Amateur Radio direction finding) or simply transmitter hunting. In North America, most hunting of hidden transmitters is conducted from automobiles, although hunts on foot are gaining popularity.

There are less pleasant RDF applications as well, such as tracking down noise sources or illegal operators from unidentified stations. Jammers of repeaters, traffic nets and other amateur operations can be located with RDF equipment. Or sometimes a stolen amateur rig will be operated by a person who is not familiar with Amateur Radio, and by being lured into making repeated transmissions, the operator unsuspectingly permits himself to be located with RDF equipment. The ability of certain RDF antennas to reject signals from selected directions has also been used to advantage in reducing noise and interference. Through APRS, radio navigation is becoming a popular application of RDF. The locating of downed aircraft is another, and one in which amateurs often lend their skills. Indeed, there are many useful applications for RDF.

Although sophisticated and complex equipment pushing the state of the art has been developed for use by governments and commercial enterprises, relatively simple equipment can be built at home to offer the Radio Amateur an opportunity to RDF. This chapter deals with antennas suitable for that purpose.

RDF by Triangulation

It is impossible, using amateur techniques, to pinpoint the whereabouts of a transmitter from a single receiving location. With a directional antenna you can determine the direction of a signal source, but not how far away it is. To find the distance, you can then travel in the determined direction until you discover the transmitter location. However, that technique can be time consuming and often does not work very well.

A preferred technique is to take at least one additional direction measurement from a second receiving location. Then use a map of the area and plot the bearing or direction measurements as straight lines from points on the map representing the two locations. The approximate location of the transmitter will be indicated by the point where the two bearing lines cross. Even better results can be obtained by taking direction measurements from three locations and using the mapping technique just described. Because absolutely precise bearing measurements are difficult to obtain in practice, the three lines will almost always cross to form a triangle on the map, rather than at a single point. The transmitter will usually be located inside the area represented by the triangle. Additional information on the technique of triangulation and much more on RDF techniques may be found in recent editions of *The ARRL Handbook*.

DIRECTION FINDING SY\STEMS

Required for any RDF system are a directive antenna and a device for detecting the radio signal. In amateur applications the signal detector is usually a transceiver and for convenience it will usually have a meter to indicate signal strength. Unmodified, commercially available portable or mobile receivers are generally quite satisfactory for signal detectors. At very close ranges a simple diode detector and dc microammeter may suffice for the detector.

On the other hand, antennas used for RDF techniques are not generally the types used for normal two-way communications. Directivity is a prime requirement, and here the word *directivity* takes on a somewhat different meaning than is commonly applied to other amateur antennas. Normally we associate directivity with gain, and we think of the ideal antenna pattern as one having a long, thin main lobe. Such a pattern may be of value for coarse measurements in RDF work, but precise bearing measurements are not possible. There is always a spread of a few (or perhaps many) degrees on the *nose* of the lobe, where a shift of antenna bearing produces no detectable change in signal strength. In RDF measure-ments, it is desirable to correlate an exact bearing or compass direction with the position of the antenna. In order to do this as accurately as possible, an antenna exhibiting a *null* in its pattern is used. A null can be very sharp in directivity, to within a half degree or less.

Loop Antennas

A simple antenna for HF RDF work is a small loop tuned to resonance with a capacitor. Several factors must be considered in the design of an RDF loop. The loop must be small in circumference compared with the wavelength. In a single-turn loop, the conductor should be less than 0.08 λ long. For 28 MHz, this represents a length of less than 34 inches (a diameter of approximately 10 inches). Maximum response from the loop antenna is in the plane of the loop, with nulls exhibited at right angles to that plane.

To obtain the most accurate bearings, the loop must be balanced electrostatically with respect to ground. Otherwise, the loop will exhibit two modes of operation. One is the mode of a true loop, while the other is that of an essentially nondirectional vertical antenna of small dimensions. This second mode is called the *antenna effect*. The voltages introduced by the two modes are seldom in phase and may add or subtract, depending upon the direction from which the wave is coming.

The theoretical true loop pattern is illustrated in **Fig 1A**. When properly balanced, the loop exhibits two nulls that are 180° apart. Thus, a single null reading with a small loop antenna will not indicate the exact direction toward the transmitter—only the line along which the transmitter lies. Ways to overcome this ambiguity are discussed later.

When the antenna effect is appreciable and the loop is tuned to resonance, the loop may exhibit little directivity, as shown in Fig 1B. However, by detuning the loop to shift the phasing, a pattern similar to 1C may be obtained. Although this pattern is not symmetrical, it does exhibit a null. Even so, the null may not be as sharp as that obtained with a loop that is well balanced, and it may not be at exact right angles to the plane of the loop.

By suitable detuning, the unidirectional cardioid pattern of Fig 1D may be approached. This adjustment is sometimes used in RDF work to obtain a unidirectional bearing, although there is no complete null in the pattern. A cardioid pattern can also be obtained with a small loop antenna by adding a *sensing element*. Sensing elements are discussed in a later section of this chapter.

An electrostatic balance can be obtained by shielding the loop, as **Fig 2** shows. The shield is represented by the broken lines in the drawing, and eliminates the antenna effect. The response of a well-constructed shielded loop is quite close to the ideal pattern of Fig 1A.

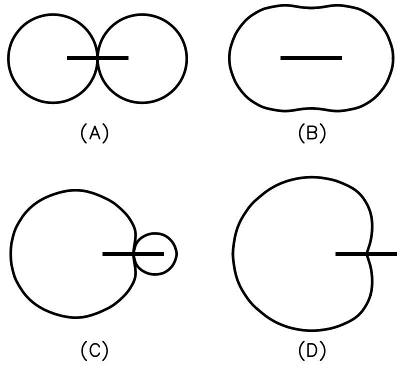

Fig 1—Small-loop field patterns with varying amounts of antenna effect—the undesired response of the loop acting merely as a mass of metal connected to the receiver antenna terminals. The straight lines show the plane of the loop.

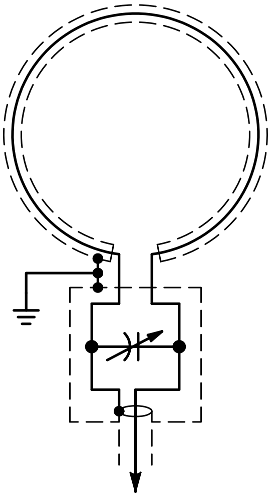

Fig 2—Shielded loop for direction finding. The ends of the shielding turn are not connected, to prevent shielding the loop from magnetic fields. The shield is effective against electric fields.

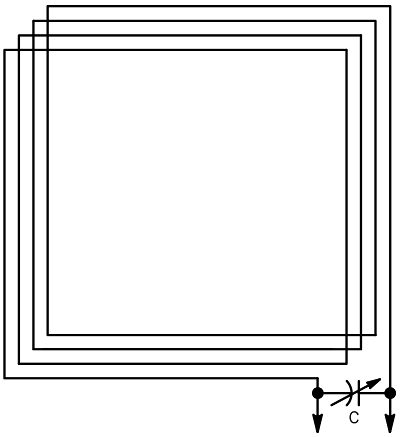

Fig 3—Small loop consisting of several turns of wire. The total conductor length is very much less than a wavelength. Maximum response is in the plane of the loop.

For the low-frequency amateur bands, single-turn loops of convenient physical size for portability are generally found to be unsatisfactory for RDF work. Therefore, multiturn loops are generally used instead. Such a loop is shown in **Fig 3**. This loop may also be shielded, and if the total conductor length remains below 0.08 λ, the directional pattern is that of Fig 1A. A sensing element may also be used with a multiturn loop.

Loop Circuits and Criteria

No single word describes a direction-finding loop of high performance better than *symmetry*. To obtain an undistorted response pattern from this type of antenna, you must build it in the most symmetrical manner possible. The next key word is *balance*. The better the electrical balance, the deeper the loop null and the sharper the maxima.

The physical size of the loop for 7 MHz and below is not of major consequence. A 4-foot diameter loop will exhibit the same electrical characteristics as one which is only an inch or two in diameter. The smaller the loop, however, the lower its efficiency. This is because its aperture samples a smaller section of the wave front. Thus, if you use loops that are very small in terms of a wavelength, you will need preamplifiers to compensate for the reduced efficiency.

An important point to keep in mind about a small loop antenna oriented in a vertical plane is that it is vertically polarized. It should be fed at the bottom for the best null response. Feeding it at one side, rather than at the bottom, will not alter the polarization and will only degrade performance. To obtain horizontal polarization from a small loop, it must be oriented in a horizontal plane, parallel to the earth. In this position the loop response is essentially omnidirectional.

The earliest loop antennas were of the *frame antenna* variety. These were unshielded antennas built on a wooden frame in a rectangular format. The loop conductor could be a single turn of wire (on the larger units) or several turns if the frame was small. Later, shielded versions of the frame antenna became popular, providing electrostatic shielding—an aid to noise reduction from such sources as precipitation static.

Ferrite Rod Antennas

With advances in technology, magnetic-core loop antennas came into use. Their advantage was reduced size, and this appealed especially to the designers of aircraft and portable radios. Most of these antennas contain ferrite bars or cylinders, which provide high inductance and Q with a relatively small number of coil turns.

Magnetic-core antennas consist essentially of turns of wire around a ferrite rod. They are also known as *loopstick* antennas. Probably the best-known example of this type of antenna is that used in small portable AM broadcast receivers. Because of their reduced-size advantage, ferrite-rod antennas are used almost exclusively for portable work at frequencies below 150 MHz.

As implied in the earlier discussion of shielded loops in this chapter, the true loop antenna responds to the magnetic field of the radio wave, and not to the electrical field. The voltage delivered by the loop is proportional to the amount of magnetic flux passing through the coil, and to the number of turns in the coil. The action is much the same as in the secondary winding of a transformer. For a given size of loop, the output voltage can be increased by increasing the flux density, and this is done with a ferrite core of high permeability. A $^1/_2$-inch diameter, 7-inch rod of Q2 ferrite (m_i = 125) is suitable for a loop core from the broadcast band through 10 MHz. For increased output, the turns may be wound on two rods that are taped together, as shown in **Fig 4**. Loopstick antennas for con-

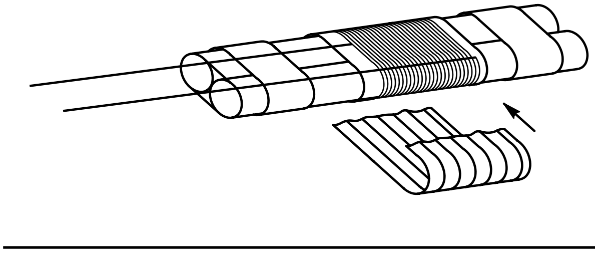

Fig 4—A ferrite-rod or loopstick antenna. Turns of wire may be wound on a single rod, or to increase the output from the loop, the core may be two rods taped together, as shown here. The type of core material must be selected for the intended frequency range of the loop. To avoid bulky windings, fine wire such as #28 or #30 is often used, with larger wire for the leads.

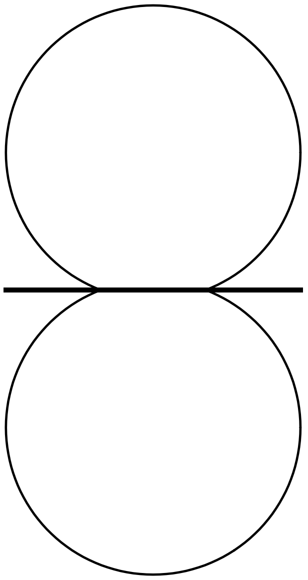

Fig 5—Field pattern for a ferrite rod antenna. The dark bar represents the rod on which the loop turns are wound.

struction are described later in this chapter.

Maximum response of the loopstick antenna is broadside to the axis of the rod as shown in **Fig 5**, whereas maximum response of the ordinary loop is in a direction at right angles to the plane of the loop. Otherwise, the performances of the ferrite-rod antenna and of the ordinary loop are similar. The loopstick may also be shielded to eliminate the antenna effect, such as with a U-shaped or C-shaped channel of aluminum or other form of *trough*. The length of the shield should equal or slightly exceed the length of the rod.

Sensing Antennas

Because there are two nulls that are 180° apart in the directional pattern of a loop or a loopstick, an ambiguity exists as to which one indicates the true direction of the station being tracked. For example, assume you take a bearing measurement and the result indicates the transmitter is somewhere on a line running approximately east and west from your position. With this single reading, you have no way of knowing for sure if the transmitter is east of you or west of you.

If more than one receiving station takes bearings on a single transmitter, or if a single receiving station takes bearings from more than one position on the transmitter, the ambiguity may be worked out by triangulation, as described earlier. However, it is sometimes desirable to have a pattern with only one null, so there is no question about whether the transmitter in the above example would be east or west from your position.

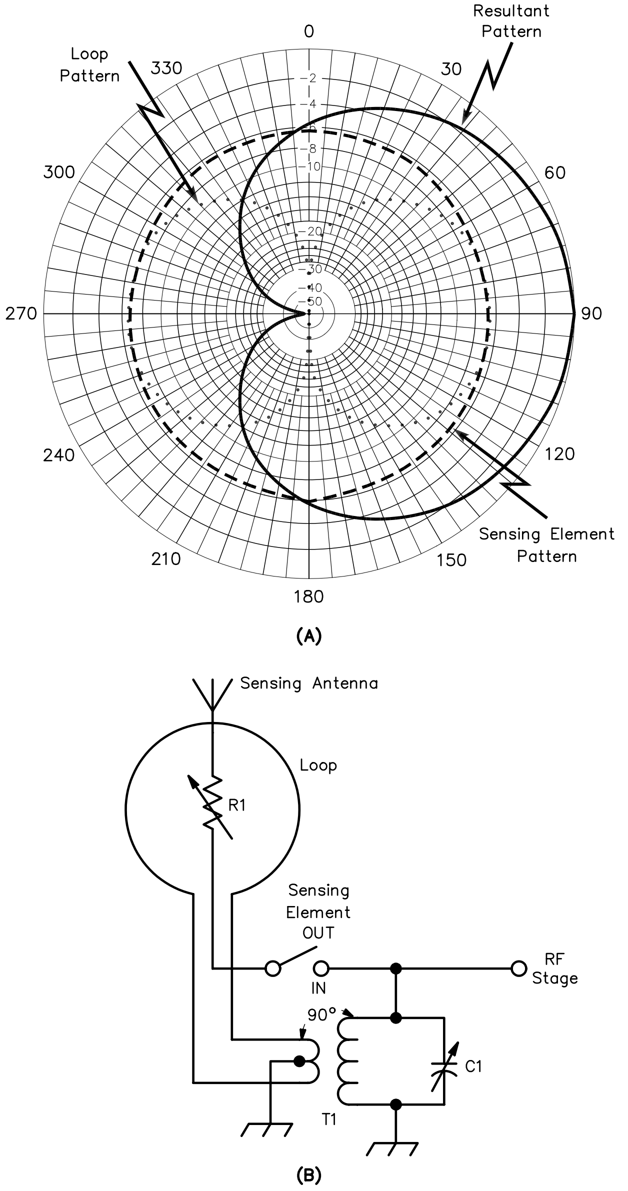

Fig 6—At A, the directivity pattern of a loop antenna with sensing element. At B is a circuit for combining the signals from the two elements. C1 is adjusted for resonance with T1 at the operating frequency.

A loop or loopstick antenna may be made to have a single null if a second antenna element is added. The element is called a *sensing antenna*, because it gives an added sense of direction to the loop pattern. The second element must be omnidirectional, such as a short vertical. When the signals from the loop and the vertical element are combined with a 90° phase shift between the two, a cardioid pattern results. The development of the pattern is shown in **Fig 6A**.

Fig 6B shows a circuit for adding a sensing antenna to a loop or loopstick. R1 is an internal adjustment and is used to set the level of the signal from the sensing antenna. For the best null in the composite pattern, the signals from the loop and the sensing antenna must be of equal amplitude, so R1 is adjusted experimentally during setup. In practice, the null of the cardioid is not as sharp as that of the loop, so the usual measurement procedure is to first use the loop alone to obtain a precise bearing reading, and then to add the sensing antenna and take another reading to resolve the ambiguity. (The null of the cardioid is 90° away from the nulls of the loop.) For this reason, provisions are usually made for switching the sensing element in an out of operation.

PHASED ARRAYS

Phased arrays are also used in amateur RDF work. Two general classifications of phased arrays are end-fire and broadside configurations. Depending on the spacing and phasing of the elements, end-fire patterns may exhibit a null in one direction along the axis of the elements. At the same time, the response is maximum off the other end of the axis, in the opposite direction from the null. A familiar arrangement is two elements spaced $^1/_4$ λ apart and fed 90° out of phase. The resultant pattern is a *cardioid*, with the null in the direction of the leading element. Other arrangements of spacing and phasing for an end-fire array are also suitable for RDF work. One of the best known is the *Adcock array*, discussed in the next section.

Broadside arrays are inherently bidirectional, which means there are always at least two nulls in the pattern. Ambiguity therefore exists in the true direction of the transmitter, but depending on the application, this may be no handicap. Broadside arrays are seldom used for amateur RDF applications however.

The Adcock Antenna

Loops are adequate in RDF applications where only the ground wave is present. The performance of an RDF system for sky-wave reception can be improved by the use of an Adcock antenna, one of the most popular types of end-fire phased arrays. A basic version is shown in **Fig 7**.

This system was invented by F. Adcock and patented in 1919. The array consists of two vertical elements fed 180° apart, and mounted so the system may be rotated. Element spacing is not critical, and may be in the range from 0.1 to 0.75 λ. The two elements must be of identical lengths, but need not be self-resonant. Elements that are shorter than resonant are commonly used. Because neither the element spacing nor the length is critical in terms of wavelengths, an Adcock array may be operated over more than one amateur band.

The response of the Adcock array to vertically polarized waves is similar to a conventional loop, and the directive pattern is essentially the same. Response of the array to a horizontally polarized wave is considerably different from that of a loop, however. The currents induced in the horizontal members tend to balance out regardless of the orientation of the antenna. This effect has been verified in practice, where good nulls were obtained with an experimental Adcock under sky-wave conditions. The same circumstances produced poor nulls with small loops (both conventional and ferrite-loop models).

Generally speaking, the Adcock antenna has attractive properties for amateur RDF applications. Unfortunately, its portability leaves something to be desired, making it more suitable to fixed or semi-portable applications. While a metal support for the mast and boom could be used, wood, PVC or fiberglass are preferable because they are nonconductors and would therefore cause less pattern distortion.

Since the array is balanced, an antenna tuner is required to match the unbalanced input of a typical receiver. **Fig 8** shows a suitable link-coupled network. C2 and C3 are null-balancing capacitors. A low-power signal source is placed some distance from the Adcock

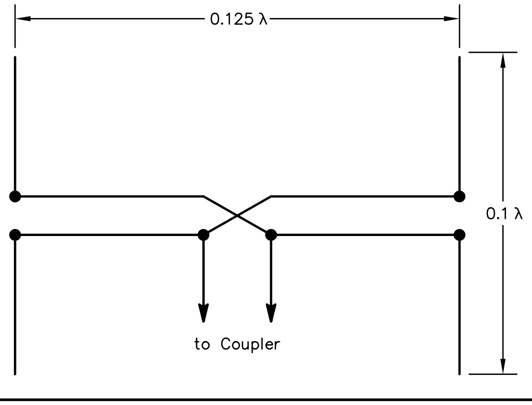

Fig 7—A simple Adcock antenna.

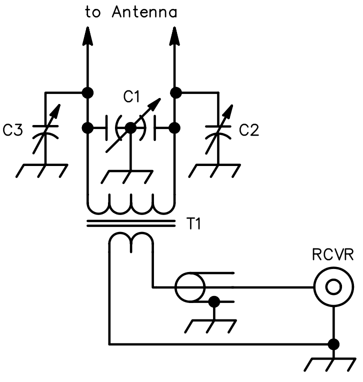

Fig 8—A suitable coupler for use with the Adcock antenna.

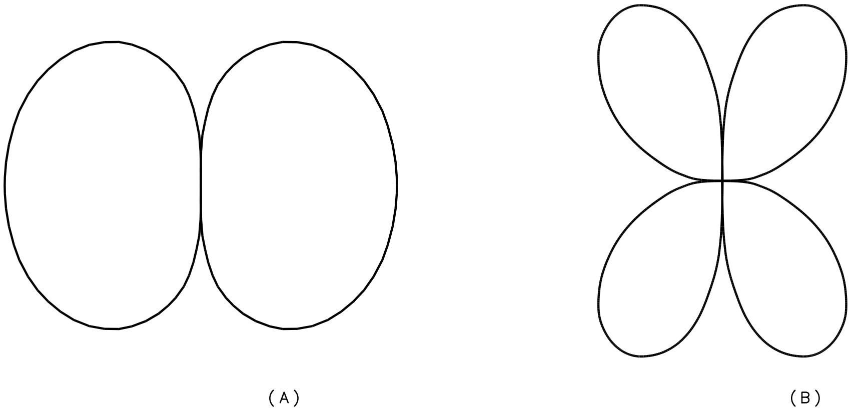

Fig 9—At A, the pattern of the Adcock array with an element spacing of $^1/_2$ wavelength. In these plots the elements are aligned with the horizontal axis. As the element spacing is increased beyond $^3/_4$ wavelength, additional nulls develop off the ends of the array, and at a spacing of 1 wavelength the pattern at B exists. This pattern is unsuitable for RDF work.

antenna and broadside to it. C2 and C3 are then adjusted until the deepest null is obtained. The tuner can be placed below the wiring-harness junction on the boom. Connection can be made by means of a short length of 300-Ω twin-lead.

The radiation pattern of the Adcock is shown in **Fig 9A**. The nulls are in directions broadside to the array, and become sharper with greater element spacings. However, with an element spacing greater than 0.75 λ, the pattern begins to take on additional nulls in the directions off the ends of the array axis. At a spacing of 1 λ the pattern is that of Fig 9B, and the array is unsuitable for RDF applications.

Short vertical monopoles are often used in what is sometimes called the *U-Adcock*, so named because the elements with their feeders take on the shape of the letter U. In this arrangement the elements are worked against the earth as a ground or counterpoise. If the array is used only for reception, earth losses are of no great consequence. Short, elevated vertical dipoles are also used in what is sometimes called the *H-Adcock*.

The Adcock array, with two nulls in its pattern, has the same ambiguity as the loop and the loopstick. Adding a sensing element to the Adcock array has not met with great success. Difficulties arise from mutual coupling between the array elements and the sensing element, among other things. Because Adcock arrays are used primarily for fixed-station applications, the ambiguity presents no serious problem. The fixed station is usually one of a group of stations in an RDF network.

LOOPS VERSUS PHASED ARRAYS

Although loops can be made smaller than suitable phased arrays for the same frequency of operation, the phased arrays are preferred by some for a variety of reasons. In general, sharper nulls can be obtained with phased arrays, but this is also a function of the care used in constructing and feeding the individual antennas, as well as of the size of the phased array in terms of wavelengths. The primary constructional consideration is the shielding and balancing of the feed line against unwanted signal pickup, and the balancing of the antenna for a symmetrical pattern.

Loops are not as useful for skywave RDF work because of random polarization of the received signal. Phased arrays are somewhat less sensitive to propagation effects, probably because they are larger for the same frequency of operation and therefore offer some space diversity. In general, loops and loopsticks are used for mobile and portable operation, while phased arrays are used for fixed-station operation. However, phased arrays are used successfully above 144 MHz for portable and mobile RDF work. Practical examples of both types of antennas are presented later in this chapter.

THE GONIOMETER

Most fixed RDF stations for government and commercial work use antenna arrays of stationary elements, rather than mechanically rotatable arrays. This has been true since the earliest days of radio. The early-day device that permits finding directions without moving the elements is called a *radiogoniometer*, or simply a *goniometer*. Various types of goniometers are still used today in many installations, and offer the amateur some possibilities.

The early style of goniometer is a special form of RF transformer, as shown in **Fig 10**. It consists of two fixed coils mounted at right angles to one another. Inside the fixed coils is a movable coil, not shown in Fig 10 to

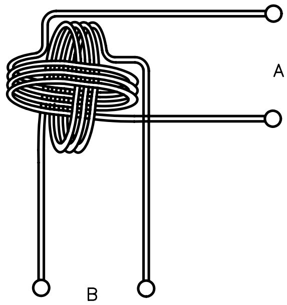

Fig 10—An early type of goniometer that is still used today in some RDF applications. This device is a special type of RF transformer that permits a movable coil in the center (not shown here) to be rotated and determine directions even though the elements are stationary.

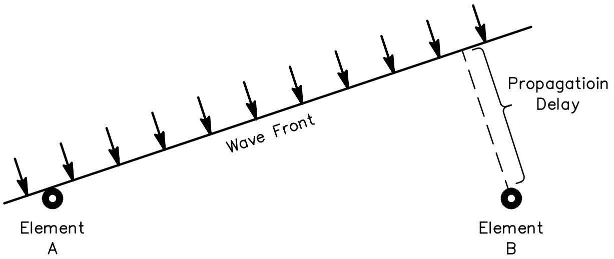

Fig 11—This diagram illustrates one technique used in electronic beam forming. By delaying the signal from element A by an amount equal to the propagation delay, the two signals may be summed precisely in phase, even though the signal is not in the broadside direction. Because this time delay is identical for all frequencies, the system is not frequency sensitive.

avoid cluttering the diagram. The pairs of connections marked A and B are connected respectively to two elements in an array, and the output to the detector or receiver is taken from the movable coil. As the inner coil is rotated, the coupling to one fixed coil increases while that to the other decreases. Both the amplitude and the phase of the signal coupled into the pickup winding are altered with rotation in a way that corresponds to actually rotating the array itself. Therefore, the rotation of the inner coil can be calibrated in degrees to correspond to bearing angles from the station location.

In the early days of radio, the type of goniometer just described saw frequent use with fixed Adcock arrays. A refinement of that system employed four Adcock elements, two arrays at right angles to each other. With a goniometer arrangement, RDF measurements could be taken in all compass directions, as opposed to none off the ends of a two-element fixed array. However, resolution of the 4-element system was not as good as with a single pair of elements, probably because of mutual coupling among the elements. To overcome this difficulty a few systems of eight elements were installed.

Various other types of goniometers have been developed over the years, such as commutator switching to various elements in the array. A later development is the diode switching of capacitors to provide a commutator effect. As mechanical action has gradually been replaced with electronics to “rotate” stationary elements, the word goniometer is used less frequently these days. However, it still appears in many engineering reference texts. The more complex electronic systems of today are called *beam-forming networks*.

Electronic Antenna Rotation

With an array of many fixed elements, beam rotation can be performed electronically by sampling and combining signals from various individual elements in the array. Contingent upon the total number of elements in the system and their physical arrangement, almost any desired antenna pattern can be formed by summing the sampled signals in appropriate amplitude and phase relationships. Delay networks are used for some of the elements before the summation is performed. In addition, attenuators may be used for some elements to develop patterns such as from an array with binomial current distribution.

One system using these techniques is the *Wullenweber* antenna, employed primarily in government and military installations. The Wullenweber consists of a very large number of elements arranged in a circle, usually outside of (or in front of) a circular reflecting screen. Depending on the installation, the circle may be anywhere from a few hundred feet to more than a quarter of a mile in diameter. Although the Wullenweber is not one that would be constructed by an amateur, some of the techniques it uses may certainly be applied to Amateur Radio.

For the moment, consider just two elements of a Wullenweber antenna, shown as A and B in **Fig 11**. Also shown is the wavefront of a radio signal arriving from a distant transmitter. As drawn, the wavefront strikes element A first, and must travel somewhat farther before it strikes element B. There is a finite time delay before the wavefront reaches element B.

The propagation delay may be measured by delaying the signal received at element A before summing it with that from element B. If the two signals are combined directly, the amplitude of the resultant signal will be maximum when the delay for element A exactly equals the propagation delay. This results in an in-phase condition at the summation point. Or if one of the signals is inverted and the two are summed, a null will exist when the element-A delay equals the propagation delay; the signals will combine in a 180° out-of-phase relationship. Either way, once the time delay is known, it may be converted to distance. Then the direction from which the wave is arriving may be determined by trigonometry.

By altering the delay in small increments, the peak of the antenna lobe (or the null) can be steered in azimuth. This is true without regard to the frequency of the incoming wave. Thus, as long as the delay is less than the period of one RF cycle, the system is not frequency sensitive, other than for the frequency range that may be covered satisfactorily by the array elements themselves. Surface acoustic wave (SAW) devices or lumped-constant networks can be used for delay lines in such systems if the system is used only for receiving. Rolls of coaxial cable of various lengths are used in installations for transmitting. In this case, the lines are considered for the time delay they provide, rather than as simple phasing lines. The difference is that a phasing line is ordinarily designed for a single frequency (or for an amateur band), while a delay line offers essentially the same time delay at all frequencies.

By combining signals from other Wullenweber elements appropriately, the broad beamwidth of the pattern from the two elements can be narrowed, and unwanted sidelobes can be suppressed. Then, by electronically switching the delays and attenuations to the various elements, the beam so formed can be rotated around the compass. The package of electronics designed to do this, including delay lines and electronically switched attenuators, is the beam-forming network. However, the Wullenweber system is not restricted to forming a single beam. With an isolation amplifier provided for each element of the array, several beam-forming networks can be operated independently. Imagine having an antenna system that offers a dipole pattern, a rhombic pattern, and a Yagi beam pattern, all simultaneously and without frequency sensitivity. One or more may be rotating while another is held in a particular direction. The Wullenweber was designed to fulfill this type of requirement.

One feature of the Wullenweber antenna is that it can operate 360° around the compass. In many government installations, there is no need for such coverage, as the areas of interest lie in an azimuth sector. In such cases an in-line array of elements with a backscreen or curtain reflector may be installed broadside to the center of the sector. By using the same techniques as the Wullenweber, the beams formed from this array may be slewed left and right across the sector. The maximum sector width available will depend on the installation, but beyond 70° to 80° the patterns begin to deteriorate to the point that they are unsatisfactory for precise RDF work.

RDF SYSTEM CALIBRATION AND USE

Once an RDF system is initially assembled, it should be calibrated or checked out before actually being put into use. Of primary concern is the balance or symmetry of the antenna pattern. A lop-sided figure-8 pattern with a loop, for example, is undesirable; the nulls are not 180° apart, nor are they at exact right angles to the plane of the loop. If you didn't know this fact in actual RDF work, measurement accuracy would suffer.

Initial checkout can be performed with a low-powered transmitter at a distance of a few hundred feet. It should be within visual range and must be operating into a vertical antenna. (A quarter-wave vertical or a loaded whip is quite suitable.) The site must be reasonably clear of obstructions, especially steel and concrete or brick buildings, large metal objects, nearby power lines, and so on. If the system operates above 30 MHz, you should also avoid trees and large bushes. An open field makes an excellent site.

The procedure is to find the transmitter with the RDF equipment as if its position were not known, and compare the RDF null indication with the visual path to the transmitter. For antennas having more than one null, each null should be checked.

If imbalance is found in the antenna system, there are two options available. One is to correct the imbalance. Toward this end, pay particular attention to the feed line. Using a coaxial feeder for a balanced antenna invites an asymmetrical pattern, unless an effective balun is used. A balun is not necessary if the loop is shielded, but an asymmetrical pattern can result with misplacement of the break in the shield itself. The builder may also find that the presence of a sensing antenna upsets the balance slightly, due to mutual coupling. Experiment with its position with respect to the main antenna to correct the error. You will also note that the position of the null shifts by 90° as the sensing element is switched in and out, and the null is not as deep. This is of little concern, however, as the intent of the sensing antenna is only to resolve ambiguities. The sensing element should be switched out when accuracy is desired.

The second option is to accept the imbalance of the antenna and use some kind of indicator to show the true directions of the nulls. Small pointers, painted marks on the mast, or an optical sighting system might be used. Sometimes the end result of the calibration procedure will be a compromise between these two options, as a perfect electrical balance may be difficult or impossible to attain.

The discussion above is oriented toward calibrating portable RDF systems. The same general suggestions apply if the RDF array is fixed, such as an Adcock. However, it won't be possible to move it to an open field. Instead, the array must be calibrated in its intended operating position through the use of a portable or mobile transmitter. Because of nearby obstructions or reflecting objects, the null in the pattern may not appear to indicate the precise direction of the transmitter. Do not confuse this with imbalance in the RDF array. Check for imbalance by rotating the array 180° and comparing readings.

Once the balance is satisfactory, you should make a table of bearing errors noted in different compass directions. These error values should be applied as corrections when actual measurements are made. The mobile or por-

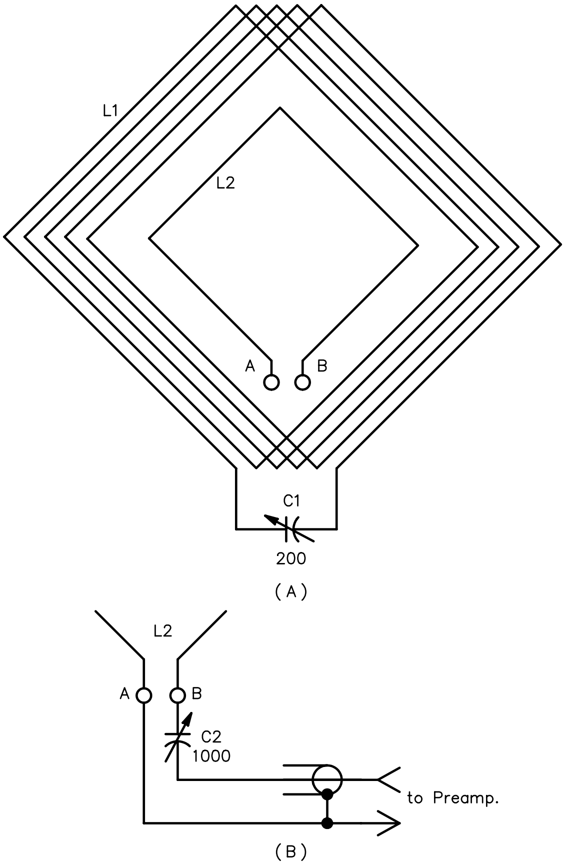

Fig 12—A multiturn frame antenna is shown at A. L2 is the coupling loop. The drawing at B shows how L2 is connected to a preamplifier.

table transmitter should be at a distance of two or three miles for these measurements, and should be in as clear an area as possible during transmissions. The idea is to avoid conduction of the signal along power lines and other overhead wiring from the transmitter to the RDF site. Of course the position of the transmitter must be known accurately for each transmission.

FRAME LOOPS

It was mentioned earlier that the earliest style of receiving loops was the frame antenna. If carefully constructed, such an antenna performs well and can be built at low cost. **Fig 12** illustrates the details of a practical frame type of loop antenna. This antenna was designed by Doug DeMaw, W1FB, and described in *QST* for July 1977. (See the Bibliography at the end of this chapter.) The circuit in Fig 12A is a 5-turn system tuned to resonance by C1. If the layout is symmetrical, good balance should be obtained. L2 helps to achieve this objective by eliminating the need for direct coupling to the feed ter-

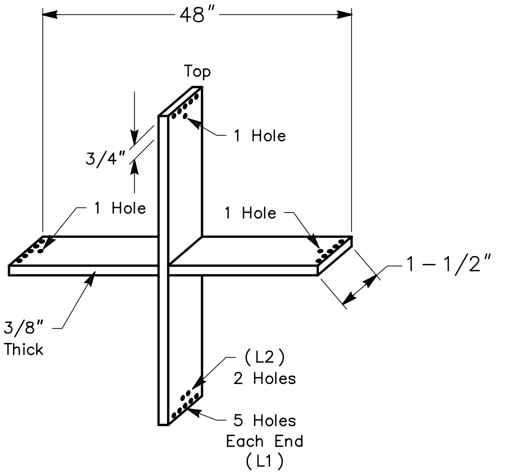

Fig 13—A wooden frame can be used to contain the wire of the loop shown in Fig 12.

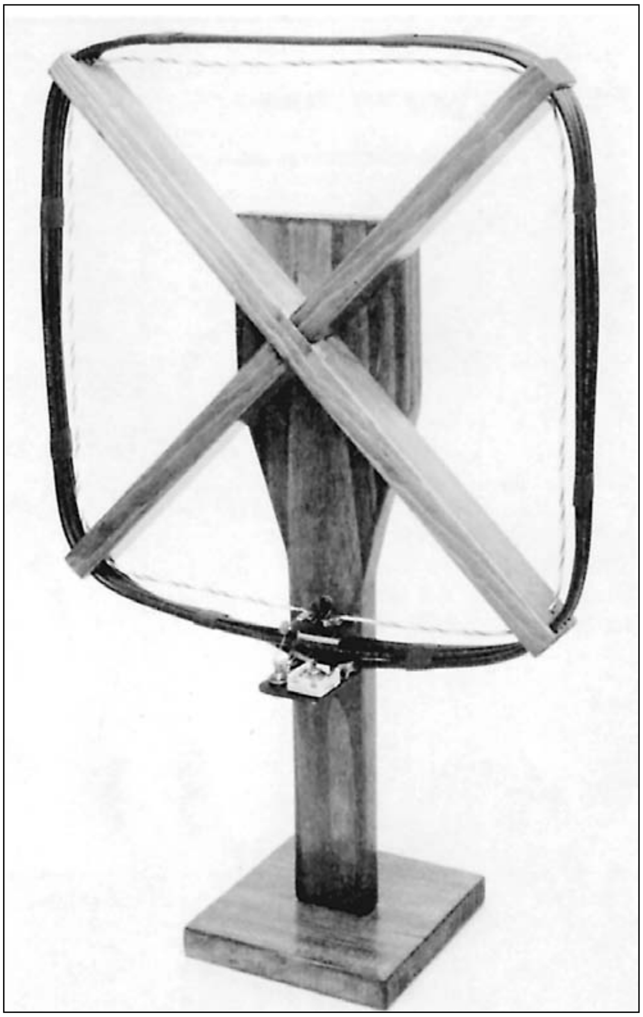

Fig 14—An assembled table-top version of the electrostatically shielded loop. RG-58 cable is used in its construction.

minals of L1. If the loop feed were attached in parallel with C1, a common practice, the chance for imbalance would be considerable.

L2 can be situated just inside or slightly outside of L1; a 1-inch separation works nicely. The receiver or preamplifier can be connected to terminals A and B of L2, as shown in Fig 12B. C2 controls the amount of coupling between the loop and the preamplifier. The lighter the coupling, the higher is the loop Q, the narrower is the frequency response, and the greater is the gain requirement from the preamplifier. It should be noted that no attempt is being made to match the extremely low loop impedance to the preamplifier.

A supporting frame for the loop of Fig 12 can be constructed of wood, as shown in **Fig 13**. The dimensions given are for a 1.8-MHz frame antenna. For use on 75 or 40 meters, L1 of Fig 12A will require fewer turns, or the size of the wooden frame should be made somewhat smaller than that of Fig 13.

SHIELDED FRAME LOOPS

If electrostatic shielding is desired, the format shown in **Fig 14** can be adopted. In this example, the loop conductor and the single-turn coupling loop are made from RG-58 coaxial cable. The number of loop turns should be sufficient to resonate with the tuning capacitor at the operating frequency. Antenna resonance can be checked by first connecting C1 (Fig 12A) and setting it at midrange. Then connect a small 3-turn coil to the loop feed terminals, and couple to it with a dip meter. Just remember that the pickup coil will act to lower the frequency slightly from actual resonance.

In the antenna photographed for Fig 14, the 1-turn coupling loop was made of #22 plastic-insulated wire. However, electrostatic noise pickup occurs on such a coupling loop, noise of the same nature that the shield on the main loop prevents. This can be avoided by using RG-58 for the coupling loop. The shield of the coupling loop should be opened for about 1 inch at the top, and each end of the shield grounded to the shield of the main loop.

Larger single-turn frame loops can be fashioned from aluminum-jacketed Hardline, if that style of coax is available. In either case, the shield conductor must be opened at the electrical center of the loop, as shown in **Fig 15** at A and B. The design example is for 1.8-MHz operation.

To realize the best performance from an electrostatically shielded loop antenna, you must operate it near to and directly above an effective ground plane. An automobile roof (metal) qualifies nicely for small shielded loops. For fixed-station use, a chicken-wire ground screen can be placed below the antenna at a distance of 1 to 6 feet.

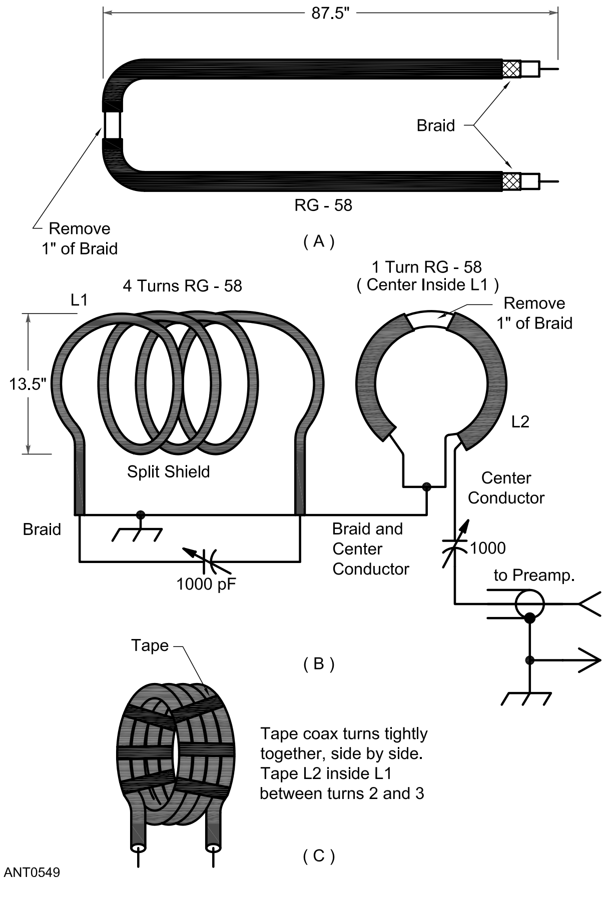
87.5"
Braid
RG - 58
Remove 1" of Braid
(A)
4 Turns RG - 58
L1
13.5"
1 Turn RG - 58 (Center Inside L1)
Remove 1" of Braid
L2
Split Shield
Center Conductor
Braid
Braid and Center Conductor
1000 pF
1000
to Preamp.
Tape
(B)
(C)
ANT0549

Tape coax turns tightly together, side by side. Tape L2 inside L1 between turns 2 and 3

Fig 15—Components and assembly details of the shielded loop shown in Fig 14.

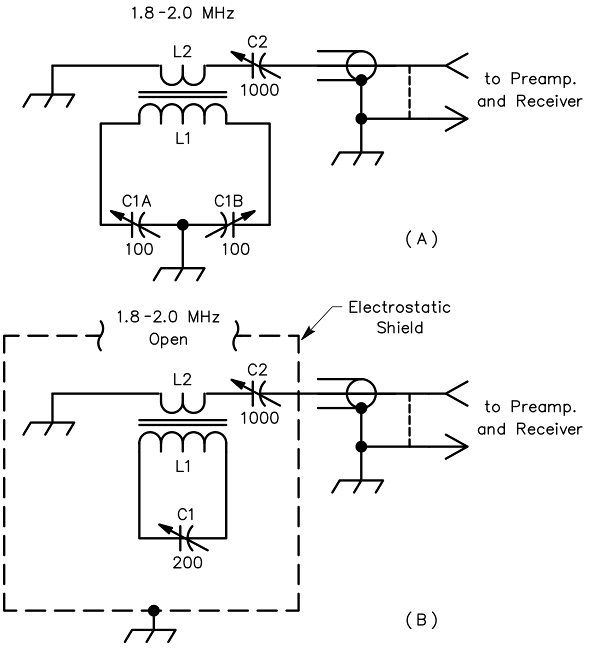
1.8 -2.0 MHz
L2
C2
1000
L1
C1A
C1B
100
100
to Preamp. and Receiver
(A)
Electrostatic Shield
1.8 -2.0 MHz Open
L2
C2
1000
L1
C1
200
to Preamp. and Receiver
(B)

Fig 16—At A, the diagram of a ferrite loop. C1 is a dual-section air-variable capacitor. The circuit at B shows a rod loop contained in an electrostatic shield channel (see text). A suitable low-noise preamplifier is shown in Fig 19.

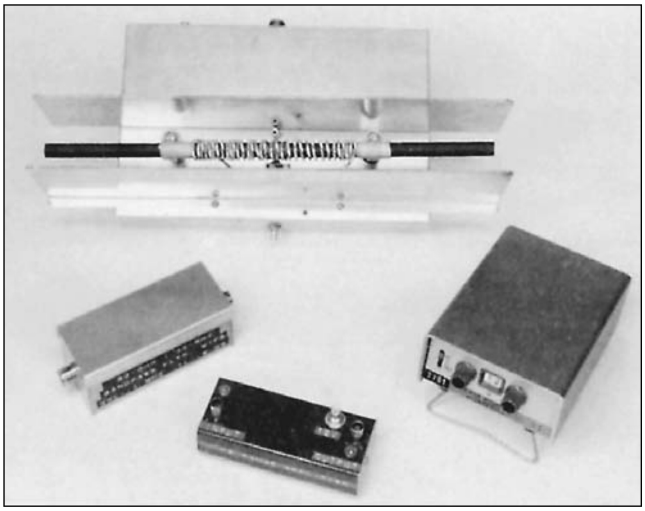

Fig 17—The assembly at the top of the picture is a shielded ferrite-rod loop for 160 meters. Two rods have been glued end to end (see text). The other units in the picture are a low-pass filter (lower left), broadband preamplifier (lower center) and a Tektronix step attenuator (lower right). These were part of the test setup used when the antenna was evaluated.

FERRITE-CORE LOOPS

Fig 16 contains a diagram for a rod loop (loopstick antenna). This antenna was also designed by Doug DeMaw, W1FB, and described in *QST* for July 1977. The winding (L1) has the appropriate number of turns to permit resonance with C1 at the operating frequency. L1 should be spread over approximately $^1/_3$ of the core center. Litz wire will yield the best Q, but Formvar magnet wire can be used if desired. A layer of 3M Company glass tape (or Mylar tape) is recommended as a covering for the core before adding the wire. Masking tape can be used if nothing else is available.

L2 functions as a coupling link over the exact center of L1. C1 is a dual-section variable capacitor, although a differential capacitor might be better toward obtaining optimum balance. The loop Q is controlled by means of C2, which is a mica-compression trimmer.

Electrostatic shielding of rod loops can be effected by centering the rod in a U-shaped aluminum, brass or copper channel, extending slightly beyond the ends of the rod loop (1 inch is suitable). The open side (top) of the channel can't be closed, as that would constitute a shorted turn and render the antenna useless. This can be proved by shorting across the center of the channel with a screwdriver blade when the loop is tuned to an incoming signal. The shield-braid gap in the coaxial loop of Fig 15 is maintained for the same reason.

Fig 17 shows the shielded rod loop assembly. This antenna was developed experimentally for 160 meters and uses two 7-inch ferrite rods, glued together end-to-end with epoxy cement. The longer core resulted in improved sensitivity for weak-signal reception. The other items in the photograph were used during the evaluation tests and are not pertinent to this discussion. This loop and the frame loop discussed in the previous section have bidirectional nulls, as shown in Fig 1A.

Obtaining a Cardioid Pattern

Although the bidirectional pattern of loop antennas

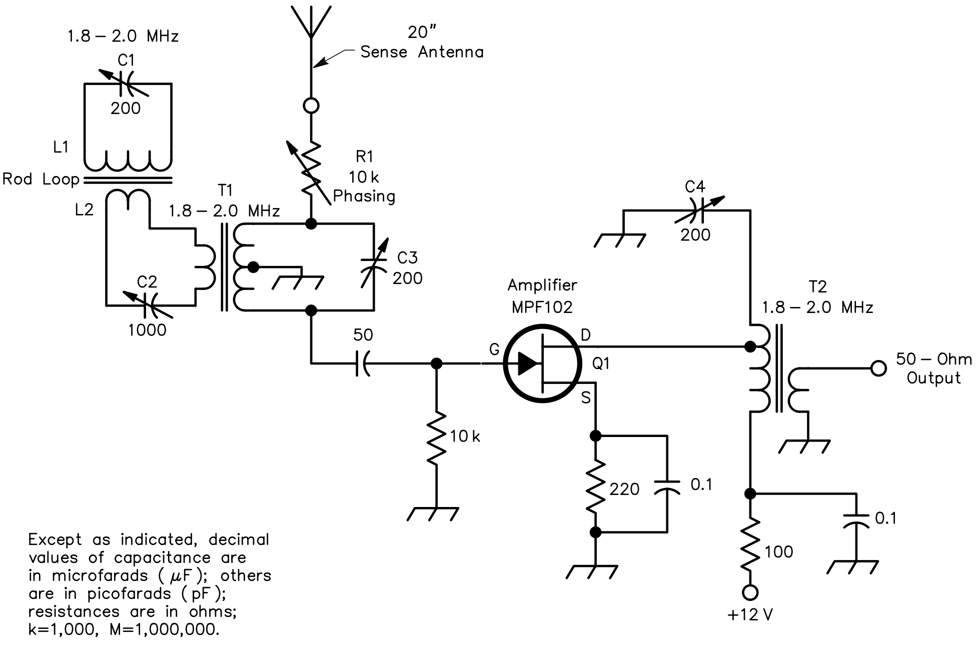
1.8 – 2.0 MHz
C1
200
L1
Rod Loop
L2
T1
1.8 – 2.0 MHz
C2
1000
20″
Sense Antenna
R1
10 k
Phasing
C3
200
50
10 k
Amplifier
MPF102
G
D
Q1
S
220
0.1
C4
200
T2
1.8 – 2.0 MHz
50 – Ohm
Output
0.1
100
+12 V
Except as indicated, decimal
values of capacitance are
in microfarads (μF); others
are in picofarads (pF);
resistances are in ohms;
k=1,000, M=1,000,000.

Fig 18—Schematic diagram of a rod-loop antenna with a cardioid response. The sensing antenna, phasing network and a preamplifier are shown also. The secondary of T1 and the primary of T2 are tuned to resonance at the operating frequency of the loop. T-68-2 to T-68-6 Amidon toroid cores are suitable for both transformers. Amidon also sells ferrite rods for this type of antenna.

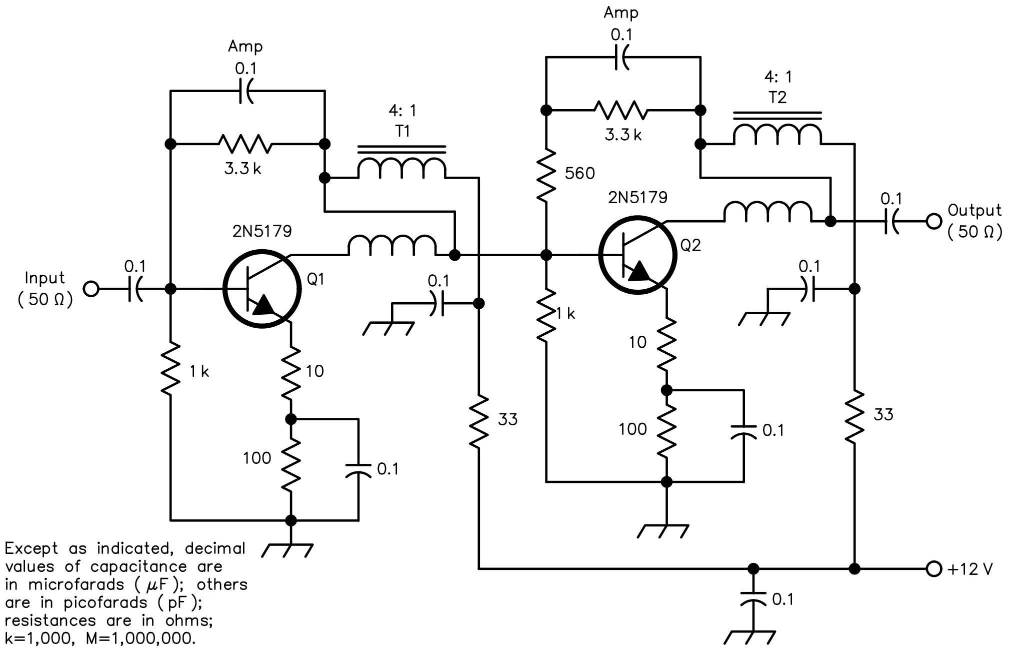
Amp
0.1
3.3 k
4: 1
T1
2N5179
Q1
Input
(50 Ω)
0.1
1 k
10
100
0.1
0.1
33
560
Amp
0.1
3.3 k
4: 1
T2
2N5179
Q2
0.1
Output
(50 Ω)
1 k
10
100
0.1
0.1
33
+12 V
0.1
Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms; k=1,000, M=1,000,000.

Fig 19—Schematic diagram of a two-stage broadband amplifier patterned after a design by Wes Hayward, W7ZOI. T1 and T2 have a 4:1 impedance ratio and are wound on FT-50-61 toroid cores (Amidon) which have a μ_i of 125. They contain 12 turns of #24 enamel wire, bifilar wound. The capacitors are disc ceramic. This amplifier should be built on double-sided circuit board for best stability.

can be used effectively in tracking down signal sources by means of triangulation, an essentially unidirectional loop response will help to reduce the time spent finding the fox. Adding a sensing antenna to the loop is simple to do, and it will provide the desired cardioid response. The theoretical pattern for this combination is shown in Fig 1D.

Fig 18 shows how a sensing element can be added to a loop or loopstick antenna. The link from the loop is connected by coaxial cable to the primary of T1, which is a tuned toroidal transformer with a split secondary winding. C3 is adjusted for peak signal response at the frequency of interest (as is C4), then R1 is adjusted for minimum back response of the loop. It will be necessary to readjust C3 and R1 several times to compensate for the interaction of these controls. The adjustments are repeated until no further null depth can be obtained. Tests at ARRL Headquarters showed that null depths as great as 40 dB could be obtained with the circuit of Fig 18 on 75 meters. A near-field weak-signal source was used during the tests.

The greater the null depth, the lower the signal output from the system, so plan to include a preamplifier with 25 to 40 dB of gain. Q1 shown in Fig 18 will deliver approximately 15 dB of gain. The circuit of **Fig 19** can be used following T2 to obtain an additional 24 dB of gain. In the interest of maintaining a good noise figure, even at 1.8 MHz, Q1 should be a low-noise device. A 2N4416, an MPF102, or a 40673 MOSFET would be satisfactory. The sensing antenna can be mounted 6 to 15 inches from the loop. The vertical whip need not be more than 12 to 20 inches long. Some experimenting may be necessary in order to obtain the best results. Optimization will also change with the operating frequency of the antenna.

A SHIELDED LOOP WITH SENSING ANTENNA FOR 28 MHz

Fig 20 shows the construction and mounting of a simple shielded 10-meter loop. The loop was designed by Loren Norberg, W9PYG, and described in *QST* for April 1954. (See the Bibliography at the end of this chapter.) It is made from an 18-inch length of RG-11 coax (either solid or foam dielectric) secured to an aluminum box of any convenient size, with two coaxial cable hoods (Amphenol 83-1HP). The outer shield must be broken at the exact center. C1 is a 25-pF variable capacitor, and is connected in parallel with a 33-pF fixed mica padder capacitor, C3. C1 must be tuned to the desired frequency while the loop is connected to the receiver in the same way as it will be used for RDF. C2 is a small differential capacitor used to provide electrical symmetry. The lead-in to the receiver is 67 inches of RG-59 (82 inches if the cable has a foamed dielectric).

The loop can be mounted on the roof of the car with a rubber suction cup. The builder might also fabricate some kind of bracket assembly to mount the loop temporarily in the window opening of the automobile, allowing for loop rotation. Reasonably true bearings may be obtained through the windshield when the car is pointed in the direction of the hidden transmitter. More accurate bearings may be obtained with the loop held out the window and the signal coming toward that side of the car.

Sometimes the car broadcast antenna may interfere with accurate bearings. Disconnecting the antenna from the broadcast receiver may eliminate this trouble.

Sensing Antenna

A sensing antenna can be added to Norberg's loop above to determine which of the two directions indicated by the loop is the correct one. Add a phono jack to the top of the aluminum case shown in Fig 20. The insulated center terminal of the jack should be connected to the side of the tuning capacitors that is common to the center conductor of the RG-59 coax feed line. The jack then takes a short vertical antenna rod of the diameter to fit the jack, or a piece of #12 or #14 solid wire may be soldered to the center pin of a phono plug for insertion in the jack. The sensing antenna can be plugged in as needed. Starting with a length of about four times the loop diameter, the length of the sensing antenna should be pruned until the pattern is similar to that of Fig 1D.

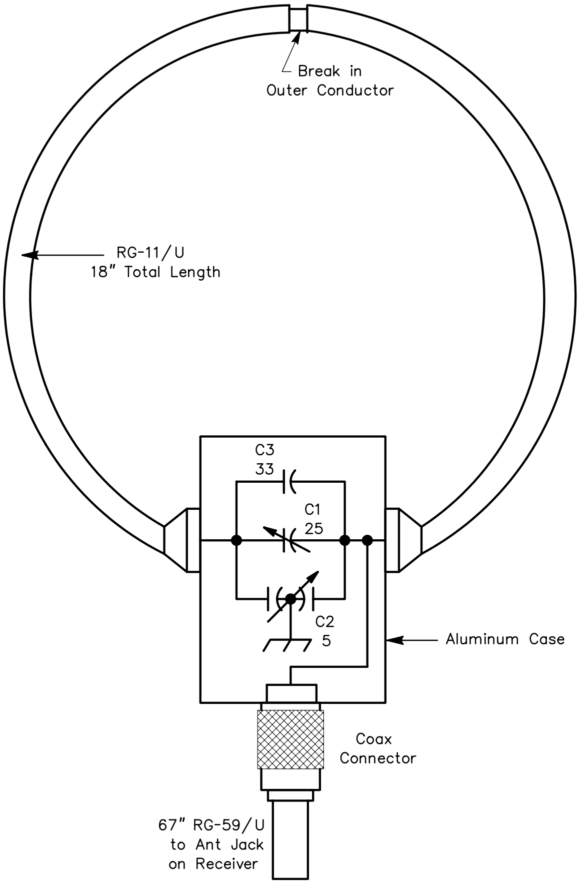

Fig 20—Sketch showing the constructional details of the 28-MHz RDF loop. The outer braid of the coax loop is broken at the center of the loop. The gap is covered with waterproof tape, and the entire assembly is given a coat of acrylic spray.

THE SNOOP LOOP—FOR CLOSE-RANGE HF RDF

Picture yourself on a hunt for a hidden 28-MHz transmitter. The night is dark, very dark. After you take off at the start of the hunt, heading in the right direction, the signal gets stronger and stronger. Your excitement increases with each additional S unit on the meter. You follow your loop closely, and it is working perfectly. You're getting out of town and into the countryside. The roads are unfamiliar. Now the null is beginning to swing rather rapidly, showing that you are getting close.

Suddenly the null shifts to give a direction at right angles to the car. With your flashlight you look carefully across the deep ditch beside the road and into the dark field where you know the transmitter is hidden. There are no roads into the field as far as you can see in either direction. You dare not waste miles driving up and down the road looking for an entrance, for each tenth of a mile counts. But what to do?—Your HF transceiver is mounted in your car and requires power from your car battery.

In a brief moment your decision is made. You park

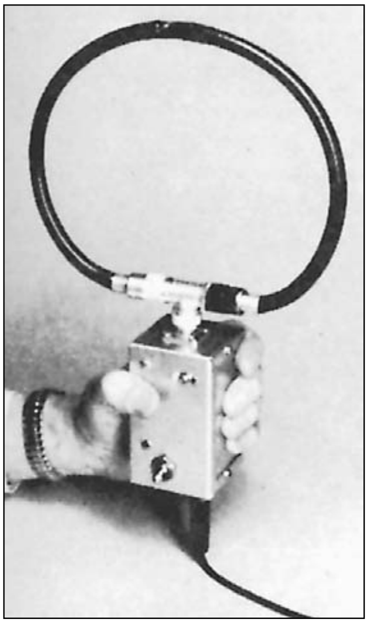

Fig 21—The box containing the detector and amplifier is also the "handle" for the Snoop Loop. The loop is mounted with a coax T as a support, a convenience but not an essential part of the loop assembly. The loop tuning capacitor is screwdriver adjusted. The on-off switch and the meter sensitivity control may be mounted on the bottom.

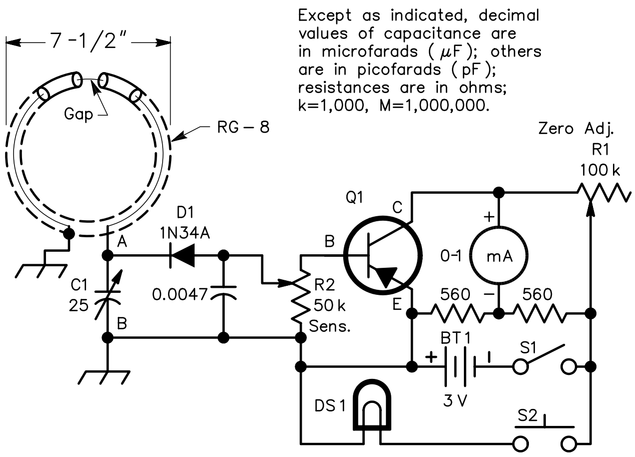
Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k=1,000, M=1,000,000.
7 -1/2″
Gap
RG – 8
Zero Adj.
R1
100 k
Q1
C
+
D1
1N34A
A
B
0-1
mA
C1
25
0.0047
R2
50 k
Sens.
E
560
−
560
B
BT1
+
S1
3 V
DS1
S2

Fig 22—The Snoop Loop circuit for 28-MHz operation. The loop is a single turn of RG-8 inner conductor, the outer conductor being used as a shield. Note the gap in the shielding; about a 1-inch section of the outer conductor should be cut out. Refer to Fig 23 for alternative connection at points A and B for other frequencies of operation.

BT1—Two penlight cells.
C1—25-pF midget air padder.
D1—Small-signal germanium diode such as 1N34A or equiv.
DS1—Optional 2-cell penlight lamp for meter illumination, such as no. 222.
Q1—PNP transistor such as ECG102 or equiv.
R1—100-kΩ potentiometer, linear taper. May be PC-mount style.
R2—50-kΩ potentiometer, linear taper.
S1—SPST toggle.
S2—Optional momentary push for illuminating meter.

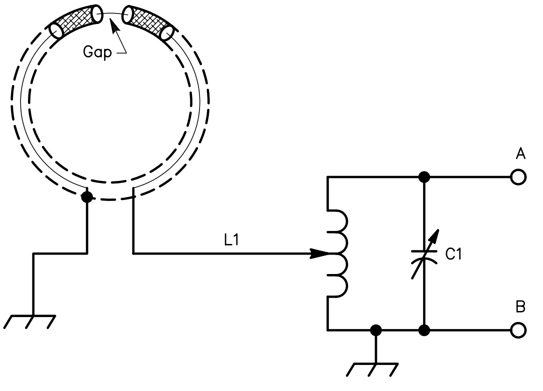

Fig 23—Input circuit for lower frequency bands. Points A and B are connected to corresponding points in the circuit of Fig 22, substituting for the loop and C1 in that circuit. L1-C1 should resonate within the desired amateur band, but the L/C ratio is not critical. After construction is completed, adjust the position of the tap on L1 for maximum signal strength. Instead of connecting the RDF loop directly to the tap on L1, a length of low impedance line may be used between the loop and the tuned circuit, L1-C1.

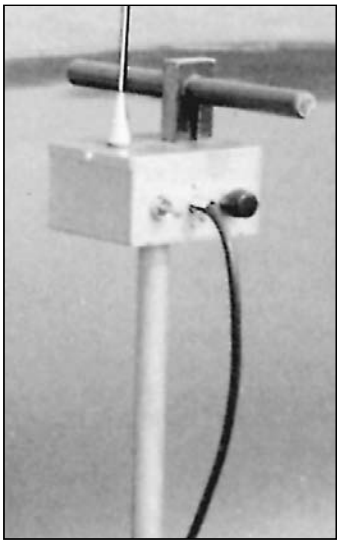

Fig 24—Unidirectional 3.5-MHz RDF using ferrite-core loop with sensing antenna. Adjustable components of the circuit are mounted in the aluminum chassis supported by a short length of tubing.

beside the road, take your flashlight, and plunge into the veldt in the direction your loop null clearly indicated. But after taking a few steps, you're up to your armpits in brush and can't see anything forward or backward. You stumble on in hopes of running into the hidden transmitter—you're probably not more than a few hundred feet from it. But away from your car and radio equipment, it's like the proverbial hunt for the needle in the haystack. What you really need is a portable setup for hunting at close range, and you may prefer something that is inexpensive. The Snoop Loop was designed for just these requirements by Claude Maer, Jr, WØIC, and was described in *QST* for February 1957. (See the Bibliography at the end of this chapter.)

The Snoop Loop is pictured in **Fig 21**. The loop itself is made from a length of RG-8 coax, with the shield broken at the top. A coax T connector is used for convenience and ease of mounting. One end of the coax loop is connected to a male plug in the conventional way, but the center conductor of the other end is shorted to the shield so the male connector at that end has no connection to the center prong. This results in an unbalanced circuit, but seems to give good bidirectional null readings, as well as an easily detectable maximum reading when the grounded end of the loop is pointed in the direction of the transmitter. Careful tuning with C1 will improve this maximum reading. Don't forget to remove one inch of shielding from the top of the loop. You won't get much signal unless you do.

The detector and amplifier circuit for the Snoop Loop

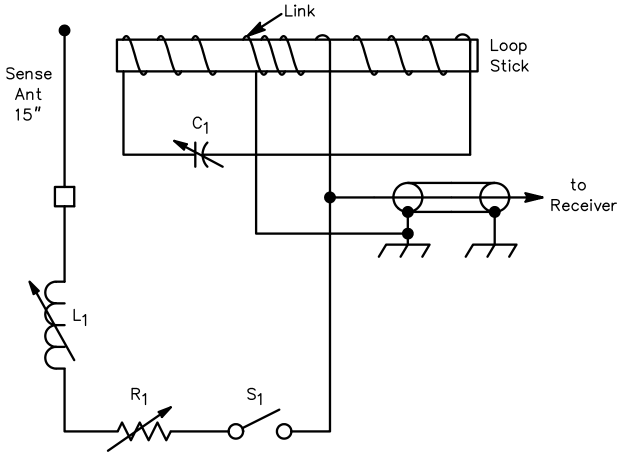

Fig 25—Circuit of the 3.5-MHz direction finder loop.

C1—140 pF variable (125-pF ceramic trimmer in parallel with 15-pF ceramic fixed.

L1—Approximately 140 µH adjustable (Miller No. 4512 or equivalent.

R1—1-kΩ carbon potentiometer.

S1—SPST toggle.

Loopstick—Approximately 15 µH (Miller 705-A, with original winding removed and wound with 20 turns of #22 enamel). Link is two turns at center. Winding ends secured with Scotch electrical tape. This type of ferrite rod may also be found in surplus transistor AM radios.

is shown in **Fig 22**. The model photographed does not include the meter, as it was built for use only with high-impedance headphones. The components are housed in an aluminum box. Almost any size box of sufficient size to contain the meter can be used. At very close ranges, reduction of sensitivity with R2 will prevent pegging the meter.

The Snoop Loop is not limited to the 10-meter band or to a built-in loop. **Fig 23** shows an alternative circuit for other bands and for plugging in a separate loop connected by a low-impedance transmission line. Select coil and capacitor combinations that will tune to the desired frequencies. Plug-in coils could be used. It is a good idea to have the RF end of the unit fairly well shielded, to eliminate signal pickup except through the loop. This little unit should certainly help you on those dark nights in the country. (Tip to the hidden-transmitter operator—if you want to foul up some of your pals using these loops, just hide near the antenna of a 50-kW broadcast transmitter!)

A LOOPSTICK FOR 3.5 MHz

Figs 24 through 26 show an RDF loop suitable for the 3.5-MHz band. It uses a construction technique that has had considerable application in low-frequency marine direction finders. The loop is a coil wound on a ferrite rod from a broadcast-antenna loopstick. The loop was designed by John Isaacs, W6PZV, and described in *QST* for June 1958. Because you can make a coil with high Q using a ferrite core, the sensitivity of such a loop is comparable to a conventional loop that is a foot or so in diameter. The output of the vertical-rod sensing antenna, when properly combined with that of the loop, gives the system the cardioid pattern shown in Fig 1D.

To make the loop, remove the original winding on the ferrite core and wind a new coil, as shown in **Fig 25**. Other types of cores than the one specified may be substituted; use the largest coil available and adjust the winding so that the circuit resonates in the 3.5-MHz band within the range of C1. The tuning range of the loop may be checked with a dip meter.

The sensing system consists of a 15-inch whip and an adjustable inductor that resonates the whip as a quarter-wave antenna. It also contains a potentiometer to control the output of the antenna. S1 is used to switch the sensing antenna in and out of the circuit.

The whip, the loopstick, the inductance L1, the capacitor C1, the potentiometer R1, and the switch S1 are all mounted on a 4 × 5 × 3-inch box chassis, as shown in **Fig 26**. The loopstick may be mounted and protected inside a piece of $^1/_2$-inch PVC pipe. A section of $^1/_2$-inch electrical conduit is attached to the bottom of the chassis box and this supports the instrument.

To produce an output having only one null there must a 90° phase difference between the outputs of the loop and sensing antennas, and the signal strength from each must be the same. The phase shift is obtained by tuning the sensing antenna slightly off frequency, using the slug in L1. Since the sensitivity of the whip antenna is greater than that of the loop, its output is reduced by adjusting R1.

Adjustment

To adjust the system, enlist the aid of a friend with a mobile transmitter and find a clear spot where the transmitter and RDF receiver can be separated by several hundred feet. Use as little power as possible at the transmitter. (Make very sure you don’t transmit into the loop if you are using a transceiver as a detector.) With the test transmitter operating on the proper frequency, disconnect the sensing antenna with S1, and peak the loopstick using C1, while watching the S meter on the transceiver. Once the loopstick is peaked, no further adjustment of C1 will be necessary. Next, connect the sensing antenna and turn R1 to minimum resistance. Then vary the adjustable slug of L1 until a maximum reading of the S meter is again obtained. It may be necessary to turn the unit a bit during this adjustment to obtain a higher reading than with the loopstick alone. The last turn of the slug is quite critical, and some hand-capacitance effect may be noted.

Now turn the instrument so that one side (not an end) of the loopstick is pointed toward the test transmitter. Turn R1 a complete revolution and if the proper side was chosen a definite null should be observed on the S meter for one particular position of R1. If not, turn the RDF 180° and try again. This time leave R1 at the setting producing

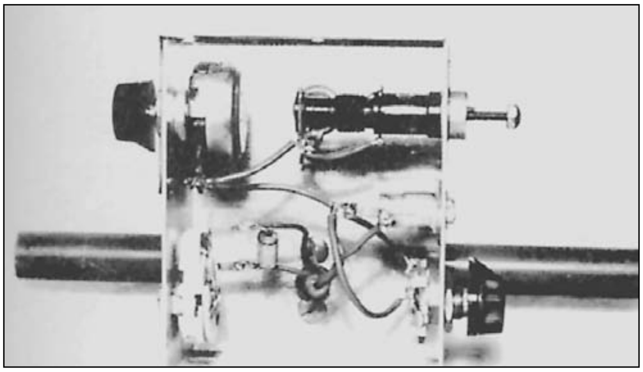

Fig 26—Components of the 3.5-MHz RDF are mounted on the top and sides of a channel-lock type box. In this view R1 is on the left wall at the upper left and C1 is at the lower left. L1, S1 and the output connector are on the right wall. The loopstick and whip mount on the outside.

the minimum reading. Now adjust L1 very slowly until the S-meter reading is reduced still further. Repeat this several times, first R1, and then L1, until the best minimum is obtained.

Finally, as a check, have the test transmitter move around the RDF and follow it by turning the RDF. If the tuning has been done properly the null will always be broadside to the loopstick. Make a note of the proper side of the RDF for the null, and the job is finished.

A 144-MHZ CARIOID-PATTERN RDF ANTENNA

Although there may be any number of different VHF antennas that can produce a cardioid pattern, a simple design is depicted in **Fig 27**. Two $^{1}/_{4}$-wavelength vertical elements are spaced one $^{1}/_{4}$-λ apart and are fed 90° out of phase. Each radiator is shown with two radials approximately 5% shorter than the radiators. This array was designed by Pete O'Dell, KB1N, and described in *QST* for March 1981.

Computer modeling showed that slight alterations in the size, spacing and phasing of the elements strongly impact the pattern. The results suggest that this system is a little touchy and that the most significant change comes at the null. Very slight alterations in the dimensions caused the notch to become much more shallow and, hence, less usable for RDF. Early experience in building a working model bore this out.

This means that if you build this antenna, you will find it advantageous to spend a few minutes to tune it carefully for the deepest null. If it is built using the techniques presented here, then this should prove to be a small task, well worth the extra effort. Tuning is accomplished by adjusting the length of the vertical radiators, the spacing between them and, if necessary, the lengths of the phasing harness that connects them. Tune for the deepest null on your S meter when using a signal source such as a moderately strong repeater.

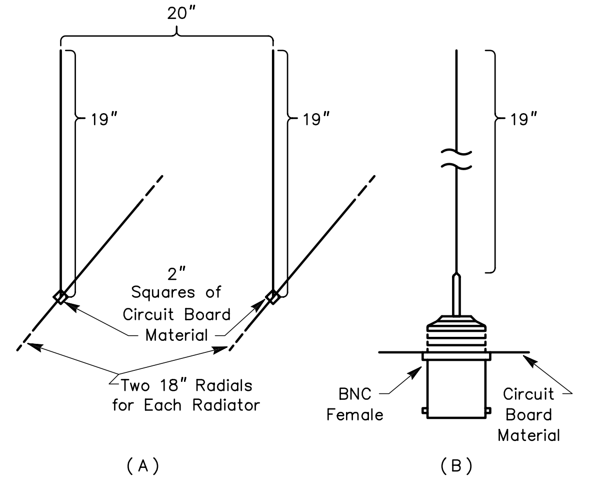

Fig 27—At A is a simple configuration that can produce a cardioid pattern. At B is a convenient way of fabricating a sturdy mount for the radiator using BNC connectors.

This should be done outside, away from buildings and large metal objects. Initial indoor tuning on this project was tried in the kitchen, which revealed that reflections off the appliances were producing spurious readings. Beware too of distant water towers, radio towers, and large office or apartment buildings. They can reflect the signal and give false indications.

Construction is simple and straightforward. Fig 27B shows a female BNC connector (RadioShack 278-105) that has been mounted on a small piece of PC-board material. The BNC connector is held upside down, and the vertical radiator is soldered to the center solder lug. A 12-inch piece of brass tubing provides a snug fit over the solder lug. A second piece of tubing, slightly smaller in diameter, is telescoped inside the first. The outer tubing is crimped slightly at the top after the inner tubing is installed. This provides positive contact between the two tubes. For 146 MHz the length of the radiators is calculated to be about 19 inches. You should be able to find small brass tubing at a hobby store. If none is available in your area, consider brazing rods. These are often available in hardware sections of discount stores. It will probably be necessary to solder a short piece to the top since these come in 18-inch sections. Also, tuning will not be quite as convenient. Two 18-inch radials are added to each element by soldering them to the board. Two 36-inch pieces of heavy brazing rod were used in this project.

The Phasing Harness

As shown in **Fig 28**, a T connector is used with two different lengths of coaxial line to form the phasing harness. This method of feeding the antenna is superior over

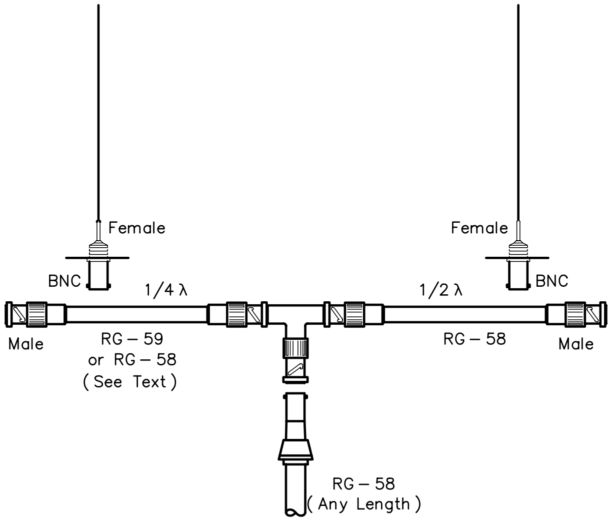

Fig 28—The phasing harness for the phased 144-MHz RDF array. The phasing sections must be measured from the center of the T connector to the point that the vertical radiator emerges from the shielded portion of the upside-down BNC female. Don't forget to take the length of the connectors into account when constructing the harness. If care is taken and coax with solid polyethylene dielectric is used, you should not have to prune the phasing line. With this phasing system, the null will be in a direction that runs along the boom, on the side of the $^1/_4$-wavelength section.

other simple systems to obtain equal currents in the two radiators. Unequal currents tend to reduce the depth of the null in the pattern, all other factors being equal.

The $^1/_2$-wavelength section can be made from either RG-58 or RG-59, because it should act as a 1:1 transformer. With no radials or with two radials perpendicular to the vertical element, it was found that a $^1/_4$-wavelength section made of RG-59 75-Ω coax produced a deeper notch than a $^1/_4$-wavelength section made of RG-58 50-Ω line. However, with the two radials bent downward somewhat, the RG-58 section seemed to outperform the RG-59. Because of minor differences in assembly techniques from one antenna to another, it will probably be worth your time and effort to try both types of coax and determine what works best for your antenna. You may also want to try bending the radials down at slightly different angles for the best null performance.

The most important thing about the coax for the harness is that it be of the highest quality (well-shielded and with a polyethylene dielectric). The reason for avoiding foam dielectric is that the velocity factor can vary from one roll to the next—some say that it varies from one foot to the next. Of course, it can be used if you have test equipment available that will allow you to determine its electrical length. Assuming that you do not want to or cannot go to that trouble, stay with coax having a solid polyethylene dielectric. Avoid coax that is designed for the CB market or do-it-yourself cable-TV market. (A good choice is Belden 8240 for the RG-58 or Belden 8241 for the RG-59.)

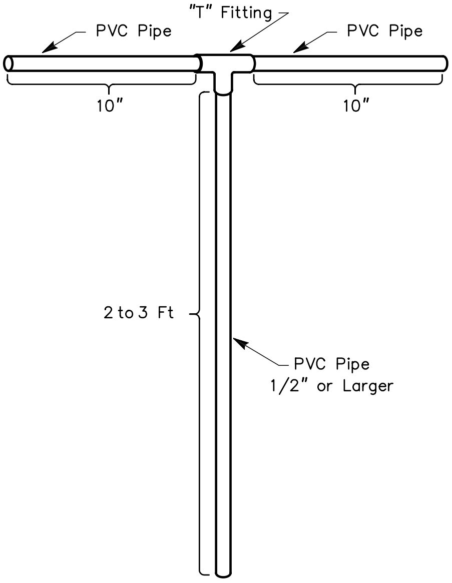

Fig 29—A simple mechanical support for the DF antenna, made of PVC pipe and fittings.

Both RG-58 and RG-59 with polyethylene dielectric have a velocity factor of 0.66. Therefore, for 146 MHz a quarter wavelength of transmission line will be 20.2 inches × 0.66 = 13.3 inches. A half-wavelength section will be twice this length or 26.7 inches. One thing you must take into account is that the transmission line is the total length of the cable *and the connectors*. Depending on the type of construction and the type of connectors that you choose, the actual length of the coax by itself will vary somewhat. You will have to determine that for yourself.

Y connectors that mate with RCA phono plugs are widely available and the phono plugs are easy to work with. Avoid the temptation, however, to substitute these for the T and BNC connectors. Phono plugs and a Y connector were tried. The results with that system were not satisfactory. The performance seemed to change from day to day and the notch was never as deep as it should have been. Although they are more difficult to find, BNC T connectors will provide superior performance and are well worth the extra cost. If you must make substitutions, it would be preferable to use UHF connectors (type PL-259).

Fig 29 shows a simple support for the antenna. PVC tubing is used throughout. Additionally, you will need a T fitting, two end caps, and possibly some cement. (By not cementing the PVC fittings together, you will have the option of disassembly for transportation.) Cut the PVC for the dimensions shown, using a saw or a tubing cutter.

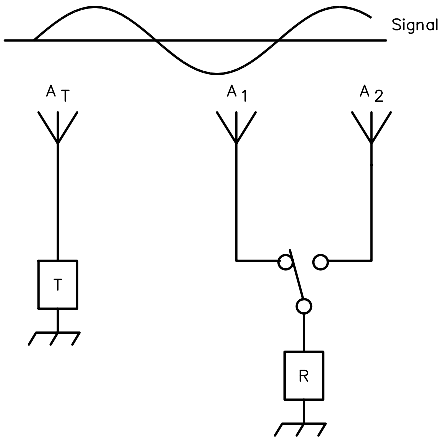

Fig 30—At the left, A_T represents the antenna of the hidden transmitter, T. At the right, rapid switching between antennas A_1 and A_2 at the receiver samples the phase at each antenna, creating a pseudo-Doppler effect. An FM detector detects this as phase modulation.

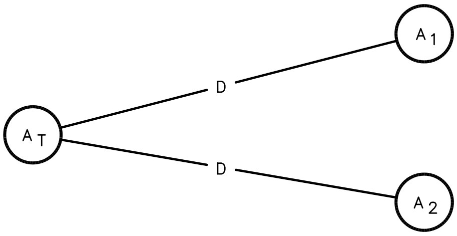

Fig 31—If both receiving antennas are an equal distance (D) from the transmitting antenna, there will be no difference in the phase angles of the signals in the receiving antennas. Therefore, the detector will not detect any phase modulation, and the audio tone will disappear from the output of the detector.

A tubing cutter is preferred because it produces smooth, straight edges without making a mess. Drill a small hole through the PC board near the female BNC of each element assembly. Measure the 20-inch distance horizontally along the boom and mark the two end points. Drill a small hole vertically through the boom at each mark. Use a small nut and bolt to attach each element assembly to the boom.

Tuning

The dimensions given throughout this section are those for approximately 146 MHz. If the signal you will be hunting is above that frequency, then the measurements should be a bit shorter. If you wish to operate below that frequency, then they will need to be somewhat longer. Once you have built the antenna to the rough size, the fun begins. You will need a signal source near the frequency that you will be using for your RDF work. Adjust the length of the radiators and the spacing between them for the deepest null on your S meter. Make changes in increments of $^1/_4$ inch or less. If you must adjust the phasing line, make sure that the $^1/_4$-wavelength section is exactly one-half the length of the half-wavelength section. Keep tuning until you have a satisfactorily deep null on your S meter.

THE DOUBLE-DUCKY DIRECTION FINDER

For direction finding, most amateurs use antennas having pronounced directional effects, either a null or a peak in signal strength. FM receivers are designed to eliminate the effects of amplitude variations, and so they are difficult to use for direction finding without looking at an S meter. Most modern HT transceivers do not have S meters.

This classic "Double-Ducky" direction finder (DDDF) was designed by David Geiser, WA2ANU, and was described in *QST* for July 1981. It works on the principle of switching between two nondirectional antennas, as shown in **Fig 30**. This creates phase modulation on the incoming signal that is heard easily on the FM receiver. When the two antennas are exactly the same distance (phase) from the transmitter, as in **Fig 31**, the tone disappears. (This technique is also known in the RDF literature as *Time-Difference-of-Arrival*, or TDOA, since signals arrive at each antenna at slightly different times, and hence at slightly different phases, from any direction except on a line perpendicular to and halfway in-between the two antennas. Another general term for this kind of two-antenna RDF technique is *interferometer*. *—Ed.*)

In theory the antennas may be very close to each other, but in practice the amount of phase modulation increases directly with the spacing, up to spacings of a half wavelength. While a half-wavelength separation on 2 meters (40 inches) is pretty large for a mobile array, a quarter wavelength gives entirely satisfactory results, and even an eighth wavelength (10 inches) is acceptable.

Think in terms of two antenna elements with fixed spacing. Mount them on a ground plane and rotate that ground plane. The ground plane held above the hiker's head or car roof reduces the needed height of the array and the directional-distorting effects of the searcher's body or other conducting objects.

The DDDF is bidirectional and, as described, its tone null points both toward and away from the signal origin. An L-shaped search path would be needed to resolve the ambiguity. Use the techniques of triangulation described earlier in this chapter.

Specific Design

It is not possible to find a long-life mechanical switch operable at a fairly high audio rate, such as 1000 Hz. Yet we want an audible tone, and the 400- to 1000-Hz range is perhaps most suitable considering audio amplifiers and average hearing. Also, if we wish to use the transmit function of a transceiver, we need a switch that will carry per-

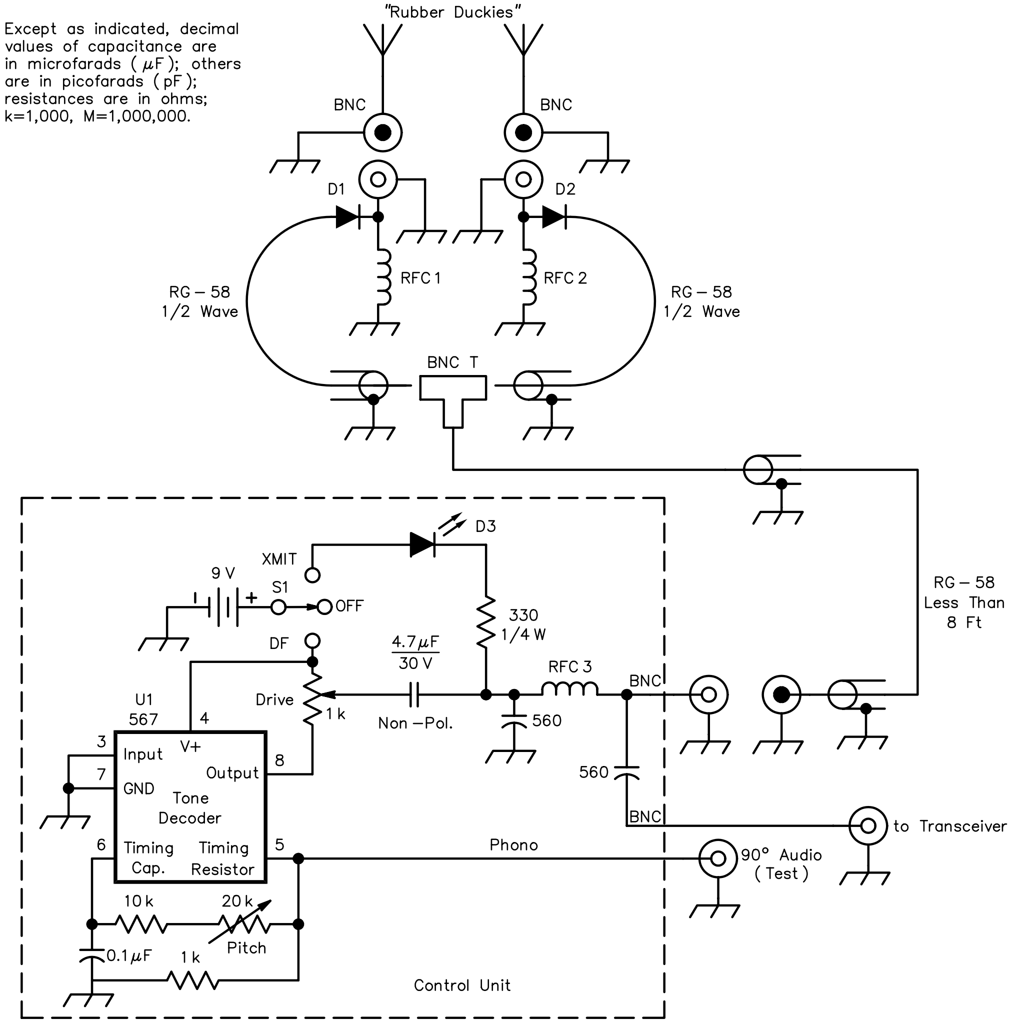
Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms; k=1,000, M=1,000,000.
"Rubber Duckies"
BNC
BNC
D1
D2
RFC 1
RFC 2
RG – 58
1/2 Wave
RG – 58
1/2 Wave
BNC T
D3
XMIT
9 V
S1
OFF
DF
330
1/4 W
4.7μF
30 V
RFC 3
BNC
RG – 58
Less Than
8 Ft
U1
567
Drive
1 k
Non –Pol.
560
3
4
V+
Input
8
Output
7
GND
Tone
Decoder
560
BNC
to Transceiver
6
Timing
Cap.
Timing
Resistor
5
Phono
90° Audio
(Test)
10 k
20 k
Pitch
0.1μF
1 k
Control Unit

Fig 32—Schematic diagram of the DDDF circuit. Construction and layout are not critical. Components inside the broken lines should be housed inside a shielded enclosure. Most of the components are available from RadioShack, except D1, D2, the antennas and RFC1-RFC3. These components are discussed in the text. S1—See text.

haps 10 W without much problem.

A solid-state switch, the PIN diode is used. The intrinsic region of this type of diode is ordinarily bare of current carriers and, with a bit of reverse bias, looks like a low-capacitance open space. A bit of forward bias (20 to 50 mA) will load the intrinsic region with current carriers that are happy to dance back and forth at a 148-MHz rate, looking like a resistance of an ohm or so. In a 10-W circuit, the diodes do not dissipate enough power to damage them.

Because only two antennas are used, the obvious approach is to connect one diode *forward* to one antenna, to connect the other *reverse* to the second antenna and to drive the pair with square-wave audio-frequency ac. **Fig 32** shows the necessary circuitry. RF chokes (Ohmite Z144, J. W. Miller RFC-144 or similar vhf units) are used to let the audio through to bias the diodes while blocking RF. Of course, the reverse bias on one diode is only equal to the forward bias on the other, but in practice this seems sufficient.

A number of PIN diodes were tried in the particular setup built. These were the Hewlett-Packard HP5082-3077, the Alpha LE-5407-4, the KSW KS-3542 and the Microwave Associates M/A-COM 47120. All worked well, but the HP diodes were used because they provided a slightly lower SWR (about 3:1).

A type 567 IC is used as the square-wave generator. The output does have a dc bias that is removed with a nonpolarized coupling capacitor. This minor inconvenience is more than rewarded by the ability of the IC to work well with between 7 and 15 volts (a nominal 9-V minimum is recommended).

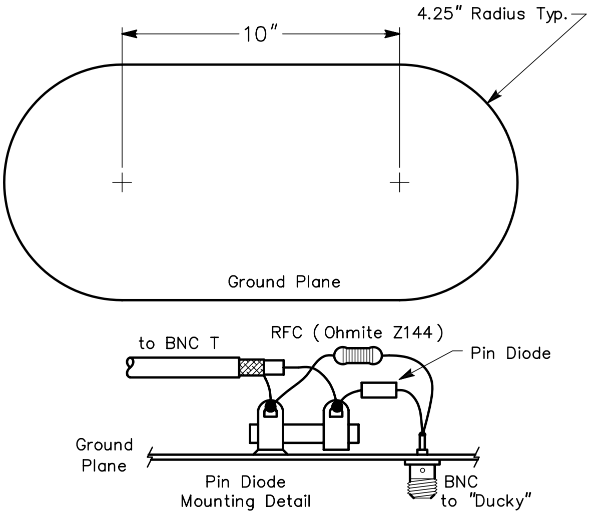

Fig 33—Ground-plane layout and detail of parts at the antenna connectors.

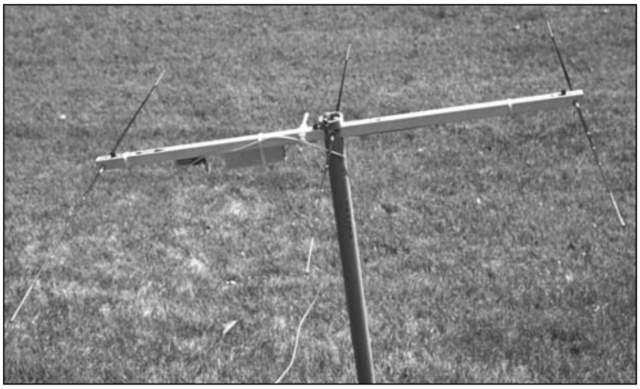

Fig 34—Photo of Fox-Hunting DF Twin 'Tenna set up as a horizontally polarized, 3-element Yagi.

The nonpolarized capacitor is also used for dc blocking when the function switch is set to XMIT. D3, a light-emitting diode (LED), is wired in series with the transmit bias to indicate selection of the XMIT mode. In that mode there is a high battery current drain (20 mA or so). S1 should be a center-off locking type toggle switch. An ordinary center-off switch may be used, but beware. If the switch is left on XMIT you will soon have dead batteries.

Cables going from the antenna to the coaxial T connector were cut to an electrical $^1/_2$ wavelength to help the open circuit, represented by the reverse-biased diode, look open at the coaxial T. (The length of the line within the T was included in the calculation.)

The length of the line from the T to the control unit is not particularly critical. If possible, keep the total of the cable length from the T to the control unit to the transceiver under 8 feet, because the capacitance of the cable does shunt the square-wave generator output.

Ground-plane dimensions are not critical. See **Fig 33**. Slightly better results may be obtained with a larger ground plane than shown. Increasing the spacing between the pickup antennas will give the greatest improvement. Every doubling (up to a half wavelength maximum) will cut the width of the null in half. A 1° wide null can be obtained with 20-inch spacing.

DDDF Operation

Switch the control unit to DF and advance the drive potentiometer until a tone is heard on the desired signal. Do not advance the drive high enough to distort or "hash up" the voice. Rotate the antenna for a null in the fundamental tone. Note that a tone an octave higher may appear.

If the incoming signal is quite out of the receiver linear region (10 kHz or so off frequency), the off-null antenna aim may present a fairly symmetrical AF output to one side, **Fig 35A**. It may also show instability at a sharp null position, indicated by the broken line on the display in Fig 35B. Aimed to the other side of a null, it will give a greatly increased AF output, Fig 35C. This is caused by the different parts of the receiver FM detector curve used. The sudden tone change is the tip-off that the antenna null position is being passed.

The user should practice with the DDDF to become acquainted with how it behaves under known situations of signal direction, power and frequency. Even in difficult nulling situations where a lot of second-harmonic AF exists, rotating the antenna through the null position causes a very distinctive tone change. With the same frequencies and amplitudes present, the quality of the tone (timbre) changes. It is as if a note were first played by a violin, and then the same note played by a trumpet. (A good part of this is the change of phase of the fundamental and odd harmonics with respect to the even harmonics.) The listener can recognize differences (passing through the null) that would give an electronic analyzer indigestion.

A FOX-HUNTING DF TWIN 'TENNA

Interferometers give sharp bearings, but they lack sensitivity for distant work. Yagis are sensitive, but they provide relatively broad bearings. This project yields an antenna that blends both on a single boom to cover both ends of the hunt. This is a condensation of a October 1998 *QST* article by R. F. Gillette, W9PE.

A good fox-hunting antenna must meet a number of criteria: (1) small size, (2) gain to detect weak signals and (3) high directivity to pinpoint the fox. Small antennas, however, do not normally yield both gain and direc-

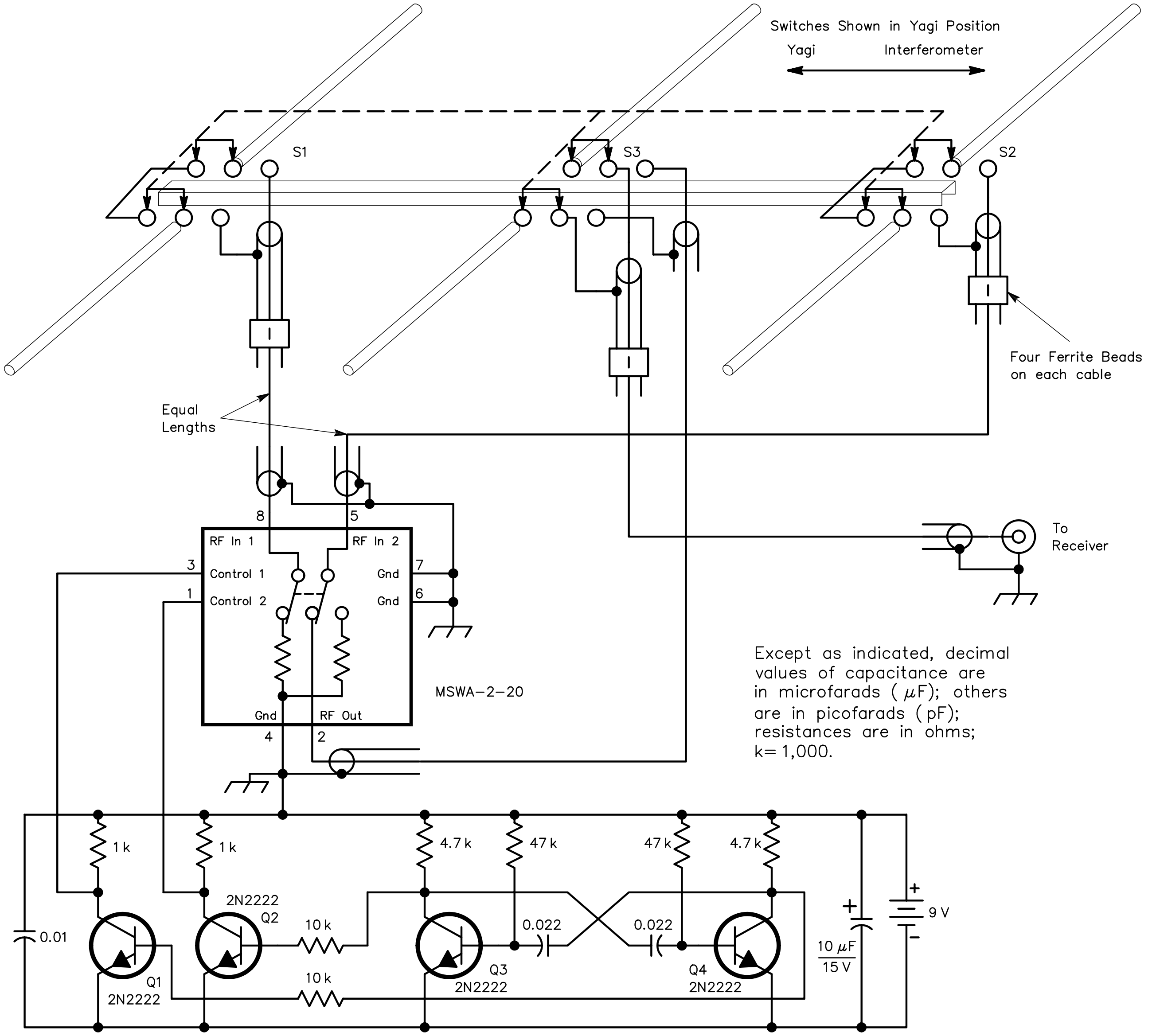
Switches Shown in Yagi Position
Yagi
Interferometer
S1
S3
S2
Four Ferrite Beads on each cable
Equal Lengths
8
5
RF In 1
RF In 2
3
Control 1
1
Control 2
Gnd
Gnd
7
6
MSWA–2–20
Gnd
RF Out
4
2
To Receiver
Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k= 1,000.
1 k
1 k
4.7 k
47 k
47 k
4.7 k
2N2222
Q2
10 k
10 k
0.01
Q1
2N2222
0.022
0.022
Q3
2N2222
Q4
2N2222
10 µF
15 V
+
+
9 V

Fig 35—Schematic of the Yagi/interferometer antenna system.

Table 1
Yagi Design

Item	*Overall Length (Inches)*	*Boom to Element Tip (Inches)*
Director length	34.75	17.00
Director to Driven El. spacing	15.75	16.00
Driven El. length	37.75	18.50
Driven El. to Reflector spacing	15.75	16.00
Reflector length	40.75	20.00

*SWR less than 1.3:1 from 144.5 to 148 MHz

tivity. By combining two antennas, all three requirements are satisfied in a way that makes a nice build-it-yourself project.

This antenna uses slide switches to configure it as either a Yagi or a single-channel interferometer. When used as an interferometer, a GaAs RF microcircuit switches the FM receiver between two matched dipoles at an audio frequency. To make the antenna compact W9PE used hinged, telescopic whips as the elements; they collapse and fold parallel to the boom for storage.

The Yagi

The Yagi is a standard three-element design, based on 0.2-λ spacing between the director, the driven element and the reflector. It yields about 7 dBi gain and a front-to-back ratio of over 15 dB. Because a slide switch is used at the center of each element and the elements have small diameters, their resonant lengths are different from typical ones. **Table 1** shows the sizes used and **Fig 34** shows the Yagi.

To make sure that radiation from the coax does not affect the pattern, the author used some ferrite beads as coaxial choke-baluns. This also prevents objects near the coax from affecting signal-strength readings. The Yagi also has a low SWR; with uncalibrated equipment, he measured less than 1.3:1 over most of the 2-meter band.

This Yagi has a lot more gain than a “rubber ducky,” but we need more directivity for fox hunting. That’s where the interferometer comes in.

An Interferometer

To form the interferometer, the two end elements are converted to dipoles and the center element is disabled. When the three switches in **Fig 35** are thrown to the right, the feed line to the receiver is switched from the center element to the RF switch output, and the end elements are connected via feed lines to the RF switch inputs. With the Yagi’s feed point open and the driven element equidistant from both interferometer antennas, the center element should have no effect on the interferometer. Nonetheless, it’s easier to collapse the driven-element whips and get them out of the way than to worry about spacing.

Now if both interferometer coax cables are of equal length (between the antennas and switch) and the two antennas are the same distance from the transmitter (broadside to it), the signals from both antennas will be in phase. Switching from one antenna to the other will have no effect on the received signal. If one antenna is a little closer to the transmitter than the other, however, there will be a phase shift when we switch antennas.

When the antenna switch is at an audio rate, say 700 Hz, the repeated phase shifts result in a set of 700 Hz sidebands. At this point, all that was needed was a circuit to switch from one antenna to the other at an audio rate. W9PE chose a low-cost Mini-Circuits MSWA-2-20 GaAs RF switch driven by a simple multivibrator and buffer. The GaAs switch is rated to 2.0 GHz, hence this switching concept can easily be scaled to other ham bands. The PC board should work through the 440 MHz ham band. The author suggests adding a ground plane under the RF portion of the PC board and testing it before using it at a higher frequency.

The RF switch is controlled by a set of equal-amplitude, opposite-phase square waves: 0 V at one control port and –8 to –12 V at the other. (Mini Circuits is unclear about maximum voltages for this device. For safety, don’t power it with more than 9 V.—*Ed*.) The opposite controls the other switch position. A 9-V battery was used as the power supply, with the positive terminal grounded. This results in a 0 V control signal to the RF switch when the buffer transistor is off and a Vsat (about 0.2 V less than the –9 V battery: –8.8 V) signal when the buffer transistor is saturated. The multi-vibrator has two outputs, and each drives a buffer resulting in the required equal-and-opposite-phase drive signals.

Table 2
Bill of Materials

Quantity	*Item*
3 ft	$^3/_4$-inch aluminum U channel
6 sets	insulated shoulder washers for elements
1	9 V battery
1	9 V battery connector
1	10 µF, 16 V electrolytic capacitor
1	0.01 µF, 25 V capacitor
2	0.022 µF, 25 V capacitor
2	1 kΩ $^1/_8$ W resistor
2	4.7 kΩ $^1/_8$ W resistor
2	10 kΩ $^1/_8$ W resistor
2	47 kΩ $^1/_8$ W resistor
2	1 kΩ $^1/_8$ W resistor
4	2N2222 transistors
1	Mini-Circuits MSWA-2-20 (Mini-Circuits Labs, 13 Neptune Ave, Brooklyn, NY 11235; tel 718-934-4500, 417-335-5935, fax 718-332-4661; e-mail **sales@minicircuits.com**; URL **www.minicircuits.com**)
3	DPDT slide switch (1$^1/_8$-inch, 29 mm, mounting centers), Stackpole, 3 A, 125 V used
10 ft	50 Ω coax (0.140-inch maximum OD)
1	coaxial connector (receiver dependent)
1	lot, mounting hardware
1	lot, heat-shrink tubing or equal
4	cable ties
1	2 × 3.5-inch single-sided fiberglass PC board
1	1-inch PVC conduit
12	#FB-20 ferrite beads 0.14-inch ID, 0.5-inch long (All Electronics Corp: PO Box 567, Van Nuys, CA 91408-0567; tel 888-826-5432, fax 818-781-2653, e-mail: **allcorp@allcorp.com**; URL **www.allcorp.com/**.)
6	20$^1/_2$-inch telescoping antenna elements (Nebraska Surplus, tel 402-346-4750; e-mail **grinnell@probe.net**)
1	Special resist film (Techniks Inc, PO Box 463, Ringoes, NJ 08551; tel 908-788-8249, fax 908-788-8837; e-mail **techniks@idt.net**; URL **www.techniks.com/**)

Circuit Construction

After he selected the Mini-Circuits RF switch, W9PE realized that its small size would be best handled with a simple PC board. He made the prototype boards with a photocopy transparency technique.

A power on-off switch was not used, as the 9-V bat-

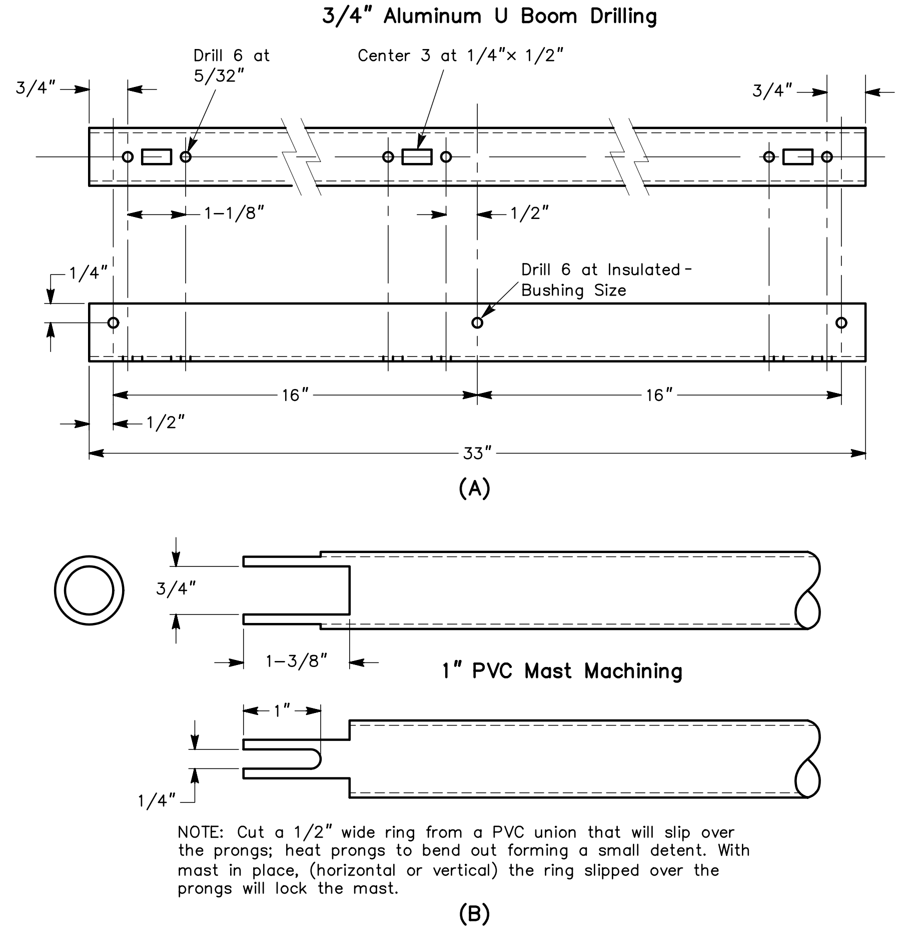

NOTE: Cut a 1/2" wide ring from a PVC union that will slip over the prongs; heat prongs to bend out forming a small detent. With mast in place, (horizontal or vertical) the ring slipped over the prongs will lock the mast.

Fig 36—Boom-drilling and mast-machining details.

tery connector serves the same function. The battery fits tightly in the 3/4-inch U channel. W9PE covered the circuit board with a plastic-lined aluminum cover, but plastic film and some aluminum foil, provide the same function. A cable tie will strap either into the U channel.

Table 2 is a complete bill of materials. You can use any telescoping elements, providing that they extend to over 20 inches and have a mounting stud long enough to accommodate the insulated washers. As an alternate to the stud, they can have ends tapped to receive a screw for the insulated mounting. The author picked up his elements at a hamfest from the vendor listed; they are also available from most electronic parts houses. The Mini-Circuit RF switch is a currently available part.

Antenna Construction

Fig 35 shows the antenna schematic. It shows all three switches in the Yagi position; each would slide to the right for interferometer use. Slide switches work pretty well at 2 meters. Each of the elements is mounted to the boom with insulating washers, and a strip of copper stock connects each element to its slide switch. (You can substitute copper braid, solder wick, coax shield or any short, low resistance, low inductance conductor for the copper stock.) This switching arrangement allows you to switch the reflector and director from being parasitic elements (electrically continuous) to being dipoles (center fed).

Because the elements telescope, you can adjust the interferometer dipoles to exactly equal lengths each time you switch the antenna configuration from Yagi to interferometer. Again, choke baluns block RF on the outside of each element's coax.

Caution: Do not transmit when the RF switch is selected. Transmit only when in the Yagi configuration. RF power will destroy the Mini-Circuits RF switch. To be safe, lock out your transmit function. Most HTs have this capability. When using a mobile radio, disconnect the microphone. It is, however, safe to transmit in the Yagi configuration—which is nice for portable operating.

Fig 36 gives dimensions for drilling a standard 3/4-inch aluminum U channel for the boom and shows how the author cut a 1-inch PVC pipe (plastic conduit) for a mast and a mast locking ring. If PVC conduit is not available in your area, PVC water pipe (and a PVC union for the locking ring) will work. This mast allows mounting the antenna for either vertical or horizontal polarization.

Be sure to test the plastic pipe you use for low RF loss. Do this by heating a sample in a microwave oven. Place a pipe sample and a glass of water in the oven. (The sample is not placed in the glass of water; the water keeps the microwave from operating without a load.) Bring the water to a boil, and then carefully check the sample's temperature. If the sample is not hot, its RF loss is low, and the plastic can be used.

Using the Antenna

When starting a hunt, set up the Yagi antenna by placing all switches in the Yagi position. Swing all of the telescoping elements perpendicular to the boom and set the whip lengths to achieve the proper element lengths, while keeping each element symmetrical about the boom. The cables or boom can be marked with the length data.

While the signal is weak, use the Yagi. It has 7 dBi gain, but its bearing resolution is only about 20°. When the signal gets stronger, use the interferometer. It has less gain, but its bearing resolution is better than 1°. If the fox transmitter begins overloading your receiver, collapse the whips (equally) to reduce the gain and continue triangulating. Near the transmitter, you should triangulate both horizontally (azimuth) and vertically (elevation). The antenna works both ways, and the transmitter may be located above or below you.

Antenna Alternative

As an alternative to the telescoping elements, George Holada, K9GLJ, suggested using fixed-length elements with banana plugs matched to banana jacks on the boom. Three pairs would be used for the Yagi, an extra driven-element pair for the interferometer mode and two short-element pairs to reduce the received signal level if an overload condition occurs. He also suggested a PVC boom allowing the elements to be stored inside the boom.

THE FOUR-WAY MOBILE DF SYSTEM

This innovative, yet simple, RDF antenna system was described in an article by Malcolm C. Mallette, WA9BVS, in November 1995 *QST*. It is derived from the TDOA design shown earlier in this chapter by David T. Geiser, WA2ANU, and by a design by Paul Bohrer, W9DUU. (See Bibliography.)

Direction-finding often involves two different activities: DFing on foot and DFing from a vehicle. Often, you must track the signal using a vehicle, then finish the hunt on foot. Whether on foot or in a vehicle, the primary problem you'll encounter when trying to locate the transmitter is multipath reception. Multipath reception involves receiving the same signal by more than one path, one signal from the true direction of the transmitter and others by reflected paths that may come from widely different directions. VHF and UHF signals bounce off almost any object and hide the true source of a signal. For example, if there's a large metal building north of you, a signal from the south may arrive from the north because the signal bounces off the building and back to you.

Multipath reception effects can be defeated by taking a number of readings from different positions and arriving at an average direction. While moving at road speeds in a vehicle, it's possible to take a number of readings from different positions and average them, and it's also possible to average a number of readings over a distance of travel by electronic means. The true bearing to the transmitter can usually be found by either method.

DFing equipment for use on foot is simpler than systems for use on a vehicle. While afoot, you can turn at will or easily rotate an antenna. Turning a vehicle while going down a street may result in a fender-bender if you're not careful!

The simplest DFing system to use while on foot consists of an S-meter-equipped hand-held receiver and a small, hand-held Yagi with an attenuator in line between the antenna and receiver. The attenuator keeps the S meter from pinning. The direction in which the beam points when the strongest signal is received is the direction of the transmitter. Of course, you'll want to take readings at several locations at least a wavelength apart to obtain an average heading, as multipath reception can still cause false readings in some locations.

Another approach that many hams have taken is the simple WA2ANU DDFF—it is now commonly known simply as the "buzzbox." Various commercial versions of the hand-held buzzbox system are available. Some sys-

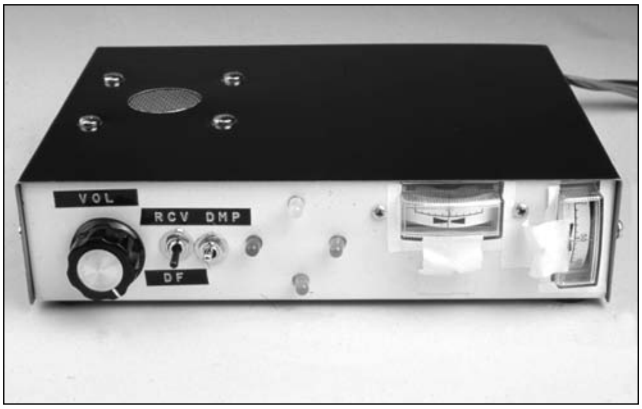

Fig 37—Front panel of the Four-Way DFer. At the extreme left of the front panel is the VOLUME control. Immediately to the right is the RCV/OFF/DF center-off toggle switch, with the damping (DMP) control switch nearby. Four LEDs mounted in a diamond pattern indicate signal direction: front (yellow), right (green), back (orange) and left (red). The horizontally mounted zero-center meter indicates left/right signal reception, the vertically mounted meter displays front/back signal reception. A small speaker is mounted on the top cover.

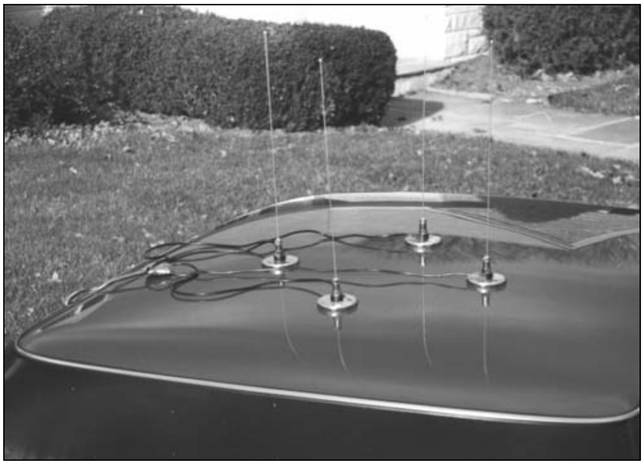

Fig 38—Placement of the four antennas on the author's car roof. The small object to the left of the antennas is the switch board.

tems have been upgraded to indicate whether the signal is arriving from the left or right of your position. The main drawback, however, to the buzzbox is that it's not as sensitive as a simple dipole and not nearly as sensitive as a beam.

In theory, you could take a buzzbox or Yagi/attenuator system in a car, stop periodically, get out and check the direction to the transmitter, then climb back in and drive off. Although this procedure works, it isn't very practical—it takes a long time to find the transmitter.

This design is for a left-right, front-back box (LRFB box) that indicates whether the received signal is to the left or right and whether it is to the front or back of the receiver. The location display consists of four LEDs arranged in a diamond pattern (see the title-page photo). When the top LED is on, the signal is coming from the front. When the top and right LEDs are on, the transmitter is between the front and the right. When only the right LED is on, the signal is directly to the right. When the bottom LED and right LED are on, the transmitter is to the right and to the back. The same pattern occurs around the clock. Therefore, four LEDs indicate eight directions. As most highways and streets have intersections that force a driver to choose moving straight ahead, right or left, the indication is sufficiently precise for practical transmitter hunting.

If the four-LED display is used alone, all parts can be obtained from your local Radio Shack store. Two zero-center 50-µA meters (50-0-50)—M1 and M2—can be used in addition to, or in place of, the LEDs, but RadioShack does not stock such meters. **Fig 37** shows the front panel layout of the LRFB.

The LRFB box uses four mag-mount $^1/_4$-λ antennas placed on the vehicle roof as shown in **Fig 38**. The whips in the mag mounts can be changed to $^1/_4$-λ 440-MHz whips and the antennas placed closer together when switching from 144-MHz to 440-MHz operation.

Circuit Description

See **Fig 39** in the following discussion (pages 26 and 27). U2, a 555 timer, generates a string of square-wave pulses at pin 3. The pulse frequency is determined by the setting of R4. The pulses are fed to the clock input (pin 14) of U3, a 4017 decade counter. On the first pulse, a positive voltage appears at U3, pin 3. On receipt of the second pulse from U2, pin 3 of U3 goes to ground and a positive voltage appears on pin 2. This sequence continues on successive pulses from U2 as pins 3, 2, 4, 7, 10, 1, 5, 6, 9 and 11 go positive in succession.

D1 through D5, and D6 through D10, OR the pulses. The result is that TP3 goes positive on the first pulse from U2, while TP2 is at 0 V. The next pulse of U2 results in TP2 going positive and TP3 going to 0 V. This sequence repeats as the counter goes around to make pin 3 positive again, and recycles.

Antenna Switching

U2 and U3 produce alternating pulses at TP2 and TP3. If we wanted only to alternately turn on and off two antennas, we could use the pulses at TP2 and TP3. The design ensures that the pulses at TP2 are the same length as the pulses at TP3. For the LRFB box, however, we need to switch between the left-right antennas many times, then switch between the front-back antennas many times.

Pin 12 of U3, CARRY OUT, emits a pulse every time U3 counts through its cycle of 10 pulses. The carry pulses from U3 go to U4, pin 14, the clock input of that 4017 counter. As U4 cycles, its output pins pulse; those pulses are, in effect, directed by D11 through D20.

As a result, TP4 is positive during the first 50 pulses from U2 and TP5 is positive during the second 50 pulses of U2. Q1 through Q6 form a quad AND gate. They AND the pulses at TP4 and TP5 with the alternating pulses at TP2 and TP3 so that the result is a pulse at the base of Q9, followed by a pulse at the base of Q10, a pulse at the base of Q9, and so on. The pulses alternate 25 times between Q9 and Q10. Then, as TP4 goes to 0 V, TP5 rises from 0 V to some positive voltage and the alternating pulses appear at the bases of Q7 and Q8. The pulses alternately go to the bases of Q7 and Q8 25 times. Then they alternate between the bases of Q9 and Q10 25 times. This pattern continues as long as the unit is in DF operation.

In **Fig 40**, two leads of a four-conductor-plus-ground cable to the antenna-switch board are connected to points A and B. The same pulses that turn Q7 and Q8 off and on turn on and off the left and right antennas. One of those two antennas is turned on and off in phase with Q7 and the other is turned on and off in phase with Q8. The PHASE switch, S3, determines which antenna is in phase with which transistor. Similarly, the two front/back antennas are turned on and off in phase with Q9 and Q10, and S4 determines which antenna is in phase with which transistor.

The pulses arriving at points A and B turn on and off the diodes connecting the coax of the left and right

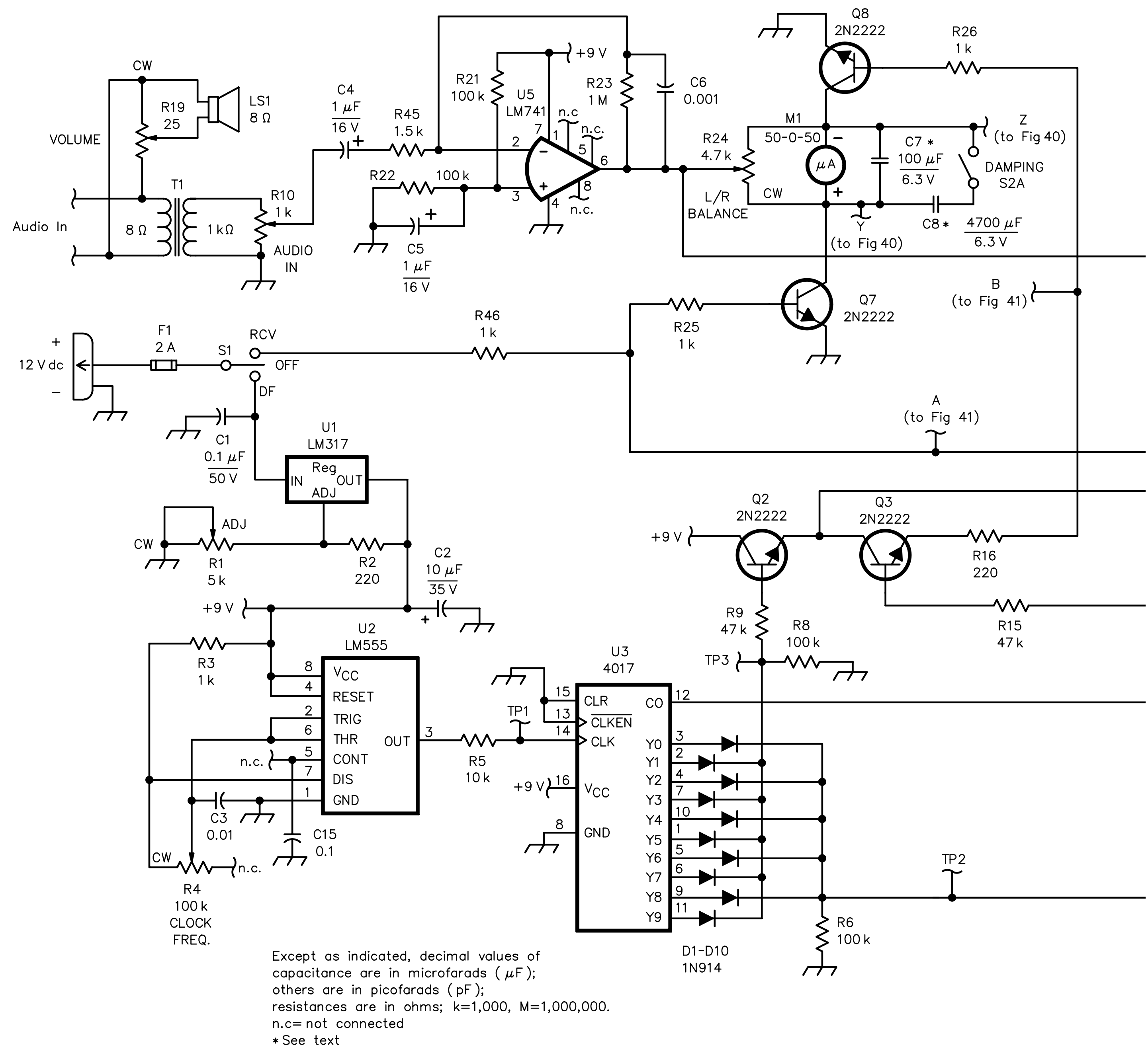
CW
VOLUME
R19
25
LS1
8 Ω
T1
Audio In
8 Ω
1 kΩ
R10
1 k
AUDIO IN
C4
1 µF
16 V
R45
1.5 k
R22
100 k
C5
1 µF
16 V
R21
100 k
U5
LM741
n.c
n.c.
+9 V
R23
1 M
C6
0.001
Q8
2N2222
R26
1 k
M1
50-0-50
µA
C7 *
100 µF
6.3 V
Z
(to Fig 40)
DAMPING
S2A
R24
4.7 k
L/R BALANCE
CW
Y
(to Fig 40)
C8 *
4700 µF
6.3 V
B
(to Fig 41)
Q7
2N2222
R25
1 k
R46
1 k
+
12 V dc
–
F1
2 A
S1
RCV
OFF
DF
A
(to Fig 41)
C1
0.1 µF
50 V
U1
LM317
Reg
IN
OUT
ADJ
ADJ
CW
R1
5 k
R2
220
C2
10 µF
35 V
+9 V
Q2
2N2222
Q3
2N2222
R16
220
R15
47 k
R9
47 k
R8
100 k
TP3
R3
1 k
U2
LM555
VCC
RESET
TRIG
THR
CONT
DIS
GND
OUT
n.c.
C3
0.01
C15
0.1
CW
n.c.
R4
100 k
CLOCK FREQ.
TP1
R5
10 k
U3
4017
CLR
CLKEN
CLK
VCC
GND
CO
Y0
Y1
Y2
Y3
Y4
Y5
Y6
Y7
Y8
Y9
TP2
R6
100 k
D1-D10
1N914
Except as indicated, decimal values of capacitance are in microfarads (µF);
others are in picofarads (pF);
resistances are in ohms; k=1,000, M=1,000,000.
n.c= not connected
∗See text

Fig 39—Unless otherwise specified, part numbers in parentheses are RadioShack. All fixed-value resistors are 1/4-W, 5%-tolerance units. Equivalent parts can be substituted.

C1, C15—0.1-µF, 50-V (272-1069)
C2—10-µF, 35-V electrolytic capacitor (272-1025)
C3—0.01-µF, 25-V disc-ceramic capacitor (272-131)
C4, C5—1-µF, 16-V electrolytic capacitor (272-1434)
C6—0.001-µF, 25-V disc-ceramic capacitor (272-126)
C7, C9—100-µF, 6.3-V bipolar (nonpolarized) capacitor; Digi-Key P-1102, available from Digi-Key Corp, 701 Brooks Ave S, PO Box 677, Thief River Falls, MN 56701-0677, tel 800-344-4539, 218-681-6674; fax: 218-681-3880; RadioShack stocks 100-µF, 35-V axial (272-1016) and radial-lead (272-1028) electrolytic capacitors.
C8, C10—4700-µF, 6.3-V bipolar capacitor (made of five 1000-µF, 6.3-V bipolar capacitors), Digi-Key P1106. Standard 1000-µF, 35-V radial and axial-lead electrolytic capacitors are available from RadioShack; a 4700-µF, 35-V axial-lead electrolytic capacitor is also available (272-1022). Note that C7, C8, C9 and C10 are non-polarized capacitors because a small reverse voltage can appear across the meter and capacitors when the system is in use. Standard polarized electrolytics have been used in a number of units using this circuit (the same detector circuit used in W9DUU's unit) without any known ill effects, however.
D1-D20—1N914 silicon switching diode (276-1620 or 276-1122)
F1—2-A fuse (270-1007)
LS1—8-W speaker (40-245)

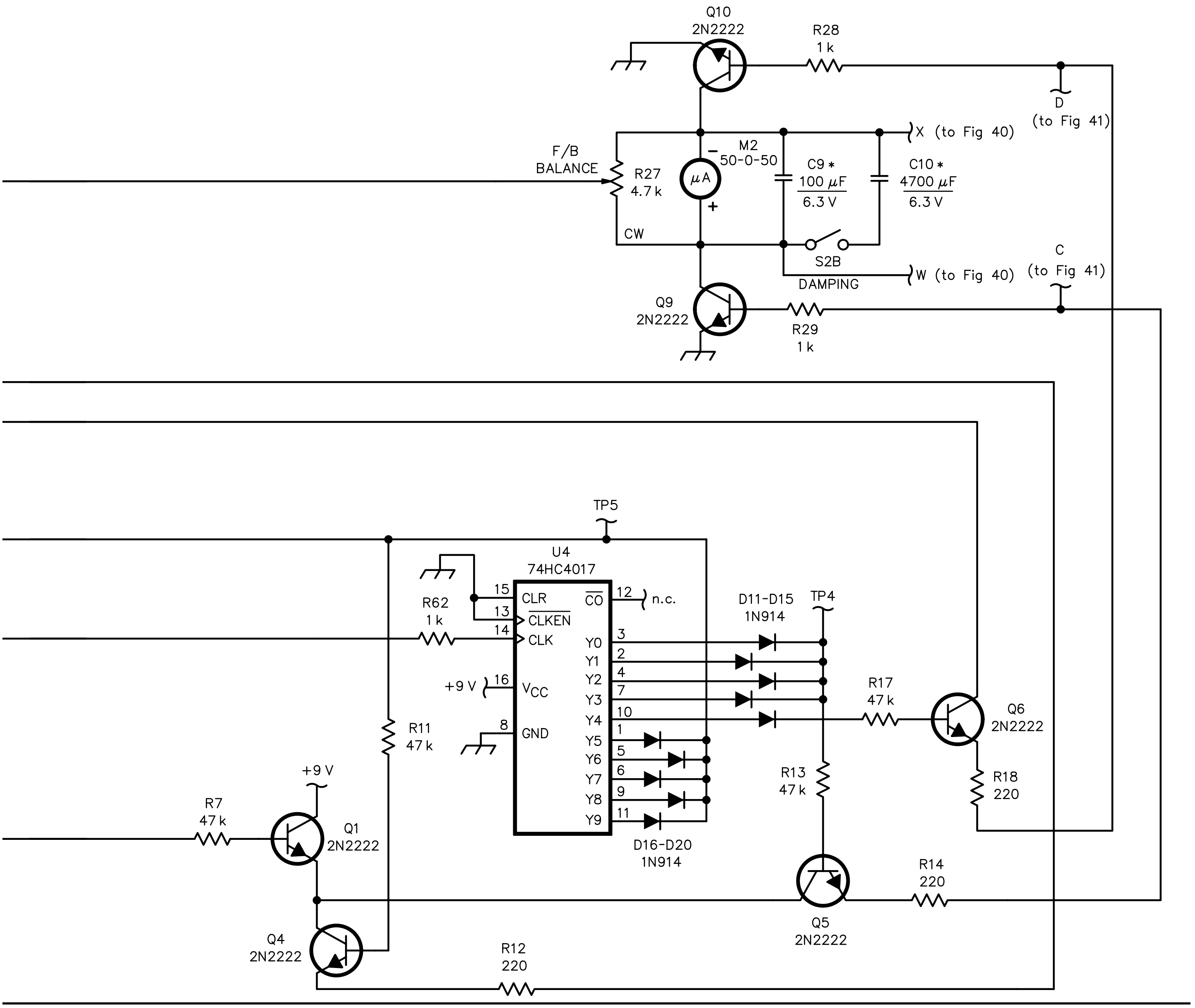
Q10
2N2222
R28
1 k
D
(to Fig 41)
X (to Fig 40)
F/B
BALANCE
R27
4.7 k
M2
50-0-50
μA
C9 *
100 μF
6.3 V
C10 *
4700 μF
6.3 V
CW
S2B
DAMPING
W (to Fig 40)
C
(to Fig 41)
Q9
2N2222
R29
1 k
TP5
U4
74HC4017
15 CLR
13 CLKEN
14 CLK
16 VCC
8 GND
CO 12 n.c.
Y0 3
Y1 2
Y2 4
Y3 7
Y4 10
Y5 1
Y6 5
Y7 6
Y8 9
Y9 11
R62
1 k
+9 V
D11-D15
1N914
TP4
R17
47 k
Q6
2N2222
R18
220
R11
47 k
R13
47 k
D16-D20
1N914
+9 V
R7
47 k
Q1
2N2222
Q5
2N2222
R14
220
Q4
2N2222
R12
220

M1, M2—Zero-center, 50-µA meter; optional—see text
Q1-Q10—MPS2222 or 2N2222 NPN silicon general-purpose transistors (276-2009)
R1, R24, R27—4.7 kΩ (271-281); note: many of the fixed-value resistors can be found in RadioShack resistor assortment packages 271-308 and 271-312.
R2, R12, R14, R16, R18—220 Ω (271-1330)
R3, R25, R26, R28, R29—1 kΩ (271-1321)
R4—100-kΩ trimmer potentiometer (271-284)
R5—10 kΩ (271-1335)
R6, R8, R21, R22—100 kΩ (271-1347)
R7, R9, R11, R13, R15, R17—47 kΩ (271-1342)
R10—1-kΩ trimmer potentiometer (271-280)
R19—25-Ω panel-mount potentiometer (271-265A)
R23—1 MΩ (271-1134)
R45—1.5 kΩ (part of 271-312 assortment)
S1—SPDT, center-off switch (275-325)
S2—DPDT switch (275-626)
T1—8-Ω to 1-kΩ audio-output transformer (273-1380)
U1—LM317T, 1.5-A, three-terminal, adjustable voltage regulator (276-1778)
U2—555 timer (276-1723)
U3, U4—4017 decade counter (276-2417)
U5—LM741 op amp (276-007)
Misc: two 8-pin IC sockets (276-1995); two 16-pin IC sockets (276-1992); experimenter's PC board (276-148) or FAR Circuits PC board set; enclosure; four mag-mount antennas, four-conductor shielded cable; in-line fuse holder (270-1281).

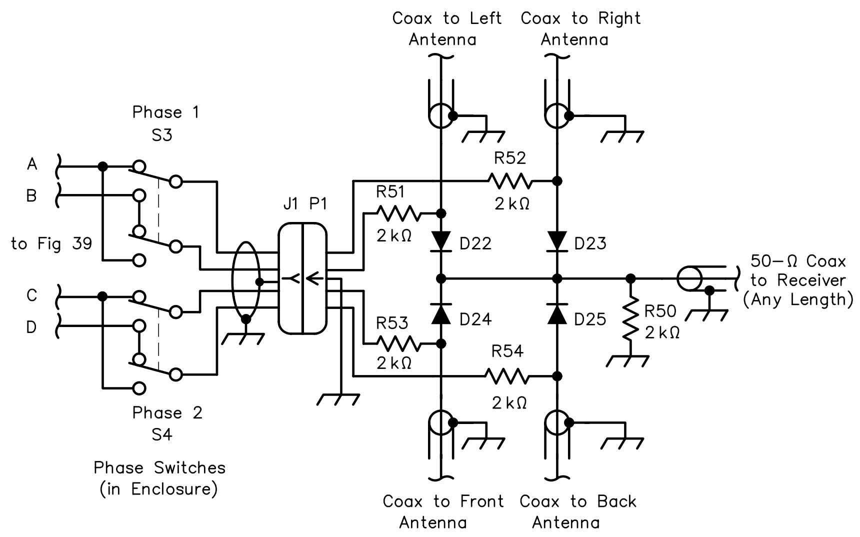
Coax to Left Antenna
Coax to Right Antenna
Phase 1
S3
A
B
to Fig 39
C
D
Phase 2
S4
Phase Switches (in Enclosure)
J1 P1
R51
2 kΩ
R52
2 kΩ
D22
D23
D24
D25
R53
2 kΩ
R54
2 kΩ
R50
2 kΩ
50-Ω Coax to Receiver (Any Length)
Coax to Front Antenna
Coax to Back Antenna

Fig 40—Schematic of the antenna switch board. Part numbers in parentheses are RadioShack. All fixed-value resistors are ¼-W, 5%-tolerance units. Equivalent parts can be substituted.

D22-D25—1N914 silicon switching diode (276-1620 or 276-1122)
J1—Six-pin female Molex connector (274-236 or 274-155)
P1—Six-pin male Molex connector (274-226 or 274-152)
R50-R54—2.2 kΩ (can be found in RadioShack resistor assortment packages 271-308 and 271-312); also available in pack of five (271-1325)
S3, S4—DPDT switch (275-626)

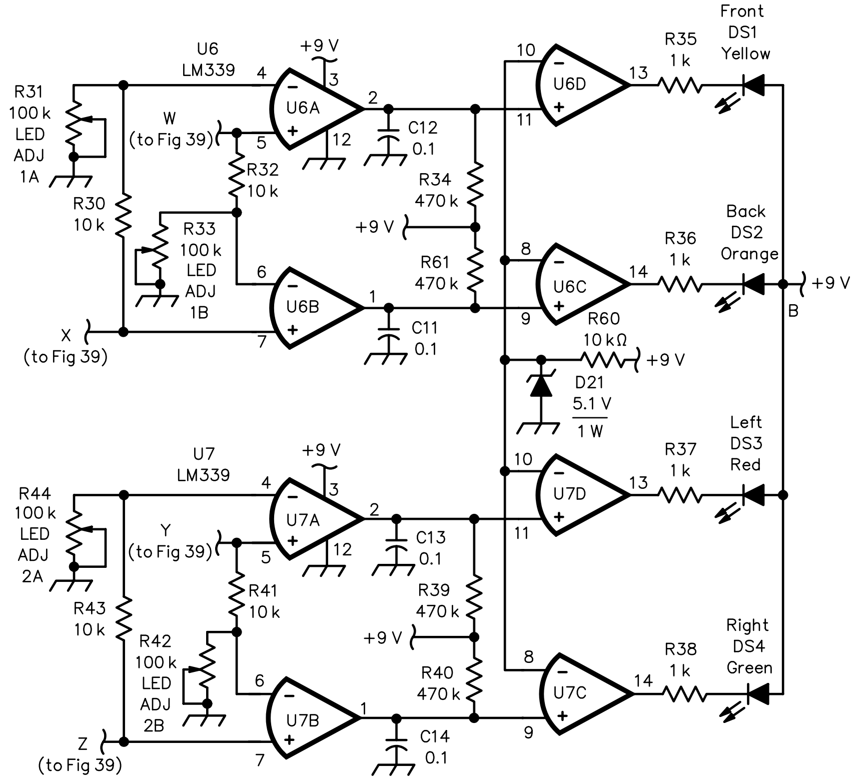
U6
LM339
+9 V
R31
100 k
LED
ADJ
1A
W
(to Fig 39)
U6A
C12
0.1
R32
10 k
R30
10 k
R33
100 k
LED
ADJ
1B
U6B
C11
0.1
X
(to Fig 39)
R34
470 k
+9 V
R61
470 k
U6D
U6C
R60
10 kΩ
+9 V
D21
5.1 V
1 W
R35
1 k
Front
DS1
Yellow
R36
1 k
Back
DS2
Orange
+9 V
B
U7
LM339
+9 V
R44
100 k
LED
ADJ
2A
Y
(to Fig 39)
U7A
C13
0.1
R41
10 k
R43
10 k
R42
100 k
LED
ADJ
2B
U7B
C14
0.1
Z
(to Fig 39)
R39
470 k
+9 V
R40
470 k
U7D
U7C
R37
1 k
Left
DS3
Red
R38
1 k
Right
DS4
Green

Fig 41—Schematic of the LED driver circuit. Part numbers in parentheses are RadioShack. All fixed-value resistors are ¼-W, 5%-tolerance units. Equivalent parts can be substituted.

C11-C14—0.1-µF, 25-V disc-ceramic capacitor (272-135)
D21—1N4733, 5.1-V, 1-W Zener diode (276-565)
DS1-DS4—LEDs; one each red (276-066); green (276-022); yellow (276-021); orange (276-012)
R30, R32, R41, R43—10 kΩ (271-1335)
R34, R39, R40, R61—470 kΩ (271-1354)
R35-R38—1 kΩ (271-1321)
R31, R33, R42, R44—100-kΩ trimmer potentiometer (271-284)
U6, U7—LM339 quad comparator (276-1712)
Misc: two 14-pin IC sockets (276-1999)

antennas to the receiver coax. This occurs 25 times, thereby switching the receiver between the left and right antennas 25 times. Similar switching then occurs between the front and the back antennas from pulses arriving at points C and D.

Detector Circuit

The detector circuit (back again in Fig 39) starts with U5, a 741 op amp that amplifies the receiver's audio output. The audio is fed into R24 and R27, two 4.7-kΩ pots. The zero-center, 50-µA meters across R24 and R27 are optional. The meters, as well as the LEDs, indicate front/back and left/right. Such meters can be expensive unless you find surplus meters, and they're not really necessary.

When the left/right antennas are active, one end of R24 is grounded by Q7 and Q8 on each alternate pulse.

If Q7 is conducting, Q8 is not conducting. On each pulse, one of the left/right antennas is turned on and one end of R24 is grounded. On the next pulse, the other left/right antenna is turned on and the other end of R24 is grounded. If there is a phase difference between the signal received by the left antenna and the signal received by the right antenna, a dc voltage is built up across R24. That voltage causes the quad comparator, U7 in **Fig 41** to turn on DS3 (red) or DS4 (green) L/R LEDs. If the optional left/right meter is installed, it deflects to indicate the direction as do the LEDs.

After 25 cycles, the left and right antennas are both turned off and the front and back antennas are cycled on and off 25 times with the same detection process, producing a voltage across R27 if there is a phase difference between the RF received by the front and the back antennas. That voltage across R27 causes quad comparator U6 to turn on DS1 or DS2.

C9 and C10, for the F/B detector, and C7 and C8, for the L/R detector, damp the voltage swings caused by multipath reception. To control damping, S2A and S2B switch the 4700-µF capacitors in or out of the circuit. You want the greatest amount of damping when you drive through an area with a lot of multipath propagation (as from buildings); a lot of damping helps under those circumstances.

Construction

The prototype was built using a pad-per-hole RadioShack board. However, a PC board makes construction a lot faster. Far Circuits offers a printed-circuit project on their Web site: **www.cl.ais.net/farcir**). Except for the optional meters and the nonpolarized capacitors, most parts are available from RadioShack.

First build the power supply so you can power the unit from your car or another 12-V source. Apply 12 V to the DFer and adjust R1 until U1's output is +9 V. (You can use a 9-V battery and omit the power-supply section, but you'd better take along a spare battery when you go DFing.)

Install U2 and its associated parts. Power up and turn on S1. A string of pulses should appear at TP1. If you have a frequency counter, set R4 for a pulse frequency of 2200 Hz at TP1. If you don't have a counter, connect a 0.1-µF capacitor from TP1 to headphones or a small speaker and set R4 for a tone of about 2 kHz. Later, you'll adjust the clock so the unit works with the passband of your receiver.

Turn off S1 and remove the power source. Install U3 and its diodes. Pin 12 of U3 need not be connected yet. Apply power and turn on S1. At TP2 and TP3, you should find alternating 1100-Hz pulses. If you have a dual-trace scope, you can see that the pulses alternate. If you have a single-trace scope, connect TP3 to TP2 and to the scope input and the trace will appear as a solid line as there is a pulse at either TP2 or TP3 at all times. If you don't have a scope, the tone in a speaker or earphones from TP2 or TP3 will sound half as high (about 1 kHz) as the tone at TP1.

Turn off S1. Install U4 and its diodes. Note that pin 12 of U3 is connected to pin 14 of U4. At TP4 and TP5, there should be long pulses—five times longer than the pulses at TP1, and the pulses should alternate between TP4 and TP5. The pulse frequency should be about 44 Hz. Power down and turn off S1. Install the remaining circuit components. When you power up, 25 alternating pulses should appear at A and B, then 25 alternating pulses should appear at C and D. Use a scope to verify that.

If you're not using the optional panel meters, connect a voltmeter across R24 (L/R BALANCE), using the lowest dc-voltage range. Note that neither end of R24 is grounded. With no audio input, adjust R24 until there is no voltage across it. Do the same with R27 (F/B BALANCE). If you use the optional meters, adjust R24 and R27 so there's no current shown on either meter.

Power down and assemble the rest of the circuit. With power applied, but with no audio input, adjust R31, 33, 42 and 44 so that the four LEDs (DS1 through DS4) are off. The objective of the following adjustments is to get the red and green LEDs to turn on with the same voltage amplitude, but opposite polarity, across R24. Move R24's wiper so a low positive voltage appears across R24, as indicated by the voltmeter connected across R24 or movement of the panel-meter needle. Adjust R44 (LED ADJ 1A) and R42 (LED ADJ 1B) so that the green LED (DS4) comes on when the voltage goes positive at one end of

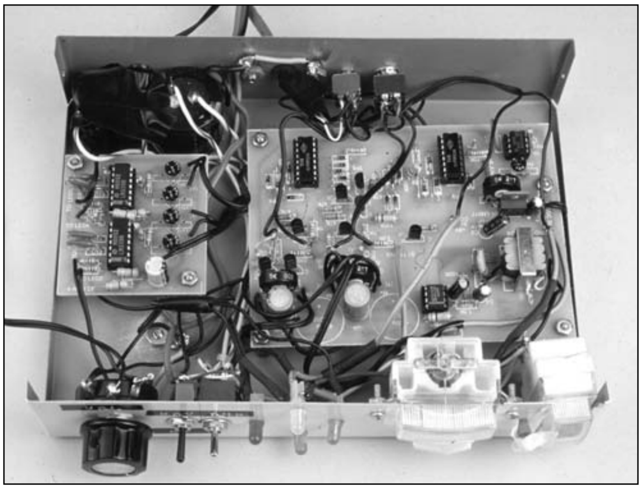

Fig 42—An inside view of one DF unit built into a $2 \times 8 \times 5^3/_4$-inch (HWD) box. Because of the height restriction, the two 4700-µF damping capacitors (C8 and C10) are not mounted on the PC board, but near the rear panel behind the smaller of the two PC boards. One of the 4700-µF damping capacitors is a standard electrolytic, the other is a parallel combination of five 1000-µF, 6.3-V bipolar (nonpolarized) capacitors wrapped in electrical tape.

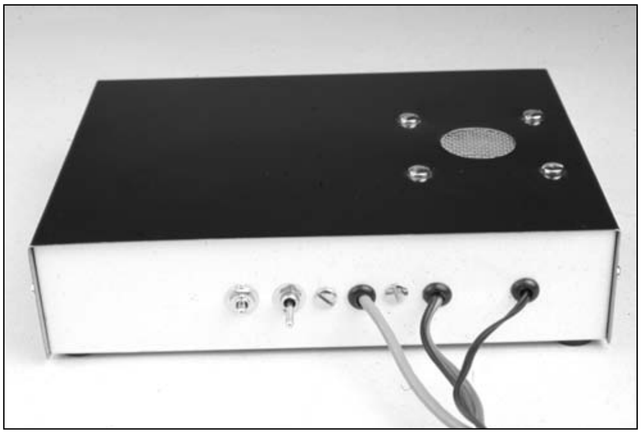

Fig 43—The rear panel of the DF unit supports the two DPDT PHASE toggle switches. Grommets in the panel holes allow abrasion-free passage of the antenna, dc-power and audio cables. The dc power cord is outfitted with an inline fuse holder and a male Jones plug. A six-pin female Molex connector (five pins are used) feeds the four antennas. The audio-input cable is terminated in a $^1/_8$-inch diameter male plug.

R24, but goes off when R24 is adjusted for 0 V across R24.

Next, adjust R24 for a slight negative-voltage indication and adjust R42 and R44 so that the red LED (DS3) comes on, but extinguishes when the voltage across R24 is 0 V. When you're done, adjusting R24's wiper slightly one way should illuminate the red LED. Both LEDs should be off when there's no voltage across R24; rotating R24's wiper slightly in the opposite direction should turn on the green LED.

Connect the voltmeter across R27 or use the panel meter as an indicator. With no audio input, adjust R27 so that there's no voltage across R27. Adjust R31 (F/B LED ADJ 1A) and R33 (F/B LED 1B) so that a F/B LED (DS1) is on when there is a slight positive voltage across R27 and the other F/B LED (DS2) is on when there is a negative voltage across R27.

Switch Board

Assemble the switch board for the four mag-mount antennas (see Fig 40). You can use half of a RadioShack dual pad-per-hole PC board (RS 276-148) as a platform. Lead length is critical only on this board and in the length of the coax from the switching board to the antennas, so avoid wire-wrap construction here.

Feed Lines

The coax lines from the switch board to each of the four antennas must be of equal length. The coax lengths should be long enough to permit each antenna to be placed slightly less than $^1/_4$ λ from its counterpart, at the lowest frequency of operation. (There's a local belief that $27^1/_2$ inches is the best length. The author used that length and it works, but other lengths might work as well.) An attempt to locate the switch board inside the vehicle and run equal-length 12-foot-long cables to the antennas failed. Keep the switch board on the vehicle's roof.

Use the same type of coax for all lines—that is, don't mix foam and polyethylene dielectric coax on the antenna lines. If the velocity factor of the lines is not equal, a phase shift in the signals will exist even when the transmitter is dead ahead and it will lead you astray.

Solder the coax from the antennas directly to the board—don't use connectors. From the switch board to the receiver, use 50-Ω coax of any type and length. Equip the receiver end of the line with a connector that mates with your receiver's antenna-input jack. Make the four-conductor shielded cable from the main DFer box to the switch board long enough to reach from the LRFB box's operating position to the roof of the car. Construct the antennas so that the whips can be changed easily for use on any frequency in which you're interested.

Mechanical Assembly

Mount the finished PC boards in a metal box of your choice. You can follow the construction method used in the prototype (see **Fig 42** and **Fig 43**), but do ensure that R4 can be adjusted easily with a tuning tool from outside the box. A hole drilled in the box at the right point will suffice. Arrange the LEDs in a diamond pattern on the front panel, with the left LED (red) to the left, the right LED (green) on the right, and the front and back LEDs at the top and the bottom.

Wrap the switch board with tape to waterproof it, or place it in a watertight box. Arrange the mag-mount antennas on top of the vehicle in a diamond shape. The distance between each antenna pair should be less than $^1/_4$ λ at the operating frequency. (In limiting the distance between antennas in a pair—F/B or L/R—to less than $^1/_4$ λ, the author followed W9DUU's example.)

Final Adjustments

It's best to start on 2 meters. Install the 2-meter whips in the antenna bases. Mount the antennas on the top of your vehicle. Identify the left and right antenna bases with L and R, and mark the front and back antenna bases, too.

A good way to find out if the antennas are properly installed is to short either the left or right antenna with a clip lead from the whip to the metal base; the L/R meter will deflect one way and the left or right LED will light. If you short one of the front and back antennas with a clip lead, the front or back LED will come on. If you short one of the L/R antennas and it makes the meter go to the right, it does not necessarily mean you have the PHASE switch in the proper position. That depends on the relative phase determined by the number of audio stages in your receiver, each of which may contribute a shift of 180°.

Connect the coax from the switch board to your FM receiver. It must be an FM receiver; an AM VHF or AM aircraft receiver won't suffice. Connect the audio output of your 2-meter receiver to the LRFB box audio input. If you're using a transceiver, disable its transmit function by removing the mike. You don't want to transmit into the switch board!

Turn on the receiver and place the LRFB box in receive by setting S1 to the RCV position. Center R10. Only one of the antennas will be turned on and the DF operation will be disabled. Back off the squelch and notice that you hear the audio from the speaker of the LRFB box. Switch to an unused simplex channel. Have a friend with an HT stand 20 feet or so in front of the vehicle. With the receiver in the car turned off, turn S1 to DF. The four LEDs should be off. If an LED lights, adjust R24 and R27 for zero voltage. If the LED is still on, readjust R31 and R33, or R42 and R44 as explained earlier. When all four LEDs are off with the antennas connected, no audio from the receiver and no RF input signal, you're ready. Turn on your receiver and have your friend transmit on the 2-meter frequency (simplex) that your receiver is set to. When he transmits, one or more of the LEDs should illuminate. Ignore the front/back LEDs, but check to see if the right or left LED is on. If the right LED is on and your friend is standing to the right of the center of the vehicle front, all is well. Have him walk back and forth in front of the vehicle and notice that when he is to the right, the green LED turns on, and when he's to the left, the red LED glows. If the indications are reversed, that is, if the LRFB box indicates left when your friend is to your right, reverse the position of PHASE switch S3.

When the L/R indicators are working properly, have your friend walk back and forth between a position 20 feet to the front and right of the car and a position 20 feet away to the rear and right of the car. The right LED should stay on, but the front LED should be on when the HT is in front of the antennas, and the back LED should be on when the HT is behind the antennas. If the front/back indications are reversed, reverse the position of PHASE switch S4.

While receiving a signal from your friend's HT, adjust R4 for maximum deflection on any one of the two optional meters, or on a voltmeter (set on the lowest dc voltage range) connected across R24 or R27. Look for the maximum deflection of the meter needle as the meter swings both ways while the signal source moves from back to front or left to right (depending, of course, on which panel meter you're looking at or which resistor—R24 or R27—your voltmeter is across). The audio passband of FM receivers varies, and if you switch from an ICOM IC-27 to an ICOM IC-W2A, for example, you'll have to change U2's master clock frequency. You may encounter receivers that don't require readjusting R4, but such readjustment should be expected. When changing receivers, you may also need to change the position of PHASE switches S3 and S4. This may also be necessary when changing from UHF to VHF, or VHF to UHF on the same receiver, as the number of receiver stages (and, hence, the audio phase) may change from band to band.

Audio Level Adjustments

With meter damping (S2) off, adjust R10 so that you have full deflection of one of the two meters (or your multimeter) with the signal source at a 45° angle from the vehicle (halfway between ahead and right), and a reasonable audio level from the speaker. Turn the rig's volume control all the way up to ensure that the audio circuit doesn't overload. If it overloads, the meters won't deflect. From zero to full blast, the meter should deflect more and more (unless the signal is straight ahead or exactly left or right). If you're using an H-T, maximum deflection of the meter should occur before the volume control is $^3/_4$ of maximum, or before the volume control is at $^1/_2$ of maximum if you're using a mobile rig. If R10 is properly adjusted, turning the volume control to maximum won't cause the meter to fall back toward zero. If increasing the volume causes the meter to deflect less, then R10's setting is too high.

Now have your friend walk around the vehicle with the HT transmitting and notice that the LEDs indicate the signal direction. On 2 meters in a clear field, the indications should be correct 80 or 90% of the time. The erroneous readings that occasionally occur are due to multipath propagation caused by the irregular shape of the vehicle. Slight adjustments in the positions of the L/R and F/B antennas may be necessary to make the zero points fall directly in front of the vehicle (neither left nor right LED on) and at the center of the antennas (neither front nor back LED on).

Try the same procedure on 440 MHz. You may have to flip the PHASE switches when you move to another band, even when using the same receiver. Remember that the total length of the 440-MHz antennas must be $^1/_4\ \lambda$ or less, and the antennas must be placed less than $^1/_4\ \lambda$ apart. The results on 440 MHz probably won't be as consistent as the results on 2 meters, as there is likely to be a lot more multipath propagation caused by the irregular shape of the vehicle.

Fox Hunting

Before heading out to find the fox, check to be certain the LRFB box is working properly. Tune to the fox's frequency and drive off. Turning on the DAMPING switch stabilizes the indication as you drive along. Follow indications generated as you travel over the road or street. If an indication is constant for 15 or 20 seconds while you're moving down the road, it's probably the true direction to the fox. It's possible to have a reflection from a mountain over a long distance down the road, however. When you can hear the fox with no antenna, it's time to get out of the car, switch to the hand-held system and hunt for the fox on foot.

If you switch to a new receiver, you may have to readjust R4, CLOCK FREQ. That's because both receivers may not have the same audio bandwidth. Author WA9BVS forgot this while chasing a balloon once and the results were comical. When chasing balloons with ham radio transmitters, the readings you get are likely to be confusing when the balloon is at a high angle with respect to the plane of the car top. Use a hand-held Yagi to verify the balloon location. Even with a simple buzzbox, you should be able to find a keyed transmitter.

A TAPE-MEASURE BEAM FOR RDFING

Joe Leggio, WB2HOL, designed this antenna while searching for a beam with a really great front-to-back ratio to use in hidden transmitter hunts. It exhibits a very clean pattern and is perfect for RDF use. You can construct this beam using only simple hand tools, and it has been duplicated many times.

WB2HOL's first design requirement was to be able to get in and out of his car easily when hunting for a hidden transmitter. He accomplished this by using steel "tape-measure" elements, which fold easily when putting the antenna into a car and yet are self supporting. They also hold up well while crashing through the underbrush on a fox hunt.

WB2HOL decided to use three elements to keep the boom from getting too long. He used inexpensive

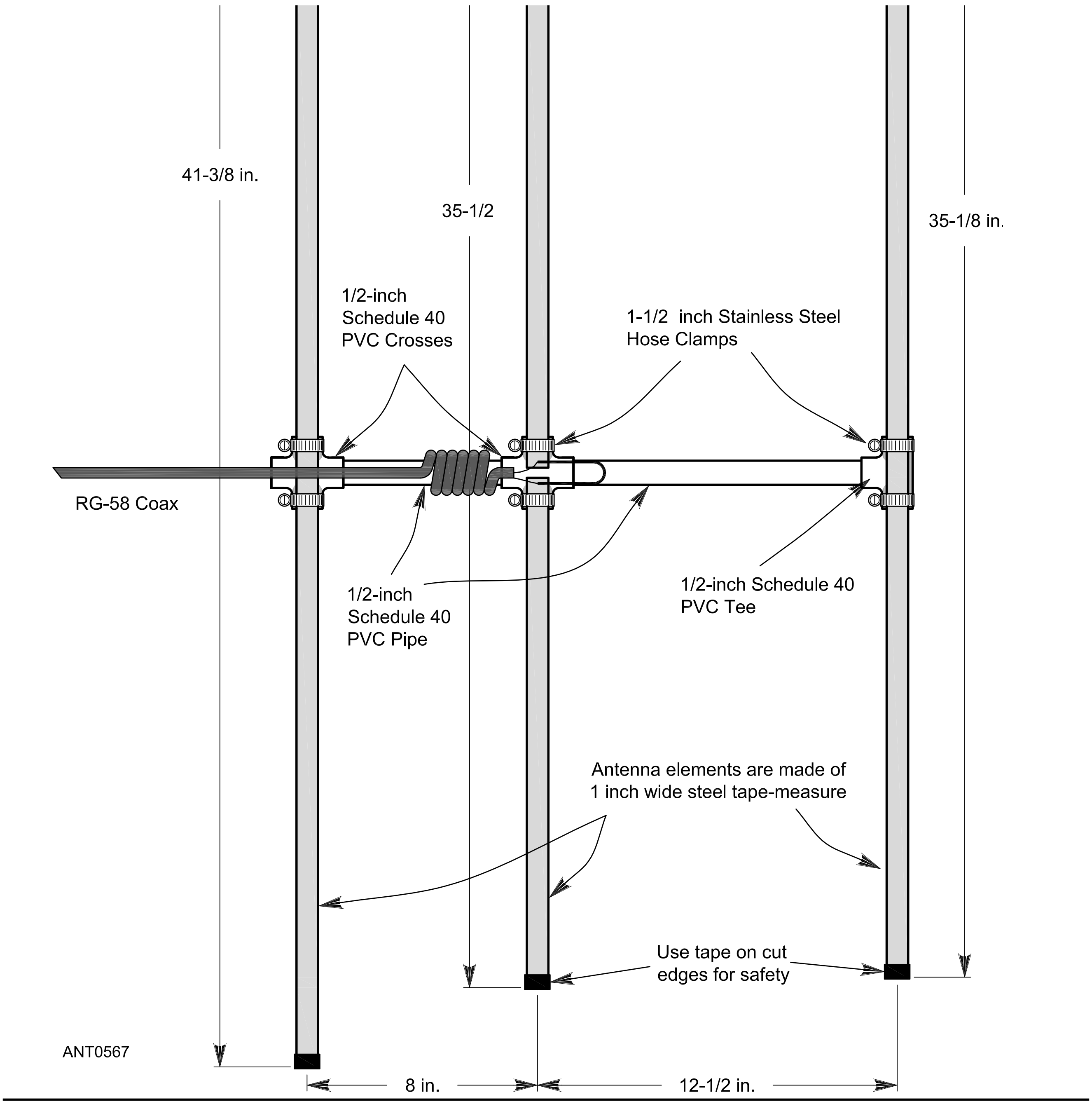
41-3/8 in.
35-1/2
35-1/8 in.
1/2-inch Schedule 40 PVC Crosses
1-1/2 inch Stainless Steel Hose Clamps
RG-58 Coax
1/2-inch Schedule 40 PVC Pipe
1/2-inch Schedule 40 PVC Tee
Antenna elements are made of 1 inch wide steel tape-measure
Use tape on cut edges for safety
ANT0567
8 in.
12-1/2 in.

Fig 44—Tape-measure beam dimensions.

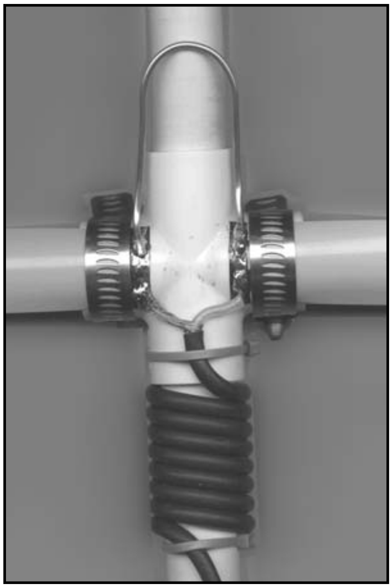

Fig 45—Photo of driven-element mounted to PVC tee using hose clamps. The hairpin match wires is shown here soldered to the tape-measure elements, along with the RG-58 feed line.

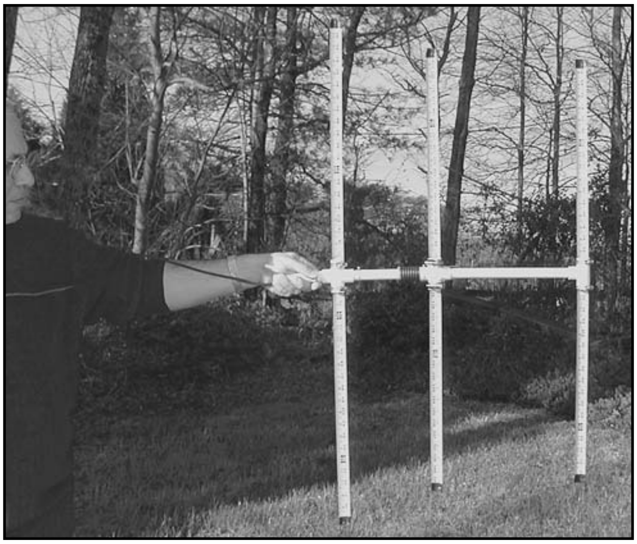

Fig 46—Photo of complete tape-measure beam, ready to hunt foxes!

Schedule-40 PVC pipe, crosses and tees that can be found at any hardware store for the boom and element supports.

He used a simple hairpin match, consisting of a 5-inch length of #14 solid wire bent into the shape of a U, with the two legs about $^3/_4$ inch apart. This gave in a very good match across the 2-meter band after he tweaked the distance (1-inch on his prototype) between the halves of the driven element for minimum SWR.

You can cut the 1-inch wide tape-measure elements with a pair of shears, chamfering the ends of the elements. Be very careful—the edges are very sharp and will inflict a nasty cut if you are careless. Use some sandpaper to remove the sharp edges and burrs and put some vinyl electrical tape on the ends of the elements to protect yourself from getting cut. Wear safety glasses while cutting the elements. See **Fig 44** for dimensions.

The RG-58 coax feed line is wound into a 8-turn coil along the boom to form a choke balun. The coil is covered with vinyl black tape to secure it to the boom. Make sure you scrape or sand the paint off the tape-measure elements where the feed line is attached. Most tape measures have a very durable paint finish designed to stand up to heavy use. You do not want the paint to insulate your feed-line connection!

If you are careful, you can solder the feed line to the element halves, but take care since the steel tape measure does not solder easily and the PVC supports can be easily melted. Tin the tape-measure elements before mounting them to the PVC cross if you decide to connect the feed line in this fashion.

If you decide not to solder to the tape-measure elements, you can use two other methods to attach the feed line. One method employs ring terminals on the end of the coax. The ring terminals are then secured under self-tapping screws or with 6-32 bolts and nuts into holes drilled in the driven-element halves. However, with this method you cannot fine-tune the antenna by moving the halves of the driven element in and out.

The simplest method is simply to slide the ends of the feed line under the driven element hose clamps and tighten the clamps to hold the ends of the coax. This is low-tech but it works just fine.

WB2HOL used $1^1/_2$-inch stainless-steel hose clamps to attach each driven-element half to the PVC cross that acts as its support. This allowed him to fine-tune his antenna for lowest SWR simply by loosening the hose clamps and sliding the halves of the driven element in or out to lengthen or shorten the element. He achieved a 1:1 SWR at 146.565 MHz (the local fox-hunt frequency) when the two elements were spaced about 1 inch apart. **Fig 45** shows the hose-clamp method for attaching the driven element to the PVC cross, along with the hairpin wire and feed-line coax.

Some builders have used rubber faucet washers between the tape-measure elements and the PVC-cross fittings on the director and reflector. These allow for the tape to fit the contour of the PVC fitting better and will make the antenna look nicer. It is normal for the reflector and director elements to buckle a bit as they are tightened to the PVC tee and cross if you don't use faucet washers. You can also eliminate the buckling if you use self-tapping screws to attach these elements instead of hose clamps. The beam will not be as rugged, however, as when you use hose clamps.

This beam has been used on fox hunts, on mountain tops, at local public-service events, outdoors, indoors in attics—just about everywhere. The SWR is typically very close to 1:1 once adjusted. Front-to-back performance is exactly as predicted. The null in the rear of the pattern is perfect for transmitter hunts.

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Chapter 15

Portable Antennas

For many amateurs, the words *portable antennas* may conjure visions of antenna assemblies that can be broken down and carried in a backpack, suitcase, golf bag, or what-have-you, for transportation to some out-of-the way place where they will be used. Or the vision could be of larger arrays that can be disassembled and moved by pickup truck to a Field Day site, and then erected quickly on temporary supports. Portable antennas come in a wide variety of sizes and shapes, and can be used on any amateur frequency.

Strictly speaking, the words "portable antenna" really means *transportable antenna*—one that is moved to some (usually temporary) operating position for use. As such, portable antennas are not placed into service when they are being transported. This puts them in a different class from mobile antennas, which are intended to be used while in motion. Of course this does not mean that mobile antennas cannot be used during portable operation. Rather, true portable antennas are designed to be packed up and moved, usually with quick reassembly being one of the design requisites. This chapter describes antennas that are designed for portability. However, many of these antennas can also be used in more permanent installations.

Any of several schemes can be employed to support an antenna during portable operation. For HF antennas made of wire, probably the most common support is a conveniently located tree at the operating site. Temporary, lightweight masts are also used. An aluminum extension ladder, properly guyed, can serve as a mast for Field Day operation. Such supports are discussed in Chapter 22, Antenna Supports.

A SIMPLE TWIN-LEAD ANTENNA FOR HF PORTABLE OPERATION

The typical portable HF antenna is a random-length wire flung over a tree and end-fed through an antenna tuner. Low-power antenna tuners can be made quite compact, but each additional piece of necessary equipment makes portable operation less attractive. The station can be simplified by using resonant impedance-matched antennas for the bands of interest. Perhaps the simplest antenna of this type is the half-wave dipole, center-fed with 50- or 75-Ω coax. Unfortunately, RG-58, RG-59 or RG-8 cable is quite heavy and bulky for backpacking, and the miniature cables such as RG-174 are too lossy.

A practical solution to the coax problem, developed by Jay Rusgrove, W1VD, and Jerry Hall, K1TD, is to use folded dipoles made from lightweight TV twin-lead. The characteristic impedance of this type of dipole is near 300 Ω, but this can easily be transformed to a 50-Ω impedance. The transformation is obtained by placing a lumped capacitive reactance at a strategic distance from the input end of the line. **Fig 1** illustrates the construction method and gives important dimensions for the twin-lead dipole.

A silver-mica capacitor is shown for the reactive element, but an open-end stub of twin-lead can serve as well, provided it is dressed at right angles to the transmission line for some distance. The stub method has the advantage of easy adjustment of the system resonant frequency.

The dimensions and capacitor values for twin-lead dipoles for the HF bands are given in **Table 1**. To pre-

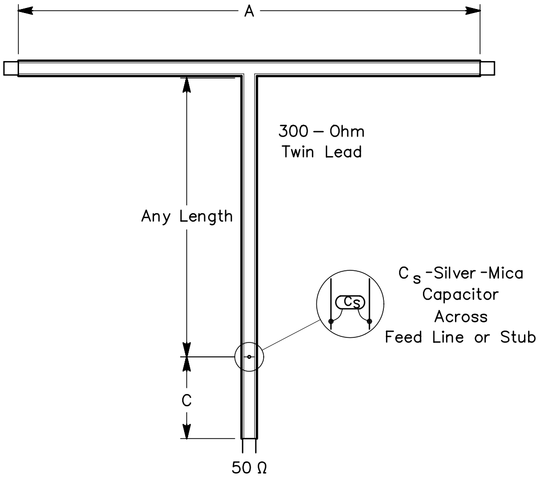

Fig 1—A twin-lead folded dipole makes an excellent portable antenna that is easily matched to 50-Ω equipment. See text and Table 1 for details.

Table 1
Twin-Lead Dipole Dimensions and Capacitor Values

Frequency	*Length A*	*Length C*	*C_S*	*Stub Length*
3.75 MHz	124' 9½"	13' 0"	289 pF	37' 4"
7.15	65' 5½"	6' 10"	151 pF	19' 7"
10.125	46' 2½"	4' 10"	107 pF	13' 10"
14.175	33' 0"	3' 5½"	76 pF	9' 10½"
18.118	25' 10"	2' 8½"	60 pF	7' 9"
21.225	22' ½"	2' 3½"	51 pF	6' 7"
24.94	18' 9"	1' 11½"	43 pF	5' 7½"
28.5	16' 5"	1' 8½"	38 pF	4' 11"

serve the balance of the feeder, a 1:1 balun must be used at the end of the feed line. In most backpack QRP applications the balance is not critical, and the twin-lead can be connected directly to a coaxial output jack—one lead to the center contact, and one lead to the shell.

Because of the transmission-line effect of the shorted-radiator sections, a folded dipole exhibits a wider bandwidth than a single-conductor type. The antennas described here are not as broad as a standard folded dipole because the impedance-transformation mechanism is frequency selective. However, the bandwidth should be adequate. An antenna cut for 14.175 MHz, for example, will present an SWR of less than 2:1 over the entire 14-MHz band.

ZIP-CORD ANTENNAS

Zip cord is readily available at hardware and department stores, and it's not expensive. The nickname, *zip cord*, refers to that parallel-wire electrical cord with brown or white insulation used for lamps and many small appliances. The conductors are usually #18 stranded copper wire, although larger sizes may also be found. Zip cord is light in weight and easy to work with.

For these reasons, zip cord can be pressed into service as both the transmission line and the radiator section for an emergency dipole antenna system. This information by Jerry Hall, K1TD, appeared in *QST* for March 1979. The radiator section of a zip-cord antenna is obtained simply by "unzipping" or pulling the two conductors apart for the length needed to establish resonance for the operating frequency band. The initial dipole length can be determined from the equation $\ell = 468/f$, where ℓ is the length in feet and f is the frequency in MHz. (It would be necessary to unzip only half the length found from the formula, since each of the two wires becomes half of the dipole.) The insulation left on the wire will have some loading effect, so a bit of length trimming may be needed for exact resonance at the desired frequency.

For installation, you may want to use the electrician's knot shown in **Fig 2** at the dipole feed point. This is a balanced knot that will keep the transmission-line part of the system from unzipping itself under the tension of dipole suspension. This way, if zip cord of sufficient length for both the radiator and the feed line is obtained, a solder-free installation can be made right down to the input end of the line.

(Purists may argue that knots at the feed point will create an impedance mismatch or other complications, but as will become evident in the next section, this is not a major consideration.) Granny knots (or any other variety) can be used at the dipole ends with cotton cord to suspend the system. You end up with a lightweight, low-cost antenna system that can serve for portable or emergency use.

But just how efficient is a zip-cord antenna system? Since it is easy to locate the materials and simple to install, how about using such for a more permanent installation? Upon casual examination, zip cord looks about like 72-Ω balanced feed line. Does it work as well?

Zip Cord as a Transmission Line

To determine the electrical characteristics of zip cord as a radio-frequency transmission line, a 100-foot roll was subjected to tests in the ARRL laboratory with an RF impedance bridge. Zip cord is properly called *parallel power cord*. The variety tested was manufactured for GC Electronics, Rockford, IL, being 18-gauge, brown, plastic-insulated type SPT-1, GC cat. no. 14-118-2G42. Undoubtedly, minor variations in the electrical-characteristics will occur among similar cords from different manufacturers, but the results presented here are probably typical.

The characteristic impedance was determined to be 107 Ω at 10 MHz, dropping in value to 105 Ω at 15 MHz and to a slightly lower value at 29 MHz. The nominal

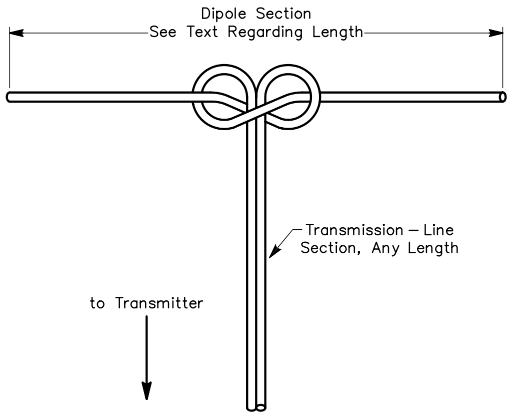
Dipole Section
See Text Regarding Length
Transmission – Line Section, Any Length
to Transmitter

Fig 2—This electrician's knot, often used inside lamp bases and appliances in lieu of a plastic grip, can also serve to prevent the transmission-line section of a zip-cord antenna from unzipping itself under the tension of dipole suspension. To tie the knot, first use the right-hand conductor to form a loop, passing the wire behind the unseparated zip cord and off to the left. Then pass the left-hand wire of the pair behind the wire extending off to the left, in front of the unseparated pair, and thread it through the loop already formed. Adjust the knot for symmetry while pulling on the two dipole wires.

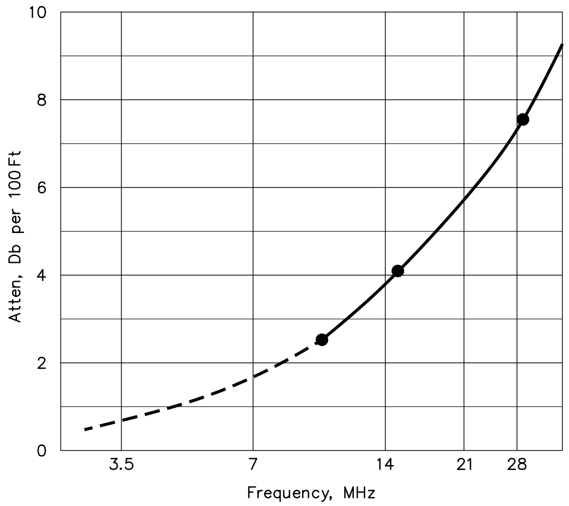

Fig 3—Attenuation of zip cord in decibels per hundred feet when used as a transmission line at radio frequencies. Measurements were made only at the three frequencies where plot points are shown, but the curve has been extrapolated to cover all high-frequency amateur bands.

value is 105 Ω at HF. The velocity factor of the line was determined to be 69.5%.

Who needs a 105-Ω line, especially to feed a dipole? A dipole in free space exhibits a feed-point resistance of 73 Ω, and at heights above ground of less than $^1/_4$ wavelength the resistance can be even lower. An 80-meter dipole at 35 feet over average soil, for example, will exhibit a feed-point resistance of about 35 Ω. Thus, for a resonant antenna, the SWR in the zip-cord transmission line can be 105/35 or 3:1, and maybe even higher in some installations. Depending on the type of transmitter in use, the rig may not like working into the load presented by the zip-cord antenna system.

But the really bad news is still to come—line loss! **Fig 3** is a plot of line attenuation in decibels per hundred feet of line versus frequency. Chart values are based on the assumption that the line is perfectly matched (sees a 105-Ω load as its terminating impedance).

In a feed line, losses up to about 1 decibel or so can be tolerated, because at the receiver a 1-dB difference in signal strength is just barely detectable. But for losses above about 1 dB, beware. Remember that if the total losses are 3 dB, half of your power will be used just to heat the transmission line. Additional losses over those charted in Fig 3 will occur when standing waves are present. (See Chapter 24, Transmission Lines.) The trouble is, you can't use a 50- or 75-Ω SWR instrument to measure the SWR in zip-cord line accurately.

Based on this information, we can see that a hundred feet or so of zip-cord transmission line on 80 meters might be acceptable, as might 50 feet on 40 meters. But for longer lengths and higher frequencies, the losses become appreciable.

Zip Cord Wire as the Radiator

For years, amateurs have been using ordinary copper house wire as the radiator section of an antenna, erecting it without bothering to strip the plastic insulation. Other than the loading effects of the insulation mentioned earlier, no noticeable change in performance has been noted with the insulation present. And the insulation does offer a measure of protection against the weather. These same statements can be applied to single conductors of zip cord.

The situation in a radiating wire covered with insulation is not quite the same as in two parallel conductors, where there may be a leaky dielectric path between the two conductors. In the parallel line, it is the current leakage that contributes to line losses. This leakage current is set up by the voltage potential that exists on the two adjacent wires. The current flowing through the insulation on a single radiating wire is quite small by comparison, and so as a radiator the efficiency is high.

In short, communications can certainly be established with a zip-cord antenna in a pinch on 160, 80, 40, 30 and perhaps 20 meters. For higher frequencies, especially with long line lengths for the feeder, the efficiency of the system is so low that its value becomes questionable.

A TREE-MOUNTED HF GROUND-PLANE ANTENNA

A tree-mounted, vertically polarized antenna may sound silly. But is it really? Perhaps engineering references do not recommend it, but such an antenna does not cost much, is inconspicuous, and it works. This idea was described by Chuck Hutchinson, K8CH, in *QST* for September 1984.

The antenna itself is simple, as shown in **Fig 4**. A piece of RG-58 cable runs to the feed point of the antenna, and is attached to a porcelain insulator. Two radial wires are soldered to the coax-line braid at this point. Another piece of wire forms the radiator. The top of the radiator section is suspended from a tree limb or other convenient support, and in turn supports the rest of the antenna.

The dimensions for the antenna are given in **Fig 5**. All three wires of the antenna are ¼ wavelength long. This generally limits the usefulness of the antenna for portable operation to 7 MHz and higher bands, as temporary supports higher than 35 or 40 feet are difficult to come by. Satisfactory operation might be had on 3.5 MHz with an inverted-L configuration of the radiator, if you can overcome the accompanying difficulty of erecting the antenna at the operating site.

The tree-mounted vertical idea can also be used for fixed station installations to make an invisible antenna. Shallow trenches can be slit for burying the coax feeder and the radial wires. The radiator itself is difficult to see unless you are standing right next to the tree.

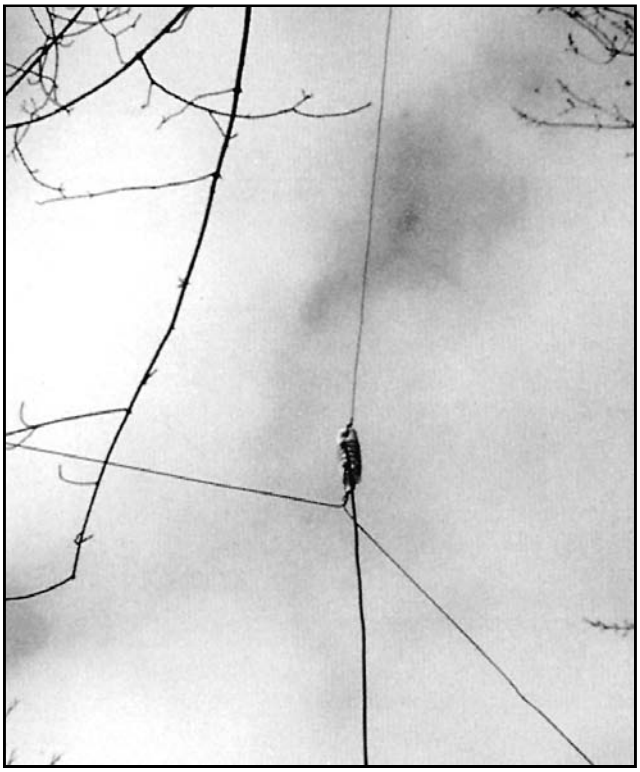

Fig 4—The feed point of the tree-mounted ground-plane antenna. The opposite ends of the two radial wires may be connected to stakes or other convenient points.

A PORTABLE DIPOLE FOR 80 TO 2 METERS

This dipole antenna, described by Robert Johns, W3JIP, in August 1998 *QST*, can be used for any band from 80 through 2 meters. One half of the dipole is an inductively loaded aluminum tube. Its length is adjustable from 4 to 11 feet, depending on how much room is available. The other half is flexible insulated wire that can be spooled out as necessary. The tube is supported by a flagpole bracket attached to a long carpenter's clamp. The clamp mounts the antenna to practically anything: a windowsill, railing, a chair or post. If there is no structure to mount the antenna (a parking lot or the beach), the clamp attaches to two light wooden legs to form a tripod, as shown in **Fig 6**.

The key to mounting flexibility is the large clamp. The key to electrical flexibility is a large adjustable coil that lets you resonate the tube on many bands. The coil is wound with #8 aluminum ground wire from RadioShack. The form is a four-inch ($4^1/_2$-inch OD) styrene drain coupling from the Home Depot or a large plumbing supply store. A movable tap adjusts the inductance to tune the upright tube to the desired band. The wire half of the antenna is always a bit less than λ/4 on each band. Hang it from any convenient support or drape it over bushes to keep it off the ground.

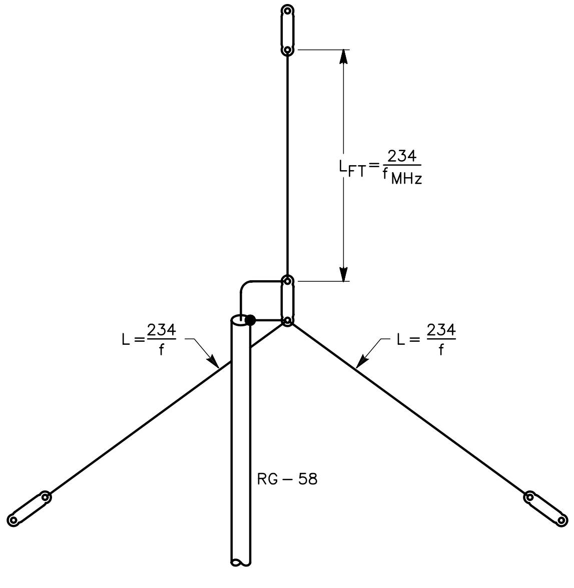

Fig 5—Dimensions and construction of the tree-mounted ground-plane antenna.

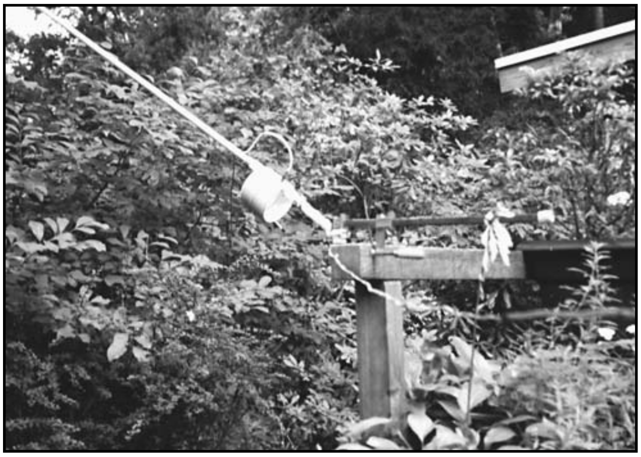

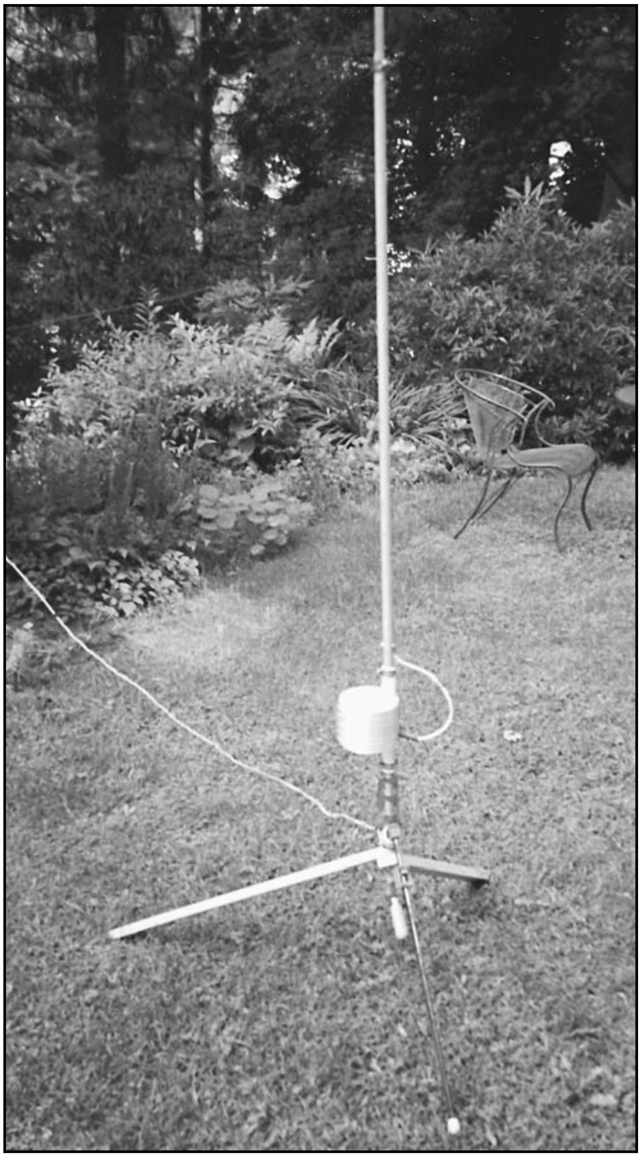

Fig 6—At top, the portable antenna in some of the many places it may be mounted around the house, porch and yard. At bottom, the simple ground-mounted legs that make a tripod.

Construction

The 18-inch carpenter's clamp (sometimes called a *bar clamp*, such as Jorgensen's No. 3718) and flagpole bracket that takes a $^3/_4$-inch pole are common hardware items. Insulate the bracket from the clamp jaw with a $1^1/_2$-inch length of 1-inch PVC pipe (see **Fig 7**). Hammer the PVC over the end clamp jaw to make it take the shape of the jaw. Secure the flagpole bracket to PVC with a large ground clamp (for $^1/_2$ or 1-inch conduit). The ground clamp includes $^1/_4$-inch bolts; enlarge the flagpole bracket holes to accept them. Some flagpole brackets have an integral cleat; the author hammered the cleat ears flat on his.

Mount an SO-239 chassis connector on the flagpole bracket using RadioShack insulated standoffs (276-1381). The standoffs tightly press the center pin of the SO-239 against the bracket surface; no other connection is needed. Other mounting hardware may require a connection from the coax center conductor to the bracket. The spooled wire's inner end wraps around a standoff and connects to a ring terminal under a screw holding the SO-239 flange to the standoff.

The 1 × 2-inch wooden legs for the tripod are each 30 inches long. Bolt them together at one end with a 1 or $1^1/_4$-inch-long bolt. Countersink the bolt head and nut below the surface of the wood so they don't interfere with the clamp jaws.

Aluminum Element

You can make this element from three lengths of telescoping aluminum tubing ($^3/_4$, $^5/_8$ and $^1/_2$ inch, 0.058-inch walls). The author used tubing with thinner walls for less weight and easier handling. A 45-inch-long, $^3/_4$-inch tube fits the flagpole bracket. He chose this length because it and the flagpole bracket make $\lambda/4$ on 6 meters. The two outer tubes are both $^5/_8$ inch, made by cutting a seven-foot aluminum clothesline pole in halves. They are

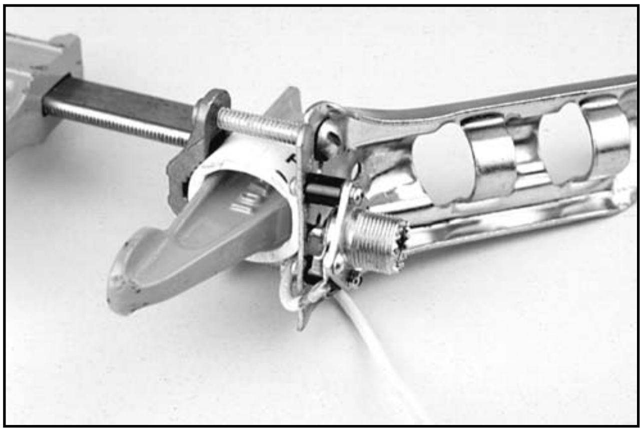

Fig 7—The flagpole bracket that supports the tubing elements is clamped to the long carpenter's clamp, but insulated from it by a small section of 1-inch PVC pipe. A coax connector is mounted to the bracket and the spool of wire is attached to the coax connector.

joined together with a copper coupling (5/8 inch ID) for 1/2-inch copper pipe. The coupling is bolted to one of the 5/8-inch sections, and a slot is cut in the free half of the coupling. The remaining 5/8-inch tube is inserted there and secured with a hose clamp. See **Fig 8**.

One 5/8-inch tube slides into the 3/4-inch tube to provide a continuously variable element length from about 4 to 7 1/2 feet. This extends from 7 1/2 to 11 feet when the two 5/8-inch sections are joined together.

Loading Coil

The loading coil has 12 turns of bare aluminum wire spaced to fill the 3 1/2-inch length of the drain coupling. Drill 9/64-inch holes at the ends of the coil form to accept the ends of the coil wire. (See **Fig 9**.) To wind the coil, feed four inches of wire through the form, make a sharp bend in the wire and start winding away from the nearby mounting hole. Wind 12 turns on the form, spacing them only approximately. Cut the wire for a 4-inch lead and feed it through the other hole in the form. Tighten the wire as best you can and bend it into another acute angle where it passes into the form. Space the turns about equally, but don't fuss with them. Final spacing will be set after the wire is tightened.

Tighten the coil wire by putting a screwdriver or a needle-nose pliers jaw under one turn, and pry the wire up and away from the surface of the coil form. While this can be done anywhere, it's best to put these kinks on the backside, away from the mounting shaft. Put kinks in every other turn, removing any slack from the coil and holding the turns in place. Should the coil ever loosen, simply retighten it with a screwdriver. If you prefer, glue the coil turns in place with epoxy or coil dope. Use a thin bead of glue that won't interfere with the clip that connects to the coil.

The coil form mounts on a nine-inch-long 3/4-inch PVC pipe. (See Fig 9 and **Fig 10**.) The inside diameter is slightly larger than the 3/4-inch aluminum, but slotting the PVC and tightening it with a hose clamp secures the tube. (Use a wide saw to cut these slots, not a hacksaw.) The coil form mounts to the PVC pipe with #6-32 × 1 1/2-inch bolts. A five-inch long, 3/4-inch aluminum tube permanently attaches to one end of the coil assembly and slides into the flagpole bracket. One end of the coil wire connects to this short tube. Flatten the wire end by hammering it on something hard, then drill a 9/64-inch hole in the flattened end and attach it to the short tube with a #6-32 × 1-inch bolt. Tighten the bolt until the 1/2-inch tube starts to flatten. This will keep pressure on the aluminum-to-aluminum joint.

The aluminum element slides into the opposite end of the coil assembly. The hose clamp there can be tightened until the element just slides in snugly.

A 12-inch clip lead connects the aluminum element to the coil. Bolt the plain wire end to the 3/4-inch tube three inches from its end. Many alligator clips will fit in the space between the turns of the coil (about 3/16 inch), but W3JIP preferred using a solid-copper clip (Mueller TC-1). Cut off most of the jaws, so that only the part close to the hinge grabs the coil. This shorter lever grips very tightly.

Wire and Spool

The lower half of the antenna is insulated wire that is about $\lambda/4$ on the band of operation. The wire is pulled from the spool, and the remaining wire forms an inductance that doesn't add much to the antenna length. The Home Depot sells #12 and #14 insulated stranded copper wire in 50 and 100-foot lengths, on plastic spools. (See **Fig 11**.) A 1/2-inch dowel fits into the spool to make a

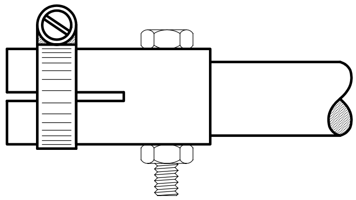

Fig 8—The joint between two sections of 5/8-inch tubing is made from a 1/2-inch copper pipe coupling, bolted to one section and hose clamped to the other.

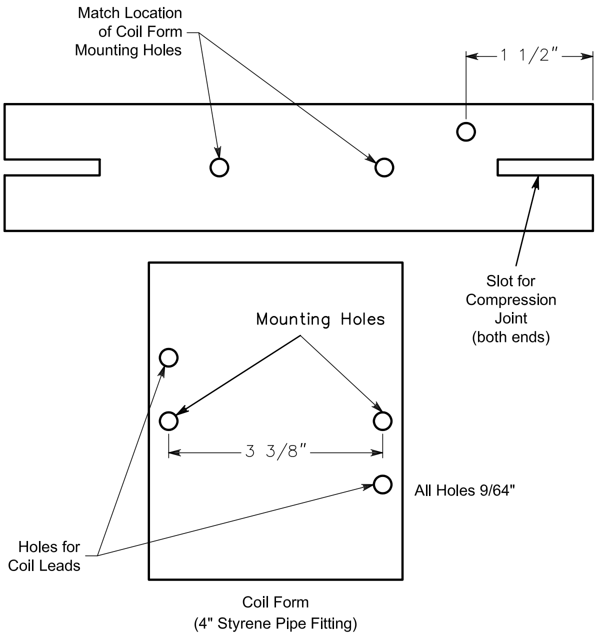

Fig 9—Holes to be drilled in the styrene coupling and the 3/4-inch PVC pipe. All holes are 9/64-inch diameter, to provide clearance for #6-32 bolts. The hole 1 1/2 inches from one end holds a bolt that serves as a stop, so that the antenna tube does not slide in too far. Space the holes for coil leads far enough from the mounting holes to clear the 3/4-inch pipe.

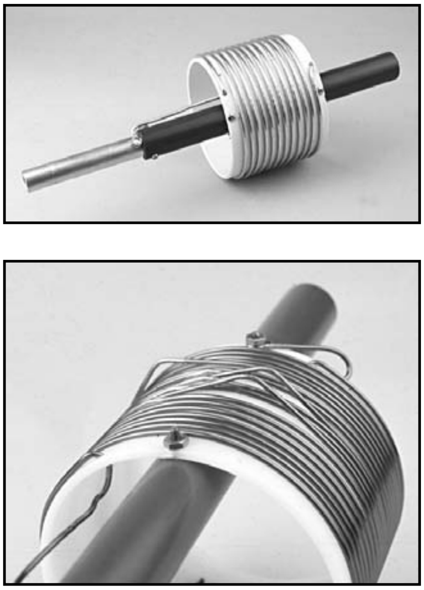

Fig 10—Top photo shows the loading coil for the 20, 30, and 40-meter band coverage. The short aluminum tube on the coil slides into the flagpole bracket, and the tubing element slides into the other end of the PVC pipe. The wire and clip connect the element to the coil. Bottom photo shows the coil for operating the antenna on 80 meters. This is placed in the flagpole bracket and the 40-meter aluminum coil plus the tubing element is inserted into it.

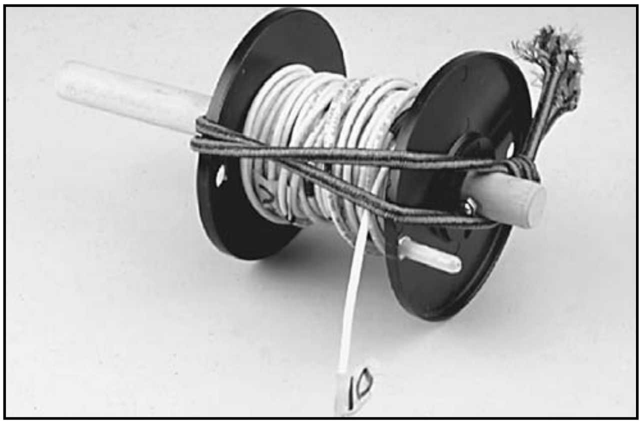

Fig 11—The wire spool has a wooden axle/handle and small handle for winding the wire. A bungee cord stretched over the spool and around the axle prevents the wire from unwinding.

Table 2

	Tubing Length (feet)	*Coil Turns*	*Wire Length (feet)*
6 meters	4	0	4
10 meters	7	0	8
	4	1.7	7
12 meters	8	0	8.3
	4	1.8	9
15 meters	10	0	10.3
	8	1.8	10
	4	3.5	10
17 meters	11	0	13
	8	2.2	13
	4	4.2	13
20 meters	11	1	16
	8	4	16
	4	6.2	16
30 meters	11	4	24
	8	7	24
	4	10.5	24
40 meters	11	9	32
	8	12	32

handle and spool axle. Bolts through the dowel on either side of the spool hold it in place. A crank handle is made by putting a one-inch-long bolt through the spool flange.

The author calibrates the wire on the spool with markers and electrical-tape flags. There's a mark (from a permanent marking pen) at each foot, a black flag every five feet and a length-marked colored flag every 10 feet. Simply mark the length for each band, if you like.

Make sure you prevent the wire from unspooling, especially when it's hanging from a window mounting. A heavy rubber band works, but it doesn't last long. A better solution is a loop of light bungee cord, preferably with a knot for grip. The bungee loop runs from the axle/handle around the spool making a half twist on the way, and then passes over the axle end on the other side of the spool. (See Fig 11.)

Operation

Table 2 lists element length, wire length and coil tap point for various bands. When the number of turns shown is zero, the coil is not needed. On all bands except 6 meters, you can simply bypass the coil with the clip lead—the extra length just lowers the frequency a bit. For 6 meters, the coil *must* be removed. The location of the unspooled wire greatly affects the settings, so these numbers are only starting points. The lengths in the table were taken with the wire one to three feet above ground, draped over and through bushes and flowerbeds. The antenna will still work if the wire is lying on the ground, but it will require less unspooled wire to resonate. A balun is not needed, and an SWR analyzer is very helpful while adjusting this antenna.

The SWR is less than 1.5:1 on all bands, and it's usually below 1.2:1. Occasionally, a band shows a higher SWR (still less than 2:1), but that can always be lowered by adjusting the length or location of the lower wire. Never set up the antenna where it could fall and injure someone, or where the unwary could get an RF burn by touching it.

The author's results with this antenna have been excellent, both from home and on vacation. If you haven't yet operated from a seashore location, be prepared for a pleasant surprise! The good ground afforded by the salt water really makes a difference.

80 Meters

It's easy to add this lower frequency band. Fig 10 shows a 35 µH coil for 80 meters. It's constructed and tightened just like the 40-meter coil, but has 20 turns of #12 magnet wire.

To operate on 75/80 meters, insert the new coil into the flagpole bracket and plug the 40-meter coil into it. Tune across the band with the movable tap on the 40-meter coil. This varies antenna resonance from below 3.5 to above 4.0 MHz, with the full 11 feet of tubing extended. If your version doesn't achieve this tuning range, adjust the spacing of the turns on the 80-meter coil.

The 80-meter coil has a five-inch length of $^3/_4$-inch aluminum tube inserted into one end of the $^1/_2$-inch PVC pipe that supports the coil form. One end of the coil is connected to this aluminum tube. The other end is secured under the bolt that holds the coil form to the PVC pipe. A second clip lead connects the base of the 40-meter coil to the outer end of the larger coil. The length of wire on the spool must also be increased to about 64 feet.

2 Meters

A λ/2 dipole for 2 meters can be made with about 15 inches of $^1/_2$-inch aluminum tubing in the flagpole bracket, and 18 inches of wire. The tubing element is shorter than normal for 2 meters because the bracket is also part of the antenna. You can also shorten the 6-meter wire a bit and operate the 6-meter antenna as a 3λ/2 on 2 meters, with a somewhat higher SWR.

Continuous Coverage

With easily changed element lengths and a continuously variable loading coil, you may operate the antenna on any frequency from 6.5 to 60 MHz, if coverage for other services is needed. With taps in the 80-meter coil at 8, 11 and 14 turns, the antenna will also tune from 4 to 7 MHz.

THE HF CABOVER ANTENNA

If you have ever had the pleasure of traveling across the country with an HF mobile in a camper, trailer or motor home you may want to duplicate this antenna for use when you park. This antenna was described in *The ARRL Antenna Compendium, Vol* 5, by Jim Ford, N6JF.

The author's camper has limited spots on which to mount an HF mobile antenna. The back ladder is a convenient place to mount a small mobile whip. However, the efficiency of typical mobile center-loaded antennas, depending on coil Q and other assumptions, is often less than 2% for 80 meters and 10% for 40 meters. (These numbers come from the excellent, easy-to-use *MOBILE* antenna design program by Leon Braskamp, AA6GL, which is on the CD-ROM bundled with this book.)

At some locations, N6JF used an 80-meter dipole, which was very efficient and worked great on all bands when fed with open-wire line and an antenna tuner. However, it took over 40 minutes to set up and about 20 minutes to tear down, working with a sling shot and many tree snags. This is too much time to make a schedule or for an early morning departure, although it's OK if you plan to stay for a while. Even more important, there were often too many trees or other barriers (perhaps some even social) to allow putting up the dipole at a campsite.

When this happened he was stuck with the mobile antenna with poor efficiency. There had to be a better antenna for camper operation. The author decided on a large vertical.

A telescoping aluminum extension pole used for roller painting would make a good bottom section for the loaded vertical. These are available at many local home supply centers. The author's was 1 inch in diameter and 6 feet long, telescoping to almost 12 feet. He disassembled both sections and cross-cut a 1-inch slot in the top of the bottom section with a hacksaw to allow compression clamping with a hose clamp. The tip of the top section was fitted with an aluminum plug that had a 3/8-24 hole tapped in it. This procedure was a simple machine-shop operation. The plug was pounded into the top section and is quite snug. He tapped some set screws through the pole into the plug, however, just to be sure. An insulated, lay-down marine antenna mount fit perfectly into the bottom of the aluminum base and was secured with a bolt that also served as the electrical connection from the capacitor matching box. See **Fig 12** showing the aluminum base plate, the laydown mount and the antenna

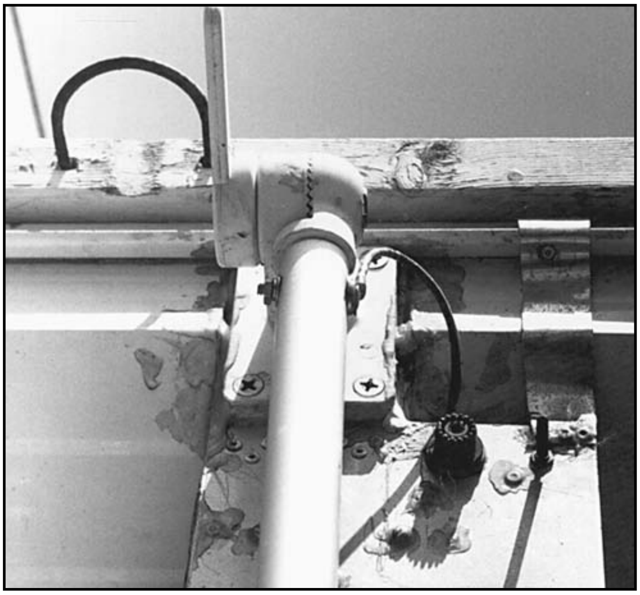

Fig 12—Photo of aluminum base plate, showing details of mounting to the camper. The four banana-plug jacks on the bottom are for extra radials, if desired.

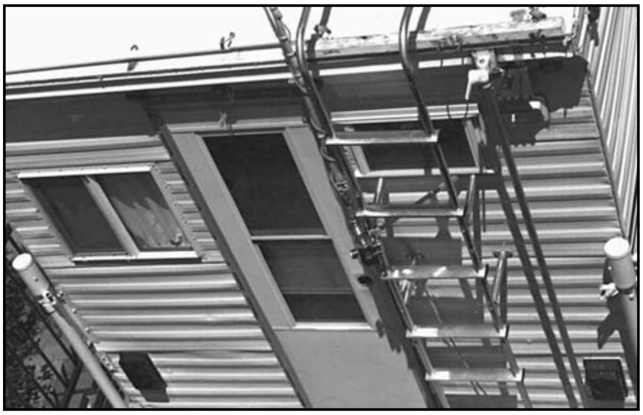

Fig 13—Photo showing the back of the camper, with the antenna in the lowered position, parallel to the ladder. The "Outback" standby mobile antenna is shown clamped to the left side of the ladder.

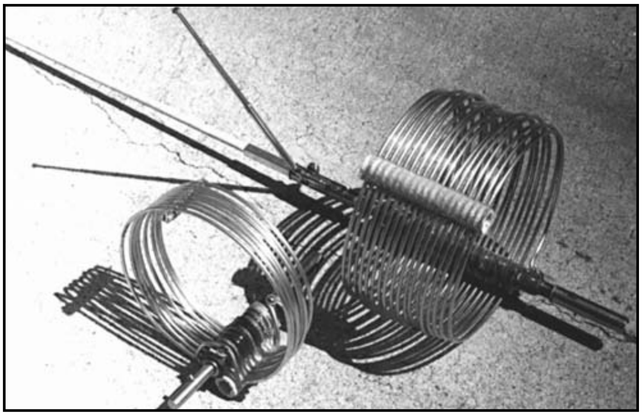

Fig 15—Close-up photo of 80 and 40-meter coils, with top section and telescoping whip antenna with swivel bracket for tuning the top section for the higher bands. Note quick-disconnect connectors at top and bottom of both coils. The top whip is a Fiberglas CB whip, used on 80 and 40 meters.

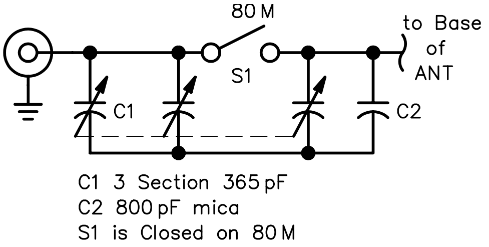

Fig 14—Schematic of tuning capacitor at base plate. C2 is an 800 pF transmitting mica capacitor. C1 is a three-section 365 pF broadcast tuning capacitor. S1 is closed for 80-meter operation.

mast itself lowered down the back of the camper. **Fig 13** shows the layout of the back of the camper, with the antenna on the right-hand side, laid down for travel.

The variable capacitor in the matching box is a surplus three-section 365-pF broadcast tuning capacitor. Two of three sections are connected in parallel and a switch parallels in the third section, along with an extra 800 pF mica capacitor for use on 80 meters. See the schematic in **Fig 14**.

The capacitor assembly was put in a custom-glued Plexiglas box to keep out the weather and mounted to a piece of plate aluminum, along with an SO-239 connector. The aluminum plate was riveted to the camper shell using a lot of aluminum rivets. Do not use steel. N6JF peeled back about a 4-inch wide section of the side of the camper for this direct aluminum-to-aluminum connection. People who are hesitant to modify their campers like this need to find an alternate low-resistance connection method. His camper was old enough not to be an issue.

For an extra low-resistance connection a $1\frac{1}{2}$-inch aluminum strip was added from the top of the base plate to the camper, as shown in Fig 12 near the 80-meter switch. The tuning knob protrudes from the side of the Plexiglas box. The four bottom holes in the plate are for banana plugs to connect ground radials if extra efficiency is desired. However, the roof of a camper is one of the better places for a mobile antenna, so the author seldom hooks up the radials. When he does use them, the tuning changes only a little.

To keep losses down, N6JF used coils wound with aluminum clothes-line wire on old mobile coil center sections with quick disconnect fittings. See **Fig 15**, which shows both the 80 and 40 meter coils, together with the top portion of the antenna. An article by Robert Johns, W3JIP, in October 1992 *QST* described techniques for building your own loading coils. The coils ended with a little more inductance than calculated and the author had to remove some turns. Both coils are spaced at 4 turns per inch. The 8-inch long 80-meter coil has 18 turns. The 7-inch long 40-meter coil has 8 turns.

The matching network is actually an L-section step-up match, using the net inductive reactance of the antenna plus the center loading coil. The PVC coil construction technique was described in W3JIP's *QST* article and a follow-up Technical Correspondence piece in October 1992 *QST*. Basically, it consists of drilling an accurate row of slightly undersized holes along a length of $\frac{1}{2}$-inch PVC pipe and then carefully sawing down the center of the row of holes with a hack saw. Then, you trap the coil wires in the grooves between the two sawed halves and tie the two halves together with string. When you are satisfied that everything is proper, you then tighten the string and apply epoxy glue to make it strong and permanent.

One advantage of aluminum clothes line wire is that it is already coiled at the approximate diameter needed when you buy it and it is easy to position on the coil form.

The clothes line wire had a plastic coating, which wasn't removed except at the contact points. Once the epoxy dries, this method of construction does a good job of holding the finished coil together and it is lightweight.

The computed coil Q from the *MOBILE* antenna program is about 800 for the 80-meter coil and about 400 for the 40-meter coil. The author accidentally made the 40-meter coil 7 inches in diameter instead of a higher-Q 6 inch diameter. Even so, the whole antenna system with a 9-foot top section calculates as being 56% efficient on 80 meters and 85% for 40 meters.

The removable top section for 80 and 40 meters is a full-size fiberglass CB whip from RadioShack. The fiberglass whip has about a #16 hole in the center of it. Be sure to sand and paint the whip for protection against UV and to protect yourself against fiberglass spurs in the hands. N6JF tried a full-size stainless steel CB whip to get a slightly higher capacitance to ground because of larger conductor size but discovered it was far too heavy. That experience reinforced his decision that aluminum was a far more practical coil and base section material for this project.

Quick-disconnect connectors found years ago at a hamfest were used for both coil forms and for the top section. Bands higher than 40 meters don't need any loading coils and the antenna length can be telescoped to get a $^1/_4$ wavelength. Ten meters doesn't require any top section. Be sure to use some NOALOX or similar compound to prevent corrosion and poor connections at all aluminum joints. This is especially true for the telescoping sections and the aluminum rivets. The matching capacitor is in the circuit at all times but when the 80-meter switch is off you can set the capacitor at minimum (about 14 pF) and it is effectively out of the circuit, even at 10 meters. The author has not tried this antenna on power levels greater than about 100 W but the weakest link would probably be the matching capacitor. The voltage at the matching capacitor is low, so 200 W should be no problem.

You can achieve a 1:1 SWR match for 80 or 40 meters and a good SWR is obtained without retuning the base matching capacitor for approximately 100 kHz on 80 meters and most of 40 meters. The top section, however, does not have such low Q and needs to be tuned. The 2:1 SWR bandwidth on 80 meters is about 25 kHz and 150 kHz for 40 meters. Tuning is accomplished by using a telescoping FM portable radio antenna connected to the top-section whip with a stainless steel hose clamp. The maximum length of the telescoping section used was 29 inches, and it collapses down to 7 inches. A whip with an elbow was used to adjust the angle of the whip as well. A telescoping whip half the length would still be long enough for the full adjustment of both bands.

Adjustment of the top section is one of the penalties paid to achieve high efficiency for operation on 80 and 40 meters. Substituting an automatic antenna tuner would likely lose efficiency, particularly on 80 meters since the base resistance calculates to about 10 Ω. N6JF has not tried to make the antenna work on 160 meters. The SWR for the higher bands was good enough without any matching network.

As light as the antenna is, it still won't hold up in a moderate wind without some support guys. N6JF used $^3/_4$-inch and $^1/_2$-inch PVC support pipes in a telescoping arrangement for storage, but expanding to give an approximate 45° support at the top of the bottom section from both directions. One end of the telescoping section was connected to the camper roof with a hinge. The other end formed a snap-fit out of a PVC barrel that was cut lengthwise. See **Fig 16** and **Fig 17** for details. Even though it formed a good snap fit, N6JF didn't trust the joint for strong winds so he glued a piece of Velcro to the joint to close up the open end. Be careful, though, because Velcro deteriorates with exposure.

Another hose clamp near the top of the bottom section holds an $^1/_8$-inch line taken up the ladder to pull up the antenna without the need of an assistant. The disadvantage is you have to climb the roof. Use a non-slip floor mat or something similar to spread the load on the roof and to avoid slipping. Once on the roof, however, the coil is at a height for easy adjustment when the telescoping section is in the down position.

An advantage of being able to assemble the whole antenna on the roof is that you don't need a lot of swing-up room and you can clear trees easily. You can put calibration marks on the upper aluminum section for resonant lengths on the higher bands but just raise the top section up all the way for 80 or 40 meters. Mark also the small

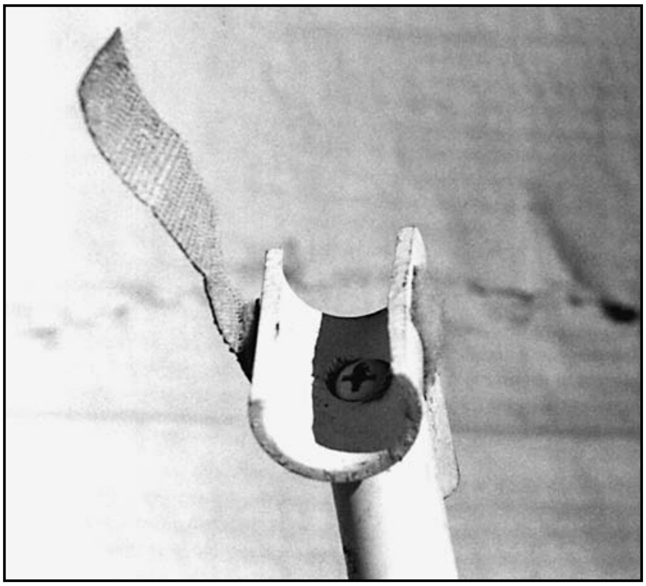

Fig 16—Close-up of one of the snap-on support brackets used to brace the antenna. Note the Velcro pieces used to ensure that the antenna doesn't pop out of the bracket in the wind.

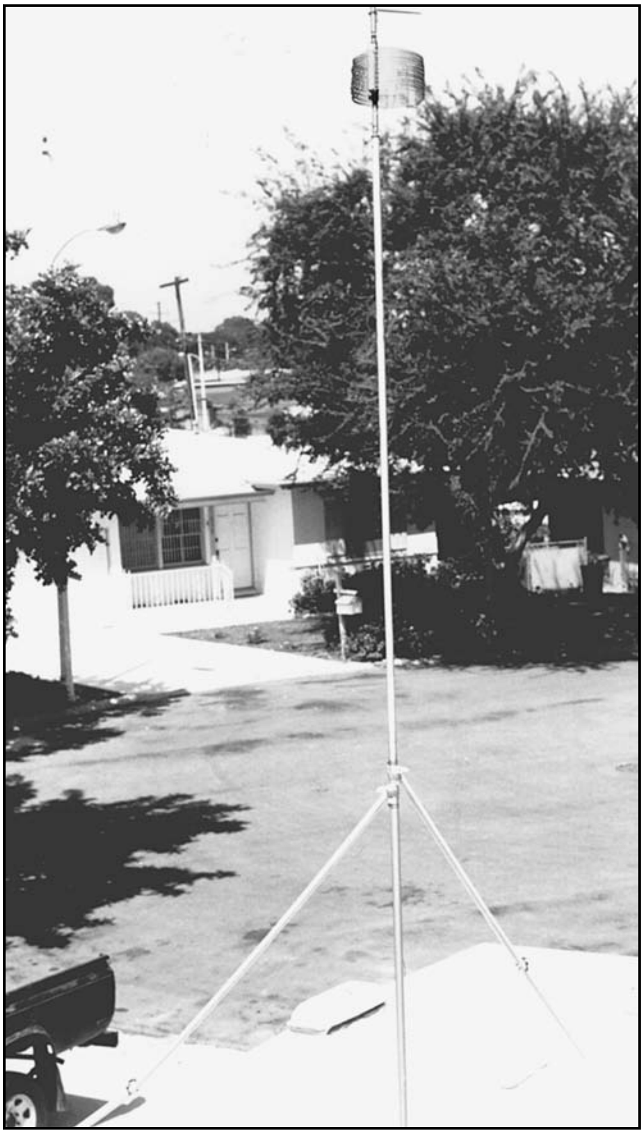

Fig 17—Photo showing the two support bracket poles bracing the bottom section of the antenna. The top tuning whip is evident above the homemade loading coil at the top of the bottom section.

coil tuning whip for 80 or 40 meters, although different locations may require slightly different settings due to detuning from nearby metal objects.

The overall length is about 21 feet. The top of the author's camper is about 10 feet high when on the truck, putting the tip at 31 feet. This antenna is definitely designed for use when you are parked at a fixed location. N6JF can put up this antenna in less than 5 minutes and can take it down in half the time. The success of this project has as much to do with knowing how and where you operate as it does paying attention to mechanical and electrical details. The antenna has been a good compromise between efficiency and convenience.

TWO PORTABLE 6-METER ANTENNAS

These antennas were described by Markus Hansen, VE7CA, in *The ARRL Antenna Compendium, Vol 5*. After years of HF operation, he became enthusiastic about VHF/UHF operation when he found a used Yaesu FT-726R VHF/UHF all-mode transceiver at a reasonable price.

But he became really enthused when he got on 6 meters and discovered the joys of driving to high mountain peaks to operate. Not only does an antenna have to be portable for this kind of operation, it must be easily assembled and disassembled, just in case you have to move quickly to a better location.

A Portable Two-Element Six-Meter Quad

VE7CA's primary objective was to construct a two-element quad using material found in any small town. It should not use a complicated matching network. The Gamma matches commonly used on quads do not hold up well when you are setting up and taking down these antennas in the field. The final design adjusted the distance between the driven and the reflector elements so that the intrinsic feed-point impedance was 50 Ω.

Fig 18 shows the dimensions for the boom and the boom-to-mast bracket. The boom is made from a 27$^1/_4$-inch length of 2 × 2. (The actual dimension of 2 × 2 is closer to 1$^3/_4$ by 1$^3/_4$ inches but it is commonly known in lumber yards as a 2 × 2.) Use whatever material is available in your area, but lightweight wood is preferred, so clear cedar or pine is ideal. Drill the four $^1/_2$-inch holes for the spreaders with a wood bit, two at each end, through one of the faces of the 2 × 2 and the other through the other face. The boom-to-mast bracket is made from $^1/_4$-inch fir plywood.

The spreaders are $^1/_2$-inch dowel. The local lumberyard had a good supply of fir dowels but other species of wood are available. The exact material is not important. Maple is stronger but expensive. Fiberglass would be ideal but it is not always available locally. Cut two of the $^1/_2$-inch dowels to a length of 83$^5/_8$ inches for the driven element spreaders and two to 88 inches for the reflector spreaders. **Fig 19** shows one end of the boom with the two spreaders inserted. The mast was made from two six-foot lengths of 1$^3/_4$-inch fir dowel. Again, use whatever you may have available. Waterproof all wooden parts with at least two coats of exterior varnish.

While you are at the lumberyard or hardware store look for plastic pipe that fits over the end of the $^1/_2$-inch spreaders. You will need a one-foot length, with some to spare. Cut it into seven equal lengths, approximately one inch long, and one to a length of 1$^1/_2$ inches. Drill a $^1/_{16}$-inch hole through the seven equal lengths $^1/_4$ inch from the ends, and two holes one above the other $^1/_4$-inch apart on the 1$^1/_2$-inch sleeve. VE7CA used #14 hard-drawn stranded bare copper wire for the elements. Do not use insulated wire unless you are willing to experimentally

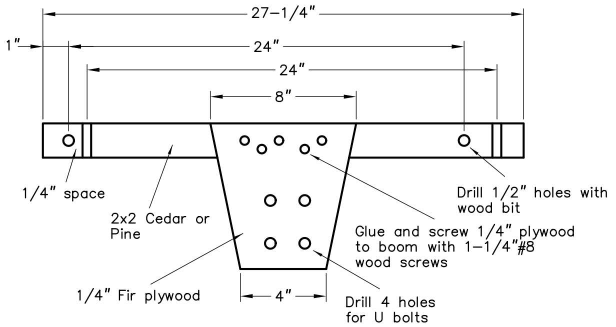
27-1/4"
1"
24"
24"
8"
1/4" space
2x2 Cedar or Pine
Drill 1/2" holes with wood bit
Glue and screw 1/4" plywood to boom with 1-1/4"#8 wood screws
1/4" Fir plywood
4"
Drill 4 holes for U bolts

Fig 18—Dimensions for the boom-to-mast bracket for VE7CA's portable two-element 6-meter quad.

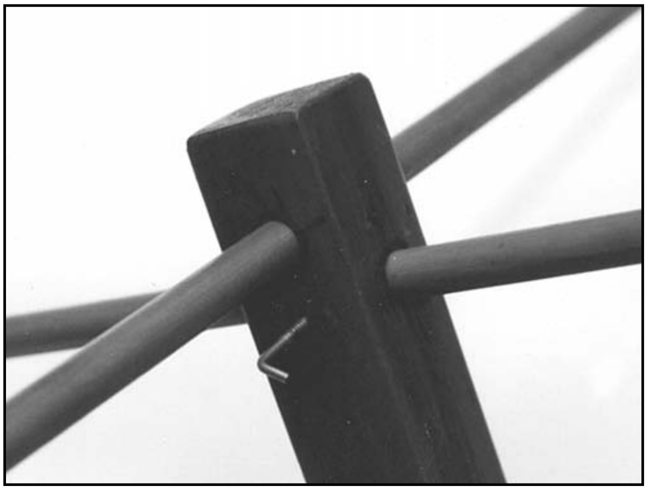

Fig 19—Photo of one end of the VE7CA quad with the two spreaders inserted.

determine the element lengths, since the insulation detunes each element slightly.

Cut the reflector element 251 inches long and slip one end of the wire through the holes you drilled in four of the plastic sleeves. Don't attempt to secure the wire to the plastic sleeves at this point. Cross the end of the reflector elements one inch from their respective ends and twist and solder together. The total circumference of the reflector element should be 249 inches when the ends are connected together.

Cut the driven element wire to 241 inches and slip three of the 1-inch sleeves onto the wire. Again, don't secure the wires to the sleeves yet. Then the ends are passed through the two holes in the $1\frac{1}{2}$-inch pipe. Wrap the ends around the pipe and twist them back onto themselves to secure the wire. The coax feed line is attached directly to the two ends at this point. The circumference of the driven-element loop from the points where the coax is attached should be $236\frac{5}{8}$ inches. Solder the coax feed line to the driven element and waterproof the coax with silicone seal. The author used RG-58, as it is lightweight. The length required for a portable installation is typically not very long, maybe 20 feet, so the loss in the small cable is not excessive. Near the feed point, coil the coax into six turns with an inside diameter of two inches. This is an effective method of choking any RF from flowing on the outside of the coax shield.

Begin assembling the quad by pushing the two reflector spreaders, without wires attached, through one end of the boom and the two shorter driven-element spreaders through the holes in the other end of the boom. Center the spreaders and mark the spreaders with a black felt-tip pen next to the boom. Now insert a $1\frac{1}{2}$ #8 wood screw or a threaded L-hook into the boom so that it just touches one of the spreaders. Take the screw or L-hook out and file the end flat, then reinsert it so that it is just snug against the spreaders. The author only used two L-hooks for the two vertical spreaders; the horizontal spreaders are held in the proper position by the tension of the wire loops. If you use an L-hook, you can unscrew it with your hands—you won't have to worry about leaving the screwdriver at home.

You are now ready to assemble the wire loops. Take the reflector loop and place the four plastic caps over the ends of the reflector spreaders. Equalize the wire lengths between the spreader so that the loop is square. Now, secure the plastic sleeve pipes by tightly wrapping wire around the sleeve and the wire element and soldering the wire in place. See **Fig 20**, a photo showing one of the plastic sleeves slipped over one of the spreader ends, with the wire element through the hole and fastened in place. Follow the same procedure with the driven element.

Fig 21 shows the quad's boom, with the plywood boom-to-mast bracket fastened with wood screws and glue. Two U-bolts are used to attach to the mast. When the quad is raised, the shape of the loop is commonly known as a diamond configuration. The mast consists of two six-foot lengths of doweling joined together with a two-foot length of PVC plastic pipe, held together with wood screws.

Make a slot the width of a #8 wood screw about one inch deep from the top of the plastic PVC pipe and then put the top mast into the plastic pipe. Insert a one inch #8 wood screw into the bottom of the slot you cut into the top of the pipe and tighten only enough so that the top mast can be removed without unscrewing it. VE7CA drove a nail into the end of the lower mast and left it exposed an inch or more. This end is placed in the ground and the nail holds the pole in place. A strip of wood approximately 1 × 3 and long enough to cross over the roof rack of the family van is used to hold the center of the antenna mast to the roof rack of the van with small diameter rope. See **Fig 22** for a photo of the quad in action next to the family van.

To disassemble the quad, lay it on its side, slip the plastic sleeves off the ends of the spreaders and roll up

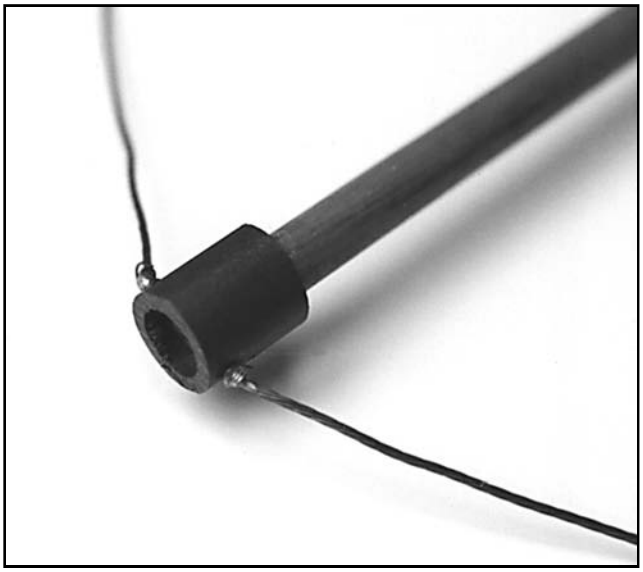

Fig 20—Photo showing one of the plastic sleeves slipped over end of a spreader to provide a mechanical mounting point and support for the wires.

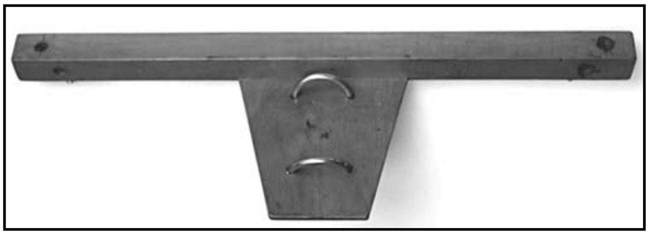

Fig 21—Photo of the two-element quad's boom, with the plywood boom-to-mast bracket secured with wood screws and glue.

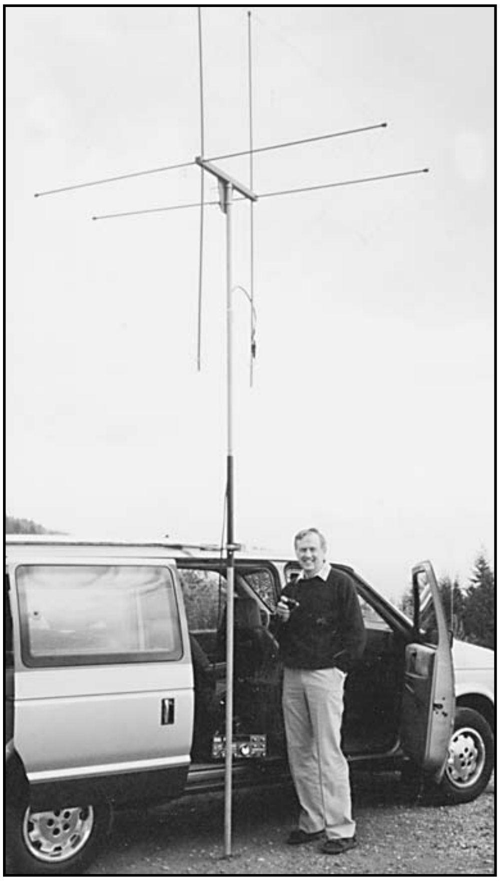

Fig 22—Ready for action! VE7CA has set up his quad next to the family van.

the wire loops. Loosen the L-hooks holding the vertical spreaders in place. Push the spreaders out of the boom, loosen the U-bolts and free the mast from the boom.

That is all there is to it. It takes about two minutes to put it up, or take it down. It is quite sturdy and has survived several high-wind storms.

A Three-Element Portable 6-Meter Yagi

The idea to build a Yagi antenna resulted when the author traded the family van for a compact car. He needed something that would fit into the trunk of the car. At close to 7-feet long, the quad spreaders were too long. Computer modeling showed that a three-element Yagi on a five-foot boom also could pick up about 1.5 dB gain over the short-boom two-element quad. A five-foot boom fits into the trunk or across the back seat of the car, but something had to be done about the nine-foot elements!

One day VE7CA noticed a box of portable-radio telescoping antenna elements at the radio parts store. They were 54 inches long when fully extended. He next found a 60-inch length of aluminum tubing that fit over the end of the telescoping elements. There are many different sizes of telescoping antenna elements, with different diameters. This is where you will have to use your scrounging skills! **Fig 23** shows how the tubing is used as a center section to join two telescoping elements together. It also serves to extend the total length of each element, since two telescoping elements themselves are not long enough to resonate on six meters. See **Table 3** for dimensions and element spacings. Each center section is slotted at both ends with a hacksaw, and stainless-steel hose clamps are used to secure the telescoping elements.

Fig 24 shows the center sections of the three elements with their mounting brackets. A square boom was used to obtain a flat surface to work with. **Fig 25** shows how the reflector is attached to the end of the boom with two $1^1/_2$-inch 10-32 bolts and wingnuts. **Fig 26A** provides the dimensions and details for the reflector and director element-to-boom brackets, which are formed from $^1/_{16}$-inch plate aluminum. The driven element is split in the center and is insulated from the boom. Fig 26B shows details for the driven-element bracket. **Fig 27** is a photo

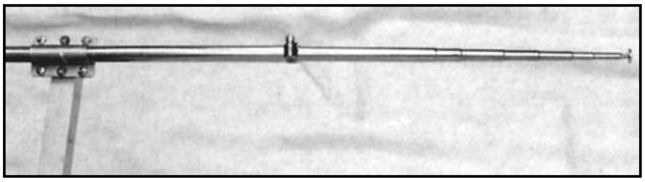

Fig 23—Photo showing a piece of aluminum tubing used as a center section to join the two telescoping tips together.

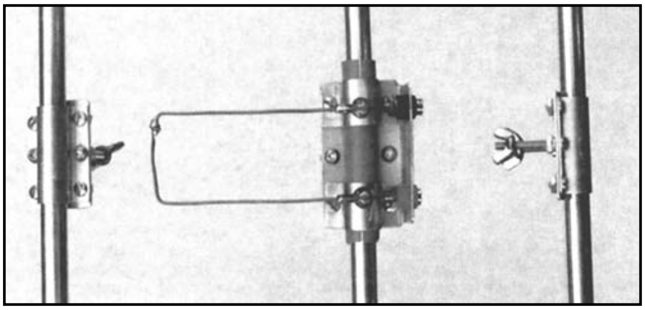

Fig 24—A view of the center sections of the three Yagi elements with their mounting brackets.

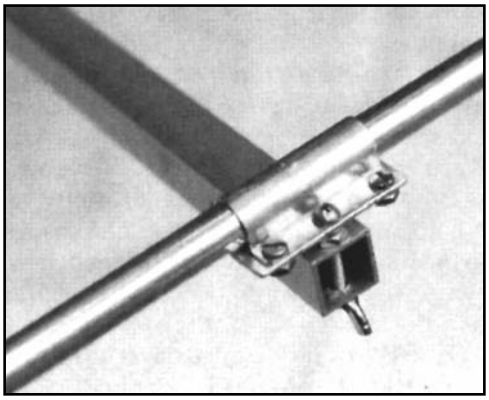

Fig 25—Photo detailing attachment of the reflector to the square-section boom, using two #10 bolts and wingnuts.

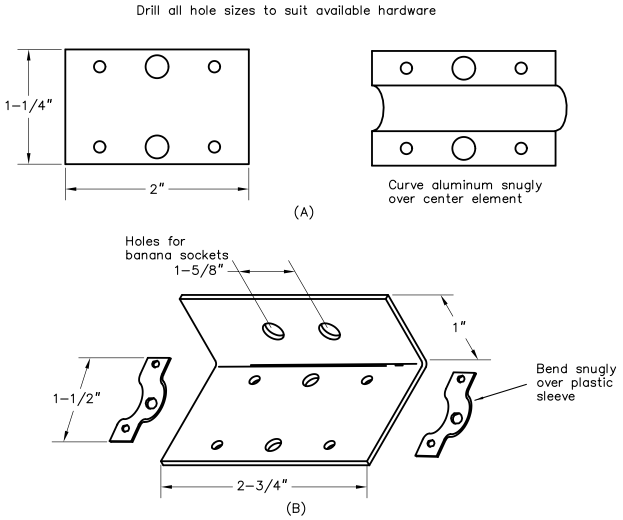
Drill all hole sizes to suit available hardware
1-1/4"
2"
Curve aluminum snugly over center element
(A)
Holes for banana sockets
1-5/8"
1"
1-1/2"
Bend snugly over plastic sleeve
2-3/4"
(B)

Fig 26—At A, details for the reflector and director element-to-boom brackets, made of $^1/_{16}$-inch plate aluminum. At B, details for the driven-element bracket. These are screwed to the square boom.

of the driven element with the hairpin matching wire and the banana plugs used to connect the coax to the driven element. You could use a female PL-259 connector if you wish. VE7CA used #14 solid bare copper wire for the hairpin. It is very durable—even after being severely warped in the car trunk, it can be bent back into shape quickly and easily.

The boom is $^3/_4$-inch square aluminum, 65 inches long. The material was found at a local hardware store. To detach the elements, just loosen the wing nuts and remove the elements from the boom. A similar method was used to attach the support mast to the boom.

As with the quad, a choke balun was used, consisting of a coil of 6 turns of coax with an inside diameter of 2 inches. To tune the hairpin match, assemble the Yagi on its mast and extend the elements. Spray switch contact solution on a cloth and wipe any dirt and grease from the elements. Push the elements together and apart a

Table 3

Three-Element Yagi, Element Lengths and Spacing Along the Boom, and Hairpin Dimensions

Element Along Boom	Spacing Section Ele. (inches)	Center Length (inches)	Telescoping (inches)	Total Length (inches)
Reflector	0	$22\,^3/_4$	$51\,^1/_2$	$125\,^3/_4$
Driven	28	$9\,^3/_4$ *	$48\,^5/_8$	$58\,^3/_{16}$
Director	$63\,^3/_8$	$14\,^1/_2$	$51\,^1/_4$	117
Hairpin	#14 wire	4 long	$1\,^5/_8$ spacing	

* Driven-element uses 2 sections insulated at center

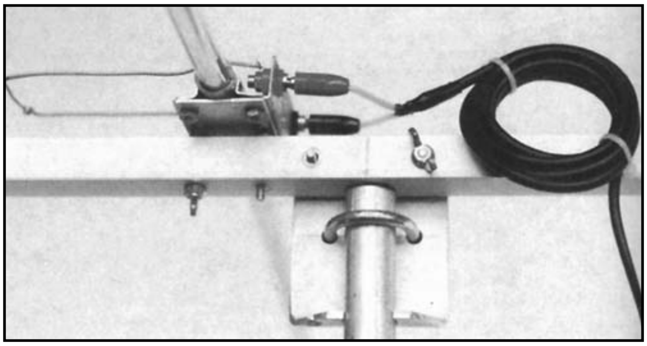

Fig 27—Photo of the driven element, complete with hairpin match and the banana plugs used to connect the coax cable to the driven element.

couple of times so that the contact solution cleans the elements thoroughly. Attach the antenna mast to your vehicle or use whatever method of support you intend to use in the field. Connect an SWR meter and a transmitter to the coax feeding the antenna. VE7CA used two alligator clips soldered together to slide along the two hairpin wires to find the position for the lowest SWR. The dimensions computed by computer were correct! The SWR was below 1.16:1 from 50.05 to 50.2 MHz.

You can take this antenna out of the trunk of the car and assemble it in less than two minutes. One caution: the telescoping elements when fully extended are quite fragile. VE7CA has not broken one as yet, but carrying a spare element just in case would be a good idea.

VE7CA 2-Element Portable HF Triband Yagis

These portable HF wire Yagis were described by Markus Hansen, VE7CA, in November 2001 *QST* and in *The ARRL Antenna Compendium, Vol 7*.

A 20/15/10-Meter Triband 2-Element Yagi

VE7CA wanted a simple 2-element wire Yagi for 20/15/10 meters that could be stored in the ski boot of his car. The basic concept comprises three individual dipole driven elements, one each for 20, 15 and for 10 meters tied to a common feed point, plus three separate reflector elements. The elements are strung between two 2.13-meter (7-foot) long, 2 × 2-inch wood spreaders, each just long enough to fit into the ski boot of his car.

By playing with the reflector-to-driven element spacing and the initial driven-element lengths, VE7CA was able to come up with a feed-point impedance on each band that allowed the use of a single setting for the shorting bar on a hairpin match. The result was a very acceptable match over the lower portions of each band. The layout of the 20/15/10-meter triband wire Yagi is shown in **Fig 28**, with the dimensions provided in **Table 4**.

The dimensions shown in Table 4 are what resulted after tuning for the lowest SWR in the middle of the lower portion of each band. VE7CA set his system up by hanging one end of the antenna from a tree and sloped it downwards at 45º, tying the lower end to a peg in the ground. The height at the feed point was 30 feet.

The feed-point impedance of an antenna is affected by many environmental factors. The presence of a reflector relatively close to the driven element has a major effect, since the impedance at the driven element in a Yagi is affected by the tuning of the driven element itself, by the spacing and length of the reflector element and to a lesser extent the height of the antenna above ground and the character of the soil itself. The real challenge in a multiband Yagi with a single feed line is to obtain a low SWR on all the bands.

The hairpin match is one of the easiest matching systems to make. It is easy to adjust and since wire is the only ingredient, it can be coiled up with the rest of the antenna when the antenna is disassembled. The feed-point impedance of the Yagi with a reflector element spaced 0.1 λ behind the driven element typically produces a resistance around 20 Ω. By shortening the driven element from its resonant length, capacitive reactance is added to the feed-point resistance. This can be cancelled by shunting the feed point with an inductor in the shape of a wire loop resembling a *hairpin*. This causes a step up of the 20-Ω feed-point resistance to 50 Ω.

Table 4
Dimensions for 20/15/10-Meter Tribander

Frequency MHz	*Spacing DE to Refl cm (feet)*	*Driven Element Half Length cm (feet)*	*Reflector Length cm (feet)*	*Hairpin Length cm (inches)*
14.1	213 (6.99)	488 (16.01)	1065 (34.94)	43 (14.9)
21.1	175 (5.74)	335 (10.99)	708 (23.23)	
28.25	125 (4.1)	254 (8.33)	531 (17.42)	

Spacing between hairpin wires is 10 cm (4 inches).

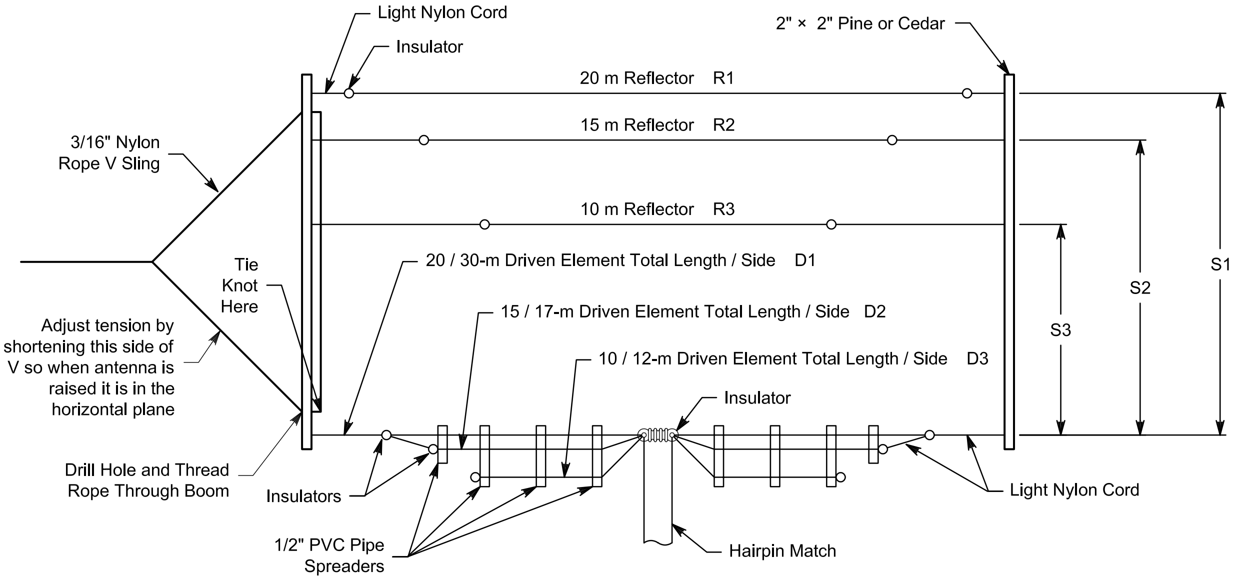
Light Nylon Cord
Insulator
2" × 2" Pine or Cedar
20 m Reflector R1
15 m Reflector R2
3/16" Nylon Rope V Sling
10 m Reflector R3
20 / 30-m Driven Element Total Length / Side D1
Tie Knot Here
15 / 17-m Driven Element Total Length / Side D2
Adjust tension by shortening this side of V so when antenna is raised it is in the horizontal plane
10 / 12-m Driven Element Total Length / Side D3
Insulator
S1
S2
S3
Drill Hole and Thread Rope Through Boom
Insulators
Light Nylon Cord
1/2" PVC Pipe Spreaders
Hairpin Match

Fig 28—Dimensions for VE7CA's 2-element 20/15/10-meter triband Yagi.

The Balun

Fig 29 shows the hairpin match and the common-mode choke balun for the 10/15/20-meter triband wire Yagi. You should let the coax drop straight down from the center insulator and attach it to the center of the hairpin shorting bar. Continue by making a coil using the coax of 8 turns, with a diameter of about 4 inches. This balun will choke off RF flowing along the outside of the coax shield that would otherwise distort the radiation pattern of the antenna. The center of the shorting bar is at a neutral potential, so there is no harm in attaching the coax feed line at that point.

Flattop or Tilted?

If DX is your main interest, then you want to tilt the antenna towards the vertical to emphasize the lower elevation angles. Remember that the radiation pattern is quite dependent on ground conductivity and dielectric constant for a vertically polarized antenna. A location close to saltwater will yield the highest gain and the lowest radiation angle. With very poor soil in the near and far field, the peak radiation angle will be higher and the gain less.

VE7CA has had numerous opportunities to test this out while operating portable at his favorite location. Using two trees as supports he can pull the antenna to horizontal with the feed line about 7 meters above the ground. In this position, with 20 meters open to Europe, he found it difficult to work DX on CW with 3 W of output power. However, when he changed the slope of the antenna so that it is nearly vertical he not only heard more DX stations, but he found it relatively easy to work DX. The sloping antenna always performs much better for working DX than a low horizontal antenna.

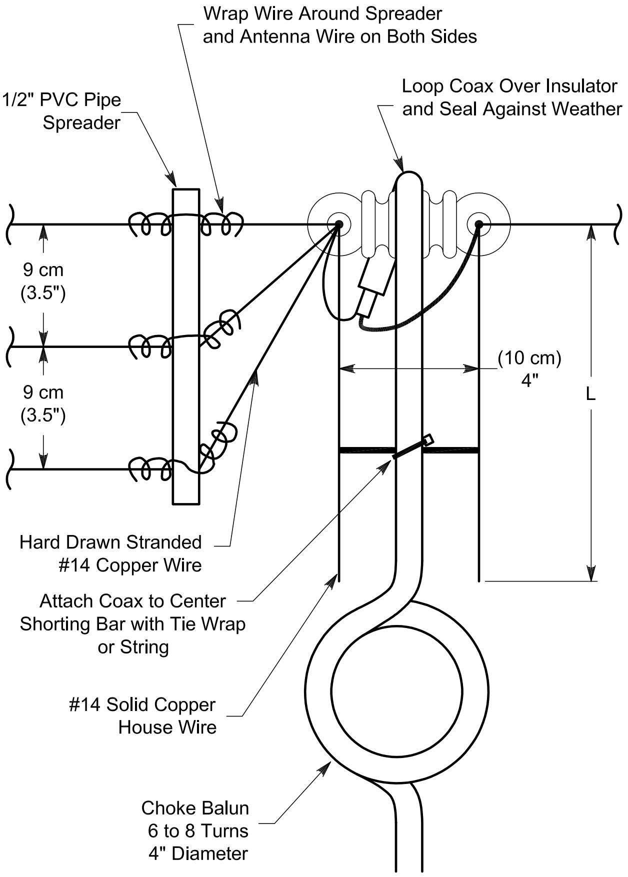
Wrap Wire Around Spreader and Antenna Wire on Both Sides
Loop Coax Over Insulator and Seal Against Weather
1/2" PVC Pipe Spreader
9 cm (3.5")
9 cm (3.5")
(10 cm) 4"
L
Hard Drawn Stranded #14 Copper Wire
Attach Coax to Center Shorting Bar with Tie Wrap or String
#14 Solid Copper House Wire
Choke Balun 6 to 8 Turns 4" Diameter

Fig 29—Details of feed point for 20/15/10-meter triband Yagi. The same mechanical support is provided for the balun and feed coax for the 30/17/12-meter tribander.

A 30/17/12-Meter Triband 2-Element Yagi

When the author attempted to add 17 and 12 meter elements to the existing 20/15/10-meter Yagi model he became exasperated. Adding two more driven elements and reflectors brings many more variables into the equation! It became clear that there was serious interaction between the elements. He could not obtain a workable feed-point impedance on all five bands that could be transformed to 50 Ω using a single hairpin match. There was also serious pattern distortion on 12 meters.

Even building a WARC-only triband Yagi for 30/17/12 meters turned out to be a real challenge. VE7CA had difficulty finding a combination that would allow him to use a single matching system to transform the feed-point impedance of the combined driven elements to 50 Ω. He couldn't create a 30/17/12 triband Yagi using the same design principles as his 20/15/10-meter version. The main problem occurred on 12 meters. Not only was the feed-point impedance unmanageable, but the radiation pattern had four lobes, not the single lobe you'd like from a Yagi.

He decided to try the *Modified Coaxial-Sleeve* method, more aptly termed by K9AY the *Coupled-Resonator (C-R)* in his article in *The ARRL Antenna Compendium, Vol 5*. The K9AY method uses a single driven element, with other elements placed in very close proximity (but not physically connected) to the driven element. By starting with the dimensions suggested by K9AY for a triband 30/17/12-meter dipole, VE7CA was able to develop a 2-element Yagi with acceptable feed-point impedances on all three bands using a single hairpin match. Notice that this WARC design uses a 2 × 2-inch wooden boom length that is 230 cm (7.5 feet) long. Of course, the antenna can't fit into a typical ski boot anymore, so VE7CA had to put it on a roof rack for transportation.

The space between the tightly coupled driven elements is only 3.7 cm (1.5 inches), so you need to use more PVC pipe spreaders than in the 20/15/10 design to make sure the driven-element wires stay as close as possible to the desired spacing without physically touching each other. The driven elements lie in the horizontal plane and the hairpin match and feed line hang down vertically from the center of the 30-meter driven element.

The spacing between the 30-meter driven elements and the other two conductors and the size of the wire all played a part in developing this antenna for a single feed line with the common hairpin match. Do not change the wire size from the recommended #14 for the driven elements unless you are willing to spend a considerable amount of time with a *NEC*-based modeling program retweaking the antenna. This is not the case with the 20/15/10 tri-band Yagi, where any convenient sized wire is acceptable.

Using #14 gauge wire allows all the Yagi antennas in this article to be used at the maximum power levels allowed in North America. The only limiting factor is the power handling capability of the feed line. However, even RG-58 should work for the relatively short length from the feed point down to ground level, where you can change to RG-8 or some other higher-power, lower-loss coaxial cable if you wish. **Fig 30** is a detailed drawing of the 30/17/12-meter driven element. The other dimensions for the 30/17/12-meter triband Yagi are shown in **Table 5**.

Assembly

When you are ready to assemble your wire Yagi, start by attaching the longest reflector element and the driven element assembly to the wood end booms. Do this with the wires and the booms on the ground. Next attach the V slings to both of the booms and with ropes attached to the V slings pull the array up off the ground between two supports (perhaps two trees). A height of 1.5 meters (5 feet) above the ground makes it easy to work on the antenna while you add the other reflector elements and adjust the V slings. Pull them tight so that the array is fairly flat. It won't stay horizontal, because the driven elements are heavier than a single reflector element. So you will need to support the 2 × 2-inch spreaders so they are horizontal. Lean the booms on something at a convenient height, such as the rungs of two step ladders. Now add the two other reflector elements, but don't pull them as tight as the longest reflector. Next attach the feed line.

Table 5
Dimensions for 30/17/12-Meter Tribander

Frequency MHz	*Spacing DE to Refl cm (feet)*	*Driven Element Length cm (feet)*	*Reflector Length cm (feet)*	*Hairpin Length cm (inches)*
10.12	230 (7.5)	713 (23.4) Half	1476 (48.4)	24.5 (9.5)
18.11	165 (5.4)	808 (26.5)	822 (27.0)	
24.91	120 (3.9)	570 (18.7)	606 (19.9)	

Spacing between hairpin wires is 10 cm (4 inches). Note that dimensions for 17 and 12-meter driven elements are full lengths, since they are not broken with insulator in the middle, unlike all driven elements for 20/15/10-meter triband design in Table 4.

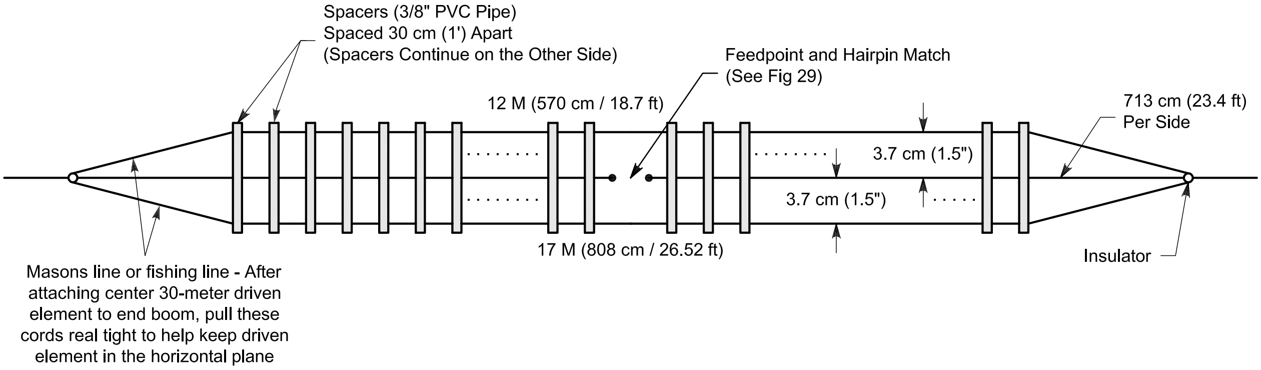
Spacers (3/8" PVC Pipe)
Spaced 30 cm (1') Apart
(Spacers Continue on the Other Side)
Feedpoint and Hairpin Match
(See Fig 29)
12 M (570 cm / 18.7 ft)
713 cm (23.4 ft)
Per Side
3.7 cm (1.5")
3.7 cm (1.5")
17 M (808 cm / 26.52 ft)
Insulator
Masons line or fishing line - After attaching center 30-meter driven element to end boom, pull these cords real tight to help keep driven element in the horizontal plane

Fig 30—Layout of 30-meter driven element with coupled resonators for 17 and 12 meters.

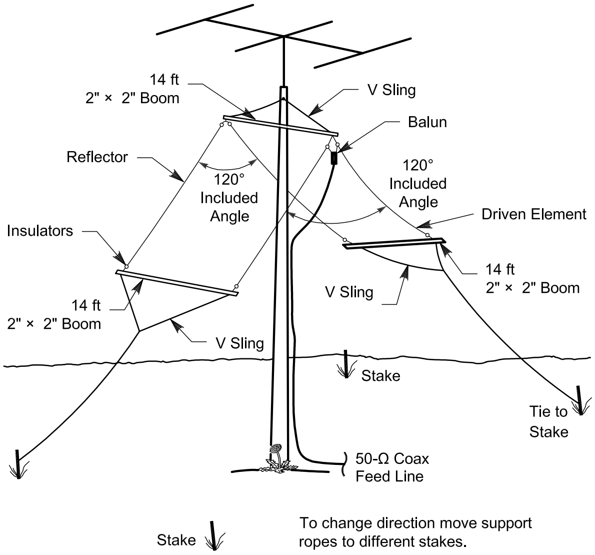
14 ft
2" × 2" Boom
V Sling
Balun
Reflector
120°
Included
Angle
120°
Included
Angle
Driven Element
Insulators
14 ft
2" × 2" Boom
V Sling
14 ft
2" × 2" Boom
V Sling
Stake
Tie to
Stake
50-Ω Coax
Feed Line
Stake
To change direction move support ropes to different stakes.

Fig 31—Layout for inverted-V 40-meter portable wire Yagi suspended from tower.

V Slings

Since the author wanted to be able to raise the 30/17/12-meter triband antenna by himself, he again used only one rope on either end of the array. One end goes over a tree limb and the other end is tied to a stake in the ground or some other nearby support, perhaps a tree trunk. Using only one attachment rope on either end makes it very easy to change beam direction by walking the antenna around the antenna support tree or tower. To accomplish this he used two V slings, one on each end attached to the 2 × 2-inch spreaders.

The secret to keeping the antenna level in the horizontal plane is that the V slings are not equilateral in shape. The combined weight of driven elements, balun and feed line is heavier than the reflectors. If the length of the sides of the V are equal, the array will rotate downwards. The driven elements will end up facing the ground, with the reflectors facing up. Adjust the V slings so that the antenna will stay level in the horizontal plane by shortening the length of the side of the V attached to the driven elements. It is quite easy to adjust in the field, and once you have it adjusted it stays balanced.

Once you raise the antenna to its operating position and in the horizontal plane, you can change direction 180° by pulling on the feed line. As you pull, the whole array will slowly turn over. Stop it from turning by holding onto the feed line once the array has swung over to face the opposite direction.

SWR Adjustment

Since you may situate your antenna in an entirely different position than VE7CA did, you may need to fine tune your antenna. Begin with the dimensions in Table 5 as a starting point. Make a temporary shorting bar using two alligator clips joined by a piece of wire and attach them at the recommended position. Next raise the antenna to the desired final position. Using an antenna analyzer (or transmitter and SWR meter) plot the SWR over all three bands. Start with the lowest band, 30 meters and adjust the shorting bar up or down to find the lowest SWR point in the portion of the band you plan to operate in. (This procedure also works if you wish to adjust the 20/15/10-meter tribander. Start with the lowest frequency.)

You shouldn't have to move the shorting bar very far from the suggested length. Now that you have determined the right shorting-bar position, adjust the other two driven element lengths for the lowest SWR in the portion of those bands in which you plan to operate. You may have to compromise with the position of the shorting bar to find a satisfactory range where the SWR is acceptable on all three bands. After satisfying himself with the position of the shorting bar, VE7CA replaced the alligator clips simply by folding one side of the parallel hair-pin wire lengths over to the other side and soldering it in the position where the alligator clips had been attached. The author does not recommend changing the reflector element lengths unless you are familiar with antenna modeling programs and are willing to model different spacing or element lengths.

40-Meter Wire Yagis

After his November 2001 *QST* article, VE7CA received several requests for a 40-meter wire Yagi. One ham mentioned that he wanted to be able to pull up a 40-meter Yagi between two towers and to be able to flip it over to change direction. Another wanted a 40-meter Yagi he could pull up on a single tower for the winter DX contests and then put it away during the summer. So VE7CA ran four different 40-meter scenarios in his computer models:

1. A horizontal 2-element wire Yagi at 65 feet.
2. A sloping 2-element wire Yagi, with one end at 65 feet and sloping downward 30° from vertical.
3. A sloping 2-element wire Yagi, with one end at 65 feet and sloping downward 65° from vertical.
4. An inverted-V 2-element wire Yagi with the apex at 65 feet and an included angle between the wires of 120°.

Fig 31 shows the layout for an inverted-V system and **Table 6** lists the element and hairpin lengths. Elevation patterns for the 40 meter antennas are compared in **Fig 32**, with a reference antenna of a single flattop dipole at 65 feet. As they say, a picture is worth a thousand words. If your interest is DX, it is very clear that horizontal and high is a very good rule of thumb for most antennas.

Yes, a $^{1}/_{4}$ wave vertical over salt water or 120 $^{1}/_{4}$-wave radials over good ground will produce very low radiation angles, but such systems are not exactly portable and we don't all live near the ocean. Mind you, if you can manage to locate antenna Number 3 (the most vertically oriented wire Yagi) next to the ocean, you would be very happy.

The point here is that if you have two towers and you're not fortunate enough to be located on a saltwater marsh, you should pull the 40-meter array up as high and as horizontal as you can. If you have only one tower and don't need to change direction often, then try the inverted-V configuration. You can still change the direction by walking each end around the tower.

However, even the sloping 40-meter Yagi with one end at 65 feet up a tower (or tree) and the other end attached with a long rope as far as possible from the tower will still put out a very respectable signal. It is directional, and you can walk it around the tower to change direction or you can

Table 6
40-Meter Wire Yagi Configurations

Configuration	*Driven Element cm (feet)*	*Reflector cm (feet)*	*Hairpin Length cm (feet)*
1. Horizontal	1978 (64.90)	2098 (68.83)	Approx 50 cm
2. –30° Sloper	1978 (64.90)	2113 (69.32)	(22 inches)
3. –65° Sloper	1978 (64.90)	2101 (68.93)	
4. Inverted V	2040 (66.93)	2126 (69.75)	

Spacing between driven element and reflector is 427 cm (14 feet). Spacing between parallel hairpin wires is 10 cm (4 inches). The lengths shown above are the total wire length for each element.

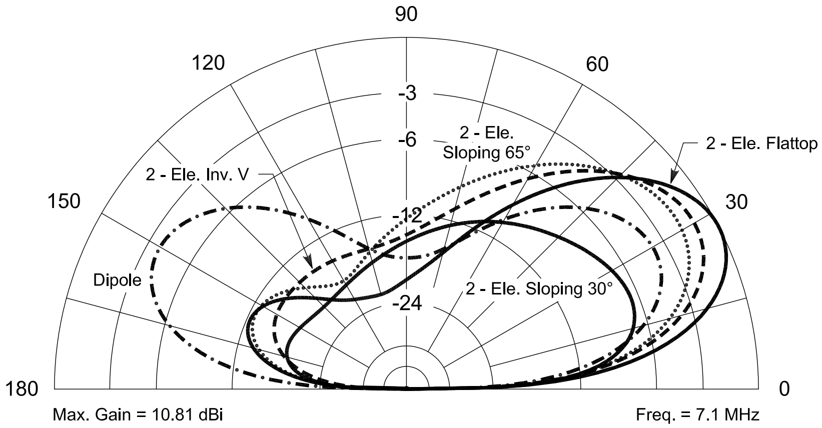

Fig 32—Comparisons of elevation patterns for five 40-meter antennas: a 2-element flattop Yagi at 65 feet; a 2-element inverted-V Yagi at 65 feet; a 2-element Yagi sloped 65° from the vertical plane; a 2-element Yagi sloped 30° from the vertical plane; and a horizontal dipole at 65 feet.

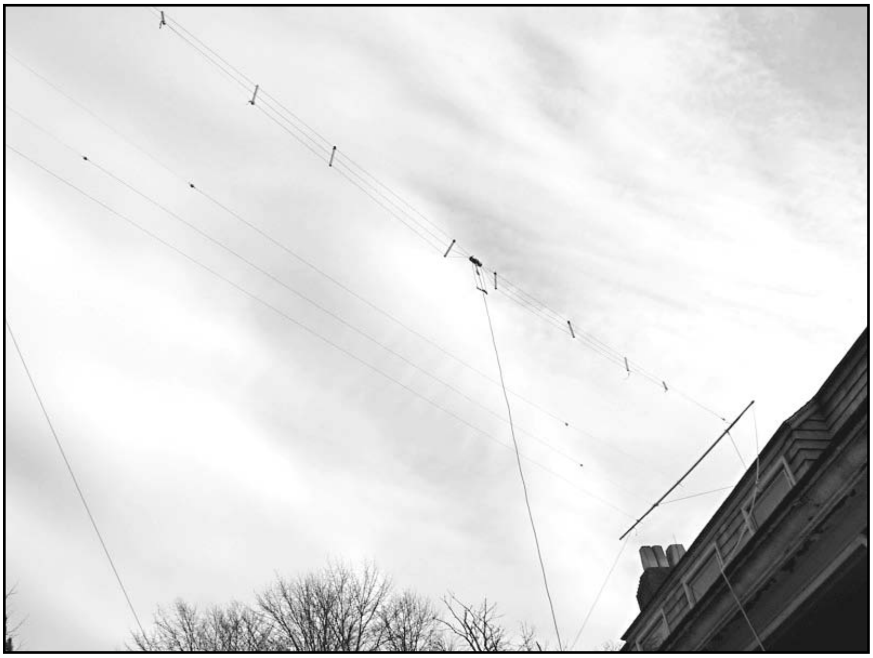

Fig 33 — VE7CA portable 2-element 20/15/10-meter wire Yagi installed at Plimoth Plantation in Plymouth, Massachusetts. (*Photo courtesy K1HTN*).

flip the antenna over and change direction 180° very quickly.

Summary

You don't need a 10-meter (60-foot) high tower, a commercial triband Yagi and a rotator to put out a good signal on the HF bands. Wire Yagis work very well and they can be inexpensive and easy-to-build, using components found at your local hardware store. **Fig 33** is a photograph of a successful portable installation in Massachusetts.

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Source material and more extended discussion of topics covered in this chapter can be found in the references given below.

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Chapter 16

Mobile and Maritime Antennas

Mobile antennas are those designed for use while antennas, most amateurs think of a whip mounted on an automobile or other highway vehicle, perhaps on a recreational vehicle (RV) or maybe on an off-road vehicle. While it is true that most mobile antennas are vertical whips, mobile antennas can also be found in other places. For example, antennas mounted aboard a boat or ship are mobile, and are usually called *maritime antennas*. **Fig 1** shows yet another type of mobile antenna—those for use on handheld transceivers. Because they may be used while in motion, even these antennas are mobile by literal definition.

Pictured in Fig 1 is a telescoping full-size quarter-wave antenna for 144 MHz, and beside it a *stubby* antenna for the same band. The stubby is a helically wound radiator, made of stiff copper wire enclosed in a protective covering of rubber-like material. The inductance of the helical windings provides electrical loading for the antenna. For frequencies above 28 MHz, most mobile installations permit the use of a full-size antenna, but sometimes smaller, loaded antennas are used for convenience. The stubby, for example, is convenient for short-range communications, avoiding the problems of a lengthier, cumbersome antenna attached to a handheld radio.

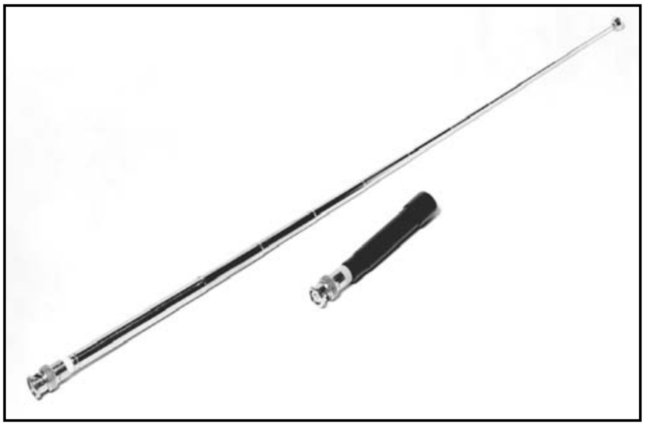

Fig 1—Two mobile antennas—mobile because they may be used while in motion. Shown here are a telescoping $^1/_4$-λ antenna and a "stubby" antenna, both designed for use at 144 MHz. The $^1/_4$-λ antenna is 19 inch long, while the stubby antenna is only $3^1/_2$ inch long. (Both dimensions exclude the length of the BNC connectors. The stubby is a helically wound radiator.

Below 28 MHz, physical size becomes a problem with full-size whips, and some form of electrical loading (as with the stubby) is usually employed. Commonly used loading techniques are to place a coil at the base of the whip (base loading), or at the center of the whip (center loading). These and other techniques are discussed in this chapter.

Few amateurs construct their own antennas for HF mobile and maritime use, since safety reasons dictate very sound mechanical construction. Several construction projects are included, however, in this chapter for those who may wish to build their own mobile antenna. Even if commercially made antennas are installed, most require some adjustment for the particular installation and type of operation desired and the information given here may provide a better understanding of the optimization requirements.

HF-MOBILE FUNDAMENTALS

Fig 2 shows a typical bumper-mounted center-loaded whip suitable for operation in the HF range. Jack Schuster, W1WEF, operates 80 through 2 meters from his car. The antenna could also be mounted on the car body itself (such as a fender), and mounts are available for this purpose. The base spring and tennis ball act as shock absorbers for the bottom of the whip, as the continual flexing while in motion would otherwise weaken the antenna. A short heavy mast section is mounted between the base spring and loading coil. Some models have a mechanism that allows the antenna to be tipped over for adjustment or for fastening to the roof of the car when not in use.

It is also advisable to extend a couple of guy lines from the base of the loading coil to clips or hooks fastened to the roof gutter on the car, or to the trunk and

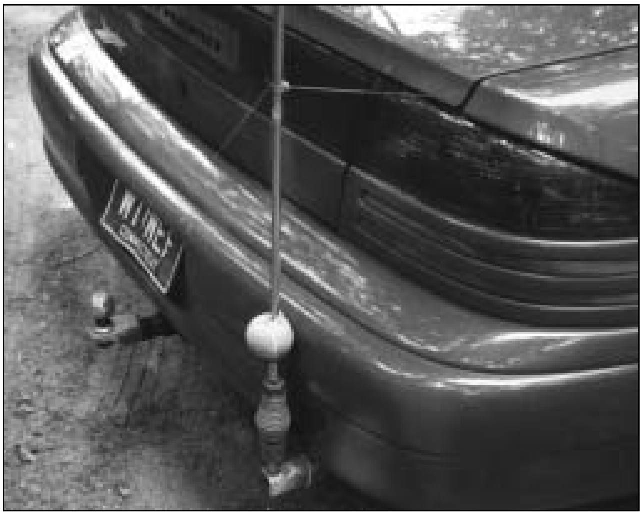

Fig 2—A typical bumper-mounted HF mobile antenna, as used by W1WEF. Note the nylon guy lines and the tennis ball used as a shock absorber. (*Photo courtesy W1WEF.*)

rear bumper, as W1WEF has done. Nylon fishing line (about 40-pound test) is suitable for this purpose. The guy lines act as safety cords and also reduce the swaying motion of the antenna considerably. The feed line to the transmitter is connected to the bumper and base of the antenna. Good low-resistance connections are important here.

Tune-up of the antenna is usually accomplished by changing the height of the adjustable whip section above the precut loading coil. First, tune the receiver and try to determine where the signals seem to peak up. Once this frequency is found, check the SWR with the transmitter on, and find the frequency where the SWR is lowest. Shortening the adjustable section will increase the resonant frequency, and making it longer will lower the frequency. It is important that the antenna be away from surrounding objects such as overhead wires by ten feet or more, as considerable detuning can occur. Once the setting is found where the SWR is lowest at the center of the desired frequency range, the length of the adjustable section should be recorded.

Propagation conditions and ignition noise are usually the limiting factors for mobile operation on 10 through 28 MHz. Antenna size restrictions affect operation somewhat on 7 MHz and much more on 3.5 and 1.8 MHz. From this standpoint, perhaps the optimum band for HF-mobile operation is 7 MHz. The popularity of the regional mobile nets on 7 MHz is perhaps the best indication of its suitability. For local work, 28 MHz is also useful, as antenna efficiency is high and relatively simple antennas without loading coils are easy to build.

As the frequency of operation is lowered, an antenna of fixed length looks (at its feed point) like a decreasing resistance in series with an increasing capacitive reactance. The capacitive reactance must be tuned out, necessitating the use of an equivalent series inductive reactance or loading coil. The amount of inductance required will be determined by the placement of the coil in the antenna system.

Base loading requires the lowest value of inductance for a fixed-length antenna, and as the coil is placed farther up the whip, the necessary value increases. This is because the capacitance of the shorter antenna section (above the coil) to the car body is now lower (higher capacitive reactance), requiring more inductance to tune the antenna to resonance. The advantage is that the current distribution on the whip is improved, increasing the radiation resistance. The disadvantage is that requirement of a larger coil also means the coil size and losses increase. Center loading has been generally accepted as a good compromise with minimal construction problems. Placing the coil $^2/_3$ the distance up the whip seems to be about the optimum position.

For typical antenna lengths used in mobile work, the difficulty in constructing suitable loading coils increases as the frequency of operation is lowered. Since the required resonating inductance gets larger and the radiation resistance decreases at lower frequencies, most of the power is dissipated in the coil's loss resistance and in other ohmic losses. This is one reason why it is advisable to buy a commercially made loading coil with the highest power rating possible, even if only low-power operation is planned.

Coil losses in the higher-power loading coils are usually less (percentage-wise), with subsequent improvement in radiation efficiency, regardless of the power level used. Of course, the above philosophy also applies to homemade loading coils, and design considerations will be considered in a later section.

Once the antenna is tuned to resonance, the input impedance at the antenna terminals will look like a pure resistance. Neglecting losses, this value drops from nearly 15 Ω at 21 MHz to 0.1 Ω at 1.8 MHz for an 8-foot whip. When coil and other losses are included, the input resistance increases to approximately 20 Ω at 1.8 MHz and 16 Ω at 21 MHz. These values are for relatively high-efficiency systems. From this it can be seen that the radiation efficiency is much poorer at 1.8 MHz than at 21 MHz under typical conditions.

Since most modern gear is designed to operate with a 50-Ω transmission line, a matching network is usually necessary, especially with the high-efficiency antennas previously mentioned. This can take the form of either a broadband transformer, a tapped coil, or an LC matching network. With homemade or modified designs, the tapped-coil arrangement is perhaps the easiest one to build, while the broadband transformer requires no adjustment. As the losses go up, so does the input resistance, and in less efficient systems the matching network may not be needed.

The Equivalent Circuit of a Typical Mobile Antenna

In the previous section, some of the general considerations were discussed, and these will now be taken up in more detail. It is customary in solving problems involving electric and magnetic fields (such as antenna systems) to try to find an equivalent network with which to replace the antenna for analysis reasons. In many cases, the network may be an accurate representation over only a limited frequency range. However, this is often a valuable method in matching the antenna to the transmission line.

Antenna resonance is defined as the frequency at which the input impedance at the antenna terminals is purely resistive. The shortest length at which this occurs for a vertical antenna over a ground plane is when the antenna is an electrical quarter wavelength at the operating frequency; the impedance value for this length (neglecting losses) is about 36 Ω. The idea of resonance can be extended to antennas shorter (or longer) than a quarter wave, and means only that the input impedance is purely resistive. As pointed out previously, when the frequency is lowered, the antenna looks like a series RC circuit, as shown in **Fig 3**. For the average 8-foot whip, the capacitive reactance of C_A may range from about –150 Ω at 21 MHz to as high as –8000 Ω at 1.8 MHz, while the radiation resistance R_R varies from about 15 Ω at 21 MHz to as low as 0.1 Ω at 1.8 MHz.

For an antenna less than 0.1 λ long, the approximate radiation resistance may be determined from the following:

$$R_R = 273 \times (\ell f)^2 \times 10^{-8} \qquad \text{(Eq 1)}$$

where ℓ is the length of the whip in inches, and f is the frequency in megahertz.

Since the resistance is low, considerable current must flow in the circuit if any appreciable power is to be dissipated in the form of radiation in R_R. Yet it is apparent that little current can be made to flow in the circuit as long as the comparatively high series reactance remains.

Antenna Capacitance

Capacitive reactance can be canceled by connecting an equivalent inductive reactance, (coil L_L) in series, as shown in **Fig 4**, thus tuning the system to resonance.

The capacitance of a vertical antenna shorter than a quarter wavelength is given by:

$$C_A = \frac{17\ell}{\left[\left(\ln\frac{24\ell}{D}\right)-1\right]\left[1-\left(\frac{f\ell}{234}\right)^2\right]} \qquad \text{(Eq 2)}$$

where

C_A = capacitance of antenna in pF
ℓ = antenna height in feet
D = diameter of radiator in inches
f = operating frequency in MHz

$$\ln\frac{24\ell}{D} = 2.3\log_{10}\frac{24\ell}{D}$$

Fig 5 shows the approximate capacitance of whip antennas of various average diameters and lengths. For 1.8, 4 and 7 MHz, the loading coil inductance required (when the loading coil is at the base) would be approximately the inductance required to resonate in the desired band (with the whip capacitance taken from the graph). For 10 through 21 MHz, this rough calculation will give more than the required inductance, but it will serve as a

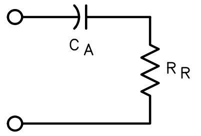

Fig 3—At frequencies below resonance, the whip antenna will show capacitive reactance as well as resistance. R_R is the radiation resistance, and C_A represents the antenna capacitance.

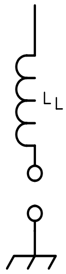

Fig 4—The capacitive reactance at frequencies below the resonant frequency of the whip can be canceled by adding an equivalent inductive reactance in the form of a loading coil in series with the antenna.

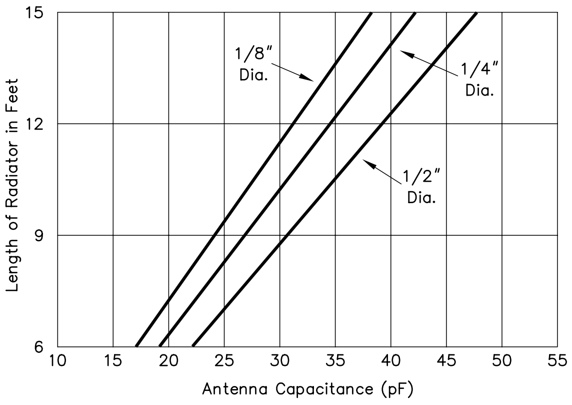

Fig 5—Graph showing the approximate capacitance of short vertical antennas for various diameters and lengths. These values should be approximately halved for a center-loaded antenna.

starting point for the final experimental adjustment that must always be made.

LOADING COIL DESIGN

To minimize loading coil loss, the coil should have a high ratio of reactance-to-resistance (that is, a high unloaded Q). A 4-MHz loading coil wound with small wire on a small-diameter solid form of poor quality, and enclosed in a metal protector, may have a Q as low as 50, with a loss resistance of 50 Ω or more. High-Q coils require a large conductor, air-wound construction, large spacing between turns, and the best insulating material available. A diameter not less than half the length of the coil (not always mechanically feasible) and a minimum of metal in the field of the coil are also necessities for optimum efficiency. Such a coil for 4 MHz may show a Q of 300 or more, with a resistance of 12 Ω or less.

The coil could then be placed in series with the feed line at the base of the antenna to tune out the unwanted capacitive reactance, as shown in Fig 4. Such a method is often referred to as *base-loading*, and many practical mobile antenna systems have been built using this scheme.

Over the years, the question has come up as to whether or not more efficient designs are possible compared with simple base loading. While many ideas have been tried with varying degrees of success, only a few have been generally accepted and incorporated into actual systems. These are center loading, continuous loading, and combinations of the latter with more conventional antennas.

Base Loading and Center Loading

If a whip antenna is short compared to a wavelength *and the current is uniform along the length ℓ*, the electric field strength E, at a distance d, away from the antenna is approximately:

$$E = \frac{120\pi I\ell}{d\lambda} \qquad \text{(Eq 3)}$$

where

I is the antenna current in amperes
λ is the wavelength in the same units as D and ℓ.

A uniform current flowing along the length of the whip is an idealized situation, however, since the current is greatest at the base of the antenna and goes to a minimum at the top. In practice, the field strength will be less than that given by the above equation, because it is a function of the current distribution on the whip.

The reason that the current is not uniform on a whip antenna can be seen from the circuit approximation shown in **Fig 6**. A whip antenna over a ground plane is similar in many respects to a tapered coaxial cable where the center conductor remains the same diameter along its length, but with an increasing diameter outer conductor. The inductance per unit length of such a cable would increase along the line, while the capacitance per unit length would decrease. In Fig 6 the antenna is represented by a series of LC circuits in which C1 is greater than C2, which is greater than C3, and so on. L1 is less than L2, which is less than succeeding inductances. The net result is that most of the antenna current returns to ground near the base of the antenna, and very little near the top.

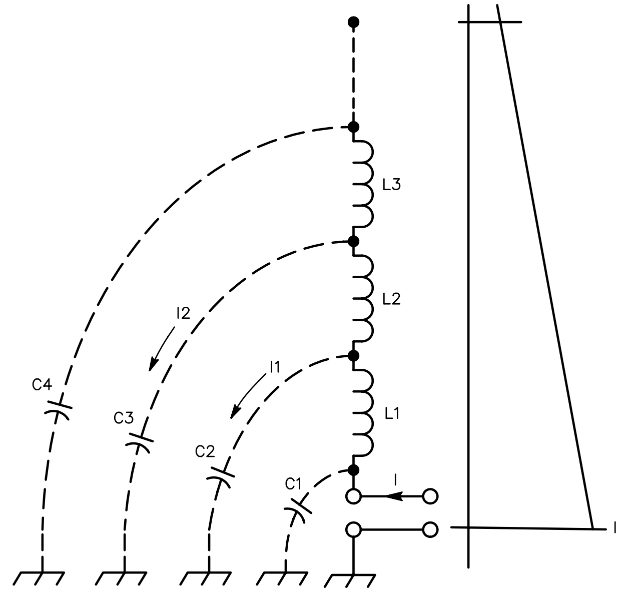

Fig 6—A circuit approximation of a simple whip over a perfectly conducting ground plane. The shunt capacitance per unit length gets smaller as the height increases, and the series inductance per unit length gets larger. Consequently, most of the antenna current returns to the ground plane near the base of the antenna, giving the current distribution shown at the right.

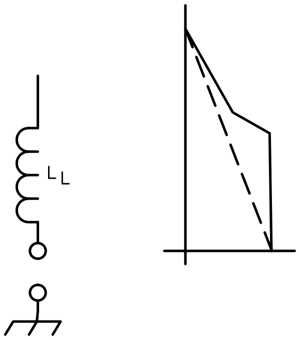

Fig 7—Improved current distribution resulting from center loading.

Two things can be done to improve this distribution and make the current more uniform. One would be to increase the capacitance of the top of the antenna to ground through the use of top loading or a capacitance hat, as discussed in Chapter 6. Unfortunately, the wind resistance of the hat makes it somewhat unwieldy for mobile use. The other method is to place the loading coil farther up the whip, as shown in **Fig 7**, rather than at the base. If the coil is resonant (or nearly so) with the

Table 1

Approximate Values for 8-ft Mobile Whip

f(MHz)	*Loading L μH*	*R_C(Q50) Ω*	*R_C(Q300) Ω*	*R_R Ω*	*Feed R* Ω*	*Matching L μH*
Base Loading						
1.8	345	77	13	0.1	23	3
3.8	77	37	6.1	0.35	16	1.2
7.2	20	18	3	1.35	15	0.6
10.1	9.5	12	2	2.8	12	0.4
14.2	4.5	7.7	1.3	5.7	12	0.28
18.1	3.0	5.0	1.0	10.0	14	0.28
21.25	1.25	3.4	0.5	14.8	16	0.28
24.9	0.9	2.6	—	20.0	22	0.25
29.0	—	—	—	—	36	0.23
Center Loading						
1.8	700	158	23	0.2	34	3.7
3.8	150	72	12	0.8	22	1.4
7.2	40	36	6	3.0	19	0.7
10.1	20	22	4.2	5.8	18	0.5
14.2	8.6	15	2.5	11.0	19	0.35
18.1	4.4	9.2	1.5	19.0	22	0.31
21.25	2.5	6.6	1.1	27.0	29	0.29

R_C = loading coil resistance; R_R = radiation resistance.
*Assuming loading coil Q = 300, and including estimated ground-loss resistance.

Table 2

Suggested Loading Coil Dimensions

Req'd L(μH)	*Turns*	*Wire Size*	*Dia. Inches*	*Length Inches*
700	190	22	3	10
345	135	18	3	10
150	100	16	$2\frac{1}{2}$	10
77	75	14	$2\frac{1}{2}$	10
77	29	12	5	$4\frac{1}{4}$
40	28	16	$2\frac{1}{2}$	2
40	34	12	$2\frac{1}{2}$	$4\frac{1}{4}$
20	17	16	$2\frac{1}{2}$	$1\frac{1}{4}$
20	22	12	$2\frac{1}{2}$	$2\frac{3}{4}$
8.6	16	14	2	2
8.6	15	12	$2\frac{1}{2}$	3
4.5	10	14	2	$1\frac{1}{4}$
4.5	12	12	$2\frac{1}{2}$	4
2.5	8	12	2	2
2.5	8	6	$2\frac{3}{8}$	$4\frac{1}{2}$
1.25	6	12	$1\frac{3}{4}$	2
1.25	6	6	$2\frac{3}{8}$	$4\frac{1}{2}$

capacitance to ground of the section above the coil, the current distribution is improved as also shown in Fig 7. The result with both top loading and center loading is that the radiation resistance is increased, offsetting the effect of losses and making matching easier.

Table 1 shows the approximate loading coil inductance for the various amateur bands. Also shown in the table are approximate values of radiation resistance to be expected with an 8-foot whip, and the resistances of loading coils—one group having a Q of 50, the other a Q of 300. A comparison of radiation and coil resistances will show the importance of reducing the coil resistance to a minimum, especially on the three lower frequency bands. **Table 2** shows suggested loading-coil dimensions for the inductance values given in Table 1.

OPTIMUM DESIGN OF SHORT COIL-LOADED HF MOBILE ANTENNAS

Optimum design of short HF mobile antennas results from a careful balance of the appropriate loading coil Q-factor, loading coil position in the antenna, ground loss resistance, and the length-to-diameter ratio of the antenna. The optimum balance of these parameters can be realized only through a thorough understanding of how they interact. This section presents a mathematical approach to designing mobile antennas for maximum radiation efficiency. Bruce Brown, W6TWW, in *The ARRL Antenna Compendium Volume 1*, first presented this approach. (See the Bibliography at the end of this chapter.)

The optimum location for a loading coil in an antenna can be found experimentally, but it requires many hours of designing and constructing models and making measurements to ensure the validity of the design. A faster and more reliable way of determining optimum coil location is through the use of a personal computer. This approach allows the variation of any single variable, while observing the cumulative effects on the system. When plotted graphically, the data reveals that the placement of the loading coil is critical if maximum radiation efficiency

Table 3
Variables used in Eqs 4 through 20

A = area in degree-amperes
a = antenna radius in English or metric units
dB = signal loss in decibels
E = efficiency in percent
f (MHz) = frequency in megahertz
H = height in English or metric units
h = height in electrical degrees
h_1 = height of base section in electrical degrees
h_2 = height of top section in electrical degrees
$I = I_{base}$ = 1 ampere base current
k = 0.0128
k_m = mean characteristic impedance
k_{m1} = mean characteristic impedance of base section
k_{m2} =mean characteristic impedance of top section
L = length or height of the antenna in feet
P_I = power fed to the antenna
P_R = power radiated
Q = coil figure of merit
R_C = coil loss resistance in Ω
R_G = ground loss resistance in Ω
R_R = radiation resistance in Ω
X_L = loading-coil inductive reactance

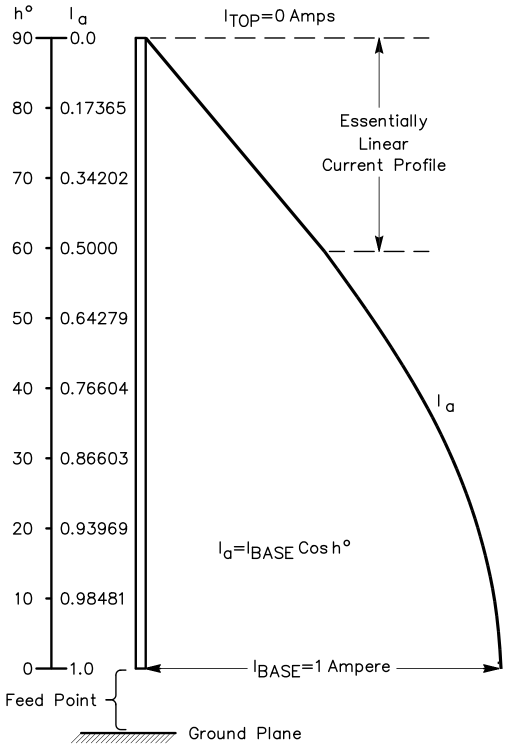

Fig 8—Relative current distribution on a vertical antenna of height h = 90 electrical degrees.

is to be realized. (See the program *MOBILE.EXE*, which is included on the CD-ROM in the back of this book.)

Radiation Resistance

The determination of radiation efficiency requires the knowledge of resistive power losses and radiation losses. Radiation loss is expressed in terms of radiation resistance. Radiation resistance is defined as the resistance that would dissipate the same amount of power that is radiated by the antenna. The variables used in the equations that follow are defined once in the text, and are summarized in **Table 3**. Radiation resistance of vertical antennas shorter than 45 electrical degrees ($^1/_8$ wavelength) is approximately:

$$R_R = \frac{h^2}{312} \qquad \text{(Eq 4)}$$

where

R_R = radiation resistance in Ω
h = antenna length in electrical degrees.

Antenna height in electrical degrees is expressed by:

$$h = \frac{\ell}{984} \times f\left(\text{MHz}\right) \times 360 \qquad \text{(Eq 5)}$$

where

ℓ = antenna length in feet
f (MHz) = operating frequency in megahertz.

End effect is purposely omitted to ensure that an antenna is electrically long. This is so that resonance at the design frequency can be obtained easily by removing a turn or two from the loading coil.

Eq 4 is valid only for antennas having a sinusoidal current distribution and no reactive loading. However, it can be used as a starting point for deriving an equation that is useful for shortened antennas with other than sinusoidal current distributions.

Refer to **Fig 8**. The current distribution on an antenna 90° long electrically ($^1/_4$ wavelength) varies with the cosine of the length in electrical degrees. The current distribution of the top 30° of the antenna is essentially linear. It is this linearity that allows for derivation of a simpler, more useful equation for radiation resistance.

The radiation resistance of an electrically short base-loaded vertical antenna can be conveniently defined in terms of a geometric figure, a triangle, as shown in **Fig 9**. The radiation resistance is given by:

$$R_R = KA^2 \qquad \text{(Eq 6)}$$

where

K is a constant (to be derived shortly)
A = area of the triangular current distribution in degree-amperes.

Degree-ampere area is expressed by

$$A = \frac{1}{2} h \times I_{base} \qquad \text{(Eq 7)}$$

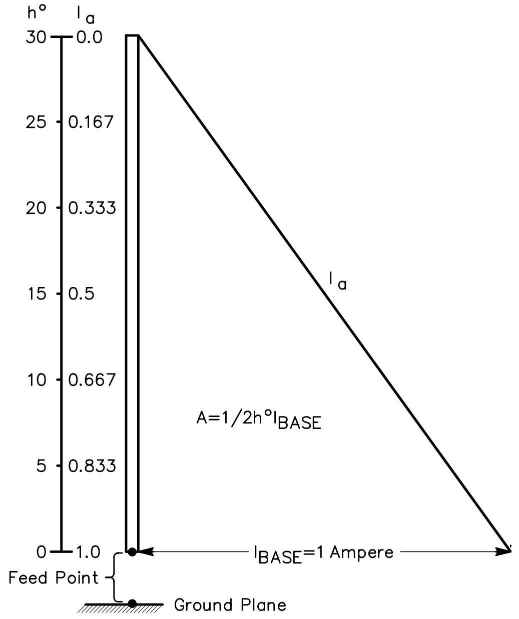

Fig 9—Relative current distribution on a base-loaded vertical antenna of height H = 30 electrical degrees (linearized). The base loading coil is not shown here.

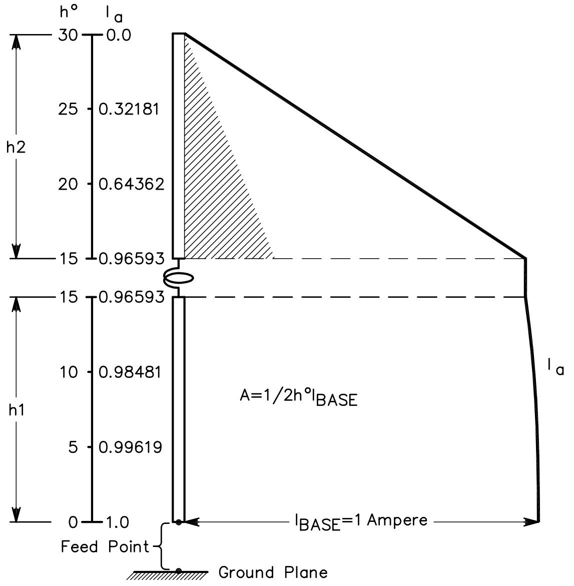

Fig 10—Relative current distribution on a center-loaded antenna with base and top sections each equal to 15 electrical degrees in length. The cross-hatched area shows the current distribution that would exist in the top 15° of a 90°-high vertical fed with 1 ampere at the base.

By combining Eqs 4 and 6 and solving for K, we get

$$K = \frac{h^2}{312 \times A^2} \qquad \text{(Eq 8)}$$

By substituting the values from Fig 9 into Eq 8 we get

$$K = \frac{30^2}{312 \times (0.5 \times 30 \times 1)^2} = 0.0128$$

and by substituting the derived value of K into Eq 6 we get

$$R_R = 0.0128 \times A^2 \qquad \text{(Eq 9)}$$

Eq 9 is useful for determining the radiation resistance of coil-loaded vertical antennas less than 30° in length. The derived constant differs slightly from that presented by Laport (see Bibliography), as he used a different equation for radiation resistance Eq 4.

When the loading coil is moved up an antenna (away from the feed point), the current distribution is modified as shown in **Fig 10**. The current varies with the cosine of the height in electrical degrees at any point in the base section. Therefore, the current flowing into the bottom of the loading coil is less than the current flowing at the base of the antenna.

But what about the current in the top section of the antenna? The loading coil acts as the lumped constant that it is, and disregarding losses and coil radiation, maintains the same current flow throughout. As a result, the current at the top of a high-Q coil is essentially the same as that at the bottom of the coil. This is easily verified by installing RF ammeters immediately above and below the loading coil in a test antenna. Thus, the coil "forces" much more current into the top section than would flow in the equivalent section of a full 90° long antenna. This occurs as a result of the extremely high voltage that appears at the top of the loading coil. This higher current flow results in more radiation than would occur from the equivalent section of a quarter-wave antenna. (This is true for conventional coils. However, radiation from long thin coils allows coil current to decrease, as in helically wound antennas.)

The cross-hatched area in Fig 10 shows the current that would flow in the equivalent part of a 90° high antenna, and reveals that the degree-ampere area of the whip section of the short antenna is greatly increased as a result of the modified current distribution. The current flow in the top section decreases almost linearly to zero at the top. This can be seen in Fig 10.

The degree-ampere area of Fig 10 is the sum of the triangular area represented by the current distribution in the top section, and the nearly trapezoidal current distribution in the base section. Radiation from the coil is not included in the degree-ampere area because it is small and difficult to define. Any radiation from the coil can be considered a bonus.

The degree-ampere area is expressed by:

$$A = \frac{1}{2}\left[h_1\left(1 + \cos h_1\right) + h_2\left(\cos h_1\right)\right] \qquad \text{(Eq 10)}$$

where

h_1 = electrical length in degrees of the base section
h_2 = electrical height in degrees of the top section.

The degree-ampere area (calculated by substituting Eq 10 into Eq 9) can be used to determine the radiation resistance when the loading coil is at any position other than the base of the antenna. Radiation resistance has been calculated with these equations and plotted against loading coil position at three different frequencies for 8- and 11-foot antennas, **Fig 11**. Eight feet is a typical length for commercial antennas, and 11-foot antennas are about the maximum practical length that can be installed on a vehicle.

In Fig 11, the curves reveal that the radiation resistance rises almost linearly as the loading coil is moved up the antenna. They also show that the radiation resistance rises rapidly as the frequency is increased. If the analysis were stopped at this point, one might conclude that the loading coil should be placed at the top of the antenna. This is not so, and will become apparent shortly.

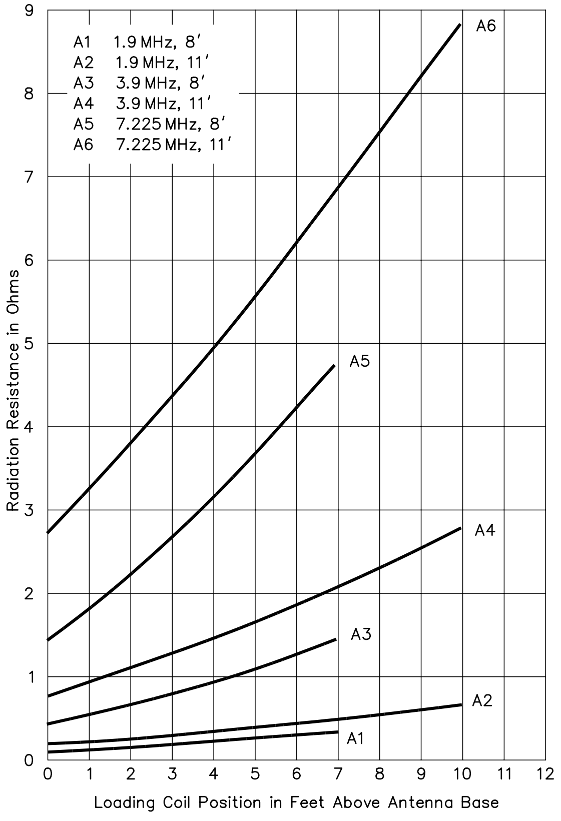

Fig 11—Radiation resistance plotted as a function of loading coil position.

Required Loading Inductance

Calculation of the loading coil inductance needed to resonate a short antenna can be done easily and accurately by using the antenna transmission-line analog described by Boyer in *Ham Radio*. For a base-loaded antenna, Fig 9, the loading coil reactance required to resonate the antenna is given by

$$X_L = -j\,K_m \cot h \qquad \text{(Eq 11)}$$

where

X_L = inductive reactance required
K_m = mean characteristic impedance (defined in Eq 12).

The $-j$ term indicates that the antenna presents capacitive reactance at the feed point. A loading coil must cancel this reactance.

The mean characteristic impedance of an antenna is expressed by

$$K_m = 60\left[\left(\ln\frac{2H}{a}\right) - 1\right] \qquad \text{(Eq 12)}$$

where

H = physical antenna height (excluding the length of the loading coil)
a = radius of the antenna in the same units as H.

From Eq 12 you can see that decreasing the height-to-diameter ratio of an antenna by increasing the radius results in a decrease in K_m. With reference to Eq 11, a decrease in K_m decreases the inductive reactance required to resonate an antenna. As will be shown later, this will increase radiation efficiency. In mobile applications, we quickly run into wind-loading problems if we attempt to use an antenna that is physically large in diameter.

If the loading coil is moved away from the base of the antenna, the antenna is divided into a base and top section, as depicted in Fig 10. The loading coil reactance required to resonate the antenna when the coil is away from the base is given by

$$X_L = j\,K_{m2}\,(\cot h_2) - j\,K_{m1}\,(\tan h_1) \qquad \text{(Eq 13)}$$

In mobile-antenna design and construction, the top section is usually a whip with a much smaller diameter than the base section. Because of this, it is necessary to compute separate values of K_m for the top and base sections. K_{m1} and K_{m2} are the mean characteristic impedances of the base and top sections, respectively.

Loading coil reactance curves for the 3.8-MHz antennas of Fig 11 have been calculated and plotted in **Fig 12**. These curves show the influence of the loading coil position on the reactance required for resonance. The curves in Fig 12 show that the required reactance decreases with longer antennas. The curves also reveal that the required loading coil reactance grows at an increasingly rapid rate after the coil passes the center of the antenna. Because the highest possible loading coil Q

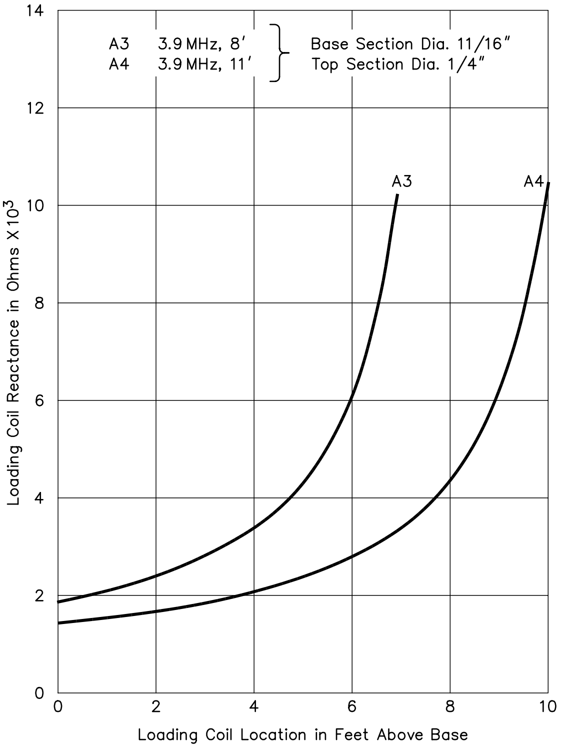

Fig 12—Loading coil reactance required for resonance, plotted as a function of coil height above the antenna base. The resonant frequency is 3.9 MHz.

factor is needed, and because optimum Q is attained when the loading coil diameter is twice the loading coil length, the coil would grow like a smoke ring above the center of the antenna, and would quickly reach an impractical size. It is for this reason that the highest loading coil position is limited to one foot from the top of the antenna in all computations.

Loading Coil Resistance

Loading coil resistance constitutes one of the losses that consumes power that could otherwise be radiated by the antenna. Heat loss in the loading coil is not of any benefit, so it should be minimized by using the highest possible loading coil Q. Loading coil loss resistance is a function of the coil Q and is given by

$$R_C = \frac{X_L}{Q} \qquad \text{(Eq 14)}$$

where

R_C = loading coil loss resistance in Ω
X_L = loading coil reactance
Q = coil figure of merit

Inspection of Eq 14 reveals that, for a given value of inductive reactance, loss resistance will be lower for higher Q coils. Measurements made with a Q meter show that typical, commercially manufactured coil stock produces a Q between 150 and 160 in the 3.8-MHz band.

Higher Q values can be obtained by using larger diameter coils having a diameter-to-length ratio of two, by using larger diameter wire, by using more spacing between turns, and by using low-loss polystyrene supporting and enclosure materials. In theory, loading coil turns should not be shorted for tuning purposes because shorted turns somewhat degrade Q. Pruning to resonance should be done by removing turns from the coil.

In fairness, it should be pointed out that many practical mobile antennas use large-diameter loading coils with shorted turns to achieve resonance. The popular “Texas Bug Catcher” coils come to mind here. Despite general proscriptions against shorting turns, these systems are often more efficient than antennas with small, relatively low-Q, fixed loading coils.

Radiation Efficiency

The ratio of power radiated to power fed to an antenna determines the radiation efficiency. It is given by:

$$E = \frac{P_R}{P_I} \times 100\% \qquad \text{(Eq 15)}$$

where

E = radiation efficiency in percent
P_R = power radiated
P_I = power fed to the antenna at the feed point.

In a short, coil-loaded mobile antenna, a large portion of the power fed to the antenna is dissipated in ground and coil resistances. A relatively insignificant amount of power is also dissipated in the antenna conductor resistance and in the leakage resistance of the base insulator. Because these last two losses are both very small and difficult to estimate, they are here neglected in calculating radiation efficiency.

Another loss worth noting is matching network loss. Because we are concerned only with power fed to the antenna in the determination of radiation efficiency, matching network loss is not considered in any of the equations. Suffice it to say that matching networks should be designed for minimum loss in order to maximize the transmitter power available at the antenna.

The radiation efficiency equation may be rewritten and expanded as follows:

$$E = \frac{I^2 R_R \times 100}{I^2 R_R + I^2 R_G + \left(I \cos h_1\right)^2 R_C} \qquad \text{(Eq 16)}$$

where

I = antenna base current in amperes
R_G = ground loss resistance in Ω
R_C = coil loss resistance in Ω.

Each term of Eq 16 represents the power dissipated in its associated resistance. All the current terms cancel, simplifying this equation to

$$E = \frac{R_R \times 100}{R_R + R_G + R_C \left(\cos^2 h_1\right)} \qquad \text{(Eq 17)}$$

For base-loaded antennas the term $\cos^2 h_1$ drops to unity and may be omitted.

Ground Loss

Eq 14 shows that the total resistive losses in the antenna system are:

$$R_T = R_R + R_G + R_c (\cos^2 h_1) \qquad \text{(Eq 18)}$$

where R_T is the total resistive loss. Ground loss resistance can be determined by rearranging Eq 18 as follows:

$$R_G = R_T - R_R - R_C \cos^2 h_1 \qquad \text{(Eq 19)}$$

R_T may be measured in a test antenna installation on a vehicle using an R-X noise bridge or an SWR analyzer. You can then calculate R_R and R_C.

Ground loss is a function of vehicle size, placement of the antenna on the vehicle, and conductivity of the ground over which the vehicle is traveling. Only the first two variables can be feasibly controlled. Larger vehicles provide better ground planes than smaller ones. The vehicle ground plane is only partial, so the result is considerable RF current flow (and ground loss) in the ground around and under the vehicle.

By raising the antenna base as high as possible on the vehicle, ground losses are decreased. This results from a decrease in antenna capacitance to ground, which increases the capacitive reactance to ground. This, in turn, reduces ground currents and ground losses.

This effect has been verified by installing the same antenna at three different locations on two different vehicles, and by determining the ground loss from Eq 19. In the first test, the antenna was mounted 6 inches below the top of a large station wagon, just behind the left rear window. This placed the antenna base 4 feet 2 inches above the ground, and resulted in a measured ground loss resistance of 2.5 Ω. The second test used the same antenna mounted on the left rear fender of a mid-sized sedan, just to the left of the trunk lid. In this test, the measured ground loss resistance was 4 Ω. The third test used the same mid-sized car, but the antenna was mounted on the rear bumper. In this last test, the measured ground loss resistance was 6 Ω.

The same antenna therefore sees three different ground loss resistances as a direct result of the antenna mounting location and size of the vehicle. It is important to note that the measured ground loss increases as the antenna base nears the ground. The importance of minimizing ground losses in mobile antenna installations cannot be overemphasized.

Efficiency Curves

With the equations defined previously, a computer

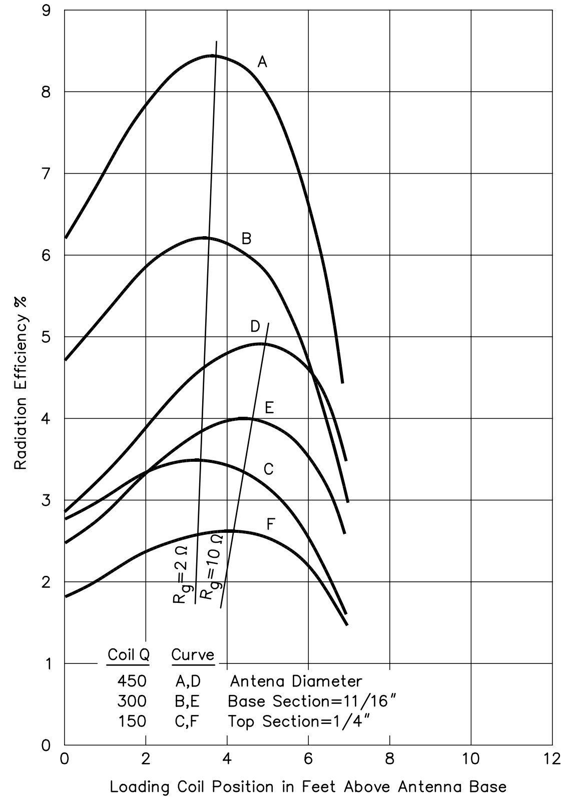

Fig 13—Radiation efficiency of 8-foot antennas at 3.9 MHz.

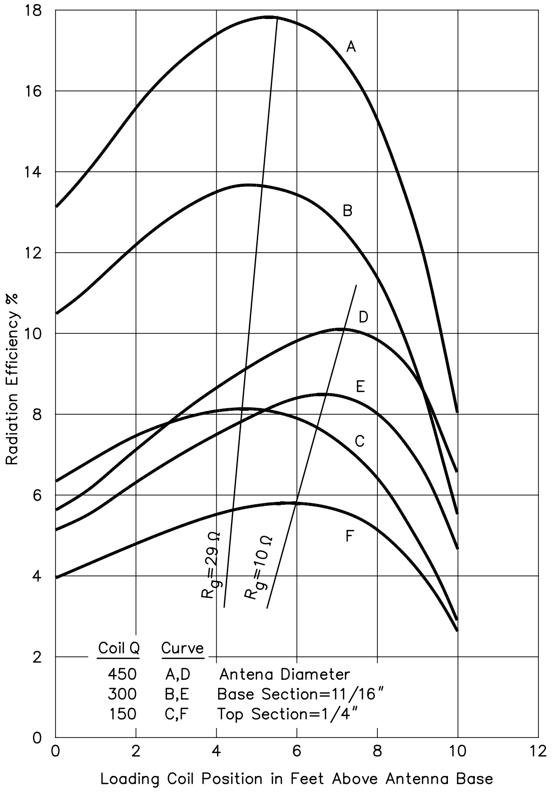

Fig 14—Radiation efficiency of 11-foot antennas at 3.9 MHz.

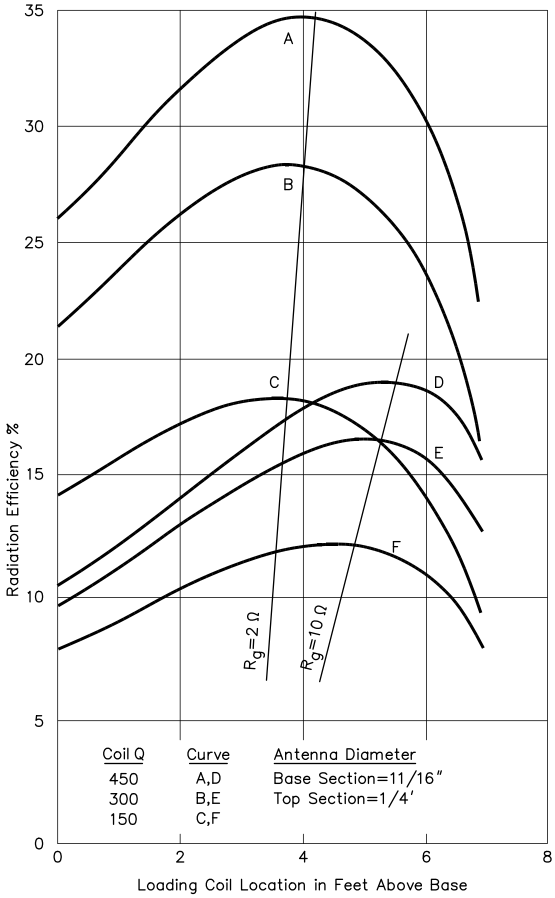

Fig 15—Radiation efficiency of 8-foot antennas at 7.225 MHz.

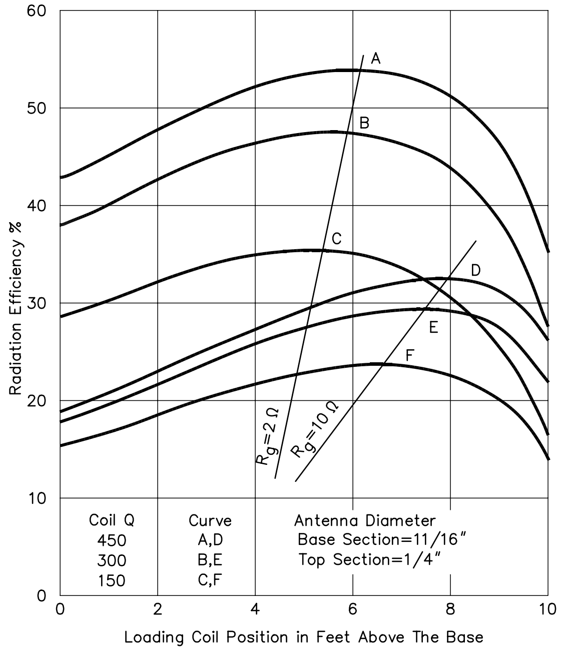

Fig 16—Radiation efficiency of 11-foot antennas at 7.225 MHz.

was used to calculate the radiation efficiency curves depicted in **Figs 13** through **16**. These curves were calculated for 3.8- and 7-MHz antennas of 8- and 11-foot lengths. Several values of loading coil Q were used, for both 2 and 10 Ω of ground loss resistance. For the calculations, the base section is $^1/_2$-inch diameter electrical EMT, which has an outside diameter of $^{11}/_{16}$ inch. The top section is fiberglass bicycle-whip material covered with Belden braid. These are readily available materials, which can be used by the average amateur to construct an inexpensive but rugged antenna.

Upon inspection, these radiation-efficiency curves reveal some significant information:

1) Higher coil Q produces higher radiation efficiencies,
2) longer antennas produce higher radiation efficiencies,
3) higher frequencies produce higher radiation efficiencies,
4) lower ground loss resistances produce higher radiation efficiencies,
5) higher ground loss resistances force the loading coil above the antenna center to reach a crest in the radiation-efficiency curve, and
6) higher coil Q sharpens the radiation-efficiency curves, resulting in the coil position being more critical for optimum radiation efficiency.

Note that the radiation efficiency curves reach a peak and then begin to decline as the loading coil is raised farther up the antenna. This is because of the rapid increase in loading coil reactance required above the antenna center. Refer to Fig 12. The rapid increase in coil size required for resonance results in the coil loss resistance increasing much more rapidly than the radiation resistance. This results in decreased radiation efficiency, as shown in Fig 11.

A slight reverse curvature exists in the curves between the base-loaded position and the one-foot coil-height position. This is caused by a shift in the curve resulting from insertion of a base section of larger diameter than the whip when the coil is above the base.

The curves in Figs 13 through 16 were calculated with constant (but not equal) diameter base and whip sections. Because of wind loading, it is not desirable to increase the diameter of the whip section. However, the base-section diameter can be increased within reason to further improve radiation efficiency. **Fig 17** was calculated for base-section diameters ranging from $^{11}/_{16}$ inch to 3 inches. The curves reveal that a small increase in radiation efficiency results from larger diameter base sections.

The curves in Figs 13 through 16 show that radiation efficiencies can be quite low in the 3.8-MHz band compared to the 7-MHz band. They are lower yet in the 1.8-MHz band. To gain some perspective on what these low efficiencies mean in terms of signal strength, **Fig 18** was calculated using the following equation:

$$\mathrm{dB} = \log \frac{100}{\mathrm{E}} \qquad \text{(Eq 20)}$$

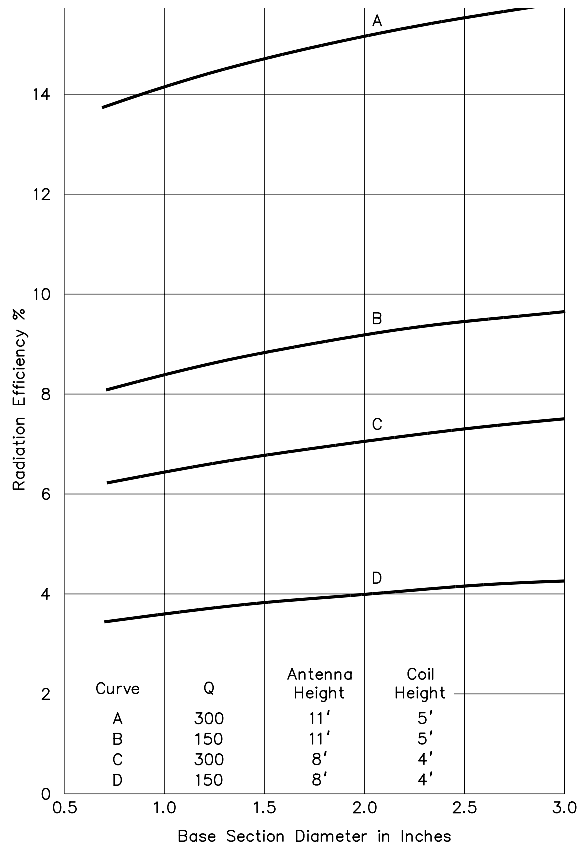

Fig 17—Radiation efficiency plotted as a function of base section diameter. Frequency = 3.9 MHz, ground loss resistance = 2 Ω, and whip section = $^1/_4$-inch diameter.

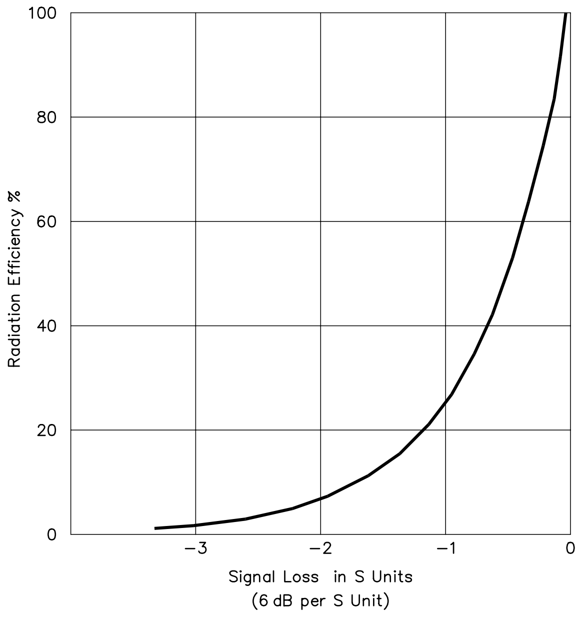

Fig 18—Mobile antenna signal loss as a function of radiation efficiency, compared to a quarter-wave vertical antenna over perfect ground.

where

dB = signal loss in decibels
E = efficiency in percent.

The curve in Fig 18 reveals that an antenna having 25% efficiency has a signal loss of 6 dB (approximately one S unit) below a quarter-wave vertical antenna over perfect ground. An antenna efficiency in the neighborhood of 6% will produce a signal strength on the order of two S units or about 12 dB below the same quarter-wave reference vertical. By careful optimization of mobile-antenna design, signal strengths from mobiles can be made fairly competitive with those from fixed stations using comparable power. And don’t forget: Moving your car near saltwater, with its high conductivity, can result in surprisingly strong signals from a mobile station!

Impedance Matching

The input impedance of short, high-Q coil-loaded antennas is quite low. For example, an 8-foot antenna optimized for 3.9 MHz with an unloaded coil Q of 300 and a ground-loss resistance of 2 Ω has a base input impedance of about 13 Ω. This low impedance value causes a standing wave ratio of 4:1 on a 50-Ω coaxial line at resonance. This high SWR is not compatible with the requirements of solid-state transmitters. Also, the bandwidth of shortened vertical antennas is very narrow. This severely limits the capability to maintain transmitter loading over even a small frequency range.

Impedance matching can be accomplished by means of L networks or impedance-matching transformers, but the narrow bandwidth limitation remains. A more elegant solution to the impedance matching and narrow bandwidth problem is to install an automatic tuner at the antenna base. Such a device matches the antenna and coaxial line automatically, and permits operation over a wide frequency range.

The tools are now available to tailor a mobile antenna design to produce maximum radiation efficiency. Mathematical modeling with a personal computer reveals that loading coil Q factor and ground loss resistance greatly influence the optimum loading coil position in a short vertical antenna. It also shows that longer antennas, higher coil Q, and higher operating frequencies produce higher radiation efficiencies.

End effect has not been included in any of the equations to assure that the loading coil will be slightly larger than necessary. Pruning the antenna to resonance should be done by removing coil turns, rather than by shorting turns or shortening the whip section excessively. Shortening the whip reduces radiation efficiency, by both shortening the antenna and moving the optimum coil position. Shorting turns in the loading coil degrades the Q of the coil.

Shortened Dipoles

Mathematical modeling techniques can be applied to shortened dipoles by using zero ground loss resistance and by doubling the computed values of radiation resistance and feed-point impedance. Radiation efficiency, however, does not double. Rather, it remains unchanged, because a second loading coil is required in the other leg of the dipole. The addition of the second coil offsets the gain in efficiency that occurs when the feed-point impedance and radiation resistance are doubled. There is a gain in radiation efficiency over a vertical antenna worked against ground, though, because the dipole configuration allows ground loss resistance to be eliminated from the calculations.

CONTINUOUSLY LOADED ANTENNAS

The design of high-Q air core inductors for RF work is complicated by the number of parameters that must be optimized simultaneously. One of these factors affecting coil Q adversely is radiation from a discrete loading coil. Therefore, the possibility of cutting down other losses while incorporating the coil radiation into that from the rest of the antenna system is an attractive one.

The general approach has been to use a coil made from heavy wire (#14 or larger), with length-to-diameter ratios as high as 21. British experimenters have reported good results with 8-foot overall lengths on the 1.8- and 3.5-MHz bands. The idea of making the entire antenna out of one section of coil has also been tried with some success. This technique is referred to as linear loading. Further information on linear-loaded antennas can be found in Chapter 6.

While going to extremes trying to find a perfect loading arrangement may not improve antenna performance very much, a poor system with lossy coils and high-resistance connections must be avoided if a reasonable signal is to be radiated.

MATCHING TO THE TRANSMITTER

Most modern transmitters require a 50-Ω output load, and because the feed-point impedance of a mobile whip is quite low, a matching network is usually necessary. Although calculations are helpful in the initial design, considerable experimenting is often necessary in final tune-up. This is particularly true for the lower bands, where the antenna is electrically short compared with a quarter-wave whip. The reason is that the loading coil is required to tune out a very large capacitive reactance, and even small changes in component values result in large reactance variations. Since the feed-point resistance is low to begin with, the problem is even more aggravated.

You can transform the low resistance of the whip to a value suitable for a 50-Ω system with an RF transformer or with a shunt-feed arrangement, such as an L network. The latter may only require a shunt coil or shunt capacitor at the base of the whip, since the net series capacitive or inductive reactance of the antenna and its loading coil may be used as part of the network. The following example illustrates the calculations involved.

Assume that a center-loaded whip antenna, 8.5 feet in overall length, is to be used on 7.2 MHz. From Table 1, earlier in this chapter, we see that the feed-point resistance of the antenna will be approximately 19 Ω, and from Fig 5 that the capacitance of the whip, as seen at its base, is approximately 24 pF. Since the antenna is to be center loaded, the capacitance value of the section above the coil will be cut approximately in half, to 12 pF. From this, it may be calculated that a center-loading inductor of 40.7 µH is required to resonate the antenna, that is, to cancel out the capacitive reactance. (This figure agrees with the approximate value of 40 µH shown in Table 1. The resulting feed-point impedance would then be 19 + *j* 0 Ω—a good match, *if* one happens to have a supply of 19-Ω coax.)

Solution: The antenna can be matched to a 52-Ω line such as RG-8 by tuning it either above or below reso-

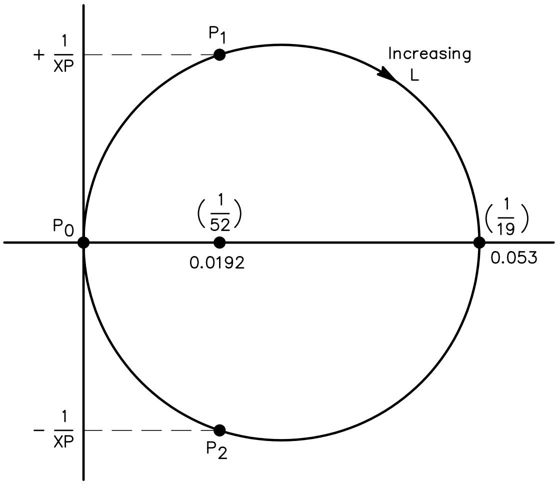

Fig 19—Admittance diagram of the RLC circuit consisting of the whip capacitance, radiation resistance and loading coil discussed in text. The horizontal axis represents conductance, and the vertical axis susceptance. The point P_0 is the input admittance with no whip loading inductance. Points P1 and P2 are described in the text. The conductance equals the reciprocal of the resistance, if no reactive components are present. For a series RX circuit, the conductance is given by

$$G = \frac{R}{R^2 + X^2}$$

and the susceptance is given by

$$B = \frac{-X}{R^2 + X^2}$$

Consequently, a parallel equivalent GB circuit of the series RX one can be found which makes computations easier. This is because conductances and susceptances add in parallel the same way resistances and reactances add in series.

nance and then canceling out the undesired component with an appropriate shunt element, capacitive or inductive. The way in which the impedance is transformed up can be seen by plotting the admittance of the series RLC circuit made up of the loading coil, antenna capacitance, and feed-point resistance. Such a plot is shown in **Fig 19** for a constant feed-point resistance of 19 Ω. There are two points of interest, P1 and P2, where the input conductance is 19.2 millisiemens, corresponding to 52 Ω. The undesired susceptance is shown as $1/X_P$ and $-1/X_P$, which must be canceled with a shunt element of the opposite sign, but with the same magnitude. The value of the canceling shunt reactance, X_P, may be found from the formula:

$$X_p = \frac{R_f\ Z_0}{\sqrt{R_f\left(Z_0 - R_f\right)}} \qquad \text{(Eq 21)}$$

where X_p is the reactance in Ω, R_f is the feed-point resistance, and Z_0 is the feed-line impedance. For Z_0 = 52 Ω and R_f = 19 Ω, X_p = ±39.5 Ω. A coil or good quality mica capacitor may be used as the shunt element. With the tune-up procedure described later, the value is not critical, and a fixed-value component may be used.

To arrive at point P1, the value of the center loading-coil inductance would be less than that required for resonance. The feed-point impedance would then appear capacitive, and an inductive shunt matching element would then be required. To arrive at point P2, the center loading coil should be more inductive than required for resonance, and the shunt element would need to be capacitive.

The value of the center loading coil required for the shunt-matched and resonated condition may be determined from the equation:

$$L = \frac{10^6}{4\pi^2 f^2 C} \pm \frac{X_S}{2\pi f} \qquad \text{(Eq 22)}$$

where addition is performed if a capacitive shunt is to be used, or subtraction performed if the shunt is inductive, and where L is in µH, f is the frequency in MHz, C is the capacitance of the antenna section being matched in pF, and

$$X_S = \sqrt{R_f\left(Z_0 - R_f\right)} \qquad \text{(Eq 23)}$$

For the example given, where Z_0 = 52 Ω, R_f = 19 Ω, f = 7.2 MHz, and C = 12 pF, X_S is found to be 25.0 Ω. The required antenna loading inductance is either 40.2 µH or 41.3 µH, depending on the type of shunt. Various matching possibilities for this example are shown in **Fig 20**. At A, the antenna is shown as tuned to resonance with L_L, a 40.7 µH coil, but with no provisions included for matching the resulting 19-Ω impedance to the 52-Ω line. At B, L_L has been reduced to 40.2 µH to make the antenna appear net capacitive, and L_M, having a reactance of 39.5 Ω, is added in shunt to cancel the capacitive reactance and transform the feed-point impedance to 50 Ω. The arrangement at C is similar to that at B except that L_L has been increased to 41.3 µH, and C_M (a shunt capacitor having a negative reactance of 39.5 Ω) is added, which also results in a 52-Ω nonreactive termination for the feed line.

The values determined for the loading coil in the above example point out an important consideration concerning the matching of short antennas—relatively small changes in values of the loading components will have a greatly magnified effect on the matching requirements. A change of less than 3% in the loading coil inductance value necessitates a completely different matching network! Likewise, calculations show that a 3% change in antenna capacitance will give similar results, and the value of the precautions mentioned earlier becomes clear. The sensitivity of the circuit with regard to frequency variations is also quite critical, and an excursion around practically the entire circle in Fig 19 may represent only 600 kHz, centered around 7.2 MHz, for the above example. This is why tuning up a mobile antenna can be very frustrating unless a systematic procedure is followed.

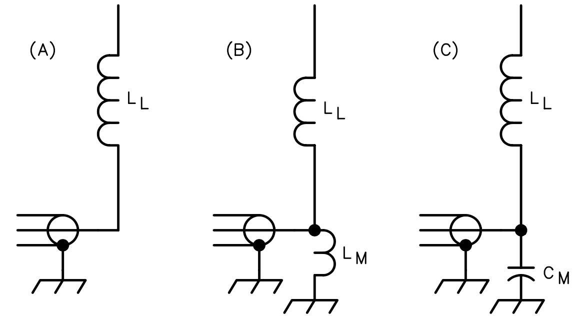

Fig 20—At A, a whip antenna that is resonated with a center loading coil. At B and C, the value of the loading coil has been altered slightly to make the feed-point impedance appear reactive, and a matching component is added in shunt to cancel the reactance. This provides an impedance transformation to match the Z_0 of the feed line. An equally acceptable procedure, rather than altering the loading coil inductance, is to adjust the length of the top section above the loading coil for the best match, as described in the tune-up section of the text.

Tune-Up

Assume that inductive shunt matching is to be used with the antenna in the previous example, Fig 20B, where 39.5 Ω is needed for L_M. This means that at 7.2 MHz, a coil of 0.87 µH will be needed across the whip feed-point terminal to ground. With a 40-µH loading coil in place, the adjustable whip section above the loading coil should be set for minimum height. Signals in the receiver will sound weak and the whip should be lengthened a bit at a time until signals start to peak. Turn the transmitter on and check the SWR at a few frequencies to find where a minimum occurs. If it is below the desired frequency, shorten the whip slightly and check again. It should be moved approximately 1/4 inch at a time until the SWR is minimum at the center of the desired range. If the frequency where the minimum SWR occurs is above the desired frequency, repeat the procedure above, but lengthen the whip only slightly.

If a shunt capacitance is to be used, as in Fig 20C, a value of 560 pF would correspond to the required –39.5 Ω of reactance at 7.2 MHz. With a capacitive shunt, start with the whip in its longest position and shorten it until signals peak up.

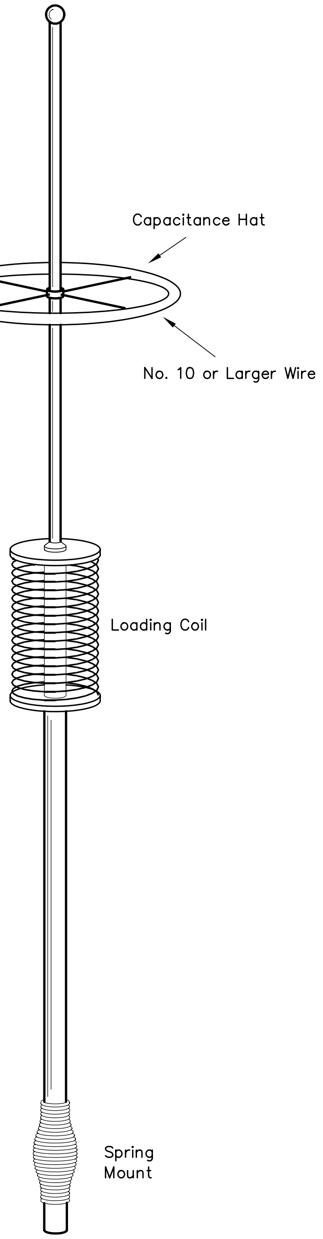
Capacitance Hat
No. 10 or Larger Wire
Loading Coil
Spring
Mount

Fig 21—A capacitance hat can be used to improve the performance of base- or center-loaded whips. A solid metal disc can be used in place of the skeleton disc shown here.

TOP-LOADING CAPACITANCE

Because the loss resistance varies with the inductance of the loading coil, the resistance can be reduced by removing turns from the coil. This must be compensated by adding capacitance to the portion of the mobile antenna that is *above* the loading coil (**Fig 21**). *Capacitance hats*, as they are called, can consist of a single stiff wire, two wires or more, or a disc made up of several wires like the spokes of a wheel. A solid metal disc could also be used, but is less practical for mobile work. The larger the capacitance hat (physically), the greater is the capacitance. The greater the capacitance, the less is the inductance required for resonance at a given frequency.

Capacitance-hat loading is applicable in either base-loaded or center-loaded systems. Since more inductance is required for center-loaded whips to make them resonant at a given frequency, capacitance hats are particularly useful in improving their efficiency.

TAPPED-COIL MATCHING NETWORK

Some of the drawbacks of the L-network can be eliminated by the use of the tapped-coil arrangement shown in **Fig 22**. Tune-up still remains critical, however, although somewhat more straightforward than for an L-network.

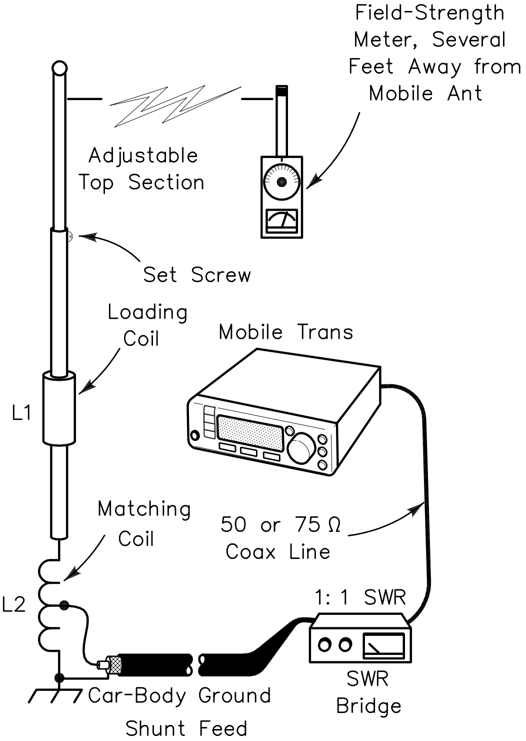
Field-Strength
Meter, Several
Feet Away from
Mobile Ant
Adjustable
Top Section
Set Screw
Loading
Coil
Mobile Trans
L1
Matching
Coil
50 or 75 Ω
Coax Line
1: 1 SWR
L2
Car-Body Ground
Shunt Feed
SWR
Bridge

Fig 22—A mobile antenna using shunt-feed matching. Overall antenna resonance is determined by the combination of L1 and L2. Antenna resonance is set by pruning the turns of L1, or adjusting the top section of the whip, while observing the field-strength meter or SWR indicator. Then adjust the tap on L2 for the lowest SWR.

Coil L2 can be inside the car body, at the base of the antenna, or at the base of the whip. As L2 helps determine the resonance of the antenna, L1 should be tuned to resonance in the desired part of the band with L2 in the circuit. The top section of the whip can be telescoped until a field-strength maximum is found. The tap on L2 is then adjusted for the lowest reflected power. Repeat these two adjustments until no further increase in field strength can be obtained; this point should coincide with the lowest SWR. The number of turns needed for L2 will have to be determined experimentally.

THE "SCREWDRIVER" MOBILE ANTENNA

Imagine QSYing from the bottom of 80 meters to the top of 10 meters, right from the driver's seat. With this antenna you will enjoy a very high Q antenna that has no taps or external adjustments, and that exhibits an SWR under 1.5:1 on all bands. Max Bloodworth, KO4TV, described this antenna in *The ARRL Antenna Compendium, Vol 7*.

The Screwdriver type of antenna was the brainchild of Don Johnson, W6AAQ, who developed it after many years of experimenting with mobile antennas. **Fig 23** is a photo of the completed antenna mounted on KO4TV's truck.

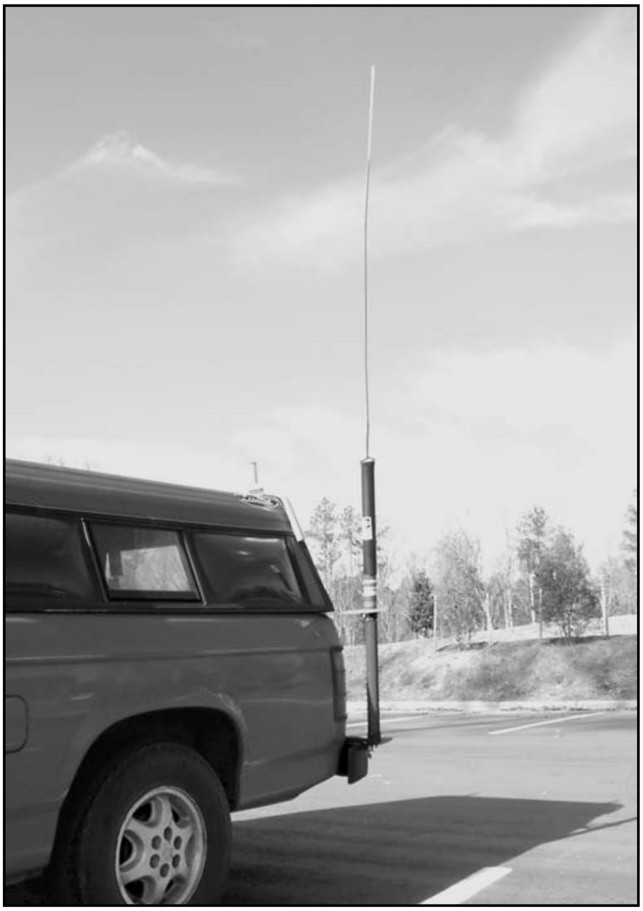

Fig 23—The completed Screwdriver antenna mounted on KO4TV's truck rear bumper. (*Photo courtesy of Gary Pearce, KN4AQ.*)

THE LOADING COIL

The general concept for the Screwdriver is that of a center-loaded antenna with an adjustable loading coil. This is an old idea; however, most previous multi-band antennas required multiple coil taps and an adjustable top whip section, as well as an impedance-matching unit at the base.

The problem of tapping a coil is well known. If you leave one end of the coil open, you have a miniature Tesla Coil, which can cause corona discharge and arcing. If you short the turns, the Q of the loading coil usually drops drastically. The Screwdriver is remarkable in that it does not have any coil taps and yet it can cover a wide range of frequencies with very high Q.

The secret is in the manner of adjusting the coil. It simply slides up or down into a metal tube (the base section), and makes contact with the top of the tube by means of "finger stock," which is made of spring-like Beryllium Copper. The coil is pushed up or down by an ordinary cordless screwdriver; hence the name, Screwdriver. This turns a section of threaded rod and moves the coil form up or down. The section of coil above the finger stock is the active loading coil, and the part of the coil just below the finger stock simply "disappears" into the base tube and is totally out of the circuit. No taps, no loose ends—just a high-Q coil in the middle of two solid metal tubes. Although this antenna is available ready-made from several commercial sources, making one is well within the capabilities of any ham who is relatively handy with ordinary hand tools, and who has access to either a small lathe or a common $1^1/_4$-inch pipe die.

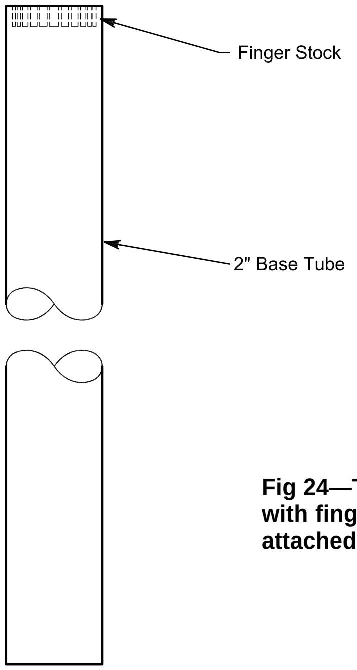

Fig 24—The base tube, with finger stock attached to the top.

CONSTRUCTING YOUR SCREWDRIVER ANTENNA

Construction begins by locating a 2-inch inside-diameter tube, about 3 to $3^1/_2$ feet long. See **Fig 24**. The author had used such diverse materials as:

- Aluminum irrigation pipe
- Schedule-20 copper tubing
- A stainless-steel hydraulic cylinder
- A section of aluminum from a 6-meter beam that was damaged by a tornado
- And even a brass bedpost salvaged from the local garbage dump.

The brass bedpost looked especially good on his vehicle, which was Burgundy with gold trim. Whatever material you use for the bottom tube, you can either leave it unfinished or painted to your taste.

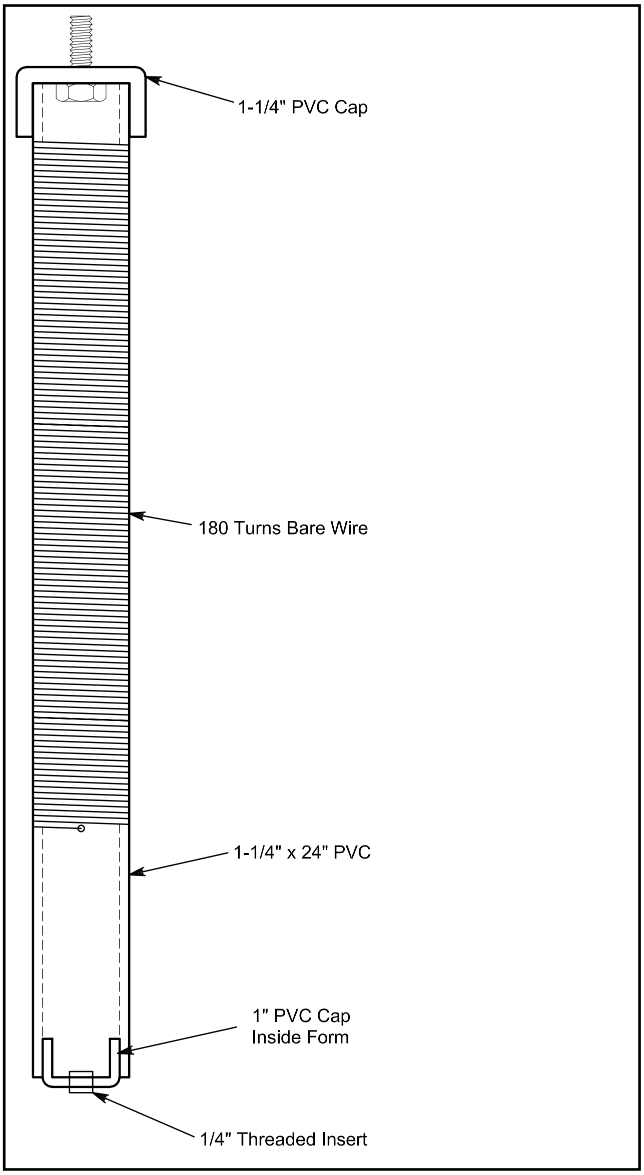

Fig 25—The coil form, with a threaded insert inserted into the bottom PVC cap inside the coil form.

The other essential item is a cordless screwdriver, minus its batteries and switch. You can often find one at yard sales or flea markets for a dollar or so, usually with dead batteries, since it is often just as cheap to buy another one new as it is to buy new batteries. So long as it will fit snugly inside the base tube, the brand name is immaterial. KO4TV has used Skil, Black & Decker, or even a Wal-Mart $8 special, all with equal success. The most difficult part of the job will be making the coil form and winding the loading coil, but with a little patience you should be able to do this satisfactorily.

Bear in mind that it is *not* a “Heathkit” type project, and it will require some innovation and ingenuity on your part. Next, obtain a 2-foot long piece of $1^1/_4$-inch PVC pipe (*not* CPVC, which is vulnerable to ultraviolet rays from the sun). With either a lathe or a pipe die, thread approximately 20 inches from one end, at 10 to 12 threads per inch (See **Fig 25**). If you use a pipe die, it helps to loosen the cutters slightly, to make the grooves shallower.

When using a lathe, temporarily insert a piece of 1-inch water pipe inside the coil form to hold it steady in the lathe. The grooves should be just deep enough to comfortably hold the wire in place when it is wound. The choice of coil wire is up to you. The author has used #16 or #18 tinned copper, bare copper, or best yet, 17-gauge aluminum electric fence wire. This is available from any

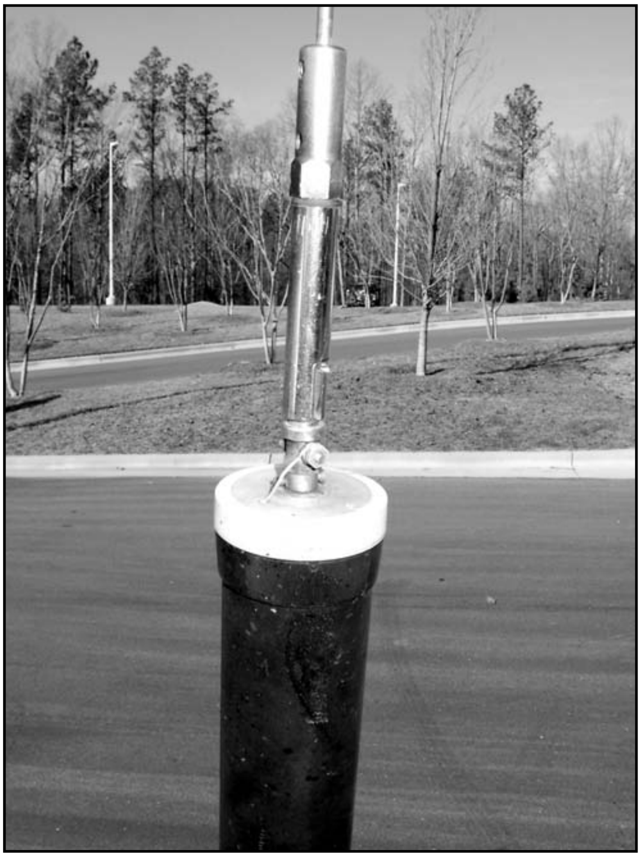

Fig 26—Photo of the top of the loading coil. (*Photo courtesy of Gary Pearce, KN4AQ.*)

farm supply store at a very reasonable cost. It will take about 65 to 70 feet of wire.

Begin by drilling a 1/16-inch hole through the PVC pipe at the bottom end of the threaded portion. Slip the end of the wire through this hole and tie a knot in it to serve as a stop. You could also insert a nut and bolt through a loop in the wire. Then carefully wind the coil to within an inch of the end of the threaded portion. The preferred method of winding is to put a stick or pipe through the holes of the wire reel and hold it between your feet and the floor, to provide the necessary tension to allow tight winding.

About an inch below the top of the coil, drill a 1/16-inch hole and thread about 6 or 8 inches of wire through it. This will be the top connection from the coil to the whip. The bottom of the coil has no electrical connection.

The method of attaching the whip to the top of the coil form is up to you. I usually drill a 3/8-inch hole through a 1 1/4-inch PVC pipe cap and place a 3/8 × 1 1/2-inch SAE bolt through the hole, with a matching washer and nut on top. The bolt can be drilled and tapped for mounting the whip, which should be about 5 to 6 feet long. (It will be pruned for resonance later.) See **Fig 26**, a photo showing the top of the coil.

A more elegant way of connecting the whip is to obtain a swivel or quick-disconnect antenna fitting from your nearest truck stop. These are widely available for use with CB antennas and are threaded 3/8-inch SAE. Do not attach the cap to the coil form until after the coil is inserted in the base tube.

Now that you have a coil form and a base tube, the next step will be to plug the bottom of the PVC coil form with a 1-inch PVC pipe cap, which fits snugly inside the coil form. Drill a hole directly in the center of this cap, and install a 1/4-20 threaded insert, available at most hardware stores for about 25 or 30 cents. These are commonly used in wooden furniture to provide a thread for attaching bolts to wood. See **Fig 27**.

It is imperative that you install this insert squarely. The best method is to screw a short bolt into it and chuck the bolt in a drill press, placing the pipe cap

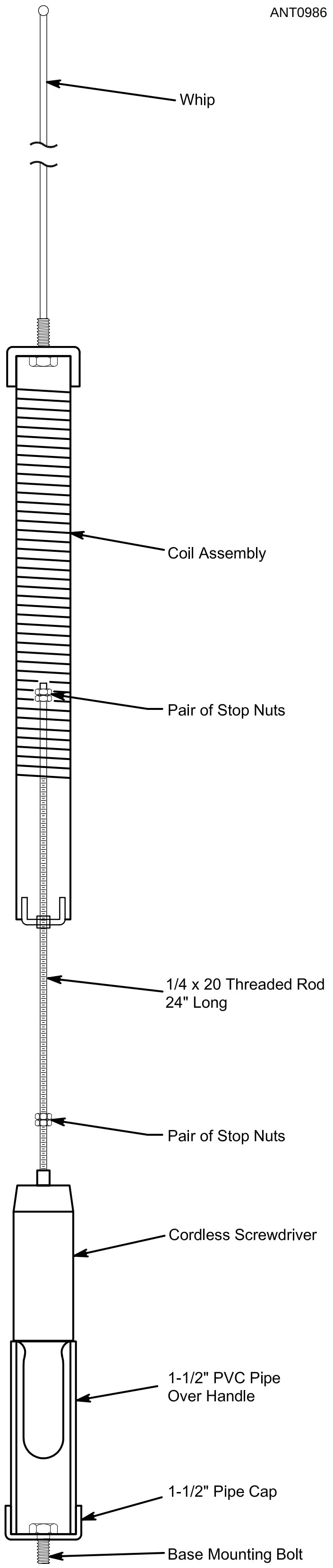
ANT0986
Whip
Coil Assembly
Pair of Stop Nuts
1/4 x 20 Threaded Rod 24" Long
Pair of Stop Nuts
Cordless Screwdriver
1-1/2" PVC Pipe Over Handle
1-1/2" Pipe Cap
Base Mounting Bolt

Fig 27—The coil assembly and cordless screwdriver drive assembly.

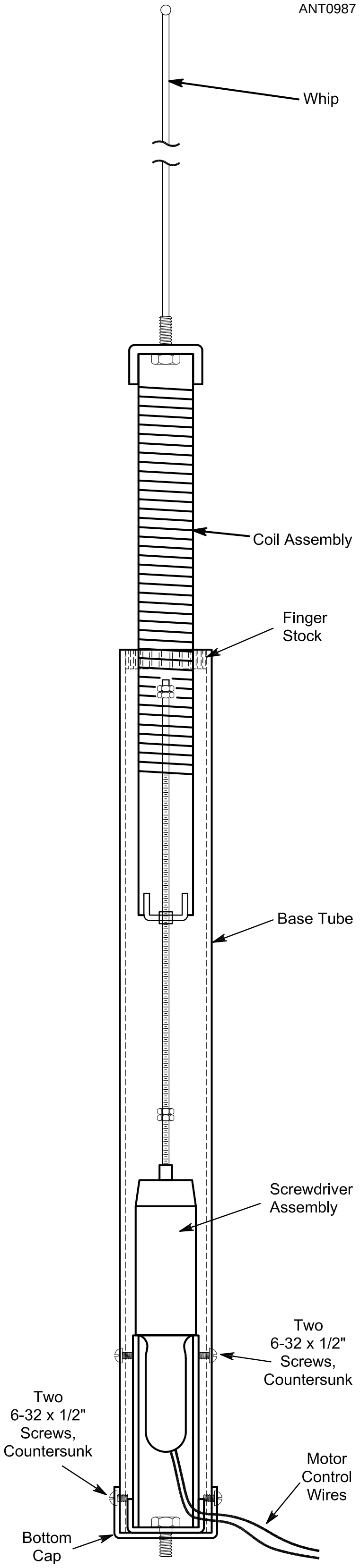
ANT0987
Whip
Coil Assembly
Finger Stock
Base Tube
Screwdriver Assembly
Two 6-32 x 1/2" Screws, Countersunk
Two 6-32 x 1/2" Screws, Countersunk
Motor Control Wires
Bottom Cap

Fig 28—The complete antenna assembly.

squarely on the drill press table. Carefully turn the drill chuck by hand until the insert is properly seated.

The Motor

Now prepare the cordless drill by removing the dead batteries and the switch. Install a pair of 1 or 1.5-Ω, 10-W resistors in series with each motor lead. Connect a 0.1 µF 50-V disc ceramic capacitor across the motor leads to suppress motor noise.

Connect a pair of wires, about a foot long, to the other ends of the resistors. These will power the screwdriver from your car's 12-V system. Next, procure a 20-inch long piece of $^1/_4$-20 threaded rod (also called "all-thread"). Insert one end of this into the cordless screwdriver chuck, and drill a $^1/_{16}$-inch or $^3/_{32}$-inch hole through both the chuck and the rod. Secure the rod in place with either a roll or cotter pin, and install a pair of $^1/_4$-inch nuts on the rod near the screwdriver chuck. This will be the lower stop for the coil travel and will be adjusted later.

Thread the rod into the threaded insert at the bottom of the coil form, and install another pair of stop nuts on the top side of the rod. It will be easier to do this before attaching the bottom plug to the coil form. Again, these nuts will be adjusted later for proper coil travel.

Place the bottom plug into the coil form, drill a couple of holes through the form and the plug and tap them for 6-32 flat head bolts. Countersink the form so that the heads will be flush with the outside. Again, see **Fig 27**.

Finger Stock

Now, let's go back to the base tube. You must install a circle of finger-stock strip on the top of the tube to make contact with the coil, as shown in Fig 24. This can either be soldered or riveted, depending on your choice of tube material. Next, insert the coil and screwdriver assembly through the bottom of the tube, making sure that the coil clears the finger stock without deforming or bending it.

The best method I have found for attaching the screwdriver to the bottom tube is to fit a piece of 1$^1/_2$-inch PVC pipe, about 8 or 10 inches long, over the handle of the screwdriver and attach it with a couple of flat-head 6-32 bolts. You may have to either grind some material off the handle or wrap it with some duct tape to make a snug fit inside the 1$^1/_2$-inch PVC pipe, which should slip snugly into the base tube.

Place a matching 1$^1/_2$-inch PVC pipe cap on the bottom of the pipe, and secure it with a couple of 6-32 screws. Drill a $^1/_4$-inch hole through one side of the cap, which will serve to pass the wires from the screwdriver motor. Drill a $^3/_8$-inch hole directly in the center of this cap for the base mount. See **Fig 28**, which is a drawing of the completed antenna assembly.

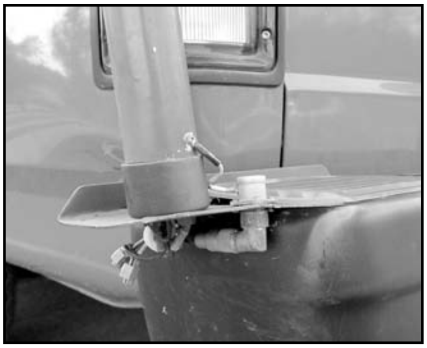

Fig 29—Base-mounting plate for Screw-driver installation on KO4TV's truck. Note the quick-disconnect dc motor con-nections and the SO-239 coax connector.

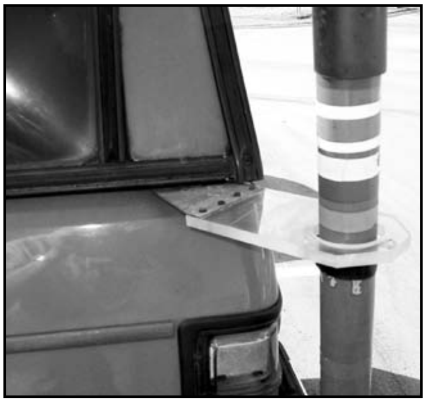

Fig 30—The support Plexiglas plate. (*Photo courtesy of Gary Pearce, KN4AQ.*)

MOUNTING THE ANTENNA

At this point you must determine exactly how you wish to mount the antenna on your vehicle. You could fasten it to a standard mobile antenna mount, but *do not* use a spring! I prefer to fasten the assembly to a thick metal plate about 6 × 18 inches in size. I mount this to the frame of the car, protruding about 4 or 5 inches from the lower car body, just behind the rear wheel. You could also fasten such a plate to the lower fender sheet metal with large sheet-metal screws. The SO-239 connector is mounted to this plate also. See **Fig 29**.

An upper bracket, made from Plexiglas or similar insulating material, can be mounted from the trunk lip with an L-angle and used to support the top of the lower tube. See **Fig 30**. With a Plexiglas bracket about 4-inches wide, a 2-inch hole can be drilled in it to pass the tube. This will make a snug and rigid fit at the top. Under no circumstances use a metal band around the tube, as this will form a shorted turn and drastically lower the antenna Q.

With a little care, this type of mounting will leave no visible holes in the vehicle, which will likely enhance its trade-in value. If you mount the antenna on a pickup truck, it can be mounted directly on the rear safety bumper with a 1$^1/_2$ inch pipe floor flange and matching adaptor on the bottom of the tube.

Electrical Connections

After mounting the base, your next job is to connect the wires from the screwdriver to a DPDT, spring-return center-off switch, mounted in a convenient location in your car. See the schematic in **Fig 31**. Connect the coax from the radio to the base tube, with the center conductor going to the base tube and the shield connected to ground at the base of the antenna.

If you like, you could install a simple base-matching network to give a perfect match on the lower bands. Even with no matching unit, SWR is usually under 2:1 on all

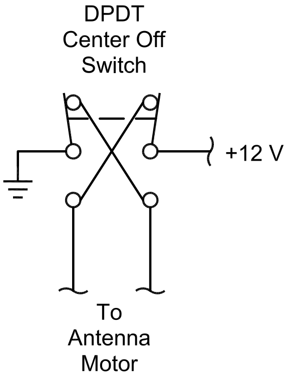

Fig 31—The DPDT center-off spring-loaded switch used to control the screwdriver motor.

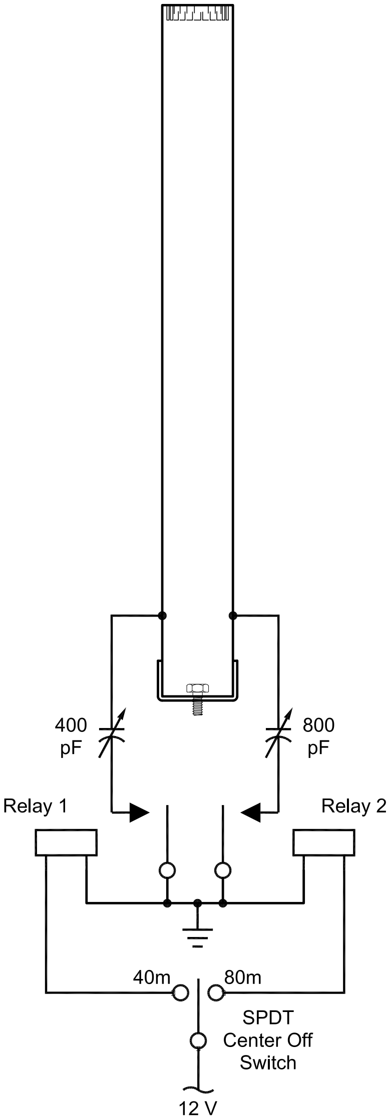

Fig 32—Relay-switched matching capacitors for 40 and 80 meters.

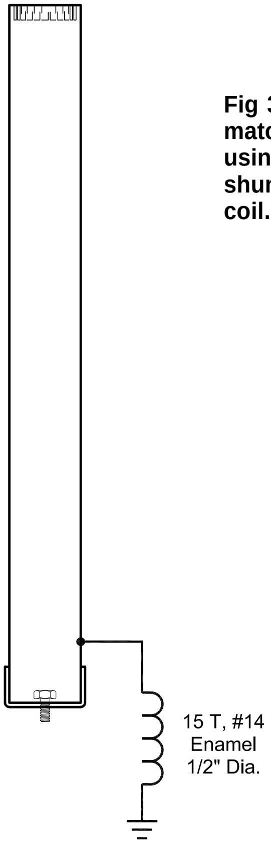

Fig 33—Alternative matching scheme using a single shunt matching coil.

bands. See **Fig 32**. One matching network consists of a couple of trimmer capacitors switched from the bottom of the base tube to ground using a pair of small relays. For 80 meters, approximately 800 pF is required, and for 40 meters about 400 pF. No matching is required for 30 meters or higher.

An alternative matching method is to install a 15-turn coil made from #14 enamel wire, about $^1/_2$ inch diameter, from the base to ground. See **Fig 33**. In either case, adjust the whip length for proper resonance at both ends of the HF spectrum over the range of movement of your coil.

This antenna may have different matching requirements, depending on the vehicle type and mounting location, so you may need to do some experimentation to obtain optimum results. If it doesn't work exactly right at first, be prepared to do a little experimenting.

A COIL COVER

Most builders will want to provide a coil cover, both for protection and appearance. KO4TV's favorite cover is made from a plastic mailing tube, about 24 to 30 inches long and about $^1/_2$ inches in diameter. You can find these at an office supply store. They have a screw-on cap on one end, which can be mounted to the top of the loading coil.

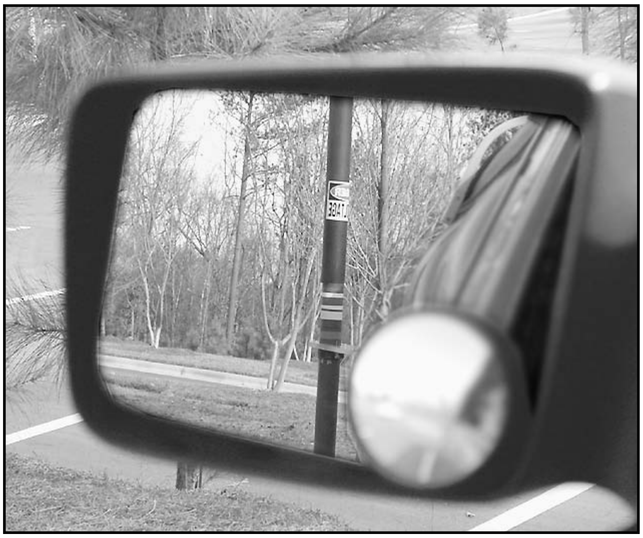

Fig 34—Remote control by the rear-view mirror—tuning by the stripes! (*Photo courtesy of Gary Pearce, KN4AQ.*)

You trim the bottom of the cover to the proper length to allow the coil to be fully retracted into the base tube while still clearing the top bracket. Other builders have used such diverse materials as:

- Several 1-liter soft drink bottles cut off, swaged and glued together
- Sections of Schedule 20 PVC pipe with matching cap
- Empty beef jerky tubes (usually available for the asking at convenience stores)
- Wands from a shop vacuum cleaner, fitted with the cap from an aerosol spray can.

Just let your imagination run wild and you may be surprised at your own ingenuity. Whatever material you do use, paint it to match your vehicle. Just be sure to use non-metallic paint.

TUNING BY THE STRIPES

The author used different colored vinyl tapes to mark the tuning points for the amateur bands along the tuning coil. The lower edge of the supporting Plexiglas middle support acts as a pointer, which he can spot from his rear-view mirror. See **Fig 34**. This may be low-tech tuning method, but it works!

THE PROOF IS IN THE PUDDING

Now, you are ready to enjoy some real mobile communications on all bands, without even stopping the vehicle to QSY. KO4TV's antenna has contacted over 100 DX countries, from as far away as Tasmania and Japan from the East Coast. He enjoys regular contacts with Israel and other stations in the Mid-East, running 100 W or less.

A MOBILE J ANTENNA FOR 144 MHz

The J antenna is a mechanically modified version of the Zepp (Zeppelin) antenna. It consists of a half-wave-length radiator fed by a quarter-wave matching stub. This antenna exhibits an omnidirectional pattern with little high-angle radiation, but does not require the ground plane that $^1/_4$-wave and $^5/_8$-wave antennas do to work properly. The material in this section was prepared by Domenic Mallozzi, N1DM, and Allan White, W1EYI.

Fig 35 shows two common configurations of the J antenna. Fig 35A shows the shorted-stub version that is usually fed with 200- to 600-Ω open-wire line. Some have attempted to feed this antenna directly with coax without a balun, and this usually leads to less than optimum results. Among the problems with such a configuration are a lack of reproducibility and heavy coupling with nearby objects. To eliminate these problems, many

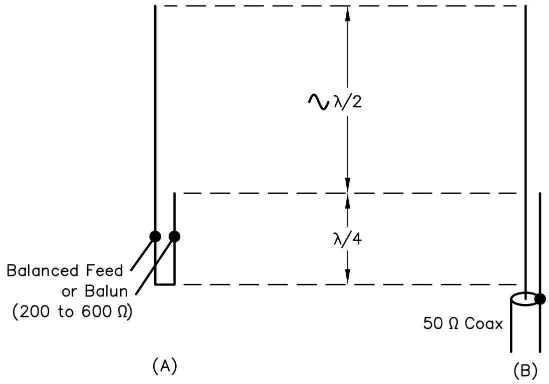

Fig 35—Two configurations of the J antenna.

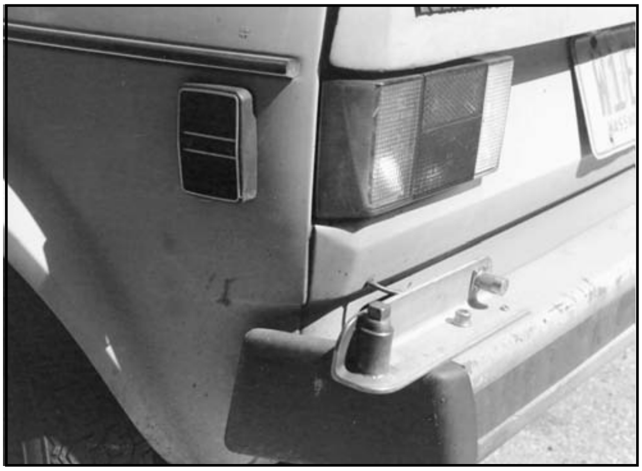

Fig 36—The mount for the mobile J is made from stainless-steel angle stock and secured to the bumper with stainless-steel hardware. Note the $^1/_2$-inch pipe plug and a PL-259 (with a copper disc soldered in its unthreaded end). These protect the mount and connector threads when the antenna is not in use.

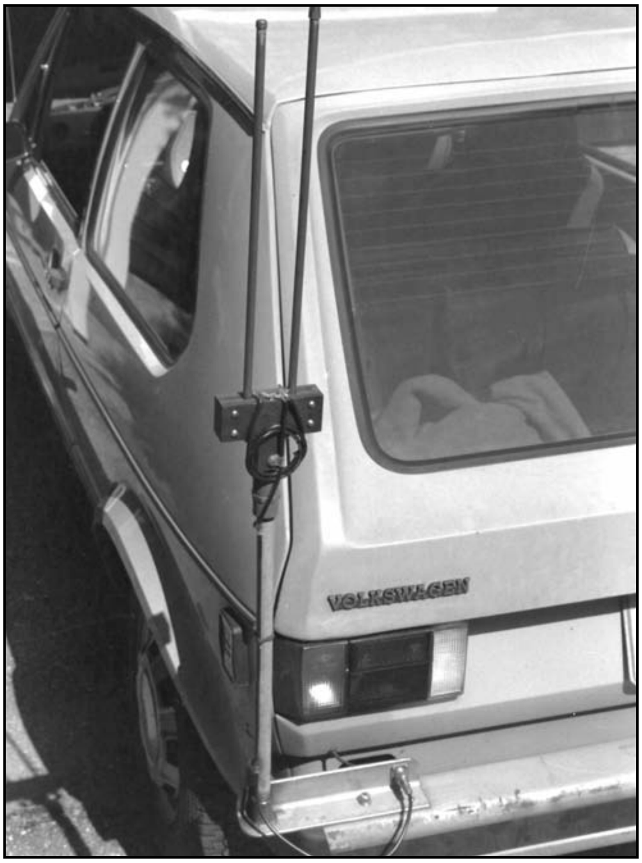

Fig 37—The J antenna, ready for use. Note the bakelite insulator and the method of feed. Tie wraps are used to attach the balun to the mounting block and to hold the coax to the support pipe. Clamps made of flashing copper are used to connect the balun to the J antenna just above the insulating block. The ends of the balun should be weatherproofed.

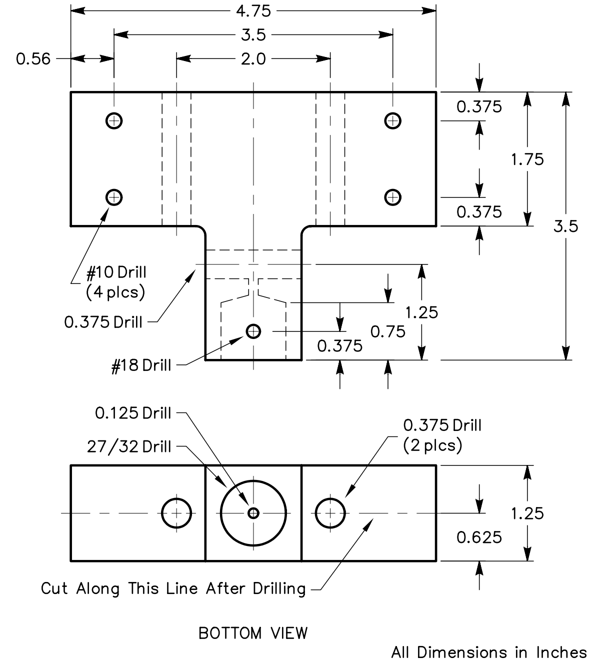

Fig 38—Details of the insulated mounting block. The material is bakelite.

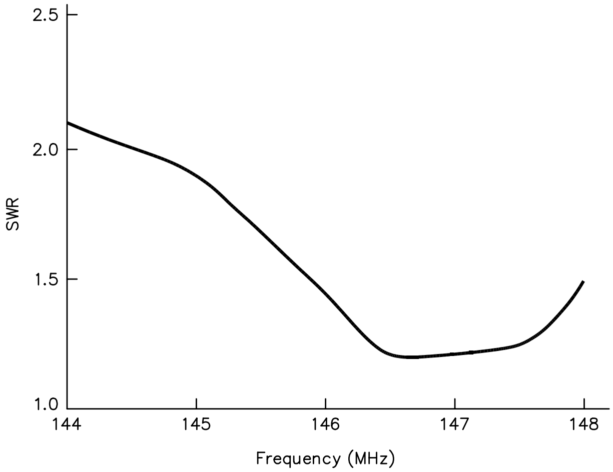

Fig 39—Measured SWR of the mobile J antenna.

amateurs have used a 4:1 half-wave balun between the feed point and a coaxial feed line. This simple addition results in an antenna that can be easily reproduced and that does not interact so heavily with surrounding objects. The bottom of the stub may be grounded (for mechanical or other reasons) without impairing the performance of the antenna.

The open-stub-fed J antenna shown in Fig 35B can be connected directly to low-impedance coax lines with good results. The lack of a movable balun (which allows some impedance adjustment) may make this antenna a bit more difficult to adjust for minimum SWR, however.

The Length Factor

Dr. John S. Belrose, VE2CV, noted in *The Canadian Amateur* that the diameter of the radiating element is important to two characteristics of the antenna—its bandwidth and its physical length. (See Bibliography at the end of this chapter.) As the element diameter is increased, the usable bandwidth increases, while the physical length of the radiating element decreases with respect to the free-space half-wavelength. The increased diameter makes the end effect more pronounced, and also slows the velocity of propagation on the element. These two effects are related to resonant antenna lengths by a factor, “k.” This factor is expressed as a decimal fraction giving the equivalent velocity of propagation on the antenna wire as a function of the ratio of the element diameter to a wavelength. The k factor is discussed at length in Chapter 2.

The length of the radiating element is given by

$$\ell = \frac{5904 \times k}{f} \quad \text{(Eq 25)}$$

where

ℓ = length in inches
f = frequency in MHz
k = k factor.

The k factor can have a significant effect. For example, if you use a $^5/_8$-inch diameter piece of tubing for the radiator at 144 MHz, the k value is 0.907 (9.3% shorter than a free-space half wavelength).

The J antenna gives excellent results for both mobile and portable work. The mobile described here is similar to an antenna described by W. B. Freely, K6HMS, in April 1977 *QST*. This design uses mechanical components that are easier to obtain. As necessary with all mobile antennas, significant attention has been paid to a strong, reliable, mechanical design. It has survived not only three New England winters, but also two summers of 370-mile weekend commutes. During this time, it has maintained consistent electrical performance with no noticeable deterioration.

The mechanical mount to the bumper is a 2 × 2-inch stainless steel angle iron, 10 inches long. It is secured to the bumper with stainless steel hardware, as shown in **Fig 36**. A stainless steel $^1/_2$-inch pipe coupling is welded to the left side of the bracket, and an SO-239 connector is mounted at the right side of the bracket. The bracket is mounted to the bumper so a vertical pipe inserted in the coupling will allow the hatchback of the vehicle to be opened with the antenna installed, **Fig 37**.

A $^1/_2$-inch galvanized iron pipe supports the antenna so the radiating portion of the J is above the vehicle roof line. This pipe goes into a bakelite insulator block, visible in Fig 37. The insulator block also holds the bottom of the stub. This block was first drilled and then split with a band saw, as shown in **Fig 38**. After splitting, the two portions are weatherproofed with varnish and rejoined with 10-32 stainless hardware. The corners of the insulator are cut to clear the L sections at the shorted end of the stub.

The quarter-wave matching section is made of $^1/_4$-inch type L copper tubing ($^5/_{16}$ inch ID, $^3/_8$ inch OD). The short at the bottom of the stub is made from two copper L-shaped sections and a short length of $^1/_4$-inch tubing. Drill a $^1/_8$-inch hole in the bottom of this piece of tubing to drain any water that may enter or condense in the stub.

A $^5/_{16}$-inch diameter brass rod, $1^1/_2$ to 2 inches long, is partially threaded with a $^5/_{16}$ × 24 thread to accept a Larsen whip connector. This rod is then sweated into one of the legs of the quarter-wave matching section. A 40-inch whip is then inserted into the Larsen connector.

The antenna is fed with 50-Ω coaxial line and a coaxial 4:1 half-wave balun. This balun is described at the end of Chapter 26. As with any VHF antenna, use high-quality coax for the balun. Seal all open cable ends and the rear of the SO-239 connector on the mount with RTV sealant.

Adjustment is not complicated. Set the whip so that its tip is 41 inches above the open end of the stub, and adjust the balun position for lowest SWR. Then adjust the height of the whip for the lowest SWR at the center frequency you desire. **Fig 39** shows the measured SWR of the antenna after adjustments are completed.

THE SUPER-J MARITIME ANTENNA

This 144-MHz vertical antenna doesn't have stringent grounding requirements and can be made from easy to find parts. The material in this section was prepared by Steve Cerwin, WA5FRF, who developed the Super-J for use on his boat.

Antennas for maritime use must overcome difficulties that other kinds of mobile antennas normally do not encounter. For instance, the transom of a boat is the logical place to mount an antenna. But the transoms of many boats are composed mostly of fiberglass, and they ride some distance out of the water—from several inches to a few feet, depending on the size of the vessel. Because the next best thing to a ground plane (the water surface) is more than an appreciable fraction of a wavelength away at 144 MHz, none of the popular gain-producing antenna designs requiring a counterpoise are suitable. Also, since a water surface does a good job of assuming the earth's lowest mean elevation (at least on a calm day), anything that can be done to get the radiating part of the antenna up in the air is helpful.

One answer is the venerable J-pole, with an extra in-phase half-wave section added on top—the Super-J antenna. The two vertical half waves fed in phase give outstanding omnidirectional performance for a portable antenna. Also, the J-pole feed arrangement provides the desired insensitivity to height above ground (or water) plus added overall antenna height. Best of all, a $^1/_4$-wave CB whip provides enough material to build the whole driven element of the antenna, with a few inches to spare. The antenna has enough bandwidth to cover the entire 144-MHz band, and affords a measure of lightning protection by being a grounded design.

Antenna Operation

The antenna is represented schematically in **Fig 40**. The classic J-pole antenna is the lower portion shown between points A and C. The half-wave section between points B and C does most of the radiating. The added half-wave section of the Super-J version is shown between points C and E. The side-by-side quarter-wave elements between points A and B comprise the J feed arrangement.

At first glance, counterproductive currents in the J section between points A and B may seem a waste of element material, but it is through this arrangement that

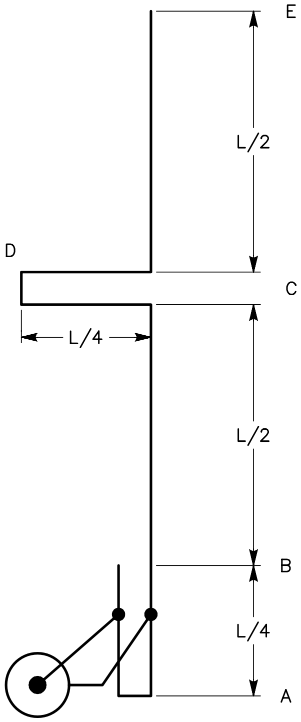

Fig 40—Schematic representation of the Super-J maritime antenna. The radiating section is two half waves in phase.

the antenna is able to perform well in the absence of a good ground. The two halves of the J feed arrangement, side by side, provide a loading mechanism regardless of whether or not a ground plane is present.

The radiation resistance of any antenna fluctuates as a function of height above ground, but the magnitude of this effect is small compared to the wildly changing impedance encountered when the distance from a ground plane element to its counterpoise is varied. Also, the J section adds $^{1}/_{4}$ wavelength of antenna height, reducing the effect of ground height variations even further. Reducing ground-height sensitivity is particularly useful in maritime operation on those days when the water is rough.

The gain afforded by doubling the aperture of a J-pole with the extra half-wave section can be realized only if the added section is excited in phase with the half-wave element B-C. This is accomplished in the Super-J in a conventional manner, through the use of the quarter-wave phasing stub shown between C and D.

Construction and Adjustment

The completed Super-J is shown in **Fig 41**. Details of the individual parts are given in **Fig 42**. The driven element can be liberated from a quarter-wave CB whip antenna and cut to the dimensions shown. All other metal stock can be obtained from metal supply houses or machine shops. Metal may even be scrounged for little or nothing as scraps or remnants, as were the parts for the antenna shown here.

The center insulator and the two J stub spacers are made of $^{1}/_{2}$-inch fiberglass and stainless steel stock, and the end caps are bonded to the insulator sections with epoxy. If you don't have access to a lathe to make the end caps, a simpler one-piece insulator design of wood or fiberglass could be used. However, keep in mind that good electrical connections must be maintained at all joints, and strength is a consideration for the center insulator.

The quarter-wave phasing stub is made of $^{1}/_{8}$-inch stainless steel tubing, **Fig 43**. The line comprising this stub is bent in a semicircular arc to narrow the vertical profile and to keep the weight distribution balanced. This makes for an attractive appearance and keeps the antenna from leaning to one side.

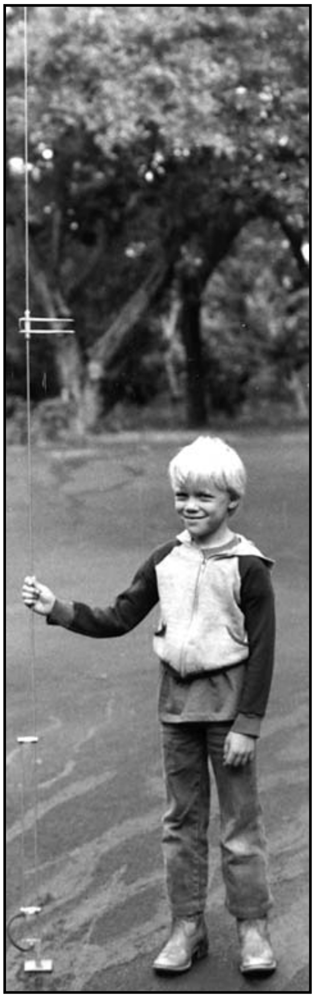

Fig 41—Andy and the assembled Super-J antenna.

The bottom shorting bar and base mounting plate are made of $^{1}/_{4}$-inch stainless steel plate, shown in **Fig 44**. The J stub is made of $^{3}/_{16}$-inch stainless-steel rod stock. The RF connector may be mounted on the shorting bar as shown, and connected to the adjustable slider with a short section of coaxial cable. RTV sealant should be used at the cable ends to keep out moisture. The all-stainless construction looks nice and weathers well in maritime mobile applications.

The antenna should work well over the whole 144-MHz band if cut to the dimensions shown. The only tuning required is adjustment of the sliding feed point for minimum SWR in the center of the band segment you use most. Setting the slider 2$^{13}/_{16}$ inch above the top of the shorting bar gave the best match for this antenna and may be used for a starting point. Four turns of coax made into a coil at the feed point or a ferrite-sleeve balun act as a common-mode choke balun to ensure satisfactory performance.

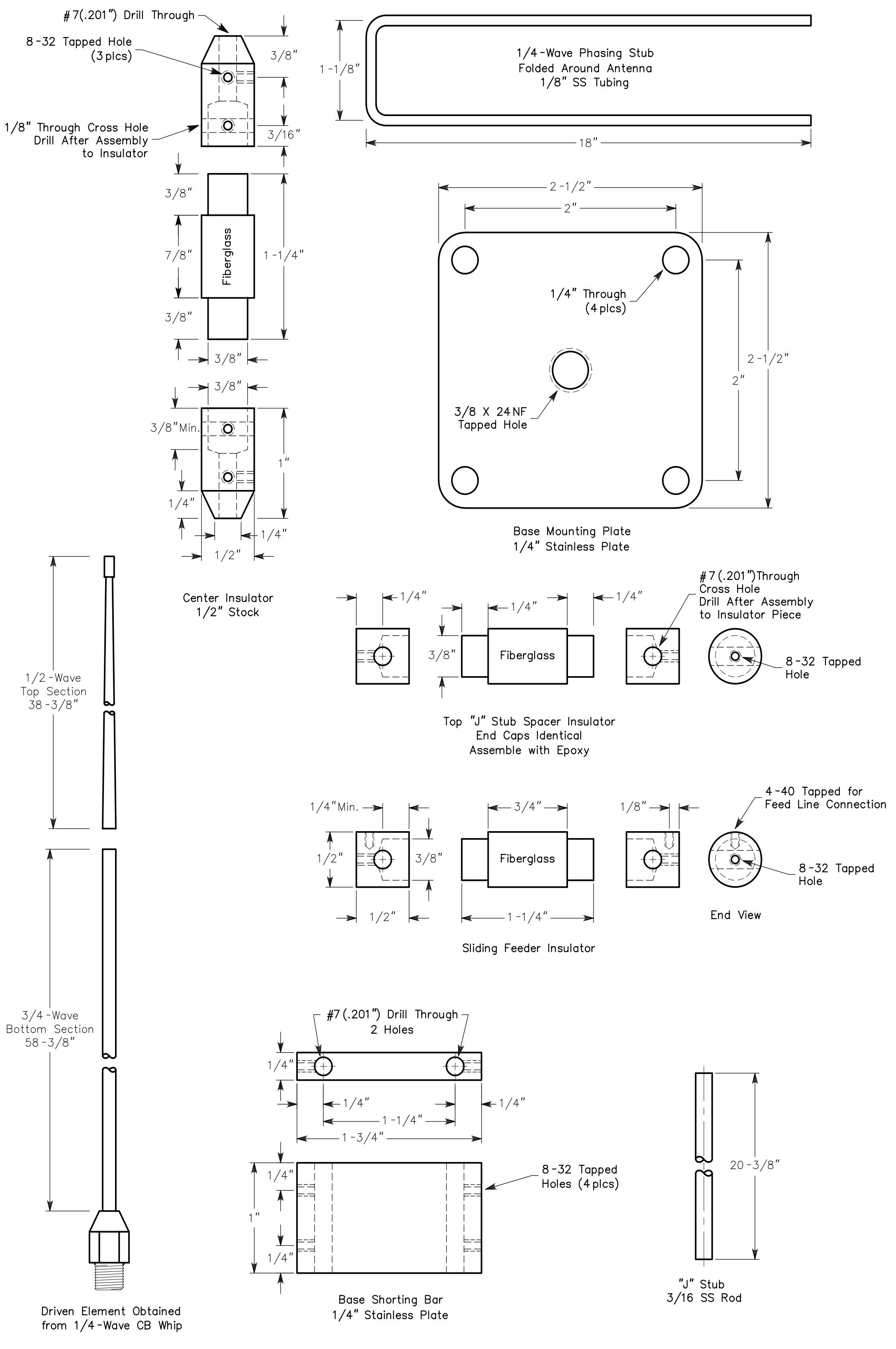
#7(.201") Drill Through
8-32 Tapped Hole (3 plcs)
3/8"
1/8" Through Cross Hole Drill After Assembly to Insulator
3/16"
3/8"
7/8"
Fiberglass
1-1/4"
3/8"
3/8"
3/8"
3/8" Min.
1"
1/4"
1/4"
1/2"
Center Insulator
1/2" Stock
1-1/8"
1/4-Wave Phasing Stub
Folded Around Antenna
1/8" SS Tubing
18"
2-1/2"
2"
1/4" Through (4 plcs)
3/8 X 24 NF Tapped Hole
2-1/2"
2"
Base Mounting Plate
1/4" Stainless Plate
1/2-Wave Top Section 38-3/8"
3/4-Wave Bottom Section 58-3/8"
Driven Element Obtained from 1/4-Wave CB Whip
1/4"
1/4"
1/4"
3/8"
Fiberglass
#7 (.201")Through Cross Hole Drill After Assembly to Insulator Piece
8-32 Tapped Hole
Top "J" Stub Spacer Insulator
End Caps Identical
Assemble with Epoxy
1/4" Min.
3/4"
1/8"
4-40 Tapped for Feed Line Connection
1/2"
3/8"
Fiberglass
8-32 Tapped Hole
1/2"
1-1/4"
End View
Sliding Feeder Insulator
#7 (.201") Drill Through
2 Holes
1/4"
1/4"
1/4"
1-1/4"
1-3/4"
1/4"
1"
1/4"
8-32 Tapped Holes (4 plcs)
Base Shorting Bar
1/4" Stainless Plate
20-3/8"
"J" Stub
3/16 SS Rod

Fig 42—Details of parts used in the construction of the 144-MHz Super-J. Not to scale.

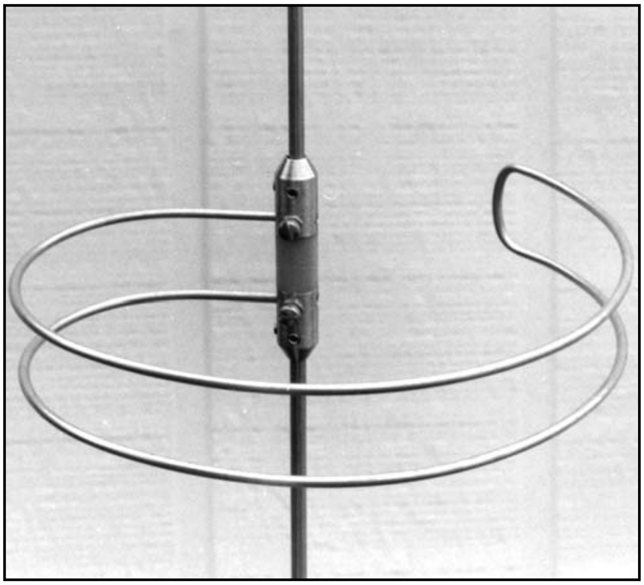

Fig 43—A close-up look at the $^1/_4$-λ phasing section of the Super-J. The insulator fitting is made of stainless-steel end caps and fiberglass rod.

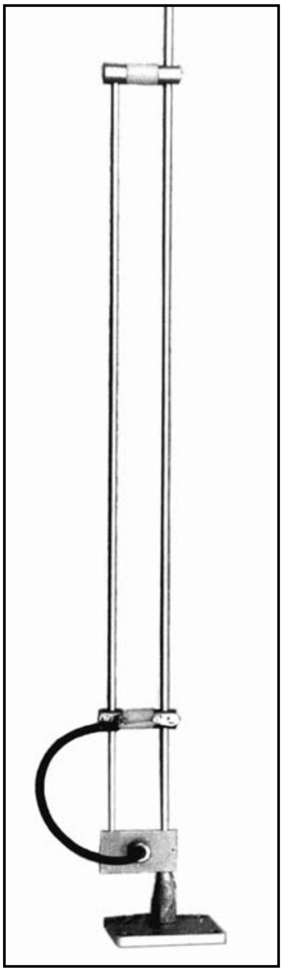

Fig 44—The bottom shorting bar and base mounting plate assembly.

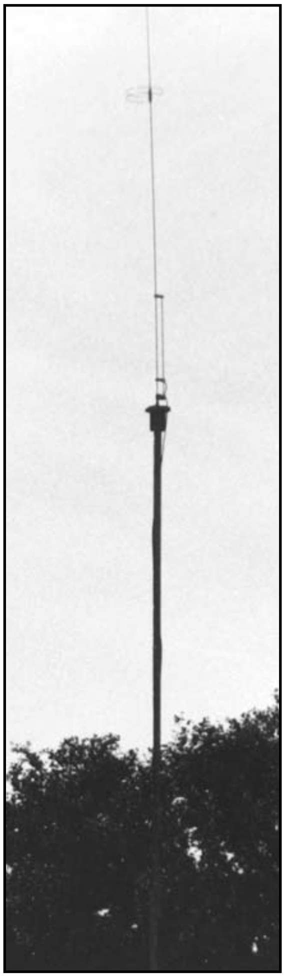

Fig 45—The Super-J in portable use at a field site.

Performance

Initial tests of the Super-J were performed in portable use and were satisfactory, if not exciting. **Fig 45** shows the Super-J mounted on a wooden mast at a portable site. Simplex communication with a station 40 miles away with a 10-W mobile rig was full quieting both ways. Stations were worked through distant repeaters that were thought inaccessible from this location.

Comparative tests between the Super-J and a commercial $^5/_8$-wave antenna mounted on the car showed the Super-J to give superior performance, even when the Super-J was lowered to the same height as the car roof. The mast shown in Fig 45 was made from two 8-foot lengths of 1 × 2-inch pine. (The two mast sections and the Super-J can be easily transported in most vehicles.)

The Super-J offers a gain of about 6 dB over a quarter-wave whip and around 3 dB over a $^5/_8$-wave antenna. Actual performance, especially under less-than-ideal or variable ground conditions, is substantially better than other vertical antennas operated under the same conditions. The freedom from ground-plane radials proves to be a real benefit in maritime mobile operation, especially for those passengers in the back of the boat with sensitive ribs!

A TOP-LOADED 144-MHz MOBILE ANTENNA

Earlier in this chapter, the merits of various loading schemes for shortened whip antennas were discussed. Quite naturally, one might be considering HF mobile operation for the application of those techniques. But the principles may be applied at any frequency. **Fig 46** shows a 144-MHz antenna that is both top and center loaded. This antenna is suitable for both mobile and portable operation, being intended for use on a handheld transceiver. This antenna was devised by Don Johnson, W6AAQ, and Bruce Brown, W6TWW.

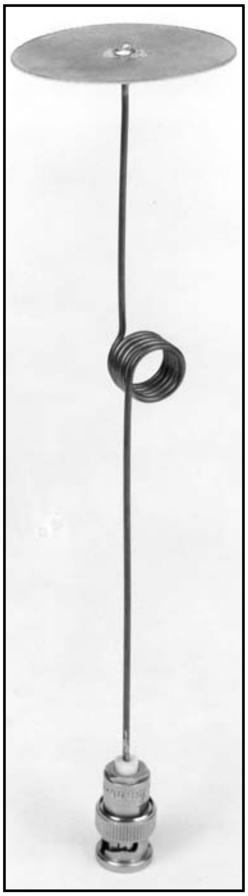

Fig 46—This 144-MHz antenna uses a combination of top and center loading. It offers low construction cost and improved efficiency over continuously loaded rubber-ducky antennas.

A combination of top and center loading offers improved efficiency over continuously loaded antennas such as the "stubby" pictured at the beginning of this chapter. This antenna also offers low construction cost. The only materials needed are a length of stiff wire and a scrap of circuit-board material, in addition to the appropriate connector.

Construction

The entire whip section with above-center loading coil is made of one continuous length of material. An 18-inch length of brazing rod or #14 Copperweld wire is suitable.

In the antenna pictured in Fig 46, the top loading disk was cut from a scrap of circuit-board material, but flashing copper or sheet brass stock could be used instead. Aluminum is not recommended.

The dimensions of the antenna are given in **Fig 47**. First wind the center loading coil. Use a $^1/_2$-inch bolt, wood dowel, or other cylindrical object for a coil form. Begin winding at a point 3 inches from one end of the wire, and wrap the wire tightly around the coil form. Wind 5$^1/_2$ turns, with just enough space between turns so they don't touch.

Remove the coil from the form. Next, determine the length necessary to insert the wire into the connector you'll be using. Cut the long end of the wire to this length plus 4 inches, measured from the center of the coil. Solder the wire to the center pin and assemble the connector. A tight-fitting sleeve made of Teflon or Plexiglas rod may be used to support and insulate the antenna wire inside the shell. An alternative is to fill the shell with epoxy cement, and allow the cement to set while the wire is held centered in the shell.

The top loading disk may be circular, cut with a hole saw. A circular disk is not required, however—it may be of any shape. Just remember that with a larger disk, less coil inductance will be required, and vice versa. Drill a hole at the center of the disk for mounting it to the wire. For a more rugged antenna, reinforce the hole with a brass eyelet. Solder the disk in place at the top of the antenna, and construction is completed.

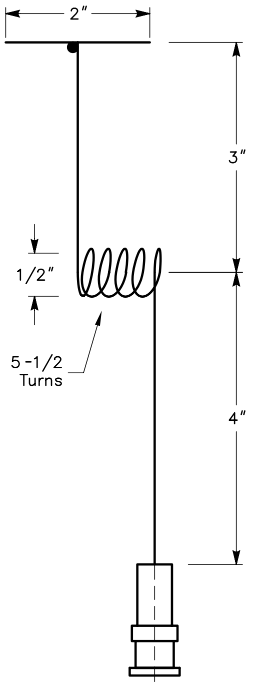

Fig 47—Dimensions for the top-loaded 144-MHz antenna. See text regarding coil length.

Tune-Up

Adjustment consists of spreading the coil turns for the correct amount of inductance. Do this at the center frequency of the range you'll normally be using. Optimum inductance is determined with the aid of a field strength meter at a distance of 10 or 15 feet.

Attach the antenna to a handheld transceiver operating on low power, and take a field-strength reading. With the transmitter turned off, spread the coil turns slightly, and then take another reading. By experiment, spread or compress the coil turns for the maximum field-strength reading. Very little adjustment should be required. There is one precaution, however. You must keep your body, arms, legs, and head in the same relative position for each field-strength measurement. It is suggested that the transceiver be placed on a nonmetal table and operated at arm's length for these checks.

Once the maximum field-strength reading is obtained, adjustments are completed. With this antenna in operation, you'll likely find it possible to access repeaters that are difficult to reach with other shortened antennas. W6AAQ reports that in distant areas his antenna even outperforms a $^5/_8$-λ vertical.

VHF QUARTER-WAVELENGTH VERTICAL

Ideally, a VHF vertical antenna should be installed over a perfectly flat reflector to assure uniform omnidirectional radiation. This suggests that the center of the automobile roof is the best place to mount it for mobile use. Alternatively, the flat portion of the trunk deck can be used, but will result in a directional pattern because of car-body obstruction.

Fig 48 illustrates how a Millen high-voltage connector can be used as a roof mount for a VHF whip. The hole in the roof can be made over the dome light, thus providing accessibility through the upholstery. RG-59 and the $^1/_4$-wave matching section, L (Fig 48C), can be routed between the car roof and the ceiling upholstery and brought into the trunk compartment, or down to the dashboard of the car. Instead of a Millen connector, some operators install an SO-239 coax connector on the roof for mounting the whip. The method is similar to that shown in Fig 48.

It has been established that in general, $^1/_4$-λ vertical antennas for mobile repeater work are not as effective as $^5/_8$-λ verticals are. With a $^5/_8$-λ antenna, more of the transmitted signal is directed at a low wave angle, toward the horizon, offering a gain of about 1 dB over the $^1/_4$-λ vertical. However, in areas where the repeater is located nearby on a very high hill or a mountain top, the $^1/_4$-λ antenna will usually offer more reliable per-

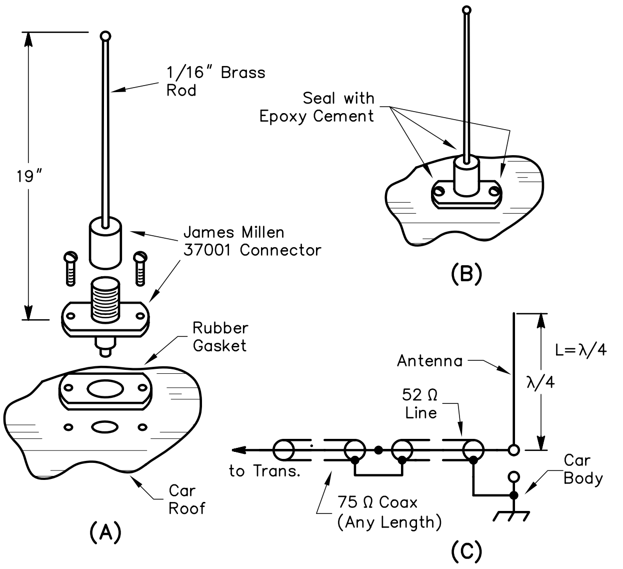

Fig 48—At A and B, an illustration of how a quarter-wavelength vertical antenna can be mounted on a car roof. The whip section should be soldered into the cap portion of the connector and then screwed into the base socket. This arrangement allows for the removal of the antenna when desired. Epoxy cement should be used at the two mounting screws to prevent the entry of moisture through the screw holes. Diagram C is discussed in the text.

formance than a $^5/_8$-λ antenna. This is because there is more power in the lobe of the $^1/_4$-λ vertical at higher angles.

144-MHz 5/8-WAVELENGTH VERTICAL

Perhaps the most popular antenna for 144-MHz FM mobile and fixed-station use is the $^5/_8$-wavelength vertical. As compared to a $^1/_4$-wavelength vertical, it has 1 dB of gain.

This antenna is suitable for mobile or fixed-station use because it is small, omnidirectional, and can be used with radials or a solid-plane ground (such as a car body). If radials are used, they need be only $^1/_4$ wavelength long.

Construction

The antenna shown here is made from low-cost materials. **Fig 49** shows the base coil and aluminum mounting plate. The coil form is a piece of low-loss solid rod, such as Plexiglas or phenolic. The dimensions for this and other parts of the antenna are given in **Fig 50**. A length of brazing rod is used as the whip section.

The whip should be 47 inches long. However, brazing rod comes in standard 36-inch lengths, so if used, it is necessary to solder an 11-inch extension to the top of the whip. A piece of #10 copper wire will suffice. Alternatively, a stainless-steel rod can be purchased to make a 47-inch whip. Shops that sell CB antennas should have such rods for replacement purposes on base-loaded antennas. The limitation one can expect with brazing rod is the relative fragility of the material, especially when the threads are cut for screwing the rod into the base coil form. Excessive stress can cause the rod to break where it enters the form. The problem is compli-

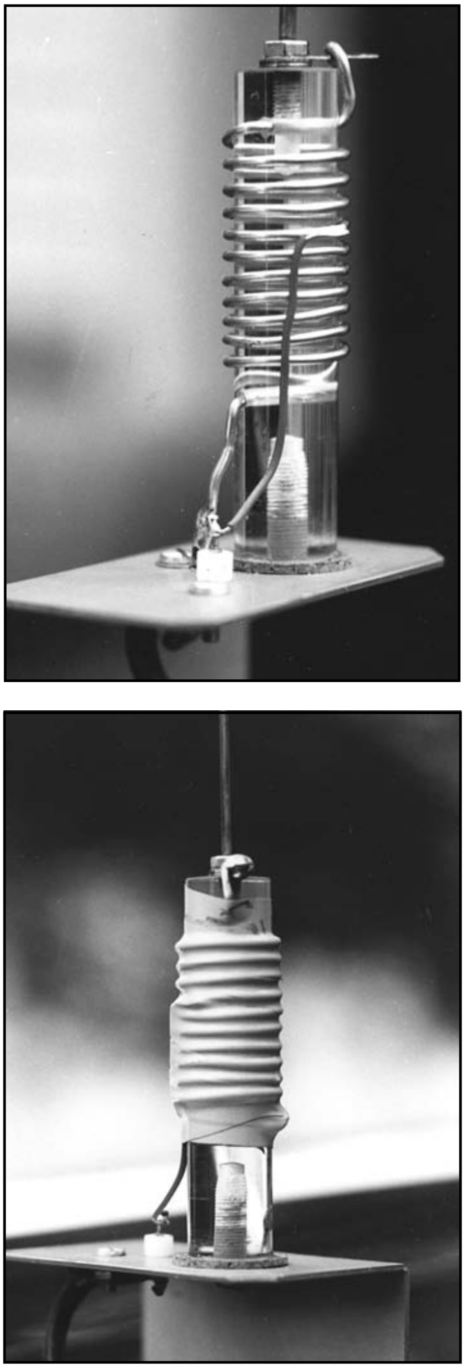

Fig 49—At top, a photograph of the $^5/_8$-λ vertical base section. The matching coil is affixed to an aluminum bracket that screws onto the inner lip of the car trunk. Above, the completed assembly. The coil has been wrapped with vinyl electrical tape to keep out dirt and moisture.

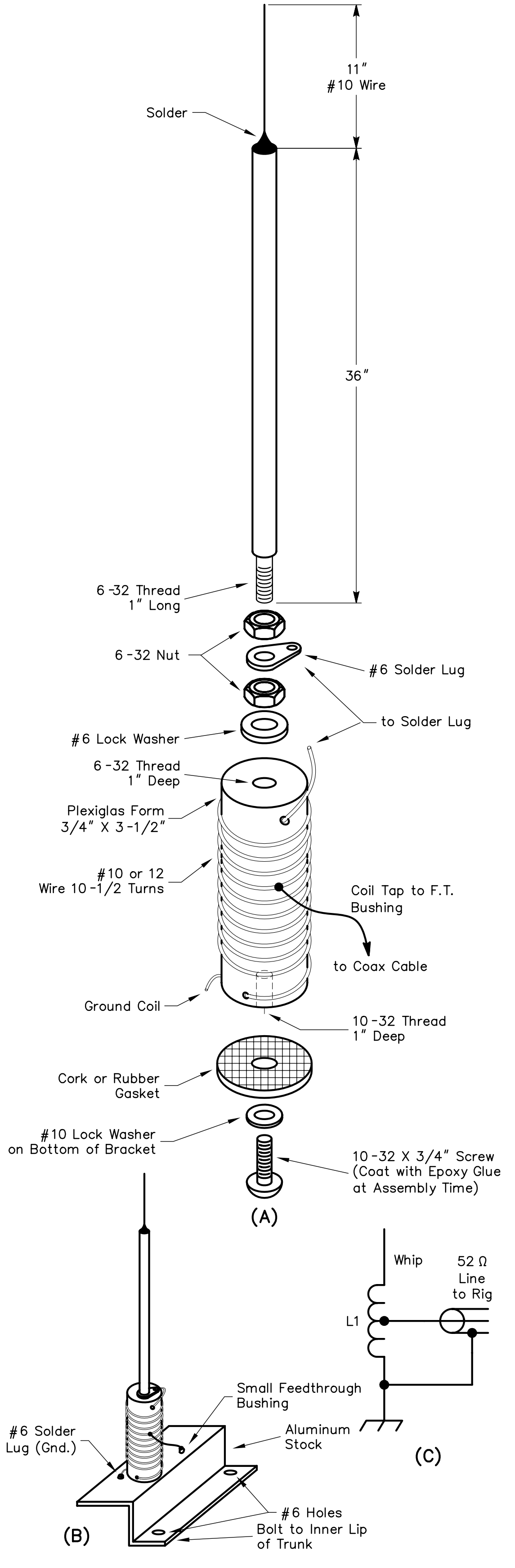
11″
#10 Wire
Solder
36″
6-32 Thread
1″ Long
6-32 Nut
#6 Solder Lug
to Solder Lug
#6 Lock Washer
6-32 Thread
1″ Deep
Plexiglas Form
3/4″ X 3-1/2″
#10 or 12
Wire 10-1/2 Turns
Coil Tap to F.T.
Bushing
to Coax Cable
Ground Coil
10-32 Thread
1″ Deep
Cork or Rubber
Gasket
#10 Lock Washer
on Bottom of Bracket
10-32 X 3/4″ Screw
(Coat with Epoxy Glue
at Assembly Time)
(A)
Whip
52 Ω
Line
to Rig
L1
(C)
Small Feedthrough
Bushing
Aluminum
Stock
#6 Solder
Lug (Gnd.)
#6 Holes
Bolt to Inner Lip
of Trunk
(B)

Fig 50—Structural details for the 2-meter $^{5}/_{8}$-λ antenna are provided at A. The mounting bracket is shown at B and the equivalent circuit is given at C.

cated somewhat in this design because a spring is not used at the antenna mounting point. Builders of this antenna can find all kinds of solutions to the problems just outlined by changing the physical design and using different materials when constructing the antenna. The main purpose of this description is to provide dimensions and tune-up information.

The aluminum mounting bracket must be shaped to fit the car with which it will be used. The bracket can be used to effect a no-holes mount with respect to the exterior portion of the car body. The inner lip of the vehicle trunk (or hood) can be the point where the bracket is attached by means of no. 6 or no. 8 sheet-metal screws. The remainder of the bracket is bent so that when the trunk lid or car hood is raised and lowered, there is no contact between the bracket and the moving part. Details of the mounting unit are given in Fig 50B. A 14-gauge metal (or thicker) is recommended for rigidity.

Wind 10$^{1}/_{2}$ turns of #10 or #12 copper wire on the $^{3}/_{4}$-inch diameter coil form. The tap on L1 is placed approximately four turns below the whip end. A secure solder joint is imperative.

Tune-Up

After the antenna has been mounted on the vehicle, connect an SWR indicator in the 50-Ω transmission line. Key the 144-MHz transmitter and experiment with the coil tap placement. If the whip section is 47 inches long, an SWR of 1:1 can be obtained when the tap is at the right location. As an alternative method of adjustment, place the tap at four turns from the top of L1, make the whip 50 inches long, and trim the whip length until an SWR of 1:1 occurs. Keep the antenna well away from other objects during tune-up, as they may detune the antenna and yield false adjustments for a match.

A 5/8-WAVELENGTH 220-MHz MOBILE ANTENNA

The antenna shown in **Figs 51** and **52** was developed to fill the gap between a homemade $^{1}/_{4}$-λ mobile antenna and a commercially made $^{5}/_{8}$-λ model. While antennas can be made by modifying CB models, that presents the problem of cost in acquiring the original antenna. The major cost in this setup is the whip portion. This can be any tempered rod that will spring easily.

Construction

The base insulator portion is made of $^{1}/_{2}$-inch Plexiglas rod. A few minutes' work on a lathe is sufficient to shape and drill the rod. (The innovative builder can use an electric drill and a file for the lathe work.)

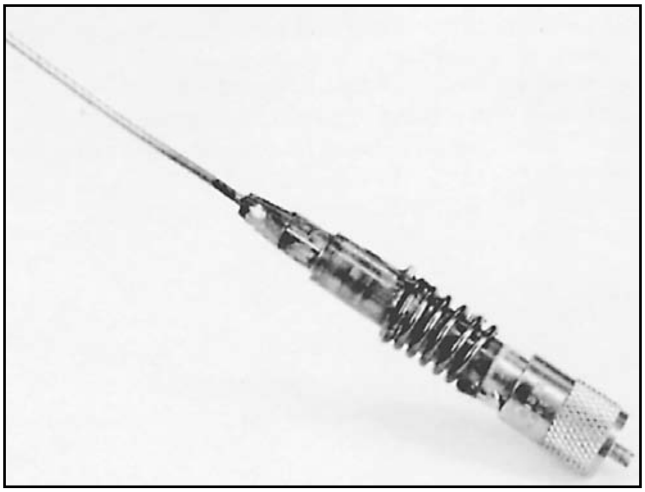

Fig 51—The 220-MHz $^5/_8$-λ mobile antenna. The coil turns are spaced over a distance of 1 inch, and the bottom end of the coil is soldered to the coax connector.

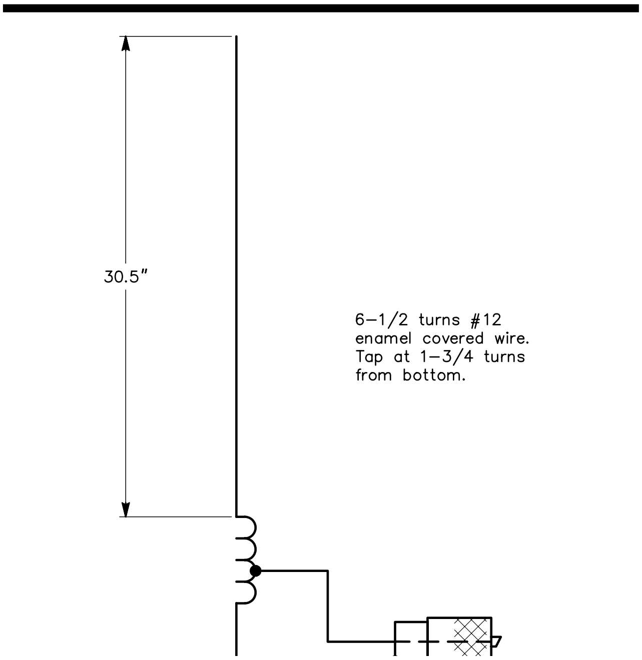

Fig 52—Diagram of the 220-MHz mobile antenna.

The bottom $^1/_2$ inch of the rod is turned down to a diameter of $^3/_8$ inch. This portion will now fit into a PL-259 UHF connector. A $^1/_8$-inch diameter hole is drilled through the center of the rod. This hole will hold the wires that make the connections between the center conductor of the connector and the coil tap. The connection between the whip and the top of the coil is also run through this opening. A stud is force-fitted into the top of the Plexiglas rod. This allows for removal of the whip from the insulator.

The coil should be initially wound on a form slightly smaller than the base insulator. When the coil is transferred to the Plexiglas rod, it will keep its shape and will not readily move. After the tap point has been determined, a longitudinal hole is drilled into the center of the rod. A #22 wire can then be inserted through the center of the insulator into the connector. This method is also used to attach the whip to the top of the coil. After the whip has been fully assembled, a coating of epoxy cement is applied. This seals the entire assembly and provides some additional strength. During a full winter's use there was no sign of cracking or other mechanical failure. The adjustment procedure is the same as for the 144-MHz version described previously.

HF Antennas For Sailboats

This material was contributed by Rudy Severns, N6LF. Many of the antenna ideas appearing earlier in this chapter can be applied to sailboats. However, the presence of the mast and the rigging, plus the prevalence of non-conducting fiberglass hulls complicates the issue. There are many possibilities for antennas aboard sailboats. This includes both permanently installed antennas and antennas that can be hoisted for temporary use at anchor:

1. ***Permanent***
   Commercial or home-brew automobile-type verticals
   Backstay verticals and slopers
   Shunt feed of uninsulated rigging

2. ***Temporary***
   Sloping dipoles
   Inverted V's
   Yagis

You should remember some basic facts of life on a sailboat:

1) On most boats the spars, standing rigging and some running rigging will be conductors. Stainless steel wire is usually used for the rigging and aluminum for the spars.
2) Topping lifts, running backstays and jackstays all may be made of conducting materials and may often change position while the boat is underway. This changes the configuration of the rigging and may affect radiation patterns and feed-point impedances.
3) Shipboard antennas will always be close to the mast and rigging, in terms of electrical wavelength. Some antennas may in fact be part of the rigging.
4) The feed-point impedance and radiation pattern can be strongly influenced by the presence of the rigging.
5) Because of the close proximity, the rigging is an integral part of the antenna and should be viewed as such.
6) The behavior of a given antenna will depend on the details of the rigging on a particular vessel. The performance of a given antenna can vary widely on different boats, due to differences in dimensions and arrangement of the rigging.
7) Even though you may be floating on a sea of salt water, grounding still requires careful attention!

ANTENNA MODELING

Because of the strong interaction between the rigging and the antenna, accurate prediction of radiation patterns and a reasonable guess at expected feed-point impedance requires that you model both the antenna and the rigging. Unless you do accurately model the system, considerable cut-and-try may be needed. This can be expensive when it has to be done in 1 × 19 stainless steel wire with $300 swaged insulator fittings!

In fact, when your antenna is going to be part of standing rigging, it's a very good idea to try your designs out at the dock. You could temporarily use Copperweld wire and inexpensive insulators in place of the stainless rigging wire and the expensive insulators. This approach can save a good deal of money and aggravation. A wide variety of modeling programs are available and can be very helpful in designing a new antenna but they have to be used with some caution:

1) The rigging will have many small intersection angles and radically different conductor diameters, this can cause problems for *NEC* and *MININEC* programs.
2) You must usually taper the segment lengths near the junctions. This is done automatically in programs like *ELNEC* and *EZNEC*.
3) It is usually necessary to use one wire size for the mast, spars and rigging. Some improvement in accuracy can be obtained by modeling the mast as a cage of 3 or 4 wires.

The predicted radiation patterns will be quite good but the feed-point impedance predictions should be viewed as preliminary. Some final adjustment will usually be required. Because of the wide variation between boats, even those of the same class, each new installation is unique and should be analyzed separately.

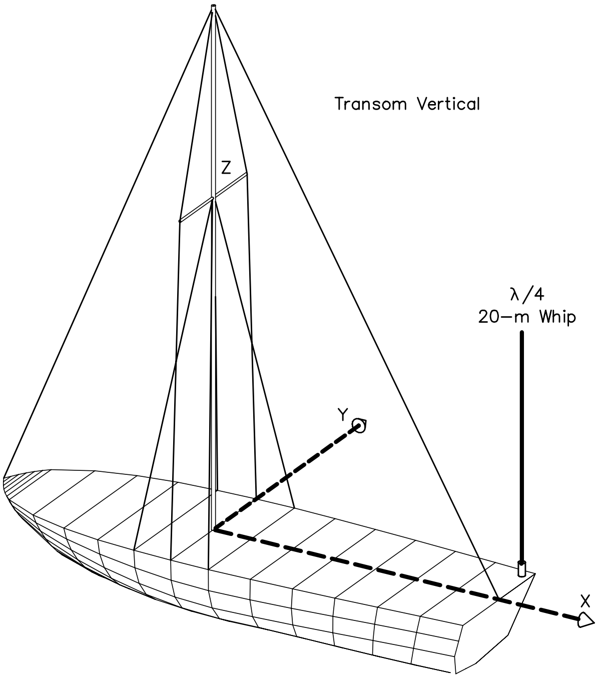

Fig 53—An example of a 20-meter λ/4 whip mounted on the transom. A local ground system must also be provided, as described in the section on grounding.

A SAFETY NOTE

Ungrounded rigging endpoints near deck level can have high RF potentials on them when you transmit. For example, the shrouds on a fiberglass boat connect to chainplates that are bolted to the hull, but are not grounded. These can inflict painful RF burns on the unwary, even while operating at low power! As a general rule all rigging, spars and lifelines near deck level should be grounded. This also makes good sense for lightning protection. For a backstay antenna with its feed point near deck level, a sleeve of heavy wall PVC pipe can be placed over the lower end of the stay as a protective shield.

TRANSOM AND MASTHEAD MOUNTED VERTICALS

A very common antenna for boats is a vertical, either a short mobile antenna or a full λ/4, placed on the transom, as shown in **Fig 53**. Note that in this example the antenna is mounted off to one side—it could also be mounted in the center of the transom. The 20-meter radiation pattern for this antenna as shown in **Fig 54**. Unlike a free standing vertical, this antenna doesn't have an omnidirectional pattern. It is asymmetrical, with a front-to-back ratio of about 13 dB. Further, the angle for maximum gain is offset in the direction the antenna is placed on the transom.

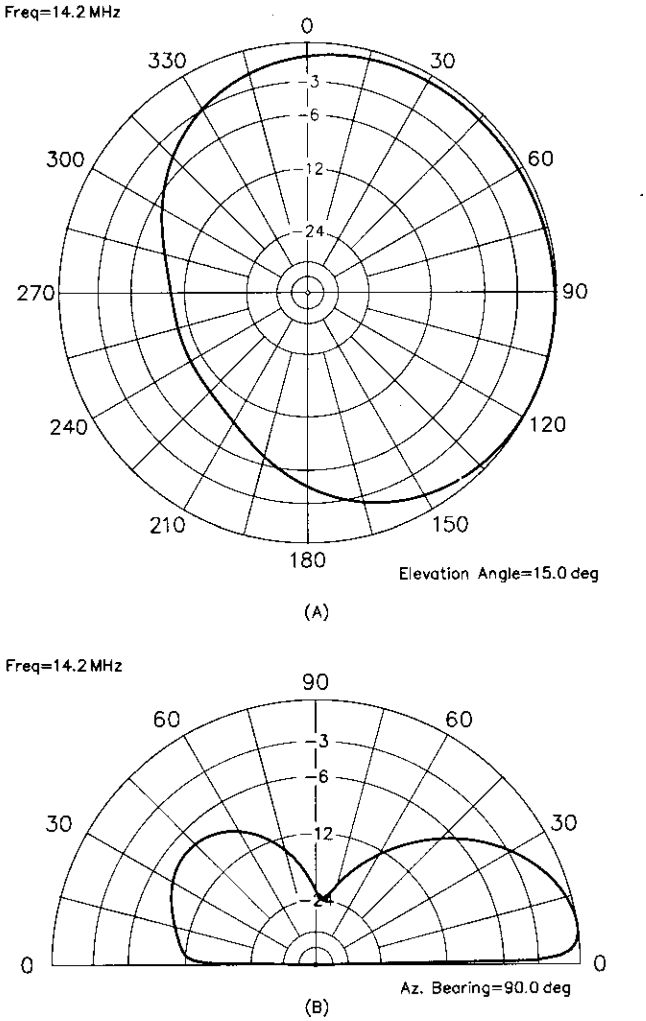

Fig 54—Typical radiation pattern for the λ/4 transom mounted whip in Fig 53.

This is a very good example of the profound effect the rigging can have on any antenna used on board a sailboat. Not only is the pattern affected but the feed-point impedance will be reduced from a nominal 36 Ω to 25 to 30 Ω.

The directive gain can be useful—if you point the boat in the right direction! Usually, however, a more uniform omnidirectional pattern is more desirable. It is tempting to suggest putting the vertical at the masthead, perhaps using a 6-foot loaded automobile whip, with the mast and rigging acting as a ground plane. **Fig 55** shows such a system. Unfortunately, this usually doesn't work very well because the overall height of the mast and antenna will very likely be > 5/8 λ. This will result in high-angle lobes, as shown in **Fig 56**. Depending on the mast height, this idea may work reasonably well on 40 or 80 meters, but

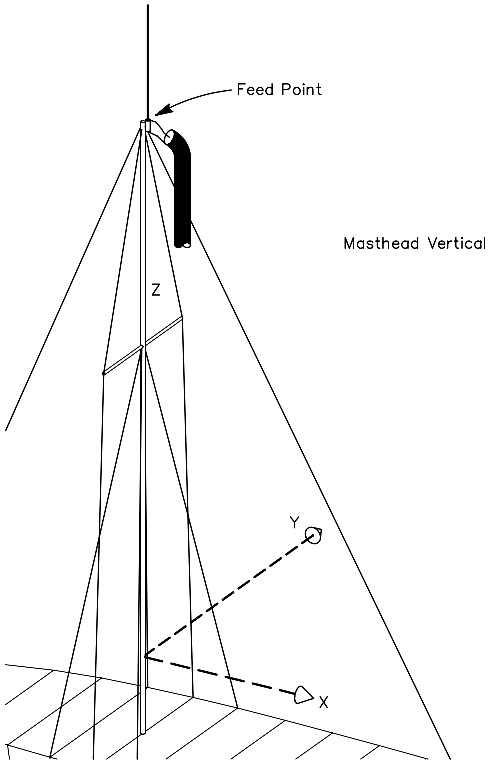

Fig 55—A whip mounted at the masthead. The feed line is fed back down the mast either inside or outside. The base of the mast and the rigging is assumed to be properly grounded.

you will still be faced with severe mechanical stress due to magnified motion at the masthead in rough sea. The masthead is usually reserved to VHF antennas, with their own radial ground plane.

THE BACKSTAY VERTICAL

A portion of the backstay can be insulated and used as a vertical as shown in **Fig 57**. The length of the insulated section will be λ/4 on the lowest band of interest. Typically, due to the loading effect of the rest of the rigging, the resonant length of the insulated section will be shorter than the classic 234/f (MHz) relation, although it can in some case actually be longer. Either modeling or trial adjustment can be used to determine the actual length needed. On a typical 35 to 40-foot sailboat, the lowest band for λ/4 resonance will be 40 meters due to the limited length of the backstay. Examples of the radiation patterns on several bands for such an an-

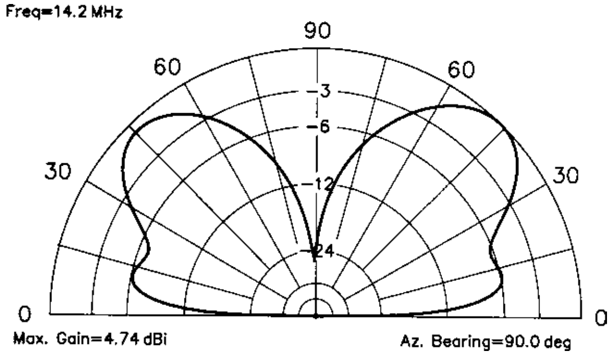

Fig 56—Typical radiation pattern for a masthead-mounted vertical. The multiple vertical lobes are due to the fact the antenna is higher than λ/2.

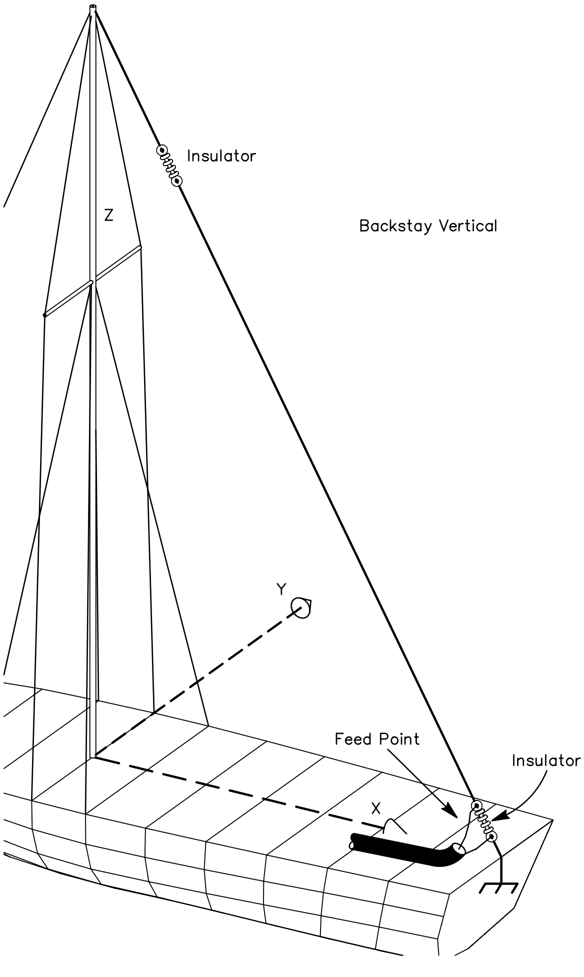

Fig 57—An example of a backstay vertical. A local ground point must be established on the transom next to the base of the backstay.

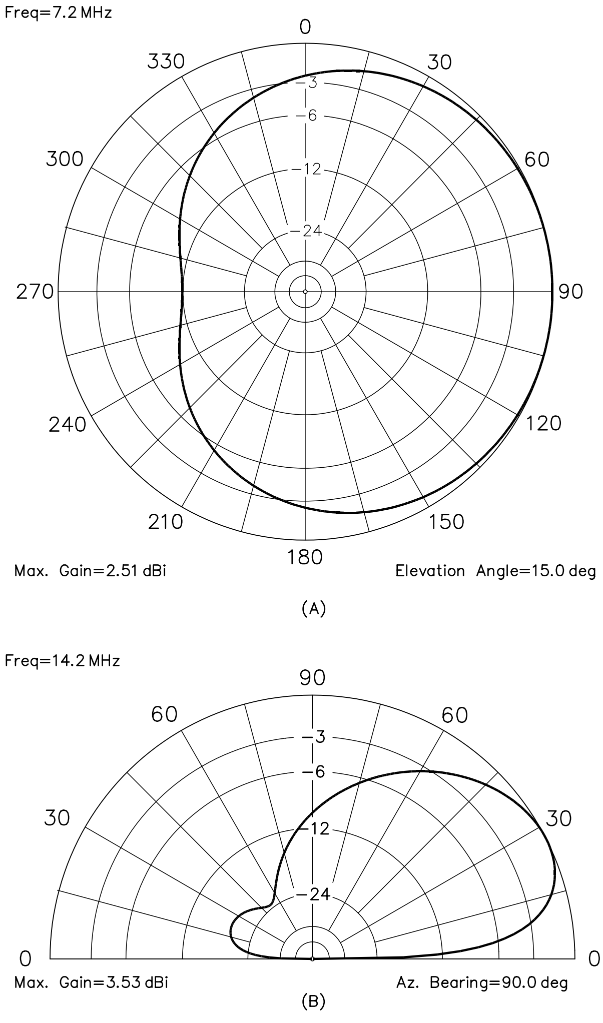

Fig 58—Typical radiation patterns on 40 meters for the backstay vertical in Fig 57.

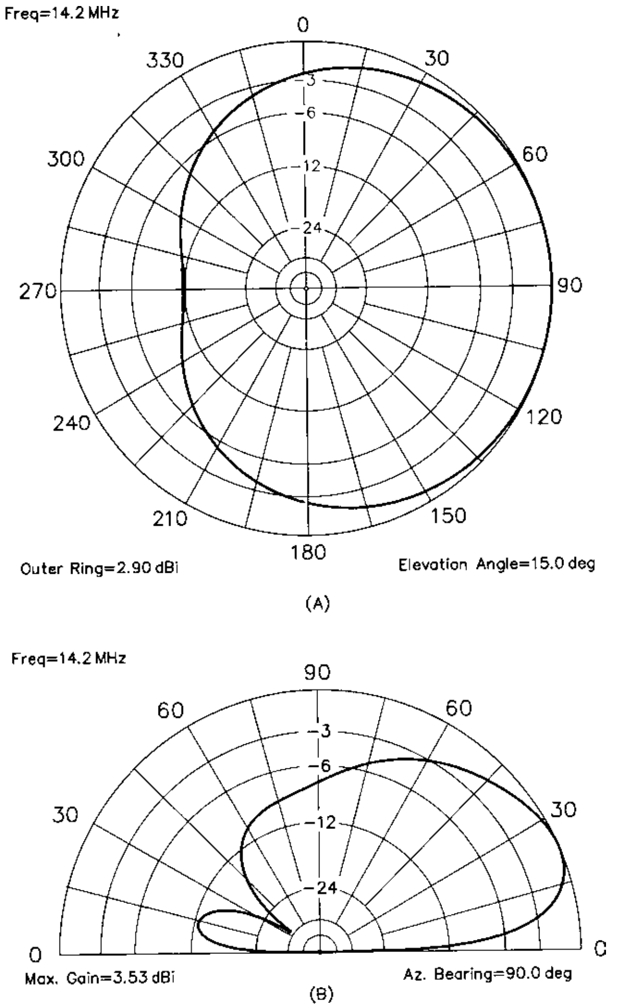

Fig 59—Typical radiation patterns on 20 meters for the backstay vertical in Fig 57.

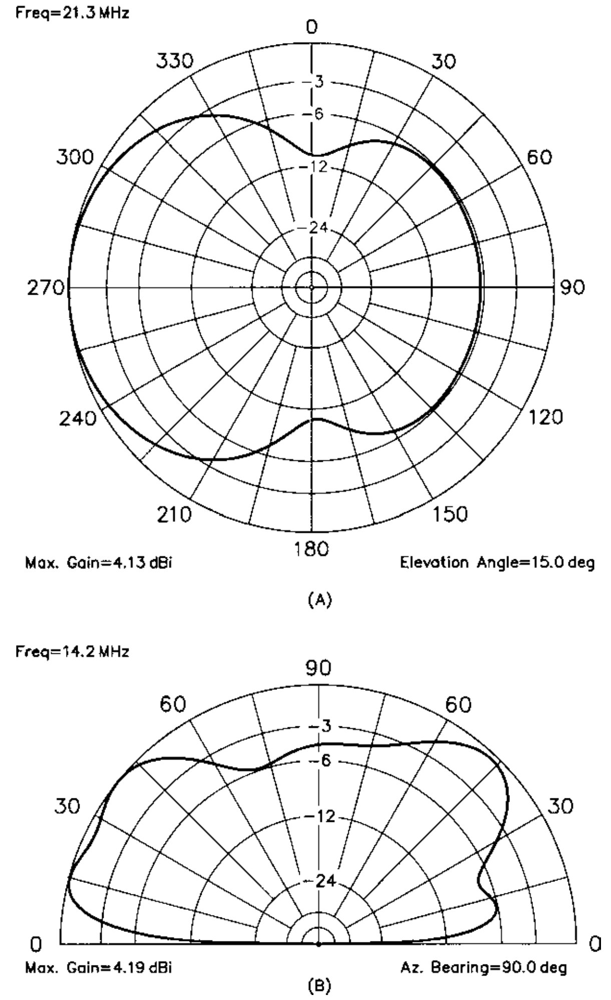

Fig 60—Typical radiation patterns on 15 meters for the backstay vertical in Fig 57.

tenna are given in **Figs 58** through **60**.

The pattern is again quite directional due to the presence of the mast and rigging. On 15 meters, where the antenna is approximately $^3/_4$ λ, higher angle lobes appear. On 40 and 15 meters, the feed point is near a current maximum and is in the range of 30 to 50 Ω. On 20 meters, however, the feed point is a very high impedance because the antenna is near λ/2 resonance. One way to get around this problem for multiband use is to make the antenna longer than λ/4 on the lowest band. If the lowest band is 40 meters then on 20 meters the feed-point impedance will be much lower. This antenna is non-resonant on any of the bands but can be conveniently fed with a tuner because the feed-point impedances are within the range of commonly available commercial tuners. Tuners specifically intended for marine applications frequently can accommodate very high input impedances, but they tend to be quite expensive.

The sensitivity of the radiation pattern to small details of the mast and rigging is illustrated in **Fig 61**. This is the same antenna as shown in Fig 57 with the exception that the forestay is assumed to be ungrounded. In this particular example, ungrounding the forestay drastically increases the front-to-back ratio. With slightly different dimensions, however, the pattern could have changed in other ways.

High-quality insulators for rigging wire can be quite expensive and represent a potential weak point—if they fail the mast may come down. It is not absolutely necessary to use two insulators in a backstay vertical. As shown in **Fig 62**, the upper insulator may be omitted. The radiation patterns are shown in **Figs 63** and **64**. In this case

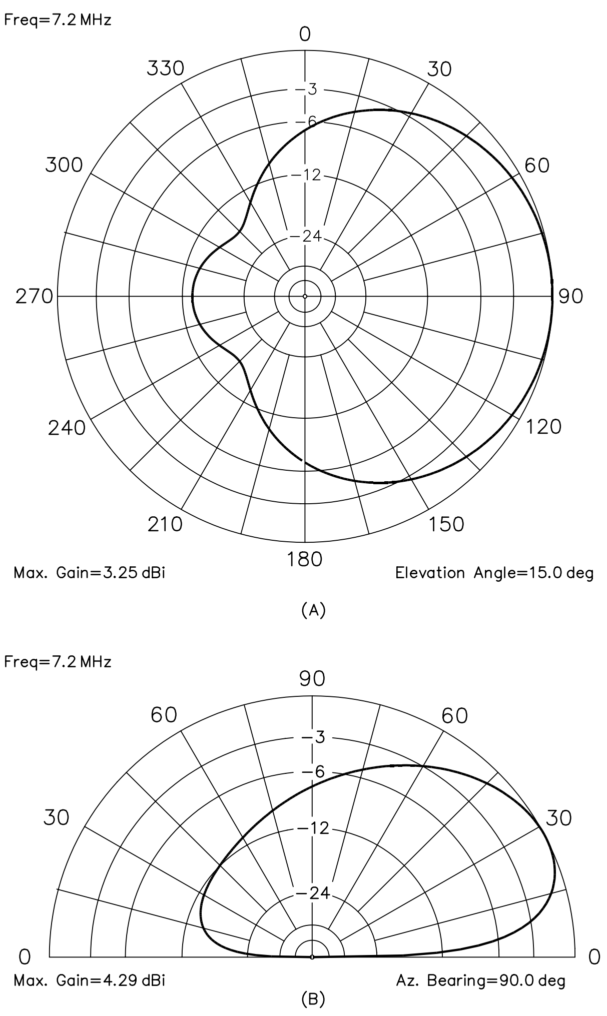

Fig 61—The effect of ungrounding the forestay on the radiation pattern. This is for 40-meter operation.

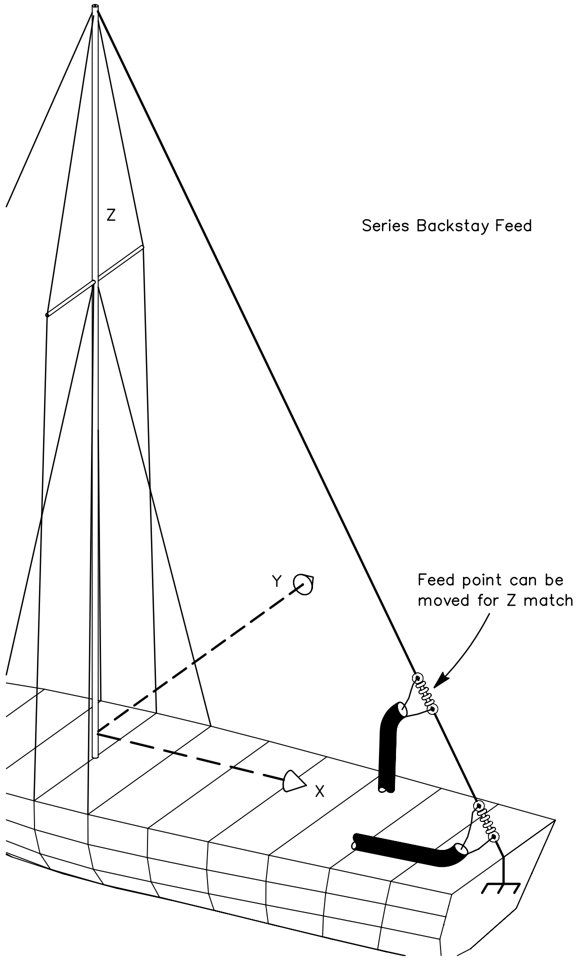

Fig 62—Feeding the backstay without an insulator at the top. The feed point may be moved along the antenna to find a point with a better match on a particular band or to provide a better range of impedances for the tuner to match. The coaxial feed line is taped to the lower portion of the backstay. Again, a good local ground is needed at the base of the backstay.

the pattern is actually more symmetrical than it was with an upper insulator—but this may not hold true for other rigging dimensions. The feed point does not have to be at the bottom of the backstay. As indicated in Fig 62, the feed point can be moved up into the backstay to achieve a better match or a more desirable feed-point impedance variation with frequency. In that case, the center of the coaxial feed line is connected to the upper section and the shield to the lower section. The cable is then taped to the lower portion of the backstay.

If single-band operation is all you want, even the lower insulator can be omitted by using shunt feed. A gamma match would be quite effective for this purpose, as discussed in Chapter 6 when driving a grounded tower.

A 40-METER BACKSTAY HALF SLOPER

A half-sloper antenna can be incorporated into the backstay, as shown in **Fig 65**. This will behave very much the same as the slopers described in Chapter 6. The advantage of this antenna for a sailboat installation is that you don’t need to create a good ground connection at the stern, as you would have to do for a transom-mounted vertical or the backstay vertical just described. This may be more convenient. The mast, shrouds and stays must still be grounded for the half-sloper but the arrangement is somewhat simpler.

TEMPORARY ANTENNAS

Not everyone needs permanent antennas. A variety

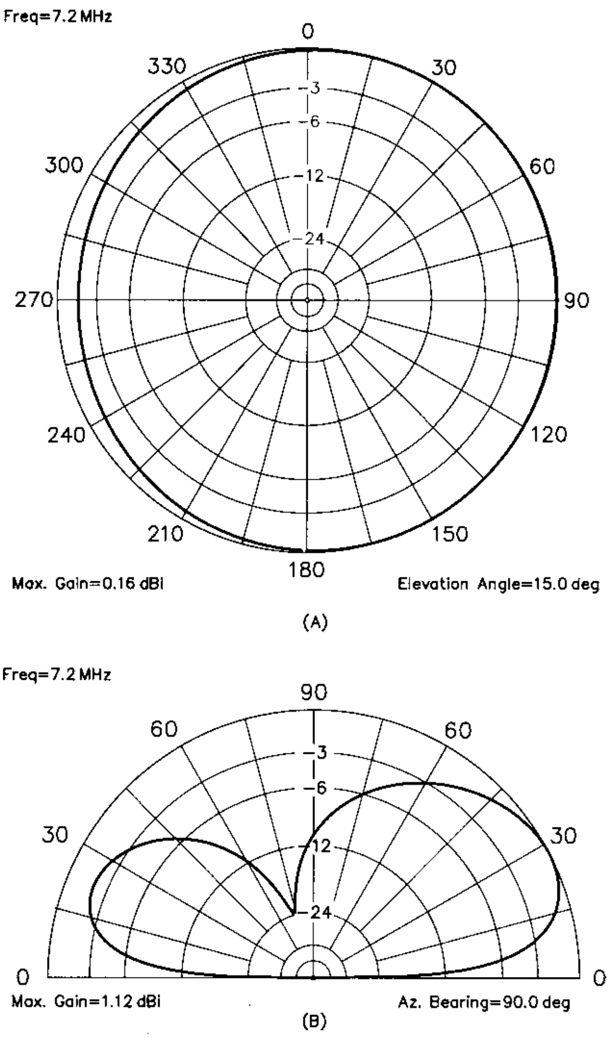

Fig 63—Typical 40-meter radiation pattern in Fig 62.

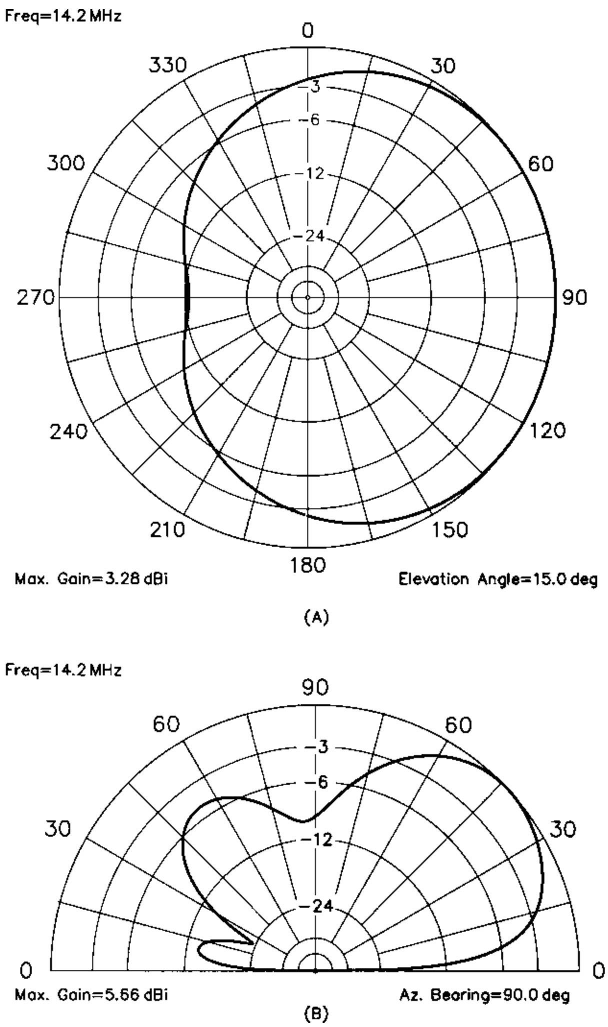

Fig 64—Typical 20-meter radiation pattern in Fig 62.

of temporary antennas can be arranged. A few of these are shown in **Figs 66** through **68**. Of all of these the rigid dipole (Fig 66) will provide the best operation and will have a pattern close to that expected from a freestanding dipole. The other two examples will be strongly affected by their close proximity to the rigging.

GROUNDING SYSTEMS

You may be sitting in the middle of a thousand miles of saltwater. This is great for propagation but you will still have to connect to that ground if you want to use a vertical. There are many possibilities, but the scheme shown in **Fig 69** is representative. First a bonding wire, or better yet a copper strap (it can be very thin!), is connected from bow-to-stern on each side, connecting the forestay, lifeline stanchions, chainplates, bow and stern pulpits and the backstay. Other bonding wires are run from the bow, stern and chainplates on both sides to a common connection at the base of the mast. The fore-and-aft bonding can be attached to the engine and to the keel bolts. The question arises: "What about electrolysis between the keel and propeller if you bond them together?" This has to be dealt with on a case-by-case basis. If your protective zincs are depleting more rapidly after you install a bonding scheme, change it by disconnecting something, the engine-shaft-propeller, for example.

Grounding will vary in every installation and has to be customized to each vessel. However, just as on shore, the better the ground system, the better the performance of the vertical!

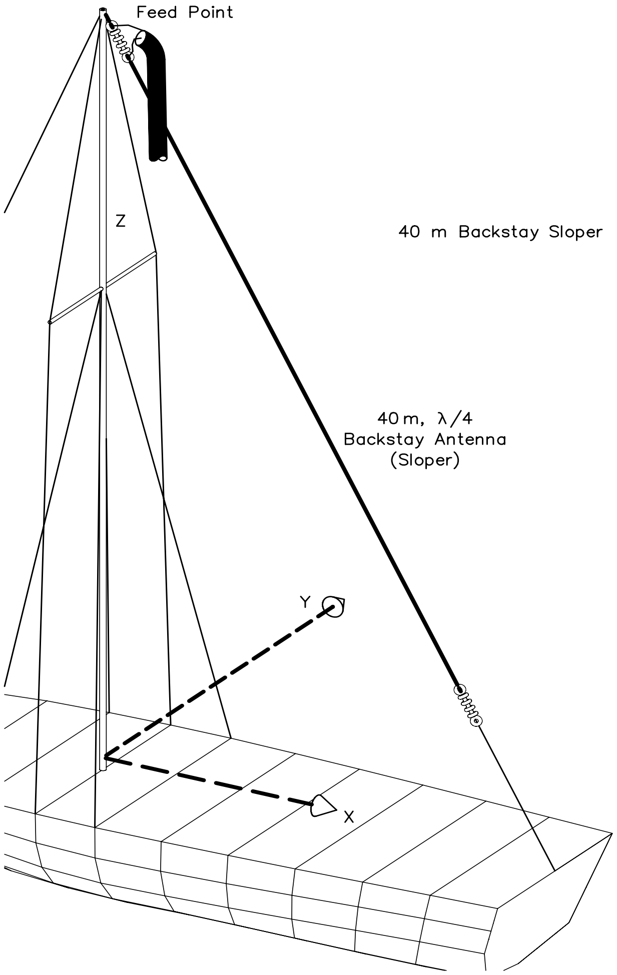
Feed Point
Z
40 m Backstay Sloper
40 m, λ/4
Backstay Antenna
(Sloper)
Y
X

Fig 65—A 40-meter half-sloper fed at the masthead.

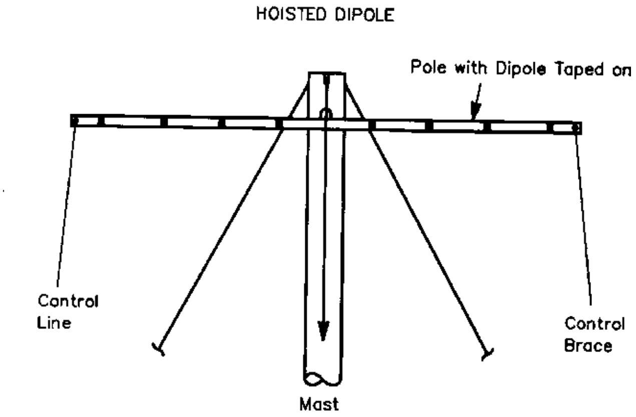
HOISTED DIPOLE
Pole with Dipole Taped on
Control
Line
Control
Brace
Mast

Fig 66—A dipole can be taped to a wood or bamboo pole and hoisted to the masthead with the main halyard while at anchor. It is possible to make this a multiband dipole.

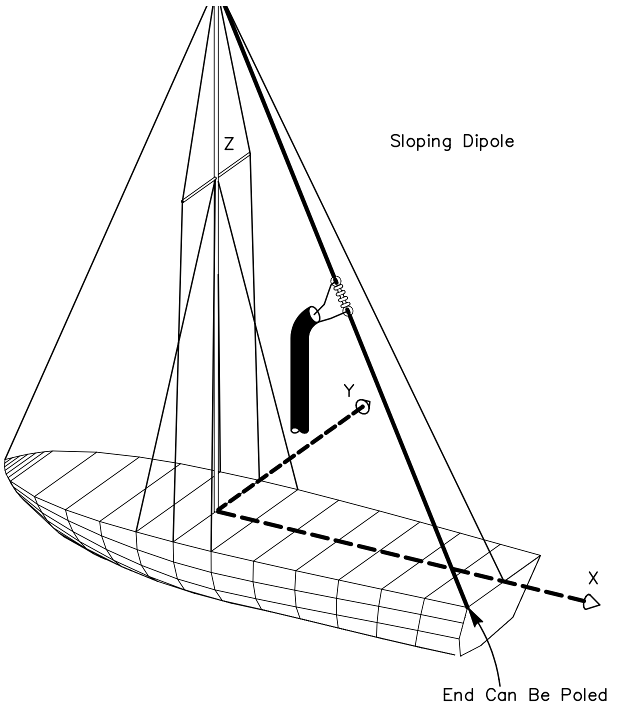
Z
Sloping Dipole
Y
X
End Can Be Poled

Fig 67—One end of dipole can be attached to the main halyard and pulled up to the masthead. The bottom end of the dipole should be pulled out away from the rigging as much as possible to reduce the impact of the rigging on the impedance.

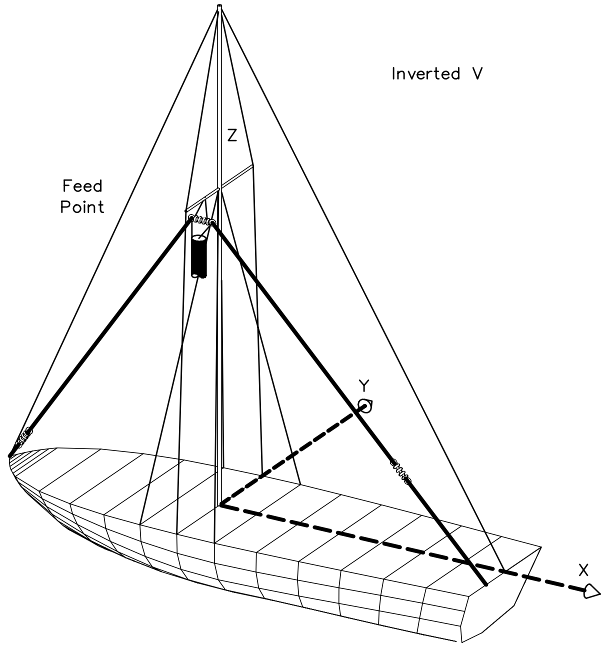
Inverted V
Z
Feed
Point
Y
X

Fig 68—The flag halyard can be used to hoist the center of an inverted V to the spreaders, or alternatively, the main halyard can be used to hoist the center of the antenna to the masthead. Interaction between the rigging and the antenna will be very pronounced and the length of the antenna will have to be adjusted on a cut-and-try basis.

Antennas for Power Boats

Powerboaters are not usually faced with the problems and opportunities created by the mast and rigging on a sailboat. A powerboat may have a small mast, but usually not on the same scale as a sailboat. Antennas for power boats have much more in common with automotive mobile operation, but with some important exceptions:

1) In an automobile, the body is usually metal and it provides a groundplane or counterpoise for a whip antenna. Most modern powerboats, however, have fiberglass hulls. These are basically insulators, and will not work as counterpoises. (On the other hand, metal-hulled power boats can provide nearly ideal grounding!)
2) A height restriction on automotive mobile whips is imposed by clearance limits on highway overpasses and also by the need to sustain wind speeds of up to 80 miles per hour on the highway.
3) In general, powerboats can have much taller antennas that can be lowered for the occasional low bridge.
4) The motion on a powerboat, especially in rough seas, can be quite severe. This places additional mechanical strain on the antennas.
5) On both powerboats and sailboats, operation in a saltwater marine environment is common. This means that a careful choice of materials must be made for the antennas to prevent corrosion and premature failure.

The problem of a ground plane for vertical antennas can be handled in much the same manner as shown in **Fig 69** for sailboats. Since there will most likely not be a large keel structure to connect to and provide a large surface area, additional copper foil can be added inside the hull to increase the counterpoise area. Because of the small area of the propeller, it may be better not to connect to the engine, but to rely instead on increasing the area of the counterpoise and operate it as a true counterpoise—that is, isolated from ground. Sometimes a number of radial wires are used for a vertical, much like that for a ground-plane antenna. This is not a very good idea unless the "wires" are actually wide copper-foil strips that can lower the Q substantially.

The problem is the high voltage present at the ends of normal ground-plane antenna radials. For a boat these radials are likely to be in close proximity to the cabin, which in turn contains both people and electronic equipment. The high potential at the ends of the radials is both a safety hazard and can result in RF coupling back into the equipment, including ham gear, navigational instruments and entertainment devices. The cook is not likely to be happy if he or she gets an RF burn after touching the galley stove! Decoupling the counterpoise from the transmission line, as discussed in Chapter 6, can be very helpful to keep RF out of other equipment.

One way to avoid many of the problems associated with grounding is to use a rigid dipole antenna. On 20 meters and higher, a rigid dipole made up from aluminum tubing, fiberglass poles or some combination of these, can be effective. As shown in **Fig 70A** the halves of the dipole can be slanted upward like rabbit ears to reduce the wingspan and increase the feed-point impedance for a better match to common coax lines. On the lower bands a pair of mobile whips can be used, as shown in Fig 70B. Home-brew coils could also be used.

For short-range communication, a relatively low dipole over saltwater can be effective. However, if long-range communication is needed, then a well-designed vertical, operating over seawater, will work much better. For these to work, of course, you must solve the ground problems associated with a vertical.

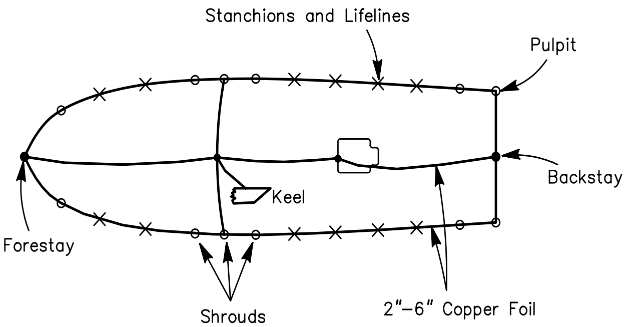

Fig 69—A typical sailboat grounding scheme.

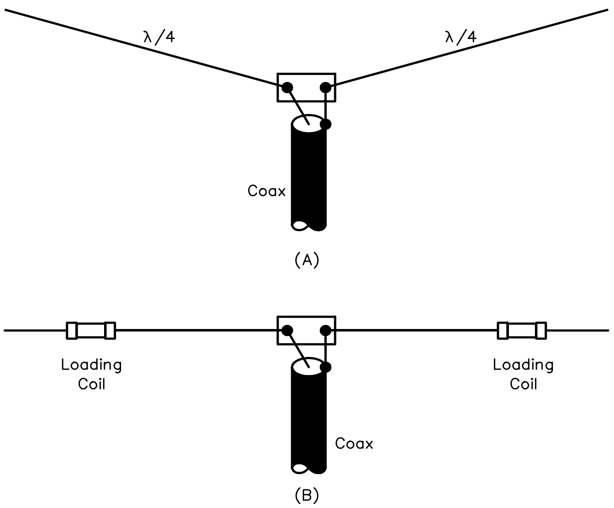

Fig 70—At A, a rigid dipole made from aluminum tubing, fiberglass poles or a combination of these. At B, a pair of mobile whips used as a dipole.

It is not uncommon for large powerboats to have a two or three-element multiband Yagi installed on a short mast. While these can be effective, if they are not mounted high (> $\lambda/2$) they may be disappointing for longer-range communication. Over saltwater, vertical polarization is very effective for longer distances. A simpler, but well-designed, vertical system on a boat may outperform a low Yagi.

The combination of a good ground system and one of the high-quality, motor-tuned multiband mobile whips now available commercially can also be very effective.

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Source material and more extended discussions of topics covered in this chapter can be found in the references given below and in the textbooks listed at the end of Chapter 2.

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J. M. Boyer, "Antenna-Transmission Line Analog," *Ham Radio*, May 1977.

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E. A. Laport, *Radio Antenna Engineering* (New York: McGraw-Hill Book Co., 1952), p 23.

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Chapter 17

Repeater Antenna Systems

There is an old adage in Amateur Radio that goes, "If your antenna did not fall down last winter, it wasn't big enough." This adage might apply to antennas for MF and HF work, but at VHF things are a bit different, at least as far as antenna size is concerned. VHF antennas are smaller than their HF counterparts, but yet the theory is the same—a dipole is a dipole, and a Yagi is a Yagi, regardless of frequency. A 144-MHz Yagi may pass as a TV antenna, but most neighbors can easily detect a radio hobbyist if a 14-MHz Yagi looms over his property.

Repeater antennas are discussed in this chapter. Because the fundamental operation of these antennas is no different than presented in earlier chapters, there is no need to delve into any exotic theory. Certain considerations must be made and certain precautions must be observed, however, since most repeater operations—amateur and commercial—take place at VHF and UHF.

Basic Concepts

The antenna is a vital part of any repeater installation. Because the function of a repeater is to extend the range of communications between mobile and portable stations, the repeater antenna should be installed in the best possible location to provide the desired coverage. This usually means getting the antenna as high above average terrain as possible. In some instances, a repeater may need to have coverage only in a limited area or direction. When this is the case, antenna installation requirements will be completely different, with certain limits being set on height, gain and power.

Horizontal and Vertical Polarization

Until the upsurge in FM repeater activity in the 1970s, most antennas used in amateur VHF work were horizontally polarized. These days, very few repeater groups use horizontal polarization. (One of the major reasons for using horizontal polarization is to allow separate repeaters to share the same input and/or output frequencies with closer-than-normal geographical spacing.) The vast majority of VHF and UHF repeaters use vertically polarized antennas, and all the antennas discussed in this chapter are of that type.

Transmission Lines

Repeaters provide the first venture into VHF and UHF work for many amateurs. The uninitiated may not be aware that the transmission lines used at VHF become very important because feed-line losses increase with frequency.

The characteristics of feed lines commonly used at VHF are discussed in Chapter 24, Transmission Lines. Although information is provided there for small-diameter RG-58 and RG-59 coaxes, these should not be used except for very short feed lines (25 feet or less). These cables are very lossy at VHF. In addition, the losses can be much higher if fittings and connections are not carefully installed.

The differences in loss between solid-polyethylene dielectric types (RG-8 and RG-11) and those using foam polyethylene are significant at VHF and UHF. If you can afford the line with the least loss, buy it.

If you must bury coaxial cable, check with the cable manufacturer before doing so. Many popular varieties of coaxial cable should not be buried, since the dielectric can become contaminated from moisture and soil chemicals. Some coaxial cables are labeled as non-contaminating. Such a label is the best way to be sure your cable can be buried without damage.

Matching

Losses are lowest in transmission lines that are matched to their characteristic impedances. If there is a mismatch at the end of the line, the losses increase. The *only way* to reduce the SWR on a transmission line is by matching the line *at the antenna*. Changing the length of a transmission line does not reduce the SWR. The SWR is established by the impedance of the line and the impedance of the antenna, so matching must be done at the antenna end of the line.

The importance of matching, so far as feed-line losses are concerned, is sometimes overstressed. But under some conditions, it is necessary to minimize feed-line losses related to SWR if repeater performance is to be consistent. It is important to keep in mind that most VHF/UHF equipment is designed to operate into a 50-Ω load. The output circuitry will not be loaded properly if connected to a mismatched line. This leads to a loss of power, and in some cases, damage to the transmitter.

Repeater Antenna System Design

Choosing a repeater or remote-base antenna system is as close as most amateurs come to designing a commercial-grade antenna system. The term *system* is used because most repeaters utilize not only an antenna and a transmission line, but also include duplexers, cavity filters, circulators or isolators in some configuration. Assembling the proper combination of these items in constructing a reliable system is both an art and a science. In this section prepared by Domenic Mallozzi, N1DM, the functions of each component in a repeater antenna system and their successful integration are discussed. While every possible complication in constructing a repeater cannot be foreseen at the outset, this discussion should serve to steer you along the right lines in solving any problems encountered.

COMPUTING THE COVERAGE AREA FOR A REPEATER

Modern computer programs can show the coverage of a repeater using readily available topographic data from the Internet. In Chapter 3, The Effects of Ground, we described the *MicroDEM* program supplied on the CD-ROM accompanying this book. Dr Peter Guth, the author of *MicroDEM*, built into it the ability to generate terrain profiles that can be used with ARRL's *HFTA* (HF Terrain Assessment) program (also included on the CD-ROM).

MicroDEM has a wide range of capabilities beyond simply making terrain profiles. It can do *LOS* (line of sight) computations, based on visual or radio-horizon considerations. **Fig 1** shows a *MicroDEM* map for the area around Glastonbury, Connecticut. This is somewhat hilly terrain, and as a result the coverage for a repeater placed here on a 30-meter (100-foot) high tower would be somewhat spotty. Fig 1 shows a "Viewshed" on the map, in the form of the white terrain profile strokes in 5° increments around the tower.

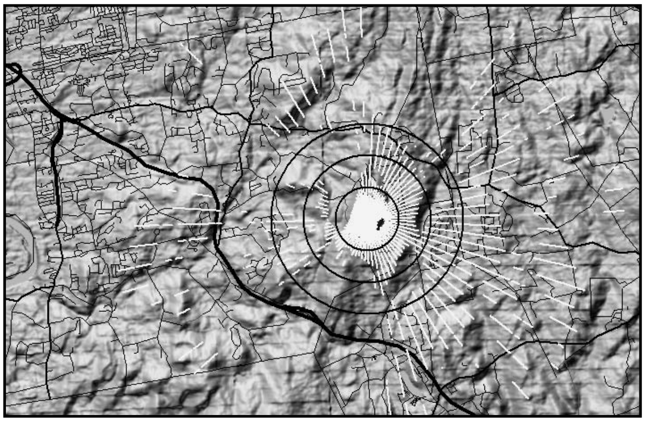

Fig 1—*MicroDEM* topographic map, showing the coverage for a repeater placed on a 30-meter high tower in Glastonbury, CT. The white radial lines indicate the coverage in 5° increments of azimuth around the tower. The range circles are 1000 meters apart.

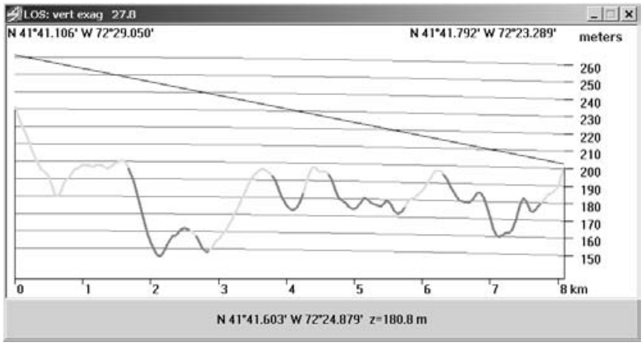
LOS: vert exag 27.8
N 41°41.106' W 72°29.050'
N 41°41.792' W 72°23.289'
meters
260
250
240
230
220
210
200
190
180
170
160
150
0
1
2
3
4
5
6
7
8 km
N 41°41.603' W 72°24.879' z=180.8 m

Fig 2—An "LOS" (line of sight) profile at an azimuth of 80° from the tower in Fig 1. The light-gray portions of the terrain profile are visible from the top of the tower, while the dark portions are blocked by the terrain.

Fig 2 shows the LOS for an azimuth of 80°, from a 30-meter high tower out to a distance of 8000 meters. The light-shaded areas on the profile are those that are illuminated directly by the antenna on the tower, while the dark portions of the profile are those that cannot be seen directly from the tower. This profile assumes that the mobile station is 2 meters high—the height of a 6-foot high person with a handheld radio.

The terrain at an 80° azimuth allows direct radio view from the top of the tower out to about 1.8 km. From here, the downslope prevents direct view until about 2.5 km, where the terrain is briefly visible again from several hundred meters, disappearing from radio view until about 2.8 km, after which it becomes visible until about 3.6 km. Note that other than putting the repeater antenna on a higher tower, there is nothing that can be done to improve repeater coverage over this hilly terrain, although knife-edge diffraction off the hill tops will help fill in coverage gaps.

The Repeater Antenna

The most important part of the system is the antenna itself. As with any antenna, it must radiate and collect RF energy as efficiently as possible. Many repeaters use omnidirectional antennas, but this is not always the best choice. For example, suppose a group wishes to set up a repeater to cover towns A and B and the interconnecting state highway shown in **Fig 3**. The available repeater site is marked on the map. No coverage is required to the west or south, or over the ocean. If an omnidirectional antenna is used in this case, a significant amount of the radiated signal goes in undesired directions. By using an antenna with a cardioid pattern, as shown in Fig 1, the coverage is concentrated in the desired directions. The repeater will be more effective in these locations, and signals from low-power portables and mobiles will be more reliable.

In many cases, antennas with special patterns are more expensive than omnidirectional models. This is an obvious consideration in designing a repeater antenna system. Over terrain where coverage may be difficult in some direction from the repeater site, it may be desirable to skew the antenna pattern in that direction. This can be accomplished by using a phased-vertical array or a com-

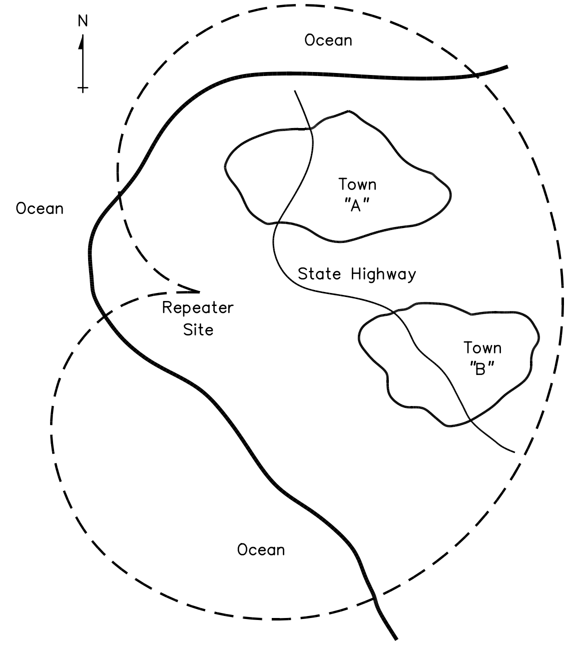

Fig 3—There are many situations where equal repeater coverage is not desired in all directions from the "machine." One such situation is shown here, where the repeater is needed to cover only towns A and B and the interconnecting highway. An omnidirectional antenna would provide coverage in undesired directions, such as over the ocean. The broken line shows the radiation pattern of an antenna that is better suited to this circumstance.

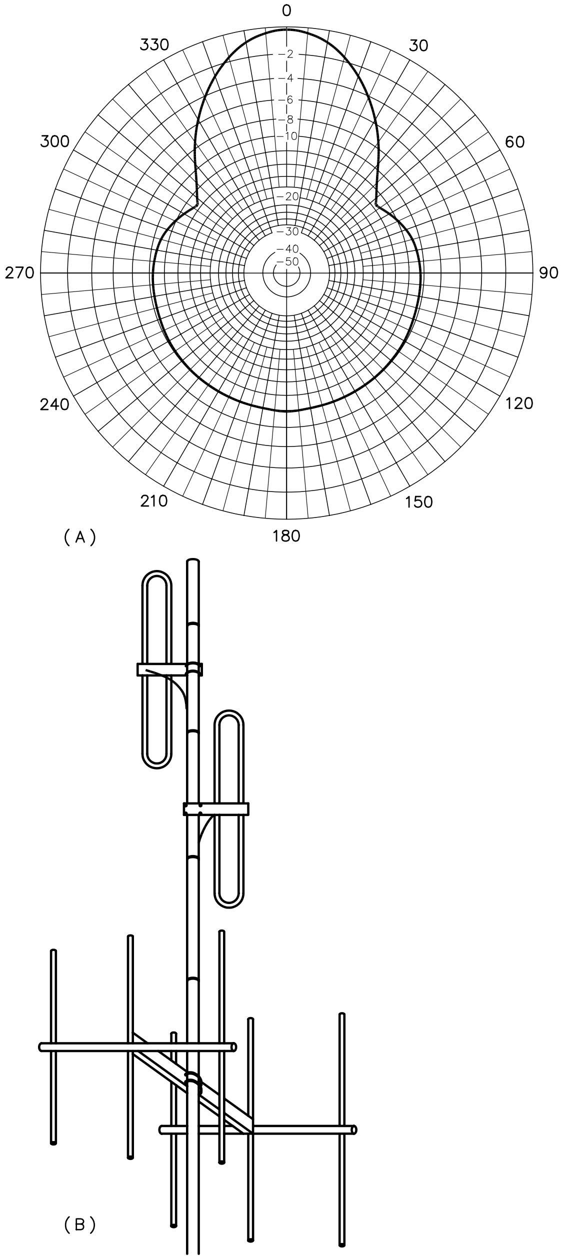

Fig 4—The "keyhole" horizontal radiation pattern at A is generated by the combination of phased Yagis and vertical elements shown at B. Such a pattern is useful in overcoming coverage blockages resulting from local terrain features. (*Based on a design by Decibel Products, Inc.*)

bination of a Yagi and a phased vertical to produce a “keyhole” pattern. See **Fig 4**.

Repeaters are common on 440 MHz and above, and many groups invest in high-gain omnidirectional antennas. A consequence of getting high gain from an omnidirectional antenna is vertical beamwidth reduction. In most cases, these antennas are designed to radiate their peak gain at the horizon, resulting in optimum coverage when the antenna is located at a moderate height over normal terrain. Unfortunately, in cases where the antenna is located at a very high site (overlooking the coverage area) this may not be the most desirable pattern. The vertical pattern of the antenna can be tilted downward, however, to facilitate coverage of the desired area. This is called *vertical-beam downtilt*.

An example of such a situation is shown in **Fig 5**. The repeater site overlooks a town in a valley. A 450-MHz repeater is needed to serve low-power portable and mobile stations. Constraints on the repeater dictate the use of an antenna with a gain of 11 dBi. (An omnidirec-

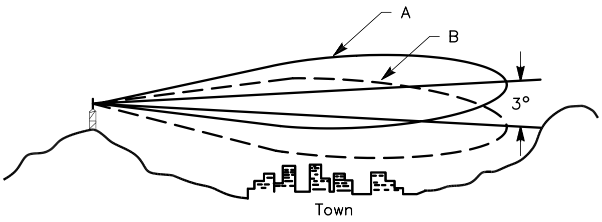

Fig 5—Vertical-beam downtilt is another form of radiation-pattern distortion useful for improving repeater coverage. This technique can be employed in situations where the repeater station is at a greater elevation than the desired coverage area, when a high-gain omnidirectional antenna is used. Pattern A shows the normal vertical-plane radiation pattern of a high-gain omnidirectional antenna with respect to the desired coverage area (the town). Pattern B shows the pattern tilted down, and the coverage improvement is evident.

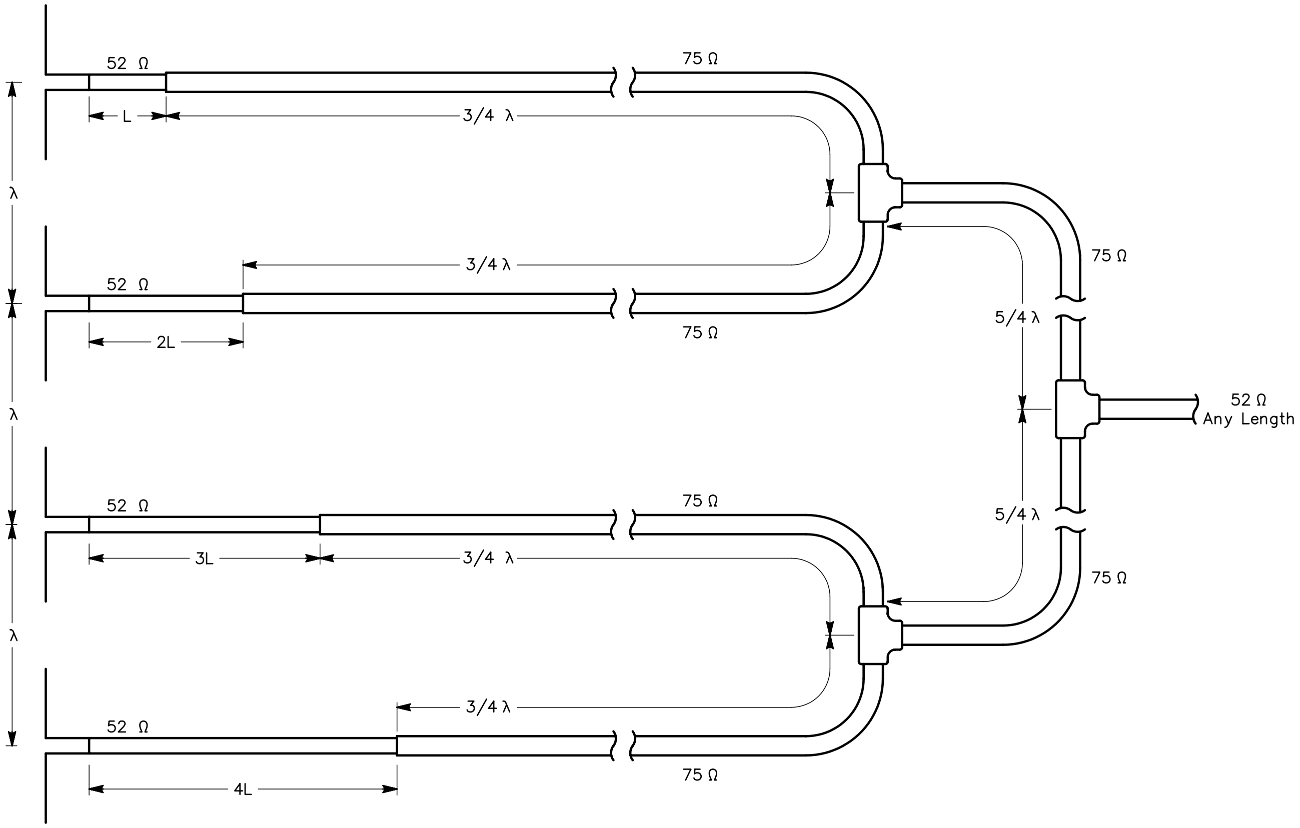

Fig 6—Vertical-beam downtilt can be facilitated by inserting 52-Ω delay lines in series with the 75-Ω feed lines to the collinear elements of an omnidirectional antenna. The delay lines to each element are progressively longer so the phase shift between elements is uniform. Odd $^1/_4$-λ coaxial transformers are used in the main (75-Ω) feed system to match the dipole impedances to the driving point. Tilting the vertical beam in this way often produces minor lobes in the vertical pattern that do not exist when the elements are fed in phase.

tional antenna with this gain has a vertical beamwidth of approximately 6°.) If the repeater antenna has its peak gain at the horizon, a major portion of the transmitted signal and the best area from which to access the repeater exists *above* the town. By tilting the pattern down 3°, the peak radiation will occur in the town.

Vertical-beam downtilt is generally produced by feeding the elements of a collinear vertical array slightly out of phase with each other. Lee Barrett, K7NM, showed such an array in *Ham Radio* magazine. (See the Bibliography at the end of this chapter.) Barrett gives the geometry and design of a four-pole array with progressive phase delay, and a computer program to model it. The technique is shown in **Fig 6**, with a free-space elevation plot showing downtilting in **Fig 7**.

Commercial antennas are sometimes available (at extra cost) with built-in downtilt characteristics. Before ordering such a commercial antenna, make sure that you really require it—they generally are special-order items and are not returnable.

There are disadvantages to improving coverage by means of vertical-beam downtilt. When compared to a standard collinear array, an antenna using vertical-beam downtilt will have somewhat greater extraneous lobes in the vertical pattern, resulting in reduced gain (usually less than 1 dB). Bandwidth is also slightly reduced. The reduction in gain, when combined with the downtilt characteristic, results in a reduction in total coverage area. These trade-offs, as well as the increased cost of a commercial antenna with downtilt, must be compared to the improvement in total performance in a situation where vertical-beam downtilt is contemplated.

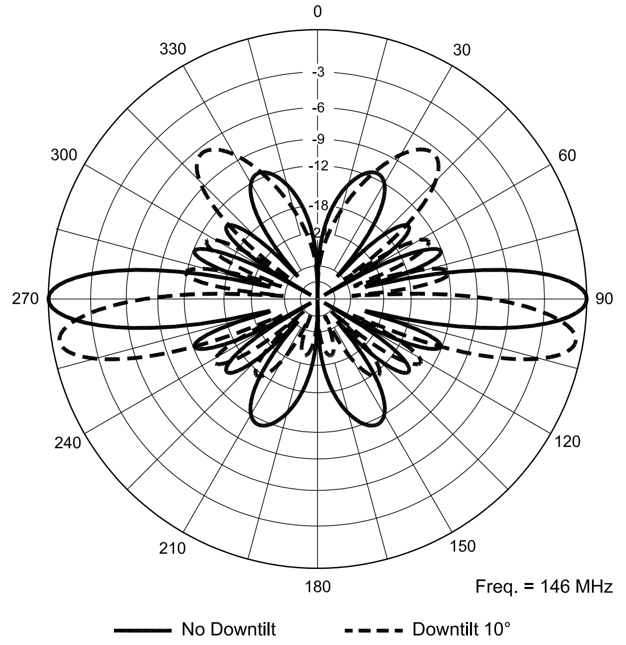

Fig 7—Free-space elevation-plane patterns showing downtilting that results from progressive phase shifts for the feed currents for the dipole in Fig 6.

Top Mounting and Side Mounting

Amateur repeaters often share towers with commercial and public service users. In many of these cases, other antennas are at the top of the tower, so the amateur antenna must be side mounted. A consequence of this arrangement is that the free-space pattern of the repeater antenna is distorted by the tower. This effect is especially noticeable when an omnidirectional antenna is side mounted on a structure.

The effects of supporting structures are most pronounced at close antenna spacings to the tower and with large support dimensions. The result is a measurable increase in gain in one direction and a partial null in the other direction (sometimes 15 dB deep). The shape of the supporting structure also influences pattern distortion. Many antenna manufacturers publish radiation patterns showing the effect of side mounting antennas in their catalogs.

Side mounting is not always a disadvantage. In cases where more (or less) coverage is desired in one direction, the supporting structure can be used to advantage. If pattern distortion is not acceptable, a solution is to mount antennas around the perimeter of the structure and feed them with the proper phasing to synthesize an omnidirectional pattern. Many manufacturers make antennas to accommodate such situations.

The effects of different mounting locations and arrangements can be illustrated with an array of exposed dipoles, **Fig 8**. Such an array is a very versatile antenna because, with simple rearrangement of the elements, it can develop either an omnidirectional pattern or an offset pattern. Drawing A of Fig 8 shows a basic collinear array of four vertical ½-λ elements. The vertical spacing between adjacent elements is 1 λ. All elements are fed in phase. If this array is placed in the clear and supported by a nonconducting mast, the calculated radiation resistance of each dipole element is on the order of 63 Ω. If the feed line is completely decoupled, the resulting azimuth pattern is omnidirectional. The vertical-plane pattern is shown in **Fig 9**.

Fig 8B shows the same array in a side-mounting arrangement, at a spacing of ¼ λ from a conducting mast. In this mounting arrangement, the mast takes on the role of a reflector, producing an F/B on the order of 5.7 dB. The azimuth pattern is shown in **Fig 10**. The vertical pattern is not significantly different from that of Fig 9, except the four small minor lobes (two on either side of the vertical axis) tend to become distorted. They are not as “clean,” tending to merge into one minor lobe at some mast heights. This apparently is a function of currents in the supporting mast. The proximity of the mast also alters the feed-point impedance. For elements that are resonant in the configuration of Fig 8A, the calculated impedance in the arrangement of Fig 8B is in the order of $72 + j\,10\ \Omega$.

If side mounting is the only possibility and an omnidirectional pattern is required, the arrangement of Fig 8C may be used. The calculated azimuth pattern takes on a slight cloverleaf shape, but is within 1.5 dB of being circular. However, gain performance suffers, and the idealized vertical pattern of Fig 9 is not achieved. See **Fig 11**. Spacings other than $^1/_4$-λ from the mast were not investigated.

One very important consideration in side mounting an antenna is mechanical integrity. As with all repeater components, reliability is of great importance. An antenna hanging by the feed line and banging against the tower provides far from optimum performance and reliability. Use a mount that is appropriately secured to the tower and the antenna. Also use good hardware, preferably stainless steel (or bronze). If your local hardware store does not carry stainless steel hardware, try a boating supplier.

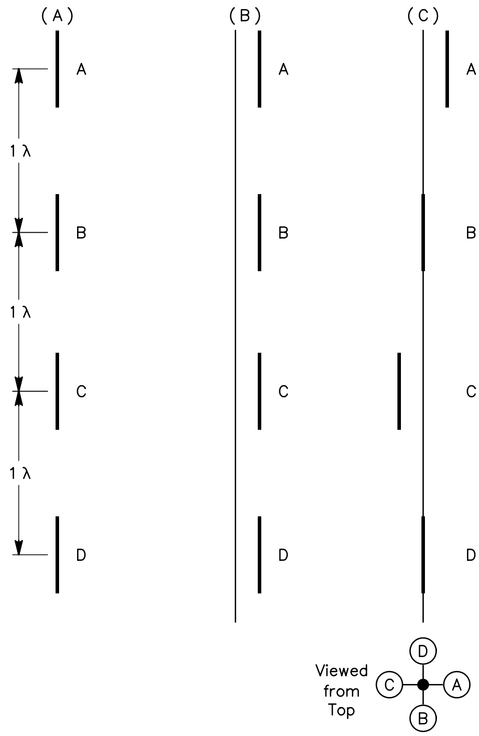

Fig 8—Various arrangements of exposed dipole elements. At A is the basic collinear array of four elements. B shows the same elements mounted on the side of a mast, and C shows the elements in a side-mounted arrangement around the mast for omnidirectional coverage. See text and Figs 9 through 11 for radiation-pattern information.

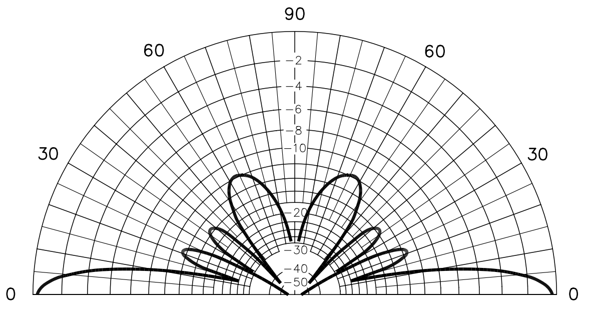

Fig 9—Calculated vertical-plane pattern of the array of Fig 8A, assuming a nonconducting mast support and complete decoupling of the feeder. In azimuth the array is omnidirectional. The calculated gain of the array is 8.6 dBi at 0° elevation; the –3 dB point is at 6.5°.

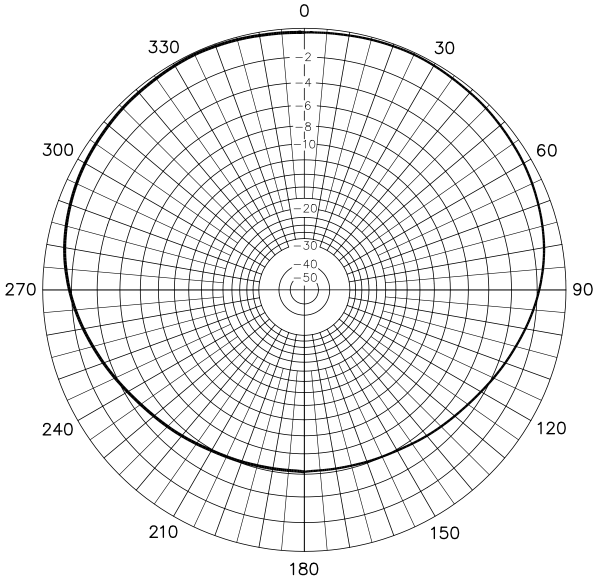

Fig 10—Calculated azimuth pattern of the side-mounted array of Fig 8B, assuming $^1/_4$-λ spacing from a 4-inch mast. The calculated gain in the favored direction, away from the mast and through the elements, is 10.6 dBi.

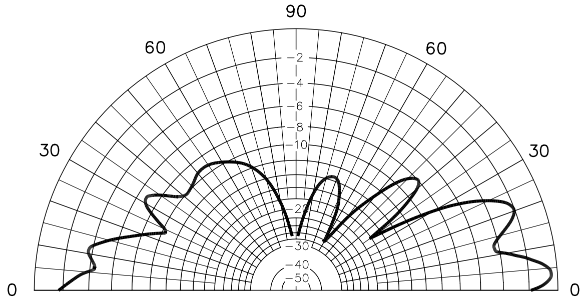

Fig 11—Calculated vertical pattern of the array of Fig 8C, assuming $^1/_4$-λ element spacing from a 4-inch mast. The azimuth pattern is circular within 1.5 dB, and the calculated gain is 4.4 dBi.

Be certain that the feed line is properly supported along its length. Long lengths of cable are subject to contraction and expansion with temperature from season to season, so it is important that the cable not be so tight that contraction causes it to stress the connection at the antenna. This can cause the connection to become intermittent (and noisy) or, at worst, an open circuit. This is far from a pleasant situation if the antenna connection is 300 feet up a tower, and it happens to be the middle of the winter!

Effects of Other Conductors

Feed-line proximity and tower-access ladders or cages also have an effect on the radiation patterns of side-mounted antennas. This subject was studied by Connolly and Blevins, and their findings are given in *IEEE Conference Proceedings* (see the Bibliography at the end of this chapter). Those considering mounting antennas on air-conditioning evaporators or maintenance penthouses on commercial buildings should consult this article. It gives considerable information on the effects of these structures on both unidirectional and omnidirectional antennas.

Metallic guy wires also affect antenna radiation patterns. Yang and Willis studied this and reported the results in *IRE Transactions on Vehicular Communications*. As expected, the closer the antenna is to the guy wires, the greater the effect on the radiation patterns. If the antennas are near the point where the guy wires meet the tower, the effect of the guy wires can be minimized by breaking them up with insulators every 0.75 λ for 2.25 λ to 3.0 λ.

ISOLATION REQUIREMENTS IN REPEATER ANTENNA SYSTEMS

Because repeaters generally operate in full *duplex* (the transmitter and receiver operate simultaneously), the antenna system must act as a filter to keep the transmitter from blocking the receiver. The degree to which the transmitter and receiver must be isolated is a complex problem. It is quite dependent on the equipment used and the difference in transmitter and receiver frequencies (offset). Instead of going into great detail, a simplified example can be used for illustration.

Consider the design of a 144-MHz repeater with a 600-kHz offset. The transmitter has an RF output power of 10 watts, and the receiver has a squelch sensitivity of 0.1 µV. This means there must be at least 1.9×10^{-16} watts at the 52-Ω receiver-antenna terminals to detect a signal. If both the transmitter and receiver were on the same frequency, the isolation (attenuation) required between the transmitter and receiver antenna jacks to keep the transmitter from activating the receiver would be

$$\text{Isolation} = 10 \log \frac{10 \text{ watts}}{1.9 \times 10^{-16} \text{ watts}} = 167 \text{ dB}$$

Obviously there is no need for this much attenuation, because the repeater does not transmit and receive on the same frequency.

If the 10-watt transmitter has noise 600 kHz away from the carrier frequency that is 45 dB below the carrier power, that 45 dB can be subtracted from the isolation requirement. Similarly, if the receiver can detect a 0.1 µ V on-frequency signal in the presence of a signal 600 kHz away that is 40 dB greater than 0.1 µV, this 40 dB can also be subtracted from the isolation requirement. Therefore, the isolation requirement is

167 dB – 45 dB – 40 dB = 82 dB

Other factors enter into the isolation requirements as well. For example, if the transmitter power is increased by 10 dB (from 10 to 100 watts), this 10 dB must be added to the isolation requirement. Typical requirements for 144- and 440-MHz repeaters are shown in **Fig 12**.

Obtaining the required isolation is the first problem to be considered in constructing a repeater antenna system. There are three common ways to obtain this isolation:

1) Physically separate the receiving and transmitting antennas so the combination of path loss for the spacing and the antenna radiation patterns results in the required isolation.
2) Use a combination of separate antennas and high-Q filters to develop the required isolation. (The high-Q filters serve to reduce the physical distance required between antennas.)
3) Use a combination filter and combiner system to

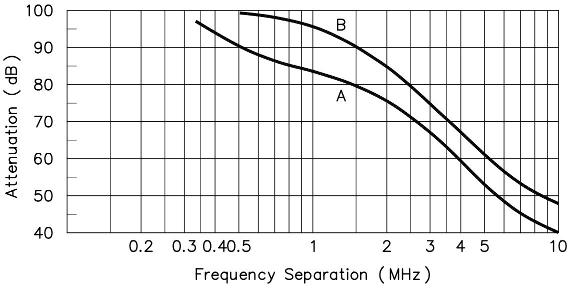

Fig 12—Typical isolation requirements for repeater transmitters and receivers operating in the 132-174 MHz band (Curve A), and the 400-512 MHz band (Curve B). Required isolation in dB is plotted against frequency separation in MHz. These curves were developed for a 100-W transmitter. For other power levels, the isolation requirements will differ by the change in decibels relative to 100 W. Isolation requirements will vary with receiver sensitivity. (The values plotted were calculated for transmitter-carrier and receiver-noise suppression necessary to prevent more than 1 dB degradation in receiver 12-dB SINAD sensitivity.)

allow the transmitter and receiver to share one antenna. Such a filter and combiner is called a *duplexer*.

Repeaters operating on 28 and 50 MHz generally use separate antennas to obtain the required isolation. This is largely because duplexers in this frequency range are both large and very expensive. It is generally less expensive to buy two antennas and link the sites by a committed phone line or an RF link than to purchase a duplexer. At 144 MHz and higher, duplexers are more commonly used. Duplexers are discussed in greater detail in a later section.

Separate Antennas

Receiver desensing (gain limiting caused by the presence of a strong off-frequency signal) can be reduced, and often eliminated, by separation of the transmitting and receiving antennas. Obtaining the 55 to 90 dB of isolation required for a repeater antenna system requires separate antennas to be spaced a considerable distance apart (in wavelengths).

Fig 13 shows the distances required to obtain specific values of isolation for vertical dipoles having horizontal separation (at A) and vertical separation (at B). The isolation gained by using separate antennas is subtracted from the total isolation requirement of the system. For example, if the transmitter and receiver antennas for a 450-MHz repeater are separated horizontally by 400 feet, the total isolation requirement in the system is reduced by about 64 dB.

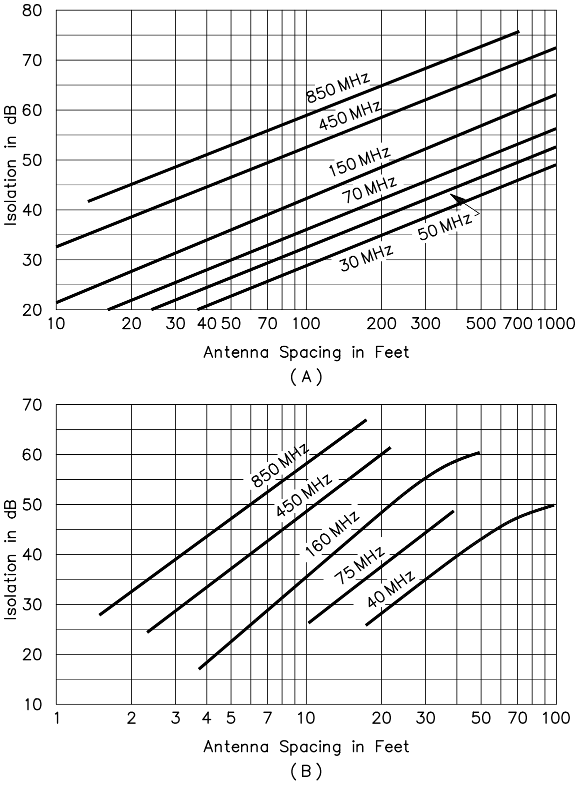

Fig 13—At A, the amount of attenuation (isolation) provided by horizontal separation of vertical dipole antennas. At B, isolation afforded by vertical separation of vertical dipoles.

Note from Fig 13B that a vertical separation of only about 25 feet also provides 64 dB of isolation. Vertical separation yields much more isolation than does horizontal separation. Vertical separation is also more practical than horizontal, since only a single support is required.

An explanation of the significant difference between the two graphs is in order. The vertical spacing requirement for 60 dB attenuation (isolation) at 150 MHz is about 43 feet. The horizontal spacing for the same isolation level is on the order of 700 feet. **Fig 14** shows why this difference exists. The radiation patterns of the antennas at A overlap; each antenna has gain in the direction of the other. The path loss between the antennas is given by

$$\text{Path loss (dB)} = 20 \log \frac{4\pi d}{\lambda} \qquad \text{(Eq 1)}$$

where

d = distance between antennas

λ = wavelength, in the same units as d.

The isolation between the antennas in Fig 14A is the path loss less the antenna gains. Conversely, the antennas at B share pattern nulls, so the isolation is the path loss added to the depth of these nulls. This significantly reduces the spacing requirement for vertical sepa-

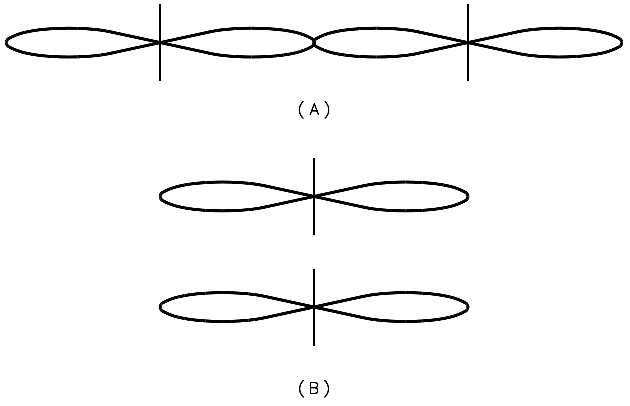

Fig 14—A relative representation of the isolation advantage afforded by separating antennas horizontally (A) and vertically (B) is shown. A great deal of isolation is provided by vertical separation, but horizontal separation requires two supports and much greater distance to be as effective. Separate-site repeaters (those with transmitter and receiver at different locations) benefit much more from horizontal separation than do single-site installations.

ration. Because the depth of the pattern nulls is not infinite, some spacing is required. Combined horizontal and vertical spacing is much more difficult to quantify because the results are dependent on both radiation patterns and the positions of the antennas relative to each other.

Separate antennas have one major disadvantage: They create disparity in transmitter and receiver coverage. For example, say a 50-MHz repeater is installed over average terrain with the transmitter and repeater separated by 2 miles. If both antennas had perfect omnidirectional coverage, the situation depicted in **Fig 15** would exist. In this case, stations able to hear the repeater may not be able to access it, and vice versa. In practice, the situation can be considerably worse. This is especially true if the patterns of both antennas are not omnidirectional. If this disparity in coverage cannot be tolerated, the solution involves skewing the patterns of the antennas until their coverage areas are essentially the same.

Cavity Resonators

As just discussed, receiver desensing can be reduced by separating the transmitter and receiver antennas. But the amount of transmitted energy that reaches the receiver input must often be decreased even farther. Other nearby transmitters can cause desensing as well. A *cavity resonator* (cavity filter) can be helpful in solving these problems. When properly designed and constructed, this type of resonator has very high Q. A commercially made cavity is shown in **Fig 16**.

A cavity resonator placed in series with a transmission line acts as a band-pass filter. For a resonator to operate in series, it must have input and output coupling loops (or probes). A cavity resonator can also be connected across (in parallel with) a transmission line. The cavity then acts as a band-reject (notch) filter, greatly attenuating energy at the frequency to which it is tuned. Only one coupling loop or probe is required for this method of filtering. This type of cavity could be used in the receiver line to "notch" the transmitter signal. Several cavities can be connected in series or parallel to increase the attenuation in a given configuration. The graphs of **Fig 17** show the attenuation of a single cavity (A) and a pair of cavities (B).

The only situation in which cavity filters would not help is the case where the off-frequency noise of the transmitter was right on the receiver frequency. With cavity resonators, an important point to remember is that addition of a cavity across a transmission line may change the impedance of the system. This change can be compensated by adding tuning stubs along the transmission line.

Duplexers

The material in this section was prepared by Domenic Mallozzi, N1DM. Most amateur repeaters in the 144-, 220- and 440-MHz bands use duplexers to obtain the necessary transmitter to receiver isolation. Duplexers have been commonly used in commercial repeaters for many years. The duplexer consists of two high-Q filters. One filter is used in the feed line from the transmitter to the antenna, and another between the antenna and the receiver. These filters must have low loss at the frequency to which they are tuned while having very high attenuation at the surrounding frequencies. To meet the high attenuation requirements at frequencies within as little as 0.4% of the frequency to which they are tuned, the filters usually take the form of cascaded transmission-line cavity filters. These are either band-pass filters, or band-pass filters with a rejection notch. (The rejection notch is tuned to the center frequency of the other filter.) The number of cascaded filter sections is determined by the frequency separation and the ultimate attenuation requirements.

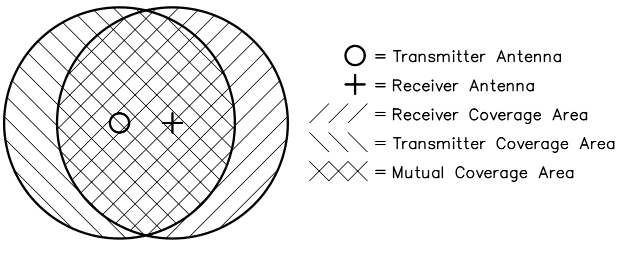
○ = Transmitter Antenna
+ = Receiver Antenna
/// = Receiver Coverage Area
\\\ = Transmitter Coverage Area
XXX = Mutual Coverage Area

Fig 15—Coverage disparity is a major problem for separate-site repeater antennas. The transmitter and receiver coverage areas overlap, but are not entirely mutually inclusive. Solving this problem requires a great deal of experimentation, as many factors are involved. Among these factors are terrain features and distortion of the antenna radiation patterns from supports.

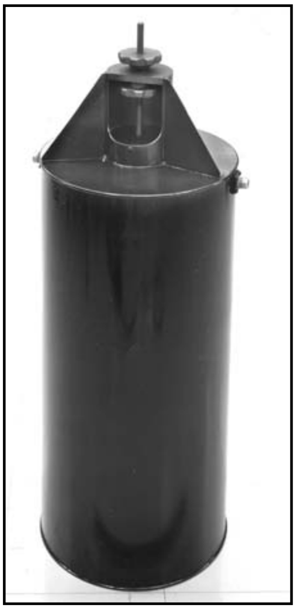

Fig 16—A coaxial cavity filter of the type used in many amateur and commercial repeater installations. Center-conductor length (and thus resonant frequency) is varied by adjustment of the knob (top).

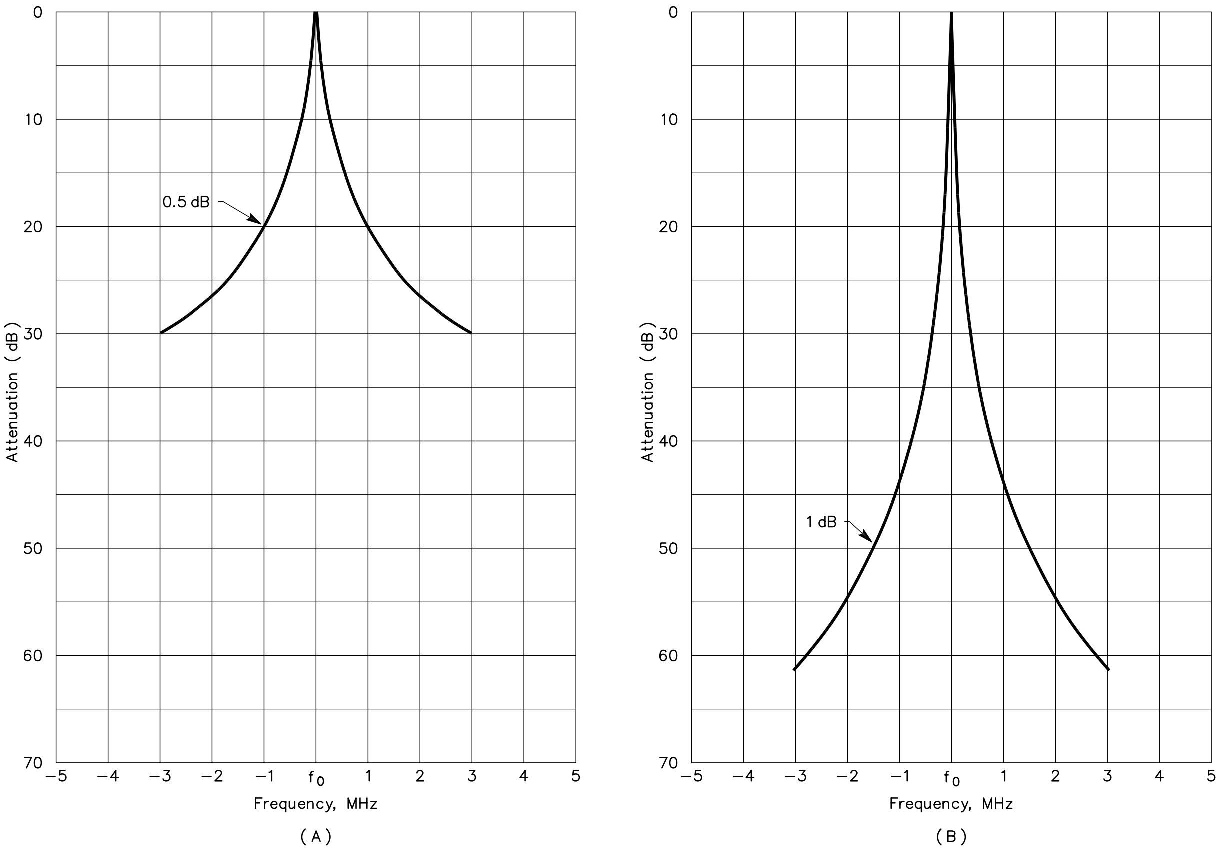

Fig 17—Frequency response curves for a single cavity (A) and two cavities cascaded (B). These curves are for cavities with coupling loops, each having an insertion loss of 0.5 dB. (The total insertion loss is indicated in the body of each graph.) Selectivity will be greater if lighter coupling (greater insertion loss) can be tolerated.

Duplexers for the amateur bands represent a significant technical challenge, because in most cases amateur repeaters operate with significantly less frequency separation than their commercial counterparts. Information on home construction of duplexers is presented in a later section of this chapter. Many manufacturers market high-quality duplexers for the amateur frequencies.

Duplexers consist of very high-Q cavities whose resonant frequencies are determined by mechanical components, in particular the tuning rod. **Fig 18** shows the cutaway view of a typical duplexer cavity. The rod is usually made of a material that has a limited thermal expansion coefficient (such as Invar). Detuning of the cavity by environmental changes introduces unwanted losses in the antenna system. An article by Arnold in *Mobile Radio Technology* considered the causes of drift in the

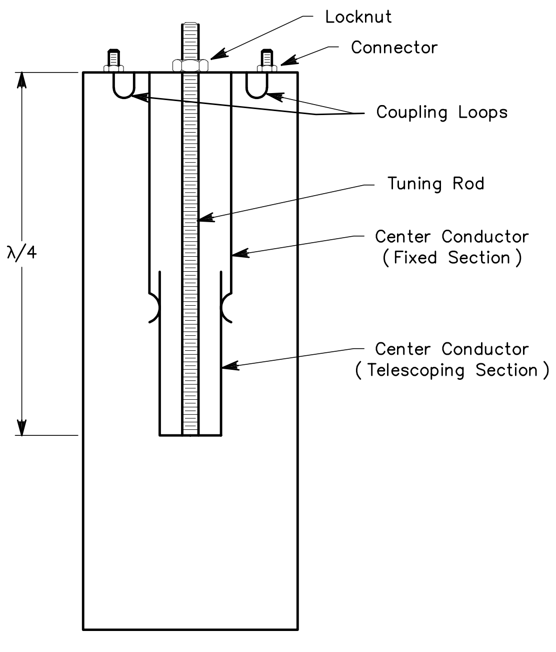

Fig 18—Cutaway view of a typical cavity. Note the relative locations of the coupling loops to each other and to the center conductor of the cavity. A locknut is used to prevent movement of the tuning rod after adjustment.

cavity (see the Bibliography at the end of this chapter). These can be broken into four major categories.

1) Ambient temperature variation (which leads to mechanical variations related to the thermal expansion coefficients of the materials used in the cavity).
2) Humidity (dielectric constant) variation.
3) Localized heating from the power dissipated in the cavity (resulting from its insertion loss).
4) Mechanical variations resulting from other factors (vibration, etc).

In addition, because of the high-Q nature of these cavities, the insertion loss of the duplexer increases when the signal is not at the peak of the filter response. This means, in practical terms, that less power is radiated for a given transmitter output power. Also, the drift in cavities in the receiver line results in increased system noise figure, reducing the sensitivity of the repeater.

As the frequency separation between the receiver and the transmitter decreases, the insertion loss of the duplexer reaches certain practical limits. At 144 MHz, the minimum insertion loss for 600 kHz spacing is 1.5 dB per filter.

Testing and using duplexers requires some special considerations (especially as frequency increases). Because duplexers are very high-Q devices, they are very sensitive to the termination impedances at their ports. A high SWR on any port is a serious problem, because the apparent insertion loss of the duplexer will increase, and the isolation may appear to decrease. Some have found that when duplexers are used at the limits of their isolation capabilities, a small change in antenna SWR is enough to cause receiver desensitization. This occurs most often under ice-loading conditions on antennas with open-wire phasing sections.

The choice of connectors in the duplexer system is important. BNC connectors are good for use below 300 MHz. Above 300 MHz, their use is discouraged because even though many types of BNC connectors work well up to 1 GHz, older style standard BNC connectors are inadequate at UHF and above. Type N connectors should be used above 300 MHz. It is false economy to use marginal quality connectors. Some commercial users have reported deteriorated isolation in commercial UHF repeaters when using such connectors. The location of a bad connector in a system is a complicated and frustrating process. Despite all these considerations, the duplexer is still the best method for obtaining isolation in the 144- to 925 MHz range.

ADVANCED TECHNIQUES

As the number of available antenna sites decreases and the cost of various peripheral items (such as coaxial cable) increases, amateur repeater groups are required to devise advanced techniques if repeaters are to remain effective. Some of the techniques discussed here have been applied in commercial services for many years, but until recently have not been economically justified for amateur use.

One technique worth consideration is the use of *cross-band couplers*. To illustrate a situation where a cross-band coupler would be useful, consider the following example. A repeater group plans to install 144- and 902-MHz repeaters on the same tower. The group intends to erect both antennas on a horizontal cross arm at the 325-foot level. A 325-foot run of $^{7}/_{8}$-inch Heliax costs approximately $2000. If both antennas are to be mounted at the top of the tower, the logical approach would require two separate feed lines. A better solution involves the use of a single feed line for both repeaters, along with a cross-band coupler at each end of the line.

The use of the cross-band coupler is shown in **Fig 19**. As the term implies, the coupler allows two signals on different bands to share a common transmission line. Such couplers cost approximately $300 each. In our hypothetical example, this represents a saving of $1400 over the cost of using separate feed lines. But, as with all compromises, there are disadvantages. Cross-band cou-

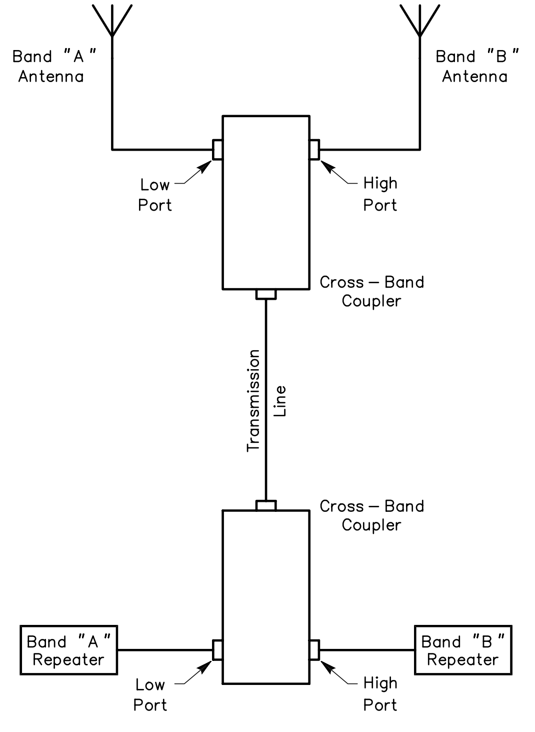

Fig 19—Block diagram of a system using cross-band couplers to allow the use of a single feed line for two repeaters. If the feeder to the antenna location is long (more than 200 feet or so), cross-band couplers may provide a significant saving over separate feed lines, especially at the higher amateur repeater frequencies. Cross-band couplers cannot be used with two repeaters on the same band.

plers have a loss of about 0.5 dB per unit. Therefore, the pair required represents a loss of 1.0 dB in *each* transmission path. If this loss can be tolerated, the cross-band coupler is a good solution.

Cross-band couplers do not allow two repeaters *on the same band* to share a single antenna and feed line. As repeater sites and tower space become more scarce, it may be desirable to have two repeaters on the same band share the same antenna. The solution to this problem is the use of a *transmitter multicoupler*. The multicoupler is related to the duplexers discussed earlier. It is a cavity filter and combiner that allows multiple transmitters and receivers to share the same antenna. This is a common commercial practice. A block diagram of a multicoupler system is shown in **Fig 20**.

The multicoupler, however, is a very expensive device, and has the disadvantage of even greater loss per transmission path than the standard duplexer. For example, a well-designed duplexer for 600 kHz spacing at 146 MHz has a loss per transmission path of approximately 1.5 dB. A four-channel multicoupler (the requirement for two repeaters) has an insertion loss per transmission path on the order of 2.5 dB or more. Another constraint of such a system is that the antenna must present a good match to the transmission line at all frequencies on which it will be used (both transmitting and receiving). This becomes difficult for the system with two repeaters operating at opposite ends of a band.

If you elect to purchase a commercial base-station antenna that requires you to specify a frequency to which the antenna must be tuned, be sure to indicate to the manufacturer the intended use of the antenna and the frequency extremes. In some cases, the only way the manufacturer can accommodate your request is to provide an antenna with some vertical-beam uptilt at one end of the band and some downtilt at the other end of the band. In the case of antennas with very high gain, this in itself may become a serious problem. Careful analysis of the situation is necessary before assembling such a system.

Diversity Techniques for Repeaters

Mobile flutter, “dead spots” and similar problems are a real problem for the mobile operator. The popularity of hand-held transceivers using low power and mediocre antennas causes similar problems. A solution to these difficulties is the use of some form of *diversity reception*. Diversity reception works because signals do not fade at the same rate when received by antennas at different locations (space diversity) or of different polarizations (polarization diversity).

Repeaters with large transmitter coverage areas often have difficulty “hearing” low power stations in peripheral areas or in dead spots. Space diversity is especially useful in such a situation. Space diversity utilizes separate receivers at different locations that are linked to the repeater. The repeater uses a circuit called a *voter* that determines which receiver has the best signal, and then selects the appropriate receiver from which to feed the repeater transmitter. This technique is helpful in urban areas where shadowing from large buildings and bridges causes problems. Space-diversity receiving, when properly executed, can give excellent results. But with the improvement come some disadvantages: added initial cost, maintenance costs, and the possibility of failure created by the extra equipment required. If installed and maintained carefully, problems are generally minimal.

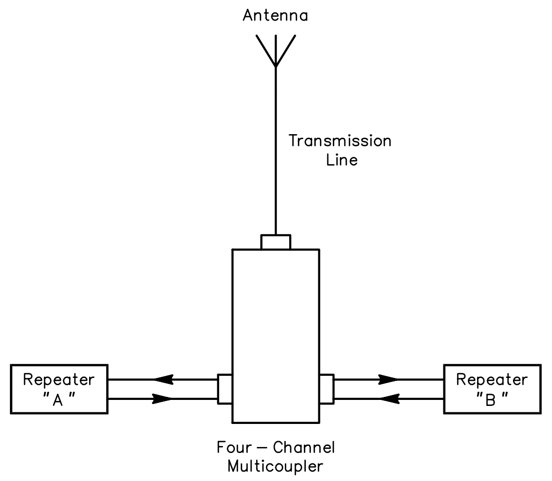

Fig 20—Block diagram of a system using a transmitter multicoupler to allow a single feed line and antenna to be used by two repeaters on one band. The antenna must be designed to operate at all frequencies that the repeaters utilize. More than two repeaters can be operated this way by using a multicoupler with the appropriate number of input ports.

A second improvement technique is the use of *circularly polarized* repeater antennas. This technique has been used in the FM broadcast field for many years, and has been considered for use in the mobile telephone service as well. Some experiments by amateurs have proved very promising, as discussed by Pasternak and Morris (see the Bibliography at the end of this chapter).

The improvement afforded by circular polarization is primarily a reduction in *mobile flutter*. The flutter on a mobile signal is caused by reflections from large buildings (in urban settings) or other terrain features. These reflections cause measurable polarization shifts, sometimes to the point where a vertically polarized signal at the transmitting site may appear to be primarily horizontally polarized after reflection.

A similar situation results from *multipath propagation*, where one or more reflected signals combine with the direct signal at the repeater, having varying effects on the signal. The multipath signal is subjected to large amplitude and phase variations at a relatively rapid rate.

In both of the situations described here, circular polarization can offer considerable improvement. This is because circularly polarized antennas respond equally to all linearly polarized signals, regardless of the plane of polarization. At this writing, there are no known sources of commercial circularly polarized omnidirectional antennas for the amateur bands. Pasternak and Morris describe a circularly polarized antenna made by modifying two commercial four-pole arrays.

EFFECTIVE ISOTROPIC RADIATED POWER (EIRP)

It is useful to know effective isotropic radiated power (EIRP) in calculating the coverage area of a repeater. The FCC formerly required EIRP to be entered in the log of every amateur repeater station. Although logging EIRP is no longer required, it is still useful to have this information on hand for repeater-coordination purposes and so system performance can be monitored periodically.

Calculation of EIRP is straightforward. The PEP output of the transmitter is simply multiplied by the gains and losses in the transmitting antenna system. (These gains and losses are best added or subtracted in decibels and then converted to a multiplying factor.) The following worksheet and example illustrates the calculations.

Feed-line loss ______ dB
Duplexer loss ______ dB
Isolator loss ______ dB
Cross-band coupler loss ______ dB
Cavity filter loss ______ dB

Total losses (L) ______ dB

G (dB) = antenna gain (dBi) –L

where G = antenna system gain. (If antenna gain is specified in dBd, add 2.14 dB to obtain the gain in dBi.)

$M = 10^{G/10}$

where M = multiplying factor

EIRP (watts) = transmitter output (PEP)×M

Example

A repeater transmitter has a power output of 50 W PEP (50-W FM transmitter). The transmission line has 1.8 dB loss. The duplexer used has a loss of 1.5 dB, and a circulator on the transmitter port has a loss of 0.3 dB. There are no cavity filters or cross-band couplers in the system. Antenna gain is 5.6 dBi.

Feed-line loss	1.8 dB
Duplexer loss	1.5 dB
Isolator loss	0.3 dB
Cross-band coupler loss	0 dB
Cavity filter loss	0 dB
Total losses (L)	3.6 dB

Antenna system gain in dB = G = antenna gain (dBi) –L

$G = 5.6 \text{ dBi} - 3.6 \text{ dB} = 2 \text{ dB}$

Multiplying factor = $M = 10^{G/10}$

$M = 10^{2/10} = 1.585$

EIRP (watts) = transmitter output (PEP) × M

EIRP = 50 W × 1.585 = 79.25 W

If the antenna system is lossier than this example, G may be *negative*, resulting in a multiplying factor less than one. The result is an EIRP that is less than the transmitter output power. This situation can occur in practice, but for obvious reasons is not desirable.

Assembling a Repeater Antenna System

This section will aid you in planning and assembling your repeater antenna system. The material was prepared by Domenic Mallozzi, N1DM. Consult Chapter 23, Radio Wave Propagation, for information on propagation for the band of your interest.

First, a repeater antenna selection checklist such as this will help you in evaluating the antenna system for your needs.

Gain needed ________ dBi
Pattern required ________ Omnidirectional
________ Offset
________ Cardioidal
________ Bidirectional
________ Special pattern (specify)
____
Mounting ________ Top of tower
________ Side of tower

(Determine effects of tower on pattern. Is the result consistent with the pattern required?)

Is downtilt required? ________ Yes
________ No
Type of RF connector ________ UHF
________ N
________ BNC
________ Other (specify)
Size (length) ________
Weight ________
Maximum cost $_______

Table 1 (see next page) has been compiled to provide general information on commercial components available for repeater and remote-base antenna systems. The various components are listed in a matrix format by manufacturer, for equipment designed to operate in the various amateur bands. See Chapter 21, Antenna Products Suppliers, for further information for these components. Although every effort has been made to make this data complete, the ARRL is not responsible for omissions or errors. The listing of a product in Table 1 does not constitute an endorsement by ARRL. Manufacturers are urged to contact the editors with updating information.

Even though almost any antenna can be used for a repeater, the companies indicated in the *Antennas* column in Table 1 are known to have produced heavy-duty antennas to commercial standards for repeater service. Many of these companies offer their antennas with special features for repeater service (such as vertical-beam downtilt). It is best to obtain catalogs of current products from the manufacturers listed, both for general information and to determine which special options are available on their products.

A 144 MHz Duplexer

Obtaining sufficient isolation between the transmitter and receiver of a repeater can be difficult. Many of the solutions to this problem compromise receiver sensitivity or transmitter power output. Other solutions create an imbalance between receiver and transmitter coverage areas. When a duplexer is used, insertion loss is the compromise. But a small amount of insertion loss is more than offset by the use of one antenna for both the transmitter and receiver. Using one antenna assures equal antenna patterns for both transmitting and receiving, and reduces cost, maintenance and mechanical complexity.

As mentioned earlier in this chapter, duplexers may be built in the home workshop. Bob Shriner, WA0UZO, presented a small, mechanically simple duplexer for low-power applications in April 1979 *QST*. Shriner's design is unique, as the duplexer cavities are constructed of circuit-board material. Low cost and simplicity are the result, but with a trade-off in performance. A silver-plated version of Shriner's design has an insertion loss of approximately 5 dB at 146 MHz. The loss is greater if the copper is not plated, and increases as the inner walls of the cavities tarnish.

This duplexer construction project by John Bilodeau, W1GAN, represents an effective duplexer. The information originally appeared in July 1972 *QST*. It is a time-proven project used by many repeater groups, and can be duplicated relatively easily. Its insertion loss is just 1.5 dB.

Fig 21 will help you visualize the requirements for a duplexer, which can be summed up as follows. The duplexer must attenuate the transmitter carrier to avoid overloading the receiver and thereby reducing its sensitivity. It must also attenuate any noise or spurious frequencies from the transmitter on or near the receiver frequency. In addition, a duplexer must provide a proper impedance match between transmitter, antenna, and receiver.

Table 1
Product Matrix Showing Repeater Equipment and Manufacturer by Frequency Band

	Antennas							*Duplexers*				*Cavity Filters*			
Source	*28*	*50*	*144*	*220*	*450*	*902*	*1296*	*144*	*220*	*450*	*902*	*144*	*220*	*450*	*902*
Austin	S	S	S	S	S	S	S								
Celwave	C	C	C	C	C	C		C	C	C	C	C	C	C	C
Comet															
Cushcraft		C	C	C	C										
Dec Prod		C	C	C	C	C		C	C		C	C		C	
MA/COM												C		C	
RF Parts			C		C	C	C								
Sinclair	C	C	C					C		C		C		C	C
TX/RX								C	C	C		C		C	C
Wacom															

	Isolators/Circulators						*Transmitter Combiners*				*Cross-Band Couplers*			
Source	*28*	*50*	*144*	*220*	*450*	*902*	*144*	*220*	*450*	*902*	*0-174 450-512*	*0-512 800-960*	*59-174 806-960*	*406-512 806-960*
Celwave			C	C	C	C	C	C	C	C		S		
Dec Prod			C		C	C		C	C	C				
Sinclair			C		C	C								
TX/RX			C		C	C	C	C	C	C	C	C	C	C
Wacom			C	C	C	C	C	C	C	C		C		C

Abbreviated names above are for the following manufacturers: Austin Antennas, Celwave RF Inc, Cushcraft Corp, Decibel Products Inc, RF Parts, Sinclair Radio Laboratories Inc, TX/RX Systems Inc and Wacom Inc. A manufacturer's contact list appears in Chapter 21.

Key to codes used:
C = catalog (standard) item
S = special-order item

Note: Coaxial cable is not listed, because most manufacturers sell only to dealers.

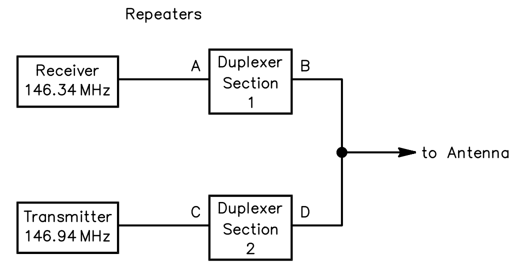

Fig 21—Duplexers permit using one antenna for both transmitting and receiving in a repeater system. Section 1 prevents energy at the transmitter frequency from interfering with the receiver, while section 2 attenuates any off-frequency transmitter energy that is at or near the receiver frequency.

As shown in Fig 21, transmitter output on 146.94 MHz going from point C to D should not be attenuated. However, the transmitter energy should be greatly attenuated between points B and A. Duplexer section 2 should attenuate any noise or signals that are on or near the receiver input frequency of 146.34 MHz. For good reception the noise and spurious signal level must be less than –130 dBm (0 dBm = 1 milliwatt into 50 Ω). Typical transmitter noise 600 kHz away from the carrier frequency is 80 dB below the transmitter power output. For 60 watts of output (+48 dBm), the noise level is –32 dBm. The duplexer must make up the difference between –32 dBm and –130 dBm, or 98 dB.

The received signal must go from point B to A with a minimum of attenuation. Section 1 of the duplexer must also provide enough attenuation of the transmitter energy to prevent receiver overload. For an average receiver, the transmitter signal must be less than –30 dBm to meet this requirement. The difference between the transmitter output of +48 dBm and the receiver overload point of –30 dBm, 78 dB, must be made up by duplexer section 1.

THE CIRCUIT

Fig 22 shows the completed 6-cavity duplexer, and **Fig 23** shows the assembly of an individual cavity. A $^1/_4$-λ resonator was selected for this duplexer design. The length of the center conductor is adjusted by turning a

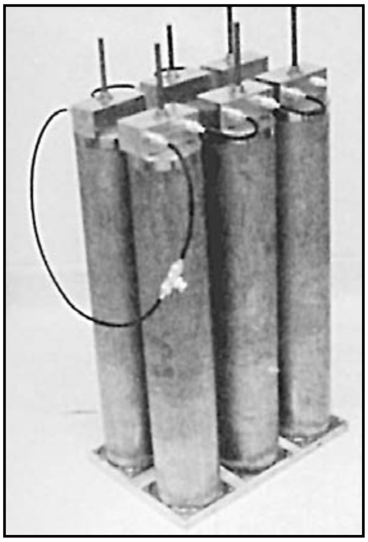

Fig 22—A six-cavity duplexer for use with a 144-MHz repeater. The cavities are fastened to a plywood base for mechanical stability. Short lengths of double-shielded cable are used for connections between individual cavities. An insertion loss of less than 1.5 dB is possible with this design.

threaded rod, which changes the resonant frequency of the cavity. Energy is coupled into and out of the tuned circuit by the coupling loops extending through the top plate.

The cavity functions as a series resonant circuit. When a reactance is connected across a series resonant circuit, an anti-resonant notch is produced, and the resonant frequency is shifted. If a capacitor is added, the notch appears below the resonant frequency. Adding inductance instead of capacitance makes the notch appear above the resonant frequency. The value of the added component determines the spacing between the notch and the resonant frequency of the cavity.

Fig 24 shows the measured band-pass characteristics of the cavity with shunt elements. With the cavity tuned to 146.94 MHz and a shunt capacitor connected from input to output, a 146.34-MHz signal is attenuated

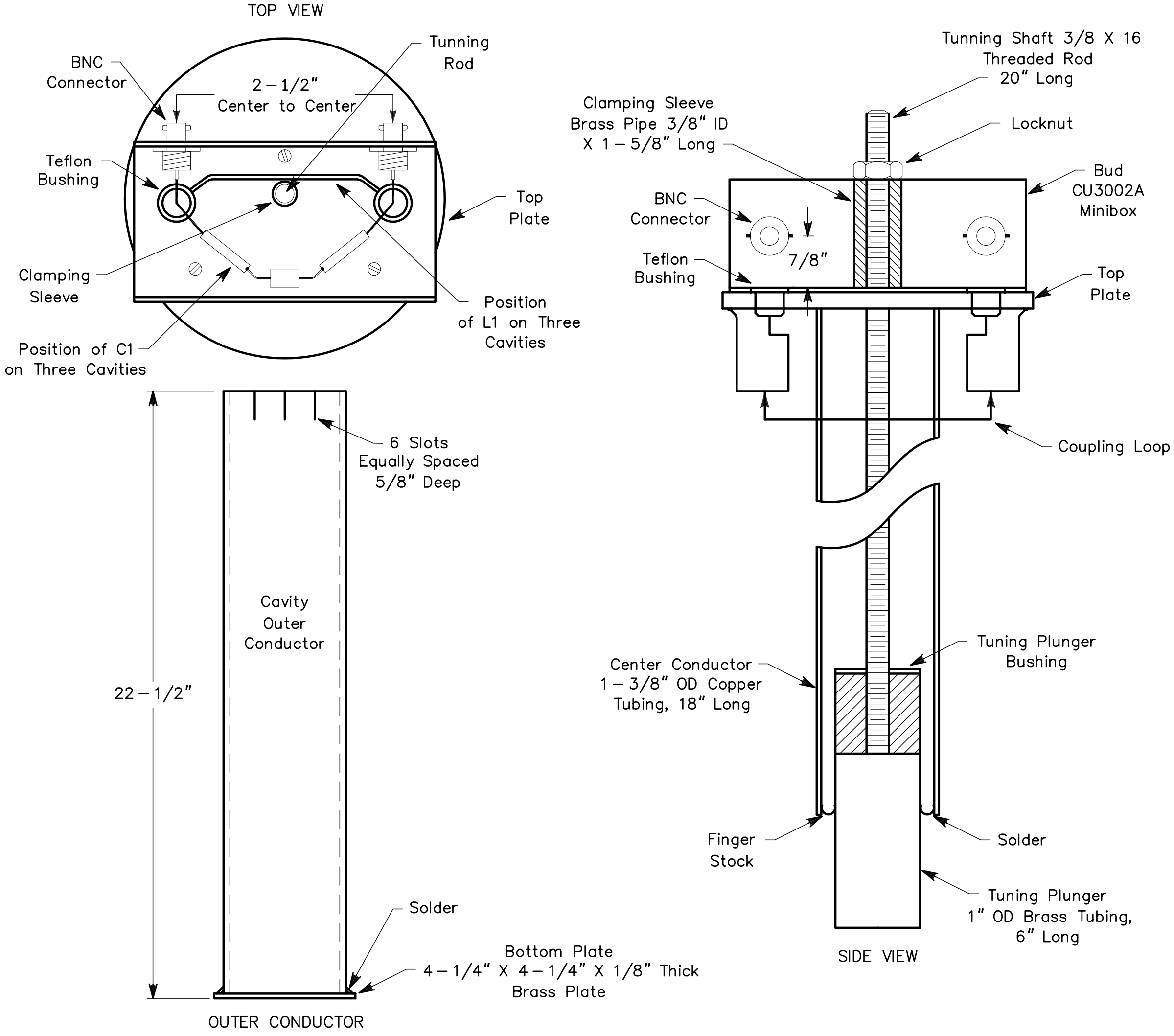
TOP VIEW
BNC Connector
2 − 1/2″ Center to Center
Tunning Rod
Teflon Bushing
Top Plate
Clamping Sleeve
Position of L1 on Three Cavities
Position of C1 on Three Cavities
6 Slots Equally Spaced 5/8″ Deep
Cavity Outer Conductor
22 − 1/2″
Solder
Bottom Plate 4 − 1/4″ X 4 − 1/4″ X 1/8″ Thick Brass Plate
OUTER CONDUCTOR
Tunning Shaft 3/8 X 16 Threaded Rod 20″ Long
Clamping Sleeve Brass Pipe 3/8″ ID X 1 − 5/8″ Long
Locknut
Bud CU3002A Minibox
BNC Connector
7/8″
Teflon Bushing
Top Plate
Coupling Loop
Center Conductor 1 − 3/8″ OD Copper Tubing, 18″ Long
Tuning Plunger Bushing
Finger Stock
Solder
Tuning Plunger 1″ OD Brass Tubing, 6″ Long
SIDE VIEW

Fig 23—The assembly of an individual cavity. A Bud Minibox is mounted on the top plate with three screws. A clamping sleeve made of brass pipe is used to prevent crushing the box when the locknut is tightened on the tuning shaft. Note that the positions of both C1 and L1 are shown, but that three cavities will have C1 installed and three will have L1 in place.

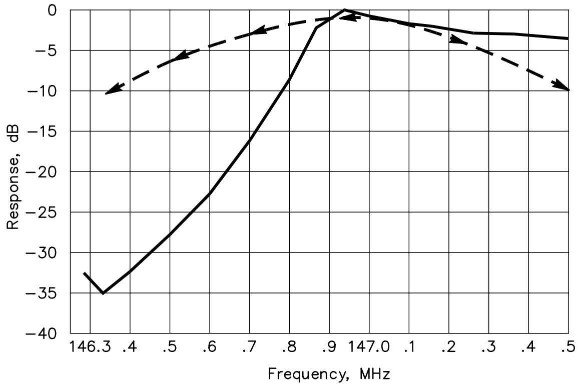

Fig 24—Typical frequency response of a single cavity of the type used in the duplexer. The dotted line represents the passband characteristics of the cavity alone; the solid line for the cavity with a shunt capacitor connected between input and output. An inductance connected in the same manner will cause the rejection notch to be above the frequency to which the cavity is tuned.

by 35 dB. If an inductance is placed across the cavity and the cavity is tuned to 146.34 MHz, the attenuation at 146.94 MHz is 35 dB. Insertion loss in both cases is 0.4 dB. Three cavities with shunt capacitors are tuned to 146.94 MHz and connected together in cascade with short lengths of coaxial cable. The attenuation at 146.34 MHz is more than 100 dB, and insertion loss at 146.94 MHz is 1.5 dB. Response curves for a six-cavity duplexer are given in **Fig 25**.

Construction

The schematic diagram for the duplexer is shown in **Fig 26**. Three parts for the duplexer must be machined; all others can be made with hand tools. A small lathe can be used to machine the brass top plate, the threaded tuning plunger bushing and the Teflon insulator bushing. The dimensions of these parts are given in **Fig 27**.

Type DWV copper tubing is used for the outer conductor of the cavities. The wall thickness is 0.058 inch, with an outside diameter of $4^1/8$ inches. You will need a tubing cutter large enough to handle this size (perhaps borrowed or rented). The wheel of the cutter should be tight and sharp. Make slow, careful cuts so the ends will be square. The outer conductor is $22^1/2$ inches long.

The inner conductor is made from type M copper tubing having an outside diameter of $1^3/8$ inches. A 6-inch length of 1-inch OD brass tubing is used to make the tuning plunger.

The tubing types mentioned above are designations used in the plumbing and steam-fitting industry. Other types may be used in the construction of a duplexer, but you should check the sizes carefully to assure that the parts will fit each other. A greater wall thickness will make the assembly heavier, and the expense will increase accordingly. Soft solder is used throughout the assembly. Unless you have experience with silver solder, do not use it. Eutectic type 157 solder with paste or acid

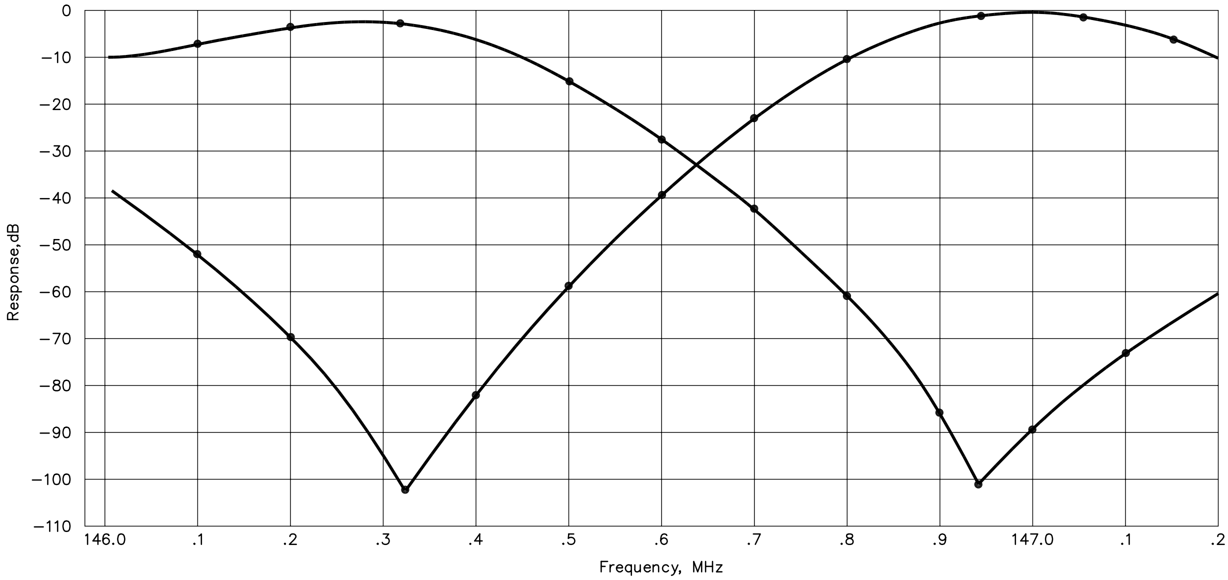

Fig 25—Frequency response of the six-cavity duplexer. One set of three cavities is tuned to pass 146.34 MHz and notch 146.94 MHz (the receiver leg). The remaining set of three cavities is tuned to pass 146.94 MHz and notch 146.34 MHz. This duplexer provides approximately 100 dB of isolation between the transmitter and receiver when properly tuned.

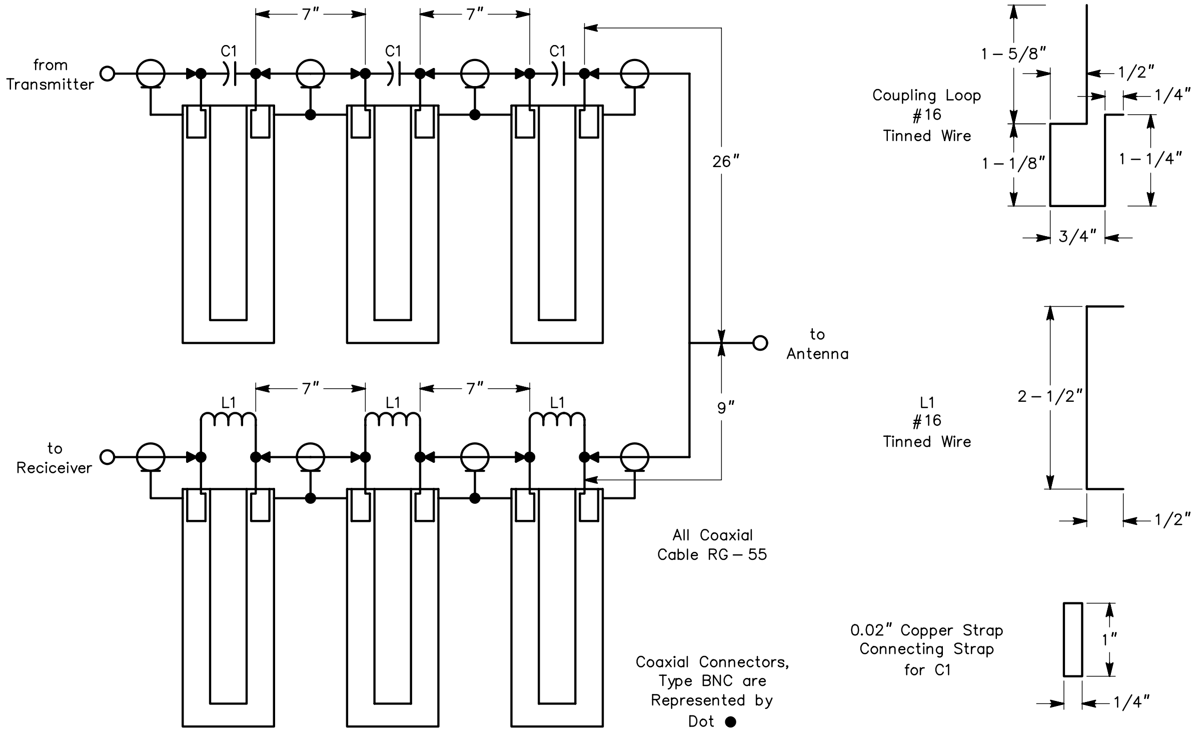
from Transmitter
C1
C1
C1
7"
7"
26"
to Antenna
9"
to Reciceiver
L1
L1
L1
7"
7"
All Coaxial Cable RG – 55
Coaxial Connectors, Type BNC are Represented by Dot ●
Coupling Loop #16 Tinned Wire
1 – 5/8"
1/2"
1/4"
1 – 1/8"
1 – 1/4"
3/4"
L1 #16 Tinned Wire
2 – 1/2"
1/2"
0.02" Copper Strap Connecting Strap for C1
1"
1/4"

Fig 26—Diagram of the six-cavity duplexer. Coaxial cable lengths between cavities are critical and must be followed closely. Double shielded cable and high quality connectors should be used throughout. The sizes and shapes of the coupling loops, L1, and the straps for connecting C1 should be observed.
C1—1.7-11 pF circuit-board mount, E. F. Johnson 189-5-5 or equiv. Set at $^3/_4$ closed for initial alignment.

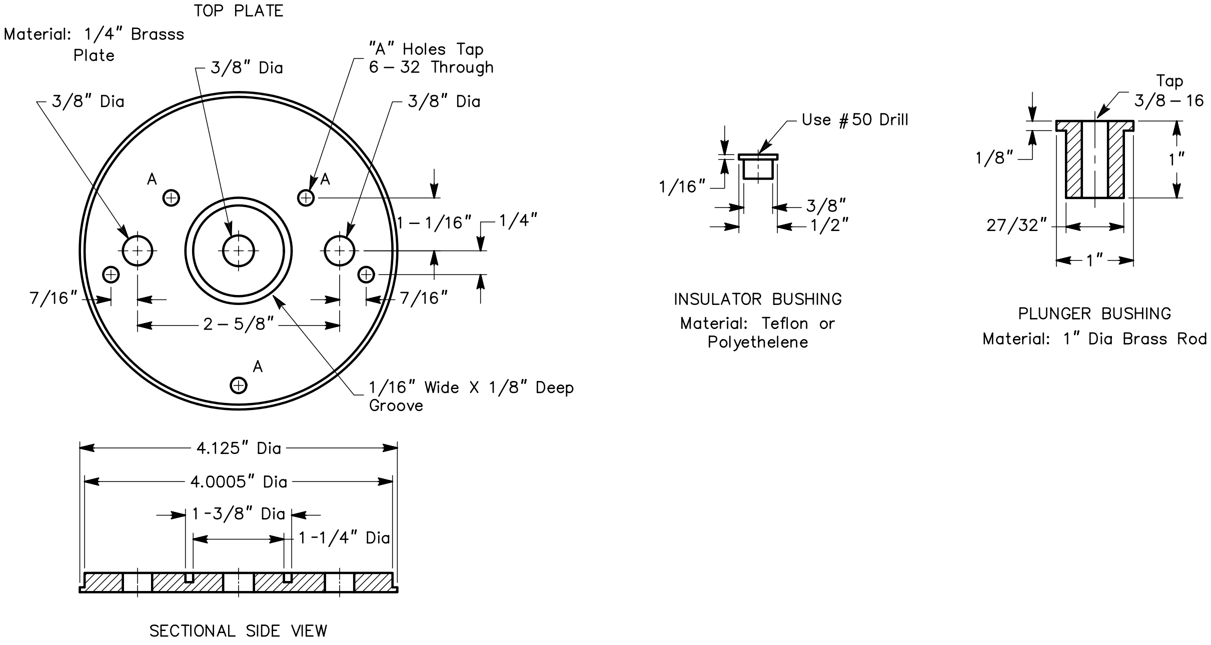
TOP PLATE
Material: 1/4" Brasss Plate
3/8" Dia
"A" Holes Tap 6 – 32 Through
3/8" Dia
3/8" Dia
A
A
A
1 – 1/16"
1/4"
7/16"
7/16"
2 – 5/8"
1/16" Wide X 1/8" Deep Groove
4.125" Dia
4.0005" Dia
1 -3/8" Dia
1 -1/4" Dia
SECTIONAL SIDE VIEW
Use #50 Drill
1/16"
3/8"
1/2"
INSULATOR BUSHING
Material: Teflon or Polyethelene
Tap 3/8 – 16
1/8"
1"
27/32"
1"
PLUNGER BUSHING
Material: 1" Dia Brass Rod

Fig 27—Dimensions for the three parts that require machining. A small metal-working lathe should be used for making these parts.

flux makes very good joints. This type has a slightly higher melting temperature than ordinary tin-lead alloy, but has considerably greater strength.

First solder the inner conductor to the top plate (**Fig 28**). The finger stock can then be soldered inside the lower end of the inner conductor, while temporarily held in place with a plug made of aluminum or stainless steel. While soldering, do not allow the flame from the torch to overheat the finger stock. The plunger bushing is soldered into the tuning plunger and a 20-inch length of threaded rod is soldered into the bushing.

Cut six slots in the top of the outer conductor. They should be 5/8 inch deep and equally spaced around the tubing. The bottom end of the 4-inch tubing is soldered to the square bottom plate. The bottom plates have holes in the corners so they can be fastened to a plywood base by means of wood screws. Because the center conductor has no support at one end, the cavities must be mounted vertically.

The size and position of the coupling loops are critical. Follow the given dimensions closely. Both loops should be 1/8 inch away from the center conductor on opposite sides. Connect a solder lug to the ground end of the loop, then fasten the lug to the top plate with a screw. The free end of the loop is insulated by Teflon bushings where it passes through the top plate for connection to the BNC fittings.

Before final assembly of the parts, clean them thoroughly. Soap-filled steel wool pads and hot water work well for this. Be sure the finger stock makes firm contact with the tuning plunger. The top plate should fit snugly in the top of the outer conductor—a large hose clamp tightened around the outer conductor will keep the top plate in place.

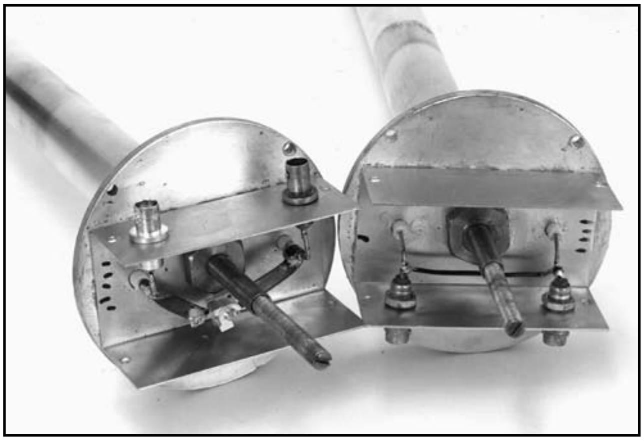

Fig 28—Two of the center conductor and top plate assemblies. In the assembly at the left, C1 is visible just below the tuning shaft, mounted by short straps made from sheet copper. The assembly on the right has L1 in place between the BNC connectors. The Miniboxes are fastened to the top plate by a single large nut in these units. Using screws through the Minibox into the top plate, as described in the text, is preferred.

ADJUSTMENT

After the cavities have been checked for band-pass characteristics and insertion loss, install the anti-resonant elements, C1 and L1. (See Fig 24.) It is preferable to use laboratory test equipment when tuning the duplexer. An option is to use a low-power transmitter with an RF probe and an electronic voltmeter. Both methods are shown in **Fig 29**.

With the test equipment connected as shown in Fig 29A, adjust the signal generator frequency to the desired repeater input frequency. Connect a calibrated step attenuator between points X and Y. With no attenuation, adjust the HP-415 for 0 on the 20-dB scale. You can check the calibration of the 415 by switching in different amounts of attenuation and noting the meter reading. You may note a small error at either high or very low signal levels.

Next, remove the step attenuator and replace it with a cavity that has the shunt inductor, L1, in place. Adjust the tuning screw for maximum reading on the 415 meter. Remove the cavity and connect points X and Y. Set the

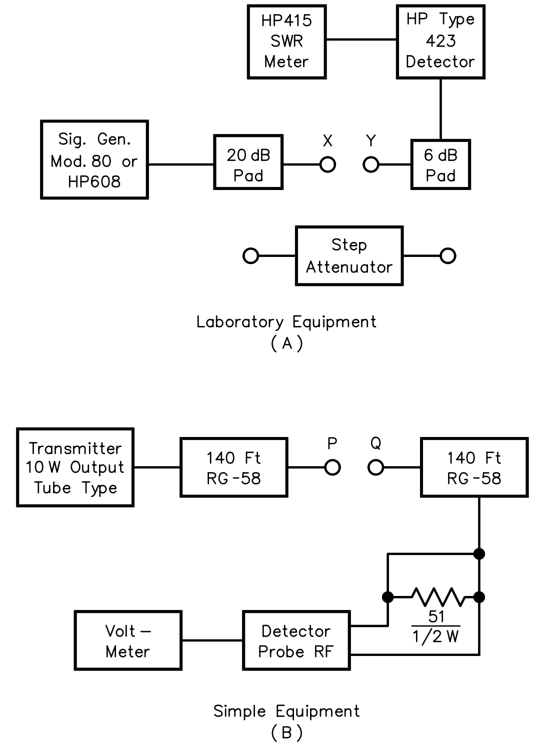

Fig 29—The duplexer can be tuned by either of the two methods shown here, although the method depicted at A is preferred. The signal generator should be modulated by a 1-kHz tone. If the setup shown at B is used, the transmitter should not be modulated, and should have a minimum of noise and spurious signals. The cavities to be aligned are inserted between X and Y in the setup at A, and between P and Q in B.

signal generator to the repeater output frequency and adjust the 415 for a 0 reading on the 20-dB scale.

Reinsert the cavity between X and Y and adjust the cavity tuning for minimum reading on the 415. The notch should be sharp and have a depth of at least 35 dB. It is important to maintain the minimum reading on the meter while tightening the locknut on the tuning shaft.

To check the insertion loss of the cavity, the output from the signal generator should be reduced, and the calibration of the 415 meter checked on the 50-dB expanded scale. Use a fixed 1-dB attenuator to make certain the error is less than 0.1 dB. Replace the attenuator with the cavity and read the loss. The insertion loss should be 0.5 dB or less. The procedure is the same for tuning all six cavities, except that the frequencies are reversed for those having the shunt capacitor installed.

Adjustment with Minimum Equipment

A transmitter with a minimum of spurious output is required. Most modern transmitters meet this requirement. The voltmeter in use should be capable of reading 0.5 volt (or less), full scale. The RF probe used should be rated to 150 MHz or higher. Sections of RG-58 cable are used as attenuators, as shown in Fig 29B. The loss in these 140-foot lengths is nearly 10 dB, and helps to isolate the transmitter in case of mismatch during tuning.

Set the transmitter to the repeater input frequency and connect P and Q. Obtain a reading between 1 and 3 volts on the voltmeter. Insert a cavity with shunt capacitors in place between P and Q and adjust the cavity tuning for a minimum reading on the voltmeter. (This reading should be between 0.01 and 0.05 volt.) The rejection in dB can be calculated by

$$dB = 20 \log (V1/V2)$$

This should be at least 35 dB. Check the insertion loss by putting the receiver on the repeater output frequency and noting the voltmeter reading with the cavity out of the circuit. A 0.5-dB attenuator can be made from a 7-foot length of RG-58. This 7-foot cable can be used to check the calibration of the detector probe and the voltmeter.

Cavities with shunt inductance can be tuned the same way, but with the frequencies reversed. If two or more cavities are tuned while connected together, transmitter noise can cause the rejection readings to be low. In other words, there will be less attenuation.

Results

The duplexer is conservatively rated at 150 watts input, but if constructed carefully should be able to handle as much as 300 watts. Silver plating the interior surfaces of the cavities is recommended if input power is to be greater than 150 watts. A duplexer of this type with silver-plated cavities has an insertion loss of less than 1 dB, and a rejection of more than 100 dB. Unplated cavities should be disassembled at least every two years, cleaned thoroughly, and then retuned.

Miscellaneous Notes

1) Double shielded cable and high quality connectors are *required* throughout the system.
2) The SWR of the antenna should not exceed 1.2:1 for proper duplexer performance.
3) Good shielding of the transmitter and receiver at the repeater is essential.
4) The antenna should have four or more wavelengths of vertical separation from the repeater.
5) Conductors in the near field of the antenna should be well bonded and grounded to eliminate noise.
6) The feed line should be electrically bonded and mechanically secured to the tower or mast.
7) Feed lines and other antennas in the near field of the repeater antenna should be well bonded and as far from the repeater antenna as possible.
8) Individual cavities can be used to improve the performance of separate antenna or separate site repeaters.
9) Individual cavities can be used to help solve intermodulation problems.

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Chapter 18

VHF and UHF Antenna Systems

A good antenna system is one of the most valuable assets available to the VHF/UHF enthusiast. Compared to an antenna of lesser quality, an antenna that is well designed, is built of good quality materials, and is well maintained, will increase transmitting range, enhance reception of weak signals and reduce interference problems. The work itself building antennas is by no means the least attractive part of the job. Even with high-gain antennas, experimentation is greatly simplified at VHF and UHF because the antennas are a physically manageable size. Setting up a home antenna range is within the means of most amateurs, and much can be learned about the nature and adjustment of antennas. No large investment in test equipment is necessary.

The Basics

Selecting the best VHF or UHF antenna for a given installation involves much more than scanning gain figures and prices in a manufacturer's catalog. There is no one "best" VHF or UHF antenna design for all purposes. The first step in choosing an antenna is figuring out what you want it to do.

Gain

At VHF and UHF, it is possible to build Yagi antennas with very high gain—15 to 20 dBi—on a physically manageable boom. Such antennas can be combined in arrays of two, four, six, eight or more antennas. These arrays are attractive for EME, tropospheric scatter or other weak-signal communications modes.

Radiation Patterns

Antenna radiation can be made omnidirectional, bidirectional, practically unidirectional, or anything between these conditions. A VHF net operator may find an omnidirectional system almost a necessity, but it may be a poor choice otherwise. Noise pickup and other interference problems are greater with such omnidirectional antennas, and omnidirectional antennas having some gain are especially bad in these respects. Maximum gain and low radiation angle are usually prime interests of the weak-signal DX aspirant. A clean pattern, with lowest possible pickup and radiation off the sides and back, may be important in high-activity areas, or where the noise level is high.

Frequency Response

The ability to work over an entire VHF band may be important in some types of work. Modern Yagis can achieve performance over a remarkably wide frequency range, providing that the boom length is long enough and enough elements are used to populate the boom. Modern Yagi designs in fact are competitive with directly driven collinear arrays of similar size and complexity. The primary performance parameters of gain, front-to-rear ratio and SWR can be optimized over all the VHF or UHF amateur bands readily, with the exception of the full 6meter band from 50.0 to 54.0 MHz, which is an 8% wide bandwidth. A Yagi can be easily designed to cover any 2.0 MHz portion of the 6-meter band with superb performance.

Height Gain

In general, higher is better in VHF and UHF antenna installations. Raising the antenna over nearby obstructions may make dramatic improvements in coverage. Within reason, greater height is almost always worth its cost, but height gain (see Chapter 23, Radio Wave Propagation) must be balanced against increased transmission-line loss. This loss can be considerable, and it increases with frequency. The best available line may not be very good if the run is long in terms of wavelengths. Line loss considerations (see Chapter 24, Transmission Lines) are important in antenna planning.

Physical Size

A given antenna design for 432 MHz has the same gain as the same design for 144 MHz, but being only one-third as large intercepts only one-ninth as much energy in receiving. In other words, the antenna has less pickup efficiency at 432 MHz. To be equal in communication effectiveness, the 432-MHz array should be at least equal in *size* to the 144-MHz antenna, which requires roughly three times as many elements. With all the extra difficulties involved in using the higher frequencies effectively, it is best to keep antennas as large as possible for these bands.

DESIGN FACTORS

With the objectives sorted out in a general way, decisions on specifics, such as polarization, type of transmission line, matching methods and mechanical design must be made.

Polarization

Whether to position antenna elements vertically or horizontally has been widely debated since early VHF pioneering days. Tests have shown little evidence about which polarization sense is most desirable. On long propagation paths there is no consistent advantage either way. Shorter paths tend to yield higher signal levels with horizontally polarized antennas over some kinds of terrain. Man-made noise, especially ignition interference, also tends to be lower with horizontal antennas. These factors make horizontal polarization somewhat more desirable for weak-signal communications. On the other hand, vertically polarized antennas are much simpler to use in omnidirectional systems and in mobile work.

Vertical polarization was widely used in early VHF work, but horizontal polarization gained favor when directional arrays started to become widely used. The major use of FM and repeaters, particularly in the VHF/UHF bands, has tipped the balance in favor of vertical antennas in mobile and repeater use. Horizontal polarization predominates in other communication on 50 MHz and higher frequencies. An additional loss of 20 dB or more can be expected when cross-polarized antennas are used.

TRANSMISSION LINES

Transmission line principles are covered in detail in Chapter 24, Transmission Lines. Techniques that apply to VHF and UHF operation are dealt with in greater detail here. The principles of carrying RF from one location to another via a feed line are the same for all radio frequencies. As at HF, RF is carried principally via open wire lines and coaxial cables at VHF/UHF. Certain aspects of these lines characterize them as good or bad for use above 50 MHz.

Properly built open-wire line can operate with very low loss in VHF and UHF installations. A total line loss under 2 dB per 100 feet at 432 MHz can easily be obtained. A line made of #12 wire, spaced $^3/_4$ inch or more with Teflon spreaders and run essentially straight from antenna to station, can be better than anything but the most expensive coax. Such line can be home made or purchased at a fraction of the cost of coaxial cables, with comparable loss characteristics. Careful attention must be paid to efficient impedance matching if the benefits of this system are to be realized. A similar system for 144 MHz can easily provide a line loss under 1 dB.

Small coax such as RG-58 or RG-59 should never be used in VHF work if the run is more than a few feet. Lines of $^1/_2$-inch diameter (RG-8 or RG-11) work fairly well at 50 MHz, and are acceptable for 144-MHz runs of 50 feet or less. These lines are somewhat better if they employ foam instead of ordinary PE dielectric material. Aluminum-jacket *hardline* coaxial cables with large inner conductors and foam insulation are well worth their cost, and can sometimes be obtained for free from local Cable TV operators as “end runs”—pieces at the end of a roll. The most common CATV cable is $^1/_2$-inch OD 75-Ω hardline. Matched-line loss for this cable is about 1.0 dB/100 feet at 146 MHz and 2.0 dB/100 feet at 432 MHz. Less commonly available from CATV companies is the $^3/_4$-inch 75Ω hardline, sometimes with a black self-healing hard plastic covering. This line has 0.8 dB of loss per 100 feet at 146 MHz, and 1.6 dB loss per 100 feet at 432 MHz. There will be small additional losses for either line if 75-to-50Ω transformers are used at each end.

Commercial connectors for hardline are expensive but provide reliable connections with full waterproofing. Enterprising amateurs have homebrewed low-cost connectors. If they are properly water proofed, connectors and hardline can last almost indefinitely. Hardline must not be bent too sharply, because it will kink. See Chapter 24, Transmission Lines, for details on hardline connectors.

Beware of any “bargains” in coax for VHF or UHF use. Feed-line loss can be compensated to some extent by increasing transmitter power, but once lost, a weak signal can never be recovered in the receiver. Effects of weather on transmission lines should not be ignored. Well-constructed open-wire line works optimally in nearly any weather, and it stands up well. Twin-lead is almost useless in heavy rain, wet snow or icing. The best grades of coax are completely impervious to weather—they can be run underground, fastened to metal towers without insulation and bent into any convenient position with no adverse effects on performance.

WAVEGUIDES

Above 2 GHz, coaxial cable is a losing proposition for communications work. Fortunately, at this frequency the wavelength is short enough to allow practical, efficient energy transfer by an entirely different means. A *waveguide* is a conducting tube through which energy is transmitted in the form of electromagnetic waves. The tube is not considered as carrying a current in the same sense that the wires of a two-conductor line do, but rather as a *boundary* that confines the waves in the enclosed space. Skin effect prevents any electromagnetic effects from being evident outside the guide. The energy is injected at one end, either through capacitive or inductive coupling or by radiation, and is removed from the other end in a like manner. Waveguide merely confines the energy of the fields, which are propagated through it to the receiving end by means of reflections against its inner walls.

Analysis of waveguide operation is based on the assumption that the guide material is a perfect conductor of electricity. Typical distributions of electric and magnetic fields in a rectangular guide are shown in **Fig 1**. The intensity of the electric field is greatest (as indicated by closer spacing of the lines of force) at the center along the X dimension (Fig 1C), diminishing to zero at the end walls. The fields must diminish in this manner, because the existence of any electric field parallel to the walls at the surface would cause an infinite current to flow in a perfect conductor. Waveguides, of course, cannot carry RF in this fashion.

Modes of Propagation

Fig 1 represents the most basic distribution of the electric and magnetic fields in a waveguide. There are an infinite number of ways in which the fields can arrange themselves in a waveguide (for frequencies above the low cutoff frequency of the guide in use). Each of these field configurations is called a *mode*.

The modes may be separated into two general groups. One group, designated *TM* (transverse magnetic), has the magnetic field entirely transverse to the direction of propagation, but has a component of the electric field in that direction. The other type, designated *TE* (transverse electric) has the electric field entirely transverse, but has a component of magnetic field in the direction of propagation. TM waves are sometimes called *E waves*, and TE waves are sometimes called *H waves*, but the TM and TE designations are preferred.

The mode of propagation is identified by the group letters followed by two subscript numerals. For example, TE_{10}, TM_{11}, etc. The number of possible modes increases with frequency for a given size of guide, and there is only one possible mode (called the *dominant mode*) for the lowest frequency that can be transmitted. The dominant mode is the one generally used in amateur work.

Waveguide Dimensions

In rectangular guide the critical dimension is X in Fig 1. This dimension must be more than $^1/_2$ λ at the lowest frequency to be transmitted. In practice, the Y dimension usually is made about equal to $^1/_2$ X to avoid the possibility of operation in other than the dominant mode.

Cross-sectional shapes other than a rectangle can be used, the most important being the circular pipe. Much the same considerations apply as in the rectangular case.

Wavelength dimensions for rectangular and circular guides are given in **Table 1**, where X is the width of a rectangular guide and r is the radius of a circular guide. All figures apply to the dominant mode.

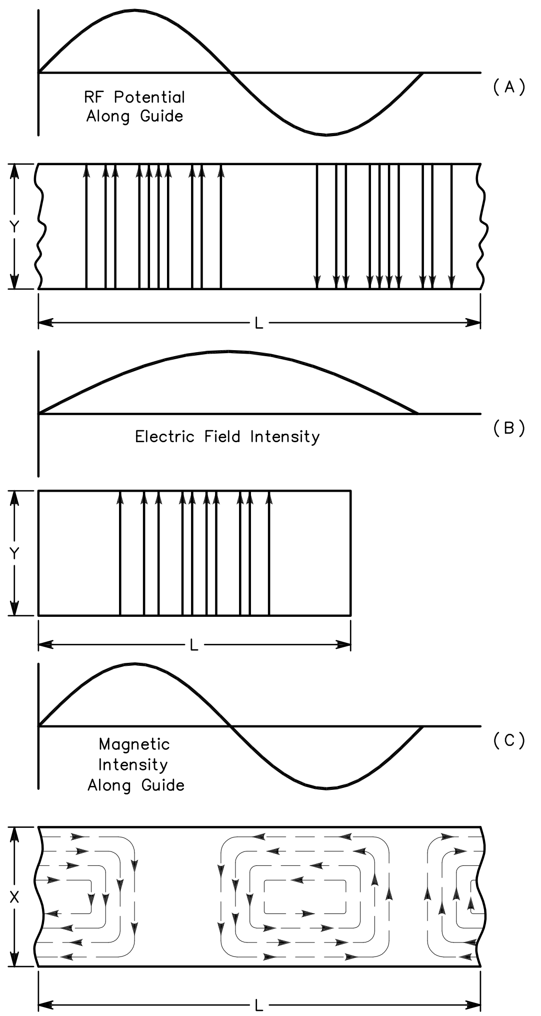

Fig 1—Field distribution in a rectangular waveguide. The TE10 mode of propagation is depicted.

Coupling to Waveguides

Energy may be introduced into or extracted from a waveguide or resonator by means of either the electric or magnetic field. The energy transfer frequently is through a coaxial line. Two methods for coupling to coaxial line are shown in **Fig 2**. The probe shown at A is simply a short extension of the inner conductor of the coaxial line, oriented so that it is parallel to the electric lines of force. The loop shown at B is arranged so that it encloses some of the magnetic lines of force. The point at which maximum coupling is obtained depends upon the mode of propagation in the guide or cavity. Coupling is maximum when the coupling device is in the most intense field.

Coupling can be varied by turning the probe or loop through a 90° angle. When the probe is perpendicular to the electric lines the coupling is minimum. Similarly, when the plane of the loop is parallel to the magnetic lines the coupling is minimum.

If a waveguide is left open at one end it will radiate energy. This radiation can be greatly enhanced by flaring the waveguide to form a pyramidal horn antenna. The horn acts as a transition between the confines of the waveguide and free space. To effect the proper impedance transformation the horn must be at least $^1/_2$ λ on a side. A horn of this dimension (cutoff) has a unidirectional radiation pattern with a null toward the waveguide transition. The gain at the cutoff frequency is 3 dB, increasing 6 dB with each doubling of frequency. Horns are used extensively in microwave work, both as primary radiators and as feed elements for more elaborate focusing systems. Details for constructing 10-GHz horn antennas are given later in this chapter.

Evolution of a Waveguide

Suppose an open-wire line is used to carry RF energy from a generator to a load. If the line has any appreciable length it must be mechanically supported. The line must be well insulated from the supports if high losses are to be avoided. Because high-quality insulators are difficult to construct at microwave frequencies, the logical alternative is to support the transmission line with $^1/_4$ λ stubs, shorted at the end opposite the feed line. The open end of such a stub presents an infinite impedance to the transmission line, provided the shorted stub is nonreactive. However, the shorting link has a finite length, and therefore some inductance. The effect of this inductance can be removed by making the RF current flow on the surface of a plate rather than a thin wire. If the plate is large enough, it will prevent the magnetic lines of force from encircling the RF current.

An infinite number of these $^1/_4$ λ stubs may be connected in parallel without affecting the standing waves of voltage and current. The transmission line may be supported from the top as well as the bottom, and when an infinite number of supports are added, they form the walls of a waveguide at its cutoff frequency. **Fig 3** illustrates how a rectangular waveguide evolves from a two-wire parallel transmission line as described. This simplified analysis also shows why the cutoff dimension is $^1/_2$ λ.

Table 1
Waveguide Dimensions

	Rectangular	*Circular*
Cutoff wavelength	2X	3.41r
Longest wavelength transmitted with little attenuation	1.6X	3.2r
Shortest wavelength before next mode becomes possible	1.1X	2.8r

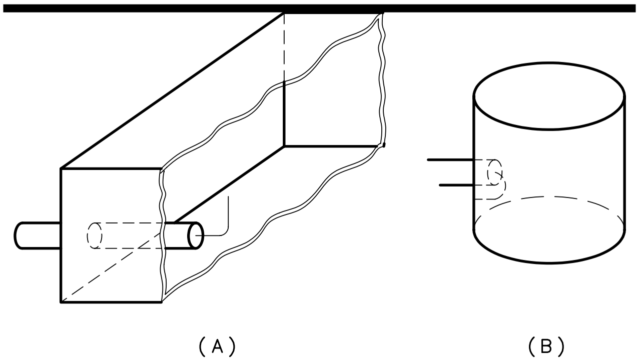

Fig 2—Coupling coaxial line to waveguide and resonators.

While the operation of waveguides is usually described in terms of fields, current does flow on the inside walls, just as on the conductors of a two-wire transmission line. At the waveguide cutoff frequency, the current is concentrated in the center of the walls, and disperses toward the floor and ceiling as the frequency increases.

IMPEDANCE MATCHING

Impedance matching is covered in detail in Chapter 25, Coupling the Transmitter to the Line, and Chapter 26, Coupling the Line to the Antenna. The theory is the same for frequencies above 50 MHz. Practical aspects are similar, but physical size can be a major factor in the choice of methods. Only the matching devices used in practical construction examples later in this chapter are discussed in detail here. This should not rule out consideration of other methods, however, and you should read the relevant portions of both Chapters 25 and 26.

Universal Stub

As its name *universal stub* implies, the double-adjustment stub of **Fig 4A** is useful for many matching purposes. The stub length is varied to resonate the system and the transmission-line attachment point is varied until the transmission line and stub impedances are equal. In practice this involves moving both the sliding short and

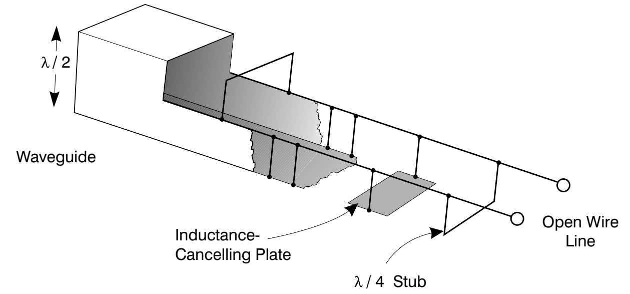

Fig 3—At its cutoff frequency a rectangular waveguide can be thought of as a parallel two-conductor transmission line supported from top and bottom by an infinite number of $^1/_4$-λ stubs.

the point of line connection for zero reflected power, as indicated on an SWR bridge connected in the line.

The universal stub allows for tuning out any small reactance present in the driven part of the system. It permits matching the antenna to the line without knowledge of the actual impedances involved. The position of the short yielding the best match gives some indication of the amount of reactance present. With little or no reactive component to be tuned out, the stub must be approximately $^1/_2$ λ from load toward the short.

The stub should be made of stiff bare wire or rod, spaced no more than $^1/_{20}$ λ apart. Preferably it should be mounted rigidly, on insulators. Once the position of the short is determined, the center of the short can be grounded, if desired, and the portion of the stub no longer needed can be removed.

It is not necessary that the stub be connected directly to the driven element. It can be made part of an open-wire line as a device to match coaxial cable to the line. The stub can be connected to the lower end of a delta match or placed at the feed point of a phased array. Examples of these uses are given later.

Delta Match

Probably the most basic impedance matching device is the *delta match*, fanned ends of an open-wire line tapped onto a $^1/_2$ λ antenna at the point of the most-efficient power transfer. This is shown in Fig 4B. Both the side length and the points of connection either side of the center of the element must be adjusted for minimum reflected power on the line, but as with the universal stub, you needn't know the impedances. The delta match makes no provision for tuning out reactance, so the universal stub is often used as a termination for it.

At one time, the delta match was thought to be inferior for VHF applications because of its tendency to radiate if improperly adjusted. The delta has come back into favor now that accurate methods are available for measuring the effects of matching. It is very handy for phasing multiple-bay arrays with open-wire lines, and its dimensions in this use are not particularly critical. It should be checked out carefully in applications like that of Fig 4C, where no tuning device is used.

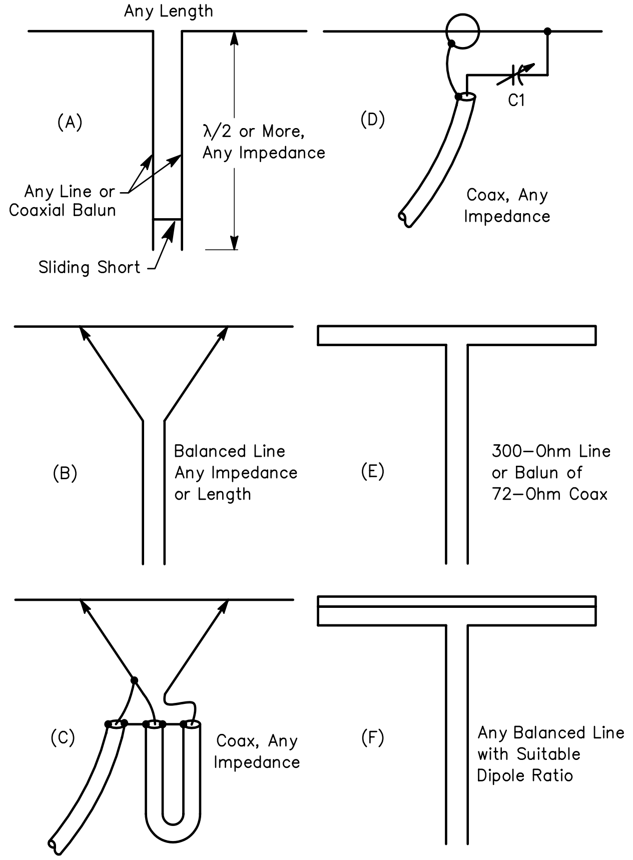
Any Length
(A)
λ/2 or More, Any Impedance
Any Line or Coaxial Balun
Sliding Short
(D)
C1
Coax, Any Impedance
(B)
Balanced Line Any Impedance or Length
(E)
300–Ohm Line or Balun of 72–Ohm Coax
(C)
Coax, Any Impedance
(F)
Any Balanced Line with Suitable Dipole Ratio

Fig 4—Matching methods commonly used at VHF. The universal stub, A, combines tuning and matching. The adjustable short on the stub and the points of connection of the transmission line are adjusted for minimum reflected power on the line. In the delta match, B and C, the line is fanned out and connected to the dipole at the point of optimum impedance match. Impedances need not be known in A, B or C. The gamma match, D, is for direct connection of coax. C1 tunes out inductance in the arm. A folded dipole of uniform conductor size, E, steps up antenna impedance by a factor of four. Using a larger conductor in the unbroken portion of the folded dipole, F, gives higher orders of impedance transformation.

Gamma and T Matches

An application of the same principle allowing direct connection of coax is the *gamma match*, Fig 4D. Because the RF voltage at the center of a $^1/_2$ λ dipole is zero, the outer conductor of the coax is connected to the element at this point. This may also be the junction with a metallic or wooden boom. The inner conductor, carrying the RF current, is tapped out on the element at the matching point. Inductance of the arm is tuned out by means of C1, resulting in electrical balance. Both the point of contact with the element and the setting of the capacitor are adjusted for zero reflected power, with a bridge connected in the coaxial line.

The capacitance can be varied until the required value is found, and the variable capacitor replaced with a fixed unit of that value. C1 can be mounted in a waterproof box. The maximum required value should be about 100 pF for 50 MHz and 35 to 50 pF for 144 MHz.

The capacitor and arm can be combined in one coaxial assembly, with the arm connected to the driven element by means of a sliding clamp and the inner end of the arm sliding inside a sleeve connected to the center conductor of the coax. An assembly of this type can be constructed from concentric pieces of tubing, insulated by plastic or heat-shrink sleeving. RF voltage across the capacitor is low when the match is adjusted properly, so with a good dielectric, insulation presents no great problem. The initial adjustment should be made with low power. A clean, permanent high-conductivity bond between arm and element is important, since the RF current is high at this point.

Because it is inherently somewhat unbalanced, the gamma match can sometimes introduce pattern distortion, particularly on long-boom, highly directive Yagi arrays. The *T-match*, essentially two gamma matches in series creating a balanced feed system, has become popular for this reason. A coaxial balun like that shown in **Fig 5** is used from the 200 Ω balanced T-match to the unbalanced 50 Ω coaxial line going to the transmitter. See the K1FO Yagi designs later in this chapter for details on practical use of a T-match.

Folded Dipole

The impedance of a $^{1}/_{2}$ λ dipole broken at its center is about 70 Ω. If a single conductor of uniform size is folded to make a $^{1}/_{2}$ λ dipole as shown in Fig 4E, the impedance is stepped up four times. Such a folded dipole can be fed directly with 300Ω line with no appreciable mismatch. If a 4:1 balun is used, the antenna can be fed with 75Ω coaxial cable. (See balun information presented below.) Higher step-up impedance transformation can be obtained if the unbroken portion is made larger in cross-section than the fed portion, as shown in Fig 4F.

Hairpin Match

The feed-point resistance of most multielement Yagi arrays is less than 50 Ω. If the driven element is split and fed at the center, it may be shortened from its resonant length to add capacitive reactance at the feed point. Then, shunting the feed point with a wire loop resembling a *hairpin* causes a step-up of the feed-point resistance. The hairpin match is used together with a 4:1 coaxial balun in the 50 MHz arrays described later in this chapter. See Chapter 26, Coupling the Line to the Antenna, for details on the hairpin match.

BALUNS AND ANTENNA TUNERS

Conversion from balanced loads to unbalanced lines (or vice versa) can be performed with electrical circuits, or their equivalents made of coaxial cable. A balun made from flexible coax is shown in Fig 5A. The looped portion is an electrical $^{1}/_{2}$ λ. The physical length depends on the velocity factor of the line used, so it is important to check its resonant frequency as shown in Fig 5B. The two ends are shorted, and the loop at one end is coupled to a dip meter coil. This type of balun gives an impedance step-up of 4:1 (typically 50 to 200 Ω, or 75 to 300 Ω).

Coaxial baluns that yield 1:1 impedance transformations are shown in **Fig 6**. The coaxial sleeve, open at the top and connected to the outer conductor of the line at the lower end (A) is the preferred type. At B, a conductor of approximately the same size as the line is used with the outer conductor to form a $^{1}/_{4}$ λ stub. Another piece of coax, using only the outer conductor, will serve this purpose. Both baluns are intended to present an infi-

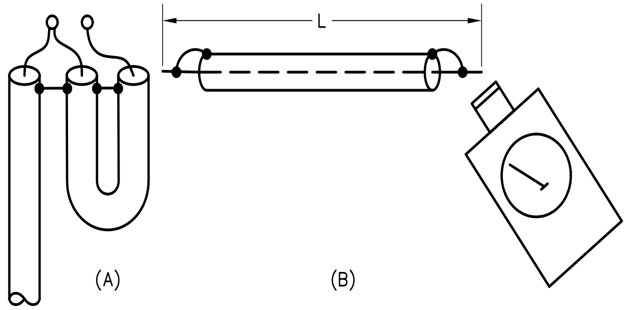

Fig 5—Conversion from unbalanced coax to a balanced load can be done with a ½-λ, coaxial balun at A. Electrical length of the looped section should be checked with a dip meter, with the ends shorted, as at B. The $^{1}/_{2}$-λ balun gives a 4:1 impedance step-up.

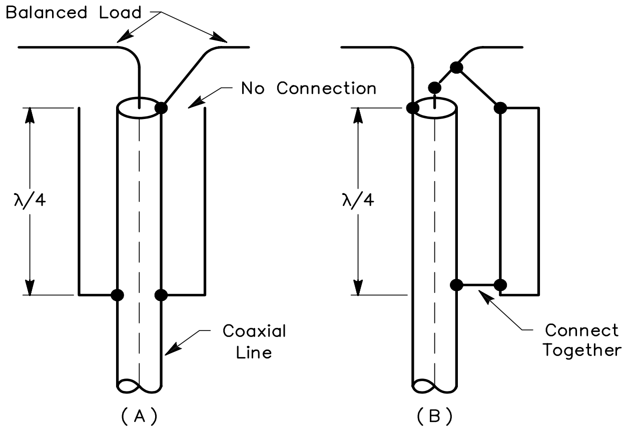

Fig 6—The balun conversion function, with no impedance transformation, can be accomplished with ¼-λ lines, open at the top and connected to the coax outer conductor at the bottom. The coaxial sleeve at A is preferred.

nite impedance to any RF current that might otherwise flow on the outer conductor of the coax.

The functions of the balun and the impedance transformer can be handled by various tuned circuits. Such a device, commonly called an *antenna tuner* or a *Transmatch*, can provide a wide range of impedance transformations. Additional selectivity inherent in the antenna tuner can reduce RFI problems.

THE YAGI AT VHF AND UHF

Without doubt, the Yagi is king of home-station antennas these days. Today's best designs are computer optimized. For years amateurs as well as professionals designed Yagi arrays experimentally. Now we have powerful (and inexpensive) personal computers and sophisticated software for antenna modeling. These have brought us antennas with improved performance, with little or no element pruning required. Chapter 11, HF Yagi Arrays, describes the parameters associated with Yagi-Uda arrays. Except for somewhat tighter dimensional tolerances needed at VHF and UHF, the properties that make a good Yagi at HF also are needed on the higher frequencies. See the end of this chapter for practical Yagi designs.

STACKING YAGIS

Where suitable provision can be made for supporting them, two Yagis mounted one above the other and fed in phase can provide better performance than one long Yagi with the same theoretical or measured gain. The pair occupies a much smaller turning space for the same gain, and their wider elevation coverage can provide excellent results. The wide azimuthal coverage for a vertical stack often results in QSOs that might be missed with a single narrow-beam long-boom Yagi pointed in a different direction. On long ionospheric paths, a stacked pair occasionally may show an *apparent* gain much greater than the measured 2 to 3 dB of stacking gain. (See also the extensive section on stacking Yagis in Chapter 11, HF Yagi Arrays.)

Optimum vertical spacing for Yagis with boom longer than 1 λ or more is about 1 λ (984/50.1 = 19.64 feet), but this may be too much for many builders of 50-MHz antennas to handle. Worthwhile results can be obtained with as little as 1/2 λ (10 feet), but 5/8 λ (12 feet) is markedly better. The difference between 12 and 20 feet, however, may not be worth the added structural problems involved in the wider spacing, at least at 50 MHz. The closer spacings give lower measured gain, but the antenna patterns are cleaner in both azimuth and elevation than with 1 λ spacing. Extra gain with wider spacings is usually the objective on 144 MHz and higher-frequency bands, where the structural problems are not as severe.

Yagis can also be stacked in the same plane (collinear elements) for sharper azimuthal directivity. A spacing of 5/8 λ between the ends of the inner elements yields the maximum gain within the main lobe of the array.

If individual antennas of a stacked array are properly designed, they look like noninductive resistors to the phasing system that connects them. The impedances involved can thus be treated the same as resistances in parallel.

Three sets of stacked dipoles are shown in **Fig 7**. Whether these are merely dipoles or the driven elements of Yagi arrays makes no difference for the purpose of these examples. Two 300 Ω antennas at A are 1 λ apart, resulting in a paralleled feed-point impedance of 150 Ω at the center. (Actually it is slightly less than 150 Ω because of coupling between bays, but this can be neglected for illustrative purposes.) This value remains the same regardless of the impedance of the phasing line. Thus, any convenient line can be used for phasing, as long as the *electrical* length of each line is the same.

The velocity factor of the line must be taken into account as well. As with coax, this is subject to so much variation that it is important to make a resonance check on the actual line used. The method for doing this is shown in Fig 5B. A 1/2 λ line is resonant both open and shorted, but the shorted condition (both ends) is usually the more convenient test condition.

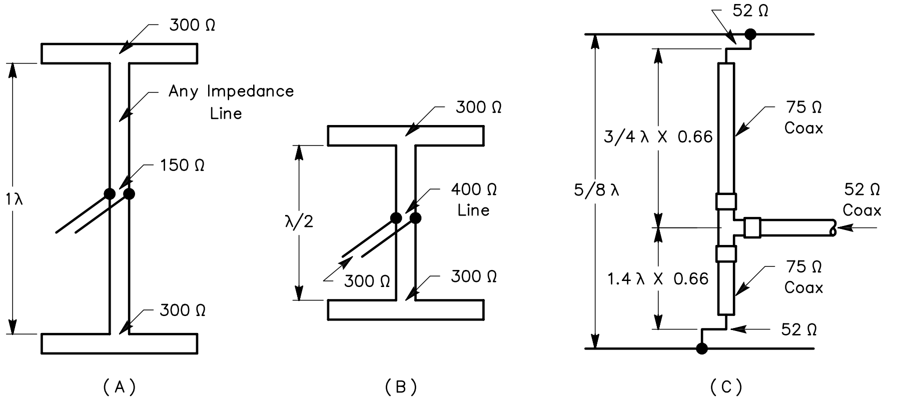

Fig 7—Three methods of feeding stacked VHF arrays. A and B are for bays having balanced driven elements, where a balanced phasing line is desired. Array C has an all-coaxial matching and phasing system. If the lower section is also 3/4 λ no transposition of line connections is needed.

The impedance transforming property of a $^1/_4$ λ line section can be used in combination matching and phasing lines, as shown in Fig 7B and C. At B, two bays spaced $^1/_2$ λ apart are phased and matched by a 400-Ω line, acting as a double-Q section, so that a 300-Ω main transmission line is matched to two 300-Ω bays. The two halves of this phasing line could also be $^3/_4$-λ or $^5/_4$-λ long, if such lengths serve a useful mechanical purpose. (An example is the stacking of two Yagis where the desirable spacing is more than $^1/_2$ λ.)

A double-Q section of coaxial line is illustrated in Fig 7C. This is useful for feeding stacked bays that were designed for 50-Ω feed. A spacing of $^5/_8$ λ is useful for small Yagis, and this is the equivalent of a full electrical wavelength of solid-dielectric coax such as RG-11.

If one phasing line is electrically $^1/_4$ λ and $^3/_4$ λ on the other, the connection to one driven element should be reversed with respect to the other to keep the RF currents in the elements in phase—the gamma match is located on opposite sides of the driven elements in Fig 7C. If the number of $^1/_4$ λ lengths is the same on either side of the feed point, the two connections should be in the same position, and not reversed. Practically speaking however, you can ensure proper phasing by using exactly equal lengths of line from the same roll of coax. This ensures that the velocity factor for each line is identical.

One marked advantage of coaxial phasing lines is that they can be wrapped around the vertical support, taped or grounded to it, or arranged in any way that is mechanically convenient. The spacing between bays can be set at the most desirable value, and the phasing lines placed anywhere necessary.

Stacking Yagis for Different Frequencies

In stacking horizontal Yagis one above the other on a single rotating support, certain considerations apply when the bays are for different bands. As a very general rule of thumb, the minimum desirable spacing is half the boom length of the higher frequency Yagi.

For example, assume the stacked two-band array of **Fig 8A** is for 50 and 144 MHz. This vertical arrangement is commonly referred to as a *Christmas tree*, because it resembles one. The 50MHz Yagi has 5elements on a 12-foot boom. It tends to look like "ground" to the 8-element 144 MHz Yagi on a 12-foot boom directly above it. [The exact Yagi designs for the examples used in this section are located on the CD-ROM accompanying this book. They may be evaluated as monoband Yagis using the *YW* (Yagi for Windows) program also supplied on the CD-ROM. In each case the bottom Yagi in the stack (at the top of the tower) is assumed to be 20 feet high.]

SWR Change in a Multi-Frequency Stack

Earlier editions of *The ARRL Antenna Book* stated that the feed-point impedance of the higher-frequency antenna would likely be affected the most by the proxim-

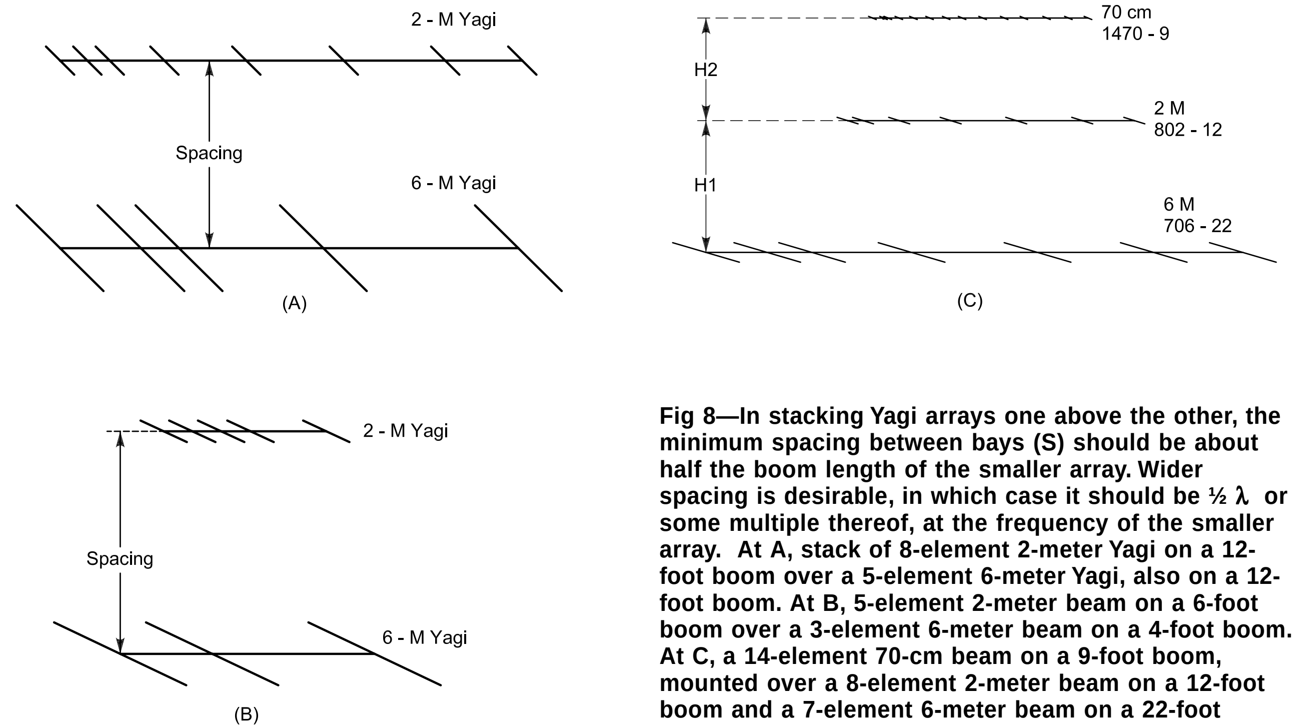

Fig 8—In stacking Yagi arrays one above the other, the minimum spacing between bays (S) should be about half the boom length of the smaller array. Wider spacing is desirable, in which case it should be ½ λ or some multiple thereof, at the frequency of the smaller array. At A, stack of 8-element 2-meter Yagi on a 12-foot boom over a 5-element 6-meter Yagi, also on a 12-foot boom. At B, 5-element 2-meter beam on a 6-foot boom over a 3-element 6-meter beam on a 4-foot boom. At C, a 14-element 70-cm beam on a 9-foot boom, mounted over a 8-element 2-meter beam on a 12-foot boom and a 7-element 6-meter beam on a 22-foot boom.

ity of the lower-frequency Yagi. Modern computer modeling programs reveal that while the feed-point SWR can indeed be affected, by far the greatest degradation is in the forward gain and rearward pattern of the higher-frequency Yagi when the booms are closely spaced. In fact, the SWR curve is usually not affected enough to make it a good diagnostic indicator of interaction between the two Yagis.

Fig 9 shows an overlay of the SWR curves across the 2-meter band for four configurations: an 8-element 2-meter Yagi by itself, and then over a 5-element 6-meter Yagi with spacings between the booms of 1, 2, 4 and 6 feet. The SWR curves are similar—it would be difficult to see any difference between these configurations using typical amateur SWR indicators for anything but the very closest (1-foot) spacing. For example, the SWR curve for the 2-foot spacing case is virtually indistinguishable from that of the Yagi by itself, while the forward gain has dropped more than 0.6 dB because of interactions with the 6-meter Yagi below it.

Gain and Pattern Degradation Due to Stacking

Fig 10 shows four overlaid rectangular plots of the azimuth response from 0° to 180° for the 8-element 2-meter Yagi described above, spaced 1, 2, 4 and 6 feet over a 5-element 6-meter beam. The rectangular presentation gives more detail than a polar plot. The most closely spaced configuration (with 1-foot spacing between the booms) shows the largest degradation in the forward gain, a drop of 1.7 dB. The worst-case front-to-rear ratio for the 6-foot spacing is 29.0 dB, while it is 36.4 dB for the 1-foot spacing—actually better than the F/R for the 8-element 2-meter Yagi by itself. Performance change due to the nearby presence of other Yagis can be enormously complicated (and sometimes is non-intuitive as well).

What happens when a different kind of 6-meter Yagi is mounted below the 8-element 2-meter Yagi? **Fig 11** compares the change in forward gain and the worst-case F/R performance as a function of spacing between the booms for two varieties of 6-meter Yagis: the 5-element design on a 12-foot boom and a 7-element Yagi on a

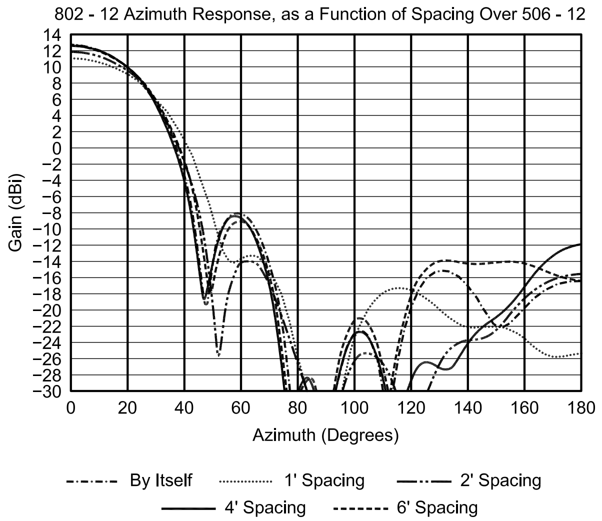

Fig 10—Plots of the 8-element 2-meter Yagi's azimuth response from 0° to 180° for spacing distances from 1 to 6 feet. The sidelobe at about 60° varies about 6 dB over the range of boom spacings, while the shape of worst-case F/R curve varies considerably due to interactions with the lower 6-meter beam. The gain for the 1-foot spacing is degraded by more than 3 dB compared to the 2-meter antenna by itself.

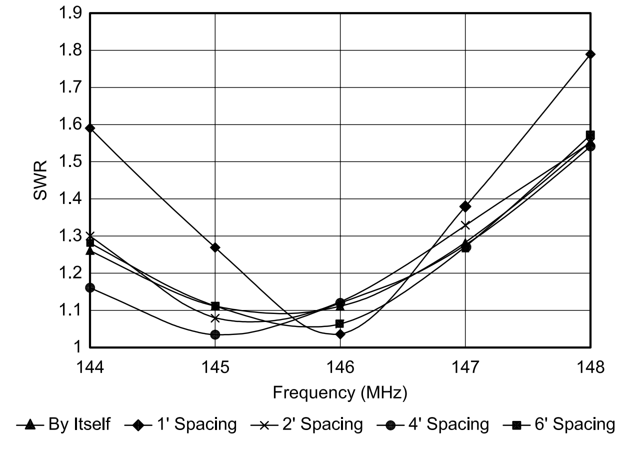

Fig 9—SWR curves for different boom spacing between 8-element 2-meter Yagi on 12-foot boom, over a 5-element 6-meter Yagi on a 12-foot boom. For spacings greater than 1 foot between the booms, differences between the SWR curves are difficult to discern.

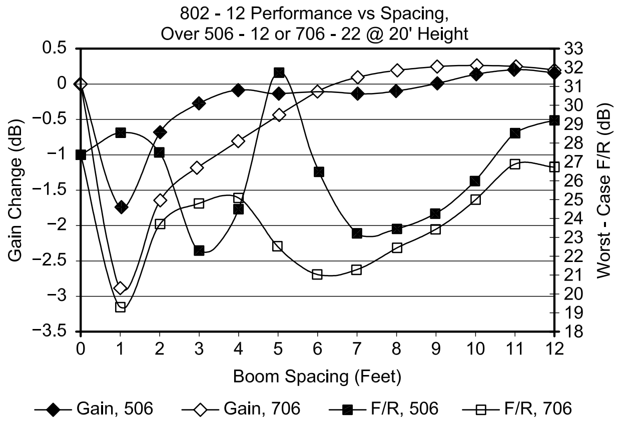

Fig 11—Plot of 8-element 2-meter Yagi's gain and worst-case F/R as a function of distance over two types of 6-meter beams, one on a 12-foot boom and the other on a 22-foot boom. Beyond a spacing of about 5 feet the performance is degraded a minimal amount.

22-foot boom. The spacing of "0 feet" represents the 8-element 2-meter Yagi when it is used alone, with no other antenna nearby. This sets the reference expectations for gain and F/R.

The most severe degradation occurs for the 1-foot spacing, as you might imagine, for both the 12 and 22-foot boom lengths. Over the 5-element 6-meter Yagi, the 2-meter gain doesn't recover to the reference level of the 8-element 2-meter beam by itself until the spacing is greater than 9 feet. However, the gain is within 0.25 dB of the reference level for spacings of 3 feet or more. Interestingly, the F/R is higher than that of the 2-meter antenna by itself for the 1, 2 and 5-foot spacings and for spacings greater than 11 feet. The 2-meter F/R in the presence of the 12-foot 5-element 6-meter Yagi remains above 20 dB for spacings beyond 1 feet.

Overall, the 2-meter beam performs reasonably well for spacings of 3 feet or more over the 5-element 6-meter Yagi. Put another way, the 2-meter beam's performance is degraded only slightly for boom spacings greater than 3 feet. A spacing of 3 feet is less than the old rule of thumb that the minimum spacing between booms be greater than one-half the boomlength of the higher-frequency Yagi, which in this case is 6 feet long.

For the 7-element 6-meter Yagi, the 2-meter gain recovers to the reference level for spacings beyond 7 feet, but the F/R is degraded below the reference level for all spacings shown in Fig 11. If we use a gain reduction criterion of less than 0.25 dB and a 20-dB F/R level as the minimum acceptable level, then the spacing must be 5 feet or more over the larger 6-meter Yagi. Again, this is less than the rule of thumb that the minimum spacing between booms be greater than one-half the boomlength of the higher-frequency Yagi.

Now, let's try a smaller setup of 2- and 6-meter Yagis stacked vertically in a Christmas-tree configuration to see if the rule of thumb for spacing the booms still holds. **Fig 12** shows the performance curves versus boom spacing for a 5-element 2-meter Yagi on a 4-foot boom stacked over a 3-element 6-meter Yagi on a 6-foot boom. Again, the 1-foot spacing produces a substantial gain reduction of about 1.3 dB compared to the reference gain when the 2-meter Yagi is used by itself. Beyond a boom spacing of 3 feet the 2-meter gain drops less than 0.25 dB from the reference level of the 2-meter Yagi by itself and the F/R remains above about 20 dB. In this example, the simple rule of thumb that the minimum spacing between booms be greater than half the boom length (half of 4 feet) of the higher-frequency Yagi does not hold up. However, the same minimum spacing of 3 feet we found for the larger 2-meter Yagi remains true. Three feet spacing is almost 0.5 λ between the booms at the higher frequency.

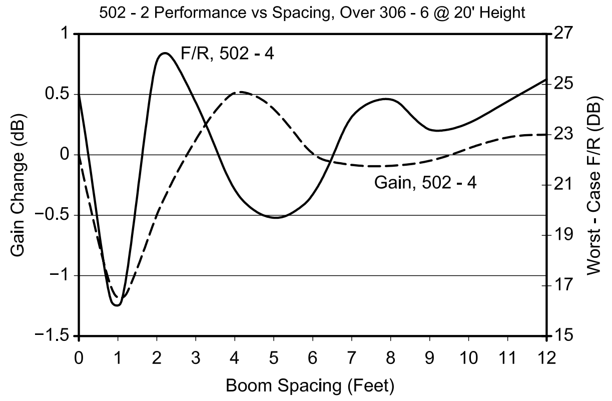

Fig 12— Plot of gain and worst-case F/R of a 5-element 2-meter Yagi on a 4-foot boom as a function of distance over a 3-element 6-meter beam on a 6-foot boom. Beyond a spacing of about 3 feet the performance is degraded a minimal amount.

Adding a 70-cm Yagi to the Christmas Tree

Let's get more ambitious and set up a larger VHF/UHF Christmas tree, with a 14-element 70-cm Yagi on a 9-foot boom at the top, mounted 5 feet over an 8-element 2-meter Yagi on a 12-foot boom. At the bottom of the stack (at the top of the tower) is either the 5-element 6-meter beam on a 12-foot boom, or a 7-element 6-meter beam on a 22-foot boom. See Fig 8C. As before, we will vary the spacing between the 70-cm Yagi and the 2-meter Yagi below it to assess the interactions that degrade the 70-cm performance.

Fig 13 compares the change in gain and F/R curves as a function of boom spacings between the 70-cm and 2-meter Yagis for the two different 6-meter Yagis (with a fixed distance of 5 feet between the 2-meter and 6-meter Yagis). In this example, the 70-cm Yagi was designed to be an intrinsic 50-Ω feed, where the F/R has been compromised to some extent. Still, the F/R is greater than 20 dB when the 70-cm Yagi is used by itself.

For spacings greater than 4 feet between the 70-cm and 2-meter booms, the 70-cm gain is equal to or even slightly greater than that of the 70-cm antenna by itself. The increase of gain indicates that the elevation pattern of the 70-cm antenna is slightly compressed by the presence of the other Yagis below it. The F/R stays above at 19.5 dB for spacings greater than or equal to 4 feet. This falls just below our desired lower limit of 20 dB, but it is highly doubtful that anyone would notice this 0.5-dB drop in actual operation. A spacing of 4 feet between booms falls under the rule of thumb that the minimum spacing be at least half the boomlength of the higher-frequency Yagi, which in this case is 9 feet.

What should be obvious in this discussion is that you should model the exact configuration you plan to build to avoid unnecessary performance degradation.

Stacking Same-Frequency Yagis

This subject has been examined in some detail in Chapter 11, HF Yagi Arrays. The same basic principles

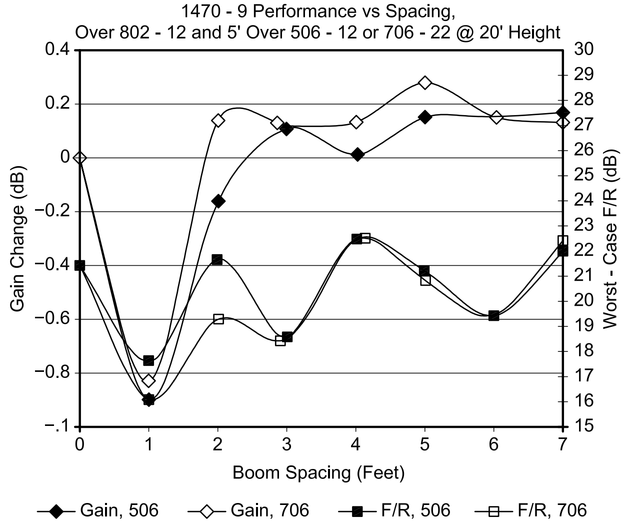

Fig 13—Performance of a 14-element 70-cm Yagi on a 9-foot boom, mounted a variable distance over an 8-element 2-meter Yagi on a 12-foot boom, which is mounted 5 feet above either a 5-element 6-meter Yagi on a 12-foot boom or a 7-element 6-meter Yagi on a 22-foot boom. Beyond a spacing of about 4 feet, the performance of the 70-cm beam is degraded a minimal amount.

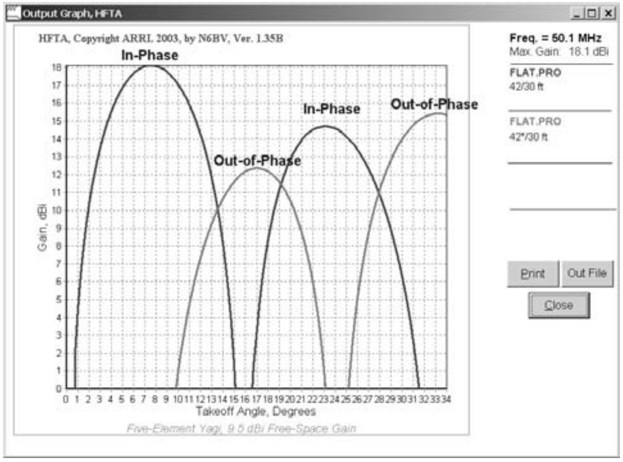

Fig 14—*HFTA* comparison plots of the elevation responses for two 5-element 6-meter Yagis mounted at 42 and 30 feet above flat ground, when they are fed in-phase and out-of-phase. By switching the phasing (adding a half-wavelength of coax to one of the antennas), the elevation angle can be controlled to enhance performance when a Sporadic-E cloud is nearly overhead.

hold at VHF and UHF as they do on HF. That is, the gain increases gradually with increasing spacing between the booms, and then falls off gradually past a certain spacing distance.

At HF, Chapter 11 emphasizes that you should avoid nulls in the antenna's elevation response—so that you can cover all the angles needed for geographic areas of interest. At VHF/UHF, propagation is usually at low elevation angles for most propagation modes, and signals are often extremely weak. Thus, achieving maximum gain is the most common design objective for a VHF/UHF stack. Of secondary importance is the cleanliness of the beam pattern, to discriminate against interference and noise sources.

Six-meter Sporadic-E can sometimes occur at high elevation angles, especially if the E_S cloud is overhead, or nearly overhead. Since Sporadic-E is exactly that, *sporadic*, it's not a good design practice to try to cover a wide range of elevation angles, as you must often do at HF to cover large geographic areas. On 6 meters, you can change to high-angle coverage when necessary. For example, you might switch to a separate Yagi mounted at a low height, or you might provide means to feed stacked antennas out-of-phase. **Fig 14** shows an *HFTA* (HF Terrain Assessment) plot of two 5-element 6-meter Yagis, fed either in-phase or out-of-phase to cover a much wider range of elevation angles than the in-phase stack alone.

Fig 15A shows the change in gain for four 2-meter stacked designs, as a function of the spacing in wavelengths between the booms. The 3-element Yagi is mounted on a 2-foot boom (occupying 0.28 λ of that boom). The 5-element Yagi is on a 4-foot boom (0.51 λ of the boom), while the 8-element Yagi is on a 12-foot boom (1.72 λ of boom). The biggest antenna in the group has 16 elements, on a 27-foot boom (4.0 λ of boom). This range of boom lengths pretty much covers the practical range of antennas used by hams.

The stack of two 3-element Yagis peaks at 3.2 dB of additional gain over a single Yagi for 0.75 λ spacing between the booms. Further increases in spacing see the gain change gradually drop off. Fig 15B shows the worst-case F/R of the four stacks, again as a function of boom length. The F/R of a single 3-element Yagi is just over 24 dB, but in the presence of the second 3-element Yagi in the stack, the F/R of the pair oscillates between 15 to 26 dB, finally remaining consistently over the desired 20-dB level for spacings greater than about 1.7 λ, where the gain has fallen about 0.6 dB from the peak possible gain. A boom spacing of 1.7 λ at 146 MHz is 11.5 feet. Thus you must compromise in choosing the boom spacing between achieving maximum gain and the best pattern.

The increase in gain of the stack of two 5-element Yagis peaks at a spacing of about 1 λ (6.7 feet), where the F/R is an excellent 25 dB. Having more elements on a particular length of boom aids in holding a more consistent F/R in the presence of the second antenna.

The gain increase for the bigger stack of 8-element Yagis peaks at a spacing of about 1.5 λ (10.1 feet), where the F/R is more than 27 dB. The 16-element Yagi's gain

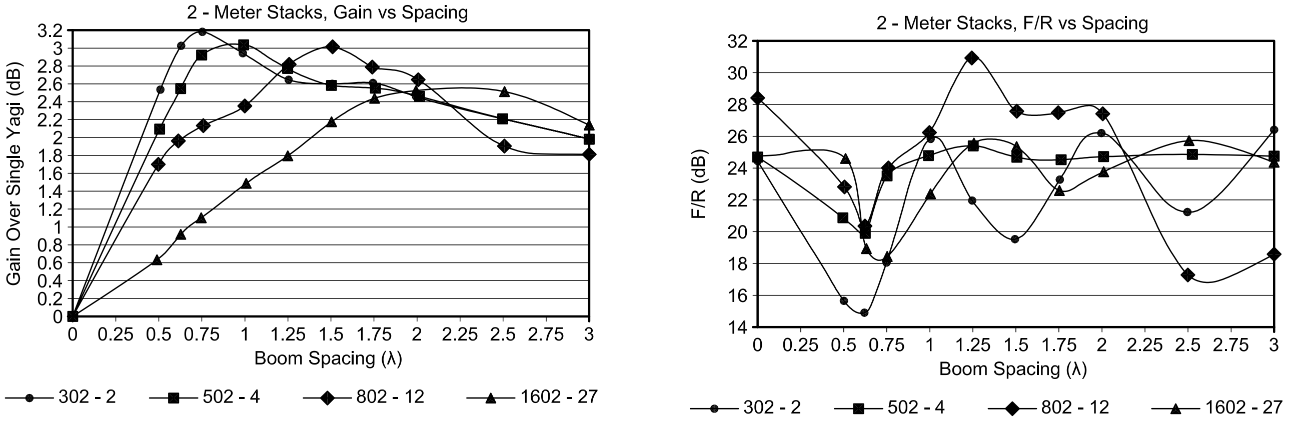

Fig 15—Performance of two different 2-meter Yagis (5-elements on 4-foot boom and 8-elements on 12-foot boom) fed in-phase, as a function of spacing between the booms. Note that the distance is measured in wavelengths.

increase is 2.6 dB for a spacing of about 2.25 λ (15.2 feet), where the F/R remains close to 25 dB. The stacking distance of 15.2 feet for an antenna with a 27-foot long boom may be a real challenge physically, requiring a very sturdy rotating mast to withstand wind pressures without bending.

These examples show that the exact spacing between booms is not overly critical, since the gain varies relatively slowly around the peak. Fig 15A shows that the boom spacing needed to achieve peak gain from a stack increases when higher-gain (longer-boom) individual antennas are used in that stack. It also shows that the increase in maximum gain from stacking decreases for long-boom antennas. Fig 15B shows that beyond boom spacings of about 1 λ, the F/R pattern holds well for Yagi designs with booms longer than about 0.5 λ, which is about 4 feet at 146 MHz.

The plots in Fig 15 are representative of typical modern Yagis. You could simply implement these designs as is, and you'll achieve good results. However, we recommend that you model any specific stack you design, just to make sure. Since the boom spacings are displayed in terms of wavelength, you can extend the results for 2 meters to other bands, provided that you use properly scaled Yagi designs to the other bands too.

You can even tweak the element dimensions and spacings of each Yagi used in a stack to optimize the rearward pattern for a particular stacking distance. This strategy can work out well at VHF/UHF, where stacks are often configured for best gain (and pattern) and are "hard-wired" with fixed lengths of feed lines permanently junctioned together.

This is in contrast to the situation at HF (and even on 6 meters). The HF operator usually wants flexibility to select individual Yagis (or combinations of Yagis) from the stack, to match the array's takeoff angle with ionospheric propagation conditions. See Chapter 11, HF Yagi Arrays. The designer of a flexible HF stack thus usually doesn't try to redo the element lengths and spacings of the Yagis to optimize a particular stack.

Stacking Stacks of Different-Frequency Yagis

The investment in a tower is usually substantial, and most hams want to put as many antennas as possible on a tower, provided that interaction between the antennas can be held to a reasonable level. Really ambitious weak-signal VHF/UHF enthusiasts may want "stacked stacks"—sets of stacked Yagis that cover different bands. For example, a VHF contester might want a stack of two 8-element 2-meter Yagis mounted on the same rotating mast as a stack of two 5-element 6-meter Yagis. Let's assume that the boom length of the 8-element 2-meter Yagis is 12 feet (1.78 λ). We'll assume a boom length of 12 feet (0.61 λ) for the 5-element 6-meter Yagis.

From Fig 15, we find the stacking distance between the 8-element 2-meter beams for peak gain and good pattern is 1.5 λ, or 10 feet, but adequate performance can be had for a boom spacing of 0.75 λ, which is 5 feet on 2 meters.

The boom spacing for two 5-element 6-meter beams is 1 λ for peak stacking gain, but a compromise of 0.625 λ (12 feet) still yields an acceptable gain increase of 2 dB over a single Yagi. The overall height of the rotating mast sticking out of the top of the tower is thus set by the 0.625 λ stacking distance on 6 meters, at 12 feet. In-between the 6-meter Yagis at the bottom and top of the rotating mast we will mount the 2-meter Yagi stack. With only 12 feet available on the mast, the spacing for symmetric placement of the two 2-meter Yagis in-between the 6-meter Yagis dictates a distance of only 4 feet between the 2-meter beams. This is less than optimal.

The performance of the 2-meter stack in this "stack within a stack" is affected by the close spacing, but the interactions are not disastrous. The stacking gain is 1.62 dB more than the gain for a single 8-element 2-meter Yagi and the F/R remains above 20 dB across the 2-meter band.

On 6 meters, the stacking gain for two 5-element 6-meter Yagis spaced 12 feet apart is 2.2 dB more than the gain of a single Yagi, while the F/R pattern remains about 20 dB over the weak-signal portion of the 6-meter band. As described in Chapter 11, HF Yagi Arrays, stacking gives more advantages than merely a gain increase, and 6-meter propagation does require coverage of a range of elevation angles because much of the time ionospheric modes are involved.

Increasing the length of the rotating mast to 18 feet sticking out of the top of the tower will increase performance, particularly on 2 meters. The stacking gain on 6 meters will increase to 2.3 dB while the F/R decreases to 18.5 dB, modest changes both. The 18-foot mast allows the 2-meter Yagis to be spaced 6 feet from each other and 6 feet away from both top and bottom 6-meter antennas. The stacking gain goes to 2.14 dB and the F/R approaches 27 dB in the weak-signal portion of the 2-meter band.

Whether the modest increase in stacking gain is worth the cost and mechanical complexity of stacking two 2-meter Yagis in-between a stack of 6-meter Yagis is a choice left to the operator. Certainly the cost and weight of a rotating mast that is 20 feet long (18 feet out of the top of the tower and 2 feet down inside the tower), a mast that must be sturdy enough to support the antennas in high winds without bending, should give pause to even the most enthusiastic 6-meter weak-signal operator.

QUADS FOR VHF

The quad antenna can be built with inexpensive materials, yet its performance is comparable to other arrays of its size. Adjustment for resonance and impedance matching can be accomplished readily. Quads can be stacked horizontally and vertically to provide high gain, without sharply limiting frequency response. Construction of quad antennas for VHF use is covered later in this chapter.

Stacking Quads

Quads can be mounted side by side or one above the other, or both, in the same general way as other beam antennas. Sets of driven elements can also be mounted in front of a screen reflector. The recommended spacing between adjacent element sides is $^1/_2$ λ. Phasing and feed methods are similar to those employed with other antennas described in this chapter.

Adding Quad Directors

Parasitic elements ahead of the driven element work in a manner similar to those in a Yagi array. Closed loops can be used for directors by making them 5% shorter than the driven element. Spacings are similar to those for conventional Yagis. In an experimental model the reflector was spaced 0.25 λ and the director 0.15 λ. A square array using four 3element bays worked extremely well.

VHF AND UHF QUAGIS

At higher frequencies, especially 420 MHz and above, Yagi arrays using dipole-driven elements can be difficult to feed and match, unless special care is taken to keep the feed-point impedance relatively high by proper element spacing and tuning. The cubical quad described earlier overcomes the feed problems to some extent. When many parasitic elements are used, however, the loops are not nearly as convenient to assemble and tune as are straight cylindrical ones used in conventional Yagis. The *Quagi*, designed and popularized by Wayne Overbeck, N6NB, is an antenna having a full-wave loop driven element and reflector, and Yagi type straight rod directors. Construction details and examples are given in the projects later in this chapter.

COLLINEAR ANTENNAS

The information given earlier in this chapter pertains mainly to parasitic arrays, but the collinear array is worthy of consideration in VHF/UHF operations. This array tends to be tolerant of construction tolerances, making it easy to build and adjust for VHF applications. The use of many collinear driven elements was once popular in very large phased arrays, such as those required in moonbounce (EME) communications, but the advent of computer-optimized Yagis has changed this.

Large Collinear Arrays

Bidirectional curtain arrays of four, six, and eight half waves in phase are shown in **Fig 16**. Usually reflector elements are added, normally at about 0.2 λ behind each driven element, for more gain and a unidirectional pattern. Such parasitic elements are omitted from the sketch in the interest of clarity.

The feed-point impedance of two half waves in phase is high, typically 1000 Ω or more. When they are combined in parallel and parasitic elements are added, the feed impedance is low enough for direct connection to open wire line or twin-lead, connected at the points indicated by black dots. With coaxial line and a balun, it is suggested that the universal stub match, Fig 4A, be used at the feed point. All elements should be mounted at their electrical centers, as indicated by open circles in Fig 16. The framework can be metal or insulating material. The metal supporting structure is entirely behind the plane of the reflector elements. Sheet-metal clamps can be cut from scraps of aluminum for this kind of assembly. Collinear elements of this type should be mounted at their centers (where the RF voltage is zero), rather than at their ends, where the voltage is high and insulation losses and detuning can be harmful.

Collinear arrays of 32, 48, 64 and even 128 elements can give outstanding performance. Any collinear array should be fed at the center of the system, to ensure balanced current distribution. This is very important in large arrays, where sets of six or eight driven elements are treated as "sub arrays," and are fed through a balanced harness. The sections of the harness are resonant lengths, usually of open wire line. The 48-element collinear array for 432 MHz in **Fig 17** illustrates this principle.

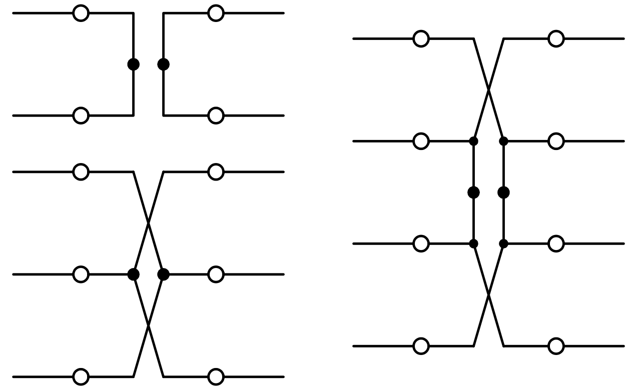

Fig 16—Element arrangements for 8-, 12- and 16-element collinear arrays. Elements are ½ λ long and spaced ½ λ. Parasitic reflectors, omitted here for clarity, are 5% longer and 0.2 λ behind the driven elements. Feed points are indicated by black dots. Open circles show recommended support points. The elements can run through wood or metal booms, without insulation, if supported at their centers in this way. Insulators at the element ends (points of high RF voltage) detune and unbalance the system.

A reflecting plane, which may be sheet metal, wire mesh, or even closely spaced elements of tubing or wire, can be used in place of parasitic reflectors. To be effective, the plane reflector must extend on all sides to at least $^1/_4$ λ beyond the area occupied by the driven elements. The plane reflector provides high F/B ratio, a clean pattern, and somewhat more gain than parasitic elements, but large physical size limits it to use above 420 MHz. An interesting space-saving possibility lies in using a single plane reflector with elements for two different bands mounted on opposite sides. Reflector spacing from the driven element is not critical. About 0.2 λ is common.

THE CORNER REFLECTOR

When a single driven element is used, the reflector screen may be bent to form an angle, giving an improvement in the radiation pattern and gain. At 222 and 420 MHz its size assumes practical proportions, and at 902 MHz and higher, practical reflectors can approach ideal dimensions (very large in terms of wavelengths), resulting in more gain and sharper patterns. The corner reflector can be used at 144 MHz, though usually at much less than optimum size. For a given aperture, the corner reflector does not equal a parabola in gain, but it is simple to construct, broadbanded, and offers gains from about 9 to 14 dBi, depending on the angle and size. This section was written by Paul M. Wilson, W4HHK.

The corner angle can be 90, 60 or 45°, but the side length must be increased as the angle is narrowed. For a 90° corner, the driven element spacing can be anything from 0.25 to 0.7 λ, 0.35 to 0.75 λ for 60°, and 0.5 to

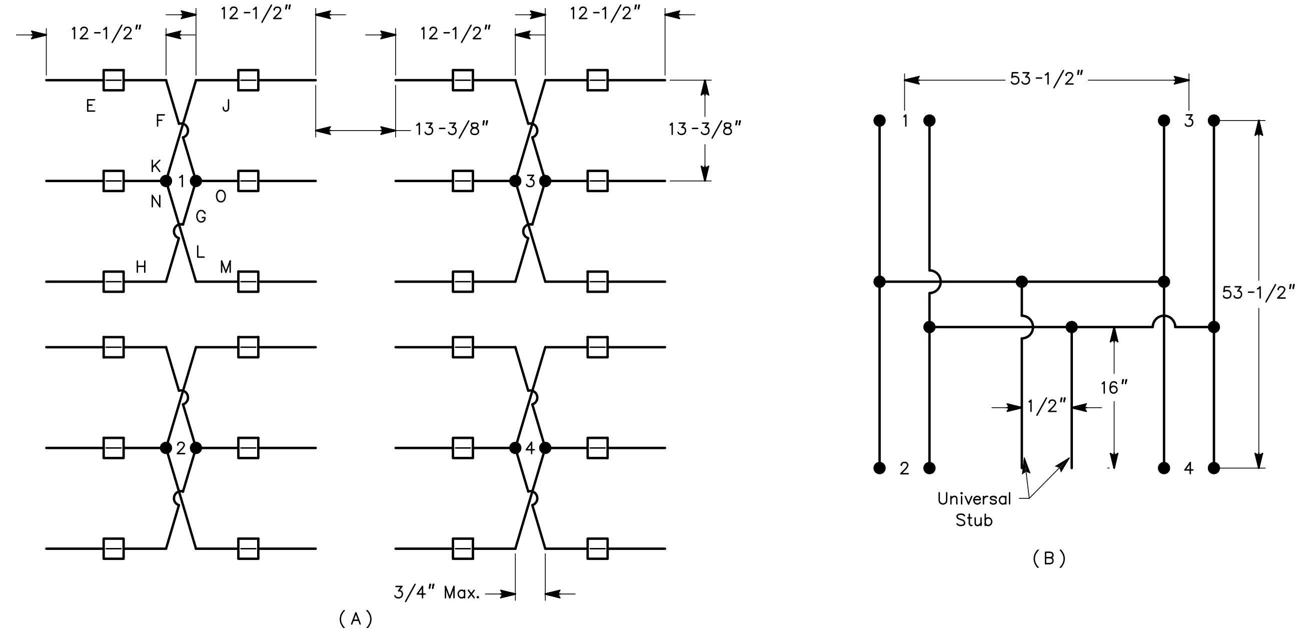

Fig 17—Large collinear arrays should be fed as sets of no more than eight driven elements each, interconnected by phasing lines. This 48-element array for 432 MHz (A) is treated as if it were four 12-element collinear antennas. Reflector elements are omitted for clarity. The phasing harness is shown at B. Squares represent insulators.

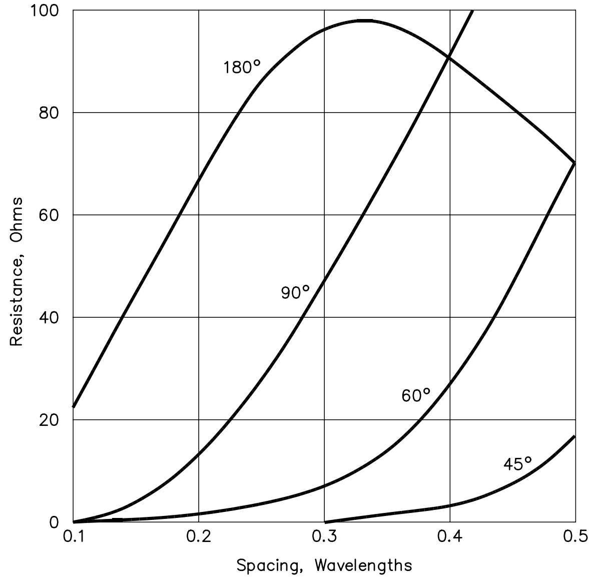

Fig 18—Radiation resistance of the driven element in a corner reflector array for corner angles of 180° (flat sheet), 90°, 60° and 45° as a function of spacing D, as shown in Fig 19.

0.8 λ for 45°. In each case the gain variation over the range of spacings given is about 1.5 dB. Because the spacing is not very critical to gain, it may be varied for impedance-matching purposes. Closer spacings yield lower feed-point impedances, but a folded dipole radiator could be used to raise this to a more convenient level.

Radiation resistance is shown as a function of spacing in **Fig 18**. The maximum gain obtained with minimum spacing is the primary mode (the one generally used at 144, 222 and 432 MHz to maintain reasonable side lengths). A 90° corner, for example, should have a minimum side length (S, **Fig 19**) equal to twice the dipole spacing, or 1 λ long for 0.5-λ spacing. A side length greater than 2 λ is ideal. Gain with a 60° or 90° corner reflector with 1-λ sides is about 10 dB. A 60° corner with 2-λ sides has about 13 dBi gain, and a 45° corner with 3-λ sides has about 14 dBi gain.

Reflector length (L, Fig 19) should be a minimum of 0.6 λ. Less than that spacing causes radiation to increase to the sides and rear, and decreases gain.

Spacing between reflector rods (G, Fig 19) should not exceed 0.06 λ for best results. A spacing of 0.06 λ results in a rear lobe that is about 6% of the forward lobe

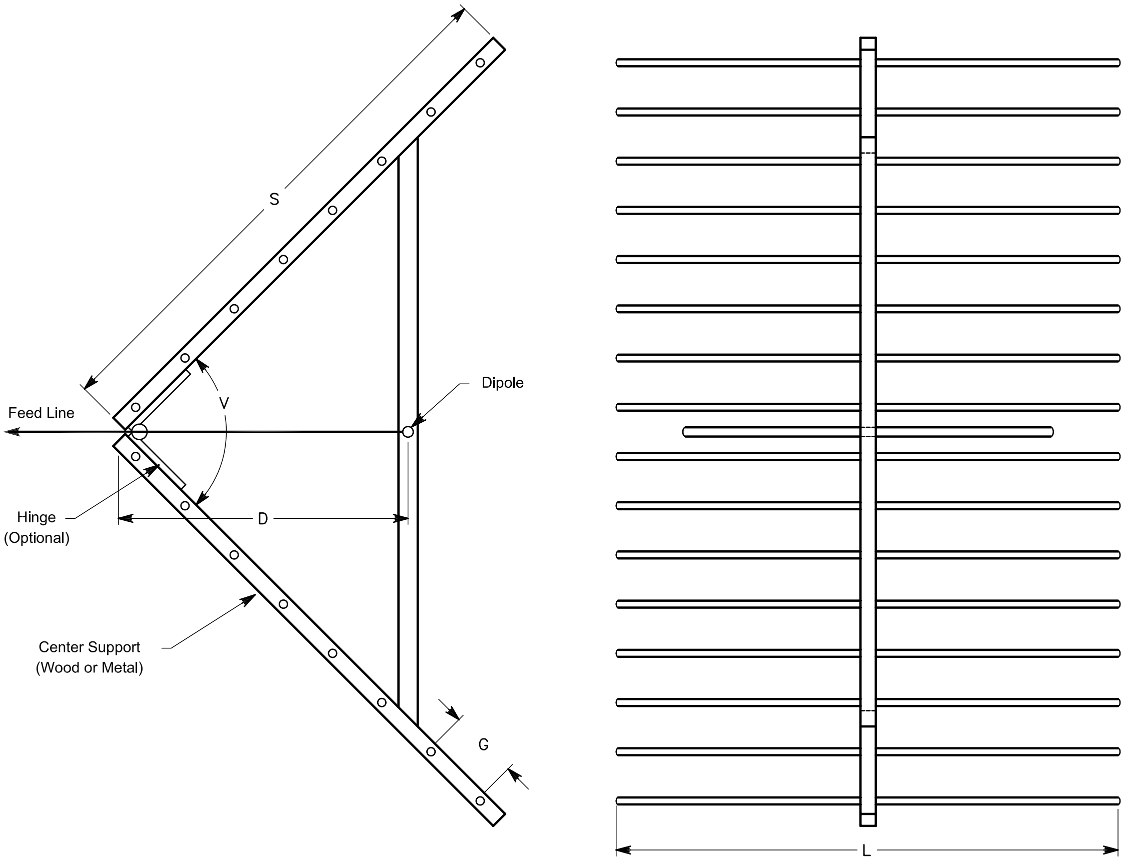

Fig 19—Construction of a corner reflector array. The frame can be wood or metal. Reflector elements are stiff wire or tubing. Dimensions for several bands are given in Table 2. Reflector element spacing, G, is the maximum that should be used for the frequency; closer spacings are optional. The hinge permits folding for portable use.

(down 12 dB). A small mesh screen or solid sheet is preferable at the higher frequencies to obtain maximum efficiency and highest F/B ratio, and to simplify construction. A spacing of 0.06 λ at 1296 MHz, for example, requires mounting reflector rods about every $^1/_2$ inch along the sides. Rods or spines may be used to reduce wind loading. The support used for mounting the reflector rods may be of insulating or conductive material. Rods or mesh weave should be parallel to the radiator.

A suggested arrangement for a corner reflector is shown in Fig 19. The frame may be made of wood or metal, with a hinge at the corner to facilitate portable work or assembly atop a tower. A hinged corner is also useful in experimenting with different angles. **Table 2** gives the principal dimensions for corner reflector arrays for 144 to 2300 MHz. The arrays for 144, 222 and 420 MHz have side lengths of twice to four times the driven element spacing. The 915 MHz corner reflectors use side lengths of three times the element spacing, 1296 MHz corners use side lengths of four times the spacing, and 2304 MHz corners employ side lengths of six times the spacing. Reflector lengths of 2, 3, and 4 wavelengths are used on the 915, 1296 and 2304 MHz reflectors, respectively. A 4 × 6 λ reflector closely approximates a sheet of infinite dimensions.

A corner reflector may be used for several bands, or for UHF television reception, as well as amateur UHF work. For operation on more than one frequency, side length and reflector length should be selected for the lowest frequency, and reflector spacing for the highest frequency. The type of driven element plays a part in determining bandwidth, as does the spacing to the corner. A fat cylindrical element (small λ/dia ratio) or triangular dipole (bow tie) gives more bandwidth than a thin driven element. Wider spacings between driven element and corner give greater bandwidths. A small increase in gain can be obtained for any corner reflector by mounting collinear elements in a reflector of sufficient size, but

Table 2
Dimensions of Corner Reflector Arrays for VHF and UHF

Freq, MHz	*Side Length S, in.*	*Dipole to Vertex D, in.*	*Reflector Length L, in.*	*Reflector Spacing G, in.*	*Corner Angle, Vo*	*Radiation Resistance, Ω*
144*	65	27½	48	7¾	90	70
144	80	40	48	4	90	150
222*	42	18	30	5	90	70
222	52	25	30	3	90	150
222	100	25	30	Screen	60	70
420	27	8¾	16¼	$2^5/_8$	90	70
420	54	13½	16¼	Screen	60	70
915	20	6½	25¾	0.65	90	70
915	51	16¾	25¾	Screen	60	65
915	78	25¾	25¾	Screen	45	70
1296	18	4½	27½	½	90	70
1296	48	11¾	27½	Screen	60	65
1296	72	18¼	27½	Screen	45	70
2304	15½	2½	20½	¼	90	70
2304	40	6¾	20½	Screen	60	65
2304	61	10¼	20½	Screen	45	70

*Side length and number of reflector elements somewhat below optimum—slight reduction in gain.

Notes:

915 MHz
Wavelength is 12.9 in.
Side length S is 3 × D, dipole to vertex distance
Reflector length L is 2.0 λ
Reflector spacing G is 0.05 λ

1296 MHz
Wavelength is 9.11 in.
Side length S is 4 × D, dipole to vertex distance
Reflector length L is 3.0 λ
Reflector spacing G is 0.05 λ

2304 MHz
Wavelength is 5.12 in.
Side length S is 6 × D, dipole to vertex distance
Reflector length L is 4.0 λ
Reflector spacing G is 0.05 λ

the simple feed of a dipole is lost if more than two elements are used.

A dipole radiator is usually employed with a corner reflector. This requires a balun between the coaxial line and the balanced feed-point impedance of the antenna. Baluns are easily constructed of coaxial line on the lower VHF bands, but become more difficult at the higher frequencies. This problem may be overcome by using a ground-plane corner reflector, which can be used for vertical polarization. A ground-plane corner with monopole driven element is shown in **Fig 20**. The corner reflector and a $^{1}/_{4}$ λ radiator are mounted on the ground plane, permitting direct connection to a coaxial line if the proper spacing is used. The effective aperture is reduced, but at the higher frequencies, second- or third-mode radiator spacing and larger reflectors can be employed to obtain more gain and offset the loss in effective aperture. A J antenna could be used to maintain the aperture area and provide a match to a coaxial line.

For vertical polarization work, four 90° corner reflectors built back-to-back (with common reflectors) could be used for scanning 360° of horizon with modest gain. Feed-line switching could be used to select the desired sector.

TROUGH REFLECTORS

To reduce the overall dimensions of a large corner reflector the vertex can be cut off and replaced with a plane reflector. Such an arrangement is known as a *trough reflector*. See **Fig 21**. Performance similar to that of the large corner reflector can thereby be had, provided that the dimensions of S and T as shown in Fig 21 do not exceed the limits indicated in the figure. This antenna provides performance very similar to the corner reflector, and presents fewer mechanical problems because the plane center portion is relatively easy to mount on the mast. The sides are considerably shorter, as well.

The gain of both corner reflectors and trough reflectors may be increased by stacking two or more and arranging them to radiate in phase, or alternatively by

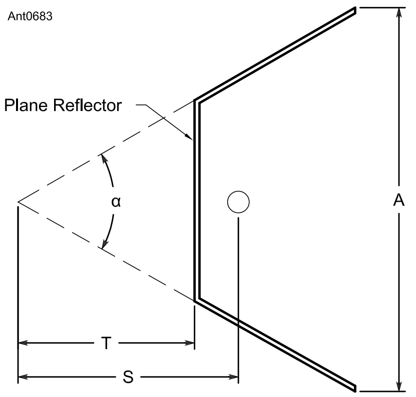

Angle *α*	*Value of S for maximum gain*	*Gain*	*Value of T*
90°	1.5 λ	13.5 dB	1λ - 1.25 λ
60°	1.75 λ	15 dB	1.0 λ
45°	2.0 λ	16 dB	1.9 λ

Fig 21—The trough reflector. This is a useful modification of the corner reflector. The vertex has been cut off and replaced by a simple plane section. The tabulated data shows the gain obtainable for greater values of S than those covered in Table 2, assuming that the reflector is of adequate size.

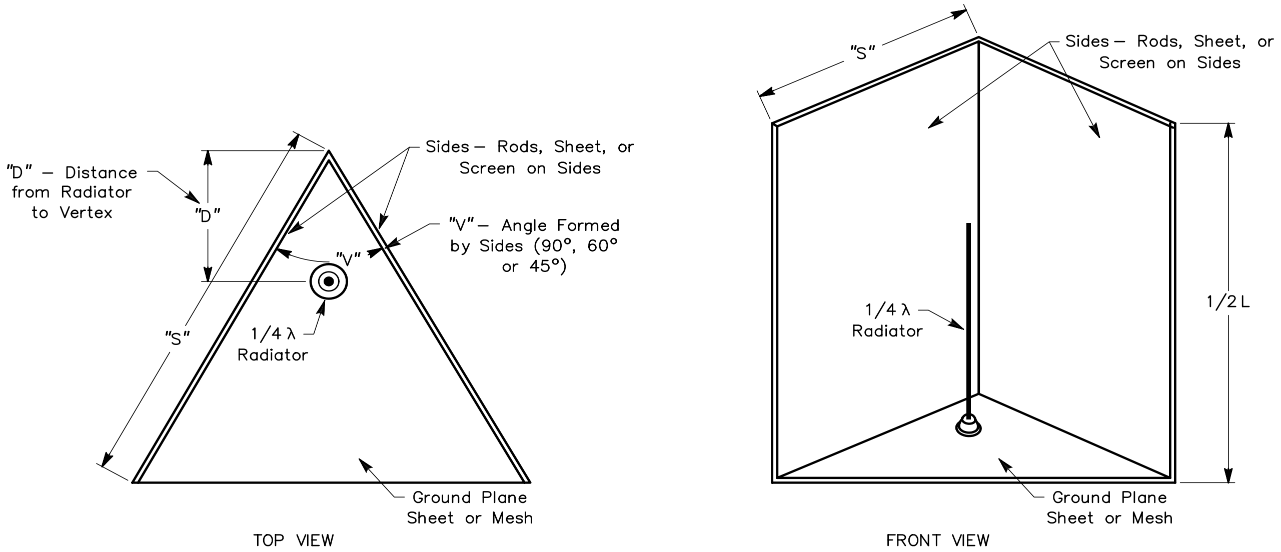
"D" — Distance from Radiator to Vertex
"D"
Sides— Rods, Sheet, or Screen on Sides
"V"— Angle Formed by Sides (90°, 60° or 45°)
"V"
"S"
1/4 λ Radiator
Ground Plane Sheet or Mesh
TOP VIEW
"S"
Sides— Rods, Sheet, or Screen on Sides
1/4 λ Radiator
1/2 L
Ground Plane Sheet or Mesh
FRONT VIEW

Fig 20—A ground-plane corner reflector antenna for vertical polarization, such as FM communications or packet radio. The dimension ½ λ in the front view refers to data in Table 2.

adding further collinear dipoles (fed in phase) within a wider reflector. Not more than two or three radiating units should be used, because the great virtue of the simple feeder arrangement would then be lost.

HORN ANTENNAS FOR THE MICROWAVE BANDS

Horn antennas were briefly introduced in the section on coupling energy into and out of waveguides. For amateur purposes, horns begin to show usable gain with practical dimensions in the 902 MHz band.

It isn't necessary to feed a horn with waveguide. If only two sides of a pyramidal horn are constructed, the antenna may be fed at the apex with a two-conductor transmission line. The impedance of this arrangement is on the order of 300 to 400 Ω. A 60° two-sided pyramidal horn with 18 inch sides is shown in **Fig 22**. This antenna has a theoretical gain of 15 dBi at 1296 MHz, although the feed system detailed in **Fig 23** probably degrades this value somewhat. A $^1/_4$ λ, 150-Ω matching section made from two parallel lengths of twin-lead connects to a bazooka balun made from RG-58 cable and a brass tube. This matching system was assembled strictly for the purpose of demonstrating the two-sided horn in a 50-Ω system. In a practical installation the horn would be fed with open-wire line and matched to 50 Ω at the station equipment.

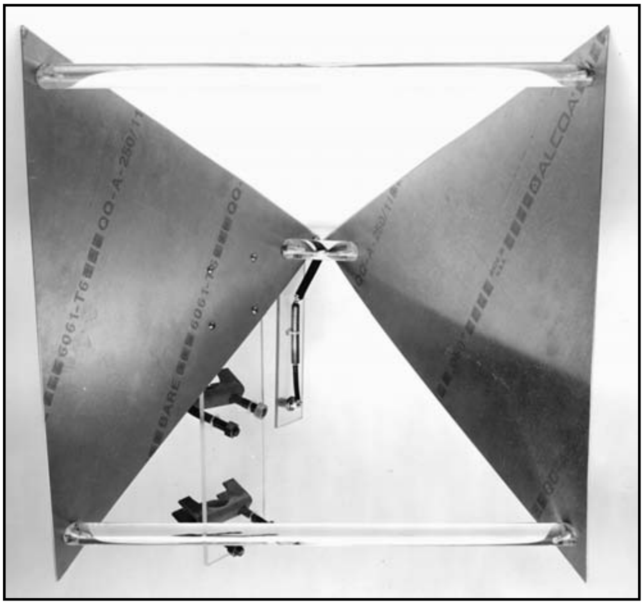

Fig 22—An experimental two-sided pyramidal horn constructed in the ARRL laboratory. A pair of muffler clamps allows mounting the antenna on a mast. This model has sheet-aluminum sides, although window screen would work as well. Temporary elements could be made from cardboard covered with aluminum foil. The horizontal spreaders are Plexiglas rod. Oriented as shown here, the antenna radiates horizontally polarized waves.

PARABOLIC ANTENNAS

When an antenna is located at the focus of a parabolic reflector (dish), it is possible to obtain considerable gain. Furthermore, the beamwidth of the radiated energy will be very narrow, provided all the energy from the driven element is directed toward the reflector. This section was written by Paul M. Wilson, W4HHK.

Gain is a function of parabolic reflector diameter, surface accuracy and proper illumination of the reflector by the feed. Gain may be found from

$$G = 10 \log k \left(\frac{\pi D}{\lambda} \right)^2 \qquad \text{(Eq 1)}$$

where

G = gain over an isotropic antenna, dBi (subtract 2.15 dB for gain over a dipole)
k = efficiency factor, usually about 55%
D = dish diameter in feet
λ = wavelength in feet

See **Table 3** for parabolic antenna gain for the bands 420 MHz through 10 GHz and diameters of 2 to 30 feet.

A close approximation of beamwidth may be found from

$$\psi = \frac{70\lambda}{D} \qquad \text{(Eq 2)}$$

where

ψ = beamwidth in degrees at half-power points (3 dB down)
D = dish diameter in feet
λ = wavelength in feet

At 420 MHz and higher, the parabolic dish becomes a practical antenna. A simple, single feed point eliminates phasing harnesses and balun requirements. Gain is dependent on good surface accuracy, which is more difficult to achieve with increasing frequency. Surface

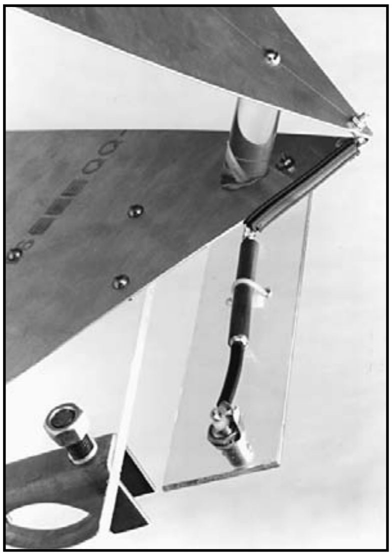

Fig 23—Matching system used to test the horn. Better performance would be realized with open wire line. See text.

Table 3
Gain, Parabolic Antennas*

	Dish Diameter (Feet)						
Frequency	*2*	*4*	*6*	*10*	*15*	*20*	*30*
420 MHz	6.0	12.0	15.5	20.0	23.5	26.0	29.5
902	12.5	18.5	22.0	26.5	30.0	32.5	36.0
1215	15.0	21.0	24.5	29.0	32.5	35.0	38.5
2300	20.5	26.5	30.0	34.5	38.0	40.5	44.0
3300	24.0	30.0	33.5	37.5	41.5	43.5	47.5
5650	28.5	34.5	38.0	42.5	46.0	48.5	52.0
10 GHz	33.5	39.5	43.0	47.5	51.0	53.5	57.0

*Gain over an isotropic antenna (subtract 2.1 dB for gain over a dipole antenna). Reflector efficiency of 55% assumed.

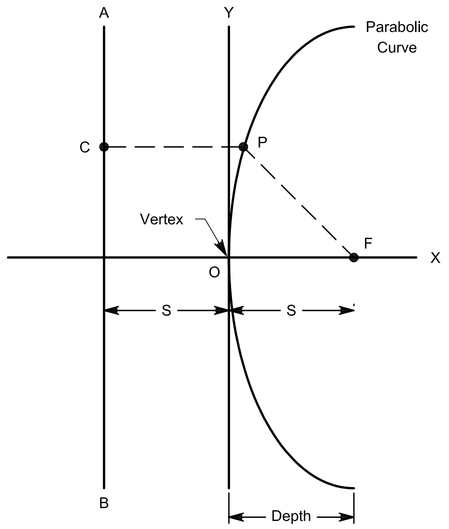

Fig 24—Details of the parabolic curve, $Y^2 = 4SX$. This curve is the locus of points that are equidistant from a fixed point, the focus (F), and a fixed line (AB) that is called the *directrix*. Hence, FP = PC. The focus (F) is located at coordinates S,0.

errors should not exceed $^{1}/_{8}\,\lambda$ in amateur work. At 430 MHz $^{1}/_{8}\,\lambda$ is 3.4 inches, but at 10 GHz it is 0.1476 inch! Mesh can be used for the reflector surface to reduce weight and wind loading, but hole size should be less than $^{1}/_{12}\,\lambda$. At 430 MHz the use of 2-inch hole diameter poultry netting (chicken wire) is acceptable. Fine mesh aluminum screening works well as high as 10 GHz.

A support form may be fashioned to provide the proper parabolic shape by plotting a curve (**Fig 24**) from

$$Y^2 = 4SX$$

as shown in the figure.

Optimum illumination occurs when power at the reflector edge is 10 dB less than that at the center. A circular waveguide feed of correct diameter and length for the frequency and correct beamwidth for the dish focal length to diameter (f/D) ratio provides optimum illumination at 902 MHz and higher. This, however, is impractical at 432 MHz, where a dipole and plane reflector are often used. An f/D ratio between 0.4 and 0.6 is considered ideal for maximum gain and simple feeds.

The focal length of a dish may be found from

$$f = \frac{D^2}{16d} \qquad \text{(Eq 3)}$$

where

f = focal length
D = diameter
d = depth distance from plane at mouth of dish to vertex (see Fig 17)

The units of focal length f are the same as those used to measure the depth and diameter. **Table 4** gives the subtended angle at focus for dish f/D ratios from 0.2 to 1.0. A dish, for example, with a typical f/D of 0.4 requires a 10-dB beamwidth of 130°. A circular waveguide feed with a diameter of approximately 0.7 λ provides nearly optimum illumination, but does not uniformly illuminate the reflector in both the magnetic (TM) and electric (TE) planes. **Fig 25** shows data for plotting radiation patterns from circular guides. The waveguide feed aperture can be modified to change the beamwidth.

One approach used successfully by some experimenters is the use of a disc at a short distance behind the aperture as shown in **Fig 26**. As the distance between the aperture and disc is changed, the TM plane patterns become alternately broader and narrower than with an unmodified aperture. A disc about 2 λ in diameter appears to be as effective as a much larger one. Some experimenters have noted a 1 to 2 dB increase in dish gain with this modified feed. Rectangular waveguide feeds can also be used, but dish illumination is not as uniform as with round guide feeds.

The circular feed can be made of copper, brass, aluminum or even tin in the form of a coffee or juice can, but the latter must be painted on the outside to prevent rust or corrosion. The circular feed must be within a proper size (diameter) range for the frequency being used.

This feed operates in the dominant circular waveguide mode known as the TE_{11} mode. The guide must be large enough to pass the TE_{11} mode with no attenuation, but smaller than the diameter that permits the next higher TM_{01} mode to propagate. To support the desirable TE_{11} mode in circular waveguide, the cutoff frequency, F_C, is given by

$$F_C\,(TE_{11}) = \frac{6917.26}{d\,(\text{inches})} \qquad \text{(Eq 4)}$$

where

F_C = cutoff frequency in MHz for TE_{11} mode
d = waveguide inner diameter

Circular waveguide will support the TM_{01} mode having a cutoff frequency

$$F_C\,(TM_{01}) = \frac{9034.85}{d\,(\text{inches})} \qquad \text{(Eq 5)}$$

The wavelength in a waveguide always exceeds the free-space wavelength and is called guide wavelength, λ_g. It is related to the cutoff frequency and operating frequency by the equation

$$\lambda_g = \frac{11802.85}{\sqrt{f_0^2 - f_C^2}} \qquad \text{(Eq 6)}$$

where

λ_g = guide wavelength, inches
f_0 = operating frequency, MHz
f_C = TE_{11} waveguide cutoff frequency, MHz

An inside diameter range of about 0.66 to 0.76 l is

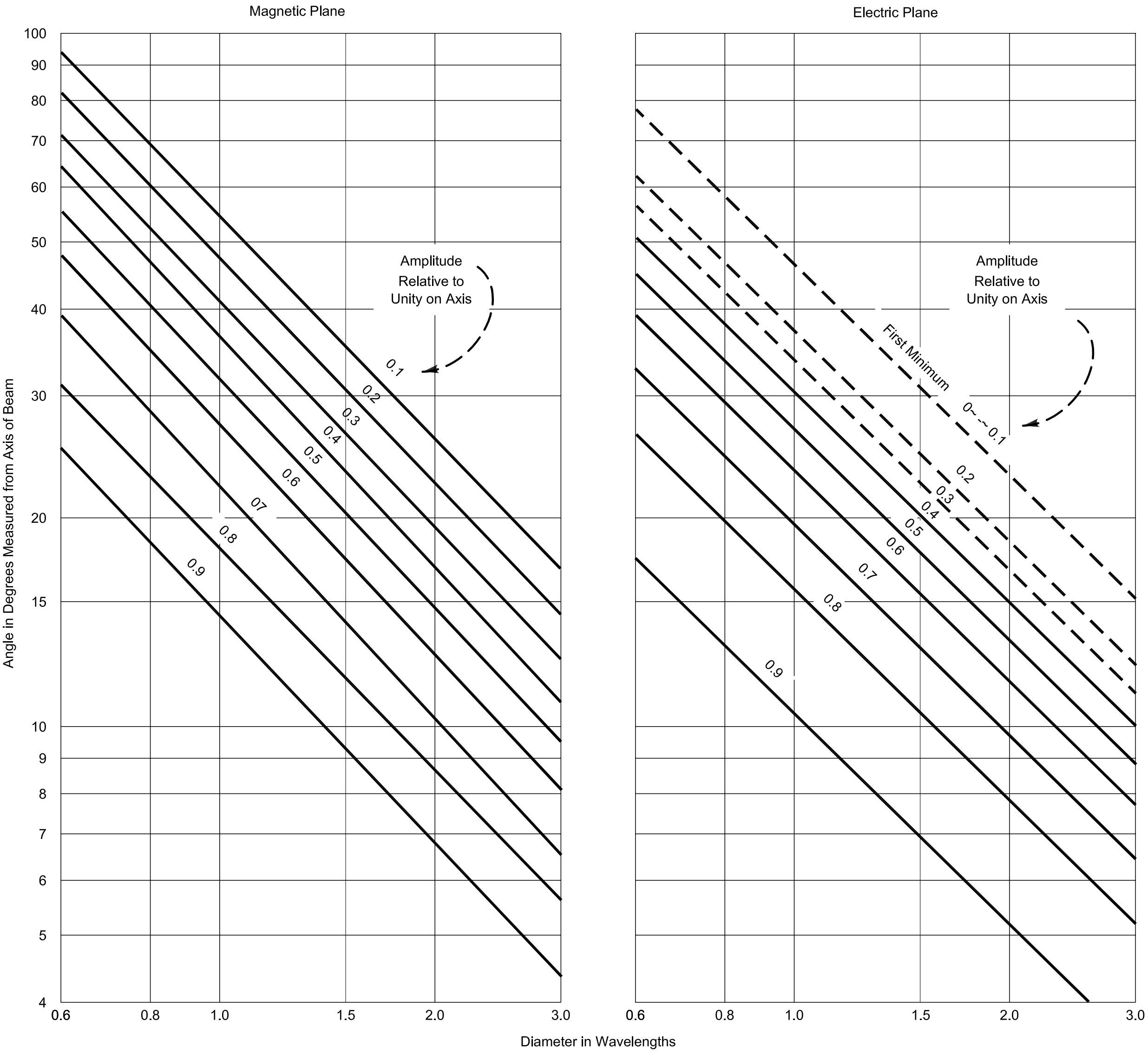

Fig 25—This graph can be used in conjunction with Table 4 for selecting the proper diameter waveguide to illuminate a parabolic reflector.

Table 4
f/D Versus Subtended Angle at Focus of a Parabolic Reflector Antenna

f/D	*Subtended Angle (Deg.)*	*f/D*	*Subtended Angle (Deg.)*
0.20	203	0.65	80
0.25	181	0.70	75
0.30	161	0.75	69
0.35	145	0.80	64
0.40	130	0.85	60
0.45	117	0.90	57
0.50	106	0.95	55
0.55	97	1.00	52
0.60	88		

Taken from graph “f/D vs Subtended Angle at Focus,” page 170 of the 1966 *Microwave Engineers’ Handbook and Buyers Guide*. Graph courtesy of K. S. Kelleher, Aero Geo Astro Corp, Alexandria, Virginia

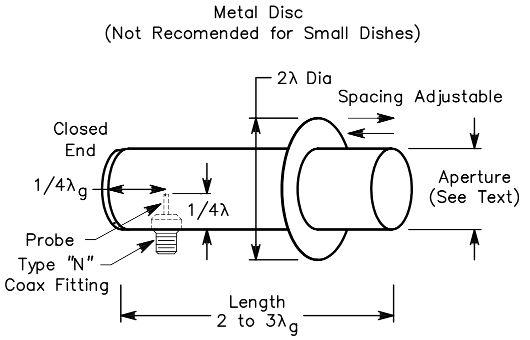

Fig 26—Details of a circular waveguide feed.

Table 5
Circular Waveguide Dish Feeds

Freq. (MHz)	*Inside Diameter Circular Waveguide Range (in.)*
915	8.52-9.84
1296	6.02-6.94
2304	3.39-3.91
3400	2.29-2.65
5800	1.34-1.55
10,250	0.76-0.88

suggested. The lower frequency limit (longer dimension) is dictated by proximity to the cutoff frequency. The higher frequency limit (shorter dimension) is dictated by higher order waves. See **Table 5** for recommended inside diameter dimensions for the 902- to 10,000-MHz amateur bands.

The probe that excites the waveguide and makes the transition from coaxial cable to waveguide is $^1/_4$ λ long and spaced from the closed end of the guide by $^1/_4$ guide wavelength. The length of the feed should be two to three guide wavelengths. The latter is preferred if a second probe is to be mounted for polarization change or for polaplexer work where duplex communication (simultaneous transmission and reception) is possible because of the isolation between two properly located and oriented probes. The second probe for polarization switching or polaplexer work should be spaced $^3/_4$ guide wavelength from the closed end and mounted at right angles to the first probe.

The feed aperture is located at the focal point of the dish and aimed at the center of the reflector. The feed mounts should permit adjustment of the aperture either side of the focal point and should present a minimum of blockage to the reflector. Correct distance to the dish center places the focal point about 1 inch inside the feed aperture. The use of a nonmetallic support minimizes blockage. PVC pipe, fiberglass and Plexiglas are commonly used materials. A simple test by placing a material in a microwave oven reveals if it is satisfactory up to 2450 MHz. PVC pipe has tested satisfactorily and appears to work well at 2300 MHz. A simple, clean looking mount for a 4-foot dish with 18 inches focal length, for example, can be made by mounting a length of 4-inch PVC pipe using a PVC flange at the center of the dish. At 2304 MHz the circular feed is approximately 4 inches ID, making a snug fit with the PVC pipe. Precautions should be taken to keep rain and small birds from entering the feed.

Never look into the open end of a waveguide when power is applied, or stand directly in front of a dish while transmitting. Tests and adjustments in these areas should be done while receiving or at extremely low levels of transmitter power (less than 0.1 watt). The US Government has set a limit of 10 mW/cm^2 averaged over a 6-minute period as the safe maximum. Other authorities believe even lower levels should be used. Destructive thermal heating of body tissue results from excessive exposure. This heating effect is especially dangerous to the eyes. The accepted safe level of 10 mW/cm^2 is reached in the near field of a parabolic antenna if the level at $2D^2/\lambda$ is 0.242 mW/cm^2. The equation for power density at the far-field boundary is

$$\text{Power density} = \frac{137.8\ P}{D^2}\ \text{mW/cm}^2 \qquad \text{(Eq 7)}$$

where

P = average power in kilowatts
D = antenna diameter in feet
λ = wavelength in feet

New commercial dishes are expensive, but surplus ones can often be purchased at low cost. Some amateurs build theirs, while others modify UHF TV dishes or circular metal snow sleds for the amateur bands. **Fig 27** shows a dish using the homemade feed just described.

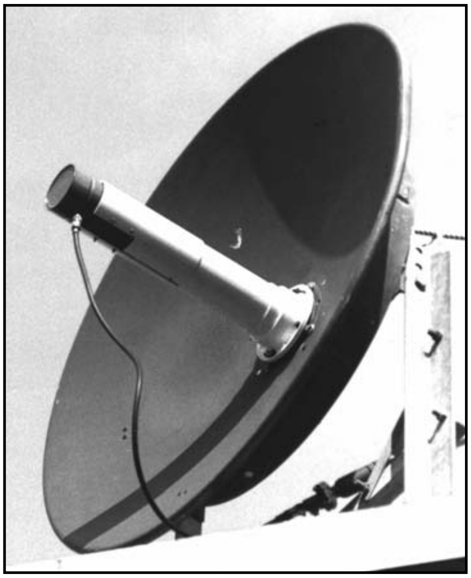

Fig 27—Coffee-can 2304 MHz feed described in text and Fig 26 mounted on a 4-ft dish.

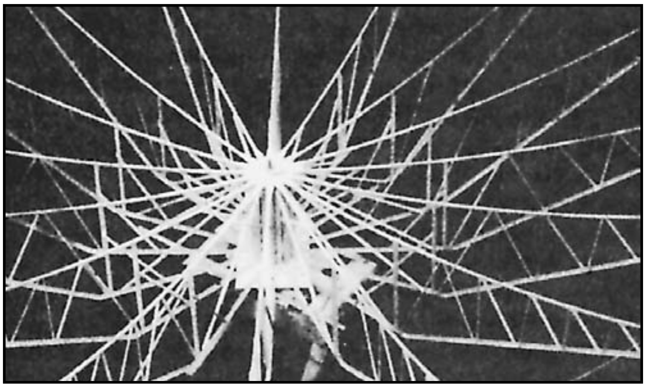

Fig 29—Detailed look at the hub assembly for the ZL1BJQ dish. Most of the structural members are made from ¾-inch T section.

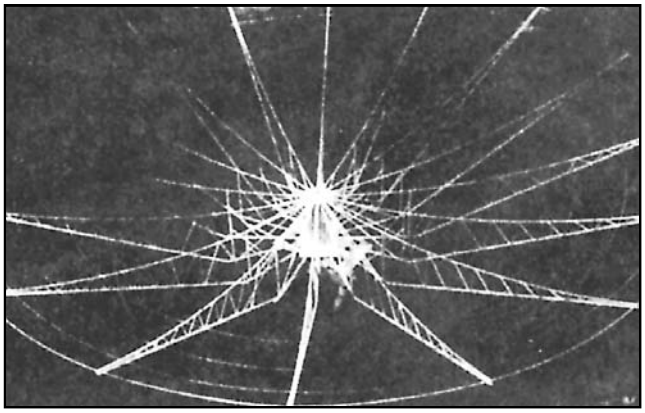

Fig 28—Aluminum framework for a 23-foot dish under construction by ZL1BJQ.

Photos showing a highly ambitious dish project under construction by ZL1BJQ appear in **Figs 28** and **29**. Practical details for constructing this type of antenna are given in Chapter 19. Dick Knadle, K2RIW, described modern UHF antenna test procedures in February 1976 *QST* (see Bibliography). Also see Chapter 19.

OMNIDIRECTIONAL ANTENNAS FOR VHF AND UHF

Local work with mobile stations requires an antenna with wide coverage capabilities. Most mobile work is on FM, and the polarization used with this mode is generally vertical. Some simple vertical systems are described below. Additional material on antennas of this type is presented in Chapter 16, Mobile and Maritime Antennas.

Ground-plane Antennas for 144, 222 and 440 MHz

For the FM operator living in the primary coverage area of a repeater, the ease of construction and low cost of a $^1/_4$ λ ground-plane antenna make it an ideal choice. Three different types of construction are detailed in Figs 30 through 43; the choice of construction method depends upon the materials at hand and the desired style of antenna mounting.

The 144-MHz model shown in **Fig 30** uses a flat piece of sheet aluminum, to which radials are connected with machine screws. A 45° bend is made in each of the radials. This bend can be made with an ordinary bench vise. An SO239 chassis connector is mounted at the center of the aluminum plate with the threaded part of the connector facing down. The vertical portion of the

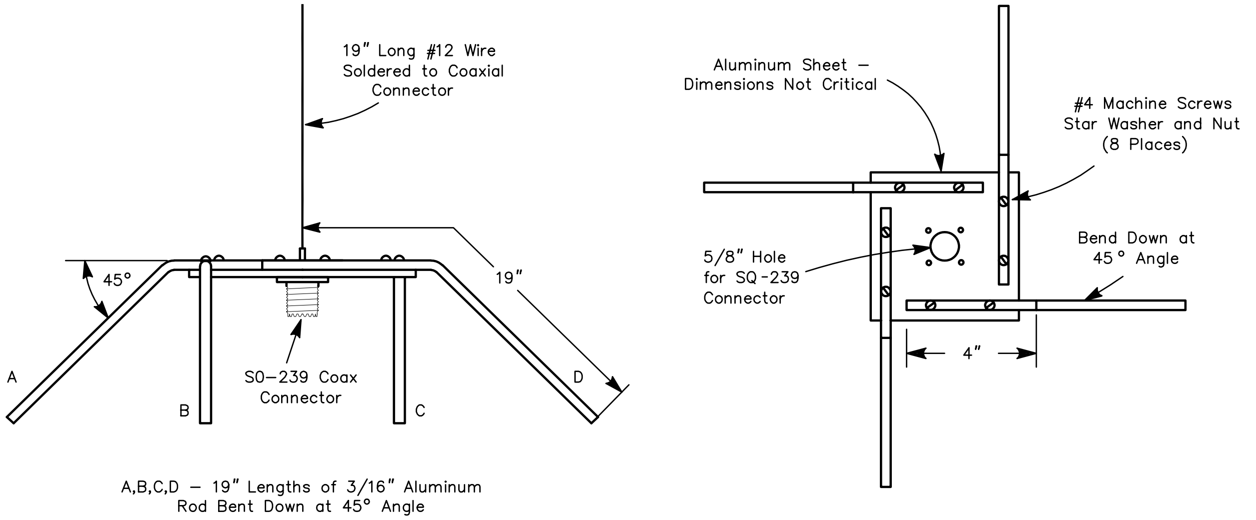
19″ Long #12 Wire
Soldered to Coaxial
Connector
45°
19″
A
B
C
D
S0–239 Coax
Connector
A,B,C,D – 19″ Lengths of 3/16″ Aluminum
Rod Bent Down at 45° Angle
Aluminum Sheet –
Dimensions Not Critical
#4 Machine Screws
Star Washer and Nut
(8 Places)
5/8″ Hole
for SQ-239
Connector
Bend Down at
45° Angle
4″

Fig 30—These drawings illustrate the dimensions for the 144-MHz ground-plane antenna. The radials are bent down at a 45° angle.

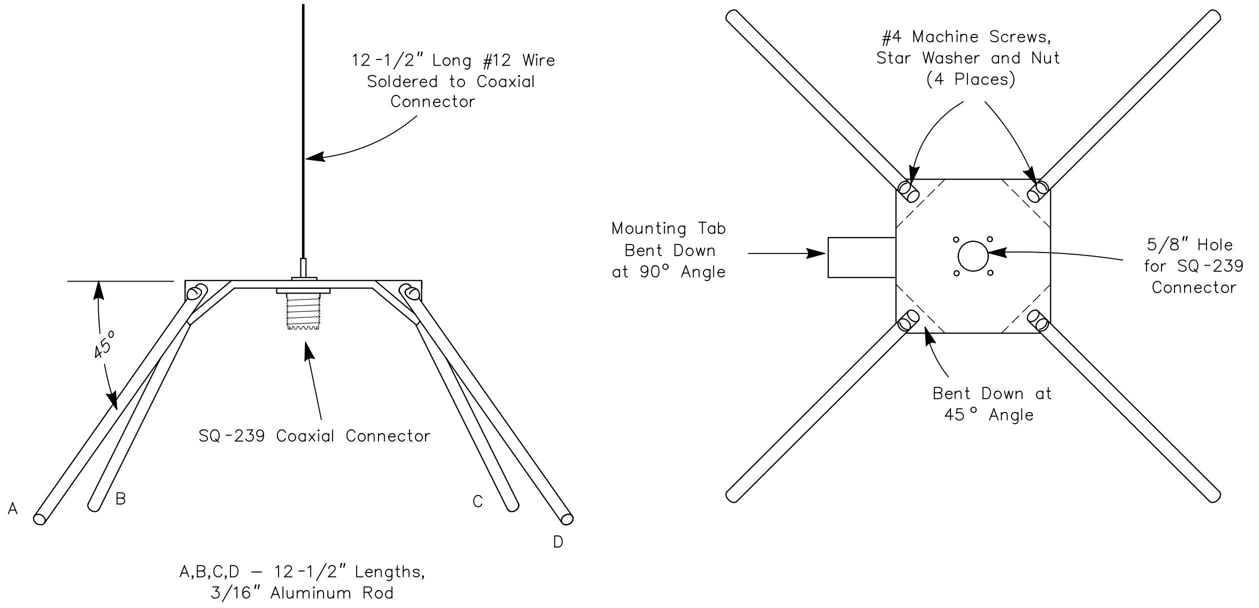
12-1/2″ Long #12 Wire
Soldered to Coaxial
Connector
45°
SQ-239 Coaxial Connector
A
B
C
D
A,B,C,D – 12-1/2″ Lengths,
3/16″ Aluminum Rod
#4 Machine Screws,
Star Washer and Nut
(4 Places)
Mounting Tab
Bent Down
at 90° Angle
5/8″ Hole
for SQ-239
Connector
Bent Down at
45° Angle

Fig 31—Dimensional information for the 222-MHz ground-plane antenna. Lengths for A, B, C and D are the total distances measured from the center of the SO-239 connector. The corners of the aluminum plate are bent down at a 45° angle rather than bending the aluminum rod as in the 144-MHz model. Either method is suitable for these antennas.

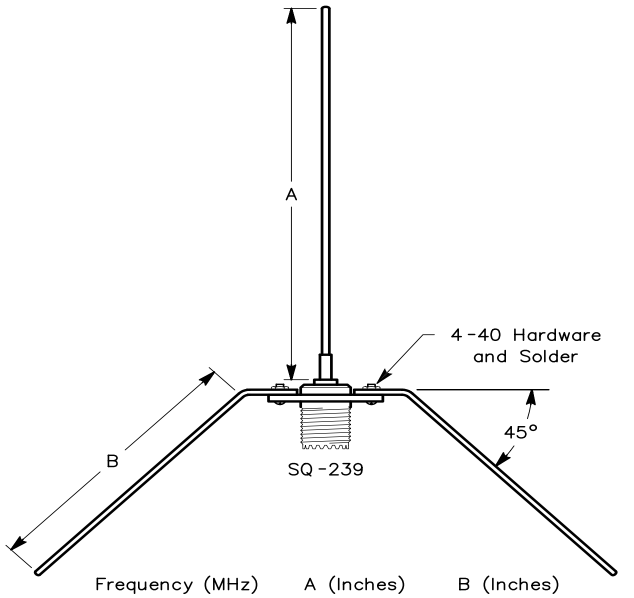

Frequency (MHz)	A (Inches)	B (Inches)
146	19-5/16″	18-11/16″
225	12-5/8″	12″
445	6-3/8″	5-3/4″

Fig 32—Simple ground-plane antenna for the 144-, 222- and 440-MHz bands. The vertical element and radials are 3/32- or 1/16-in. brass welding rod. Although 3/32-in. rod is preferred for the 144-MHz antenna, #10 or #12 copper wire can also be used.

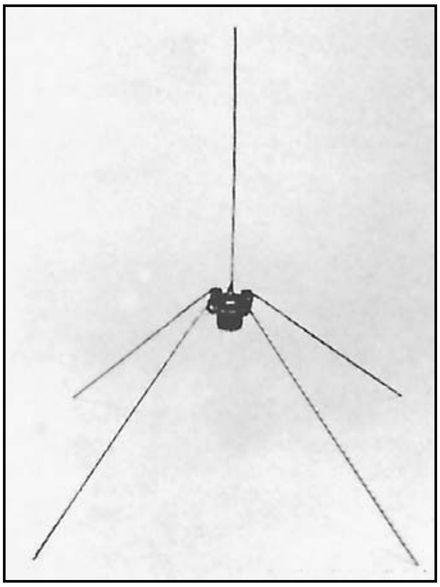

Fig 33—A 440-MHz ground-plane constructed using only an SO-239 connector, no. 4-40 hardware and 1/16-in. brass welding rod.

antenna is made of #12 copper wire soldered directly to the center pin of the SO-239 connector.

The 222-MHz version, **Fig 31**, uses a slightly different technique for mounting and sloping the radials. In this case the corners of the aluminum plate are bent down at a 45° angle with respect to the remainder of the plate. The four radials are held to the plate with machine screws, lock washers and nuts. A mounting tab is included in the design of this antenna as part of the aluminum base. A compression type of hose clamp could be used to secure the antenna to a mast. As with the 144-MHz version, the vertical portion of the antenna is soldered directly to the SO-239 connector.

A very simple method of construction, shown in **Figs 32** and **33**, requires nothing more than an SO-239 connector and some no. 4-40 hardware. A small loop formed at the inside end of each radial is used to attach the radial directly to the mounting holes of the coaxial connector. After the radial is fastened to the SO-239 with no. 4-40 hardware, a large soldering iron or propane torch is used to solder the radial and the mounting hardware to the coaxial connector. The radials are bent to a 45° angle and the vertical portion is soldered to the center pin to complete the antenna. The antenna can be mounted by passing the feed line through a mast of ¾-inch ID plastic or aluminum tubing. A compression hose clamp can be used to secure the PL-259 connector, attached to the feed line, in the end of the mast. Dimensions for the 144-, 222- and 440-MHz bands are given in Fig 32.

If these antennas are to be mounted outside it is wise to apply a small amount of RTV sealant or similar material around the areas of the center pin of the connector to prevent the entry of water into the connector and coax line.

The J-Pole Antenna

The J-Pole is a half-wave antenna that is end-fed at its bottom. Since the radiator is longer than that of a $^1/_4$-wave ground-plane antenna, the vertical lobe is compressed down toward the horizon and it has about 1.5 dB of gain compared to the ground-plane configuration. The stub-matching section used to transform the high impedance seen looking into a half-wave to 50 Ω coax is shorted at the bottom, making the antenna look like the letter "J," and giving the antenna its name.

Rigid copper tubing, fittings and assorted hardware can be used to make a really rugged J-pole antenna for 2 meters. When copper tubing is used, the entire assembly can be soldered together, ensuring electrical integrity, and making the whole antenna weatherproof. This

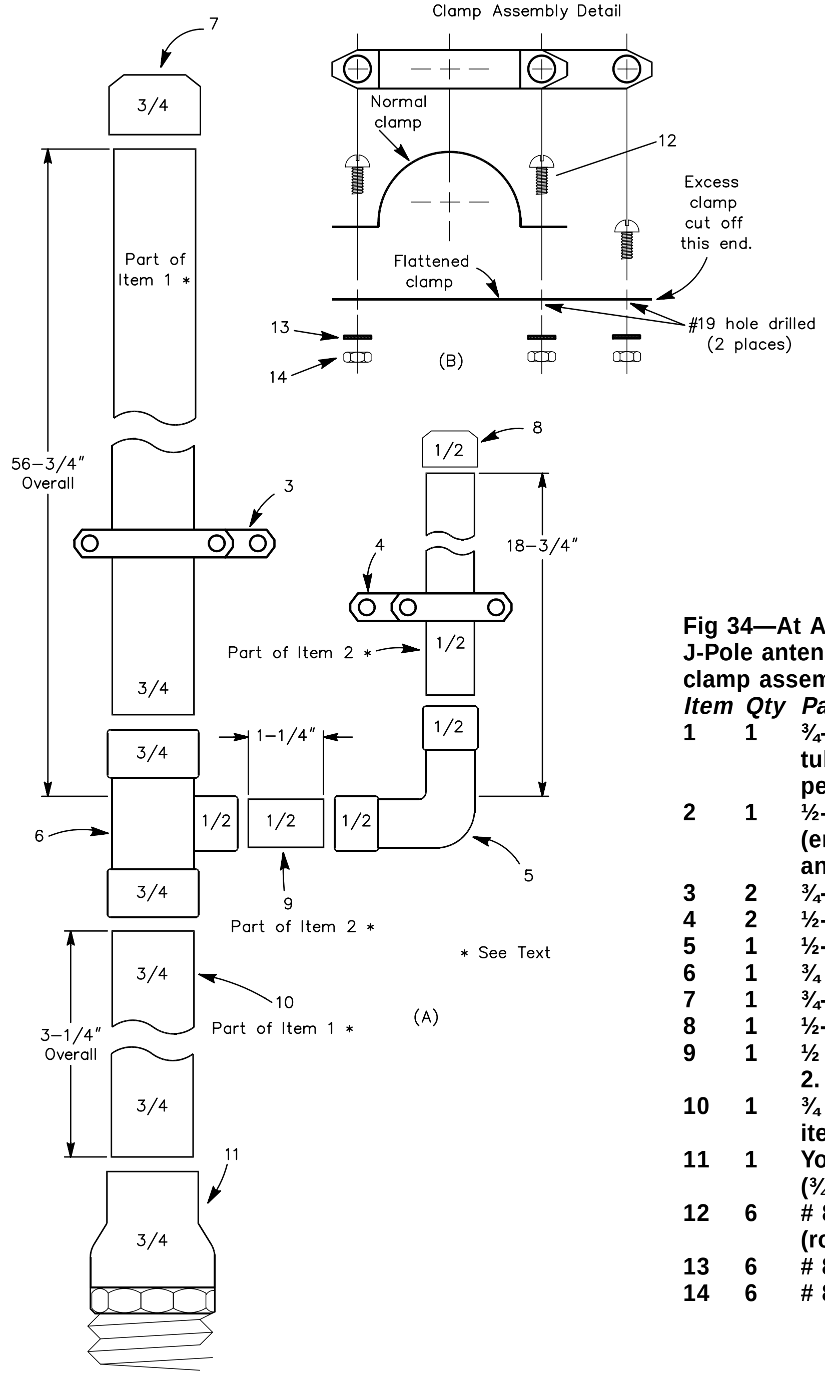
Clamp Assembly Detail
7
3/4
Normal clamp
12
Excess clamp cut off this end.
Part of Item 1 *
Flattened clamp
13
14
(B)
#19 hole drilled (2 places)
8
1/2
56–3/4″ Overall
3
18–3/4″
4
1/2
Part of Item 2 *
1/2
3/4
3/4
1–1/4″
1/2
1/2
1/2
6
5
3/4
9
Part of Item 2 *
* See Text
3/4
10
Part of Item 1 *
(A)
3–1/4″ Overall
3/4
11
3/4

Fig 34—At A, exploded assembly diagram of all-copper J-Pole antenna. At B, detail of clamp assemblies. Both clamp assemblies are the same.

Item	***Qty***	***Part or Material Name***
1	**1**	**¾-inch × 10 foot length of rigid copper tubing (enough for 2 antennas, 60 inches per antenna)**
2	**1**	**½-inch × 10 ft length of rigid copper tubing (enough for 6 antennas, 20 inches per antenna)**
3	**2**	**¾-inch copper pipe clamps**
4	**2**	**½-inch copper pipe clamps**
5	**1**	**½-inch copper elbow**
6	**1**	**¾ × ½-inch copper tee**
7	**1**	**¾-inch copper end cap**
8	**1**	**½-inch copper end cap**
9	**1**	**½ × 1¼-inch copper nipple (Make from item 2. See text)**
10	**1**	**¾ × 3 ¼-inch copper nipple (Make from item 1. See text)**
11	**1**	**Your choice of coupling to mast fitting (¾ × 1 inch NPT used at KD8JB)**
12	**6**	**# 8-32 × ½-inch brass machine screws (round, pan, or binder head)**
13	**6**	**# 8 brass flat washers**
14	**6**	**# 8-32 brass hex nuts**

material came from an article by Michael Hood, KD8JB, in *The ARRL Antenna Compendium,Vol. 4*.

No special hardware or machined parts are used in this antenna, nor are insulating materials needed, since the antenna is always at dc ground. Best of all, even if the parts aren't on sale, the antenna can be built for less than $15. If you only build one antenna, you'll have enough tubing left over to make most of a second antenna.

Construction

Copper and brass is used exclusively in this antenna. These metals get along together, so dissimilar metal corrosion is eliminated. Both metals solder well, too. See **Fig 34**. Cut the copper tubing to the lengths indicated. Item 9 is a $1^{1}/_{4}$-inch nipple cut from the 20-inch length of $^{1}/_{2}$-inch tubing. This leaves $18^{3}/_{4}$ inches for the $^{1}/_{4}$-matching stub. Item 10 is a $3^{1}/_{4}$-inch long nipple cut from the 60-inch length of $^{3}/_{4}$-inch tubing. The $^{3}/_{4}$-wave element should measure $56^{3}/_{4}$-inches long. Remove burrs from the ends of the tubing after cutting, and clean the mating surfaces with sandpaper, steel wool, or emery cloth.

After cleaning, apply a very thin coat of flux to the mating elements and assemble the tubing, elbow, tee, end caps and stubs. Solder the assembled parts with a propane torch and rosin-core solder. Wipe off excess solder with a damp cloth, being careful not to burn yourself. The copper tubing will hold heat for a long time after you've finished soldering. After soldering, set the assembly aside to cool.

Flatten one each of the $^{1}/_{2}$-inch and $^{3}/_{4}$-inch pipe clamps. Drill a hole in the flattened clamp as shown in Fig 34A. Assemble the clamps and cut off the excess metal from the flattened clamp using the unmodified clamp as a template. Disassemble the clamps.

Assemble the $^{1}/_{2}$-inch clamp around the $^{1}/_{4}$-wave element and secure with two of the screws, washers, and nuts as shown in Fig 34B. Do the same with the $^{3}/_{4}$-inch clamp around the $^{3}/_{4}$-wave element. Set the clamps initially to a spot about 4 inches above the bottom of the "J" on their respective elements. Tighten the clamps only finger tight, since you'll need to move them when tuning.

Tuning

The J-Pole can be fed directly from 50-Ω coax through a choke balun (3 turns of the feed coax rolled into a coil about 8 inches in diameter and held together with electrical tape). Before tuning, mount the antenna vertically, about 5 to 10 feet from the ground. A short TV mast on a tripod works well for this purpose. When tuning VHF antennas, keep in mind that they are sensitive to nearby objects—such as your body. Attach the feed line to the clamps on the antenna, and make sure all the nuts and screws are at least finger tight. It really doesn't matter to which element (¾-wave element or stub) you attach the coaxial center lead. The author has done it both ways with no variation in performance. Tune the antenna by moving the two feed-point clamps equal distances a small amount each time until the SWR is minimum at the desired frequency. The SWR will be close to 1:1.

Final Assembly

The final assembly of the antenna will determine its long-term survivability. Perform the following steps with care. After adjusting the clamps for minimum SWR, mark the clamp positions with a pencil and then remove the feed line and clamps. Apply a very thin coating of flux to the inside of the clamp and the corresponding surface of the antenna element where the clamp attaches. Install the clamps and tighten the clamp screws.

Solder the feed line clamps where they are attached to the antenna elements. Now, apply a small amount of solder around the screw heads and nuts where they contact the clamps. Don't get solder on the screw threads! Clean away excess flux with a non-corrosive solvent. After final assembly and erecting/mounting the antenna in the desired location, attach the feed line and secure with the remaining washer and nut. Weather-seal this joint with RTV. Otherwise, you may find yourself repairing the feed line after a couple years.

On-the-Air Performance

Years ago, prior to building the first J-Pole antenna for this station, the author used a standard $^{1}/_{4}$-wave ground plane vertical antenna. While he had no problem working various repeaters around town with a $^{1}/_{4}$-wave antenna, simplex operation left a lot to be desired. The J-Pole performs just as well as a Ringo Ranger, and significantly better than the $^{1}/_{4}$-wave ground-plane vertical.

Practical 6-Meter Yagis

Boom length often proves to be the deciding factor when one selects a Yagi design. **Table 6** shows three 6-meter Yagis designed for convenient boom lengths (6, 12 and 22 feet). The 3-element, 6-foot boom design has 8.0 dBi gain in free space; the 12 foot boom, 5-element version has 10.1 dBi gain, and the 22-foot, 7 element Yagi has a gain of 11.3 dBi. All antennas exhibit better than 22 dB front-to-rear ratio and cover 50 to 51 MHz with better than 1.7:1 SWR.

Half-element lengths and spacings are given in the table. Elements can be mounted to the boom as shown in **Fig 35**. Two muffler clamps hold each aluminum plate to the boom, and two U bolts fasten each element to the plate, which is 0.25 inches thick and 4 × 4 inches square. Stainless steel is the best choice for hardware, however, galvanized hardware can be substituted. Automotive muffler clamps do not work well in this application, because they are not galvanized and quickly rust once exposed to the weather. Please note that the element lengths shown in Table 6 are half the overall element lengths. See page 20-7 to 20-11 in Chapter 20 for practical details of telescoping aluminum elements.

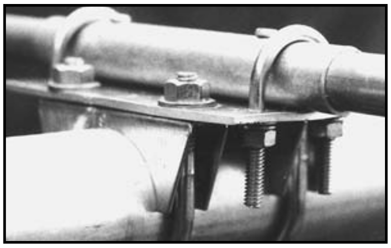

Fig 35—The element to boom clamp. U bolts are used to hold the element to the plate, and 2-in. galvanized muffler clamps hold the plates to the boom.

The driven element is mounted to the boom on a Bakelite or G-10 fiberglass plate of similar dimension to the other mounting plates. A 12-inch piece of Plexiglas rod is inserted into the driven element halves. The Plexiglas allows the use of a single clamp on each side of the element and also seals the center of the elements against moisture. Self-tapping screws are used for electrical connection to the driven element.

Refer to **Fig 36** for driven-element and hairpin match details. A bracket made from a piece of aluminum is used to mount the three SO239 connectors to the driven element plate. A 4:1 transmission-line balun connects the two element halves, transforming the 200 Ω resistance at the hairpin match to 50 Ω at the center connector. Note

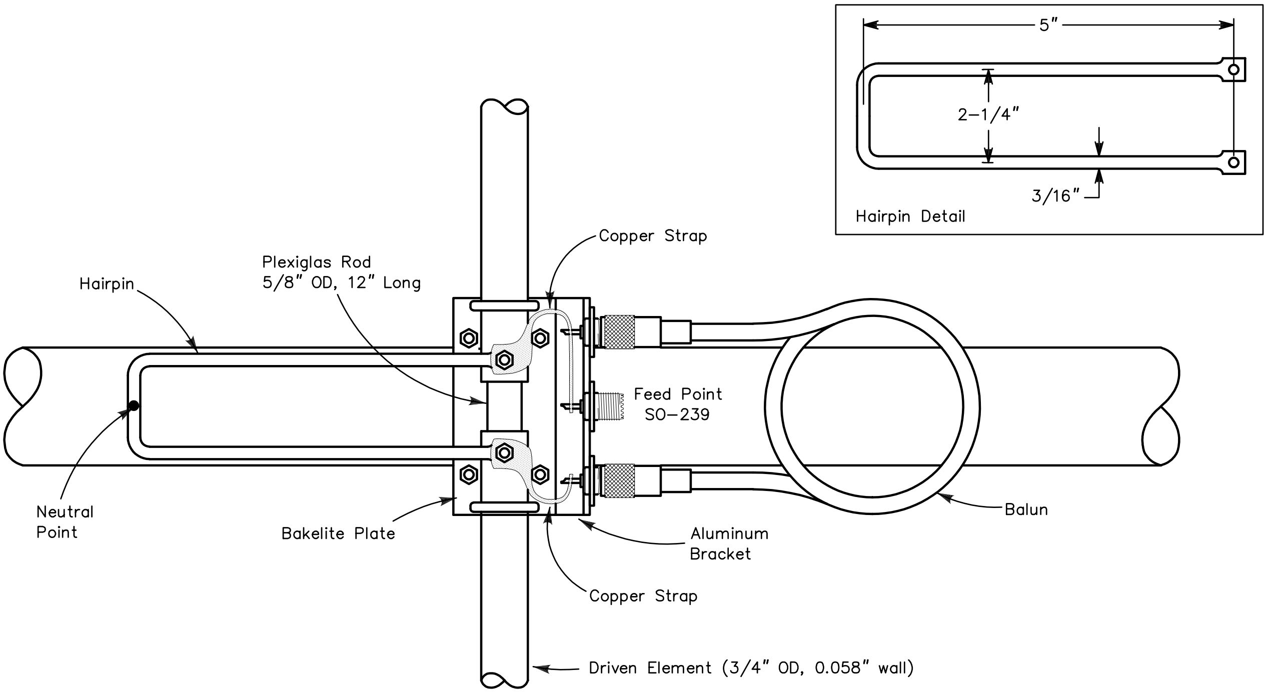

Fig 36—This shows how the driven element and feed system are attached to the boom. The phasing line is coiled and taped to the boom. The center of the hairpin loop may be connected to the boom electrically and mechanically if desired.
Phasing-line lengths:
For cable with 0.80 velocity factor – 7 ft, 10$^{3}/_{8}$ in.
For cable with 0.66 velocity factor – 6 ft, 5$^{3}/_{4}$ in.

Table 6
Optimized 6-Meter Yagi Designs

	Spacing Between Elements inches	*Seg 1 OD* Length inches*	*Seg2 OD* Length inches*	*Midband Gain F/R*
306-06				
OD		0.750	0.625	
Refl.	0	36	23.500	7.9 dBi
D.E.	24	36	16.000	27.2 dB
Dir. 1	66	36	15.500	
506-12				
OD		0.750	0.625	
Refl.	0	36	24.000	10.1 dBi
D.E.	24	36	17.125	24.7 dB
Dir. 1	12	36	19.375	
Dir. 2	44	36	18.250	
Dir. 3	58	36	15.375	
706-22				
OD		0.750	0.625	
Refl.	0	36	25.000	11.3 dBi
D.E.	27	36	17.250	29.9 dB
Dir. 1	16	36	18.500	
Dir. 2	51	36	15.375	
Dir. 3	54	36	15.875	
Dir. 4	53	36	16.500	
Dir. 5	58	36	12.500	

*See pages 20-7 to 20-11 for telescoping aluminum tubing details.

that the electrical length of the balun is λ/2, but the physical length will be shorter due to the velocity factor of the particular coaxial cable used. The hairpin is connected directly across the element halves. The exact center of the hairpin is electrically neutral and should be fastened to the boom. This has the advantage of placing the driven element at dc ground potential.

The hairpin match requires no adjustment as such. However, you may have to change the length of the driven element slightly to obtain the best match in your preferred portion of the band. Changing the driven-element length will not adversely affect antenna performance. *Do not adjust the lengths or spacings of the other elements—they are optimized already*. If you decide to use a gamma match, add 3 inches to each side of the driven element lengths given in the table for all antennas.

High-Performance Yagis for 144, 222 and 432 MHz

This construction information is presented as an introduction to the three high-performance VHF/UHF Yagis that follow. All were designed and built by Steve Powlishen, K1FO. For years the design of long Yagi antennas seemed to be a mystical black art. The problem of simultaneously optimizing 20 or more element spacings and element lengths presented an almost unsolvable set of simultaneous equations. With the unprecedented increase in computer power and widespread availability of antenna analysis software, we are now able to quickly examine many Yagi designs and determine which approaches work and which designs to avoid.

At 144 MHz and above, most operators desire Yagi antennas two or more wavelengths in length. This length (2λ) is where most classical designs start to fall apart in terms of gain per boom length, bandwidth and pattern quality. Extensive computer and antenna range analysis has proven that the best possible design is a Yagi that has both varying element spacings and varying element lengths.

This design approach starts with closely spaced directors. The director spacings gradually increase until a constant spacing of about 0.4 λ is reached. Conversely, the director lengths start out longest with the first director and decrease in length in a decreasing rate of change until they are virtually constant in length. This method of construction results in a wide gain bandwidth. A bandwidth of 7% of the center frequency at the –1 dB forward-gain points is typical for these Yagis even when they are longer than 10 λ. The log-taper design also reduces the rate of change in driven-element impedance vs frequency. This allows the use of simple dipole driven elements while still obtaining acceptable driven-element SWR over a wide frequency range. Another benefit is that the resonant frequency of the Yagi changes very little as the boom length is increased.

The driven-element impedance also changes moderately with boom length. The tapered approach creates a Yagi with a very clean radiation pattern. Typically, first side lobe levels of ~17 dB in the E plane, ~15 dB in the H plane, and all other lobes at ~20 dB or more are possible on designs from 2 λ to more than 14 λ.

The actual rate of change in element lengths is determined by the diameter of the elements (in wavelengths). The spacings can be optimized for an individual boom length or chosen as a best compromise for most boom lengths.

The gain of long Yagis has been the subject of much debate. Recent measurements and computer analysis by both amateurs and professionals indicates that given an optimum design, doubling a Yagi's boom length will result in a maximum theoretical gain increase of about 2.6 dB. In practice, the real gain increase may be less because of escalating resistive losses and the greater possibility of construction error. **Fig 37** shows the maximum possible gain per boom length expressed in decibels, referenced to an isotropic radiator. The actual number of directors does not play an important part in determining the gain vs boom length as long as a reasonable number of directors are used. The use of more directors per boom length will normally give a wider gain bandwidth, however, a point exists where too many directors will adversely affect all performance aspects.

While short antennas (< 1.5 λ) may show increased gain with the use of quad or loop elements, long Yagis (> 2 λ) will not exhibit measurably greater forward gain or pattern integrity with loop-type elements. Similarly, loops used as driven elements and reflectors will not significantly change the properties of a long log-taper Yagi. Multiple-dipole driven-element assemblies will also not result in any significant gain increase per given boom length when compared to single-dipole feeds.

Once a long-Yagi director string is properly tuned, the reflector becomes relatively non critical. Reflector spacings between 0.15 λ and 0.2 λ are preferred. The spacing can be chosen for best pattern and driven element impedance. Multiple-reflector arrangements will not significantly increase the forward gain of a Yagi which has its directors properly optimized for forward gain. Many multiple-reflector schemes such as tri-reflectors and corner reflectors have the disadvantage of lowering the driven element impedance compared to a single optimum-length reflector. The plane or grid reflector, shown in **Fig 38**, may however reduce the intensity of unwanted rear lobes. This can be used to reduce noise pickup on EME or satellite arrays. This type of reflector will usually increase the driven-element impedance compared to a single reflector. This sometimes makes driven-element matching easier. Keep in mind that even for EME, a plane reflector will add considerable wind load and weight for

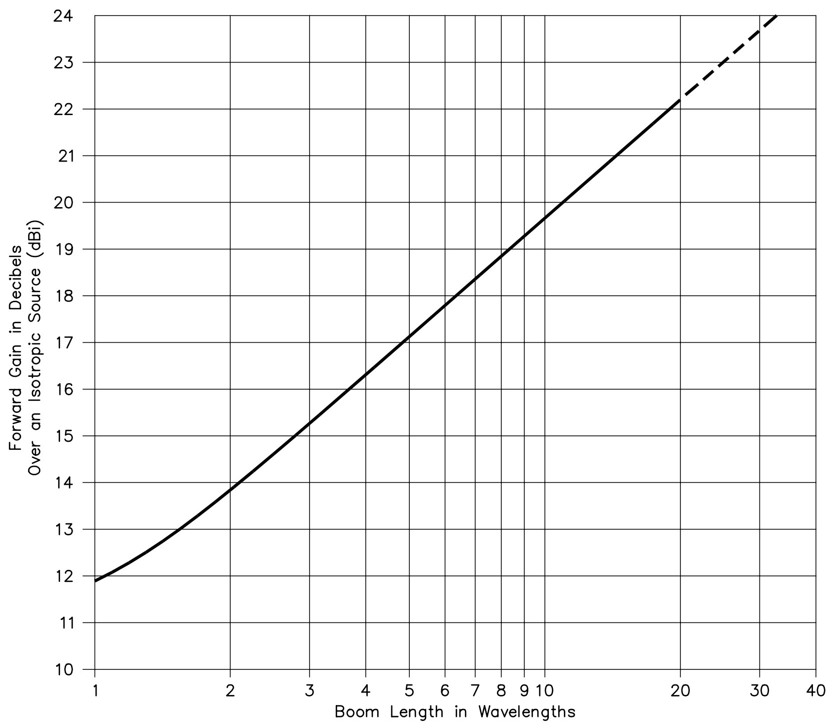

Fig 37—This chart shows maximum gain per boom length for optimally designed long Yagi antennas.

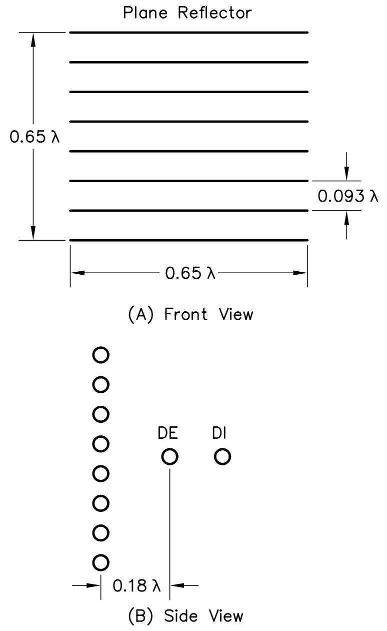

Fig 38—Front and side views of a plane-reflector antenna.

only a few tenths of a decibel of receive signal-to-noise improvement.

Yagi Construction

Normally, aluminum tubing or rod is used for Yagi elements. Hard-drawn enamel-covered copper wire can also be used on Yagis above 420 MHz. Resistive losses are inversely proportional to the square of the element diameter and the square root of its conductivity.

Element diameters of less than $^{3}/_{16}$ inch or 4 mm should not be used on any band. The size should be chosen for reasonable strength. Half-inch diameter is suitable for 50 MHz, $^{3}/_{16}$ to $^{3}/_{8}$ inch for 144 MHz and $^{3}/_{16}$ inch is recommended for the higher bands. Steel, including stainless steel and unprotected brass or copper wire, should not be used for elements.

Boom material may be aluminum tubing, either square or round. High-strength aluminum alloys such as 6061-T6 or 6063-T651 offer the best strength-to-weight advantages. Fiberglass poles have been used (where available as surplus). Wood is a popular low-cost boom material. The wood should be well seasoned and free from knots. Clear pine, spruce and Douglas fir are often used. The wood should be well treated to avoid water absorption and warping.

Elements may be mounted insulated or uninsulated, above or through the boom. Mounting uninsulated elements through a metal boom is the least desirable method unless the elements are welded in place. The Yagi elements will oscillate, even in moderate winds. Over several years this element oscillation will work open the boom holes. This will allow the elements to move in the boom. This will create noise (in your receiver) when the wind blows, as the element contact changes. Eventually the element-to-boom junction will corrode (aluminum oxide is a good insulator). This loss of electrical contact between the boom and element will reduce the boom's effect and change the resonant frequency of the Yagi.

Noninsulated elements mounted above the boom will perform fine as long as a good mechanical connection is made. Insulating blocks mounted above the boom will also work, but they require additional fabrication. One of the most popular construction methods is to mount the elements through the boom using insulating shoulder washers. This method is lightweight and durable. Its main disadvantage is difficult disassembly, making this method of limited use for portable arrays.

If a conductive boom is used, element lengths must be corrected for the mounting method used. The amount of correction is dependent upon the boom diameter in

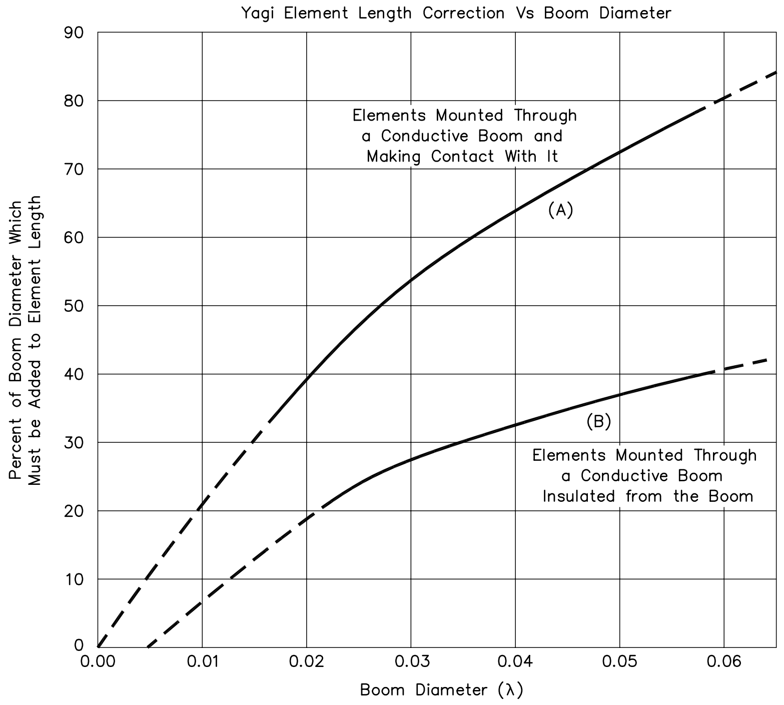

Fig 39—Yagi element correction vs boom diameter. Curve A is for elements mounted through a round or square conductive boom, with the elements in mechanical contact with the boom. Curve B is for insulated elements mounted through a conductive boom, and for elements mounted on top of a conductive boom (elements make electrical contact with the boom). The patterns were corrected to computer simulations to determine Yagi tuning. The amount of element correction is not affected by element diameter.

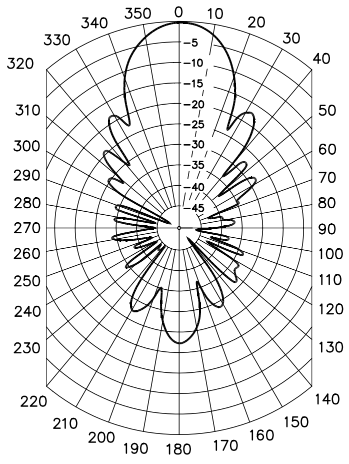

Fig 40—Measured E-plane pattern for the 22-element Yagi. Note: This antenna pattern is drawn on a linear dB grid, rather than on the standard ARRL log-periodic grid, to emphasize low sidelobes.

wavelengths. See **Fig 39**. Elements mounted through the boom and not insulated require the greatest correction. Mounting on top of the boom or through the boom on insulated shoulder washers requires about half of the through-the-boom correction. Insulated elements mounted at least one element diameter above the boom require no correction over the free-space length.

The three following antennas have been optimized for typical boom lengths on each band.

A HIGH-PERFORMANCE 432-MHz YAGI

This 22-element, 6.1-λ, 432-MHz Yagi was originally designed for use in a 12-Yagi EME array built by K1FO. A lengthy evaluation and development process preceded its construction. Many designs were considered and then analyzed on the computer. Next, test models were constructed and evaluated on a home-made antenna range. The resulting design is based on WlEJ's computer-optimized spacings.

The attention paid to the design process has been worth the effort. The 22-element Yagi not only has exceptional forward gain (17.9 dBi), but has an unusually clean radiation pattern. The measured E-plane pattern is shown in **Fig 40**. Note that a 1-dB-per-division axis is used to show pattern detail. A complete description of the design process and construction methods appears in December 1987 and January 1988 *QST*.

Table 7
Specifications for 432-MHz Yagi Family

No. of Ele.	*Boom length(λ)*	*Gain (dBi)**	*F/B ratio (dB)*	*DE imped (Ω)*	*Beamwidth E/H (°)*	*Stacking E/H (inches)*
15	3.4	15.67	21	23	30/32	53/49
16	3.8	16.05	19	23	29/31	55/51
17	4.2	16.45	20	27	28/30	56/53
18	4.6	16.8	25	32	27/29	58/55
19	4.9	17.1	25	30	26/28	61/57
20	5.3	17.4	21	24	25.5/27	62/59
21	5.7	17.65	20	22	25/26.5	63/60
22	6.1	17.9	22	25	24/26	65/62
23	6.5	18.15	27	30	23.5/25	67/64
24	6.9	18.35	29	29	23/24	69/66
25	7.3	18.55	23	25	22.5/23.5	71/68
26	7.7	18.8	22	22	22/23	73/70
27	8.1	19.0	22	21	21.5/22.5	75/72
28	8.5	19.20	25	25	21/22	77/75
29	8.9	19.4	25	25	20.5/21.5	79/77
30	9.3	19.55	26	27	20/21	80/78
31	9.7	19.7	24	25	19.6/20.5	81/79
32	10.2	19.8	23	22	19.3/20	2/80
33	10.6	9.9	23	23	19/19.5	83/81
34	11.0	20.05	25	22	18.8/19.2	84/82
35	11.4	20.2	27	25	18.5/19.0	85/83
36	11.8	20.3	27	26	18.3/18.8	86/84
37	12.2	20.4	26	26	18.1/18.6	87/85
38	12.7	20.5	25	25	18.9/18.4	88/86
39	13.1	20.6	25	23	18.7/18.2	89/87
40	13.5	20.8	26	21	17.5/18	90/88

*Gain is approximate real gain based on gain measurements made on six different-length Yagis.

Like other log-taper Yagi designs, this one can easily be adapted to other boom lengths. Versions of this Yagi have been built by many amateurs. Boom lengths ranged between 5.3 λ (20 elements) and 12.2 λ (37 elements).

The size of the original Yagi (169 inches long, 6.1 λ) was chosen so the antenna could be built from small-diameter boom material ($^{7}/_{8}$-inch and 1 inch round 6061-T6 aluminum) and still survive high winds and ice loading. The 22-element Yagi weighs about 3.5 pounds and has a wind load of approximately 0.8 square feet. This allows a high-gain EME array to be built with manageable wind load and weight. This same low wind load and weight lets the tropo operator add a high-performance 432-MHz array to an existing tower without sacrificing antennas on other bands.

Table 7 lists the gain and stacking specifications for the various length Yagis. The basic Yagi dimensions are shown in **Table 8**. These are free-space element lengths for $^{3}/_{16}$-inch-diameter elements. Boom corrections for the element mounting method must be added in. The element-length correction column gives the length that must be added to keep the Yagi's center frequency optimized for use at 432 MHz. This correction is required to use the same spacing pattern over a wide range of boom lengths. Although any length Yagi will work well, this design is at its best when made with 18 elements or more (4.6 λ). Element material of less than $^{3}/_{16}$-inch diameter is not recommended because resistive losses will reduce the gain by about 0.1 dB, and wet-weather performance will be worse.

Quarter-inch-diameter elements could be used if all elements are shortened by 3 mm. The element lengths are intended for use with a slight chamfer (0.5 mm) cut into the element ends. The gain peak of the array is centered at 437 MHz. This allows acceptable wet-weather performance, while reducing the gain at 432 MHz by only 0.05 dB.

The gain bandwidth of the 22-element Yagi is 31 MHz (at the –1 dB points). The SWR of the Yagi is less than l.4: l between 420 and 440 MHz. **Fig 41** is a network analyzer plot of the driven-element SWR vs frequency. These numbers indicate just how wide the frequency response of a log-taper Yagi can be, even with a simple dipole driven element. In fact, at one antenna gain contest, some ATV operators conducted gain vs frequency measurements from 420 to 440 MHz. The 22-element Yagi beat all entrants including those with so-called broadband feeds.

To peak the Yagi for use on 435 MHz (for satellite use), you may want to shorten all the elements by 2 mm. To peak it for use on 438 MHz (for ATV applications), shorten all elements by 4 mm. If you want to use the Yagi

Table 8

Free-Space Dimensions for 432-MHz Yagi Family

*Element correction is the amount to shorten or lengthen all elements when building a Yagi of that length. Element lengths are for $^3/_{16}$-inch diameter material.

Ele. No.	*Element Position (mm from reflector)*	*Element Length (mm)*	*Element Correction**
Refl	0	340	
DE	104	334	
D1	146	315	
D2	224	306	
D3	332	299	
D4	466	295	
D5	622	291	
D6	798	289	
D7	990	287	
D8	1196	285	
D9	1414	283	
D10	1642	281	–2
D11	1879	279	–2
D12	2122	278	–2
D13	2373	277	–2
D14	2629	276	–2
D15	2890	275	–1
D16	3154	274	–1
D17	3422	273	–1
D18	3693	272	0
D19	3967	271	0
D20	4242	270	0
D21	4520	269	0
D22	4798	269	0
D23	5079	268	0
D24	5360	268	+1
D25	5642	267	+1
D26	5925	267	+1
D27	6209	266	+1
D28	6494	266	+1
D29	6779	265	+2
D30	7064	265	+2
D31	7350	264	+2
D32	7636	264	+2
D33	7922	263	+2
D34	8209	263	+2
D35	8496	262	+2
D36	8783	262	+2
D37	9070	261	+3
D38	9359	261	+3

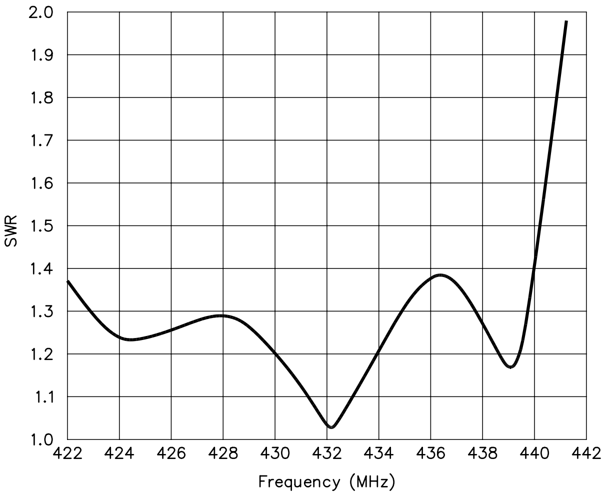

Fig 41—SWR performance of the 22-element Yagi in dry weather.

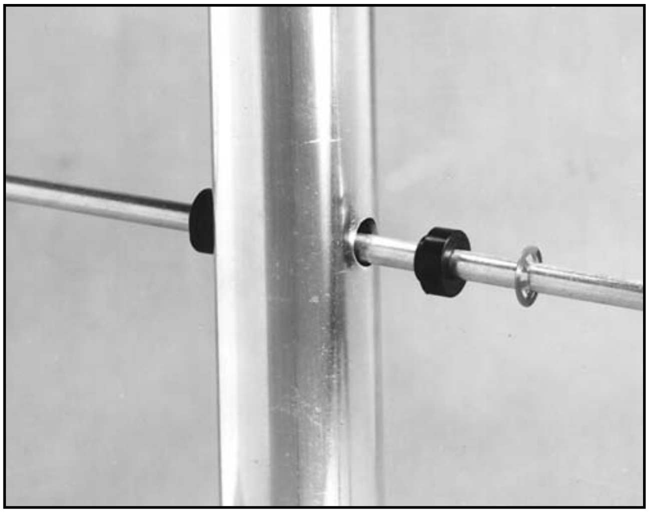

Fig 42—Element-mounting detail. Elements are mounted through the boom using plastic insulators. Stainless steel push-nut retaining rings hold the element in place.

on FM between 440 MHz and 450 MHz, shorten all the elements by 10 mm. This will provide 17.6 dBi gain at 440 MHz, and 18.0 dBi gain at 450 MHz. The driven element may have to be adjusted if the element lengths are shortened.

Although this Yagi design is relatively broadband, it is suggested that close attention be paid to copying the design exactly as built. Metric dimensions are used because they are convenient for a Yagi sized for 432 MHz. Element holes should be drilled within ±2 mm. Element lengths should be kept within ±0.5 mm. Elements can be accurately constructed if they are first rough cut with a hack saw and then held in a vise and filed to the exact length.

The larger the array, the more attention you should pay to making all Yagis identical. Elements are mounted on shoulder insulators and run through the boom (see **Fig 42**). The element retainers are stainless-steel push nuts. These are made by several companies, including Industrial Retaining Ring Co in Irvington, New Jersey, and AuVeco in Ft Mitchell, Kentucky. Local industrial hardware distributors can usually order them for you. The element insulators

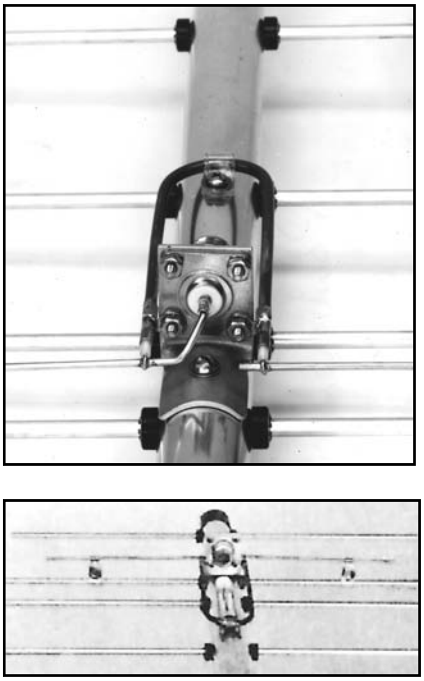

Fig 43—Several views of the driven element and T match.

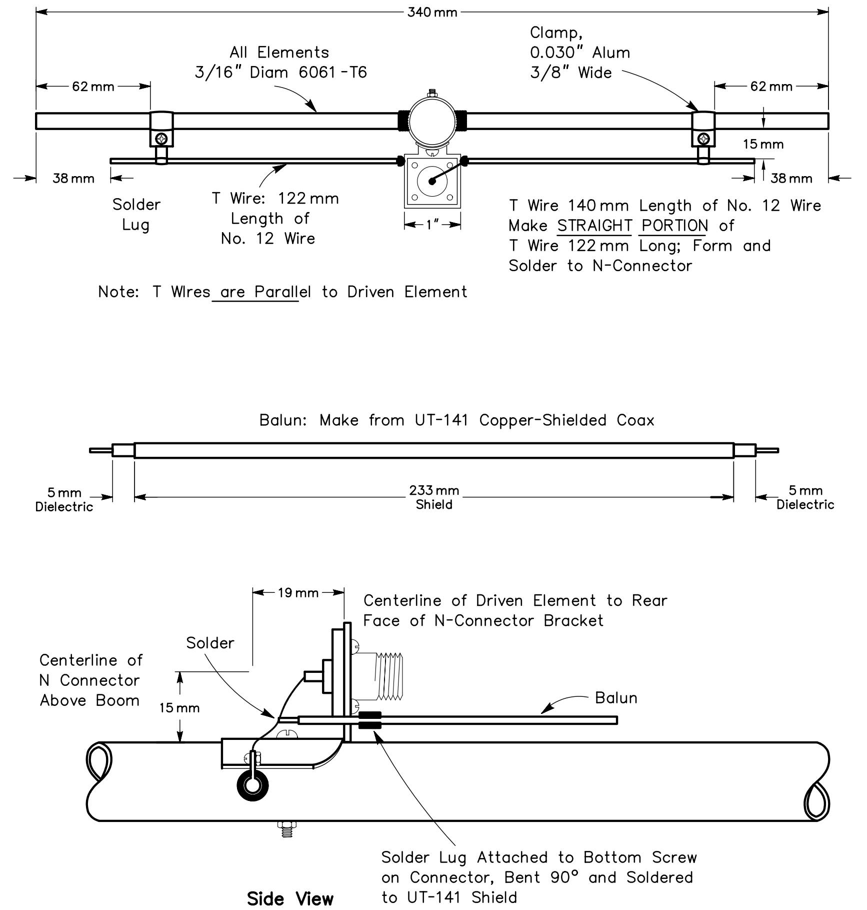
340 mm
All Elements
3/16″ Diam 6061 -T6
Clamp,
0.030″ Alum
3/8″ Wide
62 mm
62 mm
15 mm
38 mm
38 mm
Solder
Lug
T Wire: 122 mm
Length of
No. 12 Wire
1″
T Wire 140 mm Length of No. 12 Wire
Make STRAIGHT PORTION of
T Wire 122 mm Long; Form and
Solder to N-Connector
Note: T WIres are Parallel to Driven Element
Balun: Make from UT-141 Copper-Shielded Coax
5 mm
Dielectric
233 mm
Shield
5 mm
Dielectric
19 mm
Centerline of Driven Element to Rear
Face of N-Connector Bracket
Solder
Centerline of
N Connector
Above Boom
15 mm
Balun
Solder Lug Attached to Bottom Screw
on Connector, Bent 90° and Soldered
to UT-141 Shield
Side View

Fig 44—Details of the driven element and T match for the 22-element Yagi. Lengths are given in millimeters to allow precise duplication of the antenna. See text.

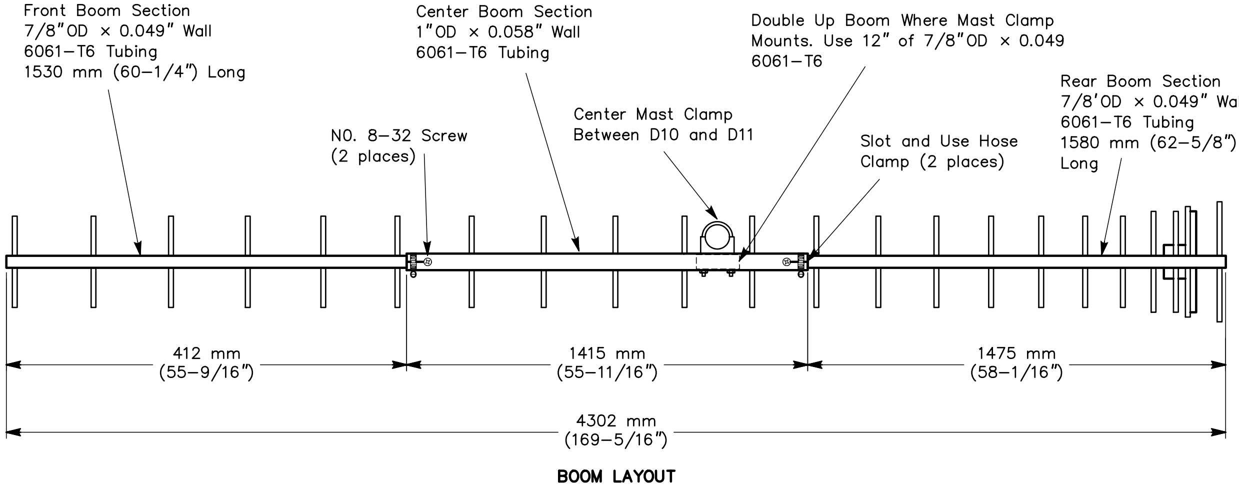
Front Boom Section
7/8″OD × 0.049″ Wall
6061–T6 Tubing
1530 mm (60–1/4″) Long
Center Boom Section
1″OD × 0.058″ Wall
6061–T6 Tubing
Double Up Boom Where Mast Clamp
Mounts. Use 12″ of 7/8″OD × 0.049
6061–T6
Rear Boom Section
7/8′OD × 0.049″ Wall
6061–T6 Tubing
1580 mm (62–5/8″)
Long
Center Mast Clamp
Between D10 and D11
NO. 8–32 Screw
(2 places)
Slot and Use Hose
Clamp (2 places)
412 mm
(55–9/16″)
1415 mm
(55–11/16″)
1475 mm
(58–1/16″)
4302 mm
(169–5/16″)
BOOM LAYOUT

Fig 45—Boom-construction information for the 22-element Yagi Lengths are given in millimeters to allow precise duplication of the antenna. See text.

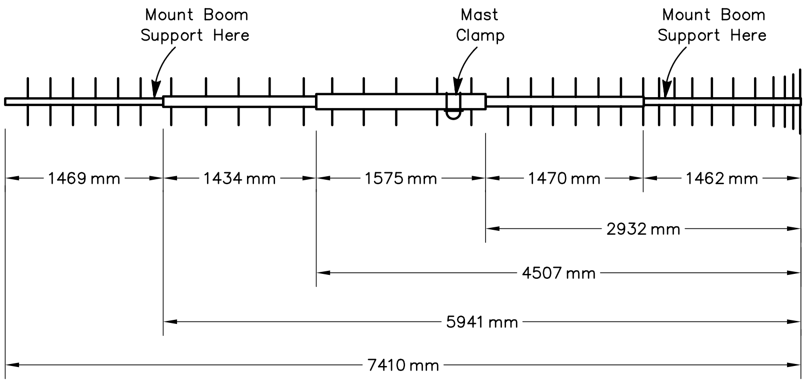

Fig 46—Boom-construction information for the 33-element Yagi. Lengths are given in millimeters to allow precise duplication of the antenna.

are not critical. Teflon or black polyethylene are probably the best materials. The Yagi in the photographs is made with black Delryn insulators, available from C3i in Washington, DC.

The driven element uses a UG-58A/U connector mounted on a small bracket. The UG58A/U should be the type with the press-in center pin. UG-58s with center pins held in by "C" clips will usually leak water. Some connectors use steel retaining clips, which will rust and leave a conductive stripe across the insulator. The T-match wires are supported by the UT-141 balun. RG-303/U or RG-142/U Tefloninsulated cable could be used if UT-141 cannot be obtained. **Fig 43A** and Fig 42B show details of the driven-element construction. Driven element dimensions are given in **Fig 44**.

Dimensions for the 22-element Yagi are listed in **Table 9**. **Fig 45** details the Yagi's boom layout. Element material can be either 3/16 inch 6061-T6 aluminum rod or hard aluminum welding rod.

A 24-foot-long, 10.6-λ, 33-element Yagi was also built. The construction methods used were the same as the 22-element Yagi. Telescoping round boom sections of 1, 1 1/8, and 1 1/4 inches in diameter were used. A boom support is required to keep boom sag acceptable. At 432 MHz, if boom sag is much more than two or three inches, H-plane pattern distortion will occur. Greater amounts of boom sag will reduce the gain of a Yagi. **Table 10** lists the proper dimensions for the antenna when built with the previously given boom diameters. The boom layout is shown in **Fig 46**, and the driven element is described in **Fig 47**. The 33-element Yagi exhibits the same clean pattern traits as the 22-element Yagi (see **Fig 48**). Measured gain of the 33-element Yagi is 19.9 dBi at 432 MHz. A measured gain sweep of the 33-element Yagi gave a –1 dB gain bandwidth of 14 MHz with the –1 dB points at 424.5 MHz and 438.5 MHz.

A HIGH-PERFORMANCE 144MHZ YAGI

This 144MHz Yagi design uses the latest log-tapered element spacings and lengths. It offers near theoretical gain per boom length, an extremely clean pattern and wide bandwidth. The design is based upon the spacings used in a 4.5-λ 432-MHz computerdeveloped design by W1EJ. It is quite similar to the 432MHz Yagi described elsewhere in this chapter. Refer to that project for additional construction diagrams and photographs.

Mathematical models do not always directly translate into real working examples. Although the computer design provided a good starting point, the author, Steve Powlishen, K1FO, built several test models before the final working Yagi was obtained. This hands-on tuning included changing the element-taper rate in order to obtain the flexibility that allows the Yagi to be built with different boom lengths.

The design is suitable for use from 1.8 λ (10 elements) to 5.1 λ (19 elements). When elements are added to a Yagi, the center frequency, feed impedance and front-to-back ratio will range up and down. A modern tapered design will minimize this effect and allow the builder to select any desired boom length. This Yagi's design capabilities per boom length are listed in **Table 11**.

The gain of any Yagi built around this design will be within 0.1 to 0.2 dB of the maximum theoretical gain at the design frequency of 144.2 MHz. The design is intentionally peaked high in frequency (calculated gain peak is about 144.7 MHz). It has been found that by doing this, the SWR bandwidth and pattern at 144.0 to 144.3 MHz will be better, the Yagi will be less affected by weather and its performance in arrays will be more predictable. This design starts to drop off in performance if built with fewer than 10 elements. At less than 2 λ, more traditional designs perform well.

Table 12 gives free-space element lengths for 1/4 inch-diameter elements. The use of metric notation allows for much easier dimensional changes during the design stage. Once you become familiar with the metric system, you'll probably find that construction is easier without the burden of cumbersome English fractional units. For 3/16 inch-diameter elements, lengthen all parasitic elements by 3 mm. If 3/8 inch diameter elements are used, shorten all of the

Table 9

Dimensions for the 22-Element 432-MHz Yagi

Element Number	*Element Position (mm from reflector)*	*Element Length (mm)*	*Boom Diam (in)*
Refl	30	346	
DE	134	340	
D1	176	321	
D2	254	311	7/8
D3	362	305	
D4	496	301	
D5	652	297	
D6	828	295	
D7	1020	293	
D8	1226	291	
D9	1444	289	
D10	1672	288	
D11	1909	286	
D12	2152	285	1
D13	2403	284	
D14	2659	283	
D15	2920	281	
D16	3184	280	
D17	3452	279	7/8
D18	3723	278	
D19	3997	277	
D20	4272	276	

Table 10

Dimensions for the 33-Element 432-MHz Yagi

Element Number	*Element Position (mm from reflector)*	*Element Length (mm)*	*Boom Diam (in)*
REF	30	348	
DE	134	342	
D1	176	323	
D2	254	313	
D3	362	307	
D4	496	303	1
D5	652	299	
D6	828	297	
D7	1020	295	
D8	1226	293	
D9	1444	291	
D10	1672	290	
D11	1909	288	
D12	2152	287	1$^1/_8$
D13	2403	286	
D14	2659	285	
D15	2920	284	
D16	3184	284	
D17	3452	283	
D18	3723	282	1¼
D19	3997	281	
D20	4272	280	
D21	4550	278	
D22	4828	278	
D23	5109	277	1$^1/_8$
D24	5390	277	
D25	5672	276	
D26	5956	275	
D27	6239	274	
D28	6524	274	1
D29	6809	273	
D30	7094	273	
D31	7380	272	

directors and the reflector by 6 mm. The driven element will have to be adjusted for the individual Yagi if the 12-element design is not adhered to.

For the 12-element Yagi, $^1/_4$-inch diameter elements were selected because smaller-diameter elements become rather flimsy at 2 meters. Other diameter elements can be used as described previously. The 2.5-λ boom was chosen because it has an excellent size and wind load vs gain and pattern trade-off. The size is also convenient; three 6-foot-long pieces of aluminum tubing can be used without any waste. The relatively large-diameter boom sizes (1$^1/_4$ and 1$^3/_8$ inches) were chosen, as they provide an extremely rugged Yagi that does not require a boom support. The 12-element 17-foot-long design has a calculated wind survival of close to 120 mph! The absence of a boom support also makes vertical polarization possible.

Longer versions could be made by telescoping smaller-size boom sections into the last section. Some sort of boom support will be required on versions longer than 22 feet. The elements are mounted on shoulder insulators and mounted through the boom. However, elements may

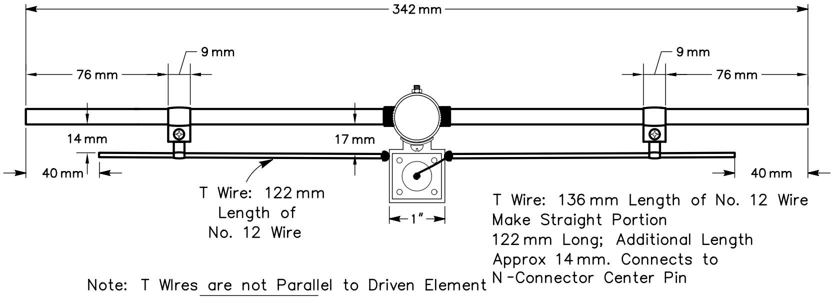

T Wire: 122 mm Length of No. 12 Wire

T Wire: 136 mm Length of No. 12 Wire Make Straight Portion 122 mm Long; Additional Length Approx 14 mm. Connects to N-Connector Center Pin

Note: T Wires are not Parallel to Driven Element

Fig 47—Details of the driven element and T match for the 33-element Yagi. Lengths are given in millimeters to allow precise duplication of the antenna.

Table 11
Specifications for the 144-MHz Yagi Family

No. of Ele.	Boom Length(λ)	Gain (dBd)	DE Imped (Ω)	FB Ratio (dB)	Beamwidth E/H (°)	Stacking E/H (°)
10	1.8	11.4	27	17	39/42	10.2/9.5
11	2.2	12.0	38	19	36/40	11.0/10.0
12	2.5	12.5	28	23	34/37	11.7/10.8
13	2.9	13.0	23	20	32/35	12.5/11.4
14	3.2	13.4	27	18	31/33	12.8/12.0
15	3.6	13.8	35	20	30/32	13.2/12.4
16	4.0	14.2	32	24	29/30	13.7/13.2
17	4.4	14.5	25	23	28/29	14.1/13.6
18	4.8	14.8	25	21	27/28.5	14.6/13.9
19	5.2	15.0	30	22	26/27.5	15.2/14.4

Table 12
Free-Space Dimensions for the 144-MHz Yagi Family
Element diameter is ¼ inch

Element No.	Element Position (mm from reflector)	Element Length
Refl.	0	1038
DE	312	955
D1	447	956
D2	699	932
D3	1050	916
D4	1482	906
D5	1986	897
D6	2553	891
D7	3168	887
D8	3831	883
D9	4527	879
D10	5259	875
D11	6015	870
D12	6786	865
D13	7566	861
D14	8352	857
D15	9144	853
D16	9942	849
D17	10744	845

be mounted, insulated or uninsulated, above or through the boom, as long as appropriate element length corrections are made. Proper tuning can be verified by checking the depth of the nulls between the main lobe and first side lobes. The nulls should be 5 to 10 dB below the first sidelobe level at the primary operating frequency. The boom layout for the 12-element model is shown in **Fig 49**. The actual corrected element dimensions for the 12-element 2.5-λ Yagi are shown in **Table 13**.

The design may also be cut for use at 147 MHz. There is no need to change element spacings. The element lengths should be shortened by 17 mm for best operation between 146 and 148 MHz. Again, the driven element will have to be adjusted as required.

The driven-element size ($^{1}/_{2}$-inch diameter) was chosen to allow easy impedance matching. Any reasonably sized driven element could be used, as long as appropriate length and T-match adjustments are made. Different driven-element dimensions are required if you change the boom length. The calculated natural driven-element impedance is given as a guideline. A balanced T-match was chosen because it's easy to adjust for best SWR and provides a balanced radiation pattern. A 4:1 half-wave coaxial balun is used, although impedance-transforming quarter-wave sleeve baluns could also be used. The cal-

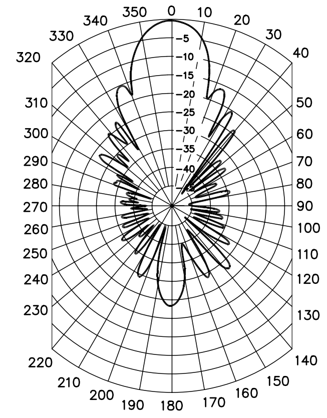

Fig 48—E-plane pattern for the 33-element Yagi. This pattern is drawn on a linear dB grid scale, rather than the standard ARRL log-periodic grid, to emphasize low sidelobes.

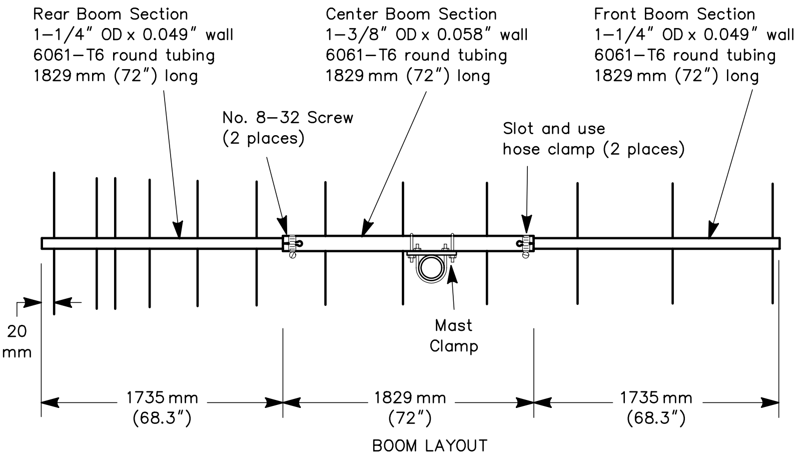
Rear Boom Section
1-1/4" OD x 0.049" wall
6061-T6 round tubing
1829 mm (72") long
Center Boom Section
1-3/8" OD x 0.058" wall
6061-T6 round tubing
1829 mm (72") long
Front Boom Section
1-1/4" OD x 0.049" wall
6061-T6 round tubing
1829 mm (72") long
No. 8-32 Screw
(2 places)
Slot and use
hose clamp (2 places)
20
mm
Mast
Clamp
1735 mm
(68.3")
1829 mm
(72")
1735 mm
(68.3")
BOOM LAYOUT

Fig 49—Boom layout for the 12-element 144-MHz Yagi. Lengths are given in millimeters to allow precise duplication.

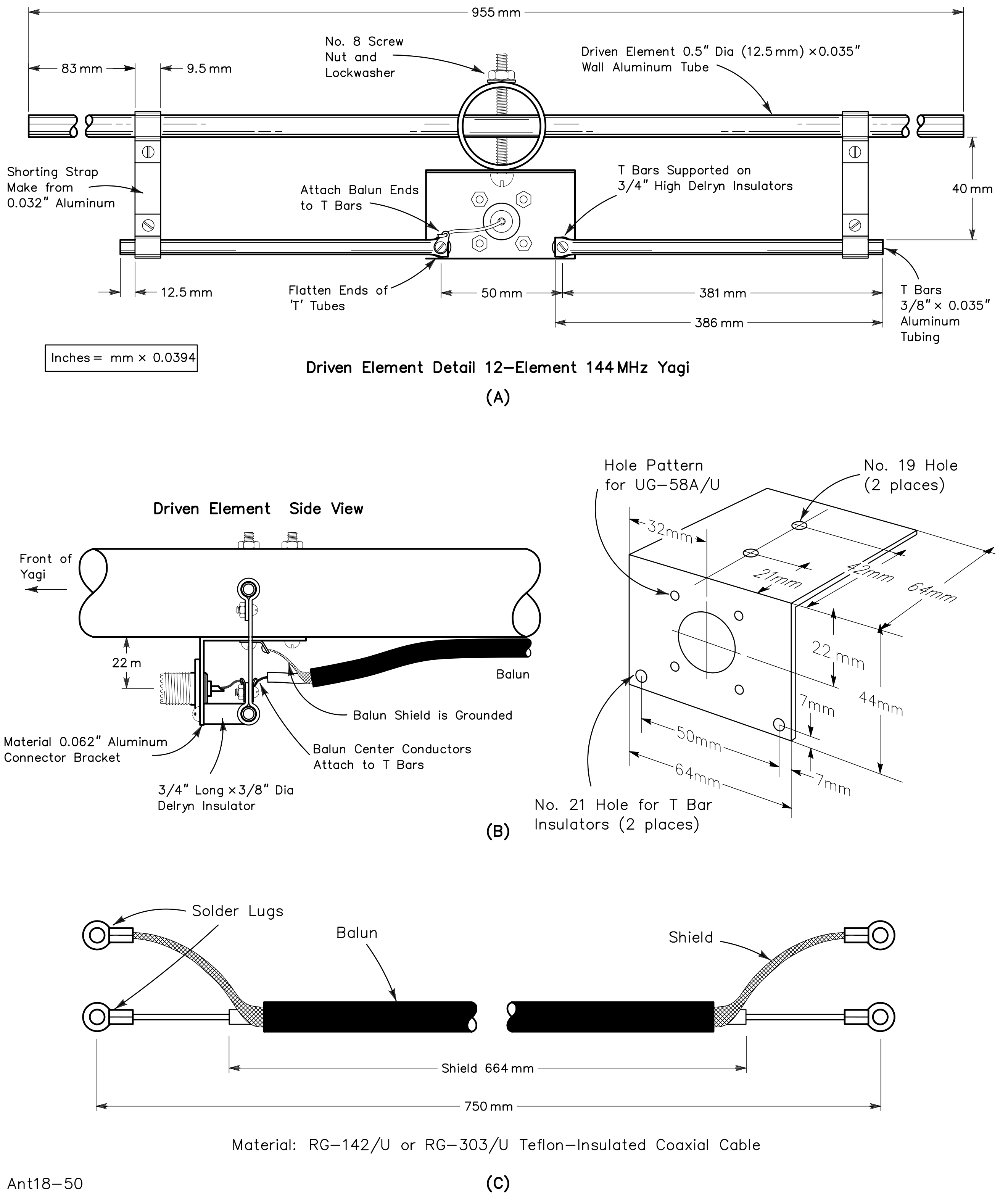
955 mm
83 mm
9.5 mm
No. 8 Screw Nut and Lockwasher
Driven Element 0.5" Dia (12.5 mm) × 0.035" Wall Aluminum Tube
Shorting Strap Make from 0.032" Aluminum
Attach Balun Ends to T Bars
T Bars Supported on 3/4" High Delryn Insulators
40 mm
12.5 mm
Flatten Ends of 'T' Tubes
50 mm
381 mm
386 mm
T Bars 3/8" × 0.035" Aluminum Tubing
Inches = mm × 0.0394
Driven Element Detail 12—Element 144 MHz Yagi
(A)
Driven Element Side View
Front of Yagi
22 m
Balun
Balun Shield is Grounded
Material 0.062" Aluminum Connector Bracket
Balun Center Conductors Attach to T Bars
3/4" Long × 3/8" Dia Delryn Insulator
(B)
Hole Pattern for UG—58A/U
No. 19 Hole (2 places)
32mm
21mm
42mm
64mm
22 mm
44mm
7mm
50mm
64mm
7mm
No. 21 Hole for T Bar Insulators (2 places)
Solder Lugs
Balun
Shield
Shield 664 mm
750 mm
Material: RG—142/U or RG—303/U Teflon—Insulated Coaxial Cable
Ant18—50
(C)

Fig 50—Driven-element detail for the 12-element 144-MHz Yagi. Lengths are given in millimeters to allow precise duplication.

Table 13

Dimensions for the 12-Element 2.5-λ Yagi

Element Number	*Element Position (mm from reflector)*	*Element Length (mm)*	*Boom Diam (in)*
Refl.	0	1044	
DE	312	955	
D1	447	962	$1^1/_4$
D2	699	938	
D3	1050	922	
D4	1482	912	
D5	1986	904	
D6	2553	898	$1^3/_8$
D7	3168	894	
D8	3831	889	
D9	4527	885	$1^1/_4$
D10	5259	882	

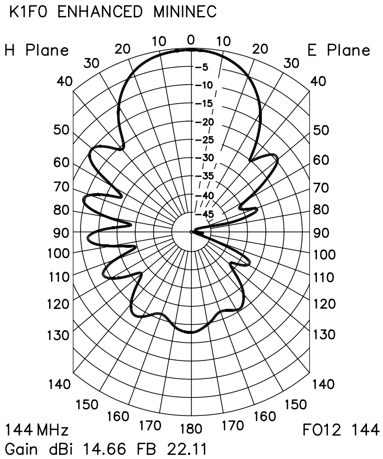

Fig 51—H- and E-plane pattern for the 12-element 144-MHz Yagi.

culated natural impedance will be useful in determining what impedance transformation will be required at the 200-Ω balanced feed point. Chapter 26, Coupling the Line to the Antenna, contains information on calculating folded-dipole and T-match driven-element parameters. A balanced feed is important for best operation on this antenna. Gamma matches can severely distort the pattern balance. Other useful driven-element arrangements are the Delta match and the folded dipole, if you're willing to sacrifice some flexibility. **Fig 50** details the driven-element dimensions.

A noninsulated driven element was chosen for mounting convenience. An insulated driven element may also be used. A grounded driven element may be less affected by static build-up. On the other hand, an insulated driven element allows the operator to easily check his feed lines for water or other contamination by the use of an ohmmeter from the shack.

Table 14

Free-Space Dimensions for the 222-MHz Yagi Family

Element diameter is $^3/_{16}$-inch.

Element No.	*Element Position (mm from reflector)*	*Element Length (mm)*
Refl.	0	676
DE	204	647
D1	292	623
D2	450	608
D3	668	594
D4	938	597
D5	1251	581
D6	1602	576
D7	1985	573
D8	2395	569
D9	2829	565
D10	3283	562
D11	3755	558
D12	4243	556
D13	4745	554
D14	5259	553
D15	5783	552
D16	6315	551
D17	6853	550
D18	7395	549
D19	7939	548
D20	8483	547

Fig 51 shows computer-predicted E- and H-plane radiation patterns for the 12-element Yagi. The patterns are plotted on a l-dB-per-division linear scale instead of the usual ARRL polar-plot graph. This expanded scale plot is used to show greater pattern detail. The pattern for the 12-element Yagi is so clean that a plot done in the standard ARRL format would be almost featureless, except for the main lobe and first sidelobes.

The excellent performance of the 12-element Yagi is demonstrated by the reception of Moon echoes from several of the larger 144MHz EME stations with only one 12-element Yagi. Four of the 12-element Yagis will make an excellent starter EME array, capable of working many EME QSOs while being relatively small in size. The advanced antenna builder can use the information in Table 11 to design a dream array of virtually any size.

A HIGH-PERFORMANCE 222-MHz YAGI

Modern tapered Yagi designs are easily applied to 222 MHz. This design uses a spacing progression that is in between the 12-element 144-MHz design, and the 22-element 432-MHz design presented elsewhere in this chapter. The result is a design with maximum gain per boom length, a clean, symmetrical radiation pattern, and wide bandwidth. Although it was designed for weak-signal work (tropospheric scatter and EME), the design is

Table 15
Specifications for the 222-MHz Yagi Family

No of Ele.	Boom Length(λ)	Gain (dBd)	FB Ratio (dB)	DE Imped (Ω)	Beamwidth E/H (°)	Stacking E/H (feet)
12	2.4	12.3	22	23	37/39	7.1/6.7
13	2.8	12.8	19	28	33/36	7.8/7.2
14	3.1	13.2	20	34	32/34	8.1/7.6
15	3.5	13.6	24	30	30/33	8.6/7.8
16	3.9	14.0	23	23	29/31	8.9/8.3
17	4.3	14.35	20	24	28/30.5	9.3/8.5
18	4.6	14.7	20	29	27/29	9.6/8.9
19	5.0	15.0	22	33	26/28	9.9/9.3
20	5.4	15.3	24	29	25/27	10.3/9.6
21	5.8	15.55	23	24	24.5/26.5	10.5/9.8
22	6.2	15.8	21	23	24/26	10.7/10.2

suited to all modes of 222-MHz operation, such as packet radio, FM repeater operation and control links.

The spacings were chosen as the best compromise for a 3.9-λ 16-element Yagi. The 3.9-λ design was chosen, like the 12-element 144-MHz design, because it fits perfectly on a boom made from three 6-foot-long aluminum tubing sections. The design is quite extensible, and models from 12 elements (2.4 λ) to 22 elements (6.2 λ) can be built from the dimensions given in **Table 14**. Note that free-space lengths are given. They must be corrected for the element-mounting method. Specifications for various boom lengths are shown in **Table 15**.

Construction

Large-diameter ($1\frac{1}{4}$- and $1\frac{3}{8}$-inch diameter) boom construction is used, eliminating the need for boom supports. The Yagi can also be used vertically polarized. Three-sixteenths-inch-diameter aluminum elements are used. The exact alloy is not critical; 6061-T6 was used, but hard aluminum welding rod is also suitable. Quarter-inch-diameter elements could also be used if all elements are shortened by 3 mm. Three-eighths-inch-diameter elements would require 10-mm shorter lengths. Elements smaller than $\frac{3}{16}$ inch-diameter are not recommended. The elements are insulated and run through the boom. Plastic shoulder washers and stainless steel retainers are used to hold the elements in place. The various pieces needed to build the Yagi may be obtained from C3i in Washington, DC. **Fig 52** details the boom layout for the 16-element Yagi. **Table 16** gives the dimensions for the 16-element Yagi as built. The driven element is fed with a T match and a 4:1 balun. See **Fig 53** for construction details. See the 432-MHz Yagi project elsewhere in this chapter for additional photographs and construction diagrams.

The Yagi has a relatively broad gain and SWR curve, as is typical of a tapered design, making it usable over a wide frequency range. The example dimensions are intended for use at 222.0 to 222.5 MHz. The 16-element Yagi is quite usable to more than 223 MHz. The best compromise for covering the entire band is to shorten all parasitic elements by 4 mm. The driven element will have to be adjusted in length for best match. The position of the T-wire shorting straps may also have to be moved.

The aluminum boom provides superior strength, is lightweight, and has a low wind-load cross section. Aluminum is doubly attractive, as it will long outlast wood and fiberglass. Using state-of-the-art designs, it is unlikely that significant performance increases will be achieved in the next few years. Therefore, it's in your best interest to build an antenna that will last many years. If suitable wood or fiberglass poles are readily available, they may be used without any performance degradation, at least when the wood is new and dry. Use the free-space element lengths given in Table 16 for insulated-boom construction.

The pattern of the 16-element Yagi is shown in **Fig 54**. Like the 144-MHz Yagi, a l-dB-per-division plot is used to detail the pattern accurately. This 16-element design makes a good building block for EME or tropo DX arrays. Old-style narrow-band Yagis often perform

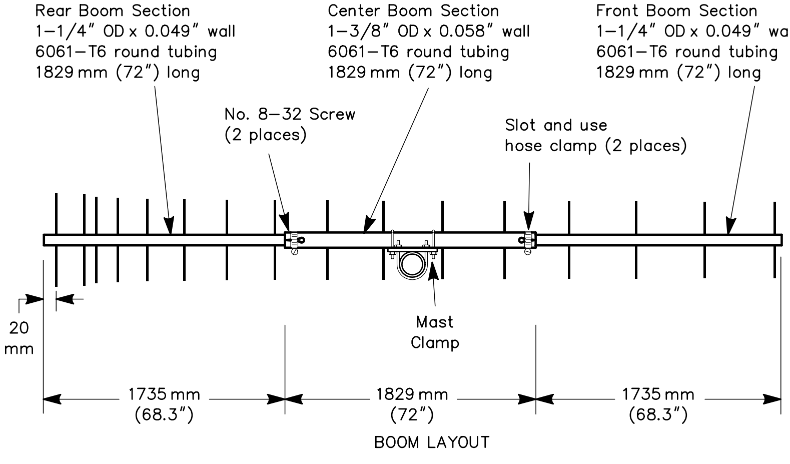

Fig 52—Boom layout for the 16-element 222-MHz Yagi. Lengths are given in millimeters to allow precise duplication.

Table 16

Dimensions for 16-Element 3.9-λ 222-MHz Yagi

Element Number	*Element Position (mm from reflector)*	*Element Length (mm)*	*Boom Diam (in)*
Refl.	0	683	
DE	204	664	
D1	292	630	
D2	450	615	
D3	668	601	$1^{1}/_{4}$
D4	938	594	
D5	1251	588	
D6	1602	583	
D7	1985	580	
D8	2395	576	
D9	2829	572	$1^{3}/_{8}$
D10	3283	569	
D11	3755	565	
D12	4243	563	
D13	4745	561	$1^{1}/_{4}$
D14	5259	560	

unpredictably when used in arrays. The theoretical 3.0-dB stacking gain is rarely observed. The 16-element Yagi (and other versions of the design) reliably provides stacking gains of nearly 3 dB. (The spacing dimensions listed in Table 15 show just over 2.9 dB stacking gain.) This has been found to be the best compromise between gain, pattern integrity and array size. Any phasing line losses will subtract from the possible stacking gain. Mechanical misalignment will also degrade the performance of an array.

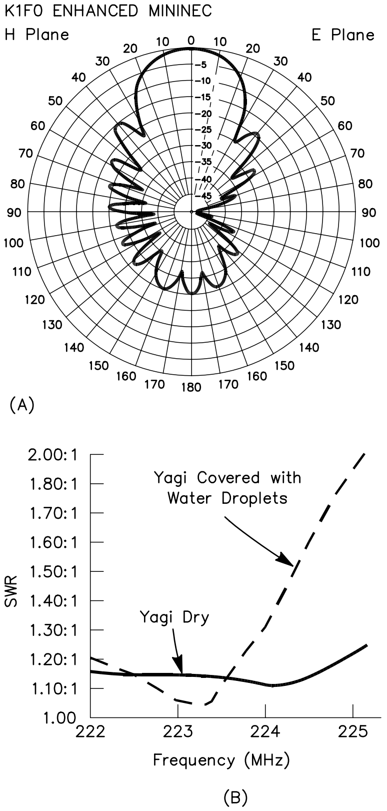

Fig 54—H- and E-plane patterns for the 16-element 222-MHz Yagi at A. The driven-element T-match dimensions were chosen for the best SWR compromise between wet and dry weather conditions. The SWR vs frequency curve shown at B demonstrates the broad frequency response of the Yagi design.

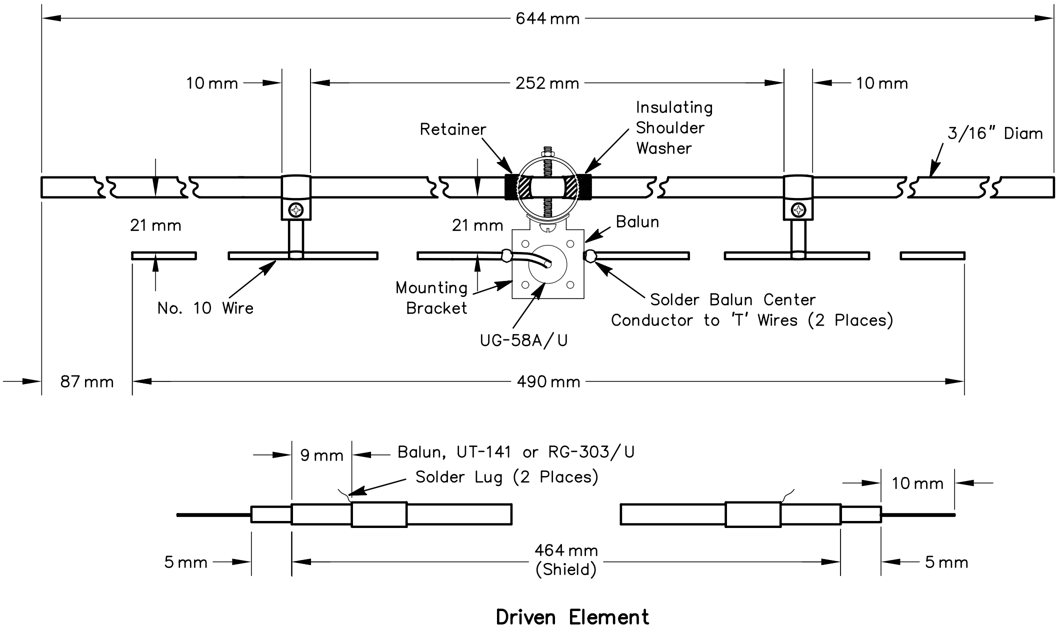
644 mm
10 mm
252 mm
10 mm
Retainer
Insulating Shoulder Washer
3/16" Diam
21 mm
21 mm
Balun
No. 10 Wire
Mounting Bracket
UG-58A/U
Solder Balun Center Conductor to 'T' Wires (2 Places)
87 mm
490 mm
9 mm
Balun, UT-141 or RG-303/U
Solder Lug (2 Places)
10 mm
5 mm
464 mm (Shield)
5 mm
Driven Element

Fig 53—Driven-element detail for the 16-element 222-MHz Yagi. Lengths are given in millimeters to allow precise duplication.

A 144 MHz 2-Element Quad

The basic 2-element quad array for 144 MHz is shown in **Fig 55**. The supporting frame is 1 × 1-inch wood, of any kind suitable for outdoor use. Elements are #8 aluminum wire. The driven element is 1 λ (83 inches) long, and the reflector five percent longer (87 inches). Dimensions are not critical, as the quad is relatively broad in frequency response.

The driven element is open at the bottom, its ends fastened to a plastic block. The block is mounted at the bottom of the forward vertical support. The top portion of the element runs through the support and is held firmly by a screw running into the wood and then bearing on the aluminum wire. Feed is by means of 50-Ω coax, connected to the driven-element loop.

The reflector is a closed loop, its top and bottom portions running through the rear vertical support. It is held in position with screws at the top and bottom. The loop can be closed by fitting a length of tubing over the element ends, or by hammering them flat and bolting them together as shown in the sketch.

The elements in this model are not adjustable, though this can easily be done by the use of stubs. It would then be desirable to make the loops slightly smaller to compensate for the wire in the adjusting stubs. The driven element stub would be trimmed for length and the point of connection for the coax would be adjustable for best match. The reflector stub can be adjusted for maximum gain or maximum F/B ratio, depending on the builder's requirements.

In the model shown only the spacing is adjusted, and this is not particularly critical. If the wooden supports are made as shown, the spacing between the elements can be adjusted for best match, as indicated by an SWR meter connected in the coaxial line. The spacing has little effect on the gain (from 0.15 to 0.25 λ), so the variation in impedance with spacing can be used for matching. This also permits use of either 50- or 75-Ω coax for the transmission line.

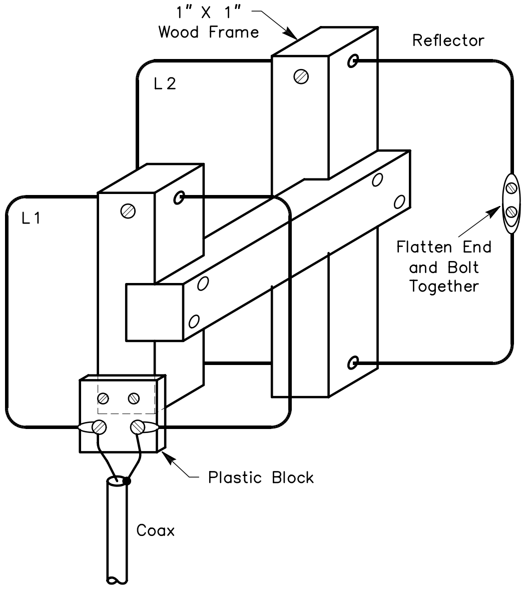

Fig 55—Mechanical details of a 2-element quad for 144 MHz. The driven element, L1, is one wavelength long; reflector L2 is 5% longer. With the transmission line connected as shown here, the resulting radiation is horizontally polarized. Sets of elements of this type can be stacked horizontally and vertically for high gain with broad frequency response. Recommended bay spacing is $^1/_2$ λ between adjacent element sides. The example shown may be fed directly with 50-Ω coax.

A Portable 144 MHz 4-Element Quad

Element spacing for quad antennas found in the literature ranges from 0.14 λ to 0.25 λ. Factors such as the number of elements in the array and the parameters to be optimized (F/B ratio, forward gain, bandwidth, etc), determine the optimum element spacing within this range. The 4-element quad antenna described here was designed for portable use, so a compromise between these factors was chosen. This antenna, pictured in **Fig 56**, was designed and built by Philip D'Agostino, W1KSC.

Based on several experimentally determined correction factors related to the frequency of operation and the wire size, optimum design dimensions were found to be as follows.

$$\text{Reflector length (ft)} = \frac{1046.8}{f_{\text{MHz}}} \qquad \text{(Eq 8)}$$

$$\text{Driven element (ft)} = \frac{985.5}{f_{\text{MHz}}} \qquad \text{(Eq 9)}$$

$$\text{Directors (ft)} = \frac{937.3}{f_{\text{MHz}}} \qquad \text{(Eq 10)}$$

Cutting the loops for 146 MHz provides satisfactory performance across the entire 144MHz band.

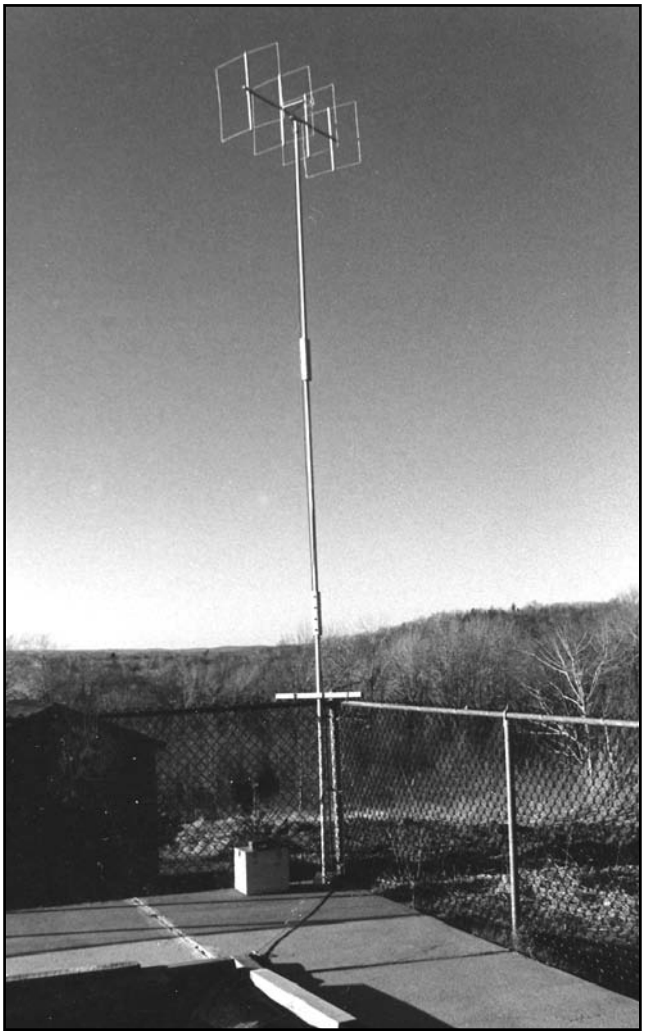

Fig 56—The 4-element 144-MHz portable quad, assembled and ready for operation. Sections of clothes closet poles joined with pine strips make up the mast. (*Photo by Adwin Rusczek, W1MPO)*

Materials

The quad was designed for quick and easy assembly and disassembly, as illustrated in **Fig 57**. Wood (clear trim pine) was chosen as the principal building material because of its light weight, low cost, and ready availability. Pine is used for the boom and element supporting arms. Round wood clothes closet poles comprise the mast material. Strips connecting the mast sections are made of heavier pine trim. Elements are made of no. 8 aluminum wire. Plexiglas is used to support the feed point. **Table 17** lists the hardware and other parts needed to duplicate the quad.

Construction

The elements of the quad are assembled first. The mounting holes in the boom should be drilled to accommodate 1$\frac{1}{2}$ inch no. 8 hardware. Measure and mark the locations where the holes are to be drilled in the element spreaders, **Fig 58**. Drill the holes in the spreaders just

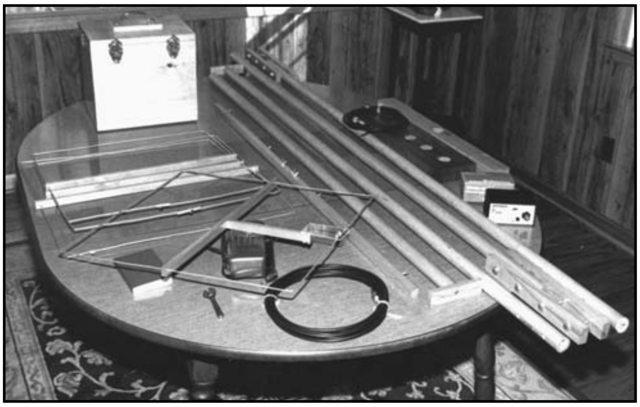

Fig 57—The complete portable quad, broken down for travel. Visible in the foreground is the driven element. The pine box in the background is a carrying case for equipment and accessories. A hole in the lid accepts the mast, so the box doubles as a base for a short mast during portable operation. *(W1MPO photo*)

Table 17
Parts List for the 144 MHz 4-element Quad

Boom: ¾ × ¾ ×48-in. pine
Driven element support (spreader):
  ½ × ¾ × 21¼ in. pine
Driven element feed point strut: ½ × ¾ × 7½ in. pine
Reflector support (spreader): ½ × ¾ × 22½ in. pine
Director supports (spreaders):
  ½ × ¾ × 20¼ in. pine, 2 req'd
Mast brackets: ¾ × 1½ × 12 in. heavy pine trim, 4 req'd
Boom to mast bracket: ½ × 1$\frac{5}{8}$ × 5 in. pine
Element wire: Aluminum ground wire
  (Radio Shack no. 15-035)
Wire clamps: ¼in. electrician's copper or zinc plated
  steel clamps, 3 req'd
Boom hardware:
  6 no. 8-32 × 1½ in. stainless steel machine screws
  6 no. 8-32 stainless steel wing nuts
  12 no. 8 stainless steel washers
Mast hardware:
  8 hex bolts, ¼-20 × 3½ in.
  8 hex nuts, ¼-20
  16 flat washers
Mast material: 1$\frac{5}{16}$ in. × 6 ft wood clothes closet poles,
  3 req'd
Feed point support plate: 3½ × 2½ in. Plexiglas sheet
Wood preparation materials:
  Sandpaper, clear polyurethane, wax
Feed line: 52-W RG-8 or RG-58 cable
Feed line terminals: Solder lugs for no. 8 or larger
  hardware, 2 req'd
Miscellaneous hardware:
  4 small machine screws, nuts, washers; 2 flat-head
  wood screws

large enough to accept the #8 wire elements. It is important to drill all the holes straight so the elements line up when the antenna is assembled.

Construction of the wire elements is easiest if the directors are made first. A handy jig for bending the elements can be made from a piece of 2 × 3-inch wood cut to the side length of the directors. It is best to start with about 82 inches of wire for each director. The excess can be cut off when the elements are completed. (The total length of each director is 77 inches.) Two bends should initially be made so the directors can be slipped into the spreaders before the remaining corners are bent. See **Fig 59**. Electrician's copper-wire clamps can be used to join the wires after the final bends are made, and they facilitate adjustment of element length. The reflector is made the same way as the directors, but the total length is 86 inches.

The driven element, total length 81 inches, requires special attention, as the feed attachment point needs to be adequately supported. An extra hole is drilled in the driven element spreader to support the feed-point strut, as shown in **Fig 60**. A Plexiglas plate is used at the feed point to support the feed- point hardware and the feed line. The feed-point support strut should be epoxied to the spreader, and a wood screw used for extra mechanical strength.

For vertical polarization, locate the feed point in the center of one side of the driven element, as shown in Fig 60. Although this arrangement places the spreader supports at voltage maxima points on the four loop conductors, D'Agostino reports no adverse effects during operation. However, if the antenna is to be left exposed to the weather, the builder may wish to modify the design to provide support for the loops at current maxima points, such as shown in Fig 60. (The element of Fig 60 should be rotated 90° for horizontal polarization.)

Orient the driven element spreader so that it mounts properly on the boom when the antenna is assembled. Bend the driven element the same way as the reflector and directors, but do not leave any overlap at the feed point. The ends of the wires should be $^{3}/_{4}$ inch apart where they mount on the Plexiglas plate. Leave enough excess that small loops can be bent in the wire for attachment to the coaxial feed line with stainless steel hardware.

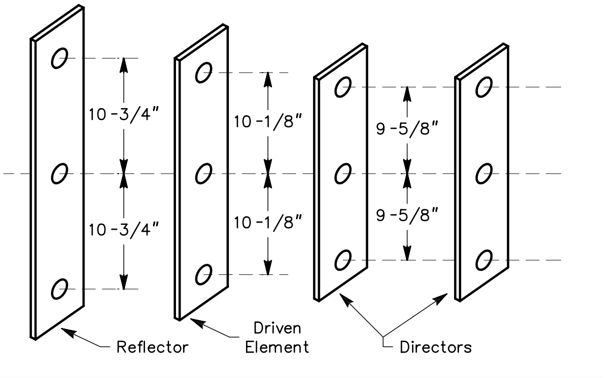

Fig 58—Dimensions for the pine element spreaders for the 144-MHz 4-element quad.

Drill the boom as shown in **Fig 61**. It is a good idea to use hardware with wing nuts to secure the element spreaders to the boom. After the boom is drilled, clean all the wood parts with denatured alcohol, sand them, and give them two coats of glossy polyurethane. After the polyurethane dries, wax all the wooden parts.

The boom to mast attachment is made next. Square the ends of a 6-foot section of clothes closet pole (a miter box is useful for this). Drill the center holes in both the boom

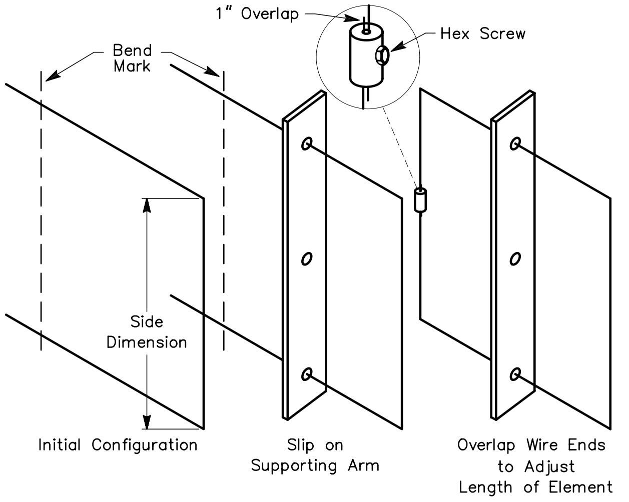

Fig 59—Illustration showing how the aluminum element wires are bent. The adjustment clamp and its location are also shown.

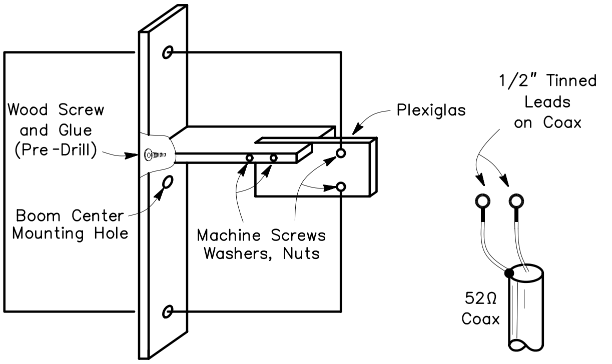
Wood Screw and Glue (Pre-Drill)
Boom Center Mounting Hole
Plexiglas
Machine Screws Washers, Nuts
1/2" Tinned Leads on Coax
52Ω Coax

Fig 60—Layout of the driven element of the 144-MHz quad. The leads of the coaxial cable should be stripped to ½ in. and solder lugs attached for easy connection and disconnection. See text regarding impedance at loop support points.

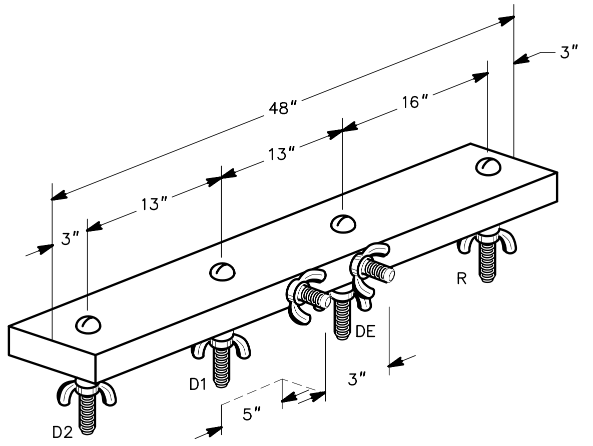

Fig 61—Detail of the boom showing hole center locations and boom to mast connection points.

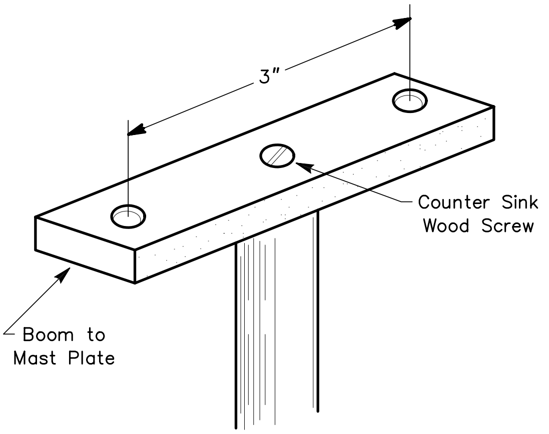

Fig 62—Boom to mast plate for the 144-MHz quad. The screw hole in the center of the plate should be countersunk so the wood screw attaching it to the mast does not interfere with the fit of the boom.

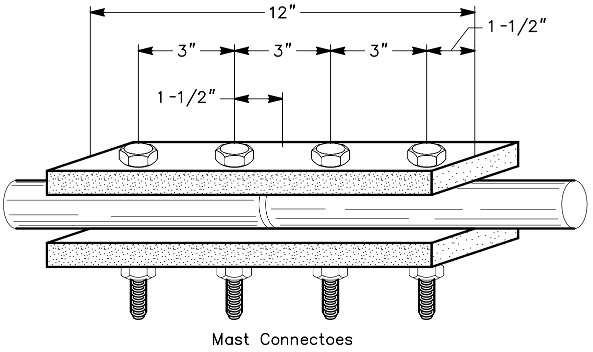

Fig 63—Mast coupling connector details for the portable quad. The plates should be drilled two at a time to ensure the holes line up.

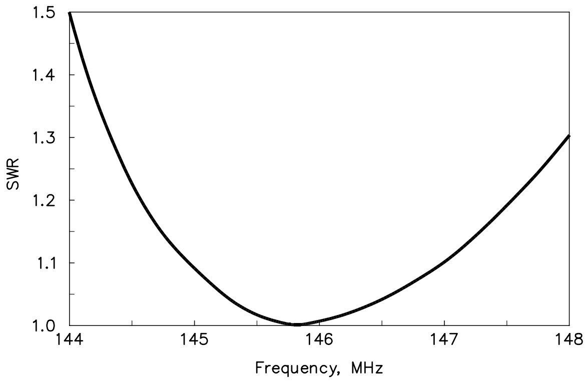

Fig 64—Typical SWR curve for the 144MHz portable quad. The large wire diameter and the quad design provide excellent bandwidth.

attachment piece and one end of the mast section (**Fig 62**). Make certain that the mast hole is smaller than the flat-head screw to be used to ensure a snug fit. Accurately drill the holes for attachment to the boom as shown in Fig 62.

Countersink the hole for the flat-head screw to provide a smooth surface for attachment to the boom. Apply epoxy cement to the surfaces and screw the boom attachment piece securely to the mast section. One 6 foot mast is used for attachment to the other mast sections.

Two additional 6-foot mast sections are prepared next. This brings the total mast height to 18 feet. It is important to square the ends of each pole so the mast stands straight when assembled. Mast-section connectors are made of pine as shown in **Fig 63**. Using $3^{1}/_{2} \times {}^{1}/_{4}$-inch hex bolts, washers, and nuts, sections may be attached as needed, for a total height of 6, 12 or 18 feet. Drill the holes in two connectors at a time. This ensures good alignment of the holes. A drill press is ideal for this job, but with care a hand drill can be used if necessary.

Line up two mast sections end to end, being careful that they are perfectly straight. Use the predrilled connectors to maintain pole straightness, and drill through the poles, one at a time. If good alignment is maintained, a straight 18-foot mast section can be made. Label the connectors and poles immediately so they are always assembled in the same order.

When assembling the antenna, install all the elements on the boom before attaching the feed line. Connect the coax to the screw connections on the driven element support plate and run the cable along the strut to the boom. From there, the cable should be routed directly to the mast and down. Assemble the mast sections to the desired height. The antenna provides good performance, and has a reasonable SWR curve over the entire 144 MHz band (**Fig 64**).

Building Quagi Antennas

The Quagi antenna was designed by Wayne Overbeck, N6NB. He first published information on this antenna in 1977 (see Bibliography). There are a few tricks to Quagi building, but nothing very difficult or complicated is involved. In fact, Overbeck mass produced as many as 16 in one day. **Tables 18** and **19** give the dimensions for Quagis for various frequencies up to 446 MHz.

For the designs of Tables 18 and 19, the boom is *wood* or any other nonconductor (such as, fiberglass or Plexiglas). If a metal boom is used, a new design and new element lengths will be required. Many VHF antenna builders go wrong by failing to follow this rule: If the original uses a metal boom, use the same size and shape metal boom when you duplicate it. If it calls for a wood boom, use a nonconductor. Many amateurs dislike wood booms, but in a salt air environment they outlast aluminum (and surely cost less). Varnish the boom for added protection.

The 144-MHz version is usually built on a 14 foot, 1 × 3 inch boom, with the boom tapered to 1 inch at both ends. Clear pine is best because of its light weight, but construction grade Douglas fir works well. At 222 MHz the boom is under 10 feet long, and most builders use 1 × 2 or (preferably) $\frac{3}{4}$ × 1$\frac{1}{4}$ inch pine molding stock. At 432 MHz, except for long-boom versions, the boom should be $\frac{1}{2}$ inch thick or less. Most builders use strips of $\frac{1}{2}$-inch exterior plywood for 432 MHz.

The quad elements are supported at the current maxima (the top and bottom, the latter beside the feed point) with Plexiglas or small strips of wood. See **Fig 65**. The quad elements are made of #12 copper wire, commonly used in house wiring. Some builders may elect to use #10 wire on 144 MHz and #14 on 432 MHz, although this changes the resonant frequency slightly. Solder a type N connector (an SO-239 is often used at 144 MHz) at the midpoint of the driven element bottom side, and close the reflector loop.

Table 19
432MHz, 15-Element, Long Boom Quagi Construction Data

Element Lengths, Inches	*Interelement Spacing, Inches*
R—28	R-DE7
DE—26$\frac{5}{8}$	DE-D1—5$\frac{1}{4}$
D1—11$\frac{3}{4}$	D1-D2—11
D21—$\frac{11}{16}$	D2-D3—5$\frac{7}{8}$
D3—11$\frac{5}{8}$	D3-D4—8$\frac{3}{4}$
D4—11$\frac{9}{16}$	D4-D5—8$\frac{3}{4}$
D5—11$\frac{1}{2}$	D5-D6—8$\frac{3}{4}$
D6—11$\frac{7}{16}$	D6-D7—12
D7—11$\frac{3}{8}$	D7-D8—12
D8—11$\frac{5}{16}$	D8-D9—11$\frac{1}{4}$
D9—11$\frac{5}{16}$	D9-D10—11$\frac{1}{2}$
D10—11$\frac{1}{4}$	D10-D11—9$\frac{3}{16}$
D11—11$\frac{3}{16}$	D11-D12—12$\frac{3}{8}$
D12—11$\frac{1}{8}$	D12-D13—1-$\frac{3}{4}$
D13—11$\frac{1}{16}$	

Boom: 1 × 2in. × 12-ft Douglas fir, tapered to $\frac{5}{8}$ in. at both ends.
Driven element: #12 TW copper wire loop in square configuration, fed at bottom center with type N connector and 52-Ω coax.
Reflector: #12 TW copper wire loop, closed at bottom.
Directors: $\frac{1}{8}$ in. rod passing through boom.

Table 18
Dimensions, Eight-Element Quagi

Element			*Frequency*		
Lengths	*144.5 MHz*	*147 MHz*	*222 MHz*	*432 MHz*	*446 MHz*
Reflector[1]	86$\frac{5}{8}$"	85"	56$\frac{3}{8}$"	28"	27$\frac{1}{8}$"
Driven[2]	82"	80"	53½"	26$\frac{5}{8}$"	25$\frac{7}{8}$"
Directors	35$\frac{15}{16}$" to 35" in $\frac{3}{16}$" steps	35$\frac{5}{16}$" to 34$\frac{3}{8}$" in $\frac{3}{16}$" steps	23$\frac{3}{8}$" to 23¾" in $\frac{1}{8}$" steps	11¾" to 11$\frac{7}{16}$" in $\frac{1}{16}$" steps	11$\frac{3}{8}$" to 11$\frac{1}{16}$" in $\frac{1}{16}$" steps
Spacing					
R-DE	21"	20½"	13$\frac{5}{8}$"	7"	6.8"
DE-D1	15¾"	15$\frac{3}{8}$"	10¼"	5¼"	5.1"
D1-D2	33"	32½"	21½"	11"	10.7"
D2-D3	17½"	17$\frac{1}{8}$"	11$\frac{3}{8}$"	5.85"	5.68"
D3-D4	26.1"	25$\frac{5}{8}$"	17"	8.73"	8.46"
D4-D5	26.1"	25$\frac{5}{8}$"	17"	8.73"	8.46"
D5-D6	26.1"	25$\frac{5}{8}$"	17"	8.73"	8.46"
Stacking Distance Between Bays	11'	10' 10"	7' 1½"	3'7"	3' 5$\frac{5}{8}$"

[1] All #12 TW (electrical) wire, closed loops.
[2] All #12 TW wire loops, fed at bottom.

The directors are mounted through the boom. They can be made of almost any metal rod or wire of about $^1/_8$-inch diameter. Welding rod or aluminum clothesline wire works well if straight. (The designer uses $^1/_8$-inch stainless-steel rod obtained from an aircraft surplus store.)

A TV type U bolt mounts the antenna on a mast. A single machine screw, washers and a nut are used to secure the spreaders to the boom so the antenna can be quickly "flattened" for travel. In permanent installations two screws are recommended.

Construction Reminders

Based on the experiences of Quagi builders, the following hints are offered. First, remember that at 432 MHz even a $^1/_8$-inch measurement error results in performance deterioration. Cut the loops and elements as carefully as possible. No precision tools are needed, but accuracy is necessary. Also make sure to get the elements in the right order. The longest director goes closest to the driven element.

Finally, remember that a balanced antenna is being fed with an unbalanced line. Every balun the designer tried introduced more trouble in terms of losses than the feed imbalance caused. Some builders have tightly coiled several turns of the feed line near the feed point to limit line radiation. In any case, the feed line should be kept at right angles to the antenna. Run it from the driven element directly to the supporting mast and then up or down perpendicularly for best results.

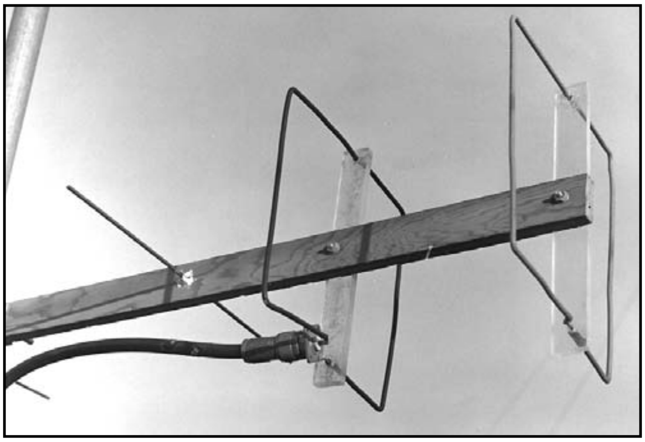

Fig 65—A close-up view of the feed method used on a 432-MHz Quagi. This arrangement produces a low SWR and gain in excess of 13 dBi with a 4-ft 10-in. boom! The same basic arrangement is used on lower frequencies, but wood may be substituted for the Plexiglas spreaders. The boom is ½-in. exterior plywood.

QUAGIS FOR 1296 MHz

The Quagi principle has recently been extended to the 1296-MHz band, where good performance is extremely difficult to obtain from homemade conventional Yagis. **Fig 66** shows the construction and **Table 20** gives the design information for antennas with 10, 15 and 25 elements.

At 1296 MHz, even slight variations in design or building materials can cause substantial changes in performance. The 1296 MHz antennas described here work every time—but only if the same materials are used and the antennas are built *exactly* as described. This is not to discourage experimentation, but if modifications to these 1296-MHz antenna designs are contemplated, consider building one antenna as described here, so a reference is available against which variations can be compared.

The Quagis (and the cubical quad) are built on $^1/_4$-inch thick Plexiglas booms. The driven element and reflector (and also the directors in the case of the cubical quad) are made of insulated #18 AWG solid copper bell wire, available at hardware and electrical supply stores. Other types and sizes of wire work equally well, but the dimensions vary with the wire diameter. Even removing the insulation usually necessitates changing the loop lengths.

Quad loops are approximately square (**Fig 67**), although the shape is relatively uncritical. The element lengths, however, *are* critical. At 1296 MHz, variations

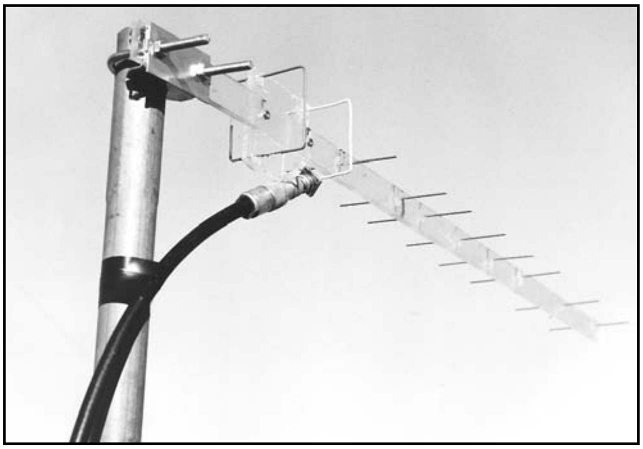

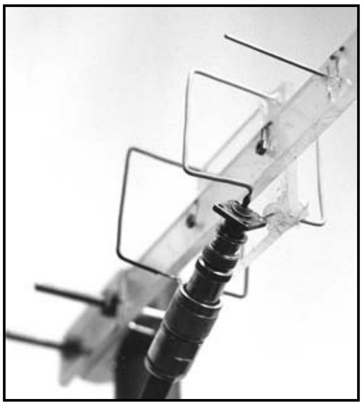

Fig 66—A view of the 10-element version of the 1296-MHz Quagi. It is mounted on a 30-in. Plexiglas boom with a 3 × 3-in. square of Plexiglas to support the driven element and reflector. Note how the driven element is attached to a standard UG-290 BNC connector. The elements are held in place with silicone sealing compound.

of $^{1}/_{16}$ inch alter the performance measurably, and a $^{1}/_{8}$ inch departure can cost several decibels of gain. The loop lengths given are *gross* lengths. Cut the wire to these lengths and then solder the two ends together. There is a $^{1}/_{8}$-inch overlap where the two ends of the reflector (and director) loops are joined, as shown in Fig 67.

The driven element is the most important of all. The #18 wire loop is soldered to a standard UG-290 chassis-mount BNC connector as shown in the photographs. This exact type of connector must be used to ensure uniformity in construction. Any substitution may alter the driven element electrical length. One end of the 9$^{1}/_{4}$ inch driven loop is pushed as far as it can go into the center pin, and is soldered in that position. The loop is then shaped and threaded through small holes drilled in the Plexiglas support. Finally, the other end is fed into one of the four mounting holes on the BNC connector and soldered. In most cases, the best SWR is obtained if the end of the wire just passes through the hole so it is flush with the opposite side of the connector flange.

Table 20

Dimensions, 1296-MHz Quagi Antennas

Note: All lengths are gross lengths. See text and photos for construction technique and recommended overlap at loop junctions. All loops are made of #18 AWG solid-covered copper bell wire. The Yagi type directors are $^{1}/_{16}$-in. brass brazing rod. See text for a discussion of director taper.

Feed: Direct with 52-Ω coaxial cable to UG-290 connector at driven element; run coax symmetrically to mast at rear of antenna.

Boom: 1$^{1}/_{4}$-in. thick Plexiglas, 30 in. long for 10-element quad or Quagi and 48 in. long for 15-element Quagi; 84 in. for 25-element Quagi.

10-Element Quagi for 1296 MHz

Element	*Length, Inches*	*Construction*	*Element*	*Interelement Spacing, In.*
Reflector	9.5625	Loop	R-DE	2.375
Driven	9.25	Loop	DE-D1	2.0
Director 1	3.91	Brass rod	D1-D2	3.67
Director 2	3.88	Brass rod	D2-D3	1.96
Director 3	3.86	Brass rod	D3-D4	2.92
Director 4	3.83	Brass rod	D4-D5	2.92
Director 5	3.80	Brass rod	D5-D6	2.92
Director 6	3.78	Brass rod	D6-D7	4.75
Director 7	3.75	Brass rod	D7-D8	3.94
Director 8	3.72	Brass rod		

15-Element Quagi for 1296 MHz

The first 10 elements are the same lengths as above, but the spacing from D6 to D7 is 4.0 in.; 07 to D8 is also 4.0 in.

Director 9	3.70	D8-D9	3.75
Director 10	3.67	D9-D10	3.83
Director 11	3.64	D10-D11	3.06
Director 12	3.62	D11-D12	4.125
Director 13	3.59	D12-D13	4.58

25-Element Quagi for 1296 MHz

The first 15 elements use the same element lengths and spacings as the 15-element model. The additional directors are evenly spaced at 3.0-in. intervals and taper in length successively by 0.02 in. per element. Thus, D23 is 3.39 in.

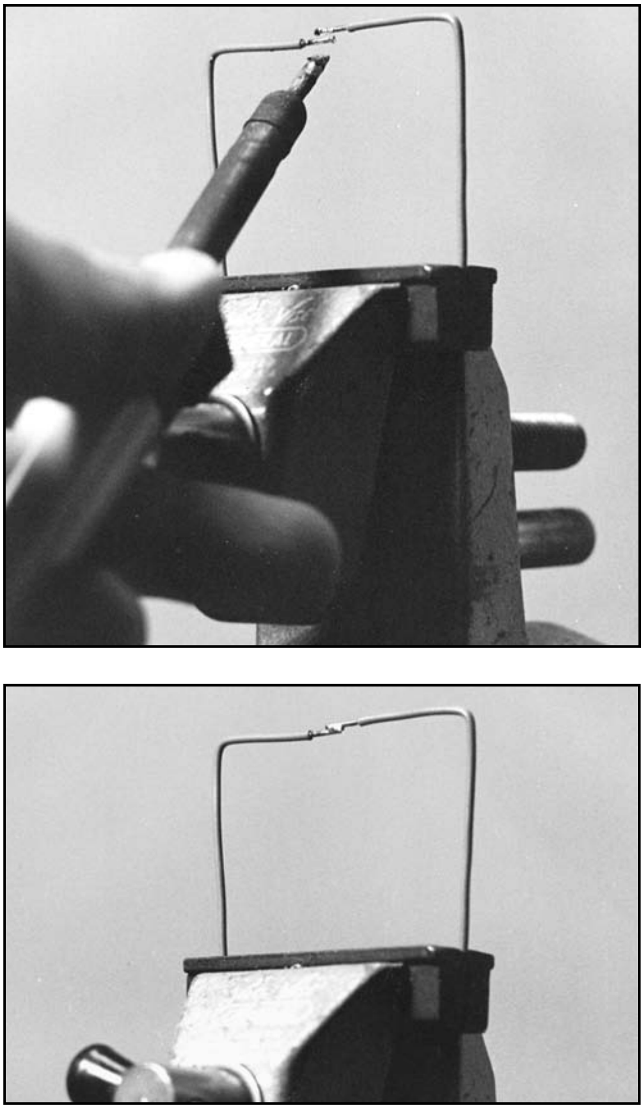

Fig 67—These photos show the construction method used for the 1296-MHz quad type parasitic elements. The two ends of the #18 bell wire are brought together with an overlap of $^{1}/_{8}$ in. and soldered.

Loop Yagis for 1296 MHz

Described here are loop Yagis for the 1296-MHz band. The loop Yagi fits into the quad family of antennas, as each element is a closed loop with a length of approximately 1 λ. Several versions are described, so the builder can choose the boom length and frequency coverage desired for the task at hand. Mike Walters, G3JVL, brought the original loop-Yagi design to the amateur community in the 1970s. Since then, many versions have been developed with different loop and boom dimensions. Chip Angle, N6CA, developed the antennas shown here.

Three sets of dimensions are given. Good performance can be expected if the dimensions are carefully followed. Check all dimensions before cutting or drilling anything. The 1296-MHz version is intended for weak-signal operation, while the 1270-MHz version is optimized for FM and mode L satellite work. The 1283-MHz antenna provides acceptable performance from 1280 to 1300 MHz.

These antennas have been built on 6- and 12-foot booms. Results of gain tests at VHF conferences and by individuals around the country show the gain of the 6-foot model to be about 18 dBi, while the 12-foot version provides about 20.5 dBi. Swept measurements indicate that gain is about 2 dB down from maximum gain at ±30 MHz from the design frequency. The SWR, however, deteriorates within a few megahertz on the low side of the design center frequency.

The Boom

The dimensions given here apply only to a ¾-inch OD boom. If a different boom size is used, the dimensions must be scaled accordingly. Many hardware stores

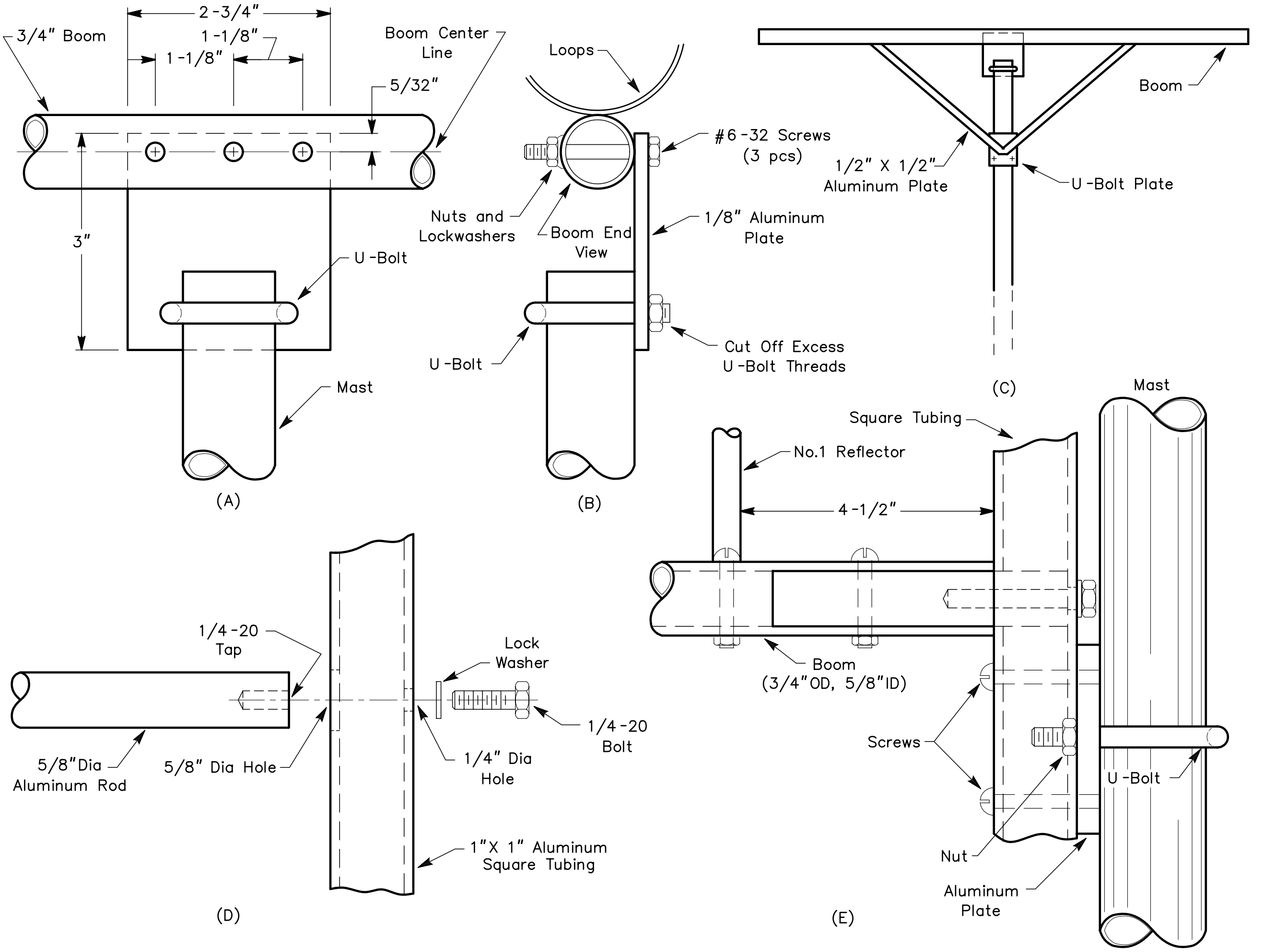
3/4" Boom
2-3/4"
1-1/8"
1-1/8"
5/32"
Boom Center Line
3"
U-Bolt
Mast
(A)
Loops
#6-32 Screws (3 pcs)
Nuts and Lockwashers
Boom End View
1/8" Aluminum Plate
U-Bolt
Cut Off Excess U-Bolt Threads
(B)
Boom
1/2" X 1/2" Aluminum Plate
U-Bolt Plate
(C)
1/4-20 Tap
Lock Washer
1/4-20 Bolt
5/8"Dia Aluminum Rod
5/8" Dia Hole
1/4" Dia Hole
1"X 1" Aluminum Square Tubing
(D)
Mast
Square Tubing
No.1 Reflector
4-1/2"
Boom (3/4"OD, 5/8"ID)
Screws
U-Bolt
Nut
Aluminum Plate
(E)

Fig 68—Loop Yagi boom-to-mast plate details are given at A. At B, the mounting of the antenna to the mast is detailed. A boom support for long antennas is shown at C. The arrangement shown in D and E may be used to rear-mount antennas up to 6 or 7 ft long.

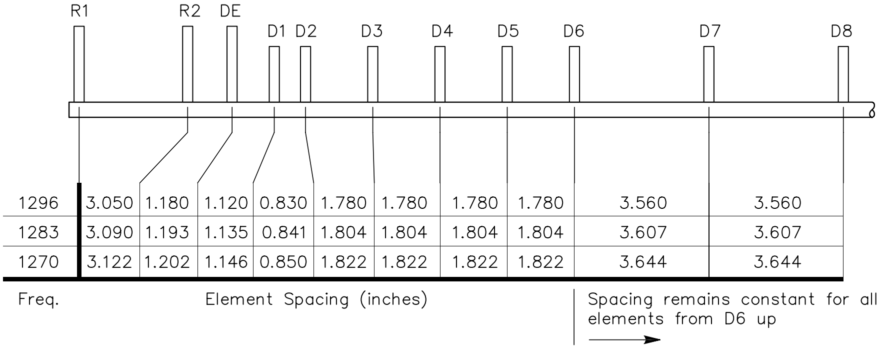

Freq.	Element Spacing (inches)									
1296	3.050	1.180	1.120	0.830	1.780	1.780	1.780	1.780	3.560	3.560
1283	3.090	1.193	1.135	0.841	1.804	1.804	1.804	1.804	3.607	3.607
1270	3.122	1.202	1.146	0.850	1.822	1.822	1.822	1.822	3.644	3.644

Spacing remains constant for all elements from D6 up

Fig 69—Boom drilling dimensions. These dimensions must be carefully followed and the same materials used if performance is to be optimum. Element spacings are the same for all directors after D6—use as many as necessary to fill the boom.

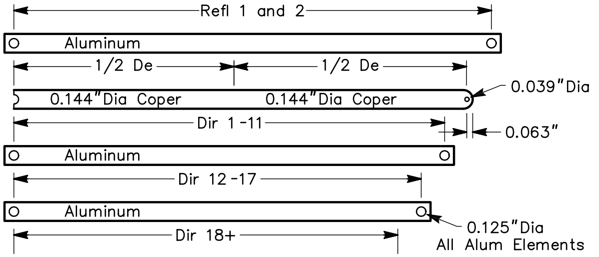

Freq	1270	1283	1296
Refl 1,2	9.929	9.829	9.700
1/2 De	4.752	4.704	4.643
Dir 1-11	8.445	8.359	8.250
Dir 12-17	8.189	8.106	8.000
Dir 18+	7.882	7.802	7.700

Element Lengths (Inches)
(Hole to Hole)

These Dimensions Apply Only to:
0.250" Element Width
0.0325" Element Thickness
0.750" Diaeter Boom

NOTE: All Dimensions are in Inches

Fig 70—Parasitic elements for the loop Yagi are made from aluminum sheet, the driven element from copper sheet. The dimensions given are for ¼-in. wide by 0.0325-in. thick elements only. Lengths specified are hole to hole distances; the holes are located $^1/_8$ in. from each element end.

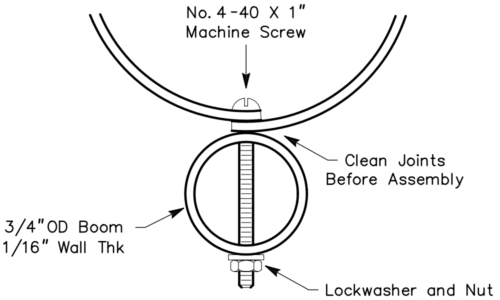

Fig 71—Element-to-boom mounting details.

carry aluminum tubing in 6- and 8-foot lengths, and that tubing is suitable for a short Yagi. If a 12-foot antenna is planned, find a piece of more rugged boom material, such as 6061-T6 grade aluminum. Do not use anodized tubing. The 12foot antenna must have additional boom support to minimize boom sag. The 6 foot version can be rear mounted. For rear mounting, allow $4^1/_2$ inches of boom behind the last reflector to eliminate SWR effects from the support.

The antenna is attached to the mast with a gusset plate. This plate mounts at the boom center. See **Fig 68**. Drill the plate mounting holes perpendicular to the element mounting holes (assuming the antenna polarization is to be horizontal).

Elements are mounted to the boom with no. 4-40 machine screws, so a series of no. 33 (0.113inch) holes must be drilled along the center of the boom to accommodate this hardware. **Fig 69** shows the element spacings for different parts of the band. Dimensions should be followed as closely as possible.

Parasitic Elements

The reflectors and directors are cut from 0.032-inch thick aluminum sheet and are $^1/_4$ inch wide. **Fig 70** indicates the lengths for the various elements. These lengths apply only to elements cut from the specified material. For best results, the element strips should be cut with a shear. If the edges are left sharp, birds won't sit on the elements.

Drill the mounting holes as shown in Fig 70 after carefully marking their locations. After the holes are drilled, form each strap into a circle. This is easily done by wrapping the element around a round form. (A small juice can works well.)

Mount the loops to the boom with no. 4-40 × 1-inch machine screws, lock washers and nuts. See **Fig 71**. It is best to use only stainless steel or plated-brass hardware. Although the initial cost is higher than for ordinary plated-steel hardware, stainless or brass hardware will not rust and need replacement after a few years. Unless the antenna is painted, the hardware will definitely deteriorate.

Driven Element

The driven element is cut from 0.032-inch copper sheet and is $^1/_4$ inch wide. Drill three holes in the strap as detailed in Fig 69. Trim the ends as shown and form the strap into a loop similar to the other elements. This antenna is like a quad; if the loop is fed at the top or bottom, it is horizontally polarized.

Driven element mounting details are shown in **Fig 72**. A mounting fixture is made from a $^1/_4$-20 × $1^1/_4$ inch brass bolt. File the bolt head to a thickness of $^1/_8$ inch. Bore a 0.144-inch (no. 27 drill) hole lengthwise through the center of the bolt. A piece of 0.141 inch semi-rigid Hardline (UT-141 or equivalent) mounts through this hole and is soldered to the driven loop feed point. The point at which the UT-141 passes through the copper loop and brass mounting fixture should be left unsoldered at this time to allow for matching adjustments when the antenna is completed, although the range of adjustment is not very large.

The UT-141 can be any convenient length. Attach the connector of your choice (preferably type N). Use a short piece of low-loss RG-8 size cable (or $^1/_2$-inch Hardline) for the run down the boom and mast to the main feed line. For best results, the main feed line should be the lowest loss 50-Ω cable obtainable. Good $^7/_8$-inch Hardline has 1.5 dB of loss per 100 feet and virtually eliminates the need for remote mounting of the transmit converter or amplifier.

Tuning the Driven Element

If the antenna is built carefully to the dimensions given, the SWR should be close to 1:1. Just to be sure, check the SWR if you have access to test equipment. Be sure the signal source is clean, however; wattmeters respond to “dirty” signals and can give erroneous readings. If problems are encountered, recheck all dimensions. If they look good, a minor improvement may be realized by changing the shape of the driven element. Slight bending of reflector 2 may also improve the SWR. When the desired match has been obtained, solder the point where the UT-141 jacket passes through the loop and brass bolt.

Tips for 1296-MHz Antenna Installations

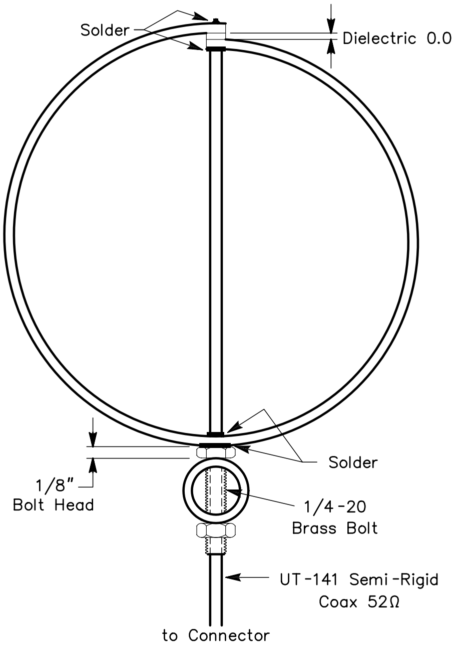

Fig 72—Driven-element details. See Fig 70 and the text for additional information.

Construction practices that are common on lower frequencies cannot be used on 1296 MHz. This is the most important reason why all who venture to these frequencies are not equally successful. First, when a proven design is used, copy it exactly¾don’t change *anything*. This is especially true for antennas.

Use the best feed line you can get. Here are some realistic measurements of common coaxial cables at 1296 MHz (loss per 100 feet).

RG-8, 213, 214: 11 dB
$^1/_2$ in. foam/copper Hardline: 4 dB
$^7/_8$ in. foam/copper Hardline: 1.5 dB

Mount the antennas to keep feed line losses to an absolute minimum. Antenna height is less important than keeping the line losses low. *Do not* allow the mast to pass through the elements, as is common on antennas for lower frequencies. Cut all U-bolts to the minimum length needed; $^1/_4$ λ at 1296 MHz is only a little over 2 inches. Avoid any unnecessary metal around the antenna.

Trough Reflectors for 432 and 1296 MHz

Dimensions are given in **Fig 73** for 432- and 1296-MHz trough reflectors. The gain to be expected is 16 dBi and 15 dBi, respectively. A very convenient arrangement, especially for portable work, is to use a metal hinge at each angle of the reflector. This permits the reflector to be folded flat for transit. It also permits experiments to be carried out with different apex angles.

A housing is required at the dipole center to prevent the entry of moisture and, in the case of the 432-MHz antenna, to support the dipole elements. The dipole may be moved in and out of the reflector to get either minimum SWR or, if this cannot be measured, maximum gain. If a two-stub tuner or other matching device is used, the dipole may be placed to give optimum gain and the matching device adjusted to give optimum match. In the case of the 1296-MHz antenna, the dipole length can be adjusted by means of the brass screws at the ends of the elements. Locking nuts are essential.

The reflector should be made of sheet aluminum for 1296 MHz, but can be constructed of wire mesh (with twists parallel to the dipole) for 432 MHz. To increase the gain by 3 dB, a pair of these arrays can be stacked so the reflectors are barely separated (to prevent the formation of a slot radiator by the edges). The radiating dipoles must then be fed in phase, and suitable feeding and matching must be arranged. A two-stub tuner can be used for matching either a single- or double-reflector system.

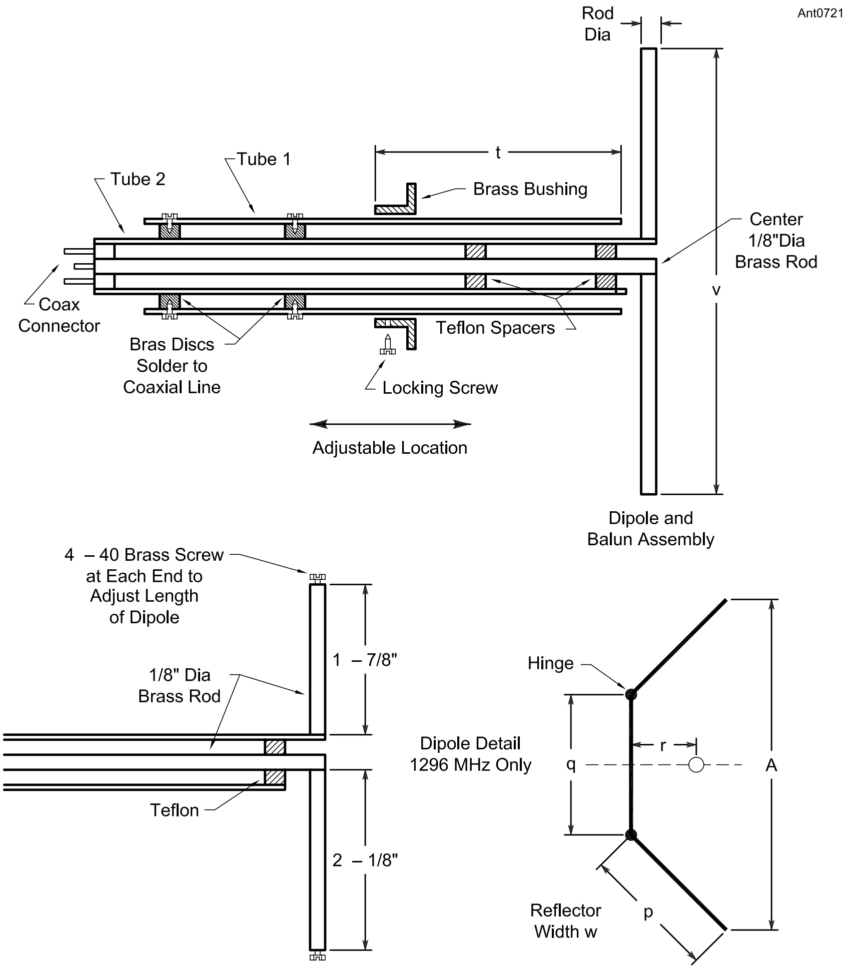
Ant0721
Rod Dia
Tube 1
Tube 2
t
Brass Bushing
Center 1/8"Dia Brass Rod
v
Coax Connector
Bras Discs Solder to Coaxial Line
Teflon Spacers
Locking Screw
Adjustable Location
Dipole and Balun Assembly
4 – 40 Brass Screw at Each End to Adjust Length of Dipole
1/8" Dia Brass Rod
1 – 7/8"
Teflon
2 – 1/8"
Dipole Detail 1296 MHz Only
Hinge
r
q
A
Reflector Width w
p

Dimensions in Inches

Band	A	p	q	r	w	t	u	v	Tube 1 Brass or Copper	Tube 2 Brass or Copper	Gain
432	120	100	50	7 – 1/2	60	6 – 1/2	1/4	12 – 3/4	1 – 1/2" ID 1/16" Wall	5/8" OD 1/16" Wall	16 dBi
1296	45	36	9 – 1/2	2 – 1/2	20	2 – 1/8	1/8	4 – 1/4	3/4" ID	3/8" OD 20 s.w.g.	15 dBi

Fig 73—Practical construction information for trough reflector antennas for 432 and 1296 MHz.

A Horn Antenna for 10 GHz

The horn antenna is the easiest antenna for the beginner on 10 GHz to construct. It can be made out of readily available flat sheet brass. Because it is inherently a broadband structure, minor constructional errors can be tolerated. The one drawback is that horn antennas become physically cumbersome at gains over about 25 dBi, but for most line-of-sight work this much gain is rarely necessary. This antenna was designed by Bob Atkins, KA1GT, and appeared in *QST* for April and May, 1987.

Horn antennas are usually fed by waveguide. When operating in its normal frequency range, waveguide propagation is in the TE_{10} mode. This means that the electric (E) field is across the short dimension of the guide and the magnetic (H) field is across the wide dimension. This is the reason for the E-plane and H-plane terminology shown in **Fig 74**.

There are many varieties of horn antennas. If the waveguide is flared out only in the H-plane, the horn is called an H-plane sectoral horn. Similarly, if the flare is only in the E-plane, an Eplane sectoral horn results. If the flare is in both planes, the antenna is called a pyramidal horn.

For a horn of any given aperture, directivity (gain along the axis) is maximum when the field distribution across the aperture is uniform in magnitude and phase. When the fields are not uniform, side lobes that reduce the directivity of the antenna are formed. To obtain a uniform distribution, the horn should be as long as possible with minimum flare angle. From a practical point of view, however, the horn should be as short as possible, so there is an obvious conflict between performance and convenience.

Fig 75 illustrates this problem. For a given flare angle and a given side length, there is a path-length difference from the apex of the horn to the center of the aperture (L), and from the apex of the horn to the edge of the aperture (L’). This causes a phase difference in the field across the aperture, which in turn causes formation of side lobes, degrading directivity (gain along the axis) of the antenna. If L is large this difference is small, and the field is almost uniform. As L decreases however, the phase difference increases and directivity suffers. An optimum (shortest possible) horn is constructed so that this phase difference is the maximum allowable before side lobes become excessive and axial gain markedly decreases.

The magnitude of this permissible phase difference is different for E-plane and H-plane horns. For the E-plane horn, the field intensity is quite constant across the aperture. For the H-plane horn, the field tapers to zero at the edge. Consequently, the phase difference at the edge of the aperture in the E-plane horn is more critical and should be held to less than 90° ($^1/_4$ λ). In an H-plane horn, the allowable phase difference is 144° (0.4 λ). If the aperture of a pyramidal horn exceeds one wavelength in both planes, the Eplane and Hplane patterns are essentially independent and can be analyzed separately.

The usual direction for orienting the waveguide feed is with the broad face horizontal, giving vertical polarization. If this is the case, the H-plane sectoral horn has a narrow horizontal beamwidth and a very wide vertical beamwidth. This is not a very useful beam pattern for most amateur applications. The E-plane sectoral horn has a narrow vertical beamwidth and a wide horizontal beamwidth. Such a radiation pattern could be useful in a beacon system where wide coverage is desired.

The most useful form of the horn for general applications is the optimum pyramidal horn. In this configuration the two beamwidths are almost the same. The E-plane (vertical) beamwidth is slightly less than the H-plane (horizontal), and also has greater side lobe intensity.

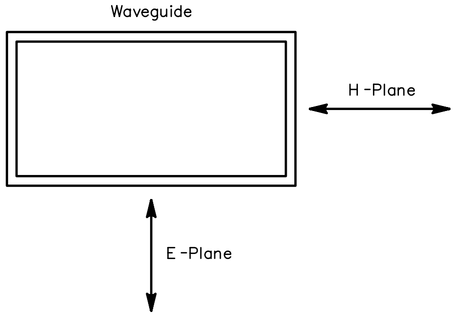

Fig 74—10-GHz antennas are usually fed with waveguide. See text for a discussion of waveguide propagation characteristics.

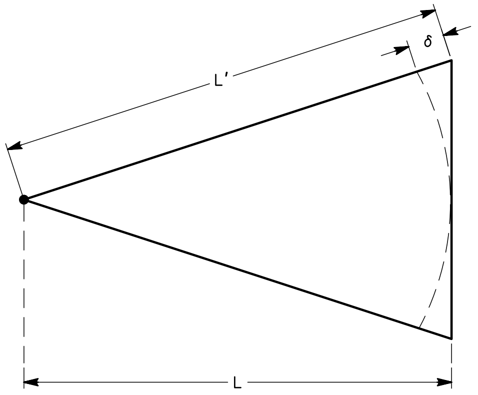

Fig 75—The path-length (phase) difference between the center and edge of a horn antenna is δ.

Building the Antenna

A 10-GHz pyramidal horn with 18.5 dBi gain is shown in **Fig 76**. The first design parameter is usually the required gain, or the maximum antenna size. These are of course related, and the relationships can be approximated by the following:

L = H-plane length (λ) = 0.0654 × gain (Eq 1)

A = H-plane aperture (λ) = 0.0443 × gain (Eq 2)

B = E-plane aperture (λ) = 0.81 A (Eq 3)

where

gain is expressed as a *ratio*; 20 dBi gain = 100

L, A and B are dimensions shown in **Fig 77.**

From these equations, the dimensions for a 20-dBi gain horn for 10.368 GHz can be determined. One wavelength at 10.368 GHz is 1.138 inches. The length (L) of such a horn is $0.0654 \times 100 = 6.54\ \lambda$. At 10.368 GHz, this is 7.44 inches. The corresponding H-plane aperture (A) is 4.43 λ (5.04 inches), and the E-plane aperture (B), 4.08 inches.

The easiest way to make such a horn is to cut pieces from brass sheet stock and solder them together. Fig 77 shows the dimensions of the triangular pieces for the sides and a square piece for the waveguide flange. (A standard commercial waveguide flange could also be used.) Because the E-plane and H-plane apertures are different, the horn opening is not square. Sheet thickness is unimportant; 0.02 to 0.03 inch works well. Brass sheet is often available from hardware or hobby shops.

Note that the triangular pieces are trimmed at the apex to fit the waveguide aperture (0.9 × 0.4 inch). This necessitates that the length, from base to apex, of the smaller triangle (side B) is shorter than that of the larger (side A). Note that the length, S, of the two different sides of the horn must be the same if the horn is to fit together! For such a simple looking object, getting the parts to fit together properly requires careful fabrication.

The dimensions of the sides can be calculated with simple geometry, but it is easier to draw out templates on a sheet of cardboard first. The templates can be used to build a mock antenna to make sure everything fits together properly before cutting the sheet brass.

First, mark out the larger triangle (side A) on cardboard. Determine at what point its width is 0.9 inch and draw a line parallel to the base as shown in Fig 77. Measure the length of the side S; this is also the length of the sides of the smaller (side B) pieces.

Mark out the shape of the smaller pieces by first drawing a line of length B and then constructing a second line of length S. One end of line S is an end of line B, and the other is 0.2 inch above a line perpendicular to the center of line B as shown in Fig 76. (This procedure is much more easily followed than described.) These smaller pieces are made slightly oversize (shaded area in Fig 77) so you can construct the horn with solder seams on the outside of the horn during assembly.

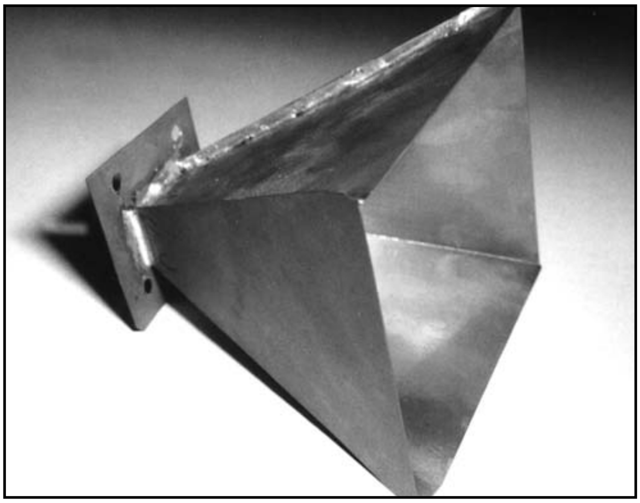

Fig 76—This pyramidal horn has 18.5 dBi gain at 10 GHz. Construction details are given in the text.

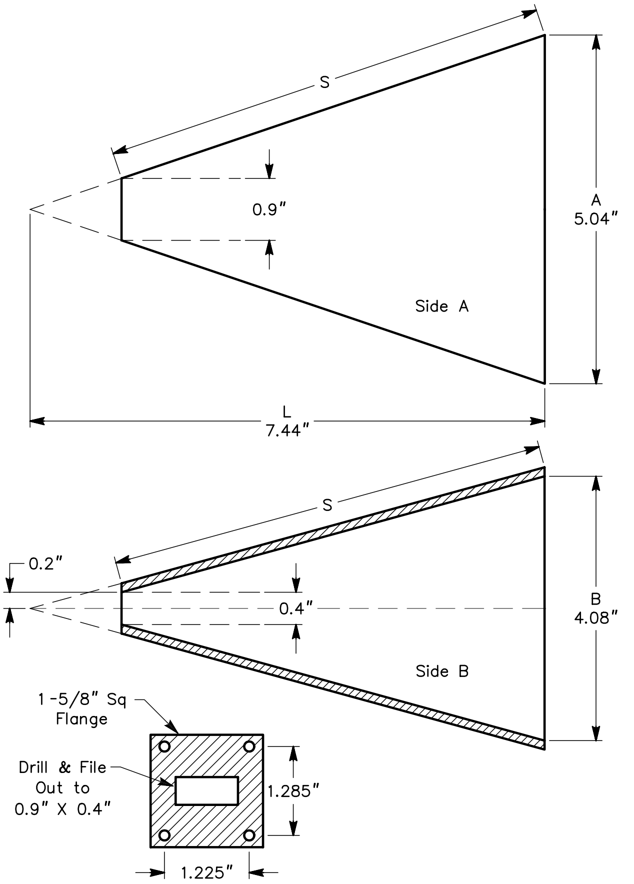

Fig 77—Dimensions of the brass pieces used to make the 10-GHz horn antenna. Construction requires two of each of the triangular pieces (side A and side B).

Cut out two cardboard pieces for side A and two for side B and tape them together in the shape of the horn. The aperture at the waveguide end should measure 0.9 × 0.4 inch and the aperture at the other end should measure 5.04 × 4.08 inches.

If these dimensions are correct, use the cardboard templates to mark out pieces of brass sheet. The brass sheet should be cut with a bench shear if one is available, because scissors type shears tend to bend the metal. Jig the pieces together and solder them on the *outside* of the seams. It is important to keep both solder and rosin from contaminating the inside of the horn; they can absorb RF and reduce gain at these frequencies.

Assembly is shown in **Fig 78**. When the horn is completed, it can be soldered to a standard waveguide flange, or one cut out of sheet metal as shown in Fig 77. The transition between the flange and the horn must be smooth. This antenna provides an excellent performance-to-cost ratio (about 20 dBi gain for about five dollars in parts).

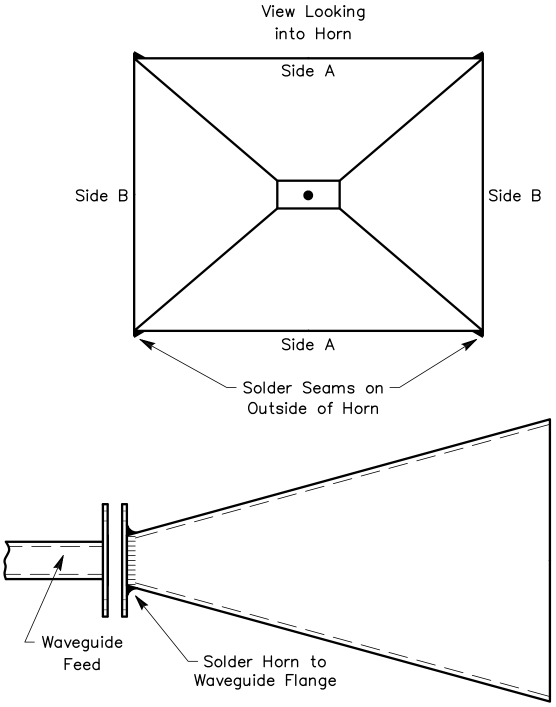
View Looking into Horn
Side A
Side B
Side B
Side A
Solder Seams on Outside of Horn
Waveguide Feed
Solder Horn to Waveguide Flange

Fig 78—Assembly of the 10-GHz horn antenna.

Periscope Antenna Systems

One problem common to all who use microwaves is that of mounting an antenna at the maximum possible height while trying to minimize feed-line losses. The higher the frequency, the more severe this problem becomes, as feeder losses increase with frequency. Because parabolic dish reflectors are most often used on the higher bands, there is also the difficulty of waterproofing feeds (particularly waveguide feeds). Inaccessibility of the dish is also a problem when changing bands. Unless the tower is climbed every time and the feed changed, there must be a feed for each band mounted on the dish. One way around these problems is to use a periscope antenna system (sometimes called a "flyswatter antenna").

The material in this section was prepared by Bob Atkins, KA1GT, and appeared in *QST* for January and February 1984. **Fig 79** shows a schematic representation of a periscope antenna system. A plane reflector is mounted at the top of a rotating tower at an angle of 45°. This reflector can be elliptical with a major to minor axis ratio of 1.41, or rectangular. At the base of the tower is mounted a dish or other type of antenna such as a Yagi, pointing straight up. The advantage of such a system is that the feed antenna can be changed and worked on easily. Additionally, with a correct choice of reflector size, dish size, and dish to reflector spacing, feed losses can be made small, increasing the effective system gain. In fact, for some particular system configurations, the gain of the overall system can be greater than that of the feed antenna alone.

Gain of a Periscope System

Fig 80 shows the relationship between the effective gain of the antenna system and the distance between the reflector and feed antenna for an elliptical reflector. At first sight, it is not at all obvious how the antenna system can have a higher gain than the feed alone. The reason lies in the fact that, depending on the feed to reflector spacing, the reflector may be in the near field (Fresnel) region of the antenna, the far field (Fraunhöffer) region, or the transition region between the two.

In the far field region, the gain is proportional to the reflector area and inversely proportional to the distance between the feed and reflector. In the near field region, seemingly strange things can happen, such as decreasing gain with decreasing feed to reflector separation. The reason for this gain decrease is that, although the reflec-

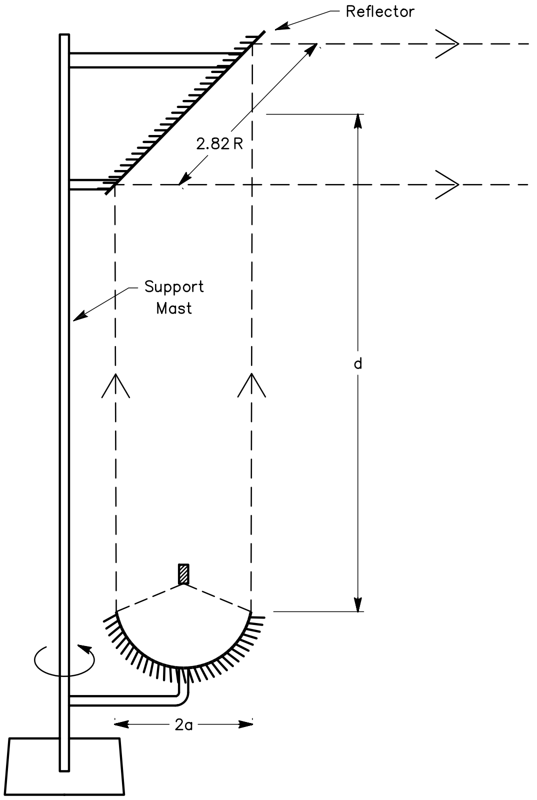

Fig 79—The basic periscope antenna. This design makes it easy to adjust the feed antenna.

tor is intercepting more of the energy radiated by the feed, it does not all contribute in phase at a distant point, and so the gain decreases.

In practice, rectangular reflectors are more common than elliptical. A rectangular reflector with sides equal in length to the major and minor axes of the ellipse will, in fact, normally give a slight gain increase. In the far field region, the gain will be proportional to the area of the reflector. To use Fig 80 with a rectangular reflector, R^2 may be replaced by A / π, where A is the projected area of the reflector. The antenna pattern depends in a complicated way on the system parameters (spacing and size of the elements), but **Table 21** gives an approximation of what to expect. R is the radius of the projected circular area of the elliptical reflector (equal to the minor axis radius), and b is the length of the side of the projected square area of the rectangular reflector (equal to the length of the short side of the rectangle).

For those wishing a rigorous mathematical analysis of this type of antenna system, several references are given in the Bibliography at the end of this chapter.

Mechanical Considerations

There are some problems with the physical construction of a periscope antenna system. Since the antenna gain of a microwave system is high and, hence, its beamwidth narrow, the reflector must be accurately aligned. If the reflector does not produce a beam that is horizontal, the

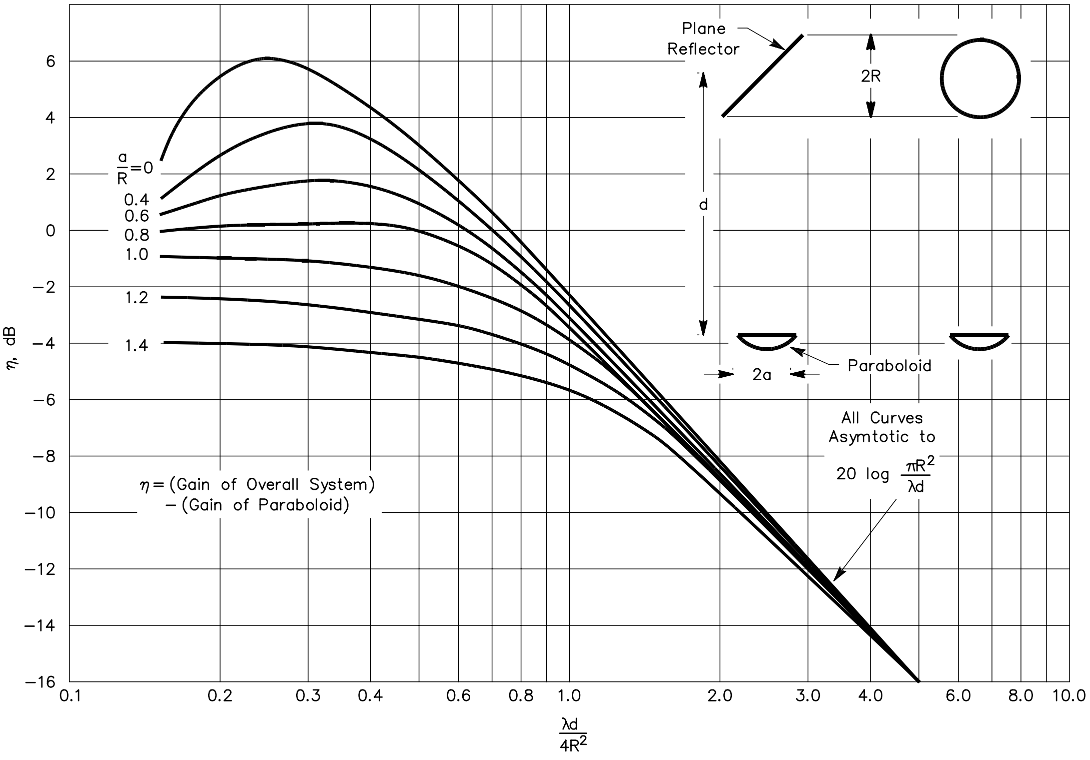

Fig 80—Gain of a periscope antenna using a plane elliptical reflector (after Jasik—see Bibliography).

Table 21

Radiation Patterns of Periscope Antenna Systems

	Elliptical Reflector	*Rectangular Reflector*
3-dB beamwidth, degrees	60 λ/2R	52 λ/b
6-dB beamwidth, degrees	82 λ/2R	68 λ/b
First minimum, degrees from axis	73 λ/2R	58 λ/b
First maximum, degrees from axis	95 λ/2R	84 λ/b
Second minimum, degrees from axis	130 λ/2R	116 λ/b
Second maximum, degrees from axis	156 λ/2R	142 λ/b
Third minimum, degrees from axis	185 λ/2R	174 λ/b

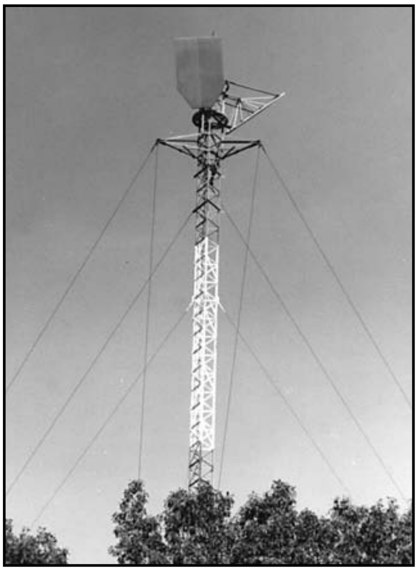

Fig 81—Commercial periscope antennas, such as this one, are often used for point-to-point communication.

useful gain of the system will be reduced. From the geometry of the system, an angular misalignment of the reflector of X degrees in the vertical plane will result in an angular misalignment of 2X degrees in the vertical alignment of the antenna system pattern. Thus, for a dish pointing straight up (the usual case), the reflector must be at an angle of 45° to the vertical and should not fluctuate from factors such as wind loading.

The reflector itself should be flat to better than $^{1}/_{10}$ λ for the frequency in use. It may be made of mesh, provided that the holes in the mesh are also less than $^{1}/_{10}$ λ in diameter. A second problem is getting the support mast to rotate about a truly vertical axis. If the mast is not vertical, the resulting beam will swing up and down from the horizontal as the system is rotated, and the effective gain at the horizon will fluctuate. Despite these problems, amateurs have used periscope antennas successfully on the bands through 10 GHz. Periscope antennas are used frequently in commercial service, though usually for point-to-point transmission. Such a commercial system is shown in **Fig 81**.

Circular polarization is not often used for terrestrial work, but if it is used with a periscope system there is an important point to remember. The circularity sense changes when the signal is reflected. Thus, for right hand circularity with a periscope antenna system, the feed arrangement on the ground should produce left hand circularity. It should also be mentioned that it is possible (though more difficult for amateurs) to construct a periscope antenna system using a parabolically curved reflector. The antenna system can then be regarded as an offset fed parabola. More gain is available from such a system at the added complexity of constructing a parabolically curved reflector, accurate to $^{1}/_{10}$ λ.

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Chapter 19

Antenna Systems for Space Communications

When we consider amateur space communications, we usually think about two basic modes: satellite and earth-moon-earth (EME—also referred to as *moonbounce*). At their essence, both modes communicate using one of the Earth's satellites—our natural satellite (the Moon) or one of a variety of manmade satellites.

There are two main differences between these satellites. The first is one of distance. The Moon is about 250,000 miles from Earth, while man-made satellites can be as far as 36,000 miles away. This 7:1 difference in distance makes a huge difference in the signals that arrive at the satellite, since transmission loss varies as the square of the distance. In other words, the signal arriving at the Moon is 20 dB weaker than that arriving at a geo-synchronous satellite 25,000 miles high, due to distance alone.

The second difference between the Moon and a man-made satellite is that the Moon is a *passive reflector*—and not a very good one at that, since it has a craggy and rather irregular surface, at least when compared to a flat mirror-like surface that would make an ideal reflector. Signals scattered by the Moon's irregular surface are thus weaker than for better reflecting surfaces. By comparison, a man-made satellite is an *active* system, where the satellite receives the signal coming from Earth, amplifies it and then retransmits the signal (usually at a different frequency) using a high-gain antenna. Think of a satellite as an ideal reflector, with gain.

The net result of these differences between a man-made satellite and the Earth's natural satellite is that moonbounce (EME) operation challenges the station builder considerably more than satellite operation, particularly in the area of antennas. Successful EME requires high transmitting power, superb receiver sensitivity and excellent operators capable of pulling weak signals out of the noise. This chapter will first explore antennas suitable for satellite operations and then describe techniques needed for EME work.

Common Ground

There are areas of commonality between satellite and EME antenna requirements, of course. Both require consideration of the effects of polarization and elevation angle, along with the azimuth directions of transmitted and received signals.

On the HF bands, signal polarization is generally of little concern, since the original polarization sense is lost after the signal passes through the ionosphere. At HF, vertical antennas receive sky-wave signals emanating from horizontal antennas, and vice versa. It is not beneficial to provide a means of varying the polarization at HF. With satellite communications, however, because of polarization changes, a signal that would disappear into the noise on one antenna may be S9 on one that is not sensitive to polarization direction. Elevation angle is also important from the standpoint of tracking and avoiding indiscriminate ground reflections that may cause nulls in signal strength.

Antennas for Satellite Work

We have amateur satellites providing links from 2 meters and up, and these provide opportunities to use antennas of many types—from the very simple to some pretty complex ones. This section was written by Dick Jansson, WD4FAB. It covers descriptions of a wide range of satellite antennas and points operators to source material for construction of many of them.

Antennas for LEO Satellites

Antenna design and construction requirements for use with Amateur satellites vary from low-gain antennas for low-earth-orbit (LEO) satellites to higher-gain antennas for the high-altitude elliptical-orbit satellites. You can operate the FM LEO satellites with a basic dual-band VHF/UHF FM transceiver or even a good FM H-T, as some amateurs have managed. Assuming that the transceiver is reasonably sensitive, you can even use a good "rubber duck" antenna. Some amateurs manage to work the FM birds with H-Ts and a multi-element directional antenna such as the popular Arrow Antenna, **Fig 1**. Of course, this means they must aim their antennas at the satellites, even as they cross overhead.

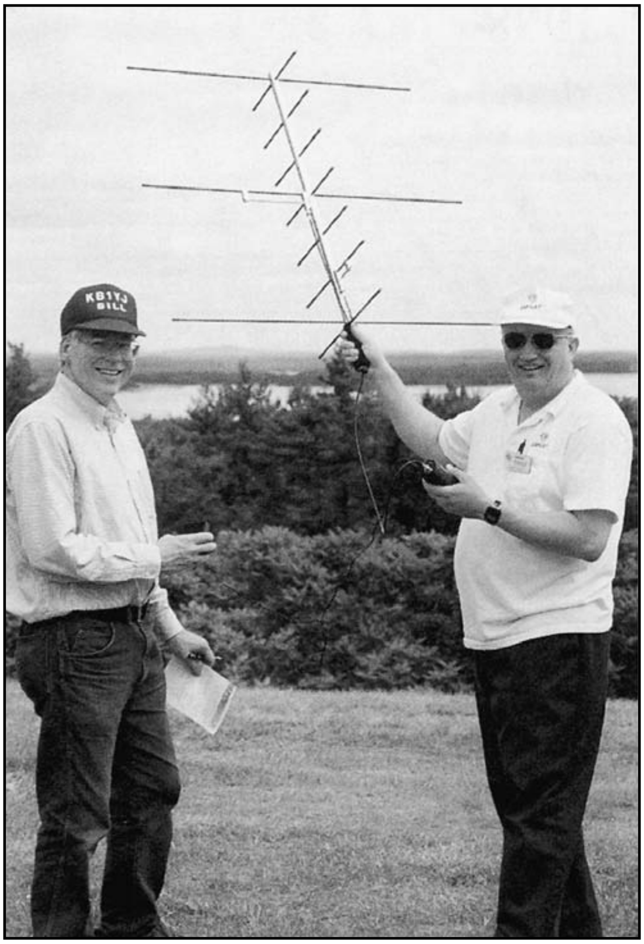

Fig 1—The hand-held "Arrow" gain antenna is popular for LEO FM operations. (*Photo courtesy* The AMSAT Journal, *Sept/Oct 1998.*)

High-quality omnidirectional antennas for LEO service come in quite a number of forms and shapes. M^2 Enterprises has their EB-144 and EB-432 Eggbeater antennas, which have proven to be very useful and do not require any rotators for control. See **Fig 2**. The turnstile-over-reflector antenna has been around for a long time, as shown in **Fig 3**. Other operators have done well using low-gain Yagi antennas, such as those shown in **Fig 4**.

For even better performance, at the modest cost of a single, simple TV antenna rotator, check out the fixed-elevation *Texas Potato Masher* antenna by K5OE, **Fig 5.** This antenna provides a dual-band solution for medium-gain directional antennas for LEO satellites. This is a considerable improvement over omnidirectional antennas and does not require an elevation rotator for good performance.

There are still two LEO satellites that work on the 10-meter band, RS-15 and the newly resurrected AO-7. Both have 10-meter downlinks in the range of 29.3 to 29.5 MHz. Low-gain 10-meter antennas, such as dipoles or long-wire antennas, are used to receive these satellites.

Antennas for High-Altitude Satellites

The high-altitude, Phase-3 satellites, such as AO-10 (and the late AO-13), have been around for quite a number of years. The greater distances to the Phase-3 satellites mean that more transmitted power is needed to access them and weaker signals are received on the ground. Successful stations usually require ground-station antennas with significant gain (12 dBi or more), such as a set of high-gain Yagi antennas. See **Fig 6**. Note the use of two Yagi antennas mounted on each boom to provide *circular polarization*, usually referred to as CP.

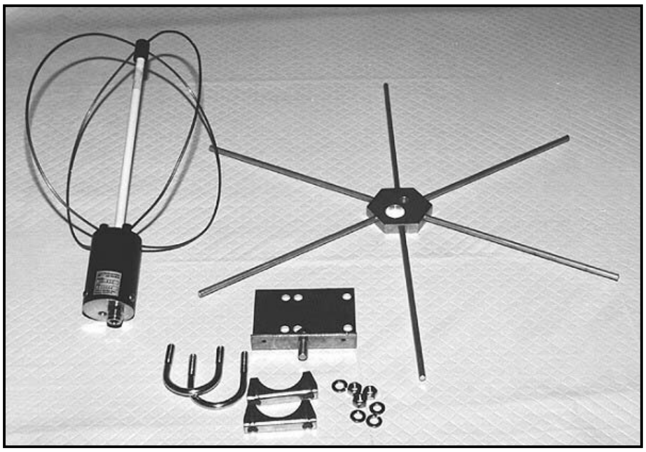

Fig 2—Eggbeater antennas are popular for base station LEO satellite operations. This EB-432 eggbeater antenna for 70 cm is small enough to put in an attic. Antenna gain pattern is helped with the radials placed below the antenna.

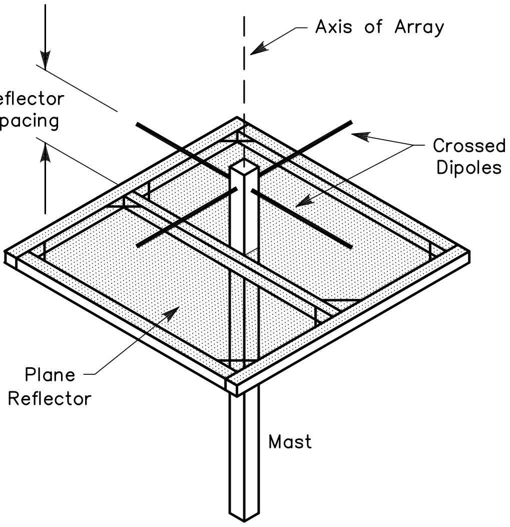

Fig 3—The Turnstile Over Reflector antenna has served well for LEO satellite service for a number of years.

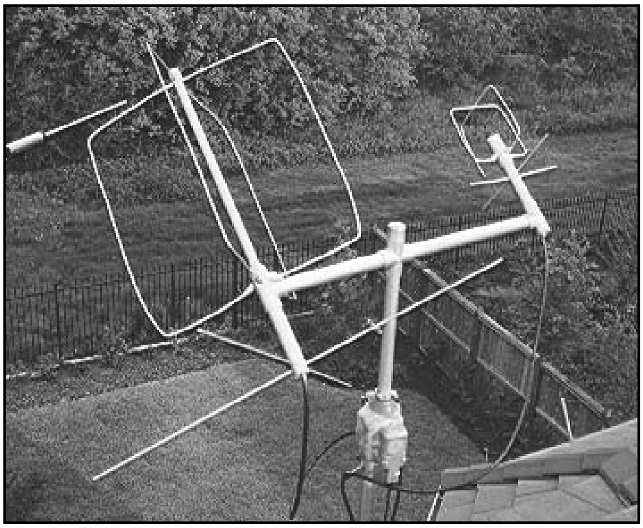

Fig 5—Jerry Brown, K5OE, uses his Texas Potato Masher antennas to work LEO satellites.

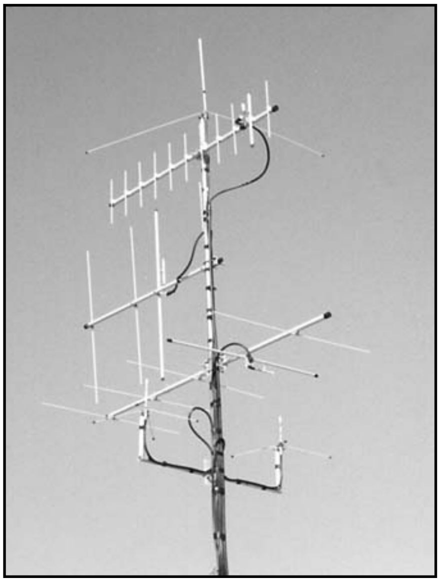

Fig 4—Simple ground plane and Yagi antennas can be used for LEO satellite contacts.

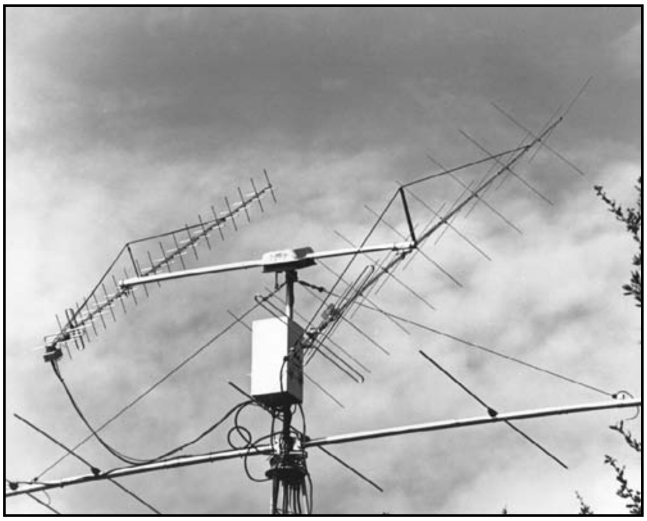

Fig 6—Dick Jansson, WD4FAB, used these 2-meter and 70-cm crossed Yagi's in RHCP for AO-10 and AO-13 operations. The satellite antennas are shown mounted above a 6-meter long-boom Yagi.

CIRCULAR POLARIZATION

Linearly polarized antennas are horizontal or vertical in terms of the antenna's position relative to the surface of the Earth, a reference that loses its meaning in space. The need to use circularly polarized (CP) antennas for space communications is well established. If spacecraft antennas used linear polarization, ground stations would not be able to maintain polarization alignment with the spacecraft because of changing orientations. The ideal antenna for random satellite polarizations is one with a circularly polarized radiation pattern.

There are two commonly used methods for obtaining circular polarization. One is with crossed linear elements such as dipoles or Yagis, as Fig 6 shows. The second popular CP method uses a helical antenna, described below. Other methods also exist, such as with the omnidirectional quadrifilar helix, **Fig 7**.

Polarization *sense* is a critical factor, especially in EME and satellite work. The IEEE standard uses the term "clockwise circular polarization" for a *receding* wave. Amateur technology follows the IEEE standard, calling clockwise polarization for a receding wave as right-hand, or RHCP. Either clockwise or a counter-clockwise (LHCP) sense can be selected by reversing the phasing harness of a crossed-Yagi antenna, see **Fig 8**. The sense of a helical antenna is fixed, determined by its physical construction.

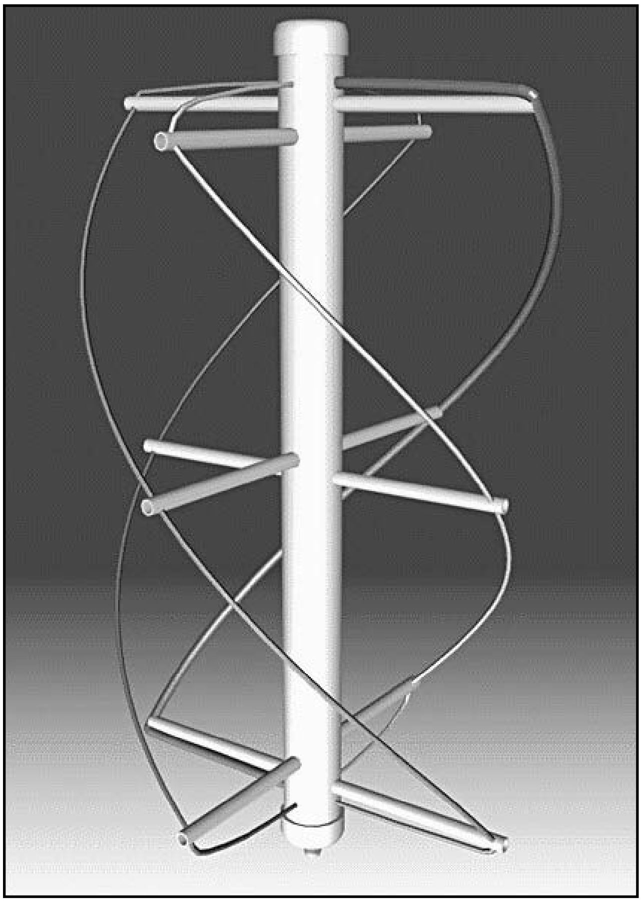

Fig 7—W3KH suggests that quadrifilar antennas can serve well for omnidirectional satellite-station antenna service.

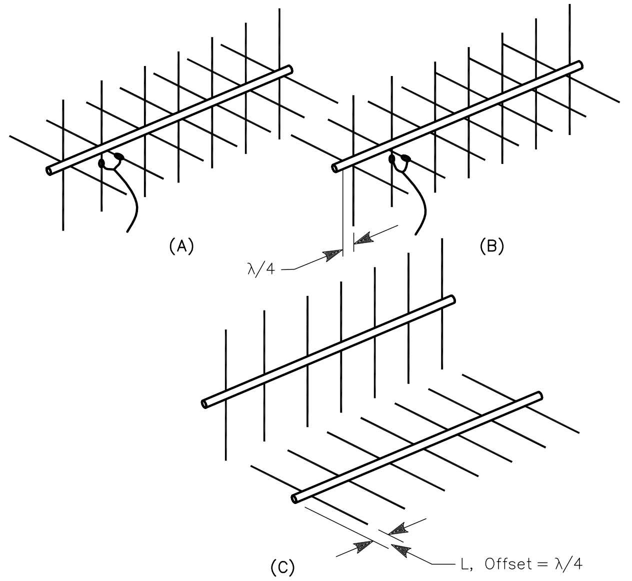

Fig 8—Evolution of the circularly polarized Yagi. The simplest form of crossed Yagi, A, is made to radiate circularly by feeding the two driven elements 90° out of phase. Antenna B has the driven elements fed in phase, but has the elements of one bay mounted $^1/_4$ λ forward from those of the other. Antenna C offers elliptical (circular) polarization using separate booms. The elements in one set are perpendicular to those of the other and are $^1/_4$ λ forward from those of the other.

See **Fig 9** for construction details.

In working through a satellite with a circularly polarized antenna, it is often convenient to have the capability of switching polarization sense. This is because the sense of the received signal of some of the LEO satellites reverses when the satellite passes its nearest point to you. If the received signal has right-hand circular polarization as the satellite approaches, it may have left-hand circularity as the satellite recedes. There is a sense reversal in EME work, as well, because of a phase reversal of the signal as it is reflected from the surface of the moon. A signal transmitted with right-hand circularity will be returned to the Earth with left-hand circularity. Similarly, the polarization is reversed as it is reflected from a dish antenna, so that for an overall RHCP performance, the feed antenna for the dish needs to be LHCP.

Crossed Linear Antennas

Dipoles radiate linearly polarized signals, and the polarization direction depends on the orientation of the antenna. It two dipoles are arranged for horizontal and vertical dipoles, and the two outputs are combined with the correct phase difference (90°), a circularly polarized wave results. Because the electric fields are identical in magnitude, the power from the transmitter will be equally divided between the two fields. Another way of looking at this is to consider the power as being divided between the two antennas; hence the gain of each is decreased by 3 dB when taken alone in the plane of its orientation.

A 90° phase shift must exist between the two antennas and the simplest way to obtain this shift is to use two feed lines to a coplanar pair of crossed-Yagi antennas. One feed-line section is $^1/_4$ λ longer than the other, as shown in Fig 8A. These separate feed lines are then paralleled to a common transmission line to the transmitter or receiver. Therein lies one of the headaches of this system. Assuming negligible coupling between the crossed antennas, the impedance presented to the common transmission line by the parallel combination is one half that of either section alone. (This is not true when there is mutual coupling between the antennas, as in phased arrays.) A practical construction method for implementing a RHCP/LHCP coplanar switched system is shown in **Fig 10**.

Another example of a coplanar crossed-Yagi antenna is shown in **Fig 11**. With this phasing-line method, any mismatch at one antenna will be magnified by the extra $^1/_4$ λ of transmission line. This upsets the current balance between the two antennas, resulting in a loss of polarization circularity. Another factor to consider is the attenuation of the cables used in the harness, along with the

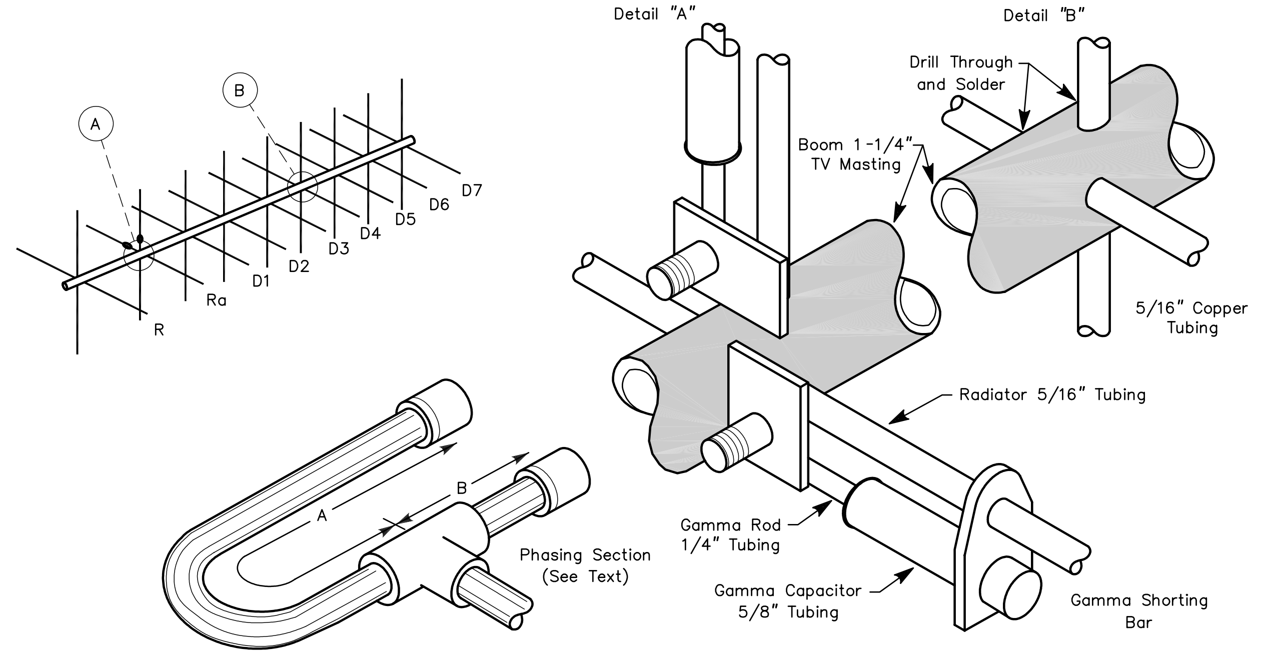
Detail "A"
Detail "B"
Drill Through and Solder
Boom 1-1/4" TV Masting
5/16" Copper Tubing
Radiator 5/16" Tubing
Gamma Rod 1/4" Tubing
Gamma Capacitor 5/8" Tubing
Gamma Shorting Bar
Phasing Section (See Text)
A
B
R
Ra
D1
D2
D3
D4
D5
D6
D7

Fig 9—Construction details of a co-planar crossed-Yagi antenna.

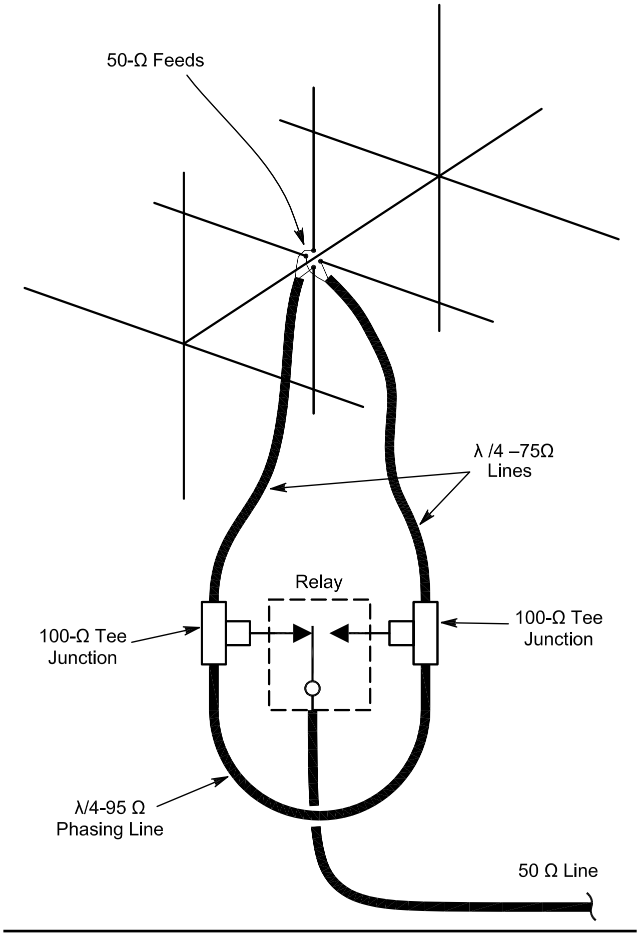
50-Ω Feeds
λ /4 –75Ω Lines
Relay
100-Ω Tee Junction
100-Ω Tee Junction
λ/4-95 Ω Phasing Line
50 Ω Line

Fig 10—Co-planar crossed Yagi, circularly polarized antenna with switchable polarization phasing harness.

connectors. Good low-loss coaxial line should be used. Type-N or BNC connectors are preferable to the UHF variety.

Another method to obtain circular polarization is to use equal-length feed lines and place one antenna $^1/_4$ λ ahead of the other. This offset pair of Yagi-crossed antennas is shown in Fig 8B. The advantage of equal-length feed lines is that identical load impedances will be presented to the common feeder, as shown in **Fig 12**, which shows a fixed circularity sense feed. To obtain a switchable sense feed with the offset Yagi pair, you can use a connection like that of **Fig 13**, although you must compensate for the extra phase added by the relay and connectors.

Fig 8C diagrams a popular method of mounting two separate off-the-shelf Yagis at right angles to each other. The two Yagis may be physically offset by $^1/_4$ λ and fed in parallel, as shown in Fig 8C, or they may be mounted with no offset and fed 90° out of phase. Neither of these arrangements on two separate booms produces true circular polarization. Instead, *elliptical* polarization results from such a system. **Fig 14** is a photo of this type of mounting of Yagis on two booms for elliptical operation.

Helical Antennas

As mentioned, the second method to create a circularly polarized signal is by means of a helical antenna. The axial-mode helical antenna was introduced by Dr John Kraus, W8JK, in the 1940s. **Fig 15** shows examples of S-band (2400-MHz), V-band (145-MHz), and U-band (435-MHz) helical antennas, all constructed by WD4FAB for satellite service.

This antenna has two characteristics that make it

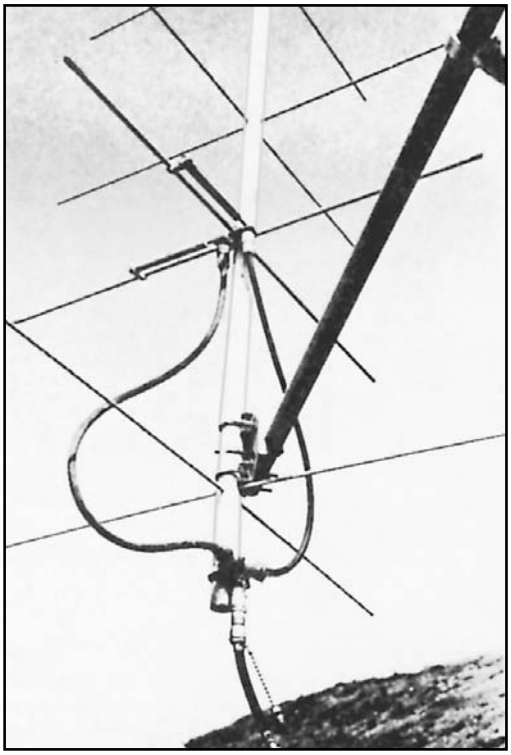

Fig 11—This VHF crossed Yagi design by KH6IJ (Jan 1973 *QST*) illustrates the co-planar, fixed-circularity Yagi.

especially interesting and useful in many applications. First, the helix is circularly polarized. As discussed earlier, circular polarization is simply linear polarization that continually rotates as it travels through space. In the case of a helical antenna, this rotation is about the axis of the antenna. This can be pictured as the second hand of a watch moving at the same rate as the applied frequency, where the position of the second hand can be thought of as the instantaneous polarization of the signal.

The second interesting property of the helical antenna is its predictable pattern, gain and impedance characteristics over a wide frequency range. This is one of the few antennas that has both broad bandwidth and high gain. The benefit of this property is that, when used for narrow-band applications, the helical antenna is very forgiving of mechanical inaccuracies.

Probably the most common amateur use of the helical antenna is in satellite communications, where the spinning of the satellite antenna system (relative to the earth) and the effects of Faraday rotation cause the polarization of the satellite signal to be unpredictable. Using a linearly polarized antenna in this situation results in deep fading, but with the helical antenna (which responds equally to linearly polarized signals), fading is essentially eliminated.

This same characteristic makes helical antennas useful in polarization-diversity systems. The advantages of circular polarization have been demonstrated on VHF voice schedules over non-optical paths, in cases where linearly polarized beams did not perform satisfactorily.

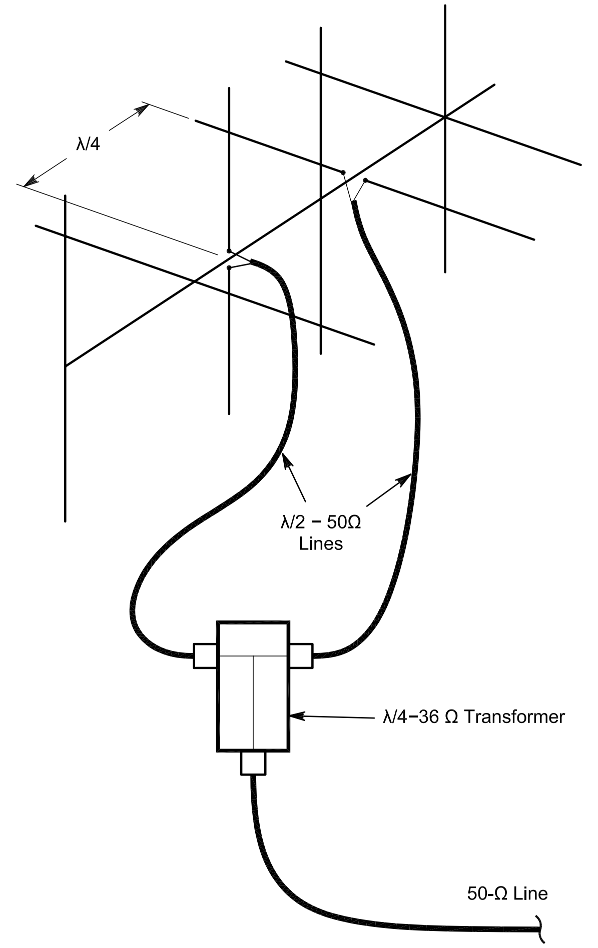

Fig 12—Offset crossed-Yagi circularly polarized antenna-phasing harness with fixed polarization.

Another use for the helical antenna is the transmission of color ATV signals. Many beam antennas (when adjusted for maximum gain) have far less bandwidth than the required 6 MHz, or have non-uniform gain over this frequency range. The result is significant distortion of the transmitted and received signals, affecting color reproduction and other features. This problem becomes more aggravated over non-optical paths. The helix exhibits maximum gain (within 1 dB) more than 20 MHz anywhere above 420 MHz.

The helical antenna can be used to advantage with multimode rigs, especially above 420 MHz. Not only does the helix give high gain over an entire amateur band, but it also allows operation on FM, SSB and CW without the need for separate vertically and horizontally polarized antennas.

Helical Antenna Basics

The helical antenna is an unusual specimen in the antenna world, in that its physical configuration gives a

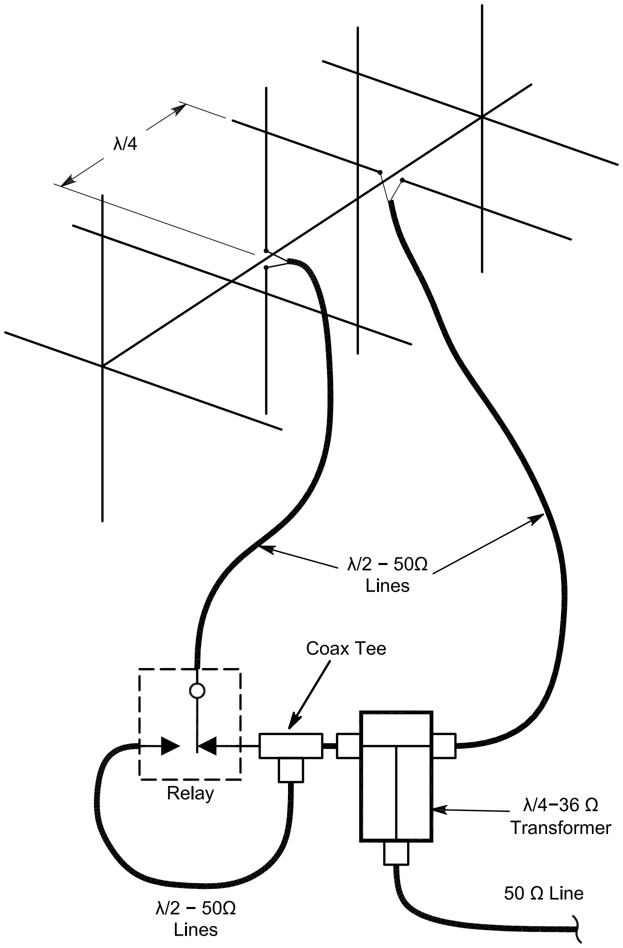

Fig 13—Offset crossed-Yagi circularly polarized antenna-phasing harness with switchable polarization.

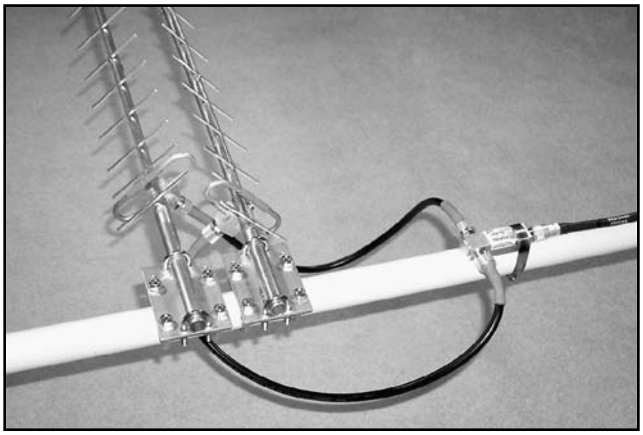

Fig 14—An example of offset crossed-Yagi circularly polarized antennas with fixed polarization. This example is a pair of M² 23CM22EZA antennas, for L band (1269 MHz), mounted on an elevation boom. (*WD4FAB photo.*)

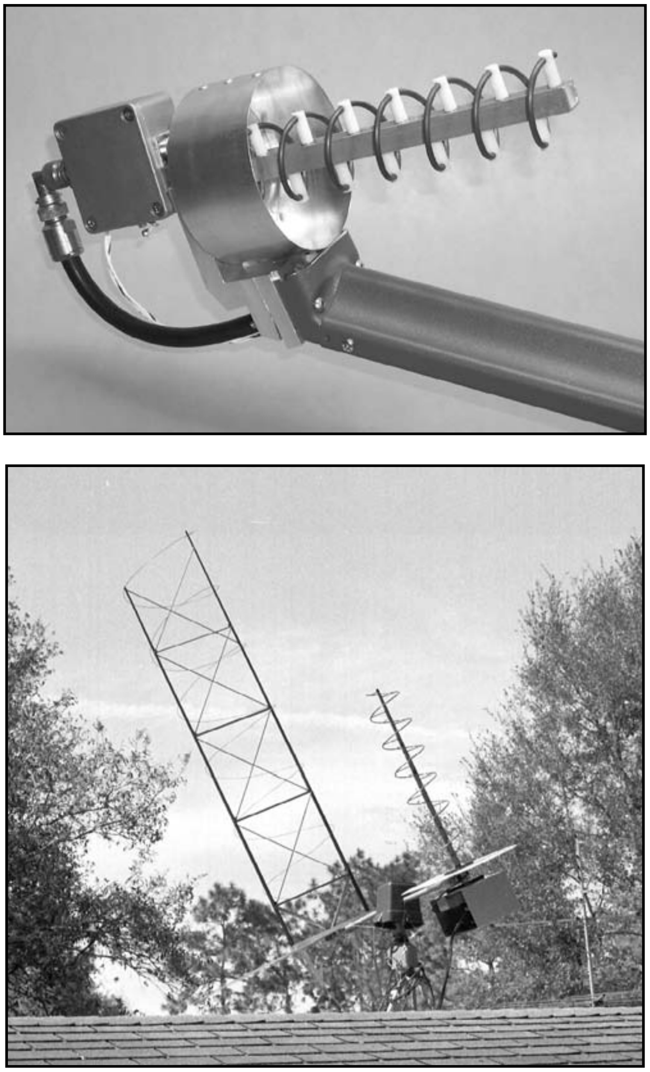

Fig 15—At top, a seven-turn LHCP helical antenna for S-band dish feed for AO-40 service. This helical antenna uses a cupped reflector and has a preamplifier mounted directly to the antenna feed point. At bottom, a pair of helical antennas for AO-10 service on 2 meters and 70 cm. The 2-meter helical antenna is not small! (*WD4FAB photos.*)

hint to its electrical performance. A helix looks like a large air-wound coil with one of its ends fed against a ground plane, as shown in **Fig 16**. The ground plane is a screen of 0.8 λ to 1.1 λ diameter (or on a side for a square ground plane). The circumference (C_λ) of the coil form must be between 0.75 λ and 1.33 λ for the antenna to radiate in the axial mode. The coil should have at least three turns to radiate in this mode. The ratio of the spacing between turns (in wavelengths), S_λ to C_λ, should be in the range of 0.2126 to 0.2867. This ratio range results from the requirement that the pitch angle, α, of the helix be between 12° and 16°, where:

$$\alpha = \arctan \frac{S_\lambda}{C_\lambda} \qquad \text{(Eq 1)}$$

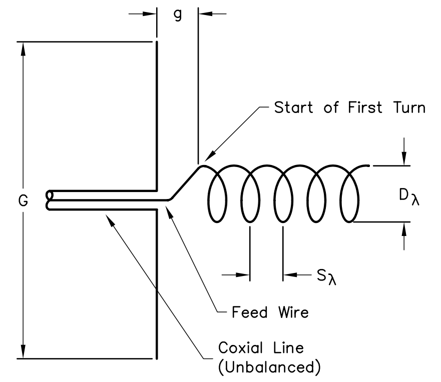

Fig 16—The basic helical antenna and design equations.

These constraints result in a single main lobe along the axis of the coil. This is easily visualized from Fig 15A. The winding of the helix comes away from the cupped reflector with a counterclockwise winding direction for a LHCP. (The winding can also be a clockwise—this results in a RHCP polarization sense.)

A helix with a C_λ of 1λ has a wave propagating from one end of the coil (at the ground plane), corresponding to an instantaneous dipole "across" the helix. The electrical rotation of this dipole produces circularly polarized radiation. Because the wave is moving along the helix conductor at nearly the speed of light, the rotation of the electrical dipole is at a very high rate, and true circular polarization results.

The IEEE definition, in simple terms, is that when viewing the antenna from the feed-point end, a clockwise wind results in right-hand circular polarization (RHCP), and a counterclockwise wind results in left-hand circular polarization (LHCP). This is important, because when two stations use helical antennas over a nonreflective path, both must use antennas with the same polarization sense. If antennas of opposite sense are used, a signal loss of at least 20 dB results from the cross polarization alone.

As mentioned previously, circularly polarized antennas can be used in communications with any linearly polarized antenna (horizontal or vertical), because circularly polarized antennas respond equally to all linearly polarized signals. The gain of a helix is 3 dB less than the theoretical gain in this case, because the linearly polarized antenna does not respond to linear signal components that are orthogonally polarized relative to it.

The response of a helix to all polarizations is indicated by a term called *axial ratio*, also known as *circularity*. Axial ratio is the ratio of amplitude of the polarization that gives maximum response to the amplitude of the polarization that gives minimum response. An ideal circularly polarized antenna has an axial ratio of 1.0. A well-designed practical helix exhibits an axial ratio of 1.0 to 1.1. The axial ratio of a helix is:

$$AR = \frac{2n+1}{2n} \qquad \text{(Eq 2)}$$

where:

AR = axial ratio
n = the number of turns in the helix

Axial ratio can be measured in two ways. The first is to excite the helix and use a linearly polarized antenna with an amplitude detector to measure the axial ratio directly. This is done by rotating the linearly polarized antenna in a plane perpendicular to the axis of the helix and comparing the maximum and minimum amplitude values. The ratio of maximum to minimum is the axial ratio.

The impedance of the helix is easily predicted. The terminal impedance of a helix is unbalanced, and is defined by:

$$Z = 140 \times C_\lambda \qquad \text{(Eq 3)}$$

where Z is the impedance of the helix in ohms.

The gain of a helical antenna is determined by its physical characteristics. Gain can be calculated from:

$$\text{Gain}\left(\text{dBi}\right) = 11.8 + 10\log\left(C_\lambda^{\,2}\, nS_\lambda\right) \qquad \text{(Eq 4)}$$

In practice, helical antennas do not deliver the gain in Eq 4 for antennas with turns count greater than about twelve. There will be more discussions in this area when practical antennas are discussed.

The beamwidth of the helical antenna (in degrees) at the half-power points is:

$$BW = \frac{52}{C_\lambda \sqrt{nS_\lambda}} \qquad \text{(Eq 5)}$$

The diameter of the helical antenna conductor should be between 0.006 λ and 0.05 λ, but smaller diameters have been used successfully at 144 MHz. The previously noted diameter of the ground plane (0.8 λ to 1.1 λ) should not be exceeded if you desire a clean radiation pattern. As the ground plane size is increased, the sidelobe levels also increase. Cupped ground planes have been used according to Kraus, as in Fig 15. (The ground plane need not be solid; it can be in the form of a spoked wheel or a frame covered with hardware cloth or screen.)

50-Ω Helix Feed

Joe Cadwallader, K6ZMW, presented this feed method in June 1981 *QST*. Terminate the helix in an N connector mounted on the ground screen at the periphery of the helix. See **Fig 17**. Connect the helix conductor to the N connector as close to the ground screen as possible (**Fig 18**). Then adjust the first quarter turn of the helix to a close spacing from the reflector.

This modification goes a long way toward curing a deficiency of the helix—the 140-Ω nominal feed-point

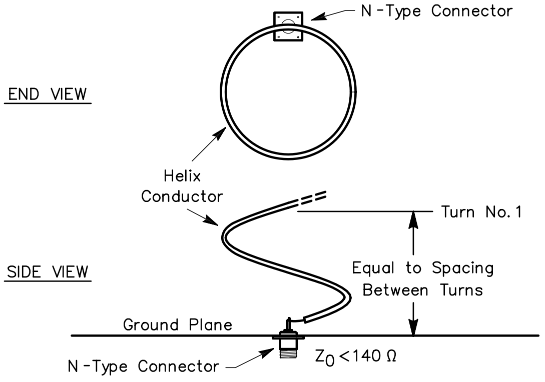

Fig 17—End view and side view of peripherally fed helix.

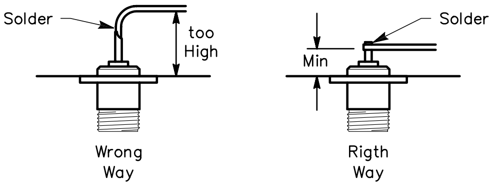

Fig 18—Wrong and right ways to attach helix to a type N connector for 50-Ω feed.

impedance. The traditional $\lambda/4$ matching section has proved difficult to fabricate and maintain. But if the helix is fed at the periphery, the first quarter turn of the helix conductor (leaving the N connector) acts much like a transmission line—a single conductor over a perfectly conducting ground plane. The impedance of such a transmission line is:

$$Z_0 = 138 \log \frac{4h}{d} \tag{Eq 6}$$

where:

Z_0 = line impedance in ohms
h = height of the center of the conductor above the ground plane
d = conductor diameter (in the same units as h).

The impedance of the helix is 140 Ω a turn or two away from the feed point. But as the helix conductor swoops down toward the feed connector (and the ground plane), h gets smaller, so the impedance decreases. The 140-Ω nominal impedance of the helix is transformed to a lower value. For any particular conductor diameter, an optimum height can be found that will produce a feed-point impedance equal to 50 Ω. The height should be kept very small, and the diameter should be large. Apply power to the helix and measure the SWR at the operating frequency. Adjust the height for an optimum match.

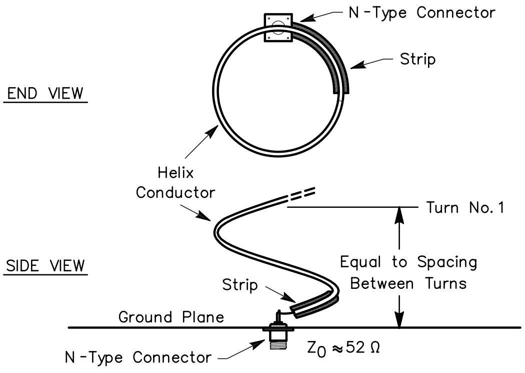

Fig 19—End view and side view of peripherally fed helix with metal strip added to improve transformer action.

Typically, the conductor diameter may not be large enough to yield a 50-Ω match at practical (small) values of h. In this case, a strip of thin brass shim stock or flashing copper can be soldered to the first quarter turn of the helix conductor (**Fig 19**). This effectively increases the conductor diameter, which causes the impedance to decrease further yet. The edges of this strip can be slit every $^1/_2$ inch or so, and the strip bent up or down (toward or away from the ground plane) to tune the line for an optimum match.

This approach yields a perfect match to nearly any coax. The usually wide bandwidth of the helix (70% for less than 2:1 SWR) will be reduced slightly (to about 40%) for the same conditions. This reduction is not enough to be of any consequence for most amateur work. The improvements in performance, ease of assembly and adjustment are well worth the effort in making the helix more practical to build and tune.

ANTENNAS FOR AO-40 OPERATIONS

Antennas for successful operations on AO-40 come in many shapes and sizes. AO-40 has provided amateurs the opportunity to broadly experiment with antennas.

Fig 20 shows the satellite antennas at WD4FAB. The Yagi antennas are used for the U- and L-band AO-40 uplinks and the V-band AO-10 downlink, while the S-band dish antenna is for the AO-40 downlink. These satellite antennas are tower mounted at 63 feet (19 meters) to avoid pointing into the many nearby trees and suffering from the resulting “green attenuation.” Of course, satellite antennas do not always need to be mounted high on a tower if dense foliage is not a problem. If satellite antennas are mounted lower down, feed-line length and losses can reduced.

Another benefit, however, to tower mounting of satellite antennas is that they can be used for terrestrial ham communications and contests. The fact that the antennas are set up for CP does not really degrade these other operating activities.

Experience with AO-40 has clearly shown the advan-

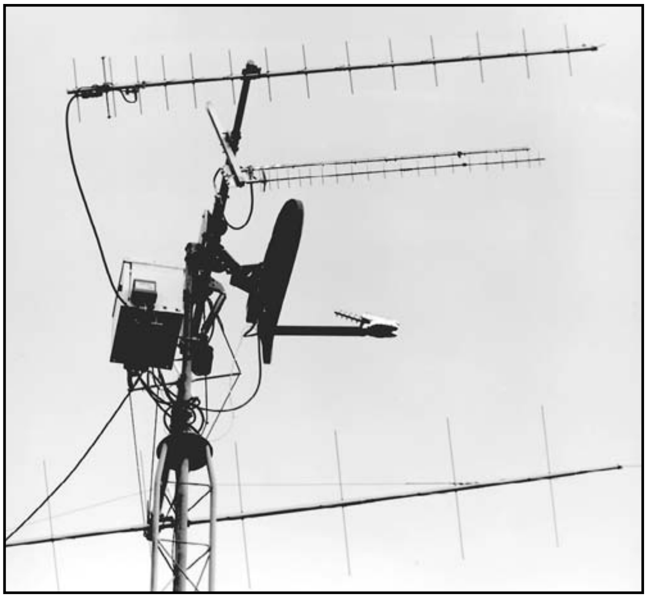

Fig 20—Details of WD4FAB's tower cluster of satellite antennas including a home-brew elevation rotator. Top to bottom: M^2 436-CP30, a CP U-band antenna; two M^2 23CM22EZA antennas in a CP array for L band; "FABStar" dish antenna with helix feed for S band; M^2 2M-CP22, a CP V-band antenna (only partially shown.) To left of dish antenna is a NEMA4 equipment box with an internal 40-W L-band amplifier, and also hosts externally mounted preamplifiers. (*WD4FAB photo*)

tages of using RHCP antennas for both the uplink and downlink communications. The antennas shown in Fig 20 are a single-boom RHCP Yagi antenna for U band, a pair of closely spaced Yagi antennas phased for RHCP for L band (see Fig 14), and a helix-fed dish antenna for S band. The antenna gain requirements for U band can easily be met with the gain of a 30-element crossed Yagi. Antennas of this size have boom lengths of 4 to 4 1/2 wavelengths. The enterprising constructor can build a Yagi antenna from one of several references, however most of us prefer to purchase well-tested antennas from commercial sources as M^2 or Hy-Gain. In the past, KLM (now out of business) had offered a 40-element CP Yagi for U-band satellite service, and many of these are still in satisfactory use today.

U-band uplink requirements for AO-40 have clearly demonstrated the need for gain less than 16 to 17 dBic RHCP, with an RF power of less than 50 W PEP at the antenna (≈ 2,500 W-PEP EIRP with a RHCP antenna) depending upon the *squint angle*. (The squint angle is the angle at which the main axis of the satellite is pointed away from your antenna on the ground. If the squint angle is less than half of the half-power beamwidth, the ground station will be within the spacecraft antenna's nominal beam width.)

A gain of 16 to 17 dBic RHCP can be obtained from a 30-element crossed Yagi, AO-13 type antenna, and is good news, considering that the satellite may be over 60,000 km (37,000 miles) from your station. Success on the U-band uplinks to AO-40 is easier than those for L band at wider squint angles more than 20°. At squint angles less than 10°, U-band uplink operation can even be done with 1-5 W power outputs to a RHCP antenna (≈ 200 W-PEP EIRP with RHCP). These lower levels mean that smaller antennas can be used. In practice, these uplinks will produce downlink signals that are 10 to 15 dB above the noise floor, or S7 signals over an S3 noise floor. The beacon will give a downlink S9 signal for these same conditions.

WD4FAB's experience with the AO-40 L-band uplink has demonstrated that 40 W-PEP delivered to an antenna with a gain of ≈ 19dBic (3,000 W-PEP EIRP with RHCP) is needed for operations at the highest altitudes of AO-40 and with squint angles ≤ 15°. This is the pretty com-

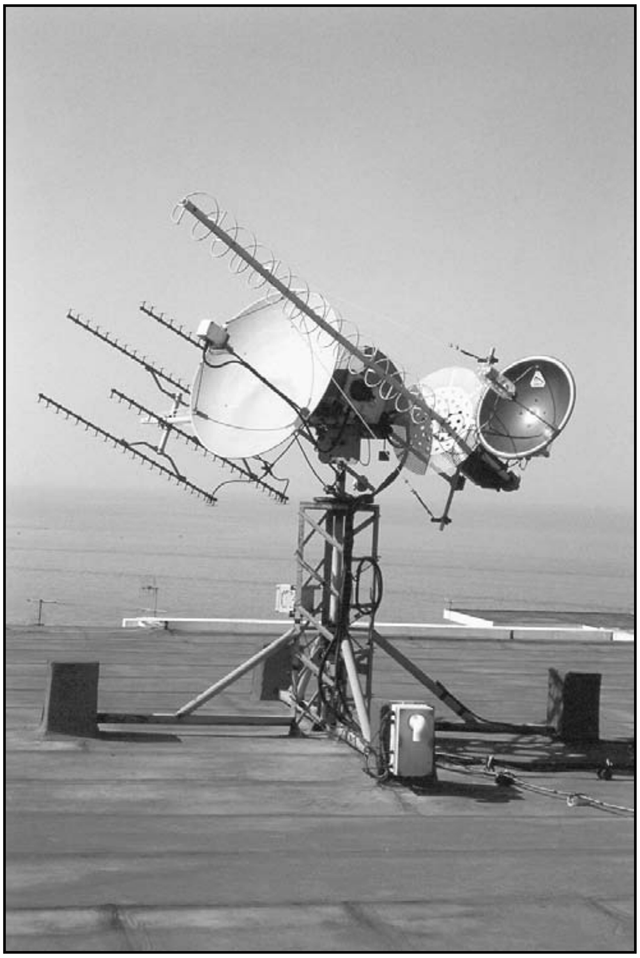

Fig 21—Domenico, I8CVS, has this cluster of satellite antennas for AO-40. Left to right: array of 4 × 23-element Yagi horizontally polarized for L band; 1.2-meter dish with 3-turn helix feed for S band; 15-turn RHCP helical antenna for U band; 60-cm dish for X band. All microwave preamplifiers and power amplifiers are homebrew and are mounted on this antenna cluster. (*I8CVS photo.*)

pact L-band antenna arrangement with two 22-element antennas in a RHCP array shown in Fig 14 and 20. Other operators have experience that using a 1.2-meter L-band dish antenna and 40 W of RF power (6,100 W-PEP EIRP with RHCP) can also provide a superb uplink for squint angles even up to 25°. A dish antenna can have a practical gain of about 21 to 22 dBic. These uplinks will provide the user a downlink that is 10 to 18 dB above the transponder noise floor. In more practical terms, this is an S7 to 8 signal over a S3 transponder noise floor, a very comfortable armchair copy.

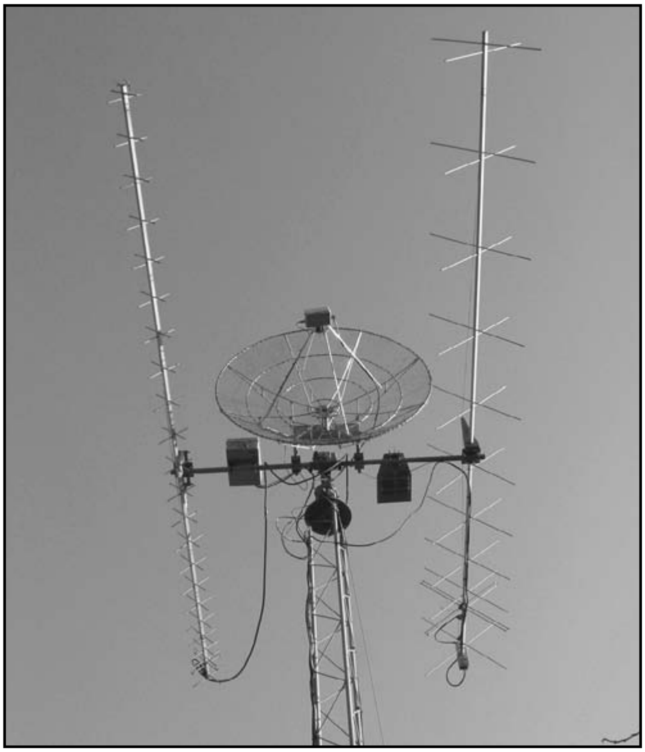

Fig 22—Wilfred Carey, ZS6JT, constructed this cluster of satellite and EME antennas. Left to right: 2 × 23-element offset feed Yagi for U band; 1.64-meter dish with 2¹/₄-turn helix feed for S band; 2 × 11-element coplanar feed Yagi for V band. (*ZS6JT photo.*)

Using the L-band uplink for AO-40, instead of the U-band uplink, allows the use of Yagi antennas that more manageable, since their size for a given gain is only one third of those for U-band. With L band there is a narrower difference between using a dish antenna and a Yagi, since a 21- to 22-dBic dish antenna would be only about 1.2 meters (4 feet) in diameter. However, some of us may not have such "real estate" available on our towers and may seek a lower wind-loading solution offered by Yagis. Long-boom rod-element Yagi, or loop-Yagi antennas are commercially offered by M^2 and DEM, although this band is about the highest for practical Yagis. The example shown in Fig 20 is a pair of rod-element Yagi antennas from M^2 in a CP arrangement with a gain of 18 to 19 dBic.

Other amateurs have successful AO-40 operation with different arrangements. **Fig 21** shows I8CVS's 4 × 23-element linear array for a 1270 MHz, a 1.2-meter solid dish for 2400 MHz, a 15-turn helical antenna for 435 MHz, and a 60-cm dish for 10,451 MHz. This arrangement clearly shows the advantage and accessibility of having a roof-mounted antenna.

Fig 22 shows ZS6JT's setup, with a 1.64-meter home-built mesh dish for 2400 MHz and two home-built crossed Yagi antennas, one for 435 MHz and the other for 145 MHz. Note that in these examples, the antennas permit terrestrial communication as well as satellite service. Two of these stations have also maintained the capability to operate the LEO satellites with U- and V-band antennas.

A number of amateurs have taken advantage of the availability of surplus C-band TVRO dishes, since most users of satellite television have moved up to the more

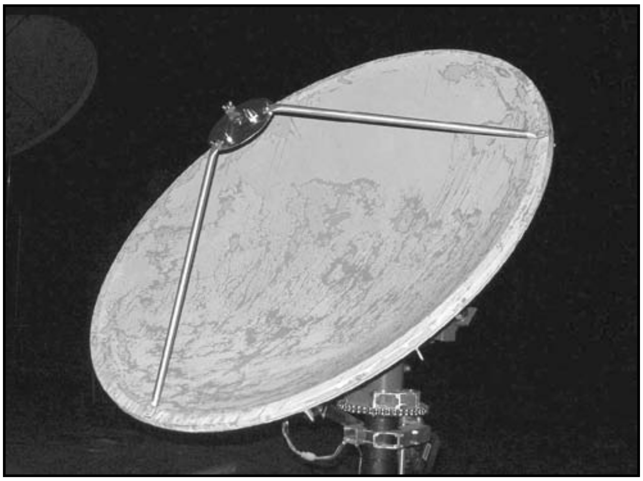

Fig 23—Robert Suding, W0LMD, modified this 4-foot dish antenna with a patch feed for S band and an Az-El mount. (*W0LMD photo.*)

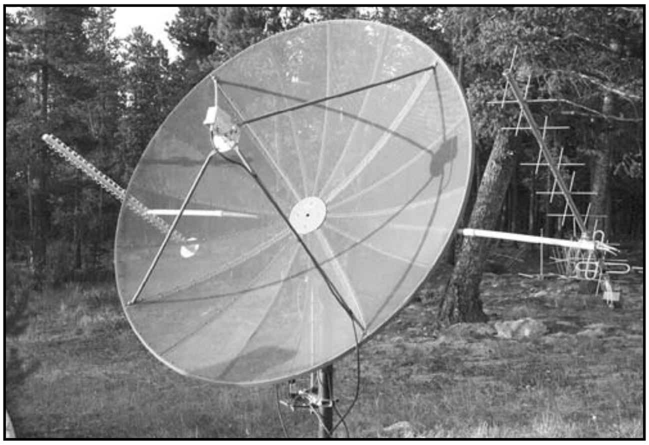

Fig 24—W0LMD graduated to this 8-foot dish with patch feed for S band for AO-40. On the left is a helical antenna for L band and on the right is a 2 × 9-element offset-feed Yagi for U band. A home-brew Az-El mount is provided. (*W0LMD photo.*)

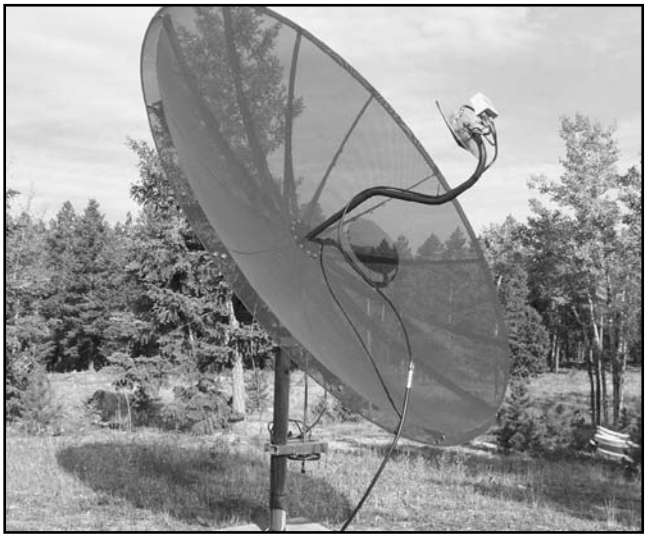

Fig 25—WØLMD increased to this 10-foot dish for AO-40 operations, with a triband patch feed for U, L, and S bands on an Az-El mount. (*WØLMD photo.*)

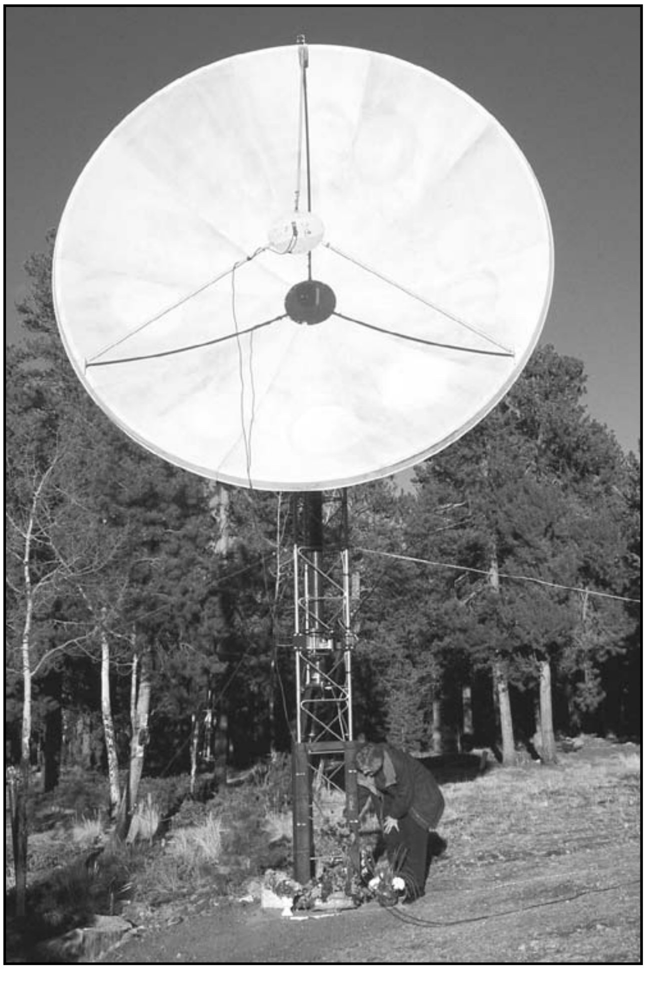

Fig 26—WØLMD found the ultimate in this 14-foot dish for AO-40, with a triband patch feed and Az-El mount. (*WØLMD photo.*)

convenient K band using 0.5-meter dishes. Some examples of these dish conversions for satellite communications are shown in **Fig 23**, a WØLMD 4-foot dish with patch feed and Az-El mount. **Fig 24** shows a WØLMD 8-foot dish with patch feed, Az-El mount, a U-band Yagi, and an L-band helical antenna.

Fig 25 is a WØLMD 10-foot dish with tri-band patch feed and Az-El mount; and **Fig 26** is also a WØLMD

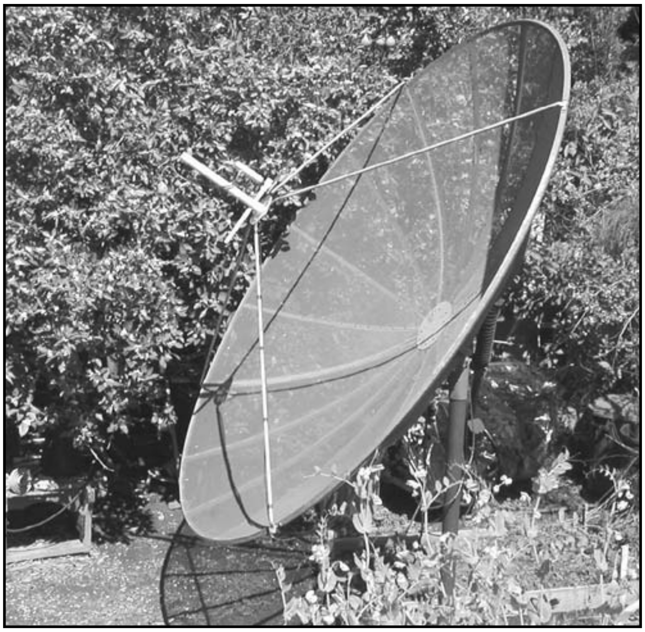

Fig 27—Clair E. Cessna, K6LG, has this 10-foot dish with S-band patch feed. This dish uses the original polar-mounting system and offsets the patch feed to compensate for AO-40's deviation from the Clarke belt. (*K6LG photo.*)

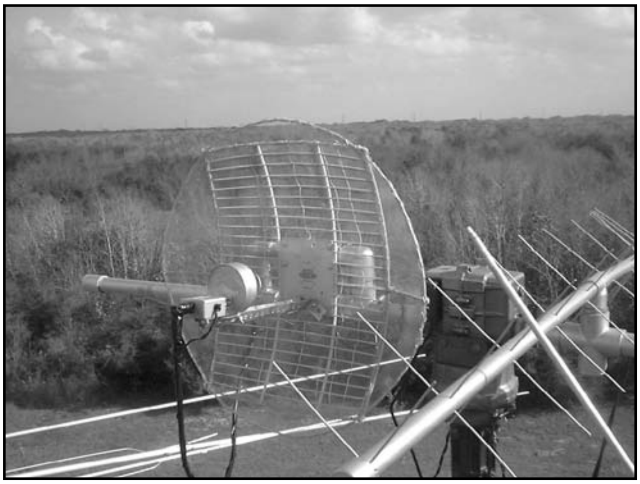

Fig 28—K5GNA's "circularized" mesh modification of an MMDS dish antenna with a helix-CP feed and DEP preamp. The dish modification reduces the spillover loss by making the antenna fully circular. (*K5OE photo.*)

14-foot dish with tri-band patch feed and Az-El mounting. Other operators, like K6LG, have been able to use TVRO dishes, **Fig 27**, with multiband patch feeds and still use, within limits, their polar-mounting system, as will be explained later.

Other hams have taken advantage of other surplus dish situations. **Fig 28** shows modified MMDS dishes, by K5GNA, and **Fig 29**, by K5OE, both using helix feeds. **Fig 30** shows a 75-cm high modified PrimeStar offset feed dish, by WD4FAB, using a longer helical feed antenna because of the higher f/D ratio of this dish configuration. This dish provides 5 dB of Sun noise, which is good performance. These efforts have rewarded their users with superb service on AO-40. Many have experimented with different feed and mounting systems. These experiments will be further illustrated.

One very popular spun-aluminum dish antenna seen in use on AO-40 has been the G3RUH-ON6UG 60-cm unit with its S-band patch feed, **Fig 31**. A kit, complete with a CP-patch feed is available from SSB-USA and has a gain of 21 dBic. It provides a 2.5-dB Sun noise signal. Surplus dishes have not been the only source for antennas for AO-40 operations, since some ingenious operators have even turned to the use of cardboard boxes. See **Figs 32** to **35**.

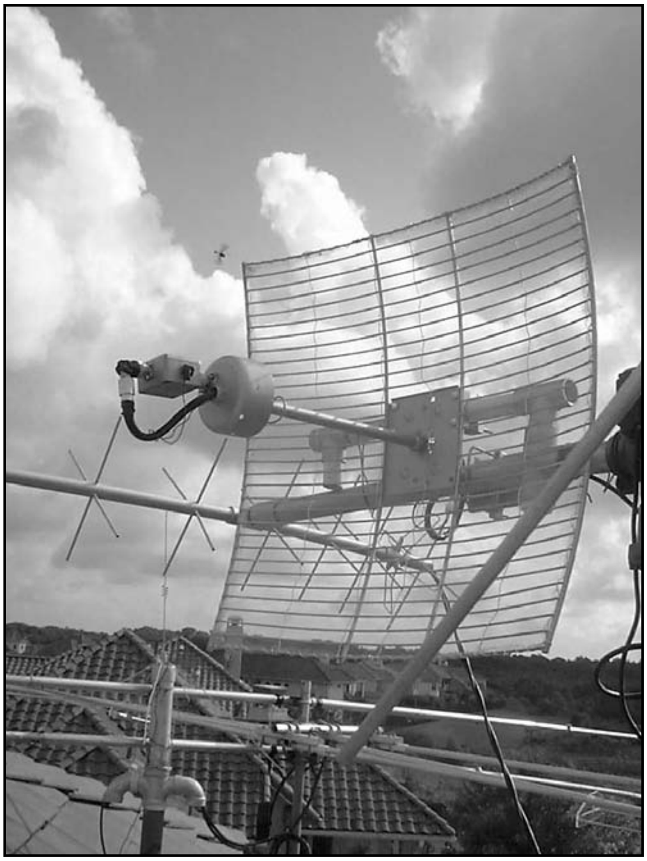

Fig 29—Mesh modification of an MMDS dish antenna by Jerry Brown, K5OE, with a helix-CP feed and DEM preamplifier mounted directly to the helix feed point. (*K5OE photo.*)

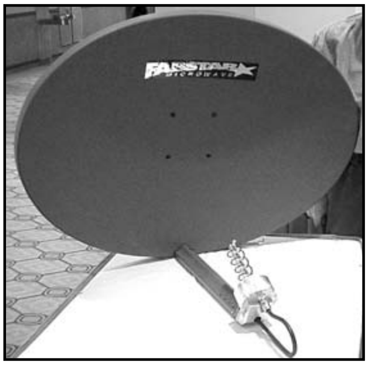

Fig 30—PrimeStar offset-fed dish with WD4FAB's helix-feed antenna. N0NSV was so pleased with the modification that he renamed the dish "FABStar," and made a new label! (*N0NSV photo.*)

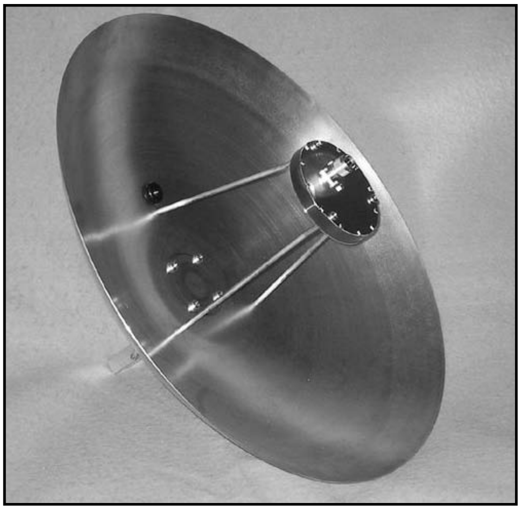

Fig 31—G3RUH's 60-cm spun-aluminum dish with CP-patch feed is available as a kit. This antenna has been popular with many AO-40 operators all over the world.

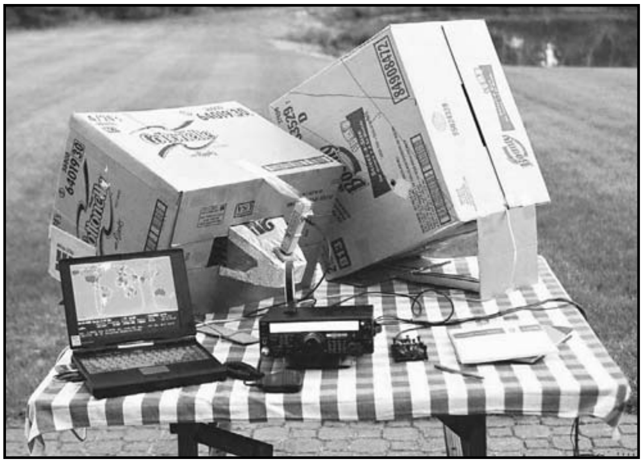

Fig 32—A complete satellite station with the tracking laptop, FT-847 transceiver, and both downlink and uplink cardboard-box antennas.

Parabolic Reflector Antennas

The satellite S-band downlinks have become very popular for a variety of reasons:

- Good performance with physically small downlink antennas
- Availability of good-quality downconverters
- Availability of preamps at reasonable prices.

A number of people advocate S-band operation, including Bill McCaa, K0RZ, who led the team that designed and built the AO-13 S-band transponder and James Miller, G3RUH, who operates one of the AO-40 command stations. Ed Krome, K9EK, and James Miller have published a number of articles detailing construction of preamps, downconverters and antennas for S band.

Some access AO-40's S-band downlink using compact S-band helical antennas. See **Fig 36**. With the demise of AO-40's S1 transmitter and its high-gain downlink antenna, enthusiasts have had to employ high-gain parabolic-dish antennas to use AO-40's S2 downlink, with its lower-gain helical antenna.

W0LMD notes that like a bulb in a flashlight, the

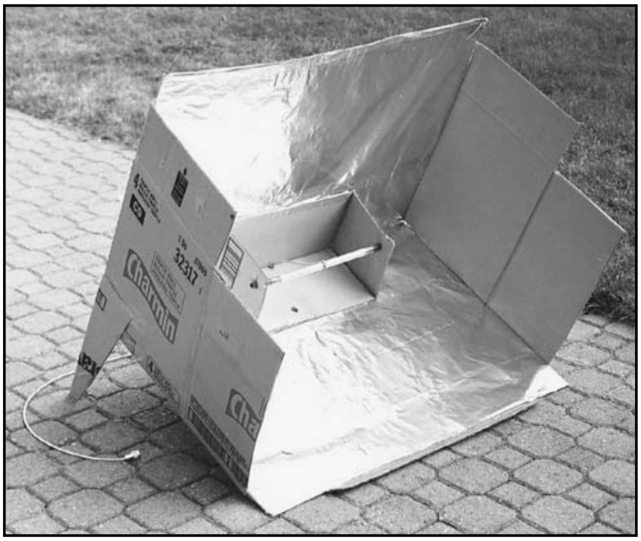

Fig 33—The completed high-performance corner-reflector uplink antenna for U band. Note how the box corners hold the reflectors and dipole feed in place. The rear legs set the antenna elevation to 20°—this gives good coverage at the design latitude but will need modification for other stations.

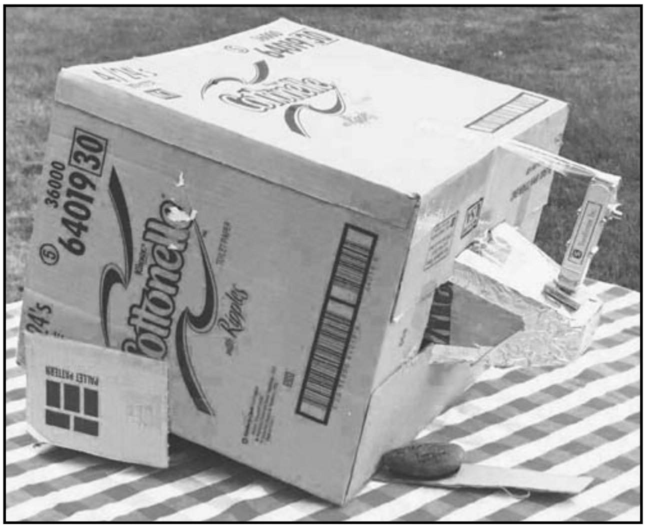

Fig 35—Side view of the downlink pyramidal horn showing the elevation control supports and how the downconverter is attached to the horn. The downconverter is pulled forward by the tape to align the probe wire parallel to the rear surface of the horn.

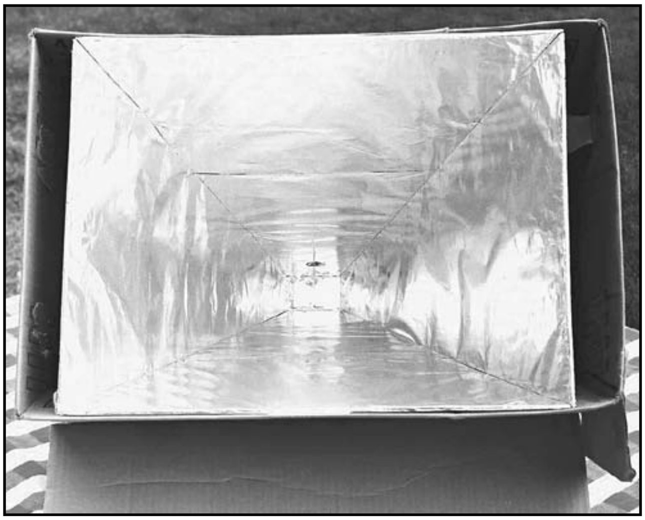

Fig 34—Front view of the downlink pyramidal horn showing how it is mounted in the support carton. Notice the coax probe at the back of the horn.

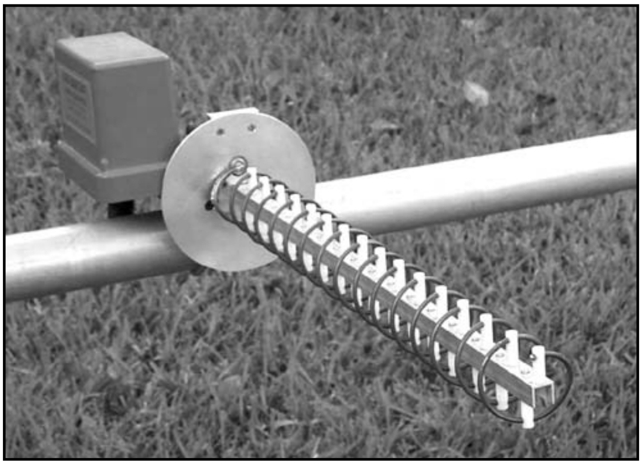

Fig 36—WD4FAB's example of a 16-turn S-band helical antenna for AO-40. This is about the maximum length of any practical helix. Note the SSB UEK2000 down-converter mounted behind the reflector of the antenna. (*WD4FAB photo.*)

parabolic reflector or dish antenna must have a feed source looking into the surface of the dish. Some dishes are designed so that the feed source is mounted directly in front of the dish. This is referred to as a *center-fed dish*. Other dishes are designed so that the feed source is off to one side, referred to as an *off-center-fed dish*, or just offset-fed dish, as shown in Fig 30. The offset-fed dish may be considered a side section of a center-fed dish. The center-fed dish experiences some signal degradation due to blockage of the feed system, but this is usually an insignificantly small amount. The offset-fed dish is initially more difficult to aim, since the direction of reception is not the center axis, as it is for center-fed dishes.

The basic design precepts of parabolic-dish antennas are covered in more detail in the EME Antenna section of this chapter. Dish antenna properties specific to satellite operations are covered here. The dish's parabola can be designed so the focus point is closer to the surface of the dish, referred to a *short-focal-length* dish, or further away from the dish's surface, referred to as a *long-focal-length* dish. To determine the exact focal length, measure the diameter of the dish and the depth of the dish.

$$f = \frac{D^2}{16d} \qquad \text{(Eq 7)}$$

The focal length divided by the diameter of the dish gives the *focal ratio*, commonly shown as f/D. Center-fed dishes usually have short-focal ratios in the range of f/D = 0.3 to 0.45. Offset-fed dishes usually have longer focal lengths, with f/D = 0.45 to 0.80. If you attach two small mirrors to the outer front surface of a dish and then point the dish at the Sun, you can easily find the focus point of the dish. Put the reflector of the patch or helix feed just beyond this point of focus.

An alternate method for finding a dish's focal length is suggested by W1GHZ (ex-N1BWT), who provides a computer program called *HDL_ANT*, available at: **www.w1ghz.org/10g/10g_home.htm**. The method literally measures a solid-surface dish by the dimensions of the bowl of water that it will form when properly positioned. (See: **www.qsl.net/n1bwt/chap5.pdf**.) WD4FAB used this method on the dish of Fig 30, carefully leveling the bowl, plugging bolt holes, and filling it with water to measure the data needed by the W1GHZ Web-site calculation.

While many of us enjoy building our own antennas, surplus-market availability of these small dish antennas makes their construction unproductive. Many AO-40 operators have followed the practices of AO-13 operators using a surplus MMDS linear-screen parabolic reflector antenna, Figs 28 and 29. These grid-dish antennas are often called *barbeque dishes*. K5OE and K5GNA have shown how to greatly improve these linearly polarized reflectors by adapting them for the CP service desired for AO-40. Simple methods can be used to *circularize* a linear dish and to further add to its gain using simple methods to increase the dish area and feed efficiency.

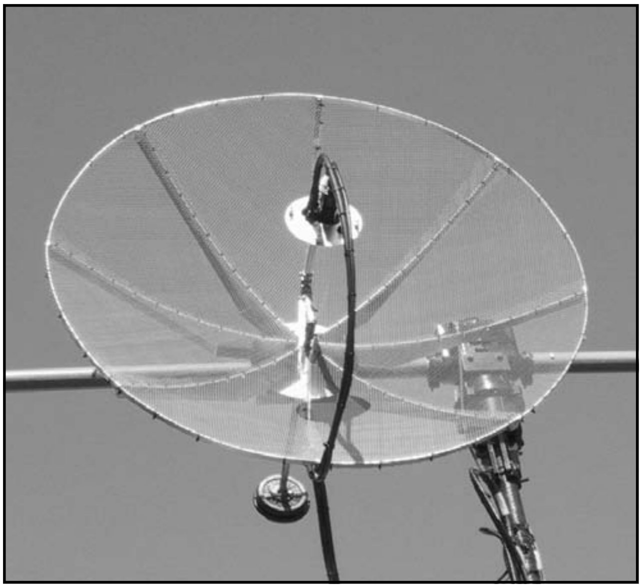

Fig 37—Prototype 1.2-meter dish by Rick Fletcher, KG6IAL, using a dual-band (L and S) patch-feed antenna for AO-40. See text. This kit dish is covered with $^1/_4$-inch mesh. (*KG6IAL photo.*)

Another approach is the construction of a kit-type dish antenna, just becoming available in 1.2-meter and 1.8-meter diameters. This ingenious design by KG6IAL is available from his Web site **www.teksharp.com/**. **Fig 37** shows the prototype of the 1.2-meter dish with an f/D of 0.30. The 1.2-meter dish is fed with a dual-band patch feed for L and S bands. The 1.8-meter dish is designed for up to three bands using a tri-band patch feed for the U, L and S bands. This dish will permit U-band operation. A Central States VHF Society measurement on a similar sized dish (by WØLMD) with a patch feed showed a gain of about 17.1 dBic (actual measurement was 12.0 dBd linearly fed). This performance along with a small V-band (145 MHz) Yagi would permit a very modest satellite antenna assembly for all of the VHF/UHF LEO satellites, as well as AO-40.

The ingenuity of the design of the KG6IAL antenna is that it is constructed of robust, $^1/_8$-inch-thick aluminum sheet that is numerically machined for the parabolic shape of the ribs. The backsides of the ribs are stiffened by a bent flange edge. The panel mesh is attached by using small tie-wraps or small aluminum wire through the mesh and holes provided along the parabolic edge. KG6IAL used $^1/_4$-inch mesh in the prototype antenna to reduce wind loading. A single formed conduit post is provided in the kit for mounting the patch-feed assembly. The post extends rearward to permit the attachment of a counterweight, if needed.

AO-40 has also provided some additional challenges to the ham operator. Besides its well-known S-band downlink, AO-40 also has a K-band downlink in the range of

24.05 GHz. This quite low-powered transmitter has provided a substantial challenge to some operators, such as N1JEZ, K5OE, W5LUA, G3WDG and others. N1JEZ documented his work in *QST* while K5OE shows his K-band work on his Web site and in the *Proceedings of the AMSAT Space Symposium*. See **Fig 38**.

Parabolic Dish Antenna Construction

In the USA large numbers of dishes can be obtained either free or at low cost. But in some parts of the world dishes are not so plentiful, so hams make their own. **Fig 39** shows G3RUH's S-band dish antenna. There are three parts to the dish antenna—the parabolic reflector, the boom and the feed. There are as many ways to construct this as there are constructors. You need not slavishly replicate every nuance of the design. The only critical dimensions occur in the feed system. After construction, you will have a 60-cm diameter S-band RHCP dish antenna with a gain of about 20 dBi and a 3-dB beamwidth of 18°. Coupled with the proper downconverter, performance will be more than adequate for S-band downlink.

The parabolic reflector used for the original antenna was intended to be a lampshade. Several of these aluminum reflectors were located in department-store surplus. The dish is 585 mm in diameter and 110 mm deep, corresponding to an f/D ratio of 585/110/16 = 0.33 and a focal length of 0.33 × 585 = 194 mm. The f/D of 0.33 is a bit too concave for a simple feed to give optimal performance but the price was right, and the under-illumination keeps ground noise pickup to a minimum. The reflector already had a 40-mm hole in the center with three 4-mm holes around it in a 25-mm radius circle.

The boom passes through the center of the reflector and is made from 12.7-mm square aluminum tube. The boom must be long enough to mount to the rotator boom on the backside of the dish. The part of the boom extending through to the front of the dish must be long enough

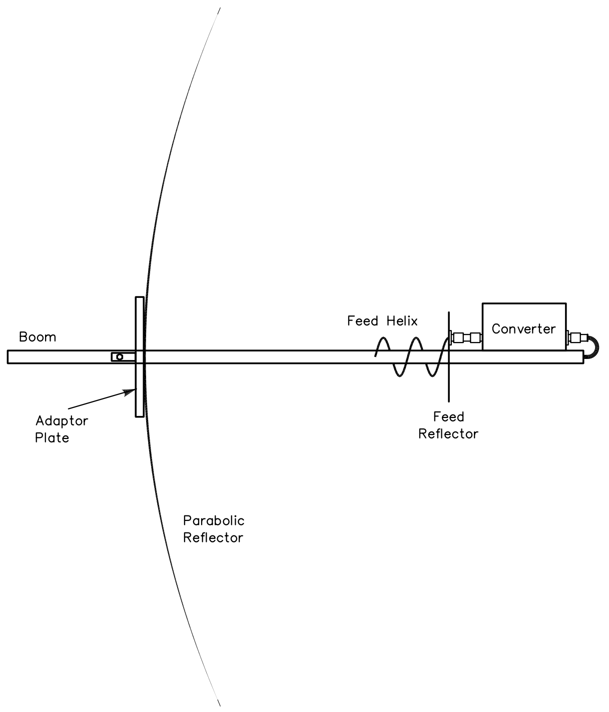

Fig 39—Detail of 60-cm S-band dish antenna with feed.

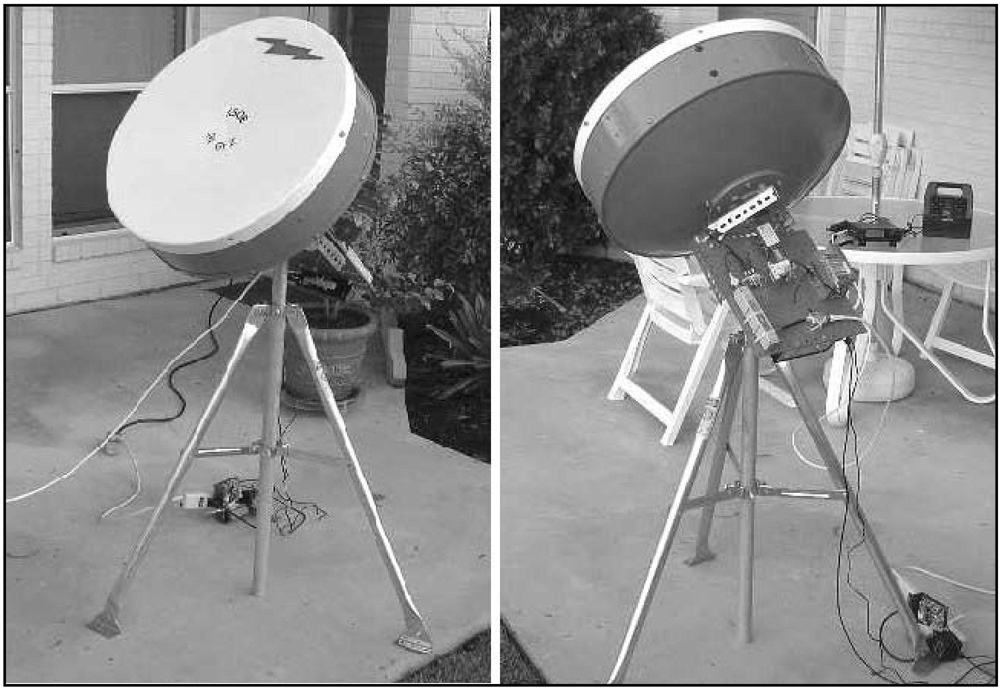

Fig 38—K5OE found this K-band dish on the Web and has set it up for the AO-40 K-band downlink. (*K5OE photo.*)

to mount the feed at the focus. If you choose to mount the downconverter or a preamp near the feed, some additional length will be necessary. Carefully check the requirements for your particular setup.

A 3-mm thick piece of aluminum, 65 mm in diameter, supports the boom at the center of the reflector. Once the center mounting plate is installed, the center boom is attached using four small angle brackets—two on each side of the reflector. See Fig 39 for details of reflector and boom assembly.

A small helix is used for the S-band antenna feed. The reflector for the helix is made from a 125-mm square piece of 1.6-mm thick aluminum. The center of the reflector has a 13-mm hole to accommodate the square center boom described above. The type-N connector is mounted to the reflector about 21.25 mm from the middle. This distance from the middle is, of course, the radius of a helical antenna for S-band. Mount the N connector with spacers so that the back of the connector is flush with the reflector surface. The helix feed assembly is shown in **Fig 40**.

Copper wire, or tubing, about 3.2 mm in diameter is used to form the helix. Wind four turns around a 40-mm diameter form. The turns are wound counterclockwise. This is because the polarization sense is reversed from RHCP when reflected from the dish surface. The wire helix will spring out slightly when winding is complete.

Once the helix is wound, carefully stretch it so that the turns are spaced 28 mm (±1 mm). Make sure the finished spacing of the turns is nice and even. Cut off the first half turn. Carefully bend the first quarter turn about 10° so it will be parallel to the reflector surface once the helix is attached to the N connector. This quarter turn will form part of the matching section.

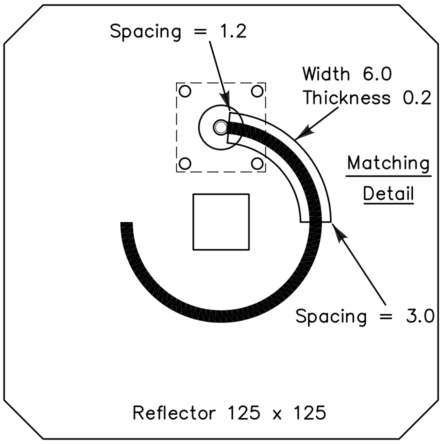

All dimensions are in mm.

Fig 40—Details of helix feed for S-band dish antennas. The type-N connector is fixed with three screws and is mounted on a 1.6-mm spacer to bring the PTFE molding flush with the reflector. An easier mounting can be using a smaller TNC connector. Reflectors should be 95 to 100 mm in diameter.

Cut a strip of brass, 0.2 mm thick and 6 mm wide, and match the curvature of the first quarter turn of the helix, using a paper pattern. Be careful to get this pattern and subsequent brass cutting done exactly right. Using a large soldering iron and working on a heatproof surface, solder the brass strip to the first $^{1}/_{4}$ turn of the helix. Unless you are experienced at this type of soldering, getting the strip attached just right will require some practice. If it doesn't turn out right, just dismantle, wipe clean and try again.

After tack soldering the end of the helix to the type-N connector, the first $^{1}/_{4}$ turn, with its brass strip in place, should be 1.2 mm above the reflector at its start (at the N connector) and 3.0 mm at its end. Be sure to line up the helix so its axis is perpendicular to the reflector. Cut off any extra turns to make the finished helix have $2^{1}/_{4}$ turns total. Once you are satisfied, apply a generous amount of solder at the point the helix attaches to the N connector. Remember this is all that supports the helix.

Once the feed assembly is completed, pass the boom through the middle hole and complete the mounting by any suitable method. The middle of the helix should be at the geometric focus of the dish. In the figures shown here, the feed is connected directly to the downconverter and then the downconverter is attached to the boom. You may require a slightly different configuration depending on whether you are attaching a downconverter, preamp or just a cable with connector. Angle brackets may be used to secure the feed to the boom in a manner similar to the boom-to-reflector mounting. Be sure to use some method of waterproofing if needed for your preamp and/or downconverter.

Dish Feeds

W0LMD describes in **www.ultimatecharger.com/** that feeding a dish has two major factors that determine the efficiency. Like a flashlight bulb, the feed source should evenly illuminate the entire dish, and none of the feed energy should spillover outside the dish's reflecting surface. No feed system is perfect in illuminating a dish. Losses affect the gain from either under-illuminating or over-illuminating the dish (spillover losses). Typical dish efficiency is 50%. That's 3 dB of lost gain. A great feed system for one dish can be a real lemon on another. A patch feed system is very wide angle, but a helix feed system is narrow angle.

W0LMD has experimented with helical feeds for low f/D antennas ("deep" dishes) shown in **Fig 41**. A short-focal-ratio center-fed dish requires a wide-angle feed system to fully illuminate the dish, making the CP patch the preferred feed system. When used with an offset-fed dish, a patch-type feed system will result in a considerable spillover, or over-illumination loss, with an increased sensitivity to off-axis QRM, due to the higher f/D of this dish. Offset-fed

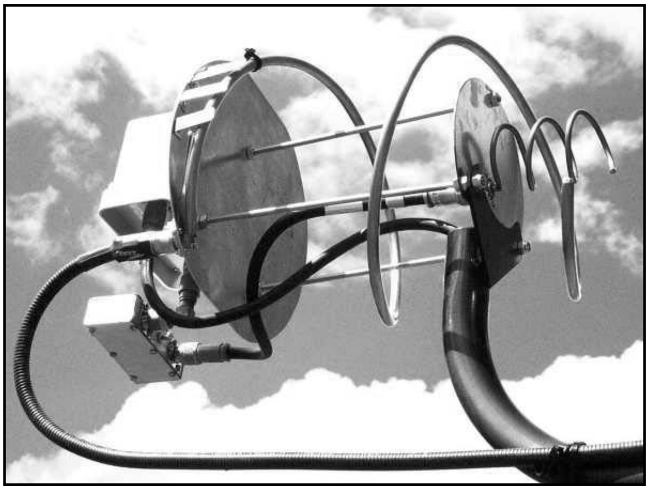

Fig 41—WØLMD's dual helix-dish feed for U and S bands. This early experimental feed was found to be wanting and he then turned to patch feeds for dishes. (*WØLMD photo.*)

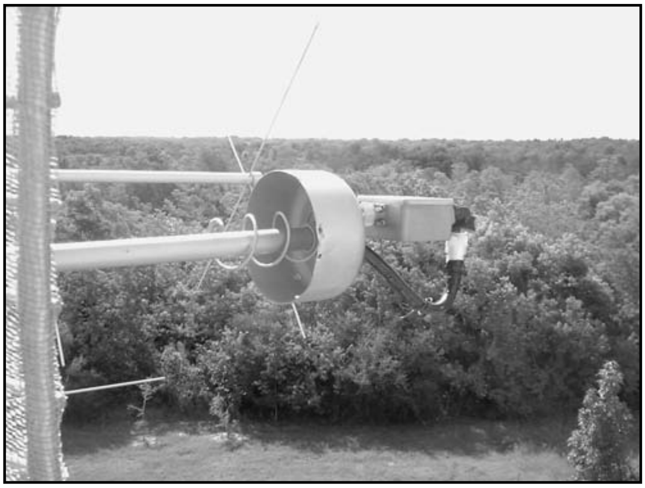

Fig 42—K5OE's helix feed for his MMDS S-band dish antenna. (*K5OE photo.*)

dishes do much better when fed with a helix antenna.

A helix feed is simplicity personified. Mount a type N connector on a flat reflector plate and solder a couple of turns wire to the inner terminal. Designs are anywhere from 2 to 6 turns. The two-turn helices are used for very short-focal-length dishes in the f/D = 0.3 region, and the 6-turn helices are used with longer-focal-length (f/D ~ 0.6) dishes, typically offset-fed dishes. Since AO-40 is right circular and the dish reflection will reverse the polarity, the helix should be wound left circular, looking forward from the connector. Helix feeds work poorly on the short-focal-length dishes but really perform well on the longer-focal-length offset-fed dishes. K5OE shows us the helix feed for his modified MMDS dish in **Fig 42**. This design employs the cupped reflector of W8JK.

A Helix Feed for an Offset-Dish Antenna

This section describes WD4FAB's surplus PrimeStar offset-fed dish antenna with a 7-turn helical feed antenna, shown in Fig 30. This S-band antenna can receive Sun noise 5 dB above sky noise. (Don't try to receive Sun noise with the antenna looking near the horizon, since terrestrial noise will be greater than 5 dB, at least in a big-city environment.) WD4FAB received the dish from NØNSV, who renamed the finished product the "FABStar."

The dish's reflector is a bit out of the ordinary, with the shape of a horizontal ellipse. It is still a single paraboloid, illuminated with an unusual feed horn. At 2401 MHz (S band) we can choose to under-illuminate the sides of the dish while properly feeding the central section, or over-illuminate the center while properly feeding the sides. WD4FAB chose to under-illuminate. The W1GHZ water-bowl measurements showed this to be a dish with a focal point of 500.6 mm and requiring a feed for an f/D = 0.79. The total illumination angle of the feed is 69.8° in the vertical direction and a feed horn with a 3-dB beamwidth of 40.3°. At 50% efficiency this antenna was calculated to provide a gain of 21.9 dBi. A 7-turn helical feed antenna was estimated to provide the needed characteristics for this dish and is shown in **Fig 43**.

The helix is basically constructed as described for the G3RUH parabolic dish above. A matching section for the first λ/4 turn of the helix is spaced from the reflector at 2 mm at the start and 8 mm at the end of that fractional turn. Modifications of the G3RUH design include the addition of a cup reflector, a design feature used by the originator of the helical antenna, John Kraus, W8JK. For the reflector, a 2-mm thick circular plate is cut for a 94 mm (0.75 λ) diameter with a thin aluminum sheet metal cup, formed with a depth of 47 mm. Employment of the cup enhances the performance of the reflector for a dish feed, as shown by K5OE. (See the K5OE material on the CD-ROM accompanying this book.)

The important information for this 7-turn helical antenna is:

- Boom: 12.7-mm square tube or "C" channel.
- Element: $^1/_8$-inch diameter copper wire or tubing.

Close wind the element on a circular 1.50-inch tube or rod; the finished winding is 40 mm in diameter and spaced to a helical angle of 12.3°, or 28 mm spacing. These dimensions work out for an element circumference of 1.0 λ about the center of the wire.

When WD4FAB tackled this antenna, he felt that the small number of helical element supports used by G3RUH would be inadequate, in view of the real-life bird traffic on the antennas at his QTH. He chose to use PTFE (Teflon) support posts every $^1/_2$ turn. This closer spacing of posts permitted a careful control of the helix-winding diameter and spacing and also made the antenna very

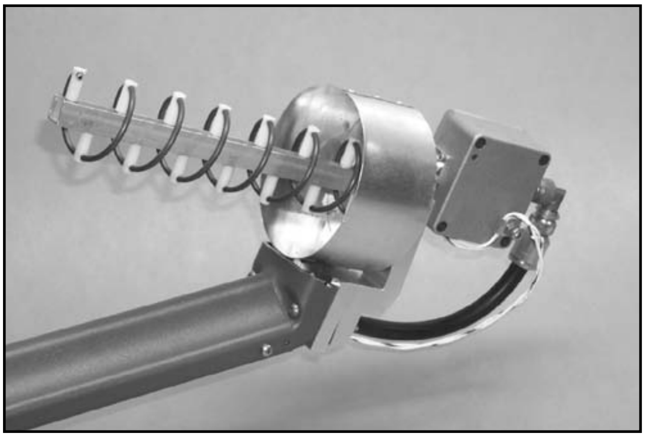

Fig 43—Seven-turn LHCP helix feed for an offset dish, long f/D, antenna, with DEM preamp. (*WD4FAB photo.*)

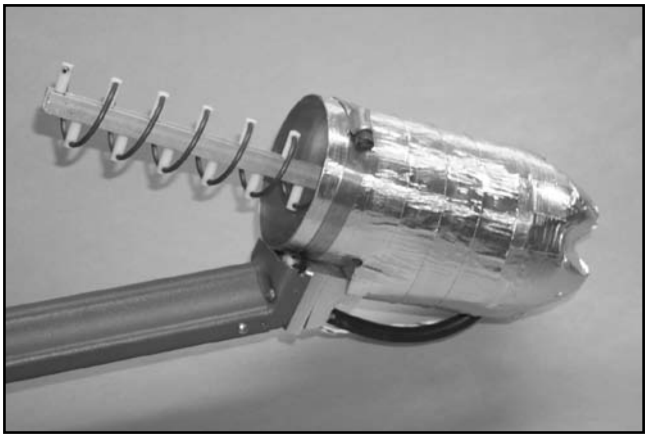

Fig 45—Rain cover for preamp using a two-liter soft-drink bottle with aluminum foil tape for protection from sun damage. (*WD4FAB photo.*)

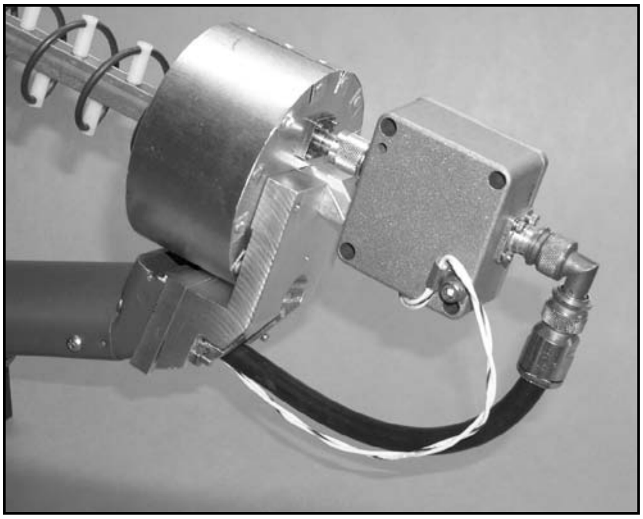

Fig 44—Mounting details of seven-turn helix and preamp. (*WD4FAB photo.*)

robust. He set up a fixture on the drill press to uniformly predrill the holes for the element spacers and boom. Attachment of the reflector is through three very small aluminum angle brackets on the element side of the boom.

Mounting of the helix to the dish requires modification of the dish's receiver-mounting boom. **Fig 44** shows these modifications using a machined mount. NM2A constructed one of these antennas and showed that a machine shop is not needed for this construction. He made a "Z" shaped mount from aluminum-angle plate and then used a spacer from a block of acrylic sheet. The key here is to get the dish focal point at the 1.5-turn point of the feed antenna, which is also at about the lip of the reflector cup.

The W1GHZ data for this focal point is 500.6 mm from the bottom edge of the dish and 744.4 mm from the top edge. A two-string measurement of this point can confirm the focal point, as shown by Wade in his writings. When mounting this feed antenna the constructor must be cautious to aim the feed at the beam-center of the dish, and not the geometric center, as the original microwave horn antenna was constructed. Taking the illumination angle information noted above, the helical feed antenna should be aimed 5.5° down from the geometric center of the dish.

As illustrated in Fig 44, a DEM preamp was directly mounted to the feed helix, using a TNC female connector on the helix, chosen for this case, since N connectors are quite large for this antenna. A male chassis connector should be mounted on the preamp so that the preamp can be directly connected to the antenna without any adaptors. This photo also illustrates how the reflector cup walls were riveted to the reflector plate.

Exposed connectors must be protected from rainwater. Commonly materials such as messy Vinyl Mastic Pads (3M 2200) or Hand Moldable Plastic (Coax Seal) are used. Since this is a tight location for such mastic applications, a rain cover was made instead from a 2-liter soft-drink bottle, **Fig 45**. Properly cutting off the top of the bottle allows it to be slid over the helix reflector cup and secured with a large hose clamp. You must provide UV protection for the plastic bottle and that was done with a wrapping of aluminum foil pressure-sensitive adhesive tape.

There are many methods for mounting this dish antenna to your elevation boom. You must give consideration to the placement of the dish to reduce the wind loading and off-balance to the rotator system. In WD4FAB's FABStar installation, the off-balance issue was not a major factor, as the dish was placed near the center of the elevation boom, between the pillow-block bearing supports. Since there is already a sizeable aluminum plate for these bearings, the dish was located to "cover" part of that plate, so as to not add measurably to the existing wind-loading area of the overall assembly.

A mounting bracket provided with the stock dish clamps to the end of a standard 2-inch pipe stanchion (actual measure: 2.38 inches in diameter). This bracket was turned around on the dish and clamped to the leg of a welded-pipe Tee assembly. See **Fig 46**. Pipe-reducing fittings were machined and fitted in the Tee-top bar, which was sawn in half for clamping over the $1^1/_2$ inch pipe used for the elevation boom. Bolts were installed through drilled holes and used to clamp this assembly.

Patch Feeds for Dish Antennas

Patch feeds are almost as simple as helix feeds. A patch is typically an N connector on a flat reflector plate with a tuned flat-metal plate soldered to the inner terminal. Sometimes the flat plate is square; sometimes it is rectangular; sometimes it is round. It could have two feed points, 90° out of phase for circular polarization, as used in the construction of the AO-40 U-band antennas. Some patches are rectangular with clipped corners to create a circular radiation pattern.

On 2401 MHz, the plate is 57 mm square and spaced 3 mm away from the reflector. The point of attachment is about halfway between the center and the edge. A round patch for 2401 MHz is about 66 mm in diameter. These patches work well on the shorter focal length center-fed MMDS and TVRO dishes. G3RUH made a CP patch feed for these short f/D dishes, shown in Fig 31 and **Fig 47**.

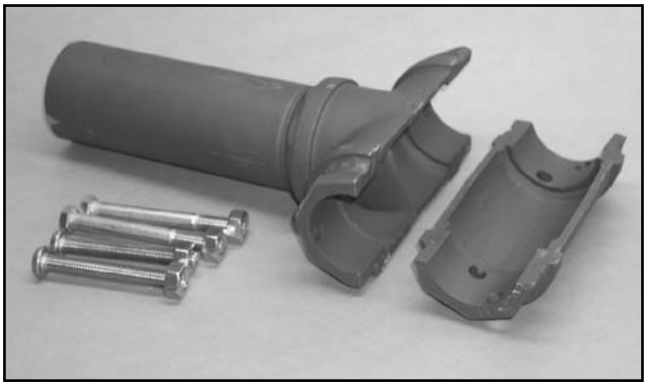

Fig 46—Welded pipefitting mount bracket for FABStar dish antenna. (*WD4FAB photo.*)

Robert, W0LMD, has done a considerable amount of experimenting with patch feeds for his dish antennas. One tri-band feed is shown in **Fig 48**. These are circular patches that have CP properties through the arrangement of the feed point and a small piston-variable capacitor that is offset from the feed point. **Fig 49** shows some of the many patches that Robert has created for his trials.

A No-Tune Dual-Band Feed for Mode L/S

Jerry, K5OE, notes that the AO-40 transponder has two uplink receivers active most of the time for CW/SSB activity. Most operators use U band at 435 MHz (70 cm). Also available, however, are two L-band (23-cm) receivers: L1 at 1269 MHz and L2 at 1268 MHz. The reasons for going to L band can be varied, but there is no arguing the benefits in reduced antenna size and AGC suppression. The types of L-band antennas are varied as well. Many use helices. Others use beams and arrays of beams. Still others use dishes, small and large.

K5OE recently acquired an old UHF TV dish measuring 1.2 meters in diameter. He wanted to use it both to receive on S band at 2401 MHz (13cm) and to transmit on the uplink on L band. He covered it with aluminum mesh and built a dual-helix feed for it, but was unhappy with the L-band performance. It seems the concentric helices interacted with each other substantially. Having had good success with patch feeds on S band, he designed, built and installed a dual-patch feed on a 1.5-meter solid dish for Field Day 2002. This arrangement worked superbly on uplink (with 25 W), but was embarrassingly deaf on receive. This second dual-band feed failure led him to experiment for months with different configurations, leading ultimately to the design presented here. The project goals were:

- Good performance on both S-band receive and L-band uplink.
- An easy-to-produce model using common hardware and simple hand tools.

Patches are better than helices as dish feeds. This revelation came to K5OE while doing investigation and

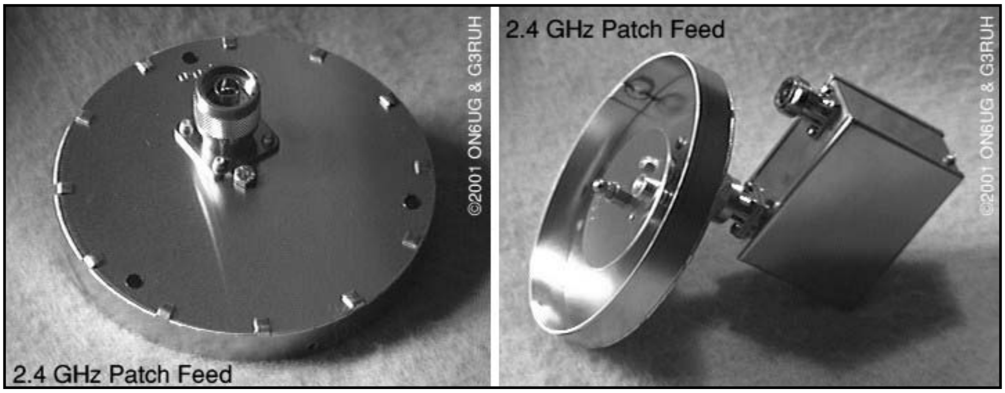

Fig 47—Details of CP-patch feed for short f/D dish antennas by G3RUH and ON6UG.

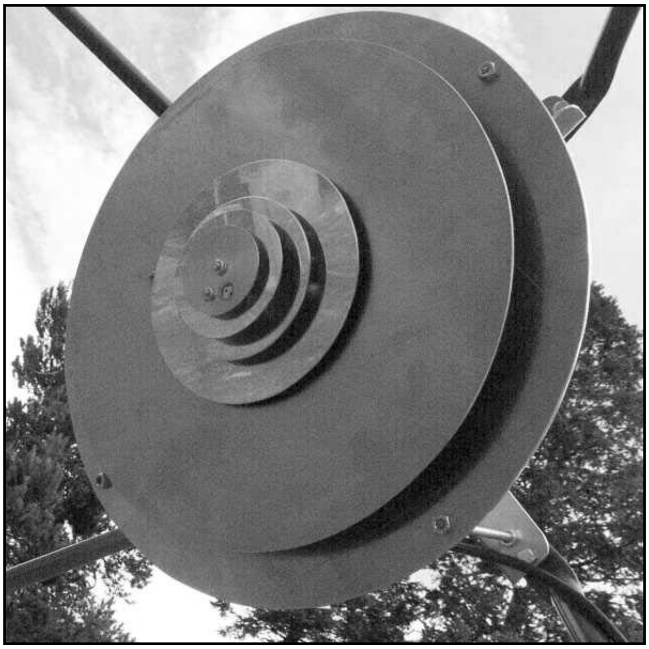

Fig 48—A triband (U, L and S bands) patch-CP feed for large dish antennas for AO-40 service. (*WØLMD photo.*)

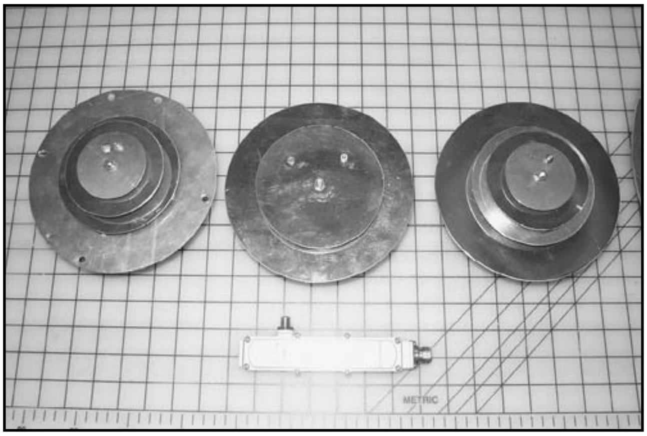

Fig 49—Some of the many experimental CP-patch-feed antennas by WØLMD. (*WØLMD photo.*)

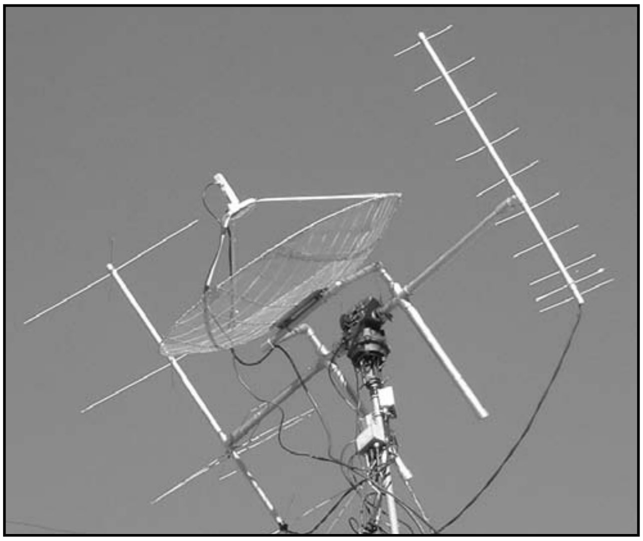

Fig 50—The 1.2-meter dish with dual-band patch feed installed. (*K5OE photo; courtesy of* The AMSAT Journal.)

experimenting with helix antennas. In the middle of this investigative foray, he saw the radiation pattern for the G3RUH patch feed published on James Miller's web site. When he modeled that pattern and input it into the W1GHZ feed pattern program, it produced an amazing 72% efficiency. The best helix he ever modeled has about 60% efficiency. I8CVS recently ran his own antenna range tests of a design similar to the G3RUH patch and produced a similarly impressive pattern.

Then K5OE came across the *truncated corners* square patch design popularized by K3TZ. This AO-40 design here is attributed to 7N1JVW, JF6BCC and JG1IIK. There are references in the literature going back over a decade for this now-common commercial design. The first model K5OE built outperformed his best helix-in-cup design by a full S unit (delta over the noise) on his FT-100 portable setup. Compared to a helix, the patch simply has better illumination efficiency with less spillover from side lobes.

Patch theory is beyond the scope of this article, but can be summarized as building a shape that resonates at the desired frequency, compensated in size by the capacitive inductance between itself and the reflector. A patch can be practically any shape since it basically acts like a parallel-plate transmission line. Current in the patch flows from the feed point to the outer edge(s), where all the radiation occurs. The reputed, but often disputed, circularity of the truncated corner patch is accomplished by effectively designing two antennas into the patch element (of two different diagonal lengths) and feeding them 90º out of phase.

For K5OE's 1.2-meter dish, shown in **Fig 50**, computations predicted 21-dBi gain on L band and almost 27 dBi on S band, with an assumed 50% efficiency:

$$G = 10\log_{10}\left[\eta A\left(\frac{4\pi}{\lambda^2}\right)\right] \qquad \text{(Eq 8)}$$

where

η = efficiency

λ = wavelength in meters.

A = aperture of the dish in meters = $\pi \times r^2$

r = dish radius in meters = diameter/2 in meters = 0.6 meters

At 1269 MHz, λ= 300/1269 = 0.236 meters:

$$G = 10\log_{10}\left[0.50 \times \left(3.14 \times 0.6^2\right) \times \frac{4 \times 3.14}{0.236^2}\right] = 21.1\,\text{dBi}$$

At 2401.5 MHz, $\lambda = 300/2401.5 = 0.125$ meters:

$$G = 10\log_{10}\left[0.50 \times \left(3.14 \times 0.6^2\right) \times \frac{4 \times 3.14}{0.125^2}\right] = 26.6\ \text{dB}^2$$

Where does the feed get mounted? The *focal point* is where the parabolic shape of the dish concentrates the reflected signal. In K5OE's case the antenna was placed flat on the garage floor to measure the depth:

$f = D^2 / 16d$ (Eq 9)

where

D = diameter of the dish in inches
d = depth of the dish in inches
$f = 48^2 / (16 \times 7.25) = 19.8$ inches (50.5 cm)

This is just one example of countless combinations of hardware and patch designs. Inherent in this design, however, are five key design and construction features developed from building and empirical testing of a number of patch feeds.

1. The specified dimensions are critical for no-tune operation. **Fig 51** shows the dimensions necessary to build the dual-feed patch. (K5OE recommends you reproduce this sketch accurately on graph paper. When you cut your patches you can lay them on the paper template for checking.) Repeat: These dimensions are critical. Even a 0.5-mm error will throw your resonance off considerably—patches are not broadband.

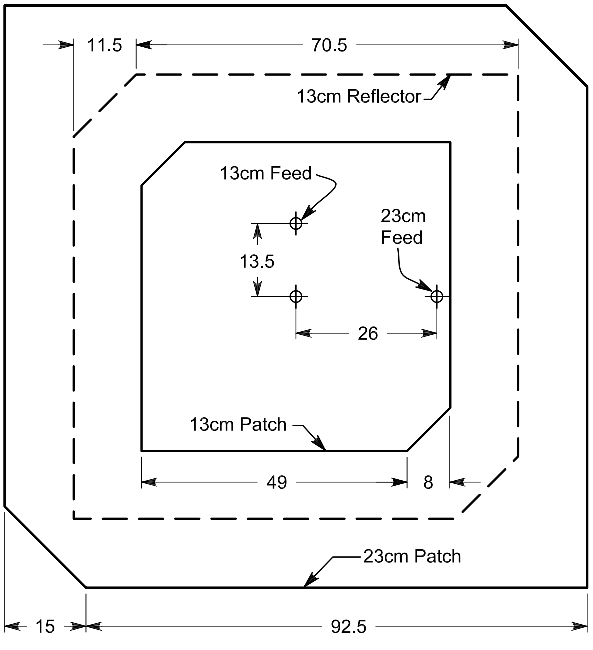

Fig 51—Dual-band patch feed dimensions, in millimeters. (*K5OE diagram; courtesy of* The AMSAT Journal.)

2. The reflector must be rigid. Spacing between the driven element (patch) and the reflector affects the resonant frequency. K5OE found 0.025-inch aluminum sheet and 26-gauge copper sheet acceptable for a single S-band patch feed, but too flimsy for an L-band reflector. Use more rigid material or provide additional stiffening for the L-band reflector, as shown in Figs **52**, **53** and **54**.
3. The patches must be electrically isolated from each other. A metallic center support works for a single patch but creates harmonic-coupling problems when patches are stacked for multiband use. The use of nylon machine screws and nuts helps solve the vexing problem of the S-band patch coupling to the L-band patch.
4. The "straight corners" of the truncated corner patch must be kept clear of any nearby metal. This includes the edges of the feed support or cup, if used. See Fig 54.
5. Feeding the patches at 90° to each other minimizes the electromagnetic interaction between the two antenna fields.

One final design issue deals with the first harmonic of the L-band antenna. You must significantly reduce the potentially destructive effect from the 1269-MHz signal's second harmonic. Severe desense of your receive signal could occur and potentially even overload and damage the first active device in your system. Sensitive preamps and downconverters without a pre-RF-amplifier filter will need an external filter. K5OE has used a G3WDG stub filter rated at 100-dB rejection with good success ahead of his preamp. His current setup, however, uses a AIDC-3731AA downconverter with its internal combline filter providing adequate filtering. Using the downconverter directly at the

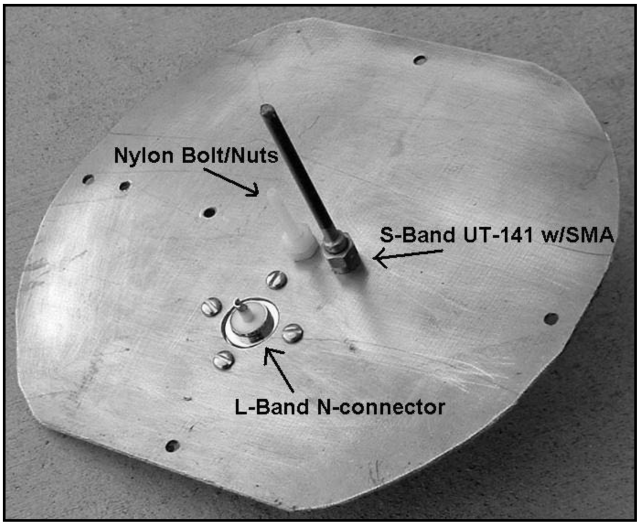

Fig 52—Assembly of the L band reflector. (*K5OE photo; courtesy of* The AMSAT Journal.)

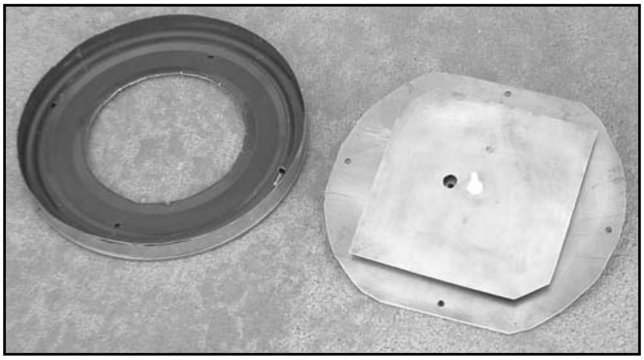

Fig 53—The support, L-band reflector and patch. (*K5OE photo; courtesy of* The AMSAT Journal.)

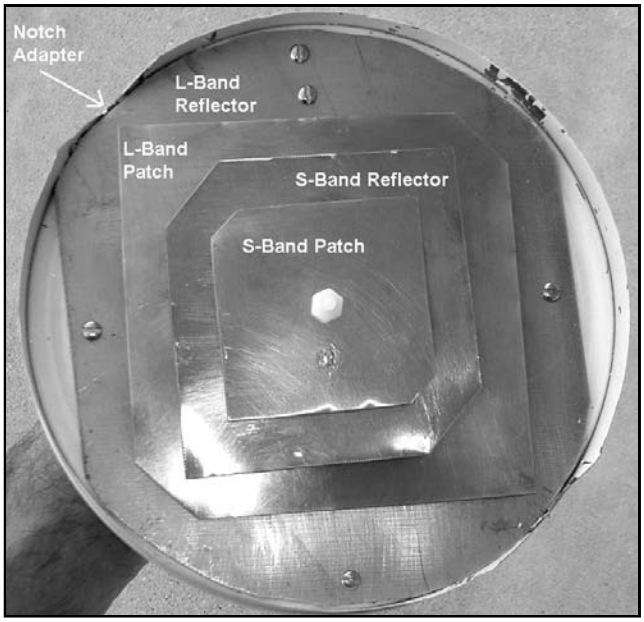

Fig 54—The completed dual-band patch feed. (*K5OE photo; courtesy of* The AMSAT Journal.)

feed point has a noise figure (NF) of 1.0 dB, compared to the cumulative NF of 1.6 dB using a filter and a preamp.

Construction of the feed begins with selection of material for both the electrical parts (the antennas) and the mechanical parts (the support structure). The L-band antenna is constructed using a 6 × 6-inch double-sided circuit board for the reflector and a piece of 26-gauge copper sheet for the driven element (patch). A flanged female type-N connector is used for the feed connection. The S-band antenna is constructed of two pieces of 26-gauge copper sheeting and the feed connection is made with a short piece of UT-141 (0.141-inch copper-clad semirigid coax) terminated in a male SMA fitting. Fig 52 illustrates the assembly of the L-band reflector with the nylon-center support bolt, the L-band N-connector, and the S-band semirigid coax terminated onto an SMA-to-N adapter through the circuit board.

The support structure began life as a paint can, measuring 155 mm in diameter. It was cut down to a 15-mm depth. Cut a hole in the middle of the bottom of the can and trim the PC board to fit inside the can bottom. Use stainless-steel $^{3}/_{8}$-inch 4-40 bolts, washers and nuts to secure the PC board to the can bottom. A 1$^{1}/_{2}$-inch 6-32 nylon bolt is secured through the center of the PC board with two nylon nuts to provide the 6-mm spacing for the L-band patch. Fig 53 shows the L-band patch in position and ready to be soldered to the N-connector. Note the hole through the L-band patch allowing the S-band UT-141 coax to pass (without making contact).

The remainder of the antenna is then assembled in order: First the L-band patch is secured with two nylon nuts and soldered to the N-connector. Then the S-band reflector is secured with one nylon nut to provide 3-mm spacing, and the UT-141 coax shield is soldered to the S-band reflector. Finally, the S-band patch is secured with a single nylon nut (3-mm spacing) and soldered to the center conductor of the UT-141 coax. To summarize the overall order of assembly: L-band reflector, two nylon nuts, L-band patch, two nylon nuts, S-band reflector, one nylon nut, S-band patch, and one nylon nut.

An electrical check with an ohmmeter of the completed feed should show the two reflectors connected, with the patches isolated from the reflectors and from each other. Fig 54 shows the completed feed. Note how the sides of the support are cut out to avoid proximity to the L-band patch and how the L-band and S-band patches are at 90° to each other. **Fig 55** shows the back of the feed, complete with an angle support for the downconverter. The flanged N-connector is for the L-band coax and the male-N adapter is secured from the other side of the feed with the SMA fitting on the UT-141 coax.

For those who are tempted to tune the patch, K5OE recommends doing it with the feed installed on the antenna—since the dish surface affects the feed-point impedance slightly. The feed-point impedance, and thus the resonant frequency, can be changed quite a bit by adjustment of the spacing of just the straight corners. There is no need to change the spacing at the center or the feed—just a slight up or down bending of the straight corners will change the tuning. Do this carefully: a little bit goes a long way. This patch design is very repeatable and will work adequately (an SWR below 1.5:1) with no adjustments.

The antenna performs to the calculated predictions above. On receive, this antenna is 4 S units better than K5OE's 45-cm dish and 3 S units above his 65-cm dish (both other dishes have similar patch feeds and the same downconverter). It also clearly outperforms his previous dual-helix arrangement on the 1.2-meter dish, but he was unable to do a side-by-side comparison.

On transmit, it does equally well, with a decent signal into the satellite with only 10 W measured at the

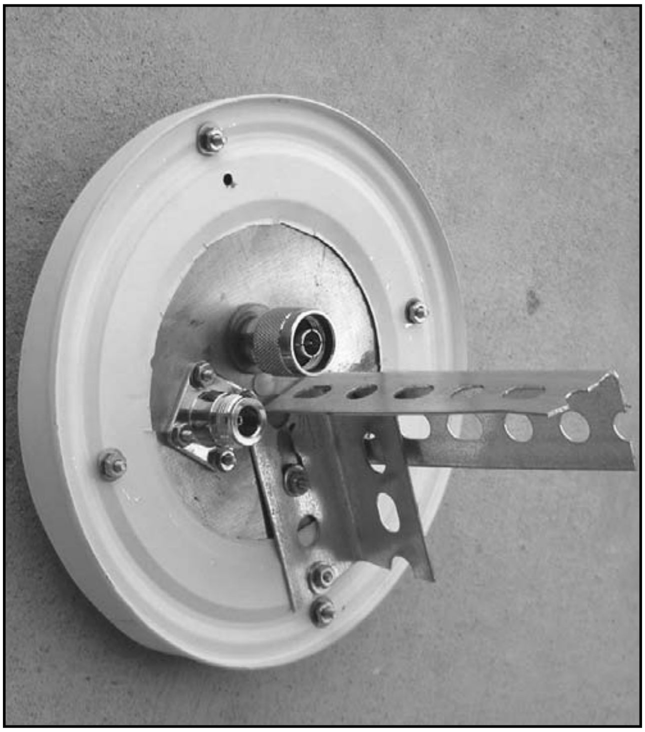

Fig 55—Rear of the completed feed. (K5OE photo; courtesy of *The AMSAT Journal.*)

antenna. The L band is noticeably improved over the helix predecessor. At low squint angles K5OE finds the L-band uplink to be about 1 S unit weaker than his U-band uplink. He later added a small plastic hat to extend over the top of the patches to keep the rain and bird droppings off—both detune the patches when built up between the patch and the reflector.

Though simple and effective, this is merely one way to construct a dual feed. Cookie-tin lids also make excellent supports. Tin snips are a good investment and much easier to use than a hacksaw. Use a flat file to remove burrs from the edges of the patches. Use stainless-steel hardware, most notably $^{3}/_{8}$-inch 4-40 machine bolts and nuts for the antenna hardware and $^{1}/_{2}$-inch 6-32 for the support-structure connections to the support arms ($^{1}/_{2}$-inch aluminum tubing). The copper sheet is much easier to solder to than aluminum. Once completed, the feed received a few coats of white enamel paint to protect the copper and to minimize the visual reflections.

This is not the only dual-band antenna on AO-40. There are many varied, innovative designs available, including G6LVB's simple and effective 1.2-meter homebrew stressed *chicken wire* dish with a dual-G3RUH helix feed. G3WDG has a 3-meter dish with L/S-band helices and a K-band (1.3-cm) feed horn, and W0LMD has developed some popular dual- and tri-band "round" patch feeds. (See the Notes and References, as well as the CD-ROM bundled with this book.)

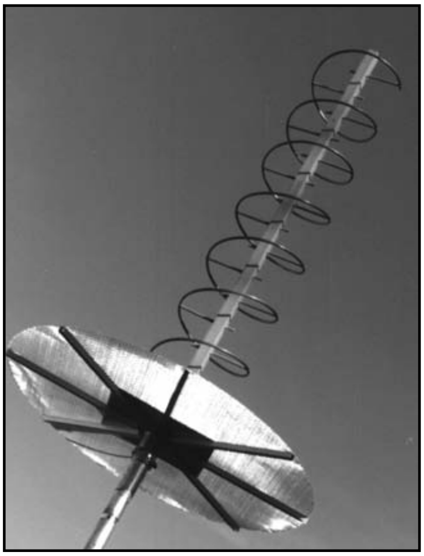

Fig 56—The portable 435-MHz helix assembled and ready for operation. (*W0CY photo.*)

For additional information on constructing antennas, feeds and equipment techniques for use at microwave frequencies, see *The ARRL UHF/Microwave Experimenter's Manual* and *The ARRL UHF/Microwave Projects Manual*. Both of these books have a wealth of information for the experimenter.

PORTABLE HELIX FOR 435 MHZ

Helical antennas for 435 MHz are excellent uplinks for U-band satellite communications. The true circular polarization afforded by the helix minimizes signal *spin fading* that is so predominant in these applications. The antenna shown in **Fig 56** fills the need for an effective portable uplink antenna for OSCAR operation. Speedy assembly and disassembly and light weight are among the benefits of this array. This antenna was designed by Jim McKim, W0CY.

As mentioned previously, the helix is about the most tolerant of any antenna in terms of dimensions. The dimensions given here should be followed as closely as possible, however. Most of the materials specified are available in any well supplied do-it-yourself hardware or building supply store. The materials required to construct the portable helix are listed in **Table 1**.

The portable helix consists of eight turns of $^{1}/_{4}$-inch soft-copper tubing spaced around a 1-inch fiberglass tube or maple dowel rod 4 feet, 7 inches long. Surplus aluminum jacket Hardline can be used instead of the copper tubing if necessary. The turns of the helix are supported by 5-inch lengths of $^{1}/_{4}$-inch maple dowel mounted through the 1-inch rod in the center of the antenna. **Fig 57A** shows the overall dimensions of the antenna. Each of these support dowels has a V-shaped notch in the end to locate the tubing, as shown in Fig 57B.

The rod in the center of the antenna terminates at the feed-point end in a 4-foot piece of 1-inch ID galva-

Table 1
Parts List for the Portable 435-MHz Helix

Qty	*Item*
1	Type N female chassis mount connector
18 feet	1/4-in. soft copper tubing
4 feet	1-inch ID galvanized steel pipe
1	5 feet × 1-inch fiberglass tube or maple dowel
14	5-inch pieces of 1/4-inch maple dowel (6 feet total)
1	1/8-inch aluminum plate, 10 inches diameter
3	2 × 3/4-inch steel angle brackets
1	30 × 30-inch (round or square) aluminum screen or hardware cloth
8 feet	1/2 × 1/2 × 1/2-inch aluminum channel stock or old TV antenna element stock
3	Small scraps of Teflon or polystyrene rod (spacers for first half turn of helix)
1	1/8 × 5 × 5-inch aluminum plate (boom-to-mast plate)
4	1½-inch U bolts (boom-to-mast mounting)
3 feet	#22 bare copper wire (helix turns to maple spacers)

Assorted hardware for mounting connector, aluminum plate and screen, etc.

nized steel pipe. The pipe serves as a counterweight for the heavier end of the antenna. The 1-inch rod material inside the helix must be nonconductive. Near the point where the nonconductive rod and the steel pipe are joined, a piece of aluminum screen or hardware cloth is used as a reflector screen.

If you have trouble locating the 1/4-inch soft copper tubing, try a refrigeration supply house. The perforated aluminum screening can be cut easily with tin snips. This material is usually supplied in 30 × 30-inch sheets, making this size convenient for a reflector screen. Galvanized 1/4-inch hardware cloth or copper screen could also be used for the screen, but aluminum is easier to work with and is lighter.

A 1/8-inch-thick aluminum sheet is used as the support plate for the helix and the reflector screen. Surplus rack panels provide a good source of this material. **Fig 58** shows the layout of this plate.

Fig 59 shows how aluminum channel stock is used to support the reflector screen. (Aluminum tubing also works well for this. Discarded TV antennas provide plenty of this material if the channel stock is not available.) The screen is mounted on the bottom of the 10-inch aluminum center plate. The center plate, reflector screen and channel stock are connected together with plated hardware or pop rivets. This support structure is very sturdy. Fiberglass tubing is the best choice for the center rod material although maple dowel can be used.

Mount the type-N connector on the bottom of the center plate with appropriate hardware. The center pin should be exposed enough to allow a flattened end of the copper tubing to be soldered to it. Tin the end of the tubing after it is flattened so that no moisture can enter it. If the helix is to be removable from the ground-plane screen, do not solder the copper tubing to the connector. Instead, prepare a small block of brass, drilled and tapped at one side for a 6-32 screw. Drill another hole in the brass block to accept the center pin of the type-N connector, and solder this connection. Now the connection to the copper tubing helix can be made in the field with a 6-32 screw instead of with a soldering iron.

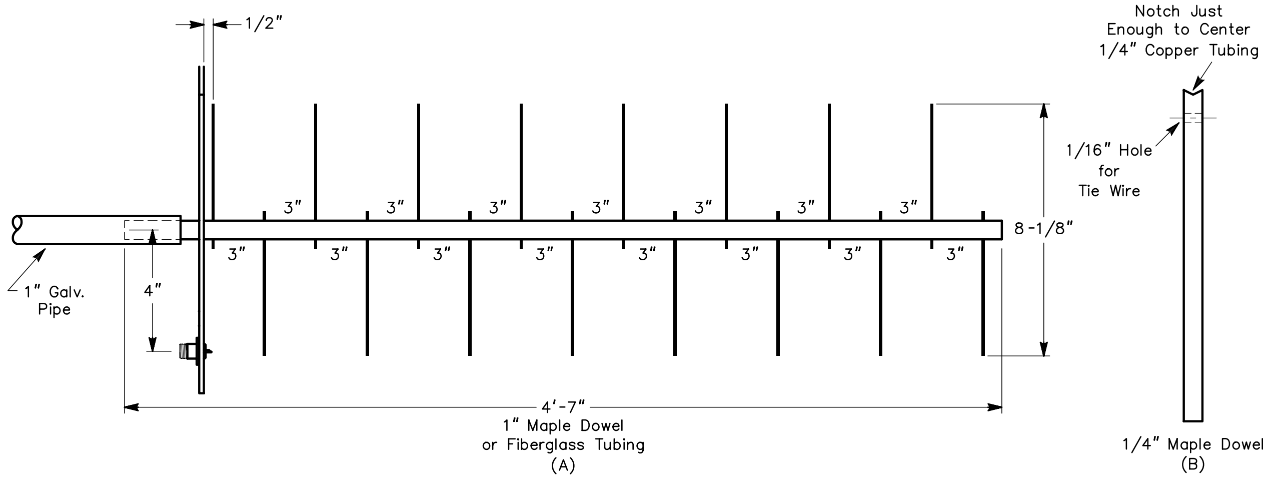

Fig 57—At A, the layout of the portable 435-MHz helix is shown. Spacing between the first 5-inch winding-support dowel and the ground plane is 1/2 inch; all other dowels are spaced 3 inches apart. At B, the detail of notching the winding-support dowels to accept the tubing is shown. As indicated, drill a 1/16-inch hole below the notch for a piece of small wire to hold the tubing in place.

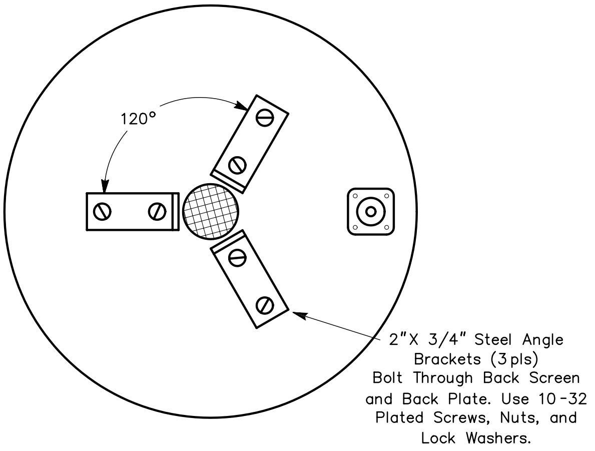
120°
2″X 3/4″ Steel Angle Brackets (3 pls) Bolt Through Back Screen and Back Plate. Use 10-32 Plated Screws, Nuts, and Lock Washers.

Fig 58—The ground plane and feed-point support assembly are shown. The circular piece is a 10-inch diameter, 1/8-inch thick piece of aluminum sheet. (A square plate may be used instead.) Three 2 × 3/4-inch angle brackets are bolted through this plate to the backside of the reflector screen to support the screen on the pipe. The type-N female chassis connector is mounted in the plate 4 inches from the 1-inch diameter center hole.

Refer to Fig 57A. Drill the fiberglass or maple rod at the positions indicated to accept the 5-inch lengths of 1/2-inch dowel. (If maple doweling is used, the wood must be weatherproofed as described below before drilling.) Drill a 1/16-inch hole near the notch of each 5-inch dowel to accept a piece of #22 bare copper wire. (The wire is used to keep the copper tubing in place in the notch.) Sand the ends of the 5-inch dowels so the glue will adhere properly, and epoxy them into the main support rod.

Begin winding the tubing in a clockwise direction from the reflector screen end. First drill a hole in the flattened end of the tubing to fit over the center pin of the type-N connector. Solder it to the connector, or put the screw into the brass block described earlier. Carefully proceed to bend the tubing in a circular winding from one support to the next.

See the earlier section entitled “50-Ω Helix Feed” and Figs 19 and 20 to see how the first half-turn of the helix tubing must be positioned close above the reflector assembly. **Fig 59B** shows also an excellent example by K9EK on matching his U-band helical antenna to a 52-Ω feed line. It is important to maintain this spacing, since extra capacitance between the tubing and ground is required for impedance-matching purposes.

Insert a piece of #22 copper wire in the hole in each support as you go. Twist the wire around the tubing and the support dowel. Solder the wire to the tubing and to itself to keep the tubing in the notches. Continue in this way until all eight turns have been wound. After winding the helix, pinch the far end of the tubing together and solder it closed.

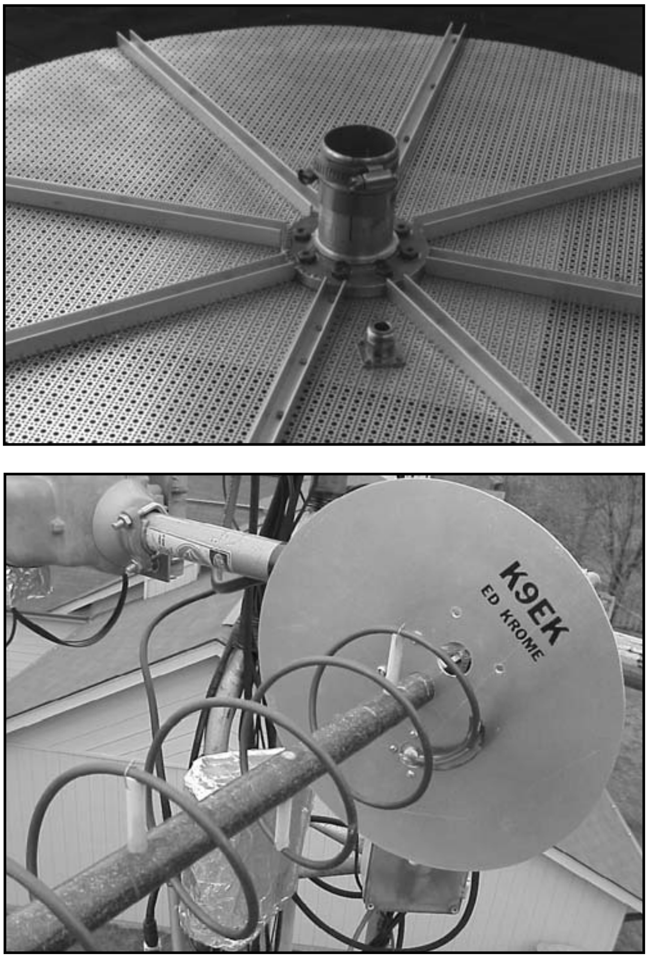

Fig 59—At top, the method of reinforcing the reflector screen with aluminum channel stock is shown. In this version of the antenna, the three angle brackets of Fig 58 have been replaced with a surplus aluminum flange assembly. (*W0CY photo.*) At bottom, this helix view shows the details of a 1/4-turn matching transformer, as discussed in the text. (*K9EK photo.*)

Weatherproofing the Wood

A word about preparing the maple doweling is in order. Wood parts must be protected from the weather to ensure long service life. A good way to protect wood is to boil it in paraffin for about half an hour. Any holes to be drilled in the wooden parts should be drilled after the paraffin is applied, since epoxy does not adhere well to wood after it has been coated with paraffin. The small dowels can be boiled in a saucepan. Caution must be exercised here—the wood can be scorched if the paraffin is too hot. Paraffin is sold for canning purposes at most grocery stores. Wood parts can also be protected with three or four coats of spar varnish. Each coat must be allowed to dry fully before another coat is applied.

The fiberglass tube or wood dowel must fit snugly with the steel pipe. The dowel can be sanded or turned down to the appropriate diameter on a lathe. If fiberglass is used, it can be coupled to the pipe with a piece of wood dowel that fits snugly inside the pipe and the tubing. Epoxy the dowel splice into the pipe for a permanent connection.

Drill two holes through the pipe and dowel and bolt them together. The pipe provides a solid mount to the boom of the rotator, as well as most of the weight needed to counterbalance the antenna. More weight can be added to the pipe if the assembly is "front-heavy." (Cut off some of the pipe if the balance is off in the other direction.)

The helix has a nominal impedance of about 105 Ω in this configuration. By varying the spacing of the first half turn of tubing, a good match to 52-Ω coax should be obtainable. When the spacing has been established for the first half turn to provide a good match, add pieces of polystyrene or Teflon rod stock between the tubing and the reflector assembly to maintain the spacing. These can be held in place on the reflector assembly with silicone sealant. Be sure to seal the type-N connector with the same material.

Exposed Antenna Relays and Preamplifiers

For stations using crossed Yagi antennas for CP operation, one feature that has been quite helpful for communicating through most of the LEO satellites, has been the ability to switch polarization from RHCP to LHCP. In some satellite operation this switchable CP ability has been essential. Operation through AO-40 has not shown a great need for such CP agility, since if the satellite is seriously off-pointed the signals are not particularly useable. When AO-40's squint angle is less than 25° the need for LHCP has not been observed. For those using helical antennas or helical-fed dish antennas, we just would not have the choice to switch CP unless an entirely new antenna is added to the cluster for that purpose. Not many of us have the luxury of that kind of space available on our towers.

For stations with switchable-circularity Yagi antennas, experience with exposed circularity switching relays and preamplifiers mounted on antennas have shown that they are prone to failure caused by an elusive mechanism known as *diurnal pumping*. Often these relays are covered with a plastic case, and the seam between the case and PC board is sealed with a silicone sealant. Preamps may also have a gasket seal for the cover, while the connectors can easily leak air. None of these methods create a true hermetic seal and as a result the day/night temperature swings pump air and moisture in and out of the relay or preamp case. Under the right conditions of temperature and moisture content, moisture from the air will condense inside the case when the outside air cools down. Condensed water builds up inside the case, promoting extensive corrosion and unwanted electrical conduction, seriously degrading component performance in a short time.

A solution for those antennas with "sealed" plastic relays, such as the KLM CX series; you can avoid problems by making the modifications shown in **Fig 60**. Relocate the 4:1 balun as shown and place a clear polystyrene plastic refrigerator container over the relay. Notch the container edges for the driven element and the boom so the container will sit down over the relay, sheltering it from the elements. Bond the container in place with a few dabs of RTV adhesive sealant. Position the antenna in an "X" orientation, so neither set of elements is parallel to the ground. The switcher board should now be canted at an angle, and one side of the relay case should be lower than the other. An example for the protective cover for an S-band preamp can be seen in the discussion on feeds for parabolic antennas.

For both the relay and preamp cases, carefully drill a 3/32-inch hole through the low side of the case to provide the needed vent. The added cover keeps rainwater off the

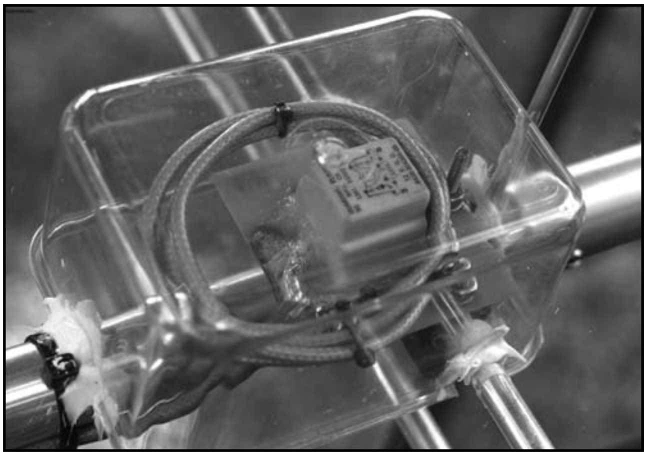

Fig 60—KLM 2M-22C antenna CP switching relay with relocated balun. The protective cover is needed for rain protection, be sure to use a polystyrene kitchen box, see text. (*WD4FAB photo.*)

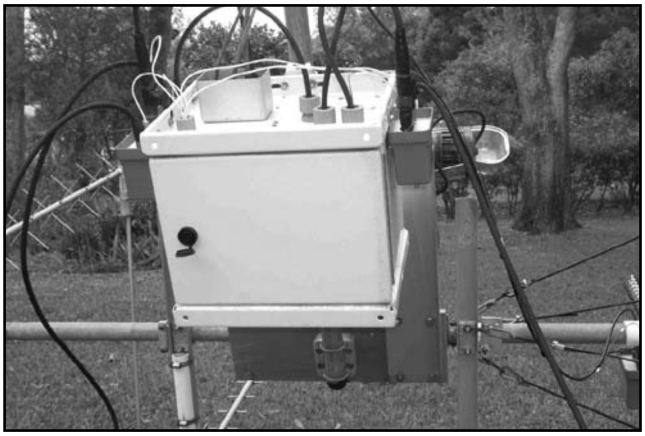

Fig 61—A NEMA4 box is used to shelter the L-band electronics and power supply. The box flanges are convenient for mounting preamplifiers. The box is shown inverted since it is on a tilt-over tower. (*WD4FAB photo.*)

relay and preamp, and the holes will prevent any buildup of condensation inside the relay case. Relays and preamplifiers so treated have remained clean and operational over periods of years without problems.

Another example for the protection of remotely, tower-mounted equipment is shown in Fig 50, illustrating the equipment box and mast-mounted preamplifiers at the top of WD4FAB's tower. The commercial NEMA4-rated equipment box, detailed in **Fig 61** (shown inverted), is used to protect the 23-cm power amplifier and its power supply, as well as a multitude of electrical connections. This steel box is very weather resistant, with an exceptionally good epoxy finish, but it is not sealed and so it will not trap moisture to be condensed with temperature changes. Be sure to use a box with at least a NEMA3 rating for rainwater and dust protection. The NEMA4 rating is just a little better protection than the NEMA3 rating. Using a well-rated equipment box is very well worth the expense of the box. As you can see, the box also provides some pretty good flanges to mount the mast-mounted preamplifiers for three bands. This box is an elegant solution for the simple need of rain shelter for your equipment. See **Fig 62**.

Elevation Control

Satellite antennas need to have elevation control to point up to the sky. This is the "El" part of Az-El control of satellite antennas. Generally, elevation booms for CP satellite antennas need to be non-conducting so that the boom does not affect the radiation pattern of the antenna. In the example shown next, the elevation boom center section is a piece of extra-heavy-wall $1^1/_2$-inch pipe (for greater strength) coupled with a tubular fiberglass-epoxy boom extension on the 70-cm end and a home-brew long extension on the 2-meter end. This uses large PVC pipe reinforced with four braces of Phillystran non-metallic guy cable. (PVC pipe is notoriously flexible, but the Phillystran cables make a quite stiff and strong boom of the PVC pipe.) For smaller installations, a continuous piece of fiberglass-epoxy boom can be placed directly through the elevation rotator.

Elevation boom motion needs to be powered, and one solution by WD4FAB, shown in **Fig 63**, uses a surplus jackscrew drive mechanism. I8CVS has also built his own robust elevation mechanism. See **Fig 64**. Note in each of these applications the methods used to provide bearings for the elevation mechanism. In WD4FAB's case, the elevation axis is a piece of heavy-duty $1^1/_2$-inch pipe,

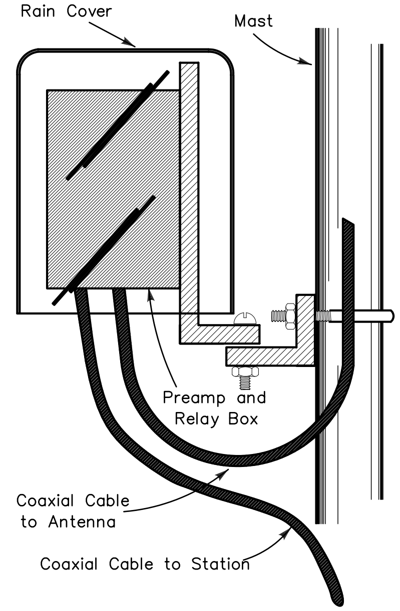

Fig 62—Protection for tower-mounted equipment need not be elaborate. Be sure to dress the cables as shown so that water drips off the cable jacket before it reaches the enclosure. One hazard for such open-bottom enclosures is that of animals liking the cable insulation as a delicacy. Flying insects also like to build their houses in these enclosures.

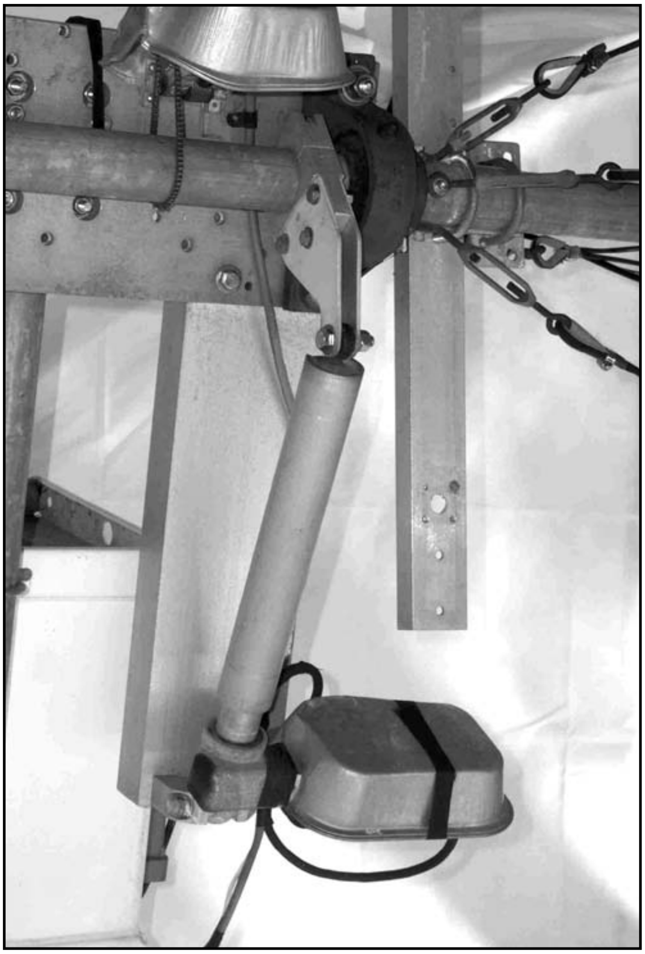

Fig 63—WD4FAB's homebrew elevation rotator drive using a surplus-store drive screw mechanism. Note also the large journal bearing supporting the elevation axis pipe shaft. (*WD4FAB photo.*)

($1^{15}/_{16}$-inch OD) and large 2 inch journal bearings are used for the motion. I8CVS uses a very large hinge to allow his motion.

Robust commercial solutions for Az-El rotators have given operators good service over the years. **See Fig 65**. Manufacturers such as Yaesu and M^2 are among these suppliers. One operator, VE5FP, found a solution for his Az-El needs by using two low-cost, lightweight TV rotators. See Fig 65B.

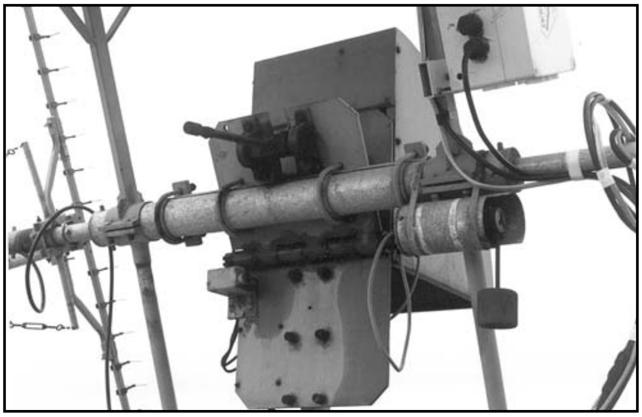

Fig 64—I8CVS's homebrew elevation mechanism using a very large, industrial hinge as the pivot and a jackscrew drive. (*I8CVS photo.*)

CONVERTED C-BAND TVRO DISHES

In working with larger, converted C-band TVRO dishes for AO-40, some operators have used only the polar mount with its jack-screw mechanism. See **Fig 66**. This dish is called *Big Ugly Dish* or just "BUD" by their users. Only using the polar mount mechanism limits the operator in the range of motion, as previously discussed. W0LMD provides for a greater degree of articulation of these dishes through several mechanisms. One of these is a sector-gear elevation drive, shown in **Fig 67**.

For the azimuth motion of our satellite antennas, most use motorized rotator drives, mainly the commercial sources previously mentioned. Most antennas are tower-mounted, allowing the placement of the rotator inside the tower. For the large wind loads of satellite antennas, these commercial rotators become rather expensive.

High loads are also prominent with the use of BUD

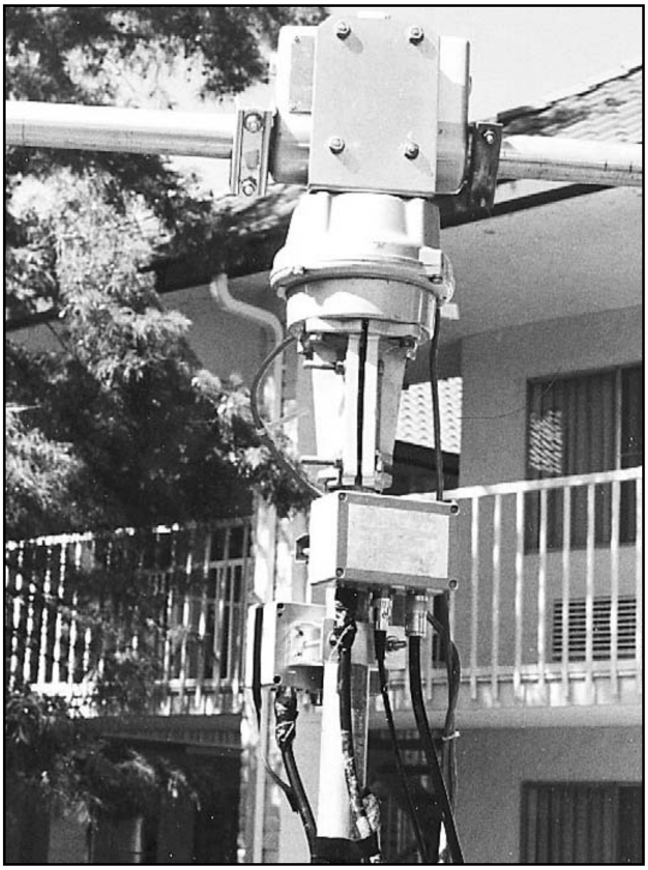

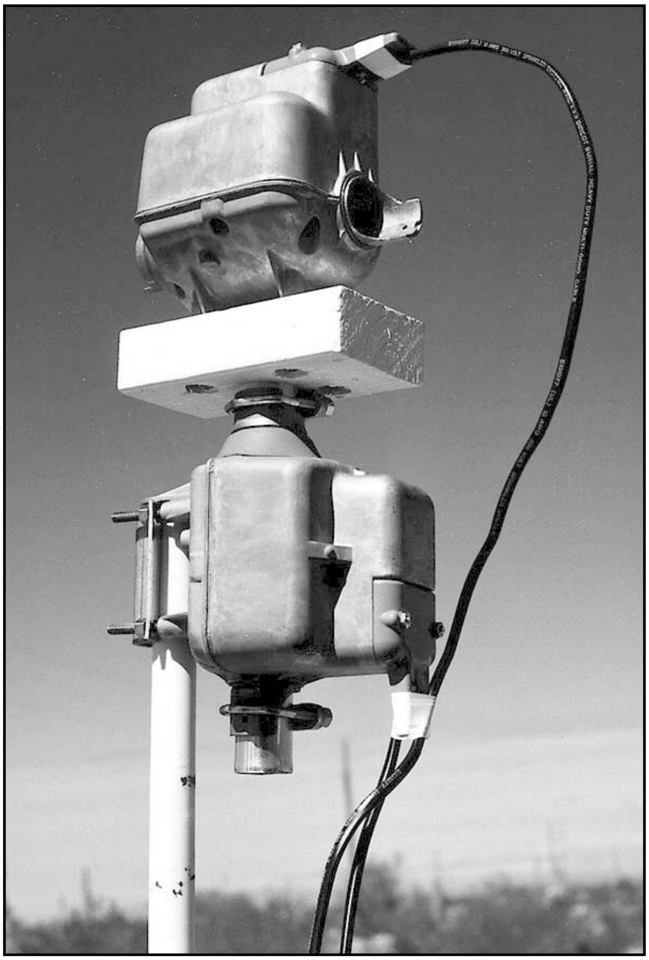

Fig 65—At left, Yaesu Az-El antenna-rotator mounting system is shown. Note that antenna loads must be more carefully balanced on this rotator than in the previously shown systems. At right, VE5FP has a solution for his Az-El rotators by bolting two of them together in his "An Inexpensive Az-El Rotator System", *QST*, December 1998.

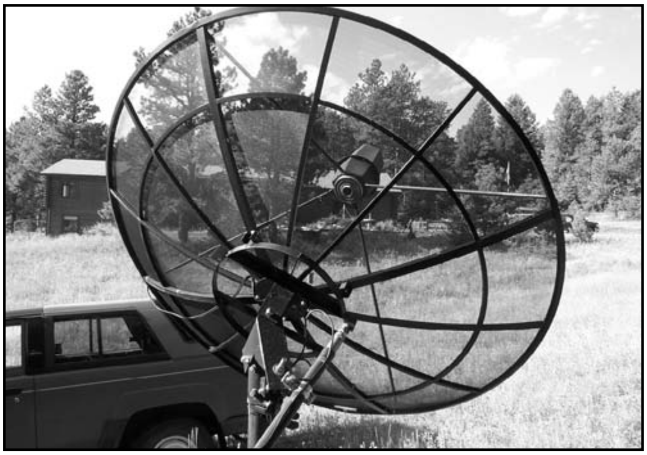

Fig 66—A TVRO dish-drive system is shown on its polar mount, using a protected drive-screw mechanism. (*W0LMD photo.*)

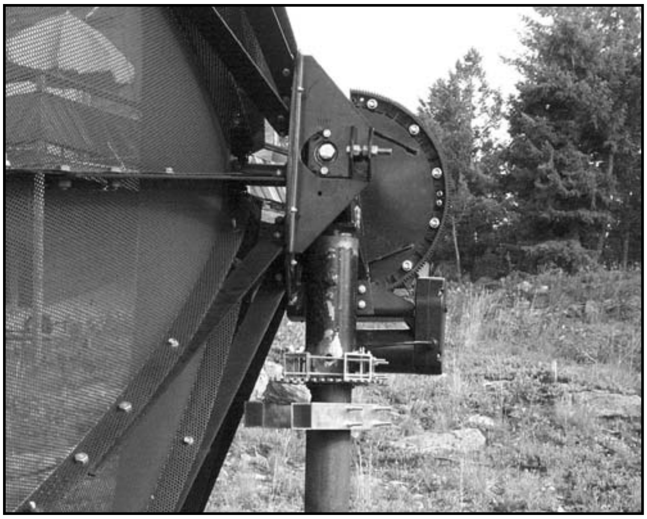

Fig 67—A modified TVRO dish mount is shown using an Az-El mount and a sector-gear drive for the elevation. (*W0LMD photo.*)

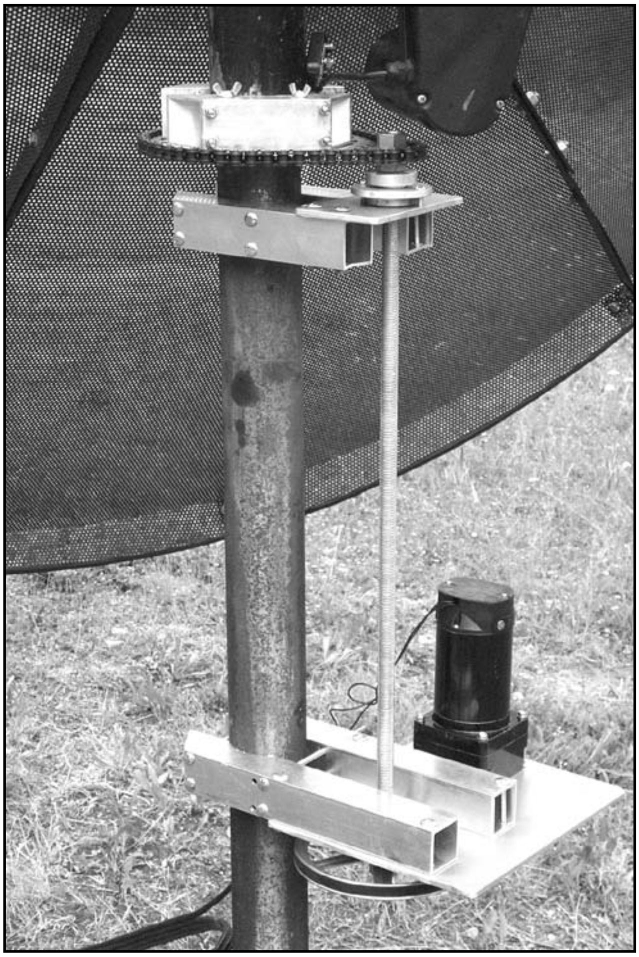

Fig 68—W0LMD constructed a very robust and low-cost Az drive mechanism. (*W0LMD photo.*)

antennas, and W0LMD has again engineered some very robust mechanisms using combinations of motorcycle-chain drives, V-belt drives and gear-head motors, as seen in **Fig 68**. An overall view of one of his BUD antennas is shown in **Fig 69**, showing the Az drive with an El drive that uses a jackscrew mechanism.

Operators through the years have employed many methods for the control of their antenna positions, ranging from true *arm-strong* manual positioning, to manual operation of the powered antenna azimuth and elevation rotators, to fully automated computer control of the rotators. While computer control of the rotators is not essential, life is greatly assisted with their use. For many years, one of the keystone control units for rotators has been the *Kansas City Tracker* (KCT) board installed in your computer. Most satellite-tracking programs can connect to the KCT with ease. One difficulty with the KCT unit is that they are 8-bit digital units, providing positioning precision of 0.35° in elevation and 1.41° in azimuth. For the larger dishes, with their narrow beamwidths, these values of precision are unacceptable. There are other options to replace the KCT unit.

A recent trend for amateur antenna control has been evolving in the form of a standalone controller that translates computer antenna-position information into controller commands with an understanding of antenna-position limits. These boxes, represented by the *EasyTrak* unit, **Fig 70**, from the Tucson Amateur Packet Radio (TAPR) group, have made this capability readily available for many amateurs. This unit is a 10-bit encoder, providing precisions of 0.09° in elevation and 0.35° in azimuth. The computer can also control the operation of your station transceiver through the radio interface provided in *EasyTrak*; you will not need any other radio interface.

Other position readout and control options are available. For many years ham operators have employed synchros, or *selsyns*, for their position readouts. These are

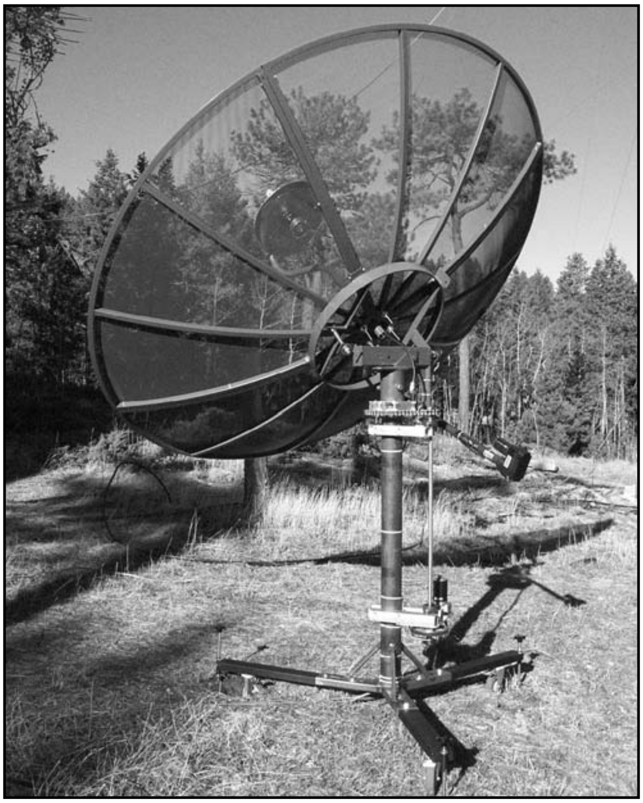

Fig 69—A completed TVRO dish Az-El mounting system is shown, using a jackscrew elevation drive. (*W0LMD photo.*)

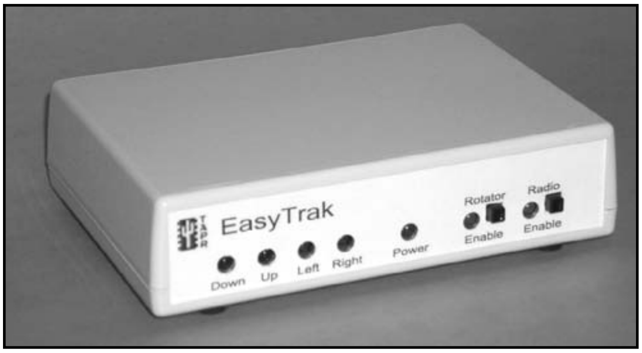

Fig 70—The EasyTrak automated antenna rotator and radio controller by TAPR. (*WD4FAB photo.*)

specialized transformers, using principles developed over sixty years ago and employed in such devices as surplus “radio compass” steering systems for aircraft. While the position readout of these devices can be quite precise, in general they only provide a visual position indication, one that is not easily adapted to computer control. I8CVS employs such a system at his station and his elevation synchro can be seen in Fig 64, using a weighted arm on the synchro to provide a constant reference to the Earth’s gravity vector.

The more up-to-date, computer-friendly position readout methods used these days are usually based on precision potentiometers or digital code wheels. **Fig 71** shows such a digital code-wheel system employed by W0LMD. He notes that such systems, while providing a very high precision of angular position, they are not absolute systems and that once calibrated, they must be continually powered so they do not lose their calibration. Precision potentiometers, on the other hand, provide an absolute position reference, but with a precision that is limited to the quality of the potentiometer, typically 0.5% (0.45° in El and 1.80° in Az) to 1.0%. So the choices have their individual limits, unless a lot of money is spent for very precise commercial systems.

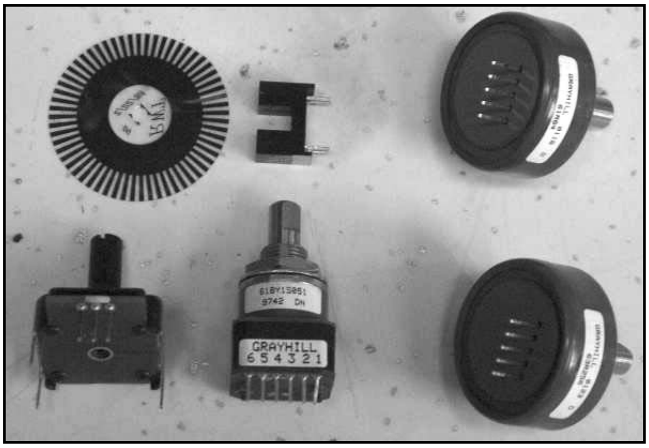

Fig 71—W0LMD has experimented with highly precise optical encoders for his antenna position systems. See text. (*W0LMD photo.*)

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Antenna Systems for EME Communications

This section was updated by David Hallidy, K2DH. As mentioned earlier, the tremendous path loss incurred over an EME circuit places stringent requirements on Earth-station performance. Low-noise receiving equipment, maximum available power and high-gain antenna arrays are required for successful EME operation. Although it is possible to copy some of the better-equipped stations with a low-gain antenna, it is unlikely that such an antenna can provide reliable two-way communications. Antenna gain of at least 20 dBi is required for reasonable EME success. Generally speaking, more antenna gain yields the most noticeable improvement in station performance, since the increased gain improves both the received and transmitted signals.

VHF/UHF EME ANTENNAS

Several types of antennas for 2 meters and 70 cm are popular among EME enthusiasts. Perhaps the most popular antenna for 144-MHz work is an array of either 4 or 8 long-boom (14 to 15 dBi gain) Yagis. The 4-Yagi array provides approximately 20 dB gain, and an 8-Yagi array gives an approximate 3 dB increase over the 4-antenna array. **Fig 72** shows the computed response at a 30° tilt above the horizon for a stack of four 14-element 2-meter Yagis, each with a boomlength of 3.1 λ (22 feet).

At 432 MHz, EME enthusiasts often use 8 or 16 long-boom Yagis in an array. Such Yagis are commercially available or they can be constructed from readily available materials. Chapter 18, VHF and UHF Antenna Systems, has details on some popular Yagi designs.

The main disadvantage of Yagi arrays is that the polarization plane of the individual Yagis cannot be conveniently changed. One way around this is to use cross-polarized Yagis and a relay switching system to select the desired polarization, as described in the previous section. This represents a considerable increase in system complexity to select the desired polarization. Some amateurs have gone so far as to build complicated mechanical systems to allow constant polarization adjustment of all the Yagis in a large array. **Fig 73** shows the K1FO 70-cm EME 16-Yagi array with full polarization control, described in *The ARRL Antenna Compendium*, *Vol 3*. This 432-MHz EME array uses open-wire phasing lines to minimize feed-line losses. **Fig 74** shows the computed response for this array, which employs rugged but lightweight 14-element Yagis on 3.1 λ (7.1 foot) booms. Feed-line losses are not explicitly accounted for in the *EZNEC Professional* computer model, but are estimated to be less than 0.25 dB.

Polarization shift of EME signals at 144 MHz is fairly rapid, and the added complexity of a relay-controlled cross-polarized antenna system or a mechanical polarization adjustment scheme is probably not worth the effort. At 432 MHz, however, where the polarization shifts at a much slower rate, an adjustable polarization system does offer a definite advantage over a fixed one.

The Yagi antenna system used by Ed Stallman, N5BLZ, is shown in **Fig 75**. His system employs twelve 144-MHz long-boom 17-element Yagi antennas. The monster 48-Yagi 2-meter array of Gerald Williamson, K5GW, is shown in **Fig 76**, and the huge 48-Yagi 70-cm EME array of Frank Potts, NC1I, is shown in **Fig 77**.

Although not as popular as Yagis, Quagi antennas (made from both quad and Yagi elements) are sometimes used for EME work. Slightly more gain per unit boom length is possible as compared to the conventional Yagi, at the expense of some robustness. Additional information on the Quagi is presented in Chapter 18, VHF and UHF Antenna Systems.

The collinear array is an older type of antenna for EME work. A 40-element collinear array has approximately

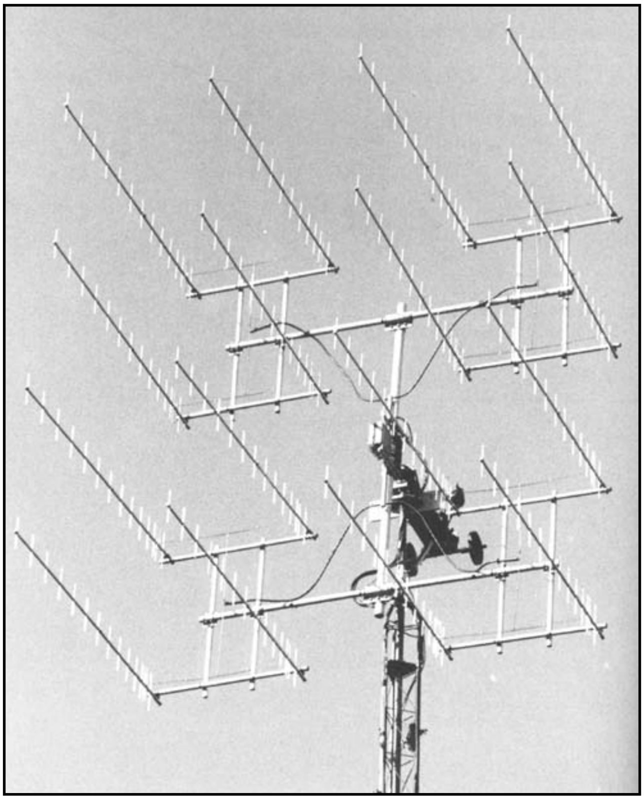

Fig 73—K1FO's variable polarization 16 × 14-element (3.6-λ boom lengths) 432-MHz EME array shown at 2° elevation and vertical polarization. (See *The ARRL Antenna Compendium, Vol 3*.)

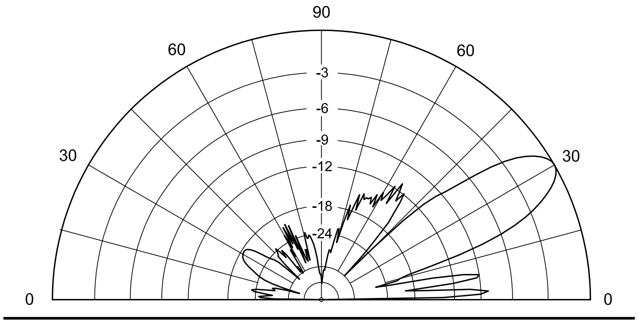

Fig 72—*EZNEC Pro* elevation pattern for four 14-element 2-meter Yagis (3.6-λ boom lengths) at an elevation angle of 30° above the horizon. The computed system gain is 21.5 dBi, suitable for 2-meter EME. This assumes that the phasing system is made of open-wire transmission lines so that feed-line losses can be kept below 0.25 dB.

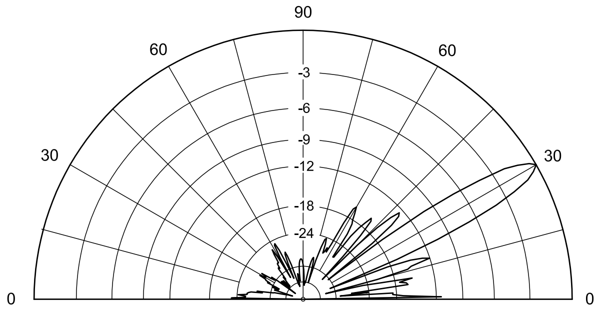

Fig 74—Computed elevation response for K1FO 16-Yagi 432-MHz array shown in Fig 73. (The *EZNEC Pro* model required 2464 segments!) With assumed phasing harness feed-line losses of 0.25 dB, the overall gain exceeds 27.5 dBi.

the same frontal area as an array of four Yagis, but produces approximately 1 to 2 dB less gain. One attraction to a collinear array is that the depth dimension is considerably less than the long-boom Yagis. An 80-element collinear is marginal for EME communications, providing approximately 19 dB gain. As with Yagi and Quagi antennas, the collinear cannot be adjusted easily for polarity changes. From a construction standpoint, there is little difference in complexity and material costs between the collinear and Yagi arrays.

DISH ANTENNAS FOR EME

On 2 meters the minimum antenna gain for reliable EME communications is about 20 dBi. While a few amateurs have had access to parabolic dishes large enough for EME work at 144 and 222 MHz, at those frequencies an array of four long Yagis is equal in gain to a dish 24 feet in diameter! To achieve truly high-gain performance from a dish on 2 meters would require a reflector diameter of nearly 96 feet (providing 32 dBi gain). Such undertakings are generally beyond amateur means, so there has been little work done with dishes at low frequencies, except for the occasional expedition to one of the large radio telescopes that have accommodated amateur EME work.

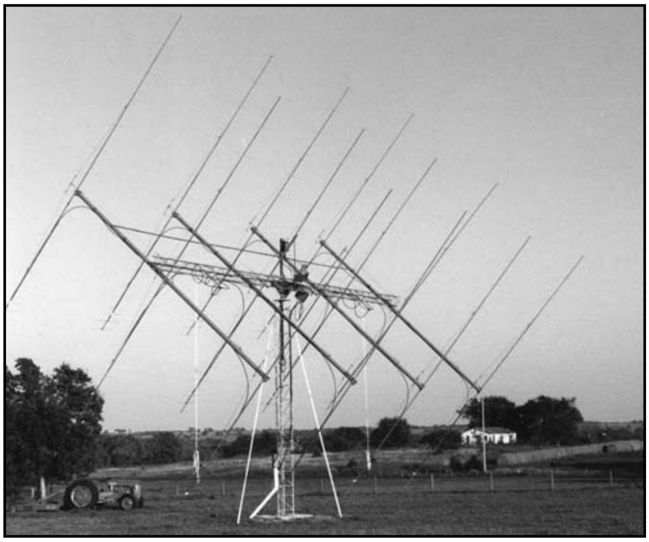

Fig 75—The EME array used at N5BLZ consists of twelve long-boom 144-MHz Yagis. The tractor, lower left, really puts this array into perspective! (*Photo courtesy N5BLZ.*)

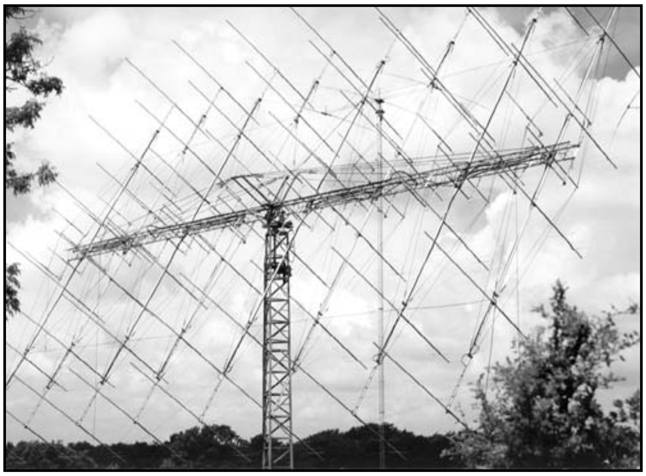

Fig 76—K5GW's huge 48-Yagi 2-meter EME array. (*Photo courtesy K5GW.*)

Microwave Parabolic Dish Antennas

The major problems associated with parabolic dish antennas are mechanical ones. A dish of about 16 feet in diameter is the minimum size required for successful EME operation on 432 MHz. With wind and ice loading, structures of this size place a real strain on the mounting and positioning system. Extremely rugged mounts are required for large dish antennas, especially when used in windy locations. **Fig 78** shows the impressive 7-meter diameter

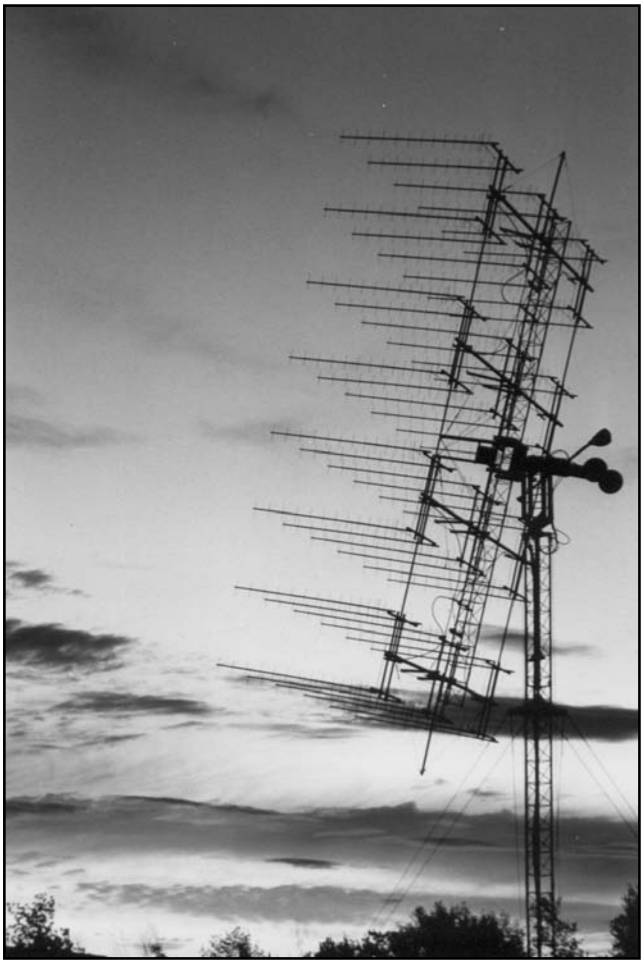

Fig 77—NC1I's magnificent 48-Yagi 70-cm EME array. (*Photo courtesy NC1I.*)

dish built by David Wardley, ZL1BJQ.

Several aspects of parabolic dish antennas make the extra mechanical problems worth the trouble, however. For example, the dish antenna is inherently broadband, and may be used on several different amateur bands by simply changing the feed. An antenna that is suitable for 432 MHz work will most likely be usable on several of the higher amateur bands too. Increased gain is available as the frequency of operation is increased.

Another advantage of a dish is the flexibility of the feed system. The polarization of the feed, and therefore the polarization of the antenna, can be changed with little difficulty. It is a relatively easy matter to devise a system to rotate the feed remotely from the shack to change polarization. Because polarization changes can account for as much as 30 dB of signal attenuation, the rotatable feed can make the difference between consistent communications and no communications at all. Further information on Parabolic Antennas can be found in Chapter 18, VHF and UHF Antenna Systems as well as in the section below.

A 12-FOOT STRESSED HOMEBREW PARABOLIC DISH

Very few antennas evoke as much interest among UHF amateurs as the parabolic dish, and for good reason. First, the parabola and its cousins—Cassegrain, hog horn and Gregorian—are probably the ultimate in high-gain antennas. One of the highest-gain antennas in the world (148 dB) is a parabola. This is the 200-inch Mt. Palomar telescope. (The very short wavelength of light rays causes such a high gain to be realizable.)

Second, the efficiency of the parabola does not change as size increases. With Yagis and collinear arrays, the losses in the phasing harness increase as the array size increases. The corresponding component of the parabola is lossless air between the feed horn and the reflecting surface. If there are a few surface errors, the efficiency of the system stays constant regardless of antenna size. This project was presented by Richard Knadle, K2RIW, in August 1972 *QST*.

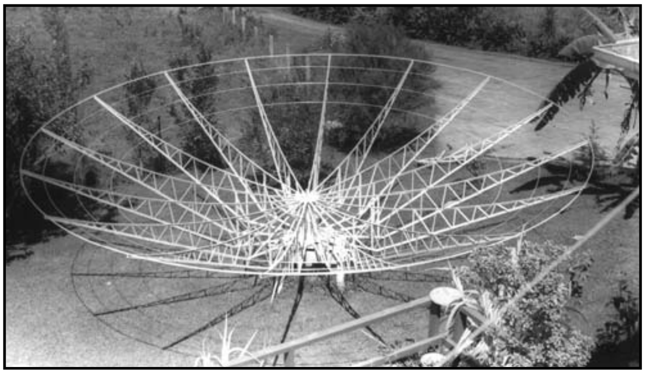

Fig 78—ZL1BJQ's homemade 7-meter (23-foot) parabolic dish, just prior to adding 1/2-inch wire mesh. (*Photo courtesy ZL1BJQ*.)

Some amateurs reject parabolic antennas because of the belief that they are all heavy, hard-to-construct, have large wind-loading surfaces and require precise surface accuracy. However, with modern construction techniques, a prudent choice of materials and an understanding of accuracy requirements, these disadvantages can be largely overcome. A parabola may be constructed with a 0.6 f/D (focal length/diameter) ratio, producing a rather flat dish, which makes it easy to surface and allows the use of recent advances in high-efficiency feed horns. This results in greater gain for a given dish size over conventional designs.

Such an antenna is shown in **Fig 79**. This parabolic dish is lightweight, portable, easy to build, and can be used for 432 and 1296-MHz mountain topping, as well as on 2304, 3456 and 5760 MHz. Disassembled, it fits into the trunk of a car, and can be assembled in 45 minutes.

The usually heavy structure that supports the surface of most parabolic dish antennas has been replaced in this design by aluminum spokes bent into a near parabolic shape by string. These strings serve the triple function of guying the focal point, bending the spokes and reducing the error at the dish perimeter (as well as at the center) to nearly zero. By contrast, in conventional designs, the dish perimeter (which has a greater surface area than the center) is farthest from the supporting center hub. For these reasons, it often has the greatest error. This error becomes more severe when the wind blows.

Here, each of the spokes is basically a cantilevered beam with end loading. The equations of beam bending

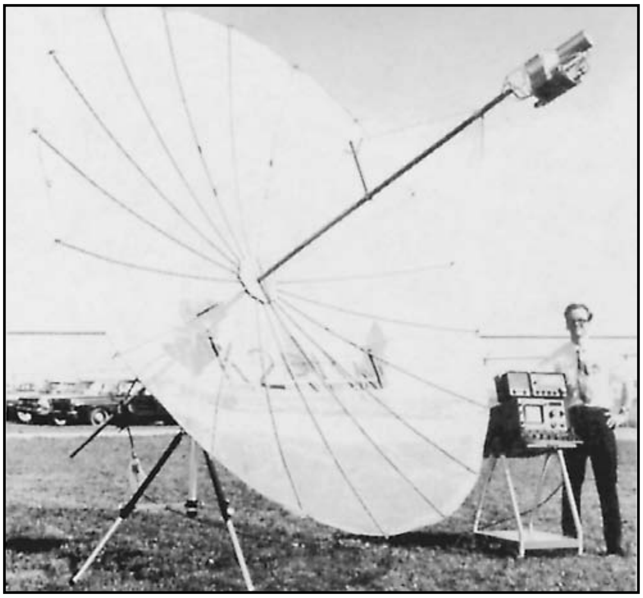

Fig 79—A 12-foot stressed parabolic dish set up for satellite signals near 2280 MHz. A preamplifier is shown taped below the feed horn. The dish was designed by K2RIW, standing at the right. From *QST*, August 1972.

predict a near-perfect parabolic curve for extremely small deflections. Unfortunately the deflections in this dish are not that small and the loading is not perpendicular. For these reasons, mathematical prediction of the resultant curve is quite difficult. A much better solution is to measure the surface error with a template and make the necessary correction by bending each of the spokes to fit. This procedure is discussed later.

The uncorrected surface is accurate enough for 432 and 1296-MHz use. Trophies taken by this parabola in antenna-gain contests were won using a completely natural surface with no error correction. By placing the transmission line inside the central pipe that supports the feed horn, the area of the shadows or blockages on the reflector surface is much smaller than in other feeding and supporting systems, thus increasing gain. For 1296 MHz, a backfire feed horn may be constructed to take full advantage of this feature. At 432 MHz, a dipole and reflector assembly produces 1.5 dB additional gain over a corner-reflector feed system. Because the preamplifier is located right at the horn on 2300 MHz, a conventional feed horn may be used.

Construction

Table 2 is a list of materials required for construction. Care must be exercised when drilling holes in the connecting center plates so assembly problems will not be experienced later. See **Fig 80**. A notch in each plate allows them to be assembled in the same relative positions. The two plates should be clamped together and drilled at the same time. Each of the 18½-inch diameter aluminum spokes has two no. 28 holes drilled at the base to accept no. 6-32 machine screws that go through the center plates. The 6-foot long spokes are cut from standard 12-foot lengths of tubing. A fixture built from a block of aluminum assures that the holes are drilled in exactly the same position in each spoke. The front and back center plates constitute an I-beam type of structure that gives the dish center considerable rigidity.

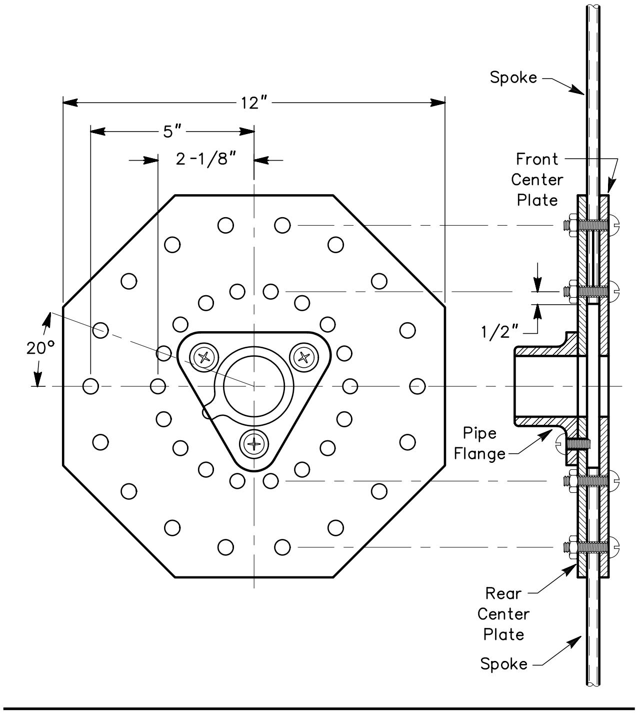

Fig 80—Center plate details. Two center plates are bolted together to hold the spokes in place.

A side view of the complete antenna is shown in **Fig 81**. Aluminum alloy (6061-T6) is used for the spokes, while 2024-T3 aluminum alloy sheet, ⅛ inch thick, is used for the center plates. (Aluminum has approximately three times the strength-to-weight ratio of wood, and aluminum cannot warp or become water logged.) The end of each of the 18 spokes has an eyebolt facing the dish focal point, which serves a dual purpose:

1) To accept the #9 galvanized fence wire that is routed through the screw eyes to define the dish perimeter, and
2) To facilitate rapid assembly by accepting the S hooks which are tied to the end of each of the lengths of 130-pound test Dacron fishing string.

The string bends the spokes into a parabolic curve; the dish may be adapted for many focal lengths by tightening or slackening the strings. Dacron was chosen because it has the same chemical formula as Mylar. This is a low-stretch material that keeps the dish from changing shape. The galvanized perimeter wire has a 5-inch overlap area that is bound together with baling wire after the spokes have been hooked to the strings.

The aluminum window screening is bent over the perimeter wire to hold it in place on the back of the spokes. Originally, there was concern that the surface perturbations (the spokes) in front of the screening might decrease the gain. The total spoke area is so small, however, that

Table 2
Materials List for the 12-Foot Stressed Parabolic Dish

1) Aluminum tubing, 12 ft × ½ in. OD × 0.049-in. wall, 6061-T6 alloy, 9 required to make 18 spokes.
2) Octagonal mounting plates 12 × 12 × ⅛ in., 2024-T3 alloy, 2 required.
3) 1¼ in. ID pipe flange with setscrews.
4) 1¼ in. × 8 ft TV mast tubing, 2 required.
5) Aluminum window screening, 4 × 50 ft.
6) 130-pound test Dacron trolling line.
7) 38 ft #9 galvanized fence wire (perimeter).
8) Two hose clamps, 1½ in.; two U bolts; ½ × 14 in. Bakelite rod or dowel; water-pipe grounding clamp; 18 eye bolts; 18 S hooks.

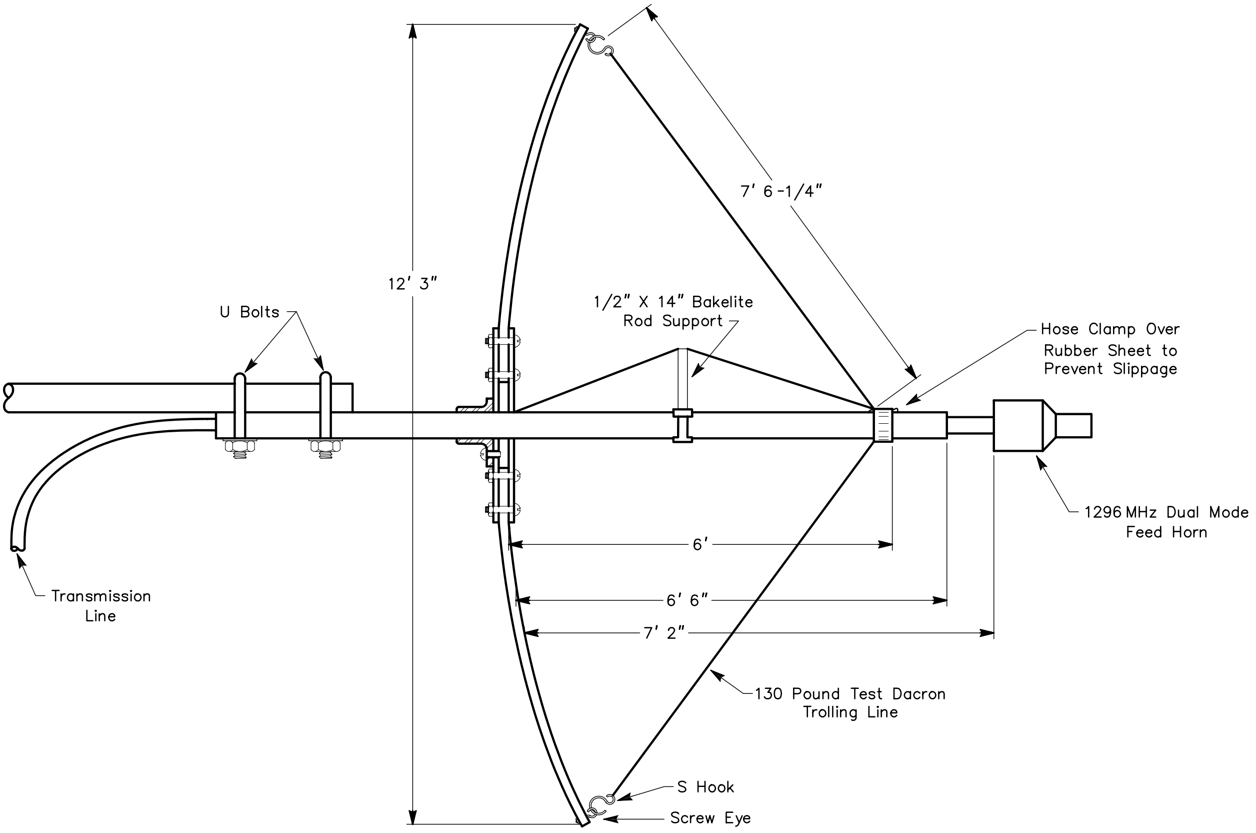
7′ 6-1/4″
12′ 3″
U Bolts
1/2″ X 14″ Bakelite Rod Support
Hose Clamp Over Rubber Sheet to Prevent Slippage
1296 MHz Dual Mode Feed Horn
6′
6′ 6″
7′ 2″
Transmission Line
130 Pound Test Dacron Trolling Line
S Hook
Screw Eye

Fig 81—Side view of the stressed parabolic dish.

this fear proved unfounded.

Placing the aluminum screening in front of the spokes requires the use of 200 pieces of baling wire to hold the screening in place. This would increase the assembly time by at least an hour. For contest and mountaintop operation (when the screening is on the back of the spokes) no fastening technique is required other than bending the screen to overlap the wire perimeter.

The Parabolic Surface

A 4-foot wide roll of aluminum screening 50 feet long is cut into appropriate lengths and laid parallel, with a 3-inch overlap between the top of the unbent spokes and hub assembly. The overlap seams are sewn together on one half of the dish using heavy Dacron thread and a sailmaker's curved needle. Every seam is sewn twice; once on each edge of the overlapped area. The seams on the other half are left open to accommodate the increased overlap that occurs when the spokes are bent into a parabola. The perimeter of the screening is then trimmed. Notches are cut in the 3-inch overlap to accept the screw eyes and S hooks.

The first time the dish is assembled, the screening strips are anchored to the inside surface of the dish and the seams sewn in this position. It is easier to fabricate the surface by placing the screen on the back of the dish frame with the structure inverted. The spokes are sufficiently strong to support the complete weight of the dish when the perimeter is resting on the ground.

The 4-foot wide strips of aluminum screening conform to the compound bend of the parabolic shape very easily. If the seams are placed parallel to the E-field polarization of the feed horn, minimum feedthrough will occur. This feedthrough, even if the seams are placed perpendicular to the E field, is so small that it is negligible. Some constructors may be tempted to cut the screening into pie-shaped sections. This procedure will increase the seam area and construction time considerably. The dish surface appears most pleasing from the front when the screening perimeter is slipped between the spokes and the perimeter wire, and is then folded back over the perimeter wire. In disassembly, the screening is removed in one piece, folded in half, and rolled.

The Horn and Support Structure

The feed horn is supported by $1^{1}/_{4}$-inch aluminum television mast. The Hardline that is inserted into this tubing is connected first to the front of the feed horn, which then slides back into the tubing for support. A setscrew assures that no further movement of the feed horn occurs. During antenna-gain competition the setscrew is omit-

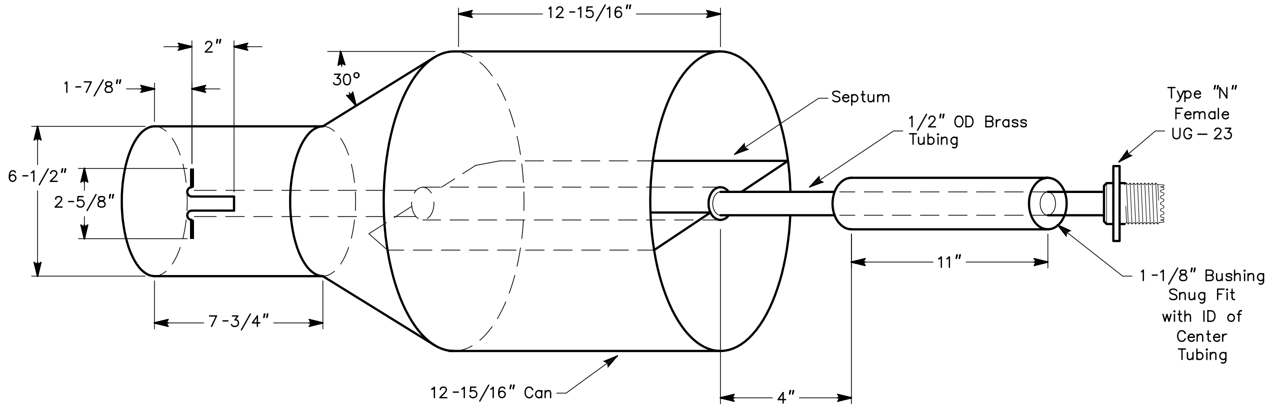

Fig 82—Backfire type 1296-MHz feed horn, linear polarization only. The small can is a Quaker State oil container; the large can is a 50-pound shortening container (obtained from a restaurant, Gold Crisp brand). Brass tubing, $^{1}/_{2}$-inch OD extends from UG-23 connector to dipole. Center conductor and dielectric are obtained from $^{3}/_{8}$-inch Alumafoam coaxial cable. The dipole is made from 3/32-inch copper rod. The septum and 30° section are made from galvanized sheet metal. Styrofoam is used to hold the septum in position. The primary gain is 12.2 dBi.

ted, allowing the $^{1}/_{2}$-inch semirigid CATV transmission line to move in or out while adjusting the focal length for maximum gain. The TV mast is held firmly at the center plates by two setscrews in the pipe flange that is mounted on the rear plate. At 2300 MHz, the dish is focused for best gain by loosening these setscrews on the pipe flange and sliding the dish along the TV mast tubing. (The dish is moved instead of the feed horn.)

The fishing strings are held in place by attaching them to a hose clamp that is permanently connected to the TV tubing. A piece of rubber sheet under the hose clamp prevents slippage and keeps the hose clamp from cutting the fishing string. A second hose clamp is mounted below the first as extra protection against slippage.

The high-efficiency 1296-MHz dual mode feed horn, detailed in **Fig 82**, weighs 5$^{3}/_{4}$ pounds. This weight causes some bending of the mast tubing, but this is corrected by a $^{1}/_{2}$-inch diameter bakelite support, as shown in Fig 81. This support is mounted to a pipe grounding clamp with a no. 8-32 screw inserted in the end of the rod. The bakelite rod and grounding clamp are mounted midway between the hose clamp and the center plates on the mast. A double run of fishing string slipped over the notched upper end of the bakelite rod counteracts bending.

The success of high-efficiency parabolic antennas is primarily determined by feed horn effectiveness. The multiple diameter of this feed horn may seem unusual. This patented dual-mode feed, designed by Dick Turrin, W2IMU, achieves efficiency by launching two different kinds of waveguide modes simultaneously. This causes the dish illumination to be more constant than conventional designs.

Illumination drops off rapidly at the perimeter, reducing spillover. The feed backlobes are reduced by at least 35 dB because the current at the feed perimeter is almost zero; the phase center of the feed system stays constant across the angles of the dish reflector. The larger diameter section is a phase corrector and should not be changed in length. In theory, almost no increase in dish efficiency can be achieved without increasing the feed size in a way that would increase complexity, as well as blockage.

The feed is optimized for a 0.6 f/D dish. The dimensions of the feeds are slightly modified from the original design in order to accommodate the cans. Either feed type can be constructed for other frequencies by changing the scale of all dimensions.

Multiband Use

Many amateurs construct multiband antenna arrays by putting two dishes back to back on the same tower. This is cost inefficient. The parabolic reflector is a completely frequency independent surface, and studies have shown that a 0.6 f/D surface can be steered seven beamwidths by moving the feed horn from side to side before the gain diminishes by 1 dB. Therefore, the best dual-band antenna can be built by mounting separate horns side by side. At worst, the antenna may have to be moved a few degrees (usually less than a beamwidth) when switching between horns, and the unused horn increases the shadow area only slightly. In fact, the same surface can function simultaneously on multiple frequencies, making crossband duplex operation possible with the same dish.

Order of Assembly

1) A single spoke is held upright behind the rear center plate with the screw eye facing forward. Two no. 6-

32 machine screws are pushed through the holes in the rear center plate, through the two holes of the spoke, and into the corresponding holes of the front center plate. Lock washers and nuts are placed on the machine screws and hand tightened.

2) The remaining spokes are placed between the machine screw holes. Make sure that each screw eye faces forward. Machine screws, lock washers and nuts are used to mount all 18 spokes.
3) The no. 6-32 nuts are tightened using a nut driver.
4) The mast tubing is attached to the spoke assembly, positioned properly, and locked down with the setscrews on the pipe flange at the rear center plate. The S hooks of the 18 Dacron strings are attached to the screw eyes of the spokes.
5) The ends of two pieces of fishing string (which go over the bakelite rod support) are tied to a screw eye at the forward center plate.
6) The dish is laid on the ground in an upright position and #9 galvanized wire is threaded through the eyebolts. The overlapping ends are lashed together with baling wire.
7) The dish is placed on the ground in an inverted position with the focus downward. The screening is placed on the back of the dish and the screening perimeter is fastened as previously described.
8) The extension mast tubing (with counterweight) is connected to the center plate with U bolts.
9) The dish is mounted on a support and the transmission line is routed through the tubing and attached to the horn.

Parabola Gain Versus Errors

How accurate must a parabolic surface be? This is a frequently asked question. According to the Rayleigh limit for telescopes, little gain increase is realized by making the mirror accuracy greater than ± $^{1}/_{8}$ λ peak error. John Ruze of the MIT Lincoln Laboratory, among others, has derived an equation for parabolic antennas and built models to verify it. The tests show that the tolerance loss can be predicted within a fraction of a decibel, and less than 1 dB of gain is sacrificed with a surface error of ±$^{1}/_{8}$ λ. (A $^{1}/_{8}$ λ is 3.4 inches at 432 MHz, 1.1 inches at 1296 MHz and 0.64 inch at 2300 MHz.)

Some confusion about requirements of greater than $^{1}/_{8}$-λ accuracy may be the result of technical literature describing highly accurate surfaces. Low sidelobe levels are the primary interest in such designs. Forward gain is a much greater concern than low sidelobe levels in amateur work; therefore, these stringent requirements do not apply.

When a template is held up against a surface, positive and negative (±) peak errors can be measured. The graphs of dish accuracy requirements are frequently plotted in terms of RMS error, which is a mathematically derived function much smaller than ± peak error (typically $^{1}/_{3}$). These small RMS accuracy requirements have discouraged many constructors who confuse them with ± peak errors.

Fig 83 may be used to predict the resultant gain of various dish sizes with typical errors. There are a couple of surprises, as shown in **Fig 84**. As the frequency is increased for a given dish, the gain increases 6 dB per octave until the tolerance errors become significant. Gain deterioration then increases rapidly. Maximum gain is realized at the frequency where the tolerance loss is 4.3 dB. Notice that at 2304 MHz, a 24-foot dish with ±2-inch peak errors has the same gain as a 6-foot dish with ±1-inch peak errors. This is quite startling, when it is realized that a 24-foot dish has 16 times the area of a 6-foot dish. Each time the diameter or frequency is doubled or halved, the gain changes by 6 dB. Each time all the errors are halved, the frequency of maximum gain is doubled. With this information, the gain of other dish sizes with other tolerances can be predicted.

These curves are adequate for predicting gain, assuming a high-efficiency feed horn is used (as described earlier), which realizes 60% aperture efficiency. At frequencies below 1296 MHz where the horn is large and causes considerable blockage, the curves are somewhat optimistic. A properly built dipole and splasher feed will have about 1.5 dB less gain when used with a 0.6 f/D dish than the dual-mode feed system described.

The worst kind of surface distortion is where the surface curve in the radial direction is not parabolic but gradually departs in a smooth manner from a perfect parabola. The decrease in gain can be severe, because a large area is involved. If the surface is checked with a template, and if reasonable construction techniques are employed, deviations are controlled and the curves represent an upper limit to the gain that can be realized.

If a 24-foot dish with ±2-inch peak errors is being used with 432 and 1296-MHz multiple feed horns, the constructor might be discouraged from trying a 2300-MHz feed because there is 15 dB of gain degradation. The dish will still have 29 dBi of gain on 2300 MHz, however, making it worthy of consideration.

The near-field range of this 12-foot stressed dish (actually 12 feet 3 inches) is 703 feet at 2300 MHz. By using the sun as a noise source and observing receiver noise power, it was found that the antenna had two main lobes about 4° apart. The template showed a surface error (insufficient spoke bending at $^{3}/_{4}$ radius), and a correction was made. A recheck showed one main lobe, and the solar noise was almost 3 dB stronger.

Other Surfacing Materials

The choice of surface materials is a compromise between RF reflecting properties and wind loading. Aluminum screening, with its very fine mesh (and weight of 4.3 pounds per 100 square feet) is useful beyond 10 GHz because of its very close spacing. This screening is easy to roll up and is therefore ideal for a portable dish. This close spacing causes the screen to be a 34% filled aperture, bring-

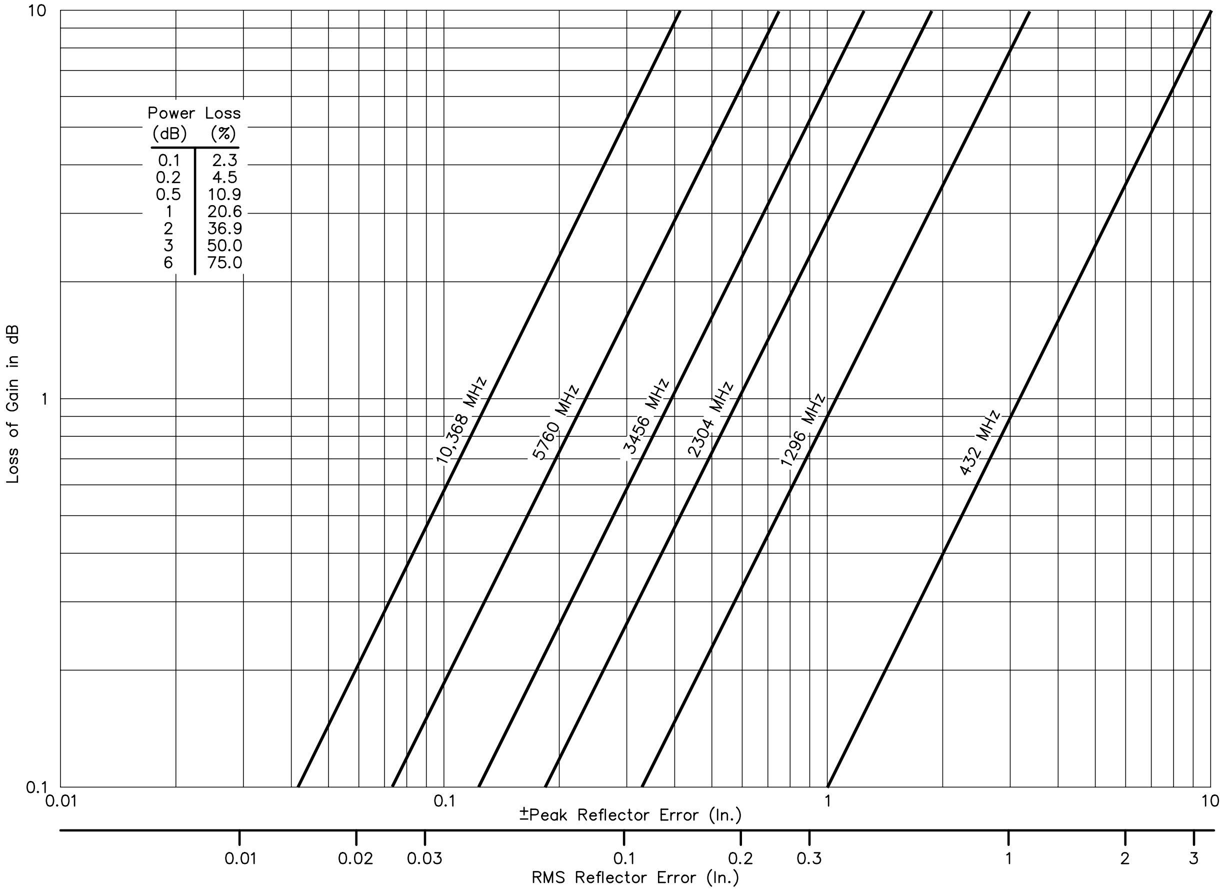

(dB)	(%)
0.1	2.3
0.2	4.5
0.5	10.9
1	20.6
2	36.9
3	50.0
6	75.0

Fig 83—Gain deterioration versus reflector error. By Richard Knadle, K2RIW.

ing the wind force at 60 mph to more than 400 *pounds* on this 12-foot dish. Those considering a permanent installation of this dish should investigate other surfacing materials.

Hexagonal 1-inch poultry netting (chicken wire), which is an 8% filled aperture, is nearly ideal for 432-MHz operation. It weighs 10 pounds per 100 square feet, and exhibits only 81 pounds of force with 60 mph winds. Measurement on a large piece reveals 6 dB of feedthrough at 1296 MHz, however. Therefore, on 1296 MHz, one fourth of the power will feed through the surface material. This will cause a loss of only 1.3 dB of forward gain. Since the low-wind loading material will provide a 30-dBi gain potential, it is still a very good tradeoff.

Poultry netting is very poor material for 2300 MHz and above, because the hole dimensions approach $^1/_2$ λ. As with all surfacing materials, minimum feedthrough occurs when the E-field polarization is parallel to the longest dimension of the surfacing holes.

Hardware cloth with $^1/_2$-inch mesh weighs 20 pounds per 100 square feet and has a wind loading characteristic of 162 pounds with 60 mph winds. The filled aperture is 16%, and this material is useful to 2300 MHz.

A rather interesting material worthy of investigation is $^1/_4$-inch reinforced plastic. It weighs only 4 pounds per 100 square feet. The plastic melts with many universal solvents such as lacquer thinner. If a careful plastic-melting job is done, what remains is the $^1/_4$-inch spaced aluminum wires with a small blob of plastic at each junction to hold the matrix together.

There are some general considerations to be made in selecting surface materials:

1) Joints of screening do not have to make electrical contact. The horizontal wires reflect the horizontal wave. Skew polarizations are merely a combination of horizontal and vertical components which are thus reflected by the corresponding wires of the screening. To a horizontally polarized wave, the spacing and diameter of only the horizontal wires determine the reflection coefficient (see **Fig 85**). Many amateurs have the mistaken impression that screening materials that do not make electrical contact at their junctions are poor reflectors.
2) By measuring wire diameter and spacings between the wires, a calculation of percentage of aperture that is filled can be made. This will be one of the major determining factors of wind pressure when the surfacing material is dry.

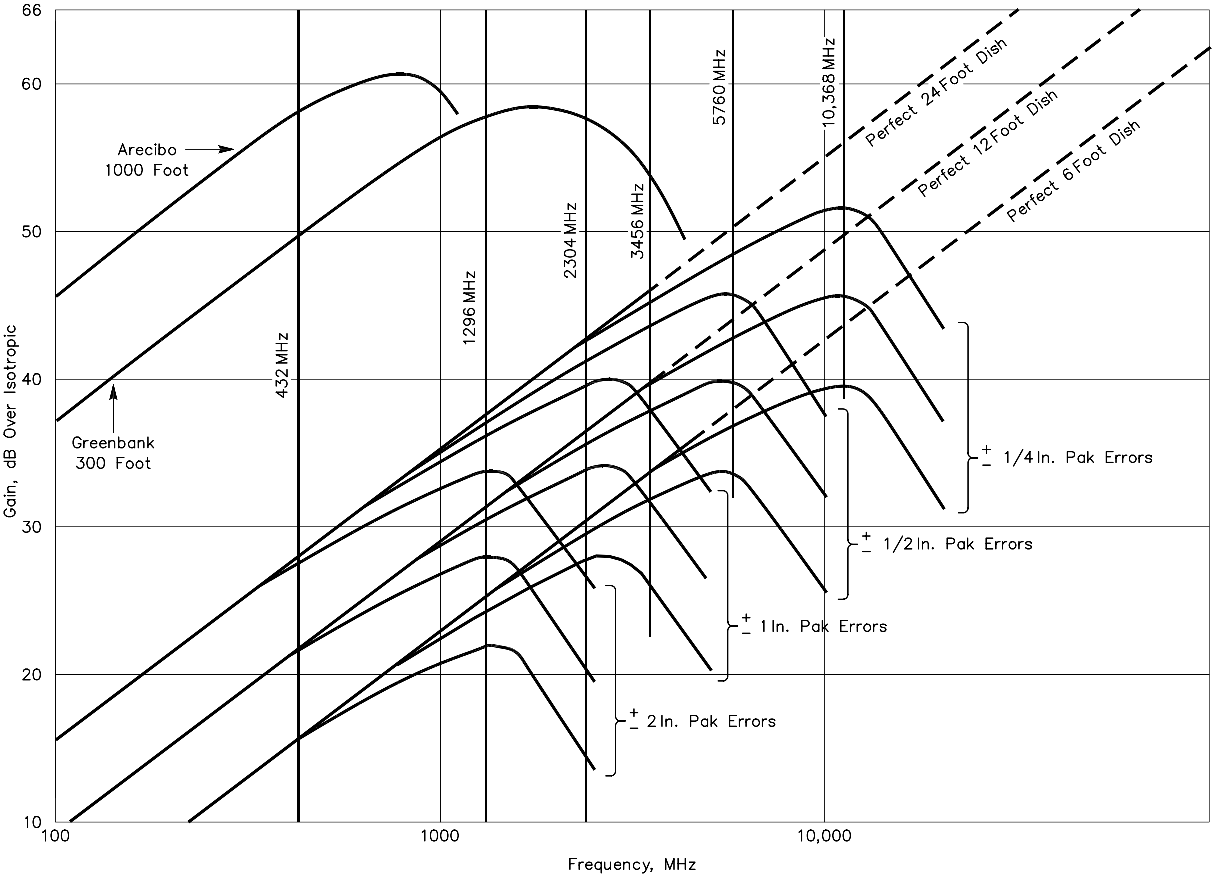

Fig 84—Parabolic-antenna gain versus size, frequency and surface errors. All curves assume 60% aperture efficiency and 10-dB power taper. Graph by K2RIW for ham bands, using display technique of J. Ruze, British IEE.

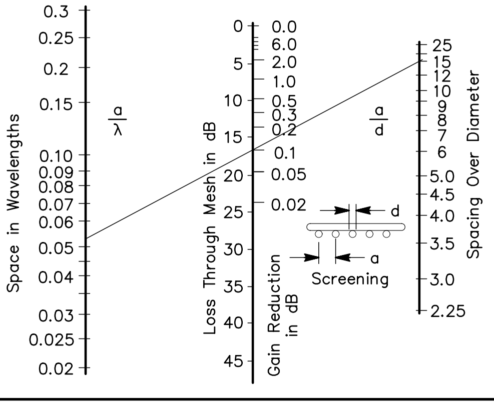

Fig 85—Surfacing material quality.

A Parabolic Template

At and above 2300 MHz (where high surface accuracy is required), a parabolic template should be constructed to measure surface errors. A simple template may be constructed (see **Fig 86**) by taking a 12-foot 3-inch length of 4-foot wide tar paper and drawing a parabolic shape on it with chalk. The points for the parabolic shape are calculated at 6-inch intervals and these points are connected with a smooth curve. For those who wish to use the template with the surface material installed, the template should be cut along the chalk line and stiffened by cardboard or a wood lattice frame. Surface error measurements should take place with all spokes installed and deflected by the fishing lines, as some bending of the center plates does take place. **Fig 87** shows the 12-foot stressed dish built by Franco Marcelo, N2UO.

Variations

All the possibilities of the stressed parabolic antenna have not been explored. For instance, a set of fishing lines or guy wires can be set up behind the dish for error correction, as long as this does not cause permanent bending of the aluminum spokes. This technique also protects the dish against wind loading from the rear. An extended piece of TV mast is an ideal place to hang a counterweight and attach the rear guys. This strengthens the structure considerably.

EME USING SURPLUS TVRO DISH ANTENNAS

Since the 1990s, there has been a significant change

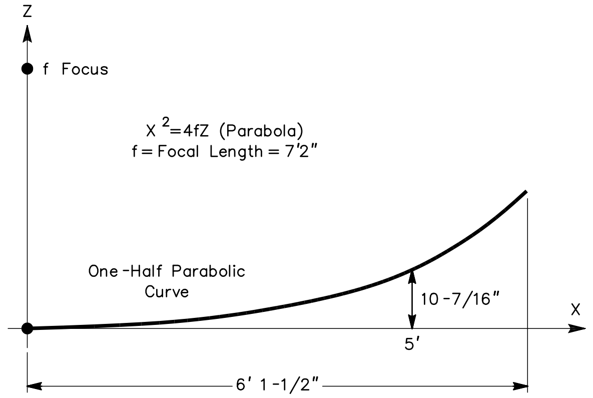

X	Z (to Nearest 1/16″)	X	Z
0.5′	1/8″	3.5′	5-1/8″
1.0′	7/16″	4.0′	6-11/16″
1.5′	15/16″	4.5′	8-1/2″
2.0′	1-11/16″	5.0′	10-7/16″
2.5′	2-5/8″	5.5′	12-11/16″
3.0′	3-3/4″	6.0′	15-1/16″

Fig 86—Parabolic template for 12-foot, 3-inch dish.

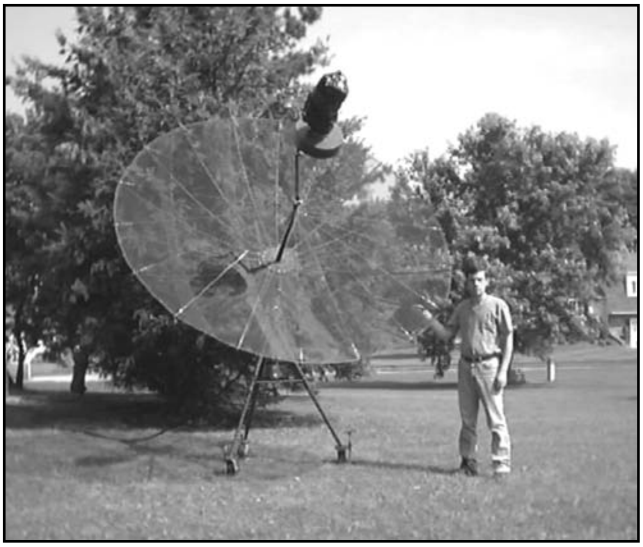

Fig 87—N2UO's homemade 12-foot stressed dish. (*Photo courtesy N2UO.*)

in the systems people use to watch satellite TV broadcasts. Formerly, C-band satellite receivers were used, along with parabolic dish antennas in the 3- to 5-meter diameter range. Now, Ku-band (12-GHz) receivers are the norm, with their associated small (usually 18-inch) dish antennas. This has provided a large body of surplus C-band dishes, which can be used for EME—certainly on the bands at 33 cm and above, and for the larger dishes (5 meters), even at 70 cm. Many times, these dishes and their mounts can be had for the asking, so they truly become an inexpensive way to build a multi-band EME antenna.

This updated article, first presented by David Hallidy, K2DH (ex-KD5RO) in the ARRL *UHF/Microwave Projects Manual*, describes the use of a 3-meter (10-foot) TVRO antenna in such an application. (Also see earlier in this chapter the section describing converted C-Band TVRO Dishes for satellite work.)

Background

Calculations show that a 3-meter dish will have about 30 dBi gain at 1296 MHz. With a state-of-the-art LNA (Low-Noise Amplifier or preamp) at the feed, an efficient feed horn illuminating the dish surface, and 200 W at 1296 MHz, lunar echoes should be easily detected and many stations can be worked. The biggest challenges to such a system are assembling the dish to its mount and steering it to track the Moon. As much as possible, the KISS ("Keep It Simple, Stupid") principle was used to accomplish this task.

In 1987, WA5TNY, KD5RO, KA5JPD, and W7CNK proved that such an EME system could work, even as high as 3.4 and 5.7 GHz, to provide the first EME contacts on those bands. An additional advantage to this (or any) small dish is its ability to be mounted to a trailer and taken out on EME expeditions. It can also be easily disassembled and stored, if necessary.

As can be seen from **Fig 88**, the entire setup is very simple, using a standard amateur tower as the main support for the dish.

Azimuth Drive

In azimuth, direct drive of the main rotating shaft was selected, and a small prop-pitch motor was used. These motors, while not as plentiful as they were some years ago, still turn up with some regularity at flea markets for very little money. The beauty of the prop-pitch motor is that it turns slowly, is reversible, provides very high torque, and requires no braking system (the gear reduction, on the order of 4000:1, provides the necessary braking). Prop-pitch motors are dc motors, and were designed to vary the pitch of propeller blades at start-up, take-off and landing of older large airplanes. Thus, they can be run at different speeds merely by varying the dc voltage to the motor, and can be reversed by reversing the polarity of the dc voltage. By mounting a thrust bearing of the appropriate size at the top of the tower, and mounting the motor directly below it at the end of the rotating shaft that turns the antenna, a simple direct-drive system can be constructed.

The dc power supply and control relays are located in a weatherproof box on the side of the tower, next to the motor. This system requires only 9 V dc at about 5 A to adequately start, turn and stop the prop-pitch motor, and this voltage turns the antenna through 360° of rotation in about $2^1/_2$ minutes. Azimuth position sensing is also a simple task. See **Fig 89**. A linear multi-turn potentiometer is driven by the rotating shaft, using a simple friction drive.

A strip of rubber is attached to the rotating shaft and a wheel is connected to the shaft of the pot. The pot is then mounted so that it presses against the rubber strip, and as the shaft turns so does the pot. If a ten-turn pot is used, and the system is aligned such that the pot is at the center of its rotation when the antenna is pointed approximately south, the pot will not rotate past the end at either extreme of the antenna's rotation (CW/CCW north), and absolute alignment is a simple task of calibrating the change in resistance (change in voltage, when the pot is fed from a constant voltage source) with degrees of rotation (see the discussion on Position Readout for details).

Elevation Drive

The elevation drive is also very simple. Most (nearly all) TVRO setups have a means of moving the dish across the sky to align it with various satellites. To do this, most companies use a device called a *Linear Actuator*. This is a dc motor to which is attached a long lead screw that pulls (or pushes) the outer shell of the actuator in or out to make it longer or shorter. The movable end of the actuator is attached to the dish and the motor end is fixed to the mount. The dish rests on pivots, which allow it to move as the actuator extends/retracts. To convert this type of mount (called a *Polar Mount*) to an Az/El mount is usually very simple.

Fig 90 shows how this can be done. Simply breaking the welds that held the mount in a polar fashion allows the mount to be turned on its side and used to pivot the dish vertically with the linear actuator. Another feature of linear actuators is that they also have some means of feeding their relative position to the satellite receiver. This is usually just a multi-turn potentiometer geared to the lead screw. All we have to do is connect this pot to a readout system, and we can calibrate the lift of the actuator in degrees. We thus have a simple means of rotating the dish and elevating it—but how do we know that it's pointed at the Moon?

Position Readout

Readout of the position of the antenna, in both azimuth and elevation is also a relatively simple task. On the

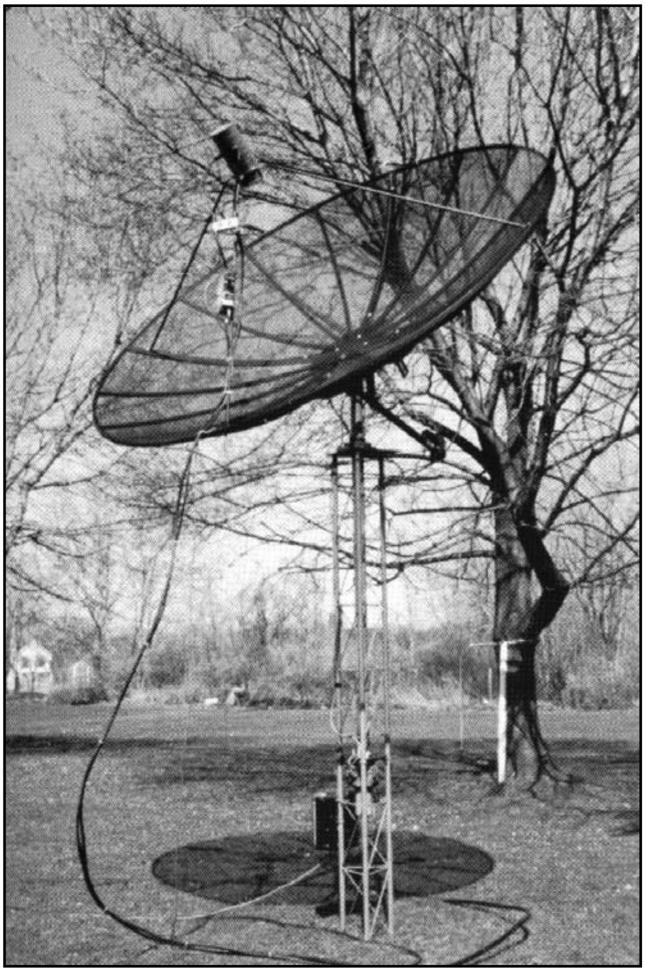

Fig 88—View of K2DH's (ex-KD5RO) complete TVRO antenna installation. (*K2DH photo.*)

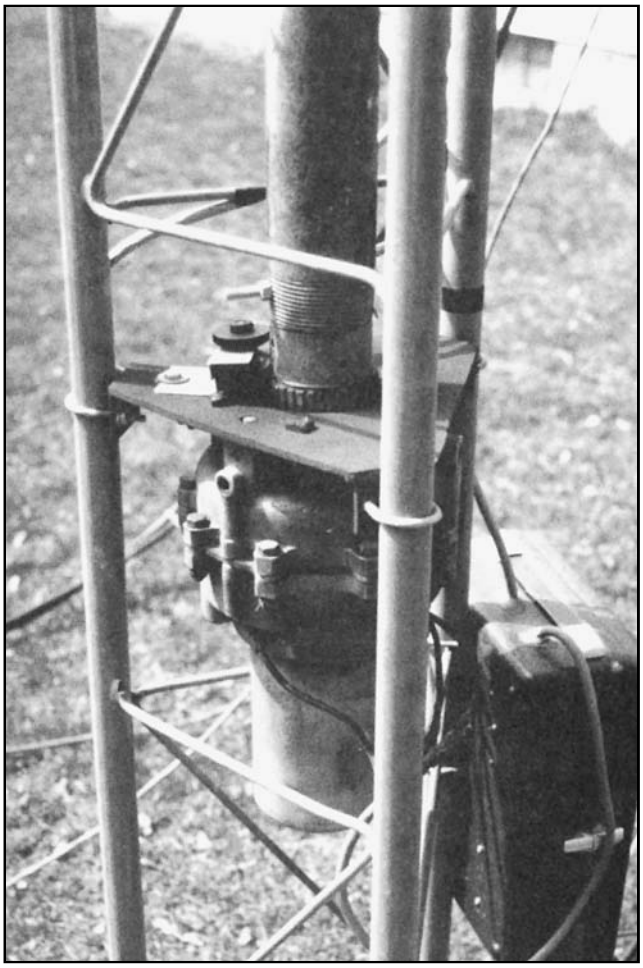

Fig 89—Azimuth rotation systems, showing prop-pitch motor and position sensor.

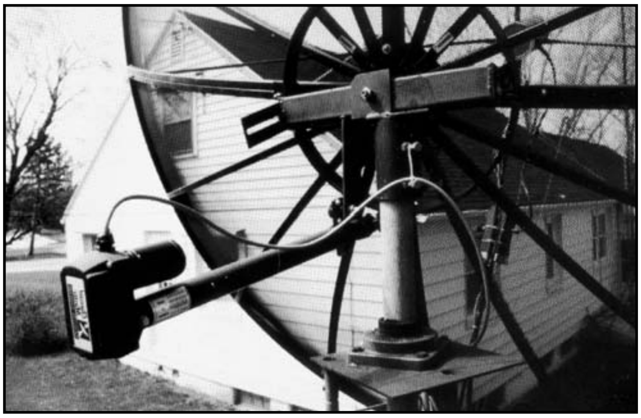

Fig 90—Elevation system, showing modified TVRO mount.

surplus market there are available Digital Volt Meters (DVMs) using LED or LCD displays that can do this job nicely, and that have more precision than is probably necessary for a dish (or Yagi array) of small size. As mentioned earlier, a multi-turn potentiometer on the elevation-drive mechanism can be used to readout elevation, and the same technique can be used for azimuth readout—a potentiometer coupled to the main rotating shaft that turns the antenna.

When using a pot for readout, the most important thing to know is how many degrees of antenna position change occur (in Az or El) for each turn of the pot. This then can be used to calibrate a voltmeter to read volts directly as degrees—for example, 3.60 V could correspond to 360° azimuth (Clockwise North), and 9.0 V could correspond

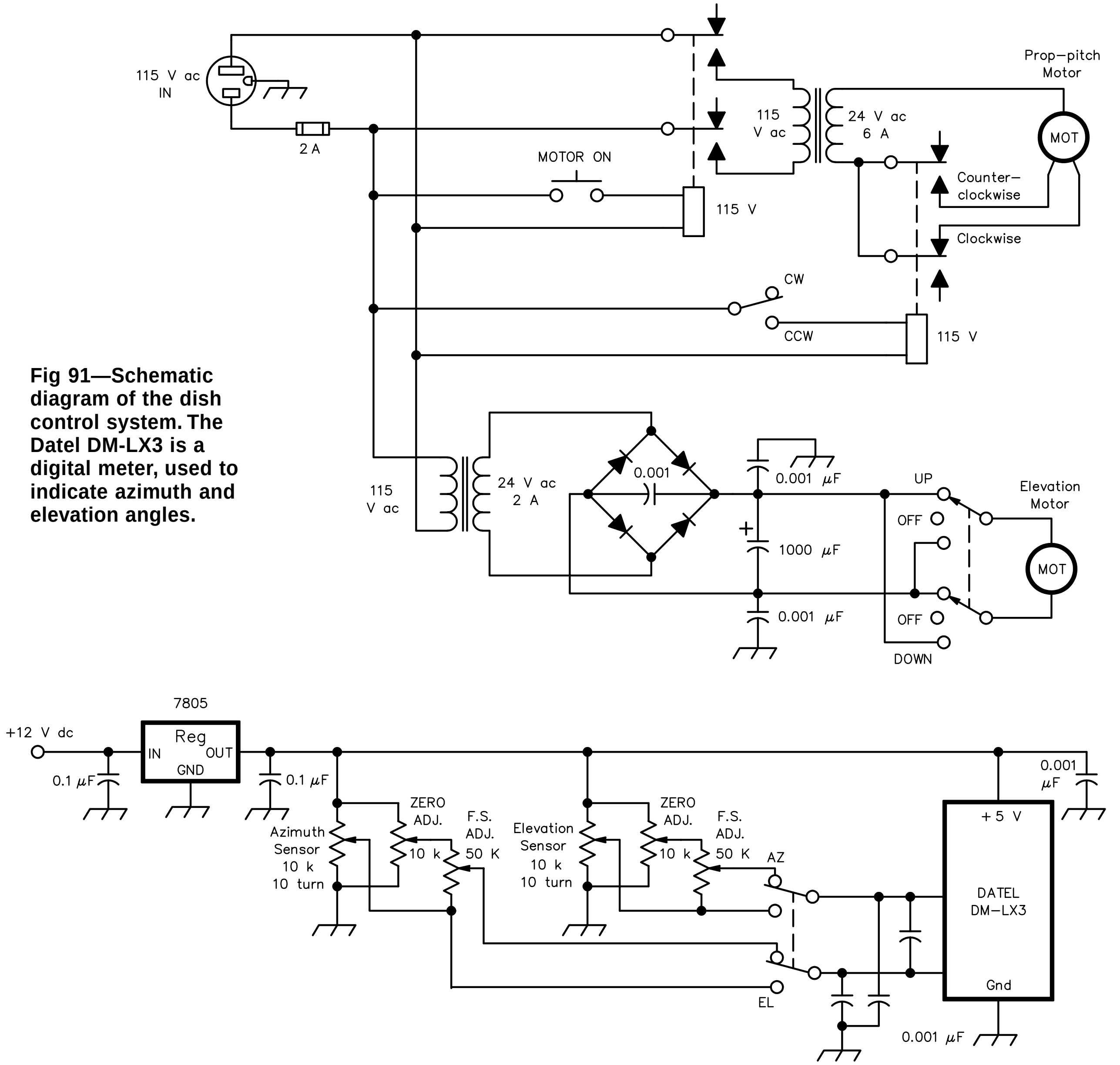
115 V ac
IN
2 A
MOTOR ON
115 V
115
V ac
24 V ac
6 A
Prop–pitch
Motor
MOT
Counter–
clockwise
Clockwise
CW
CCW
115 V
115
V ac
24 V ac
2 A
0.001
0.001 µF
1000 µF
0.001 µF
UP
OFF
OFF
DOWN
Elevation
Motor
MOT
7805
+12 V dc
Reg
IN
OUT
GND
0.1 µF
0.1 µF
Azimuth
Sensor
10 k
10 turn
ZERO
ADJ.
10 k
F.S.
ADJ.
50 K
Elevation
Sensor
10 k
10 turn
ZERO
ADJ.
10 k
F.S.
ADJ.
50 K
AZ
EL
0.001
µF
+5 V
DATEL
DM–LX3
Gnd
0.001 µF

Fig 91—Schematic diagram of the dish control system. The Datel DM-LX3 is a digital meter, used to indicate azimuth and elevation angles.

to 90° elevation (straight up).

A resistance bridge circuit is best used in this application, since it is less sensitive to changes in the supply voltage. The only thing to be careful about is that the DVM must have both the positive (high) and negative (low) inputs isolated from ground (assuming the power supply used to power the DVM is grounded). You could also use a pair of small, cheap Digital Multi-Meters (DMMs), which can sometimes be found for under $10. Because they are battery powered, the isolation issue just discussed is eliminated.

Please see **Fig 91** for a complete schematic of the azimuth, elevation and readout electronics for this antenna-drive system. Also note that while this discussion is geared towards the use of a small dish, the same positioning and readout systems could be used in a Yagi array for 2 meters or 70 cm.

Now that we know where the dish is pointed, how do we know where the Moon is? There are several software programs available to the Amateur for tracking celestial bodies such as the Moon, the Sun, certain stars (usable as noise sources), and even Amateur Satellites. Programs by W9IP, VK3UM, F1EHN and others can be obtained very reasonably and these work well to provide highly accurate position information for tracking.

Feeding the Surplus TVRO Dish

An area that needs particular attention when attempting EME with a small dish is an efficient feed system. An efficient feed system can be a real challenge with TVRO dishes, because many are "deep"—that is, their f/D (focal length to Diameter ratio) is small.

The satellite TV industry used deep dishes because they tend to be quieter, picking up less Earth noise due to spillover effects. A deep dish has a short focal length, and therefore, the feed is relatively close to the surface of the dish. To properly illuminate the reflector out to its edges, a feed horn of relatively wide beamwidth must be used. The feeds designed several years ago by Barry Malowanchuk, VE4MA, are intended for use with just such dishes, and have the advantage of being adjustable to optimize their pattern to the dish in use.

The feed that was used with this dish was modeled after VE4MA's 1296-MHz feed, and a version was even scaled for use at 2304 MHz that worked as well as the original. See **Fig 92** and also see the Notes and References section at the end of this chapter. (Also see the earlier section in the satellite portion of this chapter describing patch feeds for small dishes.)

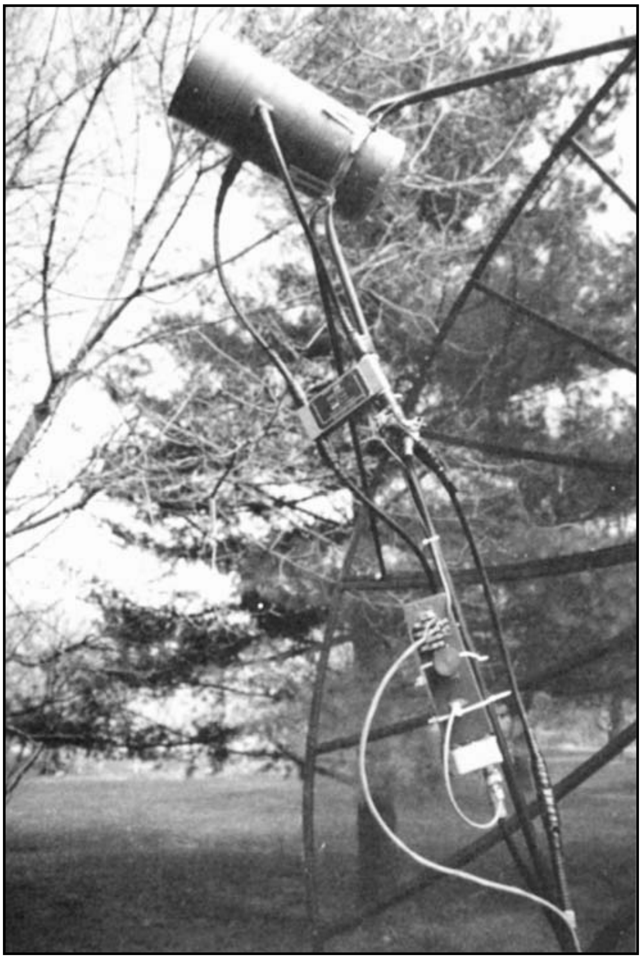

Fig 92—View of feed, showing coffee-can feed horn and hybrid coupler.

SHF EME CHALLENGES

The challenges met when successfully building a station for EME at 900 MHz to 5.7 GHz only become more significant on the SHF bands at 10 GHz and above. Absolute attention to detail is the primary requirement, and this extends to every aspect of the EME antenna system. The dish surface is probably the most difficult problem to solve. As was discussed earlier in this chapter, the shape and accuracy of the reflector contribute directly to the overall gain of the antenna.

But where slight errors in construction can be tolerated at the lower frequencies, the same cannot be said at millimetric wavelengths. Those who have attempted EME on 10 and 24 GHz have discovered that the weight of the dish reflector itself will distort its shape enough to lower the gain to the point where echoes are degraded. Stiffening structures at the back of such dishes are often found necessary. **Fig 93** illustrates the back struts added by Al Ward, W5LUA, to strengthen his dish.

Pointing accuracy is also paramount—a 16-foot dish at 10 GHz has a beamwidth about equal to the diameter of the Moon—0.5°. This means that the echo degradation due to the Moon's movement away from where the dish is pointed is almost immediate, and autotracking systems become more of a necessity than a luxury. At these frequencies, most amateurs actually peak their antennas on

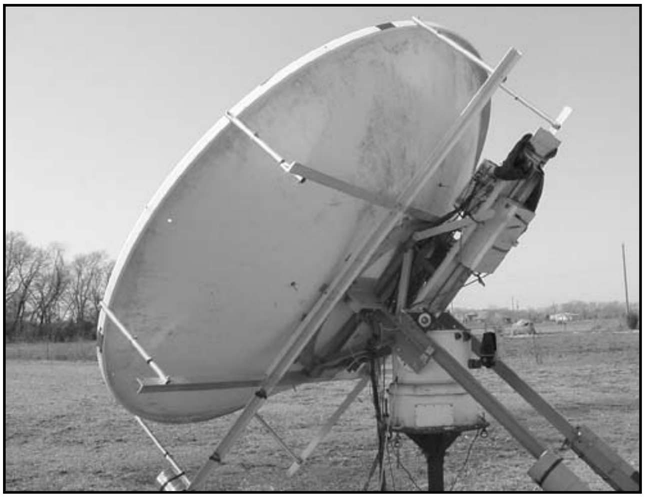

Fig 93—Strengthening struts W5LUA added to the back of his dish to hold down distortion. (*Photo courtesy W5LUA.*)

Moon Noise—the black-body Radiation from the Moon that becomes the dominant source of noise in space.

At these frequencies, the elevation of the Moon above the horizon also plays a role in the ability to communicate, since tropospheric absorption due to water vapor is greatest at low elevation angles (the signal must pass through a greater portion of the troposphere than when the Moon is highly elevated). It is beyond the abilities of most Amateurs to construct their own dishes for these frequencies, so surplus dishes for Ku-band satellite TV (typically 3 meters in diameter) are usually employed, as have high-performance dishes designed for millimetric radar and point-to-point communications at 23 and 38 GHz.

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Chapter 20

Antenna Materials and Accessories

This chapter contains information on materials amateurs use to construct antennas—what types of material to look for in a particular application, tips on working with and using various materials. Chapter 21 contains information on where to purchase these materials.

Basically, antennas for MF, HF, VHF and the lower UHF range consist simply of one or more conductors that radiate (or receive) electromagnetic waves. However, an antenna system must also include some means to support those conductors and maintain their relative positions—the boom for a Yagi antenna and the halyards for a wire dipole, for example. In this chapter we'll look at materials for those applications, too. Structural supports such as towers, masts, poles, etc. are discussed in Chapter 22.

There are two main types of material used for antenna conductors, wire and tubing. Wire antennas are generally simple and therefore easier to construct, although some arrays of wire elements can become rather complex. When tubing is required, aluminum tubing is used most often because of its light weight. Aluminum tubing is discussed in a subsequent section of this chapter.

Wire Antennas

Although wire antennas are relatively simple, they can constitute a potential hazard unless properly constructed. Antennas should never be run under or over public utility (telephone or power) lines. Several amateurs have lost their lives by failing to observe this precaution.

The National Electric Code® of the National Fire Protection Association contains a section on amateur stations in which a number of recommendations are made concerning minimum size of antenna wire and the manner of bringing the transmission line into the station. Chapter 1 contains more information about this code. The code in itself does not have the force of law, but it is frequently made a part of local building regulations, which are enforceable. The provisions of the code may also be written into, or referred to, in fire and liability insurance documents.

The RF resistance of copper wire increases as the size of the wire decreases. However, in most types of antennas that are commonly constructed of wire (even quite small wire), the radiation resistance will be much higher than the RF resistance, and the efficiency of the antenna will still be adequate. Wire sizes as small as #30, or even smaller, have been used quite successfully in the construction of "invisible" antennas in areas where more conventional antennas cannot be erected. In most cases, the selection of wire for an antenna will be based primarily on the physical properties of the wire, since the suspension of wire from elevated supports places a strain on the wire.

WIRE TYPES

Wire having an enamel coating is preferable to bare wire, since the coating resists oxidation and corrosion. Several types of wire having this type of coating are available, depending on the strength needed. "Soft-drawn" or annealed copper wire is easiest to handle; unfortunately, it stretches considerably under stress. Soft-drawn wire should be avoided, except for applications where the wire will be under little or no tension, or where some change in length can be tolerated. (For example, the length of a horizontal antenna fed at the center with open-wire line is not critical, although a change in length may require some readjustment of coupling to the transmitter.)

"Hard-drawn" copper wire or copper-clad steel wire (also known as Copperweld™) is harder to handle, because it has a tendency to spiral when it is unrolled. These types of wire are ideal for applications where significant stretch cannot be tolerated. Care should be exercised in using this wire to make sure that kinks do not develop—the wire will have a far greater tendency to break at a kink. After the coil has been unwound, suspend the wire a few feet above ground for a day or two before using it. The wire should not be recoiled before it is installed.

Several factors influence the choice of wire type and size. Most important to consider are the length of the unsupported span, the amount of sag that can be tolerated, the stability of the supports under wind pressure, and whether or not an unsupported transmission line is to be suspended from the span. **Table 1** shows the wire diam, current-carrying capacity and resistance of various sizes of copper wire. **Table 2** shows the maximum rated working tensions of hard-drawn and copper-clad steel wire of various sizes. These two tables can be used to select the appropriate wire size for an antenna.

Table 1
Copper-Wire Table

Wire Size AWG (B&S)	*Dia in Mils[1]*	*Dia in mm*	*Turns per Linear Inch Enamel*	*Feet per Pound Bare*	*Ohms per 1000 ft 25°C*	*Cont.-duty current[2] Single Wire in Open Air*
1	289.3	7.348	—	3.947	0.1264	—
2	257.6	6.544	—	4.977	0.1593	—
3	229.4	5.827	—	6.276	0.2009	—
4	204.3	5.189	—	7.914	0.2533	—
5	181.9	4.621	—	9.980	0.3195	—
6	162.0	4.115	—	12.58	0.4028	—
7	144.3	3.665	—	15.87	0.5080	—
8	128.5	3.264	7.6	20.01	0.6405	73
9	114.4	2.906	8.6	25.23	0.8077	—
10	101.9	2.588	9.6	31.82	1.018	55
11	90.7	2.305	10.7	40.12	1.284	—
12	80.8	2.053	12.0	50.59	1.619	41
13	72.0	1.828	13.5	63.80	2.042	—
14	64.1	1.628	15.0	80.44	2.575	32
15	57.1	1.450	16.8	101.4	3.247	—
16	50.8	1.291	18.9	127.9	4.094	22
17	45.3	1.150	21.2	161.3	5.163	—
18	40.3	1.024	23.6	203.4	6.510	16
19	35.9	0.912	26.4	256.5	8.210	—
20	32.0	0.812	29.4	323.4	10.35	11
21	28.5	0.723	33.1	407.8	13.05	—
22	25.3	0.644	37.0	514.2	16.46	—
23	22.6	0.573	41.3	648.4	20.76	—
24	20.1	0.511	46.3	817.7	26.17	—
25	17.9	0.455	51.7	1031	33.00	—
26	15.9	0.405	58.0	1300	41.62	—
27	14.2	0.361	64.9	1639	52.48	—
28	12.6	0.321	72.7	2067	66.17	—
29	11.3	0.286	81.6	2607	83.44	—
30	10.0	0.255	90.5	3287	105.2	—
31	8.9	0.227	101	4145	132.7	—
32	8.0	0.202	113	5227	167.3	—
33	7.1	0.180	127	6591	211.0	—
34	6.3	0.160	143	8310	266.0	—
35	5.6	0.143	158	10480	335	—
36	5.0	0.127	175	13210	423	—
37	4.5	0.113	198	16660	533	—
38	4.0	0.101	224	21010	673	—
39	3.5	0.090	248	26500	848	—
40	3.1	0.080	282	33410	1070	—

[1] A mil is 0.001 inch.

[2] Max wire temp of 212° F and max ambient temp of 135° F.

Table 2

Stressed Antenna Wire

American Wire Gauge	***Recommended Tension[1] (pounds)***		***Weight (pounds per 1000 feet)***	
	Copper-clad steel[2]	*Hard-drawn copper*	*Copper-clad steel[2]*	*Hard-drawn copper*
4	495	214	115.8	126.0
6	310	130	72.9	79.5
8	195	84	45.5	50.0
10	120	52	28.8	31.4
12	75	32	18.1	19.8
14	50	20	11.4	12.4
16	31	13	7.1	7.8
18	19	8	4.5	4.9
20	12	5	2.8	3.1

[1] Approximately one-tenth the breaking load. Might be increased 50% if end supports are firm and there is no danger of ice loading.

[2] Copperweld,™ 40% copper.

Wire Tension

If the tension on a wire can be adjusted to a known value, the expected sag of the wire (**Fig 1**) may be determined before installation using Table 2 and the nomograph of **Fig 2**. Even though there may be no convenient method to determine the tension in pounds, calculation of the expected sag for practicable working tensions is often desirable. If the calculated sag is greater than allowable it may be reduced by any one or a combination of the following:

1) Providing additional supports, thereby decreasing the span
2) Increasing the tension in the wire if less than recommended
3) Decreasing the size of the wire

Instructions for Using the Nomograph

1) From Table 2, find the weight (pounds/1000 feet) for the particular wire size and material to be used.
2) Draw a line from the value obtained above, plotted on the weight axis, to the desired span (feet) on the span axis, Fig 2. Note in Fig 1 that the span is one half the distance between the supports.
3) Choose an operating tension level (in pounds) consistent with the values presented in Table 2 (preferably less than the recommended wire tension).
4) Draw a line from the tension value chosen (plotted on the tension axis) through the point where the work axis crosses the original line constructed in step 2, and continue this new line to the sag axis.
5) Read the sag in feet on the sag axis.

Example:

Weight = 11 pounds/1000 feet
Span = 210 feet
Tension = 50 pounds
Answer: Sag = 4.7 feet

These calculations do not take into account the weight of a feed line supported by the antenna wire.

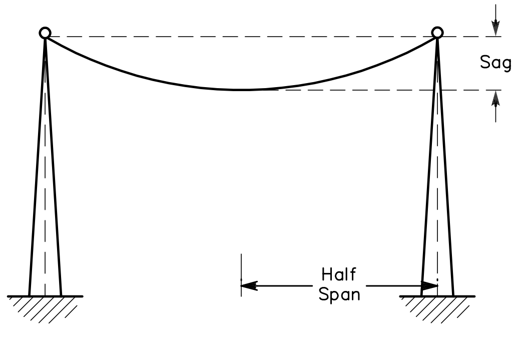

Fig 1—The half span and sag of a long-wire antenna.

Wire Splicing

Wire antennas should preferably be made with unbroken lengths of wire. In instances where this is not feasible, wire sections should be spliced as shown in **Fig 3**. The enamel insulation should be removed for a distance of about 6 inches from the end of each section by scraping with a knife or rubbing with sandpaper until the copper underneath is bright. The turns of wire should be brought up tight around the standing part of the wire by twisting with broad-nose pliers.

The crevices formed by the wire should be completely filled with rosin-core solder. An ordinary soldering iron or gun may not provide sufficient heat to melt solder outdoors; a propane torch is desirable. The joint should be heated sufficiently so the solder flows freely into the joint when the source of heat is removed momentarily. After the joint has cooled completely, it should be wiped clean with a cloth, and then sprayed generously with acrylic to prevent corrosion.

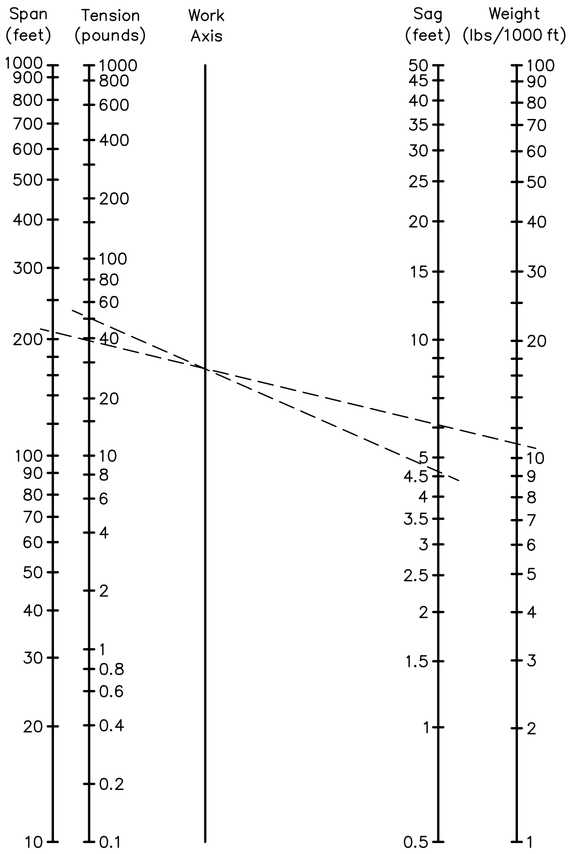

Fig 2—Nomograph for determining wire sag. (John Elengo, Jr, K1AFR)

ANTENNA INSULATION

To prevent loss of RF power, the antenna should be well insulated from ground, unless of course it is a shunt-fed system. This is particularly important at the outer end or ends of wire antennas, since these points are always at a comparatively high RF potential. If an antenna is to be installed indoors (in an attic, for instance) the antenna may be suspended directly from the wood rafters without additional insulation, if the wood is permanently dry. Much greater care should be given to the selection of proper insulators when the antenna is located outside where it is exposed to wet weather.

Insulator Leakage

Antenna insulators should be made of material that will not absorb moisture. The best insulators for antenna use are made of glass or glazed porcelain. Depending on the type of material, plastic insulators may be suitable. The length of an insulator relative to its surface area is indicative of its comparative insulating ability. A long thin insulator will have less leakage than a short thick insulator. Some antenna insulators are deeply ribbed to increase the surface leakage path without increasing the physical length of the insulator. Shorter insulators can be used at low-potential points, such as at the center of a dipole. If such an antenna is to be fed with open-wire line and used on several bands, however, the center insulator should be the same as those used at the ends, because high RF potential may exist across the center insulator on some bands.

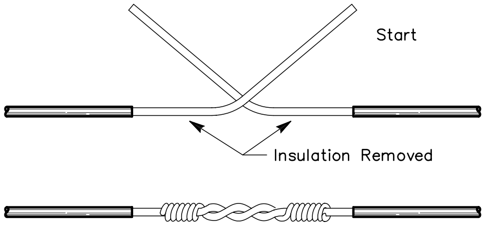

Fig 3—Correct method of splicing antenna wire. Solder should be flowed into the wraps after the connection is completed. After cooling, the joint should be sprayed with acrylic to prevent oxidation and corrosion.

Insulator Stress

As with the antenna wire, the insulator must have sufficient physical strength to support the stress of the antenna without danger of breakage. Long elastic bands or lengths of nylon fishing line provide long leakage paths and make satisfactory insulators within their limits to resist mechanical strain. They are often used in antennas of the "invisible" type mentioned earlier.

For low-power work with short antennas not subject to appreciable stress, almost any small glass or glazed-porcelain insulator will do. Homemade insulators of Lucite rod or sheet will also be satisfactory. More care is required in the selection of insulators for longer spans and higher transmitter power.

For a given material, the breaking tension of an insulator will be proportional to its cross-sectional area. It should be remembered, however, that the wire hole at the end of the insulator decreases the effective cross-sectional area. For this reason, insulators designed to carry heavy strains are fitted with heavy metal end caps, the eyes being formed in the metal cap, rather than in the insulating material itself. The following stress ratings of antenna insulators are typical:

$^5/_8$ in. square by 4 in. long—400 lb
1 in. diameter by 7 or 12 in. long—800 lb
$1^1/_2$ in. diameter by 8, 12 or 20 in. long, with special metal end caps—5000 lb

These are rated breaking tensions. The actual working tensions should be limited to not more than 25% of the breaking rating.

The antenna wire should be attached to the insulators as shown in **Fig 4**. Care should be taken to avoid sharp angular bends in the wire when it is looped through the insulator eye. The loop should be generous enough in size that it will not bind the end of the insulator tightly. If the length of the antenna is critical, the length should be measured to the outward end of the loop, where it passes through the eye of the insulator. The soldering should be done as described earlier for the wire splice.

Strain Insulators

Strain insulators have their holes at right angles, since they are designed to be connected as shown in **Fig 5**. It can be seen that this arrangement places the insulating material under compression, rather than tension. An insulator connected this way can withstand much greater stress. Furthermore, the wire will not collapse if the insulator breaks, since the two wire loops are inter-locked. Because the wire is wrapped around the insulator, however, the leakage path is reduced drastically, and the capacitance between the wire loops provides an additional leakage path. For this reason, the use of the strain insulator is usually confined to such applications as breaking up resonances in guy wires, where high levels of stress prevail, and where the RF insulation is of less importance. Such insulators might be suitable for use at low-potential points on an antenna, such as at the center of a dipole. These insulators may also be fastened in the conventional manner if the wire will not be under sufficient tension to break out the eyes.

Insulators for Ribbon-Line Antennas

Fig 6A shows the sketch of an insulator designed to be used at the ends of a folded dipole or a multiple dipole made of ribbon line. It should be made approximately as shown, out of Lucite or bakelite material about $^1/_4$ inch thick. The advantage of this arrangement is that the strain of the antenna is shared by the conductors and the plastic webbing of the ribbon, which adds considerable strength. After soldering, the screw should be sprayed with acrylic.

Fig 6B shows a similar arrangement for suspending one dipole from another in a stagger-tuned dipole system. If better insulation is desired, these insulators can be wired to a conventional insulator.

PULLEYS AND HALYARDS

Pulleys and halyards commonly used to raise and lower a wire antenna must also be capable of taking the

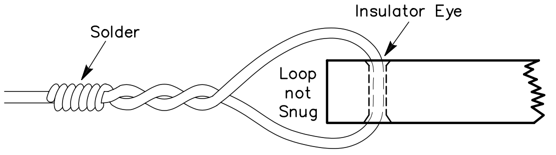

Fig 4—When fastening antenna wire to an insulator, do not make the wire loop too snug. After the connection is complete, flow solder into the turns. Then when the joint has cooled completely, spray it with acrylic.

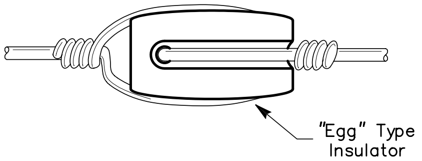

Fig 5—Conventional manner of fastening wire to a strain insulator. This method decreases the leakage path and increases capacitance, as discussed in the text.

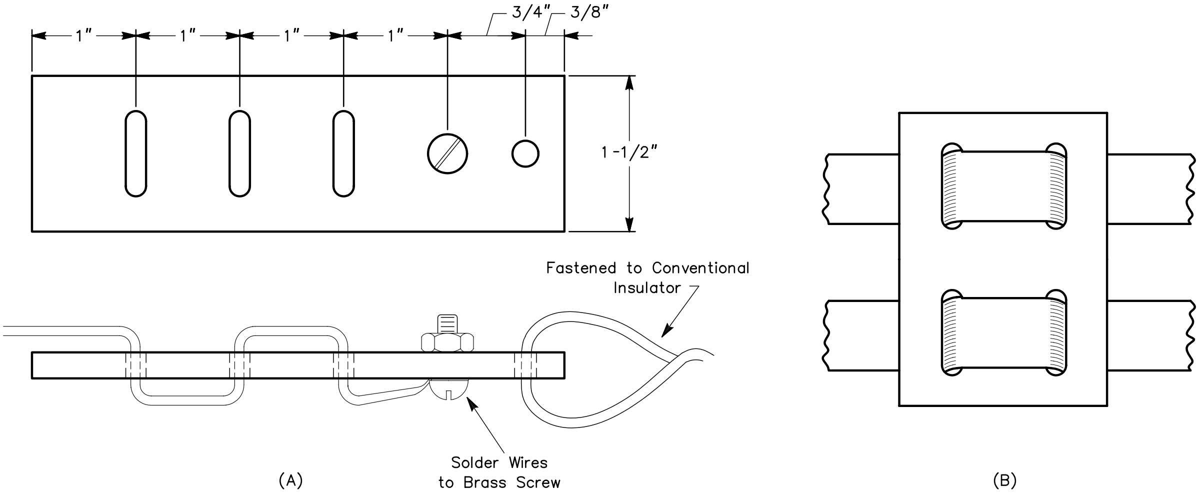
1"
1"
1"
1"
3/4"
3/8"
1-1/2"
Fastened to Conventional Insulator
Solder Wires to Brass Screw
(A)
(B)

Fig 6—At A, an insulator for the ends of folded dipoles, or multiple dipoles made of 300-ohm ribbon. At B, a method of suspending one ribbon dipole from another in a multiband dipole system.

same strain as the antenna wire and insulators. Unfortunately, little specific information on the stress ratings of most pulleys is available. Several types of pulleys are readily available at almost any hardware store. Among these are small galvanized pulleys designed for awnings and several styles and sizes of clothesline pulleys. Heavier and stronger pulleys are those used in marine work. The factors that determine how much stress a pulley will handle include the diameter of the shaft, how securely the shaft is fitted into the sheath and the size and material of the frame.

Another important factor to be considered in the selection of a pulley is its ability to resist corrosion. Galvanized awning pulleys are probably the most susceptible to corrosion. While the frame or sheath usually stands up well, these pulleys usually fail at the shaft. The shaft rusts out, allowing the grooved wheel to break away under tension.

Most good-quality clothesline pulleys are made of alloys which do not corrode readily. Since they are designed to carry at least 50 feet of line loaded with wet clothing in stiff winds, they should be adequate for normal spans of 100 to 150 feet between stable supports. One type of clothesline pulley has a 4-inch diameter plastic wheel with a ¼-inch shaft running in bronze bearings. The sheath is made of cast or forged corrosion-proof alloy. Some look-alike low-cost pulleys of this type have an aluminum shaft with no bearings. For antenna work, these cheap pulleys are of little long-term value.

Table 3
Approximate Safe Working Tension for Various Halyard Materials

Material	*Dia, In.*	*Tension, Lb*
Manila hemp rope	1/4	120
	3/8	270
	1/2	530
	5/8	800
Polypropylene rope	1/4	270
	3/8	530
	1/2	840
Nylon rope	1/4	300
	3/8	660
	1/2	1140
7×11 galvanized sash cord	1/16	30
	1/8	125
	3/16	250
	1/4	450
High-strength stranded galvanized steel guy wire	1/8	400
	3/16	700
	1/4	1200
Rayon-filled plastic clothesline	7/32	60 to 70

Marine pulleys have good weather-resisting qualities, since they are usually made of bronze, but they are comparatively expensive and are not designed to carry heavy loads. For extremely long spans, the wood-sheathed pulleys used in "block and tackle" devices and for sail hoisting should work well.

Halyards

Table 3 shows the recommended maximum tensions for various sizes and types of line and rope suitable for hoisting halyards. Probably the best type for general amateur use for spans up to 150 or 200 feet is ¼-inch nylon rope. Nylon is somewhat more expensive than ordinary rope of the same size, but it weathers much better. Nylon also has a certain amount of elasticity to accommodate gusts of wind, and is particularly recommended for antennas using trees as supports. A disadvantage of new nylon rope is that it stretches by a significant percentage. After an installation with new rope, it will be necessary to repeatedly take up the slack created by stretching. This process will continue over a period of several weeks, at which time most of the stretching will have taken place. Even a year after installation, however, some slack may still arise from stretching.

Most types of synthetic rope are slippery, and some types of knots ordinarily used for rope will not hold well. **Fig 7** shows a knot that should hold well, even in nylon rope or plastic line.

For exceptionally long spans, stranded galvanized steel sash cord makes a suitable support. Cable advertised as "wire rope" usually does not weather well. A boat winch, sold at marinas and at Sears, is a great convenience in antenna hoisting (and usually a necessity with metal halyards).

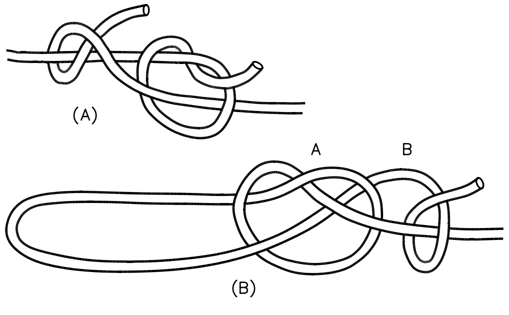

Fig 7—This is one type of knot that will hold with smooth rope, such as nylon. Shown at A, the knot for splicing two ends. B shows the use of a similar knot in forming a loop, as might be needed for attaching an insulator to a halyard. Knot A is first formed loosely 10 or 12 in. from the end of the rope; then the end is passed through the eye of the insulator and knot A. Knot B is then formed and both knots pulled tight. (Richard Carruthers, K7HDB)

Antennas of Aluminum Tubing

Aluminum is a malleable, ductile metal with a mass density of 2.70 grams per cubic centimeter. The density of aluminum is approximately 35% that of iron and 30% that of copper. Aluminum can be polished to a high brightness, and it will retain this polish in dry air. In the presence of moisture, aluminum forms an oxide coating (Al_2O_3) that protects the metal from further corrosion. Direct contact with certain metals, however (especially ferrous metals such as iron or steel), in an outdoor environment can bring about galvanic corrosion of aluminum and its alloys. Some protective coating should be applied to any point of contact between two dissimilar metals. Much of this information about aluminum and aluminum tubing was prepared by Ralph Shaw, K5CAV.

Aluminum is non-toxic; it is used in cooking utensils and to hold and cover "TV dinners" and other frozen foods, so it is certainly safe to work with. The ease with which it can be drilled or sawed makes it a pleasure to work with. Aluminum products lend themselves to many and varied applications.

Aluminum alloys can be used to build amateur antennas, as well as for towers and supports. Light weight and high conductivity make aluminum ideal for these applications. Alloying lowers the conductivity ratings, but the tensile strength can be increased by alloying aluminum with one or more metals such as manganese, silicon, copper, magnesium or zinc. Cold rolling can be employed to further increase the strength.

A four-digit system is used to identify aluminum alloys, such as 6061. Aluminum alloys starting with a 6 contain di-magnesium silicide (Mg_2Si). The second digit indicates modifications of the original alloy or impurity limits. The last two digits designate different aluminum alloys within the category indicated by the first digit.

In the 6000 series, the 6061 and 6063 alloys are a commonly used for antenna applications. Both types have good resistance to corrosion and medium strength. A further designation like T-6 denotes thermal treatment (heat tempering). More information on the available aluminum alloys can be found in **Table 4**.

SELECTING ALUMINUM TUBING

Table 5 shows the standard sizes of aluminum tubing that are stocked by most aluminum suppliers or distributors in the United States and Canada. Note that all tubing comes in 12-foot lengths (local hardware stores sometimes stock 6- and 8-foot lengths) and larger-diameter sizes may be available in lengths up to 24 feet. Note also that any diameter tubing will fit snugly into the next larger size, if the larger size has a 0.058-inch wall thickness. For example, $^5/_8$-inch tubing has an outside diameter of 0.625 inch. This will fit into $^3/_4$-inch tubing with a 0.058-inch wall, which has an inside diameter of 0.634 inch. A clearance of 0.009 inch is just right for a slip fit or for slotting the tubing and then using hose clamps. Always get the next larger size and specify a 0.058-inch wall to obtain the 0.009-inch clearance.

Table 4

Aluminum Numbers for Amateur Use

	Common Alloy Numbers
Type	*Characteristic*
2024	Good formability, high strength
5052	Excellent surface finish, excellent corrosion resistance, normally not heat treatable for high strength
6061	Good machinability, good weldability
6063	Good machinability, good weldability
7075	Good formability, high strength
	Common Tempers
Type	*Characteristics*
T0	Special soft condition
T3	Hard
T6	Hardest, possibly brittle
TXXX	Three digit tempers—usually specialized high strength heat treatments, similar to T6
	General Uses
Type	*Uses*
2024-T3	Chassis boxes, antennas, anything that will be bent or
7075-T3	Flexed repeatedly
6061-T6	Tubing and pipe; angle channel and bar stock
6063-T832	Tubing and pipe; angle channel and bar stock

A little figuring with Table 5 will give you all the information you need to build a beam, including what the antenna will weigh. The 6061-T6 type of aluminum has a relatively high strength and has good workability. It is highly resistant to corrosion and will bend without taking a "set."

SOURCES FOR ALUMINUM

Aluminum can be purchased new, and suppliers are listed in Chapter 21. But don't overlook the local metal scrap yard. The price varies, but between 35 and 60 cents per pound is typical for scrap aluminum. Some aluminum items to look for include aluminum vaulting poles, tent poles, tubing and fittings from scrapped citizen's band antennas, and aluminum angle stock. The scrap yard may even have a section or two of triangular aluminum tower.

Aluminum vaulting poles are 12 or 14 feet long and range in diameter from $1^1/_2$ to $1^3/_4$ inches. These poles are suitable for the center-element sections of large 14-MHz beams or as booms for smaller antennas. Tent poles range in length from 2½ to 4 feet. The tent poles are

Table 5
Aluminum Tubing Sizes
6061-T6 (61S-T6) Round Aluminum Tube In 12-Foot Lengths

	Wall Thickness			Approximate Weight	
Tubing Diameter	*Inches*	*Stubs Ga.*	*ID, Inches*	*Pounds Per Foot*	*Pounds Per Length*
3/16 in.	0.035	(#20)	0.117	0.019	0.228
	0.049	(#18)	0.089	0.025	0.330
1/4 in.	0.035	(#20)	0.180	0.027	0.324
	0.049	(#18)	0.152	0.036	0.432
	0.058	(#17)	0.134	0.041	0.492
5/16 in.	0.035	(#20)	0.242	0.036	0.432
	0.049	(#18)	0.214	0.047	0.564
	0.058	(#17)	0.196	0.055	0.660
3/8 in.	0.035	(#20)	0.305	0.043	0.516
	0.049	(#18)	0.277	0.060	0.720
	0.058	(#17)	0.259	0.068	0.816
	0.065	(#16)	0.245	0.074	0.888
7/16 in.	0.035	(#20)	0.367	0.051	0.612
	0.049	(#18)	0.339	0.070	0.840
	0.065	(#16)	0.307	0.089	1.068
1/2 in.	0.028	(#22)	0.444	0.049	0.588
	0.035	(#20)	0.430	0.059	0.708
	0.049	(#18)	0.402	0.082	0.984
	0.058	(#17)	0.384	0.095	1.040
	0.065	(#16)	0.370	0.107	1.284
5/8 in.	0.028	(#22)	0.569	0.061	0.732
	0.035	(#20)	0.555	0.075	0.900
	0.049	(#18)	0.527	0.106	1.272
	0.058	(#17)	0.509	0.121	1.452
	0.065	(#16)	0.495	0.137	1.644
3/4 in.	0.035	(#20)	0.680	0.091	1.092
	0.049	(#18)	0.652	0.125	1.500
	0.058	(#17)	0.634	0.148	1.776
	0.065	(#16)	0.620	0.160	1.920
	0.083	(#14)	0.584	0.204	2.448
7/8 in.	0.035	(#20)	0.805	0.108	1.308
	0.049	(#18)	0.777	0.151	1.810
	0.058	(#17)	0.759	0.175	2.100
	0.065	(#16)	0.745	0.199	2.399
1 in.	0.035	(#20)	0.930	0.123	1.476
	0.049	(#18)	0.902	0.170	2.040
	0.058	(#17)	0.884	0.202	2.424
	0.065	(#16)	0.870	0.220	2.640
	0.083	(#14)	0.834	0.281	3.372
1 1/8 in.	0.035	(#20)	1.055	0.139	1.668
	0.058	(#17)	1.009	0.228	2.736
1 1/4 in.	0.035	(#20)	1.180	0.155	1.860
	0.049	(#18)	1.152	0.210	2.520
	0.058	(#17)	1.134	0.256	3.072
	0.065	(#16)	1.120	0.284	3.408
	0.083	(#14)	1.084	0.357	4.284
1 3/8 in.	0.035	(#20)	1.305	0.173	2.076
	0.058	(#17)	1.259	0.282	3.384
1 1/2 in.	0.035	(#20)	1.430	0.180	2.160
	0.049	(#18)	1.402	0.260	3.120
	0.058	(#17)	1.384	0.309	3.708
	0.065	(#16)	1.370	0.344	4.128
	0.083	(#14)	1.334	0.434	5.208
	*0.125	1/8 in.	1.250	0.630	7.416
	*0.250	1/4 in.	1.000	1.150	14.832
1 5/8 in.	0.035	(#20)	1.555	0.206	2.472
	0.058	(#17)	1.509	0.336	4.032
1¾ in.	0.058	(#17)	1.634	0.363	4.356
	0.083	(#14)	1.584	0.510	6.120
1 7/8 in.	0.058	(#17)	1.759	0.389	4.668
2 in.	0.049	(#18)	1.902	0.350	4.200
	0.065	(#16)	1.870	0.450	5.400
	0.083	(#14)	1.834	0.590	7.080
	*0.125	1/8 in.	1.750	0.870	9.960
	*0.250	1/4 in.	1.500	1.620	19.920
2 1/4 in.	0.049	(#18)	2.152	0.398	4.776
	0.065	(#16)	2.120	0.520	6.240
	0.083	(#14)	2.084	0.660	7.920
2 1/2 in.	0.065	(#16)	2.370	0.587	7.044
	0.083	(#14)	2.334	0.740	8.880
	*0.125	1/8 in.	2.250	1.100	12.720
	*0.250	1/4 in.	2.000	2.080	25.440
3 in.	0.065	(#16)	2.870	0.710	8.520
	*0.125	1/8 in.	2.700	1.330	15.600
	*0.250	¼ in.	2.500	2.540	31.200

*These sizes are extruded. All other sizes are drawn tubes.

usually tapered; they can be split on the larger end and then mated with the smaller end of another pole of the same diameter. A small stainless-steel hose clamp (sometimes also available at scrap yards!) can be used to fasten the poles at this junction. A 14- or 21-MHz element can be constructed from several tent poles in this fashion. If a longer continuous piece of tubing is available, it can be used for the center section to decrease the number of junctions and clamps.

Other aluminum scrap is sometimes available, such as US Army aluminum mast sections designated AB-85/GRA-4 (J&H Smith Mfg). These are 3 foot sections with a 1 5/8 inch diameter. The ends are swaged so they can be assembled one into another. These are ideal for making a portable mast for a 144-MHz beam or for Field Day applications.

CONSTRUCTION WITH ALUMINUM TUBING

Most antennas built for frequencies of 14 MHz and above are made to be rotated. Constructing a rotatable antenna requires materials that are strong, lightweight and easy to obtain. The materials required to build a suitable antenna will vary, depending on many factors. Perhaps the most important factor that determines the type of hardware needed is the weather conditions normally encountered.

High winds usually don't cause as much damage to an antenna as does ice, especially ice along with high winds. Aluminum element and boom sizes should be selected so the various sections of tubing will telescope to provide the necessary total length.

The boom size for a rotatable Yagi or quad should be selected to provide stability to the entire system. The best diameter for the boom depends on several factors; most important are the element weight, number of elements and overall length. Tubing of 1-¼-inch diameter can easily support three-element 28-MHz arrays and perhaps a two-element 21-MHz system. A 2-inch diameter boom will be adequate for larger 28-MHz antennas or for harsh weather conditions, and for antennas up to three elements on 14 MHz or four elements on 21 MHz. It is not recommended that 2-inch diameter booms be made any longer than 24 feet unless additional support is given to reduce both vertical and horizontal bending forces. Suitable rein-forcement for a long 2-inch boom can consist of a truss or a truss and lateral support, as shown in **Fig 8**.

A boom length of 24 feet is about the point where a 3-inch diameter begins to be very worthwhile. This dimension provides a considerable improvement in overall mechanical stability as well as increased clamping surface area for element hardware. Clamping surface area is extremely important if heavy icing is common and rotation of elements around the boom is to be avoided. Pinning an element to the boom with a large bolt helps in this regard. On smaller diameter booms, however, the elements sometimes work loose and tend to elongate the pinning holes in both the element and the boom. After some time the elements shift their positions slightly (sometimes from day to day!) and give a rather ragged appearance to the system, even though this doesn't generally harm the electrical performance.

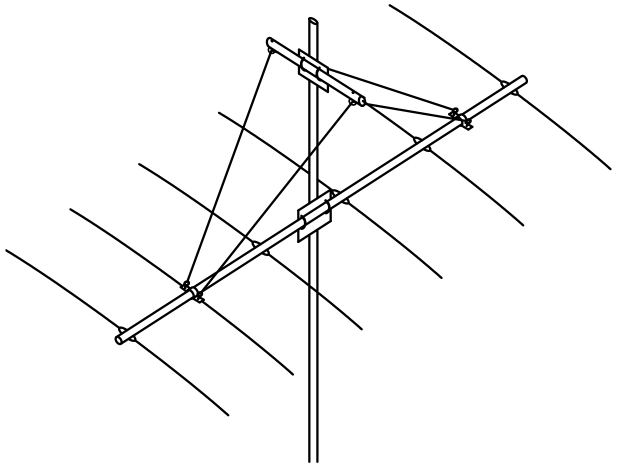

Fig 8—A long boom needs both vertical and horizontal support. The cross bar mounted above the boom can support a double truss to help keep the antenna in position.

A 3-inch diameter boom with a wall thickness of 0.065 inch is satisfactory for antennas up to about a five-element, 14-MHz array that is spaced on a 40-foot long boom. A truss is recommended for any boom longer than 24 feet.

There is no RF voltage at the center of a parasitic element, so no insulation is required in mounting elements that are centered on the boom (driven elements excepted). This is true whether the boom is metal or a nonconducting material. Metal booms have a small "shortening effect" on elements that run through them. With materials sizes commonly employed, this is not more than one percent of the element length, and may not be noticeable in many applications. It is just perceptible with $^1/_2$-inch tubing booms used on 432 MHz, for example. Design-formula lengths can be used as given, if the matching is adjusted in the frequency range one expects to use. The center frequency of an all-metal array will tend to be 0.5 to 1 percent higher than a similar system built of wooden supporting members.

Element Assembly

While the maximum safe length of an antenna element depends to some extent on its diameter, the only laws that specify the minimum diameter of an element are the laws of nature. That is, the element must be rugged enough to survive whatever weather conditions it will encounter.

Fig 9 shows tapered Yagi element designs that will survive winds in excess of 80 mi/h. With a $^1/_4$-inch thickness of radial ice, these designs will withstand winds up to approximately 60 mi/h. (Ice increases the wind area but does not increase the strength of the element.) More rugged designs are shown in **Fig 10**. With no ice loading, these elements will survive in 120-mi/h winds, and in winds exceeding 85 mi/h with $^1/_4$ inch of radial ice. If you lose an antenna made with elements like these, you'll have plenty of company among your neighbors with commercially made antennas!

Figs 9 and 10 show only half elements. When the element is assembled, the largest size tubing for each element should be double the length shown in the drawing, with its center being the point of attachment to the boom. These designs are somewhat conservative, in that they are self-resonant slightly below the frequency indicated for each design. Telescoping the outside end sections to shorter lengths for resonance will increase the survival wind speeds. Conversely, lengthening the outside end sections will reduce the survival wind speeds. [See Bibliography listing for David Leeson (W6NL, ex-W6QHS) at the end of this chapter.]

Fig 11 shows several methods of fastening antenna element sections together. The slot and hose clamp method shown in Fig 11A is probably the best for joints where adjustments are required. Generally, one adjustable joint per element half is sufficient to tune the antenna. Stainless-steel hose clamps (beware—some "stainless

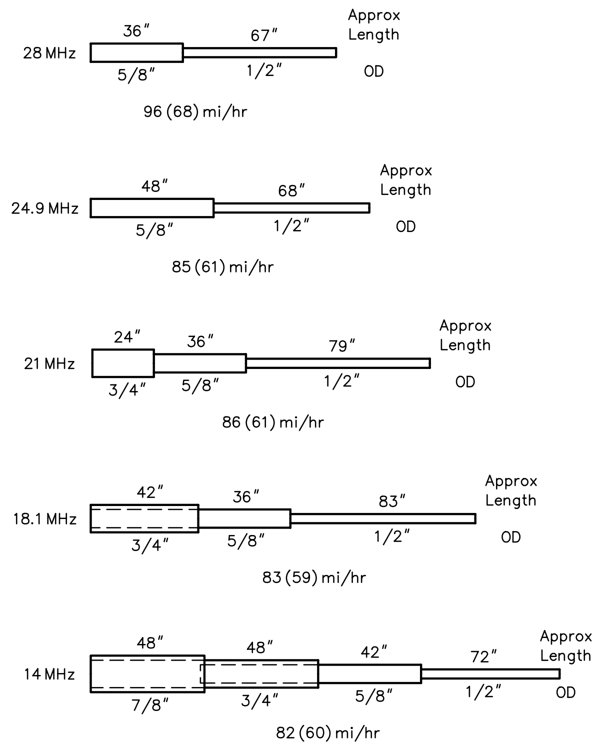
28 MHz
36″
67″
Approx Length
5/8″
1/2″
OD
96 (68) mi/hr
24.9 MHz
48″
68″
Approx Length
5/8″
1/2″
OD
85 (61) mi/hr
21 MHz
24″
36″
79″
Approx Length
3/4″
5/8″
1/2″
OD
86 (61) mi/hr
18.1 MHz
42″
36″
83″
Approx Length
3/4″
5/8″
1/2″
OD
83 (59) mi/hr
14 MHz
48″
48″
42″
72″
Approx Length
7/8″
3/4″
5/8″
1/2″
OD
82 (60) mi/hr

Fig 9—Half-element designs for Yagi antennas. The other side of the element is identical, and the center section should be a single piece twice as long as the length shown here for the largest diameter section. Use 0.058-in.-wall aluminum tubing throughout. Broken lines indicate double tubing thickness, where one tube is inserted into another. The overlap insertion depth into a tube two sizes larger, where shown, should be at least two inches. Maximum survival wind speeds without ice are shown adjacent to each design; values enclosed in parentheses are survival speeds for ¼ inch of radial ice.

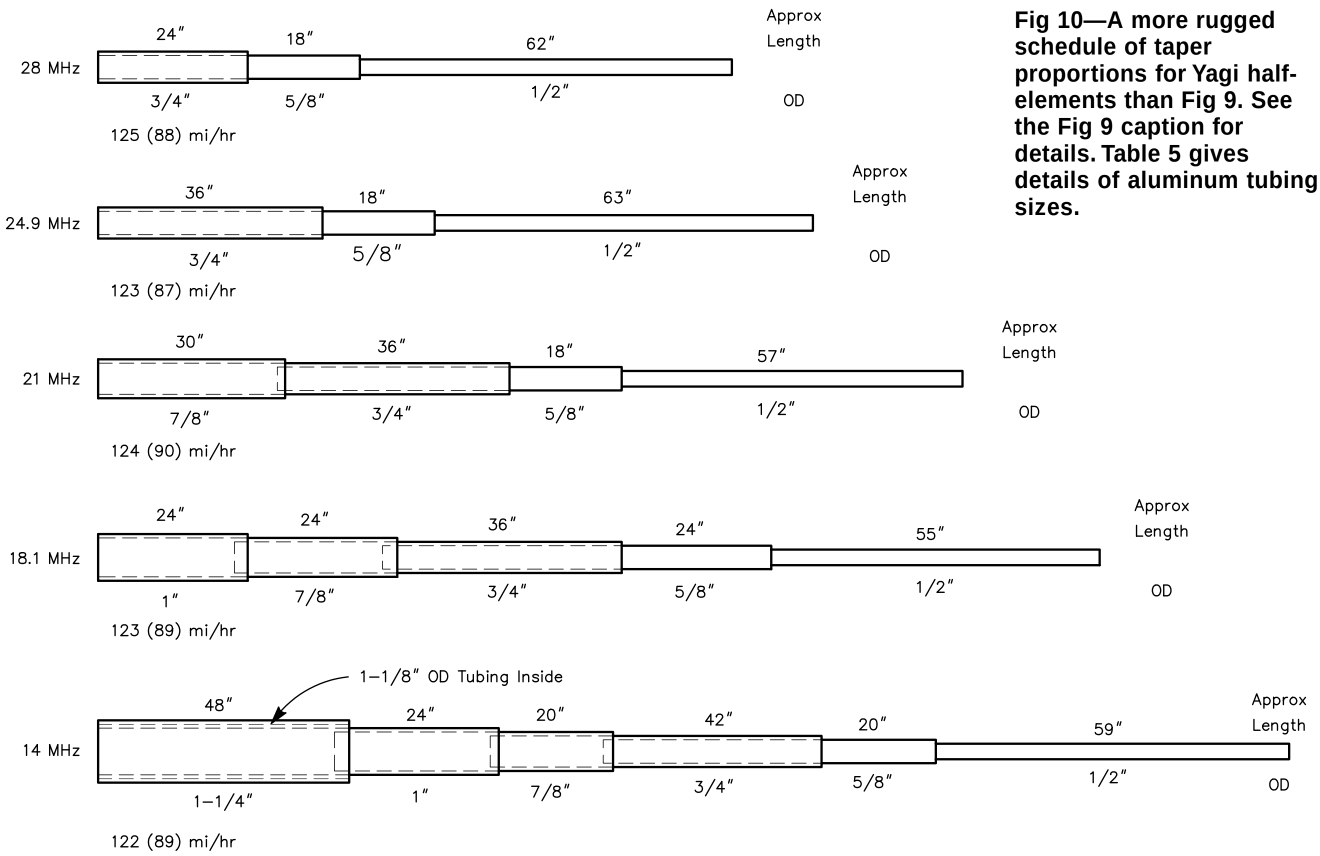
28 MHz
24″
18″
62″
Approx Length
3/4″
5/8″
1/2″
OD
125 (88) mi/hr
24.9 MHz
36″
18″
63″
Approx Length
3/4″
5/8″
1/2″
OD
123 (87) mi/hr
21 MHz
30″
36″
18″
57″
Approx Length
7/8″
3/4″
5/8″
1/2″
OD
124 (90) mi/hr
18.1 MHz
24″
24″
36″
24″
55″
Approx Length
1″
7/8″
3/4″
5/8″
1/2″
OD
123 (89) mi/hr
1–1/8″ OD Tubing Inside
14 MHz
48″
24″
20″
42″
20″
59″
Approx Length
1–1/4″
1″
7/8″
3/4″
5/8″
1/2″
OD
122 (89) mi/hr

Fig 10—A more rugged schedule of taper proportions for Yagi half-elements than Fig 9. See the Fig 9 caption for details. Table 5 gives details of aluminum tubing sizes.

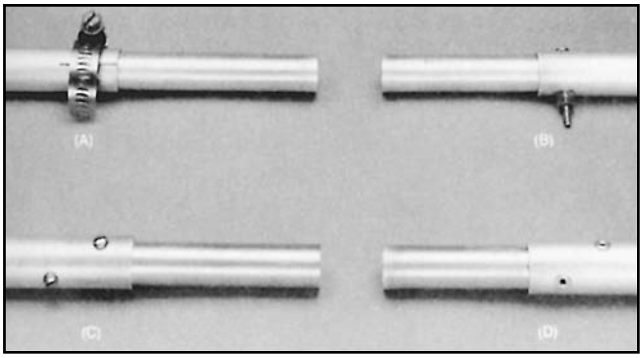

Fig 11—Methods of connecting telescoping tubing sections to build beam elements. See text for a discussion of each method.

Table 6
Hose-Clamp Diameters

	Clamp Diameter (In.)	
Size No.	*Min*	*Max*
06	7/16	7/8
08	7/16	1
10	1/2	1 1/8
12	5/8	1 1/4
16	3/4	1 1/2
20	7/8	1 3/4
24	1 1/8	2
28	1 3/8	2 1/4
32	1 5/8	2 1/2
36	1 7/8	2 3/4
40	2 1/8	3
44	2 5/16	3 1/4
48	2 5/8	3 1/2
52	2 7/8	3 3/4
56	3 1/8	4
64	3 1/2	4 1/2
72	4	5
80	4 1/2	5 1/2
88	5 1/8	6
96	5 5/8	6 1/2
104	6 1/8	7

steel" models do not have a stainless screw and will rust) are recommended for longest antenna life. **Table 6** shows available hose-clamp sizes.

Figs 11B, 11C and 11D show possible fastening methods for joints that do not require adjustment. At B, machine screws and nuts hold the elements in place. At C, sheet metal screws are used. At D, rivets secure the tubing. If the antenna is to be assembled permanently, rivets are the best choice. Once in place, they are permanent. They will never work free, regardless of vibration or wind. If aluminum rivets with aluminum mandrels are used, they will never rust. In addition, there is no danger of dissimilar-metal corrosion with aluminum rivets and aluminum antenna elements. If the antenna is to be disassembled and moved periodically, either B or C will work. If machine screws are used, however, take all possible precautions to keep the nuts from vibrating free. Use lock washers, lock nuts and flexible sealant such as silicone bathtub sealant to keep the hardware in place.

Very strong elements can be made by using a double thickness of tubing, made by telescoping one size inside another for the total length. This is usually done at the center of an element where more element strength is desired at at the boom support point, as in the 14-MHz element in Fig 10. Other materials can be used as well, such as wood dowels, fiberglass rods, and so forth.

In each case where a smaller diameter length of tubing is telescoped inside a larger diameter one, it's a good idea to coat the inside of the joint with Penetrox or a similar substance to ensure a good electrical bond. Antenna elements have a tendency to vibrate when they are mounted on a tower, and one way to dampen the vibrations is by running a piece of clothesline rope through the length of the element. Cap or tape the end of the element to secure the clothesline. If mechanical requirements dictate (a U-bolt going through the center of the element, for instance), the clothesline may be cut into two pieces.

Antennas for 50 MHz need not have elements larger than 1/2-inch diameter, although up to 1 inch is used occasionally. At 144 and 220 MHz the elements are usually 1/8 to 1/4 inch in diameter. For 420 MHz, elements as small as 1/16 inch diameter work well, if made of stiff rod. Aluminum welding rod of 3/32 to 1/8 inch diameter is fine for 420-MHz arrays, and 1/8 inch or larger is good for the 220-MHz band. Aluminum rod or hard-drawn wire works well at 144 MHz.

Tubing sizes recommended in the paragraph above are usable with most formula dimensions for VHF/UHF antennas. Larger diameters broaden the frequency response; smaller ones sharpen it. Much smaller diameters than those recommended will require longer elements, especially in 50-MHz arrays.

Element Taper and Electrical Length

The builder should be aware of one important aspect of telescoping or tapered elements. When the element diameters are tapered, as shown in Figs 9 and 10, the electrical length is not the same as it would be for a cylindrical element of the same total length. Length corrections for tapered elements are discussed in Chapter 2.

Other Materials for Antenna Construction

Wood is very useful in antenna work. It is available in a great variety of shapes and sizes. Rug poles of wood or bamboo make fine booms. Bamboo is quite satisfactory for spreaders in quad antennas.

Round wood stock (doweling) is found in many hardware stores in sizes suitable for small arrays. Wood is good for the framework of multibay arrays for the higher bands, as it keeps down the amount of metal in the active area of the array. Square or rectangular boom and frame materials can be cut to order in most lumber yards if they are not available from the racks in suitable sizes.

Wood used for antenna construction should be well seasoned and free of knots or damage. Available materials vary, depending on local sources. Your lumber dealer can help you better than anyone else in choosing suitable materials. Joining wood members at right angles can be done with gusset plates, as shown in **Fig 12**. These can be made of thin outdoor-grade plywood or Masonite. Round materials can be handled in ways similar to those used with metal components, with U clamps and with other hardware.

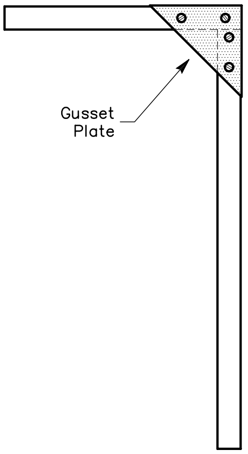

Fig 12—Wood members can be joined at right angles using gusset plates.

In the early days of Amateur Radio, hardwood was used as insulating material for antennas, such as at the center and ends of dipoles, or for the center insulator of a driven element made of tubing. Wood dowels cut to length were the most common source. To drive out moisture and prevent the subsequent absorption of moisture into the wood, it was treated before use by boiling it in paraffin. Of course today's technology has produced superior materials for insulators in terms of both strength and insulating qualities. However, the technique is worth consideration in an emergency situation or if low cost is a prime requirement. "Baking" the wood in an oven for a short period at 200° F should drive out any moisture. Then treatment as described in the next paragraph should prevent moisture absorption. The use of wood insulators should be avoided at high-voltage points if high power is being used.

All wood used in outdoor installations should be protected from the weather with varnish or paint. A good grade of marine spar varnish or polyurethane varnish will offer protection for years in mild climates, and one or more seasons in harsh climates. Epoxy-based paints also offer good protection.

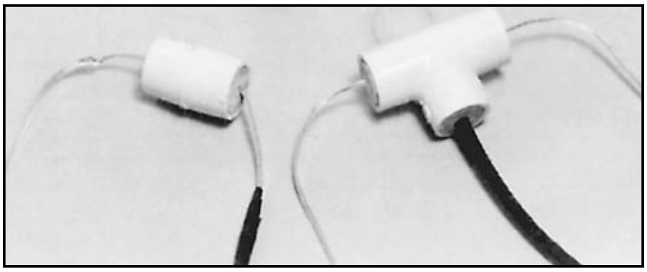

Fig 13—Plastic plumbing parts can be used as antenna center and end insulators.

Plastics

Plastic tubing and rods of various sizes are available from many building-supplies stores. The uses for the available plastic materials are limited only by your imagination. Some amateurs have built beam antennas for VHF using wire elements run inside thin PVC plumbing pipe. The pipe gives the elements a certain amount of physical strength. Other hams have built temporary antennas by wrapping plastic pipe with aluminum foil or other conductive material. Plastic plumbing pipe fittings can also be used to enclose baluns and as the center insulator or end insulators of a dipole, as shown in **Fig 13**. Plastic or Teflon rod can be used as the core of a loading coil for a mobile antenna (**Fig 14**) but the material for this use should be selected carefully. Some plastics become quite warm in the presence of a strong RF field, and the loading-coil core might melt or catch fire!

Fiberglass

Fiberglass poles are the preferred material for spreaders for quad antennas. They are lightweight, they withstand harsh weather well, and their insulating qualities are excellent. One disadvantage of fiberglass poles is that they may be crushed rather easily. Fracturing occurs at the point where the pole is crushed, causing it to lose its strength. A crushed pole is next to worthless. Some amateurs have repaired crushed poles with fiberglass cloth and epoxy, but the original strength is

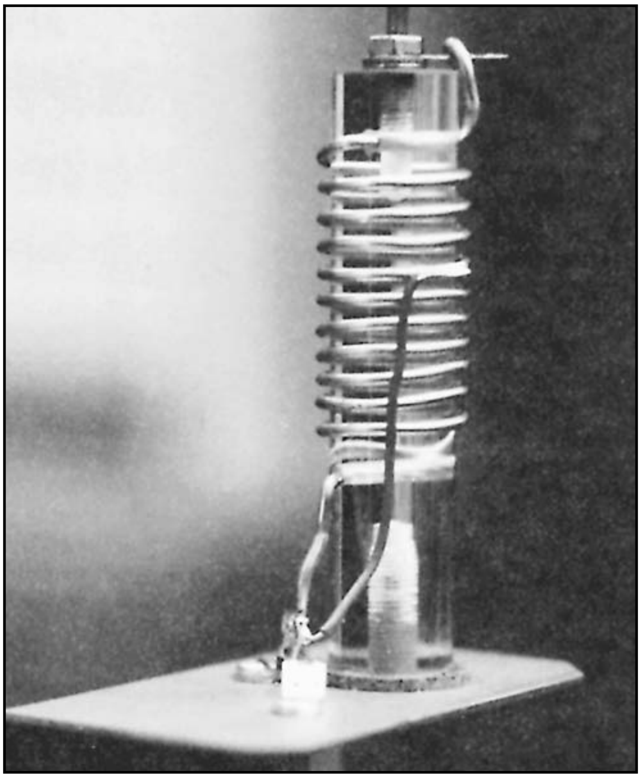

Fig 14—A mobile-antenna loading coil wound on a polystyrene rod.

nearly impossible to regain.

Fiberglass poles can also be used to construct other types of antennas. Examples are helically wound Yagi elements or verticals, where a wire is wound around the pole.

CONCLUSION

The antenna should be put together with good quality hardware. Stainless steel is best for long life. Rust will quickly attack plated steel hardware, making nuts difficult, if not impossible, to remove. If stainless-steel muffler clamps and hose clamps are not available, the next best thing is to have them plated. If you can't have them plated, at least paint them with a good zinc-chromate primer and a finish coat or two.

Galvanized steel generally has a longer life than plated steel, but this depends on the thickness of the galvanizing coat. Even so, in harsh climates rust will usually develop on galvanized fittings in a few years. For the ultimate in long-term protection, galvanized steel should be further protected with zinc-chromate primer and then paint or enamel before exposing it to the weather.

Good quality hardware is expensive initially, but if you do it right the first time, you won't have to take the antenna down in a few years and replace the hardware. When the time does come to repair or modify the antenna, nothing is more frustrating than fighting rusty hardware at the top of the tower.

Basically any conductive material can be used as the radiating element of an antenna. Almost any insulating material can be used as an antenna insulator. The materials used for antenna construction are limited mainly by physical considerations (required strength and resistance to outdoor exposure) and by the availability of materials. Don't be afraid to experiment with radiating materials and insulators.

BIBLIOGRAPHY

Source Material and more extended discussion of topics covered in this chapter can be found in the reference given below.

J. J. Elengo, Jr., "Predicting Sag in Long Wire Antennas," *QST*, Jan 1966, pp 57-58.

D. B. Leeson, *Physical Design of Yagi Antennas* (Newington, CT: ARRL).

Chapter 21

Antenna Products Suppliers

Antenna Manufacturers Products

Finding parts can be the most difficult aspect of an antenna project. Suppliers of aluminum exist in most major metropolitan areas. They can be found in the Yellow Pages of the phone book. Some careful searching of the Yellow Pages may also reveal sources of other materials and accessories. If you live away from a metropolitan area, try using telephone books for the nearest large metropolitan area; they may be available in the reference section of your local library.

Many dealers and distributors will ship their products by freight or by mail. Tables 1 through 7 list several categories of antenna products and some suppliers of them. Company names have been abbreviated where necessary. Table 8 is an address list arranged alphabetically by company name.

Product lines change often; we recommend that you

Table 1
VHF/UHF/Microwave Antenna Suppliers

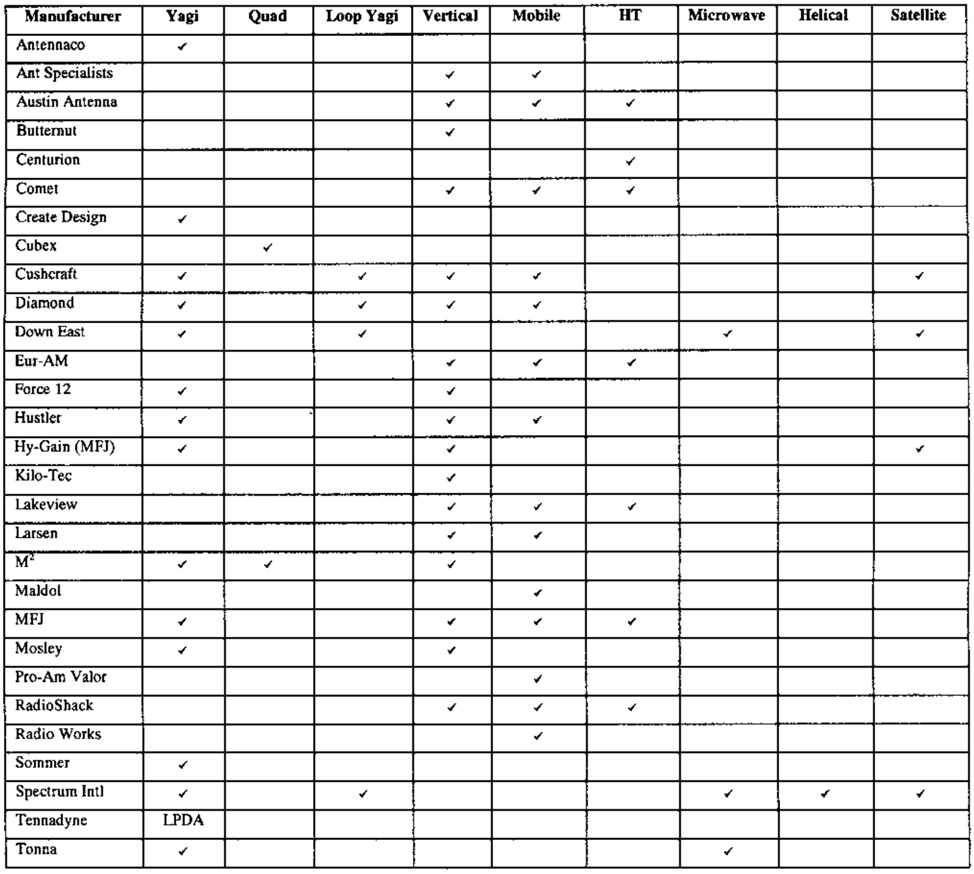

Manufacturer	Yagi	Quad	Loop Yagi	Vertical	Mobile	HT	Microwave	Helical	Satellite
Antennaco	✓								
Ant Specialists				✓	✓				
Austin Antenna				✓	✓	✓			
Butternut				✓					
Centurion						✓			
Comet				✓	✓	✓			
Create Design	✓								
Cubex		✓							
Cushcraft	✓		✓	✓	✓				✓
Diamond	✓		✓	✓	✓				
Down East	✓		✓				✓		✓
Eur-AM				✓	✓	✓			
Force 12	✓			✓					
Hustler	✓			✓	✓				
Hy-Gain (MFJ)	✓			✓					✓
Kilo-Tec				✓					
Lakeview				✓	✓	✓			
Larsen				✓	✓				
M^2	✓	✓		✓					
Maldol					✓				
MFJ	✓			✓	✓	✓			
Mosley	✓			✓					
Pro-Am Valor					✓				
RadioShack				✓	✓	✓			
Radio Works					✓				
Sommer	✓								
Spectrum Intl	✓		✓				✓	✓	✓
Tennadyne	LPDA								
Tonna	✓						✓		

request current catalogs from those manufacturers who interest you. In addition, all indications of sales policies and prices for catalogs are given for general information only and are subject to change without notice.

Antenna products for repeaters are listed separately, in Chapter 17.

Table 2
HF Antenna Suppliers

Manufacturer	Yagi	Quad	LPDA	Vertical	Dipole	Mobile	Small Xmtg	Active (RX only)
Alpha Delta				✓	✓	✓		
B & W				✓	✓			
Bilal							✓	
Butternut/Bencher	✓			✓			✓	
Create Design	✓		✓	✓	✓		✓	
Cubex		✓						
Cushcraft	✓		✓	✓	✓			
Flytecraft				✓		✓		
Force 12	✓		✓	✓	✓	✓	✓	
GAP				✓				
Gem Quad		✓						
Grove					✓	✓		✓
High Sierra				✓	✓	✓		
Hustler				✓		✓		
Hy-Gain (MFJ)	✓			✓	✓			
Lakeview/Hamstick						✓		
Lightning Bolt		✓						
M^2	✓				✓			
MFJ	✓	✓	✓	✓	✓	✓	✓	✓
Mosley	✓			✓	✓			
Palomar								✓
Pro-Am Valor						✓		
Roadrunner						✓		
Sommer	✓			✓				
Spi-Ro				✓	✓			
Tennadyne			✓					
Texas Radio					✓	✓		
Radio Works				✓	✓			
Van Gorden				✓	✓			
W1JC					✓		✓	
W9INN					✓			

Table 3
Antenna Parts

Manufacturer	Hardware	Insulators	Traps	Aluminum Tubing	Wire	Transmission Lines
Alexanderson AeroPlane Co				✓		
Barker & Williamson		✓	✓			
Cable X-Perts	✓	✓			✓	✓
Hy-Gain (MFJ)	✓	✓				
Metal & Cable, Inc	✓			✓	✓	
Ocean State Electronics	✓	✓			✓	✓
Spi-Ro		✓	✓		✓	✓
Texas Towers				✓	✓	✓
Radio Works	✓	✓			✓	✓
Van Gorden	✓	✓			✓	✓
The Wireman	✓	✓			✓	✓
W1JC		✓			✓	
W9INN					✓	

Table 4
Suppliers of Quad Antenna Parts

Company	*Material Size*
Cubex Co., Inc.	$1\frac{1}{4}$-$\frac{1}{2}$ in. × 13 ft; $1\frac{1}{2}$ in. × 13 ft cast spiders, boom-to-mast mounts.
Lightning Bolt	Custom-made fiberglass spreaders; any length.
Max-Gain Systems, Inc.	Quad spreaders; fiberglass insulators.

Table 5
Towers, Masts and Accessories

Towers
Aluma
Champion Radio
Create Design
Force 12
Glen Martin Engineering
Heights Tower
Hy-Gain (MFJ)
National Tower
RadioShack (masts only)
Rohn
Rotating Tower Systems
Tashjian Towers Corporation
Texas Tower
Trylon
Universal Manufacturing
US Tower

Climbing and Safety Equipment
Champion Radio Products
ONV
Texas Towers

Rotators
Create Design
Hy-Gain (MFJ)
M^2
RadioShack
The Rotor Doctor
Yaesu

Stacking Frames
(Unless otherwise noted these frames are for use in stacking the manufacturer's own antennas in pairs or in quads. These stacking kits are for VHF or UHF antennas only.)
C3i
Cushcraft
Down East
IIX
Spectrum International

Combiners, Power Dividers and Phasing Harnesses
Byers
C3i
Down East
Spectrum International
Tonna

Table 6
Transmission Lines

Source	Coax	Hardline	Ladder Line
Belden	✓	✓	
Cable X-Perts	✓	✓	✓
International Wire & Cable	✓		
Nemal	✓	✓	
The Radio Works	✓	✓	✓
W1JC			✓
W9INN			✓
The Wireman	✓	✓	✓

Table 7
Transmission Line Instruments and Accessories

Matching Networks
- Ameritron
- Barker & Williamson
- Cubex
- ICOM (mobile & fixed)
- Kenwood
- MFJ
- Nye
- SGC
- Ten-Tec
- Texas Radio (mobile only)
- Vectronics
- XMatch

Ferrite Cores and Rods
- Amidon
- Palomar
- The Wireman

Filters—TVI (Low Pass & High Pass)
- K-Com
- MFJ

Lightning Arresters
- Alpha Delta
- Ameritron
- Comet
- Cushcraft
- Hy-Gain (MFJ)
- Polyphaser
- Radioware
- Rohn
- The Wireman
- Zero Surge Inc

Switches (Manual, Coax)
- Alpha Delta
- Barker & Williamson
- MFJ

Switches (Remote, Coax)
- Ameritron
- MFJ

SWR and Wattmeters
- Autek
- Bird
- Coaxial Dynamics
- MFJ
- Nye
- Palomar
- RF Parts
- Texas Radio

Table 8
Suppliers Addresses

We have made every effort to ensure that this list is complete and accurate as of mid 2003. The ARRL takes no responsibility for errors or omissions. Similarly, a listing here does not represent an endorsement of a manufacturer or products by the ARRL. Refer to the product reviews in *QST* for descriptions of particular products that interest you. To the best of our knowledge the suppliers listed are willing to sell products to amateurs by mail unless indicated otherwise. This listing will be updated with each edition of *The Antenna Book* and *The ARRL Handbook* in the TISFIND manufacturer database. Check ads in *QST* and other Amateur Radio publications for any changes to this information. Suppliers who wish to be listed or update their information are urged to contact the editors.

Advanced Composites
1154 S. 300 W.
Salt Lake City, UT 84101
801-467-1204
fax 801-467-4367
e-mail
info@advancedcomposites.com

Advanced Specialties
114 Essex Street
Lodi, NJ 07644
USA
Tel: 800-926-9426
Email: advanspec@aol.com
http://advancedspec.freeyellow.com/

AEA—Div. Tempo Research Corporation
1221 Liberty Way
Vista, CA 92083
760-598-9677
fax 760-598-4898
e-mail tempo@inetworld.com
web www.aea-wireless.com

AFT
132 Boulevard Dauphinot
F-51100 Reims, France
+33 326 070 047
fax +33 326 023 654
e-mail Antennes-ft@wanadoo.fr
web www.f9ft.com

Alexander Aeroplane Co
PO Box 909
Griffin, GA 30224
800-831-2949; 404-229-2329

Alan Broadband Company
(Zap Checker)
93 Arch Street
Redwood City, CA 94062
USA
Tel: 888-369-9627 (orders)
650-369-9627
Fax: 650-369-3788
Email: ABCom@prodigy.net
http://www.alanbroadband.com/

Alpha Delta Communications
PO Box 620
Manchester, KY 40962
606-598-2029
fax 606-598-4413

Aluma Tower Co, Inc
PO Box 2806-AL
Vero Beach, FL 32961-2806
772-567-3423
fax 772-567-3432
e-mail atc-t@alumatower.com
web www.alumatower.com/index.html

Amateur Electronic Supply
5710 W Good Hope Rd
Milwaukee, WI 53223
800-558-0411
web www.aesham.com/

Ameritron Division
116 Willow Road
Starkville, MS 39759
662-323-8211 (Tech)
fax 662-323-6551
e-mail
ameritron@ameritron.com
web www.ameritron.com/ameritron

Amidon Associates, Inc.
1510 E. Edinger Avenue, Unit B
Santa Ana CA 92705
800-898-1883; 714-547-4494
fax 714-547-4433
e-mail sales@amidon-inductive.com
web www.amidon-inductive.com/

Antennaco Inc
102 Armory Road
PO Box 218
Milford, NH 03055-0218
603-673-3153
fax 603-673-4347

Allen Telecom Group
Antenna Specialists Mobile Division
30500 Bruce Industrial Parkway
Cleveland, OH 44139-3996
USA
440-349-8400
fax 440-349-8404
web www.antenna.com/

Array Solutions
350 Gloria Rd
Sunnyvale, Tx 75182
USA
Tel: 972-203-8810
Fax: 972-203-8811
Email: wx0b@arrysolutions.com
http://www.arraysolutions.com

ASA Antenna Sales
PO Box 3461
Myrtle Beach, SC 29578
800-772-2681

Associated Radio Communications
8012 Conser
Overland Park, KS 66204
913-381-5900; 800-497-1457
fax 913-648-3020
e-mail assocrad@tfs.net
web www.associatedradio.com

Austin Amateur Radio Supply
5310 Cammeron Road
Austin, TX 78723
800-423-2604; 512-454-2994
fax 512-454-3069

Austin Antenna, Ltd
10 Main St
Gonic, NH 03839
603-336-6339
fax 603-335-1756

Autek Research
PO Box 7556
Wesley Chapel, FL 33544
813-994-2199
e-mail
Mailbox@autekresearch.com
web www.autekresearch.com/
index.htm

Barker & Williamson Co
603 Cidco Rd
Cocoa, FL 32926
321-639-2545
fax 321-639-2545
e-mail
custsrvc@bwantennas.com
web www.bwantennas.com

Barry Electronics Corp
540 Broadway
New York, NY 10012
212-925-7000
fax 212-925-7001

Belden Wire & Cable
PO Box 1980
Richmond, IN 47374
317-983-5257
fax 317-983-5257
web www.belden.com

Bencher Inc.
831 North Central Avenue
Wood Dale, IL 60191
630-238-1183
fax 630-238-1186
e-mail bencher@bencher.com
web www.bencher.com/

Bilal Company
137 Manchester Dr
Florissant, CO 81816
719-687-0650
web www.isotronantennas.com/

Bird Electronics Corporation
30303 Aurora Rd.
Solon, OH 44139
866-695-4569
e-mail sales@bird-
technologies.com
web www.bird-electronic.com/

Brian Beezley, K6STI
3532 Linda Vista Dr
San Marcos, CA 92069
619-599-4962
e-mail k6sti@n2.net

Burghardt Amateur Center, Inc.
710 10th Street SW
PO Box 73
Watertown, SD 57201
800-927-4261
605-886-7314 (Service)
605-886-6914 (Fax-back
product info)
fax 605-886-3444
e-mail burghart@daknet.com
web www.burghardt-
amateur.com/

Butternut Electronics Co
See Bencher Inc.

Byers Chassis Kits
5120 Harmony Grove Road
Dover, PA 17315
717-292-4901
(6p-9p EST M-F, 8a-4p Sat)
717-292-4901 (24 hrs)

Cable X-Perts Inc.
225 Larkin Drive Suite #6
Wheeling, IL 60090-7209
800-828-3340 (orders only)
847-520-3003 (Tech. Info.)
fax 847-520-3444
e-mail cxp@cablexperts.com
web www.cablexperts.com/

CAL-AV Labs, Inc.
1802 w. Grant road, Ste. 116
Tucson, AZ 85745
USA
Tel: 520-624-1300
888-815-0400 (orders only)
Fax: 520-624-1311
Email: info@cal-av.com
http://www.cal-av.com/

Cardwell Condenser Corp
80 East Montauk Hwy
Lindenhurst, NY 11757
516-957-7200
fax 516-957-7203
web www.cardwellcondenser.com

C.A.T.S.
Formerly known as: Rotor Doctor
7368 SR 105
Pemberville, OH 43450
419-353-2287
fax 419-354-7746
e-mail mailto:craig@rotor-doc.com
web www.rotordoc.com

C-Comm
6115 15th NW
Seattle, WA 98107
206-784-7337; 800-426-6528
fax 206-784-0541

C3i
1401 K Street NW Suite 900
Washington DC 20005
(800) 224-5137
fax (202) 362-8481
e-mail info@C3iusa.com
web www.c3iusa.com/
corpover.html

Centurion International
PO Box 82846
Lincoln, NE 68501-2846
402-467-4491
fax 800-848-3825

Champion Radio Products
Box 572
Woodinville, WA 98072
425-485-7913
206-890-4188 Cell Phone
fax 360-668-1447
e-mail championradio@aol.com
web www.championradio.com/

Coaxial Dynamics
15210 Industrial Parkway
Cleveland, Ohio 44135-3308
800-262-9425
fax 216-267-3142
e-mail cdi-sales@coaxial.com
web www.coaxial.com/
home_frames.htm

Comet North America Inc.
394 Wards Corner Road
Suite 130
Cincinnati, Ohio, 45140
513-831-5000
fax 513-831-7889
e-mail
info@CometNorthAmerica.com
web www.cometnorthamerica.com/

Comet Antenna
See NCG

Comm-Pute
7946 State Street
Midvale, UT 84047
801-567-9944
fax 801-567-9494
e-mail bobwood@xmission.com
web www.comm-pute.com/

Communication Headquarters Inc.
3832 Oleander Drive
Wilmington, NC 28403
910-791-8885
800-688-0073 (orders)
fax 910-452-3891 (orders)
web www.chq-inc.com/

Communications Data Corp
1051 Main St
St Joseph, MI 49085
269-982-0404
fax 269-982-0433
e-mail mailto:did@gtm.net

Comtelco Industries Inc
501 Mitchell Rd
Glendale Heights, IL 60139
800-634-4622; 708-7790-9894
fax 708-798-9799

Create
4-8 Asano-Cho
Kawasaki-Ku
Kawasaki-City, Japan
044 (333) 6681
fax 044 (333) 6598
e-mail email@cd-corp.com

Cubex Co.
228 Hibiscus St, #9
Jupiter, FL 33458
561-748-2830
fax 561-748-2831
e-mail CubexCo@aol.com
web www.cubex.com/

Cushcraft Corp
48 Perimeter Rd.
Manchester, NH 03108
603-627-7877
e-mail sales@cushcraft.com
web www.cushcraft.com/

Dave's Hobby Shop
600 Main St.
Van Buren, AK 72956
USA
Tel: 479-471-0750
Web www.daveswebshop.com

Davis RF Co
See Radioware (distributor)
PO Box 730
Carlisle, MA 01741
978-371-1356
978-369-1738
800-328-4773 (Orders only)
fax 978-369-3484
e-mail davisrfinc@aol.com
web www.davisRF.com

Diamond Antennas
See RF Parts

Down East Microwave
954 Rt 519
Frenchtown, NJ 08825
908-996-3584
fax 908-996-3702
web downeastmicrowave.com/

Dressler Hochfrequenztechnik
GMBH
Werther Strasse 14-16
W-5190 Stolberg
Germany

DX Engineering
POB 440
Peninsula, Ohio 44264
USA
Fax: 330-657-2168
Email:
dxengineering@dxengineering.com
http://www.dxengineering.com/

EDCO - Electronic Distributors
Company
325 Mill Street
Vienna, VA 22180
703-938-8105
fax 703-938-6911
e-mail web www.elecdist.com/
index.html

EUR-AM Antennas
PO Box 225
Moultonboro, NH 03254-0225
603-476-5113
fax 603-476-5113
e-mail info@eur-am.com
web www.eur-am.com/

EZ Hang, Inc.
8645 Tower Dr.
Code C
Laurel, MD 20723
Tel: 540-286-0176
Fax: 202-260-3797
http://www.ezhang.com

Fluidmotion Incorporated
14135 233rd Place SE
Issaquah, WA 98027
425-456-0200; 800-885-8700
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e-mail sales@steppir.com
web www.steppir.com/

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Chapter 22

Antenna Supports

A prime consideration in the selection of a support for an antenna is that of structural safety. Building regulations in many localities require that a permit be obtained in advance of the erection of certain structures, often including antenna poles or towers. In general, localities having such requirements also have building safety codes that must be observed. Such regulations may govern the method and materials used in construction of, for example, a self-supporting tower. Checking with your local government building department before putting up a tower may save a good deal of difficulty later, because a tower would have to be taken down or modified if not approved by the building inspector on safety grounds.

Municipalities have the right and duty to enforce any reasonable regulations having to do with the safety of life or property. The courts generally have recognized, however, that municipal authority does not extend to aesthetic questions. The fact that someone may object to the mere presence of a pole, tower or other antenna structure because in his opinion it detracts from the beauty of the neighborhood is not grounds for refusing to issue a permit for a safe structure to be erected. Since the introduction of PRB-1 (federal preemption of unnecessarily restrictive antenna ordinances), this principle has been borne out in many courts. Permission for erecting amateur towers is more easily obtained than in the recent past because of this legislation.

Even where local regulations do not exist or are not enforced, the amateur should be careful to select a location and a type of support that contribute as much safety as possible to the installation. If collapse occurs, the chances of personal injury or property damage should be minimized by careful choice of design and erection methods. A single injury can be far more costly than the price of a more rugged support, in terms of both monetary loss and damage to the public respect for amateur radio.

This chapter has been reviewed and rewritten by Kurt Andress, K7NV.

TREES AS ANTENNA SUPPORTS

From the beginning of Amateur Radio, trees have been used widely for supporting wire antennas. Trees cost noth-

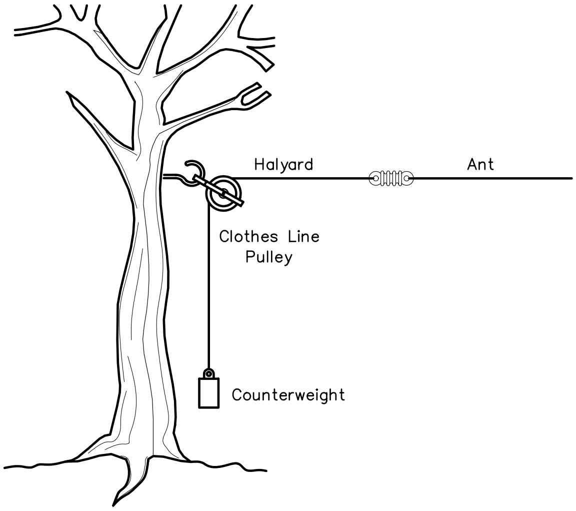

Fig 1—A method of counter weighting to minimize antenna movement and avoid its breaking from tree movement in the wind. The antenna may be lowered without climbing the tree by removing the counterweight and tying additional rope at the bottom end of the halyard. Excess rope may be left at the counterweight for this purpose, as the knot at the lower end of the halyard will not pass through the pulley.

ing to use, and often provide a means of supporting a wire antenna at considerable height. As antenna supports, trees are unstable in the presence of wind, except in the case of very large trees used to support antennas well down from the top branches. As a result, tree-supported antennas must be constructed much more sturdily than is necessary with stable supports. Even with rugged construction, it is unlikely that an antenna suspended from a tree, or between trees, will stand up indefinitely. Occasional repair or replacement usually must be expected.

There are two general methods of securing a pulley to a tree. If the tree can be climbed safely to the desired level, a pulley can be attached to the trunk of the tree, as shown in **Fig 1**. To clear the branches of the tree, the antenna end of the halyard can be tied temporarily to the tree at the pulley level. Then the remainder of the halyard is coiled up, and the coil thrown out horizontally from this level, in the direction in which the antenna runs. It may help to have the antenna end of the halyard weighted.

After attaching the antenna to the halyard, the other end is untied from the tree, passed through the pulley, and brought to ground along the tree trunk in as straight a line as possible. The halyard need only be long enough to reach the ground after the antenna has been hauled up. (Additional rope can be tied to the halyard when it becomes necessary to lower the antenna.)

The other method consists of passing a line over the tree from ground level, and using this line to haul a pulley up into the tree and hold it there. Several ingenious methods have been used to accomplish this. The simplest method employs a weighted pilot line, such as fishing line or mason's chalk line. By grasping the line about two feet from the weight, the weight is swung back and forth, pendulum style, and then heaved with an underhand motion in the direction of the treetop.

Several trials may be necessary to determine the optimum size of the weight for the line selected, the distance between the weight and the hand before throwing, and the point in the arc of the swing where the line released. The weight, however, must be sufficiently large to carry the pilot line back to ground after passing over the tree. Flipping the end of the line up and down so as to put a traveling wave on the line often helps to induce the weight to drop down if the weight is marginal. The higher the tree, the lighter the weight and the pilot line must be. A glove should be worn on the throwing hand, because a line running swiftly through the bare hand can cause a severe burn.

If there is a clear line of sight between ground and a particularly desirable crotch in the tree, it may eventually be possible to hit the crotch after a sufficient number of tries. Otherwise, it is best to try to heave the pilot line completely over the tree, as close to the centerline of the tree as possible. If it is necessary to retrieve the line and start over again, the line should be drawn back very slowly; otherwise the swinging weight may wrap the line around a small limb, making retrieval impossible.

Stretching the line out straight on the ground before throwing may help to keep the line from snarling, but it places extra drag on the line, and the line may snag on obstructions overhanging the line when it is thrown. Another method is to make a stationary reel by driving eight nails, arranged in a circle, through a 1-inch board. After winding the line around the circle formed by the nails, the line should reel off readily when the weighted end of the line is thrown. The board should be tilted at approximately right angles to the path of the throw.

Other devices that have been used successfully to pass a pilot line over a tree are a bow and arrow with heavy thread tied to the arrow, and a short casting rod and spinning reel used by fishermen. The Wrist Rocket slingshot made from surgical rubber tubing and a metal frame has proved highly effective as an antenna-launching device. Still another method that has been used where sufficient space is available is flying a kite to sufficient altitude, walking around the tree until the kite string lines up with the center of the tree, and paying out string until the kite falls to the earth. This method can be used to pass a line over a patch of woods between two higher supports, which may be impossible using any other method.

The pilot line can be used to pull successively heavier lines over the tree until one of adequate size to take the strain of the antenna has been reached. This line is then used to haul a pulley up into the tree after the antenna halyard has been threaded through the pulley. The line that holds the pulley must be capable of withstanding considerable chafing where it passes through the crotch, and at points where lower branches may rub against the standing part. For this reason, it may be advisable to use galvanized sash cord or stranded guy wire for raising the pulley.

Larger lines or cables require special attention when they must be spliced to smaller lines. A splice that minimizes the chances of coming undone when coaxed through the tree crotch must be used. One type of splice is shown in **Fig 2**.

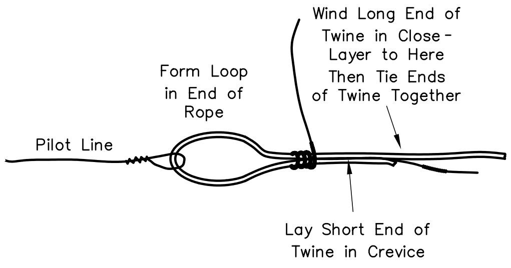
Wind Long End of Twine in Close-Layer to Here Then Tie Ends of Twine Together
Form Loop in End of Rope
Pilot Line
Lay Short End of Twine in Crevice

Fig 2—In connecting the halyard to the pilot line, a large knot that might snag in the crotch of a tree should be avoided, as shown.

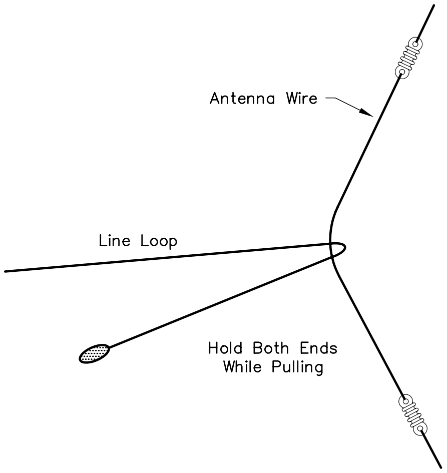

Fig 3—A weighted line thrown over the antenna can be used to pull the antenna to one side of overhanging obstructions, such as tree branches, as the antenna is pulled up. When the obstruction has been cleared, the line can be removed by releasing one end.

The crotch in which the line first comes to rest may not be sufficiently strong to stand up under the tension of the antenna. If, however, the line has been passed over (or close to) the center line of the tree, it will usually break through the lighter crotches and come to rest in a stronger one lower in the tree.

Needless to say, any of the suggested methods should be used with due respect to persons or property in the immediate vicinity. A child's sponge-rubber ball (baseball size) makes a safe weight for heaving a heavy thread line or fishing line.

If the antenna wire snags in the lower branches of the tree when the wire is pulled up, or if other trees interfere with raising the antenna, a weighted line thrown over the antenna and slid to the appropriate point is often helpful in pulling the antenna wire to one side to clear the interference as the antenna is being raised. This is shown in **Fig 3**.

Wind Compensation

The movement of an antenna suspended between supports that are not stable in the wind can be reduced by the use of heavy springs, such as screen-door springs under tension, or by a counterweight at the end of one halyard. This is shown in Fig 1. The weight, which may be made up of junkyard metal, window sash weights, or a galvanized pail filled with sand or stone, should be adjusted experimentally for best results under existing conditions. **Fig 4** shows a convenient way of fastening the counterweight to the halyard. It eliminates the necessity for untying a knot in the halyard, which may have hardened under tension and exposure to the weather.

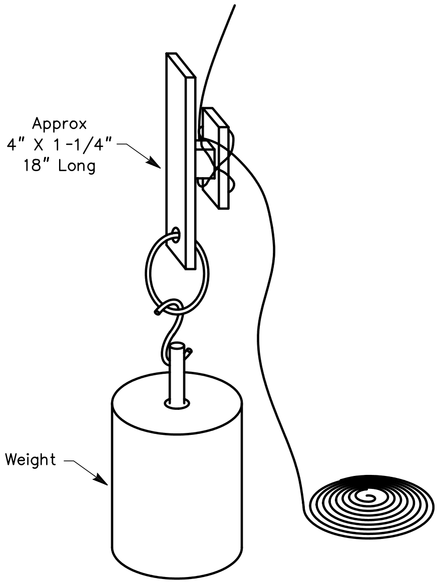

Fig 4—The cleat eliminates the need to untie a knot that may be weather hardened.

TREES AS SUPPORTS FOR VERTICAL WIRE ANTENNAS

Trees can often be used to support vertical as well as horizontal antennas. If the tree is tall and has overhanging branches, the scheme of **Fig 5** may be used. The top end of the antenna is secured to a halyard passed over the limb, brought back to ground level, and fastened to the trunk of the tree.

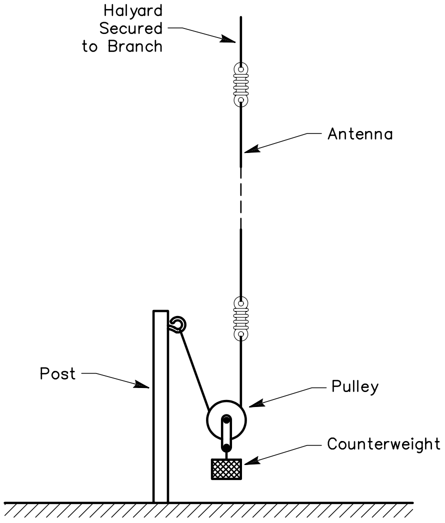

Fig 5—Counterweight for a vertical antenna suspended from an overhanging tree branch.

MAST MATERIALS

Where suitable trees are not available, or a more stable support is desired, light-duty guyed masts are suitable for wire antennas of reasonable span length. At one time, most amateur masts were constructed of lumber, but the TV industry has brought out metal masts that are inexpensive and much more durable than wood. However, there are some applications where wood is necessary or desirable.

A Ladder Mast

A temporary antenna support is sometimes needed for an antenna system for antenna testing, site selection, emergency exercises or Field Day. Ordinary aluminum extension ladders are ideal candidates for this service. They are strong, light, extendable, weatherproof and easily transported. Additionally, they are readily available and can be returned to normal use once the project is concluded. A ladder tower will support a lightweight triband beam and rotator.

With patience and ingenuity one person can erect this assembly. One of the biggest problems is holding the base down while "walking" the ladder to a vertical position. The ladder can be guyed with $^1/_4$-inch polypropylene rope. Rope guys are arranged in the standard fashion with three at each level. If help is available, the ladder can be walked up in its retracted position and extended after the antenna and rotator are attached. The lightweight pulley system on most extension ladders is not strong enough to lift the ladder extension. This mechanism must be replaced (or augmented) with a heavy-duty pulley and rope. Make sure when attaching the guy ropes that they do not foul the operation of the sliding upper section of the ladder.

There is one hazard in this system that must be avoided: Do not climb or stand on the ladder when it is being extended—even as much as one rung. Never stand on the ladder and attempt to raise or lower the upper section. Do all the extending and retracting with the heavy-duty rope and pulley!

If the ladder is to be raised by one person, use the following guidelines. First, make sure the rung-latching mechanism operates properly before beginning. The base must be hinged so that it does not slip along the ground during erection. The guy ropes should be tied and positioned in such a way that they serve as safety constraints in the event that control of the assembly is lost. Have available a device (such as another ladder) for supporting the ladder during rest periods. (See **Fig 6**.)

After the ladder is erect and the lower section guys tied and tightened, raise the upper portion one rung at a time. Do not raise the upper section higher than it is designed to go; safety is far more important than a few extra feet of height.

For a temporary installation, finding suitable guy anchors can be an exercise in creativity. Fence posts, trees, and heavy pipes are all possibilities. If nothing of sufficient strength is available, anchor posts or pipes can be driven into the soil. Sandy soil is the most difficult to work with because it does a very poor job of holding anchors. A discarded car axle can be driven into the ground as an anchor, as its mass and strength are substantial. A chain and car-bumper jack can be used to remove the axle when the operation is done.

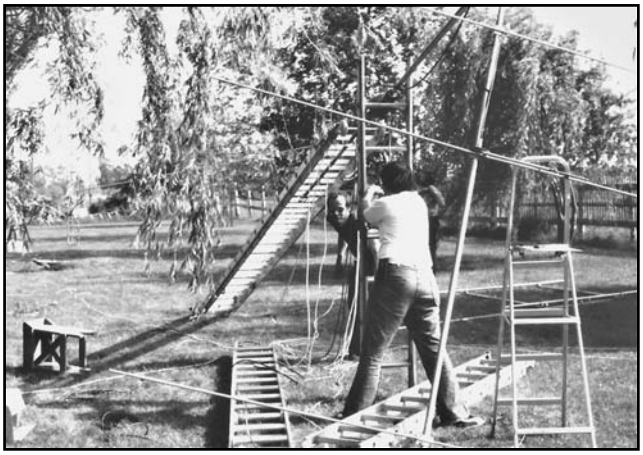

Fig 6—Walking the ladder up to its vertical position. Keith, VE2AQU, supports the mast with a second ladder while Chris, VE2FRJ, checks the ropes. (*Photo by Keith Baker, VE2XL.*)

Above all else, keep the tower and antenna away from power lines. Make sure that nothing can touch the lines if the assembly falls. Disassemble by reversing the process. Ladder towers are handy for "quickie" antenna supports, but as with any improvisation of support materials, care must be taken to ensure safe construction.

The A-Frame Mast

A light and relatively inexpensive mast is shown in **Fig 7**. In lengths up to 40 feet it is very easy to erect and will stand the pull of ordinary wire antenna systems. The lumber used is 2 × 2-inch straight-grained pine (which many lumber yards know as hemlock) or even fir stock. The uprights can be as long as 22 feet each (for a mast slightly over 40 feet high) and the cross pieces are cut to fit. Four pieces of 2 × 2 lumber, each 22 feet long, provides more than enough. The only other materials required are five $^1/_4$-inch carriage bolts $5^1/_2$ inches long, a few spikes, about 300 feet of stranded or solid galvanized wire for guying, enough glazed porcelain compression ("egg") insulators to break up the guys into sections, and the usual pulley and halyard rope. If the strain insulators are put in every 20 feet, approximately 15 of them will be enough.

After selecting and purchasing the lumber—which should be straight-grained and knot-free—sawhorses or boxes should be set up and the mast assembled as shown in **Fig 8**. At this stage it is wise to give the mast a coat of primer and a coat of outside white latex paint.

After the coat of paint is dry, attach the guys and rig the pulley for the antenna halyard. The pulley anchor should be at the point where the top stays are attached so the backstay will assume the greater part of the load tension. It is better to use wire wrapped around the mast with a small through-bolt to prevent sliding down than to use eyebolts.

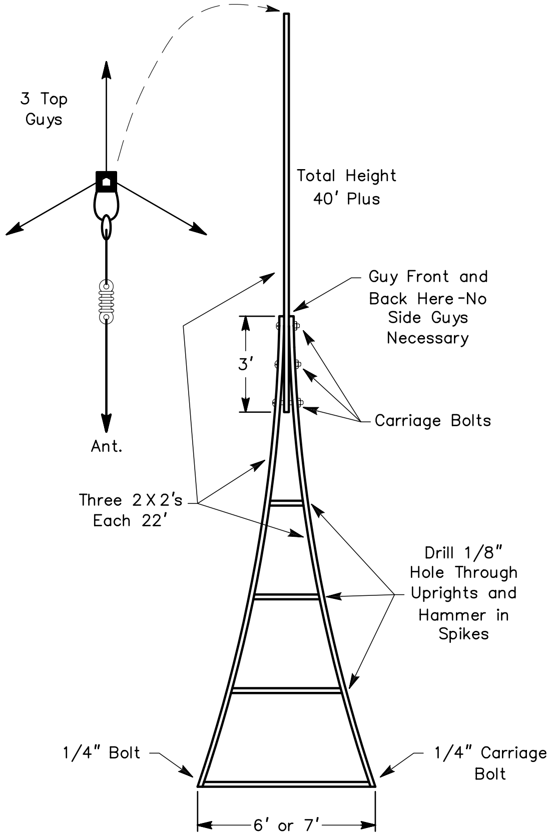
3 Top Guys
Ant.
Total Height 40' Plus
Guy Front and Back Here -No Side Guys Necessary
3'
Carriage Bolts
Three 2 X 2's Each 22'
Drill 1/8" Hole Through Uprights and Hammer in Spikes
1/4" Bolt
1/4" Carriage Bolt
6' or 7'

Fig 7—The A-frame mast is lightweight and easily constructed and erected.

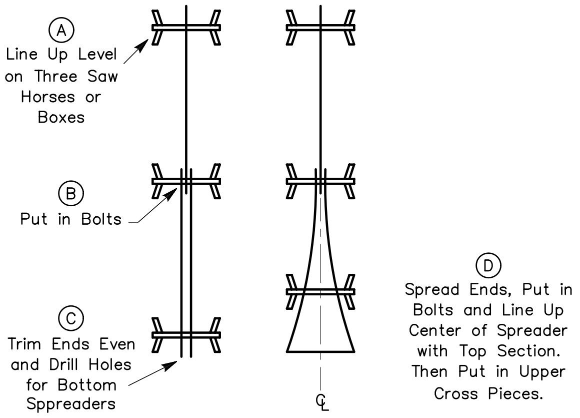
A
Line Up Level on Three Saw Horses or Boxes
B
Put in Bolts
C
Trim Ends Even and Drill Holes for Bottom Sppreaders
D
Spread Ends, Put in Bolts and Line Up Center of Spreader with Top Section. Then Put in Upper Cross Pieces.
℄

Fig 8—Method of assembling the A-frame mast on sawhorses.

If the mast is to stand on the ground, a couple of stakes should be driven to keep the bottom from slipping. At this point the mast may be "walked up" by a helper. If it is to go on a roof, first stand it up against the side of the building and then hoist it, from the roof, keeping it vertical. The whole assembly is light enough for two men to perform the complete operation—lifting the mast, carrying it to its permanent berth, and fastening the guys with the mast vertical. It is entirely practical to put up such a mast on a flat area of roof that would be too small to erect a regular tower installation, one that had to be raised vertically on the same spot.

TV Mast Material

TV mast is available in 5- and 10-foot lengths, 1¼ inches diameter, in both steel and aluminum. These sections are crimped at one end to permit sections to be joined together. A form that is usually more convenient is the telescoping mast available from many electronic supply houses. The masts may be obtained with three, four or five 10-foot sections, and come complete with guying rings and a means of locking the sections in place after they have been extended. These masts are inherently more suitable for guyed mast installations than the non-telescoping type because the diameters of the sections increase toward the bottom of the mast. For instance, the top section of a 50-foot mast is 1¼ inches diameter, and the bottom section is 2½ inches diameter.

Guy rings are provided at 10-foot intervals, but guys may not be required at every point. Guying is essential at the top and at least one other place near the center of the mast. If the mast has any tendency to whip in the wind, or to bow under the load of a horizontal wire antenna, additional guys should be added at the appropriate points.

MAST GUYING

Three guy wires in each set are usually adequate for a mast. These should be spaced equally round the mast. The required number of sets of guys depends on the height of the mast, its natural sturdiness (or stiffness), and the required antenna tension. A 30-foot-high mast usually requires two sets of guys, and a 50-foot mast needs at least three sets. One guy of the top set should be anchored to a point directly opposing the force exerted by the wire antenna. The other two guys of the same set should be spaced 120° with respect to the first, as shown in the inset in Fig 7.

Generally, the top guys should be anchored at distances from the base of the mast at least 60% of the mast height. The distance of the guy anchors from the mast determines the guy loads and the vertical load compressing the mast. At a 60% distance, the load on the guy wire opposite the wire antenna is approximately twice the antenna tension. The compression in the mast will be 1.66 times the antenna tension. With the anchors out 80% of the mast height, the guy tension will be 1.6 times larger than the antenna load and the mast compression will be 1.25 times larger.

Whenever possible, the largest available anchor spacing should be used. The additional compression on the mast, due to closer anchor spacing, increases the tendency of the mast to buckle. Buckling occurs when the compression on the unsupported spans between guys become too great for the unsupported length. The section then bows out laterally and will usually fold over, collapsing the mast. Additional sets of guys reduce the tendency for the mast to buckle under the compression by decreasing the unsupported span lengths and stabilizing the mast, keeping it in a straight line.

A natural phenomenon, called *vortex shedding*, can occur when the wind passes over the sections of a guyed mast. For every section size, shape, and length, there is a wind speed that can cause the sections to oscillate mechanically. When all the sections of an antenna support mast are close to the same size and length, it is possible for all of the mast sections to vibrate simultaneously between the guys. To reduce the potential for this, you can place the guys at locations along the mast that will result in different span lengths. This creates different mechanical resonant frequencies for each span, eliminating the possibility of all sections oscillating at the same time.

When determining the guy locations along the mast to treat this problem, you also need to consider the mast buckling requirements. Since the compression in the mast is greatest in the bottom span, and the least in the top span, the guys should be placed to make the bottom span the shortest and the top span the longest. A general guide for determining the different span lengths is to make the unguyed lengths change by 10 to 20%.

Example: For a 30-foot high mast with three guy sets, the equal-guy locations would be every 10 feet. We can make the center span, 10 feet long, and then make the lower span 15% shorter and the top span 15% longer. While this is not an exact technical method to determine the best solution, the approach will create different mechanical resonant frequencies for the spans, with the span lengths approximately adjusted for the varying buckling requirements.

You can eliminate electrical resonance from conductive guy materials that might cause distortion of the antenna radiation pattern by breaking each guy into nonresonant lengths using strain insulators (see **Figs 9** and **10**). This subject is covered in detail later in this chapter.

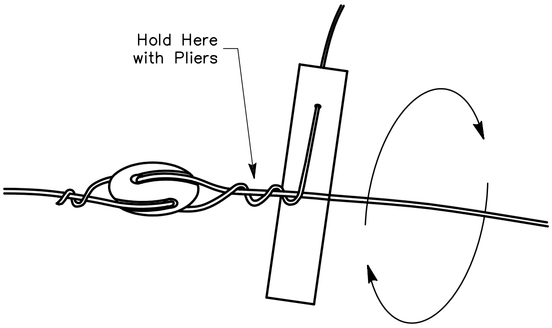

Fig 9—Simple lever for twisting solid guy wires when attaching strain insulators.

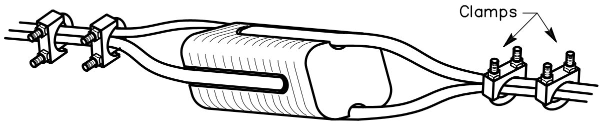

Fig 10—Stranded guy wire should be attached to strain insulators by means of standard cable clamps made to fit the size of wire used.

Guy Material

When used within their safe load ratings, you may use any of the halyard materials listed in Chapter 20 for the mast guys. Nonmetallic materials have the advantage that there is no need to break them up into sections to avoid unwanted resonant interactions. All of these materials are subject to *stretching*, however, which causes mechanical problems in permanent installations. At rated working loads, dry manila rope stretches about 5%, while nylon rope stretches about 20%. Usually, after a period of wind load and wet/dry cycles, the lines will become fairly stable and require less frequent adjustment.

Solid galvanized steel wire is also widely used for guying. This wire has approximately twice the load ratings of similar sizes of copper-clad wire, but it is more susceptible to corrosion. Stranded galvanized wire sold for guying TV masts is also suitable for light-duty applications, but is also susceptible to corrosion. It is prudent to inspect the guys every six months for signs of deterioration or damage.

Guy Anchors

Figs 11 and **12** show two different kinds of guy anchors. In Fig 11, one or more pipes are driven into the ground at right angles to the guy wire. If a single pipe proves to be inadequate, another pipe can be added in tandem, as shown, and connected with a galvanized steel cable. Heavy-gauge galvanized pipe is preferred for corrosion resistance. Steel fence posts may be used in the same manner. Fig 12 shows a *dead-man* type of

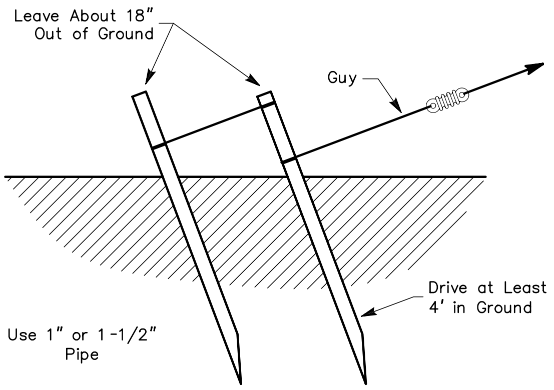

Fig 11—Driven guy anchors. One pipe is usually sufficient for a small mast. For added strength, a second pipe may be added, as shown.

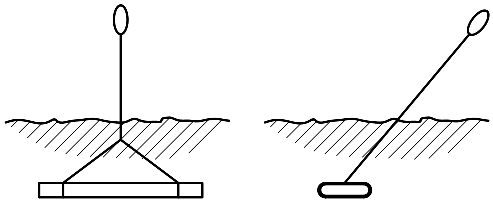

Fig 12—Buried *dead-man* guy anchor (see text).

anchor. The buried anchor may consist of one or more pipes 5 or 6 feet long, or scrap automobile parts, such as bumpers or wheels. The anchors should be buried 3 or 4 feet in the ground. The cable connecting the dead-man to the guys should be galvanized wire rope, like EHS guy cable. You should coat the buried part of the cable with roofing tar, and thoroughly dry it prior to burial to enhance resistance to corrosion.

Also available are some heavy auger-type anchors that screw into the earth. These anchors are usually heavier than required for guying a mast, although they may be more convenient to install. You should conduct annual inspections of the anchors by digging several inches below grade around the anchor to inspect for corrosion.

Trees and buildings may also be used as guy anchors if they are located appropriately. Care should be exercised, however, to make sure that the tree is of adequate size and that any fastening to a building can be made sufficiently secure.

Guy Tension

Many troubles encountered in mast guying are a result of pulling the guy wires too tight. Guy-wire tension should never be more than necessary to correct for obvious bowing or movement under wind pressure. Approximately 10% to 15% of the working load is sufficient. In most cases, the tension needed does not require the use of turnbuckles, with the possible exception of the guy opposite a wire antenna. If any great difficulty is experienced in eliminating bowing from the mast, the guy tension should be reduced or additional sets of guys are required. The mast should be checked periodically, especially after large wind events, to ensure the guys and anchors have not stretched or moved, allowing the mast to get away from the required straight alignment.

ERECTING A MAST OR OTHER SUPPORT

Masts less than 30 feet high usually can be simply walked up after blocking the bottom end securely. Blocking must be done so that the base can neither slip along the ground nor upend when the mast is raised. An assistant should be stationed at each guy wire, and may help by pulling the proper guy wire as the mast nears the vertical position. Halyards can be used in the same manner.

As the mast is raised, it may be helpful to follow the underside of the mast with a scissors rest (**Fig 13**), should a pause in the hoisting become necessary. The rest may also be used to assist in the raising if an assistant mans each leg.

As the mast nears the vertical position, those holding the guy wires should be ready to temporarily fasten the guys to prevent the mast from falling. The guys can then be adjusted until the mast is perfectly straight.

For masts over 30 feet long, a *gin pole* of some form may be required, as shown in Fig 13. Several turns of

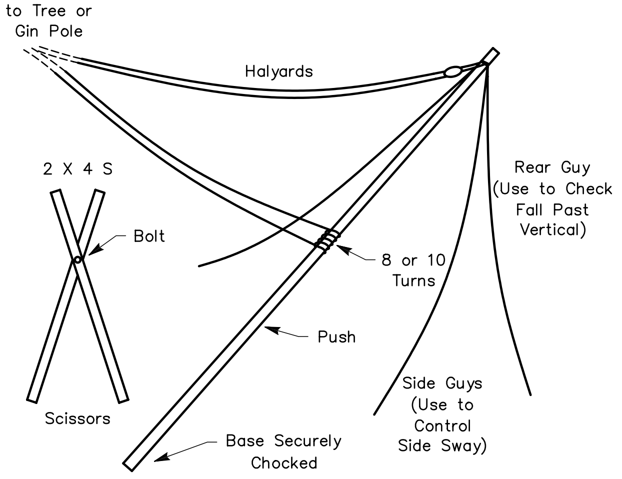

Fig 13—Pulling on a gin line fastened slightly above the center point of the mast and on the halyards can assist in erecting a tall mast. The tensions should be just enough to keep the mast in as straight a line as possible. The "scissors" may be used to push on the under side and to serve as a rest if a pause in raising becomes necessary.

rope are wound around a point on the mast above center. The ends of the rope are then brought together and passed over a tree limb. The rope should be pulled as the mast is walked up to keep the mast from bending at the center. If a tree is not available, a post, such as a 2 × 4, temporarily erected and guyed, can be used. After the mast has been erected, the assisting rope can be removed by walking one end around the mast (inside the guy wires).

Telephone poles and towers are much sturdier supports. Such supports may require no guying, but they are not often used solely for the support of wire antennas because of their relatively high cost. For antenna heights in excess of 50 feet, however, they are usually a most practical form of support.

Tower And Antenna Selection and Installation

The selection of a tower, its height, and the type of antennas and rotator is probably one of the more complex issues faced by station builders. All aspects of the tower, antenna, and rotator system are interrelated, and you should consider the overall system before making any decisions regarding specific system components.

Perhaps the most important consideration for many amateurs is the effect of the antenna system on the surrounding environment. If plenty of space is available for a tower installation and if there is little chance of causing esthetic distress on the part of family members or the neighbors, the amateur is indeed fortunate. Often, the primary considerations are purely financial. For most, however, the size of the property, the effect of the system on others, local ordinances, and the proximity of power lines and poles influence the selection of the tower/antenna system considerably.

The amateur must consider the practical limitations for installation. Some points for consideration are given below:

1) A tower should not be installed in a position where it could fall onto a neighbor's property.
2) The antenna must be located in such a position that it cannot possibly tangle with power lines, either during normal operation or if the structure should fall.
3) Sufficient yard space must be available to position a guyed tower properly. The guy anchors should be between 60% and 80% of the tower height in distance from the base of the tower on level ground—sloping terrain may require larger areas.
4) Provisions must be made to keep children from climbing the support. (Poultry netting around the tower base will serve this need.)
5) Local ordinances should be checked to determine if any legal restrictions affect the proposed installation.

Other important considerations are (1) the total dollar amount to be invested, (2) the size and weight of the antenna desired, (3) the climate, and (4) the ability of the owner to climb a fixed tower.

Most tower manufacturers provide catalogues or data packages that represent engineered tower configurations. These are provided as a convenience for users to help determine the most suitable tower configurations. The most commonly used design specifications for towers are EIA (Electronic Industries Assoc.) RS-222 and UBC (Uniform Building Code). These specifications define how the tower, antenna, and guy loads are determined and applied to the system, and establish general design criteria for the analysis of the tower. Local authorities often require the review and approval of the installation by a state licensed Professional Engineer (P.E.) to obtain building permits. All local authorities in the United States do not subscribe to the same design standards, so often the manufacturers' general-purpose engineering is not applicable.

One of the first things you need to determine in the tower selection process is the type of specification required by the local authorities, if any. Then, you must determine the *Basic Wind Speed* appropriate for the site. The *Basic Wind Speed* used in most specifications is the average wind speed for one mile of wind passing across the structure. It will be a lower value than the peak readings from an anemometer (wind gauge) installed at the site. For example, a Basic Wind Speed of 70 mph could have a maximum value of 80 mph and a minimum of 60 mph, equally distributed during the passage of the mile of wind. Basic wind speeds can be found in tables or maps contained in the appropriate specifications. Often, the basic wind speed used for the location may be obtained from the local permit authority. Check out the Web site at **www.championradio.com**, which contains EIA basic wind speed tables for every county in the USA. UBC speeds are available at almost every local library.

Antenna manufacturers also provide antenna data to assist in the selection process. Unfortunately, antenna mechanical designs do not always follow the same design standards used for towers. Proper antenna selection often means that you must determine the antenna surface areas yourself to avoid overloading the tower. More discussion about this follows later in this chapter.

It is often very helpful to the novice tower installer to visit other local amateurs who have installed towers. Look over their hardware and ask questions. If possible, have a few local experienced amateurs look over your plans—before you commit yourself. They may be able to offer a great deal of help. If someone in your area is planning to install a tower and antenna system, be sure to offer your assistance. There is no substitute for experience when it comes to tower work, and your experience there may prove invaluable to you later.

THE TOWER

Towers for supporting antennas come in a variety of different types. Each type has its own set of benefits and limitations, or conditions and requirements. Often, you can choose a particular tower type by considering issues other than pure mechanical performance. Understanding how each type of tower functions, and what its respective requirements are, are the first steps in making the best tower selection for your own situation.

Guyed Towers

The most common variety of tower is the *guyed tower* made of identical stacked sections, supported by guy cables attached to ground anchors placed symmetrically around the tower. These towers are the most economical, in terms of feet per dollar investment, and are more efficient for carrying antenna loads than non-guyed towers.

The guys resist the lateral loads on the system created by the wind. Since the guys slope down to the ground, horizontal loads due to the wind result in vertical loads applied to the tower at each tower/guy connection. The tower becomes a compression member, trying to resist the column compression generated by the guy reactions. A tower in compression can buckle, so the distance between guy connections along the tower is important.

Tower Bases for Guyed Towers

Another important phenomenon in a guyed tower is stretching of the guy cables. All guys stretch under load and when the wind blows the elongated guys allow the tower to lean over somewhat. If the tower base is buried in the concrete footing—as is commonly done in amateur installations—the bending stress at the tower base can become a significant factor. Towers that have been installed with tapered pier-pin bases much more freely absorb tower leaning, and they are far less sensitive to guy-elongation problems.

The tapered pier-pin tower installation is not without some drawbacks. These installations often require torque-arm guy brackets or six-guy torque-arm assemblies to control tower rotation due to antenna torque. They also require temporary guys when they are being installed to hold the base steady until the permanent guys are mounted. Some climbers also don't like the flexing when they start to climb these types of towers.

On the positive side, pier-pin base towers have all structural members above the concrete footing, eliminating concerns about hidden corrosion that can occur with buried towers. Most decisions regarding the type of base installation are made according to the preference of the tower builder/maintainer. While either type of base configuration can be successfully used, you would be wise to do the stress calculations (or have a professional engineer do them) to ensure safety, particularly when large antenna loads are contemplated and particularly if guys that can easily stretch are used, such as Phillystran guys.

The configuration shown in **Fig 14A** is taken from an older (1983) Unarco-Rohn catalog. This configuration has the top set of guys placed at the top of the tower with the lower set halfway up the tower. This configuration is best for most amateur installations, which usually have the antennas mounted on a rotatable mast extending

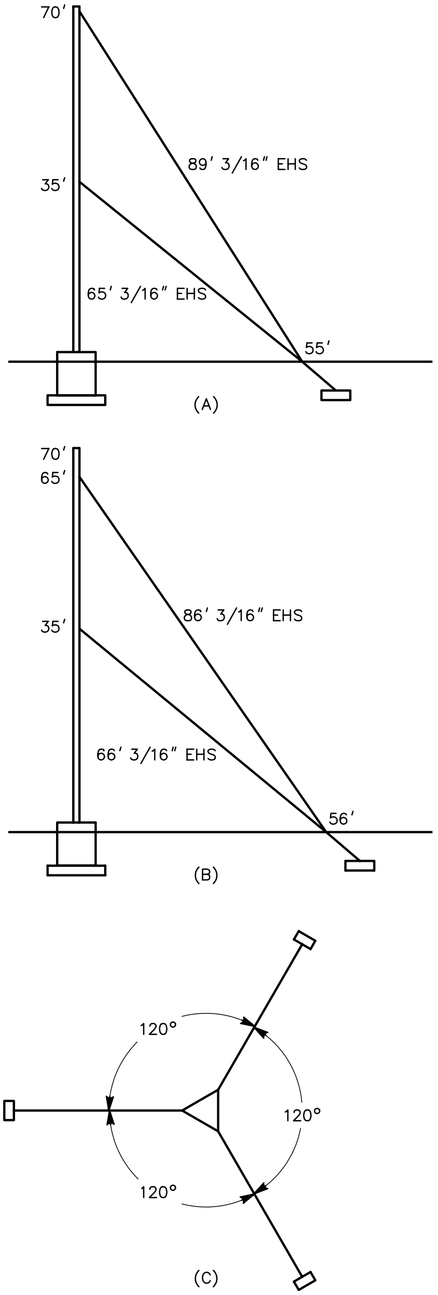

Fig 14—The proper method of installation of a guyed tower. At A, the method recommended for most amateur installations. At B, the method shown in later Rohn catalogs. This places considerable strain on the top section of the tower when large antennas are mounted on the tower.

out the top of the tower—thereby placing the maximum lateral loads when the wind blows at the top of the tower (and the bottom of the rotating mast).

The configuration shown in Fig 14B is from a newer (1998) Rohn catalog. It has 5 feet of unsupported tower extending above the top guy set. The lower guy set is approximately halfway between the top guys and the base. The newer configurations are tailored for commercial users who populate the top region of the tower with fixed arrays and/or dishes. The installation in Fig 14B cannot safely withstand the same amount of horizontal top load as can the configuration shown in Fig 14A, simply because the guys start farther down from the top of the tower.

An overhead view of a guyed tower is given in Fig 14C. Common practice is to use equal angular spacings of 120° between guy wires. If you must deviate from this spacing, the engineering staff of the tower manufacturer or a civil engineer should be contacted for advice.

Amateurs should understand that most catalogs show generic examples of tower configurations that work within the cited design specifications. They are by no means the only solution for any specific tower/antenna configuration. You can usually substantially change the load capability of any given tower by varying the size and number of guys. Station builders are encouraged to utilize the services of professional engineers to get the most out of their guyed towers. Those interested in more generic information about guyed tower behavior can find it at **www.freeyellow.com/members3/yagistress/**.

Unguyed Towers

Another commonly used type of tower is not normally guyed—these are usually referred to as *freestanding* or *self-supporting* towers. Unguyed towers come in three different styles.

One style is comprised of stacked lengths of identical tower sections, just like those used for guyed towers. The only difference is that no guys are used. Manufacturers provide the recommended configurations and allowable loads for this type of installation in their catalogs. Unguyed towers are vastly less capable of supporting antenna loads than their guyed counterparts, but have great utility for light-duty applications—when configured within their capabilities.

The second style utilizes different tower section sizes, varying from large sections at the base and tapering down to smaller sections at the top. This style is more much more efficient for freestanding applications, because the tower is sized for the varying bending loads along the tower length, and is shown in **Fig 15**.

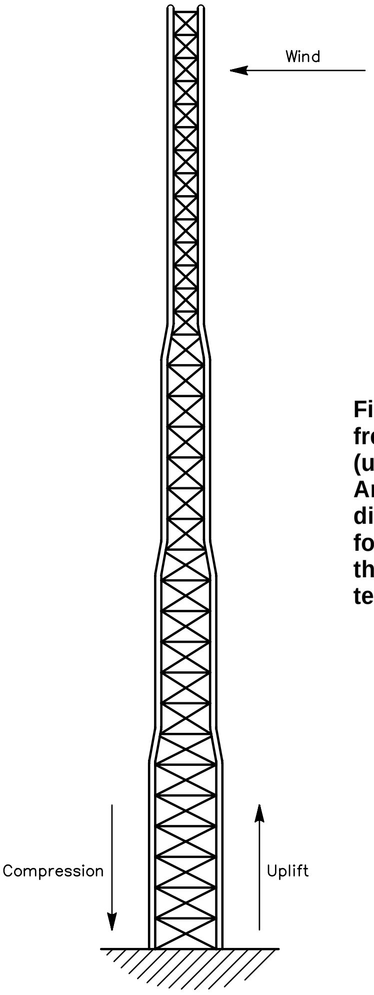

Fig 15—Typical freestanding (unguyed) tower. Arrows indicate the directions of the forces acting upon the structure. See text for discussion.

The third style of unguyed towers is commonly called a *crank-up tower*. It is a freestanding tower with telescoping sections that can be extended or retracted with a winch, cable, and pulley mechanism. This allows the tower to be raised and lowered for maintenance and antenna work. It is usually necessary to retract such towers for moderate to heavy winds. Some consider this a disadvantage because they can't operate their antennas at full height when it is windy. Two different forms of the crank-up style, freestanding tower are shown in **Fig 16**. Fig 16A shows the tubular version; Fig 16B shows the triangular space-frame version.

Some crank-up towers are used with guys and are only retracted for maintenance and antenna work. These towers are specially designed with locking mechanisms between the tower sections to carry the vertical compression created by the guys. *Do not* use guys with normal crank-up towers (those that have no locking devices between sections)! The increased tower compression will be carried by the hoisting cable, which will eventually cause it to fail.

Never climb a crank-up tower unless it is properly nested, with all load removed from the hoisting cable. For general antenna work, this can be accomplished by completely retracting it until the cable becomes loose. When servicing the rotator, the tower must be left partially extended. In this case every tower section must be

Fig 16—Two examples of *crank-up* towers.

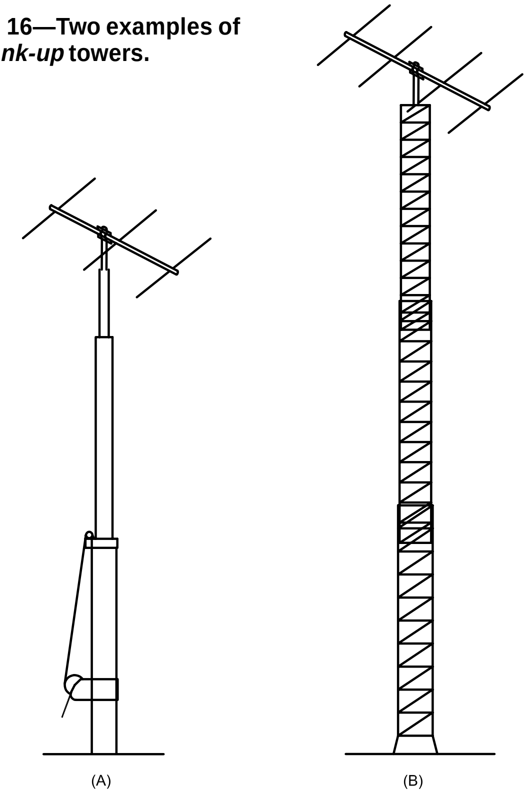

blocked with heavy timber or thick-wall tubes, installed through the tower bracing, until all sections are resting on the blocks and the hoisting cable becomes slack. Safely installing the blocks in an extended crank-up tower can be challenging. The object is to get all the blocks installed without a climber having to scale the unblocked tower, risking loss of limbs should the hoisting cable fail. An extension ladder, capable of reaching the required block elevations is the safest approach. If the necessary equipment or expertise is not available, the tower can be retracted, antennas removed, and leaned over, with the base tilt-over assembly, before extending it to access the rotator. Failure to properly block the tower before climbing can result in serious injury should the cable slip or break!

All freestanding towers share some unique characteristics. Each must support antenna and tower loads only by virtue of the bending strength of the tower sections and the tower footing connection to earth. Because of the large overturning moment at the tower base, freestanding towers require larger concrete footings than guyed towers. They are usually more expensive for the same load capability compared to guyed towers, simply because they require larger heavier tower sections and a larger footing to get the job done. The telescoping mechanisms in crank-up tower require more maintenance too.

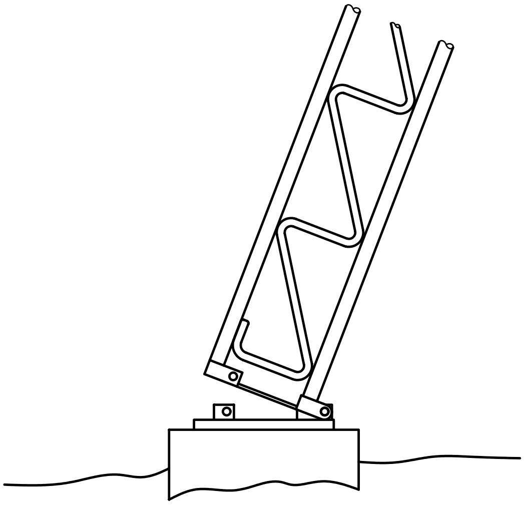

Fig 17—Fold-over or tilting base. There are several different kinds of hinged sections permitting different types of installation. Great care should be exercised when raising or lowering a tilting tower.

Freestanding towers are quite popular, and are often the best solutions for sites with limited space and ascetic concerns. When cranked down, a telescoping tower can maintain a low-profile system, out of sight of the neighbors and family.

Tilt-Over Towers

Some towers have another convenience feature—a hinged section that permits the owner to fold over all or a portion of the tower. The primary benefit is in allowing antenna work to be done close to ground level, without the necessity of removing the antenna and lowering it for service. **Fig 17** shows a hinged base used with stacked, guyed tower sections. The hinged section can be designed for portions of the tower above the base. These are usually referred to as *guyed tilt-over towers*, where a conventional guyed tower can be tilted over for installing and servicing antennas. Many crank-up towers come with optional tilt-over base fixtures that are equipped with a winch and cable system for tilting the fully nested tower from horizontal to vertical positions.

Misuse of hinged sections during tower erection is a dangerously common practice among radio amateurs. Unfortunately, these episodes can end in accidents. If you do not have a good grasp of the fundamentals of physics, it might be wise to avoid hinged towers or to consult an expert if there are any questions about safely installing and using such a tower. It is often far easier (and safer) to erect a regular guyed tower or self-supporting tower with gin pole and climbing belt than it is to try to walk up an unwieldy hinged tower.

The AB-577 Military Surplus Tower

Another light duty tower has found acceptance among many amateurs. Available from assorted military surplus dealers is the AB-577 system. This was designed to be a portable, rapid deployment antenna support for field communications. It is a guyed mast that goes up somewhat like a crank-up. The system consists of several short sections of aluminum tubing, with special end connections for joining them. These can be erected from the base fixture, which has a crank-up type winch-driven elevator platform. The tubing sections are installed in the base fixture and connected to the section above it with an over-center locking *Marmon*-style clamp. Then, the elevator platform is raised with the winch and the new tube is locked in place, high on the base fixture. Then the elevator is lowered to accept the next section. While the tower is extended, the supporting guys are adjusted via the unique *snubber* assemblies at the anchor connection. One person can erect this system, even in windy conditions, when special care is given to keeping the guys properly adjusted during each extension.

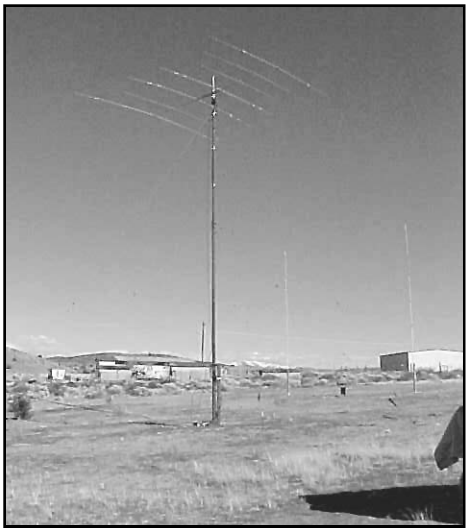

Fig 18—Installation of surplus AB-577 tower with tribander at 45 feet at K7NV. (*Photo by Kurt Andress, K7NV.*)

The standard AB-577 system, with 3 sets of guys, will support a modest triband Yagi at 45 feet. **Fig 18A** shows an installation with a Hy-Gain TH7DX at 45 feet.

TOWER BASES

Tower manufacturers can provide customers with detailed plans for properly constructing tower bases. **Fig 19** is an example of one such plan. This plan calls for a hole that is $3^{1}/_{2} \times 3^{1}/_{2} \times 6$ feet. Steel reinforcement bars are lashed together and placed in the hole. The bars are positioned so that they will be completely embedded in the concrete, yet will not contact any metallic object in the base itself. This is done to minimize the possibility of a direct discharge path for lightning through the base. Should such a lightning discharge occur, the concrete base could be damaged.

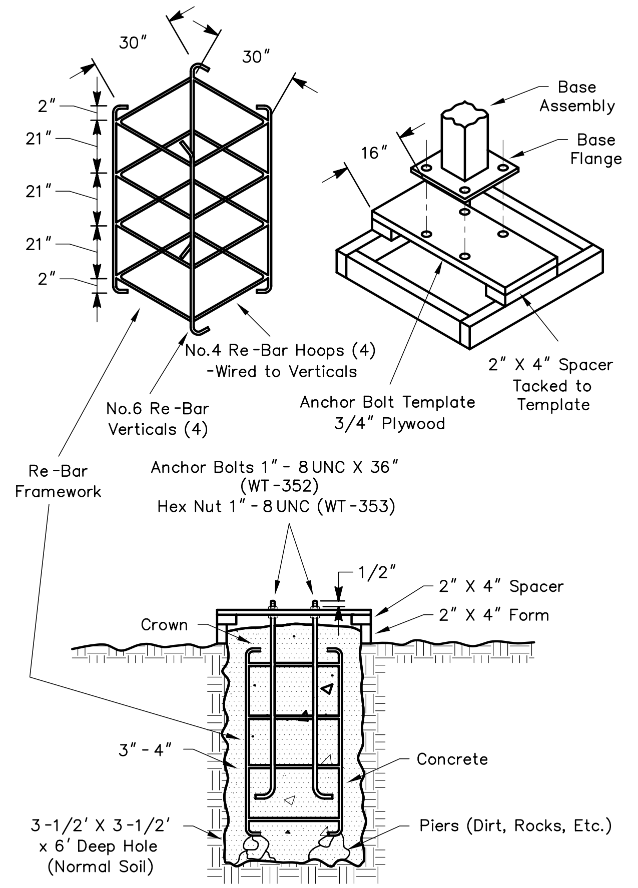
30″
30″
2″
21″
21″
21″
2″
16″
Base Assembly
Base Flange
No.4 Re-Bar Hoops (4) -Wired to Verticals
2″ X 4″ Spacer Tacked to Template
No.6 Re-Bar Verticals (4)
Anchor Bolt Template 3/4″ Plywood
Re-Bar Framework
Anchor Bolts 1″ - 8 UNC X 36″ (WT-352)
Hex Nut 1″ - 8 UNC (WT-353)
1/2″
2″ X 4″ Spacer
2″ X 4″ Form
Crown
3″ - 4″
Concrete
3-1/2′ X 3-1/2′ x 6′ Deep Hole (Normal Soil)
Piers (Dirt, Rocks, Etc.)

Fig 19—Plans for installing concrete base for Wilson ST-77B tower. Although the instructions and dimensions vary from tower to tower, this is representative of the type of concrete base specified by most manufacturers.

Providing suitable paths for the discharge of lightning energy safely for towers is a complex subject. Several companies offer products and guidance. The basic requirements for providing controlled discharge paths for lightning-induced current is to supply a low-impedance grid of conductors from the tower and feed lines to a field of interconnected ground rods around the base of the tower. Generally, the tower, station, and electrical service grounds need to be connected to prevent damaging potential differences from developing between the various components in the system.

A strong wooden form is constructed around the top of the hole. The hole and the wooden form are filled with concrete so that the resultant block will be 4 inches above grade. The anchor bolts are embedded in the concrete, and aligned with the plywood template, before it hardens. The template serves to align the anchor bolts to properly mate with the tower itself. Once the concrete has

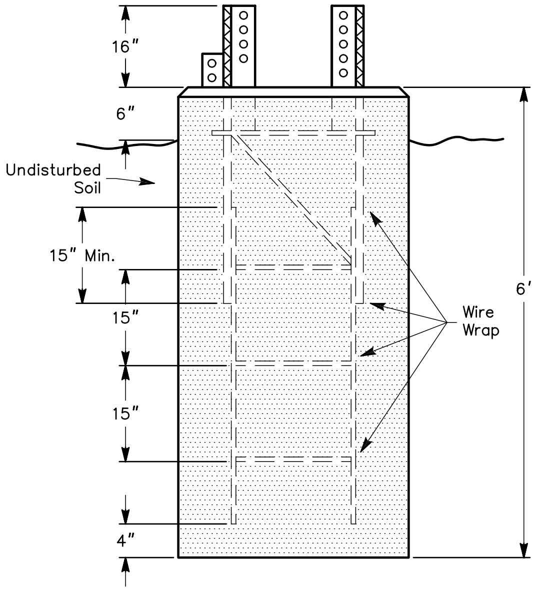

Fig 20—Another example of a concrete base (Tri-Ex LM-470).

cured, the tower base is installed on the anchor bolts and the base connection is adjusted to bring the tower into vertical alignment.

For a tower that bolts to a flat base plate mounted to the footing bolts (as shown in Fig 19), you can bolt the first tower section on the base plate to ensure that the base is level and properly aligned. Use temporary guys to hold things exactly vertical while the concrete cures. (The use of such temporary guys also works well when you place the first tower section in the base hole and plumb it vertically before pouring in the concrete.) Manufacturers can provide specific, detailed instructions for the proper mounting procedure. **Fig 20** shows a slightly different design for a tower base.

The one assumption so far is that *normal* soil is predominant in the area in which the tower is to be installed. Normal soil is a mixture of clay, loam, sand and small rocks. More conservative design parameters for the tower base should be adopted (usually, using more concrete) if the soil is sandy, swampy or extremely rocky. If there are any doubts about the soil, the local agricultural extension office can usually provide specific technical information about the soil in a given area. When this information is in hand, contact the engineering department of the tower manufacturer or a civil engineer for specific recommendations with regard to compensating for any special soil characteristics.

TOWER INSTALLATION

The installation of a tower is not difficult when the proper techniques are used. A guyed tower, in particular, is not hard to erect, because each of the individual sections is relatively lightweight and can be handled with only a few helpers and some good quality rope.

The Gin Pole and Tips on Tower Building

An essential piece of hardware for working on towers is a *gin pole*. This section came from the ARRL book *Simple and Fun Antennas for Hams*. The dictionary describes a gin pole as “a device for moving heavy objects.” See **Fig 21**, which shows a drawing of the Rohn “Erection Fixture” EF2545. This gin pole was designed to work with the nominal 10-foot long sections of Rohn 25 or 45 towers.

We’re going to assume in the following discussion that you are installing Rohn 45, which weighs about 70 pounds. This is a lot of weight, and you must refrain from adding to that during installation. That means, for example, that you *do not* attempt to lift a 10-foot section with the guy wires attached! Neither should you attempt to lift the top section with the rotator and rotor shelf installed. The gin pole (and your ground crew) will not appreciate all that strain.

The main working part of the gin pole is the pulley

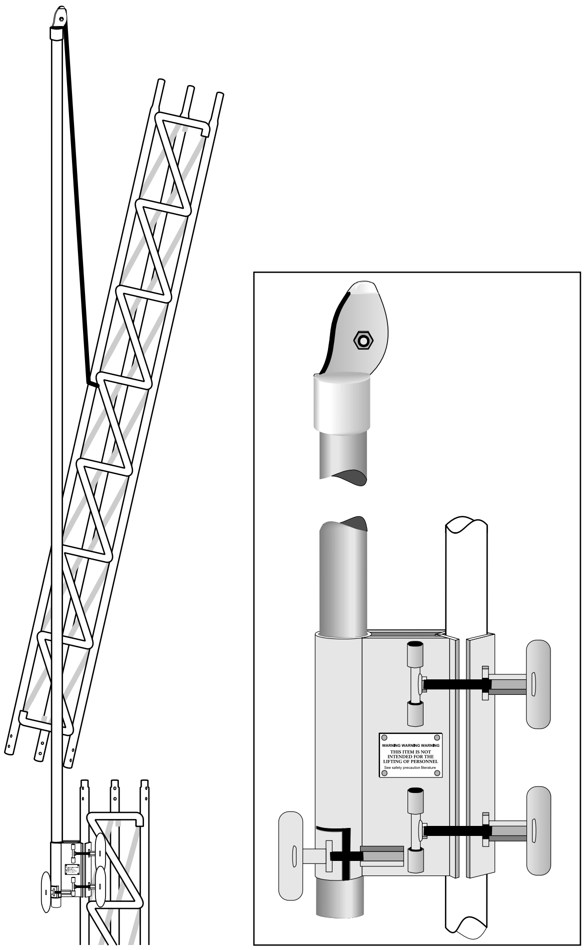
WARNING WARNING WARNING
THIS ITEM IS NOT INTENDED FOR THE LIFTING OF PERSONNEL
See safety precaution literature

Fig 21—Drawing of Rohn “Erection Fixture” EF2545, also known commonly as a “gin pole.”

mounted at the top of the 12-foot long heavy-wall aluminum tubing. This pulley has a rope going down to the ground crew through the center of the aluminum tube. At the base of the tower, the pull rope should be run through a *snatch block* attached to the tower just above ground level. This block allows the pull rope to be pulled out horizontally away from the tower base. That helps protect ground crew should a tool be dropped by the people on the tower.

An adjustable, sliding clamp towards the bottom of the aluminum tubing is clamped to the tower using a swinging L-bracket-type clamp with two clamping bolts. These have T-bar handles that can be tightened by hand. In fact, this gin pole can be moved and deployed without any tools. The clamp is positioned on the top of the tower section onto which the next tower section is to be installed. Once clamped to the top of the tower, you would loosen the T-bar handle that tightens the clamp against the sliding aluminum tube and slide the tubing up to its maximum extent.

In practice, the following steps are taken as each 10-foot section of tower is installed, one-by-one. We're assuming here that the gin pole starts out on the ground, with at least one person belted in at the top of the tower. We're also assuming that the pull rope has been threaded through the aluminum tube and the top pulley, with a knot tied to prevent it from falling back down the tube.

1. The clamp holding the aluminum tubing is loosened so that the pulley on the tube can be lowered to where it is just above the bottom clamp. Then the T-bar handle for the tube clamp is tightened.
2. The climber lowers a tag rope for the ground crew to tie to the gin-pole pull rope. (This tag rope has been looped through a temporary pulley clipped to the top of the tower. It is also used to pull up tools and other materials.) The ground crew then pulls the gin pole up to the climber, using the tag line rope. Friction of the rope against the top of the pulley-head assembly will prevent the gin-pole assembly from slipping down. [Note that some climbers prefer to "walk" the gin-pole up the tower rather than having it pulled up from the ground below. They free up their hands for climbing and temporarily holding the gin pole by using their belt lanyard looped around the tower as they climb.]
3. Once the gin-pole head reaches the top of the tower, the climber clamps the gin pole clamp securely to the top of the tower.
4. The T-bar handle for the tube clamp is loosened, and the aluminum tube is extended to its maximum height, as shown in Fig 21. Make sure you have tied the free end of the rope coming through the top pulley temporarily to the top of the tower, or else you'll have to lower the gin pole and go through this step again.
5. The free end of the pulley rope is then dropped to the ground, often using a weight such as a medium Crescent wrench or perhaps a hammer to keep the rope from waving about as it dangles down the tower, tangling with every imaginable thing as it proceeds downwards. It's amazing how even a tiny breeze can make an unweighted rope dance like that.
6. The ground crew then ties the free end of the rope *above* the balance point of the tower. For Rohn 25 or 45 there are eight horizontal cross braces per section. You want the crew to tie the rope to the fifth horizontal brace from the bottom. Please remember that you want the bottoms of the tower sections' legs to be pointed downwards, not flipped over, when the bottom of these legs approach you at the top of the tower section the climber is standing on.
7. Once the bottom of the rising tower section is just above the top of the legs of the bottom tower section, the climber guides the tower down onto the top of the three legs, while calling out to the ground crew instructions about *slowly lowering* the new section down onto the legs. See **Fig 22**, which shows the climber guiding the new section of Rohn HBX tower onto the previous section's legs. This process is considerably easier to accomplish if each section of tower has been put together on the ground to make sure that the legs fit together easily. There's nothing more frustrating that trying to manually force-fit tower sections together at the top of a tower.

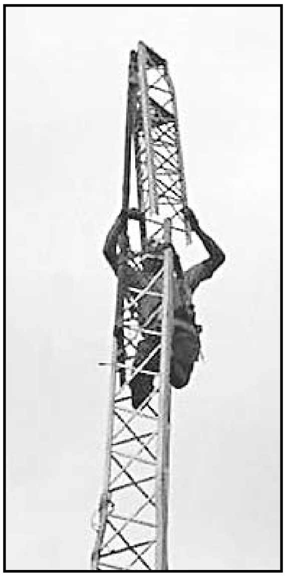

Fig 22—Climber is guiding the new section onto the top of the existing one. The gin pole attached to the left leg is bearing the weight, as the climber gives verbal instructions to the ground crew pulling on the gin-pole rope. (*Photo courtesy Mike Hammer, N2VR.*)

It seems that freight companies don't always handle heavy tower sections very gently and legs easily get bent out of alignment. A careful installer numbers tower sections in the order they've been test-fitted together on the ground, marking them with a laundry marker pen. You should also spray a small amount of WD-40 up inside mating tower legs after test-assembling them to help prevent galling and to ease fitting sections together. [Don't do this to excess—WD-40 is slippery and messy when it runs out of the bottom of tower legs.]

Another caution: Make sure before you start installing any tower that the correct ends of the bottom section's legs, "male" rather than "female," are pointed upwards. A prominent amateur (who will go unnamed) had to have Rohn make and send him a special "gender-bender" flange to turn females into males, since he had installed the base upside-down in the concrete base. You don't want to do that.

8. Once the new tower section has been guided down onto the male ends, the six pinning bolts are inserted and tightened with nuts. Note that Rohn uses two different sized bolts, with the larger diameter one on the bottom.
9. If this section of tower is one where guy wires are to be placed, they can be brought up using the gin pole rope and positioned on the tower. The maximum spacing for Rohn 25 is 30 feet between guy-wire sets, and 40 feet for Rohn 45. Thirty feet of unguyed Rohn 25 tower is wobbly, though safe. Many installers prefer to come down off the tower when setting guy-wire tension, since they do not like to be on a wobbly tower when the ground crew is moving around yanking on guy wires. Many also greatly prefer working on Rohn 45 tower, which is substantially more secure feeling and easier to stand on, with its legs 18 inches apart, while Rohn 25 legs are only 12 inches apart.
10. Finally, you reposition the gin pole for the next section of tower. The T-bar at the clamp is loosened, the tube is dropped down to the level of the clamp, and the climber walks the gin pole up to the top of the section just installed and clamps it there, ready to pull up the next tower section.

Tower Safety

One of the most important aspects of any tower installation project is the safety of all persons involved. See Chapter 1 for details on important safety issues. The use of hard hats is highly recommended for all assistants helping from the ground. Helpers should always stand clear of the tower base to prevent being hit by a dropped tool or hardware. Each person working on the tower must use a good climber's safety belt.

When climbing the tower, if more than one person is involved, one should climb into position before the other begins climbing. The same procedure is required for climbing down a tower after the job is completed. The purpose is to have the non-climbing person stand still so as not to drop any tools or objects on the climbing person, or unintentionally obstruct his movements. When two persons are working on top of a tower, only one should change position (unbelt and move) at a time.

For most installations, a good-quality $^{1}/_{2}$-inch diameter Manila hemp rope can adequately handle the workload for the hoisting tasks. The rope must be periodically inspected to assure that no tearing or chafing has developed, and if the rope should get wet from rain, it should be hung out to dry at the first opportunity. The knots used for connecting hoisting lines and hardware are critical to executing any safe installation, and special attention should be given to this detail for any work party.

Here is an important point regarding safety—the person who climbs the tower should be in charge of what happens with the ground crew. Not only does the person on the tower have a better overall view of the situation below, but also any confusion on the ground can result in serious injury to the climber.

GUY WIRES

In typical guyed tower installations, guy wires may experience loads in excess of 1000 pounds. Since the guys are the primary means of carrying the horizontal wind loads, great care should be taken in their selection and installation.

Guys come in a variety of materials and constructions. Normally, the tower manufacturer or professional engineer will specify the size and type of cable to be used. The most common type of cable used for tower guying is the EHS (Extra High Strength) galvanized steel cable. The EHS cables are very stiff and are the highest strength

Table 1
Guy Cable Comparisons

Cable	*Nominal Dia. Inches*	*Breaking Strength Lbs*	*Weight Lbs/100'*	*Elongation Inches/100'*	*%Elongation*
$^{3}/_{16}$" 1 × 7 EHS	0.188	3990	7.3	6.77	0.56%
$^{1}/_{4}$" 1 × 7 EHS	0.250	6700	12.1	3.81	0.32%
HPTG6700	0.220	6700	3.1	13.20	1.10%
HPTG8000	0.290	8000	3.5	8.90	0.74%
$^{5}/_{16}$" 1 × 7 EHS	0.313	11200	20.5	2.44	0.20%
HPTG11200	0.320	11200	5.5	5.45	0.45%
$^{3}/_{8}$" Fiberglass Rod	0.375	13000	9.7	5.43	0.45%

EHS steel cable information is taken from ASTM A 475-89, the industry standard specification for steel wire rope. The HPTG listings are for *Phillystran* aramid cables, and are based on the manufacturers' data sheets. The elongation (stretch) values are for 100 feet of cable with a 3000-pound load.

cables in the wire rope family. Other steel cables are made to be more flexible for running around pulleys. While these are easier to work with when assembling, they are not as strong as the EHS type, and should be avoided for tower guying. Non-conductive guys, such as *Phillystran* or *pultruded* fiberglass rod have become popular for eliminating resonant interaction with antennas.

Do not attempt to use cheaper cables that don't meet or exceed the criteria for those specified for your installation. Using the wrong cable, or failing to install the cable properly can have disastrous results! **Table 1** shows data for several cables commonly used for tower guying. It is important to note that the minimum breaking strength of the various cables are independent of their elongation (stretch) under load.

Guy Cable Installation

Figs 23 and **24** show methods for tensioning and safety wiring guy-wire turnbuckles. **Fig 25** shows the traditional method for fixing the end of a steel guy wire. A thimble is used to prevent the wire from breaking because of a sharp bend at the point of intersection. Conventional wisdom strongly recommends the use of thimbles that are at least one wire size larger than the cable to provide a more gentle wire bend radius. Three cable clamps follow to hold the wire securely. Be sure to follow the note in Fig 25 for which part of the clip bears against the live (loaded) cable. As a final backup measure, the individual strands of the free end are unraveled and wrapped around the guy wire. It is a lot of work, but it is necessary to ensure a safe and permanent connection.

Fig 26 shows the use of a device that replaces the clamps and twisted strands of wire. These devices are known as *dead ends*, *preformed guy grips*, or *Big Grips* and are commonly used on electrical power poles. They are far more convenient to use than are clamps, and are the recommended method for terminating Phillystran and

Fig 23—Proper tension can be placed on the guy wires with the aid of a block-and-tackle system. (*Photo by K1WA*)

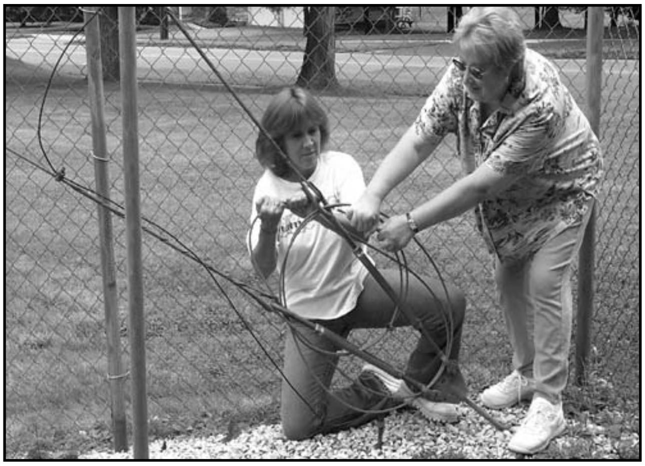

Fig 24—A length of guy cable is used to assure that the turnbuckles remain in place after they are tightened. This procedure is an absolute requirement in guyed tower systems. (*Photo by N4QX*)

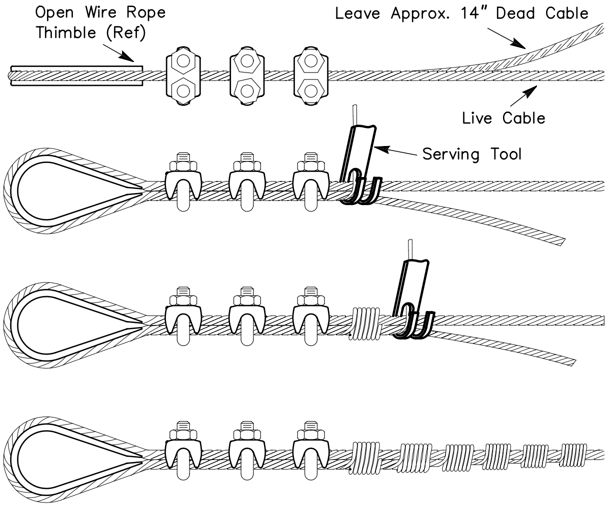

Fig 25—Traditional method for securing the end of a guy wire.

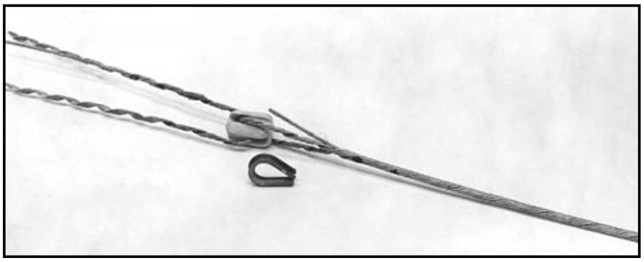

Fig 26—Alternative method for attaching guy wires using *dead ends*. The dead end on the right is completely assembled (the end of the guy wire extends beyond the grip for illustrative purposes). On the left, one side of the dead end is partially attached to the guy wire. In front, a thimble is used where a sharp bend might cause the guy wire or dead end to break.

fiberglass-rod guys. When using the guy grips, it is imperative that the recommended end sleeves are installed over the free end of the grip to prevent ice and falling hardware from sliding down the guy and unraveling the grip connection to the guy. The guy wires must be cut to the proper length. The dead end of each wire is installed into the object to which the guy wire is being attached (use a thimble, if needed to eliminate sharp cable bends). One side of the dead end is then wrapped around the guy wire. The other side of the dead end follows. Using dead ends saves time and trouble, more than making up for their slightly higher cost.

When using the non-conductive guy materials, it is highly recommended that a 25-foot length of EHS steel cable be used at the bottom for connection to the anchor. This serves a valuable purpose. The steel cable is more resistant to damage from ground activity and brush fires, and it is the preferred material for measuring cable pre-tension with commonly available devices.

Fig 27 shows two different methods for attaching guy wires to towers. At Fig 27A, the guy wire is simply looped around the tower leg and terminated in the usual manner. At Fig 27B, a *guy bracket*, with *torque arms* has been added. Even if the torque arms are not required, it is preferred to use the guy bracket to distribute the load from the tower/guy connection to all three tower legs, instead of just one. The torque bracket is more effective resisting torsional loads on the tower than the simpler installation. Rohn offers another guy attachment bracket, called a *Torque Arm Assembly*, that allows six guys to be connected between the bracket and anchors. This is by far the best method of stabilizing a tower against high torque loads, and is recommended for installations with large antennas.

There are two types of commonly used guy anchors. **Fig 28A** depicts an *earth screw*. These are usually 4 to 6 feet long. The screw blade at the bottom typically measures 6 to 8 inches diameter. Fig 28B illustrates two people installing the anchor. The shaft is tilted so that it will be in line with the mean angle of all the guys connecting to the anchor. Earth screws are suitable for use in normal soil where permitted by local building codes. Information about *screw anchors* is available from the manufacturers of these devices. Information from a supplier specializing in this type of anchor can be found at **www.abchance.com**.

The alternative to earth screws is the concrete block anchor. Fig 28C shows the installation of this type of anchor; it is suitable for any soil condition, with the possible exception of a bed of lava rock or coral. Consult the instructions from the manufacturer, or your tower designer, for the precise anchor configuration.

Turnbuckles and associated hardware are used to attach guy wires to anchors and to provide a convenient method for adjusting tension. **Fig 29A** shows a turnbuckle with a single guy wire attached to the eye of the anchor. Turnbuckles are usually fitted with either two eyes, or one eye and one jaw. The eyes are the oval ends, while the jaws are U-shaped with a bolt through each tip.

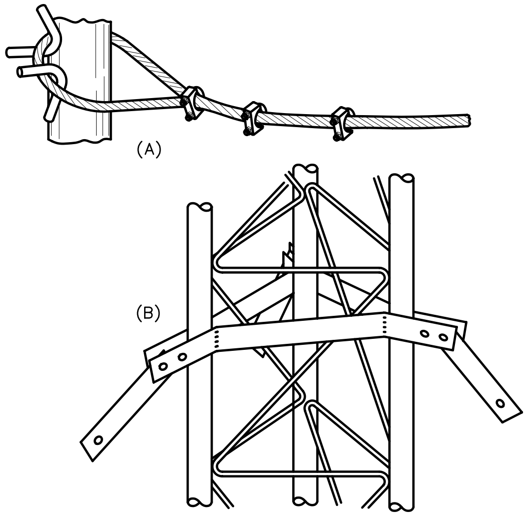

Fig 27—Two methods of attaching guy wires to tower. See text for discussion.

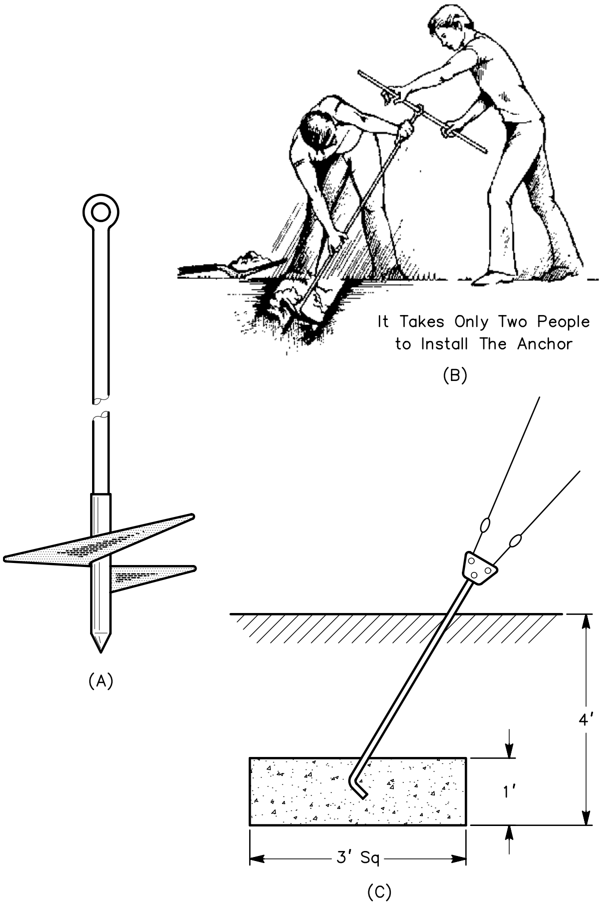

Fig 28—Two standard types of guy anchors. The earth screw shown at A is easy to install and widely available, but may not be suitable for use in certain soils. The concrete anchor is more difficult to install properly, but it is suitable for use with a wide variety of soil conditions and will satisfy most building code requirements.

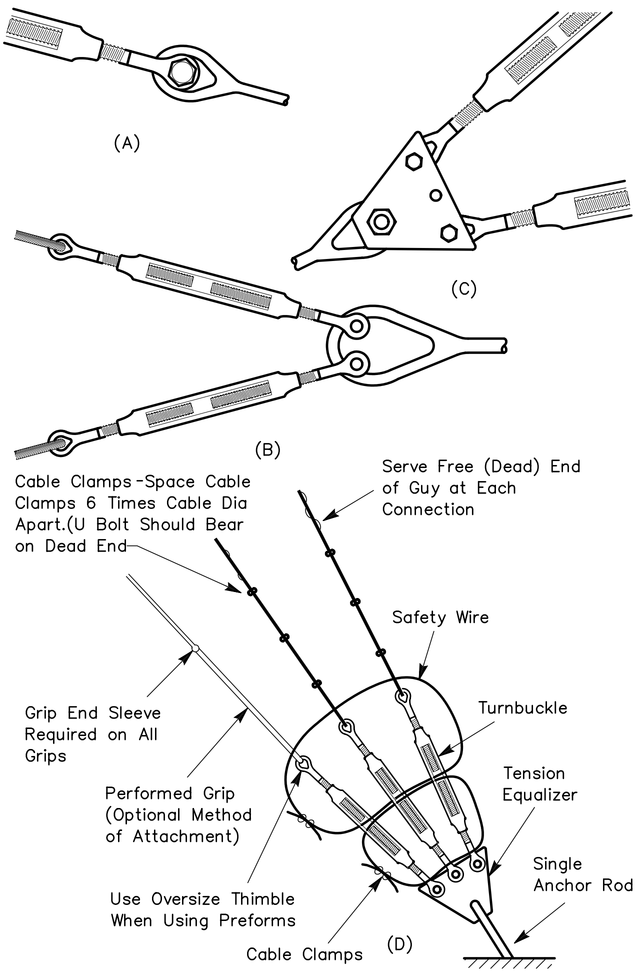
(A)
(C)
(B)
Cable Clamps-Space Cable Clamps 6 Times Cable Dia Apart.(U Bolt Should Bear on Dead End
Serve Free (Dead) End of Guy at Each Connection
Safety Wire
Turnbuckle
Grip End Sleeve Required on All Grips
Performed Grip (Optional Method of Attachment)
Tension Equalizer
Single Anchor Rod
Use Oversize Thimble When Using Preforms
Cable Clamps
(D)

Fig 29—Variety of means available for attaching guy wires and turnbuckles to anchors.

Fig 29B shows two turnbuckles attached to the eye of an anchor. The procedure for installation is to remove the bolt from the jaw, pass the jaw over the eye of the anchor and reinstall the bolt through the jaw, through the eye of the anchor and through the other side of the jaw.

If two or more guy wires are attached to one anchor, *equalizer plates* should be installed (Fig 29C). In addition to providing a convenient point to attach the turnbuckles, the plates pivot slightly to equalize the various guy loads and produce a single load applied to the anchor. Once the installation is complete, a safety wire should be passed through the turnbuckles in a figure-eight fashion to prevent the turnbuckles from turning and getting out of adjustment (Fig 29D).

All guyed towers require the guys to be installed with a certain amount of pre-tension. The tower manufacturer or designer specifies the required pre-tension values, which are usually 10% of the cable breaking strength. Pre-tension is necessary to eliminate looseness in the cable caused by the spiral wire construction and to eliminate excessive dynamic guy and tower motion under wind loading. The recommended method for adjusting the guys is to use a cable tension-measuring device such as the popular *Loos Guy Wire Tensioner*. The guy is gripped with a special clamp, such as the *Klein Cable Grip*, which is connected to the anchor below the eye (or equalizer plate) with a block and tackle arrangement (Fig 23) or a ratcheting come-along. Then the turnbuckle is adjusted to take up the load, the cable grip is released and the final guy tension is adjusted and checked.

When you adjust the guys at each level, you should check the tower for vertical alignment and straightness. This is often done with a transit from two ground points located 90° from each other.

Resonance in Guy Wires

If guy wires are resonant at or near the operating frequency, they can receive and reradiate RF energy. By behaving as parasitic elements, the guy wires may alter and thereby distort the radiation pattern of a nearby antenna. For low frequencies where a dipole or other simple antenna is used, this is generally of little or no consequence. But at the higher frequencies where a unidirectional antenna is installed, it is desirable to avoid pattern distortion if at all possible. The symptoms of re-radiating guy wires are usually a lower front to back ratio and a lower front to side ratio than the antenna is capable of producing. The gain of the antenna and the feed-point impedance will usually not be significantly affected, although sometimes changes in SWR can be noted as the antenna is rotated. (Of course other conductors in the vicinity of the antenna can also produce these same symptoms.)

The amount of re-radiation from a guy wire depends on two factors—its resonant frequency, and the degree of coupling to the antenna. Resonant guy wires near the antenna will have a greater effect on performance than those that are farther away. Therefore, the upper portion of the top level of guy wires should warrant the most attention with horizontally polarized arrays. The lower guy wires are usually closer to horizontal than the top level, but by virtue of their increased distance from the antenna, are not coupled as tightly to the antenna.

To avoid resonance, the guys should be broken up by means of egg or strain insulators. **Fig 30** shows wire lengths that fall within 10% of $^1/_2$-λ resonance (or a multiple of $^1/_2$ λ) for all the HF amateur bands. Unfortunately, no single length greater than about 14 feet avoids resonance in all bands. If you operate just a few bands, you can locate greater lengths from Fig 30 that will avoid resonance. For example, if you operate only the 14-, 21- and 24-MHz bands, guy wire lengths of 27 feet or 51 feet would be suitable, along with any length less than 16 feet.

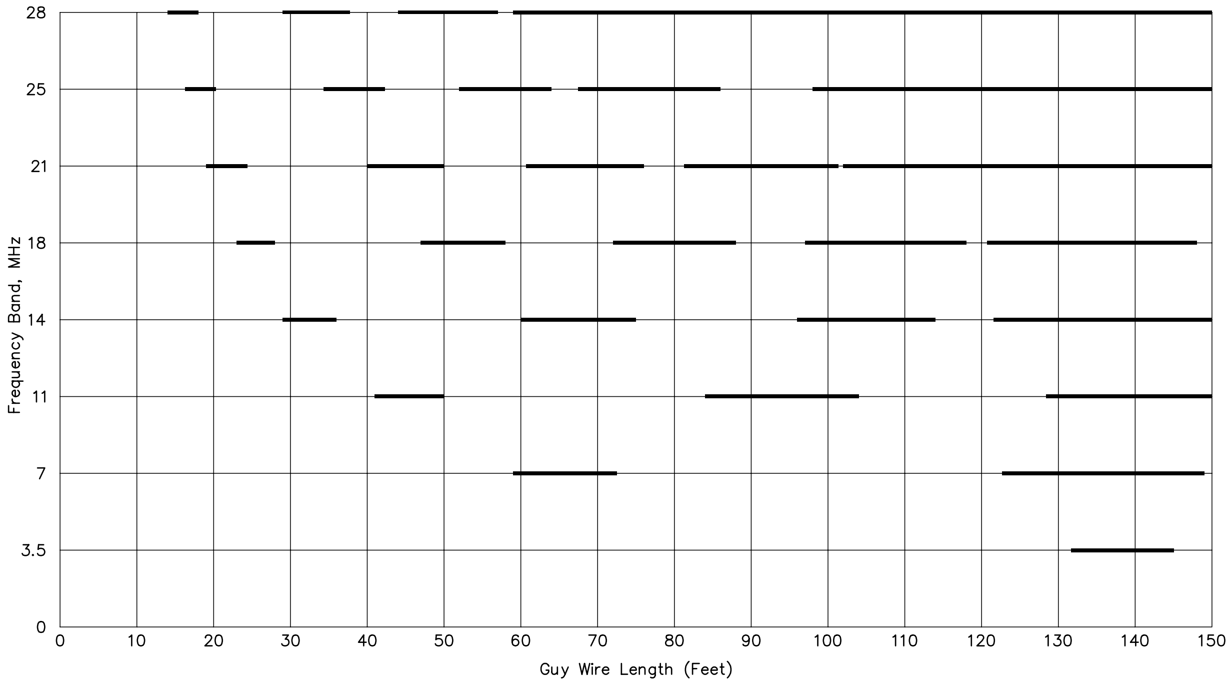

Fig 30—The black bars indicate ungrounded guy wire lengths to avoid for the eight HF amateur bands. This chart is based on resonance within 10% of any frequency in the band. Grounded wires will exhibit resonance at odd multiples of a quarter wavelength. (*By Jerry Hall, K1TD.*)

THE RIGHT TOWER FOR YOUR ANTENNA

Most manufacturers rate their towers in terms of the maximum allowable antenna load that can safely be carried at a specific wind speed. Ensuring that the specific antennas you plan to install meet the tower's design criteria, however, may not always be a straightforward task.

For most towers, the manufacturer assumes that the allowable antenna load is a horizontal force applied at the top of the tower. The allowable load represents a defined amount of exposed antenna area, at a specified wind velocity. Most tower manufacturers rate the load in terms of *Flat Projected Area* (FPA). This is simply the equivalent area of a flat rectangular surface at right angles to the wind. The FPA is not related to the actual shape of the antenna itself, only its rectangular projected area. Some manufacturers provide separate FPAs for antennas made from cylindrical sections and those made from rectangular sections.

In the realm of antenna manufacturers, however, you may encounter another wind load rating called the *Effective Projected Area* (EPA). This attempts to take into account the actual shape of antenna elements. The problem is that there is no agreed-upon standard for the conversion from EPA to load numbers. Different manufacturers may use different conversion factors.

Since most tower manufacturers have provided FPA figures for their towers—allowing us in effect to ignore design-specification details—it would be easiest for us to work only with FPA values for our antennas. This would be fine, if indeed we had good FPA figures for the specific antennas we plan to use! Unfortunately, FPAs are rarely specified for commercially built amateur antennas. Instead, most antenna manufacturers provide effective areas in their specification sheets. You may need to contact the antenna manufacturer directly for the FPA antenna area or for the antenna dimensions so that you can do your own FPA calculations.

Determining Antenna Areas

The method for determining the flat projected area of an antenna is quite simple. We'll use a Yagi antenna as an example. There are two worst-case areas that should be considered here. The first is the FPA of all the elements when the wind blows in the direction along the boom; that is, at right angles to the elements. The second FPA for a Yagi is when the wind is at right angles to the boom. One of these two orientations produces the worst-case exposed antenna area—all other wind angles present lower exposed areas. The idea is to take the highest of the FPAs for these two wind directions and call that the FPA of the antenna structure. See **Fig 31A**.

The element FPA is calculated by multiplying each element's dimension of length by its diameter and then

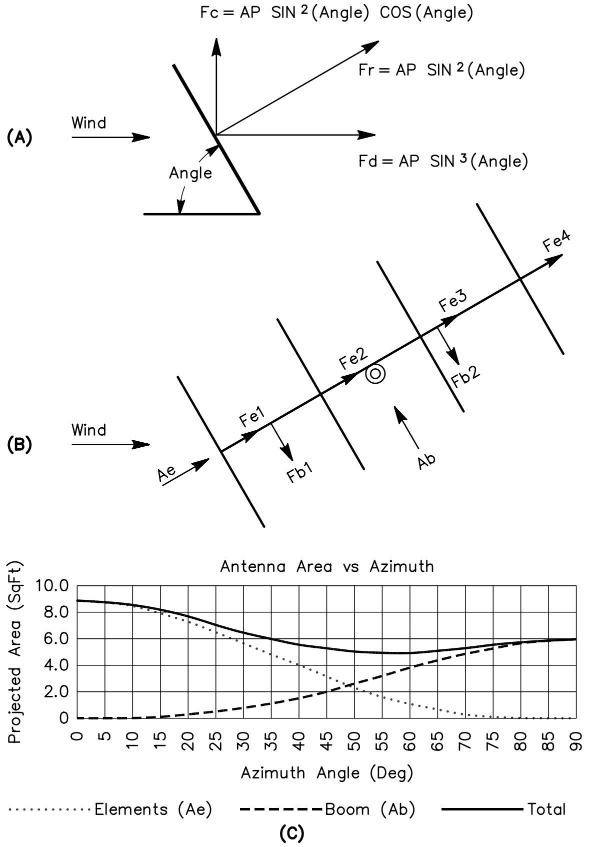

Fig 31—Description of how loads are developed on a Yagi. At A, Fr is the resultant force from the wind load on a generalized member. Fd is the load acting downwind (drag) that creates the load on the tower. Fc is the lateral component of the wind load. The term A is the flat projected area (FPA), which is the broadside area normal to the wind. The term P is the wind pressure. At B, Ae is the total element area, while Ab is the total boom area. All the loads due to the wind act normal to the antenna sections—the force on element #1 (Fe1) acts along the axis of the boom, for example. At C, a plot of the *effective FPA* as a function of the azimuthal wind direction for a Yagi, ignoring drag coefficients. The Yagi in this example has 9.0 square feet of element FPA and 6.0 square feet of boom FPA. The worst-case FPAs occur with the beam pointed in the wind and with the boom broadside to the wind. To determine the actual tower loading, the actual drag coefficients and wind pressures must be used.

summing the FPAs for all elements. The boom's FPA is computed by multiplying the boom's length by its diameter.

The reason for considering two potential peak-load orientations becomes clear when different frequency antennas are stacked on a mast or tower. Some antennas produce peak loads when the elements are broadside to the wind. This is typical of low-frequency Yagis, where the elements are long lengths of aluminum tubing. On the other hand, the boom can dominate the surface area computations in higher-frequency Yagis.

The fundamentals responsible for the need to examine both potential FPAs for Yagis relates to how wind flows over a structure and develops loads. Called *The Cross-Flow Principle*, this was introduced to the communications industry by Dick Weber, K5IU, in 1993. The principle is based on the fact that the loads created by wind flowing across an antenna member only produce forces that are normal to (or perpendicular to) the major axis of the member. The resultant and component load calculations for this method are shown in Fig 31A.

For a Yagi, this means that wind forces on the elements act in-line with the boom, while forces on the boom act in-line with the elements. Fig 31B shows a force diagram for a typical Yagi. Fig 31C shows the FPA for a Yagi rotated through 90° of azimuth.

Antenna Placement on the Mast/Tower

Another important consideration is where the antenna(s) will be placed on the tower. As mentioned before, most generic tower specifications assume that the entire antenna load is applied at the top of the tower. Most amateur installations have a tubular mast extending above the tower top, turned by a rotator mounted down inside the tower. Multiple Yagi antennas are often placed on the mast above the tower top, and you must make sure that both the tower and the mast can withstand the wind forces on the antennas.

For freestanding towers, you can determine how a proposed antenna configuration compares to the tower manufacturer's rating by using an *Equivalent Moment* method. The method computes the bending moment generated at the base of the tower by wind loads on the tower's rated antenna area located right at the top of the tower and compares that to the case when the antenna is mounted on a mast sticking out of the top of the tower.

The exact value of wind pressure is not important, so long as it is the same for both comparisons. The wind load on the tower itself can be ignored because it is the same in both comparisons and the drag coefficients for the antennas can also be ignored if all calculations are performed using flat projected antenna areas, as we've recommended previously.

Keep in mind that this approach does not calculate *actual* loads and moments relevant to any specific tower design standard, but it does allow equivalent comparisons when the wind pressure is constant and all the antenna areas are of the same type. An example is in order.

Fig 32A shows a generic tower configuration, with a concentrated antenna load at the top of the tower. We'll assume that the tower manufacturer rates this tower at 20 square feet of flat projected antenna area. Fig 32B shows a typical amateur installation with a rotating mast and an antenna mounted 7 feet above the top of the tower. To make the calculations easy, we select a wind pressure

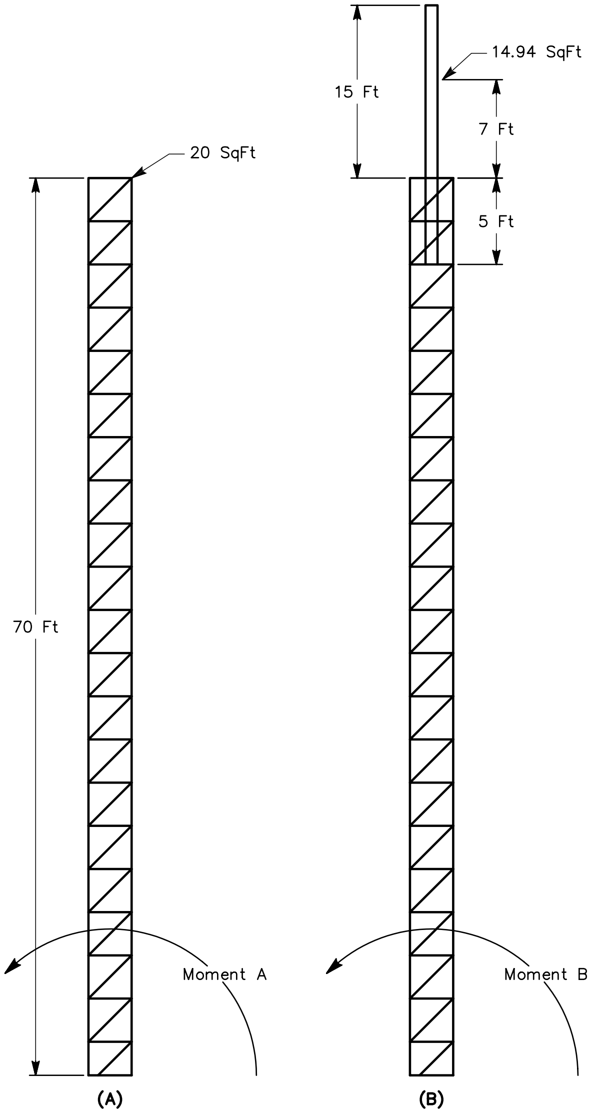

Fig 32—At A, a 70-foot tower rated for 20 square feet of antenna load at the top. At B, the same tower with a 2-inch OD × 20-foot long mast, with an antenna mounted 7 feet above the top of the tower. Both configurations produce the same tower load.

of 1 pound per square foot (1 psf). This makes the tower base moment calculation for Fig 32A:

Antenna load = 20 feet^2 × 1 psf = 20 pounds
Base moment = 70 feet × 20 pounds =
1400 foot-pounds.

This is the target value for the comparison. An equivalent configuration would produce the same base moment. For the configuration in Fig 32B, we assume a tubular 2-inch diameter mast that is 20 feet long, mounted 5 feet down inside the tower. Note that the lattice structure of the tower allows the wind to "see" the whole length of the mast and that we can consider the force distributed along the mast as being a single force concentrated at the mast's center. The flat projected area of the mast by itself, without the antenna, is:

Mast area = 20 feet × 2 inches / 12 inches/foot =
3.33 square feet

The center of the mast is located at a height of 75 feet. Using the same 1-psf-wind load, the base bending moment due to the mast alone is:

Base moment (due to mast) = 3.33 feet^2 × 1 psf ×
75 feet = 249.75 foot-pounds

Including the mast in the configuration reduces the allowable antenna load. The remaining target base moment left for the antenna is found by subtracting the moment due to the mast from the original target value:

New base target moment = 1400 - 249.75 foot-pounds
= 1150.25 foot-pounds.

The antenna in Fig 32B is located at a height of 77 feet. To obtain the allowable antenna area at this elevation we divide the new base target moment by the antenna height, yielding an allowable antenna load of:

1150.25 foot-pounds / 77 feet = 14.94 pounds.

Since we chose a wind load of 1 psf, the allowable antenna FPA has been reduced to 14.94 square feet from 20 square feet. If the projected area of the antenna we are planning to mount in the new configuration is less than or equal to this value, we have satisfied the requirements of the original design. You can use this equivalent-moment method to evaluate different configurations, even ones involving multiple antennas on the mast or situations with additional antennas placed along the tower below the tower top.

For guyed towers, the analyses become much more rigorous to solve. Because the guys and their behaviors are such a significant portion of the tower support mechanism, these designs can become very sensitive to antenna load placements. A general rule of thumb for guyed towers is never to exceed the original tower-top load rating, regardless of distributed loads along its length. Once you redistribute the antenna load placements along a guyed tower, you should do a fresh analysis, just to be sure.

You can run evaluations using the above method for antennas placed on the mast above a guyed tower top. The use of the Equivalent-Moment method for antennas mounted below the top of a guyed tower, however, can become quite suspect, since many generic tower designs have their intermediate guys sized for zero antenna loads lower down the tower. The proper approach in this case is to have a qualified mechanical engineer check the configuration, to see if guy placement and strength is adequate for the additional antennas down the tower.

Mounting the mast and antenna as shown in Fig 32B increases tower loads in the region of the mast. You should investigate these loads to ensure that the tower bracing in that area is sufficient. Now we will consider the problem of bending the rotating mast.

Mast Strength

When you mount antennas on a mast above the tower top, you should examine the bending loads on the mast to ensure that it will be strong enough. This section explains how to perform mast stress calculations for a single sustained wind speed. This procedure does not include height, exposure and gust-response factors found in most tower design standards.

Here are some fundamental formulas and values used to calculate the bending stress in a mast mounted in the top of a tower. The basic formula for wind pressure is:

$$P = .00256\ V^2 \qquad \text{(Eq 1)}$$

where

P is the wind pressure is in pounds per square foot (psf)

V = wind speed in miles per hour (mph)

This assumes an air density for standard temperature and atmospheric pressure at sea level. The wind speed is not the Basic Wind Speed discussed in other sections of this chapter. It is simply a steady state (static) wind velocity.

The formula for calculating the force created by the wind on a structure is:

$$F = P \times A \times C_d \qquad \text{(Eq 2)}$$

where

P = the wind pressure from Eq (1)

A = the flat projected area of the structure (square feet)

C_d = drag coefficient for the shape of the structure's members.

The commonly accepted *drag coefficient* for long cylindrical members like the tubing used for the mast and antenna is 1.20. The coefficient for a flat plate is 2.0.

The formula used to find the *bending stress* in a simple beam like our mast is:

$$\sigma = \frac{M \times c}{I} \qquad \text{(Eq 3)}$$

where

σ = the stress in pounds per square inch (psi)

M = *bending moment* at the base of the mast (inch-pounds)

c = ½ of the mast outside diameter (inches)

I = *moment of inertia* of the mast section (inches^4)

In this equation you must make sure that all values are in the same units. To arrive at the mast stress in pounds per square inch (psi), the other values need to be in inches and pounds also. The equation used to find the moment of inertia for the round tubing mast section is:

$$I = \frac{\pi}{4}(R^4 - r^4) \qquad \text{(Eq 4)}$$

where

I = Moment of Inertia of the section (inches^4)

R = Radius of tube outside diameter (inches)

r = Radius of tube inside diameter (inches)

This value describes the distribution of material about the mast *centroid*, which determines how it behaves under load. The equation used to compute the *bending moment* at the base of the mast (where it is supported by the tower) is:

$$M = (F_M \times L_M) + (F_A \times L_M) \qquad \text{(Eq 5)}$$

where

F_M = wind force from the mast (pounds)

L_M = Distance from tower top to center of mast (inches)

F_A = Wind force from the antenna (pounds)

L_A = Distance from tower top to antenna attachment (inches)

L_M is the distance to the center of the portion of the mast extending above the tower top. Additional antennas can be added to this formula by including their F × L. In the installation shown in Fig 32B, a wind speed of 90 mph, and a mast that is 2 inches OD, with a 0.250-inch wall thickness, the steps for calculating the mast stress are:

1. Calculate the wind pressure for 90 mph, from Eq 1:

$$P = .00256\ V^2 = .00256 \times (90)^2 = 20.736 \text{ psf}$$

2. Determine the flat projected area of the mast. The portion of the mast above the tower is 15 feet long and has an outside diameter of 2 inches, which is 2/12 feet.

Mast FPA, A_M = 15 feet × (2 inches / 12 inches/feet) = 2.50 square feet.

3. Calculate the wind load on the mast, from Eq 2:

Mast Force, $F_M = P \times A \times C_d =$ 20.736 psf × 2.50 feet^2 × 1.20 = 62.21 pounds

4. Calculate the wind load on the antenna: From Eq 2

Antenna Force, $F_A = P \times A \times C_d$ = 20.736 psf × 14.94 feet^2 × 1.20 = 371.76 pounds

5. Calculate the mast *Bending Moment*, from Eq 5:

$M = (F_M \times L_M) + (F_A \times L_A)$
= (62.21 pounds × 90 inches) + (371.76 pounds × 84 inches) = 36827 inch-pounds

where L_M = 7.5 feet × 12 inches/foot = 90 inches and L_A = 7.0 feet × 12 inches/foot = 84 inches.

6. Calculate the mast *Moment of Inertia*, from Eq 4:

$$I = \frac{\pi}{4}(R^4 - r^4) = \frac{\pi}{4}(1.0^4 - 0.75^4) = 0.5369 \text{ inches}^4$$

where, for a 2.0-inch OD and 0.250-inch wall thickness tube, $R = 1.0$ and $r = 0.75$.

7. Calculate the mast *Bending Stress*, from Eq 3:

$$\sigma = \frac{M \times c}{I} = \frac{36827 \text{ inch-pounds} \times 1.0 \text{ inches}}{0.5369} = 68592 \text{ psi}$$

If the yield strength of the mast material is greater than the calculated bending stress, the mast is considered safe for this configuration and wind speed. If the calculated stress is higher than the mast yield strength, a stronger alloy, or a larger mast, or one with a thicker wall is required.

There are many different materials and manufacturing processes for tubing that may be used for a mast. Yield strengths range from 25,000 psi to nearly 100,000 psi. Knowing the minimum yield strength of the material used for a mast is an important part of determining if it will be safe. Using unknown materials renders efforts from the preceding calculations useless!

When evaluating a mast with multiple antennas attached to it, special care should be given to finding the worst-case condition (wind direction) for the system. What may appear to be the worst load case, by virtue of the combined flat projected antenna areas, may not always be the exposure that creates the largest mast bending moment. Masts with multiple stacked antennas should always be examined to find the exposure that produces the largest mast bending moment. The antenna flat projected areas at 0° and 90° azimuths are particularly useful for this evaluation.

ANTENNA INSTALLATION

All antenna installations are different in some respects. Therefore, thorough planning is the most important first step in installing any antenna. Before anyone climbs the tower, the whole process should be discussed to be sure each crewmember understands what is to be done. And remember that the person on the tower is in charge! Coordinate beforehand what signals and commands are used: "Up" or "Up Slowly" for raising something from the ground; "Down" or "Down Slowly" for the opposite.

"Watch Out!" or 'Watch Out Below!" works for dropped hardware or tools to alert the ground crew below. Remember, once someone is on the tower, no one should be allowed to stand near the base of the tower!

Consider what tools and parts must be assembled and what items must be taken up the tower, and plan alternative actions for possible trouble spots. Extra trips up and down the tower can be avoided by careful planning.

If done properly, the actual work of getting the antenna into position can be executed quite easily with only one person at the top of the tower. The ground crew should do all the heavy work and leave the person on the tower free to guide the antenna into position. Because the ground crew does all the lifting, a large pulley, preferably on a gin pole placed at the top of the tower, is essential. Local radio clubs often have gin poles available for use by their members. Stores that sell tower materials frequently rent gin poles as well.

A gin pole should be placed along the side of the tower so the pulley is no more than 2 feet above the top of the tower (or the point at which the antenna is to be placed). Normally this height is sufficient to allow the antenna to be positioned easily. An important reason that the pulley is placed at this level is that there can be considerable strain on the gin pole when the antenna is pulled away from the tower to maneuver past guy wires.

Sometime the mast to which the antenna will be mounted is used as a place to hang the pulley. You should take care that you don't end up bending the mast by placing the pulley too high on the mast. It may be necessary to back-guy the mast on the opposite side of the tower from which the antenna is raised.

The rope (halyard) through the pulley must be somewhat longer than twice the tower height so that the ground crew can raise the antenna from ground level. The rope should be ½ or $^5/_8$ inch diameter for both strength and ease of handling. Smaller diameter rope is less easily manipulated; it has a tendency to jump out of the pulley track and foul pulley operation.

The first person to climb the tower should carry an end of the halyard so that the gin pole can be lifted and secured to the tower. Those climbing the tower must have safety belts. Belts provide safety and convenience; it is simply impossible to work effectively while hanging onto the tower with one hand.

Once positioned, the gin pole and pulley allow parts and tools to be sent up the tower. A useful trick for sending up small items like bolts and pliers is for a ground crew member to slide them through the rope strands where they are held by the rope for the trip to the top of the tower. Items that might be dislodged by contact with the tower should either be taped or tied to the halyard.

Ever present is the hazard of falling tools or hardware. It is foolish to stand near a tower when someone is working above. Ground crew member should wear hard-hats as extra insurance.

Raising the Antenna Alongside the Tower

A technique that can save much effort in raising the antenna is outlined here. First, the halyard is passed through the gin-pole pulley or the pulley mounted to the mast, and the leading end of the rope is returned to the ground crew, where it is tied to the antenna. The assembled antenna should be placed in a clear area of the yard (or the roof) so the boom points toward the tower. The halyard is then passed *under* the front elements of the beam to a position past the midpoint of the antenna, where it is securely tied to the boom (**Fig 33A**).

Note that once the antenna is installed, the tower worker must be able to reach and untie the halyard from the boom; the rope must be tied less than an arm's length along the boom from the mounting point. If necessary, a large loop may be placed around the first element located beyond the midpoint of the boom, with the knot tied near the center of the antenna. The rope may then be untied easily after completion of the installation. The halyard should be tied temporarily to the boom at the front of the antenna by means of a short piece of light rope or twine.

While the antenna is being raised, the ground crew does all the pulling. As soon as the front of the antenna reaches the top of the mast, the person atop the tower unties the light rope and prevents the front of the antenna from falling, as the ground crew continues to lift the antenna (Fig 33B). When the center of the antenna is even with the top of the tower, the tower worker puts one bolt through the mast and the antenna-mounting bracket on the boom. The single bolt acts as a pivot point and the ground crew continues to lift the back of the antenna with the halyard (Fig 33C). After the antenna is horizontal, the tower worker secures the rest of the mounting bolts and unties the halyard. By using this technique, the tower worker performs no heavy lifting.

Avoiding Guy Wires

Although the same basic methods of installing a Yagi apply to any tower, guyed towers pose a special problem. Steps must be taken to avoid snagging the antenna on the guy wires. With proper precautions, however, even large antennas can be pulled to the top of a tower, even if the

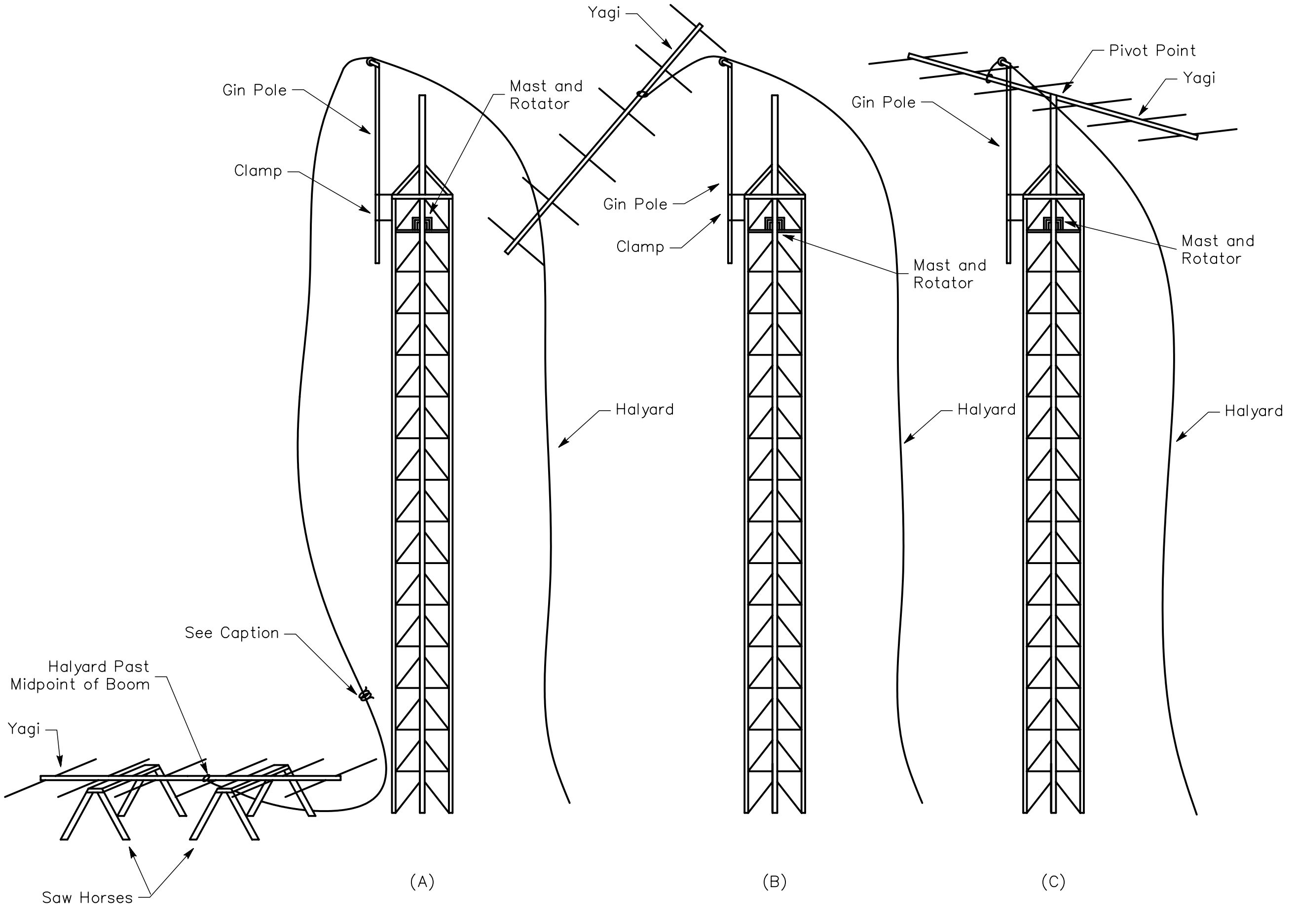

Fig 33—Raising a Yagi antenna alongside the tower. At A the Yagi is placed in a clear area, with the boom pointing toward the tower. The halyard is passed under the elements, then is secured to the boom beyond the midpoint. B shows the antenna approaching the top of the mast. The person on the tower guides it after the lifting rope has been untied from the front of the antenna. At C the antenna is pulled into a horizontal position by the ground crew. The tower worker inserts the pivot bolt and secures it. Note: A short piece of rope is tied around the halyard and the boom at the front of the antenna to stabilize the beam as it is being raised. The tower worker removes it when the boom reaches him at the top of the tower.

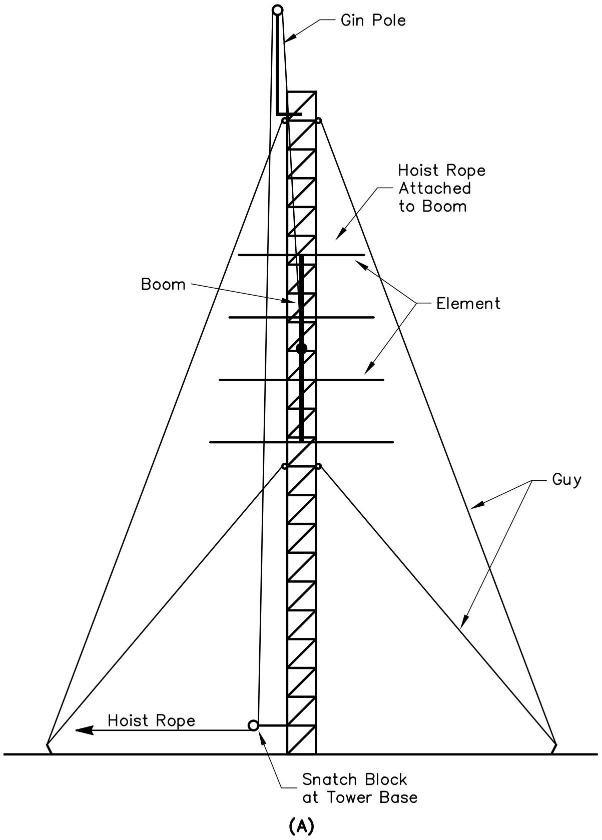
Gin Pole
Hoist Rope Attached to Boom
Boom
Element
Guy
Hoist Rope
Snatch Block at Tower Base
(A)

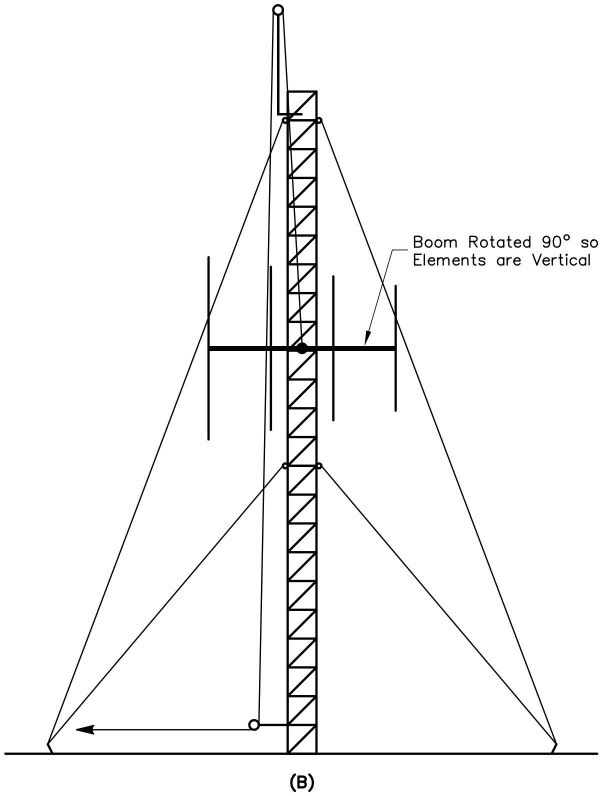
Boom Rotated 90° so Elements are Vertical
(B)

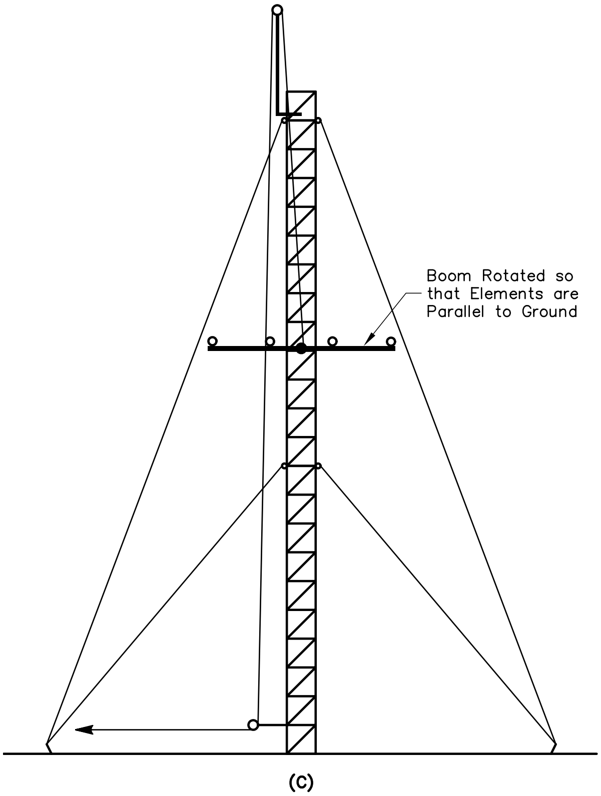
Boom Rotated so that Elements are Parallel to Ground
(C)

Fig 34—Building a Yagi partway down the tower. At A, the boom is lashed temporarily to the tower and elements are added, starting at the bottom. At B, the temporary rope securing the boom to the tower is removed and the boom is rotated 90° so that the elements are vertical. At C, the boom is rotated another 90°, "weaving through" guy wires if necessary, until the elements are parallel with the ground, whereupon the boom is secured to the tower.

mast is guyed at several levels.

Sometimes one of the top guys can provide a *track* to support the antenna as it is pulled upward. Insulators in the guys, however, may obstruct the movement of the antenna. A better track made with rope is an alternative. One end of the rope is secured outside the guy anchors. The other end is passed over the top of the tower and back down to an anchor near the first anchor. So arranged, the rope forms a narrow V-track strung outside the guy wires. Once the V-track is secured, the antenna may simply be pulled up, resting on the track.

Another method is to tie a rope to the back of the antenna (but within reach of the center). The ground crews then pull the antenna out away from the guys as the antenna is raised. With this method, some crewmembers are pulling up the antenna to raise it while others are pulling down and out to keep the beam clear of the guys. Obviously, the opposing crews must act in coordination to avoid damaging the antenna. The beam is especially vulnerable when it begins to tip into the horizontal position. If the crew continues to pull out and down against the antenna, the boom can be broken. Another problem with this approach is that the antenna may rotate on the axis of the boom as it is raised. To prevent such rotation, long lengths of twine may be tied to outer elements, one piece on each side of the boom. Ground personnel may then use these *tag lines* to stabilize the antenna. Where this is done, provisions must be made for untying the twine once the antenna is in place.

A third method is to tie the halyard to the center of the antenna. A crewmember, wearing a safety belt, walks the antenna up the tower as the crew on the ground raises it. Because the halyard is tied at the balance point, the tower worker can rotate the elements around the guys. A tag line can be tied to the bottom end of the boom so that a ground worker can help move the antenna around the guys. The tag line must be removed while the antenna is still vertical.

A fourth method is to build the antenna on the tower and then swing it into position. (See also the section below on the PVC Mount.) Building the Yagi on the tower works particularly well for Yagis mounted partway up the tower, as you might do in a stacked array. The technique works best when the vertical spacing between the guys is greater than the length of the Yagi boom.

Fig 34 illustrates the steps involved. A pull rope through a gin-pole or tower-mounted pulley is secured to the boom at the final balance point and the ground crew raises the boom in a vertical position up the tower. A tie rope is used to temporarily secure the upper end of the boom to keep it stable while the boom is being raised. The tower person removes the tie-rope once the boom is raised to the right level and has been temporarily secured to the tower.

The elements are then brought up one at a time and mounted to the boom. It helps if you have a 2- or 3-foot long *spotting mast* temporarily attached to the boom to form a 90° frame of reference. This allows the ground crew to spot from below so that the elements are all lined up in the same plane. After all the elements are mounted and aligned properly, the temporary rope securing the boom to the tower is released, suspending the antenna on the pull rope. The tower person then rotates the boom 90° so that the elements are vertical. Next the elements are rotated 90° into the tower so that they are parallel to the ground. The ground crew then moves the boom up or down using the pull rope to the final point where it is mounted to the tower.

A modification of this technique also works for building a medium-sized Yagi on the top of the tower. This technique will work if the length of the gin pole at maximum safe extension is long enough. See **Fig 35**.

As usual, the gin-pole pull rope is attached to the balance point of the boom and the boom is pulled up the tower in the vertical position, using a rope to temporarily tie the pull rope to the top end of the boom for stability. The boom is temporarily secured to the tower with rope in the vertical position so that the top end is just higher than the top of the tower. In order to clear the gin pole when the elements are mounted and the boom is raised higher to mount the next element, you must tilt the boom slightly so that the element mounted to the top end of the boom will be *behind* the mast. This is very important!

The elements are first mounted to the bottom side of the boom to provide weight down below for stability. Then the top-most element is mounted to the boom. The tower person removes the temporary rope securing the boom to the tower and the ground crew uses the pull rope

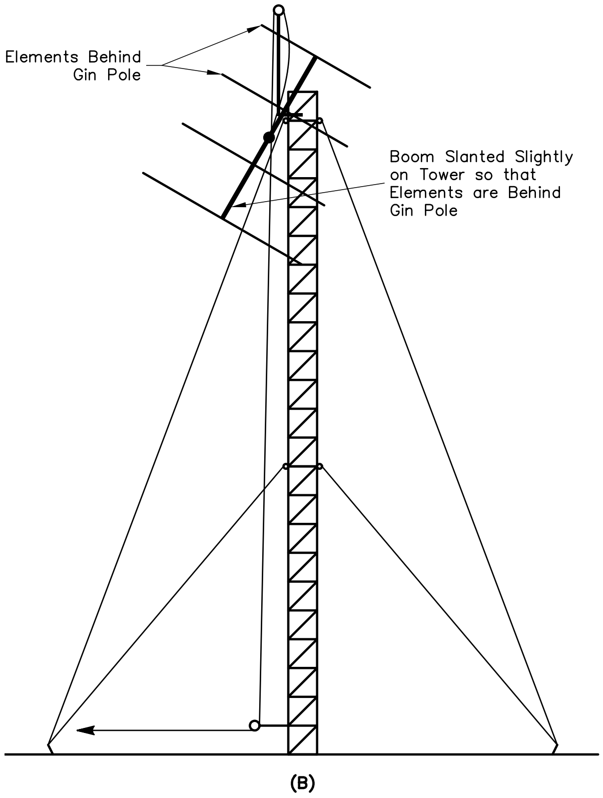
Elements Behind Gin Pole
Boom Slanted Slightly on Tower so that Elements are Behind Gin Pole
(B)

Fig 35—Building a Yagi at the top of the tower. The length of the gin pole must be longer than 1/2 the boom so that the boom can be hoisted upwards to the place where it is mounted to the mast. Usually the boom is initially lashed to the tower slanted slightly from vertical so that the top element ends up *behind* the gin pole. The elements are mounted at the bottom end of the boom first to provide stability. Then the element at the top of the boom is mounted and the boom is moved upwards using the gin-pole hoist rope so that the next-to-top element may be mounted, again behind the gin pole. This process is repeated until all elements are mounted (save possibly the middle element if it can be reached easily from the tower once the beam has been mounted to the mast). Then the boom is tilted to the final position, weaving the elements to clear guy wires if necessary.

to move the mast vertically upwards to the point where the next element from the top can be mounted. Once all the elements are mounted and aligned in the same plane (with perhaps the center element closest to the mast-to-boom bracket left on the ground until later), the temporary securing rope is removed. The boom is now swung so that the elements can be maneuvered to clear the top guy wires. Once the elements are horizontal the boom is secured to the mast and the center element is mounted.

Using a Tram

Another method to get a large Yagi to the top of the tower safely is a *tram*. A tram supports the antenna *under* the tram wire, using a pulley riding on the tram wire. The antenna can thus move more freely—without the friction it would have riding on top of a track rope, as described previously. This puts considerably less strain on the tram wire itself and on the mast to which it is tied on the tower. Some installers prefer to use a wire-rope tramline for its reduced sag.

The tram method uses an easily constructed fixture mounted to the boom of the Yagi to stabilize it from rotating away from the desired attitude as the antenna is raised. A guy-wire cable or heavy rope is fixed to the mast about two feet above the point where the antenna will mount to the mast. A come-along is often used at the ground end to tension the tram wire properly. It is often necessary to back-guy the mast to make sure it doesn't get bent, since the horizontal forces acting on the mast can be considerable in any tram (or track) operation. (Note that the tram technique works well for side-mounted antennas also, where back-guying is not necessary if you are reasonably close to a guy set, as is usually the case.)

Fig 36 is a photograph of a tram fixture built by Kurt Andress, K7NV. This consists of a pulley riding on top of the tramline. This pulley is attached using a caribiner or shackle to two equal-length wires connected to the boom to make an inverted-V shaped *sling*. The two sling wires are secured to the boom using angle irons and muffler clamps so that the antenna is perfectly balanced in the horizontal plane. Balance is very important to make sure the antenna rises properly on the tram without having the boom rotate downward on one end or the other.

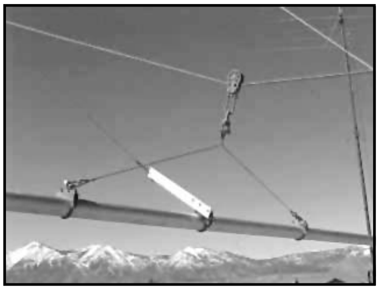

Fig 36—Photo of the tram system used by Kurt Andress, K7NV. (*Photo by K7NV.*)

The hoisting rope running through the tower-mounted gin-pole pulley (and used by the ground crew to pull the antenna up to the tower on the tram line) is attached to a 2-foot piece of angle iron. This is attached to the boom with a muffler clamp. Note that the angle iron is rotated slightly from horizontal so that the plane of the elements is tilted upwards—this allows the elements to clear the guy wires as the antenna is raised. (While the antenna is close to the ground, the angle iron is adjusted so that the elements remain horizontal. Once they are clear of the ground, the angle iron is readjusted to align the elements in the proper direction to clear the guy wires on the tower.) The force of the pull rope along the angle iron also stabilizes the antenna from yawing from side-to-side. Note in Fig 36 that the angle iron is mounted just off-center from where the boom-to-mast plate will be attached so that it clears the mast as the antenna nears the top of the tower. **Fig 37** diagrams how the tram and hoisting line are rigged to the mast.

The tower person directs the activity of the ground crew below and guides the antenna to the mast. Once the end of the pull rope reaches the mast, the tower man ties the boom temporarily to the mast so that he can undo the pull rope from the tram-fixture angle iron and retie it around the boom. Then the antenna can be raised to the point where it can be mounted to the mast.

This technique has been employed to raise Yagis with booms as long as 42 feet at the N6RO contest station on towers as high as 130 feet. As with the track, the tram system requires a good deal of open real estate. While it sounds complicated to set up, you can raise some rather large antennas in less than an hour, once you get the hang of the operation.

THE PVRC MOUNT

The methods described above for hoisting antennas are sometimes not satisfactory for really large, heavy arrays. The best way to handle large Yagis is to assemble them on top of the tower. One way to do this easily is by using the *PVRC Mount*. Many members of the Potomac Valley Radio Club have successfully used this method to install large antennas. Simple and ingenious, the idea involves offsetting the boom from the mast to permit the boom to tilt 360° and rotate axially 360°. This permits the entire length of the boom to be brought alongside the tower, allowing the elements to be attached one by one. (It also allows any part of the antenna to be brought alongside the tower for antenna maintenance.)

See **Figs 38** through **42**. The mount itself consists of a short length of pipe of the same diameter as the rotating mast (or greater), a steel plate, eight U bolts and four pinning bolts. The steel plate is the larger, horizontal one shown in Fig 38. Four U bolts attach the plate to the rotating mast, and four attach the horizontal pipe to the plate. The horizontal pipe provides the offset between the antenna boom and the tower. The antenna boom-to-mast plate is mounted at the outer end of the short pipe. Four bolts are used to ensure that the antenna ends up parallel to the ground, two pinning each plate to the short pipe. When the mast plate pinning bolts are removed and the

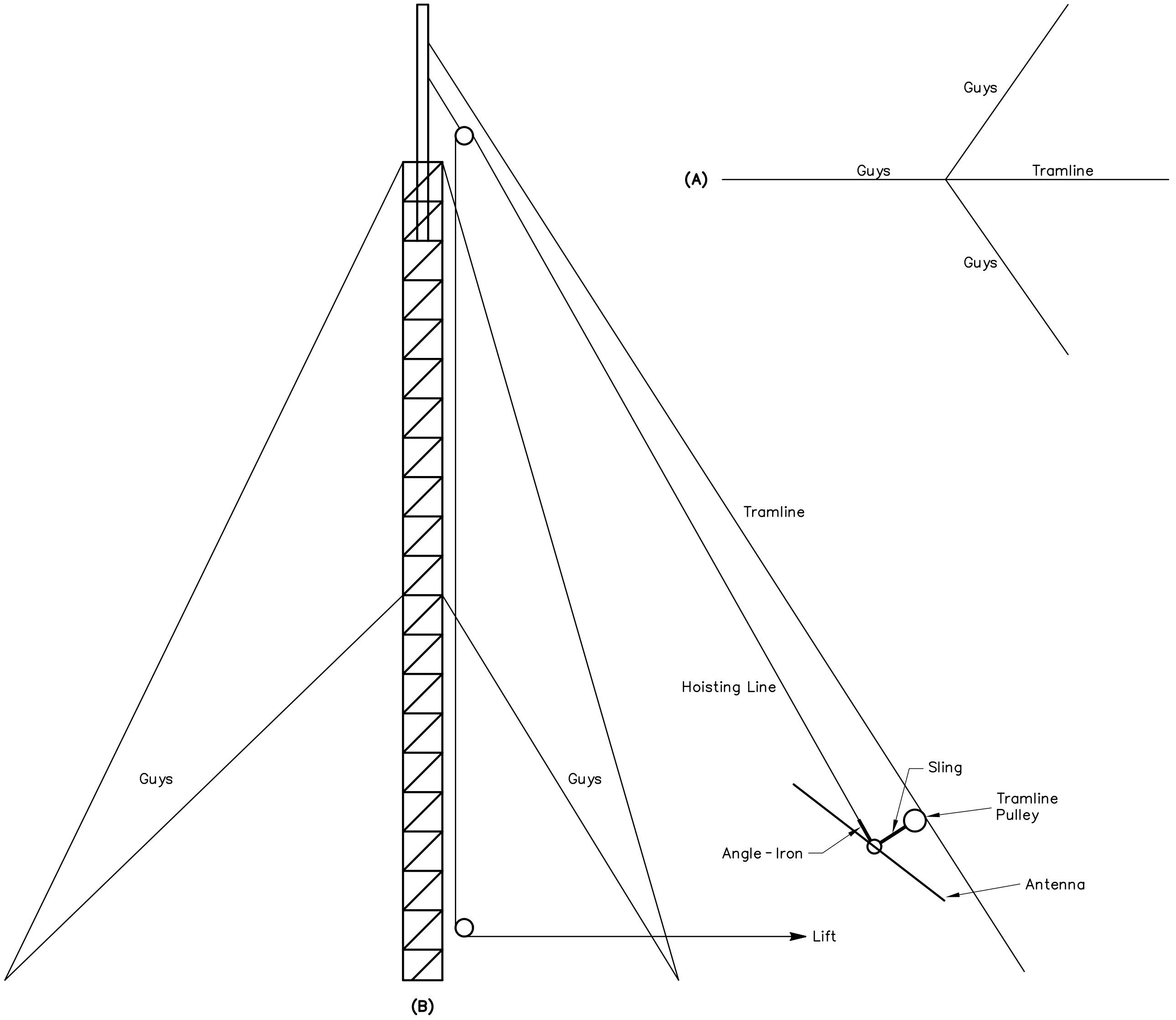

Fig 37—At A, bird's-eye view of tram system used to bring large Yagi antennas from the ground to the top of the tower. At B, side view of rigging used for tramline and hoisting line, along with the sling and tram fixture used to hold the Yagi on the tramline.

four U bolts loosened, the short pipe and boom plate can be rotated through 360°, allowing either half of the boom to come alongside the tower.

First assemble the antenna on the ground. Carefully mark all critical dimensions, and then remove the antenna elements from the boom. Once the rotator and mast have been installed on the tower, a gin pole is used to bring the mast plate and short pipe to the top of the tower. There, the top crew unpins the horizontal pipe and tilts the antenna boom plate to place it in the vertical plane. The boom is attached to the boom plate at the final balance point of the assembled antenna. It is important that the boom be rotated axially so the bottom side of the boom is closest to the tower. This will allow the boom to be tilted without the elements striking the tower.

During installation it may be necessary to loosen one guy wire temporarily to allow for tilting of the boom. As a safety precaution, a temporary guy should be attached to the same leg of the tower just low enough so the assembled antenna will clear it.

The elements are assembled on the boom, starting with those closest to the center of the boom, working out alternately to the farthest director and reflector. This procedure must be followed. If all the elements are put first on one half of the boom, it will be dangerous (if not impossible) to put on the remaining elements. By start-

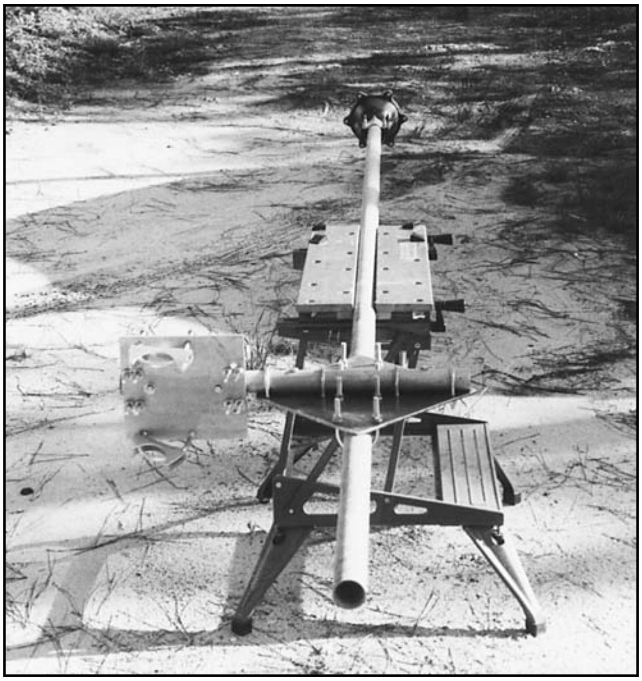

Fig 38—The PVRC mount, boom plate, mast and rotator ready to go. The mast and rotator are installed on the tower first.

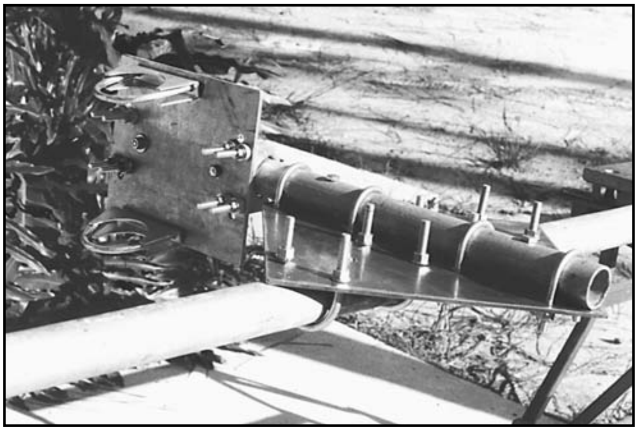

Fig 39—Close-up of the PVRC mount. The long pipe (horizontal in this photo) is the rotating mast. The U bolts in the vertical plate at the left are ready to accept the antenna boom. The heads of two locking pins (bolts) are visible at the midline of the boom plate. The other two pins help secure the horizontal pipe to the large steel mast plate. (The head of the bolt nearest the camera blends in with the right hand leg of the U bolt behind it.)

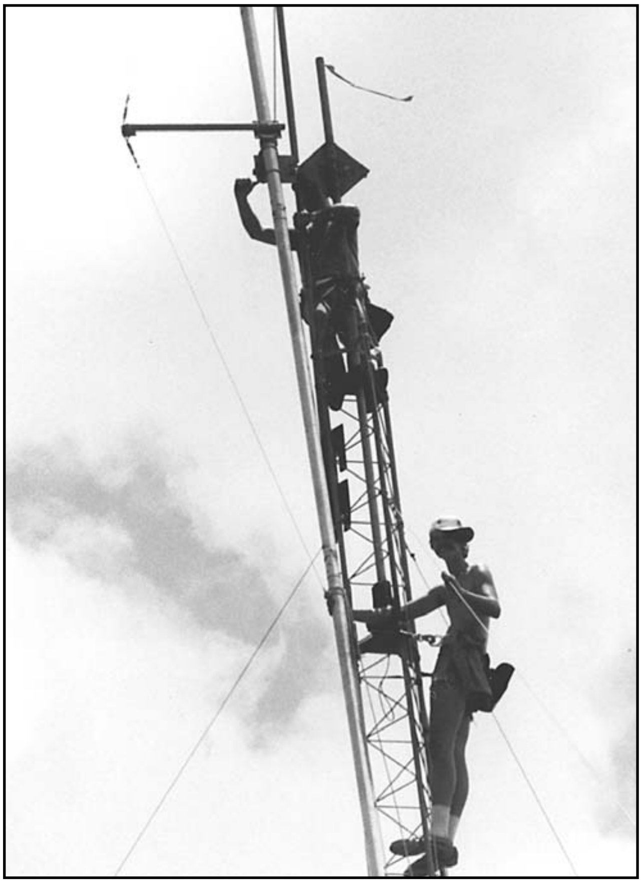

Fig 40—Working at the 70-foot level. A gin pole makes pulling up and mounting the boom to the boom plate a safe and easy procedure.

ing at the middle and working outward, the balance point of the partly assembled antenna will never be so far removed from the tower that tilting of the boom becomes impossible.

When the last element is attached, the boom is brought parallel to the ground, the horizontal pipe is pinned to the mast plate, and the mast plate U bolts tightened. At this point, all the antenna elements will be positioned vertically. Next, loosen the U bolts that hold the boom and rotate the boom axially 90°, bringing the elements parallel to the ground. Tighten the boom bolts and double check all the hardware.

Many long-boom Yagis employ a truss to prevent boom sag. With the PVRC mount, the truss must be attached to a pipe that is independent of the rotating mast. A short length of pipe is attached to the boom as close as possible to the balance point. The truss then moves with the boom whenever the boom is tilted or twisted.

A precaution: Unless you have a really strong rotator, you should consider using this mount mainly for assembling the antenna on the tower. The offset between the boom and the mast with this assembly can generate high torque loads on the rotator. Mounting the boom as close as possible to the mast will minimize the torque when the antenna is pointed into the wind.

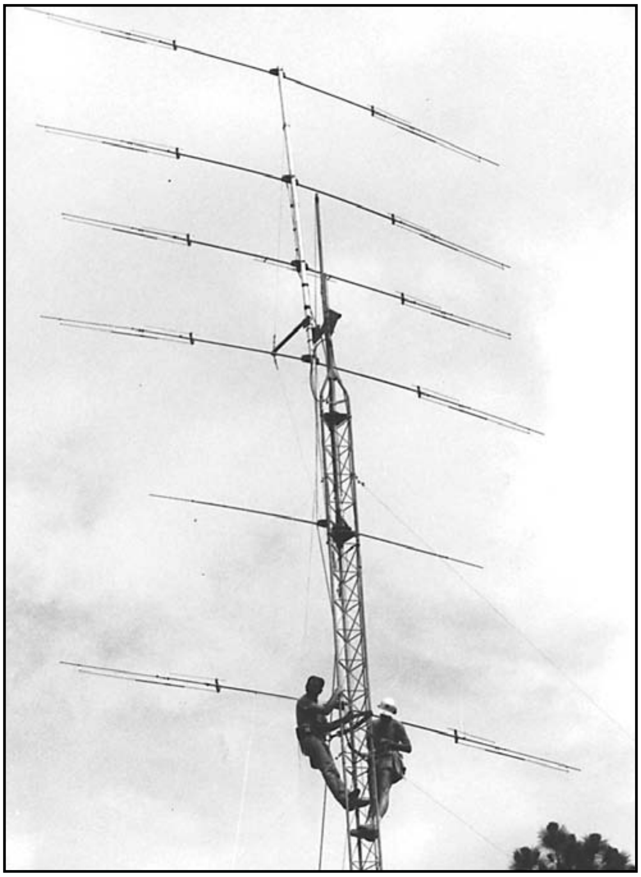

Fig 41—Mounting the last element prior to positioning the boom in a horizontal plane.

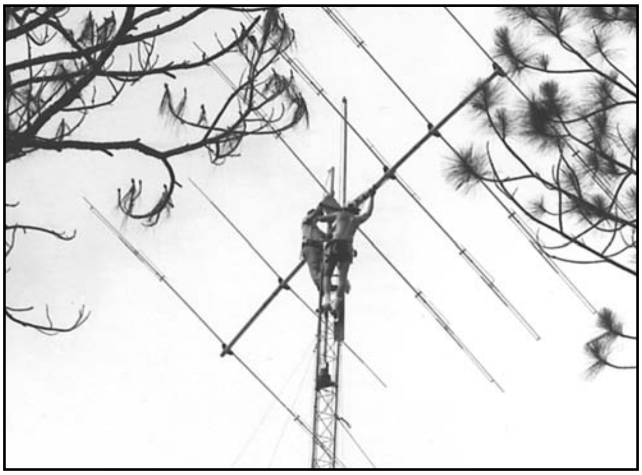

Fig 42—The U bolts securing the short pipe to the mast plate are loosened and the boom is turned to a horizontal position. This puts the elements in a vertical plane. Then the pipe U bolts are tightened and pinning bolts secured. The boom U bolts are then loosened and the boom turned axially 90°.

THE TOWER ALTERNATIVE

A cost saving alternative to the ground-mounted tower is the roof-mounted tripod. Units suitable for small HF or VHF antennas are commercially available. Perhaps the biggest problem with a tripod is determining how to fasten it securely to the roof.

One method of mounting a tripod on a roof is to nail 2 × 6 boards to the undersides of the rafters. Bolts can be extended from the leg mounts through the roof and the 2 × 6s. To avoid exerting too much pressure on the area of the roof between rafters, place another set of 2 × 6s on top of the roof (a mirror image of the ones in the attic). Installation details are shown in **Figs 43** through **46**.

The 2 × 6s are cut 4 inches longer than the outside distance between two rafters. Bolts are cut from a length of ¼-inch-threaded rod. Nails are used to hold the boards in place during installation, and roofing tar is used to seal the area to prevent leaks.

Find a location on the roof that will allow the antenna to turn without obstruction from such things as trees, TV antennas and chimneys. Determine the rafter locations. (Chimneys and vent pipes make good reference points.) Now the tower is set in place atop three 2 × 6s. A plumb line run from the top center of the tower can be used to center it on the peak of the roof. Holes for the mounting bolts can now be drilled through the roof.

Before proceeding, the bottom of the 2 × 6s and the area of the roof under them should be given a coat of roofing tar. Leave about $^1/_8$ inch of clear area around the holes to ensure easy passage of the bolts. Put the tower back in place and insert the bolts and tighten them. Apply tar to the bottom of the legs and the wooden supports, including the bolts. For added security the tripod can be guyed. Guys should be anchored to the frame of the house.

If a rotator is to be mounted above the tripod, pressure will be applied to the bearings. Wind load on the antenna will be translated into a “pinching” of one side of the bearings. Make sure that the rotator is capable of handling this additional stress.

ROTATOR SYSTEMS

There are not that many choices when it comes to antenna rotators for the amateur antenna system. Making the correct decision as to how much capacity the rotator must have is very important to ensure trouble-free operation. Manufacturers generally provide an antenna surface-area rating to help the purchase choose a suitable rotator. The maximum antenna area is linked to the rotator’s torque capability.

Some rotator manufacturers provide additional information to help you select the right size of rotator for the antennas you plan to use. Hy-Gain provides an *Effective Moment* value. Yaesu calls theirs a *K-Factor*. Both of these ratings are torque values in foot-pounds. You can compute the effective moment of your antenna by multiplying the antenna turning radius by its weight. So long

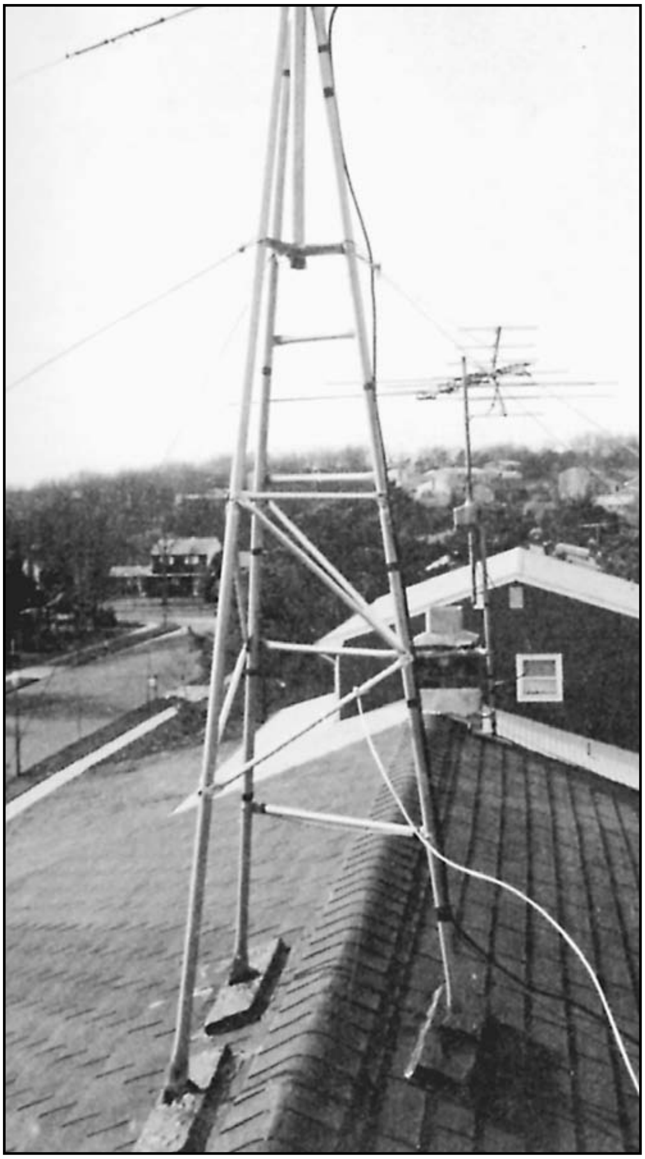

Fig 43—This tripod tower supports a rotary beam antenna. In addition to saving yard space, a roof-mounted tower can be more economical than a ground-mounted tower. A ground lead fastened to the lower part of the frame is for lightning protection. The rotator control cable and the coaxial line are dressed along two of the legs. (*Photo courtesy of Jane Wolfert.*)

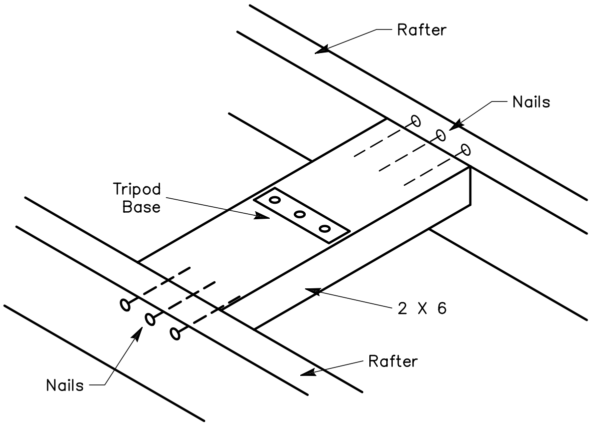

Fig 44—This cutaway view illustrates how the tripod tower is secured to the roof rafters. The leg to be secured to the crosspiece is placed on the outside of the roof. Another cross member is fastened to the underside of the rafters. Bolts, inserted through the roof and the two cross pieces, hold the inner cross member in place because of pressure applied. The inner crosspiece can be nailed to the rafter for added strength.

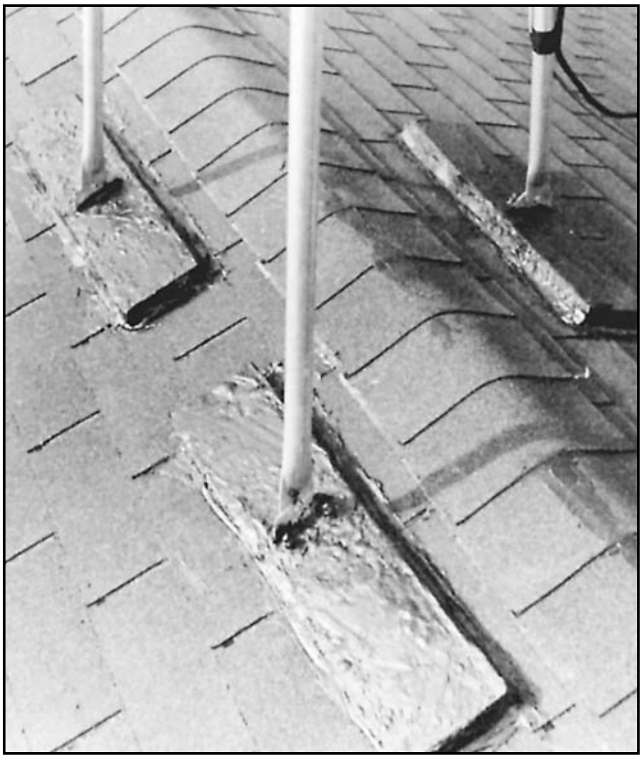

Fig 45—Three lengths of 2 × 6 wood mounted on the outside of the roof and reinforced under the roof by three identical lengths provide a durable means for anchoring the tripod. A thick coat of roofing tar guards against weathering and leaks.

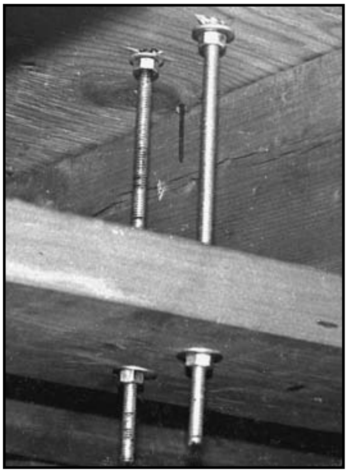

Fig 46—The strengthened anchoring for the tripod. Bolts are placed through two 2 × 6s on the underside of the roof and through the 2 × 6 on the top of the roof, as shown in Fig 43.

as the effective moment rating of the rotator is greater than or equal to the antenna value, the rotator can be expected to provide a useful service life.

There are basically four grades of rotators available to the amateur. The lightest-duty rotator is the type typically used to turn TV antennas. Without much difficulty, these rotators will handle a small 3-element tribander array (14, 21 and 28 MHz) or a single 21- or 28-MHz monoband three-element antenna. The important consideration with a TV rotator is that it lacks braking or holding capability. High winds turn the rotator motor via the gear train in a reverse fashion. Broken gears sometimes result.

The next grade up from the TV class of rotator usually includes a braking arrangement, whereby the antenna is held in place when power is not applied to the rotator. Generally speaking, the brake prevents gear damage on windy days. If adequate precautions are taken, this group of rotators is capable of holding and turning stacked monoband arrays, or up to a five-element 14-MHz system. The next step up in rotator strength is more expensive. This class of rotator will turn just about anything the most demanding amateur might want to install.

A description of antenna rotators would not be complete without the mention of the *prop pitch* class. The prop pitch rotator system consists of a surplus aircraft propeller blade pitch motor coupled to an indicator system and a power supply. There are mechanical problems of installation, however, resulting mostly from the size and weight of these motors. It has been said that a prop pitch rotator system, properly installed, is capable of turning a house. Perhaps in the same class as the prop pitch motor (but with somewhat less capability) is the electric motor of the type used for opening garage doors. These have been used successfully in turning large arrays.

Proper installation of the antenna rotator can provide many years of trouble-free service; sloppy installation can cause problems such as a burned out motor, slippage, binding and casting breakage. Most rotators are capable of accepting mast sizes of different diameters, and suitable precautions must be taken to shim an undersized mast to ensure dead-center rotation. It is very desirable to mount the rotator inside and as far below the top of the tower as possible. The mast absorbs the torsion developed by the antenna during high winds, as well as during starting and stopping.

Some amateurs have used a long mast from the top to the base of the tower. Rotator installation and service can be accomplished at ground level. A mast length of 10 feet or more between the rotator and the antenna will add greatly to the longevity of the entire system by allowing the mast to act as a torsion shock absorber. Another benefit of mounting the rotator 10 feet or more below the antenna is that any misalignment among the rotator, mast and the top of the tower is less significant. A tube at the top of the tower (a sleeve bearing) through which the mast protrudes almost completely eliminates any lateral forces on the rotator casing. All the rotator must do is support the downward weight of the antenna system and turn the array.

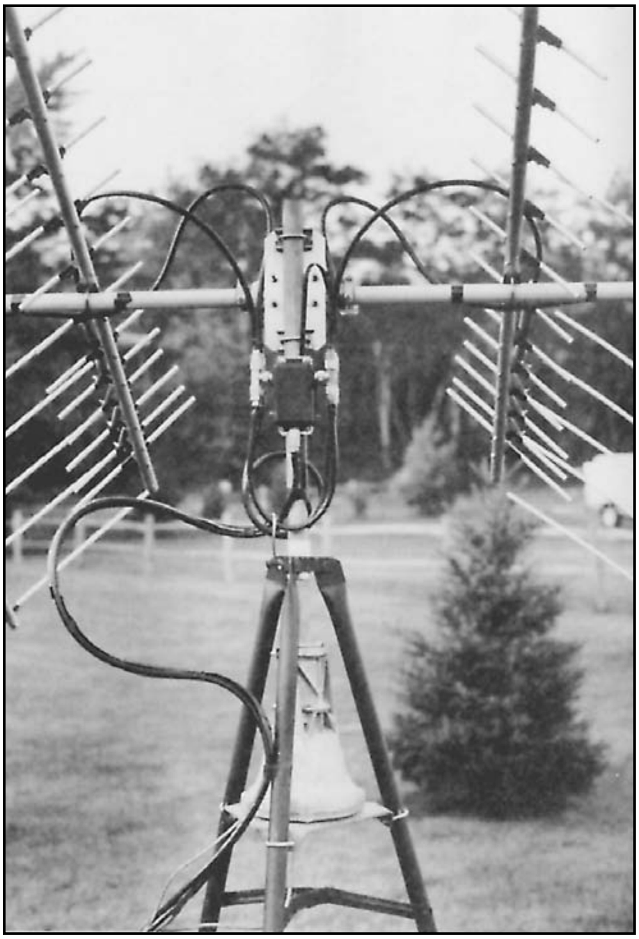

Fig 47—Rotator loop for UHF Yagi array. The feed coax is bundled with a control cable for the polarization relay. The coax/control-cable loop is taped to the rotating mast and to the top of the tower with vinyl electric tape to allow the array to be rotated.

While the normal weight of the antenna and the mast is usually not more than a couple of hundred pounds, even with a large system, one can ease this strain on the rotator by installing a thrust bearing at the top of the tower. The bearing is then the component that holds the weight of the antenna system, and the rotator need perform only the rotating task.

Don't forget to provide a loop of coax to allow your beam to rotate properly. Make sure you position the rotator loop so that it doesn't snag on anything. **Fig 47** shows a rotator loop for an elliptically polarized UHF Yagi array. Note that the coax loop is taped to the rotating mast above the top of the tower and to the tower itself.

Indicator Alignment

A problem often encountered in amateur installations is that of misalignment between the direction indicator in the rotator control box and the heading of the antenna. With a light duty rotator, this happens frequently when the wind blows the antenna to a different heading. With no brake, the force of the wind can move the gear train and motor of the rotator, while the indicator remains fixed. Such rotator systems have a mechanical stop to prevent continuous rotation during operation, and provision is usually included to realign the indicator against the mechanical stop from inside the shack. During installation, the antenna must be oriented correctly for the mechanical stop position, which is usually north.

In larger rotator systems with an adequate brake, indicator misalignment is caused by mechanical slippage in the antenna boom-to-mast hardware. Many texts suggest that the boom be pinned to the mast with a heavy-duty bolt and the rotator be similarly pinned to the mast. There is a trade-off here. If there is sufficient wind to cause slippage in the couplings without pins, with pins the wind could break a rotator casting. The slippage will act as a clutch release, which may prevent serious damage to the rotator. On the other hand, the amateur might not like to climb the tower and realign the system after each heavy windstorm.

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Chapter 23

Radio Wave Propagation

Because radio communication is carried on by means of electromagnetic waves traveling through the Earth's atmosphere, it is important to understand the nature of these waves and their behavior in the propagation medium. Most antennas will radiate the power applied to them efficiently, but no antenna can do all things equally well, under all circumstances. Whether you design and build your own antennas, or buy them and have them put up by a professional, you'll need propagation know-how for best results, both during the planning stages and while operating your station.

For station planning, this chapter contains detailed new information on elevation angles from transmitting locations throughout the world to important areas throughout the world. With this information in hand, you can design your own antenna installation for optimum capabilities possible within your budget. See the CD-ROM in back of this book.

The Nature of Radio Waves

You probably have some familiarity with the concept of electric and magnetic fields. A radio wave is a combination of both, with the energy divided equally between them. If the wave could originate at a point source in free space, it would spread out in an ever-growing sphere, with the source at the center. No antenna can be designed to do this, but the theoretical *isotropic antenna* is useful in explaining and measuring the performance of practical antennas we *can* build. It is, in fact, the basis for any discussion or evaluation of antenna performance.

Our theoretical spheres of radiated energy would expand very rapidly at the same speed as the propagation of light, approximately 186,000 miles or 300,000,000 meters per second. These values are close enough for practical purposes, and are used elsewhere in this book. If one wishes to be more precise, light propagates in a vacuum at the speed of 299.7925 meters per microsecond, and slightly slower in air.

The path of a *ray* traced from its source to any point on a spherical surface is considered to be a straight line—a radius of the sphere. An observer on the surface of the sphere would think of it as being flat, just as the Earth seems flat to us. A radio wave far enough from its source to appear flat is called a *plane wave*. From here on, we will be discussing primarily plane waves.

It helps to understand the radiation of electromagnetic energy if we visualize a plane wave as being made up of electric and magnetic forces, as shown in **Fig 1**. The nature of wave propagation is such that the electric and magnetic lines of force are always perpendicular. The plane containing the sets of crossed lines represents the wave front. The direction of travel is always perpendicular to the wave front; *forward* or *backward* is determined by the relative directions of the electric and magnetic forces.

The speed of travel of a wave through anything but a vacuum is always less than 300,000,000 meters per second. How much less depends on the medium. If it is air, the reduction in propagation speed can be ignored in most discussions of propagation at frequencies below 30 MHz. In the VHF range and higher, temperature and moisture content of the medium have increasing effects on the communication range, as will be discussed later. In solid insulating materials the speed is considerably less. In distilled water (a good insulator) the speed is $^1/_9$ that in free space. In good conductors the speed is so low that the opposing fields set up by the wave front occupy practically the same space as the wave itself, and thus cancel it out. This is the reason for "skin effect" in conductors at high frequencies, making metal enclosures good shields for electrical circuits working at radio frequencies.

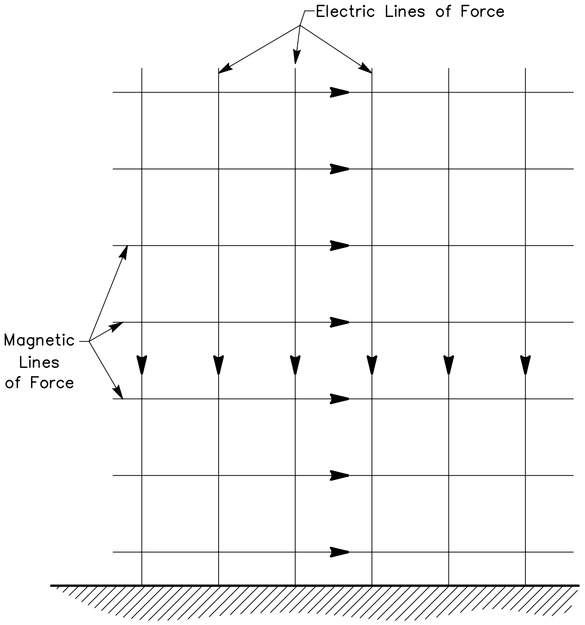

Fig 1—Representation of the magnetic and electric fields of a vertically polarized plane wave traveling along the ground. The arrows indicate instantaneous directions of the fields for a wave traveling perpendicularly out of the page toward the reader. Reversal of the direction of one set of lines reverses the direction of travel. There is no change in direction when both sets are reversed. Such a dual reversal occurs in fact once each half cycle.

Phase and Wavelength

Because the velocity of wave propagation is so great, we tend to ignore it. Only $^1/_7$ of a second is needed for a radio wave to travel around the world—but in working with antennas the *time* factor is extremely important. The wave concept evolved because an alternating current flowing in a wire (antenna) sets up moving electric and magnetic fields. We can hardly discuss antenna theory or performance at all without involving travel time, consciously or otherwise.

Waves used in radio communication may have frequencies from about 10,000 to several billion Hz. Suppose the frequency is 30 MHz. One cycle, or period, is completed in 1/30,000,000 second. The wave is traveling at 300,000,000 meters per second, so it will move only 10 meters during the time that the current is going through one complete period of alternation. The electromagnetic field 10 meters away from the antenna is caused by the current that was flowing one period earlier in time. The field 20 meters away is caused by the current that was flowing two periods earlier, and so on.

If each period of the current is simply a repetition of the one before it, the currents at corresponding instants in each period will be identical. The fields caused by those currents will also be identical. As the fields move outward from the antenna they become more thinly spread over larger and larger surfaces. Their amplitudes decrease with distance from the antenna but they do not lose their identity with respect to the instant of the period at which they were generated. They are, and they remain, *in phase*. In the example above, at intervals of 10 meters measured outward from the antenna, the phase of the waves at any given instant is identical.

From this information we can define both *wave front* and *wavelength*. Consider the wave front as an imaginary surface. On every part of this surface, the wave is in the same phase. The wavelength is the distance between two wave fronts having the same phase at any given instant. This distance must be measured perpendicular to the wave fronts along the line that represents the direction of travel. The abbreviation for wavelength is the Greek letter lambda, λ, which is used throughout this book.

The wavelength will be in the same length units as the velocity when the frequency is expressed in the same time units as the velocity. For waves traveling in free space (and near enough for waves traveling through air) the wavelength is

$$\lambda_{\text{meters}} = \frac{299.7925}{F(\text{MHz})} \qquad \text{(Eq 1)}$$

There will be few pages in this book where phase, wavelength and frequency do not come into the discussion. It is essential to have a clear understanding of their meaning in order to understand the design, installation, adjustment or use of antennas, matching systems or transmission lines in detail. In essence, *phase* means *time*. When something goes through periodic variations, as an alternating current does, corresponding instants in succeeding periods are *in phase*.

The points A, B and C in **Fig 2** are all in phase. They are corresponding instants in the current flow, at 1-λ intervals. This is a conventional view of a sine-wave alternating current, with time progressing to the right. It also represents a *snapshot* of the intensity of the traveling fields, if distance is substituted for time in the horizontal axis. The distance between A and B or between B and C is one wavelength. The field-intensity distribution follows the sine curve, in both amplitude and polarity, corresponding exactly to the time variations in the current that produced the fields. Remember that this is an *instantaneous* picture—the wave moves outward, much as a wave created by a rock thrown into water does.

Polarization

A wave like that in Fig 1 is said to be *polarized* in the direction of the electric lines of force. The polarization here is vertical, because the electric lines are perpendicular to the surface of the Earth. It is one of the laws of electromagnetics that electric lines touching the surface of a perfect conductor must do so perpendicularly, or else they would have to generate infinite currents in the conductor, an obvious impossibility. Most ground is a rather good conductor at frequencies below about 10 MHz, so waves at these

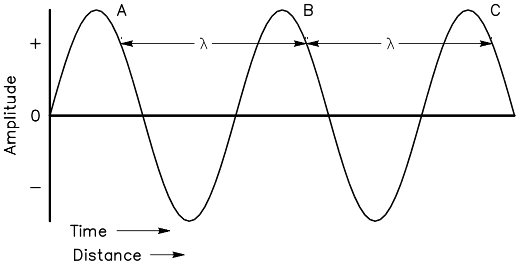

Fig 2—The instantaneous amplitude of both fields (electric and magnetic) varies sinusoidally with time as shown in this graph. Since the fields travel at constant velocity, the graph also represents the instantaneous distribution of field intensity along the wave path. The distance between two points of equal phase such as A-B and B-C is the length of the wave.

frequencies, traveling close to good ground, are mainly vertically polarized. Over partially conducting ground there may be a forward tilt to the wave front; the tilt in the electric lines of force increases as the energy loss in the ground becomes greater.

Waves traveling in contact with the surface of the Earth, called *surface waves*, are of little practical use in amateur communication. This is because as the frequency is raised, the distance over which they will travel without excessive energy loss becomes smaller and smaller. The surface wave is most useful at low frequencies and through the standard AM broadcast band. The surface wave will be covered later. At high frequencies a wave reaching a receiving antenna has had little contact with the ground, and its polarization is not necessarily vertical.

If the electric lines of force are horizontal, the wave is said to be *horizontally polarized*. Horizontally and vertically polarized waves may be classified generally under *linear polarization*. Linear polarization can be anything between horizontal and vertical. In free space, “horizontal” and “vertical” have no meaning, since the reference of the seemingly horizontal surface of the Earth has been lost.

In many cases the polarization of waves is not fixed, but rotates continually, somewhat at random. When this occurs the wave is said to be *elliptically polarized*. A gradual shift in polarization in a medium is known as *Faraday rotation*. For space communication, circular polarization is commonly used to overcome the effects of Faraday rotation. A circularly polarized wave rotates its polarization through 360° as it travels a distance of one wavelength in the propagation medium. The direction of rotation as viewed from the transmitting antenna defines the direction of circularity—right-hand (clockwise) or left-hand (counterclockwise). Linear and circular polarization may be considered as special cases of elliptical polarization.

Field Intensity

The energy from a propagated wave decreases with distance from the source. This decrease in strength is caused by the spreading of the wave energy over ever-larger spheres as the distance from the source increases.

A measurement of the strength of the wave at a distance from the transmitting antenna is its *field intensity*, which is synonymous with *field strength*. The strength of a wave is measured as the voltage between two points lying on an electric line of force in the plane of the wave front. The standard of measure for field intensity is the voltage developed in a wire that is 1 meter long, expressed as volts per meter. (If the wire were 2 meters long, the voltage developed would be divided by two to determine the field strength in volts per meter.)

The voltage in a wave is usually low, so the measurement is made in millivolts or microvolts per meter. The voltage goes through time variations like those of the current that caused the wave. It is measured like any other ac voltage—in terms of the effective value or, sometimes, the peak value. It is fortunate that in amateur work it is not necessary to measure actual field strength, as the equipment required is elaborate. We need to know only if an adjustment has been beneficial, so relative measurements are satisfactory. These can be made easily with home-built equipment.

Wave Attenuation

In free space, the field intensity of the wave varies inversely with the distance from the source, once you are in the radiating far field of the antenna. If the field strength at 1 mile from the source is 100 millivolts per meter, it will be 50 millivolts per meter at 2 miles, and so on. The relationship between field intensity and power density is similar to that for voltage and power in ordinary circuits. They are related by the impedance of free space, which is approximately 377 Ω. A field intensity of 1 volt per meter is therefore equivalent to a power density of

$$P = \frac{E^2}{Z} = \frac{1\,(\text{volt/m})^2}{377\,\Omega} = 2.65\,\text{mW/m}^2 \qquad \text{(Eq 2)}$$

Because of the relationship between voltage and power, the power density therefore varies with the square root of the field intensity, or inversely with the *square* of the distance. If the power density at 1 mile is 4 mW per square meter, then at a distance of 2 miles it will be 1 mW per square meter.

It is important to remember this so-called *spreading loss* when antenna performance is being considered. Gain can come only from narrowing the radiation pattern of an antenna, which concentrates the radiated energy in the desired direction. There is no “antenna magic” by which the total energy radiated can be increased.

In practice, attenuation of the wave energy may be much greater than the inverse-distance law would indicate. The wave does not travel in a vacuum, and the receiving antenna seldom is situated so there is a clear line of sight.

The Earth is spherical and the waves do not penetrate its surface appreciably, so communication beyond visual distances must be by some means that will bend the waves around the curvature of the Earth. These means involve additional energy losses that increase the path attenuation with distance, above that for the theoretical spreading loss in a vacuum.

Bending of Radio Waves

Radio waves and light waves are both propagated as electromagnetic energy. Their major difference is in wavelength, since radio-reflecting surfaces are usually much smaller in terms of wavelength than those for light. In material of a given electrical conductivity, long waves penetrate deeper than short ones, and so require a thicker mass for good reflection. Thin metal however is a good reflector of even long-wavelength radio waves. With poorer conductors, such as the Earth's crust, long waves may penetrate quite a few feet below the surface.

Reflection occurs at any boundary between materials of differing dielectric constant. Familiar examples with light are reflections from water surfaces and window panes. Both water and glass are transparent for light, but their dielectric constants are very different from that of air. Light waves, being very short, seem to bounce off both surfaces. Radio waves, being much longer, are practically unaffected by glass, but their behavior upon encountering water may vary, depending on the purity of that medium. Distilled water is a good insulator; salt water is a relatively good conductor.

Depending on their wavelength (and thus their frequency), radio waves may be reflected by buildings, trees, vehicles, the ground, water, ionized layers in the upper atmosphere, or at boundaries between air masses having different temperatures and moisture content. Ionospheric and atmospheric conditions are important in practically all communication beyond purely local ranges.

Refraction is the bending of a ray as it passes from one medium to another at an angle. The appearance of bending of a straight stick, where it enters water at an angle, is an example of light refraction known to us all. The degree of bending of radio waves at boundaries between air masses increases with the radio frequency. There is slight atmospheric bending in our HF bands. It becomes noticeable at 28 MHz, more so at 50 MHz, and it is much more of a factor in the higher VHF range and in UHF and microwave propagation.

Diffraction of light over a solid wall prevents total darkness on the far side from the light source. This is caused largely by the spreading of waves around the top of the wall, due to the interference of one part of the beam with another. The dielectric constant of the surface of the obstruction may affect what happens to our radio waves when they encounter terrestrial obstructions—but the radio *shadow area* is never totally dark. See Chapter 3, The Effects of Ground, for more information on diffraction.

The three terms, reflection, refraction and diffraction, were in use long before the radio age began. Radio propagation is nearly always a mix of these phenomena, and it may not be easy to identify or separate them while they are happening when we are on the air. This book tends to rely on the words *bending* and *scattering* in its discussions, with appropriate modifiers as needed. The important thing to remember is that any alteration of the path taken by energy as it is radiated from an antenna is almost certain to affect on-the-air results—which is why this chapter on propagation is included in an antenna book.

GROUND WAVES

As we have already seen, radio waves are affected in many ways by the media through which they travel. This has led to some confusion of terms in earlier literature concerning wave propagation. Waves travel close to the ground in several ways, some of which involve relatively little contact with the ground itself. The term *ground wave* has had several meanings in antenna literature, but it has come to be applied to any wave that stays close to the Earth, reaching the receiving point without leaving the Earth's lower atmosphere. This distinguishes the ground wave from a *sky wave*, which utilizes the ionosphere for propagation between the transmitting and receiving antennas.

The ground wave could be traveling in actual contact with the ground, as in Fig 1, where it is called the *surface wave*. Or it could travel directly between the transmitting and receiving antennas, when they are high enough so they can "see" each other—this is commonly called the *direct wave*. The ground wave also travels between the transmitting and receiving antennas by reflections or diffractions off intervening terrain between them. The ground-influenced wave may interact with the direct wave to create a vector-summed resultant at the receiver antenna.

In the generic term ground wave, we also will include ones that are made to follow the Earth's curvature by bending in the Earth's lower atmosphere, or *troposphere*, usually no more than a few miles above the ground. Often called *tropospheric bending*, this propagation mode is a major factor in amateur communications above 50 MHz.

THE SURFACE WAVE

The surface wave travels in contact with the Earth's surface. It can provide coverage up to about 100 miles in the standard AM broadcast band during the daytime, but attenuation is high. As can be seen from **Fig 3**, the attenuation increases with frequency. The surface wave is of little value in amateur communication, except possibly at 1.8 MHz. Vertically polarized antennas must be used, which tends to limit amateur surface-wave communication to where large vertical systems can be erected.

THE SPACE WAVE

Propagation between two antennas situated within line of sight of each other is shown in **Fig 4**. Energy traveling directly between the antennas is attenuated to about the same degree as in free space. Unless the antennas are very high or

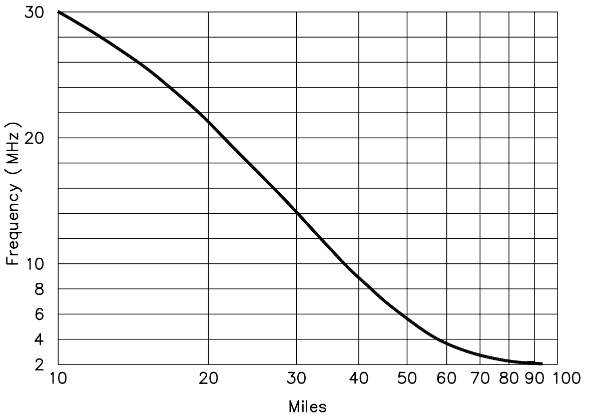

Fig 3—Typical HF ground-wave range as a function of frequency.

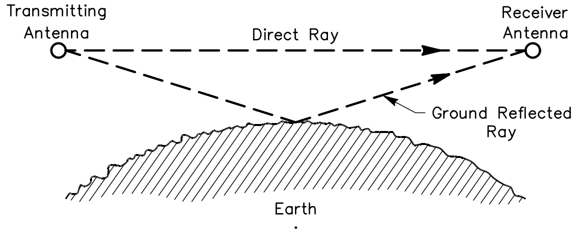

Fig 4—The ray traveling directly from the transmitting antenna to the receiving antenna combines with a ray reflected from the ground to form the space wave. For a horizontally polarized signal a reflection as shown here reverses the phase of the ground-reflected ray.

quite close together, an appreciable portion of the energy is reflected from the ground. This reflected wave combines with direct radiation to affect the actual signal received.

In most communication between two stations on the ground, the angle at which the wave strikes the ground will be small. For a horizontally polarized signal, such a reflection reverses the phase of the wave. If the distances traveled by both parts of the wave were the same, the two parts would arrive out of phase, and would therefore cancel each other. The ground-reflected ray in Fig 4 must travel a little further, so the phase difference between the two depends on the lengths of the paths, measured in wavelengths. The wavelength in use is important in determining the useful signal strength in this type of communication.

If the difference in path length is 3 meters, the phase difference with 160-meter waves would be only 360° × 3/160 = 6.8°. This is a negligible difference from the 180° shift caused by the reflection, so the effective signal strength over the path would still be very small because of cancellation of the two waves. But with 6-meter radio waves the phase length would be 360° × 3/6 = 180°. With the additional 180° shift on reflection, the two rays would add. Thus, the space wave is a negligible factor at low frequencies, but it can be increasingly useful as the frequency is raised. It is a dominant factor in local amateur communication at 50 MHz and higher.

Interaction between the direct and reflected waves is the principle cause of *mobile flutter* observed in local VHF communication between fixed and mobile stations. The flutter effect decreases once the stations are separated enough so that the reflected ray becomes inconsequential. The reflected energy can also confuse the results of field-strength measurements during tests on VHF antennas.

As with most propagation explanations, the space-wave picture presented here is simplified, and practical considerations dictate modifications. There is always some energy loss when the wave is reflected from the ground. Further, the phase of the ground-reflected wave is not shifted exactly 180°, so the waves never cancel completely. At UHF, ground-reflection losses can be greatly reduced or eliminated by using highly directive antennas. By confining the antenna pattern to something approaching a flashlight beam, nearly all the energy is in the direct wave. The resulting energy loss is low enough that microwave relays, for example, can operate with moderate power levels over hundreds or even thousands of miles. Thus we see that, while the space wave is inconsequential below about 20 MHz, it can be a prime asset in the VHF realm and higher.

VHF/UHF PROPAGATION BEYOND LINE OF SIGHT

From Fig 4 it appears that use of the space wave depends on direct line of sight between the antennas of the communicating stations. This is not literally true, although that belief was common in the early days of amateur communication on frequencies above 30 MHz. When equipment became available that operated more efficiently and after antenna techniques were improved, it soon became clear that VHF waves were actually being bent or scattered in several ways, permitting reliable communication beyond visual distances between the two stations. This was found true even with low power and simple antennas. The average communication range can be approximated by assuming the waves travel in straight lines, but with the Earth's radius increased by one-third. The distance to the *radio horizon* is then given as

$$D_{\text{miles}} = 1.415\sqrt{H_{\text{feet}}} \qquad \text{(Eq 3)}$$

or

$$D_{\text{km}} = 4.124\ \sqrt{H_{\text{meters}}} \qquad \text{(Eq 4)}$$

where H is the height of the transmitting antenna, as shown in **Fig 5**. The formula assumes that the Earth is smooth out to the horizon, so any obstructions along the path must be taken into consideration. For an elevated receiving antenna the communication distance is equal to D + D1, that is, the sum of the distances to the horizon of both

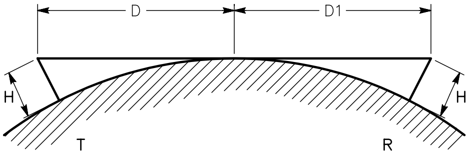

Fig 5—The distance D to the horizon from an antenna of height H is given by equations in the text. The maximum line-of-sight distance between two elevated antennas is equal to the sum of their distances to the horizon as indicated here.

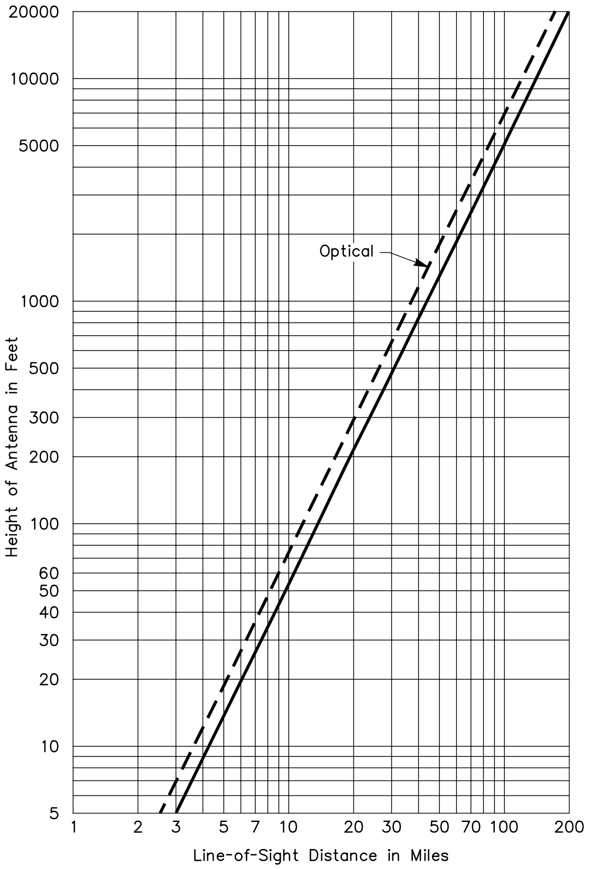

Fig 6—Distance to the horizon from an antenna of given height. The solid curve includes the effect of atmospheric retraction. The optical line-of-sight distance is given by the broken curve.

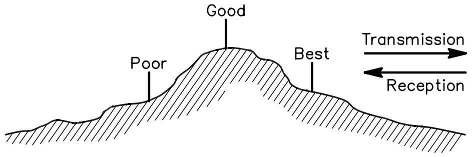

Fig 7—Propagation conditions are generally best when the antenna is located slightly below the top of a hill on the side facing the distant station. Communication is poor when there is a sharp rise immediately in front of the antenna in the direction of communication.

antennas. Radio horizon distances are given in graphic form in **Fig 6**. Two stations on a flat plain, one with its antenna 60 feet above ground and the other 40 feet, could be up to about 20 miles apart for strong-signal line-of-sight communication (11 + 9 mi). The terrain is almost never completely flat, however, and variations along the way may add to or subtract from the distance for reliable communication. Remember that energy is absorbed, reflected or scattered in many ways in nearly all communication situations. The formula or the chart will be a good guide for estimating the potential radius of coverage for a VHF FM repeater, assuming the users are mobile or portable with simple, omnidirectional antennas. Coverage with optimum home-station equipment, high-gain directional arrays, and SSB or CW is quite a different matter. A much more detailed method for estimating coverage on frequencies above 50 MHz is given later in this chapter.

For maximum use of the ordinary space wave it is important to have the antenna as high as possible above nearby buildings, trees, wires and surrounding terrain. A hill that rises above the rest of the countryside is a good location for an amateur station of any kind, and particularly so for extensive coverage on the frequencies above 50 MHz. The highest point on such an eminence is not necessarily the best location for the antenna. In the example shown in **Fig 7**, the hilltop would be a good site in all directions. But if maximum performance to the right is the objective, a point just below the crest might do better. This would involve a trade-off with reduced coverage in the opposite direction. Conversely, an antenna situated on the left side, lower down the hill, might do well to the left, but almost certainly would be inferior in performance to the right.

Selection of a home site for its radio potential is a complex business, at best. A VHF enthusiast dreams of the highest hill. The DX-minded HF ham may be more attracted by a dry spot near a salt marsh. A wide saltwater horizon, especially from a high cliff, just smells of DX. In shopping for ham radio real estate, a mobile or portable rig for the frequencies you're most interested in can provide useful clues.

ANTENNA POLARIZATION

If effective communication over long distances were the only consideration, we might be concerned mainly with radiation of energy at the lowest possible angle above the horizon. However, being engaged in a residential avocation often imposes practical restrictions on our antenna projects. As an example, our 1.8 and 3.5-MHz bands are used primarily for short-distance communication because they serve that purpose with antennas that are not difficult or expensive to put up. Out to a few hundred miles, simple wire antennas for these bands do well, even though their radiation is mostly at high angles above the horizon. Vertical systems might be better for long-distance use, but they require extensive ground systems for good performance.

Horizontal antennas that radiate well at low angles are most easily erected for 7 MHz and higher frequencies—horizontal wires and arrays are almost standard practice for work on 7 through 29.7 MHz. Vertical antennas, such as a single omnidirectional antenna of multiband design, are also used in this frequency range. An antenna of this type may be a good solution to the space problem for a city dweller on a small lot, or even for the resident of an apartment building.

High-gain antennas are almost always used at 50 MHz and higher frequencies, and most of them are horizontal. The principal exception is mobile communication with FM through repeaters, discussed in Chapter 17, Repeater Antenna Systems. The height question is answered easily for VHF enthusiasts—the higher the better.

The theoretical and practical effects of height above ground at HF are treated in detail in Chapter 3, The Effects of Ground. Note that it is the height in *wavelengths* that is important—a good reason to think in the metric system, rather than in feet and inches.

In working locally on any amateur frequency band, best results will be obtained with the same polarization at both stations, except on rare occasions when polarization shift is caused by terrain obstructions or reflections from buildings. Where such a shift is observed, mostly above 100 MHz or so, horizontal polarization tends to work better than vertical. This condition is found primarily on short paths, so it is not too important. Polarization shift may occur on long paths where tropospheric bending is a factor, but here the effect tends to be random. Long-distance communication by way of the ionosphere produces random polarization effects, so polarization matching is of little or no importance. This is fortunate for the HF mobile enthusiast, who will find that even his short, inductively loaded whips work very well at all distances other than local.

Because it responds to all plane polarizations equally, circular polarization may pay off on circuits where the arriving polarization is random, but it exacts a 3-dB penalty when used with a single-plane polarization of any kind. Circular systems find greatest use in work with orbiting satellites. It should be remembered that “horizontal” and “vertical” are meaningless terms in space, where the plane-Earth reference is lost.

Polarization Factors Above 50 MHz

In most VHF communication over short distances, the polarization of the space wave tends to remain constant. Polarization discrimination is high, usually in excess of 20 dB, so the same polarization should be used at both ends of the circuit. Horizontal, vertical and circular polarization all have certain advantages above 50 MHz, so there has never been complete standardization on any one of them.

Horizontal systems are popular, in part because they tend to reject man-made noise, much of which is vertically polarized. There is some evidence that vertical polarization shifts to horizontal in hilly terrain, more readily than horizontal shifts to vertical. With large arrays, horizontal systems may be easier to erect, and they tend to give higher signal strengths over irregular terrain, if any difference is observed.

Practically all work with VHF mobiles is now handled with vertical systems. For use in a VHF repeater system, the vertical antenna can be designed to have gain without losing the desired omnidirectional quality. In the mobile station a small vertical whip has obvious aesthetic advantages. Often a telescoping whip used for broadcast reception can be pressed into service for the 144-MHz FM rig. A car-top mount is preferable, but the broadcast whip is a practical compromise. Tests with at least one experimental repeater have shown that horizontal polarization can give a slightly larger service area, but mechanical advantages of vertical systems have made them the almost unanimous choice in VHF FM communication. Except for the repeater field, horizontal is the standard VHF system almost everywhere.

In communication over the Earth-Moon-Earth (EME) route the polarization picture is blurred, as might be expected with such a diverse medium. If the moon were a flat target, we could expect a 180° phase shift from the moon reflection process. But it is not flat. This plus the moon’s *libration* (its slow oscillation, as viewed from the Earth), and the fact that waves must travel both ways through the Earth’s entire atmosphere and magnetic field, provide other variables that confuse the phase and polarization issue. Building a huge array that will track the moon, and give gains in excess of 20 dB, is enough of a task that most EME enthusiasts tend to take their chances with phase and polarization problems. Where rotation of the element plane has been tried it has helped to stabilize signal levels, but it is not widely employed.

PROPAGATION OF VHF WAVES

The wave energy of VHF stations does not simply disappear once it reaches the radio horizon. It is scattered, but it can be heard to some degree for hundreds of miles, well beyond line-of-sight range. Everything on Earth, and in the regions of space up to at least 100 miles, is a potential forward-scattering agent.

Tropospheric scatter is always with us. Its effects are often hidden, masked by more effective propagation modes on the lower frequencies. But beginning in the VHF range, scatter from the lower atmosphere extends the reliable range markedly if we make use of it. Called *troposcatter*, this is what produces that nearly flat portion of the curves that will be described later (in the section where you can compute reliable VHF coverage range). With a decent station, you can consistently make troposcatter contacts out to 300 miles out on the VHF and even UHF bands, especially if you don’t mind weak signals and something less than 99% reliability. As long ago as the early 1950s, VHF enthusiasts found that VHF contests could be won with high power, big antennas and a good ear for signals deep in the noise. They still can.

Ionospheric scatter works much the same as the tropo version, except that the scattering medium is higher up, mainly the E region of the ionosphere but with some help from the D and F layers too. Ionospheric scatter is useful mainly above the MUF, so its useful frequency range depends on geography, time of day, season, and the state of the Sun. With near maximum legal power, good antennas and quiet locations, ionospheric scatter can fill in the skip zone with marginally readable signals scattered from ionized trails of meteors, small areas of random ionization, cosmic dust, satellites and whatever may come into the antenna patterns at 50 to 150 miles or so above the Earth. It's mostly an E-layer business, so it works all E-layer distances. Good antennas and keen ears help.

Transequatorial propagation (TE) was an amateur 50-MHz discovery in the years 1946-1947. Amateurs of all continents observed it almost simultaneously on three separate north-south paths. These amateurs tried to communicate at 50 MHz, even though the predicted MUF was around 40 MHz for the favorable daylight hours. The first success came at night, when the MUF was thought to be even lower. A remarkable research program inaugurated by amateurs in Europe, Cyprus, Zimbabwe and South Africa eventually provided technically sound theories to explain the then-unknown mode.

It has been known for years that the MUF is higher and less seasonally variable on transequatorial circuits, but the full extent of the difference was not learned until amateur work brought it to light. As will be explained in a later section in more detail, the ionosphere over equatorial regions is higher, thicker and more dense than elsewhere. Because of its more constant exposure to solar radiation, the equatorial belt has high nighttime-MUF possibilities. TE can often work marginally at 144 MHz, and even at 432 MHz on occasion. The potential MUF varies with solar activity, but not to the extent that conventional F-layer propagation does. It is a late-in-the-day mode, taking over about when normal F-layer propagation goes out.

The TE range is usually within about 4000 km (2500 miles) either side of the geomagnetic equator. The Earth's magnetic axis is tilted with respect to the geographical axis, so the TE belt appears as a curving band on conventional flat maps of the world. See **Fig 8**. As a result, TE has a different latitude coverage in the Americas from that from Europe to Africa. The TE belt just reaches into the southern continental US. Stations in Puerto Rico, Mexico and even the northern parts of South America encounter the mode more often than those in favorable US areas. It is no accident that TE was discovered as a result of 50-MHz work in Mexico City and Buenos Aires.

Within its optimum regions of the world, the TE mode extends the usefulness of the 50-MHz band far beyond that of conventional F-layer propagation, since the practical TE MUF runs around 1.5 times that of normal F_2. Both its seasonal and diurnal characteristics are extensions of what is considered normal for 50-MHz propagation. In that part of the Americas south of about 20° North latitude, the existence of TE affects the whole character of band usage, especially in years of high solar activity.

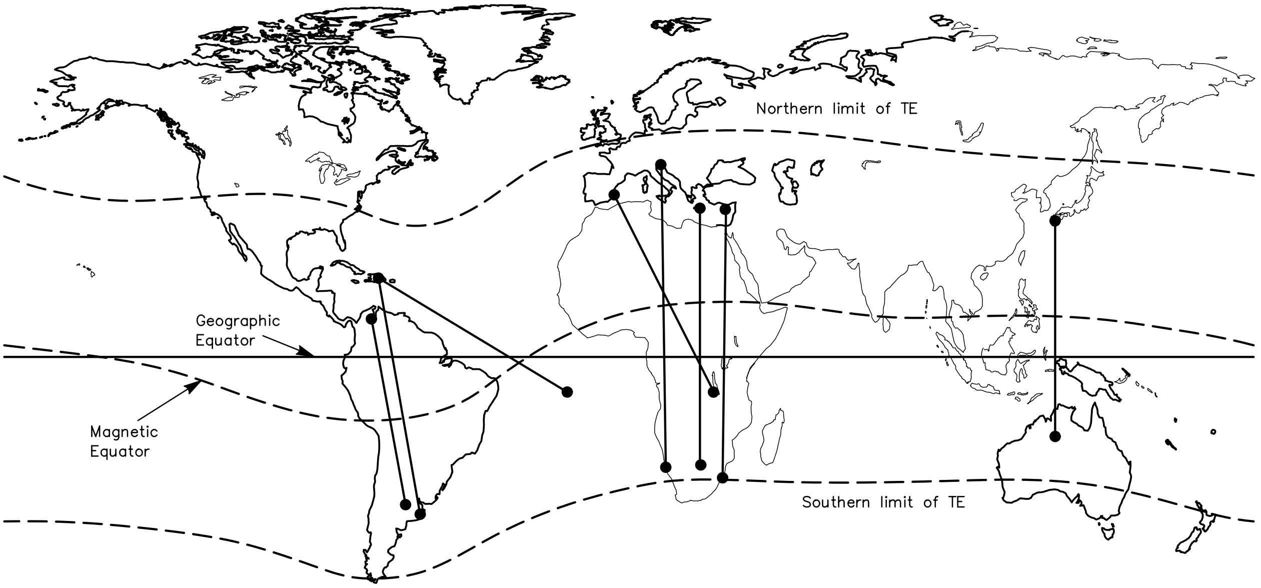

Fig 8—Transequatorial spread-F propagation takes place between stations equidistant across the geomagnetic equator. Distances up to 8000 km (5000 miles) are possible on 28 through 432 MHz. Note that the geomagnetic equator is considerably south of the geographic equator in the Western Hemisphere. (*Figure courtesy of The ARRL Handbook.*)

Weather Effects on VHF/UHF Tropospheric Propagation

Changes in the dielectric constant of the medium can affect propagation. Varied weather patterns over most of the Earth's surface can give rise to boundaries between air masses of very different temperature and humidity characteristics. These boundaries can be anything from local anomalies to air-circulation patterns of continental proportions.

Under stable weather conditions, large air masses can retain their characteristics for hours or even days at a time. See **Fig 9**. Stratified warm dry air over cool moist air, flowing slowly across the Great Lakes region to the Atlantic Seaboard, can provide the medium for east-west communication on 144 MHz and higher amateur frequencies over as much as 1200 miles. More common, however, are communication distances of 400 to 600 miles under such conditions.

A similar inversion along the Atlantic Seaboard as a result of a tropical storm air-circulation pattern may bring VHF and UHF openings extending from the Maritime Provinces of Canada to the Carolinas. Propagation across the Gulf of Mexico, sometimes with very high signal levels, enlivens the VHF scene in coastal areas from Florida to Texas. The California coast, from below the San Francisco Bay Area to Mexico, is blessed with a similar propagation aid during the warmer months. Tropical storms moving west, across the Pacific below the Hawaiian Islands, may provide a transpacific long-distance VHF medium. Amateurs first exploited this on 144, 220 and 432 MHz, in 1957. It has been used fairly often in the summer months since, although not yearly.

The examples of long-haul work cited above may occur infrequently, but lesser extensions of the minimum operating range are available almost daily. Under minimum conditions there may be little more than increased signal strength over paths that are workable at any time.

There is a diurnal effect in temperate climates. At sunrise the air aloft is warmed more rapidly than that near the Earth's surface, and as the Sun goes lower late in the day the upper air is kept warm, while the ground cools. In fair, calm weather such sunrise and sunset temperature inversions can improve signal strength over paths beyond line of sight as much as 20 dB over levels prevailing during the hours of high sun. The diurnal inversion may also extend the operating range for a given strength by some 20 to 50%. If you would be happy with a new VHF antenna, try it first around sunrise!

There are other short-range effects of local atmospheric and topographical conditions. Known as *subsidence*, the flow of cool air down into the bottom of a valley, leaving warm air aloft, is a familiar summer-evening pleasure. The daily inshore-offshore wind shift along a seacoast in summer sets up daily inversions that make coastal areas highly favored as VHF sites. Ask any jealous 144-MHz operator who lives more than a few miles inland.

Tropospheric effects can show up at any time, in any season. Late spring and early fall are the most favored periods, although a winter warming trend can produce strong and stable inversions that work VHF magic almost equal to that of the more familiar spring and fall events.

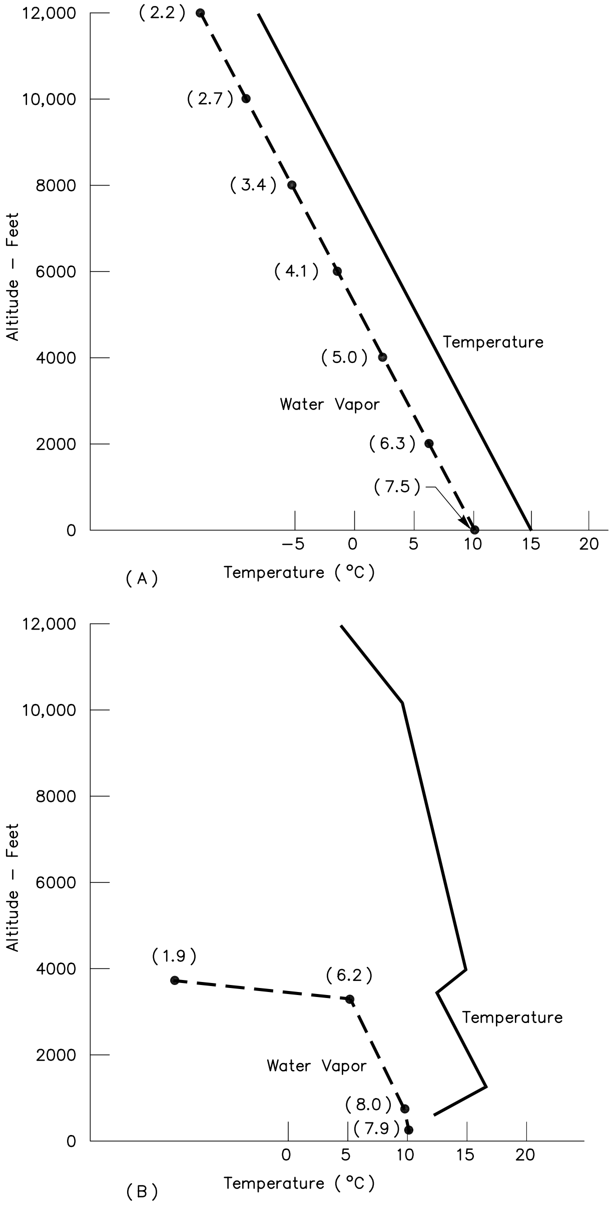

Fig 9—Upper air conditions that produce extended-range communication on the VHF bands. At the top is shown the US Standard Atmosphere temperature curve. The humidity curve (dotted) is what would result if the relative humidity were 70%, from ground level to 12,000 feet elevation. There is only slight refraction under this standard condition. At the bottom is shown a sounding that is typical of marked refraction of VHF waves. Figures in parentheses are the "mixing ratio" —grams of water vapor per kilogram of dry air. Note the sharp break in both curves at about 3500 feet.

Regions where the climate is influenced by large bodies of water enjoy the greatest degree of tropospheric bending. Hot, dry desert areas see little of it, at least in the forms described above.

Tropospheric Ducting

Tropospheric propagation of VHF and UHF waves can influence signal levels at all distances from purely local to something beyond 4000 km (2500 miles). The outer limits are not well known. At the risk of over simplification, we will divide the modes into two classes—extended local and long distance. This concept must be modified depending on the frequency under consideration, but in the VHF range the extended-local effect gives way to a form of propagation much like that of microwaves in a waveguide, called *ducting*. The transition distance is ordinarily somewhere around 200 miles. The difference lies in whether the atmospheric condition producing the bending is localized or continental in scope. Remember, we're concerned here with frequencies in the VHF range, and perhaps up to 500 MHz. At 10 GHz, for example, the scale is much smaller.

In VHF propagation beyond a few hundred miles, more than one weather front is probably involved, but the wave is propagated between the inversion layers and ground, in the main. On long paths over the ocean (two notable examples are California to Hawaii and Ascension Island to Brazil), propagation is likely to be between two atmospheric layers. On such circuits the communicating station antennas must be in the duct, or capable of propagating strongly into it. Here again, we see that the positions and radiation angles of the antennas are important. As with microwaves in a waveguide, the low-frequency limit for the duct is critical. In long-distance ducting it is also very variable. Airborne equipment has shown that duct capability exists well down into the HF region in the stable atmosphere west of Ascension Island. Some contacts between Hawaii and Southern California on 50 MHz are believed to have been by way of tropospheric ducts. Probably all contact over these paths on 144 MHz and higher bands is because of duct propagation.

Amateurs have played a major part in the discovery and eventual explanation of tropospheric propagation. In recent years they have shown that, contrary to beliefs widely held in earlier times, long-distance communication using tropospheric modes is possible to some degree on all amateur frequencies from 50 to at least 10,000 MHz.

RELIABLE VHF COVERAGE

In the preceding sections we discussed means by which amateur bands above 50 MHz may be used intermittently for communication far beyond the visual horizon. In emphasizing distance we should not neglect a prime asset of the VHF band: reliable communication over relatively short distances. The VHF region is far less subject to disruption of local communication than are frequencies below 30 MHz. Since much amateur communication is essentially local in nature, our VHF assignments can carry a great load, and such use of the VHF bands helps solve interference problems on lower frequencies.

Because of age-old ideas, misconceptions about the coverage obtainable in our VHF bands persist. This reflects the thoughts that VHF waves travel only in straight lines, except when the DX modes described above happen to be present. However, let us survey the picture in the light of modern wave-propagation knowledge and see what the bands above 50 MHz are good for on a day-to-day basis, ignoring the anomalies that may result in extensions of normal coverage.

It is possible to predict with fair accuracy how far you should be able to work consistently on any VHF or UHF band, provided a few simple facts are known. The factors affecting operating range can be reduced to graph form, as described in this section. The information was originally published in November 1961 *QST* by D. W. Bray, K2LMG (see the Bibliography at the end of this chapter).

To estimate your station's capabilities, two basic numbers must be determined: station gain and path loss. Station gain is made up of seven factors: receiver sensitivity, transmitted power, receiving antenna gain, receiving antenna height gain, transmitting antenna gain, transmitting antenna height gain and required signal-to-noise ratio. This looks complicated but it really boils down to an easily made evaluation of receiver, transmitter, and antenna performance. The other number, path loss, is readily determined from the nomogram, **Fig 10**. This gives path loss over smooth Earth, for 99% reliability.

For 50 MHz, lay a straightedge from the distance between stations (left side) to the appropriate distance at the right side. For 1296 MHz, use the full scale, right center. For 144, 222 and 432, use the dot in the circle, square or triangle, respectively. Example: At 300 miles the path loss for 144 MHz is 214 dB.

To be meaningful, the losses determined from this nomograph are necessarily greater than simple free-space path losses. As described in an earlier section, communication beyond line-of-sight distances involves propagation modes that increase the path attenuation with distance.

VHF/UHF Station Gain

The largest of the eight factors involved in station design is receiver sensitivity. This is obtainable from **Fig 11**, if you know the approximate receiver noise figure and transmission-line loss. If you can't measure noise figure, assume 3 dB for 50 MHz, 5 for 144 or 222, 8 for 432 and 10 for 1296 MHz, if you know your equipment is working moderately well. These noise figures are well on the conservative side for modern solid-state receivers.

Line loss can be taken from information in Chapter 24 for the line in use, if the antenna system is fed properly. Lay a straightedge between the appropriate points at either side of Fig 11, to find effective receiver sensitivity in decibels below 1 watt (dBW). Use the narrowest bandwidth that is practical for the emission intended, with the receiver you will be using. For CW, an average value for effective work

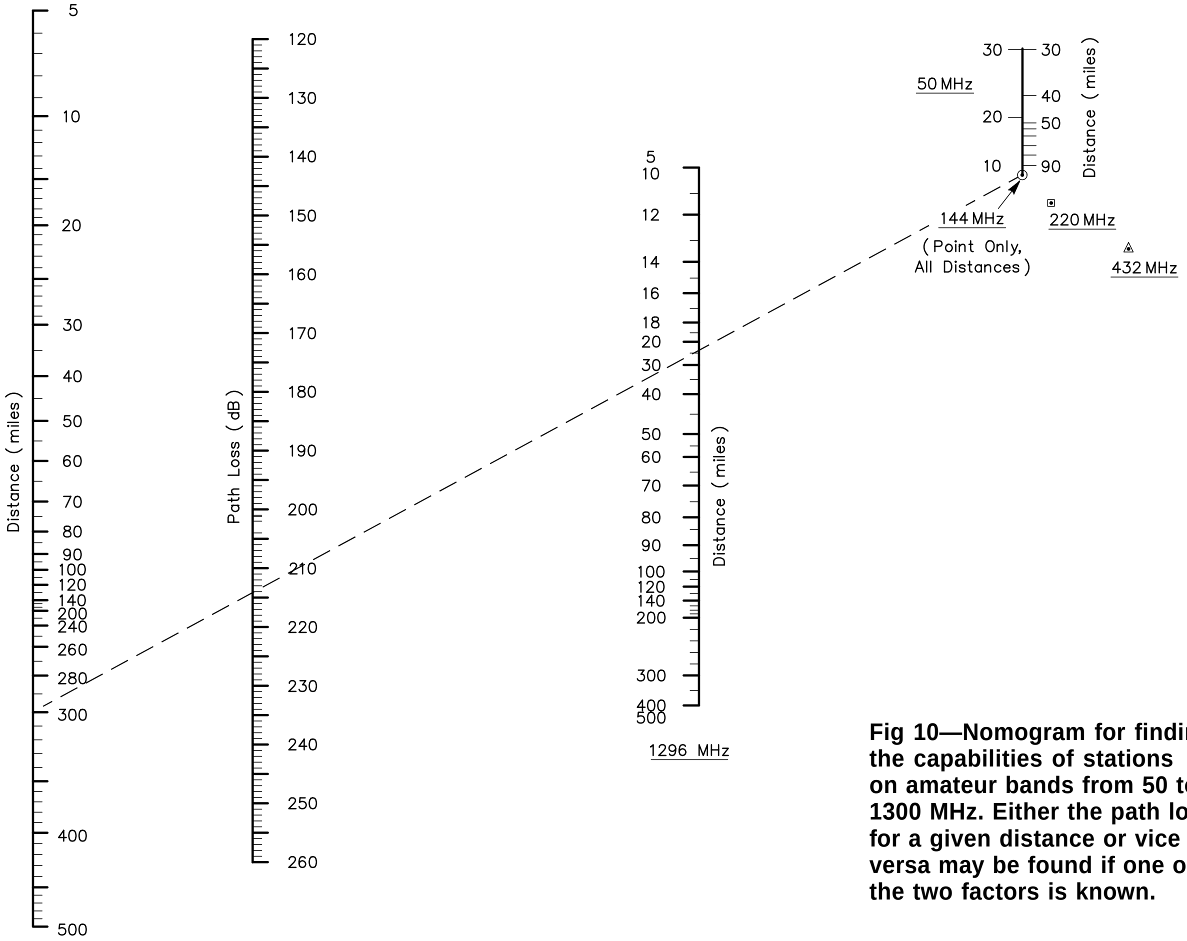

Fig 10—Nomogram for finding the capabilities of stations on amateur bands from 50 to 1300 MHz. Either the path loss for a given distance or vice versa may be found if one of the two factors is known.

is about 500 Hz. Phone bandwidth can be taken from the receiver instruction manual, but it usually falls between 2.1 to 2.7 kHz.

Antenna gain is next in importance. Gains of amateur antennas are often exaggerated. For well-designed Yagis the gain (over isotropic) run close to 10 times the boom length in wavelengths. (Example: A 24-foot Yagi on 144 MHz is 3.6 wavelengths long; 3.6 x 10 = 36, and 10 $\log_{10}$ 36 = 15.5 dBi in free space.) Add 3 dB for stacking, where used properly. Add 4 dB more for ground reflection gain. This varies in amateur work, but averages out near this figure.

We have one more plus factor—antenna height gain, obtained from **Fig 12**. Note that this is greatest for short distances. The left edge of the horizontal center scale is for 0 to 10 miles, the right edge for 100 to 500 miles. Height gain for 10 to 30 feet is assumed to be zero. For 50 feet the height gain is 4 dB at 10 miles, 3 dB at 50 miles, and 2 dB at 100 miles. At 80 feet the height gains are roughly 8, 6 and 4 dB for these distances. Beyond 100 miles the height gain is nearly uniform for a given height, regardless of distance.

Transmitter power output must be stated in decibels above 1 watt. If you have 500 W output, add 10 log (500/1), or 27 dB, to your station gain. The transmission-line loss must be subtracted from the station gain. So must the required signal-to-noise ratio. The information is based on CW work, so the additional signal needed for other modes must be subtracted. Use a figure of 3 dB for SSB. Fading losses must be accounted for also. It has been shown that for distances beyond 100 miles, the signal will vary plus or minus about 7 dB from the average level, so 7 dB must be subtracted from the station gain for high reliability. For distances under 100 miles, fading diminishes almost linearly with distance. For 50 miles, use –3.5 dB for fading.

What It All Means

Add all the plus and minus factors to get the station gain. Use the final value to find the distance over which you can expect to work reliably from the nomogram, Fig 10. Or work it the other way around: Find the path loss for the distance you want to cover from the nomogram and then figure out what station changes will be needed to overcome it.

The significance of all this becomes more obvious when we see path loss plotted against frequency for the various bands, as in **Fig 13**. At the left this is done for 50% reliability. At the right is the same information for 99% reliability.

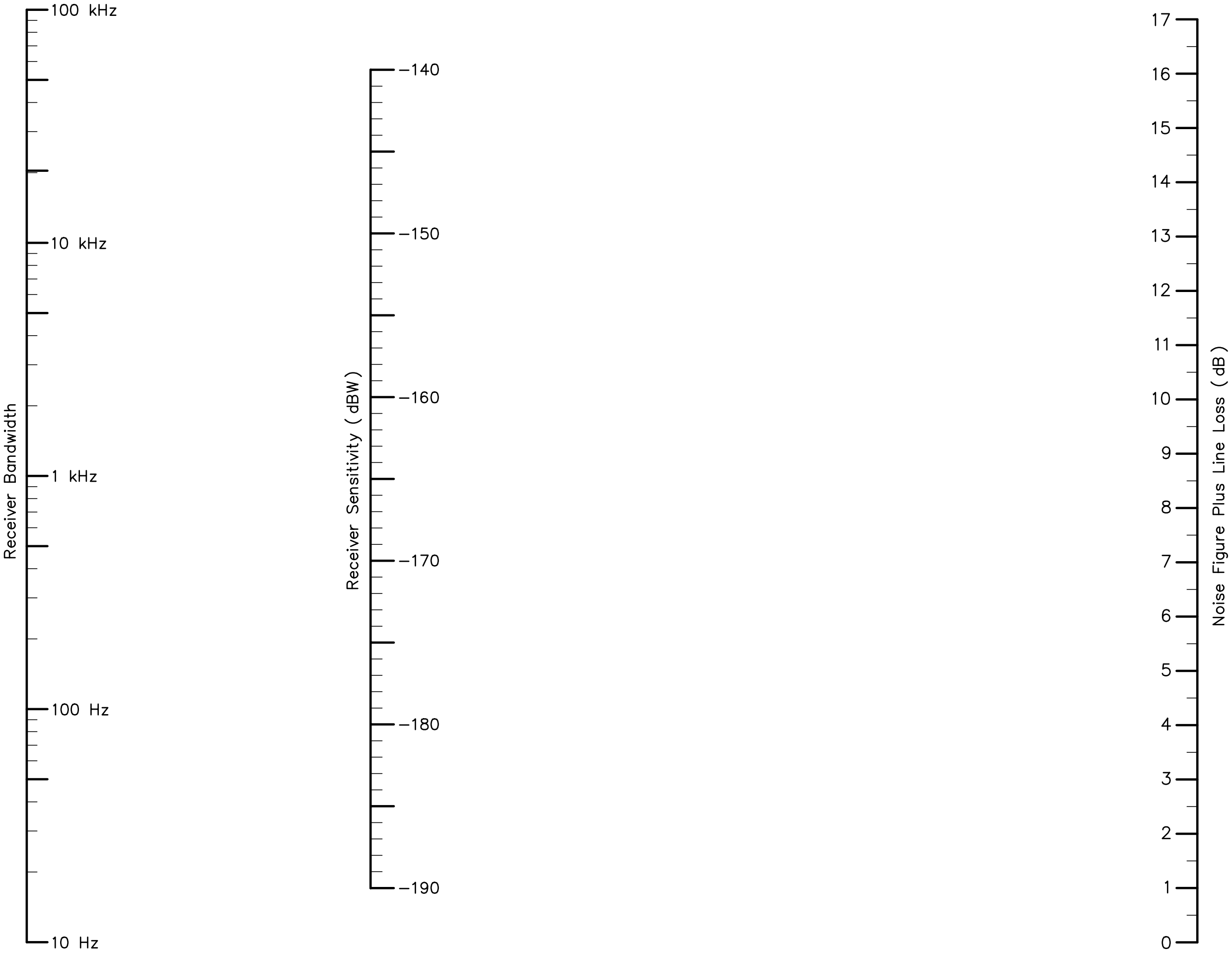

Fig 11—Nomogram for finding effective receiver sensitivity.

For near-perfect reliability, a path loss of 195 dB (easily encountered at 50 or 144 MHz) is involved in 100-mile communication. But look at the 50% reliability curve: The same path loss takes us out to well over 250 miles. Few amateurs demand near-perfect reliability. By choosing our times, and by accepting the necessity for some repeats or occasional loss of signal, we can maintain communication out to distances far beyond those usually covered by VHF stations.

Working out a few typical amateur VHF station setups with these curves will show why an understanding of these factors is important to any user of the VHF spectrum. Note that path loss rises very steeply in the first 100 miles or so. This is no news to VHF operators; locals are very strong, but stations 50 or 75 miles away are much weaker. What happens beyond 100 miles is not so well known to many of us.

From the curves of Fig 13, we see that path loss levels off markedly at what is the approximate limit of working range for average VHF stations using wideband modulation modes. Work out the station gain for a 50-W station with an average receiver and antenna, and you'll find that it comes out around 180 dB. This means you'd have about a 100-mile working radius in average terrain, for good but not perfect reliability. Another 10 dB may extend the range to as much as 250 miles. Just changing from AM phone to SSB and CW makes a major improvement in daily coverage on the VHF bands.

A bigger antenna, a higher one if your present beam is not at least 50 feet up, an increase in power to 500 W from 50 W, an improvement in receiver noise figure if it is presently poor—any of these things can make a big improvement in reliable coverage. Achieve all of them, and you will have very likely tripled your sphere of influence, thanks to that hump in the path-loss curves. This goes a long way toward explaining why using a 10-W packaged station with a small antenna, fun though it may be, does not begin to show what the VHF bands are really good for.

Terrain at VHF/UHF

The coverage figures derived from the above procedure are for average terrain. What of stations in mountainous country? Although an open horizon is generally desirable for the VHF station site, mountain country should not be

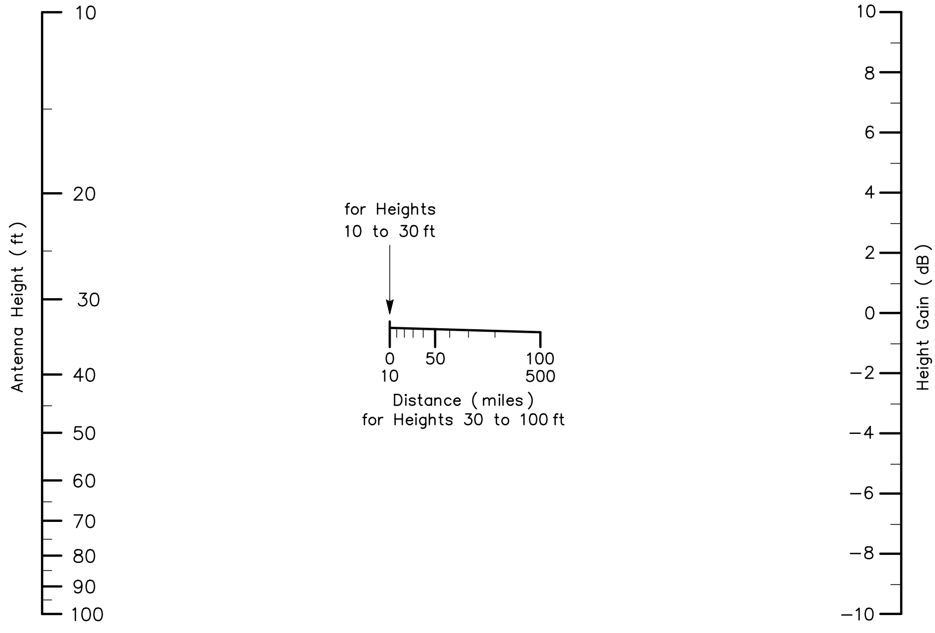

Fig 12—Nomogram for determining antenna-height gain.

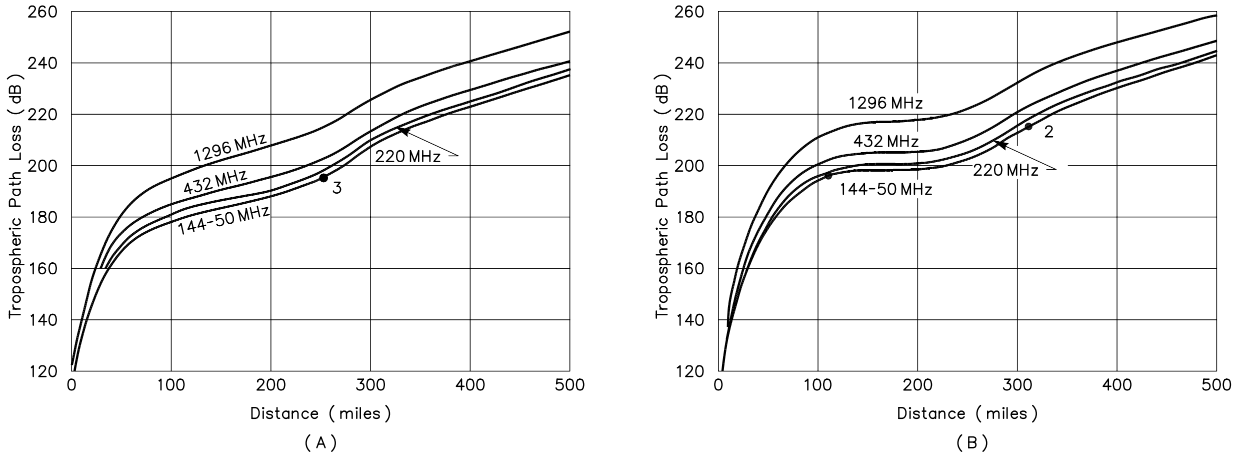

Fig 13—Path loss versus distance for amateur frequencies above 50 MHz. At A are curves for 50% of the time; at B, for 99%. The curves at A are more representative of Amateur Radio requirements.

considered hopeless. Help for the valley dweller often lies in the optical phenomenon known as *knife-edge diffraction*. A flashlight beam pointed at the edge of a partition does not cut off sharply at the partition edge, but is diffracted around it, partially illuminating the shadow area. A similar effect is observed with VHF waves passing over ridges; there is a shadow effect, but not a complete blackout. If the signal is strong where it strikes the mountain range, it will be heard well in the bottom of a valley on the far side. (See Chapter 3, The Effects of Ground, for a more thorough discussion of the theory of diffraction.)

This is familiar to all users of VHF communications equipment who operate in hilly terrain. Where only one ridge lies in the way, signals on the far side may be almost as good as on the near side. Under ideal conditions (a very high and sharp-edged obstruction near the midpoint of a long-enough path so that signals would be weak over average terrain), knife-edge diffraction may yield signals even stronger than would be possible with an open path.

The obstruction must project into the radiation patterns of the antennas used. Often mountains that look formidable to the viewer are not high enough to have an appreciable effect, one way or the other. Since the normal radiation pattern from a VHF array is several degrees above the horizontal, mountains that are less than about three degrees above the horizon, as seen from the antenna, are missed by the radiation from the array. Moving the mountains out of the way would have substantially no effect on VHF signal strength in such cases.

Rolling terrain, where obstructions are not sharp enough to produce knife-edge diffraction, still does not exhibit a complete shadow effect. There is no complete barrier to VHF propagation—only attenuation, which varies widely as the result of many factors. Thus, even valley locations are usable for VHF communication. Good antenna systems, preferably as high as possible, the best available equipment, and above all, the willingness and ability to work with weak signals may make outstanding VHF work possible, even in sites that show little promise by casual inspection.

AURORAL PROPAGATION

The Earth has a *magnetosphere* or magnetic field surrounding it. NASA scientists have described the magnetosphere as a sort of protective "bubble" around the Earth that shields us from the solar wind. Under normal circumstances, there are lots of electrons and protons moving in our magnetosphere, traveling along magnetic lines of force that trap them and keep them in place, neither bombarding the earth nor escaping into outer space.

Sudden bursts of activity on the Sun are sometimes accompanied by the ejection of charged particles, often from so-called Coronal Mass Ejections (CME) because they originate from the Sun's outer coronal region. These charged particles can interact with the magnetosphere, compressing and distorting it. If the orientation of the magnetic field contained in a large blast of solar wind or in a CME is aligned opposite to that of the Earth's magnetic field, the magnetic bubble can partially collapse and the particles normally trapped there can be deposited into the Earth's atmosphere along magnetic lines near the North or South poles. This produces a visible or radio *aurora*. An aurora is visible if the time of entry is after dark.

The visible aurora is, in effect, fluorescence at E-layer height—a curtain of ions capable of refracting radio waves in the frequency range above about 20 MHz. D-region absorption increases on lower frequencies during auroras. The exact frequency ranges depend on many factors: time, season, position with relation to the Earth's auroral regions, and the level of solar activity at the time, to name a few.

The auroral effect on VHF waves is another amateur discovery, this one dating back to the 1930s. The discovery came coincidentally with improved transmitting and receiving techniques then. The returning signal is diffused in frequency by the diversity of the auroral curtain as a refracting (scattering) medium. The result is a modulation of a CW signal, from just a slight burbling sound to what is best described as a "keyed roar." Before SSB took over in VHF work, voice was all but useless for auroral paths. A sideband signal suffers, too, but its narrower bandwidth helps to retain some degree of understandability. Distortion induced by a given set of auroral conditions increases with the frequency in use. 50-MHz signals are much more intelligible than those on 144 MHz on the same path at the same time. On 144 MHz, CW is almost mandatory for effective auroral communication.

The number of auroras that can be expected per year varies with the geomagnetic latitude. Drawn with respect to the Earth's magnetic poles instead of the geographical ones, these latitude lines in the US tilt upward to the northwest. For example, Portland, Oregon, is 2° farther north (geographic latitude) than Portland, Maine. The Maine city's geomagnetic latitude line crosses the Canadian border before it gets as far west as its Oregon namesake. In terms of auroras intense enough to produce VHF propagation results, Portland, Maine, is likely to see about 10 times as many per year. Oregon's auroral prospects are more like those of southern New Jersey or central Pennsylvania.

The antenna requirements for auroral work are mixed. High gain helps, but the area of the aurora yielding the best returns sometimes varies rapidly, so sharp directivity can be a disadvantage. So could a very low radiation angle, or a beam pattern very sharp in the vertical plane. Experience indicates that few amateur antennas are sharp enough in either plane to present a real handicap. The beam heading for maximum signal can change, however, so a bit of scanning in azimuth may turn up some interesting results. A very large array, such as is commonly used for moonbounce (with azimuth-elevation control), should be worthwhile.

The incidence of auroras, their average intensity, and their geographical distribution as to visual sightings and VHF propagation effects all vary to some extent with solar activity. There is some indication that the peak period for auroras lags the sunspot-cycle peak by a year or two. Like sporadic E, an unusual auroral opening can come at any season. There is a marked diurnal swing in the number of auroras. Favored times are late afternoon and early evening, late evening through early morning, and early afternoon, in about that order. Major auroras often start in early afternoon and carry through to early morning the next day.

HF Sky-Wave Propagation

As described earlier, the term *ground wave* is commonly applied to propagation that is confined to the Earth's lower atmosphere. Now we will use the term *sky wave* to describe modes of propagation that use the Earth's ionosphere. First, however, we must examine how the Earth's ionosphere is affected by the Sun.

THE ROLE OF THE SUN

Everything that happens in radio propagation, as with all life on Earth, is the result of radiation from the Sun. The variable nature of radio propagation here on Earth reflects the ever-changing intensity of ultraviolet and X-ray radiation, the primary ionizing agents in solar energy. Every day, solar nuclear reactions are turning hydrogen into helium, releasing an unimaginable blast of energy into space in the process. The total power radiated by the Sun is estimated at 4×10^{23} kW—that is, the number four followed by 23 zeroes. At its surface, the Sun creates about 60 *megawatts* per square meter. That is a very potent transmitter!

The Solar Wind

The Sun is constantly ejecting material from its surface in all directions into space, making up the so-called *solar wind*. Under relatively quiet solar conditions the solar wind blows around 200 miles per second—675,000 miles per hour—taking away about two million tons of solar material each second from the Sun. You needn't worry—the Sun is not going to shrivel up anytime soon. It's big enough that it will take many billions of years before that happens.

A 675,000 mile/hour wind sounds like a pretty stiff breeze, doesn't it? Lucky for us, the density of the material in the solar wind is very small by the time it has been spread out into interplanetary space. Scientists calculate that the density of the particles in the solar wind is less than that of the best vacuum they've ever achieved on Earth. Despite the low density of the material in the solar wind, the effect on the Earth, especially its magnetic field, is very significant.

Before the advent of sophisticated satellite sensors, the Earth's magnetic field was considered to be fairly simple, modeled as if the Earth were a large bar magnet. The axis of this hypothetical bar magnet is oriented about 11° away from the geographic north-south pole. We now know that the solar wind alters the shape of the Earth's magnetic field significantly, compressing it on the side facing the Sun and elongating it on the other side—in the same manner as the tail of a comet is stretched out radially in its orientation from the Sun. In fact, the solar wind is also responsible for the shape of a comet's tail.

Partly because of the very nature of the nuclear reactions going on at the Sun itself, but also because of variations in the speed and direction of the solar wind, the interactions between the Sun and our Earth are incredibly complex. Even scientists who have studied the subject for years do not completely understand everything that happens on the Sun. Later in this chapter, we'll investigate the effects of the solar wind when conditions on the Sun are *not* "quiet." As far as amateur HF skywave propagation is concerned, the results of disturbed conditions on the Sun are not generally beneficial.

Sunspots

The most readily observed characteristic of the Sun, other than its blinding brilliance, is its tendency to have grayish black blemishes, seemingly at random times and at random places, on its fiery surface. (See **Fig 14**.) There are written records of naked-eye sightings of *sunspots* in the Orient back to more than 2000 years ago. As far as is known, the first indication that sunspots were recognized as part of the Sun was the result of observations by Galileo in the early 1600s, not long after he developed one of the first practical telescopes.

Galileo also developed the projection method for observing the Sun safely, but probably not before he had suffered severe eye damage by trying to look at the Sun di-

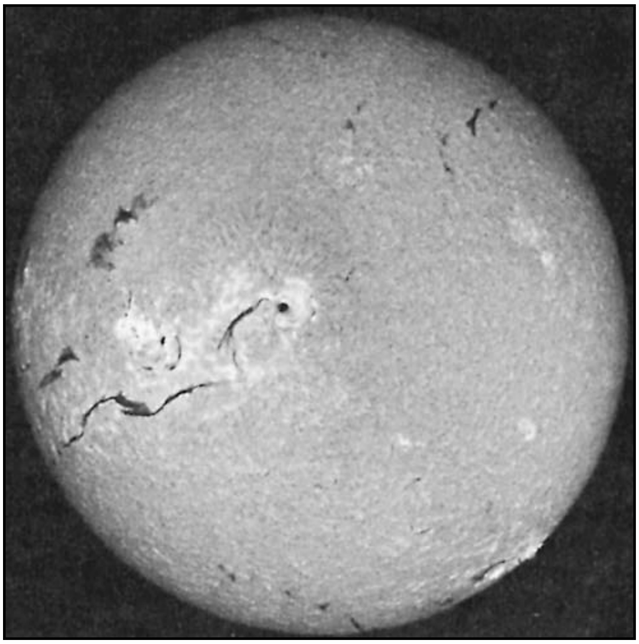

Fig 14—Much more than sunspots can be seen when the sun is viewed through selective optical filters. This photo was taken through a hydrogen-alpha filter that passes a narrow light segment at 6562 angstroms. The bright patches are active areas around and often between sunspots. Dark irregular lines are filaments of activity having no central core. Faint magnetic field lines are visible around a large sunspot group near the disc center. (*Photo courtesy of Sacramento Peak Observatory, Sunspot, New Mexico*).

rectly. (He was blind in his last years.) His drawings of sunspots, indicating their variable nature and position, are the earliest such record known to have been made. His reward for this brilliant work was immediate condemnation by church authorities of the time, which probably set back progress in learning more about the Sun for generations.

The systematic study of solar activity began about 1750, so a fairly reliable record of sunspot numbers goes back that far. (There are some gaps in the early data.) The record shows clearly that the Sun is always in a state of change. It never looks exactly the same from one day to the next. The most obvious daily change is the movement of visible activity centers (sunspots or groups thereof) across the solar disc, from east to west, at a constant rate. This movement was soon found to be the result of the rotation of the Sun, at a rate of approximately four weeks for a complete round. The average is about 27.5 days, the Sun's *synodic* rotation speed, viewed from the perspective of the Earth, which is also moving around the Sun in the same direction as the Sun's rotation.

Sunspot Numbers

Since the earliest days of systematic observation, our traditional measure of solar activity has been based on a count of sunspots. In these hundreds of years we have learned that the average number of spots goes up and down in cycles very roughly approximating a sine wave. In 1848, a method was introduced for the daily measurement of sunspot numbers. That method, which is still used today, was devised by the Swiss astronomer Johann Rudolph Wolf. The observer counts the total number of spots visible on the face of the Sun and the number of groups into which they are clustered, because neither quantity alone provides a satisfactory measure of sunspot activity. The observer's sunspot number for that day is computed by multiplying the number of groups he sees by 10, and then adding to this value the number of individual spots. Where possible, sunspot data collected prior to 1848 have been converted to this system.

As can readily be understood, results from one observer to another can vary greatly, since measurement depends on the capability of the equipment in use and on the stability of the Earth's atmosphere at the time of observation, as well as on the experience of the observer. A number of observatories around the world cooperate in measuring solar activity. A weighted average of the data is used to determine the *International Sunspot Number* or ISN for each day. (Amateur astronomers can approximate the determination of ISN values by multiplying their values by a correction factor determined empirically.)

A major step forward was made with the development of various methods for observing narrow portions of the Sun's spectrum. Narrowband light filters that can be used with any good telescope perform a visual function very similar to the aural function of a sharp filter added to a communications receiver. This enables the observer to see the actual area of the Sun doing the radiating of the ionizing energy, in addition to the sunspots, which are more a by-product than a cause. The photo of Fig 14 was made through such a filter. Studies of the ionosphere with instrumented probes, and later with satellites, manned and unmanned, have added greatly to our knowledge of the effects of the Sun on radio communication.

Daily sunspot counts are recorded, and monthly and yearly averages determined. The averages are used to see trends and observe patterns. Sunspot records were formerly kept in Zurich, Switzerland, and the values were known as *Zurich Sunspot Numbers*. They were also known as Wolf sunspot numbers. The official international sunspot numbers are now compiled at the Sunspot Index Data Center in Bruxelles, Belgium.

The yearly means (averages) of sunspot numbers from 1700 through 2002 are plotted in **Fig 15**. The cyclic nature of solar activity becomes readily apparent from this graph. The duration of the cycles varies from 9.0 to 12.7 years, but averages approximately 11.1 years, usually referred to as the 11-year solar cycle. The first complete cycle to be observed systematically began in 1755, and is numbered Cycle 1. Solar cycle numbers thereafter are consecutive. Cycle 23 began in October, 1996.

The "Quiet" Sun

For more than 60 years it has been well known that radio propagation phenomena vary with the number and size of sunspots, and also with the position of sunspots on the surface of the Sun. There are daily and seasonal variations in the Earth's ionized layers resulting from changes in the amount of ultraviolet light received from the Sun. The 11-year sunspot cycle affects propagation conditions because there is a direct correlation between sunspot activity and ionization.

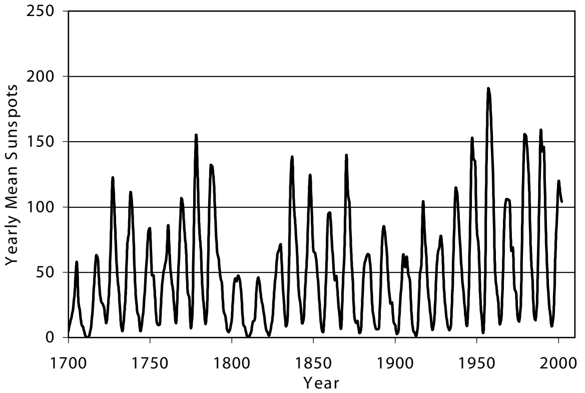

Fig 15—Yearly means of smoothed sunspot numbers from data for 1700 through 2002. This plot clearly shows that sunspot activity takes place in cycles of approximately 11 years duration. There is also a longer-term periodicity in this plot, the Gleissberg 88-year cycle. Cycle 1, the first complete cycle to be examined by systematic observation, began in 1755.

Activity on the surface of the Sun is changing continually. In this section we want to describe the activity of the so-called *quiet Sun*, meaning those times when the Sun is not doing anything more spectacular than acting like a “normal” thermonuclear ball of flaming gases. The Sun and its effects on Earthly propagation can be described in *statistical* terms—that’s what the 11-year solar cycle does. You may experience vastly different conditions on any particular day compared to what a long-term average would suggest.

An analogy may be in order here. Have you ever gazed into a relatively calm campfire and been surprised when suddenly a flaming ember or a large spark was ejected in your direction? The Sun can also do unexpected and sometimes very dramatic things. Disturbances of propagation conditions here on Earth are caused by disturbed conditions on the Sun. More on this later.

Individual sunspots may vary in size and appearance, or even disappear totally, within a single day. In general, larger active areas persist through several rotations of the Sun. Some active areas have been identified over periods up to about a year. Because of these continual changes in solar activity, there are continual changes in the state of the Earth’s ionosphere and resulting changes in propagation conditions. A short-term burst of solar activity may trigger unusual propagation conditions here on Earth lasting for less than an hour.

Smoothed Sunspot Numbers (SSN)

Sunspot data are averaged or smoothed to remove the effects of short-term changes. The sunspot values used most often for correlating propagation conditions are *Smoothed Sunspot Numbers* (SSN), often called 12-month running average values. Data for 13 consecutive months are required to determine a smoothed sunspot number.

Long-time users have found that the upper HF bands are reliably open for propagation only when the average number of sunspots is above certain minimum levels. For example, between mid 1988 to mid 1992 during Cycle 22, the SSN stayed higher than 100. The 10-meter band was open then almost all day, every day, to some part of the world. However, by mid 1996, few if any sunspots showed up on the Sun and the 10-meter band consequently was rarely open. Even 15 meters, normally a workhorse DX band when solar activity is high, was closed most of the time during the low point in Cycle 22. So far as propagation on the upper HF bands is concerned, the higher the sunspot number, the better the conditions.

Each smoothed number is an average of 13 monthly means, centered on the month of concern. The 1st and 13th months are given a weight of 0.5. A monthly mean is simply the sum of the daily ISN values for a calendar month, divided by the number of days in that month. We would commonly call this value a monthly average.

This may all sound very complicated, but an example should clarify the procedure. Suppose we wished to calculate the smoothed sunspot number for June 1986. We would require monthly mean values for six months prior and six months after this month, or from December 1985 through December 1986. The monthly mean ISN values for these months are

Dec	85	17.3	Jul	86	18.1
Jan	86	2.5	Aug	86	7.4
Feb	86	23.2	Sep	86	3.8
Mar	86	15.1	Oct	86	35.4
Apr	86	18.5	Nov	86	15.2
May	86	13.7	Dec	86	6.8
Jun	86	1.1			

First we find the sum of the values, but using only one-half the amounts indicated for the first and 13th months in the listing. This value is 166.05. Then we determine the smoothed value by dividing the sum by 12: 166.05/12 = 13.8. (Values beyond the first decimal place are not warranted.) Thus, 13.8 is the smoothed sunspot number for June 1986. From this example, you can see that the smoothed sunspot number for a particular month cannot be determined until six months afterwards.

Generally the plots we see of sunspot numbers are averaged data. As already mentioned, smoothed numbers make it easier to observe trends and see patterns, but sometimes this data can be misleading. The plots tend to imply that solar activity varies smoothly, indicating, for example, that at the onset of a new cycle the activity just gradually increases. But this is definitely not so! On any one day, significant changes in solar activity can take place within hours, causing sudden band openings at frequencies well above the MUF values predicted from smoothed sunspot number curves. The durations of such openings may be brief, or they may recur for several days running, depending on the nature of the solar activity.

Solar Flux

Since the late 1940s an additional method of determining solar activity has been put to use—the measurement of *solar radio flux*. The quiet Sun emits radio energy across a broad frequency spectrum, with a slowly varying intensity. Solar flux is a measure of energy received per unit time, per unit area, per unit frequency interval. These radio fluxes, which originate from atmospheric layers high in the Sun’s chromosphere and low in its corona, change gradually from day to day, in response to the activity causing sunspots. Thus, there is a degree of correlation between solar flux values and sunspot numbers.

One solar flux unit equals 10^{-22} joules per second per square meter per hertz. Solar flux values are measured daily at 2800 MHz (10.7 cm) at The Dominion Radio Astrophysical Observatory, Penticton, British Columbia, where daily data have been collected since 1991. (Prior to June 1991, the Algonquin Radio Observatory, Ontario, made the measurements.) Measurements are also made at other observatories around the world, at several frequencies. With some variation, the daily measured flux values increase with increasing frequency of measurement, to at least 15.4 GHz. The daily 2800 MHz Penticton value is sent to Boulder, Colorado, where it is incorporated into WWV propagation bulletins (see later section). Daily solar flux information can be of some value in determining current propagation conditions, as sunspot numbers on a given day do not relate directly to maximum usable frequency. Solar flux values are much more reliable for this purpose, when it is averaged over time, as will be discussed later in the section on computer-prediction programs.

Correlating Sunspot Numbers and Solar Flux Values

Based on historical data, an exact mathematical relationship does not exist to correlate sunspot data and solar flux values. Comparing daily values yields almost no correlation. Comparing monthly mean values (often called monthly averages) produces a degree of correlation, but the spread in data is still significant. This is indicated in **Fig 16**, a scatter diagram plot of monthly mean sunspot numbers versus the monthly means of solar flux values adjusted to one astronomical unit. (This adjustment applies a correction for differences in distance between the Sun and the Earth at different times of the year.)

A closer correlation exists when smoothed (12-month running average) sunspot numbers are compared with smoothed (12-month running average) solar flux values adjusted to one astronomical unit. A scatter diagram for smoothed data appears in **Fig 17**. Note how the plot points establish a better defined pattern in Fig 17. The correlation is still no better than a few percent, for records indicate a given smoothed sunspot number does not always correspond with the same smoothed solar flux value, and vice versa. **Table 1** illustrates some of the inconsistencies that exist in the historical data. Smoothed or 12-month running average values are shown.

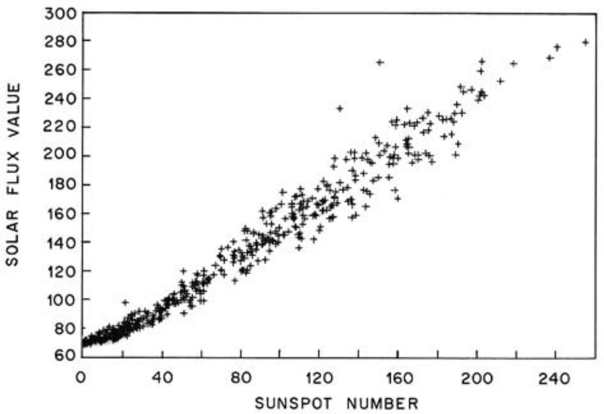

Fig 16—Scatter diagram or X-Y plot of monthly mean sunspot numbers and monthly mean 2800MHz solar flux values. Data values are from February 1947 through February 1987. Each "+" mark represents the intersection of data for a given month. If the correlation between sunspot number and flux values were consistent, all the marks would align to form a smooth curve.

Even though there is no precise mathematical relationship between sunspot numbers and solar flux values, it is helpful to have some way to convert from one to the other. The primary reason is that sunspot numbers are valuable as a long-term link with the past, but the great usefulness of solar flux values are their immediacy, and their direct bearing on our field of interest. (Remember, a smoothed sunspot number will not be calculated until six months after the fact.)

The following mathematical approximation has been derived to convert a smoothed sunspot number to a solar flux value.

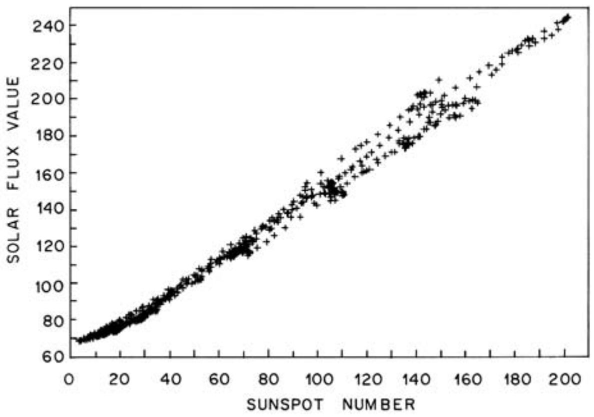

Fig 17—Scatter diagram of smoothed, or 12-month running averages, sunspot numbers versus 2800MHz solar flux values. The correlation of smoothed values is better than for monthly means, shown in Fig 16.

Table 1

Selected Historical Data Showing Inconsistent Correlation Between Sunspot Number and Solar Flux

Month	*Smoothed Sunspot Number*	*Smoothed Solar Flux Value*
May 1953	17.4	75.6
Sept 1965	17.4	78.5
Jul 1985	17.4	74.7
Jun 1969	106.1	151.4
Jul 1969	105.9	151.4
Dec 1982	94.6	151.4
Aug 1948	141.1	180.5
Oct 1959	141.1	192.3
Apr 1979	141.1	180.4
Aug 1981	141.1	203.3

$$F = 63.75 + 0.728\,S + 0.00089\,S^2 \qquad \text{(Eq 5)}$$

where

F = solar flux number

S = smoothed sunspot number

A graphic representation of this equation is given in **Fig 18**. Use this chart to make conversions graphically, rather than by calculations. With the graph, solar flux and sunspot number conversions can be made either way. The equation has been found to yield errors as great as 10% when historical data was examined. (Look at the August 1981 data in Table 1.) Therefore, conversions should be rounded to the nearest whole number, as additional decimal places are unwarranted. To make conversions from flux to sunspot number, the following approximation may be used.

$$S = 33.52\sqrt{85.12 + F} - 408.99 \qquad \text{(Eq 6)}$$

THE IONOSPHERE

There will be inevitable "gray areas" in our discussion of the Earth's atmosphere and the changes wrought in it by the Sun and by associated changes in the Earth's magnetic field. This is not a story that can be told in neat equations, or values carried out to a satisfying number of decimal places. The story must be told, and understood—with its well-known limitations—if we are to put up good antennas and make them serve us well.

Thus far in this chapter we have been concerned with what might be called our "above-ground living space"—that portion of the total atmosphere wherein we can survive without artificial breathing aids, or up to about 6 km (4 miles). The boundary area is a broad one, but life (and radio propagation) undergo basic changes beyond this zone. Somewhat farther out, but still technically within the Earth's atmosphere, the role of the Sun in the wave-propagation picture is a dominant one.

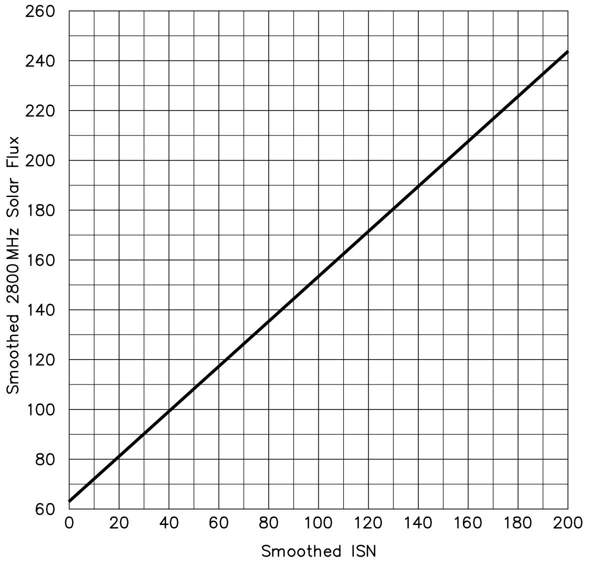

Fig 18—Chart for conversions between smoothed International Sunspot Numbers and smoothed 2800MHz solar flux. This curve is based on the mathematical approximation given in the text.

This is the *ionosphere*—a region where the air pressure is so low that free electrons and ions can move about for some time without getting close enough to recombine into neutral atoms. A radio wave entering this rarefied atmosphere, a region of relatively many free electrons, is affected in the same way as in entering a medium of different dielectric constant—its direction of travel is altered.

Ultraviolet (UV) radiation from the Sun is the primary cause of ionization in the outer regions of the atmosphere, the ones most important for HF propagation. However, there are other forms of solar radiation as well, including both hard and soft x-rays, gamma rays and extreme ultraviolet (EUV). The radiated energy breaks up, or *photoionizes*, atoms and molecules of atmospheric gases into electrons and positively charged ions. The degree of ionization does not increase uniformly with distance from the Earth's surface. Instead there are relatively dense regions (layers) of ionization, each quite thick and more or less parallel to the Earth's surface, at fairly well-defined intervals outward from about 40 to 300 km (25 to 200 miles). These distinct layers are formed due to complex photochemical reactions of the various types of solar radiation with oxygen, ozone, nitrogen and nitrous oxide in the rarefied upper atmosphere.

Ionization is not constant within each layer, but tapers off gradually on either side of the maximum at the center of the layer. The total ionizing energy from the Sun reaching a given point, at a given time, is never constant, so the height and intensity of the ionization in the various regions will also vary. Thus, the practical effect on long-distance communication is an almost continuous variation in signal level, related to the time of day, the season of the year, the distance between the Earth and the Sun, and both short-term and long-term variations in solar activity. It would seem from all this that only the very wise or the very foolish would attempt to predict radio propagation conditions, but it is now possible to do so with a fair chance of success. It is possible to plan antenna designs, particularly the choosing of antenna heights, to exploit known propagation characteristics.

Ionospheric Layer Characteristics

The lowest known ionized region, called the *D layer* (or the *D region*), lies between 60 and 92 km (37 to 57 miles) above the Earth. In this relatively low and dense part of the atmosphere, atoms broken up into ions by sunlight recombine quickly, so the ionization level is directly related to sunlight. It begins at sunrise, peaks at local noon and disappears at sundown. When electrons in this dense medium are set in motion by a passing wave, collisions between particles are so frequent that a major portion of their energy may be used up as heat, as the electrons and disassociated ions recombine.

The probability of collisions depends on the distance an electron travels under the influence of the wave—in other words, on the wavelength. Thus, our 1.8- and 3.5-MHz bands, having the longest wavelengths, suffer the highest daytime absorption loss as they travel through the D layer, particularly for waves that enter the medium at the lowest angles. At times of high solar activity (peak years of the solar cycle) even waves entering the D layer vertically suffer almost total energy absorption around midday, making these bands almost useless for communication over appreciable distances during the hours of high sun. They "go dead" quickly in the morning, but come alive again the same way in late afternoon. The diurnal (daytime) D-layer effect is less at 7 MHz (though still marked), slight at 14 MHz and inconsequential on higher amateur frequencies.

The D region is ineffective in bending HF waves back to Earth, so its role in long-distance communication by amateurs is largely a negative one. It is the principal reason why our frequencies up through the 7-MHz band are useful mainly for short-distance communication during the high-sun hours.

The lowest portion of the ionosphere useful for long-distance communication by amateurs is the *E layer* (also known as the *E region*) about 100 to 115 km (62 to 71 miles) above the Earth. In the E layer, at intermediate atmospheric density, ionization varies with the Sun angle above the horizon, but solar ultraviolet radiation is not the sole ionizing agent. Solar X-rays and meteors entering this portion of the Earth's atmosphere also play a part. Ionization increases rapidly after sunrise, reaches maximum around noon local time, and drops off quickly after sundown. The minimum is after midnight, local time. As with the D layer, the E layer absorbs wave energy in the lower-frequency amateur bands when the Sun angle is high, around mid-day. The other varied effects of E-region ionization will be discussed later.

Most of our long-distance communication capability stems from the tenuous outer reaches of the Earth's atmosphere known as the *F layer*. At heights above 100 miles, ions and electrons recombine more slowly, so the observable effects of the Sun develop more slowly. Also, the region holds its ability to reflect wave energy back to Earth well into the night. The *maximum usable frequency* (MUF) for F-layer propagation on east-west paths thus peaks just after noon at the midpoint, and the minimum occurs after midnight. We'll examine the subject of MUF in more detail later.

Judging what the F layer is doing is by no means that simple, however. The layer height may be from 160 to more than 500 km (100 to over 310 miles), depending on the season of the year, the latitudes, the time of day and, most capricious of all, what the Sun has been doing in the last few minutes and in perhaps the last three days before the attempt is made. The MUF between Eastern US and Europe, for example, has been anything from 7 to 70 MHz, depending on the conditions mentioned above, plus the point in the long-term solar-activity cycle at which the check is made.

During a summer day the F layer may split into two layers. The lower and weaker *F_1 layer*, about 160 km (100 miles) up, has only a minor role, acting more like the E than the *F_2 layer*. At night the F_1 region disappears and the F_2 region height drops somewhat.

Propagation information tailored to amateur needs is transmitted in all information bulletin periods by the ARRL Headquarters station, W1AW. Finally, solar and geomagnetic field data, transmitted hourly and updated eight times daily, are given in brief bulletins carried by the US Time Standard stations, WWV and WWVH, and also on Internet Web sites. But more on these services later.

Bending in the Ionosphere

The degree of bending of a wave path in an ionized layer depends on the density of the ionization and the length of the wave (inversely related to its frequency). The bending at any given frequency or wavelength will increase with increased ionization density and will bend away from the region of most-intense ionization. For a given ionization density, bending increases with wavelength (that is, it decreases with frequency).

Two extremes are thus possible. If the intensity of the ionization is sufficient and the frequency is low enough, even a wave entering the layer perpendicularly will be reflected back to Earth. Conversely, if the frequency is high enough or the ionization decreases to a low-enough density, a condition is reached where the wave angle is not affected enough by the ionosphere to cause a useful portion of the wave energy to return to the Earth. The frequency at which this occurs is called the vertical-incidence *critical frequency.* Each region in the ionosphere has a critical frequency associated with it, and this critical frequency will change depending on the date, time and state of the 11-year solar cycle.

Fig 19 shows a simplified graph of the electron density (in electrons per cubic meter) versus height in the ionosphere (in km) for a particular set of daytime and nighttime conditions. Free electrons are what return the signals you launch into the ionosphere back down to the Earth at some distance from your transmitter—The more free electrons in the ionosphere, the better propagation will be, particularly at higher frequencies.

Electron-density profiles are extremely complicated and vary greatly from one location to the next, depending on a bewildering variety of factors. Of course, this sheer variability makes it all the more interesting and challenging for hams to work each other on ionospheric HF paths!

The following discussion about sounding the ionosphere provides some background information about the scientific instruments used to decipher the highly intricate mechanisms behind ionospheric HF propagation.

SOUNDING THE IONOSPHERE

For many years scientists have *sounded* the ionosphere to determine its communication potential at various elevation angles and frequencies. The word "sound" stems from

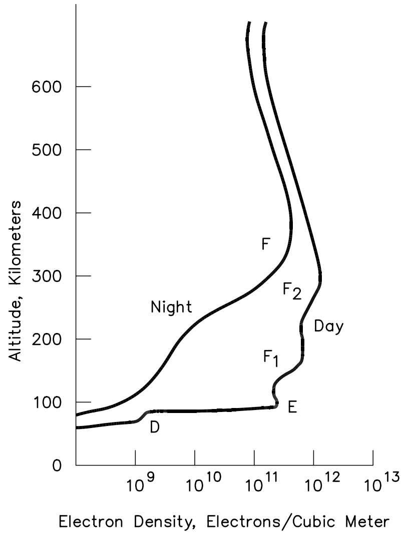

Fig 19—Typical electron densities for nighttime and daytime conditions in the various ionospheric regions.

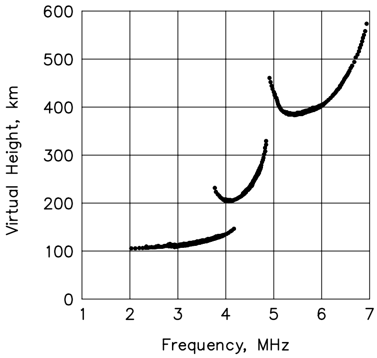

Fig 20—Very simplified ionogram from a vertical-incidence sounder. The lowest trace is for the E region; the middle for the F_1 and the upper trace for the F_2 region.

an old idea—one that has nothing to do with the audio waves that we can hear as "sounds." Long ago, sailors sounded the depths beneath their boats by dropping weighted ropes, calibrated in fathoms, into the water. In a similar fashion, the instrument used to probe the height of the ionosphere is called an *ionosonde*, or ionospheric sounder. It measures distances to various layers by launching a calibrated electronic signal directly up into the ionosphere.

Radar uses the same techniques as ionospheric sounding to detect targets such as airplanes. An ionosonde sends precisely timed pulses into the ionosphere over a range of MF and HF frequencies. The time of reception of an echo reflected from a region in the ionosphere is compared to the time of transmission. The time difference is multiplied by the speed of light to give the apparent distance that the wave has traveled from the transmitter to the ionosphere and back to the receiver. (It is an *apparent* or *virtual distance* because the speed of a wave slows very slightly in the ionosphere, just as the speed of propagation through any medium other than a vacuum slows down because of that medium.)

Another type of ionosonde sweeps the frequency of transmission, from low to high. This is called an "FM-CW," or more colorfully, a "chirp" sounder. Since a received echo takes time to travel from the transmitter up to the reflection point and then back again to the receiver, the echo will be at a lower frequency than the still-moving frequency of the transmitter. The frequency difference is an indication of the height of the echo's reflection off the various ionospheric layers.

Vertical-Incidence Sounders

Most ionosondes are *vertical-incidence sounders*, bouncing their signals perpendicularly off the various ionized regions above it by launching signals straight up into the ionosphere. The ionosonde frequency is swept upwards until echos from the various ionospheric layers disappear, meaning that the critical frequencies for those layers have been exceeded, causing the waves to disappear into space.

Fig 20 shows a highly simplified ionogram for a typical vertical-incidence sounder. The echos at the lowest height at the left-hand side of the plot show that the E region is about 100 km high. The F_1 region shown in the middle of the plot varies from about 200 to 330 km in this example, and the F_2 region ranges from just under 400 km to almost 600 km in height. You can see that the F_1 and F_2 ionospheric regions take a "U" shape, indicating that the electron density varies throughout the layer. In this example, the peak in electron density is at a virtual height of the F_2 region of about 390 km, the lowest point in the F_2 curve.

Scientists can derive a lot of information from a vertical-incidence ionogram, including the critical frequencies for each region, where raising the frequency any higher causes the signals to disappear into space. In Fig 20, the E-region critical frequency (abbreviated f_oE) is about 4.1 MHz. The F_1-region critical frequency (abbreviated f_oF_1) is 4.8 MHz. The F2-region critical frequency (abbreviated f_oF_2) is this simplified diagram is 6.8 MHz.

The observant reader may well be wondering what the subscripted "o" in the abbreviations f_oE, f_oF_1 and f_oF_2 mean. The abbreviation "o" means "ordinary." When an electromagnetic wave is launched into the ionosphere, the Earth's magnetic field splits the wave into two independent waves—the "ordinary" (o) and the "extraordinary" (x) components. The ordinary wave reaches the same height in the ionosphere whether the Earth's magnetic field is present or not, and hence is called "ordinary." The extraordinary wave, however, is greatly affected by the presence of the Earth's magnetic field, in a very complex fashion.

Fig 21 shows an example of an actual ionogram from the vertical Lowell Digisonde at Millstone Hill in Massa-

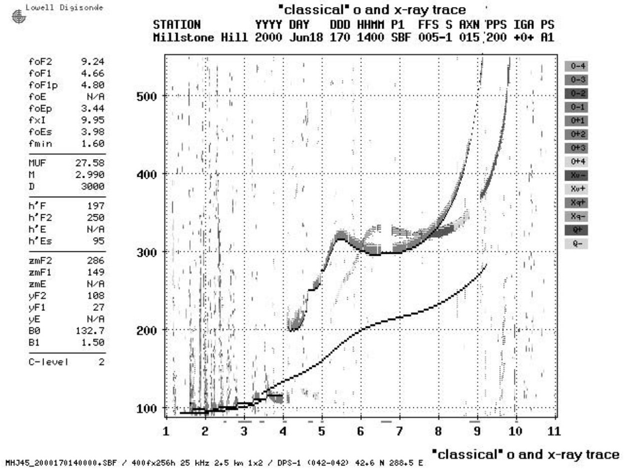

Fig 21—Actual vertical-incidence ionogram from the Lowell Digisonde, owned and operated at Millstone Hill in Massachusetts by MIT. The ordinary (o) and extraordinary (x) traces are shown for heights greater than about 300 km. At the upper left are listed the computer-determined ionospheric parameters, such as f_oF_2 of 9.24 MHz and f_oF_1 at 4.66 MHz.

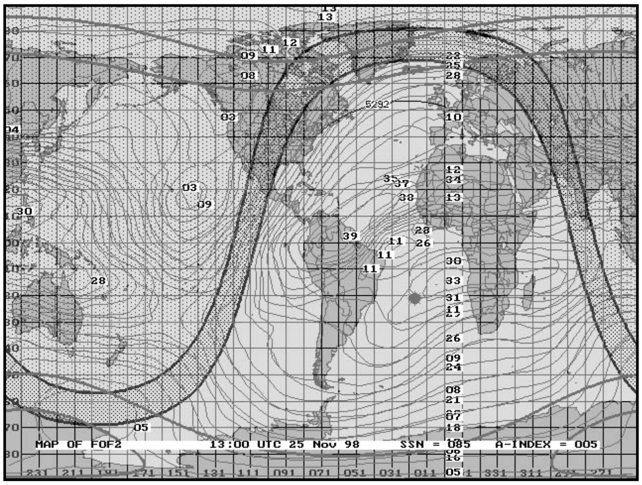

Fig 22—Computer simulation of the f_oF_2 contours for 25 November 1998, for an SSN of 85 and a quiet planetary A_p index of 5. Note the two regions of high f_oF_2 values off the upper and lower west coast of Africa. These are the "equatorial anomalies," regions of high electronic density in the F_2 region that often allow chordal-hop north-south propagation. See also Fig 8. (*PropLab Pro simulation, courtesy of Solar Terrestrial Dispatch.*)

chusetts, owned and operated by the Massachusetts Institute of Technology. This ionogram was made on June 18, 2000, and shows the conditions during a period of very high solar activity. The black-and-white rendition in Fig 21 of the actual color ionogram unfortunately loses some information. However, you can still see that a real ionogram is a lot more complicated looking than the simple simulated one in Fig 20.

The effects of noise and interference from other stations are shown by the many speckled dots appearing in the ionogram. The critical frequencies for various ionospheric layers are listed numerically at the left-hand side of the plot and the signal amplitudes are color-coded by the color bars at the right-hand side of the plot. The x-axis is the frequency, ranging from 1 to 11 MHz.

Compared to the simplified ionogram in Fig 20, Fig 21 shows another trace that appears on the plot from about 5.3 to 9.8 MHz, a trace shifted to the right of the darker ordinary trace. This second trace is the extraordinary (x) wave mentioned above. Since the x and o waves are created by the Earth's magnetic field, the difference in the ordinary and extraordinary traces is about $^1/_2$ the *gyro frequency*, the frequency at which an electron will spiral down a particular magnetic field line. The electron gyro frequency is different at various places around the Earth, being related to the Earth's complicated and changing magnetic field. The extraordinary trace always has a higher critical frequency than the ordinary trace on a vertical-incidence ionogram, and it is considerably weaker than the ordinary trace, especially at frequencies below about 4 MHz because of heavy absorption.

The Big Picture Overhead

There are about 150 vertical-incidence ionosondes around the world. Ionosondes are located on land, even on a number of islands. There are gaps in sounder coverage, however, mainly over large expanses of open ocean. The compilation of all available vertical-incidence data from the worldwide network of ionospheric sounders results in global f_oF_2 maps, such as the map shown in **Fig 22**, a simulation from the highly sophisticated *PropLab Pro* computer program.

This simulation is for 1300 UTC, several hours after East Coast sunrise on Nov 25, 1998, with a high level of solar activity of 85 and a planetary A_p index of 5, indicating calm geomagnetic conditions. The contours of f_oF_2 peak over the ocean off the west coast of Africa at 38 MHz. Over the southern part of Africa, f_oF_2 peaks at 33 MHz.

These two "humps" in f_oF_2 form what is known as the "equatorial anomaly" and are caused by upwelling "fountains" of high electron concentration located in daylight areas about ±20° from the Earth's magnetic dip equator. The equatorial anomaly is important in transequatorial propagation. Those LU stations in Argentina that you can hear on 28 MHz from the US in the late afternoon, even during low portions of the solar cycle when other stations to the south are not coming through, are benefiting from transequatorial propagation, sometimes called "chordal hop" propagation, because signals going through this area remain in the ionosphere without lossy intermediate hops to the ground.

From records of f_oF_2 profiles, the underlying electron densities along a path can be computed. And from the electron density profiles computerized "ray tracing" may be done throughout the ionosphere to determine how a wave propagates from a transmitter to a particular receiver location. *PropLab Pro* can do complex ray tracings that explicitly include the effect of the Earth's magnetic field, even taking into effect ionospheric stormy conditions.

Oblique-Angle Ionospheric Sounding

A more elaborate form of ionospheric sounder is the *oblique ionosonde*. Unlike a vertical-incidence ionospheric sounder, which sends its signals directly overhead, an oblique sounder transmits its pulses obliquely through the ionosphere, recording echos at a receiver located some distance from the transmitter. The transmitter and distant receiver are precisely coordinated in GPS-derived time in modern oblique sounders.

Interpretation of ionograms produced by oblique sounders is considerably more difficult than for vertically incident ones. An oblique ionosonde purposely transmits over a continuous range of elevation angles simultaneously and hence cannot give explicit information about each elevation angle it launches. **Fig 23** shows a typical HF oblique-sounder ionogram for the path from Hawaii to California in March of 1973, during a period of medium-level sunspot activity. The y-axis is calibrated in time delay, in milliseconds. Longer distances involve longer time delays between the start of a transmitted pulse and the reception of the echo. The x-axis in this ionogram is the frequency, just like a vertical-incidence ionogram. Note that the frequency range for this plot extends to 32 MHz, while vertical-incidence ionograms usually don't sweep higher than about 12 MHz.

Six possible modes are shown in this ionogram: $1F_2$, $2F_2$, $3F_2$, $4F_2$ and $5F_2$. These involve multiple modes of propagation (commonly called *hops*) between the ionosphere and reflections from the Earth. For example, at an operating frequency of 14 MHz, there are three modes open during the mid-morning: $2F_2$, $3F_2$ and $4F_2$. We'll discuss multiple hops later in more detail.

The lowest mode, $1F_2$ in Fig 23, employs a single F_2 hop to cover the 3900-km long path from Hawaii to California, but it is only open on 28-MHz. (Note that 3900 km is close to the maximum possible single-hop length for the F_2 region. We'll look at this in more detail later too.) In general, each mode that involves more than a single hop is weaker than a single hop. For example, you can see that the received $5F_2$ echo is weak and broken up because of the accumulation of losses at each ground-level reflection in its five hops, with absorption in the ionosphere all along its complicated path to the receiver.

The trace labeled "FOT" is the *frequency of optimum traffic*, considered the most reliable frequency for communications on this particular circuit and date/time. In this example, the FOT would be near the 21-MHz amateur band.

Another interesting point in Fig 23 is labeled "High Angle Ray." This refers to the Pedersen ray. Before we go into more details about the Pedersen high-angle wave, we need to examine how launch angles affect the way waves are propagated through the ionosphere.

Fig 24 shows a highly simplified situation, with a single ionospheric layer and a smooth Earth. This illustrates several important facts about antenna design for long-distance communication. In Fig 24, Wave #1 is launched at the lowest elevation angle (that is, most nearly horizontal to the horizon). Wave #1 manages to travel from the transmitter to the receiving location at point C in a single hop.

Wave #2 is launched at a higher elevation angle than Wave #1, and penetrates further into the ionospheric layer before it is refracted enough to return to Earth. The ground distance covered from the transmitter to point B is less for

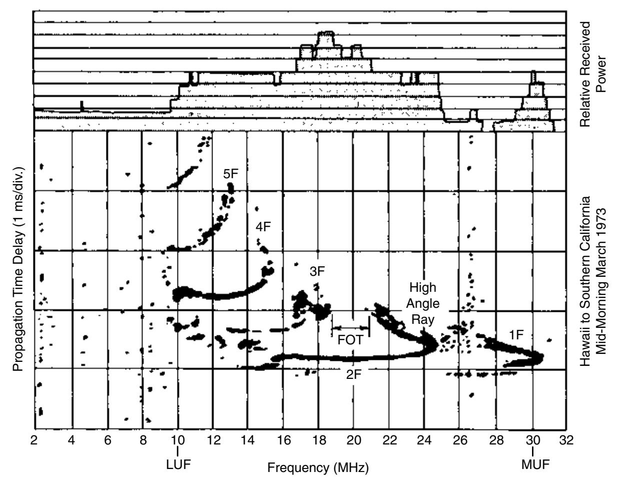

Fig 23—HF oblique-sounder ionogram. This is a typical chirpsounder measurement on a 2500-mile path from Hawaii to southern California during midmorning in March at a medium level of solar activity. Six possible modes (hops) are shown. The "FOT" is the frequency of optimum traffic, considered most reliable for this path/time.

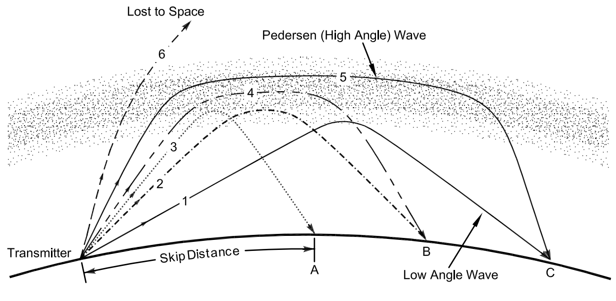

Fig 24—Very simplified smooth-Earth/ionosphere diagram showing how the ground range from transmitter to receiver can vary as the elevation angle is gradually raised. The Pedersen wave, launched at a relatively high angle, has the same ground range as the low-angle wave #1, but is weaker because it travels for a long distance in the ionosphere.

Wave #2 than for lower-angle Wave #1. Wave #3 is launched at a still-higher elevation angle. Like Wave #2 before it, Wave #3 penetrates further into the ionosphere and covers less ground downrange than #2.

Now, we see something very interesting happening for Wave #4, whose launch elevation angle is still higher than #3. Wave #4 penetrates even higher into the ionosphere than #3, reaching the highest level of ionization in our theoretical ionospheric layer, where it is finally refracted sufficiently to bend down to Earth. Wave #4 manages to arrive at the same point B as Wave #2, which was launched at a much lower elevation angle.

In other words, in the sequence from #1 to #3 we have been continually *increasing* the elevation launch angle and the ground range covered from the transmitter to the return of the signal back to Earth has been continually *decreasing*. However, starting with Wave #4, the ground range starts to *increase* with increased elevation angle. A further increase in the elevation angle causes Wave #5 to travel for an even longer distance through the ionosphere, exiting finally at point C, the same ground distance as lowest-angle Wave #1.

Finally, increasing the elevation angle even further results in Wave #6 being lost to outer space because the ionization in the layer is insufficient to bend the wave back to Earth. In other words, Wave #6 has exceeded the *critical angle* for this hypothetical ionospheric layer and this frequency of operation.

Both Waves #4 and #5 in Fig 24 are called "high-angle" or Pedersen waves. Because Wave #5 has traveled a greater distance through the ionosphere, it is always weaker than Wave #1, the one launched at the lowest elevation angle. Pedersen waves are usually not very stable, since small changes in elevation angle can result in large changes in the ground range that these high-angle waves cover.

SKIP DISTANCE

Fig 24 shows that we can communicate with the point on the Earth labeled "A" (where Wave #3 arrives), but not any closer to our transmitter site. When the critical angle is less than 90° (that is, directly overhead) there will always be a region around the transmitting site where an ionospherically propagated signal cannot be heard, or is heard weakly. This area lies between the outer limit of the ground-wave range and the inner edge of energy return from the ionosphere. It is called the *skip zone*, and the distance between the originating site and the beginning of the ionospheric return is called the skip distance. This terminology should not to be confused with ham jargon such as "the skip is in," referring to the fact that a band is open for sky-wave propagation.

The signal may often be heard to some extent within the skip zone, through various forms of scattering (discussed in detail later), but it will ordinarily be marginal in strength. When the skip distance is short, both ground-wave and sky-wave signals may be received near the transmitter. In such instances the sky wave frequently is stronger than the ground wave, even as close as a few miles from the transmitter. The ionosphere is an efficient communication medium under favorable conditions. Comparatively, the ground wave is not.

If the radio wave leaves the Earth at a radiation angle of zero degrees, just at the horizon, the maximum distance that may be reached under usual ionospheric conditions in the F_2 region is about 4000 km (2500 miles).

MULTI-HOP PROPAGATION

As mentioned previously in the discussion about Fig 24, the Earth itself can act as a reflector for radio waves, resulting a multiple hops. Thus, a radio signal can be reflected from the reception point on the Earth back into the ionosphere, reaching the Earth a second time at a still more-distant point. This effect is illustrated in **Fig 25**, where a single ionospheric layer is depicted, although this time we show both the layer and the Earth beneath it as curved rather than flat. The wave identified as "Critical Angle" travels from the transmitter via the ionosphere to point A, in the center of the drawing, where it is reflected upwards and travels through the ionosphere to point B, at the right. This shows a two-hop signal.

As in the simplified case in Fig 24, the distance at which a ray eventually reaches the Earth depends on the launch elevation angle at which it left the transmitting antenna. You have some control of the launch angle by adjusting the height of the antennas you use, as described in Chapter 3, The Effects of Ground.

The information in Fig 25 is greatly simplified. On actual communication paths the picture is complicated by many factors. One is that the transmitted energy spreads over a considerable area after it leaves the antenna. Even with an antenna array having the sharpest practical beam pattern, there is what might be described as a *cone of radiation* centered on the wave lines (rays) shown in the drawing. The reflection/ refraction in the ionosphere is also highly variable, and is the cause of considerable spreading and scattering.

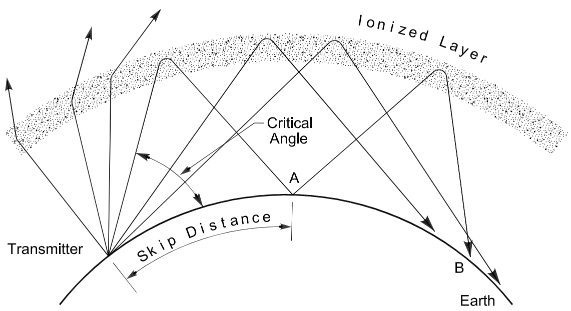

Fig 25—Behavior of waves encountering a simple curved ionospheric layer over a curved Earth. Rays entering the ionized region at angles above the critical angle are not bent enough to be returned to Earth, and are lost to space. Waves entering at angles below the critical angle reach the Earth at increasingly greater distances as the launch angle approaches the horizontal. The maximum distance that may normally be covered in a single hop is 4000 km. Greater distances are covered with multiple hops.

Under some conditions it is possible for as many as four or five signal hops to occur over a radio path, as illustrated by the oblique ionogram in Fig 23. But no more than two or three hops is the norm. In this way, HF communication can be conducted over thousands of miles.

An important point should be recognized with regard to signal hopping. A significant loss of signal occurs with each hop. The D and E layers of the ionosphere absorb energy from signals as they pass through, and the ionosphere tends to scatter the radio energy in various directions, rather than confining it in a tight bundle. The roughness of the Earth's surface also scatters the energy at a reflection point.

Assuming that both waves do reach point B in Fig 25, the low-angle wave will contain more energy at point B. This wave passes through the lower layers just twice, compared to the higher-angle route, which must pass through these layers four times, plus encountering an Earth reflection. Measurements indicate that although there can be great variation in the relative strengths of the two signals—the one-hop signal will generally be from 7 to 10 dB stronger. The nature of the terrain at the mid-path reflection point for the two-hop wave, the angle at which the wave is reflected from the Earth, and the condition of the ionosphere in the vicinity of all the refraction points are the primary factors in determining the signal-strength ratio.

The loss per hop becomes significant at greater distances. It is because of these losses that no more than four or five propagation hops are useful; the received signal becomes too weak to be usable over more hops. Although modes other than signal hopping also account for the propagation of radio waves over thousands of miles, backscatter studies of actual radio propagation have displayed signals with as many as five hops. So the hopping mode is arguably the most prevalent method for long-distance communication.

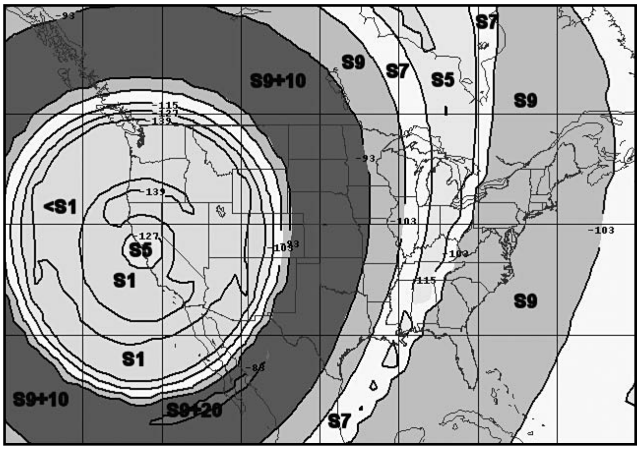

Fig 26—Modified *VOAAREA* plot for 21.2 MHz from San Francisco to the rest of the US, annotated with signal levels in S units, as well as signal contours in dBW (dB below a watt). Antennas are assumed to be 3-element Yagis at 55 feet above flat ground; the transmitter power is 1500 W; the month is November with SSN = 50, a moderate level of solar activity, at 22 UTC. The most obvious feature is the large "skip zone" centered on the transmitter in San Francisco, extending almost a 1/3 of the distance across the US.

Fig 26 shows another way of looking at propagation—a *geographic area* look. Fig 26 shows 15-meter signal levels across the US as they propagate from a transmitting station in San Francisco. This simulation of propagation conditions is for the month of November, with a medium level of solar activity (SSN = 50) at 22 UTC. Fig 26 was created using the *VOAAREA* software program, part of the *VOACAP* software suite. Transmitter power is assumed to be 1500 W, with 3-element Yagis, 55 feet high, at the transmitter and at each receiving location.

From the transmitter out to about 50 miles, signals are moderate, at about S5 on an S meter. Beyond that coverage area to almost 1/3 of the way across the country (to Colorado), there is a large and distinctive skip zone, where only very weak signals return to Earth (S1 or less). Beyond Colorado, signals rapidly build up to S9+10 dB across the middle of the US, falling to S9 and then to S7 in the vicinity of Chicago, Illinois. Beyond Chicago, the signals drop to S5 in a swath from Michigan and part of Ohio down to Alabama. All along the US East Coast, signals come back strong at S9.

The reason why the signals in Fig 26 drop down to S5 in the Midwest is that the necessary elevation angles to cover this region in a single F2 hop are extremely low even at a moderate level of solar activity. To achieve launch angles as low as 1° requires either very high antenna heights or a high mountaintop location. Beyond the Midwest, out to the US East Coast, two F2 hops are required, with higher elevation angles and hence greater antenna gain for moderate antenna heights.

Non-Hopping Propagation Modes

Present propagation theory holds that for communication distances of many thousands of kilometers, signals do not always hop in relatively short increments from ionosphere-to-Earth-to-ionosphere and so forth along the entire path. Instead, the wave is thought to propagate *inside* the ionosphere throughout some portion of the path length, tending to be *ducted* in the ionized layer.

As was shown in Fig 24, the high-angle Pedersen ray can also penetrate an ionospheric layer farther than lower-angle rays. In the less-densely ionized upper edge of the layer, the amount of refraction is less, nearly equaling the curvature of the layer itself as it encircles the Earth.

Non-hopping theory of long-distance propagation is further supported by studies of travel times for signals that go completely around the world. The time required is significantly less than would be necessary to hop between the Earth and the ionosphere 10 or more times while circling the Earth.

Propagation between two points thousands of kilometers apart may in fact consist of a combination of ducting and hopping. It may involve combinations of refractions from the E layer and the F layer. Despite all the complex factors involved, most long-distance propagation can be seen to follow certain general rules. Thus, much commercial and military point-to-point communication over long distances employs antennas designed to make maximum use of known radiation angles and layer heights, even on paths where multihop propagation is assumed.

In amateur work, however, we usually try for the lowest practical radiation angle, hoping to keep reflection losses to a minimum. Years of amateur experience have shown this to be a decided advantage under all usual conditions.

The geometry of propagation by means of the F_2 layer limits our maximum distance along the Earth's surface to about 4000 km (2500 miles) for a single hop. For higher radiation angles, this same distance may require two or more hops (with higher reflection loss). And fewer hops are better, in most cases. If you have a nearby neighbor who consistently outperforms you on the longer paths, a radiation angle difference in his favor is probably the reason.

MAXIMUM USABLE FREQUENCY

The vertical-incidence critical frequency is the *maximum usable frequency* for local sky-wave high-angle communication. It is also useful in the selection of optimum working frequencies and the determination of the maximum usable frequency for distant points at a given time. The abbreviation "MUF" for maximum usable frequency will be used hereafter.

In geographic middle latitudes, the vertical-incident critical frequency ranges between about 1 and 4 MHz for the E layer, and between 2 and 13 MHz for the F_2 layer. The lowest figures are for nighttime conditions in the lowest years of the solar cycle. The highest are for the daytime hours in the years of high solar activity. These are average figures. Critical frequencies have reached as high as 20 MHz briefly during exceptionally high solar activity in the middle latitudes. As was pointed out earlier in Fig 22, $f_o F_2$ levels approaching 40 MHz are possible at low latitudes.

While vertical-incidence critical frequencies are interesting from a scientific point of view, hams are far more concerned about how we can exploit propagation conditions to communicate, preferably at long distances. The MUF for a 4000-km (2500 miles) distance is about 3.5 times the vertical-incidence critical $f_o F_2$ frequency existing at the path midpoint. For one-hop signals, if a uniform ionosphere is assumed, the MUF decreases with shorter distances along the path. This is true because the higher-frequency waves must be launched at higher elevation angles for shorter ranges, and at these launch angles they are not bent sufficiently to reach the Earth. Thus, a lower frequency (where more bending occurs) must be used.

Precisely speaking, a maximum usable frequency or MUF is defined for communication between two specific points on the Earth's surface, for the conditions existing at the time, including the minimum elevation angle that the station can launch at the frequency in use. (This practical form of MUF is sometimes called the *operational MUF*). At the same time and for the same conditions, the MUF from either of these two points to a third point may be different.

Table 2

Time and Frequency Stations Useful for Propagation Monitoring

Call	*Frequency (MHz)*	*Location*
WWV	2.5, 5, 10, 15, 20	Ft Collins, Colorado
WWVH	Same as WWV but no 20	Kekaha, Kauai, Hawaii
CHU	3.330, 7.335, 14.670	Ottawa, Ontario, Canada
RID	5.004, 10.004, 15.004	Irkutsk, USSR*
RWM	4.996, 9.996, 14.996	Novosibirsk, USSR
VNG	2.5, 5, 8.634, 12.984, 16	Lyndhurst, Australia
BPM	5, 5.43, 9.351, 10, 15	Xiang, China
BSF	15	Taoyuan, Taiwan
JJY	2.5, 5, 8, 10, 15	Tokyo, Japan
LOL	5, 10, 15	Buenos Aires, Argentina

*The call, taken from an international table, may not be the one used during actual transmission. Locations and frequencies appear to be accurate as provided.

Therefore, the MUF cannot be expressed broadly as a single frequency, even for any given location at a particular time. The ionosphere is never uniform, and in fact at a given time and for a fixed distance, the MUF changes significantly with changes in compass direction for almost any point on the Earth. Under usual conditions, the MUF will always be highest in the direction toward the Sun—to the east in the morning, to the south at noon (from northern latitudes), and to the west in the afternoon and evening.

For the strongest signals at the greatest distance, especially where the limited power levels of the Amateur Radio Service are concerned, it is important to work fairly near the MUF. It is at these frequencies where signals suffer the least loss. The MUFs can be estimated with sufficient accuracy by using the prediction charts that appear on the ARRL Web site (**www.arrl.org/qst/propcharts/**) or by using a computer prediction program. The CD-ROM bundled in the back of this book contains detailed and summary tables for more than 175 transmitting locations around the world. (See section on "What HF Bands Are Open—Where and When?" later in this chapter.)

MUFs can also be observed, with the use of a continuous coverage communications receiver. Frequencies up to the MUFs are in round-the-clock use today. When you "run out of signals" while tuning upward in frequency from your favorite ham band, you have a pretty good clue as to which band is going to work well, right then. Of course, it helps to know the direction to the transmitters whose signals you are hearing. Shortwave broadcasters know what frequencies to use, and you can hear them anywhere, if conditions are good. Time-and-frequency stations are also excellent indicators, since they operate around the clock. See **Table 2**. WWV is also a reliable source of propagation data, hourly, as discussed in more detail later in this chapter.

The value of working near the MUF is two-fold. Under undisturbed conditions, the absorption loss decreases proportional to the square of a change in frequency. For example, the absorption loss is four times higher at 14 MHz than it is at 28 MHz. Perhaps more important, the hop distance is considerably greater as the MUF is approached. A transcontinental contact is thus much more likely to be made on a single hop on 28 MHz than on 14 MHz, so the higher frequency will give the stronger signal most of the time. The strong-signal reputation of the 28-MHz band is founded on this fact.

LOWEST USABLE FREQUENCY

There is also a lower limit to the range of frequencies that provide useful communication between two given points by way of the ionosphere. *Lowest usable frequency* is abbreviated LUF. If it were possible to start near the MUF and work gradually lower in frequency, the signal would decrease in strength and eventually would disappear into the ever-present "background noise." This happens because signal absorption increases proportional to the square of the lowering of the frequency. The frequency nearest the point where reception became unusable would be the LUF. It is not likely that you would want to work at the LUF, although reception could be improved if the station could increase power by a considerable amount, or if larger antennas could be used at both ends of the path.

For example, when solar activity is very high at the peak of a solar cycle, the LUF often rises higher than 14 MHz on the morning Eastern US-to-Europe path on 20 meters. Just before sunrise in the US, the 20-meter band will be first to open to Europe, followed shortly by 15 meters, and then 10 meters as the Sun rises further. By mid-morning, however, when 10 and 15 meters are both wide open, 20 meters will become very marginal to Europe, even when both sides are running maximum legal power levels. By contrast, stations on 10 meters can be worked readily with a transmitter power of only 1 or 2 watts, indicating the wide range between the LUF and the MUF.

Frequently, the *window* between the LUF and the MUF for two fixed points is very narrow, and there may be no amateur frequencies available inside the window. On occasion the LUF may be higher than the MUF between two points. This means that, for the highest possible frequency that will propagate through the ionosphere for that path, the absorption is so great as to make even that frequency unusable. Under these conditions it is impossible to establish amateur sky-wave communication between those two points, no matter what frequency is used. (It would normally be possible, however, to communicate between either point and other points on some frequency under the existing conditions.) Conditions when amateur sky-wave communication is impossible between two fixed points occur commonly for long distances where the total path is in darkness, and for very great distances in the daytime during periods of low solar activity.

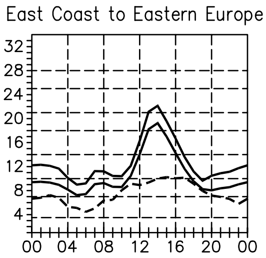

Fig 27—Propagation prediction chart for East Coast of US to Europe. This appeared in December 1994 *QST*, where an average 2800-MHz (10.7-cm) solar flux of 83 was assumed for the mid-December to mid-January period. On 10% of these days, the highest frequency propagated was predicted at least as high as the uppermost curve (the Highest Possible Frequency, or HPF, approximately 21 MHz), and for 50% of the days as high as the middle curve, the MUF. The broken lines show the Lowest Usable Frequency (LUF) for a 1500-W CW transmitter.

Fig 27 shows a typical propagation prediction from the ARRLWeb members-only site (**www.arrl.org/qst/propcharts/**, previously from the "How's DX" column in *QST*). In this instance, the MUF and the LUF lines are blurred together at about 10 UTC, meaning that the statistical likelihood of any amateur frequency being open for that particular path at that particular time was not very good. Later on, after about 11 UTC, the gap between the MUF and LUF increased, indicating that the higher bands would be open on that path.

DISTURBED IONOSPHERIC CONDITIONS

So far, we have discussed the Earth's ionosphere when conditions at the Sun are undisturbed. There are three general types of major disturbances on the Sun that can affect radio propagation here on the Earth. On the air, you may hear people grousing about *Solar Flares*, *Coronal Holes* or *Sudden Disappearing Filaments*, especially when propagation conditions are not good. Each of these disturbances causes both electromagnetic radiation and ejection of material from the Sun.

Solar Flares

Solar flares are cataclysmic eruptions that suddenly release huge amounts of energy, including sustained, high-energy bursts of radiation from VLF to X-ray frequencies and vast amounts of solar material. Most solar flares occur around the peak of the 11-year solar cycle.

The first Earthly indication of a huge flare is often a visible brightness near a sunspot group, along with increases in UV, X-ray radiation and VHF radio noise. If the geometry between the Sun and Earth is right, intense X-ray radiation takes eight minutes, traveling the 93 million miles to Earth at the speed of light. The sudden increase in X-ray energy can immediately increase RF absorption in the Earth's lowest ionospheric layers, causing a phenomenon known as a *Sudden Ionospheric Disturbance* (SID).

An SID affects all HF communications on the sunlit side of the Earth. Signals in the 2 to 30-MHz range may disappear entirely, and even most background noise may cease in extreme cases. When you experience a big SID, your first inclination may be to look outside to see if your antenna fell down! SIDs may last up to an hour before ionospheric conditions temporarily return to normal.

Between 45 minutes and 2 hours after an SID begins, particles from the mass eruption on the Sun may begin to arrive. These high-energy particles are mainly protons and they can penetrate the ionosphere at the Earth's magnetic poles, where intense ionization can occur, with attendant absorption of HF signals propagating through the polar regions. This is called a *Polar Cap Absorption* (PCA) event and it may last for several days. A PCA results in spectacular auroral displays at high latitudes.

Coronal Holes

As described earlier in the section dealing with auroral propagation at VHF, a second major solar disturbance is a so-called "coronal hole" in the Sun's outer layer (the *corona*). Temperatures in the corona can be more than four million °C over an active sunspot region but more typically are about two million °C. A coronal hole is an area of somewhat lower temperature. Solar-terrestrial scientists have a number of competing theories about how coronal holes are formed.

Matter ejected through this "hole" takes the form of a *plasma*, a highly ionized gas made up of electrons, protons and neutral particles, traveling at speeds up to 1,000 km per second (2 million miles per hour). The plasma becomes part of the solar wind and can affect the Earth's magnetic field, but only if the Sun-Earth geometry is right. A plasma has a very interesting and somewhat bizarre ability. It can lock-in the orientation of the magnetic field where it originates and carry it outwards into space. However, unless the locked-in magnetic field orientation is aligned properly with the Earth's magnetic field, even a large plasma mass may not severely disrupt our magnetosphere, and thence our ionosphere.

Presently, we don't have the ability to predict very long in advance when the Sun might erupt in a disturbance that results in Earthly propagation problems. The SOHO satellite can help determine whether a mass ejection is heading towards Earth, and the ACE satellite about 1 million miles away from Earth can give about an hour's warning whether the imbedded magnetic field in a mass ejection from the Sun might impact the Earth's magnetosphere, causing propagation problems for hams.

Statistically, coronal holes tend to occur most often during the declining phase of the 11-year solar cycle and they can last for a number of solar rotations. This means that a coronal hole can be a "recurring coronal hole," disrupting communications for several days about the same time each month for as long as a year, or even more.

Sudden Disappearing Filaments

A sudden disappearing filament (SDF) is the third major category of solar disturbance that can affect propagation. SDFs take their names from the manner in which they suddenly arch upward from the Sun's surface, spewing huge amounts of matter as plasma out into space in the solar wind. They tend to occur mostly during the rising phase of the 11-year solar cycle.

IONOSPHERIC STORMS

When the conditions are right, a flare, coronal hole or an SDF can launch a plasma cloud into the solar wind, resulting in an *ionospheric storm* here on Earth. Unlike a hurricane or a winter Nor'easter storm in New England, an ionospheric storm is not something we can see with our eyes or feel on our skins. We can't easily measure things occurring in the ionosphere some 200 miles overhead. However, we can see the indirect effects of an ionospheric storm on magnetic instruments located on the Earth's surface, because disturbances in the ionosphere are closely related to the Earth's magnetic field. The term *Geomagnetic Storm* ("Geo" means "Earth" in Greek) is used almost synonymously with ionospheric storm.

During a ionospheric storm, we may experience extraordinary radio noise and interference, especially at HF. You may hear solar radio emissions as increases of noise at VHF. A geomagnetic storm generally adds noise and weakens or disrupts ionospheric propagation for several days. Transpolar signals at 14 MHz or higher may be particularly weak, with a peculiar hollow sound or flutter—even more than normal for transpolar signals.

Depending on the severity of the disturbance to the Earth's geomagnetic field and the consequent disturbance of the ionosphere, propagation may be disrupted completely or it might be at least degraded for a period of time that ranges from a day to three or four days before returning to normal propagation conditions.

What can we do about the solar disturbances and related disturbed ionospheric propagation on Earth? The truth is that we are powerless faced with the truly awesome forces of solar disturbances like flares, coronal holes or sudden disappearing filaments. Perhaps there is some comfort, however, in understanding what has happened to cause our HF bands to be so poor. And as a definite consolation, conditions on the VHF bands are often exceptionally good just when HF propagation is remarkably poor due to solar disturbances. VHF operators enthusiastically look forward to conditions when they can engage in auroral communications—exactly the kind of conditions that have HF operators scratching their heads, wondering where the ionosphere went.

ELEVATION ANGLES FOR HF COMMUNICATION

It was shown in connection with Fig 25 that the distance at which a ray returns to Earth depends on the eleva-

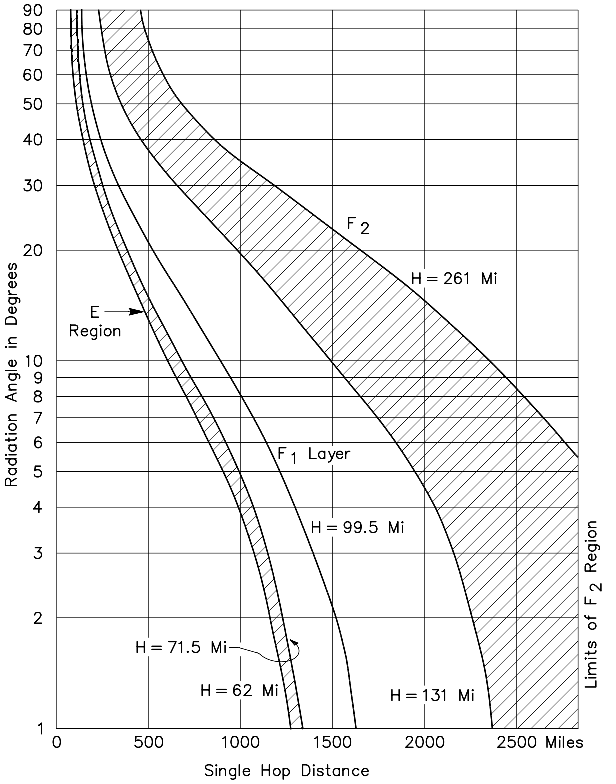

Fig 28—Distance plotted against wave angle (one-hop transmission) for the nominal range of heights for the E and F2 layers, and for the F1 layer.

tion angle at which it left the Earth (also known by other names: takeoff, launch or wave angle). Chapter 3, The Effects of Ground, in this book deals with the effects of local terrain, describing how the elevation angle of a horizontally polarized antenna is determined mainly by its height above the ground.

Although it is not shown specifically in Fig 25, propagation distance also depends on the layer height at the time, as well as the elevation angle. As you can probably imagine, the layer height is a very complex function of the state of the ionosphere and the Earth's geomagnetic field. There is a large difference in the distance covered in a single hop, depending on the height of the E or the F_2 layer. The maximum single-hop distance by the E layer is about 2000 km (1250 miles) or about half the maximum distance via the F_2 layer. Practical communicating distances for single-hop E or F layer work at various wave angles are shown in graphic form in **Fig 28**.

Actual communication experience usually does not fit the simple patterns shown in Fig 25. Propagation by means of the ionosphere is an enormously complicated business (which makes it all the more intriguing and challenging to radio amateurs, of course), even when the Sun is not in a disturbed state. Until the appearance of sophisticated computer models of the ionosphere, there was little definitive information available to guide the radio amateur in the design of his antenna systems for optimal performance over all portions of the 11-year solar cycle. Elevation angle information that had appeared for many years in *The ARRL Antenna Book* was measured for only one transmitting path, during the lowest portion of Solar Cycle 17 in 1934.

The *IONCAP* Computer Propagation Model

Since the 1960s several agencies of the US government have been working on a detailed computer program that models the complex workings of the ionosphere. The program has been dubbed *IONCAP*, short for "Ionospheric Communications Analysis and Prediction Program." *IONCAP* was originally written for a mainframe computer, but later versions have been rewritten to allow them to be run by high-performance personal computers. *IONCAP* incorporates a detailed database covering almost three complete solar cycles. The program allows the operator to specify a wide range of parameters, including detailed antenna models for multiple frequency ranges, noise models tailored to specific local environments (from low-noise rural to noisy residential QTHs), minimum elevation angles suitable for a particular location and antenna system, different months and UTC times, maximum levels of multipath distortion, and finally solar activity levels, to name the most significant of a bewildering array of options.

While *IONCAP* has a well-justified reputation for being very *unfriendly* to use, due to its mainframe, non-interactive background, it is also the one ionospheric model most highly regarded for its accuracy and flexibility, both by amateurs and professionals alike. It is the program used for many years to produce the long-term MUF charts formerly included in the "How's DX" monthly column of *QST* and now available on the Members Only ARRLWeb page.

IONCAP is not well suited for short-term forecasts of propagation conditions based on the latest solar indices received from WWV. It is an excellent tool, however, for long-range, detailed planning of antenna systems and shortwave transmitter installations, such as that for the Voice of America, or for radio amateurs. See the section later in this chapter describing other computer programs that can be used for short-term, interactive propagation predictions.

IONCAP/VOACAP Parameters

The elevation-angle statistical information contained in this section was compiled from thousands of *VOACAP* runs (an improved version of *IONCAP* developed by scientists from VOA, the Voice of America). These runs were done for a number of different transmitting locations throughout the world to important DX locations throughout the world.

Some assumptions were needed for setting *VOACAP* parameters. The transmitting and receiving sites were all assumed to be located on flat ground, with "average" ground conductivity and dielectric constant. Each site was assumed to have a clear shot to the horizon, with a minimum elevation angle less than or equal to 1°. Electrical noise at each

Table 3

Boston, Massachusetts, to All of Europe

Elev	*80 m*	*40 m*	*30 m*	*20 m*	*17 m*	*15 m*	*12 m*	*10 m*
1	4.1	9.6	4.6	1.7	2.1	4.4	5.5	7.2
2	0.8	2.3	7.2	1.4	2.8	2.8	3.7	5.3
3	0.3	0.7	4.3	3.1	2.4	2.2	4.4	7.9
4	0.5	4.1	8.7	11.6	12.2	9.4	8.1	3.9
5	4.6	4.8	7.5	12.7	14.3	13.1	9.2	11.2
6	7.1	8.9	5.5	9.2	9.6	12.2	9.2	7.2
7	8.5	6.9	7.2	4.6	7.9	7.4	10.0	5.9
8	5.1	7.0	5.4	3.2	5.9	7.4	4.8	6.6
9	3.3	5.6	3.2	3.1	2.1	3.9	8.1	9.2
10	1.0	4.0	7.9	6.3	5.1	3.7	11.1	6.6
11	1.9	3.8	9.7	10.2	7.2	5.4	3.7	7.9
12	5.6	3.4	4.8	8.5	6.9	7.4	4.8	6.6
13	11.0	3.0	2.4	4.1	5.9	4.6	3.3	2.6
14	7.6	4.8	2.0	2.7	3.8	3.9	6.3	5.9
15	5.3	7.9	2.0	1.5	2.4	1.7	1.5	2.0
16	2.8	6.4	3.8	2.9	1.5	1.3	2.6	2.6
17	5.0	3.4	4.5	3.1	1.0	1.5	0.0	0.0
18	4.2	2.0	3.1	3.1	2.0	2.2	1.8	1.3
19	5.7	1.4	1.4	2.3	1.3	0.7	0.0	0.0
20	6.6	1.4	1.2	1.8	1.1	1.3	0.7	0.0
21	4.4	1.4	0.5	0.8	0.7	0.7	0.4	0.0
22	2.3	2.4	1.0	1.1	0.6	1.3	0.7	0.0
23	1.3	1.8	0.1	0.3	0.1	0.0	0.0	0.0
24	0.6	1.0	0.5	0.5	0.4	0.7	0.0	0.0
25	0.3	0.8	0.3	0.1	0.4	0.0	0.0	0.0
26	0.0	0.5	0.7	0.2	0.1	0.4	0.0	0.0
27	0.1	0.1	0.1	0.2	0.1	0.2	0.0	0.0
28	0.0	0.3	0.1	0.2	0.0	0.2	0.0	0.0
29	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0
30	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
33	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Percentage of time a particular frequency band is open on this specific propagation path.

receiving location was also assumed to be very low.

Transmitting and receiving antennas for the 3.5 to 30-MHz frequency range were specified to be isotropic-type antennas, but with +6 dBi gain, representing a good amateur antenna on each frequency band. These theoretical antennas radiate uniformly from the horizon, up to 90° directly overhead. With response patterns like this, these are obviously not real-world antennas. They do, however, allow the computer program to explore all possible modes and elevation angles.

Looking at the Elevation-Angle Statistical Data

Table 3 shows detailed statistical elevation informa-

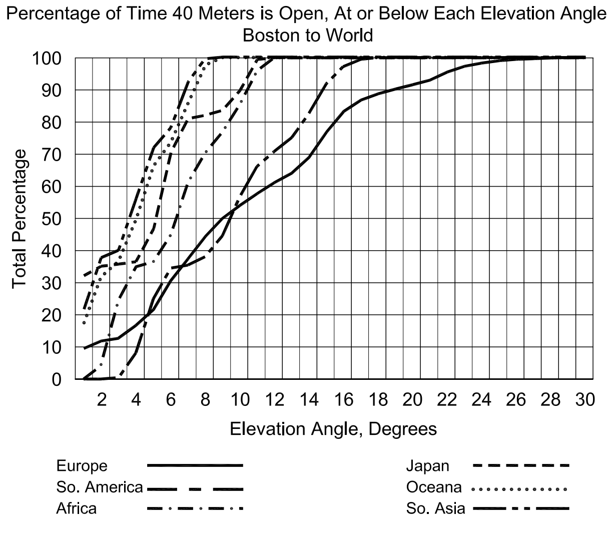

Fig 29—The cumulative distribution function showing the total percentage of time that 40 meters is open, at or below each elevation angle, from Boston to the world. For example, 50% of the time the band is open to Europe from Boston, it is at 10° or less. The angles for DX work are indeed low.

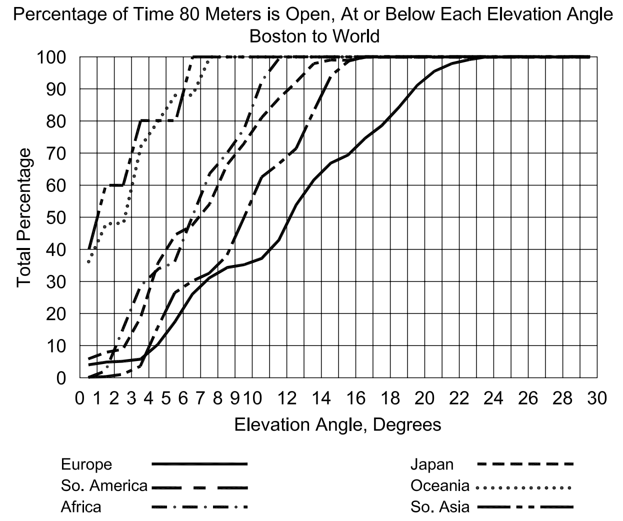

Fig 30—The cumulative distribution function showing the total percentage of time that 80 meters is open, at or below each elevation angle, from Boston to the world. For example, 50% of the time the band is open to Europe from Boston, it is at 13° or less.

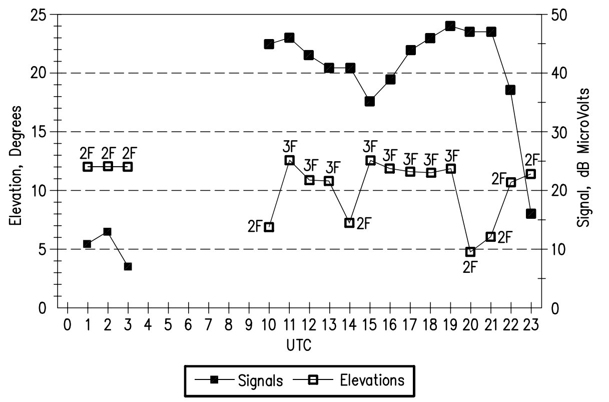

Fig 31—Overlay of signals and elevation angles, together with hop-mode information. This is for one month, October, at one level of solar activity, SSN=70, for the path from Newington, CT, to London, England. The mode of propagation does not closely follow the elevation angle. From 15 to 19 UTC the mode is 3F2 hops, and the elevation angle is approximately 12°. The same elevation angle is required from 23 to 03 UTC, but here the mode is 2F2 hops.

tion for the path from Boston, Massachusetts, near ARRL HQ in Newington, Connecticut, to all of Europe. The data incorporated into Table 3 shows the percentage of time versus elevation angle for all HF bands from 80 meters to 10 meters, over all portions of the 11-year solar cycle. The CD-ROM accompanying this book contains more tables such as this for more than 150 transmitting sites around the world. These tables are used by the *HFTA* program (and earlier *YT* program) and can also be imported into many programs, such as word processors or spreadsheets. Six important areas throughout the world are covered, one per table: all of Europe (from London, England, to Kiev, Ukraine), the Far East (centered on Japan), South America (Paraguay), Oceania (Melbourne, Australia), Southern Africa (Zambia) and South Asia (New Delhi, India).

You may be surprised to see in Table 3 that angles lower than 10° dominate the possible range of incoming angles for this moderate-distance path from New England to Europe. In fact, 1.7% of all the times when the 20-meter band is open to Europe, the takeoff angle is as low as 1°. You should recognize that very few real-world 20-meter antennas achieve much gain at such an extremely low angle—unless they just happen to be mounted about 400 feet high over flat ground or else are located on the top of a tall, steep mountain.

The situation is even more dramatic on 40 and 80 meters. **Fig 29** shows the “cumulative distribution function” of the total percentage of time (derived from Table 3) when 40 meters is open from Boston to the rest of the world, plotted against the elevation angle. For example, into Europe from Boston, 50% of the time when the band is open, it is at 10° or less. Into Japan from Boston, the statistics are even more revealing: 50% of the time when the band is open, the angle is 6° or less, and 90% of the time the angle is 13° or less!

Fig 30 shows the same sort of information for 80 meters from Boston to the world. For 50% of the time from Boston to Europe the elevation angle is 13° or less; at the 90% level the angle is 20° or less. For the path to Japan on 80 meters from Boston, 50% of the time the angle is 8° or less; at the 90% level, the angle is 13° or less. Now, to achieve peak gain on 80 meters at an elevation angle of 8° over flat land, a horizontally polarized antenna must be 500 feet high. You can begin to see why verticals can do very well on long-distance contacts on 80 meters, even when they are mounted over poorly conducting, rocky ground. Clearly, low angles are very important for successful DXing.

The Ionosphere Controls Propagation

You should always remember that it is the *ionosphere* that controls the elevation angles, *not* the transmitting antenna. The elevation response of a particular antenna only determines how strong or weak a signal is, at whatever angle (or angles) the ionosphere is supporting at that particular instant, for that propagation path and for that frequency.

If only one propagation mode is possible at a particular time, and if the elevation angle for that one mode happens to be 5°, then your antenna will have to work satisfactorily at that very low angle or else you won’t be able to communicate. For example, if your low dipole has a gain of –10 dBi at 5°, compared to your friend’s Yagi on a mountain top with +10 dBi gain at 5°, then you will be down 20 dB compared to his signal. It’s not that the elevation angle is somehow *too low*—the real problem here is that you don’t have *enough gain* at that particular angle where the ionosphere is supporting propagation. Many “flatlanders” can vividly recall the times when their mountain-top friends could easily work DX stations, while they couldn't even hear a whisper.

Looking at the Data—Further Cautions

A single propagation mode is quite common at the opening and the closing of daytime bands like 20, 15 or 10 meters, when the elevation angle is often lower (but not always) than when the band is wide open. The lower-frequency bands tend to support multiple propagation modes simultaneously. For example, **Fig 31** plots the signal strength (in dBµV) and the elevation angle for the dominant mode (with the strongest signal) over a 24-hour period from Newington to London in October, for a medium-level SSN = 70. The morning opening at 10 UTC starts out with a two-hop $2F_2$ mode (labeled 2F) at an elevation angle of 6°. By 11 UTC the mode has changed to a three-hop $3F_2$ (labeled 3F) at a 12° elevation angle. The band starts to close down with weaker signals after about 23 UTC. Note that this path actually supports both $2F_2$ and $3F_2$ modes most of the time. Either mode may be stronger than the other, depending on the particular time of day.

It is tempting to think that two-hop signals always occur at lower elevation launch angles, while three-hop signals require higher elevation angles. In reality, the detailed workings of the ionosphere are enormously complicated. From 22 UTC to 03 UTC, the elevation angles are higher than 11° for $2F_2$ hops. During much of the morning and early afternoon in Newington (from 11 to 13 UTC, and from 15 to 19 UTC), the angles are also higher than 11°. However, $3F_2$ hops are involved during these periods of time. The number of hops is not directly related to the elevation angles needed—changing layer heights account for this.

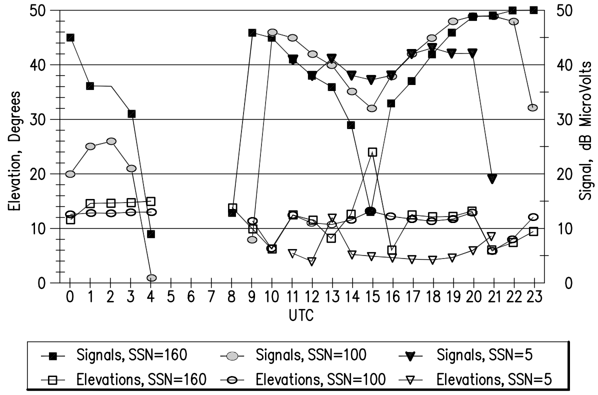

Fig 32—October 20-meter signals and elevation angles for the full range of solar activity, from W1 to England. The elevation angle does not closely follow the level of solar activity. What is important in designing a station capable of covering all levels of solar activity is to have flexibility in antenna elevation pattern response — to cover a wide range of possible angles.

Note that starting around 15 UTC, the mid-morning 20-meter "slump" (down some 10 dB from peak signal level) is caused by higher levels of mainly E-layer absorption when the Sun is high overhead. This condition favors higher elevation angles, since signals launched at lower angles must travel for a longer time through the lossy lower layer.

How does the situation change with different levels of solar activity? **Fig 32** overlays predicted signals and elevation angles for three levels of solar activity in October, again for the Newington-London path. Fig 32 shows the mid-morning slump dramatically when the solar activity is at

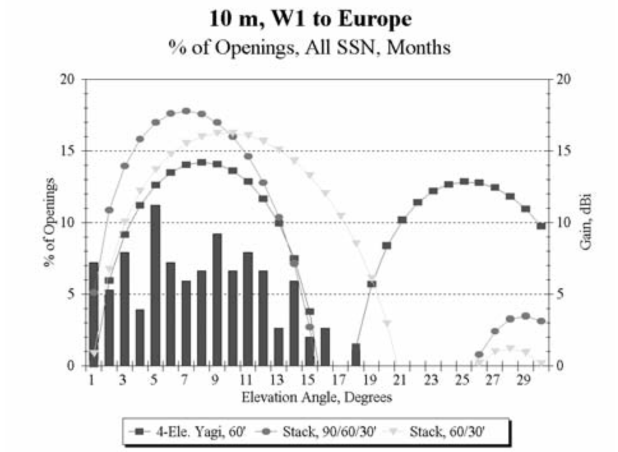

Fig 33—10-meter graph of the percentage of all openings versus elevation angles, together with overlay of elevation patterns over flat ground for three 10-meter antenna systems. Stacked antennas have wider "footprints" in elevation angle coverage for this example from New England to Europe.

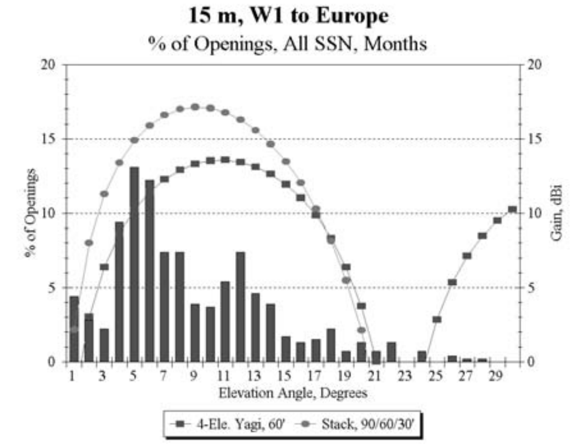

Fig 34—15-meter graph of the percentage of all openings versus elevation angles, together with overlay of elevation patterns over flat ground for two 15-meter antenna systems. Like 10 meters, 15-meter stacked antennas have wider footprints in elevation angle coverage for this example from New England to Europe.

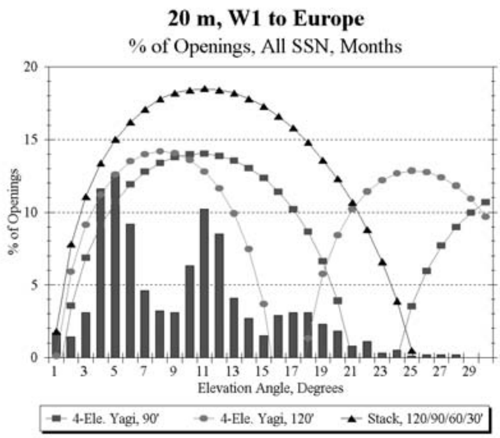

Fig 35—20-meter graph of the percentage of all openings from New England to Europe versus elevation angles, together with overlay of elevation patterns over flat ground for three 20-meter antenna systems.

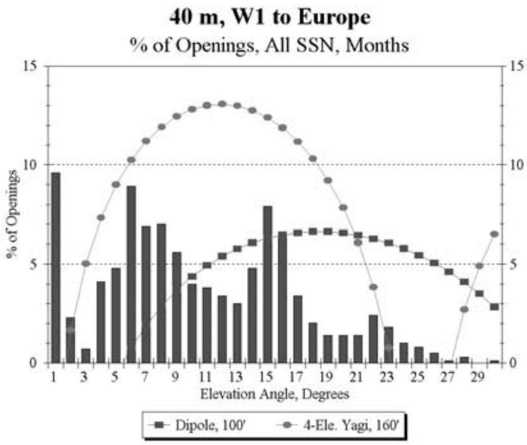

Fig 36—40-meter graph of the percentage of all openings from New England to Europe versus elevation angles, together with overlays of elevation patterns over flat ground for a 100-foot high dipole and a large 4-element Yagi at 160 feet. Achieving gain at very low elevation angles requires very high heights above ground.

a very high level, represented by SSN = 160. At 15 UTC, the signal level drops 35 dB from peak level, and the elevation angle rises all the way to 24°. By the way, as a percentage of all possible openings, the 24° angle occurs only rarely, 0.5% of the time. It barely shows up as a blip in Table 3. Elevation angles are *not* closely related to the level of solar activity.

IONCAP/VOACAP demonstrates that elevation angles do not follow neat, easily identified patterns, even over a 24-hour period—much less over all portions of the solar cycle. Merely looking at the percentage of all openings versus elevation angle, as shown in Table 3, does not tell the whole story, although it is probably the most statistically valid approach to station design, and possibly the most emotionally satisfying approach too. Neither is the whole story revealed by looking only at a snapshot of elevation angles versus time for one particular month, or for one solar activity level.

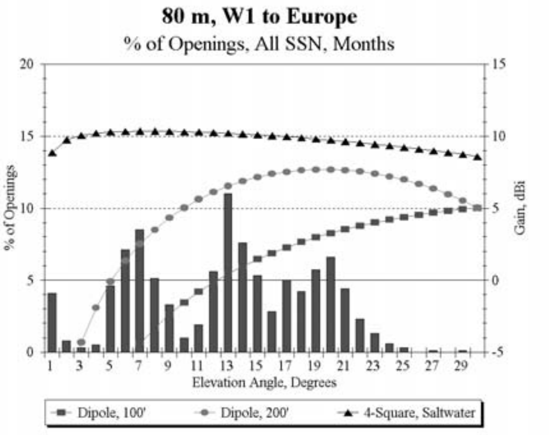

Fig 37—80-meter graph of the percentage of all openings from New England to Europe versus elevation angles, together with overlay of elevation patterns over flat ground for dipoles at two different heights. The 200-foot-high dipole clearly covers the necessary elevation angles better than does the 100-foot-high dipole, although a Four Square vertical array located over saltwater is even better for all angles needed.

What is important to recognize is that the most effective antenna system will be one that can cover the *full range* of elevation angles, over the whole spectrum of solar activity, even if the actual angle in use at any one moment in time may not be easy to determine. For this particular path, from New England to all of Europe, an ideal antenna would have equal response over the full range of angles from 1° to 28°. Unfortunately, real-world antennas have a tough time covering such a wide range of elevation angles equally well.

Antenna Elevation Patterns

Figs 33 through **37** show overlays of the same sort of elevation angle information listed in Table 3, together with the elevation response patterns for typical antennas for the HF amateur bands 80, 40, 20, 15 and 10 meters. For example, Fig 34 shows an overlay for 20 meters, with three different types of 20-meter antennas. These are a 4-element Yagi at 90 feet, a 4-element Yagi at 120 feet and a large stack of four 4-element Yagis located at 120, 90, 60 and 30 feet. Each antenna is assumed to be mounted over flat ground. Placement on a hill with a long slope in the direction of interest would lower the required elevation angle by the amount of the hill's slope. For example, if a 10° launch angle is desired, and the antenna is placed on a hill with a slope of –5°, the antenna itself should be designed for a height that would optimize the response at 15° over flat ground—one wavelength high.

In Fig 35, the large stack of four 20-meter Yagis over flat ground comes closest to being ideal, but even this large array will not work well for that very small percentage of time when the angle needed is higher than about 20°. Some hams might conclude that the tiny percentage of time when the angles are very high doesn't justify an antenna tailored for that response. However, when that new DX country pops up on a band, or when a rare multiplier shows up in a contest, doesn't it always seem that the desired signal only comes in at some angle your antenna doesn't cover well? What do you do then, if your only antenna happens to be a large stack?

The answer to this, perhaps unique, high-angle problem lies in switching to using only the top antenna in the stack. In this example, the second elevation lobe of the 120-foot high antenna would cover the angles from 20° to 30° well, much better than the stack does. Note that the top antenna by itself would not be ideal for all conditions. It is simply too high much of the time when the elevation angles are higher than about 12°. The experience of many amateurs on the US East Coast with high 20-meter antennas bears this out—they find that 60 to 90-foot high antennas are far more consistent performers into Europe.

ONE-WAY PROPAGATION

On occasion a signal may be started on the way back toward the Earth by reflection from the F region, only to come down onto the top of the E region and be reflected back up again. This set of conditions is one possible explanation for the often-reported phenomenon called *one-way skip*. The reverse path may not necessarily have the same multilayer characteristic. The effect is more often a difference in the signal strengths, rather than a complete lack of signal in one direction, and many times there may be local noises that mask signals at one end of the path. It is important to remember these sorts of possibilities when a long-distance test with a new antenna system yields apparently conflicting results. Even many tests, on paths of different lengths and headings, may provide data that are difficult to understand. Communication by way of the ionosphere is not always a source of consistent answers to antenna questions.

Fig 37 shows the 80-meter path from New England to Europe with three different antennas. A really high dipole at a height of 200 feet above flat ground would certainly be an impressive antenna. But it would still be overshadowed dramatically by a Four-Square vertical array, at least at the low elevation angles needed often on this path. This is predicated on the Four Square being located over salt water, which provides a virtually perfect RF ground. At an elevation angle of 7°, the Four Square has 7 dB more gain than the 200-foot high dipole.

SHORT OR LONG PATH?

Propagation between any two points on the Earth's surface is usually by the shortest direct route—the *great-circle path* found by stretching a string tightly between the two points on a globe. If an elastic band going completely around the globe in a straight line is substituted for the string, it will show another great-circle path, going "the long way around." The long path may serve for communication over the desired circuit when conditions are favorable along the longer route. There may be times when communication is possible over the long path but not possible at all over the short path. Especially if there is knowledge of this potential at both ends of the circuit, long-path communication may work very well. Cooperation is almost essential, because both the aiming of directional antennas and the timing of the attempts must be right for any worthwhile result. The *IONCAP/VOACAP* computations in the preceding tables were made for short-path azimuths only.

Sunlight is a required element in long-haul communication via the F layer above about 10 MHz. This fact tends to define long-path timing and antenna aiming. Both are essentially the reverse of the "normal" for a given circuit. We know also that salt-water paths work better than overland ones. This can be significant in long-path work.

We can better understand several aspects of long-path propagation if you become accustomed to thinking of the Earth as a ball. This is easy if you use a globe frequently. A

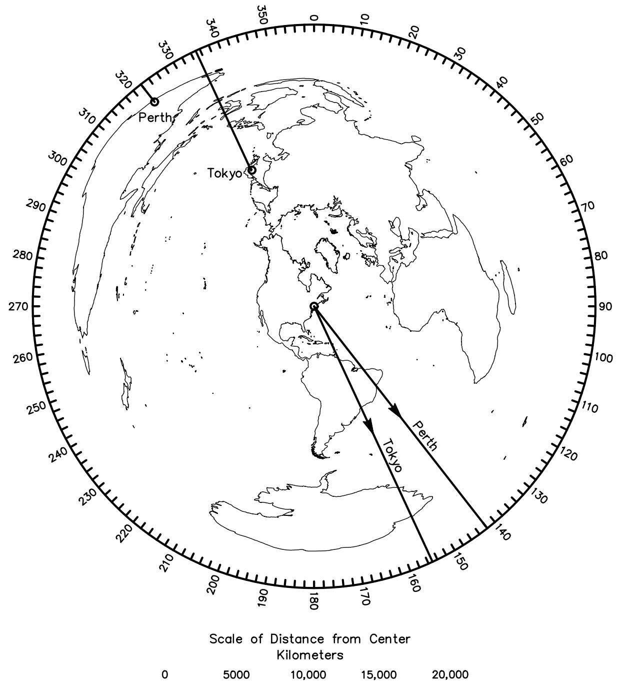

Fig 38—K5ZI's computer-generated azimuthal-equidistant projection centered on Newington, Connecticut. (See Bibliography for ordering information.) Land masses and information showing long paths to Perth and Tokyo have been added. Notice that the paths in both cases lie almost entirely over water, rather than over land masses.

flat map of the world, of the azimuthal-equidistant projection type, is a useful substitute. The ARRL World Map is one, centered on Wichita, Kansas. A similar world map prepared by K5ZI and centered on Newington, Connecticut, is shown in **Fig 38**. These help to clarify paths involving those areas of the world.

Long-Path Examples

There are numerous long-path routes well known to DX-minded amateurs. Two long paths that work frequently and well when 28 MHz is open from the northeastern US are New England to Perth, Western Australia, and New England to Tokyo. Although they represent different beam headings and distances, they share some favorable conditions. By the long path, Perth is close to halfway around the world; Tokyo is about three-quarters of the way. On 28 MHz, both areas come through in the early daylight hours, Eastern Time, but not necessarily on the same days. Both paths are at their best around the equinoxes. (The sunlight is more uniformly distributed over transequatorial paths at these times.) Probably the factor that most favors both is the nature of the first part of the trip at the US end. To work Perth by way of long path, northeastern US antennas are aimed southeast, out over salt water for thousands of miles—the best low-loss start a signal could have. It is salt water essentially all the way, and the distance, about 13,000 miles, is not too much greater than the "short" path.

The long path to Japan is more toward the south, but still with no major land mass at the early reflection points. It is much longer, however, than that to Western Australia. Japanese signals are more limited in number on the long path than on the short, and signals on the average somewhat weaker, probably because of the greater distance.

On the short path, an amateur in the Perth area is looking at the worst conditions—away from the ocean, and out across the huge land mass of North America, unlikely to provide strong ground reflections. The short paths to both Japan and Western Australia, from most of the eastern half of North America, are hardly favorable. The first hop comes down in various western areas likely to be desert or mountains, or both, and not favored as reflection points.

A word of caution: Don't count on the long-path signals always coming in on the same beam heading. There can be notable differences in the line of propagation via the ionosphere on even relatively short distances. There can be more variations on long path, especially on circuits close to halfway around the world. Remember, for a point exactly halfway around, all directions of the compass represent great-circle paths.

FADING

When all the variable factors in long-distance HF communication are taken in account, it is not surprising that signals vary in strength during almost every contact beyond the local range. In VHF communication we can also encounter some fading at distances greater than just to the visible horizon. These are mainly the result of changes in the temperature and moisture content of the air in the first few thousand feet above the ground.

On paths covered by HF ionospheric modes, the causes of fading are very complex—constantly changing layer height and density, random polarization shift, portions of the signal arriving out of phase, and so on. The energy arriving at the receiving antenna has components that have been acted upon differently by the ionosphere. Often the fading is very different for small changes in frequency. With a signal of a wideband nature, such as high-quality FM, or even double-sideband AM, the sidebands may have different fading rates from each other, or from the carrier. This causes severe distortion, resulting in what is termed *selective fading*. The effects are greatly reduced (but still present to some extent) when single-sideband (SSB) is used. Some immunity from fading during reception (but not to the distortion induced by selective fading) can be had by using two or more receivers on separate antennas, preferably with different polarizations, and combining the receiver outputs in what is known as a *diversity* receiving system.

OTHER PROPAGATION MODES

In propagation literature there is a tendency to treat the various propagation modes as if they were separate and distinct phenomena. This they may be at times, but often there is a shifting from one to another, or a mixture of two or more kinds of propagation affecting communication at one time. In the upper part of the usual frequency range for F-region work, for example, there may be enough tropospheric bending at one end (or both ends) to have an appreciable effect on the usable path length. There is the frequent combination of E and F-region propagation in long-distance work. And in the case of the E region, there are various causes of ionization that have very different effects on communication. Finally, there are weak-signal variations of both tropospheric and ionospheric modes, lumped under the term "scatter." We look at these phenomena separately here, but in practice we have to deal with them in combination, more often than not.

Sporadic E (E_s)

First, note that this is *E-subscript-s,* a usefully descriptive term, wrongly written "Es" so often that it is sometimes called "ease," which is certainly not descriptive. *Sporadic E* is ionization at E-layer height, but of different origin and communication potential from the E layer that affects mainly our lower amateur frequencies.

The formative mechanism for sporadic E is believed to be wind shear. This explains ambient ionization being distributed and compressed into a ledge of high density, without the need for production of extra ionization. Neutral winds of high velocity, flowing in opposite directions at slightly different altitudes, produce shears. In the presence of the Earth's magnetic field, the ions are collected at a particular altitude, forming a thin, overdense layer. Data from rockets entering E_s regions confirm the electron density, wind velocities and height parameters.

The ionization is formed in clouds of high density, lasting only a few hours at a time and distributed randomly. They vary in density and, in the middle latitudes in the Northern Hemisphere, move rapidly from southeast to northwest. Although E_s can develop at any time, it is most prevalent in the Northern Hemisphere between May and August, with a minor season about half as long beginning in December (the summer and winter solstices). The seasons and distribution in the Southern Hemisphere are not so well known. Australia and New Zealand seem to have conditions much like those in the US, but with the length of the seasons reversed, of course. Much of what is known about E_s came as the result of amateur pioneering in the VHF range.

Correlation of E_s openings with observed natural phenomena, including sunspot activity, is not readily apparent, although there is a meteorological tie-in with high-altitude winds. There is also a form of E_s, mainly in the northern part of the north temperate zone, that is associated with auroral phenomena.

At the peak of the long E_s season, most commonly in late June and early July, ionization becomes extremely dense and widespread. This extends the usable range from the more common "single-hop" maximum of about 1400 miles to "double-hop" distances, mostly 1400 to 2500 miles. With 50-MHz techniques and interest improving in recent years, it has been shown that distances considerably beyond 2500 miles can be covered. There is also an E_s "link-up" possibility with other modes, believed to be involved in some 50-MHz work between antipodal points, or even long-path communication beyond 12,500 miles.

When E_s is particularly strong and widespread, even the HF bands can suddenly go *short skip* producing exceptionally strong signals from distances that would normally be in the no-signal "skip zone." Editor N6BV distinctly remembers a spectacular 20-meter E_s opening in September 1994, during the "Hiram Percy Maxim/125" anniversary celebration, when he was living in New Hampshire. Signals on 20 meters were 30 to 40 dB over S9 from all along the Eastern Seaboard, from W2 to W4. One exasperated W3 complained that he had been calling in the huge pileup for 20 minutes. N6BV glanced at the S meter and saw that the W3 was 20 dB over S9, normally a very strong 20-meter SSB signal, but not when almost everybody else was 40 dB over S9!

Such short-skip conditions caused by Sporadic E are more common on 10 meters than they are on 15 or 20 meters. They can result in excellent transAtlantic 10-meter openings during the summer months—when 10 meters is not normally open for F_2 ionospheric propagation.

The MUF for E_s is not known precisely. It was long thought to be around 100 MHz, but in the last 25 years or so there have been thousands of 144-MHz contacts during the summer E_s season. Presumably, the possibility also exists at 222 MHz. The skip distance at 144 MHz does average much longer than at 50 MHz, and the openings are usually brief and extremely variable.

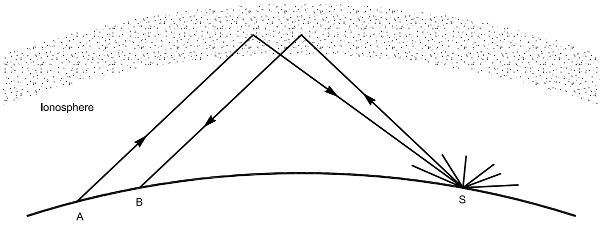

Fig 39—Schematic of a simple backscatter path. Stations A and B are too close to make contact via normal F-layer ionospheric refraction. Signals scattered back from a distant point on the Earth's surface (S), often the ocean, may be accessible to both A and B to create a backscatter circuit. (*Courtesy of The ARRL Handbook.*)

The terms "single" and "double" hop may not be accurate technically, since it is likely that cloud-to-cloud paths are involved. There may also be "no-hop" E_s. At times the very high ionization density produces critical frequencies up to the 50-MHz region, with no skip distance at all. It is often said that the E_s mode is a great equalizer. With the reflecting region practically overhead, even a simple dipole close to the ground may do as well over a few hundred miles as a large stacked antenna array designed for low-angle radiation. It's a great mode for low power and simple antennas on 28 and 50 MHz.

HF Scatter Modes

The term "skip zone" (where no signals are heard) should not be taken too literally. Two stations communicating over a single ionospheric hop can be heard to some degree by other stations at almost any point along the way, unless the two are running low power and using simple antennas. Some of the wave energy is *scattered* in all directions, including back to the starting point and farther.

Backscatter functions like a sort of HF ionospheric radar. **Fig 39** shows a schematic for a simple backscatter path. The signal launched from point A travels through the ionosphere back to earth at Point S, the scattering point. Here, the rough terrain of the land scatters signals in many directions, one of which propagates a weak signal back through the ionosphere to land at point B. Point B would normally be in the no-signal skip zone between A and S. Because backscatter signals arrive from multiple directions, through various paths through the ionosphere, they have a characteristic "hollow" sound, much like you get when you talk into a paper tube with its many internal reflections.

Because backscatter involves mainly scattering from the Earth at the point where the strong ionospherically propagated signal comes down, it is a part of HF over-the-horizon radar techniques. (The infamous 1970s-era "woodpecker" was an over-the-horizon HF radar.) Amateurs using sounding techniques have shown that you can tell to what part of the world a band is usable (single-hop F) by probing the backscatter with a directive antenna and high transmitter power, even when the Earth contact point is open ocean. In fact, that's where the mode is at its best, because ocean waves can be efficient backscatter reflectors.

Backscatter is very useful on 28 MHz, particularly when that band seems dead simply because nobody is active in the right places. The mode keeps the 10-meter band lively in the low years of the solar cycle, thanks to the never-say-die attitude of some users. The mode is also an invaluable tool of 50-MHz DX aspirants, in the high years of the sunspot cycle, for the same reasons. On a high-MUF morning, hundreds of 6-meter beams may zero in on a hot spot somewhere in the Caribbean or South Atlantic, where there is no land, let alone other 6-meter stations—keeping in contact while they wait for the band to open to a place where there is somebody.

Sidescatter is similar to backscatter, except the ground scatter zone is off the direct line between participants. A typical example, often observed during the lowest years of the solar cycle, is communication on 28 MHz between the eastern US (and adjacent areas of Canada) and much of the European continent. Often, this may start as "backscatter chatter" between Europeans whose antennas are turned toward the Azores. Then suddenly the North Americans join the fun, perhaps for only a few minutes, but sometimes much longer, with beams also pointed toward the Azores. Duration of the game can be extended, at times, by careful reorientation of antennas at both ends, as with backscatter. The secret, of course, is to keep hitting the highest-MUF area of the ionosphere and the most favorable ground-reflection points.

The favorable route is usually, but not always, south of the great-circle heading (for stations in the Northern Hemisphere). There can also be sidescatter from the auroral regions. Sidescatter signals are stronger than backscatter signals using the same general area of ground scattering.

Sidescatter signals have been observed frequently on the l4-MHz band, and can take place on any band where there is a large window between the MUF and the LUF. For sidescatter communications to occur, the thing to look for is a common area to which the band is open from both ends of the path (the Azores, in the above example), when there is no direct-path opening. It helps if the common area is in the open ocean, where there is less scattering loss than over land.

GRAY-LINE PROPAGATION

The *gray line*, sometimes called the *twilight zone*, is a band around the Earth between the Sunlit portion and darkness. Astronomers call this the *terminator*. The terminator is a somewhat diffused region because the Earth's atmosphere tends to scatter the light into the darkness. **Fig 40** illustrates the gray line. Notice that on one side of the Earth, the gray line is coming into daylight (sunrise), and on the other side it is coming into darkness (sunset).

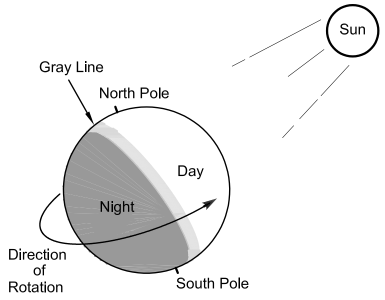

Fig 40—The gray line or terminator is a transition region between daylight and darkness. One side of the Earth is coming into sunrise, and the other is just past sunset.

Propagation along the gray line is very efficient, particularly on the lower bands, especially on 80 or 160 meters, so greater distances can be covered than might be expected for the frequency in use. One major reason for this is that the D layer, which absorbs HF signals, disappears rapidly on the sunset side of the gray line, and has not yet built up on the sunrise side.

The gray line runs generally north and south, but varies as much as 23° either side of the north-south line. This variation is caused by the tilt of the Earth's axis relative to its orbital plane around the Sun. The gray line will be exactly north and south at the equinoxes (March 21 and September 21). On the first day of Northern Hemisphere summer, June 21, it is tilted to the maximum of 23° one way, and on December 21, the first day of winter, it is tilted 23° the other way.

To an observer on the Earth, the direction of the terminator is always at right angles to the direction of the Sun at sunrise or sunset. It is important to note that, except at the equinoxes, the gray-line direction will be different at sunrise from that at sunset. This means you can work different areas of the world in the evening than you worked in the morning.

It isn't necessary to be located inside the twilight zone in order to take advantage of gray-line propagation. The effects can be used to advantage before sunrise and after sunset. This is because the Sun "rises" earlier and "sets" later on the ionospheric layers than it does on the Earth below.

What HF Bands Are Open—Where and When?

The CD-ROM included at the back of this book includes summary and detailed propagation predictions for more than 150 transmitting locations around the world. This propagation data was calculated using *CapMAN*, an upgraded variety of the mainframe propagation program *IONCAP*. The predictions were done for default antennas and powers that are representative of a "big-gun" station. Of course, not everyone has a big-gun station in his/her backyard, but this represents what the ultimate possibilities are, statistically speaking. After all, if the bands aren't open for the big guns, they are unlikely to be open for the "little pistols" too.

Let's see how propagation is affected if the smoothed sunspot number is 0 (corresponding to a smoothed solar flux of about 65), which is classified as a "Very Low" level of solar activity. And we'll examine the situation for a sunspot number of 100 (a smoothed solar flux of 150), which is typical of a "Very High" portion of the solar cycle.

Five-Band Summary Predictions

Tables 4 and **5** are Summary tables showing the predicted signal levels (in S units) from Boston, Massachusetts, to the rest of the world for the month of January. The Boston transmitting site is representative of the entire New England area of the USA. The target geographic receiving regions for the major HF bands from 80 through 10 meters are tabulated versus UTC (Universal Coordinated Time) in hours. Table 4 represents a Very Low level of solar activity, while Table 5 is for a Very High level of solar activity.

Each transmitting location is organized by six levels of solar activity over the whole 11-year solar cycle:

- VL (Very Low: SSN between 0 to 20)
- LO (Low: SSN between 20 to 40)
- ME (Medium: SSN between 40 to 60)
- HI (High: SSN between 60 to 100)
- VH (Very High: SSN between 100 to 150)
- UH (Ultra High: SSN greater than 150)

The receiving geographic regions for each frequency band are abbreviated:

Table 4

Printout of summary propagation table for Boston to the rest of the world, for a Very Low level of solar activity in the month of January. The abbreviations for the target geographic areas are: EU = Europe, FE = Far East, SA = South America, AF = Africa, AS = south Asia, OC = Oceania, and NA = North America.

```
Jan., MA (Boston), for SSN = Very Low, Sigs in S-Units. By N6BV, ARRL.
           80 Meters              40 Meters              20 Meters              15 Meters              10 Meters
UTC  EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   UTC
  0  9  -  9+ 9  9  -  9+   9  8  9+ 9+ 9  2  9+   -  8  9+ 7  4  8  9+   -  -  -  -  -  -  1     -  -  -  -  -  -  2      0
  1  9  -  9+ 9  9  -  9+   9  6  9+ 9+ 9+ 6  9+   -  4  9  4  2  6  9+   -  -  -  -  -  -  1     -  -  -  -  -  -  2      1
  2  9  -  9+ 9+ 8  1  9+   9  6  9+ 9+ 9  8  9+   -  1  8  1  2  3  9+   -  -  -  -  -  -  1     -  -  -  -  -  -  2      2
  3  9  -  9+ 9+ 8  6  9+   9  6  9+ 9+ 9  8  9+   -  -  8  2  2  -  9+   -  -  -  -  -  -  1     -  -  -  -  -  -  2      3
  4  9  -  9+ 9+ 1  8  9+   9  8  9+ 9+ 9  9  9+   -  1  8  7  2  -  9+   -  -  -  -  -  -  1     -  -  -  -  -  -  2      4
  5  9  -  9+ 9+ -  9  9+   9  8  9+ 9+ 8  9  9+   -  1  9  8  2  -  9     -  -  -  -  -  -  1     -  -  -  -  -  -  2      5
  6  9+ -  9+ 9+ -  9  9+   7  8  9+ 9+ 8  9  9+   -  1  9+ 8  -  -  9     -  -  -  -  -  -  1     -  -  -  -  -  -  2      6
  7  9  7  9+ 9  -  9  9+   7  8  9+ 9  8  9  9+   -  1  9+ 1  -  1  8     -  -  -  -  -  -  1     -  -  -  -  -  -  2      7
  8  9  8  9+ 9  -  9  9+   8  9  9+ 9  8  9+ 9+   -  1  9+ -  -  5  9     -  -  -  -  -  -  1     -  -  -  -  -  -  2      8
  9  8  8  9+ 7  6  9  9+   8  9  9+ 9  9  9+ 9+   -  -  9  1  -  7  9     -  -  -  -  -  -  1     -  -  -  -  -  -  2      9
 10  5  8  9+ 4  6  9  9+   9  9  9+ 9  9  9+ 9+   -  3  9  5  -  6  9     -  -  -  -  -  -  1     -  -  -  -  -  -  2     10
 11  3  8  9+ -  5  9  9+   8  9  9+ 7  9  9+ 9+   5  -  9+ 9  5  1* 8     -  -  -  -  -  -  1     -  -  -  -  -  -  2     11
 12  1  8  9  -  4  9  9+   7  9  9+ 4  8  9  9+   9  5  9+ 9+ 9  2* 8     -  -  5  6  -  -  1     -  -  -  -  -  -  2     12
 13  -  6  1  -  -  7  9+   6  8  9+ 1  8  9  9+   9+ 9  9+ 9  9  7  8     4  -  9+ 9  7  -  1     -  -  -  -  -  -  1     13
 14  -  -  -  -  -  1  9+   5  7  8  -  8  8  9+   9+ 9  9+ 9  9  9  9+   7  2* 9+ 9  9  -  8     -  -  5  -  -  -  1     14
 15  -  -  -  -  -  -  9+   4  6  5  -  6  7  9+   9+ 9  9+ 9  9  9  9+   7  5  9+ 9  2  2  5     -  -  5  -  -  -  -     15
 16  -  -  -  -  -  -  9+   5  6  4  2  5  4  9+   9+ 8  9+ 9+ 9  9  9+   5  1  9+ 8  2* 2  9     -  -  5  -  -  -  1     16
 17  -  -  -  -  -  -  9+   6  5  5  5  6  1  9+   9+ 5  9+ 9+ 3  9  9+   -  -  9+ 9  -  3  9+    -  -  5  -  -  -  1     17
 18  1  -  -  -  -  -  9+   8  6  6  7  6  -  9+   9+ 6  9+ 9+ 4  9  9+   -  -  9+ 9  -  7  9+    -  -  5  -  -  -  1     18
 19  3  -  -  2  -  -  9+   9  7  8  8  8  -  9+   6  6  9+ 9+ 6  9  9+   -  -  9+ 9  -  9  9+    -  -  2  -  -  -  1     19
 20  5  -  7  5  -  -  9+   9  8  9+ 9  8  4  9+   1  7  9+ 9+ 8  9  9+   -  -  9+ 4  -  9  9     -  -  -  -  -  -  1     20
 21  8  3  9  8  6  -  9+   9  8  9+ 9+ 9  7  9+   -  8  9+ 9  8  9  9+   -  -  9+ -  -  9  6     -  -  -  -  -  -  1     21
 22  9  3  9+ 9  8  -  9+   9  8  9+ 9+ 9  5  9+   -  9+ 9+ 9  8  9  9+   -  -  9  -  -  7  1     -  -  -  -  -  -  1     22
 23  9  2  9+ 9  9  -  9+   9  8  9+ 9+ 9  4  9+   -  9+ 9+ 9  5  9  9+   -  1  6  -  -  2  3     -  -  -  -  -  -  2     23
     EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA
```

Table 5

Printout of summary propagation table for Boston to the rest of the world, for a Very High level of solar activity in the month of January.

```
Jan., MA (Boston), for SSN = Very High, Sigs in S-Units. By N6BV, ARRL.
            80 Meters               40 Meters               20 Meters               15 Meters               10 Meters
UTC  EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA    UTC
 0   9+ -  9+ 9+ 8  -  9+   9+ 5  9+ 9+ 9  -  9+   1  9+ 9+ 9+ 9+ 9  9+   -  9  9+ 2  2  9+ 9+   -  1  8  -  -  8  9+      0
 1   9+ -  9+ 9+ 8  -  9+   9+ 4  9+ 9+ 9  2  9+   1  9  9+ 8  9+ 9+ 9+   -  3  9  -  7  9+ 9    -  -  -  -  -  4  2       1
 2   9+ -  9+ 9+ 7  -  9+   9+ 4  9+ 9+ 9  7  9+   1  9  9+ 8  9  9+ 9+   -  -  3  -  -  7  9    -  -  -  -  -  -  2       2
 3   9+ -  9+ 9+ 1  2  9+   9+ 4  9+ 9+ 9  9  9+   -  7  9+ 7  8  9+ 9    -  -  -  -  -  -  -    -  -  -  -  -  -  2       3
 4   9+ -  9+ 9+ -  7  9+   9+ 5  9+ 9+ 8  9  9+   -  5  9+ 9  9  9  9+   -  -  1  -  -  -  -    -  -  -  -  -  -  2       4
 5   9+ -  9+ 9+ -  8  9+   9+ 6  9+ 9+ 7  9  9+   -  5  9+ 9  9  5  9+   -  -  -  -  -  -  -    -  -  -  -  -  -  2       5
 6   9+ -  9+ 9+ -  8  9+   9+ 7  9+ 9+ 7  9  9+   -  8  9+ 8  9  5  9+   -  -  -  -  -  -  -    -  -  -  -  -  -  2       6
 7   9+ -  9+ 9+ -  8  9+   9  8  9+ 9+ 7  9+ 9+   -  9  9+ -  7  9  9+   -  -  1  -  -  -  -    -  -  -  -  -  -  2       7
 8   9  7  9+ 9  -  8  9+   9  8  9+ 9+ 8  9+ 9+   -  9  9+ -  4  9+ 9+   -  -  1  -  -  -  2    -  -  -  -  -  -  2       8
 9   8  7  9+ 7  -  8  9+   9  9  9+ 9  8  9+ 9+   -  6  9+ -  1  9+ 9+   -  -  -  -  -  -  1    -  -  -  -  -  -  2       9
10   5  8  9+ 2  3  8  9+   9  9  9+ 8  8  9  9+   4  -  9+ 9+ 1  5  9    -  -  -  -  -  -  -    -  -  -  -  -  -  2      10
11   1  8  9+ -  4  9  9+   8  9  9+ 5  8  9  9+   9+ 4* 9+ 9+ 7  -  8    -  -  9  9  -  -  -    -  -  -  -  -  -  2      11
12   -  7  8  -  1  9  9+   6  9  9+ 1  8  9  9+   9+ 9  9+ 9  9  1* 9+   9  8* 9+ 9+ 9  5* -    -  2* 9  9  1  1* 2      12
13   -  -  -  -  -  2  9+   4  8  8  -  7  9  9+   9+ 9  9+ 9  9  9+ 9+   9+ 7  9+ 9+ 9+ 3* 9    9  5* 9+ 9+ 9  6* 2      13
14   -  -  -  -  -  -  9+   2  7  4  -  5  8  9+   9+ 9  9+ 8  9  9  9+   9+ 9  9+ 9+ 9+ 9  9+   9  6* 9+ 9+ 9  1* 1      14
15   -  -  -  -  -  -  9    1  5  -  -  4  5  9+   9+ 9  9+ 9  9  9  9+   9+ 9+ 9+ 9+ 9+ 9  9+   9  5  9+ 9+ 6  6  8      15
16   -  -  -  -  -  -  8    3  4  -  -  3  1  9+   9+ 8  9  9  9  9  9+   9+ 9+ 9+ 9+ 9  9+ 9+   9  8  9+ 9+ -  8  9      16
17   -  -  -  -  -  -  8    5  3  -  2  4  -  9+   9+ 8  9+ 9+ 9  9  9+   9+ 9  9+ 9+ 1* 9+ 9+   -  8  9+ 9+ -  8  9+     17
18   -  -  -  -  -  -  9    7  4  2  5  5  -  9+   9+ 9  9+ 9+ 9  9  9+   9+ 9  9+ 9+ 1  9+ 9+   -  7  9+ 9+ -  9+ 9+     18
19   1  -  -  1  -  -  9+   8  5  6  8  7  -  9+   9+ 9  9+ 9+ 9  9  9+   -  9+ 9+ 9+ 2  9  9+   -  6  9+ 9+ -  9+ 9+     19
20   4  -  2  5  -  -  9+   9  6  9  9  8  -  9+   9+ 9  9+ 9+ 9  9  9+   -  8  9+ 9+ 3  9  9+   -  1  9+ 9  -  9  9+     20
21   7  -  8  7  1  -  9+   9+ 7  9+ 9+ 8  1  9+   8  9  9+ 9+ 9  9  9+   -  6  9+ 9+ 3  9  9+   -  -  9+ 5* -  9+ 9+     21
22   9  2  9+ 9  8  -  9+   9+ 7  9+ 9+ 9  4  9+   2  9+ 9+ 9+ 9  9  9+   -  9+ 9+ 9  1  9+ 9+   -  5  9+ 4* -  9  6      22
23   9  -  9+ 9  8  -  9+   9+ 7  9+ 9+ 9  -  9+   1  9+ 9+ 9+ 9  9  9+   -  9+ 9+ 6  -  9  9+   -  7  9+ 2* -  9  2      23
     EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA   EU FE SA AF AS OC NA
```

• EU	All of Europe
• FE	The Far East, centered on Japan
• SA	South America, centered on Paraguay
• AF	All of Africa, centered on Zambia
• AS	South Asia, centered on India
• OC	Oceania, centered on Sydney, Australia
• NA	North America, all across the USA

These propagation files show the highest predicted signal strength (in S-units) throughout the generalized receiving area, for a 1500-W transmitter and rather good antennas on both sides of the circuit. The standard antennas are:

- 100-foot high inverted-V dipoles for 80 and 40 meters
- 3-element Yagi at 100 feet for 20 meters
- 4-element Yagi at 60 feet for 15 and 10 meters.

For example, Summary Table 4 shows that in January during a period of Very Low solar activity, 15 meters is open to somewhere in Europe from Boston for only 4 hours, from 13 to 16 UTC, with a peak signal level between S4 and S7. Now look at Table 5, where 15 meters is predicted to be open to Europe during a period of Very High solar activity for 7 hours, from 12 to 18 UTC, with peak signals ranging from S9 to S9+.

Both Tables 4 and 5 represent *snapshots* of predicted signal levels to generalized receiving locations—that is, they are computed for a particular month, from a particular transmitting location, and for a particular level of solar activity. These tables provide summary information that is particularly valuable for someone planning for an operating event such as a DXpedition or a contest.

What happens if you don't have a big-gun station with high antennas or the 1500-W power assumed in the analyses above? You can discount the S-Meter readings to reflect a smaller station:

- Subtract 2 S units for a dipole instead of a Yagi at same height on 20/15/10 meters.
- Subtract 3 S units for a dipole at 50 feet instead of a Yagi at 100 feet on 20 meters.
- Subtract 1 S unit for a dipole at 50 feet rather than a dipole at 100 feet on 40/80 meters.
- Subtract 3 S units for 100 W rather than 1500 W.
- Subtract 6 S units for 5 W (QRP) rather than 1500 W.

For example, Table 4 predicts an S7 signal into Boston from Europe on 15 meters at 14 UTC. If a European station is using a dipole at 50 feet, with 100 W of power, what

20 Meters: Jan., MA (Boston), for SSN = Very High, Sigs in S-Units. By N6BV, ARRL.

UTC -->

Zone		00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
KL7 = 01		9+	9+	9+	7	-	-	-	-	-	-	-	-	-	-	-	3	9+	9+	9+	9+	9+	9+	9+	9+
VO2 = 02		9+	9	9	9	9	9	8	7	5	3	2	1	5	9+	9+	9+	9+	9+	9+	9+	9+	9+	8	9+
W6 =	03	9+	9+	9+	7	7	1	1	5	8	8	3	-	-	1	9	9+	9+	9+	9+	9	9	9+	9+	9+
W0 =	04	9+	9+	9+	8	5	5	5	5	3	2	1	-	-	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+
W3 =	05	4	2	2	2	2	2	2	3	3	3	3	2	1	1	8	9+	9+	9+	9+	9+	9+	9+	9+	9
XE1 = 06		9+	9+	7	9	9+	9+	9+	9+	9+	9+	9	8	9+	9+	9+	9+	9	9	9	9	9+	9+	9+	9+
TI =	07	9+	9+	8	9	9	9	9	9	9	9+	9	9+	9+	9+	9+	9+	9	8	9	9	9+	9+	9+	9+
VP2 = 08		9+	9+	9+	9+	9+	9+	9+	9+	9+	8	9	9+	9+	9+	9+	9+	9	9+	9+	9+	9+	9+	9+	9+
P4 =	09	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9	9	9	9	9+	9+	9+	9+	9+
HC =	10	9+	8	9+	9	9	9	9	9	7	3	1	7	9+	9+	9	5	5	5	7	8	9+	9+	9+	9+
PY1 = 11		9+	9+	9+	9	9	9+	9+	9	8	6	9	9+	8	2	1	-	-	1	4	8	9	9+	9+	9+
CE =	12	9+	9+	9+	9+	9+	9+	9+	9+	9	8	8	9+	9	8	2	1	1	-	1	3	7	9	9+	9+
LU =	13	9+	9+	9+	9+	9+	9+	9+	9+	8	8	8	9+	8	4	2	1	-	-	1	4	8	9	9+	9+
G =	14	-	-	-	-	-	-	-	-	-	-	-	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	8	2	-
I =	15	-	-	-	-	-	-	-	-	-	-	4	9	9	9	9	9	9	9+	9+	9	8	2	-	-
UA3 = 16		1	1	1	-	-	-	-	-	-	-	-	8	9	9+	9+	9+	9	8	5	-	-	-	-	1
UN =	17	1	-	-	8	7	7	7	1	-	-	-	2	9	9	9	6	-	-	2	4	8	9	5	4
UA9 = 18		6	7	6	6	9	9	9	7	4	1	-	-	8	8	6	6	5	6	7	8	9	9	8	7
UA0 = 19		9+	9	9	6	5	5	8	8	8	4	-	-	2	6	8	8	8	7	4	4	7	9	9+	9+
4X =	20	8	6	3	1	-	3	4	-	-	-	1	8	8	8	8	8	9	9	9+	9	9	8	7	7
HZ =	21	9+	9	4	3	8	8	2	-	-	-	1	7	8	9	8	8	9	9	9	9	9	9	9	9
VU =	22	7	5	8	7	6	7	5	-	-	-	-	6	9	9	9	9	3	2	2	2	8	8	9	8
JT =	23	9	9+	9	5	7	8	8	6	3	-	-	2*	8	8	5	6	8	8	8	8	9	7	5	6
VS6 = 24		9	9	9	5	4	5	7	8	6	1	-	1*	5	7	1	1	1	1	4	2	-	-	-	9
JA1 = 25		9	9	8	7	5	5	8	9	9	6	-	1	1	2	7	7	6	2	-	-	7	9	9+	9
HS =	26	9	9	6	4	2	-	-	2	1	-	-	2*	9	9	9	9	8	7	5	4	5	-	1*	1
DU =	27	9	8	7	-	-	-	5	7	7	1	-	-	1*	9	9	7	6	4	5	3	1*	1*	8	9
YB =	28	9	8	1	-	-	-	-	-	-	-	-	4*	8	9	9	9	8	8	9	9	9	9	9+	9+
VK6 = 29		3*	4*	-	-	-	-	-	-	5	3	-	-	-	5	9	9	9	8	9	9	9	9	9	8
VK3 = 30		1*	-	-	-	-	-	1	3	9	9	4	-	-	9+	9	8	2	1	-	-	1	2*	5*	4*
KH6 = 31		9	9+	9+	9+	8	2	2	6	4	-	-	-	-	-	-	-	9	9	8	7	6	4	6	7
KH8 = 32		-	2	9	9	9	5	5	9	9+	9+	5	-	-	9+	9	9	8	5	3	1	-	-	-	-
CN =	33	-	-	-	-	-	-	-	-	-	-	9	9+	9	9	8	9	9	9+	9+	9+	9+	9+	9+	7
SU =	34	9	8	3	3	-	1	4	-	-	-	2	7	8	8	8	8	9	9	9+	9+	9+	9+	8	8
6W =	35	9+	8	-	-	2	7	5	-	-	-	9+	9+	8	5	4	3	7	9	9+	9+	9+	9+	9+	9+
D2 =	36	9+	9+	5	3	9	9	8	-	-	-	3	-	-	-	-	4	4	7	8	9	9+	9+	9+	9+
5Z =	37	9+	9	2	4	8	8	1	-	-	-	2	-	-	3	5	5	7	8	9	9	9+	9+	9+	9+
ZS6 = 38		9+	9+	8	7	8	9	6	-	-	-	-	-	-	-	1*	1	2	6	8	9	9+	9+	9+	9+
FR =	39	9+	8	2	1	4	1	-	-	-	-	-	-	-	2*	3*	1*	1	3	8	9	9+	9+	9+	9+
FJL = 40		9+	9+	7	4	7	8	7	1	-	-	-	1*	8	9	9	9	9	9	9	9	9+	9+	9+	9+
Zone		00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23

UTC -->

Expected signal levels using 1500 W and 3-element Yagis at 100 feet at each station.

Fig 41—The 20-meter page from Detailed propagation-prediction for the month of January, during Very High solar conditions, from Boston to 40 CQ Zones throughout the world. There are similar pages for each month/SSN level for 160, 80, 40, 20, 15 and 10 meters. These Detailed tables are very useful for planning DX work.

would this do to the predicted signal level in Boston? You would compute: S7 – 2 S units (for a dipole instead of Yagi) – 3 S units (100 W rather than 1500 W) = an S2 signal in Boston. A QRP station with a 4-element 15-meter Yagi at 60 feet would yield: S7 – 6 S units = an S1 signal in Boston.

More Detailed Predictions

Let's now look at table in **Fig 41**, which is the Detailed 20-meter page for the same conditions in Table 5: January at a Very High level of solar activity from Boston to the world. There are six such pages per month/SSN level, covering 160, 80, 40, 20, 15 and 10 meters.

In a Detailed prediction table, the world is divided into the 40 CQ Zones, with a particular sample location in each zone. For example, Zone 14 in Western Europe is represented by a location in London, England (call sign G), while Zone 25 is represented by a location in Tokyo, Japan (call sign JA1). Note that Zones with large ham populations are highlighted with dark shadowing for easy identification. For example, Zones 3, 4 and 5 cover the USA, while Zones 14, 15 and 16 cover the majority of Europe. Zone 25 covers the big ham population in Japan.

Let's revisit the example above for computing the signal strength for a station in London, but this time on 20 meters. Again, we'll assume that the G station has a dipole at 50 feet and 100 W of transmitter power. At 14 UTC in Zone 14, the table in Fig 40 predicts a very healthy signal for the reference big-gun station, at S9+. This is a signal at least S9 + 10 dB. Here, we're going to round off the plus 10 dB to 2 S units, giving a fictional 11 S units to start. We discount this for the smaller station: S11 – 3 S units (for a dipole at 50 feet instead of a 3-element Yagi at 100 feet) – 3 S units (100 W rather than 1500 W) = S5 signal in Boston. This is a respectable signal and will probably get through, in the absence of stronger signals calling the Boston station at the same time, of course.

Here's another example of how to use the Detailed propagation-prediction tables. Let's say that at 1230 UTC in January you work a VU2 station in New Delhi on 15 meters from Boston, where the local time is 7:30 AM.

You need a 20-meter contact also for the 5-Band DXCC award, so you quickly check the table in Fig 40 for Zone 22 (VU) and find that the predicted signal strength is S9. Your new VU2 friend is willing to jump to 20 meters and so you QSY to make the contact.

But perhaps you are late leaving for work and so you ask your new VU2 friend to make a schedule with you later that evening. Again, you consult the Detailed prediction table for 20 meters and find that signals are predicted to be S8 or stronger from 20 to 23 UTC, dropping to S7 at 00 UTC. You quickly ask your new friend whether he minds waking up at 4:30 AM his time to make a schedule with you at 2300 UTC, because New Delhi is 5½ hours ahead of UTC. You determined this using the program *GeoClock*, which is included with the software on the CD-ROM in the back of this book and which you run in the background on *Windows*. Luckily, he's a very gracious fellow and agrees to meet you on a specific frequency at that time.

The Detailed propagation-prediction tables give you all the information needed to plan your operations to maximize your enjoyment chasing DX. You can use these tables to plan a 48-hour contest next month, or next year—or you can use them to plan a schedule with your ham cousin on the West Coast on Saturday afternoon.

THE PROPAGATION BIG PICTURE

A newcomer to the HF bands could easily be overwhelmed with the sheer amount of data available in the Summary (and particularly the Detailed) prediction tables on the CD-ROM included with this book. So here's a long-term, "big-picture" view of HF propagation that might help answer some common questions. For example, what month really is the best for working DX around the clock? Or what level of solar activity is necessary to provide an opening between your QTH and somewhere in the South Pacific?

Table 6 is a table showing the number of hours in a day during each month when each major HF band is open to the same receiving areas shown in Tables 4 and 5. The listing is for New England, for three levels of solar activity: Very Low, Medium and Very High. The number of hours are separated in Table 6 by slashes. (Versions of Table 6 for other areas around the US are on the CD-ROM that accompanies this book in **Fig6Tab.PDF**.)

Let's examine the conditions for New England to Europe on 15 meters for October. The entry shows "7/11/17," meaning that for a Very Low level of solar activity, 15 meters is open for 7 hours; for a Medium level, it is open for 11 hours and for a Very High level of solar activity it is open for 17 hours a day.

Even for a Very Low level of solar activity, the month with the most hours available per day from Boston to somewhere in Europe is October, with 7 hours, followed by the next largest month of March, with 6 hours. For a Very High level of solar activity, however, the 15-meter band is open to Europe for 18 hours in April, followed by 17 hours availability in September and October. Arguably, the CQ World Wide Contest Committee picked the very best month for higher-frequency propagation when they chose October for the Phone portion of that contest.

You can easily see that even at a Very High level of solar activity, the summer months are not very good to work DX, particularly on east-west paths. For example, the 10-meter band is very rarely open from New England to Europe after the month of April, even when solar activity is at the highest levels possible. Things pick up after September, even for a Medium level of solar activity. Again, October looks like the most fruitful month in terms of the number of hours 10 meters is open to Europe under all levels of solar conditions.

Ten meters is open more regularly on north-south paths, such as from New England to South America or to southern Africa. It is open as much as 10 hours a day during March and October to deep South America, and 7 hours a day in October to Africa—even during the lowest parts of the solar cycle. (Together with the sporadic-E propagation that 10 meters enjoys during the summer, this band can often be a lot of fun even during the sunspot doldrums. You just have to *be operating* on the band, rather than avoiding it because you know the sunspots are "spotty!")

Now, look at the 20-meter band in Table 6. From New England, twenty is open to somewhere in South America for 24 hours a day, no matter the level of solar activity. Note that Table 6 doesn't predict the level of signals available; it just shows that the band is open with a signal strength greater than 0 on the S meter. Look back at Summary Table 4 for the predicted signal strengths in January at a Very Low level of solar activity. There, you can see that the signal strength from New England into deep South America is always S8 or greater for a big gun station. A lot of the time during the night the band sounds dead, simply because everyone is either asleep or operating on a lower frequency.

For the 40-meter band in Table 6, during the month of January the band is open to Europe for 24 hours a day, whatever the level of solar activity is. Look now at Table 4, and you'll see that the predicted level for Very Low solar activity varies from S4 to S9. Local QRM or QRN would probably disrupt communications on 40 meters in Europe for stateside signals weaker than perhaps S3 or S4. Even though you might well be able to hear Europeans from New England during the day, they probably won't hear you because of local conditions, including local S9+ European stations and atmospheric noise from nearby thunderstorms. New England stations with big antennas can often hear Europeans on 40 meters as early as noontime, but must wait until the late afternoon before the Europeans can hear them above their local noise and QRM.

Let's say that you want to boost your country total on 80 meters by concentrating on stations in the South Pacific. The best months would be from November to

Table 6

The number of hours per day when a particular band is open to the target geographic areas in Table 4, as related to the level of solar activity (Very Low, Medium and Very High). This table is customized for Boston to the rest of the world. Some paths are open 24 hours a day, plus or minus QRM and local QRN, no matter what the level of solar activity is. See CD-ROM for other transmitting locations.

```
MA (Boston)
Hours Open to Each Region for Very-Low/Medium/Very-High SSNs

80 Meters:
Month  Europe   Far East  So. Amer.  Africa   So. Asia  Oceania   No. Amer.
Jan   17/17/16   5/ 4/ 3  17/17/16  16/16/15   8/ 7/ 5  11/10/ 9  24/24/24
Feb   17/16/15   3/ 3/ 2  17/16/16  15/15/14   6/ 4/ 4  10/ 9/ 9  24/24/24
Mar   15/15/14   3/ 2/ 1  16/16/15  15/13/13   4/ 4/ 3   9/ 8/ 7  24/24/24
Apr   13/13/12   1/ 0/ 0  16/16/14  13/13/13   3/ 3/ 1   9/ 8/ 7  24/24/24
May   12/11/10   0/ 0/ 0  16/15/14  12/11/10   2/ 1/ 1   7/ 6/ 6  24/24/24
Jun   10/ 9/ 8   0/ 0/ 0  14/14/14  11/10/10   1/ 1/ 0   6/ 5/ 5  24/24/24
Jul   11/11/ 9   0/ 0/ 0  15/14/14  11/11/11   2/ 1/ 1   7/ 6/ 5  24/24/24
Aug   13/11/11   0/ 0/ 0  16/16/14  13/12/11   3/ 2/ 1   7/ 7/ 6  24/24/24
Sep   14/13/11   2/ 1/ 0  17/16/14  13/13/12   4/ 4/ 2   9/ 8/ 8  24/24/24
Oct   15/15/13   3/ 2/ 1  17/17/16  14/14/13   5/ 4/ 4   9/ 9/ 7  24/24/24
Nov   17/17/15   4/ 4/ 2  17/17/16  16/15/14   8/ 7/ 4  11/10/ 9  24/24/24
Dec   19/18/17   7/ 6/ 4  18/18/17  16/16/16  11/ 9/ 7  12/11/11  24/24/24

40 Meters:
Month  Europe   Far East  So. Amer.  Africa   So. Asia  Oceania   No. Amer.
Jan   24/24/24  15/16/15  24/24/21  21/20/19  21/21/19  19/18/15  24/24/24
Feb   24/24/21  13/11/11  24/23/20  20/19/18  19/19/17  16/15/14  24/24/24
Mar   23/22/19  10/ 9/ 7  24/21/18  19/17/17  17/17/13  13/13/13  24/24/24
Apr   21/19/18   8/ 6/ 4  22/20/18  17/16/15  16/11/ 8  13/13/11  24/24/24
May   19/17/17   5/ 4/ 3  22/18/17  17/16/14   9/ 8/ 5  12/11/10  24/24/24
Jun   17/15/13   4/ 2/ 2  22/18/16  16/15/14   7/ 5/ 5  11/10/ 9  24/24/24
Jul   18/16/15   5/ 4/ 2  24/18/17  17/15/14   8/ 7/ 5  12/11/10  24/24/24
Aug   19/17/16   7/ 5/ 4  24/19/18  18/16/15  11/10/ 6  13/12/11  24/24/24
Sep   22/21/17   9/ 8/ 5  23/20/18  18/17/16  14/11/ 7  13/13/12  24/24/24
Oct   24/23/20  12/11/ 8  24/23/19  20/18/17  17/16/14  16/13/13  24/24/24
Nov   24/24/22  14/13/12  24/24/20  21/19/18  21/20/17  17/17/13  24/24/24
Dec   24/24/24  18/19/22  24/24/21  23/21/19  24/23/22  21/19/18  24/24/24
```

February in terms of the number of hours per day when the 80-meter band is open to Oceania. You can see by reading across the line for each month that the level of solar activity is not hugely important on 80 meters to any location. Common experience (backed by the statistical information in Table 6) is that the 80-meter band is open only marginally longer when sunspots are low.

This is true to a greater extent on 40 meters. Thus you may hear the generalization that the low bands tend to be better during periods of low solar activity, while the upper HF bands (above 10 MHz) tend to be better when the sun is more active.

Table 6 can give you a good handle on what months are the most productive for DXing and contesting. It should be no surprise to most veteran operators that the fall and winter months are the best times to work DX.

```
20 Meters:
Month  Europe   Far East  So. Amer.  Africa   So. Asia  Oceania   No. Amer.
Jan   13/16/22  15/22/22  24/24/24  20/21/21  18/20/22  18/23/22  24/24/24
Feb   12/18/23  13/21/24  24/24/24  22/22/24  15/21/24  18/23/24  24/24/24
Mar   15/18/24  17/20/24  24/24/24  22/24/24  18/21/24  16/24/24  24/24/24
Apr   15/20/24  19/22/24  24/24/24  21/24/24  19/22/24  18/24/24  24/24/24
May   19/23/24  22/24/24  24/24/24  23/24/24  23/24/24  21/24/24  24/24/24
Jun   22/24/24  24/24/24  24/24/24  24/24/24  24/24/24  24/24/24  24/24/24
Jul   19/24/24  24/24/24  24/24/24  21/24/24  24/24/24  23/24/24  24/24/24
Aug   15/20/24  20/24/24  24/24/24  20/24/24  20/24/24  19/24/24  24/24/24
Sep   16/19/24  17/21/24  24/24/24  21/24/24  18/21/24  17/24/24  24/24/24
Oct   15/21/24  16/20/24  24/24/24  22/24/24  19/22/24  17/24/24  24/24/24
Nov   14/20/23  14/22/24  24/24/24  20/24/24  17/21/24  19/23/24  24/24/24
Dec   11/17/24  13/22/24  24/24/24  17/23/24  12/22/24  16/24/24  24/24/24

15 Meters:
Month  Europe   Far East  So. Amer.  Africa   So. Asia  Oceania   No. Amer.
Jan    4/ 6/ 7   2/ 9/13  12/15/16   9/13/13   3/ 4/ 7   9/12/13  24/15/16
Feb    4/ 7/12   4/10/14  13/18/23  11/13/16   3/ 7/13   8/13/15  22/16/19
Mar    6/ 9/14   2/13/15  14/21/24  13/17/22   5/11/17  10/14/17  15/16/23
Apr    0/10/18   3/13/18  15/23/24  15/18/24   9/15/19  11/15/21  16/16/24
May    1/13/16   6/10/19  17/20/24  14/18/24  13/17/18  10/16/19  20/19/24
Jun    0/ 2/16   0/ 9/15  16/21/24  14/18/24   5/15/18  10/12/20  24/22/22
Jul    0/ 2/16   0/ 5/18  15/19/24  12/18/24   0/12/18   4/12/20  24/22/21
Aug    0/ 2/14   0/ 8/17  14/18/22  13/16/22   0/12/17   6/10/19  22/19/21
Sep    1/10/17   6/13/17  14/16/24  13/17/22   9/14/17   9/14/17  16/16/22
Oct    7/11/17  10/13/17  12/16/22  12/15/22   7/12/17  12/13/15  18/15/22
Nov    5/ 8/14   8/11/14  12/16/22  11/14/17   3/ 7/16  10/13/15  20/16/21
Dec    3/ 6/ 9   2/10/13  12/15/23   8/13/15   2/ 4/12   9/12/14  24/15/18

10 Meters:
Month  Europe   Far East  So. Amer.  Africa   So. Asia  Oceania   No. Amer.
Jan    0/ 1/ 4   0/ 1/ 8   6/11/13   0/ 7/10   0/ 1/ 3   0/ 3/11  23/24/24
Feb    0/ 2/ 7   0/ 2/10   8/12/14   0/ 9/13   0/ 3/ 5   0/ 7/13  24/24/24
Mar    0/ 0/ 8   0/ 1/10  10/14/20   1/11/14   0/ 0/ 8   0/ 7/13  23/24/24
Apr    0/ 0/ 8   0/ 0/ 8   7/14/21   0/12/17   0/ 0/13   0/ 5/11  18/24/24
May    0/ 0/ 0   0/ 0/ 1   7/12/20   1/10/17   0/ 1/12   0/ 2/11  17/20/22
Jun    0/ 0/ 0   0/ 0/ 0   7/11/18   0/ 3/17   0/ 0/ 0   0/ 0/ 2  21/19/23
Jul    0/ 0/ 0   0/ 0/ 0   2/ 9/19   0/ 2/18   0/ 0/ 7   0/ 0/ 6  16/16/24
Aug    0/ 0/ 0   0/ 0/ 0   2/10/17   0/ 1/16   0/ 0/10   0/ 0/ 8  17/17/24
Sep    0/ 0/ 8   0/ 1/10   7/13/18   0/11/16   0/ 0/10   0/ 2/ 9  19/24/24
Oct    0/ 5/ 9   0/ 2/11  10/12/16   7/12/14   0/ 5/ 9   0/ 8/12  24/24/24
Nov    0/ 4/ 8   0/ 3/11   9/12/15   5/10/13   0/ 3/ 6   4/10/12  24/24/24
Dec    0/ 3/ 6   0/ 1/ 8   8/11/13   1/ 8/12   0/ 1/ 4   2/ 7/12  23/23/24
```

Do-It-Yourself Propagation Prediction

Very reliable methods of determining the MUF for any given radio path have been developed over the last 50 years. As discussed previously, these methods are all based on the smoothed sunspot number (SSN) as the measure of solar activity. It is for this reason that smoothed sunspot numbers hold so much meaning for radio amateurs and others concerned with radio-wave propagation—they are the link to past (and future) propagation conditions.

Early on, the prediction of propagation conditions required tedious work with numerous graphs, along with charts of frequency contours overlaid, or overprinted, on world maps. The basic materials were available from an agency of the US government. Monthly publications provided the frequency-contour data a few months in advance. Only rarely did amateurs try their hand at predicting propagation conditions using these hard-to-use methods.

Today's powerful PCs have given the amateur wonderful tools to make quick-and-easy HF propagation predictions, whether for a contest or a DXpedition. The summary and detailed prediction tables described earlier in this chapter were generated using *CAPMan*, a modernized version of the mainframe *IONCAP* program, on a PC.

While tremendously useful to setting up schedules and for planning strategy for contests, both the Summary and Detailed prediction tables located on the CD-ROM accompanying this book show signal strength. They do not show

Table 7
Features and Attributes of Propagation Prediction Programs

	ASAPS V. 4	*CAPMan*	*VOACAP Windows*	*ACE-HF*	*W6ELProp V. 2.70*	*WinCAP Wizard 2*	*PropLab Pro*
User Friendliness	Good	Good	Good	Excellent	Good	Good	Poor
Operating System	Windows	DOS	Windows	Windows	Windows	Windows	DOS
Uses k or A index	No	Yes	No	No	Yes	Yes	Yes
User library of QTHs	Yes	Yes	Yes	Yes-RX	Yes	Yes	No
Bearings, distances	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MUF calculation	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LUF calculation	Yes	Yes	Yes	Yes	No	Yes	Yes
Wave angle calculation	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vary minimum wave angle	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Path regions and hops	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Multipath effects	Yes	Yes	Yes	Yes	No	Yes	Yes
Path probability	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Signal strengths	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S/N ratios	Yes	Yes	Yes	Yes	No	Yes	Yes
Long-path calculation	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Antenna selection	Yes	Yes	Yes	Yes	Indirectly	Isotropic	Yes
Vary antenna height	Yes	Yes	Yes	Yes	Indirectly	No	Yes
Vary ground characteristics	Yes	Yes	Yes	Yes	No	No	No
Vary transmit power	Yes	Yes	Yes	Yes	Indirectly	Yes	Yes
Graphic displays	Yes	Yes	Yes	Yes	Yes	Yes	2D/3D
UT-day graphs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area Mapping	No	Yes	Yes	Yes	Yes	No	Yes
Documentation	Yes	Yes	On-line	Yes	Yes	Yes	Yes
Price class	$275+	$89	free†	$99	free§	$29.95+	$150††

Price classes are for late 2003 and subject to change.
†Available on the World Wide Web: **elbert.its.bldrdoc.gov/hf.html**
§Available on the World Wide Web at: **www.qsl.net/w6elprop/**
+ Shipping and handling extra.
††Available on the World Wide Web: **www.spacew.com/www/proplab.html**

other information that is also in the underlying databases used to generate them. They don't, for example, show the dominant elevation angles and neither do they show reliability statistics. You may want to run propagation-prediction software yourself to get into the really "nitty-gritty" details.

Modern programs are designed for quick-and-easy predictions of propagation parameters. See **Table 7** for a listing of a number of popular programs. The basic input information required is the smoothed sunspot number (SSN) or smoothed solar flux, the date (month and day), and the latitudes and longitudes at the two ends of the radio path. The latitude and longitude, of course, are used to determine the great-circle radio path. Most commercial programs tailored for ham use allow you to specify locations by the call sign. The date is used to determine the latitude of the Sun, and this, with the sunspot number, is used to determine the properties of the ionosphere at critical points on the path.

Of course, just because a computer program predicts that a band will be open on a particular path, it doesn't follow that the Sun and the ionosphere will always cooperate! A sudden solar flare can result in a major geomagnetic storm, taking out HF communication anywhere from hours to days. There is still art, as well as a lot of science, in predicting propagation. In times of quiet geomagnetic activity, however, the prediction programs are good at forecasting band openings and closings.

Obtaining Sunspot Number/Solar Flux Data

After you have chosen and then set up a computer program for evaluation of a particular path, you will still need the sunspot number or solar flux level for the period in question. A caution must be stated here—for best accuracy and consistency, use the average of solar flux values taken from actual observations, perhaps from WWV/WWVH, over the previous three or four days. Many amateur packet systems archive WWV flux numbers (plus planetary k_p and A_p indices). Solar flux numbers can vary dramatically from day to day, but the Earth's ionosphere is relatively slow to respond to instantaneous changes in solar radiation. This caveat also

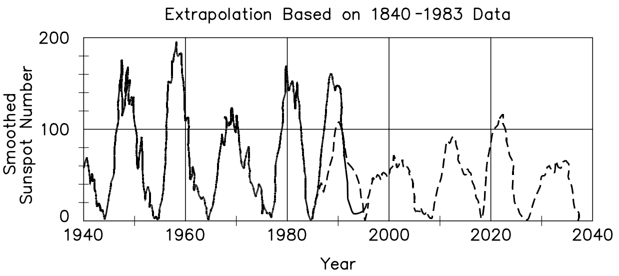

Fig 42—Smoothed sunspot number, with predictions, from 1940 to 2040. This was extrapolated based on data from 1840 to 1983. Cycle 22 actually peaked in Nov 1989, at a monthly smoothed sunspot number of 158. Propagation on the higher frequencies throughout the peak of Cycle 22 was good to excellent, since the monthly smoothed sunspot number stayed at 100 or above from July 1988 through May 1992. (*Courtesy of Naval Ocean Systems Center,* San Diego.*)*

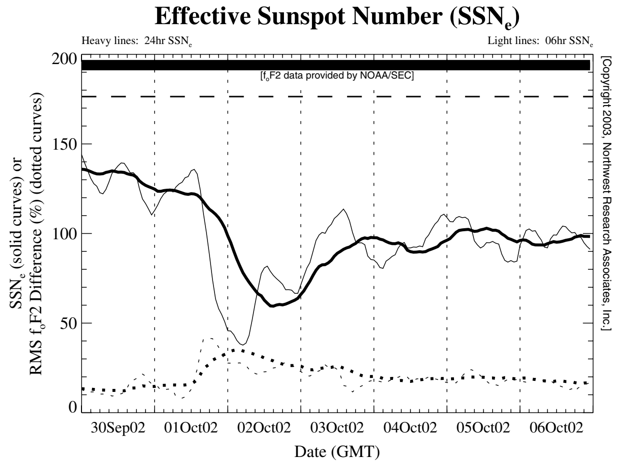

Fig 43—Effective Sunspot Number (SSN_e) produced by NWRA. Note large drop in effective SSN due to a geomagnetic storm commencing Oct 1, 2002. (*Courtesy of Northwest Research Associates.*)

holds for sunspot numbers derived, using Fig 18, from WWV/WWVH solar flux numbers.

Fig 42 shows a graph produced in the early 1980s of smoothed sunspot numbers for Solar Cycles 17 through 21, with predictions for Cycles 22 through 26. The graph covers a period of 100 years, from 1940 to 2040, and may be used for making long-term or historical calculations. Just remember that the graph shows smoothed numbers. The solar activity at any given time can be significantly lower or significantly higher than the graph indicates. In fact, Cycle 22 peaked at the end of 1989, as predicted, but with a monthly smoothed sunspot level of 158, quite a bit higher than predicted. Cycle 23 peaked in early 2002 at a level of about 115, a considerably higher level than the predicted value.

WWV PROPAGATION DATA

For the most current data on what the Sun is doing, National Institute of Standards and Technology stations WWV and WWVH broadcast information on solar activity at 18 and 45 minutes past each hour, respectively. These propagation bulletins give the solar flux, geomagnetic A-Index, Boulder K-Index, and a brief statement of solar and geomagnetic activity in the past and coming 24-hour periods, in that order. The solar flux and A-Index are changed daily with the 2118 UT bulletin, the rest every three hours—0018, 0318, 0618 UT and so on. On the Web, up-to-date WWV information can be found at: **ftp://ftp.sel.noaa.gov/pub/latest/wwv.txt** or on the NOAA Web page **www.sec.noaa.gov/**.

Some other useful Web sites are: **dx.qsl.net/propagation/**, **www.dxlc.com/solar**, **hfradio.org/propagation.html**. The Solar Terrestrial Dispatch page contains a wealth of propagation-related information: **www.spacew.com/**. You may also access propagation information on your local PacketCluster. Use the command SH/WWV/*n*, where *n* is the number of spots you wish to see (five is the default).

Another excellent method for obtaining an “equivalent sunspot number” (SSN_e) is to go to the Space Weather site of Northwest Research Services: **www.nwra-az.com/spawx/ssne24.html**. NWRA compares real-time ionospheric sounder data around the world with predictions using various levels of SSN looking for the best match. They thus “back into” the actual effective sunspot number. **Fig 43** is a typical NWRA graph, which covers the week ending 6 October 2002. Note the sudden decrease in SSN_e after a geomagnetic storm depressed SSN_e by more than 50%.

The A-Index

The WWV/WWVH A-Index is a daily figure for the state of activity of the Earth’s magnetic field. It is updated with the 2118/2145 UT bulletin. The A-Index tells you mainly how yesterday was, but it is very revealing when charted regularly, because geomagnetic disturbances nearly always recur at four-week intervals.

The K-Index

The K-Index (new every three hours) reflects Boulder readings of the Earth’s geomagnetic field in the hours just preceding the bulletin data changes. It is the nearest thing to current data on radio propagation available. With new data every three hours, K-Index trend is important. Rising is bad news; falling is good, especially related to propagation on paths involving latitudes above 30° north. Because this is a Boulder, Colorado, reading of geomagnetic activity, it may not correlate closely with conditions in other areas.

The K-Index is also a timely clue to aurora possibilities. Values of 4, and rising, warn that conditions associated with

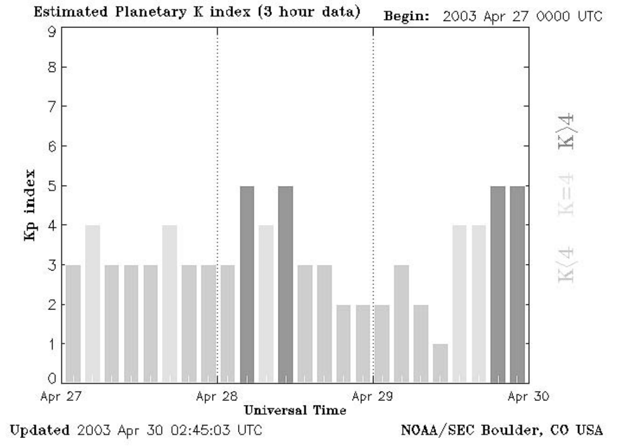

Fig 44—Plot of the estimated planetary k index, K_p, for the last four days. (*Courtesy NOAA/SEC.*)

auroras and degraded HF propagation are present in the Boulder area at the time of the bulletin's preparation. A NOAA Web site that carries up-to-date planetary K_p data is: **www.sel.noaa.gov/ftpmenu/plots/2003_plots/kp.html**. **Fig 44** is a graph from this Web site for four days starting 27 April 2003 to 30 April 2003. This was a period of significant geomagnetic activity, indicated by K_p indices of 5 and 4.

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Chapter 27

Antenna and Transmission-Line Measurements

The principal quantities measured on transmission lines are line current or voltage, and standing-wave ratio (SWR). You make measurements of current or voltage to determine the power input to the line. SWR measurements are useful in connection with the design of coupling circuits and the adjustment of the match between the antenna and transmission line, as well as in the adjustment of these matching circuits.

For most practical purposes a relative measurement is sufficient. An uncalibrated indicator that shows when the largest possible amount of power is being put into the line is just as useful, in most cases, as an instrument that measures the power accurately. It is seldom necessary to know the actual number of watts going into the line unless the overall efficiency of the system is being investigated. An instrument that shows when the SWR is close to 1:1 is all you need for most impedance-matching adjustments. Accurate measurement of SWR is necessary only in studies of antenna characteristics such as bandwidth, or for the design of some types of matching systems, such as a stub match.

Quantitative measurements of reasonable accuracy demand good design and careful construction in the measuring instruments. They also require intelligent use of the equipment, including a knowledge not only of its limitations but also of stray effects that often lead to false results. Until you know the complete conditions of the measurements, a certain amount of skepticism regarding numerical data resulting from amateur measurements with simple equipment is justified. On the other hand, purely qualitative or relative measurements are easy to make and are reliable for the purposes mentioned above.

LINE CURRENT AND VOLTAGE

A current or voltage indicator that can be used with coaxial line is a useful piece of equipment. It need not be elaborate or expensive. Its principal function is to show when the maximum power is being taken from the transmitter; for any given set of line conditions (length, SWR, etc). This will occur when you adjust the transmitter coupling for maximum current or voltage into the transmission line. Although the final-amplifier plate or collector current meter is frequently used for this purpose, it is not always a reliable indicator. In many cases, particularly with a screen-grid tube in the final stage, minimum loaded plate current does not occur simultaneously with maximum power output.

RF VOLTMETER

You can put together a germanium diode in conjunc-

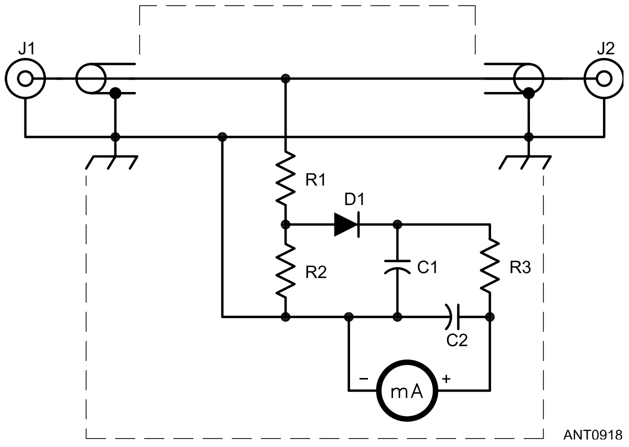

Fig 1—RF voltmeter for coaxial line.

C1, C2—0.005- or 0.01-µF ceramic.
D1—Germanium diode, 1N34A.
J1, J2—Coaxial fittings, chassis-mounting type.
M1—0-1 milliammeter (more sensitive meter may be used if desired; see text).
R1—6.8 kΩ, composition, 1 W for each 100 W of RF power.
R2—680 Ω, 1/2 or 1 W composition.
R3—10 kΩ, 1/2 W (see text).

tion with a low-range milliammeter and a few resistors to form an RF voltmeter suitable for connecting across the two conductors of a coaxial line, as shown in **Fig 1**. It consists of a voltage divider, R1-R2, having a total resistance about 100 times the Z_0 of the line (so the power consumed will be negligible) with a diode rectifier and milliammeter connected across part of the divider to read relative RF voltage. The purpose of R3 is to make the meter readings directly proportional to the applied voltage, as nearly as possible, by swamping the resistance of D1, since the diode resistance will vary with the amplitude of the current through the diode.

You may construct the voltmeter in a small metal box, indicated by the dashed line in the drawing, and fitted with coax receptacles. R1 and R2 should be carbon-composition resistors. The power rating for R1 should be 1 W for each 100 W of carrier power in the matched line; separate 1- or 2-W resistors should be used to make up the total power rating required, to the total resistance as given. Any type of resistor can be used for R3; the total resistance should be such that about 10 V dc will be developed across it at full scale. For example, a 0-1 milliammeter would require 10 kΩ, a 0-500 microammeter would take 20 kΩ, and so on. For comparative measurements only, R3 may be a variable resistor so the sensitivity can be adjusted for various power levels.

In constructing such a voltmeter, you should exercise care to prevent inductive coupling between R1 and the loop formed by R2, D1 and C1, and between the same loop and the line conductors in the assembly. With the lower end of R1 disconnected from R2 and grounded to the enclosure, but without changing its position with respect to the loop, there should be no meter indication when full power is going through the line.

If more than one resistor is used for R1, the units should be arranged end-to-end with very short leads. R1 and R2 should be kept ½ inch or more from metal surfaces parallel to the body of the resistor. If you observe these precautions the voltmeter will give consistent readings at frequencies up to 30 MHz. Stray capacitance and stray coupling limit the accuracy at higher frequencies but do not affect the utility of the instrument for comparative measurements.

Calibration

You may calibrate the meter for RF voltage by comparison with a standard such as an RF ammeter. This requires that the line be well matched so the impedance at the point of measurement is equal to the actual Z_0 of the line. Since in that case $P = I^2Z_0$, the power can be calculated from the current. Then $E = \sqrt{PZ_0}$. By making current and voltage measurements at a number of different power levels, you can obtain enough points to draw a calibration curve for your particular setup.

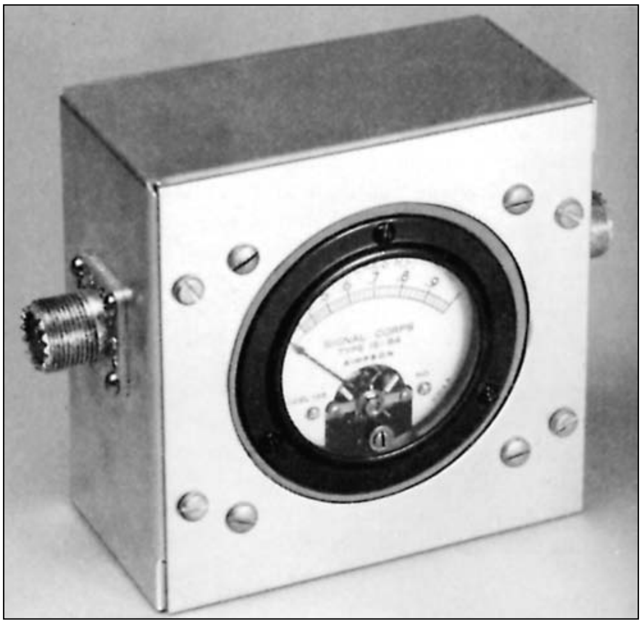

Fig 2—A convenient method of mounting an RF ammeter for use in a coaxial line. This is a metal-case instrument mounted on a thin bakelite panel. The cutout in the metal clears the edge of the meter by about ⅛ inch.

RF AMMETERS

Although they are not as widely available as they used to be, if you can find one on the surplus market or at a hamfest, an RF ammeter is a good way to gauge output power. You can mount an RF ammeter in any convenient location at the input end of the transmission line, the principal precaution being that the capacitance to ground, chassis, and nearby conductors should be low. A bakelite-case instrument can be mounted on a metal panel without introducing enough shunt capacitance to ground to cause serious error up to 30 MHz. When installing a metal-case instrument on a metal panel, you should mount it on a separate sheet of insulating material so that there is ⅛ inch or more separation between the edge of the case and the metal.

A 2-inch instrument can be mounted in a 2 × 4 × 4-inch metal box, as shown in **Fig 2**. This is a convenient arrangement for use with coaxial line. Installed this way, a good quality RF ammeter will measure current with an accuracy that is entirely adequate for calculating power in the line. As discussed above in connection with calibrating RF voltmeters, the line must be closely matched by its load so the actual impedance is resistive and equal to Z_0. The scales of such instruments are cramped at the low end, however, which limits the range of power that can be measured by a single meter. The useful current range is about 3 to 1, corresponding to a power range of about 9 to 1.

SWR Measurements

On parallel-conductor lines it is possible to measure the standing-wave ratio by moving a current (or voltage) indicator along the line, noting the maximum and minimum values of current (or voltage) and then computing the SWR from these measured values. This cannot be done with coaxial line since it is not possible to make measurements of this type inside the cable. The technique is, in fact, seldom used with open lines because it is not only inconvenient but sometimes impossible to reach all parts of the line conductors. Also, the method is subject to considerable error from antenna currents flowing on the line.

Present-day SWR measurements made by amateurs practically always use some form of *directional coupler* or RF-bridge circuit. The indicator circuits themselves are fundamentally simple, but they require considerable care in construction to ensure accurate measurements. The requirements for indicators used only for the adjustment of impedance-matching circuits, rather than actual SWR measurement, are not so stringent, and you can easily make an instrument for this purpose.

BRIDGE CIRCUITS

Two commonly used bridge circuits are shown in **Fig 3**. The bridges consist essentially of two voltage dividers in parallel, with a voltmeter connected between the junctions of each pair of *arms*, as the individual elements are called. When the equations shown to the right of each circuit are satisfied there is no potential difference between the two junctions, and the voltmeter indicates zero voltage. The bridge is then said to be in *balance*.

Taking Fig 3A as an illustration, if R1 = R2, half the applied voltage, E, will appear across each resistor. Then if $R_S = R_X$, $^1/_2$E will appear across each of these resistors and the voltmeter reading will be zero. Remember that a matched transmission line has essentially a purely resistive input impedance. Suppose that the input terminals of such a line are substituted for R_X. Then if R_S is a resistor equal to the Z_0 of the line, the bridge will be balanced.

If the line is not perfectly matched, its input impedance will not equal Z_0 and hence will not equal R_S, since you chose the latter to be equal to Z_0. There will then be a difference in potential between points X and Y, and the voltmeter will show a reading. Such a bridge therefore can be used to show the presence of standing waves on the line, because the line input impedance will be equal to Z_0 only when there are no standing waves.

Considering the nature of the incident and reflected components of voltage that make up the actual voltage at the input terminals of the line, as discussed in Chapter 24, it should be clear that when $R_S = Z_0$, the bridge is always in balance for the incident component. Thus the voltmeter does not respond to the incident component at any time but reads only the reflected component (assuming that R2 is very small compared with the voltmeter impedance). The incident component can be measured across either R1 or R2, if they are equal resistances. The standing-wave ratio is then

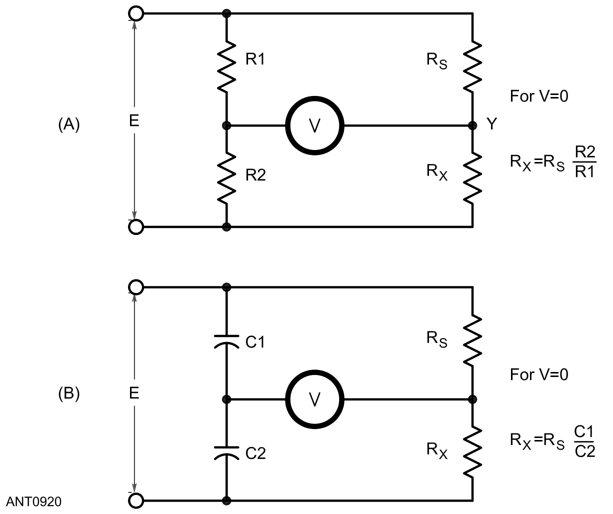

Fig 3—Bridge circuits suitable for SWR measurement. At A, Wheatstone type using resistance arms. At B, capacitance-resistance bridge ("Micromatch"). Conditions for balance are independent of frequency in both types.

$$\text{SWR} = \frac{E1+E2}{E1-E2} \qquad \text{(Eq 1)}$$

where E1 is the incident voltage and E2 is the reflected voltage. It is often simpler to normalize the voltages by expressing E2 as a fraction of E1, in which case the formula becomes

$$\text{SWR} = \frac{1+k}{1-k} \qquad \text{(Eq 2)}$$

where k = E2/E1.

The operation of the circuit in Fig 3B is essentially the same, although this circuit has arms containing reactance as well as resistance.

It is not necessary that R1 = R2 in Fig 3A; the bridge can be balanced, in theory, with any ratio of these two resistances provided R_S is changed accordingly. In practice, however, the accuracy is highest when the two are equal; this circuit is most commonly used.

A number of types of bridge circuits appear in **Fig 4**, many of which have been used in amateur products or amateur construction projects. All except that at G can have the generator and load at a common potential. At G, the generator and detector are at a common potential. You may interchange the positions of the detector and trans-

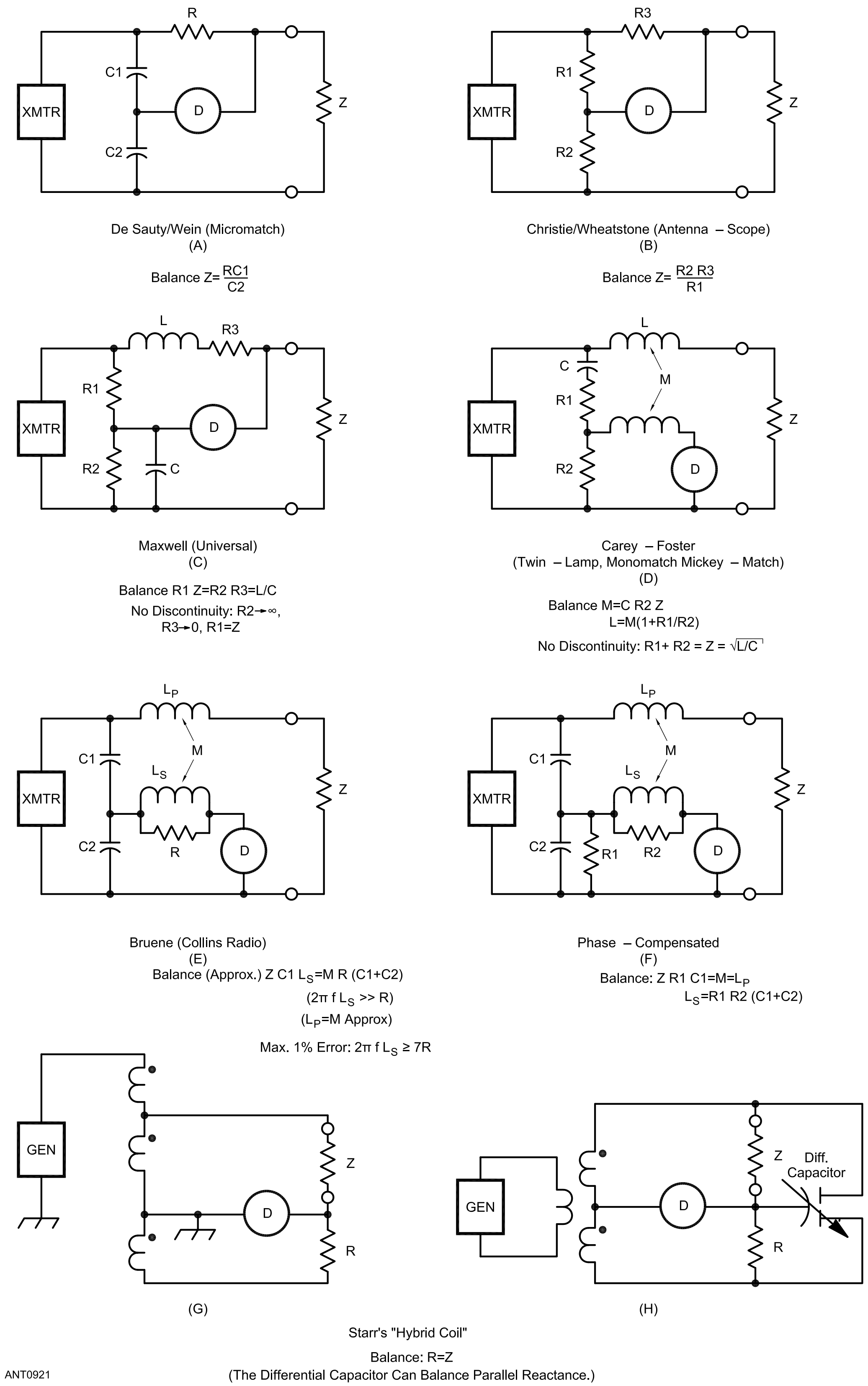
R
C1
XMTR
D
Z
C2
De Sauty/Wein (Micromatch)
(A)
Balance Z= RC1/C2
R3
R1
XMTR
D
Z
R2
Christie/Wheatstone (Antenna – Scope)
(B)
Balance Z= R2 R3/R1
L
R3
R1
XMTR
D
Z
R2
C
Maxwell (Universal)
(C)
Balance R1 Z=R2 R3=L/C
No Discontinuity: R2→∞,
R3→0, R1=Z
L
C
M
R1
XMTR
Z
R2
D
Carey – Foster
(Twin – Lamp, Monomatch Mickey – Match)
(D)
Balance M=C R2 Z
L=M(1+R1/R2)
No Discontinuity: R1+ R2 = Z = √L/C
LP
C1
M
LS
XMTR
Z
C2
R
D
Bruene (Collins Radio)
(E)
Balance (Approx.) Z C1 LS=M R (C1+C2)
(2π f LS >> R)
(LP=M Approx)
Max. 1% Error: 2π f LS ≥ 7R
LP
C1
M
LS
XMTR
Z
C2
R1
R2
D
Phase – Compensated
(F)
Balance: Z R1 C1=M=LP
LS=R1 R2 (C1+C2)
GEN
Z
D
R
Z
Diff.
Capacitor
GEN
D
R
(G)
(H)
Starr's "Hybrid Coil"
Balance: R=Z
(The Differential Capacitor Can Balance Parallel Reactance.)
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Fig 4—Various types of SWR indicator circuits and commonly known names of bridge circuits or devices in that they have been used. Detectors (D) are usually semiconductor diodes with meters, isolated with RF chokes and capacitors. However, the detector may be a radio receiver. In each circuit, Z represents the load being measured. (*This information provided by David Geiser, WA2ANU*)

mitter (or generator) in the bridge, and this may be advantageous in some applications.

The bridges shown at D, E, F and H may have one terminal of the generator, detector and load common. Bridges at A, B, E, F, G and H have constant sensitivity over a wide frequency range. Bridges at B, C, D and H may be designed to show no discontinuity (impedance lump) with a matched line, as shown in the drawing. Discontinuities with A, E and F may be small.

Bridges are usually most sensitive when the detector bridges the midpoint of the generator voltage, as in G or H, or in B when each resistor equals the load impedance. Sensitivity also increases when the currents in each leg are equal.

Resistance Bridge

The basic bridge configuration shown in Fig 3B may be home constructed and is reasonably accurate for SWR measurement. A practical circuit for such a bridge is given in **Fig 5** and a representative layout is shown in **Fig 6**. Properly built, a bridge of this design can be used for measurement of SWRs up to about 15:1 with good accuracy.

You should observe these important construction points:

1) Keep leads in the RF circuit short, to reduce stray inductance.
2) Mount resistors two or three times their body diameter away from metal parts, to reduce stray capacitance.
3) Place the RF components so there is as little inductive and capacitive coupling as possible between the bridge arms.

In the instrument shown in Fig 6, the input and line connectors, J1 and J2, are mounted fairly close together so the standard resistor, R_S, can be supported with short leads directly between the center terminals of the connectors. R2 is mounted at right angles to R_S, and a shield partition is used between these two components and the others.

The two 47-kΩ resistors, R5 and R6 in Fig 5, are voltmeter multipliers for the 0-100 microammeter used as an indicator. This is sufficient resistance to make the voltmeter linear (that is, the meter reading is directly proportional to the RF voltage) and no voltage calibration curve is needed. D1 is the rectifier for the reflected volt-

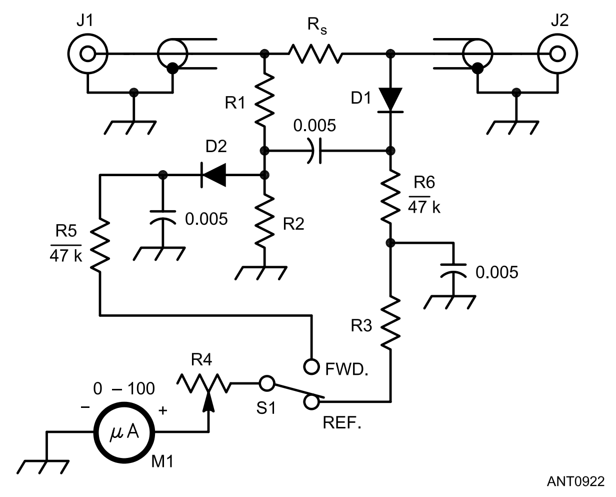

Fig 5—Resistance bridge for SWR measurement. Capacitors are disc ceramic. Resistors are $^1/_2$-watt composition except as noted below.
D1, D2—Germanium diode, high back resistance type (1N34A, 1N270, etc).
J1, J2—Coaxial connectors, chassis-mounting type.
M1—0-100 dc microammeter.
R1, R2—47 Ω, $^1/_2$-W composition (see text).
R3—See text.
R4—50-kΩ volume control.
R_S—Resistance equal to line Z_0 ($^1/_2$ or 1 W composition).
S1—SPDT toggle.

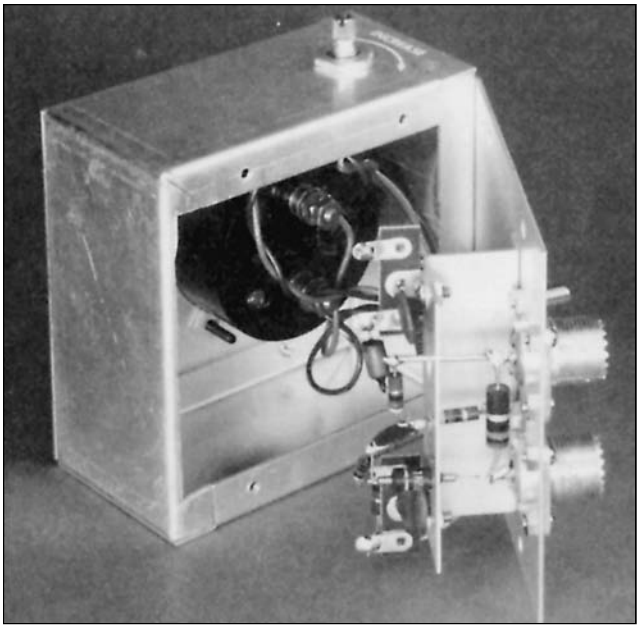

Fig 6—A 2 × 4 × 4-inch aluminum box is used to house this SWR bridge, which uses the circuit of Fig 5. The variable resistor, R4, is mounted on the side. The bridge components are mounted on one side plate of the box and a subchassis formed from a piece of aluminum. The input connector is at the top in this view. R_S is connected directly between the two center posts of the connectors. R2 is visible behind it and perpendicular to it. One terminal of D1 projects through a hole in the chassis so the lead can be connected to J2. R1 is mounted vertically to the left of the chassis in this view, with D2 connected between the junction of R1-R2 and a tie point.

age and D2 is for the incident voltage. Because of manufacturing variations in resistors and diodes, the readings may differ slightly with two multipliers of the same nominal resistance value, so a correction resistor, R3, is included in the circuit. You should select its value so that the meter reading is the same with S1 in either position, when RF is applied to the bridge with the line connection open. In the instrument shown, a value of 1000 Ω was required in series with the multiplier for reflected voltage; in other cases different values probably would be needed and R3 might have to be put in series with the multiplier for the incident voltage. You can determine this by experiment.

The value used for R1 and R2 is not critical, but you should match the two resistors within 1% or 2% if possible. Keep the resistance of R_S as close as possible to the actual Z_0 of the line you use (generally 50 or 75 Ω). Select the resistor by actual measurement with an accurate resistance bridge, if you have one available.

R4 is for adjusting the incident-voltage reading to full scale in the measurement procedure described below. Its use is not essential, but it offers a convenient alternative to exact adjustment of the RF input voltage.

Testing

Measure R1, R2 and R_S with a reliable digital ohmmeter or resistance bridge after completing the wiring. This will ensure that their values have not changed from the heat of soldering. Disconnect one side of the microammeter and leave the input and output terminals of the unit open during such measurements to avoid stray shunt paths through the rectifiers.

Check the two voltmeter circuits as described above, applying enough RF (about 10 V) to the input terminals to give a full-scale reading with the line terminals open. If necessary, try different values for R3 until the reading is the same with S1 in either position.

With J2 open, adjust the RF input voltage and R4 for full-scale reading with S1 in the incident-voltage position. Then switch S1 to the reflected-voltage position. The reading should remain at full scale. Next, short-circuit J2 by touching a screwdriver between the center terminal and the frame of the connector to make a low-inductance short. Switch S1 to the incident-voltage position and readjust R4 for full scale, if necessary. Then throw S1 to the reflected-voltage position, keeping J2 shorted, and the reading should be full scale as before. If the readings differ, R1 and R2 are not the same value, or there is stray coupling between the arms of the bridge. You must read the reflected voltage at full scale with J2 either open or shorted, when the incident voltage is set to full scale in each case, to make accurate SWR measurements.

The circuit should pass these tests at all frequencies at which it is to be used. It is sufficient to test at the lowest and highest frequencies, usually 1.8 or 3.5 and 28 or 50 MHz. If R1 and R2 are poorly matched but the bridge construction is otherwise good, discrepancies in the readings will be substantially the same at all frequencies. A difference in behavior at the low and high ends of the frequency range can be attributed to stray coupling between bridge arms, or stray inductance or capacitance in the arms.

To check the bridge for balance, apply RF and adjust R4 for full scale with J2 open. Then connect a resistor identical with R_S (the resistance should match within 1% or 2%) to the line terminals, using the shortest possible leads. It is convenient to mount the test resistor inside a cable connector (PL-259), a method of mounting that also minimizes lead inductance. When you connect the test resistor the reflected-voltage reading should drop to zero. The incident voltage should be reset to full scale by means of R4, if necessary. The reflected reading should be zero at any frequency in the range to be used. If a good null is obtained at low frequencies but some residual current shows at the high end, the trouble may be the inductance of the test resistor leads, although it may also be caused by stray coupling between the arms of the bridge itself.

If there is a constant low (but not zero) reading at all frequencies the problem is poor matching of the resistance values. Both effects can be present simultaneously. You should make sure you obtain a good null at all frequencies before using your bridge.

Bridge Operation

You must limit the RF power input to a bridge of this type to a few watts at most, because of the power-dissipation ratings of the resistors. If the transmitter has no provision for reducing power output to a very low value—less than 5 W—a simple power-absorber circuit can be made up, as shown in **Fig 7**. Lamp DS1 tends to maintain constant current through the resistor over a fairly

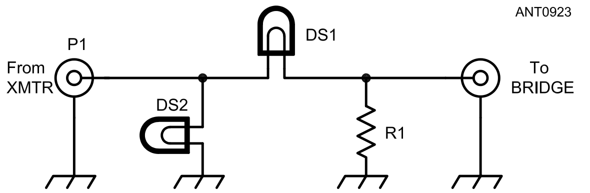

Fig 7—Power-absorber circuit for use with resistance-type SWR bridges when the transmitter has no special provisions for power reduction. For RF powers up to 50 W, DS1 is a 117-V 40-W incandescent lamp and DS2 is not used. For higher powers, use sufficient additional lamp capacity at DS2 to load the transmitter to about normal output; for example, for 250 W output DS2 may consist of two 100-W lamps in parallel. R1 is made from three 1-W 68-Ω resistors connected in parallel. P1 and P2 are cable-mounting coaxial connectors. Leads in the circuit formed by the lamps and R1 should be kept short, but convenient lengths of cable may be used between this assembly and the connectors.

wide power range, so the voltage drop across the resistor also tends to be constant. This voltage is applied to the bridge, and with the constants given is in the right range for resistance-type bridges.

To make a measurement, connect the unknown load to J2 and apply sufficient RF voltage to J1 to give a full-scale incident-voltage reading. Use R4 to set the indicator to exactly full scale. Then throw S1 to the reflected voltage position and note the meter reading. The SWR is then found by using these readings in Eq 1.

For example, if the full-scale calibration of the dc instrument is 100 µA and the reading with S2 in the reflected-voltage position is 40 µA, the SWR is

$$\mathrm{SWR} = \frac{100+40}{100-40} = \frac{140}{60} = 2.33:1$$

Instead of calculating the SWR value, you could use the voltage curve in **Fig 8**. In this example the ratio of reflected to forward voltage is 40/100 = 0.4, and from Fig 8 the SWR value is about 2.3:1.

You may calibrate the meter scale in any arbitrary units, so long as the scale has equal divisions. It is the ratios of the voltages, and not the actual values, that determine the SWR.

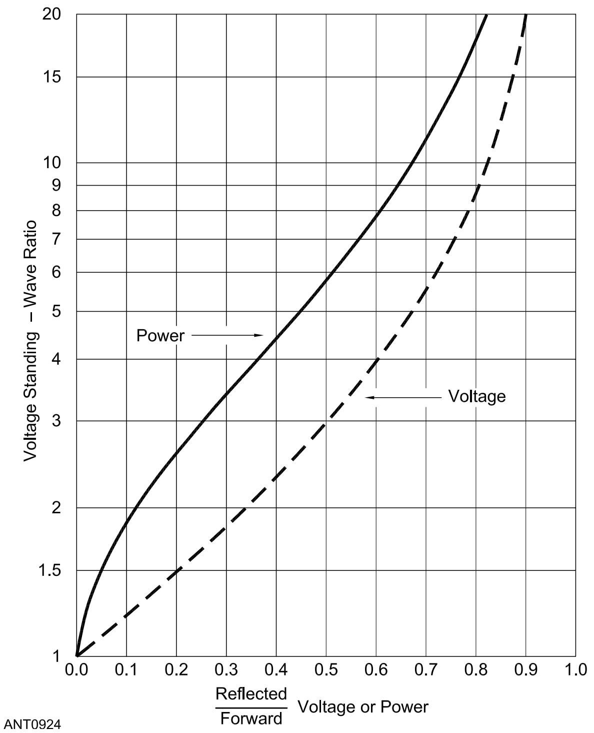

Fig 8—Chart for finding voltage standing-wave ratio when the ratio of reflected-to-forward voltage or reflected-to-forward power is known.

AVOIDING ERRORS IN SWR MEASUREMENTS

The principal causes of inaccuracies within the bridge are differences in the resistances of R1 and R2, stray inductance and capacitance in the bridge arms, and stray coupling between arms. If the checkout procedure described above is followed carefully, the bridge in Fig 5 should be amply accurate for practical use. The accuracy is highest for low standing-wave ratios because of the nature of the SWR calculation; at high ratios the divisor in the equation above represents the difference between two nearly equal quantities, so a small error in voltage measurement may mean a considerable difference in the calculated SWR.

The standard resistor R_S must equal the actual Z_0 of the line. The actual Z_0 of a sample of line may differ by a few percent from the nominal figure because of manufacturing variations, but this has to be tolerated. In the 50- to 75-Ω range, the RF resistance of a composition resistor of $^1/_2$- or 1-W rating is essentially identical with its dc resistance.

Common-Mode Currents

As explained in Chapter 26, there are two ways in which unwanted *common-mode* (sometimes called *antenna*) currents can flow on the outside of a coaxial line—currents radiated onto the line because of its spatial relationship to the antenna and currents that result from the direct connection between the coax outer conductor and (usually) one side of the antenna. The radiated current usually will not be troublesome if the bridge and the transmitter (or other source of RF power for operating the bridge) are shielded so that any RF currents flowing on the outside of the line cannot find their way into the bridge. This point can be checked by inserting an additional section of line ($^1/_8$ to $^1/_4$ electrical wavelength preferably) of the same Z_0. The SWR indicated by the bridge should not change except for a slight decrease because of the additional line loss. If there is a marked change, you may need better shielding.

Parallel-type currents caused by the connection to the antenna without using a common-mode choke balun will change the SWR with variations in line length, even though the bridge and transmitter are well-shielded and the shielding is maintained throughout the system by the use of coaxial fittings. Often, merely moving the transmission line around will cause the indicated SWR to change. This is because the outside of the coax becomes part of the antenna system—being connected to the antenna at the feed point. The outside shield of the line thus constitutes a load, along with the desired load represented by the antenna itself. The SWR on the line then is determined by the composite load of the antenna and the outside of the coax. Since changing the line length (or position) changes one component of this composite load, the SWR changes too.

The remedy for such a situation is to use a good balun or to detune the outside of the line by proper choice of length. Note that this is not a *measurement error*, since what the instrument reads is the actual SWR on the line. However, it is an undesirable condition since the line is usually operating at a higher SWR than it should—and would if the parallel-type current on the outside of the coax were eliminated.

Spurious Frequencies

Off-frequency components in the RF voltage applied to the bridge may cause considerable error. The principal components of this type are harmonics and low-frequency subharmonics that may be fed through the final stage of the transmitter driving the bridge. The antenna is almost always a fairly selective circuit, and even though the system may be operating with a very low SWR at the desired frequency, it is almost always mismatched at harmonic and subharmonic frequencies. If such spurious frequencies are applied to the bridge in appreciable amplitude, the SWR indication will be very much in error. In particular, it may not be possible to obtain a null on the bridge with any set of adjustments of the matching circuit. The only remedy is to filter out the unwanted components by increasing the selectivity of the circuits between the transmitter final amplifier and the bridge.

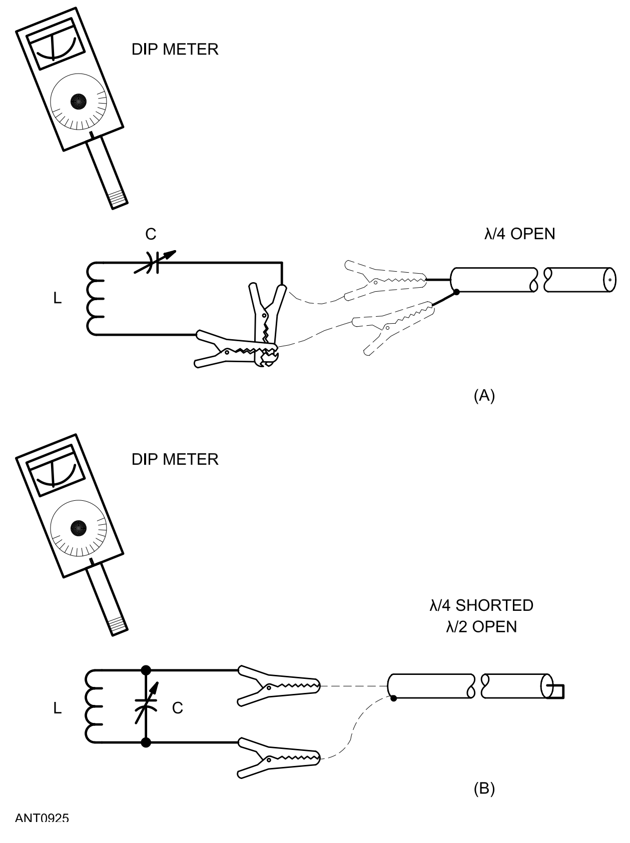

Fig 9—Methods of determining $^1/_4$ and $^1/_2$-λ line lengths. At A, $^1/_4$-λ open-circuited line; at B, $^1/_4$-λ shorted and $^1/_2$-λ open-circuited line.

MEASURING LINE LENGTH

The following material is taken from information in September 1985 *QST* by Charlie Michaels, W7XC (see Bibliography).

There is a popular myth that one may prepare an open quarter-wave line by connecting a loop of wire to one end and trimming the line to resonance (as indicated by a dip meter). This actually yields a line with capacitive reactance equal to the inductive reactance of the loop: a 4-inch wire loop yields a line 82.8° line at 18 MHz; a 2-inch loop yields an 86° line. As the loop size is reduced, line length approaches—but never equals—90°.

To make a quarter-wave open line, parallel connect a coil and capacitor that resonate at the required frequency (see **Fig 9A**). After adjusting the network to resonance, do not make further network adjustments. Open the connection between the coil and capacitor and series connect the line to the pair. Start with a line somewhat longer than required, and trim it until the circuit again resonates at the desired frequency. For a shorted quarter-wave line or an open half-wave line, connect the line in parallel with the coil and capacitor (see Fig 9B).

Another method to accurately measure a coaxial transmission line length uses one of the popular "SWR analyzers," portable hand-held instruments with a tunable low-power signal generator and an SWR bridge. While an SWR analyzer cannot compute the very high values of SWR at the input of a shorted quarter-wave line at the fundamental frequency, most include another readout showing the magnitude of the impedance. This is very handy for finding a low-impedance dip, rather than a high-impedance peak.

At the operating frequency, a shorted quarter-wave line results in a high-impedance open-circuit at the input to that line. At twice the frequency, where the line is now one-half wave long electrically, the instrument shows a low-impedance short-circuit. However, when you are pruning a line to length by cutting off short pieces at the end, it is inconvenient to have to install a short before measuring the response. It is far easier to look for the dip in impedance when a quarter-wave line is terminated in an open circuit.

Again, the strategy is to start with a line physically a little longer than a quarter-wave length. A good rule of thumb is to cut the line 5% longer to take into account the variability in the velocity factor of a typical coax cable. Compute this using:

$$\text{Length (feet)} = 0.25 \times 1.05 \times \text{VF} \times 984/\text{Freq} = \text{VF}/\text{Freq}$$

where

Freq is in MHz

VF is the velocity factor in %.

Plug the coax connector installed at one end of the line into the SWR analyzer and find the frequency for the impedance dip. Prune the line by snipping off short pieces at the end. Once you've pruned the line to the desired frequency, connect the short at the end of the line and recheck for a short circuit at twice the fundamental frequency. Seal the shorted end of the coax and you're done.

REFLECTOMETERS

Low-cost *reflectometers* that do not have a guaranteed wattmeter calibration are not ordinarily reliable for accurate numerical measurement of standing-wave ratio. They are, however, very useful as aids in the adjustment of matching networks, since the objective in such adjustment is to reduce the reflected voltage or power to zero. Relatively inexpensive devices can be used for this, since only good bridge balance is required, not actual calibration of SWR. Bridges of this type are usually frequency-sensitive that is, the meter response increase with increasing frequency for the same applied voltage. When matching and line monitoring, rather than SWR measurement, is the principal use of the device, this is not a serious handicap.

Various simple reflectometers, useful for matching and monitoring, have been described from time to time in *QST* and in *The ARRL Handbook*. Because most of these are frequency sensitive, it is difficult to calibrate them accurately for power measurement, but their low cost and suitability for use at moderate power levels, combined with the ability to show accurately when a matching circuit has been properly adjusted, make them a worthwhile addition to the amateur station.

The Tandem Match—An Accurate Directional Wattmeter

Most SWR meters are not very accurate at low power levels because the detector diodes do not respond to low voltage in a linear fashion. This design uses a compensating circuit to cancel diode nonlinearity. It also provides peak detection for SSB operation and direct SWR readout that does not vary with power level. The following information is condensed from an article by John Grebenkemper, KI6WX, in January 1987 *QST.*

DESIGN PRINCIPLES

Directional wattmeters for Amateur Radio use consist of three basic elements: a directional coupler, a detector and a signal-processing and display circuit. A directional coupler samples forward and reflected-power components on a transmission line. An ideal directional coupler would provide signals proportional to the forward and reflected voltages (independent of frequency), which could then be used to measure forward and reflected power over a wide frequency range. The best contemporary designs work over two decades of frequency.

The detector circuit provides a dc output voltage proportional to the ac input voltage. Most directional wattmeters use a single germanium diode as the detector element. A germanium, rather than silicon, diode is used to minimize diode nonlinearity at low power levels. Diode non-linearity still causes SWR measurement errors unless it is compensated ahead of the display circuit. Most directional wattmeters do not work well at low power levels because of diode nonlinearity.

The signal-processing and display circuits compute and display the SWR. There are a number of ways to perform this function. Meters that display only the forward and reflected power require the operator to compute the SWR manually. Many instruments require that the operator adjust the meter to a reference level while measuring forward power, then switch to measure reflected power on a special scale that indicates SWR. Meters that directly compute the SWR using analog signal-processing circuits have been described by Fayman, Perras,

Table 1
Performance Specifications for the Tandem Match

Power range: 1.5 to 1500 W
Frequency range: 1.8 to 54 MHz
Power accuracy: Better than ± 10% (± 0.4 dB)
SWR accuracy: Better than ± 5%
Minimum SWR: Less than 1.05:1
Power display: Linear, suitable for use with either analog or digital meters
Calibration: Requires only an accurate voltmeter

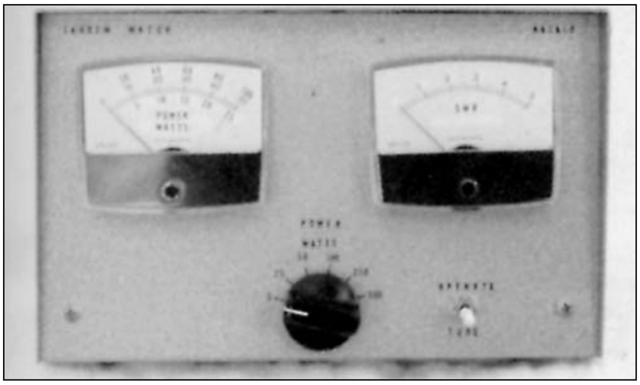

Fig 10—The Tandem Match uses a pair of meters to display net forward power and true SWR simultaneously.

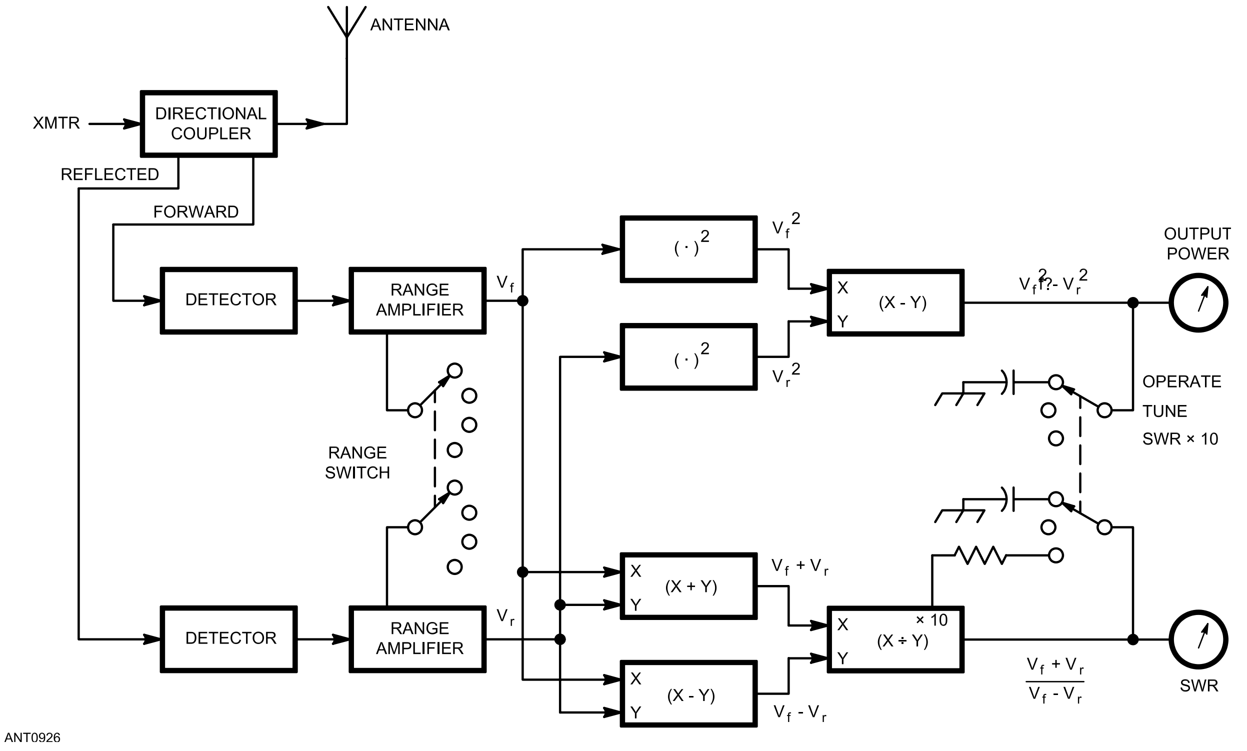

Fig 11—Block diagram of the Tandem Match.

Leenerts and Bailey (see the Bibliography at the end of this chapter).

The next section takes a brief look at several popular circuits that accomplish the functions above and compares them to the circuits used in the Tandem Match. The design specifications of the Tandem Match are shown in **Table l**, and a block diagram is shown in **Fig 11**.

CIRCUIT DESCRIPTION

A directional coupler consists of an input port, an output port and a coupled port. The device takes a portion of the power flowing from the input port to the output port and directs it to the coupled port, but *none* of the power flowing from the output port to the input port is directed to the coupled port.

There are several terms that define the performance of a directional coupler:

1) *Insertion loss* is the amount of power that is lost as the signal flows from the input port to the output port. Insertion loss should be minimized so the coupler doesn't dissipate a significant amount of the transmitted power.

2) *Coupling factor* is the amount of power (or voltage) that appears at the coupled port relative to the amount of power (or voltage) transferred from the input port to the output port. The "flatness" (with frequency) of the coupling factor determines how accurately the directional wattmeter can determine forward and reflected power over a range of frequencies.

3) *Isolation* is the amount of power (or voltage) that appears at the coupled port relative to the amount of power (or voltage) transferred from the output port to the input port.

4) *Directivity* is the isolation less the coupling factor. Directivity dictates the minimum measurable SWR. A directional coupler with 20 dB of directivity measures a 1:1 SWR as l.22:l, but one with 30 dB measures a 1:1 SWR as 1.07:1.

The directional coupler most commonly used in amateur radio was first described in 1959 by Bruene in *QST* (see Bibliography). The coupling factor was fairly flat (± l dB), and the directivity was about 20 dB for a Bruene coupler measured from 3 to 30 MHz. Both factors limit the accuracy of the Bruene coupler for measuring low values of power and SWR. It is a simple directional coupler, however, and it works well over a wide frequency range if great precision is not required.

The coupler used in the Tandem Match (see **Fig 12**) consists of a pair of toroidal transformers connected in tandem. The configuration was patented by Carl G. Sontheimer and Raymond E. Fredrick (US Patent no. 3,426,298, issued February 4, 1969). It has been described by Perras, Spaulding (see Bibliography) and others. With coupling factors of 20 dB or greater, this coupler is suitable for sampling both forward and reflected power.

The configuration used in the Tandem Match works well over the frequency range of 1.8 to 54 MHz, with a

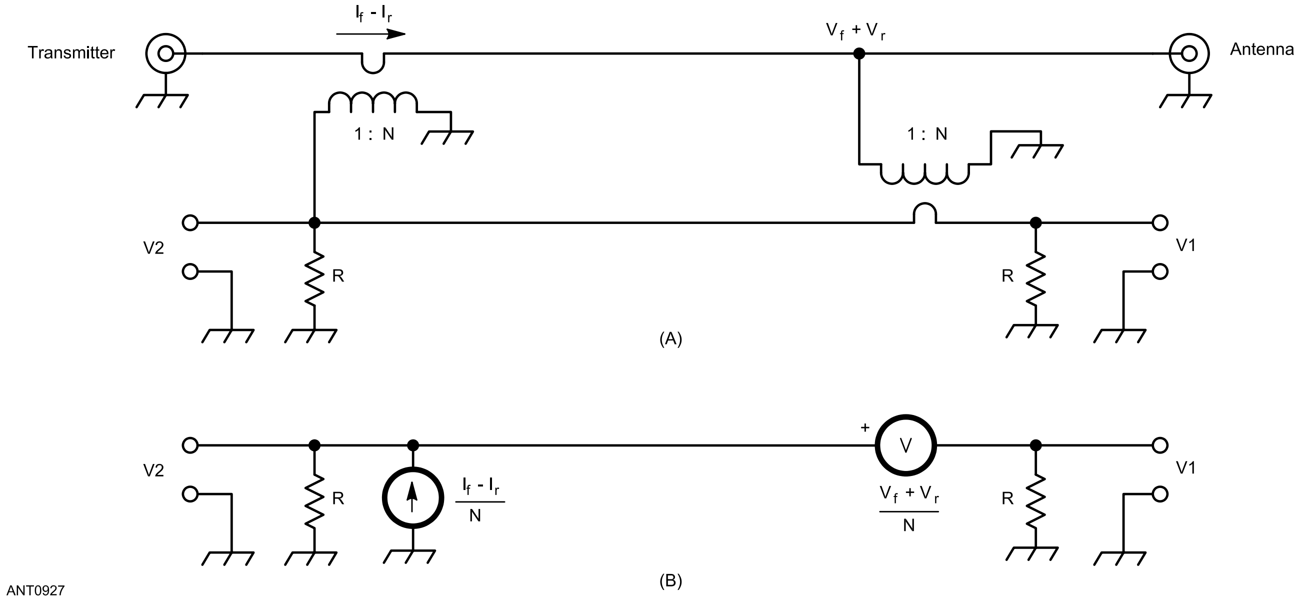
Transmitter
$I_f - I_r$
$V_f + V_r$
Antenna
1 : N
1 : N
V2
R
R
V1
(A)
V2
R
$\frac{I_f - I_r}{N}$
+
V
$\frac{V_f + V_r}{N}$
R
V1
ANT0927
(B)

Fig 12—Simplified diagram of the Tandem Match directional coupler. At A, a schematic of the two transformers. At B, an equivalent circuit.

nominal coupling factor of 30 dB. Over this range, insertion loss is less than 0.1 dB. The coupling factor is flat to within ± 0.1 dB from 1.8 to 30 MHz, and increases to only ±0.3 dB at 50 MHz. Directivity exceeds 35 dB from 1.8 to 30 MHz and exceeds 26 dB at 50 MHz.

The low-frequency limit of this directional coupler is determined by the inductance of the transformer secondary windings. The inductive reactance should be greater than 150 Ω (three times the line characteristic impedance) to reduce insertion loss. The high-frequency limit of this directional coupler is determined by the length of the transformer windings. When the winding length approaches a significant fraction of a wavelength, coupler performance deteriorates.

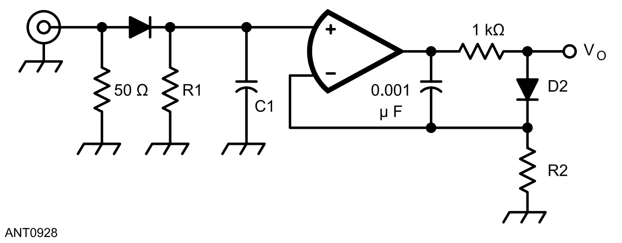
1 kΩ
V_O
+
–
50 Ω
R1
C1
0.001 μ F
D2
R2
ANT0928

Fig 13—Simplified diagram of the detector circuit used in the Tandem Match. The output voltage, V_O is approximately equal to the input voltage. D1 and D2 must be a matched pair (see text). The op amp should have a low offset voltage (less than 1 mV), a low leakage current (less than 1 nA), and be stable over time and temperature. The resistor and capacitor in the feedback path assure that the op amp will be stable.

The coupler described here may overheat at 1500 W on 160 meters (because of the high circulating current in the secondary of T2). The problem could be corrected by using a larger core or one with greater permeability. A larger core would require longer windings; that option would decrease the high-frequency limit.

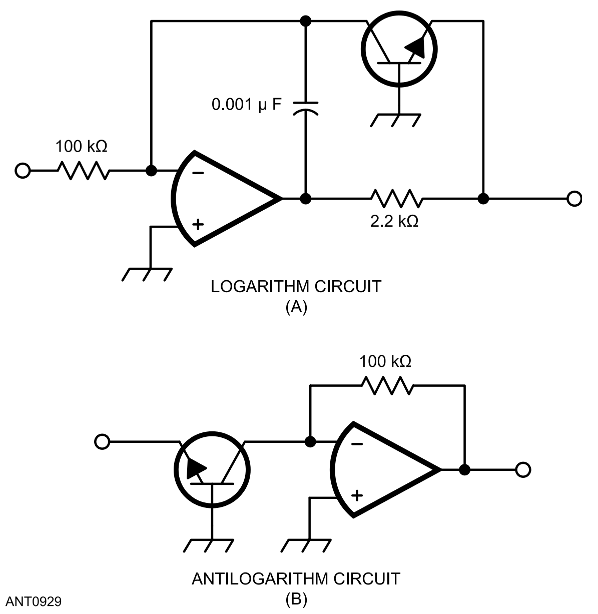
0.001 μ F
100 kΩ
–
+
2.2 kΩ
LOGARITHM CIRCUIT
(A)
100 kΩ
–
+
ANTILOGARITHM CIRCUIT
(B)
ANT0929

Fig 14—Simplified diagrams of the log circuit at A and the antilog circuit at B.

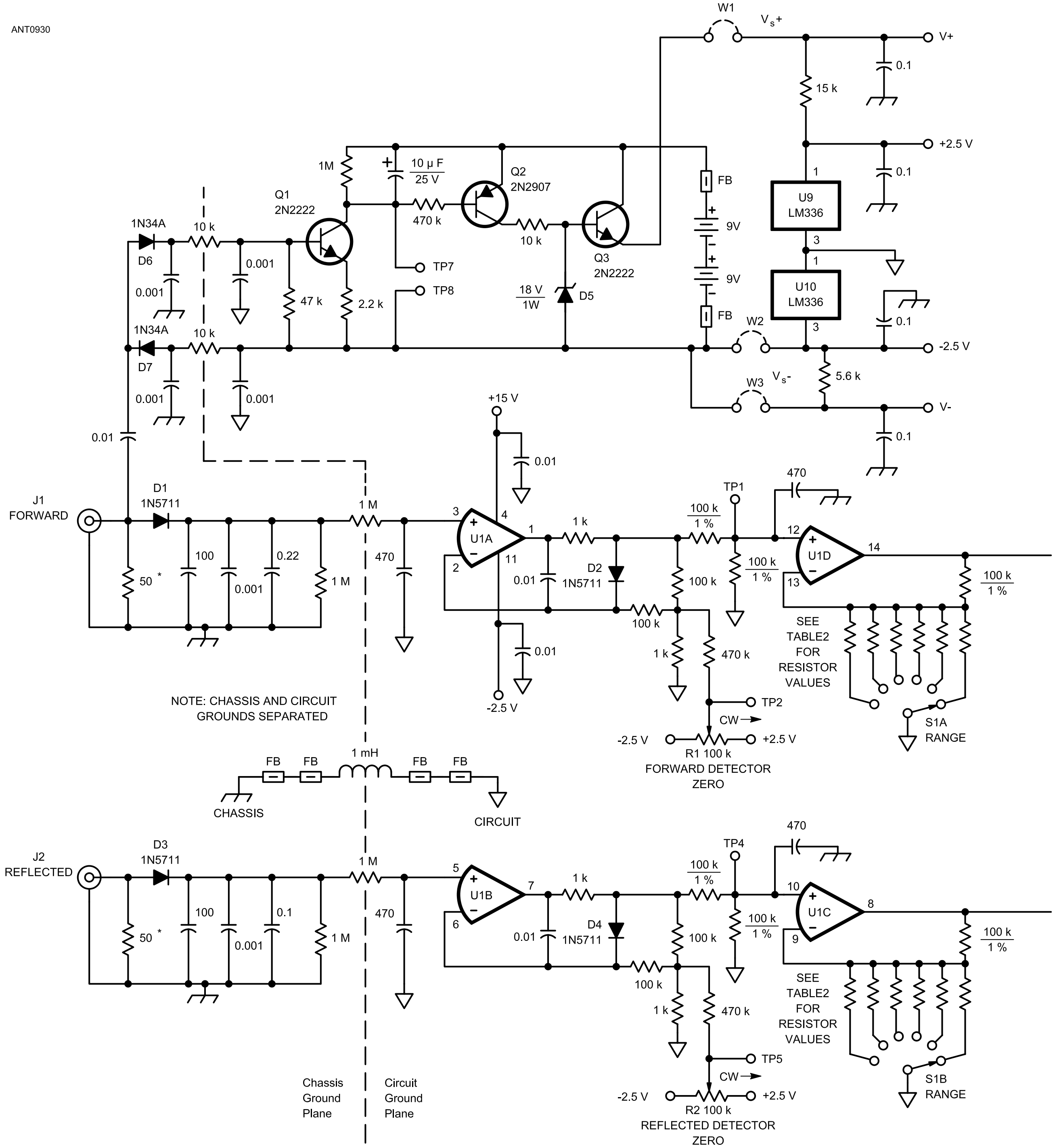
ANT0930
W1
Vs+
V+
0.1
15 k
+2.5 V
0.1
1M
10 µF
25 V
Q2
2N2907
Q1
2N2222
470 k
1N34A
10 k
D6
0.001
0.001
47 k
2.2 k
TP7
TP8
10 k
Q3
2N2222
18 V
1W
D5
FB
9V
9V
FB
U9
LM336
1
3
1
U10
LM336
3
0.1
W2
-2.5 V
1N34A
10 k
D7
0.001
0.001
0.01
W3
Vs-
5.6 k
V-
0.1
+15 V
0.01
J1
FORWARD
D1
1N5711
1 M
50 *
100
0.001
0.22
1 M
470
3
4
U1A
2
11
1
1 k
0.01
D2
1N5711
100 k
1 %
100 k
TP1
100 k
1 %
100 k
470
12
U1D
13
14
100 k
1 %
1 k
470 k
0.01
-2.5 V
SEE
TABLE2
FOR
RESISTOR
VALUES
TP2
CW
-2.5 V
+2.5 V
R1 100 k
FORWARD DETECTOR
ZERO
S1A
RANGE
NOTE: CHASSIS AND CIRCUIT
GROUNDS SEPARATED
FB
FB
1 mH
FB
FB
CHASSIS
CIRCUIT
J2
REFLECTED
D3
1N5711
1 M
50 *
100
0.001
0.1
1 M
470
5
U1B
6
7
1 k
0.01
D4
1N5711
100 k
1 %
100 k
TP4
100 k
1 %
100 k
470
10
U1C
9
8
100 k
1 %
1 k
470 k
SEE
TABLE2
FOR
RESISTOR
VALUES
TP5
CW
-2.5 V
+2.5 V
R2 100 k
REFLECTED DETECTOR
ZERO
S1B
RANGE
Chassis
Ground
Plane
Circuit
Ground
Plane

Fig 15—Schematic diagram for the Tandem Match directional wattmeter. Parts identified as RS are from RadioShack. For other parts sources, see Table 3. See Fig 17 for construction of 50-Ω loads at J1 and J2.

D1, D2—Matched pair 1N5711, or equivalent.
D3, D4—Matched pair 1N5711, or equivalent.
D6, D7—1N34A.
D8-D14—1N914.
FB—Ferrite bead, Amidon FB-73-101 or equiv.
J1, J2—SO-239 connector.
J3, J4—Open-circuit jack.
M1, M2—50 µA panel meter, RS 270-1751.
Q1, Q3, Q4—2N2222 or equiv.
Q2—2N2907 or equiv.

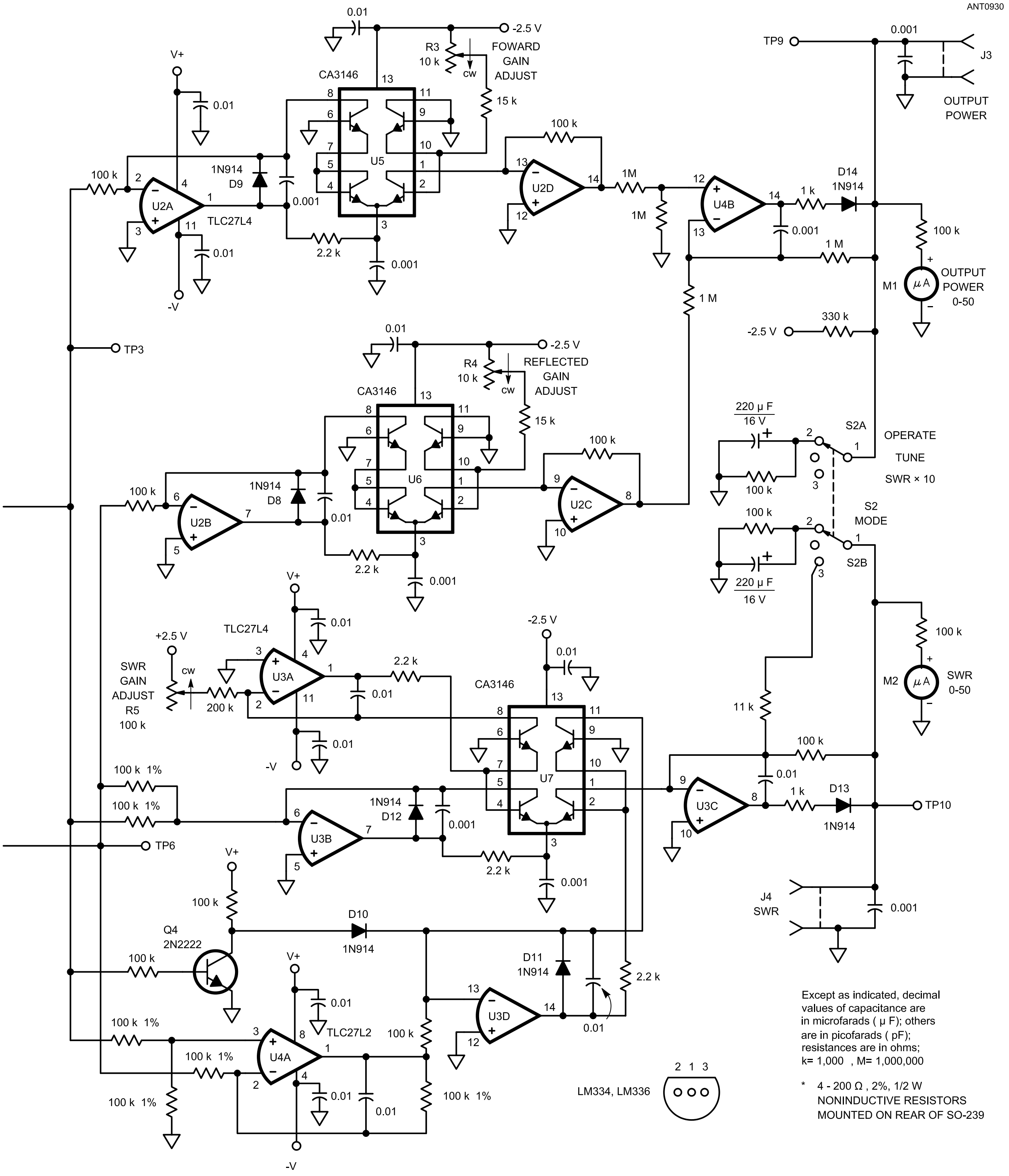
ANT0930
0.01
-2.5 V
R3
10 k
cw
FOWARD
GAIN
ADJUST
15 k
CA3146
13
8
11
6
9
7
10
5
1
4
2
U5
3
2.2 k
0.001
V+
0.01
100 k
U2A
TLC27L4
1N914
D9
0.001
-V
100 k
U2D
1M
U4B
1 k
D14
1N914
0.001
1 M
TP9
0.001
J3
OUTPUT
POWER
100 k
M1
µA
OUTPUT
POWER
0-50
330 k
-2.5 V
TP3
0.01
-2.5 V
R4
10 k
cw
REFLECTED
GAIN
ADJUST
15 k
CA3146
U6
U2B
1N914
D8
0.01
2.2 k
0.001
100 k
U2C
220 µ F
16 V
S2A
OPERATE
TUNE
SWR × 10
S2
MODE
S2B
100 k
V+
0.01
+2.5 V
TLC27L4
SWR
GAIN
ADJUST
R5
100 k
cw
200 k
U3A
2.2 k
0.01
0.01
-V
-2.5 V
0.01
CA3146
U7
100 k 1%
100 k 1%
1N914
D12
0.001
U3B
2.2 k
0.001
TP6
11 k
100 k
0.01
U3C
1 k
D13
1N914
TP10
M2
µA
SWR
0-50
J4
SWR
V+
100 k
Q4
2N2222
D10
1N914
D11
1N914
2.2 k
100 k
U3D
0.01
V+
0.01
TLC27L2
100 k 1%
100 k 1%
U4A
100 k
100 k 1%
100 k 1%
0.01
0.01
-V
LM334, LM336
2 1 3

Except as indicated, decimal values of capacitance are in microfarads (µ F); others are in picofarads (pF); resistances are in ohms; k= 1,000 , M= 1,000,000

* 4 - 200 Ω , 2%, 1/2 W NONINDUCTIVE RESISTORS MOUNTED ON REAR OF SO-239

R1, R2, R5—100 kΩ, 10-turn, cermet Trimpot.
R3, R4—10 kΩ, 10-turn, cermet Trimpot.
U1-U3—TLC27L4 or TLC27M4 quad op amp (Texas Instruments).
U4—TLC27L2 or TLC27M2 dual op amp.
U5-U7—CA3146 quad transistor array.
U8—LM334 adjustable current source.
U9-U10—LM336 2.5-V reference diode. See text.

Detector Circuits

Most amateur directional wattmeters use a germanium diode detector to minimize the forward voltage drop. Detector voltage drop is still significant, however, and an uncompensated diode detector does not respond to small signals in a linear fashion. Many directional wattmeters compensate for diode nonlinearity by adjusting the meter scale.

The effect of underestimating detected power worsens at low power levels. Under these conditions, the ratio of the forward power to the reflected power is overestimated because the reflected power is always less than the forward power. This results in an instrument that underestimates SWR, particularly as power is reduced. A directional wattmeter can be checked for this effect by measuring SWR at several power levels: the SWR should be independent of power level.

The Tandem Match uses a feedback circuit to compensate for diode nonlinearity. A simplified diagram of the compensated detector is shown in **Fig 13**. When used with the 30-dB directional coupler, the output voltage of this circuit tracks the square root of power over a range from 10 mW to 1.5 kW. The compensated diode detector tracks the peak input voltage down to 30 mV, while an uncompensated germanium-diode detector shows significant errors at peak inputs of 1 V and less. More information about compensated detectors appears in Grebenkemper's *QEX* article, "Calibrating Diode Detectors" (see Bibliography).

The compensation circuit uses the voltage across a feedback diode, D2, to compensate for the voltage drop across the detector diode, D1. (The diodes must be a matched pair.) The average current through D1 is determined by the detector diode load resistor, R1. The peak current through this diode is several times larger than the average current; therefore, the current through D2 must be several times larger than the average current through D1 to compensate adequately for the peal voltage drop across D1. This is accomplished by making the feedback-diode load resistor, R2, several times smaller than R1. The voltage at the output of the compensated detector approximates the peak RF voltage at the input. For Schottky barrier diodes and a 1 MΩ detector-diode load resistor, a 5:1 ratio of R1 to R2 is nearly optimal.

Signal-Processing and Display Circuits

The signal-processing circuitry calculates and displays transmission-line power and SWR. When measuring forward power, most directional wattmeters display the actual forward power present in the transmission line, which is the sum of forward and reflected power if a match exists at the input end of the line. Transmission-line forward power is very close to the net forward power (the actual power delivered to the line) so long as the SWR is low. As the SWR increases, however, forward power becomes an increasingly poor measure of the power delivered to the load. At an SWR of 3:1, a forward power reading of 100 W implies that only 75 W is delivered to the load (the reflected power is 25 W), assuming the transmission-line loss is zero.

The Tandem Match differs from most wattmeters in that *it displays the net forward power, rather than the sum of forward and reflected power.* This is the quantity that must be optimized to result in maximum radiated power (and which concerns the FCC).

The Tandem Match directly computes and displays the transmission-line SWR on a linear scale. As the displayed SWR is not affected by changes in transmitter power, a matching network can be simply adjusted to minimize SWR. Transmatch adjustment requires only a few watts.

The heart of the Tandem Match signal-processing circuit is the analog logarithm and antilogarithm circuitry shown in **Fig 14**. The circuit is based on the fact that collector current in a silicon transistor is proportional to the exponential (antilog) of its base-emitter voltage over a range of collector currents from a few nanoamperes to a few milliamperes when the collector-base voltage is zero (see Gibbons and Horn reference in the Bibliography). Variations of this circuit are used in the squaring circuits to convert voltage to power and in the divider circuit used to compute the SWR. With good op amps, this circuit will work well for input voltages from less than 100 mV to greater than 10 V.

(For the Tandem Match, "good" op amps are quad-packaged, low-power-consumption, unity-gain-stable parts with input bias less than 1 nA and offset voltage less than 5 mV. Op amps that consume more power than those shown may require changes to the power supply.)

CONSTRUCTION

The schematic diagram for the Tandem Match is shown in **Fig 15** (see pages 14 and 15). The circuit is designed to operate from batteries and draw very little power. Much of the circuitry is of high impedance, so take care to isolate it from RF fields. House it in a metal case. Most problems in the prototype were caused by stray RF in the op-amp circuitry.

Directional Coupler

The directional coupler is constructed in its own small ($2^3/_4 \times 2^3/_4 \times 2^1/_4$-inch) aluminum box (see **Fig 16**). Two pairs of S0-239 connectors are mounted on opposite sides of the box. A piece of PC board is run diagonally across the box to improve coupler directivity. The pieces of RG-8X coaxial cable pass through holes in the PC board.

(Note: Some brands of "mini 8" cable have extremely low breakdown voltage ratings and are unsuitable to carry even 100 W when the SWR exceeds 1:1. See the subsequent section, "High-Power Operation," for details of a coupler made with RG-8 cable.)

Begin by constructing T1 and T2, which are identi-

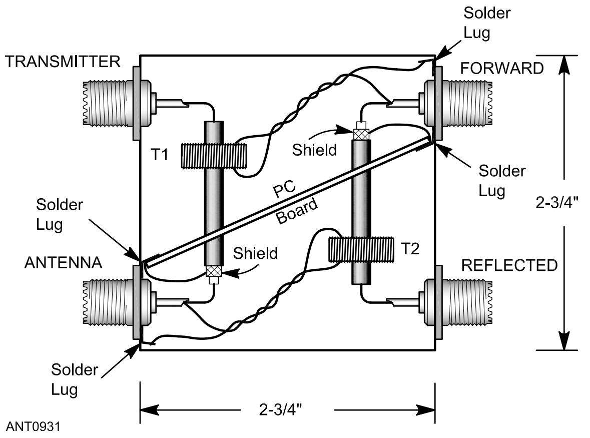

Fig 16—Construction details for the directional coupler.

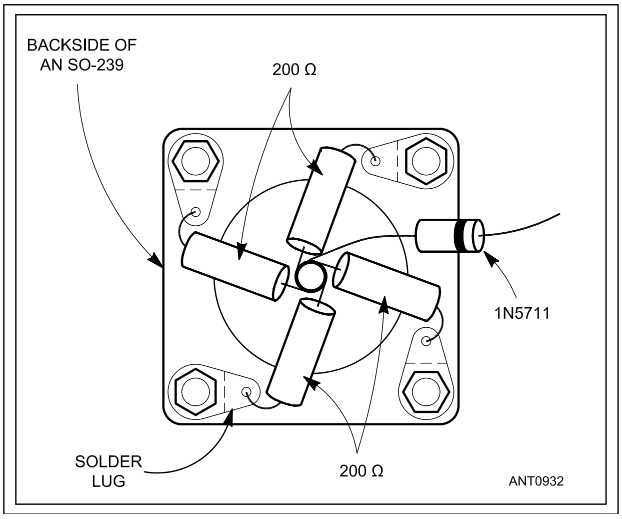

Fig 17—The parallel load resistors mounted on an SO-239 connector. Four 200-Ω, 2%, $\frac{1}{2}$-W resistors are mounted in parallel to provide a 50-Ω detector load.

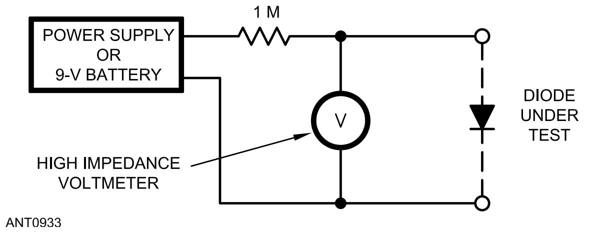

Fig 18—Diode matching test setup.

cal except for their end connections. Refer to Fig 16. The primary for each transformer is the center conductor of a length of RG-8X coaxial cable. Cut two cable lengths sufficient for mounting as shown in the figure. Strip the cable jacket, braid and dielectric as shown. The cable braid is used as a Faraday shield between the transformer windings, so it is only grounded at one end. *Important—connect the braid only at one end or the directional-coupler circuit will not work properly!* Wind two transformer secondaries, each 31 turns of #24 enameled wire on an Amidon T50-3 or equivalent powdered-iron core.

Slip each core over one of the prepared cable pieces (including both the shield and the outer insulation). Mount and connect the transformers as shown in Fig 16, with the wire running through separate holes in the copper-clad PC board. The directional coupler can be mounted separately from the rest of the circuitry if desired. If so, use two coaxial cables to carry the forward and reflected-power signals from the directional coupler to the detector inputs. Be aware, however that any losses in the cables will affect power readings.

This directional coupler has not been used at power levels in excess of 100 W. For more information about using the Tandem Match at high power levels, see the section, “High-Power Operation.”

Detector and Signal-Processing Circuits

The detector and signal-processing circuits were constructed on a perforated, copper-clad circuit board. These circuits use two separate grounds—*it is extremely important that the grounds be isolated as shown in the circuit diagram.* Failure to do so may result in faulty circuit operation. Separate grounds prevent RF currents on the cable braid from affecting the op-amp circuitry.

The directional coupler requires good 50-Ω loads. They are constructed on the back of female UHF chassis connectors where the cables from the directional coupler enter the wattmeter housing. Each load consists of four 200-Ω resistors connected from the center conductor of the UHF connector to the four holes on the mounting flange, as shown in **Fig 17**. The detector diode is then run from the center conductor of the connector to the 100-pF and 1000-pF bypass capacitors, which are mounted next to the connector. The response of this load and detector combination measures flat to beyond 500 MHz.

Schottky-barrier diodes (type 1N5711) were used in this design because they were readily available. Any RF-detector diode with a low forward voltage drop (less than 300 mV) and reverse break-down voltage greater than 30 V could be used. (Germanium diodes could be used in this circuit, but performance will suffer. If germanium diodes are used, reduce the resistance values for the detector-diode and feedback-diode load resistors by a factor of 10.)

The detector diodes must be matched. This can be done with dc, using the circuit shown in **Fig 18**. Use a high-impedance voltmeter (10 MΩ or greater). For this project, diodes are matched when their forward voltage drops are equal (within a few millivolts). Diodes from the same batch will probably be sufficiently matched.

Table 2
Range-Switch Resistor Values

Full-Scale Power Level (W)	*Range Resistor (1% Precision) (kΩ)*
1	2.32
2	3.24
3	4.02
5	5.23
10	7.68
15	9.53
20	11.0
25	12.7
30	14.0
50	18.7
100	28.7
150	37.4
200	46.4
250	54 9
300	63.4
500	100.0
1000	237.0
1500	649.0
2000	Open

The rest of the circuit layout is not critical, but keep the lead lengths of the 0.001 and 0.01-pF bypass capacitors short. The capacitors provide additional bypassing for the op-amp circuitry. D6 and D7 form a voltage doubler to detect the presence of a carrier. When the forward power exceeds 1.5 W, Q3 switches on and stays on until about 10 seconds after the carrier drops. (A connection from TP7 to TP9 forces the unit on, even with no carrier present.) The regulated references of +2.5 V and –2.5 V generated by the LM334 and two LM336s are critical. Zener-diode substitutes would significantly degrade performance.

The four op amps in U1 compensate for the nonlinearity of the detector diodes. D1-D2 and D3-D4 are the matched diode pairs discussed above. A RANGE switch selects the meter range. (A six-position switch was used here because it was handy.) The resistor values for the RANGE switch are shown in **Table 2**. Full-scale input power gives an output at U1C or U1D of 7.07 V. The forward and reflected-power detectors are zeroed with R1 and R2.

The forward and reflected-detector voltages are squared by U2, U5 and U6 so that the output voltages are proportional to forward and reflected power. The gain constants are adjusted using R3 and R4 so that an input of 7.07 V to the squaring circuit gives an output of 5 V. The difference between these two voltages is used by U4B to yield an output that is proportional to the power delivered to the transmission line. This voltage is peak detected (by an RC circuit connected to the OPERATE position of the MODE switch) to hold and indicate the maximum power during CW or SSB transmissions. SWR is computed from the forward and reflected voltages by U3, U4 and U7. When no carrier is present, Q4 forces the SWR reading to be zero (that is, when the forward power is less than 2% of the full-scale setting of the RANGE switch). The SWR computation circuit gain is adjusted by R5. The output is peak detected in the OPERATE mode to steady the SWR reading during CW or SSB transmissions.

Transistor arrays (U5, U6 and U7) are used for the log and antilog circuits to guarantee that the transistors will be well matched. Discrete transistors may be used, but accuracy may suffer. A three-position toggle switch selects the three operating modes. In the OPERATE mode, the power and SWR outputs are peak detected and held for a few seconds to allow meter reading during actual transmissions. In the TUNE mode, the meters display instantaneous output power and SWR.

A digital voltmeter is used to obtain more precise readings than are possible with analog meters. The output power range is 0 to 5 V (0 V = 0 W and 5 V = full scale). SWR output varies from 1 V (SWR = 1:1) to 5 V (SWR = 5:1). Voltages above 5 V are unreliable because of voltage limiting in some of the op amp circuits.

Calibration

The directional wattmeter can be calibrated with an accurate voltmeter. All calibration is done with dc voltages. The directional-coupler and detector circuits are inherently accurate if correctly built. To calibrate the wattmeter, use the following procedure:

1) Set the MODE switch to TUNE and the RANGE switch to 100 W or less.
2) Jumper TP7 to TP8. This turns the unit on.
3) Jumper TP1 to TP2. Adjust R1 for 0 V at TP3.
4) Jumper TP4 to TP5. Adjust R2 for 0 V at TP6.
5) Adjust R1 for 7.07 V at TP3.
6) Adjust R3 for 5.00 V at TP9, or a full-scale reading on M1.
7) Adjust R2 for 7.07 V at TP6.
8) Adjust R4 for 0 V at TP9, or a zero reading on M1.
9) Adjust R2 for 4.71 V at TP6.
10) Adjust R5 for 5.00 V at TP10, or a full-scale reading on M2.
11) Set the RANGE switch to its most sensitive scale.
12) Remove the jumpers from TP1 to TP2 and TP4 to TP5.
13) Adjust R1 for 0 V at TP3.
14) Adjust R2 for 0 V at TP6.
15) Remove the jumper from TP7 to TP8.

This completes the calibration procedure. This procedure has been found to equal calibration with expensive laboratory equipment. The directional wattmeter should now be ready for use.

ACCURACY

Performance of the Tandem Match has been compared to other well-known directional couplers and laboratory test equipment, and it equals any amateur directional wattmeter tested. Power measurement accuracy compares well to a Hewlett-Packard HP-436A power meter. The HP meter has a specified measurement error of less than ± 0.05 dB. The Tandem Match tracked the HP436A within +0.5 dB from 10 mW to 100 W, and within ± 0.1 dB from 1 W to 100 W. The unit was not tested above 100 W because a transmitter with a higher power rating was not available.

SWR performance was equally good when compared to the SWR calculated from measurements made with the HP436A and a calibrated directional coupler. The Tandem Match tracked the calculated SWR within ± 5% for SWR values from 1:1 to 5:1. SWR measurements were made at 8 W and 100 W.

OPERATION

Connect the Tandem Match in the 50-Ω line between the transmitter and the antenna matching network (or antenna if no matching network is used). Set the RANGE switch to a range greater than the transmitter output rating and the MODE switch to TUNE. When the transmitter is keyed, the Tandem Match automatically switches on and indicates both power delivered to the antenna and SWR on the transmission line. When no carrier is present, the OUTPUT POWER and SWR meters indicate zero.

The OPERATE mode includes RC circuitry to momentarily hold the peak-power and SWR readings during CW or SSB transmissions. The peak detectors are not ideal, so there could be about 10% variation from the actual power peaks and the SWR reading. The SWR ×10 mode increases the maximum readable SWR to 50:1. This range should be sufficient to cover any SWR value that occurs in amateur use. (A 50-foot open stub of RG-8 yields a measured SWR of only 43:1, or less, at 2.4 MHz because of cable loss. Higher frequencies and longer cables exhibit a lesser maximum SWR.)

It is easy to use the Tandem Match to adjust an antenna matching network: Adjust the transmitter for minimum output power (at least 1.5 W). With the carrier on and the MODE switch set to TUNE or SWR ×10, adjust the matching network for minimum SWR. Once the minimum SWR is obtained, set the transmitter to the proper operating mode and output power. Place the Tandem Match in the OPERATE mode.

DESIGN VARIATIONS

There are several ways in which this design could be enhanced. The most important is to add UHF capability. This would require a new directional-coupler design for the band of interest. (The existing detector circuit should work to at least 500 MHz.)

Those who desire a low-power directional wattmeter can build a directional coupler with a 20-dB coupling factor by decreasing the transformer turns ratio to 10:1. That version should be capable of measuring output power from 1 mW to about 150 W (and it should switch on at about 150 mW).

This change should also increase the maximum operating frequency to about 150 MHz (by virtue of the shorter transformer windings). If you desire 1.8-MHz operation, it may be necessary to change the toroidal core material for sufficient reactance (low insertion loss).

The Tandem Match circuit can accommodate coaxial cable with a characteristic impedance other than 50 Ω. The detector terminating resistors, transformer secondaries and range resistors must change to match the new design impedance.

The detector circuitry can be used (without the directional coupler) to measure low-level RF power in 50-Ω circuits. RF is fed directly to the forward detector (J1, Fig 15), and power is read from the output power meter. The detector is quite linear from 10 µW to 1.5 W.

HIGH-POWER OPERATION

This material was condensed from information by Frank Van Zant, KL7IBA, in July 1989 *QST.* In April 1988, Zack Lau, W1VT, described a directional-coupler circuit (based on the same principle as Grebenkemper's circuit) for a QRP transceiver (see the Bibliography at the end of this chapter). The main advantage of Lau's circuit is a very low parts count.

Grebenkemper used complex log-antilog amplifiers to provide good measurement accuracy. This application gets away from complex circuitry, but retains reasonable measurement accuracy over the 1 to 1500-W range. It also forfeits the SWR-computation feature. Lau's coupler uses ferrite toroids. It works well at low power levels, but the ferrite toroids heat excessively with high power, causing erratic meter readings and the potential for burned parts.

The Revised Design

Powdered-iron toroids are used for the transformers in this version of Lau's basic circuit. The number of turns on the secondaries was increased to compensate for the lower permeability of powdered iron.

Two meters display reflected and forward power (see **Fig 19**). The germanium detector diodes (D1 and D2—1N34) provide fairly accurate meter readings, particularly if the meter is calibrated (using R3, R4 and R5) to place the normal transmitter output at mid scale. If the winding sense of the transformers is reversed, the meters are transposed (the forward-power meter becomes the reflected-power meter, and vice versa).

Construction

Fig 20 shows the physical layout of the coupler. The pickup unit is mounted in a $3^1/_2 \times 3^1/_2 \times$ 4-inch box. The meters, PC-mount potentiometers and HIGH/LOW power

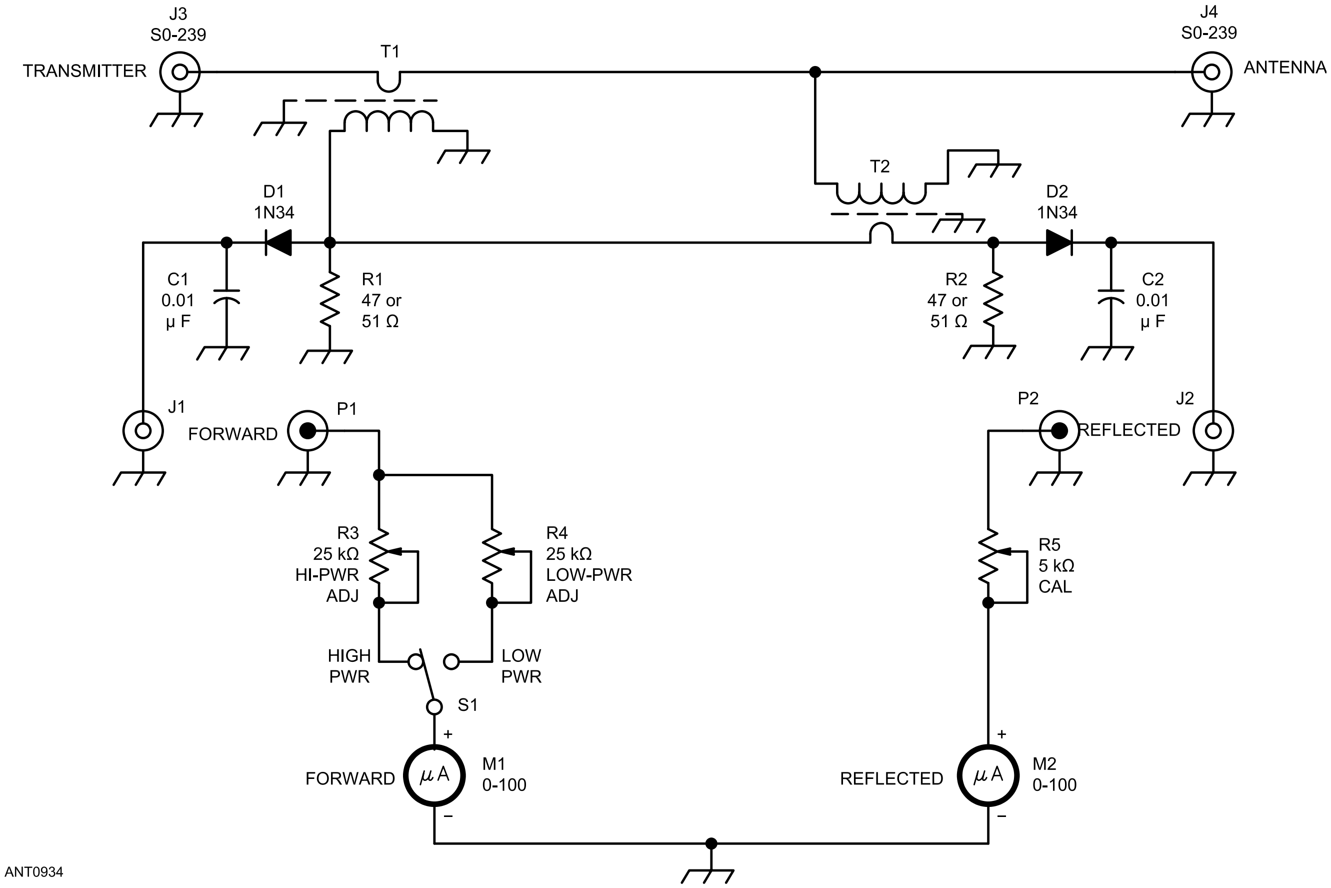
J3
S0-239
TRANSMITTER
T1
J4
S0-239
ANTENNA
T2
D1
1N34
D2
1N34
C1
0.01
μ F
R1
47 or
51 Ω
R2
47 or
51 Ω
C2
0.01
μ F
J1
FORWARD
P1
P2
REFLECTED
J2
R3
25 kΩ
HI-PWR
ADJ
R4
25 kΩ
LOW-PWR
ADJ
R5
5 kΩ
CAL
HIGH
PWR
LOW
PWR
S1
+
FORWARD
μA
M1
0-100
–
+
REFLECTED
μA
M2
0-100
–
ANT0934

Fig 19—Schematic diagram of the high-power directional coupler. D1 and D2 are germanium diodes (1N34 or equiv). R1 and R2 are 47 or 51-Ω, 1/2-W resistors. C1 and C2 have 500-V ratings. The secondary windings of T1 and T2 each consist of 40 turns of #26 to #30 enameled wire on T-68-2 powdered-iron toroid cores. If the coupler is built into an existing antenna tuner, the primary of T1 can be part of the tuner coaxial output line. The remotely located meters (M1 and M2) are connected to the coupler box at J1 and J2 via P1 and P2.

switch are mounted in a separate box or a compartment in an antenna tuner. Parts for this project are available from the suppliers listed in **Table 3**.

The primary windings of Tl and T2 are constructed much as Grebenkemper described, but use RG-8 with its jacket removed so that the core and secondary winding may fit over the cable. The braid is wrapped with fiberglass tape to insulate it from the secondary winding. An excellent alternative to fiberglass tape—with even higher RF voltage-breakdown characteristics—is ordinary plumber's Teflon pipe tape, available at most hardware stores.

The transformer secondaries are wound on T-68-2 powdered-iron toroid cores. They are 40 turns of #26 to #30 enameled wire spread evenly around each core. By using #26 to #30 wire on the cores, the cores slip over the tape-wrapped RG-8 lines. With #26 wire on the toroids, a single layer of tape (slightly more with Teflon tape) over the braid provides an extremely snug fit for the core. Use care when fitting the cores onto the RG-8 assemblies.

After the toroids are mounted on the RG-8 sections,

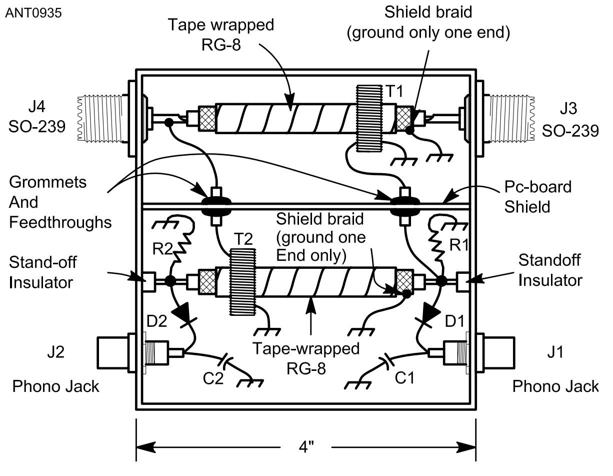
ANT0935
Tape wrapped
RG-8
Shield braid
(ground only one end)
T1
J4
SO-239
J3
SO-239
Grommets
And
Feedthroughs
Pc-board
Shield
Shield braid
(ground one
End only)
R2
T2
R1
Stand-off
Insulator
Standoff
Insulator
D2
D1
J2
Phono Jack
Tape-wrapped
RG-8
C2
C1
J1
Phono Jack
4"

Fig 20—Directional-coupler construction details. Grommets or feedthrough insulators can be used to route the secondary winding of T1 and T2 through the PC board shield. A 3 1/2 × 3 1/2 × 4-inch box serves as the enclosure.

Table 3
Parts Sources
(Also see Chapter 21)

Components	*Source*
TLC-series and CA3146 ICs	Newark Electronics 4801 N Ravenswood St Chicago, IL 60640 773-784-5100
LM334, LM336, 1% resistors, trimmer potentiometers	Digi-Key Corporation 701 Brooks Ave S PO Box 677 Thief River Falls, MN 56701 800-344-4539
Toroid cores, Fiberglass tape	Amidon Associates 240 & 250 Briggs Ave Costa Mesa, CA 92626 714-850-4660
Meters	Fair Radio Sales PO Box 1105 Lima, OH 45804 419-227-6573
Toroid cores	Palomar Engineers PO Box 462222 Escondido, CA 92046 760-747-3343
0-150/1500-W-scale meters, A&M model no. 255-138, 1N5711 diodes	Surplus Sales of Nebraska 1502 Jones St Omaha, NE 68102 402-346-4750

coat the assembly with General Cement Corp Polystyrene Q Dope, or use a spot or two of RTV sealant to hold the windings in place and fix the transformers on the RG-8 primary windings.

Mount a PC-board shield in the center of the box, between T1 and T2, to minimize coupling between the transformers. Suspend T1 between the SO-239 connectors and T2 between two standoff insulators. The detector circuits (C1, C2, D1, D2, R1 and R2) are mounted inside the coupler box as shown.

Calibration, Tune Up and Operation

The coupler has excellent directivity. Calibrate the meters for various power levels with an RF ammeter and a 50-Ω dummy load. Calculate I^2R for each power level, and mark the meter faces accordingly. Use R3, R4 and R5 to adjust the meter readings within the ranges. Diode nonlinearities are thus taken into account, and Grebenkemper's signal-processing circuits are not needed for relatively accurate power readings. Start the tune-up process using about 10 W, adjust the antenna tuner for minimum reflected power, and increase power while adjusting the tuner to minimize reflected power.

This circuit has been built into several antenna tuners with good success. The instrument works well at 1.5-kW output on 1.8 MHz. It also works well from 3.5 to 30 MHz with 1.2 and 1.5-kW output.

The antenna is easily tuned for a 1:1 SWR using the null indication provided. Amplifier settings for a matched antenna, as indicated with the wattmeter, closely agreed with those for a 50-Ω dummy load. Checks with a Palomar noise bridge and a Heath Antenna Scope also verified these findings. This circuit should handle more than 1.5 kW, as long as the SWR on the feed line through the wattmeter is kept at or near 1:1. (On one occasion high power was applied while the antenna tuner was not coupled to a load. Naturally the SWR was extremely high, and the output transformer secondary winding opened like a fuse. This resulted from the excessively high voltage across the secondary. The damage was easily and quickly repaired.)

An Inexpensive VHF Directional Coupler

Precision in-line metering devices capable of reading forward and reflected power over a wide range of frequencies are very useful in amateur VHF and UHF work, but their rather high cost puts them out of the reach of many VHF enthusiasts. The device shown in Figs 14 through 16 is an inexpensive adaptation of their basic principles. It can be made for the cost of a meter, a few small parts, and bits of copper pipe and fittings that can be found in the plumbing stocks at many hardware stores.

Construction

The sampler consists of a short section of handmade coaxial line, in this instance, of 50 Ω impedance, with a reversible probe coupled to it. A small pickup loop built into the probe is terminated with a resistor at one end and a diode at the other. The resistor matches the impedance of the loop, not the impedance of the line section. Energy picked up by the loop is rectified by the diode, and the resultant current is fed to a meter equipped with a calibration control.

The principal metal parts of the device are a brass plumbing T, a pipe cap, short pieces of $^{3}/_{4}$-inch ID and $^{5}/_{16}$-inch OD copper pipe, and two coaxial fittings. Other available tubing combinations for 50-Ω line may be usable. The ratio of outer conductor ID to inner conductor OD should be 2.4/1. For a sampler to be used with other

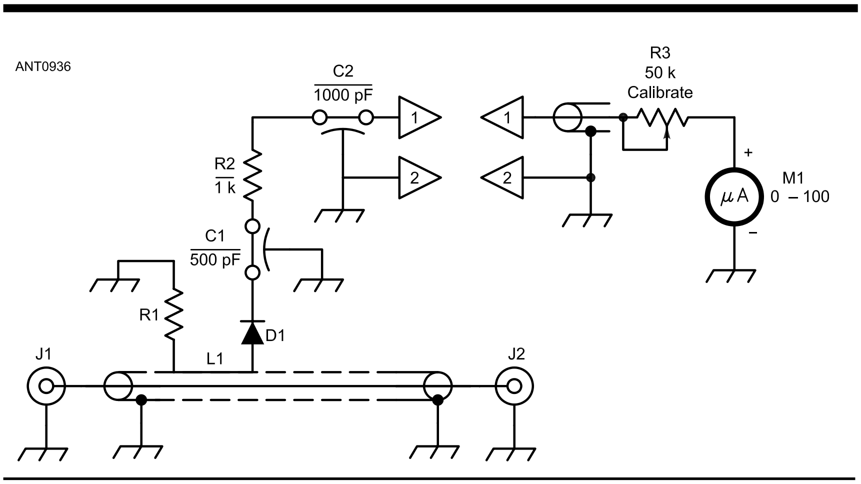

Fig 21—Circuit diagram for the line sampler.

C1—500-pF feedthrough capacitor, solder-in type.
C2—1000-pF feedthrough capacitor, threaded type.
D1—Germanium diode 1N34, 1N60, 1N270, 1N295, or similar.
J1, J2—Coaxial connector, type N (UG-58A).
L1—Pickup loop, copper strap 1-inch long × $^{3}/_{16}$-inch wide. Bend into "C" shape with flat portion $^{5}/_{8}$-inch long.
M1—0-100 μA meter.
R1—Composition resistor, 82 to 100 Ω. See text.
R3—50-kΩ composition control, linear taper.

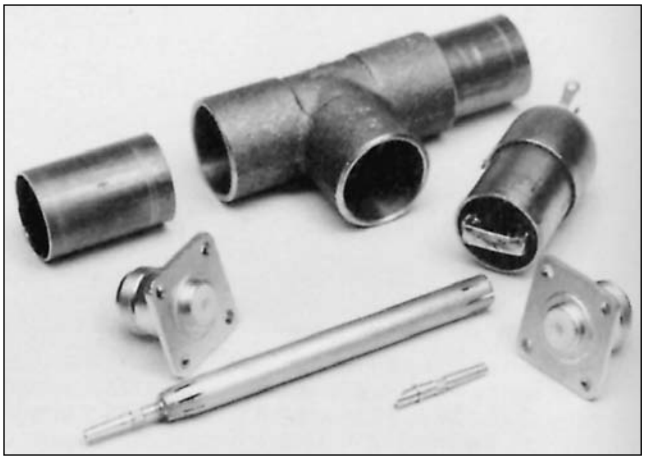

Fig 22—Major components of the line sampler. The brass T and two end sections are at the upper left in this picture. A completed probe assembly is at the right. The N connectors have their center pins removed. The pins are shown with one inserted in the left end of the inner conductor and the other lying in the right foreground.

impedances of transmission line, see Chapter 24 for suitable ratios of conductor sizes. The photographs and **Fig 21** show construction details.

Soldering of the large parts can be done with a 300-watt iron or a small torch. A neat job can be done if the inside of the T and the outside of the pipe are tinned before assembling. When the pieces are reheated and pushed together, a good mechanical and electrical bond will result. If a torch is used, go easy with the heat, as an overheated and discolored fitting will not accept solder well.

Coaxial connectors with Teflon or other heat-resistant insulation are recommended. Type N, with split-ring retainers for the center conductors, are preferred. Pry the split-ring washers out with a knife point or small screwdriver. Don't lose them, as they'll be needed in the final assembly.

The inner conductor is prepared by making eight radial cuts in one end, using a coping saw with a fine-toothed blade, to a depth of $^{1}/_{2}$ inch. The fingers so made are then bent together, forming a tapered end, as shown in **Figs 22** and **23**. Solder the center pin of a coaxial fitting into this, again being careful not to overheat the work.

In preparation for soldering the body of the coax connector to the copper pipe, it is convenient to use a similar fitting clamped into a vise as a holding fixture. Rest the T assembly on top, held in place by its own weight. Use the partially prepared center conductor to assure that the coax connector is concentric with the outer conductor. After being sure that the ends of the pipe are cut exactly perpendicular to the axis, apply heat to the coax fitting, using just enough so a smooth fillet of solder can be formed where the flange and pipe meet.

Before completing the center conductor, check its length. It should clear the inner surface of the connector by the thickness of the split ring on the center pin. File to length; if necessary, slot as with the other end, and solder the center pin in place. The fitting can now be soldered onto the pipe, to complete the 50-Ω line section.

The probe assembly is made from a $1^{1}/_{2}$ inch length of the copper pipe, with a pipe cap on the top to support the upper feedthrough capacitor, C2. The coupling loop is mounted by means of small Teflon standoffs on a copper disc, cut to fit inside the pipe. The disc has four small tabs around the edge for soldering inside the pipe. The diode, D1, is connected between one end of the loop and

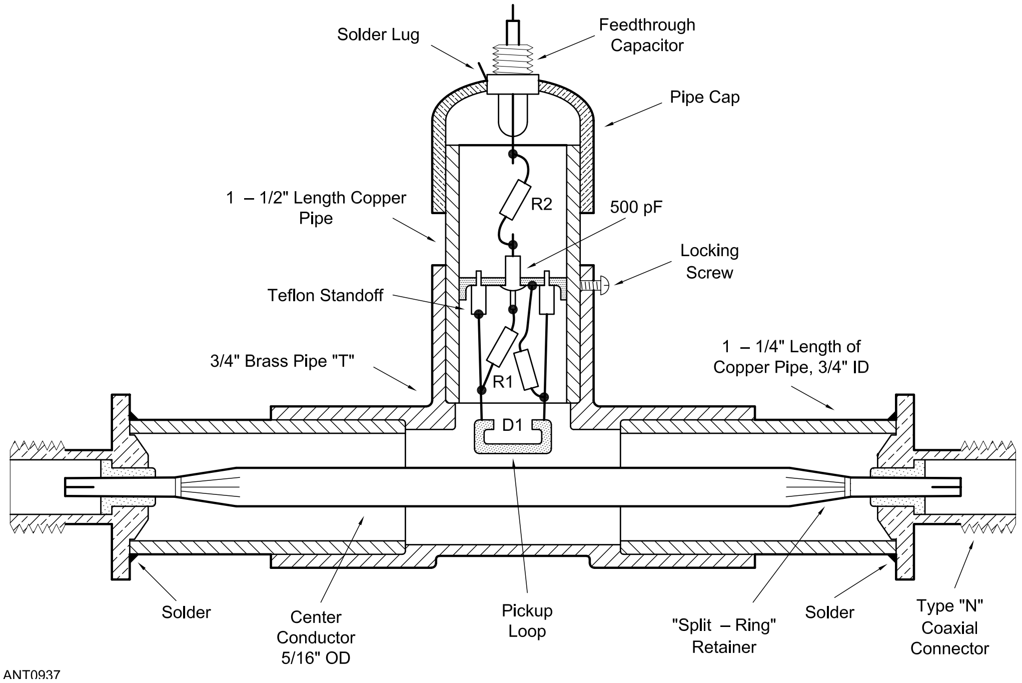
Solder Lug
Feedthrough Capacitor
Pipe Cap
1 – 1/2" Length Copper Pipe
R2
500 pF
Locking Screw
Teflon Standoff
3/4" Brass Pipe "T"
1 – 1/4" Length of Copper Pipe, 3/4" ID
R1
D1
Solder
Center Conductor 5/16" OD
Pickup Loop
"Split – Ring" Retainer
Solder
Type "N" Coaxial Connector
ANT0937

Fig 23—Cross-section view of the line sampler. The pickup loop is supported by two Teflon standoff insulators. The probe body is secured in place with one or more locking screws through holes in the brass T.

a 500-pF feedthrough capacitor, C1, soldered into the disc. The terminating resistor, R1, is connected between the other end of the loop and ground, as directly as possible.

When the disc assembly is completed, insert it into the pipe, apply heat to the outside, and solder the tabs in place by melting solder into the assembly at the tabs. The position of the loop with respect to the end of the pipe will determine the sensitivity of a given probe. For power levels up to 200 watts the loop should extend beyond the face of the pipe about $^{5}/_{32}$ inch. For use at higher power levels the loop should protrude only $^{3}/_{32}$ inch. For operation with very low power levels the best probe position can be determined by experiment.

The decoupling resistor, R2, and feedthrough capacitor, C2, can be connected, and the pipe cap put in place. The threaded portion of the capacitor extends through the cap. Put a solder lug over it before tightening its nut in place. Fasten the cap with two small screws that go into threaded holes in the pipe.

Calibration

The sampler is very useful for many jobs even if it is not accurately calibrated, although it is desirable to calibrate it against a wattmeter of known accuracy. A good 50-Ω VHF dummy load is required.

The first step is to adjust the inductance of the loop, or the value of the terminating resistor, for lowest reflected power reading. The loop is the easier to change. Filing it to reduce its width will increase its impedance. Increasing the cross-section of the loop will lower the impedance, and this can be done by coating it with solder. When the reflected power reading is reduced as far as possible, reverse the probe and calibrate for forward power by increasing the transmitter power output in steps and making a graph of the meter readings obtained. Use the calibration control, R3, to set the maximum reading.

Variations

Rather than to use one sampler for monitoring both forward and reflected power by repeatedly reversing the

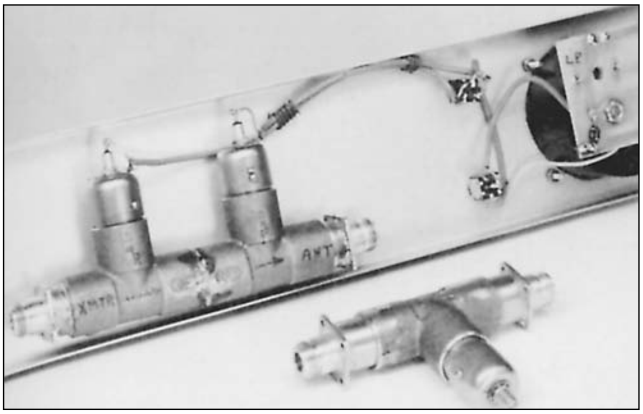

Fig 24—Two versions of the line sampler. The single unit described in detail here is in the foreground. Two sections in a single assembly provide for monitoring forward and reflected power without probe reversal.

probe, it is better to make two assemblies by mounting two T fittings end-to-end, using one for forward and one for reflected power. The meter can be switched between the probes, or two meters can be used.

The sampler described was calibrated at 146 MHz, as it was intended for repeater use. On higher bands the meter reading will be higher for a given power level, and it will be lower for lower frequency bands. Calibration for two or three adjacent bands can be achieved by making the probe depth adjustable, with stops or marks to aid in resetting for a given band. Of course more probes can be made, with each probe calibrated for a given band, as is done in some of the commercially available units.

Other sizes of pipe and fittings can be used by making use of information given in Chapter 24 to select conductor sizes required for the desired impedances. (Since it is occasionally possible to pick up good bargains in 75-Ω line, a sampler for this impedance might be desirable.)

Type-N fittings were used because of their constant impedance and their ease of assembly. Most have the split-ring retainer, which is simple to use in this application. Some have a crimping method, as do apparently all BNC connectors. If a fitting must be used and cannot be taken apart, drill a hole large enough to clear a soldering-iron tip in the copper-pipe outer conductor. A hole of up to $^3/_8$-inch diameter will have very little effect on the operation of the sampler.

A Calorimeter For VHF And UHF Power Measurements

A quart of water in a Styrofoam ice bucket, a roll of small coaxial cable and a thermometer are all the necessary ingredients for an accurate RF wattmeter. Its calibration is independent of frequency. The wattmeter works on the calorimeter principle: A given amount of RF energy is equivalent to an amount of heat, which can be determined by measuring the temperature rise of a known quantity of thermally insulated material. This principle is used in many of the more accurate high-power wattmeters. This procedure was developed by James Bowen, WA4ZRP, and was first described in December 1975 *QST*.

The roll of coaxial cable serves as a dummy load to convert the RF power into heat. RG-174 cable was chosen for use as the dummy load in this calorimeter because of its high loss factor, small size, and low cost. It is a standard 50-Ω cable of approximately 0.11 inch diameter. A prepackaged roll marked as 60 feet long, but measured to be 68 feet, was purchased at a local electronics store. A plot of measured RG-174 loss factor as a function of frequency is shown in **Fig 25**.

In use, the end of the cable not connected to the transmitter is left open-circuited. Thus, at 50 MHz, the reflected wave returning to the transmitter (after making a round trip of 136 feet through the cable) is 6.7 dB × 1.36 = 9.11 dB below the forward wave. A reflected wave 9.11 dB down represents an SWR to the transmitter of 2.08:1. While this value seems larger than would be desired, keep in mind that most 50-MHz transmitters can be tuned to match into an SWR of this magnitude efficiently. To assure accurate results, merely tune the transmitter for maximum power into the load before making

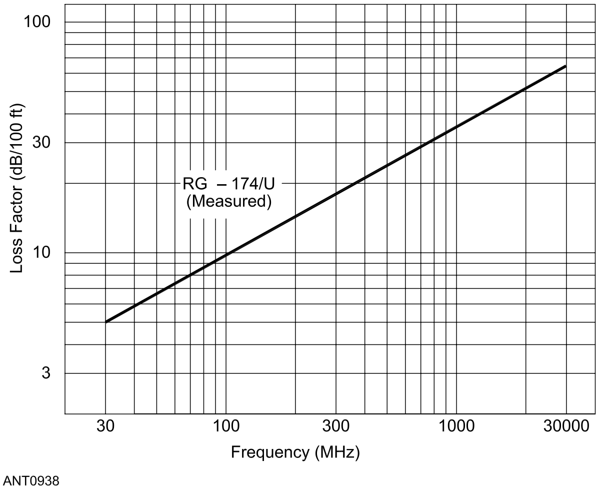

Fig 25—Loss factor of RG-174 coax used in the calorimeter.

Table 4

Calculated Input SWR for 68 Feet of Unterminated RG-174 Cable

Freq. (MHz)	*SWR*
50	2.08
144	1.35
220	1.20
432	1.06
1296	1.003
2304	1.0003

the measurement. At higher frequencies the cable loss increases so the SWR goes down. **Table 4** presents the calculated input SWR values at several frequencies for 68 feet of RG-174. At 1000 MHz and above, the SWR caused by the cable connector will undoubtedly exceed the very low cable SWR listed for these frequencies.

In operation, the cable is submerged in a quart of water and dissipated heat energy flows from the cable into the water, raising the water temperature. See **Fig 26**. The calibration of the wattmeter is based on the physical fact that one calorie of heat energy will raise one gram of liquid water 1° Celsius. Since one quart of water contains 946.3 grams, the transmitter must deliver 946.3 calories of heat energy to the water to raise its temperature 1° C. One calorie of energy is equivalent to 4.186 joules and a joule is equal to 1 W for 1 second. Thus, the heat capacitance of 1 quart of water expressed in joules is 946.3 × 4.186 = 3961 joules/° C.

The heat capacitance of the cable is small with respect to that of the water, but nevertheless its effect should be included for best accuracy. The heat capacitance of the cable was determined in the manner described below. The 68-foot roll of RG-174 cable was raised to a uniform temperature of 100° C by immersing it in a pan of boiling water for several minutes. A quart of tap water was poured into the Styrofoam ice bucket and its temperature was measured at 28.7° C. the cable was then transferred quickly from the boiling water to the water in the ice bucket. After the water temperature in the ice bucket had ceased to rise, it measured 33.0° C. Since the total heat gained by the quart of water was equal to the total heat lost from the cable, we can write the following equation:

$$(\Delta T_{WATER})(C_{WATER}) = -(\Delta T_{CABLE})(C_{CABLE})$$

where

ΔT_{WATER} = the change in water temperature
C_{WATER} = the water heat capacitance
Δ_{CABLE} = the change in cable temperature
C_{CABLE} = the cable heat capacitance

Substituting and solving:

$$(33.0 - 28.7)(3961) = -(33.0 - 100)(C_{CABLE})$$

Thus, the total heat capacitance of the water and cable in the calorimeter is 3961 + 254 = 4215 joules/° C. Since 1° F = 5/9° C, the total heat capacitance can also be expressed as 4215 × 5/9 = 2342 joules/° F.

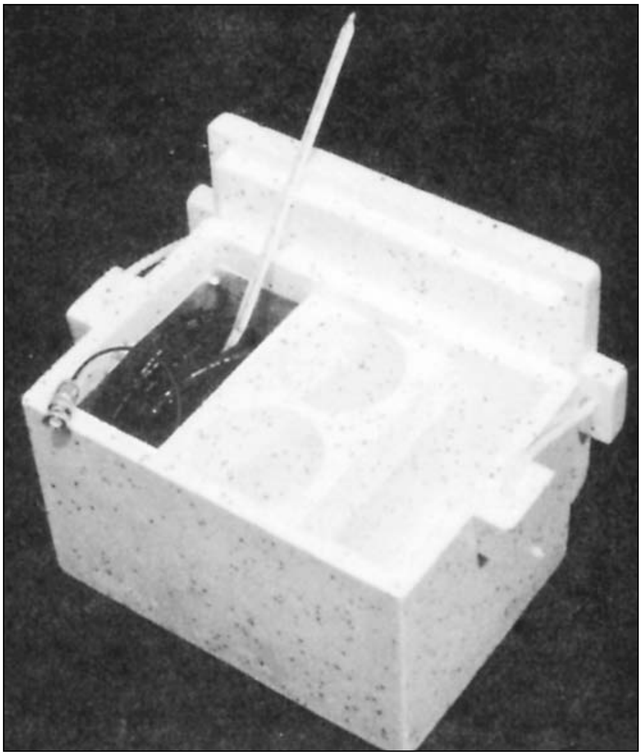

Fig 26—The calorimeter ready for use. The roll of coaxial cable is immersed in one quart of water in the left-hand compartment of the Styrofoam container. Also shown is the thermometer, which doubles as a stirring rod.

Materials and Construction

The quart of water and cable must be thermally insulated to assure that no heat is gained from or lost to the surroundings. A Styrofoam container is ideal for this purpose since Styrofoam has a very low thermal conductivity and a very low thermal capacitance. A local variety store was the source of a small Styrofoam cold chest with compartments for carrying sandwiches and drink cans. The rectangular compartment for sandwiches was found to be just the right size for holding the quart of water and coax.

The thermometer can be either a Celsius or Fahrenheit type, but try to choose one that has divisions for each degree spaced wide enough so that the temperature can be estimated readily to one-tenth degree. Photographic supply stores carry darkroom thermometers, which are ideal for this purpose. In general, glass bulb thermometers are more accurate than mechanical dial-pointer types.

The RF connector on the end of the cable should be a constant-impedance type. A BNC type connector especially designed for use on 0.11-inch diameter cable was located through surplus channels. If you cannot locate one of these, wrap plastic electrical tape around the cable near its end until the diameter of the tape wrap is the same as that of RG-58. Then connect a standard BNC connector for RG-58 in the normal fashion. Carefully seal the opposite open end of the cable with plastic tape or silicone caulking compound so no water can leak into the cable at this point.

Procedure for Use

Pour 1 quart of water (4 measuring cups) into the Styrofoam container. As long as the water temperature is not very hot or very cold, it is unnecessary to cover the top of the Styrofoam container during measurements. Since the transmitter will eventually heat the water several degrees, water initially a few degrees cooler than air temperature is ideal because the average water temperature will very nearly equal the air temperature and heat transfer to the air will be minimized.

Connect the RG-174 dummy load to the transmitter through the shortest possible length of lower loss cable such as RG-8. Tape the connectors and adapter at the RG-8 to RG-174 joint carefully with plastic tape to prevent water from leaking into the connectors and cable at this point. Roll the RG-174 into a loose coil and submerge it in the water. Do not bind the turns of the coil together in any way, as the water must be able to freely circulate among the coaxial cable turns. All the RG-174 cable must be submerged in the water to ensure sufficient cooling. Also submerge part of the taped connector attached to the RG-174 as an added precaution.

Upon completing the above steps, quickly tune up the transmitter for maximum power output into the load. Cease transmitting and stir the water slowly for a minute or so until its temperature has stabilized. Then measure the water temperature as precisely as possible. After the initial temperature has been determined, begin the test transmission, measuring the total number of seconds of key-down time accurately. Stir the water slowly with the thermometer and continue transmitting until there is a significant rise in the water temperature, say 5° to 10°. The test may be broken up into a series of short periods, as long as you keep track of the total key-down time. When the test is completed, continue to stir the water slowly and monitor its temperature. When the temperature ceases to rise, note the final indication as precisely as possible.

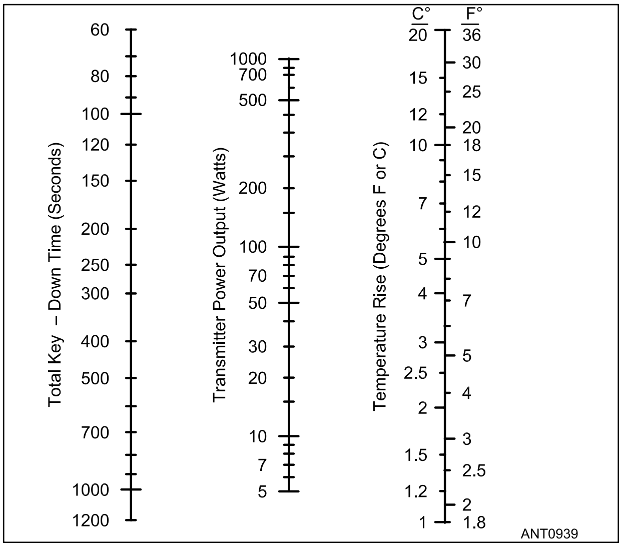

Fig 27—Nomogram for finding transmitter power output for the calorimeter.

To compute the transmitter power output, multiply the calorimeter heat capacitance (4215 for C or 2342 for F) by the difference in initial and final water temperature. Then divide by the total number of seconds of key-down time. The resultant is the transmitter power in watts. A nomogram that can also be used to find transmitter power output is given in **Fig 27**. With a straight line, connect the total number of key-down seconds in the time column to the number of degrees change (F or C) in the temperature rise column, and read off the transmitter power output at the point where the straight line crosses the power-output column.

Power Limitation

The maximum power handling capability of the calorimeter is limited by the following. At very high powers the dielectric material in the coaxial line will melt because of excessive heating or the cable will arc over from excessive voltage. As the transmitter frequency gets higher, the excessive-heating problem is accentuated, as more of the power is dissipated in the first several feet of cable. For instance, at 1296 MHz, approximately 10% of the transmitting power is dissipated in the first foot of cable. Overheating can be prevented when working with high power by using a low duty cycle to reduce the average dissipated power. Use a series of short transmissions, such as two seconds on, ten seconds off. Keep count of the total key-down time for power calculation purposes. If the cable arcs over, use a larger-diameter cable, such as RG-58, in place of the RG-174. The cable should be long enough to assure that the reflected wave will be down 10 dB or more at the input. It may be necessary to use more than one quart of water in order to submerge all the cable conveniently. If so, be sure to calculate the new value of heat capacitance for the larger quantity of water. Also you should measure the new coaxial cable heat capacitance using the method previously described.

A Noise Bridge For 1.8 Through 30 MHz

The noise bridge, sometimes referred to as an antenna (RX) noise bridge, is an instrument for measuring the impedance of an antenna or other electrical circuits. The unit shown here in **Fig 28**, designed for use in the 1.8 through 30-MHz range, provides adequate accuracy for most measurements. Battery operation and small physical size make this unit ideal for remote-location use. Tone modulation is applied to the wide-band noise generator as an aid for obtaining a null indication. A detector, such as the station receiver, is required for operation.

The noise bridge consists of two parts—the noise generator and the bridge circuitry. See **Fig 29**. A 6.8-V

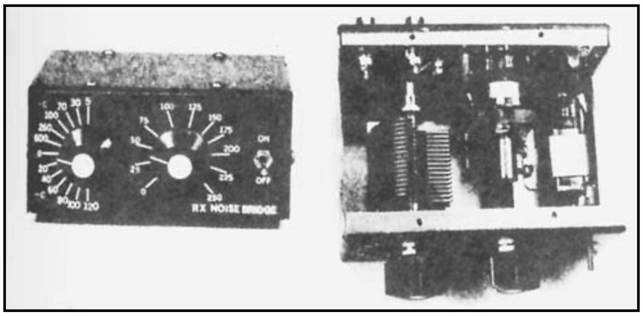
RX NOISE BRIDGE
ON
OFF

Fig 28—Exterior and interior views of the noise bridge. The unit is finished in red enamel. Press-on lettering is used for the calibration marks. Note that the potentiometer must be isolated from ground.

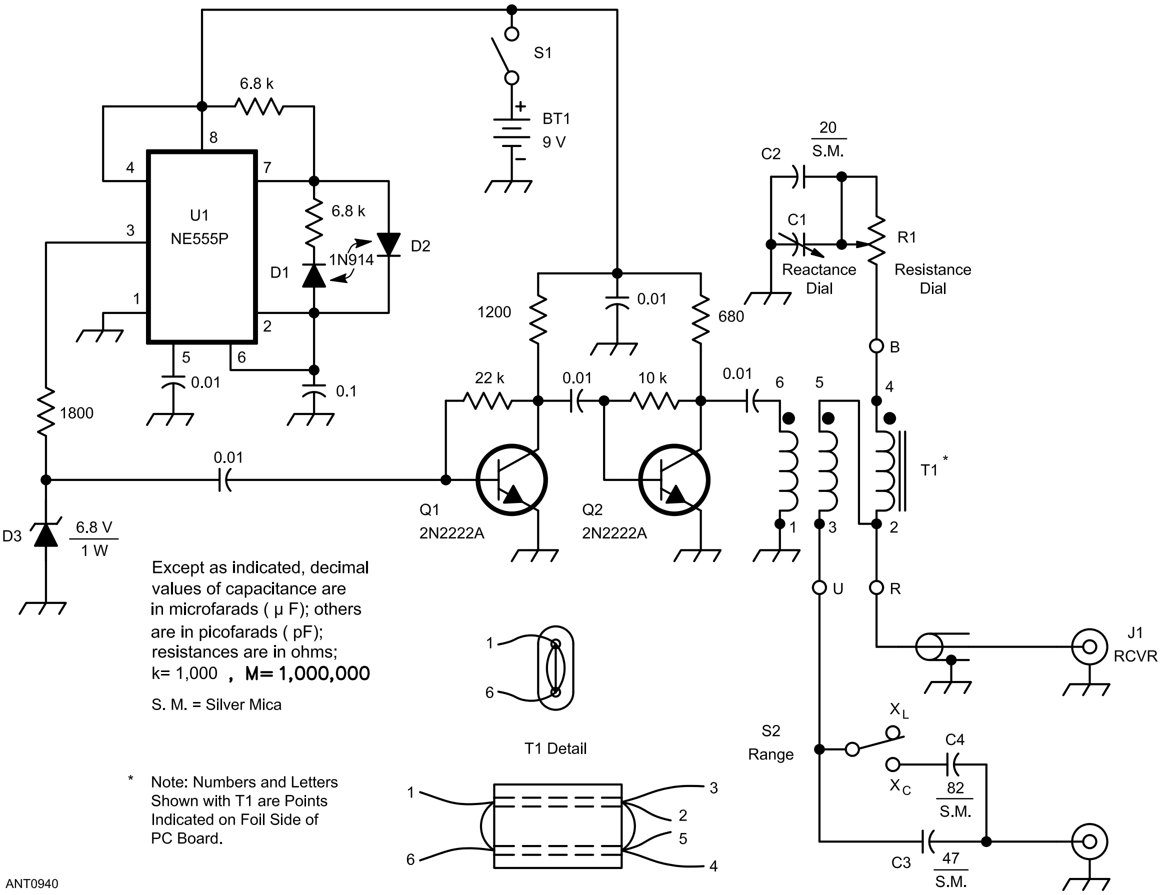
S1
BT1
9 V
6.8 k
8
4
7
3
1
2
5
6
U1
NE555P
6.8 k
D1
1N914
D2
0.01
0.1
1800
0.01
D3
6.8 V
1 W
1200
0.01
680
22 k
0.01
10 k
0.01
Q1
2N2222A
Q2
2N2222A
C2
20
S.M.
C1
R1
Reactance Dial
Resistance Dial
B
4
6
5
T1 *
1
3
2
U
R
J1
RCVR
S2
Range
X_L
X_C
C4
82
S.M.
C3
47
S.M.
1
6
T1 Detail
1
6
3
2
5
4
ANT0940

Except as indicated, decimal values of capacitance are in microfarads (μ F); others are in picofarads (pF); resistances are in ohms; k= 1,000 , M= 1,000,000

S. M. = Silver Mica

* Note: Numbers and Letters Shown with T1 are Points Indicated on Foil Side of PC Board.

Fig 29—Schematic diagram of the noise bridge. Use 1/4 W composition resistors. Capacitors are miniature ceramic units unless indicated otherwise. Component designations indicated in the schematic but not called out in the parts list are for text and parts-placement reference only.

BT1—9-V battery, NEDA 1604A or equiv.
C1—15- to 150-pF variable
C2—20-pF mica.
C3—47-pF mica.
C4—82-pF mica.
J1, J2—Coaxial connector.
R1—Linear, 250 Ω, AB type. Use a good grade of resistor.
S1, S2—Toggle, SPST.
T1—Transformer; 3 windings on an Amidon BLN-43-2402 ferrite binocular core. Each winding is three turns of #30 enameled wire. One turn is equal to the wire passing once through both holes in the core. The primary winding starts on one side of the transformer, and the secondary and tertiary windings start on the opposite side.
U1—Timer, NE555 or equiv.

Zener diode serves as the noise source. U1 generates an approximate 50% duty cycle, 1000-Hz square wave signal which is applied to the cathode of the Zener diode. The 1000-Hz modulation appears on the noise signal and provides a useful null detection enhancement effect. The broadband-noise signal is amplified by Q1, Q2 and associated components to a level that produces an approximate S9 signal in the receiver. Slightly more noise is available at the lower end of the frequency range, as no frequency compensation is applied to the amplifier. Roughly 20 mA of current is drawn from the 9-V battery, thus ensuring long battery life—providing the power is switched off after use!

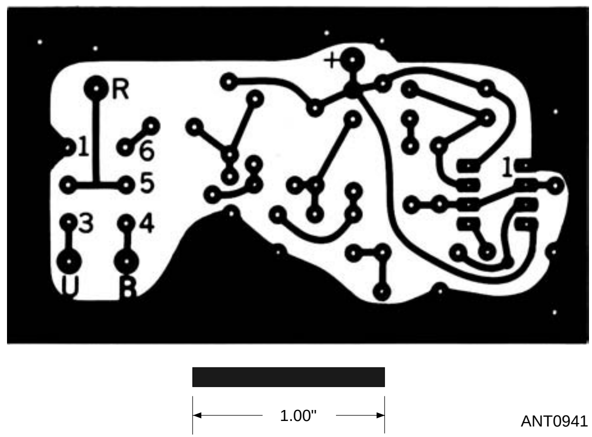

Fig 30—Etching pattern for the noise bridge PC board, at actual size. Black represents copper. This is the pattern for the bottom side of the board. The top side of the board is a complete ground plane with a small amount of copper removed from around the component holes.

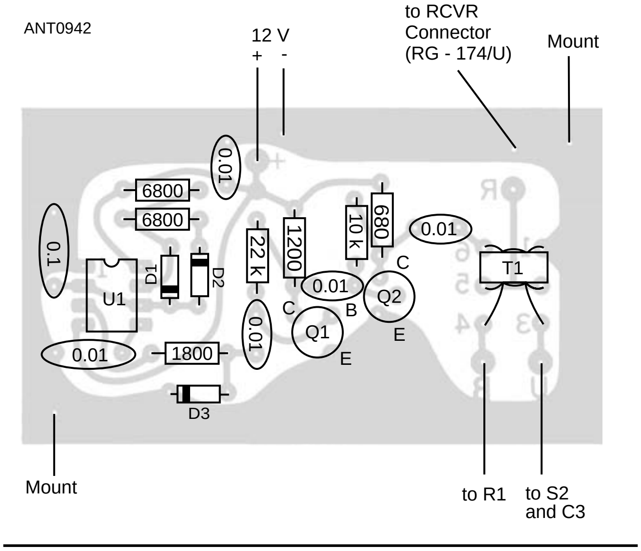

Fig 31—Parts-placement guide for the noise bridge as viewed from the component or top side of the board. Mounting holes are located in two corners of the board, as shown.

The bridge portion of the circuit consists of T1, C1, C2 and R1. T1 is a trifilar wound transformer with one of the windings used to couple noise energy into the bridge circuit. The remaining two windings are arranged so that each one is in an arm of the bridge. C1 and R1 complete one arm and the UNKNOWN circuit, along with C2, comprise the remainder of the bridge. The terminal labeled RCVR is for connection to the detector.

The reactance range of a noise bridge is dependent on several factors, including operating frequency, value of the series capacitor (C3 or C3 plus C4 in Fig 29) and the range of the variable capacitor (C1 in Fig 29). The RANGE switch selects reactance measurements weighted toward either capacitance or inductance by placing C4 in parallel with C3. The zero-reactance point occurs when C1 is either nearly fully meshed or fully unmeshed. The RANGE switch nearly doubles the resolution of the reactance readings.

CONSTRUCTION

The noise bridge is contained in a homemade aluminum enclosure that measures 5 × 2$^3/_8$ × 3$^3/_4$ inches. Many of the circuit components are mounted on a circuit board that is fastened to the rear wall of the cabinet. The circuit-board layout is such that the lead lengths to the board from the bridge and coaxial connectors are at a minimum. An etching pattern and a parts-placement guide for the circuit board are shown in **Figs 30** and **31**.

Care must be taken when mounting the potentiometer, R1. For accurate readings the potentiometer must be well insulated from ground. In the unit shown this was accomplished by mounting the control on a piece of plexiglass, which in turn was fastened to the chassis with a piece of aluminum angle stock.

Additionally, a $^1/_4$-inch control-shaft coupling and a length of phenolic rod were used to further isolate the control from ground where the shaft passes through the front panel. A high-quality potentiometer is required if good measurement results are to be obtained.

There is no such problem when mounting the variable capacitor because the rotor is grounded. Use a high-quality capacitor; do not try to save money on that component. Two RF connectors on the rear panel are connected to a detector (receiver) and to the UNKNOWN circuit. Do not use plastic-insulated phono connectors (they might influence bridge accuracy at higher frequencies). Use miniature coaxial cable (RG-174) between the RCVR connector and circuit board. Attach one end of C3 to the circuit board and the other directly to the UNKNOWN circuit connector.

Bridge Compensation

Stray capacitance and inductance in the bridge circuit can affect impedance readings. If a very accurate bridge is required, use the following steps to counter the effects of stray reactance. Because the physical location

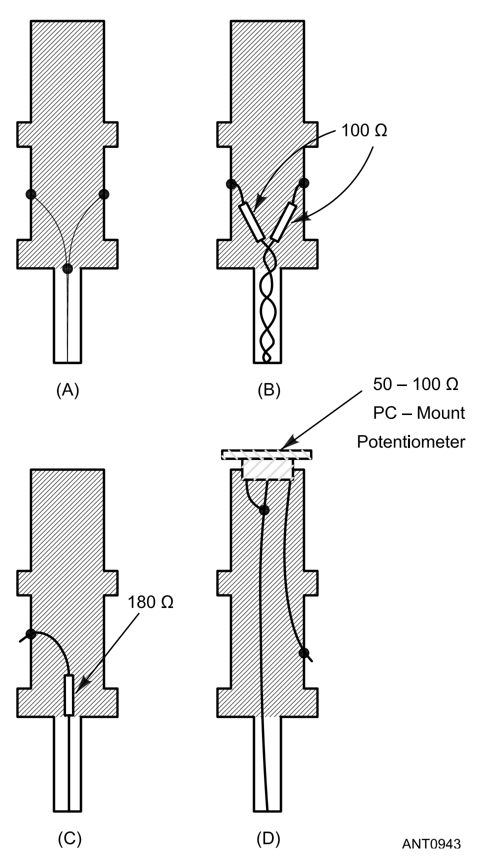

Fig 32—Construction details of the resistive loads used to check and calibrate the noise bridge. Each of the loads is constructed inside a coaxial connector that matches those on the bridge. (Views shown are cross-sections of PL-259 bodies; the sleeves are not shown.) Leads should be kept as short as possible to minimize parasitic inductance. A is a 0-Ω load; B depicts a 50-Ω load; C is a 180-Ω load; D shows a variable-resistance load used to determine the loss in a coaxial cable.

of the board, connectors and controls in the cabinet determine where compensation is needed, there is no provision for the compensation components on the printed circuit board.

Good calibration loads are necessary to check the accuracy of the noise bridge. Four are needed here: a 0-Ω (short-circuit) load, a 50-Ω load, a 180-Ω load, and a variable-resistance load. The short-circuit and fixed-resistance loads are used to check the accuracy of the noise bridge; the variable-resistance load is used when measuring coaxial-cable loss.

Construction details of the loads are shown in **Fig 32**. Each load is constructed inside a connector. When building the loads, keep leads as short as possible to minimize parasitic effects. The resistors must be noninductive (*not* wirewound).

Quarter-watt, carbon-composition resistors should work fine. The potentiometer in the variable-resistance load is a miniature PC-mount unit with a maximum resistance of 100 Ω or less. The potentiometer wiper and one of the end leads are connected to the center pin of the connector; the other lead is connected to ground.

Stray Capacitance

Stray capacitance on the variable-resistor side of the bridge tends to be higher than that on the unknown side. This is so because the parasitic capacitance in the variable resistor, R1, is comparatively high.

The effect of parasitic capacitance is most easily detected using the 180-Ω load. Measure and record the actual resistance of the load, R_L. Connect the load to the UNKNOWN connector, place S2 in the X_L position, tune the receiver to 1.8 MHz, and null the bridge. (See the section, "Finding the Null" for tips.) Use an ohmmeter across R1 to measure its dc resistance. The magnitude of the stray capacitance can be calculated by

$$C_P = C3\left(\sqrt{\frac{R1}{R2}}-1\right) \qquad \text{(Eq 4)}$$

where

R_L = load resistance (as measured)
R1 = resistance of the variable resistor
C3 = series capacitance.

You can compensate for C_P by placing a variable capacitor, C_C, in the side of the bridge with lesser stray capacitance. If R1 is greater than R_L, stray capacitance is greater on the variable resistor side of the bridge: Place C_C between point U (on the circuit board) and ground. If R1 is less than R_L, stray capacitance is greater on the unknown side: Place C_C between point B and ground. If the required compensating capacitance is only a few picofarads, you can use a gimmick capacitor (made by twisting two short pieces of insulated, solid wire together) for C_C. A gimmick capacitor is adjusted by trimming its length.

Stray Inductance

Parasitic inductance, if present, should be only a few tens of nanohenries. This represents a few ohms of inductive reactance at 30 MHz. The effect is best observed by reading the reactance of the 0-Ω test load at 1.8 and 30 MHz; the indicated reactance should be the same at both frequencies.

If the reactance reading decreases as frequency is increased, parasitic inductance is greater in the known arm, and compensating inductance is needed between point U and C3. If the reactance increases with frequency, the unknown-arm inductance is greater, and compensating inductance should be placed between point B and R1.

Compensate for stray inductance by placing a single-turn coil, made from a 1 to 2-inch length of solid wire, in the appropriate arm of the bridge. Adjust the size of this coil until the reactance reading remains constant from 1.8 to 30 MHz.

Calibration

Good calibration accuracy is necessary for accurate noise-bridge measurements. Calibration of the resistance scale is straightforward. To do this, tune the receiver to a frequency near 10 MHz. Attach the 0-Ω load to the UNKNOWN connector and null the bridge. This is the zero-resistance point; mark it on the front-panel resistance scale. The rest of the resistance range is calibrated by adjusting R1, measuring R1 with an accurate ohmmeter, calculating the increase from the zero point and marking the increase on the front panel.

Most bridges have the reactance scale marked in capacitance because capacitance does not vary with frequency. Unfortunately, that requires calibration curves or non-trivial calculations to arrive at the load reactance. An alternative method is to mark the reactance scale in *ohms* at a reference frequency of 10 MHz. This method calibrates the bridge near the center of its range and displays reactance directly, but it requires a simple calculation to scale the reactance reading for frequencies other than 10 MHz. The scaling equation is:

$$X_{u(f)} = X_{u(10)} \frac{10}{f} \qquad \text{(Eq 5)}$$

where

f = frequency in MHz

$X_{u(10)}$ = reactance of the unknown load at 10 MHz

$X_{u(f)}$ = reactance of the unknown load at f.

A shorted piece of coaxial cable serves as a reactance source. (The reactance of a shorted, low-loss coaxial cable is dependent only on the cable length, the measurement frequency and the cable characteristic impedance.) Radio Shack RG-8M is used here because it is readily available, has relatively low loss and has an almost purely resistive characteristic impedance.

Prepare the calibration cable as follows:

1) Cut a length of coaxial cable that is slightly longer than $^1/_4$ λ at 10 MHz (about 20 feet for RG-8M). Attach a suitable connector to one end of the cable; leave the other end open-circuited.
2) Connect the 0-Ω load to the noise bridge UNKNOWN connector and set the receiver frequency to 10 MHz. Adjust the noise bridge for a null. Do not adjust the reactance control after the null is found.
3) Connect the calibration cable to the bridge UNKNOWN terminal. Null the bridge by adjusting *only* the variable resistor and the receiver frequency. The receiver frequency should be less than 10 MHz; if it is above 10 MHz, the cable is too short, and you need to prepare a longer one.
4) Gradually cut short lengths from the end of the coaxial cable until you obtain a null at 10 MHz by adjusting only the resistance control. Then connect the cable center and shield conductors at the open end with a short length of braid. Verify that the bridge nulls with zero reactance at 20 MHz.
5) The reactance of the coaxial cable (normalized to 10 MHz) can be calculated from:

$$X_{i(10)} = R_0 \frac{f}{10} \tan\left(2\pi \frac{f}{40}\right) \qquad \text{(Eq 6)}$$

where

$X_{i(10)}$ = cable reactance at 10 MHz

R_0 = characteristic resistance of the coaxial cable (52.5 Ω for Radio Shack RG-8M)

f = frequency in MHz

The results of Eq 6 have less than 5% error for reactances less than 500 Ω, so long as the test-cable loss is less than 0.2 dB. This error becomes significantly less at lower reactances (2% error at 300 Ω for a 0.2-dB-loss cable). The loss in 18 feet of RG-8M is 0.13 dB at 10 MHz. Reactance data for Radio Shack RG-8M is given in **Table 5**.

Table 5

Noise Bridge Calibration Data: Coaxial-Cable Method

This data is for Radio Shack RG-8M cable (R_0 =52.5 Ω) cut to exactly $^1/_4$ λ at 10 MHz; the reactances and capacitances shown correspond to this frequency.

Reactance				***Capacitance***	
X_i	*f(MHz)*	*X_i*	*f(MHz)*	*C(pF)*	*f(MHz)*
10	3.318	–10	19.376	10	9.798
20	4.484	–20	18.722	20	9.612
30	5.262	–30	18.048	30	9.440
40	5.838	–40	17.368	40	9.280
50	6.286	–50	16.701	50	9.130
60	6.647	–60	16.062	60	8.990
70	6.943	–70	15.471	70	8.859
80	7.191	–80	14.936	80	8.735
90	7.404	–90	14.462	90	8.618
100	7.586	–100	14.044	100	8.508
110	7.747	–110	13.682	110	8.403
120	7.884	–120	13.369	120	8.304
130	8.009	–130	13.097	130	8.209
140	8.119	–140	12.861	140	8.119
150	8.217	–150	12.654		
160	8.306	–160	12.473		
170	8.387	–170	12.313		
180	8.460	–180	12.172		
190	8.527	–190	12.045		
200	8.588	–200	11.932	*C(pF)*	*f(MHz)*
210	8.645	–210	11.831	–10	10.219
220	8.697	–220	11.739	–20	10.459
230	8.746	–230	11.655	–30	10.721
240	8.791	–240	11.579	–40	11.010
250	8.832	–250	11.510	–50	11.328
260	8.872	–260	11.446	–60	11.679
270	8.908	–270	11.387	–70	12.064
280	8.942	–280	11.333	–80	12.484
290	8.975	–290	11.283	–90	12.935
300	9.005	–300	11.236	–100	13.407
350	9.133	–350	11.045	–110	13.887
400	9.232	–400	10.905	–120	14.357
450	9.311	–450	10.798	–130	14.801
500	9.375	–500	10.713	–140	15.211

With the prepared cable and calibration values on hand, proceed to calibrate the reactance scale. Tune the receiver to the appropriate frequency for the desired reactance (given in Table 5, or found using Eq 6). Adjust the resistance and reactance controls to null the bridge. Mark the reactance reading on the front panel. Repeat this process until all desired reactance values have been marked. The resistance values needed to null the bridge during this calibration procedure may be significant (more than 100 Ω) at the higher reactances.

This calibration method is much more accurate than using fixed capacitors across the UNKNOWN connector. Also, you can calibrate a noise bridge in less than an hour using this method.

Finding the Null

In use, a receiver is attached to the RCVR connector and some load of unknown value is connected to the UNKNOWN terminal. The receiver allows us to hear the noise present across the bridge arms at the frequency of the receiver passband. The strength of the noise signal depends on the strength of the noise-bridge battery, the receiver bandwidth/sensitivity and the impedance difference between the known and unknown bridge arms. The noise is stronger and the null more obvious with wide receiver passbands. Set the receiver to the widest bandwidth AM mode available.

The noise-bridge output is heard as a 1000-Hz tone. When the impedances of the known and unknown bridge arms are equal, the voltage across the receiver is minimized; this is a null. In use, the null may be difficult to find because it appears only when both bridge controls approach the values needed to balance the bridge.

To find the null, set C1 to mid-scale, sweep R1 slowly through its range and listen for a reduction in noise (it's also helpful to watch the S meter). If no reduction is heard, set R1 to mid-range and sweep C1. If there is still no reduction, begin at one end of the C1 range and sweep R1. Increment C1 about 10% and sweep R1 with each increment until some noise reduction appears. Once noise reduction begins, adjust C1 and R1 alternately for minimum signal.

MEASURING COAXIAL-CABLE PARAMETERS WITH A NOISE BRIDGE

Coaxial cables have a number of properties that affect the transmission of signals through them. Generally, radio amateurs are concerned with cable attenuation and characteristic impedance. If you plan to use a noise bridge or SWR analyzer to make antenna-impedance measurements, however, you need to accurately determine not just cable impedance and attenuation, but also electrical length. Fortunately, all of these parameters are easy to measure with an accurate noise bridge or SWR analyzer.

Cable Electrical Length

With a noise bridge and a general-coverage receiver, you can easily locate frequencies at which the line in question is a multiple of ½ λ, because a shorted ½ λ line has a 0-Ω impedance (neglecting line loss). By locating two adjacent null frequencies, you can solve for the length of line in terms of ½ λ at one of the frequencies and calculate the line length (overall accuracy is limited by bridge accuracy and line loss, which broadens the nulls). As an interim variable, you can express cable length as the frequency at which a cable is 1 λ long. This length will be represented by f_λ. Follow these steps to determine f_λ for a coaxial cable.

1) Tune the receiver to the frequency range of interest. Attach the short-circuit load to the noise bridge UNKNOWN connector and null the bridge.
2) Disconnect the far end of the coaxial cable from its load (the antenna) and connect it to the 0-Ω test load. Connect the near end of the cable to the bridge UNKNOWN connector.
3) Adjust the receiver frequency and the noise-bridge resistance control for a null. *Do not change the noise bridge reactance-control setting during this procedure*. Note the frequency at which the null is found; call this frequency f_n. The noise-bridge resistance at the null should be relatively small (less than 20 Ω).
4) Tune the receiver upward in frequency until the next null is found. Adjust the resistance control, if necessary, to improve the null, *but do not adjust the reactance control*. Note the frequency at which this second null is found; this is f_{n+2} .
5) Solve Eq 7 for n and the electrical length of the cable.

$$n = \frac{2f_n}{f_{n+2} - f_n} \qquad \text{(Eq 7)}$$

$$f_\lambda = \frac{4f_n}{n} \qquad \text{(Eq 8)}$$

where

n = cable electrical length in quarter waves, at f_n

f_l = frequency at which the cable is 1λ

ℓ = cable electrical length, in λ

For example, consider a 74-foot length of Columbia 1188 foam-dielectric cable (velocity factor = 0.78) to be used on the 10-meter band. Based on the manufacturer's specification, the cable is 2.796 λ at 29 MHz. Nulls were found at 24.412 (f_n) and 29.353 (f_{n+2}) MHz. Eq 7 yields n = 9.88, which produces 9.883 MHz from Eq 8 and 2.934 l for Eq 9. If the manufacturer's specification is correct, the measured length is off by less than 5%, which is very reasonable. Ideally, n would yield an integer. The difference between n and the closest integer indicates that there is some error.

This procedure also works for lines with an open circuit as the termination (n will be close to an odd number). End effects from the PL-259 increase the effective length of the coaxial cable; however, this decreases the calculated f_λ.

Cable Characteristic Impedance

The characteristic impedance of the coaxial cable is found by measuring its input impedance at two frequencies separated by $^1/_4$ f_λ. This must be done when the cable is terminated in a resistive load.

Characteristic impedance changes slowly as a function of frequency, so this measurement must be done near the frequency of interest. The measurement procedure is as follows.

1) Place the 50-Ω load on the far end of the coaxial cable and connect the near end to the UNKNOWN connector of the noise bridge. (Measurement error is minimized when the load resistance is close to the characteristic impedance of the cable. This is the reason for using the 50-Ω load.)
2) Tune the receiver approximately $^1/_8$ f below the frequency of interest. Adjust the bridge resistance and reactance controls to obtain a null, and note their readings as R_{f1} and X_{f1}. Remember, the reactance reading must be scaled to the measurement frequency.
3) Increase the receiver frequency by exactly $^1/_4$ fλ. Null the bridge again, and note the readings as R_{f2} and X_{f2}.
4) Calculate the characteristic impedance of the coaxial cable using Eqs 10 through 15. A scientific calculator is helpful for this.

$$\ell = \frac{f_0}{f_\lambda} \qquad \text{(Eq 9)}$$

$$R = R_{f1} \times F_{f2} - X_{f1} \times X_{f2} \qquad \text{(Eq 10)}$$

$$X = R_{f1} \times X_{f2} + X_{f1} \times R_{f2} \qquad \text{(Eq 11)}$$

$$Z = \sqrt{R^2 + X^2} \qquad \text{(Eq 12)}$$

$$R_0 = \sqrt{Z} \cos\left[\frac{1}{2} \tan^{-1}\left(\frac{X}{R}\right)\right] \qquad \text{(Eq 13)}$$

$$X_0 = \sqrt{Z} \sin\left[\frac{1}{2} \tan_{-1}\left(\frac{X}{R}\right)\right] \qquad \text{(Eq 14)}$$

$$Z_0 = R_0 + jX_0 \qquad \text{(Eq 15)}$$

Let's continue with the example used earlier for cable length. The measurements are:

f1 = 29.000 – (9.883 / 8) = 27.765 MHz
R_{f1} = 64 Ω
X_{f1} = –22 Ω × (10 / 27.765) = –7.9 Ω
f2 = 27.765 + (9.883/4) = 30.236 MHz
R_{f2} = 50 Ω
X_{f2} = –24 Ω × (10 / 30.236) = –7.9 Ω

When used in Eqs 10 through 15, these data yield:

R = 3137.59
X = –900.60
Z = 3264.28
R_0 = 56.58 Ω
X_0 = –7.96 Ω

Cable Attenuation

Cable loss can be measured once the cable electrical length and characteristic resistance are known. The measurement must be made at a frequency where the cable presents no reactance. Reactance is zero when the cable electrical length is an integer multiple of λ/4. You can easily meet that condition by making the measurement frequency an integer multiple of $^1/_4$ fλ . Loss at other frequencies can be interpolated with reasonable accuracy. This procedure employs a resistor-substitution method that provides much greater accuracy than is achieved by directly reading the resistance from the noise-bridge scale.

1) Determine the approximate frequency at which you want to make the loss measurement by using

$$n = \frac{4f_0}{f_\lambda} \qquad \text{(Eq 16A)}$$

Round n to the nearest integer, then

$$f1 = \frac{n}{4} f_\lambda \qquad \text{(Eq 16B)}$$

2) If n is odd, leave the far end of the cable open; if n is even, connect the 0-Ω load to the far end of the cable. Attach the near end of the cable to the UNKNOWN connector on the noise bridge.
3) Set the noise bridge to zero reactance and the receiver to f1. Fine tune the receiver frequency and the noise-bridge resistance to find the null.
4) Disconnect the cable from the UNKNOWN terminal, and connect the variable-resistance calibration load in its place. Without changing the resistance setting on the bridge, adjust the load resistor and the bridge reactance to obtain a null.
5) Remove the variable-resistance load from the bridge UNKNOWN terminal and measure the load resistance using an ohmmeter that's accurate at low resistance levels. Refer to this resistance as R_i.
6) Calculate the cable loss in decibels using

$$a\ell = 8.69 \frac{R_i}{R_0} \qquad \text{(Eq 17)}$$

To continue this example, Eq 16A gives n = 11.74, so measure the attenuation at n = 12. From Eq 16B, f1 = 29.649 MHz. The input resistance of the cable measures 12.1 Ω with 0-Ω load on the far end of the cable; this corresponds to a loss of 1.86 dB.

USING A BRIDGE TO MEASURE THE IMPEDANCE OF AN ANTENNA

The impedance at the end of a transmission line can be easily measured using a noise bridge or SWR analyzer. In many cases, however, you really want to measure the impedance of an antenna—that is, the impedance of the load at the far end of the line. There are several ways to handle this.

1) Measurements can be made with the bridge at the antenna. This is usually not practical because the antenna must be in its final position for the measurement to be accurate. Even if it can be done, making such a measurement is certainly not very convenient.
2) Measurements can be made at the source end of a coaxial cable—if the cable length is an exact integer multiple of $^1/_2$ λ. This effectively restricts measurements to a single frequency.
3) Measurements can be made at the source end of a coaxial cable and corrected using a Smith Chart as shown in Chapter 28. This graphic method can result in reasonable estimates of antenna impedance—as long as the SWR is not too high and the cable is not too lossy. However, it doesn't compensate for the complex impedance characteristics of real-world coaxial cables. Also, compensation for cable loss can be tricky to apply. These problems, too, can lead to significant errors.
4) Last, measurements can be corrected using the transmission-line equation. The *TLW* program included on the CD-ROM in the back of this book, can do these complicated computations for you. This is the best method for calculating antenna impedances from measured parameters, but it requires that you measure the feed-line characteristics beforehand—measurements for which you need access to both ends of the feed line.

The procedure for determining antenna impedance is to first measure the electrical length, characteristic impedance, and attenuation of the coaxial cable connected to the antenna. After making these measurements, connect the antenna to the coaxial cable and measure the input impedance of the cable at a number of frequencies. Then use these measurements in the transmission-line equation to determine the actual antenna impedance at each frequency.

Table 6 and **Fig 33** give an example of such a calculation. The antenna used for this example is a 10-meter inverted V about 30 feet above the ground. The arms of the antenna are separated by a 120° angle. Each arm is exactly 8 feet long, and the antenna is made of #14 wire. The feed line is the 74-foot length of Columbia 1188 characterized earlier.

See Fig 33A. From this plot of impedance measurements, it is very difficult to determine anything about the antenna. Resistance and reactance vary substantially over this frequency range, and the antenna appears to be resonant at 27.7, 29.0 and 29.8 MHz.

The plot in Fig 33B shows the true antenna imped-

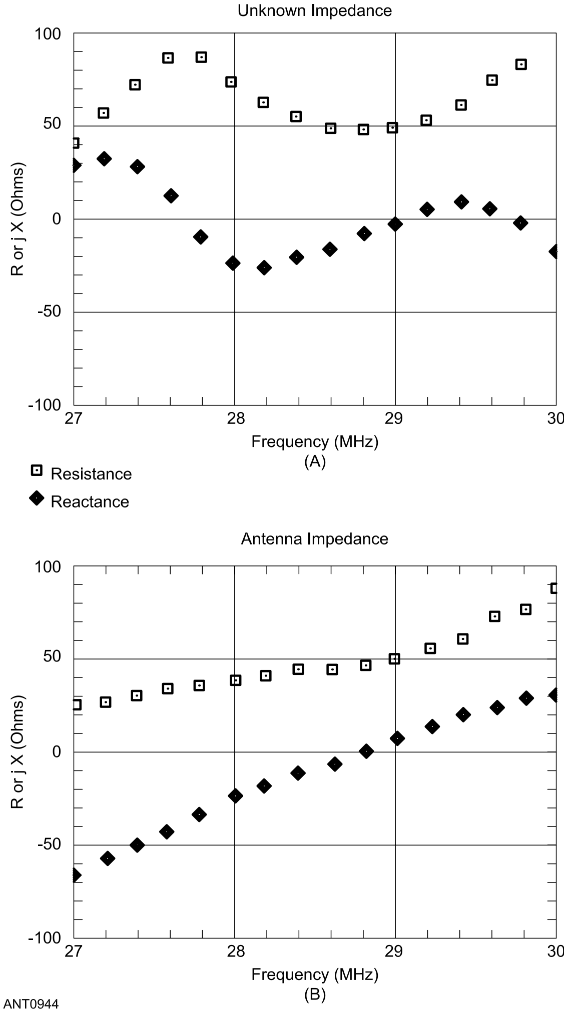

Fig 33–Impedance plot of an inverted-V antenna cut for 29 MHz. At A, a plot of resistances and reactances, measured using the noise bridge, at the end of a 74-foot length of Columbia 1188 coaxial cable. At B, the actual antenna-impedance plot (found using the transmission-line equation to remove the effects of the transmission line).

Table 6
Impedance Data for Inverted-V Antenna

Freq (MHz)	R_u *(Ω)*	X_u *@ 10 MHz (Ω)*	X_u *(Ω)*	R_L *(Ω)*	X_L *(Ω)*
27.0	44	85	31.5	24	–65
27.2	60	95	34.9	26	–56
27.4	75	85	31.0	30	–51
27.6	90	40	14.5	32	–42
27.8	90	–20	–7.2	35	–34
28.0	75	–58	–20.7	38	–24
28.2	65	–65	–23.0	40	–19
28.4	56	–52	–18.3	44	–12
28.6	50	–40	–14.0	44	–6
28.8	48	–20	–6.9	47	1
29.0	50	0	0.0	52	8
29.2	55	20	6.8	57	15
29.4	64	30	10.2	63	21
29.6	78	20	6.8	75	26
29.8	85	0	0	78	30
30.0	90	–50	–16.7	89	33

ance. This plot has been corrected for the effects of the cable using the transmission-line equation. The true antenna resistance and reactance both increase smoothly with frequency. The antenna is resonant at 28.8 MHz, with a radiation resistance at resonance of 47 Ω. This is normal for an inverted V.

When doing the conversions, be careful not to make measurement errors. Such errors introduce more errors into the corrected data. This problem is most significant when the transmission line is near an odd multiple of a $^1/_4$ λ and the line SWR and/or attenuation is high. Measurement errors are probably present if small changes in the input impedance or transmission-line characteristics appear as large changes in antenna impedance. If this effect is present, it can be minimized by making the measurements with a transmission line that is approximately an integer multiple of $^1/_2$ λ.

A Practical Time-Domain Reflectometer

A time-domain reflectometer (TDR) is a simple but powerful tool used to evaluate transmission lines. When used with an oscilloscope, a TDR displays impedance "bumps" (open and short circuits, kinks and so on) in transmission lines. Commercially produced TDRs cost from hundreds to thousands of dollars each, but you can add the TDR described here to your shack for much less. This material is based on a *QST* article by Tom King, KD5HM (see Bibliography), and supplemented with information from the references.

How a TDR Works

A simple TDR consists of a square-wave generator and an oscilloscope. See **Fig 34**. The generator sends a train of dc pulses down a transmission line, and the oscilloscope lets you observe the incident and reflected waves from the pulses (when the scope is synchronized to the pulses).

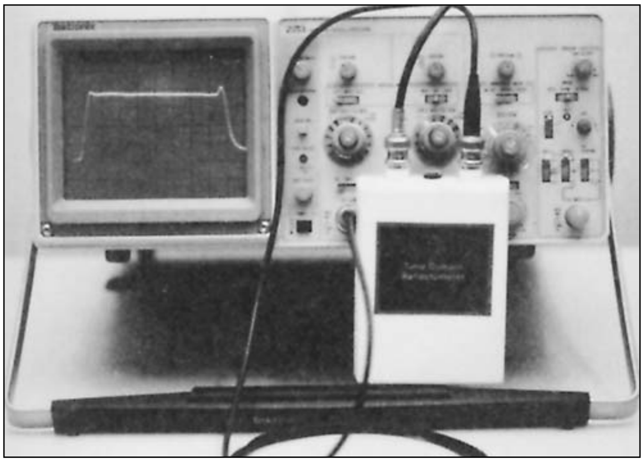

Fig 34—The time-domain reflectometer shown here is attached to a small portable oscilloscope.

A little analysis of the scope display tells the nature and location of any impedance changes along the line. The nature of an impedance disturbance is identified by comparing its pattern to those in **Fig 35**. The patterns are based on the fact that the reflected wave from a disturbance is determined by the incident-wave magnitude and the reflection coefficient of the disturbance. (The patterns shown neglect losses; actual patterns may vary somewhat from those shown.)

The location of a disturbance is calculated with a simple proportional method: The round-trip time (to the disturbance) can be read from the oscilloscope screen (graticule). Thus, you need only read the time, multiply it by the velocity of the radio wave (the speed of light adjusted by the velocity factor of the transmission line) and divide by two. The distance to a disturbance is given by:

$$\ell = \frac{983.6 \times \mathrm{VF} \times \mathrm{t}}{2} \qquad \text{(Eq 18)}$$

where

ℓ = line length in feet

VF = velocity factor of the transmission line (from 0 to 1.0)

t = time delay in microseconds (μs).

The Circuit

The time-domain reflectometer circuit in **Fig 36** consists of a CMOS 555 timer configured as an astable multivibrator, followed by an MPS3646 transistor acting as a 15-ns-risetime buffer. The timer provides a 71-kHz square wave. This is applied to the 50-Ω transmission line under test (connected at J2). The oscilloscope is connected to the circuit at J1.

Construction

An etching pattern for the TDR is shown in **Fig 37**. **Fig 38** is the part-placement diagram. The TDR is

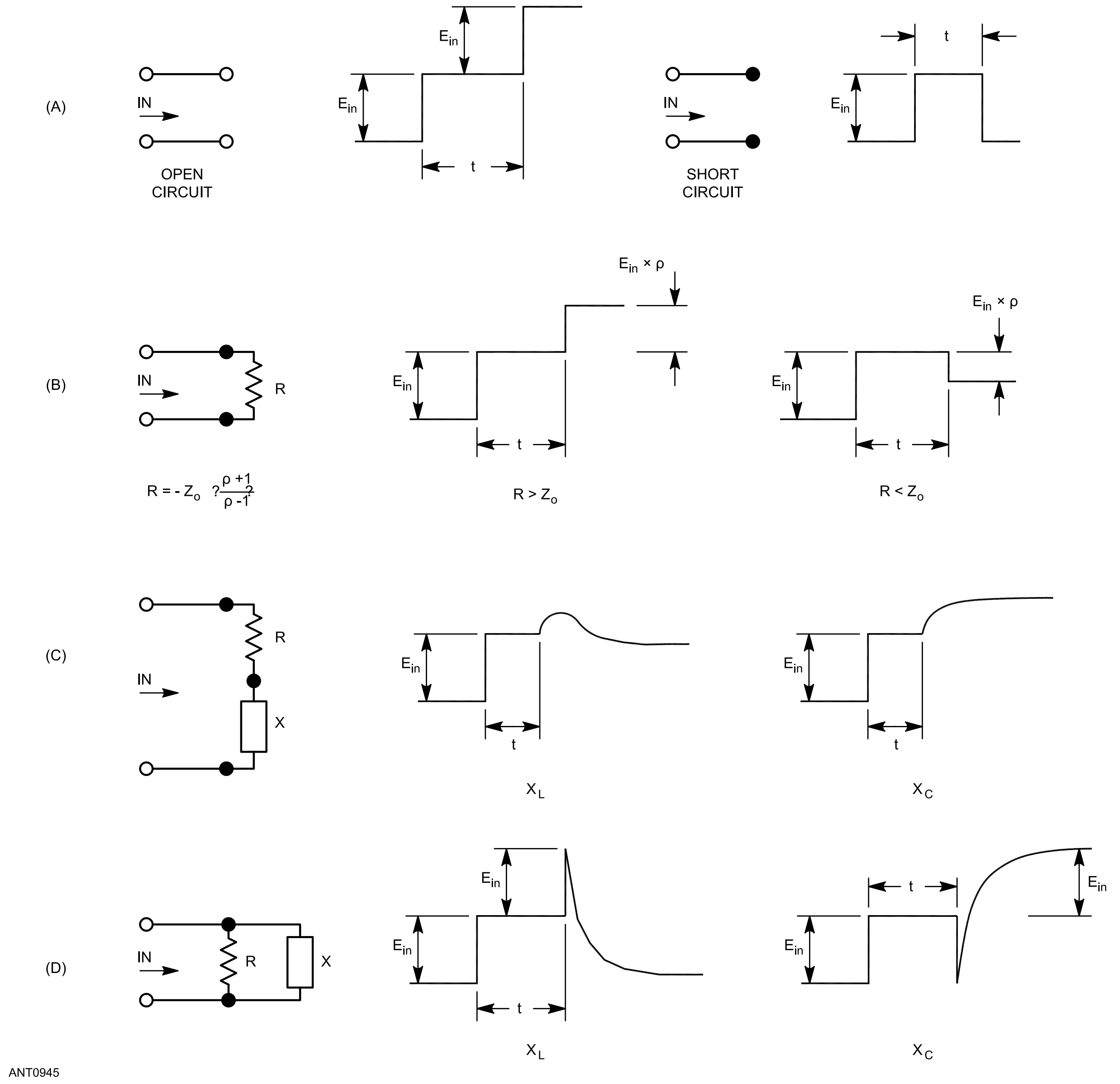

Fig 35—Characteristic TDR patterns for various loads. The location of the load can be calculated from the transit time, t, which is read from the oscilloscope (see text). R values can be calculated as shown (for purely resistive loads only—$\rho < 0$ when $R < Z_0$; $\rho < 0$ when $R > Z_0$). Values for reactive loads cannot be calculated simply.

designed for a 4 × 3 × 1-inch enclosure (including the batteries). Sl, Jl and J2 are right-angle-mounted components. Two aspects of construction are critical. First use *only* an MPS3646 for Q1. This type was chosen for its good performance in this circuit. If you substitute another transistor, the circuit may not perform properly.

Second, for the TDR to provide accurate measurements, the cable connected to J1 (between the TDR and the oscilloscope) must not introduce impedance mismatches in the circuit. *Do not make this cable from ordinary coaxial cable.* Oscilloscope-probe cable is the best thing to use for this connection.

(It took the author about a week and several phone calls to determine that scope-probe cable isn't "plain old coax." Probe cable has special characteristics that prevent undesired ringing and other problems.)

Mount a binding post at J1 and connect a scope probe to the binding post when testing cables with the TDR. R5 and C2 form a compensation network—much like the networks in oscilloscope probes—to adjust for effects of

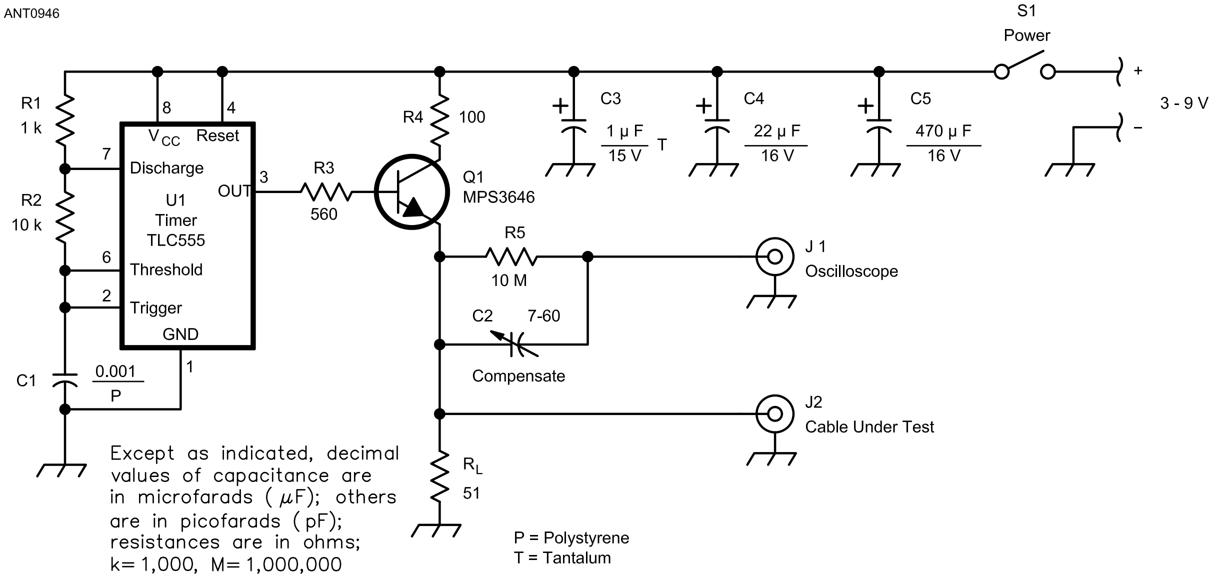
ANT0946
S1
Power
+
3 - 9 V
–
R1
1 k
8
4
VCC
Reset
7
Discharge
U1
Timer
TLC555
R2
10 k
OUT
3
R3
560
R4
100
Q1
MPS3646
C3
1 μ F
15 V
T
C4
22 μ F
16 V
C5
470 μ F
16 V
R5
10 M
J 1
Oscilloscope
6
Threshold
2
Trigger
GND
1
C2
7-60
Compensate
C1
0.001
P
J2
Cable Under Test
RL
51
Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms; k= 1,000, M= 1,000,000
P = Polystyrene
T = Tantalum

Fig 36—Schematic diagram of the time-domain reflectometer. All resistors are $^{1}/_{4}$-W, 5% tolerance. U1 is a CMOS 555 timer. Circuit current drain is 10 to 25 mA. When building the TDR, observe the construction cautions discussed in the text. C2 is available from Mouser Electronics, part no. ME242-8050. Right-angle BNC connectors for use at J1 and J2 can be obtained from Newark Electronics, part no. 89N1578. S1 can be obtained from All Electronics, part no. NISW-1. An SPST toggle switch can also be used at S1.

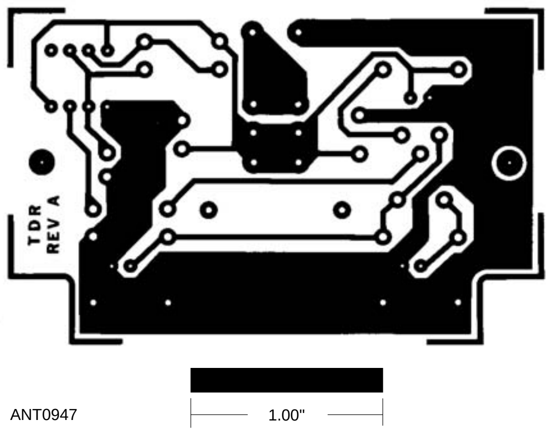
TDR
REV A
ANT0947
1.00"

Fig 37—Full-size PC-board etching pattern for the TDR. Black areas represent unetched copper foil.

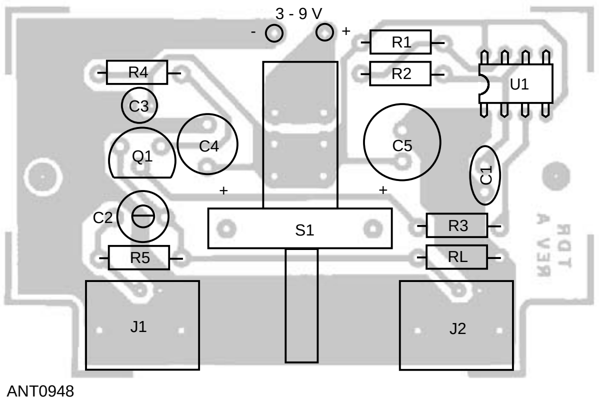
3 - 9 V
-
+
R1
R4
R2
U1
C3
C4
C5
Q1
C1
+
+
C2
S1
R3
R5
RL
J1
J2
ANT0948

Fig 38—Part-placement diagram for the TDR. Parts are mounted on the nonfoil side of the board; the shaded area represents an X-ray view of the copper pattern. Be sure to observe the polarity markings of C3, C4 and C5.

the probe wire.

The TDR is designed to operate from dc between 3 and 9 V. Two C cells (in series—3 V) supply operating voltage in this version. The circuit draws only 10 to 25 mA, so the cells should last a long time (about 200 hours of operation). U1 can function with supply voltages as low as 2.25 to 2.5.

If you want to use the TDR in transmission-line systems with characteristic impedances other than 50 Ω, change the value of R_L to match the system impedance as closely as possible.

Calibrating and Using the TDR

Just about any scope with a bandwidth of at least 10 MHz should work fine with the TDR, but for tests in short-length cables, a 50-MHz scope provides for much more accurate measurements. To calibrate the TDR, terminate CABLE UNDER TEST connector, J2, with a 51-Ω

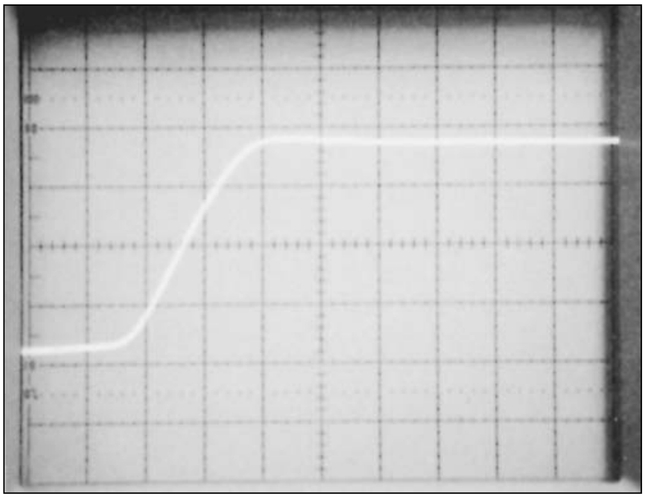

Fig 39—TDR calibration trace as shown on an oscilloscope. Adjust C2 (See Figs 36 and 38) for maximum deflection and sharpest waveform corners during calibration. See text.

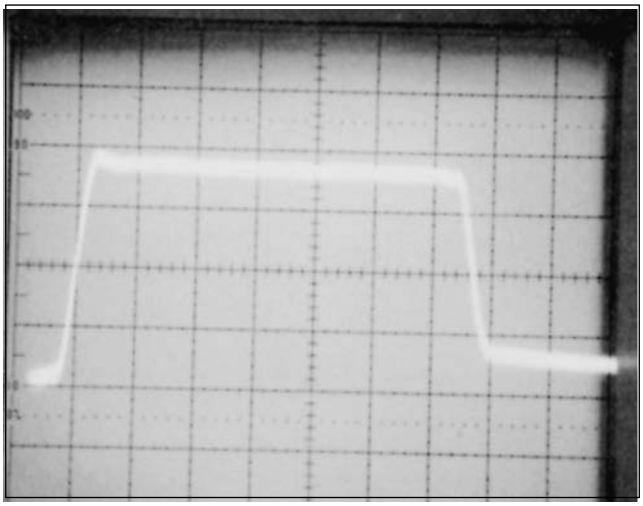

Fig 41—TDR display of the impedance characteristics of the 142-foot Hardline run to the 432-MHz antenna at KD5HM. The scope is set for 0.05 ms per division. See text for discussion.

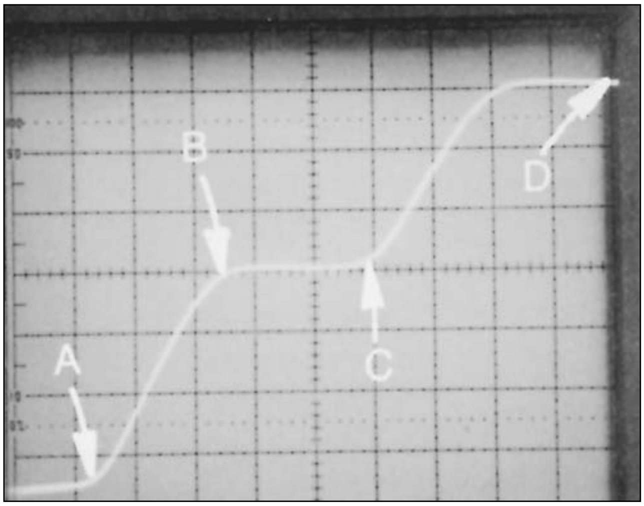

Fig 40—Open-circuited test cable. The scope is set for 0.01 ms per division. See text for interpretation of the waveform.

resistor. Connect the scope vertical input to J1. Turn on the TDR, and adjust the scope timebase so that one square-wave cycle from the TDR fills as much of the scope display as possible (without uncalibrating the timebase). The waveform should resemble **Fig 39**. Adjust C2 to obtain maximum amplitude and sharpest corners on the observed waveform. That's all there is to the calibration process!

To use the TDR, connect the cable under test to J2, and connect the scope vertical input to J1. If the waveform you observe is different from the one you observed during calibration, there are impedance variations in the load you're testing. See **Fig 40**, showing an unterminated test cable connected to the TDR. The beginning of the cable is shown at point A. (AB represents the TDR output-pulse rise time.)

Segment AC shows the portion of the transmission line that has a 50-Ω impedance. Between points C and D, there is a mismatch in the line. Because the scope trace is higher than the 50-Ω trace, the impedance of this part of the line is higher than 50 Ω—in this case, an open circuit.

To determine the length of this cable, read the length of time over which the 50-Ω trace is displayed. The scope is set for 0.01 µs per division, so the time delay for the 50-Ω section is (0.01 µs × 4.6 divisions) = 0.046 µs. The manufacturer's specified velocity factor (VF) of the cable is 0.8. Eq 1 tells us that the 50-Ω section of the cable is

$$\ell = \frac{983.6 \times 0.8 \times 0.046\,\mu\text{s}}{2} = 18.1\text{ feet}$$

The TDR provides reasonable agreement with the actual cable length—in this case, the cable is really 16.5 feet long. (Variations in TDR-derived calculations and actual cable lengths can occur as a result of cable VFs that can vary considerably from published values. Many cables vary as much as 10% from the specified values.)

A second example is shown in **Fig 41**, where a length of $^{3}/_{4}$-inch Hardline is being tested. The line feeds a 432-MHz vertical antenna at the top of a tower. Fig 41 shows that the 50-Ω line section has a delay of (6.6 divisions × 0.05 µs) = 0.33 µs. Because the trace is straight and level at the 50-Ω level, the line is in good shape. The trailing edge at the right-hand end shows where the antenna is connected to the feed line.

To determine the actual length of the line, use the same procedure as before: Using the published VF for the Hardline (0.88) in Eq 1, the line length is

$$\ell = \frac{983.6 \times 0.88 \times 0.33\ \mu\text{s}}{2} = 142.8\ \text{feet}$$

Again, the TDR-derived measurement is in close agreement with the actual cable length (142 feet).

Final Notes

The time-domain reflectometer described here is not frequency specific; its measurements are not made at the frequency at which a system is designed to be used. Because of this, the TDR cannot be used to verify the impedance of an antenna, nor can it be used to measure cable loss at a specific frequency. Just the same, in two years of use, it has never failed to help locate a transmission-line problem. The vast majority of transmission-line problems result from improper cable installation or connector weathering.

Limitations

Certain limitations are characteristic of TDRs because the signal used to test the line differs from the system operating frequency and because an oscilloscope is a broadband device. In the instrument described here, measurements are made with a 71-kHz square wave. That wave contains components at 71 kHz and odd harmonics thereof, with the majority of the energy coming from the lower frequencies. The leading edge of the trace indicates that the response drops quickly above 6 MHz. (The leading edge in Fig 40 is 0.042 µs, corresponding to a period of 0.168 µs and a frequency of 5.95 MHz.) The result is dc pulses of approximately 7 µs duration. The scope display combines the circuit responses to all of those frequencies. Hence, it may be difficult to interpret any disturbance which is narrowband in nature (affecting only a small range of frequencies, and thus a small portion of the total power), or for which the travel time plus pattern duration exceeds 7 µs. The 432-MHz vertical antenna in Fig 41 illustrates a display error resulting from narrow-band response.

The antenna shows as a major impedance disturbance because it is mismatched at the low frequencies that dominate the TDR display, yet it is matched at 432 MHz. For an event that exceeds the observation window, consider a 1-µF capacitor across a 50-Ω line. You would see only part of the pattern shown in Fig 35C because the time constant ($1 \times 10^{-6} \times 50 = 50$ ms) is much larger than the 7-µs window.

In addition, TDRs are unsuitable for measurements where there are major impedance changes inside the line section to be tested. Such major changes mask reflections from additional changes farther down the line.

Because of these limitations, TDRs are best suited for spotting faults in dc-continuous systems that maintain a constant impedance from the generator to the load. Happily, most amateur stations would be ideal subjects for TDR analysis, which can conveniently check antenna cables and connectors for short and open-circuit conditions and locate the position of such faults with fair accuracy.

Ground Parameters for Antenna Analysis

This section is taken from an article in *The ARRL Antenna Compendium, Vol 5* by R. P. Haviland, W4MB. In the past, amateurs paid very little attention to the characteristics of the earth (ground) associated with their antennas. There are two reasons for this. First, these characteristics are not easy to measure—even with the best equipment, extreme care is needed. Second, almost all hams have to put up with what they have—there are very few who can afford to move because their location has poor ground conditions! Further, the ground is not a dominant factor in the most popular antennas—a tri-band Yagi at 40 feet or higher, or a 2-meter vertical at roof height, for example.

Even so, there has been a desire and even a need for ground data and for ways to use it. It is very important for vertically polarized antennas. Ground data is useful for antennas mounted at low heights generally, and for such specialized ones as Beverages. The performance of such antennas change a lot as the ground changes.

Importance of Ground Conditions

To see why ground conditions can be important, let us look at some values. For a frequency of 10 MHz, *CCIR Recommendation 368*, gives the distance at which the signal is calculated to drop 10 dB below its free-space level as:

Conductivity (mS/meter)	*Distance for 10 dB Drop (km)*
5000	100
30	15
3	0.3

The high-conductivity condition is for sea-water. Inter-island work in the Caribbean on 40 and 80 meters is easy, whereas 40-meter ground-wave contact is difficult for much of the USA, because of much lower ground conductivity. On the other hand, the Beverage works because of poor ground conductivity.

Fig 42 shows a typical set of expected propagation curves for a range of frequencies. This data is also from *CCIR Recommendation 368* for relatively poor ground, with a dielectric constant of 4 and a conductivity of 3 mS/m (one milliSiemens/meter is 0.001 mho/meter). The same data is available in the *Radio Propagation Handbook*. There are equivalent FCC curves, found in the book *Reference Data for Radio Engineers*, but only the ones near 160 meters are useful. In Florida the author has difficulty hearing stations across town on ground

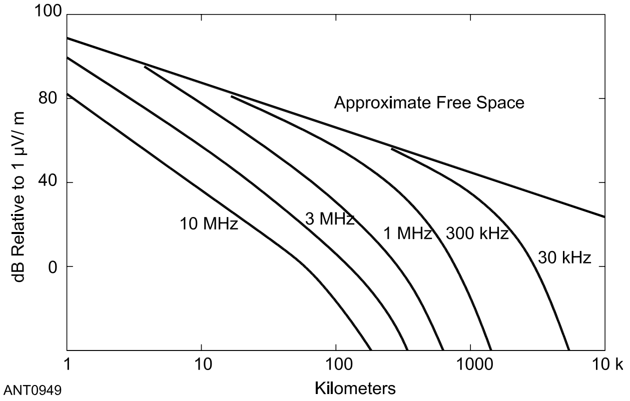

Fig 42—Variation of field strength with distance. Typical field strengths for several frequencies are shown. This is from CCIR data for fairly poor soil, with dielectric constant of 4 and conductivity of 3 mS/m. The curves for good soil are closer to the free-space line, and those for sea water are much closer to the free-space line.

wave, an indication of the poor soil conditions—reflected sky-wave signals are often stronger.

Securing Ground Data

There are only two basic ways to approach this matter of ground data. One is to use generic ground data typical to the area. The second is to make measurements, which haven't really gotten easier. For most amateurs, the best approach seems to be a combination of these—use some simple measurements, and then use the generic data to make a better estimate. Because of equipment costs and measurement difficulties, none of these will be highly accurate for most hams. But they will be much better than simply taking some condition preset into an analysis program. Having a good set of values to plug into an analysis can help you evaluate the true worth of a new antenna project.

Generic Data

In connection with its licensing procedure for broadcast stations, the FCC has published generic data for the

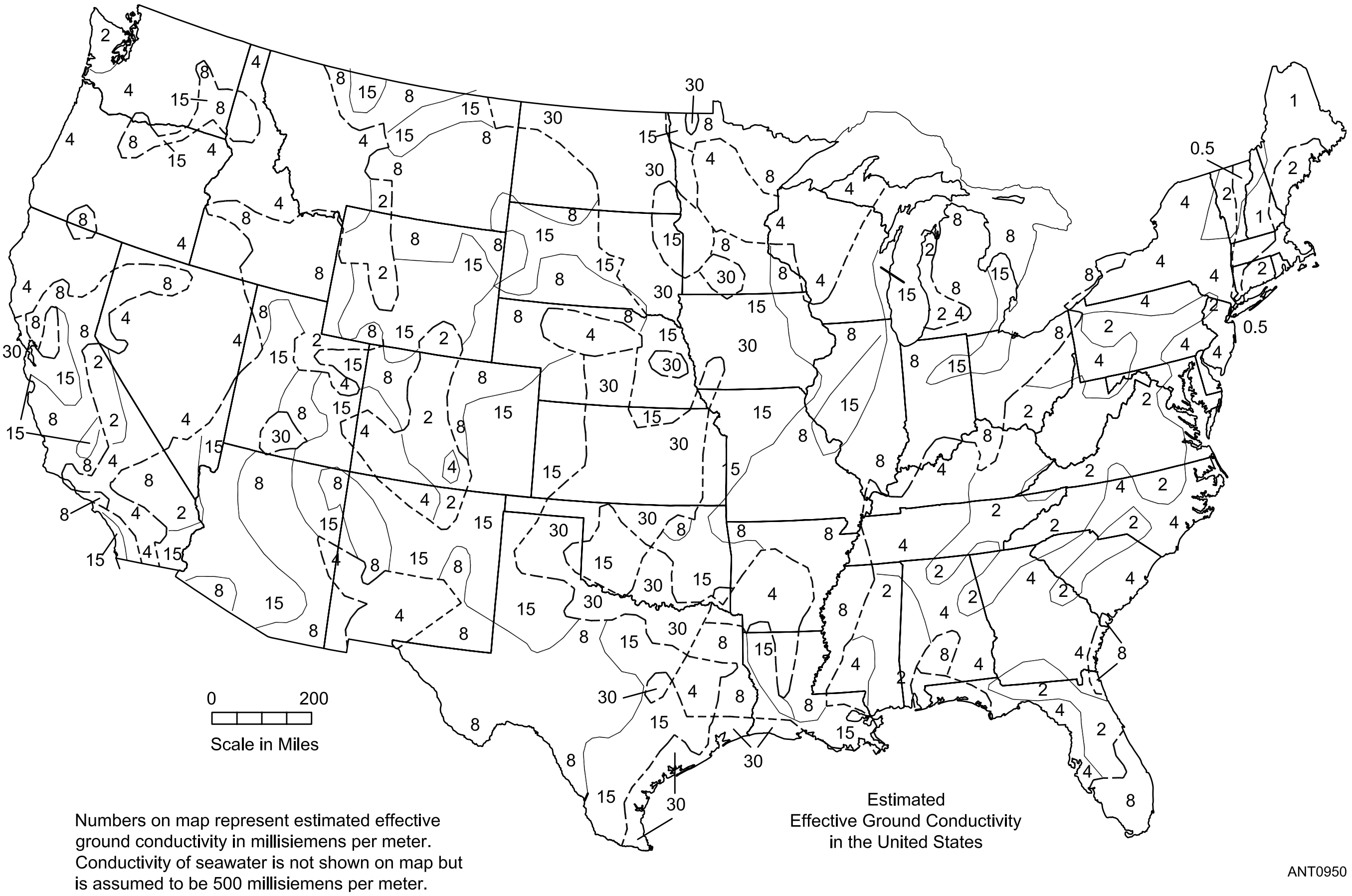

Numbers on map represent estimated effective ground conductivity in millisiemens per meter. Conductivity of seawater is not shown on map but is assumed to be 500 millisiemens per meter.

Fig 43—Estimated effective ground conductivity in the United States. FCC map prepared for the Broadcast Service, showing typical conductivity for continental USA. Values are for the band 500 to 1500 KHz. Values are for flat, open spaces and often will not hold for other types of commonly found terrain, such as seashores, river beds, etc.

entire country. This is reproduced in **Fig 43**, a chart showing the "estimated effective ground conductivity in the United States." A range of 30:1 is shown, from 1 to 30 mS/m. An equivalent chart for Canada has been prepared, originally by DOT, now DOC.

Of course, some judgment is needed when trying to use this data for your location. Broadcast stations are likely to be in open areas, so the data should not be assumed to apply to the center city. And a low site near the sea is likely to have better conductivity than the generic chart for, say, the coast of Oregon. Other than such factors, this chart gives a good first value, and a useful cross-check if some other method is used.

Still another FCC-induced data source is the license application of your local broadcast station. This includes calculated and measured coverage data. This may include specific ground data, or comparison of the coverage curves with the CCIR or FCC data to give the estimated ground conductivity. Another set of curves for ground conditions are those prepared by SRI. These give the conductivity and dielectric constant versus frequency for typical terrain conditions. These are reproduced as **Fig 44** and **Fig 45**. By inspecting your own site, you may select the curve most appropriate to your terrain. The curves are based on measurements at a number of sites across the USA, and are averages of the measured values.

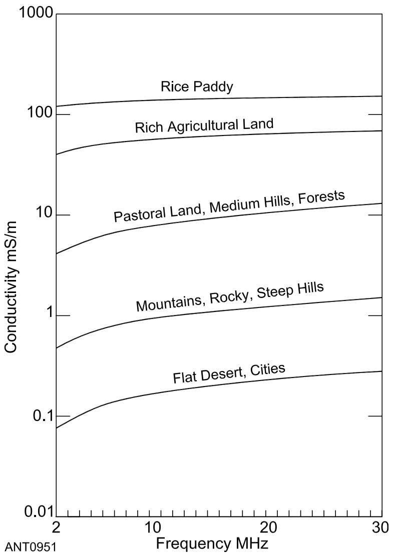

Fig 44—Typical terrain conductivities versus frequency for 5 types of soils. This was measured by SRI. Units are mS/m. Conductivity of seawater is usually taken as 5000 mS/m. Conductivity of fresh water depends on the impurities present, and may be very low. To extrapolate conductivity values (for 500 to 1500 KHz) shown in Fig 43 for a particular geographic area to a different frequency, move from the conductivity at the left edge of Fig 44 to the desired frequency. For example, in rocky New Hampshire, with a conductivity of 1 mS/m at BC frequencies, the effective conductivity at 14 MHz would be approximately 4 mS/m.

Figs 46 through 48 are data derived from these measurements. **Fig 46** gives the ground-dissipation factor. Sea water has low loss (a high dissipation factor), while soil in the desert or in the city is very lossy, with a low dissipation factor. **Fig 47** gives the skin depth, the distance for the signal to decease to 63% of its value at the surface. Penetration is low in high-conductivity areas and deep in low-conductivity soil. Finally, **Fig 48** shows the wavelength in the earth. For example, at 10 meters (30 MHz), the wavelength in sea water is less than 0.3 meters. Even in the desert, the wavelength has been reduced to about 6 meters at this frequency. This is one reason why buried antennas have peculiar properties. Lacking other data, it is suggested that the values of Figs 44 and 45 be used in computer antenna modeling programs.

Measuring Ground Conditions

W2FNQ developed a simple technique to measure low-frequency earth conductivity, which has been used by W2FMI. The test setup is drawn in **Fig 49**, and uses a very old technique of 4-terminal resistivity measurements. For probes of $^{9}/_{16}$-inch diameter, spaced 18 inches and pene-trating 12 inches into the earth, the conductivity is:

$$C = 21\ V_1/V_2 \quad \text{mS/m} \qquad \text{(Eq 19)}$$

The voltages are conveniently measured by a digital voltmeter, to an accuracy of about 2%. In soil suitable for farming, the probes can be copper or aluminum. The strength of iron or copperweld may be needed in hard soils. A piece of 2 × 4 or 4 × 4 with guide holes drilled through it will help maintain proper spacing and vertical alignment of the probes. Use care when measuring—there is a shock hazard. An isolating transformer with a 24-V secondary instead of 115 V will reduce the danger.

Ground conditions vary quite widely over even small

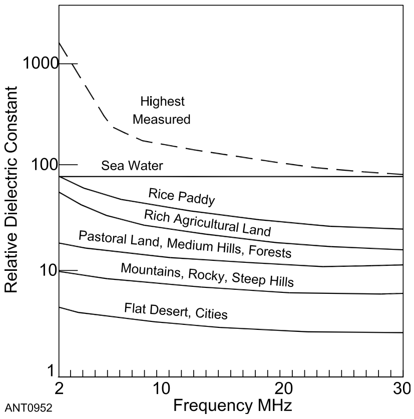

Fig 45—Typical terrain relative dielectric constant for the 5 soil types of Fig 44, plus sea water. The dashed curve shows the highest measured values reported, and usually indicates mineralization.

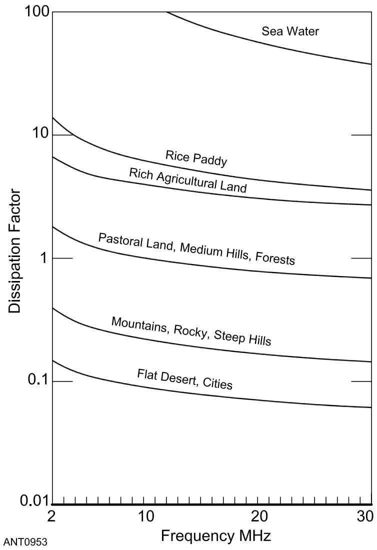

Fig 46—Typical values of dissipation factor. The soil behaves as a leaky dielectric. These curves showing the dimensionless dissipation factor versus frequency for various types of soils and for sea water. The dissipation factor is inversely related to soil conductivity. Among other things, a high dissipation factor indicates that a signal penetrating the soil or water will decrease in strength rapidly with depth.

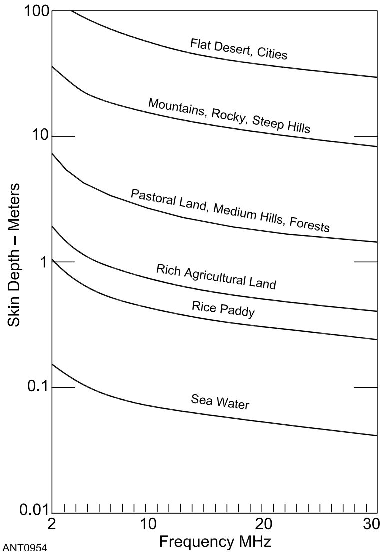

Fig 47—Typical values of skin depth. The skin depth is the depth at which a signal will have decreased to 1/e of its value at the surface (to about 30%). The effective height above ground is essentially the same as the physical height for sea water, but may be much greater for the desert. For practical antennas, this may increase low-angle radiation, but at the same time will increase ground losses.

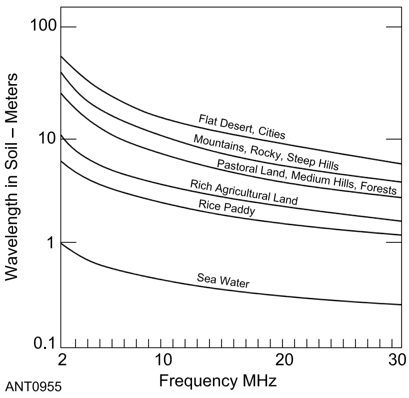

Fig 48—Typical values of wavelength in soil. Because of its dielectric constant, the wavelength in soils and water will be shorter than that for a wave traveling in air. This can be important, since in a Method of Moment the accuracy is affected by the number of analysis segments per wavelength. Depending on the program being used, adjust the number of segments for antennas wholly or partly in the earth, for ground rods, and for antennas very close to earth.

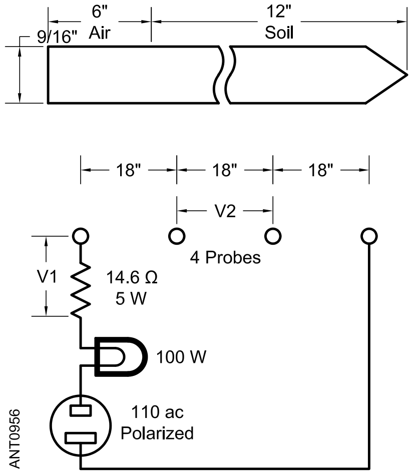

Fig 49—Low-frequency conductivity measurement system. A 60-Hz measuring system devised by W2FNQ and used by W2FMI. The basic system is widely used in geophysics. Use care to be certain that the plug connection is correct. A better system would use a lower voltage and an isolation transformer. Measure the value of V_2 with no power applied—there may be stray ground currents present, especially if there is a power station or an electric railway close.

areas. It is best to make a number of measurements around the area of the antenna, and average the measured values.

While this measurement gives only the low-frequency conductivity, it can be used to select curves in Fig 44 to give an estimate of the conductivity for the common ham bands. Assume that the 60 Hz value is valid at 2 MHz, and find the correct value on the left axis. Move parallel to the curves on the figure to develop the estimated curve for other soil conditions.

A small additional refinement is possible. If the dielectric constant from Fig 45 is plotted against the conductivity from Fig 44 for a given frequency, a scatter plot develops, showing a trend to higher dielectric constant as conductivity increases. At 14 MHz, the relation is:

$$k = \sqrt{1000/C} \qquad \text{(Eq 20)}$$

where k is the dielectric constant and C is the measured conductivity. Using these values in *MININEC* or *NEC* calculations should give better estimates than countrywide average values.

Direct Measurement of Ground Properties

For really good values, both the conductivity and dielectric constant should be measured at the operating frequency. One way of doing this is the two-probe technique described in George Hagn's article (see Bibliography). This was the technique used to secure the data for Figs 44 through 48. The principle is sketched in **Fig 50**. In essence, the two probes form a short, open-circuited, two-wire transmission line. As shown by the equations for such lines, the input impedance is a function of the conductivity and dielectric constant of the medium. A single measurement is difficult to calculate, since the end effect of the two probes must be determined, a complex task if they are pointed for easy driving. The calculation is greatly simplified if a set of measurements is made with several sets of probes that vary in length by a fixed ratio, since the measured difference is largely due to the increased two-wire length, with some change due to the change in soil moisture with depth.

The impedance to be measured is high because of the short line length, so impedance bridges are not really suitable. An RF vector impedance meter, such as the HP-4193A, is probably the best instrument to use, with a RF susceptance bridge, such as the GR-821A, next best. With care, a Q-meter can be substituted. Because of the rarity of these instruments among amateurs, this method of measurement is not explored further here.

Indirect Measurement

Since the terminal impedance and resonant frequency of an antenna change as the antenna approaches earth, measurement of an antenna at one or more heights permits an analysis of the ground characteristics. The technique is to calculate the antenna drive impedance for an assumed ground condition, and compare this with measured values. If not the same, another set of ground conditions is assumed, and the process is repeated. It is best to have a plan to guide the assumptions.

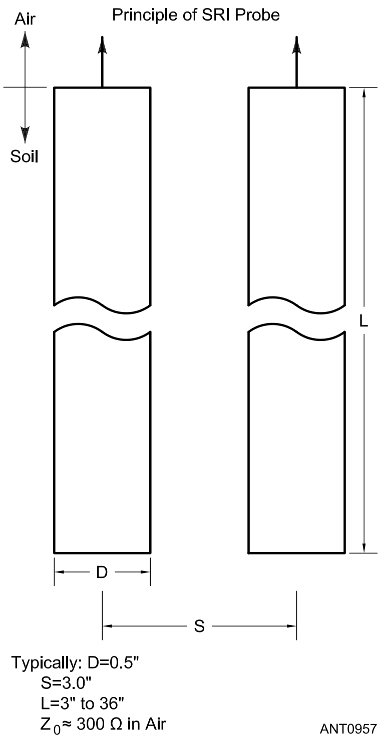

Fig 50—High-frequency conductivity/dielectric constant measurement system. System for measuring ground conditions at frequencies up to about 100 MHz, devised by SRI and used to obtain the data in Figs 44 through 48. Basically, this is a section of transmission line with soil as the dielectric. Requires measurement of high impedances to good accuracy.

In connection with his studies of transmission lines, Walt Maxwell, W2DU, made such measurements on 20, 40 and 80 meters. Some of the data was included in his book *Reflections*. The following example is based on his 80-meter data. Data came from his Table 20-1, for a 66-foot, 2-inch dipole of #14 wire at 40 feet above ground. His table gives an antenna impedance of 72.59 + *j* 1.38 Ω at 7.15 MHz.

Table 7 shows calculated antenna impedances for ground conductivities of three different ground conductivities: 10, 1 and 0.1 mS/m, and for dielectric constants of 3, 15 and 80. The nearest value to the measured drive impedance is for a conductivity of 0.1 mS/m and a dielectric constant of 3. Figs 44 and 45 indicate that these are typical of flat desert and city land. The effect on antenna performance is shown in **Fig 51**. The maximum lobe gain for soil typical of a city is over 2 dB lower than that for the high-conductivity, high-dielectric constant value. Note that the maximum lobe occurs for a radiation angle that is directly overhead.

Table 7

Calculated values of drive resistance, in ohms, for an 40 meter dipole at 40 feet elevation versus conductivity and dielectric constant.

Conductivity	*Dielectric Constant*		
(mS/m)	*3*	*15*	*50*
10	89.78 – *j* 12.12	88.53 – *j* 10.69	88.38 – *j* 7.59
1	80.05 – *j* 17.54	83.72 – *j* 10.23	87.33 – *j* 6.98
0.1	76.44 – *j* 15.69	83.18 – *j* 9.85	97.30 – *j* 6.46

The value measured by W2DU was 72.59 – *j* 1.28 Ω, and compares closest to the poor soil condition of dielectric constant of 3 and conductivity of 0.1 mS/m.

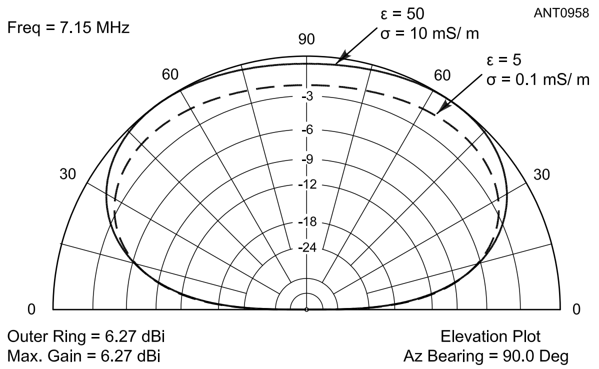

Fig 51—Plot showing computed elevation patterns for 40-foot high, 40-meter dipole for two different ground conditions: poor ground, with dielectric constant of 3 and conductivity of 0.1 mS/m, and good ground, with dielectric constant of 50 and conductivity of 10 mS/m. Note that for a low horizontal antenna, high-angle radiation is most affected by poor ground, with low-angle radiation least affected by ground characteristics.

The ground at the W2DU QTH is a suburban Florida lot, covered with low, native vegetation. The ground is very sandy (a fossil sand dune), and is some 60-70 feet above sea-level. Measurements were made near the end of the Florida dry season. The water table is estimated to be 20 to 30 feet below the surface. Thus the calculated and measured values are reasonably consistent.

In principle, a further analysis, using values around 0.1 mS/m conductivity and 3 for dielectric constant, will give a better ground parameter estimate. However, the results should be taken with a grain of salt, because the opportunities for error in the computer modeling must be considered. The antenna should have no sag, and its length and height should be accurate. The measurement must be with accurate equipment, free from strays, such as current on the outer conductor of the coax. The feed-point gap effect must be estimated. Further, the ground itself under the antenna must be flat and have constant characteristics for modeling to be completely accurate.

Finally, the feed-line length and velocity constant of the transmission line must be accurately measured for transfer of the measured values at the feeding end of the transmission line to the antenna itself. Because of all the possibilities for error, most attempts at precision should be based on measured values at two or three frequencies, and preferably at two or three heights. Orienting the antenna to right angles for another set of measurements may be useful. Obviously, this can involve a lot of detailed work.

The author was not been able to find any guidelines for the best height or frequency. The data in the book *Exact Image Method for Impedance Computation of Antennas Above the Ground* suggests that a height of 0.3 λ will give good sensitivity to ground conditions. Very low heights may give confusing results, since several combinations of ground parameters can give nearly the same drive impedance. Both this data and experience suggest that sensitivity to ground for heights above 0.75 λ is small or negligible.

If an overall conclusion about ground characteristics is needed, we can just restate from the first paragraph—it is not greatly important for the most common horizontally polarized antenna installations. But it's worth taking a look when you need to depart from typical situations, or when the performance of a vertically polarized antenna is contemplated. Then the techniques outlined here can be helpful.

A Switchable RF Attenuator

A switchable RF attenuator is helpful for making antenna-gain comparisons or for plotting antenna radiation patterns. You may switch attenuation in or out of the line leading to the receiver to obtain an initial reference reading on a signal strength meter. Some form of attenuator is also helpful for locating hidden transmitters, where the real trick is pinpointing the signal source from within a few hundred feet. At such a close distance, strong signals may overload the front end of the receiver, making it impossible to obtain any indication of a bearing.

The attenuator of **Figs 52** and **53** is designed for low power levels, not exceeding $^1/_4$ watt. If for some reason the attenuator will be connected to a transceiver, a means of bypassing the unit during transmit periods must be devised. An attenuator of this type is commonly called a *step attenuator*, because any amount of attenuation from 0 dB to the maximum available (81 dB for this particular instrument) may be obtained in steps of 1 dB. As each switch is successively thrown from the OUT to the IN position, the attenuation sections add in cascade to yield the total of the attenuator steps switched in. The maximum attenuation of any single section is limited to 20 dB because leak-through would probably degrade the accuracy of higher values. The tolerance of resistor values also becomes more significant regarding accuracy at higher attenuation values.

A good quality commercially made attenuator will cost upwards from $150, but for less than $25 in parts and a few hours of work, you can build an attenuator at home. It will be suitable for frequencies up to 450 MHz. Double-sided pc board is used for the enclosure. The version of the attenuator shown in Fig 52 has identification lettering etched into the top surface (or front panel) of the unit. This adds a nice touch and is a permanent means of labeling. Of course rub-on transfers or Dymo tape labels could be used as well.

Female BNC single-hole, chassis-mount connectors are used at each end of the enclosure. These connectors

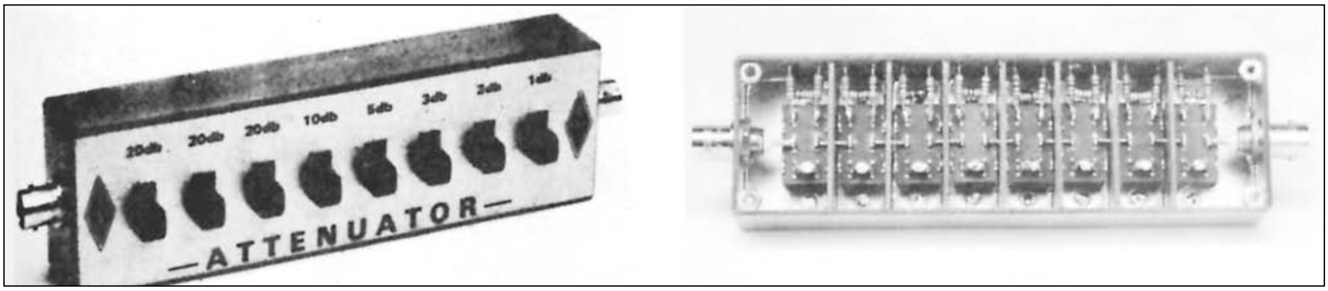

Fig 52—A construction method for a step attenuator. Double-sided circuit-board material, unetched (except for panel identification), is cut to the desired size and soldered in place. Flashing copper may also be used, although it is not as sturdy. Shielding partitions between sections are necessary to reduce signal leakage. Brass nuts soldered at each of the four corners allow machine screws to secure the bottom cover. The practical limit for total attenuation is 80 or 90 dB, as signal leakage around the outside of the attenuator will defeat attempts to obtain much greater amounts.

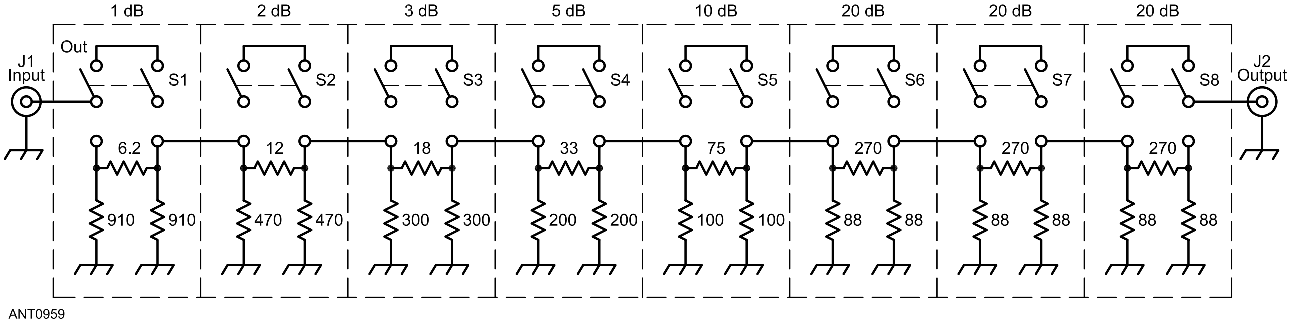

Fig 53—Schematic diagram of the step attenuator, designed for a nominal impedance of 50 Ω. Resistance values are in ohms. Resistors are $^1/_4$-watt, carbon-composition types, 5% tolerance. Broken lines indicate walls of circuit-board material. A small hole is drilled through each partition wall to route bus wire. Keep all leads as short as possible. The attenuator is bilateral; that is, the input and output ends may be reversed.

J1, J2—Female BNC connectors, Radio Shack 278-105 or equiv.

S1-S8, incl.—DPDT slide switches, standard size. (Avoid subminiature or toggle switches.) Stackpole S-5022CD03-0 switches are used here.

provide a means of easily connecting and disconnecting the attenuator.

Construction

After all the box parts are cut to size and the necessary holes made, scribe light lines to locate the inner partitions. Carefully tack-solder all partitions in position. A 25-W pencil type of iron should provide sufficient heat. Dress any pc board parts that do not fit squarely. Once everything is in proper position, run a solder bead all the way around the joints. Caution! Do not use excessive amounts of solder, as the switches must later be fit flat inside the sections. Complete the top, sides, ends and partitions. Dress the outside of the box to suit your taste. For instance, you might wish to bevel the box edges. Buff the copper with steel wool, add lettering, and finish off the work with a coat of clear lacquer or polyurethane varnish.

Using a little lacquer thinner, soak the switches to remove the grease that was added during their manufacture. When they dry, spray the inside of the switches lightly with a TV tuner cleaner/lubricant. Use a sharp drill bit (about $^3/_{16}$ inch will do), and countersink the mounting holes on the actuator side of the switch mounting plate. This ensures that the switches will fit flush against the top plate. At one end of each switch, bend the two lugs over and solder them together. Cut off the upper halves of the remaining switch lugs. (A close look at Fig 52 will help clarify these steps.)

Solder the series-arm resistors between the appropriate switch lugs. Keep the lead lengths as short as possible and do not overheat the resistors. Now solder the switches in place to the top section of the enclosure by flowing solder through the mounting holes and onto the circuit-board material. Be certain that you place the switches in their proper positions; correlate the resistor values with the degree of attenuation. Otherwise, you may wind up with the 1-dB step at the wrong end of the box how embarrassing!

Once the switches are installed, thread a piece of #18 bare copper wire through the center lugs of all the switches, passing it through the holes in the partitions. Solder the wire at each switch terminal. Cut the wire between the poles of each individual switch, leaving the wire connecting one switch pole to that of the neighboring one on the other side of the partition, as shown in Fig 52. At each of the two end switch terminals, leave a wire length of approximately $^1/_8$ inch. Install the BNC connectors and solder the wire pieces to the connector center conductors.

Now install the shunt-arm resistors of each section. Use short lead lengths. Do not use excessive amounts of heat when soldering. Solder a no. 4-40 brass nut at each inside corner of the enclosure. Recess the nuts approximately $^1/_{16}$-inch from the bottom edge of the box to allow sufficient room for the bottom panel to fit flush. Secure the bottom panel with four no. 4-40, $^1/_4$-inch machine screws and the project is completed. Remember to use caution, always, when your test setup provides the possibility of transmitting power into the attenuator.

A Portable Field Strength Meter

Few amateur stations, fixed or mobile, are without need of a field-strength meter. An instrument of this type serves many useful purposes during antenna experiments and adjustments. When work is to be done from many wavelengths away, a simple wavemeter lacks the necessary sensitivity. Further, such a device has a serious fault because its linearity leaves much to be desired. The information in this section is based on a January 1973 *QST* article by Lew McCoy, W1ICP.

The field-strength meter described here takes care of these problems. Additionally, it is small, measuring only 4 × 5 × 8 inches. The power supply consists of two 9-volt batteries. Sensitivity can be set for practically any amount desired. However, from a usefulness standpoint, the circuit should not be too sensitive or it will respond to unwanted signals. This unit also has excellent linearity with regard to field strength. (The field strength of a received signal varies inversely with the distance from the source, all other things being equal.) The frequency range includes all amateur bands from 3.5 through

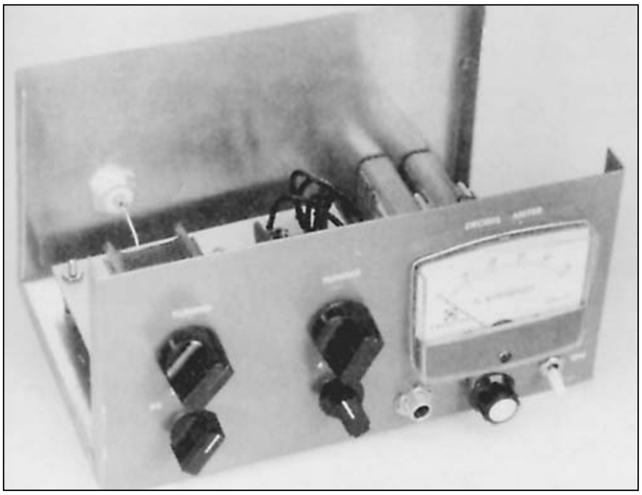

Fig 54—The linear field strength meter. The control at the upper left is for C1 and the one to the right for C2. At the lower left is the band switch, and to its right the sensitivity switch. The zero-set control for M1 is located directly below the meter.

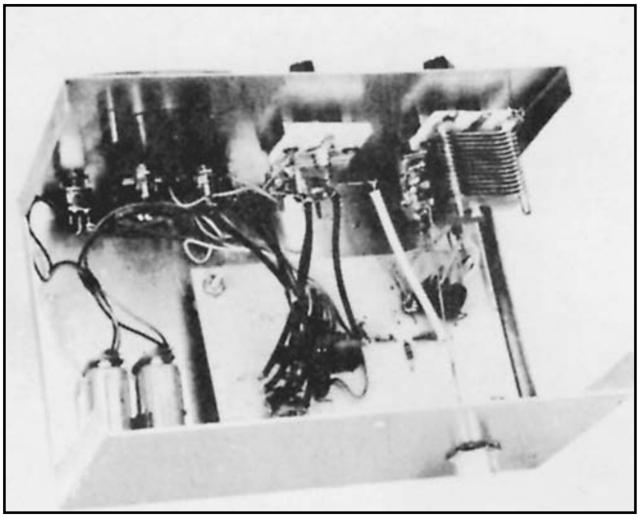

Fig 55—Inside view of the field-strength meter. At the upper right is C1 and to the left, C2. The dark leads from the circuit board to the front panel are the shielded leads described in the text.

148 MHz, with band-switched circuits, thus avoiding the use of plug-in inductors. All in all, it is a quite useful instrument.

The unit is pictured in **Figs 54** and **55**, and the schematic diagram is shown in **Fig 56**. A type 741 op-amp IC is the heart of the unit. The antenna is connected to J1, and a tuned circuit is used ahead of a diode detector. The rectified signal is coupled as dc and amplified in the op amp. Sensitivity of the op amp is controlled by inserting resistors R3 through R6 in the circuit by means of S2.

With the circuit shown, and in its most sensitive setting, M1 will detect a signal from the antenna on the order of 100 µV. Linearity is poor for approximately the first $^1/_5$ of the meter range, but then is almost straight-line from there to full-scale deflection. The reason for the poor linearity at the start of the readings is because of nonlinearity of the diodes at the point of first conduction. However, if gain measurements are being made this is of no real importance, as accurate gain measurements can be made in the linear portion of the readings.

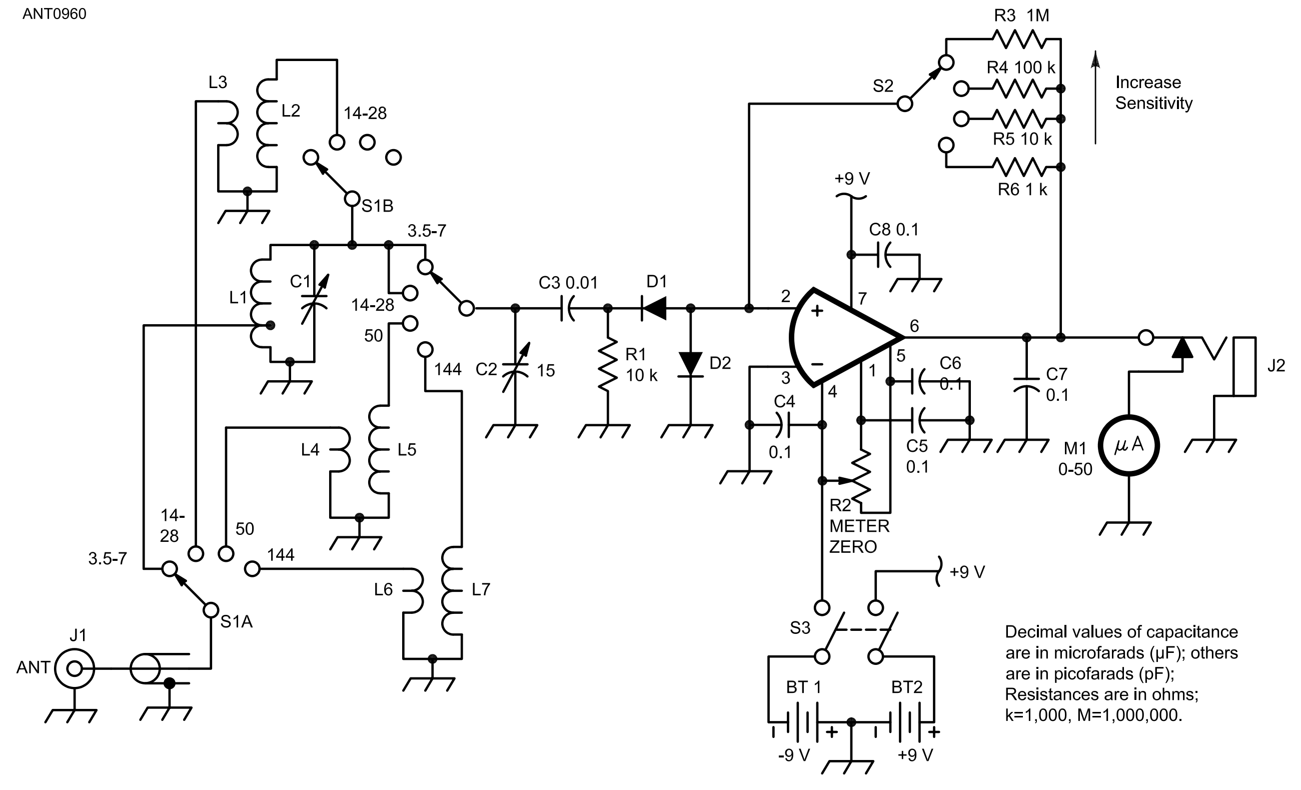

Decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); Resistances are in ohms; k=1,000, M=1,000,000.

Fig 56—Circuit diagram of the linear field strength meter. All resistors are $^1/_4$- or $^1/_2$-W composition types.

C1 — 140 pF variable.
C2 — 15-pF variable
D1, D2 — 1N914 or equiv.
L1 — 34 turns #24 enam. wire wound on an Amidon T-68-2 core, tapped 4 turns from ground end.
L2 — 12 turns #24 enam. wire wound on T-68-2 core.
L3 — 2 turns #24 enam. wire wound at ground end of L2.
L4 — 1 turn #26 enam. wire wound at ground end of L5.
L5 — 12 turns #26 enam. wire wound on T-25-12 core.
L6 — 1 turn #26 enam. wire wound at ground end of L7.
L7 — 1 turn #18 enam. wire wound on T-25-12 core.
M1 — 50 or 100 µA dc.
R2 — 10-kΩ control, linear taper.
S1 — Rotary switch, 3 poles, 5 positions, 3 sections.
S2 — Rotary switch, 1 pole, 4 positions.
S3 — DPST toggle.
U1 — Type 741 op amp. Pin numbers shown are for a 14-pin package.

The 741 op amp requires both a positive and a negative voltage source. This is obtained by connecting two 9-volt batteries in series and grounding the center. One other feature of the instrument is that it can be used remotely by connecting an external meter at J2. This is handy if you want to adjust an antenna and observe the results without having to leave the antenna site.

L1 is the 3.5/7 MHz coil and is tuned by C1. The coil is wound on a toroid form. For 14, 21 or 28 MHz, L2 is switched in parallel with L1 to cover the three bands. L5 and C2 cover approximately 40 to 60 MHz, and L7 and C2 from 130 MHz to approximately 180 MHz. The two VHF coils are also wound on toroid forms.

Construction Notes

The majority of the components may be mounted on an etched circuit board. A shielded lead should be used between pin 4 of the IC and S2. The same is true for the leads from R3 through R6 to the switch. Otherwise, parasitic oscillations may occur in the IC because of its very high gain.

In order for the unit to cover the 144-MHz band, L6 and L7 should be mounted directly across the appropriate terminals of S1, rather than on a circuit board. The extra lead length adds too much stray capacitance to the circuit. It isn't necessary to use toroid forms for the 50- and 144-MHz coils. They were used in the version described here simply because they were available. You may substitute air-wound coils of the appropriate inductance.

Calibration

The field strength meter can be used *as is* for a relative-reading device. A linear indicator scale will serve admirably. However, it will be a much more useful instrument for antenna work if it is calibrated in decibels, enabling the user to check relative gain and front-to-back ratios. If you have access to a calibrated signal generator, connect it to the field-strength meter and use different signal levels fed to the device to make a calibration chart. Convert signal-generator voltage ratios to decibels by using the equation

$$\text{dB} = 20 \log (V1/V2) \qquad \text{(Eq 21)}$$

where

V1/V2 is the ratio of the two voltages

log is the common logarithm (base 10)

Let's assume that M1 is calibrated evenly from 0 to 10. Next, assume we set the signal generator to provide a reading of 1 on M1, and that the generator is feeding a 100-µV signal into the instrument. Now we increase the generator output to 200 µV, giving us a voltage ratio of 2:1. Also let's assume M1 reads 5 with the 200-µV input. From the equation above, we find that the voltage ratio of 2 equals 6.02 dB between 1 and 5 on the meter scale. M1 can be calibrated more accurately between 1 and 5 on its scale by adjusting the generator and figuring the ratio. For example, a ratio of 126 µV to 100 µV is 1.26, corresponding to 2.0 dB. By using this method, all of the settings of S2 can be calibrated. In the instrument shown here, the most sensitive setting of S2 with R3, 1 MΩ, provides a range of approximately 6 dB for M1. Keep in mind that the meter scale for each setting of S1 must be calibrated similarly for each band. The degree of coupling of the tuned circuits for the different bands will vary, so each band must be calibrated separately.

Another method for calibrating the instrument is using a transmitter and measuring its output power with an RF wattmeter. In this case we are dealing with power rather than voltage ratios, so this equation applies:

$$\text{dB} = 10 \log (P1/P2) \qquad \text{(Eq 22)}$$

where P1/P2 is the power ratio.

With most transmitters the power output can be varied, so calibration of the test instrument is rather easy. Attach a pickup antenna to the field-strength meter (a short wire a foot or so long will do) and position the device in the transmitter antenna field. Let's assume we set the transmitter output for 10 W and get a reading on M1. We note the reading and then increase the output to 20 W, a power ratio of 2. Note the reading on M1 and then use Eq 2. A power ratio of 2 is 3.01 dB. By using this method the instrument can be calibrated on all bands and ranges.

With the tuned circuits and coupling links specified in Fig 56, this instrument has an average range on the various bands of 6 dB for the two most sensitive positions of S2, and 15 dB and 30 dB for the next two successive ranges. The 30-dB scale is handy for making front-to-back antenna measurements without having to switch S2.

An RF Current Probe

The RF current probe of **Figs 57** through **59** operates on the magnetic component of the electromagnetic field, rather than the electric field. Since the two fields are precisely related, as discussed in Chapter 23, the relative field strength measurements are completely equivalent. The use of the magnetic field offers certain advantages, however. The instrument may be made more compact for the same sensitivity, but its principal advantage is that it may be used near a conductor to measure the current flow without cutting the conductor.

In the average amateur location there may be substantial currents flowing in guy wires, masts and towers, coaxial-cable braids, gutters and leaders, water and gas pipes, and perhaps even drainage pipes. Current may be flowing in telephone and power lines as well. All of these RF currents may have an influence on antenna patterns or can be of significance in the case of RFI.

The circuit diagram of the current probe appears in Fig 58, and construction is shown in the photo, Fig 59. The winding data given here apply only to a ferrite rod of the particular dimensions and material specified. Almost any microammeter can be used, but it is usually convenient to use a rather sensitive meter and provide a series resistor to swamp out nonlinearity arising from diode conduction characteristics. A control is also used to adjust instrument sensitivity as required during operation. The tuning capacitor may be almost anything that will cover the desired range.

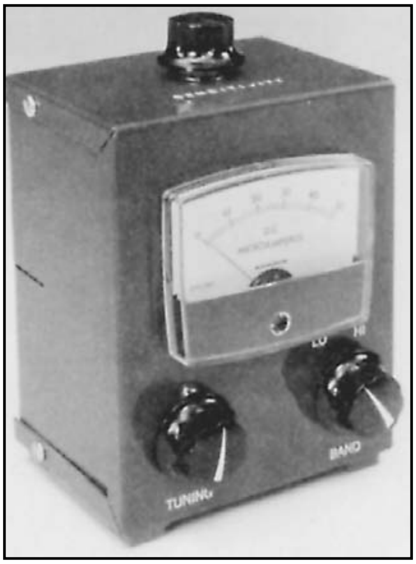

Fig 57—The RF current probe. The sensitivity control is mounted at the top of the instrument, with the tuning and band switches on the lower portion of the front panel. Frequency calibration of the tuning control was not considered necessary for the intended use of this particular instrument, but marks identifying the various amateur bands would be helpful. If the unit is provided with a calibrated dial, it can also be used as an absorption wavemeter.

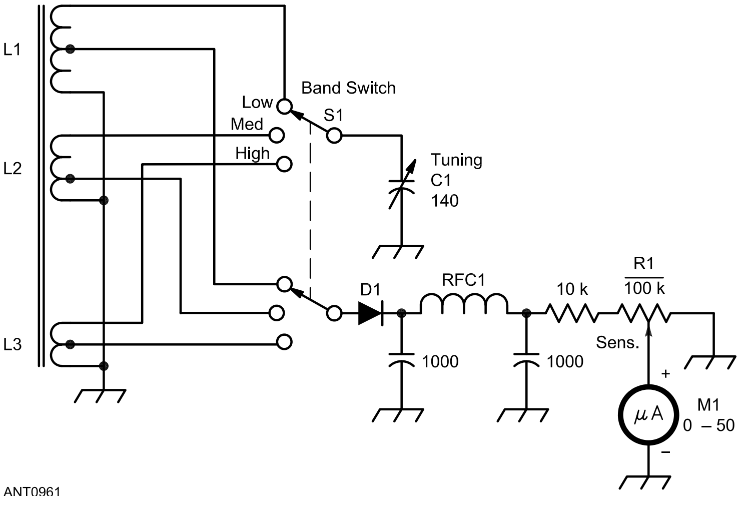

Fig 58—Schematic diagram of the RF current probe. Resistances are in ohms; k = 1000. Capacitances are in picofarads; fixed capacitors are silver mica. Be sure to ground the rotor of C1, rather than the stator, to avoid hand capacitance. L1, L2 and L3 are each close-wound with #22 enameled wire on a single ferrite rod, 4 inch long and 1/2 inch diameter, with μ = 125 (Amidon R61-50-400). Windings are spaced approximately 1/4 inch apart.

C1—Air variable, 6-140 pF; Hammarlund HF140 or equiv.
D1—Germanium diode; 1N34A, 1N270 or equiv.
L1—1.6-5 MHz; 30 turns, tapped at 3 turns from grounded end.
L2—5-20 MHz; 8 turns, tapped at 2 turns from grounded end.
L3—17-39 MHz; 2 turns, tapped at 1 turn.
M1—Any microammeter may be used. The one pictured is a Micronta meter, RadioShack no. 270-1751.
R1—Linear taper.
RFC1—1 mH; Miller no. 4642 or equiv. Value is not critical.
S1—Ceramic rotary switch, 1 section, 2 poles, 2 to 6 positions; Centralab PA2002 or PA2003 or equiv.

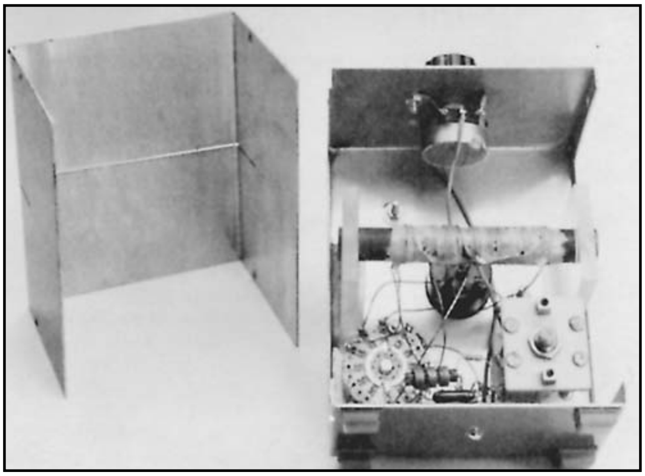

Fig 59—The current probe just before final assembly. Note that all parts except the ferrite rod are mounted on a single half of the 3 × 4 × 5-inch Minibox (Bud CU-2105B or equiv.). Rubber grommets are fitted in holes at the ends of the slot to accept the rod during assembly of the enclosure. Leads in the RF section should be kept as short as possible, although those from the rod windings must necessarily be left somewhat long to facilitate final assembly.

As shown in the photos, the circuit is constructed in a metal box. This enclosure shields the detector circuit from the electric field of the radio wave. A slot must be cut with a hacksaw across the back of the box, and a thin file may be used to smooth the cut. This slot is necessary to prevent the box from acting as a shorted turn.

Using the Probe

In measuring the current in a conductor, the ferrite rod should be kept at right angles to the conductor, and at a constant distance from it. In its upright or vertical position, this instrument is oriented for taking measurements in vertical conductors. It must be laid horizontal to measure current in horizontal conductors.

Numerous uses for the instrument are suggested in an earlier paragraph. In addition, the probe is an ideal instrument for checking the current distribution in antenna elements. It is also useful for measuring RF ground currents in radial systems. A buried radial may be located easily by sweeping the ground. Current division at junctions may be investigated. *Hot spots* usually indicate areas where additional radials would be effective.

Stray currents in conductors not intended to be part of the antenna system may often be eliminated by bonding or by changing the physical lengths involved. Guy wires and other unwanted parasitic elements will often give a tilt to the plane of polarization and can make a marked difference in front-to-back ratios. When the ferrite rod is oriented parallel to the electric field lines, there will be a sharp null reading that may be used to locate the plane of polarization quite accurately. When using the meter, remember that the magnetic field is at right angles to the electric field.

You may also use the current probe as a relative signal strength meter. When making measurements on a vertical antenna, locate the meter at least two wavelengths away, with the rod in a horizontal position. For horizontal antennas, hold the instrument at approximately the same height as the antenna, with the rod vertical.

Antenna Measurements

Of all the measurements made in Amateur Radio systems, perhaps the most difficult and least understood are various measurements of antennas. For example, it is relatively easy to measure the frequency and CW power output of a transmitter, the response of a filter, or the gain of an amplifier. These are all what might be called *bench measurements* because, when performed properly, all the factors that influence the accuracy and success of the measurement are under control. In making antenna measurements, however, the “bench” is probably your backyard. In other words, the environment surrounding the antenna can affect the results of the measurement.

Control of the environment is not at all as simple as it was for the bench measurement, because now the work area may be rather spacious. This section describes antenna measurement techniques that are closely allied to those used in an antenna measuring event or contest. With these procedures you can make measurements successfully and with meaningful results. These techniques should provide a better understanding of the measurement problems, resulting in a more accurate and less difficult task. The information in this section was provided by Dick Turrin, W2IMU, and was originally published in November 1974 *QST*.

SOME BASIC IDEAS

An antenna is simply a transducer or coupler between a suitable feed line and the environment surrounding it. In addition to the efficient transfer of power from feed line to environment, an antenna at VHF or UHF is most frequently required to concentrate the radiated power into a particular region of the environment.

To be consistent while comparing different antennas, you must standardize the environment surrounding the antenna. Ideally, you want to make measurements with the measured antenna so far removed from any objects causing environmental effects that it is literally in outer space—a very impractical situation. The purpose of the measurement techniques is therefore to simulate, under practical conditions, a *controlled environment*. At VHF and UHF, and with practical-size antennas, the environment can be controlled so that successful and accurate measurements can be made in a reasonable amount of space.

The electrical characteristics of an antenna that are most desirable to obtain by direct measurement are: (1) gain (relative to an isotropic source, which by definition has a gain of unity); (2) space-radiation pattern; (3) feed-point impedance (mismatch) and (4) polarization.

Polarization

In general the polarization can be assumed from the geometry of the radiating elements. That is to say, if the antenna consists of a number of linear elements (straight lengths of rod or wire that are resonant and connected to the feed point) the polarization of the electric field will be linear and polarized parallel to the elements. If the elements are not consistently parallel with each other, then the polarization cannot easily be assumed. The following techniques are directed to antennas having polarization that is essentially linear (in one plane), although the method can be extended to include all forms of elliptic (or mixed) polarization.

Feed-Point Mismatch

The feed-point mismatch, although affected to some degree by the immediate environment of the antenna, does not affect the gain or radiation characteristics of an antenna. If the immediate environment of the antenna does not affect the feed-point impedance, then any mismatch intrinsic to the antenna tuning reflects a portion of the incident power back to the source. In a receiving antenna this reflected power is reradiated back into the environment, and can be lost entirely.

In a transmitting antenna, the reflected power travels back down the feed line to the transmitter, where it changes the load impedance presented to that transmitter. The amplifier output controls are customarily altered during the normal tuning procedure to obtain maximum power transfer to the antenna. You can still use a mismatched antenna to its full gain potential, provided the mismatch is not so severe as to cause heating losses in the system, especially the feed line and matching devices. (See also the discussion of additional loss caused by SWR in Chapter 24.)

Similarly, a mismatched receiving antenna may be matched into the receiver front end for maximum power transfer. In any case you should clearly keep in mind that the feed-point mismatch does not affect the radiation characteristics of an antenna. It can only affect the system efficiency when heating losses are considered.

Why then do we include feed-point mismatch as part of the antenna characteristics? The reason is that for efficient system performance, most antennas are resonant transducers and present a reasonable match over a relatively narrow frequency range. It is therefore desirable to design an antenna, whether it be a simple dipole or an array of Yagis, such that the final single feed-point impedance is essentially resistive and matched to the feed line. Furthermore, in order to make accurate, absolute gain measurements, it is vital that the antenna under test accept all the power from a matched-source generator, or that the reflected power caused by the mismatch be measured and a suitable error correction for heating losses be included in the gain calculations. Heating losses may be determined from information contained in Chapter 24.

While on the subject of feed-point impedance, mention should be made of the use of *baluns* in antennas. A balun is simply a device that permits a lossless transition between a balanced system feed line or antenna and an unbalanced feed line or system. If the feed point of an antenna is symmetric, such as with a dipole, and it is desired to feed this antenna with an unbalanced feed line such as coax, you should provide a balun between the line and the feed point. Without the balun, current will be allowed to flow on the outside of the coax. The current on the outside of the feed line will cause radiation, and thus the feed line will become part of the antenna radiation system. In the case of beam antennas, where it is desired to concentrate the radiated energy is a specific direction, this extra radiation from the feed line will be detrimental, causing distortion of the expected antenna pattern. See Chapter 26 for additional details on this problem.

ANTENNA TEST SITE SET-UP AND EVALUATION

Since an antenna is a reciprocal device, measurements of gain and radiation patterns can be made with the test antenna used either as a transmitting or as a receiving antenna. In general and for practical reasons, the test antenna is used in the receiving mode, and the source or transmitting antenna is located at a specified fixed remote site and unattended. In other words the source antenna, energized by a suitable transmitter, is simply required to illuminate or flood the receiving site in a controlled and constant manner.

As mentioned earlier, antenna measurements ideally should be made under free-space conditions. A further restriction is that the illumination from the source antenna be a *plane wave* over the effective aperture (capture area) of the test antenna. A plane wave by definition is one in which the magnitude and phase of the fields are uniform, and in the test-antenna situation, *uniform over the effective area plane of the test antenna*. Since it is the nature of all radiation to expand in a spherical manner at great distance from the source, it would seem to be most desirable to locate the source antenna as far from the test site as possible. However, since for practical reasons the test site and source location will have to be near the earth and not in outer space, the environment must include the effects of the ground surface and other obstacles in the vicinity of both antennas. These effects almost always dictate that the test range (spacing between source and test antennas) be as short as possible consistent with maintaining a nearly error-free plane wave illuminating the test *aperture*.

A nearly error-free plane wave can be specified as one in which the phase and amplitude, from center to edge of the illuminating field over the test aperture, do not deviate by more than about 30° and 1 decibel, respectively. These conditions will result in a gain-measurement error of no more than a few percent less than the true gain. Based on the 30º phase error alone, it can be shown that the minimum range distance is approximately

$$S_{min} = 2\frac{D^2}{\lambda} \qquad \text{(Eq 23)}$$

where D is the largest aperture dimension and λ is the free-space wavelength in the same units as D. The phase error over the aperture D for this condition is $^1/_{16}$ wavelength.

Since aperture size and gain are related by

$$\text{Gain} = \frac{4\pi A_e}{\lambda^2} \qquad \text{(Eq 24)}$$

where A_e is the effective aperture area, the dimension D may be obtained for simple aperture configurations. For a square aperture

$$D_2 = G\frac{\lambda^2}{4\pi} \qquad \text{(Eq 25)}$$

that results in a minimum range distance for a square aperture of

$$S_{min} = G\frac{\lambda}{2\pi} \qquad \text{(Eq 26)}$$

and for a circular aperture of

$$S_{min} = G\frac{2\lambda}{\pi^2} \qquad \text{(Eq 27)}$$

For apertures with a physical area that is not well defined or is much larger in one dimension that in other directions, such as a long thin array for maximum directivity in one plane, it is advisable to use the maximum estimate of D from either the expected gain or physical aperture dimensions.

Up to this point in the range development, only the conditions for minimum range length, S_{min}, have been established, as though the ground surface were not present. This minimum S is therefore a necessary condition even under free-space environment. The presence of the ground further complicates the range selection, not in the determination of S but in the exact location of the source and test antennas above the earth.

It is always advisable to select a range whose intervening terrain is essentially flat, clear of obstructions, and of uniform surface conditions, such as all grass or all pavement. The extent of the range is determined by the illumination of the source antenna, usually a Yagi, whose gain is no greater than the highest gain antenna to be measured. For gain measurements the range consists essentially of the region in the beam of the test antenna. For radiation-pattern measurements, the range is considerably larger and consists of all that area illuminated by the source antenna, especially around and behind the test site. Ideally you should choose a site where the test-antenna location is near the center of a large open area and the source antenna is located near the edge where most of the obstacles (trees, poles, fences, etc.) lie.

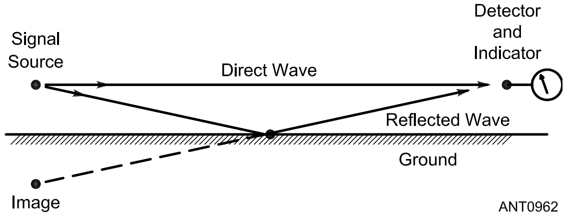

Fig 60—On an antenna test range, energy reaching the receiving equipment may arrive after being reflected from the surface of the ground, as well as by the direct path. The two waves may tend to cancel each other, or may reinforce one another, depending on their phase relationship at the receiving point.

The primary effect of the range surface is that some of the energy from the source antenna will be reflected into the test antenna, while other energy will arrive on a direct line-of-sight path. This is illustrated in **Fig 60**. The use of a flat, uniform ground surface assures that there will be essentially a mirror reflection, even though the reflected energy may be slightly weakened (absorbed) by the surface material (ground). In order to perform an analysis you should realize that horizontally polarized waves undergo a 180º phase reversal upon reflection from the earth. The resulting illumination amplitude at any point in the test aperture is the vector sum of the electric fields arriving from the two directions, the direct path and the reflected path.

If a perfect mirror reflection is assumed from the ground (it is nearly that for practical ground conditions at VHF/UHF) and the source antenna is isotropic, radiating equally in all directions, then a simple geometric analysis of the two path lengths will show that at various point in the vertical plane at the test-antenna site the waves will combine in different phase relationships. At some points the arriving waves will be in phase, and at other points they will be 180º out of phase. Since the field amplitudes are nearly equal, the resulting phase change caused by path length difference will produce an ampli-

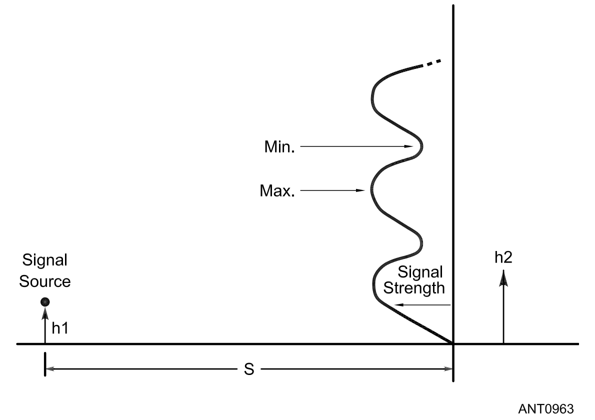

Fig 61—The vertical profile, or plot of signal strength versus test-antenna height, for a fixed height of the signal source above ground and at a fixed distance. See text for definitions of symbols.

tude variation in the vertical test site direction similar to a standing wave, as shown in **Fig 61**.

The simplified formula relating the location of h2 for maximum and minimum values of the two-path summation in terms of h1 and S is

$$h2 = n\frac{\lambda}{4} \times \frac{S}{h1} \qquad \text{(Eq 28)}$$

with n = 0, 2, 4, . . . for minimums and n = 1, 3, 5, . . . for maximums, and S is much larger than either h1 or h2.

The significance of this simple ground reflection formula is that it permits you to determine the approximate location of the source antenna to achieve a nearly plane-wave amplitude distribution *in the vertical direction* over a particular test *aperture size*. It should be clear from examination of the height formula that as h1 is decreased, the vertical distribution pattern of signal at the test site, h2, expands. Also note that the signal level for h2 equal to zero is always zero on the ground regardless of the height of h1.

The objective in using the height formula then is, given an effective antenna aperture to be illuminated from which a minimum S (range length) is determined and a suitable range site chosen, to find a value for h1 (source antenna height). The required value is such that the *first* maximum of vertical distribution at the test site, h2, is at a practical distance above the ground, and at the same time the signal amplitude over the aperture in the vertical direction does not vary more than about 1 dB. This last condition is not sacred but is closely related to the particular antenna under test.

In practice these formulas are useful only to initialize the range setup. A final check of the vertical distribution at the test site must be made by direct measurement. This measurement should be conducted with a small low-gain but unidirectional probe antenna such as a corner reflector or 2-element Yagi that you move along a vertical line over the intended aperture site. Care should be exercised to minimize the effects of local environment around the probe antenna and that the beam of the probe be directed at the source antenna at all times for maximum signal. A simple dipole is undesirable as a probe antenna because it is susceptible to local environmental effects.

The most practical way to instrument the vertical distribution measurement is to construct some kind of vertical track, preferably of wood, with a sliding carriage or platform that may be used to support and move the probe antenna. It is assumed of course that a stable source transmitter and calibrated receiver or detector are available so variations of the order of $^{1}/_{2}$ dB can be clearly distinguished.

Once you conduct these initial range measurements successfully, the range is now ready to accommodate any aperture size less in vertical extent than the largest for which S_{min} and the vertical field distribution were selected. Place the test antenna with the center of its aperture at the height h2 where maximum signal was found. Tilt the test antenna tilted so that its main beam is pointed in the direction of the source antenna. The final tilt is found by observing the receiver output for maximum signal. This last process must be done empirically since the apparent location of the source is somewhere between the actual source and its image, below the ground.

An example will illustrate the procedure. Assume that we wish to measure a 7-foot diameter parabolic reflector antenna at 1296 MHz (λ = 0.75 foot). The minimum range distance, S_{min}, can be readily computed from the formula for a circular aperture.

$$S_{min} = 2\frac{D^2}{\lambda} = 2 \times \frac{49}{0.75} = 131 \text{ feet}$$

Now a suitable site is selected based on the qualitative discussion given before.

Next determine the source height, h1. The procedure is to choose a height h1 such that the first minimum above ground (n = 2 in formula) is at least two or three times the aperture size, or about 20 feet.

$$h1 = n\frac{\lambda}{4}\frac{S}{h1} = 2 \times \frac{0.75}{4} \times \frac{131}{20} = 2.5 \text{ feet}$$

Place the source antenna at this height and probe the vertical distribution over the 7-foot aperture location, which will be about 10 feet off the ground.

$$h2 = n\frac{\lambda}{4}\frac{S}{h1} = 1 \times \frac{0.75}{4} \times \frac{131}{2.5} = 9.8 \text{ feet}$$

Plot the measured profile of vertical signal level versus height. From this plot, empirically determine whether the 7-foot aperture can be fitted in this profile such that the 1-dB variation is not exceeded. If the variation exceeds

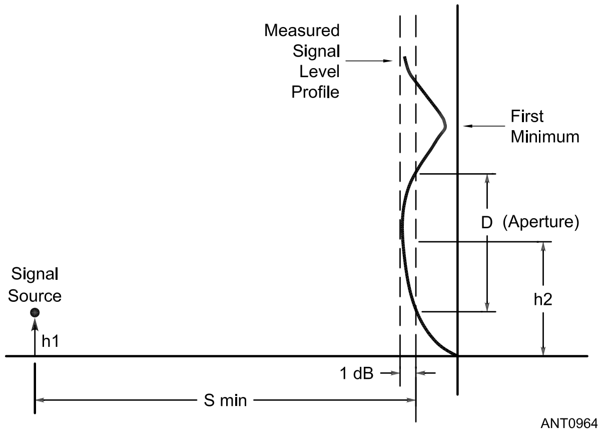

Fig 62—Sample plot of a measured vertical profile.

1 dB over the 7-foot aperture, the source antenna should be lowered and h2 raised. Small changes in h1 can quickly alter the distribution at the test site. **Fig 62** illustrates the points of the previous discussion.

The same set-up procedure applies for either horizontal or vertical linear polarization. However, it is advisable to check by direct measurement at the site for each polarization to be sure that the vertical distribution is satisfactory. Distribution probing in the horizontal plane is unnecessary as little or no variation in amplitude should be found, since the reflection geometry is constant. Because of this, antennas with apertures that are long and thin, such as a stacked collinear vertical, should be measured with the long dimension parallel to the ground.

A particularly difficult range problem occurs in measurements of antennas that have depth as well as cross-sectional aperture area. Long end-fire antennas such as long Yagis, rhombics, V-beams, or arrays of these antennas, radiate as *volumetric arrays* and it is therefore even more essential that the illuminating field from the source antenna be reasonably uniform in depth as well as plane wave in cross section. For measuring these types of antennas it is advisable to make several vertical profile measurements that cover the depth of the array. A qualitative check on the integrity of the illumination for long end-fire antennas can be made by moving the array or antenna axially (forward and backward) and noting the change in received signal level. If the signal level varies less than 1 or 2 dB for an axial movement of several wavelengths then the field can be considered satisfactory for most demands on accuracy. Large variations indicate that the illuminating field is badly distorted over the array depth and subsequent measurements are questionable. It is interesting to note in connection with gain measurements that any illuminating field distortion will always result in measurements that are lower than true values.

ABSOLUTE GAIN MEASUREMENT

Having established a suitable range, the measure-

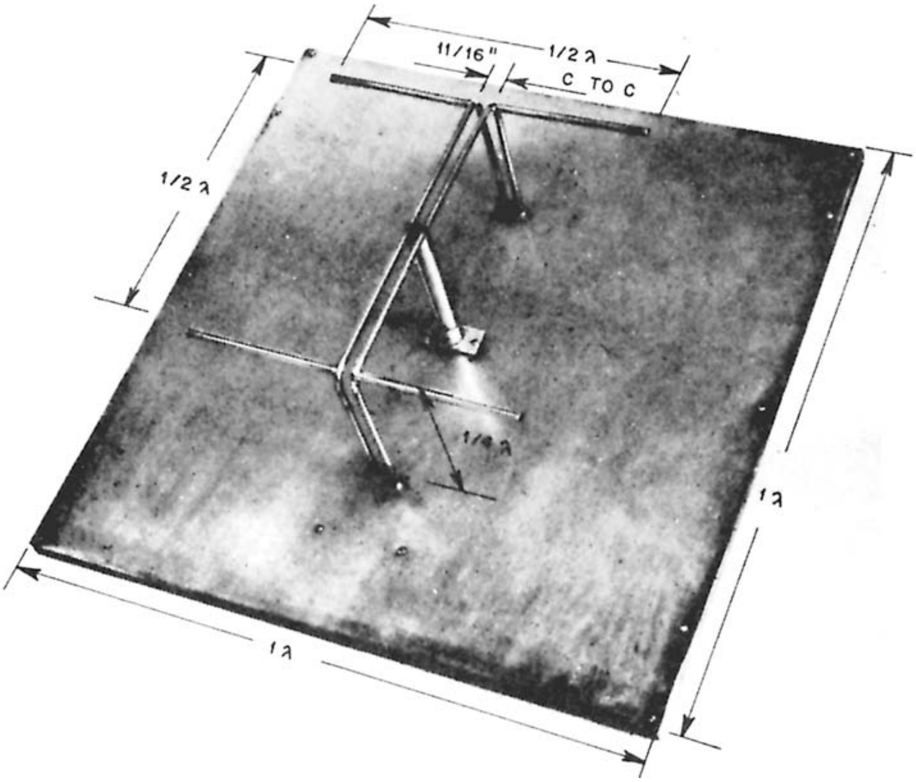

Fig 63—Standard-gain antenna. When accurately constructed for the desired frequency, this antenna will exhibit a gain of 7.7 dB over a dipole radiator, plus or minus 0.25 dB. In this model, constructed for 432 MHz, the elements are $^3/_8$-inch diameter tubing. The phasing and support lines are of $^5/_{16}$-inch diameter tubing or rod.

ment of gain relative to an isotropic (point source) radiator is almost always accomplished by direct comparison with a calibrated standard-gain antenna. That is, the signal level with the test antenna in its optimum location is noted. Then you remove the test antenna and place the standard-gain antenna with its aperture at the center of location where the test antenna was located. Measure the difference in signal level between the standard and the test antennas and add to or subtract from the gain of the standard-gain antenna to obtain the absolute gain of the test antenna. Here, *absolute* means with respect to a point source with a gain of unity, by definition. The reason for using this reference rather than a dipole, for instance, is that it is more useful and convenient for system engineering. We assume that both standard and test antennas have been carefully matched to the appropriate impedance and an accurately calibrated and matched detecting device is being used.

A standard-gain antenna may be any type of unidirectional, preferably planar-aperture, antenna, which has been calibrated either by direct measurement or in special cases by accurate construction according to computed dimensions. A standard-gain antenna has been suggested by Richard F. H. Yang (see Bibliography). Shown in **Fig 63**, it consists of two in-phase dipoles $^1/_2$ λ apart and backed up with a ground plane 1 λ square.

In Yang's original design, the stub at the center is a balun formed by cutting two longitudinal slots of $^1/_8$-inch width, diametrically opposite, on a $^1/_4$-λ section of $^7/_8$-inch rigid 50-Ω coax. An alternative method of feeding is to feed RG-8 or RG-213 coax through slotted $^7/_8$-inch copper tubing. Be sure to leave the outer jacket on the coax to insulate it from the copper-tubing balun section. When constructed accurately to scale for the frequency of interest, this type of standard will have an absolute gain of 9.85 dBi (7.7 dBd gain over a dipole in free space) with an accuracy of ± 0.25 dB.

RADIATION-PATTERN MEASUREMENTS

Of all antenna measurements, the radiation pattern is the most demanding in measurement and the most difficult to interpret. Any antenna radiates to some degree in all directions into the space surrounding it. Therefore, the radiation pattern of an antenna is a three-dimensional representation of the magnitude, phase and polarization. In general, and in practical cases for Amateur Radio communications, the polarization is well defined and only the magnitude of radiation is important.

Furthermore, in many of these cases the radiation in one particular plane is of primary interest, usually the plane corresponding to that of the Earth's surface, regardless of polarization. Because of the nature of the range setup, measurement of radiation pattern can be successfully made only in a plane nearly parallel to the earth's surface. With beam antennas it is advisable and usually sufficient to take two radiation pattern measurements, one in the polarization plane and one at right angles to the plane of polarization. These radiation patterns are referred to in antenna literature as the principal E-plane and H-plane patterns, respectively. *E-plane* means parallel to the electric field that is the polarization plane and *H-plane* means parallel to the magnetic field in free space. The electric field and magnetic field are always perpendicular to each other in a plane wave as it propagates through space.

When the antenna is located over real earth, the terms *Azimuth* and *elevation* planes are commonly used, since the frame of reference is the Earth itself, rather than the electric and magnetic fields in free space. For a horizontally polarized antenna such as a Yagi mounted with its elements parallel to the ground, the azimuth plane is the E-plane and the elevation plane is the H-plane.

The technique to obtain these patterns is simple in procedure but requires more equipment and patience than does making a gain measurement. First, a suitable mount is required that can be rotated in the azimuth plane (horizontal) with some degree of accuracy in terms of azimuth-angle positioning. Second, a signal-level indicator calibrated over at least a 20-dB dynamic range with a readout resolution of at least 2 dB is required. A dynamic range of up to about 40 dB would be desirable but does not add greatly to the measurement significance.

With this much equipment, the procedure is to locate first the area of maximum radiation from the beam antenna by carefully adjusting the azimuth and elevation positioning. These settings are then arbitrarily assigned an azimuth angle of zero degrees and a signal level of zero decibels. Next, without changing the elevation setting (tilt of the rotating axis), the antenna is carefully rotated in azimuth in small steps that permit signal-level readout of 2 or 3 dB per step. These points of signal level corresponding with an azimuth angle are recorded and plotted on polar coordinate paper. A sample of the results is shown on ARRL coordinate paper in **Fig 64**.

On the sample radiation pattern the measured points are marked with an X and a continuous line is drawn in, since the pattern is a continuous curve. Radiation patterns should preferably be plotted on a logarithmic radial scale, rather than a voltage or power scale. The reason is that the log scale approximates the response of the ear to signals in the audio range. Also many receivers have AGC systems that are somewhat logarithmic in response; therefore the log scale is more representative of actual system operation.

Having completed a set of radiation-pattern measurements, one is prompted to ask, "Of what use are they?" The primary answer is as a diagnostic tool to determine if the antenna is functioning as it was intended to. A second answer is to know how the antenna will discriminate against interfering signals from various directions.

Consider now the diagnostic use of the radiation patterns. If the radiation beam is well defined, then there is an approximate formula relating the antenna gain to the

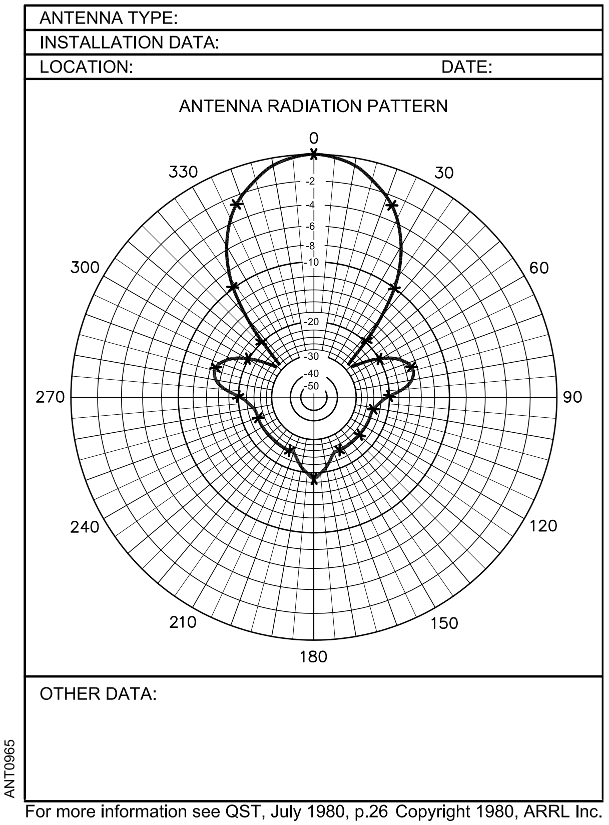

Fig 64—Sample plot of a measured radiation pattern, using techniques described in the text. The plot is on coordinate paper available from ARRL HQ. The form provides space for recording significant data and remarks.

measured half-power beamwidth of the E- and H-plane radiation patterns. The half-power beamwidth is indicated on the polar plot where the radiation level falls to 3 dB below the main beam 0-dB reference on either side. The formula is

$$\text{Gain}\left(\text{dBi}\right) \cong \frac{41{,}253}{\theta_E \phi_H} \qquad \text{(Eq 29)}$$

where θ_E and ϕ_H are the half-power beamwidths in degrees of the E- and H-plane patterns, respectively. This equation assumes a lossless antenna system, where any side-lobes are well suppressed.

To illustrate the use of this equation, assume that we have a Yagi antenna with a boom length of two wavelengths. From known relations (described in Chapter 11) the expected free-space gain of a Yagi with a boom length of 2 λ is about 13 dBi; its gain, G, equals 20. Using the above relationship, the product of $\theta_E \times \phi_H \approx 2062$ square degrees. Since a Yagi produces a nearly symmetric beam shape in cross section, $\theta_E = \phi_H = 45°$. Now if the measured values of θ_E and ϕ_H are much larger than 45°, then the gain will be much lower than the expected 13 dBi.

As another example, suppose that the same antenna (a 2-wavelength-boom Yagi) gives a measured gain of 9 dBi but the radiation pattern half power beamwidths are approximately 45°. This situation indicates that although the radiation patterns seem to be correct, the low gain shows inefficiency somewhere in the antenna, such as lossy materials or poor connections.

Large broadside collinear antennas can be checked for excessive phasing-line losses by comparing the gain computed from the radiation patterns with the direct-measured gain. It seems paradoxical, but it is indeed possible to build a large array with a very narrow beamwidth indicating high gain, but actually having very low gain because of losses in the feed distribution system.

In general, and for most VHF/UHF Amateur Radio communications, gain is the primary attribute of an antenna. However, radiation in other directions than the main beam, called *sidelobe radiation*, should be examined by measurement of radiation patterns for effects such as nonsymmetry on either side of the main beam or excessive magnitude of sidelobes. (Any sidelobe that is less than 10 dB below the main beam reference level of 0 dB should be considered excessive.) These effects are usually attributable to incorrect phasing of the radiating elements or radiation from other parts of the antenna that was not intended, such as the support structure or feed line.

The interpretation of radiation patterns is intimately related to the particular type of antenna under measurement. Reference data should be consulted for the antenna type of interest, to verify that the measured results are in agreement with expected results.

To summarize the use of pattern measurements, if a beam antenna is first checked for gain (the easier measurement to make) and it is as expected, then pattern measurements may be academic. However, if the gain is lower than expected it is advisable to make pattern measurements to help determine the possible causes for low gain.

Regarding radiation pattern measurements, remember that the results measured under proper range facilities will not necessarily be the same as observed for the same antenna at a home-station installation. The reasons may be obvious now in view of the preceding information on the range setup, ground reflections, and the vertical-field distribution profiles. For long paths over rough terrain where many large obstacles may exist, the effects of ground reflection tend to become diffused, although they still can cause unexpected results. For these reasons it is usually unjust to compare VHF/UHF antennas over long paths.

Vector Network Analyzers

The process of building and properly tuning a phased array often involves making a number of different measurements to achieve a desired level of performance, as was pointed out in Chapter 8, Multielement Arrays. This section was written by Rudy Severns, N6LF.

After erecting an array we would like to measure the resonant frequency of each element, the self-impedances of each element and the mutual impedances between the elements. We will also want to know these impedances over the whole operating band to help design a feed network. When building the feed network, we may need to check the values and Qs of the network elements and we will want to determine the electrical lengths of transmission lines.

Final tuning of the array requires that the relative current amplitudes and phases in each element be measured and adjusted, if necessary. We also will want to determine the SWR at the feed point. Doing all of this even moderately well can require quite a bit of equipment, some of which is heavy and requires ac line power. This can be a nuisance in the field, especially if the weather is not cooperating.

Professionals make these measurements by employing a *vector network analyzer* (VNA) or the somewhat simpler, *reflection-transmission test set*. These instruments can make all the necessary measurements quickly and with great accuracy. However, in the past VNAs have been very expensive, out of reach for general amateur use. But thanks to modern digital technology VNAs that work with a laptop computer are now becoming available at prices an amateur might consider. It's even possible to homebrew a VNA[1] with performance that approaches a professional instrument. Considering the cost of even a simple array, investment in a VNA makes sense.

VNAs are based on reflection and transmission measurements. To use a VNA it is very helpful to have a basic understanding of *Scattering Parameters* (S-parameters). Microwave engineers have long used these because they have to work with circuits that are large in terms of wavelength, where measurements of forward and reflected power are easy.

HF arrays are also large in terms of wavelength. The techniques for measuring forward and reverse powers work well even at 160 meters. For example, even though the array elements may be 100 feet apart, you can place your instruments in a central location and run cables out to each element. The effect of the cables from the VNA to the elements can be absorbed in the initial calibration procedure so the measurements read out at the VNA are effectively those at each element. In other words, the measurement reference points can be placed electrically at the base of the element, regardless of the physical location of the instrumentation and the interconnecting cables.

In a completed array with its feed network, the network can be excited by the VNA at the feed point and the relative current amplitudes and phases at each element can be measured over a frequency band. Then, adjustments can be made as needed. When the final values for the current amplitudes and phases are known, these values can be put back into an array model in a program like *EZNEC* to determine the pattern of the array across the whole frequency band.

S-PARAMETERS

In Chapter 24, Transmission Lines, the reflection coefficient rho (ρ) is defined as the ratio of the reflected voltage (V_r) to the incident voltage (V_i):

$$\rho = \frac{V_r}{V_i} \qquad \text{(Eq 30)}$$

If we know the load impedance (Z_L) and the transmission line impedance (Z_0) we can calculate ρ from:

$$\rho = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad \text{(Eq 31)}$$

Keep in mind that ρ is a complex number (a vector), which we represent by either amplitude and phase (|Z|, θ) or by real and imaginary parts ($R \pm j X$). The two representations are equivalent. From ρ we can then calculate SWR. That's very handy, but here we want to do something different. If we have an instrument that measures ρ and we know Z_0 then we can determine Z_L from:

$$Z_L = Z_0 \left(\frac{1+\rho}{1-\rho} \right) \qquad \text{(Eq 32)}$$

Measuring ρ is one of the things that VNAs do very well. With a VNA, the measurement can be made at one end of a long transmission line with the load at the other end. The effect of the line can be calibrated out, as mentioned above, so that we are in effect measuring right at the load.

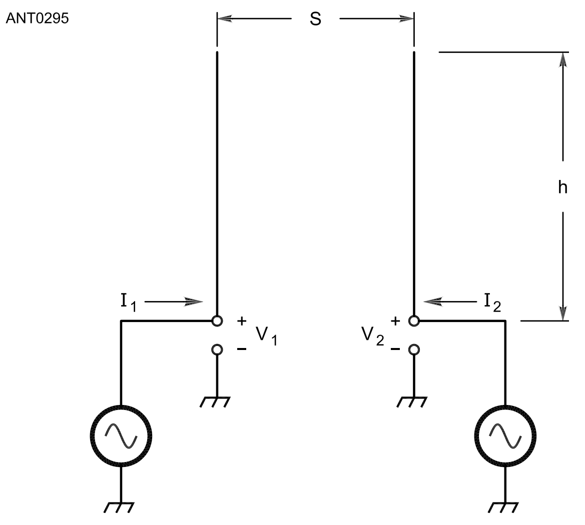

Fig 65—A 2-element array, where h is the element height and S is the spacing between the elements.

This approach can be used directly to measure the impedance and resonant frequency of a single element. By open and short circuiting elements in an array we can determine the mutual as well as self impedances for, and between, all the elements. We can also use this approach to measure component values, inductor Qs, etc.

This is an example of a *one-port* measurement; that is, a load at the end of a transmission line. However, a multi-element array actually behaves as a multi-port network, so to get the most out of a VNA, you need to generalize the above procedure. This is where S-parameters come into play. To illustrate the principles we will use a simple 2-element array like that shown in **Fig 65**.

To design a feed network to drive this array we need to know the input impedance of each element (Z_1 and Z_2) as a function of the drive currents (I_1 and I_2). The input impedances will depend on the self impedance of each element, the coupling between them (the mutual impedance) and the drive currents in each element. To manage this problem we can represent a 2-element array as a two-port network, as shown in **Fig 66**. And we can relate the port voltages, currents and impedances with Eq 33:

$$\begin{aligned} V_1 &= Z_{11}I_1 + Z_{12}I_2 \\ V_2 &= Z_{21}I_1 + Z_{22}I_2 \end{aligned} \qquad \text{(Eq 33)}$$

Normally we know I_1 and I_2 from the design of the array, but we need to determine the resulting element impedances. That's the challenge. Fortunately, an array is a linear network, so $Z_{12} = Z_{21}$, which means we need only determine three variables: the self impedances Z_{11} and Z_{22} and the mutual impedance, Z_{12}.

Once we know Z_{11}, $Z_{12,}$ Z_{22} and are given I_1 and I_2, we can determine the feed-point impedances at each element from:

$$\begin{aligned} Z_1 &= Z_{11} + \left(\frac{I_2}{I_1}\right) Z_{12} \\ Z_2 &= Z_{22} + \left(\frac{I_1}{I_2}\right) Z_{12} \end{aligned} \qquad \text{(Eq 34)}$$

This is the conventional approach. However, there are some problems here. We have to be able to accurately measure either voltages and currents or impedances in multiple elements that may be separated by large fractions of a wavelength. In addition, accurate measurements of current, voltage and impedance become increasingly more difficult as we go up in frequency.

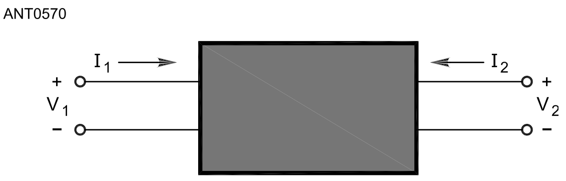

Fig 66—Two-port representation of currents and voltages in the 2-element array in Fig 65.

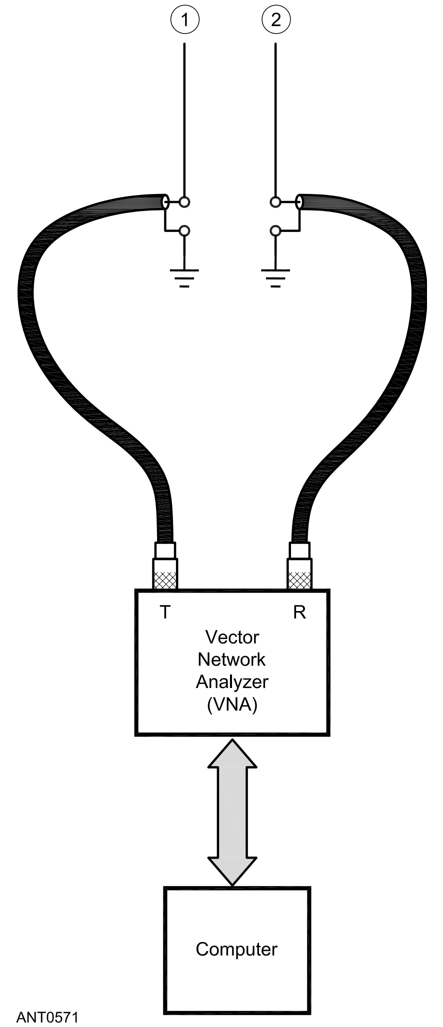

Fig 67—Test setup to measure a 2-element array using a VNA.

It turns out that we can get the information more easily by measuring incident and reflected voltages at the ports and from those measurements determine the feed-point impedances. A VNA is an instrument for measuring these voltages. It turns out to be easier to measure the ratios of two voltages rather than their absolute values.

The measurement setup using a VNA for a 2-element array is shown in **Fig 67**. VNAs usually have at least two RF connections: the transmit port (T) and the receive port (R). Professional units may have more RF connections. The T output provides an signal from a 50-Ω source and the R port is a detector with a 50-Ω input impedance. Basically we have a transmitter and a receiver. The transmit port uses a directional coupler to provide measurements of the forward and reflected signals at that output. The receive port measures the signal transmitted through the network. Transmission lines usually have $Z_0 = 50\ \Omega$ and may be of any length required by the size of the array.

Using incident and reflected voltages, the two-port network representation is now changed, as shown in **Fig 68**, where:

V_{1i} = incident voltage at port 1
V_{1r} = reflected voltage at port 1
V_{2i} = incident voltage at port 2
V_{2r} = reflected voltage at port 2

In a manner analogous to Eq 33, we can write an expression in terms of the incident and reflected voltages:

$$\begin{aligned} b_1 &= S_{11}a_1 + S_{12}a_2 \\ b_2 &= S_{21}a_1 + S_{22}a_2 \end{aligned} \qquad \text{(Eq 35)}$$

where:

$$\begin{aligned} &a_1 \frac{V_{1i}}{\sqrt{Z_0}} \qquad b_1 \frac{V_{1r}}{\sqrt{Z_0}} \\ &a_2 = \frac{V_{2i}}{\sqrt{Z_0}} \qquad b_2 = \frac{V_{2r}}{\sqrt{Z_0}} \end{aligned} \qquad \text{(Eq 36)}$$

We see that the a_n and b_n are simply the incident and reflected voltages at the two ports divided by $\sqrt{Z_o}$. Because this is a linear network, $S_{21} = S_{12}$.

What are the S_{ij} quantities? These are called the *S-parameters*, which are defined by:

$$\begin{aligned} S_{11} &\equiv \left.\frac{b_1}{a_1}\right|_{a_2=0} = \left.\frac{V_{1r}}{V_{1i}}\right|_{V_{2i}=0} \\ S_{21} &\equiv \left.\frac{b_2}{a_1}\right|_{a_2=0} = \left.\frac{V_{2r}}{V_{1i}}\right|_{V_{2i}=0} \\ S_{12} &\equiv \left.\frac{b_1}{a_2}\right|_{a_1=0} = \left.\frac{V_{1r}}{V_{2i}}\right|_{V_{1i}=0} \\ S_{22} &\equiv \left.\frac{b_2}{a_2}\right|_{a_1=0} = \left.\frac{V_{2r}}{V_{2i}}\right|_{V_{1i}=0} \end{aligned} \qquad \text{(Eq 37)}$$

Note that the S_{ij} parameters are all ratios of reflected and incident voltages, and they are usually complex numbers. The condition that $a_2 = 0 = V_{2i}$ is the same as saying that port 2 is terminated in a load equal to Z_0 and the network is excited at port 1. This means there is no reflection from the load on port 2, which makes $V_{2i} = 0$. Similarly, if we terminate port 1 with Z_0 and excite port 2, then $V_{1i} = 0 = a_1$.

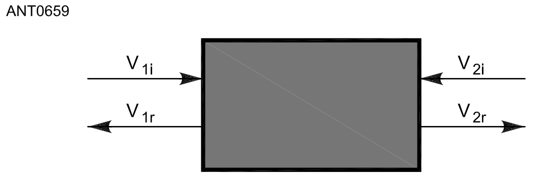

Fig 68—Two-port network with incident and reflected waves.

If we compare Eq 30 to the first line of Eq 37 we see that $S_{11} = \rho_1$, the reflection coefficient at port 1. We can now restate Eq 32 in terms of S_{11}:

$$Z = Z_0\left(\frac{1+S_{11}}{1-S_{11}}\right) \qquad \text{(Eq 38)}$$

where Z is the impedance looking into port 1 with port 2 terminated in Z_0. In the case where port 2 does not exist—that is, you are measuring a single element (for example, measuring element 1 with element 2 open-circuited) or a component, then Z is simply the self impedance (Z_{11} in Eq 33). Since S_{11} is a standard measurement for VNAs you can calculate Z using Eq 38. In many cases the VNA software will do this calculation for you automatically. You can also measure element 2 with element 1 open and determine Z_{22}.

S_{21} represents the ratio of the signal coming out of port 2 (V_{2r}) to the input signal on port 1 (V_{1i}) and is another standard VNA measurement. S_{21} is a measurement of the signal transmission between the ports through the network, or in the case of an array, the signal transmission due to the coupling between the elements. Again, port 2 is terminated in Z_0.

A full-feature VNA will measure all the S_{ij} parameters at once, but most of the lower-cost units of interest to amateurs are what we call *reflection-transmission test sets*. What this means is that they only measure S_{11} and S_{21}. To obtain S_{22} and S_{12} we have to interchange the test cables at the array elements (see Fig 67) and run the measurements again. Normally the software will accommodate this as a second entry and we end up with the full set of S_{ij} parameters.

If we do run a full set of S_{ij} parameters then we can transform these to Z_{ij} (Eq 33) using the following expressions, assuming that $S_{21} = S_{12}$:

$$\begin{aligned} Z_{11} &= \frac{(1+S_{11})(1-S_{22})+S_{12}^{\,2}}{(1-S_{11})(1-S_{22})-S_{12}^{\,2}} \\ Z_{22} &= \frac{(1-S_{11})(1+S_{22})+S_{12}^{\,2}}{(1-S_{11})(1-S_{22})-S_{12}^{\,2}} \\ Z_{12} &= \frac{(2S_{12})}{(1-S_{11})(1-S_{22})-S_{12}^{\,2}} \end{aligned} \qquad \text{(Eq 39)}$$

The example to this point has been for a 2-element array. The S-parameters can be determined for an array with any number of elements. In an n-port S-parameter measurement, all ports are terminated in Z_0 at the same time. Measurements are made between one set of ports at a time and repeated until all pairs of ports are measured.

ARRAY MEASUREMENT EXAMPLE

A good way to illustrate the use of a VNA for array measurements is to work through an example with a real array. **Fig 69** is a picture of a 2-element 20-meter phased array built by Mark Perrin, N7MQ.

Each element is λ/4 (self resonant at 14.150 MHz) and spaced λ/4 (17 feet 5 inches). In the ideal case, both elements would have the same current amplitude with a 90º phase difference. This gives the cardioid pattern shown in Chapter 8, Multielement Arrays. There are many schemes for correctly feeding such an array. The one used in this example uses two different 75-Ω transmission lines (one λ/4 and the other λ/2, electrically), as described by Roy Lewallen, W7EL.[2,3]

The first task is to resonate the elements individually. With the VNA set to measure S_{11} phase, we will get a graph like that shown in **Fig 70**.

At the λ/4 resonant frequency (f_r) we will see a sharp phase transition as we go from –180° to +180°. This is typical of any series resonant circuit. The length of each element is adjusted until the desired f_r is achieved. This is a very sensitive measurement. You can see the shift in f_r due to the wind blowing, the length of the element changing as it heats up in the sun or any interactions between the feed line and the antenna as you move the feed line around. In fact this is very good point in the process to make sure everything is mechanically stable and free of unexpected couplings. Usually you will find it necessary place choke baluns on each element to reduce stray coupling.

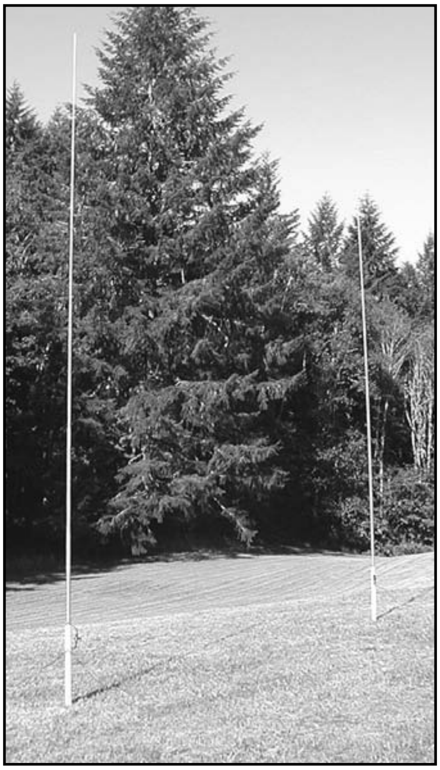

Fig 69—2-element 20-meter phased array (*Photo courtesy N7MQ*).

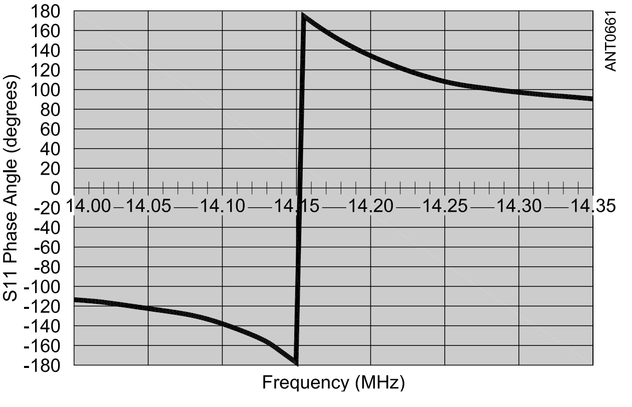

Fig 70—S_{11} phase plot for an individual element.

The next step is to determine the self (Z_{11} and Z_{22}) and mutual (Z_{12}) impedances from which the actual driving point impedances present when the array is excited can be determined. See Chapter 8, Multielement Arrays. There are two ways to go.

First, we can simply use the VNA as an impedance bridge—ie, make two S_{11} measurements at one element, first with the other element open (Z_{11} or Z_{22}) and then with it shorted (Z_1 or Z_2). We can convert the S_{11} measurements to impedances using Eq 38. The value for Z_{12} can be obtained from Eq 40:

$$Z_{12} = \pm\sqrt{Z_{11}\left(Z_{11} - Z_1\right)}$$
$$Z_{12} = \pm\sqrt{Z_{22}\left(Z_{22} - Z_2\right)} \qquad \text{(Eq 40)}$$

The second approach is to do a full two-port S-parameter measurement (S_{11}, S_{21}, S_{12} and S_{22}) and derive the impedances using Eq 38. Both approaches will work but the second approach has the advantage that the ± ambiguity in Eq 40 is eliminated.

For this example, the impedance values from the measurements at 14.150 MHz, turn out to be:

$$\begin{aligned} Z_{11} &= 51.4 + j\,0.35 \\ Z_{22} &= 50.3 + j\,0.299 \\ Z_{12} &= 15.06 - j\,19.26 \end{aligned} \qquad \text{(Eq 41)}$$

With these values we can now determine the feed-point impedances from:

$$\begin{aligned} Z_1' &= Z_{11} + \frac{I_2}{I_1} Z_{12} \\ Z_2' &= Z_{22} + \frac{I_1}{I_2} Z_{12} \\ \frac{I_1}{I_2} &= -j \end{aligned} \qquad \text{(Eq 42)}$$

Note that –*j* represents the 90° phase shift between the currents. Substituting the values from Eq 41 into Eq 42:

$$\begin{aligned} Z_1' &= 32.09 - j\,14.7 \\ Z_2' &= 69.6 + j\,15.32 \end{aligned} \qquad \text{(Eq 43)}$$

With these impedances in hand we can now design the feed network. In this particular example however, we have decided to use the λ/4 and λ/2 cables as described by Lewallen[2,3] and accept the results. So we now proceed to cut and trim the two cables to length.

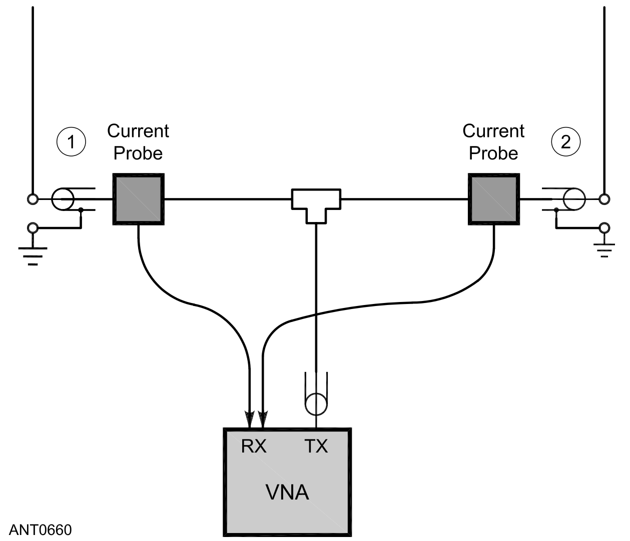

Fig 71—Current phase and amplitude ratio test setup.

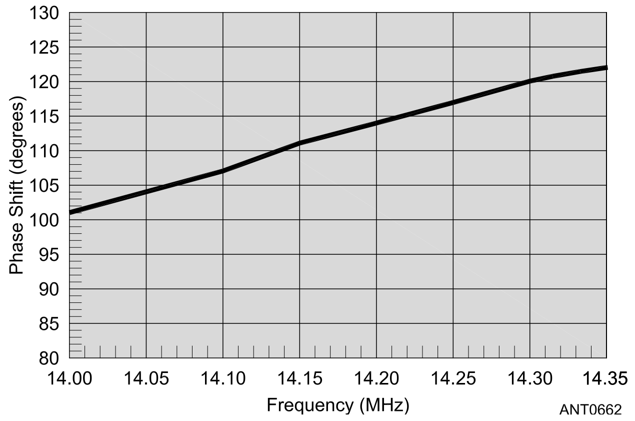

Fig 73—Measured relative current phase shift over the 20-meter band.

Again, there are two ways to go. First we can determine the frequency at which each cable is λ/4 long. At this point the input impedance of the cable will be equivalent to a series-resonant circuit and we can simply measure the phase of S_{11} as we did earlier for f_r and get a plot like that shown in Fig 70. In this example the λ/4 resonant frequencies of the two cables are 7.075 MHz and 14.150 MHz.

The second approach would be to measure S_{21} for each cable at 14.150 MHz. The phase shift in S_{21} tells you how long the cable is, in degrees, at a given frequency. Because there is a small variation in cable characteristics with frequency (dispersion) this approach is slightly more accurate since it is done at the desired operating frequency. But this is not very large effect at HF.

This brings us down to the final measurements, which are to check that the relative current amplitudes and phases between the two elements are correct. We can then determine the feed-point SWR. The phase and amplitude ratios are made using the S_{12} capability of the VNA and the test setup shown in **Fig 71**.

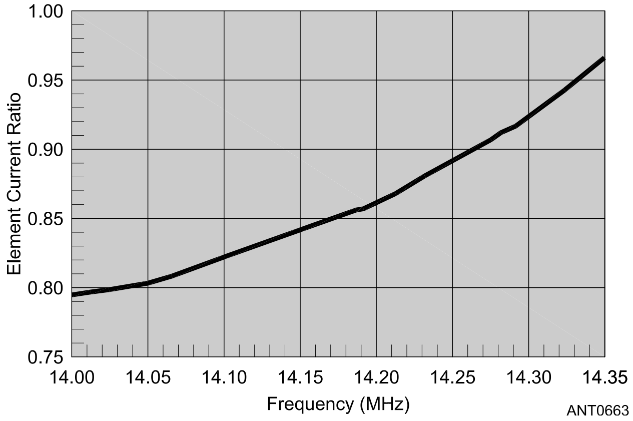

Fig 72—Measured element current ratio over the 20-meter band.

The VNA transmit port is connected to the normal feed point. A current sensor (see Chapter 8, Multielement Arrays, for a discussion of current sensors) is inserted at the base of element 1 and the output of the sensor is returned to the detector or receive port of the VNA. A calibration run is then made to normalize this path. That makes it the reference.

Next, the current sensor is shifted to element 2. The amplitude and phase plots for S_{12} obtained at this point will be the desired relative phase shift and amplitude ratio between the currents in the array when driven at the normal feed point. **Figs 72** and **73** show the behavior of the example array over the 20-meter band. Note that the amplitude ratio has been converted from dB. We can now use these values in a *EZNEC* model of the array to determine the actual radiation pattern.

Obviously the W7EL feed scheme is not perfect, but it has a definite advantage of simplicity. If better performance is desired we can use the values of Z_1' and Z_2' determined earlier to design and fabricate a new feed network and then proceed to evaluate its performance in the same way.

The final measurement is to connect the transmit port of the VNA to the feed point and measure S_{11}. From this we can calculate the SWR:

$$\mathrm{SWR} = \frac{1+|S_{11}|}{1-|S_{11}|} \qquad \text{(Eq 44)}$$

In this example, the return loss, $|S_{11}|$, is about –19 dB over the entire 20-meter band. This corresponds to SWR= 1.25:1.

Notes

[1] Paul Kiciak, N2PK, **http://n2pk.com**.

[2] Roy Lewallen, W7EL, *QST*, Aug 1979, Technical Correspondence, pp 42-43.

[3] Orr and Cowan, *Vertical Antennas*, Radio Amateur Call Book, 1986, pp 148-150.

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Chapter 28

Smith Chart Calculations

The Smith Chart is a sophisticated graphic tool for solving transmission line problems. One of the simpler applications is to determine the feed-point impedance of an antenna, based on an impedance measurement at the input of a random length of transmission line. By using the Smith Chart, the impedance measurement can be made with the antenna in place atop a tower or mast, and there is no need to cut the line to an exact multiple of half wavelengths. The Smith Chart may be used for other purposes, too, such as the design of impedance-matching networks. These matching networks can take on any of several forms, such as L and pi networks, a stub matching system, a series-section match, and more. With a knowledge of the Smith Chart, the amateur can eliminate much "cut and try" work.

Named after its inventor, Phillip H. Smith, the Smith Chart was originally described in *Electronics* for January 1939. Smith Charts may be obtained at most university book stores. Smith Charts are also available from ARRL HQ. (See the caption for Fig 3.)

It is stated in Chapter 24 that the input impedance, or the impedance seen when "looking into" a length of line, is dependent upon the SWR, the length of the line, and the Z_0 of the line. The SWR, in turn, is dependent upon the load which terminates the line. There are complex mathematical relationships which may be used to calculate the various values of impedances, voltages, currents, and SWR values that exist in the operation of a particular transmission line. These equations can be solved with a personal computer and suitable software, or the parameters may be determined with the Smith Chart. Even if a computer is used, a fundamental knowledge of the Smith Chart will promote a better understanding of the problem being solved. And such an understanding might lead to a quicker or simpler solution than otherwise. If the terminating impedance is known, it is a simple matter to determine the input impedance of the line for any length by means of the chart. Conversely, as indicated above, with a given line length and a known (or measured) input impedance, the load impedance may be determined by means of the chart—a convenient method of remotely determining an antenna impedance, for example.

Although its appearance may at first seem somewhat formidable, the Smith Chart is really nothing more than a specialized type of graph. Consider it as having curved, rather than rectangular, coordinate lines. The coordinate system consists simply of two families of circles—the resistance family, and the reactance family. The resistance circles, **Fig 1**, are centered on the resistance axis (the only straight line on the chart), and are tangent to the outer circle at the right of the chart. Each circle is assigned a value of resistance, which is indicated at the point where the circle crosses the resistance axis. All points along any one circle have the same resistance value.

The values assigned to these circles vary from zero at the left of the chart to infinity at the right, and actually represent a *ratio* with respect to the impedance value assigned to the center point of the chart, indicated 1.0. This center point is called prime center. If prime center is assigned a value of 100 Ω, then 200 Ω resistance is represented by the 2.0 circle, 50 Ω by the 0.5 circle, 20 Ω by the 0.2 circle, and so on. If, instead, a value of 50 is assigned to prime center,

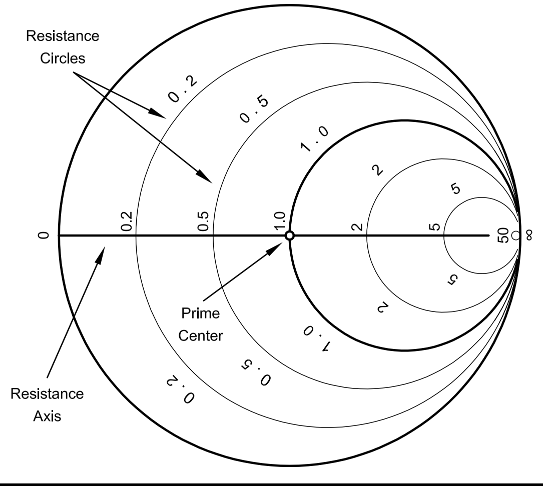

Fig 1—Resistance circles of the Smith Chart coordinate system.

the 2.0 circle now represents 100 Ω, the 0.5 circle 25 Ω, and the 0.2 circle 10 Ω. In each case, it may be seen that the value on the chart is determined by dividing the actual resistance by the number assigned to prime center. This process is called normalizing.

Conversely, values from the chart are converted back to actual resistance values by multiplying the chart value times the value assigned to prime center. This feature permits the use of the Smith Chart for any impedance values, and therefore with any type of uniform transmission line, whatever its impedance may be. As mentioned above, specialized versions of the Smith Chart may be obtained with a value of 50 Ω at prime center. These are intended for use with 50-Ω lines.

Now consider the reactance circles, **Fig 2**, which appear as curved lines on the chart because only segments of the complete circles are drawn. These circles are tangent to the resistance axis, which itself is a member of the reactance family (with a radius of infinity). The centers are displaced to the top or bottom on a line tangent to the right of the chart. The large outer circle bounding the coordinate portion of the chart is the reactance axis.

Each reactance circle segment is assigned a value of reactance, indicated near the point where the circle touches the reactance axis. All points along any one segment have the same reactance value. As with the resistance circles, the values assigned to each reactance circle are normalized with respect to the value assigned to prime center. Values to the top of the resistance axis are positive (inductive), and those to the bottom of the resistance axis are negative (capacitive).

When the resistance family and the reactance family of circles are combined, the coordinate system of the Smith Chart results, as shown in **Fig 3**. Complex impedances (R + *j*X) can be plotted on this coordinate system.

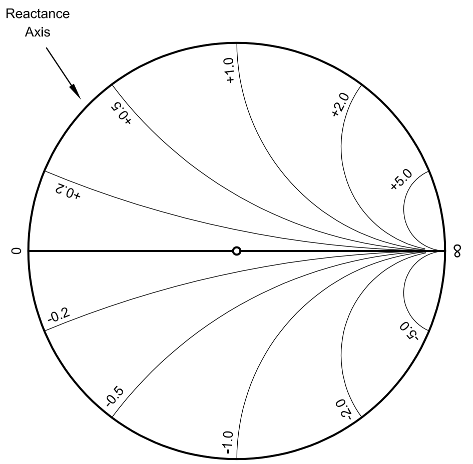

Fig 2—Reactance circles (segments) of the Smith Chart coordinate system.

IMPEDANCE PLOTTING

Suppose we have an impedance consisting of 50 Ω resistance and 100 Ω inductive reactance (Z = 50 + *j* 100). If we assign a value of 100 Ω to prime center, we normalize the above impedance by dividing each component of the impedance by 100. The normalized impedance is then 50/100 + *j* (100/100) = 0.5 + *j* 1.0. This impedance is plotted on the Smith Chart at the intersection of the 0.5 resistance circle and the +1.0 reactance circle, as indicated in Fig 3. Calculations may now be made from this plotted value.

Now say that instead of assigning 100 Ω to prime center, we assign a value of 50 Ω. With this assignment, the 50 + *j* 100 Ω impedance is plotted at the intersection of the 50/50 = 1.0 resistance circle, and the 100/50 = 2.0 positive reactance circle. This value, 1 + *j* 2, is also indicated in Fig 3. But now we have *two* points plotted in Fig 3 to represent the same impedance value, 50 + *j* 100 Ω. How can this be?

These examples show that the same impedance may be plotted at different points on the chart, depending upon the value assigned to prime center. But two plotted points cannot represent the same impedance *at the same time*! It is customary when solving transmission-line problems to assign to prime center a value equal to the characteristic impedance, or Z_0, of the line being used. This value should always be recorded at the start of calculations, to avoid possible confusion later. (In using the specialized charts with the value of 50 at prime center, it is, of course, not necessary to normalize impedances when working with 50-Ω line. The resistance and reactance values may be read directly from the chart coordinate system.)

Prime center is a point of special significance. As

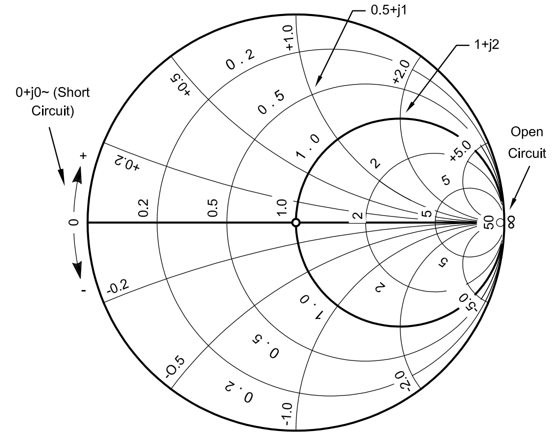

Fig 3—The complete coordinate system of the Smith Chart. For simplicity, only a few divisions are shown for the resistance and reactance values. Various types of Smith Chart forms are available from ARRL HQ. At the time of this writing, five 8½ × 11 inch Smith Chart forms are available for $2.

just mentioned, is is customary when solving problems to assign the Z_0 value of the line to this point on the chart—50 Ω for a 50-Ω line, for example. What this means is that the center point of the chart now represents 50 +*j* 0 ohms–a pure resistance equal to the characteristic impedance of the line. If this were a load on the line, we recognize from transmission-line theory that it represents a perfect match, with no reflected power and with a 1.0 to 1 SWR. Thus, prime center also represents the 1.0 SWR circle (with a radius of zero). SWR circles are also discussed in a later section.

Short and Open Circuits

On the subject of plotting impedances, two special cases deserve consideration. These are short circuits and open circuits. A true short circuit has zero resistance and zero reactance, or 0 + *j* 0). This impedance is plotted at the left of the chart, at the intersection of the resistance and the reactance axes. By contrast, an open circuit has infinite resistance, and therefore is plotted at the right of the chart, at the intersection of the resistance and reactance axes. These two special cases are sometimes used in matching stubs, described later.

Standing-Wave-Ratio Circles

Members of a third family of circles, which are not printed on the chart but which are added during the process of solving problems, are standing-wave-ratio or SWR circles. See **Fig 4**. This family is centered on prime center, and appears as concentric circles inside the reactance axis. During calculations, one or more of these circles may be added with a drawing compass. Each circle represents a value of SWR, with every point on a given circle representing the same SWR. The SWR value for a given circle may be determined directly from the chart coordinate system, by reading the resistance value where the SWR circle crosses the resistance axis to the right of prime center. (The reading where the circle crosses the resistance axis to the left of prime center indicates the inverse ratio.)

Consider the situation where a load mismatch in a length of line causes a 3-to-1 SWR ratio to exist. If we temporarily disregard line losses, we may state that the SWR remains constant throughout the entire length of this line. This is represented on the Smith Chart by drawing a 3:1 constant SWR circle (a circle with a radius of 3 on the resistance axis), as in **Fig 5**. The design of the chart is such that any impedance encountered *anywhere* along the length of this mismatched line will fall on the SWR circle. The impedances may be read from the coordinate system merely by the progressing around the SWR circle by an amount corresponding to the length of the line involved.

This brings into use the wavelength scales, which appear in Fig 5 near the perimeter of the Smith Chart. These scales are calibrated in terms of portions of an electrical wavelength along a transmission line. Both scales start from 0 at the left of the chart. One scale, running

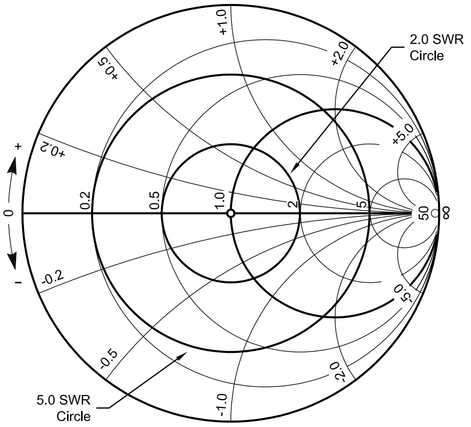

Fig 4—Smith Chart with SWR circles added.

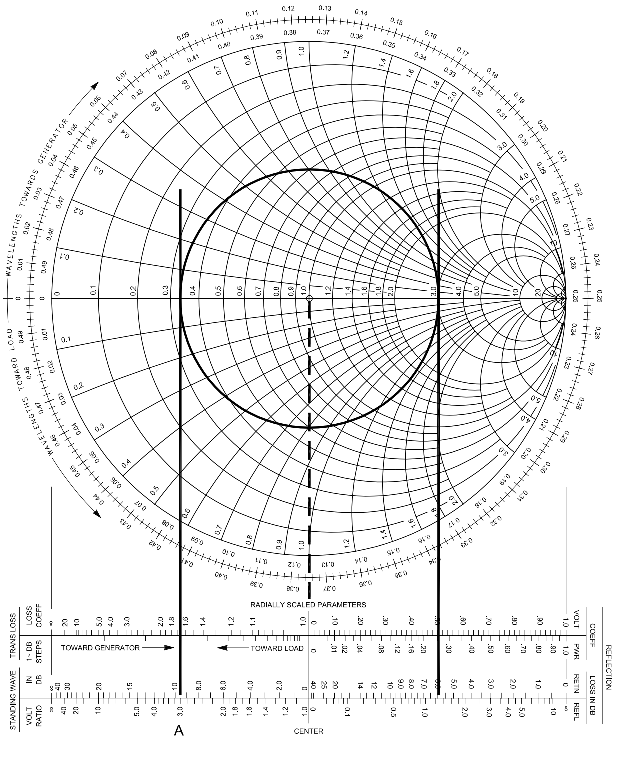

Fig 5—Example discussed in text.

counterclockwise, starts at the generator or input end of the line and progresses toward the load. The other scale starts at the load and proceeds toward the generator in a clockwise direction. The complete circle around the edge of the chart represents $^1/_2$ λ. Progressing once around the perimeter of these scales corresponds to progressing along a transmission line for $^1/_2$ λ. Because impedances repeat themselves every $^1/_2$ λ along a piece of line, the chart may be used for any length of line by disregarding or subtracting from the line's total length an integral, or whole number, of half wavelengths.

Also shown in Fig 5 is a means of transferring the radius of the SWR circle to the external scales of the chart, by drawing lines tangent to the circle. Another simple way to obtain information from these external scales is to transfer the radius of the SWR circle to the external scale with a drawing compass. Place the point of a drawing compass at the center or 0 line, and inscribe a short arc across the appropriate scale. It will be noted that when this is done in Fig 5, the external STANDING-WAVE VOLTAGE-RATIO scale indicates the SWR to be 3.0 (at A)—our condition for initially drawing the circle on the chart (and the same as the SWR reading on the resistance axis).

SOLVING PROBLEMS WITH THE SMITH CHART

Suppose we have a transmission line with a characteristic impedance of 50 Ω and an electrical length of 0.3 λ. Also, suppose we terminate this line with an impedance having a resistive component of 25 Ω and an inductive reactance of 25 Ω (Z = 25 + *j* 25). What is the input impedance to the line?

The characteristic impedance of the line is 50 Ω, so we begin by assigning this value to prime center. Because the line is not terminated in its characteristic impedance, we know that standing waves will exist on the line, and that, therefore, the input impedance to the line will not be exactly 50 Ω. We proceed as follows. First, normalize the load impedance by dividing both the resistive and reactive components by 50 (Z_0 of the line being used). The normalized impedance in this case is 0.5 + *j* 0.5. This is plotted on the chart at the intersection of the 0.5 resistance and the +0.5 reactance circles, as in **Fig 6**. Then draw a constant SWR circle passing through this point. Transfer the radius of this circle to the external scales with the drawing compass. From the external STANDING-WAVE VOLTAGE-RATIO scale, it may be seen (at A) that the voltage ratio of 2.62 exists for this radius, indicating that our line is operating with an SWR of 2.62 to 1. This figure is converted to decibels in the adjacent scale, where 8.4 dB may be read (at B), indicating that the ratio of the voltage maximum to the voltage minimum along the line is 8.4 dB. (This is mathematically equivalent to 20 times the log of the SWR value.)

Next, with a straightedge, draw a radial line from prime center through the plotted point to intersect the wavelengths scale. At this intersection, point C in Fig 6, read a value from the wavelengths scale. Because we are starting from the load, we use the TOWARD GENERATOR or outermost calibration, and read 0.088 λ.

To obtain the line input impedance, we merely find the point on the SWR circle that is 0.3 λ toward the generator from the plotted load impedance. This is accomplished by adding 0.3 (the length of the line in wavelengths) to the reference or starting point, 0.088; 0.3 + 0.088 = 0.388. Locate 0.388 on the TOWARD GENERATOR scale (at D). Draw a second radial line from this point to prime center. The intersection of the new radial line with the SWR circle represents the normalized line input impedance, in this case 0.6 – *j* 0.66.

To find the unnormalized line impedance, multiply by 50, the value assigned to prime center. The resulting value is 30 – *j* 33, or 30 Ω resistance and 33 Ω capacitive reactance. *This* is the impedance that a transmitter must match if such a system were a combination of antenna

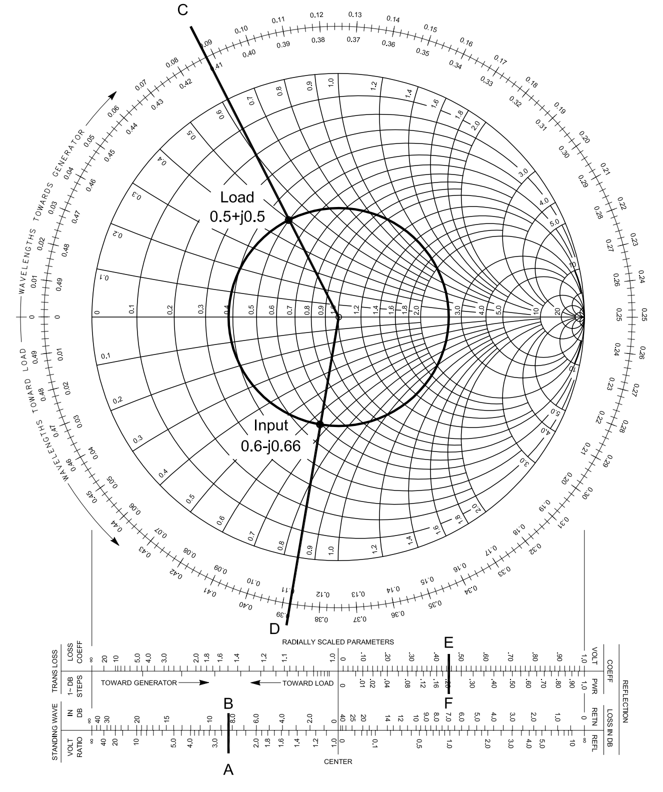

Fig 6—Example discussed in text.

and transmission line. This is also the impedance that would be measured on an impedance bridge if the measurement were taken at the line input.

In addition to the line input impedance and the SWR, the chart reveals several other operating characteristics of the above system of line and load, if a closer look is desired. For example, the voltage reflection coefficient, both magnitude and phase angle, for this particular load is given. The phase angle is read under the radial line drawn through the plot of the load impedance, where the line intersects the ANGLE OF REFLECTION COEFFICIENT scale. This scale is not included in Fig 6, but will be found on the Smith Chart just inside the wavelengths scales. In this example, the reading is 116.6 degrees. This indicates the angle by which the reflected voltage wave leads the incident wave at the load. It will be noted that angles on the bottom half, or capacitive-reactance half, of the chart are negative angles, a "negative" lead indicating that the reflected voltage wave actually lags the incident wave.

The magnitude of the voltage-reflection-coefficient may be read from the external REFLECTION COEFFICIENT VOLTAGE scale, and is seen to be approximately 0.45 (at E) for this example. This means that 45 percent of the incident voltage is reflected. Adjacent to this scale on the POWER calibration, it is noted (at F) that the power reflection coefficient is 0.20, indicating that 20 percent of the incident power is reflected. (The amount of reflected power is proportional to the square of the reflected voltage.)

ADMITTANCE COORDINATES

Quite often it is desirable to convert impedance information to admittance data—conductance and susceptance. Working with admittances greatly simplifies determining the resultant when two complex impedances are connected in parallel, as in stub matching. The conductance values may be added directly, as may be the susceptance values, to arrive at the overall admittance for the parallel combination. This admittance may then be converted back to impedance data, if desired.

On the Smith Chart, the necessary conversion may be made very simply. The equivalent admittance of a plotted impedance value lies diametrically opposite the impedance point on the chart. In other words, an impedance plot and its corresponding admittance plot will lie on a straight line that passes through prime center, and each point will be the same distance from prime center (on the same SWR circle). In the above example, where the normalized line input impedance is 0.6 – *j* 0.66, the equivalent admittance lies at the intersection of the SWR circle and the extension of the straight line passing from point D though prime center. Although not shown in Fig 6, the normalized admittance value may be read as 0.76 + *j* 0.84 if the line starting at D is extended.

In making impedance-admittance conversions, remember that capacitance is considered to be a positive susceptance and inductance a negative susceptance. This corresponds to the scale identification printed on the chart. The admittance in siemens is determined by dividing the normalized values by the Z_0 of the line. For this example the admittance is 0.76/50 + *j* 0.84/50 = 0.0152 + *j* 0.0168 siemen. Of course admittance coordinates may be converted to impedance coordinates just as easily—by locating the point on the Smith Chart that is diametrically opposite that representing the admittance coordinates, on the same SWR circle.

DETERMINING ANTENNA IMPEDANCES

To determine an antenna impedance from the Smith Chart, the procedure is similar to the previous example. The electrical length of the feed line must be known and the impedance value at the input end of the line must be determined through measurement, such as with an impedance-measuring or a good quality noise bridge. In this case, the antenna is connected to the far end of the line and becomes the load for the line. Whether the

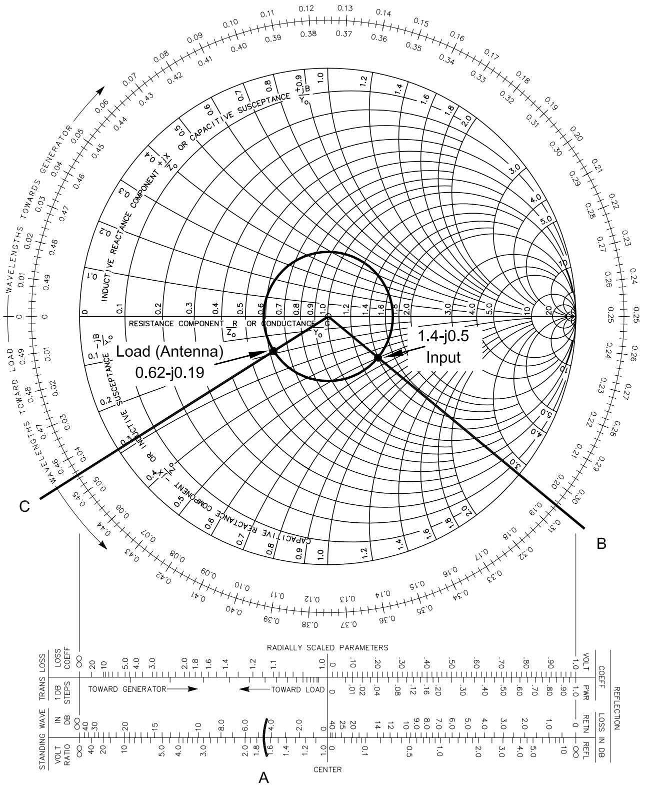
WAVELENGTHS TOWARDS GENERATOR
WAVELENGTHS TOWARD LOAD
INDUCTIVE REACTANCE COMPONENT OR CAPACITIVE SUSCEPTANCE
CAPACITIVE REACTANCE COMPONENT OR INDUCTIVE SUSCEPTANCE
RESISTANCE COMPONENT OR CONDUCTANCE
Load (Antenna)
0.62-j0.19
1.4-j0.5
Input
C
B
A
RADIALLY SCALED PARAMETERS
TOWARD GENERATOR
TOWARD LOAD
CENTER
STANDING WAVE VOLT RATIO
IN DB
TRANS LOSS 1DB STEPS
LOSS COEFF
REFLECTION COEFF VOLT
PWR
RETN LOSS IN DB
REFL.

Fig 7—Example discussed in text.

antenna is intended purely for transmission of energy, or purely for reception makes no difference; the antenna is still the terminating or load impedance on the line as far as these measurements are concerned. The input or generator end of the line is that end connected to the device for measurement of the impedance. In this type of problem, the measured impedance is plotted on the chart, and the TOWARD LOAD wavelengths scale is used in conjunction with the electrical line length to determine the actual antenna impedance.

For example, assume we have a measured input impedance to a 50-Ω line of 70 – *j* 25 Ω. The line is 2.35 λ long, and is terminated in an antenna. What is the antenna feed impedance? Normalize the input impedance with respect to 50 Ω, which comes out 1.4 – *j* 0.5, and plot this value on the chart. See **Fig 7**. Draw a constant SWR circle through the point, and transfer the radius to the external scales. The SWR of 1.7 may be read from the VOLTAGE RATIO scale (at A). Now draw a radial line from prime center through this plotted point to the wavelengths scale, and read a reference value (at B). For this case the value is 0.195, on the TOWARD LOAD scale. Remember, we are starting at the generator end of the transmission line.

To locate the load impedance on the SWR circle, add the line length, 2.35 λ, to the reference value from the wavelengths scale; 2.35 + 0.195 = 2.545. Locate the new value on the TOWARD LOAD scale. But because the calibrations extend only from 0 to 0.5, we must first subtract a number of half wavelengths from this value and use only the remaining value. In this situation, the largest integral number of half wavelengths that can be subtracted with a positive result is 5, or 2.5 λ. Thus, 2.545 – 2.5 = 0.045. Locate the 0.045 value on the TOWARD LOAD scale (at C). Draw a radial line from this value to prime center. Now, the coordinates at the intersection of the second radial line and the SWR circle represent the load impedance. To read this value closely, some interpolation between the printed coordinate lines must be made, and the value of 0.62 – *j* 0.19 is read. Multiplying by 50, we get the actual load or antenna impedance as 31 – *j* 9.5 Ω, or 31 Ω resistance with 9.5 Ω capacitive reactance.

Problems may be entered on the chart in yet another manner. Suppose we have a length of 50-Ω line feeding a base-loaded resonant vertical ground-plane antenna which is shorter than $^1/_4$ λ. Further, suppose we have an SWR monitor in the line, and that it indicates an SWR of 1.7 to 1. The line is known to be 0.95 λ long. We want to know both the input and the antenna impedances.

From the information available, we have no impedances to enter into the chart. We may, however, draw a circle representing the 1.7 SWR. We also know, from the definition of resonance, that the antenna presents a purely resistive load to the line, that is, no reactive component. Thus, the antenna impedance must lie on the resistance axis. If we were to draw such an SWR circle and observe the chart with only the circle drawn, we would see two points which satisfy the resonance requirement for the load. These points are 0.59 + *j* 0 and 1.7 + *j* 0. Multiplying by 50, we see that these values represent 29.5 and 85 Ω resistance. This may sound familiar, because, as was discussed in Chapter 24, when a line is terminated in a pure resistance, the SWR in the line equals Z_R/Z_0 or Z_0/Z_R, where Z_R=load resistance and Z_0=line impedance.

If we consider antenna fundamentals described in Chapter 2, we know that the theoretical impedance of a $^1/_4$-λ ground-plane antenna is approximately 36 Ω. We therefore can quite logically discard the 85-Ω impedance figure in favor of the 29.5-Ω value. This is then taken as the load impedance value for the Smith Chart calculations. To find the line input impedance, we subtract 0.5 λ from the line length, 0.95, and find 0.45 λ on the TOWARD GENERATOR scale. (The wavelength-scale starting point in this case is 0.) The line input impedance is found to be 0.63 – *j* 0.20, or 31.5 – *j* 10 Ω.

DETERMINATION OF LINE LENGTH

In the example problems given so far in this chapter, the line length has conveniently been stated in wavelengths. The electrical length of a piece of line depends upon its physical length, the radio frequency under consideration, and the velocity of propagation in the line. If an impedance-measurement bridge is capable of quite reliable readings at high SWR values, the line length may be determined through line input-impedance measurements with short- or open-circuit line terminations. Information on the procedure is given later in this chapter. A more direct method is to measure the physical length of the line and calculate its electrical length from

$$N = \frac{Lf}{984VF} \qquad \text{(Eq 1)}$$

where

N = number of electrical wavelengths in the line
L = line length in feet
f = frequency, MHz
VF = velocity or propagation factor of the line

The velocity factor may be obtained from transmission-line data tables in Chapter 24.

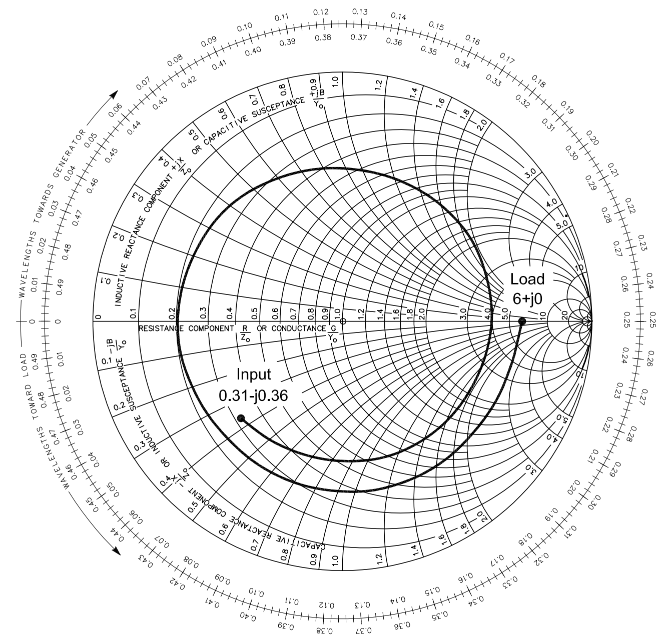

Fig 8—This spiral is the actual “SWR circle” when line losses are taken into account. It is based on calculations for a 16-ft length of RG-174 coax feeding a resonant 28-MHz 300-Ω antenna (50-Ω coax, velocity factor = 66%, attenuation = 6.2 dB per 100 ft). The SWR at the load is 6:1, while it is 3.6:1 at the line input. When solving problems involving attenuation, two constant SWR circles are drawn instead of a spiral, one for the line input SWR and one for the load SWR.

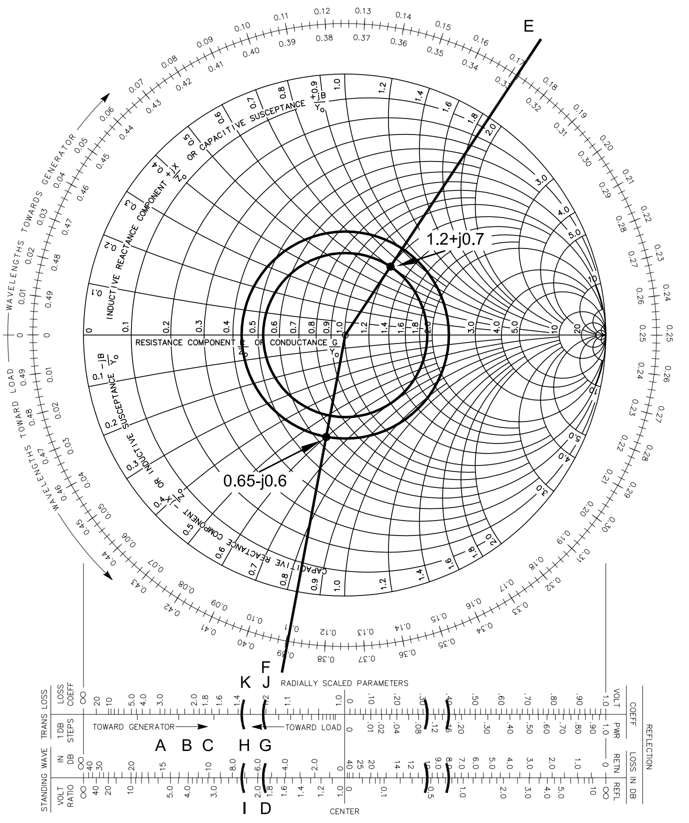

Fig 9—Example of Smith Chart calculations taking line losses into account.

LINE-LOSS CONSIDERATIONS WITH THE SMITH CHART

The example Smith Chart problems presented in the previous section ignored attenuation, or line losses. Quite frequently it is not even necessary to consider losses when making calculations; any difference in readings obtained are often imperceptible on the chart. However, when the line losses become appreciable, such as for high-loss lines, long lines, or at VHF and UHF, loss considerations may become significant in making Smith Chart calculations. This involves only one simple step, in addition to the procedures previously presented.

Because of line losses, as discussed in Chapter 24 the SWR does not remain constant throughout the length of the line. As a result, there is a decrease in SWR as one progresses away from the load. To truly present this situation on the Smith Chart, instead of drawing a constant SWR circle, it would be necessary to draw a spiral inward and clockwise from the load impedance toward the generator, as shown in **Fig 8**. The rate at which the curve spirals toward prime center is related to the attenuation in the line. Rather than drawing spiral curves, a simpler method is used in solving line-loss problems, by means of the external scale TRANSMISSION LOSS 1-DB STEPS. This scale may be seen in **Fig 9**. Because this is only a relative scale, the decibel steps are not numbered.

If we start at the left end of this external scale and proceed in the direction indicated TOWARD GENERATOR, the first dB step is seen to occur at a radius from center corresponding to an SWR of about 9 (at A); the second dB step falls at an SWR of about 4.5 (at B), the third at 3.0 (at C), and so forth, until the

15th dB step falls at an SWR of about 1.05 to 1. This means that a line terminated in a short or open circuit (infinite SWR), and having an attenuation of 15 dB, would exhibit an SWR of only 1.05 at its input. It will be noted that the dB steps near the right end of the scale are very close together, and a line attenuation of 1 or 2 dB in this area will have only slight effect on the SWR. But near the left end of the scale, corresponding to high SWR values, a 1 or 2 dB loss has considerable effect on the SWR.

Using a Second SWR Circle

In solving a problem using line-loss information, it is necessary only to modify the radius of the SWR circle by an amount indicated on the TRANSMISSION-LOSS 1-DB STEPS scale. This is accomplished by drawing a second SWR circle, either smaller or larger than the first, depending on whether you are working toward the load or toward the generator.

For example, assume that we have a 50-Ω line that is 0.282 λ long, with 1-dB inherent attenuation. The line input impedance is measured as 60 + *j* 35 Ω. We desire to know the SWR at the input and at the load, and the load impedance. As before, we normalize the 60 + *j* 35-Ω impedance, plot it on the chart, and draw a constant SWR circle and a radial line through the point. In this case, the normalized impedance is 1.2 + *j* 0.7. From Fig 9, the SWR at the line input is seen to be 1.9 (at D), and the radial line is seen to cross the TOWARD LOAD scale, first subtract 0.500, and locate 0.110 (at F); then draw a radial line from this point to prime center.

To account for line losses, transfer the radius of the SWR circle to the external 1-DB STEPS scale. This radius crosses the external scale at G, the fifth decibel mark from the left. Since the line loss was given as 1 dB, we strike a new radius (at H), one "tick mark" to the left (toward load) on the same scale. (This will be the fourth decibel tick mark from the left of the scale.) Now transfer this new radius back to the main chart, and scribe a new SWR circle of this radius. This new radius represents the SWR at the load, and is read as 2.3 on the external VOLTAGE RATIO scale. At the intersection of the new circle and the load radial line, we read 0.65 – *j* 0.6. This is the normalized load impedance. Multiplying by 50, we obtain the actual load impedance as 32.5 – *j* 30 Ω. The SWR in this problem was seen to increase from 1.9 at the line input to 2.3 (at I) at the load, with the 1-dB line loss taken into consideration.

In the example above, values were chosen to fall conveniently on or very near the "tick marks" on the 1-dB scale. Actually, it is a simple matter to interpolate between these marks when making a radius correction. When this is necessary, the relative distance between marks for each decibel step should be maintained while counting off the proper number of steps.

Adjacent to the 1-DB STEPS scale lies a LOSS COEFFICIENT scale. This scale provides a factor by which the matched-line loss in decibels should be multiplied to account for the increased losses in the line when standing waves are present. These added losses do not affect the SWR or impedance calculations; they are merely the additional dielectric copper losses of the line caused by the fact that the line conducts more average voltage in the presence of standing waves. For the above example, from Fig 9, the loss coefficient at the input end is seen to be 1.21 (at J), and 1.39 (at K) at the load. As a good approximation, the loss coefficient may be averaged over the length of line under consideration; in this case, the average is 1.3. This means that the total losses in the line are 1.3 times the matched loss of the line (1 dB), or 1.3 dB. This is the same result that may be obtained from procedures given in Chapter 24 for this data.

Smith Chart Procedure Summary

To summarize briefly, any calculations made on the Smith Chart are performed in four basic steps, although not necessarily in the order listed.

1) Normalize and plot a line input (or load) impedance, and construct a constant SWR circle.
2) Apply the line length to the wavelengths scales.
3) Determine attenuation or loss, if required, by means of a second SWR circle.
4) Read normalized load (or input) impedance, and convert to impedance in ohms.

The Smith Chart may be used for many types of problems other than those presented as examples here. The transformer action of a length of line—to transform a high impedance (with perhaps high reactance) to a purely resistive impedance of low value—was not mentioned. This is known as "tuning the line," for which the chart is very helpful, eliminating the need for "cut and try" procedures. The chart may also be used to calculate lengths for shorted or open matching stubs in a system, described later in this chapter. In fact, in any application where a transmission line is not perfectly matched, the Smith Chart can be of value.

ATTENUATION AND Z_0 FROM IMPEDANCE MEASUREMENTS

If an impedance bridge is available to make accurate measurements in the presence of very high SWR values, the attenuation, characteristic impedance and velocity factor of any random length of coaxial transmission line can be determined. This section was written by Jerry Hall, K1TD.

Homemade impedance bridges and noise bridges will seldom offer the degree of accuracy required to use this technique, but sometimes laboratory bridges can be found as industrial surplus at a reasonable price. It may also be possible for an amateur to borrow a laboratory type of bridge for the purpose of making some weekend measurements. Making these determinations is not difficult, but the procedure is not commonly known among amateurs. One equation treating complex numbers is used, but the math can be handled with a calculator supporting trig functions. Full details are given in the paragraphs that follow.

For each frequency of interest, two measurements are required to determine the line impedance. Just one measurement is used to determine the line attenuation and velocity factor. As an example, assume we have a 100-foot length of unidentified line with foamed dielectric, and wish to know its characteristics. We make our measurements at 7.15 MHz. The procedure is as follows.

1) Terminate the line in an open circuit. The best "open circuit" is one that minimizes the capacitance between the center conductor and the shield. If the cable has a PL-259 connector, unscrew the shell and slide it back down the coax for a few inches. If the jacket and insulation have been removed from the end, fold the braid back along the outside of the line, away from the center conductor.
2) Measure and record the impedance at the input end of the line. If the bridge measures admittance, convert the measured values to resistance and reactance. Label the values as $R_{oc} + j\,X_{oc}$. For our example, assume we measure $85 + j179\ \Omega$. (If the reactance term is capacitive, record it as negative.)
3) Now terminate the line in a short circuit. If a connector exists at the far end of the line, a simple short is a mating connector with a very short piece of heavy wire soldered between the center pin and the body. If the coax has no connector, removing the jacket and center insulation from a half inch or so at the end will allow you to tightly twist the braid around the center conductor. A small clamp or alligator clip around the outer braid at the twist will keep it tight.
4) Again measure and record the impedance at the input end of the line. This time label the values as $R_{sc} \pm j\,X$. Assume the measured value now is $4.8 - j\,11.2\ \Omega$.

This completes the measurements. Now we reach for the calculator.

As amateurs we normally assume that the characteristic impedance of a line is purely resistive, but it can (and does) have a small capacitive reactance component. Thus, the Z_0 of a line actually consists of $R_0 + j\,X_0$. The basic equation for calculating the characteristic impedance is

$$Z_0 = \sqrt{Z_{oc} \times Z_{sc}} \qquad \text{(Eq 2)}$$

where

$Z_{oc} = R_{oc} + jX_{oc}$

$Z_{sc} = R_{sc} + jX_{sc}$

From Eq 2 the following working equation may be derived.

$$Z_0 = \sqrt{\left(R_{oc}R_{sc} - X_{oc}X_{sc}\right) + j\left(R_{oc}X_{sc} + R_{sc}X_{oc}\right)} \qquad \text{(Eq 3)}$$

The expression under the radical sign in Eq 3 is in the form of $R + j\,X$. By substituting the values from our example into Eq 3, the R term becomes $85 \times 4.8 - 179 \times (-11.2) = 2412.8$, and the X term becomes $85 \times (-11.2) + 4.8 \times 179 = -92.8$. So far, we have determined that

$$Z_0 = \sqrt{2412.8 - j\,92.8}$$

The quantity under the radical sign is in rectangular form. Extracting the square root of a complex term is handled easily if it is in polar form, a vector value and its angle. The vector value is simply the square root of the sum of the squares, which in this case is

$$\sqrt{2412.8^2 + 92.8^2} = \sqrt{2414.58}$$

The tangent of the vector angle we are seeking is the value of the reactance term divided by the value of the resistance term. For our example this is arctan –92.8/2412.8 = arctan –0.03846. The angle is thus found to be –2.20°. From all of this we have determined that

$$Z_0 = \sqrt{2414.58\ \underline{/-2.20°}}$$

Extracting the square root is now simply a matter of finding

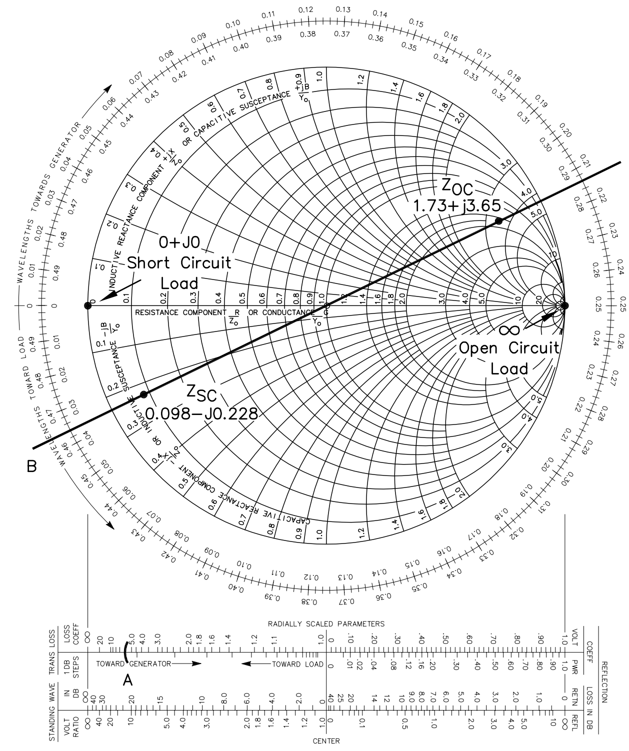

Fig 10—Determining the line loss and velocity factor with the Smith Chart from input measurements taken with open-circuit and short-circuit terminations.

the square root of the vector value, and taking half the angle. (The angle is treated mathematically as an exponent.)

Our result for this example is $Z_0 = 49.1\underline{/-1.1^\circ}$. The small negative angle may be ignored, and we now know that we have coax with a nominal 50-Ω impedance. (Departures of as much as 6 to 8% from the nominal value are not uncommon.) If the negative angle is large, or if the angle is positive, you should recheck your calculations and perhaps even recheck the original measurements. You can get an idea of the validity of the measurements by normalizing the measured values to the calculated impedance and plotting them on a Smith Chart as shown in **Fig 10** for this example. Ideally, the two points should be diametrically opposite, but in practice they will be not quite 180° apart and not quite the same distance from prime center. Careful measurements will yield plotted points that are close to ideal. Significant departures from the ideal indicates sloppy measurements, or perhaps an impedance bridge that is not up to the task.

Determining Line Attenuation

The short circuit measurement may be used to determine the line attenuation. This reading is more reliable than the open circuit measurement because a good short circuit is a short, while a good open circuit is hard to find. (It is impossible to escape some amount of capacitance between conductors with an “open” circuit, and that capacitance presents a path for current to flow at the RF measurement frequency.)

Use the Smith Chart and the 1-DB STEPS external scale to find line attenuation. First normalize the short circuit impedance reading to the calculated Z_0, and plot this point on the chart. See Fig 10. For our example, the normalized impedance is 4.8/49.1 – *j* 11.2 / 49.1 or 0.098 – *j* 0.228. After plotting the point, transfer the radius to the 1-DB STEPS scale. This is shown at A of Fig 10.

Remember from discussions earlier in this chapter that the impedance for plotting a short circuit is 0 + *j* 0, at the left edge of the chart on the resistance axis. On the 1-DB STEPS scale this is also at the left edge. The total attenuation in the line is represented by the number of dB steps from the left edge to the radius mark we have just transferred. For this example it is 0.8 dB. Some estimation may be required in interpolating between the 1-dB step marks.

Determining Velocity Factor

The velocity factor is determined by using the TOWARD GENERATOR wavelength scale of the Smith Chart. With a straightedge, draw a line from prime center through the point representing the short-circuit reading, until it intersects the wavelengths scale. In Fig 10 this point is labeled B. Consider that during our measurement, the short circuit was the load at the end of the line. Imagine a spiral curve progressing from 0 + *j* 0 clockwise and inward to our plotted measurement point. The wavelength scale, at B, indicates this line length is 0.464 λ. By rearranging the terms of Eq 1 given early in this chapter, we arrive at an equation for calculating the velocity factor.

$$VF = \frac{Lf}{984N} \qquad \text{(Eq 4)}$$

where

VF = velocity factor

L = line length, feet

f = frequency, MHz

N = number of electrical wavelengths in the line

Inserting the example values into Eq 4 yields VF = 100 × 7.15/(984 × 0.464) = 1.566, or 156.6%. Of course, this value is an impossible number—the velocity factor in coax cannot be greater than 100%. But remember, the Smith Chart can be used for lengths greater than $^1/_2$ λ. Therefore, that 0.464 value could rightly be 0.964, 1.464, 1.964, and so on. When using 0.964 λ, Eq 4 yields a velocity factor of 0.753, or 75.3%. Trying successively greater values for the wavelength results in velocity factors of 49.6 and 37.0%. Because the cable we measured had foamed dielectric, 75.3% is the probable velocity factor. This corresponds to an electrical length of 0.964 λ. Therefore, we have determined from the measurements and

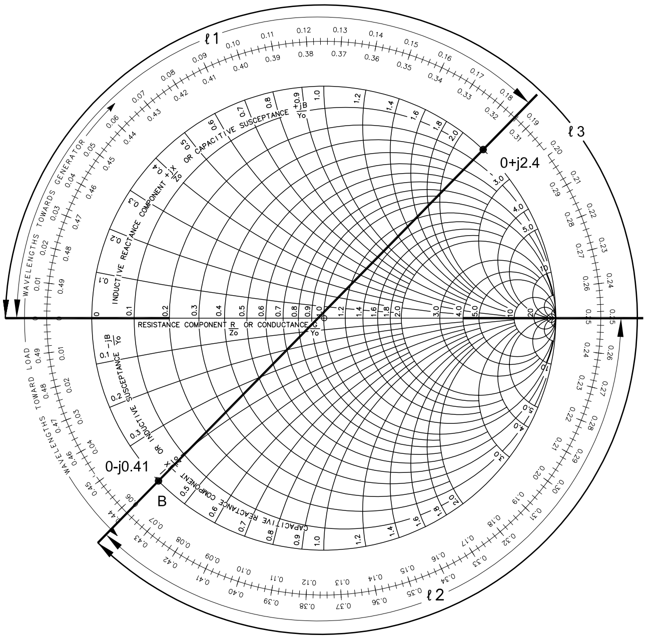
ℓ1
ℓ3
0+j2.4
ℓ2
0-j0.41
B
RESISTANCE COMPONENT (R/Zo) OR CONDUCTANCE (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo) OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo) OR INDUCTIVE SUSCEPTANCE (-jB/Yo)
WAVELENGTHS TOWARDS GENERATOR
WAVELENGTHS TOWARD LOAD

Fig 11—Smith Chart determination of input impedances for short- and open-circuited line sections, disregarding line losses.

calculations that our unmarked coax has a nominal 50-Ω impedance, an attenuation of 0.8 dB per hundred feet at 7.15 MHz, and a velocity factor of 75.3%.

It is difficult to use this procedure with short lengths of coax, just a few feet. The reason is that the SWR at the line input is too high to permit accurate measurements with most impedance bridges. In the example above, the SWR at the line input is approximately 12:1.

The procedure described above may also be used for determining the characteristics of balanced lines. However, impedance bridges are generally unbalanced devices, and the procedure for measuring a balanced impedance accurately with an unbalanced bridge is complicated.

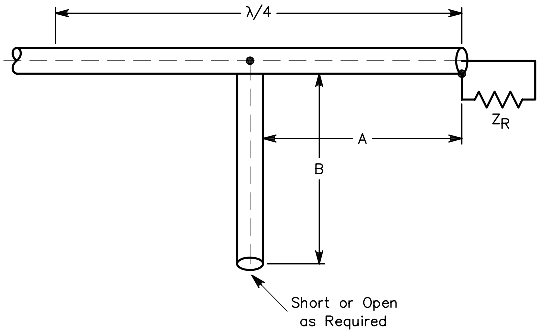

Fig 12—The method of stub matching a mismatched load on coaxial lines.

LINES AS CIRCUIT ELEMENTS

Information is presented in Chapter 24 on the use of transmission-line sections as circuit elements. For example, it is possible to substitute transmission lines of the proper length and termination for coils or capacitors in ordinary circuits. While there is seldom a practical need for that application, lines are frequently used in antenna systems in place of lumped components to tune or resonate elements. Probably the most common use of such a line is in the hairpin match, where a short section of stiff open-wire line acts as a lumped inductor.

The equivalent "lumped" value for any "inductor" or "capacitor" may be determined with the aid of the Smith Chart. Line losses may be taken into account if desired, as explained earlier. See **Fig 11**. Remember that the top half of the Smith Chart coordinate system is used for impedances containing inductive reactances, and the bottom half for capacitive reactances. For example, a section of 600-Ω line $^3/_{16}$-λ long (0.1875 λ) and short-circuited at the far end is represented by ℓ1, drawn around a portion of the perimeter of the chart. The "load" is a short-circuit, 0 + *j* 0 Ω, and the TOWARD GENERATOR wavelengths scale is used for marking off the line length. At A in Fig 11 may be read the normalized impedance as seen looking into the length of line, 0 + *j* 2.4. The reactance is therefore inductive, equal to 600 × 2.4 = 1440 Ω. The same line when open-circuited (termination impedance = ∞, the point at the right of the chart) is represented by ℓ2 in Fig 11. At B the normalized line-input impedance may be read as 0 – *j* 0.41; the reactance in this case is capacitive, 600 × 0.41 = 246 Ω. (Line losses are disregarded in these examples.) From Fig 11 it is easy to visualize that if ℓ1 were to be extended by $^1/_4$ λ, the total length represented by ℓ3, the line-input impedance would be identical to that obtained in the case represented by ℓ2 alone. In the case of ℓ2, the line is open-circuited at the far end, but in the case of ℓ3 the line is terminated in a short. The added section of line for ℓ3 provides the "transformer action" for which the $^1/_4$-λ line is noted.

The equivalent inductance and capacitance as determined above can be found by substituting these values in the equations relating inductance and capacitance to reactance, or by using the various charts and calculators available. The frequency corresponding to the line length in degrees must be used, of course. In this example, if the frequency is 14 MHz

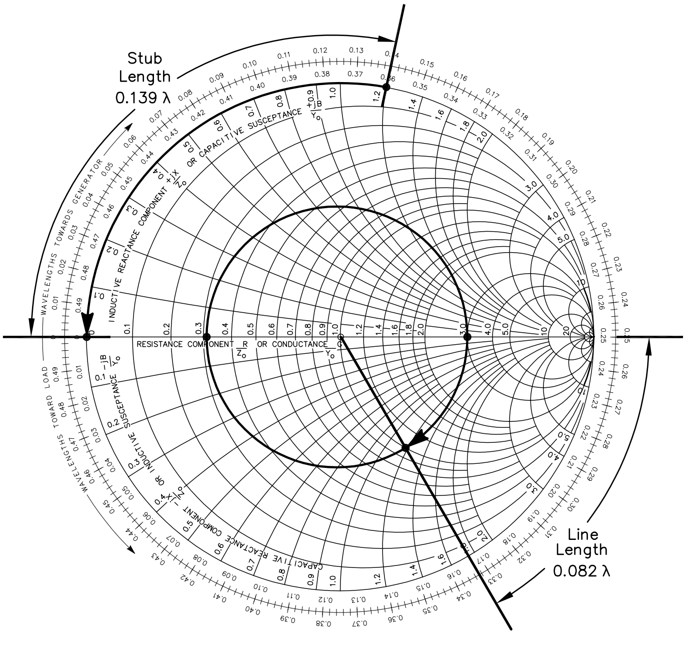

Fig 13—Smith Chart method of determining the dimensions for stub matching.

the equivalent inductance and capacitance in the two cases are 16.4 µH and 46.2 pF, respectively. Note that when the line length is 45° (0.125 λ), the reactance in either case is numerically equal to the characteristic impedance of the line. In using the Smith Chart it should be kept in mind that the electrical length of a line section depends on the frequency and velocity of propagation, as well as on the actual physical length.

At lengths of line that are exact multiples of $^1/_4$ λ, such lines have the properties of resonant circuits. At lengths where the input reactance passes through zero at the left of the Smith Chart, the line acts as a series-resonant circuit. At lengths for which the reactances theoretically pass from "positive" to "negative" infinity at the right of the Smith Chart, the line simulates a parallel-resonant circuit.

Designing Stub Matches with the Smith Chart

The design of stub matches is covered in detail in Chapter 26. Equations are presented there to calculate the electrical lengths of the main line and the stub, based on a purely resistive load and on the stub being the same type of line as the main line. The Smith Chart may also be used to determine these lengths, without the requirements that the load be purely resistive and that the line types be identical.

Fig 12 shows the stub matching arrangement in coaxial line. As an example, suppose that the load is an antenna, a close-spaced array fed with a 52-Ω line. Further suppose that the SWR has been measured as 3.1:1. From this information, a constant SWR circle may be drawn on the Smith Chart. Its radius is such that it intersects the right portion of the resistance axis at the SWR value, 3.1, as shown at point B in **Fig 13**.

Since the stub of Fig 12 is connected in parallel with the transmission line, determining the design of the matching arrangement is simplified if Smith Chart values are dealt with as admittances, rather than impedances. (An admittance is simply the reciprocal of the associated impedance. Plotted on the Smith Chart, the two associated points are on the same SWR circle, but diametrically opposite each other.) Using admittances leaves less chance for errors in making calculations, by eliminating the need for making series-equivalent to parallel-equivalent circuit conversions and back, or else for using complicated equations for determining the resultant value of two complex impedances connected in parallel.

A complex impedance, Z, is equal to R + *j* X, as described in Chapter 24. The equivalent admittance, Y, is equal to G – *j* B, where G is the conductive component and B the susceptance. (Inductance is taken as negative susceptance, and capacitance as positive.) Conductance and susceptance values are plotted and handled on the Smith Chart in the same manner as resistance and reactance.

Assuming that the close-spaced array of our example has been resonated at the operating frequency, it will present a purely resistive termination for the load end of the 52-Ω line. From information in Chapter 24, it is known that the impedance of the antenna equals Z_0/SWR = 52/3.1 = 16.8 Ω. (We can logically discard the possibility that the antenna impedance is SWR × Z_0, or 0.06 Ω.) If this 16.8-Ω value were to be plotted as an impedance on the Smith Chart, it would first be normalized (16.8/52 = 0.32) and then plotted as 0.32 + *j* 0. Although not necessary for the solution of this example, this value is plotted at point A in Fig 13. What is necessary is a plot of the admittance for the antenna as a load. This is the reciprocal of the impedance; 1/16.8 Ω equals 0.060 siemen. To plot this point it is first normalized by multiplying the conductance and susceptance values by the Z_0 of the line. Thus, (0.060 + *j* 0) × 52 = 3.1 + *j* 0. This admittance value is shown plotted at point B in Fig 13. It may be seen that points A and B are diametrically opposite each other on the chart. Actually, for the solution of this example, it wasn't necessary to compute the values for either point A or point B as in the above paragraph, for they were both determined from the known SWR value of 3.1. As may be seen in Fig 13, the points are located on the constant SWR circle which was already drawn, at the two places where it intersects the resistance axis. The plotted value for point A, 0.32, is simply the reciprocal of the value for point B, 3.1. However, an understanding of the relationship between impedance and admittance is easier to gain with simple examples such as this.

In stub matching, the stub is to be connected at a point in the line where the conductive component equals the Z_0 of the line. Point B represents the admittance of the load, which is the antenna. Various admittances will be encountered along the line, when moving in a direction indicated by the TOWARD GENERATOR wavelengths scale, but all admittance plots must fall on the constant SWR circle. Moving clockwise around the SWR circle from point B, it is seen that the line input conductance will be 1.0 (normalized Z_0 of the line) at point C, 0.082 λ toward the transmitter from the antenna. Thus, the stub should be connected at this location on the line.

The normalized admittance at point C, the point representing the location of the stub, is 1 – *j* 1.2 siemens, having an inductive susceptance component. A capacitive susceptance having a normalized value of + *j* 1.2 siemens is required across the line at the point of stub connection, to cancel the inductance. This capacitance is to be obtained from the stub section itself; the problem now is to determine its type of termination (open or shorted), and how long the stub should be. This is done by first plotting the susceptance required for cancellation, 0 + *j* 1.2, on the chart (point D in Fig 13). This point represents the input admittance as seen looking into the stub. The "load" or termination for the stub section is found by moving in the TOWARD LOAD direction around the chart, and will appear at the closest point on the resistance/conductance axis, either at the left or the right of the chart. Moving counterclockwise from point D, this is located at E, at the left of the chart, 0.139 λ away. From this we know the required stub length. The "load" at the far end of the stub, as represented on the Smith Chart, has a normalized admittance of 0 + *j* 0 siemen, which is equivalent to an open circuit.

When the stub, having an input admittance of 0 + *j* 1.2 siemens, is connected in parallel with the line at a point 0.082 λ from the load, where the line input admittance is 1.0 – *j* 1.2, the resultant admittance is the sum of the individual admittances. The conductance components are added directly, as are the susceptance components. In this case, 1.0 – *j* 1.2 + *j* 1.2 = 1.0 + *j* 0 siemen. Thus, the line from the point of stub connection to the transmitter will be terminated in a load which offers a perfect match. When determining the physical line lengths for stub matching, it is important to remember that the velocity factor for the type of line in use must be considered.

MATCHING WITH LUMPED CONSTANTS

It was pointed out earlier that the purpose of a matching stub is to cancel the reactive component of line impedance at the point of connection. In other words, the stub is simply a reactance of the proper kind and value shunted across the line. It does not matter what physical shape this reactance takes. It can be a section of transmission line or a "lumped" inductance or capacitance, as desired. In the above example with the Smith Chart solution, a capacitive reactance was required. A capacitor having the same value of reactance can be used just as well. There are cases where, from an installation standpoint, it may be considerably more convenient to connect a capacitor in place of a stub. This is particularly true when open-wire feeders are used. If a variable capacitor is used, it becomes possible to adjust the capacitance to the exact value required.

The proper value of reactance may be determined from Smith Chart information. In the previous example, the required susceptance, normalized, was +*j* 1.2 siemens. This is converted into actual siemens by dividing by the line Z_0; 1.2/52 = 0.023 siemen, capacitance. The required capacitive reactance is the reciprocal of this latter value, 1/0.023 = 43.5 Ω. If the frequency is 14.2 MHz, for instance, 43.5 Ω corresponds to a capacitance of 258 pF. A 325-pF variable capacitor connected across the line 0.082 λ from the antenna terminals would provide ample adjustment range. The RMS voltage across the capacitor is

$$E = \sqrt{P \times Z_0}$$

For 500 W, for example, E = the square root of 500 × 52 = 161 V. The peak voltage is 1.41 times the RMS value, or 227 V.

The Series-Section Transformer

The series-section transformer is described in Chapter 26, and equations are given there for its design. The transformer can be designed graphically with the aid of a Smith Chart. This information is based on a *QST* article by Frank A. Regier, OD5CG. Using the Smith Chart to design a series-section match requires the use of the chart in its less familiar off-center mode. This mode is described in the next two paragraphs.

Fig 14 shows the Smith Chart used in its familiar centered mode, with all impedances normalized to that of the transmission line, in this case 75 Ω, and all constant SWR circles concentric with the normalized value r = 1 at the chart center. An actual impedance is recovered by multiplying a chart reading by the normalizing impedance of 75 Ω. If the actual (unnormalized) impedances represented by a constant SWR circle in Fig 14 are instead divided by a normalizing impedance of 300 Ω, a different picture results. A Smith Chart shows all possible impedances, and so a closed path such as a constant SWR circle in Fig 14 must again be represented by a closed path. In fact, it can be shown that the path remains a circle, but that the constant SWR circles are no longer concentric. **Fig 15** shows the circles that result when the impedances along a mismatched 75-Ω line are normalized by dividing by 300 Ω instead of 75. The constant SWR circles still surround the point corresponding to the characteristic impedance of the line (r = 0.25) but are no longer concentric with it. Note that the normalized impedances read from corresponding points on Figs 14 and 15 are different but that the actual, unnormalized, impedances are exactly the same.

An Example

Now turn to the example shown in **Fig 16**. A complex load of Z_L = 600 + *j* 900 Ω is to be fed with 300-Ω line, and a 75-Ω series section is to be used. These characteristic impedances agree with those used in Fig 15, and thus Fig 15 can be used to find the impedance variation along the 75-Ω series section. In particular, the constant SWR circle which passes through the Fig 15 chart center, SWR = 4 in this case, passes through all the impedances (normalized to 300 Ω) which the 75-Ω series section is able to match to the 300-Ω main line. The length $\ell 1$ of 300-Ω line has the job of transforming the load impedance to some impedance on this matching circle.

Fig 17 shows the whole process more clearly, with all

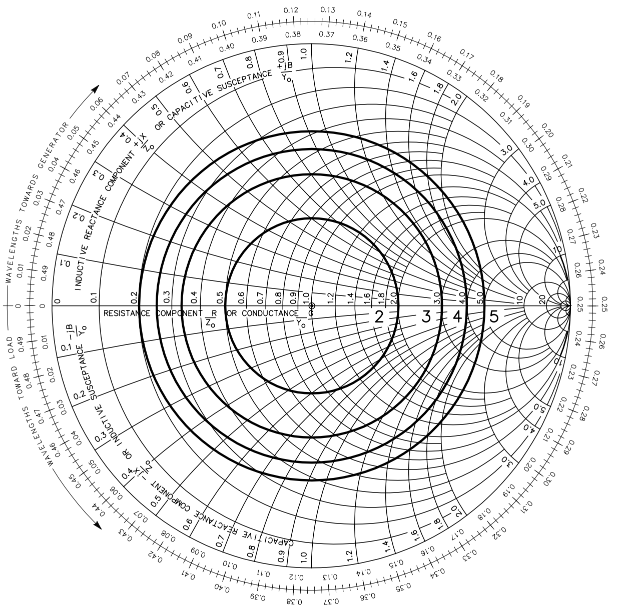

Fig 14—Constant SWR circles for SWR = 2, 3, 4 and 5, showing impedance variation along 75-Ω line, normalized to 75 Ω. The actual impedance is obtained by multiplying the chart reading by 75 Ω.

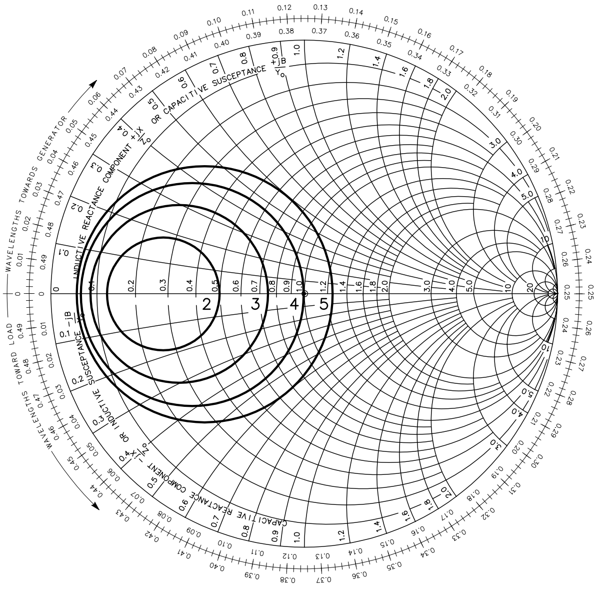

Fig 15—Paths of constant SWR for SWR = 2, 3, 4 and 5, showing impedance variation along 75-Ω line, normalized to 300 Ω. Normalized impedances differ from those in Fig 14, but actual impedances are obtained by multiplying chart readings by 300 Ω and are the same as those corresponding in Fig 14. Paths remain circles but are no longer concentric. One, the matching circle, SWR = 4 in this case, passes through the chart center and is thus the locus of all impedances which can be matched to a 300-Ω line.

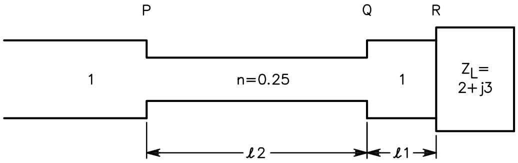

Fig 16—Example for solution by Smith Chart. All impedances are normalized to 300 Ω.

impedances normalized to 300 Ω. Here the normalized load impedance $Z_L = 2 + j\,3$ is shown at R, and the matching circle appears centered on the resistance axis and passing through the points r = 1 and $r = n^2 = (75/300)^2 = 0.0625$. A constant SWR circle is drawn from R to an intersection with the matching circle at Q or Q′ and the corresponding length $\ell 1$ (or $\ell 1'$) can be read directly from the Smith Chart. The clockwise distance around the matching circle represents the length of the matching line, from either Q′ to P or from Q to P. Because in this example the distance QP is the shorter of the two for the matching section, we choose the length $\ell 1$ as shown. By using values from the TOWARD GENERATOR scale, this length is found as 0.045 – 0.213, and adding 0.5 to obtain a positive result yields a value of 0.332 λ.

Although the impedance locus from Q to P is shown in Fig 17, the length $\ell 2$ cannot be determined directly from this chart. This is because the matching circle is not concentric with the chart center, so the wavelength scales do not apply to this circle. This problem is overcome by forming **Fig 18**, which is the same as Fig 17 except that all normalized impedances have been divided by n = 0.25, resulting in a Smith Chart normalized to 75 Ω instead of 300. The matching circle and the chart center are now concentric, and the series-section length $\ell 2$, the distance between Q and P, can be taken directly from the chart. By again using the TOWARD GENERATOR scale, this length is found as 0.250 – 0.148 = 0.102 λ.

In fact it is not necessary to construct the entire impedance locus shown in Fig 18. It is sufficient to plot Z_Q/n (Z_Q is read from Fig 17) and $Z_p/n = 1/n$, connect them by a circular arc centered on the chart center, and to determine the arc length $\ell 2$ from the Smith Chart.

Procedure Summary

The steps necessary to design a series-section transformer by means of the Smith Chart can now be listed:

1) Normalize all impedances by dividing by the characteristic impedance of the main line.
2) On a Smith Chart, plot the normalized load impedance Z_L at R and construct the matching circle

so that its center is on the resistance axis and it passes through the points r = 1 and r = n^2.

3) Construct a constant SWR circle centered on the chart center through point R. This circle should intersect the matching circle at two points. One of these points, normally the one resulting in the shorter clockwise distance along the matching circle to the chart center, is chosen as point Q, and the clockwise distance from R to Q is read from the chart and taken to be $\ell 1$.

4) Read the impedance Z_Q from the chart, calculate Z_Q/n and plot it as point Q on a second Smith Chart. Also plot r = 1/n as point P.

5) On this second chart construct a circular arc, centered on the chart center, clockwise from Q to P. The length of this arc, read from the chart, represents $\ell 2$. The design of the transformer is now complete, and the necessary physical line lengths may be determined.

The Smith Chart construction shows that two design solutions are usually possible, corresponding to the two intersections of the constant SWR circle (for the load) and the matching circle. These two values correspond to positive and negative values of the square-root radical in the equation for a mathematical solution of the problem. It may happen, however, that the load circle misses the matching circle completely, in which case no solution is possible. The cure is to enlarge the matching circle by choosing a series section whose impedance departs more from that of the main line.

A final possibility is that, rather than intersecting the matching circle, the load circle is tangent to it. There is then but one solution—that of the ¹/₄-λ transformer.

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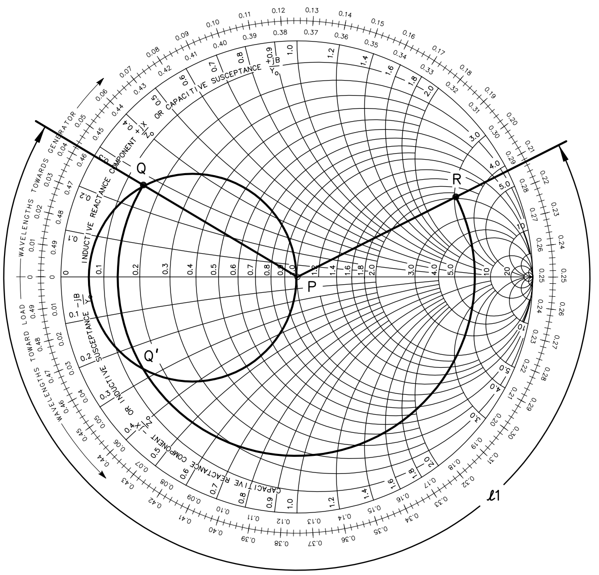
Q
R
P
Q′
ℓ1
WAVELENGTHS TOWARDS GENERATOR
WAVELENGTHS TOWARD LOAD
INDUCTIVE REACTANCE COMPONENT
OR CAPACITIVE SUSCEPTANCE
CAPACITIVE REACTANCE COMPONENT
OR INDUCTIVE SUSCEPTANCE

Fig 17—Smith Chart representation of the example shown in Fig 16. The impedance locus always takes a clockwise direction from the load to the generator. This path is first along the constant SWR circle from the load at R to an intersection with the matching circle at Q or Q′, and then along the matching circle to the chart center at P. Length ℓ1 can be determined directly from the chart, and in this example is 0.332 λ.

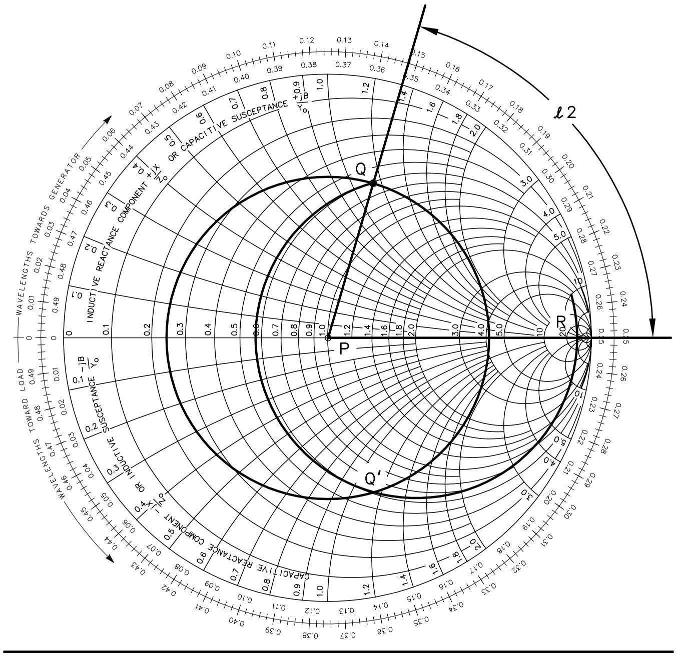
ℓ2
Q
R
P
Q′
WAVELENGTHS TOWARDS GENERATOR
WAVELENGTHS TOWARD LOAD
INDUCTIVE REACTANCE COMPONENT
OR CAPACITIVE SUSCEPTANCE
CAPACITIVE REACTANCE COMPONENT
OR INDUCTIVE SUSCEPTANCE

Fig 18—The same impedance locus as shown in Fig 17 except normalized to 75 Ω instead of 300. The matching circle is now concentric with the chart center, and ℓ2 can be determined directly from the chart, 0.102 λ in this case.

Appendix

This appendix contains a glossary of terms, a list of common abbreviations, length conversion information (feet and inches), metric equivalents and antenna-gain-reference data.

Glossary of Terms

This glossary provides a handy list of terms that are used frequently in Amateur Radio conversation and literature about antennas. With each item is a brief definition of the term. Most terms given here are discussed more thoroughly in the text of this book, and may be located by using the index.

Actual ground—The point within the earth's surface where effective ground conductivity exists. The depth for this point varies with frequency and the condition of the soil.

Antenna—An electrical conductor or array of conductors that radiates signal energy (transmitting) or collects signal energy (receiving).

Antenna tuner—A device containing variable reactances (and perhaps a balun). It is connected between the transmitter and the feed point of an antenna system, and adjusted to "tune" or resonate the system to the operating frequency.

Aperture, effective—An area enclosing an antenna, on which it is convenient to make calculations of field strength and antenna gain. Sometimes referred to as the "capture area."

Apex—The feed-point region of a V type of antenna.

Apex angle—The included angle between the wires of a V, an inverted-V dipole, and similar antennas, or the included angle between the two imaginary lines touching the element tips of a log periodic array.

Balanced line—A symmetrical two-conductor feed line that has uniform voltage and current distribution along its length.

Balun—A device for feeding a balanced load with an unbalanced line, or vice versa. May be a form of choke, or a transformer that provides a specific impedance transformation (including 1:1). Often used in antenna systems to interface a coaxial transmission line to the feed point of a balanced antenna, such as a dipole.

Base loading—A lumped reactance that is inserted at the base (ground end) of a vertical antenna to resonate the antenna.

Bazooka—A transmission-line balancer. It is a quarter-wave conductive sleeve (tubing or flexible shielding) placed at the feed point of a center-fed element and grounded to the shield braid of the coaxial feed line at the end of the sleeve farthest from the feed point. It permits the use of unbalanced feed line with balanced feed antennas.

Beamwidth—Related to directive antennas. The width, in degrees, of the major lobe between the two directions at which the relative radiated power is equal to one half its value at the peak of the lobe (half power = –3 dB).

Beta match—A form of hairpin match. The two conductors straddle the boom of the antenna being matched, and the closed end of the matching-section conductors is strapped to the boom.

Bridge—A circuit with two or more ports that is used in measurements of impedance, resistance or standing waves in an antenna system. When the bridge is adjusted for a balanced condition, the unknown factor can be determined by reading its value on a calibrated scale or meter.

Capacitance hat—A conductor of large surface area that is connected at the high-impedance end of an antenna to effectively increase the electrical length. It is sometimes mounted directly above a loading coil to reduce the required inductance for establishing resonance. It usually takes the form of a series of wheel spokes or a solid circular disc. Sometimes referred to as a "top hat."

Capture area—See aperture.

Center fed—Transmission-line connection at the electrical center of an antenna radiator.

Center loading—A scheme for inserting inductive reactance (coil) at or near the center of an antenna element for the purpose of lowering its resonant frequency. Used with elements that are less than $^1/_4$ wavelength at the operating frequency.

Coax—See coaxial cable.

Coaxial cable—Any of the coaxial transmission lines that have the outer shield (solid or braided) on the same axis as the inner or center conductor. The insulating material can be air, helium or solid-dielectric compounds.

Collinear array—A linear array of radiating elements (usually dipoles) with their axes arranged in a straight line. Popular at VHF and above.

Conductor—A metal body such as tubing, rod or wire that permits current to travel continuously along its length.

Counterpoise—A wire or group of wires mounted close to ground, but insulated from ground, to form a low-impedance, high-capacitance path to ground. Used at MF and HF to provide an RF ground for an antenna. Also see ground plane.

Current loop—A point of current maxima (antipode) on an antenna.

Current node—A point of current minima on an antenna.

Decibel—A logarithmic power ratio, abbreviated dB. May also represent a voltage or current ratio if the voltages or currents are measured across (or through) identical impedances. Suffixes to the abbreviation indicate references: dBi, isotropic radiator; dBic, isotropic radiator circular; dBm, milliwatt; dBW, watt.

Delta loop—A full-wave loop shaped like a triangle or delta.

Delta match—Center-feed technique used with radiators that are not split at the center. The feed line is fanned near the radiator center and connected to the radiator symmetrically. The fanned area is delta shaped.

Dielectrics—Various insulating materials used in antenna systems, such as found in insulators and transmission lines.

Dipole—An antenna that is split at the exact center for connection to a feed line, usually a half wavelength long. Also called a “doublet.”

Direct ray—Transmitted signal energy that arrives at the receiving antenna directly rather than being reflected by any object or medium.

Directivity—The property of an antenna that concentrates the radiated energy to form one or more major lobes.

Director—A conductor placed in front of a driven element to cause directivity. Frequently used singly or in multiples with Yagi or cubical-quad beam antennas.

Doublet—See dipole.

Driven array—An array of antenna elements which are all driven or excited by means of a transmission line, usually to achieve directivity.

Driven element—A radiator element of an antenna system to which the transmission line is connected.

Dummy load—Synonymous with dummy antenna. A nonradiating substitute for an antenna.

E layer—The ionospheric layer nearest earth from which radio signals can be reflected to a distant point, generally a maximum of 2000 km (1250 ml).

E plane—Related to a linearly polarized antenna, the plane containing the electric field vector of the antenna and its direction of maximum radiation. For terrestrial antenna systems, the direction of the E plane is also taken as the polarization of the antenna. The E plane is at right angles to the H plane.

Efficiency—The ratio of useful output power to input power, determined in antenna systems by losses in the system, including in nearby objects.

EIRP—Effective isotropic radiated power. The power radiated by an antenna in its favored direction, taking the gain of the antenna into account as referenced to isotropic.

Elements—The conductive parts of an antenna system that determine the antenna characteristics. For example, the reflector, driven element and directors of a Yagi antenna.

End effect—A condition caused by capacitance at the ends of an antenna element. Insulators and related support wires contribute to this capacitance and lower the resonant frequency of the antenna. The effect increases with conductor diameter and must be considered when cutting an antenna element to length.

End fed—An end-fed antenna is one to which power is applied at one end, rather than at some point between the ends.

F layer—The ionospheric layer that lies above the E layer. Radio waves can be refracted from it to provide communications distances of several thousand miles by means of single- or double-hop skip.

Feed line—See feeders.

Feeders—Transmission lines of assorted types that are used to route RF power from a transmitter to an antenna, or from an antenna to a receiver.

Field strength—The intensity of a radio wave as measured at a point some distance from the antenna. This measurement is usually made in microvolts per meter.

Front to back—The ratio of the radiated power off the front and back of a directive antenna. For example, a dipole would have a ratio of 1, which is equivalent to 0 dB.

Front to rear—Worst-case rearward lobe in the 180°-wide sector behind an antenna’s main lobe, in dB.

Front to side—The ratio of radiated power between the major lobe and that 90° off the front of a directive antenna.

Gain—The increase in effective radiated power in the desired direction of the major lobe.

Gamma match—A matching system used with driven antenna elements to effect a match between the transmission line and the feed point of the antenna. It consists of a series capacitor and an arm that is mounted close to the driven element and in parallel with it near the feed point.

Ground plane—A system of conductors placed beneath an elevated antenna to serve as an earth ground. Also see counterpoise.

Ground screen—A wire mesh counterpoise.

Ground wave—Radio waves that travel along the earth’s surface.

H plane—Related to a linearly polarized antenna. The plane containing the magnetic field vector of an antenna and its direction of maximum radiation. The H plane is at right angles to the E plane.

HAAT—Height above average terrain. A term used mainly in connection with repeater antennas in determining coverage area.

Hairpin match—A U-shaped conductor that is connected to the two inner ends of a split dipole for the purpose of creating an impedance match to a balanced feeder.

Harmonic antenna—An antenna that will operate on its fundamental frequency and the harmonics of the fundamental frequency for which it is designed. An end-fed half-wave antenna is one example.

Helical—A helically wound antenna, one that consists of a spiral conductor. If it has a very large winding length to diameter ratio it provides broadside radiation. If the length-to-diameter ratio is small, it will operate in the axial mode and radiate off the end opposite the feed point. The polarization will be circular for the axial mode, with left or right circularity, depending on whether the helix is wound clockwise or counterclockwise.

Helical hairpin—"Hairpin" match with a lumped inductor, rather than parallel-conductor line.

Image antenna—The imaginary counterpart of an actual antenna. It is assumed for mathematical purposes to be located below the earth's surface beneath the antenna, and is considered symmetrical with the antenna above ground.

Impedance—The ohmic value of an antenna feed point, matching section or transmission line. An impedance may contain a reactance as well as a resistance component.

Inverted V—A misnomer, as the antenna being referenced does not have the characteristics of a V antenna. See inverted-V dipole.

Inverted-V dipole—A half-wavelength dipole erected in the form of an upside-down V, with the feed point at the apex. Its radiation pattern is similar to that of a horizontal dipole.

Isotropic—An imaginary or hypothetical point-source antenna that radiates equal power in all directions. It is used as a reference for the directive characteristics of actual antennas.

Lambda—Greek symbol (λ) used to represent a wavelength with reference to electrical dimensions in antenna work.

Line loss—The power lost in a transmission line, usually expressed in decibels.

Line of sight—Transmission path of a wave that travels directly from the transmitting antenna to the receiving antenna.

Litz wire—Stranded wire with individual strands insulated; small wire provides a large surface area for current flow, so losses are reduced for the wire size.

Load—The electrical entity to which power is delivered. The antenna system is a load for the transmitter.

Loading—The process of a transferring power from its source to a load. The effect a load has on a power source.

Lobe—A defined field of energy that radiates from a directive antenna.

Log periodic antenna—A broadband directive antenna that has a structural format causing its impedance and radiation characteristics to repeat periodically as the logarithm of frequency.

Long wire—A wire antenna that is one wavelength or greater in electrical length. When two or more wavelengths long it provides gain and a multilobe radiation pattern. When terminated at one end it becomes essentially unidirectional off that end.

Marconi antenna—A shunt-fed monopole operated against ground or a radial system. In modern jargon, the term refers loosely to any type of vertical antenna.

Matching—The process of effecting an impedance match between two electrical circuits of unlike impedance. One example is matching a transmission line to the feed point of an antenna. Maximum power transfer to the load (antenna system) will occur when a matched condition exists.

Monopole—Literally, one pole, such as a vertical radiator operated against the earth or a counterpoise.

Nichrome wire—An alloy of nickel and chromium; not a good conductor; resistance wire. Used in the heating elements of electrical appliances; also as conductors in transmission lines or circuits where attenuation is desired.

Null—A condition during which an electrical unit is at a minimum. A null in an antenna radiation pattern is a point in the 360-degree pattern where a minima in field intensity is observed. An impedance bridge is said to be "pulled" when it has been brought into balance, with a null in the current flowing through the bridge arm.

Octave—A musical term. As related to RF, frequencies having a 2:1 harmonic relationship.

Open-wire line—A type of transmission line that resembles a ladder, sometimes called "ladder line." Consists of parallel, symmetrical wires with insulating spacers at regular intervals to maintain the line spacing. The dielectric is principally air, making it a low-loss type of line.

Parabolic reflector—An antenna reflector that is a portion of a parabolic revolution or curve. Used mainly at UHF and higher to obtain high gain and a relatively narrow beamwidth when excited by one of a variety of driven elements placed in the plane of and perpendicular to the axis of the parabola.

Parasitic array—A directive antenna that has a driven element and at least one independent director or reflector, or a combination of both. The directors and reflectors are not connected to the feed line. Except for VHF and UHF arrays with long booms (electrically), more than one reflector is seldom used. A Yagi antenna is one example of a parasitic array.

Phasing lines—Sections of transmission line that are used to ensure the correct phase relationship between the elements of a driven array, or between bays of an array of antennas. Also used to effect impedance transformations while maintaining the desired phase.

Polarization—The sense of the wave radiated by an antenna. This can be horizontal, vertical, elliptical or circular (left or right hand circularity), depending on the design and application. (See H plane.)

Q section—Term used in reference to transmission-line matching transformers and phasing lines.

Quad—A parasitic array using rectangular or diamond shaped full-wave wire loop elements. Often called the "cubical quad." Another version uses delta-shaped elements, and is called a delta loop beam.

Radiation pattern—The radiation characteristics of an antenna as a function of space coordinates. Normally, the pattern is measured in the far-field region and is represented graphically.

Radiation resistance—The ratio of the power radiated by an antenna to the square of the RMS antenna current, referred to a specific point and assuming no losses. The effective resistance at the antenna feed point.

Radiator—A discrete conductor that radiates RF energy in an antenna system.

Random wire—A random length of wire used as an antenna and fed at one end by means of an antenna tuner. Seldom operates as a resonant antenna unless the length happens to be correct.

Reflected ray—A radio wave that is reflected from the earth, ionosphere or a man-made medium, such as a passive reflector.

Reflector—A parasitic antenna element or a metal assembly that is located behind the driven element to enhance forward directivity. Hillsides and large man-made structures such as buildings and towers may act as reflectors.

Refraction—Process by which a radio wave is bent and returned to earth from an ionospheric layer or other medium after striking the medium.

Resonator—In antenna terminology, a loading assembly consisting of a coil and a short radiator section. Used to lower the resonant frequency of an antenna, usually a vertical or a mobile whip.

Rhombic—A rhomboid or diamond-shaped antenna consisting of sides (legs) that are each one or more wavelengths long. The antenna is usually erected parallel to the ground. A rhombic antenna is bidirectional unless terminated by a resistance, which makes it unidirectional. The greater the electrical leg length, the greater the gain, assuming the tilt angle is optimized.

Shunt feed—A method of feeding an antenna driven element with a parallel conductor mounted adjacent to a low-impedance point on the radiator. Frequently used with grounded quarter-wave vertical antennas to provide an impedance match to the feeder. Series feed is used when the base of the vertical is insulated from ground.

Stacking—The process of placing similar directive antennas atop or beside one another, forming a "stacked array." Stacking provides more gain or directivity than a single antenna.

Stub—A section of transmission line used to tune an antenna element to resonance or to aid in obtaining an impedance match.

SWR—Standing-wave ratio on a transmission line in an antenna system. More correctly, VSWR, or voltage standing-wave ratio. The ratio of the forward to reflected voltage on the line, and not a power ratio. A VSWR of 1:1 occurs when all parts of the antenna system are matched correctly to one another.

T match—Method for matching a transmission-line to an unbroken driven element. Attached at the electrical center of the driven element in a T-shaped manner. In effect it is a double gamma match.

Tilt angle—Half the angle included between the wires at the sides of a rhombic antenna.

Top hat—See capacitance hat.

Top loading—Addition of a reactance (usually a capacitance hat) at the end of an antenna element opposite the feed point to increase the electrical length of the radiator.

Transmatch—An antenna tuner.

Trap—Parallel L-C network inserted in an antenna element to provide multiband operation with a single conductor.

Unipole—See monopole.

Velocity factor—The ratio of the velocity of radio wave propagation in a dielectric medium to that in free space. When cutting a transmission line to a specific electrical length, the velocity factor of the particular line must be taken into account.

VSWR—Voltage standing-wave ratio. See SWR.

Wave—A disturbance or variation that is a function of time or space, or both, transferring energy progressively from point to point. A radio wave, for example.

Wave angle—The angle above the horizon of a radio wave as it is launched from or received by an antenna. Also called elevation angle.

Wave front—A surface that is a locus of all the points having the same phase at a given instant in time.

Yagi—A directive, gain type of antenna that utilizes a number of parasitic directors and a reflector. Named after one of the two Japanese inventors (Yagi and Uda).

Zepp antenna—A half-wave wire antenna that operates on its fundamental and harmonics. It is fed at one end by means of open-wire feeders. The name evolved from its popularity as an antenna on Zeppelins. In modern jargon the term refers loosely to any horizontal antenna.

Abbreviations

Abbreviations and acronyms that are commonly used throughout this book are defined in the list below. Periods are not part of an abbreviation unless the abbreviation otherwise forms a common English word. When appropriate, abbreviations as shown are used in either singular or plural construction.

-A-
A—ampere
ac—alternating current
AF—audio frequency
AFSK—audio frequency-shift keying
AGC—automatic gain control
AM—amplitude modulation
ANT—antenna
ARRL—American Radio Relay League
ATV—amateur television
AWG—American wire gauge
az-el—azimuth-elevation

-B-
balun—balanced to unbalanced
BC—broadcast
BCI—broadcast interference
BW—bandwidth

-C-
ccw—counterclockwise
cm—centimeter
coax—coaxial cable
CT—center tap
cw—clockwise
CW—continuous wave

-D-
D—diode
dB—decibel
dBd—decibels referenced to a dipole
dBi—decibels referenced to isotropic
dBic—decibels referenced to isotropic, circular
dBm—decibels referenced to one milliwatt
dBW—decibels referenced to one watt
dc—direct current
deg—degree
DF—direction finding
dia—diameter
DPDT—double pole, double throw
DPST—double pole, single throw
DVM—digital voltmeter
DX—long distance communication

-E-
E—ionospheric layer, electric field
ed.—edition
Ed.—editor
EIRP—effective isotropic radiated power
ELF—extremely low frequency
EMC—electromagnetic compatibility
EME—earth-moon-earth
EMF—electromotive force
ERP—effective radiated power
E_S—ionospheric layer (sporadic E)

-F-
f—frequency
F—ionospheric layer, farad
F/B—front to back (ratio)
F/R—worst-case front to rear (ratio)
FM—frequency modulation
FOT—frequency of optimum transmission
ft—foot or feet (unit of length)
F_1—ionospheric layer
F_2—ionospheric layer

-G-
GDO—grid- or gate-dip oscillator
GHz—gigahertz
GND—ground

-H-
H—magnetic field, henry
HAAT—height above average terrain
HF—high frequency (3-30 MHz)
Hz—hertz (unit of frequency)

-I-
I—current
ID—inside diameter
IEEE—Institute of Electrical and Electronic Engineers
in.—inch
IRE—Institute of Radio Engineers (now IEEE)

-J-
j—vector notation

-K-
kHz—kilohertz
km—kilometer
kW—kilowatt
kW—kilohm

-L-
L—inductance
lb—pound (unit of mass)
LF—low frequency (30-300 kHz)
LHCP—left-hand circular polarization
ln—natural logarithm
log—common logarithm
LP—log periodic
LPDA—log periodic dipole array
LPVA—log periodic V array
LUF—lowest usable frequency

-M-
m—meter (unit of length)
m/s—meters per second
mA—milliampere
max—maximum
MF—medium frequency (0.3-3 MHz)
mH—millihenry
MHz—megahertz
mi—mile
min—minute
mm—millimeter
ms—millisecond
mS—millisiemen
MS—meteor scatter
MUF—maximum usable frequency
mW—milliwatt
MW—megohm

-N-
NC—no connection, normally closed
NiCd—nickel cadmium
NIST—National Institute of Standards and Technology
NO—normally open
no.—number

-O-
OD—outside diameter

-P-
p—page (bibliography reference)
P-P—peak to peak
PC—printed circuit
PEP—peak envelope power
pF—picofarad
pot—potentiometer
pp—pages (bibliography reference)
Proc—Proceedings

-Q-
Q—figure of merit

-R-
R—resistance, resistor
RF—radio frequency
RFC—radio frequency choke
RFI—radio frequency interference
RHCP—right-hand circular polarization
RLC—resistance-inductance-capacitance
r/min—revolutions per minute
RMS—root mean square
r/s—revolutions per second
RSGB—Radio Society of Great Britain
RX—receiver

-S-
s—second
S—siemen
S/NR—signal-to-noise ratio
SASE—self-addressed stamped envelope
SINAD—signal-to-noise and distortion
SPDT—single pole, double throw
SPST—single pole, single throw
SWR—standing wave ratio
sync—synchronous

-T-
tpi—turns per inch
TR—transmit-receive
TVI—television interference
TX—transmitter

-U-
UHF—ultra-high frequency (300-3000 MHz)
US—United States
UTC—Universal Time, Coordinated

-V-
V—volt
VF—velocity factor
VHF—very-high frequency (30-300 MHz)
VLF—very-low frequency (3-30 kHz)
Vol—volume (bibliography reference)
VOM—volt-ohm meter
VSWR—voltage standing-wave ratio
VTVM—vacuum-tube voltmeter

-W-
W—watt
WPM—words per minute
WRC—World Radio Conference
WVDC—working voltage, direct current

-X-
X—reactance
XCVR—transceiver
XFMR—transformer
XMTR—transmitter

-Z-
Z—impedance

-Other symbols and Greek letters-
°—degrees
λ—wavelength
λ/dia—wavelength to diameter (ratio)
μ—permeability
μF—microfarad
μH—microhenry
μV—microvolt
Ω—ohm
φ—angles
π—3.14159
θ—angles

Length Conversions

Throughout this book, equations may be found for determining the design length and spacing of antenna elements. For convenience, the equations are written to yield a result in feet. (The answer may be converted to meters simply by multiplying the result by 0.3048.) If the result in feet is not an integral number, however, it is necessary to make a conversion from a decimal fraction of a foot to inches and fractions before the physical distance can be determined with a conventional tape measure. Table 1 may be used for this conversion, showing inches and fractions for increments of 0.01 foot. The table deals with only the fractional portion of a foot. The integral number of feet remains the same.

For example, say a calculation yields a result of 11.63 feet, and we wish to convert this to a length we can find on a tape measure. For the moment, consider only the fractional part of the number, 0.63 foot. In Table 1 1ocate the line with "0.6" appearing in the left column. (This is the 7th line down in the body of the table.) Then while staying on that line, move over to the column headed "0.03." Note here that the sum of the column and line heads, 0.6 + 0.03, equals the value of 0.63 that we want to convert. In the body of the table for this column and line we read the equivalent fraction for 0.63 foot, $7^{9}/_{16}$ inches. To that value, add the number of whole feet from the value being converted, 11 in this case. The total length equivalent of 11.63 feet is thus 11 feet $7^{9}/_{16}$ inches.

Similarly, Table 2 may be used to make the conversion from inches and fractions to decimal fractions of a foot. This table is convenient for using measured distances in equations. For example, say we wish to convert a length of 19 feet $7^{3}/_{4}$ inches to a decimal fraction. Considering only the fractional part of this value, $7^{3}/_{4}$ inches, locate the decimal value on the line identified as "7-" and in the column headed "$^{3}/_{4}$," where we read 0.646. This decimal value is equivalent to $7 + ^{3}/_{4} = 7^{3}/_{4}$ inches. To this value add the whole number of feet from the value being converted for the final result, 19 in this case. In this way, 19 feet $7^{3}/_{4}$ inches converts to 19 + 0.646 = 19.646 feet.

Table 2
Conversion, Inches and Fractions to Decimal Feet

	Fractional Increments							
	0	*$^{1}/_{8}$*	*$^{1}/_{4}$*	*$^{3}/_{8}$*	*$^{1}/_{2}$*	*$^{5}/_{8}$*	*$^{3}/_{4}$*	*$^{7}/_{8}$*
0-	0.000	0.010	0.021	0.031	0.042	0.052	0.063	0.073
1-	0.083	0.094	0.104	0.115	0.125	0.135	0.146	0.156
2-	0.167	0.177	0.188	0.198	0.208	0.219	0.229	0.240
3-	0.250	0.260	0.271	0.281	0.292	0.302	0.313	0.323
4-	0.333	0.344	0.354	0.365	0.375	0.385	0.396	0.406
5-	0.417	0.427	0.438	0.448	0.458	0.469	0.479	0.490
6-	0.500	0.510	0.521	0.531	0.542	0.552	0.563	0.573
7-	0.583	0.594	0.604	0.615	0.625	0.635	0.646	0.656
8-	0.667	0.677	0.688	0.698	0.708	0.719	0.729	0.740
9-	0.750	0.760	0.771	0.781	0.792	0.802	0.813	0.823
10-	0.833	0.844	0.854	0.865	0.875	0.885	0.896	0.906
11-	0.917	0.927	0.938	0.948	0.958	0.969	0.979	0.990

Table 1
Conversion, Decimal Feet to Inches (Nearest 16th)

	Decimal Increments									
	0.00	*0.01*	*0.02*	*0.03*	*0.04*	*0.05*	*0.06*	*0.07*	*0.08*	*0.09*
0.0	0-0	$0^{1}/_{8}$	$0^{1}/_{4}$	$0^{3}/_{8}$	$0^{1}/_{2}$	$0^{5}/_{8}$	$0^{3}/_{4}$	$0^{13}/_{16}$	$0^{15}/_{16}$	$1^{1}/_{16}$
0.1	$1^{3}/_{16}$	$1^{5}/_{16}$	$1^{7}/_{16}$	$1^{9}/_{16}$	$1^{11}/_{16}$	$1^{13}/_{16}$	$1^{15}/_{16}$	$2^{1}/_{16}$	$2^{3}/_{16}$	$2^{1}/_{4}$
0.2	$2^{3}/_{8}$	$2^{1}/_{2}$	$2^{5}/_{8}$	$2^{3}/_{4}$	$2^{7}/_{8}$	3-0	$3^{1}/_{8}$	$3^{1}/_{4}$	$3^{3}/_{8}$	$3^{1}/_{2}$
0.3	$3^{5}/_{8}$	$3^{3}/_{4}$	$3^{13}/_{16}$	$3^{15}/_{16}$	$4^{1}/_{16}$	$4^{3}/_{16}$	$4^{5}/_{16}$	$4^{7}/_{16}$	$4^{9}/_{16}$	$4^{11}/_{16}$
0.4	$4^{13}/_{16}$	$4^{15}/_{16}$	$5^{1}/_{16}$	$5^{3}/_{16}$	$5^{1}/_{4}$	$5^{3}/_{8}$	$5^{1}/_{2}$	$5^{5}/_{8}$	$5^{3}/_{4}$	$5^{7}/_{8}$
0.5	6-0	$6^{1}/_{8}$	$6^{1}/_{4}$	$6^{3}/_{8}$	$6^{1}/_{2}$	$6^{5}/_{8}$	$6^{3}/_{4}$	$6^{13}/_{16}$	$6^{15}/_{16}$	$7^{1}/_{16}$
0.6	$7^{3}/_{16}$	$7^{5}/_{16}$	$7^{7}/_{16}$	$7^{9}/_{16}$	$7^{11}/_{16}$	$7^{13}/_{16}$	$7^{15}/_{16}$	$8^{1}/_{16}$	$8^{3}/_{16}$	$8^{1}/_{4}$
0.7	$8^{3}/_{8}$	$8^{1}/_{2}$	$8^{5}/_{8}$	$8^{3}/_{4}$	$8^{7}/_{8}$	9-0	$9^{1}/_{8}$	$9^{1}/_{4}$	$9^{3}/_{8}$	$9^{1}/_{2}$
0.8	$9^{5}/_{8}$	$9^{3}/_{4}$	$9^{13}/_{16}$	$9^{15}/_{16}$	$10^{1}/_{16}$	$10^{3}/_{16}$	$10^{5}/_{16}$	$10^{7}/_{16}$	$10^{9}/_{16}$	$10^{11}/_{16}$
0.9	$10^{13}/_{16}$	$10^{15}/_{16}$	$11^{1}/_{16}$	$11^{3}/_{16}$	$11^{1}/_{4}$	$11^{3}/_{8}$	$11^{1}/_{2}$	$11^{5}/_{8}$	$11^{3}/_{4}$	$11^{7}/_{8}$

Metric Equivalents

Throughout this book, distances and dimensions are usually expressed in English units—the mile, the foot, and the inch. Conversions to metric units may be made by using the following equations:

km = mi × 1.609

m = ft (′) × 0.3048

mm = in. (″) × 25.4

An inch is $^1/_{12}$ of a foot. Tables in the previous section provide information for accurately converting inches and fractions to decimal feet, and vice versa, without the need for a calculator.

Gain Reference

Throughout this book, gain is referenced to an isotropic radiator (dBi) or to an isotropic radiator with circular polarization (dBic).

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MFJ TUNERS

MFJ *IntelliTuner*™ Automatic Tuners

The MFJ-993B *IntelliTuner*™ lets you tune any antenna *automatically -- ultra fast.*

It's a comprehensive automatic *antenna tuning center* complete with SWR/Wattmeter, antenna switch for two antennas and 4:1 current balun for balanced lines.

MFJ's exclusive *IntelliTuner*™, *Adaptive Search*™ and *Instant Recall*™ algorithms give you *ultra fast* automatic tuning with over 20,000 *VirtualAntenna*™ Memories.

You get a highly efficient L-network, 6-1600 ohm matching at 300 Watts SSB/CW or *extra-wide* 6-3200 Ohm matching at 150 Watts SSB/CW, 1.8-30 MHz coverage, Cross-Needle *and* digital meters, audio SWR meter, *backlit* LCD, remote control port, radio interface, heavy-duty 16 amp/1000V relays.

The MFJ-993B automatically tunes for minimum SWR and remembers your frequency and tuner settings. The next time you operate on that frequency and antenna, these tuner settings are instantly restored and *you're ready to operate in milliseconds!* 10W x2¾ Hx9D". Use 12-15 VDC/1 amp or 110 VAC with **MFJ-1316, $21.95**. Radio interface cables, remote control available. See ***www.mfjenterprises.com***

MFJ
MFJ IntelliTuner™
AUTOMATIC ANTENNA TUNER
MODEL MFJ-993B
Dual Power Level 300/150 Watts
MFJ ENTERPRISES, INC. STARKVILLE, MS USA
TRANSMITTER
BALANCED LINE
ANTENNA 1
ANTENNA 2
Do not connect WIRE and ANTENNA 1 at same time!

MFJ-993B
$259.95

600 Watt MFJ Automatic Tuner

MFJ
MFJ Automatic Antenna Tuner

Like MFJ-993B but handles 600 Watts SSB/CW, matches 12-800 Ohms. 10,000 memories. Does not have LCD display, antenna switch, 4:1 current balun, audio SWR meter/feedback. 10Wx2¾Hx9D in.

MFJ-994B
$359.95

***No Matter What*™ Warranty**

Every MFJ tuner is protected by MFJ's famous one year *No Matter What*™ limited warranty. We will repair or replace your MFJ tuner (at our option) for a full year.

More hams use MFJ tuners than all other tuners in the world!

MFJ-9982 *2500 Watt* Tuner

2500 Watt Antenna Tuner
MFJ

MFJ-9982
$699.95

The MFJ-9982 *ContinuousCarrier*™ antenna tuner handles 2500 Watts *continuous carrier* output on all modes and all HF bands into most unbalanced antennas -- even 160 Meters. 6-position antenna switch, 4-core balun, 1.5kW dummy load, true *peak*/average SWR/Wattmeter, 13¾Wx7Hx6¼D".

MFJ-989D *Legal Limit* Tuner

MFJ VERSA TUNER V
MFJ

MFJ-989D
$369.95

New, improved MFJ-989D *legal limit* antenna tuner gives you better efficiency, lower losses and a new *true* peak reading meter. Easily handles *full* 1500 Watts SSB/CW, 1.8-30 MHz, including MARS/WARC bands. Six position antenna switch, dummy load. *New* 500 pF air variable capacitors. *New* improved *AirCore*™ Roller Inductor. *New* high voltage current balun. *New* crank knob. 12⅞Wx6Hx11⅝D".

MFJ-962D *compact* kW Tuner

MFJ VERSA TUNER III
MFJ

MFJ-962D
$279.95

A few more dollars steps you up to a KW tuner for an amp later. Handles 1.5 KW PEP SSB amplifier input power (800W output). Ideal for Ameritron's AL-811H! *AirCore*™ roller inductor, gear-driven turns counter, pk/avg lighted Cross-Needle SWR/Wattmeter, antenna switch, balun, Lexan front, 1.8-30MHz. 10¾Wx4½Hx10⅞D in.

MFJ-969 300W *Roller Inductor* Tuner

Superb *AirCore*™ Roller Inductor tuning. Covers *6 Meters* thru 160 Meters! 300 Watts PEP SSB. *Active* true peak reading lighted Cross-Needle SWR Wattmeter, *QRM-Free PreTune*™, antenna switch, dummy load, 4:1 balun, Lexan front panel. 10½Wx3½Hx9½D inches.

MFJ-969
$199.95

MFJ-949E *deluxe* 300 Watt Tuner

MFJ DELUXE VERSA TUNER II

***More** hams use MFJ-949s than any other antenna tuner in the world!*

Handles 300 Watts. Full 1.8 to 30 MHz coverage, custom inductor switch, 1000 Volt tuning capacitors, *full size* peak/average lighted Cross-Needle SWR/ Wattmeter, 8 position antenna switch, dummy load, *QRM-Free PreTune*™, scratch proof Lexan front panel. 10⅝Wx3½Hx7D inches.

MFJ-949E
$169.95

MFJ-948, $139.95. Economy version of MFJ-949E, less dummy load, Lexan front panel.

MFJ-941E *super value* Tuner

MFJ VERSA TUNER II

***The** most for your money!*

Handles 300 Watts PEP, covers 1.8-30 MHz, *lighted* Cross-Needle SWR/ Wattmeter, 8 position antenna switch, 4:1 balun, 1000 volt capacitors, Lexan front panel. Sleek 10½Wx2½Hx7D".

MFJ-941E
$129.95

MFJ-945E HF/6M *mobile* Tuner

MFJ MOBILE TUNER
MFJ

Extends your mobile antenna bandwidth so you don't have to stop, go outside and adjust your antenna. Tiny 8Wx2Hx6D in. *Lighted* Cross-Needle SWR/Wattmeter. Lamp and bypass switches. Covers 1.8-30 MHz *and* 6 Meters. 300 Watts PEP. **MFJ-20, $6.95,** mobile mount.

MFJ-945E
$119.95

MFJ-974HB *Balanced Line* Tuner

MFJ Balanced Balun Line Tuner

The MFJ-974HB *true* fully balanced antenna tuner tunes any balanced lines. Matches 12-2000 Ohms. Covers 1.8-54 MHz *continuously* including all WARC bands. 300 Watts SSB/150 Watts CW. Lighted Cross-Needle SWR/Wattmeter. 7½Wx6Hx8D in.

MFJ-974HB
$199.95

MFJ-976, $499.95. 1500 Watt *fully balanced* antenna tuner. 1-30 MHz.

MFJ-971 *portable/QRP* Tuner

MFJ PORTABLE TUNER

Tunes coax, balanced lines, random wire 1.8-30 MHz. Cross-Needle Meter. SWR, 30/300 or 6 Watt QRP ranges. Matches popular MFJ transceivers. 6Wx6½Hx2½D in.

MFJ-971
$109.95

MFJ-902 *Tiny Travel* Tuner

MFJ Travel Tuner

Tiny 4½Wx2¼Hx3D", full 150 Watts, 80-10 Meters, has tuner bypass switch, for coax/random wire.

MFJ-902
$89.95

MFJ-904H, $139.95. Same but adds Cross-needle SWR/Wattmeter and 4:1 balun for balanced lines. 7¼Wx2¼Hx2¾D in.

MFJ-16010 *random wire* Tuner

Operate all bands anywhere with MFJ's reversible L-network. Turns random wire into powerful transmitting antenna. 1.8-30 MHz. 200 Watts PEP. Tiny 2Wx3Hx4D inches.

MFJ-16010
$59.95

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or call toll-free 800-647-1800

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MFJ-259B *Antenna Analyzer*

The world's most popular antenna analyzer gives you a complete picture of your antenna performance 1.8 to 170 MHz. Super easy-to-use -- makes tuning your antenna quick and easy. Read antenna SWR, complex impedance, return loss, reflection coefficient. Determine velocity factor, coax cable loss in dB, length of coax and distance to a short or open in feet. Read inductance in uH and capacitance in pF at RF frequencies. Large easy-to-read two line LCD screen and side-by-side meters clearly display your information. Built-in frequency counter, Ni-Cad charger circuit, battery saver, low battery warning and smooth reduction drive tuning.

MFJ-259B
$\$279^{95}$

MFJ-99B, $88.80. Accessory Package for MFJ-259B. Includes MFJ-29C custom foam-filled carrying case, MFJ-66 dip meter adapters, MFJ-1312D 110VAC adapter and 10-pack high capacity Ni-MH MFJ *SuperCell*™ batteries. ***Save $7!***

MFJ
POWER
97.158 MHz 1.2
R= 39 X= 0 SWR
MFJ HF/VHF SWR ANALYZER
MODEL MFJ-259B
SWR
IMPEDANCE
GATE
MODE
TUNE
FREQUENCY MHz

1.8-170 MHz *plus* 415-470 MHz *Antenna Analyzer*

MFJ-269
$\$379^{95}$

All-in-one handheld antenna test lab lets you quickly check/tune HF, VHF, ***UHF*** antennas anywhere. Measures: SWR, Return Loss, Reflection Coefficient, R, X, Z, Phase Angle, Coax cable loss, Coax cable length, Distance to short/open in coax, Inductance, Capacitance, Resonant Frequency, Bandwidth, Q, Velocity Factor, Attenuation, more!

MFJ *Weather-Proof* Antenna *Feedthrough* Panel

Bring three coax-fed HF/VHF/UHF antennas, balanced line, random wire and ground into your hamshack without drilling through walls . . . ***New!*** MFJ-4602 **$\$59^{95}$**

Indoor View

MFJ's Weather-proof *Antenna Feedthrough Panel* mounts in your window sill. Lets you feed three coax-fed antennas, balanced line, random wire and ground without drilling through walls.

Simply place in window sill and close window. One cut customizes it for any window up to 48 inches. Use horizontally or vertically. High-quality pressure-treated wood with excellent 3/4 inch thick insulating properties is painted with heavy coat of white outdoor enamel paint. Edges sealed by weather-stripping. Seals and insulates against all weather conditions. Gives years of trouble-free service. ¾Dx3½Hx48W in.

Inside/outside stainless steel plates bond all coax shields to ground. Stainless steel ground post brings outside ground connection inside. 3 *Teflon*(R) SO-239 coax connectors, *ceramic* balanced line/randomwire feedthru insulators.

COAX 1
COAX 2
COAX 3
BALANCED LINE
RANDOM WIRE
GROUND
MFJ
Stainless Steel Bonding Plate

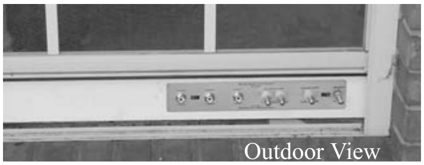
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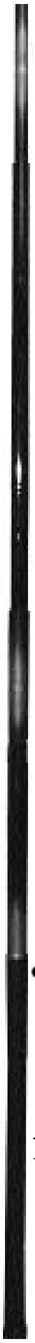

Current Balun/Center Insulator

MFJ-918
$\$24^{95}$

True *1:1 Current Balun/Center Insulator* forces equal antenna currents in dipoles. *Improves all dipoles/ doublets!* Reduces coax feedline radiation, field pattern distortion, TVI, RFI, RF hot spots. SO-239. 1.8-30 MHz, 1.5kW. Stainless steel hardware. *Direct* wire connection to antenna. 5x2 inches.

Antenna Switches

MFJ-1702C 2 position antenna coax switch. Exclusive lightning arrestor and center pos. ground, lightning arrestor. 2.5 kW PEP, 1 kW CW. Loss below .2 dB. 50 dB isolation @ 450 MHz. 50 Ohms. 3x2x3". **MFJ-1704.** Like MFJ-1702C but has 4 positions. 6¼x4¼ x1¼ in. 50 load. SWR 1.1: 1 to 30 MHz; 1.5:1, 30-650 MHz. SO-239.

MFJ-1702C
$\$34^{95}$

MFJ-1704
$\$74^{95}$

All Band G5RV Antennas

160-10 Meters with tuner. 102 foot.1.5 kW. Use as Marconi on 160 Meters with tuner/ ground. Ladder line/SO-239. **MFJ-1778M, $34.95.** *Half-size*, 52 ft. G5RV-Jr. 60-10 Meters with tuner. 1.5 kW.

MFJ-1778
$\$39^{95}$

33 Foot *fiberglass* Mast

MFJ-1910
$\$79^{95}$

33 foot super strong fiberglass *telescoping* mast collapses to 3.8 feet, weighs 3.3 lbs. Huge, strong 1¾ inch bottom section. Flexes to resist breaking. Resists UV. Put up *full size* inverted Vee dipole/vertical antenna in minutes and get *full size performance!*

MFJ-915 RF Isolator

MFJ
MFJ-915
RF Isolator

MFJ-915
$\$29^{95}$

MFJ-915 *RF Isolator* prevents unwanted RF from traveling on the outside of your coax shield into your transceiver. Clears up RFI. Eliminates painful RF "bites" on your rig or microphone. Keeps your transceiver and vehicle displays and settings from locking up. Plugs between coax and transceiver. 5x2 inches. 1.8-30 MHz, 1.5 kW.

6-Band *Rotatable* mini-Dipole

MFJ-1775
$\$239^{95}$

Low-profile mini 14 foot rotatable dipole has tiny 7-foot turning radius. Fits on smallest roof -- perfect for town houses, apartments and condos.

Easily turned by TV rotator.

It's no Wimp! Good *directivity* reduces QRM/noise and lets you *focus* your signal in the direction that you want -- so you can work some *real* DX.

Operate 40, 20, 15, 10, 6, 2 meters. Run *full 1500 Watts* SSB/CW on all HF bands!

Ham radio's most versatile rotatable dipole features automatic band switching. Uses highly efficient end-loading with its *entire length* always radiating.

No lossy traps! Has separate, efficient end-loading *Teflon*™ coils on fiberglass forms and capacitance hats for each HF band. 6/2 Meters are *full-length* dipoles.

Built-to-last -- super strong solid fiberglass center insulator, 6063 T-6 aircraft strength aluminum tubing. Assembles in an afternoon.

MFJ-1775W, $239.95. WARC band version for 12, 17, 30, 60 Meters only.

MFJ W9INN Balun Box

W9INN BALUN BOX
MODEL MFJ-912
TRANSMITTER
GND
MFJ

MFJ-912
$\$59^{95}$

Converts unbalanced coax line to balanced ladder transmission line. *Giant* 2-core 4:1 balun wound with *Teflon*(R) wire. 3¼x2¼x7 inches. Heavy duty ceramic feed-through insulators. 1500 Watts full legal limit. SO-239. Ground post, mounting holes.

MFJ Field Strength Meters

Huge 3" meter. Telescoping ground-independent *dipole*. .1-500 MHz. Sensitivity control. Remote sensor, MFJ-802R, $24.95. **MFJ-801, $24.95.** *Monopole* field strength meter, 1¼" meter.

MFJ-802
$\$44^{95}$

Clamp-On RF Ammeter

MFJ-854
$\$109^{95}$

Clamp-On RF Ammeter snaps over cables up to ½ inch diameter. Measure RF currents in antenna elements, radials, ground wires, coax shield. Five *calibrated* ranges to 3 Amps. 1-30 MHz. 2½Wx5½Hx1½D inches.

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and Nearest Dealer . . . 800-647-1800

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hy-gain® HF VERTICALS

Self-supporting -- no guys required . . . Remarkable DX performance -- low angle radiation, omnidirectional . . . Handles 1500 Watts . . . Low SWR . . . Automatic band switching . . . Aircraft quality aluminum tubing . . . Stainless steel hardware . . . Recessed SO-239 connector . . . Two year limited Warranty . . .

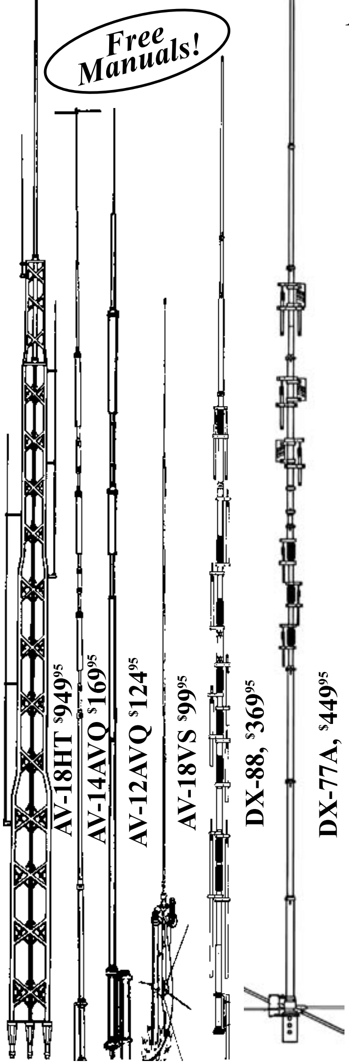

hy-gain$^{(R)}$ *Classics*

All hy-gain multi-band vertical antennas are entirely self supporting -- no guys required.

They offer remarkable DX performance with their extremely low angle of radiation and omnidirectional pattern.

All handle 1500 Watts PEP SSB, have low SWR, automatic bandswitching (except AV-18VS) and include a 12-inch heavy duty mast support bracket (except AV-18HT).

Heavy duty, slotted, tapered swaged, aircraft quality aluminum tubing with full circumference compression clamps is used for radiators.

Includes all stainless steel hardware. Recessed SO-239 prevents moisture damage.

Hy-gain verticals go up easily with just hand tools and their cost is surprisingly low.

Two year limited warranty.

AV-18HT, $949.95. (10,12,15,20,40,80 M, 160, 17 Meters optional). 53 ft., 114 lbs.

Standing 53 feet tall, the famous *Hy-Gain HyTower* is the world's best performing vertical! The AV-18HT features automatic band selection achieved through a unique stub-decoupling system which effectively isolates various sections of the antenna so that an electrical 1/4 wavelength (or odd multiple of a 1/4 wavelength) exists on all bands. Approximately 250 kHz bandwidth at 2:1 VSWR on 80 Meters. The addition of a base loading coil (**LC-160Q, $109.95**), provides exceptional 160 Meter performance. **MK-17, $89.95**. Add-on 17 Meter kit. 24 foot tower is all rugged, hot-dip galvanized steel and all hardware is iridited for corrosion resistance. Special tilt-over hinged base for easy raising & lowering.

AV-14AVQ, $169.95. (10,15,20,40 Meters). 18 ft., 9 lbs. The Hy-Gain AV-14AVQ uses the same trap design as the famous Hy-Gain Thunderbird beams. Three separate air dielectric Hy-Q traps with oversize coils give superb stability and 1/4 wave resonance on all bands. Roof mount with Hy-Gain AV-14RMQ kit, $89.95.

AV-12AVQ, $124.95. (10, 15, 20 Meters). 13 ft., 9 lbs. AV-12AVQ also uses Thunderbird beam design air dielectric traps for extremely Hy-Q performance. This is the way to go for inexpensive tri-band performance in limited space. Roof mount with AV-14RMQ kit, $89.95.

AV-18VS, $99.95. (10,12,15,17,20,30,40,80 Meters). 18 ft., 4 lbs. High quality construction and low cost make the AV-18VS an exceptional value. Easily tuned to any band by adjusting feed point at the base loading coil. Roof mount with Hy-Gain AV-14RMQ kit, $89.95.

DX-88, $369.95. (10, 12, 15,17,20,30,40,80 Meters, 160 Meters optional). 25 ft., 18 lbs.

All bands are *easily* tuned with the DX-88's *exclusive* adjustable capacitors. 80 and 40 Meters can even be tuned from the ground without having to lower the antenna. Super heavy-duty construction. DX-88 OPTIONS: 160 Meter add-on kit, KIT-160-88, $199.95. Ground Radial System, GRK-88, $99.95. Roof Radial System, RRK-88, $99.95.

DX-77A, $449.95. (10, 12, 15, 17, 20, 30, 40 Meters). 29 ft., 25 lbs.

No ground radials required! Off-center-fed Windom has 55% greater bandwidth than competitive verticals. Heavy-duty tiltable base. Each band independently tunable.

hy-gain^{R} PATRIOT

Hy-Gain's new PATRIOT HF verticals are the best built, best performing and best priced multiband verticals available today. For exciting DX make full use of your sunspot cycle with the PATRIOT's *low 17 degree angle* signal.

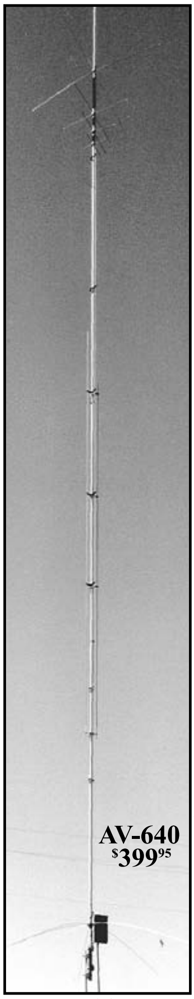

No ground or radials needed

Effective counterpoise replaces radials and ground.

Automatic bandswitching

Single coax cable feed. Each band is individually tunable. Extra wide VSWR bandwidth. End fed with broadband matching unit.

Sleek and low-profile

Low 2.5 sq. ft. wind surface area. Small area required for mounting. Mounts easily on decks, roofs and patios.

Full legal limit

Handles 1500 Watts key down continuous for two minutes.

Built-to-last

High wind survival of 80 mph. Broadband matching unit made from all *Teflon*^{R} insulated wire. Aircraft quality aluminum tubing, stainless steel hardware.

hy-gain*^{R} *warranty

Two year limited warranty. All replacement parts in stock.

AV-640, $399.95. (6,10,12, 15,17,20,30,40 Meters). 25.5 ft., 17.5 lbs. The AV-640 uses quarter wave stubs on 6, 10, 12 and 17 meters and efficient end loading coil and capacity hats on 15, 20, 30 and 40 meters -- no traps. Resonators are placed in parallel not in series. End loading of the lower HF bands allows efficient operation with a manageable antenna height.

AV-620, $299.95. (6,10,12,15,17,20 Meters). 22.5 ft., 10.5 lbs. The AV-620 covers all bands 6 through 20 Meters with no traps, no coils, no radials yielding an uncompromised signal across all bands.

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and Nearest Dealer . . . 800-973-6572
Call your dealer for your best price!

hy-gain®

Antennas, Rotators & Towers
308 Industrial Park Road, Starkville, MS 39759 USA
Toll-free Customer Sales Hotline: 800-973-6572
• TECH: 662-323-9538 **• FAX:** 662-323-6551
http://www.hy-gain.com

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Model #	Price	Bands	Max Power	Height	Weight	Wind Surv.	Rec. Mast
AV-18HT	$949.95	10,15,20,40,80	1500 W PEP	53 feet	114 pounds	75 MPH	------
AV-14AVQ	**$169.95**	**10,15,20,40**	**1500 W PEP**	**18 feet**	**9 pounds**	**80 MPH**	**1.5-1.625”**
AV-12AVQ	$134.95	10/15/20 M	1500 W PEP	13 feet	9 pounds	80 MPH	1.5-1.625”
AV-18VS	**$99.95**	**10 - 80 M**	**1500 W PEP**	**18 feet**	**4 pounds**	**80 MPH**	**1.5-1.625”**
DX-88	$369.95	10 - 40 M	1500 W PEP	25 feet	18 pounds	75 mph no guy	1.5-1.625”
DX-77A	**$449.95**	**10 - 80 M**	**1500 W PEP**	**29 feet**	**25 pounds**	**60 mph no guy**	**1.5-1.625”**

Antennas *built-to-last . . . Use* hy-gain *parts!*

FAMOUS Heavy Duty *hy-gain* BALUNS

BN-86, $79.95. Broadband 50 Ohm ferrite balun. Useable from 3 to 30 MHz. Recommended for all HF Yagi antennas. It provides improved front-to-back ratio. Comes with clamp to bolt to boom, SO-239 connector.

BN-4000B, $109.95. **B**roadband 50 Ohm Yagi current balun is potted to seal out moisture. Rated at 4000 Watts for increased power handling capabilities. 1 to 54 MHz. SO-239 connector. **BN-4000D, $109.95.** dipoles. **BN-4000N, $119.95.** "N" connector.

hy-gain Center Dipole Insulators

C-1, $29.95. Center Insulator for multiband dipole antenna.

C-1C, $29.95. Similar to C-1, but has SO-239 antenna connector.

E-1, $6.95. 6 inch super high-power, high-voltage *end insulator* for Multi-band doublet antenna. Set of 2.

Arrowpoint Anchor

APA-3, $14.95. Up to 2000 lbs. pull-out resistance to secure antennas, towers. Use one per guy wire. **DR-3, $29.95**. Drive Rod.

Glazed Ceramic Insulator

E-2 **79¢** **each**

E-26 **$4.56** **6-Pack**

Extra-strong -- will not break, arc over or melt even under full legal power. Molded ridges give extra-long path to prevent high-voltage breakdown.

Ground Rod

GR-1 **$6.95**

Durable four foot by 3/8 inch diameter *copper bonded* steel earth ground rod. Sharp point makes it easy to insert into ground. Bleed off static/RFI. Prevent RF hot spots. Use several to form a good RF ground.

hy-gain Rotator

HAM-IV **$559.95**

World's most rugged rotator! Many in use after 25 years. Highly resistant to lightning, static, RFI. Bell design gives total weather protection. 15 sq. ft. windload, 5-sec. brake delay, 5000 in-lb steel wedge brake, ring gear handles 100,000 PSI, dual 98 ball bearing race, -30° F operation. Max mast $2\frac{1}{16}$”

ATM-65 **$199.95**

hy-gain Aluminum Tubing

6063 T832 round, drawn aluminum tubing sold in 2 styles: ***6' standard*** or ***6' slitted*** *one end, (.083" gaps, 1-2" slit lengths*).

Tubing are sized to allow telescoping into one another from .625 OD to 2 inches OD. Select slitted tubing for telescoping. Use Hy-gain Stainless Steel hose clamps to secure.

OD x Wall-Th x ID	6'stnrd; p/n, price/ea	6'slitd; p/n, price/ea.	Ad'l/ft.
.625"x.035"x.555"	810-0625C-6U, $5.70	810-0625C-6S, $6.90	$1.00
.750"x.058"x.634"	810-0750E-6U, $10.55	810-0750E-6S, $12.66	$1.85
.875"x.058"x.759"	810-0875E-6U, $8.72	810-0875E-6S, $9.92	$1.53
1.000"x.058"x.884"	810-1000E-6U, $11.46	810-1000E-6S, $12.66	$2.01
1.125"x.058"x1.009"	810-1125E-6U, $10.03	810-1125E-6S, $11.23	$1.76
1.250"x.058"x1.134"	810-1250E-6U, $11.57	810-1250E-6S, $12.77	$2.03
1.375"x.058"x1.259"	810-1375E-6U, $13.17	810-1375E-6S, $14.37	$2.31
1.500"x.058"x1.384"	810-1500E-6U, $17.95	810-1500E-6S, $19.16	$3.15
1.625"x.058"x1.509"	810-1625E-6U, $21.32	810-1625E-6S, $22.52	$3.74
1.750"x.058"x1.634"	810-1750G-6U, $27.86	810-1750G-6S, $29.62	$4.88
2.000'x.120"x1.760"	810-2000I-6U, $38.93	810-2000I-6S, $41.03	$6.83

hy-gain Stainless Steel Hose Clamps

Part No.	Price	Description
745-3106S	$1.00	#6 Clamp for .75" OD to .875" OD tubing
745-3110S	$1.00	#10 Clamp for 1" OD to 1.125" OD tubing
745-3116S	$1.25	#16 Clamp for 1.25" OD to 1.50" OD tubing
745-3128S	$2.84	#28 Clamp for 1.75" OD to 2" OD tubing

←*hy-gain* Telescopic *Aluminum Mast*

ATM-65, $199.95. Pictured left. 11-section *multi-purpose* aluminum telescopic pole can be used as a vertical antenna or as a mast. Great for portable, temporary use and permanent use -- traveling, camping, etc. Includes one size of each slitted tube listed above and ten hose clamps. 65 ft. fully extended, 6 ft. collapsed without clamps. Guying required if mast is extended beyond 30 feet. Top section is .625" OD. Bottom section is 2 inches OD x .120 wall.

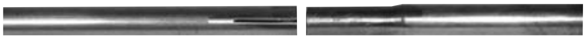

810-2000I-6W, $44.95 each. Unique tubing has one end slitted and one end swaged to make it stackable. Slide one end into another tubing for longer poles. Secure with standard host clamp. Strong, 2"OD x .120" wall. Good for base sections of vertical antennas. Standard 6-ft. length, longer sections, to 20 ft. available. Add $6.83 each add'l foot. **6** ft. lengths ship by UPS, longer units must ship UPS *oversize*/truck.

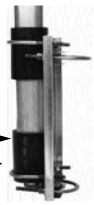

hy-gain Base Mount Assembly Kit→

877200, $69.95. ***New!*** Complete ATM-65 base assembly kit with base mounting plate, insulators, hardware.

hy-gain Custom *Precision* Antenna Hardware

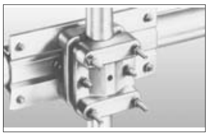

BMC-249, $79.95. ***Boom to Mast Clamp*** Heavy duty $1\frac{1}{4}$" OD thick aluminum die casted boom to mast clamp designed for heavy antennas. Supports 2-inch boom antennas, such as the TH-11DX, Long John Monobanders and other beams with a 2" boom. The BMC-249 allows mast to extend past the top of the clamp. This feature allows stacking of several antennas on one mast. Clamp is adjustable for mast sizes from $1\frac{1}{4}$" to $2\frac{3}{4}$" OD. The tilt-over feature permits easy assembly of the elements and simplifies maintenance of the antenna. 4Wx4Hx$1\frac{1}{4}$" thick. Kit comes complete with stainless steel hardware.

Element Insulators These element insulators are made to fit the element bracket (right). Precision injection molded with black UV resisted ABS plastic.

Part No.	Price	Fits these Element sizes	Insulator Size	Fits Element to boom clamp
465216	$3.42	$\frac{7}{16}$" OD	$\frac{7}{8}$"OD x $2\frac{3}{4}$"	163409
461057	$4.40	$\frac{5}{8}$" OD	$1\frac{1}{4}$" OD x 3"	165919
463767	$4.40	$\frac{7}{8}$" OD	$1\frac{1}{4}$" OD x 3"	165919
465833	$4.80	$1\frac{1}{4}$" OD	$1\frac{1}{2}$" OD x 4"	165920

hy-gain TH-series HF Beam Trap Caps

A. 464723, $.75 ea. Trap caps, for large Hy-gain TH-series traps.
B. 466221, $1.59 ea. Trap caps for Hy-gain TH-3Jr. traps.

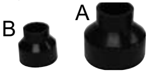

Element to Boom Clamps

Made from high tensile strength aluminum alloy. Custom die is used to stamp these clamps. No miss-drilled holes. They fit perfect everytime. Required 2 clamps per element. Element Insulators available (left).

Part#	Price	Boom OD"	Element OD w/o insulator	Element OD w/insulator	Description	Insulator
161409	$2.71	2"	$\frac{5}{8}$"	---	$2\frac{1}{2}$x7"x.08 Thick, #12	None
163764	$3.80	2"	$\frac{7}{8}$"	$\frac{7}{16}$"	$2\frac{3}{8}$x$7\frac{1}{8}$"x.08 Thick, #4	465216
165919	$5.32	2"	$1\frac{1}{4}$"	$\frac{5}{8}$", $\frac{7}{8}$"	$3\frac{1}{4}$x$7\frac{1}{4}$"x.125 Thick, #13	463767, 461057
165920	$6.28	2"	$1\frac{1}{2}$"	$1\frac{1}{4}$"	$3\frac{1}{4}$x$9\frac{1}{2}$"x.125 Thick, #14	465833
160055	$1.22	$1\frac{1}{4}$"	$\frac{7}{16}$"	---	$\frac{3}{4}$x5"x.063 Thick, #0	None
161422	$3.63	$1\frac{1}{4}$"	$\frac{5}{8}$"	---	$2\frac{1}{2}$x$6\frac{1}{2}$"x.08 Thick, #11	None
165141	$3.76	$1\frac{1}{4}$"	$\frac{7}{8}$"	$\frac{7}{16}$"	$2\frac{5}{16}$x$6\frac{5}{8}$"x.08 Thick, #12	465216
165138	$5.20	$1\frac{1}{4}$"	$1\frac{1}{4}$"	$\frac{5}{8}$", $\frac{7}{8}$"	$2\frac{3}{4}$x$6\frac{5}{8}$"x.08 Thick, #1	463767, 461057
872223	$6.60	Stainless steel screws, nuts and washers for 1 set of element-to-boom clamp				

hy-gain Vertical Antenna Hardware

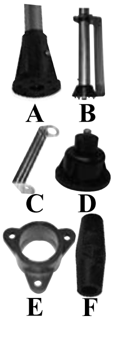

A. 463011, $14.00, Base tubing insulator, fits $1\frac{1}{4}$" OD tube. Six $\frac{5}{16}$" mounting holes. Super strong fiberglass filled ABS. Used in Hy-tower to isolate tower legs from ground. Tubing not included.
B. 877130, $28.64, Vertical antenna bracket assembly. Includes bracket (C), base cover insulator (D), support insulator (E) and SO-239. Fits $1\frac{1}{4}$" tubing. Tubing not included.
C. 160043-1, $11.84, Base mount bracket. Custom-tooled $\frac{1}{8}$" thick x 12 inch length aluminum bracket with vertical ridges for super strength. Pre-punched holes for SO-239 or N-connector.
D. 863427, $6.90, Base tubing insulator. Molded pin connects base tubing to SO-239 or N-connector.
E. 463056, $3.12, Base antenna support insulator. Made to fit top support of antenna bracket (C). Hole fits $1\frac{1}{4}$" OD tubing.
F. 460316, $12.96, Tubing coupler/insulator. Used to couple/ insulate 1" tube to $\frac{7}{8}$" tubing. Made of fiberglass filled ABS, 5" long.

hy-Gain Tower Bases

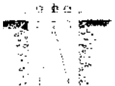

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TB-52	HG-52SS	$299.95	80 lbs.*
TB-54	HG-54HD	$299.95	90 lbs.*
TB-70	HG-70HD	$349.95	102 lbs.*

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Usage 450 MHz and Higher.

PL259
Connector

PL259 CONNECTORS EACH END

Part #	Footage	Price
600C125	125 ft	$235.95
600C100	100 ft	$205.95
600C75	75 ft	$175.95
600C50	50 ft	$145.95
600C25	25 ft	$115.95
600C3	3 ft	$ 88.95

PL259(UHF) TO "N" MALE CONNECTOR

Part #	Footage	Price
600CN100	100 ft	$187.95

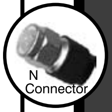
N
Connector

"N" MALE CONNECTORS EACH END

Part #	Footage	Price
600N100	100 ft	$168.95
600N75	75 ft	$139.95
600N50	50 ft	$108.95
600N25	25 ft	$ 77.95
600N15	15 ft	$ 66.49
600N6	6 ft	$ 55.49

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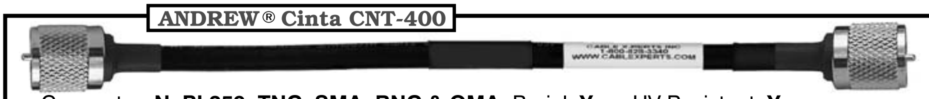
CABLE X-PERTS INC
1-800-828-3340
WWW.CABLEXPERTS.COM
RG8U SIZE
SHOWN

Connector: **N, PL259, TNC, SMA, BNC & QMA,** Burial: **Yes**, UV Resistant: **Yes**.
Shields: **2** (100% bonded foil +90% TC Braid) **VP 85%,** Attenuation 6.0dB @ 2 GHz at 100ft.
Usage 450 MHz and Higher.

PL259
Connector

PL259 CONNECTORS EACH END

Part #	Footage	Price
400C100	100 ft	$ 82.49
400C75	75 ft	$ 63.95
400C50	50 ft	$ 45.49
400C25	25 ft	$ 27.49
400C6	6 ft	$ 14.95
400C3	3 ft	$ 11.95

N
Connector

"N" MALE CONNECTORS EACH END

Part #	Footage	Price
400N50	50 ft	$ 54.95
400N6	6 ft	$ 22.95
400N3	3 ft	$ 20.95

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ANDREW® Cinta CNT-240

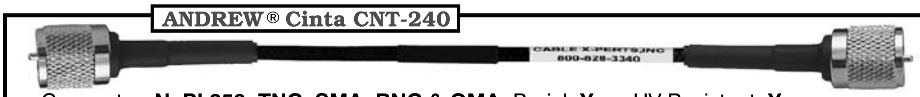
CABLE X-PERTS,INC
800-828-3340
RG8X SIZE
SHOWN

Connector: **N, PL259, TNC, SMA, BNC & QMA,** Burial: **Yes**, UV Resistant: **Yes**.
Shields: **2** (100% bonded foil +90% TC Braid) **VP 84%,** Attenuation 3.0dB @ 150 MHz at 100ft.
Usage 1 MHz and Higher.

PL259
Connector

PL259 CONNECTORS EACH END

Part #	Footage	Price
240C6	6 ft	$ 14.75
240C3	3 ft	$ 12.95

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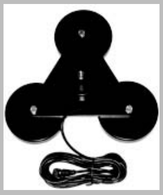

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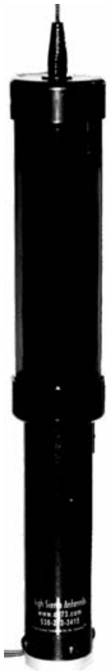

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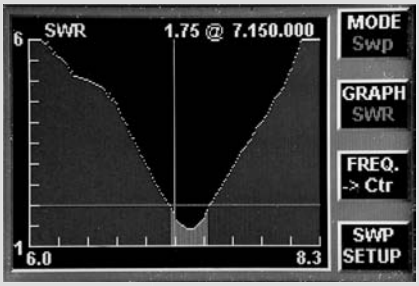
6
SWR
1.75 @ 7.150.000
1
6.0
8.3
MODE
Swp
GRAPH
SWR
FREQ.
-> Ctr
SWP
SETUP

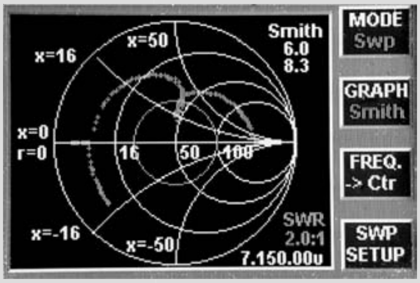
x=16
x=50
Smith
6.0
8.3
x=0
r=0
16
50
100
x=-16
x=-50
SWR
2.0:1
7.150.000
MODE
Swp
GRAPH
Smith
FREQ.
-> Ctr
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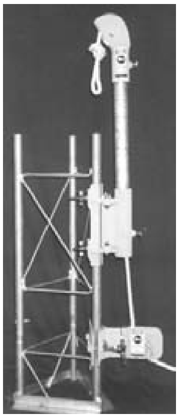

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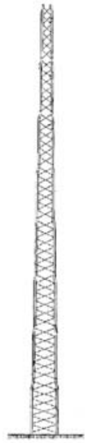

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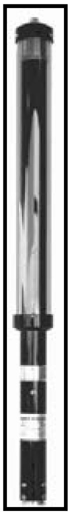

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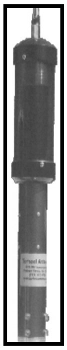

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"Stubby"
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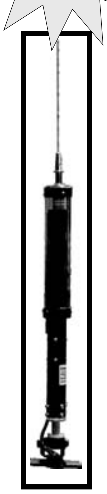

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Little Tarheel II * 3.5 Mhz-54.0 MHz * 200 watts PEP * 1-1/4" coil 16" base * 32" whip * 1.9 lbs * 48" @ 54.0 MHz * 54" @ 3.5 MHz

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Model 100 * 3.4 Mhz - 30.0 * 1.5 Kw PEP * 2" coil * 3' base * 6' whip 8 lbs * 9' 4" tall @ 30.0 MHz * 12' tall @ 3.5 MHz

Model 200 * 3.4 Mhz - 28.0 MHz * 1.5 Kw PEP * 2" coil * 4' base 6' whip * 10' 4" tall @ 28.0 MHz * 12' tall @ 3.5 MHz

Model 300 * 1.8 Mhz - 30.0 MHz * 400 watts PEP * 2" coil * 3' base 6' whip * 8.5 lbs * 9' 4" tall @ 30.0 MHz * 11' tall @ 1.8 MHz

Model 400 * 1.8 Mhz - 28.0 MHz * 400 watts PEP * 2" coil * 4' base 6' whip * 9 lbs * 10' 4" tall @ 28.0 MHz * 12' tall @ 1.8 MHz

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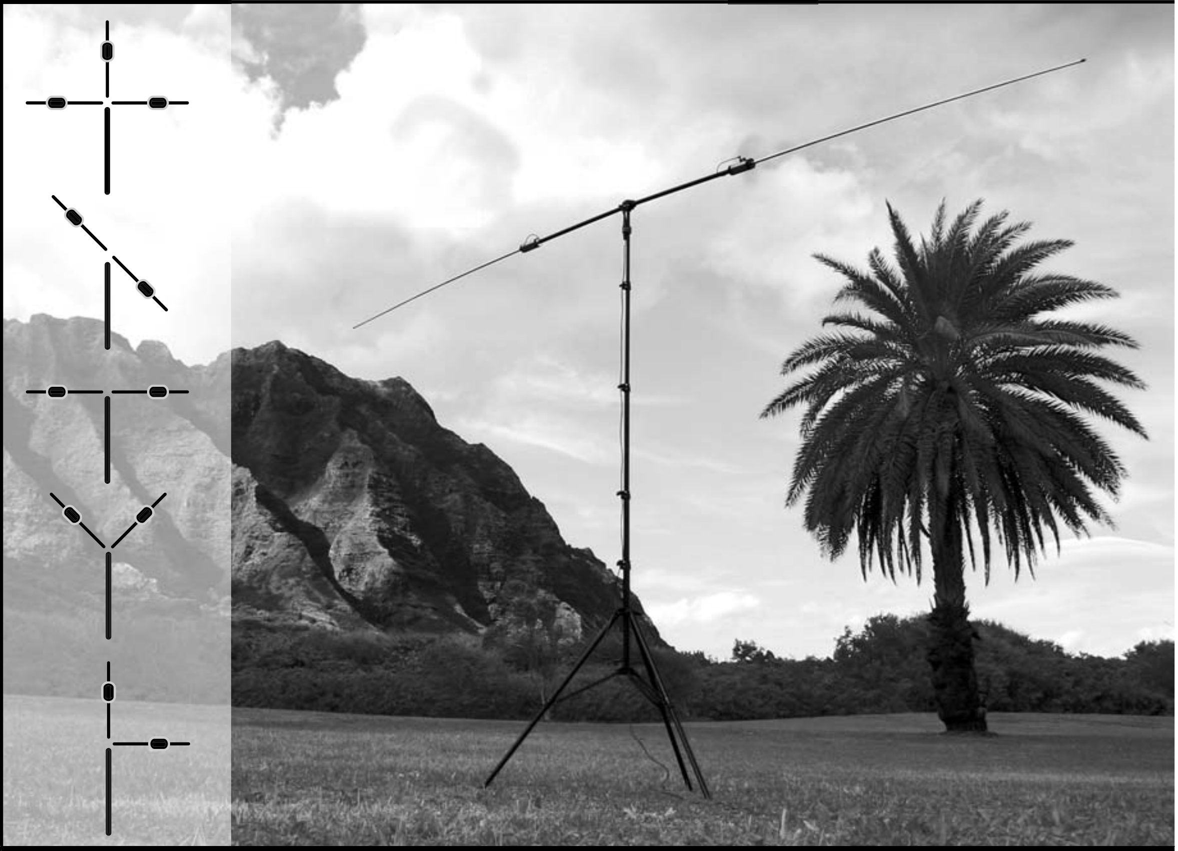

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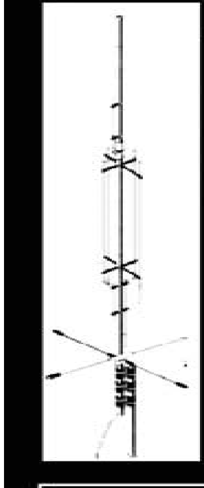

TITAN DX

10m, 12m, 15m, 17m, 20m, 30m, 40m, & 80m

25' tall 25 lbs

Mounts on 1-1/4" OD mast

No radials required.

*VSWR under 2:1 on 80m 100 KHz

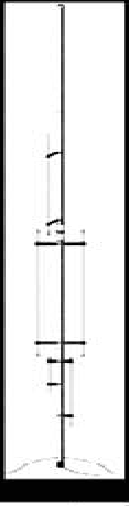

CHALLENGER DX

2m, 6m, 10m, 12m, 15m, 20m, 40m, & 80m

31.5' tall 21 lbs

Drop in ground mount supplied.

3 counterpoises required 25' long.

*VSWR under 2:1 on 80m 130 KHz

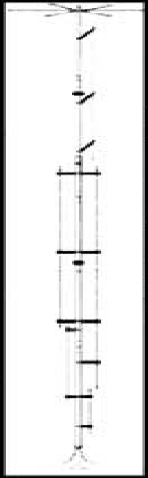

VOYAGER DX

20m, 40m, 80m, & 160m

45' tall 39 lbs

Supllied with hinged ground mount.

3 counterpoises required 57' long.

*VSWR under 2:1 on 160m 90 KHz

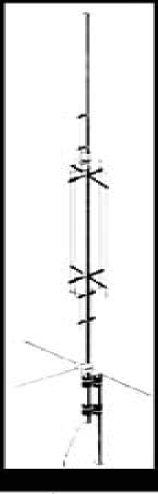

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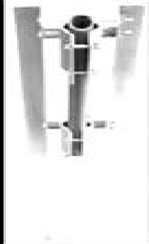

Accomdates 1 1/4" 2" OD Mast

LADDER MOUNT

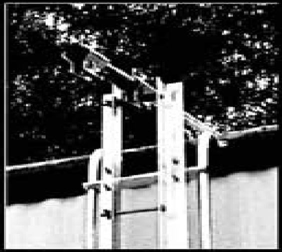

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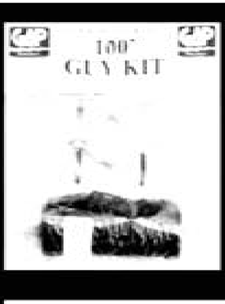

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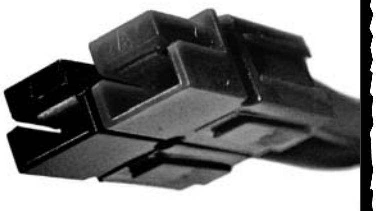

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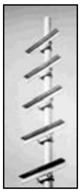

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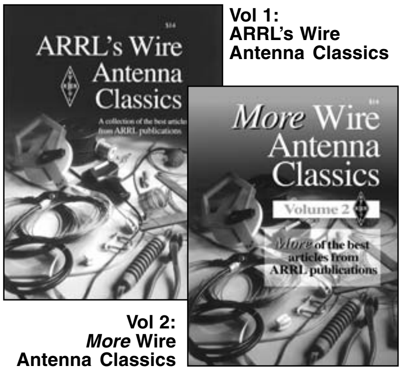

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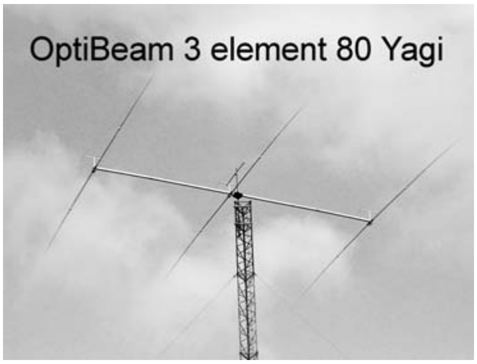
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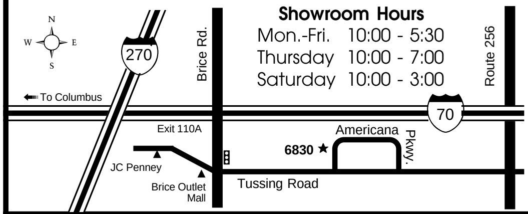

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Volume 7

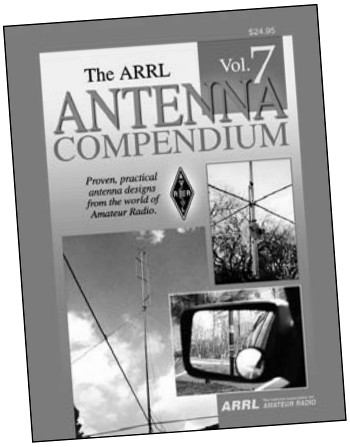
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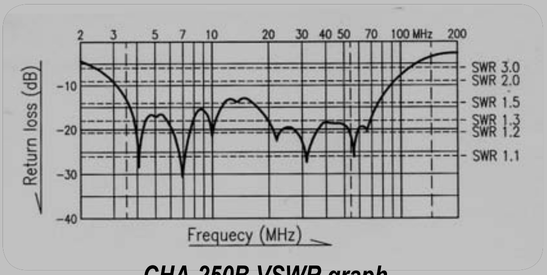

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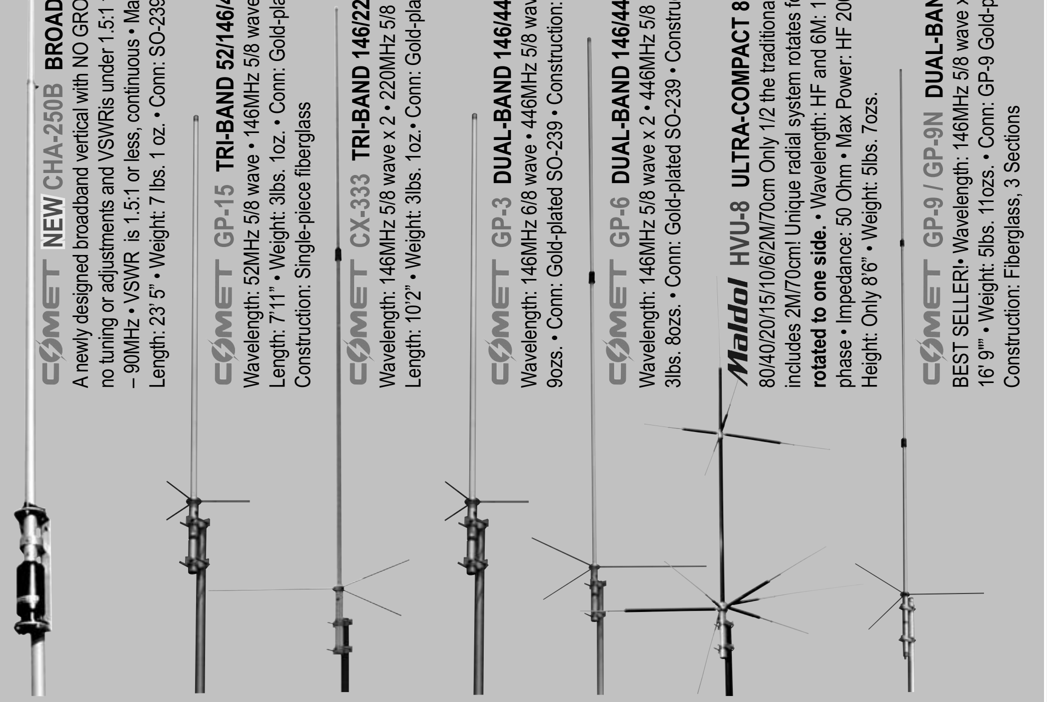

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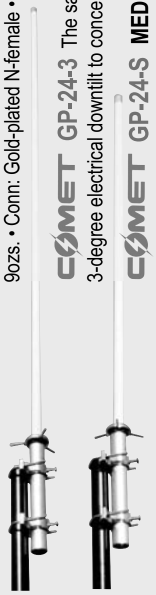

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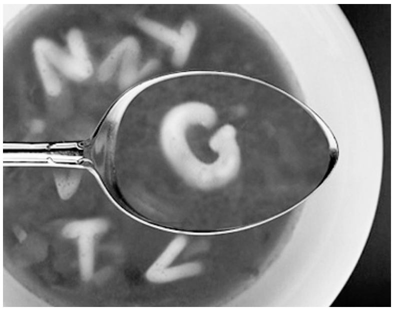

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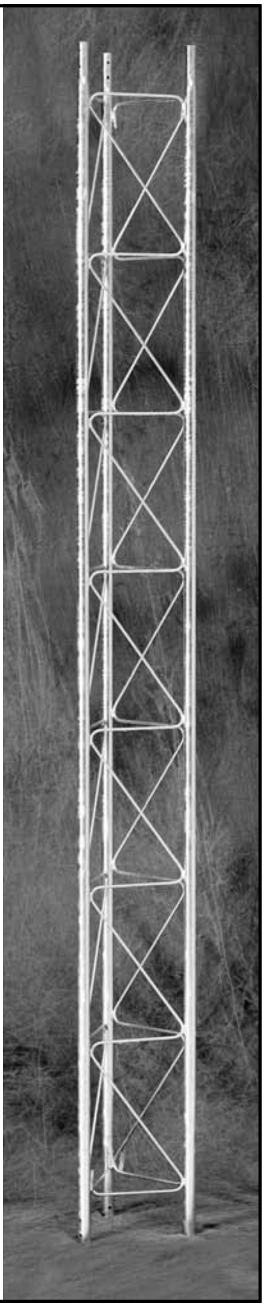

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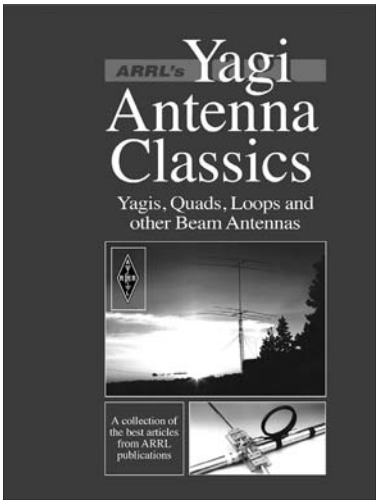

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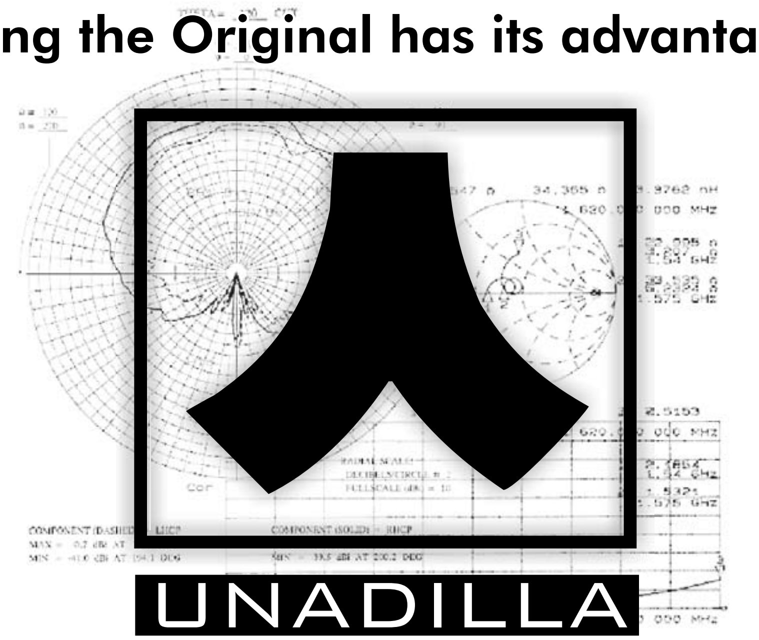

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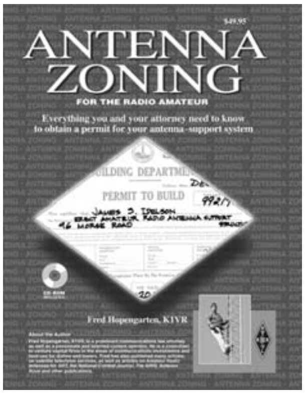

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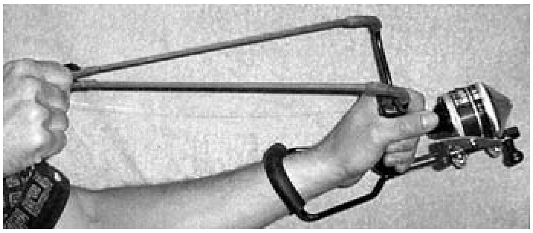

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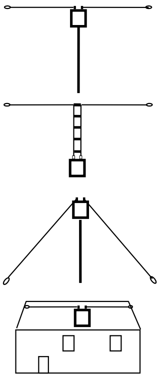

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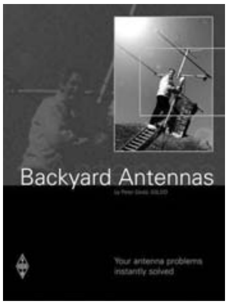

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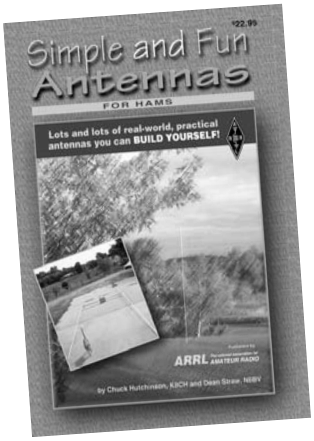
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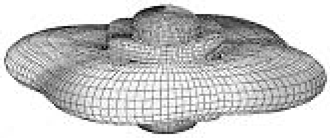

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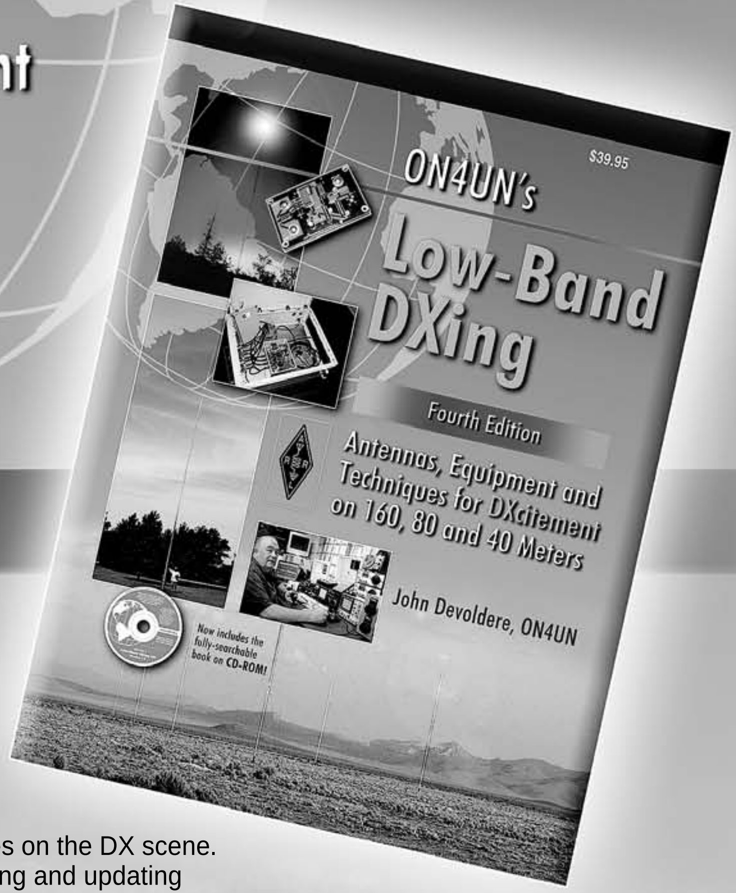
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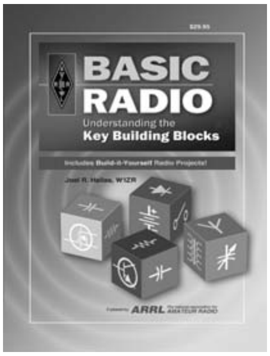
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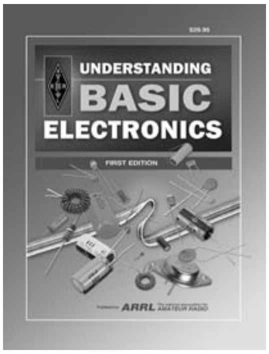
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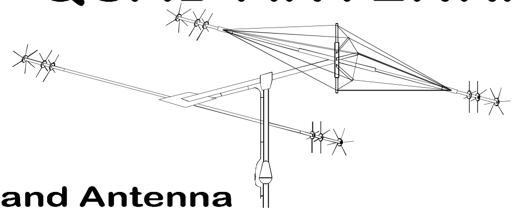

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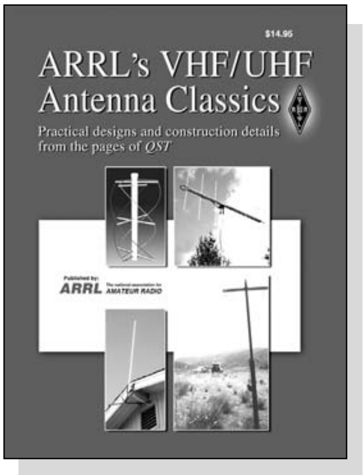
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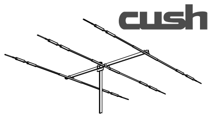

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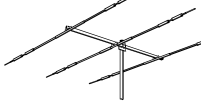

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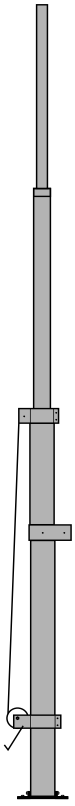

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Introduction to the CD-ROM Edition
The ARRL Antenna Book, 21st Edition

> "In recent years it has been borne home on us most forcibly that there is greater room for increased performance through superior antenna systems than in any other part of the equipment."
>
> —*from the Foreword to the First Edition,*

Much has changed since 1939, including the possible ways of delivering information—this CD-ROM is evidence of that! One thing that hasn't changed is that antennas and antenna systems are still the make-or-break component of any amateur station. We are pleased to bring you this 21st edition of *The ARRL Antenna Book* on CD-ROM. The CD-ROM book contains all of the text, drawings and photos contained in the printed 21st edition. And exclusive to the CD-ROM are over 70,000 pages of propagation tables that can help you determine what HF propagation to expect throughout the world, throughout the year and throughout the sunspot cycle.

Make sure you try out the software included for the PC. Follow the instructions for installation of the software and data files.

Using this CD-ROM

This CD-ROM is viewed using Adobe's *Reader* software. Version 7.0 of the software is included on the CD-ROM. The book and the companion files include hyperlinks. These links will appear in blue or green text. Clicking on the text of a hyperlink will cause *Reader* to display another, related part of the book. (See the *Reade*r Help documentation for information on configuring this feature.)

The version of *Acrobat Reader* used with this CD-ROM includes Acrobat Search capability, which allows rapid full-text search of the entire book. This functions as an instant index for every chapter and word in the book. We strongly recommend that you take a few minutes to view the on-line documentation available from *Acrobat Reader*'s Help menu.

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To install *Acrobat Reader* for *Windows*:
Select **Run** from the *Windows* **Start** menu.

1. Type or Browse to **d:\AdbeRdr709_en_US.exe** (where d: is the drive letter of your CD-ROM drive; if the CD-ROM is a different drive on your system, use the appropriate letter) and press **Enter**.
2. Follow the instructions that appear on your screen.

To install *Acrobat Reader* for the Macintosh:

1. From the top-level folder of the CD, double click on the file "Adobe_Reader_MAC_708.dmg" to open up the disk image. Then double click the Adobe Reader Installer icon to launch the installer.

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Choices, Summary and Detailed Propagation Tables

USA

W1B	Boston, MA
W2A	Albany, NY
W2N	NYC, NY
W3D	Washington, DC
W4A	Montgomery, AL
W4F	Miami, FL
W4G	Atlanta, GA
W4K	Louisville, KY
W4N	Raleigh, NC
W4T	Memphis, TN
W5A	Little Rock, AR
W5H	Houston, TX
W5L	New Orleans, LA
W5M	Jackson, MS
W5N	Albuquerque, NM
W5O	Oklahoma City, OK
W5T	Dallas, TX
W6L	Los Angeles, CA
W6S	San Francisco, CA
W7A	Phoenix, AZ
W7I	Boise, ID
W7M	Helena, MT
W7N	Las Vegas, NV
W7O	Portland, OR
W7U	Salt Lake City, UT
W7W	Seattle, WA
W7Y	Cheyenne, WY
W8M	Detroit, MI
W8O	Cincinnati, OH
W8W	Charleston, WV
W9C	Chicago, IL
W9I	Indianapolis, IN
W9W	Milwaukee, WI
W0C	Denver, CO
W0D	Bismarck, ND
W0I	Kansas City, MO
W0K	Middle of US, KS
W0M	St. Louis, MO
W0N	Omaha, NE
W0S	Pierre, SD

Other, North America

6Y	Kingston, Jamaica
8P	Bridgetown, Barbados
HP	Panama City, Panama
KL7	Anchorage, Alaska
KP2	Virgin Islands
TI	San Jose, Costa Rica
V3	Belmopan, Belize
VE1	Halifax, Nova Scotia
VE2	Montreal, Quebec
VE3	Toronto, Ontario
VE4	Winnipeg, Manitoba
VE5	Regina, Saskatchewan
VE6	Edmonton, Alberta
VE7	Vancouver, BC
VE8	Yellowknife, NWT
VO1	St. John's, NFL
VP2	Anguilla
VP5	Turks & Caicos
XE1	Mexico City, Mexico

Europe

CT	Lisbon, Portugal
DL	Bonn, Germany
EA	Madrid, Spain
EI	Dublin, Ireland
ER	Kishinev, Moldava
F	Paris, France
G	London, England
I	Rome, Italy
JW	Svalbard
OH	Helsinki, Finland
OK	Prague, Czech Republic
ON	Brussels, Belgium
OZ	Copenhagen, Denmark
SV	Athens, Greece
TF	Reykjavik, Iceland
UA3	Moscow, Russia
UA6	Rostov, Russia
UR	Kiev, Ukraine
YO	Bucharest, Romania
YU	Belgrade, Yugoslavia

South America

CE	Santiago, Chile
CP	La Paz, Bolivia
FY	Cayenne, French Guiana
HC	Quito, Ecuador
HC8	Galapagos Islands
HK	Bogota, Columbia
LU	Buenos Aires, Argentina
OA	Lima, Peru
P4	Aruba
PY1	Rio de Janeiro, Brazil
PY0	Fernando de Noronha
YV	Caracas, Venezuela
YV0	Aves Island
ZP	Asuncion, Paraguay

Asia

1S	Spratly Islands
3W	Ho Chi Minh City, Vietnam
4J	Baku, Azerbaijan
4S	Columbo, Sri Lanka
4X	Jerusalem, Israel
9N	Katmandu, Nepal
A6	Dubai, UAE
AP	Karachi, Pakistan
BY1	Beijing, China
BY4	Shanghai, China
BY0	Lhasa, China
HS	Bangkok, Thailand
HZ	Riyadh, Saudi Arabia
JA1	Tokyo, Japan
JA3	Osaka, Japan
JA8	Sapporo, Japan
JT	Ulan Bator, Mongolia
TA	Ankara, Turkey
UA9	Perm, Russia
UA0	Khabarovsk, Russia
UN	Alma-Ata, Kazakh
VR2	Hong Kong
VU	New Delhi, India
VU7	Andaman Islands
XZ	Rangoon, Myanmar

Oceania

3D2	Fiji Islands
DU	Manila, Philippines
FO	Tahiti
H4	Honiara, Solomon Islands
JD1	Ogasawara Island
KHØ	Saipan, Mariana Islands
KH5K	Kingman Reef
KH6	Honolulu, Hawaii
KH8	American Samoa
V7	Kwajalein, Marshall Islands
VK2	Sydney, Australia
VK6	Perth, Australia
VK8	Darwin, Australia
YB	Jakarta, Indonesia
ZL1	Aukland, New Zealand
ZL3	Christchurch, New Zealand

Africa

3B9	Rodrigues
3C	Bata, Equatorial Guinea
3V	Tunis, Tunisia
5N	Lagos, Nigeria
5R	Antananarivo, Madagascar
5U	Niamey, Niger Republic
5Z	Nairobi, Kenya
6W	Dakar, Senegal
7Q	Lolongwe, Malawi
7X	Algiers, Algeria
9J	Lusaka, Zambia
9L	Freetown, Sierra Leone
9X	Kigali, Rwanda
C9	Maputo, Mozambique
CN	Casablanca, Morroco
CT3	Madeira Islands
D2	Luanda, Angola
EA8	Canary Islands
IG9	Lampedusa, Italy
J2	Djibouti
ST	Khartoum, Sudan
SU	Cairo, Egypt
VQ9	Chagos, Diego Garcia
XT	Burkina Faso
ZS1	Capetown, So. Africa
ZS6	Johannesburg, So. Africa

These PDF files contain propagation prediction tables valid from the transmitting site indicated in the filename to seven generalized receiving locations throughout the world in the Summary Tables and for the 40 CQ Zones in the Detailed Tables. The user selects a single transmitting site closest to his/her location. You can access this data by opening *Adobe Acrobat Reader* and selecting **Prop Index.pdf**. Or you can operate from the main table of contents in the left pane of the opening window.

Each transmitting location is organized by five levels of solar activity over the whole 11-year solar cycle:

VL (Very Low: SSN between 0 to 20)
LO (Low: SSN between 20 to 40)
ME (Medium: SSN between 40 to 60)
HI (High: SSN between 60 to 100)
VH (Very High: SSN between 100 to 150)
UH (Ultra High: SSN greater than 150)

The seven generalized locations throughout the world for the Summary Tables are:

EU = Europe (all of Europe)
FE = Far East (centered on Tokyo, Japan)
SA = South America (centered on Asuncion, Paraguay)
AF = Africa (centered on Lusaka, Zambia)
AS = southern Asia (centered on New Delhi, India)
OC = Oceania (centered on Sydney, Australia)
NA = North America (all of USA).

Both types of propagation files show the highest predicted signal strength (in S-units) throughout the generalized receiving area, for a 1500-W transmitter and rather good antennas on both sides of the circuit. The standard antennas are 100-foot high inverted-V dipoles for 80 and 40 meters, a 3-element Yagi at 100 feet for 20 meters, and a 4-element Yagi at 60 feet for 15 and 10 meters. Discount the S-Meter readings in the tables to represent a smaller station:

Subtract 2 S units for a dipole instead of a Yagi
Subtract 3 S units for a dipole at 50 feet instead of a Yagi at 100 feet
Subtract 1 S unit for a dipole at 50 feet rather than a dipole at 100 feet
Subtract 3 S units for 100 W rather than 1500 W.
Subtract 6 S units for 5 W rather than 1500 W.

Shown below is an image of a Summary Table printout from Boston to the rest of the world, for Very High solar activity in January. This table could be used, for example, to help plan which bands to operate when on a DXpedition to some exotic location.

The Detailed Table printout from Boston to the rest of the world on 20 meters for January from Boston during a Very High level of the solar cycle is shown on the following page. It shows the predicted signal strength in each of the 40 CQ Zones around the world. Note that long-path openings are predicted by an asterisk appended to the end of the predicted signal strength.

Also located on the CD-ROM in the \Propagation subdirectory is the **Fig6Tab.pdf** file described in Chapter 3 of the printed book. This set of tables shows the hours open to each of 10 regions throughout the USA for Very-Low/Medium/Very-High levels of SSN.

Enjoy the software. We would appreciate any feedback or bug reports you might have.

73,

R. Dean Straw, N6BV
Editor, *The ARRL Antenna Book*
email: **n6bv@arrl.org**

Sample Summary Propagation-Prediction Table, January from Boston to the World

Jan., MA (Boston), for SSN = Very High, Sigs in S-Units. By N6BV, ARRL.

	80 Meters							40 Meters							20 Meters							15 Meters							10 Meters							
UTC	EU	FE	SA	AF	AS	OC	NA	EU	FE	SA	AF	AS	OC	NA	EU	FE	SA	AF	AS	OC	NA	EU	FE	SA	AF	AS	OC	NA	EU	FE	SA	AF	AS	OC	NA	UTC
0	9+	-	9+	9+	8	-	9+	9+	5	9+	9+	9	-	9+	1	9+	9+	9+	9+	9	9+	-	9	9+	2	2	9+	9+	-	1	8	-	-	8	9+	0
1	9+	-	9+	9+	8	-	9+	9+	4	9+	9+	9	2	9+	1	9	9+	8	9+	9+	9+	-	3	9	-	7	9+	9	-	-	-	-	-	4	2	1
2	9+	-	9+	9+	7	-	9+	9+	4	9+	9+	9	7	9+	1	9	9+	8	9	9+	9+	-	-	3	-	-	7	9	-	-	-	-	-	-	2	2
3	9+	-	9+	9+	1	2	9+	9+	4	9+	9+	9	9	9+	-	7	9+	7	8	9+	9	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3
4	9+	-	9+	9+	-	7	9+	9+	5	9+	9+	8	9	9+	-	5	9+	9	9	9	9+	-	-	1	-	-	-	-	-	-	-	-	-	-	2	4
5	9+	-	9+	9+	-	8	9+	9+	6	9+	9+	7	9	9+	-	5	9+	9	9	5	9+	-	-	-	-	-	-	-	-	-	-	-	-	-	2	5
6	9+	-	9+	9+	-	8	9+	9+	7	9+	9+	7	9	9+	-	8	9+	8	9	5	9+	-	-	-	-	-	-	-	-	-	-	-	-	-	2	6
7	9+	-	9+	9+	-	8	9+	9	8	9+	9+	7	9+	9+	-	9	9+	-	7	9	9+	-	-	1	-	-	-	-	-	-	-	-	-	-	2	7
8	9	7	9+	9	-	8	9+	9	8	9+	9+	8	9+	9+	-	9	9+	-	4	9+	9+	-	-	1	-	-	-	2	-	-	-	-	-	-	2	8
9	8	7	9+	7	-	8	9+	9	9	9+	9	8	9+	9+	-	6	9+	-	1	9+	9+	-	-	-	-	-	-	1	-	-	-	-	-	-	2	9
10	5	8	9+	2	3	8	9+	9	9	9+	8	8	9	9+	4	-	9+	9+	1	5	9	-	-	-	-	-	-	-	-	-	-	-	-	-	2	10
11	1	8	9+	-	4	9	9+	8	9	9+	5	8	9	9+	9+	4*	9+	9+	7	-	8	-	-	9	9	-	-	-	-	-	-	-	-	-	2	11
12	-	7	8	-	1	9	9+	6	9	9+	1	8	9	9+	9+	9	9+	9	9	1*	9+	9	8*	9+	9+	9	5*	-	-	2*	9	9	1	1*	2	12
13	-	-	-	-	-	2	9+	4	8	8	-	7	9	9+	9+	9	9+	9	9	9+	9+	9+	7	9+	9+	9+	3*	9	9	5*	9+	9+	9	6*	2	13
14	-	-	-	-	-	-	9+	2	7	4	-	5	8	9+	9+	9	9+	8	9	9	9+	9+	9	9+	9+	9+	9	9+	9	6*	9+	9+	9	1*	1	14
15	-	-	-	-	-	-	9	1	5	-	-	4	5	9+	9+	9	9+	9	9	9	9+	9+	9+	9+	9+	9+	9	9+	9	5	9+	9+	6	6	8	15
16	-	-	-	-	-	-	8	3	4	-	-	3	1	9+	9+	8	9	9	9	9	9+	9+	9+	9+	9+	9	9+	9+	9	8	9+	9+	-	8	9	16
17	-	-	-	-	-	-	8	5	3	-	2	4	-	9+	9+	8	9+	9+	9	9	9+	9+	9	9+	9+	1*	9+	9+	-	8	9+	9+	-	8	9+	17
18	-	-	-	-	-	-	9	7	4	2	5	5	-	9+	9+	9	9+	9+	9	9	9+	9+	9	9+	9+	1	9+	9+	-	7	9+	9+	-	9+	9+	18
19	1	-	-	1	-	-	9+	8	5	6	8	7	-	9+	9+	9	9+	9+	9	9	9+	-	9+	9+	9+	2	9	9+	-	6	9+	9+	-	9+	9+	19
20	4	-	2	5	-	-	9+	9	6	9	9	8	-	9+	9+	9	9+	9+	9	9	9+	-	8	9+	9+	3	9	9+	-	1	9+	9	-	9	9+	20
21	7	-	8	7	1	-	9+	9+	7	9+	9+	8	1	9+	8	9	9+	9+	9	9	9+	-	6	9+	9+	3	9	9+	-	-	9+	5*	-	9+	9+	21
22	9	2	9+	9	8	-	9+	9+	7	9+	9+	9	4	9+	2	9+	9+	9+	9	9	9+	-	9+	9+	9	1	9+	9+	-	5	9+	4*	-	9	6	22
23	9	-	9+	9	8	-	9+	9+	7	9+	9+	9	-	9+	1	9+	9+	9+	9	9	9+	-	9+	9+	6	-	9	9+	-	7	9+	2*	-	9	2	23
	EU	FE	SA	AF	AS	OC	NA	EU	FE	SA	AF	AS	OC	NA	EU	FE	SA	AF	AS	OC	NA	EU	FE	SA	AF	AS	OC	NA	EU	FE	SA	AF	AS	OC	NA	

Sample Detailed Propagation Table for 20 Meters, January, Boston to World for Very High SSN

20 Meters: Jan., MA (Boston), for SSN = Very High, Sigs in S-Units. By N6BV, ARRL.

UTC -->

Zone	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
KL7 = 01	9+	9+	9+	7	-	-	-	-	-	-	-	-	-	-	-	3	9+	9+	9+	9+	9+	9+	9+	9+
VO2 = 02	9+	9	9	9	9	9	8	7	5	3	2	1	5	9+	9+	9+	9+	9+	9+	9+	9+	9+	8	9+
W6 = 03	9+	9+	9+	7	7	1	1	5	8	8	3	-	-	1	9	9+	9+	9+	9+	9	9	9+	9+	9+
W0 = 04	9+	9+	9+	8	5	5	5	5	3	2	1	-	-	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+
W3 = 05	4	2	2	2	2	2	2	3	3	3	3	2	1	1	8	9+	9+	9+	9+	9+	9+	9+	9+	9
XE1 = 06	9+	9+	7	9	9+	9+	9+	9+	9+	9+	9	8	9+	9+	9+	9+	9	9	9	9	9+	9+	9+	9+
TI = 07	9+	9+	8	9	9	9	9	9	9	9+	9	9+	9+	9+	9+	9+	9	8	9	9	9+	9+	9+	9+
VP2 = 08	9+	9+	9+	9+	9+	9+	9+	9+	9+	8	9	9+	9+	9+	9+	9+	9	9+	9+	9+	9+	9+	9+	9+
P4 = 09	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	9	9	9	9	9+	9+	9+	9+	9+
HC = 10	9+	8	9+	9	9	9	9	9	7	3	1	7	9+	9+	9	5	5	5	7	8	9+	9+	9+	9+
PY1 = 11	9+	9+	9+	9	9	9+	9+	9	8	6	9	9+	8	2	1	-	-	1	4	8	9	9+	9+	9+
CE = 12	9+	9+	9+	9+	9+	9+	9+	9+	9	8	8	9+	9	8	2	1	1	-	1	3	7	9	9+	9+
LU = 13	9+	9+	9+	9+	9+	9+	9+	9+	8	8	8	9+	8	4	2	1	-	-	1	4	8	9	9+	9+
G = 14	-	-	-	-	-	-	-	-	-	-	-	9+	9+	9+	9+	9+	9+	9+	9+	9+	9+	8	2	-
I = 15	-	-	-	-	-	-	-	-	-	-	4	9	9	9	9	9	9	9+	9+	9	8	2	-	-
UA3 = 16	1	1	1	-	-	-	-	-	-	-	-	8	9	9+	9+	9+	9	8	5	-	-	-	-	1
UN = 17	1	-	-	8	7	7	7	1	-	-	-	2	9	9	9	6	-	-	2	4	8	9	5	4
UA9 = 18	6	7	6	6	9	9	9	7	4	1	-	-	8	8	6	6	5	6	7	8	9	9	8	7
UA0 = 19	9+	9	9	6	5	5	8	8	8	4	-	-	2	6	8	8	8	7	4	4	7	9	9+	9+
4X = 20	8	6	3	1	-	3	4	-	-	-	1	8	8	8	8	8	9	9	9+	9	9	8	7	7
HZ = 21	9+	9	4	3	8	8	2	-	-	-	1	7	8	9	8	8	9	9	9	9	9	9	9	9
VU = 22	7	5	8	7	6	7	5	-	-	-	-	6	9	9	9	9	3	2	2	2	8	8	9	8
JT = 23	9	9+	9	5	7	8	8	6	3	-	-	2*	8	8	5	6	8	8	8	8	9	7	5	6
VS6 = 24	9	9	9	5	4	5	7	8	6	1	-	1*	5	7	1	1	1	1	4	2	-	-	-	9
JA1 = 25	9	9	8	7	5	5	8	9	9	6	-	1	1	2	7	7	6	2	-	-	7	9	9+	9
HS = 26	9	9	6	4	2	-	-	2	1	-	-	2*	9	9	9	9	8	7	5	4	5	-	1*	1
DU = 27	9	8	7	-	-	-	5	7	7	1	-	-	1*	9	9	7	6	4	5	3	1*	1*	8	9
YB = 28	9	8	1	-	-	-	-	-	-	-	-	4*	8	9	9	9	8	8	9	9	9	9	9+	9+
VK6 = 29	3*	4*	-	-	-	-	-	-	5	3	-	-	-	5	9	9	9	8	9	9	9	9	9	8
VK3 = 30	1*	-	-	-	-	-	1	3	9	9	4	-	-	9+	9	8	2	1	-	-	1	2*	5*	4*
KH6 = 31	9	9+	9+	9+	8	2	2	6	4	-	-	-	-	-	-	-	9	9	8	7	6	4	6	7
KH8 = 32	-	2	9	9	9	5	5	9	9+	9+	5	-	-	9+	9	9	8	5	3	1	-	-	-	-
CN = 33	-	-	-	-	-	-	-	-	-	-	9	9+	9	9	8	9	9	9+	9+	9+	9+	9+	9+	7
SU = 34	9	8	3	3	-	1	4	-	-	-	2	7	8	8	8	8	9	9	9+	9+	9+	9+	8	8
6W = 35	9+	8	-	-	2	7	5	-	-	-	9+	9+	8	5	4	3	7	9	9+	9+	9+	9+	9+	9+
D2 = 36	9+	9+	5	3	9	9	8	-	-	-	3	-	-	-	-	4	4	7	8	9	9+	9+	9+	9+
5Z = 37	9+	9	2	4	8	8	1	-	-	-	2	-	-	3	5	5	7	8	9	9	9+	9+	9+	9+
ZS6 = 38	9+	9+	8	7	8	9	6	-	-	-	-	-	-	-	1*	1	2	6	8	9	9+	9+	9+	9+
FR = 39	9+	8	2	1	4	1	-	-	-	-	-	-	-	2*	3*	1*	1	3	8	9	9+	9+	9+	9+
FJL = 40	9+	9+	7	4	7	8	7	1	-	-	-	1*	8	9	9	9	9	9	9	9	9+	9+	9+	9+
Zone	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23

UTC -->

Expected signal levels using 1500 W and 3-element Yagis at 100 feet at each station.

1

Basic Principles of Radiofrequency Identification

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1.1 Basics of RFID....1
1.2 Passive versus Active RFID Systems....5
1.3 Functional Classification of RFID Transponders....6
1.4 Applications and Frequency Selection....7

Although the widespread use of radiofrequency identification (RFID) is recent, the technology itself is several years old. RFID was first developed during World War II in order to distinguish between friend and enemy aircraft. Several years later, thanks to the technological advances in microelectronics, wireless communications, and computer networks, RFID has come of age. It has now become a technology that is mature enough to be mass-marketed at competitive cost and become a critical player in the global market. This chapter introduces the reader to the different parts that make up a RFID system and provides an overview of the different concepts that will be described in depth in the upcoming chapters.

1.1 Basics of RFID

The basic function of an RFID system is to automatically retrieve the information that has been previously inserted into specific integrated circuits, as seen in Figure 1.1. RFID systems were first developed in automatic identification laboratories as a natural evolution of the different technologies they use. Different automatic identification systems use different methods to transmit the identifying information. For example, bar code technology uses light as the transmission media, while RFID systems use radio waves. In this context, the two main elements of RFID systems are the devices used to carry this information and the equipment used to automatically capture or retrieve the information.

The devices that store and carry the information are called *transponders* or *tags* and are shown in Figure 1.2. Although the industry commonly refers to them as *tags* mainly due to their physical shape and the fact that they are

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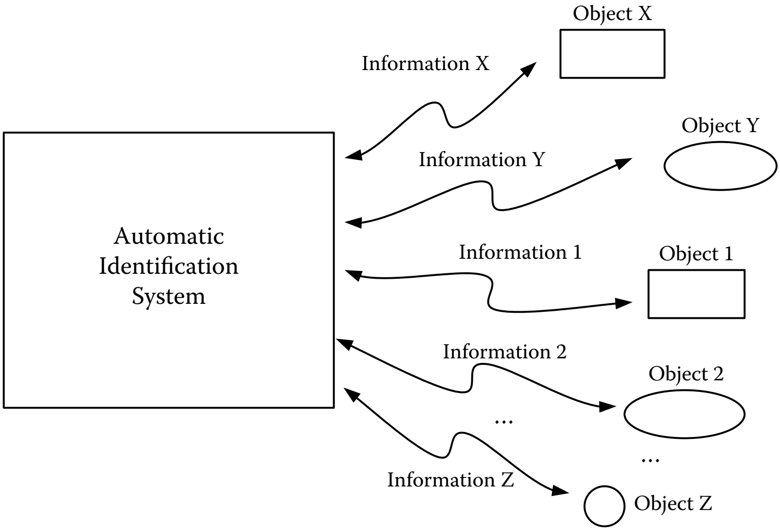
Object X
Information X
Object Y
Information Y
Automatic Identification System
Information 1
Object 1
Information 2
Object 2
...
...
Information Z
Object Z

FIGURE 1.1
Information transfer in an automatic identification system.

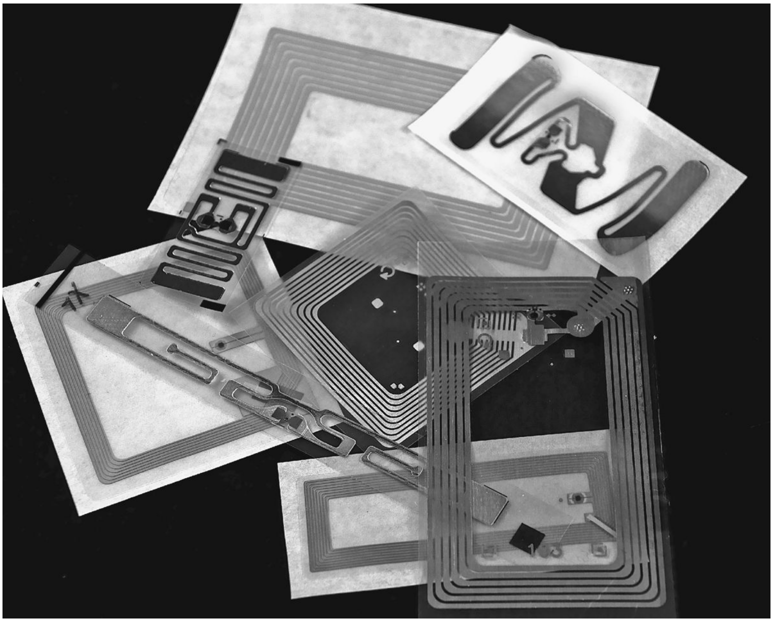

FIGURE 1.2
Several types of transponders used in RFID systems.

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mostly used to tag pallets or cases of goods, the name *transponder* reflects better the function of these devices.

The device that is used to capture and transfer information is commonly called a *reader*, because in earlier RFID systems they were only able to read the information sent by the transponders. However, with the development of new functions and applications of RFID systems, the name *interrogator* reflects better the function of this subsystem. Therefore, this book will use the names *transponder* and *interrogator* when referring to these elements.

Transponders must have the circuitry needed to harvest power from the electromagnetic fields generated by the interrogator, the necessary memory elements, as well as the different control circuits. The simplest transponders contain only read-only memory (ROM), while more sophisticated transponders also include random access memory (RAM) and nonvolatile programmable read-only memory (PROM) or electrically erasable programmable read-only memory (EEPROM). ROM usually contains the identification string for the transponder and instructions for its operating system. RAM is normally used for temporary data storage when the transponder communicates with the interrogator. PROM or EEPROM is normally used to incorporate additional functionality depending on the application. The memory capacity of transponders ranges from a single bit to several kilobits. Single-bit transponders are typically used in retail electronic surveillance in which there are only two possible states: *article paid* and *article not paid*. Memory sizes of up to 128 bits are enough to store the individual transponder identification number with several check bits. Memories up to 512 bits are normally user programmable, in which in addition to the individual identification number the memory can hold additional information required by its application. Higher capacity memories can be seen as carriers for the transport of data files. They are also used in applications in which there are several sensors attached to the transponder.

Interrogators have vastly different complexity levels depending on the type of transponders they support as well as their specific purpose. In any case, they all must provide the basic functionality to communicate with the transponders, first by energizing them and second by establishing a communications link. The complexity of the communications link can also vary considerably depending on the desired reliability. The reliability of the communications link between transponder and interrogator can be enhanced by adding parity checks, error detection, and error detection and correction. However, the use of these schemes will result in a lower transmission rate. Figure 1.3 shows a picture of a basic interrogator in which it is possible to see the coiled antenna and some of the electronic circuits.

RFID systems contain more elements in addition to the transponder and interrogator. First, the communication between transponder and interrogator is not possible—or becomes extremely deficient—without the appropriate radiant elements that will transfer the information between these two subsystems in the form of electromagnetic energy. Both transponder and

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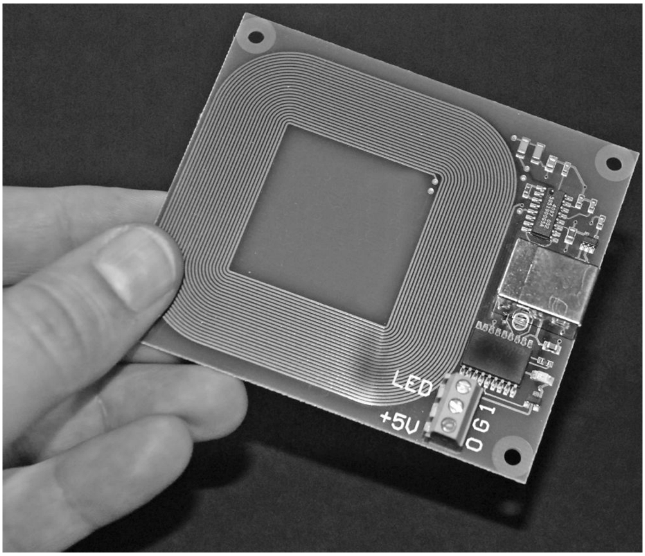

FIGURE 1.3
Basic RFID interrogator operating in the low-frequency (LF) range.

interrogator need to use the appropriate antennas to transfer information. As will be discussed in Chapter 2, the antenna dimensions in commercially available transponders and interrogators are much shorter than their ideal dimensions. This results in seriously limiting the transfer of energy between interrogators and transponders.

In addition to the transponders, the interrogators, and their antennas, the RFID system requires a *host computer* connected to the interrogator. This host computer provides a certain level of intelligence and acts like the interface between the RFID system and the ultimate application. Therefore, the interrogator must have the means to at least perform basic communication functions with the interrogator. A large number of today's applications require more than one interrogator running on a network rather than the single, stand-alone interrogator that was typical of earlier systems. Finally, an *edge server* is normally used between the host computer and the network in which the application is running.

In addition to these elements (shown in Figure 1.4), most of them hardware based, a typical RFID system contains several software elements. The *firmware* is the software that runs inside the interrogator in order to provide it with its basic functions. Some interrogators may also run one or more software *applications* that enhance the versatility of the interrogator. The name *middleware* encompasses the software applications that run in the background of the system, typically after the host computer. Finally, most applications require the use of one or several *databases* used to link the stored message

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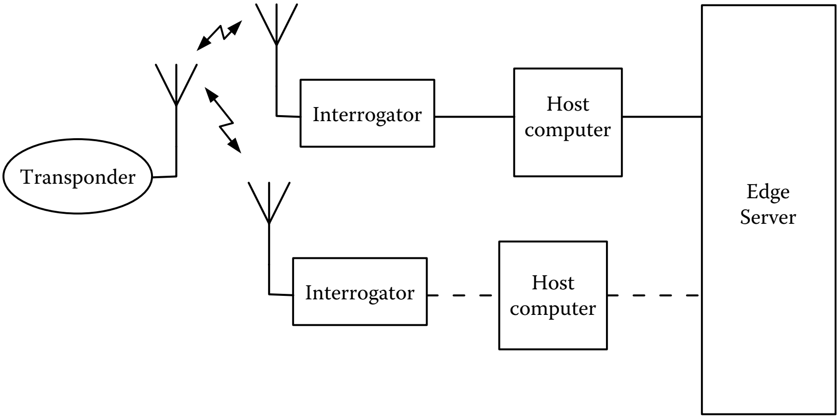

FIGURE 1.4
Basic structure of an RFID system.

sent by the transponder with more detailed information that can identify the transponder and provide additional information.

1.2 Passive versus Active RFID Systems

Passive RFID systems are those systems that use passive transponders. Passive transponders do not have an internal power source. They harvest the energy needed by their internal circuits from the electromagnetic field generated by the interrogator. For this reason, they have a short range, limited to a few feet and often, more realistically, to a few inches. Because they don't have an internal source of energy, the user does not need to worry about the status of the battery. Furthermore, their manufacturing and production costs are very low. The RFID transponders and systems described in this book are all passive.

Active RFID systems, on the other hand, use active transponders. Active transponders have an internal power source, typically a battery that allows broadcasting the signal to the interrogator. Because of not being limited to the power harvested by the antenna, they have an extended read range, typically several hundred feet. However, the inclusion of the power source increases their cost in two ways: the cost of the battery itself as well as the maintenance costs required to check the status of the internal power source and replace it when it has reached an unacceptably low level. The cost of an active transponder is approximately 100 times higher than the cost of a passive transponder. Active transponders typically operate in the ultra-high-frequency (UHF) and microwave ranges. A new type of active RFID transponder is

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linked to the use of RFID-enabled cell phones that can emulate an active tag. In this case, the problem of battery maintenance is solved as the user keeps the cell phone charged as part of its regular maintenance.

A third type of transponder is called *semipassive* or *battery-assisted transponder*. These transponders also include a battery, but contrary to active transponders, the battery is not used to generate the power to transmit the signal to the interrogator. Instead, the battery is used to support secondary functions like the data logging from different types of sensors. These transponders also harvest the energy from the electromagnetic field generated by the interrogator to power its internal circuits other than the sensing and data-logging parts.

1.3 Functional Classification of RFID Transponders

A functional classification of RFID transponders is based on their electronic product code (EPC) class. EPC is the application of one specific type of RFID technology within the consumer packaged goods industry. Within this classification, RFID transponders are divided into different classes and generations:

Generation 1, Class 0: Passive tags with read-only functionality. These are also called *write one, read many* (WORM) transponders. These transponders are programmed at the factory with their unique identification number. The user is not able to change it or include additional information.

Generation 1, Class 0+: These are also WORM transponders. They differ from Generation 1, Class 0 transponders in that it is the user who programs them. After they have been programmed by the user, no further programming or changing of data is allowed.

Generation 1, Class 1: These transponders were similar to Generation 1, Class 0 or 0+ transponders, but could be read by interrogators from other companies. Gen 1, Class 1 transponders have evolved into the different transponders from Generation 2.

Whereas Generation 1 transponders employ proprietary data structures and can be read only by interrogators manufactured by the same vendor, Generation 2 transponders are vendor neutral in their specifications. This means that as they have developed (following agreed upon standards), they can be read with interrogators from multiple vendors. These transponders provide additional features, for example the elimination of duplicate reads within the read range. They are also more reliable than Generation 1 transponders and support faster read rates. The user of Generation 2 transponders

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can access specific parts of their memory as these are rewritable transponders.

Generation 2, Class 1: These transponders are WORM transponders. They are also programmed at the factory, but they can be read with equipment from different vendors, support the higher read rates, and have more noise immunity than the Generation 1 transponders.

Generation 2, Class 2: These transponders are rewritable transponders. They can be written several times by the user using equipment different from the vendor's equipment.

Generation 2, Class 3: These transponders are the semipassive or battery-assisted transponders.

Generation 2, Class 4: This refers to active transponders.

Generation 2, Class 5: These transponders are essentially interrogators. Transponders that follow Generation 2, Class 5 must be able to power other transponders.

1.4 Applications and Frequency Selection

RFID systems come in different flavors from the point of view of the frequency they use. Selecting the most adequate frequency is a function of two variables: the technological developments of systems at the different operating frequencies—directly related to the cost of systems—as well as the properties of electromagnetic waves at those different frequencies.

The initial users of RFID systems found systems operating in the low-frequency (LF) range followed a few years later by systems operating in the high-frequency (HF) range. Therefore, their selection of systems was limited to these two broad frequency ranges even if those were not the most adequate for their specific applications. Recent years have seen an increase in the number of available RFID systems operating in the UHF range as well as a reduction of their economic cost. It is possible to expect a similar trend in upcoming years for RFID systems operating in the microwave range to become more available and more affordable. This will help the final users to make decisions on what type of RFID systems to deploy based on technical reasons rather than based on the availability and cost of these systems.

Table 1.1 presents a broad view of the frequency spectrum used by RFID systems as well as the most common frequencies for each band. It is necessary to note that Table 1.1 is not exhaustive because it is possible to find systems, within each frequency band, operating at other frequencies.

The LF band has been used by RFID systems for several years. This fact, together with the less stringent requirements of the electronics operating in this frequency range, has made these systems very cost-effective. Their

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TABLE 1.1

Commonly Used Frequency Band for RFID Systems

Frequency Band	Frequency Range	Typical Frequencies Used in RFID Systems
Low Frequency (LF)	100 kHz – 500 kHz	125 kHz 134.2 kHz
High Frequency (HF)	10 MHz – 15 MHz	13.56 MHz
Ultra High Frequency (UHF)	400 MHz – 950 MHz	866 MHz Europe 915 MHz United States
Microwaves (μW)	2.4 GHz – 6.8 GHz	2.45 GHz 3.0 GHz

major drawback is that due to the low frequency of the carrier, these systems can only communicate at low frequency rates. The main advantage of LF RFID systems is that electromagnetic waves operating in the LF range are the least affected by the presence of metals due to the penetration depth of these frequencies. This makes them ideal to be used in applications in which the transponders are surrounded by large metallic masses. Furthermore, LF waves can travel through water with minimal attenuation compared to waves of higher frequencies. This property makes them the frequency range of choice for the identification of animals due to their high water content. Most of these applications are based on implanting these transponders in livestock and pets. Figure 1.5 shows a picture of two different transponders that operate in the LF range in which it is possible to see the multiple loops used by these transponders.

RFID systems operating in the HF range can support higher read rates than LF systems. Although signals in the HF range are more affected by metal and have more attenuation when traveling through water, the transponders used for HF systems can be manufactured at a lower cost than the transponders operating in the LF range. This is due to the fact that the antennas for HF transponders can be made smaller, as shown in the two transponders seen in Figure 1.6. The need for less conductive material to construct the antennas results in a lower cost. Finally, the global uniformity across the world in the frequency of 13.56 MHz makes HF systems able to operate in any country.

While HF RFID systems operate at the single frequency of 13.56 MHz, UHF RFID systems can operate at different frequencies in the UHF band. Moreover, different countries have established different frequency ranges for their UHF RFID operation, making the compatibility between systems more difficult. For example, in North America the assigned band is from 902 MHz to 928 MHz, while in Europe it is from 860 MHz to 868 MHz and in Japan is from 950 MHz to 956 MHz. Other countries and regions have other different allocated frequency ranges. Despite this challenge and due to the developments in microelectronics that allowed the decrease in cost for these

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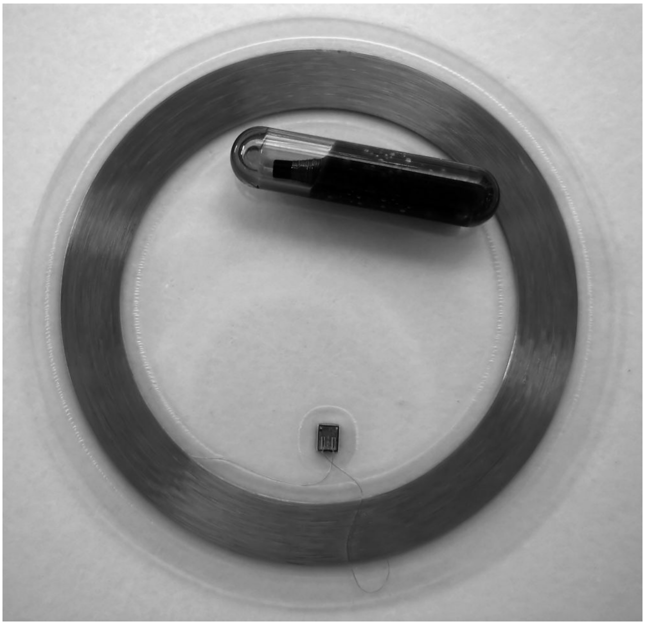

FIGURE 1.5
Low-frequency (LF) RFID transponders require antennas of several hundred feet of coiled wire.

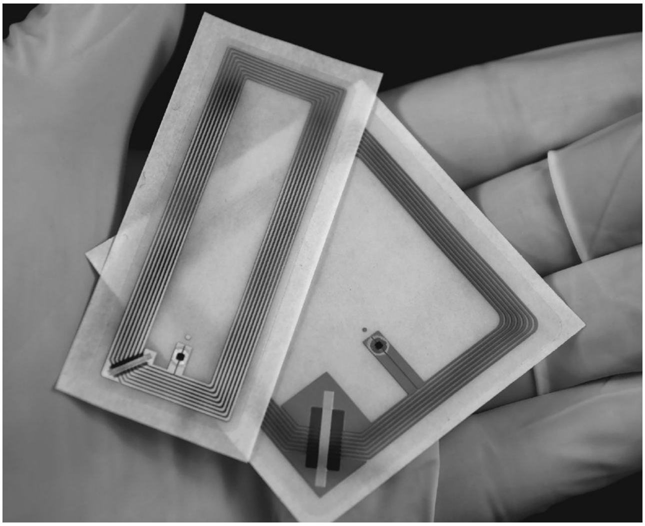

FIGURE 1.6
High-frequency (HF) RFID transponders can use shorter, smaller antennas.

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systems, UHF systems have established themselves as a viable alternative to the existing LF and HF systems. One of the main advantages of UHF RFID systems is that their higher carrier frequency allows for a much faster read rate of the transponder information, thus allowing the transmission of higher amounts of data. The communication between transponder and interrogator used in UHF systems is by electrical field instead of the magnetic coupling used by LF and HF systems. The antennas required by UHF systems can also be smaller than the antennas used for LF and HF systems, resulting in higher efficiency. These last two factors contribute to extended read ranges for UHF RFID systems. However, UHF systems also present several drawbacks compared to HF and LF systems. The antennas for transponders operating in the UHF range have very different physical dimensions depending on the parameters that the manufacturer wants to optimize in a given transponder. Figures 1.7 and 1.8 show examples of several UHF transponders in which it is possible to notice these differences.

UHF systems do not work well around metals as these reflect their electromagnetic waves. In addition, water absorbs UHF waves, making them unusable for animal implantation. Furthermore, the extended read range of UHF transponders may become a drawback for those applications that want to keep the read of transponders confined to a certain area.

Although 2.45 GHz is within the UHF range (UHF extends from 300 MHz to 3 GHz), the RFID systems operating in the frequency range extending from 2.45 GHz to 5.8 GHz are commonly called *microwave RFID systems*. In this frequency range, the propagation is limited to line of sight. Microwave signals are also attenuated by water and reflected by metallic objects. The cost of interrogators and transponders used in the microwave range is higher

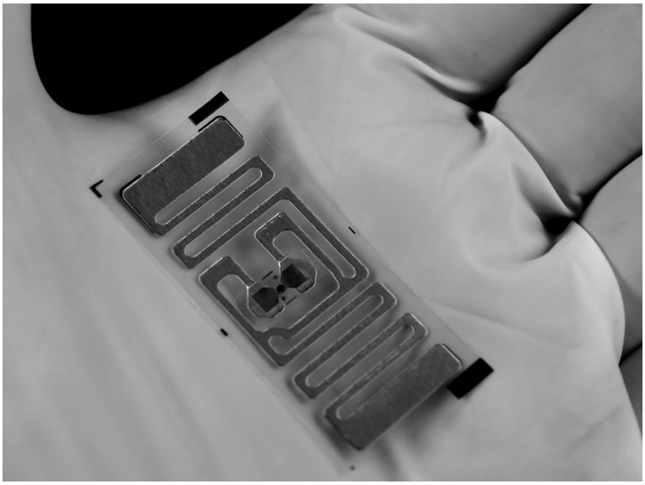

FIGURE 1.7
Ultra-high-frequency (UHF) RFID transponder.

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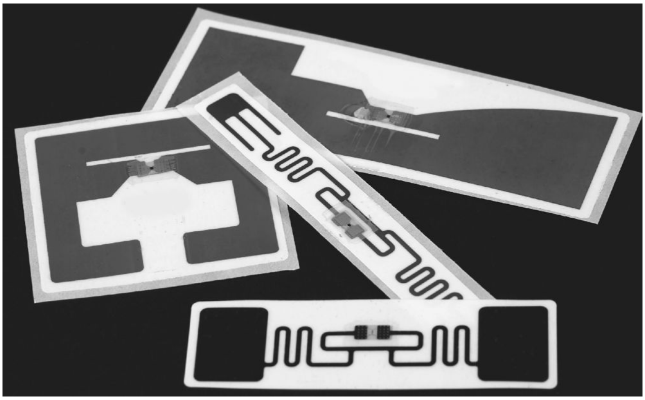

FIGURE 1.8
Several types of antennas used by ultra-high-frequency (UHF) RFID transponders.

than for any other type of system. On the positive side, it is possible to achieve very high read rates, and with the help from spread spectrum techniques, it is possible to achieve very high reliability rates and noise immunity. The higher end of the range, from 5.5 GHz to 6.8 GHz, is still currently under research and development.

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2

Antennas for RFID Transponders

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The purpose of the antenna in the transponder of an RFID system is multiple: first, it has to collect power from the electromagnetic field generated by the interrogator. In addition, the antenna must transfer the collected power to its load that is the chip in the transponder in order to turn it on. Finally, the antenna must radiate the data signals generated by the chip back to the interrogator. The antenna should be optimized to minimize energy losses during this process by choosing the type and dimensions of the antenna suited for a specific application and matching its impedance to the impedance of the load. Because these requirements may lead to contradictory solutions, the designer of the system must evaluate them carefully when considering the possible solutions.

This chapter explores the design and performance considerations for antennas in transponders. It starts by presenting a basic review of antenna theory with special emphasis on the differences used for systems in the low-frequency (LF) and high-frequency (HF) ranges compared to the antennas used for ultra-high-frequency (UHF) systems. The chapter continues by describing the types of antennas found in commercial transponders. This is followed by considering the requirements for antenna tuning and

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antenna matching. The following section describes the different methods for attaching the antenna to the chip on the transponder. The chapter finishes with a review of other antenna factors that affect their performance.

2.1 Review of Basic Antenna Theory for RFID Transponders

2.1.1 Antennas for RFID Transponders Operating in the LH and HF Regions

Electrical current flowing through a conductor generates electromagnetic fields. From the point of view of the concepts described in this chapter, it is possible to distinguish two field regions. The first region is called the *far-field region*. In this region, the generated fields are radiated fields, meaning that the energy propagates through the space with an energy density proportional to the inverse of the distance. The second area is called the *near-field region*. In this area, radiated fields are not prevalent. Instead, attenuating fields, in which the strength of the field decreases with $1/r^3$, are dominant. Furthermore, the power in this region is reactive.

Given these two regions, it seems obvious that antennas for RFID transponders should be designed to operate in the far-field region. However, the boundaries between far-field and near-field regions depend on the relationship between the physical dimensions of the antenna and the wavelength of the propagating signal. In particular, the dimensions of the antenna should be comparable to the wavelength of the signal in order to achieve optimal performance. The wavelength of signals operating in the LF region is around 2.4 km (1.5 miles), while the wavelength for signals operating in the HF region is 24 m (78 feet). Therefore, at these frequencies it would not be practical to build antennas with dimensions similar to the wavelength of their signals. Any antennas that can be built in a practical manner for RFID transponders operating in the LF or HF ranges will be electrically small and therefore highly inefficient. In contrast, RFID signals operating in the UHF region have a wavelength of approximately 30 cm. Although this dimension is still very large for building practical antennas, the following sections will explore how they can be modified to obtain antennas for UHF transponders that will operate in the far-field region.

RFID transponders operating in the LF or HF frequencies cannot use dipole antennas because of the mismatch in dimensions. An alternative solution to this problem is to use a small-loop antenna instead of a dipole. While the near fields radiated by a dipole are mainly electrical fields, the near field from a loop antenna is a magnetic field. A small-loop antenna is a closed loop with a maximum dimension that is less than about a tenth of the wavelength of the signal. It can be shown that the small-loop antenna is the dual equivalent of an ideal dipole, thus making it suitable for antennas incorporated in transponders operating at LF or HF frequencies.

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Let's consider a conductor of infinite length carrying a magnitude of current of I amps. The magnetic field (B_Φ) measured at a distance of r meters from the conductor can be found using Ampere's law as

$$B_\phi = \frac{\mu_0 I}{2\pi r} \; (Weber/m^2) \tag{2.1}$$

where μ_0 is the permeability of free space ($4\pi\,10^{-7}$ H/m).

However, a conductor of infinite length is not realistic. Its practical implementation is based on building a loop antenna by bending the original, finite wire, which carries a current of I amps in a circle with a radius of a meters. In practice, the wire is bent in such a way that produces a total of N turns as this allows using a longer wire with a relatively small diameter. In this situation, the value of the magnetic field in the z-coordinate direction (B_z) for a point located at a distance of r meters from the plane of the coil and located along the axis of the coil, as shown in Figure 2.1, can be found as

$$B_z = \frac{\mu_0 I N a^2}{2\,(a^2 + r^2)^{3/2}} \; (Weber/m^2) \tag{2.2}$$

where a is the radius of the loop in meters.

Assuming that the distance at which the field is measured, r, is much larger than the radius of the coil ($r^2 >> a^2$), equation (2.2) can be simplified as follows:

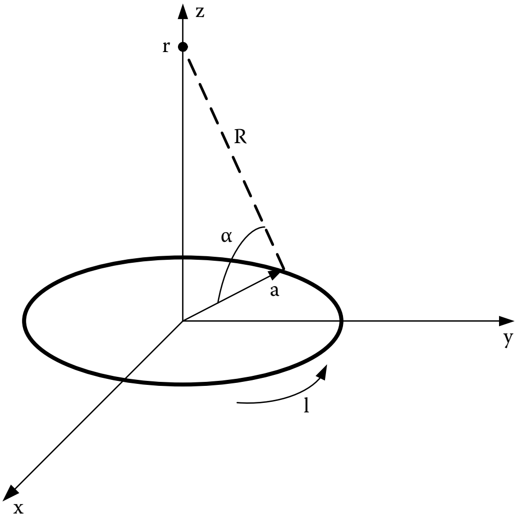

FIGURE 2.1
Magnetic field produced by loop antenna.

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$$B_z = \frac{\mu_0 I N a^2}{2 r^3} \quad (Weber / m^2) \tag{2.3}$$

As shown by equation (2.3), the magnetic field created by the small-loop antenna is dependent on $1/r^3$. This causes a strong decrease of field intensity as one moves away from the location of the coil antenna, and will seriously limit the read range of transponders using this type of antenna. However, even with this limitation, the small-coil antenna is more desirable than an electrically small dipole.

The antenna in the RFID transponder has to be both a receiving antenna and a transmitting antenna. It has to collect enough energy from the electromagnetic field generated by the interrogator to be able to power its integrated circuit, and it also has to transmit the data signal generated by the chip back to the interrogator. The *reciprocity theorem* indicates that the receiving and transmitting patterns for a given antenna are identical, and therefore the same antenna can be used for either task.

The voltage induced in a coil consisting of N loops immersed in a time-variant magnetic field can be calculated using Faraday's law as

$$V = -N \frac{d\Psi}{dt} \tag{2.4}$$

with Ψ being the magnetic flux.

The magnetic flux, in turn, can be calculated as

$$\Psi = \int B \bullet dS \tag{2.5}$$

where

B = the magnitude of the time-variant magnetic field

S = the surface area of the coil

$\cdot$ = the inner product operator

Equation (2.5) indicates that the magnetic flux, and consequently the voltage induced in the coil, is dependent on the relative orientation between the coil and the magnetic field. This has some important implications at the time of using interrogators and transponders. Assuming that the magnetic field B was generated by the interrogator using another loop antenna, the maximum received voltage will occur when both coils are placed parallel to each other. Because the voltage generated in the coil that will be used to power the chip in the transponder is proportional to the intensity of the magnetic field (B), this voltage will also be dependent on ($1/r^3$). This is important because

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it limits the maximum distance between the interrogator and transponder coils that will produce the threshold voltage necessary to power the chip on the transponder.

Although the previous equations describe the full underlying relationships between the variables involved in this process, it is more desirable from a practical point of view to study how these equations evolve in specific cases. Assuming that the coil is specifically tuned to the frequency of the time-variant magnetic field, the induced voltage in the coil is as follows:

$$V_0 = 2\pi f N S Q B_0 \cos\beta \tag{2.6}$$

where

V_0 = the induced voltage in the coil
f = the frequency of the time-variant magnetic field
B_o = the intensity of the field
N = the number of loops in the coil
Q = the quality factor of the coil antenna
S = the area of the coil
β = the angle between the plane of the coil and the direction of the field

Keeping in mind that the magnetic field generated by the coil in the interrogator is perpendicular to its plane, and that equation (2.6) will be maximized when $\beta = 0$, the induced voltage will be maximized when the interrogator and transponder coils are placed parallel to each other. Once again, the limiting factor in equation (2.6) comes from the intensity of the magnetic field (B_0) decreasing with the cube of the distance between coils ($1/r^3$).

2.1.2 Inductance of Coil Antennas Operating in the LF and HF Regions

Because, as shown in equation (2.6), the induced voltage is proportional to the quality factor (Q factor) of the coil antenna, it is desirable to increase the Q factor as much as possible. This can be achieved by carefully choosing the value of the inductance of the antenna. This section discusses the values of inductance found in typical antennas operating in the LF and HF regions.

Typical RFID systems use inductance values for antennas in transponders of few mH, while antennas for the interrogators have typical values between 10 and 100 times lower. It is necessary to keep in mind that the calculation of inductance values presented here can only be considered as approximated values. These calculations do not take into consideration the finite value of the conductivity of the wire that results in Ohmic losses, and, more importantly, they do not take into account the distributed stray capacitances that appear in the coil. A more detailed and comprehensive analysis and calculations of inductance values in antennas are beyond the scope of this book, but

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they can be found in any book on electromagnetism. If the designer requires an accurate value of inductance, the best option is to measure it with a complex impedance meter. This instrument is also able to measure the Q factor of the antenna, providing good characterization of the antenna.

The inductance of the coil shown in Figure 2.2, made with a single layer of wire and with n turns and a core of air, is approximately:

$$L = \frac{d^2\, n^2}{18d + 40l}\,(\mu H) \tag{2.7}$$

where

d = the diameter of the coil in inches

n = the number of turns

l = the length of the coil in inches

Equation (2.7) shows the square relationship between inductance and number of turns; if the number of turns is doubled, the resulting inductance is quadrupled.

Example 2.1:

Calculate the number of turns required to achieve an inductance of 10 μH by winding a piece of wire over an air core with a diameter of 1 inch. The length of the resulting coil must be equal to 1.25 inches.

Solution:

In this situation, l = 1.25 inches, and d = 1.0 inches. Therefore, we can write

$$10 = \frac{(1.0)^2\, n^2}{18 \cdot 1.0 + 40 \cdot 1.25}$$

Solving for n gives n = 26.07 turns. Given the limitations of the approximation for equation (2.7) plus the stray capacitance issues mentioned earlier, a good starting point would be to choose 26 turns. In this case, the value of inductance that we would measure in practice is likely to differ from 10 μH. The designer would have to adjust the number of turns after measuring the actual value of inductance. A recommended procedure is to start by choosing a larger number of turns and therefore a larger number of inductance, and proceed by removing turns until the coil achieved the required inductance.

Although this type of structure to create the antenna for an RFID system is not the most commonly used, it is nevertheless employed in some applications, especially in those that required a hermetically sealed transponder. Figure 2.3 shows an RFID transponder operating in the LF frequency in which it is possible to see the coil antenna and its windings.

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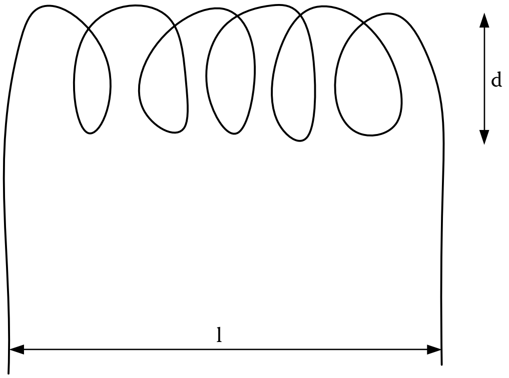

FIGURE 2.2
Single-layer, air-core coil.

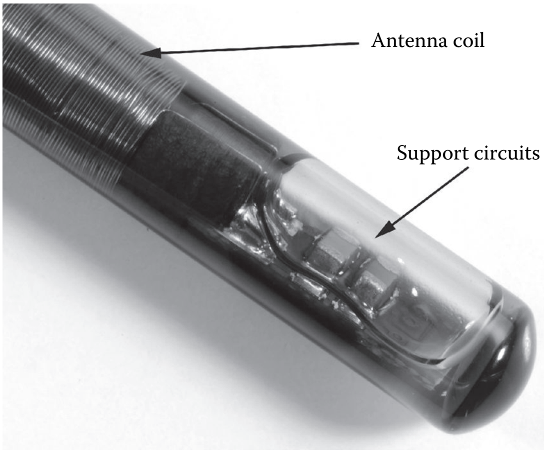

FIGURE 2.3
Detail of coil antenna in a commercial radiofrequency identification (RFID) transponder for the low-frequency (LF) range.

The practical problem associated with the use of this type of antenna is the three-dimensional space that it requires. Such antennas are not practical for applications that require a flat transponder, such as a credit card, and they are limited to applications that can support the tubular shape, for example in animal implantation. For this reason, the majority of transponders in the LF and HF frequency regions use antennas formed on a single plane, using several layers of conductor to achieve the desired inductance. Figure 2.4 shows this configuration for a multilayer circular coil with n turns.

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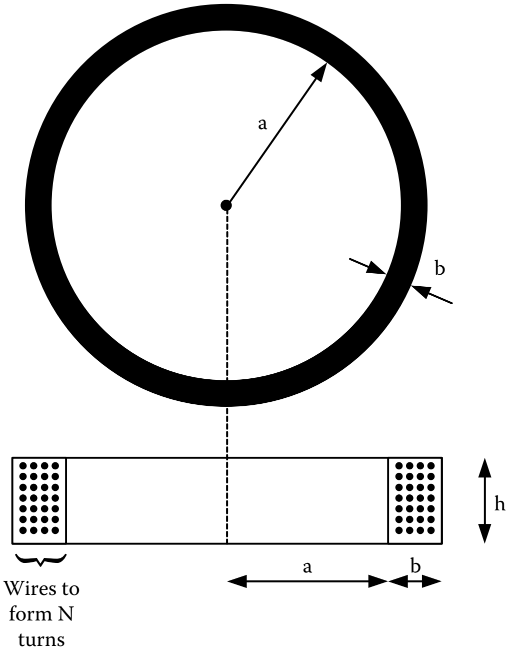

FIGURE 2.4
Multilayer, circular-coil, *N*-turn antenna.

The inductance of this coil is

$$L = \frac{0.31 a^2 n^2}{6a + 9h + 10b} \quad (\mu H) \tag{2.8}$$

where

a = the radius of the coil in cm
n = the number of turns
b = the winding thickness of the coil in cm
h = the winding height in cm

This configuration allows building coils with the required amount of inductance with minimal thickness, therefore minimizing the transponder's footprint. A variation of this antenna that results in an even thinner antenna is the spiral wound coil with a single layer shown in Figure 2.5.

The inductance of a single-layer spiral antenna is

$$L = \frac{0.3937\, a^2 n^2}{8a + 11b} \quad (\mu H) \tag{2.9}$$

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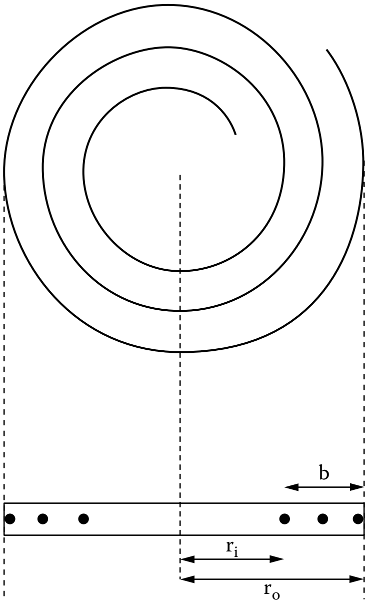

FIGURE 2.5
Single-layer, spiral-coil antenna.

where

a = the average radius of the coil in cm $(a = \frac{r_i + r_o}{2})$

b = ro – ri in cm

n = the number of turns in the spiral

This structure results in a thinner antenna, although the number of turns in the antenna is limited to the number of turns that is possible to pack in a single layer. This limits the inductance of the antenna as this value depends on the square of the number of turns. Other forms of planar coil antennas are the multilayer square-loop coil antenna with n turns and the multilayer rectangular-loop coil antenna, also with n turns, shown in Figure 2.6.

The inductance for the planar multilayer square loop coil antenna with n turns, shown in Figure 2.6(a), is

$$L = 0.008\, a\, n^2 \left[2.3 \log\left(\frac{a}{h+b} \right) + 0.2235 \frac{b+h}{a} + 0.726 \right] (\mu H) \tag{2.10}$$

where

n = the number of turns

a = the distance from the center of the coil to the side in cm

h = the thickness of the winding in cm

b = the width of the winding in cm

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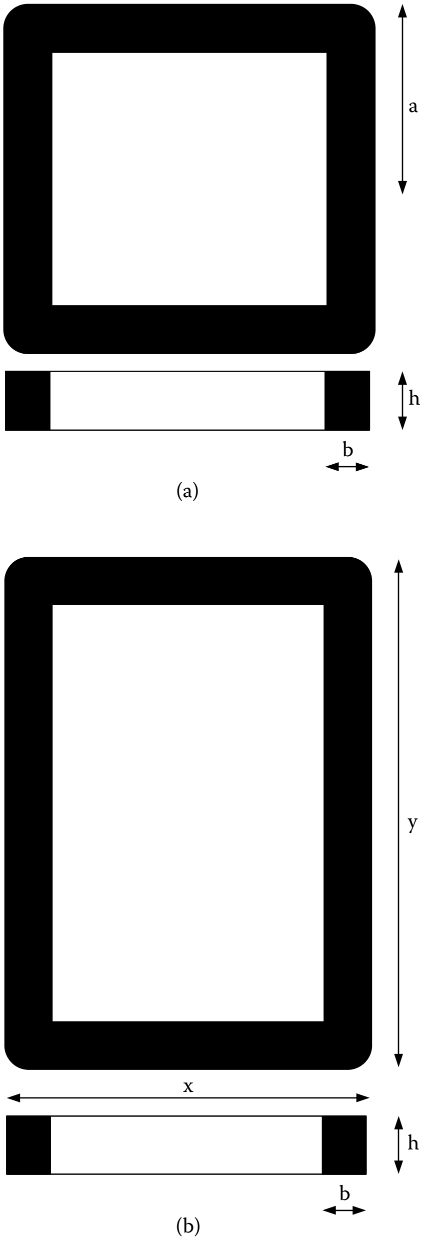

(a)

(b)

FIGURE 2.6
(a) Multilayer, square-coil antenna. (b) Multilayer, rectangular-coil antenna.

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The inductance for the planar multilayer rectangular-loop antenna with n turns, shown in Figure 2.6(b), is

$$L = \frac{0.0276\, n^2 (x + y + 2h)^2}{1.908\,(x + y + 2h) + 9b + 10h} \quad (\mu H) \tag{2.11}$$

where

x and y = the dimensions of the coil in cm
h = the thickness of the coil in cm
b = the width of the winding in cm
n = the number of turns

It is necessary to state once again that these equations, used to calculate the inductance of various coils are only approximations and need to be taken with some care. In particular, equation (2.11) is valid only when the dimensions x and y of the coil are quite different. For example, if the two dimensions of the coil in equation 2.11 (x and y) were identical, thus resulting in a square coil, the inductance values calculated by equations (2.10) and (2.11) will be different. These equations are provided as a starting point for the designer of antennas for RFID transponders.

Some antennas in transponders are configured as planar rectangular spiral structures, as shown in Figure 2.7. Figure 2.8 shows an example of a commercial transponder using this type of antenna.

There is not a full and closed equation to calculate the inductance of this type of antenna. However, its inductance can be calculated as the sum of the self-inductances for all the straight segments minus the sum of the mutual inductances existing in the arrangement. The mutual inductance is

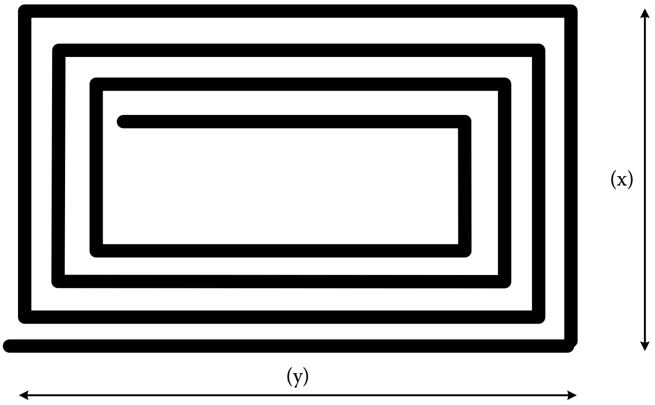

FIGURE 2.7
Single-layer, rectangular planar spiral antenna.

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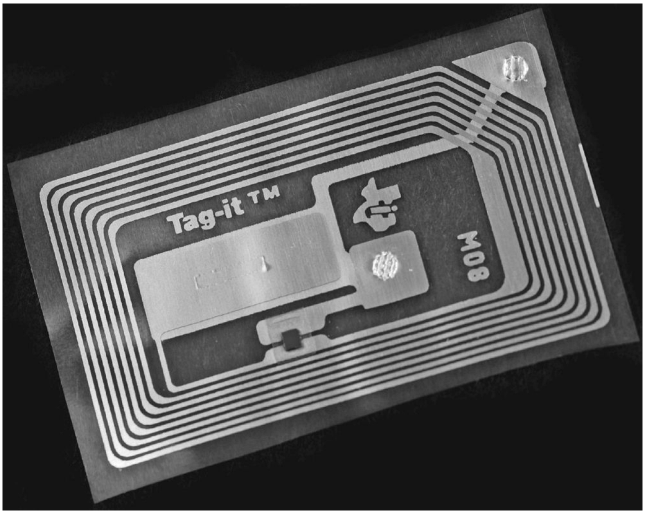

FIGURE 2.8
Commercial transponder using a planar, rectangular-spiral antenna.

the inductance that results from the magnetic fields produced by adjacent conductors. This mutual inductance will be positive when the direction of the current in the conductors is the same, and it will be negative when it is opposite.

2.1.3 Antennas for RFID Transponders Operating in the UHF Region

When the transponder is operating in the UHF region, the wavelength of the electromagnetic radiation is now comparable to the dimensions of the antenna. Because the antenna is no longer electrically small, a dipole can now be used. A *short dipole* is defined as a dipole whose length does not exceed one-fiftieth of the wavelength of the current signal. A short dipole, as depicted in Figure 2.9, produces an electric field that in near-field conditions has both radial and zenithal components, as given by equation (2.12):

$$\begin{aligned} E_r &= \frac{2I_0 l}{4\pi} k^2 \eta_0 \, e^{-jkr} \left(\frac{1}{(kr)^2} - \frac{j}{(kr)^3} \right) \cos\theta \\ E_\theta &= \frac{I_0 l}{4\pi} k^2 \eta_0 \, e^{-jkr} \left(\frac{j}{kr} - \frac{1}{(kr)^2} - \frac{j}{(kr)^3} \right) \sin\theta \end{aligned} \tag{2.12}$$

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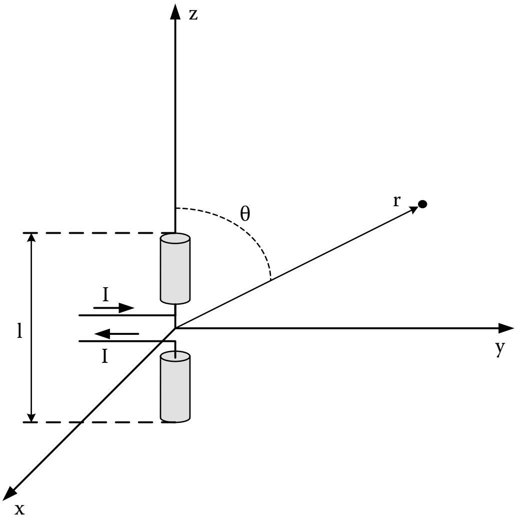

FIGURE 2.9
Electric field produced by a short dipole.

where
k = the wavenumber $\left(k = \frac{2\pi}{\lambda}\right)$
η_0 = the intrinsic impedance of free space $\left(\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \approx 120\pi\right)$
r = the distance for the center of the dipole at which the field is measured
θ = the zenith angle at which the field is measured

Assuming that the far-field approximation is valid ($r >> \lambda$), the radial component of the electrical field can be neglected, and therefore equation (2.12) becomes

$$E_\theta = \frac{jI_0 l}{4\pi} k\eta_0 \frac{e^{-jkr}}{r} \sin\theta \tag{2.13}$$

The short dipole, however, does not radiate effectively because it has a very small radiation resistance, normally below 1 Ω, making it unsuitable for a good impedance match. Therefore, other dipole alternatives are preferred when possible, such as the half-wave dipole. The *half-wave dipole,* depicted in Figure 2.10, receives its name because its length equals half of the wavelength of the current signal traveling through the antenna.

A half-wave dipole also produces an electric field only in the zenith component that can be described by equation (2.14):

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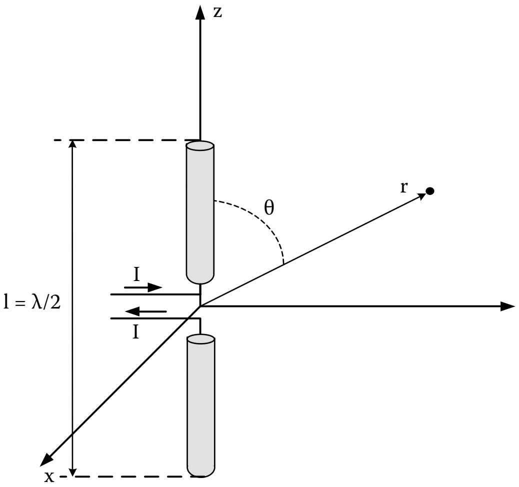

FIGURE 2.10
Electric field produced by a half-wave dipole.

$$E_\theta = \frac{j\,60 I_0}{r}\left(\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right)e^{-jkr} \tag{2.14}$$

One of the main advantages of the half-wave dipole is that its radiation resistance, around 73 Ω, is much larger than the radiation resistance of the short dipole. This makes the half-wave dipole better suited to match the impedance presented by its load, the integrated circuit in the transponder.

The wavelength for the typical UHF RFID frequency of 915 MHz is approximately 33 cm. Therefore, the length of a half-wave dipole is 16.5 cm. This value is valid only for free space; for an antenna mounted on an inlay, the actual value of its half wavelength decreases as the dielectric constant of the substrate increases. Although this distance is achievable, it presents some drawbacks. First of all, 16.5 cm may still be too large for some applications that require or would benefit from smaller transponders. More importantly, the power transfer characteristics for this antenna are very small and therefore require substantial matching approaches. Antenna matching is described in further detail in Section 2.2.

The space required by the antenna can be shortened while keeping the length of the conductors to the required 16.5 cm, for example by bending or even folding the wires that make up the dipole, as shown in Figure 2.11. This process can be repeated several times, bending the wires of the antenna in different directions as shown in Figure 2.12, which results in the structure known as the *meandered dipole*.

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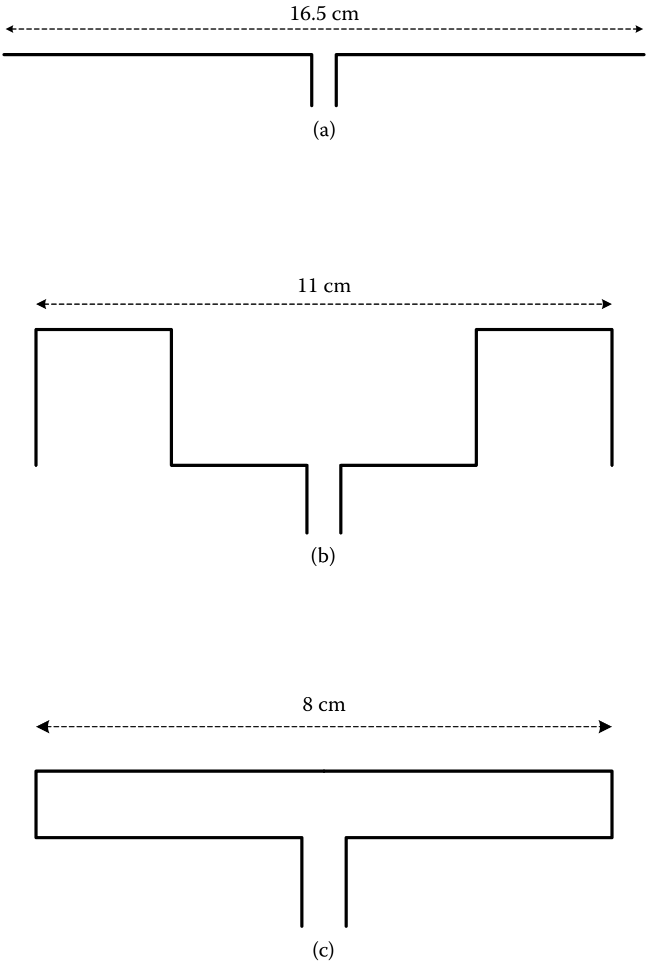

FIGURE 2.11
Strategies for reducing the size of ultra-high-frequency (UHF) antennas. (a) Original half-wave dipole. (b) Bent dipole. (c) Folded dipole.

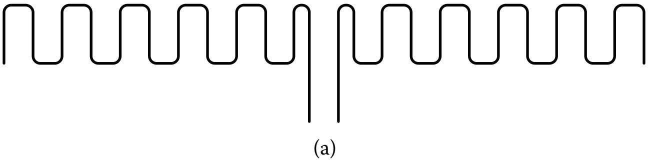

FIGURE 2.12
Examples of meandered dipole antennas. (a) Meandered dipole in a single direction. (b) Meandered dipole in two directions.

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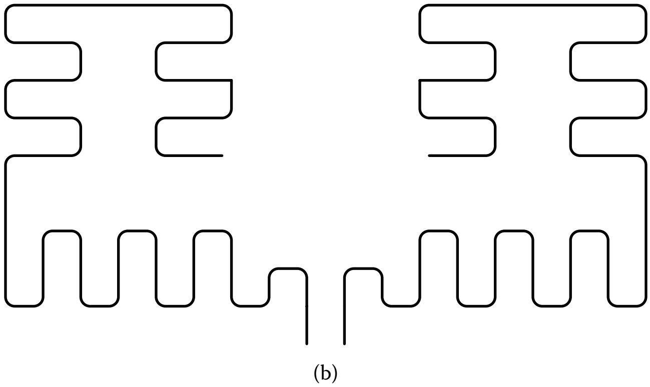

FIGURE 2.12 (Continued)
Examples of meandered dipole antennas. (a) Meandered dipole in a single direction. (b) Meandered dipole in two directions.

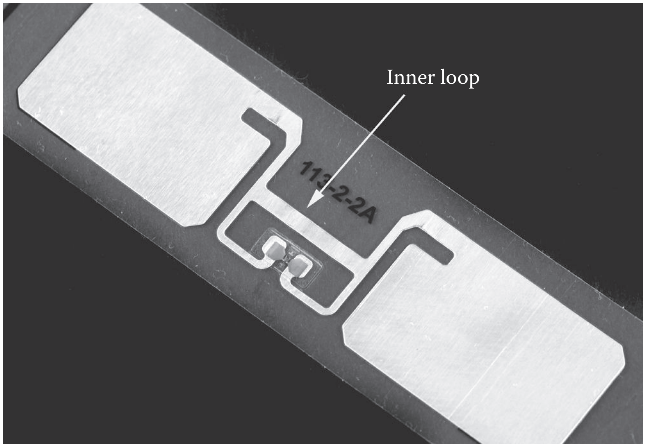

FIGURE 2.13
Detail of the inner loop used in some UHF antennas.

However, bending the dipole degrades the electrical characteristics of the antenna: the current lines flowing in opposite directions through adjacent paths have a canceling effect that in turn increases the radiation resistance of the antenna. Because this effect depends on the distance between the paths, the canceling effect becomes stronger when the antenna has multiple bends closely packed. In practice, the total length of a bent or meandered dipole is longer than the straight half-wave wavelength, although the total size of the antenna will be smaller.

Some antennas operating at the UHF range also incorporate a low DC resistance path closer to the center of the antenna known as the *inner loop*. This inner loop, shown in Figure 2.13, presents a series of advantages that makes its use common in this type of antenna.

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First, the inner loop presents a low DC resistance that helps reduce the potential of damage to the integrated circuit due to high-voltage electrostatic discharges that may occur in the antenna or its vicinity. Second, the inductance of the inner loop can be used in conjunction with the input capacitance of the integrated circuit to form a resonance circuit that will couple with the magnetic near field, producing enough voltage to power the integrated circuit. Near-field communications for UHF RFID systems, although not very common yet, are growing rapidly. Third, the inner loop can be used like a transformer to help match the impedance of the integrated circuit to the antenna. Finally, the impedance of the antenna can be lowered or increased by changing the width of the trace in the inner loop.

2.2 Antenna Tuning for RFID Transponders

Antenna tuning for RFID transponders operating at LF or HF frequencies attempts to make the antenna resonant at the frequency of transmission, thus maximizing the current or the voltage in the system. Because the antenna has a marked inductive component, resonance is achieved by placing a capacitor of the adequate value in series or in parallel with the antenna.

When the capacitor is placed in series with the antenna, the resulting series resonant circuit has an impedance minimum at the resonance frequency and therefore maximizes the current being delivered to its load. This type of configuration is typical for interrogators and will be studied in Chapter 4. When the capacitor is placed in parallel with the antenna, the result is a parallel circuit that exhibits an impedance maximum at the resonant frequency and therefore maximizes the voltage across its terminals. This is the typical configuration for transponders. The tuning capacitor in RFID transponders can be created over the same substrate as shown in Figure 2.14.

The resonant circuit can therefore be modeled as a parallel circuit, similar to the one shown in Figure 2.15, in which L represents the inductance of the antenna, C represents the capacitance of the capacitor that must be added, R represents the resistance of the load that is the integrated circuit that must be powered, and the value r represents the resistance of the coil. Because normally $r \ll R$, the value r will be ignored in the calculations needed to find the value of required capacitance. However, the resistance r of the inductor contributes to degrading the overall performance of the antenna. These effects will be studied in the last section of this chapter.

The complex impedance presented by the circuit shown in Figure 2.15, neglecting the Ohmic losses r, is

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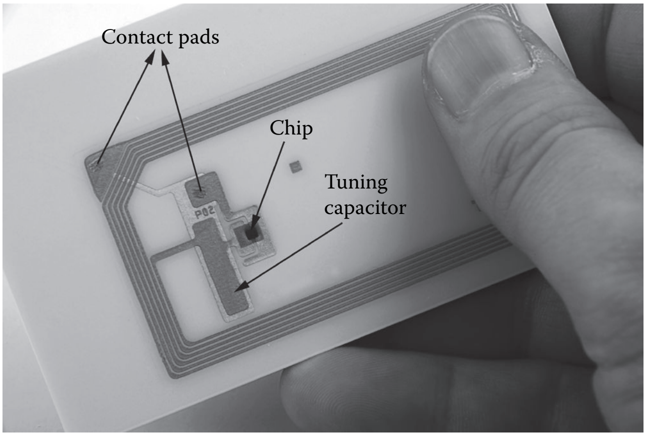

FIGURE 2.14
Tuning capacitor in the antenna of a high-frequency (HF) transponder.

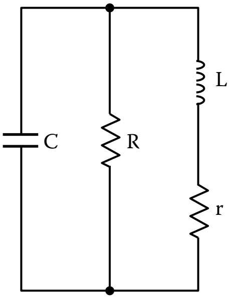

FIGURE 2.15
Parallel resonant model used to analyze antenna resonance. L: antenna inductance. C: external tuning capacitor. R: load (chip to energize). r: Ohmic losses in the antenna.

$$Z(j\omega) = \frac{\frac{j\omega}{C}}{\left(\frac{1}{LC} - \omega^2\right) + j\frac{\omega}{RC}} \tag{2.15}$$

where ω = 2πf.

The resonant frequency for the parallel circuit is the frequency that creates the maximum for *Z(j*ω*)*. This frequency is

$$\omega_o = \sqrt{\frac{1}{LC}} \quad or \qquad f_o = \frac{1}{2\pi\sqrt{LC}} \tag{2.16}$$

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From equation (2.15), it can be seen that at the resonant frequency, the impedance of the parallel circuit is real and equal to the value of the resistance of the load. This is the maximum value for the impedance.

Example 2.2:

Consider the value of inductance for the antenna in Example 2.1 (10 μH). Calculate the value of parallel capacitance required to make the antenna resonant at the typical RFID frequencies of (a) 125 kHz for LF systems and (b) 13.56 MHz for HF systems.

Solution:

Solving for *C* in equation (2.16) yields

$$C = \frac{1}{L(2\pi f)^2}$$

Therefore, the values of capacitance required for resonance are as follows:
$C_{125\ \mathrm{kHz}} = 162$ nF
and
$C_{13.56\ \mathrm{MHz}} = 13.7$ pF

The same calculations for resonant frequency can be applied to the devices that communicate data by tuning and detuning the antenna. This can be accomplished by using, for example, two capacitors or two inductors in the parallel RCL circuit. In order to detune the antenna, the controlling device can, for example, shorten one of the capacitors or inductors, resulting in a new resonant frequency. This, in turn, results in a minimal transfer of energy back to the interrogator.

The devices MCRF355 and MCRF360 from Microchip Technologies operate following this principle. Figure 2.16 shows one of the configurations used. Here, the antenna will be tuned when both inductors are active and will be detuned when the device shortens the inductor L_2.

Using equation (2.13), the resonant frequency when the antenna is tuned is $f_{\mathrm{tuned}} = 1/2\pi\sqrt{L_T\,C}$, with L_T being the total inductance between point A and ground. When the device detunes the antenna by shortening inductor L_2, the new resonant frequency becomes $f_{\mathrm{detuned}} = 1/2\pi\sqrt{L_1\,C}$. Because $L_T > L_1$ ($L_T = L_1 + L_2 + 2k\sqrt{L_1 L_2}$, with *k* being the coupling coefficient between the coils), $f_{\mathrm{tuned}} < f_{\mathrm{detuned}}$.

The difference between the tuned and detuned frequencies must be chosen to maximize the Modulation Index and the read range. If it is necessary to choose the tuned and detuned frequencies such as $f_{\mathrm{tuned}} < f_{\mathrm{detuned}}$, this can be achieved by using the configuration shown in Figure 2.17.

The operation is similar as shown before. Here, $f_{\mathrm{tuned}} = 1/2\pi\sqrt{L\,C_T}$, with $C_T = C_1C_2/\ C_1 + C_2$. The device detunes the circuit by shortening the capacitor

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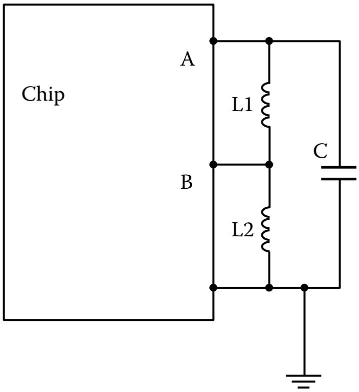

FIGURE 2.16
Tuned and detuned circuit using two inductors and one capacitor. This configuration results in $f_{\text{tuned}} < f_{\text{detuned}}$.

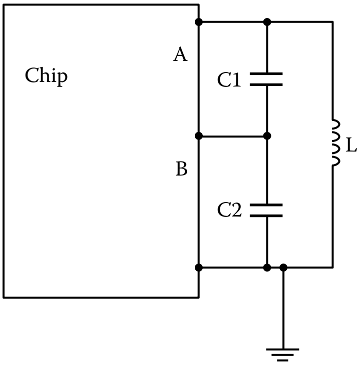

FIGURE 2.17
Tuned and detuned circuit using two capacitors and one inductor. This configuration results in $f_{\text{tuned}} > f_{\text{detuned}}$.

C_2, resulting in the following detuned frequency: $f_{\text{detuned}} = 1/2\pi\sqrt{LC_1}$. Because $C_T < C_1$, this results in $f_{\text{tuned}} < f_{\text{detuned}}$.

Equation (2.15) can also be used to calculate the bandwidth of the system defined as its –3 dB cutoff. This is

$$B = \frac{1}{2\pi RC} \quad (Hz) \tag{2.17}$$

An important parameter in a resonant circuit is its quality factor (Q), which compares the energy stored in the circuit with the energy that it dissipates:

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$$Q = \frac{f_o}{B} \tag{2.18}$$

Equation (2.17) can be rewritten taking into account the values of components in the resonant circuit by combining equations (2.16) and (2.17):

$$Q = R\sqrt{\frac{C}{L}} \tag{2.19}$$

Equation (2.6), found earlier, was used to calculate the voltage induced in the coil. Substituting equation (2.19) into equation (2.6) yields

$$V_0 = 2\pi f N\, S\, Q B_0 \cos\beta \;\; = \; 2\pi f N\, S R\sqrt{\frac{C}{L}}\, B_0 \cos\beta \tag{2.20}$$

This equation indicates that the voltage induced in the antenna transponder is inversely proportional to the square root of its inductance, and proportional to both the number of turns in the coil and its surface.

2.3 Antenna Matching for RFID Transponders

The purpose of matching an antenna to its load is to ensure that the antenna transfers the maximum amount of power to its load. In an RFID transponder, the load of the antenna is the integrated circuit that will be powered by the energy supplied by the antenna. Antenna matching is generally based on altering the complex impedance presented by the antenna at its operating frequency, by modifying its physical dimensions, inserting a reactive component, or a combination of both.

Consider a simple circuit, as shown in Figure 2.18. The power transferred by the voltage source V_s to the load resistance R_L is

$$P_L = \frac{R_L}{(R_L + R_s)^2}\, V_s^2 \tag{2.21}$$

The goal of power matching is to find a relationship between R_s and R_L that will maximize the power transferred to the load. In mathematical terms, this

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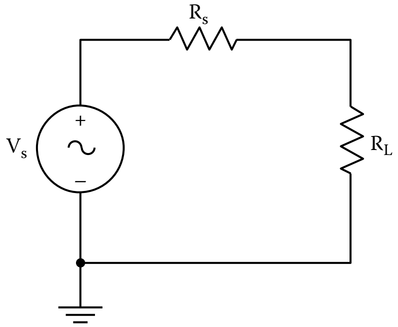

FIGURE 2.18
Simplified model for power transfer calculations.

is equivalent to finding the relationship between R_L and the rest of the circuit elements that will make the first derivative of equation (2.21) zero. That is,

$$\frac{dP_L}{dR_L} = \frac{(R_L + R_s)^2 - 2R_L\ (R_L + R_s)}{(R_L + R_s)^4} V_s^2 = 0 \quad \Rightarrow\ R_L = R_s \tag{2.22}$$

In a transponder, the voltage source models the voltage induced in the antenna, and the load models the integrated circuit that must be powered. These are not purely resistive elements such as those depicted in Figure 2.18, but they have resistance and reactance. Therefore, a more accurate model for this situation is shown in Figure 2.19.

Equation (2.23) shows the power transferred to the load that is the real part of the impedance of the integrated circuit:

$$P_L = \frac{R_{ic}}{2\left[\left(R_{ant} + R_{ic}\right)^2 + \left(X_{ant} + X_{ic}\right)^2\right]} V_{ant}^2 \tag{2.23}$$

There are now two conditions that must be met in order to transfer the maximum amount of power between the source (voltage generated by the antenna) and the load (integrated circuit to be powered). These are

$$\begin{cases} R_{ic} = R_{ant} \\ X_{ic} = -X_{ant} \end{cases} \tag{2.24}$$

Equation (2.24) can now be understood by saying that the amount of power transferred from the antenna to the integrated circuit will be maximum when their impedances are conjugate. This is an advantageous condition for RFID systems as the impedance of the antenna has an inductive behavior and the

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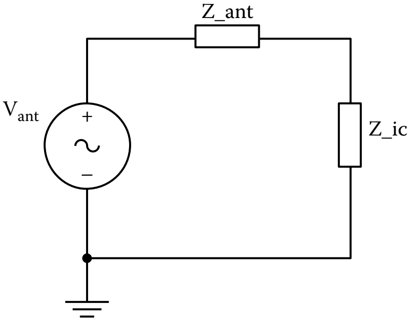

FIGURE 2.19
Model for power transfer calculations in an RFID transponder.

input impedance of the integrated circuit presents a capacitive behavior. The model shown in Figure 2.19 can be further refined as the model shown in Figure 2.20.

It is necessary to point out that the series impedance model used in Figure 2.20 is not the most common way to represent the input impedance of an integrated circuit or any other electronic device. Generally, input impedance is expressed using a parallel model with the input resistance and the input capacitance. However, to preserve the parallelism used in Figures 2.18 and 2.19, it is more convenient to express it using the series model. Given the values of parallel resistance and capacitance, it is possible to find their equivalent series values using equation (2.25):

$$\begin{cases} R_s = \dfrac{R_p}{1+(\omega R_p C_p)^2} \\ C_s = \dfrac{1+(\omega R_p C_p)^2}{\omega^2 R_p^2 C_p} \end{cases} \tag{2.25}$$

Example 2.3:

The specifications for the chip MCRF200 from Microchip used in RFID transponders indicate a parallel capacitance of 2 pF. Assuming a parallel resistance of 3 kΩ, find the equivalent series model at the frequency of 915 MHz.

Solution:

Equation (2.25) gives the following values of the equivalent series model:

$R_s = 2.6\ \Omega$ and $C_s = 1.96$ pF. In general, the values of series and parallel capacitance will be approximately the same. However, the values of the series and parallel resistances are very different for each model.

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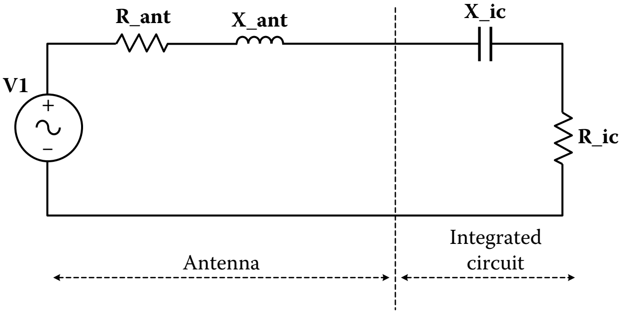

FIGURE 2.20
Series model for the transponder antenna and chip to be energized.

It is also interesting to calculate the gain or attenuation between the voltage delivered to the integrated circuit and the voltage generated by the antenna in the optimal case of maximum power transfer. Using the model shown in Figure 2.16, the voltage across the integrated circuit produced by the antenna can be calculated as follows:

$$V_{ic} \approx j \frac{1}{2\pi\omega R_{ic} C_{ic}} V_{ant} \tag{2.26}$$

Example 2.4:

Using the values given in Example 2.3, calculate the voltage gain or attenuation at the input of the integrated circuit at the frequency of 915 MHz.

Solution:

Using equation (2.26), V_{ic} / V_{ant} is equal to 34. This means that the voltage at the input of the integrated circuit in the transponder at the resonance frequency will be 34 times larger than the voltage generated by the antenna. In practice, this number will be lower because equation (2.26) has not considered factors such as the effect of the Q factor and other losses in the system. Typical voltage gains in practice are around 10 to 15. In any case, this represents an important benefit for the designer of the RFID system.

It is necessary to consider that, in practice, there will be some mismatch between the impedance of the integrated circuit and the impedance of the antenna as these will not be perfect conjugates. This mismatch will produce losses in the power being delivered to the integrated circuit, resulting in decreasing the sensitivity and read range for the transponder. This factor becomes more important for UHF antennas designed for global operations that have a frequency bandwidth of 860 MHz to 960 MHz rather than those

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designed for operation at a single frequency. In this case, the usual design approach is to place the matched frequency at the geometrical mean of the two frequency ends, resulting in 908 MHz. This will result, however, in mismatch losses at frequencies close to 860 MHz and frequencies close to 960 MHz.

2.4 Antennas in Commercial RFID Transponders

Coil antennas are used in the different type of encapsulated glass transponders, similar to Figure 2.21, operating in the LF region manufactured by Texas Instruments. Glass transponders are hermetically sealed, making them waterproof and therefore suitable to be immersed in water and other fluids.

These transponders are marketed toward access control, vehicle identification, container tracking, asset management, animal identification, and waste management applications, as described by the literature provided by their manufacturer. Texas Instruments has different versions of these transponders depending on the size of the memory in the chip and its ability to be rewritten by the user. The transponders are also available in different sizes, in particular lengths of 12 mm, 23 mm, and 32 mm. Figure 2.22 shows the different sizes of these glass transponders that operate at the central frequency of 134.2 kHz, corresponding to the LF range. Other operational characteristics of these glass transponders are listed in Table 2.1.

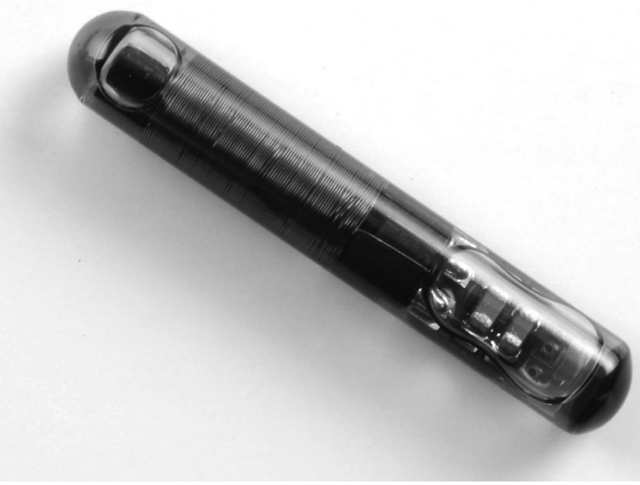

FIGURE 2.21
Glass transponder used for RFID applications in the LF range.

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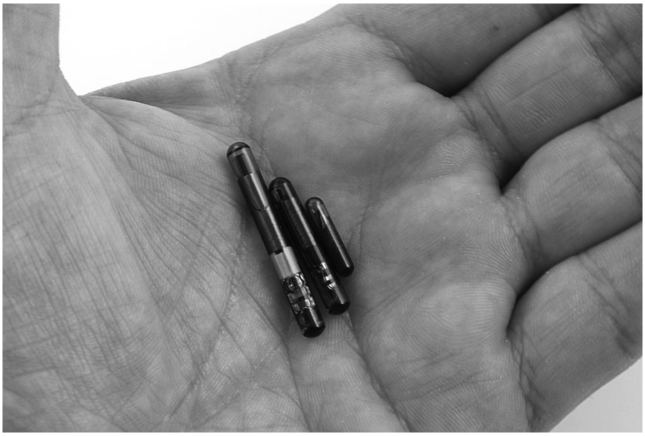

FIGURE 2.22
Three commercial glass transponders of different sizes used for application in the LF range.

TABLE 2.1
Operational Characteristics of Glass Transponders

Main Operational Parameters Glass Transponders Texas Instruments – LF Region	
Modulation	FSK: 134.2 kHz and 123.2 kHz
Transmission Principle	Half Duplex
Read Range	Less than 100 cm
Maximum Operating Temperature Range	– 25°C to + 85°C
Read Time	Less than 70 ms
Case material	Glass
Protection	Hermetic seal
Weight	0.8 grams
Memory on board	4 different options depending on specific part number

Other transponders operating in the LF region use planar coil antennas similar to those shown in Figure 2.23. The dimensions of the larger transponder are 25 mm for the outer ring and 20 mm for the inner ring, while the dimensions for the smaller antenna are 14 mm for the outer ring and 9 mm for the inner ring.

These antennas consist of a length of conductor wire coiled multiple times in order to create the desired inductance. The manufacturer specifies their use for the same general type of applications as the glass transponders, with the advantage of being much thinner.

Antennas for transponders operating in the HF frequency (13.56 MHz) are normally planar antennas, having a structure similar to the planar antennas used in the LF region. However, because HF antennas require a lower

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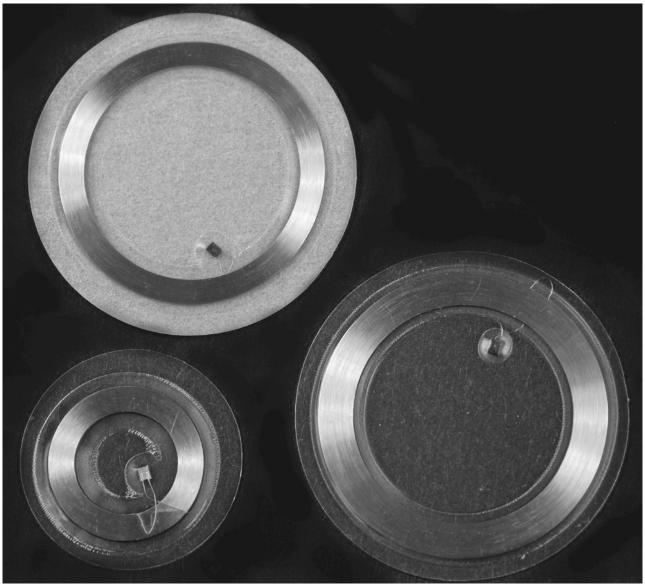

FIGURE 2.23
Commercial planar coil antennas.

inductance, the number of turns for these antennas is much lower, normally less than 10 turns. Planar antennas for RFID transponders operating in the HF region are also manufactured in different sizes and thicknesses depending on the intended application. Figure 2.8 showed a picture of an HF transponder manufactured by Texas Instruments under the name of Tag-it™. This type of transponder is marketed toward product authentication, library applications, supply chain management, asset management, and ticketing or stored value applications. The antennas are built over a polyethylene-terephthalate (PET) substrate giving a maximum thickness of 0.085 mm for the antenna area and 0.355 mm for the chip area. Figure 2.24 shows three antennas from this same family. The larger rectangular antenna has maximum dimensions of 75 mm × 45 mm and consists of seven turns; the small rectangular antenna has a maximum dimension of 39 mm × 22 mm and has six turns; the square antenna has maximum dimensions of 45 mm × 45 mm and contains nine turns.

The number and type of different antennas for transponders operating in the UHF region are higher as each commercial product has been optimized with an application in mind in terms of the different antenna parameters or the type of substrate better suited for a specific purpose. Figures 2.25, 2.26, and 2.27 show three examples of the diverse UHF transponders manufactured by Alien Technology.

Figure 2.25 shows the Alien ALN-9640 Squiggle® Inlay from Alien Technology. This is a general-purpose transponder used for packages that

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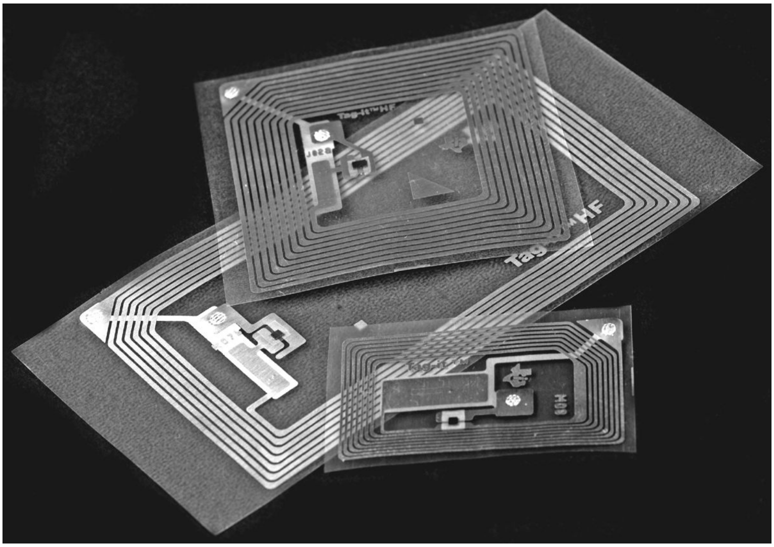

FIGURE 2.24
Diverse planar rectangular antennas used in commercial HF transponders.

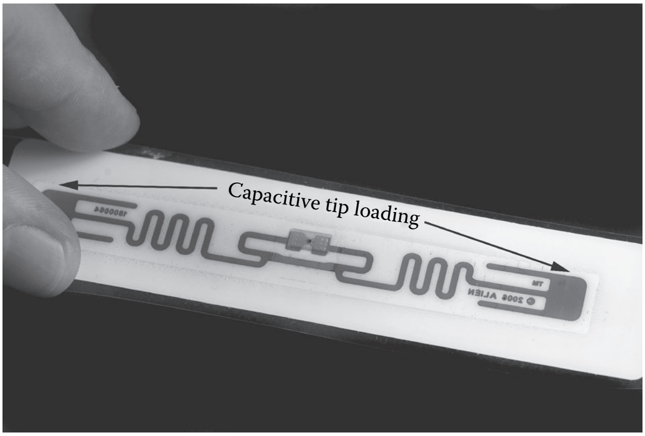

FIGURE 2.25
Commercial UHF transponder based on a meandered dipole and using capacitive tip loading.

include metal or water. The largest length dimension of this antenna is 98 mm, and the largest width of the overall antenna is 8 mm. This antenna exhibits a radiation pattern similar to a half-wave dipole. This antenna is based on a half-wave dipole that has been made shorter by bending the wires and adding shunt and series inductors to create the adequate resonant frequency for the integrated circuit that will be powered by the antenna. The large conductive areas located at each end of the antenna serve as capacitors

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used to increase the antenna capacitance. This technique is known as *capacitive tip loading*. Since the magnitude of capacitive reactance decreases as the capacitance increases, a tip-loaded dipole exhibits a more inductive behavior than a dipole of the same length without the additional capacitance at its ends.

Figure 2.26 shows the Alien ALN-9534 2x2 Inlay from Alien Technology. This antenna exhibits a more omnidirectional radiation pattern and is marketed toward item-level tagging applications such as apparel or baggage. The maximum dimensions of this antenna are 46 mm × 40 mm. This type of antenna, in which the conductors are thicker than the previously studied wire antennas, presents the advantage of having higher capacitance and lower inductance than the wire antennas, therefore making it easier to match to the characteristics of its integrated circuits. Furthermore, these antennas made with thicker conductors exhibit a wider bandwidth than the wire antennas.

Figure 2.27 shows the Alien ALN-9554 M Inlay from Alien Technology. This antenna exhibits a better omnidirectional radiation pattern and is marketed toward tagging plastic totes, pallets, and other reusable assets. The maximum dimensions of this antenna are 98 mm × 38 mm. This type of antenna presents the higher bandwidth for the same reasons described earlier. When using conductive inks to create the antenna, the additional ink required to create them results in a cost increase for this type of antenna.

Figure 2.28 shows an example of a meandered dipole antenna with an inner loop for use in the UHF range manufactured by RSIID technologies.

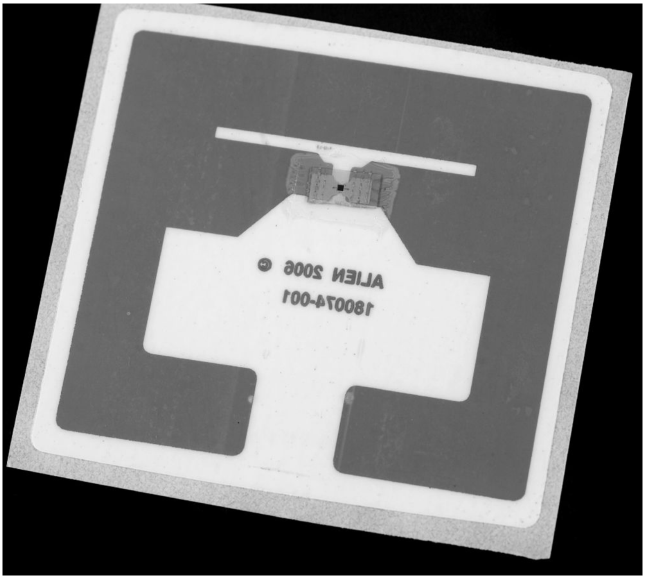

FIGURE 2.26
Commercial UHF transponder using a more omnidirectional antenna.

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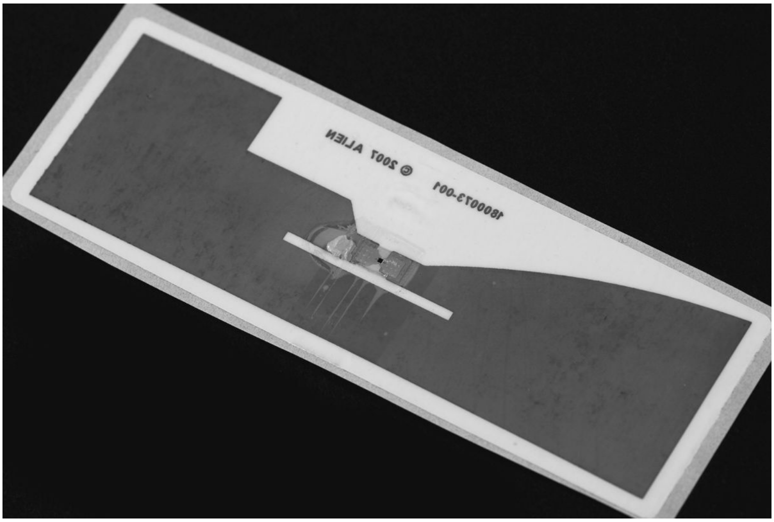

FIGURE 2.27
Commercial UHF transponder having a higher bandwidth response.

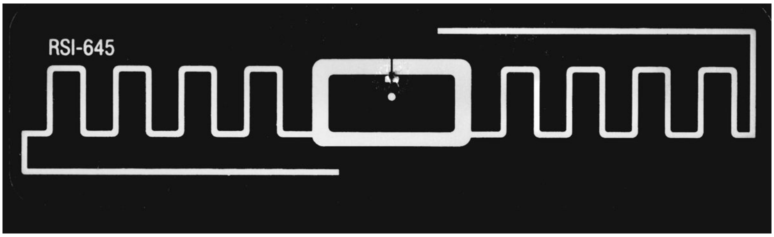

FIGURE 2.28
Meandered dipole antenna for UHF applications.

The maximum dimensions of this antenna are 67 mm × 13.5 mm, thus making it suitable for applications with limited available space. Figure 2.28 is just one example of the different configurations available for meandered dipoles.

Figure 2.29 shows a dual dipole transponder. These transponders have two dipole antennas to make them more insensitive to the orientation of the transponder in reference to the interrogator. The potential drawback of this approach is the additional space required by the transponder that may not be suitable for all products. Furthermore, the front end of the integrated circuit that will be powered by the antenna increases in complexity as it needs to respond to two different antennas. However, for longer range applications in which the position of the object can change, this type of antenna presents a clear advantage.

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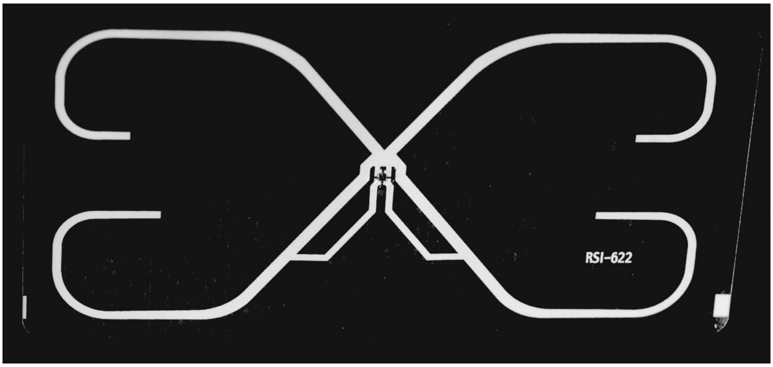

FIGURE 2.29
Dual dipole antenna for UHF transponders.

While the majority of transponders operating in the UHF range are powered by far-field electromagnetic radiation, in some cases the relatively large area that they require may be larger than the available surface in the transponder. The solution in this case is to use UHF antennas that operate in the near-field region, accepting the drawbacks associated with this mode of operation. These antennas operate based on the same inductive coupling principles used by LF and HF antennas. However, it is possible to add shunt and series inductors or capacitive tip loads to create what are known as *hybrid antennas*. These hybrid antennas, examples of which are shown in Figures 2.30 and 2.31, are able to operate in the near and far fields even though the performance in the far-field region is degraded compared to the performance of a typical dipole antenna.

2.5 The Connection between the Chip and the Antenna in RFID Transponders

A critical step in the manufacture of RFID transponders is the connection between the antenna and the integrated circuit in the transponder. There are main methods of doing this connection: chip-on-board and direct die attachment.

Chip-on-board (COB) is an assembly technology for semiconductors in which the electronic chip is directly mounted on and connected to its final board instead of undergoing the traditional packaging process for integrated circuits. This process reduces space requirements and cost, and also increases the performance of the system due to the decrease in connection lengths and increase in reliability. This approach is normally used for wire-wound antennas. During the COB process, the capacitor used to create resonance is also packaged in the device. The device is then covered in epoxy in such a

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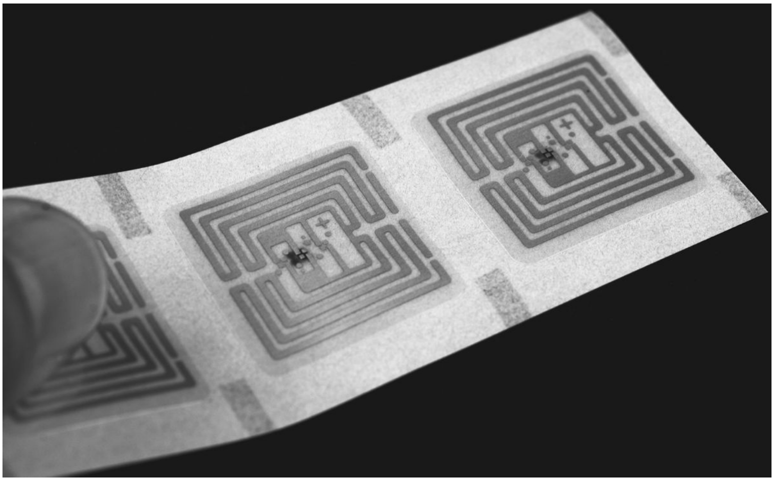

FIGURE 2.30
Hybrid UHF antenna able to communicate in near field and far field.

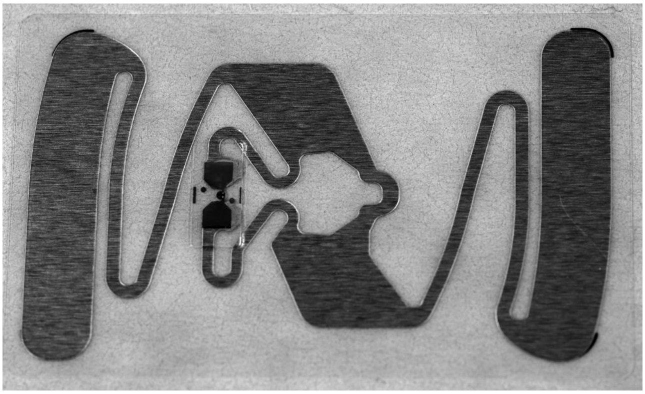

FIGURE 2.31
Hybrid UHF antenna with tip loading.

way that only the two cables to connect to the antenna emerge from the package, as shown in Figure 2.32. The majority of COB packages are used in cards that need to meet the requirements for standard thickness of these cards at 0.76 mm. With this requirement, the typical thickness of COB packages is about 0.41 mm. Although the COB package is designed to protect the internal silicon device during the card lamination process, it is necessary to be careful to prevent mechanical cracks on the device as a result of the mechanical pressures and hot temperatures.

Direct die attachment can be achieved using two techniques: wire bonding or flip-chip. Flip-chip is a technology for interconnecting semiconductor

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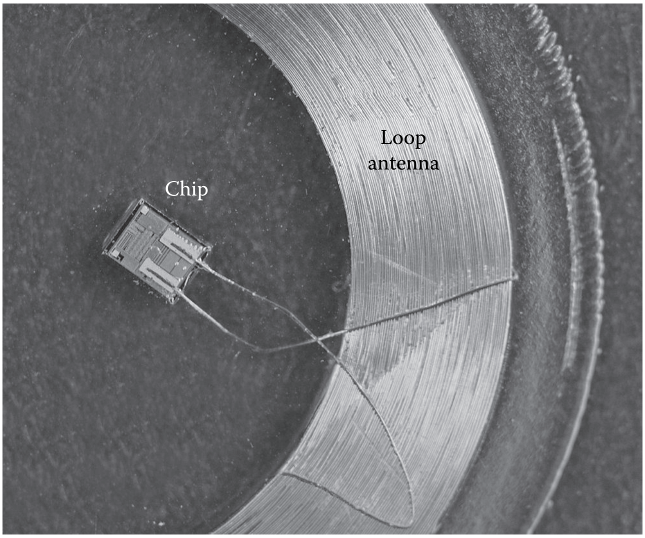

FIGURE 2.32
Connection of the antenna wires to the chip in the transponder.

devices by creating conductive bumps in the pads of the chip. In order to connect the chip, this has to be flipped so the bond pads are in contact with the matching pads in the circuit. In the wire-bonding technology, the chip is mounted upright and wires are used to connect the chip to the circuit. In the case of RFID transponders, the bumps or wires are connected to the antenna, thus being an ideal method to use for printed, etched, or stamped antennas. In this case, the resonance capacitor can also be etched on the substrate of the transponder, and therefore this technology does not require binding it with the chip as COB does. Figure 2.33 shows an example of this type of connection.

The choice between printing, etching, or stamping the antenna is a trade-off between cost and performance. The Q factor of the antenna, which as discussed earlier has a strong effect on the read range for the transponder, is inversely proportional to the resistance of the antenna. With this in mind, it is desirable to use an etched antenna instead of a printed antenna made of conductive material. The etching process is also less expensive than the printing process. For large antennas, however, etching and stamping waste too much unwanted material. In this case, a printed antenna becomes a more desirable solution. Figure 2.34 shows the general structure of the chip-to-antenna connection, independently of the specific technique being used. The antenna is connected between one of the terminals in the die and its ground connection (GND).

This connection creates a problem due to the crossing of the connection to the antenna with the ground ring around the die, creating a parasitic

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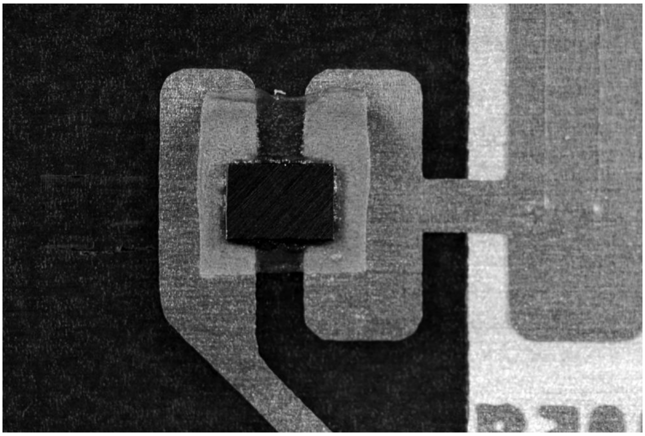

FIGURE 2.33
Direct connection between the chip and the antenna in the transponder.

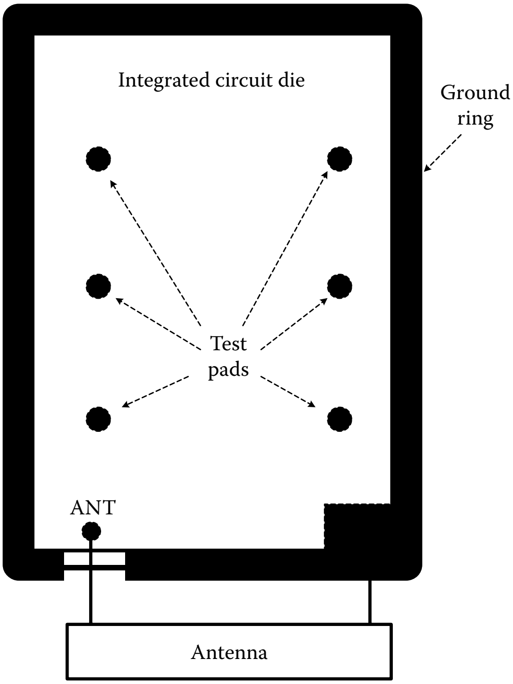
Integrated circuit die
Ground ring
Test pads
ANT
Antenna

FIGURE 2.34
Strategy for reducing the stray capacitance when connecting the chip to the antenna in an RFID transponder.

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capacitance. Depending on the technology being used to make this connection, the parasitic capacitance can have a value of up to 20 fF, influencing the resonant frequency for the antenna. To limit this effect, the ground ring around the die is narrowed in the vicinity of the pad for the antenna connection, thus reducing the parasitic capacitance.

2.6 Additional Factors That Affect the Performance of Antennas in RFID Transponders

As discussed in the preceding sections, the quality factor of an antenna is influenced by its Ohmic losses. For the coil antennas used for transponders operating in the LF region, these Ohmic losses come from the wire used to build the coil. The resistance in DC of a conductor of length *l*, with a uniform cross-section *S*, is

$$R_{DC} = \frac{l}{\sigma S} \tag{2.27}$$

where σ is the conductivity of the material.

Because of the need to manufacture the antenna as small as possible, designers opt for choosing the narrowest possible diameter, resulting in an increase in its resistance as shown by equation (2.27). More important, however, for the design of antennas is their losses in AC. The density of AC current through a wire is not constant through its surface, but the current tends to flow through the outer section of the wire, thus decreasing its effective area. This is known as the *skin effect*. Similarly, the *skin depth* for a conductor is defined as the value of its depth at which the current density falls to 37% of the current density along the surface. As shown in equation (2.28), for a given material, its skin depth is dependent on the frequency of the AC current:

$$\delta = \frac{1}{\sqrt{\pi \mu \sigma f}} \tag{2.28}$$

where

δ = the skin depth

μ = the permeability of the material

σ = the conductivity of the material

f = the frequency of the AC current through the material

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Example 2.5:

Calculate the skin depth for copper wire at (a) 125 kHz and (b) at 13.56 MHz.

Solution:

Copper has a relative permeability of 1, so its total permeability is $\mu = 4\ \pi\ 10^{-7}$ H/m. Its conductivity is equal to $\sigma = 5.8\ 10^{7}$ mho/m. Therefore, equation (2.28) can be rewritten for copper as

$$\delta = \frac{0.066}{\sqrt{f}} \quad (m)$$

A. The skin depth of copper at 125 kHz is equal to 0.186 mm. This means that the current density of a point located 0.186 mm away from the surface of the conductor is only 37% of the current density on the surface.
B. The skin depth of copper at 13.56 MHz is equal to 0.018 mm. At this frequency, the skin depth is about one-tenth of the skin depth at 125 kHz. Therefore, at 135 MHz the majority of the current is flowing through the surface of the conductor.

The total resistance of a wire to AC current (R_{ac}) is a combination of its DC resistance (R_{DC}) and its skin depth (δ):

$$R_{ac} = R_{DC}\frac{a}{2\delta} \tag{2.29}$$

where a is the radius of the wire.

For etched coil antennas, commonly found in planar transponders, the AC resistance is given by equation (2.30):

$$R_{ac} = \frac{1}{(w+t)}\sqrt{\frac{\pi \mu f}{\sigma}} \tag{2.30}$$

where

w = the width

t = the thickness of the conductor on the substrate

Etching is a wasteful process as metal is removed from the substrate in order to create the antenna. Although some of the materials may be recycled, etching also requires large amounts of chemicals and energy to use in the process. To respond to this concern, newer processes based on conductive inks or copper deposits have been developed, especially for antennas operating in the UHF frequency range. Because of the higher conductivity of copper compared to silver-based conductive inks, antennas made with deposited copper can be substantially thinner than those made with conductive inks. In general, both materials can be effectively used to create antennas.

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3

Transponders

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The two main components of a transponder are its internal circuits and its antenna. The antenna, studied in Chapter 2, is used to collect energy from the electromagnetic fields in which the transponder is embedded as well as to transmit the information back to the interrogator. The integrated circuit, also known as the *chip* or *device*, is the key component in the transponder, and for this reason this chapter uses the names *transponder*, *chip*, and *device* interchangeably. The integrated circuits have the ability to store information to be transmitted to the interrogator, execute a series of commands, and, in some cases, store new information sent by a remote station.

This chapter describes the fundamental blocks that make up the transponder. Because there are a large number of transponders in the market, each one with its own specific differences, this chapter focuses on the functional blocks common to them using commercial transponders to illustrate these concepts. Therefore, the devices used in the examples should not be seen as an exhaustive list of transponders but just as examples used to illustrate specific concepts and ideas. This chapter starts by describing the analog front end commonly encountered in these devices. The analog front end contains the radiofrequency section that is necessary to match the electrical properties of the device to the electrical properties of the antenna as well as the circuits used for harvesting and managing the power necessary to turn on the device. This section is followed by the description of the main encoding and modulation methods commonly used by transponders. This is followed

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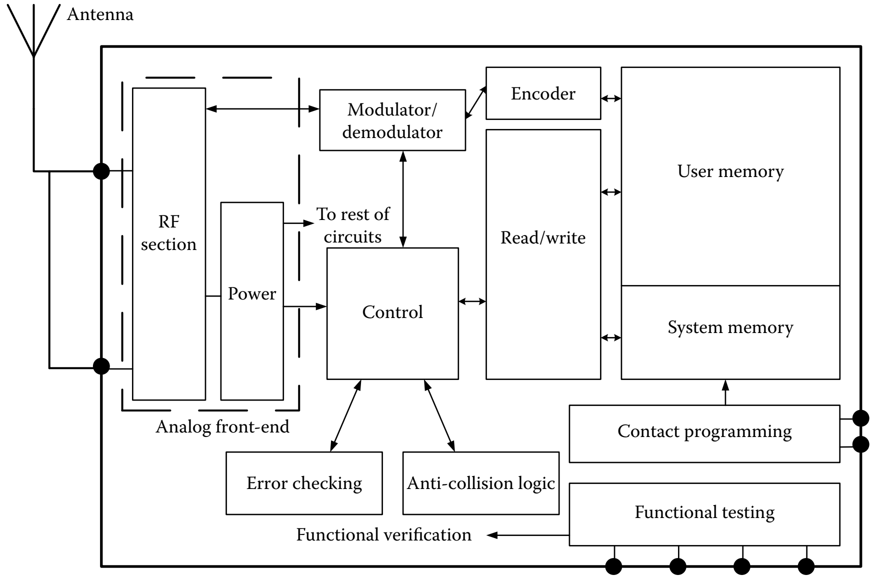
Antenna
Modulator/
demodulator
Encoder
User memory
RF
section
Power
To rest of
circuits
Read/write
Control
System memory
Analog front-end
Contact programming
Error checking
Anti-collision logic
Functional testing
Functional verification

FIGURE 3.1
Block diagram of a generic RFID transponder highlighting its main functional components.

by the description of the different memory structures to store data and configuration parameters as well as the codes used to ensure the integrity of the digital data. The next section briefly describes the methods for programming the transponder by either a contact programmer or a contactless programmer. The last two sections in this chapter present a summary of the electrical and mechanical specifications found in commercial transponders as well as a description of their most common assembly methods.

Figure 3.1 depicts the block diagram of a basic and generic RFID transponder showing its main functional blocks. It is important to note that not all the blocks shown in the figure will be always present in any transponder depending on its use, intended application, and cost.

3.1 The Analog Front End

3.1.1 Radiofrequency Stage

When the transponder is immersed in an electromagnetic field of the appropriate frequency, a radiofrequency voltage appears across the antenna terminals. The task of the front-end stage is to rectify that radiofrequency voltage and convert it into a continuous voltage (DC) with a value high enough to power the rest of the circuits inside the device. Different transponders have

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different requirements regarding the minimum voltage required to become operational depending on their internal structure and fabrication technology.

The first step in the energy conversion process between the electromagnetic field and the DC voltage is the resonant circuit tuned to the frequency of the field. The different possible configurations for the external resonant circuit described in Section 2.2 are now studied, taking into account the structures used in commercial transponders. Figure 3.2 shows the possible alternatives for the external resonant circuit using two commercial devices: the MCRF355 and the MCRF450, both from Microchip Technology and both operating at 13.56 MHz.

Some devices incorporate one or two capacitors inside their integrated circuit, eliminating the need for using an external capacitor and therefore reducing the size required for the overall transponder inlay. Figure 3.3 shows the resonant circuit using commercial devices that incorporate one or two capacitors in their internal circuitry.

The devices MCRF360, MCRF451, and MCRF455 from Microchip Technology have a single internal capacitor with values of 100 pF, 95 pF, and 50 pF, respectively. The device MCRF422, also from Microchip Technology, has two internal capacitors of 50.6 pF and 65.4 pF. All these devices operate at 13.56 MHz.

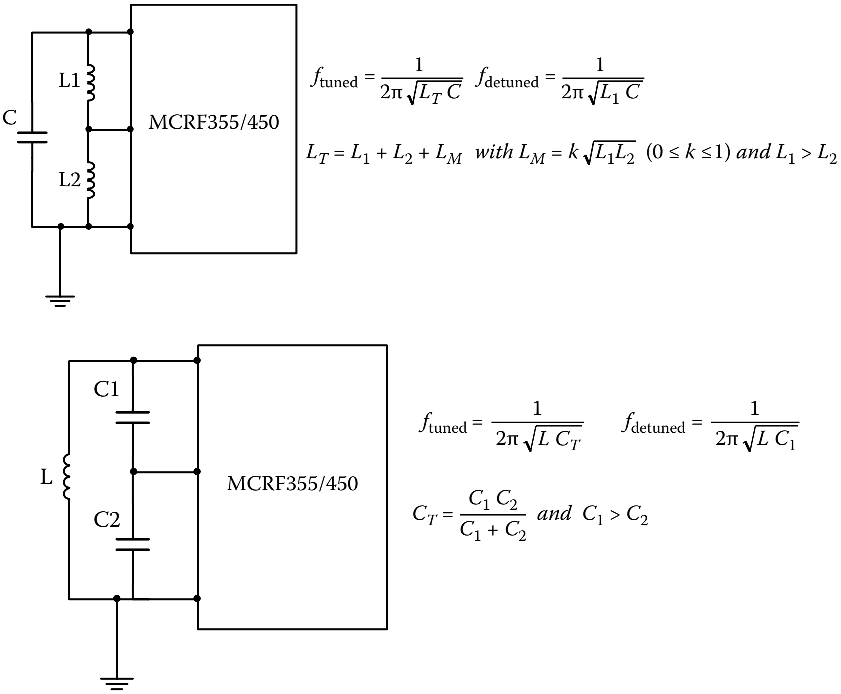
C
L1
L2
MCRF355/450
$f_{\text{tuned}} = \frac{1}{2\pi\sqrt{L_T C}}$
$f_{\text{detuned}} = \frac{1}{2\pi\sqrt{L_1 C}}$
$L_T = L_1 + L_2 + L_M$ with $L_M = k\sqrt{L_1 L_2}$ $(0 \le k \le 1)$ and $L_1 > L_2$
C1
L
C2
MCRF355/450
$f_{\text{tuned}} = \frac{1}{2\pi\sqrt{L C_T}}$
$f_{\text{detuned}} = \frac{1}{2\pi\sqrt{L C_1}}$
$C_T = \frac{C_1 C_2}{C_1 + C_2}$ and $C_1 > C_2$

FIGURE 3.2
Alternatives for the external resonant circuit found in commercial transponders. These transponders require a capacitor in the inlay to create the resonant circuit. The inductor in the circuits models the antenna.

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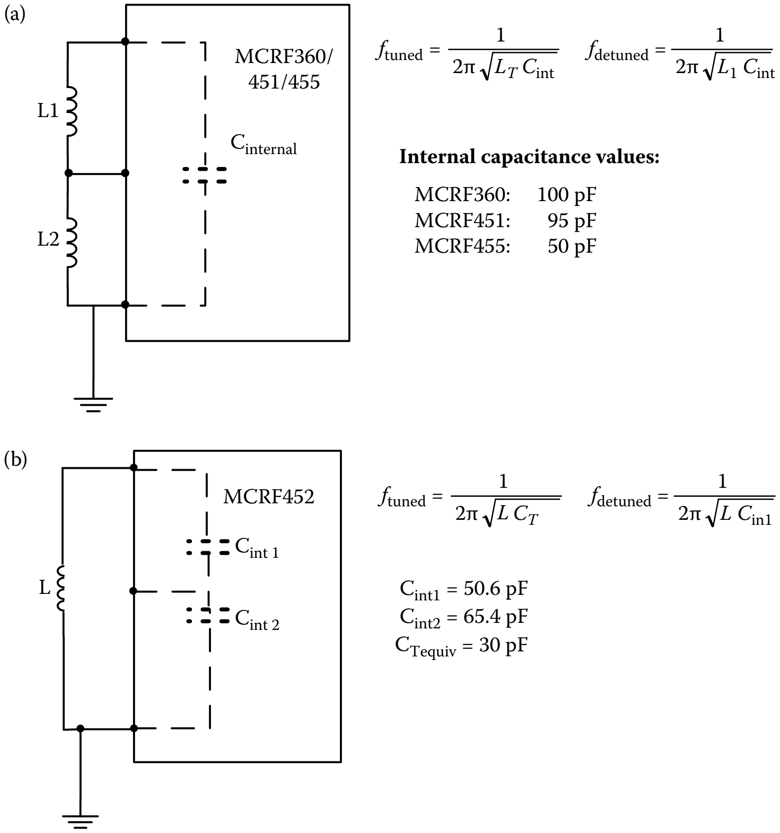

$$f_{\text{tuned}} = \frac{1}{2\pi\sqrt{L_T\,C_{\text{int}}}} \qquad f_{\text{detuned}} = \frac{1}{2\pi\sqrt{L_1\,C_{\text{int}}}}$$

Internal capacitance values:

MCRF360:	100 pF
MCRF451:	95 pF
MCRF455:	50 pF

$$f_{\text{tuned}} = \frac{1}{2\pi\sqrt{L\,C_T}} \qquad f_{\text{detuned}} = \frac{1}{2\pi\sqrt{L\,C_{\text{in1}}}}$$

$C_{\text{int1}} = 50.6$ pF
$C_{\text{int2}} = 65.4$ pF
$C_{\text{Tequiv}} = 30$ pF

FIGURE 3.3
Alternatives for the external resonant circuit for devices that incorporate the resonance capacitor in the die of the integrated circuit. (a) Structure with a single internal capacitor. (b) Structure with two internal capacitors.

The path between one of the antenna connection nodes and ground, shown in Figures 3.2 and 3.3, is shortened according to a control signal. The path is shortened using a transistor, called a *modulation transistor,* that exhibits a low ON resistance, normally below 5 Ω and a very high OFF resistance of several MΩ. In this situation, the transponder exhibits two different resonant frequencies.

The resulting resonance frequency when the modulation transistor is OFF is chosen to be equal to the frequency of the electromagnetic field emitted by the interrogator. As shown in Figure 3.4, because of the resonance condition, the energy of the field is transmitted through the front end to the device, resulting in the radiofrequency voltage at the input of the device being maximal. This situation is called *uncloaking*. When the modulation transistor is turned ON, it shortens one of the inductors or capacitors, resulting in a resonant frequency for the circuit different from the frequency of the electromagnetic field. When it shortens one of the two inductors connected

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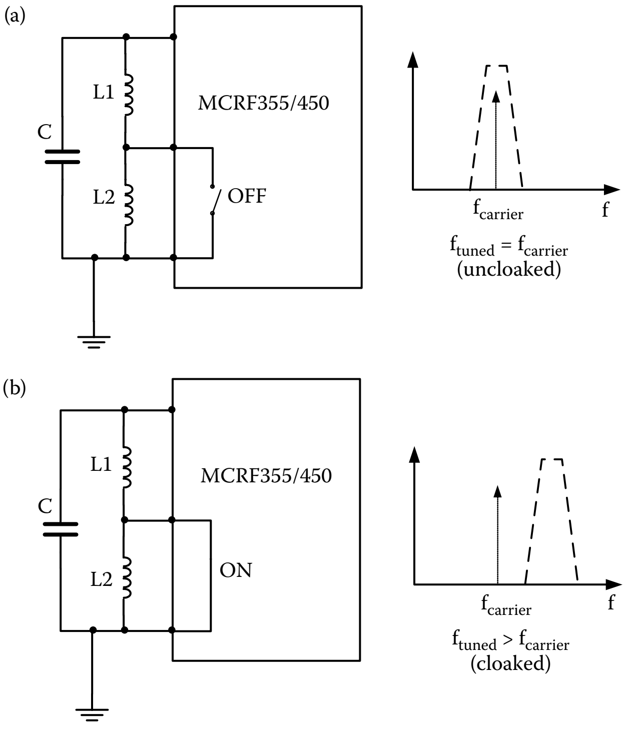

FIGURE 3.4
Cloaking and uncloaking modes produced by the control transistor in the transponder and the different resonant frequencies generated. (a) Uncloaked. (b) Cloaked.

in series, the resulting resonant frequency is higher than the frequency of the field; when it shortens one of the two capacitors connected in series, the resulting resonant frequency is lower. In any case, the frequency of the circuit and the frequency of the field are different, and therefore most of the energy of the electromagnetic field is rejected by the filter, resulting in the voltage generated at the input of the device being minimal, ideally zero. This situation is called *cloaking*. The same cloaking–uncloaking approach is used by the transponder to transmit data to the interrogator. Using this approach, the digital signal controls the modulation transistor.

Example 3.1:

Calculate the values of the external inductors needed to use in a transponder based on the MCRF451 device.

Solution:

The MCRF451 has an internal capacitance of 95 pF and operates at a frequency of 13.56 MHz. Using the equations shown in Figure 3.3, the total inductance

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necessary is $L_T = 1.45$ μH. With this inductance, the circuit resonates at 13.56 MHz, and therefore the energy from the electromagnetic field is passed to the device. The $L_T = 1.45$ μH of external inductance will be split between L_1 and L_2.

The value of L_1 can be calculated using the equations from Figure 3.3 now for the case of detuned frequency. The detuned frequency should be between 3 MHz and 6 MHz away from the tuned frequency. For the structure used by the MCRF451 device, the detuned frequency will be higher than the tuned frequency. Using for example a frequency shift of 4 MHz, the detuned frequency becomes 17.56 MHz, resulting in a value of L_1 equal to 864 nH. Assuming initially a value for the coupling coefficient between L_1 and L_2 equal to zero ($k = 0$), the required value for L_2 is 586 nH. It can be observed that $L_1 > L_2$ as it is required. In a more realistic situation, the value of the coupling coefficient will be between 0 and 1, resulting in a lower value for L_2.

3.1.2 Power Management

In order to be operative, the transponder needs to convert the radiofrequency voltage detected by the antenna into a DC voltage. The voltage required to bias the internal components in the transponder is higher than the voltage detected by the antenna. Therefore, the transponder requires the use of voltage multipliers to reach the values necessary by the biasing voltage.

A voltage multiplier is a circuit that converts a lower AC voltage into a higher DC voltage. Figure 3.5 shows the basic structure of a simple voltage multiplier called a *voltage doubler.*

Assuming initially ideal diodes for simplicity, diode D1 is forward biased during the phase of negative input voltage, while diode D2 is reverse biased and therefore capacitor C2 is disconnected from the rest of the circuit. In this stage, capacitor C1 charges to a DC voltage ideally equal to the amplitude of the AC signal. Afterward, during the phase of positive input voltage, the biasing of the diodes reverses: D2 is forward biased, and D1 becomes reverse biased. This causes capacitor C2 to be directly connected to the input of the AC signal. Taking into consideration the voltage at which capacitor C1 was originally charged, the DC voltage at capacitor C2 will be equal to twice the amplitude of

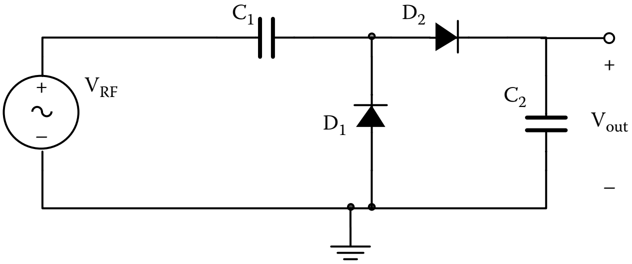

FIGURE 3.5
Structure of a single-stage basic voltage multiplier. V_{RF} models the voltage generated by the electromagnetic field in which the transponder is immersed.

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the input voltage. Considering now the minimum ON voltage for real diodes, the voltage at the output of the structure shown in Figure 3.5 is

$$V_{out} = 2(V_p - V_{ON}) \tag{3.1}$$

where

V_{out} = the output DC voltage,

Vp = the peak voltage detected at the antenna terminals

V_{ON} = the minimum direct voltage across the diode to turn it on

Figure 3.6 shows the intermediate signals observed at the different nodes in the voltage doubler structure. The voltage supply models the radiofrequency signal detected at the terminals of the antenna in the transponder. The graph of the output voltages shows how the output capacitor is being charged until it reaches the steady-state level predicted by equation (3.1). Once the transient disappears, the output voltage stabilizes and will remain at that level as long as the transponder is immersed in that electromagnetic field.

In practical RFID systems, because the RF voltage detected at the antenna terminals is relatively small, the voltage doubler structure shown in Figure 3.5 does not produce a high enough voltage to power the integrated circuit in the transponder. This situation can be resolved by connecting additional voltage doublers. The resulting structure is known as a *Dickson charge pump*, resulting in an output DC voltage equal to

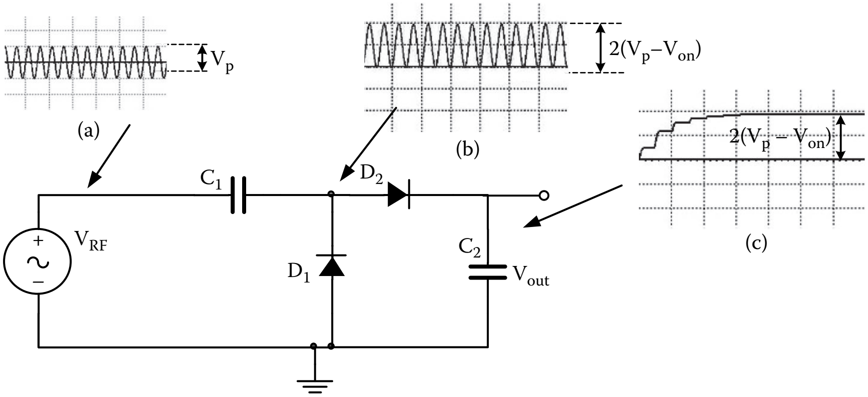

FIGURE 3.6
Signals observed at diverse points in the single-stage voltage multiplier. (a) Input signal. (b) Intermediate signal consisting of the input signal plus a DC component equal to its peak value. (c) Output signal. After the transient disappears, the output signal is a DC signal with a value equal to the double of the peak amplitude of the input signal.

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$$V_{out} = 2N(V_p - V_{ON}) \tag{3.2}$$

where N is the number of basic voltage doubler cells.

Figure 3.7 shows a three-stage Dickson charge pump. Its output voltage is equal to six times the peak voltage for the input minus the turn-on voltage for the diodes. Figure 3.8 shows the intermediate signals observed at several nodes in this structure. The sensitivity of the different graphs in volts per division has been kept the same to better observe how at each intermediate node, the AC signal has an additional offset equal to its peak value. The final DC output voltage is predicted by equation (3.2).

There is, however, a practical limit to the number of stages that is reasonable to consider for use in a practical application. As the number of stages increases, the number of required diodes increases by a factor of 2, and therefore the power dissipated by the charge pump also increases in the same ratio, decreasing the overall efficiency of the circuit. The efficiency of the charge pump is given by equation (3.3):

$$\eta_{pump} = \frac{P_{load}}{P_{load} + P_{consumed}} = \frac{V_{out}}{V_{out} + 2N\,V_{ON}} \tag{3.3}$$

where N is the number of stages in the charge pump.

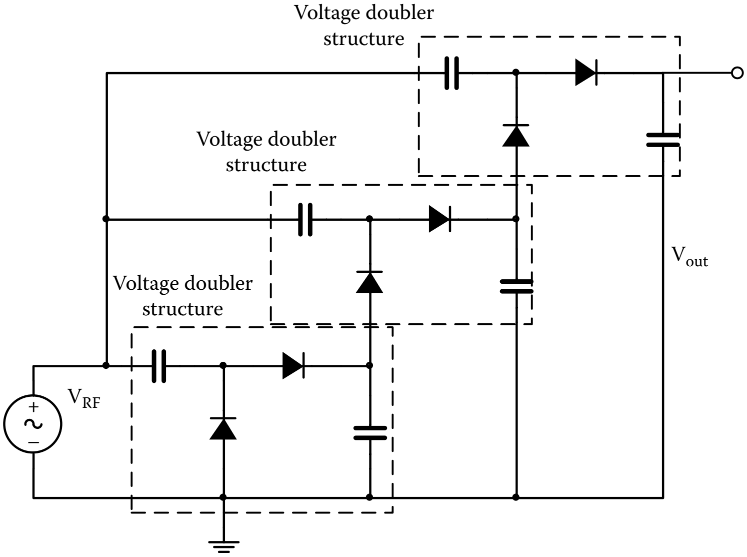
Voltage doubler structure
Voltage doubler structure
Voltage doubler structure
V_out
V_RF
+
−

FIGURE 3.7
Dickson charge pump structure used to increase the DC voltage extracted from the radiofrequency signal generated by the electromagnetic field in which the transponder is immersed.

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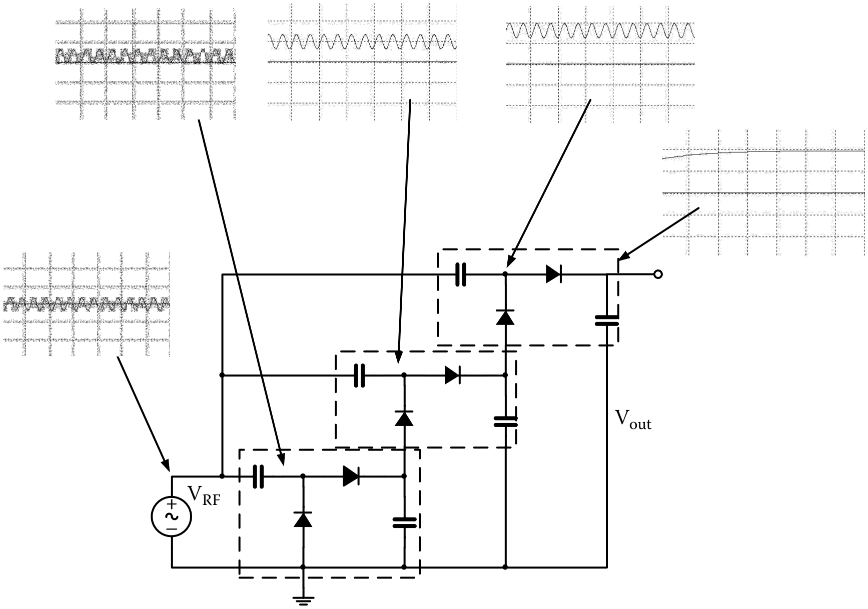

FIGURE 3.8
Signals observed at different points in the Dickson charge pump. After each stage, the overall signal increases its DC component until it only contains a DC component at the output of the last stage.

Equation (3.3) shows that the efficiency of the charge pump will increase by using diodes with a lower turn-on voltage. To this extent, several types of devices have been used and several more types are being currently investigated. The most common approach is to use Schottky diodes due to their electrical characteristics that make them extremely attractive for this purpose. However, using Schottky diodes increases the complexity of manufacturing the transponder, thus resulting in a higher cost. For this reason, the use of ultra-low-power complementary metal oxide semiconductor (CMOS) diodes appears to be an attractive alternative as they can be manufactured with the rest of the transponder and therefore they will not increase the cost of manufacturing the transponder.

3.2 Signals in the Transponder

3.2.1 Signal Encoding

The digital signals in the transponder are encoded using one or more of these common encoding schemes that are represented in Figure 3.9.

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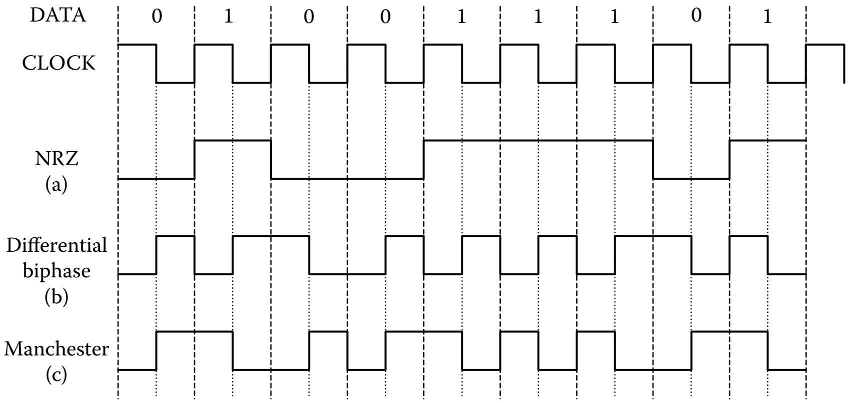

FIGURE 3.9
Common signal-encoding techniques. (a) Nonreturn-to-zero (NRZ): *1* represented by a high logic level; *0* represented by a low logic level. (b) Differential biphase: *1* represented by a change in level at the start of the clock period; *0* represented by no change in level at the start of the clock period. There is always a change of level at the middle of the clock period. (c) Manchester: *1* represented by a high-to-low transition at the middle of the clock period; *0* represented by a low-to-high transition at the middle of the clock period.

These encoding techniques are as follows:

NRZ (nonreturn to zero): There is no data encoding done. The 1's and 0's are clocked from the data array directly to the output transistor that will close or open the switch in the analog front end, as was shown in Figure 3.4. Although extremely simple, this encoding technique presents problems if the data to transmit have long strings of 1's or 0's because these may be misunderstood as the presence of a DC voltage in the line.

Differential biphase: Multiple encoding approaches using this method. This method embeds clocking information with the data and will help to synchronize the interrogator to the bit stream. In this approach, a level change occurs at the middle of every bit clock period. *1* is represented by a change in level at the start of the clock. *0* is represented by no change in level at the start of the clock.

Manchester code (biphase level, biphase_L, or split phase): This is a variation of the previous encoding method. There is not always a transition at the clock edge, but there is always a transition in the middle of the clock cycle, thus allowing one to extract the clock signal from the data signal. In Manchester code, a *1* is represented by a high to low level change in the middle of the clock. A *0* is represented by a low to high level change at the start of the clock. This type of encoding is used in the MCRF355/360 and the MCRF45X family of transponders manufactured by Microchip Technology.

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Example 3.2:

Assume that we are using a biphase-L format (Manchester) for encoding the digital data at a frequency of 70 kHz. The data bit *0* is sent by first detuning (cloaking) the device during 7 μs and then tuning (uncloaking) the device for an additional 7 μs. The data bit *1* is sent by uncloaking the device and then cloaking it for the same time periods.

3.2.2 Modulation and Demodulation

Modulation refers to changing one or more parameters in the carrier radiofrequency signal as a method to transmit the encoded signal. In practice, only one of the parameters (amplitude, frequency, or phase) of the radiofrequency is usually changed when transmitting simple digital data.

When the amplitude of the carrier changes depending on the encoded signal, the resulting modulated signal is called *amplitude shift keying*, or ASK. In this case, a high voltage in the envelope of the radiofrequency signal signifies a logic level *1*, while a low voltage in the envelope signifies a logic level *0*, following the appropriate signal-encoding method being used. ASK modulation is also known as *direct modulation* in RFID systems. ASK modulation offers the possibility of high data rates due to the simplicity of the process. The spectrum of the ASK signal is relatively narrow as it contains only energy at the frequency of the carrier signal and at each of the two sidebands. One sideband is located at the frequency of the carrier minus the frequency of the modulating signal, and the other sideband is located at the frequency of the carrier plus the frequency of the modulating signal. The bandwidth efficiency of a binary-modulated ASK signal is 1 bit/second/Hz. The detection of the ASK signal can be done using a coherent detector or a noncoherent detector. Noncoherent detection increases the simplicity of the overall system, although it reduces the ability to differentiate between the desired signal and noise. The immunity to noise can be increased by using a coherent detector, although the immunity to noise is overall lower than using an FSK or PSK modulation process. The bit error probability for noncoherent ASK modulation, assuming an additive white Gaussian noise limited channel, is

$$P|_{\substack{ASK \\ NONCOH}} = 0.5e^{\frac{-E_b}{4N_0}} + 0.5erfc\left(\sqrt{E_b/2N_0}\right) \tag{3.4}$$

where

P = the bit error probability

E_b/N_0 = the average bit power

$erfc(x)$ = the complementary error function for the argument x

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Similarly, the bit error probability for coherent ASK modulation is

$$P\Big|_{\substack{ASK\\COH}} = 0.5 erfc\left(\sqrt{E_b / 2N_0}\right) \tag{3.5}$$

Figure 3.10 shows the bit error probability values obtained using equations (3.4) and (3.5) for different values of energy transmitted. From this graph it is possible to observe the decrease in bit error rates for coherent ASK modulation, which is especially significant when increasing the energy per bit transmitted.

When the encoding signal changes the amplitude of the carrier being transmitted, the resulting modulated signal is called *frequency shift keying*, or FSK. When the modulating signal is binary, FSK results in using two different frequencies for transmitting the digital data. The most common approach to FSK in RFID systems is called Fc/8/10: this means that a *0* is transmitted as an amplitude modulated clock cycle with a period corresponding to the carrier frequency divided by 8, and a *1* uses a period that corresponds to the carrier frequency divided by 10. Figure 3.11 shows the time representation for this FSK modulation.

The logic level *0* is transmitted by sending a total of eight cycles of the RF signal; the first four cycles have a higher amplitude than the last four cycles. The logic level *1* is transmitted by sending a total of ten RF cycles,

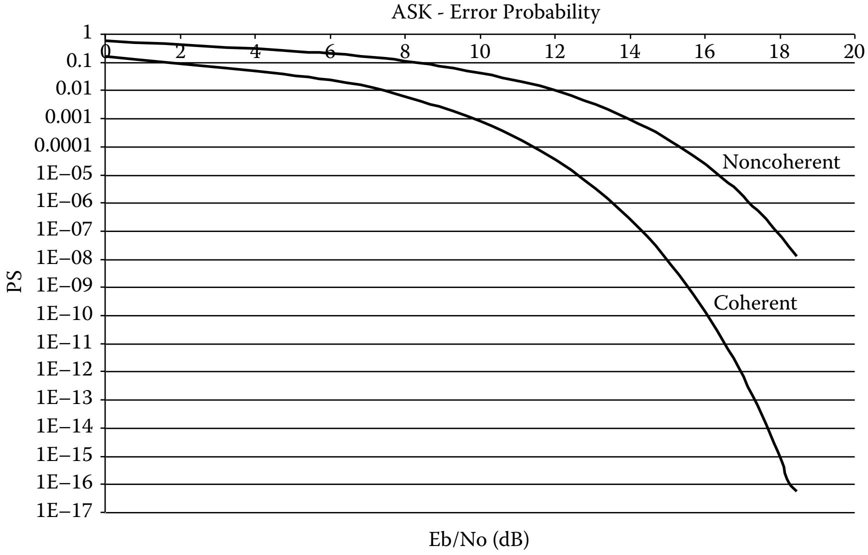

FIGURE 3.10
Error probability (Ps) for coherent and noncoherent ASK modulation as a function of the energy received (Eb/No).

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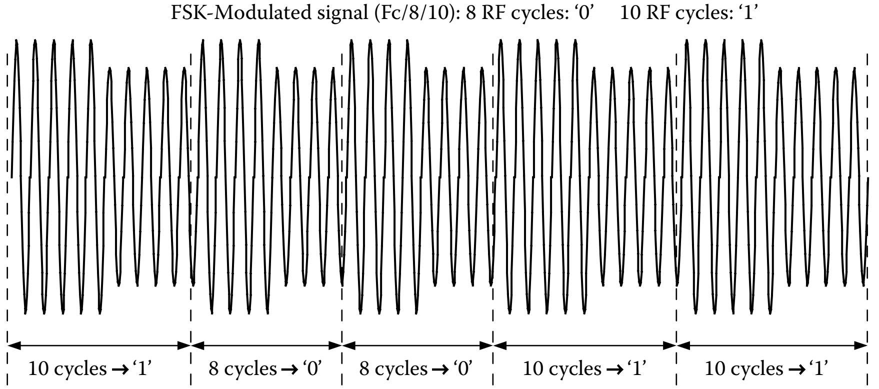

FIGURE 3.11
Structure of the FSK-modulated signal. The symbol *1* is represented by sending 10 RF cycles, while the symbol *0* is represented by sending 8 RF cycles. The message sent in the figure is *10011*.

with the first five cycles having a higher amplitude than the last five cycles. The change in amplitude between the first and second halves of the cycles allows one to count the number of cycles between transitions and therefore to differentiate between logic levels. In other words, the *1* and *0* are differentiated by looking at the number of periods between transitions.

Other FSK approaches used by other transponders are Fc/10/8, Fc/5/8, and Fc/8/5. Table 3.1 lists the relation between the encoding signal and the data transmitted.

The bandwidth required by the FSK signal is dependent on the existence or not of phase changes when changing frequencies. Obviously, in those FSK modulation approaches that exhibit abrupt phase changes, there will be more spectral components at higher frequencies, thus increasing the bandwidth. The bandwidth efficiency of a binary-modulated FSK signal depends on how the modulation process has been performed, but it approaches 2 bits/second/Hz. Similarly to ASK modulation, FSK signals can be recovered using noncoherent detectors or coherent detectors, with a coherent detector providing stronger noise immunity. The calculation of the bit error rate for FSK signals depends on the separation between the frequencies used to transmit the FSK signal. The optimal frequency selection occurs when these frequencies are a multiple of the frequency of the encoding signal. These are called *orthogonal frequencies*.

The bit error probability for noncoherent FSK modulation, assuming an additive white Gaussian noise limited channel, is

$$P\,\Big|_{\substack{FSK\\NONCOH}} = 0.5e^{\frac{-E_b}{2N_0}} \tag{3.6}$$

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TABLE 3.1

Different FSK Modulation Approaches

	Logic Level "0"	Logic Level "1"
Fc/8/10	8 RF cycles	10 RF cycles
Fc/10/8	10 RF cycles	8 RF cycles
Fc/5/8	5 RF cycles	8 RF cycles
Fc/8/5	8 RF cycles	5 RF cycles

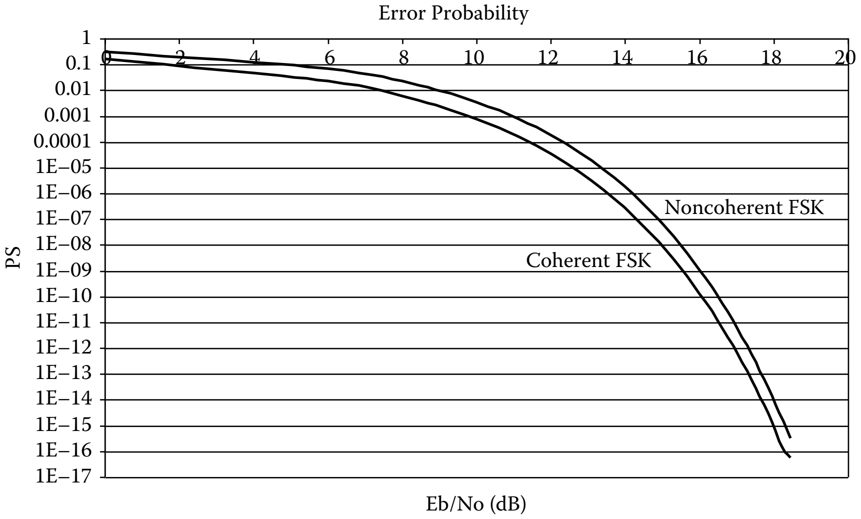

FIGURE 3.12
Error probability (Ps) for noncoherent FSK and coherent FSK as a function of the energy received (Eb/No).

The bit error probability for coherent FSK modulation is

$$P|_{\substack{FSK \\ COH}} = 0.5erfc\left(\sqrt{E_b / 2N_0}\right) \tag{3.7}$$

Comparing equations (3.5) and (3.7) shows that if the two frequencies that make the FSK signal are chosen to be orthogonal, then the bit error rates for coherent ASK and coherent FSK signals are essentially the same. Figure 3.12 shows the probability of bit error as predicted by equations (3.3) and (3.4) for different values of energy per bit. This figure shows that the difference in performance between noncoherent detection and coherent detection for FSK signals is lower than for ASK signals. This has resulted in the widespread use of noncoherent FSK modulation due to its simplicity.

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Example 3.3:

Calculate the bit error rate for coherent and noncoherent ASK and FSK demodulation for the following signal-to-noise ratios (E_b/N_o): (a) 5 dB, (b) 10 dB, and (c) 15 dB.

Solution:

The bit error rates for each type of demodulation are given by equations (3.4) to (3.7). The first step is to express the signal-to-noise ratio in linear units. This results in the following values:

A. $E_b/N_o = 5$ dB ➔ $E_b/N_o = 3.16$ (linear units)
B. $E_b/N_o = 10$ dB ➔ $E_b/N_o = 10.0$ (linear units)
C. $E_b/N_o = 15$ dB ➔ $E_b/N_o = 31.6$ (linear units)

Bit error rates for noncoherent ASK demodulation are predicted by equation (3.4), resulting in the following:

With $E_b/N_o = 3.16$ (5 dB): $P_s = 0.264$ (approximately 1 error every 4 bits transmitted)
With $E_b/N_o = 10.0$ (10 dB): $P_s = 0.042$ (approximately 1 error every 24 bits transmitted)
With $E_b/N_o = 31.6$ (15 dB): $P_s = 0.185\ 10^{-3}$ (approximately 1 error every 5400 bits transmitted)

Bit error rates for coherent ASK demodulation are predicted by equation (3.5), resulting in the following:

With $E_b/N_o = 3.16$ (5 dB): $P_s = 0.037$ (approximately 1 error every 30 bits transmitted)
With $E_b/N_o = 10.0$ (10 dB): $P_s = 0.78\ 10^{-3}$ (approximately 1 error every 1300 bits transmitted)
With $E_b/N_o = 31.6$ (15 dB): $P_s = 9.47\ 10^{-9}$ (approximately 1 error every 100 million bits transmitted)

Bit error rates for noncoherent FSK demodulation are predicted by equation (3.6), resulting in the following:

With $E_b/N_o = 3.16$ (5 dB): $P_s = 0.103$ (approximately 1 error every 10 bits transmitted)
With $E_b/N_o = 10.0$ (10 dB): $P_s = 3.37\ 10^{-3}$ (approximately 1 error every 300 bits transmitted)
With $E_b/N_o = 31.6$ (15 dB): $P_s = 6.87\ 10^{-8}$ (approximately 1 error every 14.5 million bits transmitted)

Bit error rates for coherent FSK demodulation are predicted by equation (3.7), resulting in the following:

With $E_b/N_o = 3.16$ (5 dB): $P_s = 0.037$ (approximately 1 error every 30 bits transmitted)
With $E_b/N_o = 10.0$ (10 dB): $P_s = 0.78\ 10^{-3}$ (approximately 1 error every 1300 bits transmitted)
With $E_b/N_o = 31.6$ (15 dB): $P_s = 9.47\ 10^{-9}$ (approximately 1 error every 100 million bits transmitted)

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> These results show that the performance of coherent demodulation has a much better performance than noncoherent demodulation. Even for relatively noisy signals, coherent ASK shows a much lower bit error rate than when the demodulation is performed noncoherently. Therefore, it seems obvious to choose a coherent demodulation scheme when using ASK. While coherent FSK demodulation also shows a lower bit error rate than noncoherent FSK demodulation, the difference is not as strong as in the ASK case. For this reason, a noncoherent FSK demodulation may be preferred as it will reduce the complexity of the system without excessively degrading its performance.

When the encoding signal changes the phase of the carrier, the resulting modulated signal is called *phase shift keying* (PSK), as shown in Figure 3.13. PSK is basically the same approach as FSK with the difference being that only one frequency is used. The information is encoded here in the change of phase between clock cycles. PSK also allows for different approaches on this encoding. Because the receiver is only looking for changes of phase, it is possible to transmit information in a smaller number of radiofrequency cycles, resulting in using faster data transfer rates compared to FSK.

Some devices like the MCRF200 and the MCRF250, both from Microchip Technology, support two PSK modulation modes called PSK_1 and PSK_2. In PSK_1, the phase of the RF signal changes when the encoding data change. This means that, for example, the phase of the RF signal will change when the encoding signal changes from *1* to *0* or from *0* to *1*. In

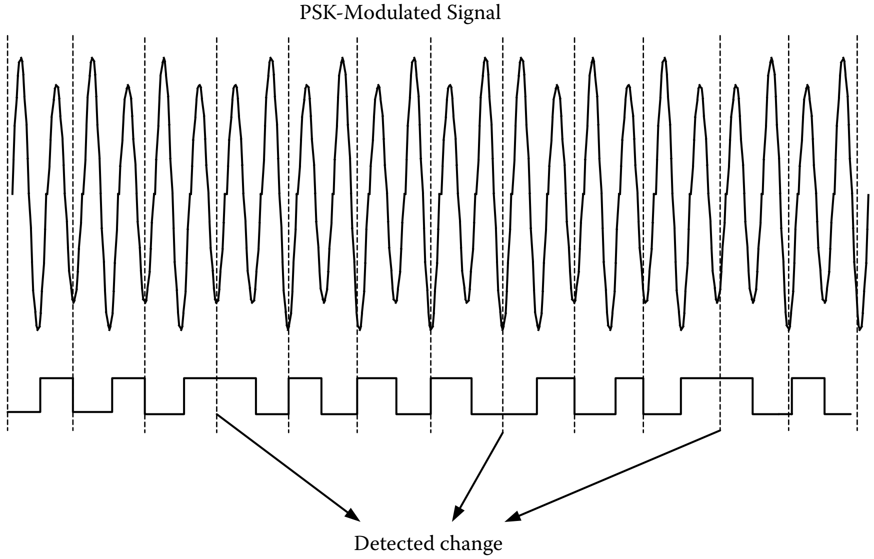

FIGURE 3.13
A generic PSK-modulated signal. The figure shows that the PSK signal requires less RF cycles to transmit the digital data.

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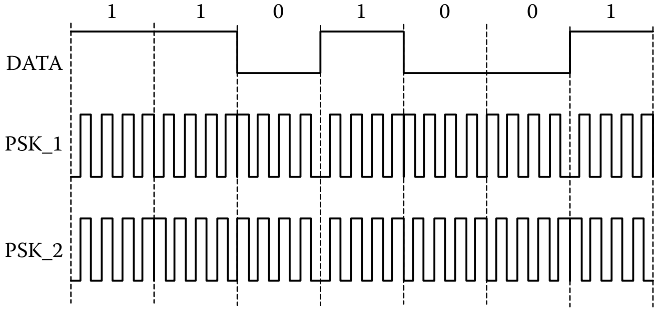

FIGURE 3.14
Two variations of PSK modulation. In PSK_1, the phase of the carrier changes every time there is a change in the symbol transmitted. In PSK_2, the phase of the carrier changes every time the symbol transmitted is *1*.

PSK_2, the phase of the RF signal changes every time the encoding data have the logic level *1*. For example, the phase will change when the encoding data change from *0* to *1* or from *1* to *1*, but it will not change when the encoding data move from *1* to *0* or from *0* to *0*. Figure 3.14 depicts these two PSK modulation approaches.

A third PSK modulation mode available in some other devices—for example, the T5557 from Atmel®—is based on a phase change on the rising edge of the encoding signal.

The spectral occupancy of the PSK signal is identical to the ASK signal assuming that there are no phase changes abruptly occurring at the symbol boundaries. However, in contrast to ASK and FSK, the detection of PSK signals requires a coherent demodulator. The bit error rate for PSK signals is

$$P\big|_{\substack{PSK\\COH}} = 0.5\,erfc\left(\sqrt{E_b / N_0}\right) \tag{3.8}$$

When comparing the different modulation methods and assuming equal average energy per symbol transmitted, the different PSK modulation approaches present the strongest immunity against noise. Coherent FSK modulation with orthogonal symbols or coherent ASK modulation is the next best approach followed by the noncoherent FSK modulation. Noncoherent ASK modulation exhibits the poorest performance. For example, a bit error rate of 10^{-6} requires a value of Eb/No slightly above 10 dB for a PSK signal, but it will require a value of Eb/No of about 18 dB for a noncoherent ASK signal. Similarly, an energy Eb/No of 10 dB will result in a bit error rate of 1.5 10^{-5} in using PSK, but the bit error rate will increase up to 1.5 10^{-2} when using noncoherent ASK. This represents moving from 1.5 errors every 100,000 bits transmitted (PSK) to 1.5 errors every 100 bits transmitted (noncoherent ASK).

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3.3 The Logic System

3.3.1 Data Memory

The memory of RFID transponders is divided into data memory and configuration memory. Data memory stores the information that will be transmitted back to the interrogator. Configuration memory stores data regarding the configuration parameters for the transponder. Memory varies in size, rewriting capabilities, structure, and characteristics similar to those found in memory used in other products. The size of the memory ranges from 1 bit to 64 kbits or even larger, with the most common values being around a few hundred bits. One of the most important differences between transponders is whether the data stored in their memory can be rewritten by the user. This gives rise to the distinction between *read-only* transponders and *read/write* transponders. Because memory types, sizes, and structures can greatly differ between different transponders, the following examples are not intended to be viewed as a comprehensive guide, but to highlight some of the most commonly used approaches to memory in transponders.

The device MCRF200 from Microchip Technology contains a memory of 140 bits; 128 bits are data bits, and the remaining 12 bits are used for the configuration register. This is a one-time programmable (OTP) device that operates as a read-only device once it is programmed. The data memory can be programmed by the user using a contactless programmer or can be directly programmed by the factory at the time of production. The configuration register can only be programmed at the time of production. The manufacturer specifies memory data retention better than 200 years.

Figure 3.15 shows the block diagram of this device. The EEPROM memory is addressed by the column and row decoders at the clock rate. The output from the memory array is a bit stream that is directly fed into the modulation control and modulation circuit in order to be transmitted back to the interrogator. Figure 3.16 shows the description of the different bits for the configuration register in this memory.

CB12 is the bit that allows programming the device. Once CB12 is set to 1, the device cannot be programmed or erased. Because the MCRF200 does not support anticollision, bit CB11 is always 0. However, for the device MCRF250 that is similar to the MCRF200 with the only exception that MCRF250 supports anticollision, its bit CB11 is always set to 1. CB10 is used to establish the transmission rate when PSK modulation has been selected. Bits CB9 and CB8 establish the modulation for the encoded data using the modulation types shown in Section 3.2.2. Bits CB7 and CB6 determine how the data are encoded, as described in Section 3.2.1. Bit CB5 is always set to 0. Bits CB4, CB3, and CB2 are used to set the baud rate at which data are transferred. The default timing (CB4 = CB3 = CB2 = 0) is MOD128, meaning that the transmission rate is set at 128 RF cycles for bit.

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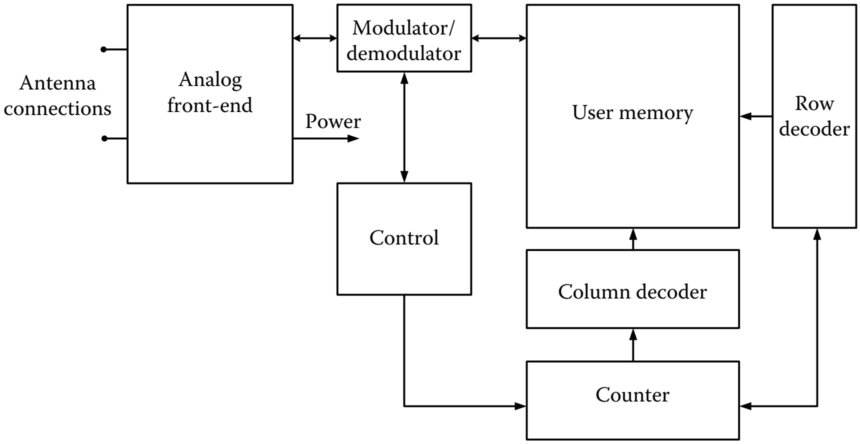

FIGURE 3.15
Structure of the circuitry for memory reading, writing, and control.

Because the MCRF250/251 device operates in the LF range, assuming a carrier frequency of 128 kHz, this setting will result in a transmission rate of 1 kHz. Conversely, the fastest transmission rate is MOD16, which will result in a transmission rate of 8 kHz. It is also important to keep in mind that MOD128 is the data rate used when programming the device. Finally, CB1 is used to specify the size of the data memory of 128 bits or 96 bits depending upon the needs of the user.

Example 3.4:

The configuration register for a MCRF 200 device is set to $08D. Describe the settings for the device.

Solution:

The binary values for the configuration register are shown as follows:

CB12	CB11	CB10	CB9	CB8	CB7	CB6	CB5	CB4	CB3	CB2	CB1
0	0	0	0	1	0	0	0	1	1	0	1

CB12 = 0. The device has not been programmed yet.
CB11 = 0. MCRF200 does not support anticollision; therefore, CB11 is set to 0.
CB10 = 0. Rate of PSK modulation is equal to half of the carrier frequency.
CB9 = 0 and CB8 = 1. The modulation chosen is PSK_1. This means that the phase of the modulation signal changes at the change of the encoded data.
CB7 = CB6 = 0. Data encoded using nonreturn to zero level (NRZ_L).
CB5 = 0. No special meaning because CB5 is always set to 0.
CB4 = 1; CB3 = 1; CB2 = 0. Baud rate is MOD32, resulting in a 4 kHz baud rate.
CB1 = 0. Memory size is 128 bits.

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Example 3.5:

State the configuration register for a transponder based on the MCRF250 device with the following parameters:

Blank (not programmed device)
Modulation: PSK_1.
PSK rate: Frequency half of the carrier frequency
Data encoding: NRZ_L
Baud rate: MOD 32
Memory size: 128 bits

Solution:

The MCRF250 is a device similar to the MCRF200, with the only difference being that it supports anticollision. Therefore, the configuration bit CB11 will be set to 1. The rest of the configuration bits have the same meaning as the MCRF200. The values of the configuration bits in this case are as follows:

CB12	CB11	CB10	CB9	CB8	CB7	CB6	CB5	CB4	CB3	CB2	CB1
0	1	0	0	1	0	0	0	1	1	0	1

Therefore, the hexadecimal value stored in the configuration register is $48D.

The devices MCRF355 and MCRF360, also manufactured by Microchip Technology, operate at the HF frequency of 13.56 MHz. They both have a total of 154 bits of memory that must be programmed using a contact programmer. This makes them act as read-only devices when they are used in the field but gives them the flexibility to be reprogrammed by the user when necessary. The data retention specified by the manufacturer is also better than 200 years.

The family of devices MCRF450/451/452/455 also operates in the HF frequency range at 13.56 MHz. As was discussed in Chapter 2, the different devices in this family use internal or external capacitors to modulate the radiofrequency signal. In discussing their internal memory structure, the concepts described for the device MCRF450 are also valid for the rest of the devices in this family. All of these devices have their memory organized in two areas: main memory and stored cyclic redundancy check (SCRC) memory. SCRC memory is used in the operation of the cyclic redundancy code necessary for the operation of the anticollision algorithm, as all of these devices support anticollision. The explanation of the CRC procedure is shown in Section 3.3.2.

The main memory of the MCRF450 and similar devices contains a total of 1024 bits and is structured in 32 blocks, each one with 32 bits. The SCRC memory is organized in 32 blocks, each one with 16 bits. Figure 3.17 shows the structure of the user memory in these devices.

The first three blocks (B0–B2) of the main memory are used to set up the operation of the device in a manner similar to a configuration register, while the remaining 29 blocks (B3–B31) are for user data. All the blocks of the main

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	BYTE 3								BYTE 2								BYTE 1								BYTE 0							
	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Block 0	FR	TF	TFT		DF		MT		TM			Available touser																				
Block 1									32-bit unique identification code for transponder																							
Block 2								Bits for write-protect mode. Each bit write-protects one block																								
Block 3									Data Fields for Fast Read Response (LS Block)																							
Block 4									Data Fields for Fast Read Response																							
Block 5									Data Fields for Fast Read Response (MS Block)																							
Block 6	DATA																															
Block 7	DATA																															
...	...																															
Block 31	DATA																															

FIGURE 3.17
Structure of the user memory for the MCRF 450 family of transponders.

memory with the exception of Block 1, which contains the ID or serial number of the transponder, can be individually rewritten block by block by a contactless programmer. Block 1 is programmed at the factory and is protected against being rewritten. The main memory is read or written in blocks of 32 bits, with the exception of bits 30 and 31 in Block 0 that can be selected individually. Blocks 3 to 5 constitute the fast read field (FRF) that is used by the interrogator in the transmission of commands to the transponder.

Block 0 is split into 21 bits of general memory available to the user and 11 bits containing operational parameters for the transponder. These operational bits, shown in Figure 3.17, are as follows:

FR (Bit 31). When FR = 0, the transponder will respond to the *fast read bypass* (FRB) command but will not respond to the *fast read request* (FRR) command from the interrogator. When FR = 1, the previous situation is reversed. These interrogator commands are further explained and described in Chapter 6.

TF (Bit 30). TF = 0 sets the transponder in *interrogator talks first* (ITF) mode. This means that it will wait for an FRR command. TF = 1 sets the transponder in *tag talks first* (TTF) mode if FR = 1. In this case, the transponder will send a *fast read response* without waiting for an FRR.

TFT (Bits 29–28). These two bits set the value for the parameter TCMAX when the transponder is in TTF mode. TCMAX is the number of

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TABLE 3.2

Configurations for TFT Bits

Bit 29	Bit 28	TCMAX
0	0	1
0	1	2
1	0	4
1	1	Continuous

TABLE 3.3

Configuration for DF Bits

Bit 27	Bit 26	TCMAX
0	0	32 Bits
0	1	48 Bits
1	0	64 Bits
1	1	96 Bits

fast read responses that the transponder can send after an FRR command, as shown in Table 3.2. For example, TCMAX = 2 means that the transponder can send its response twice for acknowledgment. If TCMAX is set to continuous mode, the transponder will send its response approximately every 80 ms until it receives the correct response from the interrogator. This is the default mode.

DF (Bits 27–26). These two bits set the length of the data transmitted by the transponder according to Table 3.3. The default data length is 32 bits.

MT (Bits 25–24). These two bits are hardwired and cannot be changed by the user. At the current state of production, these two bits are both set to 0. The remaining values are reserved for future applications.

TM (Bits 23–22–21). These three bits set up the total memory size. These three bits are also hardwired. Currently, there are only two possibilities allowed: 000 and 001. The code *000* describes a transponder with 512 bits of memory, while the code *001* describes a transponder with a memory size of 1 kbit.

Block 1 contains a unique 32-bit identification number for the transponder. This identification word is serialized by the manufacturer.

Block 2 contains the bits that set each block in write-protect mode. Each bit corresponds to its 32-bit block. For example, bit 5 will set Block 5 as writable or write-protected. When the write-protect bit is set to 1, the block is writable; when the bit is set to 0, the block is write-protected. It is important to note that once a block is write-protected, it cannot be changed back to being

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writable. The transponders are shipped to the user with all the write-protect bits to 1 with the exception of bit 1. This means that Block 1, which contains the unique ID for the transponder, cannot be changed by the user. Bits 31 and 30 in Block 0 (bits FR and TF) are not write-protectable, thus allowing the user to change how the transponder is operating. Finally, it is also important to note that Block 2 can also be set to be write-protected.

Blocks 3 to 5 contain data bits for the fast response. The size of the fast response was set by bits 27 and 26 (bits DF) in Block 0.

The SCRC memory section is organized into 32 blocks, each one with 16 bits as shown in Figure 3.18. The blocks contain the CRC code for the corresponding memory block sent back to the interrogator in order to check for anticollision.

One of the family of transponders operating at 13.56 MHz manufactured by Atmel® has an internal user memory ranging from 1 kbit to 64 kbits with the distinct feature that this memory is encrypted, thus providing an additional layer of protection. The *CryptoRF EEPROM* family offers user memory of 1 kbit, 2 kbits, 4 kbits, 8 kbits, 16 kbits, 32 kbits, and 64 kbits. In addition to the user memory, all these devices have a configuration memory of 2 kbits. This configuration memory is used to store eight sets of passwords for reading and writing, four crypto key sets, security access registers for each user zone and password, and key registers for each zone. The transponders in this family also support anticollision. Figure 3.19 shows the block diagram for these types of devices. As shown in the figure, while the analog front end is similar to that of any transponder, it differs in the existence of authentication and password verification prior to the device sending data.

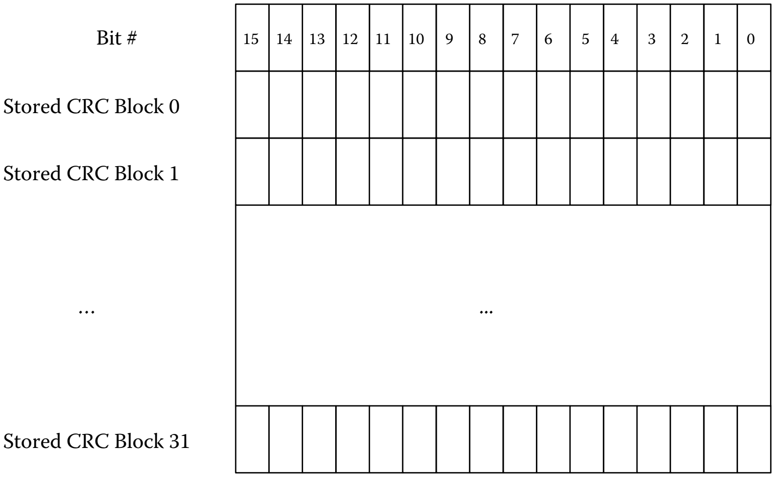

FIGURE 3.18
Structure of the stored CRC memory used in the MCRF 450 family of transponders.

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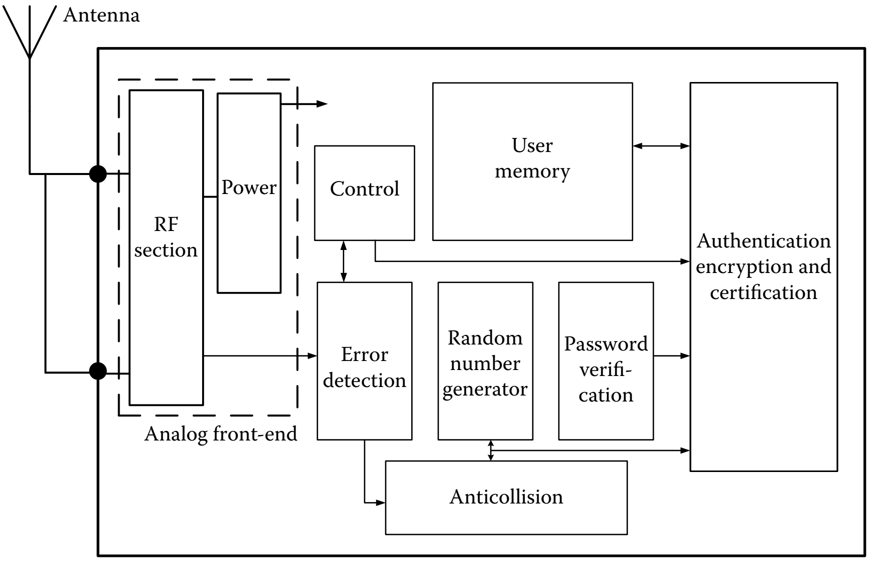
Antenna
Power
Control
User memory
RF section
Authentication encryption and certification
Error detection
Random number generator
Password verifi-cation
Analog front-end
Anticollision

FIGURE 3.19
Transponder with encrypted memory showing the additional components needed for this process.

In the transponders with user memory size of 64 kbits, 32 kbits, or 16 kbits, the EEPROM user memory is divided into 16 user zones. Figure 3.20 shows the memory map for the 64 kbit memory transponder. As seen in the figure, each user zone is configured for storing 512 bytes (4096 bits), giving a total user memory of 64 kbits. For the 32 kbit transponder, its memory is also divided into 16 user zones, each one of 256 bytes (2048 bits); for the 16 kbit memory, the size of each user zone is 128 bytes (1024 bits).

The transponder from the same family with a memory of 8 kbits has a similar structure, although the memory is divided into eight different user zones. Each zone can store 128 bytes (1024 bits). The memory for the transponders with 4 kbits, 2 kbits, and 1 kbit of user memory are all divided into four user zones. For the 4 kbit memory, each user zone stores 128 bytes (1024 bits); for the 2 kbit memory, each user zone stores 64 bytes (512 bits); and for the 1 kbit memory, each user zones stores 32 bytes (256 bits).

In all cases, the access to the user zones is only possible after having some security requirements are met. These are defined by the user during the setup of the device. The initial state for the transponders in this family is to have all the security features disabled. The user must set up the level of protection by configuring the security requirements for the transponder. These security requirements are stored in the configuration memory.

All the transponders in the CryptoRF family have a configuration memory of 2048 bits. This memory stores passwords, keys, codes, and security

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	Address	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
User Zone 0	0								
	1								
	...	Total of 512 bytes (4096 bits) in Zone 0							
	512								
User Zone 1	0								
	1								
	...	Total of 512 bytes (4096 bits) in Zone 1							
	512								
User Zones 2 to 14	...								
User Zone 15	0								
	1								
	...	Total of 512 bytes (4096 bits) in Zone 15							
	512								

FIGURE 3.20
Memory map divided into 16 user zones, each one containing 4096 bits for a total of 65,536 bits (64 kbits).

definitions for each one of the user zones. The access rights to the configuration memory are defined in the control logic and cannot be altered by the user. The transponder can be programmed so each zone uses a different set of passwords. This is especially useful in the case of different users accessing the transponder. In addition, the transponders include three fuses that must be blown during the setup process. The fuses lock some of the portions of the configuration memory.

Atmel® also manufactures families of transponders that operate in the LF range, as well as in the UHF range. For example, the transponder ATA5558 can operate between 100 kHz and 200 kHz, while the ATA5590 operates in the UHF range from 860 MHz to 960 MHz. Both devices contain an internal EEPROM divided into a user memory of 1024 bits and a system memory of 320 bits. The user memory is organized in pages of 128 bits, and each page in blocks of 32 bits. Each one of the blocks must be programmed separately. Pages are protected against overwriting by the use of a lock bit that, as shown in Figure 3.21, is the most significant bit of each block.

The system memory in the ATA5590 transponder contains a page with the identification information for the transponder (Tag_ID page), a page with system-level information available to the user, and two blocks with system-level information for the manufacturer of the transponder.

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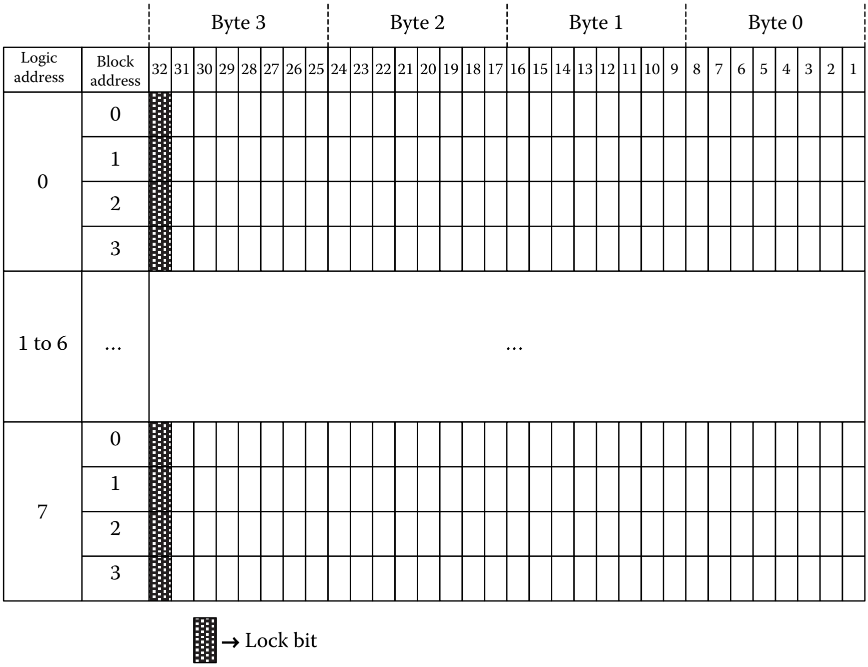

FIGURE 3.21
Memory map with lock bit. The lock bit is located at the MSB in each address.

3.3.2 Cyclic Redundancy Check for Error Detection

The cyclic redundancy check is the most used method for ensuring the integrity of the digital signals in some RFID transponders. In particular, CRC is used as a method of error detection in the digital stream transmitted and received by the transponders that support CRC. It is important to note that although the CRC algorithms detect the existence of errors, they do not make corrections.

The CRC method is based on appending additional information to the message being transmitted. This additional information is mathematically related to the message and therefore is redundant. At the receiving end, the receiver checks this additional information to verify that it agrees with the message being transmitted. This allows the receiver to determine with a certain degree of probability the existence of an error in the transmission. However, this method implies that not all errors are subject to detection. Simply stated, the CRC method is implemented by dividing the entire numeric binary value of the message by a constant. This constant is called a *generator polynomial*. The reminder in the division is then appended to the message. The polynomial that is used for the division is chosen from a family of polynomials with certain mathematic properties whose study is beyond the scope of this book. The transponders from Atmel and Microchip both use a polynomial known as the CRC-CCITT-16, although their specific

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implementation is somewhat different. This polynomial is also used in other digital transmissions such as CDMA and Bluetooth, among others. The CRC-CCITT-16 polynomial is

$$CRC-CCITT-16: x^{16}+x^{12}+x^{5}+x^{0}$$

Reading the polynomial from most significant bit (MSB) to least significant bit (LSB) (normal representation) results in a value of 1021 hexadecimals. We must take into consideration that CRC polynomials have always had their MSB equal to 1, and for this reason it is not considered in the calculation of their values. Reading the polynomial from LSB to MSB (reverse representation) results in the value of 8048 hexadecimals. Microchip Technology uses reverse representation, while Atmel® uses normal representation.

CRC can be hardware-implemented using shift registers and exclusive-OR (XOR) gates in the feedback process shown in Figure 3.22. The encoder shown in Figure 3.22 consists of 16 shift registers and the exclusive-OR gates. The initial value loaded into the shift registers is $FFF in the Microchip Technology approach and $000 for the Atmel approach. The encoder performs the exclusive-OR function and shifts the registers until the last bit of the data stream is entered. At that point, the CRC value of the data set is equal to the values in the shift registers. When the transponder transmits data, the calculated CRC value is attached to the data.

The receiver performs an identical process and verifies that the CRC code generated by the receiver is equal to the CRC code appended to the message. The advantage of the CRC method is that the current state of one of the shift registers is a result of considerable past history, as it has to go through a lengthy process. Therefore, it is unlikely that a burst of errors will produce a CRC code equal to the one generated in the absence of errors. In fact, the CRC-CCIT-16 code is able to detect all error bursts of 16 bits or less as well as 99.9% of error bursts of more than 16 bits.

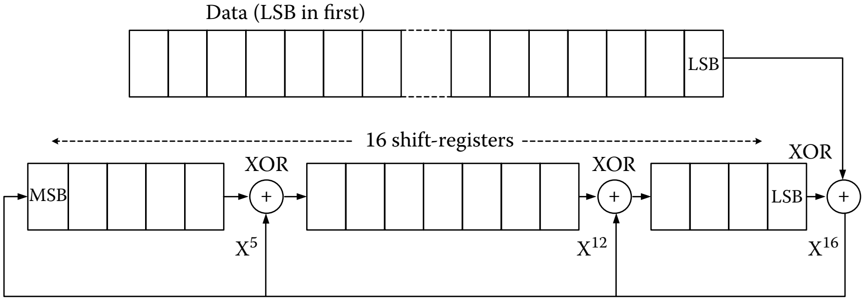

FIGURE 3.22
Structure of a generic CRC encoder using the CRC-CCITT-16 polynomial.

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Different manufacturers may also follow different approaches as to whether they append the CRC value with its LSB or MSB first. The specification documents for the transponders describe how the CRC value is attached to the data. The previous section described the structure of memory in some specific transponders. For example, the user memory for the MCRF450 family of transponders from Microchip Technology is divided into 32 blocks. When the interrogator tries to write data into any of these blocks, before doing any processing, the transponders check the CRC. If the CRC data are correct, the transponder proceeds with storing the data and the CRC in memory. Then, the transponder immediately transmits back the data and stored CRC to the interrogator for verification. If the CRC received by the transponder is incorrect, the transponder ignores the received message and waits for the next command with a valid CRC.

3.4 Transponder Programming

The programming of the transponders can be done by the manufacturer at the time of production or by the end user. *Programming the transponders* means to store a unique identification number in its memory, as well as to set up the configuration parameters for the communication between the transponder and the interrogator and additional parameters such as password protection. Transponders can be programmed using contact or noncontact methods.

The MCRF200/250 family of transponders manufactured by Microchip Technology is an example of a contactless programmable device. Because the MCRF200/250 family is made up of one-time programmable devices, the device can only be programmed when it is blank from the manufacturing process. Programming this device requires a specific sequence of radiofrequency signals applied following this sequence:

Initial, power-up RF signal (125 kHz for the MCRF200/250 family) lasting between 80 μs and 180 μs.

Absence of RF field lasting between 50 μs and 100 μs.

A continuous FSK signal that serves as a *verify* signal, lasting 131 ms. This signal is required for the transponder to be energized in order to output all the data contained in its 128 bits of memory. Because the device is blank at the time of programming, the output data are all *1*.

Programming data: After completing the verify mode, the device enters the programming mode. The device is programmed starting with bit 1 and finishing with bit 128. The symbol *1* is programmed by sending a low-power RF signal with an amplitude similar to the one used for the initial power-up. The symbol *0* is programmed by sending a high-power RF signal with an amplitude approximately equal to 2.2 times the amplitude used for the symbol *1*.

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Device response: After the 128 bits have been programmed, the device responds by transmitting the programmed data.

The MCRF355/360 family of transponders, also from Microchip Technology, has 154 bits of memory that can be programmed by using a contact programmer. Also, the memory in this family of devices can be reprogrammed. Figure 3.23 shows the pin diagram for this device.

Note that Pin 3 (Ant. A) and Pin 6 (Ant. B) are used to connect the external capacitors and inductors, as was shown in Figures 2.16 and 2.17, while Pin 5 (Vss) serves a ground. In order to program these devices, Pins 3, 6, and 5 are connected to ground, Pin 8 (Vdd) is connected to the positive voltage source, Pin 2 (CLK) is connected to the clock, and Pin 1 (Vprg) is connected to the signal that will be programmed in the transponder.

Some specific codes are used to carry out specific functions in the memory of the device. For example, because this device is reprogrammable, when the user wants to write new data into memory, the existing data must be erased first. This is done by sending the code 0111010100 through the VPRG pin, as shown in Figure 3.24.

Similarly, to start the programming sequence, the user must transmit the code 0111010010, followed by the data bits to store in memory. In total, there will be a total of 166 bits sent to the device: the first 12 bits are the command to program, and the remaining 154 bits are the data to be stored in memory. Finally, the data stored in memory can be read by transmitting the code 0111010110 to the device. After this code has been transmitted, the device will output the data stored in its memory.

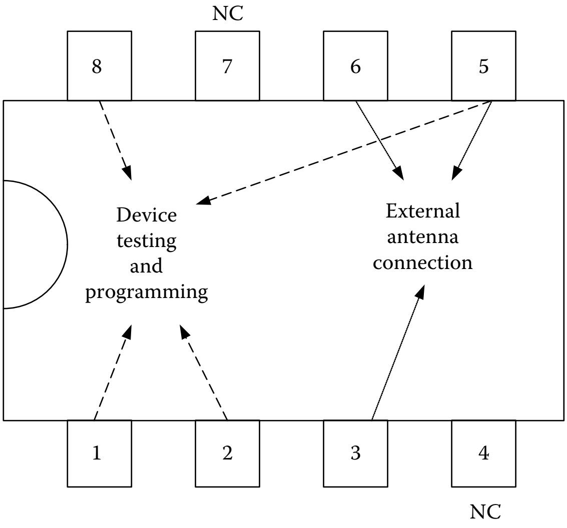

Pin	Function
1	VPRG
2	CLK
3	Antenna A
4	NC
5	V_{ss}
6	Antenna B
7	NC
8	V_{dd}

FIGURE 3.23
Pins for the MCRF355/360 transponders.

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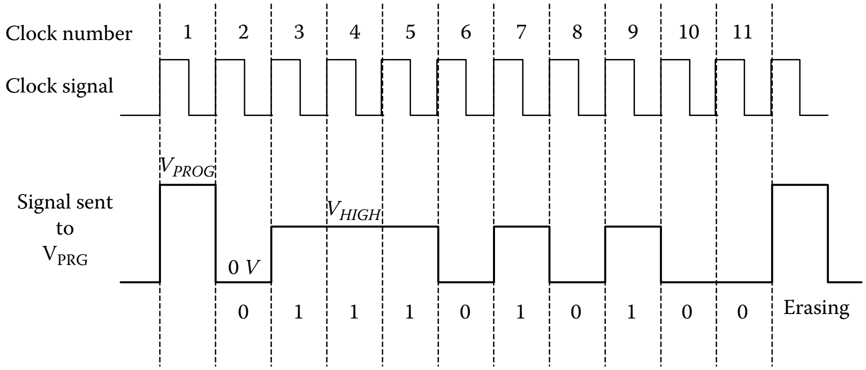

FIGURE 3.24
Code sent to erase existing data in memory using a contact programmer.

3.5 Summary of Electrical Specifications for RFID Transponders

The manner in which manufacturers specify the performance of their transponders varies greatly, not only among different manufacturers but also for devices from the same manufacturer. Tables 3.4 to 3.7 attempt to show the most important performance specifications from different manufacturers of RFID transponders. Table 3.4 does not pretend to be an exhaustive list of available devices, but just aims to show specific examples of device performance. The values of the parameters found in Tables 3.4 to 3.7 should be seen as somewhat typical performance values.

Table 3.4 shows the performance characteristics of three RFID transponders manufactured by Microchip Technology. The device MCRF200 is listed as a *125 kHz microID® Passive RFID Device*; the MCRF250 is exactly similar to the MCRF200 but incorporates anticollision; the MCRF355/360 family of devices is listed as *13.56 MHz Passive RFID Devices with Anti-Collision Feature*; and the devices in the MCRF450 family are listed as *13.56 MHz Read/Write Passive RFID Devices.*

Table 3.5 shows the electrical performance characteristics for four transponders manufactured by Atmel®. The ATA5567 device is listed as a *Multifunctional 330-Bit Read/Write RF Identification IC*; the ATA5570 is listed as a *Multifunctional 330-Bit Read/Write RF Sensor Identification IC*; the ATA 5558 is listed as a *1 kbit R/W IDID® with Deterministic Anticollision*; and the T5557 is listed as a *Multifunctional 330-Bit Read/Write RF Identification IC.*

Table 3.6 shows the performance parameters of two additional transponders from Atmel®. The device TK5530 is listed as a *read-only transponder,* while the TK5551 is listed as a *standards read/write ID transponder with anticollision.* The difference between these transponders and those evaluated earlier is

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TABLE 3.4

Summary of Electrical Parameters for Several RFID Transponders Manufactured by Microchip Technology

Parameter	MCRF 200/250	MCRF 350/360	MCRF 450/451/452/455
Operating frequency	100 kHz to 400 kHz	13.56 MHz	2 MHz to 35 MHz
Dynamic coil current	50 µA		
Operating current	5 µA	7 µA	20 µA
Maximum current through antenna pads	50 mA	40 mA	40 mA
Current leakage		10 nA	
Turn-on voltage	10 Vpp between antenna pads 2 V_{DC}		
Reading voltage		2.4 V	2.8 V
Testing voltage		4.0 V	
Programming voltage		V_{IH}: 2.8 V V_{IL}: 1.2 V	
Coil voltage while reading		4 Vpp	4 Vpp
Coil clamp voltage		32 Vpp	
Programming time	2 sec (for all 128 bit array)		5 ms (for a 32-bit block)
Sleep time		50 ms to 200 ms	
Modulation resistance		< 4 Ω	< 5 Ω
Internal capacitance	2 pF	100 pF	95 pF (MCRF451) 30 pF (MCRF 452) 50 pF (MCRF 455)
Data retention	200 years	200 years	200 years
Maximum storage temperature	-65°C to +150°C	-65°C to +150°C	-65°C to +150°C
Maximum ambient temperature	-40°C to +125°C		-40°C to +125°C
Maximum dissipated power			500 mW

[a] Blank spaces in the table indicate that the manufacturer did not provide information for that specific parameter.

that the ones shown below incorporate the coil for the antenna within the transponder. Moreover, the operating characteristics are given as strength of magnetic field instead of voltage or current.

Table 3.7 summarizes the most important characteristics of several transponders manufactured by Texas Instruments under their Tag-it™ commercial name. The manufactured has also chosen to specify their reading and writing thresholds as field intensity.

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TABLE 3.5

Summary of Electrical Parameters for Several RFID Transponders Manufactured by Atmel®

Parameter	ATA5567	ATA5570	ATA5558	T5557
Operating frequency	100 kHz – 150 kHz	100 kHz – 150 kHz	100 kHz – 250 kHz	100 kHz – 150 kHz
Supply current read mode	4 µA	4 µA	7 µA	4 µA
Supply current programming	40 µA		40 µA	40 µA
Maximum DC current	20 mA	20 mA	20 mA	20 mA
Maximum AC current	20 mA	20 mA	20 mA	20 mA
Coil voltage normal mode	3.6 V		4 V	4 V
Coil voltage Read / Write	> 6 V	> 10 V	> 6 V	> 6 V
Coil voltage Programming	> 8 V		> 6 V	> 8 v
Clamp voltage	17 V – 23 V	17 V – 23 V	7 V – 16 V	17 V – 23 V
Internal capacitance	78 pF	340 pF	78 pF	78 pF
Start-up time	< 1 msec	< 3 msec	< 3 msec	< 3 msec
Programming cycles	100,000 cycles	100,000 cycles	100,000 cycles	100,000 cycles
Data Retention	50 years	50 years	50 years	50 years
Maximum storage temperature	-40°C to +150°C	-40°C to +150°C	-40°C to +150°C	-40°C to +150°C
Maximum operating temperature	-40°C to +85°C	-25°C to +105°C	-40°C to +85°C	-40°C to +85°C
Maximum dissipated power	100 mW	100 mW	100 mW	100 mW

3.6 Mechanical Considerations and Transponder Assembly

The integrated circuits or chips in which the transponders are based are available in different packages. While commercial transponders use the chip-on-board (COB) technique described in Chapter 2, this package is not adequate for the development of prototypes. For this reason, most of the transponders are also available in the more common plastic dual-in-line packages (PDIPs) or small outline plastic packages (SOICs).

For example, some of the transponders described in this chapter, such as the MCRF200/250, the MCRF355/360, and the family of MCRF450 transponders, all manufactured by Microchip Technology, are available in these three packages (COB, SOIC, and PDIP). In their SOICs or PDIPs, these are available in eight pins; four of the pins are for testing purposes, two of the pins are for

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TABLE 3.6

Summary of Electrical Parameters for Several RFID Transponders Manufactured by Atmel®

Parameter	TK5530	TK5551
Resonance frequency	121.4 kHz – 129.2 kHz	120 kHz – 130 kHz
Inductance	3.95 mH	3.8 mH
Quality factor	13	13
Max field strength before modulation	2 A/m	4 A/m
Field strength operation	30 A/m (-40°C) – 17 A/m (+85°C)	30 A/m (-40°C) – 17 A/m (+85°C)
Field strength programming mode		50 A/m
Modulation Range	4.0 V (20 A/m) – 8.0 V (100 A/m)	4.0 V (20 A/m) – 8.0 V (100 A/m)
Programming time		16 ms per block
Data retention		10 years
Programming cycles		100,000 cycles
Absolute maximum field strength	1000 A/m	1000 A/m
Maximum storage temperature	-40°C to +125°C	-40°C to +125°C
Maximum operating temperature	-40°C to +85°C	-40°C to +85°C

connecting the transponder antenna, and the two remaining pins are not-connect pins. The devices ATA5570 and ATA5567/5558 from Atmel® are also available in COB packages and PDIPs, also using eight pins. The ATA5570 uses four not-connect pins, two pins for connecting the antenna, one pin for ground, and one pin for connecting the output of an external sensor. Because the ATA5567 and ATA5558 do not use an external sensor, their pinout is much simpler using six not-connect pins and two pins for connecting the external antenna. The dimensions of the COB version for all these transponders are 8 mm × 5 mm with a thickness of 0.4 mm. This extremely reduced size makes it ideal for incorporating the transponder and its antenna into the inlay. Transponders, especially in their COB form, are extremely sensitive to issues such as electrostatic discharge and their exposure to ultraviolet light that may result in erasing the contents in their memory cells. However, the use of X-rays for die inspection does not harm the device or erase their memory cell contents.

The process for assembling the whole transponder varies depending on the frequency range at which it will operate as well as the specifications for the final product. For transponders operating in the LF region, the assembly process starts by preparing the die and the capacitor and testing the functionality of the combined die-capacitor element. This is followed with preparing the antenna coil used in this frequency range and creating the inlay formed by the coil and the COB. After the inlay has successfully passed the test, the finished transponder is processed depending on the

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desired final product, such as card lamination and plastic molding. The last step in this process is a final functional test.

Transponders operating in the HF region can be assembled using three different methods. The first method, which results in the transponder with the COB, is based on the same assembly process as described earlier for LF transponders. A second method results in creating the transponder with direct wire bonding to the antenna that can be etched, printed, or stamped. This assembly method starts by preparing the die; preparing the antenna on the substrate etched, printed, or stamped; and then making the inlay by direct wire bonding to the antenna. After the inlay test, the finished transponder is created by using card lamination, plastic molding, or another method. The last step is a final functional test. The third method creates a transponder with a flip-chip process using a bumped die. The process starts by die bumping for flip-chip assembly, preparing the antenna on the substrate by etching, printing, or stamping it. The inlay is then created using the flip-chip process to attach the antenna to the die. This is also followed by the inlay test, and the finishing of the transponder by lamination or plastic molding. As always, the last step is a final functional test.

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4

Antennas for Interrogators

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This chapter describes the principles of design for interrogator antennas. The basic theory that describes the behavior of the antennas used in interrogators is the same that was used to describe the behavior of antennas used in transponders. However, in the case of antennas for interrogators, the size of the antenna is much less critical: because the interrogator has less size restrictions, the antenna can have larger dimensions. This results in an increased antenna performance. Furthermore, antennas for interrogators can be created with thicker conductors that can substation higher currents, resulting in stronger electromagnetic fields. The chapter starts by describing the basic principles used in the design of antennas for interrogators operating in the high-frequency (HF) and low-frequency (LF) bands. It continues by describing auxiliary elements such as tuning indicators, multiplexers, and preamplifiers used with those antennas in order to improve the overall performance of the system. The next section describes the basic principles used in the design of antennas in interrogators operating in the ultra-high-frequency (UHF) band. The last section in this chapter shows different examples of commercially available antennas for interrogators.

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4.1 Antennas for HF and LF Interrogators

4.1.1 Design of Antennas for HF and LF Interrogators

Antennas for interrogators operating in the HF and LF ranges are designed for parameters such as maximum read distance for transponders, transponder read rate, as well as regulations such as the maximum field allowed in some specific conditions. The majority of antennas used in HF and LF interrogators are variations of the coil antenna that generates a magnetic field. These antennas are typically called *portal antennas* because due to their physical dimensions and geometry, they can be placed in portals. A small number of antennas for HF and LF interrogators are based on a small dipole that generates an electric field. These antennas are normally called *stick antennas*.

In general, the distance at which a transponder can be read increases with the size of the antenna. However, this size cannot increase arbitrarily. This is due to the practical limitations in using an antenna of a large size and also to the limitations due to regulatory issues. Examples of these factors are the decrease in the signal-to-noise ratio as the size of the antenna increases; the potential for exceeding the regulatory limits of field strength; the need for shielding nearby electronic equipment to avoid unwanted interaction with the generated field; the increase in the area of null zones in which the generated field is zero; and the increase in the inductance of the antenna to a point that makes matching the antenna to the reader extremely difficult, if not impossible.

Interrogators working in the HF range expect an antenna tuned at the frequency of 13.56 MHz, with an input impedance of 50 Ω and a loaded quality factor (Q factor) of less than 20. Similarly, interrogators operating in the LF range expect an antenna tuned to the appropriate LF frequency, an input impedance of 50 Ω, and a loaded Q factor of less than 20. In both cases, for best performance, the match of the interrogator with the antenna should have a *voltage standing wave ratio* (VSWR) lower than 1.2.

The VSWR is a measure of how much of the energy sent through a transmission line is reflected back to the transmitter instead of being transferred to the antenna in order to be converted to the electromagnetic field. Standing waves occur as a result of the existence of incident and reflected waves. The ratio of reflected voltage to incident voltage is called the *reflection coefficient* and is denoted by the symbol Γ. Mathematically, the reflection coefficient is

$$\Gamma = \frac{E_r}{E_i} \tag{4.1}$$

where

Γ = the reflection coefficient

E_r = the reflected voltage

E_i = the incident voltage

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The reflection coefficient can also be expressed in terms of the impedance of the transmission line and the impedance of the load as

$$\Gamma = \frac{Z_L - Z_o}{Z_L + Z_o} \tag{4.2}$$

where Z_L = the impedance of the load and Z_o = the characteristic impedance of the transmission line.

Equation (4.2) shows that when the transmission line is terminated with a load with an impedance equal to its characteristic impedance, the reflection coefficient is zero. This means that all the energy present in the line has been transferred to the load. When the line is terminated with either an open circuit or a short circuit, the absolute value of the reflection coefficient is equal to 1. This indicates that none of the energy present in the line has been transferred to the load, but is being reflected back to the transmitter. For any other terminations, including complex impedance values, the value of the reflection coefficient is, in absolute value, between 0 and 1. This indicates that a portion of the energy present in the line has been transferred to the load and some other portion of the energy remains in the line.

The VSWR is defined as the ratio of the maximum voltage in the line ($E_{\max}$) compared to the minimum voltage in the line ($E_{\min}$):

$$VSWR = \frac{E_{\max}}{E_{\min}} \tag{4.3}$$

The VSWR can also be defined as a function of the reflection coefficient (Γ):

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{4.4}$$

Equation (4.4) shows that in the case of maximum reflection due to the transmission line terminated in an open or a short circuit, which results in $|\Gamma| = 1$, the value of the VSWR is infinity. Conversely, when the line is terminated with its characteristic impedance that results in $|\Gamma| = 0$, the value of VSWR is equal to zero.

Example 4.1:

The designer of a RFID system specifies a match between an interrogator and the antenna, resulting in a VSWR better than 1.2 using a 50 Ω coaxial cable as the transmission line. Calculate the maximum reflection coefficient and the allowed range of antenna impedance, assuming it is perfectly resistive.

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Solution:

The relationship between VSWR and the reflection coefficient is given by equation (4.4). Algebraic manipulation of this equation yields $|\Gamma| = 0.1$. This is the maximum value allowed for the reflection coefficient.

The relationship between the reflection coefficient and the impedance of the load is given by equation (4.2). When solving for the value of Z_L using this equation, it is necessary to consider the two signs associated with the previous result of $|\Gamma| = 0.1$ as the impedance of the load can exceed or be below the impedance of the line.

$\Gamma = 0.1$ results in $Z_L = 61\ \Omega$, while $\Gamma = -0.1$ results in $Z_L = 41\ \Omega$. Therefore, an antenna impedance ranging from 41 Ω to 61 Ω will result in a VSWR better than 1.2.

Note than the range of allowed load impedances is not symmetric referred to the impedance of the line (Z_o). There is more tolerance for values above Z_o than for values below Z_o.

A transmission line that is not perfectly matched (i.e., a VSWR value higher than 1) reduces the amount of power from the interrogator that reaches the antenna. More importantly, however, is the fact that a fraction of the power that remains in the transmission line can break down the dielectric of the line or increase its temperature due to the power dissipated. Therefore, it is critical to achieve the best possible matching.

Antenna analyzers are a very versatile and useful tool at the time of designing antennas and matching them to their transmission lines. Figure 4.1 shows an image of a low-cost antenna analyzer. The configuration of this analyzer is done through software, and the results are displayed and stored in a personal computer.

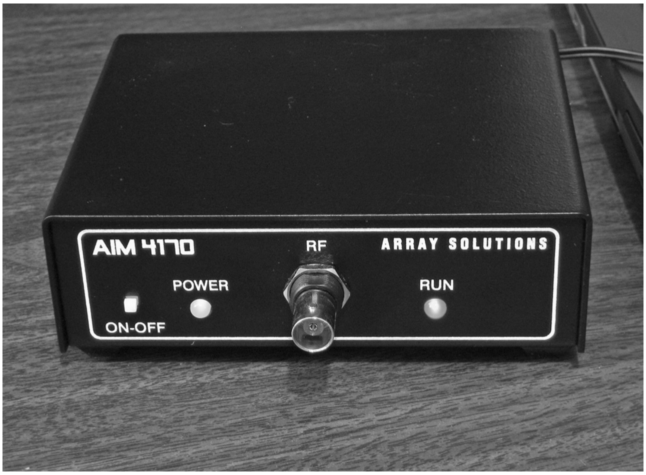

FIGURE 4.1
Antenna analyzer from Array Solutions. The control of the unit and the display of results are done by software.

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This unit shown in Figure 4.1 allows the measurement of the complex impedance of a transmission line or an antenna, the measurement of reflection coefficient, insertion losses, and other parameters of interest. The front panel only contains an ON/OFF switch, two light-emitting diodes (LEDs) that indicate whether the unit is energized and whether the unit is running a test, and a single Bayonet Neill-Concelman (BNC) connector. The back panel contains the power supply connection and a DB9 connector for a serial cable from the control computer to configure the instrument and transmit the results. The user can select the range of frequencies for the sweep-starting frequency, ending frequency, and step-or central frequency and bandwidth. This unit can also act as a fixed radio frequency source by generating a user-selected single frequency signal. The output values are shown graphically on the screen as conventional graphs (parameter versus frequency) or Smith charts. The data can also be stored as a text file for further processing. The graph can display one or more of the following parameters: impedance magnitude, impedance phase, reflection coefficient, return loss, stationary wave ratio, series load circuit, or parallel load circuit. Figure 4.2 shows an example of the output showing the magnitude and phase of a transmission line between 25 MHz and 40 MHz.

Figure 4.2 depicts the magnitude and phase of the impedance measured by the antenna analyzer for a transmission line with an electrical length

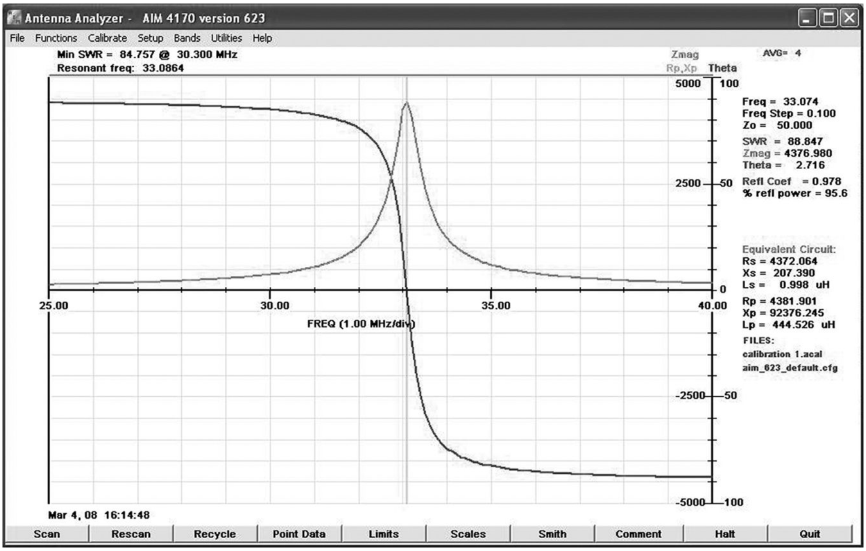
Antenna Analyzer - AIM 4170 version 623
File
Functions
Calibrate
Setup
Bands
Utilities
Help
Zmag
Rp,Xp
Theta
AVG= 4
5000
100
2500
50
0
-2500
-50
-5000
-100
25.00
30.00
35.00
40.00
FREQ (1.00 MHz/div)
Scan
Rescan
Recycle
Point Data
Limits
Scales
Smith
Comment
Halt
Quit

Min SWR = 84.757 @ 30.300 MHz
Resonant freq: 33.0864

Freq = 33.074
Freq Step = 0.100
Zo = 50.000

SWR = 88.847
Zmag = 4376.980
Theta = 2.716
Refl Coef = 0.978
% refl power = 95.6

Equivalent Circuit:
Rs = 4372.064
Xs = 207.390
Ls = 0.998 uH
Rp = 4381.901
Xp = 92376.245
Lp = 444.526 uH

FILES:
calibration 1.acal
aim_623_default.cfg

Mar 4, 08 16:14:48

FIGURE 4.2
Frequency behavior of a transmission line terminated with a short circuit for frequencies around a quarter wavelength. This display shows the magnitude and the phase of the impedance at the near end.

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equal to one-quarter of the wavelength, terminated in a short circuit. Due to the impedance transformations at this specific electrical length, the theoretical value of the transformed impedance seen at the near end of the line is infinity. In practice, the losses of the line make the impedance have a large, yet finite, value. The output also displays other values described earlier in this section, such as the reflection coefficient and the VSWR, among others. Similar results could also be obtained using other commercially available antenna analyzers.

When designing the antenna, it is also necessary to take into consideration the write range of transponders that is about 70% of their read range. This is due to the higher amount of power needed to rewrite a transponder compared with just reading it. The orientation of the antenna with respect to the transponder is also a factor in determining the maximum read range in a given application. As shown in Figure 4.3, the field generated by the coil antenna does not have the same strength in all the spatial directions, but instead it has regions of maximum values alternating with regions of minimal strength.

An additional parameter that may limit the maximum read range of a system is the presence of metal objects in the vicinity of the antenna. Metal objects close to the antenna have the effect of detuning it, and therefore it loses its efficiency at the desired frequency. As the size of the antenna increases, the minimum required separation distance between the antenna and the metal objects also increases. For antennas operating in the HF frequency range, the minimum distance between antenna and metal has to be greater than 10 cm.

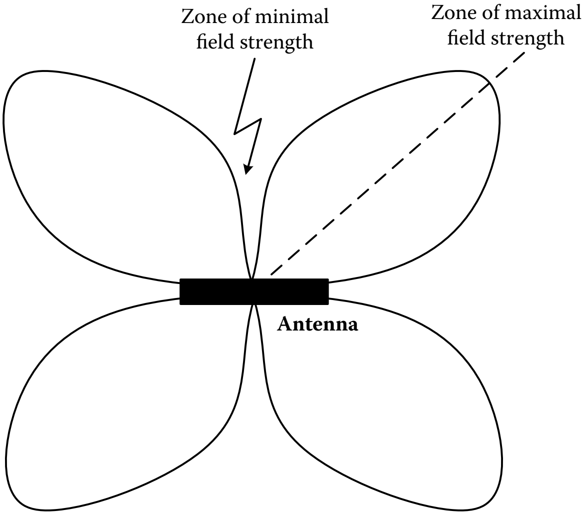
Zone of minimal field strength
Zone of maximal field strength
Antenna

FIGURE 4.3
The radiation diagram for the loop antenna in the interrogator shows areas of maximum and minimum field strength.

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Even at 30 cm of separation, there is a considerable decrease in the reading range. When the distance between antenna and metal object reaches 50 cm, there is no measurable difference. Similarly, the presence of other antennas in the vicinity also affects the overall performance of the system.

Antennas can be built using any conductive material. However, they are normally built using copper or aluminum. The type of material used for the antenna and the dimensions of the tube or strip lines depend on the desired mechanical parameters of the antenna as well as the maximum inductance that must be matched to the interrogator. In addition to the conductors, the matching process requires the use of capacitors and resistors. These must be rated for the high voltages that may arise in resonant antennas as well as for the power that they must dissipate. Typical power values for these resistors range from 2 W to 50 W.

The dimensions of the antenna have an effect on the read distance between interrogators and transponders. The strength of the magnetic field for an electrically small-loop antenna is

$$B_z = \frac{\mu_0 I N a^2}{2\,(a^2 + r^2)^{3/2}} \quad (Weber / m^2) \tag{4.5}$$

with a being the radius of the loop and r being the radial distance from the center of the loop. To study the effects of the antenna radius, the rest of the parameters in equation (4.5) can be considered constant. Assuming that all antennas have the same amount of current and also the same number of turns, the only parameter that changes is the radius of the loop. Figure 4.4 depicts the values of magnetic fields for coils with three different radii (0.2 m, 0.4 m, and 0.8 m). Because the graph is only intended to highlight the dependence of the field with the distance from the center of the coil, it uses arbitrary units for the strength of the field depicted in the vertical axis.

It is interesting to note that, although larger coils produce stronger fields, this only happens after a certain distance threshold has been reached. In particular, for read distances closer to the antenna, the stronger fields are produced by the coils with the smallest radius. Antennas with smaller radii produce stronger fields in the vicinity of the antenna, but these fields decrease faster for longer distances. Therefore, the design of the antenna must consider the range of distances between transponders and the interrogator when selecting the size of the loop.

The resonant frequency of an antenna (ω_o or f_o) is

$$\begin{gathered} \omega_o = \sqrt{\frac{1}{LC}} \quad or \\ f_o = \frac{1}{2\pi\sqrt{LC}} \end{gathered} \tag{4.6}$$

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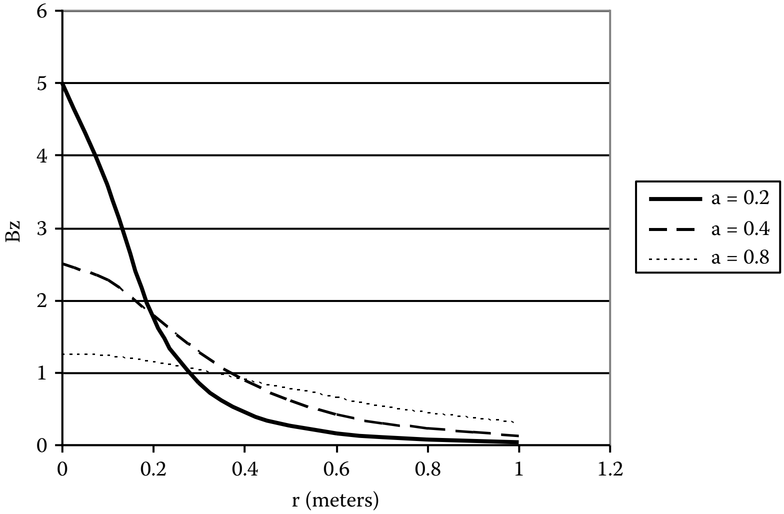

FIGURE 4.4
Strength of the magnetic field as a function of the distance from the coil for loop antennas of different diameters.

An antenna will reach its resonant frequency when its inductive impedance is equal to its capacitive impedance. The loop antenna has an inherently inductive behavior. Therefore, it needs an external capacitor to provide the capacitive impedance required for resonance. The value of this external capacitor can be calculated using equation (4.6). It is important to note that the capacitance and inductance of the antenna are inversely related. A problem may arise if the inductance of the antenna increases to a point that may make it difficult to use a capacitor of suitable value. For example, a loop antenna with an inductance of 5 µH operating in the HF range requires a matching capacitor of 27 pF. For these small capacitance values, the parasitic capacitances that have not been taken into account when modeling the antenna may contribute significantly to the overall capacitance and therefore modify its resonant frequency. It is then important for antennas to be designed with lower inductive values. This may require one to use, for example, low-resistance conductive tube instead of wire at the expense of increasing its physical dimensions.

The inductance of the antenna made with copper tube, shown in Figure 4.5, can be estimated as

$$L(\mu H) = 0.008\ a\left[\ln\left(0.707\,\frac{a}{d}\right) + 0.379\right] \tag{4.7}$$

where

L = the estimated value of inductance

d = the diameter of the tube in cm

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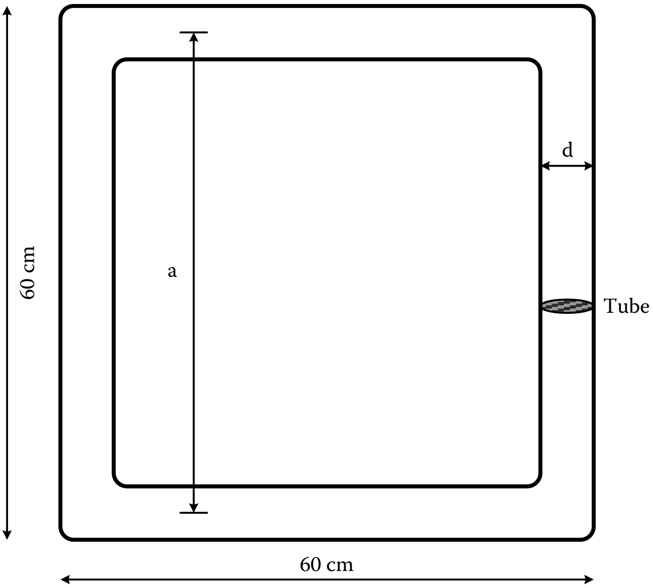

FIGURE 4.5
Basic structure of a loop antenna made with copper tube.

a = the length of the side of the antenna from center to center (as shown in Figure 4.5)

Example 4.2:

An interrogator operating at HF uses a loop antenna made of copper tube with a diameter of 2 cm, with a rectangular shape of 60 cm × 60 cm. Estimate the value of the inductance for the antenna. Estimate also the value of the capacitor required to tune the antenna for resonance.

Solution:

Using equation (4.7) with $d = 2$ and $a = 59$ yields $L = 1.6$ μH. This value of inductance can now be used in equation (4.6) to calculate the estimated value of capacitance. The estimated value of capacitance is 86 pF.

The previous equations provide an estimated value of antenna inductance. After the antenna has been built, its inductance must be measured in order to choose the correct value for the tuning capacitor. This can be done with an impedance analyzer that allows the selection of the measurement frequency. However, impedance analyzers are expensive and may not be available in most cases. In this case, a low-cost LCR (inductance [L], capacitance [C], and resistance [R]) meter that operates at the frequency of 1 kHz can give a reasonable approximation of the antenna inductance. The antenna analyzer shown in Figure 4.1 is another low-cost alternative for measuring

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the inductance of the antenna and the resonant frequency of the antenna-capacitor system.

The last parameter that needs to be calculated and measured when designing the antenna is its Q factor. The Q factor is a measure the frequency selectivity of an antenna. The Q factor is related to the range of frequencies above and below its resonant frequency that the antenna will be able to transmit or receive with losses below 3 dB. The Q factor can be estimated as

$$Q = \frac{f_r}{BW_{-3dB}} \tag{4.8}$$

where Q is the quality factor of the antenna, f_r is its resonant frequency, and $BW_{-3\text{dB}}$ is the bandwidth of the antenna at 3dB of attenuation.

A high Q factor indicates an antenna that is very narrow in frequency, that is, highly selective. This may be good in order to reject interfering signals that otherwise would be detected by the antenna. However, the RFID signal has a certain bandwidth. If the antenna is too selective, it may distort the components of the transmitted signal that fall outside the selectivity of the antenna, as shown in Figure 4.6. A good experimental compromise is to choose a Q factor of around 20.

If the Q factor of the system made of the antenna and capacitor is higher than 20, it needs to be brought down by using a dampening resistor in parallel with the antenna in order to widen its bandwidth. This technique is shown in Figure 4.7.

The introduction of the dampening resistor produces Ohmic losses in the system, lowering the Q factor. The Q factor is related to the parallel resistance as

$$Q = \frac{R_{par}}{2\pi f L} \tag{4.9}$$

An additional problem arises when using equation (4.9) in order to select the value of the parallel dampening resistor: the value R_{par} in the equation is the combination of the external dampening resistor (R_{damp}) in parallel with the resistance of the antenna at the frequency of interest (R_{ant}). The measurement of the resistance of the antenna at the operating frequency is difficult and requires the use of expensive instrumentation. However, the Q factor for an antenna is relatively easy to measure experimentally with an antenna analyzer or using a radiofrequency signal generator and a spectrum analyzer. Therefore, the resistance of the antenna R_{ant} at the operating frequency can be calculated indirectly by measuring the Q factor of the antenna without an external dampening resistor. Once this value has been found, it is now possible to calculate the required value of the total parallel resistance R_{par} to achieve the desired value of Q. Because R_{par} is the parallel of R_{ant} and the

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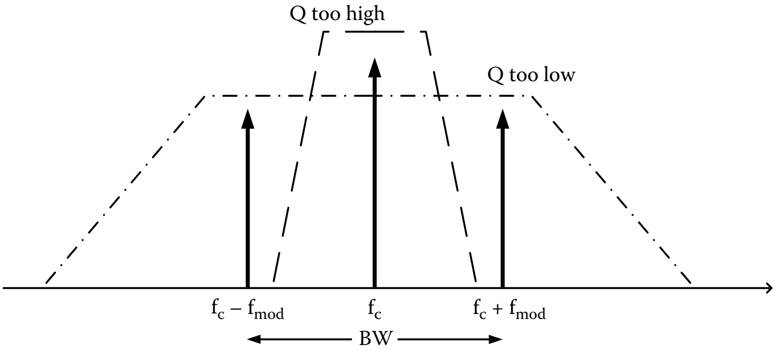

FIGURE 4.6
Q factor of an antenna and its relationship with the antenna performance. (a) A very low quality factor (Q factor) does not provide adequate selectivity. (b) A very high Q factor may reject components of the transmitted signal.

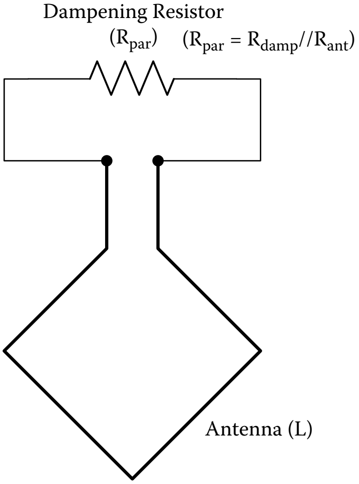

FIGURE 4.7
Dampening resistor connected in parallel with the antenna. This is used to lower the Q factor to the desired value.

external dampening resistor R_{damp}, it is now possible to estimate the value of this external resistor. Example 4.3 illustrates this procedure.

Example 4.3:

Consider the antenna for the RFID system from Example 4.2. Estimate the value of the external dampening resistor necessary for the system to achieve a Q factor of 20. The initial measurement of the Q factor for the antenna-capacitor system resulted in a value of 55.

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Solution:

Using equation (4.9) with a Q factor of 55, an inductance value for the antenna of 1.6 µH, and a frequency of 13.56 MHz results in a resistance equal to 7.5 kΩ. Because the Q factor of 55 was measured without the use of external resistors, the value of resistance obtained is the resistance of the antenna: $R_{ant} = 7.5$ kΩ.

Now, we must calculate the value of the total parallel resistance needed to reduce the Q factor to the desired value of Q. We use again equation (4.9) with the same operational parameters as before, with the exception that the new value for Q results in a resistance equal to $R_{par} = 2.7$ kΩ.

Considering that the total value of the resistance found above is equal to the resistance of the antenna in parallel with the dampening resistor ($R_{par} = R_{ant} // R_{damp}$), it is now possible to calculate the value of the external dampening resistor. This results in $R_{damp} = 4.2$ kΩ. Because this is not a standard resistor value, the designer should use the next standard value, which is 4.3 kΩ.

Therefore, the addition of 4.3 kΩ results in lowering the Q factor from its initial value of 55 to the desired value of 20. Because the value of inductance used for this calculation could be an estimated value, the design process involves measuring the Q factor with the external dampening resistor of 4.3 kΩ and adjusting its value if necessary to reach a Q factor of 20. Finally, it is also necessary to keep in mind that this external dampening resistor must be sized to dissipate the power transmitted by the interrogator.

4.1.2 Antenna Matching

Matching the impedance of the antenna to the impedance of the transmission line (normally a coaxial cable of 50 Ω) ensures that all the power from the interrogator is transferred to the antenna, and there is no power reflected in the line. In practice, a VSWR of 1.2 or lower is acceptable as the majority of the power is transmitted to the antenna. From the several approaches to match an antenna to its transmission line, the most widely used matching methods for interrogator antennas in RFID systems are gamma matching, T-matching, transformer matching, and capacitance matching.

Gamma matching is a technique based on connecting the two conductors of the coaxial cable that make up the transmission line to the two points in the antenna that exhibit a resistive impedance equal to 50 Ω. The shield of the coaxial cable is normally connected to the point in the antenna that is opposite to the gap used to connect the resonance capacitor and the dampening resistor. The central connector of the coaxial cable is then connected, by means of an additional conductor, to the appropriate point in the antenna as shown in Figure 4.8.

In practice, the point at which the central conductor of the coaxial cable is connected (point A) must be determined by experimentation. The designer of the system connects an antenna analyzer at the far end of the coaxial cable and moves point A until the antenna analyzer reads a VSWR value equal to 1. This indicates that the impedance of the antenna between point A and the connection of the central conductor is equal to 50 Ω. The value of the capacitor used to tune the antenna to the resonance frequency was

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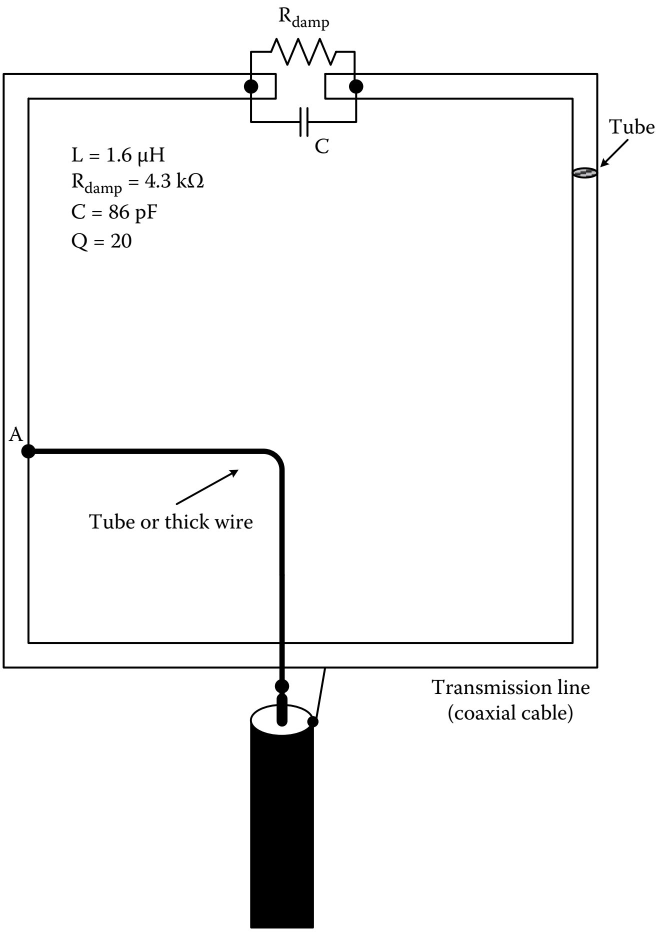

FIGURE 4.8
Connections for gamma matching.

determined using an approximation for the value of the antenna inductance. Therefore, a variable capacitor is initially used in order to tune the antenna to its resonant frequency. Once the correct value of capacitance has been determined, it is then possible to substitute the bulkier variable capacitor with a fixed capacitor.

T-matching is similar to gamma matching with the difference being that in T-matching, both the internal and external conductors of the coaxial cable are tapped to two points in the antenna, as shown in Figure 4.9. It is based on the fact that two points of the antenna, equidistant from the center, exhibit a purely resistive impedance.

The two tapping points are located symmetrically with respect to the gap used for connecting the tuning capacitor and the dampening resistor. The

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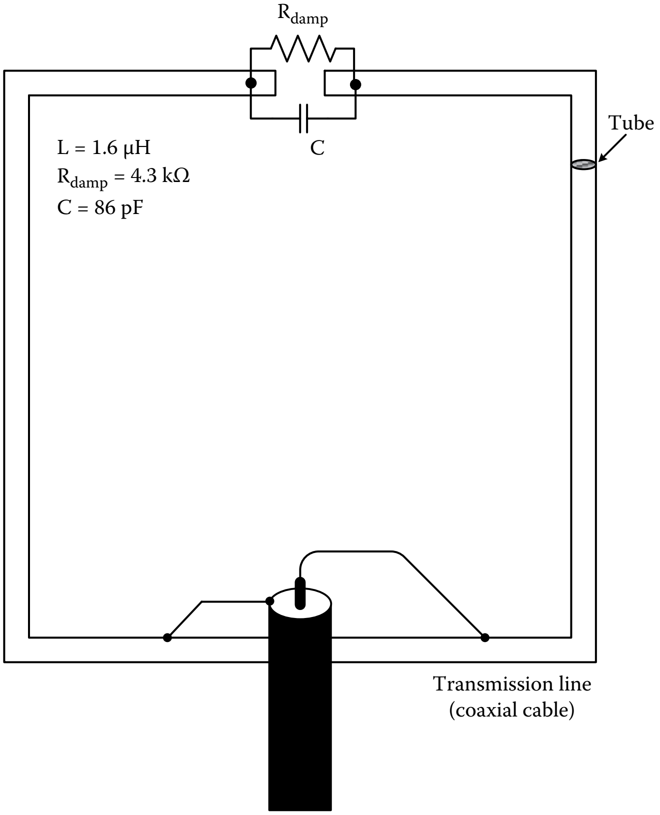

FIGURE 4.9
T-matching.

two tapping points are found by using an antenna analyzer until the VSWR value is equal to 1. Higher values of the Q factor results in the two matching points being closer together.

Transformer matching has the advantage that it electrically isolates the antenna from the interrogator, thus breaking the Ohmic continuity between these two parts of the system. This is useful when the RFID system is affected by noise as it breaks any ground loop that may exist. Figure 4.10 shows the electric diagram of transformer matching. It is important to note that the matching occurs at the gap in the antenna that is used to connect the resonance capacitor and the damping resistor instead of their opposite point, as it happens with gamma and T-matching.

Transformer matching requires the design of two elements: the matching transformer and a balum (balanced–unbalanced) transformer. The design of the matching transformer requires one to size the number of turns of the primary (*N*) that is connected to the transmission line and the secondary (*M*)

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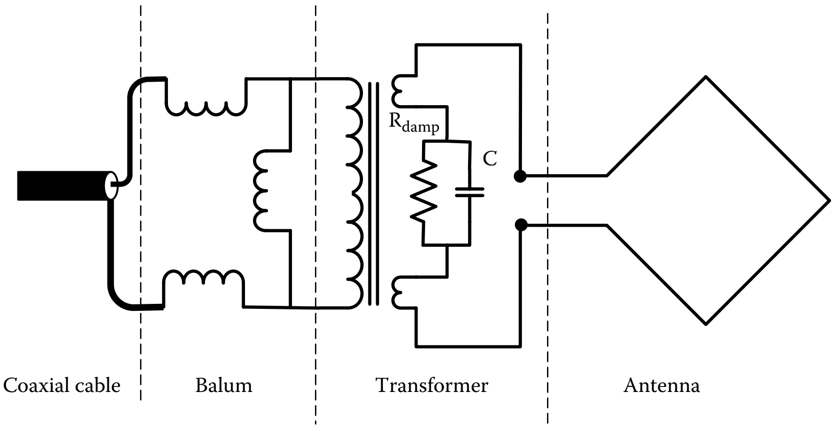

FIGURE 4.10
Transformer matching. Notice how the matching point is the same point at which the capacitor and resistor are connected.

that is connected to the antenna. The ratio of turns can be found using the following:

$$\left(\frac{N}{M}\right)^2 = \frac{Z_o R_{par}}{(2\pi f L)^2} \tag{4.10}$$

where (N/M) is the primary to secondary ratio of turns, Z_o is the impedance of the transmission line, R_{par} is the parallel resistance of the antenna and the dampening resistor, and L is the inductance of the antenna.

Example 4.4:

Using the values from the previous examples in this chapter, calculate the number of turns for the primary and secondary of the matching transformer. Assume a characteristic impedance of 50 Ω.

Solution:

Using equation (4.10) with R_{par} = 2.7 kΩ, L = 1.6 μH, and f = 13.56 MHz, the ratio of turns is equal to 2.7. Using, for example, M = 3 results in N = 8 windings.

The balum transformer is used to connect unbalanced transmission lines such as a coaxial cable to balanced antennas such as the loop antenna. Although they can be connected directly, as with the gamma matching, the common mode currents that appear in the antenna and line due to the unbalance may cause excessive noise and disturb the circuits. In this case, the connection of a balum transformer between line and transformer

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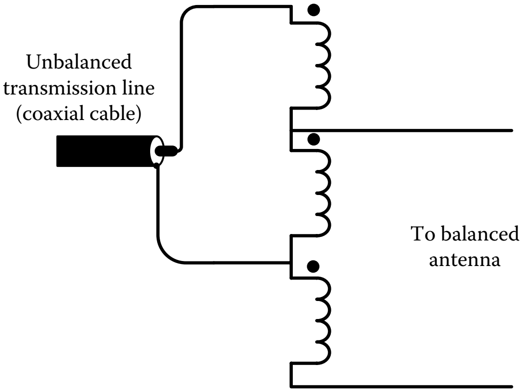

FIGURE 4.11
A balum is used to connect unbalanced transmission lines to balanced antennas.

solves these problems. The structure of a balum transformer is shown in Figure 4.11.

Both the matching transformer and the balum transformer are normally made with a toroid ferrite core. The balum transformer can be tested by connecting a 50 Ω load to the balanced side and measuring the VSWR through a coaxial cable connected to the unbalanced side. The VSWR should be close to 1.0.

Capacitance matching attempts to match the antenna and its transmission line by adding to external capacitors between the resonance capacitor and the dampening resistor, as shown in Figure 4.12.

Because of the stray capacitances inherent to the system, it is very difficult to predict the adequate values for the two matching capacitors, which requires extensive experimentation. Furthermore, for larger antennas, the values of the two matching capacitors tend to be very small, making the matching process very sensitive to stray capacitances. In Figure 4.12, the series combination of C_1 and C_2 must be equal to the capacitance value required to tune the antenna at the correct frequency.

The value of the matching capacitor C_{m1} can be estimated as

$$C_2 = C_{tuning} \sqrt{\frac{R_{par}}{R_{out}}} \tag{4.11}$$

where C is the total capacitance required for tuning the antenna, R_{par} is the equivalent value of the AC resistance of the antenna in parallel with the damping resistor, and R_{out} is the desired matching impedance, typically 50 Ω. The value of C_1 can be calculated through the series capacitance of C_1 and C_2.

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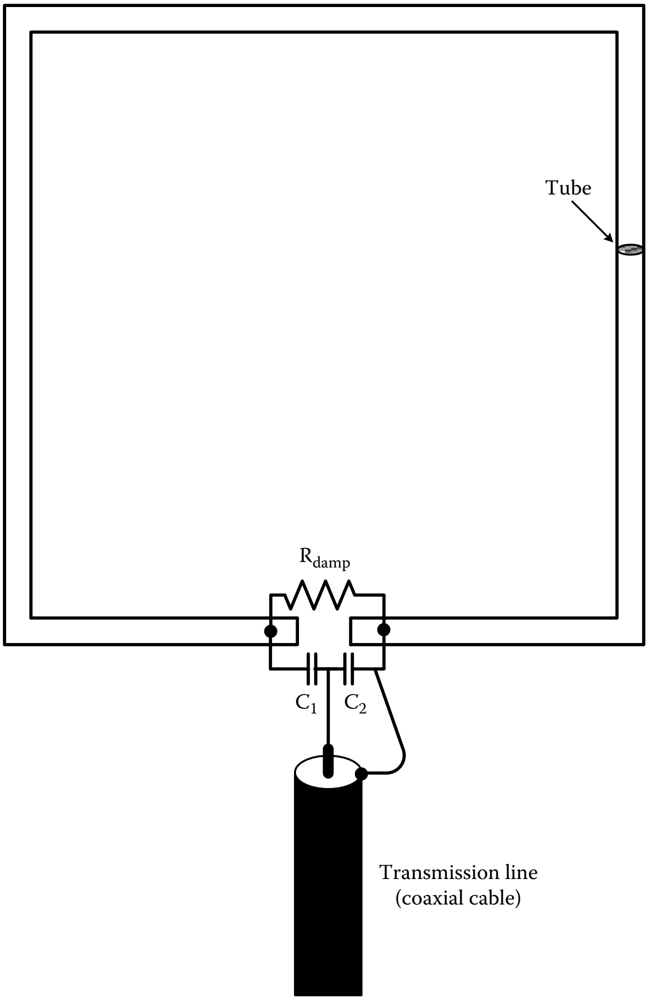

FIGURE 4.12
Capacitance matching.

Example 4.5:

The antenna used in Example 4.4 must be matched to a 50 Ω transmission line using capacitance matching. Calculate the values of the two matching capacitors required.

Solution:

The required tuning capacitor has a value of 86 pF, and the parallel resistance has a value of 2.7 kΩ. The required value for R_{out} is 50 Ω. Using equation (4.11) yields a value of C_2 = 632 pF. The equivalent series capacitance is 86 pF, allowing one to calculate the value of C_1 equal to 99 pF.

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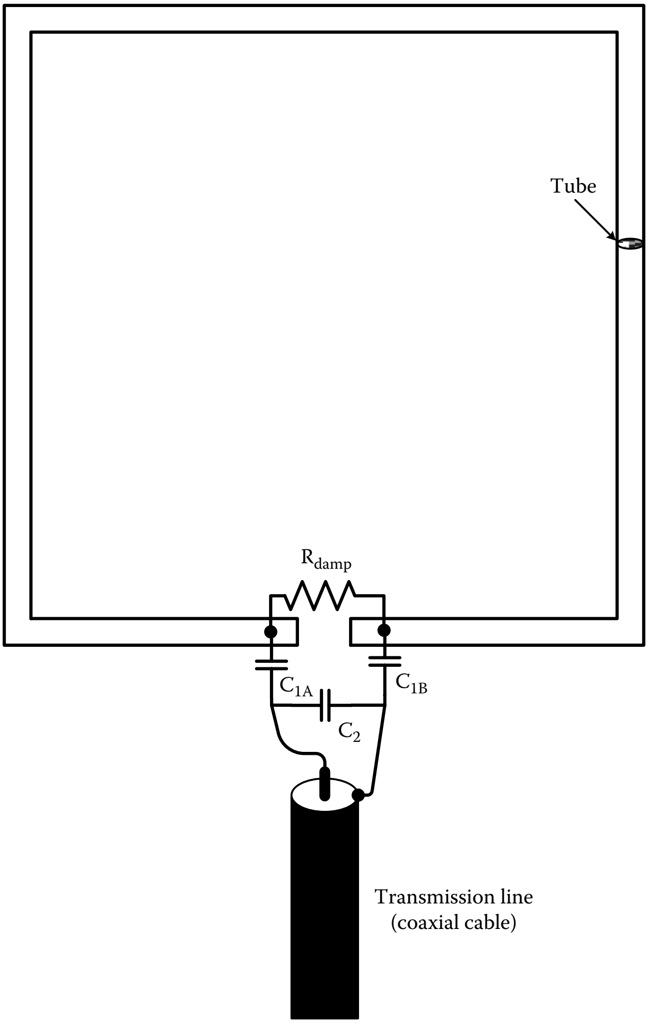

FIGURE 4.13
Balanced capacitance matching.

Some antennas require a matched capacitance so the capacitance seen by both conductors of the coaxial cable is the same. This can be achieved by using the structure shown in Figure 4.13. In this structure, the value of C_1 is doubled and added to each side of C_2.

Example 4.6:

Using the results of Example 4.5, calculate the capacitor values required for balanced matched capacitance.

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Solution:

From Example 4.5: C_1 = 99 pF and C_2 = 632 pF. To achieve balanced capacitance, $C_{1A} = C_{1B}$ = 198 pF. C_2 remains at the same value of 632 pF.

4.1.3 Multiple Antenna Systems

It is not uncommon for several antennas to be located in close proximity. This may be due to different interrogators being close to each other or for multiple antennas to be connected to a single interrogator. When designed correctly, the mutual coupling between the antennas can enhance the performance of the overall system. However, a careless positioning of the multiple antennas may result in their mutual coupling, severely degrading their performance.

When several single-antenna interrogators coexist in close vicinity to each other, it is necessary to minimize their interaction with each other. The coupling between these antennas depends on the distance between them as well as their relative angles. Although the radiation pattern of a single antenna is well known and easy to predict, this radiation pattern becomes distorted due to the coupling. The best approach for locating the optimal placement of two or more antennas is by using an antenna analyzer in order to find the minimum of radiation by measuring the voltage generated in the nearby antenna.

A technique sometimes used to enhance the radiation pattern of the antenna in a single interrogator is to place another matched but unconnected antenna, opposite to the antenna connected to the interrogator. This connected antenna is a *driven antenna*, while the unconnected antenna is a *reflective antenna*. The combination of both antennas directs the energy from the driven antenna to a narrower area. Once again, an antenna analyzer should be used in order to determine the best arrangement between the two antennas.

Instead of leaving the second antenna unconnected, making it a reflective antenna, it is also possible to drive it with the signal from the interrogator by means of a splitter. In this case, the output of the interrogator is connected to the input of the splitter, and each output from the splitter is connected to a matched antenna. Splitters also offer the possibility to have the two output signals in-phase or out-of-phase. Splitters introduce losses, but when the two signals are connected in-phase, the reading distance between interrogator and transponders increases more than the reading distance with just one antenna without the losses from the splitter. The increase in the reading distance is at the cost of reducing the radiation pattern in the directions perpendicular to the arrangement of antennas. Therefore, this technique is only useful when the transponders are located only in known areas. When the signals fed to the two antennas are out-of-phase, the radiation pattern changes significantly, resulting in a pattern opposed to when the two signals are in phase. This gives the designer of the system the ability to configure the radiation pattern depending on the needs of the system.

Other techniques based on systems with multiple antennas are directed toward specific applications. In one of them, two identical antennas located

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in a crossed arrangement are connected to the output of a splitter but use different lengths of transmission line. In particular, if the different between lengths is a quarter of a wavelength, the two fields are shifted in 90°. This produces a field that changes the direction of its maximum, giving the appearance of a rotating field. Some other commercial antennas have an additional input that allows connecting an out-of-phase signal from a complementary antenna in order to maximize field strength in a single direction.

4.2 Auxiliary Elements for LF and HF Interrogator Antennas

4.2.1 Antenna-Tuning Indicators

Tuning indicators are used to facilitate the process of antenna tuning without the need to use antenna analyzers or other instrumentation. They present the advantage of being a self-contained system that has been optimized for specific interrogators and antennas. On the other hand, because of their specific nature, they can only be used with a limited number of antennas.

For example, Texas Instruments manufactures the RI-ACC-ATI2 antenna-tuning indicator used to help tune their LF antennas. The tuning indicator is connected to the interrogator and indicates to the user if the inductance or capacitance in the interrogator needs to be increased or decreased until the optimal value has been achieved. Some interrogators have a tuning capacitor, while some others have a tuning inductance that can be adjusted for optimal performance.

4.2.2 Antenna Multiplexers

Antenna multiplexers are used to connect multiple antennas to a single interrogator. This can be done to take advantage of the multiple coupling between antennas or when it is necessary to read data from multiple interrogators located at distant points not covered by a single antenna. The majority of multiplexers in the market work with two, four, or eight antennas. The multiplexer is connected between the radiofrequency output of the interrogator and the antennas, as shown in Figure 4.14.

It is not necessary for all the antennas connected to the multiplexer to have the same inductance. This presents the advantage of being able to choose the antenna most adequate for a specific application without having to physically connect and disconnect them from the interrogator. However, because most multiplexers do not include a tuning feature, each antenna must be tuned to the appropriate resonance frequency with their own individual tuning method described in Sections 2.2 and 2.3.

Antenna multiplexers are normally created by the manufacturers of interrogators, although there are some third-party companies that also

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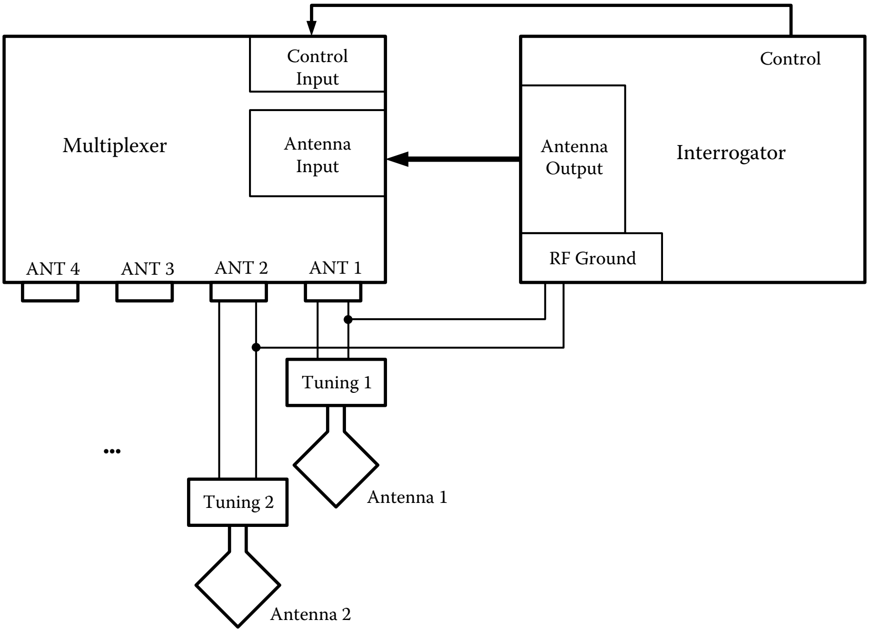

FIGURE 4.14
Multiplexer for connecting multiple antennas to a single interrogator.

manufacture them. For example, Skyetek manufactures multiplexers for the HF frequency range that can control four or eight antennas, having insertion losses lower than 0.7 dB and isolation between adjacent channels better than 45 dB.

4.2.3 Preamplifiers

Increasing the reading distance between interrogators and transponders requires a double approach. First, the electromagnetic field transmitted by the interrogator has to increase in order to generate enough power to turn on the distant transponders. This is relatively easy to do and is mainly limited by standards and regulations on maximum power and maximum allowed field strength. Second, reading distant transponders requires the interrogator to detect signals closer to the noise level. The increase in the detection sensitivity can be achieved with the use of preamplifiers, as shown in Figure 4.15.

The factor that limits the read range in RFID is ultimately the inherent noise that accompanies the signal received by the interrogator. A correctly designed preamplifier is able to increase the level of the signal without degrading the signal-to-noise ratio. The design of the main preamplifier is normally based on a low pass filter in order to reject the frequency generated by the field and

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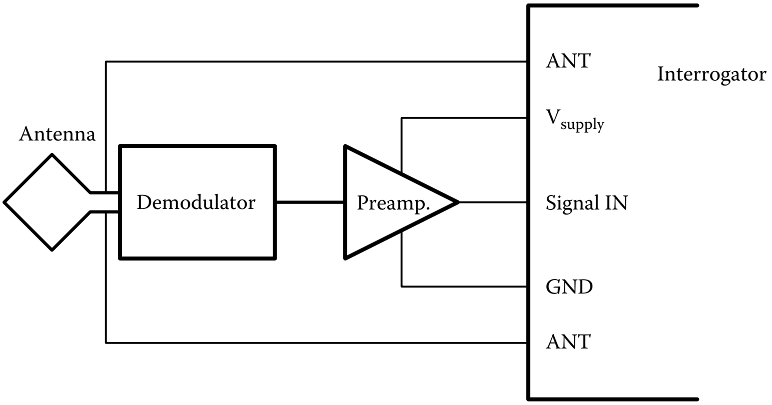

FIGURE 4.15
Preamplifier for extending reading distance.

allow the transmission of data. This stage is followed by an AC amplifier that increases the signal levels to the point that can be easily understood by the interrogator. The design of the preamplifier must consider the trade-offs between increasing the reading distance and the settling time required by the system. This means that the interrogator will be optimized for reading distance or for settling time, but cannot be optimized for both parameters.

Even when using preamplifiers, it is necessary to minimize the other potential sources of noise in the system. These can be the use of bad connectors between the interrogator and the antenna, improper installation of the transmission line between interrogator and antenna, an antenna that is not tuned correctly, the existence of interfering signals from nearby electronic equipment, and noise emanating from the power supply lines, among others. The designer of the RFID system should ensure that all these sources are minimized or at least known, and their values measured.

4.3 Antennas for UHF Interrogators

4.3.1 Design of Antennas for UHF Interrogators

Given the wavelength of signals in the UHF range, it is possible to design antennas for interrogators that operate in the far-field region as interrogators do not have the same space limitations of transponders. The resulting radiation pattern of two dipoles located at a short distance from each other can be easily modified by carefully arranging the distance between them as well as the phase shift of the signals that they radiate. A further modification of the radiation pattern comes from placing a large metal surface at a

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specific distance from the two dipoles. The metal surface acts like a shield that effectively removes half of the radiation pattern. Furthermore, if the distance between the antennas and the metal shield is one-fourth of the signal wavelength, the phase shift due to the distance between antenna and shield, combined with the phase shift created by the reflection in the metal shield, places the reflected signals in phase with the signals originated by the antenna. This, in turn, has the effect of doubling the power transmitted in the area away from the metal shield, as shown in Figure 4.16. It is necessary to remember that the increase of power in that specific direction comes at the expense of having no power in the area behind the metal shield, also known as a *passive reflector*. This structure is commonly used in *patch* or *flat* antennas.

An additional advantage of working in the far-field region is the possibility to take advantage of polarization. Polarized signals have their electric fields oscillating in a known and constant direction in space. This way, the signal recovered by the receiving antenna has a marked dependence on the geometrical relationship between the direction of the electric field and the direction of the antenna. Therefore, the energy recovered by the antenna in the interrogator ranges from a maximal value to zero depending on the relative orientation between the antennas in the interrogator and transponder. Using polarized signals allows discriminating between transponders. When the discrimination between transponders is

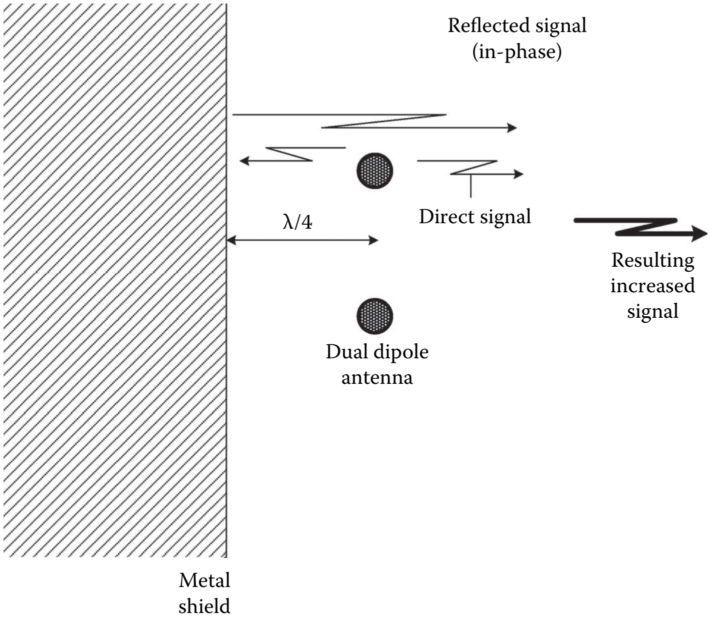

FIGURE 4.16
Metal shield increases effective radiated power in one specific direction.

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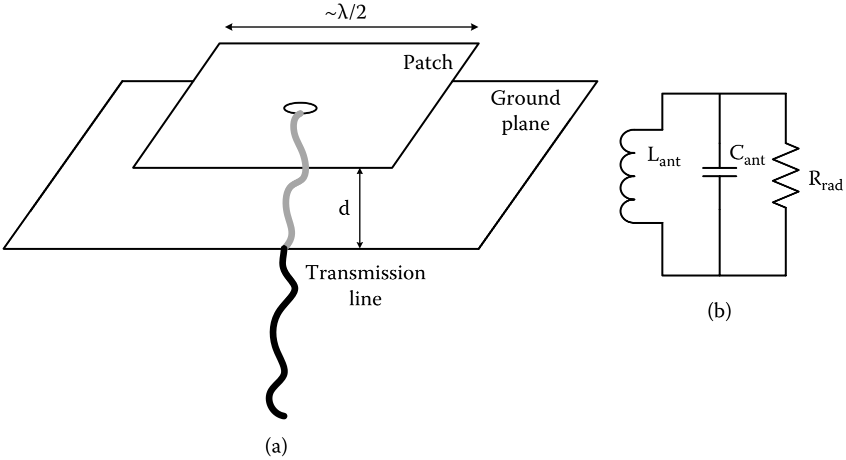

FIGURE 4.17
(a) Basic structure of a patch antenna. (b) Parallel equivalent circuit for a patch antenna.

not required, the use of dual dipole antennas in the transponders ensures that the interrogator will receive an adequate amount of energy.

The design of an antenna for the UHF RFID band represents an increased engineering challenge compared to designing it for the HF or LF bands because of the higher bandwidth needed for signals in the UHF band. It also becomes more difficult to maximize the performance of the antenna over the wider frequency range allocated for RFID systems in the UHF band. For this reason, while most of the HF and LF antennas follow the same basic design, engineers have developed several approaches to the design of UHF antennas for interrogators based on different performance parameters. This is especially critical for handheld applications in which the limited size of the antenna degrades its performance.

The patch antenna shown in Figure 4.17(a) is one of the most commonly used antennas for UHF interrogators. In its basic form, it consists of a metal patch of approximately one-half of a wavelength long and mounted over a ground plane. Figure 4.17(b) shows its equivalent electrical model.

Typical values for the equivalent circuit shown in Figure 4.17(b) are around 150 Ω for the radiation resistance of the antenna, between 9 and 10 pF for its capacitance, and from 2 to 4 nH for its inductance. The matching of the transmission line with a 50 Ω characteristic impedance to the relative high radiation resistance of the antenna is done by changing the location at which the transmission line feeds into the metal patch away from its center. The bandwidth of the patch antenna is a function of its dimensions and the separation between the metal patch and the ground plane. The type of dielectric used between the planes is also important, as dielectrics other than air will increase its equivalent capacitance.

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The patch antenna, by its very own design of using a ground reference as part of the antenna, is an unbalanced antenna. Because unbalanced antennas do not operate well when they are close to dielectric materials, and the human body can be essentially considered as a dielectric material at UHF frequencies, patch antennas are not the best choice for handheld interrogators. Furthermore, the size and weight limitations required by mobile and handheld interrogators further limit the use of patch antennas in these applications. A better solution for handheld and mobile interrogators are balanced antennas, that is, antennas with symmetric and opposed currents as shown in Figure 4.18.

When the antenna is fed using an unbalanced transmission line, such as a coaxial cable, it is necessary to use a balum transformer to match the unbalanced line to the balanced antenna. The basic theory behind this balum is the same as was described for HF and LF antennas. Although the structure shown in Figure 4.18 is technically feasible, an additional problem may arise due to the size required by half of a wavelength, especially for handheld interrogators. At the frequency of 915 MHz, the length of half of a wavelength is equal to 16 cm. While this is a very reasonable distance for a stationary antenna, it may be excessively large for applications involving handheld readers. In this case, it is possible to bend the dipoles in a similar way as is done for the antennas in transponders, as shown in Figure 4.19.

The reduction in size for the bent dipoles comes at the expense of degrading the electrical specifications of the antenna. In particular, its radiation resistance decreases and therefore the bandwidth of the bent dipole structure also decreases compared to the bandwidth of the regular dipole.

A different type of antenna used in UHF interrogators (either stationary or mobile) is based on the Yagi-Uda antenna. This structure, shown in Figure 4.20, consists of a driven element and two or more parasitic elements: one reflector and one or more directors. The parasitic elements direct the majority of the

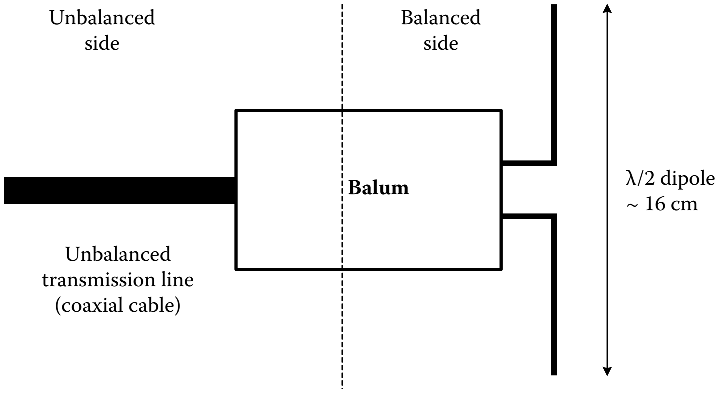

FIGURE 4.18
Balanced half-wavelength antenna.

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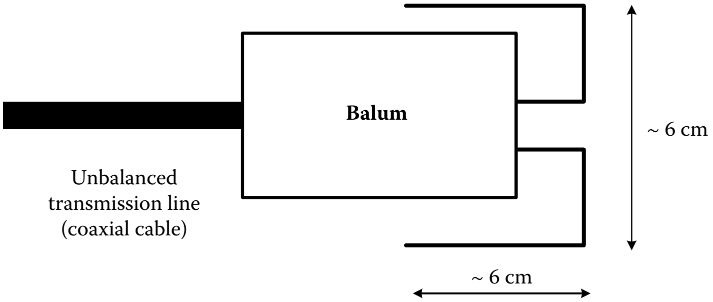
Balum
~ 6 cm
Unbalanced
transmission line
(coaxial cable)
~ 6 cm

FIGURE 4.19
Bent dipole for a UHF interrogator antenna.

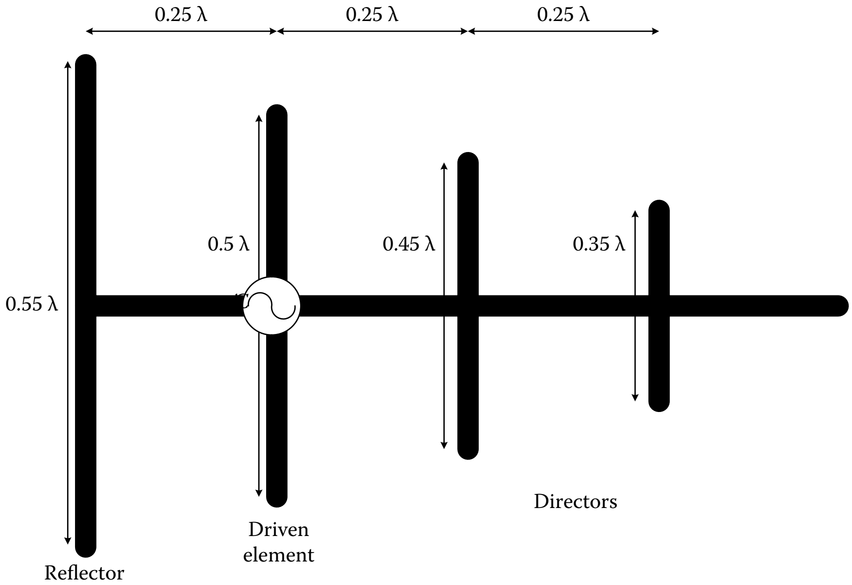
0.25 λ
0.25 λ
0.25 λ
0.5 λ
0.45 λ
0.35 λ
0.55 λ
Directors
Driven
element
Reflector

FIGURE 4.20
Yagi-Uda antenna.

energy radiated by the antenna toward the director. Therefore, this structure helps to minimize the interaction of the radiated field with a person who may be holding an antenna for handheld interrogators. Moreover, because this is a balanced antenna, this interaction between the energy radiated by the antenna and that radiated by the human body is further minimized.

In its original form, however, Yagi-Uda antennas can still be considered too large to use with handheld interrogators. In this case, it is possible to bend the dipole and longer elements, as described above. The existence of the parasitic elements will provide additional gain compared to the single dipole.

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4.3.2 Transmission Lines and Connectors for UHF Interrogators

Contrary to LF and HF systems, the coaxial cables and connectors typically used in UHF RFID systems have the potential to extremely degrade the signal they transmit. The main reason for this problem is the skin depth. *Skin depth* describes the effect that the current flowing through a conductor flows through a portion of its inner surface. Equation (4.12) shows that the skin depth (δ) is inversely proportional to the frequency of the signal:

$$\delta = \sqrt{\frac{1}{\pi \mu \sigma f}} \tag{4.12}$$

where δ is the skin depth, μ the magnetic permeability of the conductor, σ its conductivity, and f the frequency of the current flowing through the conductor.

Therefore, an increase in the signal frequency results in a smaller portion of the conductor being used to transmit the signal. For a typical conductor made of copper, the skin depth for an LF signal is 0.2 mm, the skin depth for an HF signal is 55 µm, and for a UHF signal it is 2 µm. Consider a copper conductor with a radius of 0.2 mm. At LF frequencies and below, the current will flow through all the conductor area. When the frequency increases to 13.56 MHz, only the first 55 µm are actually available as a path for the current. The effective area has been reduced to a half of the area available for an LF signal. Because the conductivity of the conductor depends on its area, the conductivity of this conductor at HF is about half of its conductivity at LF. The situation changes more dramatically at UHF frequencies, as the skin depth of 2 µm means that current can flow only through the outer 1 percent of the conductor. With this, the conductivity of the copper wire for UHF signals has been reduced in a factor of 62 compared to the conductivity at LF. This strong decrease in conductivity introduces considerable losses that may render the system unusable. Figure 4.21 further illustrates this situation.

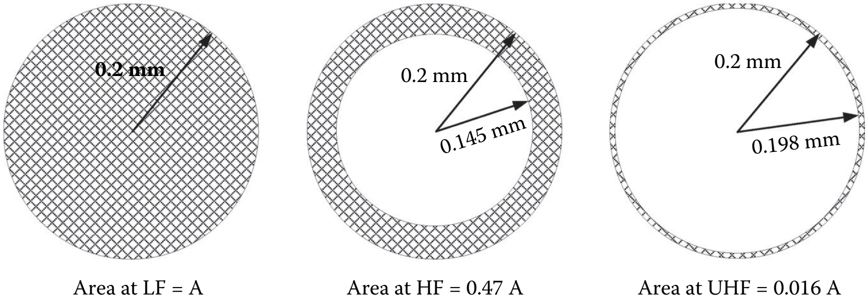

Area at LF = A   Area at HF = 0.47 A   Area at UHF = 0.016 A

FIGURE 4.21
Skin effect at (a) low frequency (LF), (b) high frequency (HF), and (c) ultra-high frequency (UHF). Current flows through the shaded areas.

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With these considerations, the layout of the transmission line used to connect the UHF interrogator to its antenna becomes critical. The most effective approach to improving the performance of the system is to minimize the length of transmission line between the output of the interrogator and its antenna. It can also be possible to use transmission lines with larger diameter wires; however, the slight increase in effective area does not compensate for the additional cost of these lines or their increased rigidity. It is also important to choose a coaxial cable that has a continuous outer conductor instead of a multistrand ribbon for its shield.

The use of adequate connectors is also critical for RFID systems working in the UHF band. The BNC connectors that are commonly used in the LF and HF bands could be used without significant performance degradation in UHF applications. However, other types of connectors, specifically designed for higher frequencies, produce more reliable results. TNC connectors were conceived as a threaded version of the BNC connectors, being suitable for use up to 10 GHz. Type-N connectors are commonly used in high-frequency applications as they are suitable to carry signals up to 10 GHz and even 18 GHz with their recent enhancements. They are also mechanically robust and well suited for outdoor use. Figure 4.22 shows a male type-N connector, while Figure 4.23 shows a female type-N connector.

Because type-N connectors are available in 50 Ω and 75 Ω versions and the connectors are typically not labeled, it is very easy to confuse them, originating an impedance mismatch. Furthermore, the dimensions of their inner conductors are slightly different, so mismatching the connectors may

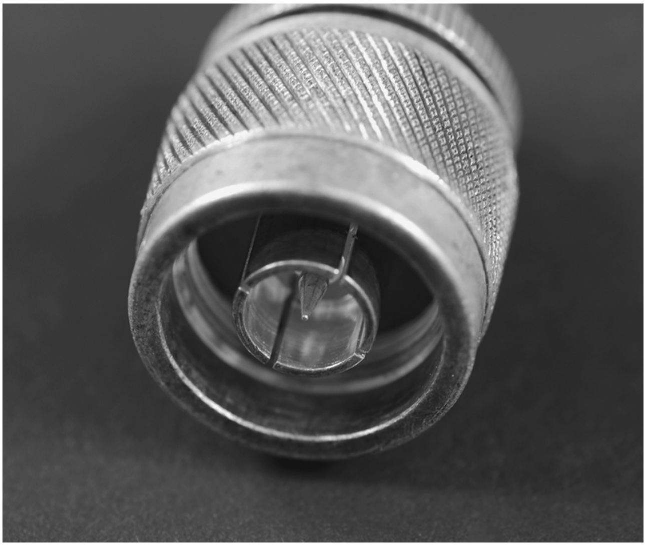

FIGURE 4.22
Male type-N connector.

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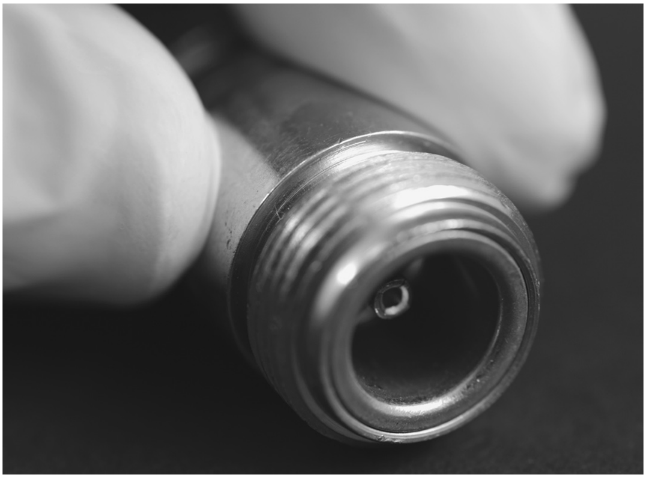

FIGURE 4.23
Female type N-connector.

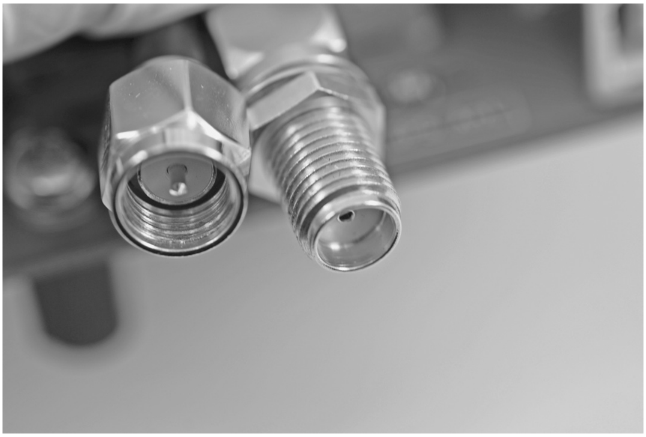

FIGURE 4.24
Male and female subminiature version A (SMA) connectors.

also damage them physically. Subminiature version A (SMA) connectors, shown in Figure 4.24, are perhaps the most widely used microwave connector and are becoming more used in RFID systems. SMA connectors can transfer signals up to 18 GHz and have a 50 Ω impedance. The main problem using this type of connector is that they have not been designed to be connected and disconnected constantly, like for example a BNC connector. Even with the best of care, they cannot exceed a few hundred connections and disconnections.

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4.4 Commercial Antennas for RFID Interrogators

4.4.1 Antennas for RFID Interrogators

Antennas for interrogators are available from the same manufacturers that make transponders and interrogators, as well as third-party vendors that build interrogator antennas for specific applications. Some manufacturers offer systems in which the antenna and the interrogator are integrated together, as is the case with handheld RFID systems.

Texas Instruments manufactures two types of antennas for the LF band under the generic name of Series 2000. These antennas are divided into *gate antennas* and *stick antennas*. Table 4.1 shows the specifications of these antennas.

As shown on Table 4.1, gate antennas mainly differ in their size. Designers of RFID systems choose the size of the antennas based on the required application, depending on the area that they have to cover. The stick antennas S01C and S02C are identical, with the only difference being the length of their coaxial cable: 1 meter for S01C and 3 meters for S02C. Choosing between gate antennas and stick antennas is also application dependent. In general, gate antennas offer a larger read zone and more read distance, while stick antennas offer a more focused zone. Therefore, if for example it is necessary to distinguish between different transponders, stick antennas will be more useful due to their more defined radiation field.

Some manufacturers have designed HF antennas that are shaped in a particular way for a specific application. For example, Unified Transponder Concepts, Inc., produces several antennas specific for laundry systems. One of them is shaped like a garment portal to be used with standard garment racks for clothes with an embedded RFID transponder. Another example from the same manufacturer is an antenna in the shape of a chute, used for the detection and control of deposited items tagged with the appropriate transponders. In addition, they also manufacture the more traditional panel and handheld antennas. The power levels accepted by these antennas ranges from 1 W to 4 W, and they all exhibit a resistance of 50 Ω at 13.56 MHz.

TABLE 4.1

Specifications for Some Texas Instruments Series 2000 Antennas Operating in the LF Band (134.2 kHz)

	Model	Inductance	Dimensions	Weight
Gate Antennas	G01E	27 µH	0.7 m x 0.2 m	745 grams
	G02E	27 µH	0.2 m x 0.2 m	425 grams
	G04E	26 µH	1.1 m x 0.52 m	2500 grams
Stick Antennas	S01C	27 µH	0.14 m x 2mm (Ø)	134 grams
	S02C	27 µH	0.14 m x 2 mm(Ø)	185 grams
	P02A	116 µH	0.13 m x 21.3 mm (Ø)	105 grams

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TABLE 4.2

Specifications for UHF Antennas Manufactured by NetHome

	Dimensions (mm)	Gain	Polarization	Connector
NT-900-SPP	90 x 90 x 25	0 dBi	Right / Left hand	SMA
NT-900-MPP	120 x 120 x 25	0 dBi	Circular	SMA
NT-900-CP	200 x 200 x 25	6 dBi	Right / Left had	SMA
NT-900-FP	360 x 260 x 25	6 dBi	Circular	TNC

TABLE 4.3

Specifications for MTI Wireless Edge Antennas Operating in the 400 MHz Range

Model	Frequency (MHz)	Dimensions (mm)	Gain	Polarization	Connector
MT182018	430 – 440	305 x 305 x 25	3.5 dBi	Circular LH	N-type Female
MT182016	430 – 437	370 x 370 x 30	9 dBi	Circular LH	N-type Female
MT181033	430 – 440	305 x 305 x 25	3 dBi	Linear	N-type Female
MT182011	405 – 450	370 x 370 x 40	8 dBi	Linear	N-type Female

TABLE 4.4

Specifications for MTI Wireless Edge Antennas Operating in the 865 MHz to 870 MHz Range

Model	Dimensions (mm)	Gain	Polarization	Connector
MT242032	190 x 190 x 30	7 dBi	Circular LH or RH	N-type Female
MT242040	190 x 190 x 30	7.5 dBi	Circular LH or RH	N-type Female
MT242033	540 x 470 x 220	8.5 dBi	Circular LH or RH	N-type Female
MT242034	685 x 626 x 220	8.5 dBi	Circular LH or RH	N-type Female
MT242027	260 x 260 x 30	8.5 dBi	Circular LH or RH	N-type Female
MT242014	305 x 305 x 25	8.5 dBi	Circular LH or RH	N-type Female
MT242017	371 x 371 x 40	10 dBi	Circular LH or RH	N-type Female
MT243017	650 x 320 x 40	11 dBi	Circular LH or RH	N-type Female

There is a larger number of independent manufacturers for antennas operating in the UHF range. For example, the Korean manufacturer NetHom offers flat, patch antennas that operate in the 902 MHz to 928 MHz range and have an input impedance of 50 Ω, as shown in Table 4.2.

Another manufacturer, MTI Wireless Edge Ltd., offers a vast array of standalone antennas for a wide number of frequencies and applications. Table 4.3 shows specifications for their line of antennas in 400 MHz UHF RFID range. All the antennas shown in Table 4.3 have a maximum input power of 6 W and an input impedance of 50 Ω.

The same manufacturer also offers antennas that operate in the 865 MHz to 870 MHz frequency range, have an input impedance of 50 Ω, and have a maximum allowable power of 6 W. Table 4.4 shows the rest of the specifications for these antennas.

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TABLE 4.5

Specifications for MTI Wireless Edge Antennas Operating in the 2.4 GHz Range

Model	Dimensions (mm)	Gain	Polarization	Connector
MT343024	190 x 190 x 30	13 dBi	Circular LH or RH	N-type Female
MT344034	305 x 305 x 15	15.5 dBi	Circular LH or RH	N-type Female
MT345014	371 x 371 x 40	19 dBi	Circular LH or RH	N-type Female

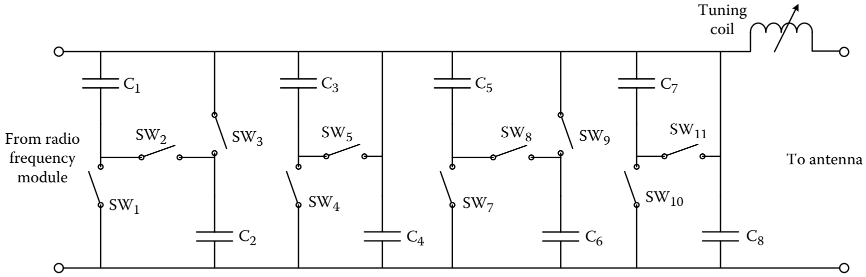

FIGURE 4.25
Schematic for the tuning board in the Series 2000 Reader from Texas Instruments.

It is also possible to purchase antennas similar to those shown in Table 4.4 dual polarized, that is, being both right-hand (RH) and left-hand (LH) circularly polarized. In this case, the antennas have two N-type female connectors, one for each polarization. Other models for antennas in the same frequency range of 865–870 MHz are available for linear polarization. In addition, this manufacturer also offers antennas for the 902–928 MHz and 950–956 MHz frequency ranges with dimensions and gains similar to those shown in Table 4.4 for either single or dual polarization.

Table 4.5 shows the specifications for a sample of antennas from MTI Wireless Edge Ltd. operating in the 2.4 GHz to 2.5 GHz frequency band and having an input impedance of 50 Ω.

Once again, antennas with similar dimensions and gains for the 2.4 GHz range are also available for single- and dual-linear polarizations.

4.4.2 Tuning Boards for Interrogator Antennas

Tuning boards are the circuits that are used to provide the high resonance needed to increase the strength of the field generated by the antennas in the system. Tuning boards can be found as stand-alone systems or as part of the interrogators. This subsection describes the Antenna Tuning Board that is part of the 2000 Series Reader System manufactured by Texas Instruments as an example of this type of circuits. As shown in Figure 4.25, the tuning board consists of a series of capacitors that are connected in parallel with the inductance of the antenna by means of several switches

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TABLE 4.6

Resulting Capacitance for Different Configurations of Switches in Tuning Board

Switch	Capacitance (nF)	Connection
SW1	33	C_2 ON
SW2	16.5	C_1, C_2 in series
SW3	33	C_1 ON
SW4	33	C_4 ON
SW5	16.5	C_3, C_4 in series
SW7	15	C_6 ON
SW8	7.5	C_5, C_6 in series
SW9	15	C_5 ON
SW10	10	C_8 ON
SW11	5	C_7, C_8 in series

(SW1–SW11) in the same board, thus allowing one to match a wide range of antenna inductances.

Table 4.6 shows the capacitive effect of each one of the switches in the tuning module. It can be seen that the lowest capacitance occurs when only SW11 is closed, resulting in a total capacitance of 5 nF. The highest capacitance that can be achieved with the board is equal to 139 nF, which occurs when SW1, SW3, SW4, SW7, SW9, and SW10 are closed.

The initial, coarse tuning adjustment is done with the capacitors, while the fine tuning due to the steps in the overall capacitance is done with the tuning coil located at the end of the tuning board. This process is repeated while monitoring the strength of the field generated by the antenna until it reaches a maximum.

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5

Interrogators

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Interrogators have two basic functions: to generate and transmit the radiofrequency signal used to energize the transponders and to receive and decode the backscattered signal generated by the transponders. In addition, some interrogators may also transmit specific commands to the transponders. The interrogator also handles the bidirectional communication with a host computer used to process the information from the transponders and to issue commands to the interrogator. Figure 5.1 shows a basic block diagram of a generic interrogator with its basic constituent blocks.

If the transponder is able to accept commands from the interrogator, the radiofrequency signal generated by the interrogator has to be further modulated with the specific code; otherwise, the interrogator will only transmit the radiofrequency carrier. In either case, the radiofrequency signal is then amplified to specific power levels and passed through the tuning circuits before reaching the antenna. The antenna is also used to detect the backscatter signal generated by the transponder, which, after being filtered, is

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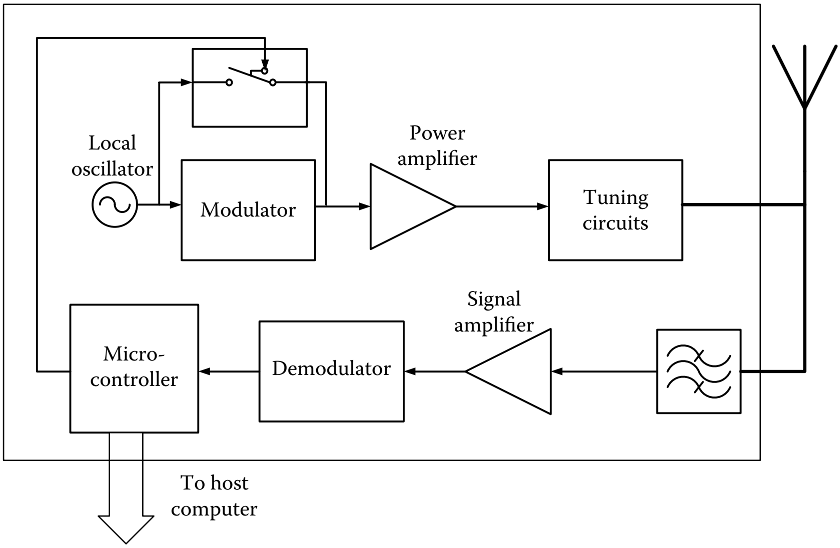

FIGURE 5.1
Basic block diagram of a generic interrogator.

then amplified and demodulated if necessary. The resulting signal is then sent to a microcontroller that will transmit it to the host computer using the appropriate communications protocol. The microcontroller also manages the timing for the interrogator to act as a transmitter or a receiver.

This chapter starts describing the transmitter and receiver sections in an interrogator. It continues by studying the most commonly used digital modulations in RFID systems. Afterwards, the chapter discusses issues related to extending the read range between transponder and interrogator as well as the requirements for interrogator synchronization when two or more interrogators coexist within the same general area. The last section in this chapter provides a description of the structure in different commercial interrogators.

5.1 Transmitter and Receiver

The basic structure of the transmitter section in the RFID interrogator contains an oscillator operating at the frequency of interest, a voltage or power amplifier, and the tuning circuits to match the impedance of the transmitter to the characteristics of the antenna. In addition to providing the radiofrequency signal to energize the transponders, some interrogators also transmit commands to the transponder. They can also be able to write new data into

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the transponder's memory. Transmitters in a RFID system must generate an accurate radiofrequency signal while minimizing the spurious radiation that they produce. *Spurious radiation*, common to all transmitters, is the amount of energy that falls outside the desired transmission band. In addition, they have to be as efficient as possible in order to reduce the amount of energy dissipated as heat. Excessive heat can severely reduce the life span of electronic components and must be reduced to acceptable levels.

For read-only transponders, the interrogator continuously transmits the radiofrequency signal and receives the response from the transponders. This mode of operation is known as *tag talks first*. When read/write transponders are being used, the interrogator must send commands for reading or writing them. For example, in the devices used by Microchip Technology, the interrogator uses amplitude modulation to transmit commands to the transponders. The communication starts by the interrogator sending specially timed gap pulses called *fast read request* (FRR) and *fast read bypass* (FRB). These gaps that are periods of time without electromagnetic field, are 175 μs wide, having a 100% modulation depth. The FRR or FRB pulses contain five of these gaps within 1.575 ms, as shown in Figure 5.2.

For RFID systems using magnetic coupling, one of the easiest approaches to drive the resonant circuit connected to the antenna is by using a D-drive circuit. Although either a full-bridge or a half-bridge will work correctly, most of the circuits use the half-bridge structure as it is less costly and easier to implement. Figure 5.3 shows a basic schematic for the half-bridge drive.

With a digital signal driving the circuit, the voltage at the node V_S is a square signal with voltages between V_{SS} and V_{DD}. Depending on the resonant quality factor (Q factor), the voltage across the antenna can reach a few hundred volts peak to peak. This is important to note at the time of selecting the electronic components used. An additional advantage of this structure is that although the driving digital signal has a very rich harmonic component,

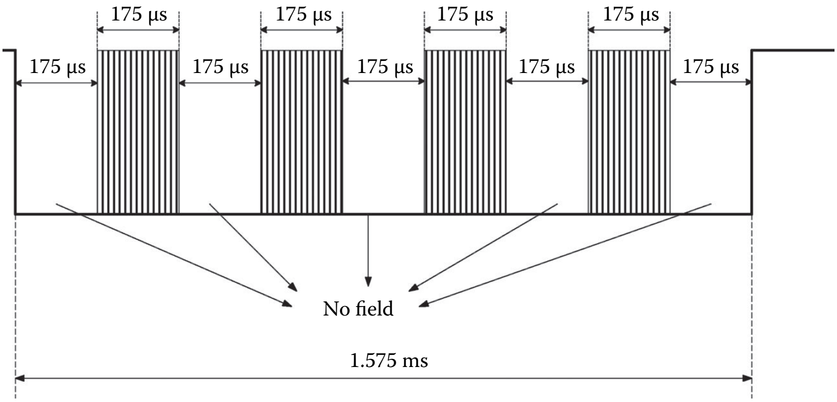

FIGURE 5.2
Fast read request (FRR) and fast read bypass (FRB) pulses.

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the signal across the antenna consists mostly of the fundamental component due to the filtering effect and the high Q factor value at the antenna. There are several devices commercially available that integrate the inverter and the two metal oxide semiconductors (MOSs) or metal oxide semiconductor field effect transistors (MOSFETs) in a single package. In addition to being able to operate at the high voltages generated, the capacitors used must have very low tolerance values due to the requirements for an elevated Q factor.

The typical rise and fall times for the signals using the circuit shown in Figure 5.3 range between 120 µs and 200 µs. This limits the data transmission rate that can be achieved. A modification of the circuit to increase transmission rates by reducing rise and fall times needs to accelerate the turn-on or turn-off response of the driver. This can be achieved by using the modified driver circuit shown in Figure 5.4.

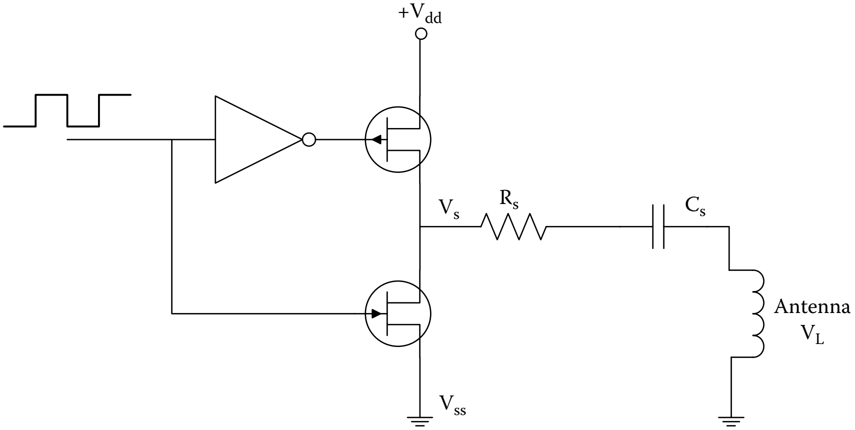

FIGURE 5.3
Half-bridge structure used to drive the resonant circuit.

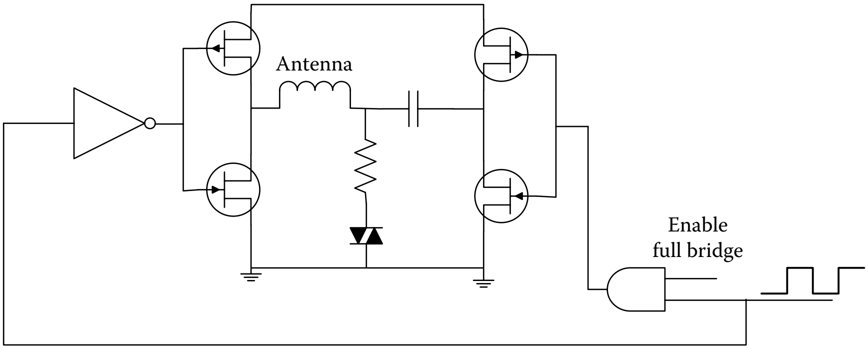

FIGURE 5.4
Modified bridge for increased transmission rates.

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The idea behind this circuit is to decrease the start-up time by starting the driver in full-bridge mode until the voltage has reached the desired value, at which point it can be switched back to half-bridge mode. Because the driver is started by driving the two half-bridges 180° out of phase, it effectively operates like doubling the input source voltage. With this structure, the circuit can respond up to three times faster. It is also necessary to keep in mind that the voltage across the capacitor will also increase and therefore the capacitor must be rated for that higher voltage. In order to reduce the electromagnetic interference generated by the circuit, the Triac is typically fired at zero.

The basic structure of the receiver in the RFID interrogator also contains a detector, typically an envelope detector, a signal amplifier, filters, and the appropriate pulse-shaping circuits. These circuits convert the distorted received signal at the output of the filters into pulses. These pulses are, in turn, connected to the input of a microcontroller that will send the appropriate data to the middleware or host computers for further processing.

Selectivity and sensitivity are key parameters for any radiofrequency receiver. *Selectivity* is defined as the extent to which a receiver can differentiate between the desired signal and unwanted signals present in its bandwidth. *Sensitivity* is defined as the minimum input signal that produces the minimal required output to be interpreted as information. Other important characteristics for receivers are their dynamic range, cross-modulation, and intermodulation distortion. *Dynamic range* refers to the range of signal levels simultaneously applied to the input for which the receiver will operate correctly. *Cross-modulation* and *intermodulation distortion* originate as a result of the nonlinear effects in the receiver that cause it to create new, undesired components.

For RFID systems with magnetic coupling, the transponder communicates with the interrogator by changing the value of the magnetic field. The transponder is magnetically coupled to the front end of the receiver in the interrogator. In this structure, changes in the magnetic field become voltage changes at the antenna in the interrogator. Figure 5.5 shows a basic block diagram following this approach. The peak detector extracts the envelope of the signal being transmitted. The peak detector is followed by a filter to remove the DC component of the envelope. A further low-pass filter removes the radiofrequency component, leaving only the envelope of the modulated signal. The output of the comparator is a digital signal with the information from the transmitted signal.

The peak detector must operate with the relative high voltages that may appear at the input of the tuning circuit. Moreover, it should not become a load to the tuning circuit either. Other requirements for the peak detector are to reduce the ripple in the carrier as much as possible, maintain the modulation of the signal, and possess low setting times, among others. It is not possible to optimize all these parameters simultaneously, thus requiring the designer of the system to find an acceptable compromise depending on its overall requirements.

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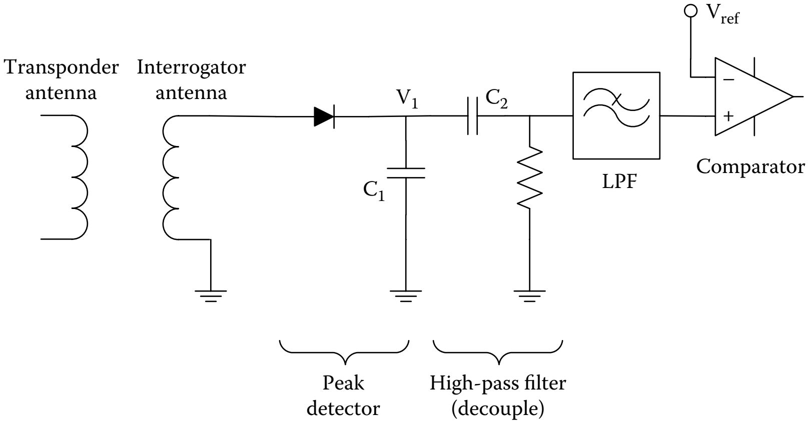

FIGURE 5.5
Basic structure for the detector in the RFID interrogator.

Example 5.1:

Discuss possible solutions for reducing ripple in the carrier.

Solution:

The ripple in the carrier can be reduced by increasing the value of the capacitor used in the peak detector. However, increasing the value of the capacitor will degrade the settling time for the detector, and will increase its loading effects. A possible solution would be to use an active peak detector. However, given the range of voltages expected at the input of the detector, the cost of the detector would significantly increase.

The voltage at node V_1 increases quickly when the input voltage increases due to the low impedance of the diode in forward mode. When the input voltage decreases, the voltage at node V_2 decreases extremely slowly due to the very high impedance presented by the diode in reverse conduction. This situation could be solved to some extent by placing a resistor in parallel with capacitor C_1 to help discharge it. However, this resistor has to be large enough for the peak detector to avoid loading the input circuits. A value of 10 MΩ is typically used.

The goal for the decoupling stage is to reject the high DC voltages present in the signal without excessive loading the front end. This stage should also have a fast dynamic response and stabilize quickly after detecting energy. The time constant of this stage is equal to the product of the resistance by capacitance C_2. The component values can be calculated by considering the delay time in establishing the communication after detecting the presence of radiofrequency energy as well as the minimum allowable voltage after the settling time. The cutoff frequency of the resulting high-pass filter has a strong effect in distorting and attenuating the digital signal that contains the information. With these conflicting requirements for the time constant, the

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simple RC circuit is not appropriate for removing the DC component of the received signal. Instead, it is necessary to use a circuit with either a nonlinear or a controllable time constant, as shown in Figure 5.6.

The diodes start conducting when the voltage across the resistor is above $(V_{REF} + V_{ON})$ or below $-(V_{REF} + V_{ON})$. This results in lowering the effective resistance seen by the circuit, and therefore it lowers its time constant. An additional benefit from using the diodes is that they protect the low-pass filter against positive or negative voltage spikes. The additional resistor R_2 is controlled by the switch. The switch is closed during transient periods and opened when data are being received by the circuit.

The low-pass filter stage is best implemented using an operational amplifier configured as an inverting amplifier, as shown in Figure 5.7. This structure not only allows controlling the gain in the pass band, but also minimizes its output impedance.

The cutoff frequency depends on the values of R_f and C_f. This frequency should be chosen at least two decades above the cutoff frequency from the DC blocker. It is also necessary to limit the gain of the filter to avoid the saturation of the operational amplifier. For some systems, the simple filter shown in Figure 5.7 may not provide enough attenuation at the desired frequencies. If this is the case, it can be substituted by a more complex filter. The three most common active filter topologies are Chebyshev, Butterworth, and Bessel filters. Chebyshev filters have the steepest transition between the pass and stop band, although they have ripple in the pass band. Butterworth filters have the flattest pass band, but their transition is not as steep as Chebyshev filters. Bessel filters have linear phase response with a smooth transition between

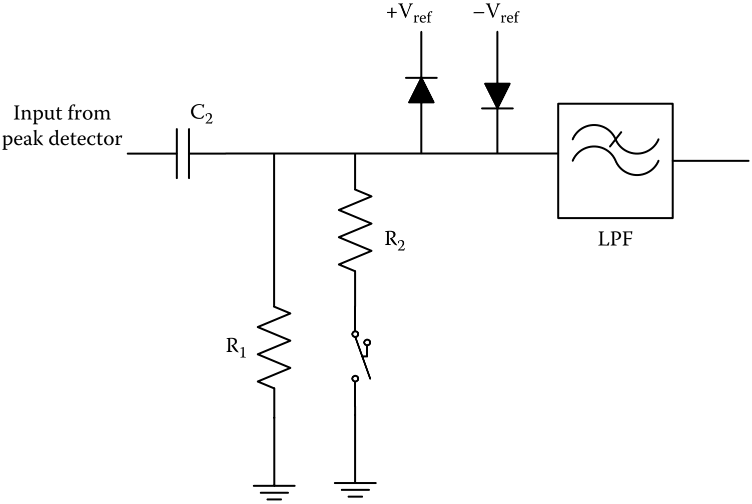

FIGURE 5.6
Circuit for implementing a nonlinear time constant.

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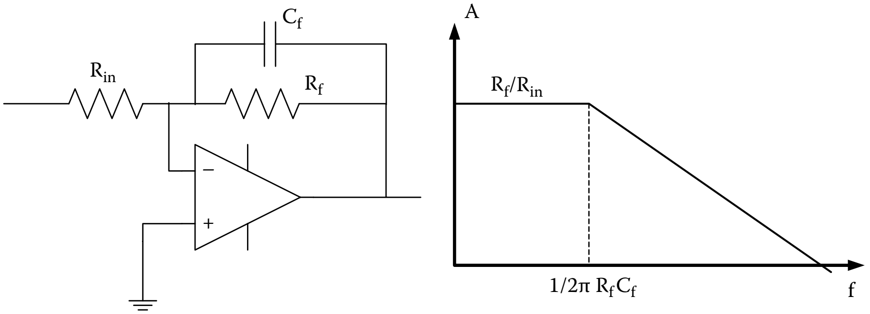

FIGURE 5.7
Low-pass filter stage.

pass band and stop band. When selecting one of these filter structures, it is necessary to consider not only their frequency response but also their transient response. For example, although Chebyshev filters have the best frequency response due to the fast transition between pass and stop bands, this results in an underdamped transient response with overshoot and ringing. Therefore, it has a very long settling time. Although Butterworth filters have a better transient response, they still exhibit some overshoot. The Bessel filter, although it has the worst frequency response, exhibits the best and fastest transient response and therefore is a very attractive candidate for this type of application.

The final stage is a comparator with some degree of hysteresis. The level of hysteresis is chosen to provide the required immunity against noise. The output of the comparator should be a digital signal that can be directly connected to the input of a microcontroller for further processing and transmission.

5.2 Modulator and Demodulator

5.2.1 Amplitude-Shift Keying (ASK) Modulation

Amplitude-shift keying (ASK) is the most basic form of modulation for digital signals. In ASK, data are represented as variations in the amplitude of the radiofrequency carrier. In binary ASK, there are only two symbols to be transmitted: the symbol *1* is normally represented by the full amplitude of the carrier, while the symbol *0* is represented by the minimal amplitude of the carrier. In this case, these two different symbols are represented by a single bit. In general, for *M*-ary ASK symbols, *n* bits are used to represent *M* symbols as

$$M = 2^n \tag{5.1}$$

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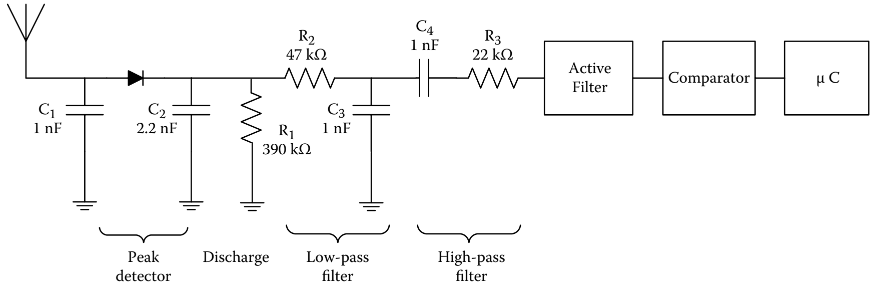

FIGURE 5.8
Detector in the receiver section of a commercial interrogator.

A *M*-ary ASK system requires distinguishing between *M* different amplitude levels for the radiofrequency carrier. While *M*-ary systems increase the transmission rate because each symbol encodes *n* different bits, the amplitude levels of the different symbols become closer to each other, making the system more susceptible to transmission errors. Therefore, there is a trade-off between the transmission rate and acceptable transmission errors.

The ASK signal is demodulated by detecting the envelope of the carrier, normally using a half-wave rectifier. This detects the peak amplitude of the signal generated by the transponder and feeds it into an RC circuit that charges and discharges accordingly. The time constant of the RC circuit must be chosen with these two considerations: (1) it must be small enough so the voltage across the capacitor diminishes fast enough in order to keep with the changes in the envelope of the signal, and (2) it must be high enough to avoid excessive ripple in the detected signal. After the envelope has been detected, the resulting signal is passed through a low-pass filter and a signal-shaping circuit and finally fed into a microcontroller. Figure 5.8 shows the schematic of the detector in the receiver section of a commercially available interrogator working in the LF range at 125 kHz.

The capacitor C_1 provides the resonance for the inductance of the antenna. An additional advantage of this structure is that because C_1 is grounded, the carrier finds a path to ground. The diode and C_2 form the half-wave rectifier for which the resistor R_1 provides a discharging path. The time constant of this circuit is approximately 850 µs. The signal is further low-pass and high-pass filtered before entering the comparator for processing.

5.2.2 Frequency-Shift Keying (FSK) Modulation

Frequency-shift keying (FSK) is a form of modulation in which the digital signal to be transmitted changes the frequency of the carrier within a predetermined set of available frequencies. The most basic case, in which only two instantaneous frequencies can be transmitted, is called *binary FSK* (2FSK). For more complex systems, and in order to increase the bit transmission rate, the number

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of possible instantaneous carrier frequencies is higher, normally a power of 2. This situation is called M-ary FSK, where M represents the total number of different possible instantaneous frequencies, as shown in equation (5.1).

Binary FSK transmits two different frequencies f_0 and f_1 to represent a logic *0* or a logic *1* following an established protocol. The transmission of 2FSK can be easily accomplished by having two oscillators operating at frequencies f_0 and f_1, followed by a switch that selects one or the other based on the digital input. Although this is a simple procedure, it results in discontinuities of the carrier frequency at the time of switching, thus resulting in a greater prominence of high-frequency components that implies the need for a much wider bandwidth transmission. 2FSK can also be generated using the VCO approach as is done for analog signals. Because the digital modulating signal will never have a zero rise or settling time, this digital modulation is in fact an analog modulation with a very short transition time. In this case, the carrier has a continuous and smooth transition, therefore guaranteeing phase continuity and requiring a narrower spectrum for transmission. This method is known as continuous-frequency shift keying (CPSK) and can also be readily applied for multilevel modulation systems.

FSK signals can be detected by *noncoherent detection* or *coherent detection*. Noncoherent detection is based on simultaneously injecting the 2FSK signal into two band-pass filters, each one tuned to the transmitted frequencies, f_0 or f_1, as shown in Figure 5.9. In this case, the output of each filter is connected to an envelope detector and their outputs are combined to reconstruct the baseband modulating signal.

An alternative method for noncoherent FSK detection is based on injecting the FSK signal to the input of a phase-locked loop (PLL). The output of the internal *voltage-controlled oscillator* (VCO) will switch between frequencies following the signal at the output of the PLL, thus locking on to the incoming FSK signal so that the output changes between the logic levels of *0* and *1*, depending on the frequency of the incoming signal.

Figure 5.10 shows the basis for coherent detection of FSK signals. This approach requires the generation of two carriers with the same exact frequencies and phases as those used by the transmitter. In this case, only one

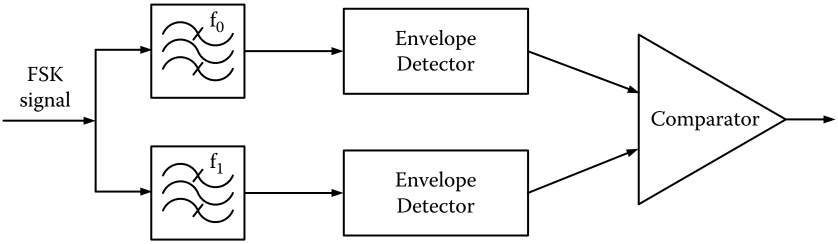

FIGURE 5.9
Noncoherent frequency-shift keying (FSK) demodulator.

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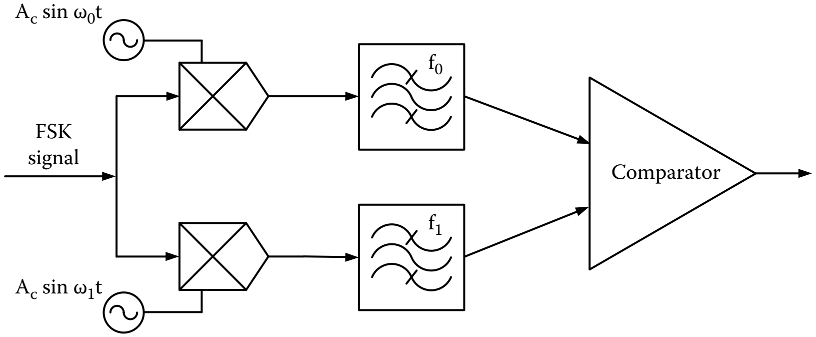

FIGURE 5.10
Coherent FSK demodulator.

of the filter outputs contains a signal at any given time. Therefore, after the addition of the two paths, the transmitting signal is recovered.

The coherent detection of FSK-modulated signals requires a more complex receiver than the noncoherent detection of the same signal, although it decreases the rate of errors for the transmission. Consequently, the designer of the system must consider the trade-offs between bit error rates and system complexity.

5.2.3 Phase-Shift Keying (PSK) Modulation

Phase-shift keying (PSK) modulation is one of the most effective methods to transmit digital signals. In PSK, the information is contained in the instantaneous phase of the modulated carrier. Usually, this phase is imposed and measured with respect to a known and selected phase of the carrier. For 2PSK, in which the modulating signal has two levels, the phase states are 0° and 180°. In M-ary modulation systems, the phase associated to each transmitted symbol is distributed equidistantly from each other around the 360° circle. When $M = 4$ ($n = 2$ bits), the resulting modulation is called *quadriphase phase-shift keying* (QPSK). QPSK, in which the phases are separated by 90°, is a common modulation used in communication systems.

Figure 5.11 shows a simplified version of one of the methods to generate a 2PSK signal. After the radiofrequency carrier is shifter by 180°, the resulting signal as well as the original signal are fed at the input of a 2-to-1 selector. This selector is driven by the digital signal. The output of the selector is either signal (a) or signal (b), depending on the value of the digital signal that controls the output of the selector.

PSK signals always require coherent demodulation, and therefore the PSK detector needs to know perfectly the phase of the unmodulated carrier. This requirement can be problematic as any phase error of the locally generated carrier reduces the effective voltage at the output of the detector in cos(Φ), thus degrading the signal-to-noise ratio. A solution to this problem is by the

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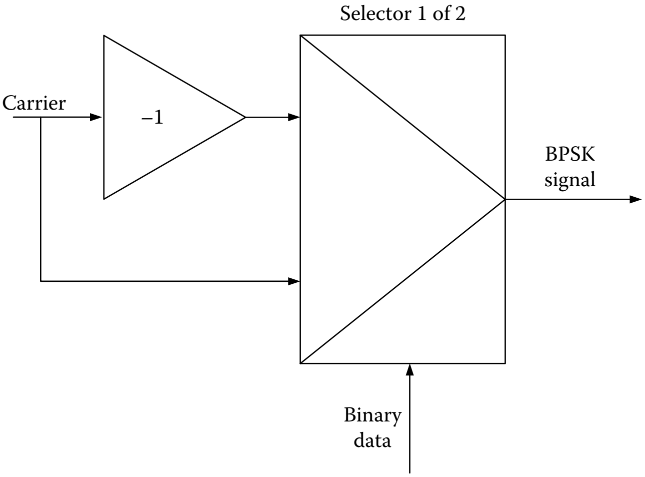

FIGURE 5.11
Binary phase-shift keying (2PSK) generation.

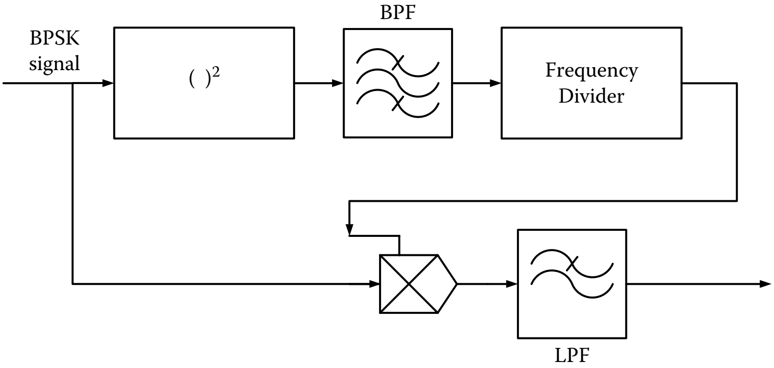

FIGURE 5.12
2PSK demodulation.

demodulator itself deriving a phase coherent reference to use in the demodulation process, as shown in Figure 5.12.

The output of the squaring circuit contains information at DC as well as at a double of the radiofrequency carrier. The band-pass filter eliminates the DC component. The frequency divider divides the frequency of the resulting signal by two and shifts its phase. The resulting signal is then multiplied by the original 2PSK signal that, after being filtered, will result in a DC signal with amplitude either positive or negative, thus shifted in 180°.

Figure 5.13 shows the generation process for QPSK signals. The digital-modulating signal $v_m(t)$ is connected to a 2-bit serial to parallel converter, so the resulting signals $v_1(t)$ and $v_2(t)$ change at half the rate of $v_m(t)$. This has the

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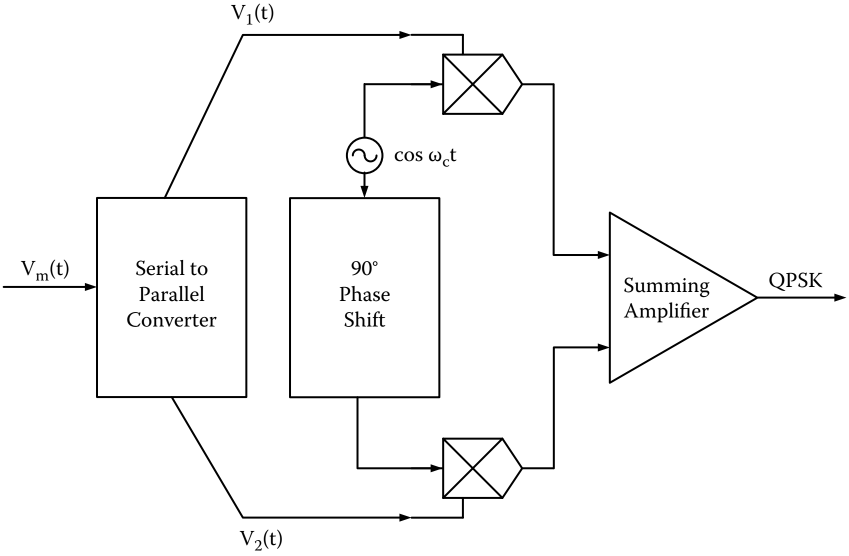
V1(t)
cos ωct
Vm(t)
Serial to Parallel Converter
90° Phase Shift
Summing Amplifier
QPSK
V2(t)

FIGURE 5.13
Quadriphase phase-shift keying (QPSK) generation.

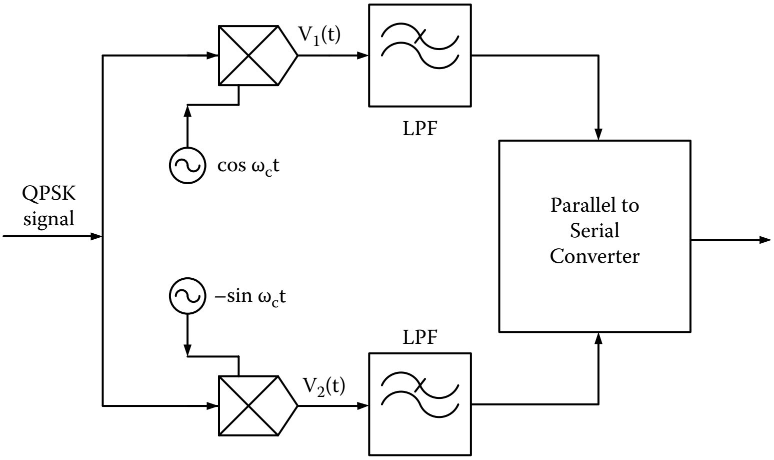
V1(t)
LPF
cos ωct
QPSK signal
Parallel to Serial Converter
−sin ωct
LPF
V2(t)

FIGURE 5.14
QPSK demodulation.

advantage of reducing the required transmission bandwidth as is the case of *M*-ary modulations. The output QPSK signal contains two components at the same frequency but shifted in 90°, and therefore there is no interference between them as they are in quadrature. That is, all the spectral components of the first term are 90° out of phase with those of the second term, making them independent from each other.

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The detection of the QPSK signal, as shown in Figure 5.14, follows an inverse process. The intermediate output signals $V_1(t)$ and $V_2(t)$ contain energy at DC as well as a frequency double the radiofrequency signal. This last component is eliminated by the low-pass filter, resulting in two separate streams of digital data. There are combined into a single data stream by the parallel-to-digital converter, thus recovering the original digital-modulating signal. QPSK modulation allows for sending information at twice the speed of 2PSK using the same bandwidth without compromising the performance of the system from the point of view of error rates.

Figure 5.15 shows a basic diagram of a 2PSK demodulator used in a commercial RFID interrogator operating in the LF range at 125 kHz. Capacitor C_1 provides the capacitance for resonance with the inductance of the antenna. The two diodes are used for detecting the envelope of the signal; each diode is on during half of the cycle. The 1 MΩ resistor is used to discharge the voltage store in capacitor C_2 used for the envelope detection. The envelope signal is fed into a series of active filters and pulse-shaping circuits not shown in Figure 5.15. The output of the last pulse-shaping circuit is a square wave at a frequency that is half of the radiofrequency carrier signal. This signal exhibits a 180° phase shifts according to the digital data sent by the transponders. This signal is now used as the clock for a D-type flip-flop. The input to the flip-flop is a signal at the same frequency derived from the transmitting signal. As the phase of the detected signal V_{out} changes, the output of the flip-flop also changes, thus recovering the digital information sent by the transponder.

One of the major problems with the design shown previously is that the phase of the returned signal can be, in certain conditions, unpredictable. For example, if the transitions of the incoming signal and the reference signal occur at the same time, the output of the flip-flop becomes unpredictable. This situation can be avoided with additional circuitry that intentionally shifts the phase between the signals to 90°, making it ideal for PSK detection.

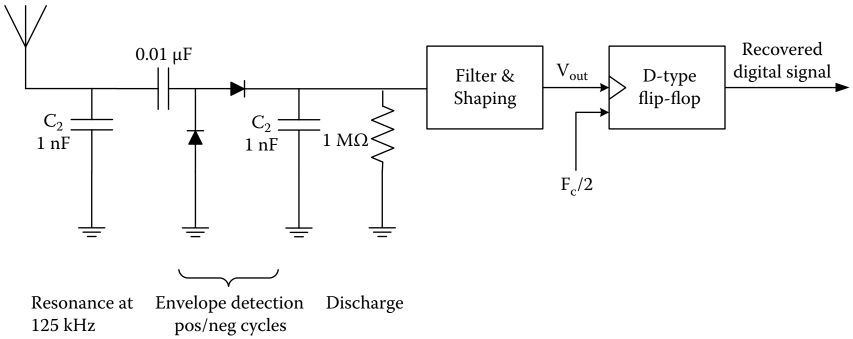

FIGURE 5.15
2PSK demodulator in a commercial interrogator.

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5.3 Long-Range Considerations

When evaluating the read range of transponders, it is necessary to understand that long-range operation may not always be a desirable condition. For example, in an environment where several interrogators communicate with their own transponders, it is necessary to ensure that a specific interrogator reads data from only the transponders that it has been assigned. Data from a distant transponder would then be treated like an interfering signal.

If long range is truly needed, it can be achieved by one or more of the following design considerations:

Increasing the transmitter output power. This can be achieved by designing the power amplifiers in the transmitter section in the interrogator with higher gain. Alternatively, when it is not possible to modify the interior of the interrogator, it is then possible to use an external preamplifier. In any case, it is necessary to comply with the limits set by the appropriate regulatory agencies on limits of power for different frequency range. Also, some regulatory agencies may also limit the ability of a user to modify a system that has already been approved and certified by the regulatory agency. This comes from the fact that the modification of the gain in the amplifiers can have effects on the frequency stability, spectral purity, and other characteristics of the transmitted signal that are specified by the regulatory agencies.

Modifying the size of the antenna. As described in Chapter 4, the size of the antenna and its quality factor (Q factor) affect the characteristics of the signal being transmitted and therefore the range at which transponders receive enough energy to activate their internal circuits. A correctly sized antenna becomes critical for long-range applications.

Optimizing the sensitivity of the receiver. Merely increasing the power in the transmitter section may not have a significant effect in the read range of the system if the signals generated by the transponder cannot be detected by the receiver. Therefore, interrogators to be used for long-range applications must have front-end amplifiers with high enough sensitivity that will allow them to detect the signals from the transponders at the longest distance from the interrogator that has been specified. In addition to the optimal design of the receiver, the sensitivity of the interrogator can be increased by reducing the amount of noise and interference added to the desired signal. This can be achieved by appropriate shielding of the front-end components, by placing the interrogator away from electrically noisy sources and using pass-band filters.

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5.4 Interrogator Synchronization

Synchronization is used to prevent interference between the interrogators in applications that have multiple interrogators operating in the same area. Synchronization is based on preventing interference by coordinating their transmission and reception windows. Synchronization is only required when the different interrogators are located physically close to each other. Therefore, when working with multiple interrogators, it is critical to determine if synchronization is required. However, the distance between interrogators alone is not sufficient to determine the need for synchronization. The electrical path between interrogators is affected by the presence of metallic structures such as buildings, the existence of conveyors, the layout of nearby power or data cables, and even the existence of reinforcing metal bars in concrete floors. Assuming only radiated signals, Texas Instruments has published some guidelines for the maximum distances that require synchronization for interrogators using some of their antennas as shown in Table 5.1. It is important to note that Table 5.1 assumes the two interrogators are using the same antenna type.

Table 5.1 shows that antennas with larger dimensions require more separation. Because this table assumes only radiated signals, in more realistic situations, this distance can be highly reduced due to the additional paths available to the different radiofrequency signals. This table can also be used as a starting point when working with interrogators using different antennas.

The next step, after determining that synchronization between interrogators is needed, is to decide on the method used to synchronize them. Although the following are the synchronization methods available to some of the Texas Instruments interrogators, the same methods are used by interrogators from other manufacturers.

5.4.1 No Synchronization at the Interrogator Level

This method can only be used with a single reader or in the case of synchronization by software. It represents the fastest method for receiving

TABLE 5.1

Separation between Interrogators After Which Synchronization Is No Longer Necessary Assuming Only Radiated Signals

Antenna Type	Antenna Dimensions	Minimum Separation Distance
S02-C (stick antenna)	Ø = 21 mm; l =140 mm	18 meters
G02-E (gate antenna)	200 mm x 200 mm	32 meters
G01-E (gate antenna)	715 mm x 170 mm	55 meters
G04-E (gate antenna)	1018 mm x 518 mm	105 meters

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information from the transponders. If all the interrogators are connected to the same network, the coordination can be carried out by the host computer issuing commands to read transponders simultaneously and buffering the results, or issuing different commands to different interrogators in turn. In any case, the coordination is done by the host computer rather than by the interrogators.

5.4.2 Wireless Synchronization

In wireless synchronization, when a specific interrogator detects increased energy at the frequency of the carrier, it assumes that this energy has been generated by another interrogator. This makes it stop itself before starting its own cycle. Obviously, this method only works when the background noise is low for the type of antenna being used. Larger antennas, which are more sensitive, present a clear disadvantage in this situation. When the environmental conditions change and there are additional reflections of signals in the immediate electrical environment, this approach is not valid either.

The receiver in each individual interrogator is adjusted in order to determine the level of background noise in the absence of signals from other interrogators. This determines the level after which the interrogator assumes that another interrogator is transmitting and therefore waits for a predetermined amount of time before starting its own cycle. This situation is illustrated in two situations depicted in Figure 5.16.

Figure 5.16(a) shows a time diagram involving wireless synchronization when the interrogator has not detected the presence of other signals. The interrogator starts by transmitting the radiofrequency signal for 50 ms that is used to energize the transponder. After the transponder is energized and recognizes the end of the radiofrequency energy burst, it starts transmitting its data for 20 ms. Once the transponder has finished sending its data, the interrogator waits for another 20 ms before starting the whole process again. This additional period is build as a precaution to avoid corrupting the data from other transponders to other interrogators. Because the interrogator does not detect any signals during this last 20 ms period, the whole cycle takes 90 ms.

In Figure 5.16(b), however, after the transponder has completed sending its information to the interrogator, the interrogator detects the presence of radiofrequency energy, and therefore responds by waiting 70 ms before starting its new cycle. This additional period gives enough time for the second interrogator to finish its own cycle. After the 140 ms have elapsed, the first interrogator starts its own cycle regardless of the presence of radiofrequency energy. This is done in order to prevent the interrogators always giving priority to other interrogators and therefore not being able to read their own transponders.

Wireless synchronization has the advantages that it does not need wires to interconnect the interrogators and all the interrogators are autonomous

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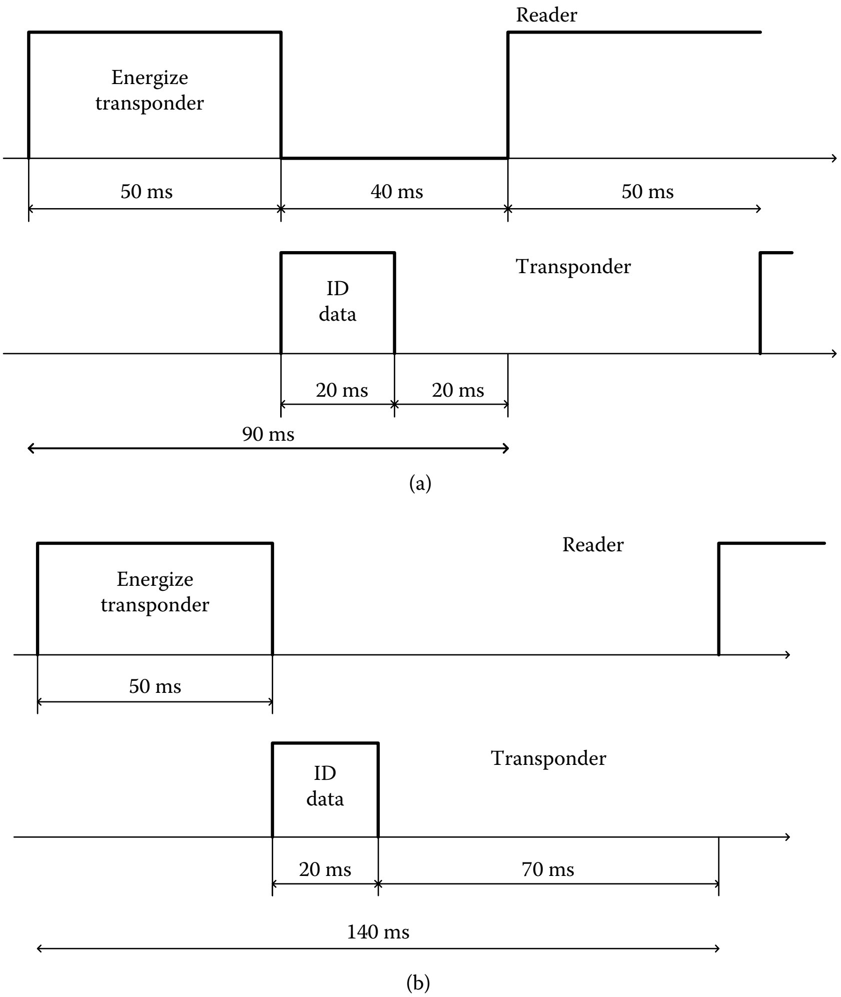
Reader
Energize transponder
50 ms
40 ms
50 ms
Transponder
ID data
20 ms
20 ms
90 ms
(a)
Reader
Energize transponder
50 ms
Transponder
ID data
20 ms
70 ms
140 ms
(b)

FIGURE 5.16
Wireless synchronization: (a) no other interrogators detected, and (b) delayed cycle due to other interrogators detected.

as there is not a master unit. It is very useful when handheld units have to coexist with fixed interrogators for these reasons. Wireless synchronization, however, is not adequate when large antennas are used in noisy environments because these large antennas are too sensitive to the background noise levels. Also, it cannot be used when the environmental conditions change, for example when vehicles enter or leave the read area as it changes the background energy. Finally, it cannot be used when other interrogators write data to the transponders.

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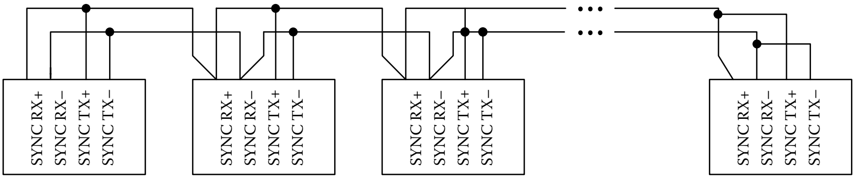

FIGURE 5.17
Structure of the control modules in interrogators using wired synchronization.

5.4.3 Wired Synchronization

The approach in wired synchronization is the same as for wireless synchronization with the only difference being that it uses wires to detect the presence of other interrogators instead of detecting radiofrequency energy. Therefore, the cycle for a single interrogator lasts 90 ms or 140 ms as described for wireless synchronization. This presents the advantage of being able to operate regardless of the environmental noise level, using a single twisted pair cable. This approach does not need a master unit. The main problem with wired synchronization is that if the power for a single interrogator fails, the bus fails and therefore the whole system fails. It is also not suitable for read/write transponders. Figure 5.17 shows the standard connection for the control modules of the interrogators using wired synchronization using the following nomenclature:

SYNC RX+: Noninverted data input
SYNC RX–: Inverted data input
SYNC TX+: Noninverted data output
SYNC TX–: Inverted data output
GND: Signal ground

5.4.4 Combined Wired–Wireless Synchronization

Using this approach, interrogators synchronized using a hard wire connection are also detecting the amount of radiofrequency energy to decide if another interrogator is already operational. This method resolves the individual disadvantages of each single approach.

5.4.5 Master–Slave Synchronization

In this approach, which is probably the most commonly used method of synchronization, one of the interrogators is configured as the master while the rest of the interrogators are configured as its slaves. Master–slave synchronization can be carried out using three variants:

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Master–slave without acknowledgment. This method is the fastest approach for reading transponders as it assumes that all the interrogators are part of the same synchronization bus. This requires the interrogators to have a synchronization bus that connects all the readers, using for example a single twisted pair as shown in Figure 5.18.

Once the master has finished a complete read cycle, it transmits a synchronization pulse in the bus. Any slave that has finished its own cycle is waiting for this pulse in order to start a new cycle, as shown in Figure 5.19.

This approach presents the advantage of needing only a single twisted pair. It also has the fastest read rate and can be used when transponders are rewritten by interrogators. It is necessary, however, to keep in mind that if the master fails, the rest of the units stop working. Also, if a slave reads a transponder and the master does not, the slave may miss the next pulse as it is busy processing the information from its transponder.

Master–slave with acknowledgment. In this approach, the master has to wait until all the slaves have completed their cycles before starting a new master cycle. This requires using four wires: two for the pulse from the master and two for the information from the slaves to the master, as shown in Figure 5.20.

All the interrogators are running free while buffering the data via a point of data connection. A slave will not respond to a command from the host computer unless it has received the pulse from the master. This method presents the advantage that all the interrogators wait for the slowest to be complete and all the units are able to write to the transponders. This happens at the price of using a twin twisted pair instead of a single.

Master–slave triggered synchronization. This is similar to the previous approach, although in this case, the pulse is generated by an external device instead of an interrogator in the chain. All the interrogators

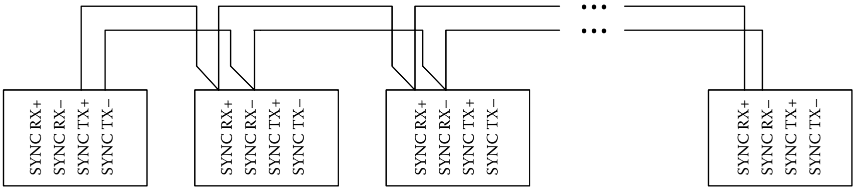

FIGURE 5.18
Structure of the control modules in interrogators using master–slave synchronization without acknowledgment.

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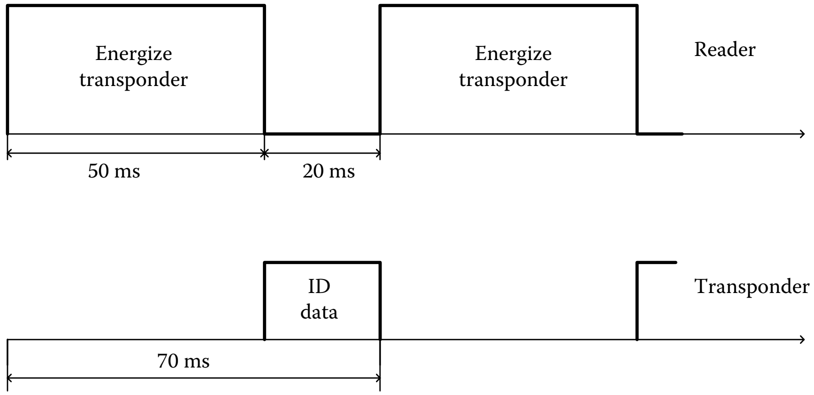

FIGURE 5.19
Master–slave synchronization without acknowledgment.

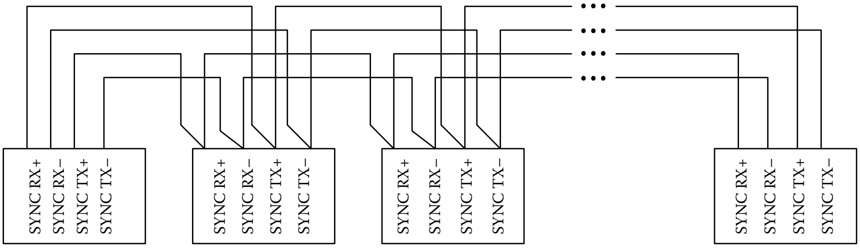

FIGURE 5.20
Structure of the control modules in interrogators using master–slave synchronization with acknowledgment.

are configured as slaves with the external master issuing the synchronization pulses at suitable intervals. This is required for interrogators that must read and write to multipage transponders in which different interrogators require different window times. In this case, the master has total control over the coordination of the devices in the chain. However, the master must be a more complex system and requires additional intelligence.

5.4.6 Carrier Phase Synchronization

This method is used when several antennas are located close together with the possibility that the field generated by each one of them may interact with the others. Because of the different transmission phases at each interrogator, the interaction may result in destructive interference. To avoid this effect, all the interrogators must be operated from the same carrier signal.

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5.5 Structure of Commercially Available Interrogators

Interrogators for RFID systems take different approaches depending on the specific needs of their intended application: from large and complex systems to single-chip interrogators. The following pages describe these different approaches through examples from commercial interrogators. It is necessary to view them just as specific examples as the number of available systems is higher, each one of them using a different approach. However, these examples provide valuable information about the structure of interrogators.

5.5.1 Interrogators for LF RFID Systems

The Series Reader 2000 from Texas Instruments is an example of a complex interrogator for an RFID system operating in the low-frequency range. Its main component is the S251B reader. This interrogator has a communications interface as RS232, RS422, or RS485; eight general-purpose input/output lines; two open collector outputs; one synchronization bus; one carrier phase synchronization bus; as well as a power connector and an antenna connector. Table 5.2 shows the electric specifications of the eight general-purpose input/output (I/O) lines in this unit.

This interrogator supports two different communication protocols: the ASCII protocol or Texas Instruments' own TIRIS protocol. The ASCII protocol that is used to send commands to the interrogator can only be used with the RS232 or RS422 interface. The TIRIS bus protocol is a binary protocol between a host computer and one or more interrogators.

The interrogator has two main modules: the *control module* and the *radiofrequency module*. The control module contains all the electronics needed for the communication between the interrogator and the host computer in order to control the radiofrequency module. It also has circuits used to optimize the performance of the antenna by correctly tuning the module. The radiofrequency module handles all the analog functions needed to generate the

TABLE 5.2

Electrical Specifications of S251B Reader (Texas Instruments)

Parameter		Minimum	Maximum
General Purpose I/O Voltage			
	Low Level	---	0.9 V
	High Level	3.15 V	5.25 V
General Purpose I/O Current			
	Low Level	----	25 mA
	High Level	----	16 mA
General Purpose I/O 1 to 4 Total output current		----	10 mA
General Purpose I/O 5 to 8 Total output current		----	10 mA

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signal that energizes the transponders, send commands to the transponders, and detect their responses. These two modules will be studied in deeper detail in Sections 5.5.1.1 and 5.5.1.2.

The synchronization bus operates in differential mode with a maximum data rate of 10 Mbits/s and allows for a maximum cable length of 1200 m. It can handle up to 32 different drives or receivers on the line. The outputs of the bus are protected against short circuits with a current limit of 150 mA to ground and 250 mA to the power supply. In addition, this unit contains three banks of dual in-line package (DIP) switches that allow for configuration changes. One of the banks is for setting up the control module, another bank for the settings of the communications protocol, and the third one for synchronization settings.

5.5.1.1 Radiofrequency Modules

The functions of the radiofrequency modules in the RFID system are to transmit the radiofrequency signal to the transponder via the antenna, to receive and demodulate the response of the transponder, and to write information to the transponder. Figure 5.21 shows a simplified block diagram of a generic radiofrequency unit in an interrogator.

For the modules that are part of the Series 2000 Reader manufactured by Texas Instruments, it is possible to distinguish the following submodules:

Power supply. This submodule provides the necessary voltage to power the rest of the electronics in the radiofrequency module. The majority

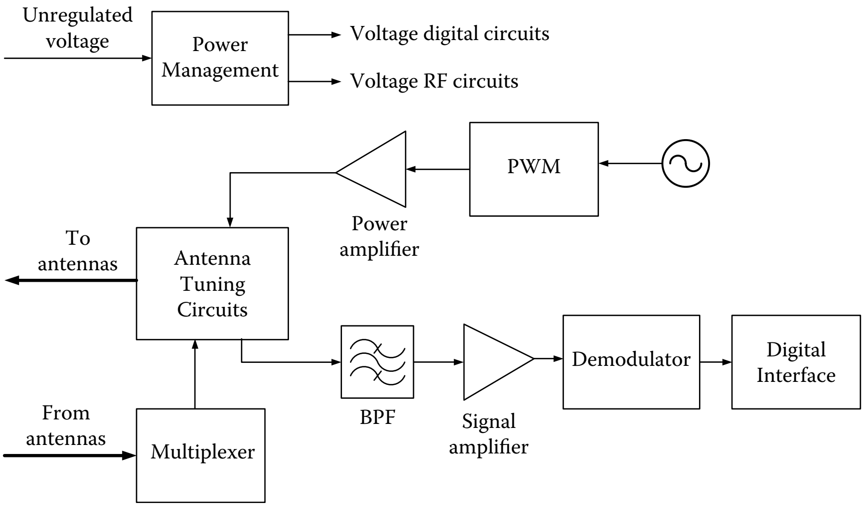
Unregulated voltage
Power Management
Voltage digital circuits
Voltage RF circuits
PWM
Power amplifier
To antennas
Antenna Tuning Circuits
BPF
Signal amplifier
Demodulator
Digital Interface
From antennas
Multiplexer

FIGURE 5.21
Simplified block diagram for the radiofrequency unit.

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of modules contain two voltage regulators, one to power the logic circuits and the other to power the rest of the module.

The manufacturer stresses not using a switching power supply, as at their typical frequency of operation their harmonics will create strong interfering signals.

Transmitter. The radiofrequency signal is generated by a crystal oscillator operating at the RFID frequency of 134.2 kHz. This signal is then fed into the pulse width modulator for which the user can select the width ratio between 3% and 50%. It is necessary to consider that decreasing this ratio also decreases the energy of the transmitted signal, thus providing a method to control the power transmitted by the interrogator.

Antenna circuit. The purpose of this submodule, shown in Figure 5.22, is to match the impedance of the transmitter to the impedance of the antenna in order to maximize the radiated power as well as its Q factor.

The circuit consists of the inductance of the antenna in series with an adjustable inductance for fine tuning as well as the capacitive part formed by the capacitors C_1, C_2, C_3, C_4, and C_{couple}. The switch is used to connect or disconnect C_4 for coarse tuning. It is necessary to connect several capacitors in series because of the high voltages that can be developed across the antenna terminals during resonance.

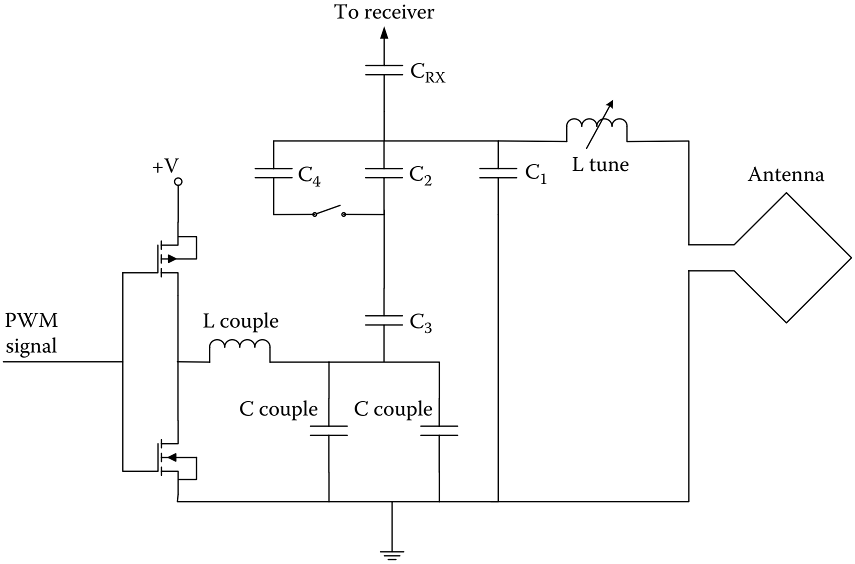

FIGURE 5.22
Antenna-tuning circuit.

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The capacitive resonator is driven by the *pulse-width modulation* (PWM) signal from the transmitter by two MOSFET power transistors through the inductor L_{couple}.

Receiver. The receiver in this module demodulates the FSK signals generated by the transponders, with a low symbol specified by a frequency of 134.2 kHz and a high symbol by a frequency of 123.2 kHz. The module can operate with a single antenna used for transmission and reception or with specific transmission and reception antennas. The path for the received signal depending on the type of antenna used is selected by the multiplexer at the front end.

Table 5.3 describes the different pins and its connections for the standard radiofrequency module in the Series 2000 Reader from Texas Instruments. Modules from other manufacturers have similar connections.

The most important electrical characteristics for these pins and connectors are shown in Table 5.4.

As shown in Table 5.4, the radiofrequency module incorporates a signal strength detector whose output is the RXSS- pin. This allows adjusting the threshold level for the detection of radiofrequency energy required by wireless synchronization. The adjustment is done by means of a potentiometer on the board. Different types of antennas require different threshold levels even if they operate in the same environment.

TABLE 5.3

Pins and Connectors in Standard Radiofrequency Module

Signal Name	Connection	Description
GND	IN	Ground logic circuits
TXCT-	IN	Transmitter control input for activation
VSL	IN	Supply voltage
RXDT	OUT	Receiver data signal output
RXSA	IN / OUT	Adjustment for receiver threshold level
RXCK	OUT	Clock output receiver
GNDP	IN	Ground power stage
RXA0	IN	Select signal for multiplexer
GNDP	IN	Ground power stage
RDTP	OUT	Test pin for receiver
VSP	IN	Supply voltage power stage
RSTP	OUT	Test pin for receiver
VSP	IN	Supply voltage power stage
RXSS-	OUT	Signal strength output in receiver
VD	IN / OUT	Internally regulated voltage
RCTP	OUT	Test pin for receiver

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TABLE 5.4

Summary of Electrical Characteristics Radiofrequency Module

Parameter	Min	Typ	Max	Unit
Internal regulated voltage	4.75	5.00	5.25	V
Supply current receive mode		9.0		mA
Supply current transmit mode		11.0		mA
Low level input voltage at TXCT- and RXA0	0		0.8	V
High level input voltage at TXCT- and RXA0	2.4		5.0	V
Low level output voltage at RXDT and RXCK	0		0.8	V
High level output voltage at RXDT and RXCK	4.0			V
Low level output voltage at RXSS-			0.8	V
Cable length for connection to control module		0.5	2.0	m
Number of slave modules that can be driven		1	5	
Inductance of antenna tuning coil	1.3	3.0	4.7	µH
Total antenna resonator capacitor	46	47	48	nF

This radiofrequency module, as well as most of the modules available in the market, can be used with the transmit–receive antenna or with special receive-only antennas. The type of antenna to be used is selected by a multiplexer in the receiver section.

5.5.1.2 Control Module

The control modules provide the functionality needed for the radiofrequency module to communicate with the rest of the devices. They control the Transmit and Receive commands from the radiofrequency modules according to the commands sent by the host computer. They also process the information from the transponders received by the radiofrequency modules, decode them, check their validity, and convert the signals to the protocol used for communication with the host computer. The control modules used in conjunction with the radiofrequency modules described in the previous section are available using the RS232C, RS422, or RS422/485 interfaces depending on the needs of the user. These control modules also handle the different synchronization methods described in Section 5.4 that need to be followed when more than a single interrogator is being used.

During the *charge time*, the control module activates the transmitter in the radiofrequency module. As long as this is active, the antenna resonates at the oscillator frequency and generates a radiofrequency field around its vicinity. This field charges the capacitor incorporated in the transponders energizing them. The typical length of the charge time is 50 ms. During this time, the receiver is disabled and cannot read any data. The charge time is followed by the *read time*, as shown in Figure 5.23. This time typically lasts 20 ms, during which the transponder sends the information back to the interrogator.

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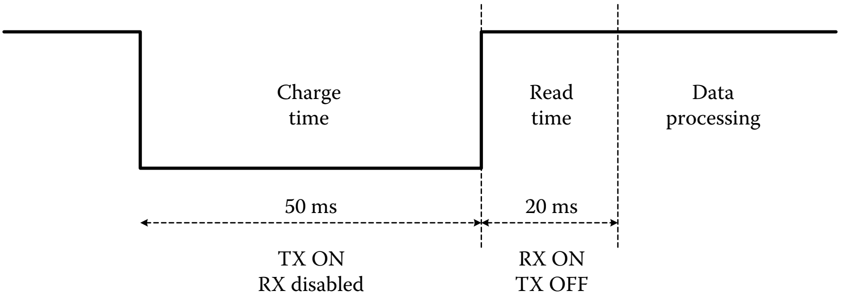

FIGURE 5.23
Charge and read times.

All the data formats consist of 128 bits. After being received by the radiofrequency module, they are checked by the control module. The different types of transponders supported by these interrogators are differentiated from each other by using different Start, Stop, and End bytes. The data structure for these transponders is shown in Figure 5.24. It is important to note that the first bit being transmitted is the least significant bit (LSB) and the last bit is the most significant bit (MSB).

The data structure for read-only transponders is shown in Figure 5.24(a). The data format starts with 16 pre-bits that are all set at zero, followed by the start byte ($7E). The next 64 bits are the identification data bits programmed into the transponder at the time of manufacturing; they cannot be changed by the user. The next 16 bits comprise the data protection bits (BCC). The following byte is the stop byte, which has the same structure as the start byte ($7E). Afterward, the transponder sends 16 end bits, all of them set to zero. During the last bit, the transponder discharges its capacitor, therefore deenergizing its internal circuits.

Figure 5.24(b) shows the data structure for read/write transponders. It also starts with the 16 pre-bits set at zero followed by the start byte that in this case is set at $FE. This tells the interrogator that the data come from a read/write transponder. The next 80 bits are the data bits that can be programmed by the user. The manufacturer recommends splitting these bits into 64 bits of data identification transmitted first and 16 bits for data protection bits (block check character, or BCC). The stop byte that is transmitted next has the same value as the start byte ($FE). The final 16 bits reflect the 16 LSBs of the read data that must be checked for validity by the control module. Once again, the last of these 16 bits makes the transponder discharge its capacitor and deenergize its internal circuits.

The data structure for the multipage read/write transponder is shown in Figure 5.24(c). The data start again with the 16 pre-bits set at zero, followed by the start byte with a value of $7E. This start byte is the same as for read-only transponders, meaning that the distinction between these two structures will be possible after the reception of the read address and read address frame

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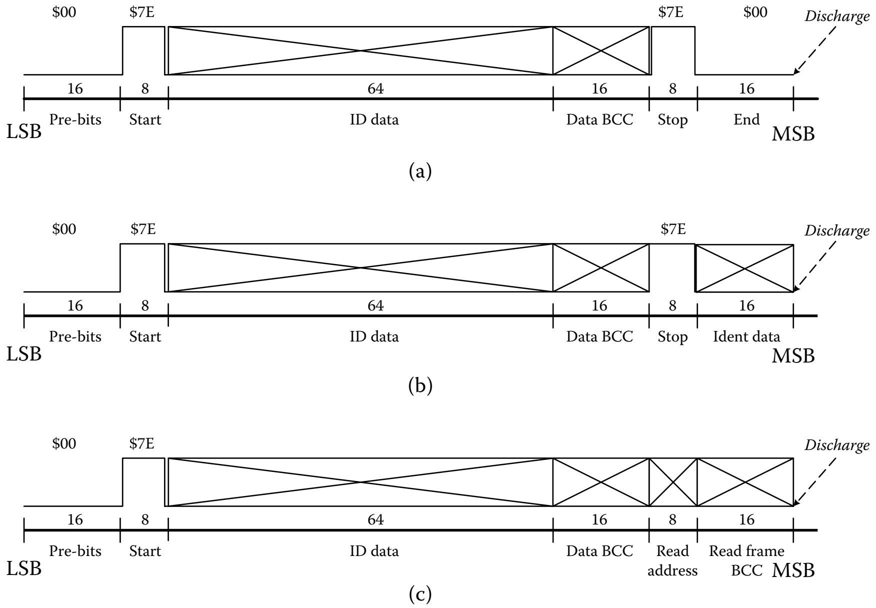
$00
$7E
$7E
$00
Discharge
16
8
64
16
8
16
Pre-bits
Start
ID data
Data BCC
Stop
End
LSB
MSB
(a)
$00
$7E
$7E
Discharge
16
8
64
16
8
16
Pre-bits
Start
ID data
Data BCC
Stop
Ident data
LSB
MSB
(b)
$00
$7E
Discharge
16
8
64
16
8
16
Pre-bits
Start
ID data
Data BCC
Read address
Read frame BCC
LSB
MSB
(c)

FIGURE 5.24
Data structure for several transponders: (a) read-only transponders, (b) read/write transponders, and (c) multipage read/write transponders.

BCC. The start byte is followed by 80 data bits that can be programmed by the user. The manufacturer also recommends splitting them into the first 64 data identification bits and 16 bits for protection data (BCC). The next 8 bits make up the read address byte; this contains a status field (2 bits), which is transmitted first, and a page field (6 bits). The 2 bits that make up the status field inform the control module about the function that the transponder has executed and the type of page that has been received. The final 16 bits make up the read frame BCC. One bit after having sent the first 128 bits, the transponder discharges the capacitor and deenergizes its internal circuits.

The function of the 16 pre-bits is to give enough time to the radiofrequency module to recover from the overload that it may have experienced during the 50 ms in which the transmitter has generated the radiofrequency signal. This is especially important because the transponders may start transmitting data immediately after having been energized. This period is known as the *waiting time*, lasting less than 1 ms.

After this time has elapsed, it is necessary to detect the first low-to-high transition for the start byte. After successful detection, the radiofrequency module synchronizes its clock and its data. The control module must also ensure that it receives all the high bits in the start byte. Otherwise, if a low bit is received, the process tops and the control module goes back to waiting for the detection of the low-to-high transitions. If the start byte has been successfully detected,

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the control module receives the next 80 bits and starts the generation of the cyclic redundancy check (CRC) to ensure the validity of the data. The last step in the decoding process is to determine whether the transponder that generated the data stream was a read-only transponder or a multipage read/write transponder as they both use the same start byte. This is done by checking the content of the CRC generator at the end of the process. If this value is equal to $0000, this indicates that a multipage read/write transponder originated the data. Otherwise, it indicates that it came from a read-only transponder. Figure 5.25 shows an overview of this sequence for the control module.

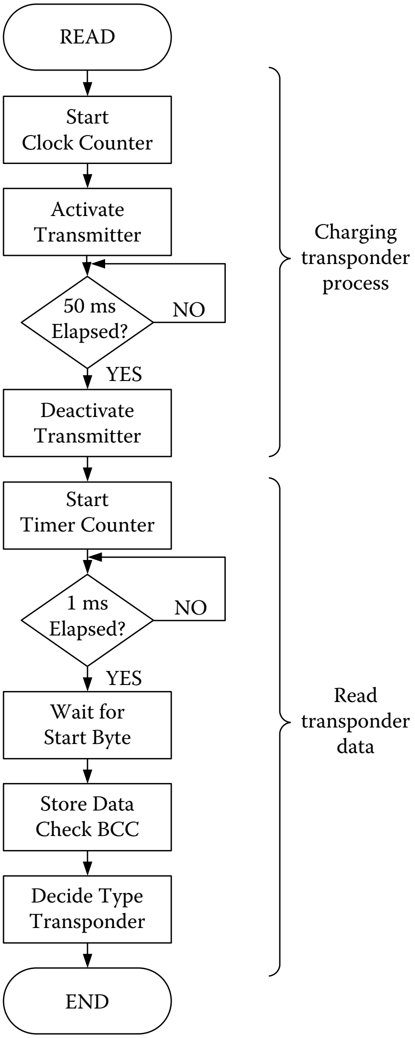
READ
Start
Clock Counter
Activate
Transmitter
50 ms
Elapsed?
NO
YES
Deactivate
Transmitter
Charging
transponder
process
Start
Timer Counter
1 ms
Elapsed?
NO
YES
Wait for
Start Byte
Store Data
Check BCC
Decide Type
Transponder
Read
transponder
data
END

FIGURE 5.25
Control module sequence.

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The control module is also used to control the flow for writing to the transponder. Writing to the transponder is used to transfer commands, addresses, and data to the transponder. Before writing to the transponder, this must be energized. Therefore, writing to the transponder occurs after the transmitter has sent the 50 ms radiofrequency pulse to energize the circuits in the transponder. The actual process of writing is done by switching the transmitter off and on. To write a high bit, the transmitter is inactive during 1 ms followed by being active during 1 ms. To write a low bit, the transmitter is inactive during 0.3 ms followed by being active during 1.7 ms. The total time for writing a single bit is 2.0 ms.

To program the write data into the transponder's memory, the transmitter must be active for at least 15 ms immediately after the previously described write function has been executed. This is known as the *programming time*. Having the transmitter on for this time enables it to energize the circuits in the transponder. The write data format is shown in Figure 5.26.

All the data bits are transmitted to the transponder with the LSB first. The 8-bit write keyword ($BB) and the 8-bit write password ($EB) are sent to the transponder to initiate the transmission of the 80-bit data. The manufacturer recommends splitting the 80-bit data into 64-bit identification data transmitted first followed by 16 protection data bits (BCC). The write data format is terminated by a 16-bit write frame that must be set to $0300. After write frame, the transmitter will be active for 15 ms to allow the transponder to program the received data into its memory. The actual programming will only take place if the write keyword and write password bytes are received, the write data have the correct number of bits, and the radiofrequency field generated by the transmitter is high enough to produce the voltage required to program the transponder's memory. This voltage exceeds the voltage required to read the memory. Once after the programming time has elapsed, the transponder responds by sending the data that it has stored into its memory. This data follow the 128-bit format described previously in this section. If the read data received are structurally valid, they must be compared against the write data that were sent to the transponder to ensure that the correct data were written into the transponder. If the structure or the contents of the read data are not valid, the process must be repeated.

The last main function for the control module is to handle the synchronization tasks between different interrogators. For this to occur, a synchronization

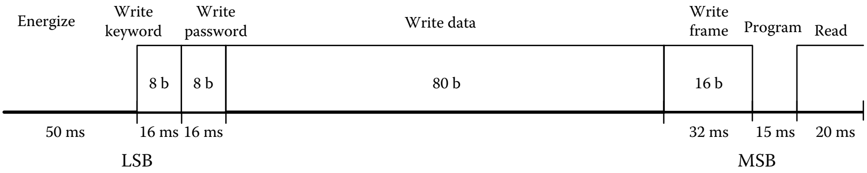

FIGURE 5.26
Format for writing data.

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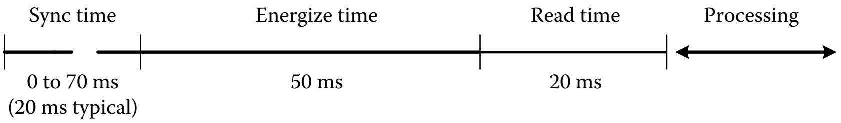

FIGURE 5.27
Synchronization sequence.

time must exist before the transmitter in the interrogator generates the radiofrequency signal to energize the transponders, as shown in Figure 5.27.

The synchronization allows the different interrogators in the overall system to detect each other and delay the activation of their own transmitters until other interrogators have finished their read functions. For this reason, the synchronization times vary depending on the number of interrogators in the application as well as the relative order of one interrogator in reference to the others in its vicinity.

5.5.2 Interrogators for HF RFID Systems

The Series Reader 6000 from Texas Instruments is an example of an RFID interrogator that operates in the HF range. The structure of the system is similar to the 2000 Series Reader described in the previous section. The Midrange Reader Module in this system provides the communication between transponder and interrogator. Output power levels can be adjusted between 100 mW and 1000 mW by means of a potentiometer placed on the radiofrequency module of the interrogator. The communication from the interrogator to the transponder is by ASK modulation, normally at 20%. The communication from the transponder to the interrogator is done by FSK modulation.

The TRF7960/1 also from Texas Instruments comprises multistandard fully integrated circuits containing the analog front end and the data-framing system. Their internal receiver enables them to modulate ASK and PSK, and it also includes automatic gain control and selectable bandwidth. In addition, the receiver includes a framing system allowing one to perform CRC checks, parity checks, or both. The output data are then sent to a microcontroller. The output of the transmitter only needs to be connected to the same impedance-matching circuit used for reception. Figure 5.28 shows the basic structure of the RFID system using this integrated circuit.

The receiver has two inputs that must be connected to an external filter. The external filter also converts the PSK modulation from the transponder into an amplitude-modulated signal. The two receiver inputs are multiplexed to two receiver channels: a main receiver and an auxiliary receiver. The main receiver contains a radiofrequency detection stage, a gain, a filter with automatic gain control, a digitizing stage, and an indicator for the strength of the received signal. The auxiliary receiver has a similar structure, although it is mainly used to measure the strength of the received signal.

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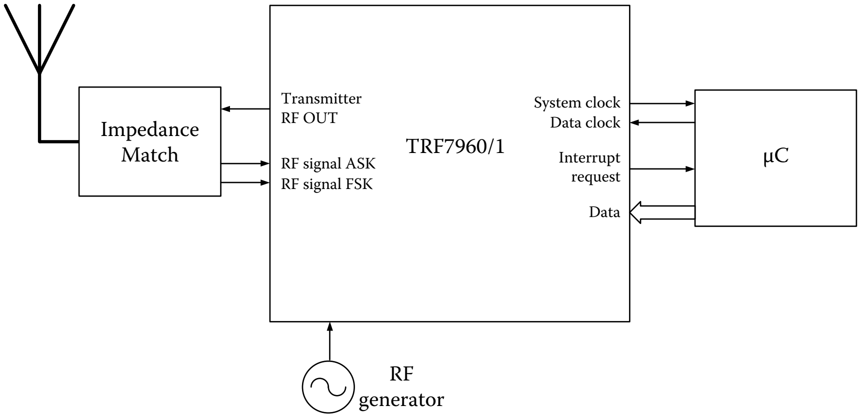

FIGURE 5.28
Structure of an interrogator using the TRF7960/1 circuits.

This is done by measuring the voltage of the demodulated signal and latching at its peak value.

The digital part of the receiver contains the bit decoders for the various protocols that supports the framing logic. The bit decoders convert the decoded signal into a bit stream. It has been specifically designed for maximum error tolerance, thus allowing the correct decoding of signals that have been partially corrupted due to noise or interference. The framing section packages the received bits into bytes, removing the control bytes sent by the transponder. This results in raw data that are sent to the microcontroller.

The transmitter contains the radiofrequency oscillator at 13.56 MHz, the processing circuits, and the radiofrequency power stage. The power levels available are 20 dBm (100 mW) or 23 dBm (200 mW) when the circuit is powered with 5V. When it is powered with 3 V, the available power levels are 15 dBm (33 mW) or 18 dBm (70 mW). The digital portion of the transmitter is very similar to that of the receiver as these circuits frame the command signals originated by the microcontroller.

5.5.3 Single-Chip Interrogators

In contrast to the complex systems described earlier, some interrogators have minimal components, normally an integrated circuit containing the transmitter and receiver and circuitry to communicate with a microcontroller or a microprocessor.

The core of the Series 6000 Reader from Texas Instruments is the RI-R6C-001 Integrated Circuit manufactured by the same company. This chip, whose block diagram is depicted in Figure 5.29, is a transceiver that provides the transmit and receive functions necessary for communication with transceivers operating at that frequency range.

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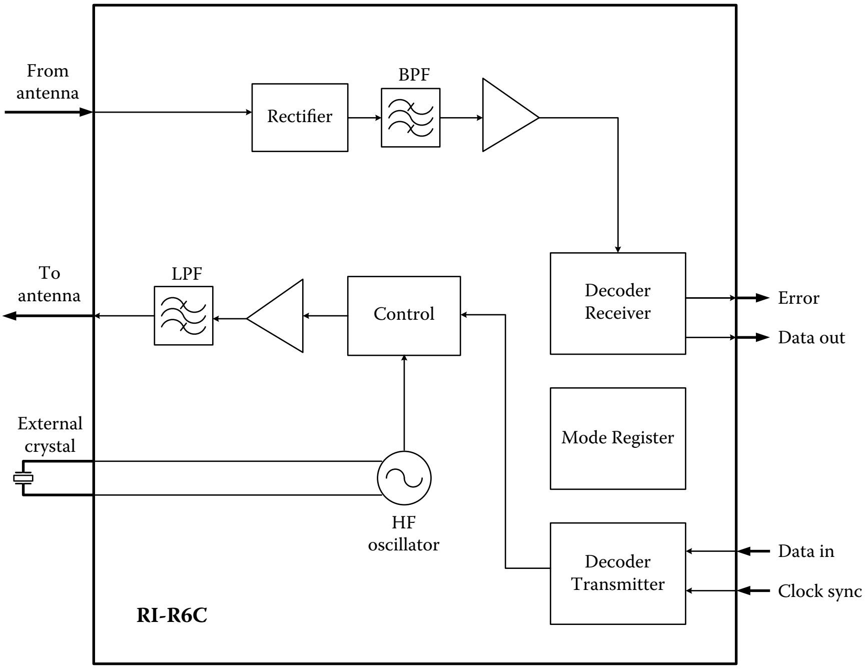
From antenna
Rectifier
BPF
To antenna
LPF
Control
Decoder Receiver
Error
Data out
Mode Register
External crystal
HF oscillator
Decoder Transmitter
Data in
Clock sync
RI-R6C

FIGURE 5.29
Simplified structure of the RI-R6C integrated circuit.

This transceiver integrated circuit communicates with its remote controller, normally a microprocessor, by a simple three-wire serial link. The communication between the transceiver and the transponders is generated by the microprocessor that sends the commands directly to the transceiver. The transceiver, in turn, applies the necessary carrier modulation and generates the radiofrequency signal.

The U2270B integrated circuit manufactured by Atmel® is another example of a single chip that serves as an interrogator. As shown in Figure 5.30, the U2270B incorporates an on-board power supply, an oscillator, tuning circuits, and other signal-processing circuits to produce an output that can be read by a microcontroller.

This specific chip has been designed to operate in the low-frequency range. It can be configured to work with different ranges of voltages for power supplies (from 5 V to 16 V). The low-pass filter in the receiver is a fourth-order Butterworth designed to remove the remaining energy of the carrier signal and other high frequencies after the demodulation process. The cutoff frequency can be selected by the user depending on the type of communication between the chip and the transponder that is being used. The possible choices are a Manchester code or biphase modulation typically at 5 kbaud.

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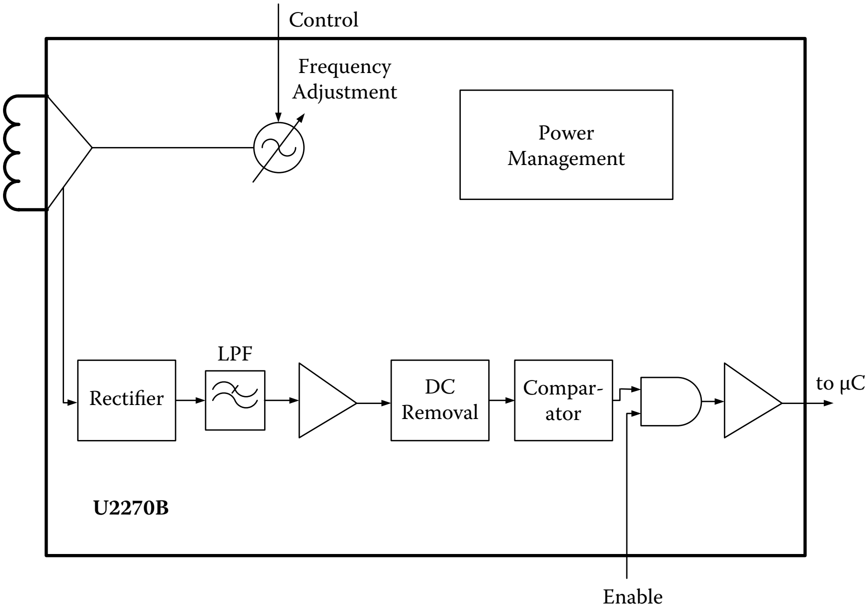
Control
Frequency Adjustment
Power Management
LPF
Rectifier
DC Removal
Compar-ator
to μC
U2270B
Enable

FIGURE 5.30
Simplified structure of the U2270B integrated circuit.

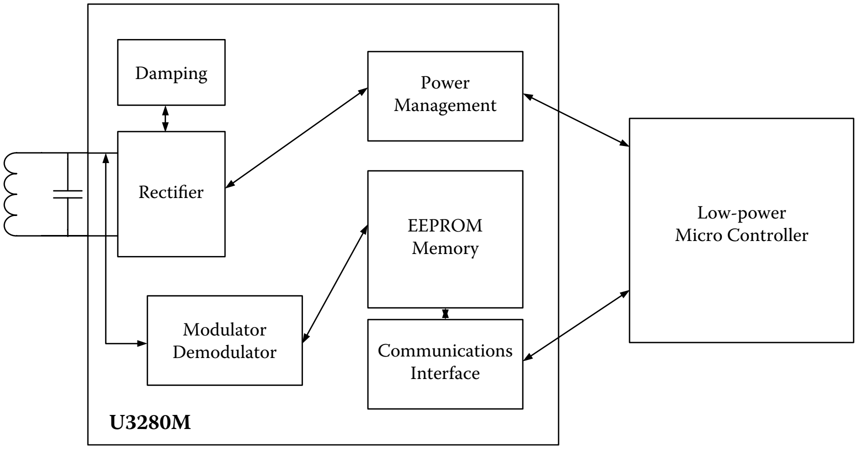
Damping
Power Management
Rectifier
EEPROM Memory
Low-power Micro Controller
Modulator Demodulator
Communications Interface
U3280M

FIGURE 5.31
Simplified structure of the U3280M integrated circuit.

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One of the main applications of this chip is as an electronic immobilizer for the automotive industry in order to reduce auto theft. The interrogator and the associated microcontroller are located inside the vehicle, while the transponder with its unique identifier code is carried by the lawful owner or user in the vehicle. Unless the interrogator receives a valid code from a transponder, the microcontroller keeps the electronic ignition of the vehicle disabled. An additional benefit of this approach is that because the power to the transponder is supplied by the interrogator through the electromagnetic field it generates, the user of the vehicle does not need to worry about carrying fresh batteries like in traditional wireless fobs.

Atmel® also manufactures another chip, the U3280M shown in Figure 5.31, which, although marketed as a transponder interface for microcontrollers, functions as an interrogator. The chip can supply the energy required to power an external microcontroller and can also accept an external battery. The distribution of power is controlled by a power management circuit that either operates in automatic mode or is controlled by the microcontroller. The communication of this device with its microcontroller is carried out following a serial format. Modulation is carried out by changing the magnetic field generated by the antenna by varying its load. For example, a high logic level results in an increase of current through the antenna while the voltage becomes damped. The low logic level is generated by a decrease of current through the antenna that results in an increase in its voltage.

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6

Interrogator Communication and Control

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Interrogators communicate with the host computers in order to transmit commands to the transponders and collect their information. This chapter explores some of the protocols used for linking interrogators with the host computers using as examples the different protocols employed by some interrogators manufactured by Texas Instruments. These examples show the basic communication processes between interrogators and their host computers as a stepping-stone to understand the control of interrogators from other manufacturers. The chapter starts by describing the TIRIS Bus Protocol, developed by Texas Instruments. It continues by studying how the ASCII protocol is used in some commercial interrogators. The next section explains the protocol used in some LF interrogators manufactured by Texas Instruments. The chapter ends by describing the communication protocols used in interrogators operating in the HF range.

6.1 TIRIS Bus Protocol: Texas Instruments

The TIRIS Bus Protocol is a proprietary protocol developed by Texas Instruments for communications between its interrogators or between interrogators and a host. This is a half-duplex byte-count protocol. It allows efficient communication between a single master and multiple slaves. The protocol allows communication with a single slave unit on a RS232 line and up to 31 slaves on a RS422 or RS485 line or using parallel links.

All the data transfers using the TIRIS protocol are initiated by the host; the slave units only send data upon request from the host unit, therefore

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eliminating the possibility of data collision on the bus. Furthermore, the protocol uses positive acknowledgment with the slave units indicating the reception of a message from the master. All the messages have the same format independently of the direction they travel. Table 6.1 shows the structure of an *N*-byte message using this protocol.

Command-message-codes describe the action that the master requires from the slave. Its most significant bit (MSB; Bit 7) is the *queued-response flag*, while the following seven bits contain the command code. When the queued-response flag is set to 1, it indicates to the destination unit that it should acknowledge and execute the command but its response should be queued until requested by the master. This is normally used with commands that have a delayed response in order to avoid suspension of the line activity. When the flag is set to zero, the response is immediate following the execution of the command.

TABLE 6.1

TIRIS Bus Protocol Format

Byte	Content
0	Start Mark[a]
1	Destination Address[b]
2	Source Address[c]
3	Message Code[d]
4	Data length
5	Data field (1)
6	Data field (2)
…	…
N + 4	Data field (N)
N + 5	MSB for CRC-field (1)
N + 6	CRC – field
N + 7	End Mark

[a] The *start mark* signifies the beginning of a message and is represented by $01. This corresponds to the ASCII character Start-of-Heading.

[b] The second byte, *destination address,* indicates the address of the unit to which the message is directed. The binary value of this byte corresponds to the ID of the destination address. The ID for the different units ranges from $00 to $FE, although the maximum number of units in a specific application is limited by the physical limitations of the link. Broadcast messages are indicated by using a destination address of $FF.

[c] The *source address* is the third byte in the message format. It indicates the ID of the unit sending the message.

[d] The fourth byte is the *message code* byte. This byte is used to define the content of the message. When the message is from the master to the slave, this byte is a *command-message-code*. When the message is from slave to master, this byte is a *response-message-code*.

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The response-message-code describes the acknowledgment that the slave unit has received the command. The four MSBs in the code are flags, while the four remaining least significant bits (LSBs) are the response code. The different flags are as follows:

The MSB (Bit 7) is the *error-flag*. When it is set to 1, it indicates that the slave has detected an error in the transmission or in the contents of the command. The error code is indicated in the last four bits.

Bit 6 is the *busy-flag*. When it is set to 1, it indicates that the slave is temporarily unable to accept commands.

Bit 5 is the *data-available-flag*. When it is set to 1, it indicates to the master that there is at least one message in the output queue in the slave. In order to read this message, the master must send the appropriate command.

Bit 4 is the *broadcast-received-flag*. When it is set to 1, it indicates that a broadcast message, issued previously, has been received correctly. The response to the broadcast command is placed in the queue. The master can read the response by issuing the appropriate commands at which point the flag is reset to 0.

Bits 5-8 in the Response-Message-Code byte indicate the type of response. Their meaning varies depending on the state of the Error-Flag bit as shown in Table 6.2.

Bit 5 in the TIRIS protocol is the *data length* byte. This byte shows the number of bytes that follow as data field. If the command or response does not require any data, this value will be zero.

The following N bytes in the TIRIS protocol make up the *data field,* with N being the value specified in the previous byte (Data Length byte). The content of this field depends on the message being sent.

The two bytes after the Data-Field bytes are *CRC-field* bytes. These bytes contain the Cyclic Redundancy Check values to ensure the integrity of the message. The TIRIS Bus protocol supports two methods of generating the CRC field. The first method is the Reverse CRC-CCITT algorithm that was described in Section 3.3.2. The second method supported by this protocol is called Longitudinal Redundancy Check (LRC). This is based on XORing each character with the previous value and storing the result in the LSB byte fin the CRC-Field. The MSB byte of the CRC-Field is generated by storing the 1′s complement of the LSB byte. Using this method, if the MSB and LSB are ANDed together, the result should be zero. Consequently, any value different from zero indicates an error in the received message. This method is not as secure as the Reverse CRC method but it is faster.

The final byte is the *end mark* byte that indicates the end of the message. This is represented by $04 that corresponds to the ASC II character *end of transmission*.

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TABLE 6.2

Response Codes

Bit	Error-Flag = 0 Process Response		Error-Flag = 1 Error-Response	
0	Command Complete	A non-queued command received and executed correctly	Transmission Error	Slave received a message with its ID but found error on data
1	Accepted	A queued response command received correctly. Response will be placed on the queue	Command Invalid	Message received correctly but command code is not valid for this slave
2	Queue Empty	No message in the queue	Error – Data field length	Data field length wrong. Command not executed
3	Nothing to Resend	No information to resend available	Error - Parameter	Invalid parameter. Command not executed

Note: The following *N* bytes make up the *data field,* with *N* being the value specified in the previous byte (data length byte). The content of this field depends on the message being sent.

Using a two-wire, half-duplex circuit is not possible to execute flow control. Therefore, all the units in the bus must be able to receive and buffer the maximum length of the message at the operating speed for the line. When a unit is unable to handle correctly the incoming data, it cannot send an error message until the original message has ended. At that point, it can transmit the appropriate error message.

The data flow for the commands that do not require queuing from the slaves is always controlled by the master. The first steps for the master unit are to enable the transmitter, send the command message, and disable the transmitter. The slave unit, which is always monitoring the line, receives the incoming message and checks for the correct destination address. If the destination address is incorrect, it ignores the message and returns to monitoring the line. Because in this case the slave does not give any response to the master, the master will resend the command.

If the destination address is correct, the slave unit checks for errors in the message. If it detects errors, it sends an error response to the master, disables its transmitter, and returns to monitoring the line. Upon reception of the error response, the master unit processes the error code and resends the original command. If no errors are detected, the slave unit processes the command, sends the appropriate response message, disables the transmitter, and returns to monitoring the line. Upon reception of the response message, the master processes it and proceeds to transmitting the next command.

Broadcast messages transmitted by the master are not acknowledged in the normal way. After the master has sent the broadcast command, the slave checks for errors in the received message. If it detects errors, it ignores the message, sets the error flag, and returns to monitoring the line. If it does not detect errors, it sets the broadcast-received flag, processes the command, and places the response in its queue. The master accesses the special status bit in

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the response-code field in the slave's response to evaluate the correct reception of the previous message.

Example 6.1:

Describe the operations taken by a master unit that wants to initiate an operation on all slaves simultaneously.

Solution:

The master unit sends a command with a destination ID of $FF. The master unit then waits the expected operation time and proceeds to poll each individual slave. The master is looking for the *broadcast-received-flag* that verifies the correct reception of the command. The absence of this flag in a slave unit triggers the master to broadcast the command again.

Queued messages use a slightly different format from the format used by broadcast or immediate commands. The *N*th data field byte contains a sequence number, given by the master, that is used to have a reference when the queued messages are requested from the slave units. The slave unit indicates that a command requiring a queued response has been received and is being processed by sending a response message to the master with the accepted flag set. This response is not transmitted directly by the slave unit, but it is placed on its queue for the master unit to access it when ready.

When interrogators are asked to queue a response, these responses are placed in a 30-position circular buffer. The buffer has two pointers: store-next-message and read-next-message. Because of the circular structure of the buffer, it is not necessary to delete responses as they are overwritten when the pointer is incremented.

6.2 ASCII Protocol for TIRIS Interrogators: Texas Instruments

Some of the interrogators from Texas Instruments accept commands using a simple ASCII protocol. This ASCII protocol can only be used with a RS232 or RS422 communications line. Once the interrogator reinitializes, the first character to be transmitted is $02 (Start of Text, or STX), followed by $0D (Carriage Return) and $0A (Line Feed) through the serial interface. Any characters that may have been transmitted before the STX character are treated as random characters generated by the start-up process and therefore discarded.

Using this protocol, the interrogator can operate on four different modes: execute, normal, line, and gate. In execute mode, the interrogator triggers a single command, while in the other modes the read function is continuously triggered. The interrogators are also able to distinguish between three types of transponders: read-only, read/write, and multipage. The serial communications protocol from the interrogator to the host computer is

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introduced as a single character that describes the type of interrogator that originated the message: R (read-only), W (read/write), or M (multipage).

After receiving data from a transponder, the interrogator performs a data check. The result of this data check is one of the following: *identification received correctly*, *identification invalid*, or *no identification detected*. After receiving a correct identification, the interrogator proceeds to send the information through the bus. This is done by placing the identification string in a buffer that is accessed, read, and cleared by the host computer. The TIRIS protocol can distinguish between two groups of transponder identification: animal code numbers and industrial (nonanimal) code numbers.

6.3 Series 2000 Micro-Reader System: Texas Instruments

The Series 2000 RFID interrogators operate in the LF range. Table 6.3 describes the structure of an *N*-byte message sent from the host computer to the interrogator in these systems.

The following set of bytes are the *data field* bytes. These bytes only exist if required by the command field.

TABLE 6.3

Series 2000 Host-to-Interrogator Message Format

Byte	Content
0	Start Mark[a]
1	Message length[b]
2	Command Field[c] (1)
3	Command Field (2) - not always present
4	Data field (1)
5	Data field (2)
…	…
N + 3	Data field (N)
N + 4	BCC

Note: If the second command field is not used, the length of the message is $N + 3$ bytes. In addition, messages are limited to a total of 41 bytes.

[a] The first byte is the *start mark* that indicates the start of a message.

[b] The second byte is the *message length* byte that indicates the length, in bytes, of the command and data fields that follow.

[c] The third and fourth bytes (when the second command field byte exists) are the *command field* bytes. These bytes define the mode of operation for the interrogator and determine the operation that the interrogator must carry out on the transponder. Depending on the type of command, the information in the data fields may or may not be transmitted to the transponder. The meaning of the different bits for the command field (1) is described in Table 6.4.

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TABLE 6.4

Command Field (I) Bit Description

Bit	Description	Value	Operation
0 and 1	Operation Mode	00	Perform single command
		01	Read in continuous Normal Mode
		10	Read in continuous Line Mode
		11	Send interrogator software version
2	FBCC Calculation	0 or 1	1 = interrogator calculates FBCC
3	Power burst I	0 or 1	1 = duration determined in data field
4	Power burst pause	0 or 1	1 = duration determined in data field
5	Power burst II	0 or 1	1 = duration determined in data field
6	Data	0 or 1	1 = determined in data field
7	Command Expansion Field	0 or 1	1 = Command Field (2) is used

TABLE 6.5

Command Field (2) Bit Description

Bit	Description	Value	Operation
0	Special write timing	0 or 1	1 = Must be determined in data field.
1	Wireless synchronization	0 or 1	1 = Wireless synchronization being used.
2	Database consistency check (DBCC) calculation	0 or 1	1 = Interrogator calculates DBCC.
3 to 7	Reserved	0 or 1	Reserved.

The following set of bytes are the *data field* bytes. These bytes only exist if required by the command field.

The last byte in the message is the *block check character* (BCC) byte. This is a one-byte value that results from XORing each one of the bytes in the preceding message with the exception of the start mark byte.

As shown in Table 6.4, the existence of command field (2) is set by bit 7 of command field (1). Table 6.5 shows the meaning of the bits in command field (2) when it is present in the message.

Example 6.2:

Calculate the BCC for a message containing the following hex bytes: 04 23 38.

Solution:

BCC is calculated by XORing the bytes of the message. Start by first XORing 04 and 23:

04	0000 0100
23	0010 0011
XOR	0010 0111

The resulting value (0010 0111) is now XORed with 38:

Previous XOR	0010 0111
38	0011 1000
XOR	0001 1111

Therefore, the resulting BCC is $1F.

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The following three examples illustrate the structure of messages between the host computer and the interrogator for a variety of different commands and applications.

Example 6.3:

The following is the structure of a message transmitted from the host computer to the interrogator in commanding the interrogator to read a read-only transponder:

Byte	Code	Content	Description
0	$01	Start Mark	Start Mark
1	$02	Length	Two bytes follow (excludes BCC)
2	$08	Command Field (1)	Perform single command – Power burst
3	$32	Data Field (1)	Power burst for 50 ms to energize transponder
4	$38	BCC	BCC over previous bytes excluding Start Mark

Example 6.4:

The following is the structure of a message transmitted from the host computer to the interrogator in commanding the interrogator to write the following data in a read/write transponder.

```
00  0A      FE      32      66      00      00      01
MSB                                                 LSB
```

Byte	Code	Content	Description
0	$01	Start Mark	Start Mark
1	$11	Length	17 bytes follow (excludes BCC)
2	$E8	Command Field (1)	Perform single command, no FBCC calculations, send power burst to energize transponder for reading and writing. Data command on following field
3	$06	Command Field (2)	Use wireless synchronization
4	$32	Data Field (1)	Power burst to energize transponder for reading (50 ms)
5	$0F	Data Field (2)	Power burst to energize transponder for writing (15 ms)
6	$0C	Data Field (3)	12 data bytes follow
7	$BB	Data Field (4)	Write Keyword
8	$EB	Data Field (5)	Write Password
9	$01	Data Field (6)	LSB of data to write
10	$00	Data Field (7)	Data to write
11	$00	Data Field (8)	Data to write
12	$66	Data Field (9)	Data to write
13	$32	Data Field (10)	Data to write
14	$FE	Data Field (11)	Data to write

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Byte	Code	Content	Description
15	$0A	Data Field (12)	Data to write
16	$00	Data Field (13)	MSB of data to write
17	$00	Data Field (14)	Write frame
18	$03	Data Field (15)	Write frame
19	$9C	BCC	BCC over previous bytes excluding Start Mark

Example 6.5:

The following is the structure of a message transmitted from the host computer to the interrogator in commanding the interrogator to read page 2 of a multipage transponder.

Byte	Code	Content	Description
0	$01	Start Mark	Start Mark
1	$04	Length	Four bytes follow (excludes BCC)
2	$48	Command Field (1)	Perform single command – Power burst with data
3	$32	Data Field (1)	Power burst for 50 ms to energize transponder
4	$01	Data Field (2)	One data field follows
5	$08	Data Field (3)	Write address specifying general read of page 2
6	$77	BCC	BCC over previous bytes excluding Start Mark

The structure of the messages sent from the interrogator to the host computer is described in Table 6.6.

The bytes following BCC are the *data* field bytes.

TABLE 6.6

Series 2000 Interrogator-to-Host Message Format

Byte	Content
0	Start Mark[a]
1	Message length[b]
2	Status[c]
3	Data field (1) LSB byte
4	Data field (2)
…	…
N + 2	Data field (N) MSB byte
N + 3	BCC

[a] The first byte is the *start mark* that indicates the start of a message.

[b] The second byte is the *message length* byte that indicates the length, in bytes, of the command and data fields that follow.

[c] The third byte is the *status byte*. This provides feedback about the preceding read or programming operation according to Table 6.7.

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TABLE 6.7

Description of Bits in the Status Byte

Bit	Value	Operation
0 and 1	00	Read Only transponder
	01	Read/Write transponder
	10	Multipage transponder
	11	Other transponder
2	0 or 1	1 = Start byte was successfully detected
3	0 or 1	1 = DBCC was successfully performed
4	0 or 1	1 = DBCC was successfully performed
5	0 or 1	1 = Software version for interrogator follows
6–7	Reserved	

TABLE 6.8

Description of Data Field Bytes

Type of Response	Number of Bytes in Data Field	Description
Read Only	8	Identification data. LSB first
Read/Write	8	Identification data. LSB first
Multipage	9	Identification data. LSB first and Read Address
Other	14	Complete transponder protocol without pre-bits assuming a successful start byte was detected
No Read	0	No data fields, no start byte. Status is $03
Software version	1	Software version. For example $12 means software version 1.2

The last byte in the message is the *BCC* byte. This is a one-byte value that results from XORing each one of the bytes in the preceding message with the exception of the start mark byte.

The length and meaning of the data field bytes are shown in Table 6.8.

Example 6.6:

The following is the structure of a message transmitted from the interrogator to the host computer after a successful read of a read-only transponder.

Byte	Code	Content	Description
0	$01	Start Mark	Start Mark
1	$09	Length	Nine bytes follow (excludes BCC)
2	$0C	Status	Valid RO, Start byte detected, DBCC is correct
3	$6A	Data Field (1)	Identification data (LSB)
4	$58	Data Field (2)	Identification data

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Byte	Code	Content	Description
5	$4C	Data Field (3)	Identification data
6	$00	Data Field (4)	Identification data
7	$00	Data Field (5)	Identification data
8	$00	Data Field (6)	Identification data
9	$00	Data Field (7)	Identification data
10	$00	Data Field (8)	Identification data (MSB)
11	$7B	BCC	BCC over previous bytes excluding Start Mark

Example 6.7:

The following is the structure of a message transmitted from the interrogator to the host computer after an unsuccessful read attempt.

Byte	Code	Content	Description
0	$01	Start Mark	Start Mark
1	$01	Length	One byte follows (excludes BCC)
2	$03	Status	Other, no Start byte detected, DBCC is not correct
3	$02	BCC	BCC over previous bytes excluding Start Mark

Example 6.8:

The following is the structure of a message transmitted from the interrogator to the host computer after successfully programming page 2 of a multipage transponder.

Byte	Code	Content	Description
0	$01	Start Mark	Start Mark
1	$0A	Length	Ten bytes follow (excludes BCC)
2	$1E	Status	Valid Multipaage, Start byte detected, DBCC is correct
3	$47	Data Field (1)	Identification data (LSB)
4	$C6	Data Field (2)	Identification data
5	$2D	Data Field (3)	Identification data
6	$00	Data Field (4)	Identification data
7	$00	Data Field (5)	Identification data
8	$00	Data Field (6)	Identification data
9	$00	Data Field (7)	Identification data
10	$00	Data Field (8)	Identification data (MSB)
11	$09	Data Field (9)	Read address specifying successful programming of page 2
12	$7B	BCC	BCC over previous bytes excluding Start Mark

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6.4 High-Frequency Interrogators: Texas Instruments

6.4.1 TIRIS Protocol for Series 6000 Reader System Interrogators

The Series 6000 Reader System interrogators are RFID interrogators operating in the HF band, manufactured by Texas Instruments. These interrogators use a RS232 line to communicate with the host computer. The data packet from the host to the interrogator is known as the *request*, while the data from the interrogator to the host are known as the *response*. All communication sequences are initiated by the host that is the primary station. Using this protocol, the host waits for the response before continuing, thus assuring that the host does not have to handle large sequences of open requests. This is a binary, byte-count-oriented protocol in which the data length is passed as a parameter in the message.

Table 6.9 shows the structure of the messages used by these interrogators for the request message (host to interrogator).

The contents of byte 5 (command flags) are used to control the actions of the interrogator. The meanings of the different bits in this byte are shown in Table 6.10.

The BCC, used to ensure the integrity of the message, is a 16-bit code calculated on all the bytes of the packet including the start mark. The BCC contains two parts: its least significant byte is a longitudinal redundancy check (LCR) calculated by performing a cumulative XOR operation on all the bytes of the packet. The most significant byte in the BCC is the one's complement of the LCR.

The structure of the message sent from the interrogator to the host (response) is shown in Table 6.11. Most of these bytes are similar to the bytes in the request message.

The data field in response messages is limited to a maximum of 23 bytes. The contents of byte 5 (command flags) are used to report on the actions of the interrogator. The meanings of the different bits in this byte are shown in Table 6.12.

The different error codes that the interrogator transmits to the host computer when bit 4 of the command flag byte is set to 1 are described in Table 6.13.

The contents of byte 5 (command flags) are used to control the actions of the interrogator. The meanings of the different bits in this byte are the same as for the request message shown in Table 6.10.

6.4.2 Host Protocol for Tag-it™ Series 6000 Reader System Interrogators

This protocol defines the communications between the Tag-it™ Series 6000 Reader System Interrogators and the host computer. It handles the communication between the host and the interrogator, and carries out the requests

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TABLE 6.9

Series 6000 Host-to-Interrogator Message Format

Byte	Content
0	Start of Frame[a]
1	Message length[b] - LSB
2	Message length - MSB
3	Node address[c] - LSB
4	Node address - MSB
5	Command flags[d]
6	Command[e]
7	Data[f]
8	Data
…	Data
N+6	Data
N+7	BCC[g]
N+8	BCC

[a] The first byte is the *start mark* that indicates the start of a message. This byte is equal to $01.

[b] The second and third bytes are the *message length* bytes that indicate the length of the whole packet, including the start mark.

[c] Bytes 3 and 4 constitute the *node address*. Its value is $0000.

[d] Byte 5 is the *command flags* byte. It controls the actions taken by the interrogator. The value of this byte is dependent on the command being transmitted.

[e] Byte 6 is the *command* byte. It specifies the actions that must be taken by the interrogator. The value of this byte is dependent on the command being transmitted.

[f] The following *N* bytes are the *data* bytes. These contain the parameters and the data for the command.

[g] The last two bytes are the *BCC* bytes used to ensure the integrity of the preceding message. BCC is performed on the previous bytes, including the start mark.

TABLE 6.10

Bit Functionality in Command Flag Byte (Request)

Bit	Description
0	Reserved for future use
1	Reserved for future use
2	Reserved for future use
3	Reserved for future use
4	1 = Command to be performed only on transponders with an address that matches the data section of the message
5	Reserved for future use
6	Reserved for future use
7	Reserved for future use

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TABLE 6.11

Series 6000 Interrogator-to-Host Message Format

Byte	Content
0	Start of Frame
1	Message length - LSB
2	Message length - MSB
3	Node address - LSB
4	Node address - MSB
5	Command flags
6	Command
7	Data
8	Data
…	Data
N+6	Data
N+7	BCC
N+8	BCC

TABLE 6.12

Bit Functionality in Command Flag Byte (Response)

Bit	Description
0	Reserved for future use
1	Reserved for future use
2	Reserved for future use
3	Reserved for future use
4	Error flag. 1 = command was unsuccessful. Data section of response packet contains the code of the error
5	Reserved for future use
6	Reserved for future use
7	Reserved for future use

TABLE 6.13

Error Codes

Code	Description
$01	Transponder not found
$02	Command not supported
$03	Packet BCC invalid
$04	Packet flags invalid for command
$05	General write failure
$06	Write failure because of locked blocks
$07	Transponder does not support command
$0F	Undefined error

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for commands as well as their responses. Additionally, the protocol manages some aspects of the functionality of the reader and enhances the functionality of basic transponders by requesting the execution of compounded commands. This protocol is intended for point-to-point, half-duplex communications in which the host is the primary station. In some situations, however, the host may receive responses without sending a request first. This is a binary, byte-count-oriented protocol in which the data length is passed as a parameter in the message. Similar to the TIRIS protocol, the message from the host to the interrogator is called a *request*, while the message from the interrogator to the host is called a *response*.

The communication between host and interrogator is performed using a frame structure. The frame structure is essentially the same for requests and responses with the exception of the flag as they have different meanings. Requests use control flags, while responses use status flags. In this protocol, the length of the message data is limited to 4091 bytes. Table 6.14 describes the structure of the request and response frames.

In *pass-through-service* mode, the interrogator passes the information that it has received from the host to the transponder immediately without doing any other action. When the interrogator receives a response from the transponder, it also passes it directly to the host without further action. If the interrogator does not receive a response from the transponder in a specified period of time, it sends a message to the host with the error flag set and the

TABLE 6.14

Structure of Request and Response Frames

	Description	
Byte	**Request Frame**	**Response Frame**
1	Start Code[a]	Start Code
2	Data Length[b]	Data Length
3	Data Length	Data Length
4	Service Code[c]	Service Code
5	Control Flag	Status Flag
6	Message Data	Message Data
…	Message Data	Message Data
N-1	Message Data	Message Data
N+6	BCC	BCC
N+7	BCC	BCC

[a] The first byte contains the *start code*. This is the start frame delimiter using the value $D5.

[b] The next block is the two *data length* bytes that specify the number of data bytes that follow that block. The minimum length is 4 bytes (the service code, control flag, and two BCC bytes), while the maximum length is limited to 4095 bytes.

[c] The *service code* indicates the type of command that is being sent, as shown in Table 6.15.

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TABLE 6.15

Service Codes

Code	Description
$01	Pass-through Service
$02	Single Service
$03	Compound Service
$04	Ancillary Service

appropriate error code. Using pass-through service, the host directly controls the transponder.

In *single-service* mode, after receiving a request from the host, the interrogator analyzes and verifies it before formatting and sending a single command to the transponder. Also, when the interrogator receives a response from the transponder, it analyzes it, verifies it, formats it, and sends a unique response to the host.

The *compound-service* mode is used by the host to instruct the interrogator to perform specific actions on transponders using the transponder protocol. The difference between these actions and the actions from a single-service request is that in compound service, the interrogator performs complex operations involving multiple commands before returning a response to the host computer. After receiving a compound-service request, the interrogator also analyzes and verifies it before sending the appropriate commands to the transponder. The interrogator also analyzes and verifies all the responses received from the transponder before sending a single response to the host. This response, however, may consist of more than one frame depending on its size. Compound service increases the performance of the system because, for example, it takes less time to send a single command to read four blocks of memory and transmit the information to the host, rather than issuing four different reading commands while transmitting the intermediate information to the host after each one has been performed.

Ancillary-service mode is used to instruct the interrogator to perform certain actions that do not involve communication with the transponder. Examples of such actions are interrogator reset, read interrogator version, and perform interrogator diagnostics. They are also used to upload new software versions in the interrogator or to set up new communication parameters.

Table 6.16 lists the available service codes with the exception of the pass-through-service codes as they are defined by the transponder protocol. The different transponder protocols are described in Chapter 7. The different commands are described in further detail in the next sections of this chapter. Table 6.16 can also be used to understand the type of commands available for each service code.

For control flags, four of the bits in byte 5 are used to specify instructions to the interrogator or they carry information about the message, as shown in Table 6.17.

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TABLE 6.16

Commands Available for Different Service Codes

		Service Code		
Command	**Command Code**	**Single**	**Compound**	**Ancillary**
Tag Version	$03	$02		
Read Block	$12	$02		
Read Multiblock	$02	$02	$03	
Read Block SID	$FE		$03	
Read Multiblock SID	$FD		$03	
Write Block	$05	$02		
Write and Lock Block	$07	$02		
Write Multiblock	$06	$02	$03	
Lock Block	$08	$02		
Lock Multiblock	$09	$02	$03	
Repeat Last Request	$01			$04
Send Last Request	$02			$04
Stop Continuous	$04			$04
Start Synch	$05			$04
Reader Reset	$10			$04
Reader Version	$11			$04
Reader Diagnostic	$12			$04
Read Reader Setup	$13			$04
Start Flash Loader	$16			$04
Factory Lock Block	$3D	$02		
Write SID Code	$3E	$02		
Factory Programming Off	$3F	$02		

The next byte, byte 5, is the *control flags* byte. This byte has a different meaning depending on the direction of the message. For Request Frames (host-to-interrogator), byte 5 is called the *control flag byte*. For response frames (interrogator-to-host), byte 5 is called the *status flag byte*.

For status flags, four of the bits in byte 5 are used to provide information about the result of the request, as shown in Table 6.18.

Bit 0 (exception flag) indicates whether the request was successfully routed to the interrogator. When bit 0 is reset to 0, it indicates that no exception occurred and the request was completed satisfactorily. When bit 0 is set to 1, it indicates that an exception occurred. In this case, the error code that describes the exception can be found in the first byte of the message. These errors are shown in Table 6.19.

Bit 1 (more flag) informs the interrogator whether more data follow (bit 1 = 1). Bit 2 (emulation flag) informs the interrogator whether the transponder completed the request using a compound command to emulate a complex command (bit 2 = 1). Bit 3 (auto-repeat flag) informs the interrogator where

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TABLE 6.17

Bits for Control Flags

Code	Description
0 (LSB)	Reserved
1[a]	More Flag
2[b]	Emulation Flag
3[c]	Auto Repeat Flag
4[d]	BCC Flag
5 to 7	Reserved

[a] When bit 1 (more flag) is set to 1, it indicates to the interrogator that it should expect more frames until the host sends a frame in which bit 1 is reset to 0. When bit 1 is reset to 0, it indicates to the interrogator that there are no more data associated with the request either in a single message or at the end of a series of messages.

[b] Bit 2 (emulation flag) indicates the interrogator if it is allowed to emulate a complex request by sending multiple single requests. This results in substituting a complex command with a compound command. When bit 2 is set to 1, this means that if the command cannot be performed using the current transponder version, the interrogator will attempt to use a compound command. When bit 2 is reset to 0, the substitution is not allowed.

[c] Bit 3 (auto-repeat flag) specifies whether or not the interrogator should automatically repeat the execution of the request. When Bit 3 is set to 1, auto-repeat is on. In this case, the interrogator will execute the request, send the response it has received from the transponder back to the interrogator, wait for a specified amount of time, and send the request again. This process is repeated until it receives another instruction with bit 3 reset to 0.

[d] Bit 4 is the BCC flag. It specifies the type of block code check used to ensure the integrity of the message. When bit 4 is reset to 0, the message uses CRC-CCIT, while when bit 4 is set to 1, the message uses LRC. Although LRC is simpler to implement and requires less processing time than CRC, it does not offer as much protection as CRC.

TABLE 6.18

Bits for Status Flags

Code	Description
0 (LSB)	Exception Flag
1	More Flag
2	Emulation Flag
3	Auto Repeat Flag
4	BCC Flag
5 to 7	Reserved

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TABLE 6.19

Error Messages Associated to Exception Flag

Code	Description
$00	Reserved
$01	Request data corrupted and not executed
$02	Application not supported
$03	Data format error and request aborted
$04	Continuous mode not available for this request
$05	Reserved
$06	Reserved
$07	Reserved
$08	Reserved
$09	Reserved
$0A	Reserved
$0B	Reserved
$0C	Reserved
$0D	Reserved
$0E	Reserved
$0F	Undefined error and request aborted

TABLE 6.20

Structure of Single Service Messages

Length	Description
5 bytes	Frame
1 byte	Command
1 byte	Format
1 byte	Synch
≤ 4088 bytes	Message Data
2 bytes	Frame

the transponder performed the request once (bit 3 = 0) or continuously (bit 3 = 1). Bit 4 (BCC flag) specifies the method used to generate the BCC byte: CRC (bit 4 = 0) or LRC (bit 4 = 1).

The next byte or set of bytes are the *message data* bytes that carry the actual message. The actual format of the message depends on the type of command that was specified in the service code byte. In pass-through-service messages, the interrogator is transparent to the request from the host to the transponder. The communication from the host to the transponder uses the transponder protocol. Because this is a bit-oriented protocol, it may be necessary to add the necessary bits to the message to ensure that the whole frame falls within a byte-oriented protocol. These are called *pad bits*. The structure for single-service messages is shown in Table 6.20.

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TABLE 6.21

Format Byte for a Request Message

Bit	Name	Description
0 (LSB)	Reserved	
1	Code Extension	0 = No extension code 1 = Code extension used
2	Addressing	0 = Not addressed 1 = Addressed. Address contained in first 4 bytes of data field
3	Format	0 = Fixed format 1 = Variable format
4	Transmitter control	0= Turn transmitter off after executing command 1 = Leave transmitter on
5	Reserved	
6	Reserved	
7 (MSB)	Reserved	

TABLE 6.22

Format Byte for a Response Message

Bit	Name	Description
0 (LSB)	Error	0 = No error 1 = Error occurred. Status code is first byte of data field after any address information
1	Code Extension	0 = No extension code 1 = Code extension used
2	Addressing	0 = Not addressed 1 = Addressed. Address contained in first 4 bytes of data field
3	Format	0 = Fixed format 1 = Variable format
4	Reserved	
5	Reserved	
6	Reserved	
7 (MSB)	Reserved	

The structure for single-service messages is shown in Table 6.20.

The format byte contains information about the format and status of the message. The contents are different depending on whether the message is a request or a response. Table 6.21 shows the description of the format byte for a request message, while Table 6.22 shows the description of the format byte for a response message.

Table 6.23 shows the meaning of the synchronization codes for both request and response messages.

The structure for compound messages is shown in Table 6.24.

Tables 6.25 and 6.26 show the structure of the format byte for request messages and response messages, respectively.

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TABLE 6.23

Synch Byte for a Request or for a Response Message

Bit	Name	Description
0–2	Synchronization type	000 = No synchronization 001 = Master Slave synchronization (Master) 010 = Master Slave synchronization (Slave) 011 = Cascaded synchronization
3	Action on "No Transponder"	0 = All responses sent to host 1 = "No transponder" responses not sent to host
4	Alternate Operation during continuous mode	0 = All valid data responses sent to host 1 = Identical responses sent to host only once
5	Reserved	
6	Reserved	
7	Reserved	

TABLE 6.24

Structure of Compound Messages

Length	Description
5 bytes	Frame
1 byte	Command
1 byte	Format
1 byte	Synch
≤ 4088 bytes	Message Data
2 bytes	Frame

TABLE 6.25

Format Byte for a Request Compound Message

Bit	Name	Description
0 (LSB)	Reserved	
1	Reserved	
2	Addressing	0 = Not addressed 1 = Addressed. Address contained in first 4 bytes of data field
3	Format	0 = Fixed format 1 = Variable format
4	Transmitter control	0= Turn transmitter off after executing command 1 = Leave transmitter on
5	Reserved	
6	Reserved	
7 (MSB)	Reserved	

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TABLE 6.26

Format Byte for a Response Compound Message

Bit	Name	Description
0 (LSB)	Error	0 = No error 1 = Error occurred. Status code is first byte of data field after any address information
1	Reserved	
2	Addressing	0 = Not addressed 1 = Addressed. Address contained in first 4 bytes of data field
3	Format	0 = Fixed format 1 = Variable format
4	Reserved	
5	Reserved	
6	Reserved	
7 (MSB)	Reserved	

TABLE 6.27

Structure of Ancillary Messages

Length	Description
5 bytes	Frame
1 byte	Command
≤ 4090 bytes	Message Data
2 bytes	Frame

Note: Because this type of command does not involve communication with the transponder, it does not require the format or sync bytes present in the other types of messages. The last two bytes contain the BCC code of either CRC or LRC. This is performed over all the preceding data with the exception of the start-of-frame byte.

The description of the synchronization bit is the same as for single messages that was shown in Table 6.23. The structure of ancillary messages is shown in Table 6.27.

The method of flow control demands for each request to receive a response. The flags in the response message indicate the presence of an error or other exceptions. After a certain time without receiving a response, the request can time out. The control is done by the host that acts as the primary station. Data lengths are variable for each message, although the maximum data length in a single message is 4091 bytes.

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7

The Air Communication Link

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This chapter describes the communication methods used to transfer information from the interrogator to the transponder and from the transponder to the interrogator. The communication from interrogator to transponder is usually known as the *forward communications link*. This consists mostly of commands sent from the host computer to the transponder via the interrogator. It also contains the data to be written for those transponders whose memories can be rewritten. The communication from transponder to interrogator is known as the *return link* or the *backscattered communication*. This consists mostly of the transmission of the data stored in the transponder's memory.

While there are several standards that specify the critical elements of the communications protocol, the implementation of these standards especially varies not only among different manufacturers but also among different products from the same manufacturers. Therefore, this chapter does not pretend to be a comprehensive collection of all the air communication methods employed by RFID systems. Instead, this chapter explores the most common

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approaches to the communication between these elements of the RFID system using specific systems as general examples. This should give the readers the basic information while preparing them to search for more specific details if they so require.

This chapter starts by describing the different air communication protocols followed by the study of the elements that make up the forward and the return communications link. It continues by talking about the different modes of operation available to transponders. The last section in this chapter describes the different arbitration methods and the anticollision procedures that allow effective communication when there is more than a single transponder in the radiofrequency field.

7.1 Communication Protocols

7.1.1 Communication Protocols for Systems Operating in the LF and HF Ranges

The T5557 is a transponder with a 300-bit memory manufactured by Atmel® that operates in the low-frequency range and is similar to other transponders from different families of manufacturers. The communication between transponder and interrogators starts with the chip in the transponder being initialized after it has reached its threshold voltage. Afterward, the chip will be ready or will experience an additional delay of 67 ms depending on the status of one of its configuration bits. In read mode, the data from the memory are transmitted serially by modulating the load across the antenna terminals, starting with bit 1 from block 1. This process continues until the last bit from the specified number of blocks has been transmitted. The number of blocks to be read is defined by one of the bits in the transmitted command.

The transmission from the transponder to the interrogator uses amplitude-shift keying (ASK) modulation by switching a load connected to the antenna terminals on and off. Figure 7.1 shows the waveform across the load for different types of coding.

The transponder has the ability to insert a special pattern in order to synchronize the interrogator before transmitting the first block. This pattern consists of four bit periods in which the modulation is turned off and on, as shown in Figure 7.2.

In order to write data to the transponders, the interrogator uses on-off keying. It interrupts on and off the electromagnetic field generated as shown in Figure 7.3. The time between the gaps is used to encode the data to be transmitted: 24 periods of the RF field for a *0* and 54 periods of the RF field for a *1*. The process finishes after the transponder has detected that there is no gap

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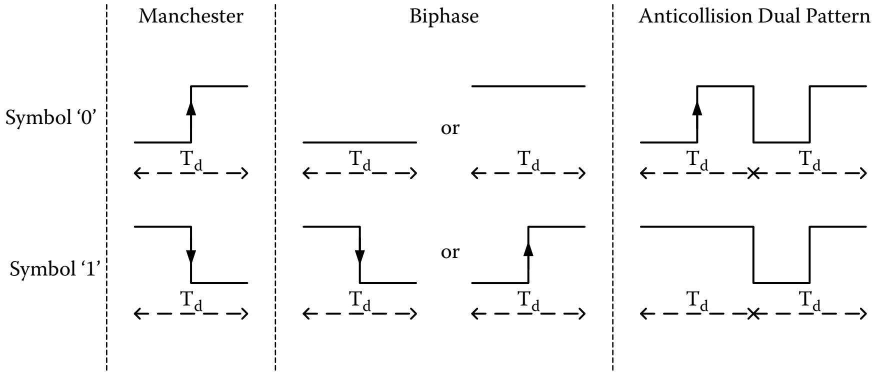
Manchester
Biphase
Anticollision Dual Pattern
Symbol '0'
Symbol '1'
or
or
T_d

FIGURE 7.1
Waveforms across load for different types of coding.

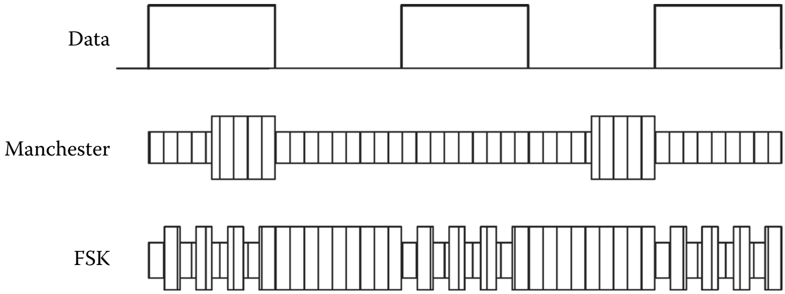
Data
Manchester
FSK

FIGURE 7.2
Synchronization patterns for Manchester and frequency-shift keying (FSK) modulations.

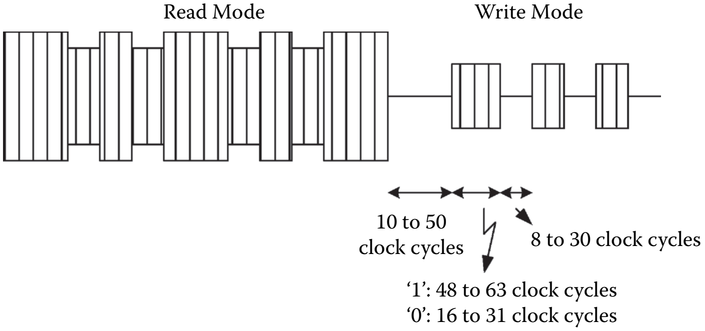
Read Mode
Write Mode
10 to 50
clock cycles
8 to 30 clock cycles
'1': 48 to 63 clock cycles
'0': 16 to 31 clock cycles

FIGURE 7.3
Gap sequences used in data transmission.

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for more than 64 periods. The initial gap triggers the communication from the interrogator to the transponder. This initial gap can be accepted at any time after the system has been initialized.

After the initial gap, the transponder expects to receive a valid command sequence. A standard write command needs the operation code, the lock bit, the 32 bits that make up the data, and the 3-bit address. Writing to a protected transponder requires the additional 32-bit password that is placed between the operation code and the data address bits. The password bits are compared bit by bit with the contents of the password stored in memory. If the bits do not match, the transponder returns to read mode. The complete writing process is shown in Figure 7.4.

After all the information has been correctly received, the transponder can be programmed. There is, however, a delay of one clock period between the end of the writing sequence and the start of the programming. The typical programming time is 5.6 ms, including the reading for data verification. Figure 7.5 displays the voltage measured across the antenna after programming a memory block.

For the Tag-it™ family of transponders manufactured by Texas Instruments, the communication between interrogator and transponder is done by amplitude modulation of the carrier. This allows the interrogator to generate enough energy to power the chips on board the transponders while simultaneously sending data. The encoding for the logic symbols *1* and *0* is done

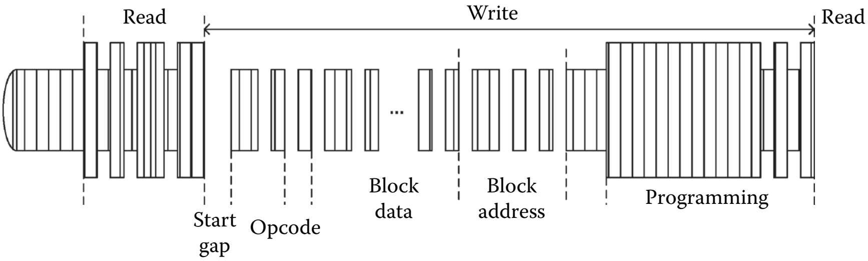

FIGURE 7.4
Writing sequence.

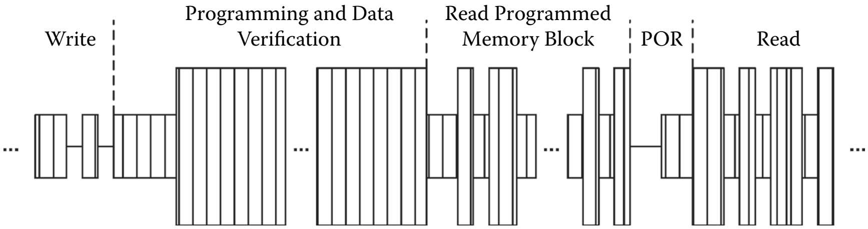
Write
Programming and Data Verification
Read Programmed Memory Block
POR
Read
...
...
...
...

FIGURE 7.5
Voltage across antenna terminals after programming a block.

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by pulse width modulation: *1* is encoded as a power burst lasting 150 µs, while *0* is encoded by power bursts lasting 100 µs. Data are framed between a start-of-frame (SOF) signal and end-of-frame (EOF) signal. SOF consists of a 50 µs burst followed by a standard duration pulse, terminating with a 150 µs pulse. The EOF signal consists of a 50 µs burst followed by a standard duration pulse, terminating with a 100 µs pulse.

The communication between the transponder and the interrogator uses the modulation of the antenna as it tunes and detunes the signal to generate the backscattered information. The signals being transmitted are encoded using a Manchester code, taking advantage of the clock frequency being embedded in the transmitted signal. With the load modulation, a Manchester high level is represented by a frequency of 423.75 kHz, while a Manchester low level is represented by a frequency of 484.29 kHz.

7.1.2 Communication Protocols for Systems Operating in the UHF Range

Transponders operating in the UHF range manufactured by Atmel® are based on the *interrogator talks first* (ITF) approach to establish communication with the interrogator. The communication always starts with a forward message, that is, a message from the interrogator to the transponder. After receiving this initial message, the transponder responds by backscattering a message to the interrogator. This is known as the *return link*. This backscatter communication is done using a binary phase-shift keying (2PSK) modulation based on changing the imaginary part of the input impedance in the transponder as a function of the message between sent.

The communication is based on a system of frames, as shown in Figure 7.6. The first frame is the header frame that is used to adjust the timing. The second frame is the data frame that is used to transport the data. The length of this frame depends on the command sent and the addressing mechanism being used. The last frame is the end-of-transmission (EOT) frame that marks the end of the transmission. Once the transmission has finished, the interrogator enters into listening mode after having received another header frame.

While the interrogator is transmitting data, the transponder remains in listening mode. During the transmission of the interrogator header frame, it is possible for the transponder to operate in full duplex. It transmits data back to the interrogator in a loop until the EOF frame is sent.

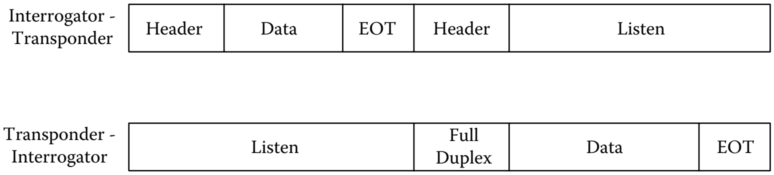

FIGURE 7.6
Frame communications during default transmissions.

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The communication between transponder and interrogator must be reliable even in the noisy environments in which these systems normally operate. To improve the reliability of the communication link, the interrogator transmits periodic clock ticks to the transponders, ensuring reliability because it helps to block other radiofrequency sources. In addition, the link between transponder and interrogator operates synchronously, and because the interrogator controls the speed and modulation ticks, the resulting transmission has a higher signal-to-noise ratio than an asynchronous communication.

The general structure of the frames is different between the forward or return link as well as the type of commands that it carries. All the frames start with a header frame. The data frame in the forward link depends on the type of command carried, as shown in Figure 7.7, which shows frames for different types of commands. Data frames contain the command and its cyclic redundancy check (CRC), data-setting parameters, address information, and data for programming. For example, short commands consist of 6 bits and its 2-bit CRC, while long commands consist at least of the command fame, the CRC, and the parameter field. In the transmission of a long command, these frames are followed by a CRC frame of 16 bits. The transmission ends with an end-of-transmission frame that is made of two EOF symbols.

Figure 7.8 shows the general structure for the return link frames. The communication link starts with a header frame that is used to obtain reference symbols, adjust modulation, and set the timing for the EOF characters. This is followed by a data frame, a CRC frame 16 bits long, and an

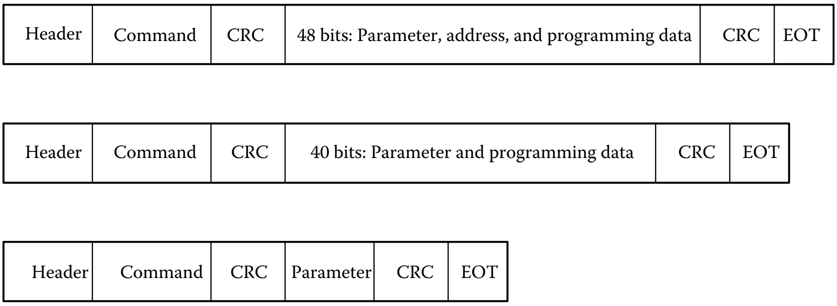
Header
Command
CRC
48 bits: Parameter, address, and programming data
CRC
EOT
Header
Command
CRC
40 bits: Parameter and programming data
CRC
EOT
Header
Command
CRC
Parameter
CRC
EOT

FIGURE 7.7
Examples of data frames in a forward link.

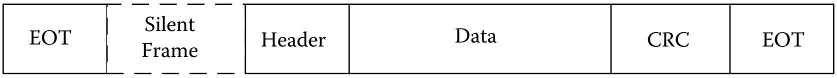
EOT
Silent Frame
Header
Data
CRC
EOT

FIGURE 7.8
General structure for return link frames.

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end-of-transmission frame. The data frame can have a length of 8 or 16 bits depending on the type of data carried. The silent frame shown in Figure 7.8 is only used during programming. During the silent frame period, the interrogator only transmits a continuous wave. The length of this period depends on the strength of the electromagnetic field.

The general structure of the communications flow for these transponders is shown in Figure 7.9. The transponder is continuously waiting for a notch indicating the presence of the external field. After it has been received, it will check for a valid header frame that indicates the beginning of a transmission. After the header frame has been received correctly, the transponder performs several additional verifications while transmitting the different parts of the message, including checking for the anticollision requests. The process ends after receiving the EOF data.

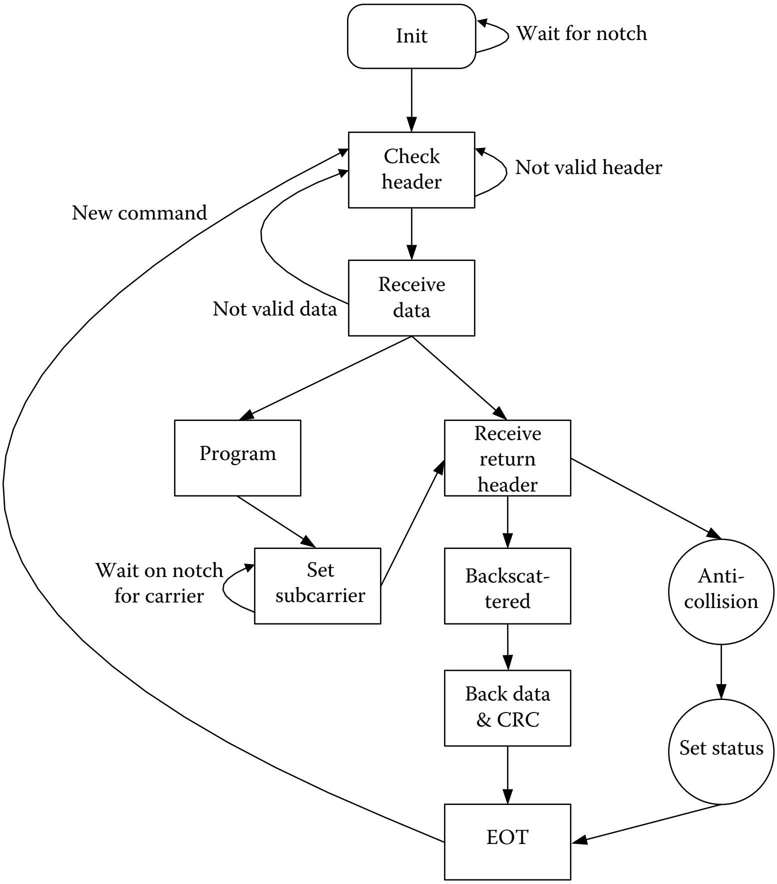
Init
Wait for notch
Check header
Not valid header
New command
Receive data
Not valid data
Program
Receive return header
Wait on notch for carrier
Set subcarrier
Backscat-tered
Anti-collision
Back data & CRC
Set status
EOT

FIGURE 7.9
General structure of communications flow.

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7.2 The Communications Link

7.2.1 Elements of the Communications Link

Because the transponder is powered by the electromagnetic field generated by the interrogator, it must measure the strength of this field continuously. If the strength of the field decreases in such a way that causes the voltage after the rectifier to be lower than a certain threshold, the circuits in the transponder activate an internal reset. For voltages higher than this threshold, the oscillator and the rest of the circuits in the transponder circuit are enabled. Figure 7.10 shows the time events between the different signals involved after the transponder is turned on for some transponders manufactured by Atmel®.

The duration of the power on reset (POR) period depends on how fast the signal ramps up. This in turn depends on the strength of the electromagnetic field. After the POR has executed, there is an additional waiting period called the *band gap* that is needed for stabilization of the rest of the internal circuits before the signal to enable the oscillator switches its state. Finally, there is a delay of 64 clock cycles (approximately 160 μs) before the oscillator in the transponder achieves operational status.

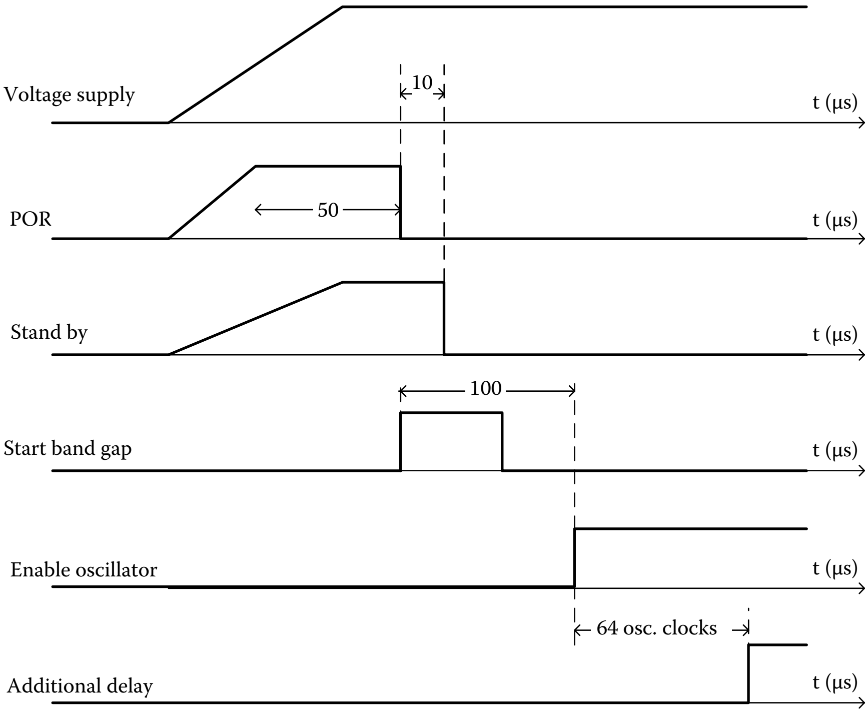

FIGURE 7.10
Chronogram of signals during power up.

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When the electromagnetic field decreases, the voltage after the internal rectifier also decreases. Once it reaches a certain threshold level, the oscillator stops. This results in lowering the current required by the circuit that in turn results in the voltage supply decreasing with a lower slope as shown in Figure 7.11. Finally, if the voltage decreases below another threshold, the circuit executes a reset. The difference between the two voltage levels allows for taking into account variations in the strength of the field without having to execute a reset.

The communication between transponder and interrogator normally happens in a noisy environment. Therefore, the designers of the system must ensure bit error rates as low as possible. This is achieved by using a combination of several techniques including generating notches in the system clock, making the return link synchronous to notch signals generated by the interrogator, using different coding techniques, and using CRC to protect the integrity of the data. CRCs for commands are 2 bits long, while CRCs for data are 16 bits long. Figure 7.12 shows the concept of notch timing, which results from generating notches at periodic intervals in the signal generated. For a typical value of signal level between 450 mV and 600 mV, T_1 lasts 4 μs and T_{notch} lasts 2 μs.

Other techniques include using *pulse interval encoding* to define the symbols *1* and *0*, whose timing and timing differences are controlled by the interrogator as an additional element to increase the robustness of the link. The fact that the return link is synchronous to the interrogator allows it to close the communication as soon as it detects a transmission error.

The communication from the interrogator to the transponder is known as the *forward link*, while the communication from the transponder back to the interrogator is known as the *return link*. The forward link carries the different type of commands to the transponder, while the return link carries the data from the transponder to the interrogator. These data will only be available for those commands that require the return of data. Because the

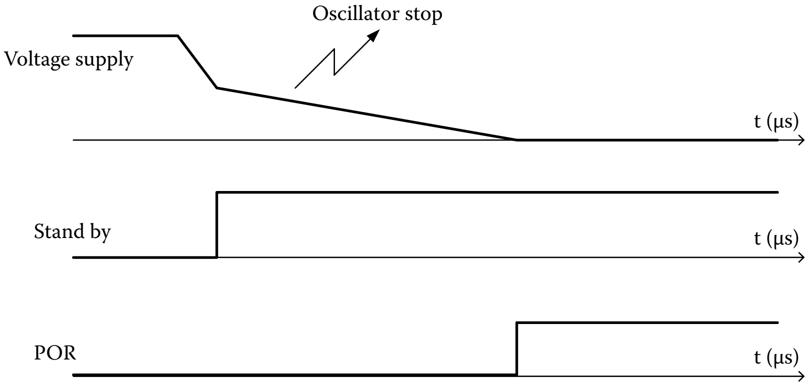

FIGURE 7.11
Chronogram of signals during power down.

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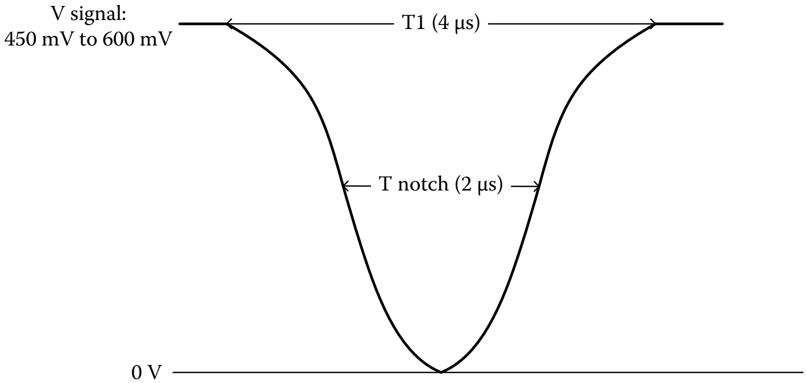

FIGURE 7.12
Notch timing chronogram.

handover mechanism from the forward to the return link happens synchronously, there is no need to wait for a cycle between them. Once the forward link sends its last frame that consists of an end-of-transmission message, the transponder is ready to transmit its return link header.

Texas Instruments RFID systems operating at low frequency use a frequency of 134.2 kHz to encode a low bit and a frequency of 123.2 kHz to encode a high bit. Because each bit uses 16 radiofrequency cycles to transmit, the duration of a low bit is different from the duration of a high bit. The low bit needs 119.9 μs to transmit, while a high bit needs 129.2 μs. The interrogator sends information to the transponder to transfer commands, addresses, or data. The writing process is always initiated by turning the radiofrequency transmitter on for a period of time of up to 50 ms. Afterward, the interrogator starts sending the bits that make up the command and associated data. Write bits last 2 ms. The differentiation between high and low bits is based on the duty cycle for each one of these bits. As shown in Figure 7.13, a high bit has a duty cycle approximately equal to 50%, while the low bit has a duty cycle approximately equal to 20%. The program phase consists of a continuous radiofrequency field for the duration of this period.

7.2.2 Forward Link

The forward header in most Atmel® transponders has four symbols, as shown in Figure 7.14. This header is accepted by the transponder if the length of the symbols *check1* and *EOF** is larger than the length of the symbol *0**.

Figure 7.15 shows that the information being transmitted is encoded in the timing between pulses. After the frame has been accepted and the

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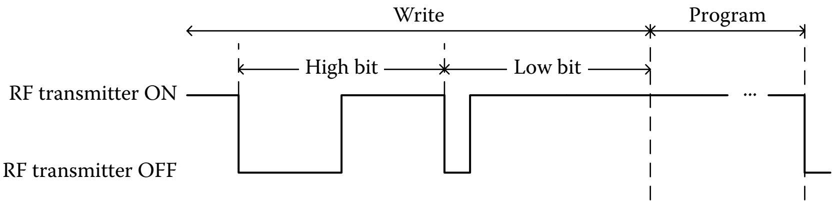
Write
Program
High bit
Low bit
RF transmitter ON
RF transmitter OFF
...

FIGURE 7.13
Write and program signals.

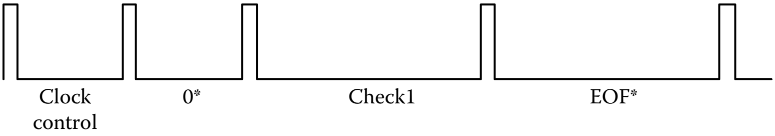
Clock control
0*
Check1
EOF*

FIGURE 7.14
The four symbols in the forward header.

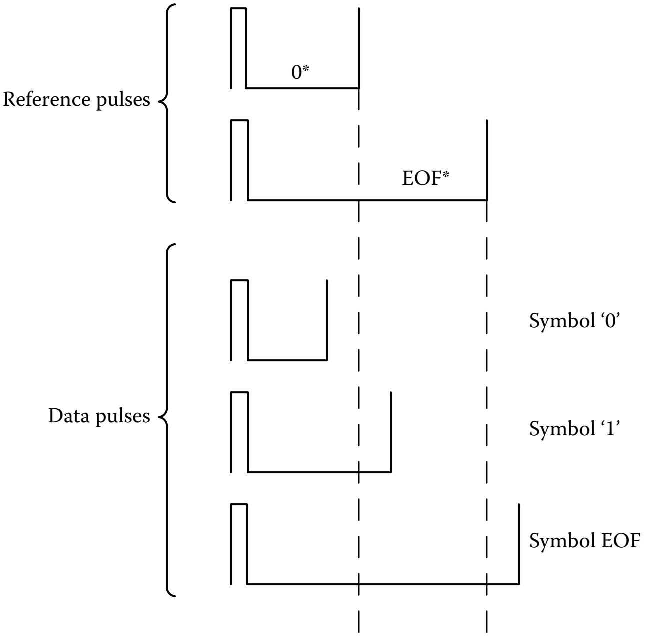
Reference pulses
0*
EOF*
Data pulses
Symbol '0'
Symbol '1'
Symbol EOF

FIGURE 7.15
Pulse timing used to encode information.

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interrogator transmits data, the transponder measures the time between two pulses or notch signals. This is used by the transponder to decide whether the received symbol is a *0* or a *1* by comparing its length with the length of the symbols *0** and *EOF**, as shown in Figure 7.15.

This figure shows that a symbol will be interpreted as a *0* if its timing is shorter than the time that was sent in the Header for the symbol *0**. A symbol will be interpreted as a *1* if the time used by that symbol is longer than for the symbol *0** but shorter than the time used in the header for the symbol *EOF**. Finally, EOF will be interpreted for a symbol that lasts longer than the *EOF** symbol. This approach increases the reliability of the link as the transponder does not have to measure absolute but relative time intervals.

The communication from the interrogator to the transponder for the Series 2000 Texas Instruments RFID systems is based on transmitting bursts of energy of specific duration at specific intervals. For example, the commands used to read read-only or read/write transponders consist of an initial power burst lasting 50 ms followed by a period of 20 ms in which the radiofrequency field is turned off. In fact, all these transponders use the 50 ms power burst as the initial identifier for an upcoming command in addition to providing the energy to power the transponder. The following are some examples of formats for the different commands supported by these transponders. Figure 7.16 shows the protocol to transmit the command used to program a rewritable transponder.

The command starts with the 50 ms power burst followed by the specific command keyword and the password if necessary. These are followed by the 80 data bits used by this family of transponders and the 16 bits that make up the write frame. The last information being sent is the PBII, after which the transponder will read the new data stored in its memory to be verified by the interrogator. Figures 7.17 and 7.18 show the communication protocols for the commands *lock page* (of multipage transponders) and *selective read page* (of multipage transponders), respectively.

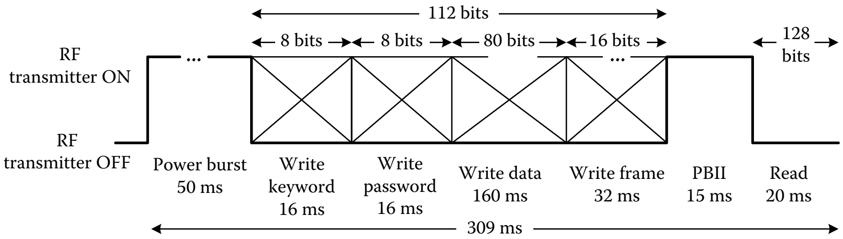

FIGURE 7.16
Protocol used to transmit a command to program a rewritable transponder.

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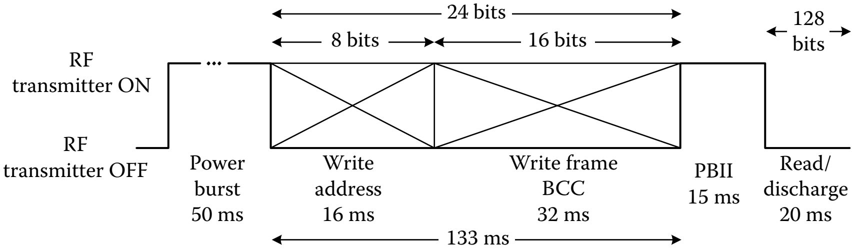
24 bits
8 bits
16 bits
128 bits
RF transmitter ON
RF transmitter OFF
Power burst 50 ms
Write address 16 ms
Write frame BCC 32 ms
PBII 15 ms
Read/ discharge 20 ms
133 ms

FIGURE 7.17
Protocol for the *lock page* command.

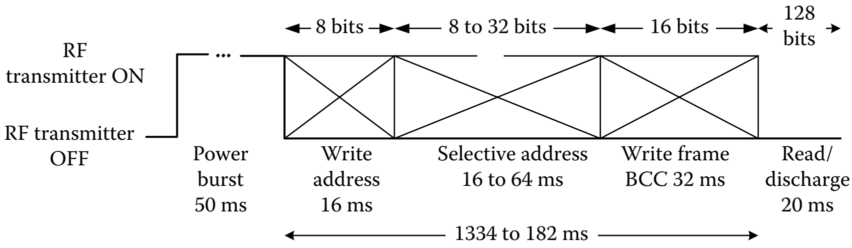
8 bits
8 to 32 bits
16 bits
128 bits
RF transmitter ON
RF transmitter OFF
Power burst 50 ms
Write address 16 ms
Selective address 16 to 64 ms
Write frame BCC 32 ms
Read/ discharge 20 ms
1334 to 182 ms

FIGURE 7.18
Protocol for the *selective read page* command.

7.2.3 Return Link

The return link in the majority of Atmel® transponders uses synchronous communication and angular modulation (binary PSK) in order to increase the signal-to-noise ratio and reduce the bit error rates because the return signals have extremely low power values. The synchronicity occurs as the transponder transmits its signal between two notches from the signal generated by the interrogator.

The return link starts with the return link header that is used to provide the timing information for the signal similar to the forward link header. Figure 7.19 shows the structure of the return link header for different types of coding styles used for the communication. In any case, the return link header always contains four symbols. The function and structure of each one of these symbols are shown in Table 7.1.

The return link header waits for a notch in the radiofrequency field generated by the interrogator before starting the generation of the reference timing. The data in the return link can be encoded using any of these coding techniques: bit stream (raw data), notch-locked non-return-to-zero-inverted (NRZI) encoding, soft-locked NRZI, FM0, and 3phase1. The EOT frame contains two EOF symbols.

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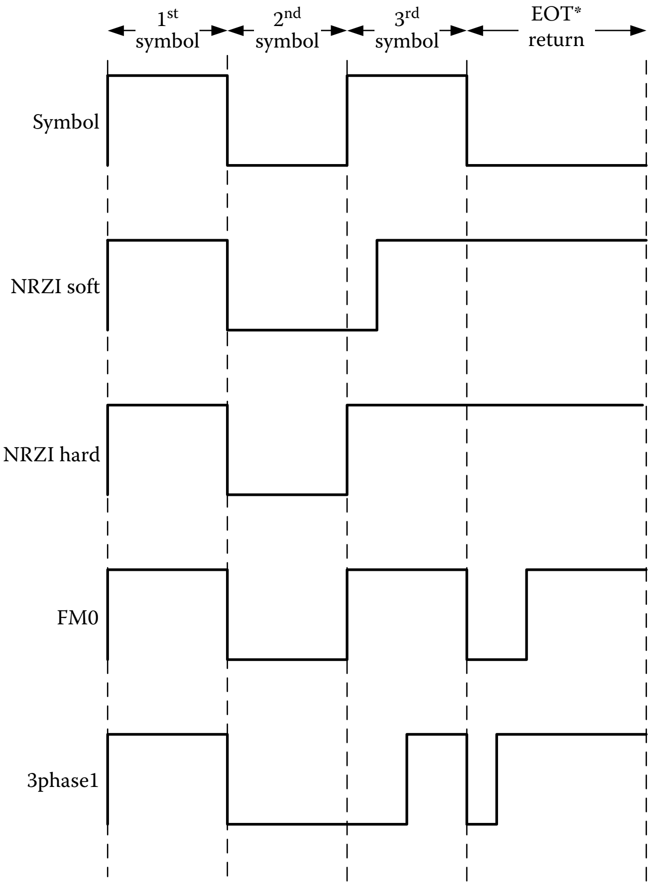

FIGURE 7.19
Structure of the return link header for different coding styles.

TABLE 7.1
Function of the Symbols in the Return Link Header

Symbol	Function	Additional Comments
1st	Main timing and power management	Used by interrogator to affect transmission rate of return link
2nd	Timing Reference	Used for anticollision control
3rd	Same timing as symbol 4	When using NIRZ, modulation is on
4th	Timing reference for EOF detection	

Figure 7.20 shows the transmission protocol used by the transponder to send information back to the interrogator as its response to a Read Data command for Texas Instruments transponders using their TIRIS protocol. All parts of this message are transmitted, with the least significant bit (LSB) being the first bit transmitted.

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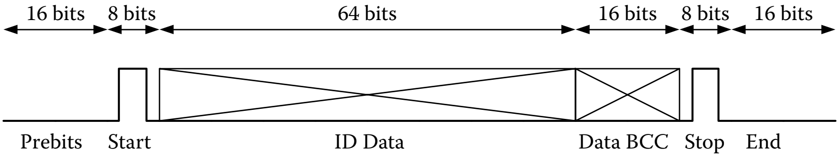

FIGURE 7.20
Transponder data sent back to the interrogator.

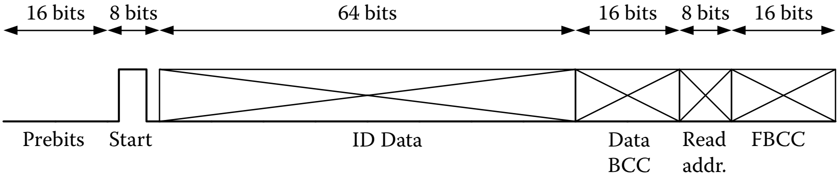

FIGURE 7.21
Return link for a multipage transponder.

After transmitting the pre-bits and eight bits that specify the start sequence, the transponder sends the 80 bits stored in its memory. The 64 first bits are the data bits, while the following 16 bits are the block check code (BCC) used to ensure the integrity of the data. These are followed by the stop and end bits. In order to be ready for a new activation, the transponder finishes the process by discharging its internal capacitor at the end of the transmission. The same protocol is used for rewritable transponders. Figure 7.21 shows the return link when accessing a multipage transponder.

In this case, following the BCC data, the transponder transmits the read address. This consists of a 2-bit status field that provides information about the function that that transponder has executed and a 6-bit page field that provides information about the page that was affected by the execution. The data format ends with reading the frame block check character (FBCC).

7.3 Transponder Operating Modes

7.3.1 Transponders Operating in the LF and HF Bands

After the transponders are initialized, they can enter into two different states, *interrogator talks first* (ITF) or *public mode* or *electronic surveillance*, depending on the status of their operating mode flags. In ITF mode, the data stream received through modulation from the interrogator

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undergoes different verifications. If they all result in a valid status, the transponder is synchronized with the data stream. At that point, the transponder is ready for communication. This communication always starts with a forward message, which is a message from the interrogator to the transponder. This communication method is used in multitransponder applications due to its anticollision capabilities. In this mode of operation, the transponder can be in any of the following states: *power down*, *ready*, *selected*, or *quiet*.

When the transponder is not able to harvest enough energy from the surrounding electromagnetic field to energize its internal chip, it enters power down state. The transponder can also enter the ready state after having received a reset command. The transponder enters the selected mode after having received an explicit command with its own serial number from the interrogator. It is possible to set several transponders into the ready state by sending a specific command containing a matching partial identification number. It is necessary to set a transponder into the selected mode before being able to access it. The quit state is entered after a selected state after the interrogator selects another transponder or receives a specific command to enter this state.

Public mode communications start with the SOF pattern, which is followed by continuously streaming the data from the user memory. As shown in Figure 7.22, the first bit being sent is bit 31 from data block 0. When the transponder reaches its final data block, it starts transmitting data block 0 again. This process terminates when the electromagnetic field that energizes the transponder is turned off or when the transponder receives the appropriate command from the interrogator.

Electronic surveillance mode is a particular operating mode in which the transponders are attached to specific retail articles. By programming all bits in block 0 of the user memory to *0*, the transponder is set to an *unpaid state*. After the article has been purchased, the cash register sets the bits of block 0 to *1*, thus entering the *paid state*. Additional security can be achieved by protecting the bits of block 0 with a write password. If a transponder in the *unpaid state* enters the electromagnetic field generated by the interrogator located at the doors of the store, it will modulate the field. Consequently, the presence of a transponder marked in the *unpaid state* will be detected by the

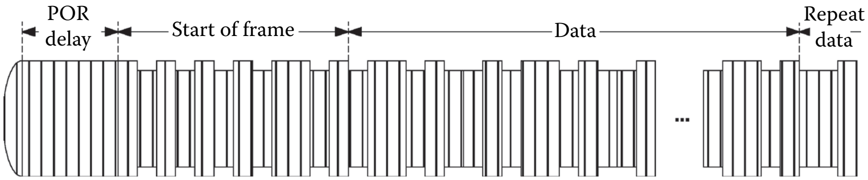

FIGURE 7.22
Initial sequence for the public mode.

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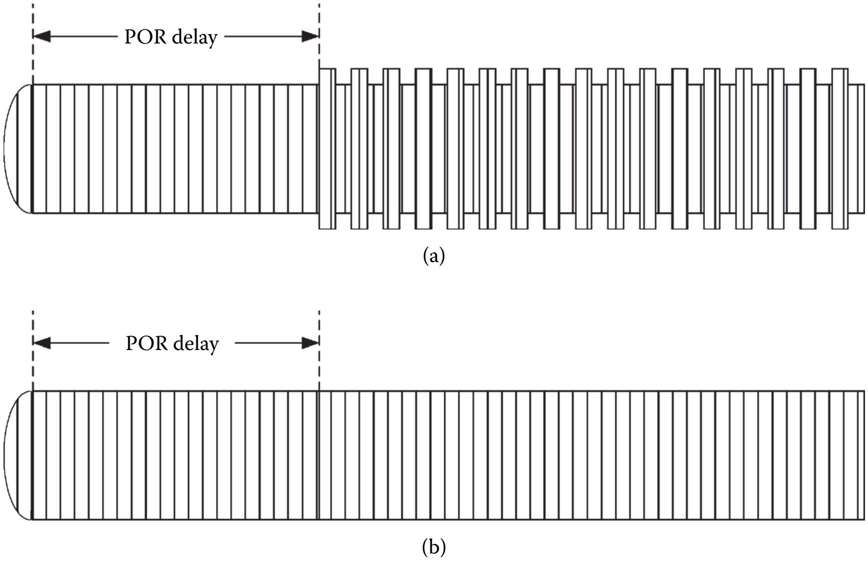

FIGURE 7.23
Signals from the transponder in electronic surveillance mode: (a) article unpaid, and (b) article paid.

interrogator, triggering the appropriate alarms. Conversely, a transponder marked as being in the *paid state* will not alter the electromagnetic field and will be transparent to the interrogator. Figure 7.23 shows the signals for these two cases.

Figure 7.24 shows the relationships between the different states for the transponders depending on their operational mode.

7.3.2 Transponders Operating in the UHF Bands

The possible states for the transponders manufactured by Atmel® operating in the UHF band are RF Field OFF, RF Field ON, Start, Mute, Observe, Ready, Active, and Isolated. These states and the paths between them are shown in Figure 7.25 and discussed here.

- The initial state is the *RF Field Off* state. Here, the transponder is not able to operate because there is no external radiofrequency field for which it can draw power. The transponder is able to store some configuration information for about 8 seconds after the field has ceased. After this time, the contents of these registers become undefined.
- When the transponder enters a region with an existing radiofrequency field whose magnitude allows the transponder to power

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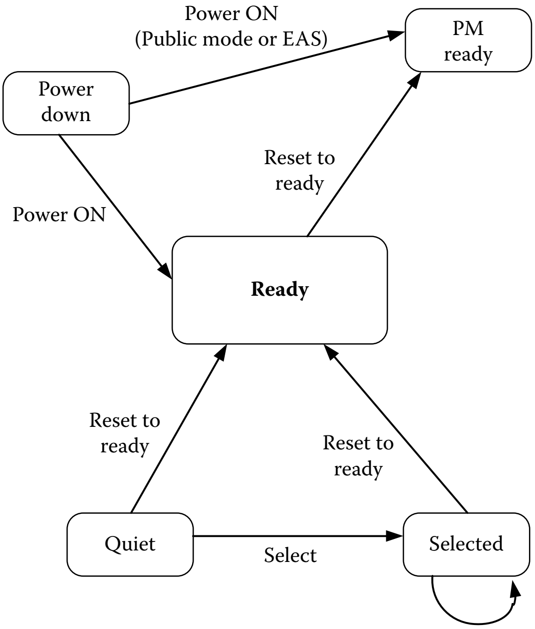
Power ON
(Public mode or EAS)
PM
ready
Power
down
Reset to
ready
Power ON
Ready
Reset to
ready
Reset to
ready
Quiet
Select
Selected

FIGURE 7.24
Different transponder states.

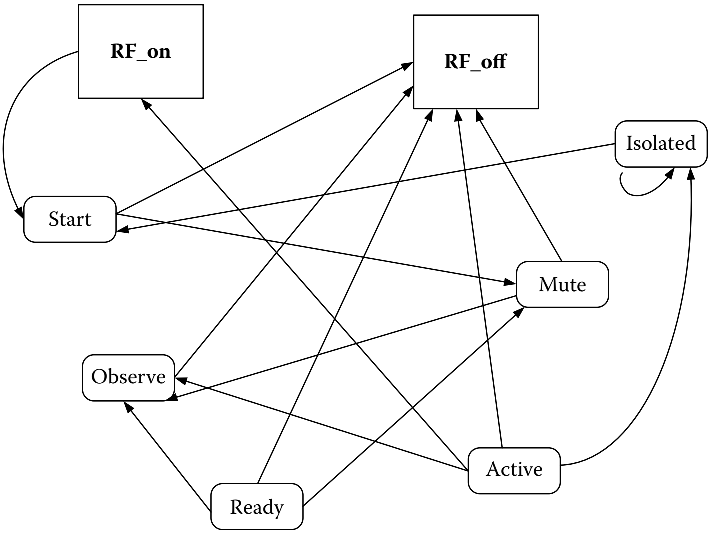
RF_on
RF_off
Isolated
Start
Mute
Observe
Active
Ready

FIGURE 7.25
Operational states for UHF transponders.

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its internal circuitry, this generates a power on reset. This is the *RF Field On* state. After the POR has occurred, the internal oscillator in the transponder is switched on. It is important to note that for this process to occur, the frequency of the external radiofrequency field must match the resonant frequency of the transponder's antenna and associated circuitry. Once this process has finished, the transponder moves into the *Start* state.

- In the *Start* state, the transponder refreshes the contents of the status registers and reads their configuration from its memory, enabling or disabling its trigger function. After this process, the transponder is able to detect the modulation ticks that signify information being sent from the interrogator. From this state, the transponder can move to the *Mute* state or to the *Observe* state.
- In the *Mute* state, the transponder cannot respond to operations such as programming, arbitration, or backscattering data. The transponder leaves the *Mute* state after some of its internal configuration registers have been modified.
- The *Observe* state allows the transponder to become synchronous with the interrogator for performing operations such as programming. To become synchronous the transponder checks that the forward header received from the interrogator is valid, that the command received is within the list of known commands, and that its CRC is also valid. If all these checks are passed successfully, the transponder moves to the *Ready* state.
- During the *Ready* state, the transponder receives the parameters associated with the type of commands sent by the interrogator. If any of the parameters are false, the transponder enters the *Mute* state. Otherwise, the transponder enters the *Active* state.
- In the *Active* state, the transponder is able to execute the command sent by the interrogator after receiving and checking the rest of the forward frame. If there are any errors in the information sent after the header frame, the transponder moves into an *Isolated* state or *Mute* state depending on the type of errors received. If the information sent in the forward frame is correct, the transponder executes the command. Once the transponder has finished the execution it moves back into the *Ready* state. Figure 7.26 shows with more detail the processes that occur during the *Active* state.
- The first step in this process is to verify the length of the received stream. If this is correct, the transponder checks for the validity of the position of the end-of-transmission frame. Depending on the result of this check, the transponder knows if the anticollision procedure has been activated in order to select that specific transponder. If this is the case, the transponder will enter the appropriate

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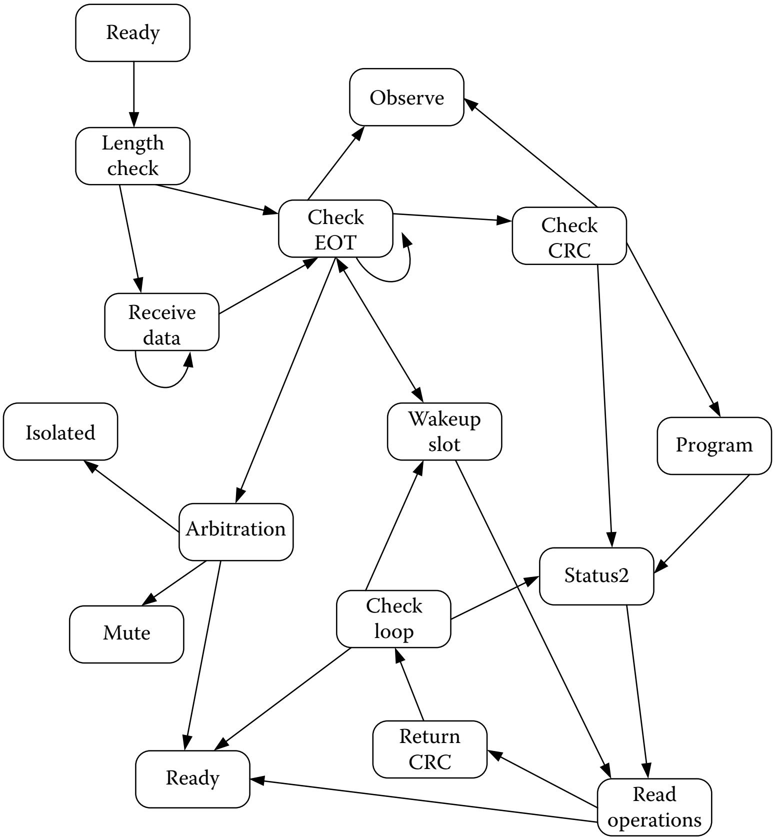
Ready
Observe
Length check
Check EOT
Check CRC
Receive data
Isolated
Wakeup slot
Program
Arbitration
Status2
Mute
Check loop
Return CRC
Ready
Read operations

FIGURE 7.26
Processes during the active state of transponders.

anticollision and arbitration procedures. The transponder can also enter into receiving wakeup commands or other types of commands sent by the interrogator.

- In the *Isolated* state, the transponder is isolated and waits for either a POR or reset command to leave this state.

7.4 Arbitration for Transponders

7.4.1 Principles of Arbitration

When there is more than one transponder immersed in the electromagnetic field generated by an interrogator, it is necessary to develop and establish a

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procedure to select a single transponder or a specific group of transponders for carrying out specific functions. Alternatively, it can also be necessary to isolate a specific transponder or a group of transponders so they do not disturb communications. In some applications it may also be interesting to know whether there are transponders in the field or not. All these functions require the use of arbitration procedures. The two main types of arbitration procedures are *deterministic arbitration procedures* and time-slot based procedures, also known as *aloha procedures*.

Deterministic procedures are based on a *tree-walking function* in which the interrogator acting as the control node uses the individual IDs of transponders to select one or a group of them. The interrogator starts by polling all the transponders in the field. If there is more than one, their responses will collide and the interrogator will not receive the message. Therefore, in the next step, the interrogator polls only a specific subgroup of transponders based on their IDs. If the responses also collide, the interrogator reduces the population by polling only a specific subgroup from the previous subgroup. This process is repeated until the interrogator receives a response from a single transponder.

Aloha procedures are controlled by slot commands. After the transponders are turned on, they calculate random values for as long as they are powered. Once the transponder has received a slot command, it creates a random number from its generator, which points to a slot number in the chip. After receiving a start command, the transponders transmit their information to the reader during the first slop. If the random number matches the first slot number, it calculates a new one during this slot. When the random number matches the slot number controlled by the interrogator, that transponder becomes active. This allows the transponder to communicate with the interrogator. If the numbers do not match, the transponder enters a mute state and therefore does not respond to any commands. When the transponder receives a new slot command, it calculates if it is supposed to be active or mute.

7.4.2 Principles of Anticollision

The aim of anticollision procedures is to detect and identify the transponders that are present within the range of the electromagnetic field generated by the interrogator. While the implementation of specific anticollision procedures may vary between manufacturer and models, the principles of anticollision are common to all of them. For transponders manufactured by Atmel®, the communication with a single transponder or a group of transponders is controlled by the interrogator. The arbitration is initiated by the interrogator issuing a command for the transponders to transmit their identification numbers. The command can be tailored to the transponders that the interrogator expects to be in its area of influence. If the interrogator does not know anything about the transponders that are expected to be, the command is general and the detection encompasses all transponders. Otherwise,

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the command can use parameters such as a partial transponder identification number that will cause only transponders with partially matching IDs to respond to the command.

After the interrogator receives responses from the transponders, it scans their ID number from the most significant to the least significant bits. Each time slot corresponds to a specific bit position in the ID number. Because all transponders respond simultaneously with their modulated signal, their responses will be superimposed on one another. Therefore, because of the modulation being used, a damped signal overwrites a nondamped signal. With this, a logical *1* prevails over a logical *0*. Consequently, the transponders with these ID numbers are removed from the process. When the interrogator detects a logical *1*, it responds by broadcasting a gap in the radiofrequency field. The detection of a logical *0* does not originate any response from the interrogator. The gap in the field that is created as a response to the logical *0* is monitored by the transponders in the field and deduces, by comparing their ID number to the gap that was just broadcasted, if that specific transponder should continue in the current anticollision loop or eliminate itself from it. The transponders that are eliminated are muted and return to the ready state, in which they will remain until the interrogator initiates a new anticollision loop.

The transponders that have not been eliminated remain in the current loop as long as the final bit of the identification number has not been reached yet, and the process repeats itself. By the time the last bit has been interrogated, there will be a single transponder active as all the other transponders will have been eliminated through the previous steps. At this point, the interrogator is able to identify the associated ID for that specific transponder, and the transponder enters into the Selected state. Now, the transponder can establish direct communication with the interrogator and can be read or written. The transponder remains in the Selected state until the interrogator starts a new anticollision loop.

The MCRF450 family of transponders manufactured by Microchip Technology also supports anticollision. Their algorithm is based on time division multiplexing the transponder responses in which each transponder is only allowed to communicate with the interrogator during its time slot. This algorithm contains four control loops: Detection, Processing, Sleeping, and Reactivation.

The control of these loops is done by five commands as well as the transponder internal flag bits. The commands that control the anticollision loops are as follows:

- *Fast read request (FRR).* With an internal flag set, the transponder will respond only to an FRR command. An FFR command consists of five timed gap pulses, as shown in Figure 7.27, in which the period of the gap contains specific information. There are a total of nine possible pulse positions allowed in this protocol.

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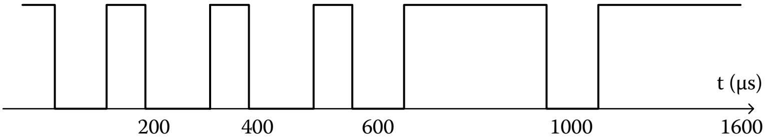

FIGURE 7.27
Structure of a fast read request (FRR).

- *Fast read bypass (FRB).* This command is used in the reactivation loop. Upon reception of this command, the transponder responds with a block of data. The structure of this command is similar to the FRR command, with the difference being in the period of the gaps.
- *Matching code 1 (MC1).* This command is used with the transponder and does not require any further processing. The command consists of time calibration pulses and pulse position modulation (PPM) signals. Upon the reception of this command, a transponder in the detection loops enters the sleeping loop.
- *Matching code 2 (MC2).* When a transponder in the detection loop receives this command, it enters the processing loop. The structure of this command is similar to that of MC1.
- *End process (EP).* This command causes a transponder in the processing loop to exit it and enter the sleeping loop.

Transponders can enter the detection loop by waiting for an FFR command or by transmitting a fast read (FR) response without waiting for a command. The first operation mode is called *interrogator talks first* (ITF), while the second operation mode is called *tag talks first* (TTF). The read and write operations are carried out during the processing loop. Only transponders with a special flag set in this loop respond to write or read operations. The sleeping loop is used to keep all processed devices in a silent condition in which they do not respond to external commands. The reactivation loop is used as an intermediate step by the interrogator to set transponders into different loops depending on the command that is transmitted to transponders in this loop.

7.4.3 Deterministic Anticollision Procedures

Deterministic anticollision procedures are based on the transponder backscattering the information to the interrogator only if the result of a compare condition is true. The compare condition is set up by the interrogator while broadcasting a specific command. Deterministic anticollision procedures are also called tree-based procedures. The interrogator sends a series of queries, each one with a prefix that is part of the transponder's ID code. Only those transponders with matching IDs respond to the interrogator's query. If there is more than one transponder with matching partial IDs, these transponders respond at the same time

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- Wee Willy 75 M DSB Transceiver
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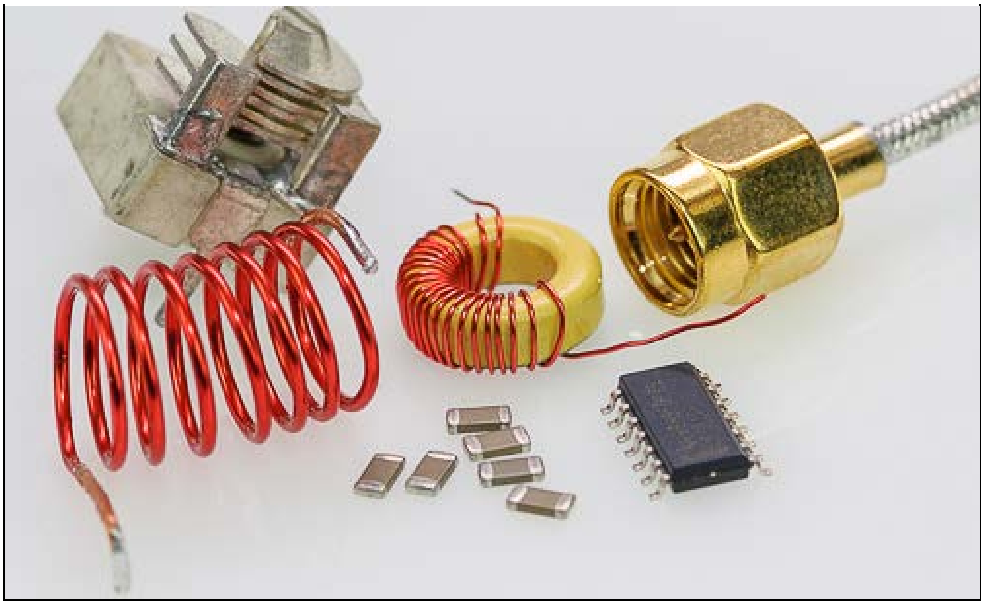

Make it — then measure it!

RF — Test and Measurement

Frequently Asked Questions

1. How to you make your schematics?

I hand draw my schematics using the Paint Program that ships with all Microsoft Windows(tm) operating systems.

I strive to make schematics as clear and as small in file size as possible.The Windows Clipboard is used extensively to copy and paste the desired components from previous schematics to new schematics — very few new components are ever drawn; rather they are recycled from schematic to schematic. My system allows me to paste color 3-D labels and small photographic bitmaps into schematics.

The raw 24-bit bitmap drawings are compressed to 16-bit png files. Prior to May 17, 2010, bitmaps were compressed as 8-bit gif files. An example drafted circuit using the Windows 7 Paint program follows.

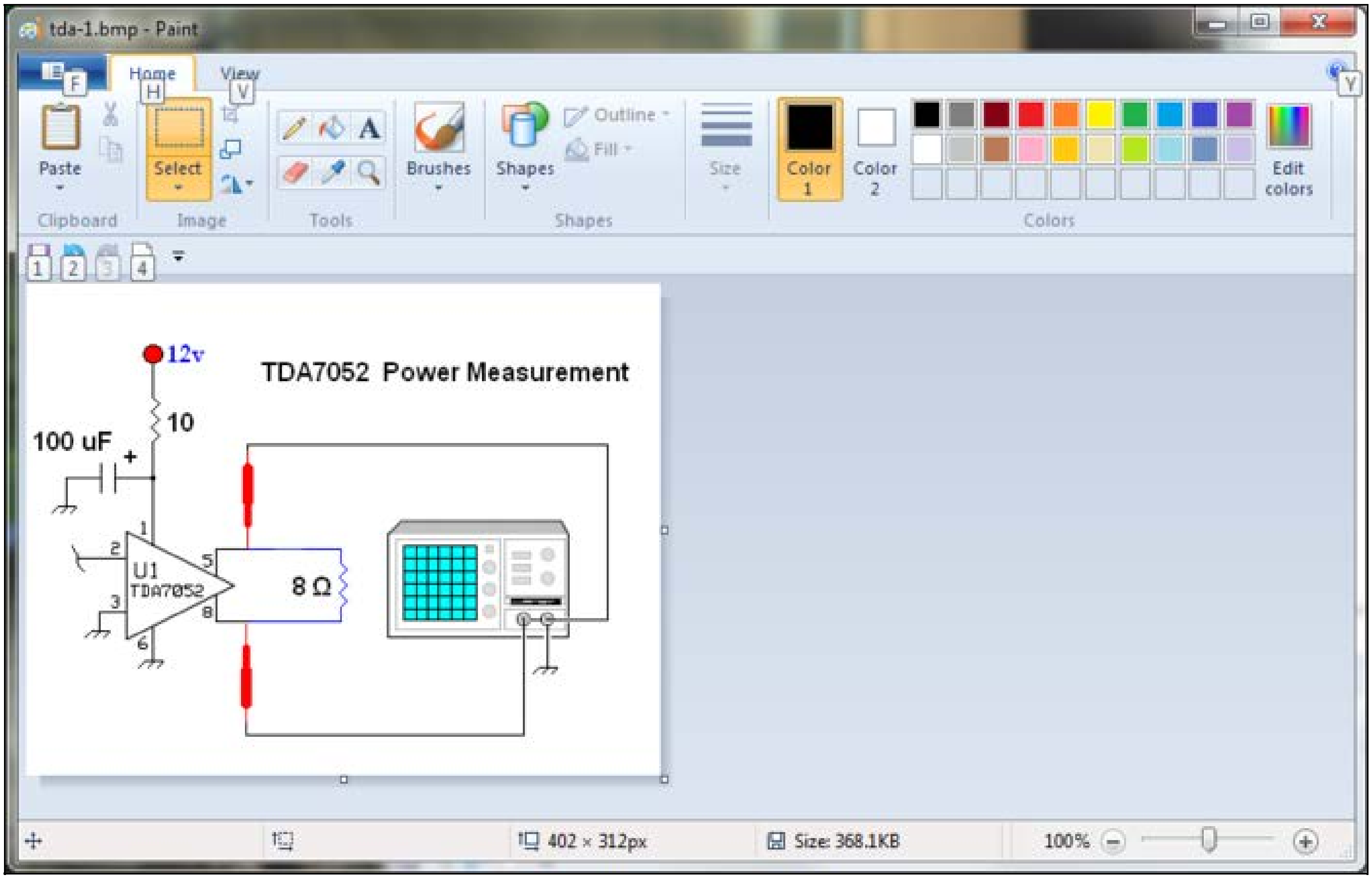
tda-1.bmp - Paint
Home
View
Paste
Select
Brushes
Shapes
Outline
Fill
Size
Color 1
Color 2
Edit colors
Clipboard
Image
Tools
Shapes
Colors
12v
TDA7052 Power Measurement
10
100 uF
+
1
2
3
5
6
8
U1
TDA7052
8 Ω
402 × 312px
Size: 368.1KB
100%

At least 25 people have sent or recommended software for making schematics. Thank you for this kind gesture, but I prefer my current method and after 15 years — make schematics quickly.

2. How come you don't supply parts lists? Other people do.

The answer is simple; lack of time. It takes considerable time and effort to put up a new web page and also to maintain a large web site. I save time by leaving the parts list up to the builder. In addition, this site is about experimentation and using what parts you have on hand.

3. Why didn't you answer my email?

I answer all legitimate emails as soon as possible. Our POP3 server gets an average of 2016 spam emails per month (December 2013 data), however, our software removes 99.27% of these and I never see them. Occasionally, legitimate emails are filtered in error and I apologize. I've received as many as 83 legitimate emails in a single day so can get behind. Please keep emailing — when readers stop emailing, I'll know the site has fallen totally obsolete [it may already be obsolete] and delete it.

Our mail server software logs and analyzes the network information of all spammers and may automatically filter and/or block their addresses or even their entire ISPs at the router level. Analysis indicates that 90% of our SPAM comes from just 3 countries and if you happen to live in one of these countries, the filtering will be especially sensitive.

This sounds dogmatic and unfriendly, however, until you've set up a domain and must handle ++ spam emails, endure and then develop router control software and other strategies to handle DDoS attacks and so forth, your completely naive about the 'dark side' of running a homebrew web server. Massive amounts of bandwidth might be otherwise wasted by allowing unwanted server use unless we actively counter these activities to keep the site running well for legitimate hobbyists. Not to mention all the wasted time. Further:

The 3 host web servers, the power, the server software, the security apps, the internet bandwidth etc.are owned or purchased by my family, and as you know, nothing is free. Despite many offers by companies to place ads on my pages, I've kept the site advertisment free and running pops.net costs us a few thousand dollars each year. We ask you to please respect our site for the sake of the experimenters who visit.

Pops.net server rack in our warehouse.

While I appreciate that some people might want to email invite me onto their social networks, I do not have time to participate. All email traffic from or involving social networks see this page for a list is deleted automatically by our POP3 server control software.

I **never** buy or sell parts via email, nor exchange hyperlinks. Never. I do give free parts to those in need though.

All email with the .info domain is blocked.

The number of people selling kits has jumped up by ~4 dB in the past 5 years. Increasingly, builders who need help with kits were emailing me for support. I rarely build kits and my knowledge regarding kit building is nearly 0. Please contact your kit seller for help.

You may wish to enquire with the kit seller about their online support polices and promptness prior to purchase. Additionally you might try the "support" email address provided and see if and how promptly they reply. Most of the popular kit sellers (AADE, Kits and Parts, etc.) provide excellent support to their customers. Like anything else online; buyer beware.

4. How come you didn't link to my web site - I linked to yours?

A big thanks to the folks who link to this web site! The QRP/SWL HomeBuilder site focus is content, not web links. Making a lot of links means spending time testing for and tracking down dead links - the so called "link rot". Time spent on the web site is time away from the electronics work bench. In addition, it is not logistically possible to reciprocate in kind, as hundreds of web sites and blogs have linked this site.

5. I see the word "popcorn" used a lot on this site- what's this all about?

Popcorn connotes the essential theme of the web site; simple, frugal, without fuss and over use of technical jargon, or complex math and engineering techniques. The QRP/SWL HomeBuilder web site is referred to as the popcorn site by many. The site targets hobbyists. The emphasis is fun. The hope is that it will attract new people to electronic design, measurement and experimentation. Hopefully, this site stimulates interest in QRP homebrew electronics.

Soon after I began building electronic circuits, my teachers and the popular electronic-related media of the day pushed me towards etched, printed circuit boards. I complied and this killed my passion for electronics. For me, habitually stuffing circuit boards lacks creativity and freedom.

Later, I discovered people were building guitar and bass amps using point to point wiring techniques with terminal strips and partial circuit boards. I became interested in building and repairing guitar amps and this passion continues today. In 1992, the discovery of 2 QST articles changed everything *for me (complete reference provided):* The Ugly Weekender: parts 1 and 2 by Roger Hayward, KA7EXM and Wes Hayward, W7ZOI; published in QST for August 1981 and June 1992. This was my first exposure to Ugly Construction and it was immediately adopted as the defacto standard bread boarding method in my electronics work shop. In fairness, etched circuit boards are a great tool, but not essential for the experimenter.
After working with Ugly Construction over time, considerable progress was made in understanding RF circuits and one output was the launch of this web site in 1998.

Currently, little has changed, I continue to prefer scratch-homebrew rather than kit-homebrew electronics. My interest in Short Wave radio and analog electronics has grown considerably. For me, electronic circuits hold a certain mystique which arouses my curiosity to learn, enjoy and share. As a lay person, this web site has facilitated meeting some awesome people through email from all continents and it has been a privilege to learn from them, my mentors, book and web authors and often enough; from my mistakes.

5. What do you mean by a 5K1 or 3K3 resistor value?

For E24 or 5% tolerance resistors 5K1 = 5.1K, 3K3 = 3.3K and so on. For E96 or 1% resistors 31.6K is written as 31.6K. All resistors are 1/4 watt unless otherwise specified.

6. How do you measure audio amp output power?

Please see Figure 4 on this web page. Any amp when cranked, outputs much greater power than when it is providing a clean sine wave. The quoted power for any audio power amp on this web site is the maximum average power it will give before the pure sine wave becomes distorted.

7. I noticed a new web page appears and then it is edited for 1-2 weeks. When is the web page completed?

When a new web page is added, it takes a week or so to find and change some of the grammar and spelling errors. Sometimes new ideas or feedback will cause me to further edit a web page at any point in time. This whole web site is a work in progress. The last date any given web page was edited is posted on the bottom of the web page.

8. Do you buy or sell stuff?

No and no. I receive numerous emails from people asking me to sell them stuff. I do not sell anything - no parts, books, coffee cups, ball caps, tee-shirts, ad space — nothing. I do not buy parts in commercial-quantity volumes and have no need to make contracts for obtaining any electronic components. Every week, Asian companies email to ask about buying their parts — please note, my answer is *always* the same: no thank you.

9. Questions and concerns about printing and printability

Each year, a few readers email to complain how poorly the web pages print. This is true and I apologize.

Some people prefer pdf files for easy printing. I have resisted going to pdf format for 3 main reasons:

1. The web site audience is international and many are using web translators. PDF files are 8-bit graphic image files and do not translate.
2. More and more readers are using mobile computer devices and pdf files are a pain for them.
3. We should all print less often to save resources

As an experimenter, I dislike crammed, small-size schematics and feel they should be drawn for *maximum* clarity. Therefore, my schematics tend to have a lot of white space and color contrast. I try to make them no wider than 700 pixels, although sometimes it's impossible to do this. Big schematics are *not* printer friendly. The only practical solution is to click on and open them in a separate browser window for easier sizing and printing.

I also feature big photos which burn up a lot of printer paper. Project photos are important to me; they provide a more intimate glimpse into the bench work and promote the real purpose of the site — building stuff.

A potential printing solution for Microsoft Explorer 8 users; Click

10. I have noticed in your CMOS logic photographs, you don't always ground unused input gates. Isn't this bad?

Proper CMOS logic practice mandates the grounding of all unused input gates. In prototypes and experiments, I don't always do this as I generally want to re-use the IC in other experiments. This is a cost saving measure. When you build a lot of stuff, it can get expensive and recycling parts makes sense. In keeper circuits or critical prototypes, unused input gates are directly soldered to the copper clad board. This also anchors the IC very well.

11. What is the proper URL of the home page?

http://www.qrp.pops.net

The following pre-2006 URL was decommissioned August 6, 2010: http://www.qrp.pops.net/default.htm

12. What are the QRPHB Design Centers and Professor Ivanenko character about?

This web site is about design and not just providing circuits to copy; I'm hopeful that the QRPHB Design Center concept initiated in 2011 will invigorate the site. Design Centers are the presentation of simple, but useful algorithms for amateur builders to advance their skills on the bench.

Professor Vasily Ivanenko ( ), a *fictitious* retired Russian physics professor wants to share his knowledge and give back to society. He signifies each Design Center. Professor Ivanenko was drawn for me by Rod Adams in 1996 using the Paint program that ships with Windows (the same app I make my schematics with). Rod did all of the other original bitmap art for this website including the coil guy and junk box pictures. This character was inspired by one of my favorite photographers: Irving Penn — this photograph, which is all over the web.

A new character; Dr. Natasha Petrovna appeared in late Summer 2012.

The professors are just a good bit of fun — add intrigue, characters on whom to focus and a means of identifying Design Centers. Electronics with just math and physics bores us all. Adding splash, color, clear photographs and characters such as the coil guy or the Professors boosts the site's appeal and provides a creative outlet for me.

13. Why did you kill your blog?

Time mostly. *My* blog wasted *yours* and my time. I carefully analyzed my personal yield from blogs in 2012 to 2013 — for the most part, blogs just entertain + share trivia, or rehash someone elses idea(s), or 'innocently' attract you in hope to sell stuff — and sometimes, just fulfill the author's need for attention. I don't seek, nor have time for entertainment or spectacle within my RF hobby and I certainly don't wish to waste *your* time. Each to his own, I suppose.

My analysis showed that unfortunately, blogs rarely boosted my understanding of electronic design or measurement practices. My ardent focus is to learn + improve and then pay some of this knowledge forward on a web site. Of course, everything in context — many exceptional people blog. For example, Dave AA7EE, or Jason, NT7S.

Most of the RF design and measurement people I follow keep old fashion web sites and provide generous email support. Design and measurement web sites, plus reputable and/or peer-reviewed industry and hobbist books, journals and multimedia work best for me.

Further, great elmers don't just publicly hang-out on blogs, or web server groups, or publish Utube videos — some just check their emails and when asked — give wonderful support without fanfare. Hats off to these humble folks. Thank you!

14. What oscilloscope should I buy?

Yikes — a tough question I get nearly every month. Please do your research. My best answer is buy the best 'scope you can afford. Are you a casual experimenter, or sit in your lab a lot? I prefer DSO's , however, made due with a old boat- anchor CRT for my first 10 years. The Rigol 1052/1152 seem popular entry-level choices due to their cost versus performance ratio. On the other hand, view this video to see how much Rigol DSO technology has changed.

I owned and sold my 1052 to a builder in Michigan — a worthy choice like many other 'scopes. IMHO, the FFT and math functions on the 1052 and 1152 suffer due to low memory depth and clock jitter.

Even if you only work at HF, a bandwidth 5X higher than your main frequencies of interest works better for showing harmonics. Again, I advise people to simply buy the best 'scope they can afford since it will form the heart of your test bench.

15. I'm a beginner — what toroids should I buy?

Opinions will vary, but here's what I recommend. Buy any quantity you wish, but sometimes minimum quantities apply and shipping to some countries costs dearly, so I tend to order enough parts to last me for awhile.

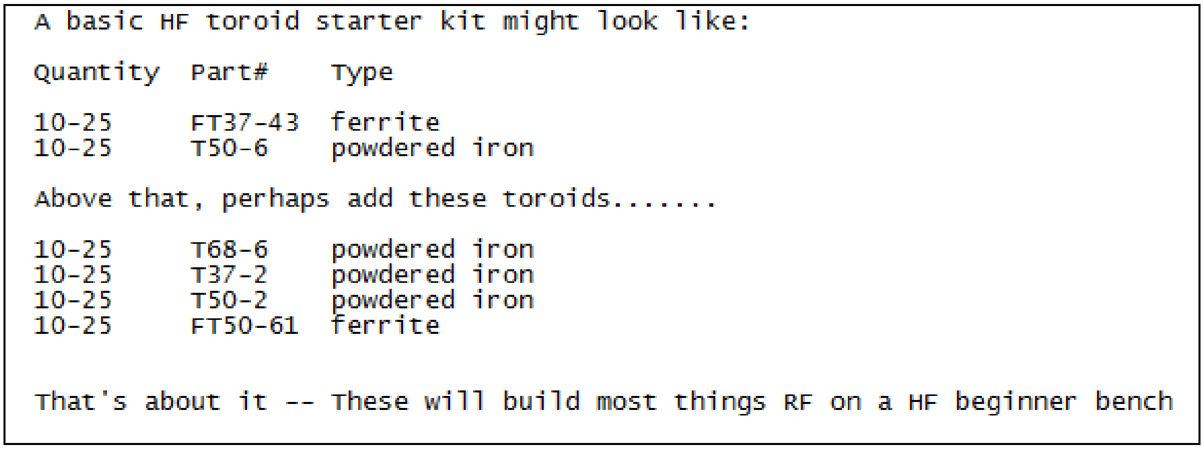

```
A basic HF toroid starter kit might look like:

Quantity  Part#    Type

10-25     FT37-43  ferrite
10-25     T50-6    powdered iron

Above that, perhaps add these toroids.......

10-25     T68-6    powdered iron
10-25     T37-2    powdered iron
10-25     T50-2    powdered iron
10-25     FT50-61  ferrite


That's about it -- These will build most things RF on a HF beginner bench
```

QRP — Log: Updates To Permanent Content

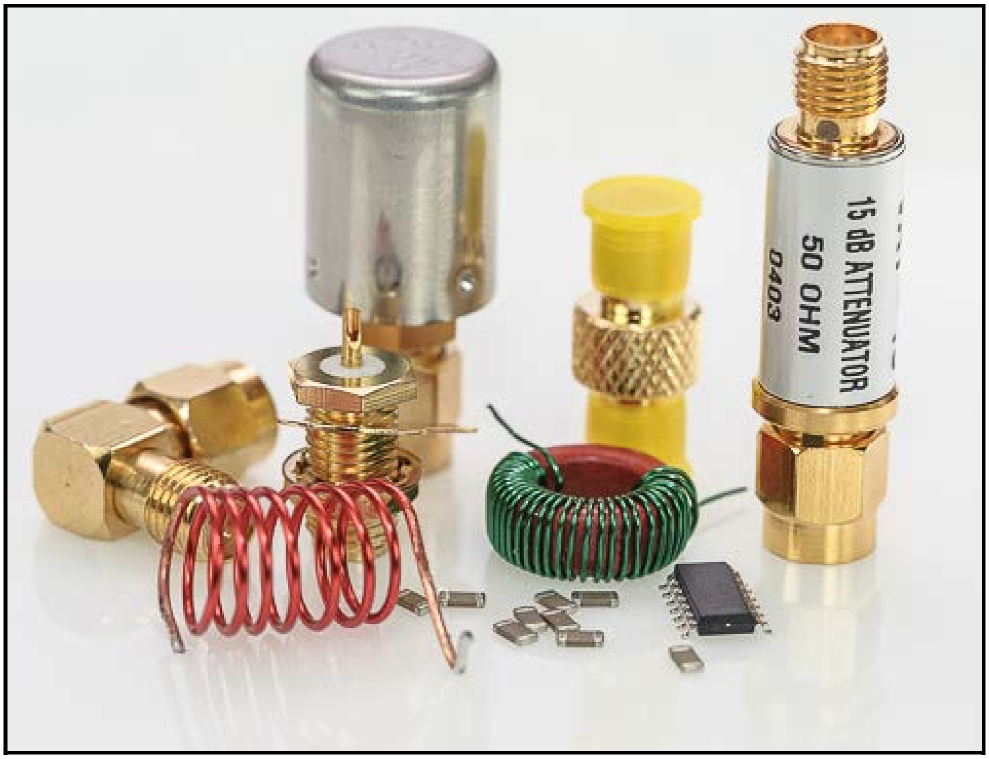

Oct 5, 2014 --- The end of QRPHB? Expect the Qrp site to go down each day for 1-4 hours. As I wrote before, we're losing an average of 10% of the outgoing packets and this peaks as high as 40% when many people are accessing the site. See an example graph below.

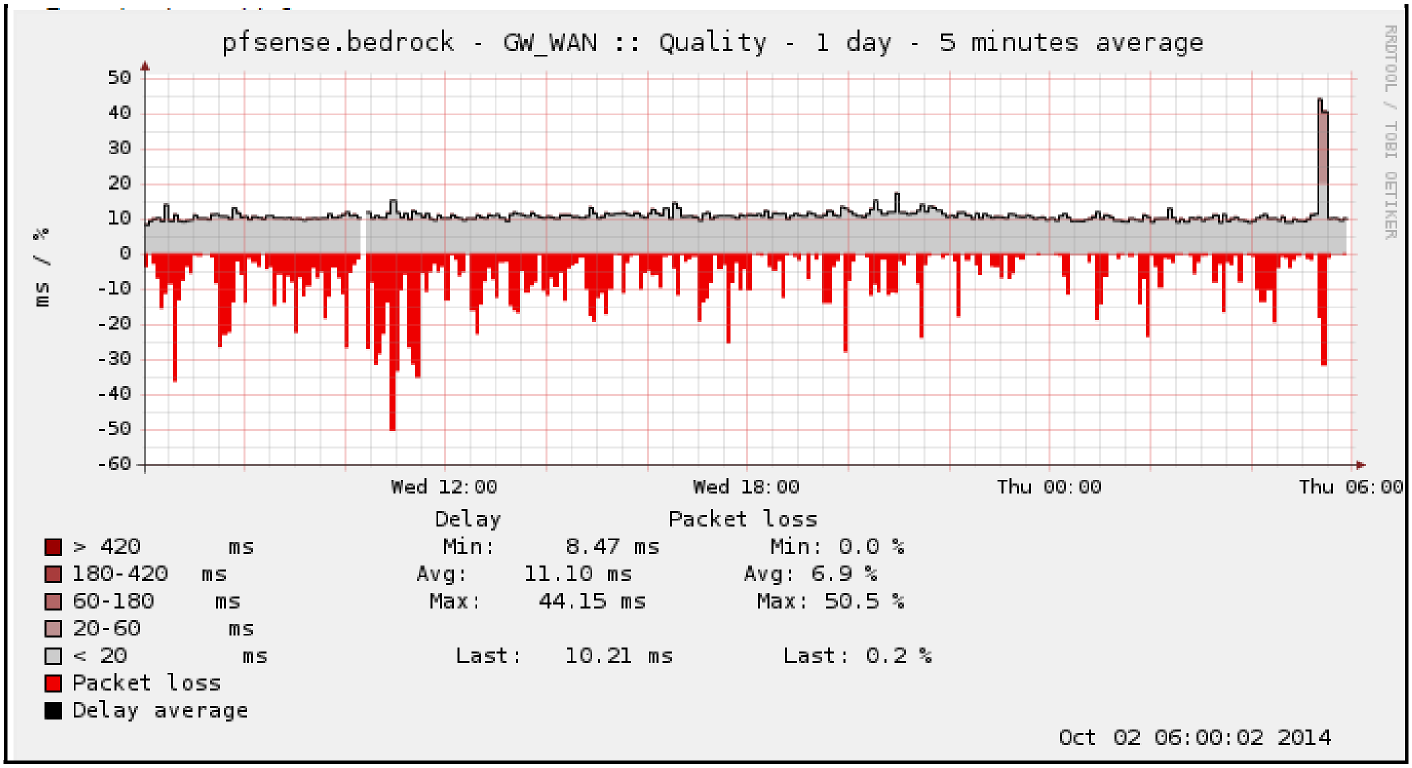

On Oct 2, 1 of our ISP's techs came and tested our WAN -- "it's better than most" he said. Hopefully they can do something to boost the performance on their side. Wave bought out all the local competition and we're stuck with them [this is happening everywhere]. Click for 1 of the many links writing about the emerging internet cable company monopoly.

You'd think that in 2014 we could properly host a web site like we've done since 1998? To boot, Stuart is paying for a high bandwidth business account and getting less than 1% of the promised bandwidth. We chatted today and will wait patiently for Wave to improve our outflow - but only for so long.

If Wave can't or won't boost performance, I am leaning towards taking this web site down as opposed to moving it -- it's been a good run. QRPHB creates a lot of work and I could get way more done without the web site hassles. So, 2014 might be it for me. If so, thanks for coming here all these years and best of luck with your experiments!

--- Sep. 19 --- Wave Broadband, our Internet provider suffered major problems recently and I shut the site down for 4 days rather than have it limp along pathetically. Well the Wave saga *continues*: the site loads slowly and pictures are missing etc.

Our email server remains working even when the main site is down. You can always email me if the site is not working for you -- or if you have a comment or question.

Vistor volume rose this Summer so we added a better router that provides bit by bit data performance collection and new features to help throughput. At minimum user bandwidth, a unique visitor hits the site every ~0.7 minutes. I'll start formal bench experiments on October 3 --- to kick off the sites' 16th season.

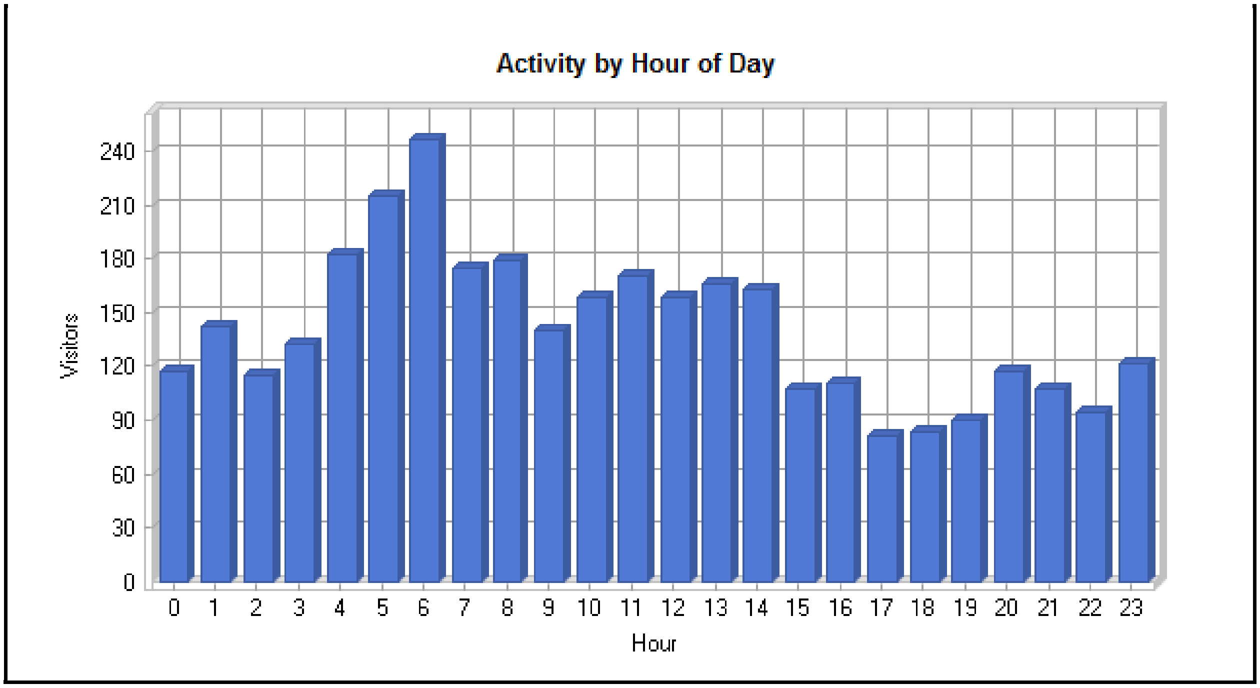

August 31, 2014 — Kit to upgrade my HP frequency counter to 3 GHz added as Section 5 on Caitlyn 310 — UHF Beginnings.

August 18, 2014 — QRP-POS Data on the Sundry Web Page. Look at the end of Section 8: Popcorn AF Amps For Receivers — Reprise. This new, all-discrete AF stage will go into the Funster Line receiver and ranks as 1 of my best in terms of power and headroom.

August 12, 2014 — Funster Line: a QRP 40M band CW trans-receiver added to HF Embarcadero web page as Menu item 4. Click here for Funster. Only the transmitter is presented for now.

June 18, 2014 — I tweaked the page now called About... on the top level menu. Also, on this web page, I added a new essay for 2014 just under the essay for 2010. I'm off the bench until Fall, but hope to add a little content on rainy days or such. I'm about 2 years behind in presenting some of my experiments.

May 22 and 26, 2014 — New Supplemental Web Page for VHF-FM launched. This page and another supplement will house some new receivers over time. The new supplement is linked on the original VHF-FM web page in section number 4.

May 5, 2014 — Section 7: NE612 Mixer Diddy added to VHF Veronica

April 14, 2014 — Completion of Return Loss Bridge Experiments [added Bridge #4] on Caitlyn 310.

April 7, 2014 — Return loss and VCO experiments added to Caitlyn 310.

March 7, 2014 — Section 3 added to VHF-FM. A DC Converter for VCOs. **March 25** QRP-POSDATA for March 2014 Poor Hams Scalar Network Analyzer (PHSNA) added to Section 1 of Sundry.

February 14, 2014 — Caitlyn 310 — New repository web page for my venture into UHF. Click. Surprisingly, the site averages ~ 3000 unique visitors every 24 hours. Click for the Feb 25 tally

January 15, 2014 — The FAQ was often missed and therefore moved to the top level menu + editted/augmented.

January 4, 2014 — A follow-on version of the K3NHI QEX power meter added to RF Workbench 5 as section 6.

December 15, 2013 — I added Section 3 to HF Embarcadero. VXO and VCXO Notes. I significantly updated the VFO-2011 web page on Dec 17, 2013.

November 7, 2013 — Section 6 added to VHF — Véronique. 1 photo added to the end of the Ugly Construction page. Severe Fall weather conditions took down the server for ~1 hour today.

November 1, 2013 — I added Section 2 to HF Embarcadero. A vestigal set of notes regarding my attempts to update the Popcorn Superhet receiver.

October 31, 2013 — Section 5 added to VHF — Véronique.

October 27, 2013 — VHF-FM re-formatted and Section 2 added. I imagine this page will disinterest many.

October 18, 2013 — 3 rarely accessed web pages removed from drop down menu, but not deleted from the server. New QRP-Posdata added to HF-Ragbag (near the end). Section 3 edited and Section 4 added to VHF — Véronique.

October 11, 2013 — Build Season 15 begins [I bench experiment Oct to May]. I added HF Embarcadero to hold all my HF and perhaps AF experiments this season. I'll also add content to VHF FM, VHF — Véronique and RF Workbench 6 over the next 12 months. Thanks.

September 9, 2013 — Blog deleted.

August 8, 2013 — Section 2 of RF Workbench 6 added. Measuring PA collector V and I to calculate efficiency. On August 16 — I added a new essay on the Ugly Construction page called Is Ugly Construction Less Reproducible than Manhattan?

June 25, 2013 — I started RF Workbench 6. It will take 1 year to complete

April 14, 2013 — I added Section 3: 50 Ω MMIC Bench Amplifer to the VHF 2013 Veronica web page.

March 31, 2013 — I started a new content page called Pin Outs

March 25, 2013 — Section 9: an essay about the 1981 Progressive Receiver, plus the final section — 10: Miscellaneous Pictures and Figures added to Sundry 2012-13

March 18, 2013 — Section 8. Popcorn AF Amplifier for Receivers — Reprise added to Sundry 2012-13

March 10, 2013 — I added a new VHF content page for 2013: VHF-2013 - Veronica

February 16, 2012 — I added Section **7** -- A Journey Above HF -- to the Sundry Experiments 2012-13 web page.

February 14, 2012 — I added Section **6** -- Non-Mechanical Iambic Paddle -- to the Sundry 2012-13 web page.

February 1, 2013 — A seperate QRP—POSDATA added to RF Workbench 4. Now QRP— POSDATA 1, 2 and 3.

December 15, 2012 — I added Section 4 to Sundry Experiments 2012 - 2013 . A PLL circuit from EMRFD.

January 5, 2013 — I added Section 5 to Sundry Experiments 2012 - 2013 . A simple AF feedback amp. An essay concerning L-C meters was also added on RF Workbench 5. Section **5.**

December 22, 2012 — I deleted the web page ***Tuning VFOs with a PN Junction*** since some of the experiments were poor quality and performed back in 1998 when I was more ignorant than now. I've learned much since then and my new VCOs from the past 1-2 years reflect this knowledge. The ***Selected QRP Reading list*** and ***Cascode 7 Receiver*** web pages were also wiped.

December 15, 2012 — I added Section 4 to Sundry Experiments 2012 - 2013 . A PLL circuit from EMRFD.

December 3, 2012 — I added Section 3 to Sundry Experiments 2012 - 2013 . Interview with Jason from Etherkit

November 13, 2012 — QRP — Posdata added to the VHF to the Max web page. Section 5: Z-Comm VCO.

November 1, 2012 — Sundry Experiments 2012 - 2013 web page added.
QRP — PosData added to Section 2 of **Power Meter Calibrators** on RF Workbench 5 and updated again on Nov 22, 2012.

October 16, 2012 — VHF FM web page added. Already, it has spawned a first supplemental web page

Sept 24, 2012 — QRP — Posdata added to the end of the HF Ragbag web page. I added a bypass and decouple network for HF to lower VHF.

August 17, 2012 — QRP — Posdata #2 added to bottom of the Receiver Band-pass Filters web page.

August 6, 2012 — Section 5: **Some Experiments with RF Bypass Capacitors** added to the HF Ragbag web page. Also a new QRP — Posdata added to the bottom of the Crystal Parameter Checker web page.

August 1, 2012 — QRP — Posdata added to the Receiver Band-pass Filters web page.

July 12, 2012 — I added a corrected schematic on the Wee Willy page: Wayne. M0WAY — 14 MHz PA under August 25, 2011. Also, added a new essay on **Microphonics in DC Receivers**. See Section 4 on the HF Ragbag Page

June 23, 2012 — RF Workbench 5 added. Click here.

May 31, 2012 — Galina discovered that I neglected to publish the proper version of the Hobby and Fun 2011 page and corrected my error. A fine-tuneable Wien Bridge Oscillator idea from Ken Kuhn now appears at the page bottom.

April 21, 2012 — I heavily edited RF Workbench 1 and 2.

April 13, 2012 — Web site purge. I removed RF Filters, VFO 1998, QRP Workshop Ideas, Miscellaneous Schematics and Photos, Base-biased VFO, Funster Transceiver, Miscellaneous Circuits and Ideas 2005 and Crystal Oscillator Offsets. **Reason:** substandard.

April 6, 2012 — 50 MHz Receiver Pre-amp and Filter added to VHF to the Max web page .Section 4.

March 26, 2012 — HF Ragbag web page added to top-level menu. Non-VHF experiment repository for 2012.

March 19, 2012 — VHF to the Max web page added to top-level menu. 50 MHz VCO experiments added to this page in Section 3.

March 14, 2012 — EMRFD review edited.

February 29, 2012 — Minor edits to the Audio Transistor Input Impedance Experiments web page. Also, I updated the calculation of the common emiiter amplifier base input resistance using the better formula: **Rin = (B+1)*(re + RE')** [while ignoring REB]. This is my favorite web page on the site.

February 26, 2012 — QRP— Posdata added to the bottom of the 2nd NDB web page

February 17, 2012 — I introduced a new miscellaneous VHF page: VHF to the Max — I'll slowly add stuff over 2012. Major editing done to the Broadband Transformer web page.

February 4, 2012 — RF Workbench 1 and 2 significantly edited. 2 new photos added.

January 28, 2012 — QRP — Posdata added to Crystal Parameter Checker web page and to QRP Modules 2011 under 7 MHz VCO Experiments on this web page. I re-wrote the temperature compensation section of the VFO-2011 web page and added 3 photographs.

January 3, 2012 — Web site change: I update web essays with an "epilogue section". In 2012 and on, they will be called QRP — Posdata (Spanish for post-script or epilogue). Posdata #2 added to the RF Workbench 4 web page.

December 17, 2011 — The Butler Did It ! - First VHF Experiments 2011 web page added. A 50 MHz frequency doubler added Dec 26, 2011.

Nov 12, 2011 — Our server went down for 16 hours. Both AC power and cable Internet to the warehouse failed after a rain storm and wind gusts knocked down some trees that severed the hydro and cable wires. Expect more weather-related down time as Winter approaches.

Oct 15, 2011 — VFO-2011 added.

Oct 2, 2011 — RF Workbench Page 4 added. On **Oct 17, 2011** I added an epilogue.

Sept 20, 2011 — Double Stacked Toroid VFO 2008 web page pulled off. It was substandard and some of the material will re-emerge on a VFO 2011 page this Winter.

Sept 19, 2011 — I updated the SWL essay since it was 6 years old and much has changed with respect to Internet radio. Over time I have received ++ emails expressing different views. I am more a SWL than a Ham and offer just 1 opinion and live by a "each to his own" mantra. Context is everything - this is a radio electronic experimenters site that recognizes SWL'ers are important members of the radio community. Click. Wee Willy web page updated again!

Sept 12, 2011 — Design Center concerning popcorn receiver band-pass filters added. Click.

Aug 26, 2011 — Minor update at the end of Wee Willy DSB transceiver. ***New Junk Box Blog format***. Change is good.

July 30, 2011 — New web page QRP Modules listed on the main menu. Currently under construction.

March 31, 2011 — 2 photos added to the Ugly Construction web page

March 19, 2011 — New content; Hobby and Fun 2011 . I'll slowly add more stuff over the year.

Feb 12, 2011 — New content. Miscellaneous RF Experiments 2011

Dec 29, 2010 — New content. RF Workbench Page 3

Dec 12, 2010 — Final additions to the the 2010 Hobbyist Page added — these concern matching FETs, BJTS and diodes.

Nov 10, 2010 — Some editing and 2 photos added to RF Workbench page 2.

Oct 9, 2010 — This October marks the 12th season of experiments for the site. I have 4 partially completed web pages on the go — pure craziness. I decided to finish them 1 at a time and then add them sequentially. Today, a new web page was added and is 1 of 2 supplements to a future main QRP audio page: Audio Transistor Input Impedance Experiments. The first new "permanent" content since March 2010.

Oct 7, 2010 —The Junk box page lay out was simplified: Accommodating the various modern Web devices plus screen resolutions proved difficult with the old html code. Although less impressive, the new format updates quickly and looks the same on every computer.

Aug 15, 2010 — The cable supplying the Internet connection failed. The site went down for 25 hours. Expect more shut downs over the next couple of days as we resolve any remaining problems.

August 6, 2010 — I decommissioned the historic home page URL http://www.qrp.pops.net/default.htm. This page was a html hard-coded parallel version of the the *correct* home page URL http://www.qrp.pops.net. It was just too much work to continue to update the old (pre-2006) home page in addition to the proper home page.

June 28, 2010 — Web subtitle change : **Amateur Radio Electronic Design** to shorten the name and reflect the site's main purpose.

Effective May 17, 2010 — Schematics now use the 16-bit png format. I have abandoned the 8-bit gif format

May and June 2010: The pops.net net control crew rest up for the next big wind storm. The servers lost power for many hours on May 4 and June 12 due to bad weather. Severe storms arising from the Pacific Ocean threaten our AC power lines each Spring.

March 2010

Wide Range L-C Oscillator added to Hobbyist 2010 page. Link **March 7**

JavaScript Applet **K** added to the QRP Tools page **March 11**

RF Workbench Page 2 added. Link **March 15**

February 2010

JavaScript Applet **J** added to the QRP Tools page **Feb 6**

Editing of the Low Noise Crystal Oscillator web page **Feb 22**

RF Workbench Page 1 added. Link **Feb 18**

January 2010

Experiment #6 added to the Hobbyist page **Jan 2**

New content Low Noise Crystal Oscillator **Jan 10**

2 photos added to the bottom of the Ugly Construction web page. **Jan 12**

1 photo added to the Broadband Transformers page **Jan 12**

New content Hobbyist Page 2010 **Jan 13**

New content: Supplement to JavaScript Applet G which is located on the QRP Tools page **Jan 11**

Additions to the Low Noise Crystal Osc page: the DSO versus CRO essay, plus 5 MHz crystal oscillator added **Jan 31**

JavaScript Applets H and I added to the QRP Tools web page **Jan 31**

December 2009

It has been brought to my attention that the email replies I am sending are not compatible with some of the latest email software such as Thunderbird etc. The reason was that I was using a homebrew email program written over 10 years ago. It is now obsolete. A new email platform is now in place along with a completely **new email address**. Consult the email web page for more information. **Dec 30**

Experiment #5 added to the Hobbyist page FAQ updated and edited. **Dec 30**

Experiment #4 added to the Hobbyist page **Dec 26**

Experiment #3 added to the Hobbyist page **Dec 23**

What does the output of a diode ring mixer look like in your oscilloscope? This has become a FAQ. The question is answered in a contribution by Wes, W7ZOI. Big thanks to Wes for this content. **Dec 22**

I am very pleased to present the **Mike, KL7R Memorial Receiver Experiments**. Click here **Dec 19**

New bulleted list format added to this page to improve readability **Dec 19**

A minor addition was added to the bottom of the Ugly Construction web page. Flux pen photo and text. **Dec 19**

Minor updates to the VFO 2008 "Stacked Toroids" web page under **Epilogue - December 19, 2009**

Update to JavaScript applet **Item E: Calculate Cut off Frequency for an RC Low Pass Filter**. Now has a capacitor range from 0.1 nF to 1500 nF. QRP tools page. **Dec 19**

Editing plus a photo added to the broadband transformer page. This page was improved to support an upcoming project. **Dec 17**

Drafting errors on this schematic corrected (fuse position+ negative rail LED polarity). From this web page. Thanks to Paul, K0EET and Tom for the good eyes and their emails. **Dec 16**

VFO Experiments 2009 updated again; 3 images added. Supplemental web page added and updated **Dec 13**

New JavaScript applet added to QRP Tools page; **Item F: dBm calculator. Dec 12**

Nov 22-27, 2009

1 Hertz Precision Time Base added to the Hobbyist Page.
VFO Experiments 2009 added
The top level menu item "Java Tools" was renamed **QRP Tools.** This menu provides a link to my Webmaster's page and some basic JavaScript applets. Some new material will appear on the Junk Box page during this time.

Nov 20, 2009

Finally; Fall-Winter experiments begin. A small update on the VFO 2008 web page under A 3.5 MHz VFO for Diode Ring Mixers was added.
The RF Preamp page was updated with some content that was first presented on the Junk Box web page. I have received a lot of email about these amps and decided to permanently add them to the site.
The W7ZOI file linked on this page is now in pdf format.

Nov 1, 2009

The Ugly Construction web page was augmented and re-written. 2 new photos were added. This term actually came from Wes and Roger Hayward.
A new Electronic Hobbyist page was added to the drop down 2009 menu.

Oct 25, 2009

Some small updates to the Junk Box page were made. I don't ever think I have been so excited about upcoming Fall and Winter experiments as there are a number of cool, new ideas in my notebook. Extra work and travelling have kept me off the bench, but this will cease in mid November. After that, it's back to the work bench. The Fall-Winter experiments will include some HAM, SWL, general electronics and tube guitar amp experiments. Thanks for your feedback and ideas!

Oct 19, 2009

RSS feed. Click on the **orange RSS icon** above to establish a feed. I will only show 1 item; the latest addition of major new content to the site. Additions to the Junk Box page will occasionally be counted as "new content" and will be included on the feed.

Can anyone guess what brand of beer is in the tool box ? Yes.... its

Oct 12, 2009

Fall weather has come to Western North America! Thanks to Cor, PA3COR for debugging the JavaScript code on this page. Apps number D and E now work in Firefox. Rediscover the fun and learning of scratch homebrew electronics!

RF — Test and Measurement

About My Web Site

OUT
GEN2
GEN1

Welcome Friends!

Introduction

Welcome to the QRP and SWL Homebuilder web site. I write about my experiments with relatively simple and primitive electronic circuits.

Avoiding excessive algebra and obscure parts, I emphasize and show fundamental bench practices.

Through real experiments I examine topics to challenge and intrigue amateur designers — providing examples and describing ways to plan, problem solve, breadboard and measure your circuits.

As amateur experimenters we ought to advance in our hobby; not just perform cookbook electronics. Designing and improving your circuits requires considerable knowledge and effort. Fortunately, others selflessly share their ideas to teach us.

In time, you may recognize your electronics workbench as your greatest teacher. Bench experiments involve us thinking about and measuring our circuits so we know what's happening instead of relying too much on folklore, guessing and copying others. Designing and/or simulating circuits with software can enhance your learning but does not obviate the need to spend time in the trenches with meters, wires and solder.

People often learn skills by modeling others. We need sound examples of how other builders work and think to inform our own designs — inspired, creative and active learning driven by experience and reflection.

At some level, our bench experiences are stories of growth and realization sparked by going and doing. For example, why did the designer choose a particular resistor value? You try different resistor values while measuring the results and increase your knowledge. Collecting schematics, kit building or just thinking do not provide as intimate a learning experience as soldering your ideas on a bare copper board. Talking, tweeting or day dreaming about design is not the same as *doing it*.

Russian novelist Fyodor Dostoyevsky describes the contrast between real life and passivism; "love in action is a harsh and dreadful thing compared to love in dreams", The Brothers Karamazov, Братья Карамазовы. Dare to dream, but better yet, dare to innovate — to design and build *your own* circuits. You may start by just modifying a favorite circuit or scaling a stage to another frequency. We need more innovators and less imitators to grow and sustain our great hobby.

Electronic design produces more than a completed circuit. On the bench, even joy is experiential – a moment of discovery (or several discrete moments) yields more pleasure than stuffing a circuit board or operating a piece of gear. Creativity trumps process every time!

I hope this site demonstrates my passion for building basic, "popcorn" circuits and sharing ideas. Please remember I am just a lay person experimenter and not an electrical engineer.

Regards, Todd, VE7BPO

Essay for 2010

Building or buying test equipment and acquiring a good reference library are important to your experiments. Spurred by the realization that sound bench measurement practices are at the heart of good design, test equipment receives greater focus in 2010 and on.

A reference library is vital to our electronic experiments; good examples lead to better experiments. Poor circuits are everywhere and some builders can't tell a good design from a bad one. Minimalism and simplicity aren't excuses for sloppy design when your goal is to learn. Collecting and sharing well designed circuits helps us avoid wasting time and experiencing frustration. Circuits with attributes like well defined input or output impedances, low noise or harmonic distortion are desirable to fuel experimentation. Look for better quality circuit examples in 2010 and on.

The Internet is changing how we read and write. The prevalence of small portable web devices such as iPhones, ever increasing numbers of web sites and blogs, and the use of search engines create fierce competition among sites. Modern sites attract your attention with varied visual, aural and textural media and unfortunately, hype and pseudo-journalism. Narrative writing is more skimmed than read. Brief is in — bullets, subtitles, lists and graphics replace long lines of narrative prose which no one seems to have time for anymore.

Have you noticed the changes on this website? New content still contains lots of narrative writing, but assumes an active voice, with emphasis on brevity, clarity and speaking directly to you, the reader. Sharing mostly obsolete, analog 1970's-style circuits, QRP/SWL HomeBuilder attracts a tiny, niche audience. I believe the success of this website depends on providing good and diverse content — not Tags, RS feeds, adopting net-speak, or self promotion. You be the judge.

Essay for 2014

The Internet of Everything?

Bucking the trend, my contribution to amateur RF homebrew remains informational and not social. Why?

Social media information represents a Pandora’s Box of good science and opinion, mediocre thought, or trash potentially created and/or disseminated by anyone who’s connected. We accept that much of our social media content doesn’t come from the best or brightest — some people are just plain interesting, or express themselves vigorously, seem like-minded, or touch our hearts.

Some builders, like me, seek objectivity and not just “likes” and “follows” based on sentiment and spectacle. While a few radio builders may prefer to join hands and sing Kumbaya, or pat themselves and others on the back simply because their breadboard actually works, a trifling of us care more about how and why our circuits work. We *like* measures and measurement tools and *follow* science, experiments and the works of those who shine brightly.

What’s wrong with plain information, unfettered discovery, experimental rigor, objectivity and rational, kind thought?

It’s not that these characteristics don’t attribute social web clients — they do, but the negative impacts of social media worry me a little. A brief list of concerns: loss of privacy, the threat of wasting time while really just isolating ourselves from our real friends + family. The numbing exposure to the Internet of Ads and Spam. Still too, bubbling up like purulent sores come the charlatans, the misinformation peddlers, the opinion spammers, and those who anonymously leave stinging sarcasm, or outright hatred [hostile online comments that attack people, or divert a healthy flow of ideas].

Running a low-tech web site with nearly 0 commercials suits me better.

SEO — Search Engine Optimization

I’ve read that Google analyses your web site content, the number and quality of the sites that link to your pages, their search engine clicks and so forth. In part, Google seems to rank a site based on how relevant and authoritative they believe it is. Some people specifically employ SEO techniques to gather in more traffic.
To my surprise, each year, tens of thousands come to this site via search engines like Google. I don’t think my material seems too relevant or authoritative. I’ve made no effort at SEO, so I conclude that you, my readers have more to do with the site’s success than anything I’ve ever done.

Thank you.

Hope Invigorates

Invigorated by the excellent work either emailed to me by experimenters such as Michel F6FEO, or Dick, N4HAY; or posted on blogs or Community sites like Yahoo, I feel hopeful about the future of our hobby in 2014. The PHSNA Yahoo group leaders, the recent work of Jason, NT7S, Steve VE7SL and many others show that *amateur design* experiments still have a pulse + respirations.
The aforementioned get my vote for their MOF like behavior: a strong blend of creativity, tradition and quality.

Looking Ahead — Future Site Content

Most of my new receiver work involves quadrature and in-phase mixers fed with (2) local oscillators; 1 output shifted 90 degrees from the other — essentially, EMRFD Chapter 9. Even my Funster [a personal, lowbrow trans-receiver I drag onto hill and dale] now contains phasing receiver circuitry to reduce the opposite sideband by 20 dB along with further low-pass filtering. I hope to add some Funster content to HF Embarcadero in Winter 2014. Like many of you, the 1 resource I lack the most is time.
While I'm thrilled with the notion of a receiver appliance that contains just an antenna, LNA, ADC and some sort of "wonderfall" display or speaker, I'm still smitten by analog design with hardware. Still, the I-Q mixer will offer a nice transition into SDR should I ever wish to spend my free time writing C# and not melting solder.

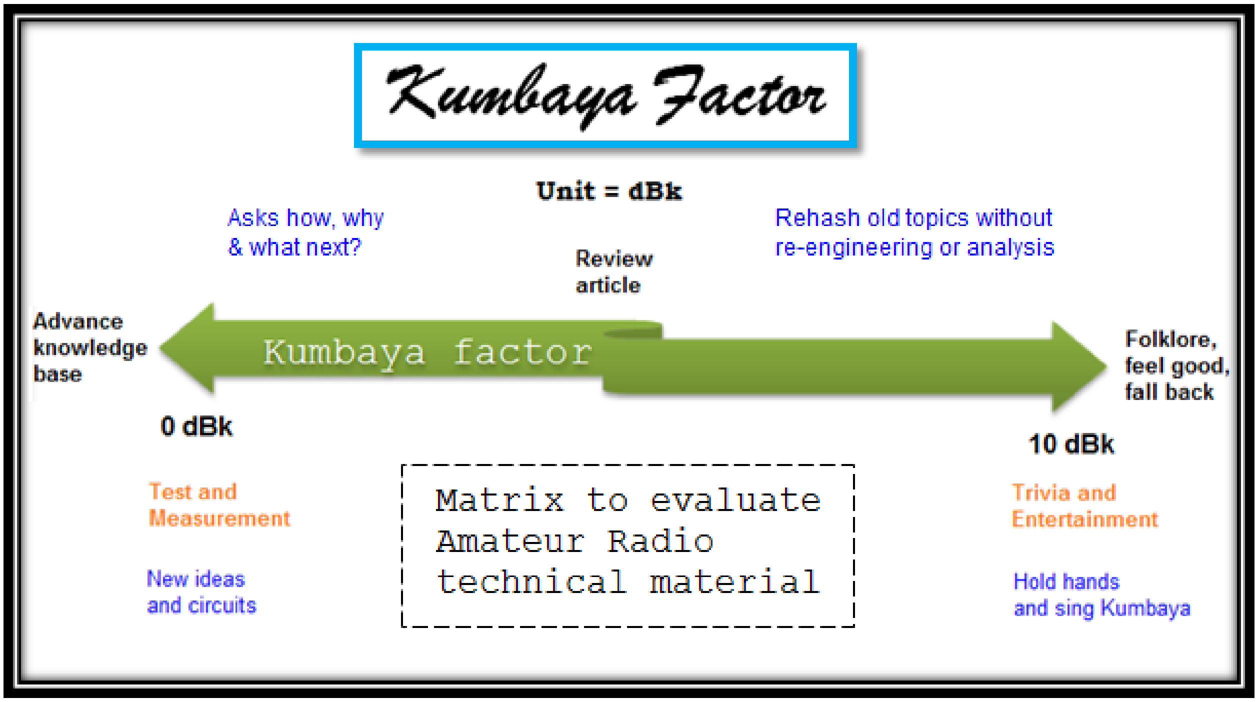
Kumbaya Factor
Unit = dBk
Asks how, why & what next?
Review article
Rehash old topics without re-engineering or analysis
Advance knowledge base
Kumbaya factor
Folklore, feel good, fall back
0 dBk
10 dBk
Test and Measurement
New ideas and circuits
Matrix to evaluate Amateur Radio technical material
Trivia and Entertainment
Hold hands and sing Kumbaya

Best to you!

Miscellaneous

My special thanks to Wes Hayward, W7ZOI for his generous support and elmering over many years.

EMRFD is the main reference of my site

All permanant content circuits were built and tested. Schematics are drafted as carefully as possible. Please accept that bench and/or drafting errors may occur. No liability arising from the application, use, or misuse of these projects that results in direct or indirect damage or loss is assumed.

Full price is paid for all parts used and no monies are or were received for promoting any products or companies on this web site. Any ads, hyperlinks or mention of commercial products or companies is out of courtesy only.

"Until you build and measure it, you don't know what you don't know";
Rick Campbell, KK7B; VHF Open Sources — Design of Low Power High-Stability Low Phase Noise Single Frequency VHF Sources with High Spectral Purity; 2008

Information Regarding the Compression of Schematics

I see many electronics web authors compressing black and white schematics as jpg files. This results in distortion of the schematic. Schematics are best compressed using the 8-bit, lossless LZW algorithm which means converting the file to a png, gif, or even pdf format. The files sizes will typically be smaller than .jpg compression, have no distortion and can be edited easily.

- RAC is the National Amateur Radio Society of Canada
- For my web page concerning support of the **Radio Amateurs of Canada**, please click here

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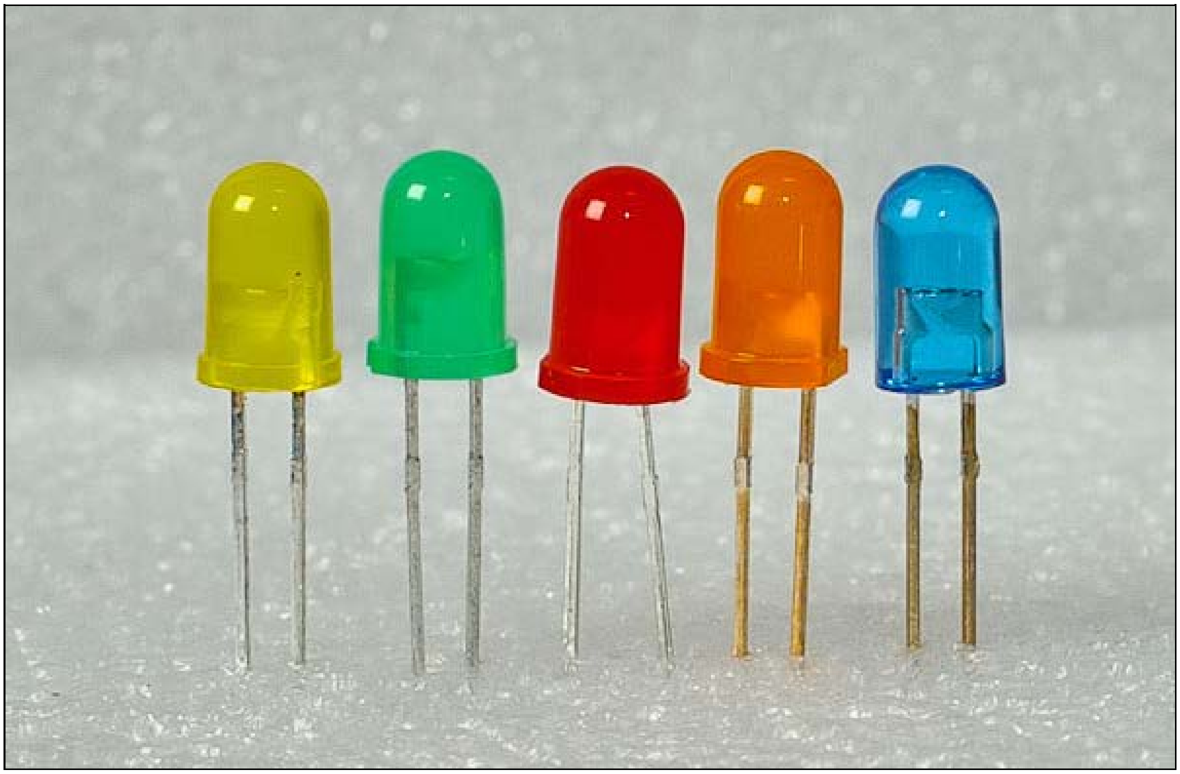

The hand drawn image bitmaps on this web site (logo etc.) are by Rod Adams. All website photographs were taken by VE7BPO except as indicated.

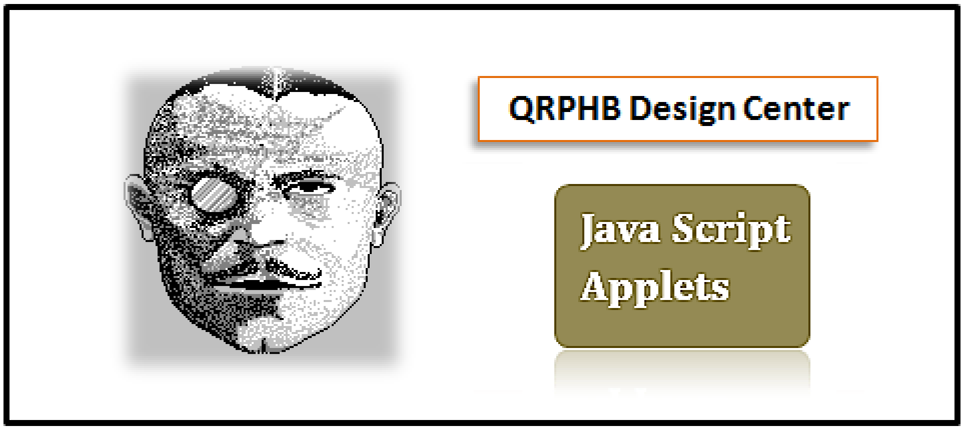
QRPHB Design Center
Java Script Applets

1. Click for the old QRP HomeBuilder Graphics page. Click for my Pin Outs page. Click for my Homepage

---

2. Some simple tools written in JavaScript for the QRP/SWL HomeBuilder:
`Minimal input error checking`

A. Calculate DC Voltage Divider Bias

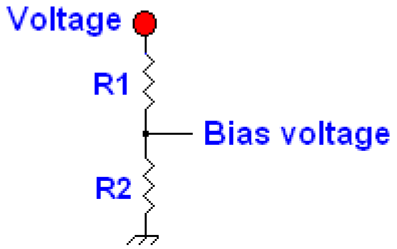
Voltage
R1
Bias voltage
R2

Enter Voltage:

Enter R1:

Enter R2:

Bias voltage =

B. Calculate Inductive Reactance

Enter Inductance in uH:

Enter Freq in MHz:

XL (ohms) =

C. Calculate DC Current for a Current Mirror

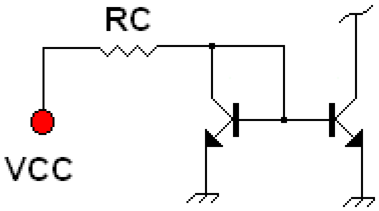

Enter VCC:

Enter RC in ohms

Current (mA) =

D. Calculate # of Turns To Obtain a Desired Inductance on a Ferrite Torroid

Enter Inductance in millihenries: Select Core: FT37-43 Turns =

The *AL for this ferrite core is* =

E. Calculate Cut off Frequency for an RC Low Pass Filter

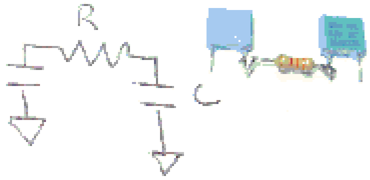

Enter resistor value in ohms: Select capacitor values in uF: 0.01 3 dB down frequency (Hertz) =

F. Calculate Power in dBm and mW from Peak to Peak Voltage

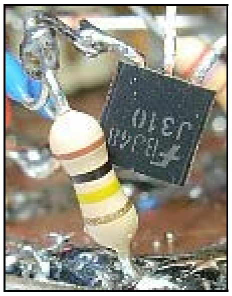

Enter measured peak-to-peak voltage into a 50 ohm load: dBm, mW

Application Note: This web site follows the EMRFD standard for dBm power measurement. dBm = the power delivered into a 50 Ohm resistive load which is temporarily substituted at that point in the signal chain.

G. Calculate Lm and Cm For a Crystal using the G3UUR Method

ABRACON
5.0000
AB 0436

Enter frequency in **MHz** written on crystal (series resonant frequency):

Enter measured frequency in **MHz** with switch open: Enter measured frequency in **MHz** with switch thrown:

Enter crystal capacitance in **pF**: Enter open switch circuit capacitance in **pF**:

Cm = femto Farads , **Lm** = Henries

Supplemental web page for this applet: Crystal filter measurement and adjustment Link

---

H. Calculate Decibel Power Gain or Loss from 2 Peak-peak Voltages

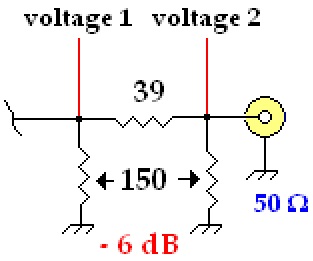

Enter voltage 1: Enter voltage 2 dB gain or loss =

I. Calculate Decibel Power Gain or Loss from Input and Output power

Enter input power in watts: Enter output power in watts dB gain or loss =

J. Calculate dBm and mW from RMS Voltage (50 ohms)

Enter RMS voltage dBm mW

K. Calculate Return Loss and VSWR (50 Ohms Detector)

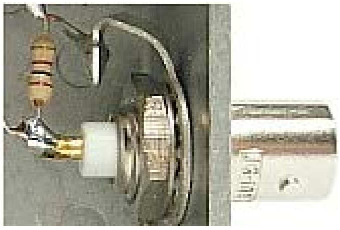

Enter the detector signal in pk-pk volts when the unknown port is terminated in an open circuit: Enter the detector signal in pk-pk volts when the unknown port is terminated in the unknown impedance:

Return loss = dB, VSWR=1:

Measurements per Figure 7.41 EMRFD. Schematic here

L. Calculate Power from the DC Output of an AD8307 Meter

1. Linear calibration steps:

Enter measured DVM voltage at -10 dBm: Enter measured DVM voltage at -20 dBm:

2. Calculate power in dBm from DVM voltage:

Enter measured DVM voltage: Power =

M. L-C-C Tee Network

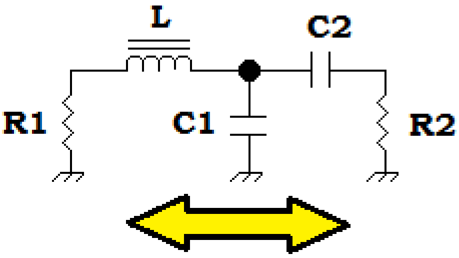

Enter **frequency** in MHz:

Enter **R1** in Ω: Enter **R2** in Ω: *R1 must be < R2, but the network is bi-directional*

Enter Q: *Perhaps start with 2-5*

C1 = pF, C2 = pF, L = uH

N. Parallel Resistor Values (2-4 resistors)

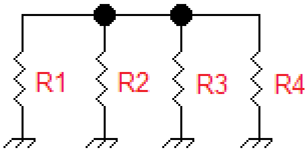

Enter R1: Enter R2 Enter R3: Enter R4:

R = ohms

O. LCR -- a Reactance Calculator In beta -- do not use !

Mode: L C to Reactance Inductance: uH Enter frequency in MHz

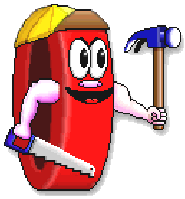

This page last updated: September 21, 2013

Short Wave Listening коротковолновое радио

Introduction to Short and Medium Wave Radio Listening

Short wave radio listening was a childhood passion and I enjoy being an SWL just as much today and log at least 800 hours of SWL per year. There seems to be many web pages devoted to construction of radio equipment for the amateur radio experimenter but relatively few for the shortwave radio devotee. I decided to expand this web site to include projects for the SWL Homebuilder in 2005.

My favorite bands are 49 meters (5.9 - 6.2 MHz) at night-time and 19 meters (15.1-15.8 MHz) during the daylight hours. I also listen to medium wave DX around 1400 - 1600 KHz.

Why Listen to Analog Short Wave Radio?

Is analog short wave radio dead? I think not.

No doubt, short wave radio has passed its prime and is slowly dying, however, it's still fun and/or relevant to some.

World band radio: Almost 1/2 of the world's population lives on $2.00 *USD* or less per day. The Internet (the main alternative to shortwave radio) poses a luxury to many poor people living in lower-income countries — experienced travelers or those who support people in developing countries will understand this statement. In some countries now, ranking in the middle class just means you have a full-time job. In addition, oppressive governmental regimes may limit foreign media and Internet access: LW, MW and SW radio can break through obstacles such as natural or man-made disasters, borders, poverty and censorship.

For SWL hobbyists, analog shortwave radio entertains, informs and best of all, provides opportunities to analyze propagation and experiment with real radio topics including static, solar flares, QRN, antennas, grounding, baluns, coax, and wire. SWLing poses an adventure — it's unpredictable, challenging and increasingly difficult as stations decrease and QRN increases. I've built many antennas and even some noise cancelling circuits just to pull in a few Dx stations. The sport of SWL lies in making DX contacts: a theme shared with Ham radio.

What About Internet Radio?

Radio by definition is the transmission and reception of electromagnetic waves of **radio frequency**; but perhaps blue-tooth or Wi-Fi reception from a hot spot qualifies as *radio* in the modern era? Just as peanuts aren't nuts, Internet server or webcasted radio is not RF broadcasted radio. I think Internet radio is great, but fundamentally a very different medium from that enjoyed by SWL fans

Internet radio involves a radio player decoding a stream of compressed bits fed from a Internet radio station or virtual receiver. In some cases, the material originates from a real radio station that also broadcasts an AM or FM signal. For example, you can tune FM station Rooskie Radio "Русское Радио" in much of Slavik Europe or play them on a computer device anywhere you can get an Internet connection.

For lovers of foreign content, listening to Internet radio makes sense; providing convenience, a good signal when bandwidth is high and 24 hour per day listening on 1 IP address. Internet radio offers a much cheaper way for content providers to beam their news and music services around the globe — we've seen numerous large broadcast radio services such as the BBC World Service reduce or drop analog SW and add Internet radio, satellite and digital SW transmissions for their customers.

The exciting growth of independent and niche Internet radio stations increases personal freedom of choice and provides opportunities for unique interest providers and consumers to find each. Media streaming companies and manufacturers of Internet radio *players* and their worldwide distributors benefit too.

This technology is a far cry from tuning the SW bands with a homebrew or commercial radio frequency *receiver* and a length of wire slung in a tree. Perhaps, the greatest advantages of Internet radio are that you don't have to get up early, or stay up late to pull in some rare Dx, nor do you need any radio skills or special equipment — perfect for the majority of listeners. But we're SWL radio hobbyists: people who listen for both content and because we love radio propagation and gear.

There is nothing wrong with Internet radio, or any of the modern data streaming techniques however, SWL aficionados driven by skill, the thrill of Dx and love of their experimental hobby share a special bond that Internet radio doesn't give them.

ICOM
IC-R75
COMMUNICATIONS RECEIVER
10.000.00
S-AM
MEMO
SSB
CW/RTTY
FIL
AM
FM
TS
AF-⊙-RF/SQL
TWIN PBT
PHONES
POWER
ANT SET
CLOCK
P.AMP
ATT
NR
ANF
NB
AGC
V/M
MW
CLR
SEL
SCAN
▼DN
UP▲
ENT

Assembling a station The most important component in your radio shack is your antenna. Don't hesitate to safely experiment with the many antenna designs available on the world wide web. Your sure to find a commercial unit or home brew antenna design that suits your real estate and budget.

Your next task is to find a receiver. It is difficult to recommend any one receiver because there are so many excellent commercial receivers to choose from. If you are thinking about purchasing a used receiver, you might consider checking eBay to find a receiver or to learn the going price for used gear. The ultimate SWL experience in my opinion is to build and operate a receiver on at least 1 band.

Favorite SWL and SWL-related Web Sites

Wikipedia-Shortwave Bands A good description of the bands and their general propagation.

Canada's SWL-DXer website 🍁 Hard core Canadian web site dedicated to SWL. Thanks gentlemen!

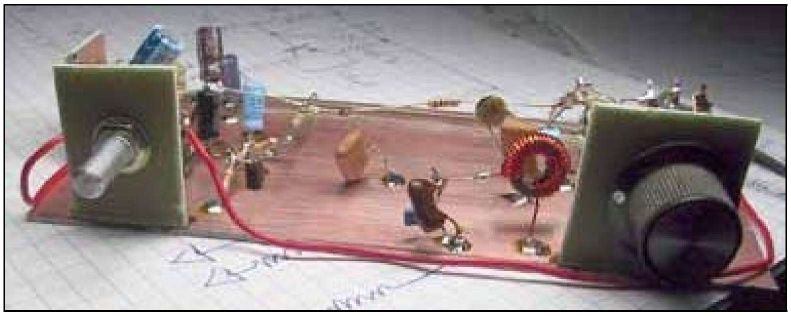

http://www.bobsamerica.com/swl

http://www.dxing.info/

Doug's Shortwave Radio Page

AA6V's SWL Links

Method for soldering a PL-259 to RG-213 or RG-8

Digital Modes For SWL Fans

PSK31

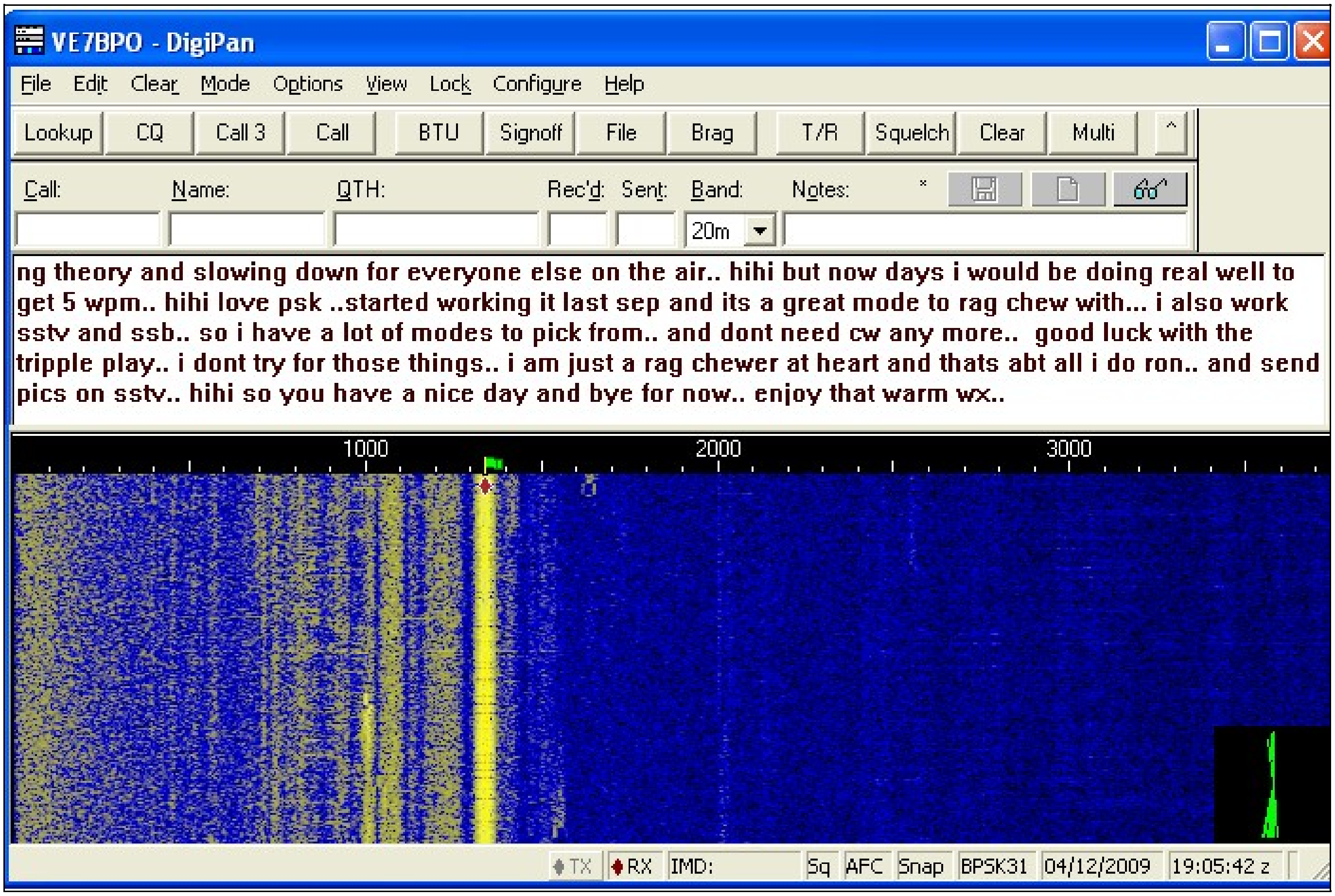
VE7BPO - DigiPan
File Edit Clear Mode Options View Lock Configure Help
Lookup CQ Call 3 Call BTU Signoff File Brag T/R Squelch Clear Multi
Call: Name: QTH: Rec'd: Sent: Band: Notes:
1000
2000
3000
TX RX IMD: Sq AFC Snap

Band: 20m

ng theory and slowing down for everyone else on the air.. hihi but now days i would be doing real well to get 5 wpm.. hihi love psk ..started working it last sep and its a great mode to rag chew with... i also work sstv and ssb.. so i have a lot of modes to pick from.. and dont need cw any more.. good luck with the tripple play.. i dont try for those things.. i am just a rag chewer at heart and thats abt all i do ron.. and send pics on sstv.. hihi so you have a nice day and bye for now.. enjoy that warm wx..

BPSK31 04/12/2009 19:05:42 z

There are a number of good sites about this relatively new HAM mode. All that you minimally need is a receiver dialed in at 14.070 USB (or another

PSK31 frequency), a microphone hooked to your computer sound card and some free software. The software (DigiPan 2.0) is available at http://www.digipan.net/ .

I use a USB interfaced microphone and place it about 2 cm from my receiver speaker. If HAMs are operating; you should hear some warbles and see some waterfalls on your screen. Click on one of the waterfalls to begin receiving the text. I knew nothing about this mode, but was up and running in 15 minutes.

Additional Short Wave and Medium Wave Receiver Photos

OPTIMUS
FM
MW
LW
SW
MHz
kHz

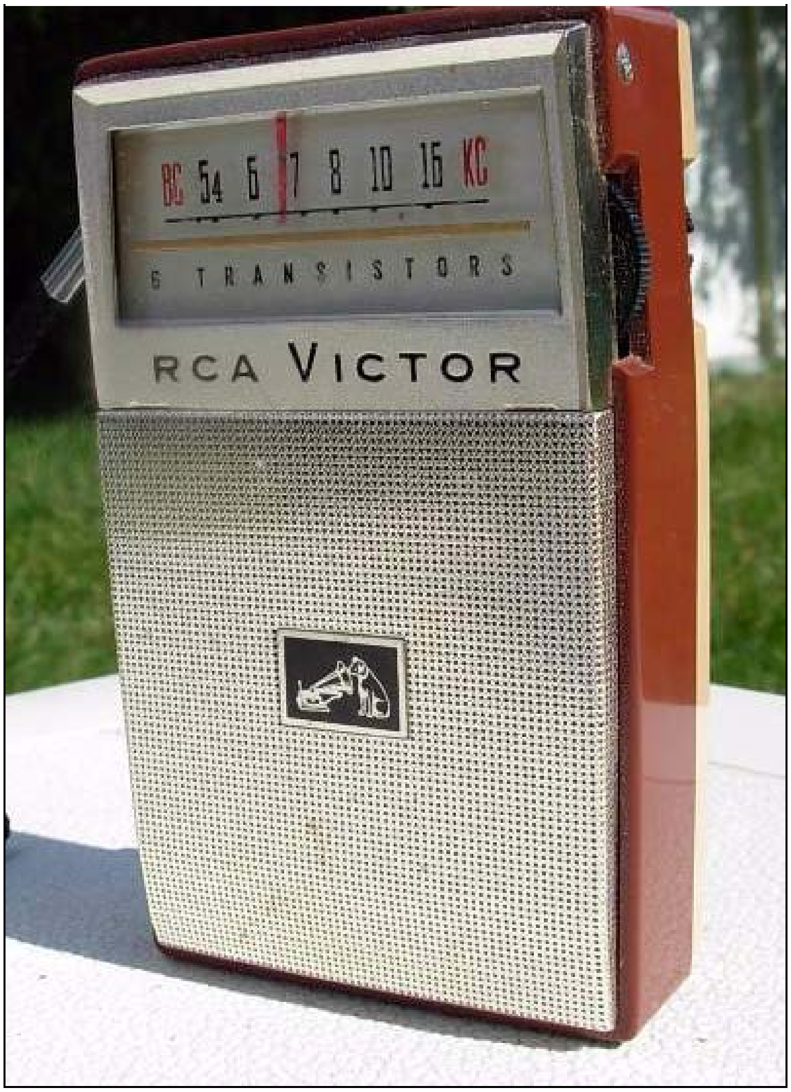
BC 54 6 7 8 10 16 KC
6 TRANSISTORS
RCA VICTOR

RCA VICTOR
SISTOR
DIO
MODEL GP-626
RCA VICTOR
RCA VICTOR

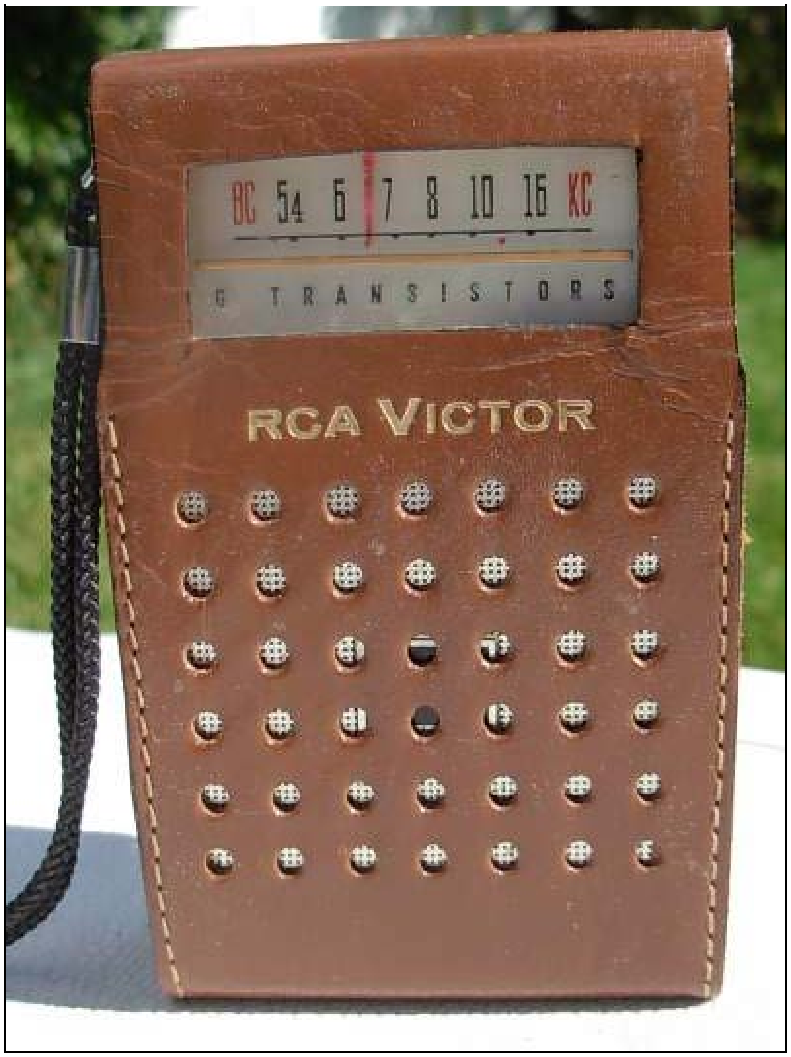
BC 54 6 7 8 10 16 KC
6 TRANSISTORS
RCA VICTOR

Amateur and Short Wave Radio Electronics Experimenter's Web Site

RF Preamps

W1FB 6M RF Preamp

Discussion:

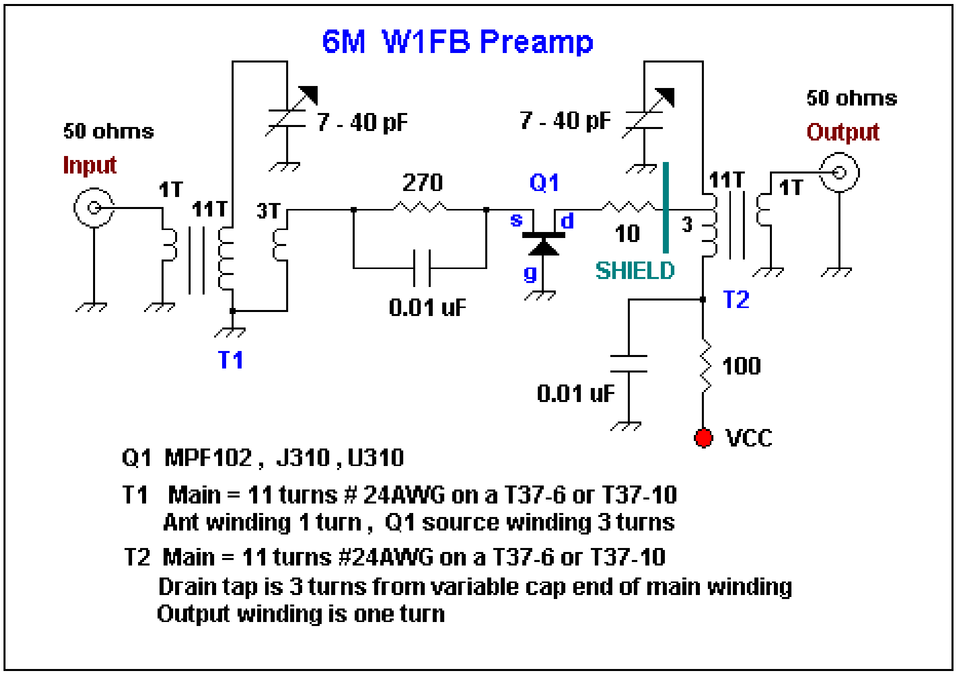
6M W1FB Preamp
50 ohms
Input
1T
11T
3T
7 - 40 pF
270
0.01 uF
T1
Q1
s
d
g
7 - 40 pF
10
SHIELD
3
11T
1T
50 ohms
Output
T2
0.01 uF
100
VCC
Q1 MPF102 , J310 , U310
T1 Main = 11 turns # 24AWG on a T37-6 or T37-10
Ant winding 1 turn , Q1 source winding 3 turns
T2 Main = 11 turns #24AWG on a T37-6 or T37-10
Drain tap is 3 turns from variable cap end of main winding
Output winding is one turn

Here is a schematic sent to me by W1FB many years ago. It is very similar to a 6M two-stage preamp that he published in QST in the mid eighties. Doug really favored the grounded gate FET for narrow band preamps. His published work is replete with examples of them on just about every band. I built that amp and remember getting about 10 dB gain, which is all that I wanted for the 6M direct conversion receiver using a diode ring detector that I was building. The great feature of the amp is that it combines a band pass filter and preamp in one. I lost the original schematic that Doug sent me but was delighted to see that I made a bitmapped drawing of it on a floppy disk that was recently re-discovered when we were moving an old desk. The shield shown in the schematic was a small piece of grounded ,double sided PC board in which, I made a small chamfered hole in to pass the lead going to the T2 tap. The shield, along with very short component leads will help minimize parasitic oscillations. The T2 tap is 3 turns down from the end of the T2 main winding that connects to the variable capacitor. Doug specified T37-10 cores for the inductors, but I substituted T37-6 cores and used the same number of windings as specified for the T37-10 core inductors. It worked fine.

VE7GC Popcorn RF Preamp

Discussion:

Here is an easy RF preamp by Dick Pattinson, VE7GC. It uses a single tuned circuit at the front end and can connect directly to a mixer or product detector in a simple receiver project. Note how Dick provided adjustable RF gain control for this circuit in his Wee Willy project on this website. If you can not find Tak Lee green 10.7 MHz IF coils, probably any other brand of 10.7 MHz slug tuned IF transformer would work. The Mouser catalog number is 421F123 . If your 10.7 MHz IF coil has a built in capacitor at the base , remove it. A fixed inductor may also be wound using a powdered iron torroid core and then all or a portion of the C1 capacity would be made variable. The input impedance is 50 ohms and the output impedance is low due to the Q2 emitter follower stage.

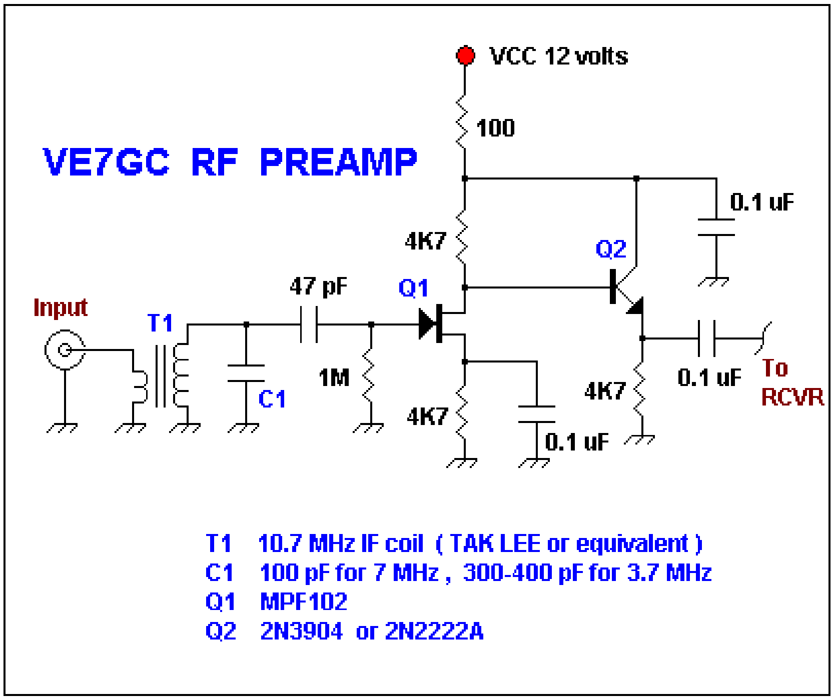
VE7GC RF PREAMP
VCC 12 volts
100
0.1 uF
4K7
Q2
47 pF
Q1
Input
T1
C1
1M
4K7
0.1 uF
4K7
0.1 uF
To RCVR
T1 10.7 MHz IF coil (TAK LEE or equivalent)
C1 100 pF for 7 MHz , 300-400 pF for 3.7 MHz
Q1 MPF102
Q2 2N3904 or 2N2222A

A Low Noise, High Dynamic Range Broadband RF Amp

Discussion:

This schematic is a version of a circuit developed and patented by David Norton and Allen Podell in June 1974. This variation was described by Joe Reisert, W1JR in the now defunct Ham Radio Magazine. The Norton design uses transformer coupling to achieve "noiseless negative feedback" and is really outstanding.
A great article utilizing and augmenting on this technique receivers is by Jacob Makhinson, N6NWP in QST magazine for Feb 1993 with "A High Dynamic Range MF/HF Receiver Front End". Makhinson arranged 2 in push-pull to obtain excellent results. Obtain a back-issue of QST for closer study. **Note** that the fore mentioned Feb QST article has the coil phasing wrong and the correct phasing can be seen at this web site from QST for July 1996. There is also information about Norton feedback RF amplifiers in EMFRD.

If you are building a contest-grade receiver and need a good RF preamp and/or post mixer amplifier, the Norton type is quite suitable. An amp built using a 2N5109 can have a noise figure in the 2.5 - 3dB range. I have also built them with 2N3866, MRF517, MRF581 and a 2N5179 although the last transistor would be a somewhat poorer choice. This schematic with a 2N5109 is good from 1.8 to 150 MHz with a 1.2:1 VSWR or less according to Joe Reisert. I have even put one in a friends CB radio and he was delighted.

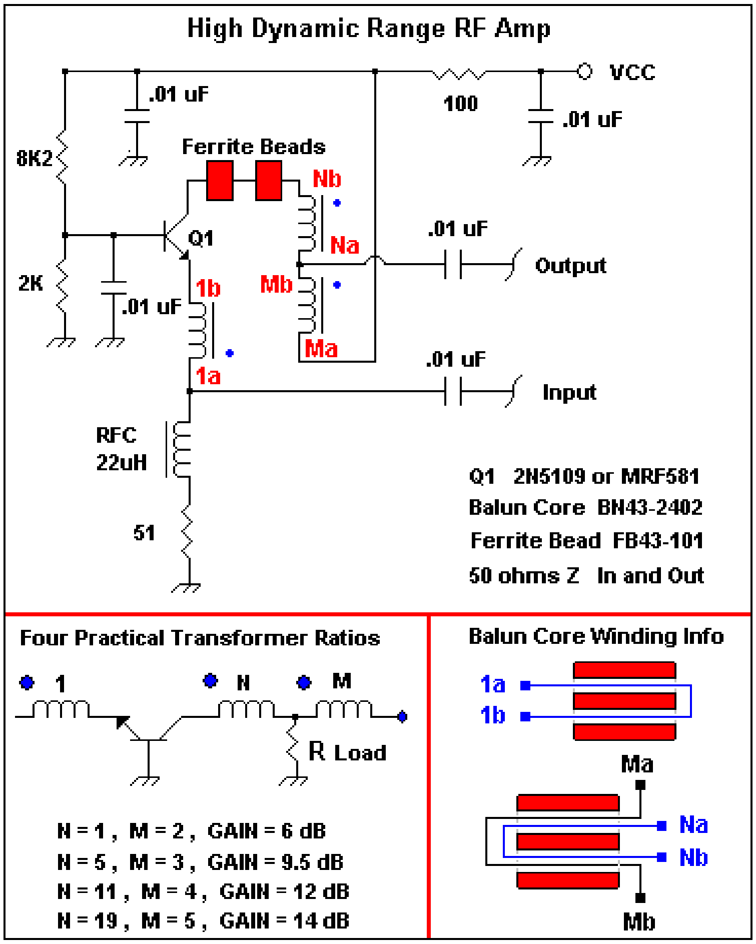
High Dynamic Range RF Amp
.01 uF
100
VCC
.01 uF
8K2
Ferrite Beads
Nb
Na
Q1
.01 uF
Output
2K
.01 uF
1b
Mb
Ma
1a
.01 uF
Input
RFC 22uH
51
Q1 2N5109 or MRF581
Balun Core BN43-2402
Ferrite Bead FB43-101
50 ohms Z In and Out
Four Practical Transformer Ratios
1
N
M
R Load
N = 1 , M = 2 , GAIN = 6 dB
N = 5 , M = 3 , GAIN = 9.5 dB
N = 11 , M = 4 , GAIN = 12 dB
N = 19 , M = 5 , GAIN = 14 dB
Balun Core Winding Info
1a
1b
Ma
Na
Nb
Mb

Winding and Construction Hints

Making the Norton amps requires some planning to keep all component leads as short as possible. The transistor leads and any connecting components should be trimmed as short as practical to promote stability. Sketch the component layout on a piece of paper and modify it until you are satisfied you have designed a good layout. The ferrite beads on the transistor collector aid in stability and should be used to preserve the noise figure by squashing any oscillations should they develop. The 22 uH choke can be the little epoxy coated units that are color coded and look somewhat like resistors. Do not use a choke less than 22 uH.

Before winding, the builder must first decide how much gain is needed from the amp. For an RF preamp, the stage should have gain equal to or greater than the passive stages after it. Also there will be losses in the transformer, so the theoretical gain of the Norton amp maybe 1 dB off and will need to be factored in. For the purposes of discussion, a 9.5 dB amp is desired , so N = 5 and M = 3. The first step is to mark one side of the core with a dab of liquid paper, paint or a small piece of tape. This will allow you to keep track of the transformer later. To mark, hold the core so that both channels are parallel to the floor, one on top of the other. Apply your dab of paint to the top of the core and use the marked top to denote the A windings. 1a, Ma and Na will all start from the top channel in the balun core. Using 32 AWG wire for all three windings, start with winding 1 and wind the single turn from point 1a to 1b. Cut off the leads so they are shorter than 5 centimeters (2 inches). Next, wind Ma to Mb three complete turns through the binocular core and trim the leads if needed. Tie a small knot in the wire at both ends. This will clearly mark this M winding. Both windings should look like the diagram under the schematic. 1a to 1b are on the left of the balun core and winding Ma to Mb are on the right side of the core. Mb has a distinguishing knot at the tip of both wire ends. Ma starts from the top of the core which you have marked with a dab of paint or something. Finally, wind Na to Nb five complete turns through the core in the same direction as the previous winding M. Strip wires Na and Mb (Mb has the knot), twist together and solder. Scrape the enamel off the leads **very** gently with a sharp hobbyist knife.

Insert the transformer in your circuit and cut the leads to their proper length and then solder away. It maybe preferable to pre-strip the leads on winding 1 as it is hard to strip the enamel off a fine wire that has only one turn and it may accidentally pull out of the core. If it does, just re-insert it into the balun core on the correct side. Once you have soldered Na and Mb you can always identify the windings later because you have marked the top of the balun core which denotes the A windings. Try and make your windings gently tight as if there is too much slack you may have difficulty getting the last few windings thru the core channels. A 14 dB gain amp maybe **impossible** to wind with 32 AWG wire, it may best to use 34 AWG for that amplifier. I have never built one for greater than 12 dB. The transformers are a bit tedious to wind, however persevere and the results will be well worth it. For HF, you can substitute 0.1 uF caps for the 0.01 caps shown if you like.

Toroidal Inductor Norton Amp Experiments

Discussion:

The amp shown in the schematic to the right uses a ferrite torroid for the transformer and has ~10 dB gain. Winding 1 turn of wire over the cold end as shown in the schematic is tricky. Try to keep this link as short as possible. A ferrite bead or a 22-51 ohm resistor on the transistor collector is desirable. You can try increasing the turns (1:21:5 etc) to experimentally obtain more gain from this amp. The torroid version is a valid option for builders who do not have balun (binocular) core ferrites in their junk box. Toroidal inductors are certainly easier to wind then binocular core versions.

In 2007, I built several Norton "noiseless feedback" RF amps using FT50-43 and FT37-43 ferrite torroids. These are outstanding and I recommend using them in projects. The input and output Z is 50 ohms. The overall BJT topology is reminiscent of a common base amp. I have some basic information concerning this amp on this web page . They are straight forward to build. The biggest problem is the phasing of the single turn link. Get it wrong and your amp can turn into an oscillator.

Figure 1

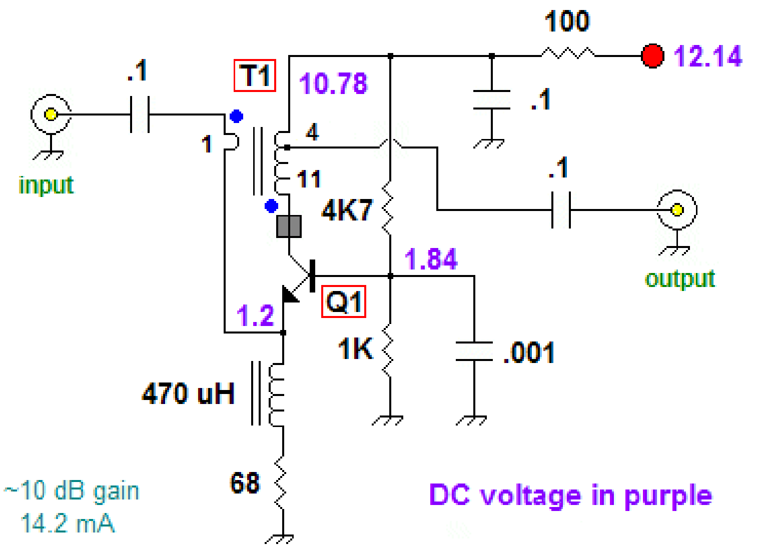

Q1 = 2N5109 or NTE 123 etc
T1 = Secondary: 15 turns with a tap a 4
turns from the cold end.
Primary: 1 link over cold end
T1: use FT50-43 or FT37-43 ferrite

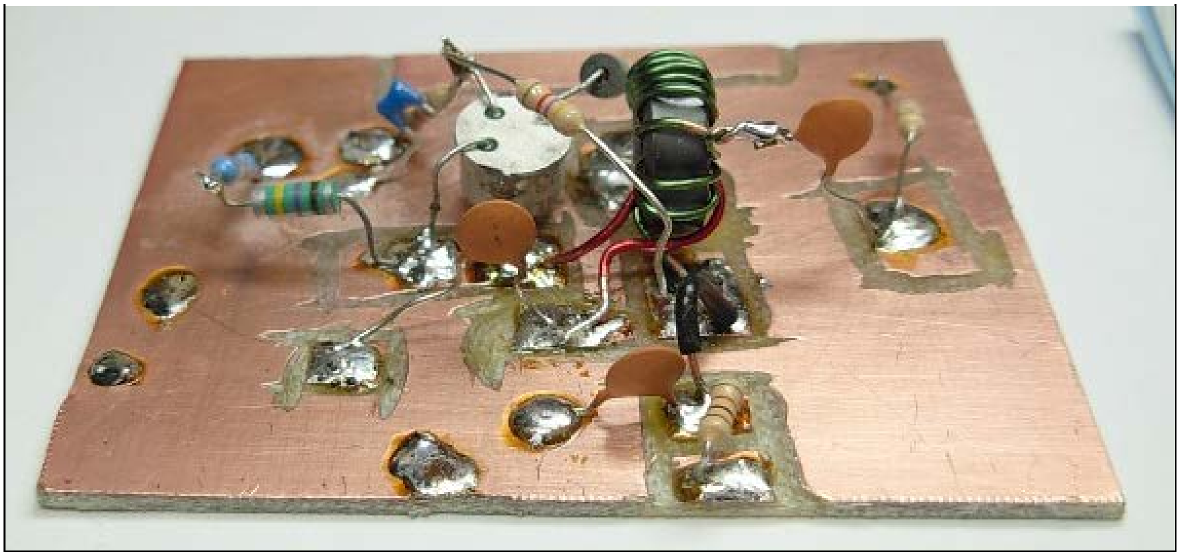

Shown above. The breadboard of Figure 1.

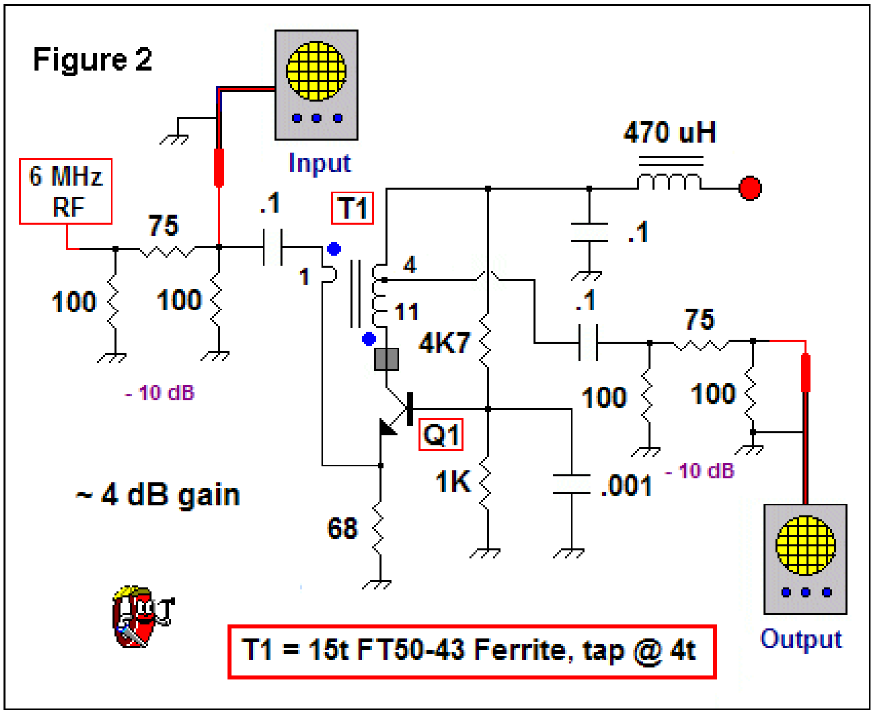
Figure 2
Input
6 MHz RF
75
100
100
- 10 dB
.1
T1
1
4
11
4K7
470 uH
.1
.1
75
100
100
- 10 dB
Q1
1K
.001
68
~ 4 dB gain
T1 = 15t FT50-43 Ferrite, tap @ 4t
Output

Shown above is the Figure 1 amp above (labeled Figure 2) with a 50 ohm -10 dB pad on the input and output, so gain is low. I used these pads to evaluate the amp in a number of experiments. I never got around to writing up these experiments on the web site and likely never will. I wish I had more time as my notebooks are full of unpublished experiments that would be great content for this web site.

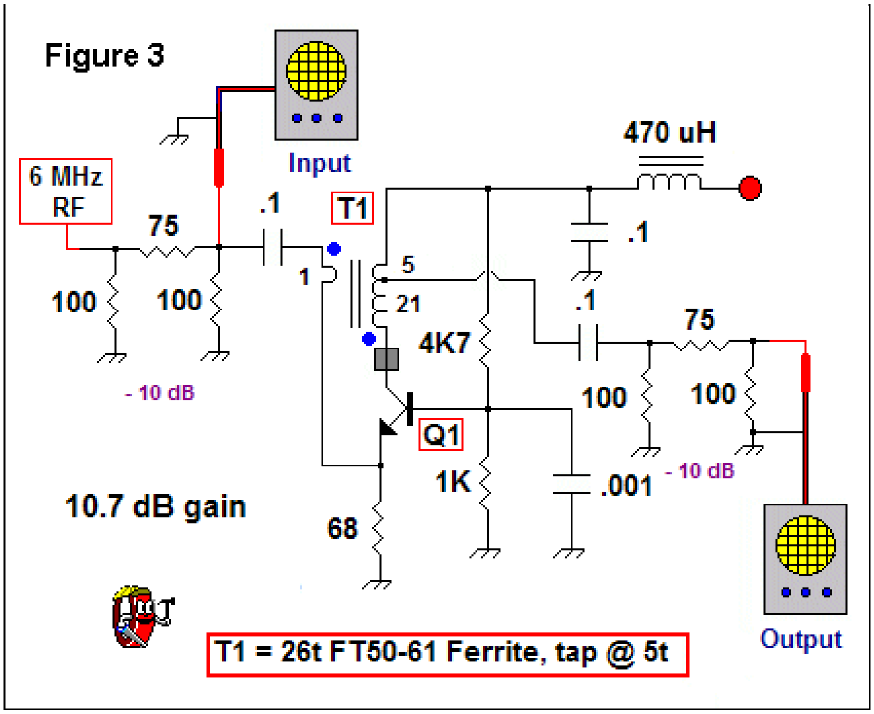

Figure 3
Input
470 uH
6 MHz RF
75
.1
T1
1
5
21
.1
100
100
4K7
.1
75
- 10 dB
100
100
Q1
1K
.001
- 10 dB
10.7 dB gain
68
T1 = 26t FT50-61 Ferrite, tap @ 5t
Output

The amp above (labeled Figure 3) is a hot one; 10.7 dB gain even with 10 dB of attenuation. You can leave off the input pad and decrease the output pad to -6dB if you want or require a wide band, low noise RF amp with lots of guts. Most builders use binocular ferrite cores for the inductor, but torroids work fine for many applications.

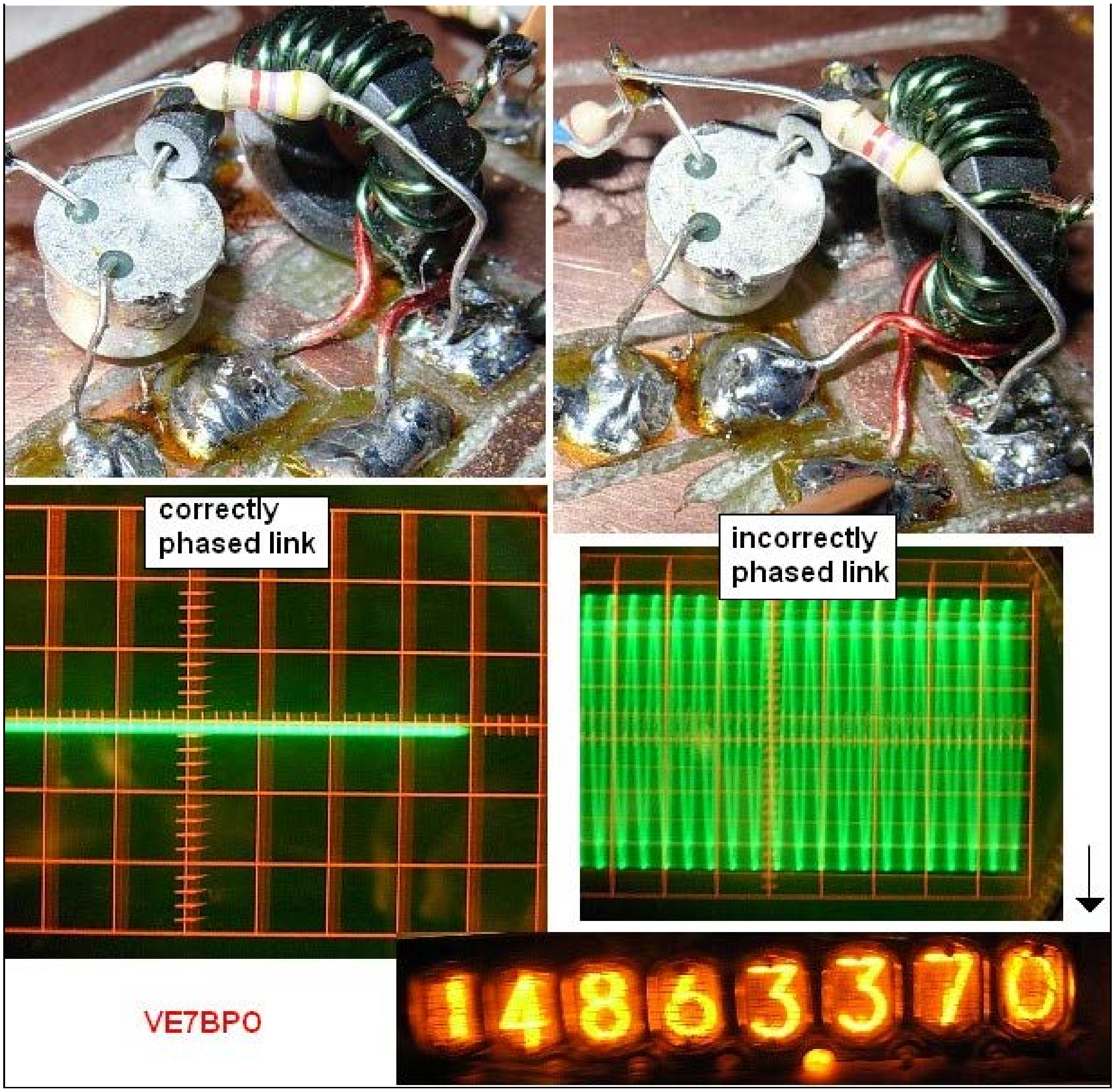
correctly
phased link
incorrectly
phased link
VE7BPO
14863370

Shown above is a photograph of 1 of the experiments from 2007. The one turn link from the Norton amplifiers just above is shown phased correctly and then phased incorrectly. Note the oscillation in the "badly wired" amp at 14.86 MHz. I routinely check all of my noiseless RF amps using the oscilloscope. Occasionally, I will put a shunt coil and cap (from input to ground) on the input to "exaggerate" any oscillations. This has proven to be a useful technique for testing if the phasing of the one turn link was done correctly.

RF preamp for the 40 Meter band with 3 tuned filters

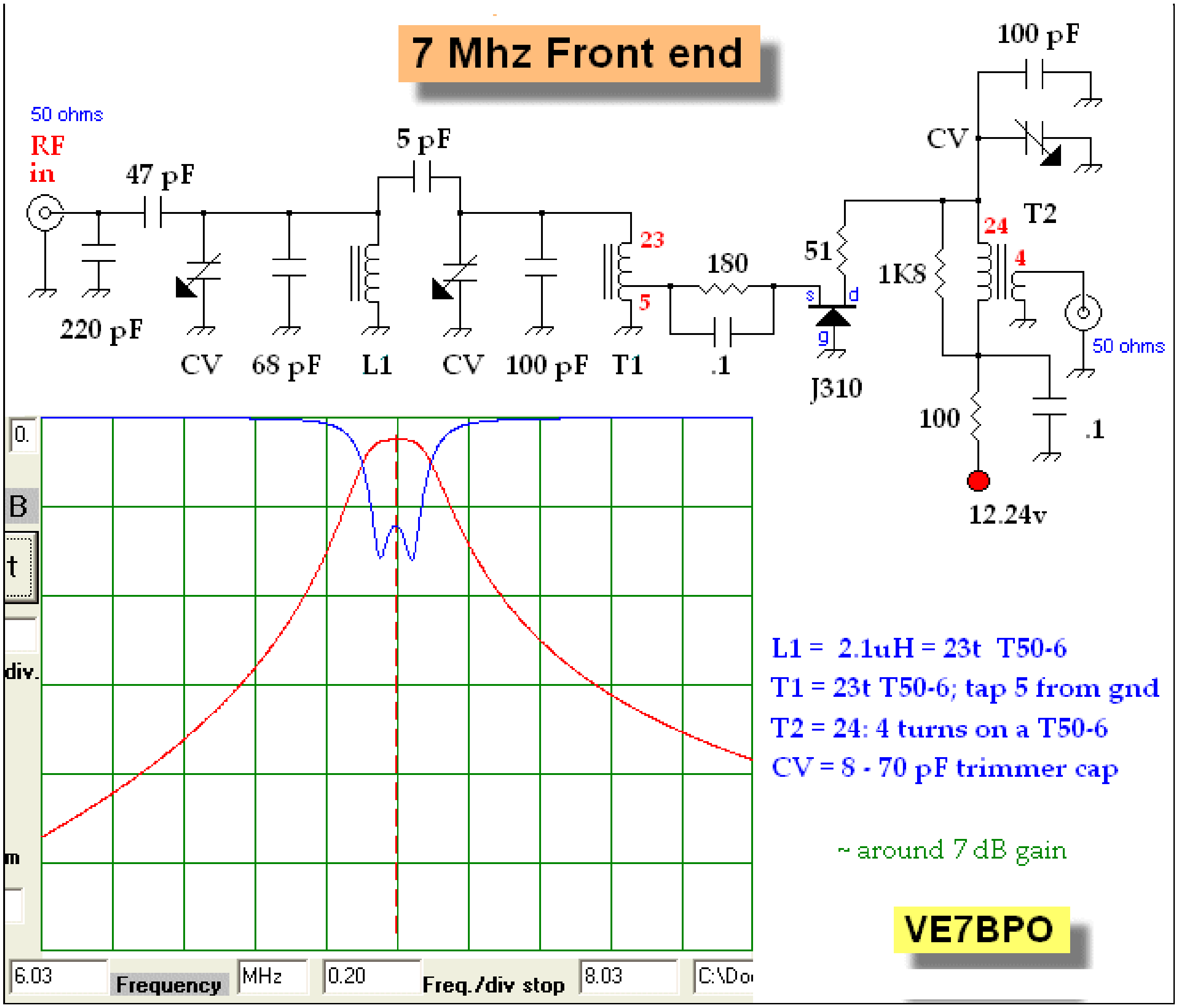
7 Mhz Front end
50 ohms
RF in
47 pF
5 pF
220 pF
CV
68 pF
L1
CV
100 pF
T1
23
5
180
.1
51
s
d
g
J310
1K8
100 pF
CV
T2
24
4
50 ohms
100
.1
12.24v
L1 = 2.1uH = 23t T50-6
T1 = 23t T50-6; tap 5 from gnd
T2 = 24: 4 turns on a T50-6
CV = 8 - 70 pF trimmer cap
~ around 7 dB gain
VE7BPO
0.
B
t
div.
m
6.03
Frequency
MHz
0.20
Freq./div stop
8.03
C:\Do

An experimenter's 40 Meter band front end for CW. This has a double-tuned filter and a low gain, lower noise RF amp. Great circuit for isolation of a product detector or mixer in a popcorn receiver.

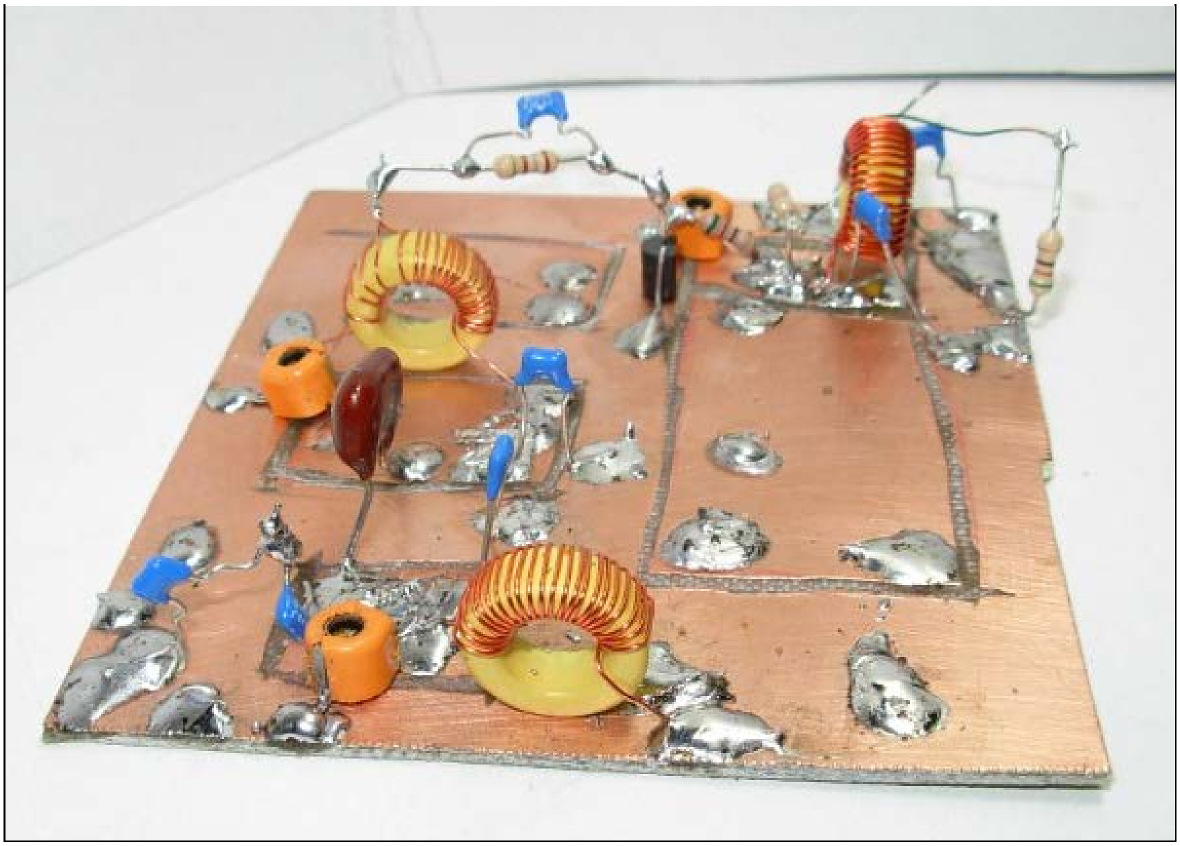

A photograph of the above 40 meter band front end, double-tuned filter plus tuned common gate RF amplifier. Input and output Z is 50 ohms.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

QRP HomeBuilder Software

Disclaimer:

THE QRP HOMEBUILDER SOFTWARE OFFERED HEREIN ("THE SOFTWARE") DOES NOT COME WITH ANY WARRANTY, EXPRESS OR IMPLIED. IF YOU MAKE USE OF THE SOFTWARE, PLEASE BE AWARE THAT YOU DO SO AT YOUR OWN RISK. NEITHER THE AUTHORS OF THE SOFTWARE AT JENNA DESIGN NOR ANY OTHER PARTY WILL ACCEPT RESPONSIBILITY FOR ANY OCURRING OR UNFORESEEN CONSEQUENCES OR DAMAGES THAT ARISE AS A RESULT OF THE USE OR MISUSE OF THE SOFTWARE.

Technical Info and Distribution

The QRP HomeBuilder applications are written in C++ for speed and compactness. Apps will specified as GUI (graphical user interface) or 32-bit console based (DOS look). Anyone may display or distribute these applications via website or diskette providing that they do not charge for the program(s). I know longer have a C++ compiler and no future work on these applications is anticipated.

QRP - RELATED APPLICATIONS FOR DOWNLOADING

CoilBuilder_99

CoilBuilder_99 is a powdered iron inductor winding application. Enter desired inductance, select core size and mix and press the Calculate button to determine the correct number of windings for your inductor. Data is also given showing, core color, permeability, frequency range, AL value and maximum number of turns versus wire guage for the chosen core size. Encompasses 12 different core sizes and 8 different mixes of powdered iron. Calculated results can be stored on a disk file or printed out.

Style: GUI, File size: 90K, zipped, 44K.

Bug Fixes: Some missing AL values for # 7 material added April 24/99. K6WHP's superior version is linked below.

Current Version is: 4 / 24 / 1999

Download the CB99.zip file

PI Filter Designer

PI Filter Designer is a simple 3 element 50 ohm input and output impedance pi filter designing application. This program allows the user to design simple lowpass filters by selecting from a variety of standard capacitor values either empirically or to suit what you have on hand. The filter 3 dB cutoff frequency and required L1 inductance are automatically calculated and displayed. In addition, the user may select an additional capacitor value to put in parallel with both caps C1 and C2. In this app XL = XC = 50 ohms impedance. No other impedances can be calculated with this program.

Style: GUI, File size: 47K, zipped, 22K.

Current Version is: 1 / 14 / 1999

Download the pifilter.zip file

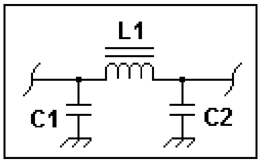

CapCoder

CapCoder gives the capacitance in microfarads, nanofarads and picofarads and tolerance of any capacitor code entered into its input section. Example : 104J. This app uses numeric spin-buttons and a combo box so that no typing is required for data entry.

Style: GUI, File size: 48K, zipped, 22K.

Bug Fixes : A nanofarad conversion error was corrected July 2, 1999.

Current Version is: 07 / 02 / 1999
Download the capcoder.zip file

Resistor Coder

Resistor Coder gives the resistance in ohms of any resistor color code entered into its input section. Four or five band resistors can be accommodated by this program. This app uses drop-down combo boxes so that no typing is required for data entry. Results may be saved to a disk file or directly printed.

Style: GUI, File size: 58K, zipped, 27K.

Current Version is: 1 / 16 / 1999
Download the resistor coder.zip file

Ferrite

Ferrite is used to calculate the number of turns required on toroidal ferrite cores to achieve the desired millihenry-value inductance. 15 different ferrite toroids are included in this application. This program will calculate the winding data for an inductance range of 0.001 to 27 millihenries.

Style: Console, File size: 64K, zipped, 31K.

Bug Fixes: Thanks to PA3CKR for the bug report; fixed Jan 19/99.

Current Version is: 1 / 19 / 1999
Download the ferrite.zip file

Universal Diplexer

Universal Diplexer calculates the inductance and capacitance values for a Bridge-Tee diplexer based upon a chosen superhet receiver intermediate frequency. The diplexer is the Joe Reisert, W1JR popularized design discussed under Diplexer Topics on this web site. The user inputs an IF and presses the Calculate button to have the capacitor and inductor values given in pF and uH respectively. The diplexer schematic is included in the application. Note that the this is for the Q = 1 version of the Bridge-Tee Diplexer.

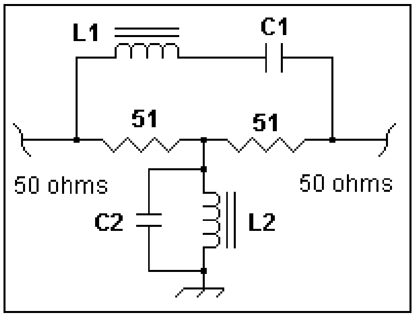

Style: GUI, File size: 49K, zipped, 22K.

Current Version is: 1 / 19 / 1999
Download the diplexer.zip file

HF Dipole

A very basic program for calculating the length of each leg of a 1/2 wave wire dipole antenna. Program good for 1 - 500 MHz, although intended for MF - HF useage. This app does nothing more than the standard 468/freq (MHz) type calculations. It was written for DOS many years ago and ported to Windows. The output shows the 1/2 wavelength and 1/4 wavelength design wire length in feet and meters. This app is probably of no help to experienced antenna designers.

Style: GUI, File size: 46K, zipped, 22K.

Update : Minor improvements made Feb 9, 1999

Current Version is: 2 / 9 / 1999
Download the hf_dipole.zip file

Resonator

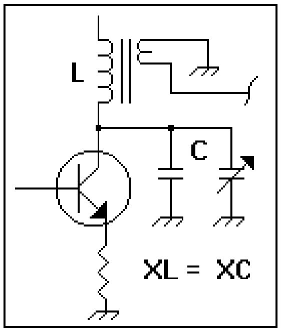

This application calculates the inductor and capacitor values for the tank circuit of a simple bipolar transistor RF amp. The basic schematic is shown above. Enter the center frequency plus the inductive/capacitive reactance you desire and press the Calculate button to calculate the necessary inductance and capacitance for L and C respectively.

Style: GUI, File size: 50K, zipped, 21K.

Current Version is: 1 / 23 / 1999

Download the resonator.zip file

NPN DC-BIAS

This application calculates the various voltages and currents of a simple voltage divider bias NPN bipolar transistor amp. The following is calculated: IB, IC, IE, VE, VB, VC, VCE and detection of Saturation or Cutoff. The user can alter the VCC, VBE, transistor beta and any of four resistor values R1, R2, RC and RE by picking the transistor value from a standard-value resistor table or manually entering the value. The schematic illustrates some of the voltage measuring points on the transistor schematic. *This app is in final BETA.*

Style: GUI, File size: 73K, zipped, 32K.

Current Version is: 16 / 04 / 1999

Download the nbias.zip file

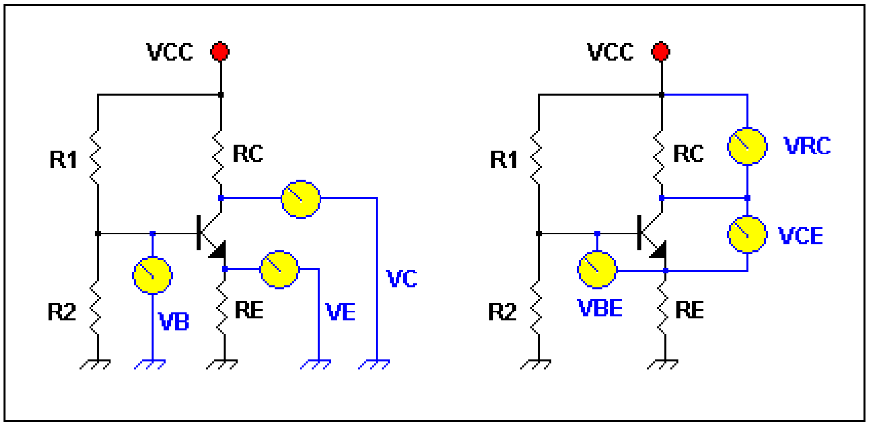

QRP SWL HOMEBUILDER

Amateur and Short Wave Radio Electronics Experimenter's Web Site

Popcorn Direct Conversion Main Frame

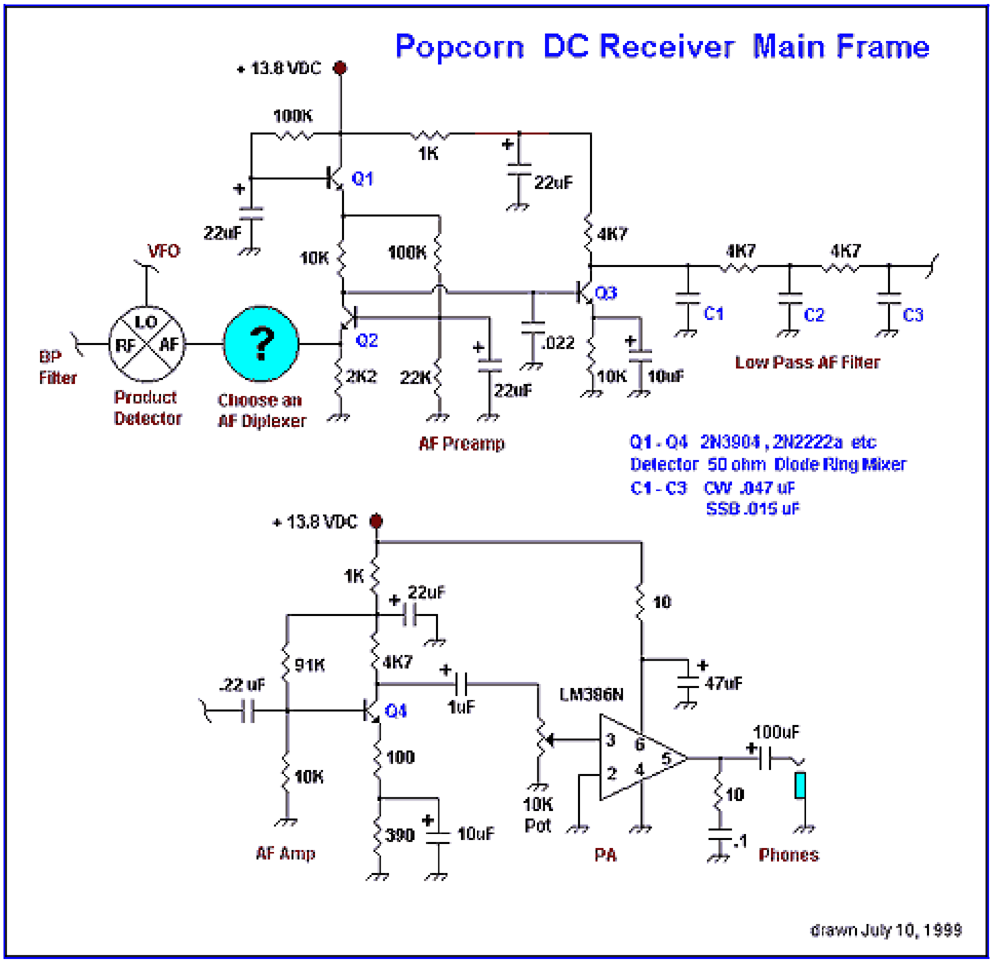
Popcorn DC Receiver Main Frame
+ 13.8 VDC
100K
1K
22uF
Q1
22uF
10K
100K
4K7
4K7
4K7
VFO
LO
RF
AF
BP Filter
Product Detector
?
Choose an AF Diplexer
Q2
Q3
2K2
22K
22uF
.022
10K
10uF
C1
C2
C3
Low Pass AF Filter
AF Preamp
Q1 - Q4 2N3904 , 2N2222a etc
Detector 50 ohm Diode Ring Mixer
C1 - C3 CW .047 uF
SSB .015 uF
+ 13.8 VDC
1K
22uF
10
91K
4K7
47uF
.22 uF
Q4
1uF
LM386N
100uF
100
10K
3
6
2
4
5
10
390
10uF
10K Pot
.1
AF Amp
PA
Phones
drawn July 10, 1999

Discussion:

Note: if you click on a schematic, a larger version will appear in a new web browser window.

Shown to the right is the schematic to a low cost popcorn direct conversion receiver main frame. To complete the receiver, a front end band pass filter and a VFO with an output power of 7 dBm is required. This is indeed a frugal project using 4 cheap transistors, an RC low pass filter and an LM386N for output power to a pair of low-impedance headphones. The builder also has a choice of 5 diplexers and an optional mute circuit. This receiver is easily built using Ugly Construction and can be built in 3-4 hours with a bit of luck.

Product Detector and Diplexers

The 50 ohm diode ring product detector can be commercial units such as the Mini-Circuits SBL1 or TUF-1 or homebrewed 50 ohm impedance units. Five simple "diplexers" are shown in the lower "Adjuncts" schematic for you to choose from. The one you choose will depend on available parts, cost and your requirements in a popcorn receiver such as this. These diplexers are mostly of the low pass filter variety and provide a ~50 ohm termination to the diode ring mixer and some matching to preserve the product detector dynamic range. I realize that except for (A) and (D) these audio frequency filters are not truly diplexers and will not provide DC to daylight matching. The intent of this web site is not high performance-high cost

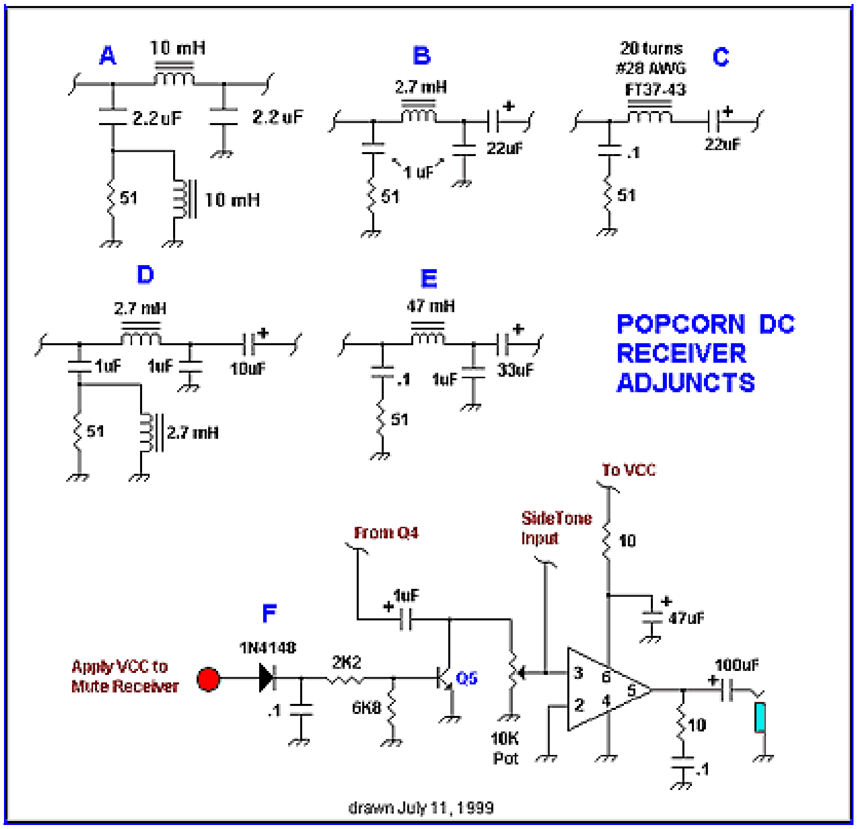
A
10 mH
2.2uF
2.2uF
51
10 mH
B
2.7 mH
22uF
1 uF
51
20 turns
#28 AWG
FT37-43
C
.1
22uF
51
D
2.7 mH
1uF
1uF
10uF
51
2.7 mH
E
47 mH
.1
1uF
33uF
51
POPCORN DC
RECEIVER
ADJUNCTS
To VCC
SideTone
Input
10
From Q4
F
1uF
47uF
1N4148
2K2
Apply VCC to
Mute Receiver
Q5
3
6
5
2
4
100uF
.1
6K8
10K
Pot
10
.1
drawn July 11, 1999

design and please do not confuse it as such. Note that electrolytic capacitors that bypass to ground such as the 1 uF caps must be non-polarized or bipolar for best results.

The (A) diplexer is by W7ZOI and is described on the Diplexer Web Page on this site.

The (B) and (D) diplexers are my designs and the (D) diplexer is the (B) diplexer with out the high pass component.

The (B) diplexer shown has a 3000 hertz 2 pole high pass/2 pole low pass design. This 2nd order filter provides reasonable overall matching Capacitors are standard-value, non-polar electrolytic types.

The (C) diplexer is a very basic, but very practical choice for this receiver.

The (E) diplexer is one that I used in one of my first DC receivers and the 47 millihenry inductor is a standard value unit sold by Mouser Electronics and others.

Another diplexer choice for this receiver might be the unit described by Rick Campbell, KK7B in his Binaural I-Q receiver project published in the March 1999 issue of QST.

Update May 15, 2009

There was confusion regarding the 2.7 to 47 mH inductors mentioned on this web page. I originally wound just the 2.7 mH inductor on a ferrite, but not the others. This is not a great idea as losses are high. For millihenries-value inductors, commercial parts should be purchased. A good brand to consider might be Epcos. Sorry for causing confusion.

10 milliHenry inductor
* Not wound at home

AF Preamps

The AF preamp section follows that of the Ugly Weekender Receiver designed by Wes Hayward, W7ZOI. I tried many other configurations and came to the conclusion that these two simple but elegant stages give a winning combination of low noise, good gain, low parts count, low hum and good AM broadcast band rejection. The Q1 transistor decouples the receiver preamp very well and no hum was detected in the headphones providing a well filtered DC power supply was used. The Q2 grounded base amp provides a low impedance termination of the product detector and diplexer stages. Q2 and Q3 are direct coupled and provide lots of gain to drive the succeeding low pass filter without it adding a huge abundance of noise to the signal. The bypass capacitor (0.022 uF) is essential to bypass any broadcast AM detected in the Q1 stage to ground. Other values of capacitors maybe tried, but do not omit this critical part.

Low Pass Filter

I cannot handle listening to a DC receiver on a crowded band without some low pass filtering. The high pitch heterodynes effect my concentration and give me a headache. Nevertheless, it is neat to temporarily listen to an unfiltered DC receiver; to hear the pure and wonderful signals possible by beating RF directly into audio. I prefer low pass to band pass filters at audio and have used many combinations of active filters using discrete components and op-amps, as well as passive designs using AF inductors to build wave filters. This receiver uses none of these devices, however they could be easily substituted for the filter shown. Connected to Q3 is a simple, cheap RC low pass filter based upon the design criteria given on the Discrete Component RC Audio Filters web page on this web site. The cutoff values you calculate will be ballpark and values of 0.047 uF for CW and 0.015 uF for SSB were chosen, but other values could just as easily been used and please do not hesitate to experiment with the caps and/or the resistors to suit the parts you have on hand. For the capacitors in the low pass filters, avoid using ceramic disk type caps if you want the best possible performance. Polyester, polypropylene, polystyrene or polyester film type are all suitable, however, ceramic caps will work if you are really going junk box/low cost.

I attempted to make a wave file to demonstrate the low pass filter. I came right off the headphone jack into the input of the of my 16-bit PC sound card via a step up audio transformer and the results were a little disappointing. Sixty-cycle hum and distortion of loud stations were added by the sound card. The sound file is big (636 KB) and is a digital recording of me tuning through a 30 meter pile-up using the lowest sample rate and frequency possible on my computer. The low sample rate/frequency also degraded the sound somewhat as well, but I decided to put it on the page, warts and all. The DX station was a VK2 and sure did cause a lot of excitement on 30 meters that night around sunset on the left coast. Actually the wave file demonstrates how good the receiver sensitivity and AM radio immunity is. In addition, the low receiver background noise is also very apparent underneath the constant 60 cycle hum. The 60 cycle hum and clipping of loud CW signals is not heard in the headphones and is a soundcard manifestation. Perhaps the best method would be to come of Q4 and go right into the sound card with a smaller line-in signal voltage. Download the popdc wave file

---

AF Driver and Final Amp

Connected to the input and output of the Q4 stage are small value capacitors to provide some high pass filtering for the receiver amplifier chain. Some emitter degeneration is used on Q4 to provide a better termination of the preceding RC low pass filter. The receiver amplifier chain has a lot of gain and when the 10K pot is turned to minimal resistance (cranked) , the LM386N can be driven into distortion. You may want to limit the maximum gain with a series resistor connected to the 10K pot after building and testing this receiver.

The final AF amp is the perennial LM386N, a low cost, easy to use AF amp. Turn it upside down and solder pins 2 and 4 right to your copper ground plane to anchor this part. It can easily be configured to drive a small speaker.

An optional mute circuit is shown in the "Adjuncts" schematic and is labeled (F). This circuit is a simple transistor switch which grounds the output from Q4 and mutes the receiver audio. This circuit switches rapidly and there are no annoying pops or clicks to be heard in the headphones when it is switched. Apply the VCC to the diode as shown to mute the receiver during transmit if the receiver is used in conjunction with a transmitter. Q5 in the mute circuit can be a 2N3904 or 2N2222a or substitute.

In addition, a suggested side tone input to the LM386N is shown. I have started to use simple one section RC filters on the output of my side tone oscillators to smooth the waveform into a more pleasing audio tone.

Conclusion:

This popcorn receiver can be made very inexpensively and has good sensitivity and a reasonable noise level and selectivity. I tested this main frame on 30 and 40 meters and really enjoyed it. This receiver main frame could be combined with an inexpensive VFO using tuning diodes to keep cost down and the popcorn factor up. Although it does not use tuning diodes, a 40 Meter band VFO schematic has been placed on the VFO page.

Here is a YouTube Link using the receiver with a different front end filter and VFO. This is not my radio or video.

A blog post from Peter AK6L --- it's good to see builders moving beyond kits.

---

40 Meter Popcorn Superhet Receiver

Discussion:

Note: if you click on a schematic, a larger version will appear in a new web browser window.

To the right is the schematic for a no-frills, relatively low-cost CW superhet receiver with a 4.00 MHz Intermediate frequency. There is no AGC or RF gain control, however this receiver has good large signal handling capability. This receiver uses just 6 bipolar transistors and an op amp for reasonable volume into headphones. Much of the ideas/design of the various stages must be credited to Wes Hayward as I borrowed heavily from his previous work and through ideas obtained by discussion. If one were to homebrew the diode ring mixers, indeed this would be a very low cost receiver giving reasonable performance which outperforms any NE602 based superhet receivers that I have built or listened to. Below the main schematic is a diplexer diagram that allows the builder to choose from one of two RF and AF diplexers used to terminate the diode ring mixers.

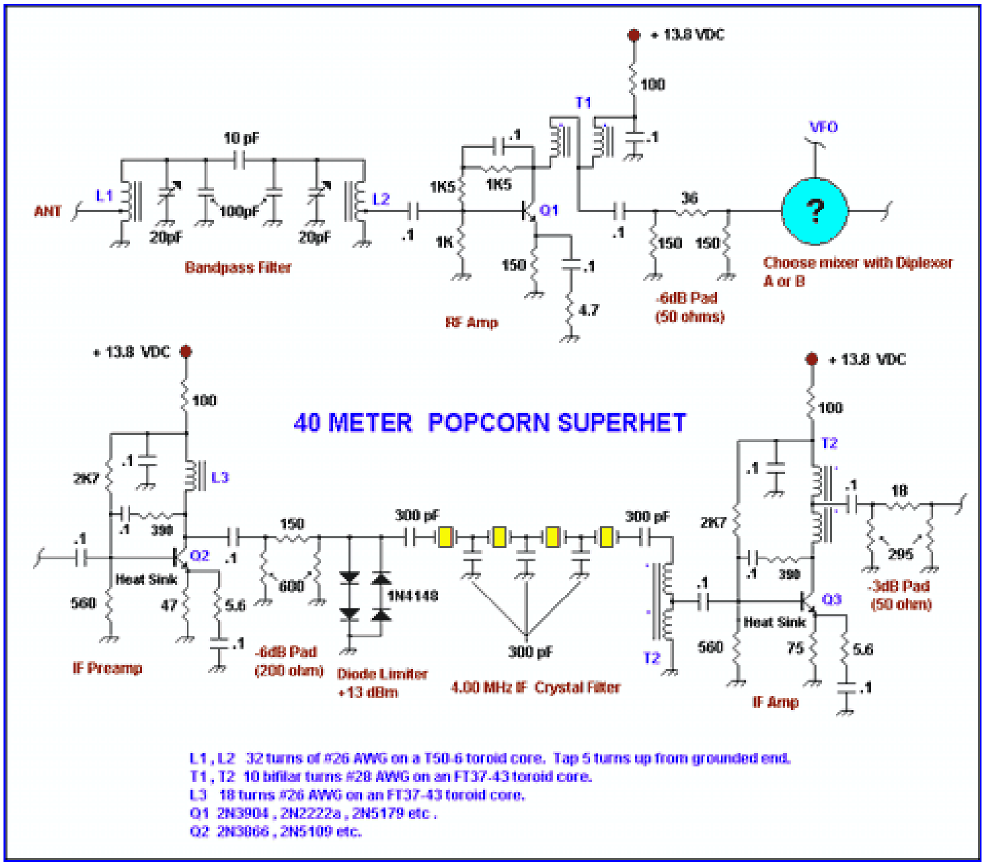
+ 13.8 VDC
100
T1
.1
.1
VFO
10 pF
1K5
1K5
ANT
L1
L2
Q1
100pF
20pF
20pF
.1
.1
36
?
1K
150
150
150
.1
Bandpass Filter
Choose mixer with Diplexer A or B
4.7
-6dB Pad (50 ohms)
RF Amp
+ 13.8 VDC
+ 13.8 VDC
100
100
40 METER POPCORN SUPERHET
T2
2K7
.1
L3
.1
.1
18
2K7
.1
390
150
300 pF
300 pF
295
.1
Q2
.1
.1
390
Heat Sink
600
1N4148
-3dB Pad (50 ohm)
Q3
560
47
5.6
.1
Heat Sink
-6dB Pad (200 ohm)
300 pF
560
75
5.6
IF Preamp
T2
Diode Limiter +13 dBm
4.00 MHz IF Crystal Filter
.1
IF Amp
L1 , L2 32 turns of #26 AWG on a T50-6 toroid core. Tap 5 turns up from grounded end.
T1 , T2 10 bifilar turns #28 AWG on an FT37-43 toroid core.
L3 18 turns #26 AWG on an FT37-43 toroid core.
Q1 2N3904 , 2N2222a , 2N5179 etc .
Q2 2N3866 , 2N5109 etc.

Band pass Filter and RF Preamp

From the 50 ohm receiver antenna jack, first off is a double-tuned band pass filter which was designed by Rick Campbell, KK7B and works very well. The trimmer caps can be the 5 - 20 pF units sold by Digi-key and Mouser. The fixed-value caps in my prototype were inexpensive monolithic ceramic capacitors purchased from Digi-key. Rick used an NP0 ceramic for the 10 pF coupling cap plus silver-mica type for the 100 pF caps in his original design. For possible lower insertion loss, the probable best/cheapest way would be to use all NPO ceramics for the fixed value caps in this filter.

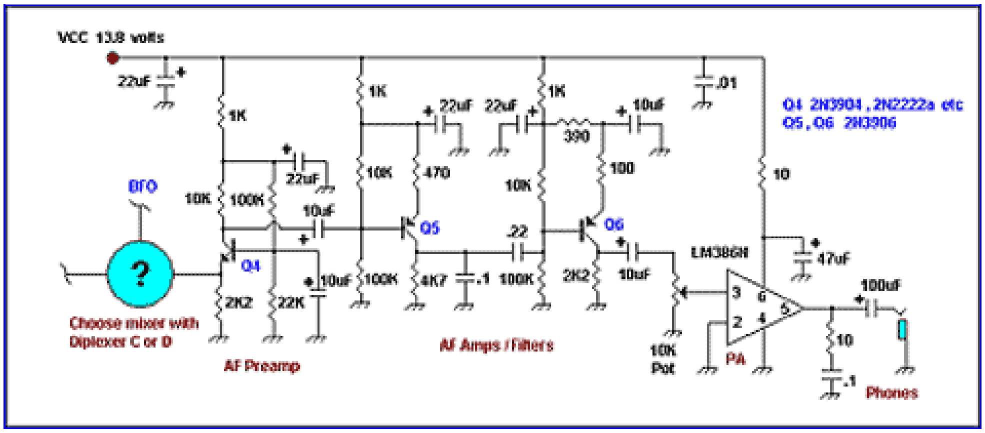
VCC 13.8 volts
22uF
1K
1K
1K
.01
22uF
22uF
10uF
Q4 2N3904 , 2N2222a etc
Q5 , Q6 2N3906
390
22uF
10K
470
100
BFO
10K
100K
10K
10
10uF
Q5
.22
Q6
Q4
LM386N
47uF
?
10uF
100K
4K7
.1
100K
2K2
10uF
100uF
2K2
22K
3
6
5
2
4
Choose mixer with Diplexer C or D
10
AF Amps / Filters
10K Pot
PA
AF Preamp
.1
Phones

The RF amp is my favorite popcorn RF amp ; a 50 ohm feedback amp. A grounded-gate JFET amp was tried in its place and was also found to be quite suitable and does not require the -6dB pi attenuator that follows the feedback amp as shown in the schematic. The feedback amp's 50 ohm input impedance properly terminates the band pass filter. The -6 dB attenuator pad following the amp to helps provide a 50 ohm input impedance for the mixer and to reduce stage gain which aids in preserving the signal to noise ratio of the receiver. If a builder wants a little more sensitivity, the pi attenuation pad could be reduced to -3 dB however this may effect the receiver dynamic range. The transformer T1 is one of 2 broadband transmission line transformers in this receiver. It transforms the 200 ohm collector impedance to 50 ohms for the succeeding stage.

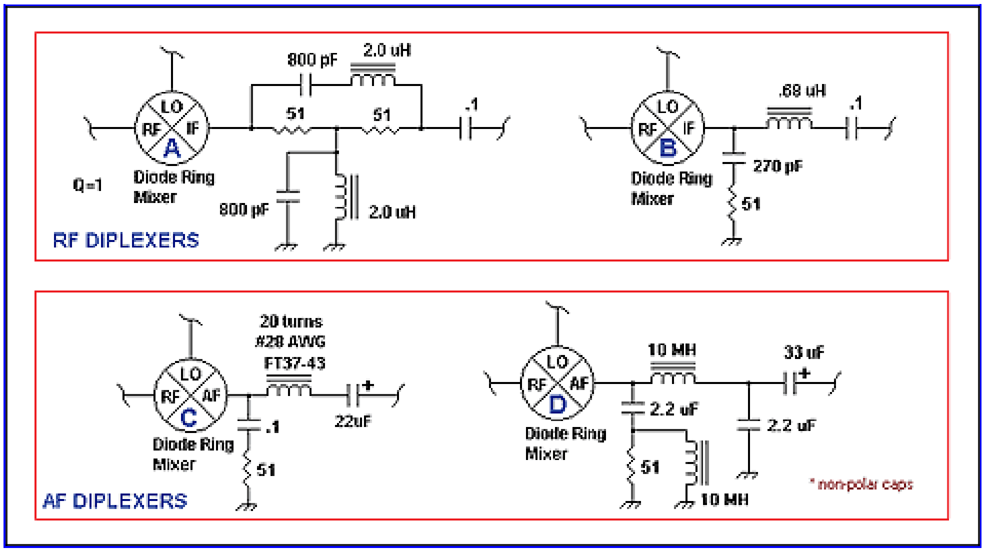

Mixer and Diplexer

A 50 ohm diode ring mixer (7dBm) such as the Mini Circuits SBL-1 or TUF-1 or homebrew are all suitable. Following the mixer is an RF diplexer of your choice. The more complex Brifge-Tee (Q = 1)diplexer (A) is an excellent design, however maybe overkill in a popcorn superhet such as this. For the (A) diplexer, to get the necessary 800 pF for the capacitors, simply parallel a 470 with a 330 pF or a 120 pF with a 680 pf capacitor. The inductors at 2.0 uH are wound on powdered-iron torroids. You can use # 26 AWG wire and it requires 22 turns on a T37-2 core or 20 turns on a T50-2 core. In addition, you can use a #6 material torroid to wind the inductors. This diplexer is described elsewhere on this web site.

The simpler (B) diplexer uses a ~3 times the IF frequency that I have seen this basic design in many textbooks and articles and provides reasonable matching with a 50 ohm inductive and capacitive reactance. The cutoff frequency chosen was 11.78 MHz as this allows the use of a standard value capacitor (270pF). To wind the 0.68 uH inductor use 13 turns on a T37-2 torroid or 12 turns on a T50-2 powdered iron torroid core. You can easily use 24 - 26 AWG wire for the inductor.

IF Preamp , Crystal Filter and IF Amplifier

Except for the inductors, the IF preamp and IF amp are identical and both warrant a small clip-on heat sink as they draw reasonable current. The standing current maybe increased or reduced by changing the 47 and 75 ohm resistors connected to the Q2 and Q3 emitter respectively. Factors such as available power supply current versus dynamic range requirements may come into play. One may want to stand more current in the IF preamp and less current in the IF amp. For example, the 75 ohm resistor on the Q3 emitter could be increased considerably and/or the 5.6 ohm degeneration resistor could be increased as well if less stage current draw is wanted. The 2N3866 transistor is usually a cheaper way to go for these amps than the 2N5109, but the choice is up to you as you may have something available in your junk box. The 200 ohm -6dB pad following the IF preamp should not be omitted as it helps prevents the stage from seeing reactance's created ahead by the crystal filter. The four diodes form a 13dB limiter to protect the crystal filter should a catastrophically large signal be present in the receiver's front end. They maybe omitted. A -3dB 50 ohm resistive pad terminates the IF amp and helps establish a 50 ohm input impedance for the product detector ahead. **Click here** for more on the IF preamp.

This receiver has a narrow IF Cohn Crystal filter. Bandwidth is ~ 405 hertz, which unfortunately makes tuning quite sharp however this filter is very nice for crowded band conditions. The IF filter crystals should be closely matched in frequency to prevent unwanted ripple in the pass band. Generally, you have to buy 10 and then if you have a frequency counter, use the receiver BFO stage to test your crystals for matching. Pick the closest 4 crystals and use them in your filter. It does not matter if the crystals have series or 20 pF load capacitance, but it does matter that they are matched in frequency within 40 hertz of one another or better for this receiver. For my prototype receiver, I purchased ten 20 pF load capacitance 4 MHz crystals and luckily found 4 that matched each other within 9 hertz! For those builders who do not have a frequency counter, some QRP parts retailers sell matched sets of crystals. It is important to note that the BFO should be set on the high side of the IF frequency as simple crystal ladder filters have a steeper upper passband than lower pass band.

The crystal filter is terminated by the 4:1 transmission line transformer and then 50 ohm impedance of the IF amplifier. The -3dB pad following the IF feedback amplifier helps to terminate the crystal filter by helping ensure a 50 ohm IF amp input impedance and should not be omitted. Place a 75 and a 220 ohm resistor in series to get the required 295 ohm resistance on each leg of the pi attenuator.

Many may balk at just one stage of IF amplification, but since there is no AGC and this is a CW receiver, it works well. A feedback amp is once again used to provide correct input and output impedances for stages connected to the IF amp. Following the IF amp is another attenuator set for -3dB and then a 50 ohm diode ring mixer.

Product Detector, AF Diplexer and Audio Amplifiers

The mixer/detector can be SBL-1 or TUF-1 types or homebrew if you want to reduce costs further as the mixers are the single most expensive components in this receiver.

Again a choice of diplexers is required. The (C) AF diplexer is very simplistic but very practical if you are trying to keep costs low. The (D) diplexer is designed by W7ZOI and is from the Diplexer Web Page on this site.

Following the diplexer, a grounded base audio amp provides a 50 ohm termination to the product detector. AF gain and some AF filtering are provided by Q5 and Q6 which together attenuate frequencies less than 72 hertz and greater than 638 hertz. This amplifier pair are described on the discrete AF filters web page on this web site. Keep your leads short on all the AF transistors.

The final AF amp is the perennial LM386N, a low cost, easy to use AF amp. Turn it upside down and solder pins 2 and 4 right to your copper ground plane to anchor this part. There are a number of low-noise alternatives to the LM386 available which are generally more expensive but would be quite suitable. Discrete component AF amps can also be used, but a popcorn part such as the LM386N maybe cheaper and easier.

VFO and BFO

VFO schematic

BFO schematic

Alternate version of this receiver

Construction Ideas

When constructing any project, build in small modules and test each one separately. For instance, the AF amp should be built first and then tested by injecting a very low-level audio frequency tone into that stage and listening for output in your headphones. Every QRP workbench should have a simple AF tone oscillator from a schematic similar to the ones used for keying side tones in CW transmitters. The encased oscillator should have to a 100K or so potentiometer connected to the output to vary the output signal amplitude. Generally use maximum resistance on the 100K pot to start with and reduce this resistance slowly as the in-test amplified oscillator output could be very loud!. After testing the AF amp, build the 3rd AF preamp stage including the 10K panel mounted pot so you can vary the gain going into the AF amp. Now inject the AF oscillator output into the input on the pot and vary the 10K pot to ensure that the stage you built is working. It should be a lot louder now and should go up and down in volume with the 10K pot. Finally build the remaining preamp stage and once again test the circuit with your AF oscillator. The output into the phones should be painfully loud now when cranked up! The next stage to build would be the BFO. If you do not have a scope, peak the tuned circuit by watching the S meter on a radio receiver located nearby. Ensure that you put a load on the output winding of the BFO such as 47 ohm resistor to ground. A small piece of wire can be used as an antenna if the BFO signal is too weak to activate the S meter on your receiver. Once peaked, you can now use the BFO to match your IF crystals. To use the BFO to match your crystals, use a small wire to bypass or disconnect the 60 pF variable capacitor that is used to connect the crystal to ground. In other words, the bottom lead of the crystal is connected to ground with a short piece of wire. This makes testing your crystals a little more scientific as the variable capacitor cannot influence the crystal frequency during testing. You can also use the BFO in conjunction with a scope or voltage probe to test the various RF amps in the receiver. I do this all the time with my scope. Proceed with this build a stage, test a stage method and you should be rewarded with a functional end product.

KK4RF's version of the 40 Meter Band Popcorn Superhet

Marty, KK4RF emailed me and described his version of the popcorn superhet from this web page and contributed some great info and photos of his receiver. Of note is Marty's use of Radio Shack IC boards for mounting the components for each stage other than the VFO circuit. This is yet another variation from ugly construction that I have also used which works extremely well. Marty built the VFO using pure ugly construction and I was glad to hear that he is enjoying good frequency stability even with the lid off the VFO enclosure.

He built the receiver into an old Heathkit HW-12 single-bander case from the 1960's and it is a very attractive receiver to say the least. He found an old National Velvet Vernier Drive at the Virginia Beach Hamfest this year and used it to tune the VFO. Don't you love Hamfests! For the BFO he used an BFO circuit with a 4 mHz crystal from a different receiver project (a project that never quite worked.) He built a small power supply and located it along with the BFO under the chassis.

I like Marty's generous use of ground plane and neat stage layout. He reports good selectivity with his IF filter and apparently built four superhets that did not work before building this popcorn version. This is more a testimony to Marty's perservance to home building than to this receiver design in my opinion. I won't tell you how many rig failures I have personally incurred, as it would take a long time! Many thanks to Marty, KK4RF for the feedback and great pictures.

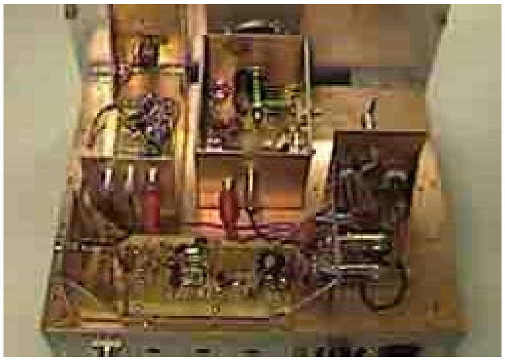
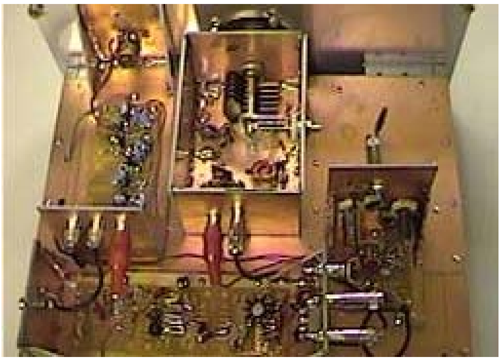

Amateur and Short Wave Radio Electronics Experimenter's Web Site

Broadband Transformers plus Diode Ring Mixers

Discussion

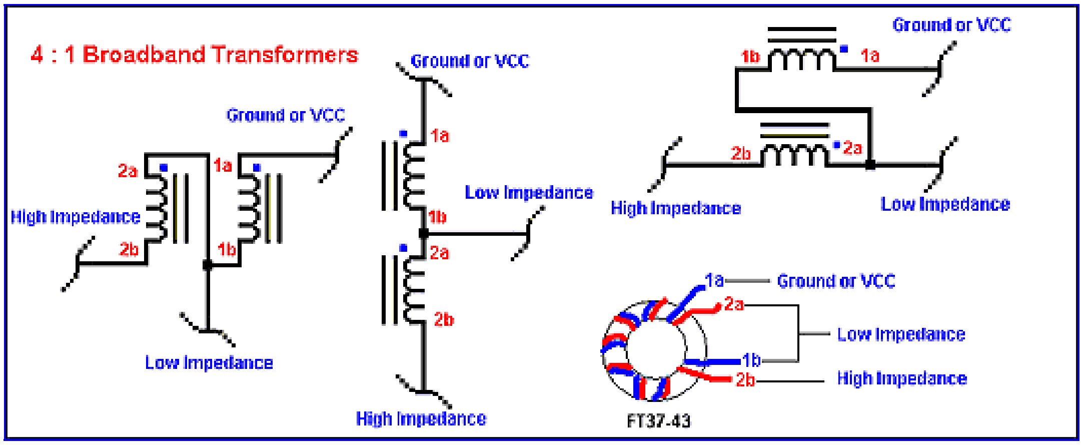

There are 2 basic types of broadband transformers used in most QRP work — conventional and transmission line style. Both types may be wound on ferrite toroids, pot cores or rods, however, I only discuss the toroidal transformers we employ to give a 4:1 impedance transformation.

I use these transmission line transformers on many projects on the QRP / SWL HomeBuilder web site. For MF and HF uses, a ferrite core permeability of 850-900 is generally required and the FT37-43 ferrite core proves suitable. Shown above are 3 equivalent schematics of the 4:1 transmission line transformer. You'll probably find that the center drawing easiest to conceptualize, however, with closer examination, all 3 schematics are the same and transform signals from unbalanced 50 Ω impedance up to 200 Ω unbalanced impedance or visa-versa.

The high impedance is 200 Ω and the low impedance is 50 Ω in all cases. It is important to know that these transformers are symmetrical and the points labeled Ground or VCC can be switched with the point labeled High Impedance. *Click on the schematic to enlarge it.*

Winding the 4:1 Transformers

Wire Twisting

Transmission line transformers are wound with bifilar (2 wires — generally twisted together). Winding these transformers is very easy. All you need are two ~18 cm (7 inch) pieces of #28 AWG enamel coated wire and an FT37-43 ferrite toroidal core.

A shop vise, a ruler, plus a brace and bit hand drill may aid your construction — I bought my brace and bit drill at a garage sale for 2 dollars. You need to twist the 2 pieces of wire together to get ~3-4 twists per cm (8-10 twists per inch) in the wire. To do this, loosely twist the wires at one end and place these twisted ends in a bench vise. Next, place the free wire ends together in your brace and bit drill chuck (no drill bit) and tighten up the chuck so that the wires are held securely.

Try to keep wire length and tension equal. Start turning your drill to twist the wires together and every once and a while measure how many twists per cm with a ruler. When you get to 3-4 twists per cm (8-10 twists per inch) you're done and then may trim the excess leads with a wire cutter in preparation for final winding and soldering.

At VHF, I often use just 3 or 4 total turns on an FT23-43 toroid with a piece of wire just a few cm long. I place the 2 wires in the vise and twist them using a pair of pliers held parallel to the wire.

Transmission line transformers will also work if the wires are untwisted. 3-4 twists per cm only serves as a non-criticial guide. Never wind your simple 4:1 transformers with bare wire.

A brace and bit hand drill plus a vise provides a good way to twist your wires.

Final Wiring and Soldering

Leaving a 2.5 cm (1 inch) lead, wind ten complete loops through the toroidal core leaving a small gap between the start and finish leads.

Untwist the leads a little so that you have 4 separate wires. One set of these wires wires will be called winding #1 and the other winding #2. You need to identify them and further break them into 1a, 1b and 2a and 2b. Generally I regard the the top two windings as (A) and the the bottom two wires (B), however, use whatever system works best for you. Strip off the enamel at the tips of all four leads and then get your ohmmeter or better yet, a beeping continuity tester.

Start on one of the top (A) wires by connecting the ohmmeter or continuity beeper to it and then touch one of the bottom wires and then the other bottom wire. Whatever bottom wire (B) shows continuity with your top wire should be marked along with the source top (A) wire with paint, liquid paper, tape, or whatever you like.

I prefer to wind 2 different colored wires if possible.

Designate the marked wire pair winding number 1. You may also want to test for a short circuit — there should be no connection between wire set 1 and wire set 2 at all. So now you have 2 wires sets, winding set 1 is marked and winding set 2 is unmarked. The top two wires are arbitrarily labeled A and the bottom two wires are labeled B . Refer to the schematic above for clarification. Connect 1b to 2a and twist them together and then solder. Your done!

It's really easy to make these things don't you think?.

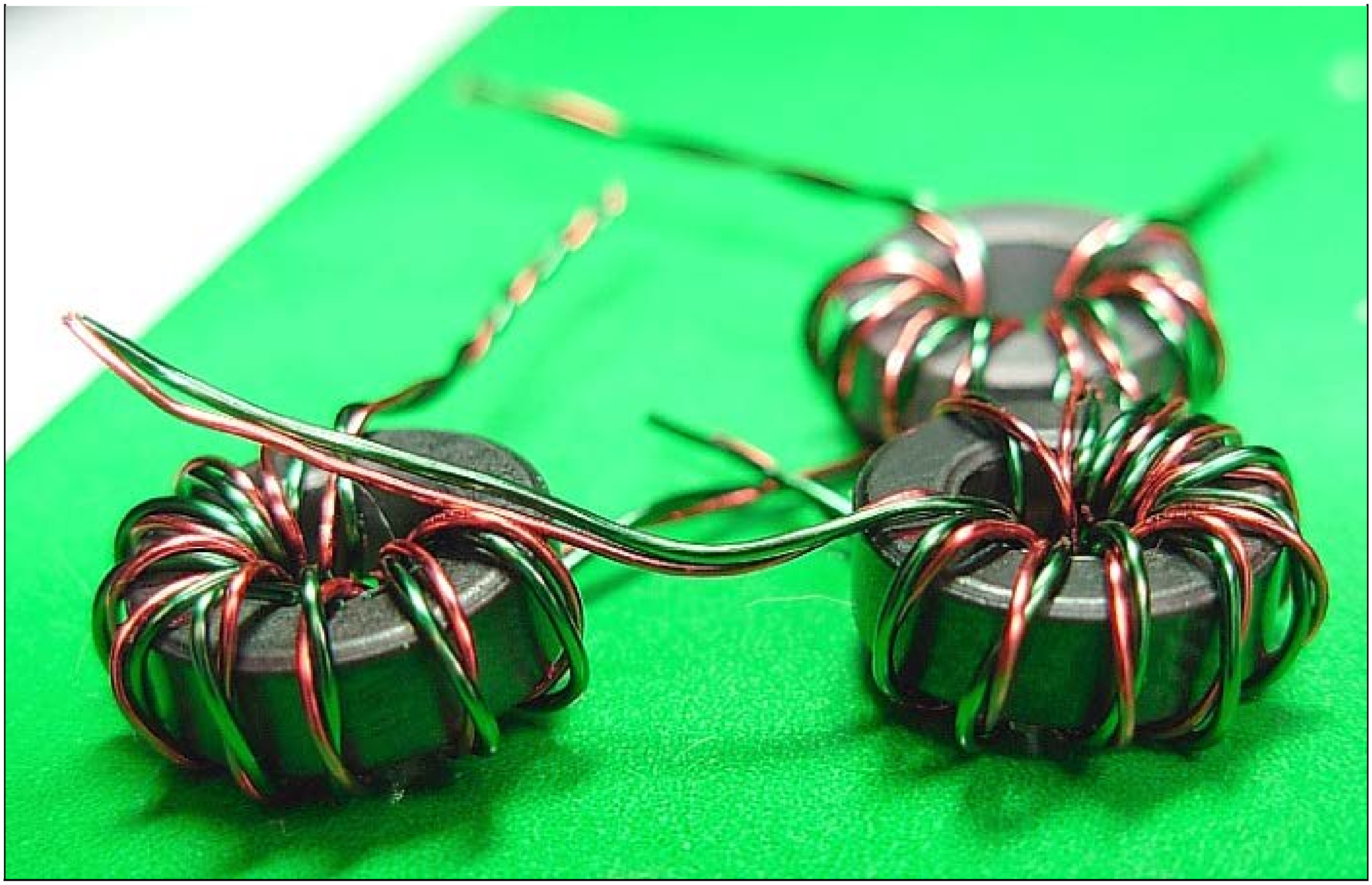

A trio of bifilar transformers wound on FT37-43 ferrite toroids. 2 colors of wire reduces errors and speeds up construction. Consider making up 5 at a time, so you have them on hand and do not have to interrupt your experiments.

Homebuilding Diode Ring Mixers

Discussion:

Easy to make, homebuilt diode ring mixers give a low-cost alternative to commercial diode ring mixers. A double-balanced diode ring mixer has 2 unbalanced to balanced transformers and a diode ring. The impedances at the three ports is 50 Ω. The transformers are wound with #28 AWG enamel coated wire on a FT37-43 ferrite toroidal core using a trifilar (3 wire) technique.

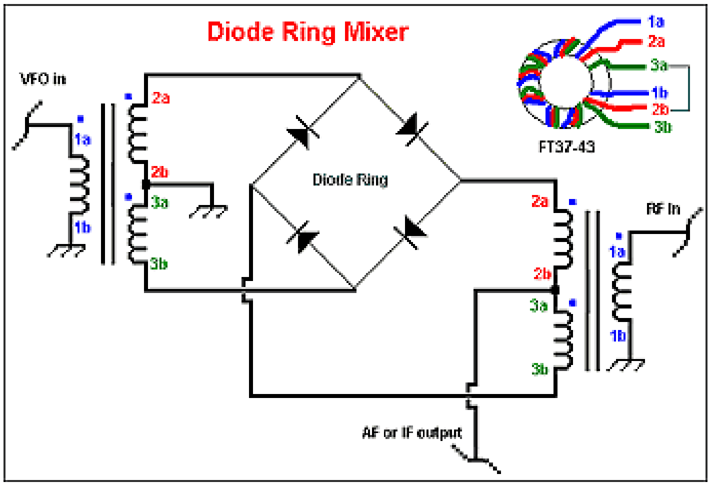
Diode Ring Mixer
VFO in
1a
1b
2a
2b
3a
3b
Diode Ring
2a
2b
3a
3b
1a
1b
RF In
AF or IF output
1a
2a
3a
1b
2b
3b
FT37-43

The wire twisting and winding technique is done as described above for the bifilar transformers. The connections 2b and 3a are twisted together and soldered. Again you will have to develop a technique to help you distinguish the wires from 1 another. *Click on the schematic to enlarge*

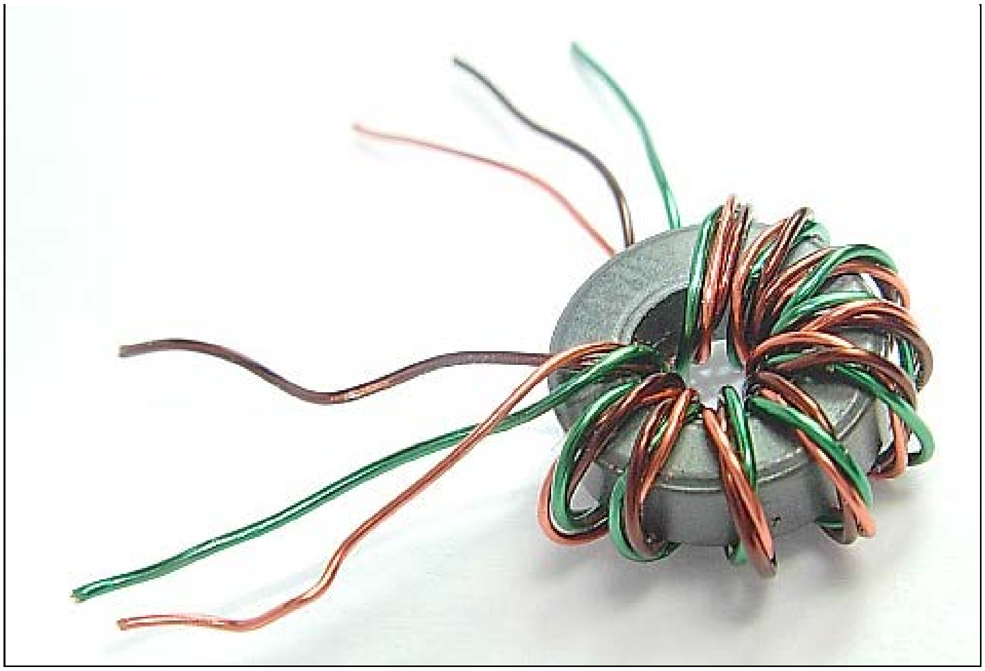

A trifilar transformer wound using 3 colors of wire on an FT37-43 toroid

#32 BELD. 1/4 LB.
20
30
28
24

A sample of the enamel coated copper wire collection I wind inductors and transformers with. In stock are wire gauges from 18 to 34. Like everything else, this collection started small and grew over time. Be vigilant for bargains and when you find a good price, purchase a whole bunch as it does not go bad. The Belden wire (orange spool ends) is over 40 years old and the enamel insulation remains perfect.

Diode Matching for Mixers

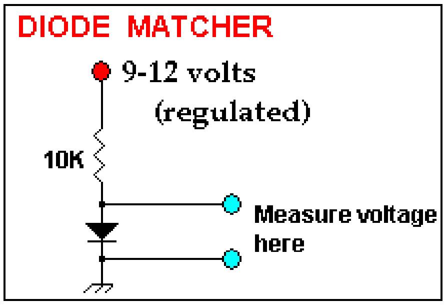

Discussion

For optimal results Schottky or Hot-Carrier diodes should be used. However, common diodes such as the 1N914, 1N4148 or 1N4454 are all quite suitable and are much cheaper. The four ring diodes should be matched to help mixer balance and thus carrier suppression. At MF and HF the most critical matching required is the forward voltage drop across the diode and this is easily performed with a sensitive voltmeter.

Set your voltmeter on the 2 volt scale to give you 3 decimal places for matching the voltage drops. Try and find 4 diodes close to one another. In addition, best results maybe obtained if all the diodes are the same type (i.e. all 1N4148) and if they are all from the same manufacturer. Look above for easy schematic to match your diodes with a voltmeter. Give the diode under test at least 20 seconds to warm up and stabilize before taking your voltage measurement.

RF — Test and Measurement

Diplexers Topics

Introduction

My original web page on diplexers was rather incomplete and received some criticism from electronic engineers albeit the focus of this web site is "popcorn" designs. Wes Hayward, W7ZOI provided me some excellent schematics, analysis and simulations for diplexers which terminate doubly balanced mixers and these are presented below. After this section, the W1JR Bridge-Tee RF Diplexer from the original QRP HomeBuilder diplexer web page is presented along with new commentary and simulations by W7ZOI.

The final section presents a practical diplexer for terminating a product detector. All graphical images labeled as Figures 1-24 are copyright and property of W7ZOI and may not be presented elsewhere. Updated September 23, 2000.

W7ZOI Diplexer Notes

The usual amplifier is a two-port circuit. That is, it has an input port consisting of two terminals and an output consisting of two more. One terminal (ground) can be shared between the ports. Many filters are also two-port networks, including most of the ladders networks we use so often. Many other networks have three or even more ports. A common example is a mixer, which has three ports. Another example of a three port network is a diplexer. This linear network is usually designed around two port filters where one end of two different filters are paralleled to form an input port. This is illustrated as Figure 1. The purpose of a diplexer is usually to force a frequency constant impedance to occur at the input port, even though we usually only use one of the two output ports for signals. The simplest form of diplexer uses a pair of 1 element filters, a low pass and a high pass. This is shown in Figure 2.

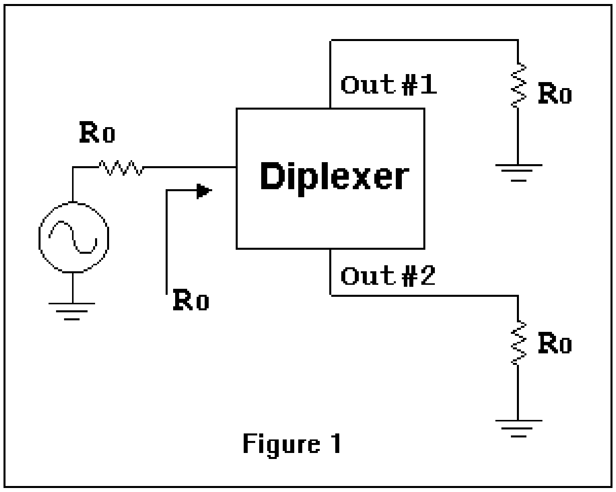

Figure 1

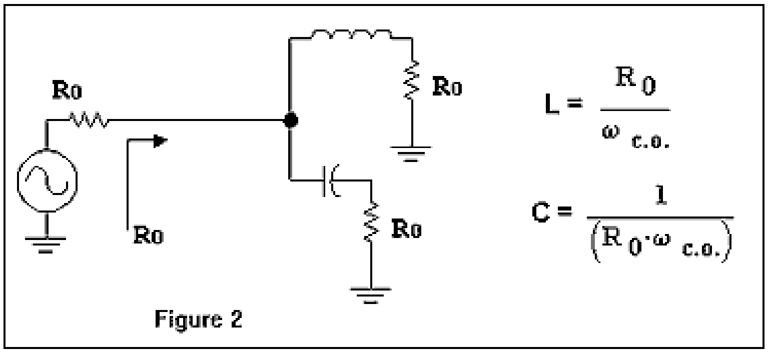

Figure 2

Where the equations give the L and C that provide a perfect match. The angular frequency is called the cross-over. A familiar example is the cross over used in audio systems. The network that splits signals is a diplexer. Here is an example where both outputs are used. Another form of diplexer is the band pass/band-stop combination. This is shown in Figure 3:

Let's now consider further some examples, some that work and some that don't work as well. First, let's look at an audio diplexer that follows a product detector in a DC receiver. The load of interest is the first audio stage, which has a 50 Ohm input resistance. The diplexer offered is Figure 4. Note that this is not the combination of filters. It just looks like a low pass with an extra resistor. The response of this circuit is shown in Figure 5. The transmitted signal never gets up to the desired 1 volt in the low pass passband while the impedance match, represented by reflection coefficient, never gets down to the desired zero. The response is just that of a lossy low pass filter.

In 2012; Click on many of the diplexer images to see the original sized version

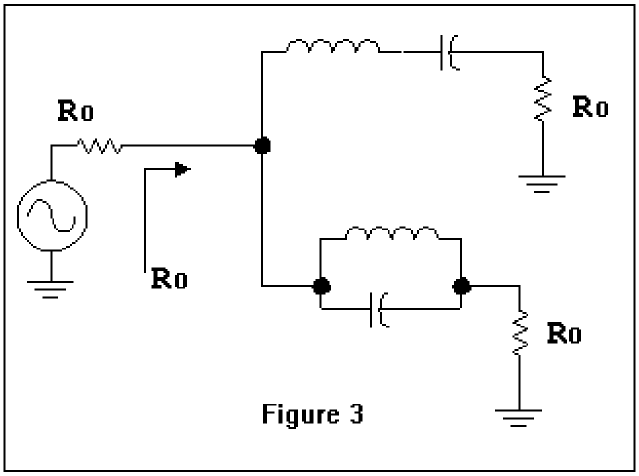

Figure 3

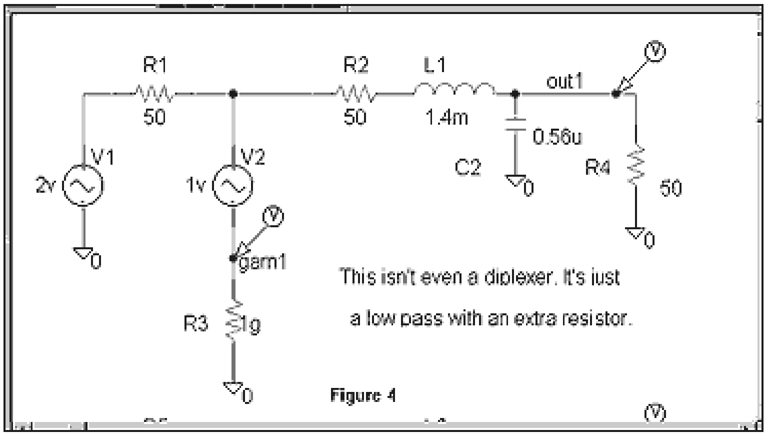
R1
50
R2
50
L1
1.4m
out1
0.56u
C2
R4
50
V1
2v
V2
1v
gam1
R3
1g
0
This isn't even a diplexer. It's just
a low pass with an extra resistor.

Figure 4

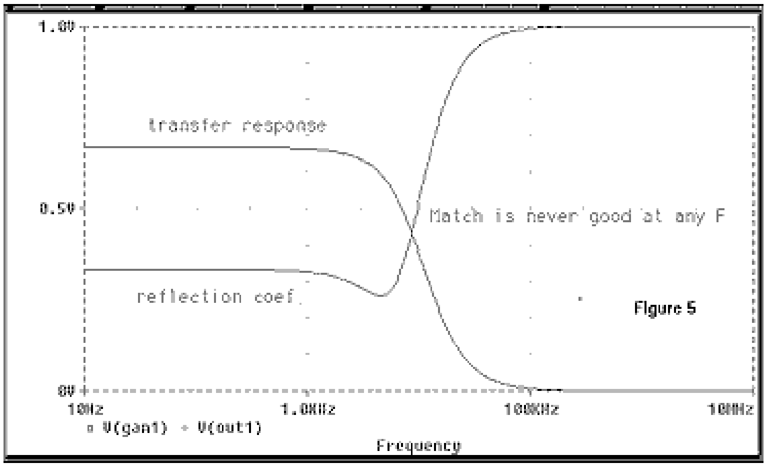

Figure 5

The normal filter circuit without the extra resistor is Figure 6. The corresponding output response is shown in Figure 7. Note that the transmitted signal is now up at 1 while the reflection is down to zero, both within the passband. Transmission goes to zero while reflection is 1 in the stopband.

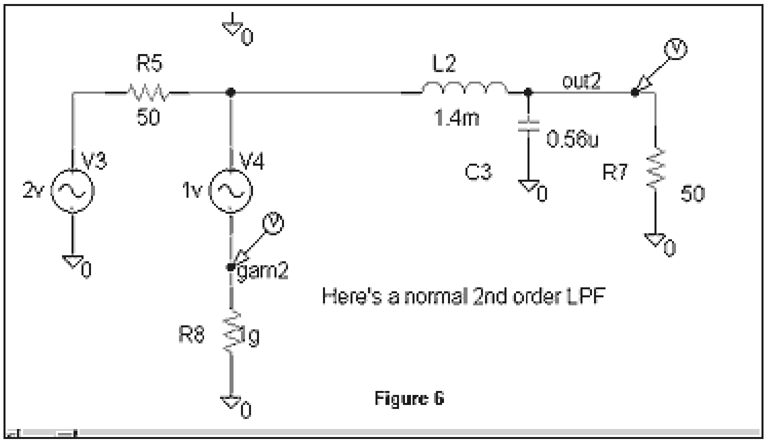
R5
50
L2
1.4m
out2
0.56u
C3
R7
50
V3
2v
V4
1v
gam2
R8
1g
0
Here's a normal 2nd order LPF

Figure 6

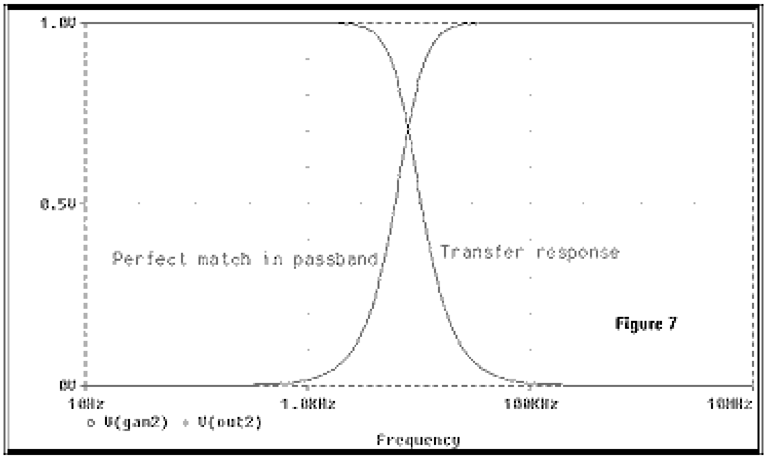

Figure 7

Now let's use the low pass and put a high pass with it to try to form a diplexer. This is shown in Figure 8 where we now have just guessed at component values. The response, shown in Figure 9, has high pass and low pass outputs that we might expect. The match is good at the frequency extremes, but is only so-so in the transition band.

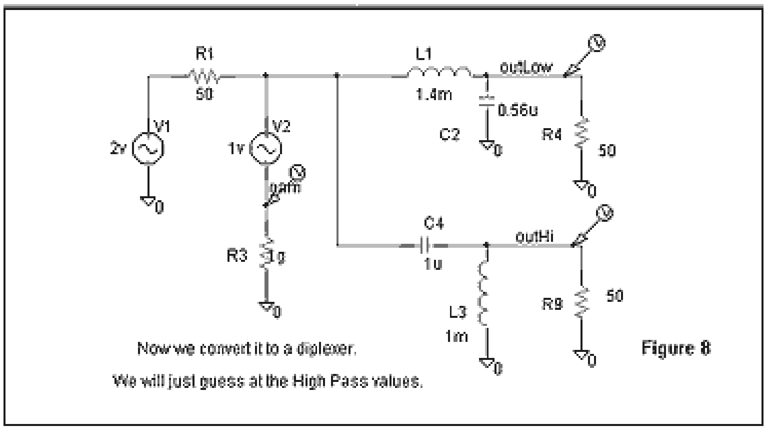
R1
50
V1
2v
V2
1v
gam
R3
1g
L1
1.4m
outLow
C2
0.56u
R4
50
C4
1u
outHi
L3
1m
R9
50
0
Now we convert it to a diplexer.
We will just guess at the High Pass values.
Figure 8

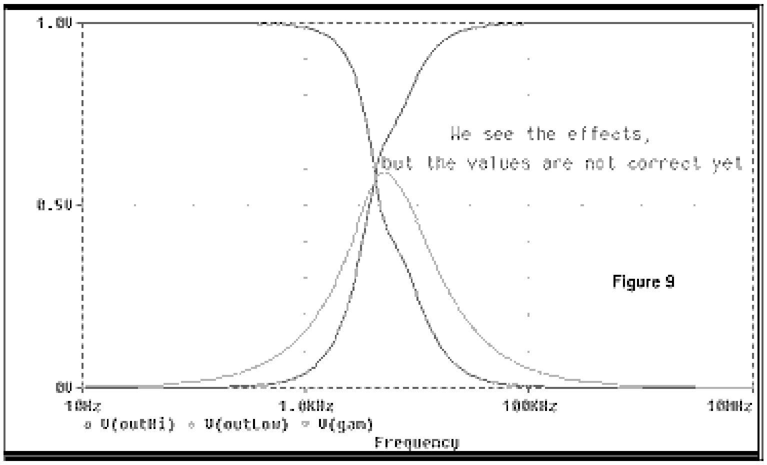

Let's now look at a carefully designed pair of two element filters. The circuit is Figure 10 an is a final example. The corresponding response is Figure 11. It is hard to see, for the response merges in with the baseline. However, the reflection is zero and it is zero everywhere. This filter was designed for a 1 kHz crossover, so it can be scaled to other frequencies with ease.

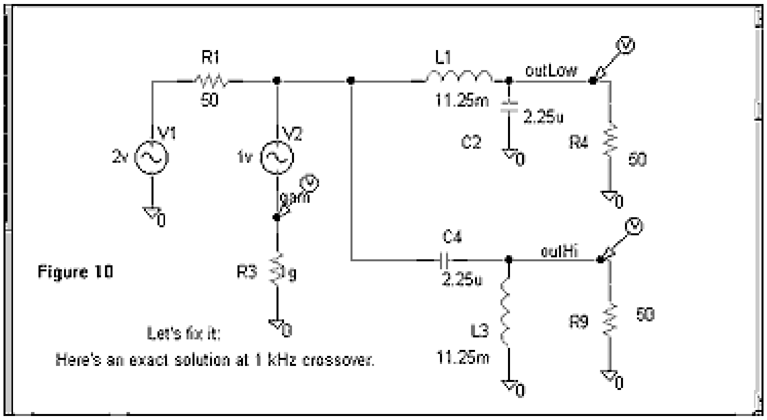
R1
50
V1
2v
V2
1v
gam
R3
1g
L1
11.25m
outLow
C2
2.25u
R4
50
C4
2.25u
outHi
L3
11.25m
R9
50
0
Figure 10
Let's fix it:
Here's an exact solution at 1 kHz crossover.

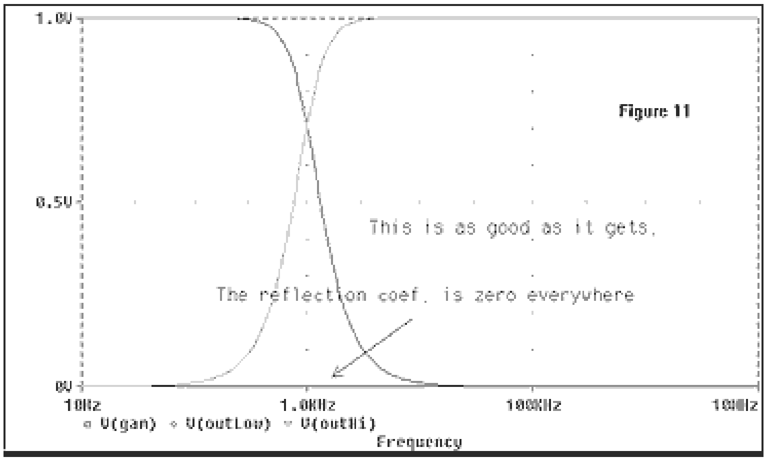

Figure 12 is another final audio example. This circuit is very similar to the one used in the past by Roy Lewallen, W7EL, although the inductor was smaller at 100 uH in his Optimized rig. The response of this diplexer is shown in Figure 13. This is not perfect, but it is probably quite a good performer in typical receiver situations.

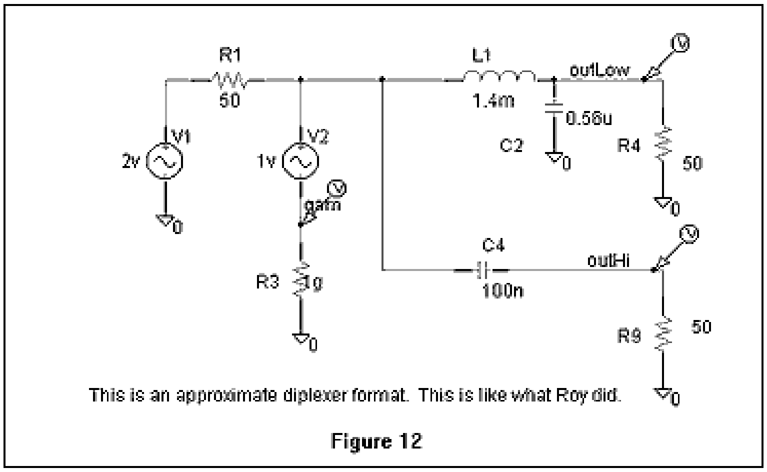
R1
50
V1
2v
V2
1v
gam
R3
1g
L1
1.4m
outLow
C2
0.56u
R4
50
C4
100n
outHi
R9
50
0
This is an approximate diplexer format. This is like what Roy did.
Figure 12

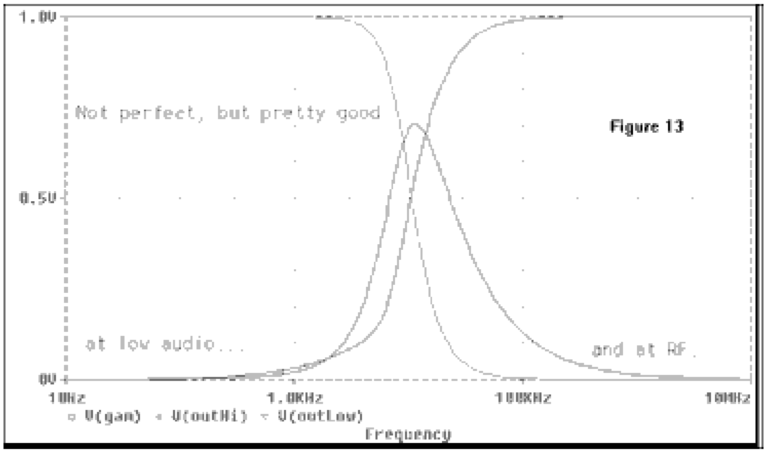

Finally, here's a higher frequency example. 5th order low pass and high pass filters are combined. The filters have a cross over at about 150 MHz. Note that there is a slight reflection in the transition band. This is probably just the result of our having rounded some values in the design process. Figures 14 and 15. An outstanding reference on this is Nic Hamilton, G4TXG, "Improving Direct Conversion Receiver Design," Radio

Communications, April 1991.

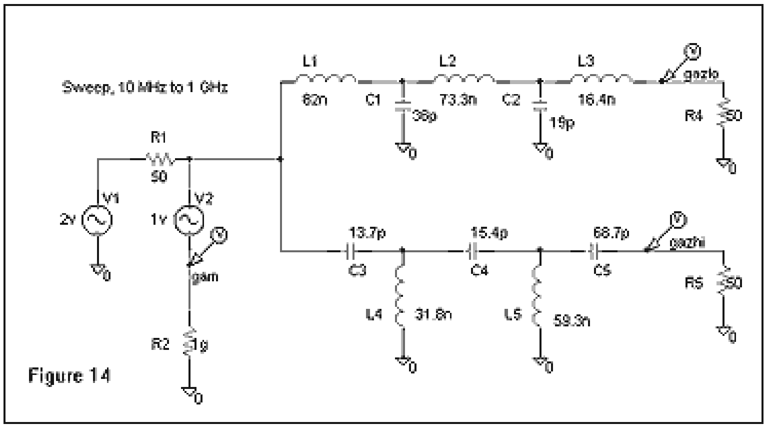
Figure 14

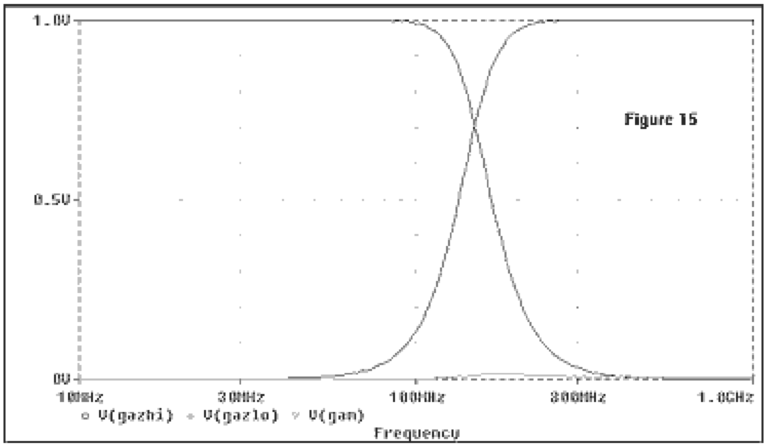
Figure 15

Bridge-Tee RF Diplexer

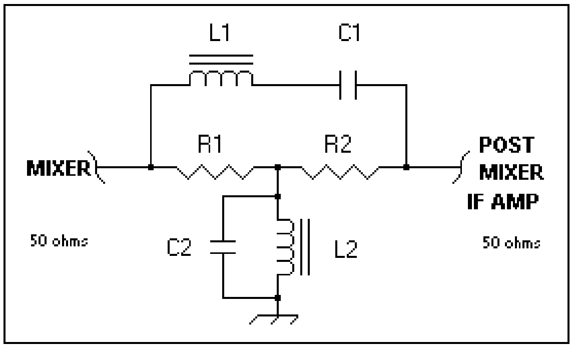

This is an excellent bandstop/bandpass diplexer popularized by Joe Reisert W1JR. This easy to build diplexer has a low parts count and is easily built using Ugly Construction. Resistors R1 and R2 present a 50 ohm impedance to the mixer output and a 50 ohm impedance to the input of the post mixer amplifier. The IF frequency is passed through the diplexer while out of passband RF is given a low impedance path to ground. The capacitance for C1 is generally built up by substituting the nearest standard value capacitor or by placing 2 or more capacitors in parallel with each other to achieve the desired value. The same procedure is then repeated for the C2 capacitance. For more strenuous purposes, a portion of C1 and C2 or the inductors L1 and L2 can be variable and adjusted on the bench. The inductors can easily wound on powdered-iron toroid cores. I have used T50-2 or T50-6 type toroids with good results. The Q of the inductors is 1.

It is possible to design a more generalized form of this diplexer with a higher loaded Q in the resonators. The diplexer shown and used in the program has a Q of 1. This was used by W1JR in his VHF/UHF World Column in the now defunct HAM Radio Magazine for March and November 1984. It was also more recently used by Jacob Makhinson, N6NWP in his A High-Dynamic Range MF/HF Receiver Front End in QST for February 1993. The actual formulae for this diplexer is far more complex than the simplified formula shown below or used in the program, but both provide a very good approximation for the Q = 1 version as used by W1JR and N6NWP. If you wanted Q=10, the series tuned circuit would use L that is 10 times as high with C to resonate. The parallel tuned circuit would then use C that was 10 times higher with L to resonate.

A supplemental web page with some hard-core mathematics for this diplexer can be found on the Diplexer Supplemental Page.

Simplified Formulae (Q = 1):

R1 and R2 are always 51 ohm resistors.
Inductors L1 and L2 -> 50 / (6.283 * frequency in Megahertz)
Capacitors C1 and C2 -> 1 / (6.283 * 50 * frequency in Hertz)

Example 1: For a 9 Mhz IF , L1 and L2 = 0.88 microhenrys and C1 and C2 = 350 picofarads
Example 2: For a 4.92 MHz IF , L1 and L2 = 1.62 microhenries and C1 and C2 = 647 picofarads

I wrote a simple program to do the math for the Q = 1 version. Download the Bridge-Tee RF Diplexer Diplexer Program

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Comments and analysis by W7ZOI

This is a double ended version of the first order bandpass/bandstop design presented earlier. But it's a good one, within the constraints of what it can do. The first is the simulation schematic for the diplexer, which is better termed a Bridge-Tee Diplexer. (There are bridge Tee filters and attenuators too.) That figure is entitled Figure 16.

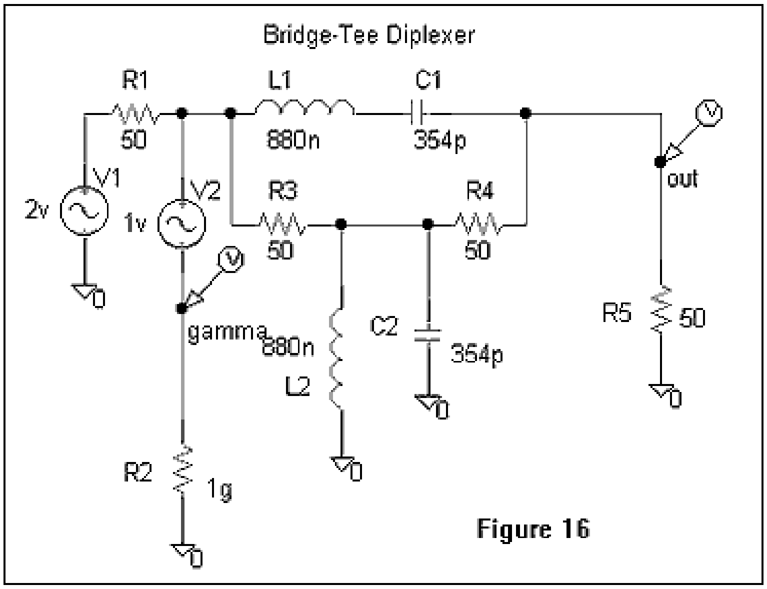
Bridge-Tee Diplexer
R1
50
L1
880n
C1
354p
V1
2v
V2
1v
R3
50
R4
50
out
gamma
880n
L2
C2
354p
R5
50
R2
1g
0

Figure 16

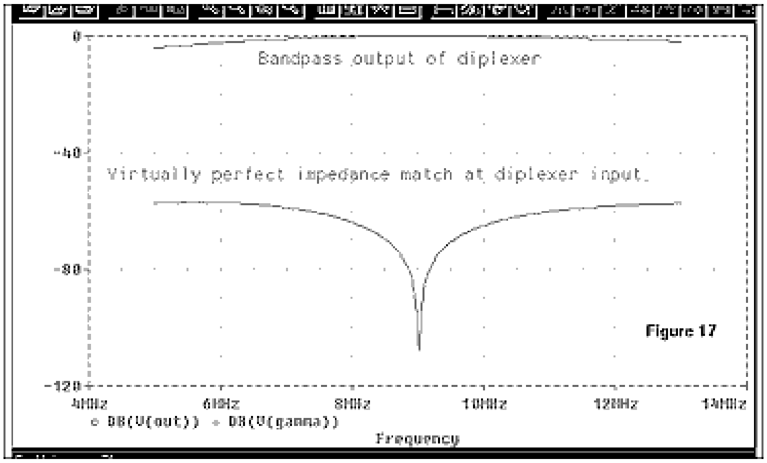

Figure 17

The response for this circuit is shown in Figure 17. This is extremely good. The through response is very flat owing to the low Q of the series tuned circuit. But even better is the match. It is very good. Indeed, it would have been perfect except for slight roundoff errors that occurred as we designed the networks.

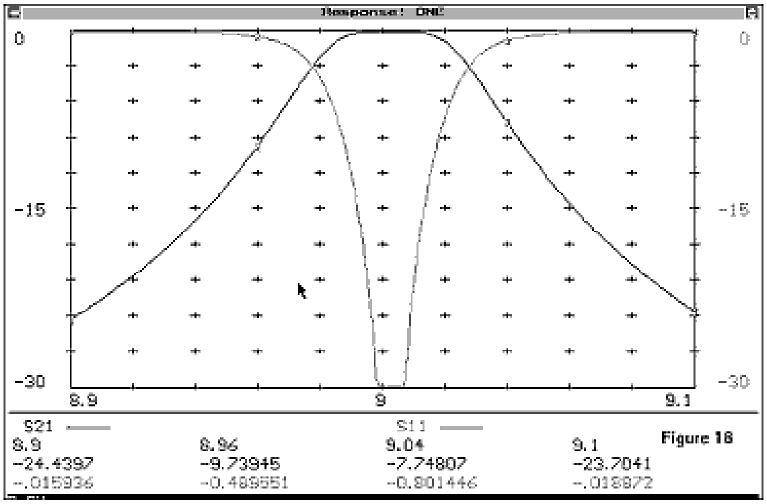

```
S21 ——              S11 ——
8.9        8.96        9.04        9.1
-24.4397   -9.73945    -7.74807    -23.7041
-.015936   -0.489551   -0.801446   -.018872
```

Figure 18

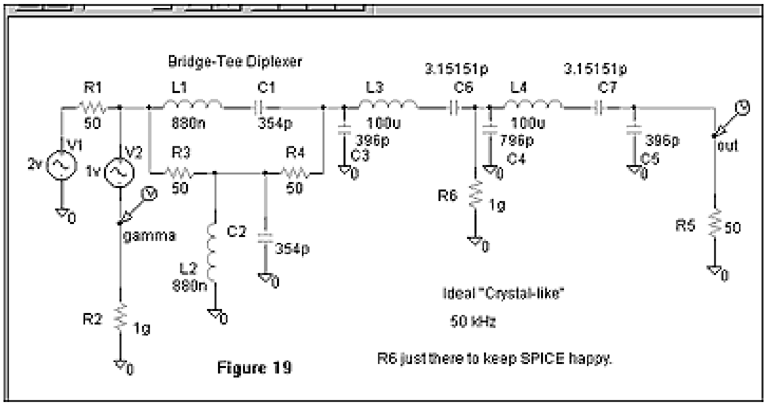
Bridge-Tee Diplexer
R1
50
L1
880n
C1
354p
L3
100u
3.15151p
C6
L4
100u
3.15151p
C7
396p
C3
796p
C4
396p
C5
2v
V1
1v
V2
R3
50
R4
50
out
R6
1g
gamma
C2
354p
L2
880n
R5
50
R2
1g
Ideal "Crystal-like"
50 kHz
R6 just there to keep SPICE happy.
0

Figure 19

This kind of thing works fine if you really have a perfect match following the diplexer. But what if you don't. There are some places where they do not do the job that some folks think they will do. For example, a diplexer WILL NOT cause the impedance to be flat if it is followed by a filter. The diplexer must still be properly terminated at both output ports. In Todd's usual applications, he is worried about providing a good mixer termination for a product detector. The audio amp that he uses will usually have a common base first stage and that will present a good wideband load to the diplexer, so he is okay. But other folks have placed a diplexer after a switching mode mixer that then drives a narrow filter. The diplexer then does little good. To illustrate this situation, I designed a "crystal like" two pole LC bandpass filter with a 50 kHz bandwidth. This represents the general case where we try to put a diplexer between a mixer and a filter. The filter response by itself is shown in Figure 18. The schematic for the diplexer and following filter is in Figure 19.

The response for the combination is in Figure 20. Here we see a passband response that is fine; it's just the repeat of the filter response we already saw. However, the input impedance looking into the diplexer, the impedance that would be seen by a mixer, is terrible. The return loss is 0 dB at all frequencies except where we get within the passband of the filter.

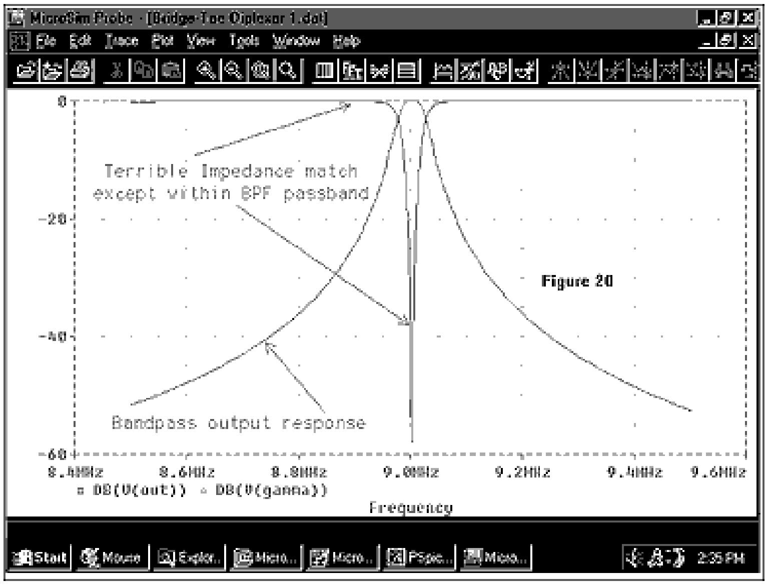
MicroSim Probe - [Bridge-Tee Diplexer 1.dat]
File Edit Trace Plot View Tools Window Help
Terrible Impedance match
except within BPF passband
Bandpass output response
0
-20
-40
-60
8.4MHz
8.6MHz
8.8MHz
9.0MHz
9.2MHz
9.4MHz
9.6MHz
DB(V(out)) DB(V(gamma))
Frequency
Start
Mouse
Explor...
Micro...
Micro...
PSpic...
Micro...
2:35 PM

Figure 20

Practical Diplexer for Popcorn Receivers

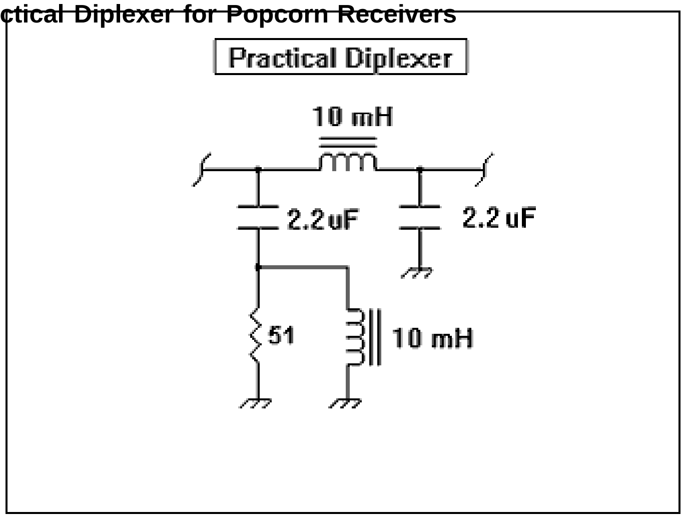
Practical Diplexer
10 mH
2.2 uF
2.2 uF
51
10 mH

Building a diplexer to follow a product detector is not a cheap endeavor. Audio inductors and capacitors such as metalized polyester film types are not common in many builder's junk boxes. I really like the design shown in Figure 10 and wished to use it because it uses just 2 inductors and capacitors which is in keeping with the popcorn nature of this website. The main difficulty is that the inductors and capacitors are not standard value types and series connecting components to achieve the desired values would add to both the cost and size of the finished product.

Obviously, it will not likely match from DC to daylight. That is not the intention of this simple design or this web site in general. I asked Wes to place just 2 standard value capacitors and inductors in the Figure 10 diplexer design and see what happens.

Here was his response to my request:
OK, here are some "practical values." Note that things don't really change that much. We start with 11.x mH and 2.25 uF. Change the inductor to 10 mH and get Figure 21. Then change the cap to 2.2 uF and see almost no change in Figure 22.

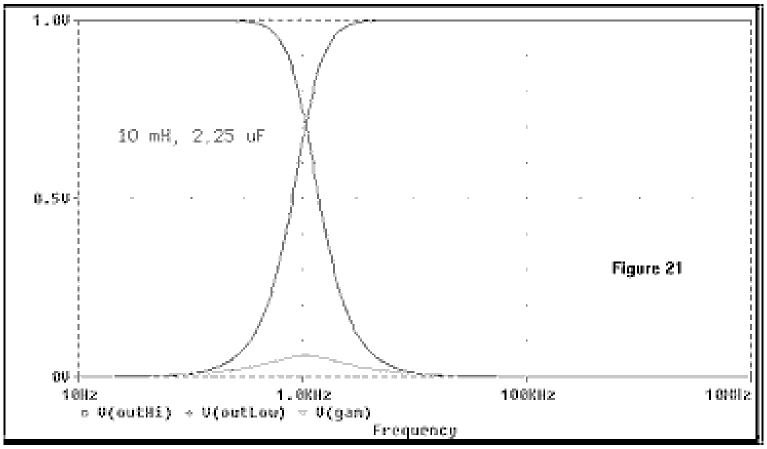

Figure 21

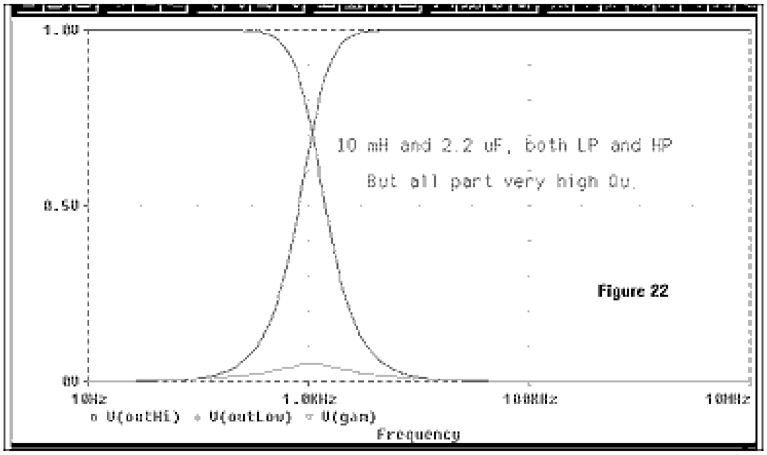

Figure 22

But now move into the world of even greater reality and acknowledge that many of the inductors we use at audio are very low Q. Change Qu of L to 10 at 1 kHz, so I put 6.3 Ohms in series with each L to get Figure 23. And do the same thing, but with a dB scale, for Figure 24. Note that we can see the difficulties, but things are still pretty good. We see some loss (about 1 dB) in the low pass path and less than perfect match. But the match is still very good. 20 dB is about 1.1:1 vswr, much better than 99.9% of the hams can really measure. (A 10 dB match is about 2:1.) Hope this is what you were after....Wes

It was and I will use this "practical" diplexer in my next popcorn DC receiver project. Note that the practical diplexer input and output impedance is 50 ohms and the 2.2 uF caps should not be polarized capacitors such as regular electrolytic types which have a positive and negative polarity.

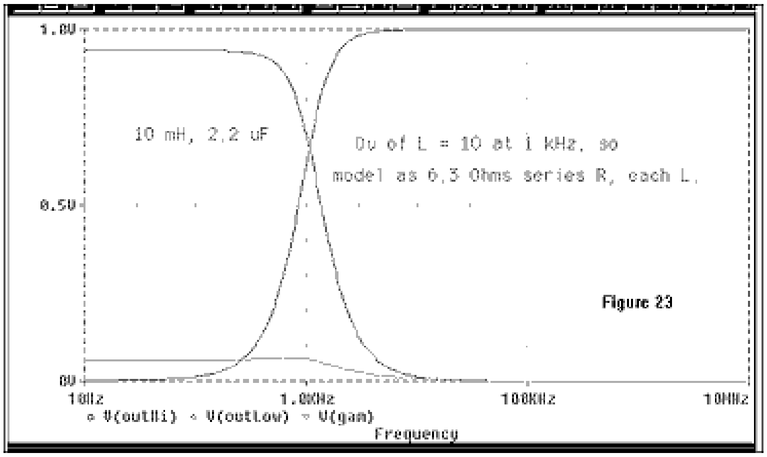

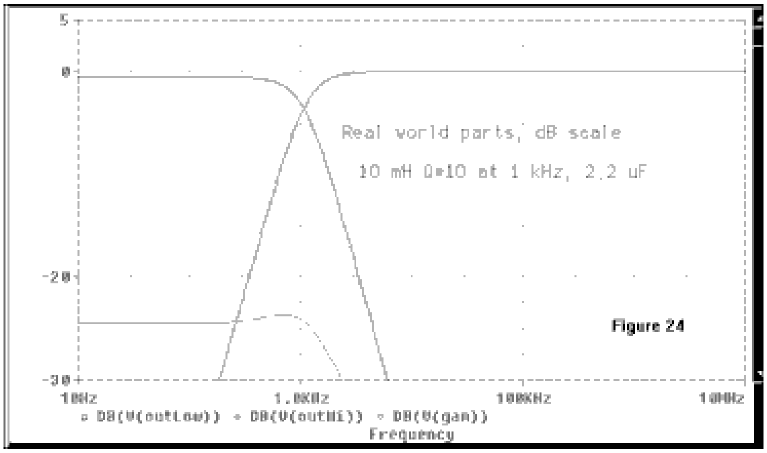

Many thanks to Wes Hayward, W7ZOI for his work on this page.
A version of this web page in Russian Cyrillic

Ugly Construction

Discussion

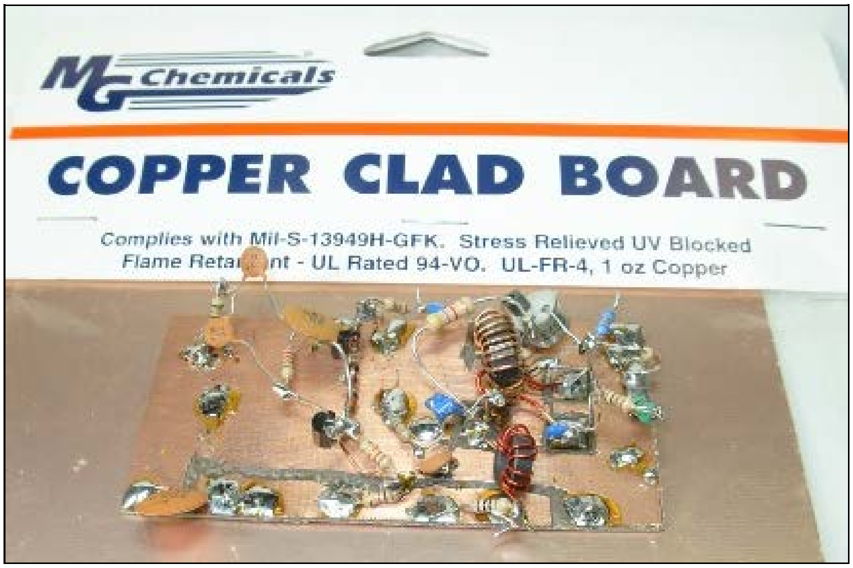
MG Chemicals
COPPER CLAD BOARD
Complies with Mil-S-13949H-GFK. Stress Relieved UV Blocked
Flame Retardant - UL Rated 94-VO. UL-FR-4, 1 oz Copper

We enjoy many ways to build electronic circuits. For example, you might breadboard on a perforated circuit board, an etched PC board, a sheet of copper clad board, or even a piece of copper wire. In the hay day of tube electronics, builders used terminal strips and point-to-point wiring within the project chassis. I mostly breadboard using Ugly Construction.

Ugly Construction, "dead bug", or "ground-plane construction" involves building circuits on top of a double or single-sided copper clad board (copper side up for single-sided board). The copper ground-plane provides a low impedance ground and mechanically supports the parts soldered to it. Component leads requiring grounding are soldered *directly* to the copper surface, while the ungrounded leads of these parts anchor any ungrounded parts connected to them. Isolated sections called stand-offs hold other ungrounded or remotely located parts.

Example stand-offs include high value resistors (10 Megohm or greater), terminal strips, or small copper islands glued onto or cut into the copper ground-plane. Parts such as transistors, IC's or commercial diode ring mixers are generally flipped upside down and anchored by their grounded lead(s). Metal encased parts such as crystals can be grounded by a short wire or directly soldered upside down to the copper board.

DC voltage wires, or decoupling resistors may be supported by soldering 1 lead of a bypass capacitor to the ground plane while the other lead holds the DC voltage carrying part up off the copper board a short distance. I mostly use grounded caps for stand-offs and not 10M resistors.

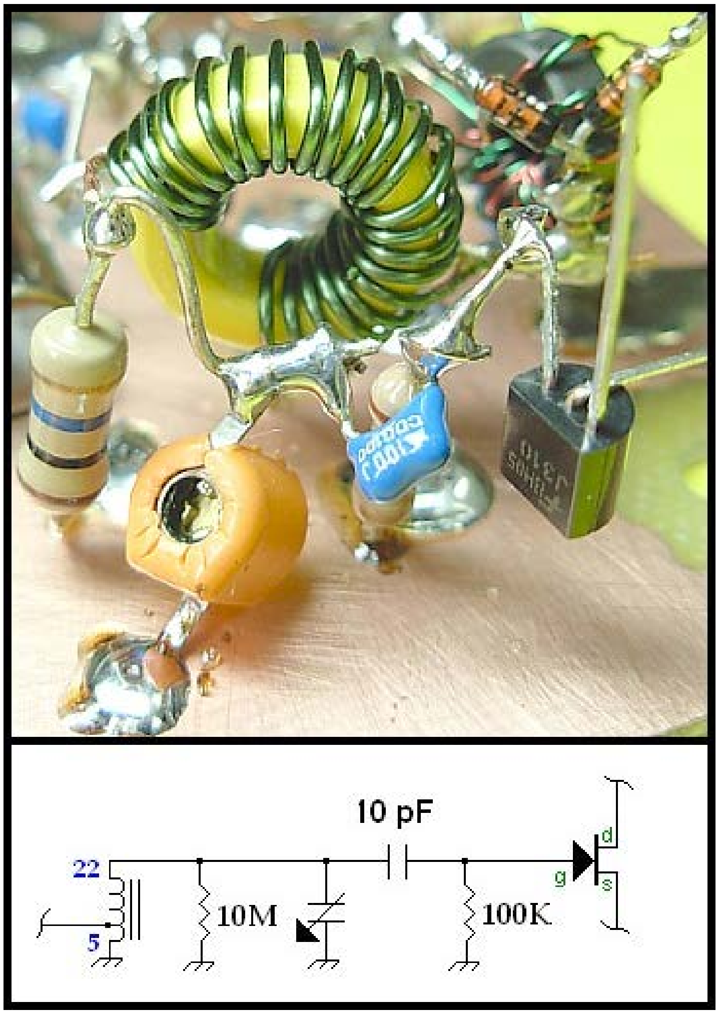

Shown above — a 10 Megohm, half-watt, stand-off resistor anchors the "hot" inductor terminal plus supports the ungrounded trimmer capacitor terminal. The coil's 24 gauge wire provides additional mechanical stability. The signal loss from adding the 10M resistor was about 0.1 volts peak to peak in 1 experiment.

Ugly Construction allows the experimenter total control over the design of a project and in my opinion, its greatest strength is *speed*. Ugly Construction yields rapid and flexible bread boarding — very appealing for prodigious home builders.

The Origin of the Term "Ugly Construction"

Roger Hayward, KA7EXM and Wes Hayward, W7ZOI coined the term "Ugly Construction" while writing the "Ugly Weekender" published in the August 1981 issue of QST. I asked Wes about this in 2009. The term was a takeoff from the 1958 book entitled The Ugly American by William Lederer and Eugene Burdick.

A big part of the learning of the QST article was Ugly Construction! The term and the bread boarding technique emphasized the fact that there is no correlation between the "prettiness" of a construction project and the way it works. According to Wes, the goal had a couple of corollaries. "First, people like myself who do NOT have the knack for doing pretty projects can still build successful radios. Second, is that we all need to look at our projects after the fact to discover what it is that really makes them work well. In the case of the Ugly Weekender, the thing that makes it fly is that there is a wonderful ground plane with that PC board material".

Indeed, this transceiver functions very well; especially after you temperature compensate the VFO. Wes also built versions for the 30 and 80 meter bands. I have versions on 15, 40 and 80 meters. The transmitter portion is a true QRP classic; both as a Ham radio transmitter and because it promoted "ugly" ground-plane or dead bug bread boarding techniques to the scratch homebrew community.

Classic Ugly Construction

This term emerged in Spring 2010 and describes the archetype popularized by Roger and Wes Hayward. All ungrounded leads not anchored to other parts are attached to the copper ground-plane via high ohm resistors — *no* glued pads or islands cut in the copper board.

In-situ comparisons of a 10 megohm resistor versus islands cut into the ground plane and glued-on Manhattan-style pads demonstrated that the resistor had the lowest capacitance; around 1 pF versus 4 pF or greater for the pads or islands. Click for a high resolution transmitter chain built with 100% Classic Ugly Construction. Click for a crystal oscillator.

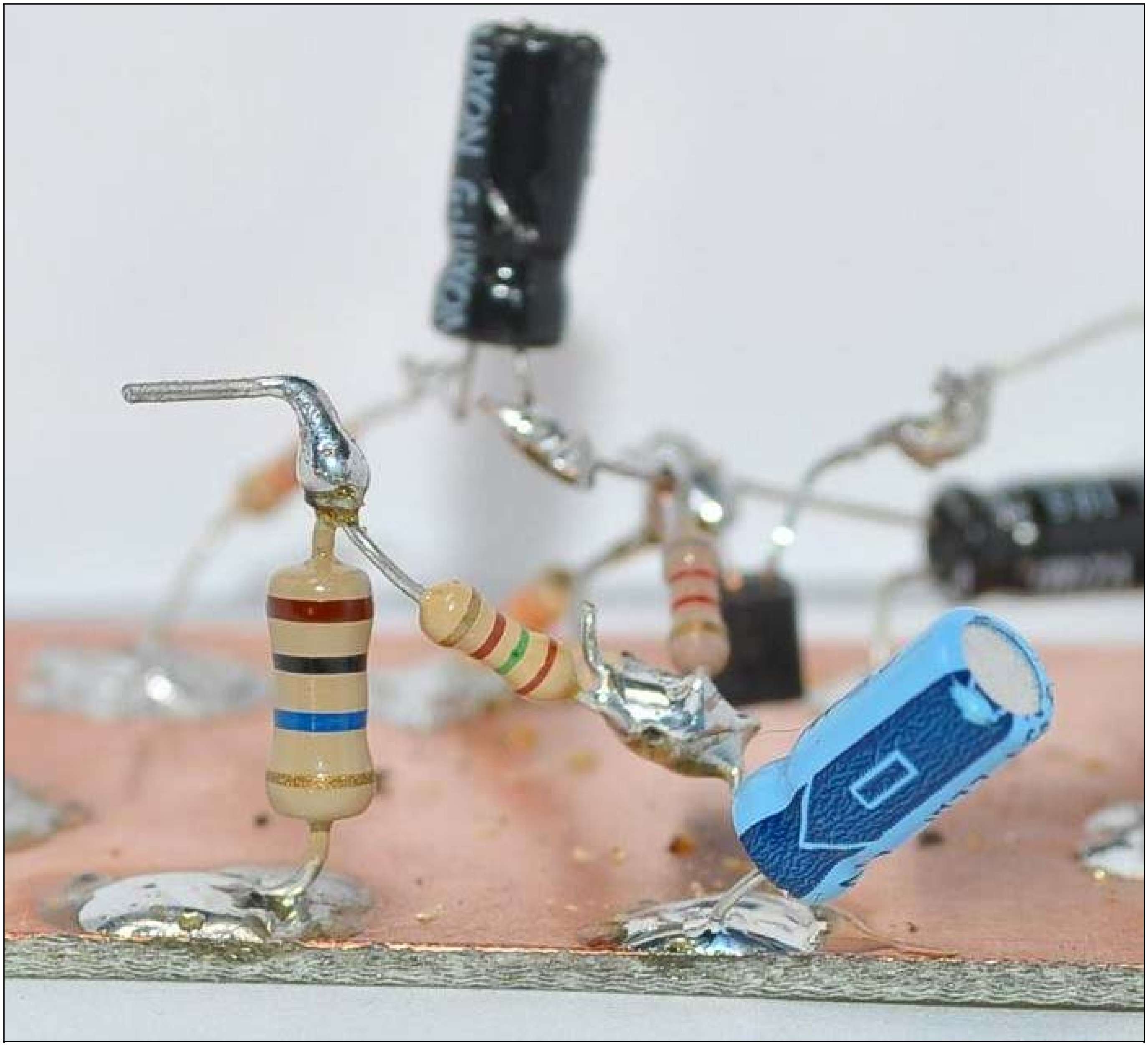

Above — *Classic* Ugly Construction using a high ohm stand-off resistor. The top of the 10 megohm resistor is the VCC connection point. It feeds a 150 ohm / 47 uF decoupling network connected to a transistor collector resistor. Bypass capacitors also serve as stand-offs and I prefer thick lead (100 volt or greater) caps for stand-off duty.

EAR
VOL
JUNKBOX RECEIVER
UGLY QRP TRANSMITTER
KA7EXM
VFO
TUNE
KEY
SPOT

Above — The original Ugly Weekender. Photograph used by permission of Roger, KA7EXM.

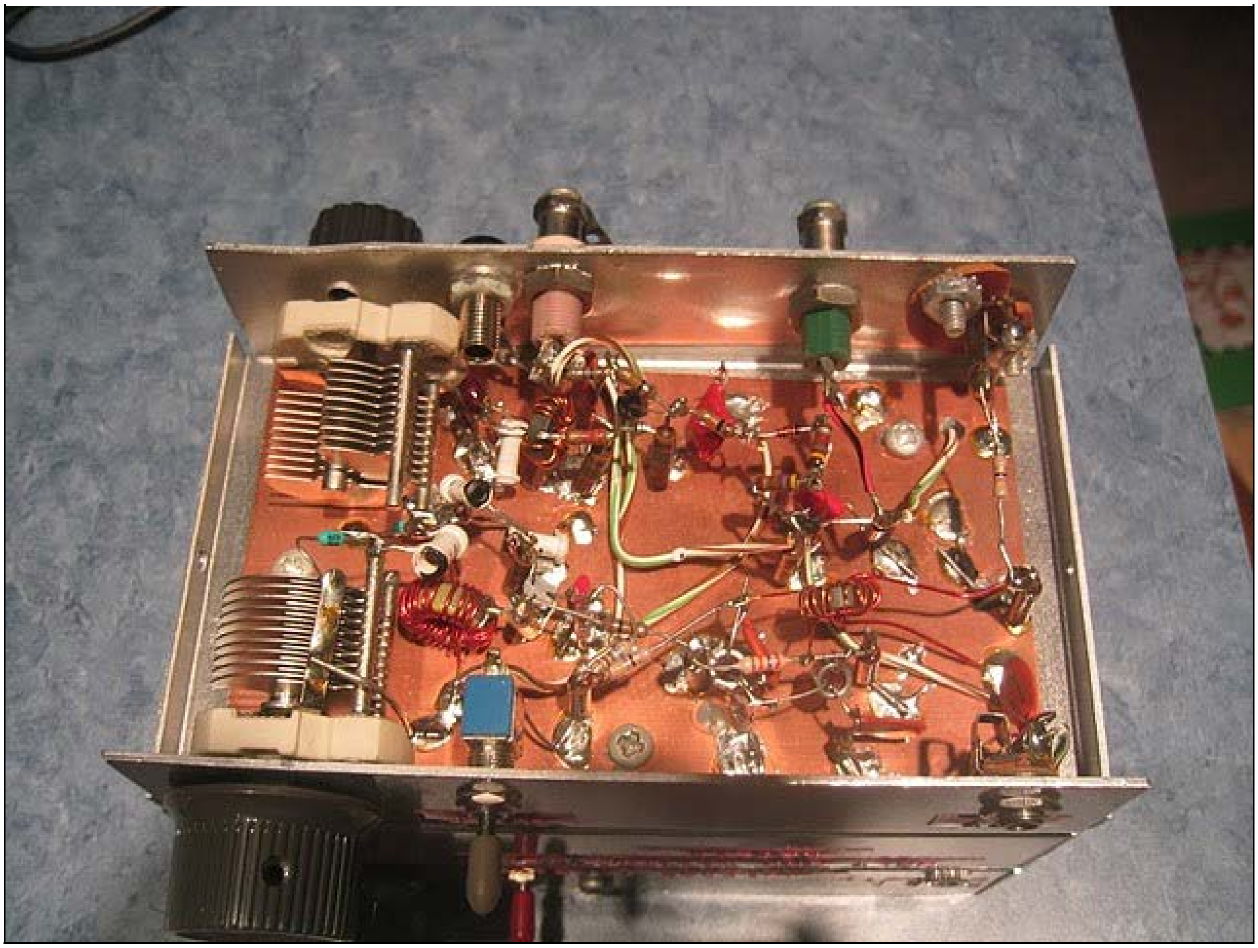

Above — The original Ugly Weekender. Now this is *Classic* Ugly Construction. Please refrain from building this transceiver and adding modern notions such as a PIC microcontroller keyer — that's just wrong!

Photograph used by permission of Roger, KA7EXM.

Ugly Construction Variants

The most popular Ugly Construction variant is called Manhattan style. Manhattan or "paddy board" construction uses small square or round pads cut or stamped from PC board that are glued copper side up onto a large copper clad board also placed copper side up. The small pads or "islands" serve to anchor ungrounded components. Components soldered to the pads such as transistors or ICs are generally not positioned upside down like in Classic Ugly Construction. Many Manhattan style builders use IC sockets as well. These hobbyists sometimes build beautiful looking layouts — Manhattan is a wonderful bread boarding technique. Google for more information. The best Manhattan construction and copper board chassis bashing I've seen comes from Dave, AA7EE. Click for a blog describing his version of the WBR regenerative receiver. *Linked with the permission of Dave, AA7EE.*

Another interesting variant is used by Dick Pattinson, VE7GC. The circuit board is placed copper side up and holes are drilled and countersunk so that the holes are isolated from the ground plane. Ungrounded components are connected underneath the main board through the countersunk holes. There are many such variations. Each Ugly Construction variant has advantages and disadvantages.

On this website, stand-offs are created by cutting a few lines into the copper board with a small, motorized hobbyist cutting tool; with high megohm value resistors, and occasionally by a small Manhattan style pad or 2. Manhattan pads are great for supporting components needing solid anchoring such as a trimmer capacitor or potentiometer.

Classic Ugly Construction dominates circuits breadboarded after May 2010.

The motor tool may also be used to grind off the copper underneath where VFO toroidal inductors will lie, so that the inductor Q is not effected by the being glued onto a copper surface. In audio projects, I may also grind off the copper around the copper board mounting bolts so that they are isolated from the chassis and do not provide multiple grounds and create the potential for ground loops.

Is Ugly Construction Less Reproducible than Manhattan?

I've received well over 1000 emails about Ugly Construction since launching the site in 1998. Some feel that circuits made with Manhattan pads are more reproducible than Classic Ugly Construction builds. This might be true, but to my knowledge nobody has performed a comparison trial.

The important question is why would this happen? I've read/heard opinions that the stray L and C from the long component leads associated with Ugly Construction might wreck circuit reproducibility, but respectfully disagree from DC to HF. In microwave breadboards, we fabricate lumped element inductors and capacitors (*i.e. precisely dimensioned Manhattan pads*) right into the PC board — Manhattan pads glued all around a breadboard may potentially exhibit much more stray L and C than a few component leads in an Ugly build. Also, wise Ugly builders keep their lead lengths short where it counts: for example, RF bypass + ground and at the input/output of a BJT or FET that offers gain into UHF.

I conjecture human error probably inflicts more problems for Ugly Construction builders — Manhattan building, with its slower pace might trigger less mistakes by newbies. Still, too, Manhattan builders tend to make prettier, squared and aligned circuits and it's easier to spot trouble — plus they look nicer in photographs and some builders carefully document and photograph their builds for others to admire and strictly copy. I've see Manhattan build photos where every resistor tolerance band pointed in the same direction — wow! I think it might be difficult to put such a 'work of art' into an RF-tight metal box for much-sought isolation.

Further, in Ugly Construction — upside down parts might wreak havoc on the "spatially challenged" builder. Who knows? I'm comforted knowing that kit sellers who provide a screened printed circuit board with explicit instructions, still must provide major email support to mitigate build errors. To err in an ugly fashion is human?

Whatever variant of construction you choose, it's sure to be a winner!

Further Discussion

Wire

Non-stranded (solid core) copper wire such as the 22 AWG 3-color package sold by Radio Shack seems a good choice for hook up wire. With non-stranded wire, you do not have to worry about little stay wire hairs causing shorts and it's easier to wrap around components leads. I use red for wires that carry positive voltage, green for grounding and black for wires that carry AC signals short distances. In addition, RG-174 or shielded wire is used to carry AC signals for distances greater than 10 cm, and for connecting stages requiring 50 ohm input or output impedances such as diode ring mixers or low-pass filters.

2781306
NEXXTECH
Hook Up Wire
22 Gauge Solid

Your Health

Please consider the following safety comments:

For regular soldering, ensure ventilation of your room — flux fumes can be harmful. Open your shop window and/or use a small fan to improve fresh air intake;

Whenever possible, perform high wattage soldering outdoors;

When grinding paths on copper clad boards, wear a small particulate respirator, gloves, plus ear and eye protection and most importantly; **do it outside** for yours and your family's health;

Wash your hands after soldering and handling freshly cut, fiberglass dust laden copper clad boards.

Soldering Irons

For soldering copper clad boards together, AC grounds on tube guitar amp chassis and performing antenna work, I currently use a Weller SP 80L (80 watt) soldering iron. It is heavy and unwieldy, so you have to be very careful when its plugged in. These high wattage soldering irons produce lots of smoke.

Weller
SP 80L

Shown above is an 80 watt "heat torch". My main soldering irons are typically in the 30-35 watt range. Consider keeping at least 1 back up soldering iron, as you never know when a soldering iron is going to burn up. My current 35 watt iron is shown below. These Weller irons have a built in lamp which lights when they are plugged in; a very nice feature. I also keep a small stock of new soldering iron tips.

Weller
SP23L

Copper Clad Board

Some builders ask about sources for copper clad board. I personally use boards made by MG Chemicals as they have dealers in my city and are reasonably priced and good quality. Try the search words **copper clad board** plus **your country name** in your favorite web search engine. A few links follow, but as I have only used boards sold locally, I can't comment about the online companies.

MG Chemicals Worldwide distributer index

Electronic Goldmine Online store

Circuit Specialists Online store

Miscellaneous

Shown below is a schematic and the Ugly Constructed version of it.

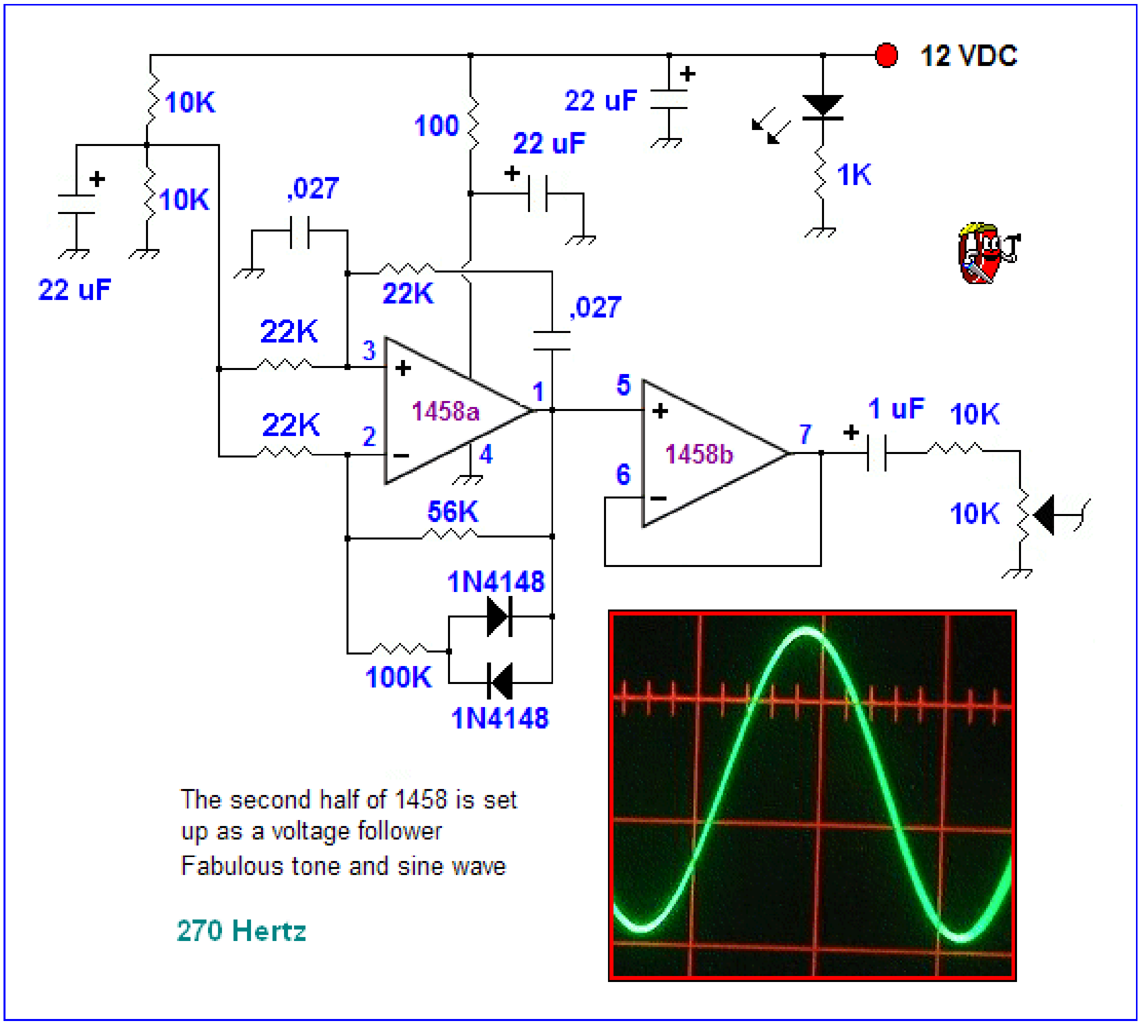
12 VDC
10K
100
22 uF
22 uF
1K
10K
,027
22 uF
22K
,027
22K
3
+
1458a
1
22K
2
−
4
56K
5
+
1458b
7
6
−
1 uF
10K
+
10K
1N4148
100K
1N4148
The second half of 1458 is set
up as a voltage follower
Fabulous tone and sine wave
270 Hertz

Above. The schematic of an adapted sine wave audio frequency oscillator taken with permission from EMRFD , Figure 12.4. EMRFD is the main reference for this web site. The original schematic author was Wes, W7ZOI

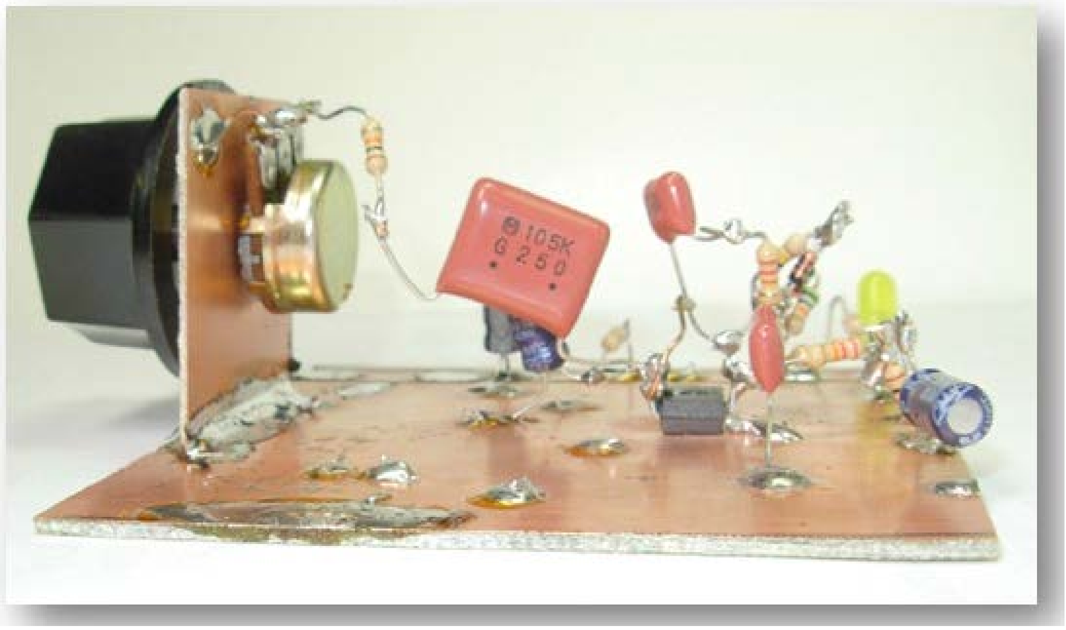

Above. I built this circuit from start to scope in about 25 minutes. This was a scrap, pre-used board with a positive voltage path and a potentiometer holder already on it When miniaturization is not your goal, construction is much easier and faster. I re-use parts and boards to save money. You may remove entire stages from 1 board and solder them onto another.

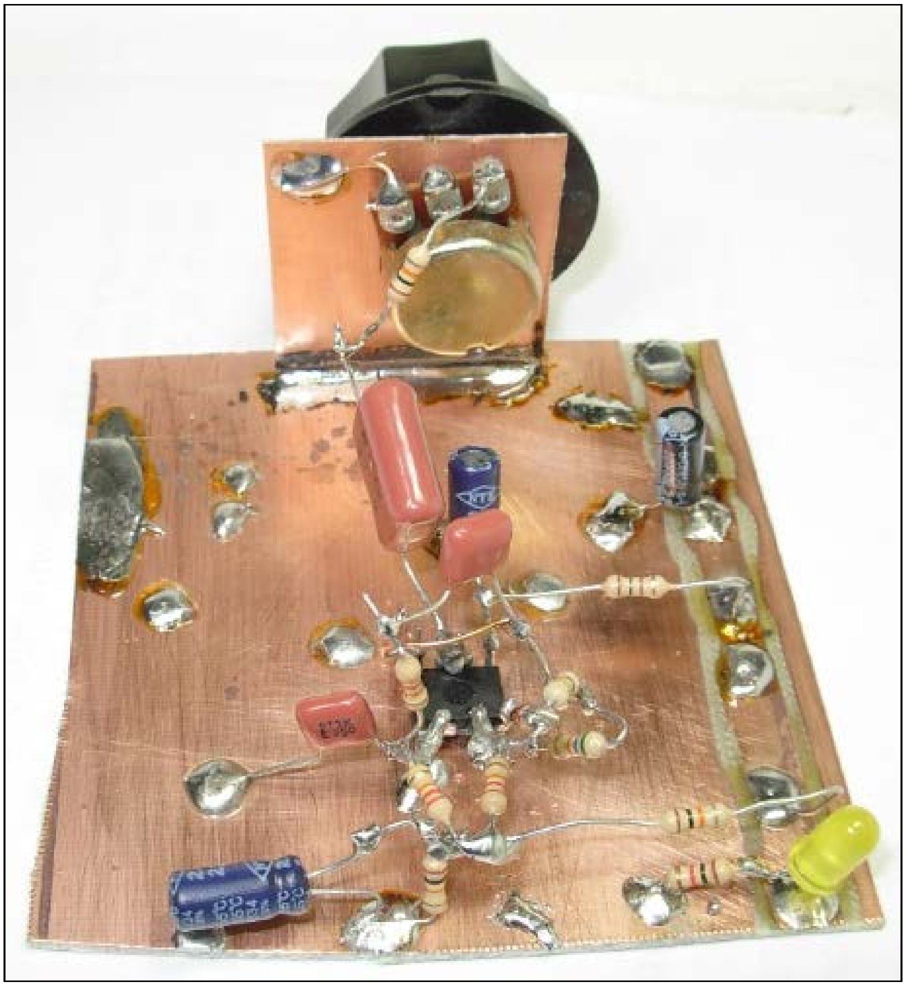

Above. Note how the 10K output potentiometer holder is soldered to the main copper clad board. The grounded 10K resistor is used to anchor the 22K resistors connected to IC pins 2 and 3 and can be seen in the foreground.

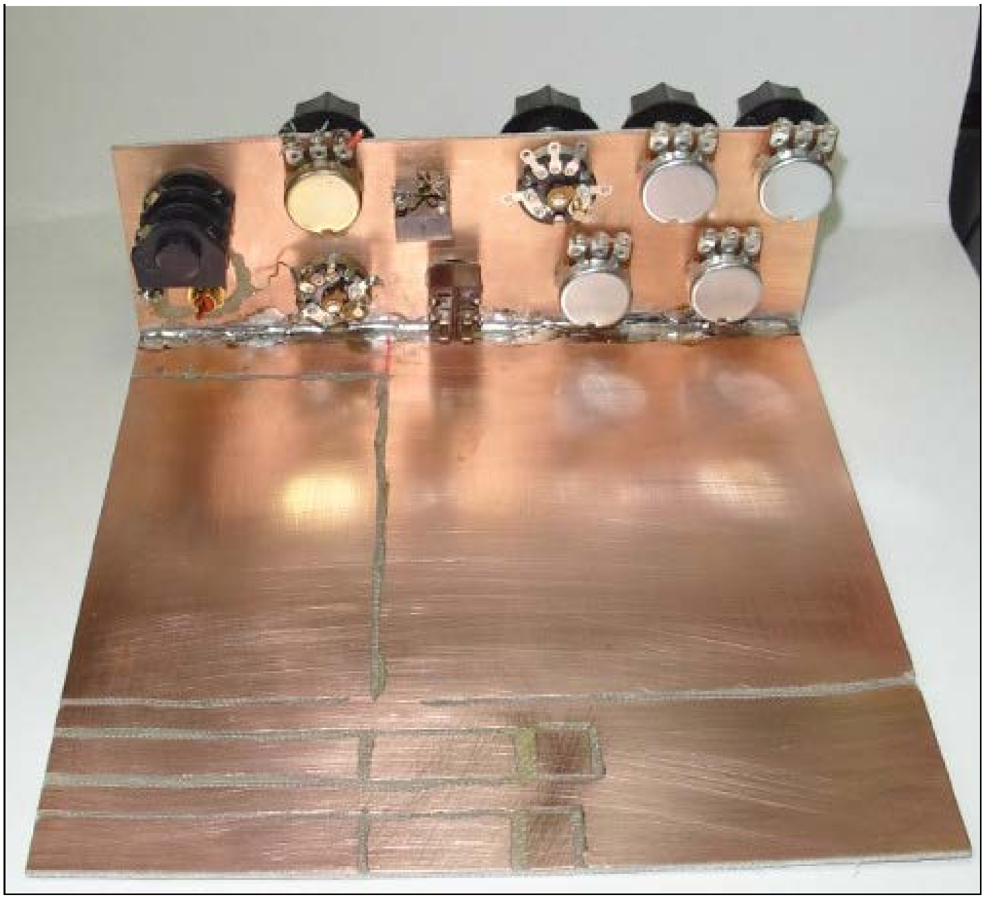

Shown above is another project. Entire control panels can be built from copper clad board for prototype circuits. In this board are numerous cut paths, 7 potentiometers, 3 jacks and a switch. Do not build an LC VFO over double sided copper clad board; lest it become "a capacitor" and affect your frequency stability.

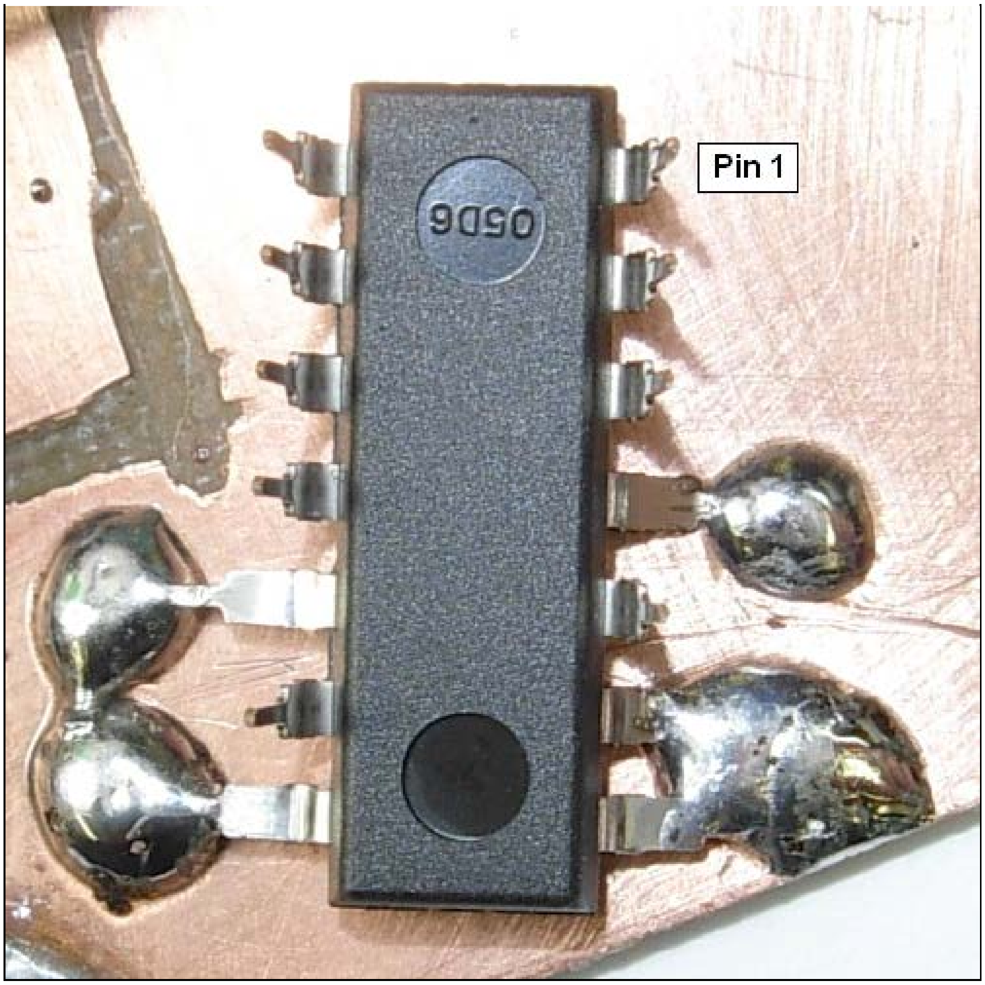

Shown above is a CD4013B D Flip-Flop soldered "dead bug" style. Pins 4, 6,7, 8 and 10 are grounded to the copper surface; well anchoring this part. Using proper static precautions, I have never had a CMOS device failure using Ugly Construction and also save the price of an IC socket.

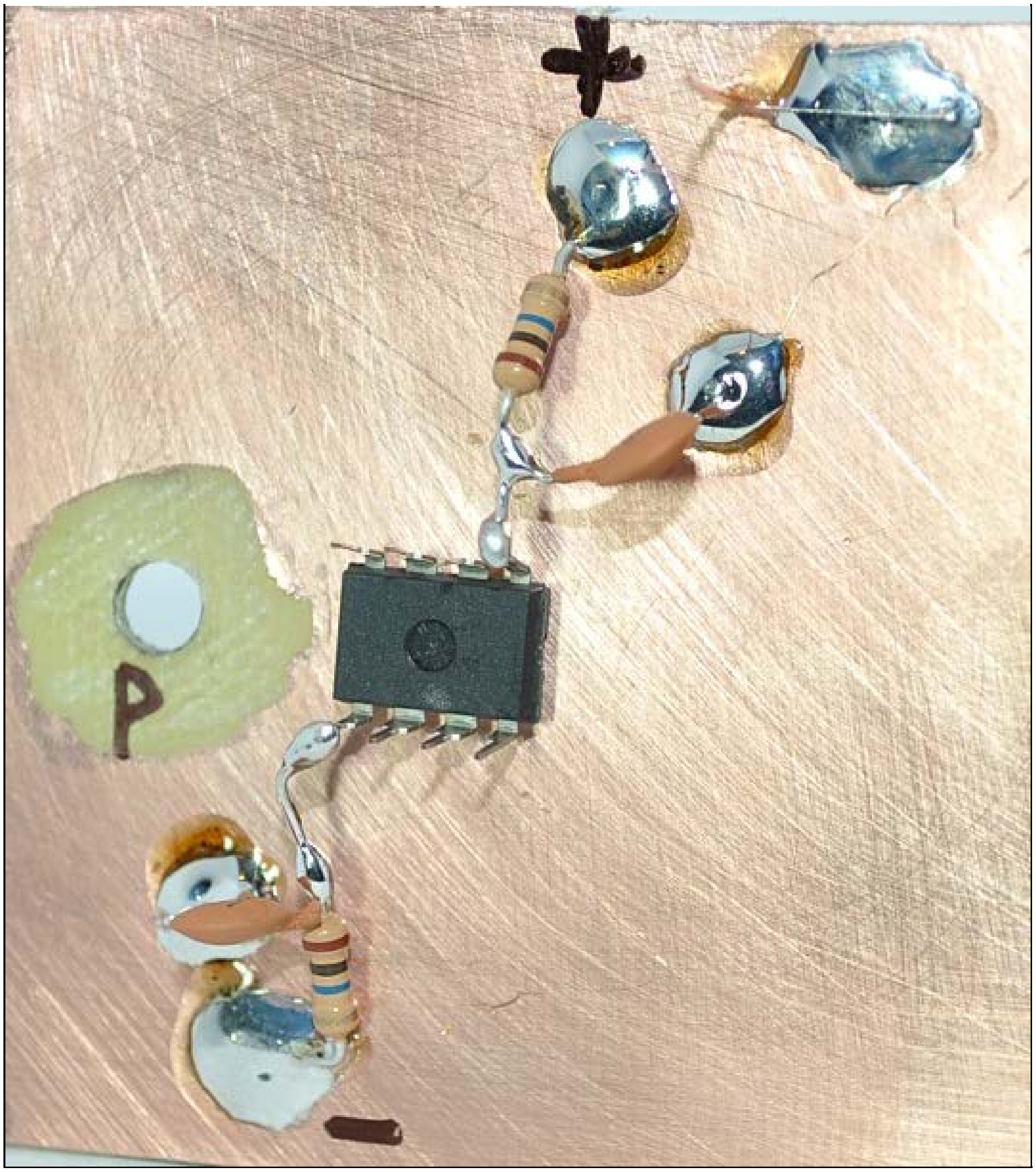

Above — a method to anchor op-amps using a split (negative and positive) power supply. Pins 4 and 8 are soldered to the copper board via a 10 megohm resistor. A 0.1 uF ceramic bypass capacitor is also connected to these pins. The resistor leads were left a little long to allow easy connection of the power supply wires. I write each pin's polarity on the board to avoid wiring mistakes.

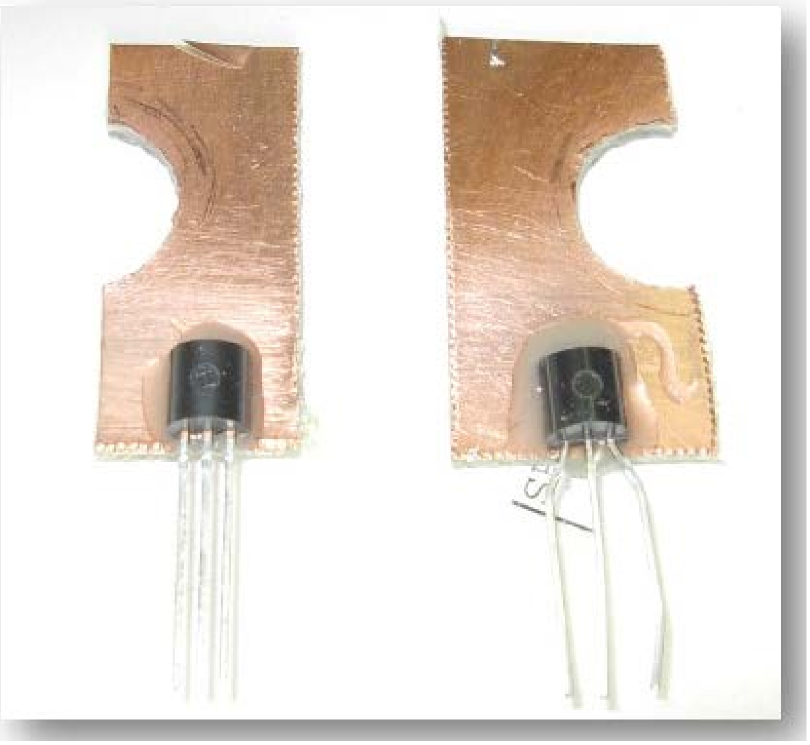

Shown above is another use for copper clad board; heat sinks. In this case, 2 scraps are epoxy glued to 2N3904 and 2N3906 transistors.

MG Chemicals
ROSIN FLUX PEN
Cat. No. 835-P Net. Fill 10 ml
Non-Corrosive RA Type Flux. FLAMMABLE / INFLAMMABLE

A flux pen like this one from MG chemicals is a handy item for the QRP workshop. They are great for applying liquid flux to allow easy and precise soldering of SMT components. Also sometimes when adding components to ground in already built up circuit boards, it can be difficult to get your soldering iron down at a low angle for proper heat transfer. Some flux can help solder a part to the copper ground plane in these situations.

Shown above are the basic tools used to cut copper clad board. A felt pen marker, small square and a set of straight aviation shears. If you press one end of the copper board into the side of your bench and keep pressure on the handle of the aviation shears with your thigh, it is possible to make long, straight cuts. The board will flex and move out of the way as you cut. Your leg provides the force to advance the aviation shears.

The motorized grinding/cutting tool used to carve out small pathways in copper clad board.

NET CONTENTS
6 ROLLS
BULL DOG
CAUTION:
GLOVES RECOMMENDED
WHEN USING THIS PRODUCT
SUPERFINE
STEEL WOOL
MANUFACTURED BY
THAMESVILLE METAL PRODUCTS LIMITED
THAMESVILLE - ONTARIO

Steel wool used to clean up copper clad board before construction. A box like this will last for years.

OLFA SILVER

For 15 years, I've used this 9 mm cutter to scrape the enamel insulation off the magnet wire wound on toroidal inductors.

QRP SWL HOMEBUILDER

Amateur and Short Wave Radio Electronics Experimenter's Web Site

VE7GC Wee Willy 75 Meter DSB Transceiver Project

Introduction

I meet a lot of interesting amateur radio enthusiasts online and on the air. Among them is Dick Pattinson, VE7GC who was first licensed in 1934. When Dick isn't sailing he builds and operates his homebrew QRP gear to hams around the west coast of Canada and the U.S.

Presented is a double sideband transceiver that Dick calls "Wee Willy". This rig has a low parts count and is easily built using non-etched PC board techniques. Dick even makes his own radio case using copper clad PC board for the front and back panels and cardboard for the rest of the case. The set itself is in a case 1 1/4 by 2 1/4 by 5 1/2 inches. There is a separate container which holds a 6 volt rechargeable battery and speaker. The speaker/battery case is about 2 1/2 inches cubed and is not shown.

The circuits are built in three sections on the circuit board, namely TX, RX, and VFO. An electret condenser microphone is on front panel along with T/R switch, volume and frequency adjust. The back panel has the antenna jack, power input cord and the speaker jack. The battery pack has a 100 uF capacitor to across the power leads for additional filtering and is shown in the VFO schematic.

The text that follows is clipboard pastings from email that Dick sent me with some additional comments and expansions by me. Dick's project exemplifies practicality and innovation and with that is a major contribution for the QRPHB site.

Construction Methods

Dick's electronic construction method is quite fascinating and represents yet another derivation of ugly construction. The electronic wiring is done on single sided PC board, copper side up. Small holes are drilled through the PC board material to allow component leads to pass through them. Then the holes carrying active leads are chamfered (countersunk) with a larger drill bit which is not run all the way through the PC board. This leaves an ground-insulated side to the hole and prevents a component lead short circuit. The copper being topside allows both convenient and short component grounding. The Wee Willy parts layout is extremely neat and compact. Dick, presumably through practice has great skill with this technique and I plan to try it in the future.

The project case is constructed from 1/16th inch cardboard which is cut and bent to fit the electronic PC board. Once cut, the outer surface and edges at the front are covered with tissue paper or Kleenex (tm) type tissues soaked in white glue. The applied tissue paper and glue is allowed to dry and then additional coats are added to build up a body. Alternately, the cardboard case can be coated with lots of glue and the covering material imbedded in the glue. The air bubbles are pressed out and extra glue is added where necessary. When enough material has been added to cover up and strengthen the case joints and the glue is perfectly dry, the case is painted with Rust Coat Enamel available at hardware stores. The end result is a glossy, durable finish which looks very sharp.

Transmitter

This transmitter uses an electret condenser microphone (Dick used an Archer 270-90). The mic is built right into the front panel of the chassis and this of course guarantees short mic leads. A 741 op amp is used as a speech amplifier which in turn drives the balanced modulator a Signetics NE602 doubly balanced mixer. The input and output impedance of the NE602 mixer is around 1500 ohms.

To adjust the transmitter, set the bias control on the VN10 stage to ground and tweak L1 to resonance using an RF probe or scope on the VN10 input. The input signal must be audio, spoken into the front panel microphone to get the DSB. Once L1 is tuned, connect a 50 ohm load to the antenna with some sort of RF indicator (such as a RF power meter) and advance the bias control to give a watt or so output. Then speaking into the microphone should result in a DSB signal suitable for communicating on QRP! No audio input should result in no RF output. The supplied voltage should be kept at 6 volts, remembering that NE602's cannot stand voltage greater than 9 volts. With suitable voltage control such as a 6.8 volt zener diode on these chips, one could use higher input voltage with a corresponding RF output.

There is another way of setting the bias on the VN10. After aligning L1, with a ammeter in the six volt supply line, advance the bias control until the input current increases about 10 mA (with no modulation). If you do not have an FT37-77 ferrite core, substitute 10 bifilar turns on a FT37-43 ferrite core for the T1 transformer

.

Wee Willy Transmitter

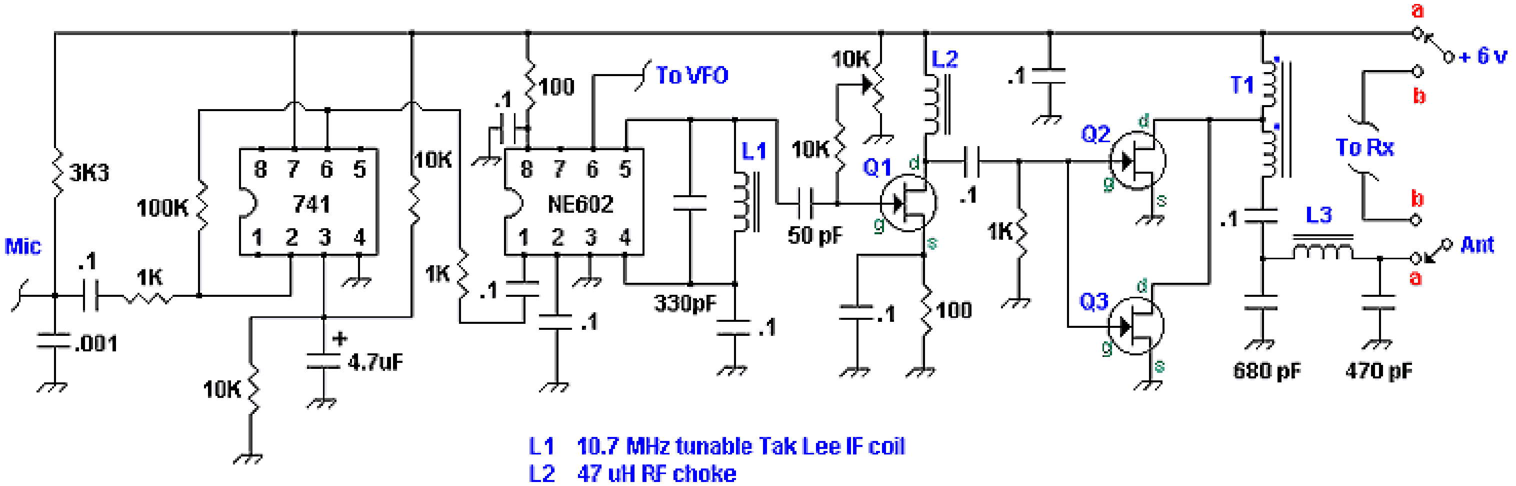

L1 10.7 MHz tunable Tak Lee IF coil
L2 47 uH RF choke
L3 22 turns # 24 AWG on a T50-2 Powdered Iron Core
T1 T1 is 6 turns Bifilar wound #24 wire on FT37-77 core
Q1 - Q3 VN10 nJFETs

Receiver

The receiver is a direct conversion type with a manual RF gain control in the form of a 5K potentiometer. Listening to a weak signal on the desired frequency the RF stage and the mixer core (T1 and T2) adjustments are made until you hear the loudest possible signal, keeping the input test signal as low as possible. When the receiver is connected to a doublet antenna there is no lack of incoming signal, which can be controlled by the front panel RF gain control.

The antenna and 6 volt supply is switched manually from TX to RX mode and back by a front panel mounted switch. If you can not find Tak Lee green 10.7 MHz IF coils, probably any other brand of 10.7 MHz slug tuned IF transformer would work. The Mouser catalog number 421F123 would work well and in another 80 meter project I used it with a 470 pF capacitor instead of the 330 pF cap shown. I would start with Dick's 330 pf cap and if it will not tune to resonance sharply, slightly increase the cap value up to see if a bit more capacity is required to resonate it on the desired 75 Meter frequency. Note that the secondary coil on the L1 transformer in the transmitter schematic is unused. If your 10.7 MHz IF coil has a built in capacitor at the base, remove it.

During receive, the standby drain current at 6.0 volts was 24 mA and on loud signals it rose to 100 mA. If this is too much, probably the easiest thing to do would be to put in a series resistor from positive to the LM386 to limit the drain current. To get output on the speaker it is a matter of how loud you want it for the drain you draw. If earphone only reception is okay, then the drain could be reduced considerably.

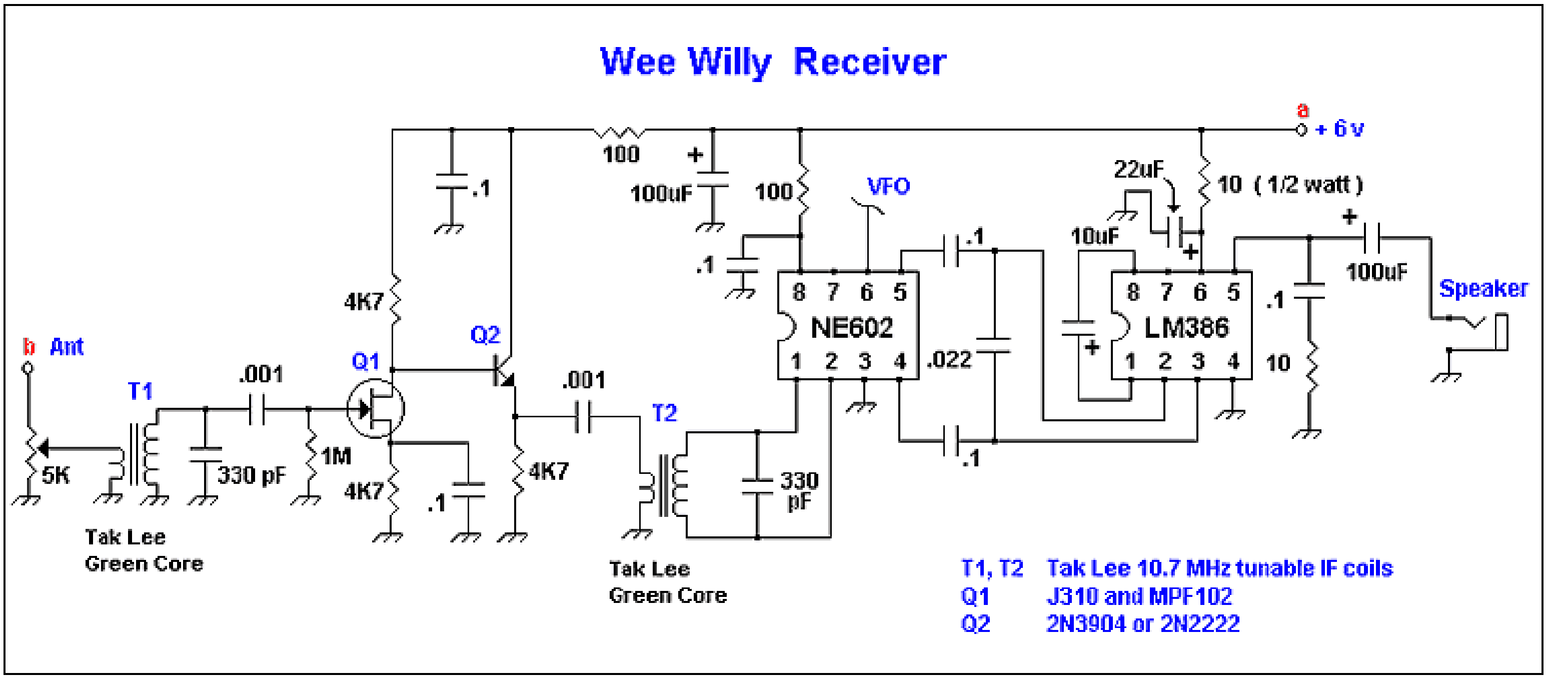
Wee Willy Receiver
a + 6 v
100
100uF
100
.1
.1
VFO
22uF
10 (1/2 watt)
10uF
.1
100uF
Speaker
8 7 6 5
NE602
1 2 3 4
8 7 6 5
LM386
1 2 3 4
.022
.1
10
.1
b Ant
T1
.001
Q1
Q2
4K7
.001
T2
5K
330 pF
1M
4K7
.1
4K7
330 pF
Tak Lee Green Core
Tak Lee Green Core
T1, T2 Tak Lee 10.7 MHz tunable IF coils
Q1 J310 and MPF102
Q2 2N3904 or 2N2222

VFO

Dick's diagram indicate that this VFO was based upon a design presented in SPRAT for summer 1995. The main inductor L1 is wound with #32 AWG wire on a 1/4 inch slug-tuned coil former. This coil would have an XL somewhere between 250 - 310 ohms, so if you cannot find a coil former as described , you could easily wind one on a powdered iron toroid and make a portion of the C1 capacity variable for adjustment. A suggested alternate inductor is 53 turns of #26 AWG on a T68-6 core powdered iron core.

Dick suggests checking an old television to find suitable coil formers such as the one he used. It would probably be best to distribute the 120 pF C1 capacity among 3-4 capacitors to enhance stability. These caps should be NP0 ceramic for best results with frequency stability.

Dick's oscillator uses the slug tuned core to put VFO frequency close in frequency to where you want to operate and the variable resistor tuner on the front panel allows adjustment around the incoming signal to get the correct pitch. The desired band-edge is easily set by adjusting the slug while listening to the VFO frequency as audio on another receiver that has a frequency readout or directly with a frequency counter.

The L2 150 uH RF choke can be a simple epoxy unit which resembles a resistor. The D1 variable capacitance diode is a BB104 which has ~ 35 pF capacitance on each side. These are available at Dan's Small Parts and Kits whose URL is in the Links section of the site info web page. Experimentation with other tuning diodes could produce a practical alternative to the specified D1 part.

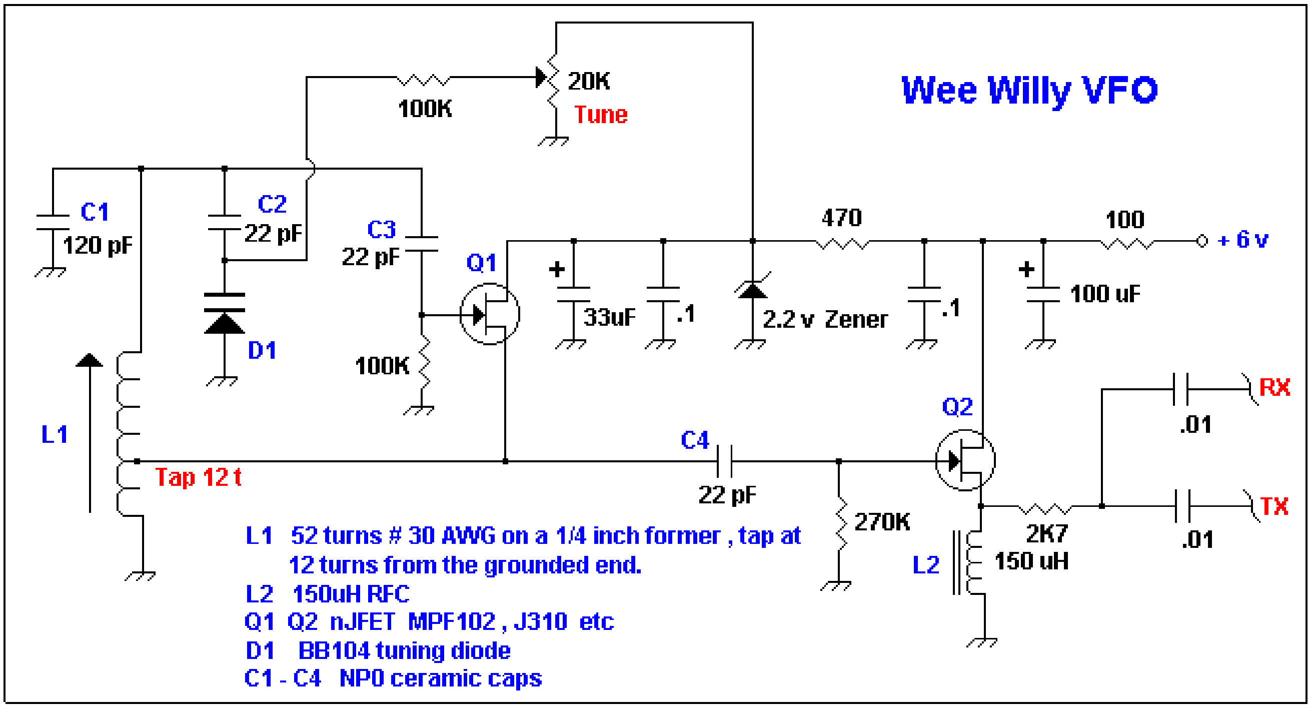
Wee Willy VFO
100K
20K
Tune
C1
120 pF
C2
22 pF
C3
22 pF
Q1
470
100
+ 6 v
33uF
.1
2.2 v Zener
.1
100 uF
D1
100K
L1
Tap 12 t
C4
22 pF
Q2
.01
RX
270K
2K7
.01
TX
L2
150 uH
L1 52 turns # 30 AWG on a 1/4 inch former , tap at 12 turns from the grounded end.
L2 150uH RFC
Q1 Q2 nJFET MPF102 , J310 etc
D1 BB104 tuning diode
C1 - C4 NP0 ceramic caps

Operating Wee Willy

Dick sent me Willy in the mail and the first available moment I fired the little rig up and spanned the VFO which tuned from ~ 3721 to 3738 KHz. I then proceeded to tune 3729, the frequency of BCEN, our SSB provincial public service net and on my first break was able to check in with one call sign repeat to the net control station. The band conditions were noisy and most signals were S8 or lower, however Wee Willy's 1.5 watts P.E.P. were able to check me in with my folded Marconi antenna. I later changed the L1 slug and worked some stations higher up the band. My audio reports were favorible and no one knew I was running DSB. This is a fun radio and it looks cute to boot!

When transmitting, I had to be careful to keep my hand away from the VFO compartment to prevent pulling the VFO frequency with the capacitance change from my hand. The VFO has reasonable long term frequency stability and copying CW stations with the receiver was possible without frequent tuning readjustments.

The following are some digital photos of Wee Willy taken by VE7ZAC.

Move your mouse over the images for a larger version.

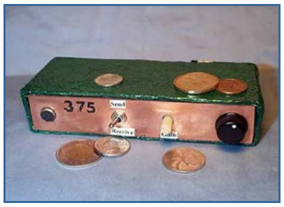

From left to right the electret mic, TX/RX switch, RF gain control and VFO tuning control. The number 375 is Dick's project identification number. He has given me many schematics of his projects and each has a unique number and case color. For the non-Canadians, the large coin on top of Willy is our "Loonie" a 1 dollar coin. The large 2 color coin in front of the rig is our "Toonie" a 2 dollar coin.

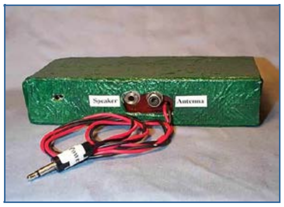

The hole on the left of this rear panel shot is for adjusting the L1 slug for the VFO. From wherever on the band the VFO is set a front panel tuning range of about 17 KHz was possible. Also shown are the speaker jack , BNC antenna connection and DC power leads.

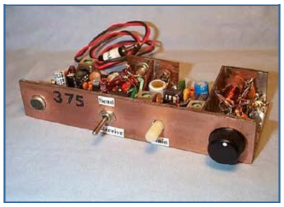

Wee Willy with the cover off.

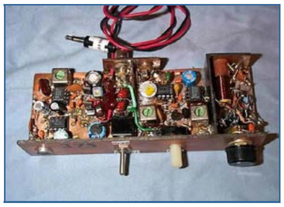

These top view shots clearly shows the 3 distinct compartments. From left to right the TX , RX and VFO sections. The VFO has a PC board seperator for shielding. Dick's construction method is well illustrated with this photo. The IC's are in sockets. The 3 VN10s have a small tab on the top. There are no heat sinks on the VN10 finals and they do require any for a 6 volt supply voltage. The rear panel jacks and VFO inductor are all mounted in PC board material.

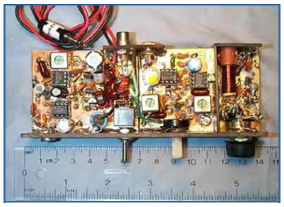

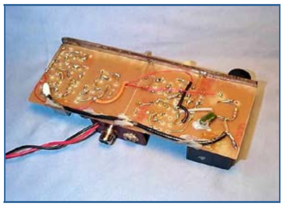

Here is a bottom shot showing the connecting wiring through the chamfered PC board holes. Many thanks to Dick Pattinson, VE7GC for allowing me to present one of his projects.

Wee Wee Willy by NM8T

NM8T Builds Wee Wee Willy

Steve White, NM8T emailed me a few weeks ago that he was building Wee Willy and was not getting the expected output power. I forwarded his email to Dick and they problem solved the issue. It turns out that the V10KM's were the culprit.

Here are their final two emails:

Steve: I think you have found a solution to your problem. I did not know that VN10's are different. I bought mine in 1994 from a radio parts supplier and they are marked VN10KM F324A1. Have fun with your new rig and let us know how you are doing with it. 73, Dick

Dick, I have completed my little rig and have had a blast with it so far. My first CQ yielded me 3 contacts in Pittsburg, Pa. My friend across town gave me a 20 over S9 report. The three hams in Pa. were astounded that I had only 1.5 watt PEP. I had to use 12 volts and used small 5 volt regulators to feed the NE602's. This works very well. I even used a little homebrew tuner with it and got my swr flat. I am going to take the little rig to Dayton Hamvention next year. I go every year and take a little project each year to show everyone. I hope it is ok to call my little rig Wee Wee Willy, since it is a little smaller than your version. I want to thank you for your help in getting this rig completed and also thank Todd for his help in getting me in contact with you. Your little rig is very neat and right up my alley for a QRP rig. I look forward to working you someday on QRP. I'm 47yrs. old on the 24th of this month. I have a whole room full of QRP rigs such as HW-7, HW-8, HW-9, Argonaut 509, 515, Powermite PM-3a. Have built a Cascade, LCK, Spider, MXM, Keyers, Tuners, and all kind of other projects. I love QRP and hope to build many more soon. The Wee Willy is one of my favorite rigs. Here are some pictures for you and Todd. Thanks and Hpe CU Agn. 73's NM8T (No more 8 Tracks)
Steve White - Fayetteville, WV

75m DSB
Tune – Wee Wee WILLY – Gain
MIC

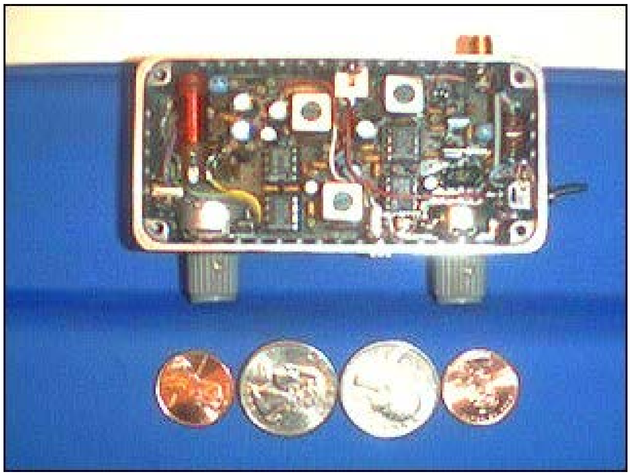

My special thanks to Steve White and Dick Pattinson.

Countless builders have constructed the Wee Willy on several bands. Here are 2 more examples. Paul, KE7HR Link1 and Link 2. The finals even made it into the the BITX17 transceiver. Allan Yates published some good work on the final amp.

I've also tweaked Dick's design, but decided to leave his little rig and this web page alone out of respect to him. It's always easier to improve rather than actually *design* something. I'll never better the experiences I had operating and documenting his transceiver.

Update February 15, 2011

I lost touch with Dick and decided to call him on Feb 10, 2011. He's 95 years old and no longer building. Sadly, his wife Christina died 2 years ago. She was a beautiful person and a gifted painter. Dick remains astonished that Wee Willy - Project 375 QRP Radiophone has been built by at least 50 people (that I know about) world wide, the subject of blogs and the basis/inspiration for numerous radio projects. I met Dick on 80 meters and my wife and I once visited his residence and spent 2 glorious, days on Saltspring Island with he and his wife.

Dick sent me the radio and documentation on Aug 13, 1998. He was a hardcore builder and a professional electronics technician who, for a time, flew his float plane to service equipment in the Gulf Islands of British Columbia. Dick keeps many binders full of his carefully numbered and well documented projects. He gave me a few sheets for my reference library as a gift. Dick's work inspired me early on and I cherish the time I had Wee Willy in my radio shack - blown away by DSB, QRP and such a novel little radio.

Dick asked me to send his greetings to all QRP Homebuilders everywhere.

More Updates

Aug 25, 2011

Hi. Been viewing your web site for a while, lot of great information for builders. I thought i would let you know that I built the "Wee Willy", it works great, so good that I decided to try building one for 20m. I built the 20m version with a 14.318 crystal instead of a VFO ideal for my local net, also changed the PA circuit using IRF510 giving me 2.5W output, the transistor can run 5W, but it does get rather hot, I must say that the quality of the transmitted audio is amazing, everyone comments how good it is and some do not believe it is home-brew!!! I have put a few CQ calls out with a simple dipole and made contacts into Belgium, Netherlands, Finland and Saudi Arabia. Many thanks again for putting the Wee Willy on your website, it has opened my eyes to how well you get get out with QRP power.

Regards Wayne. M0WAY. Click for Wayne's fabulous Wee Willy bread board.

Sept 19, 2011

Wayne, M0WAY wrote again,

I built another Wee Willy and put it into a box, but with a few extra bits:

A new VFO was added that runs 14.190 – 14.350 MHz (an 11 MHz crystal oscillator + a 3.2 MHz VFO + a band-pass filter) I got the power up to 4W, however the audio was a little over powered from the extra RF, so I had to reduce the audio gain and added an antenna switching circuit, after I burnt out my receive circuit with the 4W output.

Here's Wayne's PA (from the NE602 on ** updated July 12, 2012 **) Click for a photo of his latest incarnation. Thanks again!

Oct 19, 2011

Mark, WA4JAT built a "0 cost" Wee Willy from 100% junk box parts including a CB radio transistor for the final. Click and click. Mark tunes the VFO using an air variable capacitor mounted in the former Heath Kit signal tracer project chassis. The cable running out of the front is the microphone coax with an electret mic at the end. Employing large size VFO, Rx and Tx boards facilitate easy future modifications. Awesome work Mark!

JFET BIASING TUTORIAL BY W7ZOI

This tutorial is copyright © 2000-2001 by Wes Hayward, W7ZOI.

JFET Biasing and an Amplifier Design   W7ZOI, 30Dec00.

Junction Field Effect Transistors (JFETs) are generally no more difficult to bias than a bipolar transistor. In many ways they behave essentially like a classic triode vacuum tube. The current flowing between FET drain and source is controlled by the gate-to-source voltage, V_{GS}. (This is the voltage you would measure with a voltmeter connected between the gate and the source.)

The Fig. 1 schematic defines the parameters we use to describe the DC behavior of a JFET. The 100 Ohm resistor is added to preserve UHF stability during measurements. The gate voltage, V, is then varied while measuring drain current. The results are then plotted, as shown in Fig. 1. The FET is characterized by the simple quadratic equation below the schematic with the two FET related parameters of I_{DSS} and V_P. I_{DSS} is the drain current when the gate is short circuited to the source. The pinchoff voltage, V_P, is V_{GS} when the drain current is essentially zero. The example in Fig. 1 has I_{DSS}=20 mA and V_P=-4 volts. Source and drain current are identical in the JFET.

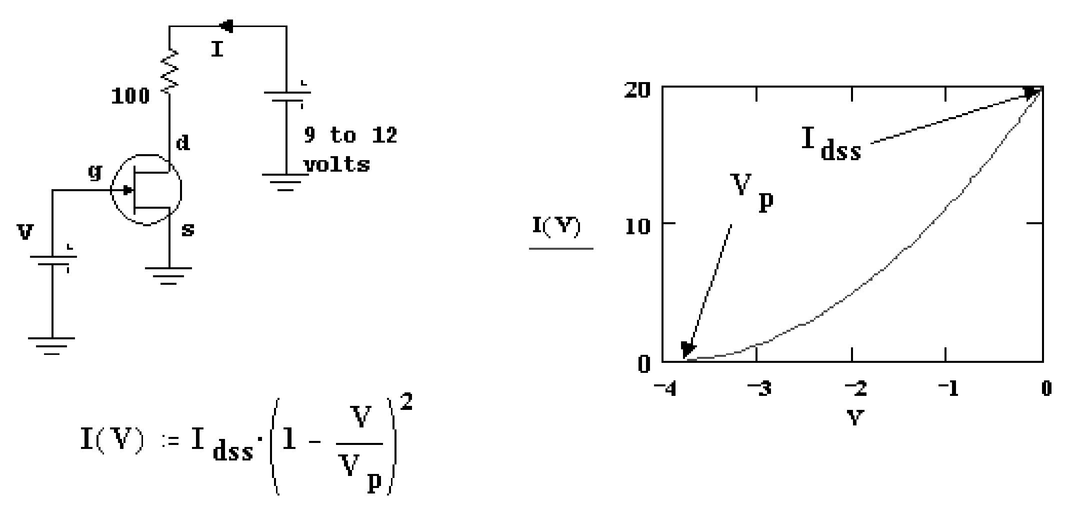

$$I(V) := I_{dss} \cdot \left(1 - \frac{V}{V_p}\right)^2$$

$I_{dss} := 20$ mA $\quad V_p := -4$ volts

Figure 1

Basic behavior of an N-Channel depletion mode JFET.
The numbers shown basically illustrate the ideas.

The experimenter wishing to use a JFET in a circuit will most often use the method called "self biasing" where a resistor is placed in the source lead. The gate is grounded. The FET current also flows in the resistor. The current generates a voltage drop that elevates the source voltage above that of the gate, which is the same as biasing the gate negative with respect to the source. This establishes a drain current less than I_{DSS}.

Drain voltage is not critical so long as it is a few volts greater than the source.

The resistor value for a desired bias is calculated with Equation 1 if I_{DSS} and V_P are known. But these parameters are rarely well specified. For example, the popular J310 is characterized only by ranges: I_{DSS} is 24 to 60 mA and V_P is -2 to -6.5 volts.

$$R_s := \frac{V_p}{I_D} \cdot \left(\sqrt{\frac{I_D}{I_{dss}}} - 1\right) \qquad \text{Eq.1}$$

I_{DSS} and V_P are easily measured for a specific FET with the circuit shown in Fig. 2. The circuit is built with a variety of source resistor values and the source voltage is then measured for each with a high impedance voltmeter. The pinchoff voltage will then be the negative of the source voltage when R_S is a large value such as 100K. Grounding the source through a current meter generates a direct reading of I_{DSS}. This brief measurement will provide enough data to allow biasing.

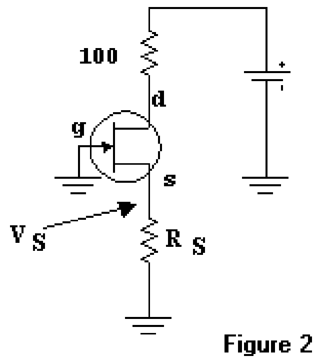

Figure 2

Circuit used to determine FET DC parameters.

This experiment was performed with a junk box 2N5454, producing the parameters I_{DSS}=11 mA and V_P=-2.8 volts. The current equation from Fig. 1 is plotted in Fig. 3 with these parameters. Additional points were measured producing points close to the curve.

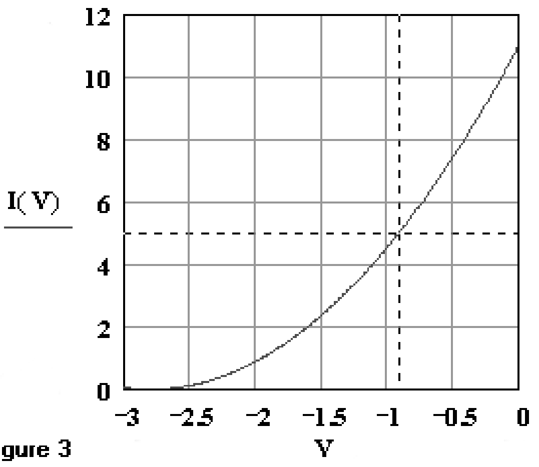

Figure 3

Data and smooth curve for a 2N5454 we measured.
This FET has a pinch off of -2.8 volts and a IDSS of 11 mA.

This exercise SHOULD be done with virtually every FET that the experimenter uses. It is not enough to obtain data for a given FET type, although if a group of parts are available from one manufacturing batch, moderate uniformity might be expected.

We mentioned the J310 earlier with an I_{DSS} spread from 24 to 60 mA. That 2.5:1 span range is one of the better of commonly available parts. The historically popular MPF-102 has a 10:1 spread in I_{DSS} (2 to 20 mA) with V_P extending from -0.5 to -7.5 volts! Clearly, this part should be used only with extreme care. It's a good RF part, but one MPF-102 may not resemble the next.

Assume the FET we summarized in Fig. 3 was to be used in an amplifier and that we wished to bias the FET for 5 mA. The 5 mA point can be picked on the graph and matches V_{GS} of approximately -0.9 volt. 0.9 volt drop from 5 mA matches a resistor of 180 Ohms. Application of Eq. 1 produces 182 Ohms. Crosshairs indicating the 5 mA point are included in Fig. 3.

Once a FET has been biased, it can be used in a small-signal amplifier. The significant gain parameter is the transconductance, given by Eq. 2. Transconductance is the drain signal current flowing for each volt of signal applied to the gate. Note that g_M depends upon the bias current. The g_M value given in data sheets corresponds to operation at I_{dss}.

$$g_m = 2 \cdot \frac{I_{dss}}{V_p} \cdot \left(1 - \frac{V_{GS}}{V_p}\right) \qquad \text{Eq.2}$$

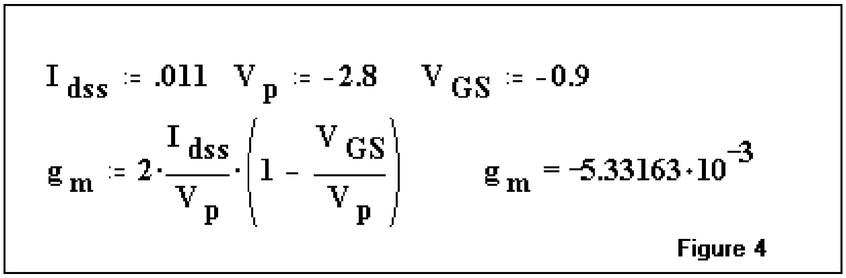

$$I_{dss} := .011 \quad V_p := -2.8 \quad V_{GS} := -0.9$$

$$g_m := 2 \cdot \frac{I_{dss}}{V_p} \cdot \left(1 - \frac{V_{GS}}{V_p}\right) \qquad g_m = -5.33163 \cdot 10^{-3}$$

Figure 4

Data used to produce transconductance for the FET used in our sample amplifier.

Evaluation of g_M from Eq. 2 for our 5 mA bias produces the data in Fig. 4.

Consider the amplifier shown in Fig. 5. We will use this as an output buffer for an oscillator. Assume that we have tapped a signal from the oscillator tank where a voltage of 1 volt peak-to-peak is available. When this is applied to the FET gate, a current of 5.33 mA pk-pk will flow. The transformer uses a 15 turn drain winding and a 3 turn output link on a FT37-43 ferrite toroid. This turns ratio transforms the 50 Ohm load to appear as 1250 Ohms in the drain line. A current of 5.3 mA pk-pk flowing here produces a voltage of 6.25 V pk-pk. The no-signal drain voltage will be about 11 volts, so positive and negative 3 volt excursions will not cause voltage limiting. The current will vary from the 5 mA DC value down to nearly 3 mA (still well above zero) and up to nearly 8 mA, still below I_{dss}. The signal at the 50 Ohm load is reduced by the transformer to 1.33 V pk-pk. This is about +6 dBm, enough power to drive a diode ring mixer. This simple circuit is a low noise, efficient, and very useful amplifier.

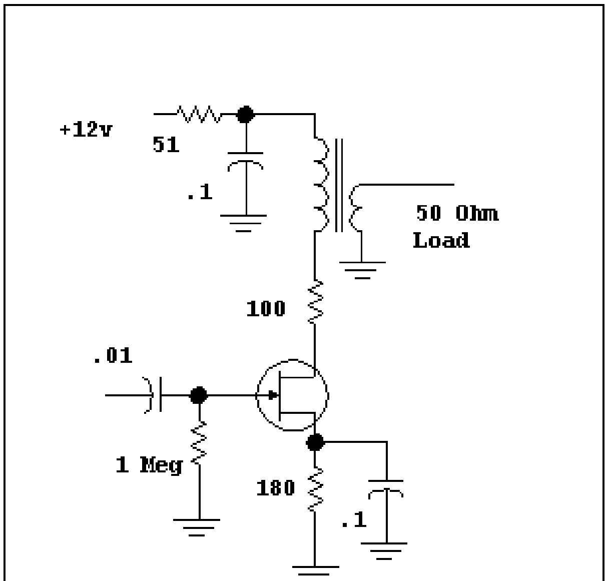

Figure 5

Common source amplifier biased for 5 mA drain current.

Figure 6 shows a FET amplifier that uses "long tail" biasing. A negative power supply is now used, forcing the biasing resistor to behave like a constant current source. This method can accommodate a wide range of FETs of a given type if the bias is set up for $I_d<I_{dss}$-min.

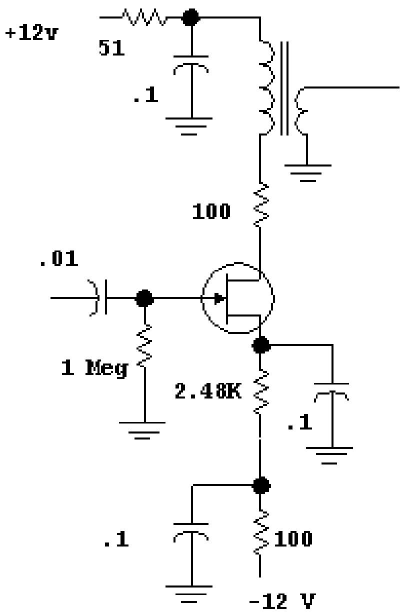
+12v
51
.1
100
.01
1 Meg
2.48K
.1
.1
100
-12 V

Figure 6

Amplifier with "long tail" biasing. This amplifier is biased for 5 mA and is identical in performance to that of Figure 5, but does not require the careful device characterization.

RF — Test and Measurement

EMRFD Review

Experimental Methods in RF Design

$49.95
EXPERIMENTAL METHODS in RF DESIGN
Wes Hayward, W7ZOI
Rick Campbell, KK7B
Bob Larkin, W7PUA
Published by ARRL The national association for AMATEUR RADIO
CD-ROM INCLUDED

First published by the ARRL in 2003, EMRFD serves as the main QRP/SWL Homebuilder site reference.

Written by Wes Hayward, W7ZOI, Rick Campbell, KK7B and Bob Larkin, W7PUA, EMRFD is the follow-on to the 1977 ARRL publication, Solid State Design For The Radio Amateur (SSD).

A treasure trove of narrative and tabled information, schematics, references and photographs adorn this lengthy (512 page) book that comes with a data CD filled with software and key reference papers. With the included CD, EMRFD is about twice the size of the original SSD.

Wes and crew emphasize fundamental radio equipment design and bench testing rather than providing the usual catalog of circuits to just casually copy and not carefully examine.

Since we amateur builders own varied skills, abilities and test equipment, some sections may intimidate readers, while others may inspire and drive your bench practices to a higher level of competence and joy. The heart of RF design lies in measurement and reason: EMRFD emphasizes this and in doing so alienates some readers.

For some, homebrew radio electronics and kit building are synonymous — plenty of kits are sold to builders who chose to build someone else's design, rather than capture their own ideas on a scrap of copper board, or at least, to modify their equipment to suit their needs. EMRFD may appeal to builders who enjoy learning about RF *design*, or want more innovative and creative bench experiences — 1 stage at a time.

Although stressing that *build and measure* = a proven way to improve in this hobby, Wes and team share other pearls including bread boarding techniques, parts lay out, hot parts and pitfalls to avoid.

The first chapter is simply called Getting Started. On page 8, Wes shares his first simple receiver design — this page starts your breadboarding in haste! EMRFD features information and designs for all levels of experimenters, although basic electronics knowledge and some experience are needed to get the most out of its content.

Replete with sidebar examples about measuring or calculating data for common circuits, EMRFD also offers general purpose stages including a universal monoband superhet receiver front end or AF chain instead of less versatile, single- application circuits. The design information feels vibrant and flexible and some of the material is original, or presented in a way that adds to the existing amateur radio knowledge base. For example, new front-end mute circuits, or the cascode JFET mixer and RF amplifier.

Wes also shares some new ideas for RF and IF amplifiers ranging from simple to state-of-the-art. This book has something for everyone — I prefer to describe EMRFD's influence on our hobby in simple action verbs such as: improve, innovate, inspire, explore and transform.

Software:

The Microsoft Windows programs run on everything up to and including Windows 7. While a few programs are new, others represent updates of the historic W7ZOI Ladpac applications. Upon mastery of the Ladpac program suite, you'll generate the needed stages to boost *your* designs.

For example you can design complex double or triple tuned band-pass filters for your projects without any math — the software gives you the series capacitor values so you need not worry about putting links on your inductors to match input or output impedances.

EMRFD = the **must have** reference book for your homebrew workshop.

See CD-ROM contents which immediately follows Chapter 12.
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Supplemental CD for
Experimental Methods in RF Design
First Edition

ARRL EMRFD web link

Link to the W7ZOI errata page for EMRFD

QRP SWL HOMEBUILDER

RF — Test and Measurement

Tapped Capacitor Impedance Transformation in LC Bandpass Filters

copyright © Wes Hayward, W7ZOI, April 30, 2003.

We often use a pair of capacitors to match impedances at the termination ends of LC bandpass filters. The circuit consists of a shunt capacitor at the termination followed by a series capacitor connecting to the high Z end of a parallel tuned circuit. Some readers have asked about how the capacitors are picked. Although there is considerable flexibility in some of the choices, it is not empirical as some have guessed. A simplified double tuned circuit design sequence is presented in the sidebar on page 3.14 of EMRFD and this is the beginning of the analysis used in the programs DTC.exe and TTC.exe contained on the EMRFD CD. I'll not go into too much detail here, for it's in EMRFD, beginning on page 3.8, and in chapter 3 of IRFD. Here is what happens in the programs:

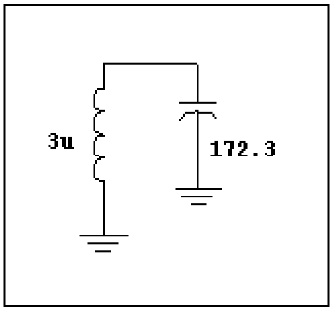

Bandpass filter design begins with an almost arbitrary choice of inductor. We pick 3 uH for a 7 MHz double tuned bandpass filter that we will use to illustrate the ideas. This L resonates at 7 MHz with 172.3 pF.

A bandwidth and center frequency are picked for the filter. This establishes a filter Q. The Q of an end section is then determined by the desired filter shape (Butterworth, etc)Let's say we want to do a 7 MHz center frequency Butterworth filter with BW=0.2 MHz. Filter Q is then 35=7/0.2. QE will then be 35x(root(2))= 49.5. The QE value in the sidebar (p3.14) includes the effect of finite inductor Q. Assume a lossless inductor for this example.

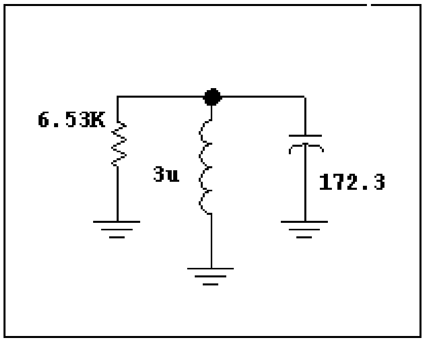

So what does this mean? It means that the end tuned circuit, when not coupled to the rest of the filter, needs to be set up to have a Q of 49.5. This is experimentally significant. (ref: QST, Dec, 1991). The reactance at 7 MHz of our 3 uH inductor is X=131.9 Ohms, so we need to load each end with a resistance R=QX=6.53K-Ohm.

What this means is that we would realize our double tuned bandpass filter with center frequency of 7 MHz and bandwidth of 200 kHz if we terminated a simple double tuned circuit in 6.5K at each end. The filter is shown below where we have used additional equations (EMRFD p 3.14) to calculate the coupling and tuning capacitors.

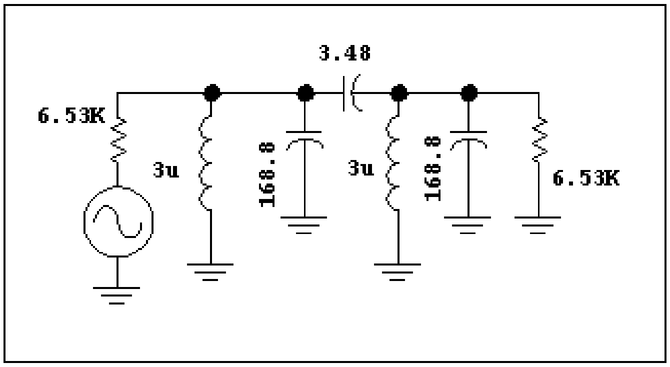

This is a useable filter design, for it will generate the desired shape and bandwidth. But, it is not very practical; it does not fit in our low impedance world.

The filter can be redesigned. One classic, but usually impractical solution is to scale the filter to lower impedance levels. For example, if we dropped L from 3 uH to 23 nH, we could directly load our filter with 50 Ohms and get the required end section Q. But this is not at all practical. First, it's difficult to build inductors with L this small and still have reasonable Q at 7 MHz. Second, the parasitic inductance of the rather large (high C) capacitors that we would attach to this inductor would begin to compare to 23 nH. A better re-design would use transformation circuits, schemes that will let us use a 50 Ohm termination (or whatever we need) and make it function as a 6.5K resistance when seen by the inductor.

One such scheme is a transformer. This could be realized with ferrite cores or with links inductors wound on the existing 3 microHenry parts. But link coupling with design precision is a challenge of it's own. Conventional two and three element transforming networks (L, pi, Tee) are also suitable.

The simplest transforming circuit uses a series capacitor. Let's do some analysis to see how this works:

We have arbitrarily picked a 10 pF capacitor to illustrate the idea. At 7 MHz, the reactance of a 10 pF capacitor is 2274 Ohms. Hence, the complex impedance of the 50 Ohm resistance and the series capacitor is Z=50-j2274. The impedance transformation behavior of this circuit is studied by transforming the series impedance to a parallel admittance. Recall that Y=1/Z. So Y=1/(50-j2274). The result is Y=(G+jB)=9.67E-6 + j4.4E-4. Of special importance is the resistive real part of the admittance.

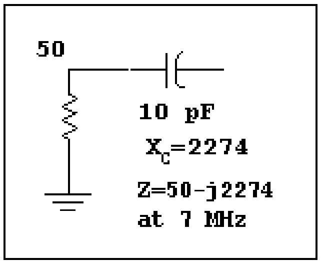

The 10 pF series capacitor in our example makes the 50 Ohm resistor look like a 103 K-Ohm resistor in parallel with a capacitor that is nearly 10 pF. The general case causes a R0 value resistor to look like a value of Rp with a series capacitor with reactance given by

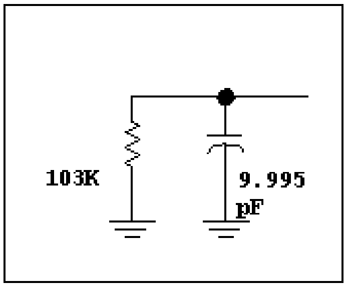

This equation is #3.1-5 from IRFD where it is derived.

$$X_C = \sqrt{R_p \cdot R_0 - R_0^2} \qquad \text{Eq. AA}$$

Our original example filter needed a parallel resistance, Rp, of 6.5K-Ohms, which is produced by a series capacitor with a reactance of 568 Ohms. This is a capacitor of 40 pF. Another version of our double tuned bandpass filter is then

Notice that the tuning capacitors, the elements across the inductor, have dropped as C is added at the ends.

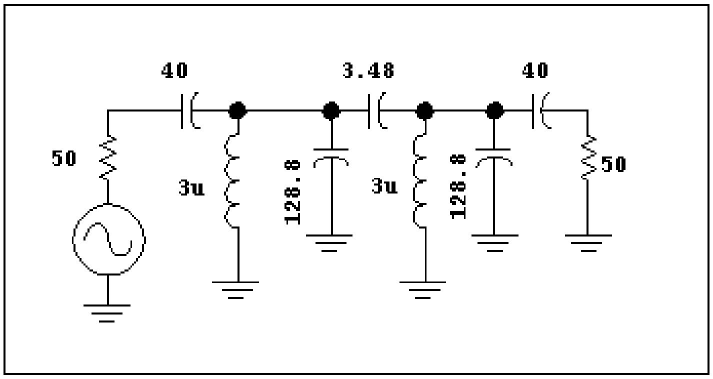

A capacitor in series with a resistance produces higher equivalent resistance. Consider a parallel combination. Here we pick a value of 200 pF as the parallel C and calculate the admittance. This is then converted to an impedance with Z=1/Y and the individual components are evaluated. This result is shown to the right.

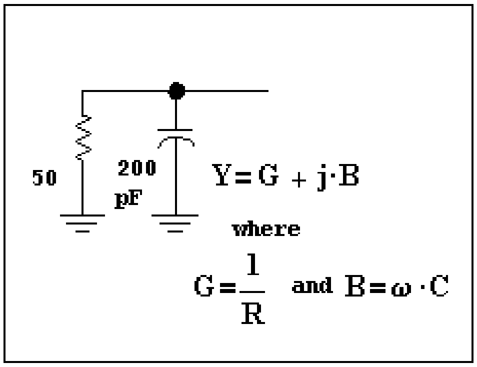

$$Y = G + j \cdot B$$

where

$$G = \frac{1}{R} \quad \text{and} \quad B = \omega \cdot C$$

The parallel capacitor transforms the 50 Ohms to behave like a lower value.
In this case, we obtain about 42 Ohms in series with a 1236 pF capacitor.

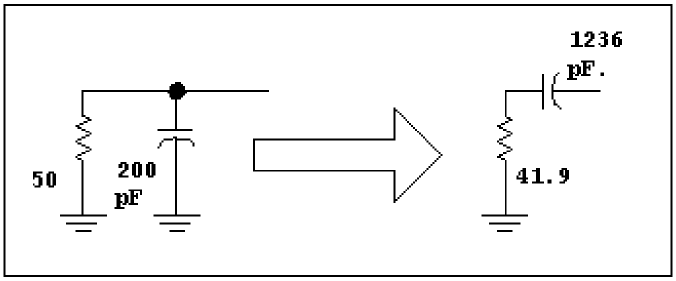

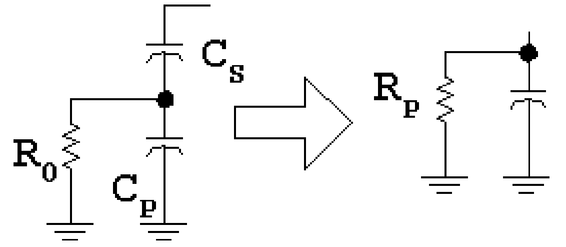

$$C_p = \sqrt{\frac{R_p \cdot C_s^2}{R_0} - \frac{1}{R_0^2 \cdot \omega^2}} - C_s$$

Eq. BB

A series capacitor transforms a termination to “look like” a higher resistance while a parallel capacitor “transforms to” a lower R. Clearly, the combination of the two can generate about any result we need, realizing that they will also produce reactance that must be absorbed into the existing tuned circuits. The mathematics (now symbolic and not just number manipulation) is messy, but not difficult. A resistive termination R0 (50 Ohms or whatever) is paralleled by a capacitor Cp. The admittance is calculated and is converted to an impedance. The impedance of a series capacitor, Cs, is then added. The result is converted back to an admittance. The resistive real part is extracted and inverted to yield Rp. This expression is then solved to yield a design equation:

This is the equation used in the programs. A related expression provides the equivalent capacitance, needed to calculate the tuning capacitor for each resonator.

If we use the program with the center frequency and bandwidth presented earlier, we find that the minimum allowed series capacitance is 40 pF. If we then insert a value of 47 pF, we see that parallel 240 pF capacitors are needed to properly load the resonators. This variation is shown to the right. Circuits using the capacitor tap are practical, for they allow existing junk box parts to be used. The topology has little other utility, offering virtually the same response as a filter using only series capacitors for loading.

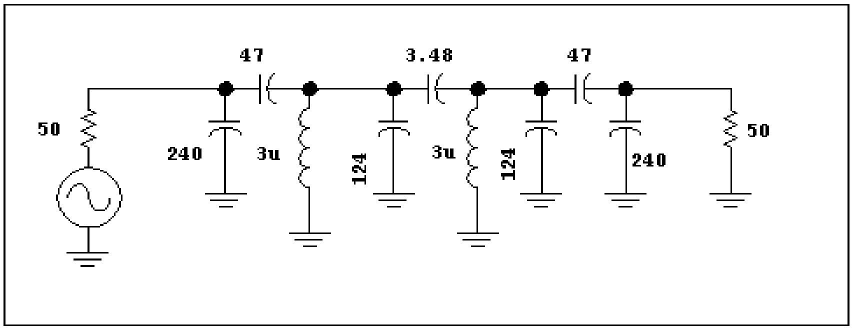

Useful link shared by Tim, KE7VYD on Feb 4, 2014. Click

QRP SWL HOMEBUILDER

Amateur and Short Wave Radio Electronics Experimenter's Web Site

More Active Antenna Experiments

Introduction

Many builders emailed me requesting a simple, broadband VPA (voltage probe antenna) design with more power gain than the common gate versions I have presented elsewhere on this web site. Connecting a whip antenna to a cascode JFET stage described by W7ZOI in Experimental Methods in RF Design is 1 method I considered.

I built the version shown in Figure 1 almost 2 years ago. This VPA. although more powerful, overloaded the front end of my test receiver with multiple RF signals. Clearly some tuning on the input was needed.

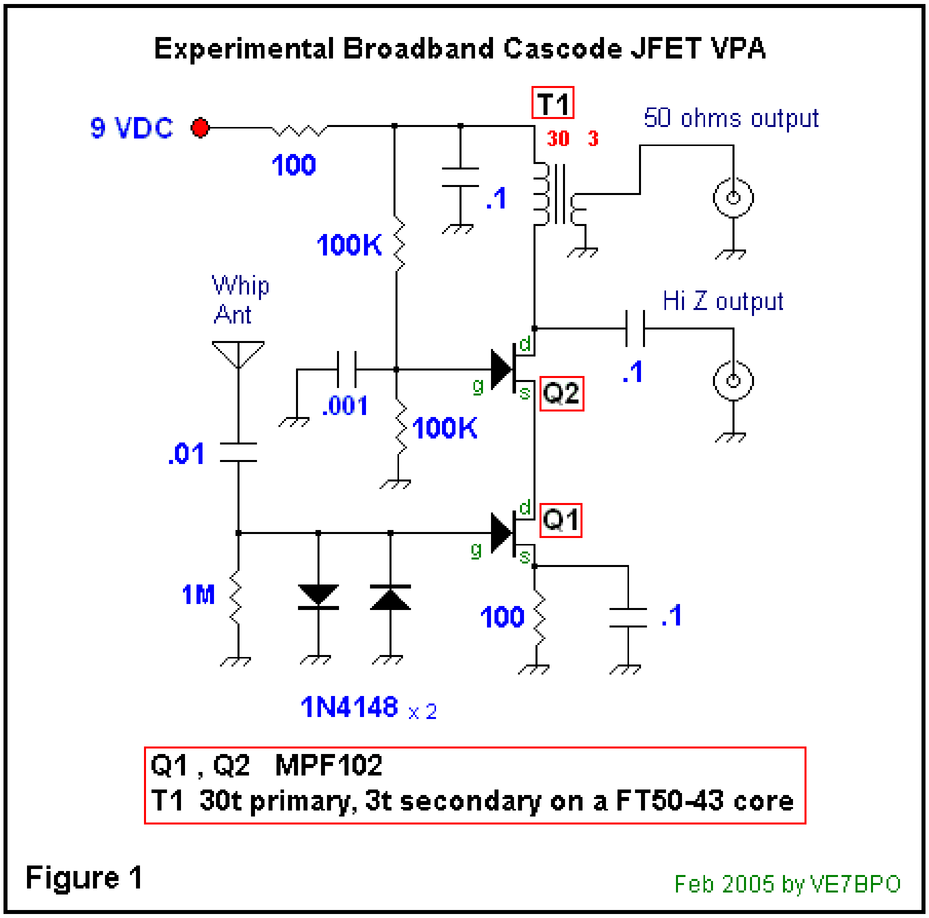
Experimental Broadband Cascode JFET VPA
9 VDC
100
.1
T1
30
3
50 ohms output
100K
Whip
Ant
Hi Z output
.001
.1
g
d
s
Q2
100K
.01
d
Q1
g
s
1M
100
.1
1N4148 x 2
Q1 , Q2 MPF102
T1 30t primary, 3t secondary on a FT50-43 core
Feb 2005 by VE7BPO

Figure 1

The Tuned Whip

Previous experimentation confirmed that it is easy to tune a short whip antenna by connecting it to the hot end of an L C (inductor and capacitor) tank circuit. The high impedance whip antenna was "matched" to a JFET RF amplifier by placing a high value (1 megohm or greater) on the JFET gate to ground. Although this method is practical, I desired a network to transform the output impedance of the tuned whip tank tank circuit to a known impedance. I do not possess the knowledge or mathematical skill to design such a network and asked Wes Hayward if he might consider doing this for me. My desired parameters for the network were 10.0 MHz, a 50 ohm output impedance and a 4 foot (122 cm) whip. Please refer to Wes' calculations and schematic in Figure 2 below. This math is difficult, however, a practical design for experimentation is provided.

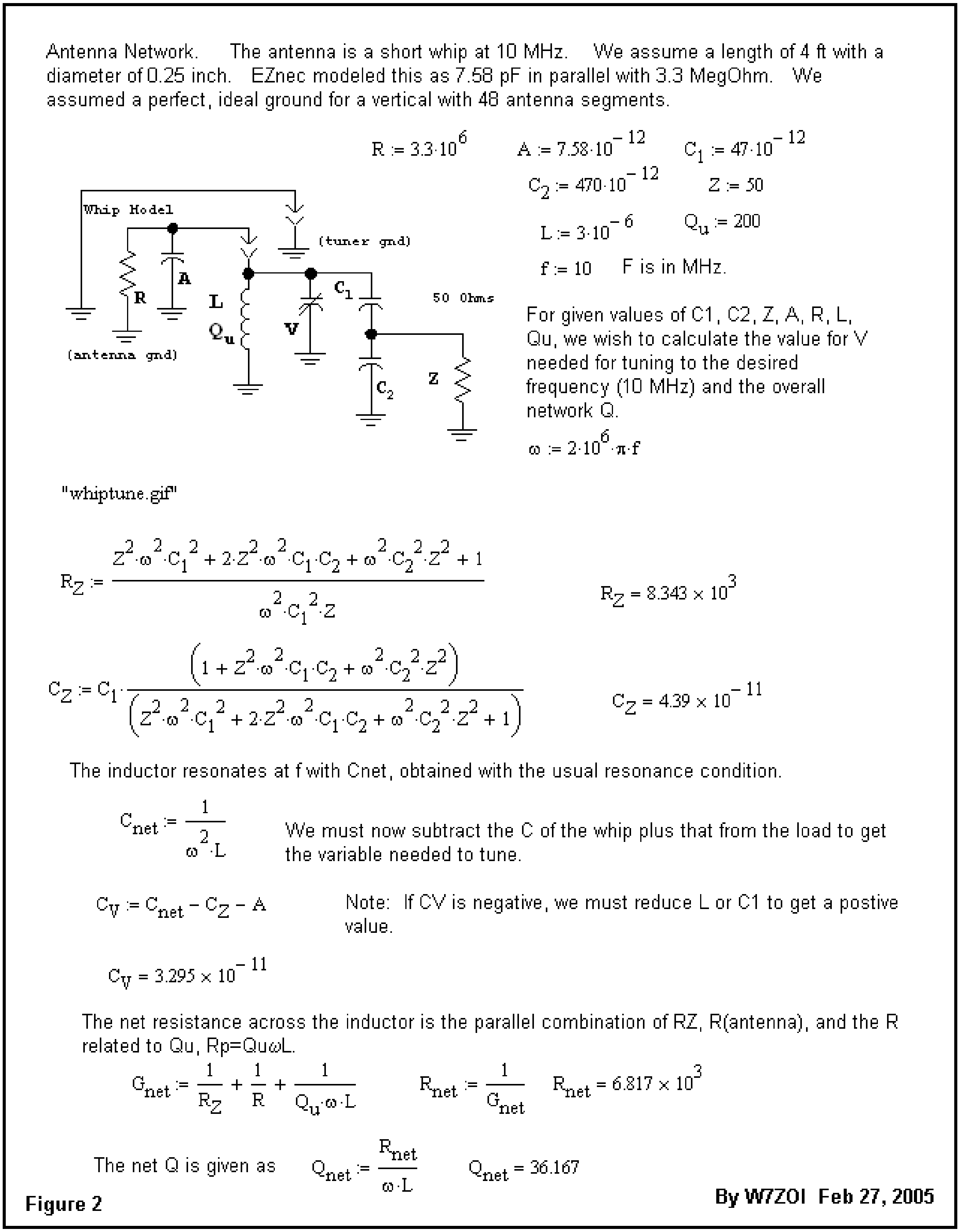

Antenna Network. The antenna is a short whip at 10 MHz. We assume a length of 4 ft with a diameter of 0.25 inch. EZnec modeled this as 7.58 pF in parallel with 3.3 MegOhm. We assumed a perfect, ideal ground for a vertical with 48 antenna segments.

$R := 3.3\cdot10^{6}$ $A := 7.58\cdot10^{-12}$ $C_1 := 47\cdot10^{-12}$

$C_2 := 470\cdot10^{-12}$ $Z := 50$

$L := 3\cdot10^{-6}$ $Q_u := 200$

$f := 10$ F is in MHz.

For given values of C1, C2, Z, A, R, L, Qu, we wish to calculate the value for V needed for tuning to the desired frequency (10 MHz) and the overall network Q.

$\omega := 2\cdot10^{6}\cdot\pi\cdot f$

"whiptune.gif"

$$R_Z := \frac{Z^2\cdot\omega^2\cdot C_1^{\,2} + 2\cdot Z^2\cdot\omega^2\cdot C_1\cdot C_2 + \omega^2\cdot C_2^{\,2}\cdot Z^2 + 1}{\omega^2\cdot C_1^{\,2}\cdot Z} \qquad R_Z = 8.343\times10^{3}$$

$$C_Z := C_1\cdot\frac{\left(1 + Z^2\cdot\omega^2\cdot C_1\cdot C_2 + \omega^2\cdot C_2^{\,2}\cdot Z^2\right)}{\left(Z^2\cdot\omega^2\cdot C_1^{\,2} + 2\cdot Z^2\cdot\omega^2\cdot C_1\cdot C_2 + \omega^2\cdot C_2^{\,2}\cdot Z^2 + 1\right)} \qquad C_Z = 4.39\times10^{-11}$$

The inductor resonates at f with Cnet, obtained with the usual resonance condition.

$$C_{net} := \frac{1}{\omega^2\cdot L}$$

We must now subtract the C of the whip plus that from the load to get the variable needed to tune.

$$C_V := C_{net} - C_Z - A$$

Note: If CV is negative, we must reduce L or C1 to get a postive value.

$$C_V = 3.295\times10^{-11}$$

The net resistance across the inductor is the parallel combination of RZ, R(antenna), and the R related to Qu, Rp=QuωL.

$$G_{net} := \frac{1}{R_Z} + \frac{1}{R} + \frac{1}{Q_u\cdot\omega\cdot L} \qquad R_{net} := \frac{1}{G_{net}} \qquad R_{net} = 6.817\times10^{3}$$

The net Q is given as $Q_{net} := \dfrac{R_{net}}{\omega\cdot L}$ $Q_{net} = 36.167$

Figure 2

By W7ZOI Feb 27, 2005

Common Gate Amplifier Version

I built the circuit shown in Figure 3 and Figure 4 and tested it on a medium grade SWL receiver (Realistic DX 300), rather than an expensive Amateur Radio receiver. I required this active antenna for experimenting with a 10 MHz WWV superheterodyne receiver I am designing. For practical analysis, VE7TW and I did listening tests with a commercially made 4 foot telescopic whip antenna that is fitted to a standard PL-259 connector (Figure 5) and his deluxe multi-band commercial SWL antenna up a 25 foot tower.

The Figure 3 VPA was very quiet
and pulled in WWV much better

than the plain 4 foot whip of Figure 5, however, received station signal strength was quite weak when compared to the outside antenna. Our conclusion was that considering the significant losses of the 4 foot whip antenna it was connected to, the common gate RF amp does not likely have enough voltage gain to please most builders. This amp did present a low impedance to the whip network and no spurious oscillation were measured on the bench. Do not omit the 22 ohm or similar value resistor in the drain of the FET. It is used to to push the UHF parasitic oscillation tendency into the ground. Such oscillations will trash your receiver mixer intermodulation performance.

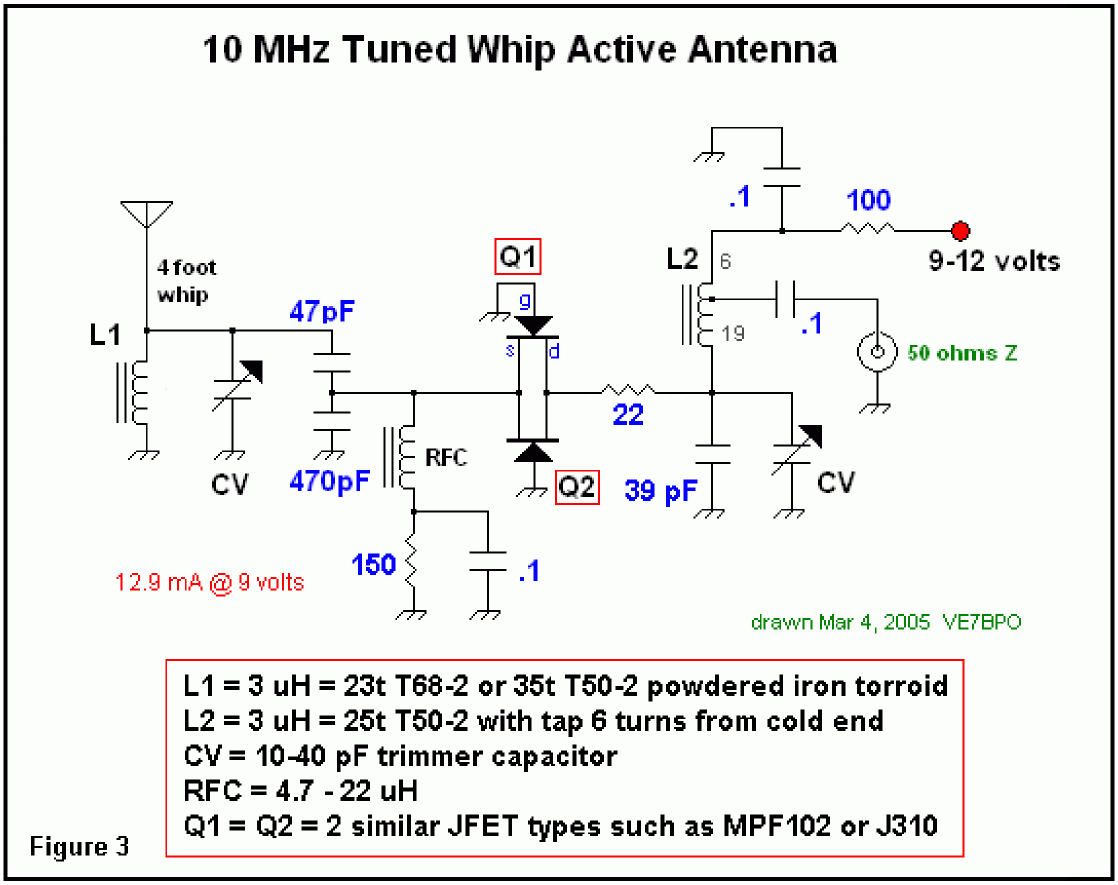

L1 = 3 uH = 23t T68-2 or 35t T50-2 powdered iron torroid
L2 = 3 uH = 25t T50-2 with tap 6 turns from cold end
CV = 10-40 pF trimmer capacitor
RFC = 4.7 - 22 uH
Q1 = Q2 = 2 similar JFET types such as MPF102 or J310

Figure 3

The 150 ohm source resistor can be increased in value and/or 1 of the JFETs removed if you wish to reduce the current draw on a 9 volt battery. It might be better to substitute 1 better JFET such as the J310 rather than use the "popcorn" MPF102 as shown. This VPA may be practical for a receiver that has an existing broadband RF preamplifier. The tap on L2 was found experimentally and the output impedance is probably higher than 50 ohms, but is likely a reasonable low impedance match to most receiver front ends. A broadband transformer for L2 might also be a good choice.

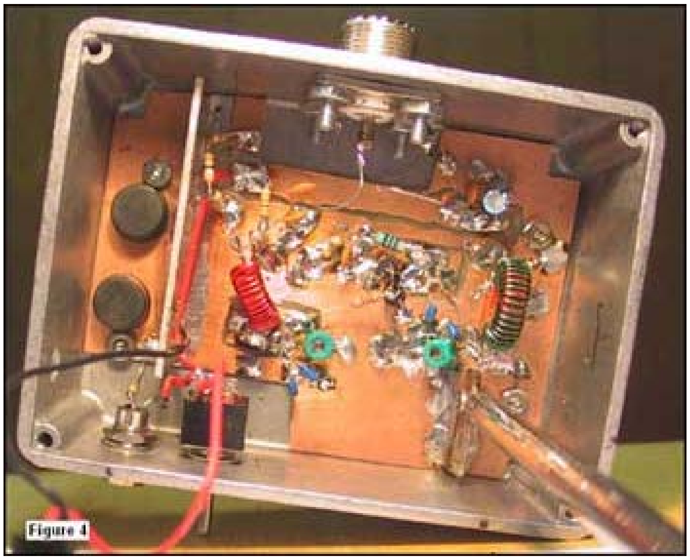
Figure 4

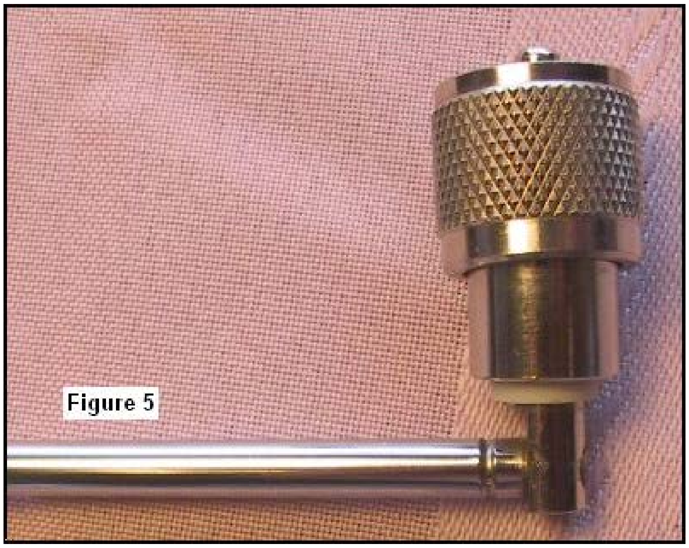
Figure 5

Figure 4 above: For the whip network, it is critical that you use a inductor that has an unloaded Q of 200 or above. Practically speaking, this means you cannot use a fixed value inductor such as an epoxy coated or molded RF choke. Use a powdered iron torroid instead. In my test VPA designs, for L1, I used a T68-2 core wound with (the green) 22 gauge enamel coated wire to get as high an unloaded Q as possible. If you use the T50-2 core, use 24 gauge wire if possible. Higher Q = lower losses.

Figure 5 above: This is a 4 foot whip antenna factory connected to a PL-259 that came with the Realistic DX300. It presents a very high impedance to the test receiver front end and probably wasn't a good choice to compare the VPA designs to.

Cascode JFET Amplifier Version

It was decided to use a cascode JFET amplifier to obtain more power gain. The whip network was changed to try to match the 10K input of the JFET amplifier shown in Figure 6. The whip network capacitor values (150 and 33 pF) were calculated to the best of my ability. This amplifier was tested in the same manner as the Figure 3 design. It worked very well. The WWV signal that morning was not very strong and could not even be heard with the plain 4 foot whip. The signal strength of the tuned whip was just below that of the outside antenna. The outside antenna was much quieter however and had less fading. The tuned whip antenna was quite noisy in comparison. The high gain RF amp brought up the strength of the environmental noise sources in the house. The RF gain of the receiver was reduced to compensate for the added noise.

Another problem was noted with this and other tuned drain versions of the cascode JFET amplifier; instability.

Recently, I connected a tuned drain version of the Figure 1 VPA to a receiver that contained a tuned input stage and was able to measure oscillations in the VPA with my scope. The FET drain tank and the tuned input amp seemed to be interacting.

A "swamping" resistor was placed across the VPA drain tank circuit. I had to use a resistor value of less than 1200 ohms to eliminate this instability. This greatly reduced the gain and selectivity advantage of a tuned output and I realized that output tuning may be impractical for many reasons. Some SWL builders use regenerative receivers and such a problem would be disastrous. I sent the Figure 6 schematic to Wes Hayward and he suggested using a broad or wide band amplifier as shown in Figure 8.

Instability can also occur in broadband output versions and a swamping resistor is still necessary but is used mostly to force an output impedance so that a transformer can be designed.

All of the cascode JFET amplifiers shown have fixed bias on Q2. Variable gain is possible by changing the bias voltage on Q2 with a voltage divider and/or modifying the amplifier circuit to give a greater range of bias controlled voltage gain. Please refer to EMRFD page 6.17 for information regarding this. A switchable resistor attenuator might also be practical for some builders.

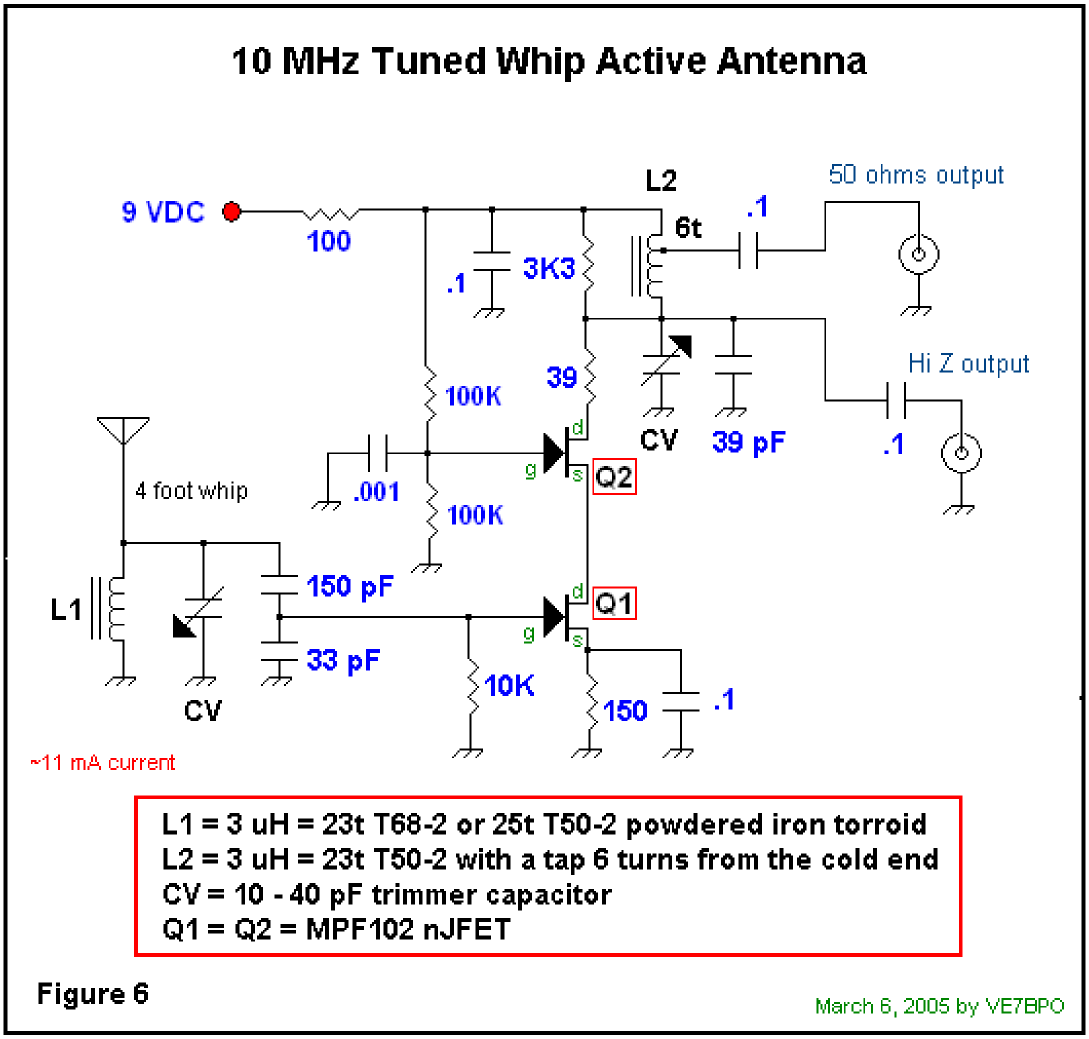
10 MHz Tuned Whip Active Antenna
9 VDC
100
.1
3K3
L2
6t
.1
50 ohms output
39
CV
39 pF
Hi Z output
.1
100K
d
g
s
Q2
4 foot whip
.001
100K
L1
150 pF
d
Q1
g
s
CV
33 pF
10K
150
.1
~11 mA current
L1 = 3 uH = 23t T68-2 or 25t T50-2 powdered iron torroid
L2 = 3 uH = 23t T50-2 with a tap 6 turns from the cold end
CV = 10 - 40 pF trimmer capacitor
Q1 = Q2 = MPF102 nJFET
March 6, 2005 by VE7BPO

Figure 6

Figure 6 above: The tuned whip network is connected to a cascode JFET amplifier. A dual gate MOSFET would also be a great choice. I have many on hand, but chose the cascode JFET topology because many builders no longer have access to these devices or prefer not to use the more available surface mount types. They are also more expensive.

Figure 7 to the right: Detail of the tapped L2 inductor should you decide to experiment with a tuned drain version or need one for another project. Wind your coil and leave an extra long loop for your wire tap. Cut the tapped loop at the midpoint and use a small piece of folded ~150 grit sandpaper to remove the enamel from each of the 2 wires. Twist the now bare wires together and lightly solder them. Cut the end wires to the required length and use the sandpaper to remove the enamel. A method to strip enamel off wire is a frequently asked question for me and sandpaper works well.

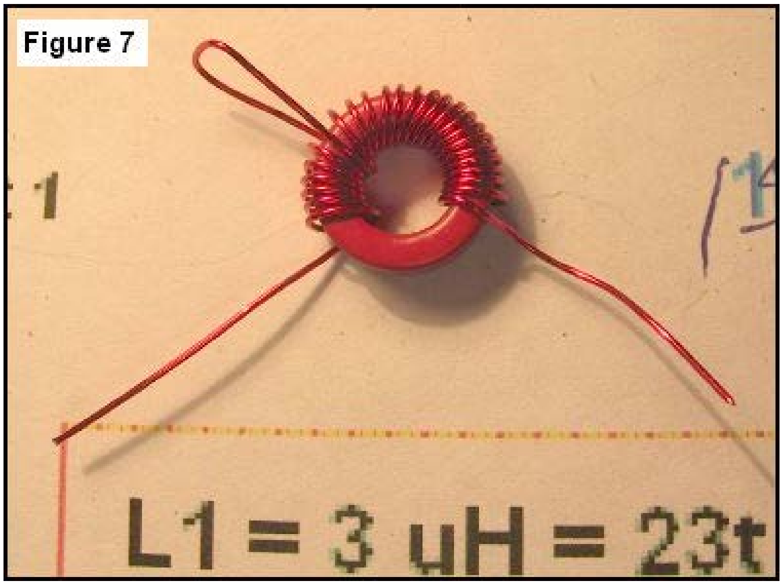

Figure 7

Broadband Output Version

Figure 8: The broadband version W7ZOI suggested to try building. I modified the output transformer in the Figure 6 project and tested it with Tom, VE7TW. We really liked it. By adjusting the network trimmer capacitor, I was also able to tune the 30 meter Amateur radio band as well. For 30 meter band use, I peaked the tank circuit at 10.125 MHz by listening to receiver noise with a home brew direct conversion receiver and was suitably impressed.

This is the active antenna design I wll use for my future projects where strong voltage gain is required. If your receiver has a higher impedance such as 500 ohms, you might try using a couple more links on the output transformer secondary winding.

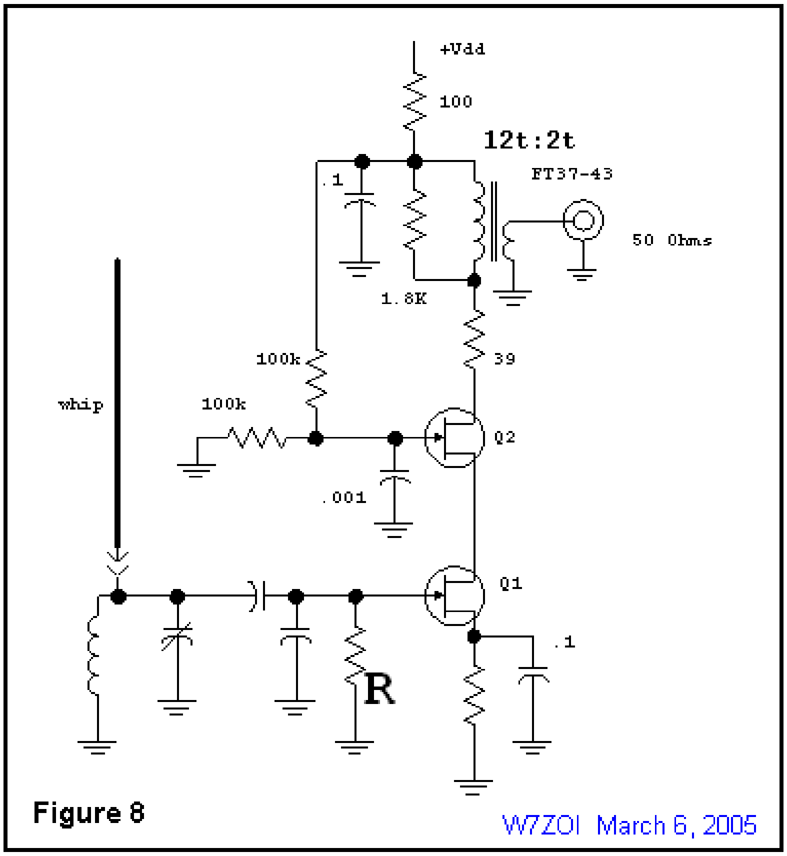

Figure 8

Tuning a Whip To Other Frequencies

The ability to calculate the network values for different frequencies may prove difficult for those who lack software and/or math skills. To that end, a table follows which has some radio frequency bands and some suggested starting values for the Figure 9 parameters. Please note these are calculated and are suggested starting points based upon my limited understanding of radio electronics. Experimentation is the best method to find what component values will work for you.

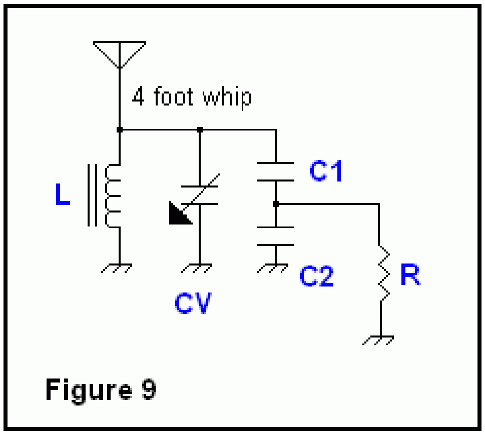

Figure 9

Emails regarding the component values used in actual experiments is greatly welcomed.

The **R** value is the input impedance of your RF amplifier. In the case of the cascode JFET amp, it is the Q1 gate resistor.

Note that the actual circuit CV value is typically much lower than the suggested (calculated) CV value from the chart. CV is used to **resonate** the tank. CV is dependent on several factors including the capacitance of the whip antenna, your RF amplifier input capacitance , your circuit layout, component lead lengths and variations in the powdered iron core and C1 and C2 capacitors values. Expect that your whip antenna will exhibit between 8 and 15 pF of capacitance. You need to subtract this from the suggested (calculated) CV value from the Figure 10 table.

Wes, W7ZOI told me that the whip antenna capacitance will remain constant as you change frequency providing you are below 1/4 wavelength for a given frequency. Here is a good web site applet to calculate wire or whip 1/4 or 1/2 wave lengths per frequency: http://www.csgnetwork.com/antennagenericfreqlencalc.html.

The actual circuit CV might include a trimmer capacitor plus a parallel fixed value capacitor.

How to find the correct trimmer capacitor for any tuned circuit you wish to resonate

I suggest you chose a circuit CV value by placing a variable trimmer capacitor in your circuit that when set to minimum will be below half or more than the calculated CV value. Then peak the whip tank circuit using a test oscillator and scope or RF probe or by just using receiver noise. Now temporarily add a 5-10 pF capacitor in parallel with trimmer capacitor. Just barely solder it in place or even just hold it in place without touching the leads. If the output increases, you were under the correct circuit CV value. Add more capacitance and check again. Repeat until you are satisfied with your chosen circuit CV value.

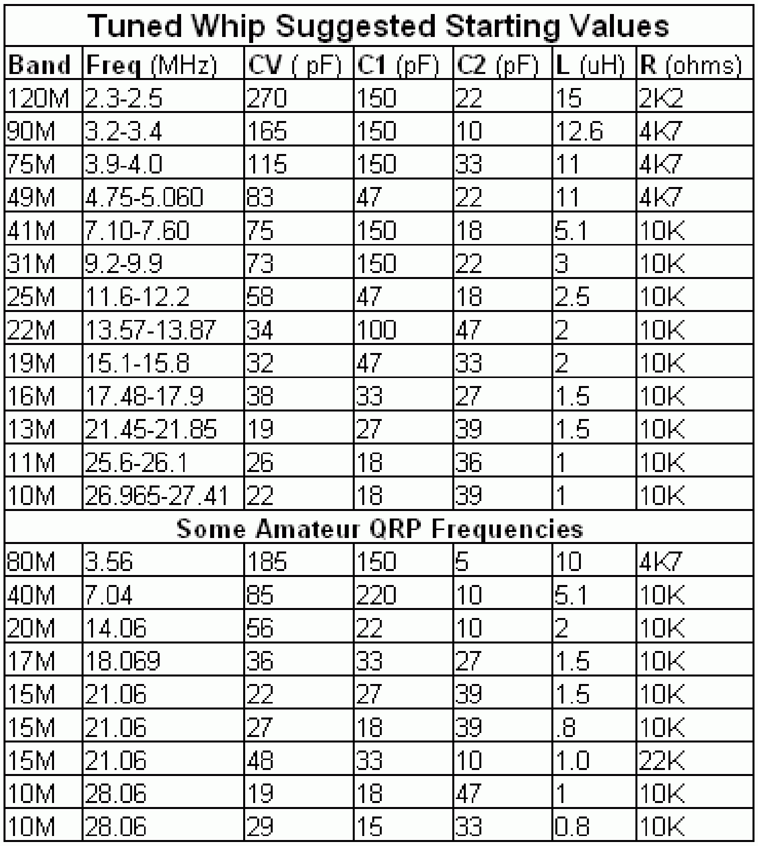

Tuned Whip Suggested Starting Values						
Band	**Freq** (MHz)	**CV** (pF)	**C1** (pF)	**C2** (pF)	**L** (uH)	**R** (ohms)
120M	2.3-2.5	270	150	22	15	2K2
90M	3.2-3.4	165	150	10	12.6	4K7
75M	3.9-4.0	115	150	33	11	4K7
49M	4.75-5.060	83	47	22	11	4K7
41M	7.10-7.60	75	150	18	5.1	10K
31M	9.2-9.9	73	150	22	3	10K
25M	11.6-12.2	58	47	18	2.5	10K
22M	13.57-13.87	34	100	47	2	10K
19M	15.1-15.8	32	47	33	2	10K
16M	17.48-17.9	38	33	27	1.5	10K
13M	21.45-21.85	19	27	39	1.5	10K
11M	25.6-26.1	26	18	36	1	10K
10M	26.965-27.41	22	18	39	1	10K
Some Amateur QRP Frequencies						
80M	3.56	185	150	5	10	4K7
40M	7.04	85	220	10	5.1	10K
20M	14.06	56	22	10	2	10K
17M	18.069	36	33	27	1.5	10K
15M	21.06	22	27	39	1.5	10K
15M	21.06	27	18	39	.8	10K
15M	21.06	48	33	10	1.0	22K
10M	28.06	19	18	47	1	10K
10M	28.06	29	15	33	0.8	10K

Figure 10

If after adding the initial 5-10 pF capacitor, the output decreases, try peaking the tank again to see if you can restore the signal strength you had before you added the temporary capacitor. If after peaking, the signal strength is down, you now have too much capacitance and can remove the temporary capacitor.

You just might also have too much capacitance. You might try a smaller variable cap or reduce the value of any fixed capacitors in parallel with your trimmer to make sure your minimum capacitance is not too high to properly resonate the input tank circuit.

The point is you need to be able to tell if you have too little or too much capacitance for CV and by going under and over you can tell if you are truly resonating the tank when you adjust the trimmer capacitor. Experimentation will tell you.

Another option is to put in a front panel adjusted variable capacitor. Front panel switchable inductors might also allow other bands to be tuned with 1 tuned whip network.

Moving your body as you adjust the trimmer capacitor can change the tuning, so please keep this in mind.

Figure 10 above. Picking an inductor value for the whip network can be tricky and sometimes trial and error is required. This table may be used to find starting values for the Figure 9 network. Below 41 meters, I suggest trying a lowered RF amp input impedance as shown to allow practical component values. Most of these calculations have not been tested.

I think an indoor active antenna for 74 meters or below might just be a noise generator.

I chose a frequency mid band for any given SWL band on the chart. The bandwidth of the input network is wide enough so this should be suitable to cover a good portion of the band.

Building An Active Antenna

To build this active antenna, chose the input tank network values from the Figure 10 chart or from your own calculations and then use them in the Figure 6 circuit. The Q1 source resistor can practically be from 100 to 390 ohms depending on how long you need your 9 volt battery to last. Increasing this resistor value will reduce the amplifier power gain. Try different values and see for yourself!

Some Practical Examples: 40 and 41 Meter Band

An active antenna that would provide coverage of the entire 40 meter Amateur Radio and 41 meter Shortwave band was designed. A varactor diode was used as the tuning element. The tuning voltage to the varactor was controlled by a 10K potentiometer which also had an integral switch. The finished VPA is shown in Figures 11 and 12.

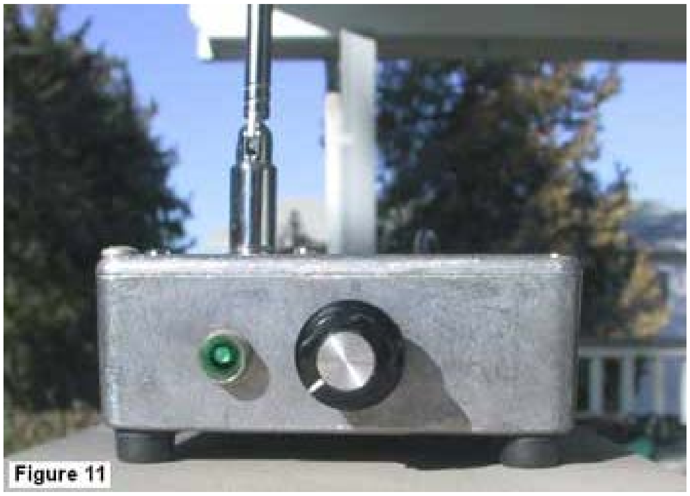
Figure 11

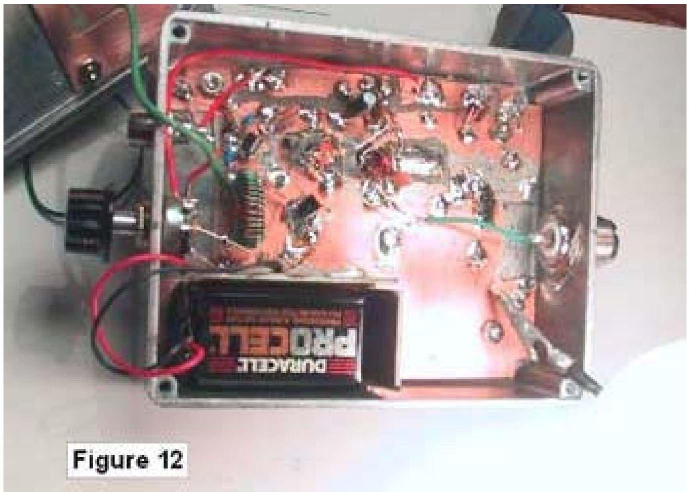
Figure 12

Figure 13 below: A hotter JFET, the J310 was used in this VPA. In the test receiver, I was able to peak a signal from ~ 6.90 to 7.60 MHz. Tuning is very sharp but peaking is easily performed by turning the potentiometer gently back and forth while listening to receiver noise or a station. It might have been better to use a smaller value zener diode as when the 9 volt battery fades below 7.5 VDC, the zener diode will not conduct and the voltage regulation will fail. Having said that, this "hotter" VPA is intended for use with an external power supply as current draw at 9 and 12 volts is 19 mA and 28.9 mA respectively.

I tried using this VPA as the antenna for the Cascode 7 receiver shown elsewhere on this web site. When the VPA was peaked at the receiver tuning frequency, loud oscillations occurred. The receiver and the VPA were about 1 meter apart. I had to turn on the -10 dB attenuator and detune the VPA for the oscillations to stop. Moving my hand near the whip antenna varied the oscillations. The high gain, tuned circuits of the Cascode 7 receiver are not a good choice for an active antenna.

Future receivers projects will have a integral VPA and clearly the front end of these receivers will have to be designed carefully. A low cost Grundig receiver was also overloaded with this VPA.

This VPA worked well with other receivers which did not have a tuned, high gain preamp.

Figure 14: From the chart, the MV209 exhibits about 44 pF (guessing) when 0 volts are

applied to it.

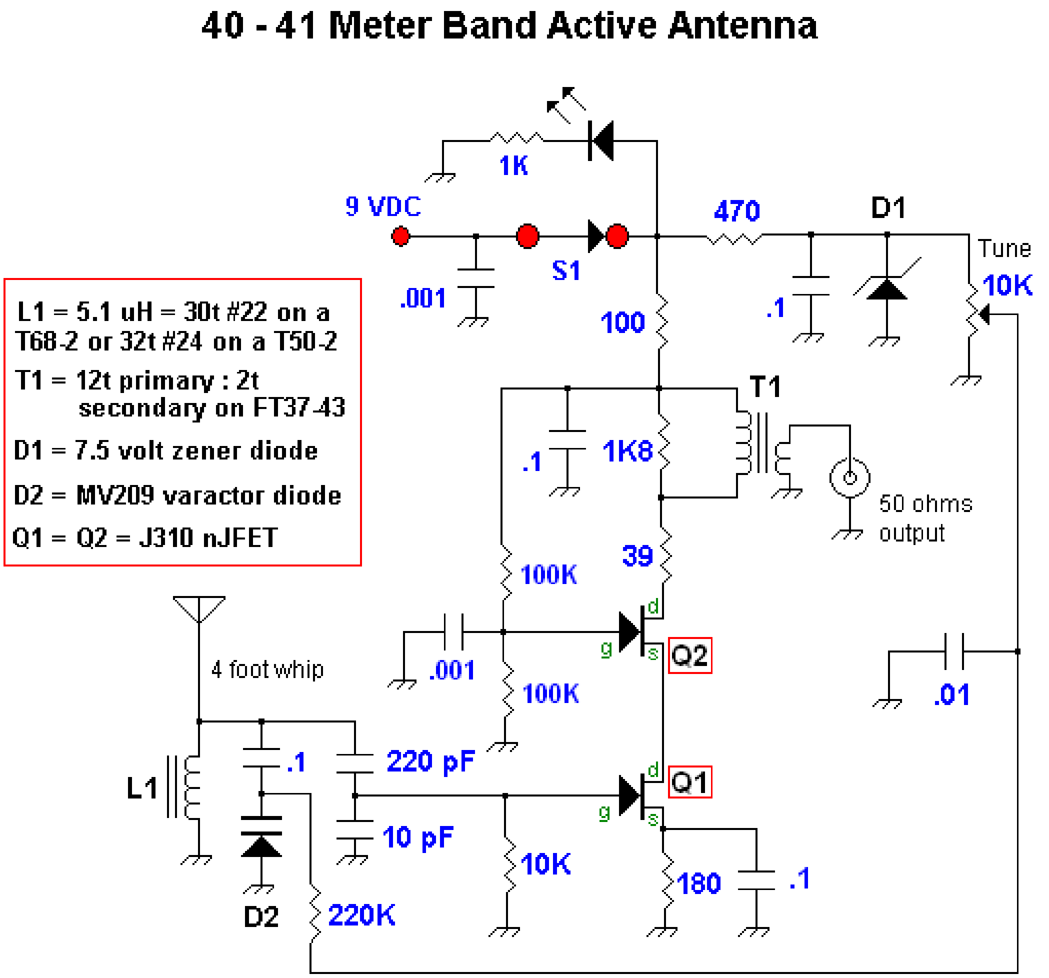
40 - 41 Meter Band Active Antenna
1K
9 VDC
S1
.001
470
D1
Tune
10K
100
.1
L1 = 5.1 uH = 30t #22 on a T68-2 or 32t #24 on a T50-2
T1 = 12t primary : 2t secondary on FT37-43
D1 = 7.5 volt zener diode
D2 = MV209 varactor diode
Q1 = Q2 = J310 nJFET
T1
.1
1K8
50 ohms output
100K
39
d
g
s
Q2
4 foot whip
.001
100K
.01
.1
220 pF
d
Q1
L1
g
s
10 pF
10K
180
.1
D2
220K
Mar 12, 2005 VE7BPO

Figure 13

The VPA was built and tested before the tuning diode components were added. A 7.039 MHz crystal oscillator with a piece of wire for an antenna was used as an RF source. The T2 secondary was connected to ground via a 47 ohm load resistor.

A 47 pF fixed capacitor was lightly soldered in parallel with L1 and the voltage was measured with an oscilloscope. A 10 pF capacitor was then carefully held across L1 and the voltage increased by 0.25 volts. A 22 pF capacitor was then tried and the voltage decreased much below that of just the 47 pF capacitor. The nearest standard value I had on hand above 47 pF was 56 pF. The 47 pF capacitor was removed and replaced with the 56 pF one. I tried holding a 5 pF capacitor in parallel with the 56 pF and the measured voltage decreased. I had experimentally determined that to resonate L1 at 7.039 MHz I needed between 47 and 56 pF for the CV value. This range should be close enough to resonate the tank at 7.0 MHz as well.

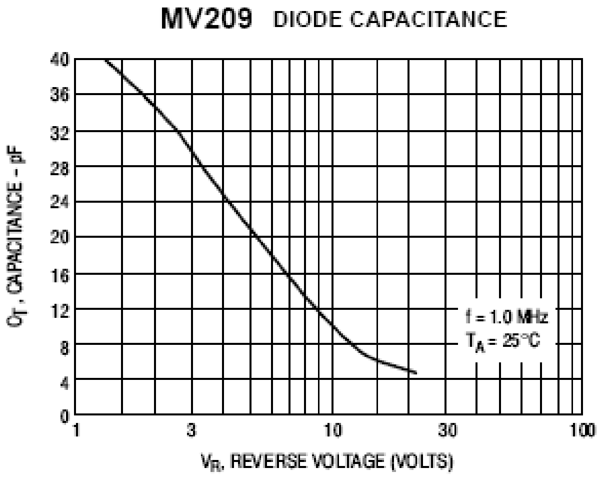

Figure 14

I then chose a varactor diode. The MV209 would be perfect for my project based upon the Figure 14 chart. I anticipated that I might have to place a small trimmer capacitor in parallel with the varactor to resonate the tank at the my lowest design frequency which was 7.0 MHz. As it turned out, in addition to the varactor capacitance, the voltage control circuit added additional capacitance and I actually needed 0.30 volts (measured between the 10K pot and the 220K resistor) to resonate the whip at 7.039 MHz. This was perfect; I did not need a trimmer capacitor! At 0 volts to the varactor diode, my whip resonated ~ 6.90 MHz.

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5 MHz WWV Cascode Bipolar Amplifier

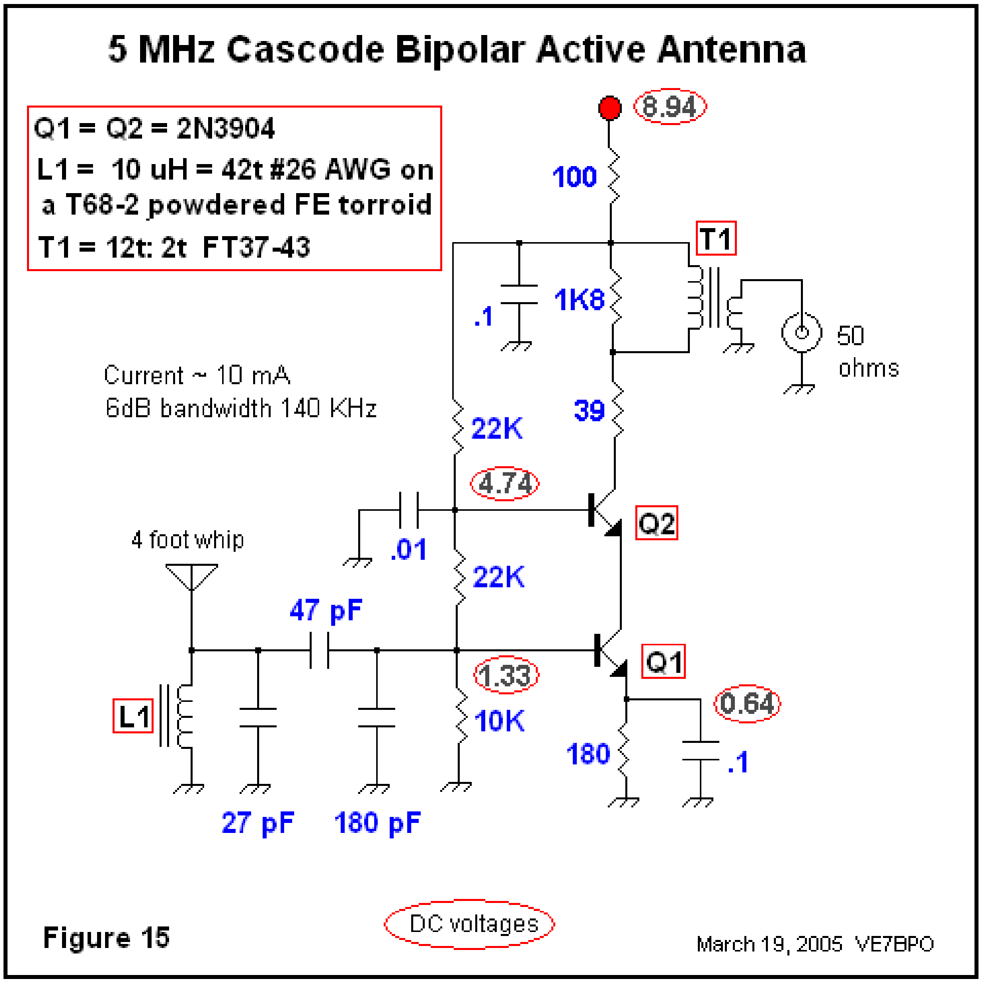

Figure 15

I wanted to build a non-FET version as shown in Figure 15. The tuned whip tank was originally resonated with a 5 - 40 pF trimmer capacitor. I unsoldered this trimmer capacitor and measured it with a meter; it was 27 pF. A 27 pF fixed value capacitor was soldered in and tested. The circuit was resonant at 4.98 MHz. This was close enough for me and also the 3 high Q fixed value capacitors provided a very narrow 6 dB bandwidth along with the inductor. The output impedance value of the tuned whip is around 200 ohms to match the Q1 bipolar amp input impedance.

Listening tests indicated that this circuit probably had too much gain at 5 MHz. It might be favorable to lower the Q1 emitter current to 7 mA or so by raising the Q1 emitter resistor or decreasing the Q1 bias voltage. Also, a series feedback, degenerative resistor on the Q1 emitter might be considered. This active antenna was comparable to the outdoor reference aerial for signal strength, however, predictably was much noisier.

Final Comments

I found that using lower Q trimmer and fixed value capacitors undesirably increased the tuned whip bandwidth presumably by lowering the resonant circuit Q. The inductor unloaded Q was the dominant factor however. The worst case scenario was a tuned whip built with junk-quality parts which had a -6 dB bandwidth of ~390 KHz.

I also learned that you should expect high gain amplifiers to oscillate and specifically design to reduce or suppress this tendency.

The 2005 Active Antenna experiments were fun and provided many learning opportunities. An active antenna is a perfect weekend project. There is no substitute to learning by building and testing electronic circuits with your own hands.

My sincere thanks to all of the friends who helped me with these experiments.

Experiments by Other Builders

What follows are some VPA experiments by others that were sent to me by email. I seek your feedback and photographs to help improve this web site and also to gain motivation to add more new content.

Joe, K9LY
Hi, Todd :

Attached are some photos of a voltage probe amplifier that I built using ideas from your excellent website. I use a TenTec 1254 receiver in the car and listen to some shortwave broadcasts during the daily commute to and from work. The antenna is a 4-foot whip that screws into the trunk-lip mount shown. The amplifier is held to the bottom of the trunk lid by a magnet and has survived for several weeks without falling off.

The amplifier is tuned by a varicap diode and covers approx. 9-14 MHz. The tuning voltage comes from a potentiometer that I added to the front panel of the receiver.

I decided to use the 2N3904 cascode amplifier because I liked the idea of using the most common transistor possible. The LC-tuned input is nice because the antenna whip is held at chassis ground potential, which should help prevent damage to the amp caused by static buildup.

The TenTec 1254 Receiver. http://radio.tentec.com/kits/Receiver

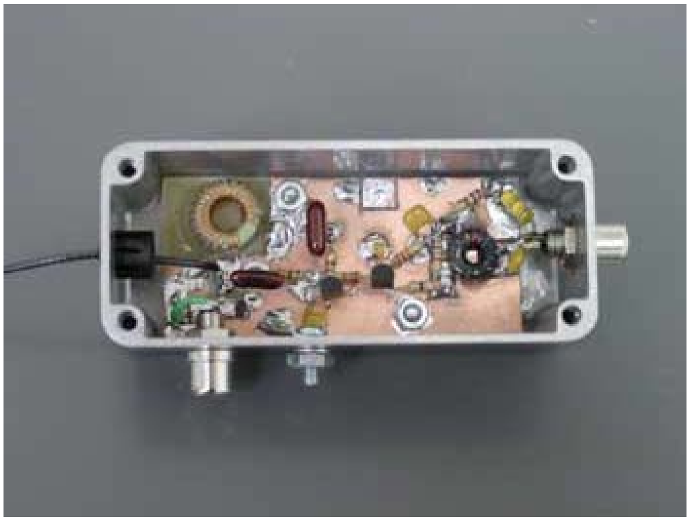

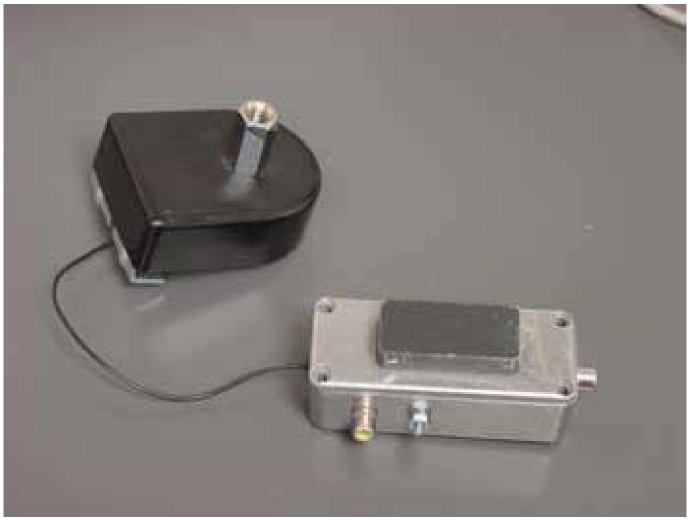

Above left: Inside Joe's trunk lid SWL Active antenna. Great ugly construction in a sturdy Hammond chassis.
Above right: Joe's remotely tuned SWL active (or voltage probe) antenna amp and whip holder. Thanks Joe!

QRP SWL

HOMEBUILDER

Amateur and Short Wave Radio Electronics Experimenter's Web Site

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Fun with LEDs

Introduction

This summer I built several LED projects including sequential LED chasers (sequentially left to right) and also "Nite-Rider" style which go (sequentially left-right-left-right-etc). Many more LED schematics can be found on the World Wide Web via a Google search. LED projects are great fun for both HAM's and SWL's alike. They are also a lot of fun for children to experiment with. Currently, I am experimenting with PIC microcontrollers to perform LED "tricks".

I also built several very bright LED flashlights which run on a single 1.5 volt battery. For ultra-bright LED flashlight schematics, check out Dick Cappel's excellent and very informative web site. He has a number of LED driver circuits and other great schematics and theory. To wind the inductor for these LED flashlights, I had good success using an FT-37-43 ferrite torroid core. I used at least 40 turns of wire which is generally center tapped.

LED Chasers

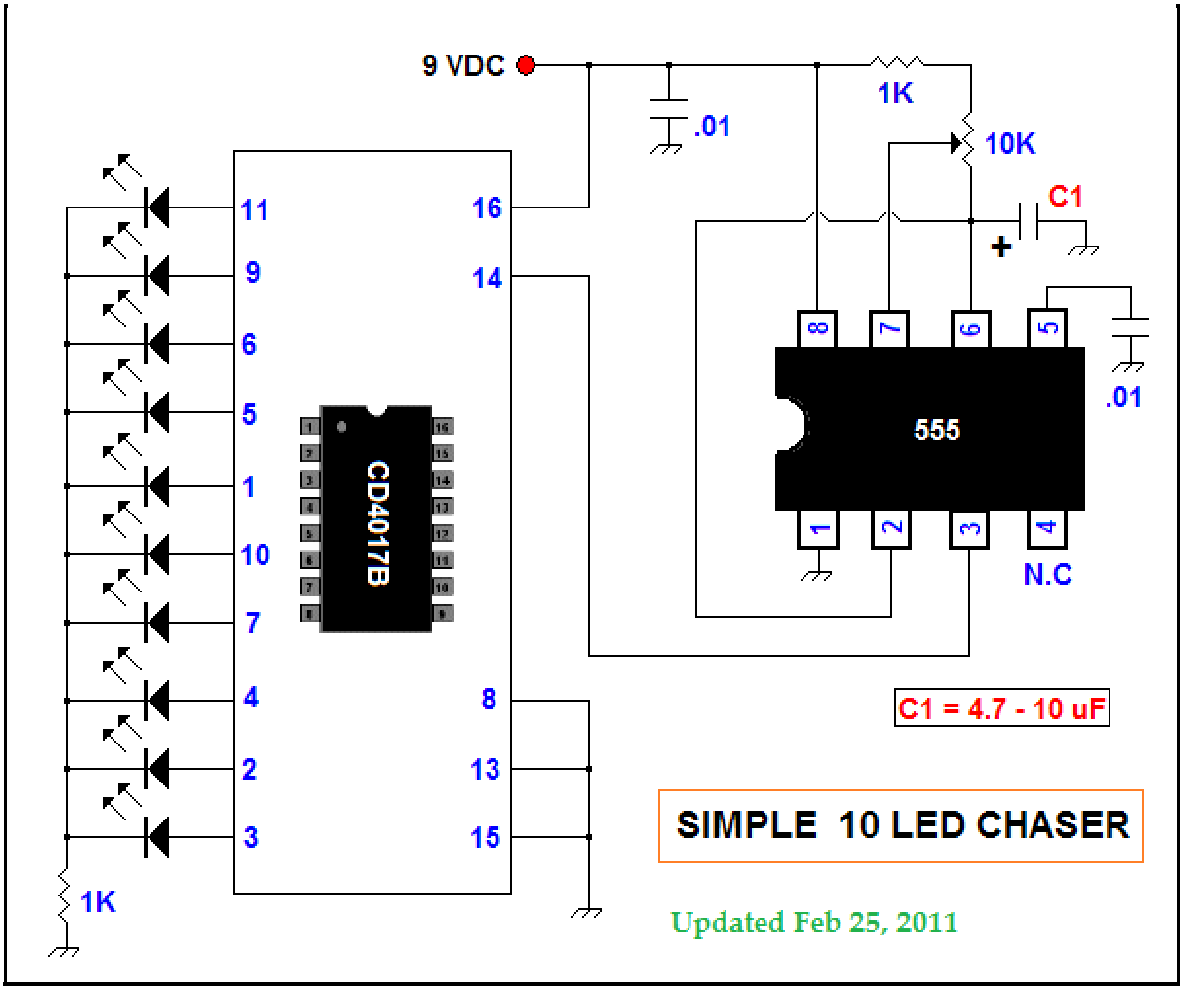

Above. This is the schematic for a ***very*** basic 10 LED chaser I built. I prefer my "chasers" to run slower than most and chose a 10 uF capacitor for C1. The 10K pot can reduce the flash speed from not moving to whatever minimum time constant is possible with the C1 value you choose. Don't bother with ultra-bright LEDs for these "chaser" projects as cheaper, lower millicandela (mcd) LEDS work fine. I favor blue and green LEDS. The 4017 decade counter is a fabulous part and can be driven to flash a row of LEDs with a 555 timer chip or a discrete BJT multivibrator.

Update Feb 25, 2011: Many "experts" have emailed, or flamed me on web forums to say this circuit can't possibly work. I really hope these unhappy men cultivate enough humility to study and understand the 555 and more importantly; to reap some of the happiness and joy that comes from being positive and helpful to others. Since 2005, greater than 300 builders have emailed to say this simple circuit works and they want to learn more about electronics.

My intent was to have the least number of parts to flash some LEDs. Some new builders become overwhelmed when the parts count is high — I once shared this fear and relate. You'll see a number of different bias circuits for the 555. Many builders run the reset pin; **Pin 4** high (connected to the 9 volt battery) and as a rule, this is a good thing to do, but it's not necessary for the circuit to work. Pin 7 is an open collector output to ground — its primary purpose is to discharge the capacitor.

It's important for the DC voltage in the pot wiper to not become too close to the + 9 volt rail or VCC (This happens when when the pot is rotated so that maximal DC voltage appears on pin 7), as pin 7 would draw excessive current. In my original schematic I left out a series resistor from VCC to the pot to eliminate this problem. After some thought, I added a 1K resistor on Feb 25, 2011, although this limits the rate somewhat. I run the pot on my circuit about mid-range and it hasn't been re-adjusted (or turned off) since 2005.

Also, the rotated pot wiper shouldn't get within a couple of hundred ohms of the capacitor as that too would cause excessive current spikes into pin 7. Generally, I prefer not to have much current on the wiper of a pot or, at least, try to keep the current small. Often, you can use a pot to set the desired timer speed and then remove, measure and substitute 2 standard value fixed resistors. A better way is to use math and calculate the resistor values, but this involves math and some people want nothing to do with equations.

This circuit is meant to provide a minimalist working circuit, but doesn't provide a great example of 555 design. Happily, for those wanting to learn more, countless great 555 tutorials may be found on the web. One of my 555 favorite sites is that managed by fellow Canadian Rob Paisley. Increasingly, I am exchanging electronics-related emails with model railroad enthusiasts across the globe and many of them know of Rob's wonderful web site.

Matthew Ritchie built and posted a nice version of the LED Chaser on YouTube. A reader sent in this breadboard photo.

By far, the coolest device incorporating the LED chaser lies within a sculpture called Cyanic by Seattle-area artist Allet. Click for his web site. Cyanic may be found on the New Sculpture Build section on his web site. You have to start the Quick Time video manually with a mouse click. I love Allett's work and his lastest light sculpture exemplifies how the Internet can unite creative people with a positive attitude.

A 10 LED sequential flasher in a blue Hammond chassis. The schematic is shown above.

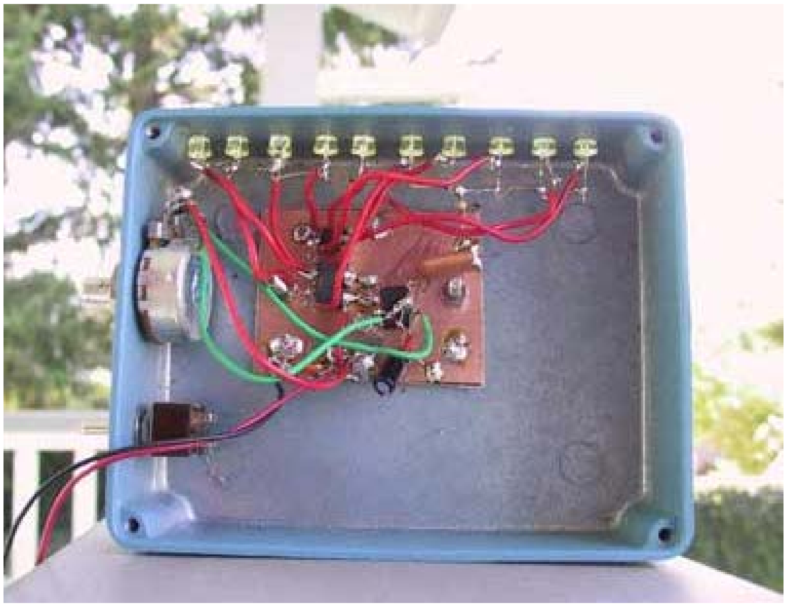

An RC oscillator designed for a 3 volt LED chaser. It oscillates quite slowly so the LED chaser it triggers will not be overly distracting. Some RC oscillator design details are discussed later. This oscillator triggered a 4017 decade counter instead of the 555 timer chip shown in the "Simple 10 LED Chaser" schematic. There are many links describing the theory of the 2 transistor astable multivibrator on the World Wide Web. I also have some information on this web page.

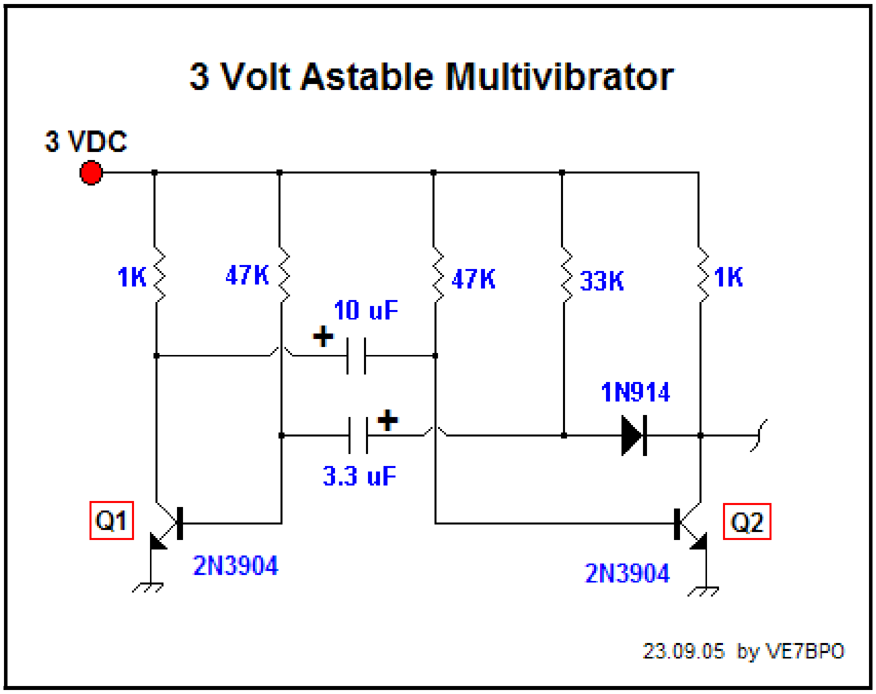

Above . This is a tiny 3 volt chaser which uses an LED bar instead of discrete LEDs. It draws 3.8 mA peak current on pulses. It uses the optimized BJT astable multivibrator shown directly above which fires at ~120 cycles per minute (slowly). The 3 volt battery pack is hidden behind it and should last several months. Soldering the LED bar was not an easy task. The plastic Hammond case measures 2.46 by 1.38 inches (6.25 by 3.5 cm).

A schematic to allow the 4017 decade counter to sequentially flash 6 LEDS left-right-left-right-etc. Connect your favorite square wave oscillator to pin 14. I built 4 of these using various oscillators and LED colors. You might consider using lower DC voltages and if so, may adjust the 1K current limiting resistor by using ohm's law. The 10 small signal diodes may be any appropriate type including the 1N914 or 1N4148. None of my 4 projects exceeded 6 mA peak current draw, so battery life is excellent. I increased the 1K resistor to 1K5 in my 4th project as I found the LED's that I used too bright.

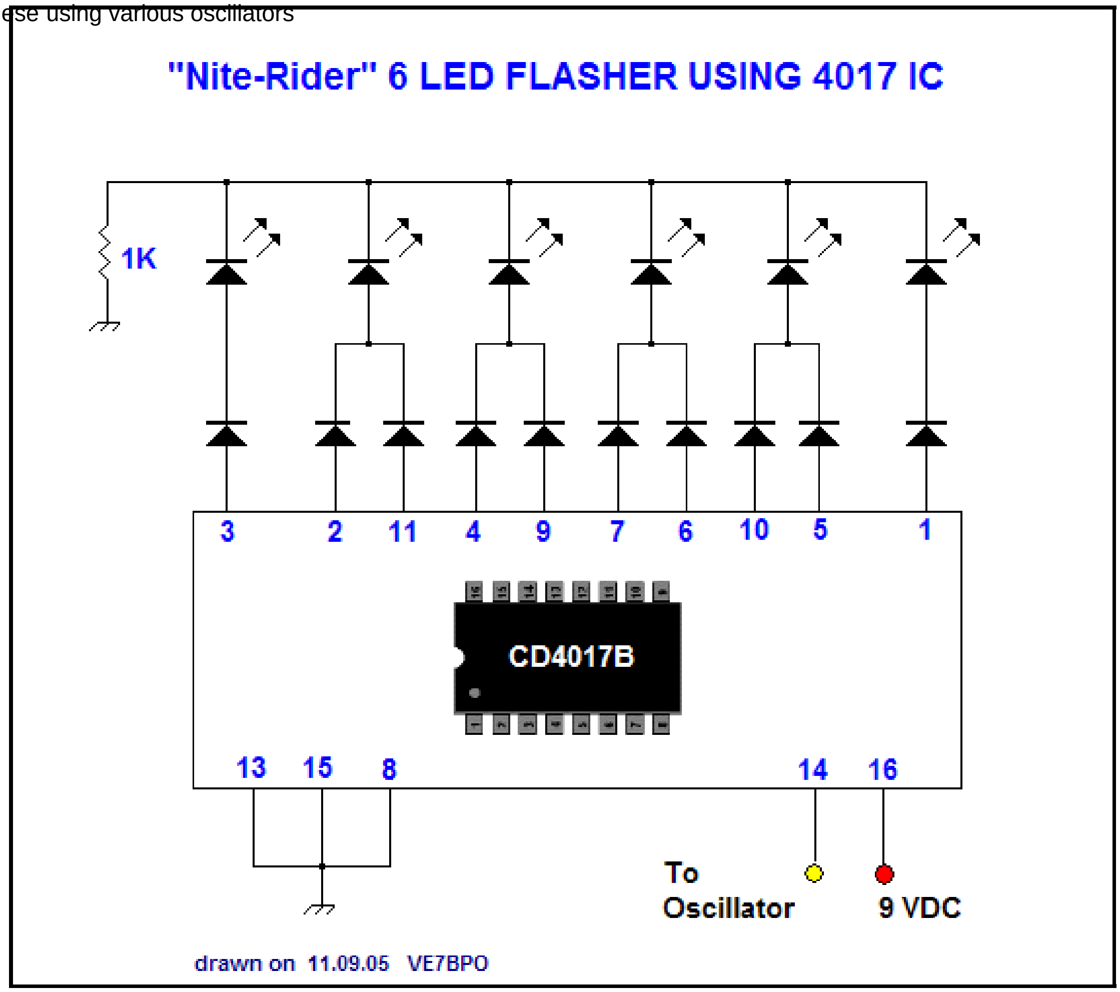
"Nite-Rider" 6 LED FLASHER USING 4017 IC
1K
3
2
11
4
9
7
6
10
5
1
CD4017B
13
15
8
14
16
To Oscillator
9 VDC
drawn on 11.09.05 VE7BPO

The prototype "nite-rider" project with messy wiring. The holes for the LEDs were bored with a hand drill and it shows! The discrete transistor multivibrator can be seen behind the 4017 IC.

One of the four "nite-rider"

project chassis I built. After completion, this one was given to the son of VE7KPB. When drilling in a plastic chassis, I learned it is best to use a drill press set to a lower speed.

Sequentially Off LED Pulser

This circuit uses a series of transistors with an RC pair to pulse a string of LEDs.

This the favorite LED experiment I performed this summer. This flasher circuit is different in that it turns **off** alternate LEDs for about 1 second in sequence. When you connect this circuit to the 9 volt battery, all of the transistors are usually placed in saturation and therefore all the LEDs are **on**. Closing the switch on the base terminal of Q1 for a moment initiates the correct pulse sequence. The pulse initiates in Q1 which turns off the LED connected to the Q1 collector for about 1

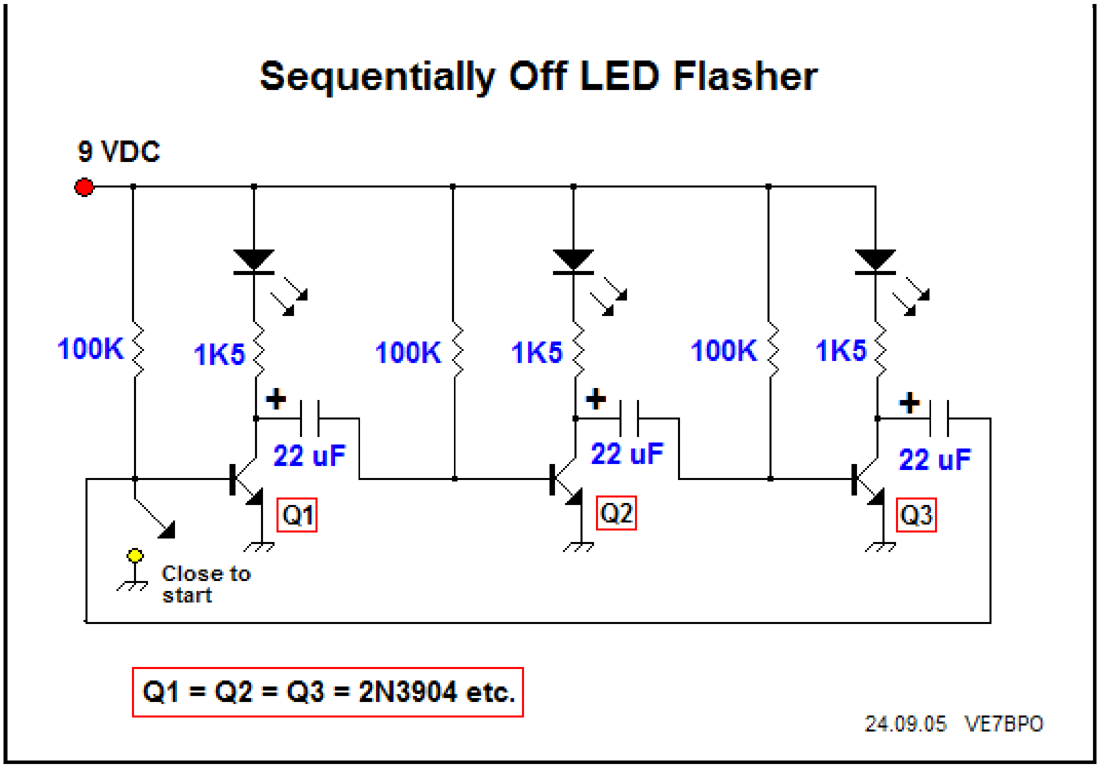
Sequentially Off LED Flasher
9 VDC
100K
1K5
100K
1K5
100K
1K5
+
22 uF
+
22 uF
+
22 uF
Q1
Q2
Q3
Close to start
Q1 = Q2 = Q3 = 2N3904 etc.
24.09.05 VE7BPO

second. When Q1 turns back on (goes into saturation), Q2 turns off. When Q2 turns back on then Q3 turns off and so on. The circuit is a closed loop and many more stages may be added.

You can experiment with different base resistor and coupling capacitor values to vary the speed of the LED string or to create a sense of randomness by varying each transistor's RC stage separately. This is a fun circuit!

Youtube link (not mine).

The prototype 3 transistor version. I just used a piece of wire to ground the Q1 base terminal and establish the correct pulse sequence after powering it up. For the LEDs, transistors, resistors and capacitors you can use whatever appropriate parts that you happen to have on hand. Current draw is less than 10 mA with a fresh 9 volt battery. Decrease the 1K5 current limiting resistor to 1K or so if you want brighter LEDs at the expense of more current draw. Do not operate this circuit above 9 volts unless you connect diodes from the transistor emitters to ground to prevent emitter-base breakdown.

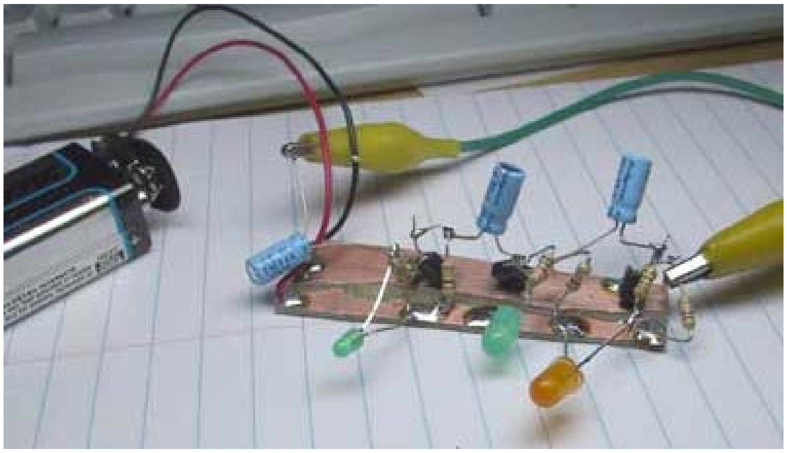

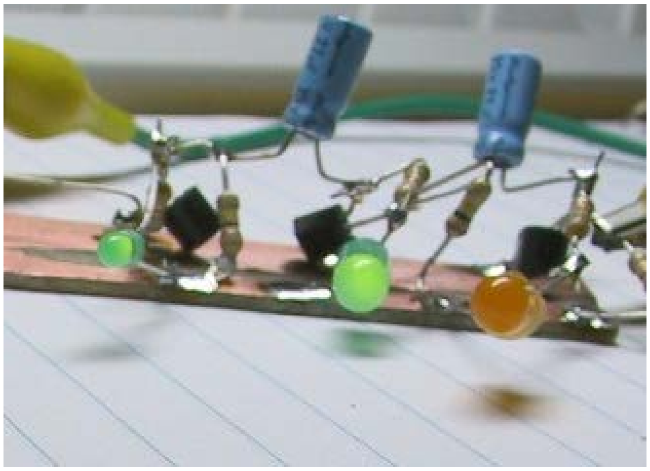

LED 1 and 2 are on and LED 3 is off at this moment in time.

Above and below photographs. This low current version has 9 LEDs connected in a chain and is powered by 3 volts. The 10th LED (extreme right hand side) is a flashing LED which is directly connected to the 3 volt supply and also uses a 1K current limiting resistor. Total peak current draw is only ~ 7 mA, yet it is still bright enough to see at night-time. The power supply is 2 D-cell batteries connected in series and then to the circuit by soldering wires directly onto the batteries with a 100 watt soldering iron.

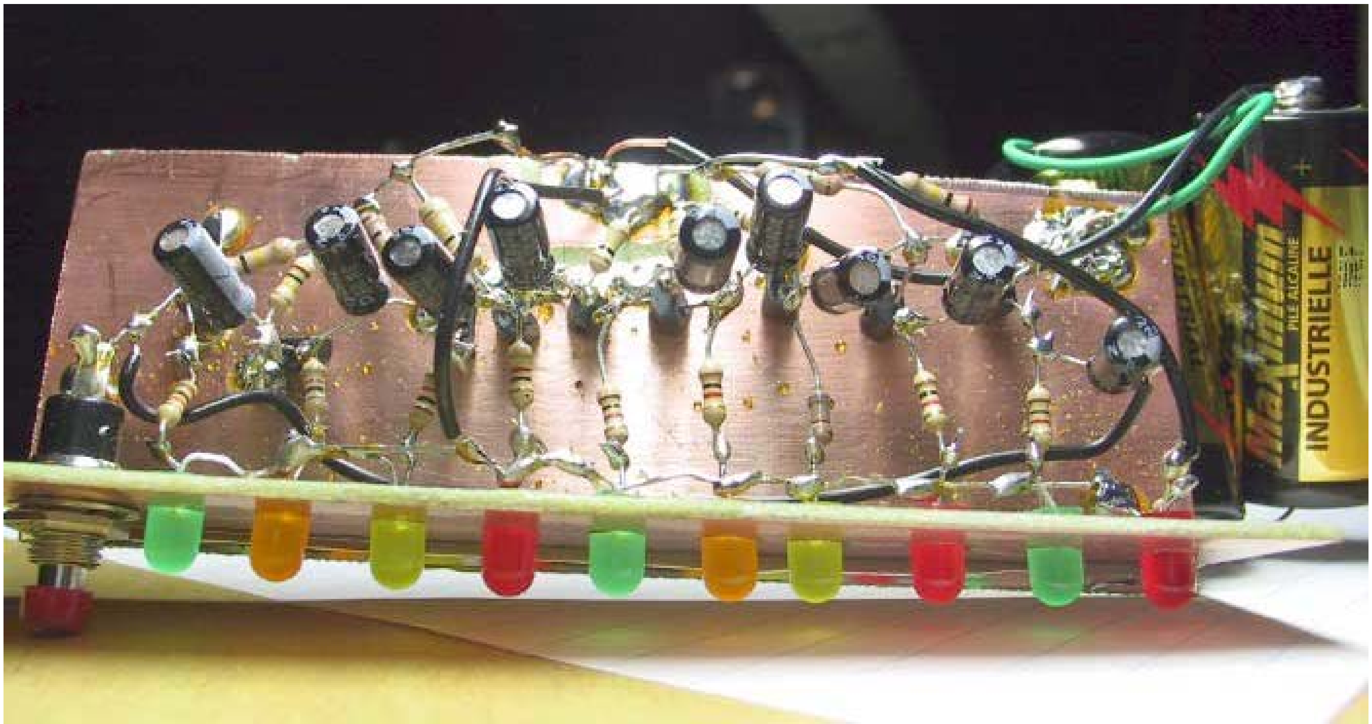

NoNot counting the 10th flashing LED, 5 of the 9 LEDs are on at any given moment. A sequential flash effect is noted (the state of each LED flip-flops and shifts over 1 position each flash). If you build this project with an even number of LEDs, the sequential effect is not seen. Half of the LEDS (spaced every other LED) are on and the other half are off at any moment. The same LEDs are lit or unlit each pulse. Thus the effect is more like a typical multivibrator LED flasher. This variable, even versus odd number of stages property makes the circuit quite versatile.

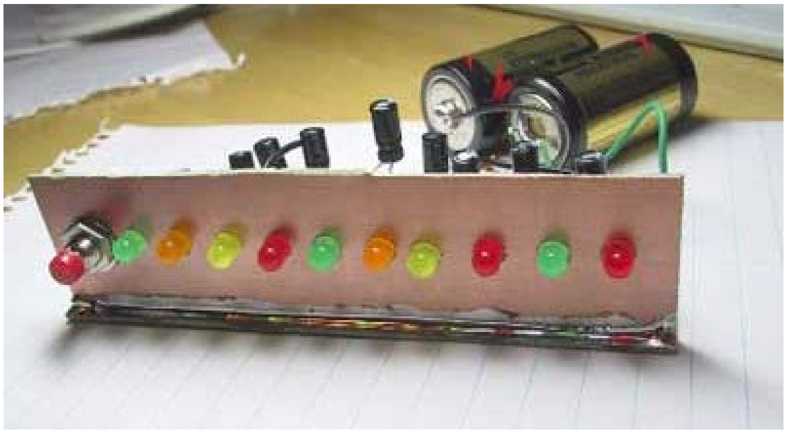

Conclusion

I hope that you have some fun experimenting with these and other circuits.

Amateur Radio Electronics Designer's Web Site

SWL Receiving Antenna Experiments

Introduction

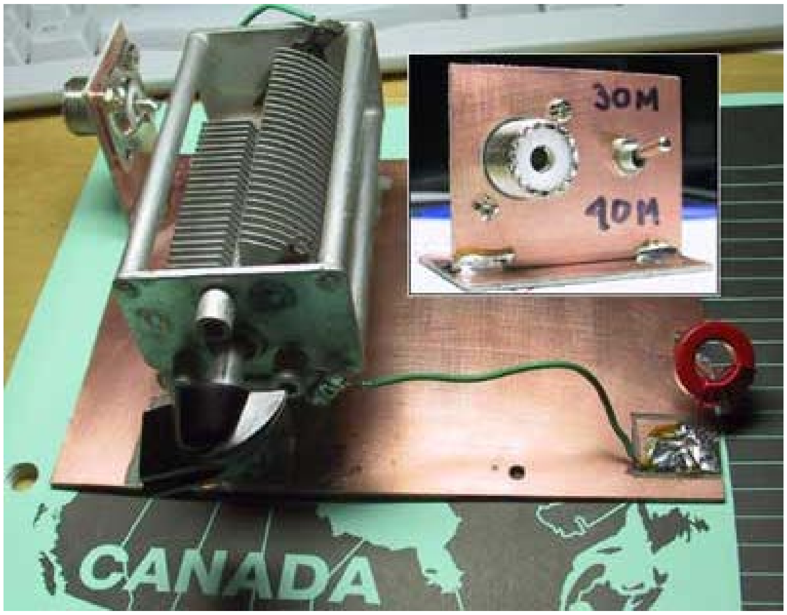

I have a lot to learn about SWL antennas. What follows are some brief experiments I performed in late October 2005. I have been experimenting with a half wavelength end-fed wire for use as a portable 40M band HAM transceiver (receive and transmit) antenna. This wire antenna is 67 feet long. End fed wires are very popular with those who pack a small portable transceiver when backpacking and camping. No feed line is required and the far end of the wire can be strung up using objects such as nearby trees or collapsible, portable poles. An elaborate ground system is not required. The return for the RF energy to ground might be grounding rod(s), short or long radial(s), or even just capacitively coupling to the local environment (including the operator!). Simple tuners are easily built to transform the high (thousands of ohms) wire impedance to the 50 ohms or so required by the transmitter.

I wanted to know if I could use this antenna as a tunable receive antenna for the the 30 and 31 Meter bands in addition to a tunable transmit/receiver antenna for my HAM radio work on 40 Meters. **What I verified is that tuning a multiband receive only antenna is not very practical.** When you tune a receive antenna you increase received noise and desired signals proportionally and therefore do not improve the signal to noise ratio in a meaningful way. Sometimes until you perform some experimentation, you don't really believe even good advice.

To the right: A computer simulation of a 40 Meter band end-fed Wire performed by W7ZOI on W7EL's EZnec program. The simulation was for 10.1 and 7.0 MHz with a 22 and 12 gauge wire. One 33 ft radial was used from the base of the 23.7 ft piece up 0.3 feet from the ground in this simulation. Z is impedance. Z and j are complex numbers used to represent the multi-dimensional quantities of the AC analysis of this antenna. In actual fact, j is an imaginary number. I suggest you might just ignore j unless your are well informed about impedance arithmetic.

Antenna Matching

A tuner can help match the impedance of the wire antenna and feed line (if used) to the input impedance of the receiver at a given frequency. This will result in more received signal and noise voltage to the receiver's input. HAM radio enthusiasts use antenna tuners to transform the impedance between the radio and the antenna tuner to 50 ohms to allow maximal output power from their transmitter. Non- amateur radio operators, can not use transmitters to

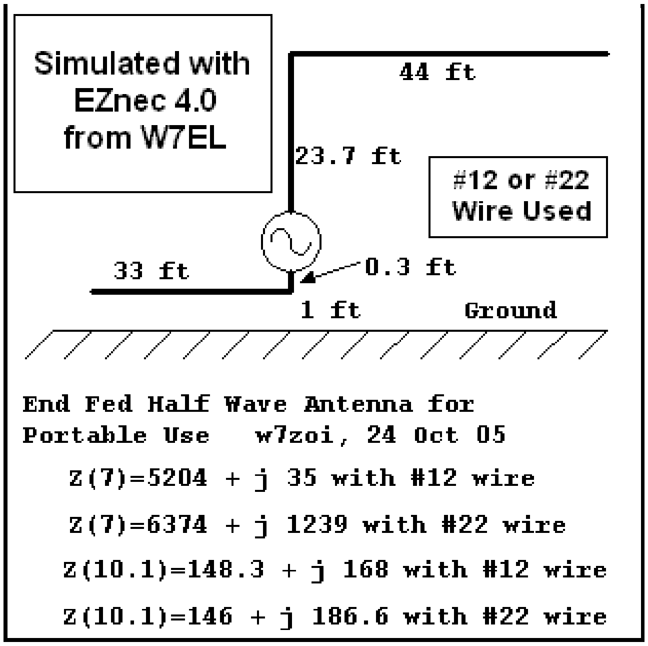
Simulated with
EZnec 4.0
from W7EL
44 ft
23.7 ft
#12 or #22
Wire Used
33 ft
0.3 ft
1 ft
Ground
End Fed Half Wave Antenna for
Portable Use w7zoi, 24 Oct 05
Z(7)=5204 + j 35 with #12 wire
Z(7)=6374 + j 1239 with #22 wire
Z(10.1)=148.3 + j 168 with #12 wire
Z(10.1)=146 + j 186.6 with #22 wire

match their antennas. This leaves either using receiver noise, S-Meter or an antenna analyzer such as the MFJ259. I just used my ears and S-meter. All of the tuners presented work as transmitter tuners as well. Any network used for transmitter work must be able to handle the output power of the transmitter final amplifier.

The Wire Antenna Experiments

I tried 3 different antenna tuners to see if I could tune an 18 gauge wire on 40-41 and 30-31 meters. My wire went from my computer room in the basement out a hole in the wall and sloped at ~ 50 degrees up to a rope tied to a tree in my backyard. The tip of the antenna is about 50 feet (15 meters) high. A 10 gauge insulated ground wire also passes from the computer room outside under the back lawn. It is "earthed" to two, 2 meter copper grounding rods hammered into the ground. No direct connection to the house ground system and the outside antenna grounding system should be made as this may result in increased receiver noise.

Antenna Tuner 1

The schematic on the left below, is very popular with HAMS who use it to to tune monoband end-fed wires. It is very simple and works reasonably well. Although the capacitor was able to resonate the 35 turns inductor, the T1 turns ratio was wrong and reducing it to 28:3 was required to get the maximum receiver signal in my experiments on the 40 and 41 meter bands. The alternative was to shorten or lengthen the wire antenna which is not very practical as it meant repeatedly climbing a tree.

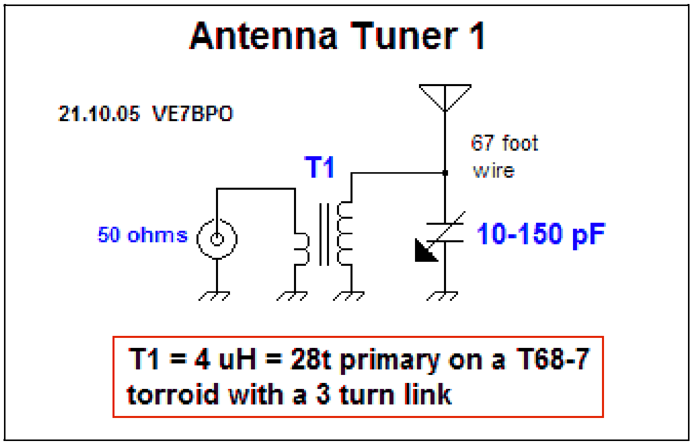
Antenna Tuner 1
21.10.05 VE7BPO
T1
67 foot
wire
50 ohms
10-150 pF
T1 = 4 uH = 28t primary on a T68-7
torroid with a 3 turn link

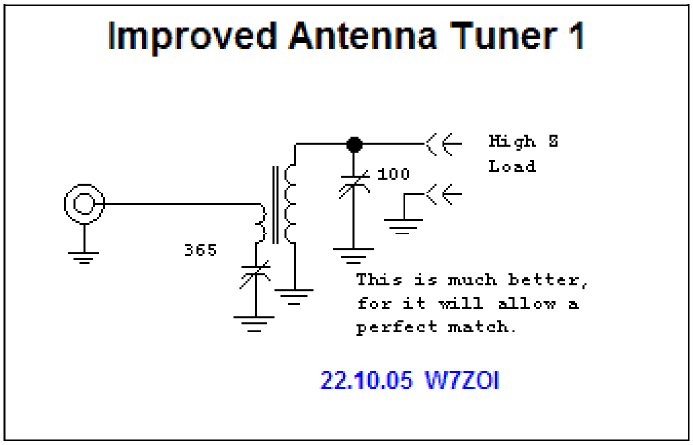
Improved Antenna Tuner 1
High Z
Load
100
365
This is much better,
for it will allow a
perfect match.
22.10.05 W7ZOI

Above right: An improved version of the Antenna Tuner 1 schematic from W7ZOI. This tuner has 2 user "tweaking" adjustments much like most modern commercial antenna tuners (which typically also have a band changing adjustment).
I did not build this version.

In addition, this tuner would not tune the 67 foot wire on the 30 or 31 meters band. This was no surprise. When I turned the variable capacitor, I noticed some change in received signal, but not much. The signal strength was very poor and I could not hear much of anything.

Below. Two built up views of the Antenna Tuner 1 schematic. I soldered the antenna wire to the circuit in the isolated area connecting the inductor and capacitor. The outside antenna ground wire was soldered to the large copper ground plane.

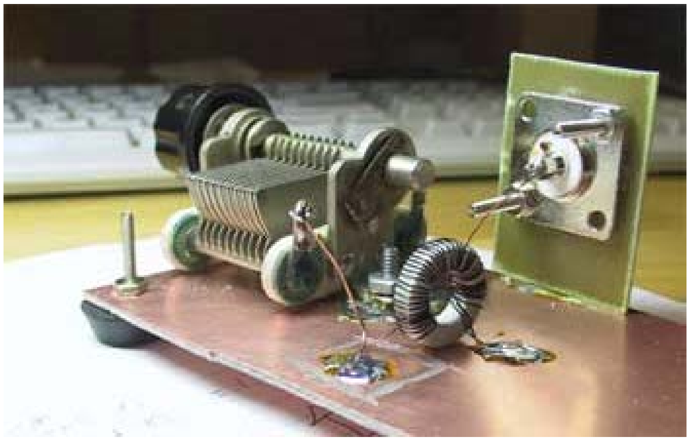

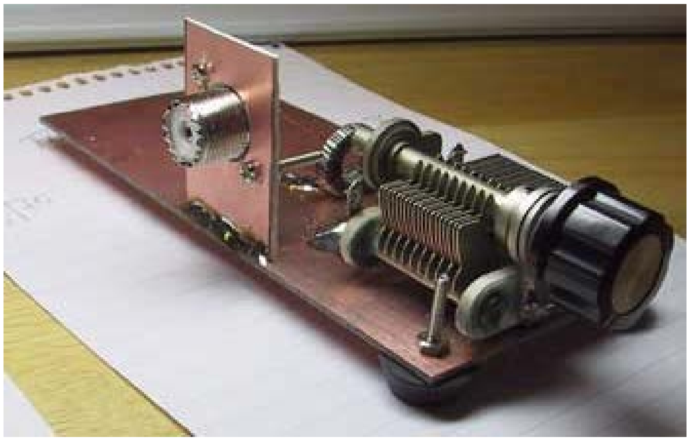

Antenna Tuner 2

This was the next tuner I built. Antenna tuner 2 tuned very sharply on the 40 and 41 Meter bands. It is designed to match a high impedance antenna, so it could not match the medium impedance (~150 ohms) wire to the 30 and 31 meter bands very well at all. Since ~ 150 ohms is fairly close to my receivers 50 ohm input impedance, I just connected the wire antenna directly to my receiver. The received noise and signals were then much stronger than those with the Antenna Tuner 2 network in the circuit on 30-31 meters.

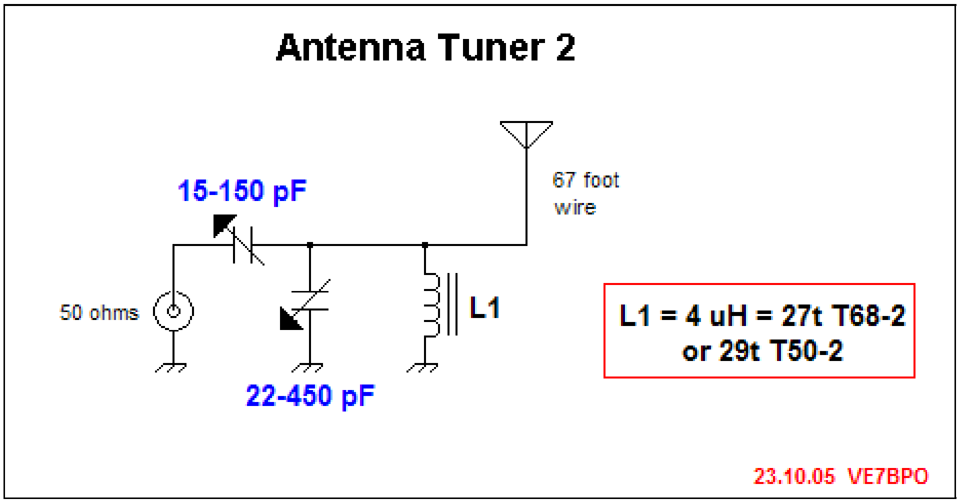

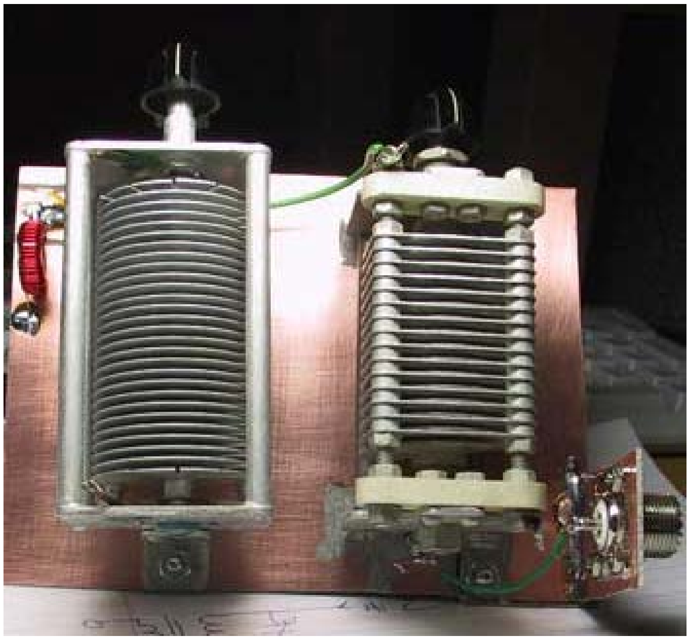

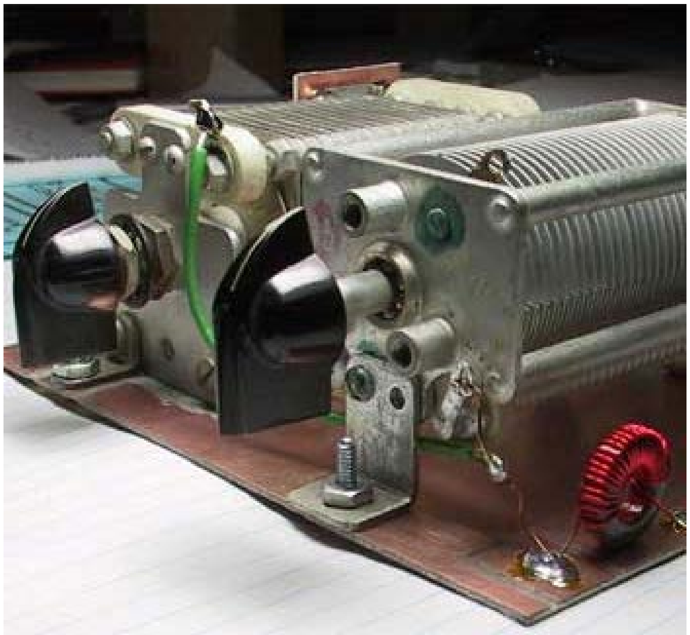

Above: Two constructed views of the Antenna Tuner 2 schematic. The variable capacitors were bought at a HAM festival in 1992 for 2 dollars each.

Antenna Tuner 3

The next antenna tuner topology I tried was the familiar L network. Circuit **A** is configured in a shunt L (inductor to ground) and series C (capacitor) and is a high pass L network. Circuit **B** is configured in a series L and shunt C and is a low pass L network.

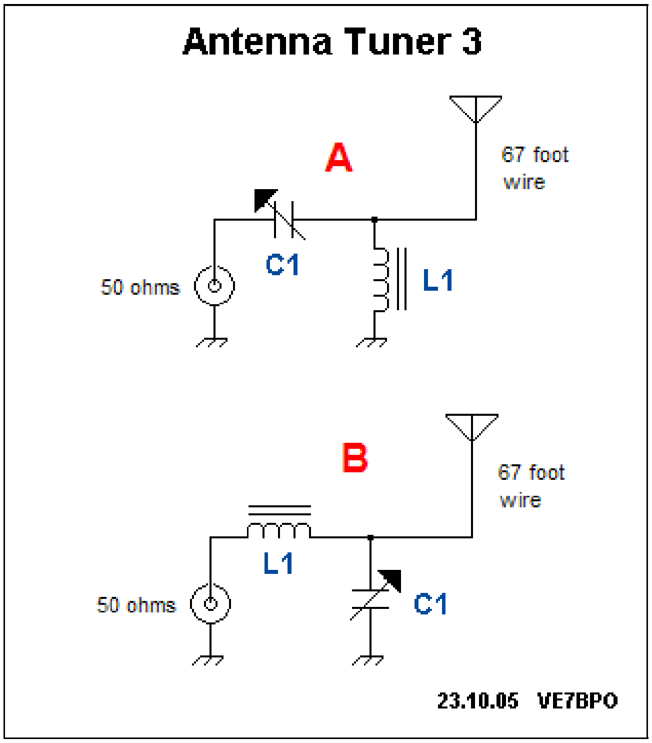
Antenna Tuner 3
A
67 foot wire
50 ohms
C1
L1
B
67 foot wire
L1
50 ohms
C1
23.10.05 VE7BPO

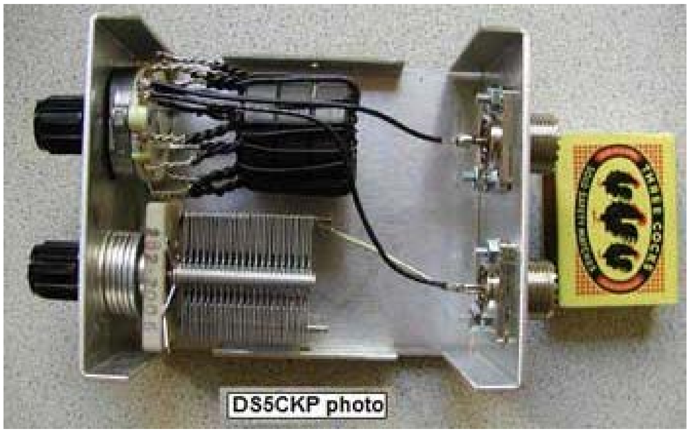
DS5CKP photo

L networks (especially the low pass form) are very popular as random wire tuners. MFJ sells an excellent version as the model MFJ-16010. A photograph of this tuner is shown below right. The above left photograph was taken by **DS5CKP** who also sells a random wire antenna tuner at: http://user.chollian.net/~cyberline/ckptuner.htm

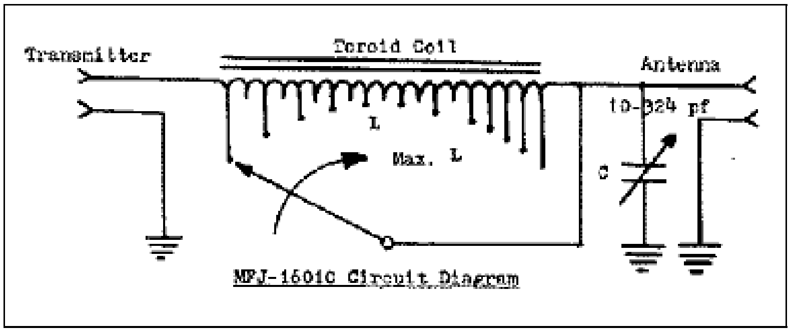
Transmitter
Toroid Coil
Antenna
L
10-324 pf
Max. L
C
MFJ-16010 Circuit Diagram

INDUCTANCE
CAPACITANCE
MFJ ANTENNA TUNER
Model MFJ-16010

Above. MFJ web publishes their manual including the schematic for the MFJ-16010 random wire antenna tuner. The inductor is actually wound on 3 stacked (probably ferrite) cores which are tapped. The taps are connected to a front panel mounted 12 position switch. This allows coverage from 2-30 MHz. As a simple experiment, I tried stacking 2 and then 3 FT-50-61 ferrite cores and was able to get a wind range of inductances from the 6 taps I made on my test inductor.

Numerous examples of the L network antenna tuner can be found on the web and in print including the 2006 A.R.R.L. handbook. I decided to try the high pass L network topology to experiment with.

I built part **A** of the Antenna Tuner 3 schematic with shunt L and series C. On the 40-41 meter bands I tried 3 different inductors; 4 uH, 2.1 uH and 1.3 uH. I tuned the network to get the greatest receive noise and S meter reading and measured the variable capacitor value. At 7.30 MHz, the capacitance values were 86 pF, 141 pF and 182 pF respectively. Although non-critical, I settled on a 2.6 uH inductor (23 turns on a T50-2 powdered iron torroid) so I could use a junk-box 10-150 pF variable capacitor to resonate it. Later I decided just a trimmer capacitor might do. You need around 125 pF at 7.30 MHz to tune the network with a 2.6 uH inductor (to give you a ballpark C value to start with).

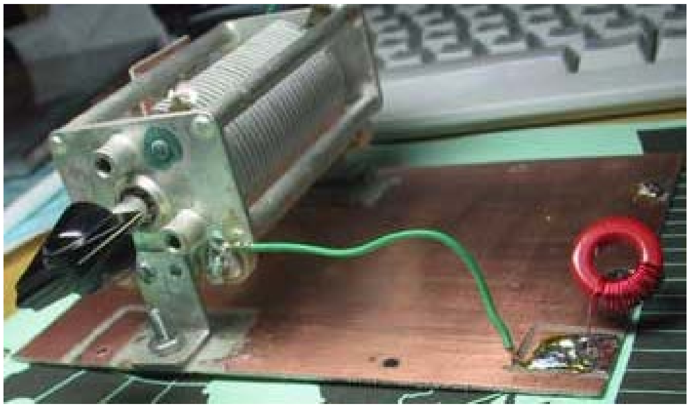

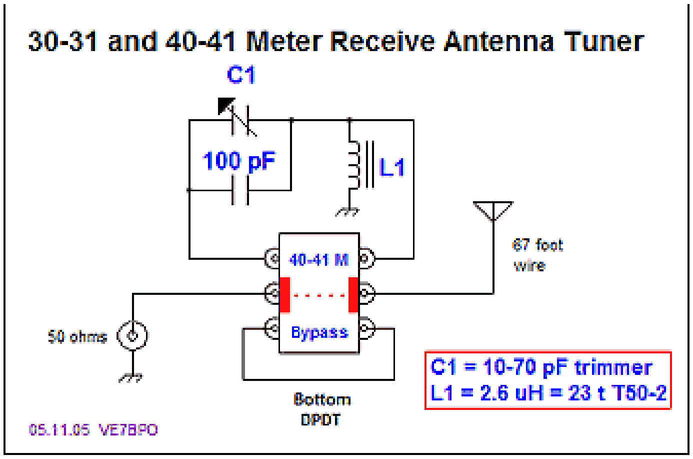
30-31 and 40-41 Meter Receive Antenna Tuner
C1
100 pF
L1
67 foot wire
40-41 M
Bypass
50 ohms
Bottom DPDT
C1 = 10-70 pF trimmer
L1 = 2.6 uH = 23 t T50-2
05.11.05 VE7BPO

Schematic to the right: A very small receiver tuner that allowed the L network to be switched in and out of the antenna path was constructed. The L network is tuned on 40-41 meters via a small trimmer cap on top of the double pole, double throw switch. A small plastic alignment screw driver is used for signal peaking. An air variable capacitor would be much easier to tune as you move up and down these bands.

Below left: Front view. Technically, the switch label should indicate **40M** and **bypass** as the bypassed antenna could be used on any band.

Below right: Rear view The trimmer cap can be seen on top of the switch.

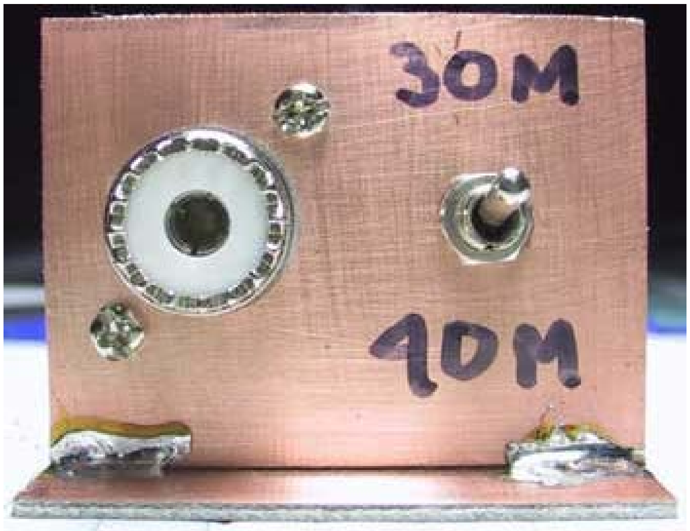

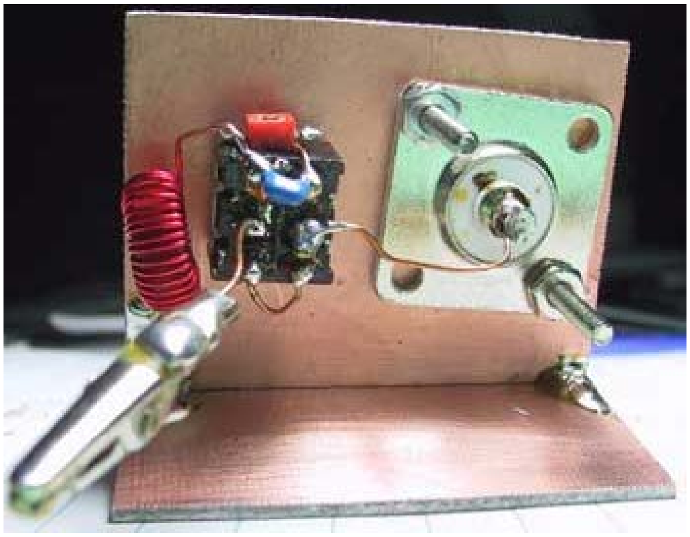

Below left: Side view, the antenna wire is held via an alligator clip. This allows me to unclip and ground the antenna when it is not in use. The antenna ground wire is soldered to the copper ground plane.

Below right: A T6-8 core wound with with 24 gauge wire. I used larger powered iron torroids to wind my inductors, however, they can also be wound on ferrite cores or be air-wound. The core size, wire gauge and type of inductor used can affect the selectivity and insertion loss of the tuner network, however for practical receiving purposes it is not a major concern.

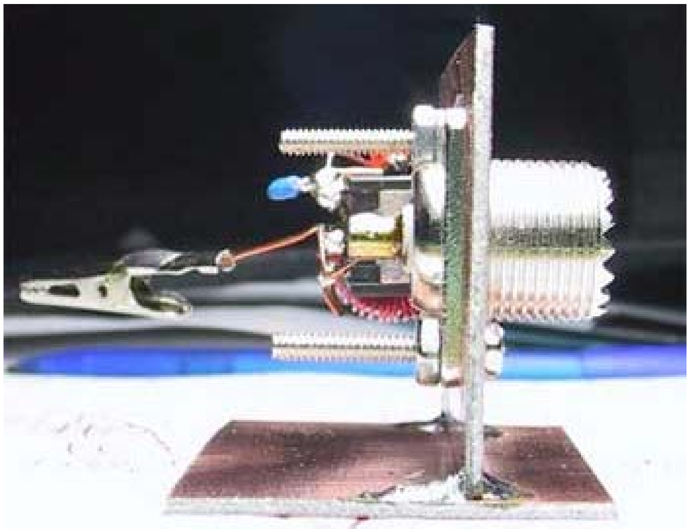

Conclusion

The final experiment allow me to easily switch between a matched and direct 67 foot wire antenna on 40 and 41 meters. I performed several listening tests and generally agree with those who say receive antenna tuners offer little to no improvement in signal readability. The only advantages I can think of for matching a receive antenna to a reasonably quiet and sensitive receiver are:

1. There may be some improvement in the receiver front end filter function as these filters are designed to have a specific input impedance.
2. Certain balanced mixers may function better with the correct impedance on their RF port.
3. The tuner itself (depending on design) may marginally improve the front end selectivity of the receiver it is connected to.

I do like the noise roar and louder signals with the matched antenna on 40 and 41 meters, although this is totally subjective. I think the reason for this is that as a HAM radio operator who always matches the antenna for any band I am on, I am used to louder signals and noise levels. I also spent most of my first 10 years of HAM radio operation on 80 and 160 meters which are relatively noisy bands and have been conditioned so that noise is "normal".

On 30-31 meters the bypassed antenna worked quite well and the L network can be switched in as an attenuator. Perhaps you might build up a tuner and try for yourself!

Although they are simple, low cost and easy to put up, it is likely unwise to use an end-fed wire without coaxial feed line as a receiving antenna. The ground wire is part of the antenna system and easily picks up household generated noise which will present to your receivers input. The time honored and easiest methods to reduce receiver noise are to get your antenna away from the house and other noise sources, use buried coaxial cable feed line to the house and directly earth ground the shield of the feed line with stakes. Antenna/ feed line "link coupling" by a transformer may also reduce noise (especially if the antenna system is balanced) and this topic begs further study.

Suggested Links

There are some fabulous web sites on the topic of SWL antennas and reducing receiver noise. I suggest these 5. Try a Google search for more.

http://www.dxing.info/equipment/

http://www.hard-core-dx.com/nordicdx/antenna/feed/feed1.html

http://www.aa5tb.com/efha.html

http://www.nyx.net/~dgrunber/

As usual, I learned a great deal from the process of experimenting. I look forward to spring when some more antenna experiments can be performed.

Experiments with JFET Biasing

The most common way of biasing a Junction Field Effect Transistor (JFET) is with a source resistor. This method, shown in Fig 1 below, has the advantage of offering negative feedback to stabilize the bias conditions. This is the same thing that happens when a bipolar transistor uses an emitter resistor. Self bias can be used as a method to evaluate a JFET to determine the critical parameters that describe it: Idss and Vp. These are discussed in Chapter 2 of **Experimental Methods in RF Design** and many other places.

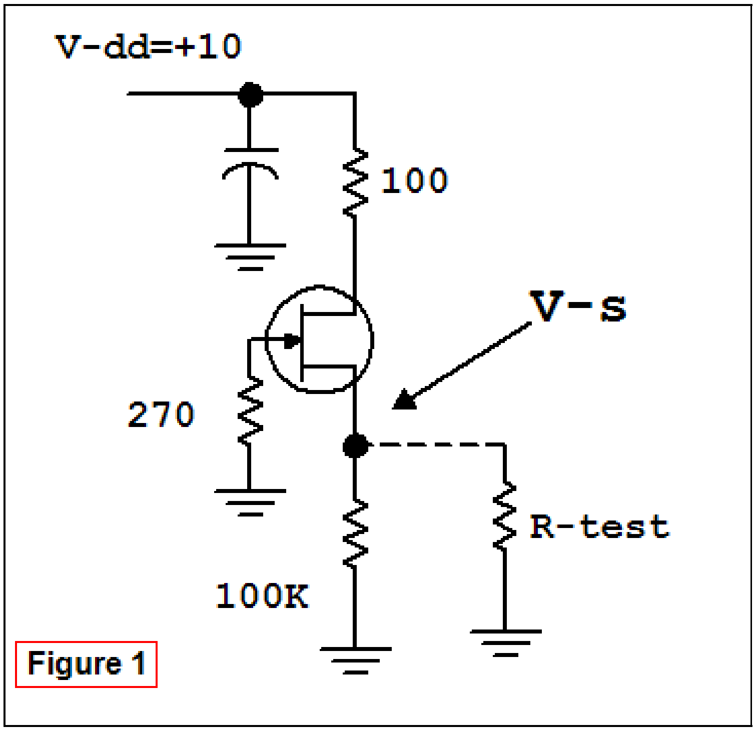

Figure 1

The method used in our experiment is to set up the FET of interest in a test fixture with a power supply, bypass capacitor, resistors in the drain and gate to suppress parasitic oscillations, and a handful of extra resistors, R-test, that can be paralleled with an existing 100K source resistor. A digital volt meter (DVM) is the basis for the measurements. We begin by using the DVM to measure the resistance of our test resistors, for the values will be used in calculations. The DVM is then attached to the FET source to measure the DC voltage. The first value we measure is with no attached R-test. The measured value will be very close to the FET pinchoff voltage.

The measurements we will perform infer drain current as a function of gate to source voltage. The physics of the FET support the model that there is no gate current so long as the gate is not forward biased with regard to the source. Hence, the drain current equals that in the source. We will measure the source current by measuring the voltage drop across the source resistor. The gate is at ground potential, for there is no gate current, so the gate to source voltage is just the negative of the source to ground voltage.

The resistors that I pulled from my stock for some measurements were marked as 22, 39, 68, 100, 150, 300, 510, 680, 1K, 2K, 3.3K, 6.8K, and 10K Ohm. The measured values are shown in attached figures. A systematic pattern was noticed with all of the measured resistances under the marked value, suggesting an error in the calibration of my DVM, a Fluke Model 73. All resistors were 2% carbon film 0.25 Watt. However, when I measured a 499 Ohm, 1% metal film resistor, it came up exactly at 500 Ohms. The differences between the measured values and those marked on the part were small enough that I neglected the details and used measured values for calculations.

The first FET I examined was a 2N5454, a common JFET that I had in my junk box. The source voltage was 3.26 with nothing but the 100K for source bias. I started my measurements with the largest resistor, 10K. The voltage dropped to 2.90 and was stable. I merely held the resistor in place rather than soldering it. The resistor was kept in place long enough to get a stable reading that I could record in my lab notebook. All results were of the same character until I got to the 300 Ohm resistor. At that point I started to notice a slight heating effect. The source voltage was 1.523, but slowly dropped to 1.518 volts. This behavior continued through the lower value resistors. The 22 Ohms produced 264 mV on the source that then dropped to 256 mV.

Later I examined a J310 JFET. This is a much larger area part than the 2N5454 with an Idss that is about three times larger. With the 22 Ohms in the test fixture, V-source went to 701 mV, but settled at 652 mV. The drain current was then 32 mA. With a 10 volt power supply, there was nearly 200 mW dissipated in the FET. This is within ratings, but high enough to produce heating. Operation at higher voltages and at Idss would further tax the part. One must take care when doing these measurements to be sure that the source voltage is observed quickly.

Attached are the MathCad documents that I used to examine the data. A spread sheet such as Excel could be used, but I prefer the graphics of MathCad. The second page for the 2N5454 shows a graph for the observed data as well as a calculated one. The two FET parameters for the 2N5454 were varied to obtain a good correspondence between the two. The part had Idss=15 mA with Vp=-3.5 volts. This is similar to the popular MPF-102, but close to the high Idss extreme for that part.

The data presented for the J310 is more abbreviated with only two points shown. I picked the 22 Ohm and 1K source resistors. This still produced data that is very close to that obtained with many more data points.

My initial analysis suggested that we could characterize the FET by measuring the source voltage with 100K in place to approximately determine Vp, and to then short circuit the source through the mA scale on the DVM to obtain Idss. This is a reasonable start. However, the pinchoff will usually be a few percent more negative (for an N-channel depletion mode part). The long leads in the source also make me feel uncomfortable with regard to parasitic oscillations.

After the DC measurements were done, I thought it wise to look at the potential for oscillation. The J310 was in the test circuit at this time. The TO-92 J310s are parts that are well known for their propensity for oscillation, so I guessed that it would not be difficult to coax this one into such a mode. But this was not what I found. I eliminated the 100 Ohm drain resistor, but moved the FET close to the 0.1 uF bypass. This bypass is not a very good one for VHF and upward. No oscillation was seen. I then eliminated the gate resistor, replacing it with the normal gate lead. Still no oscillation. I eventually added a gate inductor and a parallel tuned circuit in the source. The source bias resistor had a RF choke in series with it. I finally saw a robust VHF oscillation, but nothing else up through 1.5 GHz.

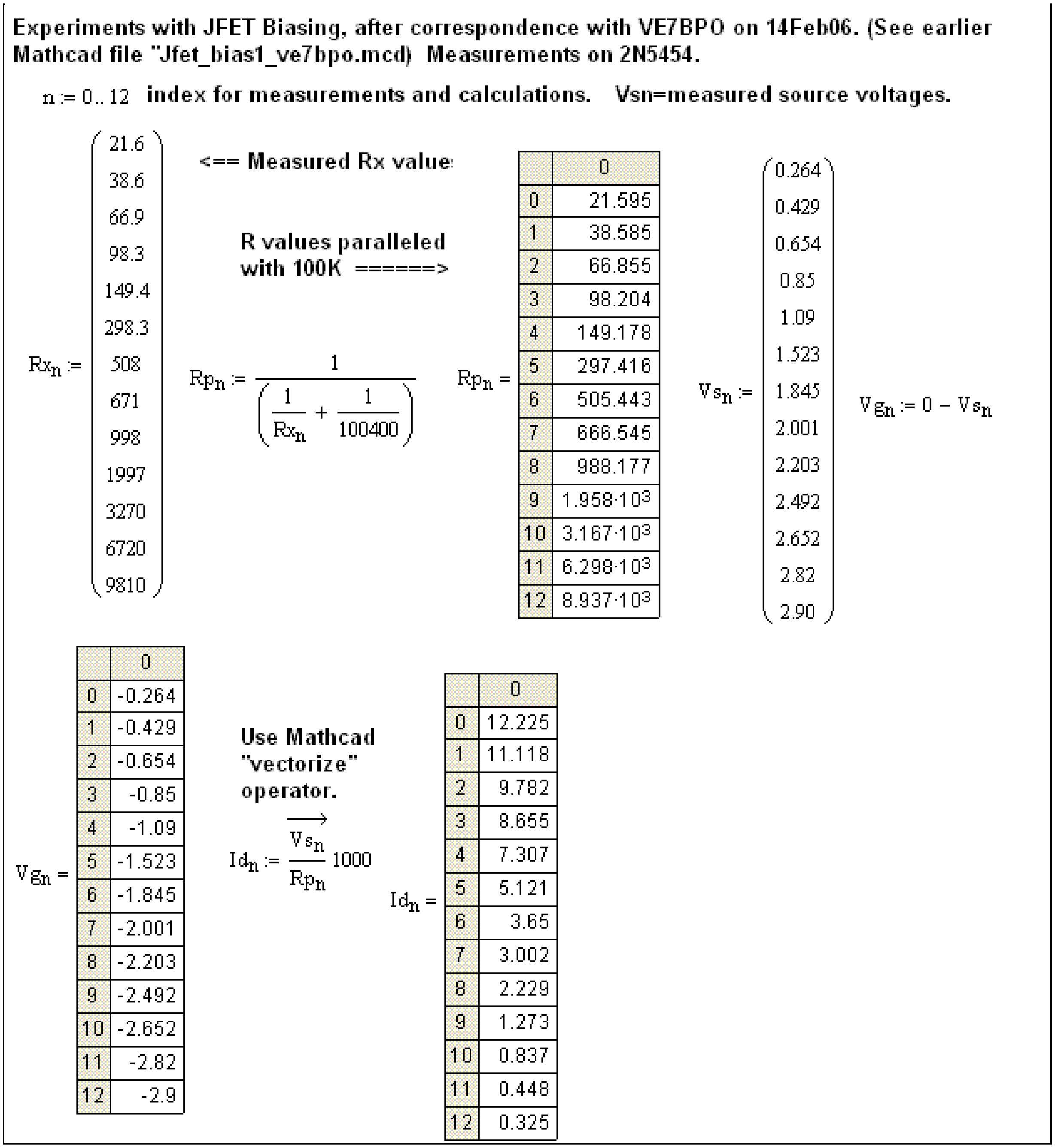

Experiments with JFET Biasing, after correspondence with VE7BPO on 14Feb06. (See earlier Mathcad file "Jfet_bias1_ve7bpo.mcd) Measurements on 2N5454.

$n := 0..12$ **index for measurements and calculations. Vsn=measured source voltages.**

$$Rx_n := \begin{pmatrix} 21.6 \\ 38.6 \\ 66.9 \\ 98.3 \\ 149.4 \\ 298.3 \\ 508 \\ 671 \\ 998 \\ 1997 \\ 3270 \\ 6720 \\ 9810 \end{pmatrix}$$

<== Measured Rx value

R values paralleled with 100K ======>

$$Rp_n := \frac{1}{\left(\frac{1}{Rx_n} + \frac{1}{100400}\right)}$$

$Rp_n =$

	0
0	21.595
1	38.585
2	66.855
3	98.204
4	149.178
5	297.416
6	505.443
7	666.545
8	988.177
9	$1.958 \cdot 10^3$
10	$3.167 \cdot 10^3$
11	$6.298 \cdot 10^3$
12	$8.937 \cdot 10^3$

$$Vs_n := \begin{pmatrix} 0.264 \\ 0.429 \\ 0.654 \\ 0.85 \\ 1.09 \\ 1.523 \\ 1.845 \\ 2.001 \\ 2.203 \\ 2.492 \\ 2.652 \\ 2.82 \\ 2.90 \end{pmatrix}$$

$Vg_n := 0 - Vs_n$

$Vg_n =$

	0
0	-0.264
1	-0.429
2	-0.654
3	-0.85
4	-1.09
5	-1.523
6	-1.845
7	-2.001
8	-2.203
9	-2.492
10	-2.652
11	-2.82
12	-2.9

Use Mathcad "vectorize" operator.

$$Id_n := \overrightarrow{\frac{Vs_n}{Rp_n}}\, 1000$$

$Id_n =$

	0
0	12.225
1	11.118
2	9.782
3	8.655
4	7.307
5	5.121
6	3.65
7	3.002
8	2.229
9	1.273
10	0.837
11	0.448
12	0.325

Let pinchoff be $u_p := -3.5$ and $I_{dss} := 15$

$u := -3, -2.9 .. 0$

$$I(u) := I_{dss} \cdot \left(1 - \frac{u}{u_p}\right)^2$$

Try various values for pinchoff and Idss to get a reasonable match.

Blue is measured data while red shows calculated behavior.

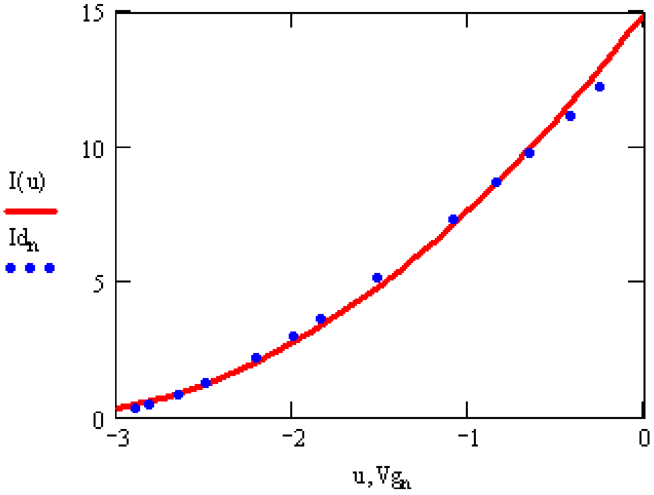

Experimental Note: During the measurements, I noticed a definite thermal change in Idss when dissipation was high. This occurred at higher currents, with low source bias resistors. The Vg values I used in my data were the first ones recorded with the DVM. The most extreme case was with the 22 Ohm source R. The source V started at 264 mV and went down to 256 mV. The effect was more dramatic with a larger part, a J310. That part, when operated with a 22 Ohm R, started with 701 mV and dropped to 652 mV.

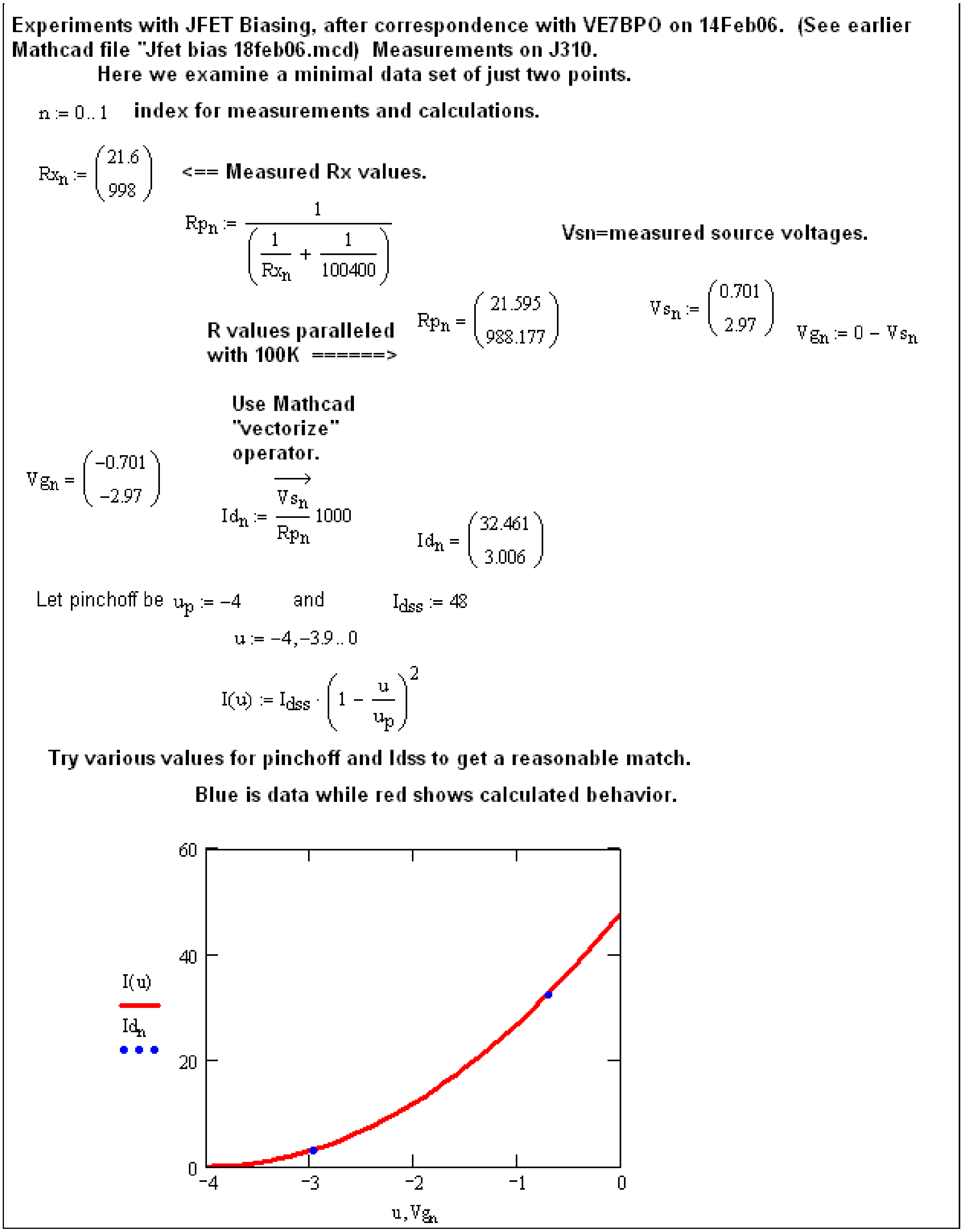

Experiments with JFET Biasing, after correspondence with VE7BPO on 14Feb06. (See earlier Mathcad file "Jfet bias 18feb06.mcd) Measurements on J310.

Here we examine a minimal data set of just two points.

$n := 0..1$ **index for measurements and calculations.**

$Rx_n := \begin{pmatrix} 21.6 \\ 998 \end{pmatrix}$ **<== Measured Rx values.**

$$Rp_n := \frac{1}{\left(\frac{1}{Rx_n} + \frac{1}{100400}\right)}$$

Vsn=measured source voltages.

R values paralleled with 100K ======> $Rp_n = \begin{pmatrix} 21.595 \\ 988.177 \end{pmatrix}$

$Vs_n := \begin{pmatrix} 0.701 \\ 2.97 \end{pmatrix}$ $Vg_n := 0 - Vs_n$

$Vg_n = \begin{pmatrix} -0.701 \\ -2.97 \end{pmatrix}$

Use Mathcad "vectorize" operator.

$$Id_n := \overrightarrow{\frac{Vs_n}{Rp_n}}\,1000$$

$Id_n = \begin{pmatrix} 32.461 \\ 3.006 \end{pmatrix}$

Let pinchoff be $u_p := -4$ and $I_{dss} := 48$

$u := -4, -3.9 .. 0$

$$I(u) := I_{dss} \cdot \left(1 - \frac{u}{u_p}\right)^2$$

Try various values for pinchoff and Idss to get a reasonable match.

Blue is data while red shows calculated behavior.

18 Feb, 2006 by W7ZOI

Many thanks to Wes, W7ZOI for this contribution.

QRP SWL HOMEBUILDER

Amateur and Short Wave Radio Electronics Experimenter's Web Site

10 MHz WWV Receiver Experiments

New feature: Click on a schematic to load it into a separate browser page for printing

Introduction

For nearly a year, I have been trying to develop a tuned radio frequency (TRF) 10 MHz, WWV, AM receiver. My initial RF stages were common emitter or common source stages with tuned input and output. Despite careful layout, parasitic oscillations plagued these designs and they were discarded. Later, I discovered that only tuning the input of RF stages reduced this tendency towards instability and still provided reasonable selectivity. Different detectors were also tried and evaluated.

A simple receiver that sounds great and is fun to build and experiment with follows. My special thanks to Wes, W7ZOI for performing many of the simulations and providing suggestions which kept me going.

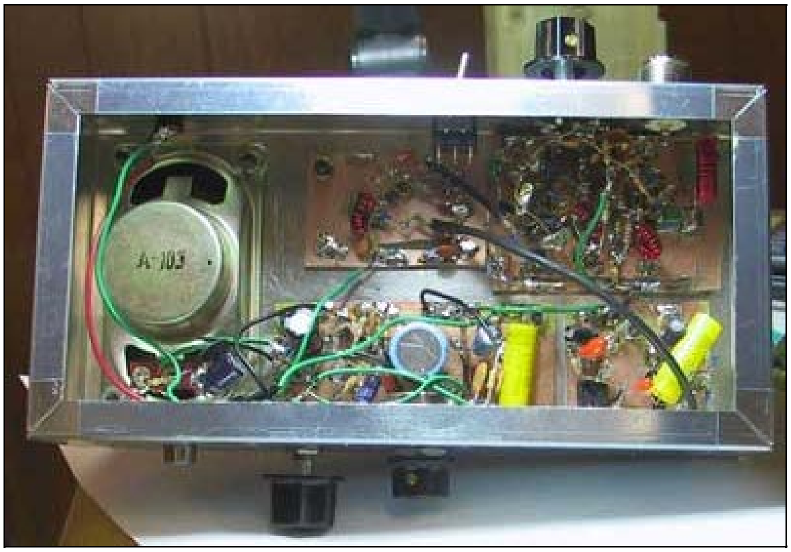

WWV Audio Files from Sept 26, 2006

WWV File 1

WWV File 2

WWV File 3

The audio was digitally recorded using an electret condenser microphone held 3 cm away from the receiver speaker. The files were compressed using the WMA format.

Supplemental Web Page added June 29, 2007

Receiver Front End

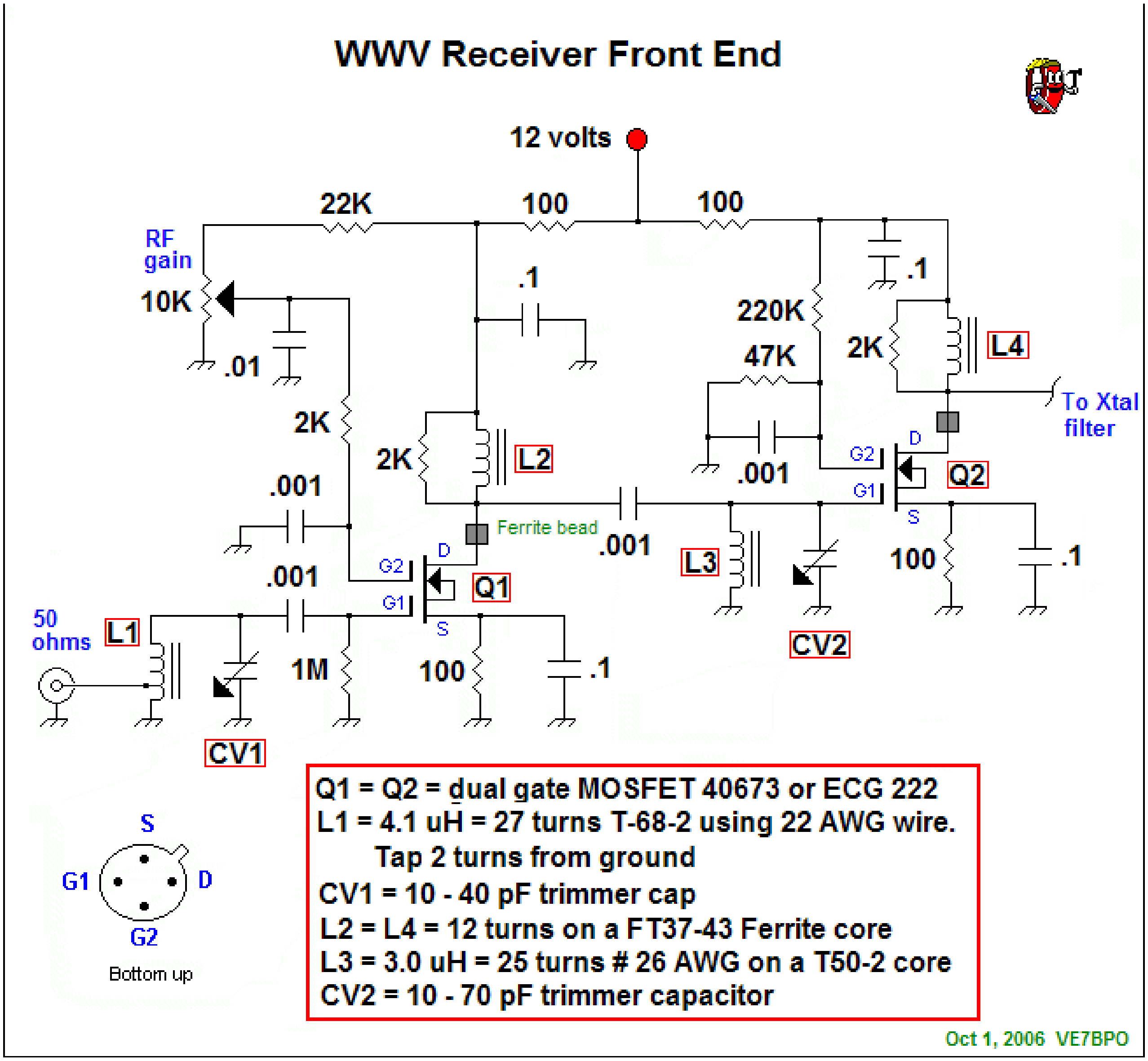

WWV Receiver Front End
12 volts
22K
100
100
RF gain
10K
.01
.1
220K
.1
47K
2K
L4
To Xtal filter
2K
2K
L2
.001
.001
G2
D
Q2
G1
S
Ferrite bead
.001
L3
100
.1
.001
G2
D
Q1
G1
S
50 ohms
L1
1M
100
.1
CV2
CV1
S
G1
D
G2
Bottom up
Oct 1, 2006 VE7BPO

Q1 = Q2 = dual gate MOSFET 40673 or ECG 222
L1 = 4.1 uH = 27 turns T-68-2 using 22 AWG wire.
Tap 2 turns from ground
CV1 = 10 - 40 pF trimmer cap
L2 = L4 = 12 turns on a FT37-43 Ferrite core
L3 = 3.0 uH = 25 turns # 26 AWG on a T50-2 core
CV2 = 10 - 70 pF trimmer capacitor

Above schematic. The receiver front end has just 1 single-pole filter. For even greater selectivity (but greater insertion loss), consider moving the L1 tap to 1 turn from ground. My receiver was connected to a 80 meter dipole via an antenna tuner. The antenna tuner provided additional selectivity. No local broadcast band (BCB) signals were heard when the chassis lid was tightened on. You may require additional RF high pass or band pass filtering in your location.

The RF gain control is very basic and only the first 1/3 of the 10K pot is used to go from minimal to maximal gain. Modifications to allow more precise variation in RF gain for dual gate MOSFETs or cascode JFETS are shown in EMRFD. The method shown works fine. For the most part, I keep it set to minimal gain. Using higher gain than necessary, increases receiver noise and may overdrive the detector.

TRF receivers require careful layout. A piece of wire greater than 2-3 cm between the stages may be enough to plague your receiver with local BCB interference depending on your layout and chassis integrity. For interstage connections that had greater than a 2 cm gap, shielded 50 ohm cable was used to prevent BCB interference.

Dual gate MOSFETs provide adequate gain and low noise. you might consider cascoding 2 JFETS for each RF stage if you cannot obtain them. titleernatively, bipolar feedback amplifiers may be used and examples are provided later on this web page.

XTal Filter and RF Amplifier

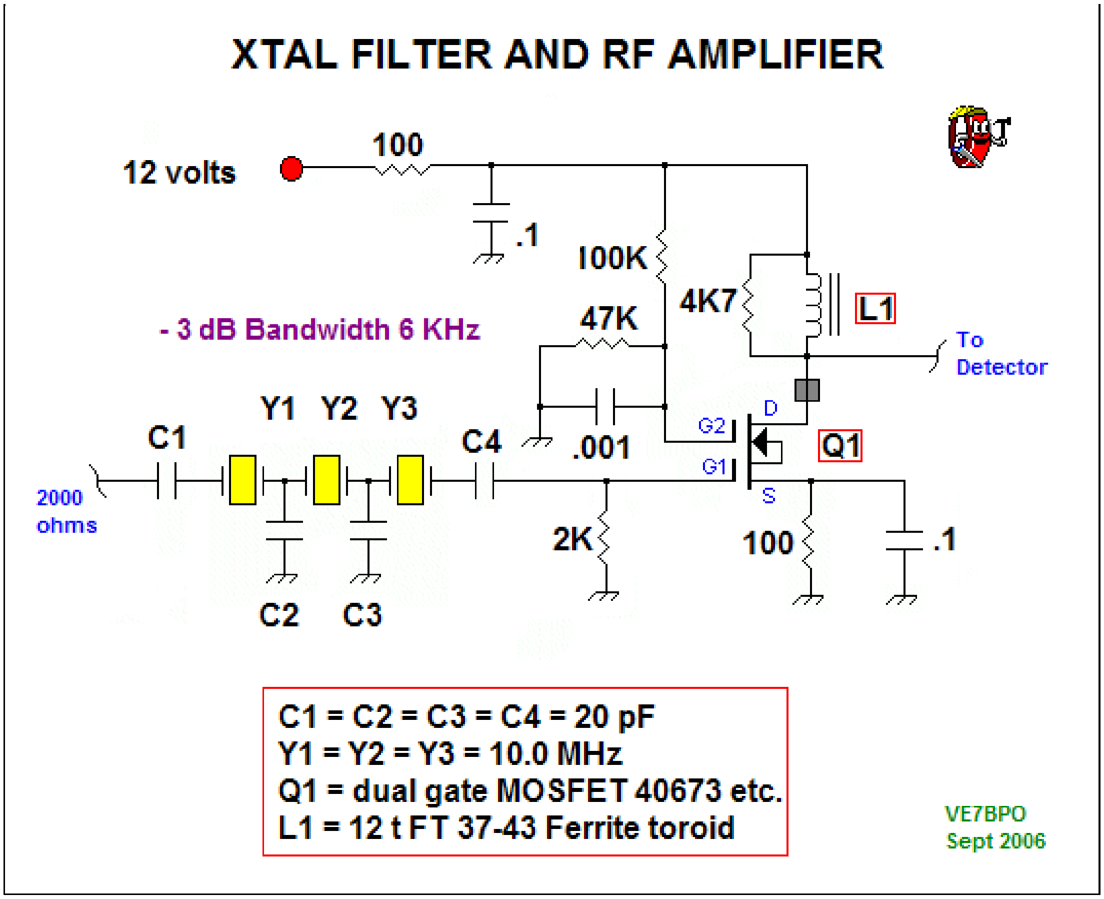
XTAL FILTER AND RF AMPLIFIER
12 volts
100
.1
100K
47K
4K7
L1
To Detector
- 3 dB Bandwidth 6 KHz
Y1 Y2 Y3
C1
C4
.001
G2
G1
D
S
Q1
2000 ohms
2K
100
.1
C2 C3
C1 = C2 = C3 = C4 = 20 pF
Y1 = Y2 = Y3 = 10.0 MHz
Q1 = dual gate MOSFET 40673 etc.
L1 = 12 t FT 37-43 Ferrite toroid
VE7BPO
Sept 2006

Schematic: The Q2 output impedance is 2000 ohms to match the input impedance of the Cohn crystal filter. This filter was designed by Wes, W7ZOI. Matched, computer grade, 10 MHz crystals were used. Choose 10 MHz crystals that are marked for a 20 pF or 32 pF load capacitance if possible. Using a 10 MHz crystal oscillator, find 3 that are closest to one another in frequency.

You may substitute 2K2 resistors instead of the specified 2K with a slight penalty in pass band shape.

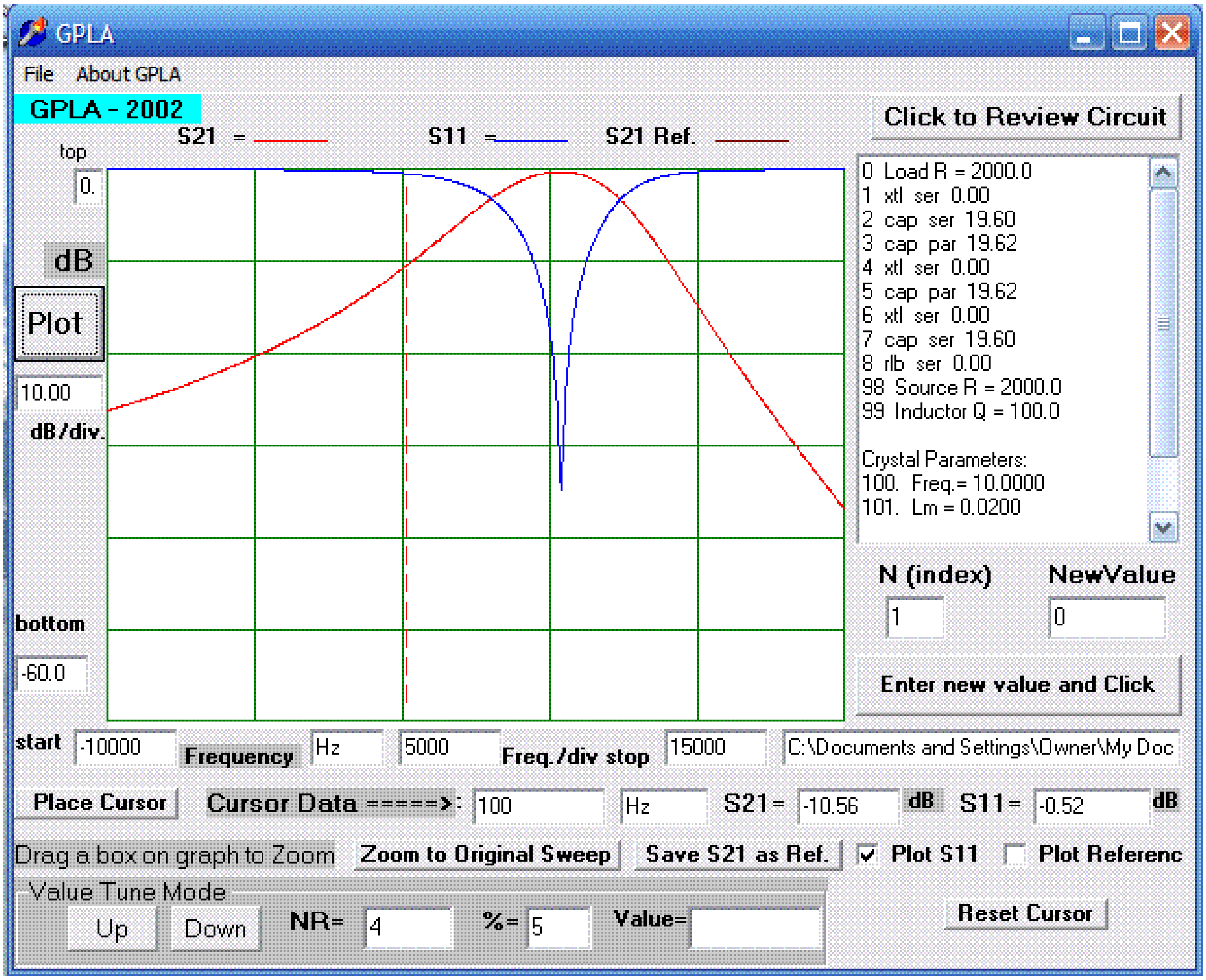
GPLA
File
About GPLA
GPLA - 2002
S21 =
S11 =
S21 Ref.
dB
Plot
Click to Review Circuit
Enter new value and Click
Place Cursor
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Value Tune Mode
Up
Down
Reset Cursor

top 0.

10.00 dB/div.

bottom -60.0

0 Load R = 2000.0
1 xtl ser 0.00
2 cap ser 19.60
3 cap par 19.62
4 xtl ser 0.00
5 cap par 19.62
6 xtl ser 0.00
7 cap ser 19.60
8 rlb ser 0.00
98 Source R = 2000.0
99 Inductor Q = 100.0

Crystal Parameters:
100. Freq.= 10.0000
101. Lm = 0.0200

N (index) 1
NewValue 0

start -10000 Frequency Hz 5000 Freq./div stop 15000 C:\Documents and Settings\Owner\My Doc

Cursor Data =====>: 100 Hz S21= -10.56 dB S11= -0.52 dB

☑ Plot S11 ☐ Plot Referenc

NR= 4 %= 5 Value=

Above graphic. A simulation of the receiver crystal filter using GPLA, a program written by Wes, W7ZOI that comes with EMRFD. EMRFD is the major reference for this web site and I recommend that you add this book and companion software to your home library. The pass band is not symmetrical. It is mistuned for the lower pass band frequencies and would serve better as an upper sideband filter. Nevertheless, it works reasonably well and is simple to build and tolerant to component variation and match. At certain times, a very strong shortwave station at 9.985 MHz can be heard along with WWV. This usually occurs in the early evening when the WWV signal is not that strong at my location. For most of the day and night, whether WWV is present or not, very little interference has been detected.

Bypassing the crystal filter is an interesting experiment. As many as 5 stations were heard simultaneously and these varied as time passed. I heard Radio Vatican, Radio Habana and many other broadcasts during 1 evening. At one point I heard a station at 9.75 MHZ, WWV and a strong CW carrier at 10 .110 MHz!

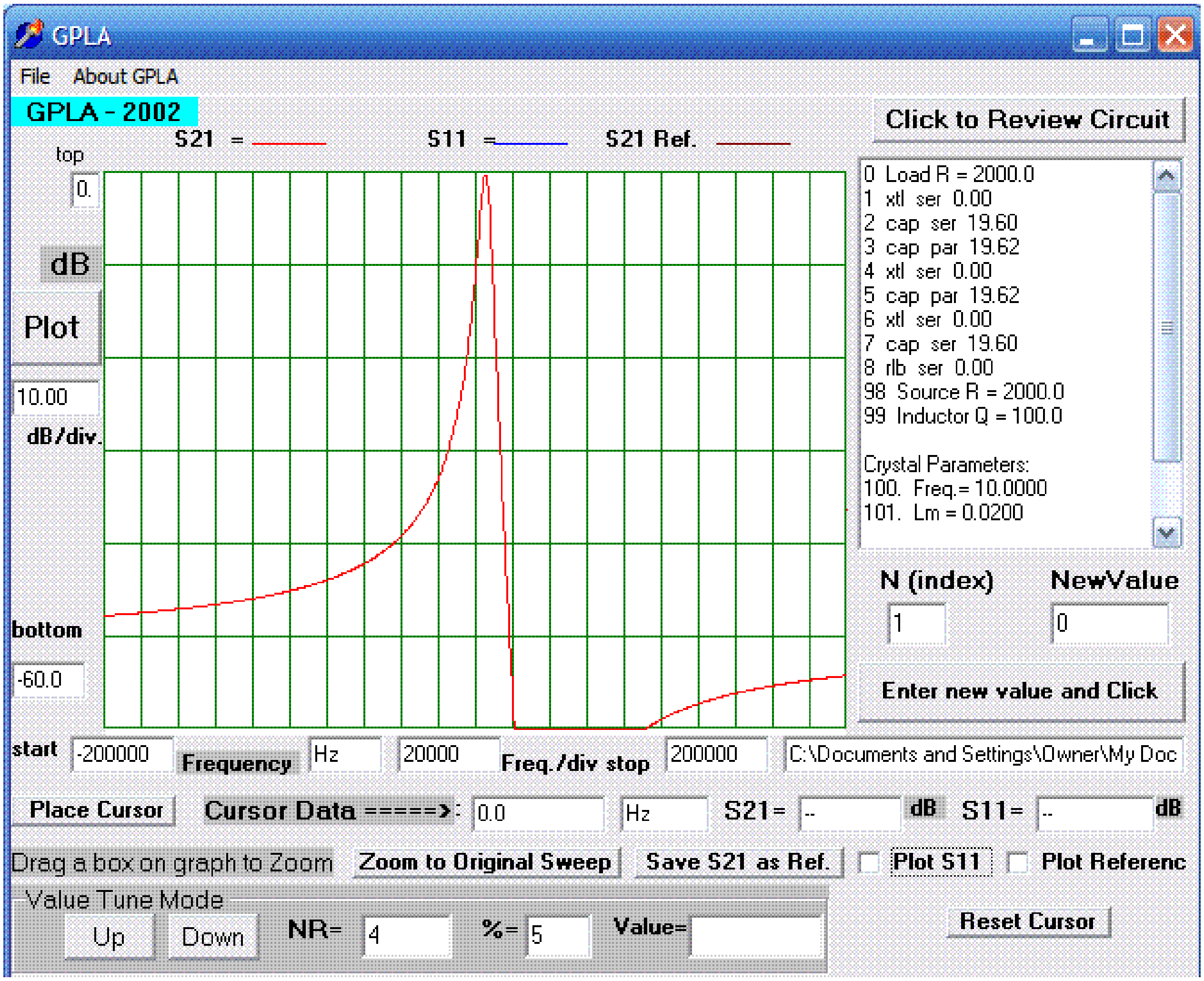
GPLA
File
About GPLA
GPLA - 2002
S21 =
S11 =
S21 Ref.
top
dB
Plot
dB/div.
bottom
Frequency
Freq./div
Click to Review Circuit
N (index)
NewValue
Enter new value and Click
Place Cursor
Cursor Data =====>:
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
☐ Plot S11
☐ Plot Referenc
Value Tune Mode
Up
Down
Reset Cursor

top 0.
10.00 dB/div.
bottom -60.0
start -200000 Hz
Freq./div 20000
stop 200000
C:\Documents and Settings\Owner\My Doc

```
0  Load R = 2000.0
1  xtl  ser  0.00
2  cap  ser  19.60
3  cap  par  19.62
4  xtl  ser  0.00
5  cap  par  19.62
6  xtl  ser  0.00
7  cap  ser  19.60
8  rlb  ser  0.00
98  Source R = 2000.0
99  Inductor Q = 100.0

Crystal Parameters:
100.  Freq.= 10.0000
101.  Lm = 0.0200
```

N (index) 1
NewValue 0
Cursor Data 0.0 Hz
S21= -- dB
S11= -- dB
NR= 4
%= 5
Value=

Above graphic. This is a sweep that goes from 200 kHz below to 200 kHz above 10 MHz to show the stop band response of this filter. This filter has a pretty decent response considering the low cost and effort involved.

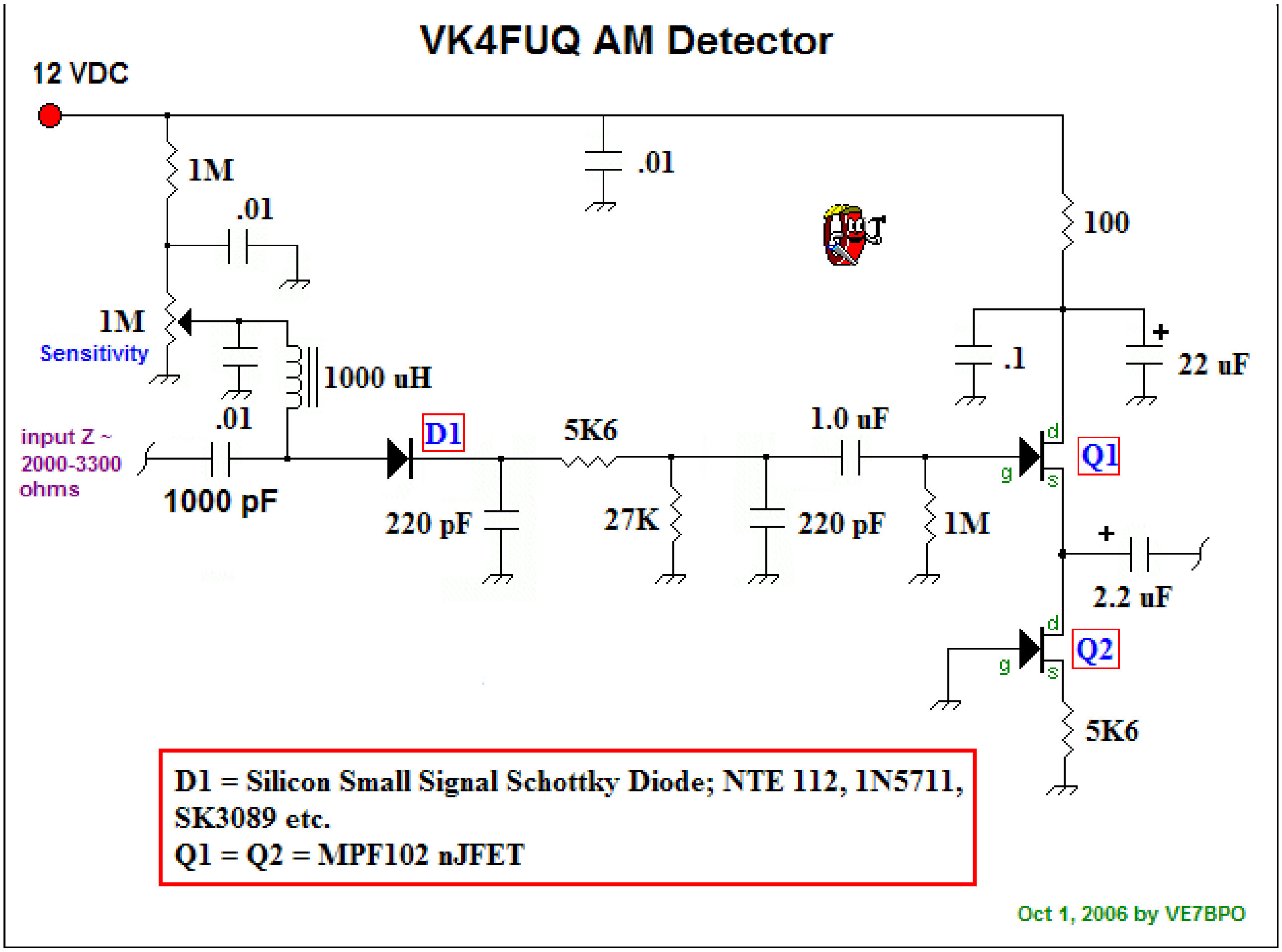
VK4FUQ AM Detector
12 VDC
1M
.01
.01
100
1M
Sensitivity
1000 uH
.1
+
22 uF
input Z ~
2000-3300
ohms
.01
D1
5K6
1.0 uF
d
g
s
Q1
1000 pF
220 pF
27K
220 pF
1M
+
2.2 uF
d
g
s
Q2
5K6
D1 = Silicon Small Signal Schottky Diode; NTE 112, 1N5711, SK3089 etc.
Q1 = Q2 = MPF102 nJFET
Oct 1, 2006 by VE7BPO

Above schematic. This detector is fabulous. It was designed by Felix Scerri, VK4FUQ. He has a web page explaining his high fidelity detectors at the Elliot Sound Products (ESP) site: http://sound.westhost.com/articles/am-radio.htm

The ESP web site is a personal favorite. Rod Elliot has one of the best do-it-yourself electronic web sites available. The main URL for his site is http://sound.westhost.com/index2.html

My sincere thanks to Rod and Felix for permission to present Felix's detector on this web page.

His improved AM detector has 3 positive advantages; it has high bandwidth, low distortion and incredible (and variable) sensitivity. I cannot get over how nice this detector sounds compared to others I have built and analyzed during weak and strong signal testing. The variable bias control allows the listener to adjust the bias to maintain detected audio fidelity even when the RF signal is weak.

This detector uses a UHF mixer diode often found in older television sets. Increasing the diode bias from O volts towards maximum causes three things to happen:

1. Increased sensitivity.
2. Increased audio high frequency response.
3. Slight increase in receiver noise.

When the WWV RF signal is weak, turning the bias off may result in the detected WWV signal disappearing. Increasing the bias will bring WWV back in. I generally run the bias control pot about 1/2 way and of course, higher as WWV fades out. I like the fidelity that the bias adds even when the WWV signal is strong. Note how the WWV audio quality continues to be high in fidelity as WWV fades out in this sound file.

Felix called for a 1 mH radio frequency choke. The largest I had in stock was a 1000 uH choke. I had to decouple it as shown to prevent oscillations from occurring in my receiver. For the 1 uF and 2.2 uF capacitors, I used polyester film types which sounded better than electrolytic capacitors.

Oct 13, 2006: Note. The 1000 pf input cap to the detector was omitted in error in the original schematic which is now correct.

To the right: The detector board. On the left is an op amp preamp stage that was later disconnected as it was not needed. Note the copper is removed where the chassis mounting nut contacts the copper board. Both audio boards were isolated from chassis ground and star grounded to a single point. The speaker negative terminal was also directly connected to this point. There is no hum.

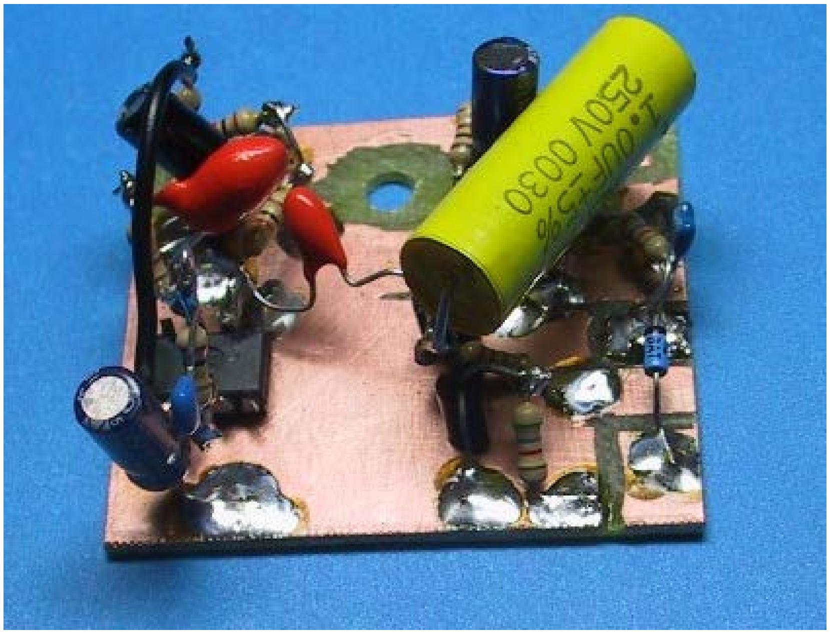
1.0uF±5%
250V 0030

Audio Amplifier

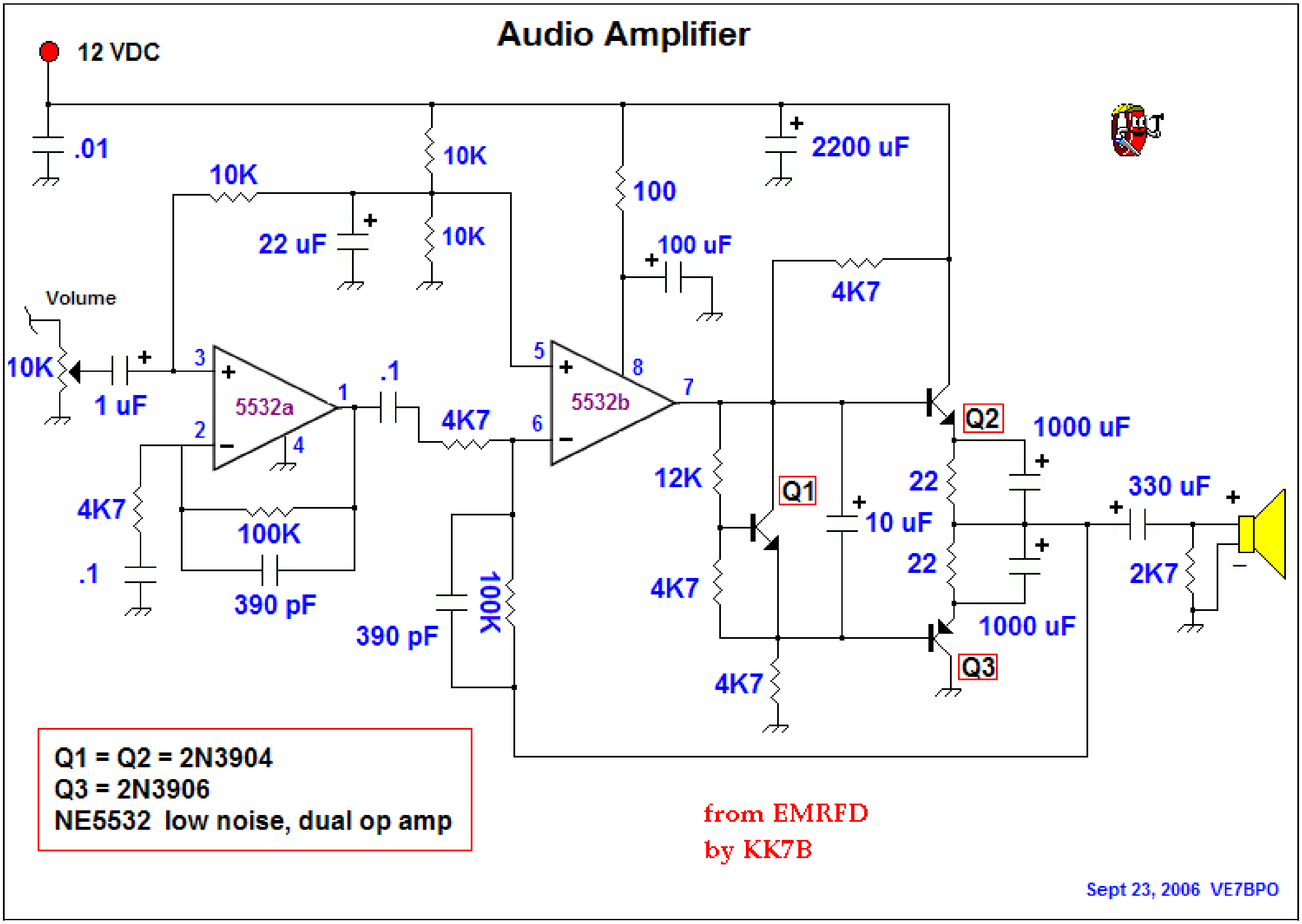
Audio Amplifier
12 VDC
.01
10K
10K
22 uF
10K
100
2200 uF
100 uF
4K7
Volume
10K
1 uF
3
5532a
1
2
4
.1
4K7
5
6
5532b
8
7
Q2
1000 uF
4K7
100K
.1
390 pF
390 pF
100K
12K
Q1
10 uF
22
22
330 uF
2K7
4K7
4K7
1000 uF
Q3
Q1 = Q2 = 2N3904
Q3 = 2N3906
NE5532 low noise, dual op amp
from EMRFD
by KK7B
Sept 23, 2006 VE7BPO

Above schematic. Rick, KK7B designed this low noise audio amplifier. It is from EMRFD. This superb AF amp greatly compliments the VK4FUQ detector. This is the best speaker audio amp under 1 watt I have ever used. Distortion is very low as long as it is not over-driven. I increased some capacitor values compared to the original schematic. Please refer to EMRFD for details on this stage. The chassis of this receiver greatly increases the low frequency response. On the 1 second pulses of WWV, the receiver "knocks" like a metronome. This does not occur when the chassis lid is off.

WWV web site: http://tf.nist.gov/stations/wwv.html All the often subtle pulses and tones transmitted at various times during the hour can be heard with this receiver.

To the right: A bread board of the AF amp. This is the audio amp I shall use in future projects which contain a speaker. Kudos to KK7B.

Below 3 images: Different views of the TRF receiver. On the front from left to right are the bias "sensitivity" control, volume control with integral power switch and blue LED "power on" indicator.

On the rear from left to right are the 12 VDC input jack, an unused switch (was an -10 dB attenuator at 1 point), the RF gain control and a coaxial SO239 connection.

Further Experiments

What follows are some of the ideas and circuits tried over the past year.

Schematic to the right: A 10 MHz, double tuned RF band pass filter that may be used ahead of the receiver. Insertion loss is ~ 3 dB and this filter uses a 5 pF coupling capacitor which are not too difficult to find. Filters with bandwidths of 150 - 180 KHz were also tested.

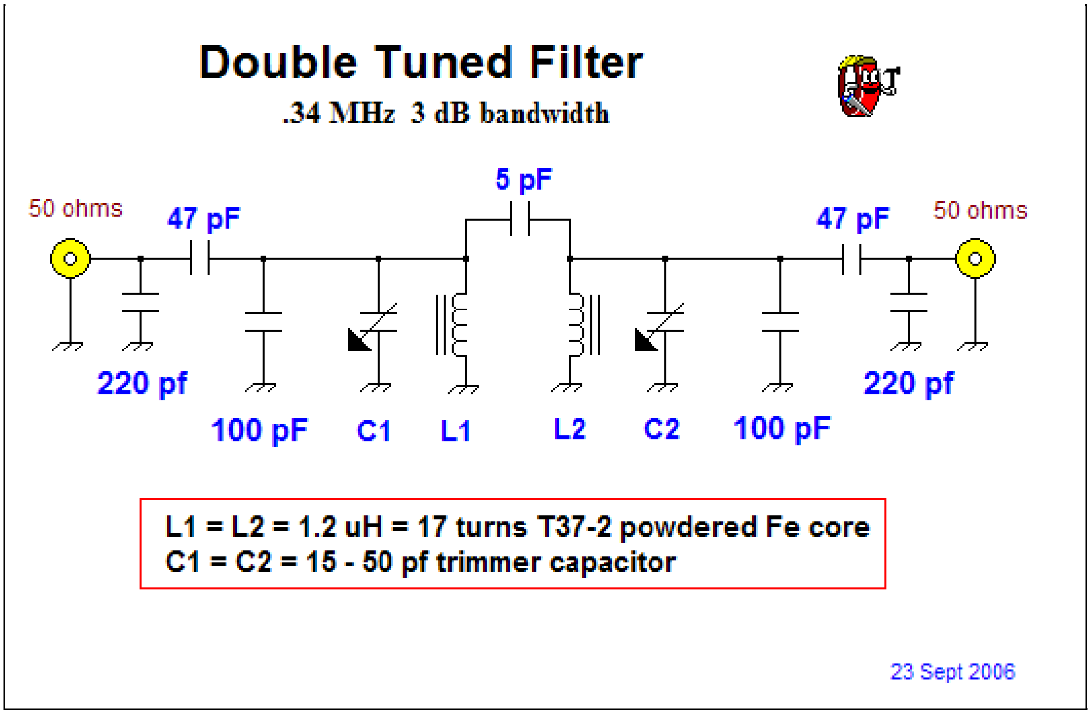
Double Tuned Filter
.34 MHz 3 dB bandwidth
50 ohms
47 pF
5 pF
47 pF
50 ohms
220 pf
100 pF
C1
L1
L2
C2
100 pF
220 pf
L1 = L2 = 1.2 uH = 17 turns T37-2 powdered Fe core
C1 = C2 = 15 - 50 pf trimmer capacitor
23 Sept 2006

To the right: A GPLA simulation of the popcorn DTC shown above. titlehough a little mistuned, it is reasonable for a filter that uses common junk box values and has low insertion loss.

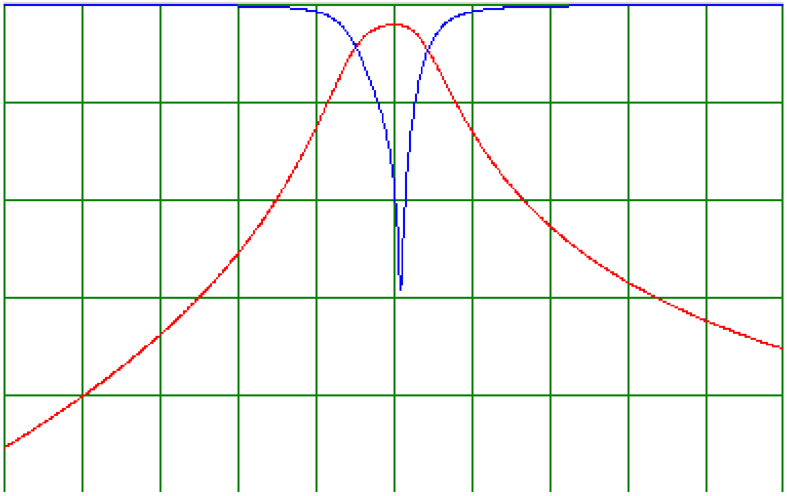

L-Match AM Detector

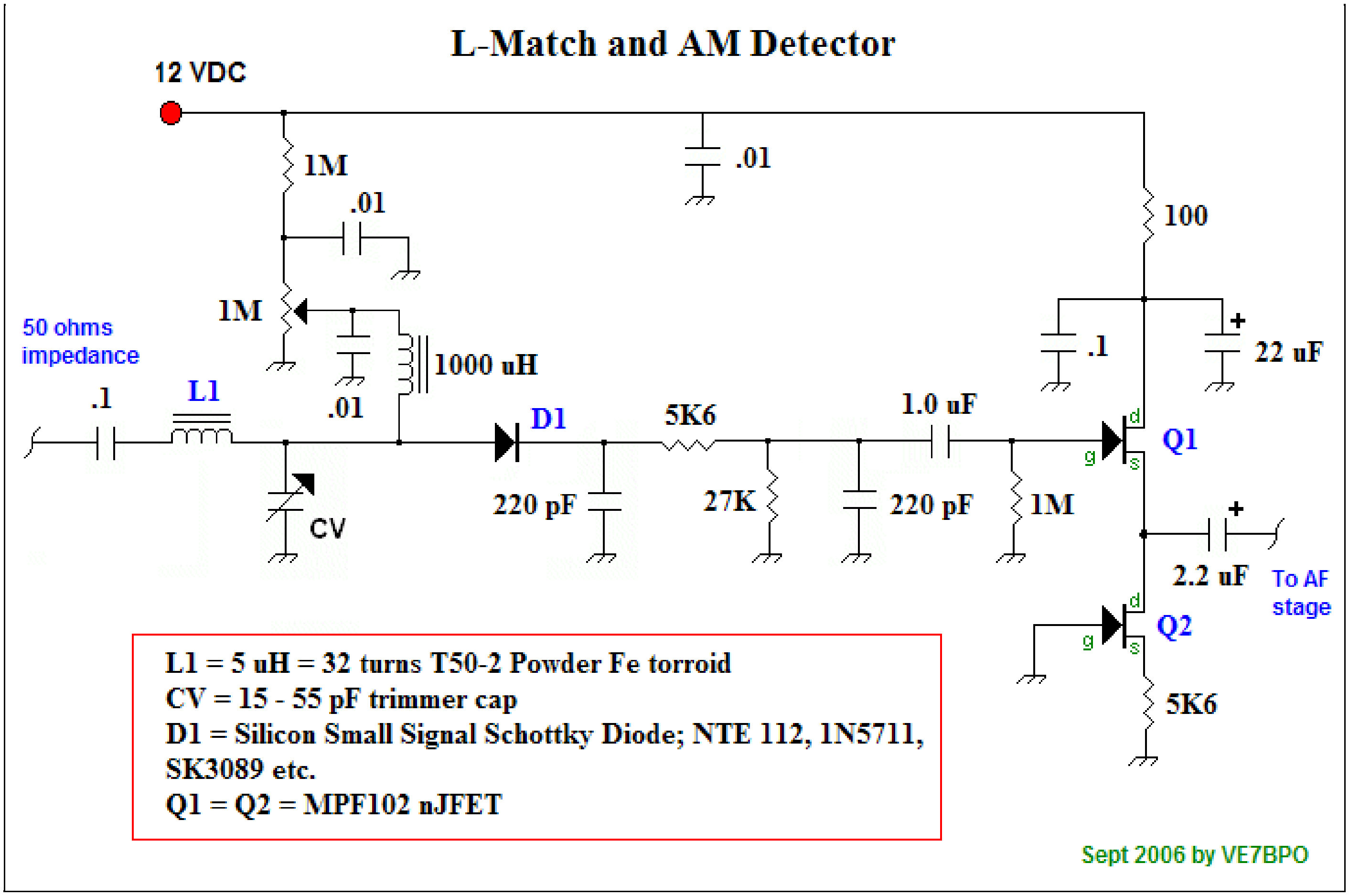
L-Match and AM Detector
12 VDC
1M
.01
.01
100
50 ohms
impedance
1M
1000 uH
.1
22 uF
+
.1
L1
.01
D1
5K6
1.0 uF
Q1
d
g
s
CV
220 pF
27K
220 pF
1M
+
2.2 uF
To AF
stage
Q2
d
g
s
5K6
Sept 2006 by VE7BPO

L1 = 5 uH = 32 turns T50-2 Powder Fe torroid
CV = 15 - 55 pF trimmer cap
D1 = Silicon Small Signal Schottky Diode; NTE 112, 1N5711, SK3089 etc.
Q1 = Q2 = MPF102 nJFET

Above schematic. The VK4FUQ detector can also be used to follow a 50 ohm output impedance stage by using an L-match as shown. The L match tunes very sharply. I peaked the L-match with the bias at 0 volts.

The input impedance of the detector is related to the DC current flowing in the diode. This is established by the adjustable bias current or "sensitivity control". The input resistance will be 26/I, where I is the current in mA.

For example, if the current in the diode is 10 microamps (0.01 mA) the input Z is 2600 Ohms. I have found that any input Z value from 2000 to 5100 ohms worked well with this detector.

Image to the right: A photograph of the L-match connected to a - 6dB 50 ohm pad which terminated the 50 ohm feedback amplifier that drove the L-match.

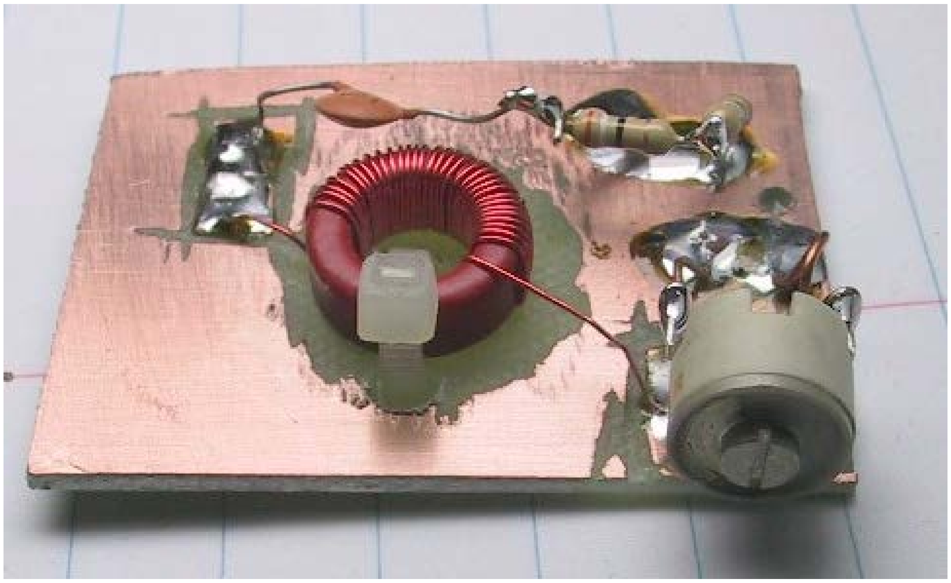

Feedback amplifiers

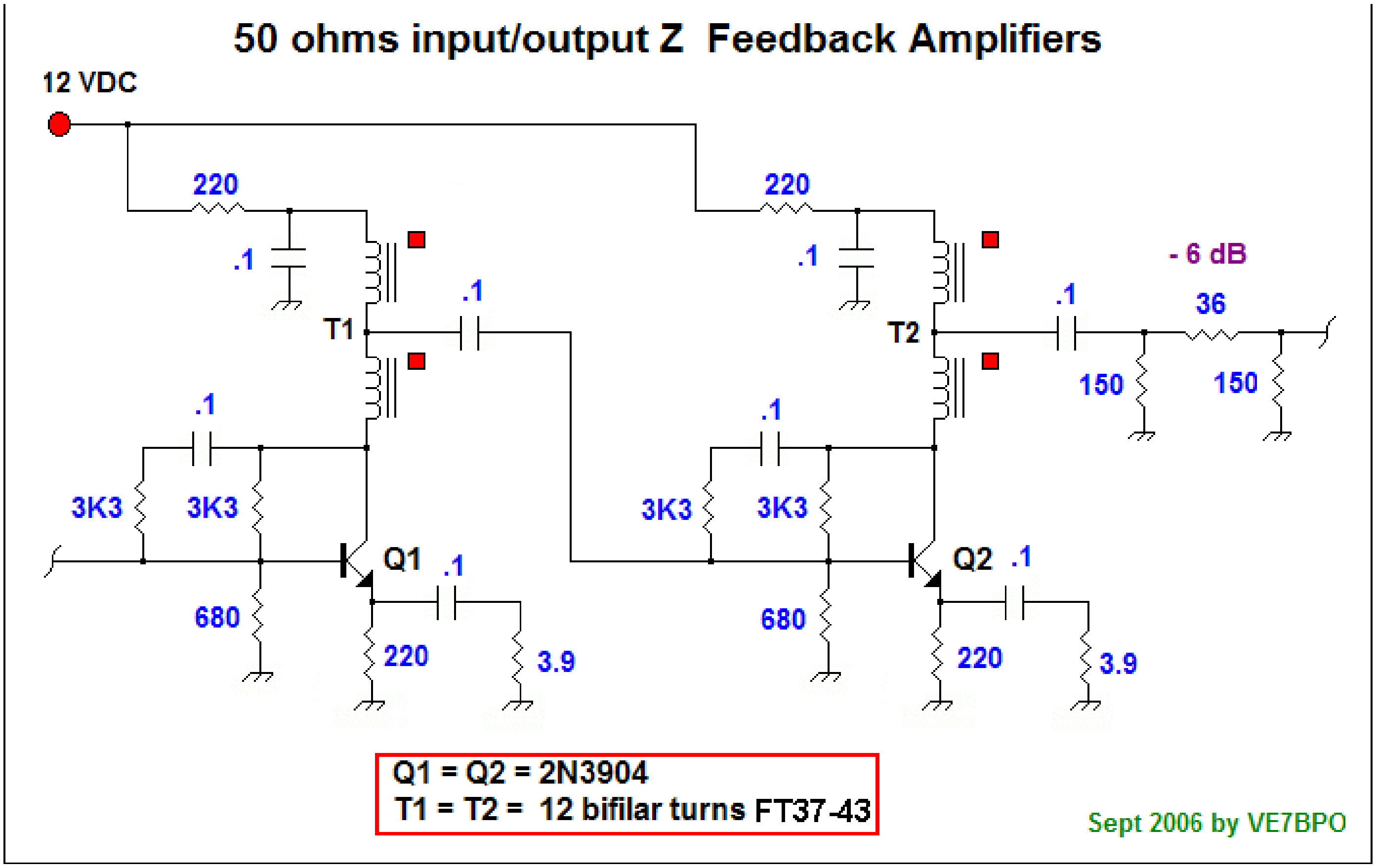
50 ohms input/output Z Feedback Amplifiers
12 VDC
220
.1
T1
.1
.1
3K3
3K3
Q1
.1
680
220
3.9
220
.1
T2
.1
3K3
3K3
Q2
.1
680
220
3.9
- 6 dB
.1
36
150
150
Q1 = Q2 = 2N3904
T1 = T2 = 12 bifilar turns FT37-43
Sept 2006 by VE7BPO

Above schematic. Feedback amplifiers may be used as RF amplifiers for a TRF receiver. This stage followed the crystal filter in one version of my TRF receiver. Stability was excellent. This feedback amplifier was designed by Wes, W7ZOI. It has ~ 20 dB gain and draws a little over 5 mA current.

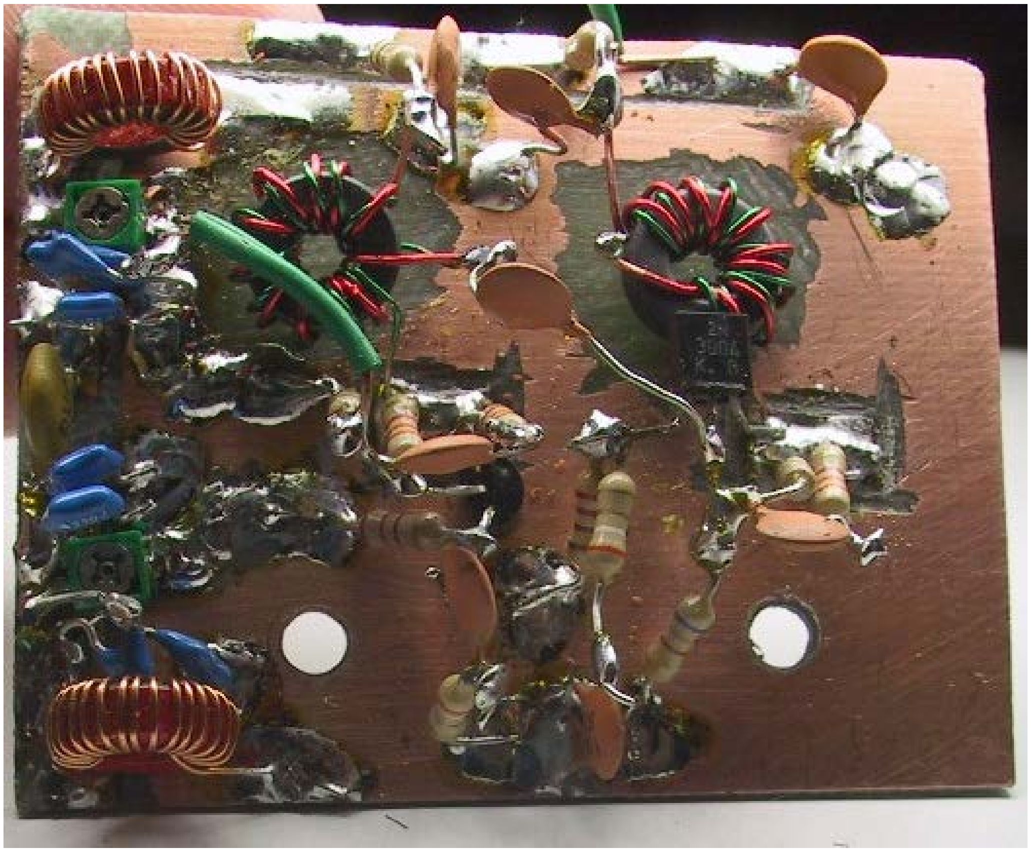

Above graphic. 2 feedback amplifiers are shown on this breadboard. The double tuned filter (DTC) shown earlier is also built on this board. In this version, the crystal filter was omitted and replaced with the DTC.

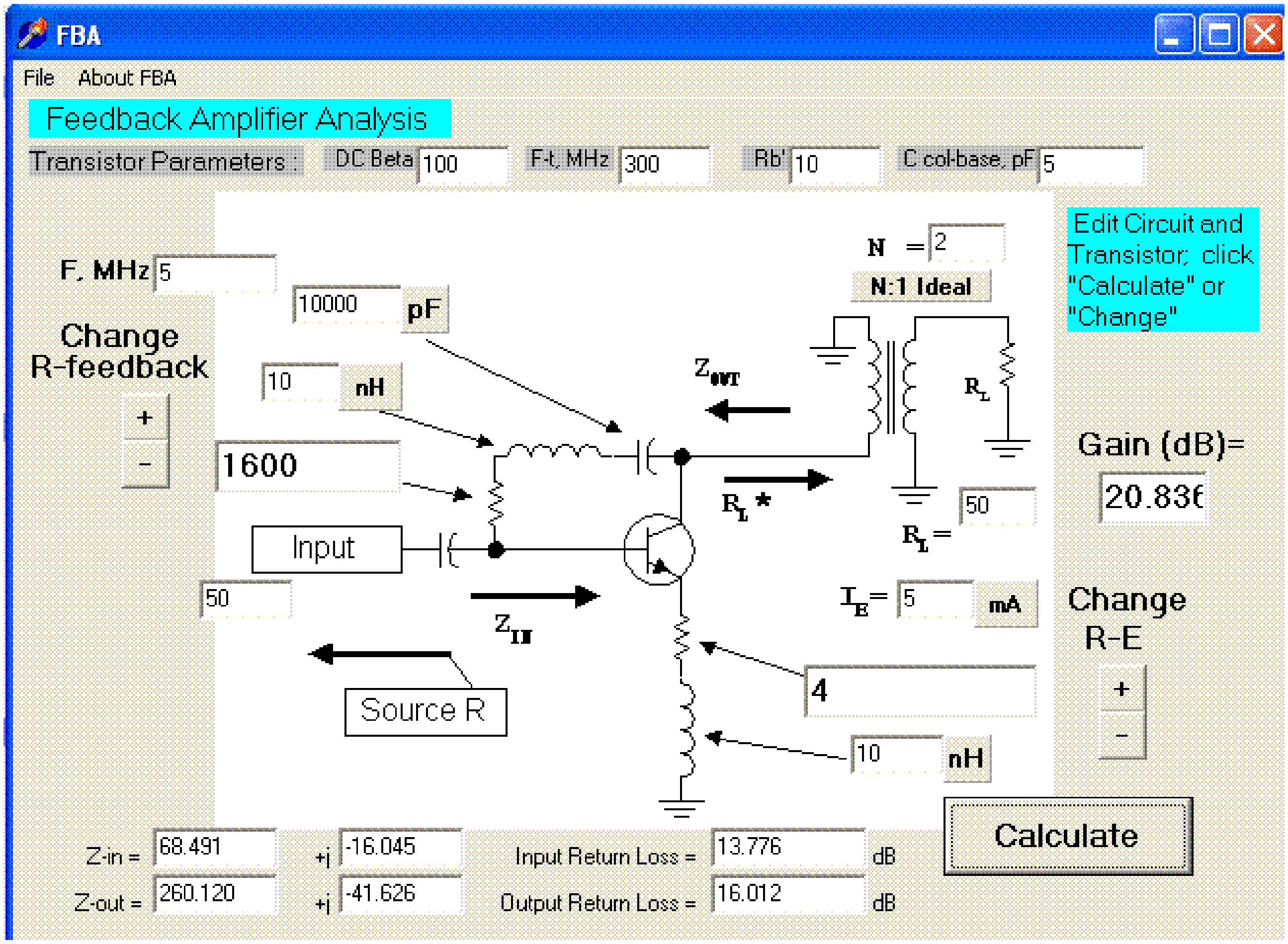
FBA
File
About FBA
Change R-feedback
+
-
Input
Source R
Z_{OUT}
Z_{IN}
R_L *
R_L
Change R-E
+
-
Calculate

Feedback Amplifier Analysis

Transistor Parameters : DC Beta 100 F-t, MHz 300 Rb' 10 C col-base, pF 5

F, MHz 5

10000 pF

10 nH

1600

50

N = 2

N:1 Ideal

Edit Circuit and Transistor; click "Calculate" or "Change"

R_L = 50

I_E = 5 mA

4

10 nH

Gain (dB)= 20.836

Z-in = 68.491 +j -16.045 Input Return Loss = 13.776 dB

Z-out = 260.120 +j -41.626 Output Return Loss = 16.012 dB

Above graphic. Using software that ships with EMRFD, W7ZOI designed the feedback amplifier used in this version of the receiver.

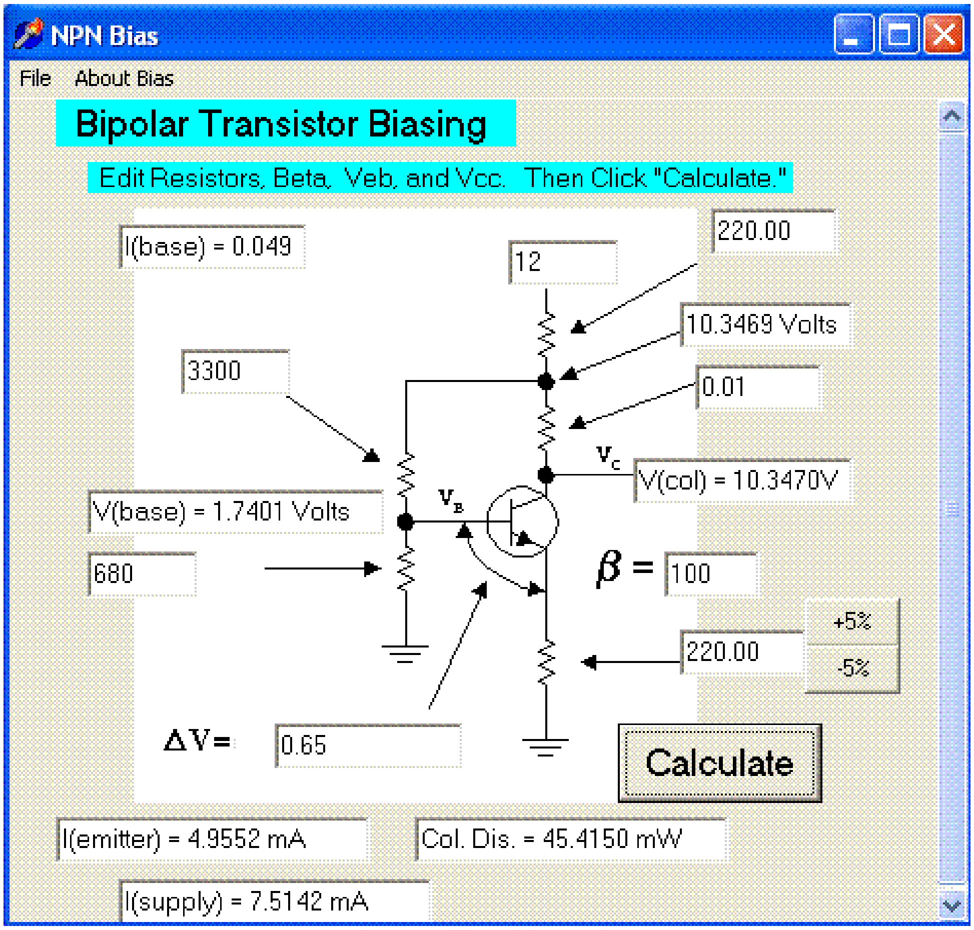
NPN Bias
File
About Bias
V_C
V_B
+5%
-5%
Calculate

Bipolar Transistor Biasing

Edit Resistors, Beta, Veb, and Vcc. Then Click "Calculate."

I(base) = 0.049

12

220.00

10.3469 Volts

3300

0.01

V(col) = 10.3470V

V(base) = 1.7401 Volts

680

β = 100

220.00

ΔV= 0.65

I(emitter) = 4.9552 mA

Col. Dis. = 45.4150 mW

I(supply) = 7.5142 mA

Above graphic. The feedback amplifier bias resistor values were also calculated using software written by W7ZOI and included with EMRFD.

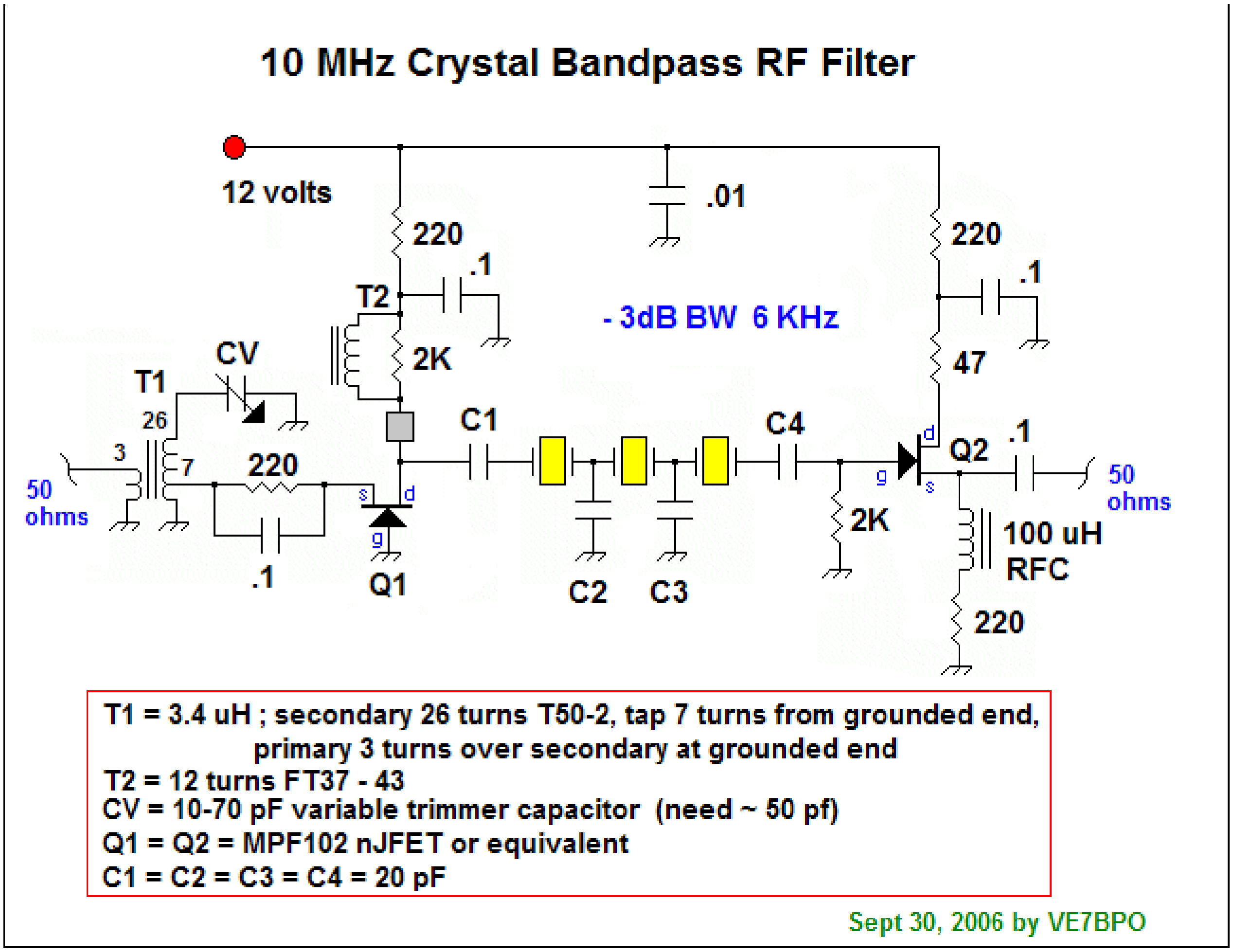
10 MHz Crystal Bandpass RF Filter
12 volts
220
.01
220
.1
.1
T2
- 3dB BW 6 KHz
2K
47
CV
T1
26
3
7
50 ohms
220
.1
C1
C4
d
Q2
.1
s
g
d
g
50 ohms
2K
100 uH RFC
Q1
C2
C3
220

T1 = 3.4 uH ; secondary 26 turns T50-2, tap 7 turns from grounded end,
primary 3 turns over secondary at grounded end
T2 = 12 turns FT37 - 43
CV = 10-70 pF variable trimmer capacitor (need ~ 50 pf)
Q1 = Q2 = MPF102 nJFET or equivalent
C1 = C2 = C3 = C4 = 20 pF

Sept 30, 2006 by VE7BPO

Above schematic. This circuit has the crystal filter matched to 50 ohms input and output stages using JFETs. The JFETs also serve to provide a little more gain. Careful layout is required to reduce BCB interference for all stages in a TRF receiver.

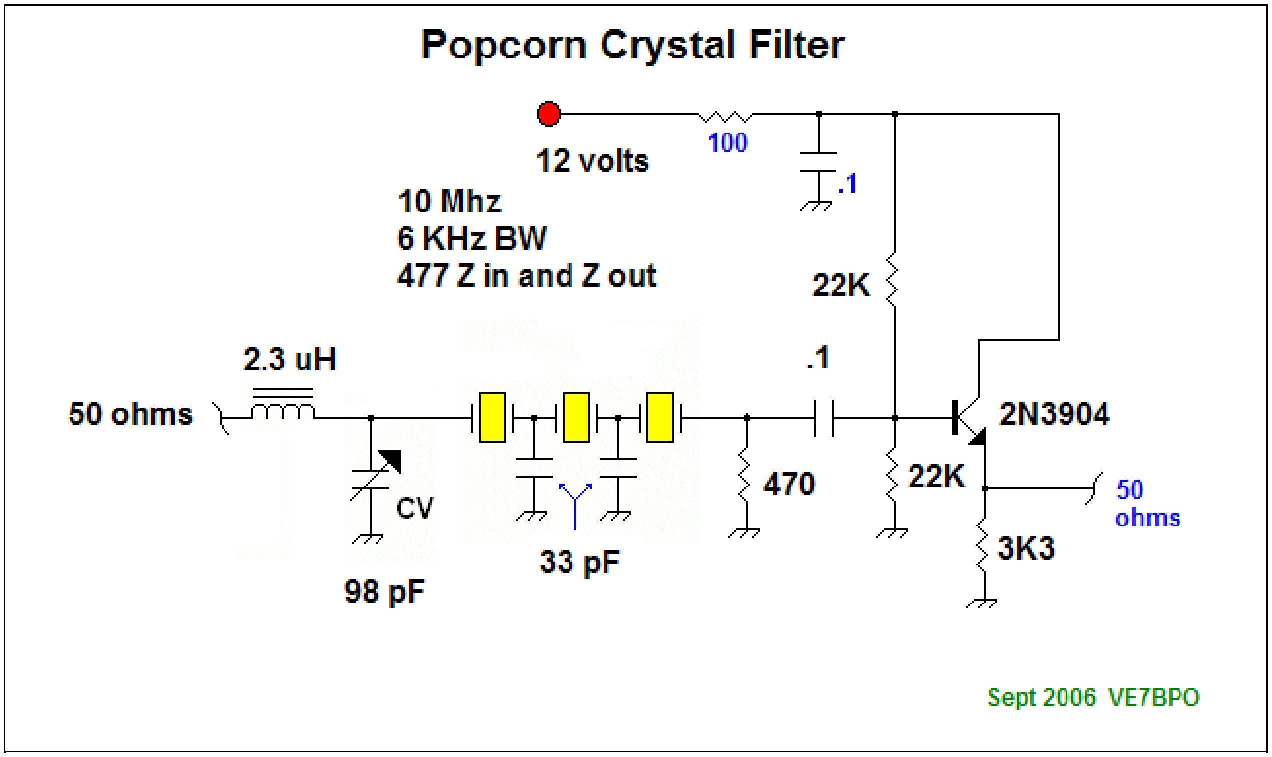
Popcorn Crystal Filter
12 volts
100
.1
10 Mhz
6 KHz BW
477 Z in and Z out
22K
2.3 uH
.1
50 ohms
2N3904
CV
470
22K
50 ohms
3K3
98 pF
33 pF
Sept 2006 VE7BPO

Above schematic. This is the original crystal filter that I designed. The input and output impedance is 477 ohms. The input was matched to the preceding 50 ohm stage using an L-network. A emitter follower is used to match the output to the 50 ohm stage which followed. Later, the emitter follower was replaced with the source follower (with a 470 ohm gate resistor) that is shown in the schematic directly above. The source follower had greater immunity to BCB interference and provided a better termination for this filter. This popcorn filter worked well, titlehough occasionally there was another station in addition to WWV, in the pass band. This also happened with the filter used in the final version of this receiver.

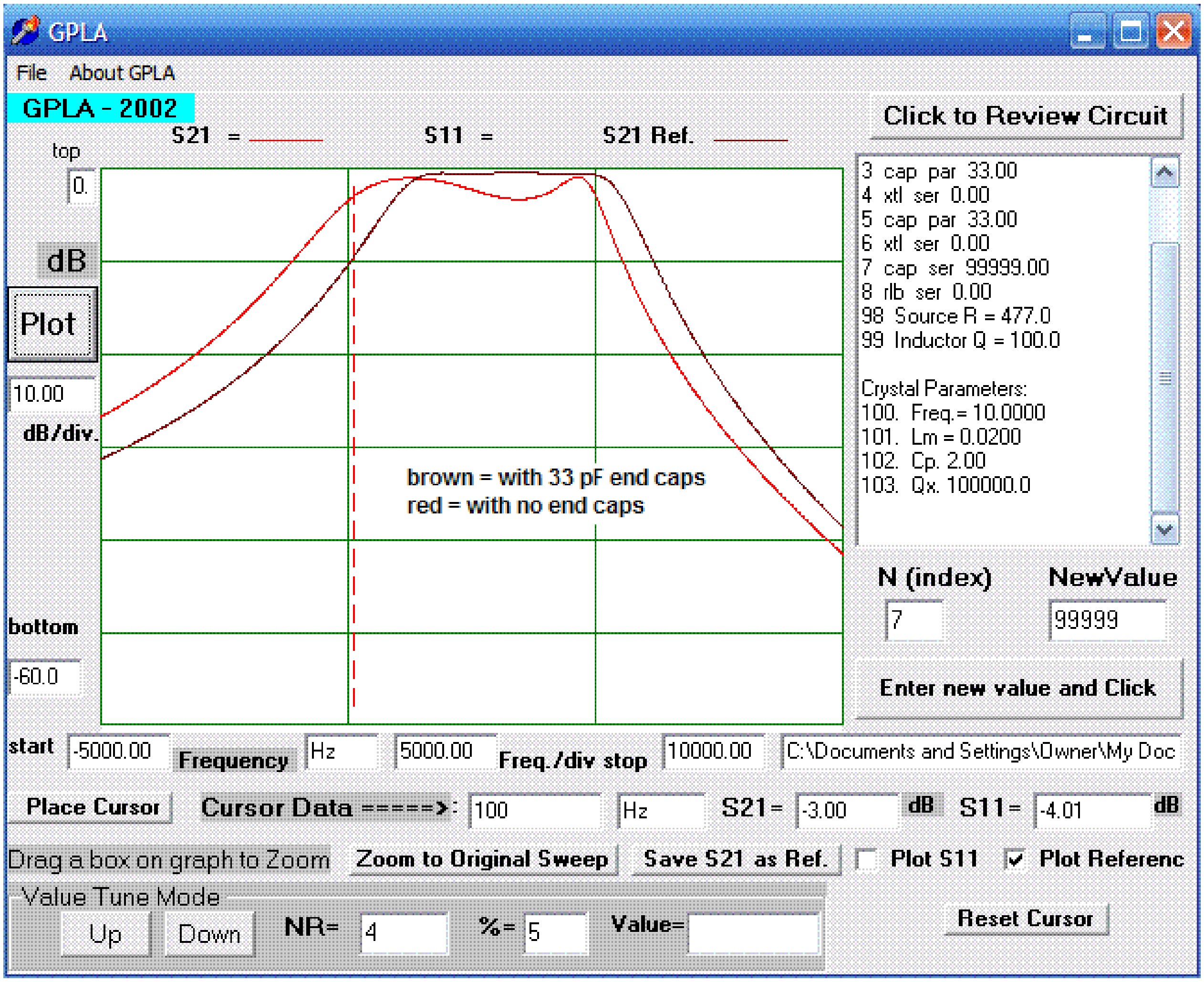
GPLA
File
About GPLA
GPLA - 2002
S21 =
S11 =
S21 Ref.
dB
Plot
Click to Review Circuit
Enter new value and Click
Place Cursor
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Value Tune Mode
Up
Down
Reset Cursor

brown = with 33 pF end caps
red = with no end caps

```
3  cap  par  33.00
4  xtl  ser  0.00
5  cap  par  33.00
6  xtl  ser  0.00
7  cap  ser  99999.00
8  rlb  ser  0.00
98  Source R = 477.0
99  Inductor Q = 100.0

Crystal Parameters:
100.  Freq.= 10.0000
101.  Lm = 0.0200
102.  Cp. 2.00
103.  Qx. 100000.0
```

top 0.

10.00 dB/div.

bottom -60.0

N (index) 7

NewValue 99999

start -5000.00 Frequency Hz

5000.00 Freq./div

stop 10000.00

C:\Documents and Settings\Owner\My Doc

Cursor Data =====>: 100 Hz S21= -3.00 dB S11= -4.01 dB

☐ Plot S11 ☑ Plot Referenc

NR= 4 %= 5 Value=

Above graphic. Here are GPLA simulations of the popcorn filter with and with out 33 pF series end capacitors which serve to tune the filter. The brown tracing illustrates that it is better to include a series 33 pF cap at each end of the "popcorn" crystal filter. I did not use this filter because the dual gate MOSFET RF amps used in the final version, have better gain driving or following the 2000 ohm filter designed by W7ZOI.

GPLA is a "must-have" program. You can "tune" filters with different or asymmetric input/output impedances.

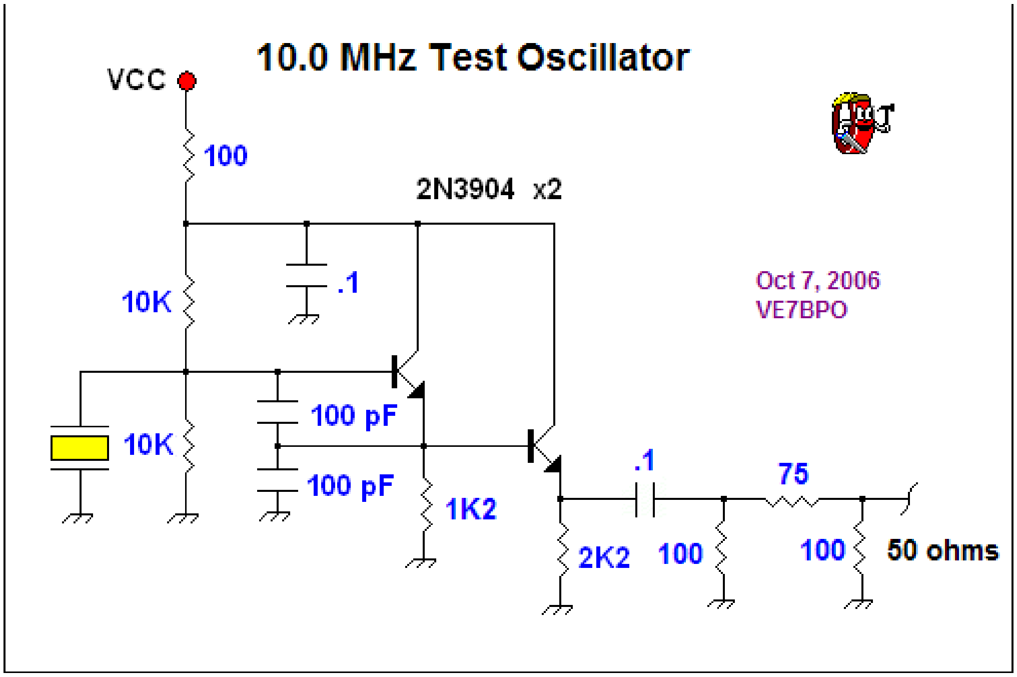
10.0 MHz Test Oscillator
VCC
100
2N3904 x2
.1
10K
Oct 7, 2006
VE7BPO
100 pF
10K
100 pF
.1
75
1K2
2K2
100
100
50 ohms

Above schematic. This 10.0 MHz crystal oscillator has a - 10 dB, 50 ohm pad on the output and was used to match the crystals, test the RF amps and align the filters used in these experiments.

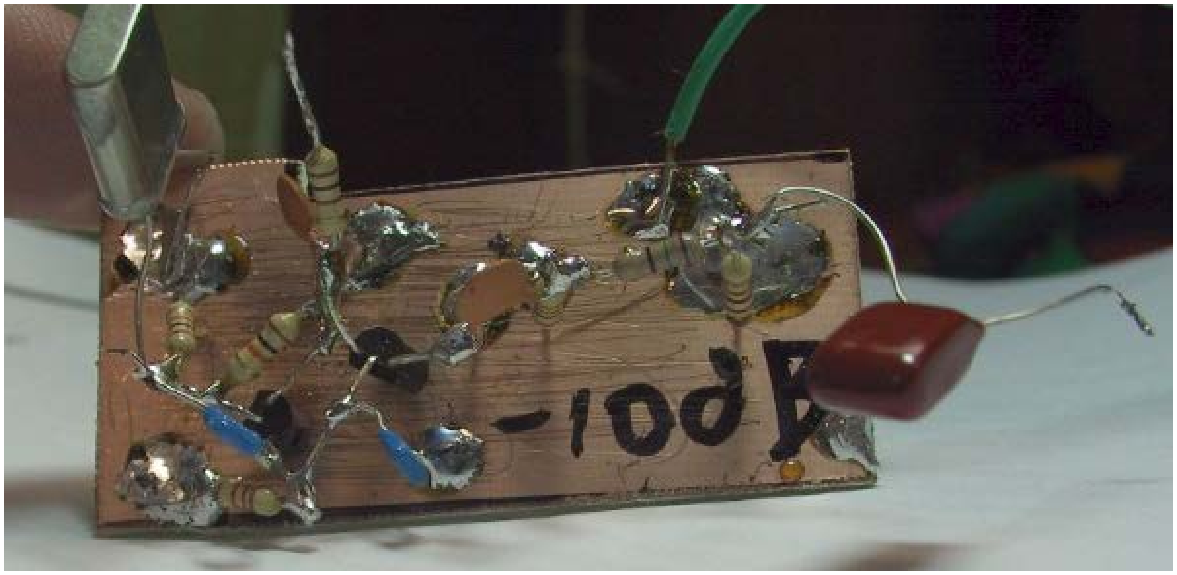

Above graphic. A breadboard of the test oscillator shown above.

Above graphic. Some of the bread boards developed during experimentation. My final receiver layout (and potentiometer positioning) is not optimal, however this is a prototype and I had no idea what the finished version would look like.

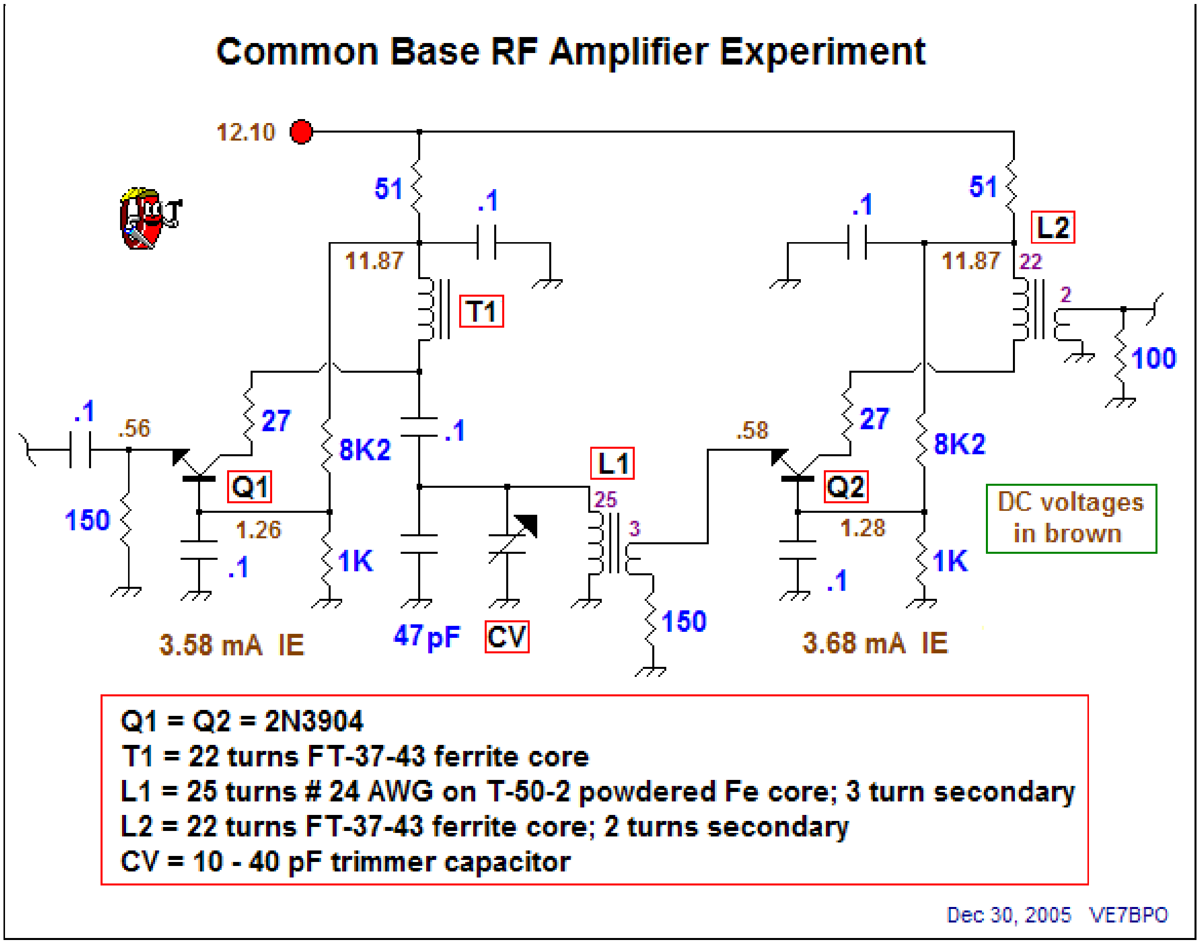
12.10
51
.1
11.87
T1
27
8K2
.1
.56
Q1
150
1.26
.1
1K
3.58 mA IE
47 pF
CV
L1
25
3
150
.58
Q2
27
8K2
1.28
.1
1K
3.68 mA IE
.1
51
L2
11.87
22
2
100
DC voltages in brown

Common Base RF Amplifier Experiment

Q1 = Q2 = 2N3904
T1 = 22 turns FT-37-43 ferrite core
L1 = 25 turns # 24 AWG on T-50-2 powdered Fe core; 3 turn secondary
L2 = 22 turns FT-37-43 ferrite core; 2 turns secondary
CV = 10 - 40 pF trimmer capacitor

Dec 30, 2005 VE7BPO

Above schematic. This is one RF amp that was built for this receiver. The turns ratios on L1 is too drastic to afford much gain.

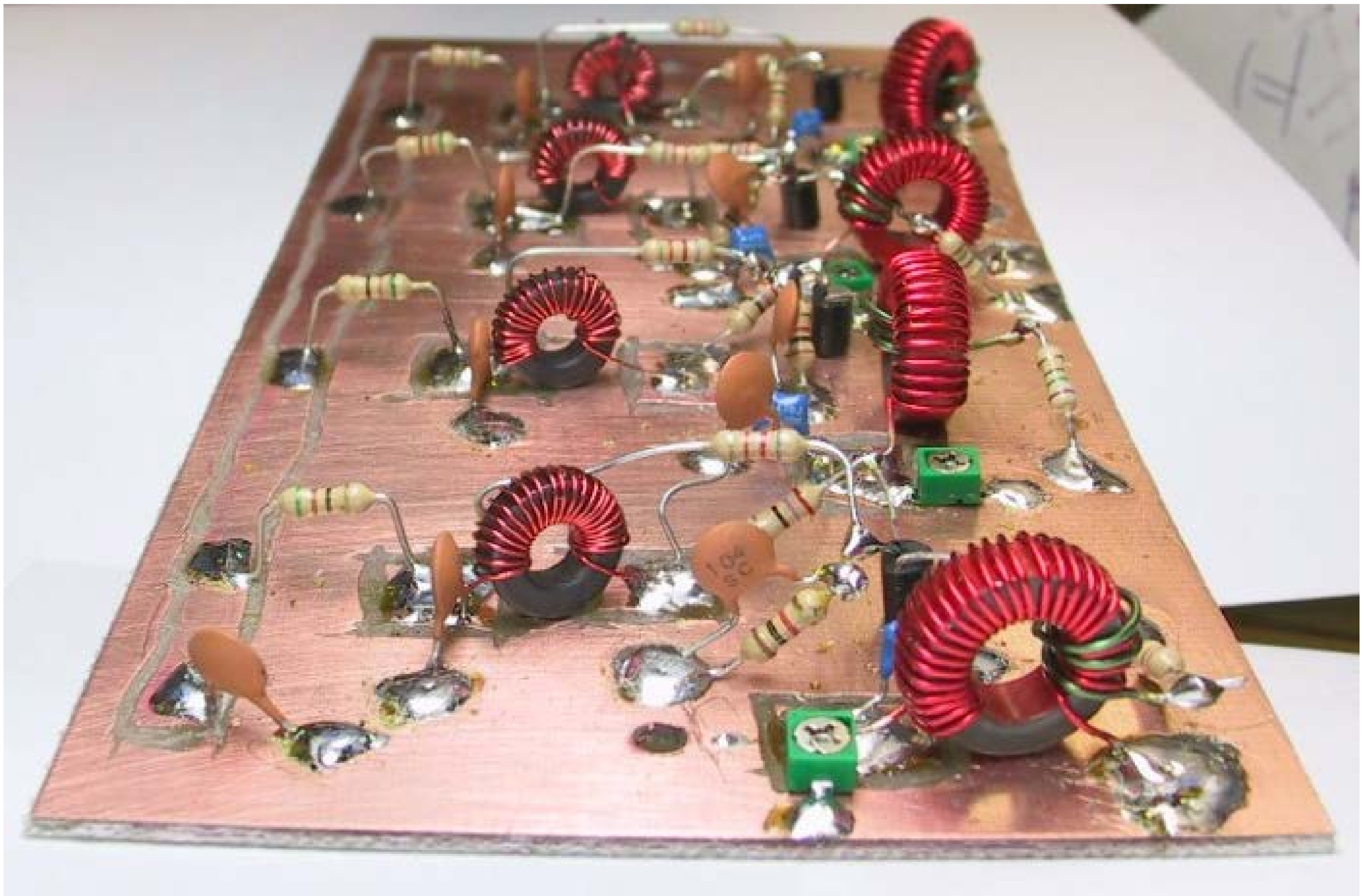

Above graphic. I have been told many times that my breadboards are very ugly looking. This breadboard of the schematic directly above, shows that occasionally, I can build a nice looking circuit!

Conclusion

The highlights of these experiments were VK4FUQ's detector and KK7B's AF amplifier.

When constructing such a receiver, *build backwards*. Install the speaker and then build and test the AF amp. Test it by touching your finger to the input and listening for noise or BCB radio. Turn the 10K pot and verify that the noise increases or decreases appropriately. Perhaps test it using an AF oscillator.

If it works, you get immediate positive feedback and motivation to continue. If it does not work, you only have 1 stage to trouble shoot.

Next, build the detector. To test it, connect a piece of wire about 25 cm long between the RFC and the anode of the diode. You should then hear local BCB radio. Slowly turn the bias potentiometer from 0 to fully on. Notice how increasing the bias may bring in 2 or more stations compared to when it was at 0. Also notice how it changes the tone and sensitivity of the detector. Try shortening the "test antenna" and observing how sensitive this detector is with the bias increased.

If all went well, you now have an AM radio!

Next add in the Q3 RF amp and again test it using a short piece of wire. Then continue on until you arrive at the antenna connection for your receiver.

Best regards, VE7BPO

Amateur and Short Wave Radio Electronics Experimenter's Web Site

MF and HF Receiving Antenna

Introduction

GRUNDIG
1600
S350

My first shortwave antenna was a simple end-fed wire which started at my bedroom window and extended out horizontally to a tree which was 25 feet away from our house. The antenna feed line was a short piece of wire that connected to the near end of the antenna and entered the house through a small hole I made in my wooden window sill. This feed line was directly connected to my receiver's high impedance antenna input. My station ground was long piece of wire that was connected to a copper pipe located in the bathroom next door. While this antenna brought in "the world" to my bedroom, it was extremely noisy. Directly connecting your antenna feed line and house ground system to your receiver are not good RFI reduction practices. This web page will explore some experiments in trying to minimize the Radio Frequency Interference (RFI) arising from my local environment.

Indoor RFI sources are usually plentiful. Electrical appliances such as washing machines, televisions, DVD players, computers and electrical wiring may all emit RFI which your antenna, or directly connected house ground system may pick up and feed to your receiver. Certain indoor devices may be really strong RFI sources and will have to be eliminated or decoupled. Outside of your house are also potential sources of RFI. These may include such things as power transformers, electric fence and garage door openers. RFI location and reduction is out of scope for this web page, however a good place to learn more is the ARRL RFI book (out-of-print: search on Amazon). To find RFI sources in your home and neighborhood, try using a battery powered AM radio. At my QTH, I located a noisy VCR inside the house my Grundig S350. We rarely use this VCR and now just leave it unplugged until we actually need to operate it. I tuned the receiver to an empty frequency and found this VCR by trial and error. **Please note this web page is concerned with feeding a shortwave listening antenna and does not describe providing protection against lightning.** For web sites which covers lightening plus RF ground please refer to this offering from W8JI or eHam.net.
Protect your home and family from lightening !!

Outdoor MF and HF Antenna

The schematic to the left summarizes the outdoor VE7BPO MF and HF receiving antenna system for summer 2007. Although modest for a big city lot, this antenna seems to pull in the DX and is relatively free of RFI. This antenna was just a case of "putting as much wire in the sky as possible" and the dimensions are indicated for interest sake only. The 27 meter long horizontal section is supported between 2 trees at a height of about 14 meters high. The weight of the

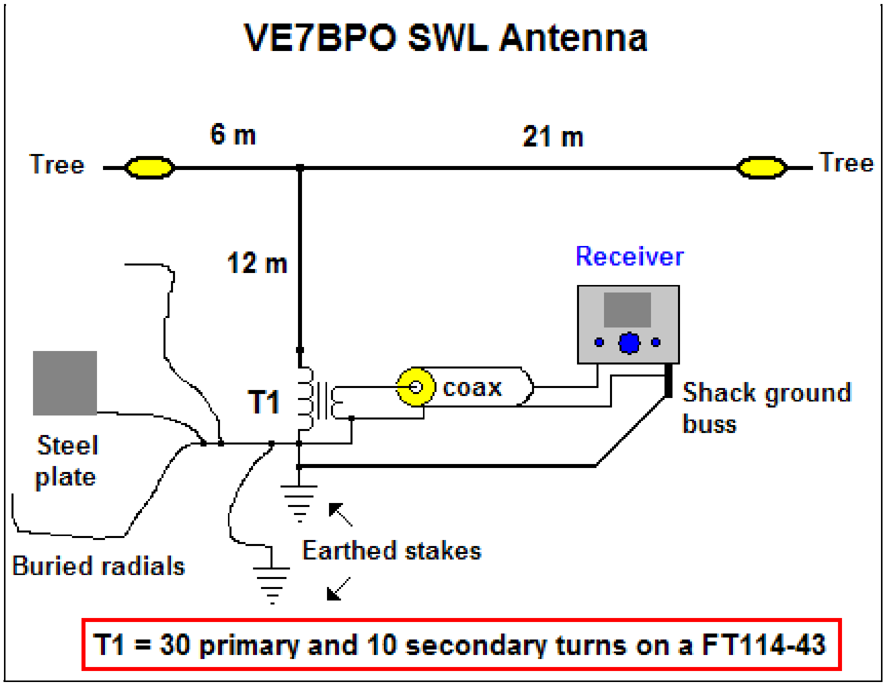

vertical element wire plus slack in the horizontal wire droop it to about 13 meters high in the center. The vertical section is soldered to the horizontal wire 6 meters from the nearest anchoring tree and runs straight down to the antenna feed point which is about 1 meter off the ground. The feed point is a piece of copper-clad PC board (with isolated sections created with a hobbyist motor tool) and is bolted to a long copper pipe which serves as the first station earth-grounding stake. A transformer (T1) configured as a UNUN **(unbalanced-to-unbalanced)** is used to interface the antenna with 50 ohm coax that runs through the house and into the radio shack. Some rudimentary experiments with the UNUN and the earth-grounding system were undertaken.

The methods I used to potentially lower unwanted RFI to my antenna system are as follows:

1. The receiver and power supply are independently connected to a single, central ground point (ground buss) in the radio shack.
2. 6-10 gauge wire is used for my ground system (not including the radials which are bare 12 gauge wire).
3. The ground wire connecting to my first earth stake to the station ground buss is just outside the shack window and is short as possible to provide a low impedance and low inductance path for MF and HF frequencies.
4. There is a second ground stake located 1 meter from the primary ground stake (I will add 2-4 more in time).
5. I have a large piece of steel buried underneath the soil tied in to my system as well as 3 bare copper radials. The radials are 3 - 7 meters in length.
6. New RG58/U coax was used as the feed line.
7. All wire splices in the grounding system are soldered and taped up. I used conductive grease (to prevent oxidation at the wire-stake interface) on any clamps connected to ground stakes. My ground stakes are ~ 2 meters long.
8. The earth grounding area soil is moist and peat-laden and is watered regularly.
9. I plan to maintain this ground system every 2 years.

4:1 UNUN

My antenna is almost an end-fed wire with both a vertical and horizontal section. I do not have the gear to measure the impedance versus frequency in the MF and HF bands. I do know that on some bands it may present an impedance of several thousand ohms and a transformer can smooth out the variation in impedance versus frequency so my receiver sees a relatively low impedance on most bands. The transformer also serves to help reduce RFI from my antenna system by eliminating unwanted common mode currents flowing on the outside of the coax braid. Grounding the antenna via the UNUN will also prevent static electricity from building up on the antenna. My first UNUN had a 4:1 impedance ratio. It is shown to the right. The antenna connects to point **A**. The ground stake connects to point **B.** Point **C** connects to the inner wire of the coax and point **D** is connected to the braid and also the grounding stake. I used 24 AWG wire and A FT114-43 ferrite core. You can clearly see there are 20 primary windings and 10 secondary windings loosely coupled. I chose the FT114-43 core because I had it on hand and the 24 gauge wire provides good mechanical support for the coil. I could have used an FT50-43 ferrite torroid as well with a smaller wire gauge. You can also use a bifilar transmission line type transformer. I was very happy with this UNUN and however it did not have as much signal strength as I expected on the 160 meter amateur band and below.

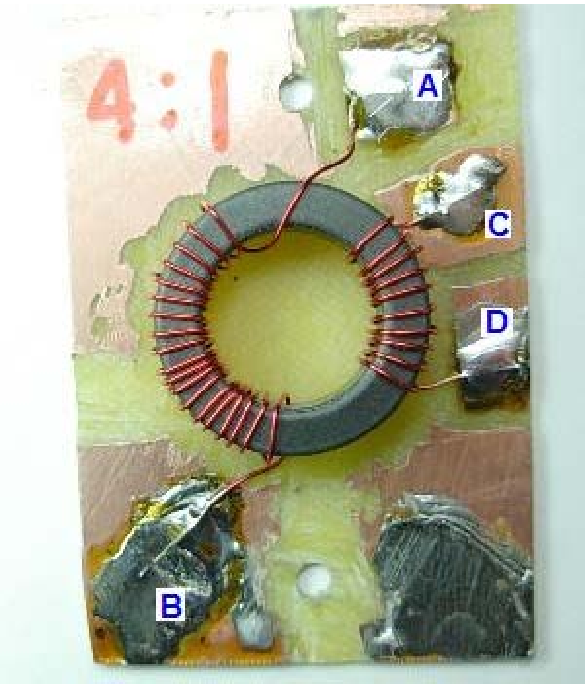

9:1 UNUN

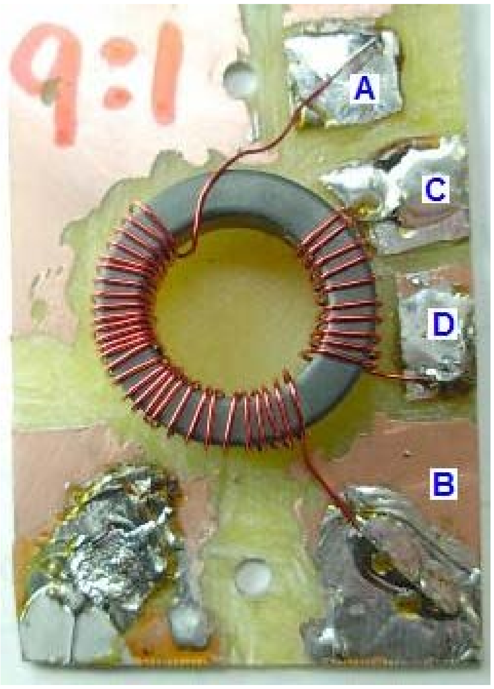

Next I tried a 9:1 impedance ratio UNUN. This an extremely popular impedance transformation ratio for end-fed or random wire SWL antennas. I wound 30 primary and 10 secondary turns on a FT114-43 ferrite torroid. The connection points are identical to those described in the above 4:1 UNUN. Remember that the impedance transformation ratio is the square of the actual turns ratio on your transformer; thus my 3:1 turns ratio is a 9:1 impedance ratio. Electrical engineers commonly use a rule when winding broadband transformers such as these. The inductive reactance (XL) of the smaller winding must be at least 4 times the load impedance at the lowest frequency that the transformer "looks" into. So for 50 ohm coax, the XL should be at least 200 ohms at 500 KHz which is the lowest frequency I intend to receive. The formula for XL is **XL = 6.28 X F X L**. Frequency (F) is in Hertz and L is the inductance in Henries.

At 500 KHz my inductor has an XL of 189 ohms which is almost perfect. I should have used 11 turns which is an XL of 229 ohms and strictly observes the 4X rule. Therefore my UNUN ideally should have used 33:11 turns on the FT114-43 torroid. If you use a FT50-43 torroid, use the same 33:11 turns ratio; this will provide 198 ohms XL at 500 KHz. For practical purposes, my 30:10 UNUN should work fine as I rarely tune frequencies less than 1000 KHz. I found this UNUN to have strong signals all the way down to MF and decided to use a 9:1 impedance ratio for my antenna system. Many experimenters and a few commercial UNUNs recommend the 9:1 impedance ratio for multiband end-fed or random wire antennas. Eventually I will encase it in a water and UV proof enclosure.

Conclusion

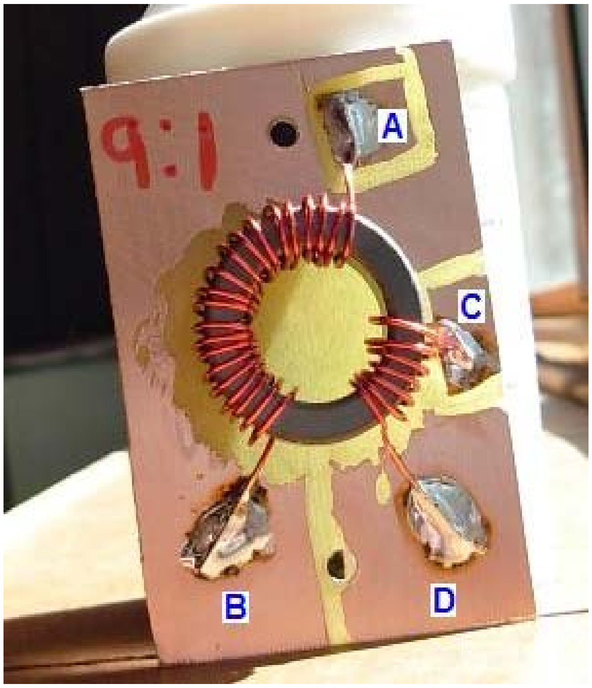

My experiments while constructing a reasonable quality MF and HF receiving antenna confirmed that using a UNUN, coax and a good RF ground system can reduce common mode RFI in my receivers.
I also tried temporarily connecting my ground system to a copper water pipe located in my shack while listening to WWV at 5 MHz and immediately the noise level rose 2 S-units on my receiver.
This pipe was clearly not grounded in my house where there is a mixture of plastic and copper water pipes. Additionally, my antenna wire and feed point is away from the house in a quiet area according to listening tests using a Grundig S350.

It is relatively easy to construct a UNUN on your bench using a ferrite torroid. Many builders have emailed me to say they do not feel comfortable winding torroids. Torroids are easy to use and by winding a couple and experiencing some success, your confidence working with them will surely improve. If you live in a part of the world where you can not easily obtain a suitable ferrite core, just email me and I may send you an FT50-43. You can also choose a ferrite with a different core permeability. Some builders use number 75 material. I used the FT114-43 because I get all my torroids from W8DIZ and just use what he has in stock for my projects. If you really do not want to construct a UNUN, commercial products are available on the web on sites such as http://www.arraysolutions.com/Products/baluns.htm.

I wish you good luck with your own antenna experiments and please be safe!

Some SWL Antenna Related Links

L.B. Cebik, W4RNL was a respected antenna expert. There is great information on his web pages

Build a Shortwave Antenna. A good overview of home brew multi-band antennas by N4UJW

Amateur and Short Wave Radio Electronics Experimenter's Web Site

MF and HF Receive Antenna Splitter

Introduction

As a radio experimenter, I have numerous MF and HF receivers to listen to but usually only 1 main outdoor antenna. Typically, this means that only my main radio receiver is connected to the outdoor antenna and my other receivers must use small indoor antennas with or without RF preamplifiers. I wanted to to permanently connect my main radio shack receiver and the receiver in the room directly above the shack to my main MF and HF antenna at the same time. The solution was to build a simple antenna splitter which allows the 2 radio receivers to connect to the single coaxial antenna feed line while preserving the correct impedance at all connection points. This project is based upon the splitter presented in EMRFD labeled Figure 3.81.

Each receiver and the antenna feed line have a 50 ohm characteristic impedance. This in-phase splitter is passive and has a loss of just over 3 dB. It is designed to operate from 500 KHz up to 30 MHz.

Please do not transmit through this device.

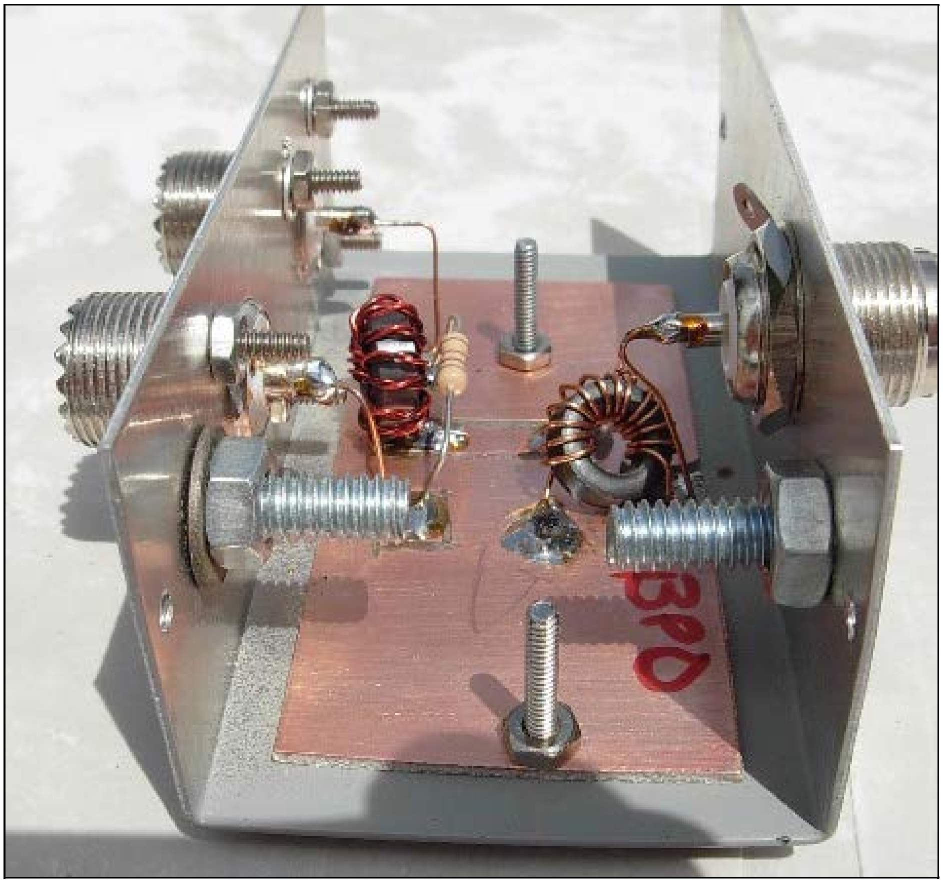

Project Schematic

The schematic to the left illustrates the entire splitter network from the antenna input to the input of the 2 receivers. T1 and T2 are broadband ferrite transformers with enough inductive reactance to tune down to the bottom of the broadcast band. If you only require a splitter for HF, then wind T1 with 10 total turns and a tap at 7 turns from the grounded end and T2 with just 10 bifilar windings. I used FT50-43 cores to allow the use of

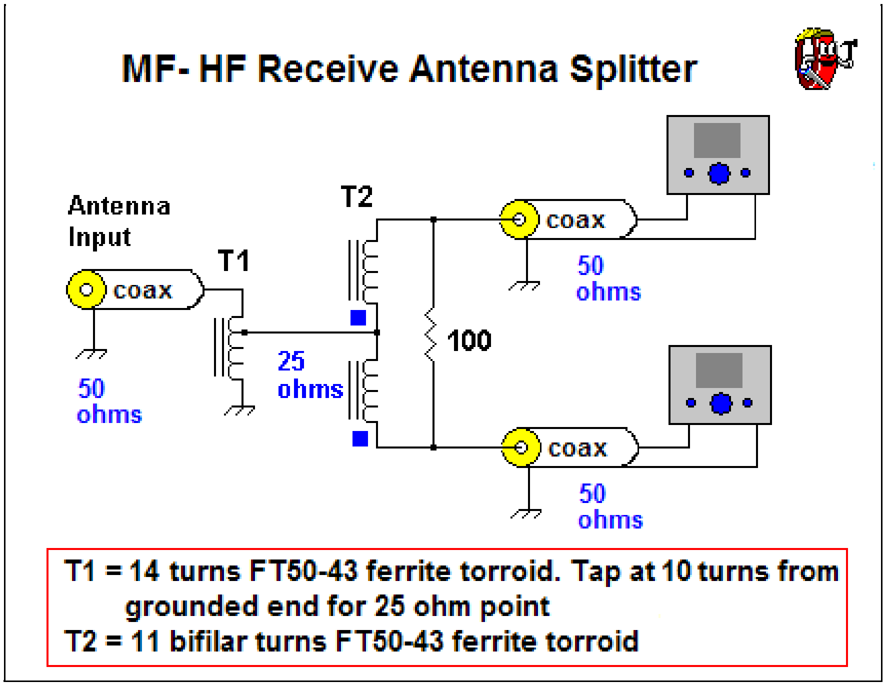
MF- HF Receive Antenna Splitter
Antenna Input
T1
T2
coax
coax
coax
50 ohms
25 ohms
100
50 ohms
50 ohms
T1 = 14 turns FT50-43 ferrite torroid. Tap at 10 turns from grounded end for 25 ohm point
T2 = 11 bifilar turns FT50-43 ferrite torroid

thicker gauge wire which provides reasonable securement of the coils without external anchors, and because bigger inductors are easier to photograph. The FT37-43 ferrite core would also be a good choice, especially if miniaturization is a design goal.

Circuit Building Details

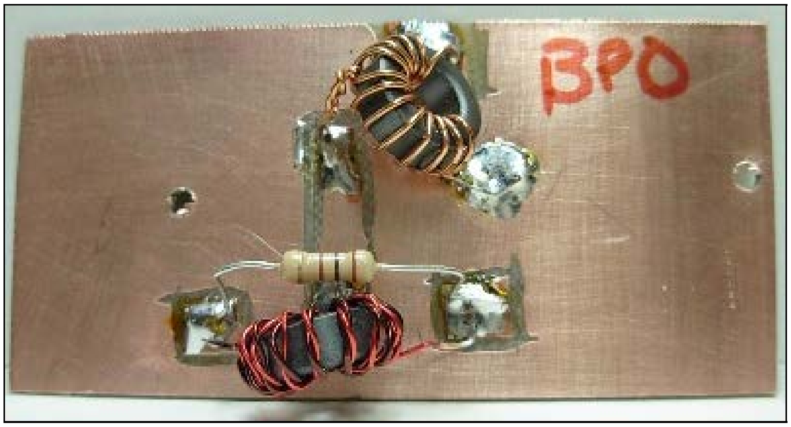

The antenna splitter breadboard is shown to the right. I used 3 colors of 22 gauge enamel covered wire to make my inductors. T2 is the actual splitter network coil and is the lower transformer in the photograph. The 100 ohm resistor serves to isolate the 2 ports connected to the receivers and absorbs impedance mismatches which may present when one terminal is not properly terminated. Note that the characteristic impedance at the input of this 3 port network is only 25 ohms. You can choose to ignore this or use an additional network such as a broadband transformer or an L- match between your antenna coax and the splitter to match this 25 ohm impedance.

I chose to use T1 which is an autotransformer with a tap at approximately the 25 ohm point. The splitter network worked well during my tests. Having only 1 receiver versus 2 receivers connected made no difference to the signal strength due to the excellent output port isolation.

Note that Wes, W7ZOI uses this 3 port network network several times in EMRFD. One example is the Lichen transceiver while another is the 6M superhet receiver presented in Chapter 6. Consult EMRFD for further discussion of this and other multiple port networks.

T2 is a bifilar transformer. The 2 wires were twisted together by securing one end of the 2 wires in a vise and the other end of these 2 wires in the chuck of a brace and bit (manual) hand drill. I twisted the hand drill until I had 8 twists per inch on the 2 wires . I used 2 color wire for ease of construction, however, it is almost as easy to tell the windings from one another by using an ohm meter or audible continuity tester.

Chassis

To the right is the completed project showing the SO-239 connectors which are wired to the antenna splitter output ports. A chassis from an old project was recycled for this new project. The large bolts seen in some of the of the photos were used to fill in holes which had been drilled for the old project. This was done to provide improved RF shielding. The bolts also increased the weight of the chassis and help keep it from tipping over. Although it does not look as attractive as if I had used a brand new project chassis, considerable cost savings were realized. These little Hammond project boxes are getting very expensive. Also the splitter is kept an the back of my main radio desk where it is out of sight anyway.

Update August 10, 2008 - Contribution by Dave, G4AON

This original network was designed for use in the MF to HF spectrum. Limiting this network is the input matching transformer T1 which negatively effects the T2 output port isolation; especially at 41 meters and higher. Testing by Dave, G4AON confirmed this. Dave designed, built and tested a trifilar wound, UNUN input matching transformer which provides a much flatter response for T2 port isolation from 0.1 to 52 MHz.

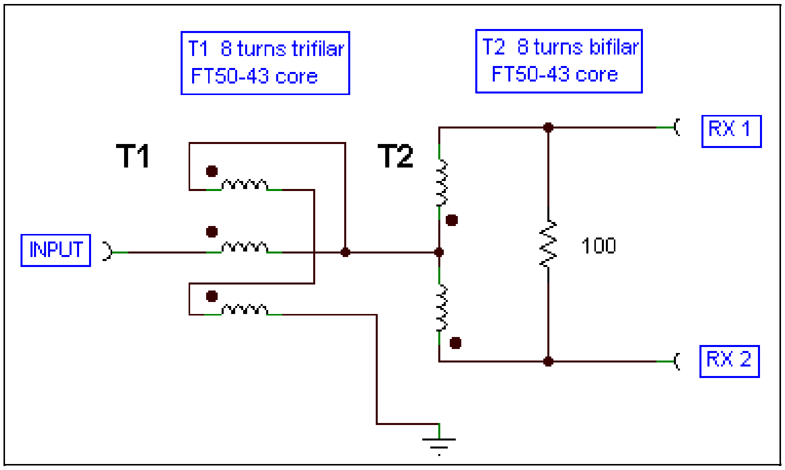

To the left you can see the G4AON input circuit for T1. In keeping with a design optimized for higher frequencies, less total turns are used on the transformers. His trifilar wound input transformer version is going to generate an impedance of (16/24)^2 x 50 = 22 Ohms at mid-band. My variation will generate (10/14)^2 * 50 = 25.5 ohms at mid-band. Using his version of T1 as opposed to my simple auto-transformer, Dave was able to provide better isolation of the output ports than the original design across a wider range of frequencies.

In the two popular, commercially sold RF splitters we have examined, the company did not even bother to match the input to the T2 transformer and some builders have written me to say they just omitted T1 and for their typical SWL listening this worked out fine for them. Increasing isolation across a wider frequency band and also matching the T2 input are issues that you the builder will have to consider. Certainly the lossy and often non-predictable #43 ferrite material is a factor which might affect your transformer performance. While a trifilar transformer is a little more difficult build for a novice as compared to an auto-transformer, this improved design might work very well at your QTH. Testing like Dave did is certainly the way to go and I greatly appreciate his contribution.

To the right are Dave's excellent bench measurements. He used a Marconi 2018 signal generator, a Racal 9301 RF millivoltmeter and a Bird load on the other port. Kudos to Dave for performing this experiment and contributing to the receive antenna splitter knowledge base.

Dave's web site.

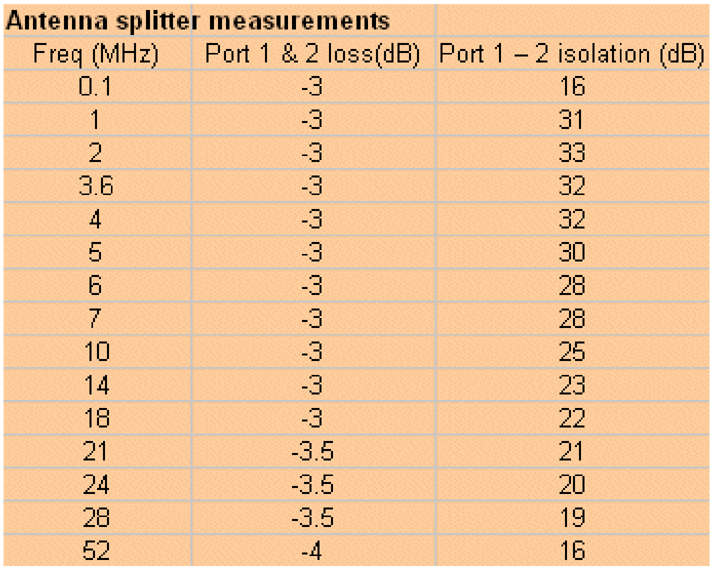

Antenna splitter measurements		
Freq (MHz)	Port 1 & 2 loss(dB)	Port 1 – 2 isolation (dB)
0.1	-3	16
1	-3	31
2	-3	33
3.6	-3	32
4	-3	32
5	-3	30
6	-3	28
7	-3	28
10	-3	25
14	-3	23
18	-3	22
21	-3.5	21
24	-3.5	20
28	-3.5	19
52	-4	16

Conclusion

It is really awesome to be able to connect 2 receivers to the same outdoor antenna. The 3 port network and cabling to the additional receiver does not seem to increase receive noise levels from RFI in the house. Most likely this is due to the fact I am using shielded coax, a shielded project box and have a good RF ground system.

This is a simple project you can build in one evening.
I hope you receive some good DX! 73 es CUL, VE7BPO

Here is a link from F6AOJ

Additional Photos

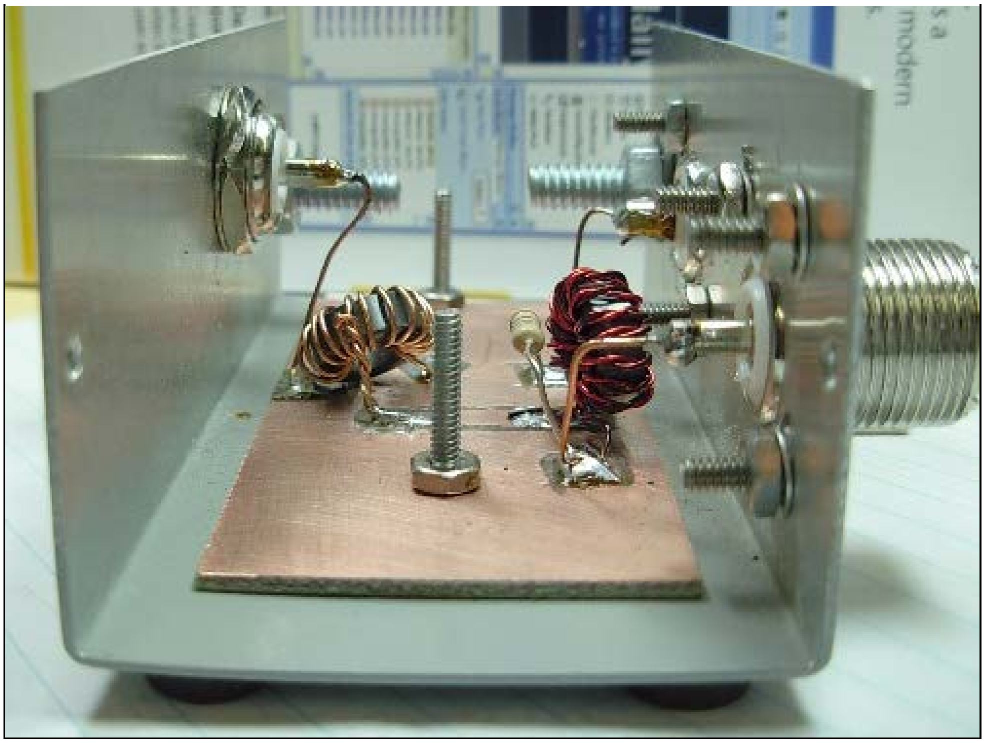

Medium Frequency TRF Receiver

Introduction

This series of experiments was initiated in 2006, stalled, and was finally completed 16 months later with the inspiration provided by work regarding zero power receivers web-published by Wes, W7ZOI in late summer 2007.

Described is a complete receiver, built and presented backwards from the audio stage to the antenna. The design goals were to build a Tuned Radio Frequency broadcast band receiver with one RF amplifier, a high performance detector and a simple, headphone-level audio stage.

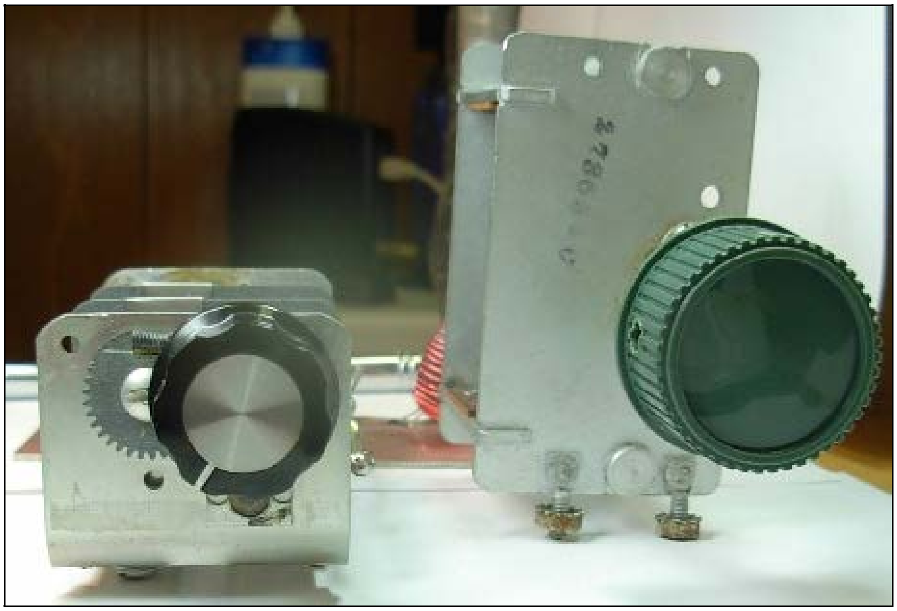

Receiver Block Diagram

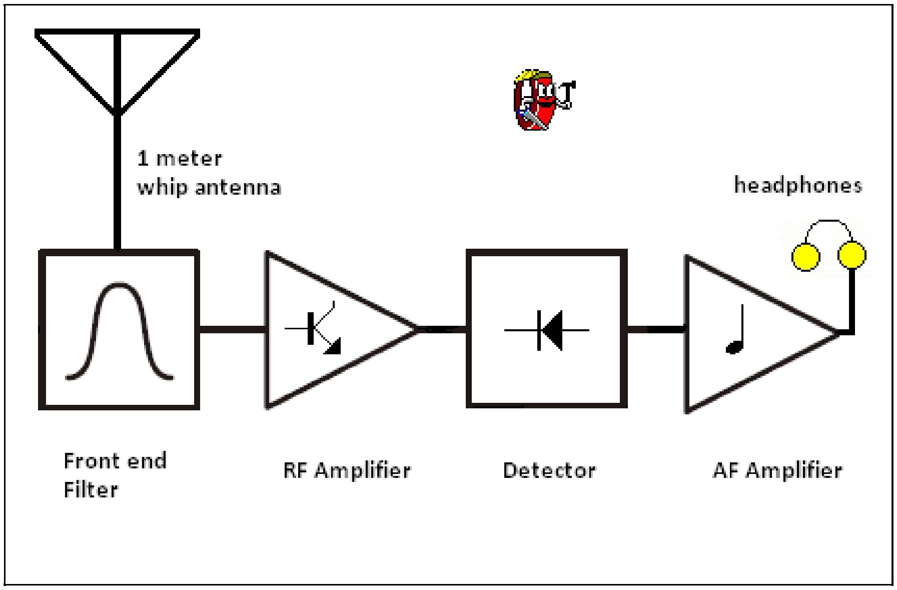

The receiver block diagram is shown to the left. The antenna is a ~ 1 meter long whip purchased from Radio Shack in the USA. A single cascode bipolar junction transistor amplifier boosts the RF voltage and drives an envelope detector which is terminated by a JFET source follower. The source follower connects to a 10K volume potentiometer which controls the AF signal voltage into a headphone-level audio amplifier. Like most of the projects on this site, the intention is to present some circuits and ideas for experimentation. This receiver is designed for local broadcast band AM radio reception, however, the various circuits could be used in or titleered for DX receivers as well.

A Supplemental Page can be found here

Audio Stage

The AF amplifier is a superb design by Rick, KK7B and is featured in many projects in EMRFD. This audio amplifier uses one 5532 op amp and has low noise and high gain. The 220 pF feedback capacitors can be increased to boost the low frequency response. I have built 6 or 7 versions of this stage and have used feedback capacitors up to 560 pF for this purpose. In the audio path, polyester film capacitors were used to try to improve the audio quality. Additionally, the value of the 15 uF capacitor connected to pin 2 is flexible. The quiescent current draw of this stage at 12.2 VDC is 12. 3 mA. Some builders may have to increase the 100 uF filter capacitor on the main 12.2 volt line to overcome motorboat oscillation. None occurred in my breadboard version. I suggest using this audio stage instead of the LM386 or discrete component final audio amplifiers in all projects which call for a headphone-level audio power amplifier on this web site.

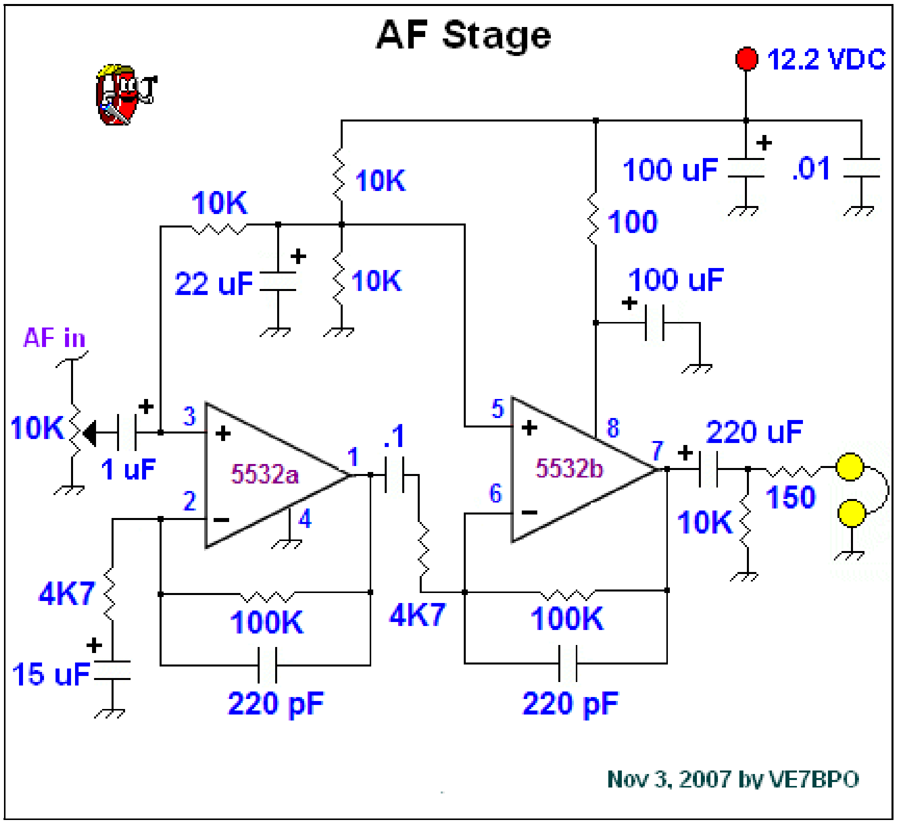
AF Stage
12.2 VDC
10K
10K
22 uF
+
10K
100 uF
+
.01
100
100 uF
+
AF in
10K
1 uF
+
3
+
5532a
1
.1
2
−
4
4K7
100K
15 uF
+
220 pF
4K7
5
+
5532b
8
7
6
−
220 uF
+
150
10K
100K
220 pF
Nov 3, 2007 by VE7BPO

Close up of the KK7B audio amplifier breadboard from the 10K potentiometer to headphone jack

Cascode BJT RF Amplifier and High Performance Detector

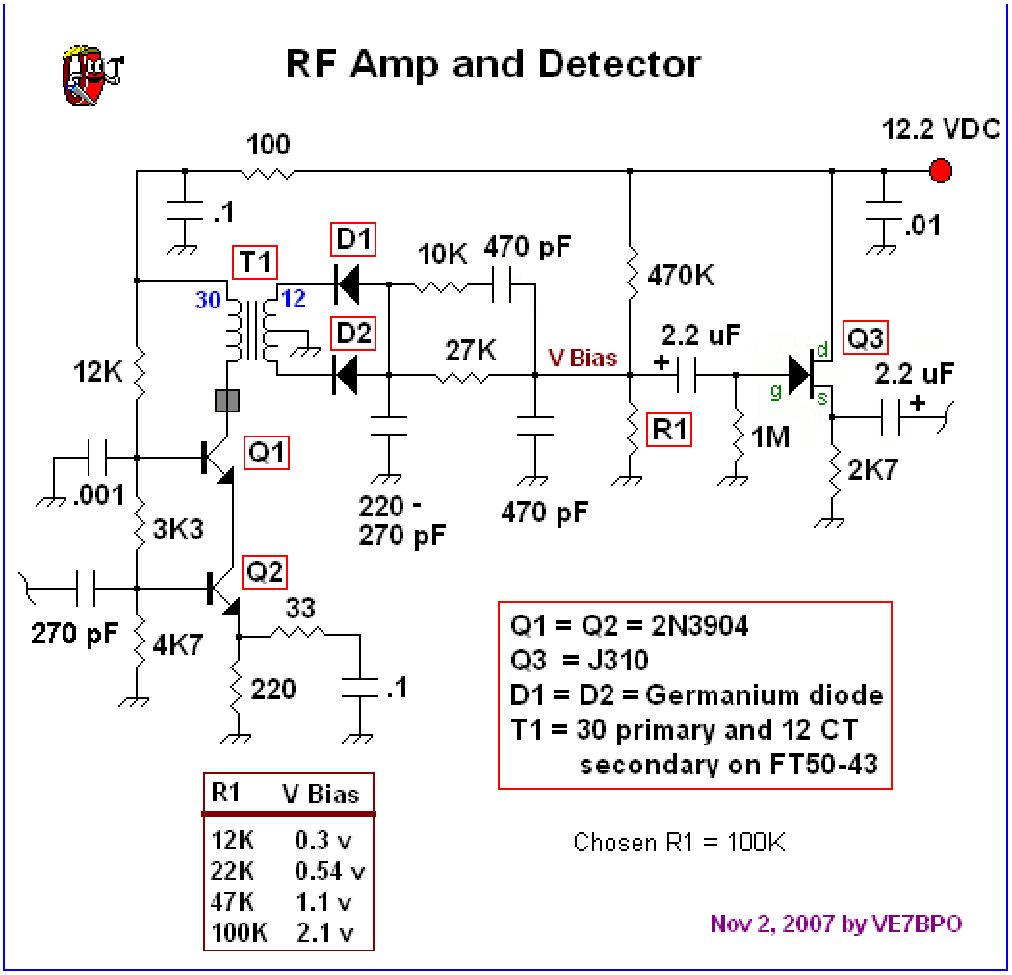
RF Amp and Detector
100
12.2 VDC
.1
.01
T1
D1
D2
10K
470 pF
470K
30
12
27K
V Bias
2.2 uF
+
Q3
d
g
s
2.2 uF
+
12K
R1
1M
2K7
Q1
.001
220 -
270 pF
470 pF
3K3
Q2
270 pF
4K7
33
220
.1
Q1 = Q2 = 2N3904
Q3 = J310
D1 = D2 = Germanium diode
T1 = 30 primary and 12 CT
secondary on FT50-43
Chosen R1 = 100K
Nov 2, 2007 by VE7BPO

R1	V Bias
12K	0.3 v
22K	0.54 v
47K	1.1 v
100K	2.1 v

Above is the combined RF amplifier, detector and JFET source follower schematic.

Cascode BJT RF Amplifier

To the left is a simplified RF amp diagram taken from the schematic above indicating the measured DC voltages for reference purposes.

T1, the output transformer was wound on an FT-50-43 ferrite toroid. An FT37-43 would also be suitable. Number 28 gauge enamel coated magnet wire was used for the 30 turn primary and 26 gauge wire was wound over top to make the secondary 12 turn, center-tapped winding. The 26 gauge wire was used for the secondary winding because it provided good anchoring of the transformer by the center tapped ground connection.

You may consider substituting a 22 to 100 ohm resistor for the ferrite bead on Q1. It suppresses VHF oscillations.

Detector

To the right is a photograph of the detector from the Q1 transformer through to the JFET source follower. Schottky/hot carrier diodes or germanium diodes such as the 1N34A with a low forward voltage drop are strongly recommended. I have found there to be significant variation in

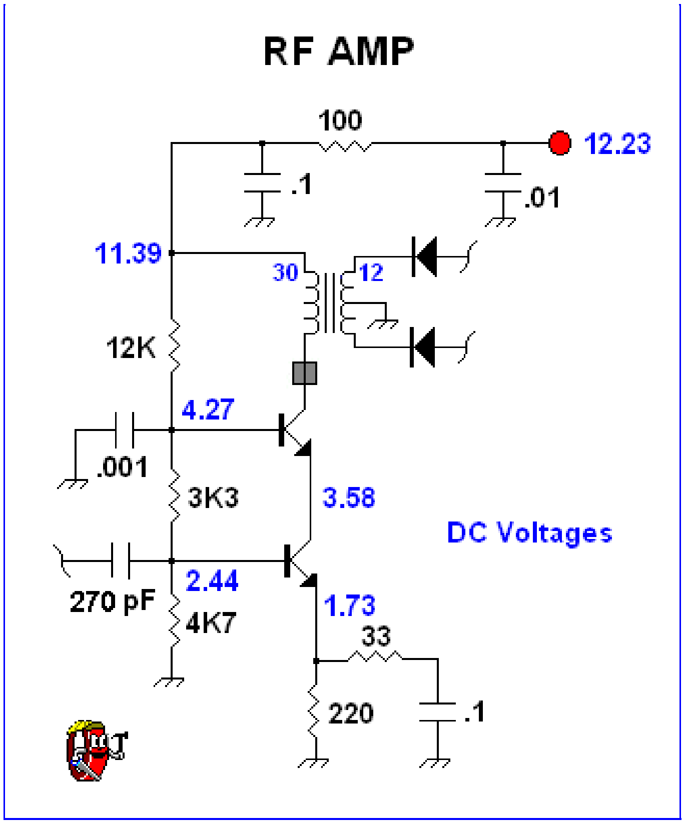

sensitivity between different types of these diodes. The 2 germanium diodes I used were matched as described on this web page. A number of detectors were built and tested for this receiver, however, the design shown had the best audio quality when compared to the others. The virtues of this detector include low noise, high bandwidth, high sensitivity and low distortion. although a little complex, this is a detector worthy of consideration in your AM receiver projects. The center-tapped Q2 transformer secondary and the 2 diodes provide full wave detection. This serves to reduce distortion somewhat and cancel even-order harmonics in the carrier signal. You may eliminate one of the diodes and convert the Q2 transformer secondary to a conventional, single link.

A 470K ohm resistor and R1 form a voltage divider that sets the detector bias voltage (V Bias). Some measured R1 values and corresponding bias voltages are shown in the schematic. I chose an R1 value of 100K for my final version. You may have to increase or decrease the R1 value to suit your local detector sensitivity requirements. You could also substitute a bias potentiometer for front panel adjustment of the receiver sensitivity. In this detector, changing the R1 value also changed the detector frequency response. I built a separate voltage divider with roughly the same V bias consisting of a 68K and a 15K resistor and swapped it for the 470K and 100K pair. Interestingly, the 470 K and 100K pair had better low frequency response and slightly higher sensitivity than the 68K and 15K voltage divider.
Diode detectors are best driven with a high impedance source and followed by a high impedance load. Q3, a simple JFET source follower provides a high impedance load. You might want to substitute a "popcorn" MPF102 for the high Idss J310 indicated in the schematic as a J310 is not really required here. If you substitute a MPF102, please increase the source resistor from 2K7 to 4K7 ohms.

Front-end Band Pass Filter and Antenna

In late summer 2007, Wes, W7ZOI conducted experiments with zero power receivers (crystal sets and such). He wound some inductors using ferrites with an unloaded Q of over 270 at MF! Please check out Wes' web site. His work with high Q ferrite inductors illustrates the importance of quantitative measurement and also provided the following revelation; we really do not have to resort to large, air core, Litz wire coils to build high-performance inductors at MF! The early prototype front end for this project was built using FT50-61 ferrite cores, however after Wes emailed me his work on zero power

receivers, I had to get some FT-114-61 ferrites for the front end of this receiver. The next day, I emailed Mark Laurain from Amidon Associates Inc and ordered some FT-114-61 ferrite toroids. The arrival of these ferrites prompted me to finish this project and put it up on the web.

The schematic on the right is the final band pass filter used for the front end. I initially tried using just L3 for the front end, but I was unable to just tune a single station. In my city, there are 2 powerful AM radio stations at 630 and 1150 KHz. With a single inductor, I could peak one of the stations, but the other could be heard in the background. Thus, the double-tuned band pass filter presented was designed and built. Now only one station can be detected with this circuit and tuning is sharp. Most builders would use a dual-ganged variable tuning capacitor, however, I elected to use 2 separate variable capacitors. Considerable flexibility with this circuit is possible. You will have to experiment to best determine your local sensitivity versus selectivity needs and to suit the variable capacitors you have available. Large AM receiver capacitors are getting hard to find. I obtained the 2 variable capacitors shown in the photographs below from 2 old receivers found in a second hand store. One of the receivers was a Marconi tube radio that was in poor condition. I paid $5.00 for both radios and harvested the 2 beautiful variable capacitors as well as some other parts such as knobs, switches and terminal strips. Never pass up on an old, derelict radio as a potential variable capacitor source!

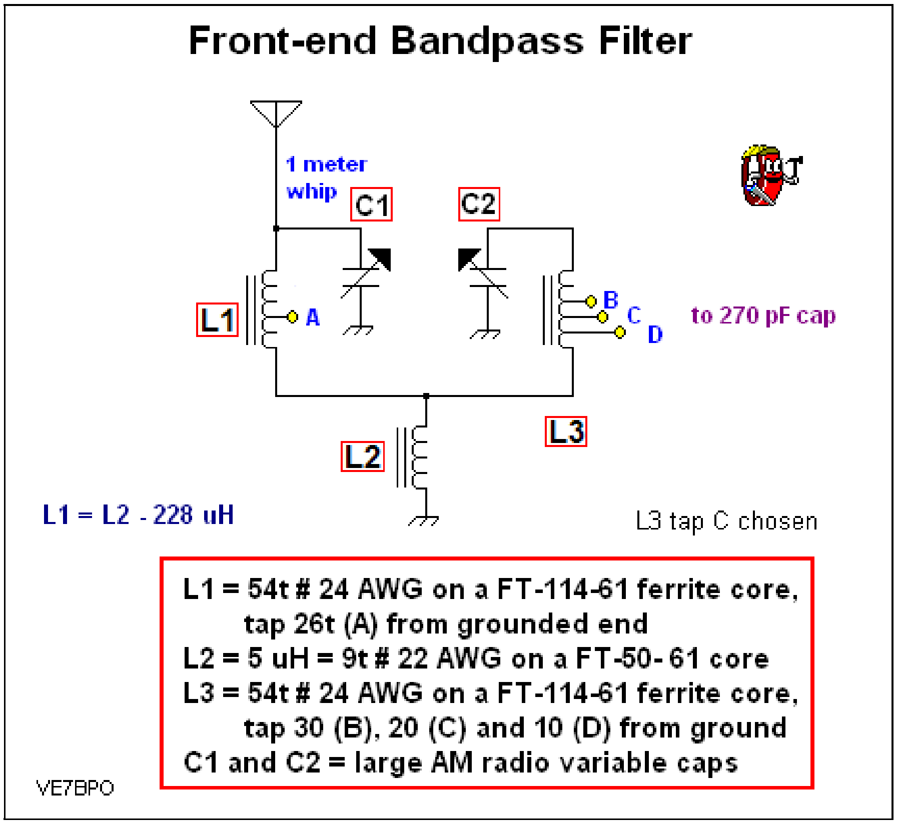

Front-end Bandpass Filter

L1 = 54t # 24 AWG on a FT-114-61 ferrite core,
tap 26t (A) from grounded end
L2 = 5 uH = 9t # 22 AWG on a FT-50-61 core
L3 = 54t # 24 AWG on a FT-114-61 ferrite core,
tap 30 (B), 20 (C) and 10 (D) from ground
C1 and C2 = large AM radio variable caps

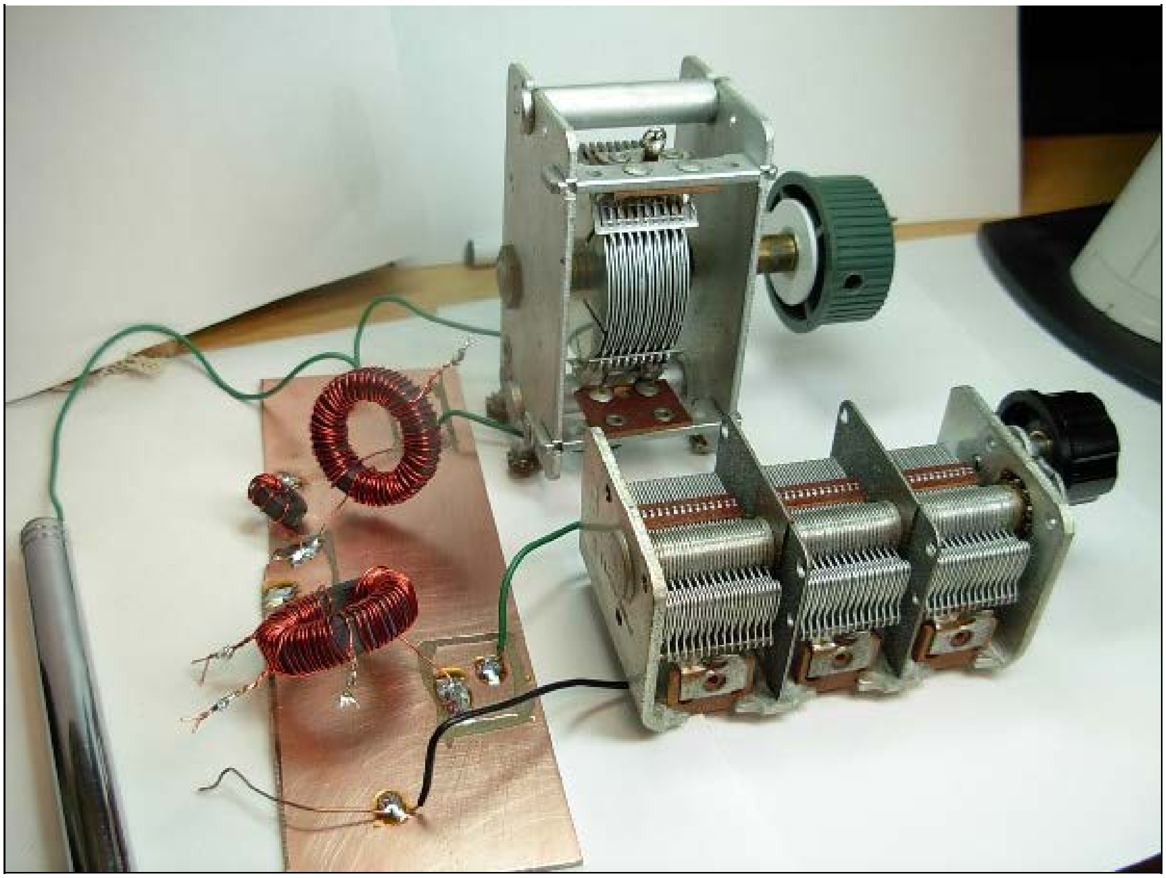

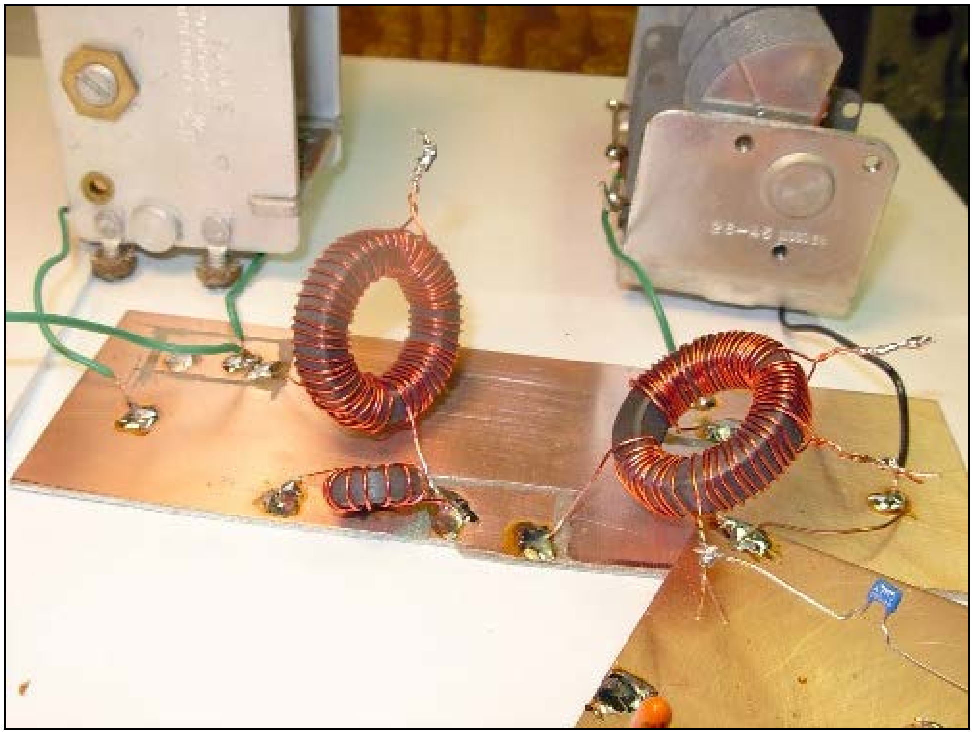

Shown above are 2 photographs of the band pass filter breadboards. The 2 variable capacitors had a variation of ~ 24 to 500 pF. There is considerable interplay between the 2 capacitors. For my QTH, it was better to peak C2 first and afterward to peak C1. Consider that L1 and L2 have a hot end and a grounded end. The antenna is connected to the the hot end of L1. Predictably, when substituting the L1 center tap as the antenna connection, the selectivity of the L1-C1 tank is increased and the sensitivity or received signal strength is reduced. This also occurs when testing the various tap points on L3 to feed the RF amplifier-detector stages. In the final circuit, I settled on Point C, 20 turns from ground. Using Point D, reduces sensitivity and increased selectivity. The opposite is true when using Point B. You the builder, have to determine which L1 and L3 connection points to use based on your own experiments and local factors. You may also change the receiver sensitivity by making changes such as increasing or decreasing the 270 pF coupling capacitor value, the emitter degeneration on Q2, or the detector bias.

Band pass Filter Analysis

It is impractical to sweep a BCB band filter using variable capacitors, so some analysis using GPLA, a program that ships with EMRFD was used to plot and better understand the double-tuned band pass filter response. A worst case inductor unloaded Q of 200 was used, but I imagine that the actual Q of L1 and L3 is much higher. For the source impedance, 100K ohm was used conjecturing that a short whip antenna at 1150 KHz would have a very high input impedance and not load down the L1 inductor. In reality, it is likely the antenna input impedance might be closer to 1 Megohm, however, I am using the worst case scenario. If the filter performs better than simulated - all is great! Higher source and load impedances and higher unloaded Q inductors would decrease the bandwidth of this filter which is desirable.
Note that I am concerned that L2 at 5 uH may may overcouple the 2 tank circuits. I did not see a double humped response on GPLA analysis, however, experimentation with L2 may be in order for the more astute homebuilder. You might consider lowering the L2 value to 3 or 4 uH and performing some testing. The load impedance for L3 was rather arbitrarily chosen. Considering that various taps on L3 may be used, the XC of the 270 pF coupling capacitor and the input impedance of the RF amplifier, I just chose 47K as the L3 load impedance. Below are 2 screen captures of GPLA plots. The top graph is the double tuned band pass filter and below it is the single tuned band pass filter consisting just of L3 and C3.
These graphs lead to 2 main conclusions:

1. The final band pass filter design appears to be reasonably sound.
2. We can understand why I could not tune in a single radio station with just L3 and C3 as the band pass filter; the filter skirts are not very steep and the second unwanted station was also amplified and detected.

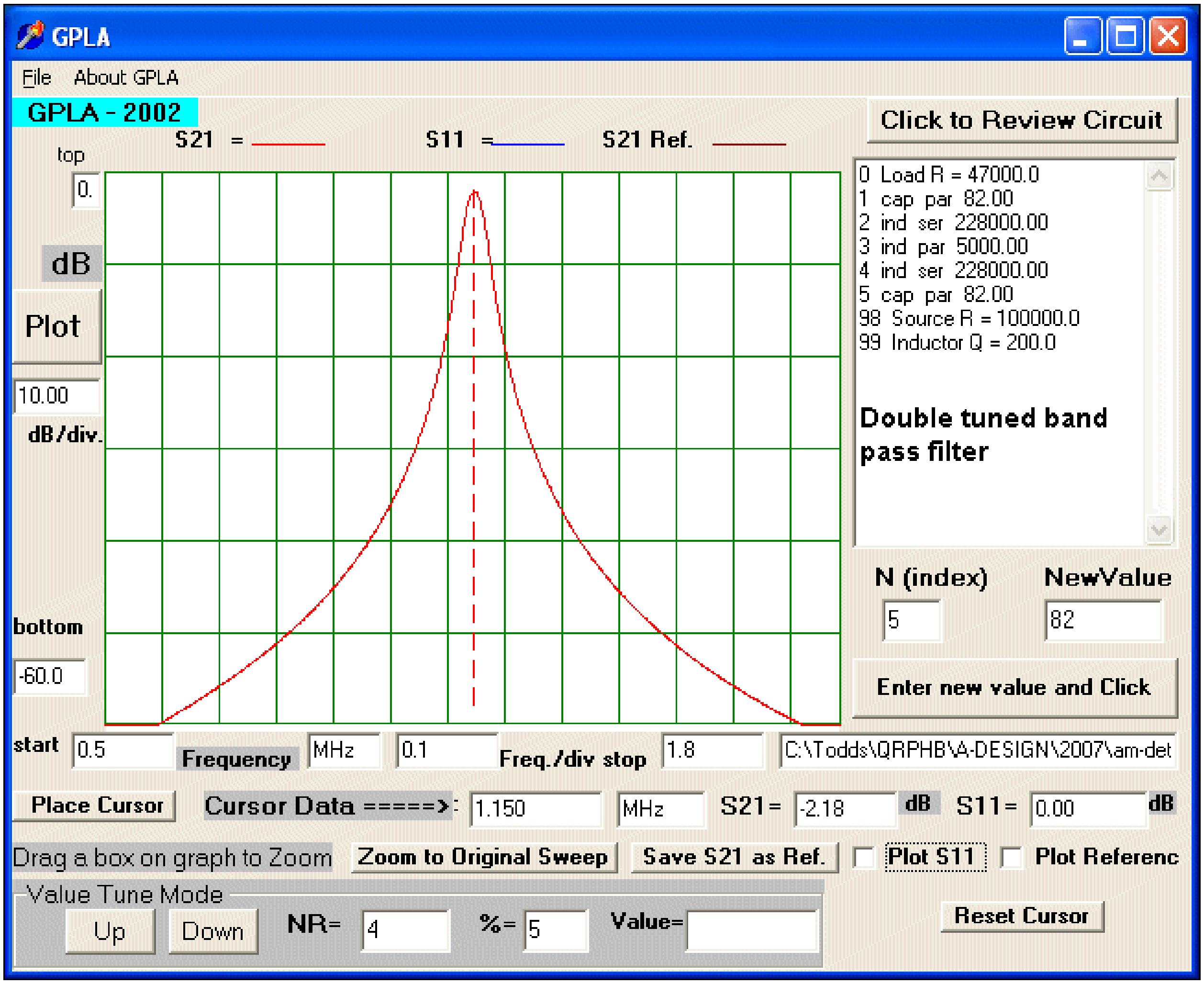
GPLA
File
About GPLA
GPLA - 2002
S21 =
S11 =
S21 Ref.
Click to Review Circuit
dB
Plot
dB/div.
Frequency
Freq./div stop
Place Cursor
Cursor Data =====>
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Plot S11
Plot Referenc
Value Tune Mode
Up
Down
Value=
Reset Cursor
Enter new value and Click

```
0  Load R = 47000.0
1  cap  par  82.00
2  ind  ser  228000.00
3  ind  par  5000.00
4  ind  ser  228000.00
5  cap  par  82.00
98  Source R = 100000.0
99  Inductor Q = 200.0
```

Double tuned band pass filter

top: 0.

10.00 dB/div.

bottom: -60.0

start: 0.5 MHz; Freq./div: 0.1; stop: 1.8

C:\Todds\QRPHB\A-DESIGN\2007\am-det

Cursor Data: 1.150 MHz; S21= -2.18 dB; S11= 0.00 dB

N (index): 5; NewValue: 82

☐ Plot S11 ☐ Plot Referenc

NR= 4; %= 5; Value=

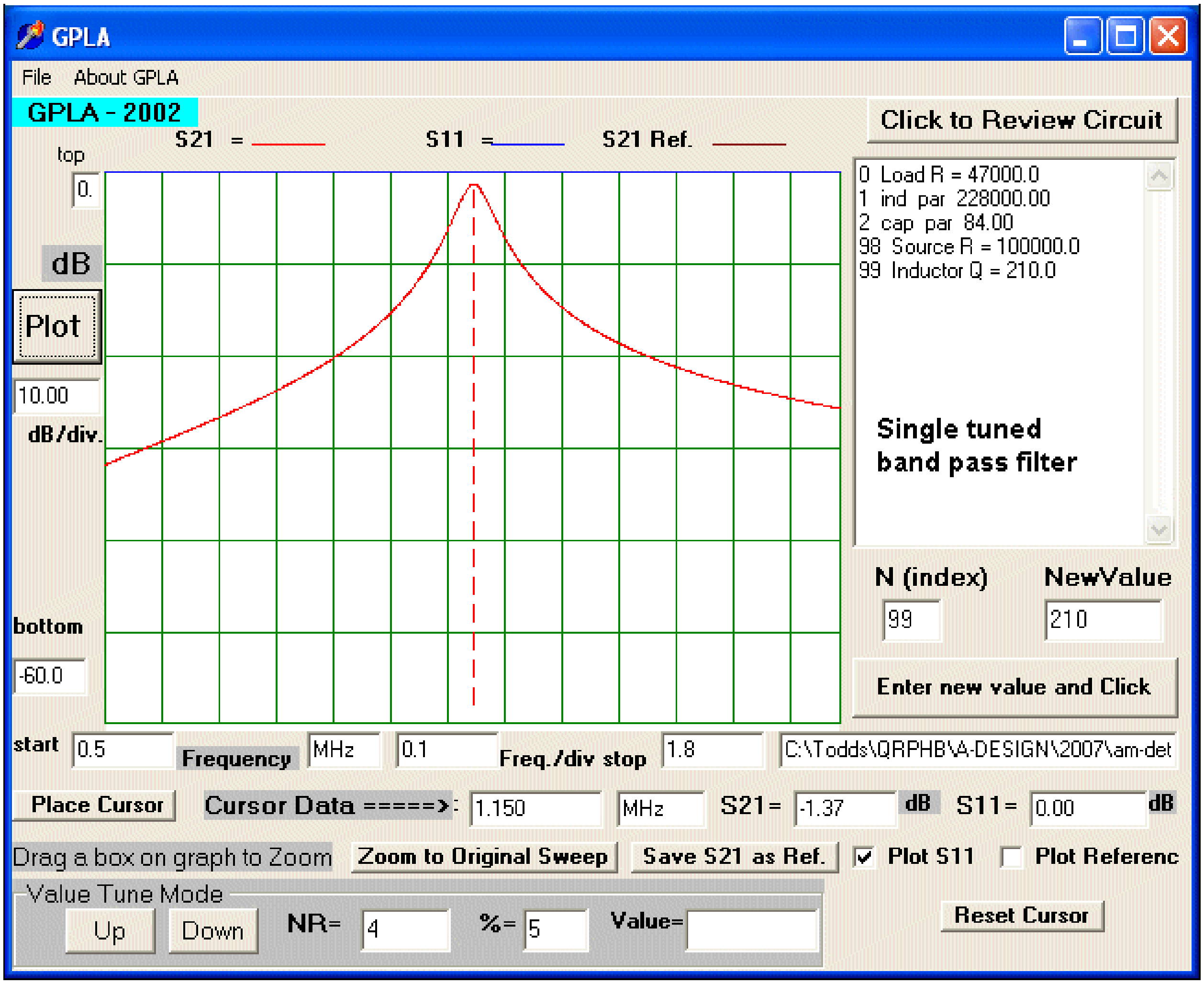
GPLA
File
About GPLA
GPLA - 2002
S21 =
S11 =
S21 Ref.
Click to Review Circuit
dB
Plot
Frequency
Place Cursor
Enter new value and Click
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Value Tune Mode
Up
Down
Reset Cursor

0 Load R = 47000.0
1 ind par 228000.00
2 cap par 84.00
98 Source R = 100000.0
99 Inductor Q = 210.0

Single tuned band pass filter

top 0.
10.00 dB/div.
bottom -60.0
start 0.5 MHz
Freq./div 0.1
stop 1.8
C:\Todds\QRPHB\A-DESIGN\2007\am-det
N (index) 99
NewValue 210
Cursor Data =====> 1.150 MHz S21= -1.37 dB S11= 0.00 dB
☑ Plot S11
☐ Plot Referenc
NR= 4 %= 5 Value=

Varactor Tuned Front-end Filter

On November 11, 2007, I decided to investigate whether or not variable capacitance or varactor diodes could effectively replace the air variable capacitors in the band pass filter. In my parts cabinet were several MVAM -109 which is an obsolete but still readily available part. Another varactor, especially designed for tuning AM receivers is the 1SV149. This varactor is manufactured from Toshiba and is also appropriate.

While not comparable to the Q of 300 or greater of a good quality air variable capacitor, varactors are smaller, cheaper and can be easily ganged together so that only 1 potentiometer is required to tune the front-end filter. To the right is a photo of the varactor tuned front-end filter breadboard.

To the left is the schematic of the varactor tuned front-end band pass filter. The air variable capacitors were unsoldered from the original filter breadboard and a small board drilled and fitted with two 250K potentiometers was soldered to it.

Varactor Controlled Bandpass Filter

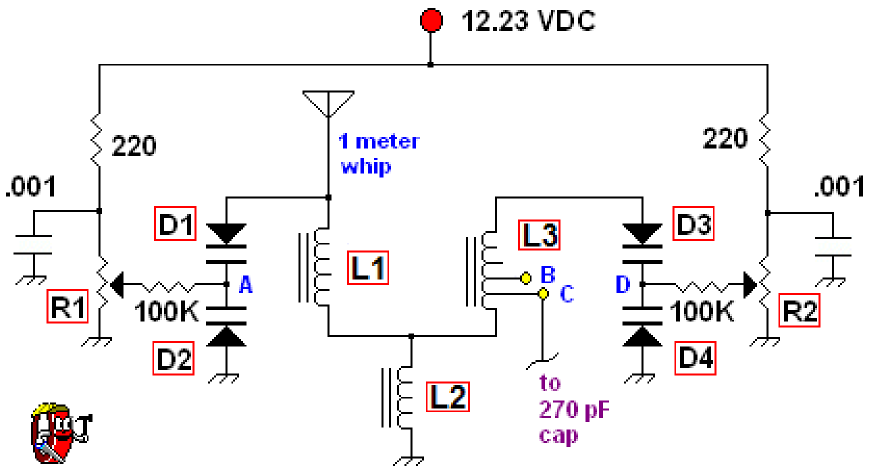

Tuning voltages	630 KHz	A = 0.76v	D = 1.0v
	1150 KHz	A = 4.42v	D = 4.77v

L1 = 228 uH = 54t FT-114-61 ferrite torroid
L2 = 5 uH = 9t FT-50-61 ferrite torroid
L3 = same as L1 with tap 15t (B) and 10t (C) from ground
R1 = R2 = 250K potentiometer
D1 = D2 = D3 = D4 = MVAM-109 varactor diode

L3 was also modified to have taps at 10 and 15 turns from ground. I conjectured that since the varactor diodes have less Q than their air variable cousins, it would be wise to tap down on L3 to try and increase the selectivity of the L3 tank circuit. In the end, I used the tap at 10 turns from ground for my receiver as signal strength was still acceptably strong. You may choose to use the tap at 15 or some other point to suit your local selectivity/sensitivity requirements.

I was able to tune in single stations as I previously did with the air variable capacitors. Tuning is "touchy". Ten-turn pots would be a better choice, however, are not very frugal for such a project. You get used to tuning with conventional potentiometers after a few minutes or so. I measured the reverse voltages required to tune the 2 main local AM radio stations and they are tabled in the schematic. The L1 tank requires slightly more capacitance to resonate than the L3 tank. Thus it takes a little less applied reverse voltage to the varactor pair resonating the L1 tank compared to the varactor pair resonating the L3 tank .A side view photograph of the varactor breadboard is shown directly below. The component leads have been kept long so that I can recycle parts from experimental project to project as possible. This helps contain costs. Shorter lead lengths and proper lay out should be pursued in any final projects you build.

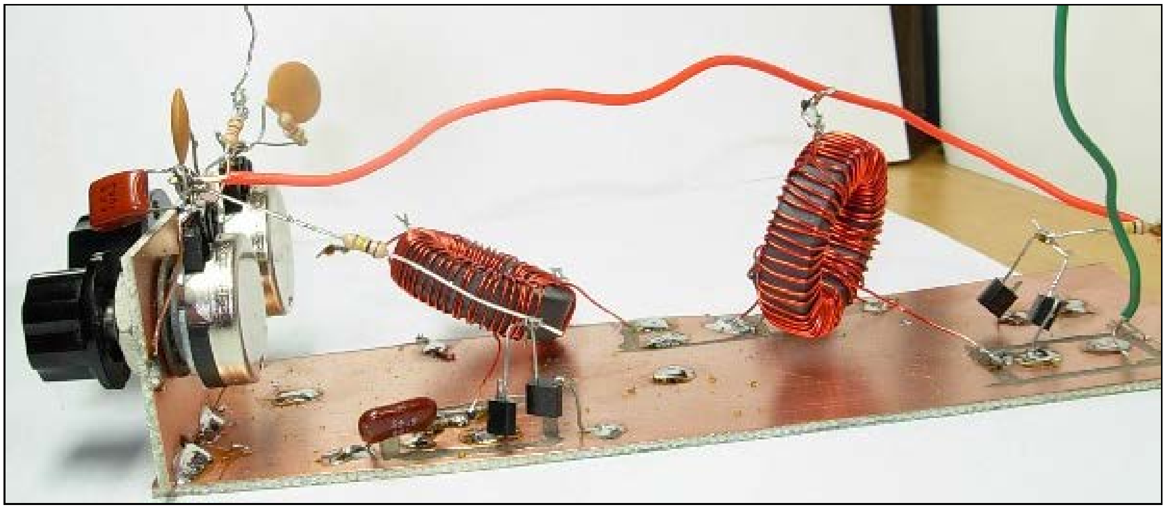

Single Varactor Tuned Front-end Filter

Tuning with a single potentiometer ganged to both varactors is easy to do after learning from the experiment above. All that is required is a method to compensate for the differences in capacitance between the the 2 LC tanks. I placed a high-Q (Q=300) variable trimmer capacitor in parallel with L1. By listening to the receive signal strength and tuning in one radio station using the potentiometer, I was able to peak CV for the strongest signal. I did this for both 650 and 1150 KHz and actually unsoldered CV and measured its value with a capacitance meter. The CV value was ~ 6 pF for both frequencies. I decided to replace CV with a fixed 5 pF silver mica capacitor and left it there in my final filter version. Your results will probably be different. I suggest just leaving CV

Single Pot Varactor-Tuned BP Filter

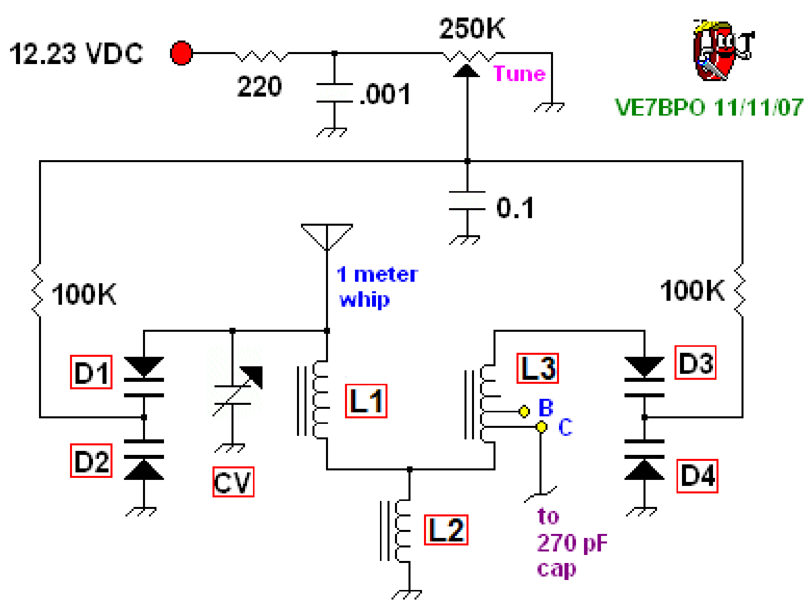

L1 = 228 uH = 54t FT-114-61 ferrite torroid
L2 = 5 uH = 9t FT-50-61 ferrite torroid
L3 = same as L1 with tap 15t (B) and 10t (C) from ground
CV = 2.7 - 10 pF trimmer cap
D1 = D2 = D3 = D4 = MVAM-109 varactor diode

and using this trimmer cap to peak the signal once you have tuned a desired radio station with the main tuning potentiometer. An alternative to using CV is to vary L1. You could try compressing the number of L1 windings to allow tracking of the 2 LC tank circuits.

For the varactors, I used back-to-back VVC diodes as opposed to just a single varactor to resonate each tank. This was done in an effort preserve the highest varactor Q possible. The RF voltage of the AM RF signal may be high enough to forward bias a single varactor during a portion of the AC signal and degrade Q. This does not happen when back-to-back diodes are used. Almost all high-grade FM tuner schematics I have seen use back-to-back varactor diodes in their various ganged, tunable band pass filters. The major drawback of back-to-back diodes is your tuning range is reduced because you now have 2 capacitors in series. Experimentation may be required to achieve the BCB band-spread that you desire. You can add another pair of varactors in parallel or add some parallel fixed capacitance or even change the L1 and L3 inductance values for example.

This receiver tunes nicely and sounds fabulous. Last evening I was able to tune in 5 different AM stations, however, other than the local 2 radio stations, the others were quite faint. This is not bad considering this receiver has only 1 RF amp and a 1 meter long antenna. This band pass filter could be adapted as a pre-selector for AM radio reception. To match 50 ohms, lower L1 and L3 tap points could be chosen or a few links of wire may be wound around the inductors.

In the photograph below, you can see the 5 pF capacitor soldered in parallel with the MVAM-109 pair associated with L1. The antenna also connects to the ungrounded end of the 5 pF capacitor. Below in the last photograph; since only one potentiometer is used for tuning, a large knob was screwed on to the pot control shaft to make tuning a little easier. The solder-laden 220 ohm resistor is the connection point for the regulated 12.2 VDC. The 220 ohm resistor on the left has been cut from the 12.2 VDC connection point so 0 voltage goes to the left potentiometer.

Final Thoughts

I emailed Wes, W7ZOI and asked him why it is better to inductively couple a tuned circuit which use air variable tuning capacitors. Wes wrote his answer in the form of a complete web article entitled Coupling Methods in the Double Tuned Circuit. Big thanks Wes! From his summary, when the inductors used to resonate each tuned circuit are constant, and inductive coupling is used, the coupling of the resonators will remain constant as the variable capacitors are tuned across the band. Please download and study his web article for it not only discusses coupling in the double tuned circuit, but provides some insight into using his LadBuild and GPLA software from EMRFD.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

Junk Box NDB Low Pass Filter

Introduction

With winter approaching, many HAM and SWL hobbyists find intrigue in tuning in NDB or **N**on-**D**irectional **B**eacons. Although the tunable NDB band depends on your location, in Canada it may be found in a band ranging from about 190 to 535 KHz. Canadian beacons either have just a carrier (no offset)or are tuned using the USB with about a 400 Hertz offset, however, different offset frequencies and certainly LSB are used when receiving DX from other countries.

Less than 10 Km away from my QTH is a 10 KW AM radio station at 1150 KHz. On my test receiver, the S-meter reads off the scale (> 60 dB over S-9) when tuned to this frequency. This local radio station causes spurious, second-order intermodulation products (direct mixing) that all but wipes out some weaker NDB stations that I am trying to tune in. Certainly, having a 500 Hertz crystal IF filter is useful, but attenuating this local QRM is also desirable and is the topic of this web page. Many general coverage receivers offer limited or in some cases no filtering of the NDB band, however an outboard filter is an easy project to build in one afternoon.

Update Oct 11, 2010: Here is a link to a version of this project built by Robert, K5TD

Project Schematic

To the left is the project schematic. It seems odd to build a low pass filter to reduce BCB interference (as usually a high pass filter is required for this purpose at HF) however for NDB, an aggressive low pass filter is required. For simplicity sake, a 7 element Chebychev low pass filter was chosen. Since it is easy to wind reasonably high-Q inductors for 10 uH and greater inductance using number 61 material on a ferrite torroid, the FT50-61 core was chosen for all of the inductors. Number 22 gauge wire was used for the coils to keep the unloaded Q as high as possible. The FT37-61 ferrite is also suitable, but will have less Q and require smaller gauge wire. Use 19 turns instead of 17 for the 20.2 uH and 21 turns instead of 19 for the 24.1 uH coil. Do not use number 43 material ferrite cores.

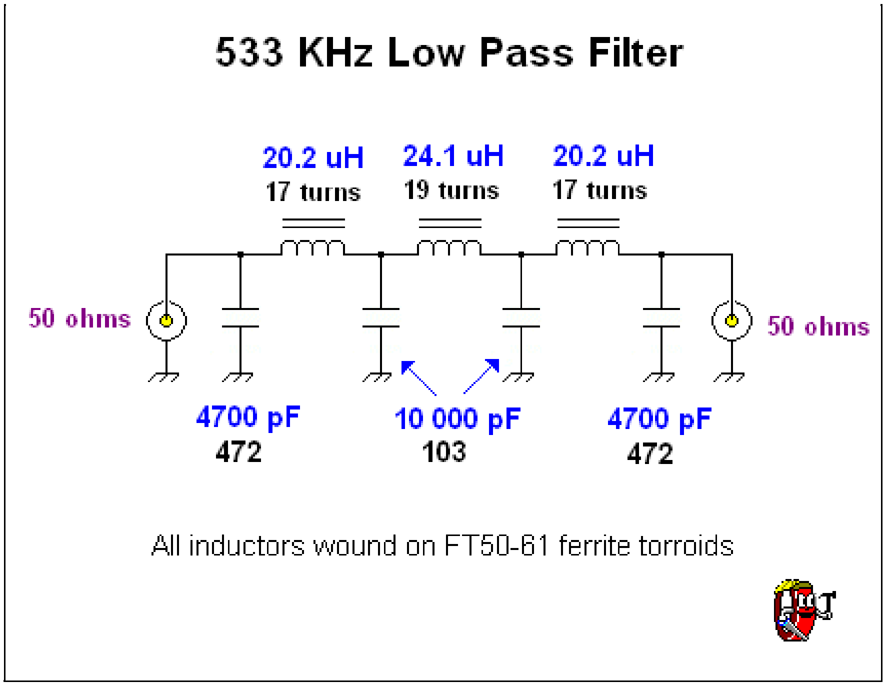
533 KHz Low Pass Filter
20.2 uH
17 turns
24.1 uH
19 turns
20.2 uH
17 turns
50 ohms
50 ohms
4700 pF
472
10 000 pF
103
4700 pF
472
All inductors wound on FT50-61 ferrite torroids

Components

I do not stock RF capacitors greater than 2200 pF, so junk box ceramic capacitors were used to build this filter. In fact, this design specifically uses more common, standard value capacitors to reduce cost and to not have to order in parts. Certainly, the astute builder could use higher quality capacitors or even large powdered iron torroids instead of the ferrite cores for inductors if higher performance is desired. Try to use high Q capacitors if you can find or are purchasing them. Poly or silver mica caps would be great choices. You can substitute a 5000 pF capacitor for the 4700 pF called for in the schematic.

To the right is a photograph of the components I used in the project breadboard.

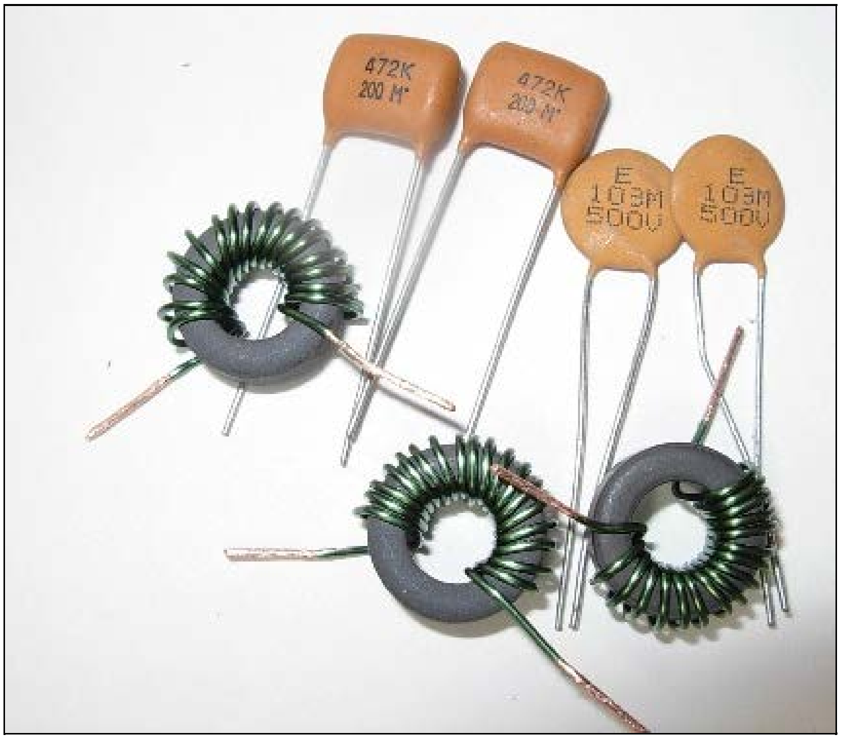
472K
200 M
472K
200 M
E
103M
500V
E
103M
500V

Breadboard

To the left is the completed project. Ugly construction as always, was used. The inductors were spaced at least 2.5 cm (1 inch) apart at right angles to try to minimize unwanted coupling.

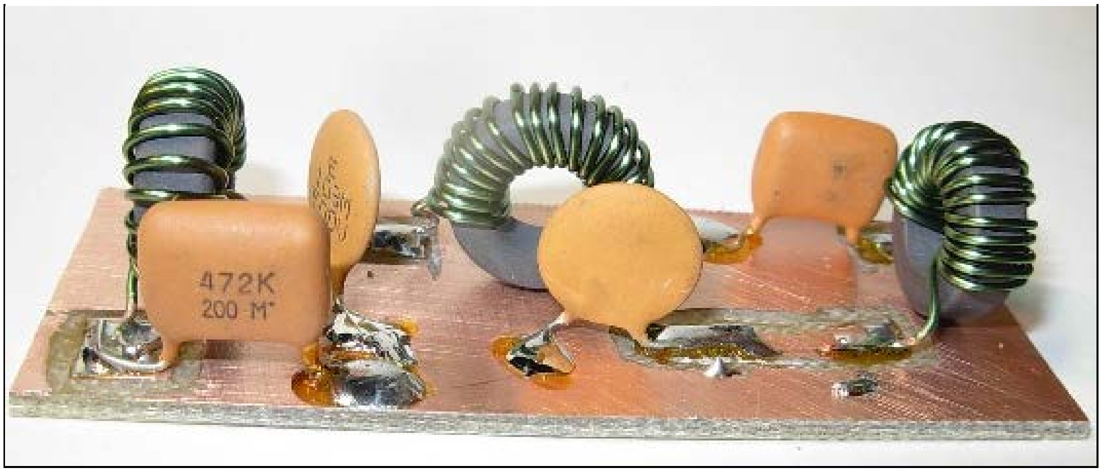

GPLA Simulation

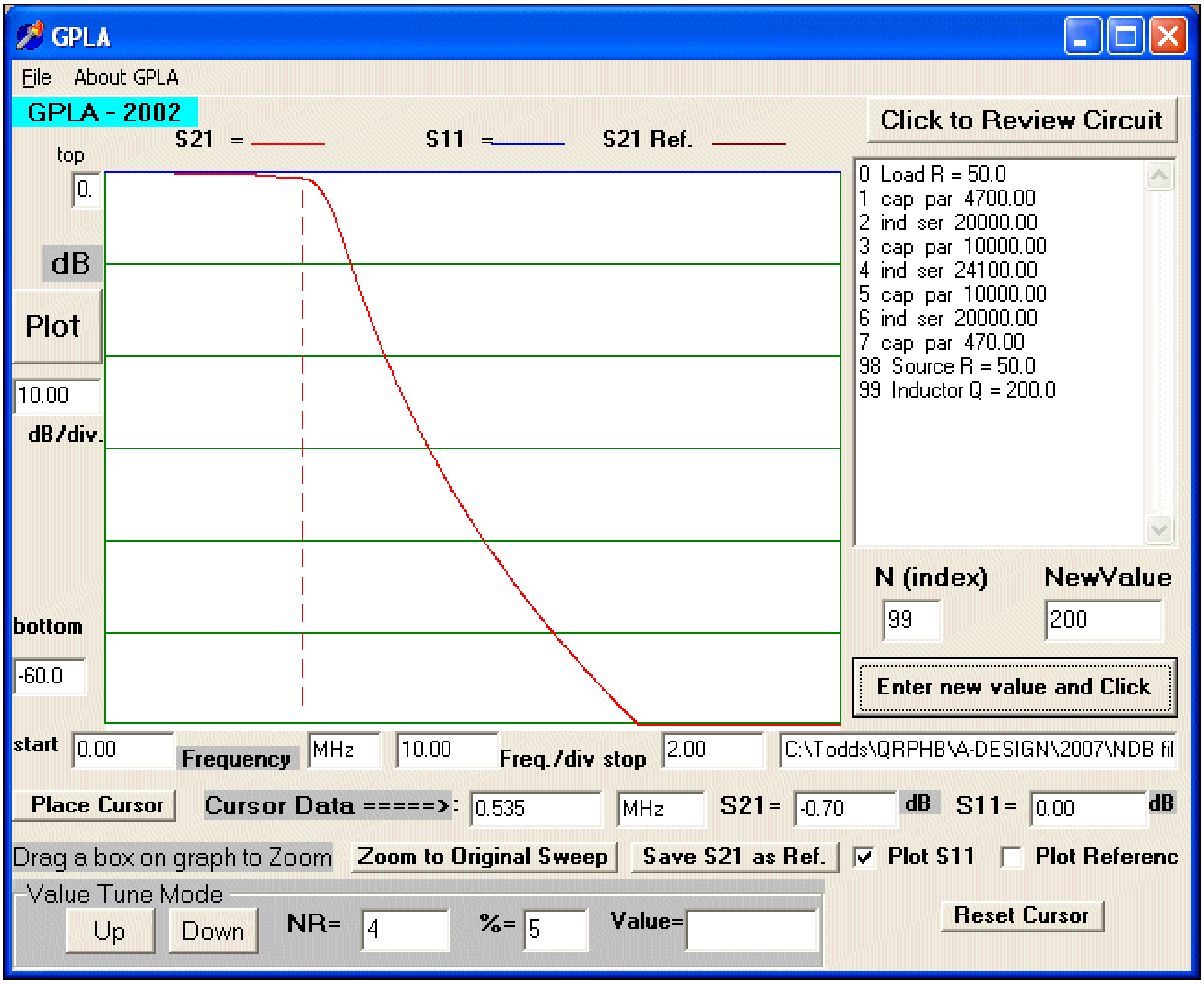

GPLA
File
About GPLA
GPLA - 2002
Click to Review Circuit
S21 =
S11 =
S21 Ref.
top
dB
Plot
dB/div.
bottom
N (index)
NewValue
Enter new value and Click
Frequency
Freq./div stop
Place Cursor
Cursor Data =====>:
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Plot S11
Plot Referenc
Value Tune Mode
Up
Down
Reset Cursor

0 Load R = 50.0
1 cap par 4700.00
2 ind ser 20000.00
3 cap par 10000.00
4 ind ser 24100.00
5 cap par 10000.00
6 ind ser 20000.00
7 cap par 470.00
98 Source R = 50.0
99 Inductor Q = 200.0

top: 0.
dB/div.: 10.00
bottom: -60.0
N (index): 99
NewValue: 200
start: 0.00
Frequency: MHz
10.00
Freq./div stop: 2.00
C:\Todds\QRPHB\A-DESIGN\2007\NDB fil
Cursor Data =====>: 0.535 MHz
S21= -0.70 dB
S11= 0.00 dB
☑ Plot S11
☐ Plot Referenc
NR= 4
%= 5
Value=

Above is the plot of the filter during simulation with GPLA. The simulation calculated an attenuation of ~46dB at 1150 KHz. At 1000 KHz the signal was 40 dB down, at 800 KHz it was ~24 dB down and at 630 KHz, the attenuation was only ~5.7 dB! Clearly this filter is not suitable if the offending BCB interference is from a station significantly less than 0.8 MHz. For my situation, this filter is acceptable. A 5 element Chebychev filter was also designed and plotted but was discarded as there was only 32 dB attenuation at 1150 KHz.
Since I wanted to tune as high as 535 KHz, the 533 KHz cutoff frequency was chosen. Additional work to help those with strong BCB interference at the lower BCB will be attempted in the future and presented on another web page.

Receiver Testing and Comments

USB
RX
DSP
0.389.00
ANT 1
F.AGC
S1 3 5 7 9 20 40 60dB
MEMO 22

Click on the picture to the left to hear the beacon YWB at 389 KHz with a 500 crystal hertz IF filter engaged on a borrowed Icom R-75 receiver. W7ZOI did some measurements on his R75 receiver S-meter using a signal generator and step attenuator. From S9 on up to 60 over, the steps were very accurate. However, below S9, correlation was poor. The built in attenuator is -20 dB when engaged. On my test receiver, I did some A/B testing with the filter in or out. For 1150 KHz (without the low pass filter) I had to engage the receiver's attenuator as without it, the S-meter reads off scale. With the attenuator engaged, the S-meter reads 50 dB over S-9 when tuned to 1150 KHz.

With the filter connected between the receiver and the feed line, (and the attenuator engaged) the S-meter read S-9.This is a drop of about 50 dB at 1150 KHz which means that this filter pretty much works as designed. I love the Icom R75 receiver; it is good value with it's many features in a compact package. Further testing was undertaken on other frequencies.

When listening to **WWV**; At 2.5 MHz, without the filter, the S-meter read S-9. With the filter inline, I could not hear WWV or see any S-meter reading. At 5 MHz without the filter, the S-meter read was at 20 dB over S-9. With the filter inline, I could still hear WWV very faintly, but the S-meter did not register. There was little noticeable attenuation at less than 700 KHz when using this filter.

Additional Photos and information

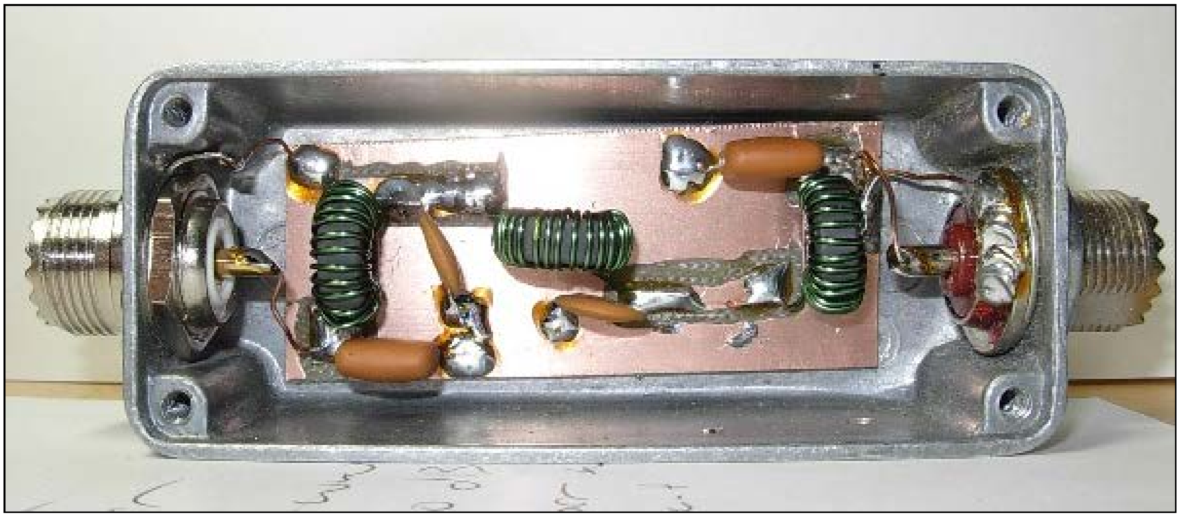

Shown above is the completed project in a Hammond die-cast case with SO-239 connectors at each end.

Shown above a photo of the Skookum beacon SX. It is on 389 KHz. This NDB is located in Skookumchuck BC, Canada

Links

My friend and fellow NDB enthusiast, Ken, VE7KPB has a posting on his web site showing some of the beacons he has logged from his QTH. Consider trying some of these frequencies from your own QTH to get used to finding beacons. Note you must temporarily allow pop ups to see his excellent log.

We recommend this non-directional beacon search and log utility program called WWSU from VE3GOP It must be registered and is a wonderful low cost tool.
I was near beacon L in Balti, Moldova (Балти, Молдова) in 2006. Below is a snippet from the VE3GOP program showing beacon L and also some nearby beacons. (Я изучаю русский язык). Приветствую Вас дорогие друзья!

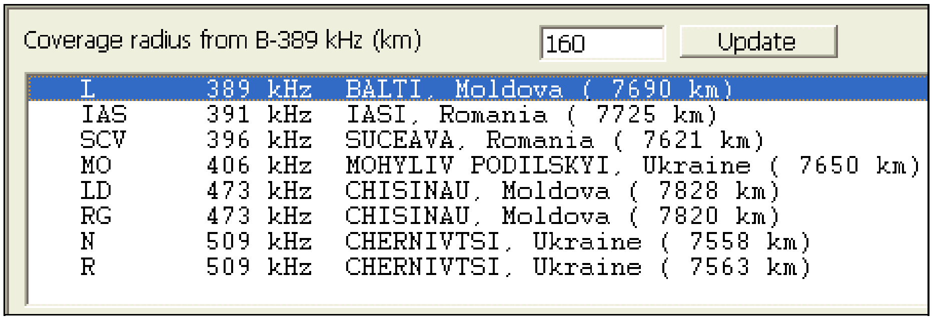

Coverage radius from B-389 kHz (km) 160

```
L        389 kHz  BALTI, Moldova ( 7690 km)
IAS      391 kHz  IASI, Romania ( 7725 km)
SCV      396 kHz  SUCEAVA, Romania ( 7621 km)
MO       406 kHz  MOHYLIV PODILSKYI, Ukraine ( 7650 km)
LD       473 kHz  CHISINAU, Moldova ( 7828 km)
RG       473 kHz  CHISINAU, Moldova ( 7820 km)
N        509 kHz  CHERNIVTSI, Ukraine ( 7558 km)
R        509 kHz  CHERNIVTSI, Ukraine ( 7563 km)
```

Martin Francis has an excellent NDB web site including the free program called NDB WEBLOG for a number of platforms

Some beacons may be located using this NavAid web site

Clint, KA7OEI has an informative web site regarding NDB listening including using digital computer processing to dig out weak signals. This is also a great overview site for newcomers to NDB.

Conclusion

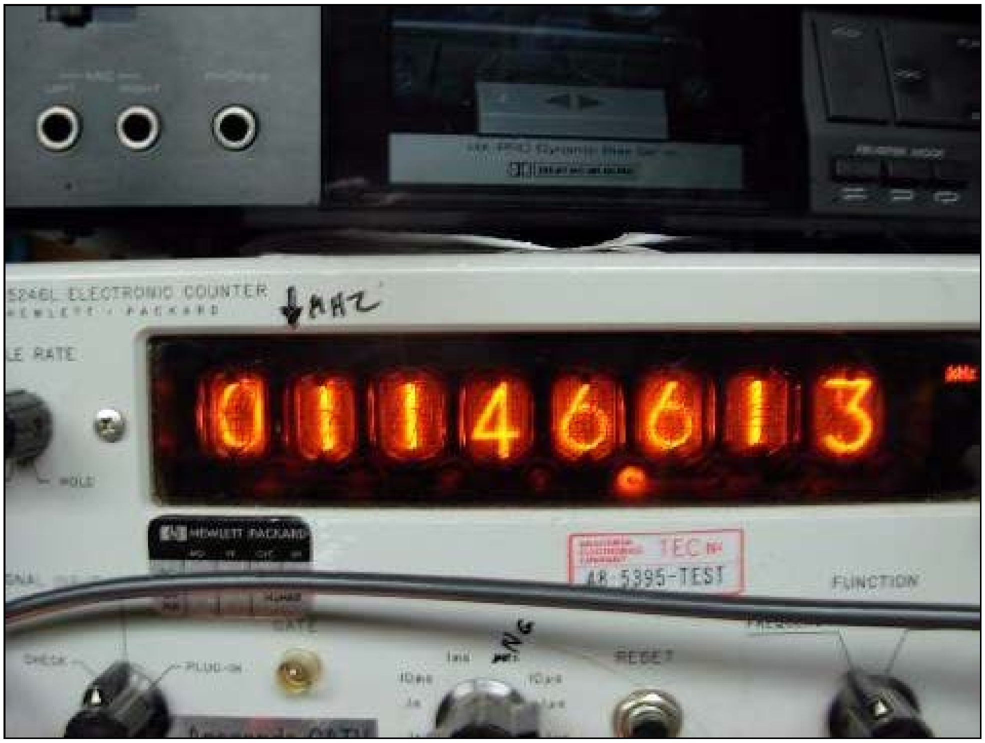

To the right is the outcome when I connect my frequency counter directly to my antenna coax cable feed line. 1150 KHz is my nemesis frequency! Happily it can be tamed with a little filtering to allow NDB listening and logging.

To the right is the outcome with my SWL antenna coaxial feed line connected directly to the scope. The scope was on the 0.5 volts per cm scale, so the peak to peak voltage is 0.2 volts. In just about any high-gain audio amplifier I build, if I touch my finger to the input, I can hear AM 1150 loud and clear - no wonder!

Good luck with your own NDB adventures!

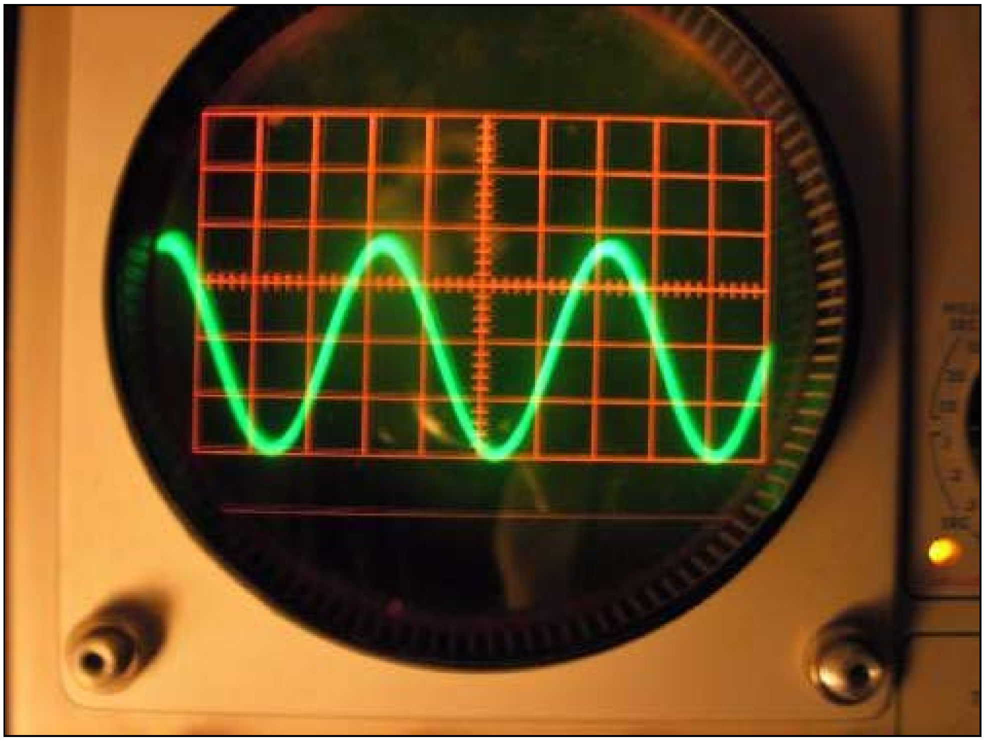

SWL HOMEBUILDER

Amateur and Short Wave Radio Electronics Experimenter's Web Site

More NDB Information and Circuits

Introduction

Latest Update: December 3, 2012

This web page holds a collection of NDB-related ideas, experiences and hopefully will include some feedback from fellow NDB enthusiasts.

I devoted a new notebook to this topic and hopefully with inspiration from band listening and communicating/learning from others, I will fill it over time. New content will be added to the bottom of the existing material as QRP-Postadata

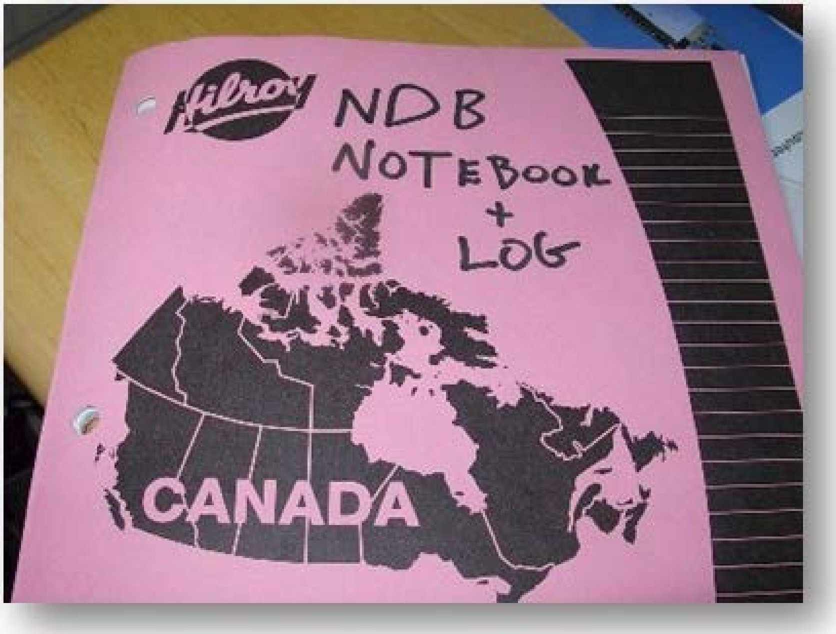

Improved NDB Chebyshev Low Pass Filter

A popcorn or "junk box" low pass filter was designed and presented on this web page. After discussion with VE7TW and testing a Realistic DX-300 and other receivers, it became apparent that even more attenuation of a strong local BCB station at 1150 KHz was desirable. In addition, there are other moderately strong AM radio stations from 630 to 800 KHz (especially at night time) which maybe causing mixer intermodulation distortion products. A fault of the junk box low pass filter is poor attenuation below 800 KHz and a better design was a prudent goal. Building on the learning obtained from the junk box filter experiments, an improved 7 element Chebyshev low pass filter was designed and is presented directly below. The 3 dB cut off of this filter is calculated to be 526 KHz. This is the filter that I now use for my home radio station. At my

nemesis frequency of 1150 KHz (where a powerful local radio station broadcasts), the attenuation is calculated to be 68 dB. It takes careful layout and a conductive chassis to realize this level of attenuation, but the effort is worth it. In very strong AM BCB locations, you might consider placing 2 such filters in series between your antenna and receiver if required.

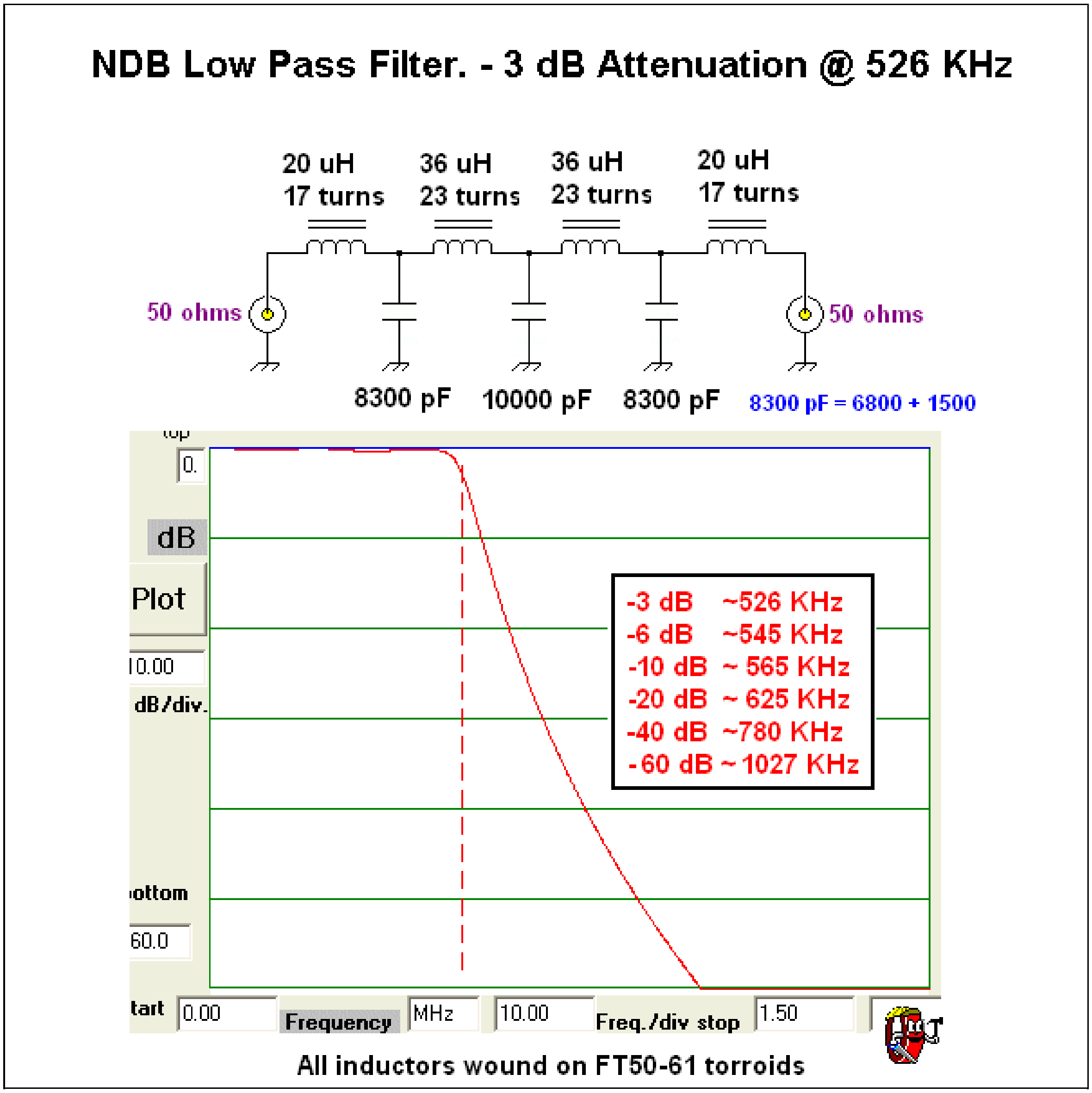
NDB Low Pass Filter. - 3 dB Attenuation @ 526 KHz
20 uH
17 turns
36 uH
23 turns
36 uH
23 turns
20 uH
17 turns
50 ohms
50 ohms
8300 pF
10000 pF
8300 pF
8300 pF = 6800 + 1500
top
0.
dB
Plot
10.00
dB/div.
bottom
60.0
start
0.00
Frequency
MHz
10.00
Freq./div stop
1.50
-3 dB ~526 KHz
-6 dB ~545 KHz
-10 dB ~ 565 KHz
-20 dB ~ 625 KHz
-40 dB ~780 KHz
-60 dB ~ 1027 KHz
All inductors wound on FT50-61 torroids

The schematic and simulation of the improved NDB low pass filter is shown above.

Non-directional Beacon Identification

It is interesting to visit nearby beacons. In the photograph to the right is XC which broadcasts at 242 KHz.

I have learned that it is very important to confirm the NDB stations your hear via a database or list. What you hear on the air should match the database/list for **both** call sign and frequency, else suspect that you may have copied it incorrectly. **RNA**, the definitive signal list for North and Central America plus Hawaii may be found here.

Three Questions

Steve Ratzlaff, AA7U is an experienced NDB DXer and has been listening to beacons since the mid-1980's.
I asked him the following 3 questions:

1. LF beacons do little more than send their station identification in Morse code, are mostly low power and generally might be perceived by some people as boring and low tech. Yet, on the World Wide Web, one finds numerous web sites, software, projects and commercial equipment all passionately dedicated to NDB listening. What's all this fuss about listening to beacons?

Steve: It's a hobby that requires quite a bit of skill and technical accomplishment to get the most from the equipment. Most folks have AC noise to deal with, which can be particularly bad at LF. Finding an antenna that works at LF and that can be used at your own location can be a major task; finding a radio that has decent LF sensitivity, or an LF converter to use with an existing radio--all these must be detitle with just to begin hearing anything at LF. I find it to be quite a challenge. If it were easy to receive LF beacons then I probably would have lost interest years ago! It's true that in recent years several software programs have become available that allow finding beacons somewhat easier--one simply looks for them on the computer screen and decodes the dots and dashes of the beacon being received. This is quite popular among beginners and veterans alike. But the traditional method of aurally listening for the morse code idents of beacons is probably used more often, though many are combining both aural and software techniques now.

2. Let's say I live in a small city lot or even an apartment. I have modest equipment and/or not a huge amount of cash to spend on gear for NDB listening. From the antenna through to the headphones, what are some basic recommendations you might give to a newcomer wanting to get started in NDB listening?

Steve: The radio must have decent sensitivity at LF, or else an LF converter must be used. Due to high local AC noise, any type of LF antenna used indoors will be a poor substitute to one that can be placed outdoors. A few portable radios cover the LF NDB frequency range that will work for hearing local beacons, though the radio may need to be used outside to get away from AC noise. The discontinued Sony 2010 was the standard for portable radios for reasonable LF performance. Newer radios like the Degen DE1103 have been found to work reasonably well at LF and can be bought for well under $100 by mail order from eBay sellers; or the more expensive Kaito 1103 version, which has a warranty, can be obtained from several distributors like Universal Shortwave. The much more expensive semi-portable Eton E1 works well at LF, but is more in the price range of a tabletop radio. The Icom R75 is currently the best bargain in a tabletop radio that has very good LF sensitivity as well as 1 Hz tuning, which is an asset if a narrow external audio filter is used. I'm not too optimistic about what someone living in an apartment or high rise building might do to successfully receive LF beacons indoors. Often the AC noise level is too high to be able to use an indoor antenna. But some have been able to use loop antennas indoors for the stronger signals. An example of a top of the line commercial loop would be the Wellbrook ALA1530 or LFL1010. Unlike at shortwave frequencies, where simply tossing a wire out the window to a nearby tree or other support, or even running the wire around the room inside, will usually work fairly well, at LF a wire less than several hundred feet generally doesn't perform very well. It can be argued that an active whip antenna makes a very good LF antenna, and doesn't take up much room, but it must be used outdoors. And if there are strong AMBCB signals, then the active antenna, either loop or whip, must have very good overload resistance otherwise it can generate distortion of its own from the strong BCB signals.

3. What kind of distances are considered DX for NDB?

Steve: NDB DX is pretty much a relative thing. One just starting out might be thrilled to hear a beacon from the next town, or from the other side of his own state or province. As one improves his listening setup and gains experience, then usually DX goals also expand to try to hear beacons farther and farther away. NDB DXing generally is not a competitive hobby, unlike amateur radio with its various competitive "contests". Each person's listening setup, local noise level, etc. is usually very different from someone else's, even someone in the same town or general area. One person might live in the suburbs and have a lower noise level than his friend who lives right in town and has a much higher noise level. One might have room to put an antenna in a quiet spot; the other might be limited to much less. People who live near an ocean generally have a much better chance at hearing something exotic offshore than folks living far inland. Folks living in the central or eastern part of North America have many more beacons available to be heard than folks in western North America. But there are always a few beacons that are much stronger than most, and can be heard from long distances of 1000 miles or more, pretty much anywhere in North America at night. One example would be 206 GLS in Galveston, Texas, which runs around 2000 watts, has a large antenna, and is generally readily heard anywhere in North America at night--that beacon might be 1500 miles or more away, and might be considered real DX. However another 25 watt beacon from the same general area in Texas might be hard to hear only several hundred miles from that beacon. So "DX" is pretty much a relative term. Ndblist, an international email list devoted to beacons, is open to anyone with an interest in beacons--members post their loggings there. What might be a local beacon to someone might be DX to someone in a different part of the country. All levels of experience are welcome.

Thanks Steve.

NDB High Pass Filter

A high pass filter using standard value capacitors was designed using GPLA. although, such a filter would not help AC line noise and RFI generated in the house, I suspected my antenna was picking up local noise from below the NDB band. This filter was mounted inside a die-cast Hammond box with a SO-239 at each end. I used 22 gauge enamel covered wire for the inductors. A photo of the filter is shown to the right.
For the 0.01 uF caps, I used junk box ceramic capacitors with a 20% tolerance, however, I did measure a bunch and found 2 within 5% tolerance for my filter bread board.

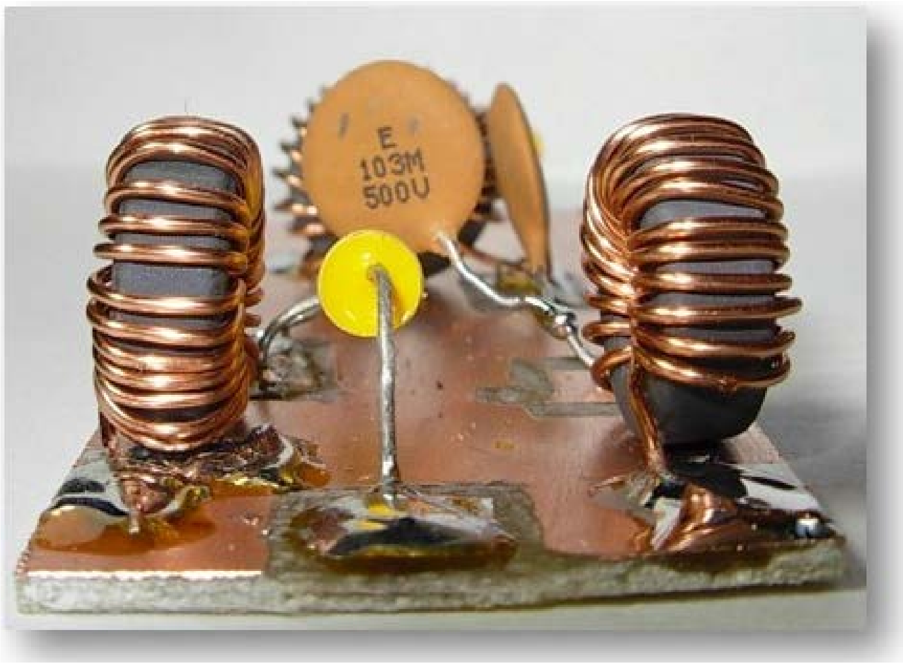

To the left is the filter schematic. This is an N = 7 Chebyshev high pass filter with a 3 dB cut off of 157 KHz. This cutoff frequency allowed the use of common, standard value capacitors and also even turns numbers to reach the desired inductance for the inductors when wound with FT50-61 ferrite cores.

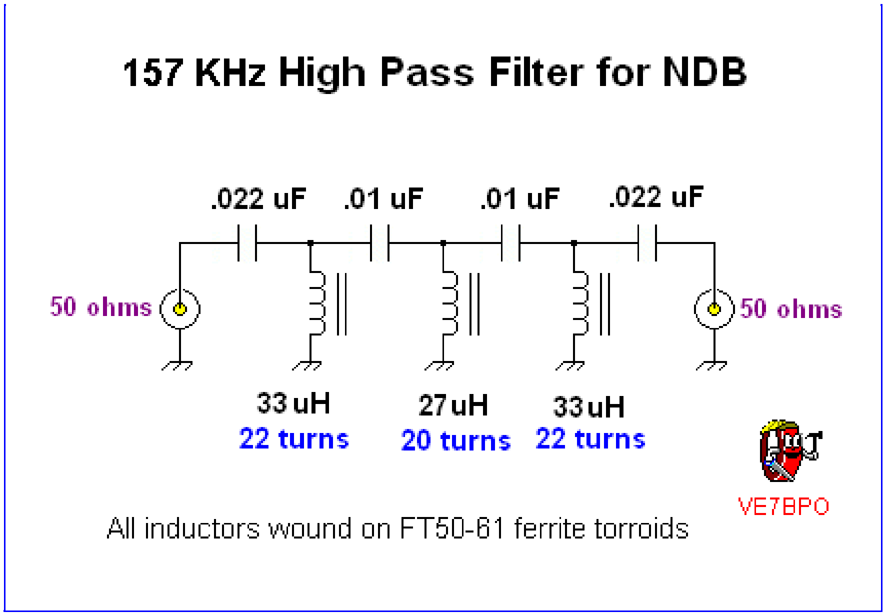
157 KHz High Pass Filter for NDB
.022 uF
.01 uF
.01 uF
.022 uF
50 ohms
50 ohms
33 uH
22 turns
27 uH
20 turns
33 uH
22 turns
VE7BPO
All inductors wound on FT50-61 ferrite torroids

Use 5% tolerance, high Q caps such as polystyrene or NP0 ceramic and **not** junk box bypass-grade ceramic capacitors as possible. I used trashy ceramic caps for the 0.01 uF parts due to lack of better parts at the time of building and testing.

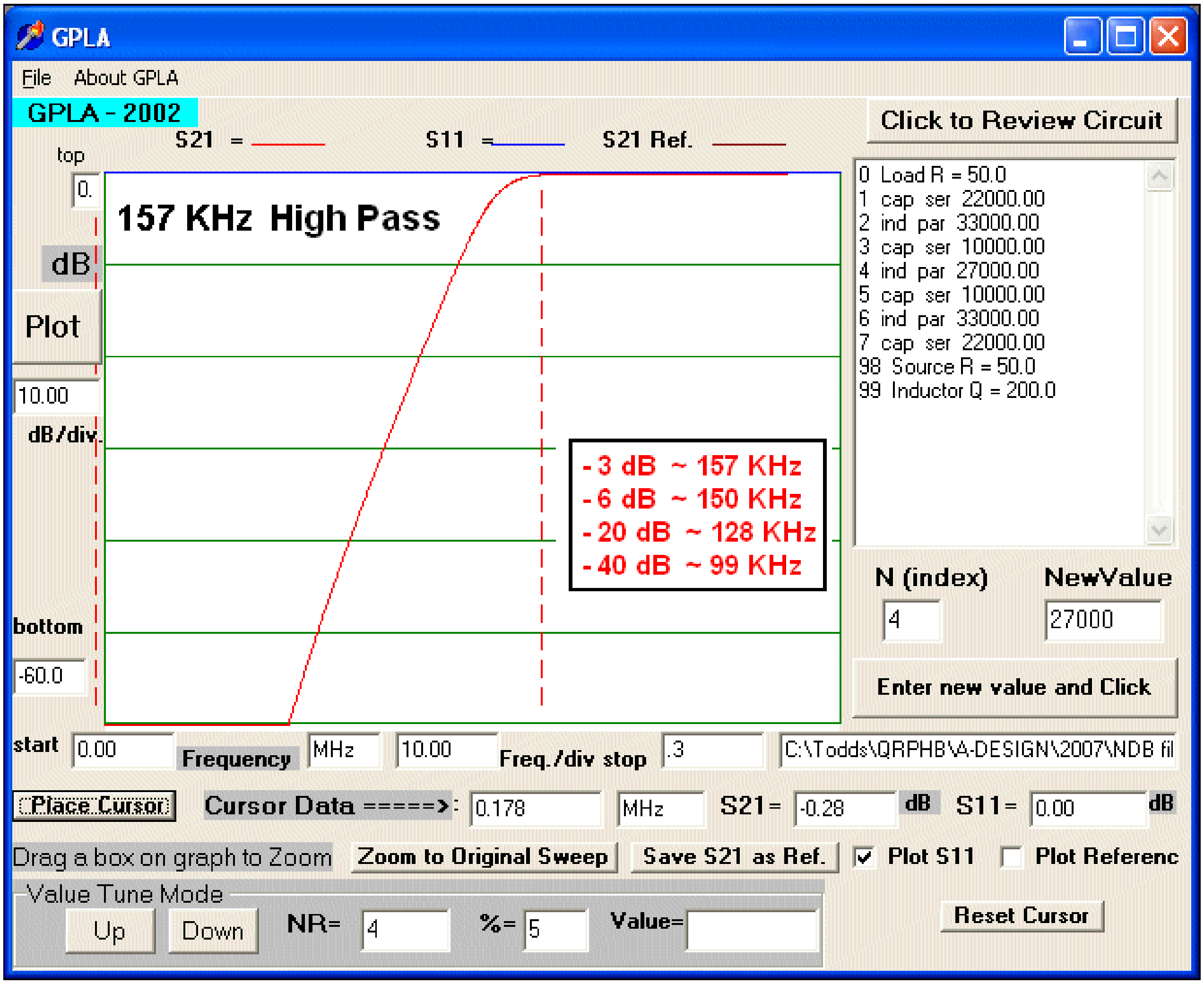
GPLA
File
About GPLA
GPLA - 2002
S21 =
S11 =
S21 Ref.
Click to Review Circuit
top
dB
Plot
dB/div
bottom
157 KHz High Pass
start
Frequency
Freq./div stop
Place Cursor
Cursor Data =====>:
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Plot Reference
Value Tune Mode
Up
Down
Reset Cursor
Enter new value and Click

-3 dB ~ 157 KHz
-6 dB ~ 150 KHz
-20 dB ~ 128 KHz
-40 dB ~ 99 KHz

0 Load R = 50.0
1 cap ser 22000.00
2 ind par 33000.00
3 cap ser 10000.00
4 ind par 27000.00
5 cap ser 10000.00
6 ind par 33000.00
7 cap ser 22000.00
98 Source R = 50.0
99 Inductor Q = 200.0

N (index) 4
NewValue 27000

top 0.
10.00 dB/div
bottom -60.0
start 0.00 MHz
10.00
Freq./div stop .3
C:\Todds\QRPHB\A-DESIGN\2007\NDB fil
Cursor Data =====>: 0.178 MHz S21= -0.28 dB S11= 0.00 dB
☑ Plot S11
☐ Plot Referenc
NR= 4
%= 5
Value=

Above is the filter GPLA simulation. In particular, I have harsh noise from about 110 KHz on down. At 78 KHz, where this filter has a calculated attenuation of ~ 56 dB, I made an audio file of the band noise. This is in AM mode with the filter out for a few seconds and then in line. With the high pass filter in line, there is pronounced attenuation of the noise and my local 10 KW BCB station at 1150 KHz suddenly appears. Prior to this it was hidden by the harsh noise. At frequencies less than ~200 KHz (without my low pass filter) I can hear this BCB station intermittently as I tune around. I suspect that the R75 filtering down at 200 KHz and down is insufficient to stop this monster station.

At my QTH, using a high pass filter reduces some of the noise on the NDB band. At my location, a high pass plus a low pass filter in cascade between my antenna and my receiver results in less QRN and easier weak signal copying.

Long Wave Broadcast Radio Filter

I learned about LW Broadcast radio from Steve Ratzlaff. In particular, радио россий "Rah-deo RaSEE" (make sure you roll the R!) can occasionally be heard on the west coast and broadcasts at night-time using 500-1000 KW power. The frequencies he recommended to try were 153, 180, 189, and perhaps 171, 234 and 279 KHz. I have terrible problems with a local BCB radio station at 1150 KHZ that causes intermodulation distortion and/or blow-by detection at and below 200 KHz in addition to a terrible noise source at 78-120 KHz. Therefore, I built another cascade low pass/high pass filter and placed it in the same chassis as my regular NDB low pass/high pass combination filter for use when tuning LWBC and perhaps for when listening to frequencies less than 200 KHz.

1800±5%
CDE
153J

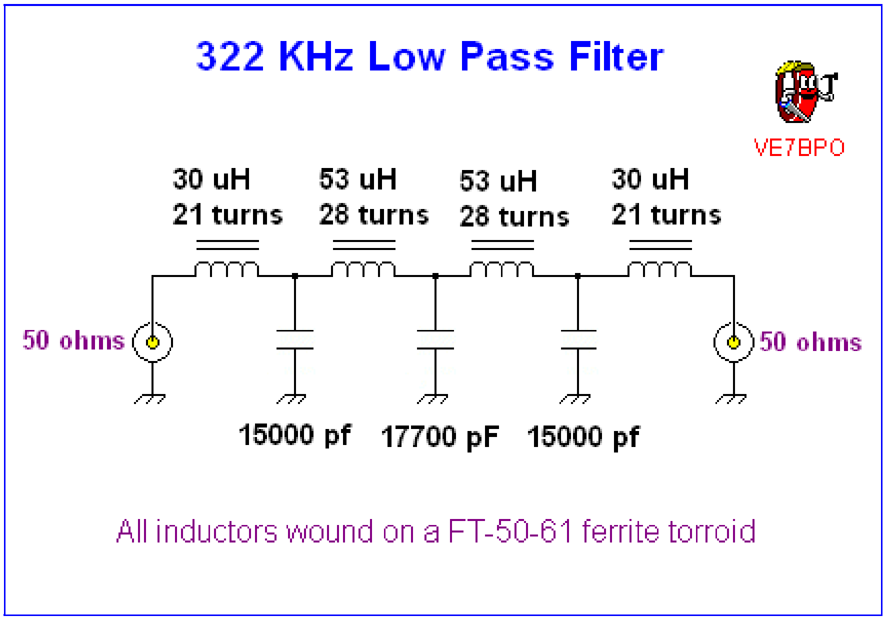
322 KHz Low Pass Filter
VE7BPO
30 uH
21 turns
53 uH
28 turns
53 uH
28 turns
30 uH
21 turns
50 ohms
50 ohms
15000 pf
17700 pF
15000 pf
All inductors wound on a FT-50-61 ferrite torroid

Above is. the schematic of the 322 KHz low pass filter. In the photograph above, you can see a 50 ohm pad at the input that was used only during testing. This filter offers a calculated attenuation of ~ 98 dB to my 1150 KHz interfering station. In reality it is not possible to achieve this level of attenuation, however, there is no detectable 1150 KHz signal interference with the filter in line which makes me happy. Click here to listen to the dramatic difference with regard to interference this filter makes at my QTH with my receiver tuned to 199 KHz. The receiver is set for wide band AM detection; first without the LWBC filter and then with the filter switched in. When the filter is switched in, the BCB interference disappears and a Canadian NDB (UAB @ 200 KHz can faintly be heard along with our cat meowing in the background. It is not possible to listen to LF without aggressive low pass/high pass filtering at my QTH.

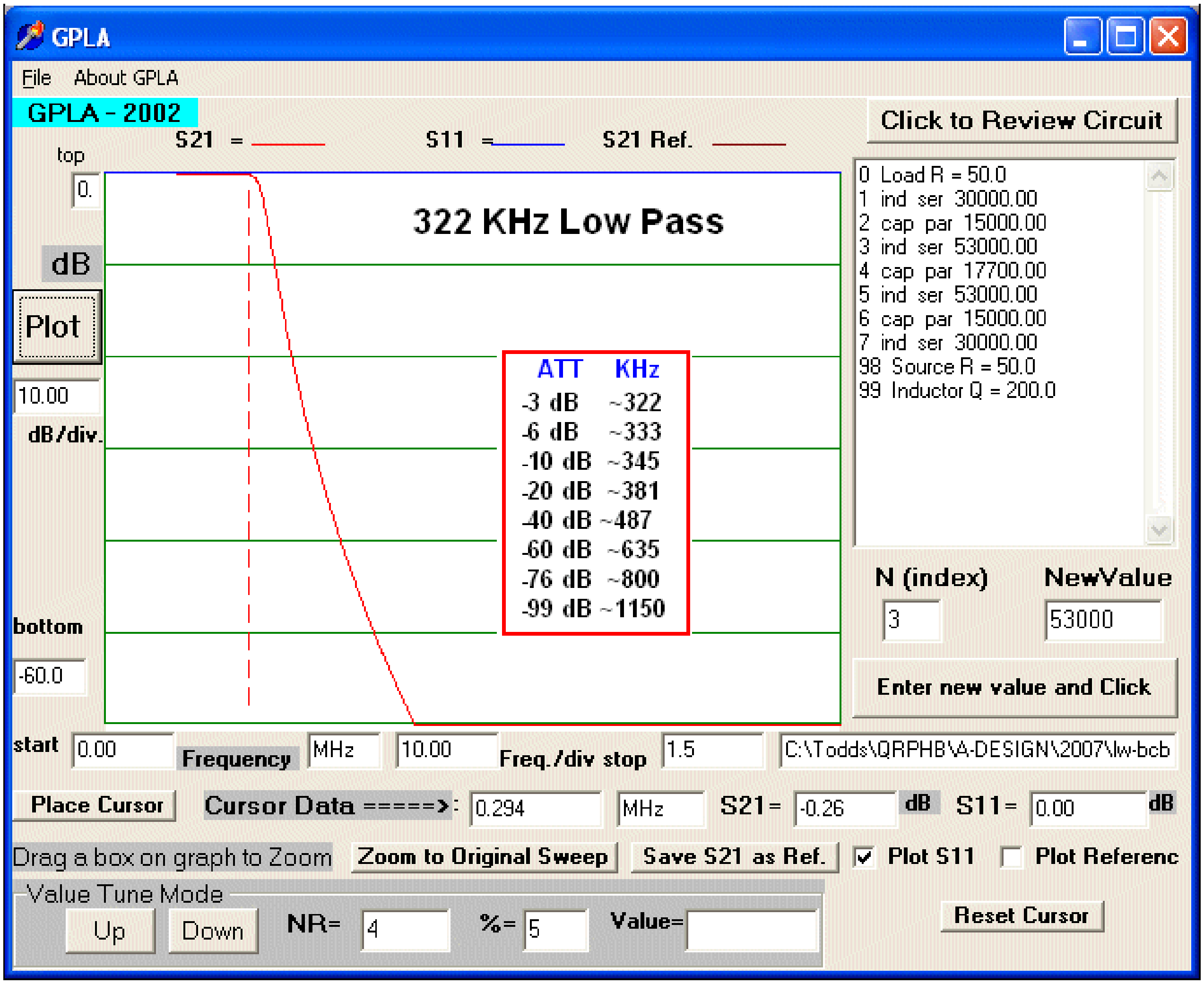
GPLA
File
About GPLA
GPLA - 2002
Click to Review Circuit
S21 =
S11 =
S21 Ref.
top
dB
Plot
dB/div.
bottom
Place Cursor
Cursor Data =====>
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Enter new value and Click
Value Tune Mode
Up
Down
Reset Cursor

322 KHz Low Pass

ATT	KHz
-3 dB	~322
-6 dB	~333
-10 dB	~345
-20 dB	~381
-40 dB	~487
-60 dB	~635
-76 dB	~800
-99 dB	~1150

```
0  Load R = 50.0
1  ind  ser  30000.00
2  cap  par  15000.00
3  ind  ser  53000.00
4  cap  par  17700.00
5  ind  ser  53000.00
6  cap  par  15000.00
7  ind  ser  30000.00
98  Source R = 50.0
99  Inductor Q = 200.0
```

top: 0.

10.00 dB/div.

bottom: -60.0

start 0.00 Frequency MHz 10.00 Freq./div stop 1.5

C:\Todds\QRPHB\A-DESIGN\2007\lw-bcb

N (index) 3

NewValue 53000

Cursor Data =====>: 0.294 MHz S21= -0.26 dB S11= 0.00 dB

☑ Plot S11

☐ Plot Referenc

NR= 4

%= 5

Value=

Above is the GPLA simulation of the LWBC low pass filter.

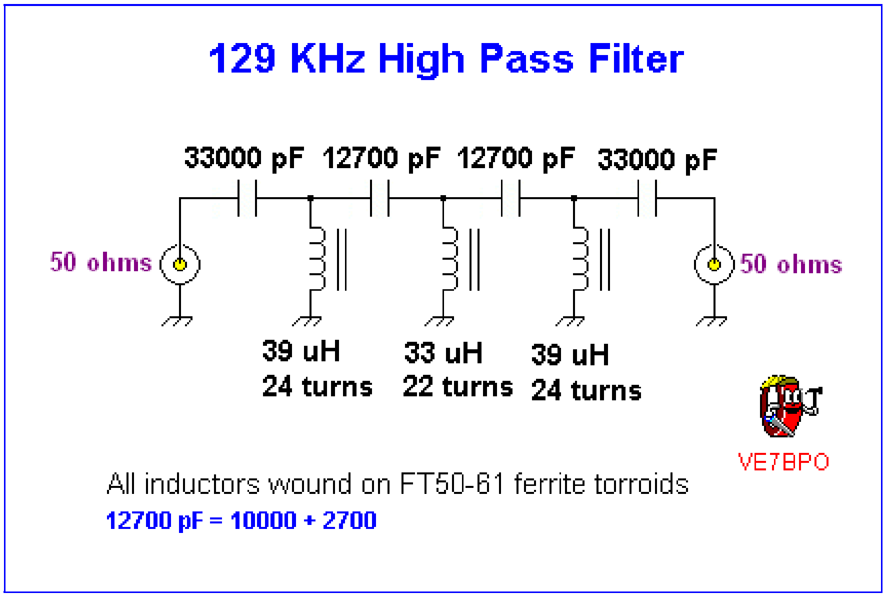
129 KHz High Pass Filter
33000 pF
12700 pF
12700 pF
33000 pF
50 ohms
50 ohms
39 uH
24 turns
33 uH
22 turns
39 uH
24 turns
VE7BPO

All inductors wound on FT50-61 ferrite torroids

12700 pF = 10000 + 2700

Above is the schematic of the 129 KHz LWBC high pass filter. In either of the 2 filters, capacitor values can be obtained using 1 or 2 standard value capacitors in parallel. The cutoff frequencies of both filters were chosen to allow using practical component values.

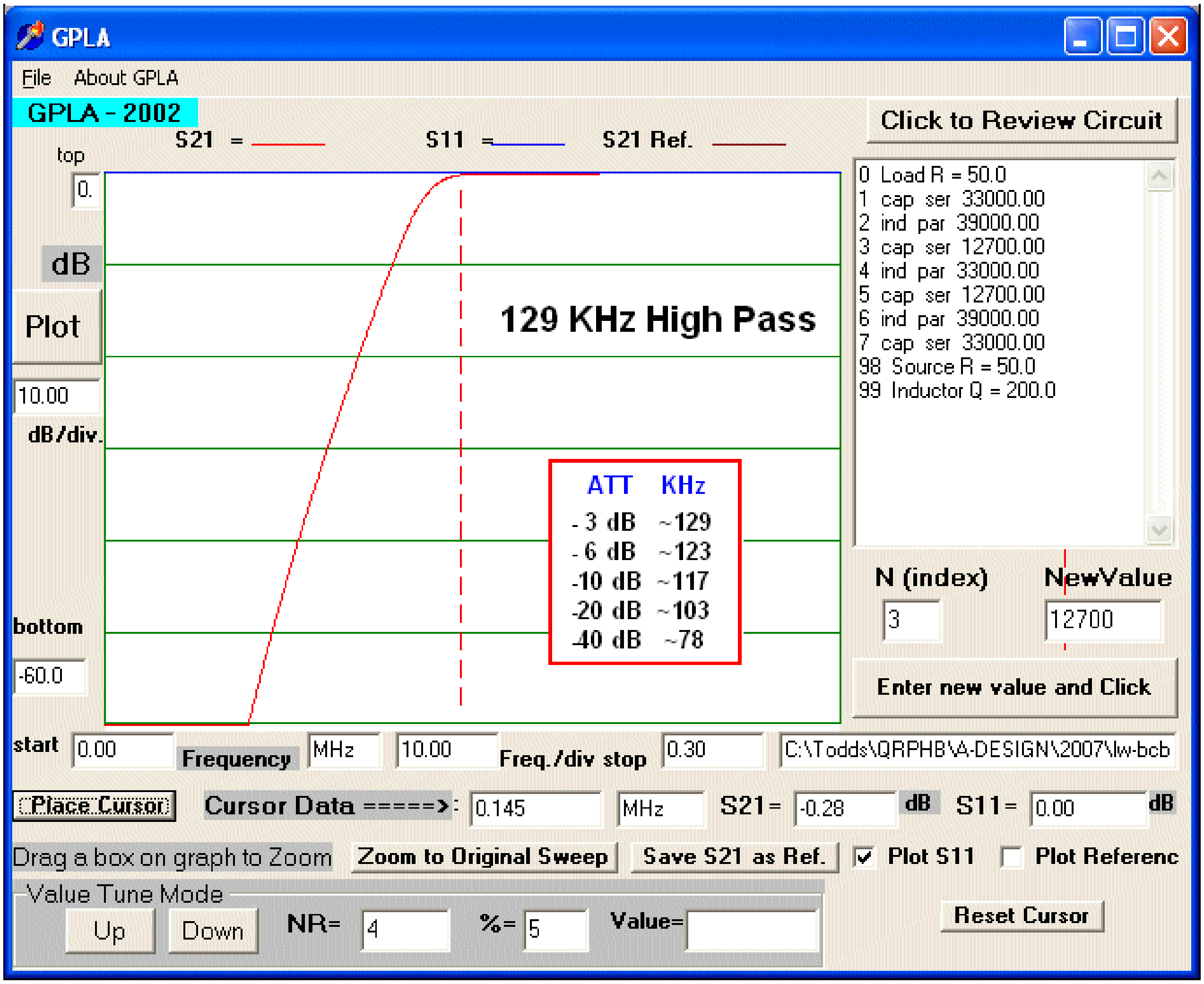
GPLA
File
About GPLA
GPLA - 2002
S21 =
S11 =
S21 Ref.
Click to Review Circuit
dB
Plot
Enter new value and Click
Frequency
Place Cursor
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Value Tune Mode
Up
Down
Reset Cursor

129 KHz High Pass

ATT	KHz
- 3 dB	~129
- 6 dB	~123
-10 dB	~117
-20 dB	~103
-40 dB	~78

0 Load R = 50.0
1 cap ser 33000.00
2 ind par 39000.00
3 cap ser 12700.00
4 ind par 33000.00
5 cap ser 12700.00
6 ind par 39000.00
7 cap ser 33000.00
98 Source R = 50.0
99 Inductor Q = 200.0

top 0.
10.00 dB/div.
bottom -60.0
start 0.00 MHz
Freq./div 10.00
stop 0.30
C:\Todds\QRPHB\A-DESIGN\2007\lw-bcb
Cursor Data =====>: 0.145 MHz S21= -0.28 dB S11= 0.00 dB
N (index) 3
NewValue 12700
☑ Plot S11
☐ Plot Referenc
NR= 4
%= 5
Value=

Above is the GPLA simulation of the LWBC high pass filter. The high pass filter might not be needed at your QTH. My LWBC filter has the low pass filter before the high pass filter. I.e. they are in series or cascaded.

Dual NDB and LWBC Filters

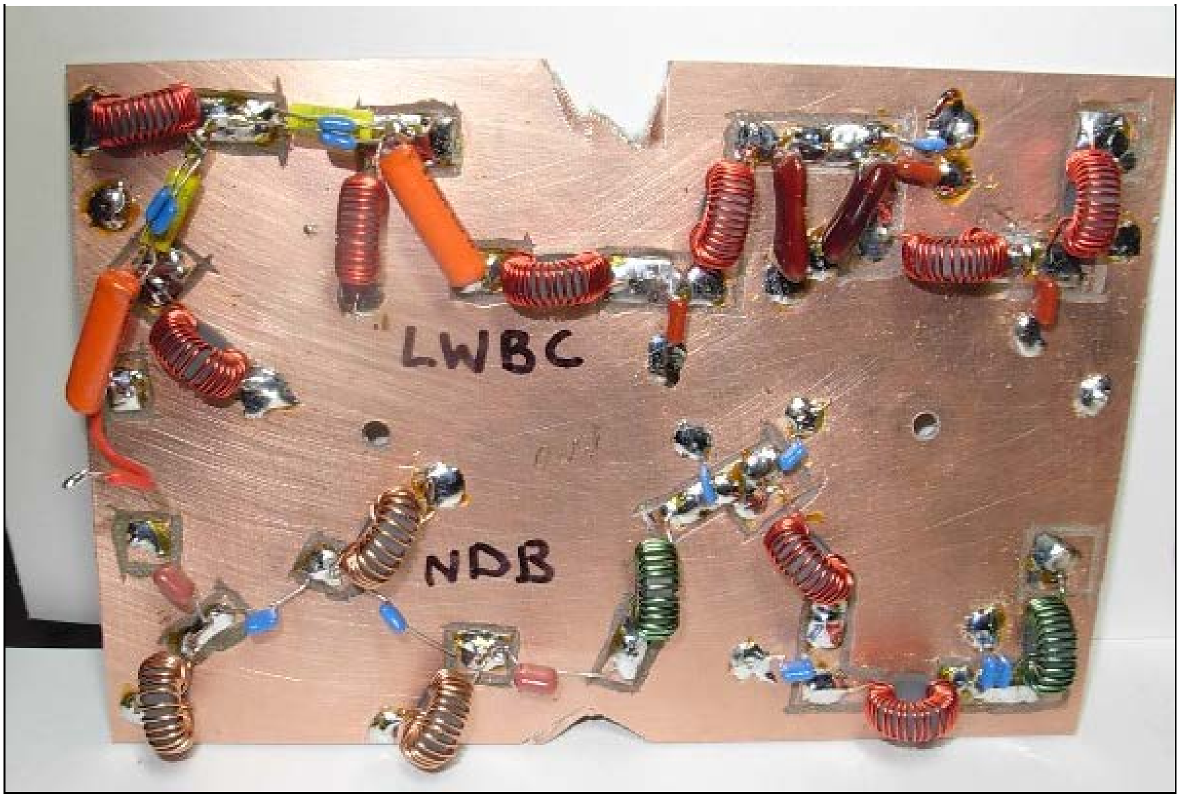

For use in my radio shack, I built LWBC and NDB filters inside 1 chassis with separate inputs and outputs. Some photos of this project are shown directly above and below. The NDB filter is the 526 KHz low pass filter in series with the 157 KHz high pass filter. The LWBC filter is the 322 KHz low pass filter in series with the 129 KHz high pass filter. High Q caps were used and the inductors were wound with either 22 or 24 gauge wire to obtain a relatively high unloaded Q. The large Hammond project case allowed reasonable spacing of the inductors and a nice long input to output layout.

Beacon XJ @326 KHz

Above is NDB XJ in Fort St. John, BC. Photo by VE7KPB in August 2008.

QRP — Posdata: NDB Low-pass Filter with Trap

An email from Rick, NU7Z spawned this 2012 addition.

Depending on their design, typical NDB low-pass filters provide less than 20 dB attenuation at 620 - 630 KHz, and if you hear a strong station on this frequency — good luck!

Rick sought a filter with a trap at ~ 620 KHz — after mulling around, we encountered design problems with a trap frequency so close to the low-pass cut-off frequency and later asked Wes, W7ZOI if he might help design our filter.

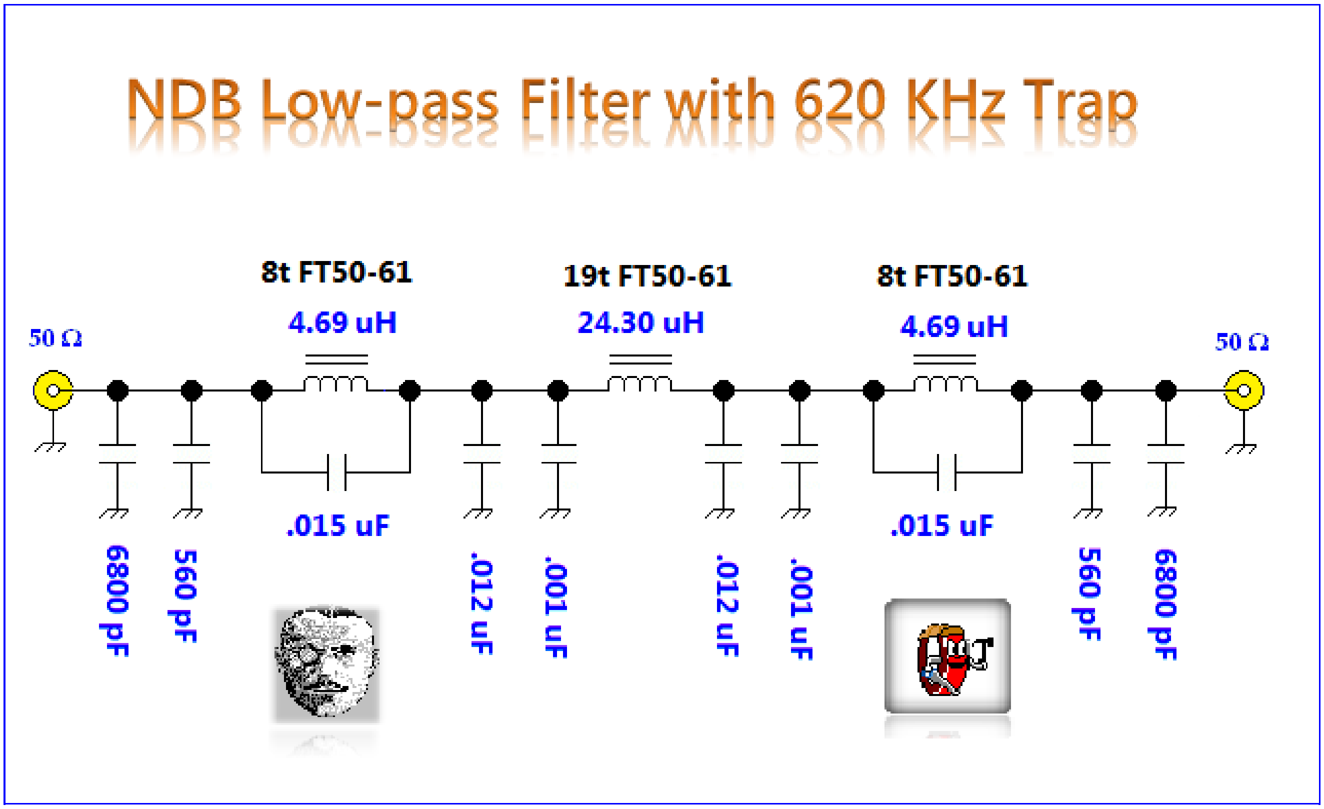
NDB Low-pass Filter with 620 KHz Trap
50 Ω
8t FT50-61
4.69 uH
19t FT50-61
24.30 uH
8t FT50-61
4.69 uH
50 Ω
6800 pF
560 pF
.015 uF
.012 uF
.001 uF
.012 uF
.001 uF
.015 uF
560 pF
6800 pF

Above — My version of the Wes, W7ZOI designed NDB low-pass filter with a trap. **Red** filter below

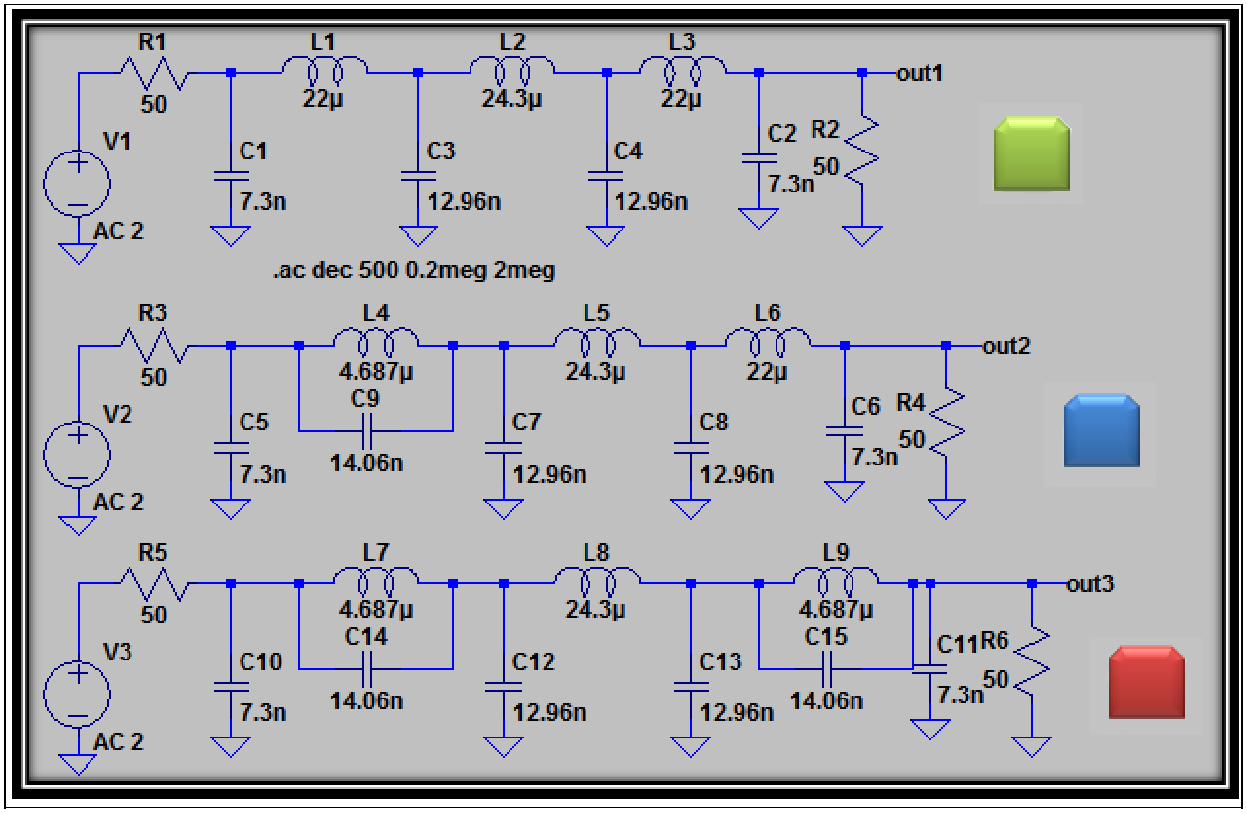
R1
50
L1
22µ
L2
24.3µ
L3
22µ
out1
V1
AC 2
C1
7.3n
C3
12.96n
C4
12.96n
C2
7.3n
R2
50
.ac dec 500 0.2meg 2meg
R3
50
L4
4.687µ
C9
14.06n
L5
24.3µ
L6
22µ
out2
V2
AC 2
C5
7.3n
C7
12.96n
C8
12.96n
C6
7.3n
R4
50
R5
50
L7
4.687µ
C14
14.06n
L8
24.3µ
L9
4.687µ
C15
14.06n
out3
V3
AC 2
C10
7.3n
C12
12.96n
C13
12.96n
C11
7.3n
R6
50

Above — A 7th order, 0.1 dB ripple **Chebyshev low-pass filter** with a 550 KHz cut-off filter evolved to include **1 trap**, and then **2 traps** at 620 KHz.

We learned that in simple situations, you may modify the elements of a low-pass filter so that the usual inductor is replaced by a parallel trap. See Wes' work in EMRFD Chapter 3; in particular, Figure 3.10.

Wes wrote he's employed this technique successfully before — for example, to add harmonic suppression to a simple output network for a QRP transmitter, although he hadn't added traps to higher order filters like the 1 we wanted. Click for a file containing the math contributed by Wes, W7ZOI.

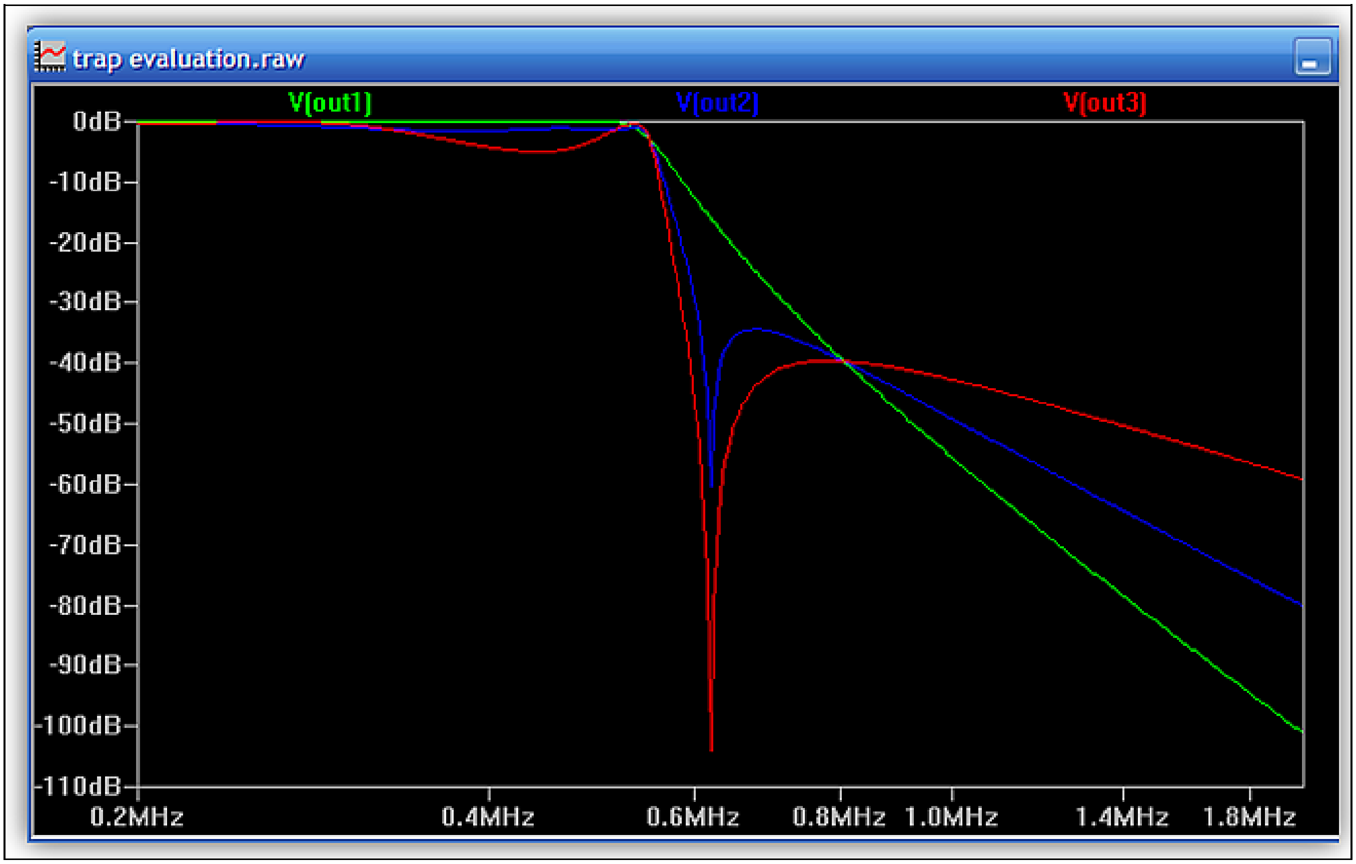

Above — The SPICE analysis of the 3 color-coded filters above. This design excludes the impact of finite L and C and the unloaded Q that could significantly affect function since the trap frequency is close to the low-pass cutoff frequency. These factors usually worsen the insertion loss near cutoff, but since we're using this filter in a noisy RF environment, filter misperformance should be tolerable.

In the future, Wes recommended designing an elliptical low-pass filter with software such as that distributed by AADE.

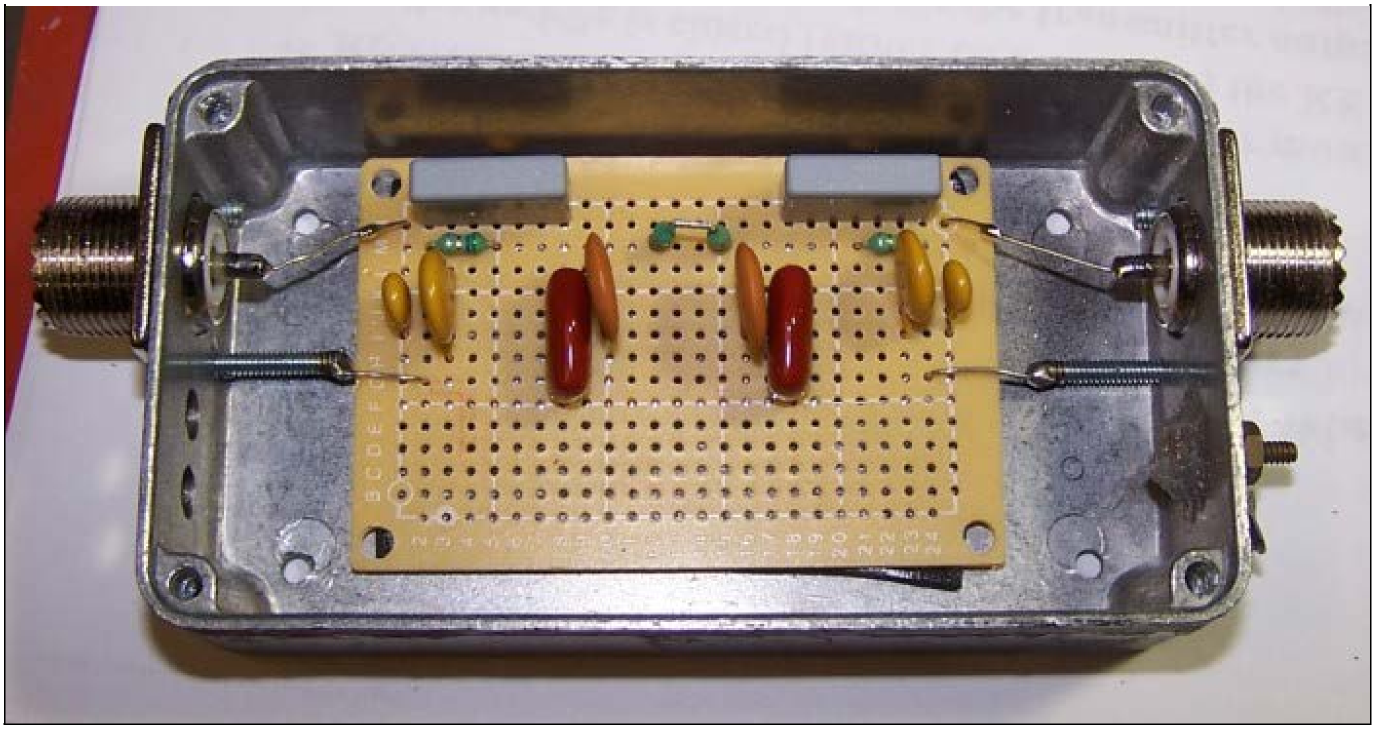

Above — A version of the filter built by Rick, NU7Z using epoxy-coated inductors for the L's. The insertion loss with these inductors = ~ 5 dB, although he runs a 40 dB receive preamp and can accommodate such losses.

Despite employing a loop receiving antenna, he could not listen around 500 KHz due to a loud, local broadcast station at 630 KHz. Inserting this filter reduced this 630 KHz signal from 40 dB over S-9 down to S-1 on his receiver S-meter.

Fantastic! Big thanks (большое спасибо) to Wes, W7ZOI.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

440 Hertz Peaked Low Pass Audio Filter Experiments

Introduction

At audio frequencies, low pass filtering can go a long way to improving CW and beacon reception. It has a been a long time since I built one and therefore decided to experiment with some designs using the 5532 op amp. EMRFD has a great section on RC active audio filters starting at Chapter 3.5 and this is where I began. After some experimentation, I remembered a peaked low pass filter designed and published by Wes, W7ZOI in the 1970's. This filter became very popular in Russia after publication in a 1971 Russian Amateur Radio Journal. I asked Wes if he might design another low pass filter peaked for 440 Hertz, which is my favorite CW beat note frequency. This filter is intended for use as an out board headphone jack device for the Icom R75 or other receiver.

AF LOW PASS
PHONES
INPUT

Base Project Schematic

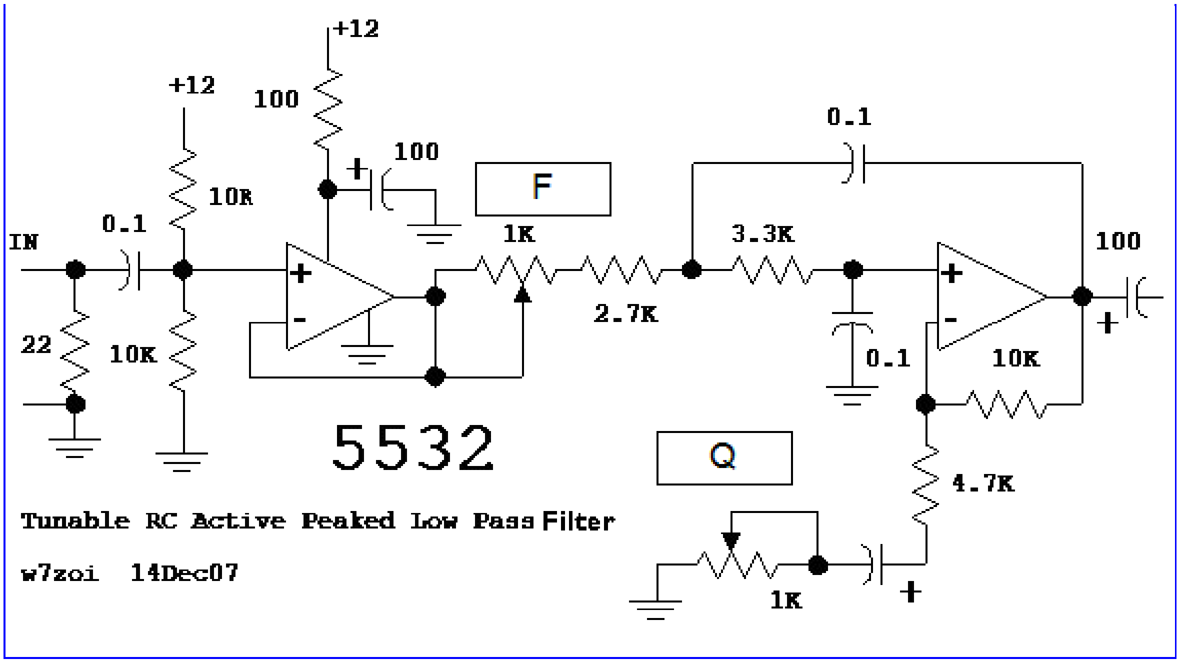
+12
+12
100
100
0.1
10K
IN
0.1
F
1K
3.3K
100
2.7K
22
10K
0.1
10K
5532
Q
4.7K
Tunable RC Active Peaked Low Pass Filter
w7zoi 14Dec07
1K

Above is the filter designed by Wes, W7ZOI. It has two 1K pots you can tweak; a subtle frequency control and a Q adjustment. It is theoretically possible to adjust the Q too strongly as to cause oscillation, although this did not happen with my bread board.

Schematic and Circuit Building Details

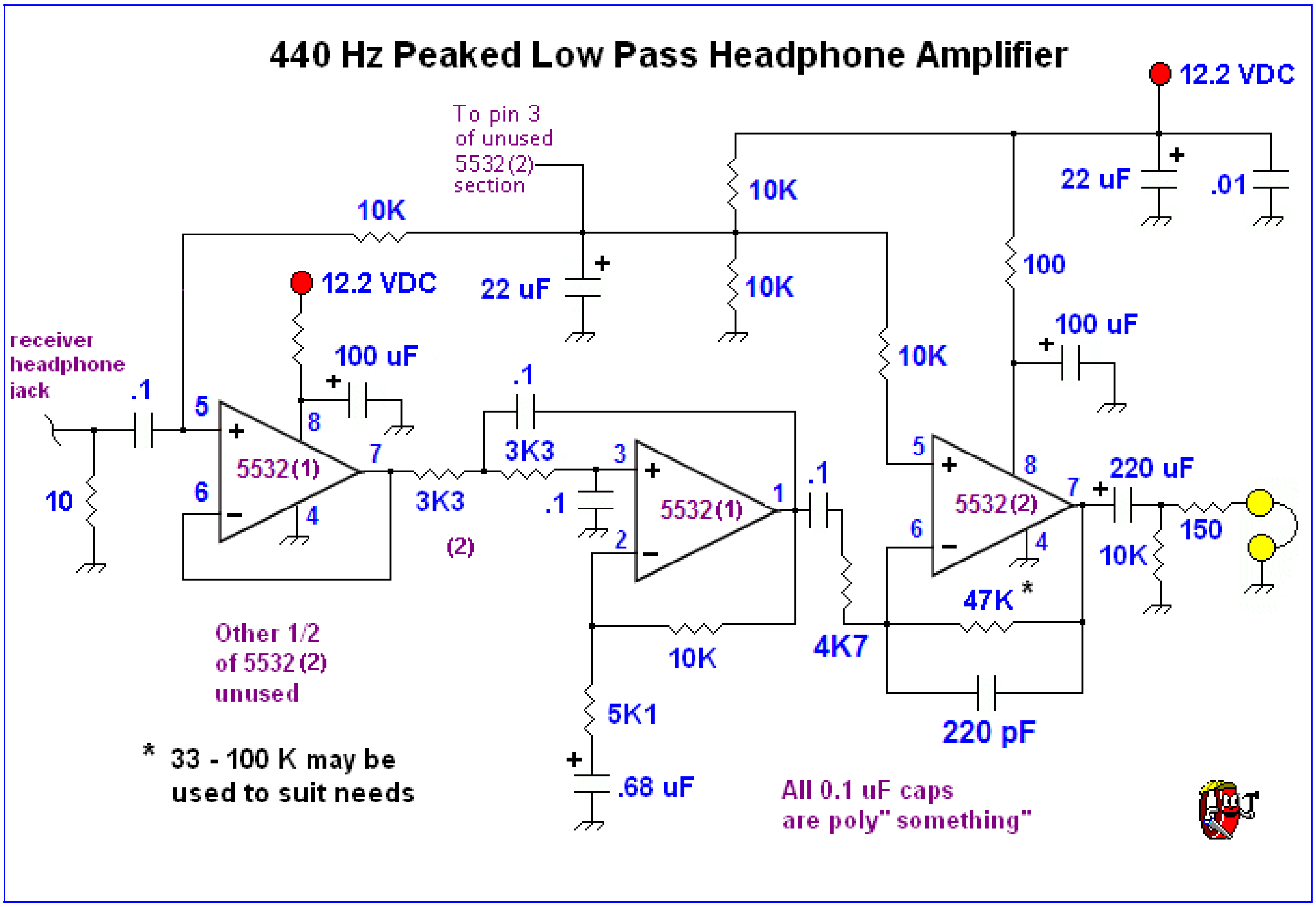
440 Hz Peaked Low Pass Headphone Amplifier
12.2 VDC
To pin 3 of unused 5532(2) section
10K
10K
22 uF
.01
12.2 VDC
22 uF
10K
100
receiver headphone jack
100 uF
10K
100 uF
.1
.1
5
8
3K3
3
5
8
10
6
5532(1)
7
3K3
.1
5532(1)
1
.1
5532(2)
7
220 uF
4
2
6
4
150
(2)
10K
47K *
4K7
Other 1/2 of 5532(2) unused
10K
5K1
220 pF
* 33 - 100 K may be used to suit needs
.68 uF
All 0.1 uF caps are poly"something"

Above is the final filter design. My prototype filter had 2 variable pots and I disconnected and measured them after discovering my favorite setting and then constructed the version shown above using fixed-value resistors instead of the potentiometers. If you like to tweak knobs, you might leave 1 or both of the pots in. The 0.68 uF cap can be raised as high as 4.7 uF if you have poly caps this large in capacitance value. although, it seems wasteful, I did not use one half of the second 5532 op amp. Feel free to add another pole of low pass filtering or something else to utilize this stage if you like. Pin 3 of the unused, second op amp 1/2 is connected to the 10K/10K voltage divider bias with a wire as indicated in the text.

This filter sounds the best when the R75 volume control is minimally turned on as I suspect some of the wide band noise heard is from the ICOM AF chain. More importantly, If the R75 audio gain control is turned too high, the filter will be overdriven and sound distorted This is especially true when using the 2.4 KHz wide SSB filter on the R75. The 10 ohm filter input resistor attenuates the receiver output and makes it more difficult to overdrive the audio filter. The 500 Hz filter at the 9 MHz Receiver IF has quite a bit of of loss and with this filter switched in, it is difficult to overdrive the audio filter. For best results, an audio filter should be placed just after the first AF preamp stage, however, using the headphone jack is the only option available for adding AF filtering in most commercial receivers I have used.
The second op amp stage is used to increase the headphone volume and the 47K feedback resistor can be adjusted to suit your needs. It is really important to experiment with the component values which will match your receiver and the IF filters and antenna you have. For example the input shunt resistor may be increased from 10 to 18-22 ohms if you always use a narrow IF filter during CW and beacon listening or received signals are low in volume. This is an experimenter's circuit, not a finished project. Overall, this circuit has low output volume and is really gentle on the ears in terms of noise and amplitude.

Project Breadboard and Samples

Shown to the right is a side photo of the experimental project. The big yellow Mallory polyester caps were used as I did not have any other desirable AF filtering caps in my parts stock. The day after, I built this filter, my parts order (including a big selection of polyester film audio caps) from Digi-Key arrived, however this is Murphy's law. These Mallorys are good quality capacitors- just a little large!

Low pass filters can really help reduce noise during reception. Two example audio files follow. These were heard in the NDB band using a 2.4 KHz SSB IF filter.
290 YYF
312 UNT
The occasional scratchy noises are me moving as I held the headphones around the microphone.

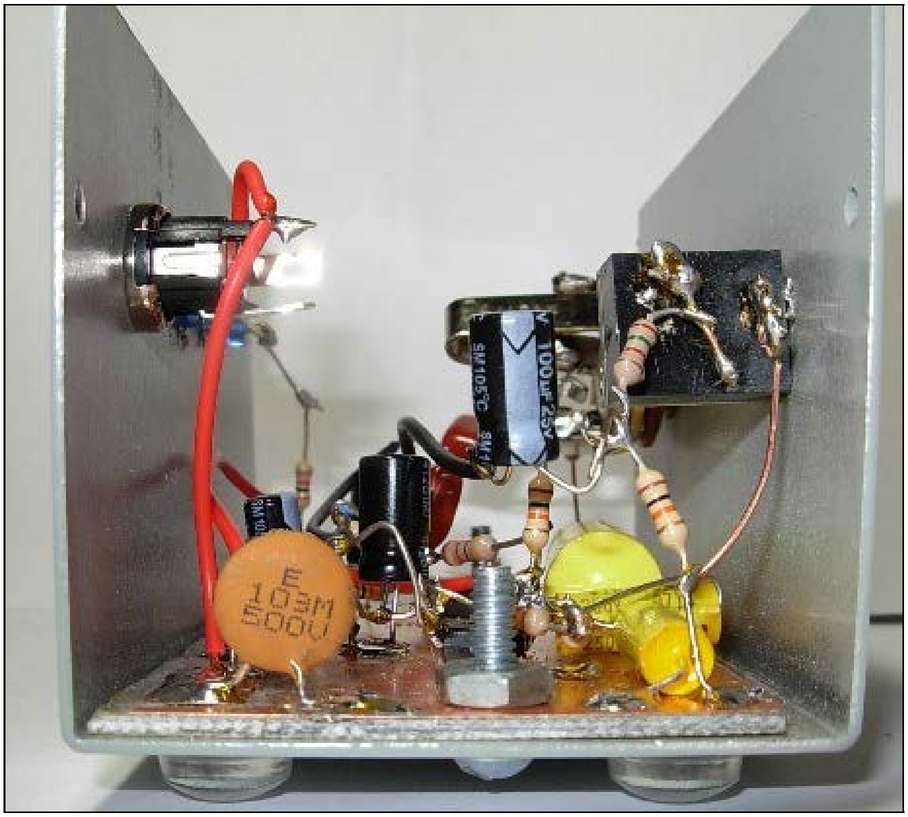

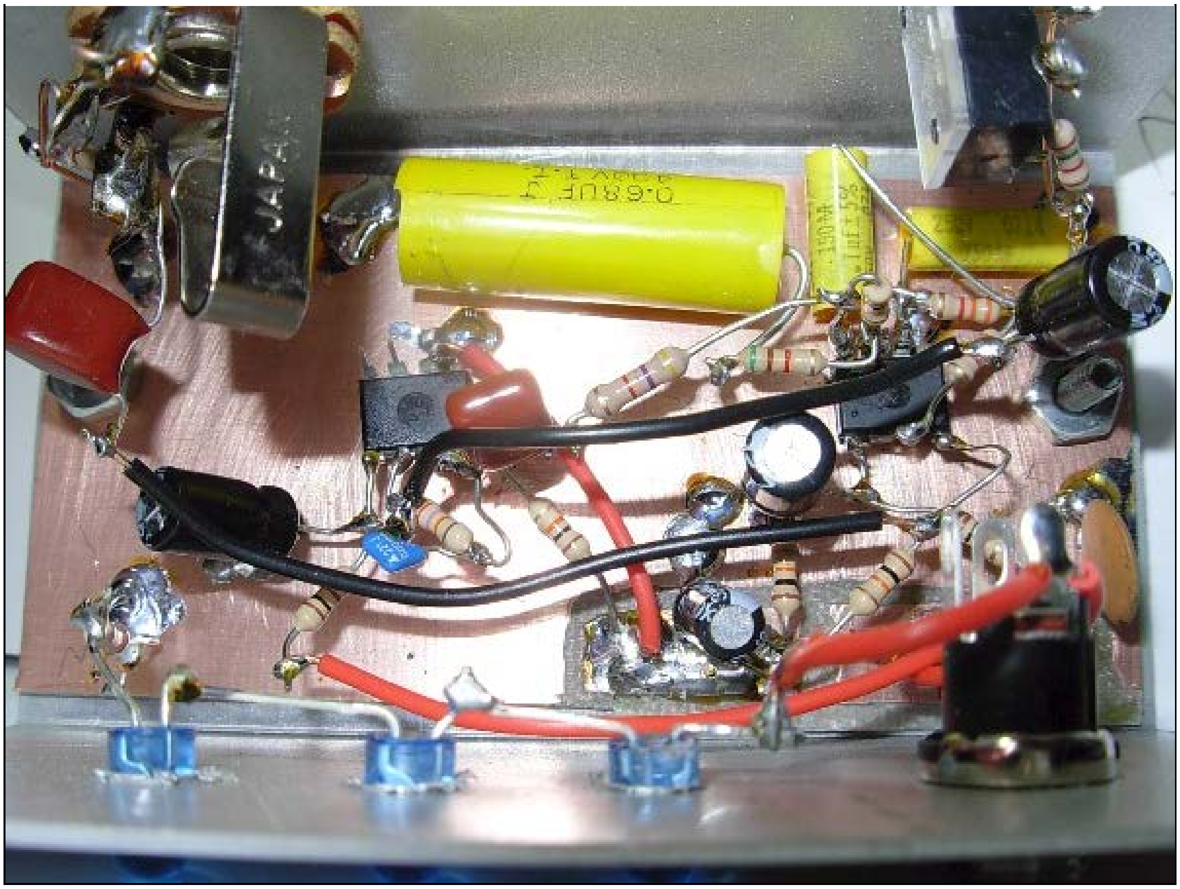

Above is the filter photographed from above. The 3 blue LEDs are used to light the lower row of buttons on the R75 as it is difficult to see them with a low level of light in the radio shack. No hum is heard with this filter. When you build AF amps or filters with the 5532, after soldering pin 4 to the copper ground plane, start out by connecting the components associated with pins 6 and 7 and then 1 and 2. I suggest this as placing components between adjacent pins is often the most difficult part of building when using ugly construction with op amps.
If by accident you make an unintentional solder bridge between 2 adjacent pins on an op amp, simply heat the 2 bridged pins up and gently drive a small screw driver between the pins. This should remove your unwanted solder bridge. The 5532 op amp is quiet and relatively inexpensive. In EMRFD, there are countless examples of how one can use them in a variety of applications.

Additional Information and Photographs

Above is a photo of the audio filter in action on the NDB band. The blue LED reflection can be seen on the receiver. For serious NDB and CW pile up work, narrow band pass audio filters are generally required. This simple audio filter experiment might be useful as a spring board for your own AF filter experiments and to learn the filter requirements of your own particular receiver.

Above is the filter photographed from the rear. The DC power cord has a built in RFI filter. For homebuilt projects, DC power cords can be obtain by cutting the power cord off old unwanted or broken "wall wart" power supplies. This provides you with a nice cord with a built-in plug. I collect old AC "wall wart" transformers for this purpose. This filter is powered by the main 12 volt DC supply on my radio bench.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

Cascode Hybrid-Based WWV Receiver for 5 MHz

Introduction

This was my favorite project of 2007. When I web published the original TRF WWV receiver for 10 MHz in 2006, there were many complaints that I used hard-to-find dual-gate MOSFETs and also that the AF stage lacked the popcorn factor that this web site has become strongly associated with. In this experimental project, these 2 concerns are addressed.

The cascode JFET and BJT amplifier stage used in this receiver is based upon the amplifer described in the Hybrid Cascode IF Amplifier article which was published in QST for December 2007 and designed by W7ZOI and WA7MLH. This amplifier topology has many advantages including high gain + low noise, that it can function well at DC voltages less than 12 VDC and that the noise figure does not degrade when the BJT bias (and stage gain) is lowered during AGC action. Please read the QST article and also refer to the W7ZOI web site for more details on the IF amplifier and the cascode hybrid topology.

RF GAIN
Volume

Receiver Block Diagram

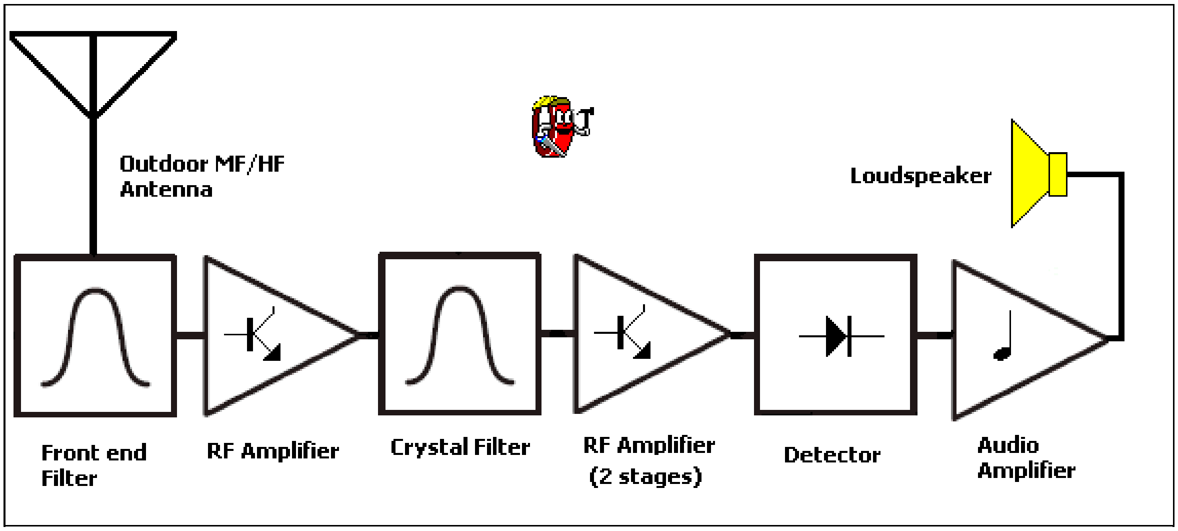
Outdoor MF/HF Antenna
Loudspeaker
Front end Filter
RF Amplifier
Crystal Filter
RF Amplifier (2 stages)
Detector
Audio Amplifier

The receiver block diagram is shown above. To hear digitally recorded examples of this receiver, click here , here or here. No attempt was made to make these files sound better than they really are- there is signal fading, room noise etc. A electret microphone was placed near the loud speaker to record these audio samples. *Note I am now compressing audio files in the mp3 format to allow listening by those who use Linux as their operating system.* **A supplemental web page** to this main web page is linked here

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Receiver Front End: Band Pass Filter and First RF Amplifier

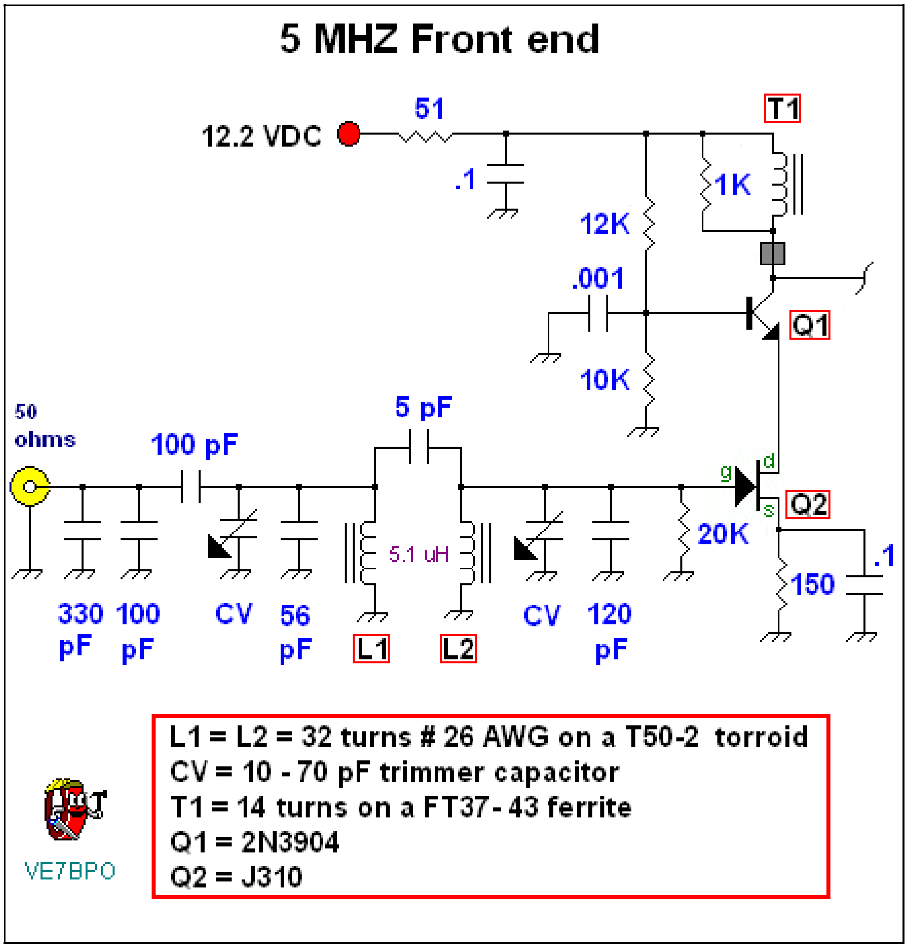
5 MHZ Front end
12.2 VDC
51
.1
12K
1K
T1
.001
Q1
10K
5 pF
50 ohms
100 pF
g
d
s
Q2
20K
.1
150
5.1 uH
330 pF
100 pF
CV
56 pF
L1
L2
CV
120 pF
L1 = L2 = 32 turns # 26 AWG on a T50-2 torroid
CV = 10 - 70 pF trimmer capacitor
T1 = 14 turns on a FT37- 43 ferrite
Q1 = 2N3904
Q2 = J310
VE7BPO

This receiver is meant to interface with a standard 50 ohm feed line. Testing was performed using my MF/HF antenna.
I built 3 separate bread boards of this receiver and tried varying the number of RF amps, using different detectors (as well as different detector followers) and eventually built and tested this basic receiver design for 5, 6 and 10 MHz. With respect to using the cascode hybrid amp (and probably any other amplifier type) **in a TRF receiver**, I learned 3 things:

1. Do not operate the RF amps at maximum gain. I built some very powerful amps with a Q2 source resistor of 47 ohms and over 6 volts bias on Q1. While powerful, this amp broke into oscillation and also consumed much current (nearly 20 ma).

2. Keep the RF stages at least 2-3 cm apart to reduce the chance of parasitic oscillations.

3. Keep the input band pass filter at least 2 cm from the Q1/Q2 amp or you might encounter some unwanted oscillations.

For the front end band pass filter, a reasonably narrow bandwidth was desired. When sweeping early filter designs using a signal generator and oscilloscope, a double humped response was noted. These filter designs used a 10 pF coupling capacitor. The coupling capacitor was then decreased to 5 pF. To obtain the required 5 pF, two 10 pF capacitors were placed in series as shown in the photograph directly to the right.

I struggled with this filter design because one end is terminated in the gate resistance of Q2 of the hybrid cascode amplifier and was not the standard 50 ohm impedance termination. My early filter designs suffered severe insertion loss or poor selectivity. I asked Wes, W7ZOI, for some instruction on solving my filter problems. I learned that this filter topology is referred to as a singly terminated, double tuned band pass filter. Wes designed the front end band pass filter for the 5 MHz receiver for us all to learn from and for this I am very grateful to him.

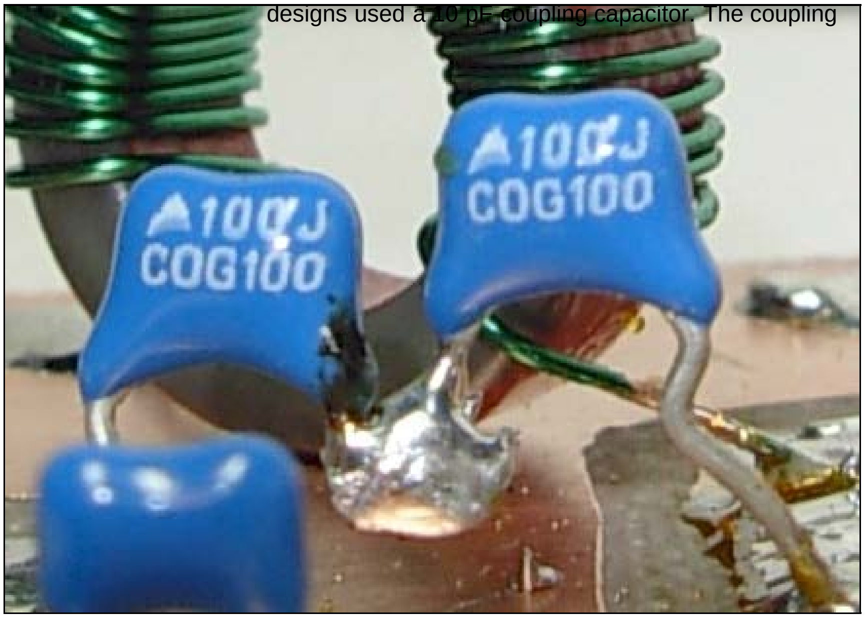
A100J
COG100
A100J
COG100

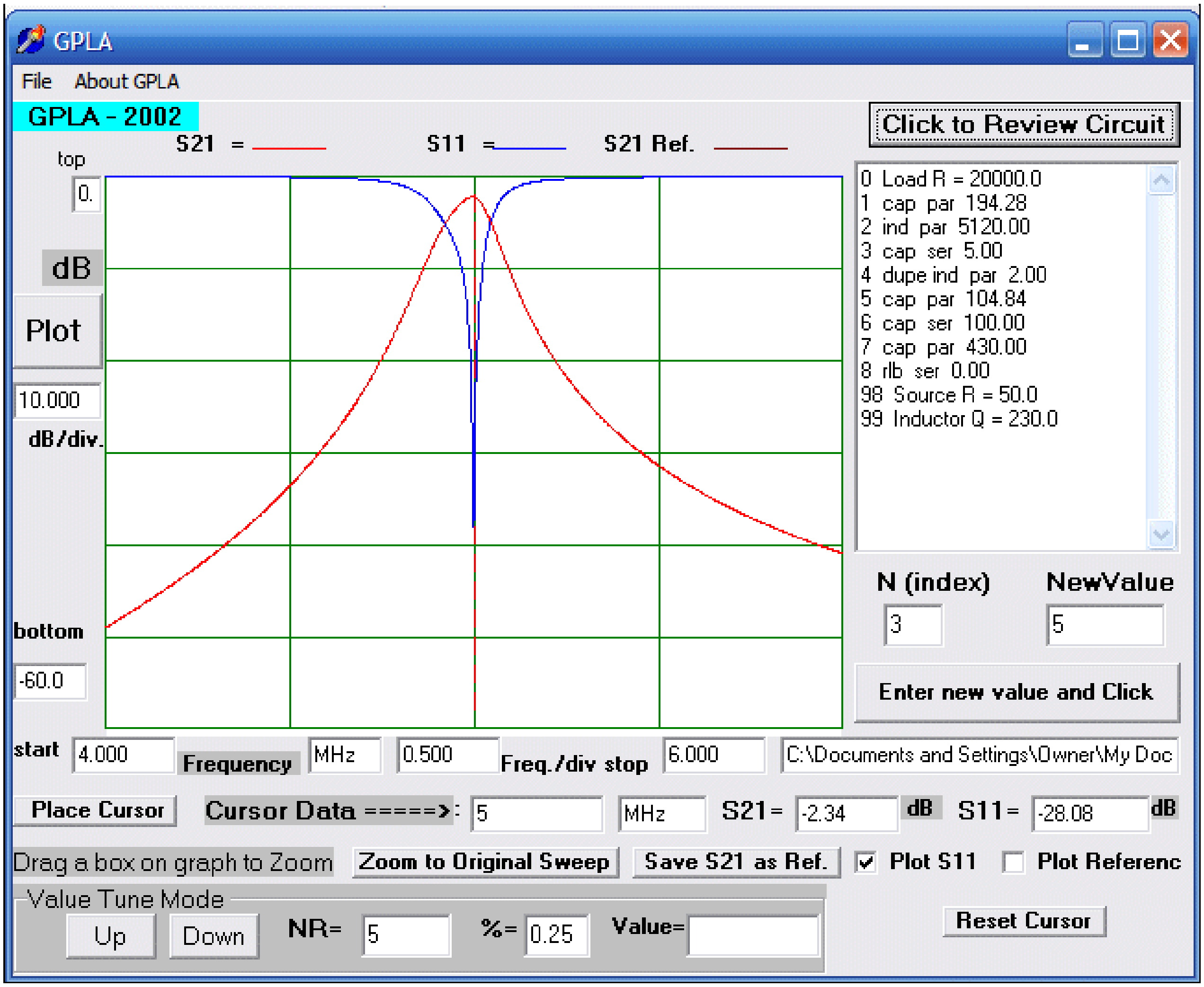
GPLA
File
About GPLA
GPLA - 2002
S21 =
S11 =
S21 Ref.
Click to Review Circuit
dB
Plot
Place Cursor
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Value Tune Mode
Up
Down
Enter new value and Click
Reset Cursor

0 Load R = 20000.0
1 cap par 194.28
2 ind par 5120.00
3 cap ser 5.00
4 dupe ind par 2.00
5 cap par 104.84
6 cap ser 100.00
7 cap par 430.00
8 rlb ser 0.00
98 Source R = 50.0
99 Inductor Q = 230.0

top 0.
10.000 dB/div.
bottom -60.0
start 4.000 Frequency MHz 0.500 Freq./div stop 6.000 C:\Documents and Settings\Owner\My Doc
Cursor Data =====>: 5 MHz S21= -2.34 dB S11= -28.08 dB
☑ Plot S11 ☐ Plot Referenc
N (index) 3
NewValue 5
NR= 5 %= 0.25 Value=

Above. A GPLA simulation of the singly terminated, double tuned filter designed by W7ZOI. A double tuned circuit is mandatory ahead of the WWV receiver as local BCB and other RF energy will be amplified by the first RF amp and may distort the WWV signal in the crystal filter or even might blow-by the crystal filter and be detected and heard in the speaker.

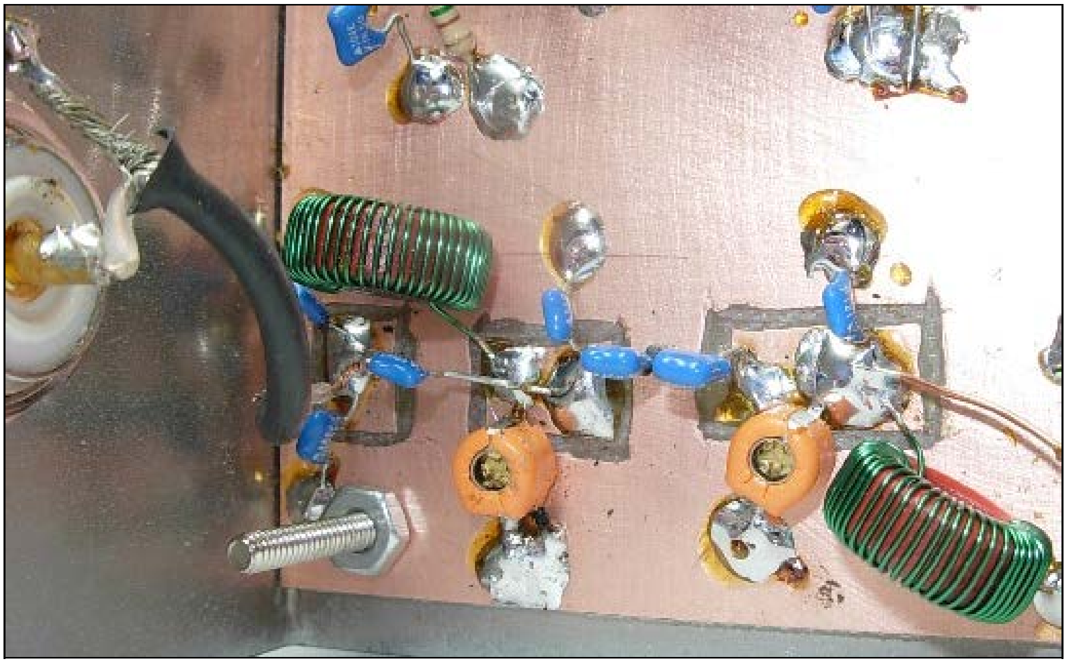

Directly above is a close up photograph of the input filter bread board. Filter tuning was done by ear (and screwdriver!) Simply tune the trimmer capacitors for the loudest audible WWV pulses in the speaker and you are set. If you can't locate a 20K gate resistor for Q2, a 22K resistor will work okay.

Crystal Filter and Second RF Amplifier Stage

In the schematic to the right is the crystal filter and second RF amplifier. The input impedance of the crystal filter is established by the 1K shunt resistor across the output transformer on Q1. The output impedance of the crystal filter is set by the 1K gate resistor of Q4. A filter input/output Z of 1000 ohms gave the best overall shape and bandwidth during my testing.

Developing this filter was difficult. My first batch of junk box crystals had a low motional inductance and with the filter I built I could hear stations ~400 KHz below and/or above the filter center frequency in addition to WWV. After giving up in frustration for nearly 2 months, a batch of 10 crystals were ordered from Digi-Key. These were microprocessor crystals; ones with 18 pF load capacitance in a HC49/U holder. The new filter was tweaked and tested and now provides single signal reception of WWV. Your own results may vary according to your crystal parameters. The Digi-Key part number is provided for reference purposes only.

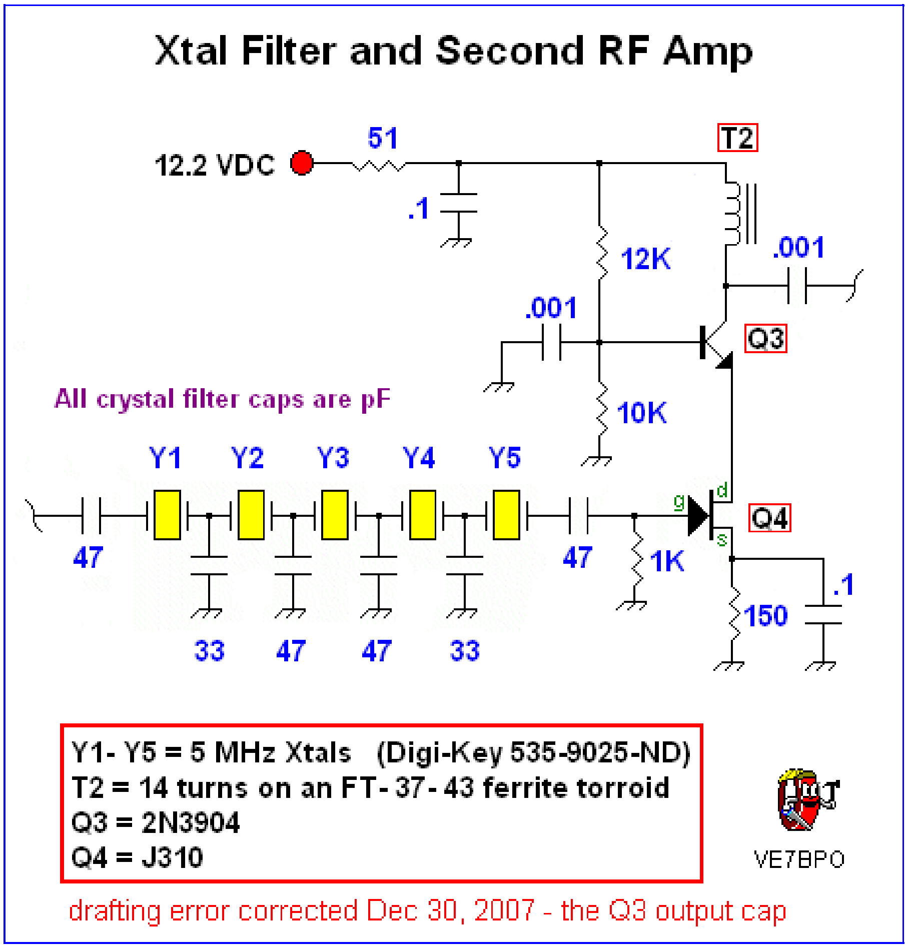
Xtal Filter and Second RF Amp

Y1- Y5 = 5 MHz Xtals (Digi-Key 535-9025-ND)
T2 = 14 turns on an FT- 37 - 43 ferrite torroid
Q3 = 2N3904
Q4 = J310

drafting error corrected Dec 30, 2007 - the Q3 output cap

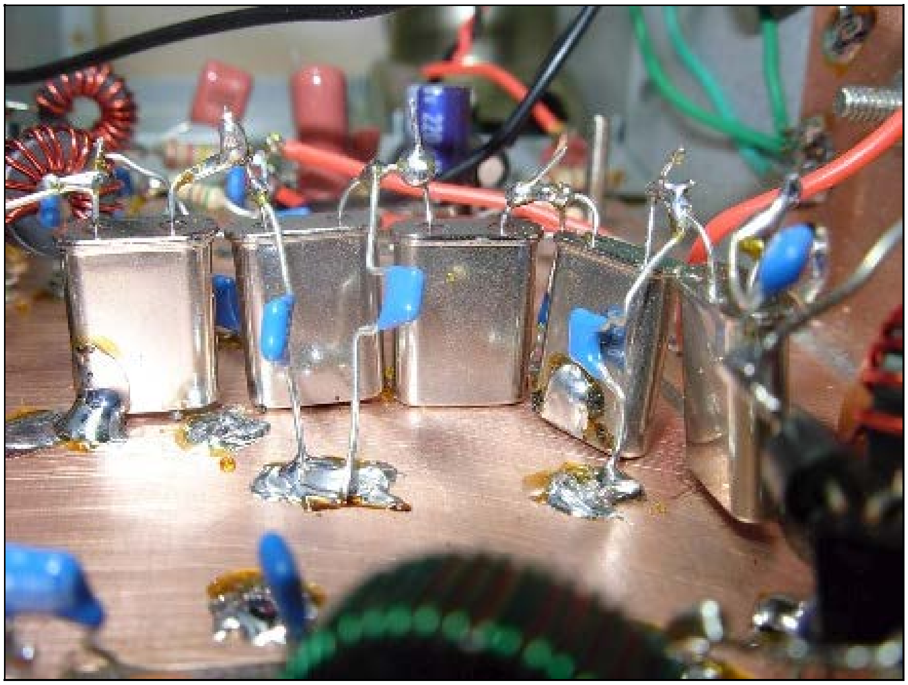

To the left is a close up photograph of the 5 MHz crystal filter. The crystals were turned upside down and the outer cases were directly soldered to the copper ground plane as you can easily see in the crystal to the left of the others. The rest of the crystals as well as one of the 47 pF tuning capacitors were soldered on the other side and solder points are hidden from view. The crystals were positioned to keep the output of Q1 away from the input of Q4. ***Stage lay out is very important in TRF receivers.*** I found stage layout to be far more important than keeping lead lengths short from my experimentation.

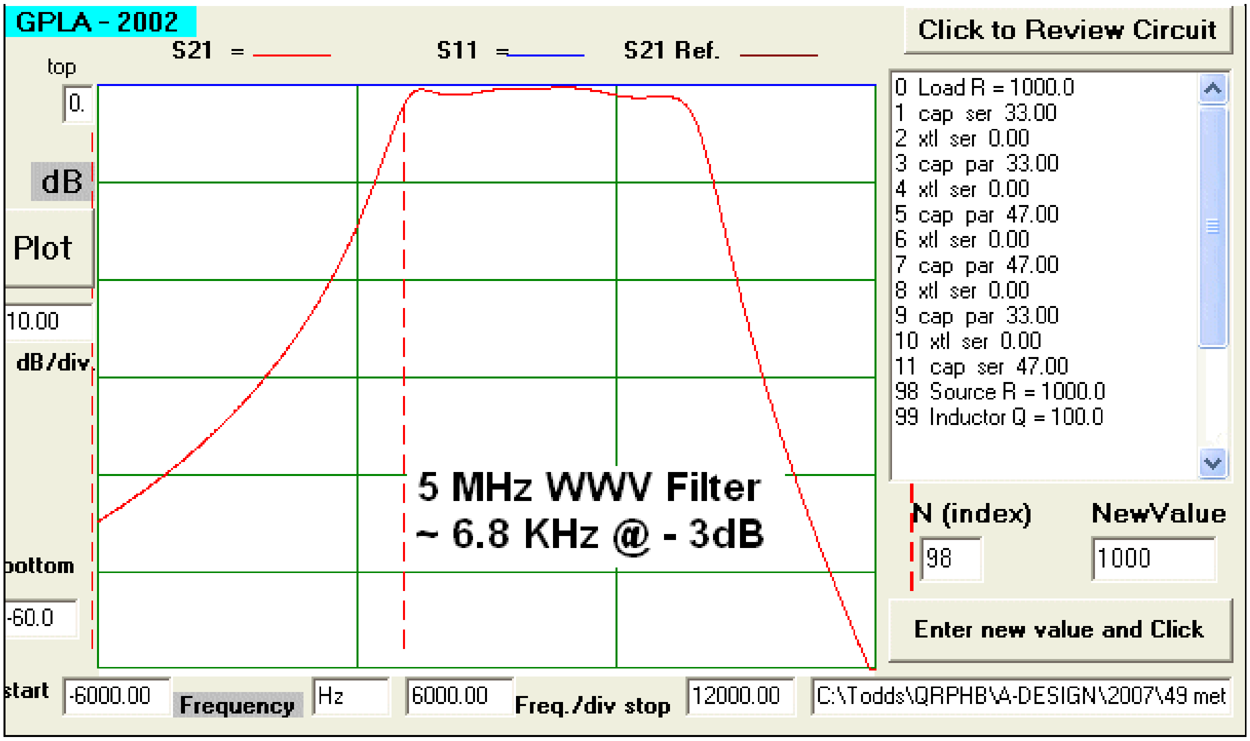

0 Load R = 1000.0
1 cap ser 33.00
2 xtl ser 0.00
3 cap par 33.00
4 xtl ser 0.00
5 cap par 47.00
6 xtl ser 0.00
7 cap par 47.00
8 xtl ser 0.00
9 cap par 33.00
10 xtl ser 0.00
11 cap ser 47.00
98 Source R = 1000.0
99 Inductor Q = 100.0

top 0.
10.00 dB/div
bottom -60.0
start -6000.00 Frequency Hz
6000.00 Freq./div
stop 12000.00
C:\Todds\QRPHB\A-DESIGN\2007\49 met
N (index) 98
NewValue 1000

Directly above is the GPLA simulation of my crystal filter. The 5 MHz point is not centered exactly in the middle of the pass band, but a reasonable AM filter was built nonetheless. Crystal parameters, especially motional inductance and capacitance can make or break your filter. Motional inductance and capacitance describe the L and C values that make up the crystal's electrical LC model. Very large inductive and capacitive reactance values at the specified operating frequency give the crystal its extraordinarily high "quality factor" or "Q". For example, If the motional L is too low, your filter may not work as expected; providing single signal reception of WWV. The Lm was 0.02 and the Cp was 5 in the crystals which I used for my filter. In general, low Q crystals will give poor results. Oppositely, crystals with very high Q may give a lower then expected bandwidth and this may reduce AM receive fidelity. Experimentation is necessary.

Third RF Amplifier Stage and Detector

To the left is schematic of the final RF stage and the envelope detector. This RF stage has variable gain by means of a front-panel mounted 10K potentiometer which is used to vary the bias on Q5. The input Z of this stage is 100 K and is set by the Q6 gate resistor. The output of Q5 is AC coupled to a detector designed by Wes, W7ZOI. I performed considerable experimentation with basic diode detectors as well as detector source followers; some of which I sent to Wes for his consideration. He designed and emailed me back this simple, good sounding detector design which uses the gate voltage of Q7 to bias the germanium diode. Other types of diodes such as as hot carrier diodes will likely not have the output voltage of the Germanium type. Germanium diodes, when biased, had more noise and high frequency response in addition to higher output when compared to others I tried during my experiments. Diode detector guru, Felix, VK4FUQ advised me of an excellent diode he is now using called the BAT46. The audio samples of a local AM radio station using this diode and his other hi-fi lab equipment that he sent me are beyond fantastic.

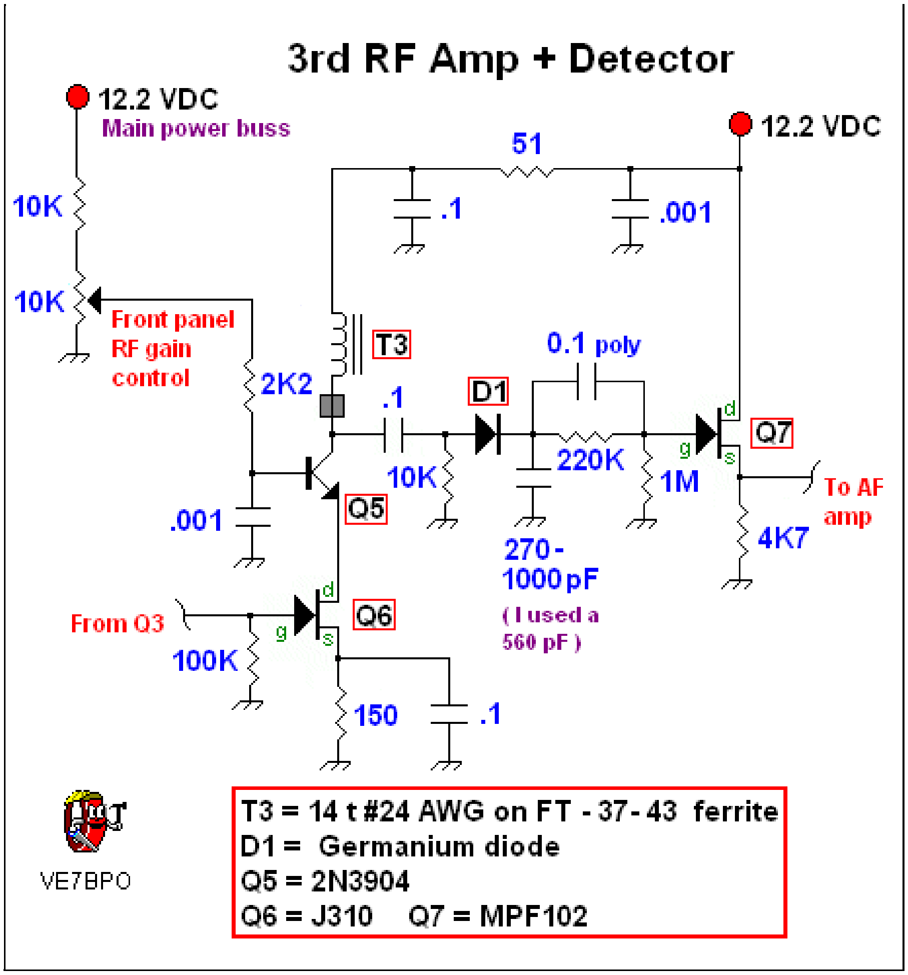
3rd RF Amp + Detector
12.2 VDC
Main power buss
12.2 VDC
51
.1
.001
10K
10K
Front panel
RF gain
control
2K2
T3
0.1 poly
D1
.1
Q7
d
g
s
220K
10K
1M
To AF
amp
.001
Q5
4K7
270 -
1000 pF
(I used a
560 pF)
From Q3
d
Q6
g
s
100K
150
.1
T3 = 14 t #24 AWG on FT - 37 - 43 ferrite
D1 = Germanium diode
Q5 = 2N3904
Q6 = J310 Q7 = MPF102
VE7BPO

The photograph on the right is a close up of the enveloped detector designed by W7ZOI. The germanium diode was purchased from The Source in Canada (Radio Shack in the USA). The blue, partially hidden shunt capacitor is a multi-layer ceramic 560 pF cap. The other capacitors are metalized, polyester film types. Ensure correct diode polarity.

Audio Stage

To the left is the schematic of the audio stage. The very "popcorn" LM386 AF chip is used to please the audience who complained about my AF stages not having enough popcorn factor. A 4K7 resistor was inserted between pins 1 and 8 to reduce the gain somewhat. Thus, the LM386 is still being operated in the high gain mode but won't hurt your ears with loud noise and distortion. The 470 pF cap on pin 3 may be changed or eliminated. It is a simple low pass filter.

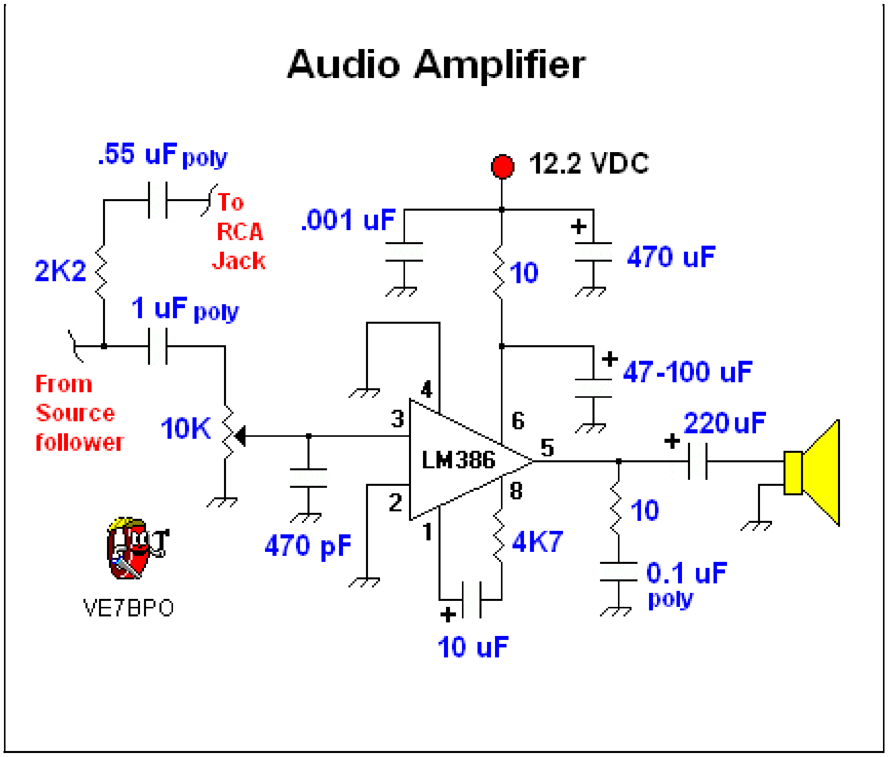

A secondary, audio output connects to a front panel mounted RCA phono jack. This allows me to use my lab grade ([KK7B AF amp]) and turn the audio off on the normal receiver AF amp.

The photograph to the right is a close up of the LM386-based audio stage. This is where I started. After drilling the chassis, wiring the speaker, installing the chassis potentiometers, making the main power buss and LED indicator, the AF stage was built on the main board. The main board was then temporarily soldered in and tested. (Some connections were made via alligator clips such as the speaker wires). When the AF amp worked as expected, the main board was removed from the receiver chassis and the net stage was built. Up next were the detector and source follower. After bread boarding these, again the main board was laid in the chassis, wired, tested and then removed when all was functioning well. To test the detector I touched my finger to the input and heard local BCB radio. Following this, RF Amp #3 was added to the main board and again the main board was temporarily wired up and tested by touching the input of Q6 with my finger and observing that a local broadcast radio station increased/decreased in amplitude when the RF gain control was turned up and down. DC voltages were also measured and considered from project start to finish.

Actually, all you need to do is connect a band pass filter such [as this] to Q6 and the components after and you will have a nice TRF BCB AM radio. Each successive stage was built and tested, so when the receiver was finished, I already knew that it worked. I cannot emphasize enough how important it is to build your receiver backwards and test each stage as you go. There is strong temptation to start at the antenna connection and work until you get to the speaker, but please consider doing the opposite.

The bare copper wire in the photograph is the positive connection point for the speaker wire. It was trimmed somewhat during final assembly to reduce the possibility of it shorting.

Miscellaneous Photographs

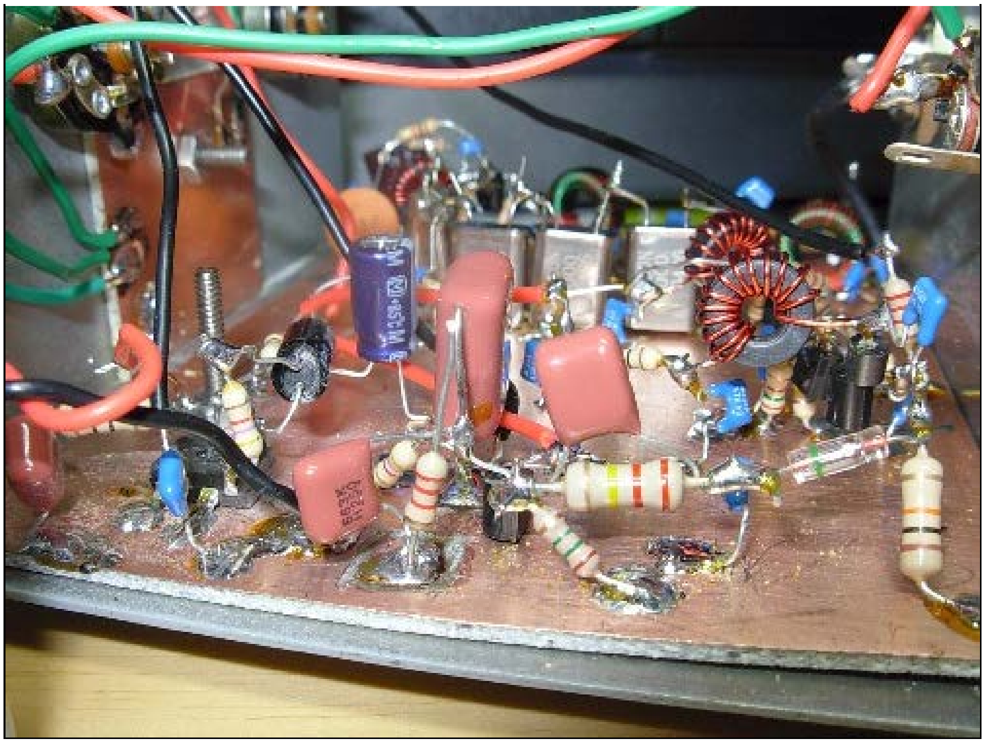

The photograph above shows some of the detail of the receiver main board from the right hand side which contains the detector, source follower and audio amp stages from right to left.

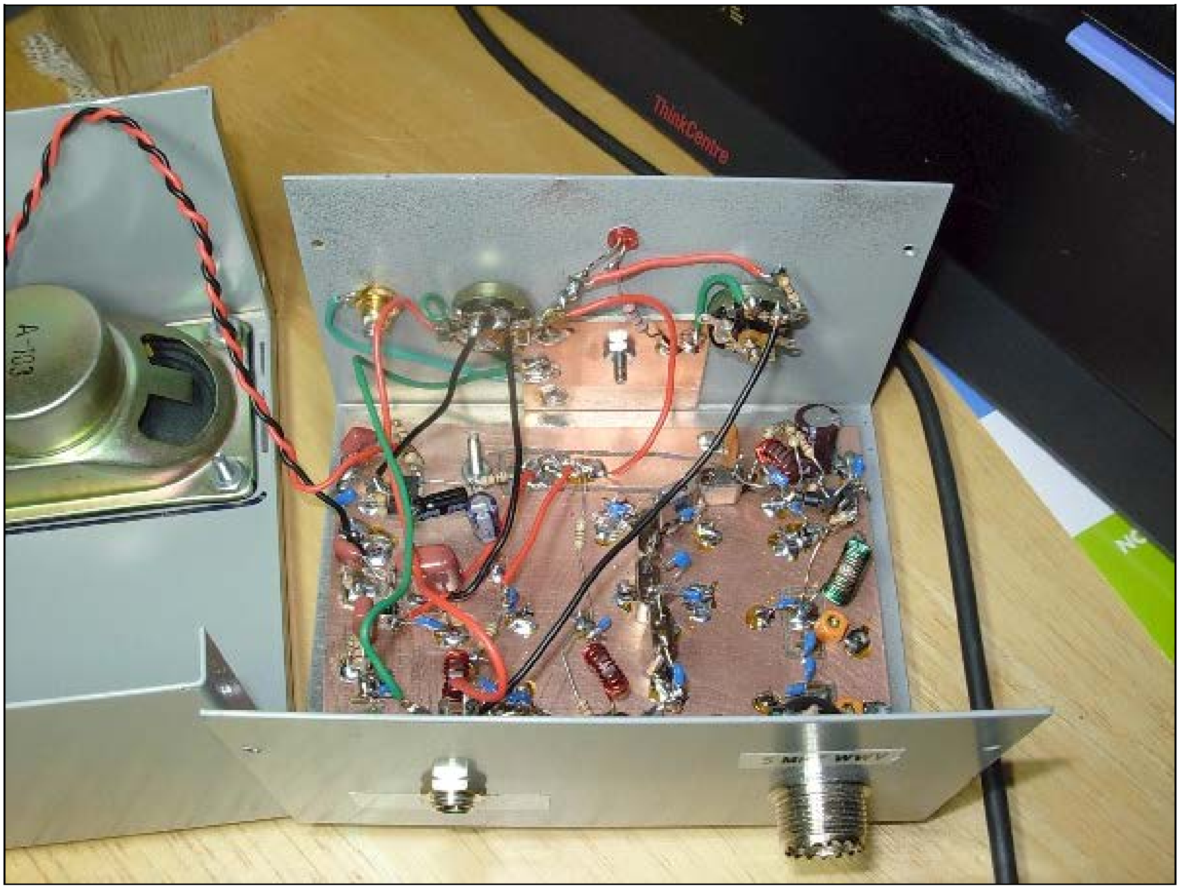

The photograph above shows a top view of the main chassis and also the chassis cover with the speaker bolted on and wired up.

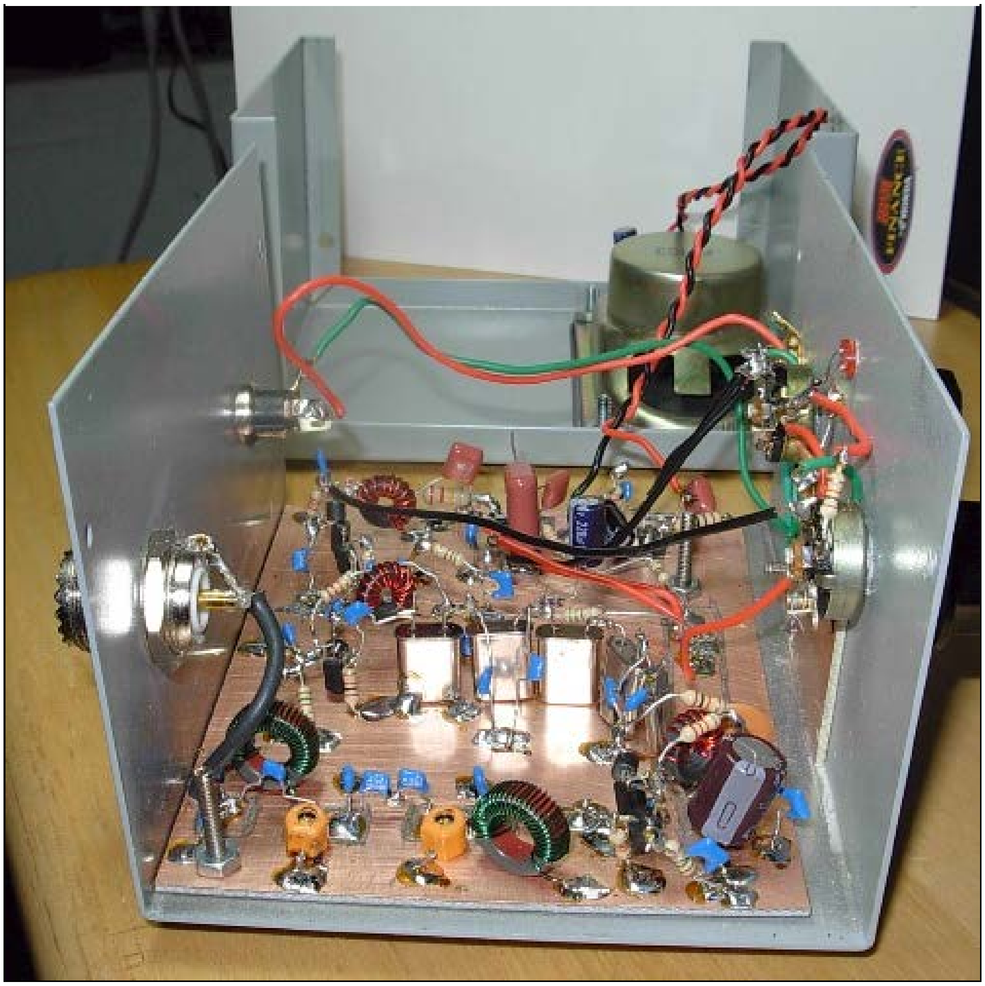

This wider angle photograph shows the main board from the left side. From left to right in the nearground are the SO-239 antenna connector, LC band pass filter and first RF amplifier.

The photograph above shows the speaker attached to the Hammond chassis top. Holes were drilled in the chassis lid with a drill press to allow the sound to pass through.

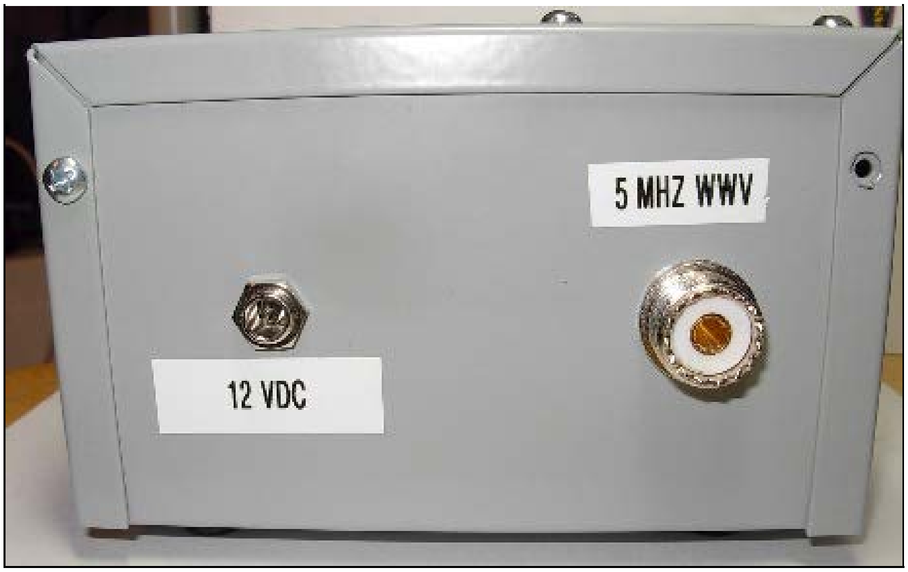
5 MHZ WWV
12 VDC

The photograph above shows the reverse view of the receiver chassis.

Complementary-Symmetry Amplifier Biasing Basics

Introduction

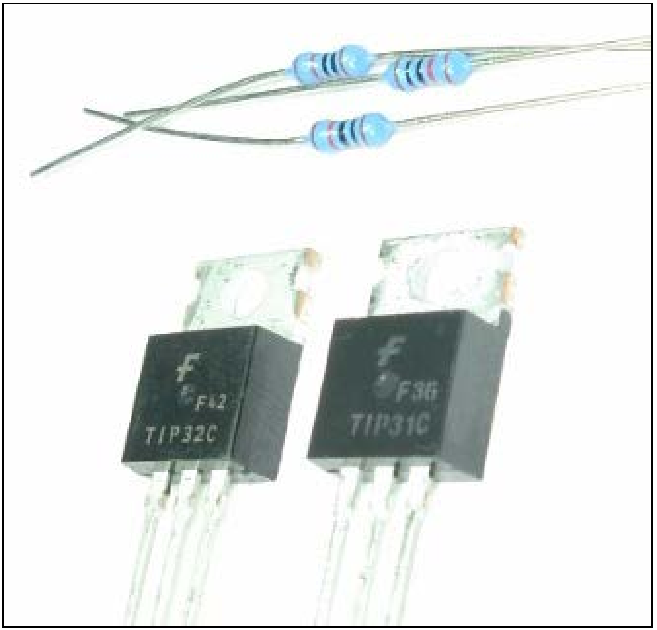

This page provides information concerning the biasing of Class-AB, complementary-symmetry audio amplifiers. These schematics should be considered theoretical, as design considerations such as thermal stability, negative feedback and component power ratings are minimized or excluded for sake of clarity.

The basic 2 transistor complementary-symmetry amplifier may be used as a simple low power AF amp or as a building block for a high powered stage such as a 50 watt guitar amplifier. It is important to understand how to properly bias your AF power amps to reduce distortion and to promote easy troubleshooting when problems arise. This web page describes the hows and whys of biasing in a progressive manner with minimal math.

Discussion

Figure 1

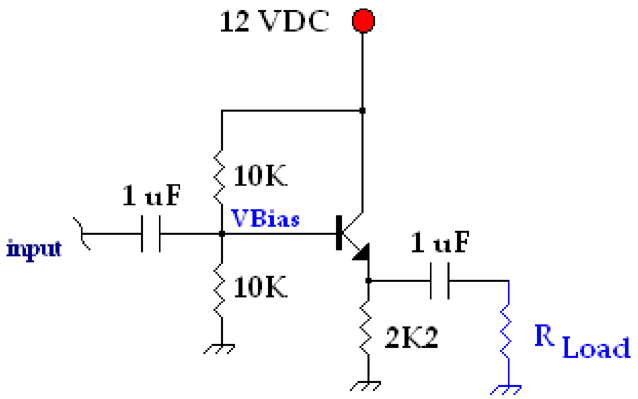

A review of the common collector amplifier (which is more commonly called the emitter follower) is a good place to start. We may refer to the complementary-symmetry transistor pair as complementary emitter followers since they are an NPN and PNP emitter follower connected in series. An emitter follower amp is shown in Figure 1. Its properties include:

- ✓ input on the base - output on the emitter
- ✓ high input impedance and low output impedance
- ✓ a voltage gain of 1
- ✓ good current and power gain

In an appropriate configuration, these qualities are perfect for driving a low impedance load such as an 8 ohm speaker with large output currents that are not provided by our typical transistor or op amp voltage amplifier stages. In many cases, we bias the emitter follower with a voltage divider network comprised of 2 identical value resistors. In Figure 1, the voltage divider consists of a series pair of 10K resistors and thus VBias = 6 volts. These 10K bias resistors will be used throughout this web page as the circuits evolve.

In Figure 2 is a pair of complementary emitter followers which have their bases biased with our now familiar series connected 10K bias network for a VBias of 6 volts. When the power is turned on, output capacitor C2 charges through the NPN transistor until it reaches about 6 volts *(theoretical value used to keep things simple)*. When the voltage at point V Emitter reaches 6 volts, the NPN transistor goes into cutoff because VBias voltage now equals the V emitter voltage. Recall that the NPN transistor base must be positive with respect to the emitter for current to flow. Both the NPN and the PNP transistor are in cutoff. This is the amplifier's quiescent state *(assuming no signal is applied to the input via C1)* and is called Class B bias.

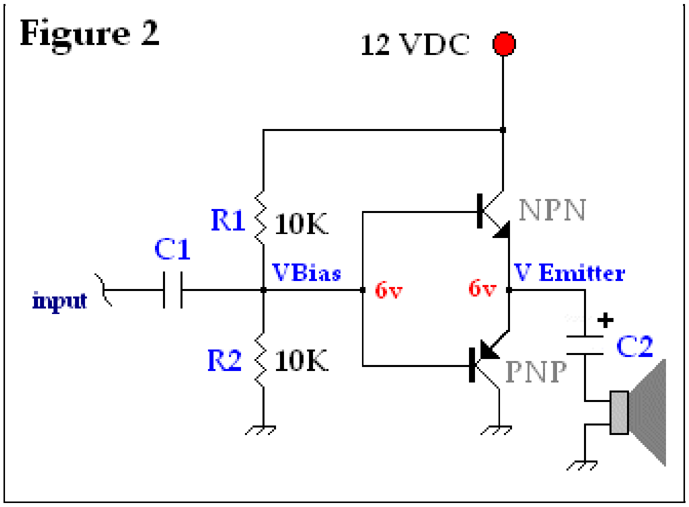

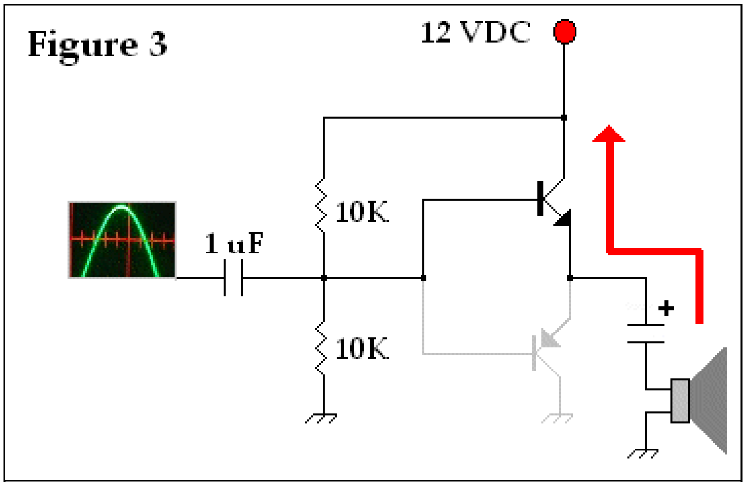

In Figure 3, a positive going signal is applied to the input capacitor. The NPN transistor becomes forward biased and turns ON. Current flows **through the NPN transistor** and charges capacitor C2 to a higher potential. The PNP transistor stays in cut off. The NPN transistor is an emitter follower connected to the speaker.

In Figure 4 a negative going signal the (negative half-cycle) is applied to the input. Q3 turns ON and discharges the output capacitor through the speaker as shown in **red.** The PNP transistor is an emitter follower connected to the speaker.

Thus the NPN and the PNP transistor conduct on alternate half cycles which causes AC current to flow through the speaker. The complementary emitter followers are said to be in push-pull operation.

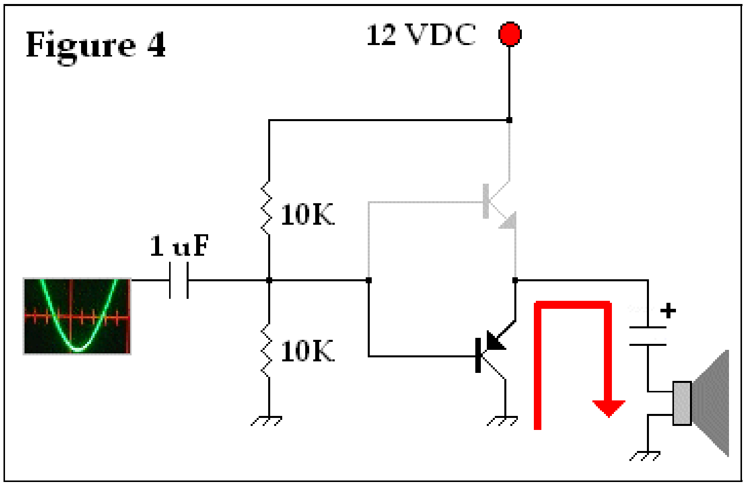

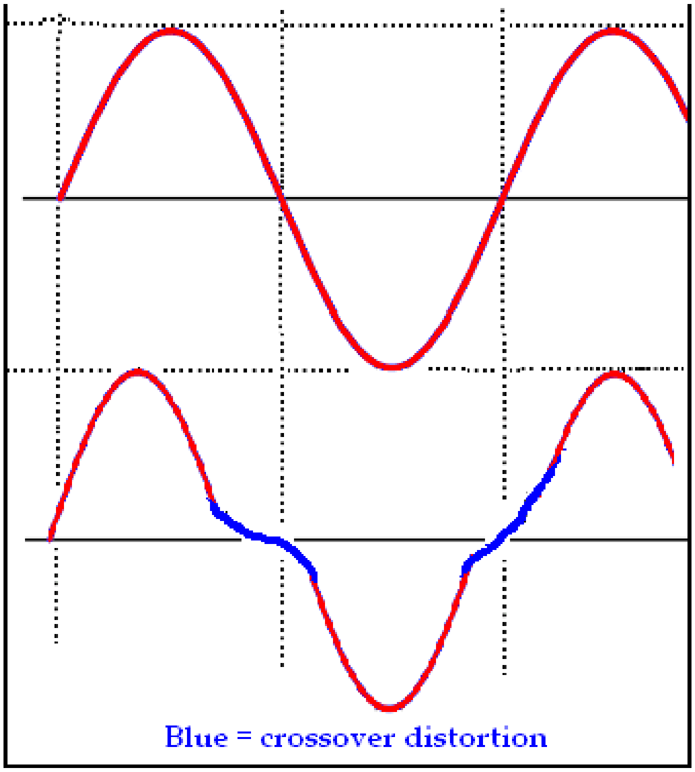

The circuit of Figure 2 has a significant problem; output signal distortion. Silicon transistors such as the 2N3904 and 2N3906 will not conduct until their bases are forward biased by somewhere around 0.7 volts. For the NPN transistor, this means that it will not conduct until the input signal has gone positive by about 0.7 volts. Oppositely, the PNP transistor will remain in cut off until the input signal goes negative by approximately 0.7 volts. As a result, there is a dead zone during the point in time when one transistor cuts OFF and the other turns ON. Shown above is a normal sinusoidal AC waveform in red and another with the distorted waveform of Figure 2 in red and blue. This distortion is called crossover distortion because it occurs at the zero crossing point of the AC waveform. This introduces odd-order harmonics into the output signal. Such is the drawback of the Class B amplifier.

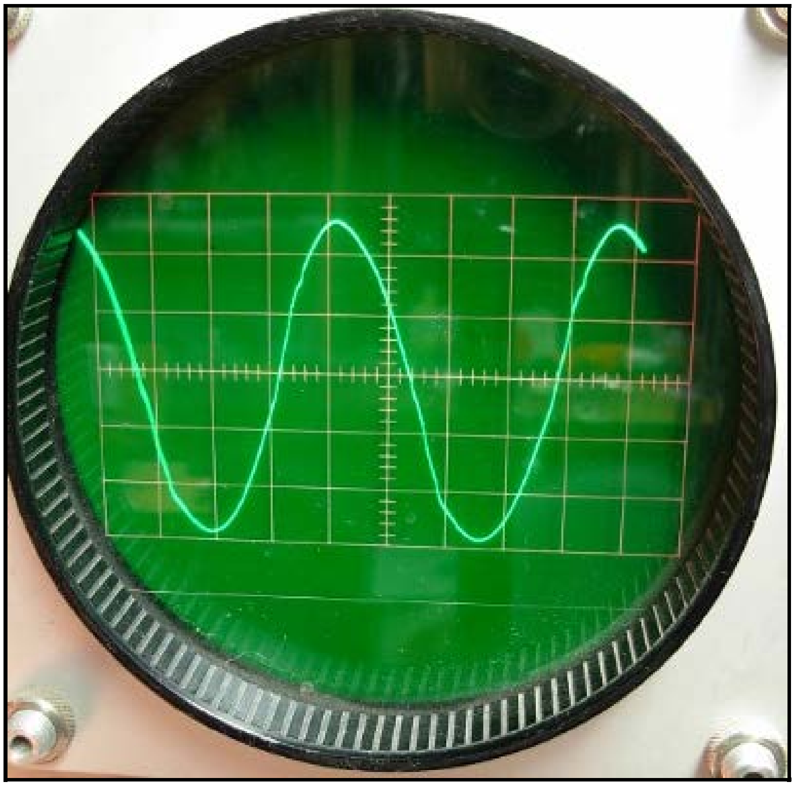

The above photograph shows crossover distortion in an under-biased power amp.

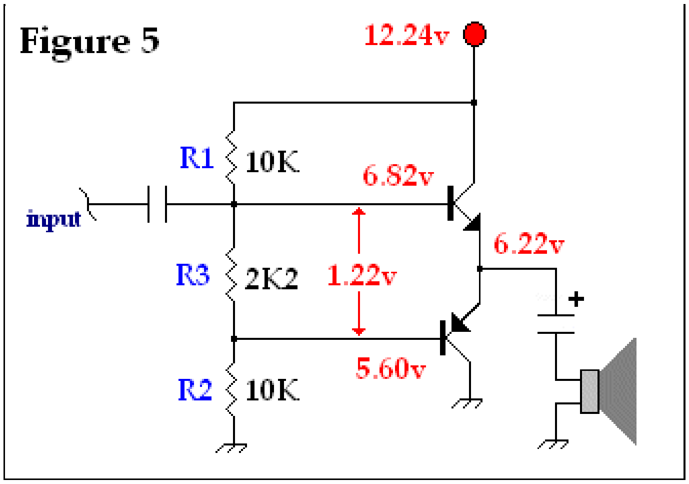
Figure 5

Figure 5 shows the principle technique used to reduce crossover distortion; both transistors are (slightly) forward biased almost to conduction in their quiescent state. As a result, any amplitude of positive or negative going signal will bias the appropriate transistor into conduction. An easy way to achieve this biasing is by adding 1 resistor to our 10K voltage divider network. In Figure 5 is a circuit I built, measured and listened to. R3, a 2K2 ohm resistor was placed in between R1 and R2, our usual 10K bias resistors. As a result , both transistors are forward biased.

That is: the base of the PNP transistor is negative with respect to its emitter and the the base of the NPN transistor is positive with respect to its emitter. As a rule of thumb, you need to drop at least 1 volt across R3. I chose a 2K2 resistor and it worked fine in my particular amp. The Figure 5 biasing topology is rarely used as it puts a series resistance on the PNP input among other problems; however, it exemplifies the basic principles of biasing our complimentary pair. With the forward bias on the transistor pair we now are in Class AB. The output capacitor serves to block the quiescent DC current from flowing through the speaker.

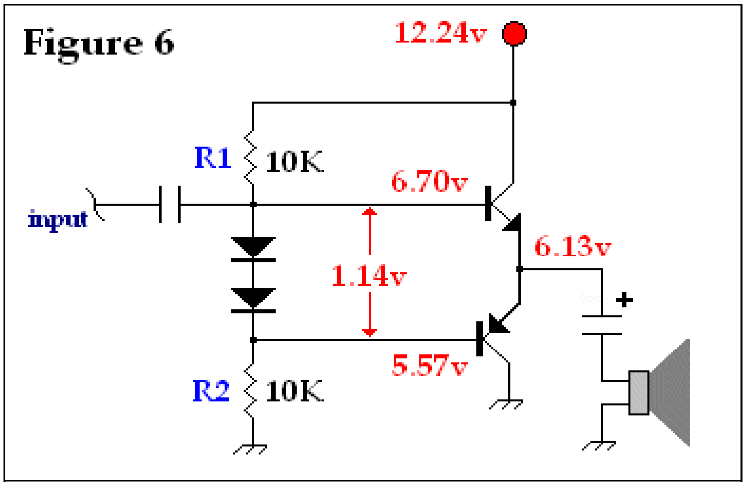
Figure 6

Figure 6 illustrates an improved biasing method over that of Figure 5 by using a pair of silicon diodes. You see this circuit used a lot by hobbyists. The voltage divider consists of 2 resistors and the 2 diodes. The 2 series connected diodes are connected in parallel to the NPN and PNP transistor base-emitter junctions which serves to keep the transistors turned on slightly. The net effect of the diode pair is the same as R3 in Figure 5. The voltage drop per diode was measured at 0.57 volts. The AC resistance of these 2 forward biased diodes is non-significant. There is major problem with the diode/resistor voltage divider; no way to adjust the diodes forward voltage drop. If each diode's forward threshold voltage is unequal to the base-emitter junction voltage of each transistor, either not enough forward bias is applied, or the 2 transistors may be turned on too much reducing efficiency and possibly cause excessive heating. Additionally, the pair of diodes lack the ability to provide temperature compensation when the transistors get hot.

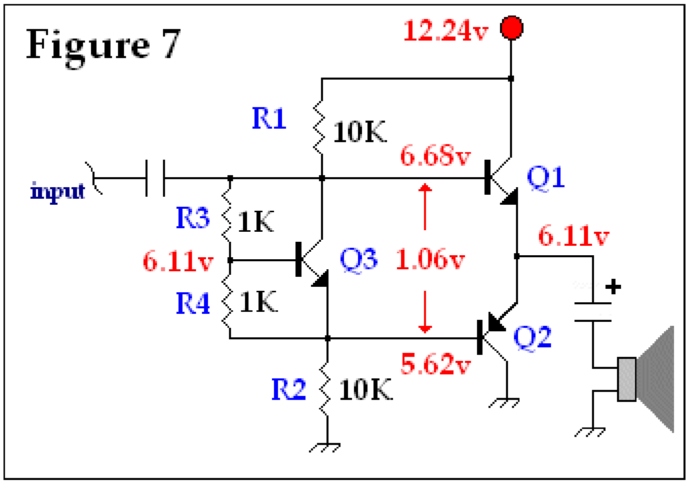
Figure 7

Figure 7 shows the best way to bias our complimentary pair. Our familiar 10K-10K voltage divider is kept, but a transistor Q3 with its own biasing resistors R3 and R4 are added. You might think of R3 and R4 as a voltage divider within a voltage divider. Q3 is referred to as an amplified diode or DC level shifter. It often receives local thermal feedback from the power follower output transistors. This usually involves mounting Q3 on the same heat sink as the finals. If the output transistors heat up, so does Q3 and this results in a a smaller voltage drop across Q3 which translates into less forward bias to Q1 and Q2. Within limits, Q3 with its own base-emitter junction provides variable forward bias for the output transistors.

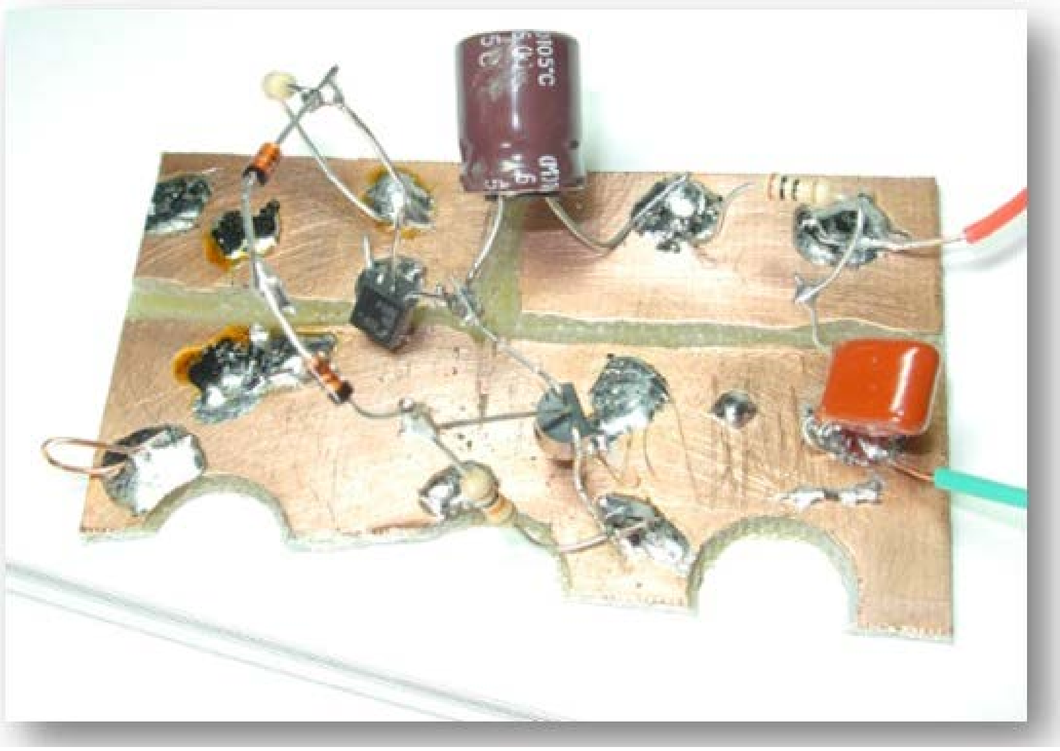

Shown above is the breadboard of the Figure 6 circuit built on scrap of copper clad board. Transistors were 2N3904 and 2N3906 types, diodes were 1N4148. The capacitor and resistor to the right were a low pass filter (10 ohm and 0.1 uF) to stabilize the output. The unseen speaker was connected to the red and green wires.

Figure 8

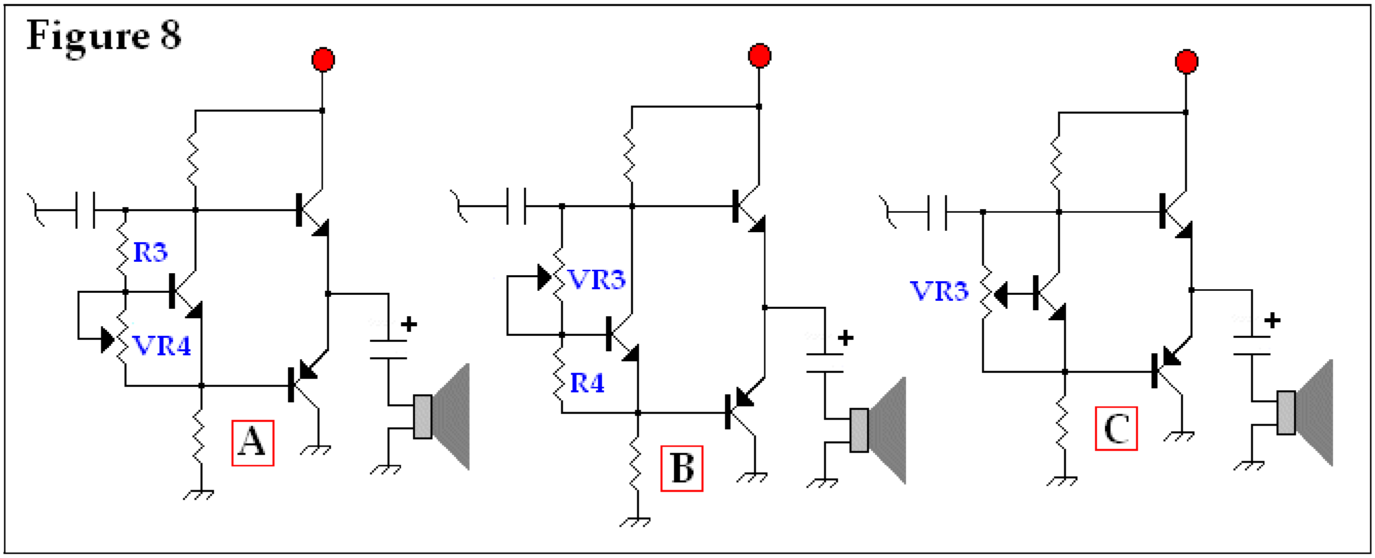

In practice, either R3 or R4 is often replaced with a trimmer potentiometer or a trimmer potentiometer is used instead of R3 and R4 and sometimes R3 and R4 are not of equal value. Shown above in Figure 8 are 3 variable bias topologies for Q3 that I have used. In some cases you will notice that the builder places a fixed value resistor or even a diode in series with the potentiometer in circuits like A or B. Using a potentiometer allows precise adjustment of the quiescent bias current and the ability to dial in the lowest crossover distortion possible. You can set the bias current using any combination of an oscilloscope and signal generator, a voltmeter, an ammeter or possibly try do it by ear when listening for and removing crossover distortion at low volume levels. The procedure I have read to adjust the bias by listening is as follows: Allow some low level signal through the amp so you can just hear it in the speaker. Turn the potentiometer from 1 extreme to another until crossover distortion is heard. Move the pot in the opposite direction until the crossover distortion disappears.
From my limited experience; in some amplifiers under 2 watts or so, you may not hear much of an audible change in crossover distortion when adjusting the bias control potentiometer, so the listening method is not useful in certain cases. It is worth mentioning, that crossover distortion sounds awful and you can usually hear it in amplifiers that are under biased.

Many builders just have a multimeter. In this case, measure the voltage drop across Q3 (the amplified diode) and ensure that is a least 1.1 volts and then slowly adjust the bias up or down from that point. Ultimately, you may have to just make the final bias setting by deciding what voltage drop across Q3 and/or what complementary pair quiescent current you want to establish. It is really not that difficult. *Whatever method you use,*

always re-check the Q3 voltage drop and amplifier bias current with no input signal to inform yourself of what is happening.
I am uncertain of the best method to measure the amplifier quiescent current, however I normally measure it using an ammeter connected in series with the emitter of the NPN transistor of the complementary pair.

Shown to the right and below are more images of what crossover distortion can look like in an under-biased power follower stage. The *right* output waveform also contains a little harmonic distortion, however that's a separate issue. I listened to this amp when connected to a speaker and music audio source; the audio had a noticeable "grungy" distorted sound. As mentioned, crossover distortion sounds terrible. The bias to the power followers (a complimentary pair of two 2N3906 and two 2N3904 transistors set up as Darlington emitter followers) was increased and the crossover distortion disappeared. A post bias adjustment audio listening test confirmed that the crossover distortion was gone.

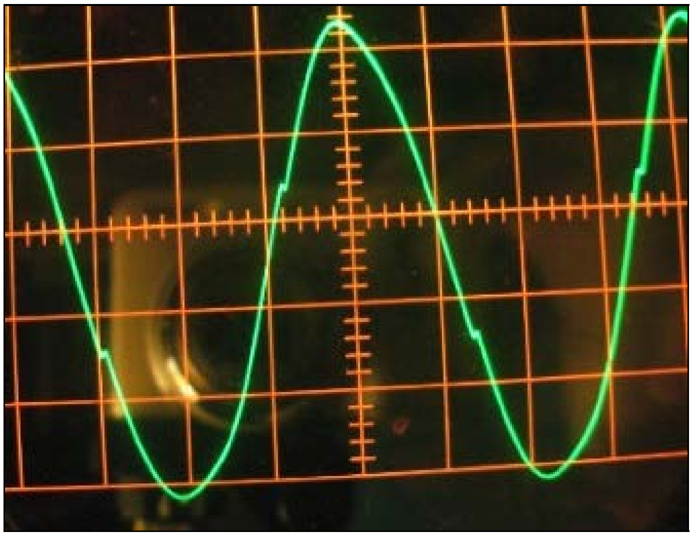

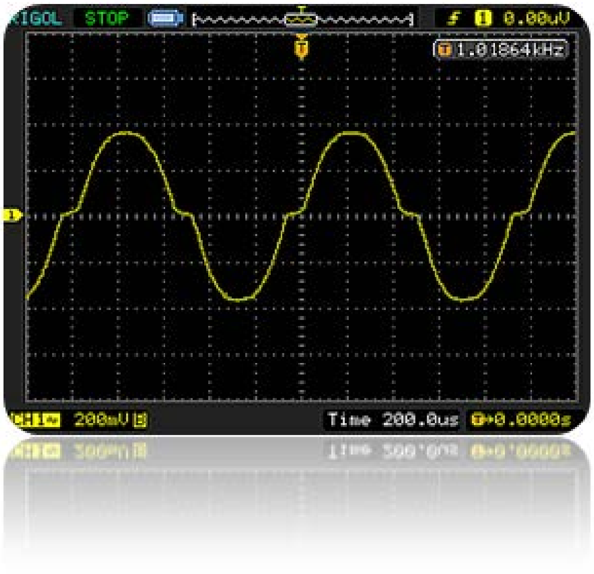

Click for a Russian language mp3 audio file. Vladimir (Volodya), a fellow builder in Ukraine, wanted an A - B comparison of Class AB versus Class B (cross-over distortion). In this audio file, I tweak a potentiometer biasing a pair of power followers to give contrast between the 2 amplifier classes. Under biased AF amps sound terrible in any language! The audio source was a cassette player. The speaker output was recorded, digitized and stuffed into the mp3 file.

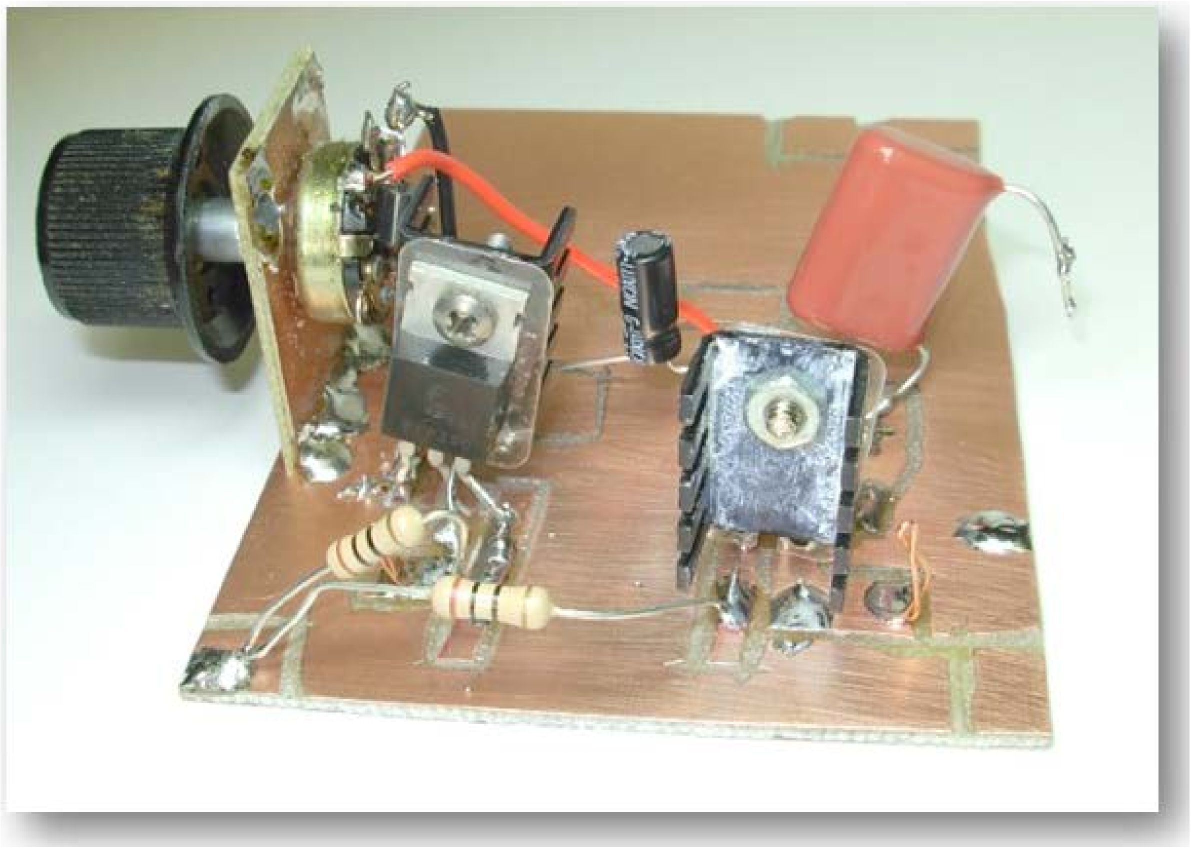

Shown above is a bread board of a complete amplifier utilizing a 10K pot to vary the bias on the amplified diode *(see Figure 8 c)*. With a 12.22 volt power supply, turning the potentiometer from one extreme to the other varied the current draw of the amplifier from about 0 to 95 mA. The average quiescent current draw of a properly biased **single complimentary pair** was somewhere between 5 and 10 mA in my bread boards.

Figure 9

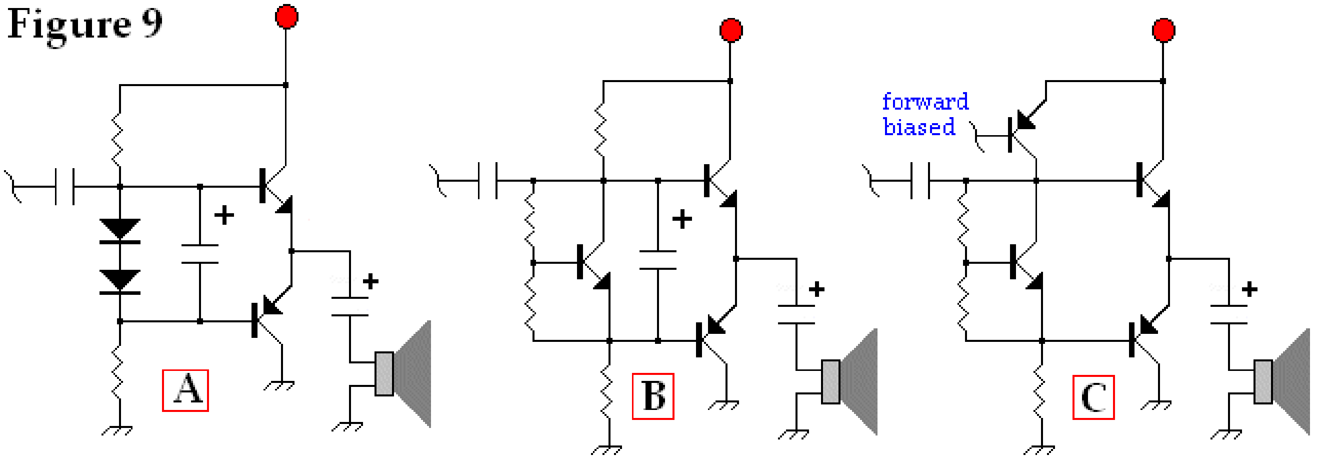

You may see a capacitor inserted between the output transistor bases as shown in Figure 9A and 9B. I have seen capacitor values from 4.7 uF to 100 uF used and the value is not critical, however, from my experiments, I have learned it is mandatory. This capacitor serves to keep the bias voltage constant as the AC signal swings up and down. Some engineers refer to the amplified diode an **NPN shifter bias amplifier** or a **level shifter**. Its function is to charge up the capacitor between the bases of the power follower NPN and PNP pair to a voltage difference that establishes the quiescent current.

In 9C, R1 has been replaced with a PNP transistor which is usually forward biased by another transistor. You may observe any number of variations of the basic biasing circuit presented in Figures 6 and 7, including 3 or more small signal diodes, 2 amplified diodes, current sources, feedback loops and more. although the techniques vary, the authors are still just biasing the complementary emitter followers to achieve low crossover distortion, stability and/or thermal tracking.

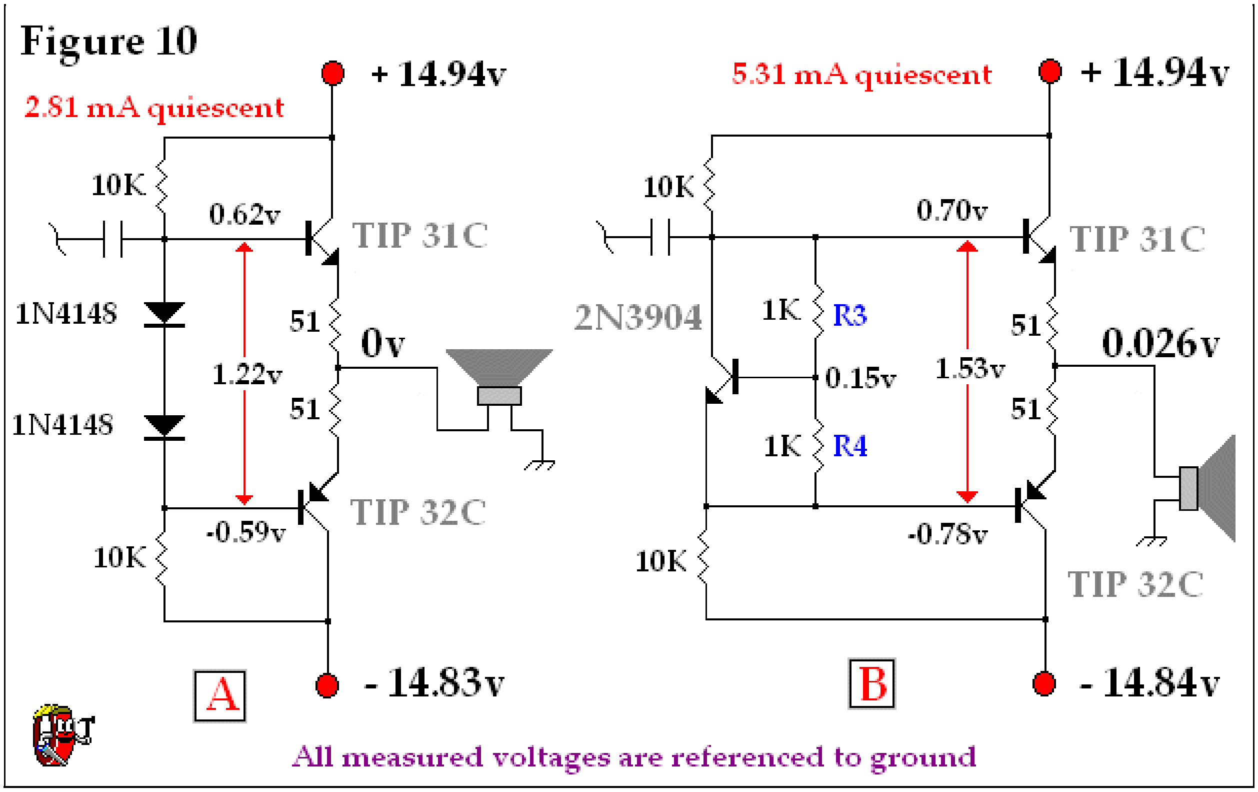

Figure 10
2.81 mA quiescent
+ 14.94v
10K
0.62v
TIP 31C
1N4148
51
0v
1.22v
51
1N4148
TIP 32C
-0.59v
10K
- 14.83v
A
5.31 mA quiescent
+ 14.94v
10K
0.70v
TIP 31C
2N3904
1K
R3
51
0.026v
0.15v
1.53v
51
1K
R4
-0.78v
10K
TIP 32C
B
- 14.84v
All measured voltages are referenced to ground

Shown above in Figure 10 are 2 amplifiers using a split power supply. The split power supply offers increased headroom due to a greater AC voltage swing as well as increases the available RMS output power without using super high AC power transformer secondary voltages. In addition, the split supply works well with op amps and if desired, enables you to reduce the number of coupling capacitors by allowing direct coupling of the preamp and speaker to the power amplifier. Coupling capacitors alter frequency response and perhaps may present phase shift issues. In some cases, we as builders use coupling capacitors to provide effects such as high pass filtering, however in Hi-Fi amps, enhanced low frequency response is usually desired; which necessitates the use of high value coupling caps in single power supply amplifiers. In split supply amps, the choice of using a coupling capacitor or not is available to you. In the Figure 10 a and b circuits above, the speaker is directly coupled to the complementary emitter followers output. Note that the voltage at this point is 0 or nearly 0 volts. For any given power supply voltage you chose (split or not), please ensure the amplifier components can handle the current and subsequent heat when a signal voltage is applied. This topic is out of scope. Build and measure...build and measure...

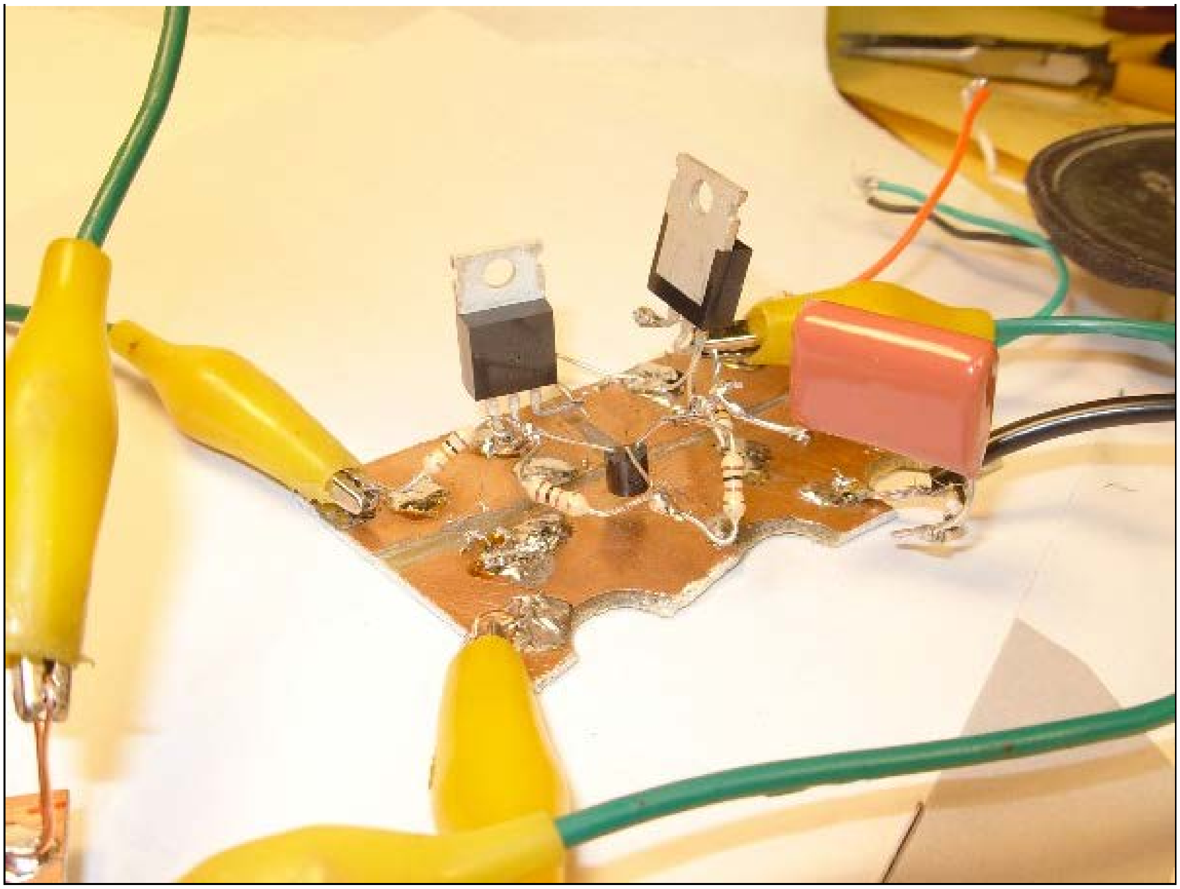

Shown above is a breadboard of the Figure 10b circuit. Additional experiments using even higher voltages were also performed, hence the moderate power TIP transistors were utilized. I burnt up four 2N3904/6 transistors performing many experiments with biasing over 3 nights. Some of the outputs of these experiments will be presented in future projects.

Figure 11

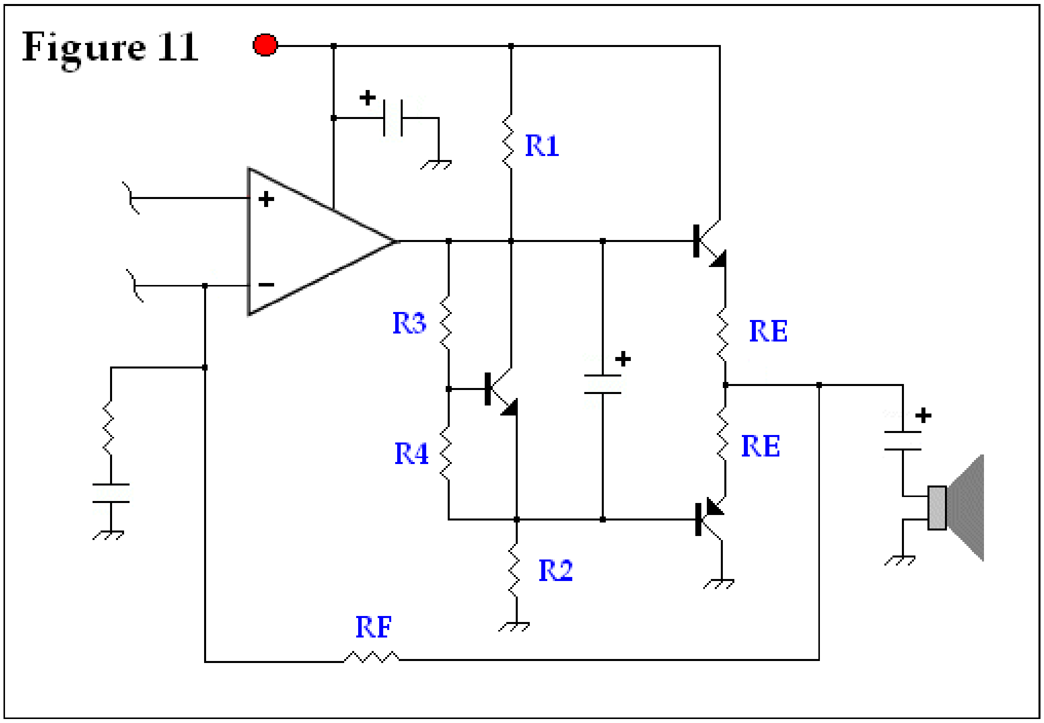

Shown above in Figure 11 is a complimentary emitter follower pair directly coupled to an op amp. The amplified diode and its biasing network is inside the op amp feedback loop. There are examples of this circuit in EMRFD and also on this web site. In single supply powered op amps, it is possible to omit R1. An example of this may be found in Figure 12.30 in EMRFD. Using a low noise op amp such as the NE5532 to drive your power followers can give outstanding results.

Figure 12

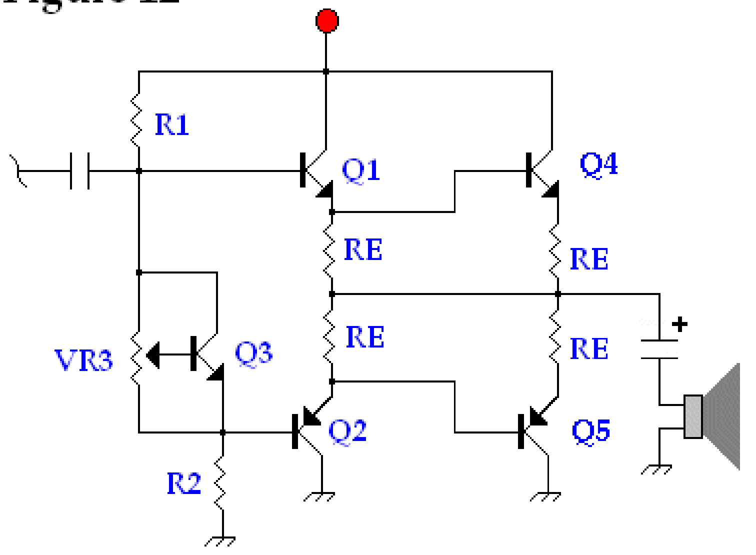

Shown above in Figure 12 is another theoretical power amp which illustrates the building block aspects of the simple stage we have been discussing. Q4 and Q5 are cascaded with Q1 and Q2 to build up the current (Darlington emitter followers). Such an amp could have several watts of output power depending on the supply voltage. The emitter resistors on Q4 and Q5 are often 0.47 to 1 ohm power resistors.

References

EMRFD Although Rick Campbell and Bob Larsen contributed chapters and circuits, the principal author is Wes Hayward. It amazes me that any human being could know so much about electronics and is so willing to share his knowledge. Respect.

Henderson, John. Electronic Devices Published in 1991 by Prentice Hall

Oleksy, Jerome E. Practical Solid-state Circuit Design Published 1974 by Howard W. Sams and Co.,Inc

Slone, Randy G. Understanding Electricity and Electronics Published 1996 by TAB Books-McGraw Hill

Low Power Audio Amp Experiments

Introduction

This web page contains some experiments on simple, low power, speaker output audio amplifiers. Presented are ideas, some measurements and examples of audio amplifiers which will likely sound better than the IC audio chips commonly seen in many receiver projects. This web page is a follow-on to this one and is a completely new area of experimentation for me. Audio amps were built using both split and positive power supplies. In all cases the complimentary power followers were driven by an op-amp. I tried building some power amps using discrete transistor differential amplifier stages with current sources as the driver, but the noise performance and simplicity of the NE5532 or NE5534 op-amp was superior.

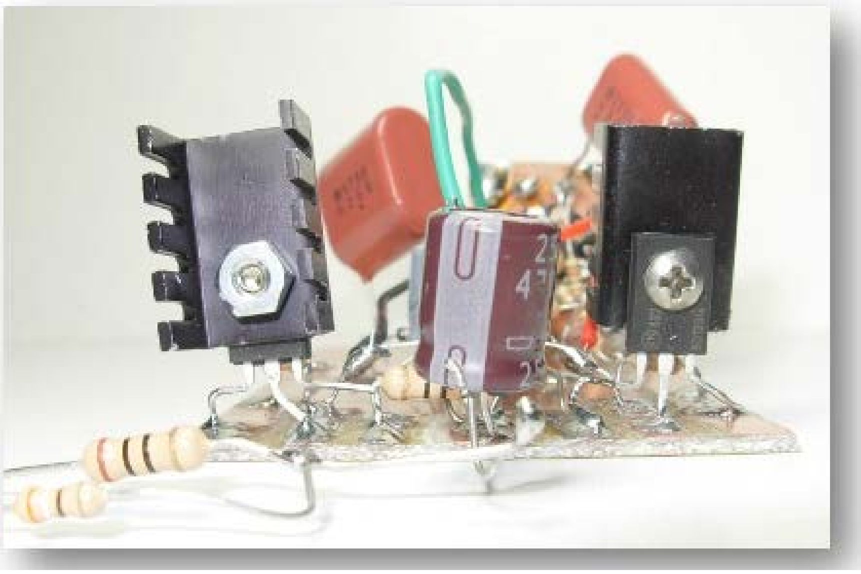

Split or Bi-polar Power Supply Audio Amplifiers

Figure 1

Split Power Supply

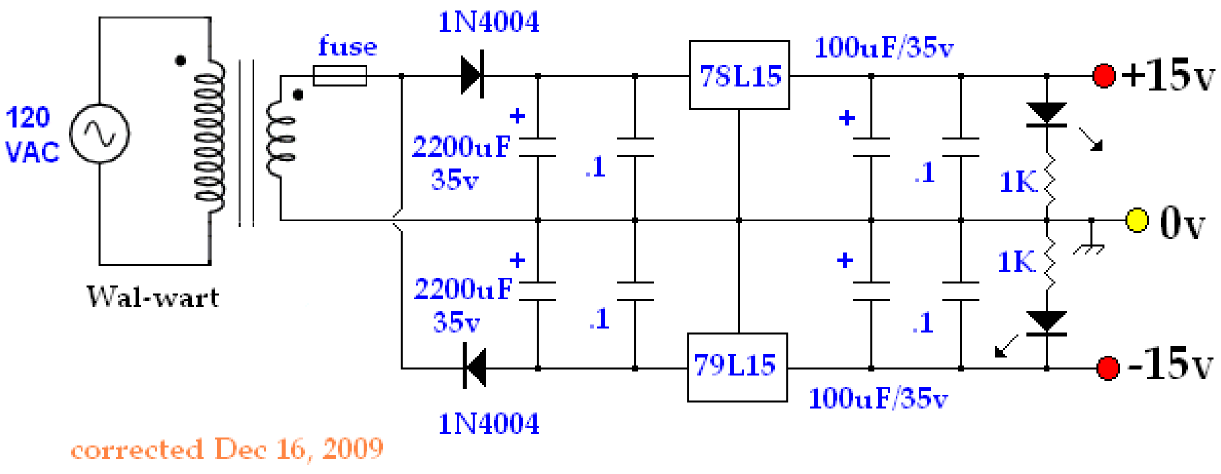

corrected Dec 16, 2009

In order to build up some split power supply amplifiers, a basic power supply was constructed and the schematic is shown in Figure 1 above. I found it was essential to regulate the voltage or hum would appear on the output. Choose a standard value fuse that is rated somewhere just above the maximum current you measure. I used 2 different AC output power transformers which were in the 18-24 volt, 375 mA to 1 amp range. The LEDS are strongly suggested. They inform you when there is power applied and their relative brightness will also often fall when higher current is being drawn on one side or the other. This alerted me to an accidental solder bridge to ground on more than 1 occasion.

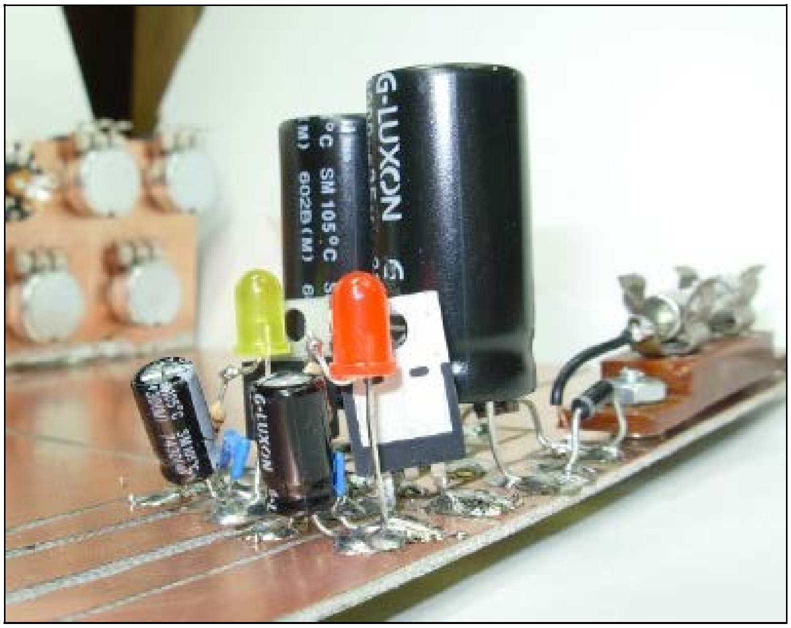

The split power supply is shown in the photograph to the left. The retro Bakelite fuse holder is from an old tube audio amplifier. If you are wondering why the copper clad board is so large, the power supply is part of a future project. Some builders would use even greater value filter capacitors than those shown. Heat sinks on the voltage regulators are required for supplying DC to higher power amplifiers.

Rod Elliot Headphone Amp

Figure 2

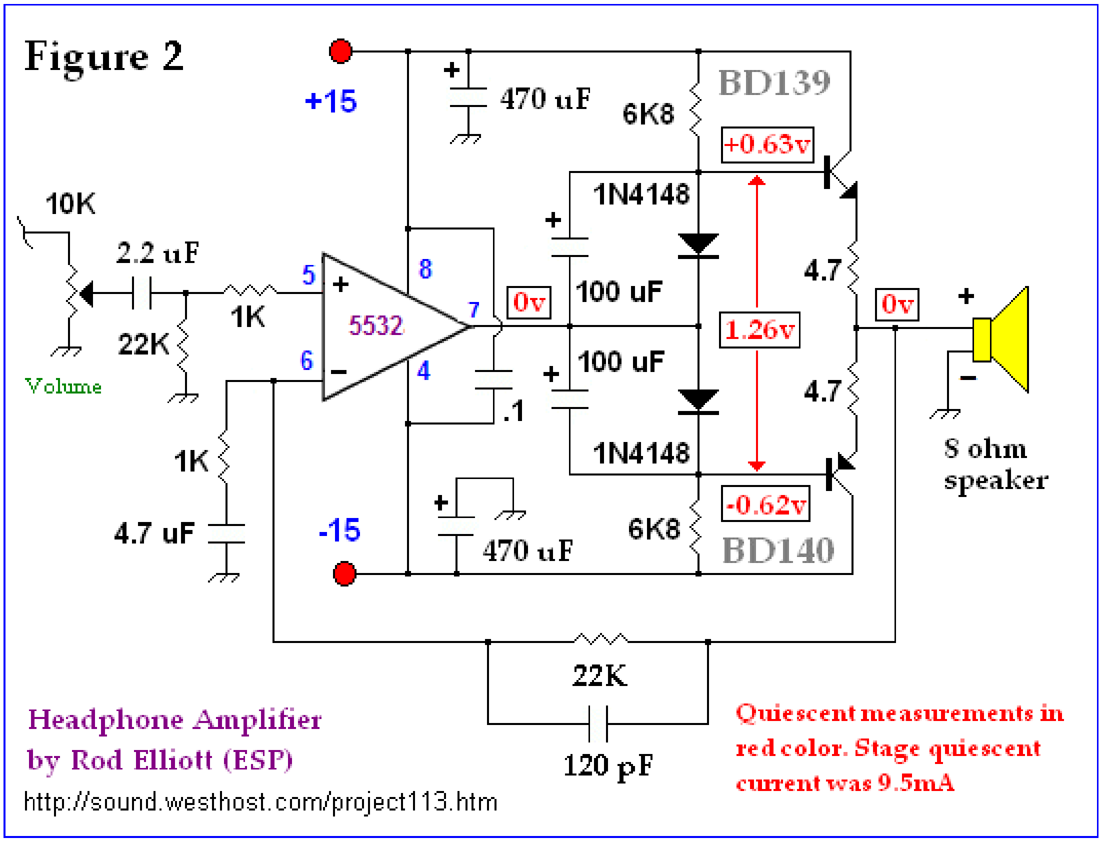

Headphone Amplifier
by Rod Elliott (ESP)
http://sound.westhost.com/project113.htm

Quiescent measurements in red color. Stage quiescent current was 9.5mA

The first amp I built is shown in the Figure 2 schematic above. This amplifier was designed by Rod Elliot and is used with his permission. Rod's ESP web site is a virtual treasury of audio design information. If you are into understanding audio design, visiting his web site is strongly recommended. Rod sells printed circuit boards for all of his circuits if you prefer this building method . Note I have made some minor modifications to some part values. although primarily designed as a low distortion, high power, headphone amplifier, it drives an 8 ohm speaker very well. I was able to drive this amplifier as high as 0.68 watts average power with a pure sine wave output during analysis. Power measurement is discussed in the next section. Note that on this web page, I quote the entire stage quiescent current. Since the op-amp and the

2 (or more) power followers are a "package", it is a lot easier to just measure the current at the power supply lead(s) of the stage than unsolder and lift up a transistor lead. In this case, with no input single, the stage current was about 9.5 mA. I did check and about half the current is going to the op-amp with the other half to the transistor pair. This is a wonderful sounding amplifier and Rod has an entire web page devoted to it, so I will not comment further.

There are a variety of suitable transistor pairs for audio power amplifiers depending on the power output you are choosing. I stock just a few; BD139-140, TIP 41C-42C, NTE 128-129. The higher beta 2N3904-3906 or 2N4401-4403 pairs worked well in the low power, single power supply amplifiers shown on this web page. I also performed some higher output power experiments which required the TIP and BD transistors and these are not shown.

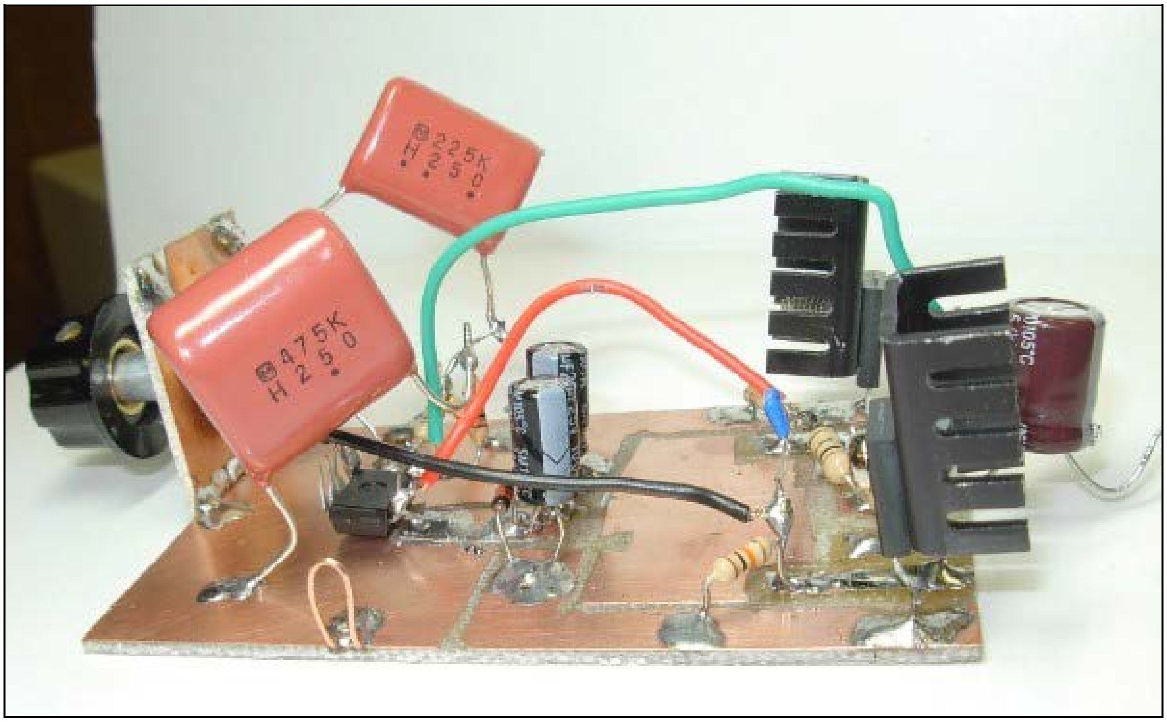

Above photograph. A breadboard of the Rod Elliot headphone amplifier. This early version had a temporary output capacitor. When first testing a new circuit that has a direct speaker output, it might be a good idea to temporarily use an output capacitor until you measure your voltages and current and feel your transistor temperatures. This will save your speaker if you made a big mistake and/or blow up the transistors when you first power it up.

Amplified Diode Biased Audio Amp

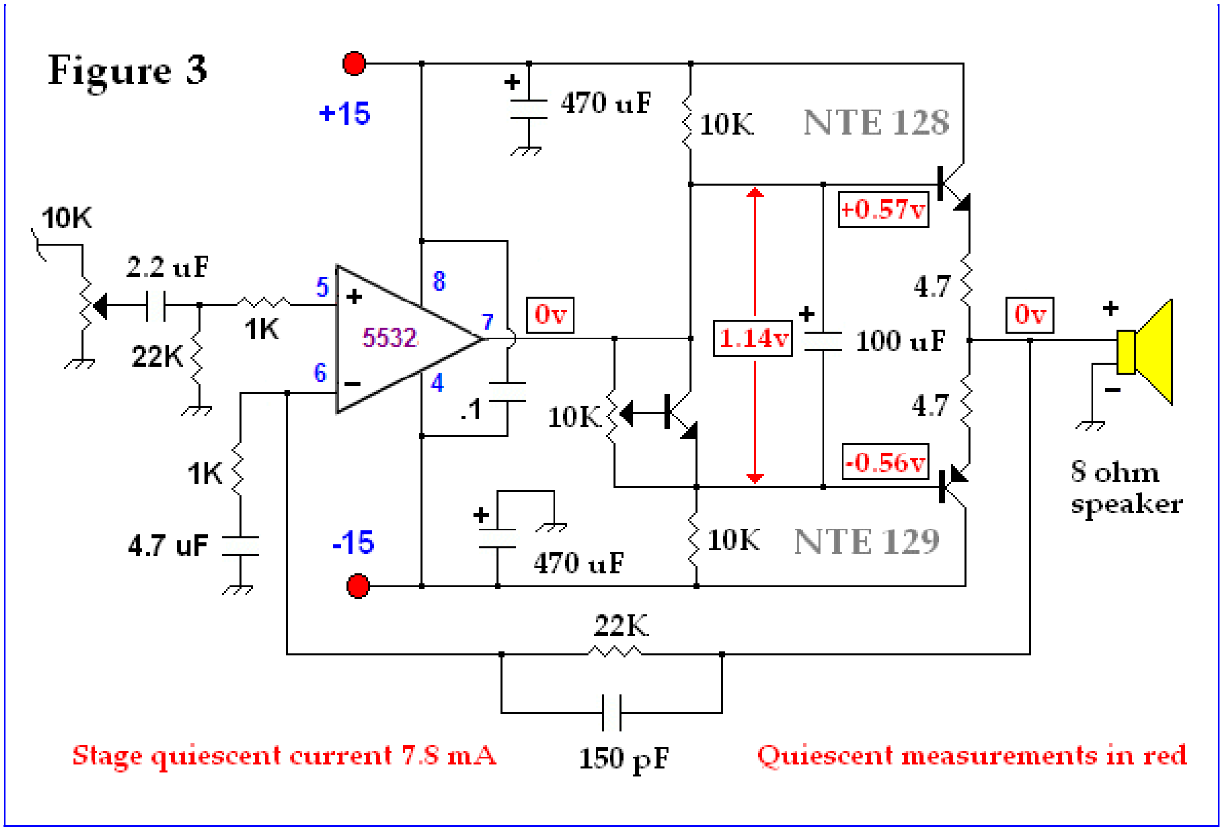
Figure 3

Stage quiescent current 7.8 mA

Quiescent measurements in red

Above in Figure 3 is a split power supply audio amp using an "amplified diode" to control the bias. The bias transistor was wedged between one of the output transistors and a piece of copper clad board to allow thermal tracking. The 10K bias control resistor was a trimmer type suspended over the copper clad board in most of my bread boards. Usually, you just need to set and forget about this resistor after initial set up. I adjusted the bias by watching in my oscilloscope with a low level, 1 KHz sine wave connected to the input. I measured the various voltages and stage current at quiescent and have indicated these values in red for learning purposes. The bias current range was 7.2 to 154 mA when turning the 10K trimmer pot from 1 extreme to the other. The maximal clean output average power of this amp was 0.78 watts. I used press on heat sinks for the NTE128-129 pair and they ran quite warm to touch. These TO39 type packaged transistors are somewhat difficult to heat sink compared to the TIP/BD transistor packages where you can just bolt on a heat sink of any size that is required. Please remember that the metal tab on the TIP and BD transistors is connected to the collector terminal.

In the above photograph is my first bread board of the Figure 3 amplifier. This particular version had TIP transistors, a 4 ohm speaker and an 470 uF output capacitor. Note the full size 10K bias control potentiometer on the left hand side. This was purely a experimenter's bread board, but it sounded amazing when listening to music through it.

Harmonic Distortion and Measuring Output Power

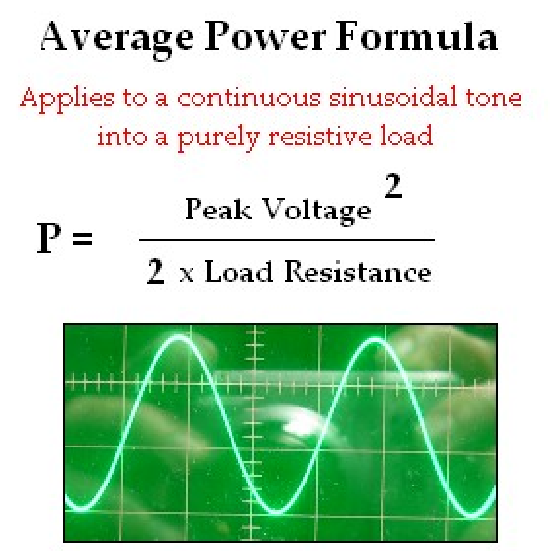

Average Power Formula

Applies to a continuous sinusoidal tone into a purely resistive load

$$P = \frac{\text{Peak Voltage}^2}{2 \times \text{Load Resistance}}$$

Figure 4

In Figure 4 is the formula used to calculate the average power of the circuits on this web page. For example if you measure 6 volts peak to peak on the oscilloscope, (3 volts peak voltage) and your resistive load is 8 ohms, the average power is 560 milliwatts. At any point in an AC waveform there is power and it may be reported using a variety of ways. Was it clean? distorted? a peak value? an RMS value? - often it is unclear.

To be clear, I measured the peak voltage on a pure, undistorted sine wave into an 8 ohm resistor. Stated power values are the mean sine wave power calculated with the formula shown. See this somewhat controversial link for details. You may not agree with my methodology, however, it allows you to compare the circuits on this web page. If you really must know the peak power, multiply the stated average sine wave power by 2. I will leave the power measurement and calculation debate up to scholars; as a lay-person, I need something simple.

The bench voltage measurement was as follows: The amplifier was connected to a 1 KHz pure sine wave generator and the 10K volume control pot was advanced just until any sign of distortion of the amplifier output sine wave appeared. Voltage measurement was taken at the point just before distortion occurred.

It is difficult to photograph a sine wave without a tripod. Motion, the angle, light reflection and jpeg graphic compression all wreck the perfect sine wave. In the Figure 4 graphic above is a typical 1 KHz output waveform from my power amplifiers (squeaky clean) at the amplifiers maximum average power level.

To the right is a photograph of my AF signal generator. This is an old, tube device but the output sine wave is beautiful. I did not perform spectrum analysis with a computer audio sound card program and will leave this up to audiophiles. These audio amps sound great; especially when compared to the IC audio power amps that many of us tend to use in our receivers.

Heathkit
AUDIO GENERATOR
POWER
FREQUENCY
OUTPUT

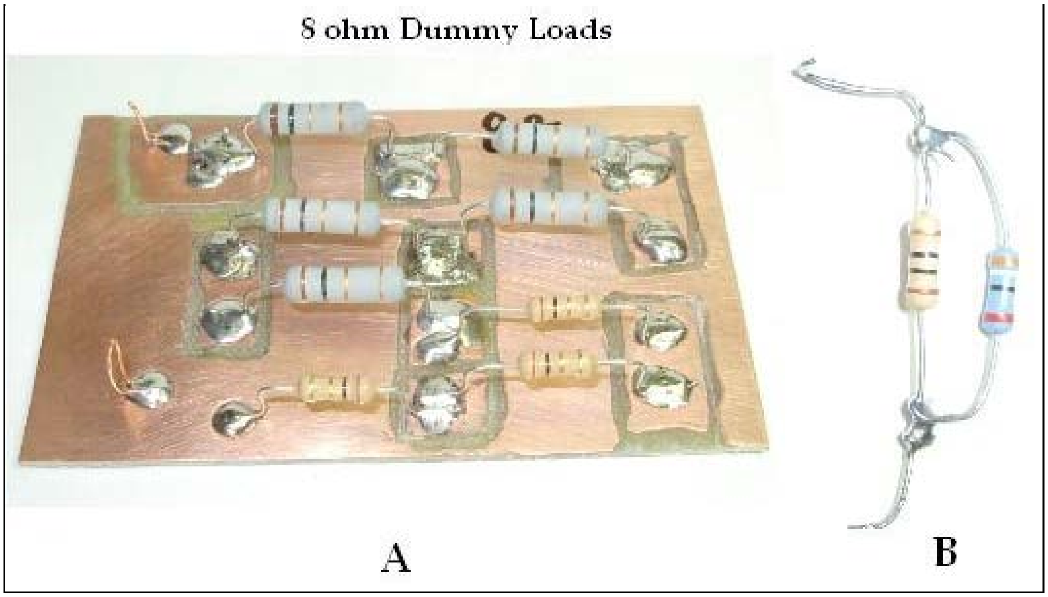

In the above photograph is **A**, an 8 x 1 ohm resistor load and **B**, an 8 ohm load made from parallel 1/2 watt 10 and 39 ohm resistors. In dummy load **A**, I used 5 two watt metal film resistors plus 3 half watt resistors. In the future, I will obtain 3 more 2 watt resistors and replace the 1/2 watt resistors for a 16 watt rating. For a quick resistive load, **B** is the way to go for most of the circuits on this web page.. You can make a 4 ohm load from parallel 4.7 and 27 ohm resistors. In truth, a single resistor or any combination of resistors adding up to the desired load R value will work.

Figure 5

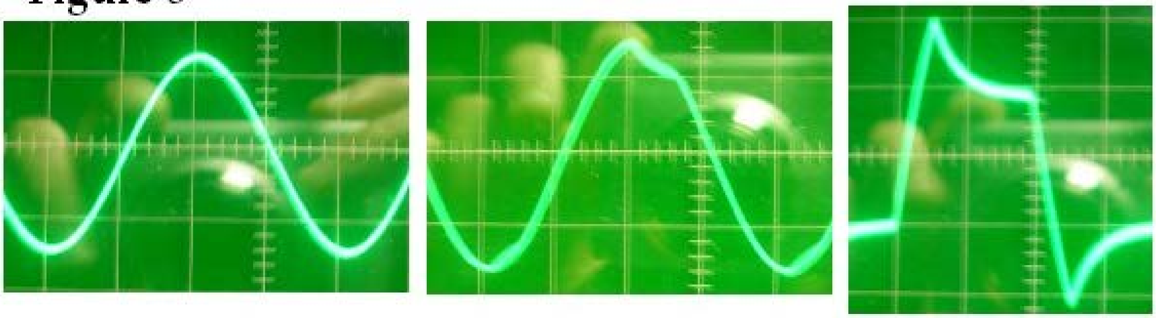

In Figure 5 above are some scope waveforms ranging from mildly distorted to full-on dirty.

Power Amplifier Concerns

Although the amplifiers on this page are 0.15-0.8 watts or so, they can consume relatively large current compared to the usual voltage amplifier circuits we build. Some potentially helpful tips to help keep away ground loops, oscillations and thermal run away are suggested as follows:

✓ Connect your negative speaker terminal directly to the AF power amp (do not use a common ground for the negative speaker terminal).
✓ Use big power supply line bypass capacitors (no 10 uF caps here)
✓ Keep your audio amplifier copper clad board separate from the rest of your circuit boards and star ground it to your main power supply ground point.
✓ Use heat sinks on your final transistors and voltage regulator(s) when you go for bigger power
✓ Watch your layout - keep the output away from the input etc.
✓ Watch your emitter resistor power ratings in "higher wattage" amplifiers. Burning resistors stink.

Single Power Supply Audio Power Amps

Since most 12 volt power supplies are actually closer to 14 volts; these experiments were performed with a typical radio bench DC power supply at 13.69 volts.. Figure 6, 7a and 7b represent evolving experiments aimed at obtaining greater output power.

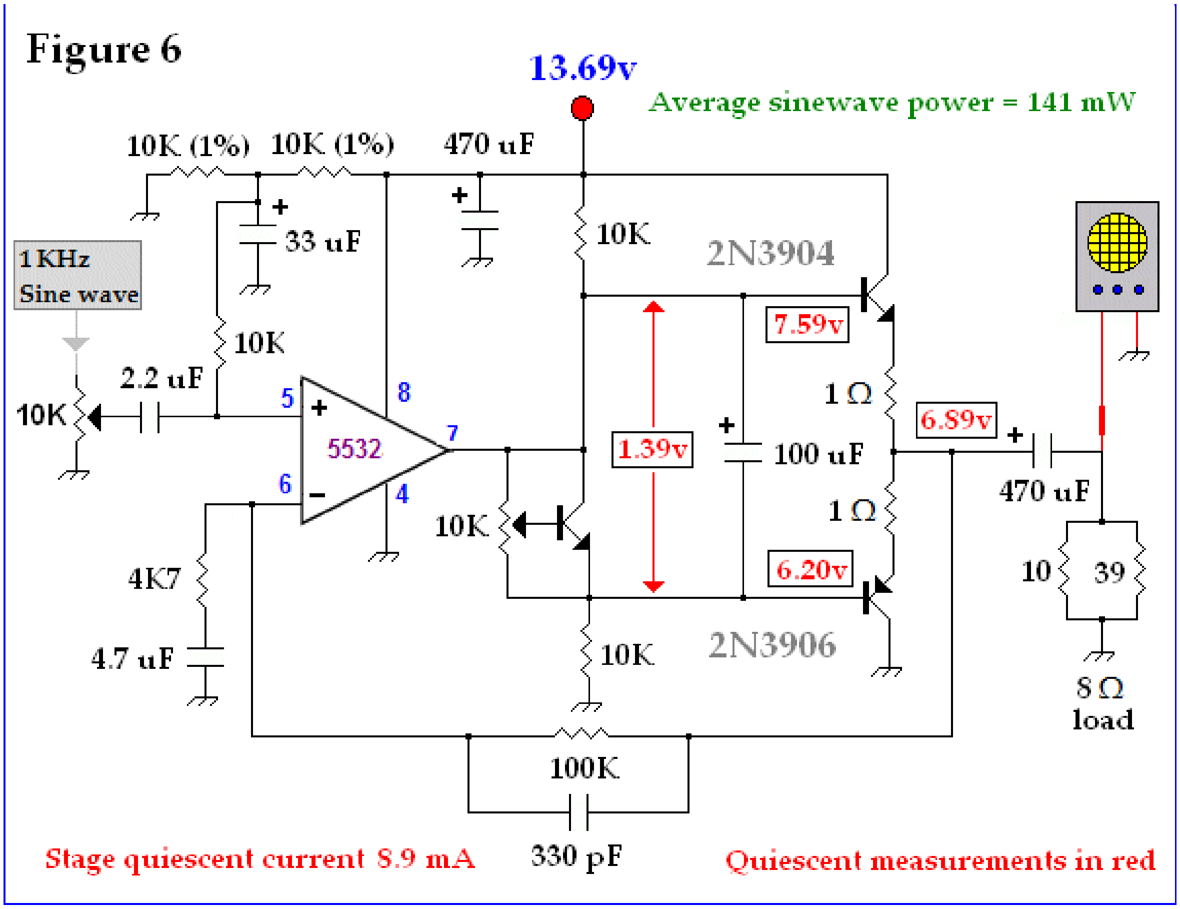
Figure 6
13.69v
Average sinewave power = 141 mW
10K (1%)
10K (1%)
470 uF
33 uF
10K
2N3904
1 KHz
Sine wave
10K
2.2 uF
10K
5
8
7
6
4
5532
7.59v
1 Ω
6.89v
1.39v
100 uF
470 uF
1 Ω
10K
4K7
6.20v
10
39
4.7 uF
10K
2N3906
8 Ω
load
100K
330 pF
Stage quiescent current 8.9 mA
Quiescent measurements in red

Shown above in Figure 6 is the fundamental design using one op-amp and 2 power followers. It is shown in an AC output power measurement configuration. The bias current range was about 5 to 100 mA when turning the 10K trimmer bias control pot from one extreme to the other. Maximal sine wave average output power was only 141 mW. Nevertheless, it might be loud enough for some receiver applications.

I connected this amplifier to a VCC of 15 volts. The maximal sine wave average output power was then 220 mW. In all of the single supply audio amps presented , increasing the VCC increased the maximal power output. Driving these amplifiers beyond a pure sine wave output power resulted in predictable harmonic distortion plus the re-emergence of crossover distortion in the output. This was an incredible learning; how could there be crossover distortion re-emerging in a amp that was properly biased to begin with? Increasing the bias current to the maximum level did not remove this crossover distortion. After emailing this question to Rick, KK7B and Wes, W7ZOI, and reading their replies, my best guess was that at some power level, the 5532 op-amp can not provide enough current to properly drive the complementary symmetry pair. The AC current in the output transistors may be limited by the base drive of the op-amp and they were no longer forward biased at the crossover point.

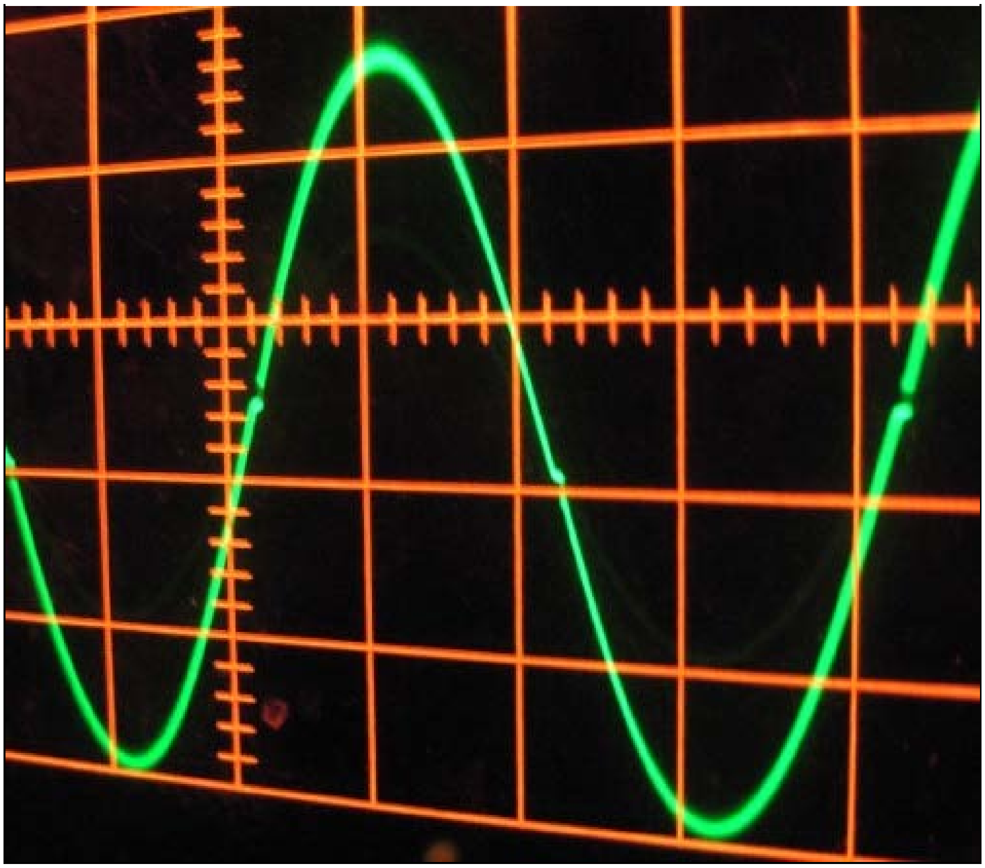

Above photograph. This is the Figure 6 amp driven past the point where the sine wave is pure. Note the crossover distortion blips on the sine wave. The base drive current for the power follower pair all comes from the op-amp. At this point there is likely not enough base drive to keep the base emitter junctions forward biased.

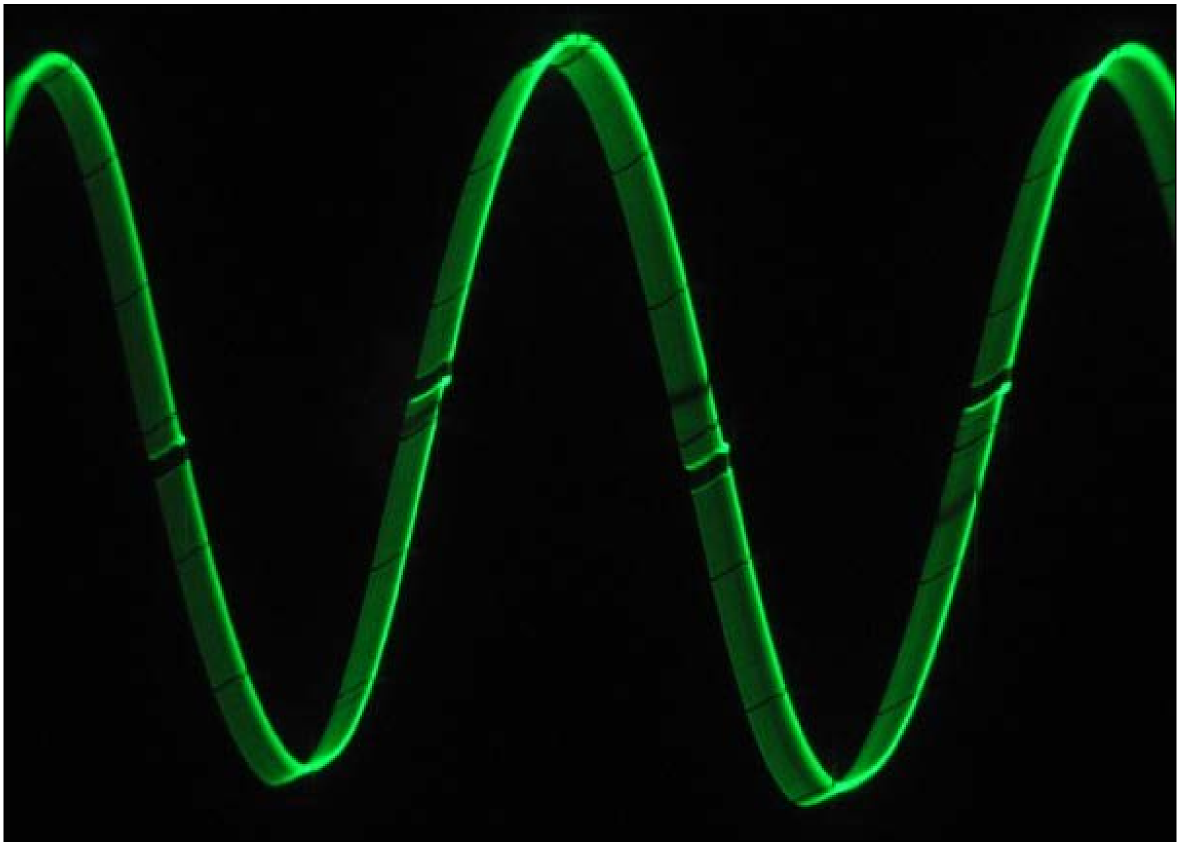

In the above photograph I blacked out the room and photographed the same scope waveform as above while shaking the camera from side to side. This adds some horizontal spreading of the signal and provided more information about what was happening as compared to a single,

clear oscilloscope trace.
I should mention that this crossover distortion blip occurred in all of the Figure 2 to 6 amps when they were driven past the point where a pure sine wave was seen. It is clear that maximal available power from a simple audio amplifier like this **(one NE5532 op-amp plus 2 power followers)** is constrained and thus its application is limited. Greater output power is possible using a split supply per Figures 2 and 3, however, a typical radio project has a 12 volt, single power supply. These basic amplifiers with a single power supply, may be very appropriate for projects such as a compact radio receivers or a code practice oscillator project, but not for applications where you require louder audio.

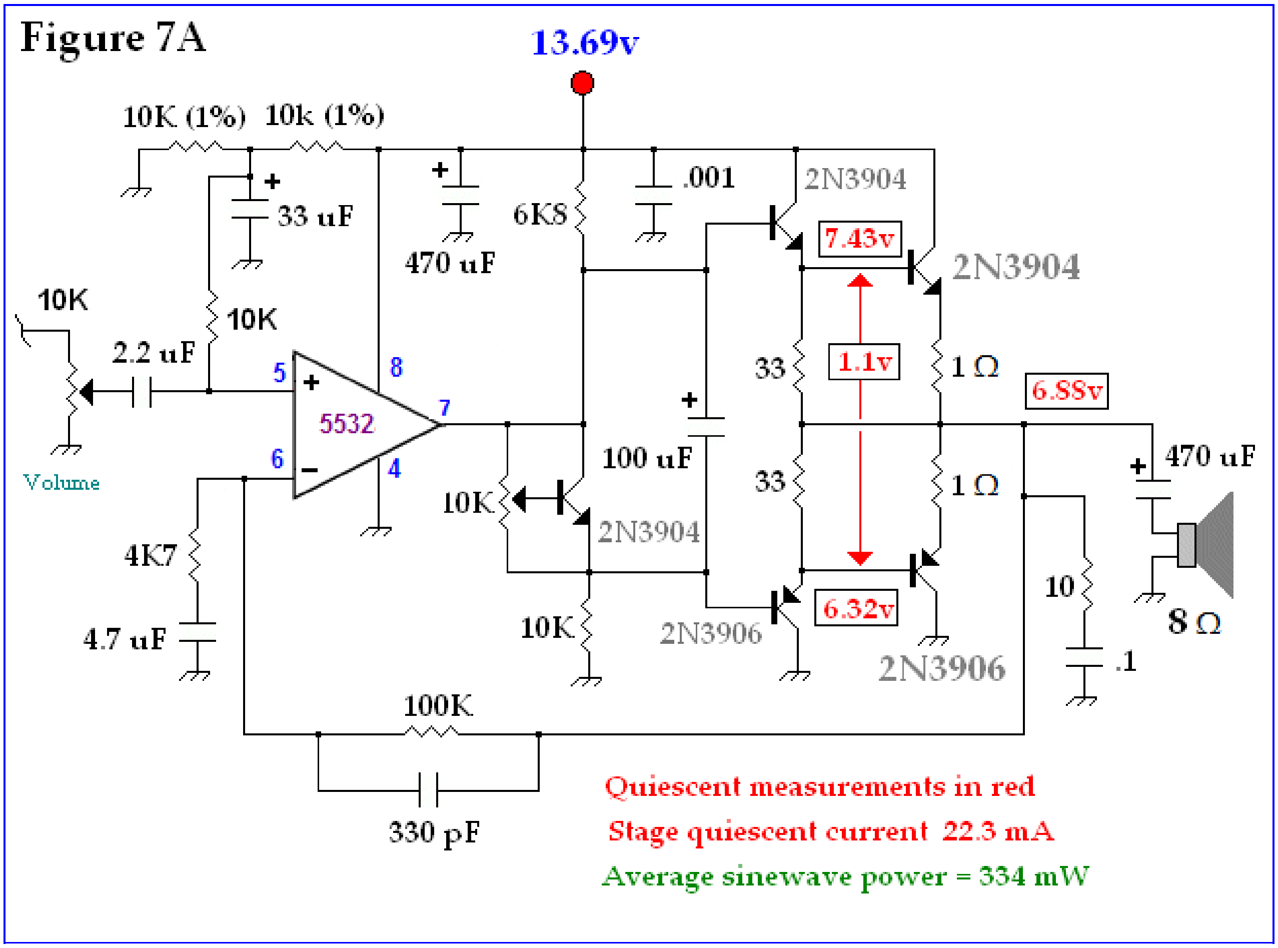

Quiescent measurements in red
Stage quiescent current 22.3 mA
Average sinewave power = 334 mW

Shown above in Figure 7a is an easy method to get more output power from the Figure 6 amplifier; add another set of complimentary pair current amplifiers. I found 33-39 ohms to be a good emitter resistor value during my experiments. Many hi-fi amp builders will use greater emitter resistor values, however, a design goal was to get more output power from our 12 volt supply. Series emitter resistors are used to improve linearity and operating-point stability. I kept the final power follower pair emitter resistor values at 1 ohm to get maximal output power. An output 10 ohm + 0.1 uF low pass filter was used to help prevent oscillations in view of the low emitter resistor values on the finals.

Biasing

The top 10K bias resistor was lowered to 6K8 to facilitate "more linear" setting of the output transistor bias with the 10K trimmer potentiometer. It did not help much. Setting the bias is very delicate procedure and you must turn the screw driver very slowly. In my bread board, the optimal stage bias current was 22.3 mA but anything around 20 mA should be fine. If you do not have an oscilloscope, after ensuring that there is no input signal, connect an ammeter in series with the positive power supply lead. Turn the bias potentiometer with with the screwdriver until you get close to 22 mA. If you only have a voltmeter, the rule of thumb of 1.1 seems to work... Measure the voltage across the final 2N3904-2N3906 bases and ensure the difference is at least 1.1 volts while adjusting the 10K trimmer pot. Personally I do my biasing with an oscilloscope at at least 2 different frequencies on the signal generator, however the for mentioned methods will work okay. This is a popcorn stage and a popcorn web site after all!

For the lowest potential noise, consider using metal film type resistors in your audio amps and "polysomething" capacitors wherever AC signal is coupled to another component or ground, excluding the output capacitor.

Figure 7b

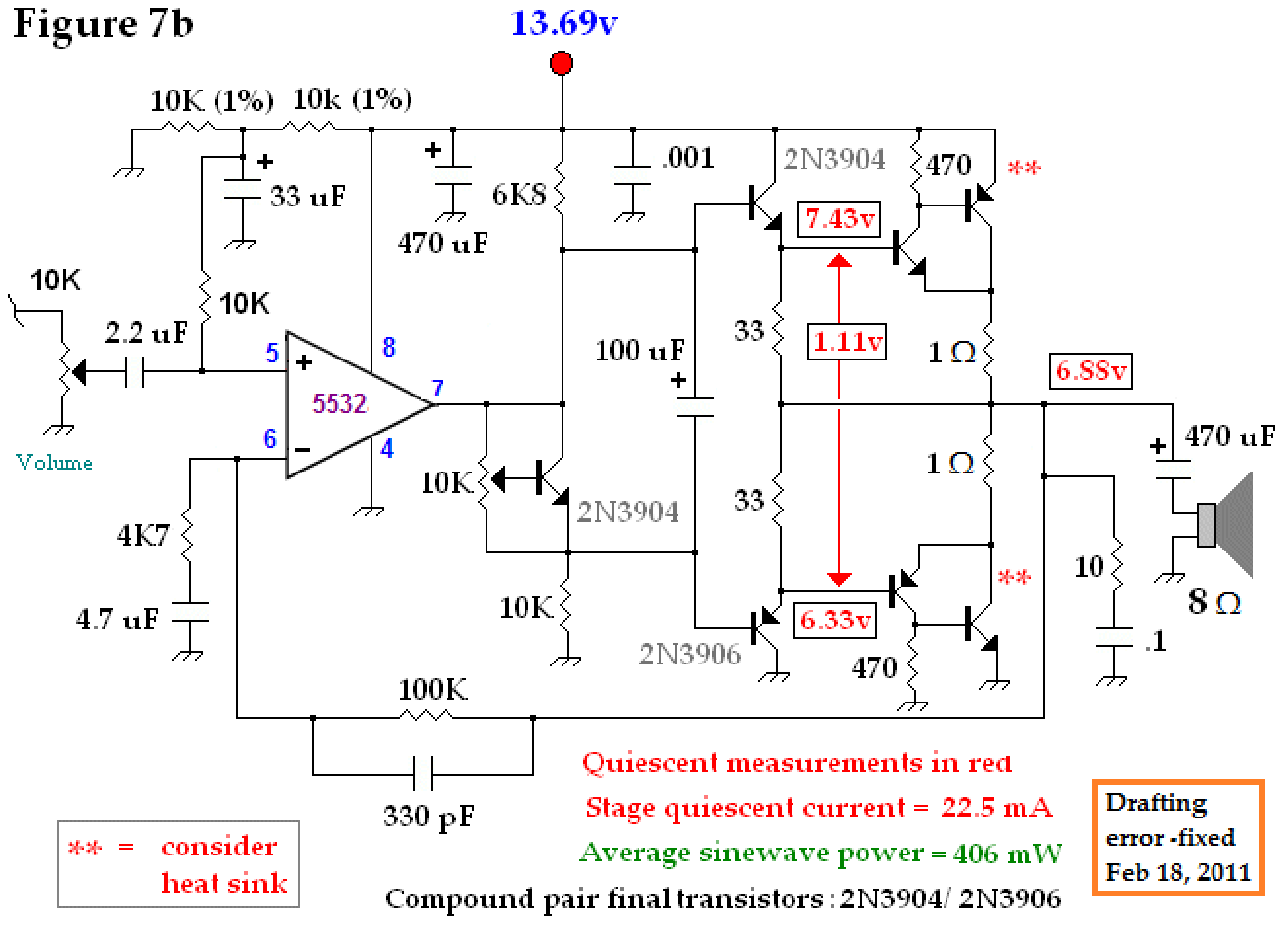
13.69v
10K (1%)
10k (1%)
33 uF
470 uF
6K8
.001
2N3904
470
**
7.43v
10K
10K
2.2 uF
5
8
5532
7
6
4
100 uF
33
1.11v
1 Ω
6.88v
Volume
10K
2N3904
33
1 Ω
470 uF
4K7
10
8 Ω
4.7 uF
10K
6.33v
**
2N3906
470
.1
100K
330 pF

Quiescent measurements in red

Stage quiescent current = 22.5 mA

Average sinewave power = 406 mW

Compound pair final transistors : 2N3904/ 2N3906

** = consider heat sink

Drafting error -fixed Feb 18, 2011

Further experiments to increase output power were frustrating. Finally a compound or Sziklai pair was trialed and increased the average power to over 400 mW as shown in Figure 7b . I used a small piece of copper clad board on the finals for a heat sink, although they really didn't get that warm. Ideally, the amplified diode should also be glued onto one of the heat sink boards for thermal tracking. This amplifier is now in a chassis as a bench reference audio amp for receiver testing.

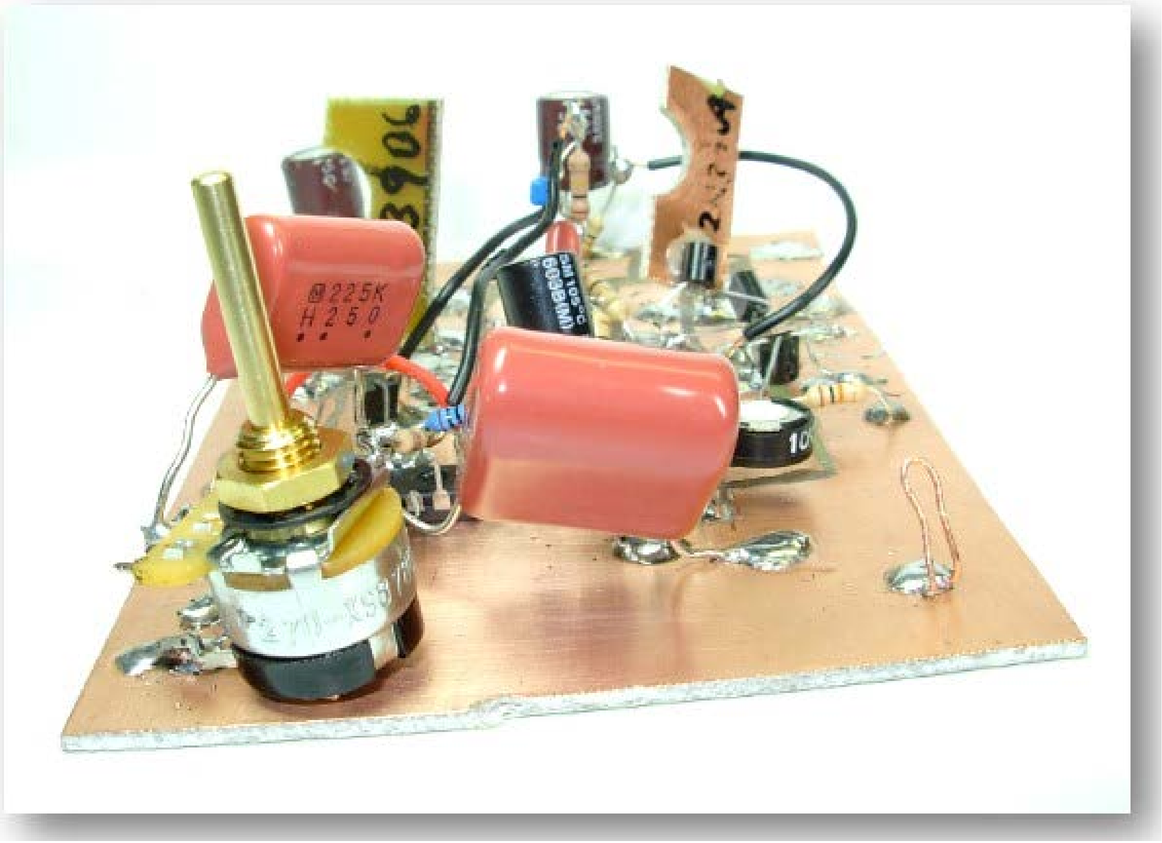

In the above photograph is the Figure 7b prototype. I am using a new miniature potentiometer for my experiments that I bought from Digi-Key. The base has 2 leads which can be soldered right on the copper clad board for easy anchoring and removal after testing.

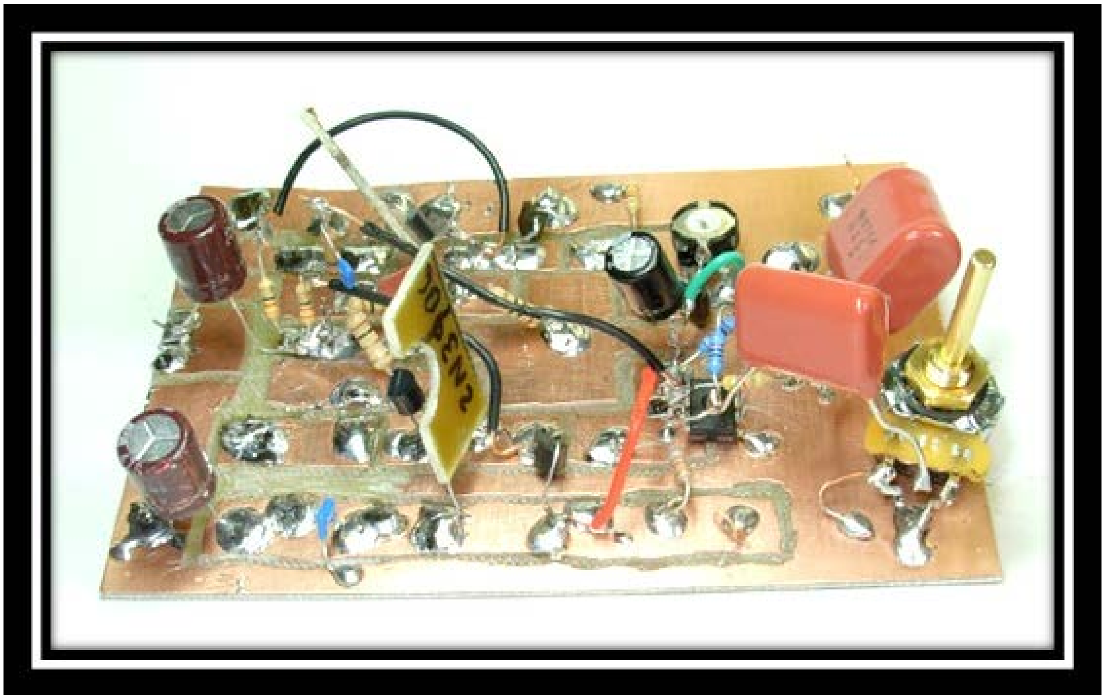

Another view of the bread board on which the Figure 6, 7a and 7b experiments were conducted.

KK7B Headroom Boosting Emitter Capacitors

We first learned about using large value emitter caps in audio amp complimentary pairs from EMRFD. Experimentation revealed that these capacitors do 2 things: **1.** Can increase the amplifier sine wave headroom and **2.**

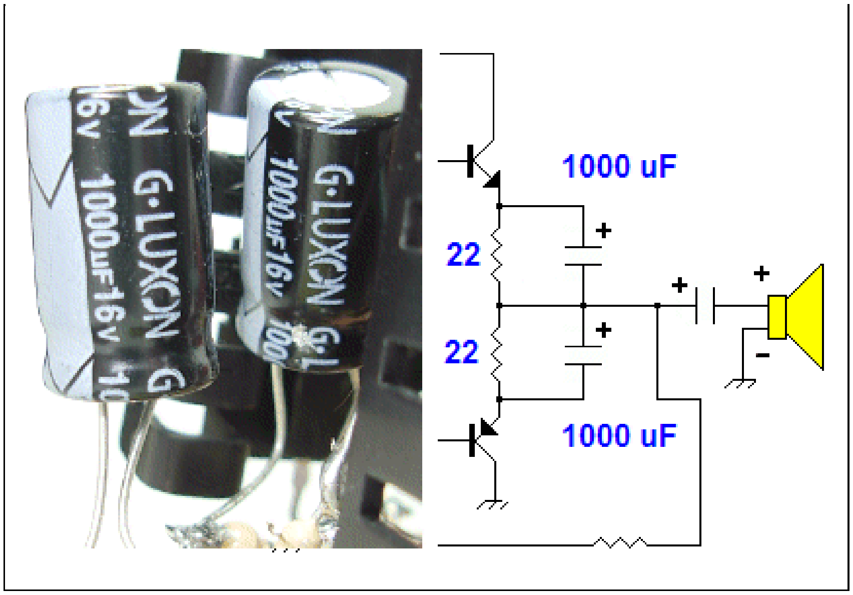

Add some low pass filtering. I learned from Rick, KK7B, that he designed his EMRFD amp to achieve low output power, low distortion and lower DC current drain. He desired a clean output audio amplifier for his R2 series of receivers without needing a lot of quiescent current or heat sinks on the 2N3904-2N3906 pair. The caps were added to make the amplifier think it had much lower emitter resistors at AC than the 22 ohm resistors he used in the EMRFD projects. When Rick made measurements and simulations of the amplifier, it was very stable, had low distortion and provided a very nice clean sound at all signal levels, from very weak signals in a few milliwatts of noise, to music driving the speaker. The result is outstanding and Rick's design was the catalyst for my own interest in audio amplifier experimentation.

I performed experiments with these capacitors and found that they increased my amplifier power and head room in some cases, and that the boost is indirectly proportional to the emitter resistor value. With 1 ohm output transistor emitter resistors the boost is generally not that significant. With 4.7 ohm or greater emitter resistors, they can make a big difference and you might consider trialing them for more power and headroom as appropriate. They can also add a nice, warm sound to your audio amp. Refer to EMRFD for numerous examples of this technique.

Popcorn Audio Amplifier

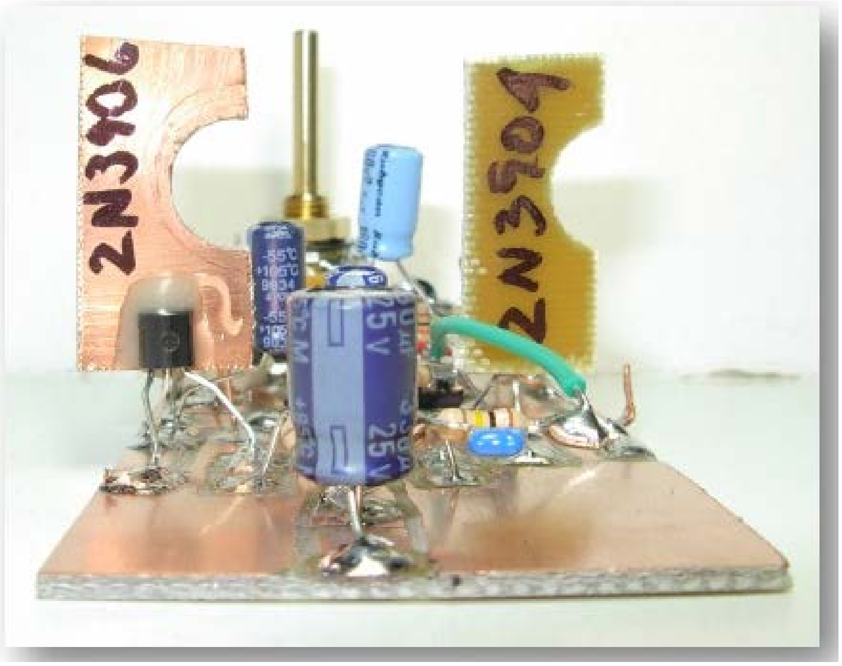

What follows is a popcorn or "poor man's" audio power amp using the 2N3904-2N3906 pair. To meet true popcorn criteria, all of the capacitors used in my breadboard were electrolytic and you can substitute different values from your own junk box. It would be better to use "polysomething" capacitors for the NE5532 pin 5 and 6 signal capacitors if you have them. I normally use a 1 uF to 4.7 uF poly-type capacitor in series with the 4K7 resistor on pin 6. The 270 pF feedback capacitor could be omitted or substituted with a higher or lower value to suit whatever high frequency roll off you desire.

The transistor glue-on heat sinks seen in the 1 bread board photograph are completely unnecessary. This BJT pair were used in other higher power experiments as well. The 22 uF capacitor between the transistor bases is essential from my experimentation. Without this capacitor, the amplifier headroom decreases and crossover distortion occurs. You can use the other half of the 5532 for a preamplifier or use a NE5534 instead. A 741 op-amp would be a horrible substitution. The NE5532 performance is breathtaking considering its low cost. 181 mW is surprisingly loud. All resistors are quarter watt rated. What a fun little amplifier! The schematic is Figure 8.

Figure 8

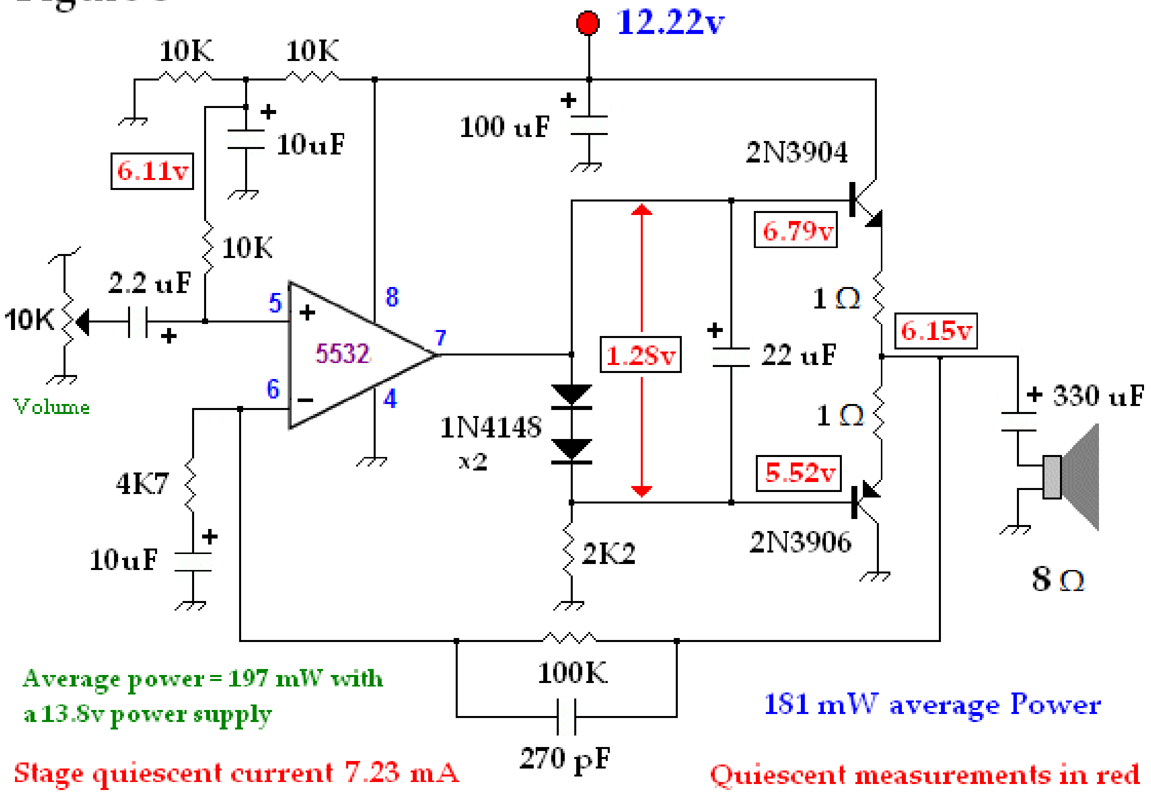
12.22v
10K
10K
10uF
100 uF
6.11v
2N3904
6.79v
10K
2.2 uF
10K
5
8
1 Ω
6.15v
5532
7
1.28v
22 uF
6
4
Volume
1N4148
x2
1 Ω
330 uF
5.52v
4K7
10uF
2K2
2N3906
8 Ω
100K
270 pF

Average power = 197 mW with a 13.8v power supply

181 mW average Power

Stage quiescent current 7.23 mA

Quiescent measurements in red

missing
10K pot

The bread board of the Figure 8 popcorn amplifier using transistors without heat sinks.

Additional Outputs

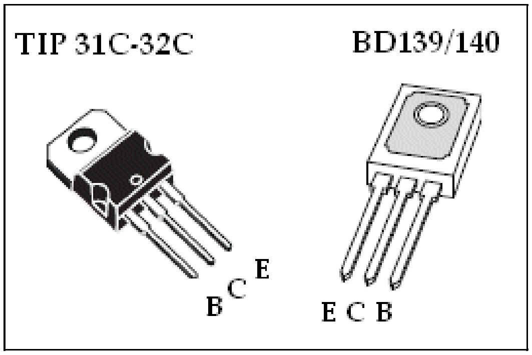
TIP 31C-32C
BD139/140
B
C
E
E C B

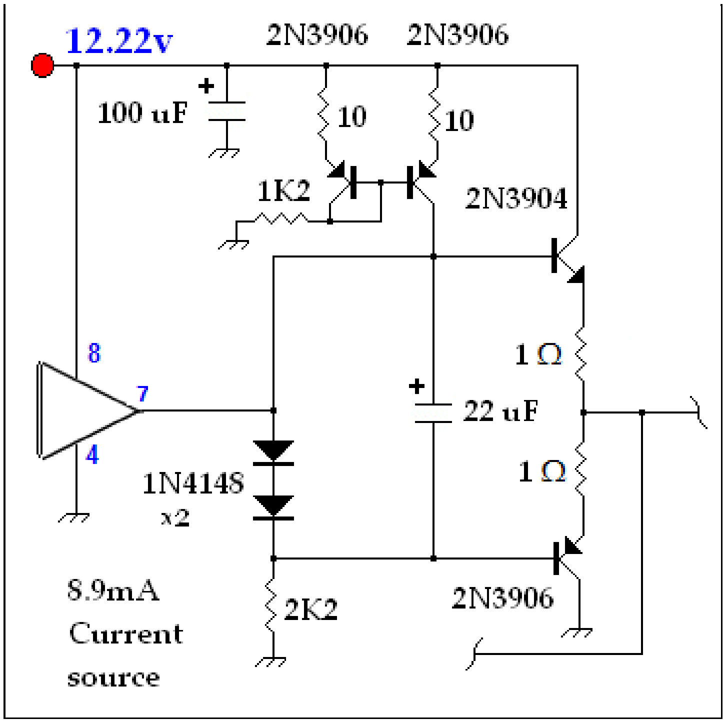
12.22v
2N3906
2N3906
100 uF
10
10
1K2
2N3904
8
7
4
1 Ω
22 uF
1 Ω
1N4148
x2
8.9mA
Current
source
2K2
2N3906

I tried putting a current source on the Figure 8 bias and it made no difference to the amplifier characteristics according to my simple oscilloscope, listening and DC analysis.

AC
DANGER!
2200uF100V
VR(M)

One of the full wave rectifier, voltage regulator and filter bread boards used in these experiments. I went as high as 24 VCC on some single supply amps I tested and was getting over 5 watts average output power

NPN

Amateur and Short Wave Radio Electronics Experimenter's Web Site

Two Bravo Receiver Experiments

Introduction

An experimental direct conversion receiver is presented. This 1990's style receiver was built to re-familiarize with DC receivers and try out a few new ideas. Design-on-the-bench bread boarding was used exclusively and was a pleasant way to both learn and pass time. Feedback has been received stating that that certain stages of previous receiver experiments were either too basic or too complex and thus a particular receiver was not built. This web site is as much a cookbook as anything. Kludge together whatever receiver stages you want; no project is meant to be set in stone. This receiver has a high popcorn factor with MPF102 and 2N3904s as the main semiconductors.

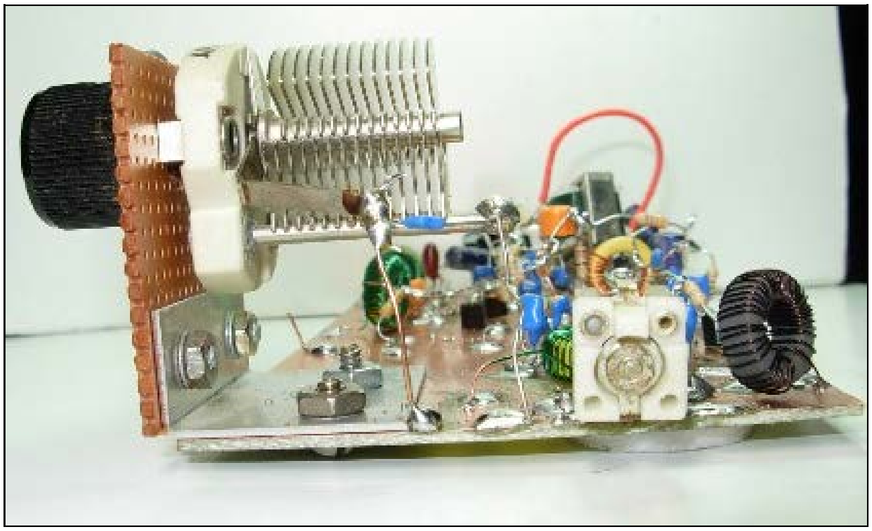

Variable Frequency Oscillator

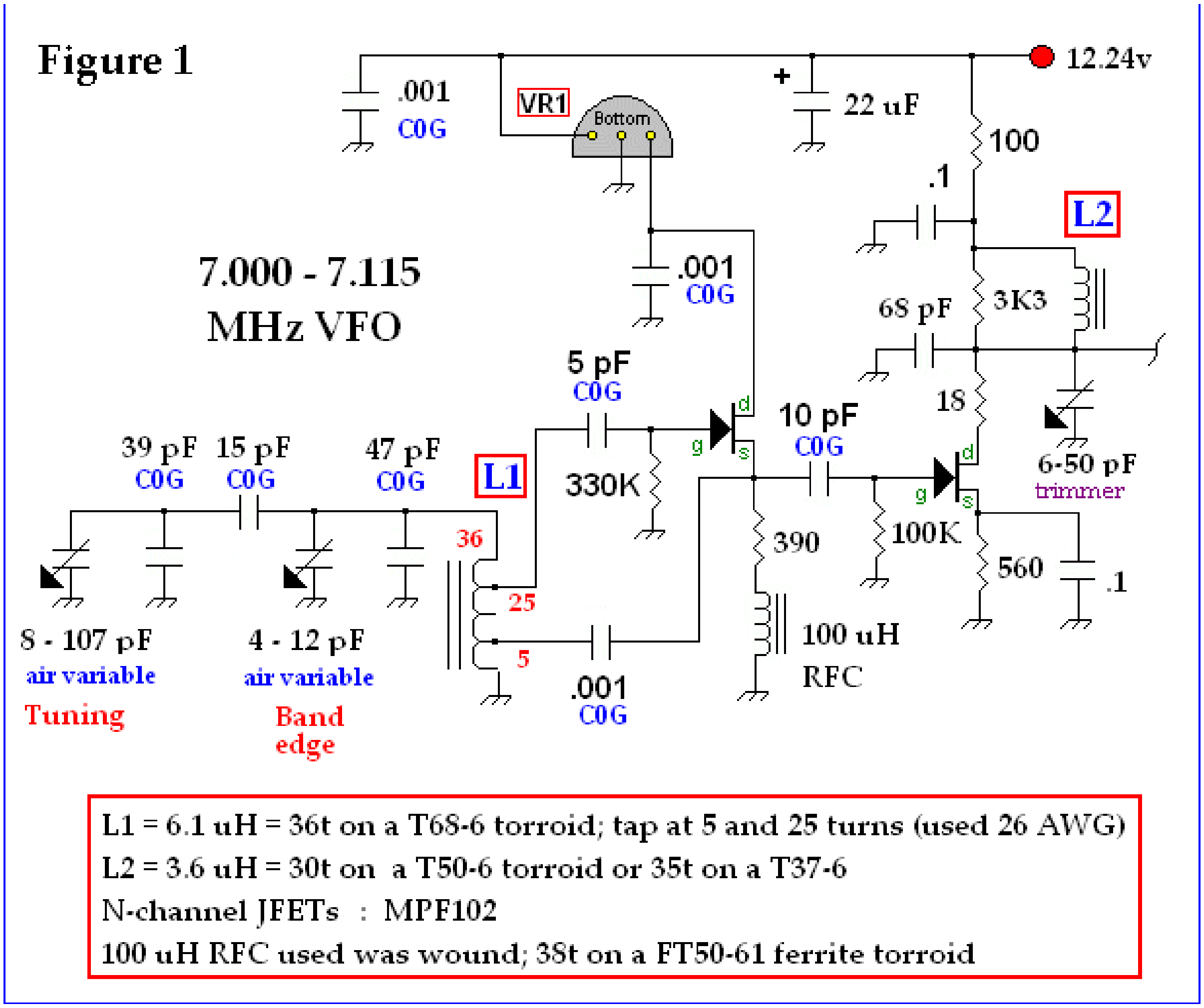

Figure 1

7.000 - 7.115 MHz VFO

L1 = 6.1 uH = 36t on a T68-6 torroid; tap at 5 and 25 turns (used 26 AWG)
L2 = 3.6 uH = 30t on a T50-6 torroid or 35t on a T37-6
N-channel JFETs : MPF102
100 uH RFC used was wound; 38t on a FT50-61 ferrite torroid

The first stage built was the VFO shown above in Figure 1. The oscillator portion is based upon Figure 4.15 from EMRFD. The VFO resonator tank is isolated from the JFET by tapping down as shown. This is an outstanding VFO topology. See this web page for a few more details and a coil tap calculator. I favor high L to C ratios in my RF tanks, although this does not affect the VFO function. The tapped inductor in this oscillator allows you to use a high RF voltage (low C + high L) while still keeping the FET gate AC voltage at a reasonable level. The buffer amp was designed for high output power and supplies nearly 5 volts peak to peak to the product detector local oscillator port. You can vary the output voltage by increasing or decreasing the 15 pF coupling capacitor for use in other projects.
To peak the L2 tank trimmer capacitor, use a scope, RF voltmeter, or temporarily connect a 10K (or greater value) resistor load to ground via a 10 - 47 pF output capacitor and adjust this capacitor while listening with a nearby CW receiver. (Use a short piece of wire as an antenna.) Additionally, you could also peak this trimmer cap while listening to a CW signal with the completed 2 Bravo receiver. It takes around 100 pF to resonate the L2 tank at 7.040 MHz in case you are wondering.

Since air variable capacitors were used for tuning and to set the band edge, Q is high and frequency stability is excellent. My 1 hour frequency drift was 50 Hertz uncovered. The high RF energy in the tank circuit results in low noise. The L1 taps also allow the use of a 5 pF gate coupling capacitor rather than the hard to locate 3.3 pF cap used in many example VFO schematics. With different buffer/amps as required, this is now my number 1 VFO topology and it is nothing short of stellar. Note that the 100 uH RFC can be wound with 15 turns on an FT37-43 ferrite torroid, or replaced with a fixed value choke.

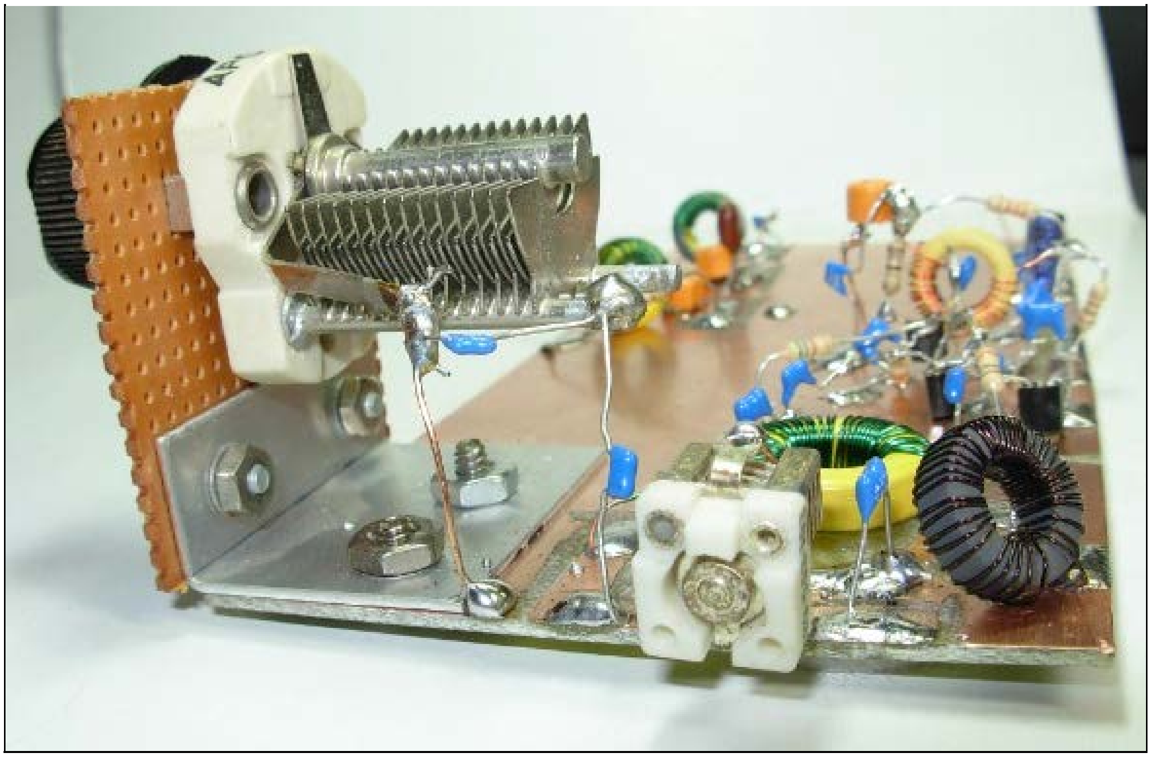

In the above photograph is the VFO bread board. I used 26 gauge wire for the inductor and took my time to make sure the wire was laying flat on the T68-6 torroidal core. You can pull the wire tighter if you wash your hands before winding.

Band pass Filter and Product Detector

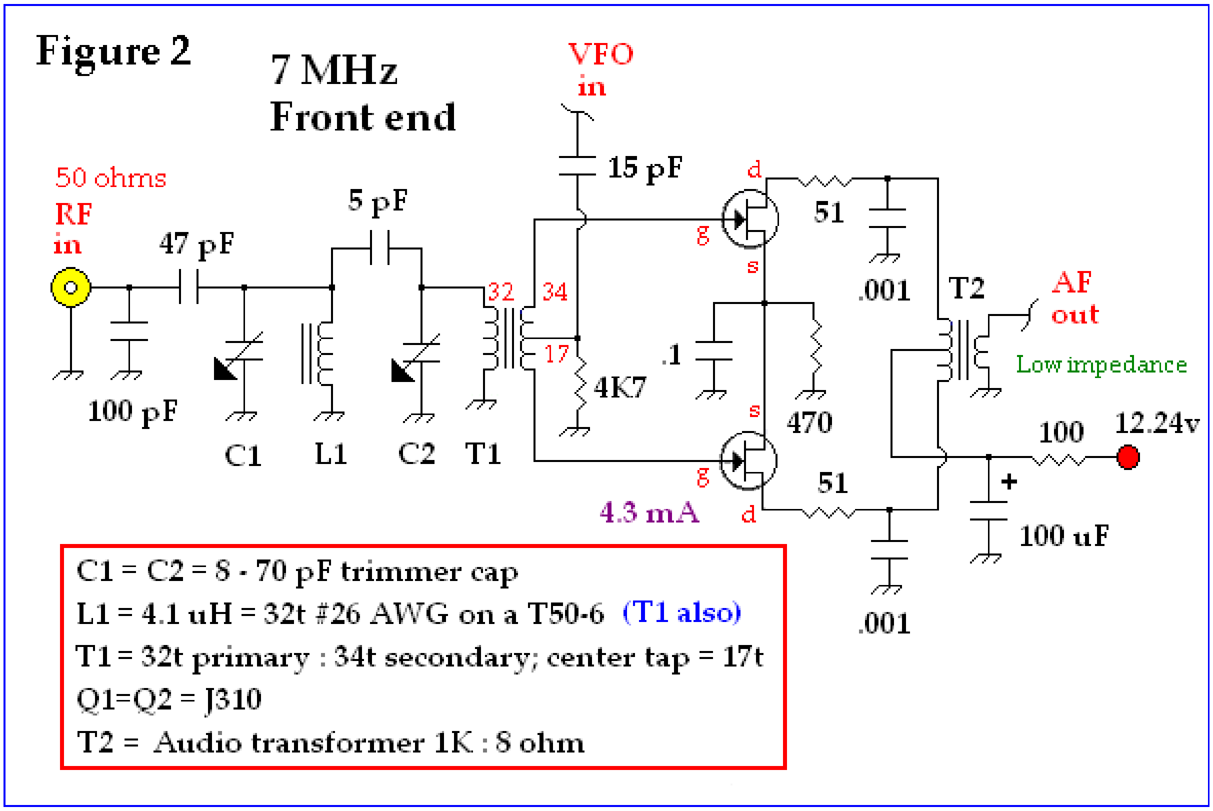

Figure 2

7 MHz
Front end

VFO in
15 pF
50 ohms RF in
47 pF
5 pF
100 pF
C1
L1
C2
T1
32
34
17
4K7
d
g
s
51
.001
.1
470
T2
AF out
Low impedance
100
12.24v
+
100 uF
4.3 mA
51
.001

C1 = C2 = 8 - 70 pF trimmer cap
L1 = 4.1 uH = 32t #26 AWG on a T50-6 (T1 also)
T1 = 32t primary : 34t secondary; center tap = 17t
Q1=Q2 = J310
T2 = Audio transformer 1K : 8 ohm

Please refer to Figure 2. The second stage constructed was the double tuned band pass filter. You will need about 50-54 pF to resonate L1 and T1 at 7.040 MHz. The C1 and C2 values chosen are thus perfect for tuning the 40 Meter CW band. I peaked my particular front end filter at a center frequency of 7.025 MHz using a 50 ohm output impedance RF generator and then did some fine tuning with an antenna connected after the receiver was constructed. You may also just tune C1 and C2 for maximum signal strength when listening to band noise and QSOs. Filter bandwidth is sufficient to cover the whole CW sub-band. No AM broadcast band radio was heard during several nights of testing.

The product detector is single balanced for improved port isolation and BCB rejection. Lay out your circuit to try to achieve symmetry. The schematic calls for J310s. I built the first prototype with MPF102 that were matched for Idss. To find two with the same Idss, I had to measure 16 transistors! This is too painful, and I recommend just using a pair of J310s. The words "matched" and "MPF102" should not be used in the same sentence! Ideally, your J310s should be matched, however, the process should not take as long as for MPF102 JFETS. The choice is yours to make. T1 is a little tricky to wind, however, your best effort should be good enough.
Some builders will be unhappy with using a audio transformer (T2), however, they are still in catalogs and online stores, or can be harvested from an old transistor radio. CB radio modulation transformers are also a possible source. A higher impedance audio transformer, will likely give even more conversion gain. Without the 51 ohm drain resistors, oscillations occurred in my bread board.

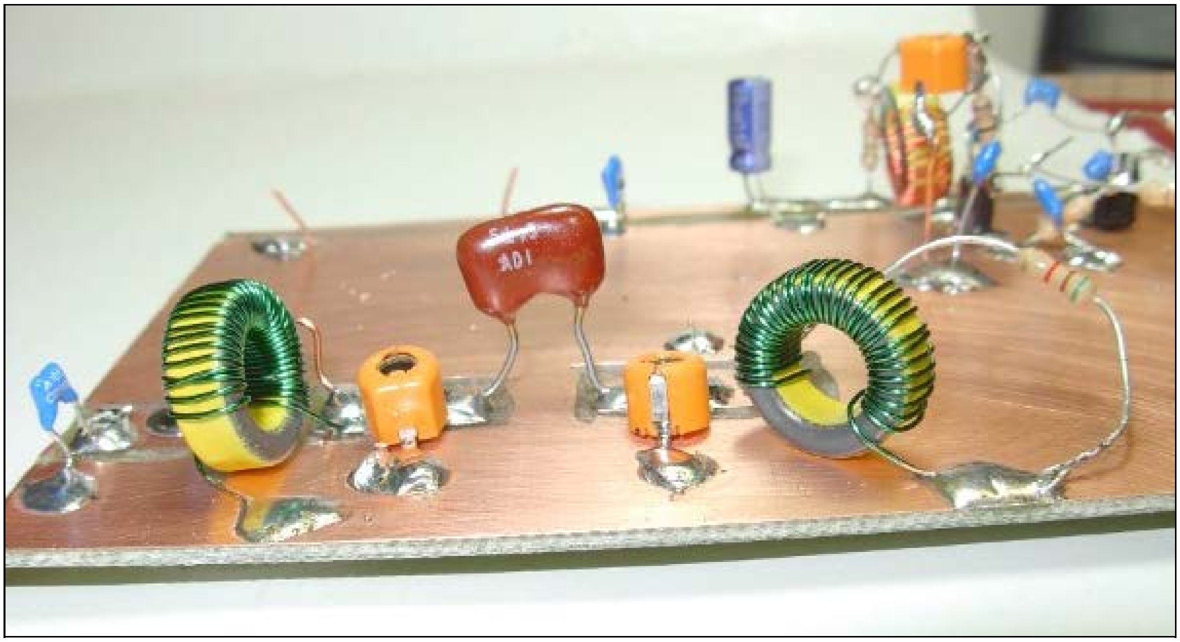

Above. A temporary 5K1 (5.1K) resistor was soldered across the second tank for testing when the front end filter was designed on my work bench.

Audio Pre-amplifier

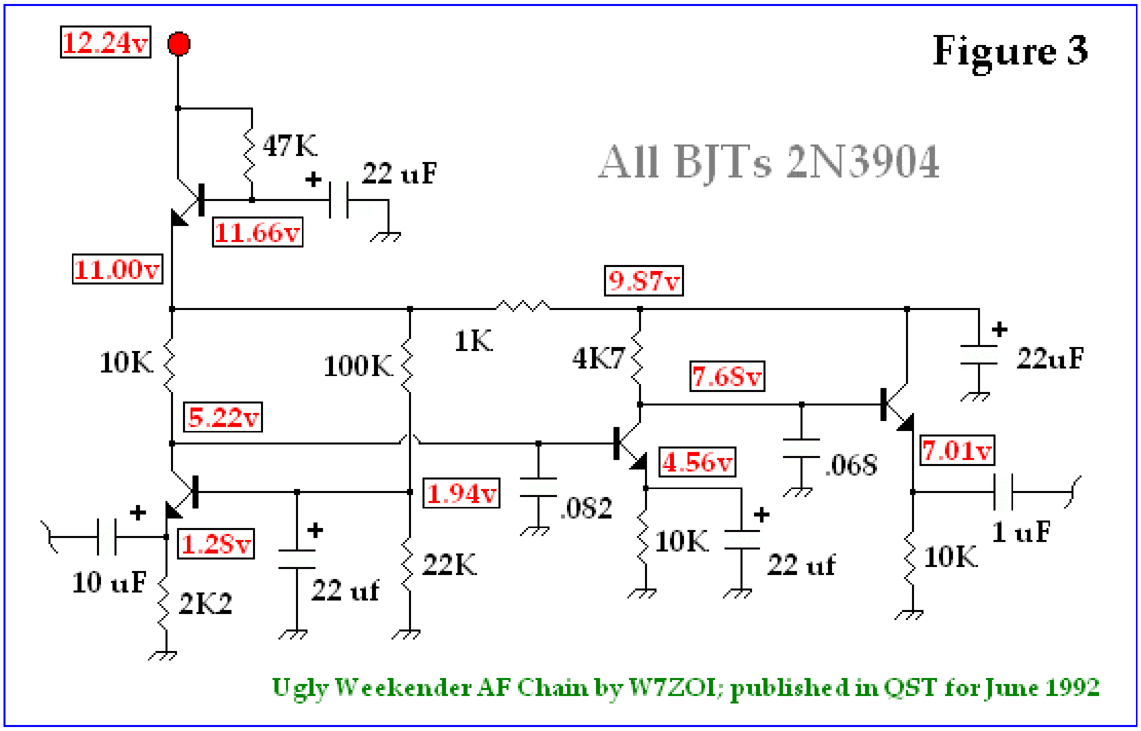
Figure 3
All BJTs 2N3904
12.24v
47K
22 uF
11.66v
11.00v
9.87v
1K
10K
100K
4K7
7.68v
22uF
5.22v
4.56v
.068
7.01v
1.94v
.082
1.28v
10 uF
2K2
22 uf
22K
10K
22 uf
10K
1 uF
Ugly Weekender AF Chain by W7ZOI; published in QST for June 1992

To match the low impedance winding of the audio transformer, a common base amp topology was chosen. I decided to use a favorite circuit; the

audio chain from the first amateur band receiver that I ever built -The Ugly Weekender. The final common emitter feedback amplifier from the original schematic was omitted as the 3 stages above provided enough voltage gain. The Figure 3 amplifier is worth studying. It is difficult to DC couple audio amplifier stages and not end up with your second and/or third stage in saturation. This example of good design by W7ZOI illustrates how to do it. The third stage, a common emitter amp is a level shifter and drops the DC voltage back down, although this stage is AC coupled to the volume potentiometer. For lower noise, you could AC couple the first common base amp to a 5532 op-amp, although, this would reduce the popcorn factor a bit. Do not expect ear blasting voltage gain from this humble circuit. It provides reasonable drive to the power amp stage.
The 0.82 and 0.68 uF capacitors shunt any detected RF energy to ground and also provide some low pass filtering. The original schematic called for 0.1 uF capacitors and which values work the best is yours to decide. Polyester film type capacitors were used in the bread board.

Photographed above is the Figure 3 bread board. You can also see the VFO buffer/amp and the audio transformer. I tried several AF preamplifiers, but preferred Figure 3 to all others.

Audio Power Amplifier

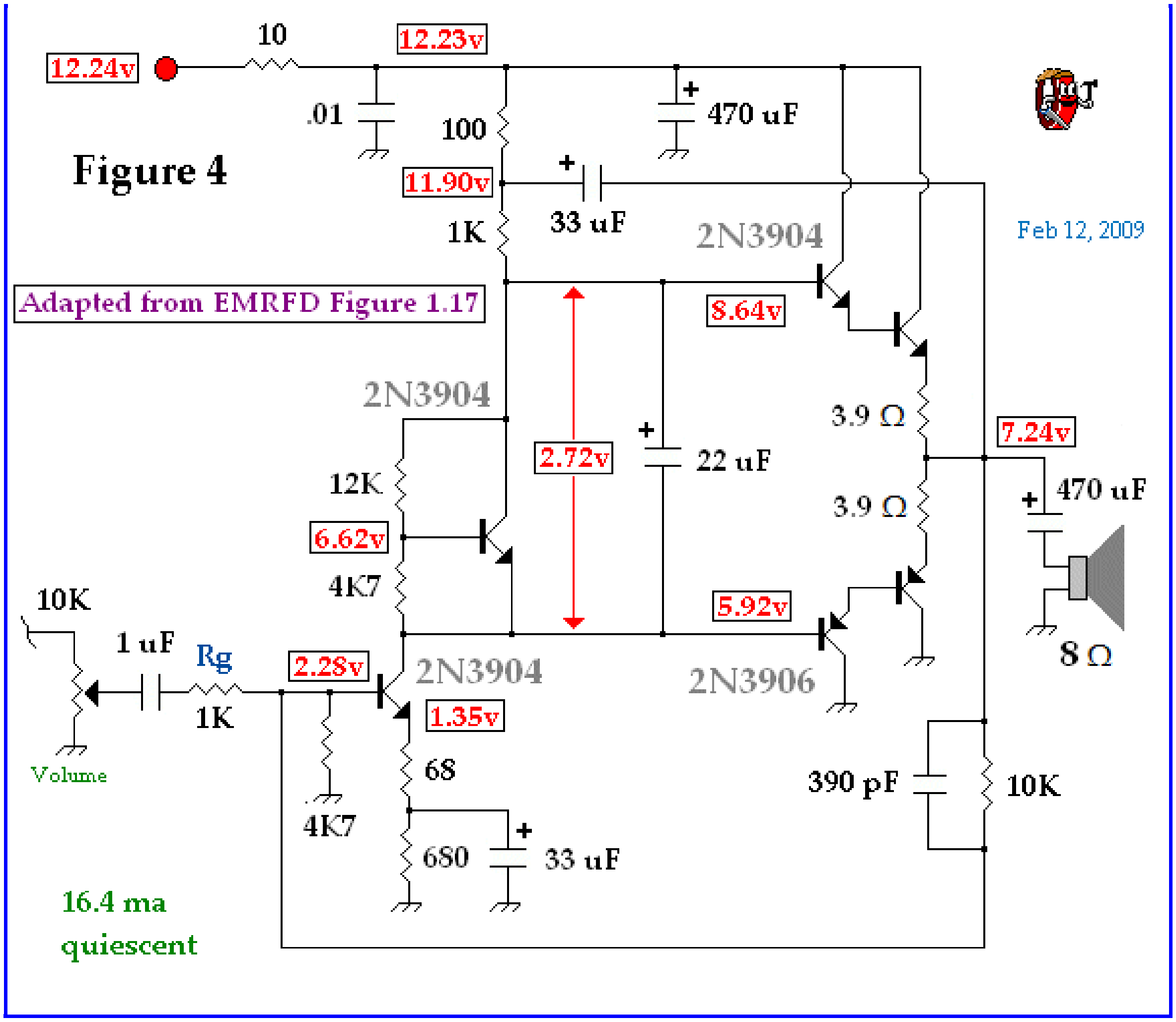
12.24v
10
12.23v
.01
100
470 uF
Figure 4
11.90v
33 uF
1K
2N3904
Feb 12, 2009
Adapted from EMRFD Figure 1.17
8.64v
2N3904
2.72v
22 uF
3.9 Ω
7.24v
12K
3.9 Ω
470 uF
6.62v
4K7
10K
5.92v
1 uF
Rg
2.28v
2N3904
2N3906
8 Ω
1K
1.35v
Volume
68
390 pF
10K
4K7
680
33 uF
16.4 ma
quiescent

Figure 4 provided 3 nights of experimentation. The base circuit for this amplifier was Figure 1.17 from EMRFD. To increase power gain and reduce harmonic distortion, Darlington configured emitter follower pairs were employed. This worked, except the power followers were under biased and had serious crossover distortion. To remedy this, the amplified diode (level shifter) bias was increased until a sine wave was seen on the oscilloscope. This was achieved by replacing the 10K resistor (R6 in the original schematic) with a 4K7 ohm resistor. The next task was to try to increase the voltage gain. Rg in EMRFD Figure 1.17 called for a 3K3 resistor. Rg was dropped to 1K; this worked. The degenerative feedback on the common emitter amplifier of EMRFD Fig 1.17 was also dropped somewhat. Next some bootstrapping feedback was AC coupled to the collector of the main common emitter amplifier. Each of the 2 collector resistor values was changed around and the outcome was recorded. Ultimately the 100 ohm plus 1K ohm resistor series pair was chosen and provided a boost of 0.85 volts peak-to-peak clean voltage gain to the output waveform. The power follower emitter degeneration resistors were also decreased from 22 to 3.9 ohms. The result is a low distortion power amp with about 150 mW of clean average power output. This receiver is not super loud, but it is reasonably loud and the audio is bell clear. If you use this amplifier stage in other projects that have a higher gain pre-amplifier, I recommend keeping Rg at 3K3 ohms as this amplifier will likely exhibit lower distortion characteristics.

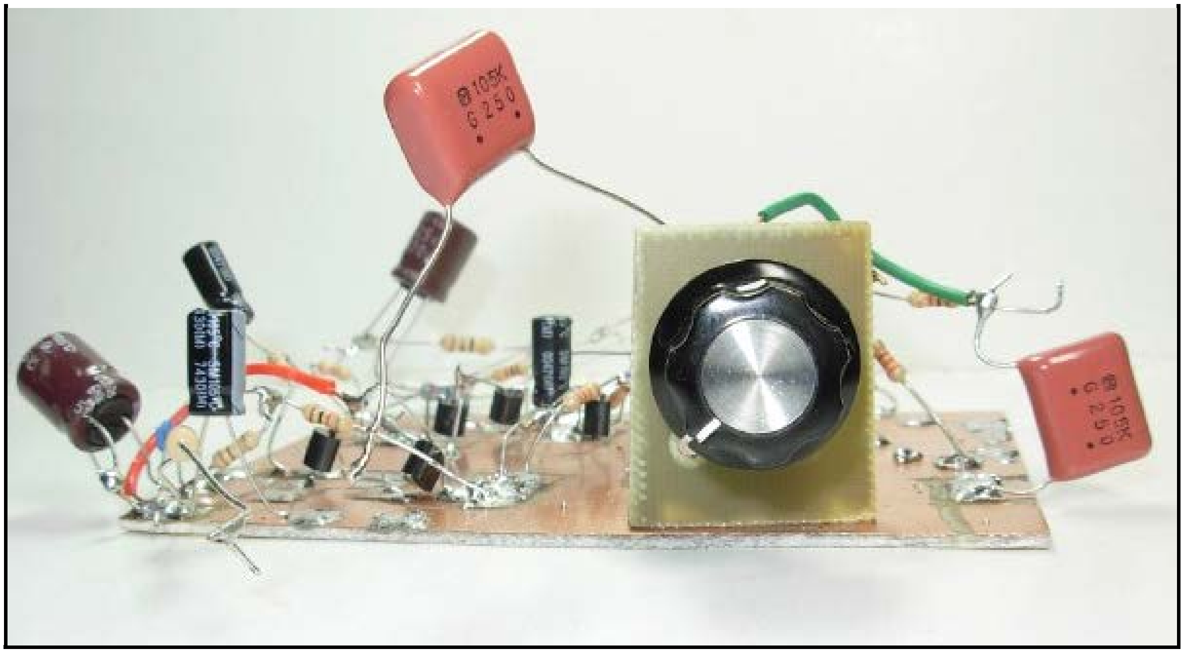

Shown above is the Figure 4 bread board. A 10 ohm resistor was used to decouple this stage. Without the resistor, audio oscillations at around 850 Hz manifested when the volume was greater than about half way up. The voltage drop across the 10 ohm resistor is trivial. You may have to increase this resistor value if you experience instability. Expect all amplifiers to oscillate and decouple them accordingly. The 390 pF feedback capacitor is required. The Figure 4 amplifier exhibits greater gain as frequency increases and in a direct conversion filter with no low pass filtering, this would be very harsh indeed. Feel free to experiment with the value of this feedback capacitor. Kudos to W7ZOI for the EMRFD Figure 1.17 schematic which serves as a great specimen to inform and challenge us experimenters. The original common emitter amplifier (Q1 in EMRFD Figure 1 .17) bias current is perfect and although I tried increasing and decreasing it, I returned to the originally specified bias resistor values.

Additional Outputs

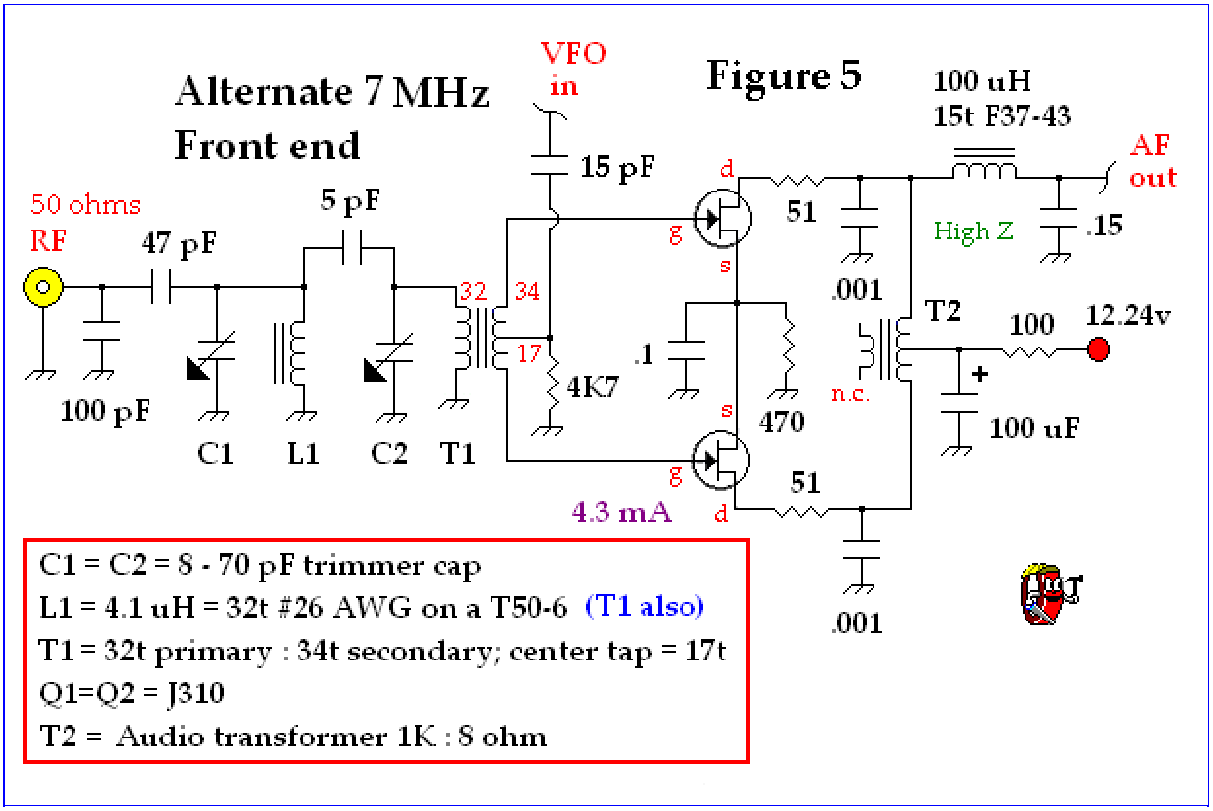
Alternate 7 MHz
Front end
VFO
in
Figure 5
100 uH
15t F37-43
AF
out
50 ohms
RF
47 pF
5 pF
15 pF
d
g
s
51
.001
High Z
.15
100 pF
C1
L1
C2
T1
32
34
17
4K7
.1
470
n.c.
T2
100
12.24v
+
100 uF
s
g
d
51
4.3 mA
.001

C1 = C2 = 8 - 70 pF trimmer cap
L1 = 4.1 uH = 32t #26 AWG on a T50-6 (T1 also)
T1 = 32t primary : 34t secondary; center tap = 17t
Q1=Q2 = J310
T2 = Audio transformer 1K : 8 ohm

Figure 5 depicts the product detector with a high impedance output. From my experiments at least, it was better to use the low Z coil for improved product detector balance and audio voltage gain.

Figure 6

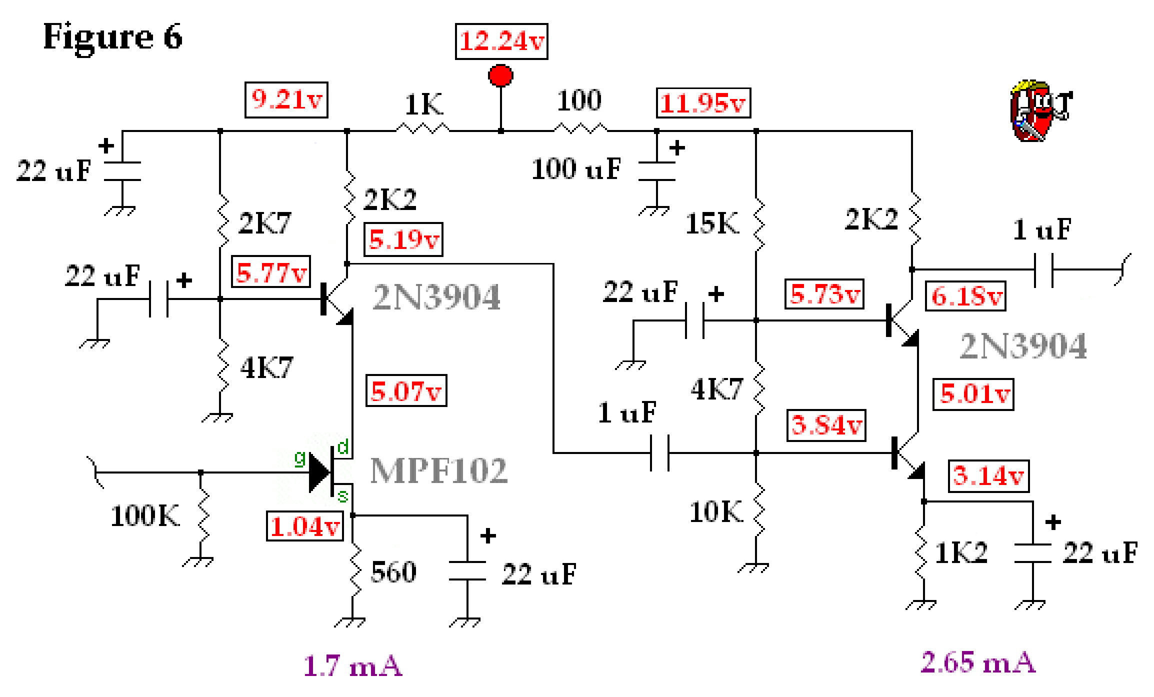
12.24v
9.21v
1K
100
11.95v
22 uF
100 uF
2K7
2K2
5.19v
15K
2K2
1 uF
22 uF
5.77v
2N3904
22 uF
5.73v
6.18v
2N3904
4K7
5.07v
4K7
5.01v
1 uF
3.84v
g
d
MPF102
3.14v
s
100K
1.04v
10K
1K2
22 uF
560
22 uF
1.7 mA
2.65 mA

Figure 6: A high impedance input audio stage. The first stage is a hybrid cascode. The second stage is common emitter, common base cascode. Care was taken with transistor biasing to try to optimize distortion characteristics. Certainly, I am a total novice with such amplifiers and more time on the bench and also with computer simulation is required to better understand these amplifiers. At any rate, the schematics with DC voltages are posted for others to study and hopefully improve.

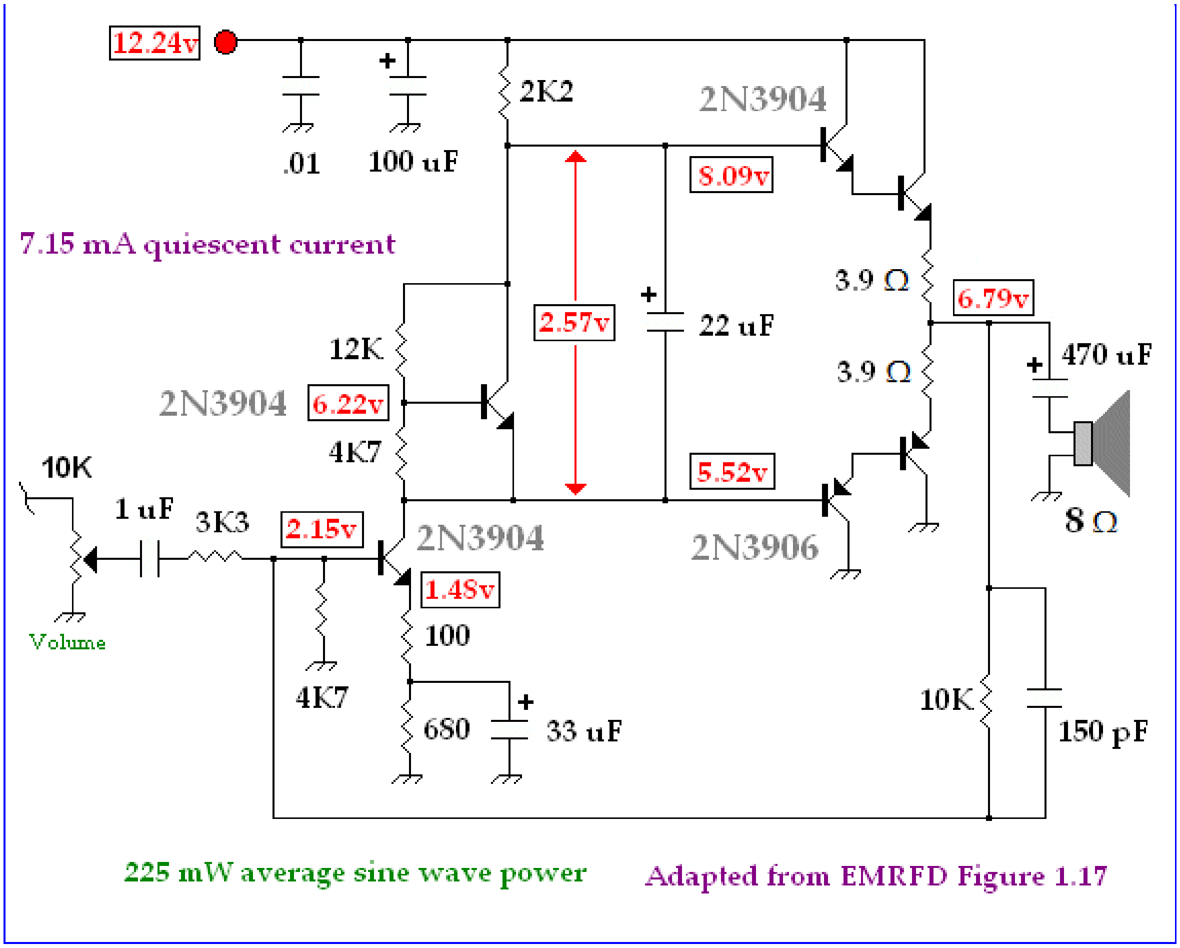
12.24v
.01
100 uF
2K2
2N3904
8.09v
7.15 mA quiescent current
3.9 Ω
6.79v
2.57v
22 uF
470 uF
12K
3.9 Ω
2N3904
6.22v
4K7
10K
5.52v
1 uF
3K3
2.15v
2N3904
2N3906
8 Ω
1.48v
Volume
100
4K7
680
33 uF
10K
150 pF
225 mW average sine wave power
Adapted from EMRFD Figure 1.17

I have 3 adapted versions of the EMRFD Figure 1.17 amplifier in my note book. This is my favorite and has the greatest clean maximum average power output of all of the 3 versions. This power amplifier somewhat lacks sufficient voltage gain for the 2 Bravo receiver (with its relatively low gain audio pre-amplifier) and thus Figure 4 was chosen as the more suitable power amplifier. You could lower the 3K3 resistor to increase the voltage gain. This circuit begs experimentation.

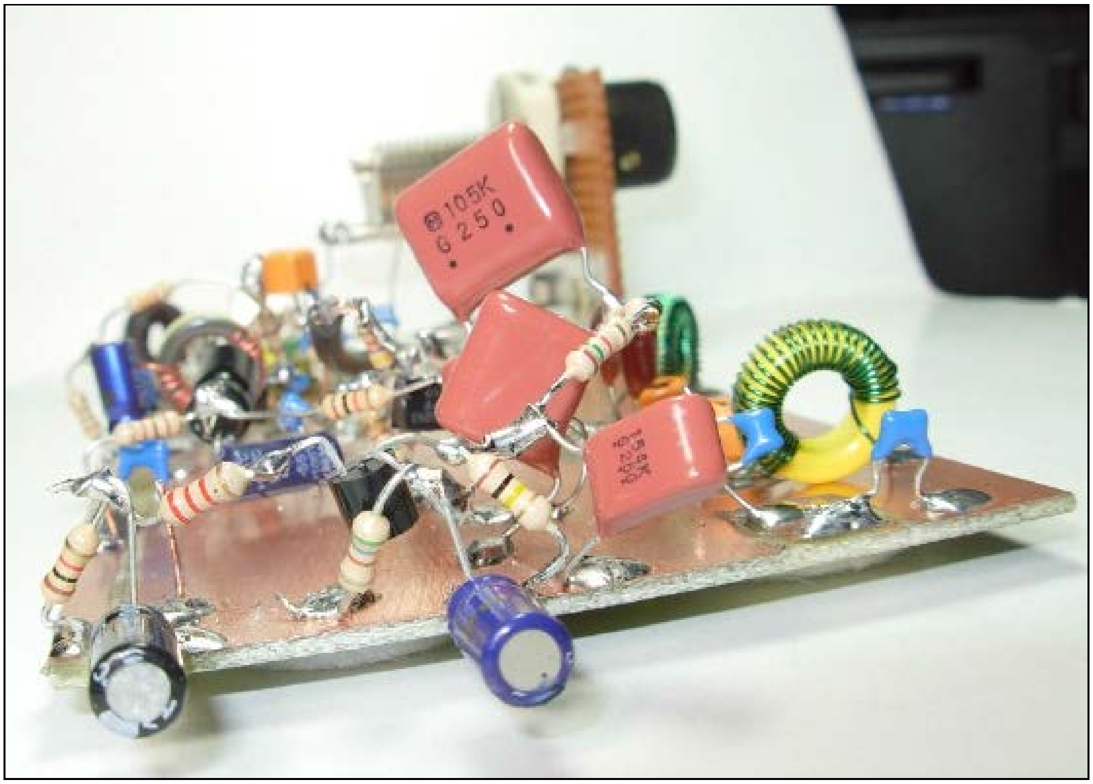
105K
G 250
154K
G 250

A couple of low pass RC audio filters were tried but later abandoned. One filter with its 1 uF AC coupling capacitors is shown in the photo above. It is quite an experience to hear an unfiltered direct conversion receiver. I love the purity. This is okay for an experimental or casual receiver, but not for a contest rig. Low pass filtering is definitely required in that context.

A different angle photo of the VFO bread board. My "build most of the project on 1 copper clad board" construction technique is not really suitable for "a keeper" receiver. VFOs should ideally be in a shielded box. Proper construction techniques and grounding ideas for DC receivers can be found in EMRFD, so they are not covered on this web page.

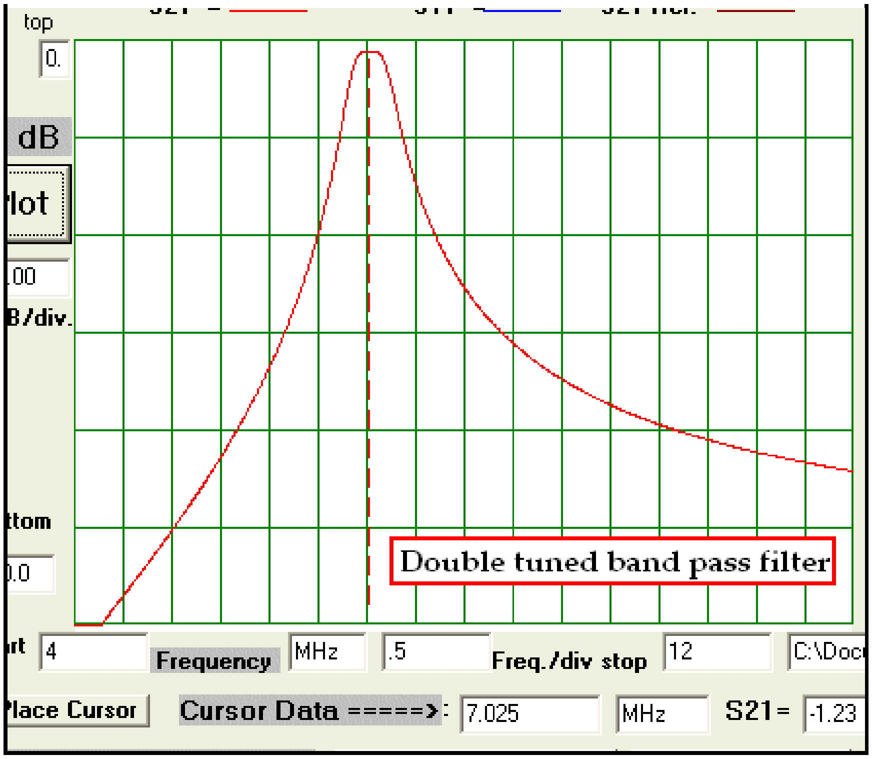
S21 =
S11 =
S21 ref.
dB
lot
Double tuned band pass filter
lace Cursor

top 0.

00 B/div.

ttom .0

rt 4 Frequency MHz .5 Freq./div stop 12 C:\Doc

Cursor Data =====>: 7.025 MHz S21= -1.23

A GPLA simulation of the front end band pass filter centered at 7.025 MHz.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

ICOM IC-7200 Listening Tests and Observations

Introduction

In Spring 2009, I evaluated and photographed the ICOM IC-7200 transceiver. For this web page, only its receiver was evaluated for HAM and SWL purposes by using my eyes and ears. For technical evaluation, please click on these assessments written by Adam, VA7OJ/AB4OJ or Peter, G3SJX . Additionally, eHam.net has a review web page to consult and the ARRL publication, QST for June 2009 has a review. With my modest camera and lighting equipment, it was difficult to well photograph this very dark colored transceiver indoors.

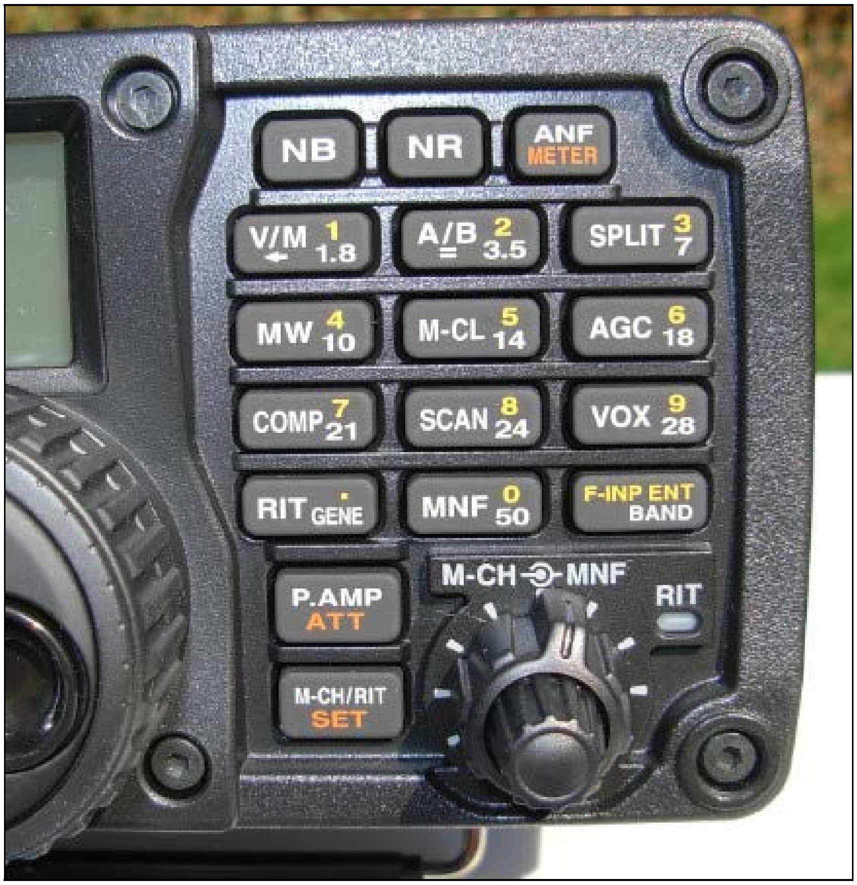
NB
NR
ANF METER
V/M 1 1.8
A/B 2 3.5
SPLIT 3 7
MW 4 10
M-CL 5 14
AGC 6 18
COMP 7 21
SCAN 8 24
VOX 9 28
RIT . GENE
MNF 0 50
F-INP ENT BAND
M-CH MNF
RIT
P.AMP ATT
M-CH/RIT SET

I like ICOM radio equipment and am therefore biased in my review. Please consider trying this and any other radio out before you purchase it. Our needs, expectations and budgets tend to be uniquely different. Like others, I would rather own the new ICOM IC-7600, Yaesu FT2000D or Elecraft K3, however, my budget does not allow this.

It appears that the target audience for this transceiver is as follows: portable or field/emergency communication usage and/or it is oriented towards entry level HAMs or perhaps those wishing a modern DSP-filtered back up rig. My review is from a SWL/HAM perspective.

HF/50MHz TRANSCEIVER
ICOM IC-7200
TWIN PBT
AF-RF/SQL
MIC
PHONES
MODE
TS
TUNER
FILTER
NB
NR
ANF
V/M
A/B
SPLIT
MW
M-CL
AGC
COMP
SCAN
VOX
RIT
MNF
P.AMP ATT
M-CH/RIT SET
M-CH-MNF
RIT

General Thoughts

Although modern and stylish, this radio is very easy to use. The owners manual is well written with clear examples of how to perform the various setting changes. After reading the manual and and trying the radio buttons and knobs out, I pretty much mastered receive operation on my first night. The LCD display is small, however is reasonably adequate considering that this whole radio is compact. I believe some operators will have difficulty with this diminutive display. The S-meter is a little difficult to see. You can push a front panel button which announces the S-Meter reading, set frequency and mode in English or Japanese language if you can't quite see the display at an odd viewing angle.

The VFO knob has adjustable resolution and works well, however, it lacks that silky smooth/weighted feeling of many other radios including the R75 receiver. The ICOM engineers had there work cut out for them; include all the modern interference fighting features; place them in a small chassis; make it easy to use and come in on budget. They did it! This radio is full of useful interference management tools. One example is the (DSP) manual notch filter; it works superbly. There is no FM mode. I imagine by dropping FM mode capability , the designers were able to use the specified 6 KHz roofing filter at the second IF which has the potential to improve dynamic range at close-in signal spacing for some modes. When I started in Amateur Radio many years ago, roofing filters were never mentioned, but have become a huge marketing lever and seemingly a topic of much confusion.

DSP IF Filtering

The DSP IF filtering works very well. Does it function better than more traditional crystal IF filtering? Yes and no. It is a question of compromise for me. The greatest DSP attribute is that there are no expensive crystal filters to purchase. Additionally, you can customize the desired IF filter bandwidth (wide, medium and narrow) for each mode and also set a "hard" versus "soft" filter shape. The soft shape equates less ringing and potentially less listener fatigue than the hard setting. I have never liked listening to CW signals through stiff, 6-8 pole 250-500 Hz crystal filters on any receiver, so for me, adjustable DSP IF filtering is preferable. DSP IF filtering is not perfect as authors like Rob Sherwood, NC0B have presented, however, ICOM have a pretty good DSP platform out now and I am pretty sure their latest technology from the IC-7600/PRO 3 on down have also been used in this receiver. After all, you can always try to find an old Drake and order some crystal filters for it, or spend significantly more cash on a high-end transceiver if you need better performance.

Shown to the the left is a few front panel controls and the front firing speaker. This speaker is reasonably nice sounding. There seems to be less harmonic distortion and audio gain than the R75 receiver. The radio front panel controls are well thought out and seemed intuitive to use after reading the manual and/or just trying them out. The various hardware components such as potentiometers, rotary switches, microphone jack, PL-259 jack etc seem not to be of the highest quality. When you compare such components to that used in their older designs, there is

HF/50MH
ICOM IC-720
TWIN PBT
AF-RF/SQL
MIC
PHONES
MODE
TS
TUNER
FILTER
SPCH

evidence of modern cost containment. I have seen many reviews describing this transceiver as rugged. Certainly the diecast frame is solid, and I hope the forementioned hardware is as well. There is only one antenna connection. I believe that any radio offering the 6 meter band should offer two SO239 antenna connections, however, this likely would have crowded the back panel layout and increased cost for the RF in/out switching.

The VFO knob (shown to the right) looks and feels a little cheap. Functionally, however, the knob spins very well and precise tuning is easy to perform. One of my first tasks was to input various the frequencies I use for both amateur and short wave listening into the (201 maximum) memory slots. This was very easy to do and each memory channel also stores the mode and filter setting.

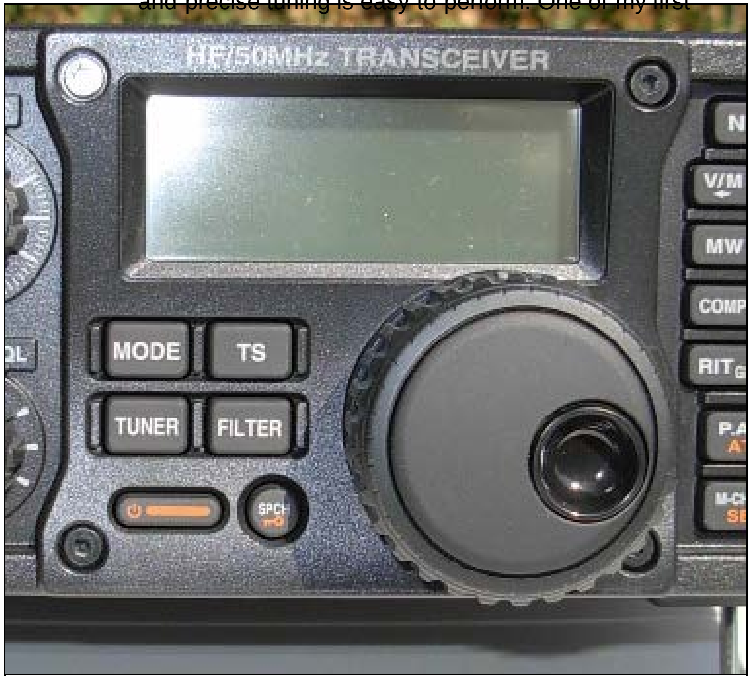

AM Reception (R75 versus IC-7200)

The IC-7200 is a good short wave receiver. With a high quality external speaker connected, pleasant and warm sounding AM audio may be heard; however it is not Hi-Fi. That is; the IC-7200 is not an audiophile AM receiver. There is no synchronous AM detection and no 15 KHz wide IF filter for example. For AM reception, the user may choose from an 8000 to 800 Hz IF bandwidth in the 3 switchable filter settings. During testing, I set my wide filter setting to 8000 Hz, my medium setting to 6000 Hz and my narrow setting to 3000 Hz for AM reception. Of course these bandwidths can be further adjusted at any time. Local MW broadcast radio sounded great with an 8000 Hz IF bandwidth during testing. The various AM reception appropriate interference controls such as pass band tuning (PBT), automatic notch filter (ANF) and digital noise reduction are all configurable or adjustable and I found the ANF and digital noise reduction helpful when listening on the crowded 49 meter band during a rain storm.
I performed A/B comparisons with the IC-7200 and the R75 simultaneously hooked to the same antenna. For AM reception, they are comparable with the R75 having marginally better sounding (more Hi-Fi) audio. I had the R75 IF filter bandwidth set at 15 KHz and the IC-7200 IF bandwidth set at 8 KHz (both at their maximum IF bandwidth).

CW/SSB Reception (R75 versus IC-7200)

In CW mode, both were set to have a 500 Hertz IF bandwidth.(The R75 had the FL-100 model 500 Hertz crystal filter in its 9 MHz IF slot). The IC-7200 was quieter, clearer and less overloaded by adjacent stations during pile ups. There were occasionally weak signals I was able to copy on the IC-7200 that I could not even hear on the R75 due to noise. The IC-7200 is a joy to use on CW; really fantastic.
On SSB, I found both receivers fairly comparable, but the IC-7200 was better for pulling weak signals out of the noise as the noise floor was a little quieter and the audio a little more crisp. My wife also agreed with me in her "independent tests" of the CW and SSB reception. I am certain to catch flak because my subjective comments are based upon listening tests and not measurements. It is interesting to note that in almost every aspect of our lives, preferences are made using 1 or more of our 5 senses. From listening, observing and also reading the reviews of others, it seems ICOM has a hit with the IC-7200.

Mouse over the images below left to view a full size photograph

The IC-7200 in the sun.

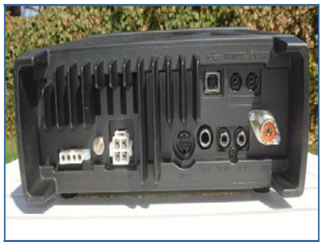

Rear view of the transceiver.

Top angle view. There are ventilation holes at the top right hand side. You can just see the ventilation screen just next to the right top panel screw.

Reverse angle top view. The military look is attractive.

The IC-7200 and R75 side by side.

Another photograph of the 2 radios from the front angle for comparison. The LCD display size difference is quite obvious in this shot.

The receivers at a right angle. The IC-7200 is a glad update, although, I would likely not upgrade from the R75 to the IC-7200 just for receiving purposes. If I was considering choosing the IC-718 (transceiver version of the R75), the IC-7200 is worth the extra money. It is also an excellent transceiver consideration for an entry-level rig, for back up purposes. or for the budget-minded operator.

Conclusion

The IC-7200 is a serious choice for amateurs seeking a good, modern HF plus 6 Meter transceiver. It is more than adequate as an SWL receiver if you are an amateur radio operator plus SW listener like myself. Please try one out for yourself if you are considering this transceiver.

Amateur Radio Electronic Design

Electronic Hobbyist Circuits

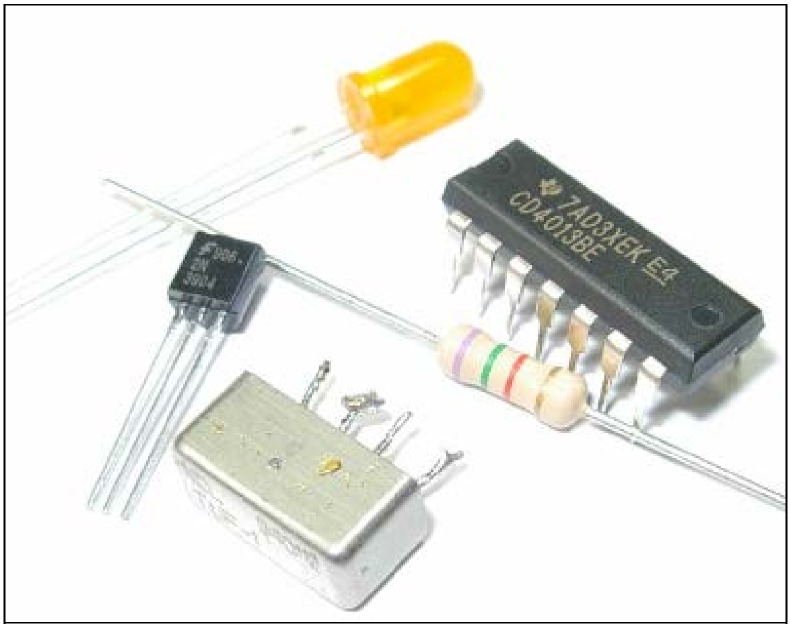

This page will house a collection of brief hobbyist experiments.

1. Pseudo-Random Number Generator

This circuit describes a simple, 6-bit random number pseudo-generator used to study binary counters and in particular, shift registers. Some very basic background information about binary counters and shift registers is provided. In reality there are dozens of different shift register topologies available and it can get quite complex. If you wish to find a good logic tutorial website, I strongly recommend Ken Bigelow's site as it has interactive diagrams. Flip-flops are also covered well on wikipedia and many other web sites.

Binary Counter: The circuit most often used as a counter is called a binary flip-flop. The basic flip-flop can be viewed as a toggle switch having either an ON or OFF position. This is the binary state 1 (HIGH) or 0 (LOW). Like the toggle switch, the binary flip-flop has 2 binary states 1 or 0. A binary flip flop counter counts in a sequence such as 0, 1, 0 ,1 etc. A straight binary counter can be built by using 1 or more flip-flops connected in a manner that the binary number stored in these flip-flops will represent the total number of trigger pulses received at the counter input.

Ring Counter: A ring counter has 2 or more flip-flops cascaded so that the output from one flip-flop becomes the input of the next flip-flop. The flip-flops are connected so that all of their outputs are at the binary state 0 except for one flip-flop. By pulsing the input of the ring counter, it will sequentially change the binary state of the succeeding flip-flop from binary 0 to binary 1. The flip-flop that contains the binary 1 indicates the count of this binary counter. The maximum number of pulses that can be counted by N flip-flops is N pulses.

Shift Register: A serial entry shift register is similar to a ring counter, except that the output flip-flop is not connected to the input flip-flop. Like the ring counter, the flip-flops are cascaded so that the output from one flip-flop becomes the input of the next flip-flop. All the set trigger and reset trigger inputs are tied together to form what is called a shift bus. Clock pulses are applied to the shift bus to cause the stored binary information to shift from left to right; one bit position per each received clock pulse. In Figure 2, this serial input/output + parallel output register has its 5th and 6th bits exclusive ORed to the serial input to form a pseudo-random sequencer, which is called a pseudo-random number generator by some.

The CMOS logic ICs used were one 4070 XOR (Exclusive OR) and three CD4013B D flip-flops. Junk box LEDs were used to observe the binary state of the clock and each of the 6 bits of the shift register.

Figure 1

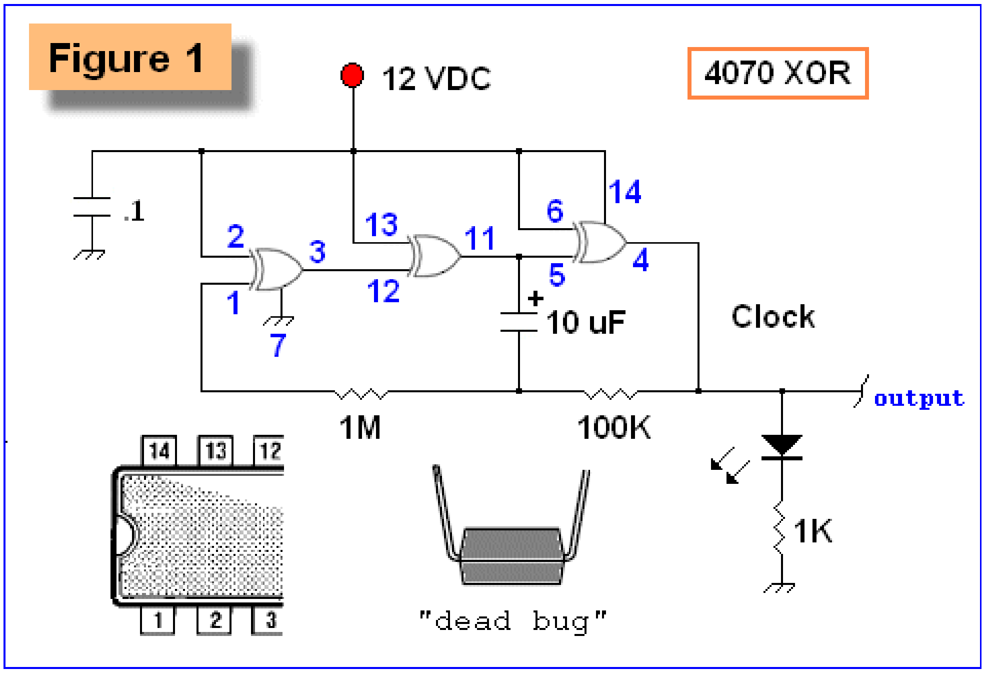
12 VDC
4070 XOR
.1
2
3
1
7
13
12
11
6
14
5
4
+
10 uF
Clock
output
1M
100K
1K
14
13
12
1
2
3
"dead bug"

Since only one XOR gate is needed for the shift register, the remaining gates were configured to make the clock. These gates are essentially wired up as inverters to form an astable multivibrator with a frequency of about 0.45 Hertz or 27 pulses per minute. Shown above in Figure 1 is the clock schematic and the pin 1 marking for all of the digital ICs on this web page. The output LED is not mandatory, but will instantly tell you whether or not your clock is working. I built this whole circuit using Ugly Construction with the ICs flipped upside down in a "dead bug" fashion. You can increase the clock speed by decreasing the 100K resistor or the capacitor values. F Hertz = 1/ (2.2 * R * C) with R in ohms and C in farads. The slow clock speed was chosen to better observe the digital output of the shift register.

Figure 2

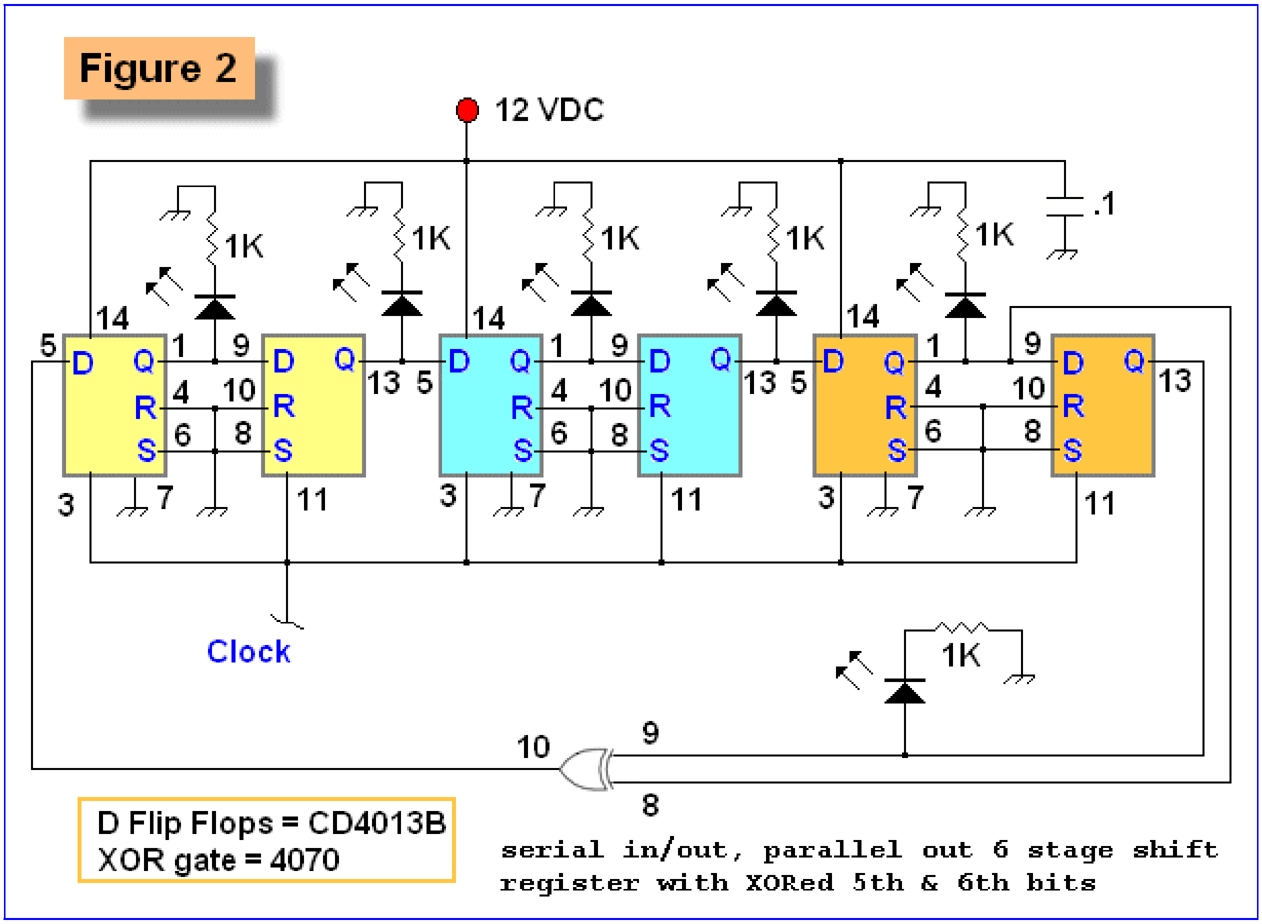
12 VDC
1K
1K
1K
1K
1K
.1
14
14
14
D
Q
R
S
5
1
9
4
10
6
8
3
7
11
13
Clock
1K
10
9
8
D Flip Flops = CD4013B
XOR gate = 4070
serial in/out, parallel out 6 stage shift register with XORed 5th & 6th bits

In Figure 2 is the shift register. Each 4013 was wired up as 2 cascaded flip-flops and connected to the clock. Power was applied and then a test lead was used to bring pin 5 of the first flip-flop HIGH (connected to 12 volts for 1-2 seconds) . Both flip-flop state monitor LEDS turned ON in sequence with subsequent clock pulses. Afterwards, pin 5 was set LOW (shorted to ground with a test lead for a couple of seconds) and each LED turned OFF in sequence with subsequent clock pulses. The remaining two 4013s were wired up and tested the the same way and then finally the last XOR gate was wired up.

To avoid error, frequent pin counting and a systematic approach is recommended. For example, for each 4013, I soldered the ground pins, wired the pin 14 VDD, connected the clock to pins 3 and 11, then wired up the pin 1 and pin 13 LEDs. Systematic construction techniques are something that you the experimenter can develop and perfect over time. This approach saves time and grief. On some projects, when you have a lot of pins wired up, tracing and repairing an early mistake can be difficult.

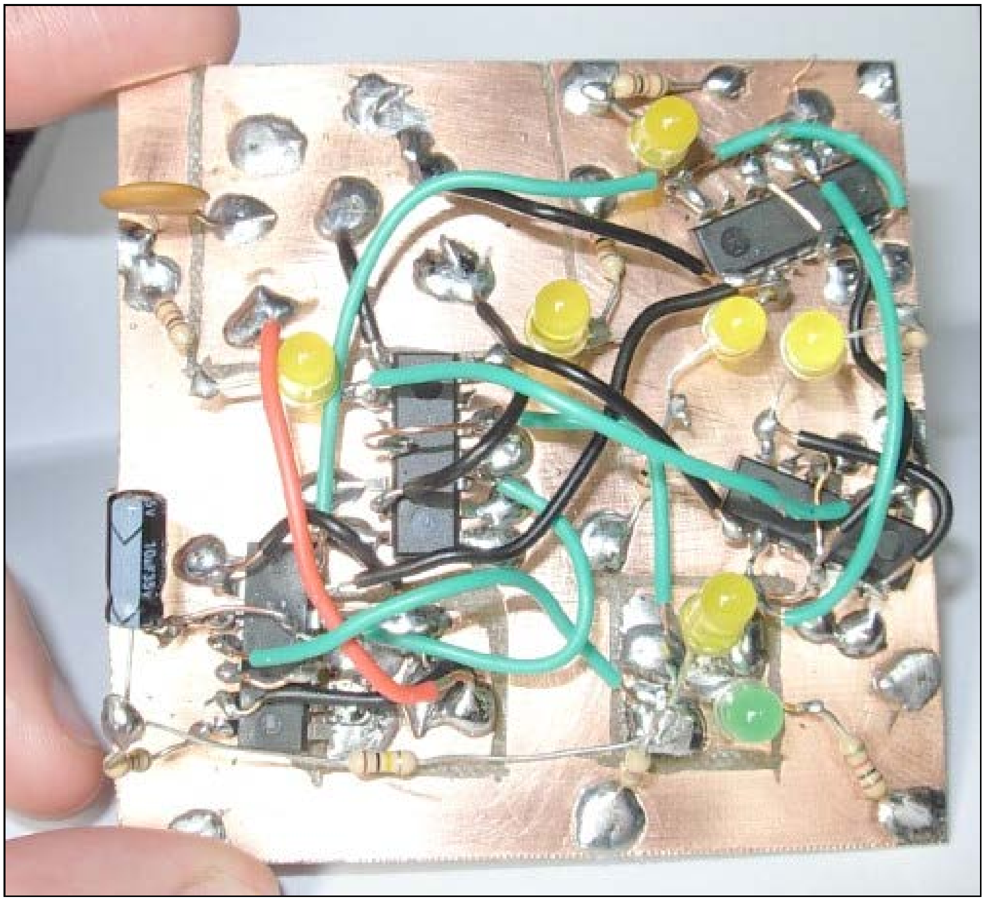

Shown above is a bread board of the entire pseudo-random number generator. I just built in on a scrap of board and did not lay it out so the LEDs were in a row, as I am not going to keep this project. The clock state monitor is the green colored LED. There are 63 possible states or combinations of the 6 bits (111000, 100110, 100101, 000101, 000001 etc.) State 000000 is disallowed and will hang up the shift register. If your clock LED is flashing and no shift register LEDs are lit, then "reset" by momentarily setting pin 5 of the first flip-flop HIGH (momentarily apply 12 volts). Long live the reset switch!

Pseudo-random numbers are now mostly generated by computer microprocessors controlled by software and have applications in cryptography, electronic music, security and many other applications. This "hardware" pseudo-random number generator experiment was really cool and if you want to randomly flash some LEDs, this could be the project to use!

If you are new to digital electronics; (like me) Welcome! Starting small with projects like this one will hopefully lead to increased confidence and problem solving skills for even bigger projects. You can also build the shift registers with J-K flip-flops, but it is more difficult and 4013s or other series D flip-flops are cheap as Борщ (borscht).

Figure 3

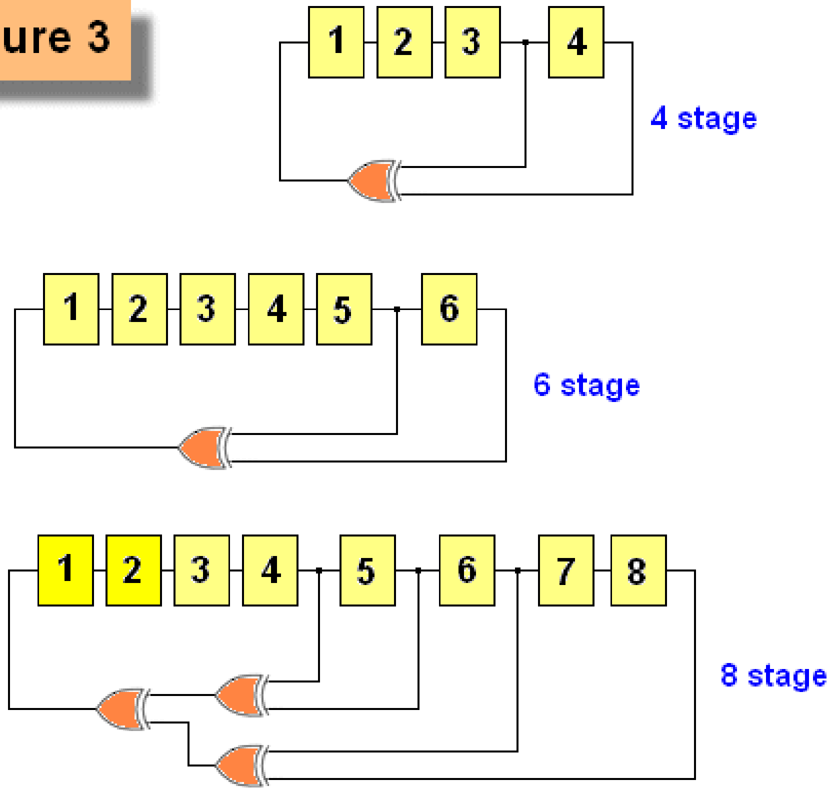
1
2
3
4
4 stage
1
2
3
4
5
6
6 stage
1
2
3
4
5
6
7
8
8 stage

Shown above in Figure 3 is how to hook up the XOR gate(s) for 4, 6 and 8 stage pseudo-random number generators. The 6 stage shift-register is of course, Figure 2 above and is presented for reference purposes. The 8 stage version = 1 byte.

2. One Hertz Precision Time Base

Digital clocks are very interesting. In the past 6 months, 10 -15 RC clocks have been constructed and tested. RC oscillators in the KHz to Hertz range are surprisingly frequency stable. For many projects, a plain RC clock is adequate, however, like in radio design, a crystal controlled time reference is sometimes required. Two examples of projects requiring precision clocks are time of day clocks and frequency counters. Presented is a 1 Hertz clock built from two 4000 series CMOS Logic ICs. Here is a great 4000 series tutorial with pin outs and more.

Figure 4

One Hertz Clock

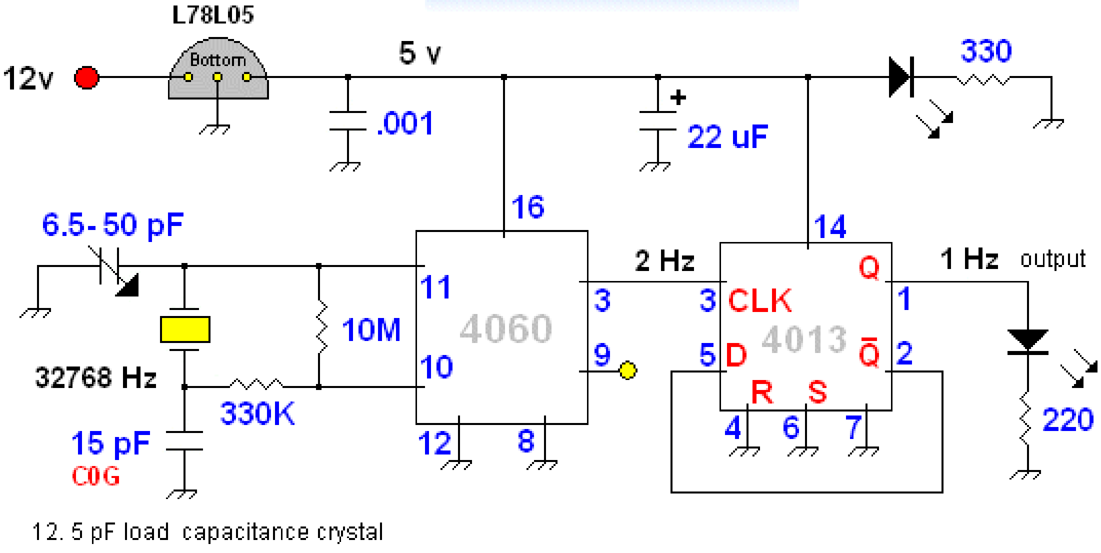
L78L05
Bottom
12v
5 v
.001
22 uF
+
330
6.5- 50 pF
16
14
2 Hz
1 Hz output
11
4060
10M
10
3
9
12
8
3 CLK
5 D
4013
R
S
Q
Q̄
1
2
4
6
7
32768 Hz
330K
15 pF
C0G
220
12. 5 pF load capacitance crystal

Shown above in Figure 4 is the complete schematic with an output LED for testing. In the past, the MM5369 17 Stage Oscillator/Divider was popular for hobbyist precision time bases, however, it has gone obsolete. The 4060 ripple counter is a good "modern" replacement, although a different crystal is required. A 32768 Hertz crystal was used and is divided 16384 times to provide a 2 Hz output. The 4060 then drives a 4013 D Flip-flop configured as a divide by 2 to provide a 1 Hz output frequency. Key parts references may be found on the Webmaster's page.

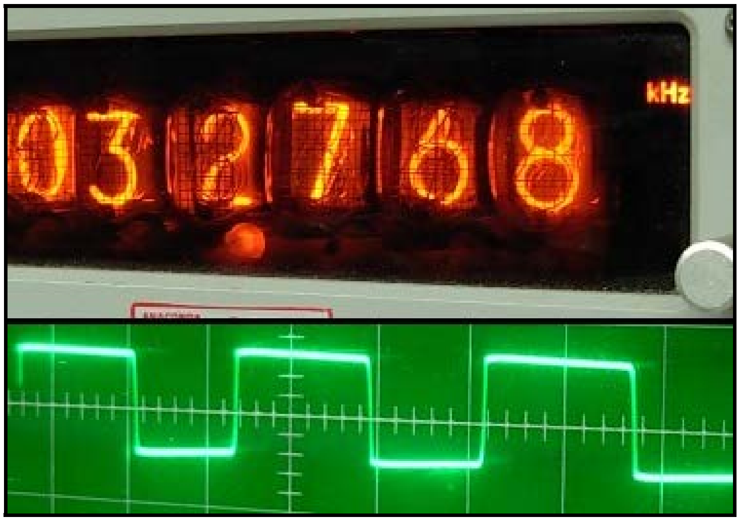

Shown above is the frequency and output waveform when a frequency counter and oscilloscope are (respectively) connected to pin 9 of the 4060 in Figure 4. The 6.5-50 pF trimmer pot is used for calibration. Originally, I used a trimmer cap instead of the fixed 15 pF capacitor shown between the 330K resistor and the crystal. After adjusting this trimmer capacitor for the best looking waveform, I removed the trimmer cap and measured it at 13 pF. I substituted the nearest standard value I had in my parts collection; 15 pF. It was interesting to measure the 4013 output frequency at 1 Hz.

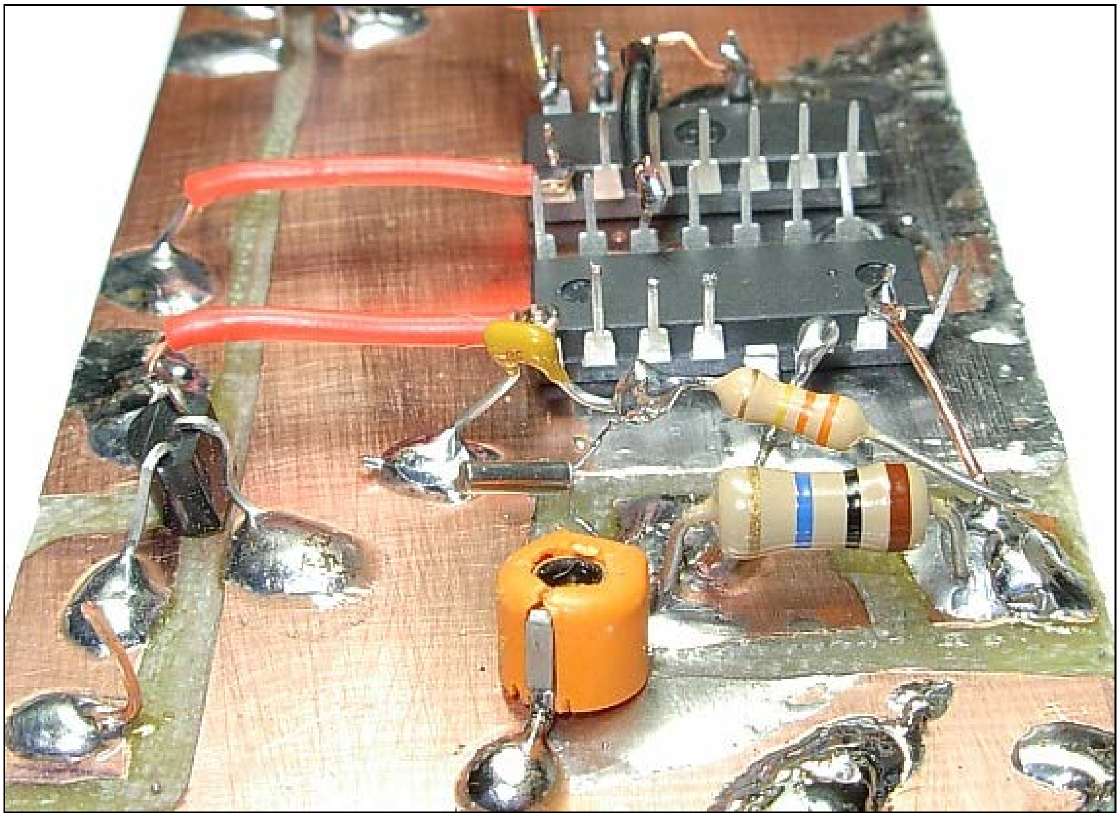

A close up photo of the 4060 oscillator/divider breadboard. The 10M resistor used was a 1/2 watt rated R as I have dozens of these in my parts collection. You can see the tiny cylindrical crystal just above and left of the orange Murata trimmer capacitor. It is oriented horizontally. This is a useful time base for the QRP workshop.

3. 10000 and 5000 Hz Multivibrator Clock

It is fun to occasionally build circuits using discrete semiconductors rather than with ICs. A 5000 Hz digital clock was needed for an experiment. It was decided to use multivibrators for the basic oscillator and a divide by 2.

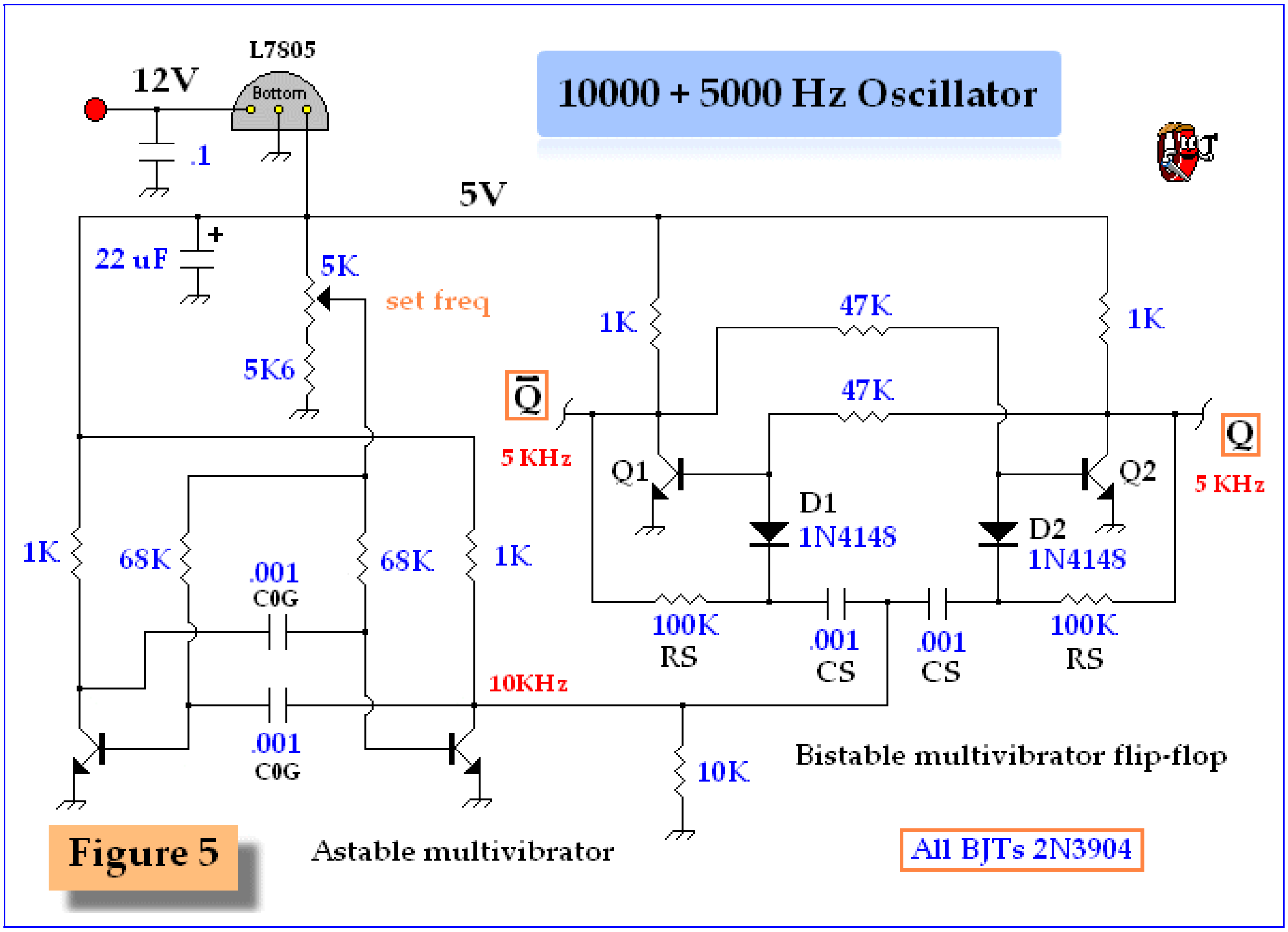

Figure 5

Figure 5 is the entire circuit. The tuning range of the astable multivibrator was about 7060-10650 Hz. The 5K pot was slowly adjusted until 10000 Hz was measured in a frequency counter. Following testing of the astable multivibrator, the flip flop was built and examined. Astable multivibrator function has been discussed previously on this web site.

Please refer to the bistable multivibrator. It is a one input circuit set up for toggle or flip-flop operation. Negative edge pulses applied between the two 0.001 capacitors will cause the binary state of Q1 and Q2 to change to the opposite state. The multivibrator circuit is made up of Q1, Q2 and the 47K and 1K base and collector resistors respectively. The other components D1, D2, the RS resistors and CS capacitors comprise a steering circuit to generate the proper response to the negative edge pulses. When a negative input pulse arrives, it is guided to the base terminal of the ON transistor, but prevented from reaching the base terminal of the OFF transistor.

In order to study this circuit at DC, I temporarily exchanged the 0.001 timing capacitors in the astable multivibrator with some 22 uF electrolytic caps to slow it down. Referring back to the bistable multivibrator, let us assume that Q1 is OFF and Q2 is ON. The collector voltage of Q1 is high (cut off). The collector voltage of Q2 is low (saturation). The Q1 collector is connected to the cathode of D1 by the 100K RS resistor. The cathode of D1 is reverse biased by the high Q1 collector voltage and also because its anode is held close to 0 volts by the 47K resistor connected to the collector terminal of Q2. It would take a very strong negative input pulse to forward bias D1 enough to reach the Q1 base terminal. The Q2 collector voltage is nearly 0 volts and therefore the D2 cathode has little to no reverse bias voltage via its RS. Thus, any small amplitude negative input pulse will cause D2 to become forward biased, reach the base of Q2 and drive Q2 OFF. Once Q2 switches off, in turn Q1 is toggled ON and its collector voltage goes low. The large reverse bias on D1 disappears. However, Q2 is now OFF and D2 will now be strongly reverse biased which will steer the next negative input pulse to the base of Q1. This is the basis of the circuit's negative edge flip-flop operation.

In another experiment, I changed the .001 C0G capacitors of the astable multivibrator to 470 pF. This gave a usable range of 22968 to 14832 Hertz (11484-7416 Hz at the Q1 and Q2 output) . Looking at the output of the flip-flop in the oscilloscope; at the higher frequency range, the flip-flop could not keep up and failed to divide by 2. I found experimentally that the time constant of each of the CS and RS components seemed to be the problem. When the CS capacitors were also decreased to 470 pF, the flip-flop worked properly.
As you increase the flip-flop operation frequency, speed up bypass capacitors might also be required across the 47K base resistors of Q1 and Q2 . A suggested starting value to try is 220 pF. Some builders also bypass the resistors in the RS steering circuit at higher frequencies, however, this is getting a little crazy. It is really important to look at the output waveform in the oscilloscope to ensure reasonable performance.

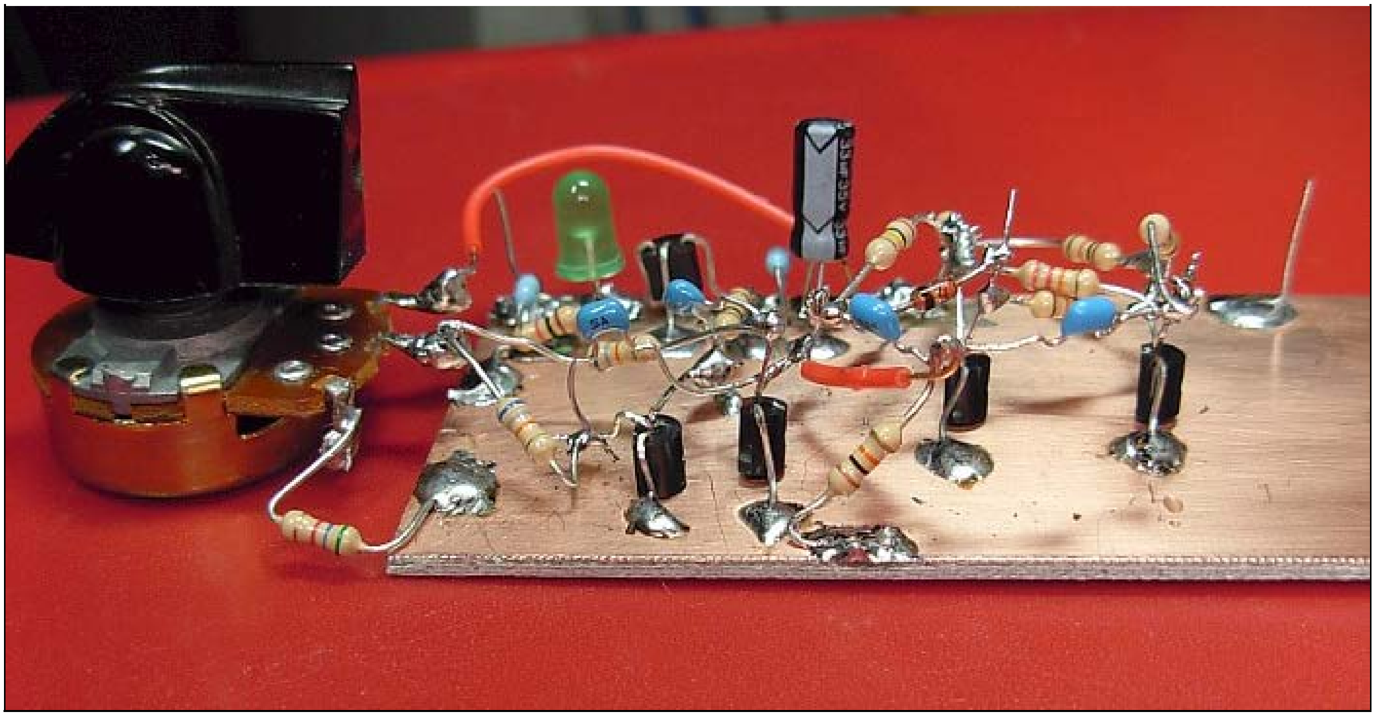

Shown above is the Figure 5 breadboard prototype.

Figure 6

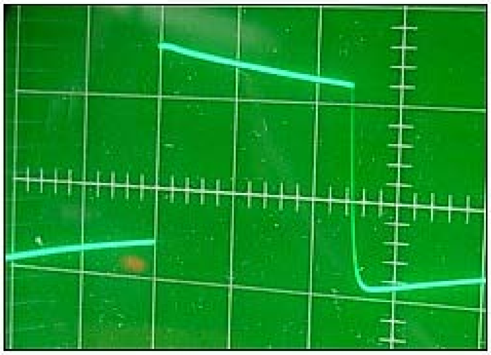

5 KHz output waveform of Q2

4. One KHz Digital and Analog Oscillator

A 1 KHz oscillator with 5 volt digital outputs 180 degrees apart and an analog output was sought. The frequency had to be near to, but not exactly 1000 Hertz. A major question to answer was how much low pass filtering is needed to remove the odd harmonics from digital circuits?

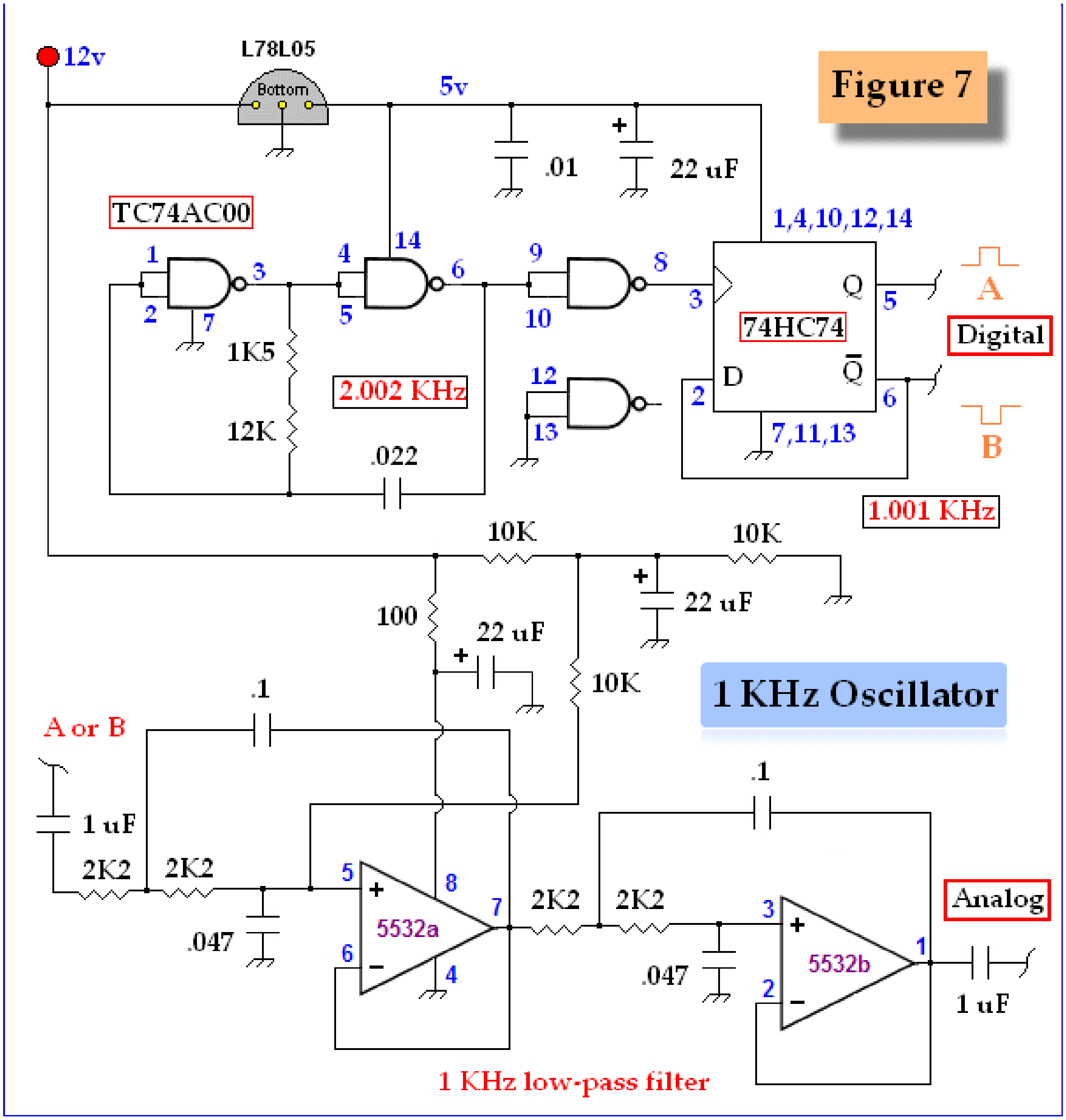
12v
L78L05
Bottom
5v
Figure 7
.01
+
22 uF
TC74AC00
1
2
3
7
4
5
14
6
9
10
8
1,4,10,12,14
3
74HC74
Q
5
A
Digital
D
Q̄
2
6
B
12
13
7,11,13
1K5
12K
2.002 KHz
.022
1.001 KHz
10K
10K
+
22 uF
100
22 uF
+
10K
1 KHz Oscillator
A or B
.1
1 uF
2K2
2K2
.047
5
8
7
6
4
5532a
2K2
2K2
.047
.1
3
2
1
5532b
Analog
1 uF
1 KHz low-pass filter

Figure 7 shows the complete schematic. NAND gates from a 74AC00 were wired as inverters and with the 13.5 K resistance and a 0.022 uF polyester capacitor, the frequency was 2002 Hertz. To improve the digital waveform and get the desired 2 outputs, a D flip-flop was used. The output frequency was 1001 Hertz. The digital part was completed!

For the analog filtering, active low-pass filters were tried, and in total 4 poles with a 1 KHz cuff off worked reasonably well. The filter uses the 5532 op-amp with common vales capacitors and resistors. Poly"something" caps were utilized.

Figure 8

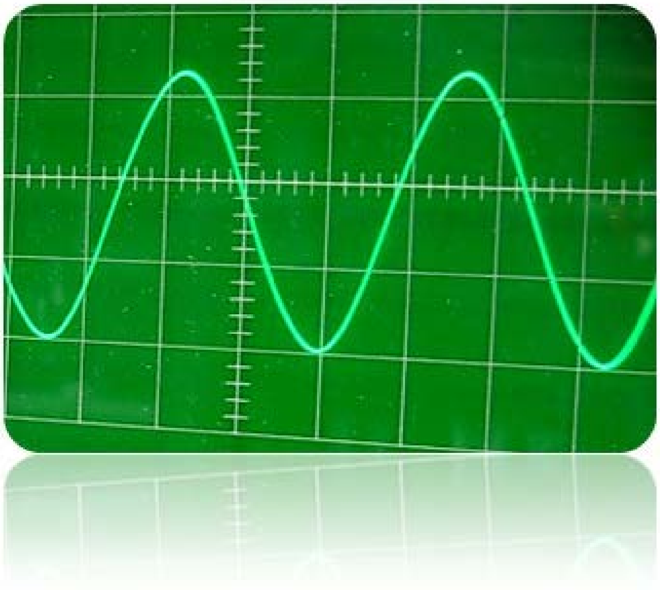

In Figure 8 is the output waveform of the low pass filter stages. A pretty nice sine wave was achieved and this oscillator could see duty for testing audio amplifiers. The scope was photographed at an angle to avoid the camera reflection and this distorts the sine waves a little.

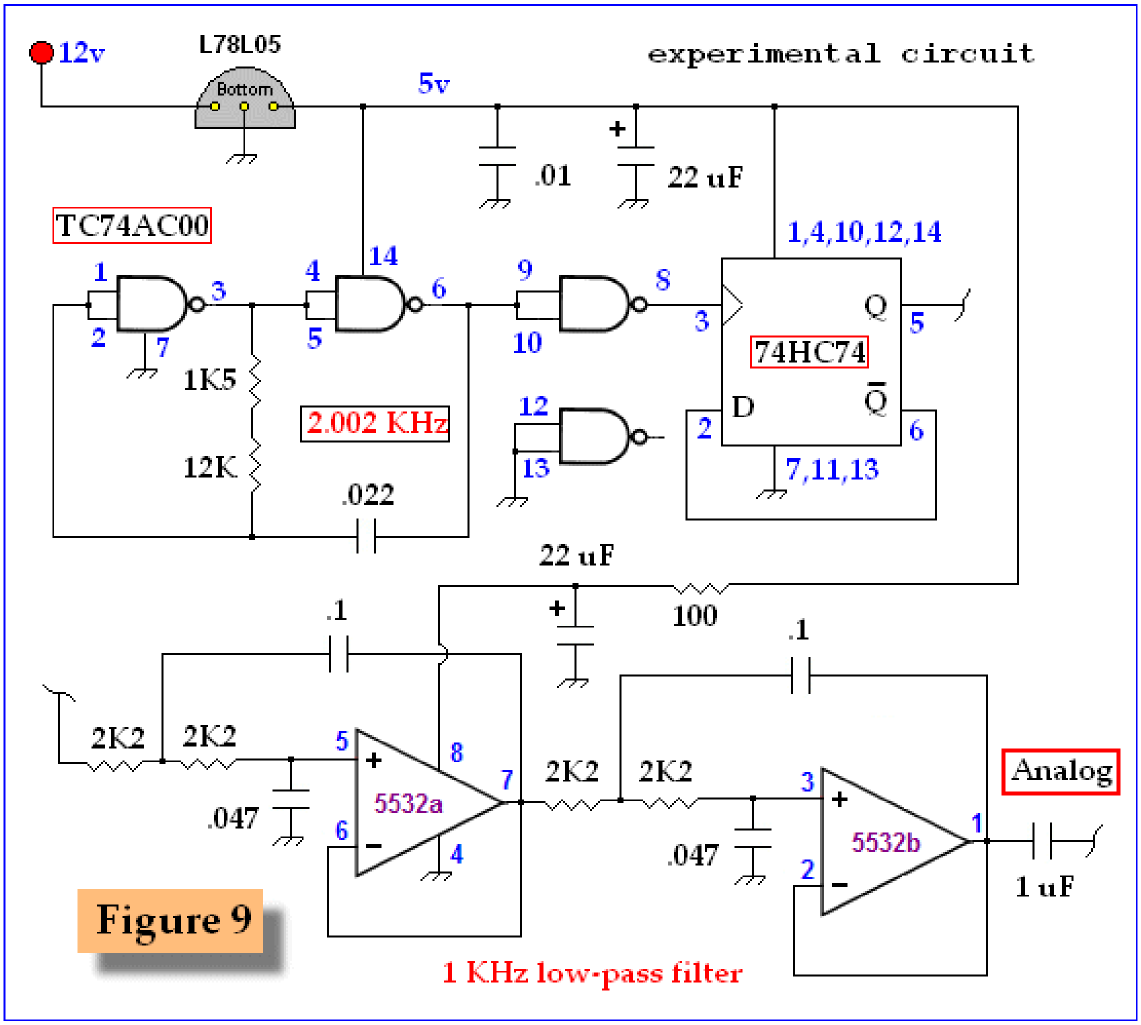
12v
L78L05
Bottom
5v
experimental circuit
.01
22 uF
TC74AC00
1,4,10,12,14
1
2
3
7
4
5
14
6
9
10
8
3
Q
5
74HC74
D
Q̄
2
6
12
13
7,11,13
1K5
12K
2.002 KHz
.022
22 uF
100
.1
.1
2K2
2K2
5
8
7
6
4
5532a
.047
2K2
2K2
3
2
1
5532b
.047
Analog
1 uF
1 KHz low-pass filter

Figure 9

Figure 9 depicts an experiment with the op-amp biasing. If the op-amp is run at 5 volts VCC, the bias requirement is 1/2 VCC or 2.5 volts. The DC voltage at the output of the D flip-flop was 2.55 volts. The 2K2 resistor was connected directly to this output and this eliminated the VCC/2 resistor bias network and a coupling capacitor.

Figure 10

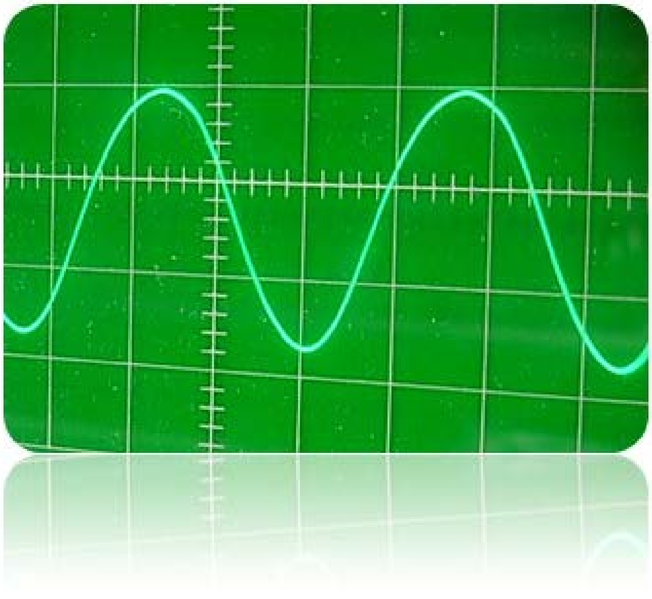

Figure 10 shows the output waveform of Figure 9. The AC waveform has harmonic distortion and thus the Figure 9 circuit will not be kept nor utilized.

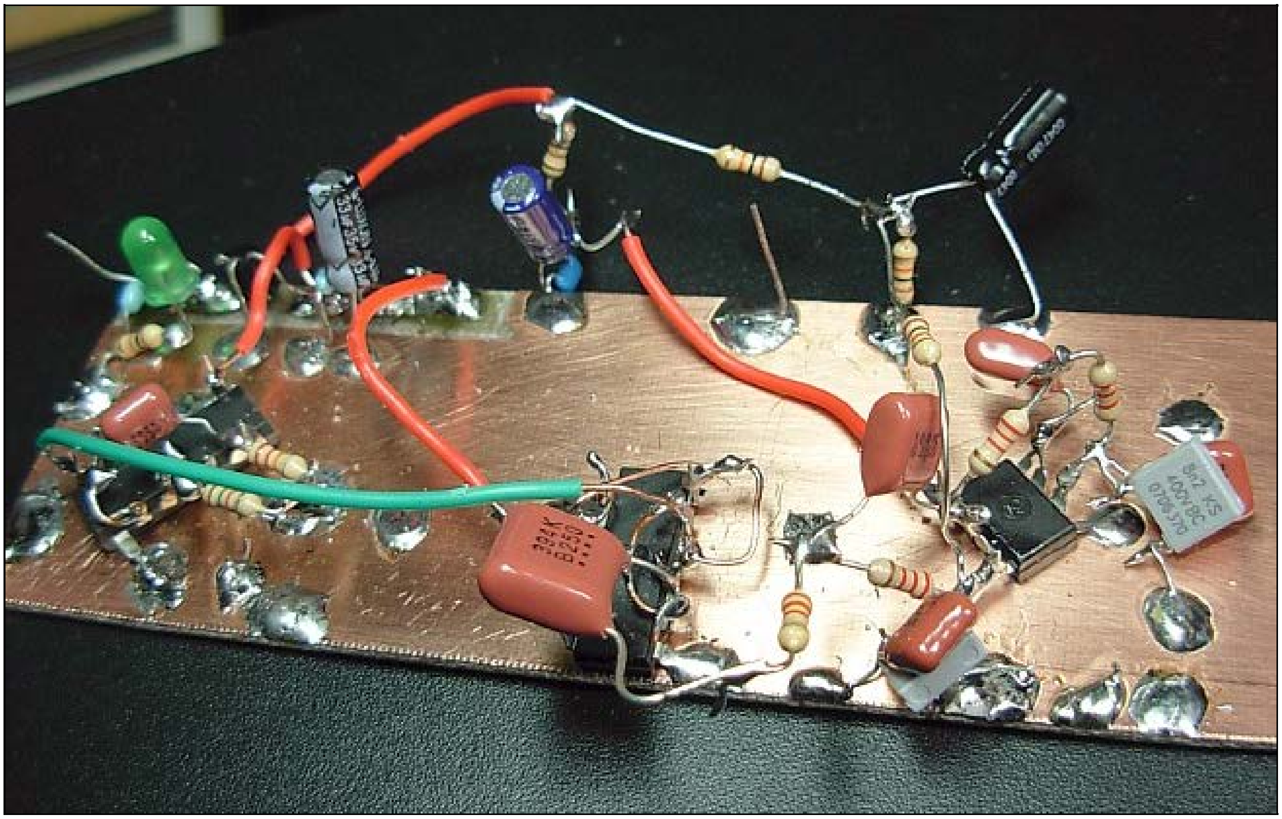

The Figure 7 breadboard. A 0.39 coupling capacitor (not 1 uF) was used between the D flip-flop and 5532a in this particular version. Unfortunately, no 0.047 uF caps were available for the low-pass filters and therefore a 0.039 plus a 0.0082 were placed in parallel for each of the .047 uF caps.

5. One KHz Low Distortion Signal Generator

Although I own a variable frequency wein bridge oscillator, it has been been set to 1 KHz for 2-3 years and is large and temperamental. It was decided to make a low distortion sine wave oscillator for just this one frequency. The circuit will be placed in a box along with another signal generator.

There are a number of ways to build signal generators using op amps. Countless example circuits may be found on the World Wide Web and some of them are really fantastic. Chose whichever method works best for you. Some might find my circuit to be overkill, but to each his own.

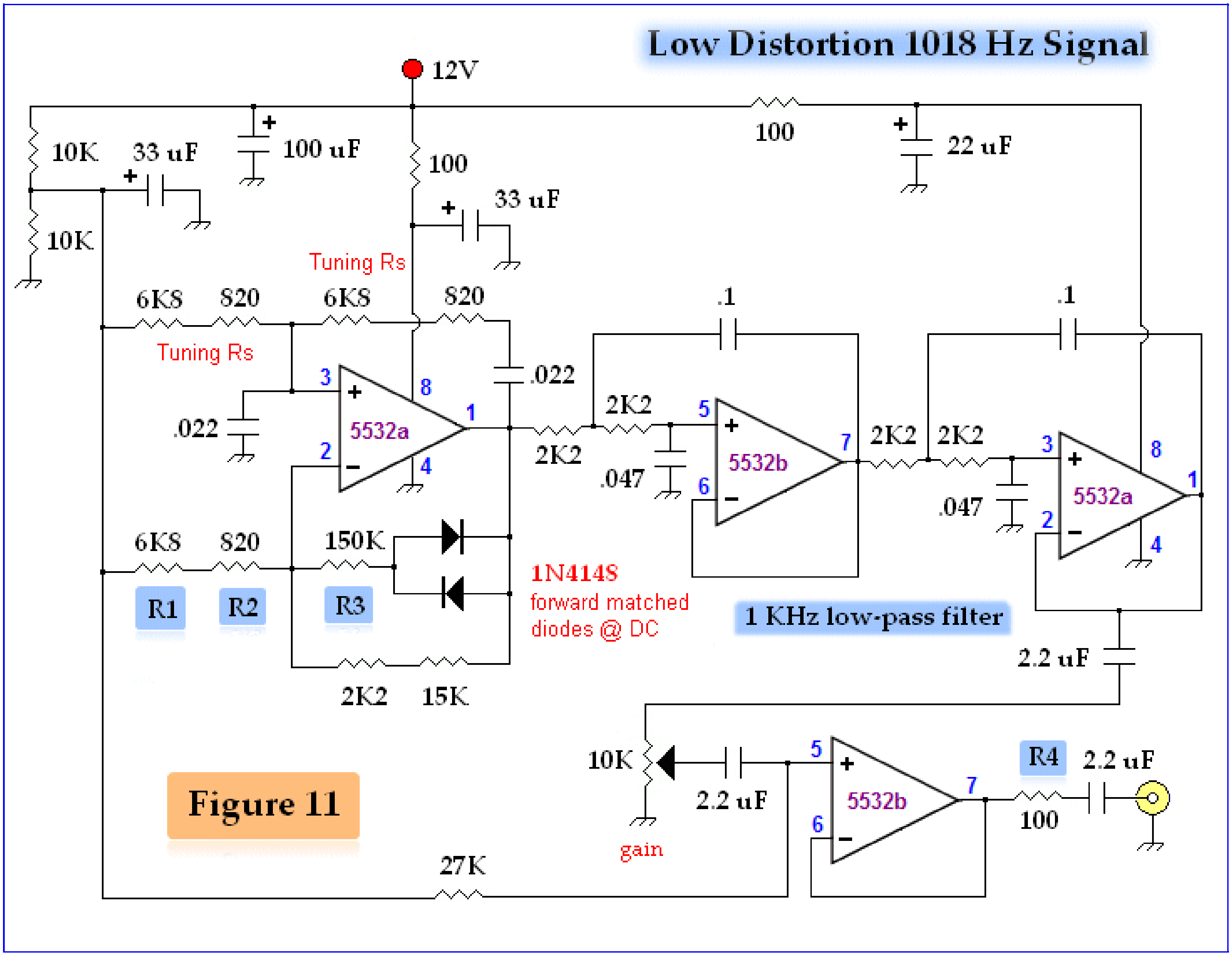
Low Distortion 1018 Hz Signal
12V
10K
33 uF
100 uF
100
100
33 uF
22 uF
10K
Tuning Rs
6K8
820
6K8
820
Tuning Rs
.022
.022
5532a
3
2
8
1
4
.1
.1
2K2
2K2
.047
5532b
5
6
7
2K2
2K2
.047
5532a
3
2
8
1
4
6K8
820
150K
R1
R2
R3
1N4148
forward matched
diodes @ DC
1 KHz low-pass filter
2K2
15K
2.2 uF
10K
2.2 uF
5532b
5
6
7
R4
2.2 uF
100
gain
Figure 11
27K

Figure 11 shows the entire circuit. The Wein bridge oscillator is from EMRFD and was designed by Wes, W7ZOI.

A 0.22 uF capacitor was chosen for the tuned circuits. Using resistors from my parts collection, 1018 Hz was the closest I could get to 1 KHz. This is the 6K8 + 820 ohms resistors labeled "tuning Rs". Other values were tried. For example, a single 6K8 gave 1142 Hz and a single 8K2 gave 939 Hz.

When the circuit was first built, I used a 10K on the VCC/2 bias point to pin 2 and a 22K feedback R from pin 1 back to pin 2. The sine wave had mild distortion. By experimentation, it was learned that the resistance from the VCC/2 bias point to pin 2 significantly affected the waveform purity. The 2K2+15K plus the R1 + R2 resistance values shown were determined by using a potentiometers rather than fixed resistors. Care was taken to adjust the feedback resistance from pin 1 back to pin 2 to keep away any overdrive distortion. I do not understand this, but even changing the 820 ohm R2 to 570 ohms, altered the sine wave purity.

The best looking sine wave came when the resistance from the VCC/2 bias point to pin 2 was the same as the tuning resistance; 6K8 plus 820 ohms. Later, the pin 1 to pin 2 feedback resistance was chosen for an unclipped; waveform with a reasonable output voltage using a potentiometer. The potentiometer was removed and measured at 17.1K, thus the 15K + 2K2 were soldered in. It was also discovered that by increasing R3 from 56K or 100K to 150K slightly improved the waveform.

The Figure 7 low-pass filter was connected to the main oscillator as shown. The final op-amp stage was used as a buffer between the low-pass filter and the gain control. R4 is used to set whatever output impedance you choose. Practically speaking, it could be any value between 47 and 620 ohms. Many AF oscillators have an output impedance of 600 ohms and 620 is the nearest E24 standard value. For my project, a 100 ohm

R4 was chosen. Output peak to peak voltage is 0.0 to 4.84v continuously.

Figure 12

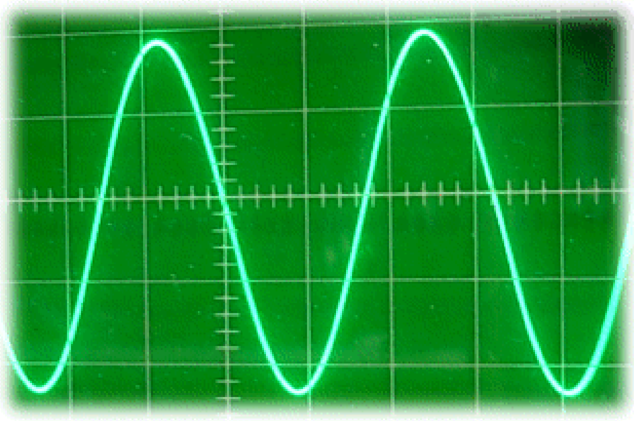

Here is the raw output of the basic Wien bridge oscillator. It is hard to photograph well, but it is stellar to say the least.

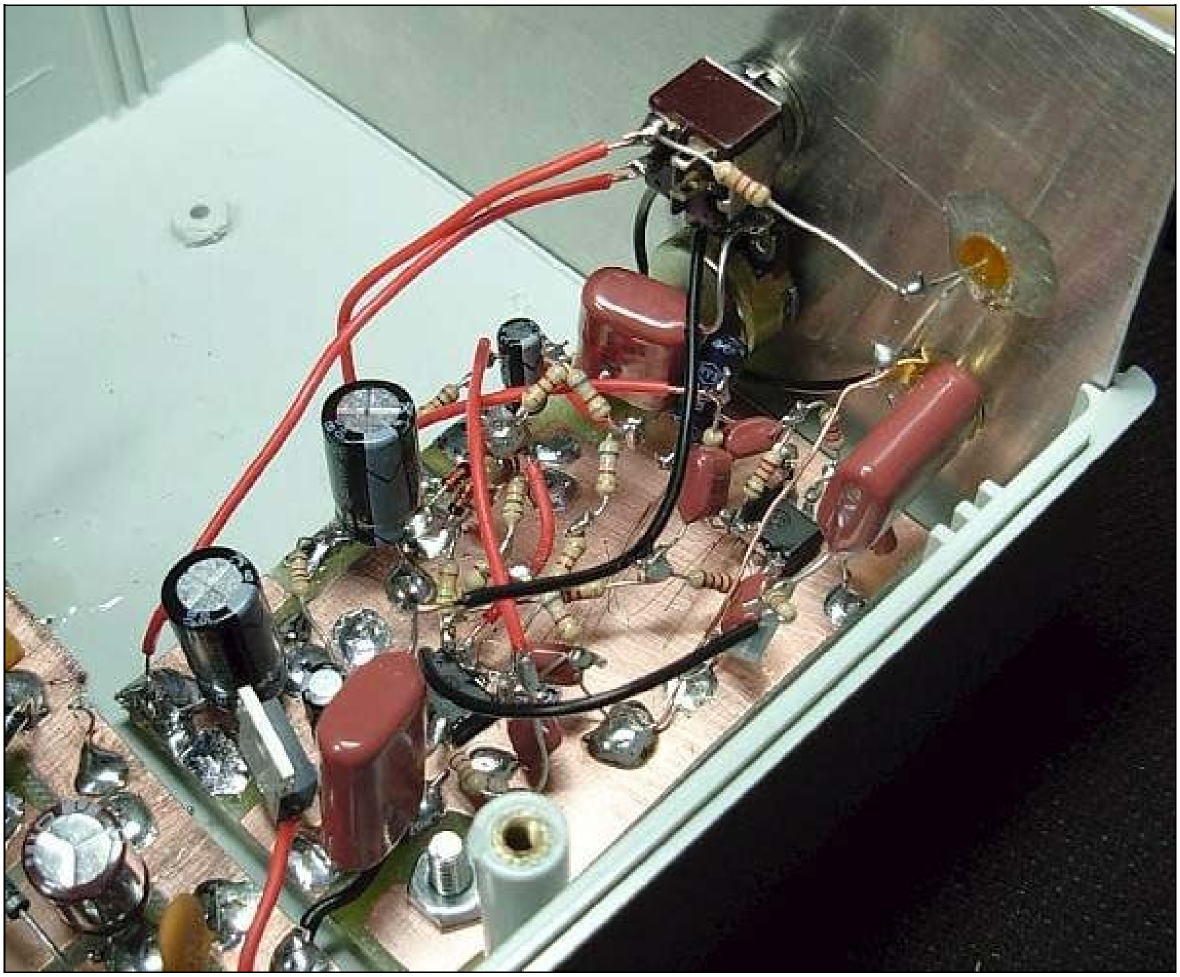

The Figure 11 breadboard mounted in a plastic Hammond chassis. The voltage regulator seen to the left of the bottom polyester cap is a 7812. This project has its own regulated power supply. [Other view](#) of Fig 11. Two 10 Megohm standoff resistors were used to help support all the resistors soldered to pins 1, 2 and 3 of the main oscillator.

1018 HERTZ
OFF
GAIN

A front view photo of the AF oscillator. A separate 7 plus 14 MHz oscillator circuit and controls will be placed on the right hand side of this box. The orange power ON indicator LED was epoxy glued into the chassis hole. Putting circuits in cabinets is one of the most expensive aspects of homebrew construction. One must be ever vigilant for bargain chassis boxes and hardware to keep costs down. Techniques such as gluing in the LED rather than purchasing a separate holder and recycling knobs and switches are also practiced for cost containment.

Figure 13

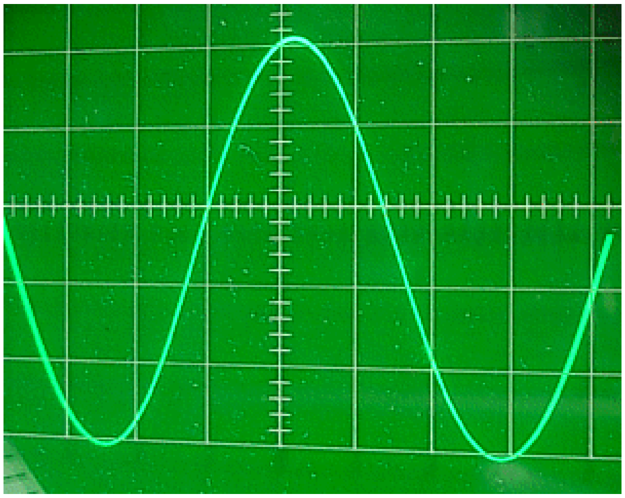

The output of Figure 11 is shown in Figure 13. This is the best sine wave seen ever on my scope. I looked at it closely and there is no change in line thickness or symmetry anywhere. It inverts with no change on the scope. Testing audio amplifiers will now be much more fun.

6. LM386 Power Experiments

The LM386 is an IC audio amp that has been used in thousands of hobbyist projects over the past 2 decades. By adding a capacitor +/- a resistor between pins 1 and 8, this device's internal gain can be changed from x20 to up to x200.

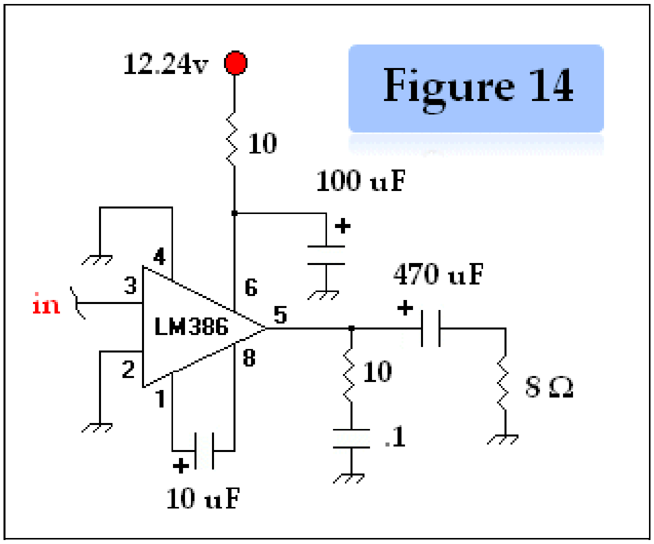
Figure 14
12.24v
10
100 uF
+
4
3
in
6
LM386
5
470 uF
+
8
2
1
10
8 Ω
.1
+
10 uF

Test circuit schematic in Figure 14.

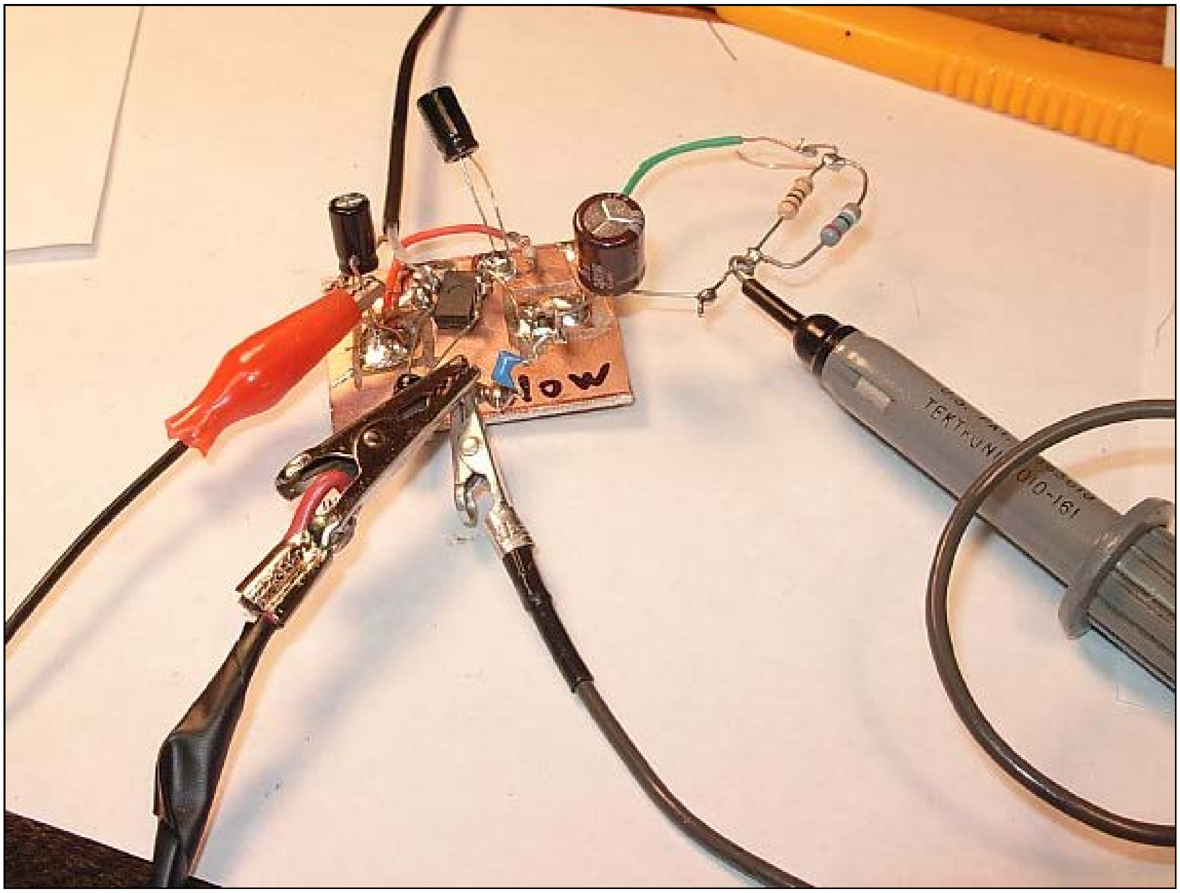

The experiment breadboard is shown above. A very standard configuration. The amplifier drove an 8 ohm, 1 watt resistive load.

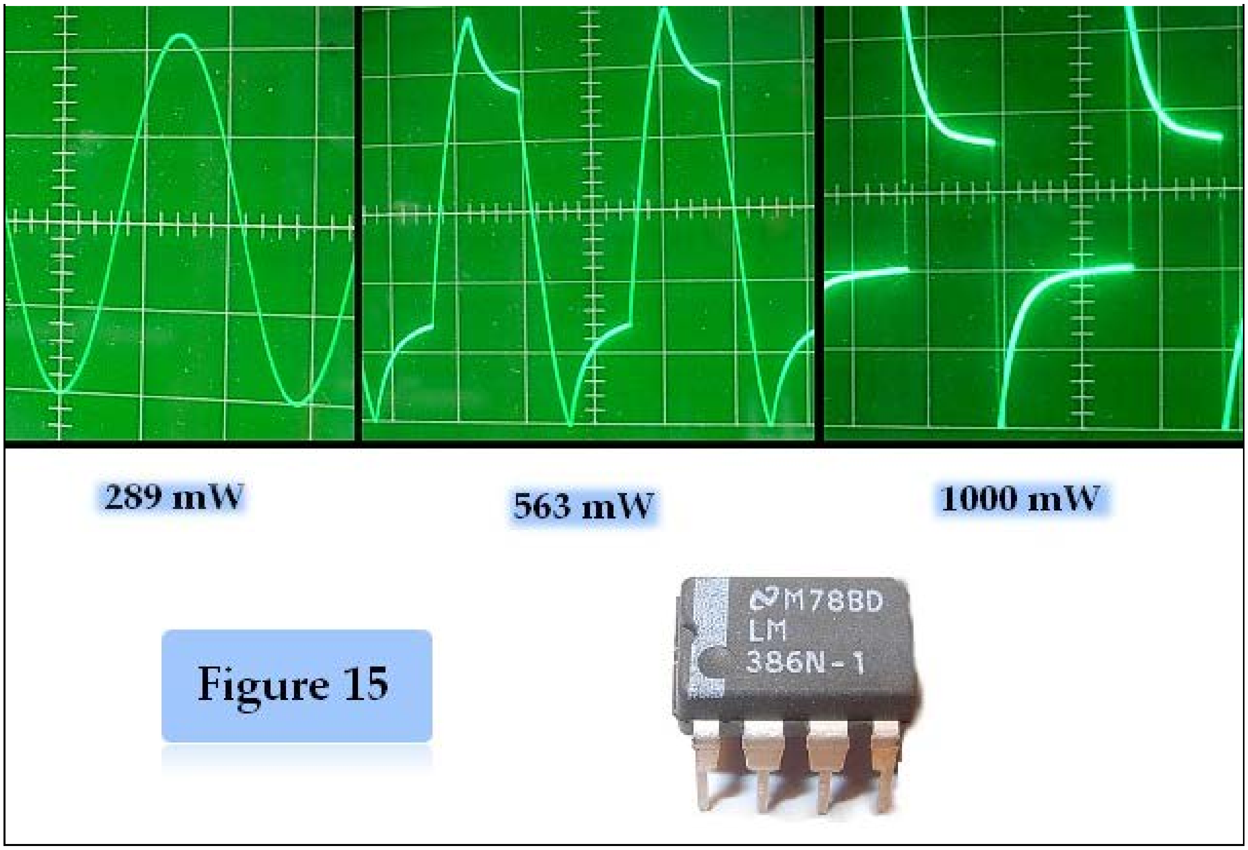

Figure 15

Over the years, I have noticed some kit sellers and project authors claiming that their LM386 based AF stages gave 1 or occasionally even 2 watts of output power into an 8 ohm speaker. This was confirmed on the bench. This device will output 1 watt into 8 ohms at 1018 Hertz with little problem. However, this is clearly 1 watt of square wave distortion.

The quiescent current of the LM386 was around 7 mA. The signal generator gain was increased until the first signs of distortion appeared. The gain was then backed off a little so a pure sine wave was observed in the oscilloscope. The current was ~ 155 mA and the measured power was 289 mW. Please refer to Figure 15 for the 289 mW sine wave. This was the clean signal power of the LM386 on my bench. The output waveforms at 563 mW and 1 watt are also shown. Extreme harmonic distortion occurred above 300 mW. This device will draw 240 mA or more when driven and clipping hard. It is not my intention to malign the LM386. It is a useful part, albeit a little dated. Its AF gain capability versus size is something to behold. Many builders have moved to the TDA7052 audio amplifier IC, or like myself, build their own low noise audio power amps.

1018 HERTZ
OFF
GAIN
ON
12.24 VDC

The 12.24 volt DC supply and the 1018 Hz AF audio oscillator used in these experiments.

SWL HOMEBUILDER

RF — Test and Measurement

Time Domain Output from a Diode Ring Mixer

22 Dec 2009, w7zoi

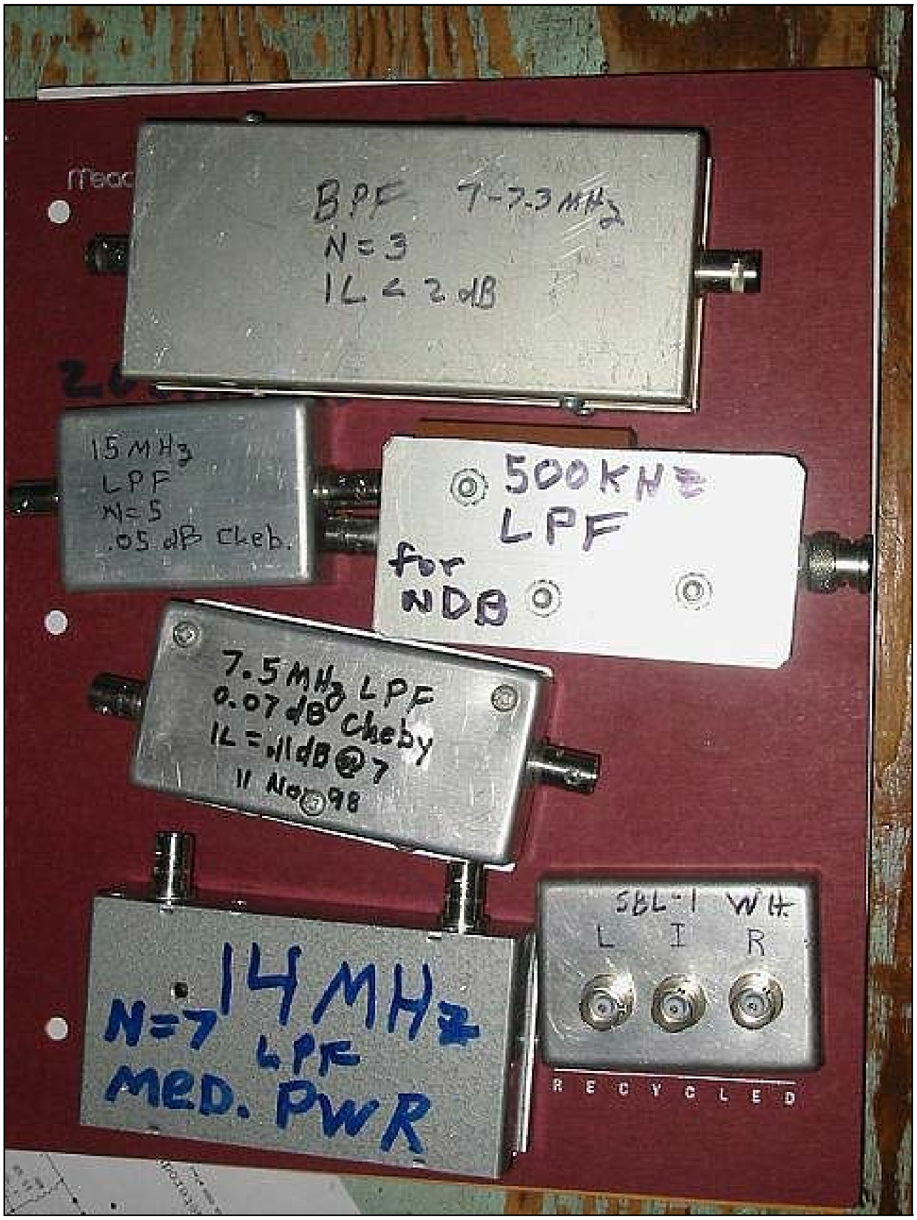
BPF 7-7.3 MHz
N=3
IL < 2 dB
1.5 MHz
LPF
N=5
.05 dB Cheb.
500 KHz
LPF
for
NDB
7.5 MHz LPF
0.07 dB Cheby
IL = .11 dB @ 7
11 Nov 98
N=7
14 MHz
LPF
MED. PWR
SBL-1 WH
L
I
R
RECYCLED

Figure 1. Some available experimental modules.

Some folks wonder about the output that they should see on their oscilloscope when looking at the output from a diode ring mixer. There is no set, pat answer. The output can change dramatically as levels, frequencies, and even terminations are changed. This complication is illustrated here with a few screen shots, taken with a Rigol DS1052E 50 MHz bandwidth digital storage oscilloscope. The experiments started with the following pile of modules. Your collection will probably differ.

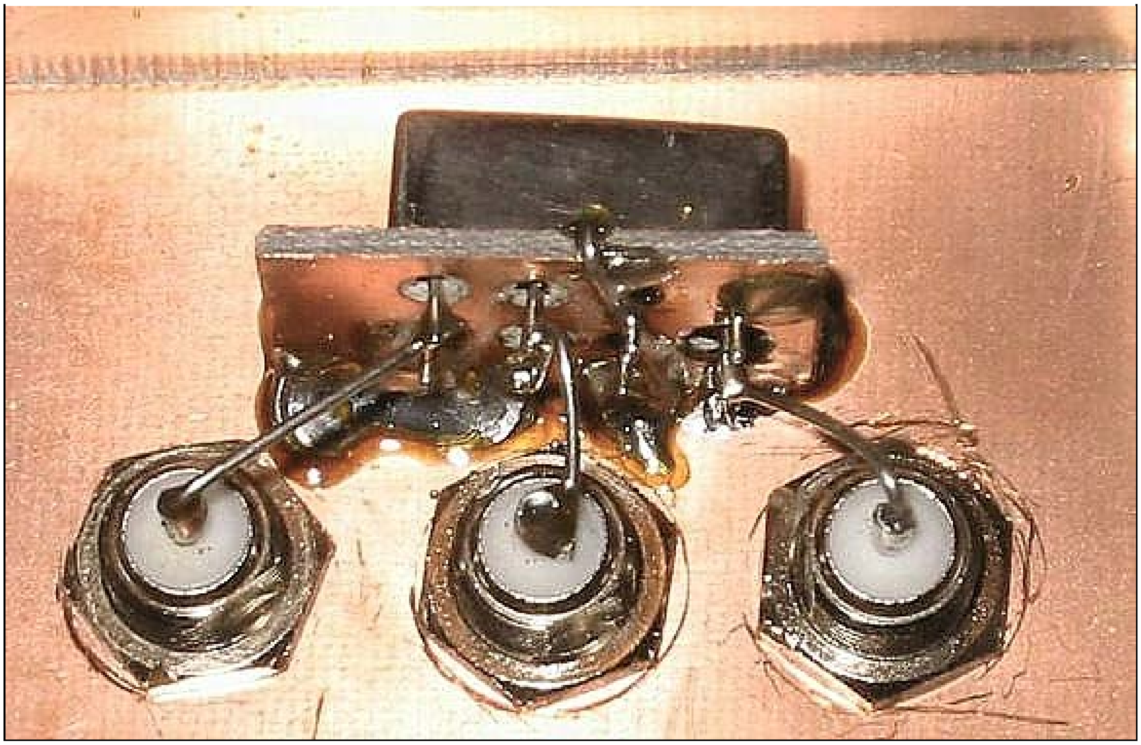

Figure 2. The inside of the module containing a Mini-Circuits SBL-1 diode ring mixer. This is a standard part that is essentially generic.

The first experiment was to set up a pair of 10 MHz signal sources. One was from a homebrew generator, shown below.

Figure 3

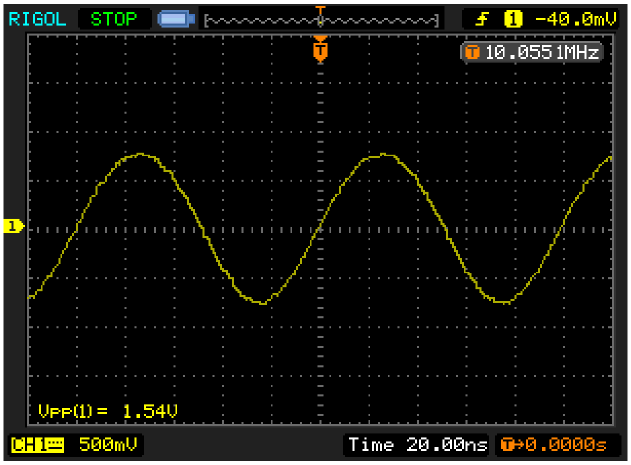
RIGOL
STOP
-40.0mV
10.0551MHz
Vpp(1)= 1.54V
CH1
500mV
Time 20.00ns
T→0.0000s

Figure 3. The 10 MHz signal from a homebrew signal source. The 1.54 volt peak to peak signal is applied to a 50 Ohm terminator at the oscilloscope. The delivered power is then +7.7 dBm.

This signal was filtered with a 14 MHz low pass circuit. This caused the amplitude to drop by 0.2 dB. The source was then attached to the LO (local oscillator) port of the SBL-1 mixer.

Figure 4

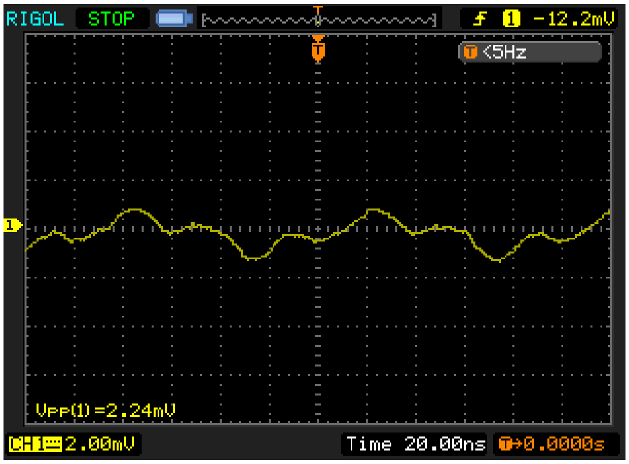

Figure 4. The IF output from the mixer when there is nothing attached to the RF port. Note the scope sensitivity of 2 mV/div.

Next, we attached a 50 Ohm terminator to the R mixer port.

Figure 5

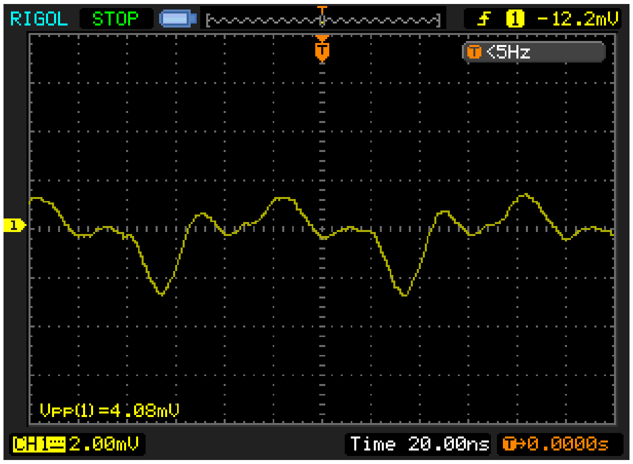

Figure 5. The IF output with LO drive, but without an R signal. But the R port is now terminated. This waveform, when compared with Fig 4, shows just how sensitive the mixer can be to termination.

In the next experiment, a -20 dBm signal was applied to the R port. The frequency was very close to the 10 MHz LO that is still present.

Figure 6

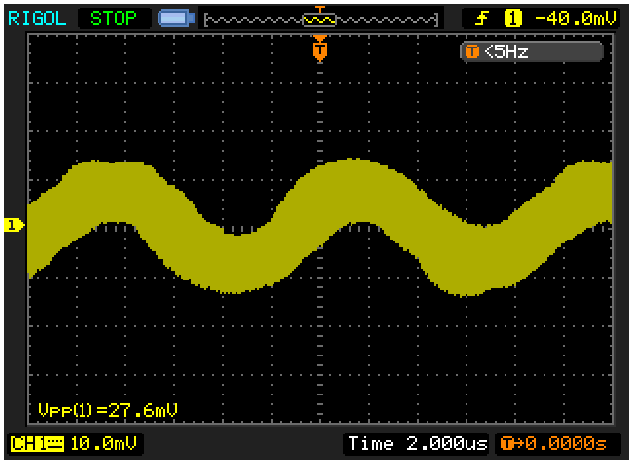

Fig 6. There are two dominant signals from the mixer. One is a low frequency at 100 kHz. But this is accompanied by a high frequency of about 20 MHz. These two outputs, a sum and difference frequency, are expected from any mixer.

A filter can isolate the two dominant outputs. This is shown below where a 500 kHz low pass filter is inserted in the line between the mixer and the oscilloscope. A 6 dB pad is between the mixer and the filter, for direct insertion would upset the termination of the mixer.

Figure 7

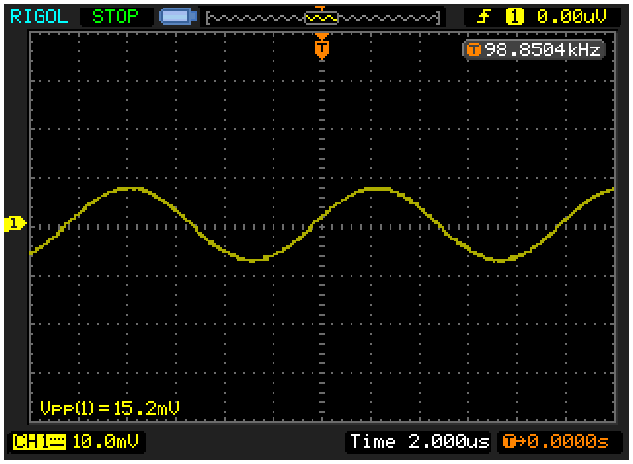

Figure 7. The output of about 100 kHz after a low pass filter is inserted in the mixer output.

The next experiments emulate a SSB transmitter. We start with a signal at 11.06 MHz with strength -20 dBm. (This is a common IF used in homebrew SSB transceivers such as the BITX-20.) This is applied to the mixer R port. The L port is driven with a +7 dBm signal at 3.19 MHz. The LO signal is low pass filtered to attenuate harmonics, a measure that is probably not necessary, but the filters were there. The IF output is shown below.

Figure 8

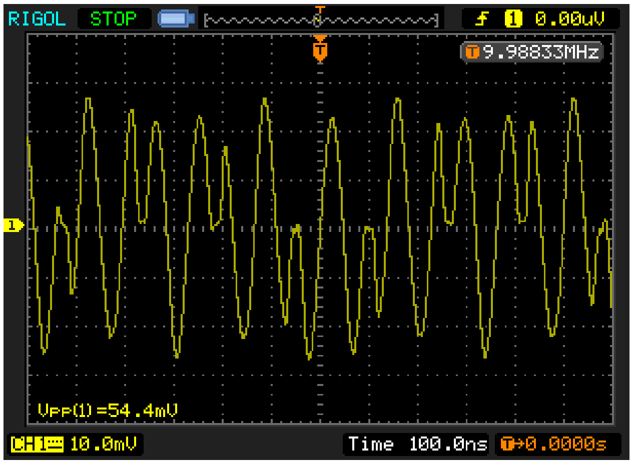

Figure 8. Time domain output of a SBL-1 set up as the "transmit" mixer in a SSB rig. This is far from the "perfect sine wave" that some folks tell us we should observe. This waveform contains many different frequency components. The counter output should not be interpreted to have any meaning. (I should have turned it off.)

The signal of Fig 8 can also be viewed with a spectrum analyzer. This is shown below. This measurement was taken with the August 1998 QST Spectrum Analyzer and not the FFT routine in the DSO. The Rigol scope has a nice display for an analyzer.

Figure 9

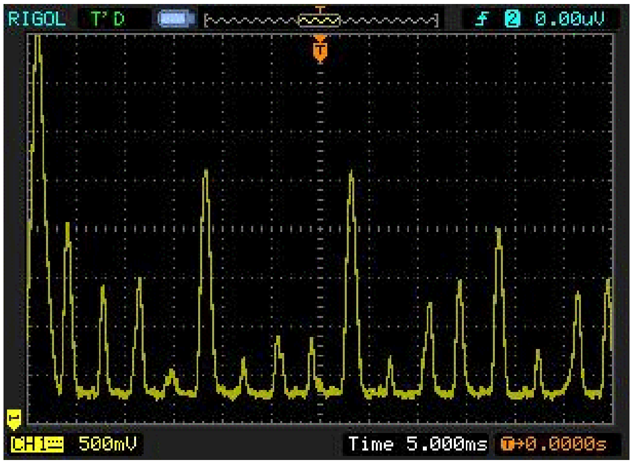

Figure 9. Spectrum of the signal shown in Fig 8. The largest signal on screen is that at the left, which is the spectrum analyzer zero spur. This is a spurious output that is typical of most SA systems. The desired signal at 11.06+3.19=14.25 MHz is just to the right of center. But the image is also present at the different frequency of 7.87 MHz at about 3 major divisions from the left edge.

Alas, I didn't find a 14 MHz bandpass filter in the junk box. Such a filter would have allowed selection of the dominant 14 MHz component while attenuating all the rest of the junk shown. The many other signals are the result of harmonic mixing. That is, we observe IF outputs at N x FLO +/- M x FRF where N and M are integers. Some of these spurious outputs can be quite strong with diode ring mixers. They are best avoided with high frequency LO signals. In this case, a LO at 14.25+11.06=25.31 MHz would produce a much cleaner output spectrum. It is much easier to obtain LO stability with an oscillator built at 3.19 MHz.

Bottom Line

It is not reasonable to have a well defined, predictable time domain (i.e., normal oscilloscope) output from a mixer. The exact results depend upon too many variables. A spectrum analyzer can be used to garner much more information.

RF — Test and Measurement

Low Noise Crystal Oscillators

Introduction

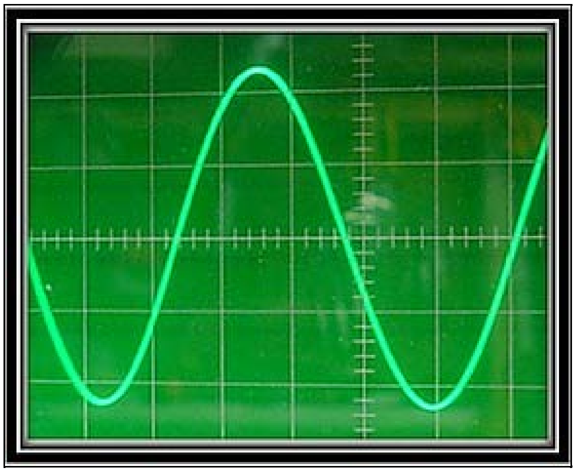

Some experiments were conducted to build a low noise crystal oscillator with 50 ohm output at 7 and 14 MHz for the test bench.

Some readers might wonder why build such an oscillator? Although a variable RF signal generator is an important bench tool, it is also nice to have a fixed frequency signal source on your favorite HAM band. This RF source can be connected to other 50 ohm modules such as band-pass filters, diode ring mixers or feedback amplifiers to conduct experiments at a whim. The project goal was a low noise oscillator with 2 outputs so it could drive a divide by 2 flip-flop for 40 meter band digital mixer work, or fundamental frequency use on the 20 and 40 meter bands.

Presented are some experiments carried out to realize this goal. Only some of the better experiments and circuits are shown. An additional circuit was added Jan 31, 2010.

First Steps

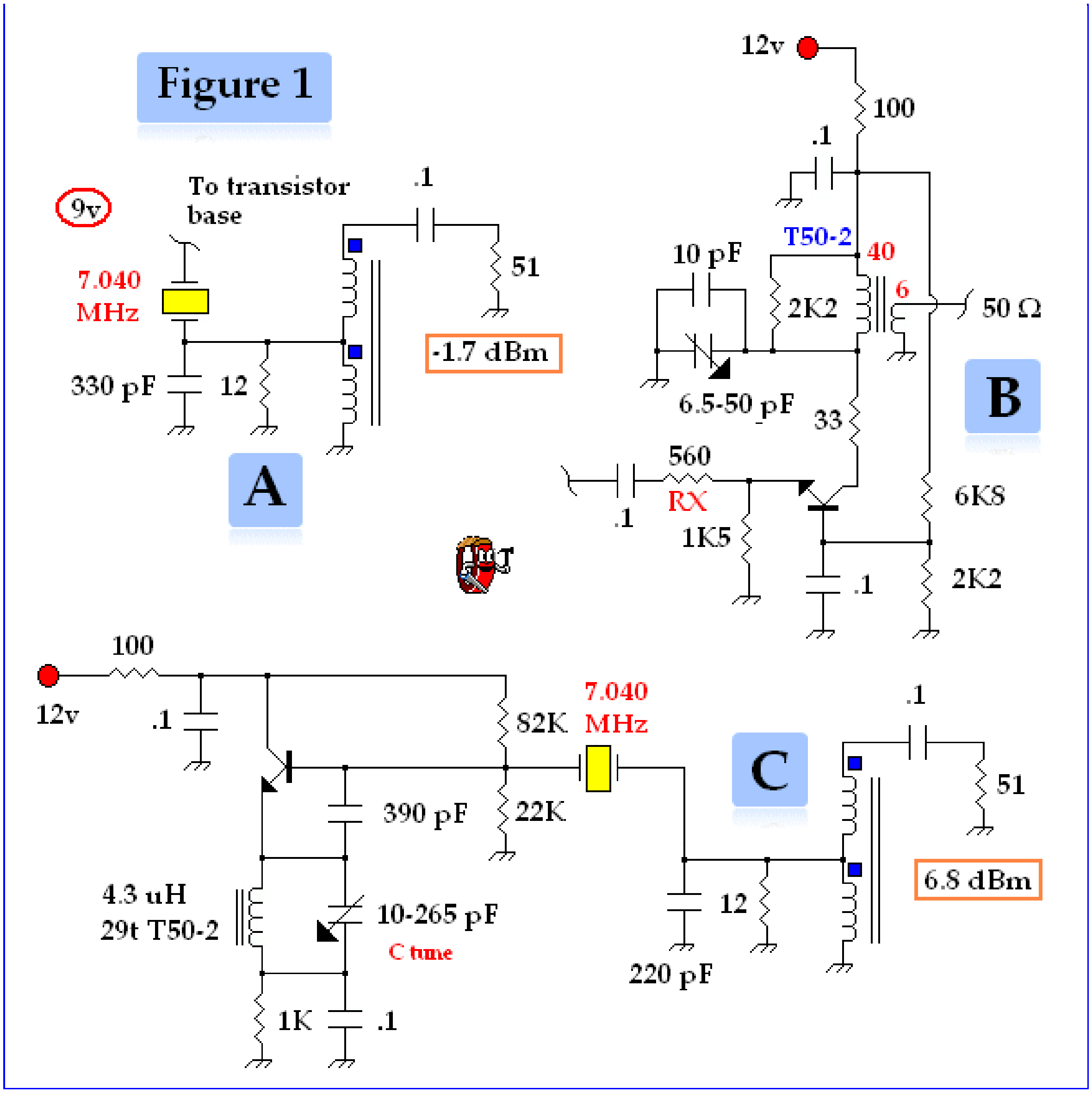
Figure 1

9v
To transistor base
.1
51
7.040 MHz
-1.7 dBm
330 pF
12
A
12v
100
.1
T50-2
10 pF
40
2K2
6
50 Ω
6.5-50 pF
33
B
560
RX
.1
1K5
6K8
.1
2K2
100
12v
.1
82K
7.040 MHz
.1
C
51
390 pF
22K
6.8 dBm
4.3 uH
29t T50-2
10-265 pF
C tune
12
220 pF
1K
.1

The 7.040 MHz crystal used is an AT cut, HC6-U holder part made locally by West Crystal. I reviewed the information concerning crystal oscillators in Chapter 4.5 of EMRFD and then started melting solder. The oscillator output was extracted as described in EMRFD Figure 4.24. The output is low distortion, low impedance and low gain. Like in most experiments, I built it, measured the DC voltages and then looked at the AC voltages in the oscilloscope.

In order to measure the output, a 51 ohm load was transformer coupled as shown in Figure 1a. I am uncertain if this was a good method for power measurement, however, it allowed comparison of the experimental circuits. As shown, the output with a 9 volt regulated power supply is low; -1.7 dBm. Still, a circuit like EMRFD Figure 4.24 can be used with a variety of crystal frequencies and has great utility.

Figure 2

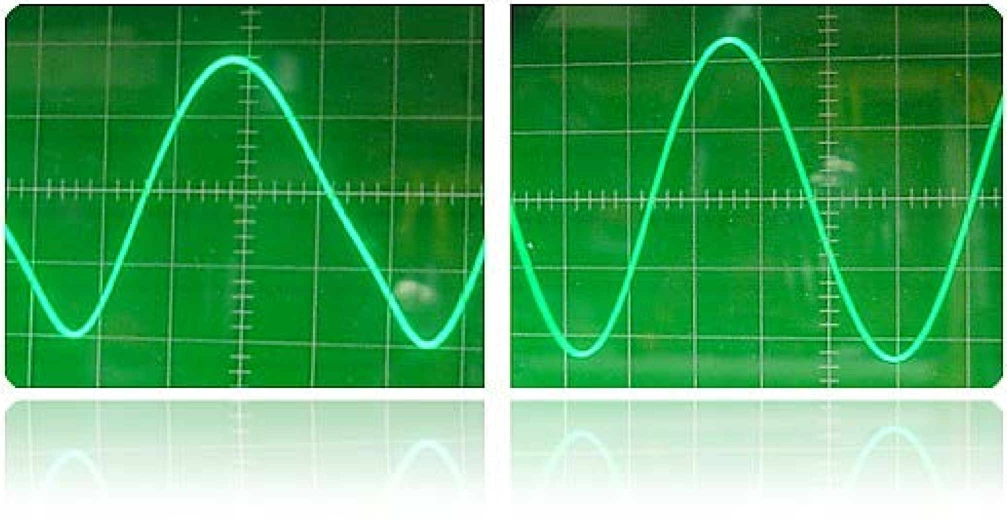

Signal from BJT emitter

Signal from between cap and crystal

Figure 2 shows two output waveforms taken from my crystal oscillator. When a signal is taken from the emitter of the main oscillator transistor (what we typically do) harmonic distortion occurs as shown in the above left. Actually, the distorted waveform photo above left looks better than most do. Typically, they look like this. Many builders will just place a low pass filter on such an oscillator's output and be very satisfied with the harmonic content in their signal. Certainly this is a good, common and practical way to go. However, for some builders, the experimenter's journey is what counts. That is, the fun and learning occurs during designing/building/testing and not just operating home built gear.

When the output is taken from between the shunt capacitor and the crystal per Figure 1A, a much cleaner sine wave is available. The photo above right tells this story. The focus of all of the experiments on this web page is boosting this lower distortion, lower phase noise signal into something useful. To increase the base oscillator output voltage, the VCC was raised to 12 VDC and the BJT emitter circuit was tuned per Figure 1C. Resident on my work bench are a few potentiometers and a 10-254 pF air variable capacitor with short attached leads. These parts are inserted into test circuits to allow tweaking of R or C as desired. Once the desired tweaking is performed, the potentiometer or variable capacitor is removed and measured. The closest fixed value R or C is then substituted as appropriate. In this experiment, the highest output voltage occurred when the variable capacitor measured 181.7 pF. Thus in my version, 33 pF and 150 pF capacitors were placed in parallel and are shown later in Figure 3.

The Figure 1A output transformer circuit was again used and the power output was 6.8 dBm. Being tuned to 1 crystal frequency is the biggest drawback of the 1C circuit. Tuning a crystal oscillator as described earlier is easy to do however.

The next task was to design and build a buffer/amplifier. To match the low impedance of the Figure 1C crystal oscillator, a common base amp was built. The circuit was morphed over time, however, the initial design is shown as Figure 1B. It was interesting to note that a series resistor (RX) is required to keep the waveform pure. Any RX value less than 470 ohms compromised the sine wave purity. The 560 ohm R shown was perfect, however, as expected, attenuated the oscillator signal. In order to get a decent output voltage, the common base amp had to be run at 5 mA or greater current and ultimately collector tuning was added to try and realize an output voltage greater than 4 dBm.

Through experimentation I learned that adjusting Fig 1B's tuning, emitter current and RX value all could distort the output of the main oscillator at certain values or settings. Running high current also invites parasitic oscillations and soon it was realized that common base was perhaps not the best choice (at least for me) as another separate amplifier stage would be required to get a decent output voltage with or without an attenuator pad.. After trying a number of different buffer-amplifiers including a 50 ohm feedback amp, I chose a favorite circuit which I know has excellent gain plus back to front isolation and would not distort the oscillator waveform; a lightly coupled JFET amp.

---

7 MHz Circuit

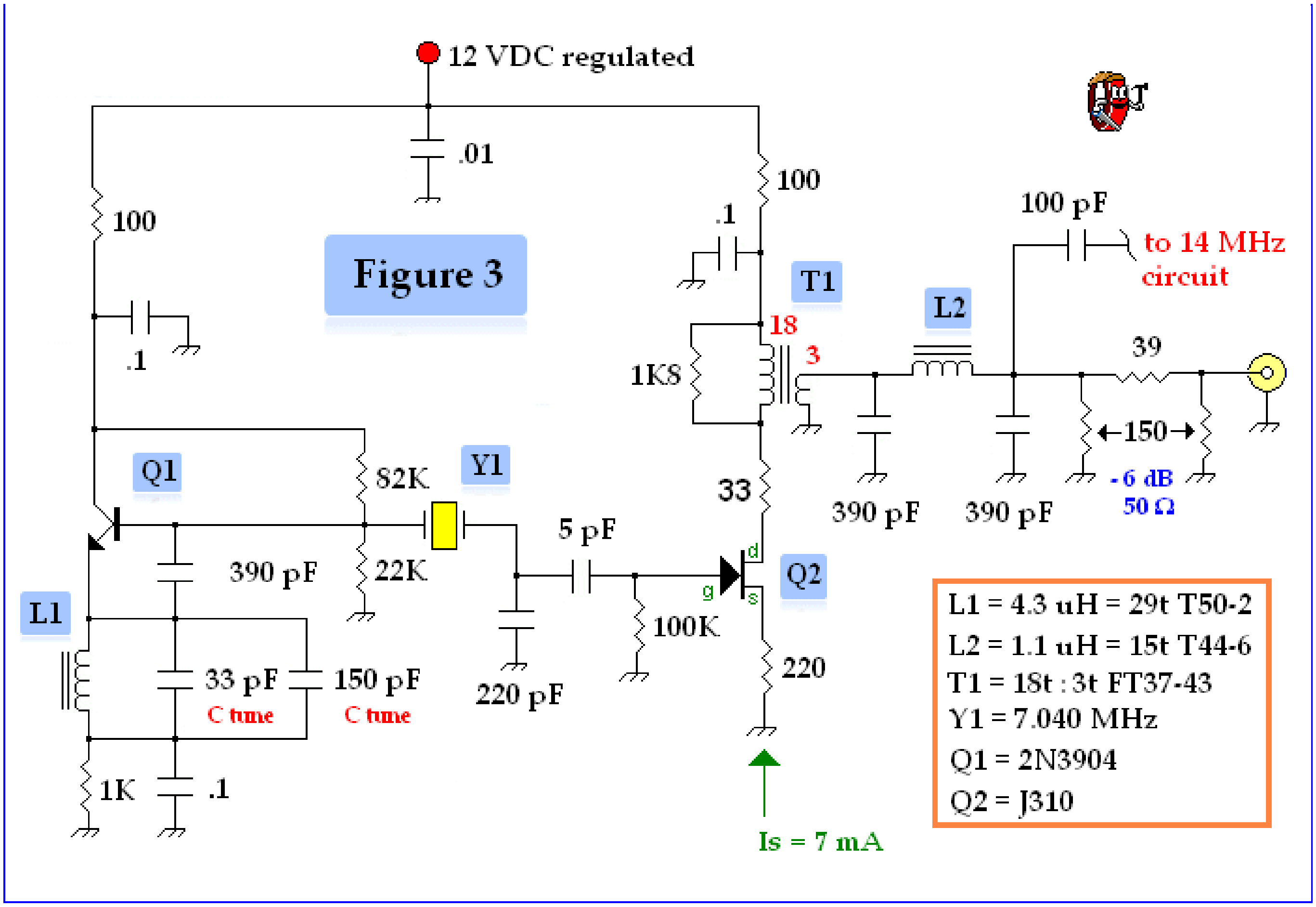
12 VDC regulated
.01
100
100
.1
.1
Figure 3
T1
L2
100 pF
to 14 MHz circuit
18
3
1K8
39
←150→
-6 dB
50 Ω
82K
Y1
Q1
33
390 pF
390 pF
5 pF
390 pF
22K
d
Q2
g
s
L1
100K
220
33 pF
C tune
150 pF
C tune
220 pF
1K
.1
Is = 7 mA
L1 = 4.3 uH = 29t T50-2
L2 = 1.1 uH = 15t T44-6
T1 = 18t : 3t FT37-43
Y1 = 7.040 MHz
Q1 = 2N3904
Q2 = J310

In Figure 3 is the complete schematic of the 7 MHz portion of the low distortion crystal oscillator. The output was 0.52 dBm. A 6 dB 50 ohm pad ensures a well-buffered 50 ohm termination. This aids in calculating gain or loss in circuits it drives. You could easily decrease this to a -3 or -4 dB pad. This reflects the wisdom handed down by our mentors who encourage building RF stages in 50 ohm impedance blocks. A Q2 source bypass capacitor was not placed as it increased harmonic distortion in the output signal. The output is filtered with a simple pi filter. The 100 pF coupling capacitor connect this circuit to Figure 6; the 14 MHz circuit.

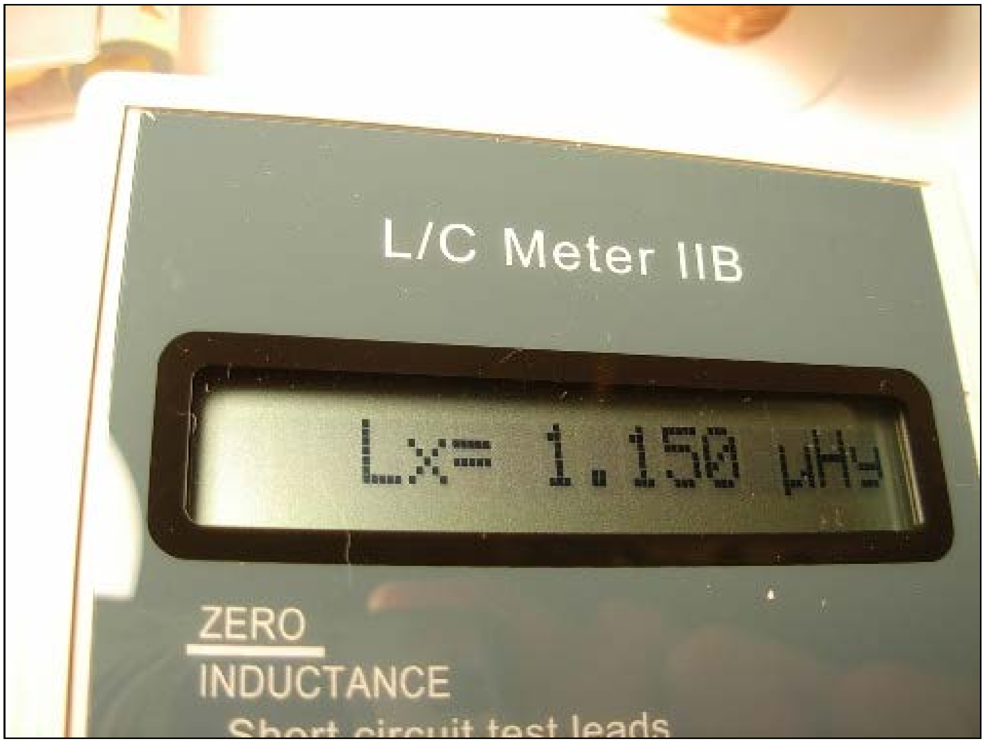
L/C Meter IIB
Lx= 1.150 μHy
ZERO
INDUCTANCE
Short circuit test leads

L2 was wound and measured. It is desirable (but not absolutely necessary) to perform measurement on powdered iron toroids to compensate for variations in wire spacing and toroid permeability. I used a T44-6 core; use whatever appropriate powdered iron toroid you want.

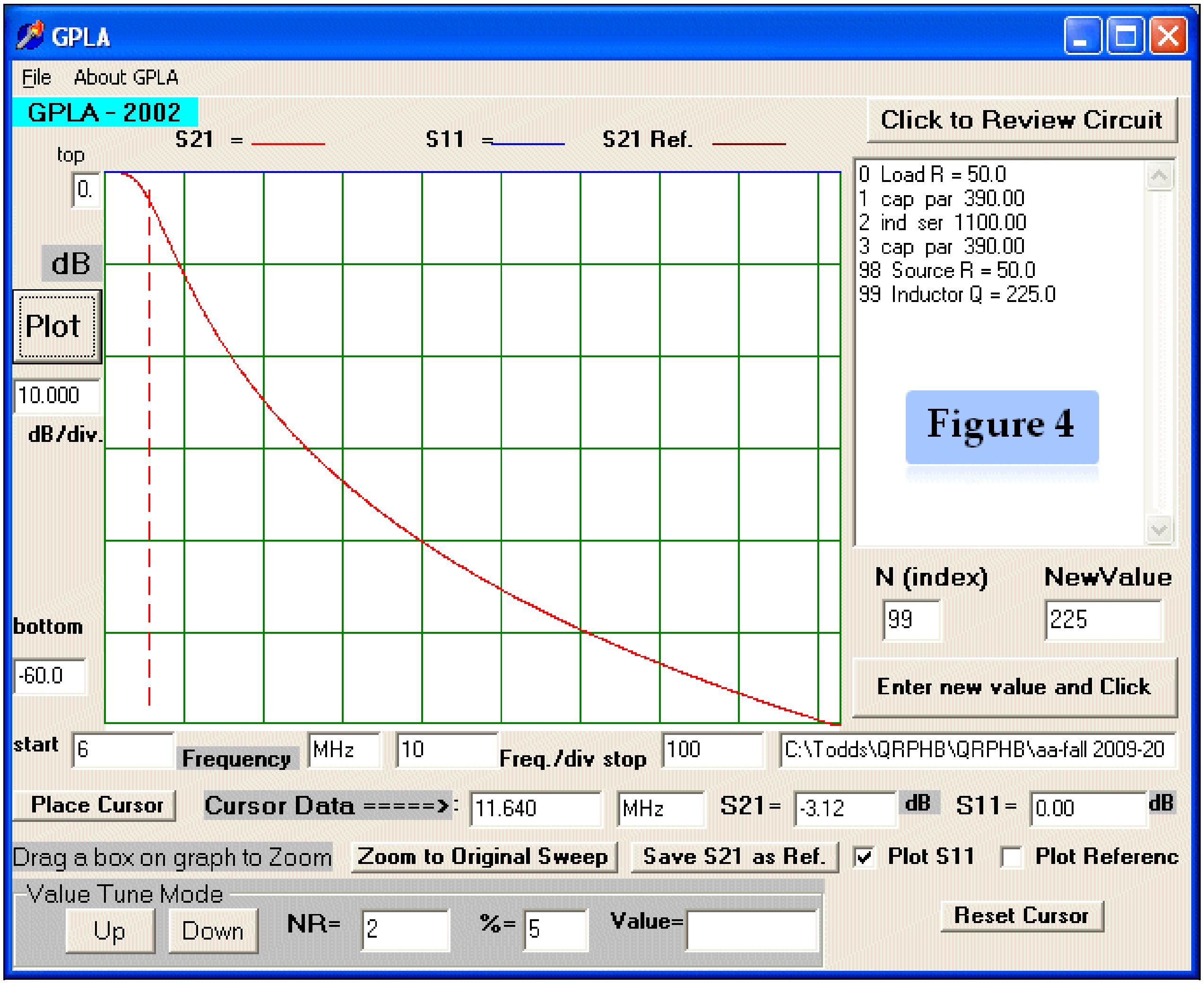
GPLA
File
About GPLA
GPLA - 2002
Click to Review Circuit
S21 =
S11 =
S21 Ref.
dB
Plot
Freq./div
Place Cursor
Cursor Data =====>
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Value Tune Mode
Up
Down
Enter new value and Click
Reset Cursor

Figure 4

0 Load R = 50.0
1 cap par 390.00
2 ind ser 1100.00
3 cap par 390.00
98 Source R = 50.0
99 Inductor Q = 225.0

top: 0.
dB/div.: 10.000
bottom: -60.0
start: 6
Frequency: MHz
Freq./div: 10
stop: 100
C:\Todds\QRPHB\QRPHB\aa-fall 2009-20
Cursor Data: 11.640 MHz
S21= -3.12 dB
S11= 0.00 dB
N (index): 99
NewValue: 225
☑ Plot S11
☐ Plot Referenc
NR= 2
%= 5
Value=

A GPLA analysis of the Pi low-pass filter is shown in Figure 4. The basic circuit was designed with PI Filter Designer on this page and tweaked in GPLA. You may wish to omit this filter or perhaps design a better one yourself.

Figure 5

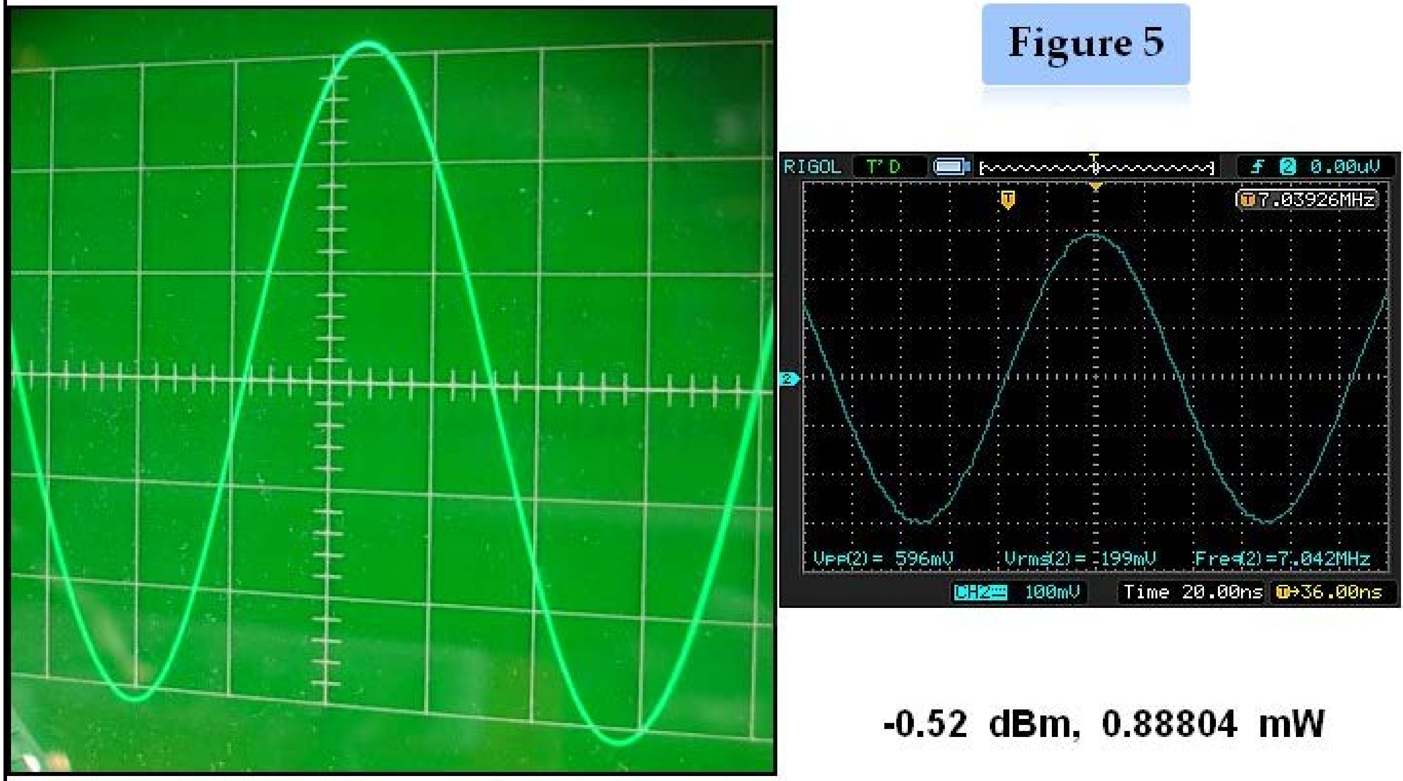

-0.52 dBm, 0.88804 mW

The 7 MHz output waveform on the Tektronix (left) and the Rigol oscilloscopes. On the Tek scope, the output power was 0.50 dBm and on the Rigol scope it was 0.52 dBm. The Rigol is an amazing oscilloscope, but only has 256 horizontal lines of resolution, therefore cannot replicate the stellar and beautiful waveform tracings of the ancient Tek scope. In reality, probably, no other modern scope can. I have received many positive comments about the old Tektronix oscilloscope waveforms. It is important to mention, that Rigol waveform viewing is not bad, just very different. The visual display is incredibly accurate and its triggering options, bandwidth, sampling rate and waveform display tools are fantastic. фантастический !

During these experiments, the 40 year old (plus) Tektronix scope was distorting frequencies greater than 10 MHz and breaking into oscillations. After 3 major repairs in 2009, the scope replaced with a Rigol DS1052E. Signal viewing will certainly different; that is for sure. The decision to move from a cathode ray oscilloscope (CRO) to a digital storage scope (DSO) was not taken lightly.

DSO versus CRO - some comments from the workbench

Choosing a CRO versus a DSO is an individualized process. It is your decision alone. Questions to ask yourself may include: What are my needs? What is my budget? Do I have weight and/or space constraints? Carefully weigh the advantages and disadvantages of each.

Proponents of CROs state that these scopes cannot generate artifacts, nor distort the signal. This of course is true as long as the scope bandwidth is adequate. Further, some people feel that aliasing or artifact generated in DSOs due to undersampling (taking too few samples of a waveform) is unacceptable. They may even feel that DSOs are not precision measurement instruments as a result. Limited horizontal screen resolution in DSOs is also a bugaboo for some experimenters and provides further evidence of DSO inferiority in the minds of these folks. These concerns are indeed valid; however, black and white thinking is a little out of fashion in a world more containing shades-of-gray.

The DSO takes a series of samples and stores them in memory. When sufficient samples are present, they are assembled and displayed. The sampling rate of a DSO is variable and depends on the time base setting used. Modern DSOs, like the Rigol, Tektronix Oscilloscopes and Agilent Oscilloscopes have better sampling rates and larger memories than their predecessors and hence aliasing is less of a problem than before; although in some measurement situations, undersampling can occur. One must always well consider and interpret whatever you are measuring and if you use a DSO, always keep undersampling in mind. When first using a DSO, you are on the bottom of a learning curve, however, with attentiveness and practice, one can learn to look for and possibly mitigate undersampling should it occur. In certain cases, a CRO will be superior to a DSO. In my discussions with others about Rigol signal viewing , only 1 significant "aliasing" problem has been noted by a builder when he tested a balanced modulator. The display did not give the expected result (was not filled in as expected) and a CRO was pulled out and the problem was verified. The builder knew there was a problem and could understand why it occurred. This builder also wrote that this was not so much a problem, as a reality of using a DSO.

Some techniques I have gleaned from the Internet about detecting aliasing may include the following:

Vary the time base over several ranges. Events occurring near the time base should be reproducible and if they are not, undersampling might be occurring.

As possible, use a single sweep and dot display. The 'dots' will indicate just where the scope took each sample. If the dots are far apart relative to the waveform timing, aliasing is a possibility.

Some techniques to minimize aliasing:

Choose linear interpolation when using math functions.

Use bandwidth limiting in low level measurements (The Rigol seems to automatically use B/W limiting in these situations).

Use trace averaging for low level measurements as possible.

The Rigol weighs 50 times less than my old scope and fits on a small shelf in my small workspace. As a hobbyist, it meets my needs and budget plus has some very cool features. Undersampling is considered and in some cases, such as low level measurement, an analog scope might be a better choice. Happily, a CRO is available to me if I really stress out over it. Signal viewing was taken for granted with my old scope. In some ways, this DSO has prompted me to dig deeper; to become more vigilant and thoughtful about signal measurement and display. If you have a spectrum analyzer, and use a DSO for signal viewing, the ability to perform slow sweeps while maintaining a perfect display is quite enjoyable. Again, please decide the CRO versus DSO issue for yourself (or maybe get a hybrid). The DSO is not a perfect solution to every signal viewing situation, but their constraints are quite livable considering their numerous modern features.

DSO's: “They are not your father’s oscilloscope”; that is certain!

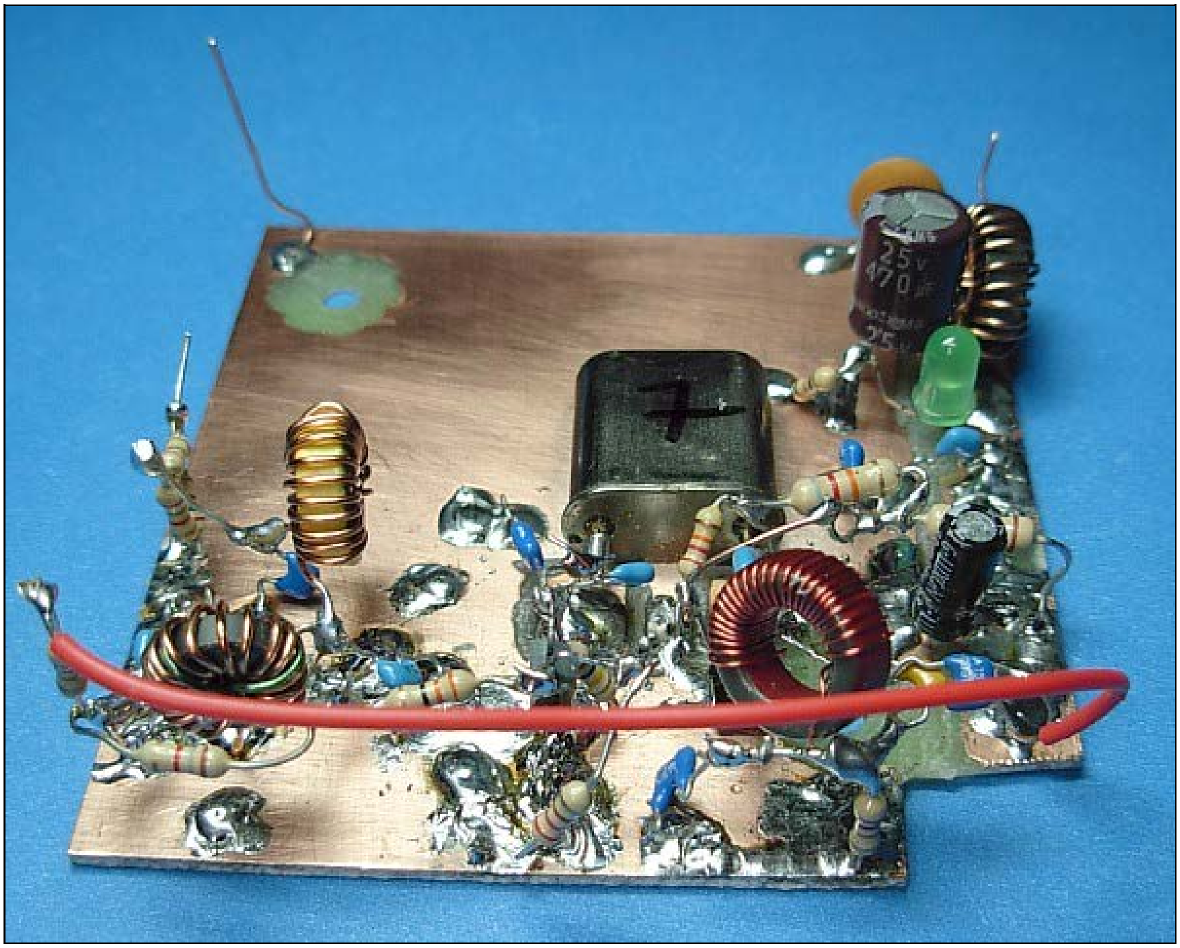

The Figure 3 breadboard. AWG 24 to 26 gauge wire was used in the various inductors and transformers to better secure or anchor these parts.

---

14 MHz Circuit

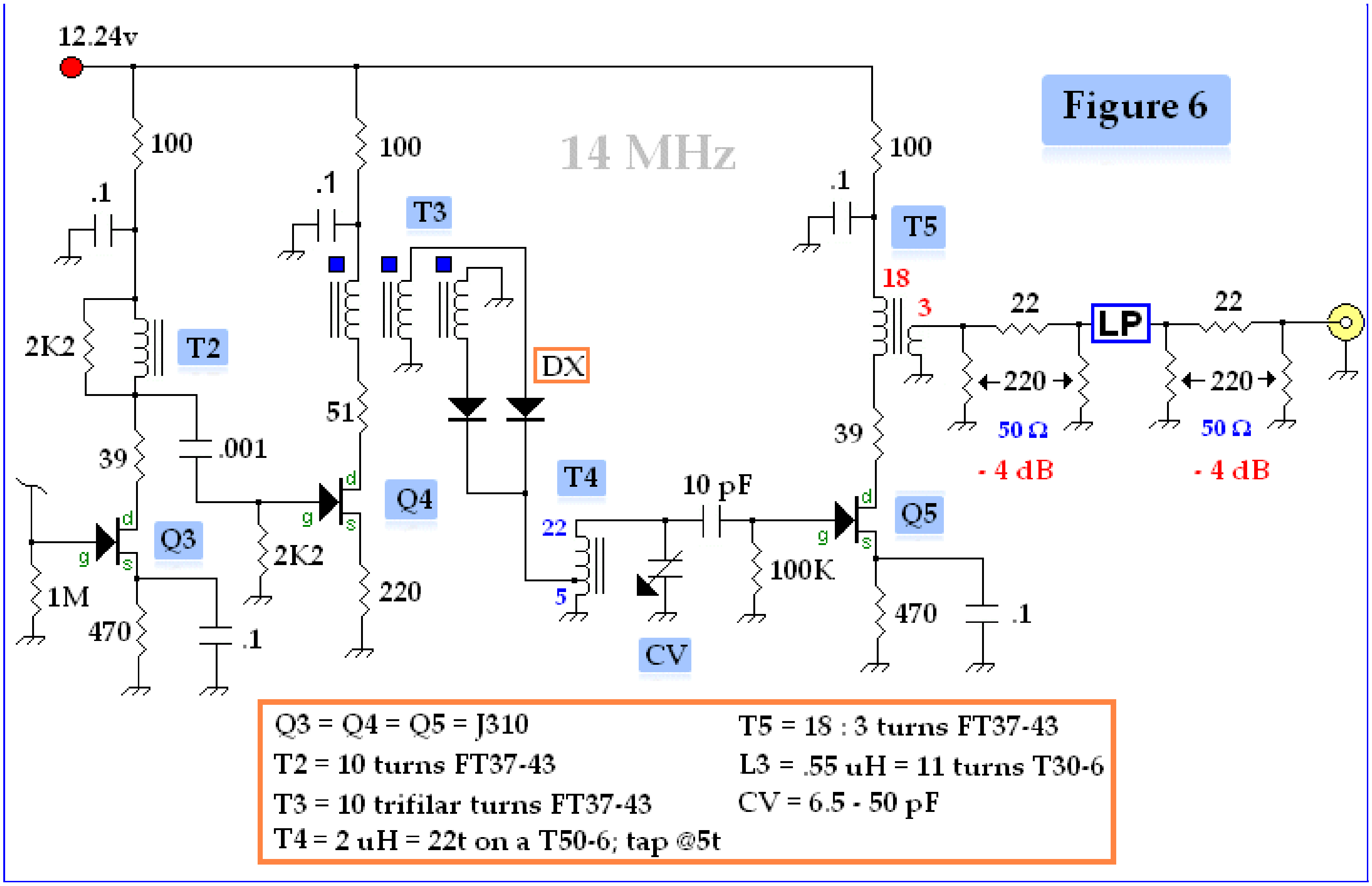
12.24v
14 MHz
100
100
100
.1
.1
.1
T3
T5
18
3
22
22
LP
2K2
T2
DX
←220→
←220→
50 Ω
50 Ω
- 4 dB
- 4 dB
51
39
39
.001
d
g
s
Q4
T4
10 pF
Q5
22
5
Q3
2K2
1M
470
220
100K
470
.1
.1
CV

Figure 6

Q3 = Q4 = Q5 = J310
T2 = 10 turns FT37-43
T3 = 10 trifilar turns FT37-43
T4 = 2 uH = 22t on a T50-6; tap @5t
T5 = 18 : 3 turns FT37-43
L3 = .55 uH = 11 turns T30-6
CV = 6.5 - 50 pF

Figure 6 is the final schematic for the 14 MHz circuit as developed on the workbench. Your design might look very different than mine. In the first version of this circuit, there were only 2 JFET amplifiers and the resultant output voltage was too low (even without a 50 ohm attenuation pad). To compensate, I ran the source current of the JFETs above 15 mA, placed a source bypass capacitor on Q4 and also used a 1000 pF capacitor to couple the input to Figure 2. Some fairly bad harmonic distortion was measured at the output and it seemed crazy to run so much current. Therefore it was decided to run a third JFET amplifier and use only modest current in the trio of JFET amplifiers.

CV tunes very sharply and required some care when peaking the output voltage.

Figure 7

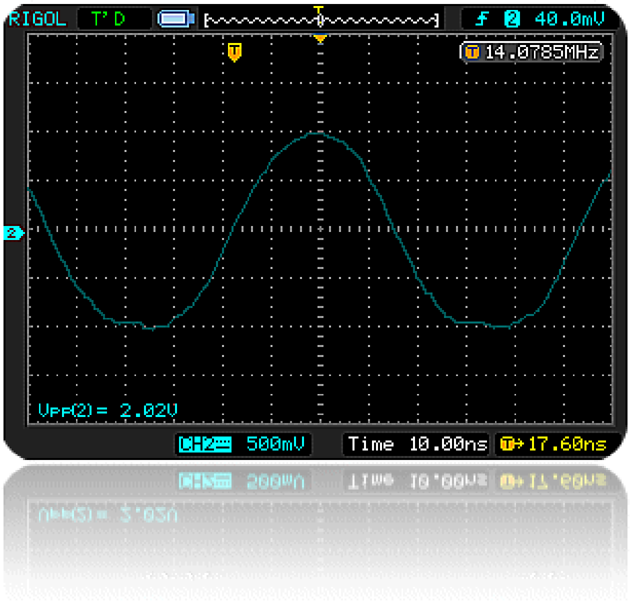
RIGOL
T'D
40.0mV
14.0785MHz
Vpp(2)= 2.02V
CH2 500mV
Time 10.00ns
17.60ns

Figure 7 is a screen capture of the 14 MHz circuit output measured using a sensitive 50 ohm terminated oscilloscope. This was with no low-pass filtering. The output is distorted. Presumably this happened in the diode frequency doubler. This is not a low-distortion oscillator.

15.3 MHz Low-pass Filter

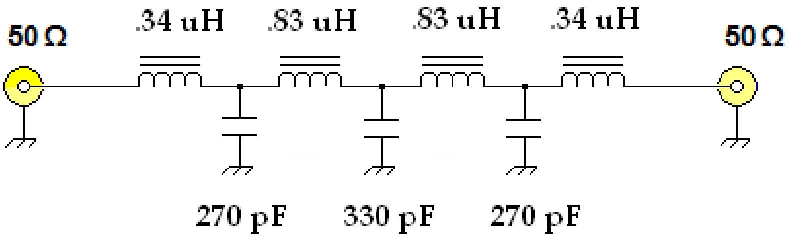
50 Ω
.34 uH
.83 uH
.83 uH
.34 uH
50 Ω
270 pF
330 pF
270 pF

A N = 7 Chebyshev low-pass filter was inserted in Figure 6 at point LP. I checked with a spectrum analyzer and the 2nd harmonic was down 38 dB. There were no other measurable harmonics after that.

Figure 7b

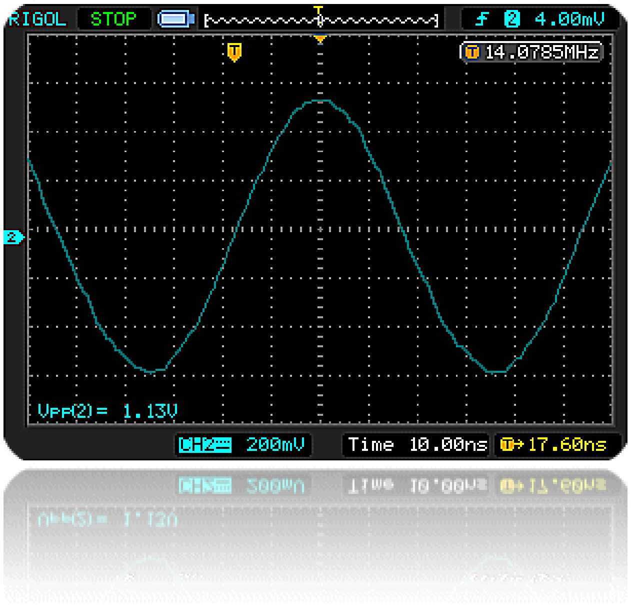
RIGOL
STOP
2 4.00mV
14.0785MHz
Vpp(2)= 1.13V
CH2 200mV
Time 10.00ns
17.60ns

Figure 7b is a screen capture of the 14 MHz circuit output after the low-pass filter and final attenuator pad. Vpp on this graphic = peak to peak voltage = 1.13 volts. The output power is 5.04 dBm, or 3.19 mW . The Q4 and Q5 source resistors and the output attenuator pads are 2 areas of the circuit where you might easily change the output power. In the end, the circuit labeled Figure 6 was chosen. Your output voltage will probably vary, but can be easily adjusted as described.

Figure 8

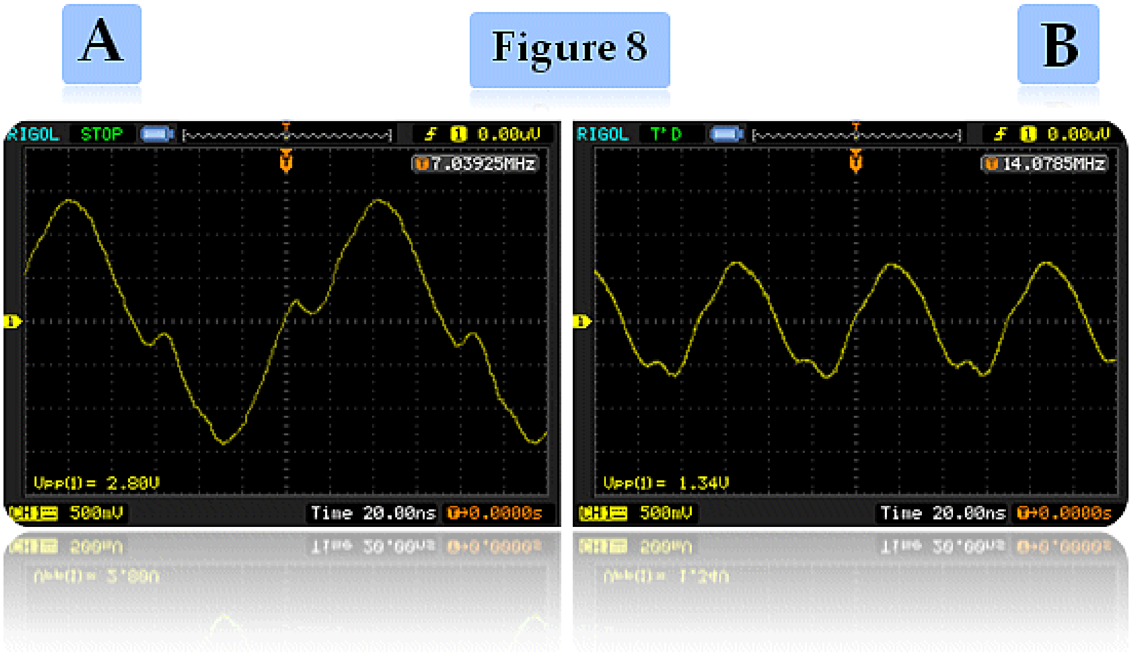
A
B
RIGOL
STOP
1 0.00uV
7.03925MHz
Vpp(1)= 2.80V
CH1 500mV
Time 20.00ns
0.0000s
RIGOL
T'D
1 0.00uV
14.0785MHz
Vpp(1)= 1.34V
CH1 500mV
Time 20.00ns
0.0000s

Figure 8 are Rigol digital screen captures. Figure 8A is a measurement taken from the anode at point DX from Figure 6. Figure 8B is a measurement taken at the cathode of DX and shows distortion caused by the diodes, reduced AC voltage and of course, frequency doubling.

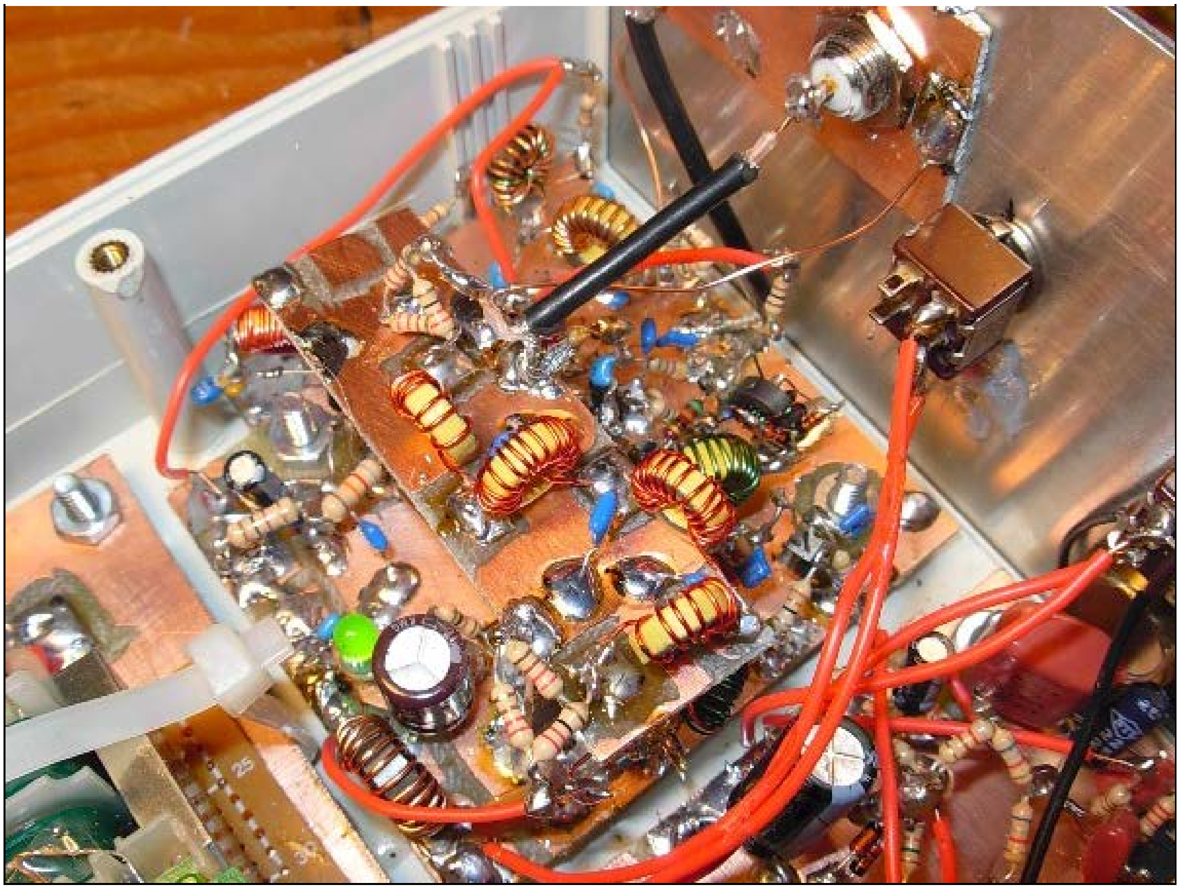

The 7 and 14 MHz circuits bread boarded and mounted in a chassis. The 7.039 MHz and 14.079 MHz outputs are connected to BNC jacks via RG-174 cable. The 15.3 MHz Chebyshev low-pass filter and -4 dB attenuator pads are on a raised Ugly Construction board. Some VCC decoupling parts are also on the bottom RF board.

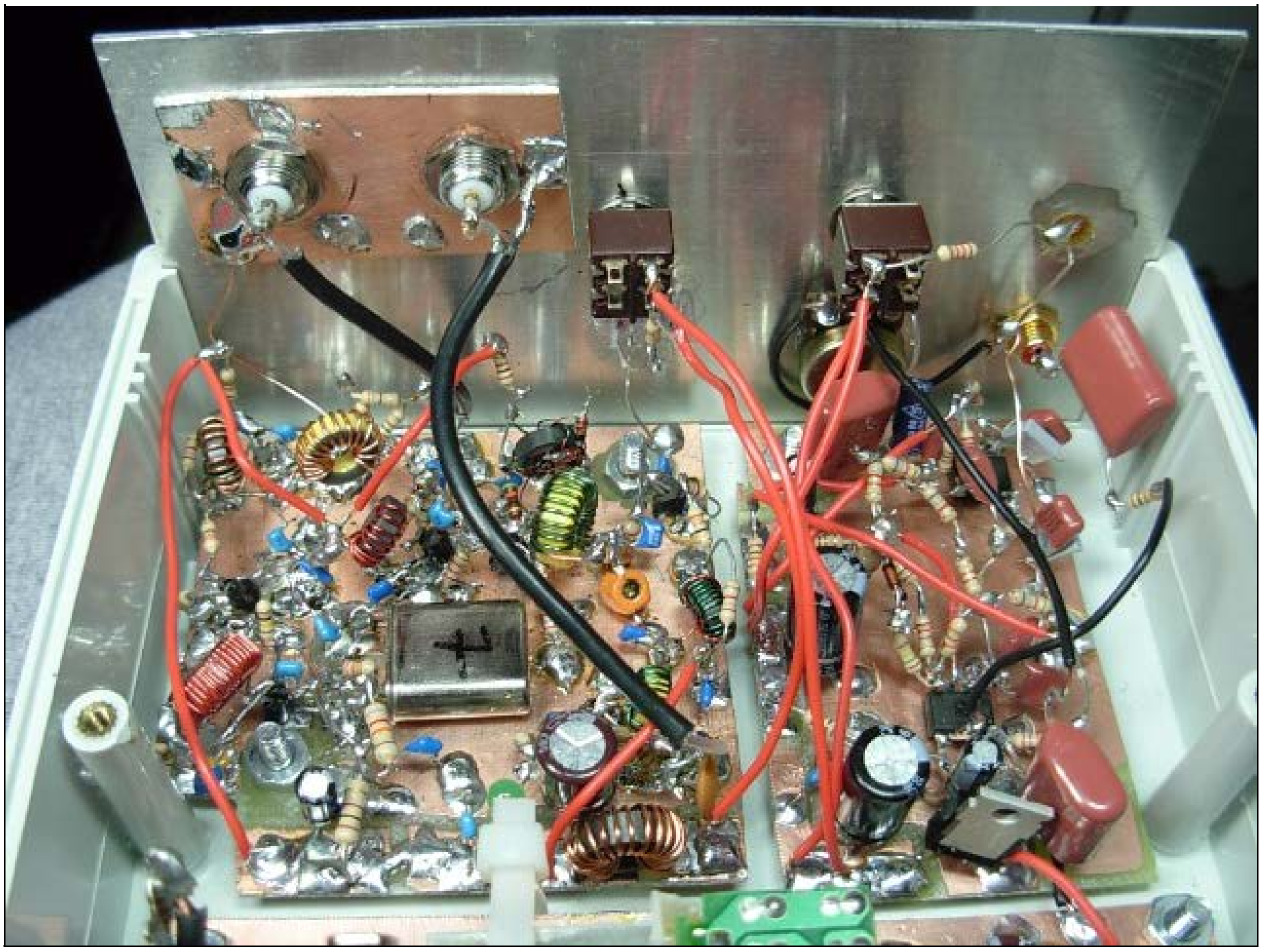

The 7 and14 MHz crystal oscillator board mounted in a project chassis along with a 1 KHz low noise oscillator This photo was a prototype version that did not have a Chebyshev low-pass filter after the 14 MHz stage.

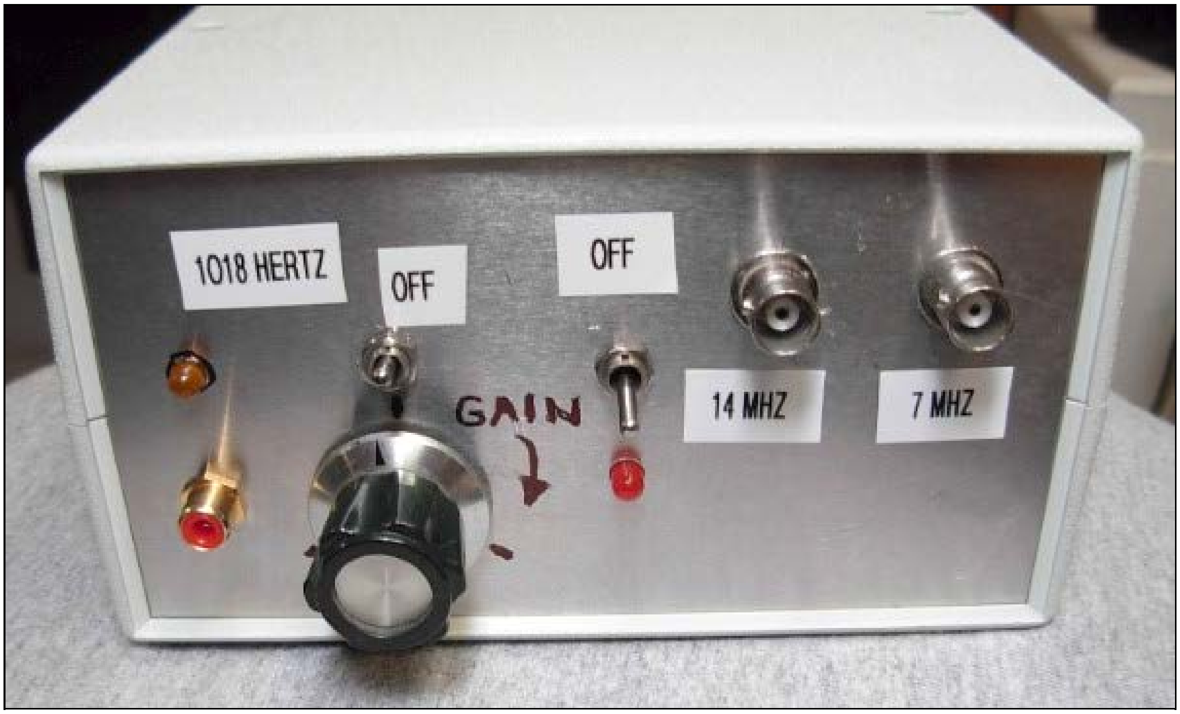

Front view of the .001, 7 & 14 MHz oscillator. It is really fun to build your own test equipment.

Transformer Notes and Conclusion

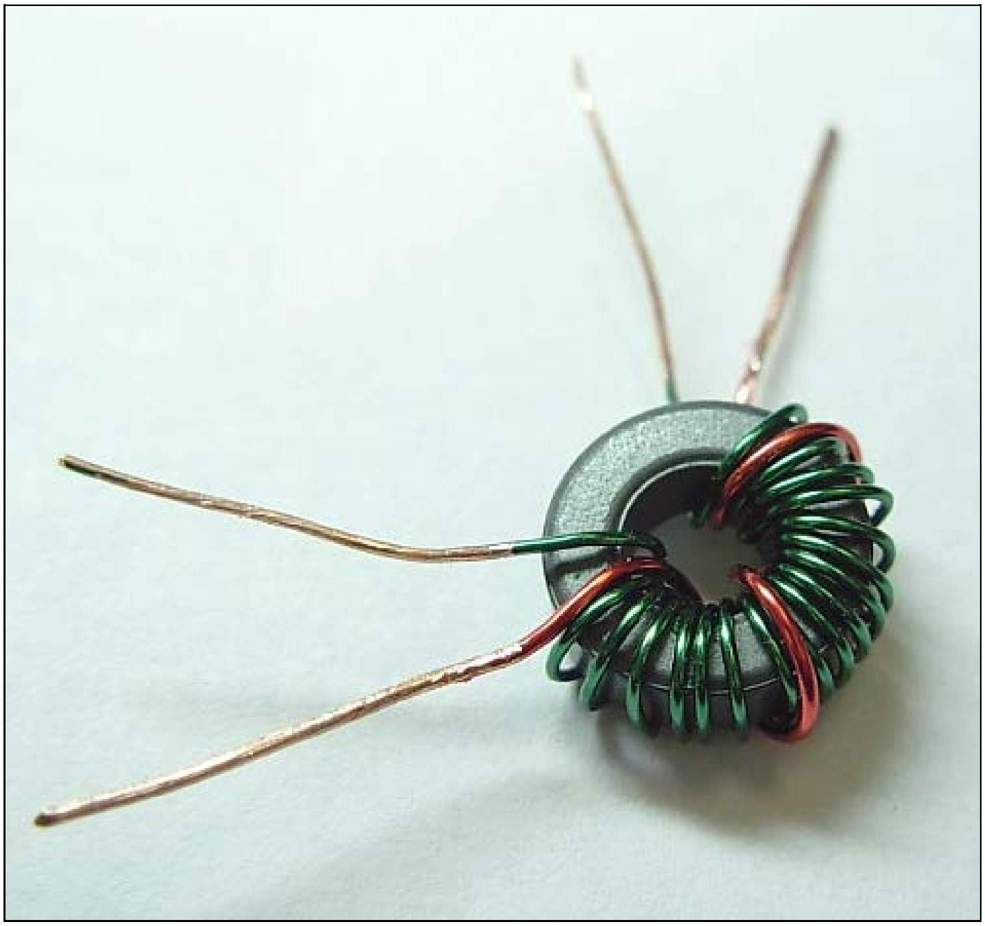

A photo of T5 from Figure 6. Some builders have emailed and stated they do not like to wind inductors/ transformers. I always ask them why? Often these builders were concerned with little details such as wire gauge and spacing, choosing the core size and which magnetic material to use. The Radio Amateur literature is replete with great tutorials on winding coils using toroids. Truly; the more toroids you wind, the easier it gets. Here are some simple points for beginners:

Powdered iron toroids are generally for tuned circuits. I.e. A capacitor and the inductor are tuned to a center frequency. Powdered irons containing the #2 and #6 material tend to tune sharply and have fairly high Q

Ferrites toroids are generally for use in broadband or wideband (untuned) applications. #43 material is relatively low Q and lossy as compared to the number #2 and #6 powdered iron toroids

Wind your inductors with enamel coated magnet wire. Popular gauges include 28, 26 and 24, but this is quite variable.

Minimally, you could get by with just #43 ferrite and #6 powdered iron toroids. For example, FT37-43 ferrites and T50-6 plus T68-6 powdered iron toroids could build a lot of inductors/transformers. In the photo above, I used #24 AWG wire for the 18 turns and #22 AWG wire for the 3-turn link. The 3 turn link is grounded on one end and well anchors the transformer. Thicker wire was chosen because Ugly Construction was used and the part is really anchored with the #22 AWG wire.

Conclusion

It took quite a lot of experimentation to reach the project goal. The experience was pleasant and comparing the old and new oscilloscopes was an added bonus. Perhaps, the circuits are overly complicated, however, they are critical signal generators for my workbench. Well designed signal generators have extensive RF-proof shielding to allow serious attenuation. These will have to do.

Addition - Jan 31, 2010 5 MHz JFET Low Noise Oscillator

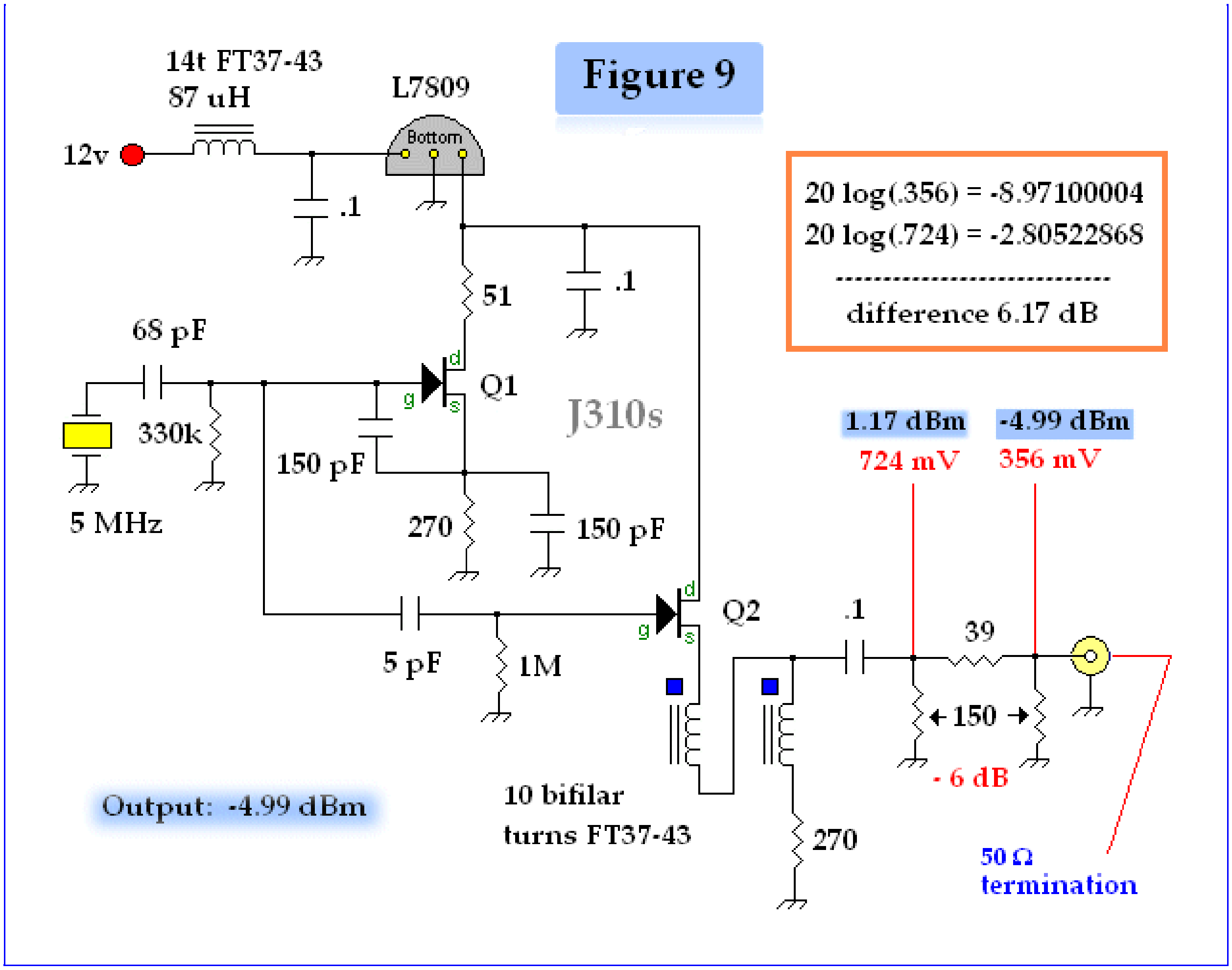
Figure 9
14t FT37-43
87 uH
L7809
Bottom
12v
.1
51
.1
68 pF
Q1
d
g
s
J310s
330k
150 pF
5 MHz
270
150 pF
5 pF
1M
Q2
d
g
s
.1
39
150
- 6 dB
10 bifilar
turns FT37-43
270
50 Ω
termination
Output: -4.99 dBm
1.17 dBm
724 mV
-4.99 dBm
356 mV
20 log(.356) = -8.97100004
20 log(.724) = -2.80522868
difference 6.17 dB

Another experimental low noise oscillator was built for 5 MHz. The desired output power was -5 dBm. The schematic and peak-peak output voltages and powers are shown in Figure 9. The 68 pF capacitor in series with the crystal was found experimentally by using a variable capacitor and measuring the output voltage and observing the scope waveform. When these appeared to be optimal, the trimmer capacitor was removed and measured at 67.17 pF. This circuit can easily be adjusted to give higher output power such as 7 dBm. To increase power, you may consider increasing the VCC to 12 volts, add a 0.1 uF source bypass capacitor in parallel with the 270 Ohm resistor of Q2 and/or adjust the pad attenuation. There are other circuit alterations to increase power, but the aforementioned are a good start.

It is important to measure your output voltages with a 50 ohm load connected to the device. Standard value resistors were used which throw off the value somewhat, but the actual attenuation of the pad is very close to the 6 dB attenuation expected. The math can be done with software such as Applets H and I on the QRP tools web page.

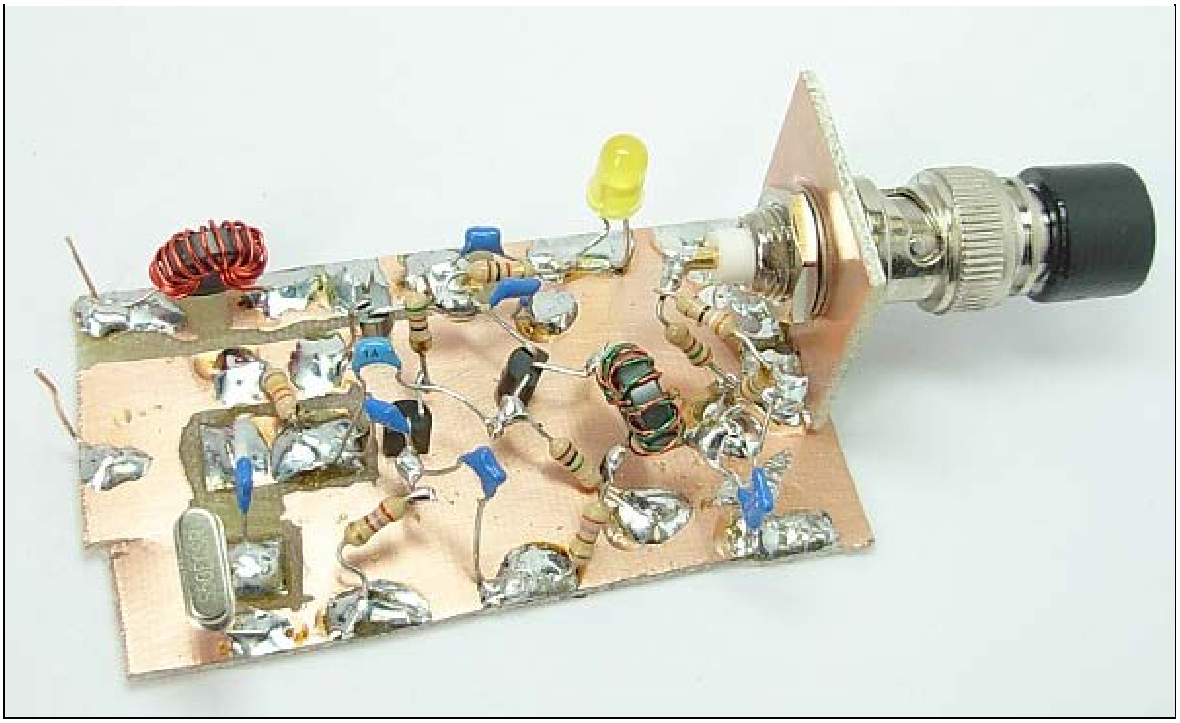

The breadboard of Figure 9 is shown above. The - 5 dBm output was required for some upcoming experiments and to study log and power measurements. The black BNC appliance is a 50 ohm load. These are very handy, but not a necessity. In most cases, a simple 51 ohm resistor to ground is the load.

Figure 10

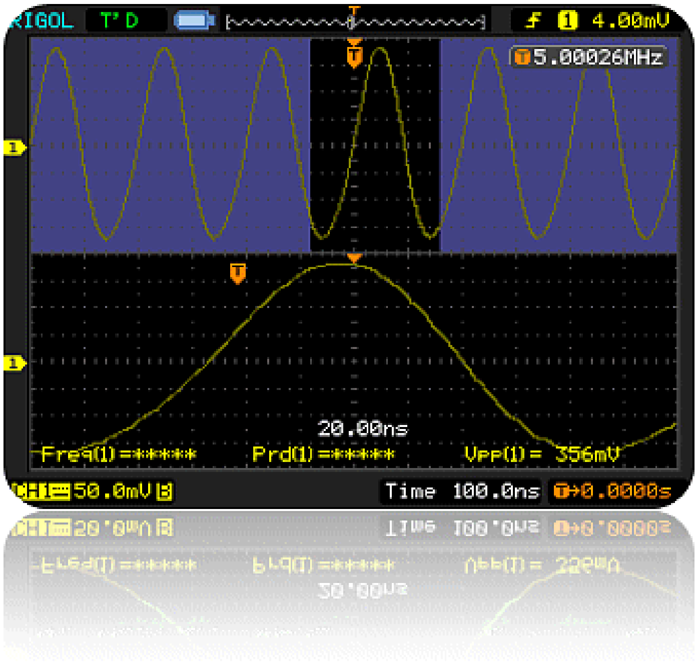
RIGOL T'D
4.00mV
5.00026MHz
20.00ns
Freq(1)=*****
Prd(1)=*****
Vpp(1)= 356mV
CH1 50.0mV
Time 100.0ns
0.0000s

A screen capture from Figure 9 signal viewing maneuvers.

Figure 11

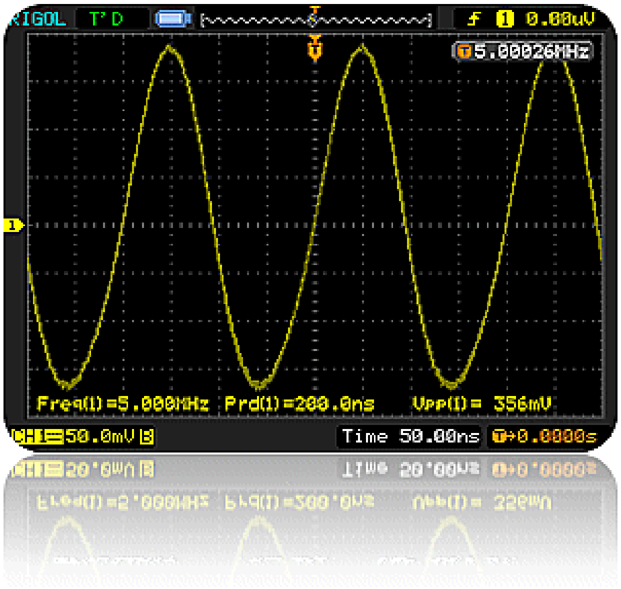
RIGOL T'D
0.00uV
5.00026MHz
Freq(1)=5.000MHz Prd(1)=200.0ns Vpp(1)= 356mV
CH1 50.0mV
Time 50.00ns
0.0000s

The output waveform looks good - even on a DSO!

Spectrum Analysis

Figure 12

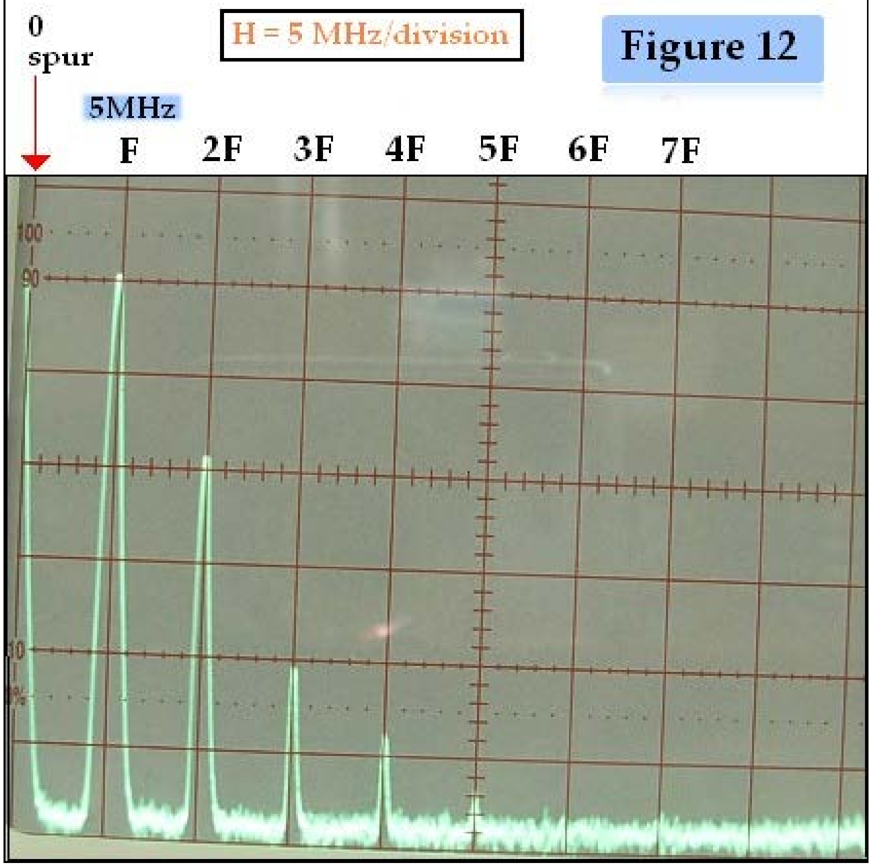

The output of the Figure 9 oscillator was further attenuated -19 dB for analysis in a spectrum analyzer. The -19 dB was chosen as this 50 ohm pad uses near standard resistor values and would well ensure a very safe signal level for the spectrum analyzer. The pad is shown in the Figure 14 schematic. The second harmonic (2F) is down about 20 dB from the fundamental. Each horizontal division is 5 MHz and each vertical division is 10 dB. Compared to other more conventional oscillators that were checked in the spectrum analyzer, this oscillator has low harmonic content.

Figure 13

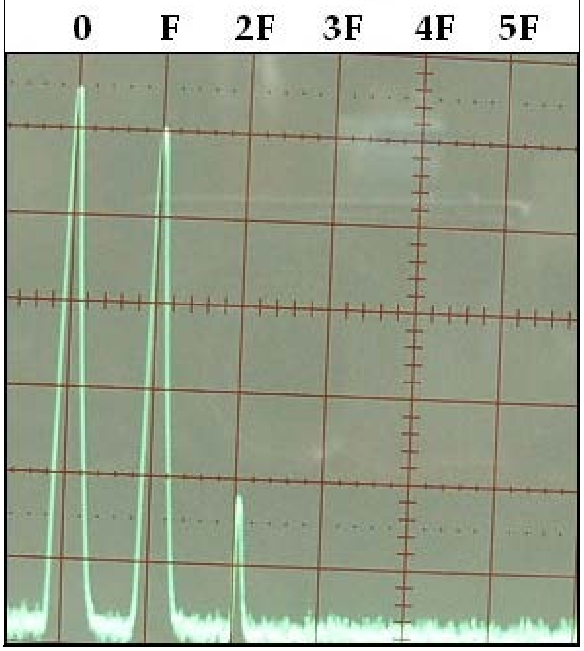

A N=5 or 5 element Chebyshev low-pass filter was placed after the Figure 9 oscillator and connected to the spectrum analyzer to see what happens. The 3 dB down frequency of this low-pass filter was 6.53 MHz. The second harmonic is now ~42 dB down. There are no measureable harmonics after 2F. It is really cool to "see" what a filter does to a signal.

Figure 14

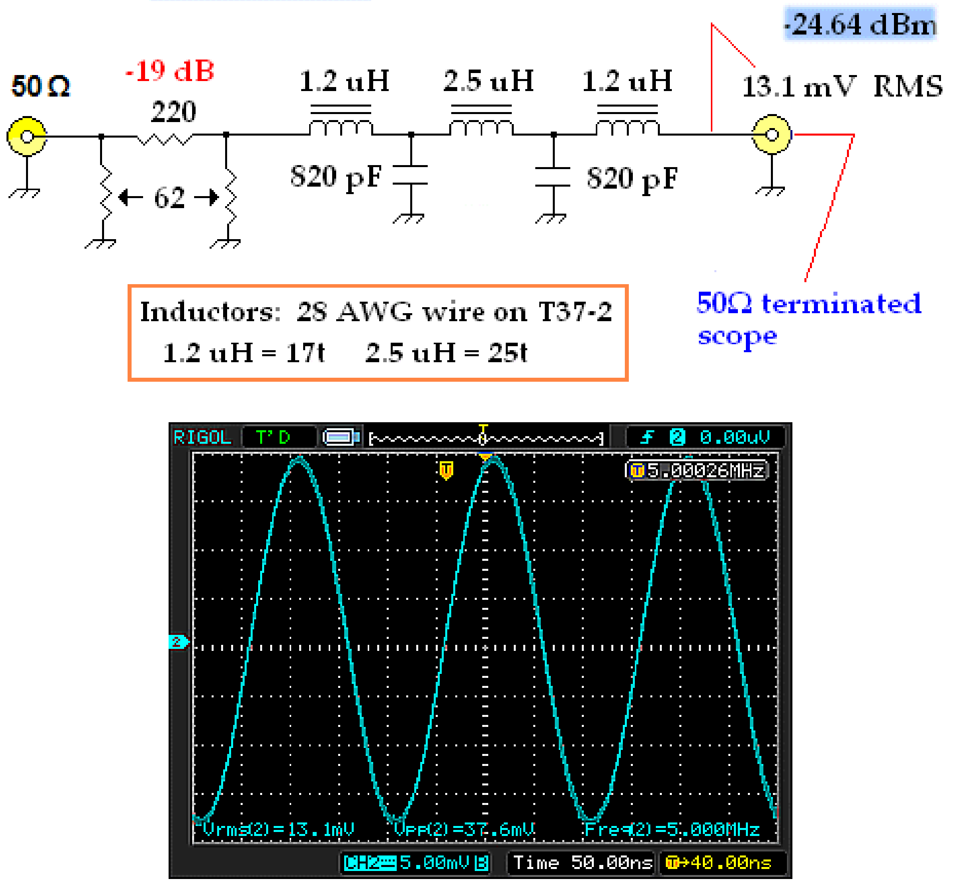
-24.64 dBm
50 Ω
-19 dB
220
62
1.2 uH
2.5 uH
1.2 uH
820 pF
820 pF
13.1 mV RMS
50Ω terminated scope
Inductors: 28 AWG wire on T37-2
1.2 uH = 17t 2.5 uH = 25t
RIGOL T'D
0.00uV
5.00026MHz
Vrms(2)=13.1mV
Vpp(2)=37.6mV
Freq(2)=5.000MHz
CH2 5.00mV
Time 50.00ns
T→40.00ns

The schematic of the -19 dB attenuator pad and the low-pass filter is shown. To measure the output, the 10X probe was disconnected. The circuit was connected to the oscilloscope via 50 ohm coaxial cable and the scope input was terminated with 2 paralleled 100 ohm resistors. The 50 ohm scope termination technique will be discussed in a future web page addition. The RMS voltage values were inputted into Applet J on the QRP Tools page to calculate the output power. The RMS output was 0.131 volts which calculated to an output power of -24.6 dBm.

RF — Test and Measurement

Crystal Parameter Checker

ABRACON
5.0000
AB 0436

Introduction

This web page is a supplement to JavaScript Applet **G** on this web page. This software does the math using a simpified version of the method to determine motional inductance and capacitance developed by David, G3UUR. This is a very basic tutorial meant as an introductory guide for novice builders.

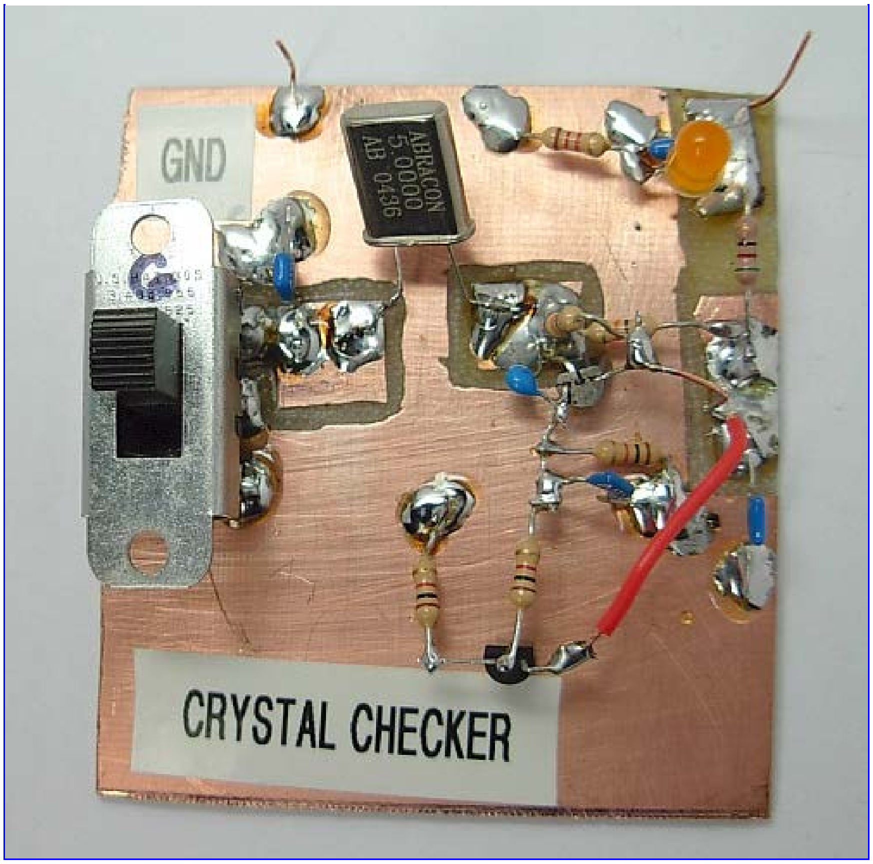

Shown in the photo above is 1 of my crystal parameter checkers. The schematic may be found in many places including EMRFD Figure 3.35 (See Errata) and on this pdf by Nick, WA5BDU. A power indicator LED has been added, but the circuit is the standard design. In this breadboard, the crystal being measured is tack soldered in.

Many builders just copy other builder's I.F. filter schematics, however, your crystal filters will perform better if your design is based upon the exact parameters of the crystals you have. For the simple design or optimization of a crystal filter, it is necessary to measure crystal parallel capacitance plus take other measurements to calculate motional inductance and capacitance. Determining your crystal parameters is not difficult if you have a capacitance meter, a frequency counter and some math skills. It is easiest to use a program to crunch the math; hence I wrote a stupid-simple JavaScript applet.

Designing filters is another story; it takes knowledge, practice and good software for this. Filter design theory has been extensively covered by Anatoly Zverev, Wes Hayward and others. The work of Nick, WA5BDU is also greatly appreciated. His presentations and references are excellent for those keen on learning more about filter design.

A four crystal 5.00 MHz SSB I.F. filter was desired. 20 crystals were on hand — they were from the same batch. The crystals were all placed in the above oscillator and their frequency was measured. The 4 crystals closest matching in frequency were set aside. The crystal parameters of these 4 were then determined. Typically these values are averaged and this average is used to design or tweak the filter using software.

---

1. Measure Capacitance

The procedure for determining the parameters of 1 crystal is described.

The first step is to measure the crystal capacitance (called parallel capacitance) using a capacitance meter.

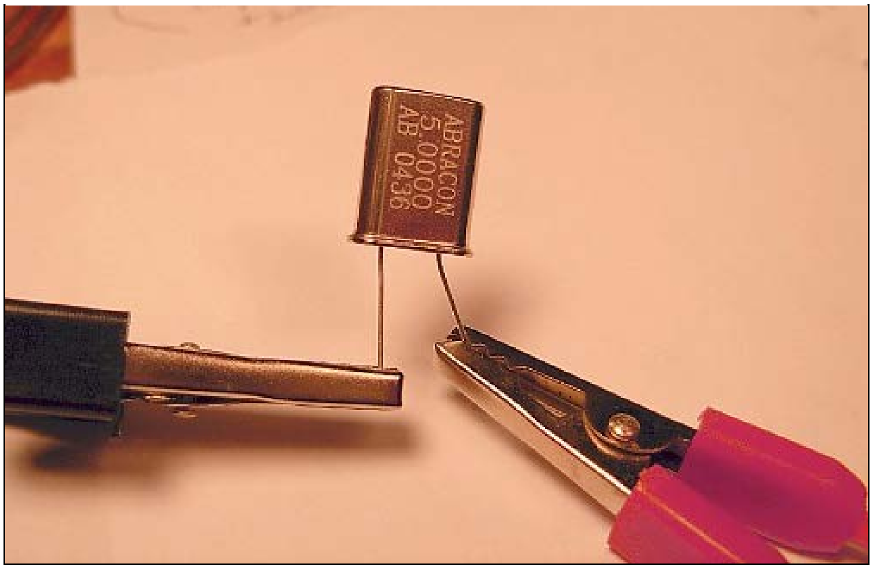

Measuring the crystal parallel capacitance

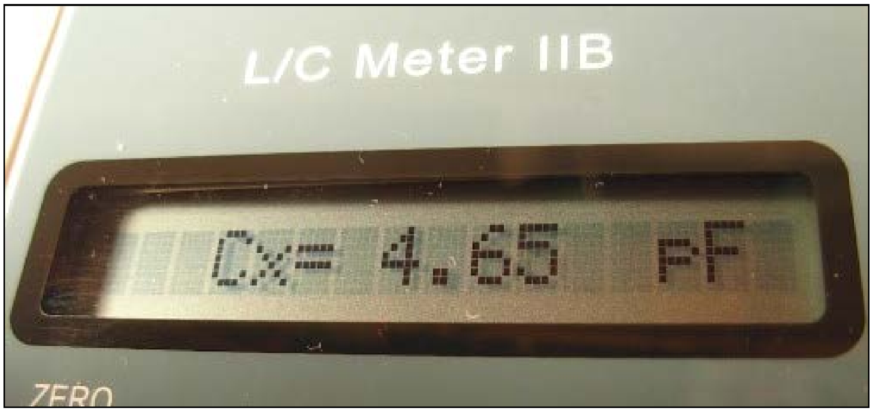

Parallel capacitance of the above 5.0 MHz crystal in an AADE LC meter

L/C Meter IIB
Cx= 41.19 pF

Next, measure the capacitance of the open switch plus the 33 pF fixed value cap wired in-situ. This will give you the total circuit capacitance of the open switch, the 33 pF fixed value capacitor, and any stray capacitance from your crystal holder, wires, etc. The switch itself plus stray wiring will be a few pF so the total should be around 36 to 40 pF or so. In my test oscillator, the result = 41.19 pF as shown. On my other crystal checker with a better switch, it's 36.9 pF.

In the calculation of crystal Lm and Cm, the parallel capacitance and the switch circuit capacitance will be summed.

---

2. Measure Frequencies

A crystal is put in the oscillator with the switch open. Record the frequency. Your counter must have resolution down to 1 Hertz. After recording this value, throw the switch and measure and record this frequency. You now have all the measured values required to calculate motional parameters and adjust or design a filter. Motional parameters are calculated in Applet G.

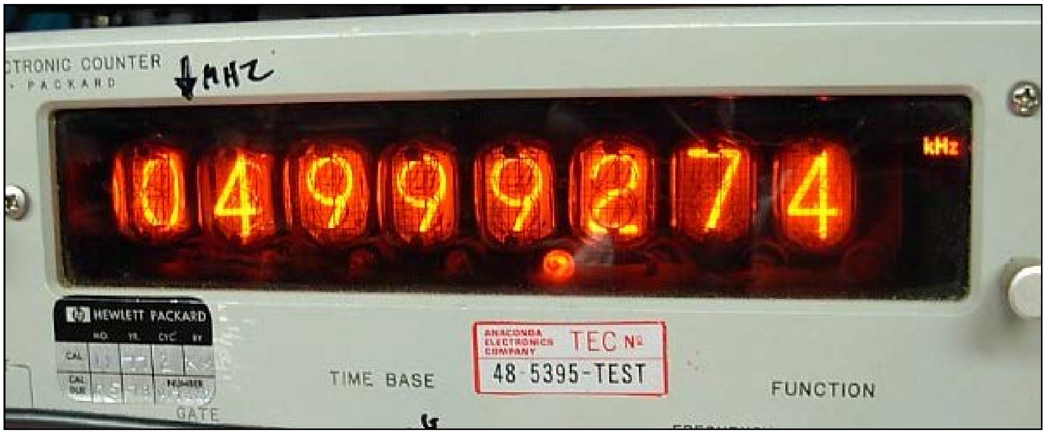
ELECTRONIC COUNTER
PACKARD
MHZ
04999274
kHz
HEWLETT PACKARD
TIME BASE
ANACONDA ELECTRONICS COMPANY TEC No
48-5395-TEST
FUNCTION
GATE

Frequency measured with the switch open = 4.999274 MHz

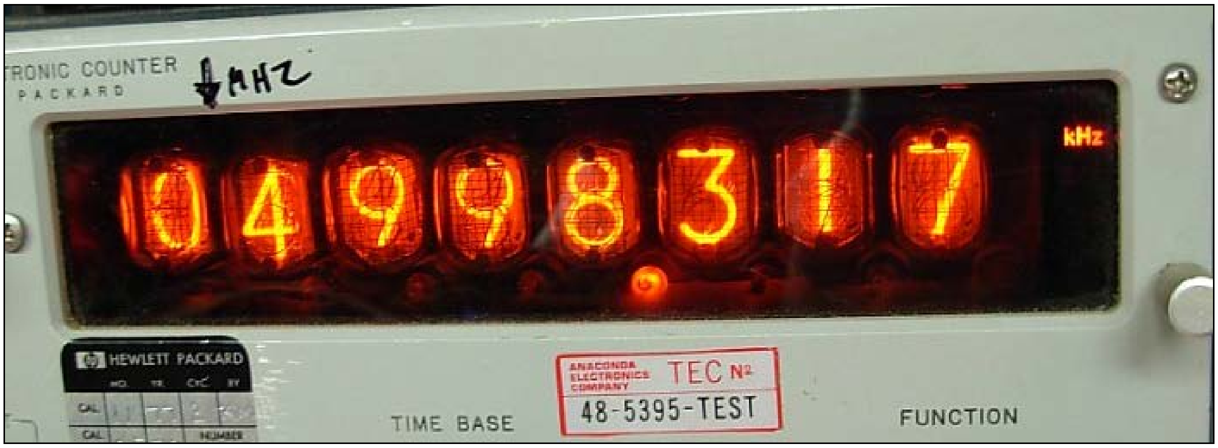
ELECTRONIC COUNTER
PACKARD
MHZ
04998317
kHz
HEWLETT PACKARD
TIME BASE
ANACONDA ELECTRONICS COMPANY TEC No
48-5395-TEST
FUNCTION

Frequency measured with the switch thrown = 4.998317 MHz

---

3. Do Math by Hand or with Software

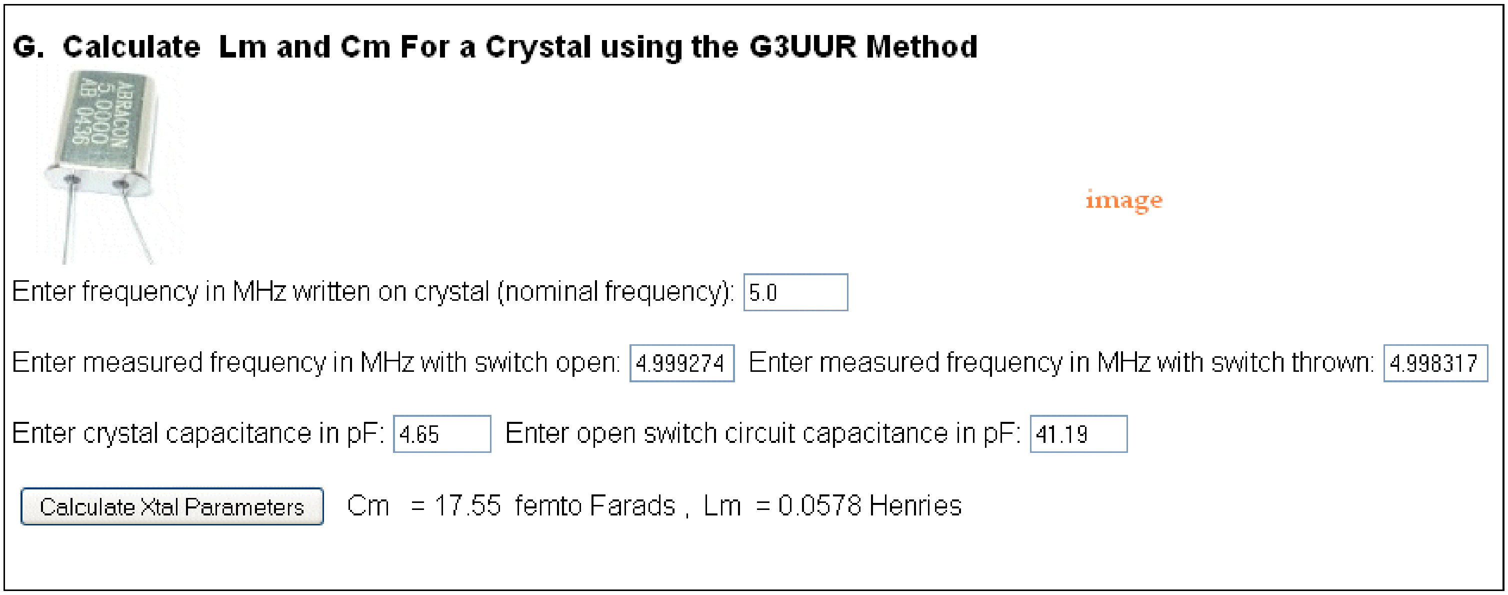

G. Calculate Lm and Cm For a Crystal using the G3UUR Method

ABRACON
5.0000
AB 0436
image

Enter frequency in MHz written on crystal (nominal frequency): 5.0

Enter measured frequency in MHz with switch open: 4.999274 Enter measured frequency in MHz with switch thrown: 4.998317

Enter crystal capacitance in pF: 4.65 Enter open switch circuit capacitance in pF: 41.19

Calculate Xtal Parameters

Cm = 17.55 femto Farads , Lm = 0.0578 Henries

The applet **G** calculation of the crystal parameters using the above measured values

---

4. Example Filter Adjustment

It is assumed that most builders will use software to design or tweak their crystal filters. The only 2 programs tried *(to date)* include AADE Filter Design and the Ladpac software collection that supplements EMRFD. I am more familiar with the Ladpac programs written by Wes, W7ZOI. Only these programs are demonstrated. Please read the instructional file Ladpac2008 Manual.pdf to understand these programs. *The Ladpac software bundle includes GPLA.*

The purpose of this tutorial is not to teach crystal filter design, but to describe a relatively simple method to tweak an existing design using your measured crystal parallel capacitance and its calculated motional inductance.

The first step is to digitally format your filter into a file that can be analyzed in GPLA. In my opinion, the easiest way to do this is to use the ladder circuit editor ladbuild02.exe or better yet, its update - ladbuild08.exe. The model filter follows:

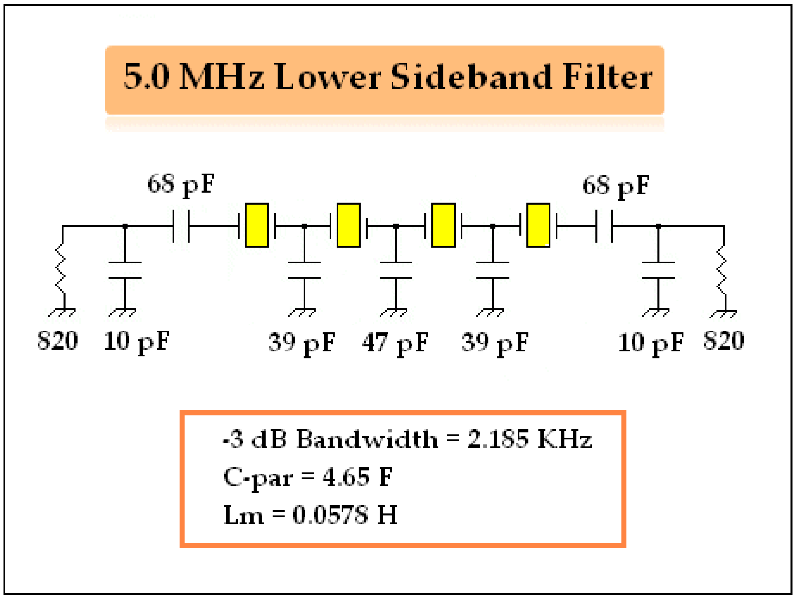
5.0 MHz Lower Sideband Filter
68 pF
68 pF
820
10 pF
39 pF
47 pF
39 pF
10 pF
820
-3 dB Bandwidth = 2.185 KHz
C-par = 4.65 F
Lm = 0.0578 H

The model 5 MHz SSB filter

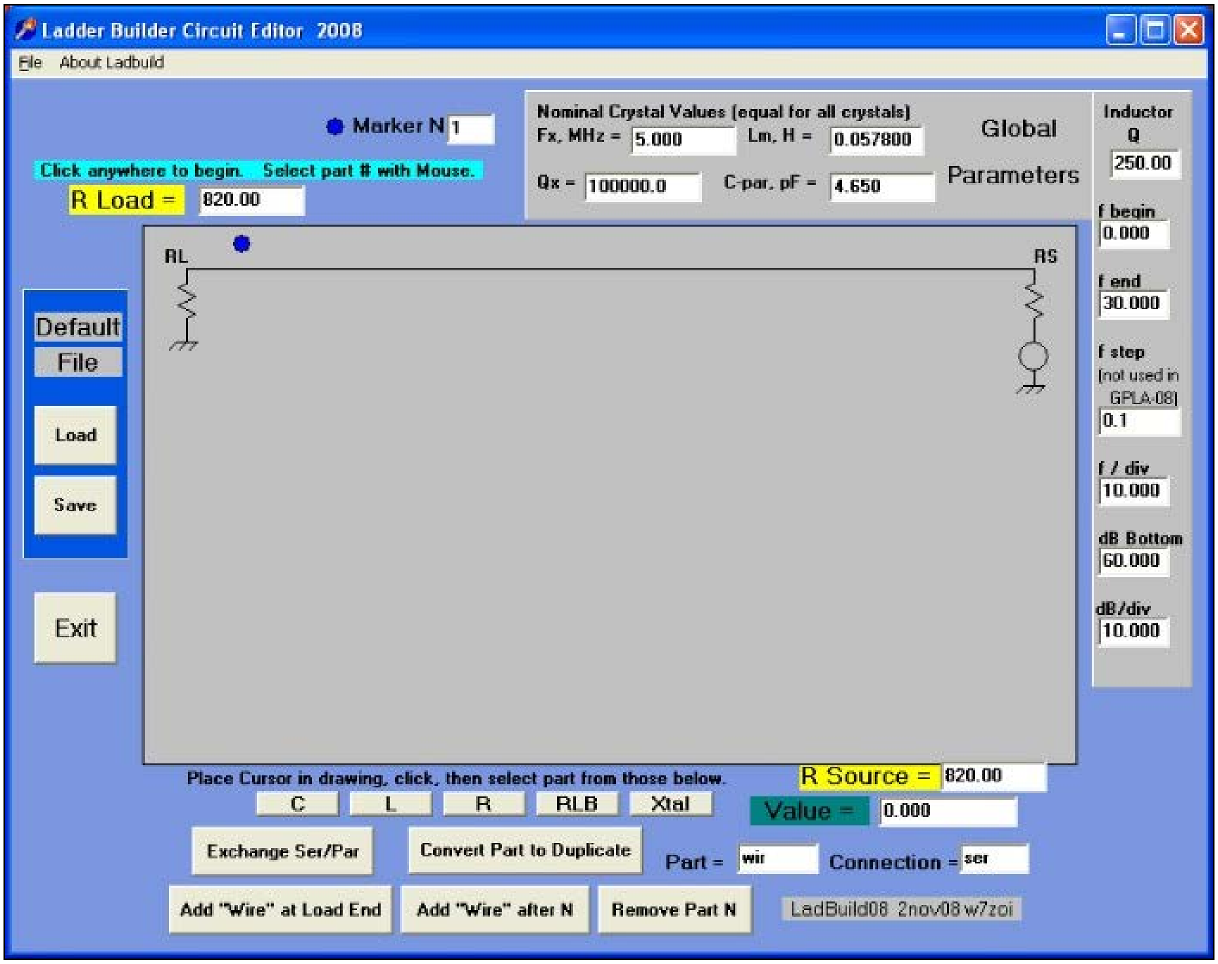
Ladder Builder Circuit Editor 2008
File
About Ladbuild
Global
Parameters
RL
RS
Default
File
Load
Save
Exit
C
L
R
RLB
Xtal
Exchange Ser/Par
Convert Part to Duplicate
Add "Wire" at Load End
Add "Wire" after N
Remove Part N
LadBuild08 2nov08 w7zoi

Marker N 1

Click anywhere to begin. Select part # with Mouse.

R Load = 820.00

Nominal Crystal Values (equal for all crystals)

Fx, MHz = 5.000

Lm, H = 0.057800

Qx = 100000.0

C-par, pF = 4.650

Inductor Q 250.00

f begin 0.000

f end 30.000

f step (not used in GPLA-08) 0.1

f / div 10.000

dB Bottom 60.000

dB/div 10.000

Place Cursor in drawing, click, then select part from those below.

R Source = 820.00

Value = 0.000

Part = wir

Connection = ser

Clear any existing components and enter the termination R, C-par and Lm values. Qx is set at 100000

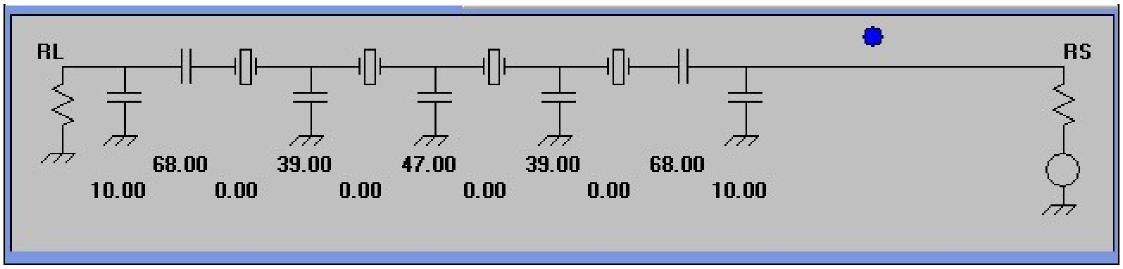
RL
RS
68.00
39.00
47.00
39.00
68.00
10.00
0.00
0.00
0.00
0.00
10.00

Build your filter within the editor. Save your work. Start up GPLA and load your newly saved filter.

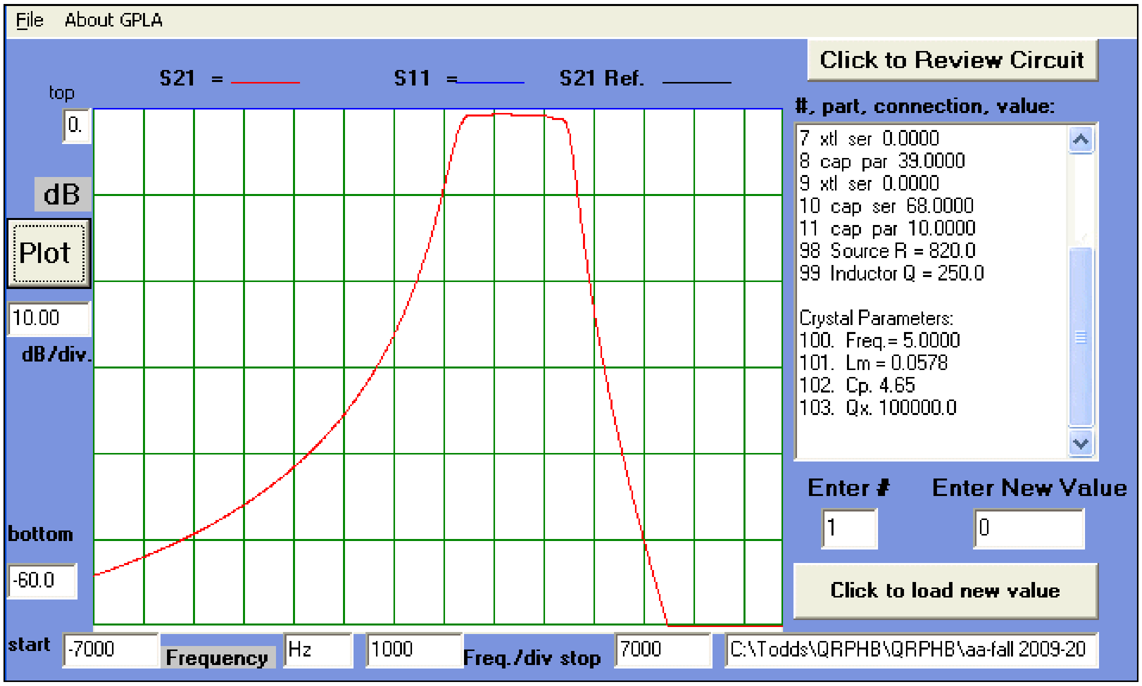
File
About GPLA
S21 =
S11 =
S21 Ref.
dB
Plot
Click to Review Circuit
#, part, connection, value:
Click to load new value
Frequency
Freq./div stop

top 0.

10.00 dB/div.

bottom -60.0

start -7000 Hz 1000 7000 C:\Todds\QRPHB\QRPHB\aa-fall 2009-20

7 xtl ser 0.0000
8 cap par 39.0000
9 xtl ser 0.0000
10 cap ser 68.0000
11 cap par 10.0000
98 Source R = 820.0
99 Inductor Q = 250.0

Crystal Parameters:
100. Freq.= 5.0000
101. Lm = 0.0578
102. Cp. 4.65
103. Qx. 100000.0

Enter # 1

Enter New Value 0

Set a sweep and **x** axis increment (-7000, 1000 and 7000 in this example). Push the Plot button

Let's say you wanted to use this filter design and have determined the average parameters of the 5.00 MHz crystals in your parts collection. Let's assume that for your crystals, C-par = 3.1 pF, and Lm = 0.098H. Input these values in GPLA.

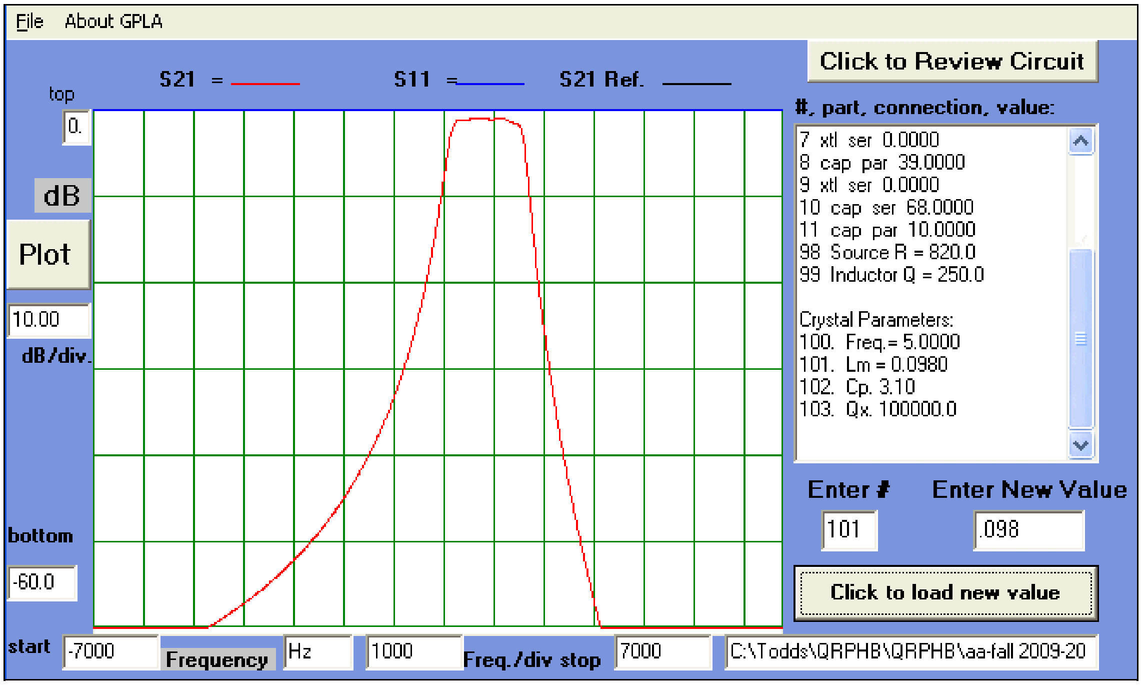
File
About GPLA
S21 =
S11 =
S21 Ref.
dB
Plot
Click to Review Circuit
#, part, connection, value:
Click to load new value
Frequency
Freq./div stop

top 0.

10.00 dB/div.

bottom -60.0

start -7000 Hz 1000 7000 C:\Todds\QRPHB\QRPHB\aa-fall 2009-20

7 xtl ser 0.0000
8 cap par 39.0000
9 xtl ser 0.0000
10 cap ser 68.0000
11 cap par 10.0000
98 Source R = 820.0
99 Inductor Q = 250.0

Crystal Parameters:
100. Freq.= 5.0000
101. Lm = 0.0980
102. Cp. 3.10
103. Qx. 100000.0

Enter # 101

Enter New Value .098

Look what happened to the crystal filter's bandwidth. Our - 3dB bandwidth is now somewhere around 1464 Hertz. This simple experiment illustrates how important it is to use the parameters of your crystals to obtain a desired filter response.

Experiment with the various functions in GPLA to learn how to use it. Set whatever reasonable sweep you want. This program is best learned by using it repeatedly.

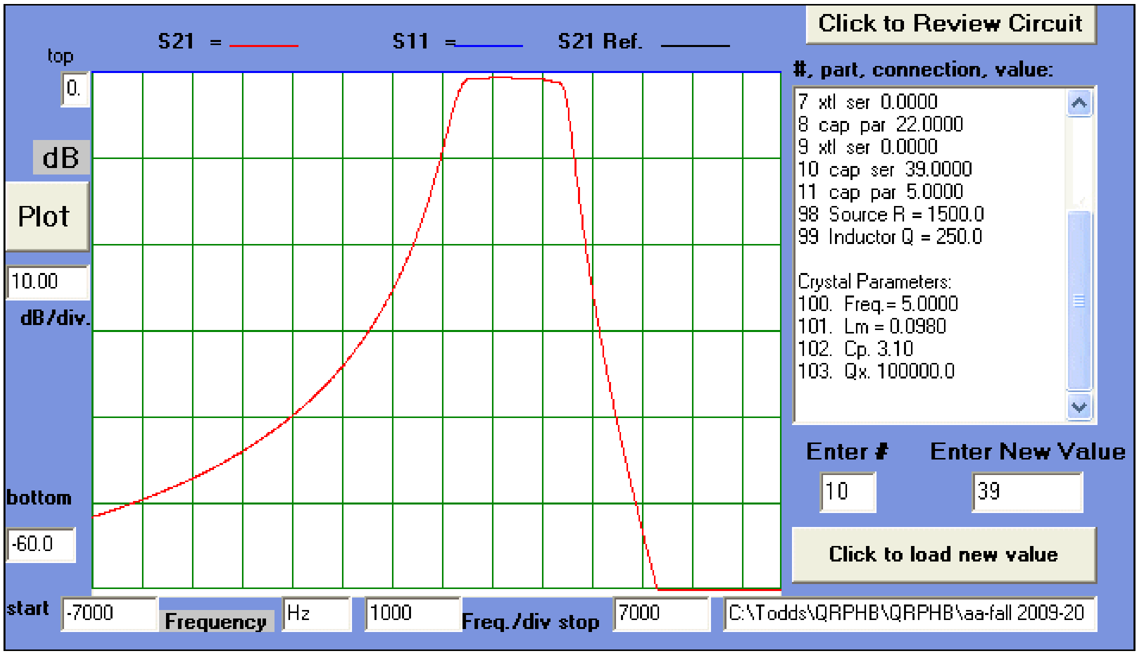

top 0.

10.00 dB/div.

bottom -60.0

start -7000 Hz

Freq./div 1000

stop 7000

C:\Todds\QRPHB\QRPHB\aa-fall 2009-20

#, part, connection, value:

```
7 xtl ser 0.0000
8 cap par 22.0000
9 xtl ser 0.0000
10 cap ser 39.0000
11 cap par 5.0000
98 Source R = 1500.0
99 Inductor Q = 250.0

Crystal Parameters:
100. Freq.= 5.0000
101. Lm = 0.0980
102. Cp. 3.10
103. Qx. 100000.0
```

Enter # 10

Enter New Value 39

In the above screen capture, the above filter was tweaked to "re-establish" a -3dB bandwidth of ~2.172 KHz. All adjustment was performed entirely in GPLA by swapping capacitor values and observing the resultant waveform. When you get an overall pleasing bandwidth plus shape, but there is too much ripple at the top, generally you must increase the terminating R values. This is the brute-force, manual way to tune filters. For this method, you need not understand terminology such as as series resistance, MESH, K or Q values, Butterworth response, or Chebyshev with 0.1 dB of ripple.

Admittedly, at first, this method can be quite time consuming and tedious, however, with practice, you may be able to tweak a filter in only a few minutes. Clearly, the more you dig into understanding crystal filter design, the better your filters can be, however, getting overly complex can scare off builders who are new to this hobby. Note these filters use standard value capacitors and resistors; perfect for popcorn I.F. filters.

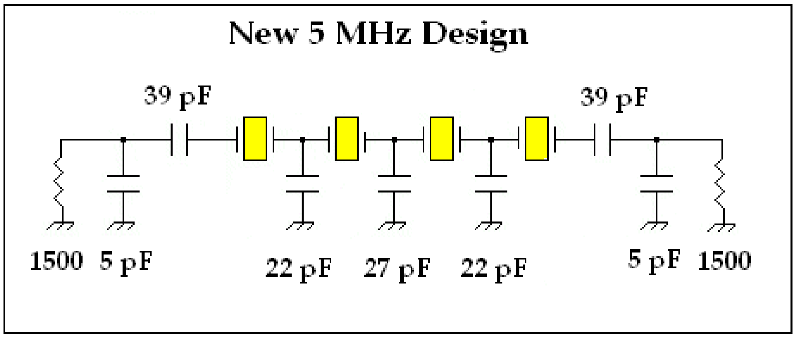

The original 5 MHz Model filter with updated C and R values using Lm = 0.098 and C-par = 3.1

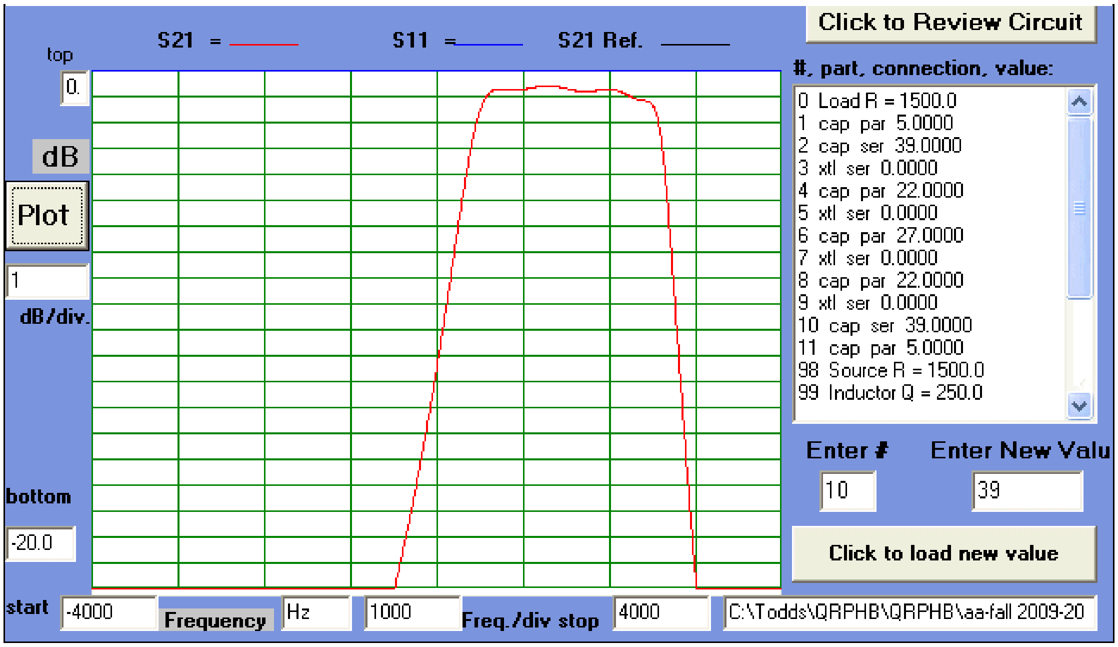

top 0.

1 dB/div.

bottom -20.0

start -4000 Frequency Hz 1000 Freq./div stop 4000

C:\Todds\QRPHB\QRPHB\aa-fall 2009-20

#, part, connection, value:

0 Load R = 1500.0
1 cap par 5.0000
2 cap ser 39.0000
3 xtl ser 0.0000
4 cap par 22.0000
5 xtl ser 0.0000
6 cap par 27.0000
7 xtl ser 0.0000
8 cap par 22.0000
9 xtl ser 0.0000
10 cap ser 39.0000
11 cap par 5.0000
98 Source R = 1500.0
99 Inductor Q = 250.0

Enter # 10

Enter New Valu 39

GPLA zoom of the **Y** axis showing the first 20 dB of attenuation.

---

5. The Model 5 MHz SSB filter Design

Although this page is not about crystal filter design, an example follows for reference purposes.

For designing filters, the application xlad08.exe is a good choice. The following 3 screen captures show the raw design process and GPLA analysis of the model 5 MHz Lower Sideband filter shown earlier with C-par = 4.65 pF and Lm = .0578. There are some great articles in print and on the Web to study if you want to learn about filter design. The Ladpac software from EMRFD is excellent. My special thanks to Wes, W7ZOI for answering my questions about his software. From this information, I was able to make this web page.

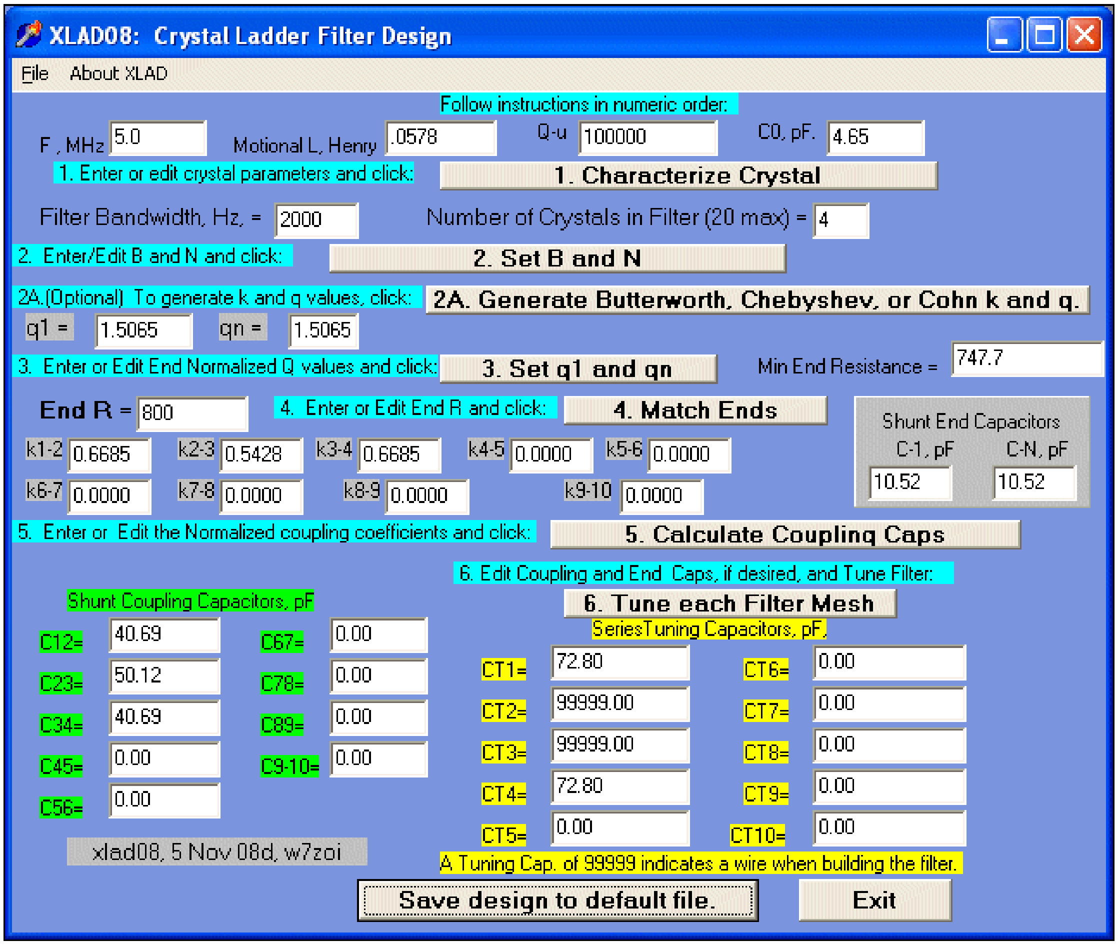
XLAD08: Crystal Ladder Filter Design
File
About XLAD
1. Characterize Crystal
2. Set B and N
2A. Generate Butterworth, Chebyshev, or Cohn k and q.
3. Set q1 and qn
4. Match Ends
5. Calculate Coupling Caps
6. Tune each Filter Mesh
Save design to default file.
Exit

Follow instructions in numeric order:

F, MHz 5.0

Motional L, Henry .0578

Q-u 100000

C0, pF. 4.65

1. Enter or edit crystal parameters and click:

Filter Bandwidth, Hz, = 2000

Number of Crystals in Filter (20 max) = 4

2. Enter/Edit B and N and click:

2A.(Optional) To generate k and q values, click:

q1 = 1.5065

qn = 1.5065

3. Enter or Edit End Normalized Q values and click:

Min End Resistance = 747.7

End R = 800

4. Enter or Edit End R and click:

Shunt End Capacitors

C-1, pF 10.52

C-N, pF 10.52

k1-2 0.6685

k2-3 0.5428

k3-4 0.6685

k4-5 0.0000

k5-6 0.0000

k6-7 0.0000

k7-8 0.0000

k8-9 0.0000

k9-10 0.0000

5. Enter or Edit the Normalized coupling coefficients and click:

6. Edit Coupling and End Caps, if desired, and Tune Filter.

Shunt Coupling Capacitors, pF

C12= 40.69

C23= 50.12

C34= 40.69

C45= 0.00

C56= 0.00

C67= 0.00

C78= 0.00

C89= 0.00

C9-10= 0.00

SeriesTuning Capacitors, pF.

CT1= 72.80

CT2= 99999.00

CT3= 99999.00

CT4= 72.80

CT5= 0.00

CT6= 0.00

CT7= 0.00

CT8= 0.00

CT9= 0.00

CT10= 0.00

xlad08, 5 Nov 08d, w7zoi

A Tuning Cap. of 99999 indicates a wire when building the filter.

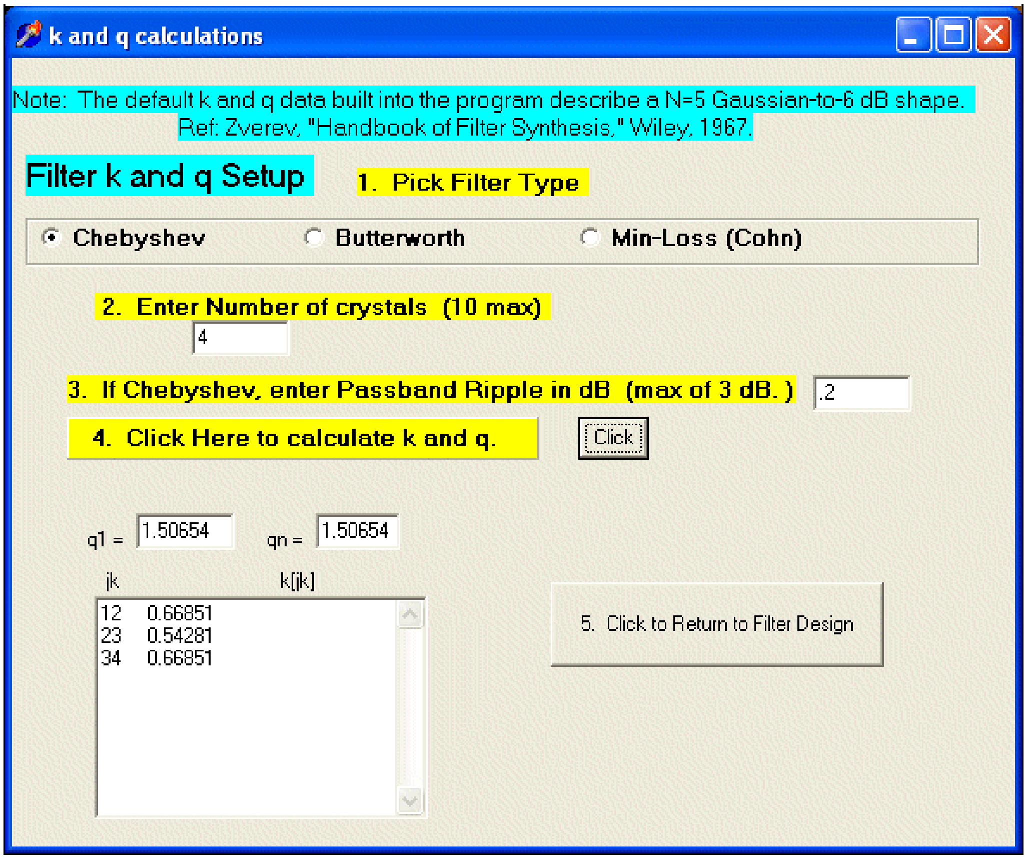

k and q calculations

Note: The default k and q data built into the program describe a N=5 Gaussian-to-6 dB shape.
Ref: Zverev, "Handbook of Filter Synthesis," Wiley, 1967.

Filter k and q Setup

1. Pick Filter Type

● Chebyshev ○ Butterworth ○ Min-Loss (Cohn)

2. Enter Number of crystals (10 max): 4

3. If Chebyshev, enter Passband Ripple in dB (max of 3 dB.): .2

4. Click Here to calculate k and q. Click

q1 = 1.50654 qn = 1.50654

jk	k[jk]
12	0.66851
23	0.54281
34	0.66851

5. Click to Return to Filter Design

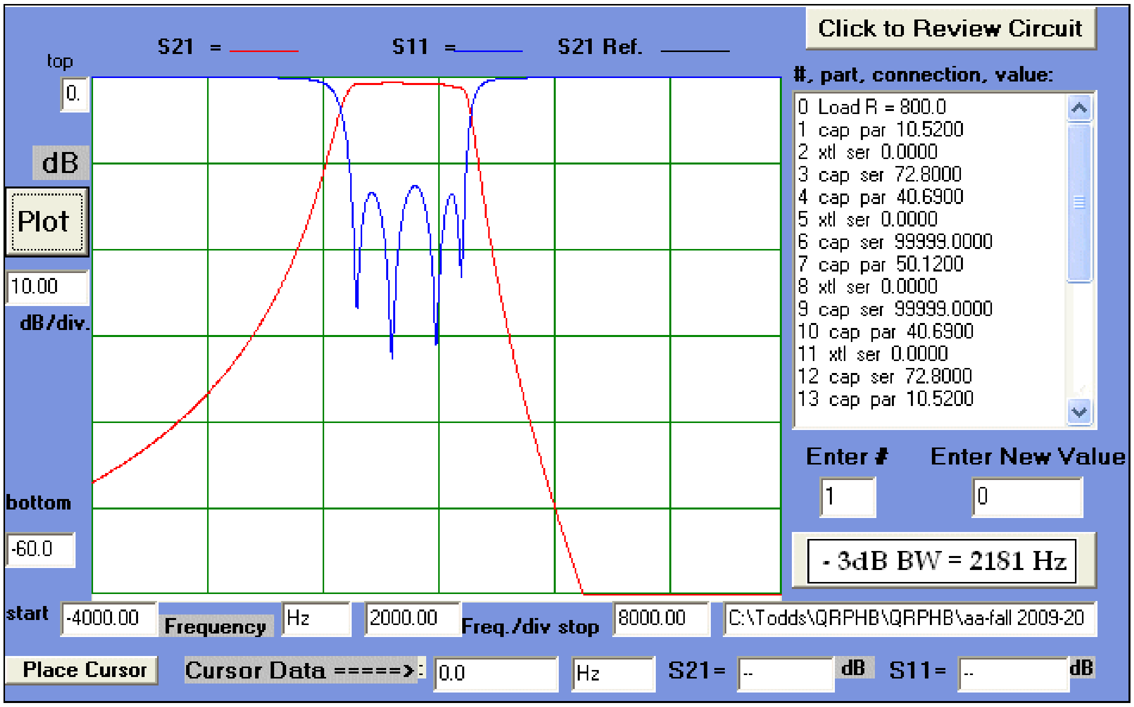

Click to Review Circuit

top: 0.

dB

10.00 dB/div.

bottom: -60.0

#, part, connection, value:

```
0 Load R = 800.0
1 cap par 10.5200
2 xtl ser 0.0000
3 cap ser 72.8000
4 cap par 40.6900
5 xtl ser 0.0000
6 cap ser 99999.0000
7 cap par 50.1200
8 xtl ser 0.0000
9 cap ser 99999.0000
10 cap par 40.6900
11 xtl ser 0.0000
12 cap ser 72.8000
13 cap par 10.5200
```

Enter #: 1 Enter New Value: 0

- 3dB BW = 2181 Hz

start -4000.00 Frequency Hz 2000.00 Freq./div stop 8000.00 C:\Todds\QRPHB\QRPHB\aa-fall 2009-20

Cursor Data =====> 0.0 Hz S21= -- dB S11= -- dB

6. Conclusion

This web page presents a brief method to calculate crystal motional parameters and as required, to adjust crystal filter circuits to function optimally. This approach like my Java-script applet are simplistic to avoid the fear factor associated with crystal ladder design.

Listening tests are also valuable for assessing crystal filter function. Is the bandwidth as you expected? Does the filter ring excessively? Does it sound tinny? In the recent past, the crystal filters in 2 kit receivers/transceivers were tweaked as a favor to friends. *Please note, I have total respect for people who sell kits and appreciate the contribution they make to our hobby.*

The crystals of these Cohn type filters were removed and analyzed and the bandwidth was not as specified. In 1 case, the filter shape looked terrible in GPLA. Clearly, the kit sellers provided crystals which had markedly different parameters from those used by the original circuit designer. The I.F. filter capacitors were replaced with appropriate values and the R values were adjusted via either resistors and/or transformer ratios and the improved filters sounded pleasant.

It is a real treat to listen to a receiver with a well designed crystal filter — sadly, I don't enjoy this experience that often.

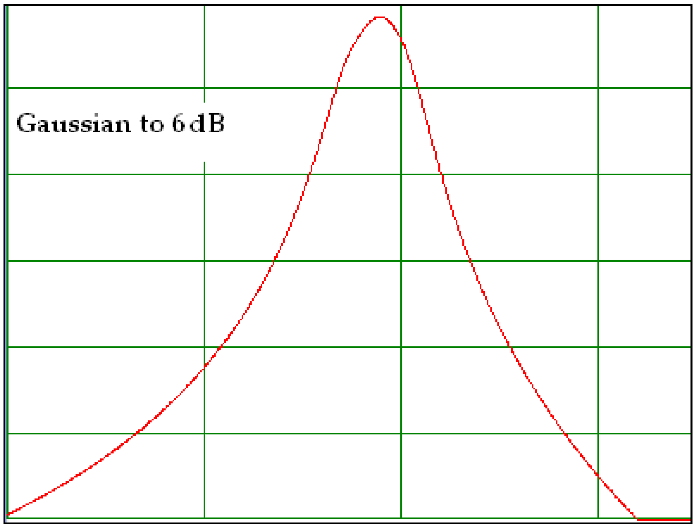

In my opinion, the best sounding CW crystal filter design is the Gaussian to 6 dB. Some operators would never use such a filter in a contest-grade receiver as the filter skirts are not steep enough for them. There are tricks to make the stop band better (more like a Chebyshev response, but without the ringing), however, this topic is out of scope.

I sincerely ask for your feedback on the G. JavaScript Applet. Does it work correctly? How could it be improved? Can you contribute better code? Thanks and 73.

QRP — Posdata for January 2012 — More on Crystal Ladder Design

Important to both superheterodyne receivers and single sideband transmitters, crystal ladder filter design lies juxtaposed as both a favorite and feared RF design topic. Newer builders may lack math skills, and/or become paralyzed by the terminology — or lack the ambition to learn or apply good bench practices. Even a cursory Internet search returns many fabulous files to read — witnessing a crystal ladder filter design article explosion.

The difficulty characterizing and building filters has progressively declined since the advent of the first handheld computers — improvements in personal computers and filter design software allows astute builders to pursue even complex xtal filter response shapes in 2012.

In QST for July 1987. Wes, W7ZOI wrote **Designing and Building Simple Crystal Filters**. This article promoted Cohn or Min-loss filters and its intent was to transcend the math and measurement associated with xtal ladder filters of the day and allow builders to just frequency match some crystals, and then go experiment.

In my estimation, this article proved revolutionary — soon after, builders around the globe, Elecraft, and other kit companies embraced this technique/topology and the rest is history. *(I call it the paper that launched a thousand kits).* If you're a new builder and feel overwhelmed by the material on or referenced by this web page, please consider first obtaining this article.

Learning about crystal ladder filter design is time well spent.

In 2011/2012 I explored the works of 3 builders who share their work via the web and/or journals.

Horst Steder, DJ6EV and Jack Hardcastle, G3JIR

The Steder and Hardcastle works emphasize that we need to measure/calculate crystal L and C parameters, plus the coupling and tuning capacitances (not just frequency). Through emails with Horst, DJ6EV, I learned many things, but 3 stand out:

1. It's better to design a good filter than fix a bad one.
2. Careful measurement of your crystal parameters plus software design and simulation = the best chance for getting your desired performance.
3. Deriving motional parameters from a 3 dB bandwidth measurement remains a great way to characterize multiple xtals. *In my opinion, the G3UUR method is the easiest way to characterize a small batch of xtals.*

Some of the earliest references to modern crystal ladder design I've found were written by Jack Hardcastle and published in RadCom and QST — I later confirmed this by reading work by Wes, W7ZOI and others. Hardcastle's and Haywards' work proved foundational for the experimenters that followed including David Gordon-Smith, Chris Trask, Jim Kortge and many others.

Steder and Hardcastle's combined experience assessing and/or documenting crystal ladder design spans decades.

Their QEX article **Crystal Ladder Filters for All** may be legally downloaded from the ARRL website here.

Program download URL: http://www.arrl.org/qexfiles (select 2010, "11x09_Steder_Hardcastle.zip")

The QEX article describes Steder's Microsoft Windows™ program, methods to derive motional parameters, plus cites many important references. The main program calculates practical lower-sideband crystal ladder filters based on the exact equations published by M. Dishal in 1965. Hardcastle transformed these equations into a computer useable form in 1983 and Steder incorporated these equations into a modern, easy-to-use and interactive application with nice graphing and table displays.

For simplicity, the program assumes lossless crystals, however, the calculated values can easily be transferred into another simulation program such as GPLA to add or refine parameters such as loss resistance.

The main "Dishal" application calculates filters with Butterworth, Chebychev and constant-k (Cohn) properties and the so-called "QER" filter type by G3UUR (a low ripple version of the Cohn filter). Further; sub-programs in the top-level menu calculate xtal parameters (by both the G3UUR and 3 dB method), plus L-C impedance matching and ladder termination networks. An extensive help file well explains the program.

Iacopo Giangrandi — Introduction to Crystal Ladder Filters

Link: http://www.giangrandi.ch/electronics/crystalfilters/xtalintro.html

Iacopo (Jack) uses a transmission measurement to infer the motional parameters — inserting a series capacitance and measuring the series resonant frequency shift was also described in 1998 by Rolf-Dieter Mergner, DJ9FG.

His web article/applications provides what is likely needed by most builders — simple filter synthesis while avoiding expensive test gear. His filters plots/figures are spectrum analyzer measurements that I really like. Although his program can generate aymmetrical filters that some builders might not be used to, the frequency domain plots indicate proper function.
Giangrandi's filter design programs appear to be based on Jack Hardcastle's work and possibly content published in a paper by Patrick Magnin, F6HYE and Bernard Borcard, F3BB in Radio REF for April 1990.

I encourage you to try all the methods and applications mentioned to discover what works best for you. Don't lose heart, for characterizing crystals with a vector network analyzer is also a time-consuming endeavor and simple often = best on the QRP Workbench.

QRP — Posdata for August 2012 — Measuring Crystal Q

Prior to July 26, 2012, I could not measure Xtal Q. Why? I tried to measure crystal Q with the shunt-series tuned method (essentially the crystal acts as a trap and a step attenuator is used to calculate the insertion loss the xtal exhibits when centered in the notch) but failed because I could not precisely set the frequency with my homebrew L-C oscillator.

You really need a DDS or a Si570 based signal generator and preferably a spectrum analyzer to exact the measurement with the "trap method". The DDS is critical, while the SA only preferable — a power meter, or a 50 ohm terminated 'scope can work as the detector if a low-pass filter is placed just after the xtal.

On July 26, 2012 Wes, W7ZOI developed a simplified method and wrote a pdf file called **Simplified Measurement of Crystal Q** after feedback from myself and John Larkin about Q measurement difficulties without a digital-based signal generator. Unfortunately, this pdf file is no longer offered for download by W7ZOI. His method works well and I'm glad that as of now, I can *completely* characterize any crystal I own.

I present an experiment showing how I measured the Q of a 10 MHz crystal applying the new method developed by Wes, W7ZOI.

The crystal is evaluated as a N=1 low-pass filter resonated by a shunt capacitor at each end. I stuck with Wes' suggestion to try 1000 pF at 9 to 10 MHz. For lower frequency xtals he recommended trying larger value shunt capacitors. Just experiment with the shunt capacitance — if you use too high a C for a given crystal, your xtal low-pass filter bandwidth might get too narrow to measure with an L-C based signal generator.

The following diagrams employ 2 programs from the Ladpac software that ship with EMRFD

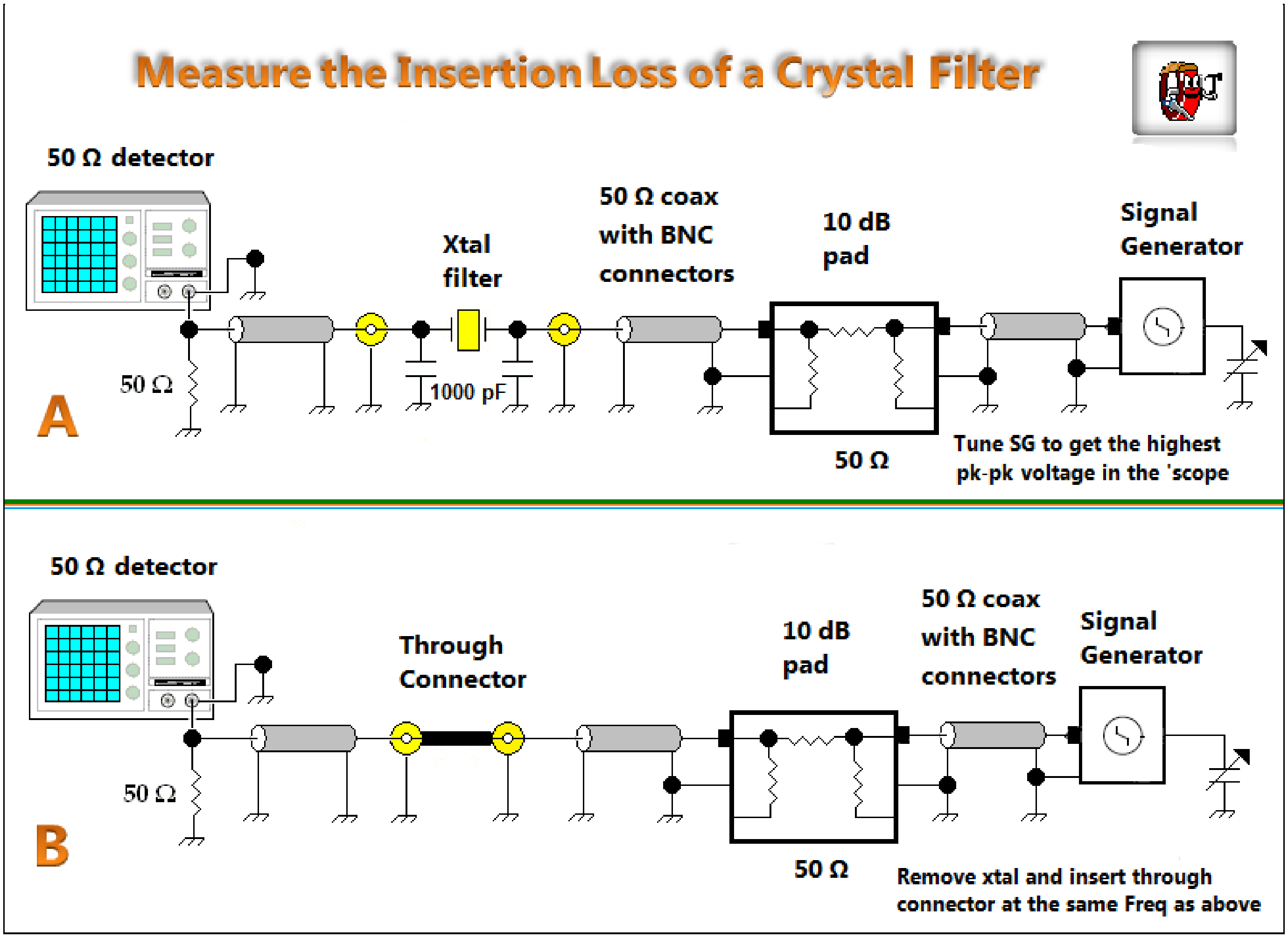
Measure the Insertion Loss of a Crystal Filter
50 Ω detector
50 Ω
A
Xtal
filter
1000 pF
50 Ω coax
with BNC
connectors
10 dB
pad
50 Ω
Signal
Generator
Tune SG to get the highest
pk-pk voltage in the 'scope
50 Ω detector
50 Ω
B
Through
Connector
10 dB
pad
50 Ω
50 Ω coax
with BNC
connectors
Signal
Generator
Remove xtal and insert through
connector at the same Freq as above

Above — Measurement of crystal filter insertion loss. In Part A, I carefully tuned my signal generator to get the highest peak-peak voltage in my 50 Ω terminated oscilloscope. I recorded this AC voltage as V Fil. In Part B, I removed the crystal filter board and replaced it with a BNC clad RF through-connector. I recorded this AC voltage as V Cal.

I discuss this standard method to measure the insertion loss or gain of a *device under test* in RF Workbench 2.

Even with the simplified method, you'll need a signal generator with good tuning resolution. My generator is shown on VFO 2011 as the 2.8-10.5 MHz Signal Generator. This is my version of the EMRFD Figure 7.27 generator.

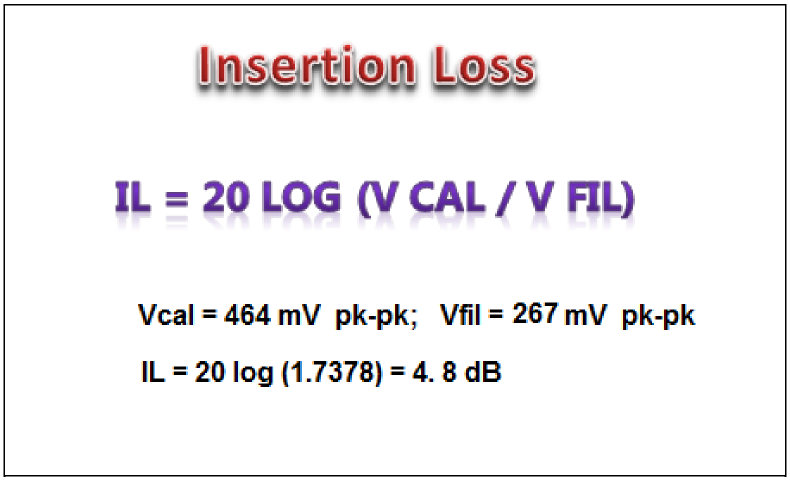

Insertion Loss

IL = 20 LOG (V CAL / V FIL)

Vcal = 464 mV pk-pk; Vfil = 267 mV pk-pk

IL = 20 log (1.7378) = 4. 8 dB

Above — The formula for insertion loss using peak-peak voltages. With my 10.0 MHz crystal, V Cal = 464 mV pk-pk and V Fil = 267 mV pk-pk. The insertion loss of my crystal = 4.8 dB.

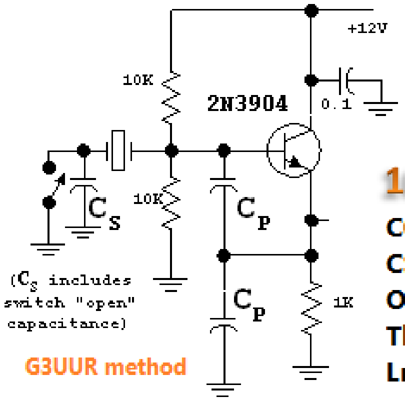
+12V
10K
2N3904
0.1
C_S
10K
C_P
C_P
1K
(C_S includes switch "open" capacitance)
G3UUR method

$$C_M = 2 \cdot C_S \cdot \frac{\Delta F}{F}$$ Old Equation, p 3.19.

$$C_M = 2 \cdot (C_S + C_0) \cdot \frac{\Delta F}{F}$$ Updated Equation

10 MHz Xtal

C0 = 4.87 pF

CS = open switch + cap = 37.4 pF

Open switch F = 9.998710 MHz

Thrown switch F = 9.996104 MHz

Lm = 0.0115 H

Measure C0

Calculate Lm

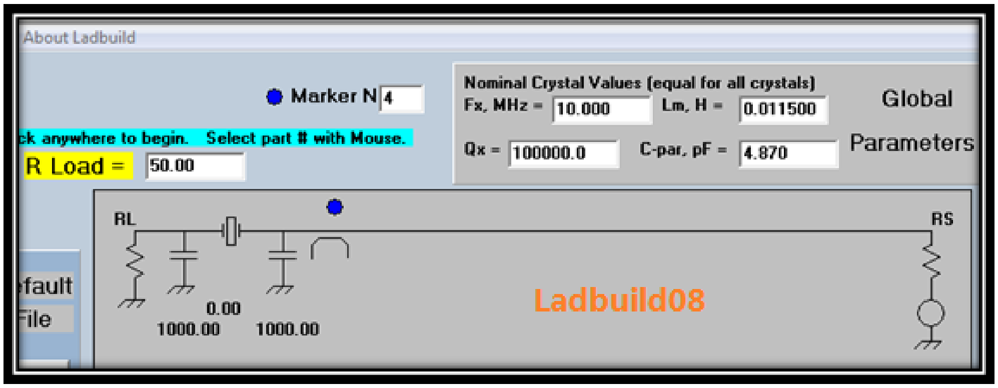
About Ladbuild

Marker N 4

ck anywhere to begin. Select part # with Mouse.

R Load = 50.00

Nominal Crystal Values (equal for all crystals)

Fx, MHz = 10.000 Lm, H = 0.011500

Qx = 100000.0 C-par, pF = 4.870

Global Parameters

fault
File
RL
RS
0.00
1000.00
1000.00
Ladbuild08

Above — First I measured C0 (C-par) and then with the G3UUR method, calculated the motional inductance of my xtal. Finally, I entered all the needed variables into Ladbuild08 to make a filter to analyze in GPLA.

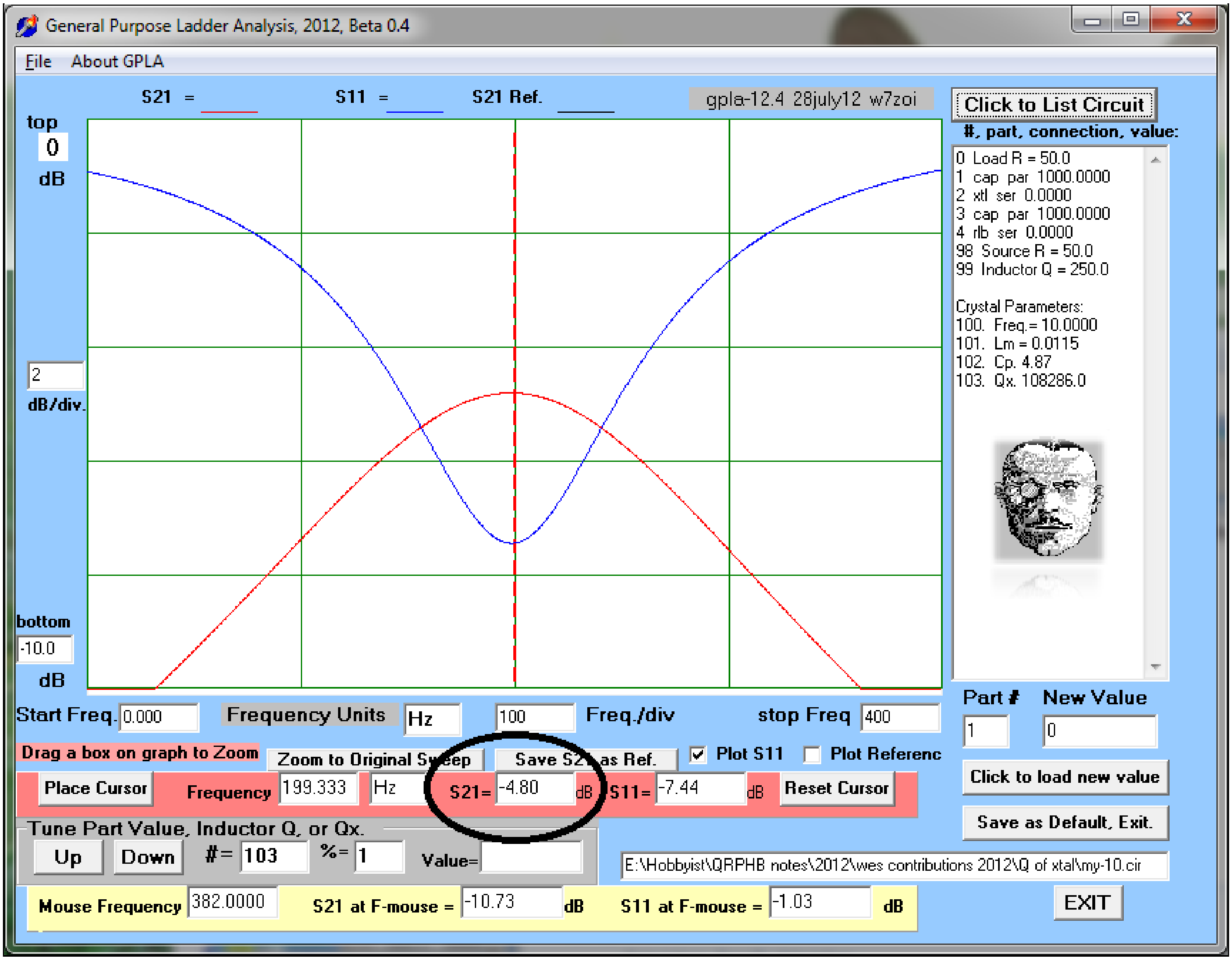
General Purpose Ladder Analysis, 2012, Beta 0.4
File
About GPLA
S21 =
S11 =
S21 Ref.
gpla-12.4 28july12 w7zoi
Click to List Circuit
#, part, connection, value:
top
dB/div.
bottom
dB
Frequency Units
Freq./div
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Plot Referenc
Place Cursor
Reset Cursor
Tune Part Value, Inductor Q, or Qx.
Up
Down
Part #
New Value
Click to load new value
Save as Default, Exit.
EXIT

0 Load R = 50.0
1 cap par 1000.0000
2 xtl ser 0.0000
3 cap par 1000.0000
4 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 250.0

Crystal Parameters:
100. Freq.= 10.0000
101. Lm = 0.0115
102. Cp. 4.87
103. Qx. 108286.0

top: 0 dB
dB/div.: 2
bottom: -10.0 dB
Start Freq. 0.000
Frequency Units: Hz
Freq./div: 100
stop Freq: 400
☑ Plot S11
☐ Plot Referenc
Frequency 199.333 Hz
S21= -4.80 dB
S11= -7.44 dB
#= 103
%= 1
Value=
Part # 1
New Value 0
E:\Hobbyist\QRPHB notes\2012\wes contributions 2012\Q of xtal\my-10.cir
Mouse Frequency 382.0000
S21 at F-mouse = -10.73 dB
S11 at F-mouse = -1.03 dB

Above — With GPLA, I adjusted the value for *Qx* up or down until my *centered* S21 value indicated -4.8 dB (the insertion loss of my crystal determined earlier). My crystal Q = Qx = 108286.

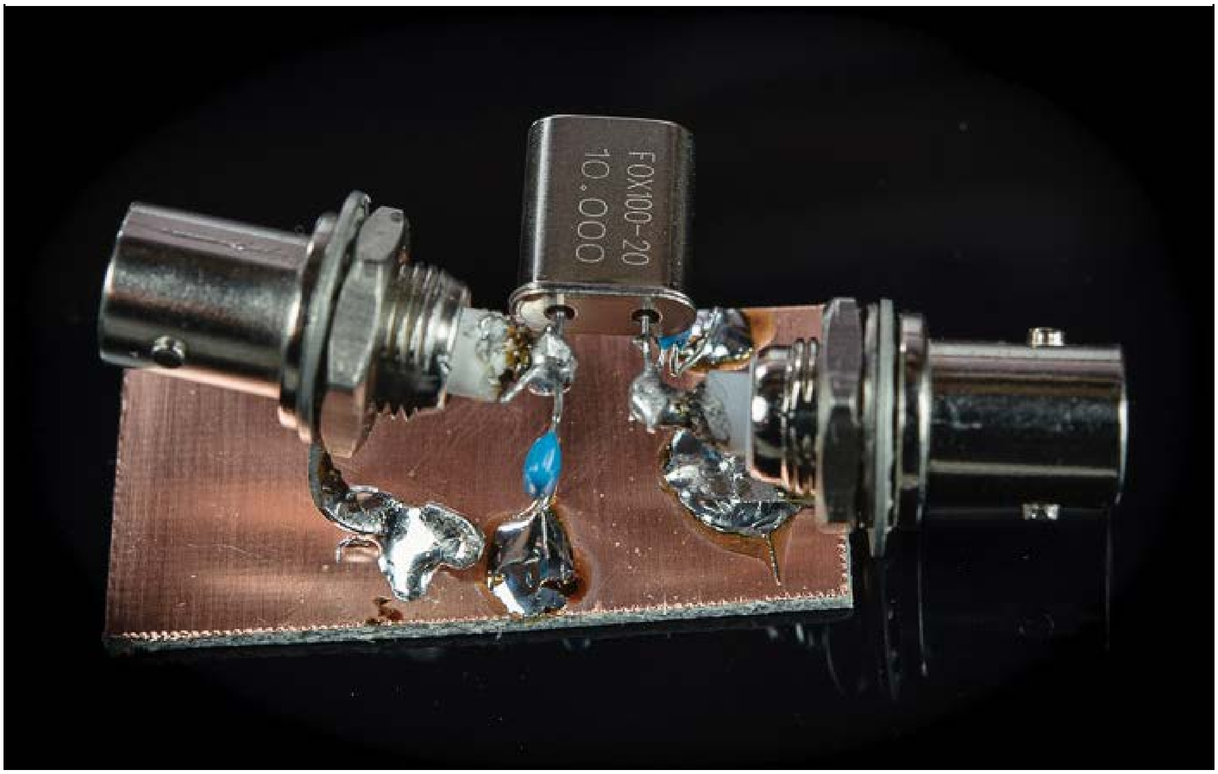
FOX100-20
10.000

Above — 10 MHz Crystal filter breadboard.

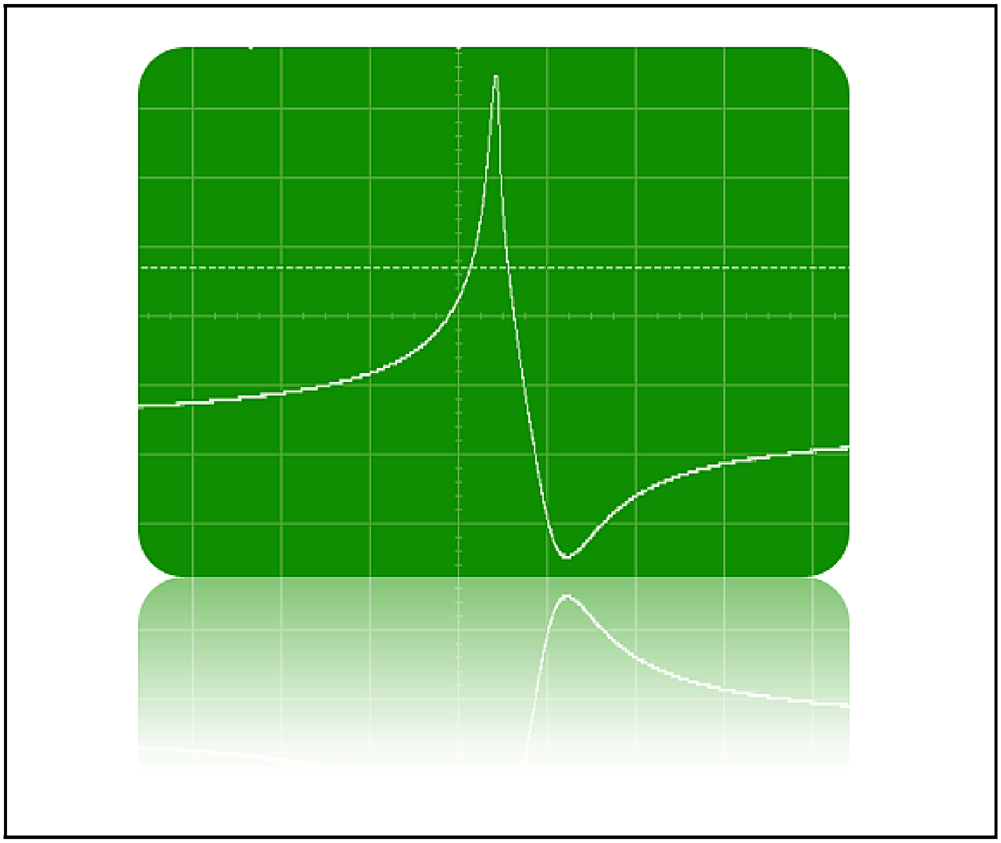

Above — A sweep of the 10 MHz Crystal filter used to determine the Crystal Q

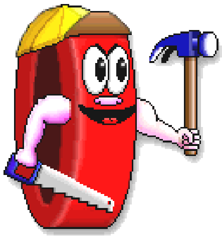

Amateur Radio Electronic Design

Electronic Hobbyist Circuits 2010

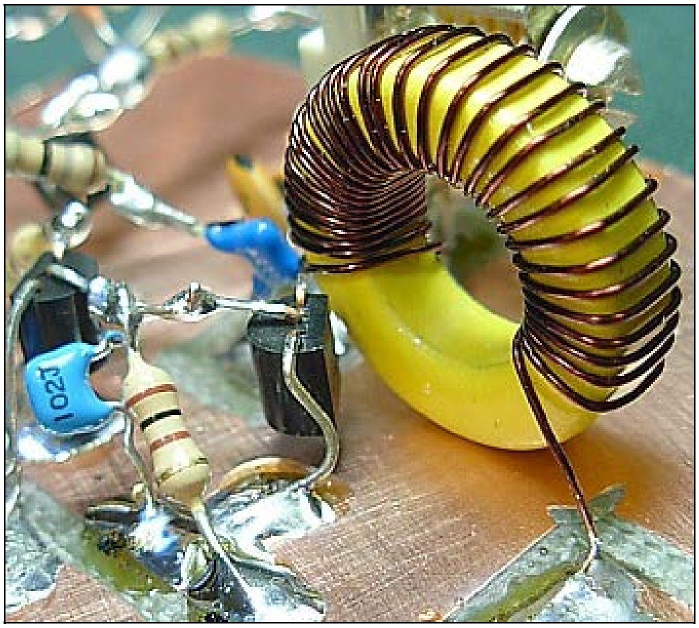

This page houses a collection of brief hobbyist experiments.

1. LM380 Power Examination

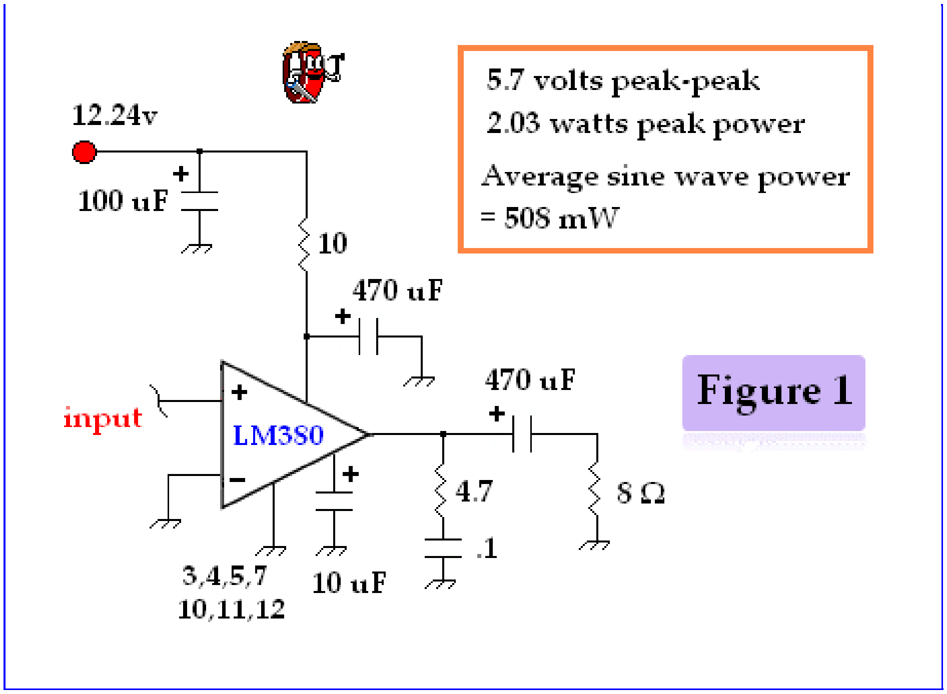
12.24v
100 uF
10
470 uF
input
LM380
470 uF
4.7
.1
8 Ω
3,4,5,7
10,11,12
10 uF
5.7 volts peak-peak
2.03 watts peak power
Average sine wave power = 508 mW
Figure 1

Figure 1 shows the test set up. This is a good part with an input impedance of 150kΩ. The gain is internally fixed at 34 dB. The average clean power was 508 mW. The test input frequency was 1018 Hertz.

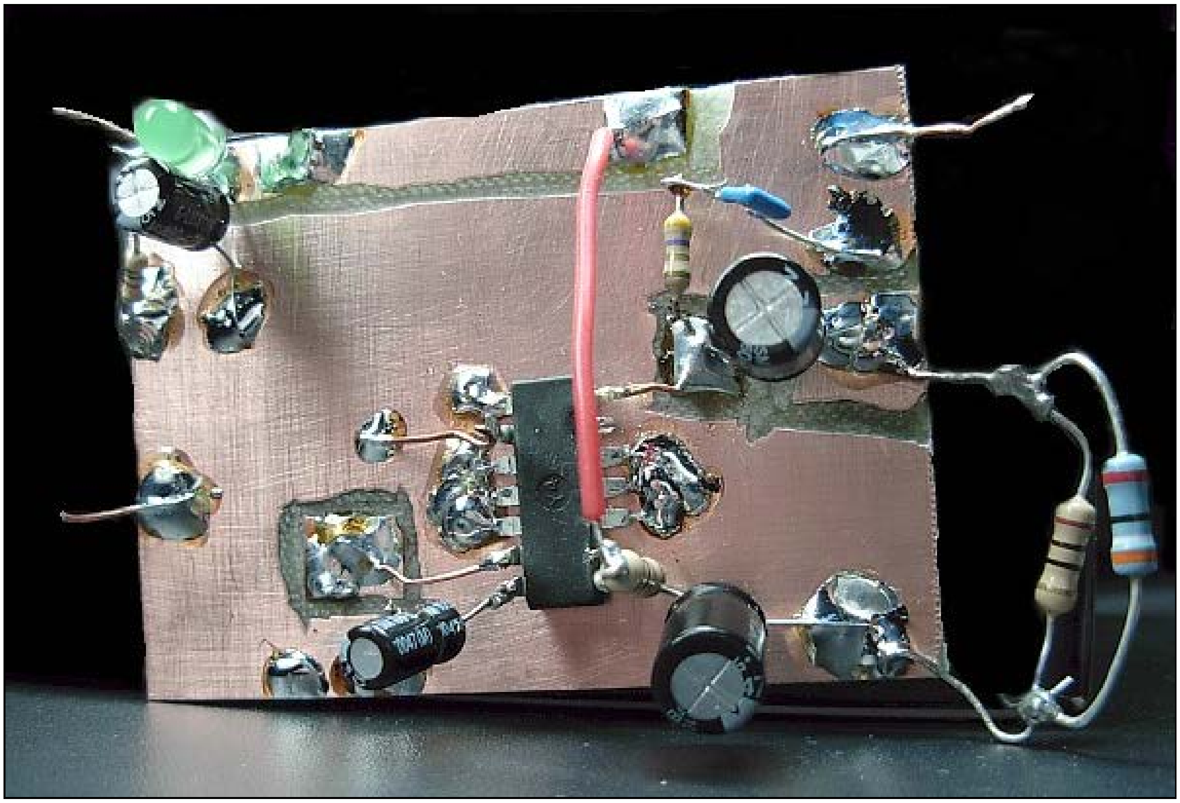

The breadboard of Figure 1 is shown above.

2. Wide Range L- C Oscillator

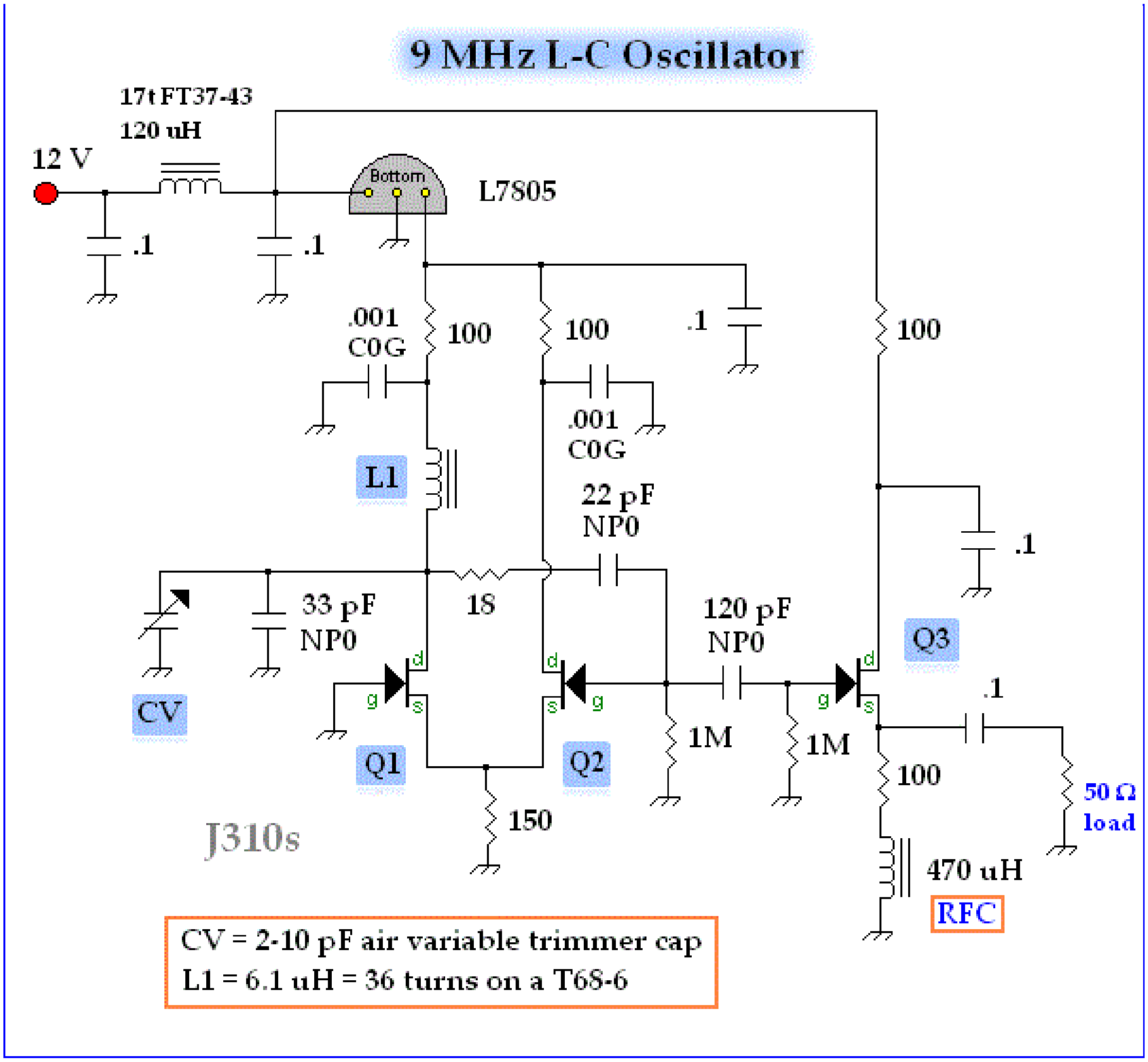
9 MHz L-C Oscillator
17t FT37-43
120 uH
12 V
.1
.1
Bottom
L7805
.001
C0G
100
100
.1
100
.001
C0G
L1
22 pF
NP0
18
33 pF
NP0
120 pF
NP0
Q3
.1
CV
d
g
s
d
s
g
1M
1M
d
g
s
Q1
Q2
100
50 Ω
load
150
J310s
470 uH
RFC
CV = 2-10 pF air variable trimmer cap
L1 = 6.1 uH = 36 turns on a T68-6

Shown above is a single frequency version of a VFO topology which allows a wide frequency range when additional switched inductors and/or capacitors plus a tuning variable capacitor are used. One good usage example would be a to use such a VFO to drive a bridge to make a wide range antenna analyzer. Q1 is essentially a common gate amplifier. The source is driven and the output is taken off the drain. This FET exhibits no signal phase shift. Q2 is a source follower that is AC coupled through that 22 pF capacitor The 18 ohm resistor is used to kill UHF parasitic oscillations. The Q2 follower also has no phase shift. Connecting the output of Q2 back to stage Q1 gives zero phase shift. The L-C tank will select the frequency where 0 phase shift is obtained. The tank will show phases other than 0 away from its resonance.

Q3 is an AC-coupled source follower to further buffer the VFO from its load. The RFC can be anything from your junk box, although it should likely be low Q. The low-pass decoupling filter on the the 12 volt supply path can also be anything reasonable. I wound mine using 17 turns on an FT37- 43 ferrite toroid. Its purpose is to keep RF from traveling down the 12 volts DC voltage wire to other parts of your circuit.

Any component connected to the L-C tank (at the Q1 drain, or the cold end of L1) can affect VFO tuning and drift. Temperature compensation will be necessary to achieve perfect stability. I use NP0 and C0G caps interchangeably. In the design shown, stability was good and the output had low measured distortion. This VFO will pretty much oscillate with any reasonable L and C values in the tank circuit. I found frequency stability was a little better with a higher L to C ratio. This is a great experimenter's circuit. One version built oscillated at 150 MHz.

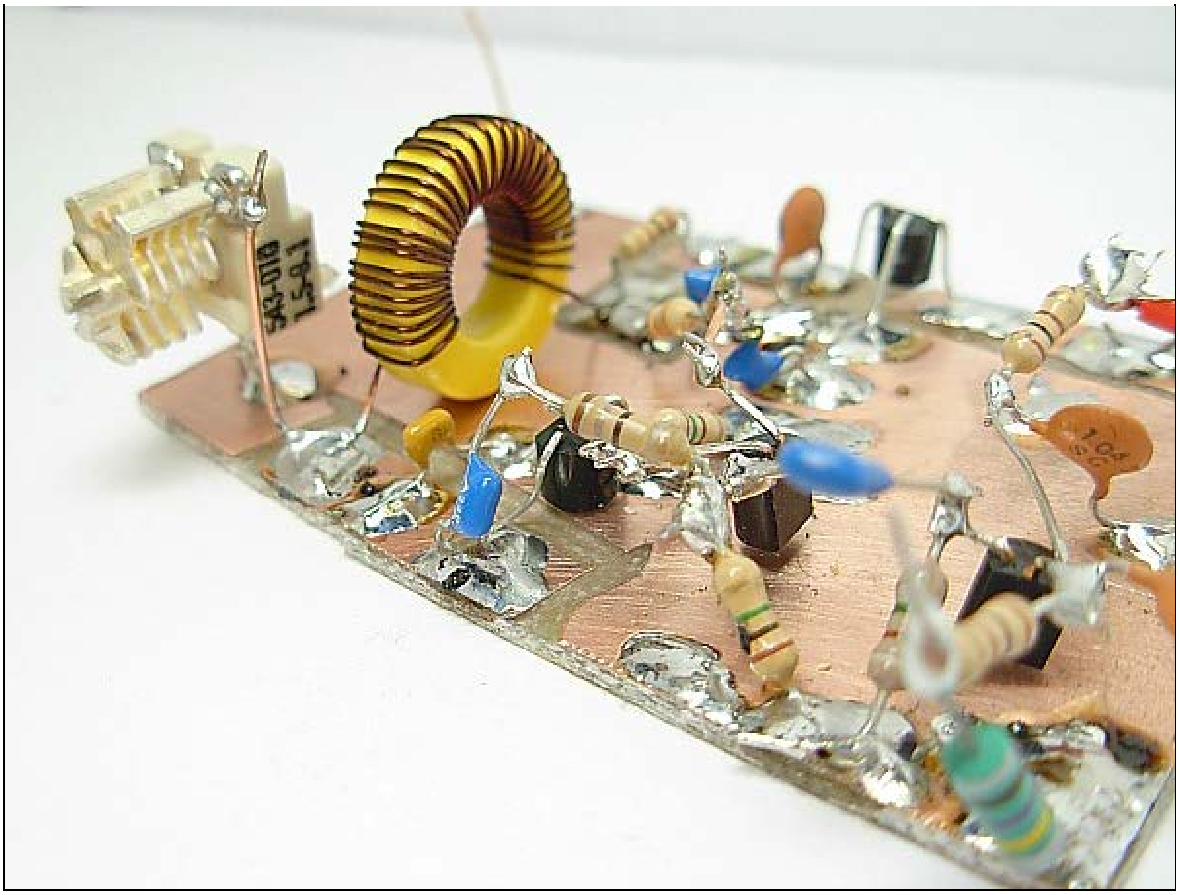

The breadboard of the above schematic. Pull the wire on your #6 powdered iron toroids tight to prevent air gaps between the toroid and the wire. Number 26 gauge wire was used on L1 as shown. High Q tank parts will garner the best results.

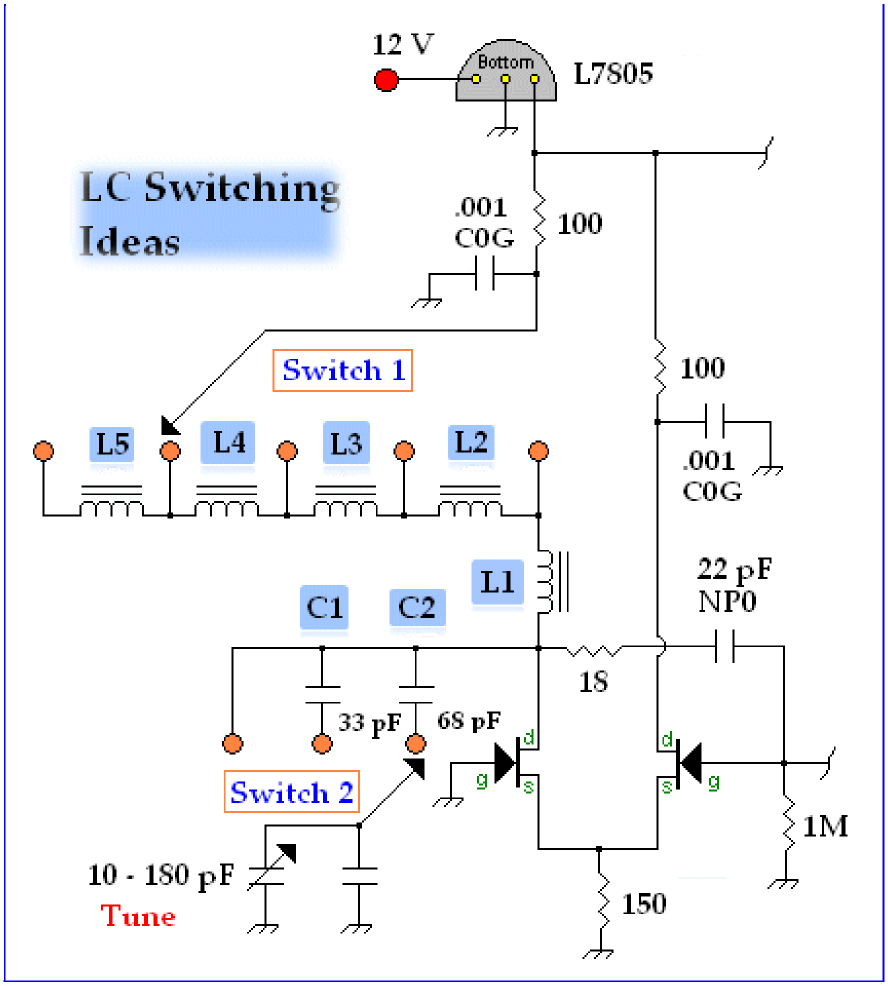
12 V
Bottom
L7805
LC Switching Ideas
.001
C0G
100
Switch 1
100
L5
L4
L3
L2
.001
C0G
L1
22 pF
NP0
C1
C2
18
33 pF
68 pF
d
g
s
d
s
g
Switch 2
1M
10 - 180 pF
Tune
150

Some potential switching ideas are presented above. The builder is in total control of the tuning range and must calibrate the L and C values according to needs and the parts on hand. Output power will vary according to the L-C ratios and some designs include automatic signal amplitude leveling and/or RF gain controls.

3. FET Matching

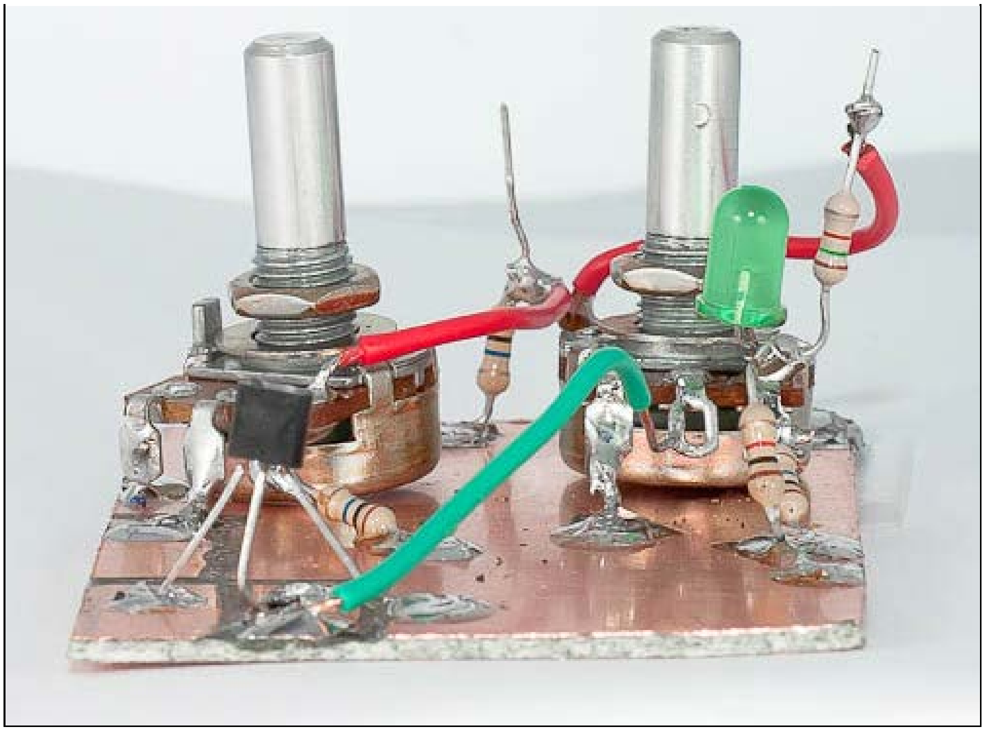

I find matching high IDSS FETs like the J310 to be a pain. I generally matched them for IDSS and occasionally for IDSS and VP. Observations that when the IDSS of 2 or more FETs match, their pinch-off voltage (VP) also matches, led me to not measure VP. In addition, the variability of VP measurements causes me distress. Click here for a tutorial if you don't understand the terms IDSS and VP.

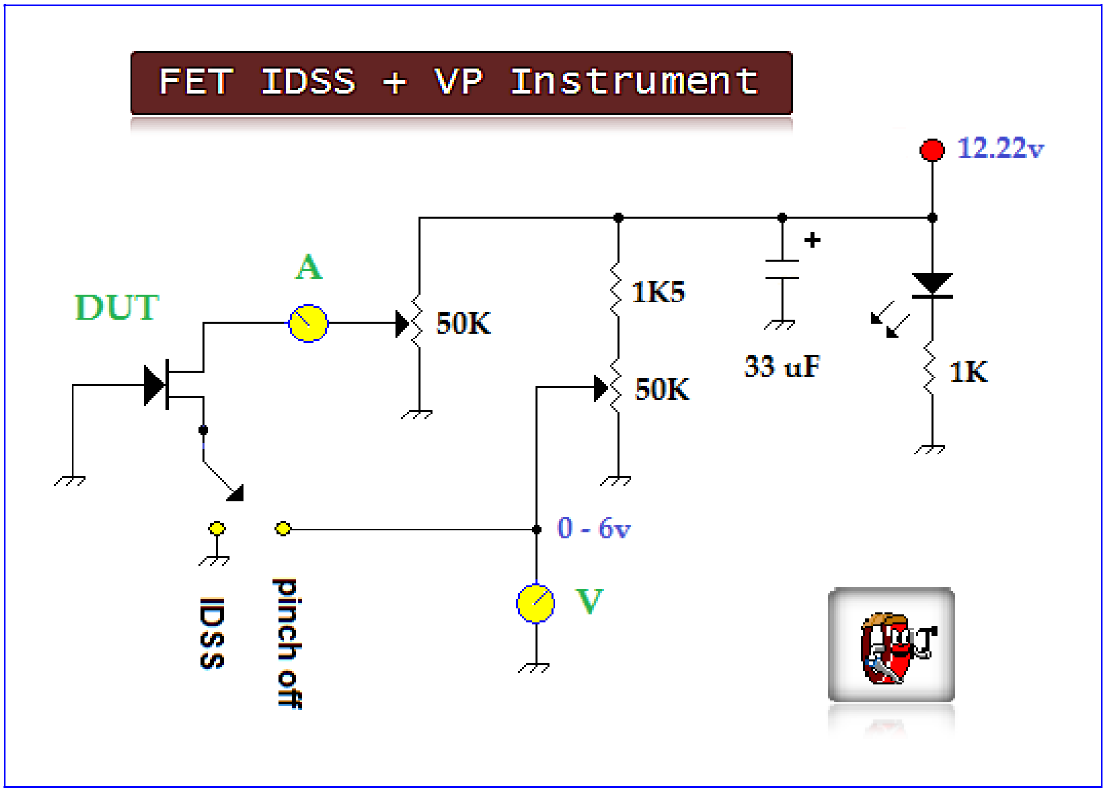

Above — The device I use to measure IDSS and VP. From Ken Kuhn's web site.

Conceptually IDSS and VP aren't difficult to understand — measuring them is another story. With the above device, first IDSS is measured; the final drain voltage potentiometer setting is left and then I measure VP. While measuring IDSS in high IDSS FETs, heating can occur and you may actually see current start to drop as you increase the drain voltage (negative temperature coefficient). On J310 specification sheets, the manufacturers state they pulse the current during measurement to prevent heating. While performing IDSS measurements, I am fearful of destroying the FET I am trying to characterize! Measuring VP is also problematic.

I have tried 3 methods to quantify VP:

Adjust the 0 - 6 volt supply until I think the current goes to 0. Serial measurements 1 day apart can vary by a variation of as much as 0.5 volts; it's quite subjective.

Adjust the 0 - 6 volt supply and measure the gate voltage that produces a drain current somewhere between 0.1 and 1 percent of IDSS and declare that to be VP.

Adjust the 0 - 6 volt supply so the ammeter reads ¼ IDSS and multiply this voltage by - 2.0. Refer to Ken Kuhn's site for details. Although reasonably accurate, the second order math is only a rough approximation — the real math is impossible to do by hand as it involves fractional exponents and these exponents and other factors vary as a function of the physical JFET geometry.

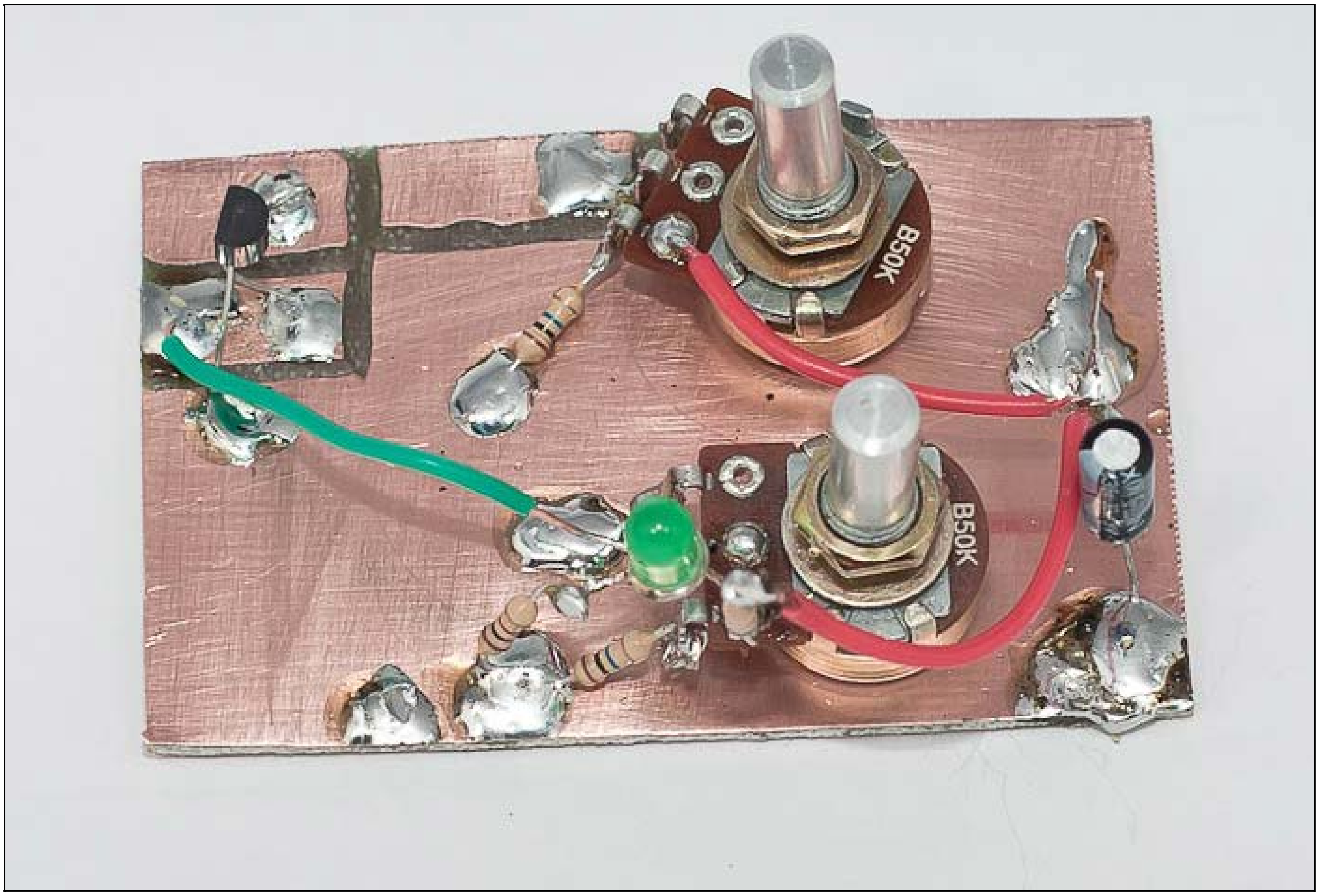

Above — The breadboard of the device I use to measure IDSS and VP. There is no actual switch, I either ground the green wire to the copper board, or tack solder it to the 0 - 6 volt potentiometer wiper. 10 megohm resistors plus the pot ground wire anchor each pot to the copper clad board.

All 3 methods to quantify VP frustrate me. There must be a way to match J310s or other FETs without characterizing them. I frequently collaborate with readers to problem solve and learn. A potential solution contributed by a supportive reader follows:

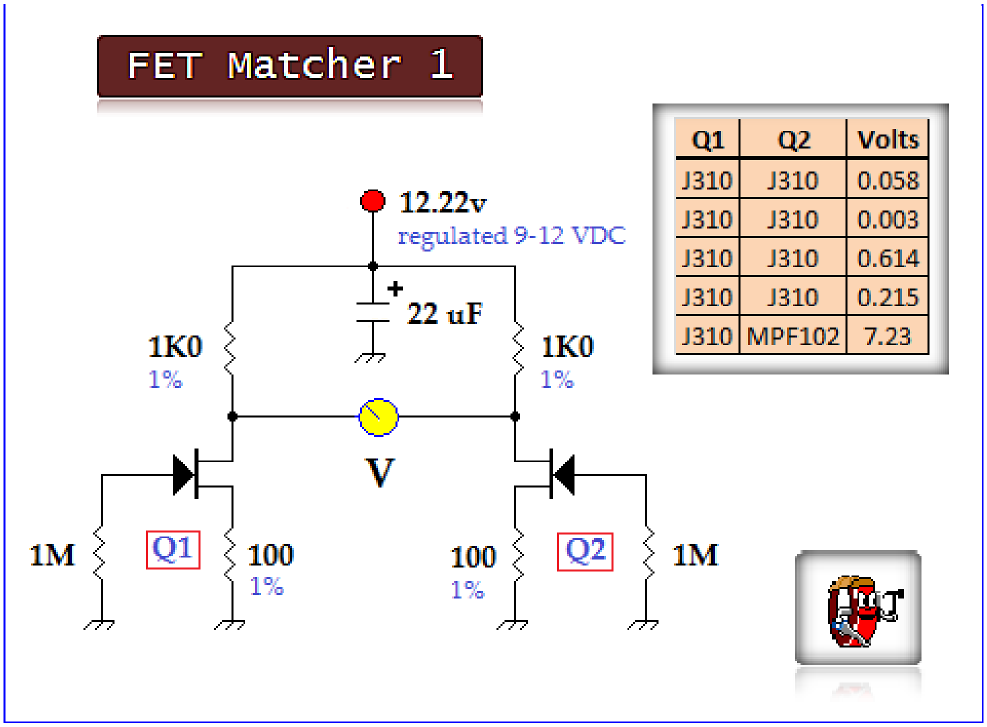

Q1	Q2	Volts
J310	J310	0.058
J310	J310	0.003
J310	J310	0.614
J310	J310	0.215
J310	MPF102	7.23

Above — A bridge is used to match a pair of JFETS. It's often best to match devices in a circuit that closely resembles the one that you intend to use them in. The differential output of each drain is measured by placing a DVM lead on each drain and recording the voltage. Generally, I stick a FET in the Q2 slot and put FETs from my parts bin in the Q1 slot to match it. The results of 5 different FET pairs are tabled above. A match <= 50 mV is probably acceptable and in 1 case, I found a match of 3 mV! You can match 1 FET with many using this device.

Note the poor match when an MPF102 and a J310 were tested. 1% tolerance resistors are recommended for the bridge.

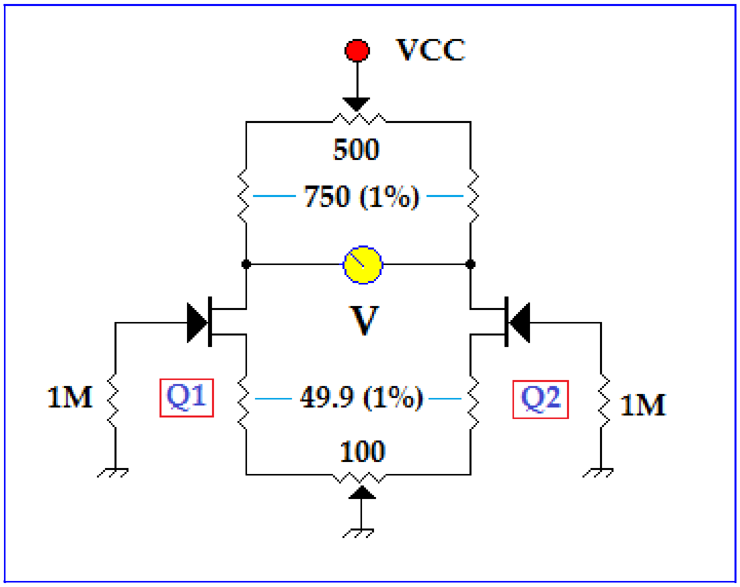

Above — A set and forget precision bridge using trimmers to establish a perfect DC match on both halves. If you don't have 1% parts, the trimmer resistors offer a solution. You can place a trimmer at either the drain or source end as shown and just use 5% resistors. Calibrate each half of the bridge with your ohm meter. I cover bridges on this web page if you need more information on them.

Above — A differential FET matcher breadboard. This version had a 9.1M gate resistor on Q1 by accident, although it made no difference to the experiment, as no DC gate current flows.

4. BJT and Diode Matching

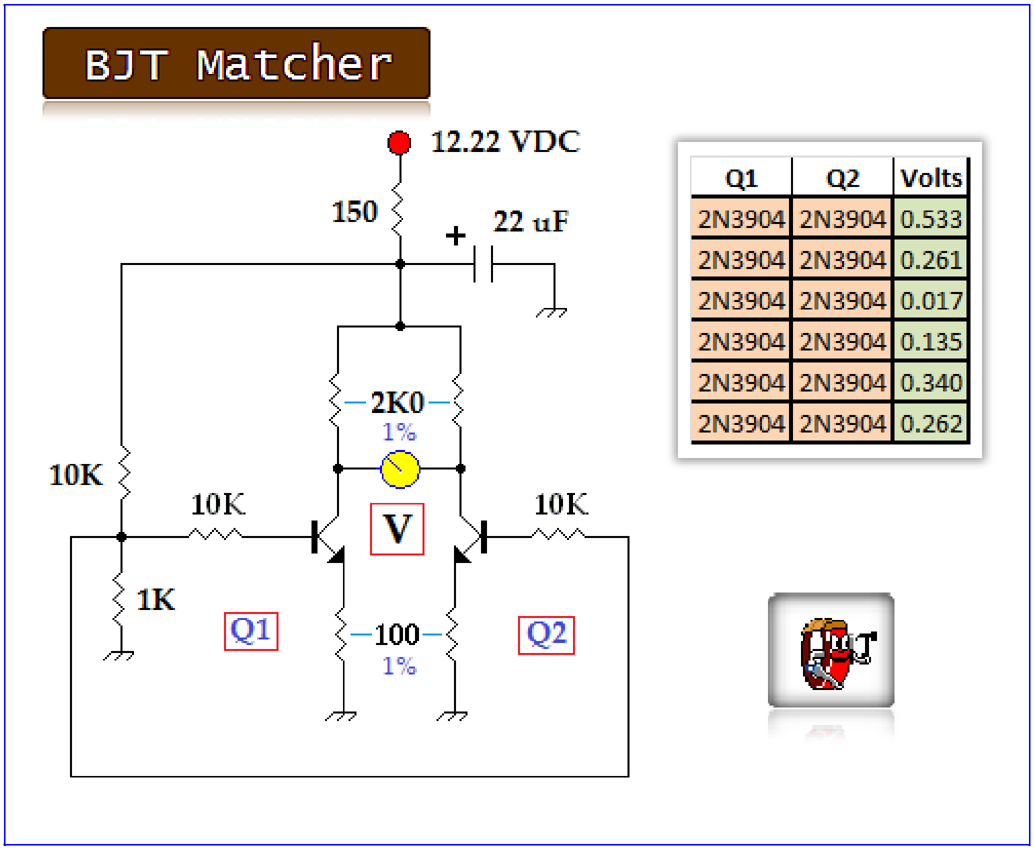

Q1	Q2	Volts
2N3904	2N3904	0.533
2N3904	2N3904	0.261
2N3904	2N3904	0.017
2N3904	2N3904	0.135
2N3904	2N3904	0.340
2N3904	2N3904	0.262

Above — Differential BFT matcher. Differential voltage matching works for bipolar junction transistors and diodes also. PN junctions are thermally sensitive — let them stabilize before testing. I measured 6 2N3904 transistors and the tabled results remind us why this transistor isn't the best choice for matched BJT circuits.

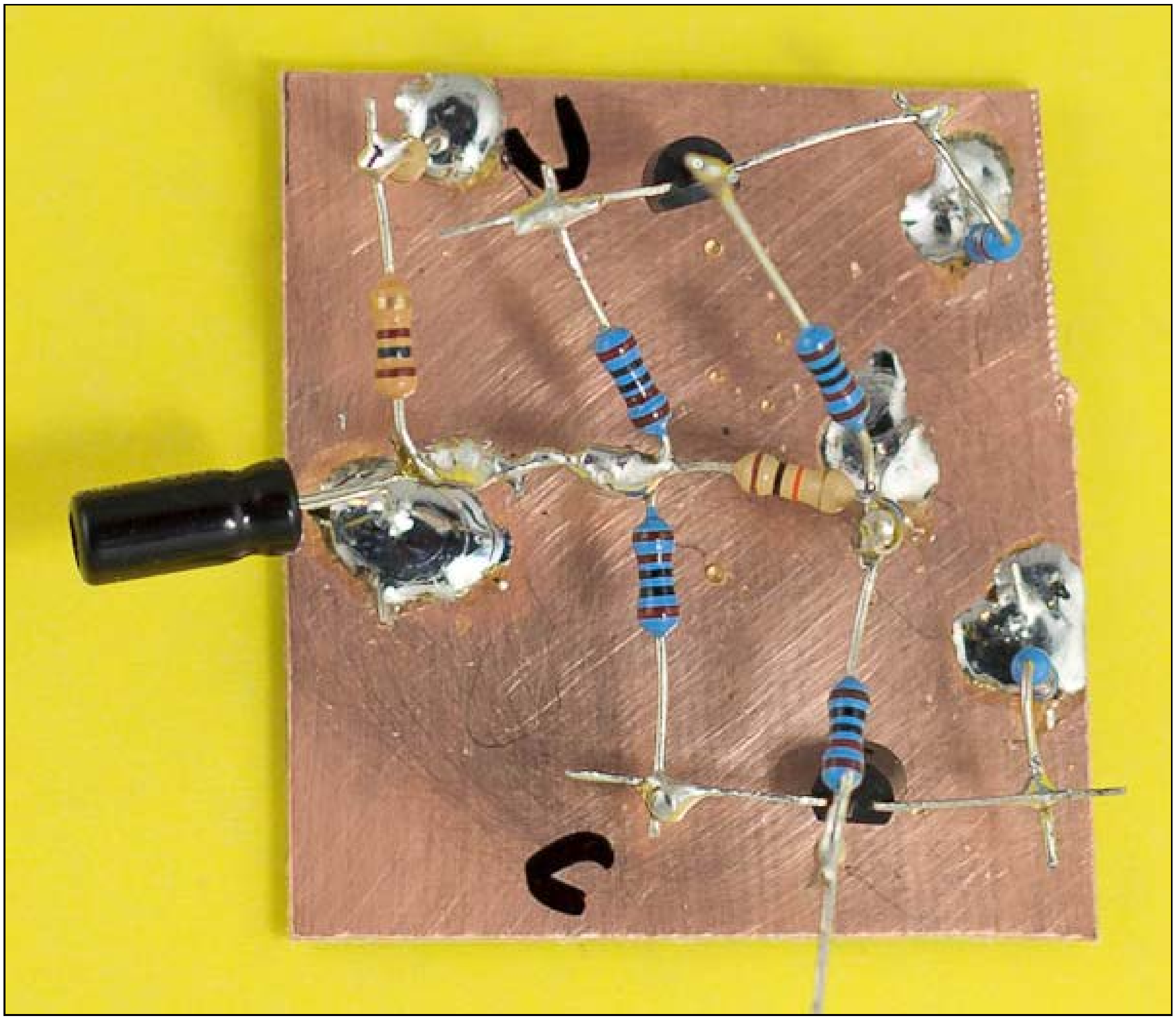

Above — The breadboard of the differential transistor matcher. Any reasonable resistor values will work fine, but don't run the current too high — my circuit has a nominal emitter current of 2.25 mA.

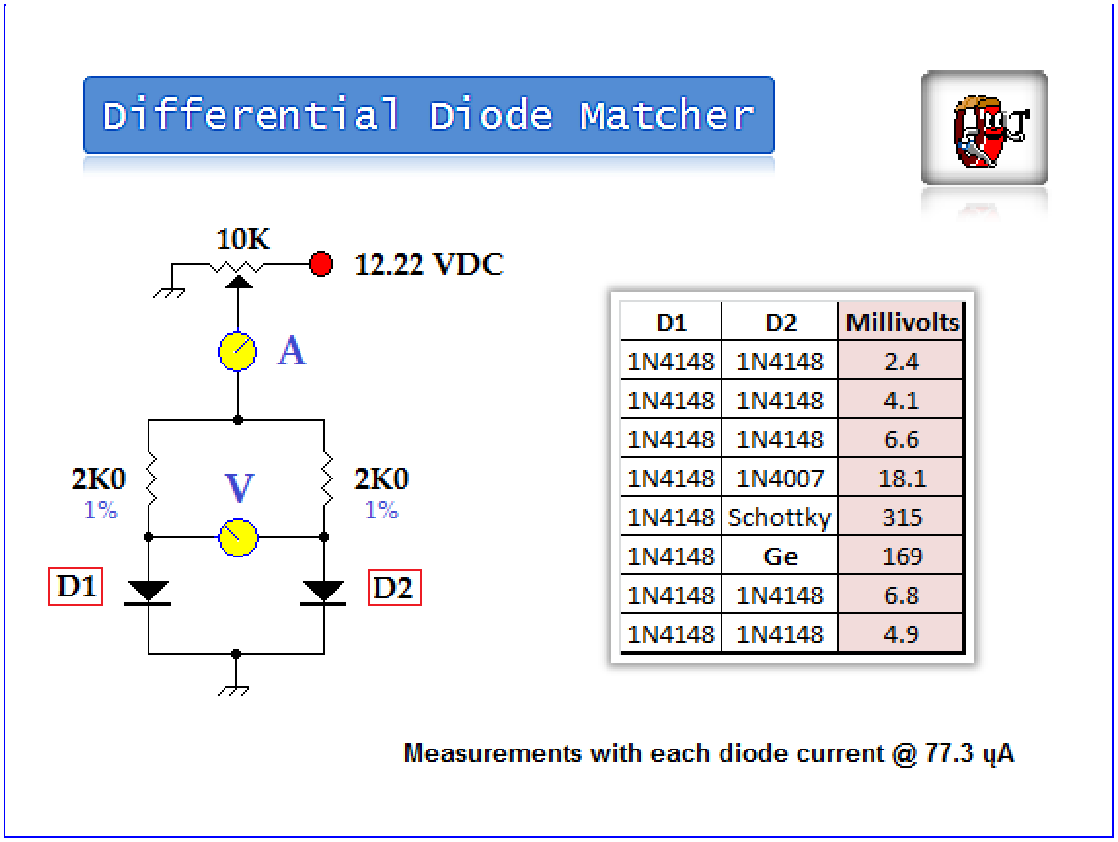

Differential Diode Matcher

D1	D2	Millivolts
1N4148	1N4148	2.4
1N4148	1N4148	4.1
1N4148	1N4148	6.6
1N4148	1N4007	18.1
1N4148	Schottky	315
1N4148	Ge	169
1N4148	1N4148	6.8
1N4148	1N4148	4.9

Measurements with each diode current @ 77.3 ųA

Above — The differential diode matcher. The 10K pot allows you to vary the current to suit your needs. The ammeter reads double the diode current. Considering only 1 diode; the current ranges from 0.01 to 5.82 mA. You can drop the 1% metal film 2K0 resistors down as low as 470 ohms or so if you need serious current. Tabled are some measurements performed with the 10K pot dialed to give 0.636v (77.3 uA per diode). This provided excellent sensitivity. Measurement was performed on my DVMs 200 mV scale. Builders might experiment with diode current to assess measurement sensitivity and linearity or even to match the diodes across a range of current values.

Clear glass passivated diodes can be affected by light — photons will pass through the glass and knock electrons through the barrier. Ensure each D.U.T is exposed to the same amount of ambient light. Some microwave detector diodes can be damaged with as little as 1 mA of current. Replace the 2K0 resistors with 10-15K resistors, or lower VCC to prevent damage .

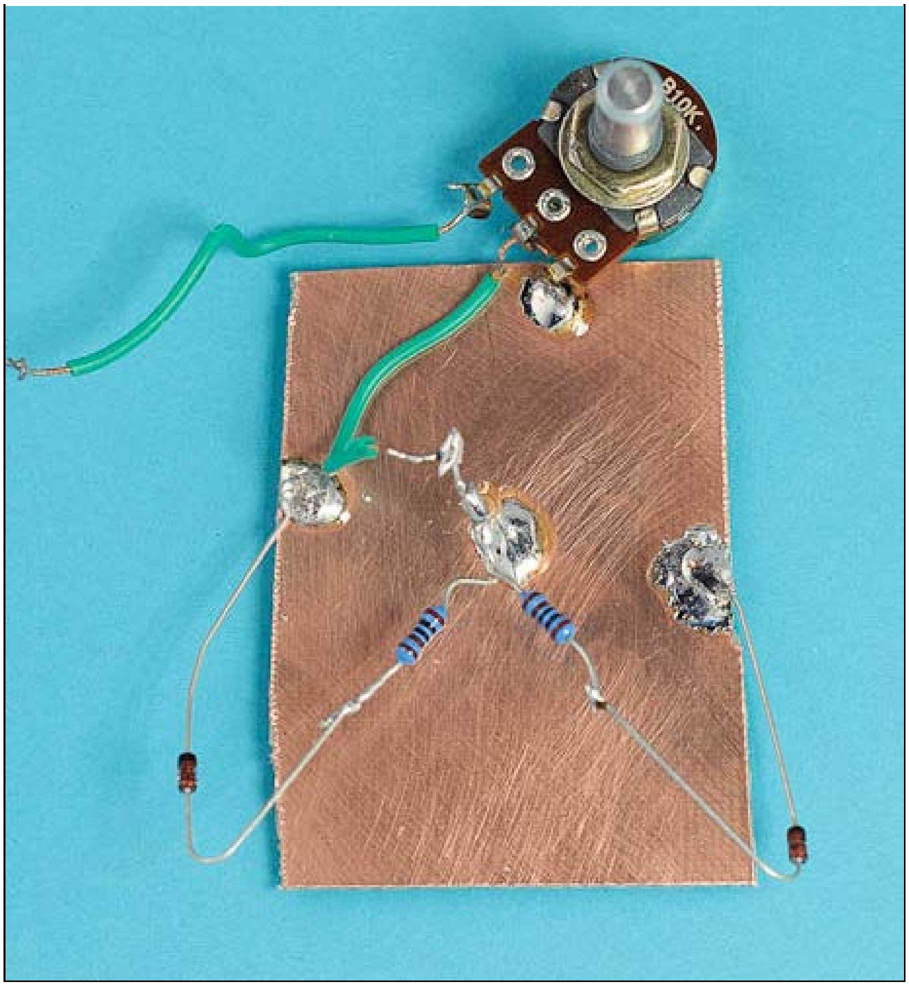

Above — Breadboard of the differential diode matcher. The 2K0 resistors are suspended by a vertically mounted 10M stand-off resistor.

5. Bipolar Junction Transistor Beta Tester

Bipolar Transistor Beta Tester

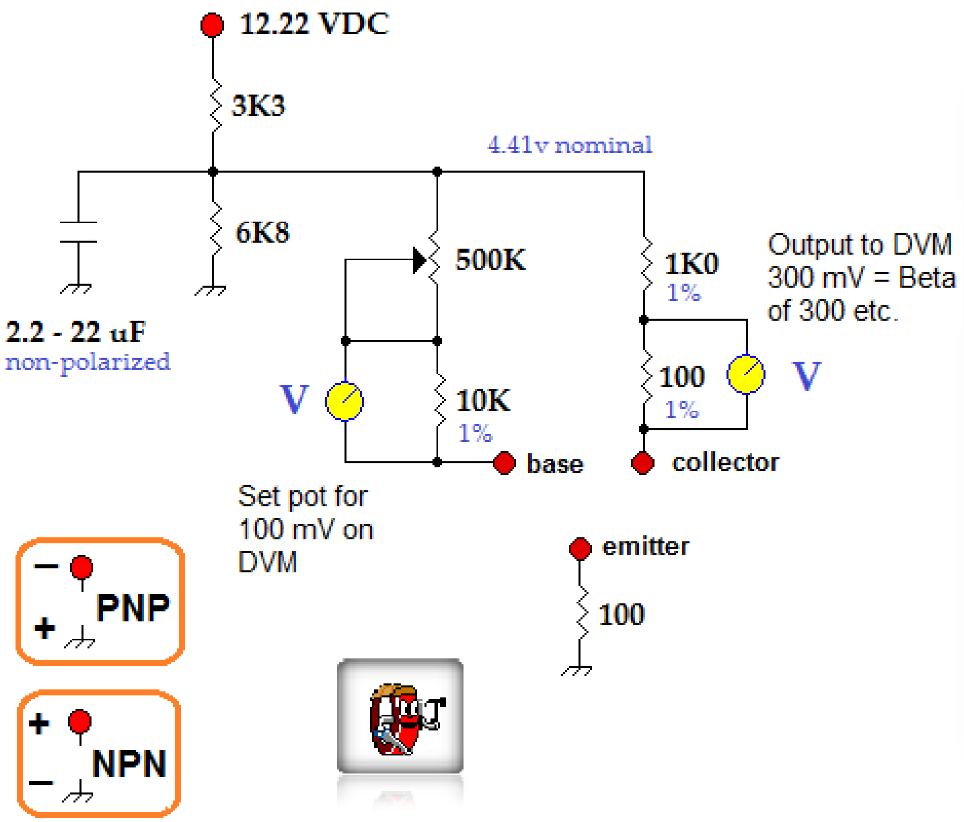

BJT	Beta
2N3904	193
2N2222a	354
2N3904	172
2N3904	173
2N3904	167
2N3904	151
2N3866	349
2N5109	348
2N4401	236
2N4401	221
2N3906	234
2N3906	139
2N3906	230
2N3906	209
2N3906	227

Above — Disappointed with the transistor beta testers in our common, low-cost digital multimeters, we did the logical thing; designed and built our own. This collaborative project was more an experiment with BJTs than anything else. It's about as simple a beta measurement device as you can make and still get good results. Preventing damage to our parts inventory underpins this design — the 100 Ω emitter resistor plus ~ 10 microamps of base bias keeps the IC low to help avoid smoke since most new small signal transistors have a beta of 100-400.

Ensure the correct polarity for PNP versus NPN transistors. The voltage divider targets 5 volts using a standard ~12 volt supply; I just used whatever resistors were handy and ended up with the 6K8 — 3K3 pair. VCC should be regulated. Perform the measurements with a single multimeter allowing time for stabilization.

To use: Set the potentiometer so that the voltage drop across the 10K resistor is 100 mV. Then move your DMM leads to the 100 Ω resistor and measure the beta. This device measures beta, the static gain at DC.

Measuring beta is a bit inexact since beta is affected by so many variables as follows:

Beta tends to be low at low operating currents and rises and plateaus for medium currents and then falls at higher currents.

Beta tends to increase with temperature.

Beta is affected by the voltage between the collector and emitter -- this is a weak effect except when the voltage is very small.

The beta can vary as the battery depletes in DMM beta testers.

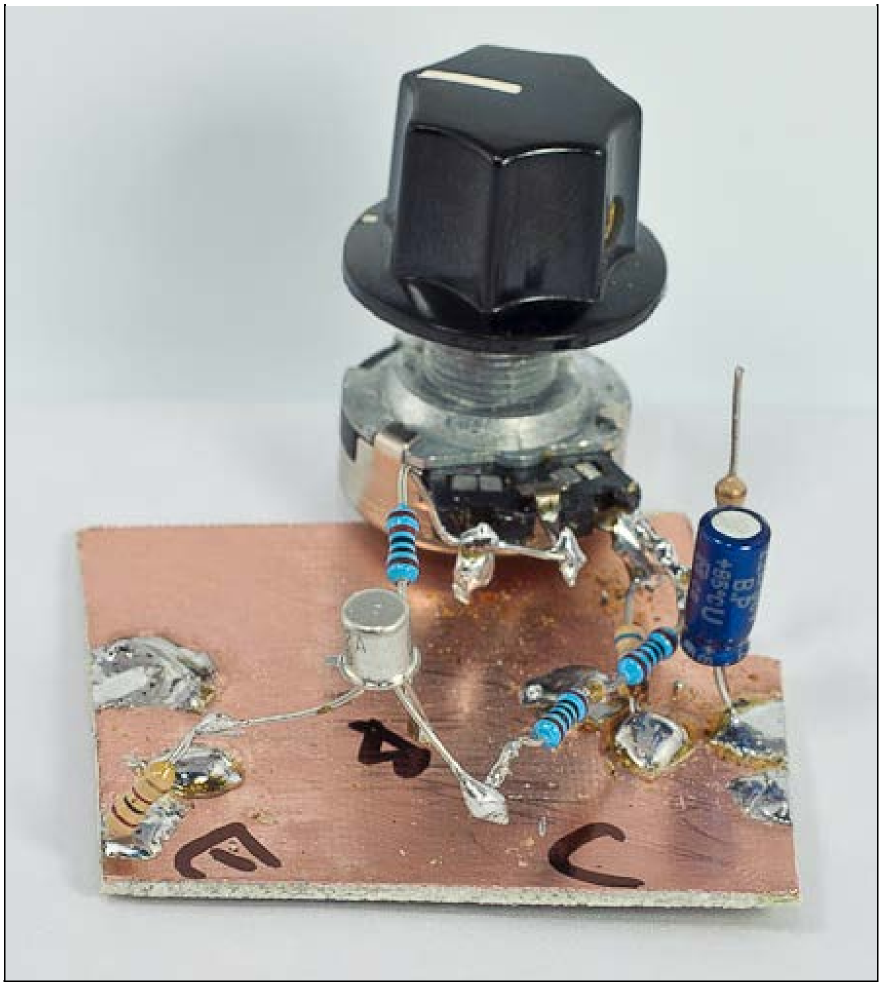

Above — Breadboard of the QRP beta tester. We hope you have as much fun with this circuit as we did.

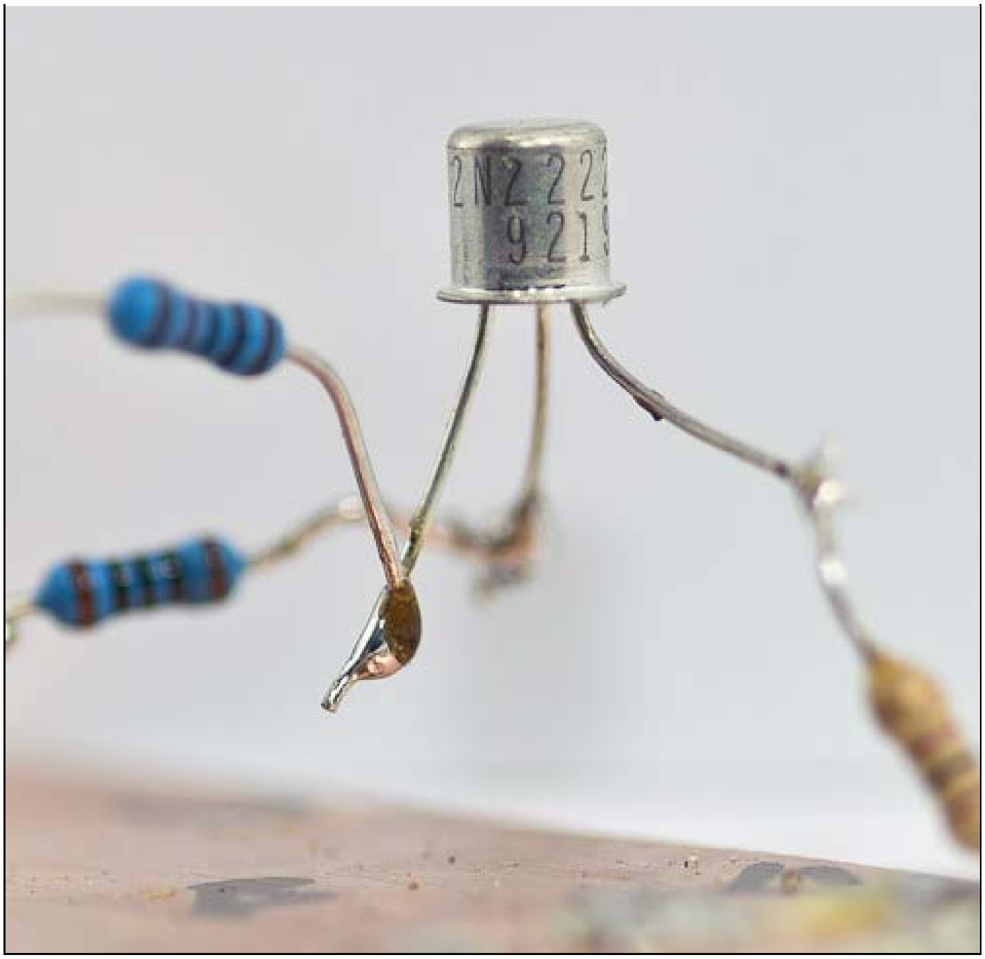

Above — Testing a 2N2222a. We found measuring transistors to be very instructive; comparing our results to specification sheets, handling the different BJTs, gaining experience — all part of the exciting world of bench electronics. Such circuits, although simple, are great for both learning and design.

6. FET Tester - VGS Measurement Tool

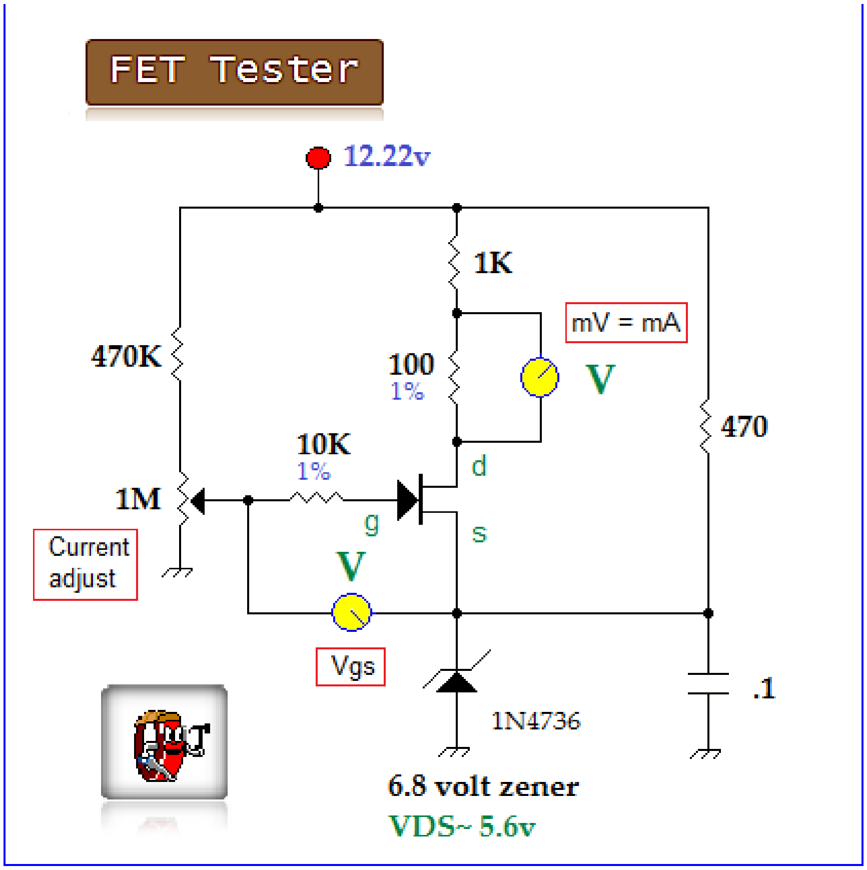

Above — A FET VGS Tester. The final collaborative output from late December 2010: a device to examine VGS. A zener diode value from 6 -7.5 volts or so should work okay. VDS should be greater than the nominal VP for greatest accuracy. The VDS using 7.5 volt zener diode was 4.85 volts. The range of VGS on my breadboard was roughly 6 to -6 VDC without the 470K range limiting resistor; it's up to you if you want to limit the VGS range.

Using the mV scale on your DVM, potentiometer adjust the current until the meter just reads 0. Then move your leads to the VGS test points to read the pinch-off voltage.

The 0 current point will only ever be close. The interesting issue with the 0 point as defined is it never goes to true zero — just zero enough — that point may be hidden if your meter scale truncates lower current measurements to zero. If you're able to repeatedly get consistent VP measurements with whatever method your using, then it's likely accurate.

We thought about measuring gate leakage current across the 10K gate resistor, but accurate measurement is impossible with this device. The gate leakage current is going to be in the low nanoampere region at the very highest unless the JFET is bad. The expected voltage across the 10K resistor would be a few 10s of microvolts. A better way to measure gate leakage is to use the 10M resistance of a DVM instead of this resistor. The DVM then acts as a current meter by measuring the voltage across the 10M resistance. A reading of 200 mV would mean a current of 20 nA.

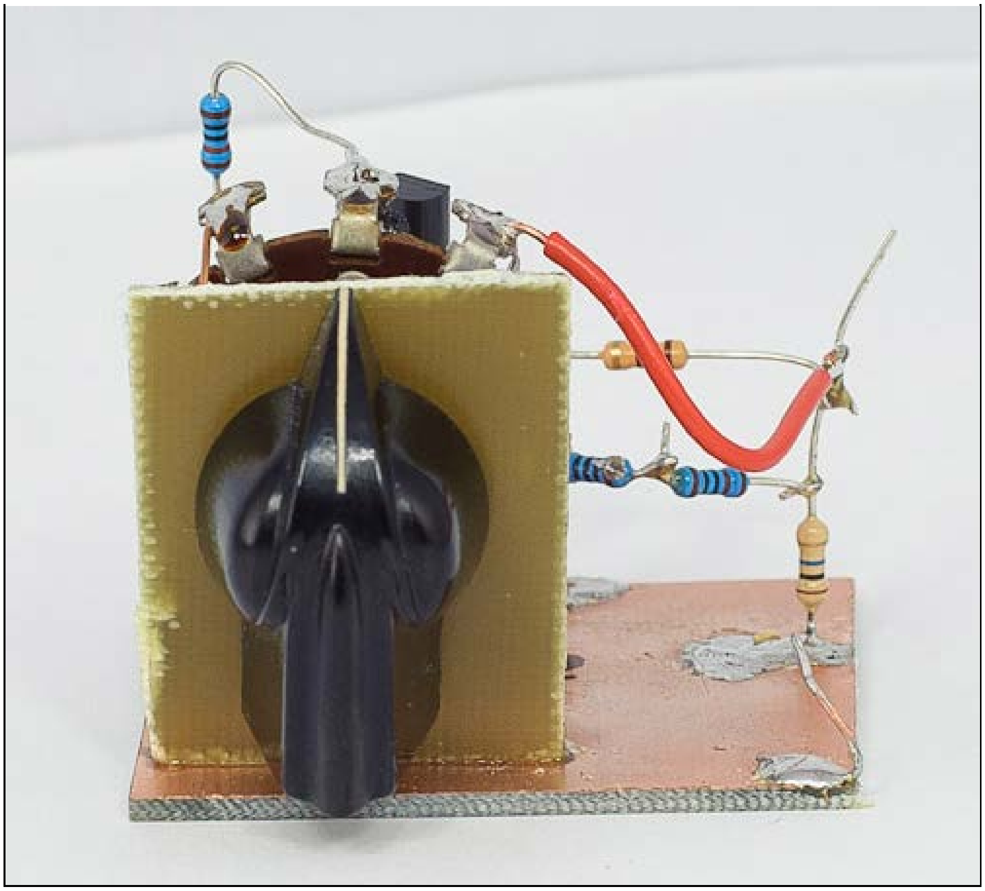

Above — Front view of the FET tester with a "chicken head" knob on the potentiometer.

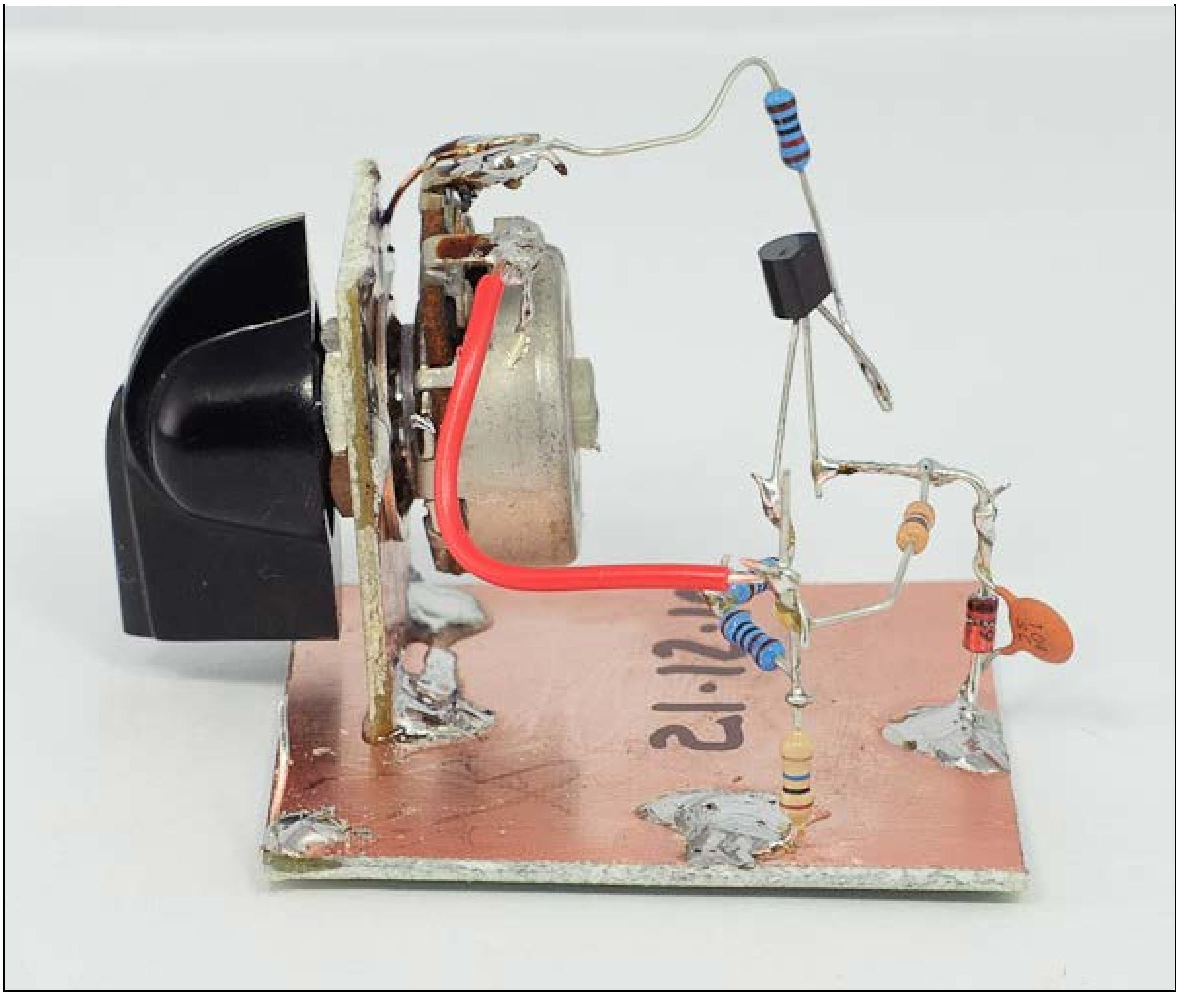

Above — Measuring a J310 with the FET tester prototype breadboard.

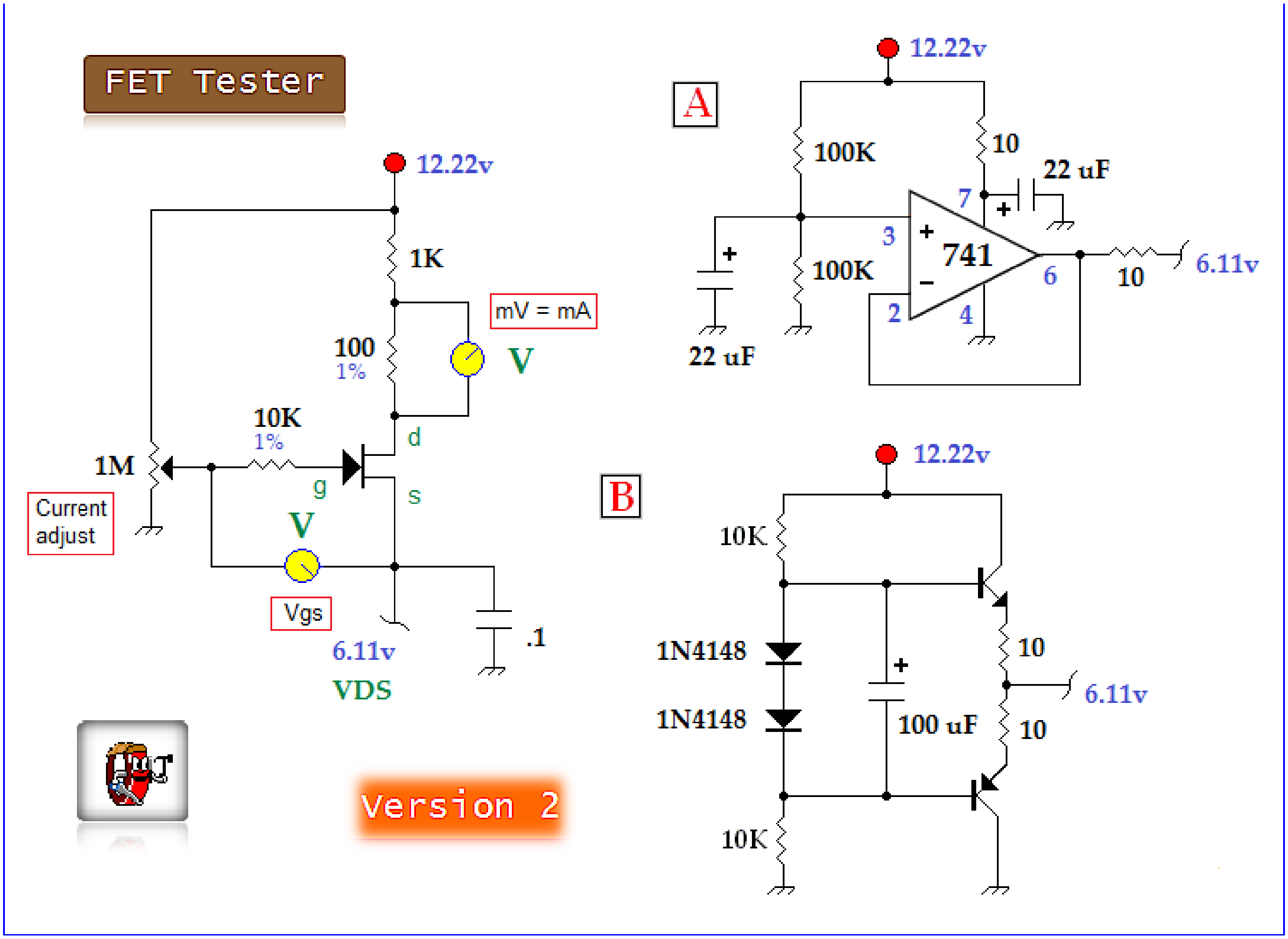
FET Tester
12.22v
1K
mV = mA
100
1%
V
10K
1%
d
1M
g
s
Current adjust
V
Vgs
6.11v
VDS
.1
Version 2
A
12.22v
100K
10
22 uF
7
3
741
100K
6
10
6.11v
2
4
22 uF
B
12.22v
10K
1N4148
10
6.11v
1N4148
100 uF
10
10K

Above — Instead of a zener diode, low impedance VCC/2 splitters are shown as A and B; the zener diode is easier.

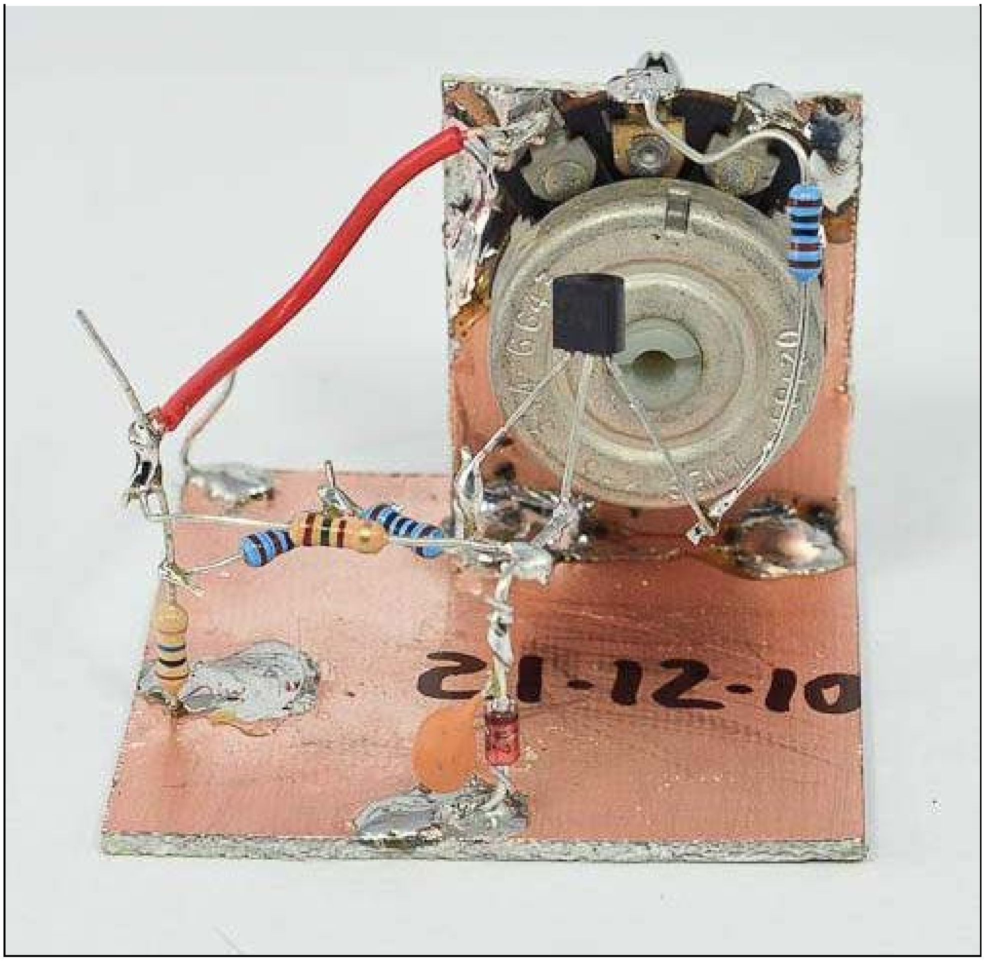

Above — Reverse view. I didn't bother with the 470K VGS range limiting resistor in my breadboard.

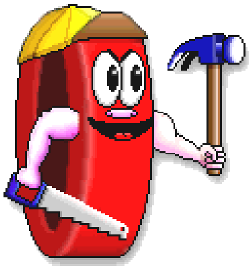

QRP SWL
HOMEBUILDER

RF — Test and Measurement

RF Workbench Page 1

The first installment of a multi-part series exploring basic 50 Ω RF circuit measurement. This web series borrows heavily from the work of Wes, W7ZOI.

RF Workbench 1 shows a way to measure AC signals and quantify power. As circuit builders, knowing the power gain *or loss* in dB of stages like filters or amplifiers; or the absolute power in dBm of our RF signal sources dominates our bench work.

Ignite your bench measurement — Better measurement fidelity inspires confidence, creativity and fun!

Calculate Power Gain from your Oscilloscope Peak-Peak Voltage

An oscilloscope peak-to-peak voltage provides a popular way to determine power gain or absolute power.

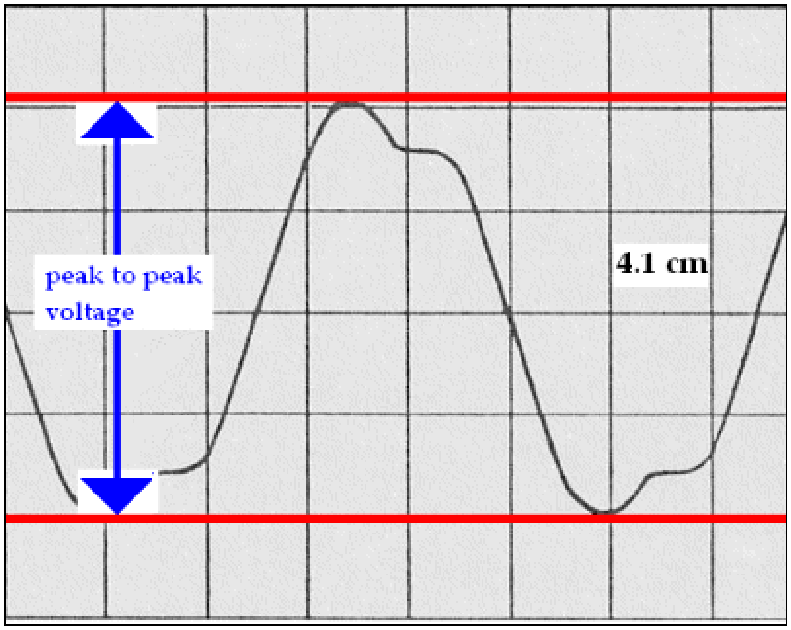

To calculate the power of a sinusoidal waveform, you measure its AC voltage. Assuming your 'scope is calibrated, the first step is to measure the amount of vertical deflection on the screen.

In the figure shown left, the vertical deflection = 4.1 cm. Multiply this measurement by the volts/cm setting of your scope. Lets assume your scope was set to 0.1 volts/cm. Thus the result = 0.41 volts. One final multiplication is required; you must multiply the resultant voltage by the attenuation ratio of the probe. In most cases, a 10X probe is used. Therefore, the measured peak-to-peak voltage is 0.41 x 10 = 4.1 volts. DSOs output numeric voltage readings in addition to that shown — a nice feature.

This signal exhibits a major problem; it's distorted. To calculate the power from peak-to-peak voltage, you require a sine wave. To obtain a sine wave, this distorted signal must be low-pass filtered. Let's examine this topic with some real experiments.

Signal Viewing versus Power Experiments

Measuring 'scope signals takes some skill to get accurate, reproducible results. Consider the following signals taken from an 8 MHz VFO.

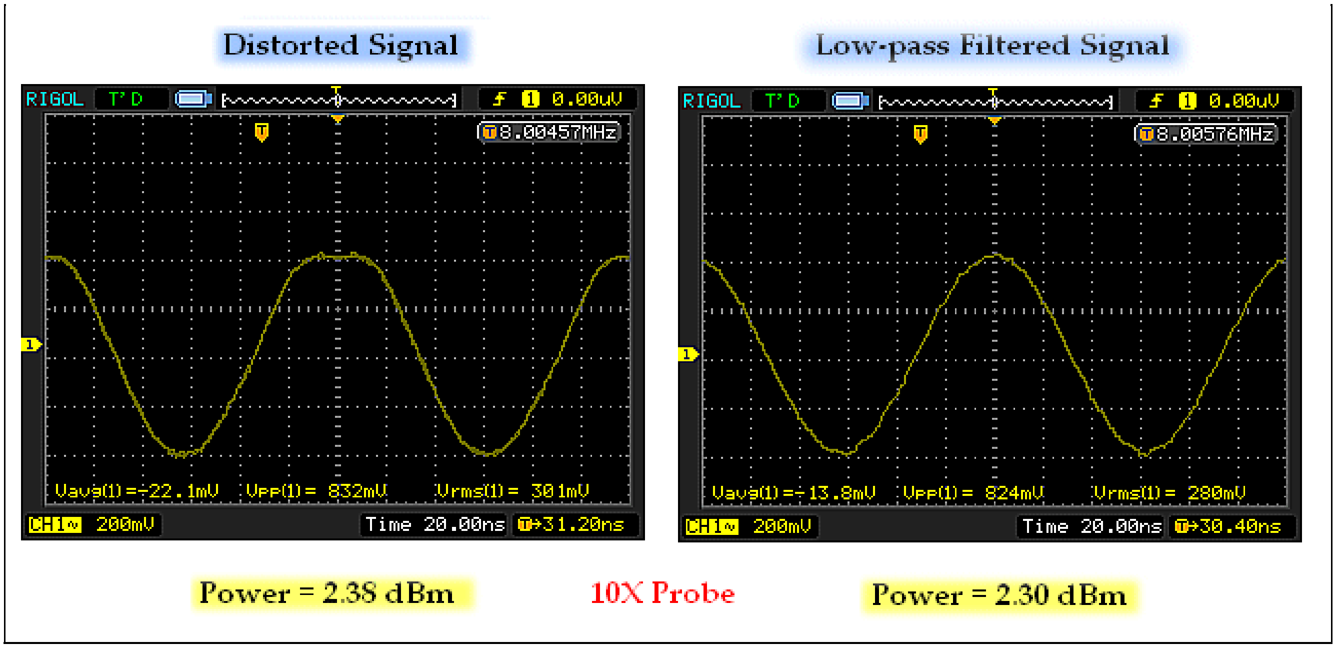
Distorted Signal
Low-pass Filtered Signal
RIGOL T'D
1 0.00uV
8.00457MHz
Vavg(1)=-22.1mV Vpp(1)= 832mV Vrms(1)= 301mV
CH1 200mV
Time 20.00ns
T→31.20ns
RIGOL T'D
1 0.00uV
8.00576MHz
Vavg(1)=-13.8mV Vpp(1)= 824mV Vrms(1)= 280mV
CH1 200mV
Time 20.00ns
T→30.40ns
Power = 2.38 dBm
10X Probe
Power = 2.30 dBm

Examine the distorted signal on the left and compare it to same signal after low-pass filtering. I calculated the power in dBm from the peak-peak voltages (Vpp) shown as 832 mV and 824 mV: left to right respectively.

Only the sinusoidal power proves accurate. I'll discuss the formula to assess power soon.

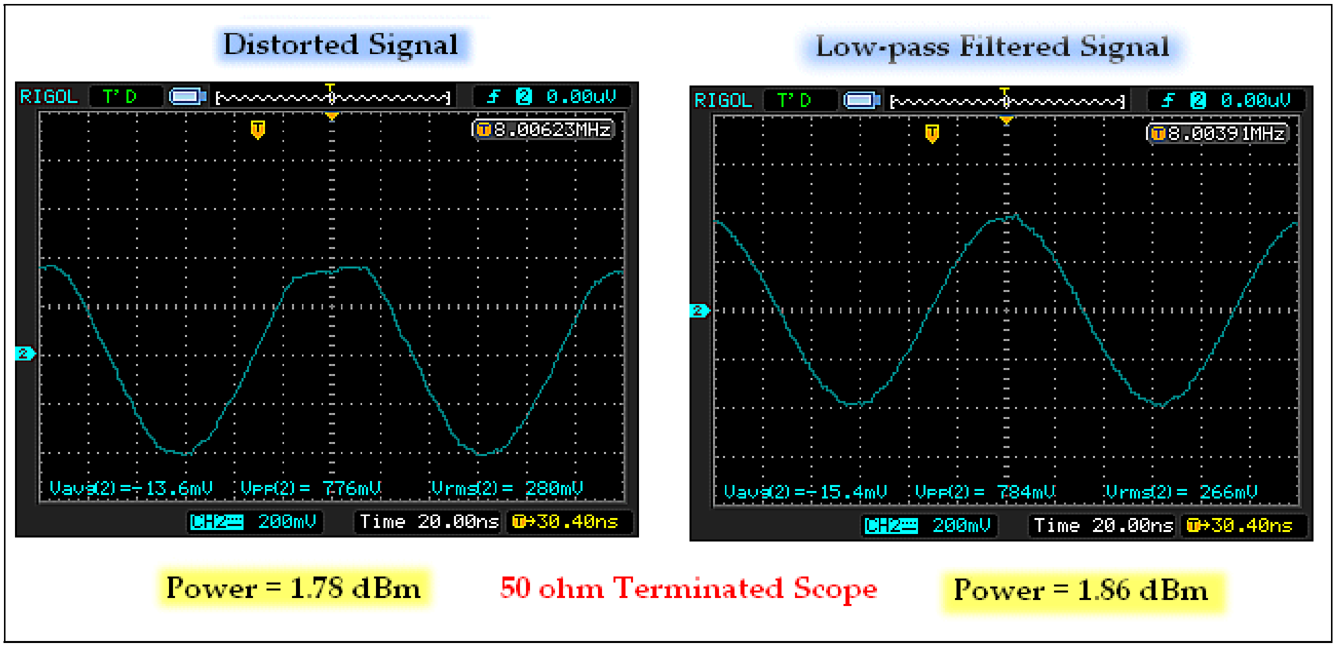
Distorted Signal
Low-pass Filtered Signal
RIGOL T'D
2 0.00uV
8.00623MHz
Vavg(2)=-13.6mV Vpp(2)= 776mV Vrms(2)= 280mV
CH2 200mV
Time 20.00ns
T→30.40ns
RIGOL T'D
2 0.00uV
8.00391MHz
Vavg(2)=-15.4mV Vpp(2)= 784mV Vrms(2)= 266mV
CH2 200mV
Time 20.00ns
T→30.40ns
Power = 1.78 dBm
50 ohm Terminated Scope
Power = 1.86 dBm

The same 8 MHz VFO examined with a 50 Ω terminated oscilloscope; a superb measurement technique that offers greater sensitivity. In all 4 cases shown, the vertical scale = 0.2 volts/cm.

To better compare the distorted and filtered signals, I attenuated the output of the VFO to allow safe examination with a spectrum analyzer. A spectrum analyzer graphs the power (in dBm) of all measured frequencies on its Y axis against a user defined frequency range on the X axis.

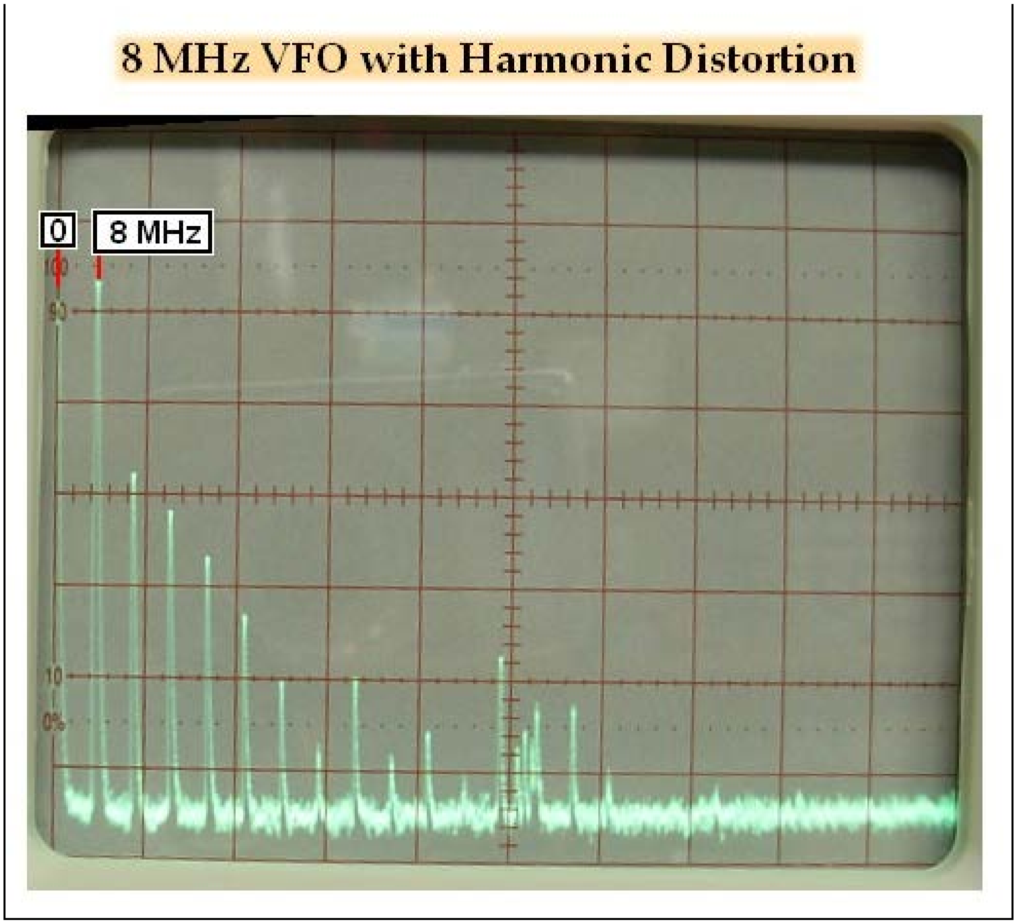

Spectral analysis of the distorted 8 MHz signal. The second harmonic (16 MHz) is about 22 dB down from the fundamental. The signal is rich in harmonics that causes error in the calculation of the output power. Each vertical square is 10 dB. Each horizontal square = 20 MHz. The harmonics go 2x fundamental, 3x fundamental, 4x fundamental and so on.

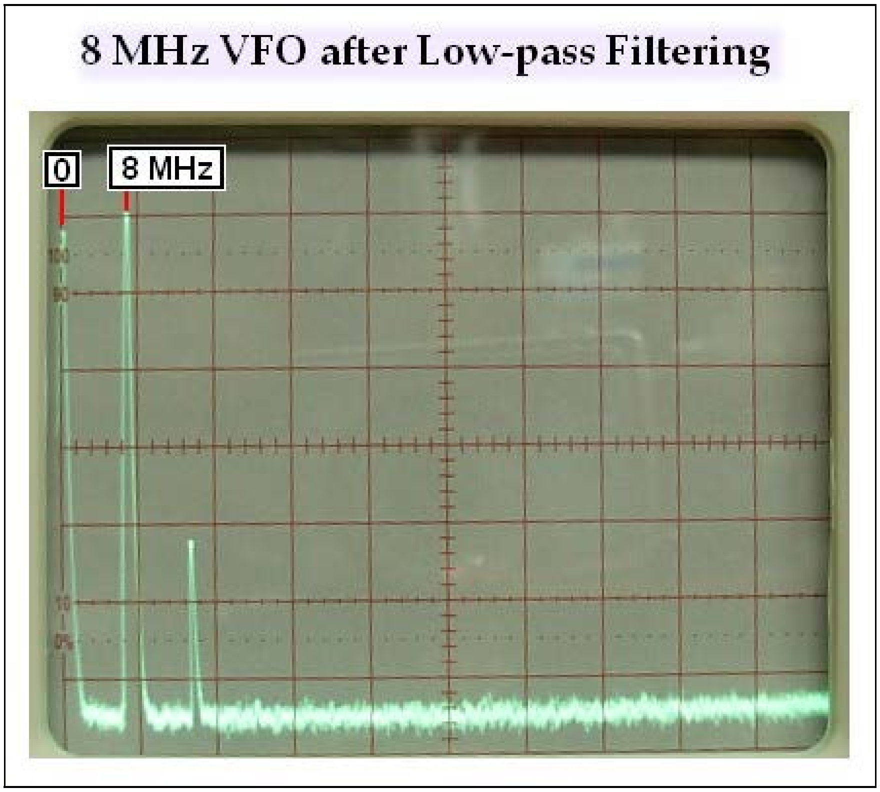

Spectral analysis of the 8 MHz VFO after passing through an N = 5 Chebyshev low-pass filter. The second harmonic now lies about 40 dB down from the 8 MHz carrier (-40 dBc) and the 3rd harmonic is almost down in the noise. Each horizontal square = 10 MHz.

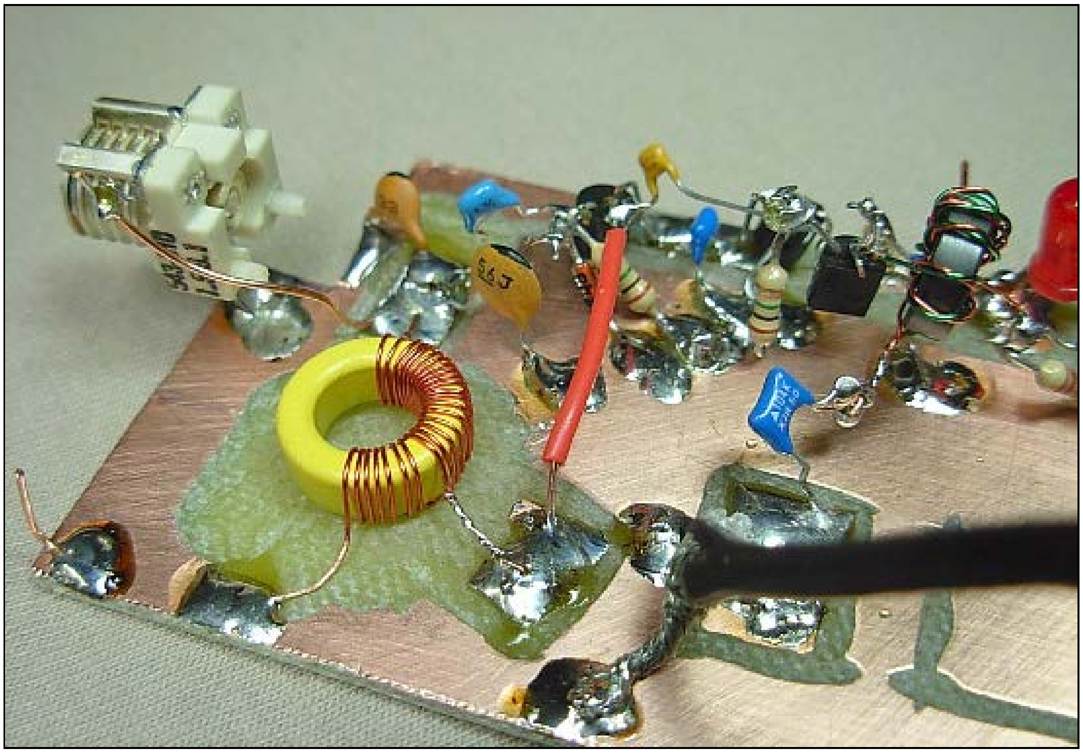

The breadboard of the 8 MHz oscillator oscillator from the above experiments. The output drove a BJT amp biased to give distortion and a 50 Ω output. I adjusted the frequency with the high Q air-variable trimmer capacitor seen to the left.

Low-pass Filter

Some builders wonder why I only employ sine wave signal generators on this web site. To calculate power, they require no low-pass filtering — now you know why. If you're calculating power from a distorted signal, a stiff low pass filter helps ensure measurement fidelity. All of my signal sources feature a 2nd harmonic response of at least -30 dBc, but -50 dBc is typical. To filter receiver front ends, signal generators, or mixer outputs, I keep several 7 element low-pass filter bench modules on hand that cover several 3 dB cut-off frequencies between 3 and 60 MHz.

Although, any old low-pass filters might work fine, Wes, W7ZOI suggests an N = 5 Chebyshev with 0.2 dB of ripple at about 1.2x the signal frequency as a starting point for designing a test-bench low-pass filter. If you don't know how to design low-pass filters choose a pre-designed filter from a filter table. For the experiments above, I selected a filter from an ARRL Handbook. See the schematic below:

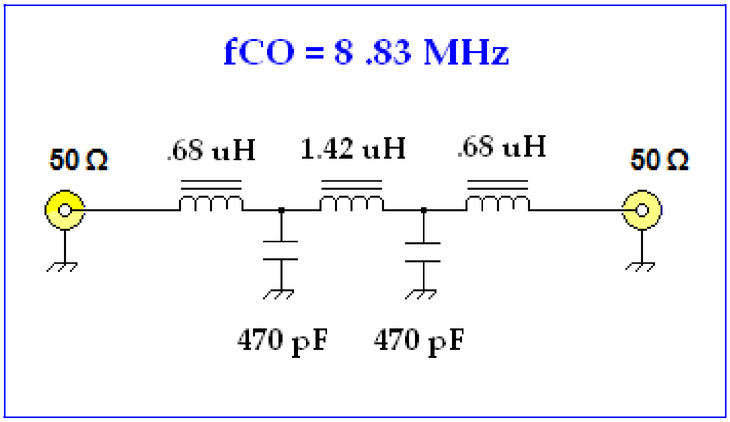

Calculating Power (dBm and mW) from Peak-to-Peak Voltage

To calculate the power from peak-peak voltage, the load impedance (Z) must be known. In RF design, the standardized impedance value = 50 Ω. For CATV and video, 75 Ω is common, and in audio and telecommunication design, a 600 Ω impedance dominates. Although we can technically employ any Z, this web site conforms to the 50 Ω RF impedance standard.

The SI unit of power is the watt. In radio, we might see the term dB used, however, dB is a decibel comparison between 2 signals and not an absolute value like the watt. On the bench, dBm serves as the most common and useful term — dBm is the measured power ratio in decibels referenced to 1 milliwatt.

dBm represents an absolute power — so useful because both large and small signals are quantified with 1 number. Some important bullets follow:

0 dBm = 1 mW

3 dBm = ~2mW; so doubling the power from 0 dBm equals a 3 dB increase in power

Increasing the power from 0 dBm to 10 dBm boosts power by 10 dB. The power is now 10X baseline or 10 mW

20 dBm = 100 mW

-27 dBm means that the output has ~500 times less power than 1 milliwatt. -27 dBm = 0.002 mW or 2 microwatts

Hopefully over time, you' ll ingrain the concept of logarithmic power gain or loss (in dB) and power referenced to 1 mW (in dBm). This is bread and butter radio design information you must know.

50 Ω Measurement Virtues

You build a VFO, measure it with your 'scope; calculate the output power into a 49.9 Ω resistor and then record this power in dBm. Let's say it's 6 dBm. VFO output power = 6 dBm.

Next, you place a 6 dB attenuator pad on the VFO output. VFO output power now = 0 dBm.

Finally you connect a 10 dB gain RF amplifer to your VFO. Your VFO output now = 10 dBm. What a beautiful system ! ..... it really gets fun when we measure down at - 30 dBm and so forth.

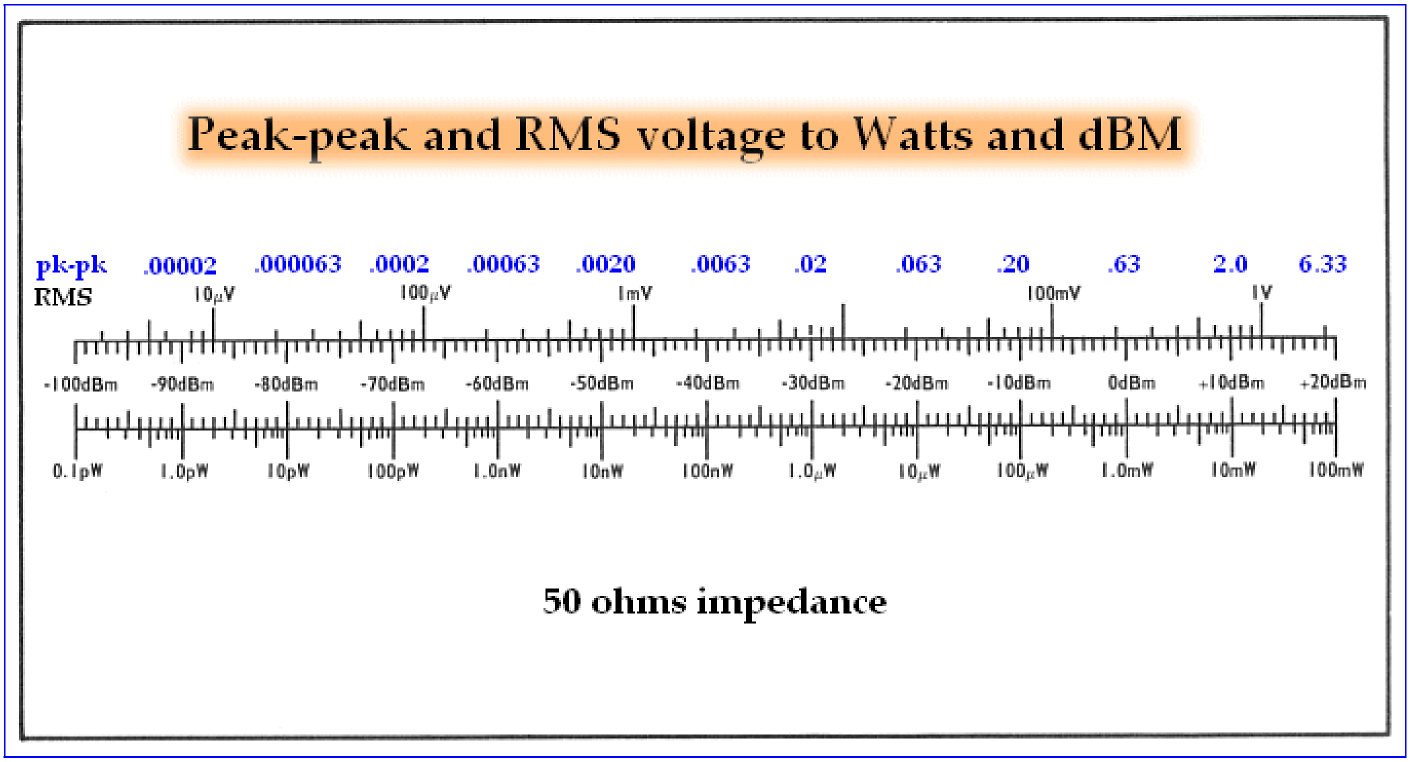

The chart above really helps you visualize the relationships of mW, AC voltages and dBm

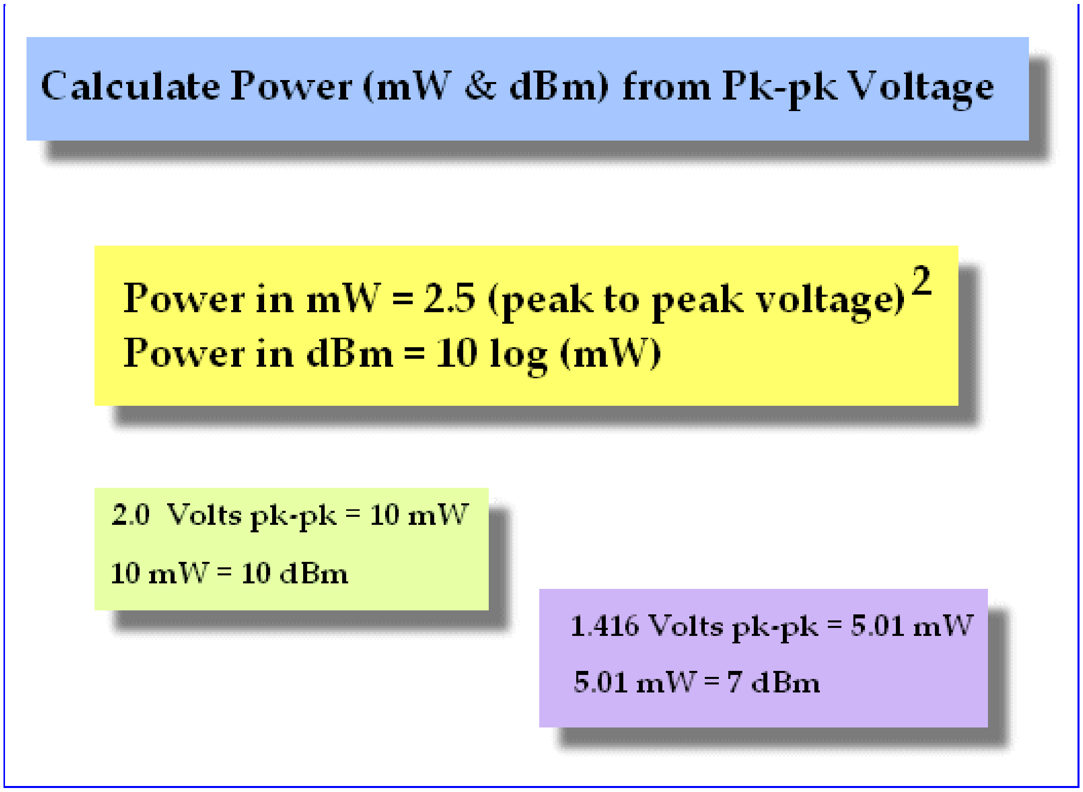

Calculate Power (mW & dBm) from Pk-pk Voltage

Power in mW = 2.5 (peak to peak voltage)^2
Power in dBm = 10 log (mW)

2.0 Volts pk-pk = 10 mW
10 mW = 10 dBm

1.416 Volts pk-pk = 5.01 mW
5.01 mW = 7 dBm

In order to get from peak-to-peak voltage to power, math is required. I show the formula above. You may elect to skip the math and calculate dBm or mW from peak-to-peak voltage with software. A number of programs are available; I wrote 1 here as Applet **F**.

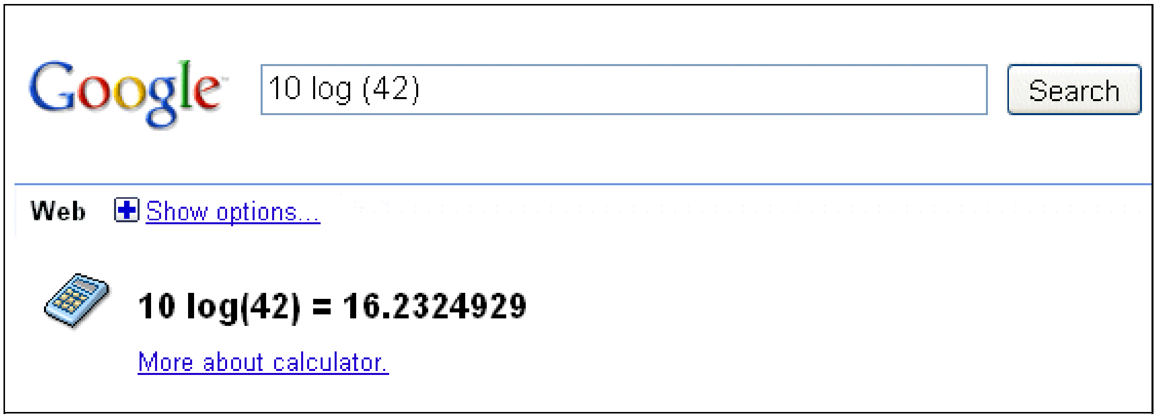

10 log (42)

10 log(42) = 16.2324929

More about calculator.

If you lack a scientific calculator, Google has math functions. Shown above = a logarithm calculation

In Search of 50 Ohms

How do I establish a 50 Ω output impedance in my RF amplifier? I get this question often.

From my experience, in **simple** amplifiers lacking negative feedback, a 50 Ω output impedance must be created by inserting a resistor somewhere in the circuit that forces a 50 Ω output impedance.

For example, we might use a 50 Ω collector resistor in a BJT amplifier (or a 50 Ω drain resistor in a JFET amplifier), or place a fixed resistor in parallel with the collector/drain transformer and use a secondary winding to establish the 50 Ω output impedance. Sometimes we'll place a series resistor (say from 22 to 51 ohms) on the output of an emitter or source follower to bring the low output impedance up to 50 Ω. These form basic explanations and usage examples may be found on many schematics on the QRP / SWL website.

We experimenters also employ negative **feedback** with or without output transformers to establish a 50 Ω input and/or output Z and I show many examples on this site.

The following diagram explores 1 method to get a 50 Ω output impedance in a simple amplifier. It doesn't matter if the transistor is a JFET or a BJT, the principle is the same. This diagram and tutorial are simplistic and meant to help novice builders learn to design their own amplifier stages. You may connect any resistor value across the output of a transformer to calculate power, however, this web site only considers 50 ohms.

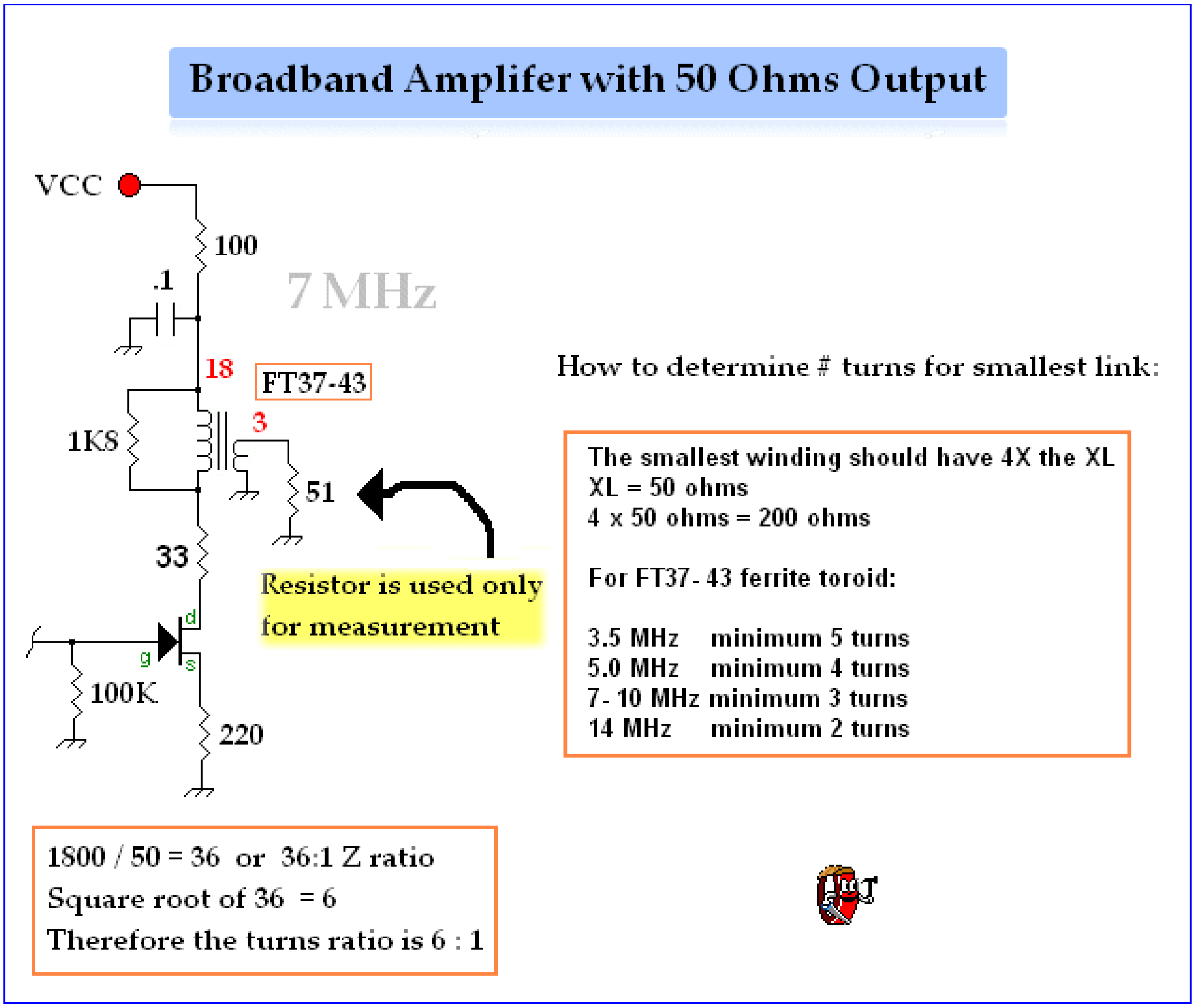

Broadband Amplifer with 50 Ohms Output

How to determine # turns for smallest link:

The smallest winding should have 4X the XL
XL = 50 ohms
4 x 50 ohms = 200 ohms

For FT37-43 ferrite toroid:

3.5 MHz	minimum 5 turns
5.0 MHz	minimum 4 turns
7- 10 MHz	minimum 3 turns
14 MHz	minimum 2 turns

1800 / 50 = 36 or 36:1 Z ratio
Square root of 36 = 6
Therefore the turns ratio is 6 : 1

The above diagram describes a broadband (untuned) amplifier. I employed a FT37-43 ferrite toroid: a common part. Other ferrite toroids may be substituted, however the table depicting the minimum number of turns won't apply.

Consider the BJT amp shown. The transformer primary winding is shunted with a parallel 1800 Ω resistor. The 1K8 resistor "forces" a 1K8 ohm collector output resistance in the primary winding.

To transform the 1800 Ω primary impedance to 50 ohms; use a 3 turn secondary link. Calculate the primary to secondary turns ratio as follows:

1800 ohms divided by 50 ohms = 36. The impedance ratio = 36:1.
The turns ratio is the square root of the impedance ratio; thus the turns ratio is 6:1. The primary winding must have 6X the number of turns of the secondary winding. In the 3rd RF Workbench web page, you'll see that the above explanation pertains to the "ideal transformer", however, the concept is useful — especially to the target audience of this website.

New builders might ask — why not wind 6 turns for the primary winding and 1 turn for the secondary winding? We avoid this because the smaller or secondary winding should have have a minimum inductive reactance (XL) of 4X the impedance it is connected to. Thus for a 50 ohm circuit, the minimum XL = 200 Ω at the design frequency.

This design rule serves only as a rough guide. We employ the minimum 4X rule because employing an XL less than 4X may create unwanted signal losses and affect the smaller winding's impedance. The table to the right of the amplifier shows the minimum numbers of secondary turns for a few common frequencies with the FT37-43 ferrite toroid.

Thus for our 7 MHz amplifier, we need at least 3 secondary turns and multiply this number by the turns ratio to give a 18:3 turns ratio. You might also choose 24:4.

For ferrites other than the FT37-43, calculate the minimum number of turns with the XL= 2 pi * F*L formula and detemine L from the turns versus AL toroid data, or measure L with an inductance meter.

For AC measurement a 50 Ω purely resistive load should be temporarily connected between the output link and ground. This might be a 51 ohm resistor, a 49.9 ohm 1% metal film resistor, 2 parallel 100 ohm resistors, or some other "50 Ω" load. We measure peak-to-peak voltage across the load and then calculate the power in dBm or mW. After measurement, the temporary 50 Ω load is removed and the circuit connected to the succeeding stage.

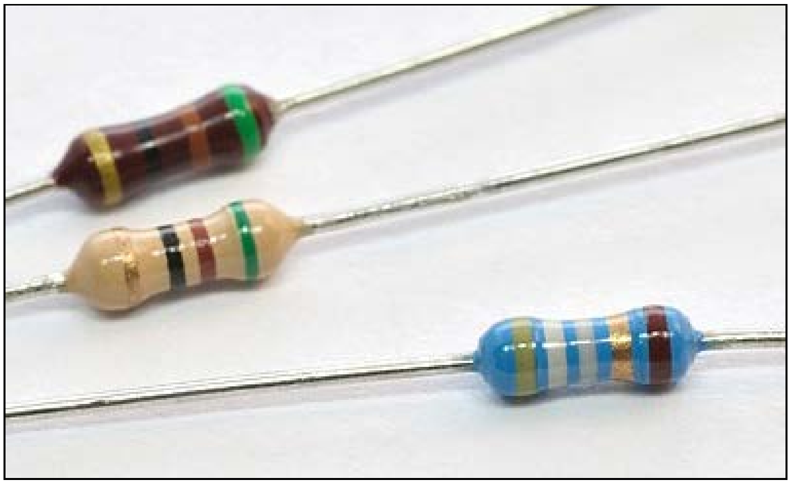

51 and 49.9 Ω resistors

We measure the peak-peak voltage across this 50 ohm resistor with a 10X 'scope probe; or alternately may connect the device output to a 50 Ω terminated scope to measure peak-peak voltage to calculate power.

I normally measure in a 50 Ω measurement environment and temporarily solder a BNC connector onto my breadboard and connect this port to a 50 Ω terminated scope with coax. After testing and voltage measurement, I remove the RF connector and then build and test the next stage.

Case Study

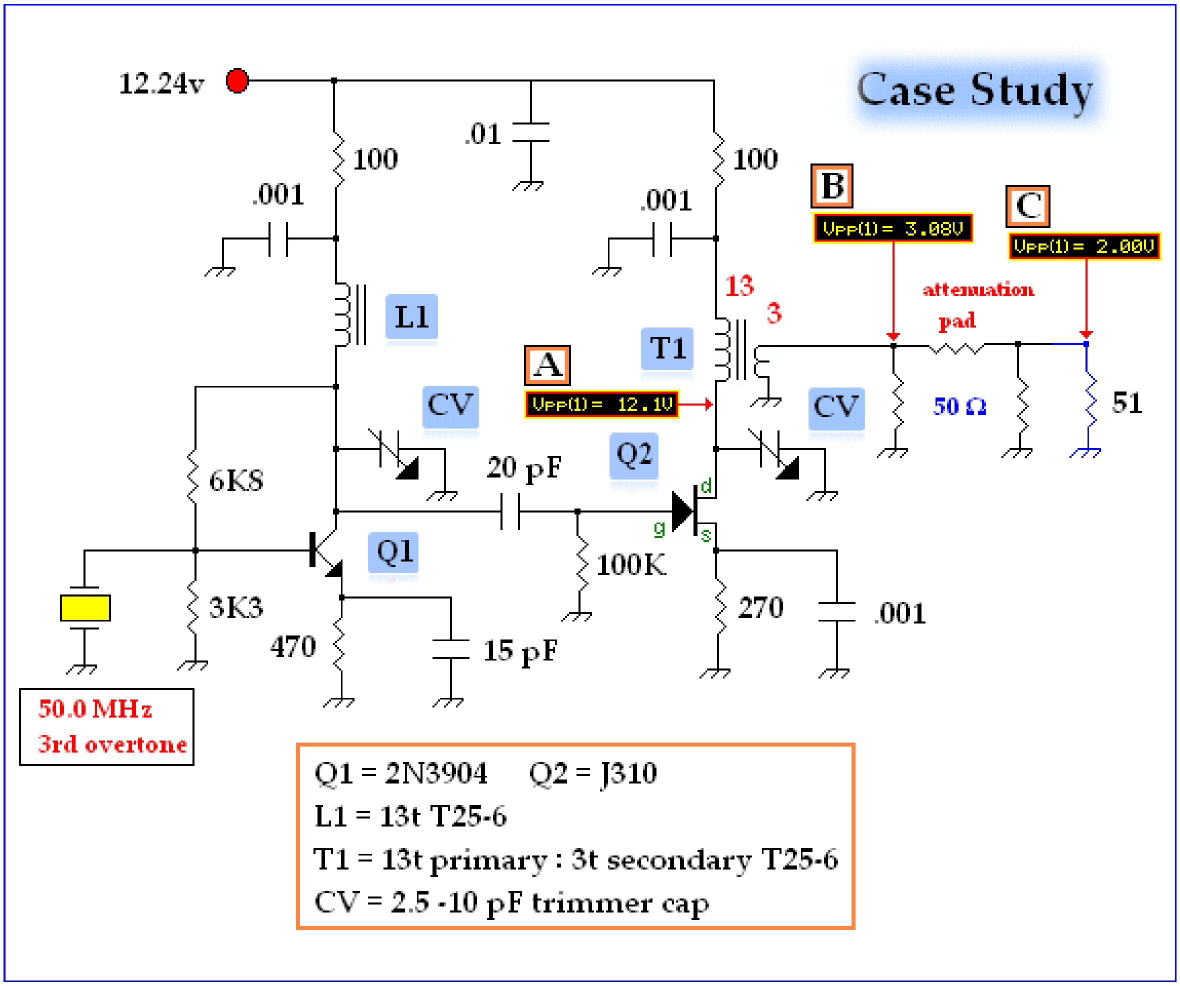
Case Study
12.24v
100
.01
100
.001
.001
B
Vpp(1)= 3.08V
C
Vpp(1)= 2.00V
13
3
attenuation
pad
L1
T1
A
Vpp(1)= 12.1V
CV
CV
50 Ω
51
6K8
20 pF
Q2
d
g
s
Q1
100K
3K3
270
.001
470
15 pF
50.0 MHz
3rd overtone

Q1 = 2N3904 Q2 = J310
L1 = 13t T25-6
T1 = 13t primary : 3t secondary T25-6
CV = 2.5 -10 pF trimmer cap

Pretend that you breadboarded the above circuit entitled "Case Study". This is a 50 MHz crystal oscillator and buffer. The crystal fundamental frequency = 16.7 MHz, but the L1 tank is tuned to its 3rd overtone; 50.0 MHz. You measure and record the peak-to-peak voltages at the points labeled A, B and C.

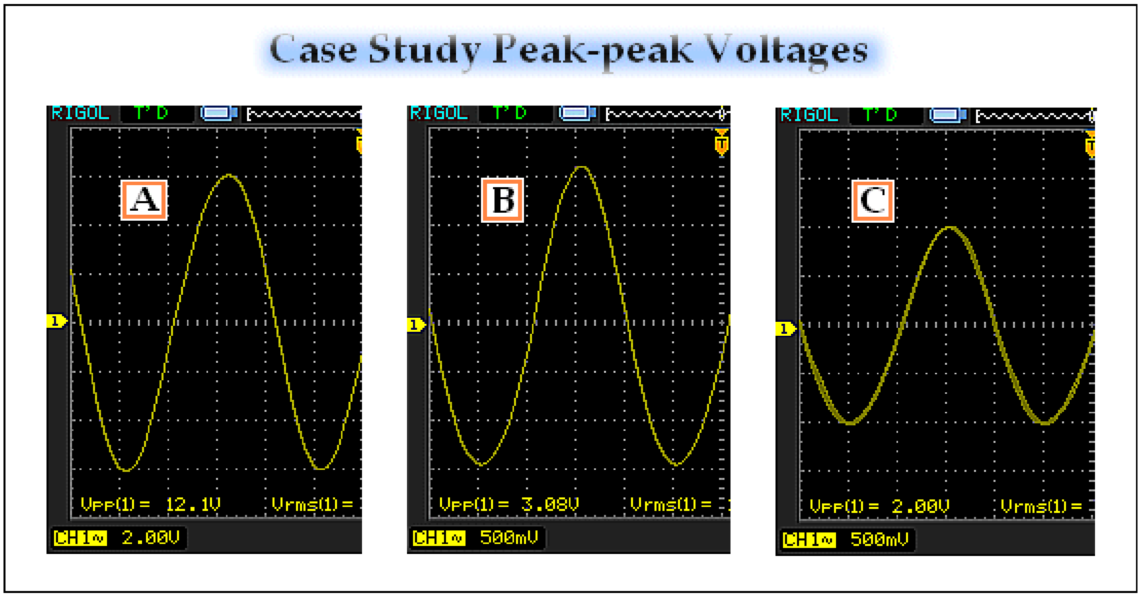

The peak-to-peak voltages are shown as Vpp. The vertical scale (volts/cm) is shown on the bottom of each figure.

Examine Point A. The AC voltage = 12.1 volts peak-peak. Compare this to the peak-peak voltage at Point B. Note the difference. Some builders emailed me after they measured similar differences on the primary and secondary transformer windings of their circuits with a 10X probe. These builders felt something must be wrong. All normal; you can expect the peak to peak voltage to roughly decrease (or increase) by the transformer turns ratio.

The 12.1 volts peak-peak decreased by a factor of 4.3 (13 / 3 turns ratio) which is 2.8 volts peak-peak. In our case, the measured secondary peak-peak voltage was 3.08 volts — in the ballpark. Please remember this serves as a **coarse** guide only. It helps you to know what to reasonably expect during signal viewing.

Peak-to-peak voltage changing in accordance with the transformer turns ratio represents a simplistic explanation describing the "ideal transformer". To understand real world transformer function, you must contemplate factors such as Ohm's law for AC, conservation of energy (this is what causes the voltage to drop while preserving power) and basic transformer behavior. These principles are explained in publications such as The ARRL Handbook for Radio Communications, or the RSGB Radio Communication Handbook. An old high school physics text book might prove a better reference.

Here are the case questions:

1. Calculate the power in dBm at point B
2. Calculate the power in dBm at point C
3. What is the attenuation in dB of the 50 ohms attenuation pad?
4. What is the output power in mW of this stage?

Click on this link for the answers and to see the actual resistor values of the attenuator pad.

Finally, placing a 10X probe at Point **A** will de-tune the L-C tank circuit somewhat and thus alter the AC voltage. In real-world building; to tune Q2, tweak the variable capacitor (CV) with your 10X probe connected to Point C.

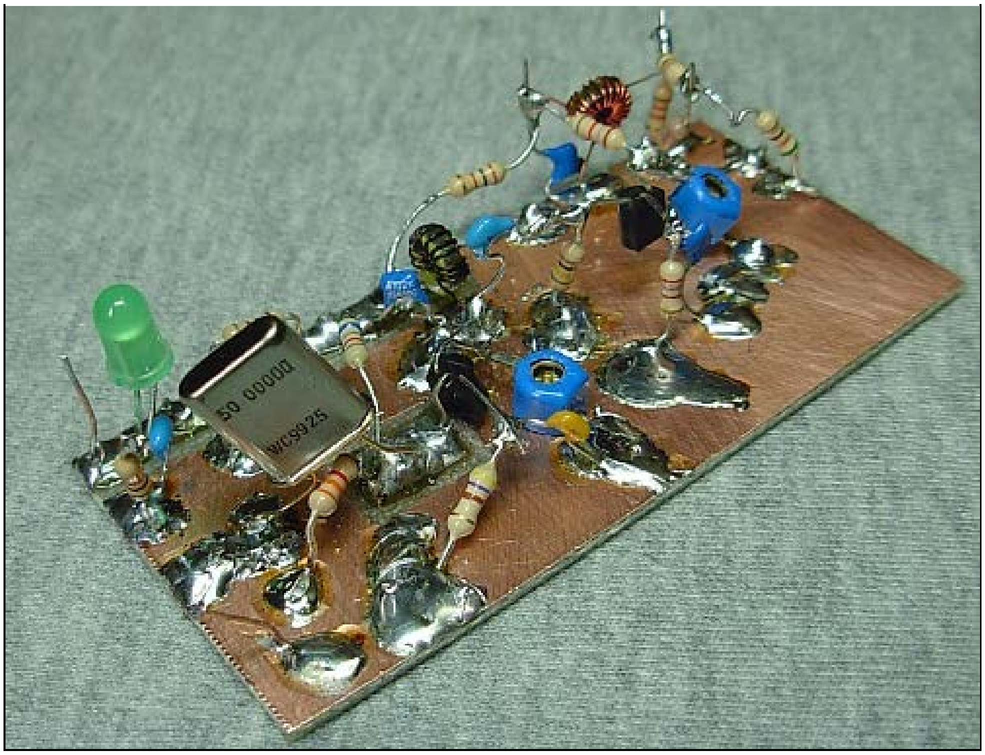

The breadboard of the 50 MHz oscillator prototype.

Oscilloscope Probing

10X Oscilloscope Probe

Please refer to EMRFD Chapter 7 for great information about measuring power in RF circuits. The 10X oscilloscope probe is one of the most important measurement tools to have on your bench. There are countless web articles concerning the 10X probe, so I don't have much to add.

Take care of your 10X probe: don't solder components you've clipped your probe to; avoid setting heavy objects on the cable; store it carefully and inspect it frequently.

When do you use a 10X probe ? Measure with a 10X probe for in-situ ("in place", or "in circuit") voltage measurement and in situations where you can afford a 10X reduction in sensitivity. In low level measurements such as millivolt level measurements, the reduced sensitivity of a 10X probe may reduce or disallow accurate measurement. Additionally, the 20 pF or so capacitance of a 10X probe can detune resonant circuits; especially at VHF on up.

Close up of the Rigol oscilloscope probe 10X and 1X switch.

50 ohm Terminated Oscilloscope

At RF, we generally work with (or try to work with) circuits with 50 Ω impedances. If possible consider performing your measurements in a purely 50 ohm environment.

That is — instead of using a 10X probe, shunt the oscilloscope input port to ground through a 50 Ω resistor and connect your test circuit to the 'scope with 50 ohm impedance coaxial cable. On my 'scopes, I have Channel 1 set up for the 10X probe work and Channel 2 set up for a 50 ohm environment.

I asked Wes about the benefits of performing measurement in a 50 Ω environment. I learned the main advantage of a 50 ohm approach is a well defined port impedance. The second virtue; a 10X greater voltage sensitivity — the increased sensitivity for low level measurement amazes me. In some cases, small signals that I couldn't accurately measure with a 10X probe, gave an excellent scope tracing with more consistent voltage readings in a 50 Ω environment.

You also may enjoy improved signal viewing. For example, in a few cases I have observed harmonic distortion with a 50 ohm terminated scope unseen with a 10X probe I confirmed this distortion with a spectrum analyzer.

If you have never performed measurement in a 50 Ω environment, consider trying it out — you'll enjoy it. You may buy commercial 50 Ω feed-through devices that connect to your oscilloscope input, or homebrew your own, but try to keep the 50 ohm termination as close to the oscilloscope input as possible.

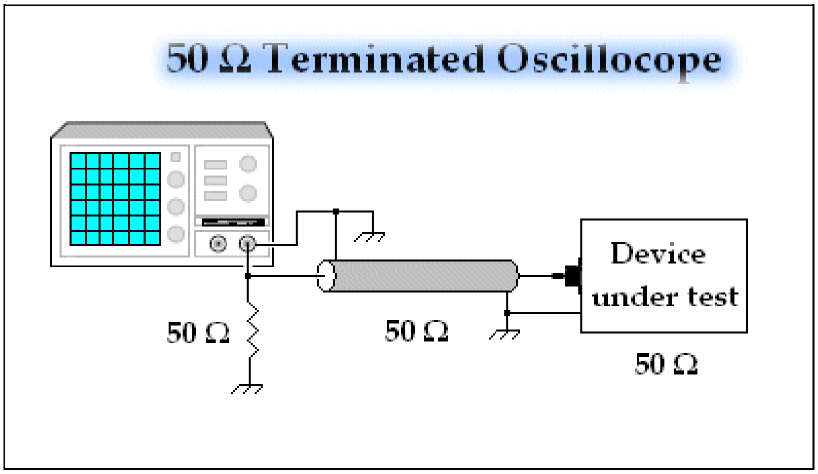

Establishing a 50 Ω impedance measuring environment. The oscilloscope input is terminated with a 50 Ω resistance and connected to a device with a 50 Ω output impedance via 50 Ω coaxial cable.

Try not to routinely connect a feed-through attenuator pad to your feedthrough 50 Ω 'scope terminator — error may arise.

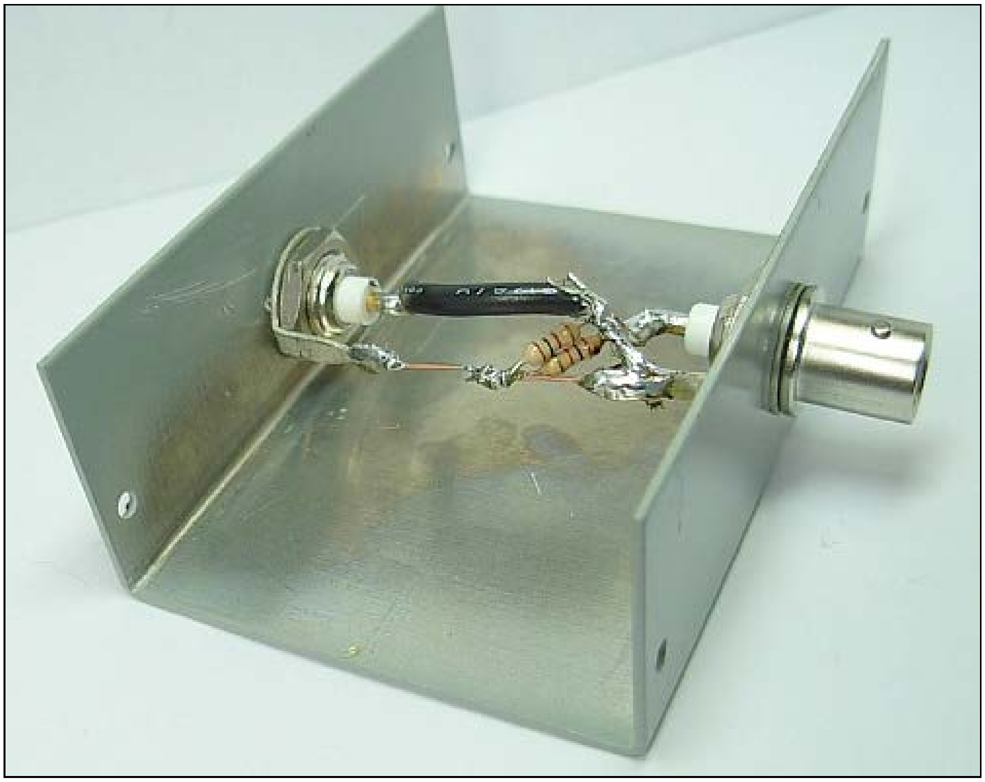

My very first homebrew 50 Ω scope terminator module with 2 female connectors. I connected this module to my oscilloscope input via a commerical 9 cm long 50 Ω coaxial cable with a male connector on each end.

Two parallel 100 ohm resistors formed the 50 Ω load. Ideally, the 50 Ω shunt resistor should be right at the 'scope's female BNC jack — so this homebrew module shown fell short as a stalwart 50 Ω terminator. Inspired to move to a 50 Ω environment and lacking a male BNC connector, it did the job until my commercial version came by mail. You might find oscilloscope feedthrough terminators for sale at Ham festivals.

An ideal homebrew solution — place a male and female BNC connector in a small metal box very close together to allow a very short interconnecting wire. The box would hang off of the oscilloscope. Better still are commercial, shielded 50 Ω feed through terminators which thread right onto the oscilloscope's female BNC input jack.

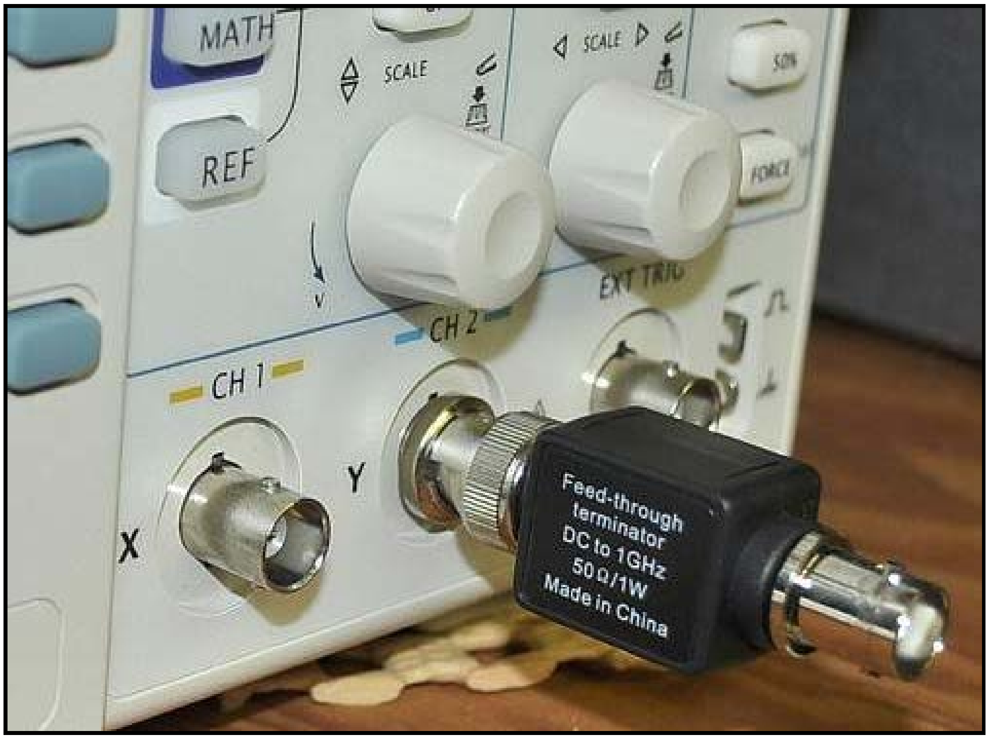

Above — a commercial 50 Ω feed-through BNC terminator on my oscilloscope input.

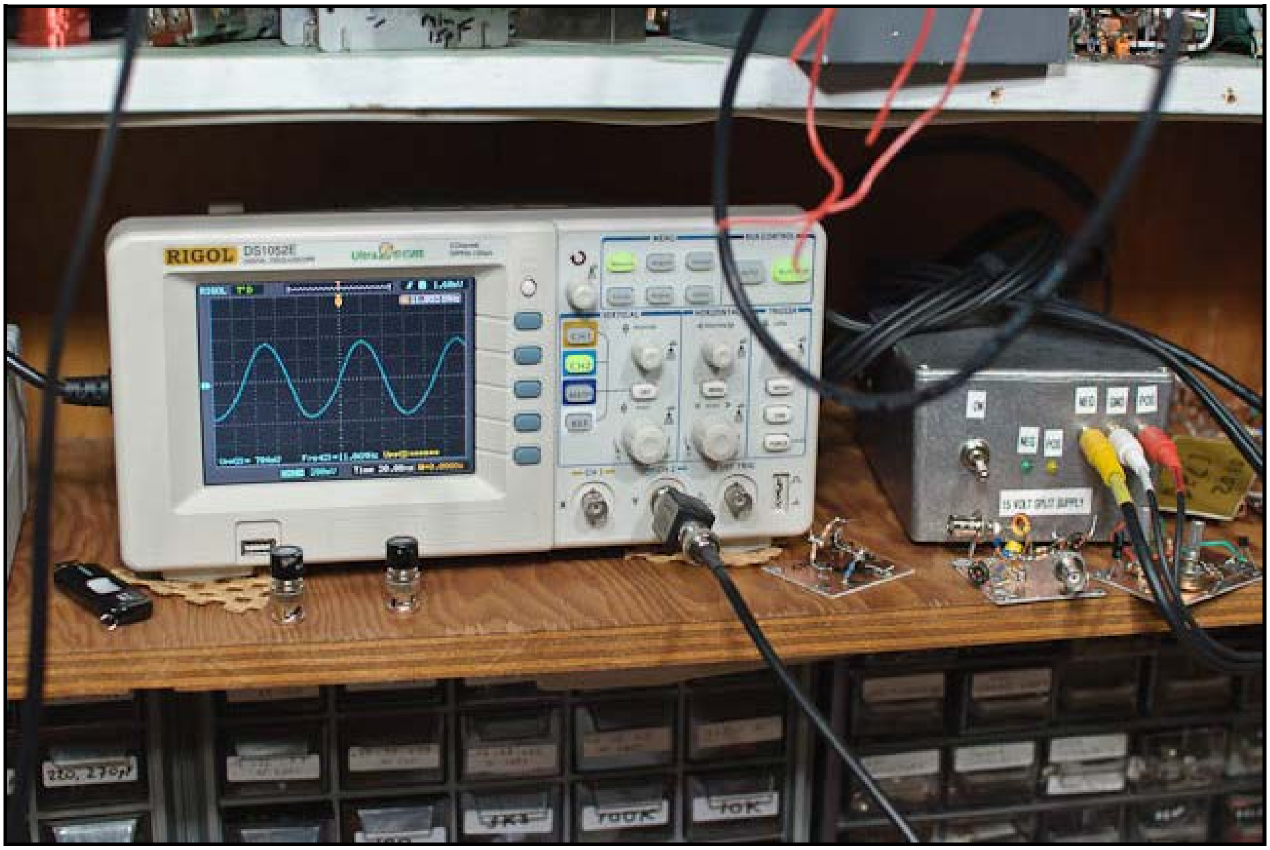

Above — Measuring in a 50 Ω environment. Bliss!   Я люблю это.

RF Current Sampler

Figure 1

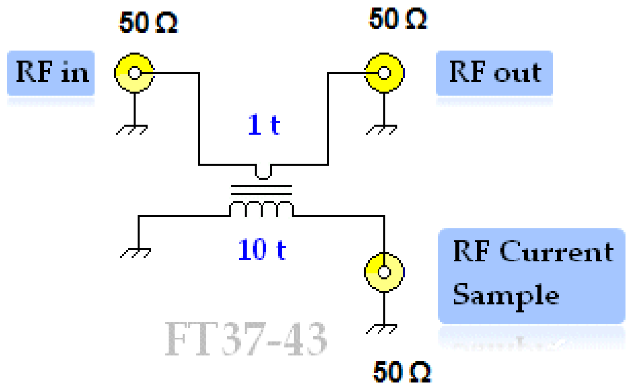

All ports are terminated in 50 Ohms

RF sample port will present as 0.5 Ohms in series with the RF signal path

Figure 1 shows a basic circuit to sample RF current from a power stage such as a QRP transmitter. Many experimenters lack 50 Ω step attenuators rated to handle transmitter-level power. One basic solution is to sample the RF current of the power amplifier using a wideband step-

down transformer. Terminate the RF current sample port with a 50 Ω impedance device. This may include a spectrum analyzer, power meter, receiver with an attenuator, or a 50 Ω terminated oscilloscope.
A usage example = examining a transmitter's spectral purity with a spectrum analyzer. The output power at the sample port will drop by 20-22 dB. A 50 Ω impedance step attenuator can be used to further reduce this power level to whatever you want. For this chore, a typical experimenter's 1-2 watt step attenuator works, since it never "sees" the higher wattage transmitter power.

For example, a 5 watt amplifier 20 dB down is 0.05 watts or 50 mW at the RF current sampler port. 50 mW = 17 dBm. To examine this signal with a spectrum analyzer you may wish to decrease the power down to -27 dBm. The following chart shows the basic process.

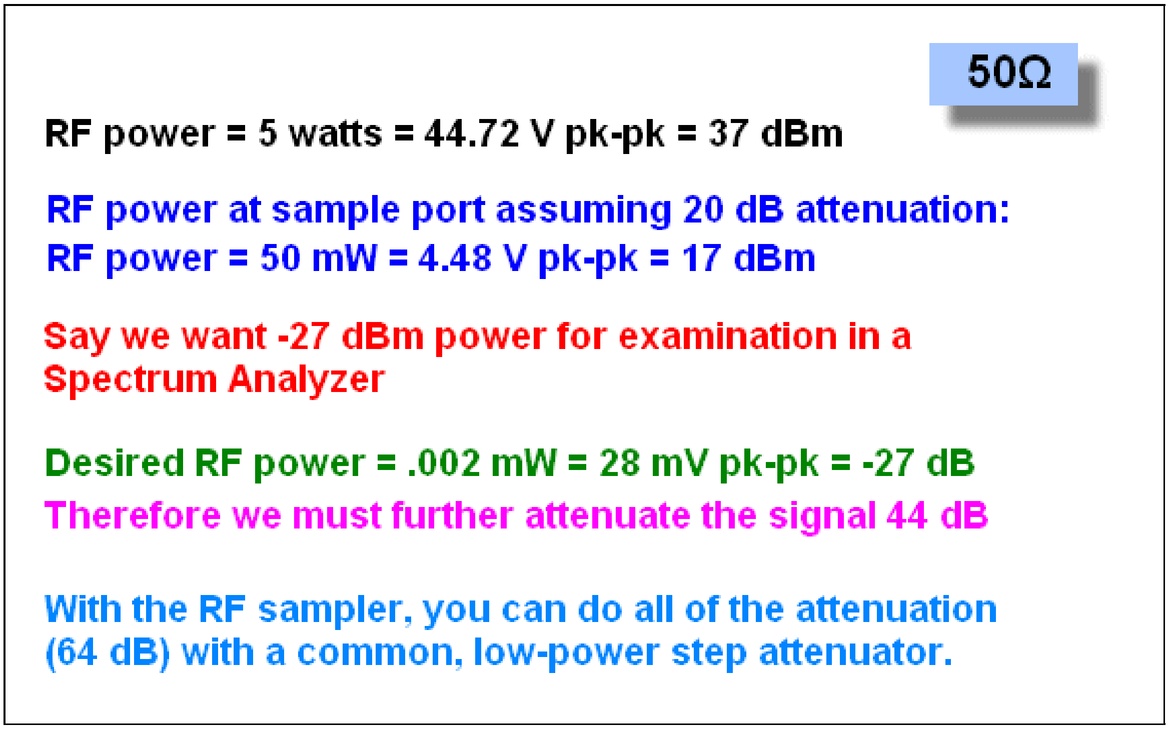

50Ω

RF power = 5 watts = 44.72 V pk-pk = 37 dBm

RF power at sample port assuming 20 dB attenuation:
RF power = 50 mW = 4.48 V pk-pk = 17 dBm

Say we want -27 dBm power for examination in a Spectrum Analyzer

Desired RF power = .002 mW = 28 mV pk-pk = -27 dB
Therefore we must further attenuate the signal 44 dB

With the RF sampler, you can do all of the attenuation (64 dB) with a common, low-power step attenuator.

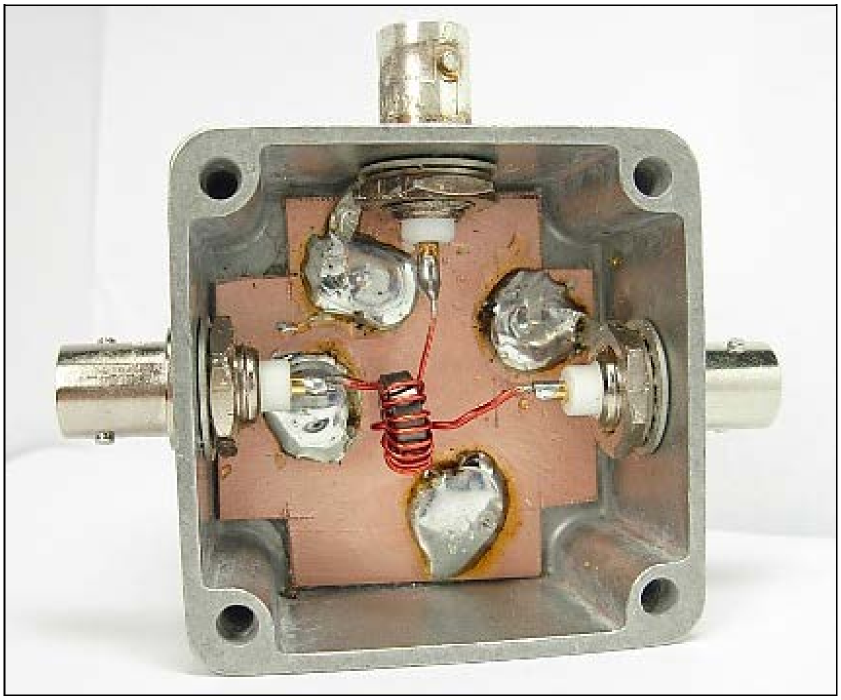

A Hammond chassis shields the RF current sampler used on my bench.

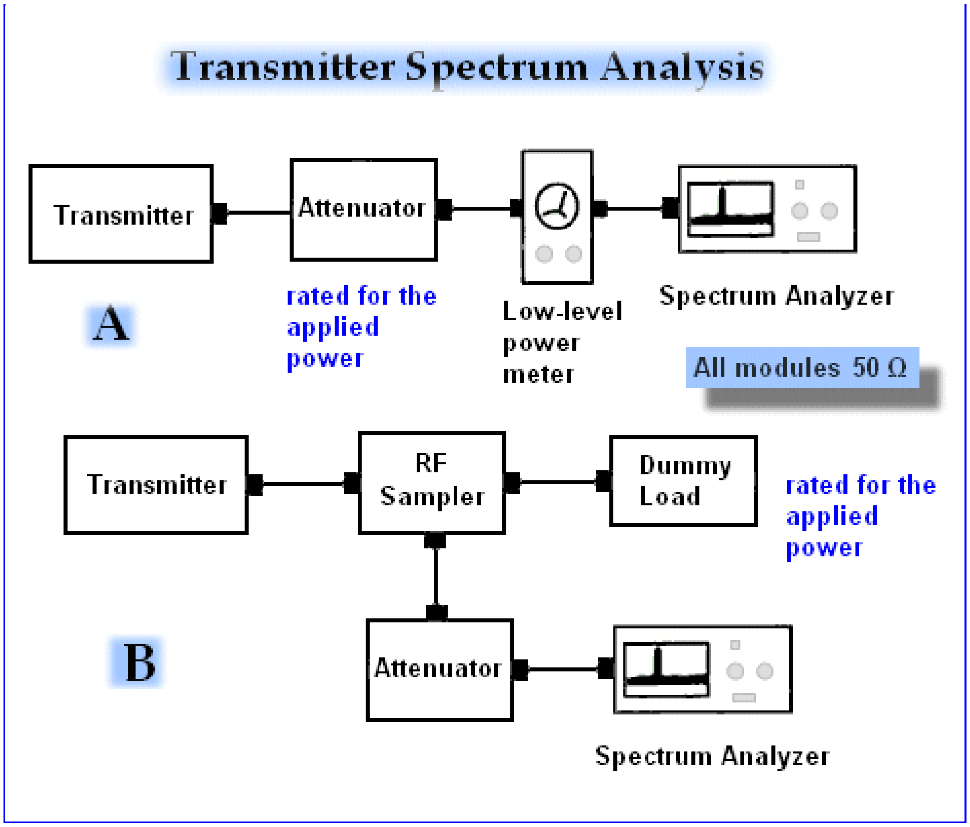
Transmitter Spectrum Analysis
Transmitter
Attenuator
rated for the applied power
Low-level power meter
Spectrum Analyzer
A
All modules 50 Ω
Transmitter
RF Sampler
Dummy Load
rated for the applied power
B
Attenuator
Spectrum Analyzer

The above graphic illustrates 2 methods to examine the output of a transmitter in a spectrum analyzer. Method B is described above. The dummy load must handle the transmitter output power, however a 5 or 10 watt dummy load is easy to make. Method A requires a step-attenuator which can handle the transmitter output power. The low-level power meter promotes the need to quantify the output power before you connect anything to the output of the attenuator. This is also true for Method B.

Always measure the output power at the RF sample port with your oscilloscope or low-level power meter before hooking up any expensive low-level measurement device such as a spectrum analyzer! осторожно!

Miscellaneous Photos

Feed-through
terminator
DC to 1GHz
50Ω/1W
Made in China

TA051
CE
Sales order 62403
BNC feedthrough 50R 1W 1GHz
Pico Technology Limited
www.picotech.com

MALE TERMINATOR 50Ω +1%

Above — a 50 Ω BNC terminator. These are essential QRP work bench items and may be found on eBay for cheap.

Click for a photograph of 4 of my BNC RF port terminators: 27, 50, 75 and 100 ohms from left to right — useful to calibrate and test RF circuitry.

RF — Test and Measurement

RF Workbench Page 2

Welcome to part 2 of a web series exploring basic RF measurement and bench practices. This installment builds on the information from the RF Workbench Page 1

I share introductory and practical content on attenuation, the return loss bridge, insertion loss or gain and spectrum analyzers. Consult EMRFD and use your favorite web search engine for more information.

The Attenuator Network

Like onions in your kitchen, the importance of attenuators can't be overstated. On the bench, attenuator pads go in nearly every test circuit to deliver correct power and/or help match port impedances.

Think of attenuators as passive networks that intentionally insert power loss between 2 components independent of frequency. For example: you might follow a 50 Ω signal source with an attenuator to decrease its power, increase its return loss, and/or buffer it from downstream impedance changes.

Most attenuator networks have fixed input and output impedances.

The input and output impedances may be the same, or different.

Attenuation may be fixed or variable. Most often, we use simple, fixed resistive pads that function as voltage dividers.

Express attenuation in dB.

Attenuators increase return loss and reduce VSWR.

Attenuators may function as buffers to isolate stages.

All attenuators on this web site feature 50 Ω input and output ports.

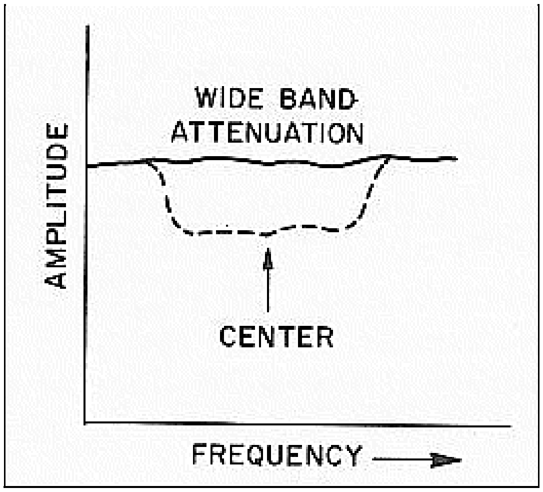

The desired response of an attenuator network. Practically speaking, device construction techniques including shielding will limit how high in frequency your attenuator will properly operate.

GENERAL ELECTRIC
AEROSPACE
ELECTRONICS DEPT.
INSERTION LOSS 0DB
Attenuator
MODEL 30-0
Zo= 50 OHMS
IN
20DB
20DB
20DB
20DB
10DB
5DB
3DB
2DB
1DB
KAY ELECTRIC CO.
PINE BROOK, N.J.

A pair of commercial 50 Ω input/output impedance step attenuators from the past. Occasionally, you'll find them for sale at Ham festivals or estate sales. Most work well for HF and perhaps even VHF work depending on their design and condition. Visually examine and test the attenuator before use.

How to Design and Build Attenuator Networks

To design attenuators with a 50 Ω input and output impedance, I recommend viewing a table. Click for a table.

After choosing the degree of precision; solder up 2 or 3 resistors and you're done. Nearest value 5% tolerance resistors offer reasonable precision for our popcorn circuits, but combining 1% and 5% tolerance resistors works too.

Choose low inductance resistor such as carbon film types and strive for short lead lengths. Well consider resistor power dissipation — for example, an 8 dB attenuator pad will dissipate 84% of the RF passed through it. I have seen attenuator pads that were exposed to high power and some or all of the resistors were burnt and turned to charcoal. Clearly the operator did not regard the power rating of the attenuator resistors. Refer to EMRFD Section 7.4 for practical information concerning attenuator design and power dissipation.

Three of the attenuator pads from my bench attenuator drawer. When using Ugly Construction or its variants, you can solder in, change, or remove attenuator pads at a whim. A small stock of these pads speeds up your work flow.

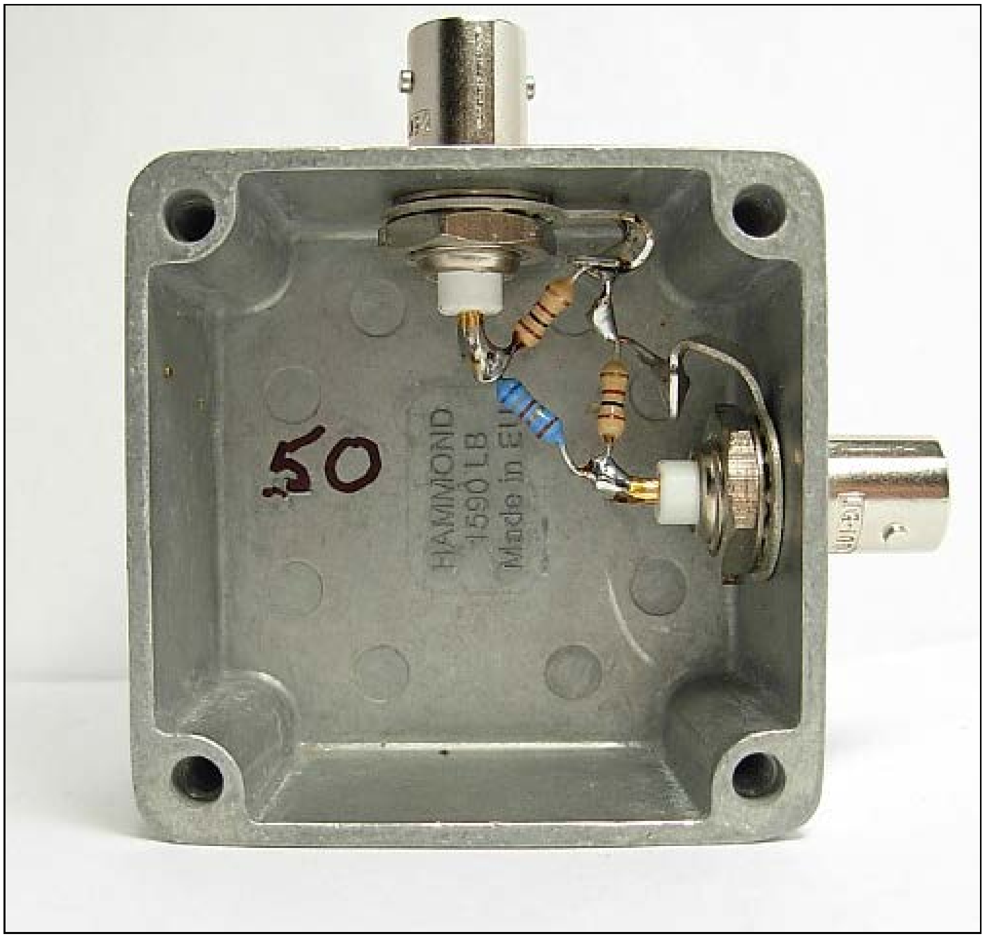

A 10 dB attenuator pad from my collection. This box uses two 100 Ω (5%) resistors and a 68 ohm (1%) resistor for the 96.2 and 71.2 ohm resistances called for. I used the 1% tolerance part because all my 68 Ω resistors are metal film 1% tolerance 1/4 watt types. Perhaps, I'll pursue a closer match to the calculated resistor values 1 day, but this module works okay. You may also stick 2 seperate attenuators in the little Hammond box shown.

6dB ATTEN
FREQUENCY:D
10dB ATTEN
FREQUENCY:D

Two commercial BNC feed-through (in-line) attenuators. I use these *every* day and prefer them over homebrew R networks since they don't require a coaxial cable. I own many: two 6 dB, two 10 dB, one 3 dB and a 20 dB: all were purchased on eBay.

VAT-15
15 dB ATTENUATOR
50 OHM
VAT-6
6 dB ATTENUATOR
50 OHM

Two commercial SMA in-line attenuators for my VHF and UHF experiments: 6 and 15 dB. Click for a marker table with 4 data points derived from sweeping these 2 filters.

Step Attenuators

A step attenuator belongs on every serious RF workbench. They allow in-situ attenuation adjustment with a degree of precision as low as 1 dB. Step attenuators are nothing more than switched calibrated resistances and the switches can be SPDT, relays, rotary or digitally-controlled types. The quality and price of commercial attenuators varies widely. Experimenter concerns include the minimum attenuator insertion loss, power rating, return loss, noise from switch contacts and noise from the resistors themselves.

A homebrew step attenuator makes a great weekend project and almost every radio handbook contains 1. Web linked projects plus commercial kits may be found online — use your favorite search engine to find them.

Some homebuilders prefer 1% metal film resistors to keep resistor noise down. Stick your step attenuators in a metal, RF-proof box and insert quality interfaces such as BNC, N or SMA connectors. Your needs, budget and parts collection determine the outcome when you home build one.

Serebriakova Attenuator - Серебрякова аттенюатор (50 Ом)

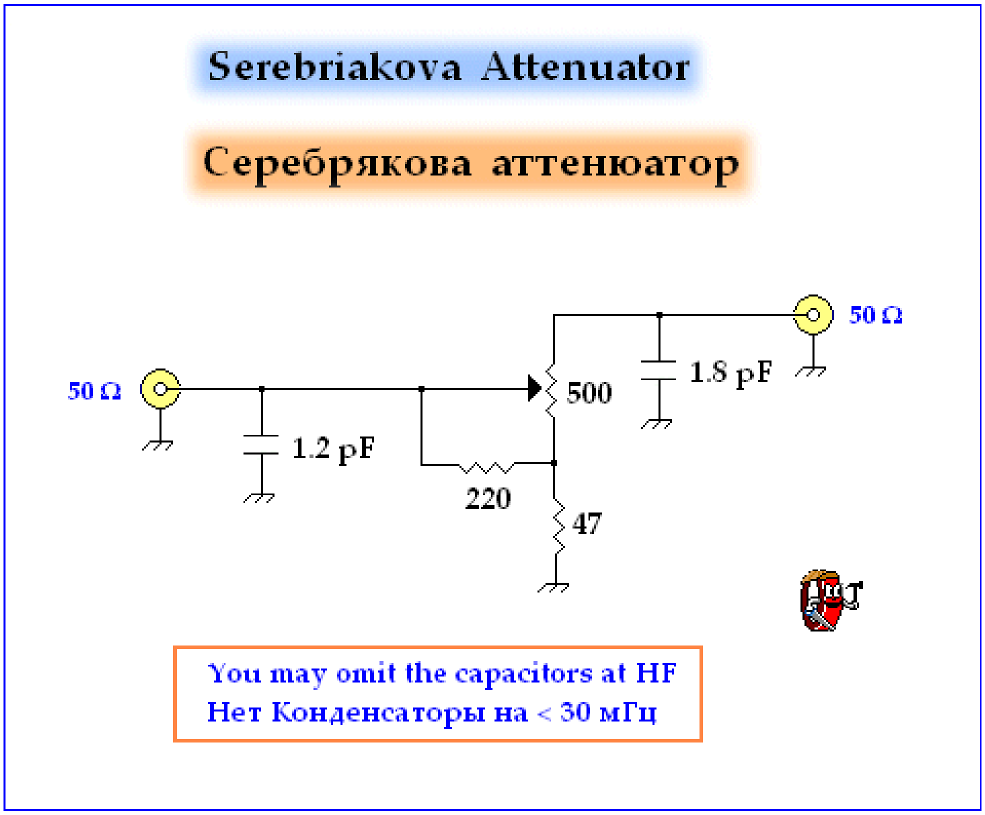

The Serebriakova; a simple, variable attenuator well suited for QRP homebuilding. Filled with gratitude to its Russian designer's family, I share this contribution with my readers. This attenuator network makes signals smaller or larger in a 50 ohm environment via a potentiometer. My analysis indicates acceptable performance considering its simplicity. The input match is close to 50 Ω across the range of the potentiometer. The output match across the potentiometer range is mediocre. Click here for a DC match analysis from Wes, W7ZOI. As shown, you wouldn't place this device on your main bench signal generator output as the output impedance diverges widely during amplitude adjustment.

Add fixed attenuator pads on the input and/or output to improve matching into 50 ohms. This circuit could serve in multiple applications including an RF gain control on a receiver front end, for bench measurement (when adapted) and for a low-level transmitter gain control. The Serebriakova attenuator may function up to 500 MHz in a carefully constructed, shielded box. The input and output capacitors may be omitted below 30 MHz. The attenuation varies a minimum of 20 dB when turning the potentiometer from CCW to CW. Click for a build by he yl.

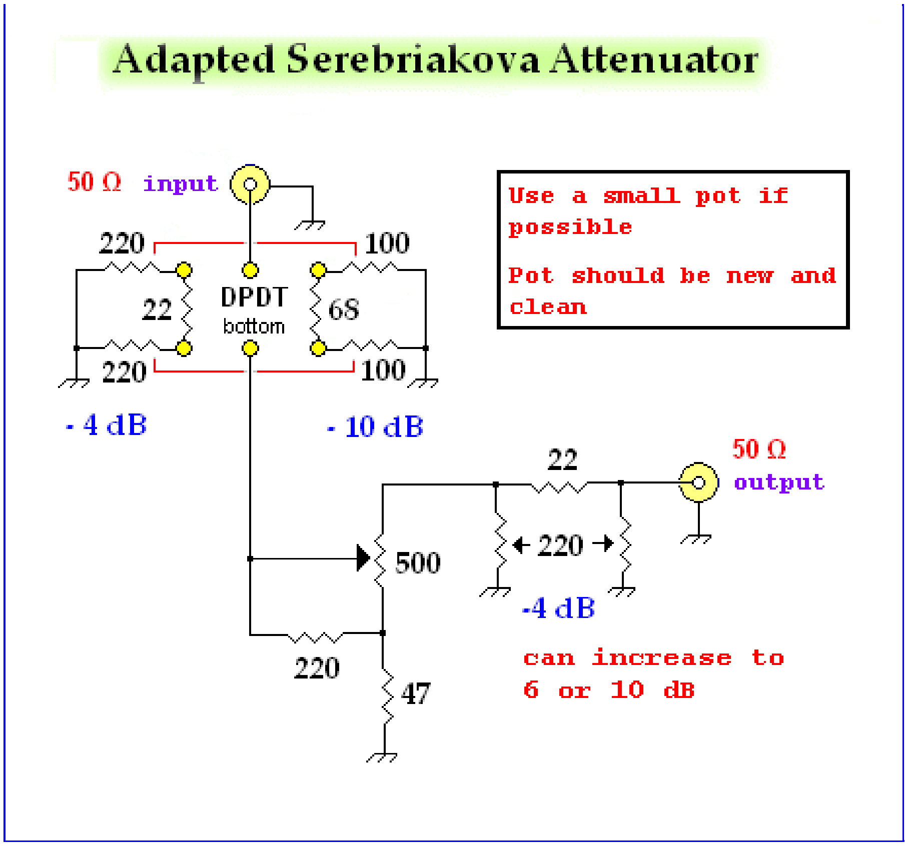

Adapted Serebriakova Attenuator

Use a small pot if possible

Pot should be new and clean

can increase to 6 or 10 dB

A variant of the Serebriakova attenuator is shown above. Input and output matching are enhanced by fixed attenuator pads. The input match into 50 ohms is fine. After testing, I learned that the fixed 4 dB output attenuator pad is likely too low to ensure a wide range output match into 50 ohms. A 6 or 10 dB output pad is preferable, however, if this is your only variable attenuator, the device would then only be usable for very low-level work. You can decide what value of input or output pads to use.

A new, clean and small size 500 ohm pot works best. Store your potentiometer collection in sealed plastic bags to keep out workshop and house dust.

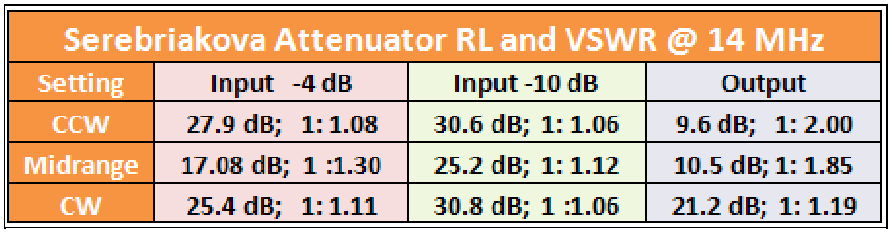

Serebriakova Attenuator RL and VSWR @ 14 MHz

Setting	Input -4 dB	Input -10 dB	Output
CCW	27.9 dB; 1: 1.08	30.6 dB; 1: 1.06	9.6 dB; 1: 2.00
Midrange	17.08 dB; 1 :1.30	25.2 dB; 1: 1.12	10.5 dB; 1: 1.85
CW	25.4 dB; 1: 1.11	30.8 dB; 1 :1.06	21.2 dB; 1: 1.19

Shown above are return loss (RL) and VSWR measurements performed on the adapted Serebriakova attenuator shown above. Clearly the input match is better than the output match. The output match did not significantly change when the attenuation switch was moved from 4 to 10 dB attenuation or back.

Based upon these values, it might be a better compromise to put a 3 to 4 dB pad on the input and a 10 dB attenuator pad on the output to ensure an output RL of at least 20 dB. Some might argue that the output RL should be higher. Perhaps, but the match is pretty good for such a simple circuit. Let's put it in perspective; a commercial signal generator that sells on the Internet for $450.00 U.S dollars was measured by a builder I know in the UK and he found a best case RL of 10 dB ! Jim later sold it and built a homebrew signal generator with a 35 dB return loss at all frequencies.

Fixed attenuator pads provide a good remedy for mismatched ports and I discuss why and how in the next section.

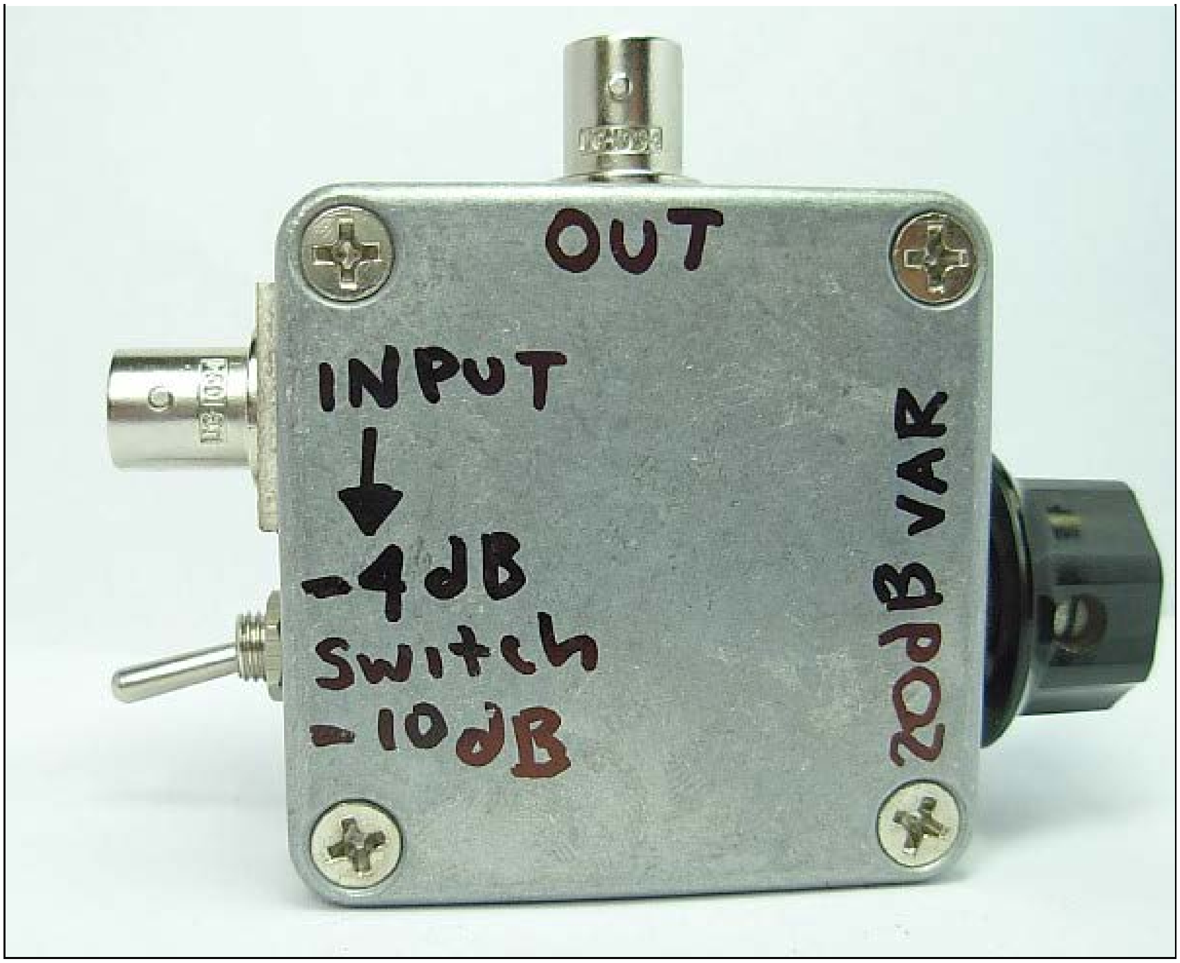

The shielded, adapted, Serebriakova attenuator. When home building your personal version, strive to make the AC connections as short as possible. The above device has nearly 23 dB of variable attenuation at 14 MHz. If you can't build, find, nor afford a precision step attenuator for your QRP workbench, this device may work okay for you.

Impedance Matching, Return Loss and VSWR

We radio folks build, buy and apply lots of gear with a stated *nominal 50 Ω input or output impedance*. In truth, a *pure* 50 Ω impedance occurs rarely and components in an RF system are frequently mismatched. Almost every Ham radio operator matches their antenna impedance to their feed line + radio to maximize transmitter output power — but radio and antenna system matching is often the only case where these Hams match their gear.

In contrast, we experimenters, tirelessly match our 50 ohm RF system components — this work flow avails our **modus operandi** on the bench**.** And so, we builders match the input and/or output ports of *all* our RF stages: signal generators, filters, splitters, antennas and so on. You can easily measure the impedance match of your RF components with a basic device based upon a Wheatstone bridge; the return loss bridge. First, let's discuss matching a little more:

On the RF Workbench, we talk about return loss, reflection coefficient and VSWR to quantify impedance matching. I only consider return loss and VSWR on this web site.

When 2 system components are impedance matched, maximal power transfers from 1 device to the other. If the impedances are different, RF power is reflected back to the signal source. This reduces the amount of power delivered to the load. Transmitted and reflected waves moving along a transmission line superimpose and cause standing or stationary waves. The greater the impedance mismatch between the 2 components, the larger the amplitude of the standing waves. Mathematical formulas compute how much power is lost due to mismatch. Consider reading a great tutorial on SWR, Return Loss, and Reflection Coefficient linked here by Wenzel Associates.

Return Loss

Return Loss = the difference between the outgoing incident power and the reflected power as a result of the mismatch between the the signal source and its load. Return loss is expressed in dB as a positive number on this web page. The higher the return loss, the better the impedance match. An ideal prefect match would have a RL of infinity; that is, no power is reflected back to the signal source and all of the incident power is delivered to the load. If a circuit has no load (open circuit), the RL is 0 dB — all of the power is reflected back to the signal source.

Other terms quantifying return loss are S11 and S22, however S11/S22 are the negative of return loss: RL = 20 dB or S11/S22 = -20 dB. We say S11 as S — one — one and S22 as S — two — two. I discuss these S-numbers, or Scattering Parameters elsewhere.

VSWR

Voltage standing wave ratio is another measure of how well the components in an RF network are impedance matched. Increasing the return loss lowers the VSWR and vice-versa. Most amateur radio enthusiasts are familiar with VSWR and often refer to it as "match" or "SWR". RL and VSWR can be derived mathematically from one other. VSWR = [10^(RL/20) + 1] / [10^(RL/20) - 1]. **Note X ^ Y means X raised to the power of Y therefore 2^3 = 2x2X2 = 8.**

Thus a RL of **10 dB** = 1: 1.92 VSWR and **20 dB** = 1:1.2 VSWR and **30 dB** = 1:1.07 VSWR

In EMRFD, Wes presents a return loss bridge as Figure 7.41. This circuit, shown below is easy to build and use.

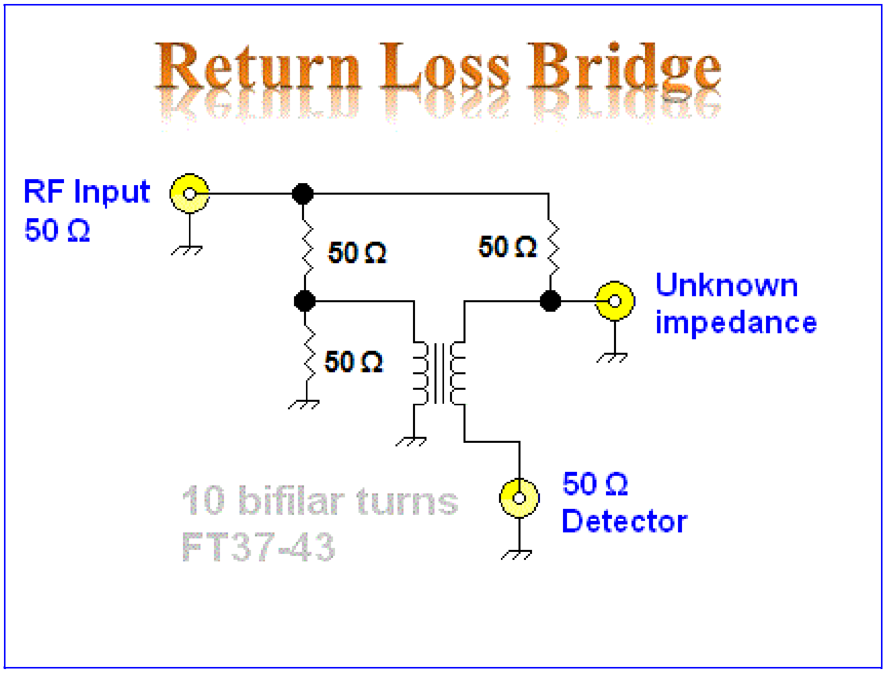

The 50 Ω impedance detector may include a spectrum analyzer, power meter, receiver with an attenuator, or a 50 Ω terminated oscilloscope. On my bench, a 50 ohm terminated scope is favored.

Let's measure the return loss of a 27 Ω resistor to learn how. The procedure with a 50 Ω terminated 'scope follows:

Connect a 50 Ω output impedance signal generator to the bridge RF input port with 50 ohm coax;

Connect a 50 ohm terminated oscilloscope to the detector port via 50 ohm coaxial cable;

Record the peak-to-peak (open circuit) voltage with no load on the end of a short coax cable connected to the unknown Impedance port;

Record the peak-to-peak voltage with "unknown" coaxial cable terminated with the 27 Ω resistor

Calculate the power difference in dBm between these 2 peak-to-peak voltages.

Return loss = the difference in dB between these 2 values calculated by hand or with software. Please refer to the RF Workbench Page 1 for information how to calculate power. I wrote a JavaScript Applet that take these 2 peak-to-peak voltages and calculates RL and VSWR; its labeled **K** on this web page.

Before measuring the unknown RL of a circuit, we usually connect a 50 Ω terminator to the unknown impedance port and calculate the best possible return loss: we refer to this value as bridge directivity — the best possible match for that return loss bridge at that test frequency. I keep a permanent 50 Ω terminator + a barrel connector on my bench for this purpose.

Click for a photo of the gear I use for all RL measurement. *Best viewed at full resolution*

Lets run through the procedure to measure the return loss of a 27 Ω resistor again, but with added photographs and 'scope captures. I tested at 14.070 MHz.

Above — We'll measure the return loss of this device; a 27 Ω resistor soldered on a BNC connector. We call this a resistive terminator and I keep a small collection of 27 - 100 Ω terminators on-hand for calibration purposes.

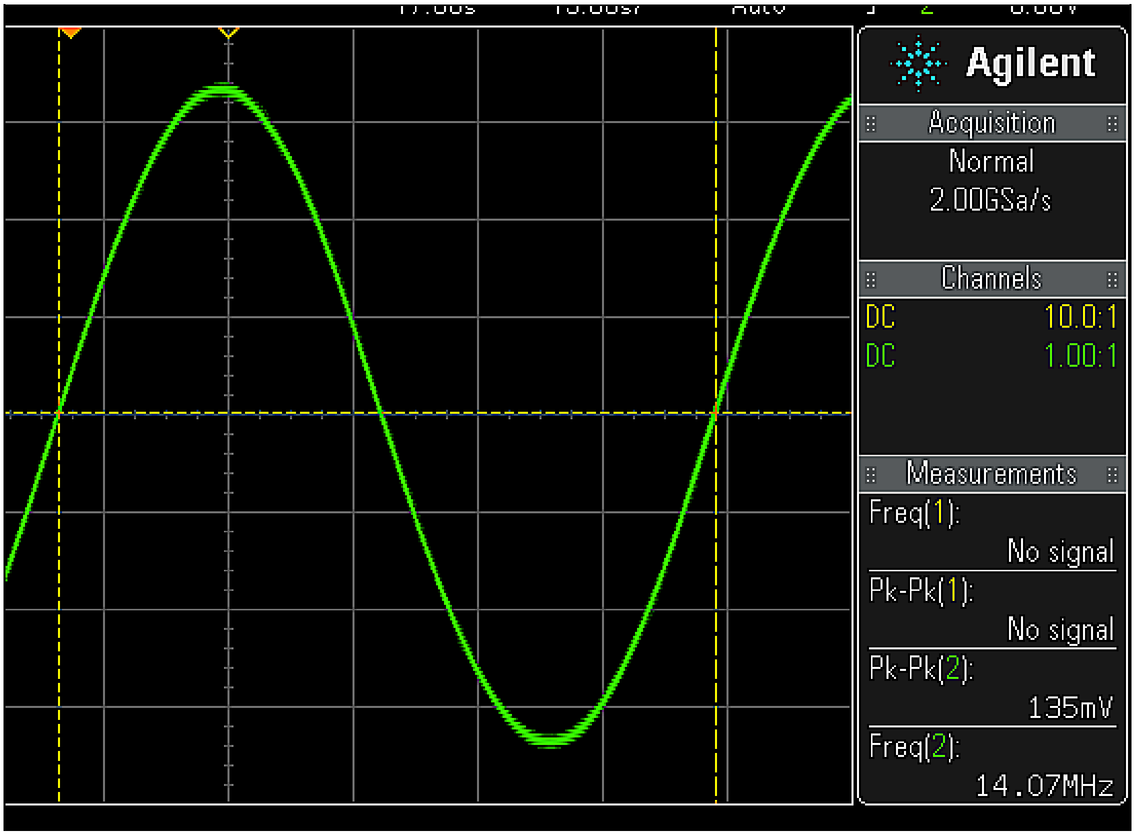

Acquisition

Normal
2.00GSa/s

Channels

DC 10.0:1
DC 1.00:1

Measurements

Freq(1): No signal
Pk-Pk(1): No signal
Pk-Pk(2): 135mV
Freq(2): 14.07MHz

Shown above — The peak-peak voltage with a 14.07 MHz oscillator connected to the RF port; a 50 Ω terminated scope connected to the detector port; and a 20 cm — unterminated — 50 Ω cable connected to the unknown impedance port. **The open circuit measurement.**

Above — Next, I connected the 27 Ω terminator to the unknown impedance coaxial cable with a through-connector interface.

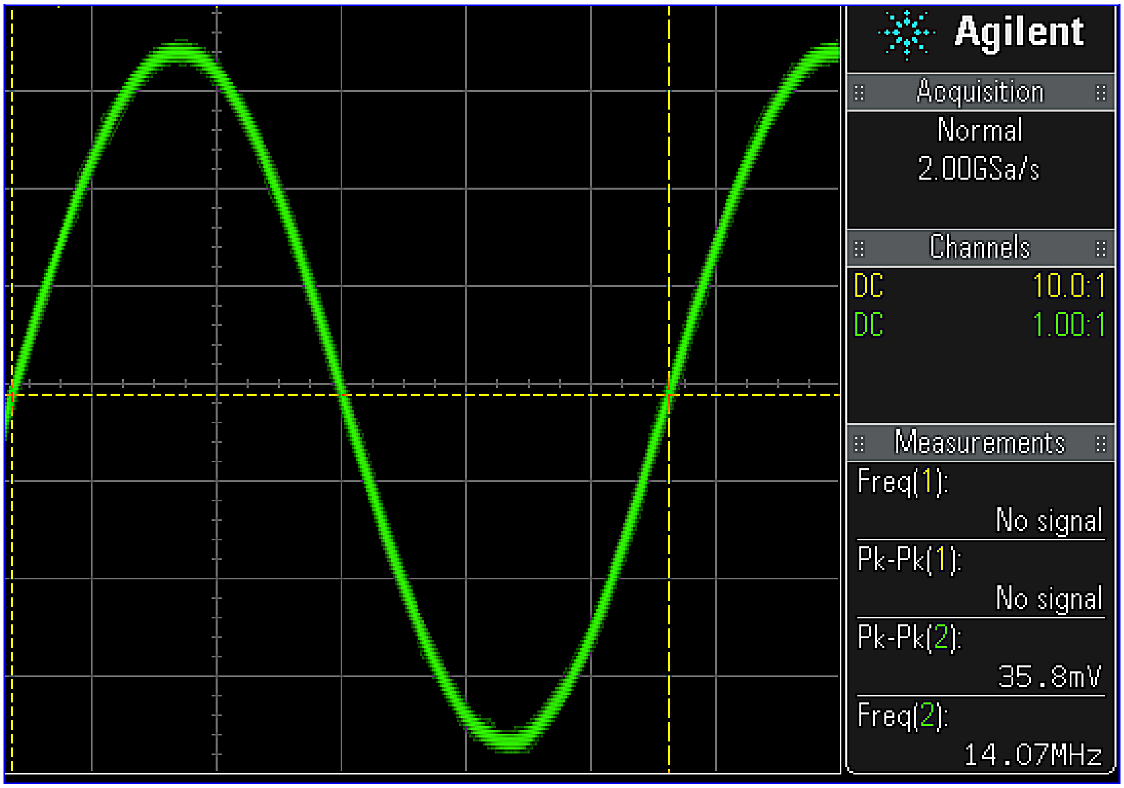

Acquisition
Normal
2.00GSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Freq(1):
No signal
Pk-Pk(1):
No signal
Pk-Pk(2):
35.8mV
Freq(2):
14.07MHz

Shown above — The peak-peak voltage with a 14.07 MHz oscillator connected to the RF port; a 50 Ω terminated scope connected to the detector port; and a 27 Ω resistive terminator across the end of the unknown impedance cable**. The reflected signal from a 27 Ω resistor.**

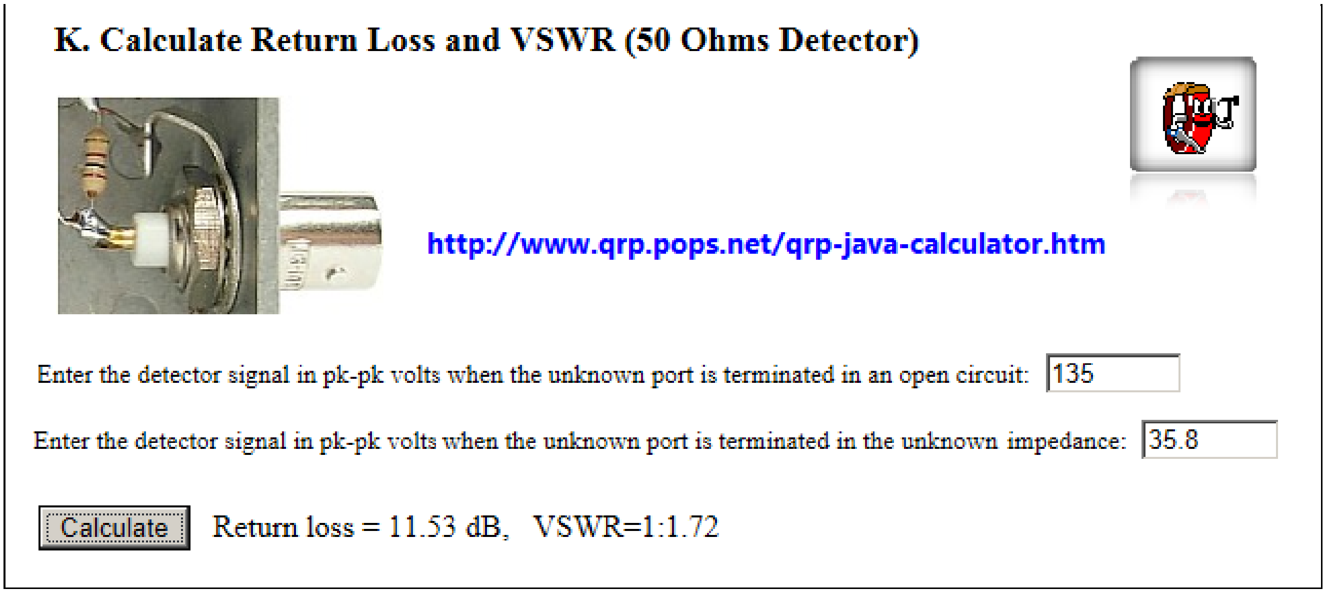

K. Calculate Return Loss and VSWR (50 Ohms Detector)

http://www.qrp.pops.net/qrp-java-calculator.htm

Enter the detector signal in pk-pk volts when the unknown port is terminated in an open circuit: 135

Enter the detector signal in pk-pk volts when the unknown port is terminated in the unknown impedance: 35.8

Return loss = 11.53 dB, VSWR=1:1.72

Shown above — Calculating the return loss and VSWR of the 27 Ω resistor with my JavaScript Applet **K**. mV versus volts peak-peak does not matter since we calculate a ratio of power.

Use the return loss measurement procedure depicted above to measure the return loss of any device you choose. If your D.U.T. has 2 ports, terminate the unmeasured port in 50 Ω. I show further RL measurment examples on RF Workbench 3.

I measured the return loss of some commercial gear in my shack and yard and will share 2 examples: 1) An expensive commercial transceiver I borrowed had an input port return loss of 15 dB (a 1.4:1 VSWR) The return loss of 15 dB indicates that the reflected wave power is 15 dB lower in power than the incident wave. 2) With a borrowed commercial bridge, my tuner-matched antenna revealed a return loss of ~60 dB.

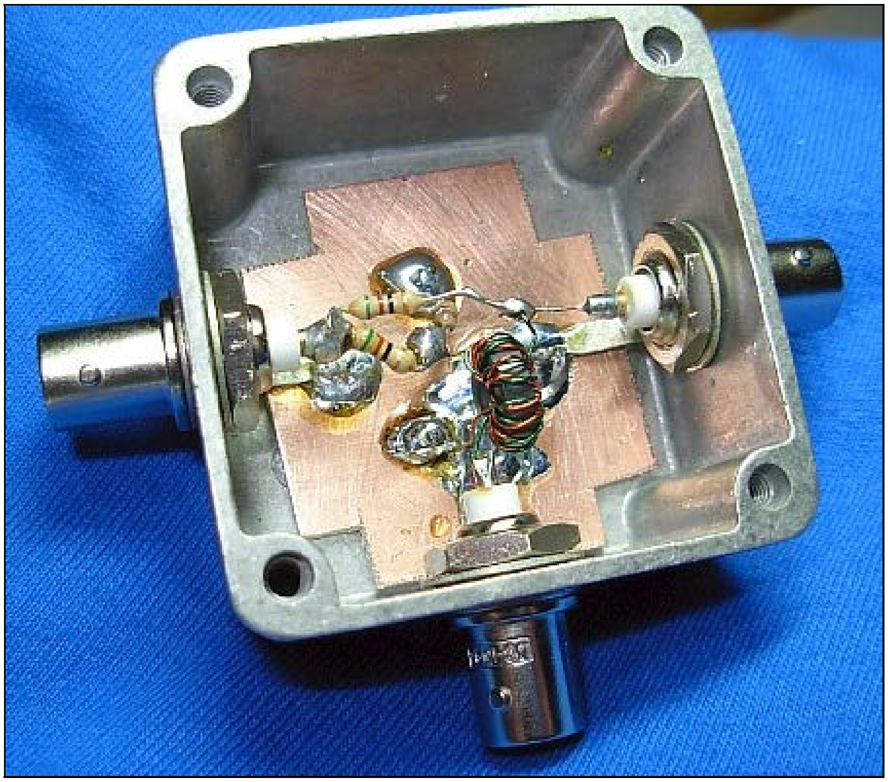

A RL bridge from my bench built with 51 Ω 5% tolerance resistors. I show a better RL bridge and some other experiments on RF Workbench 3.

Return Loss and the Attenuator Network (How Do Attenuator Pads Improve Component Matching?)

We routinely employ attenuator pads to increase return loss in a 50 Ω RF environment. For example, let's say you're testing a signal generator and measure a return loss of 6 dB. If you place a 10 dB attenuator pad after the signal generator, the return loss increases to 26 dB. If we used a 6 dB pad instead, the return loss would now = 18 dB. In both cases the return loss is increased by 2x the attenuator pad value. The doubling of return loss occurs because both the incident wave and reflected signals pass through the attenuator pad — that's how attenuator pads improve matching.

Attenuator pads reduce power, but that is why somebody invented the RF amplifier.

What is the minimally acceptable return loss for a device such as a signal generator? No single answer exists. The minimum return loss depends on the context: are you making precision circuits or just tuning an antenna?

Precision Circuits:

For amateur experimenter bench circuits, aim for a return loss of at least 20 dB. This often means adding an attenuator pad to the ports of your signal generator, amplifier, or other device to get a minimum 20 dB return loss. For an electronic engineer, the minimal return loss is probably higher; maybe 30 dB or so. I have read conflicting opinions about this and for some people — me included — design overkill is normal.

Antenna tuning:

When tuning an antenna for full transmitter output power, the minimal return loss is around 14 dB (a VSWR of 1:1.5). If you measure an antenna system return loss of 14 dB or better, the match is fine. Many Hams will protest a 1:1.5 VSWR and ardently chase a 1:1 VSWR on every frequency with their antenna tuner.

A Method to Measure Insertion Loss or Gain

Often, we want to measure the gain of an amplifier, or the insertion loss of a filter, or attenuator pad. I show how to do this with a 50 Ω terminated scope:

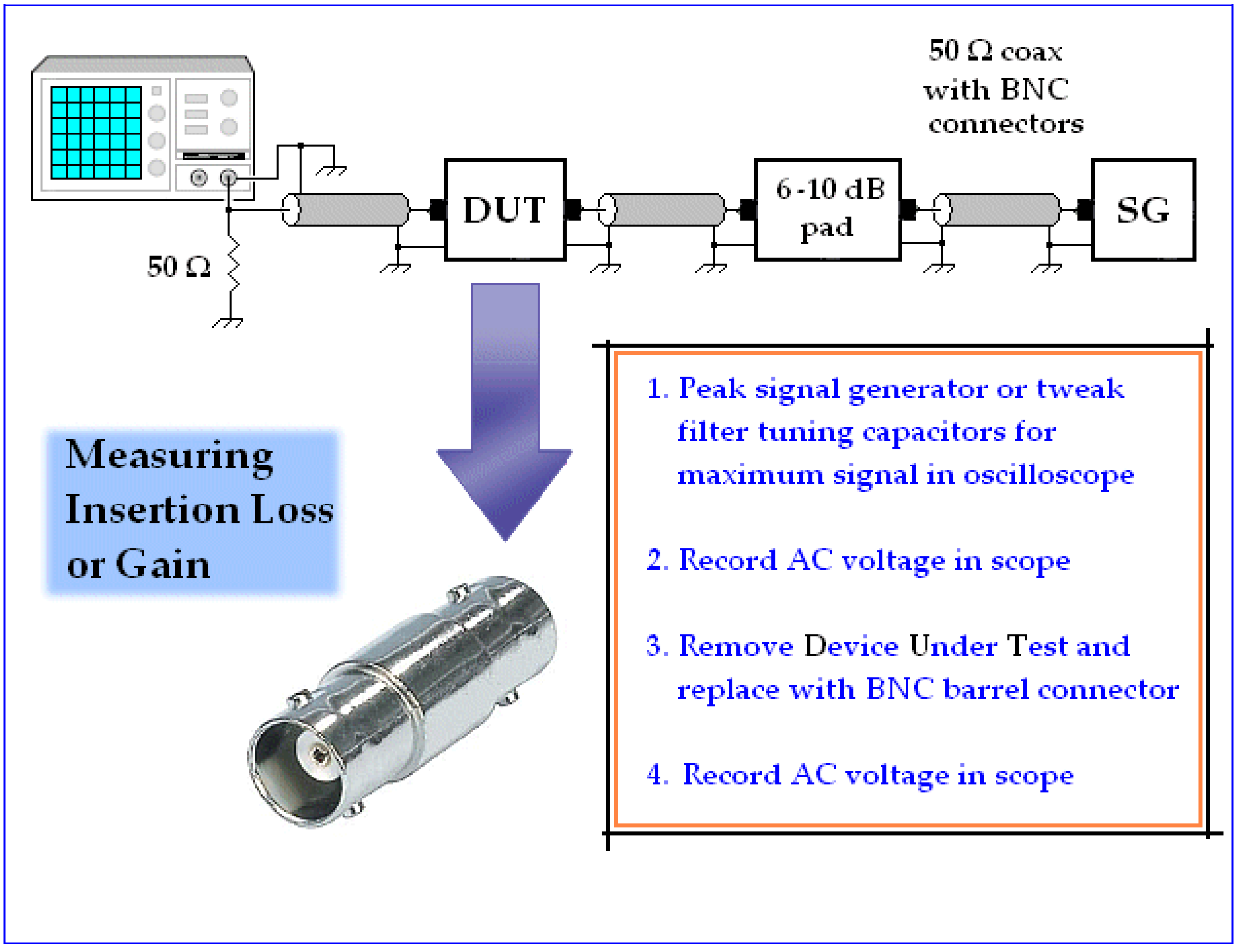

1. Peak signal generator or tweak filter tuning capacitors for maximum signal in oscilloscope

2. Record AC voltage in scope

3. Remove Device Under Test and replace with BNC barrel connector

4. Record AC voltage in scope

The circuit starts with a signal generator set to the frequency of interest. I show an attenuator pad in this diagram to stress that the signal generator output port must have a return loss >= 20 dB.

Connect the input of the 50 Ω **D**evice **U**nder **T**est to the generator output via 50 Ω coax

Connect the 50 Ω output of the D.U.T. to your 50 Ω terminated oscilloscope

Turn on the signal generator and if needed, peak the signal; In the case of a low-pass filter, the signal generator frequency control is tweaked to give a maximum pk-pk voltage in your 'scope. When evaluating a band-pass filter, tweak the filter trimmer capacitors for the maximum signal at the desired center frequency. Signal peaking ensures that losses caused by the filters are not caused by the filter mistuning, or in the case of the low-pass filter, to allow for cutoff frequency deviation caused by component value variations. It may be necessary to increase the signal generator amplitude to view a good quality signal in your 'scope.

Record the peak-to-peak voltage.

Remove the DUT and replace it with a BNC through-connector and record this peak-to-peak voltage.

Calculate the power in dBm of the 2 recorded voltages — their difference equals the insertion loss or gain in dB. I wrote a JavaScript Applet to do this. Click and scroll to **H**

This awesome measurement technique controls the input and output impedance and uses the same coaxial cables with and without the D.U.T. for accuracy. Some builders might choose to terminate the D.U.T. with a 50 Ω resistor and measure with a 10X scope. The capacitance of the probe may alter measurement in some cases. As always, choose your measurement technique based upon whatever gear you own and how exacting your standards are.

Insertion Loss of an N = 5 Chebyshev Low-pass Filter

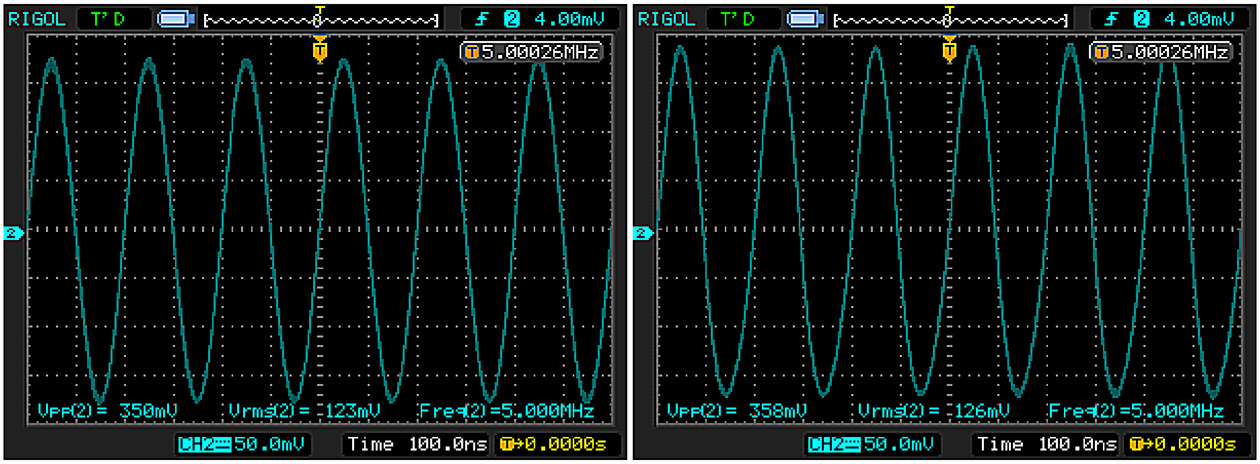

Filter -5.14 dBm

No Filter -4.94 dBm

Insertion loss = 0.2 dB

Spectrum Analyzers - Comments from the Workbench

Electronics professionals ruminate that spectrum analyzers are uncommon because experimenters perceive them as esoteric and difficult. My own opinion differs. Spectrum analyzers are relatively uncommon because of one reason - cost. I have watched prices on sites like eBay with amazement. The ads go something like this: 1.5 GHz spectrum analyzer for sale. Built in 1982. Ships in 2 pieces weighing over 22 kilograms. Minimum bid $1850.00. *And...sorry, I live in Florida, U.S.A. and in all likelihood, shipping these 2 heavy pieces is going to cost you a fortune. In the attached ad photos you can see lots of wear and tear, plus some screen burn-in on the display....* Guaranteed to turn on however!

Perhaps I exaggerate or even lampoon the perceived value of old boat anchor spectrum analyzers, but I have bought and sold cars for less money. Be prepared - spectrum analyzers are not cheap. They are however, very cool and open the door into a truly fascinating world. Frequency domain circuit measurement (spectrum analysis) addicts and intrigues. Homebuilding a spectrum analyzer is a serious option, but requires advanced building skills. Click and click for the W7ZOI/K7TAU project.

In recent times, the Rigol DSA-815 spectrum analyzer with tracking generator proved a game-changer to the bloated price of heavy, old and tired gear. Click for a Rigol datasheet. Signalhound also sells spectrum analyzers and tracking generators . A tracking generators *plus* spectrum analyzer allows you to sweep your device under test over a range of frequencies.

Prior to using a spectrum analyzer, I casually considered shielding stages or placing critical pieces in RF-proof boxes. Quickly I learned that RF in our home and community can and does get into your projects. p>

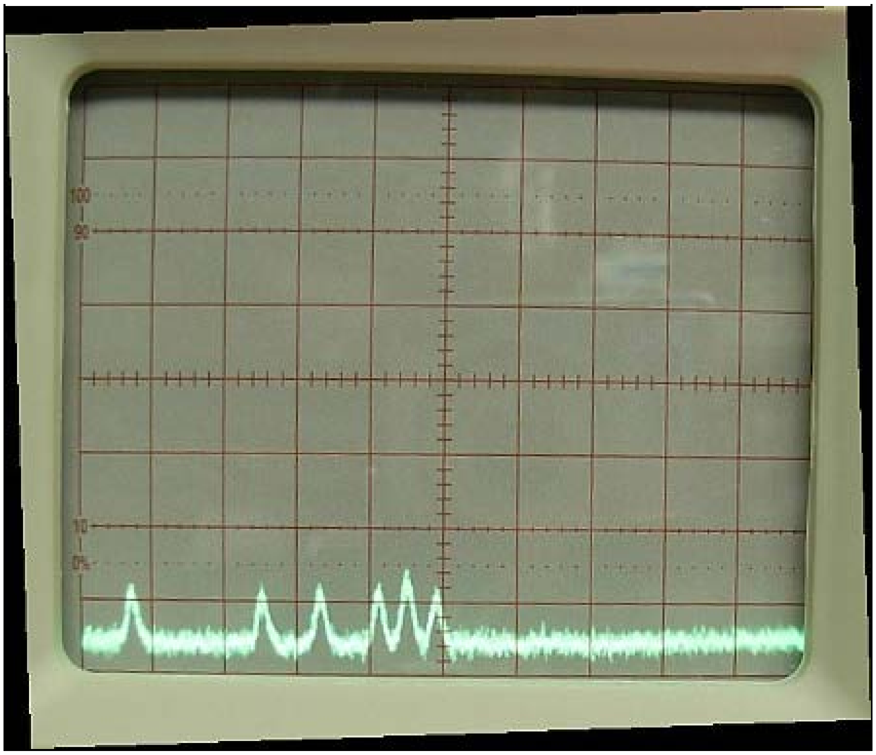

The center frequency of the display = ~150 MHz. The signal spikes appeared and disappeared after 4-9 seconds or so — after a little detective work with my scanner, I learned they were local police and ambulance FM radio conversations. I noticed this interference when I took the lid off a RF-tight band-pass filter — these signals arose in a 28 MHz superhet receiver !! While low in amplitude, experiences like this inform us to watch for lurking RFI.

I found numerous sources of RF in our home with a spectrum analyzer — the clothes washing machine during its spin cycle proved to be the worse RFI generator. RF-tight shielding with SMA, or BNC connectors and DC feed-through capacitors and aggressively decoupling and bypassing DC lines eliminated many of RFI problems during my experiments. I now better appreciate these anti-RFI techniques.

Spectrum Analyzer Calibrator

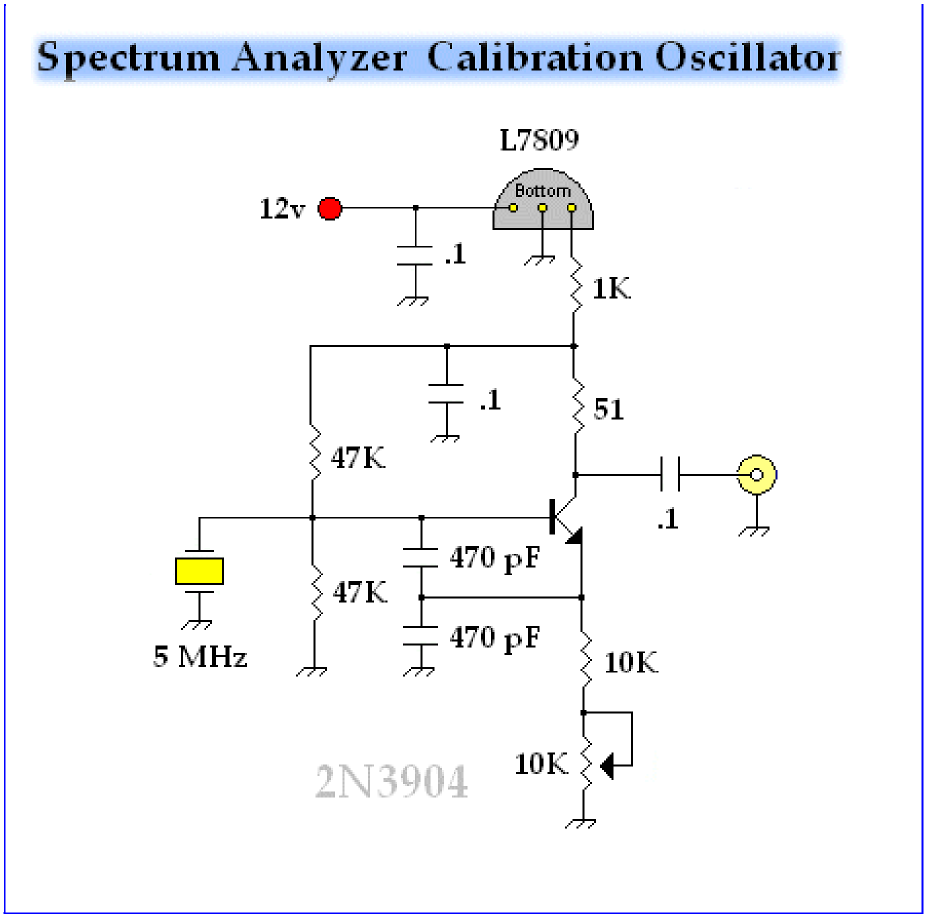
Spectrum Analyzer Calibration Oscillator
L7809
Bottom
12v
.1
1K
.1
51
47K
.1
470 pF
47K
470 pF
5 MHz
10K
10K
2N3904

A harmonic rich, spectrum analyzer calibrator designed by Wes, W7ZOI and displayed with his permission. Adjust the 10K potentiometer to provide the output power needed to calibrate your spectrum analyzer. I set mine to -27 dBm. Be careful when connecting signal generators to your spectrum analyzer, since a higher than rated input power may destroy the mixer/front-end of your spectrum analyzer and cost you dearly.

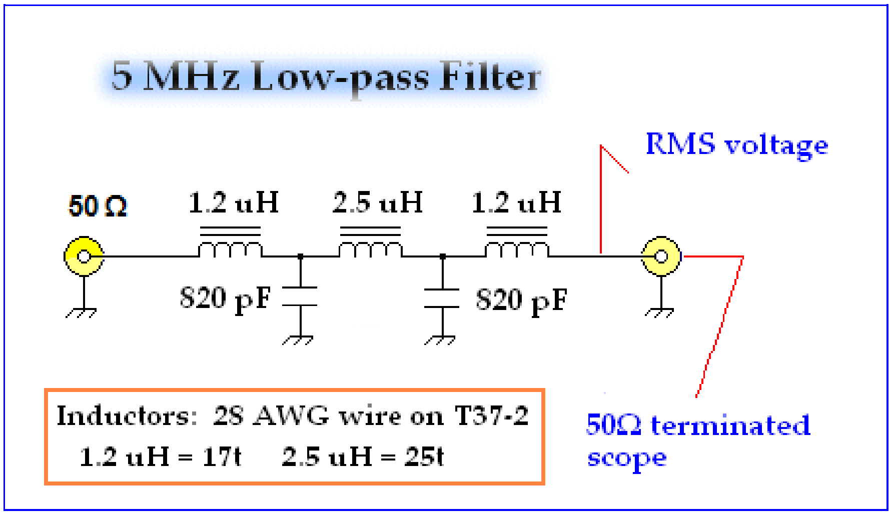
5 MHz Low-pass Filter
RMS voltage
50 Ω
1.2 uH
2.5 uH
1.2 uH
820 pF
820 pF
Inductors: 28 AWG wire on T37-2
1.2 uH = 17t 2.5 uH = 25t
50Ω terminated scope

I used this filter to set the -27 dBm power needed to calibrate my spectrum analyzer.

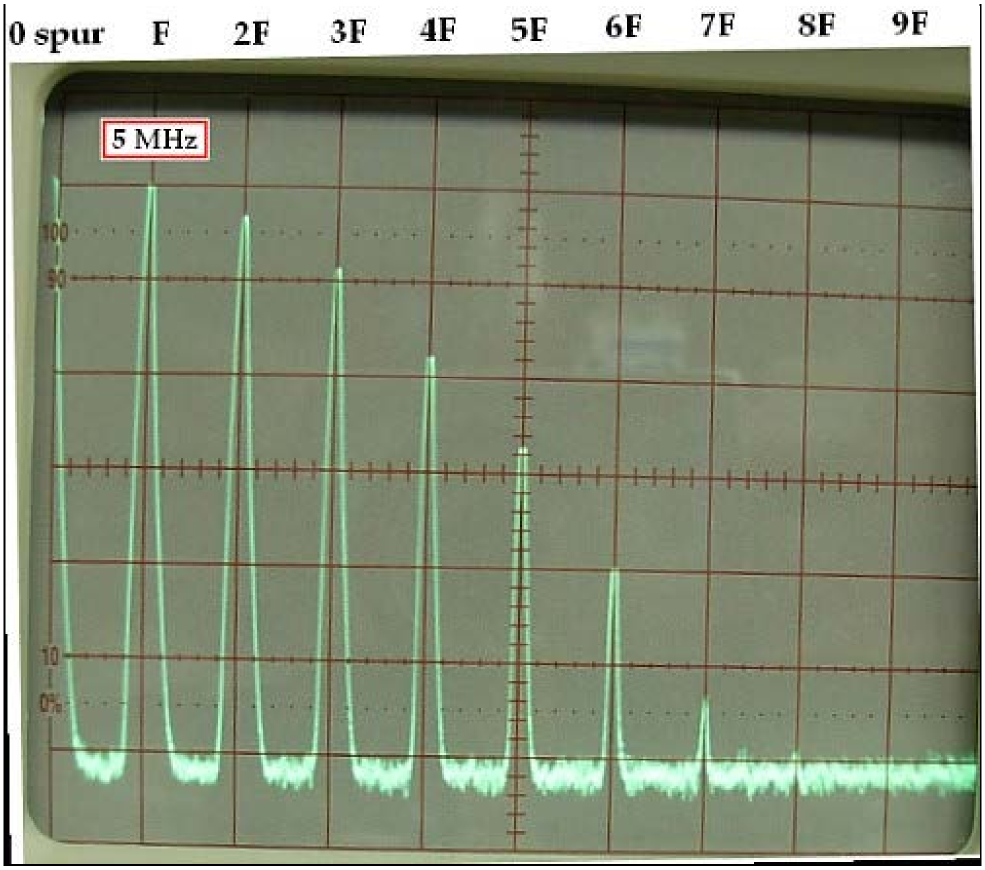

Spectrum analysis of the 5 MHz spectrum analyzer calibrator.

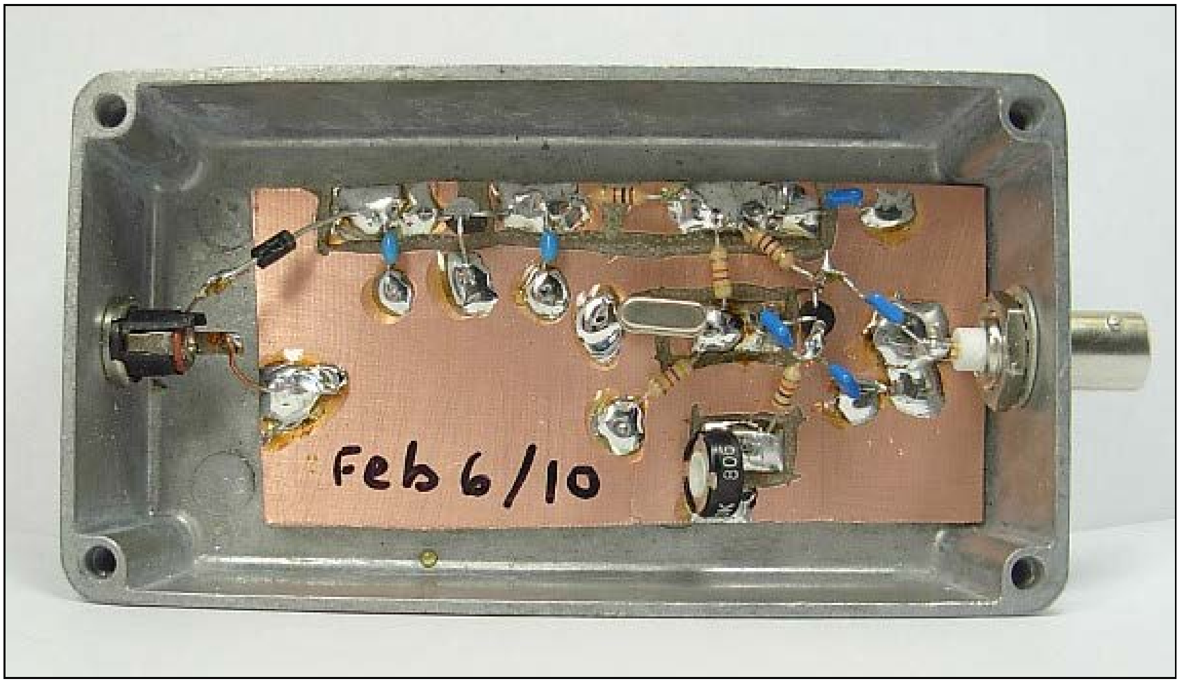

Breadboard of the 5 MHz spectrum analyzer calibrator.

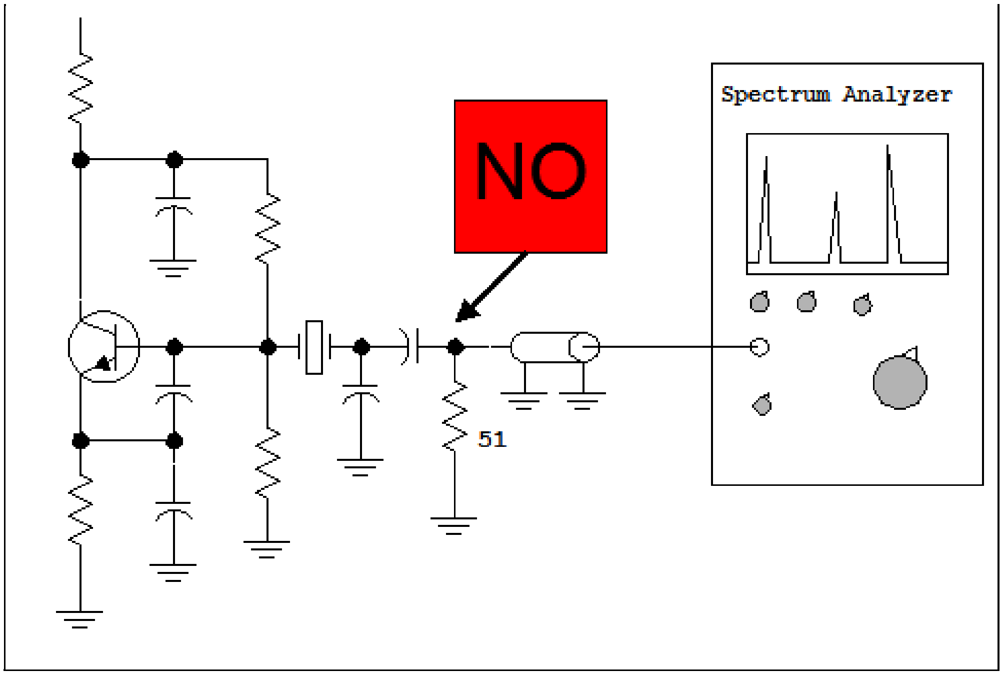
Spectrum Analyzer
NO
51

Don't use a "50 ohm" termination when measuring with a 50 Ω impedance spectrum analyzer.

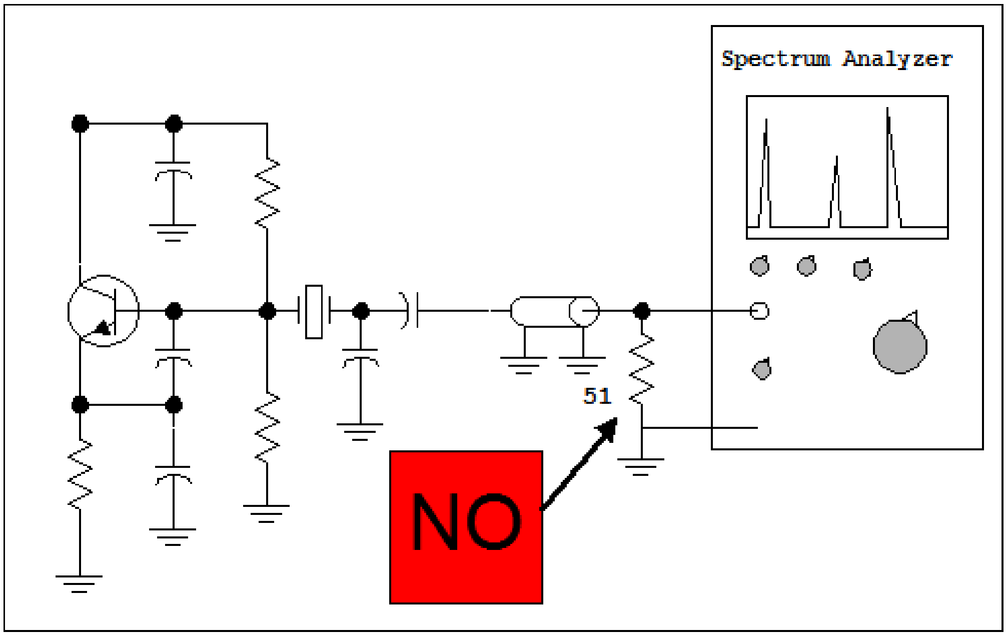
Spectrum Analyzer
51
NO

No resistor is required, as the the input impedance of the SA is 50 Ω.

Miscellaneous Photos and Notes

-10 DB PAD
50 OHMS
RETURN-LOSS BRIDGE
RF
?
DETECTOR
MENT
MPLER
S

Some of the 50 Ω modules built during the RF Workbench page 1 and 2 experiments

1
3
6
9
30
dB
10 WATT LOAD

15542
HAT-6+
6 dB ATTENUATOR
50 OHM
15542
VAT – 6
6 dB ATTENUATOR

QRP SWL HomeBuilder

Amateur Radio Electronic Design

Audio Transistor Input Impedance Experiments

Introduction

I examined audio transistor amplifier input impedance during Spring — Summer 2010 and generated enough content for a web page.

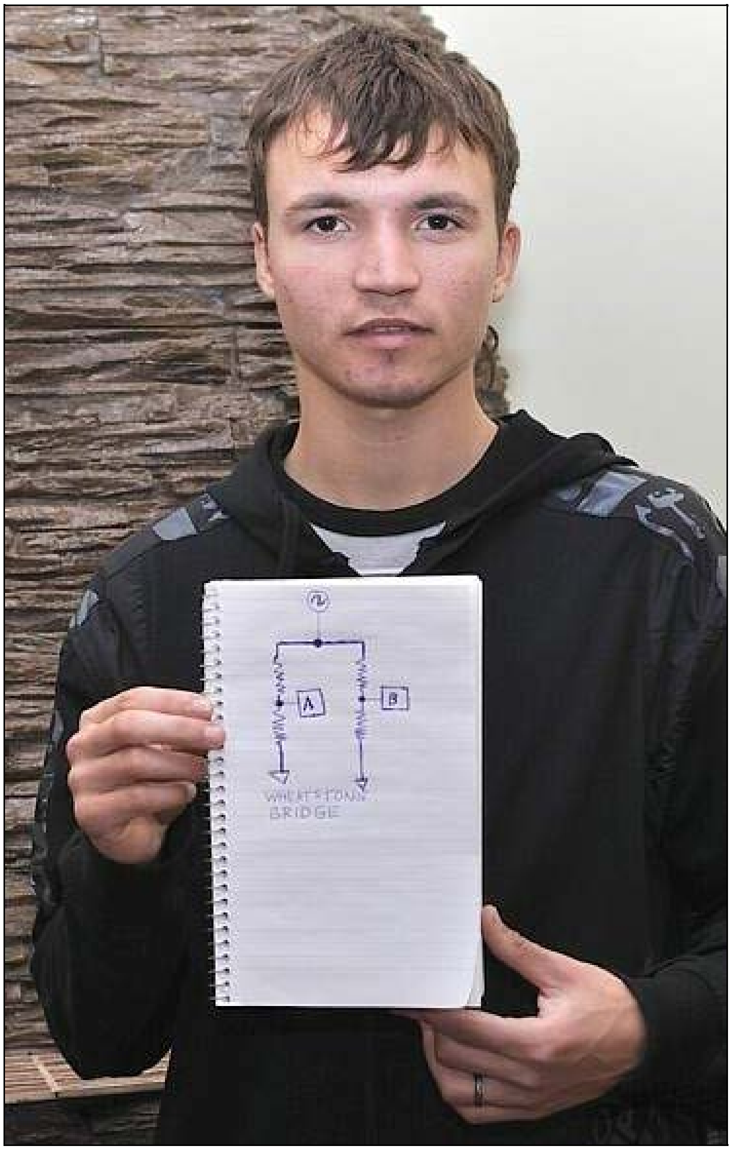

On this web page, I explore determining AF amplifier input impedance by using network theory and calculation, plus direct measurement with instruments containing a Wheatstone bridge. This content emphasizes learning through performing bench experiments and I hope it sparks your own experiments and research into impedance measurement test equipment and theory.

Many RF circuits require termination with stages containing a well defined input impedance. Consider, for example, amplifiers that follow L-C low-pass filters, diode ring mixers or crystal filters — a known impedance (usually 50 ohms) must terminate these stages to optimize return loss. A special case is the diode ring product detector; which must be followed by a 50 ohm input impedance audio amplifier. How do we design or assess a small-signal audio amplifier that has a 50 ohm input impedance? This question spawned every experiment on this web page — the content grew and evolved along with my understanding of this topic.

Audio transistor input impedance may be calculated with equations or software, however, doing the math or using or affording these programs might be problematic for some amateur builders. Additionally, component variances such as transistor Beta and different power supply voltages can causes significant differences between the theoretical and the actual input impedance realized. Further, amplifiers, such as a feedback pair that involve combinations of series or shunt feedback can be difficult to analyze accurately using equations during small or large signal analysis. It may be easier for experimenters to just measure and tweak amplifier components on the bench — the focus of this web page!

As an rank amateur, I have much to learn, and by no means am an expert in electronic design. If you see an error on this web site, disagree with my analysis, or have suggestions for improvement, please email them — I am an amateur hobbyist, who earns no money from this site, and who relies on the assistance of others to keep the content as accurate and vibrant as possible.

The topics:

Part 1: Some basic transistor network theory and how to calculate input Z

- Part 2: 50 ohm input impedance Wheatstone bridge measurement
- Part 3: Measuring unknown impedances
- Part 4: Miscellaneous circuits, scans and photographs.

Notes:

Small signal analysis refers to modeling or examining an amplifier at a single operating point (its bias point) and applying linear equations which assess the amplifier with no signal applied. In small signal analysis, we assume that the signal is so small that transistor gain, capacitance and other factors are static.

Part 1: Some Basic Transistor Network Theory and How to Calculate Input Z

Some basic network theory plus methods to calculate the input impedance of common emitter and common base audio amplifiers.

Three basic small-signal transistor parameters include *beta,* emitter resistance *Re*, and bulk resistance *REB*.

Beta is the term used to designate the current gain of a common emitter circuit — it's the ratio of collector (output) current to base (input) current.

Small-signal emitter resistance; Re = 26 / IE ,or, 26 divided by the emitter current in millamperes. For example, an emitter bias current of 0.52 mA gives a small-signal emitter resistance of 50 ohms, or visa versa . Re is the resistance seen looking into the emitter whether the stage input is the transistor base or emitter terminal. Re is the dynamic resistance of the input junction due to carrier action.

REB represents the bulk resistance of the semiconductor not arising from contact resistance; in other words, it's the DC resistance of the base and emitter leads plus the pn junction. Typically REB = 2 to 6 ohms and is often ignored (your choice) when the current is low — say, for example, < 9 mA for a typical common-emitter voltage amplifier. In large power transistors or for switching operations, the typical REB value may vary. REB, in part, limits the maximal gain of a transistor.

The constant 26 used when calculating the dynamic resistance of a forward-biased PN junction is derived via calculus. Professor Kuhn's website link containing the math.

There is also a base spreading resistance generally known as 'rbb' that, in effect exists laterally across the transistor. A simple model puts rbb at about 100 ohms in series with the base and it's one of the causes of finite transistor frequency response. While interesting, rbb isn't discussed further.

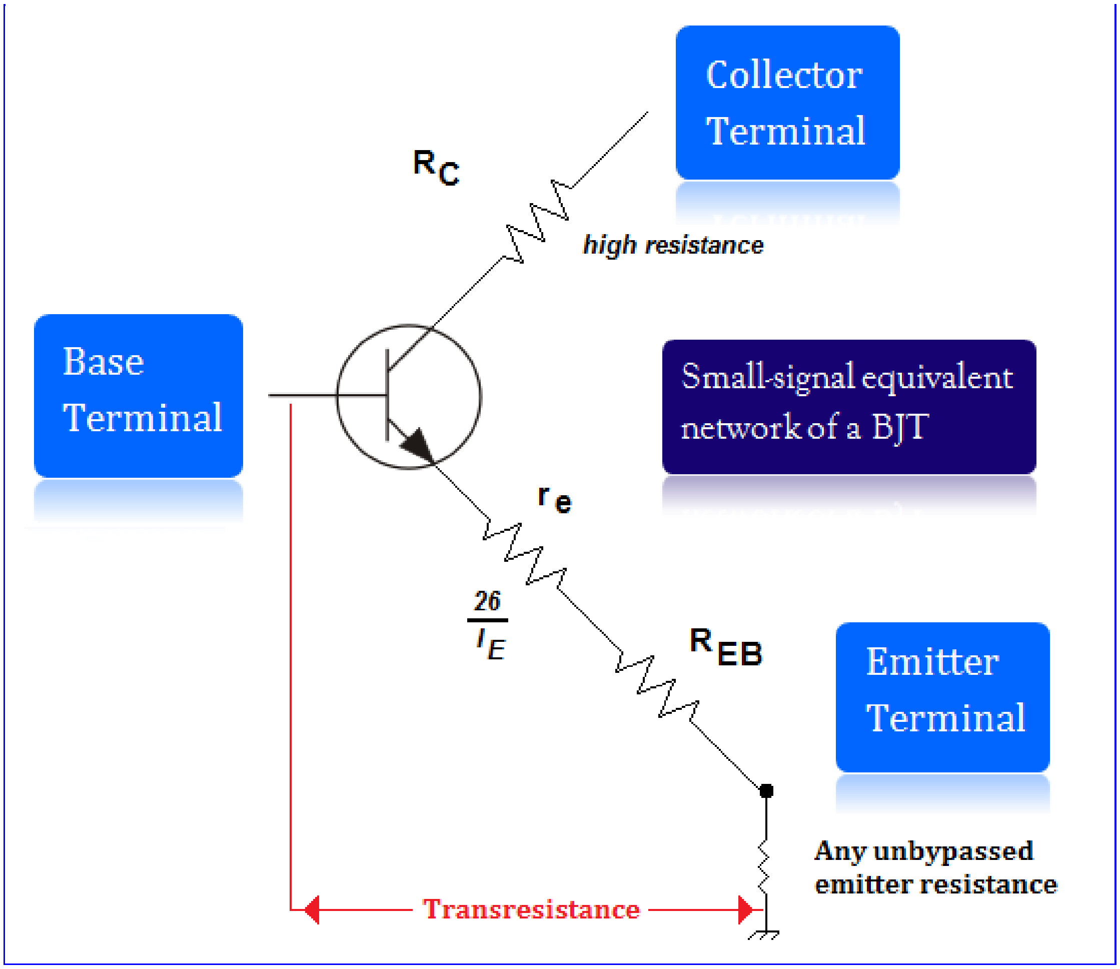
Collector Terminal
R_C
high resistance
Base Terminal
Small-signal equivalent network of a BJT
r_e
$\frac{26}{I_E}$
R_{EB}
Emitter Terminal
Any unbypassed emitter resistance
Transresistance

Above — the small-signal equivalent network of any transistor. re = 26/IE. Also, re + REB + any unbypassed external resistor may be termed the *Transresistance*, a DC ohmic value representing the total resistance of the emitter. The collector resistance RC is high because of its reverse bias. Collector resistance is not considered when calculating input impedance of simple AF transistor stages.

Calculating the input resistance of a common base stage

Calculating the input impedance of a common base amplifier is easy. Input impedance = 26/ emitter current (IE). You can either bench measure or calculate the emitter current using DC analysis. Click for the formula to calculate emitter current . A complete example follows:

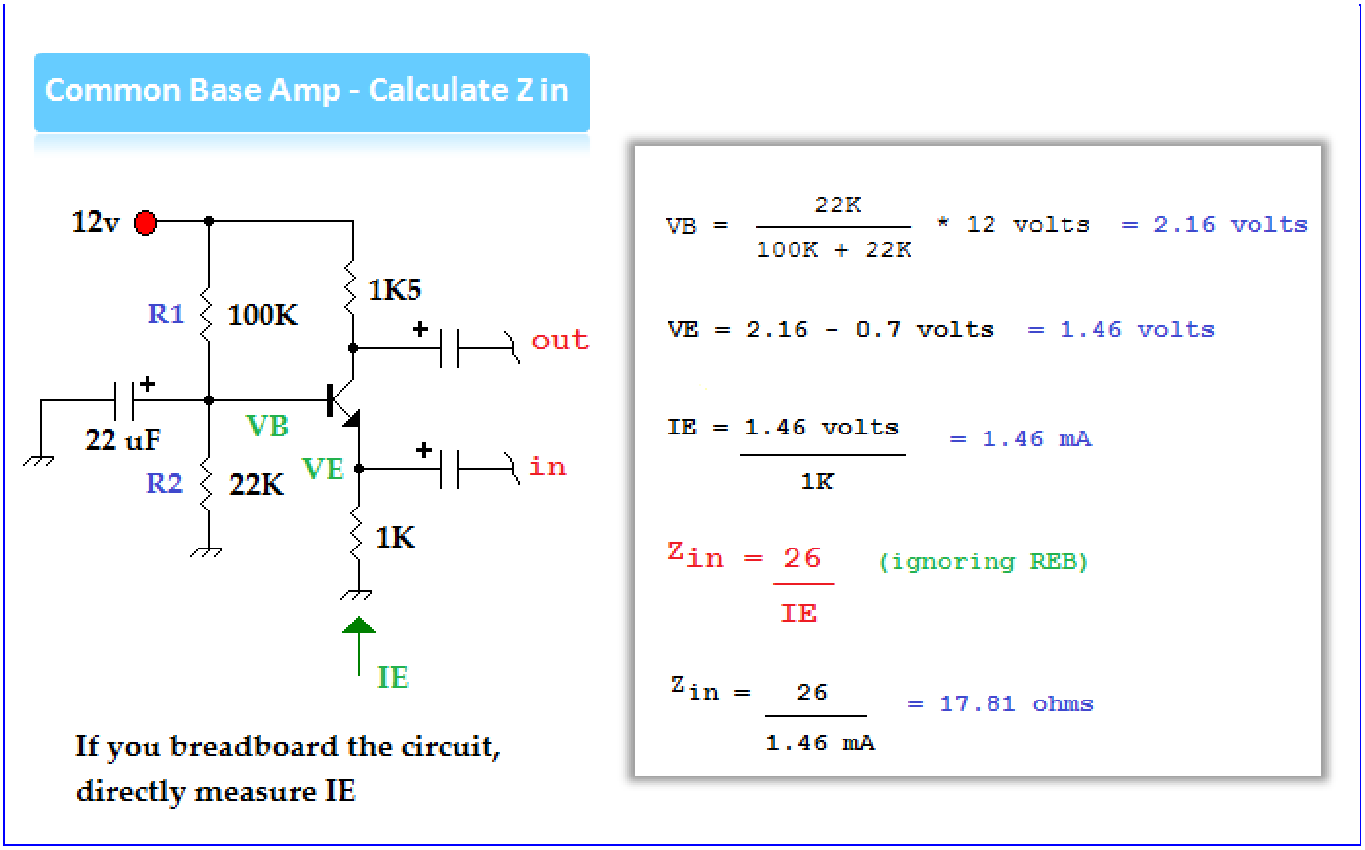
Common Base Amp - Calculate Z in

12v
R1
100K
1K5
out
22 uF
VB
VE
in
R2
22K
1K
IE

If you breadboard the circuit, directly measure IE

$$VB = \frac{22K}{100K + 22K} * 12 \text{ volts} = 2.16 \text{ volts}$$

$$VE = 2.16 - 0.7 \text{ volts} = 1.46 \text{ volts}$$

$$IE = \frac{1.46 \text{ volts}}{1K} = 1.46 \text{ mA}$$

$$Z_{in} = \frac{26}{IE} \quad \text{(ignoring REB)}$$

$$Z_{in} = \frac{26}{1.46 \text{ mA}} = 17.81 \text{ ohms}$$

Above — An example common base amplifier and its input impedance calculation. In this example, emitter current is calculated using DC analysis. On the bench, it's better to un-ground the 1K emitter resistor and connect your ammeter between this resistor and ground to directly measure IE. REB was ignored and = 0.

Consider the 50 ohm input Z common base amplifier we often use after a diode ring product detector plus diplexer:

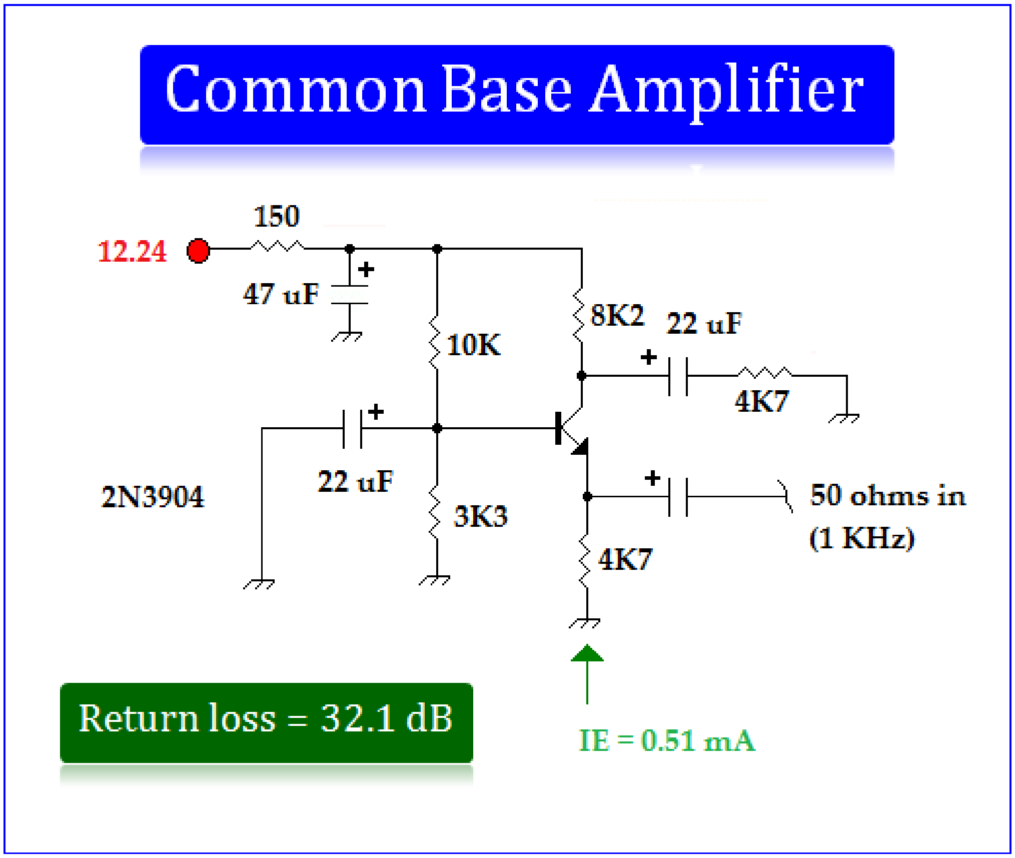
Common Base Amplifier

150
12.24
47 uF
10K
8K2
22 uF
4K7
22 uF
2N3904
3K3
50 ohms in
(1 KHz)
4K7
Return loss = 32.1 dB
IE = 0.51 mA

Above — A common base amplifier built for a direct conversion receiver in Spring 2010. This amplifier is shown in test setup for bench analysis

— with a DC decoupling network and an AC coupled 4K7 resistive load. The emitter current established using 5% tolerance resistors was 0.51 mA. Therefore, the calculated input Z is 26/0.51 = 51 ohms. The return loss of this amplifier as measured with the *active* 50 ohm Wheatstone bridge device described later on this web page was a spectacular 32.1 dB! If a different power supply voltage or biasing/emitter resistors were used, the IE would change and along with IE, the input impedance and return loss.

This amp illustrates that testing and tweaking AF amplifiers on the bench will garner the best results. If I just copy someone else's design; perhaps with a different DC voltage, or decoupling network and don't adjust the emitter current by tweaking the base biasing or emitter resistor resistors, the input impedance could differ significantly. Whenever you build a common base amplifier, measure its DC current and as necessary, tweak resistors to get the current needed for a perfect impedance match. It is good practice to measure all the DC voltages and emitter current on any amplifier you build — you will learn what is normal, what to expect and perhaps detect errors or parts failure(s).

Performing return loss measurement is also a fantastic way to ensure good matching to the 50 ohm impedance diode ring product detector that feeds this amplifier.

Calculating the input resistance of a common emitter stage

Calculating the input impedance of a common emitter amplifier is also straight forward, but not as easy as the common base amplifier.

In the **common base amplifier**, the emitter is the input element, therefore the input signal resistance is 26 / IE + REB. Often we ignore REB. If current of the common base amplifier is for example, 2 mA or so, then the 2-6 ohms of REB may be significant as 26 / 2 mA = 13 ohms. REB may be a factor because 2-6 ohms is a significant percentage of the total input resistance.

For a **common emitter amplifier**, the input resistance looking into the base is Beta (26/IE + REB + RE). Again REB is often ignored. We need to include any transistor DC biasing resistors which are also seen by the input signal as it moves through the transistor base. An example follows:

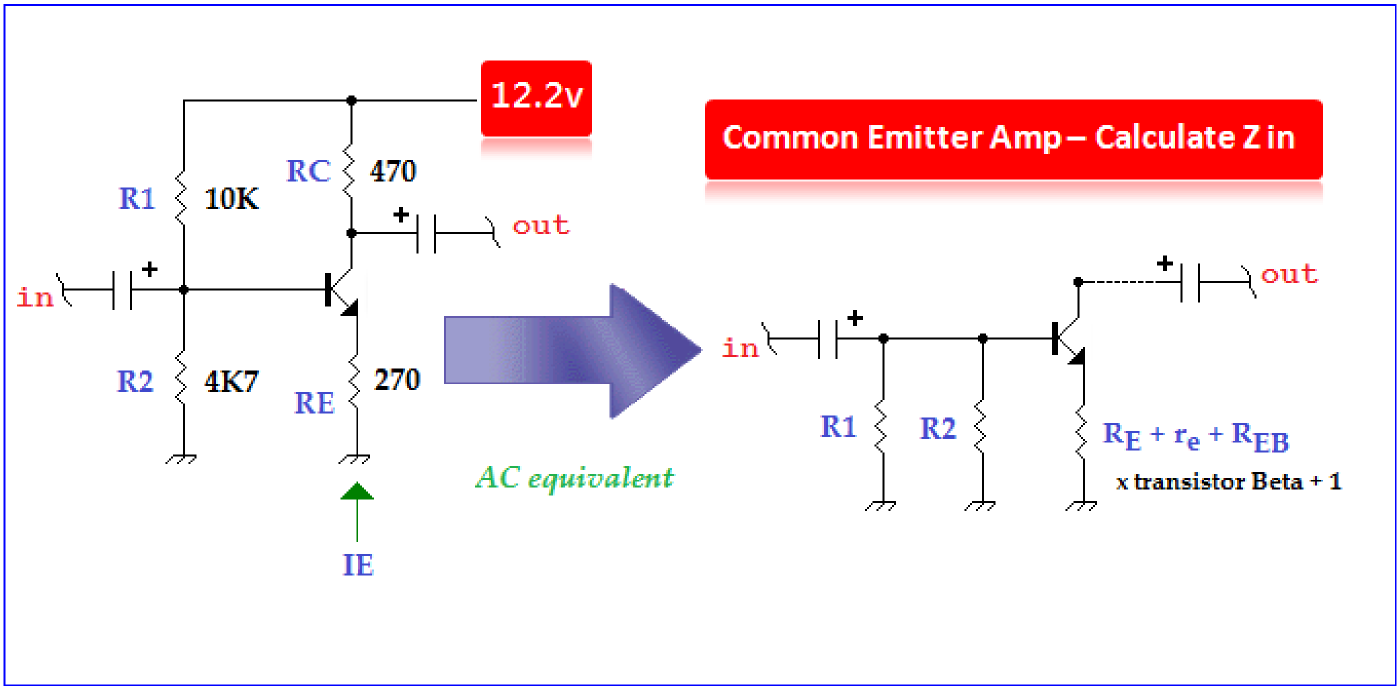

Above — An example common emitter amplifier re-drawn to illustrate how the input resistances combine to provide the AC input impedance. In this case, the 270 ohm emitter resistor RE is un-bypassed. R1, R2 and the components RE, re and REB are in parallel as the DC supply acts as a short to ground for the AC input signal. The components RE, re and REB (if used) must be multiplied by the transistor Beta value (+ 1) since the resistance looking into the base is Beta times that looking into the emitter.

Therefore: Rin = (B+1)*(re + REB + RE'). Normally we ignore REB so practically speaking Rin = (B+1)*(re + RE')

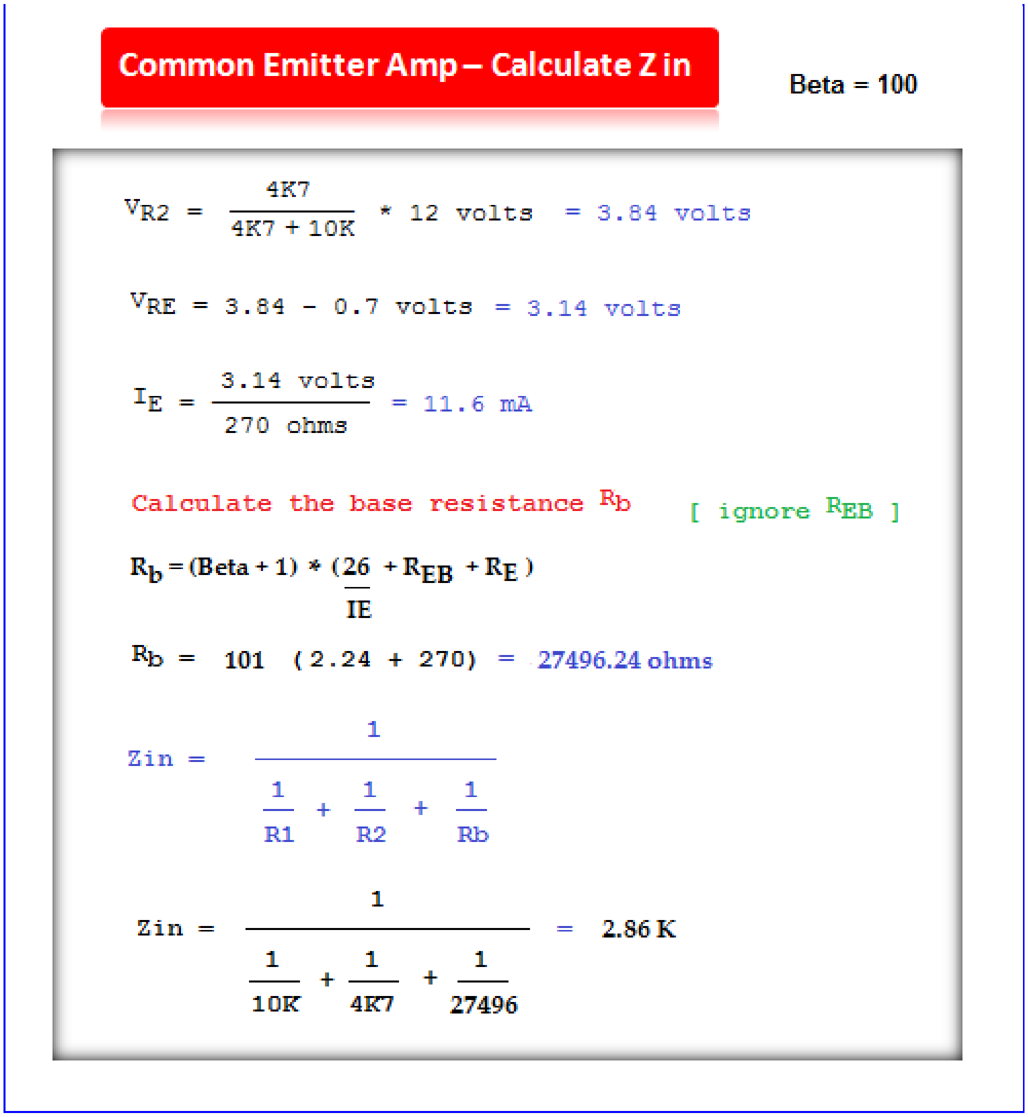

Common Emitter Amp – Calculate Z in

Beta = 100

$$V_{R2} = \frac{4K7}{4K7 + 10K} * 12 \text{ volts} = 3.84 \text{ volts}$$

$$V_{RE} = 3.84 - 0.7 \text{ volts} = 3.14 \text{ volts}$$

$$I_E = \frac{3.14 \text{ volts}}{270 \text{ ohms}} = 11.6 \text{ mA}$$

Calculate the base resistance R_b [ignore R_{EB}]

$$R_b = (\text{Beta} + 1) * \left(\frac{26}{IE} + R_{EB} + R_E\right)$$

$$R_b = 101 \; (2.24 + 270) = 27496.24 \text{ ohms}$$

$$\text{Zin} = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{Rb}}$$

$$\text{Zin} = \frac{1}{\frac{1}{10K} + \frac{1}{4K7} + \frac{1}{27496}} = 2.86 \text{ K}$$

Above — The math for the common emitter circuit shown directly above using DC analysis to calculate the current. On the bench, we just measure the emitter current (no need to calculate it). We assume IE = IC for a common emitter amplifier. REB = 0 (when ignored). If the 270 ohm resistor RE was bypassed with an electrolytic capacitor, the 270 ohm resistance would also = 0; and then Rb = Beta + 1 * (26/IE).

Conclusion

This theory explains how to calculate input impedance in 2 basic transistor AF amplifiers. Consult an electronics text for further explanation. Although the arithmetic is simple, quite frankly, it's a little boring. Let's go to the bench and have some fun. I was quite naive about measuring AF amplifier input impedance; however, my experiments yielded some knowledge and a strong appreciation for the Wheatstone bridge network. Onward...

Part 2: 50 ohm Input Impedance Wheatstone Bridge Measurement

Testing for a NULL or measuring the return loss of AF amplifiers with a 50 ohm input impedance.

Refer to the diagram on the right. Redrawn in a way more familiar to builders, the Wheatstone bridge network is just a pair of voltage dividers in parallel. We measure the difference in AC voltage between the ports labeled Out 1 and Out 2. The bridge is said to be balanced and produce NULL or 0 output when Out 1 and Out 2 are equal in voltage. Another description — when in perfect balance, the signal loss due to mismatch between the output ports is infinite. However, if this balance is disturbed by a mismatch between ports Out 1 and Out 2, an AC voltage appears and the return loss decreases in proportion to the mismatch (within limits and providing your instrument can measure accurately).

Let's focus on some practical bench applications in the new millennia: On your bench, you might employ a Wheatstone bridge network to measure return loss (or VSWR) or to simply to detect a NULL indicating a close impedance match between 2 stages. Specific examples include tuning your feed line and antenna, checking the match between a signal generator and a filter, or measuring an audio amplifier input impedance. In my estimation, the Wheatstone bridge lies among the most important test circuits in the amateur designer's arsenal; worthy of study and experimentation.

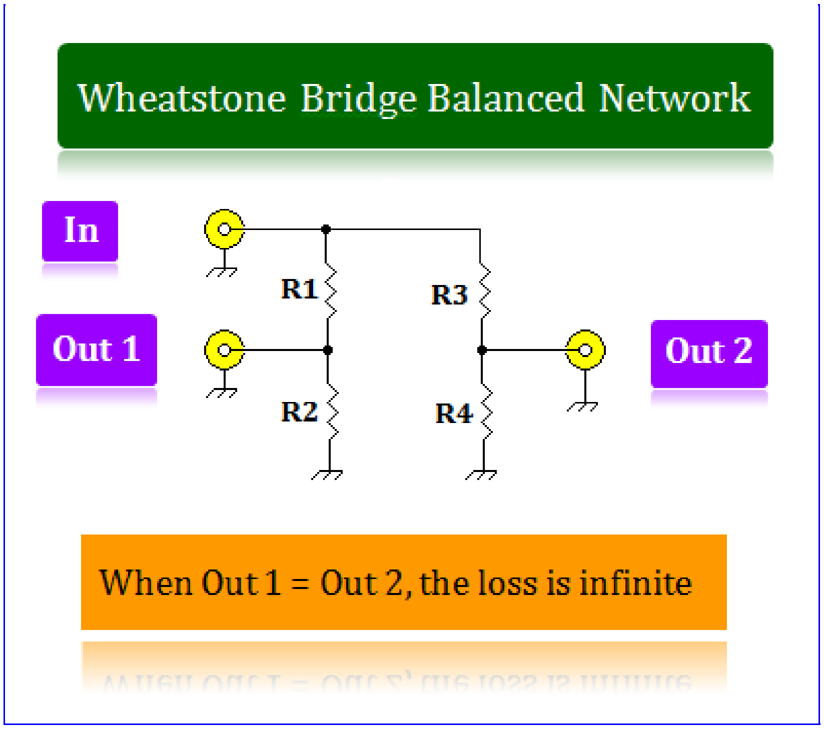
Wheatstone Bridge Balanced Network
In
Out 1
Out 2
R1
R2
R3
R4
When Out 1 = Out 2, the loss is infinite

Notes:

- The input signal can be AC or DC, but all discussion is confined to an AC signal source
- E96 (1%) metal film resistors were used in all Wheatstone bridges
- All bridges were tested at 1 KHz
- Ensure you do not overdrive your bridge; lest distortion occur! When a bridge is overdriven, you might cancel the fundamental frequency when balancing the bridge, but not the harmonics! Therefore, parasitic harmonics appear in the output that skew the the NULL or return loss values. I learned low pass filtering the amplified bridge output is really important.
- Any distortion in the bridge output means you must reduce your input signal drive level; however, this may reduce the accuracy of the RL measurements. There is no free lunch! You generally want just enough input signal to accurately measure the signal with the bridge at NULL.

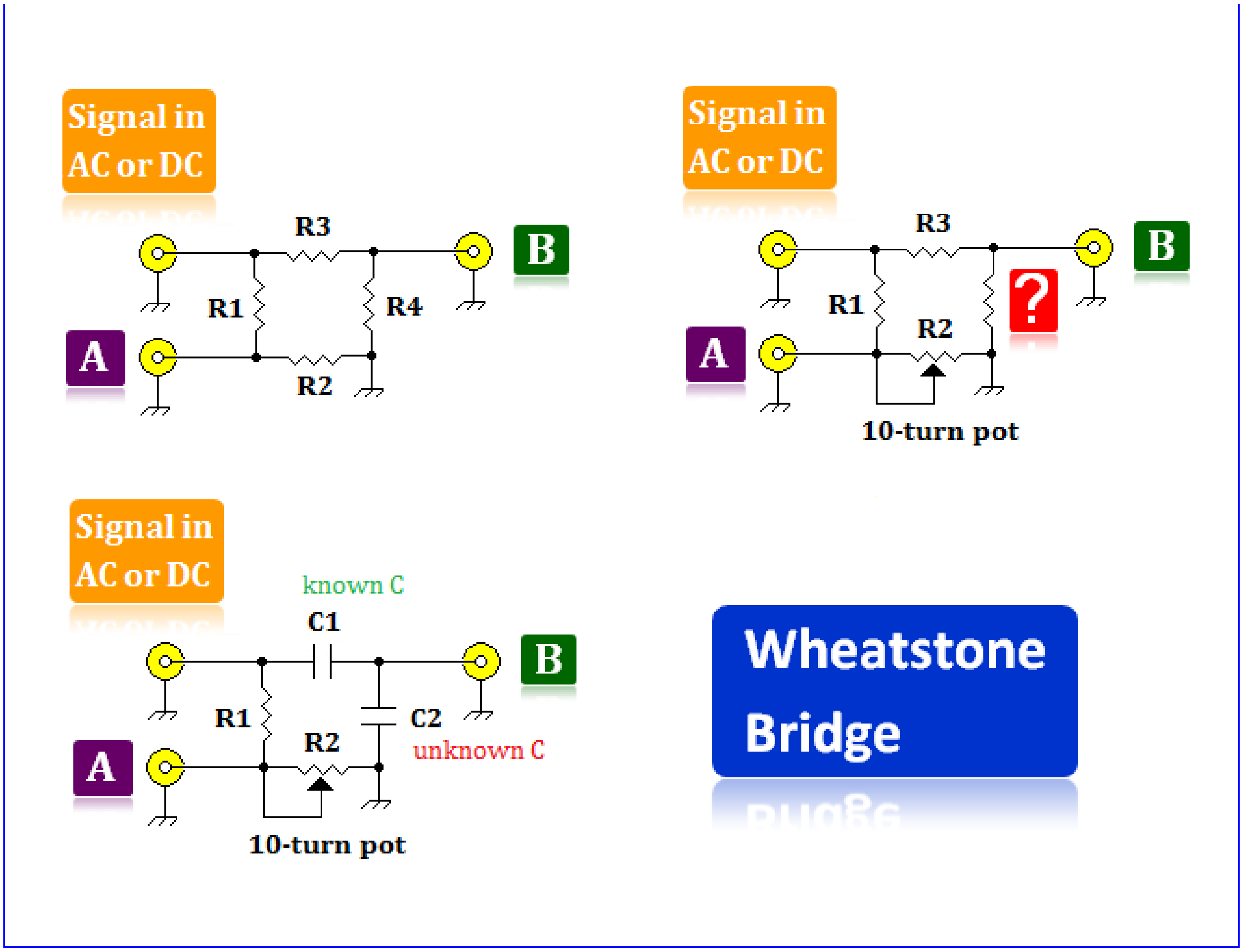

Comments from the Workbench

Above — an evolution of the 4 resistor bridge into a device to measure impedance and capacitance. In its classic form, each bridge leg is a resistor voltage divider with a detector connected across ports A and B. If ports A and B have equal voltages and R1 = R2, then R3 and R4 must also be equal; the bridge lies balanced or in a NULL state. If you remove R4 and measure an unknown resistance, the bridge will return to balance after adjusting pot R2 to equal the unknown resistance. In most cases, R2 is calibrated and the impedance is read directly off the potentiometer dial. Bridges can be arranged to measure unknown capacitance, inductance , frequency and other parameters by using precision 1% fixed components, calibrating the 10 turn pot to indicate the desired parameter, or for deriving the unknown value via equations.

Builders of lore used bridges to quantify many values on the bench. Although we have better ways to measure inductance and capacitance today, the Wheatstone bridge is still the *king* when it comes to simple measurement of network impedances; for example, QRP antenna tuners. Some builders use an LED to indicate bridge imbalance.

Building a passive instrument to measure the return loss of a 50 ohm input Z audio preamplifier.

Non-radio folks don't generally understand this — to properly terminate a diode ring mixer, 50 Ω impedance stages are needed. The inspiration driving *all* the experiments on this web page was to design a 50 ohm input impedance common emitter audio preamplifier to follow a diode ring mixer. I could have just used the familiar common-base amplifier popularized by Roy, W7EL, but of course, wouldn't learn anything. Somehow, I became drawn in by curiosity and generated enough content to fill a whole web page.

I decided to try and build some return loss bridges and test them by using known, fixed-value resistors as the unknown impedance. My first bridge, was an AF version of this RF return loss bridge using a junk box 600 ohm, 1:1 audio isolation transformer. It didn't work until I rearranged it as shown in the schematic below.

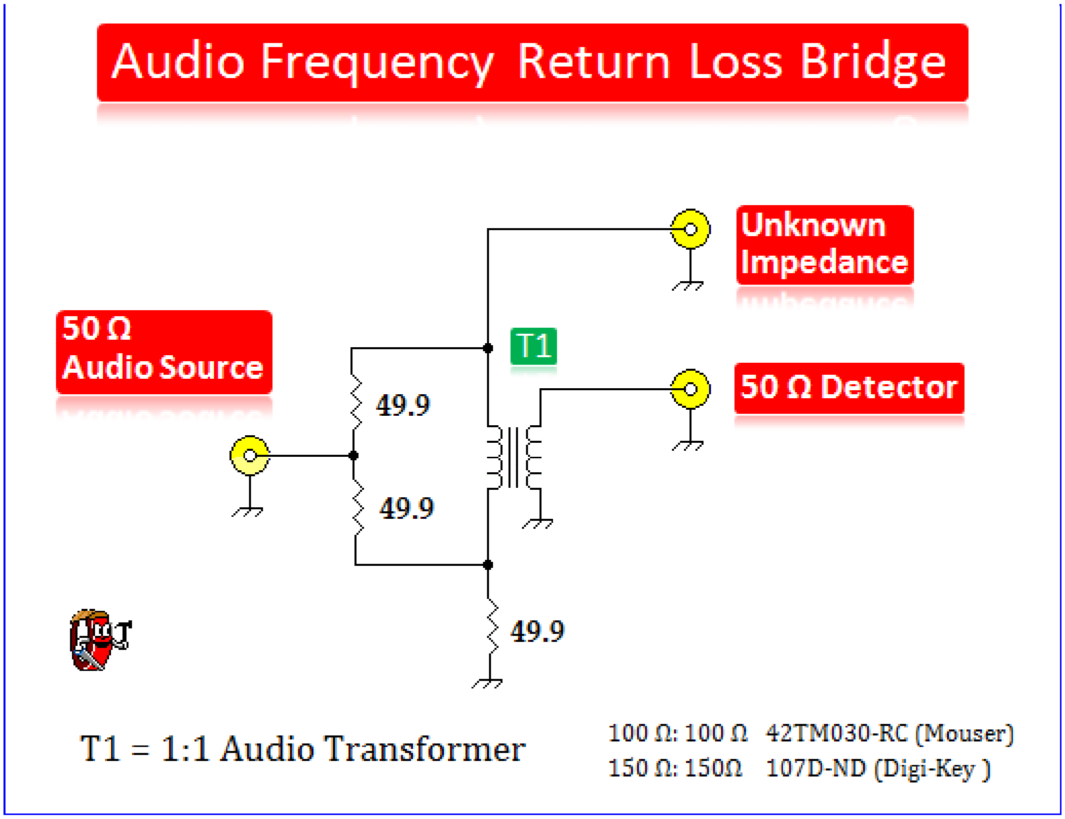
Audio Frequency Return Loss Bridge
Unknown Impedance
50 Ω Audio Source
T1
50 Ω Detector
49.9
49.9
49.9
T1 = 1:1 Audio Transformer
100 Ω: 100 Ω 42TM030-RC (Mouser)
150 Ω: 150Ω 107D-ND (Digi-Key)

Above — A simple return loss bridge using an AF transformer and 50 ohm detector. Suitable detectors are described here in the section covering return loss bridges — I used a 50 ohm terminated scope. Using 20 log (peak-peak voltage) to crunch the 50 Ω AC voltage into dB, the bridge was measured at open circuit, plus with various fixed 5% tolerance resistors terminating the Unknown Z port. Using a junk box 600 ohm 1:1 AF transformer, my results initially seemed good, but upon analysis were fraught with error. Note the suggested transformers in the schematic.

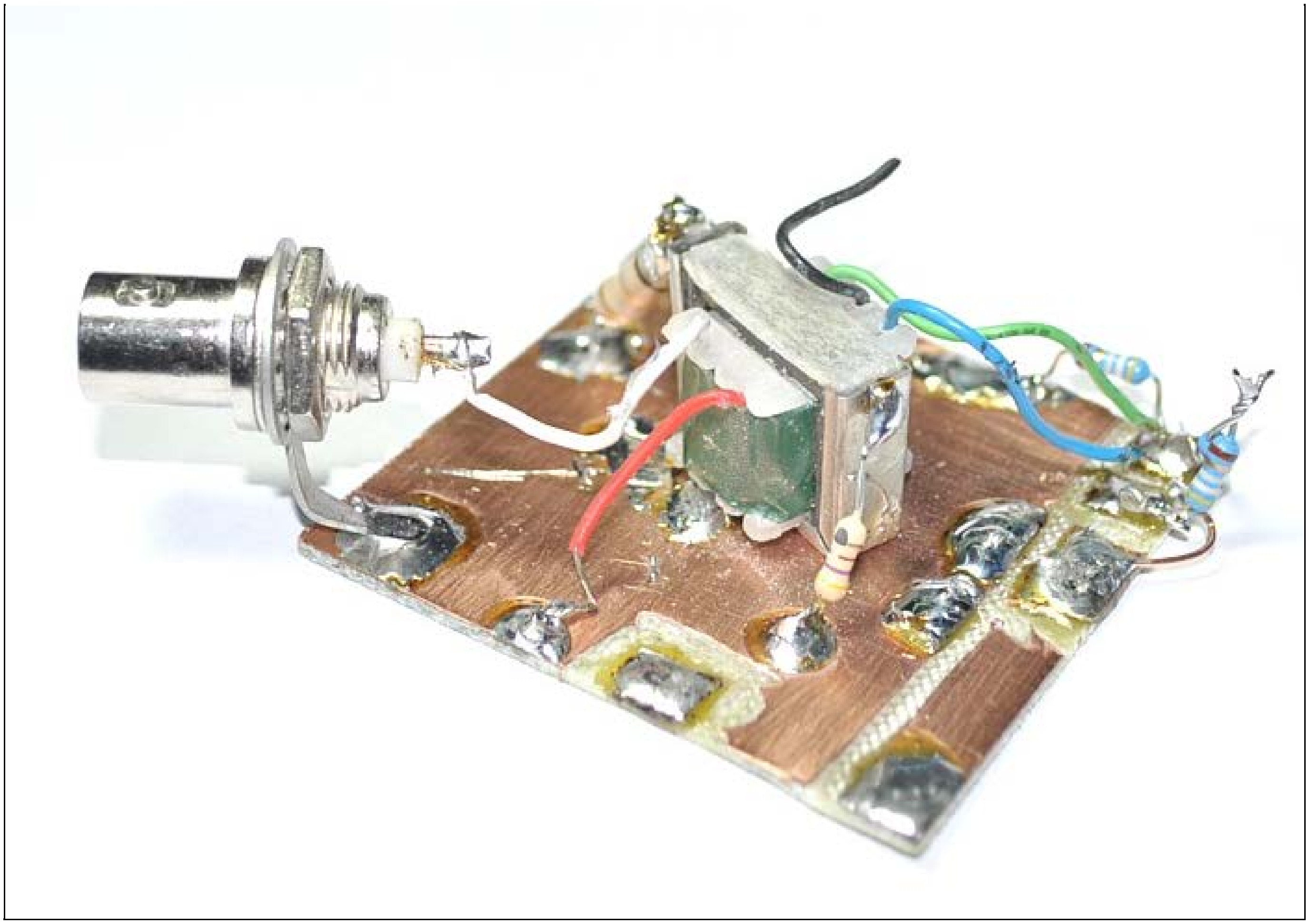

Above — The very first AF return loss bridge built. Anchored to the ground plane with resistors, the transformer was a 600 ohm *junk box* special. Although I was able to achieve a deep NULL using a 49.9 ohm resistor, the return loss was 86 dB; not possible. Additionally, other fixed resistors gave return loss values more than 4-5 dB away from the proper value. Likely, my junk box transformer lacked sufficient inductance for 1 KHz. For testing your bridge, use a formula to inform you of what RL value to expect for a given fixed resistor.

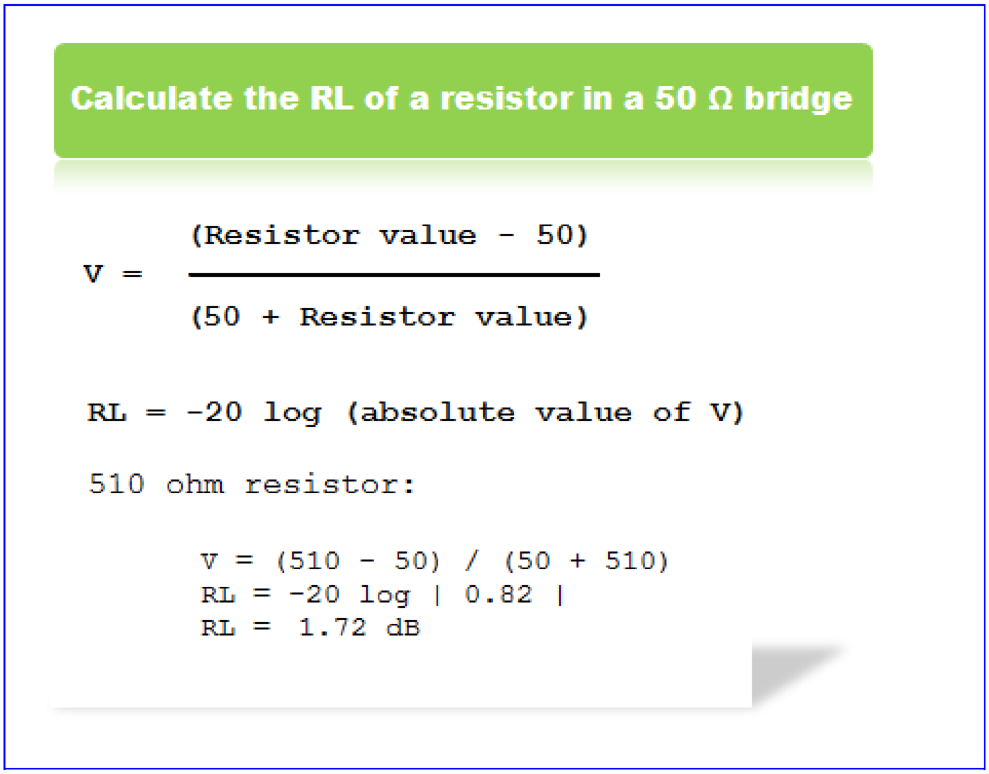

Calculate the RL of a resistor in a 50 Ω bridge

$$V = \frac{(\text{Resistor value} - 50)}{(50 + \text{Resistor value})}$$

RL = -20 log (absolute value of V)

510 ohm resistor:

```
V = (510 - 50) / (50 + 510)
RL = -20 log | 0.82 |
RL =  1.72 dB
```

Above — The formula to calculate the expected return loss for a fixed resistor placed in the Unknown Impedance port on a Wheatstone bridge. Click for a table of Return Loss values for some non 50 ohm resistors. Your RL values, will rarely be exact, but should be close to the predicted value. A well functioning bridge should yield a return loss of > 40 dB using a 51 to 47 ohm resistor as the Unknown Impedance.

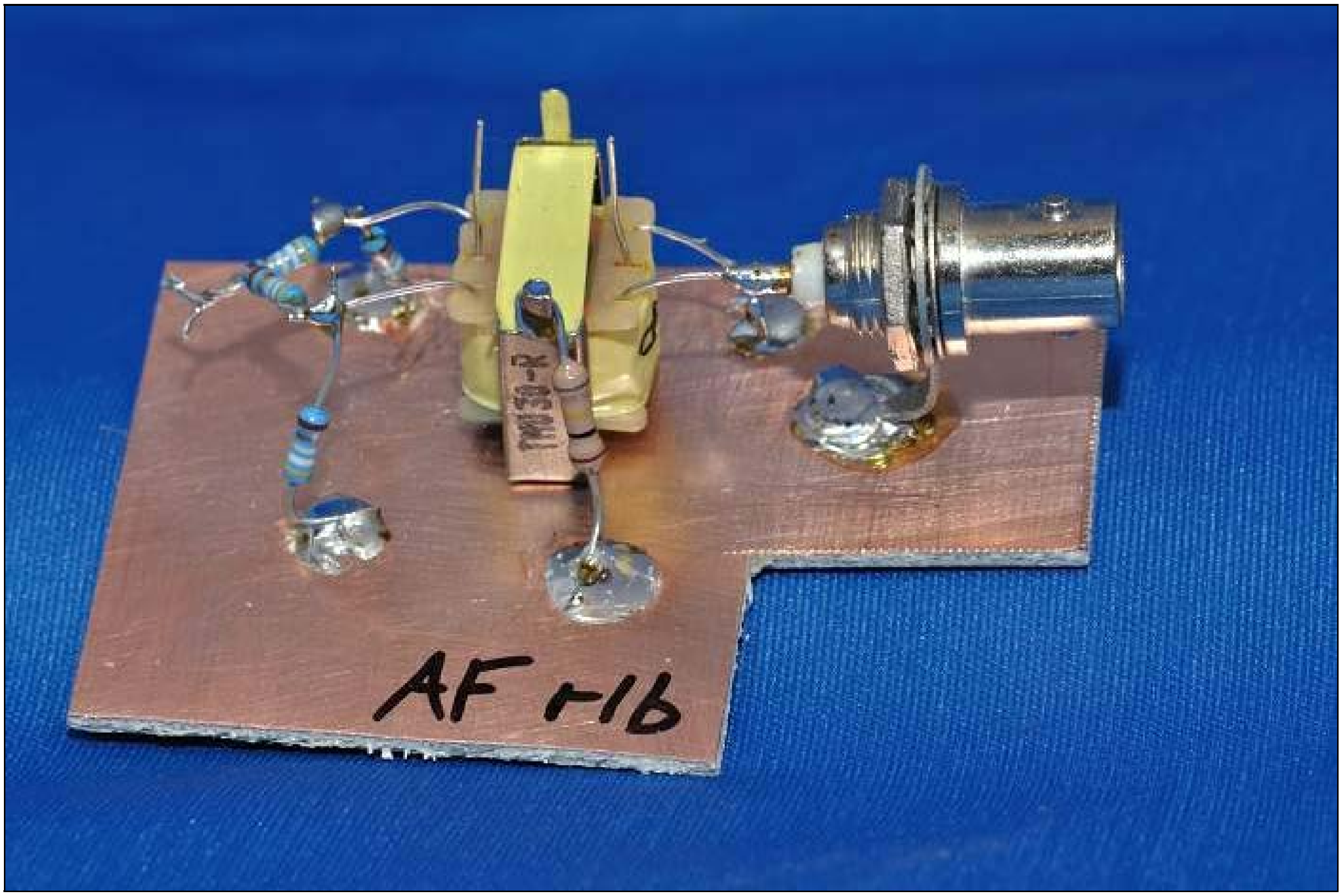

Above — A second bridge was built after obtaining a 100 Ω : 100 Ω AF transformer from Mouser Electronics. This transformer was ideal (each coil has ~ 1H in inductance!). Bench testing indicated good function. My results are tabled below:

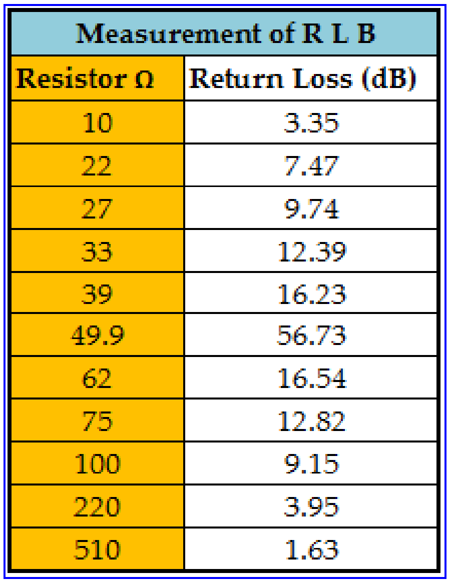

Measurement of R L B	
Resistor Ω	**Return Loss (dB)**
10	3.35
22	7.47
27	9.74
33	12.39
39	16.23
49.9	56.73
62	16.54
75	12.82
100	9.15
220	3.95
510	1.63

Above — A table of the above 50 ohm Wheatstone bridge return loss measurements. These results are acceptable. The NULL with a 49.9 ohm resistor was incredibly sharp and garnered a RL of 56.73 dB. My AF source was a low noise 1 KHz, 50 ohm output impedance signal generator.

If you do not need return loss, and only require a NULL to indicate a match, a common 600 ohm transformer may work okay for you.

Building an active instrument to measure the return loss of a 50 ohm input Z audio preamplifier.

The results of my early experiments with a passive bridge were encouraging. Noting that most builders would have difficulty obtaining a 100 Ω : 100 Ω AF transformer, a version using op-amps was sought. My first 3 designs did not work properly and I became discouraged. Some guidance from Wes, W7ZOI allowed me to problem solve and experience success.

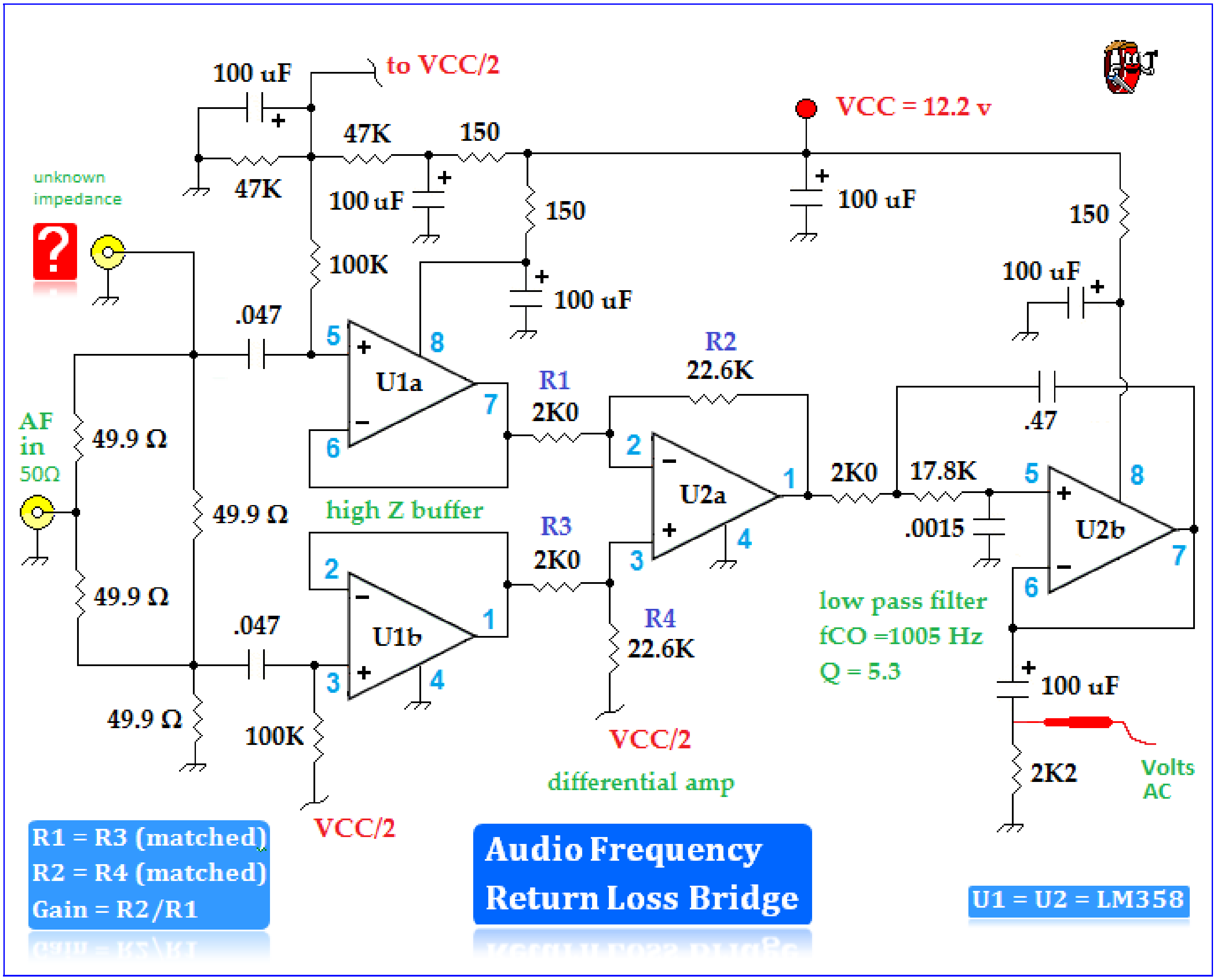
100 uF
to VCC/2
VCC = 12.2 v
47K
150
unknown impedance
47K
100 uF
150
100 uF
150
100K
100 uF
100 uF
.047
5
8
U1a
6
7
R1
2K0
R2
22.6K
.47
AF in 50Ω
49.9 Ω
49.9 Ω
high Z buffer
R3
2K0
2
U2a
1
3
4
2K0
17.8K
.0015
5
8
U2b
6
7
49.9 Ω
.047
2
U1b
1
3
4
R4
22.6K
low pass filter
fCO =1005 Hz
Q = 5.3
100 uF
49.9 Ω
100K
VCC/2
differential amp
2K2
Volts AC
VCC/2
R1 = R3 (matched)
R2 = R4 (matched)
Gain = R2/R1
Audio Frequency
Return Loss Bridge
U1 = U2 = LM358

Above — Schematic of my active Wheatstone bridge, amplifier and low-pass filter for measuring the Return Loss of 50 ohm input impedance AF amplifiers. I built 3 copies of the above device; best results occurred when careful layout and planning were employed. Optimal performance occurred when encased in a metal box.

The bridge was built from 1% metal film resistors. 0.047 polyester film capacitors lightly couple the bridge to high impedance op-amp buffers labeled U1a + U1b. My experiments informed me that to minimize loading on the bridge is important. The LM358 is an excellent op-amp choice, but almost any other op-amp could be employed successfully. U2a is the differential amplifier and matching R1 + R3 and R2 + R4 with 1% tolerance resistors is critical; 5% resistors did not work well. The gain is non-critical — feel free to choose reasonable resistor ratios based upon the resistors you have in stock. The differential amp promotes the unfortunate side effect of amplifying both the desired AF source plus any common mode signals. Although common mode suppression is an important consideration when designing instrumentation amps, fortunately, performance is fine. A amplifier topology using a differential amp across the bridge was trialed, but functioned identically to the simpler differential amp shown. Consult a textbook for more information on Instrumentation amps. Much information was gleaned from Professor Ken Kuhn's web site.

The output is low-pass filtered by a single stage Sallen-Key low-pass filter with a peak frequency of 1 kHz and a Q of 5. This filter gain at 5 at 1 kHz is 0.328 at 2 kHz and 0.123 at 3 kHz. Thus, the second harmonic is reduced by a factor of (5/0.328) = 15.2 and the third harmonic is reduced by a factor of 40.6. **Do not omit a low pass filter**. I chose a 1 KHz cutoff, but experimentation indicated a low-pass cut-off frequency as high as 10 KHz may work okay if you plan to use the bridge at frequencies other than 1 KHz.

Power supply decoupling proved important. When less DC low-pass filtering (less than the 150 Ω plus the 100 uF capacitors shown) was employed, some low frequency audio noise appeared in the output.

I measured using a X1 oscilloscope probe on the output of U2b.

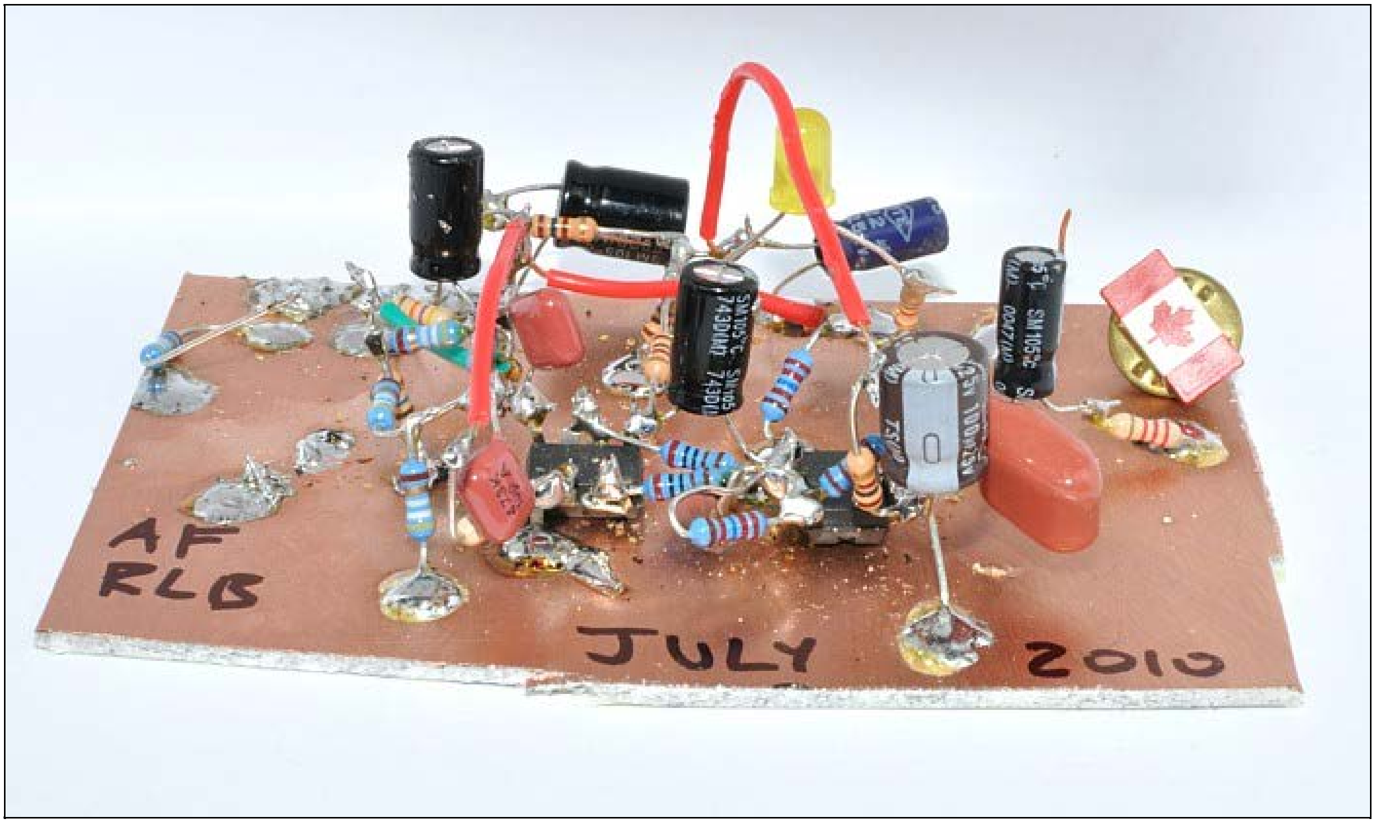

Above — A breadboard of the active Wheatstone bridge schematic located above. When tested with fixed value resistors, the RL @ 49.9 ohms was 55.4 dB and close to predicted value with other test resistors. This instrument will be put in a metal case and become a permanent part of my test equipment arsenal.

Part 3: Measuring Unknown Impedances

Building an instrument to measure the input impedance of an audio preamplifier using a NULL.

330
500
680
220
150
75
50
820

Above — One of several Wheatstone bridge circuits built in the Spring-Summer of 2010. In these bridges, the potentiometer was calibrated and the panel labeled using fixed resistances for calibration. One big challenge is range or resolution; dependent on the bridge resistor values and what impedance you are trying to measure. Greatest accuracy is associated with 5 or 10 turn potentiometers, but these are expensive. Often, I used standard, linear taper pots to save money during my experiments. Over 7 different bridges were built and tested. To save time, I didn't photograph many of my projects from the summer.

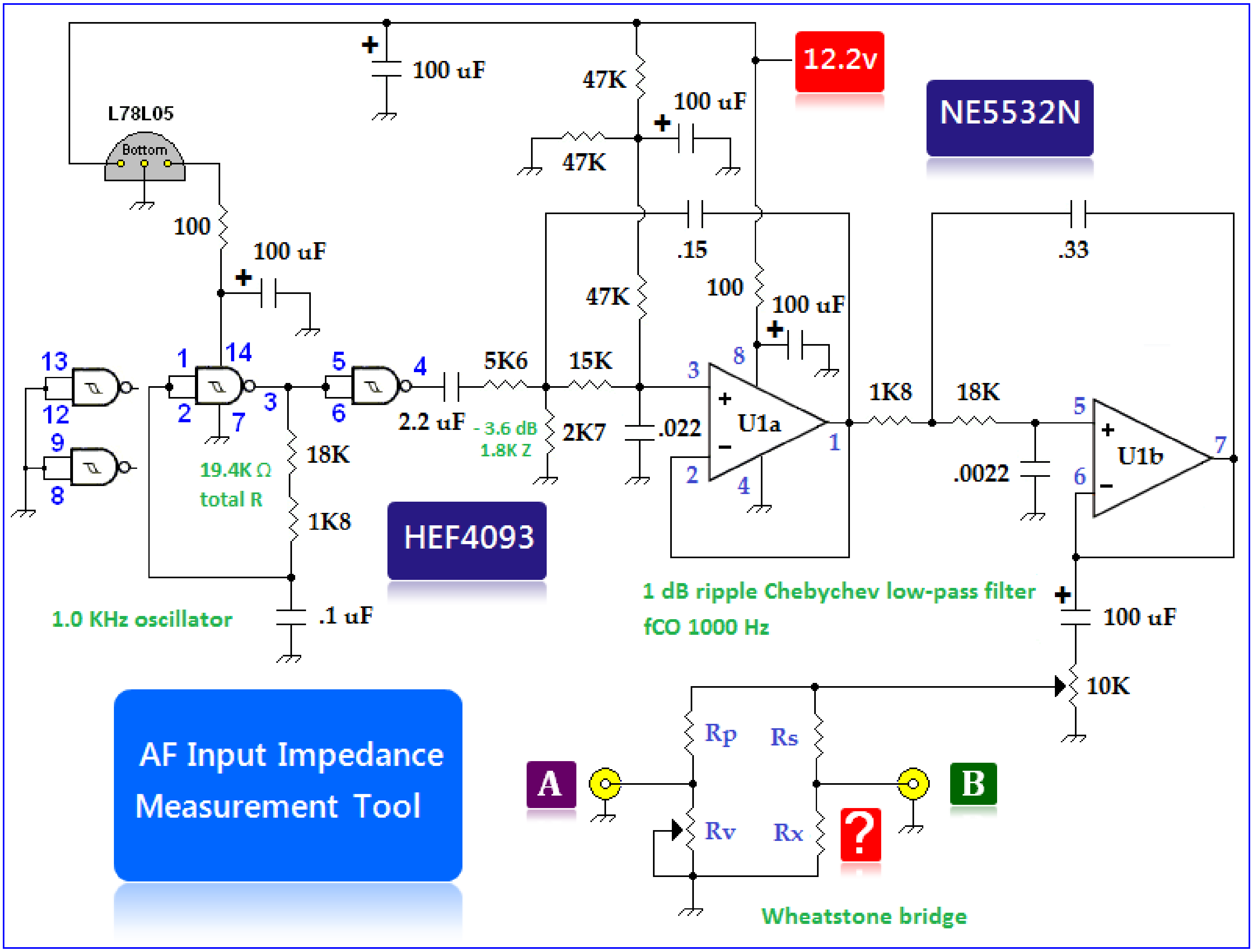
100 uF
L78L05
Bottom
47K
100 uF
47K
12.2v
NE5532N
100
100 uF
.15
.33
47K
100
100 uF
13
12
9
8
1
2
14
7
3
5
6
4
5K6
15K
2.2 uF
- 3.6 dB
1.8K Z
2K7
.022
3
8
U1a
2
4
1
1K8
18K
5
U1b
6
7
.0022
19.4K Ω
total R
18K
1K8
HEF4093
1.0 KHz oscillator
.1 uF
1 dB ripple Chebychev low-pass filter
fCO 1000 Hz
100 uF
10K
AF Input Impedance
Measurement Tool
A
Rp
Rs
Rv
Rx
?
B
Wheatstone bridge

Above — A complete 1 KHz signal generator, low-pass filter and bridge circuit which became the prototype for most of my experiments in this section. Click for a high resolution photo of 1 of the breadboards during construction.

The 1 KHz signal generator is a digital oscillator built with 2 gates from a 4093. This excellent oscillator uses a single R + C network for tuning and requires a voltage regulator for frequency stability. The output signal is attenuated 3.6 dB and low-pass filtered by 4 poles of active filtering. A 10K pot controls the drive into the bridge circuit. The bridge outputs are labeled **A** and **B** and require buffering, amplification and low-pass filtering similar to the active bridge shown earlier. These functions and some comments on the bridge resistors come later.

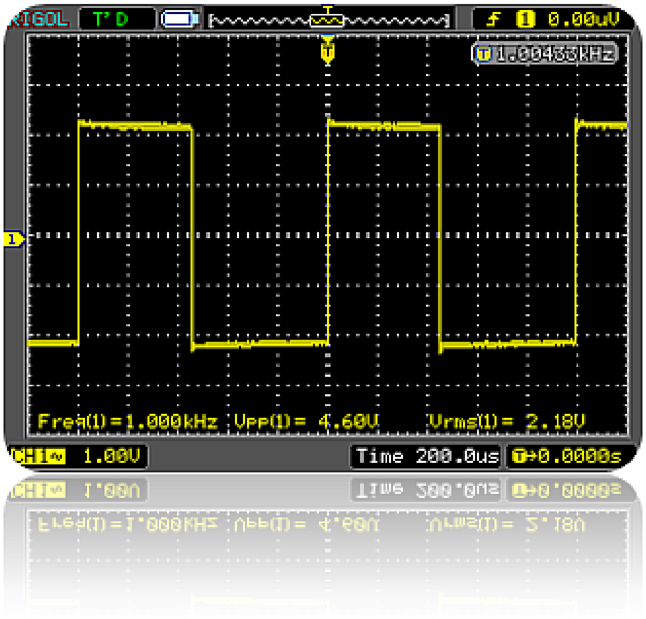
RIGOL
T'D
0.00uV
1.00433kHz
Freq(1)=1.000kHz
Vpp(1)= 4.60V
Vrms(1)= 2.18V
CH1 1.00V
Time 200.0us
0.0000s

Above — The oscilloscope waveform from the digital 1 KHz oscillator. Digital clocks fascinate me and this was an untried design. Initially a CMOS 555 timer was considered, however, I own many 4000 series NAND Schmitt triggers and pressed 1 into service. Another good choice might be the 74HC132. The first NAND gate (inverter) contributes 180 degrees of phase shift, while the RC low-pass filter tank circuit digitally shifts the AC the other 180 degrees. Output noise is filtered by both the low-pass filter and the input Schmitt trigger dead band or hysteresis. The result is a fairly crisp square wave that may rival the 555.

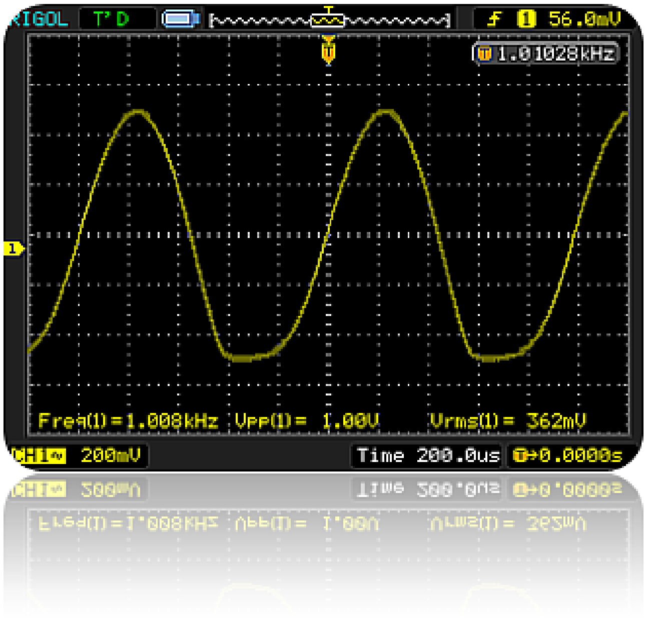
RIGOL
T'D
56.0mV
1.01028kHz
Freq(1)=1.008kHz
Vpp(1)= 1.00V
Vrms(1)= 362mV
CH1 200mV
Time 200.0us
0.0000s

Above — The output of the 1 KHz low-pass filter. A sine wave is desirable, but not critical; suppression of energy in the range of 5-10 KHz, informed the filter design goal. At 8000 Hz, the attenuation is > 80 dB. All good.

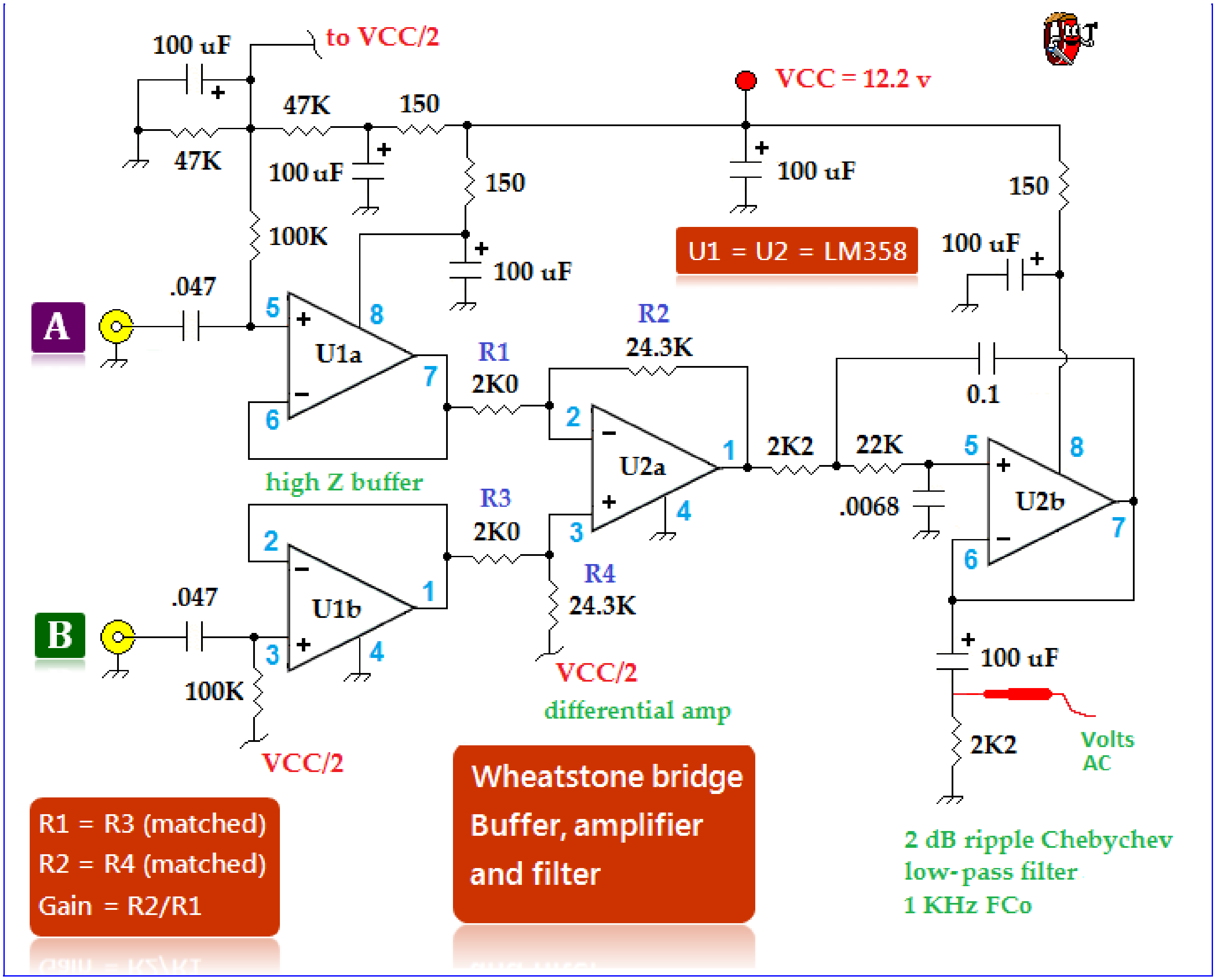
100 uF
to VCC/2
VCC = 12.2 v
47K
150
47K
100 uF
150
100 uF
150
100K
100 uF
U1 = U2 = LM358
100 uF
.047
A
5
8
U1a
7
6
R1
2K0
R2
24.3K
0.1
2
U2a
1
2K2
22K
5
8
U2b
7
6
.0068
high Z buffer
R3
2K0
3
4
2
U1b
1
B
.047
3
4
R4
24.3K
100K
VCC/2
100 uF
VCC/2
differential amp
2K2
Volts AC
Wheatstone bridge Buffer, amplifier and filter
R1 = R3 (matched)
R2 = R4 (matched)
Gain = R2/R1
2 dB ripple Chebychev low-pass filter
1 KHz FCo

Above — The buffer, differential amplifier and low-pass filter employed during this series of experiments. Function is identical to the similar stage described earlier.

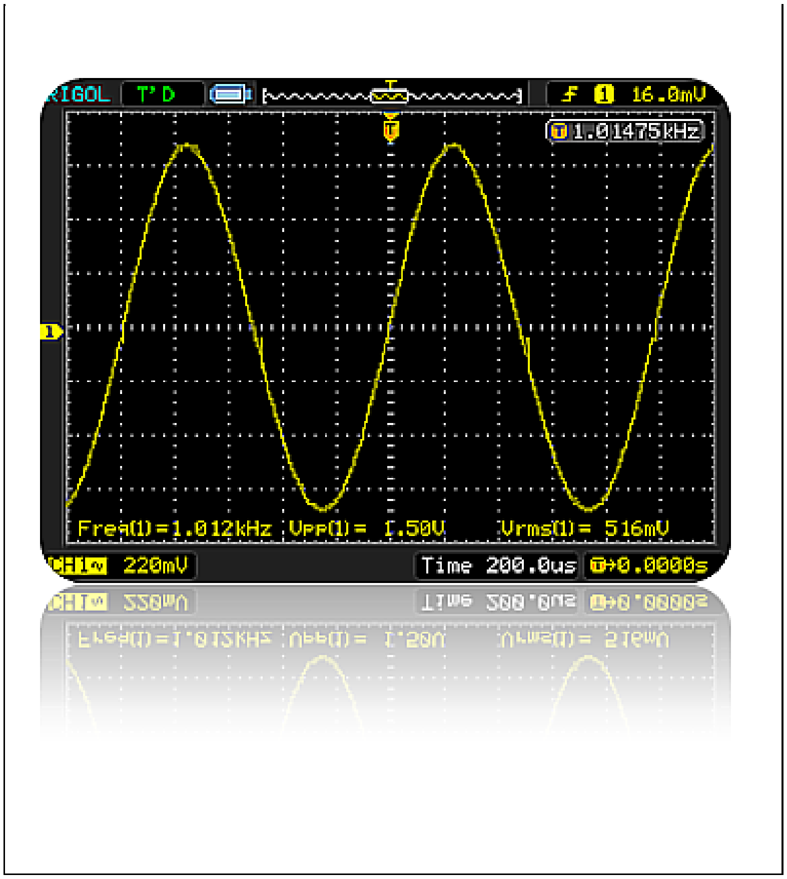
RIGOL
T'D
16.0mV
1.01475kHz
Freq(1)=1.012kHz
Vpp(1)= 1.50V
Vrms(1)= 516mV
CH1 220mV
Time 200.0us
0.0000s

Above — The output of amplified and filtered Wheatstone bridge at open circuit (no resistance at the Unknown Impedance port).

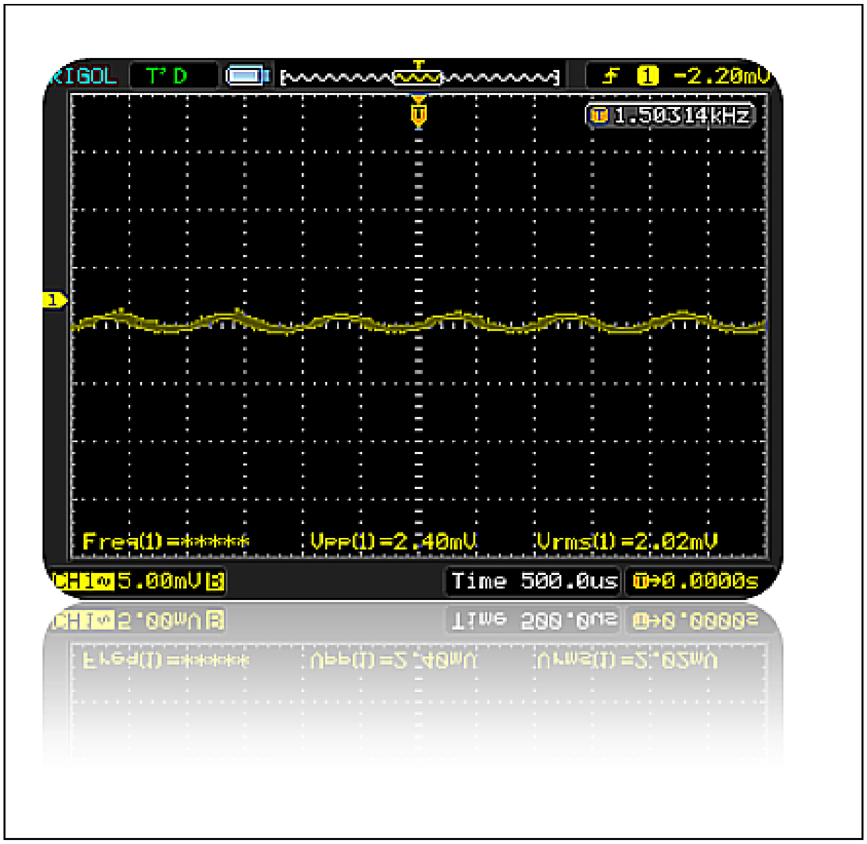
RIGOL
T'D
-2.20mV
1.50314kHz
Freq(1)=*****
Vpp(1)=2.40mV
Vrms(1)=2.02mV
CH1 5.00mV B
Time 500.0us
0.0000s

Above — the output of the amplified and filtered Wheatstone bridge at NULL (potentiometer setting balanced to match the resistance at the Unknown Impedance port. Below 2 mV, accuracy is lost.

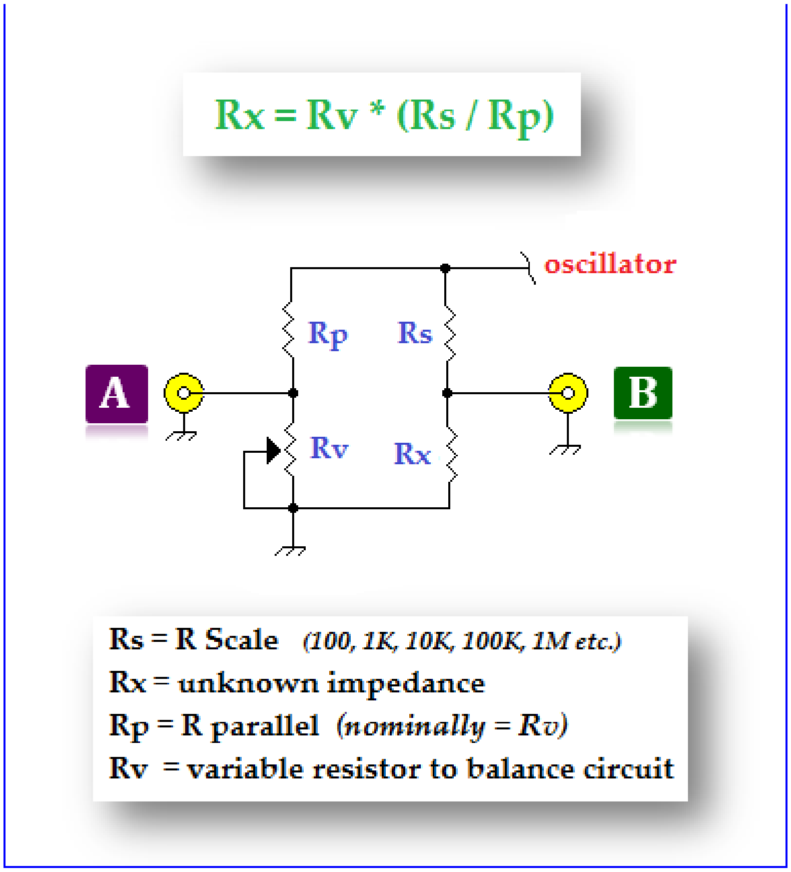

$$Rx = Rv * (Rs / Rp)$$

Rs = R Scale *(100, 1K, 10K, 100K, 1M etc.)*
Rx = unknown impedance
Rp = R parallel *(nominally = Rv)*
Rv = variable resistor to balance circuit

Above — The math behind the bridge. I found when R Variable (Rv) was the same resistance as the fixed resistor R parallel (Rp), reasonable resolution was possible. "Reasonable resolution" means your pot has a good range of rotation as you go from the lowest to highest measureable impedance. Generally, Rv has to be less than the maximal impedance you are trying to measure.

R Scale (Rs) can be switched in decades via a panel mount switch to cover a wide range of resistance with good resolution, or just be 1 or 2 values. It's your design call.

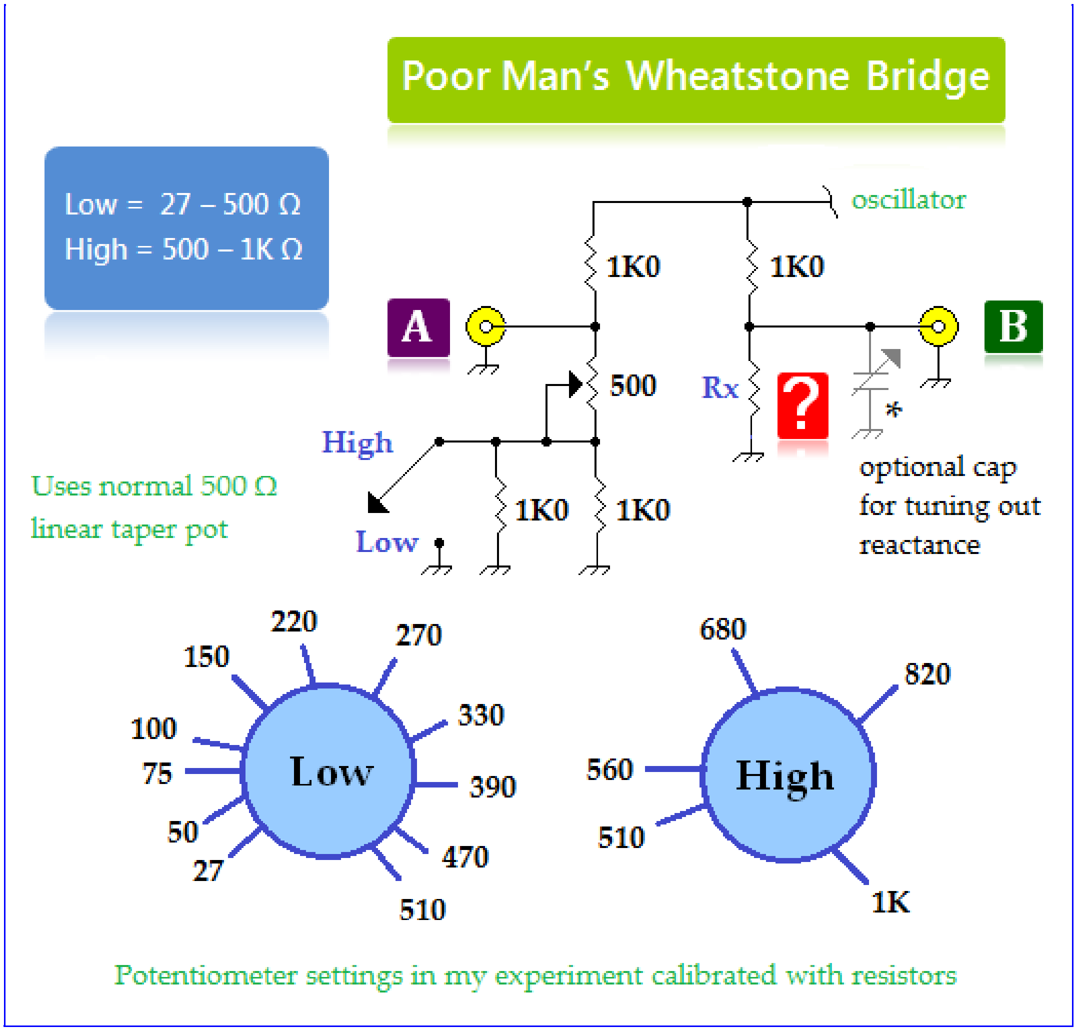
Poor Man's Wheatstone Bridge
Low = 27 – 500 Ω
High = 500 – 1K Ω
oscillator
1K0
1K0
A
B
500
Rx
?
*
High
Low
1K0
1K0
Uses normal 500 Ω
linear taper pot
optional cap
for tuning out
reactance
Low
220
150
270
330
100
75
390
50
27
470
510
High
680
820
560
510
1K
Potentiometer settings in my experiment calibrated with resistors

Above — My poor man's impedance measurement device that uses a common 500 ohm linear taper pot as the balancing resistor. In order to get good pot resolution, the desired range is switched. This bridge measures impedances at the Unknown Port from about 27 ohms up to 1K with decent resolution. The blue circles depict how I calibrated the front panel of my device using 2 colors. This device had an average return loss of 32.5 dB when a NULL was obtained.

Measuring resistors to calibrate a bridge is quite different from real-world measurement of reactive AF amplifier loads — if the unknown resistance has a large inductive or capacitive reactance, obtaining good bridge balance might prove difficult. Your bridge can *only* null the in-phase signal. An extension to the standard bridge involves adding a series or shunt capacitance (depending on the phase of the reactance) to the A or B port. This may allow you to null the reactive part and also provide the reactive impedance value as well. An outstanding reference may be located with your favorite search engine: Look for the manual for the **General Radio GR1650 Impedance Bridge.** I found a copy and the download was very slow, but worth it. This manual may be the greatest reference every published on the Wheatstone bridge and comprehensively covers tuning out the reactance of complex impedances amid a myriad of other topics.

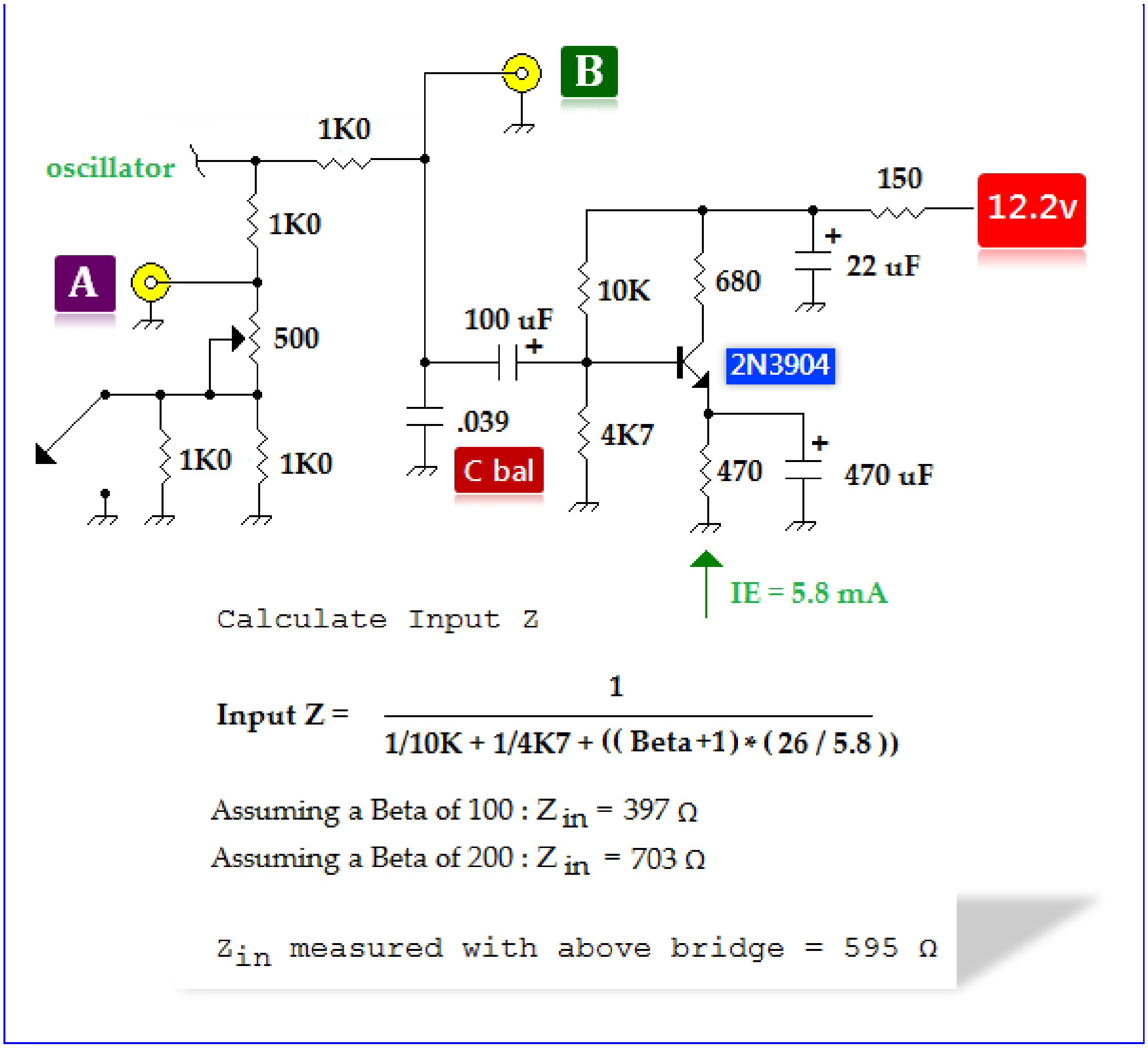

Calculate Input Z

$$\text{Input Z} = \frac{1}{1/10K + 1/4K7 + ((\text{Beta}+1) * (26 / 5.8))}$$

Assuming a Beta of 100 : Z_{in} = 397 Ω

Assuming a Beta of 200 : Z_{in} = 703 Ω

Z_{in} measured with above bridge = 595 Ω

Above — The poor man's bridge measurement of a test AF amplifier on my bench. The reactive component of the amplifier input impedance was minimized using a 0.039 uF capacitor found experimentally. Of particular interest, is the difference between the *calculated* input Z and the *actual* input Z measured with the bridge.

The Beta of the 2N3904's in my collection ranges from about 100 to 225. Calculations with 2 different Beta values are shown (RE is *well* bypassed with a 470 uF capacitor, so, re = (Beta * 26/5.8 mA) . The measured input Z was 595 ohms. I confirmed this by removing the 0.039uF tuning capacitor, plus connecting a fixed 595 ohm resistance to the Unknown Impedance port. I then turned the potentiometer fully clockwise and adjusted it for a NULL. When the bridge was nulled, the potentiometer knob pointed at the same mark as when the amplifier was connected to this Unknown Impedance port.

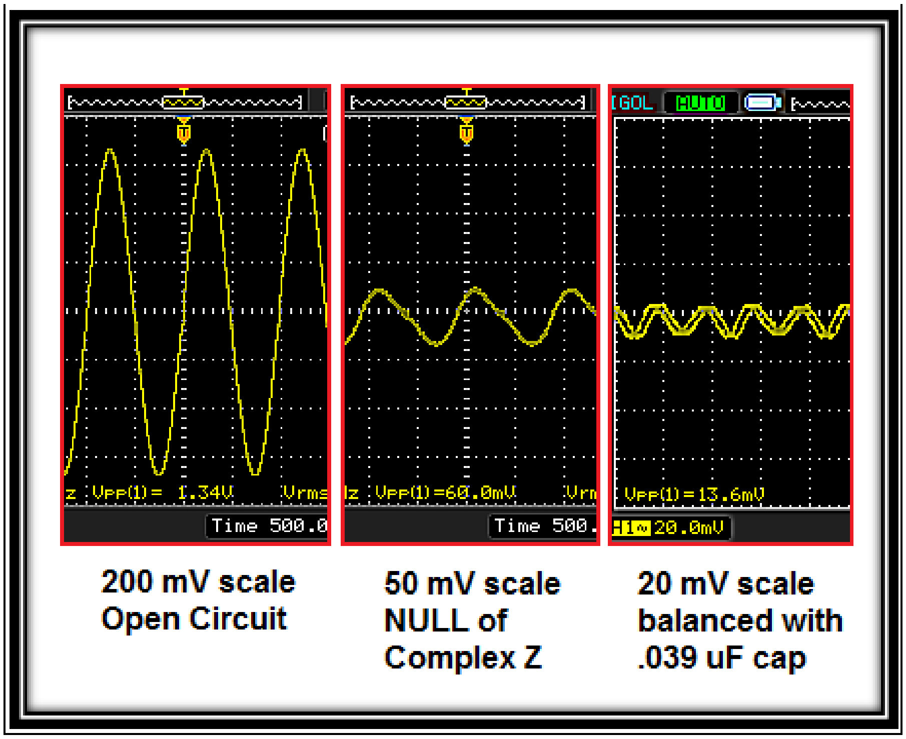
Vpp(1)= 1.34V
Vrms
Time 500.0
Vpp(1)=60.0mV
Vrm
Time 500.
GOL
AUTO
Vpp(1)=13.6mV
20.0mV
200 mV scale
Open Circuit
50 mV scale
NULL of
Complex Z
20 mV scale
balanced with
.039 uF cap

Above — The oscilloscope output waveform of the amplifier circuit shown above: open circuit, with the potentiometer balanced as well as possible and finally, the potentiometer balanced with the addition of a 0.039 uF capacitor attached to Port B. Although, I was able to get a NULL without the capactitor by just tweaking the potentiometer, slightly better precision was obtained after adding the 0.039 uF balancing capacitor.

Part 4: Miscellaneous Circuits, Scans and Photographs

1
2
3
CW
VISHAY
SPECTROL
PRECISION
POTENTIOMETER
1009 MEX
MOD 534

Above — More accurate results will be obtained with a calibrated 10 turn potentiometer to balance your bridge. A local store sold me this precision 10-turn, 10K pot for about 11 dollars (still expensive for me). They normally sell for twice this price in Canada.

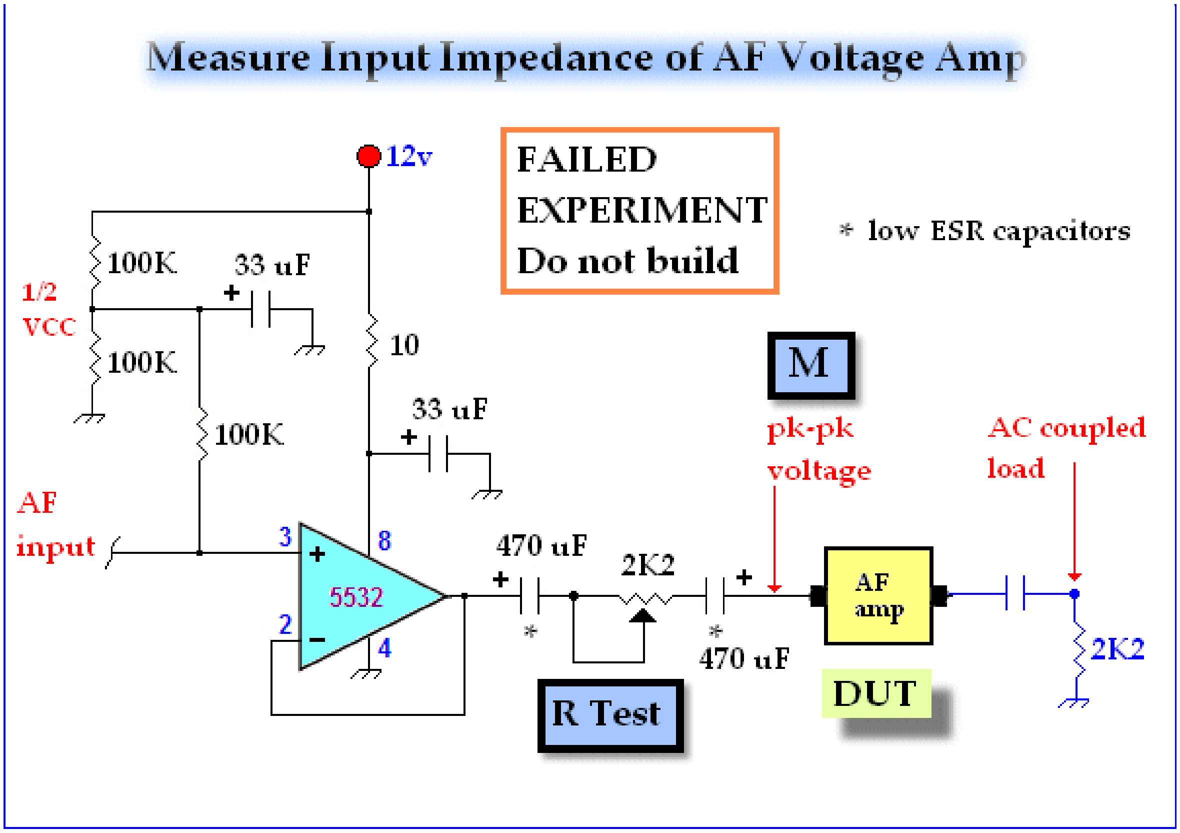

Above — My first input impedance measurement device that didn't work. It turns out my experiments were performed *incorrectly*, however, I'm glad because this failure spurred me to investigate bridge networks. The series resistance method *is* worth understanding and happily, Jeff, AD6MX described the correct procedure in a private email received December 2010. I quote him below:

"The series resistance method for input impedance should start with the variable resistor disconnected from the node to be measured. The open circuit voltage at the end of that resistor is measured (the resistor value doesn't affect the open circuit voltage since there's no current into an open circuit.)

Next the free end of the variable resistor is then connected to the input node and the resistor is finally adjusted for half the open circuit voltage at the same end of the resistor, at the input node being measured. What happens is the variable resistor and the node input impedance form a voltage divider, with equal arms or branches.

The value of the resistor when measured out of the circuit is the same as the input impedance at the measured input node. This scheme has some assumptions: the driving amplifier has negligible output impedance compared to the measured impedance, and the input impedance is purely resistive, with no reactance or V-I phase shift.

The phase shift condition may be checked by taking these 3 voltage measurements: across each branch of the divider separately, and also the driving source voltage (across both branches in series.) The sum of the separate branch voltages should match the source voltage when there is little phase shift.

This 3 voltage scheme is used in some antenna analyzers in order to measure phase shift. For checking for the resistive condition, it's not important the 3 voltage method has a sign ambiguity which needs an additional step to resolve. Your description seemed to suggest starting with zero series resistance, but you see that is not the same as the procedure above. The applied voltage needs to be small enough that the amplifier remains operating in its linear range during the measurement".

Thanks for this info Jeff!

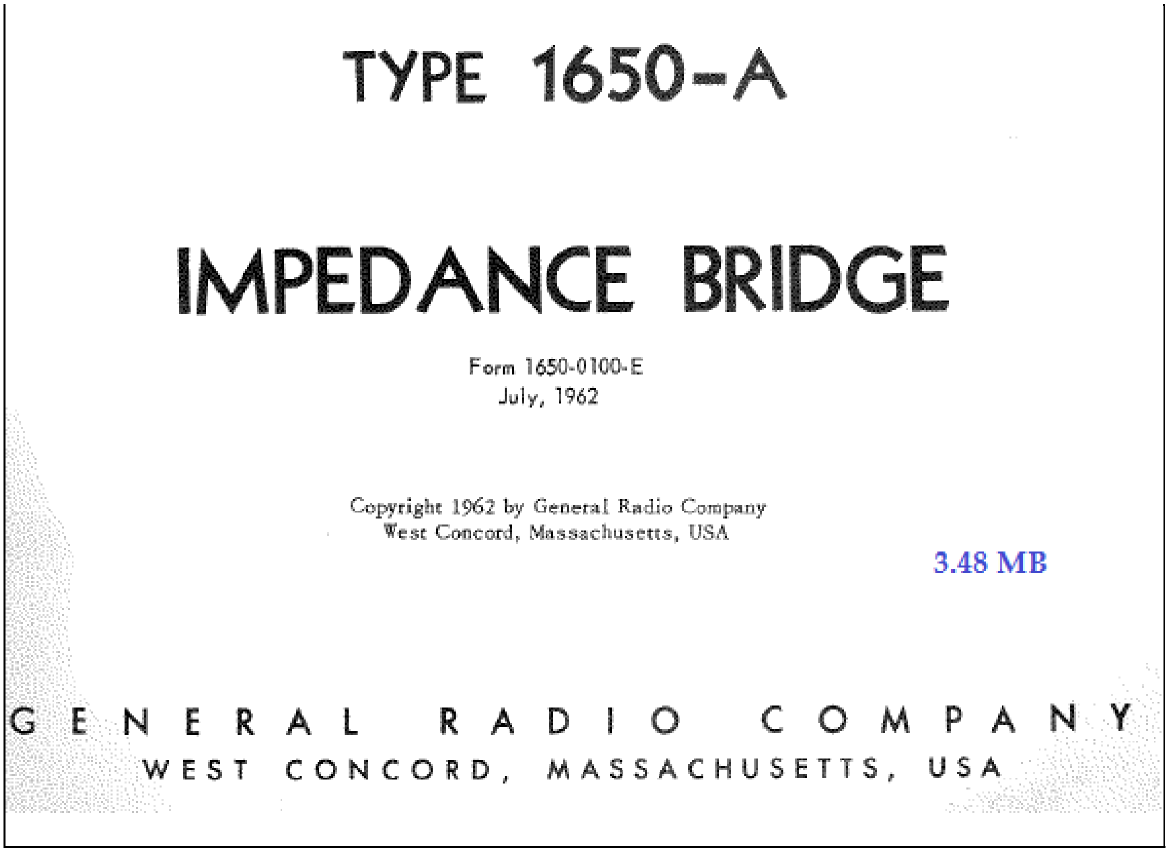

TYPE 1650-A

IMPEDANCE BRIDGE

Form 1650-0100-E
July, 1962

Copyright 1962 by General Radio Company
West Concord, Massachusetts, USA

3.48 MB

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

Above — A modified scan of General Radio's *über awesome* manual for the Type 1650-A Impedance Bridge.

RF — Test and Measurement

RF Workbench Page 3

This web page is the third installment of a 6 part series that explores basic measurement of RF circuits.

Part 3, further examines Return Loss Bridges from a bench-practice viewpoint.

I borrow heavily from the work of Wes, W7ZOI per correspondence, direct contributions and from EMRFD.

I focus on measuring low-level, HF circuits with a return loss bridge — topics such as using the bridge for antenna matching are omitted and readily found on the web. This web page contains minimal text and just relies on simple diagrams and photographs to transfer ideas and knowledge. Information regarding wideband bridge network function may be found elsewhere on this and other web sites and in EMRFD.

More on Return Loss

Gear

Equipping for a 50 Ω measurement environment in 2010 greatly improved my design capacity. The 50 Ω terminated oscilloscope makes a sensitive and accurate detector for return loss measurement. Discussion about using a 50 Ω oscilloscope termination is on the RF Workbench 1 web page.

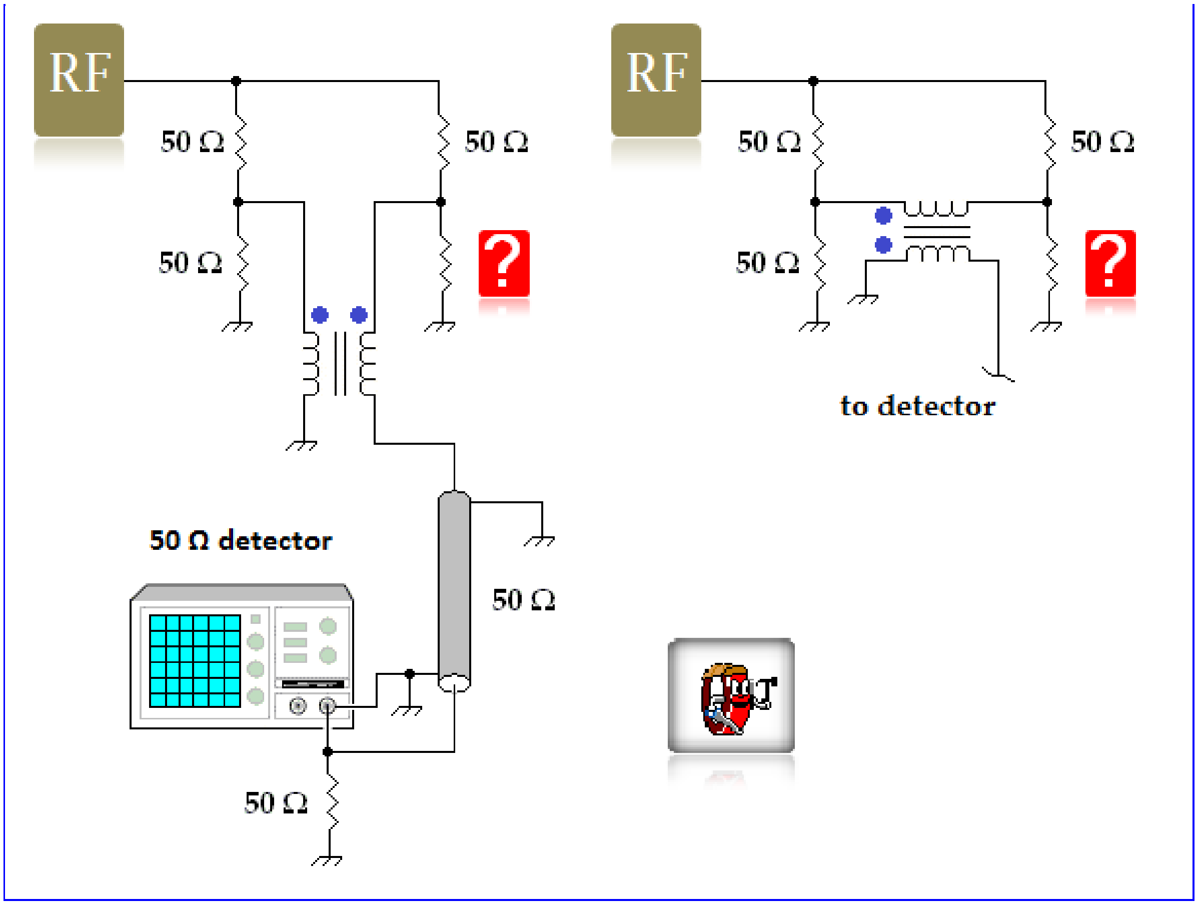
RF
50 Ω
50 Ω
50 Ω
50 Ω
?
50 Ω detector
50 Ω
50 Ω
RF
50 Ω
50 Ω
50 Ω
50 Ω
?
to detector

Above left — The RLB and measurement set up from EMRFD. Occasionally, you may see bridges using a different balun transformer wiring as shown to the right of this figure.

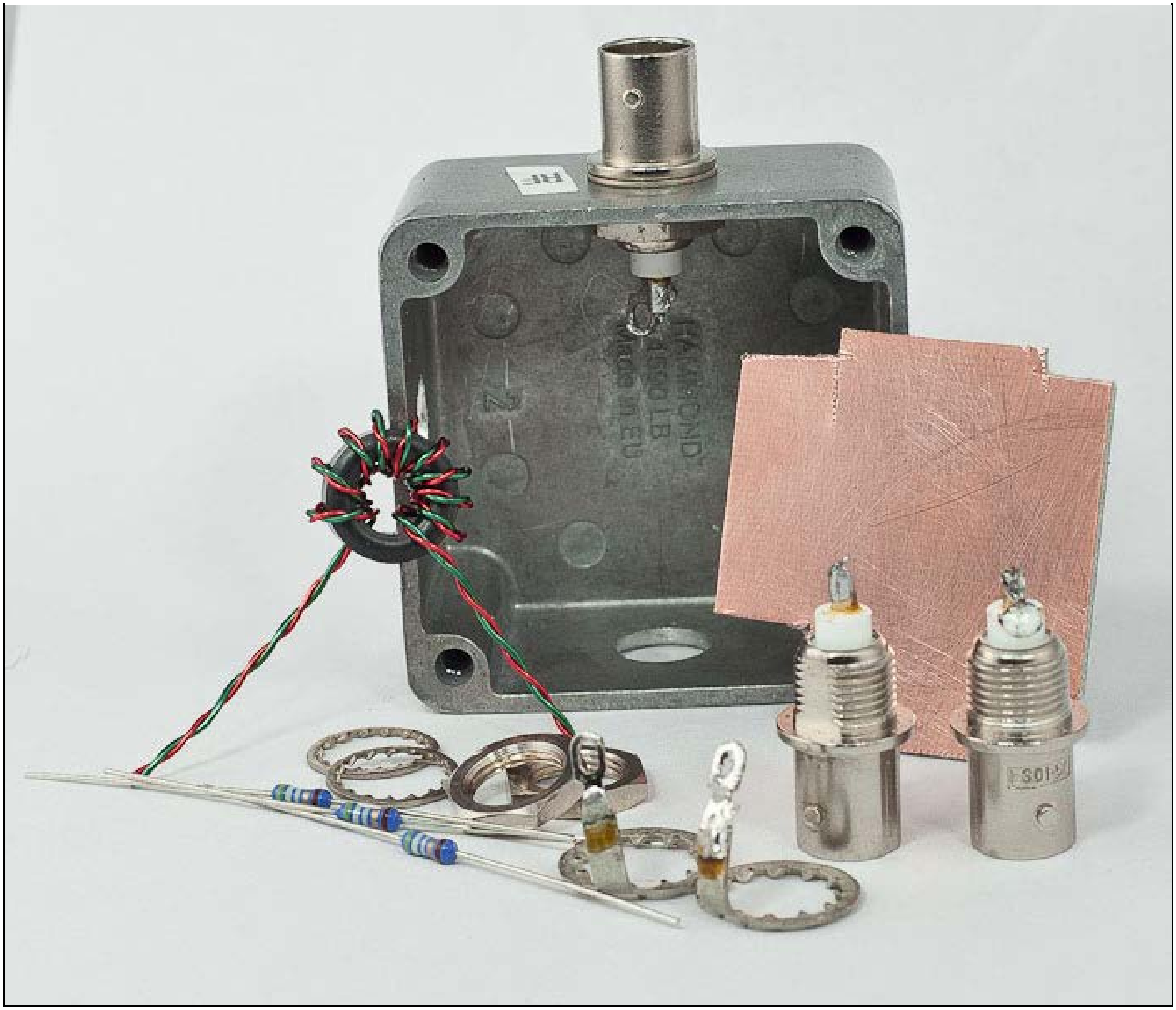

Above — All the needed parts to home build a return loss bridge. For some, the parts investment might seem substantial, but what hobby isn't expensive? If you consider the cost of commercially manufactured bridges, a homebrew solution seems a bargain. Recycled parts and a home-built chassis are inviting cost-containment techniques. See the web site of Jim, K8IQY for an example of a homebrew RLB chassis. Jim, a Manhattan style construction wizard, builds the nicest looking gear — he puts me to shame.

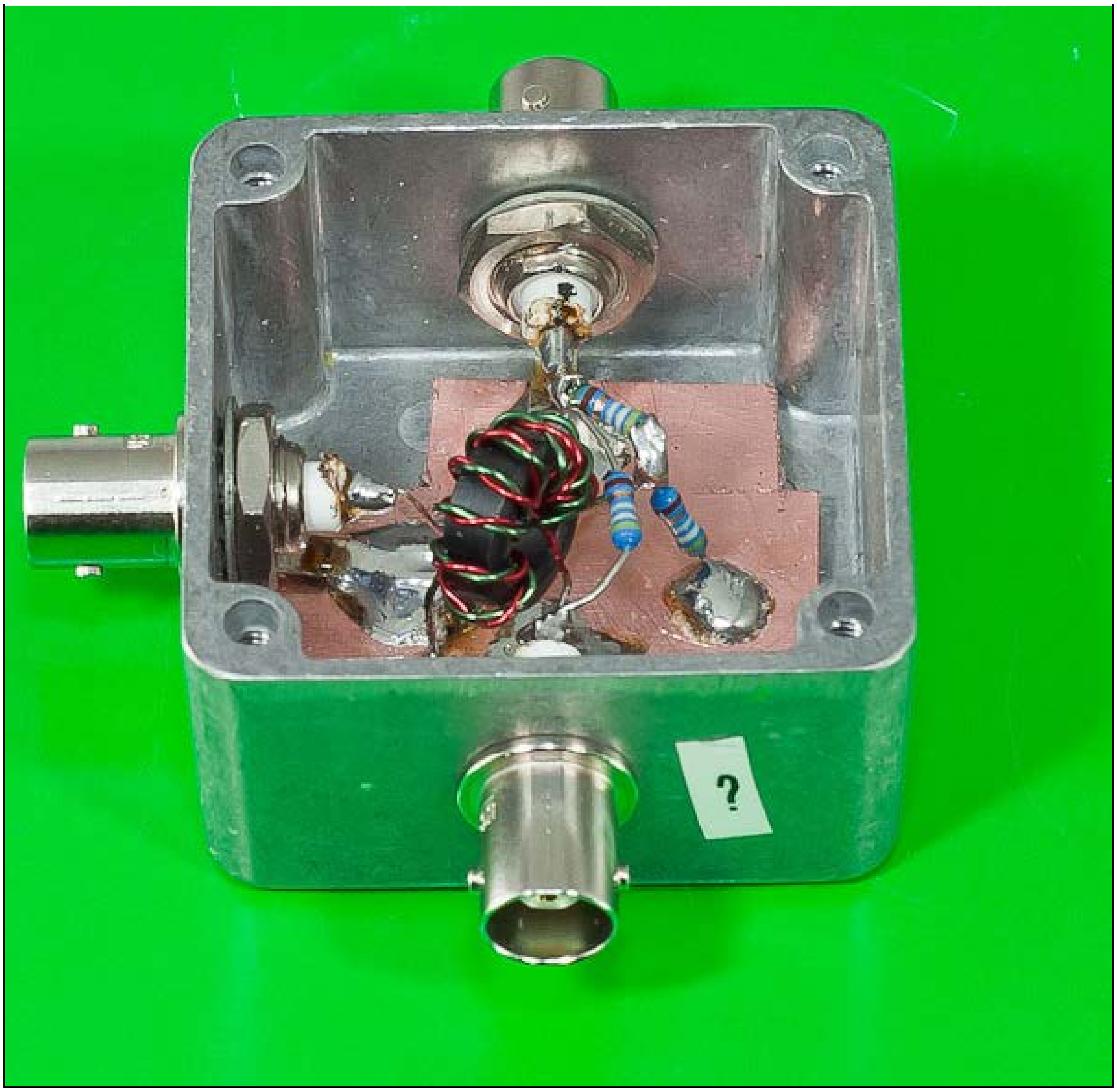

Above — A completed bridge. I used 1% tolerance 49.1 ohm resistors and an FT50-43 ferrite toroid for the bifilar wound transformer. Inductance = 38.4 uH. Many builders use the FT37-43 ferrite core. I prefer using 2 colors of enamel coated wire to avoid confusion when building stuff with transmission line style transformers and all I had in 2 colors was 24 gauge wire The bigger size ferrite toroid better accommodates the 24 gauge wire, plus photographs better.

Bridge directivity of the above RLB was 30 dB at 7 MHz, 34 dB at 14 MHz, 35.6 dB at 21 MHz, 42.1 dB at 50 MHz and 43.4 dB at 100 MHz.

If you build a circuit with a return loss close to 30 dB, it's a good day.

RETURN~LOSS BRIDGE
RF
?
DETECTOR
D

Above — The completed RF-tight bridge. Don't forget to label your network ports.

Measurement Technique

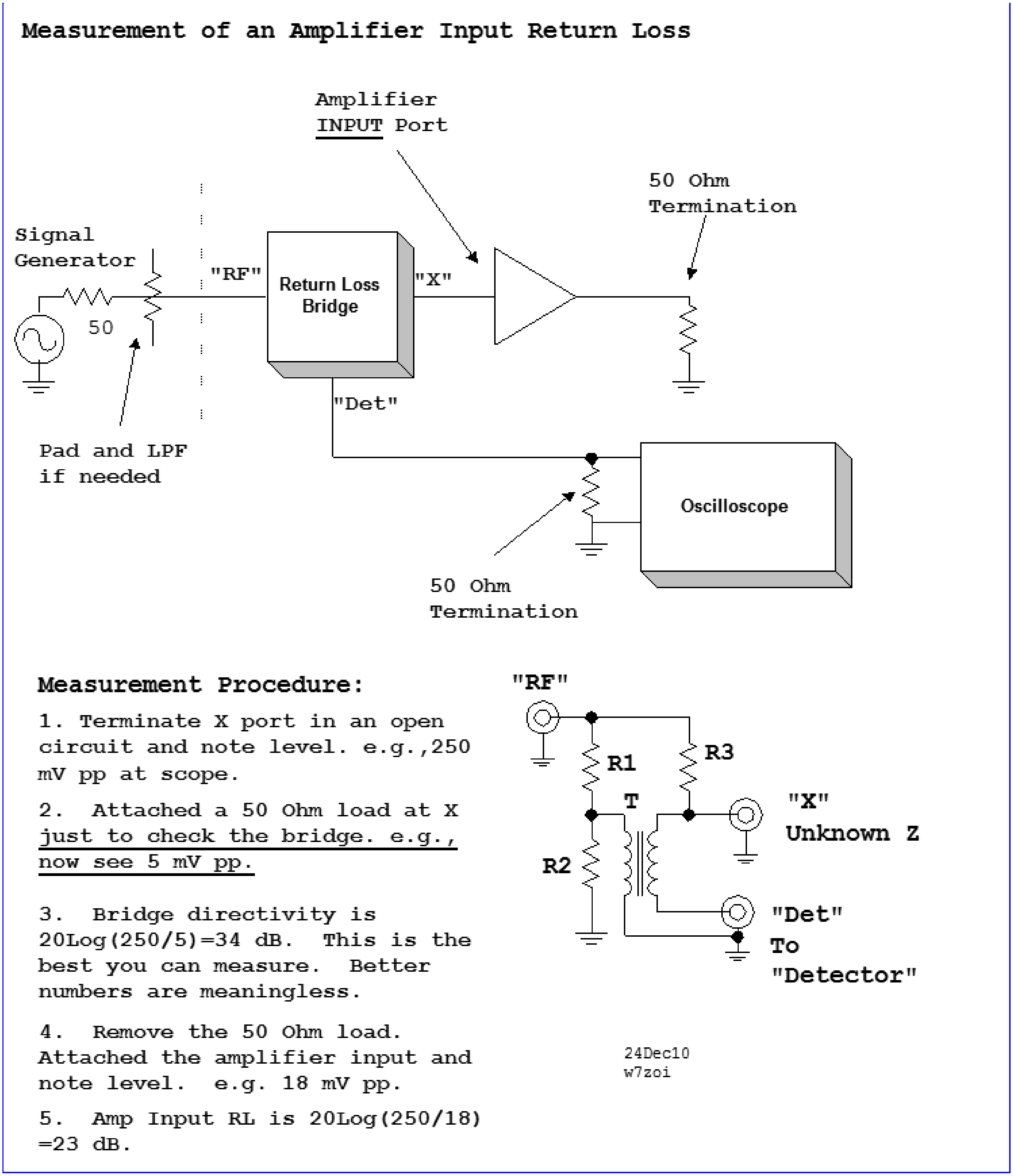

Amplifier
INPUT Port
50 Ohm
Termination
Signal
Generator
50
"RF"
Return Loss
Bridge
"X"
"Det"
Pad and LPF
if needed
Oscilloscope
50 Ohm
Termination
"RF"
R1
R3
T
R2
"X"
Unknown Z
"Det"
To
"Detector"
24Dec10
w7zoi

Measurement of an Amplifier Input Return Loss

Measurement Procedure:

1. Terminate X port in an open circuit and note level. e.g.,250 mV pp at scope.

2. Attached a 50 Ohm load at X just to check the bridge. e.g., now see 5 mV pp.

3. Bridge directivity is 20Log(250/5)=34 dB. This is the best you can measure. Better numbers are meaningless.

4. Remove the 50 Ohm load. Attached the amplifier input and note level. e.g. 18 mV pp.

5. Amp Input RL is 20Log(250/18) =23 dB.

Above — Measure the return loss input of an amplifier. You'll need at least one 50 ohm BNC feed-through terminator on your bench to test amplifiers with wired-in BNC connectors (such as on this amp); else just solder a 47, 49.9 or 51 ohm resistor from the amplifier output to ground. The BNC connectors allow you to quickly and solderlessly interface components such as filters, attenuators, oscilloscopes or **50 Ω** signal generators.

A typical amp measurement work flow may go something like this: Measure gain using a signal generator and the 50 ohm terminated scope; add the bridge and measure input return loss; finally, flip the amplifier around and measure output return loss. All 3 functions can be performed in 2

— 5 minutes including time to drink coffee + perform calculations by computer or with a HP scientific calculator.

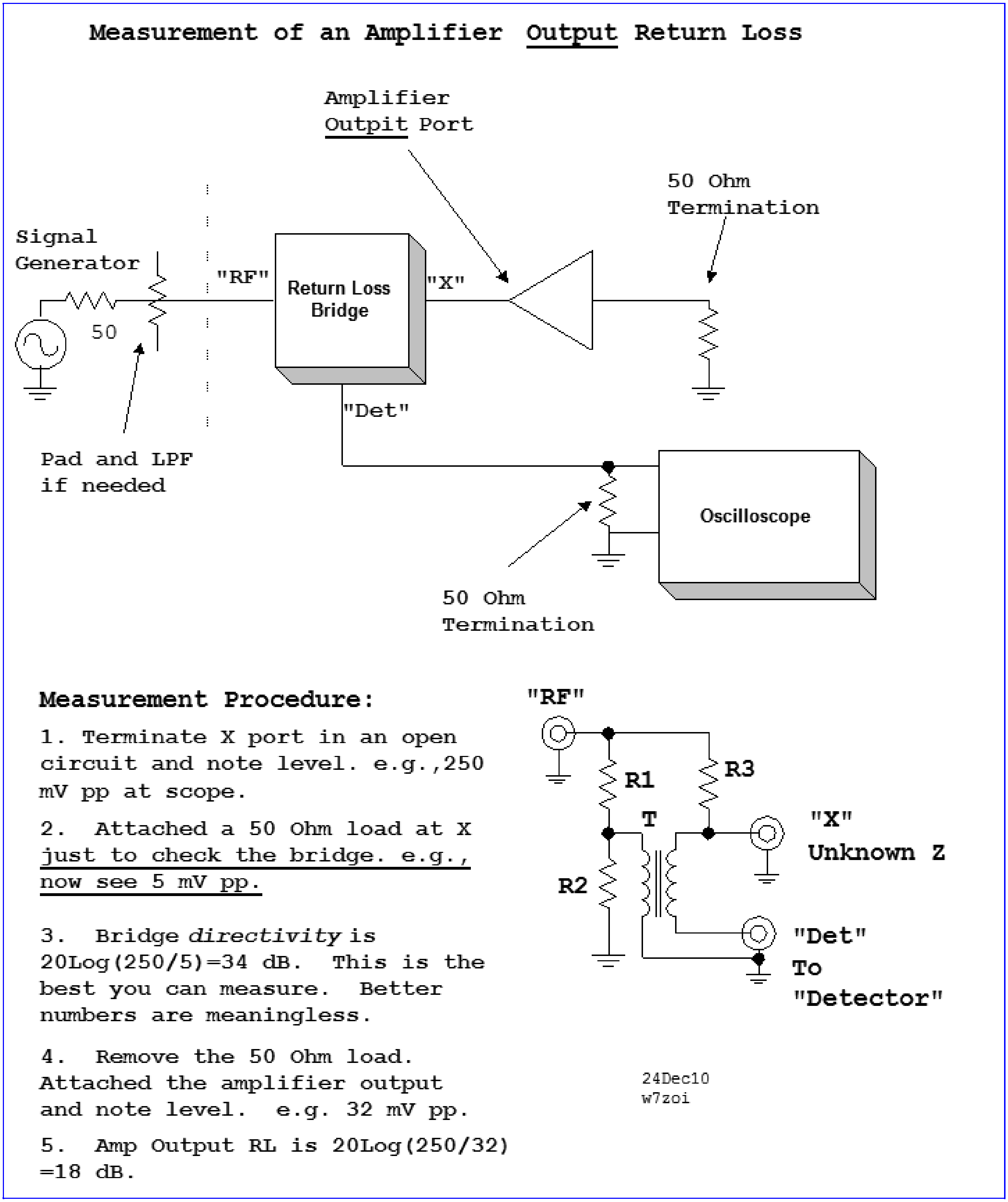

Measurement of an Amplifier Output Return Loss

Amplifier
Outpit Port
50 Ohm
Termination
Signal
Generator
50
"RF"
Return Loss
Bridge
"X"
"Det"
Pad and LPF
if needed
Oscilloscope
50 Ohm
Termination
"RF"
R1
R3
T
R2
"X"
Unknown Z
"Det"
To
"Detector"
24Dec10
w7zoi

Measurement Procedure:

1. Terminate X port in an open circuit and note level. e.g.,250 mV pp at scope.

2. Attached a 50 Ohm load at X just to check the bridge. e.g., now see 5 mV pp.

3. Bridge *directivity* is 20Log(250/5)=34 dB. This is the best you can measure. Better numbers are meaningless.

4. Remove the 50 Ohm load. Attached the amplifier output and note level. e.g. 32 mV pp.

5. Amp Output RL is 20Log(250/32) =18 dB.

Above — Measure the return loss output of an amplifier. The above 2 procedural diagrams provided by Wes, W7ZOI. Many thanks to Wes. These figures are copyrighted © by Wes Hayward, 2010.

Your signal generator should have a return loss of at least 20 dB for greatest accuracy — all of my bench test generators have at least 30 dB of return loss. If you have a signal generator with a low impedance output and place a 10 dB attenuation pad on the output, you'll have at least 20 dB of return loss.

In the above figures, Wes gives an open circuit return loss of 250 mV; I set my signal generator output so the open return loss is somewhere between 170 and 250 mV; this allows you to accurately measure a really good 50 ohm return loss at >= 5 mV or so. Some people may have trouble going any lower than 5 mV due to scope accuracy. This is just something to consider.

Bench Exploration

For me at least, a special case of return loss measurement exists; measuring the return loss of a local oscillator. Since the oscillator under test must be *on* during measurement, it's emitting a signal at the same frequency as the bridge signal generator and interferes with measurement. If some 50 ohm attenuation is added to reduce the local oscillator under test output signal amplitude, this increases the return loss of the local oscillator under test. This is normally a good thing, however, we seek the **raw** output return loss or output impedance of the local oscillator under test.

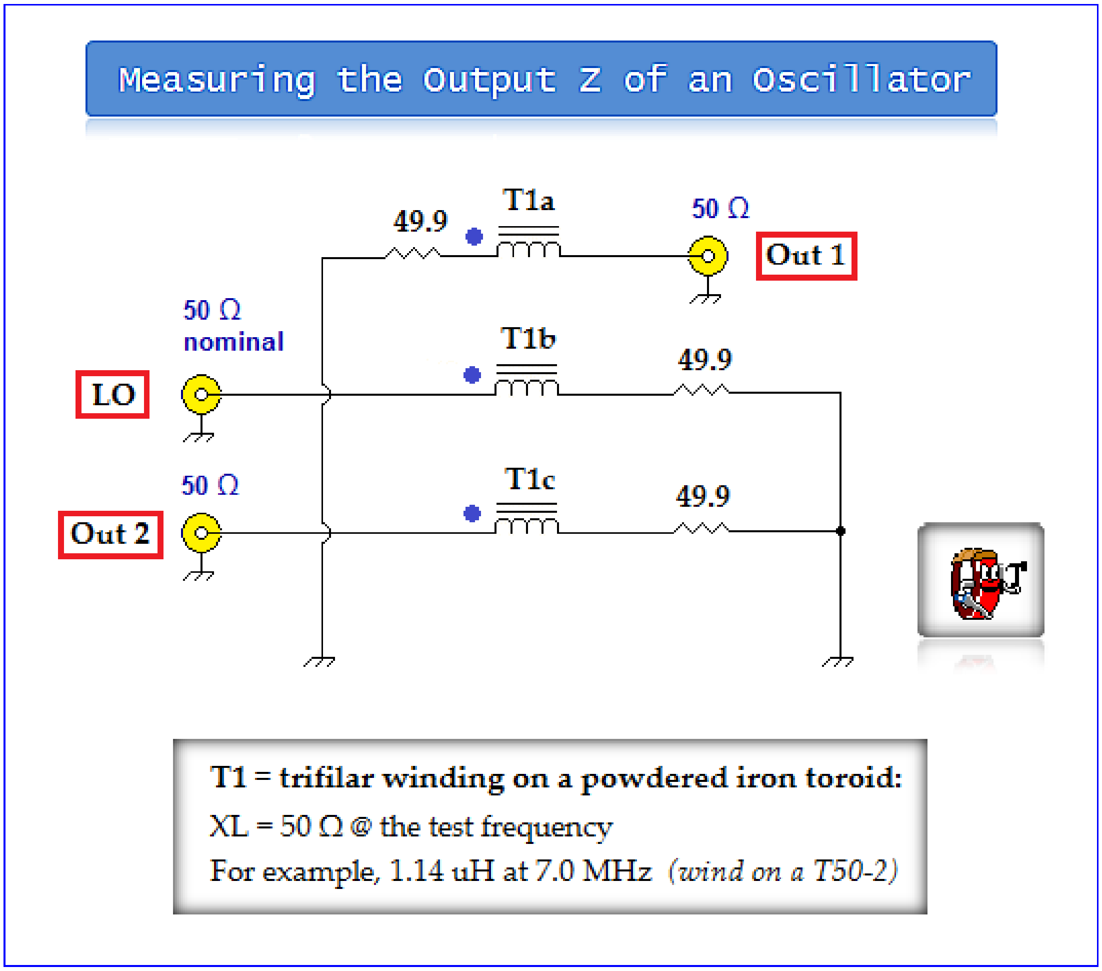

Measuring the Output Z of an Oscillator

T1 = trifilar winding on a powdered iron toroid:
XL = 50 Ω @ the test frequency
For example, 1.14 uH at 7.0 MHz *(wind on a T50-2)*

Above — An initial experiment that a builder from Michigan, USA and I first used to measure the output impedance of a local oscillator consistent with the breadth and scope of this web site. We wanted something simple and wished to avoid building a vector network analyzer or performing ugly algebra. I built a simple crystal oscillator for 7.0 MHz using an output transformer wound to give a low impedance output. The circuit was measured and calculated using the instrument above and the formula and procedure below.

The calculated output Z was 33.2 ohms. I build a standard value resistor 6 dB attenuator pad from this table. After fitting the pad, I re-measured and re-calculated the output impedance at 46.8 ohms. This seemed okay. I built a couple of oscillators for other frequencies and the output impedances were hundreds of ohms! — disappointing. Still, we were on the bench in a solution-focused mode and needed to try something else.

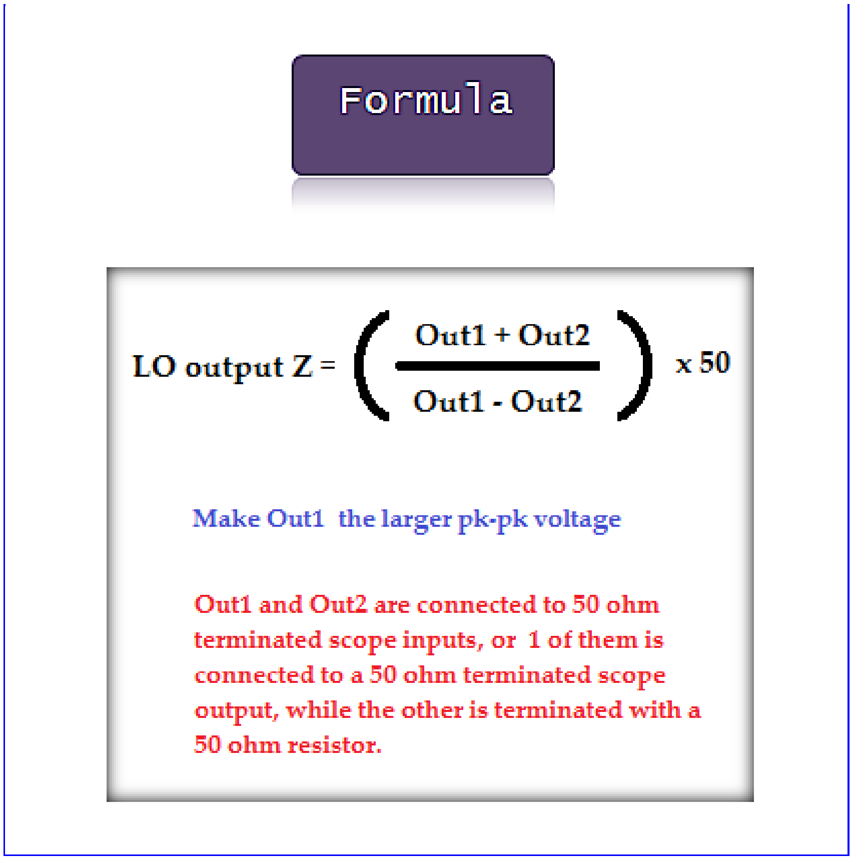

Formula

$$\text{LO output Z} = \left(\frac{\text{Out1} + \text{Out2}}{\text{Out1} - \text{Out2}} \right) \times 50$$

Make Out1 the larger pk-pk voltage

Out1 and Out2 are connected to 50 ohm terminated scope inputs, or 1 of them is connected to a 50 ohm terminated scope output, while the other is terminated with a 50 ohm resistor.

Above — The formula for calculating the output impedance with the *experimental* local oscillator output Z device.

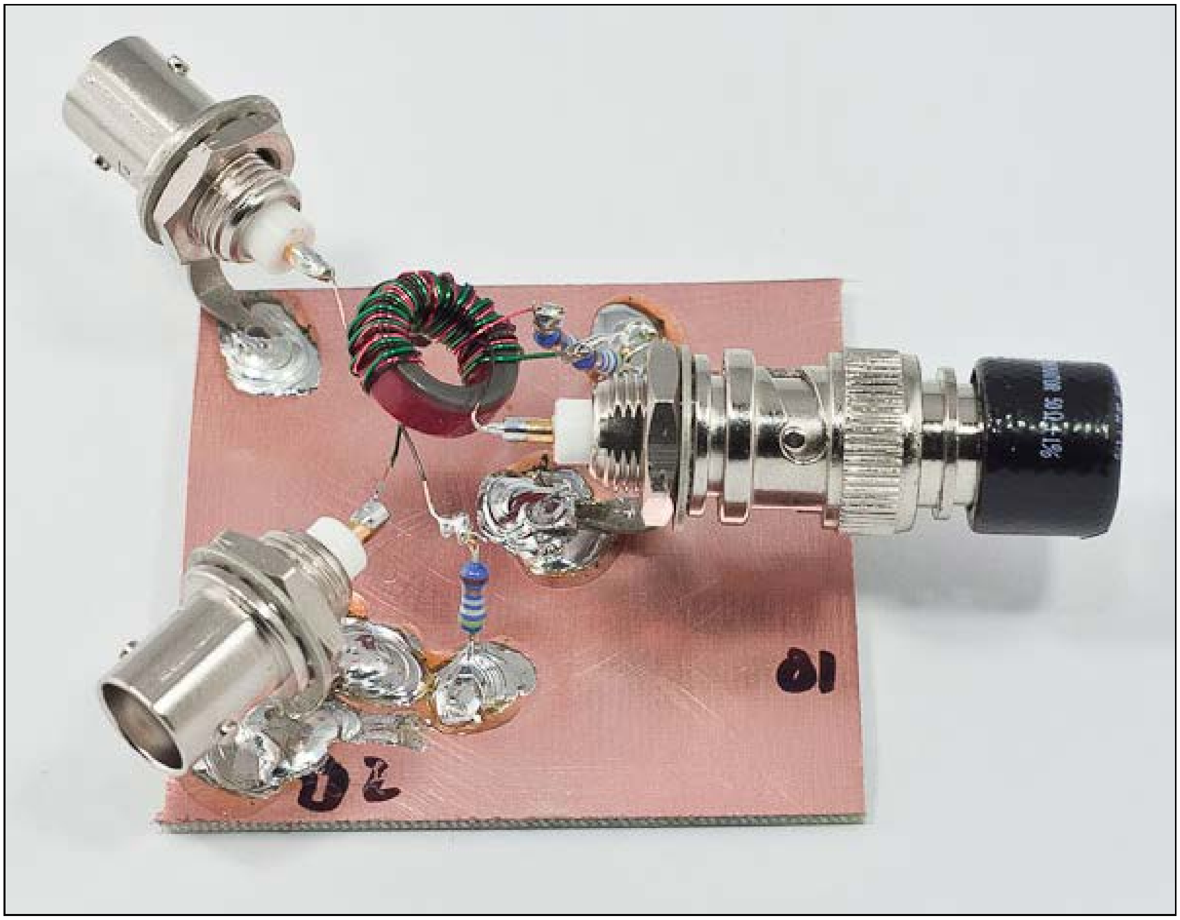

Above — Breadboard of the experimental L.O. output impedance bridge with a 50 ohm feed-through terminator on the Output 1 port. It failed to work as expected. Skillful adult problem solving goes something like this:

1. Identify the problem.
2. Brainstorm to generate some potential solutions.
3. Try out one of your ideas.
4. If that doesn't work, try another idea.
5. If none of your ideas work, wait a while, or ask an expert.

Well, we ran out of ideas and decided to ask experts for some more ideas; Professor Kuhn and Wes, W7ZOI.

I'll share their key messages. First, accurately measuring the output impedance of an RF oscillator can be difficult — measuring the return loss of a buffer amplifier is much easier. For this, some builders run the bridge signal generator on a slightly different frequency than the oscillator under test while using a spectrum analyzer as the 50 ohm RLB detector.

Another way is to short circuit the tank on the oscillator and measure the buffer output in the normal way — a popcorn solution indeed!

We tried calculating oscillator output impedance using different equations and 1 example is shown below. Failing to account for inductive and/or capacitive reactance plus resistance in the output circuit (including the transformer), plus upsetting the circuit during AC voltage measurement adds uncertainty to calculations — measurement seems more reliable.

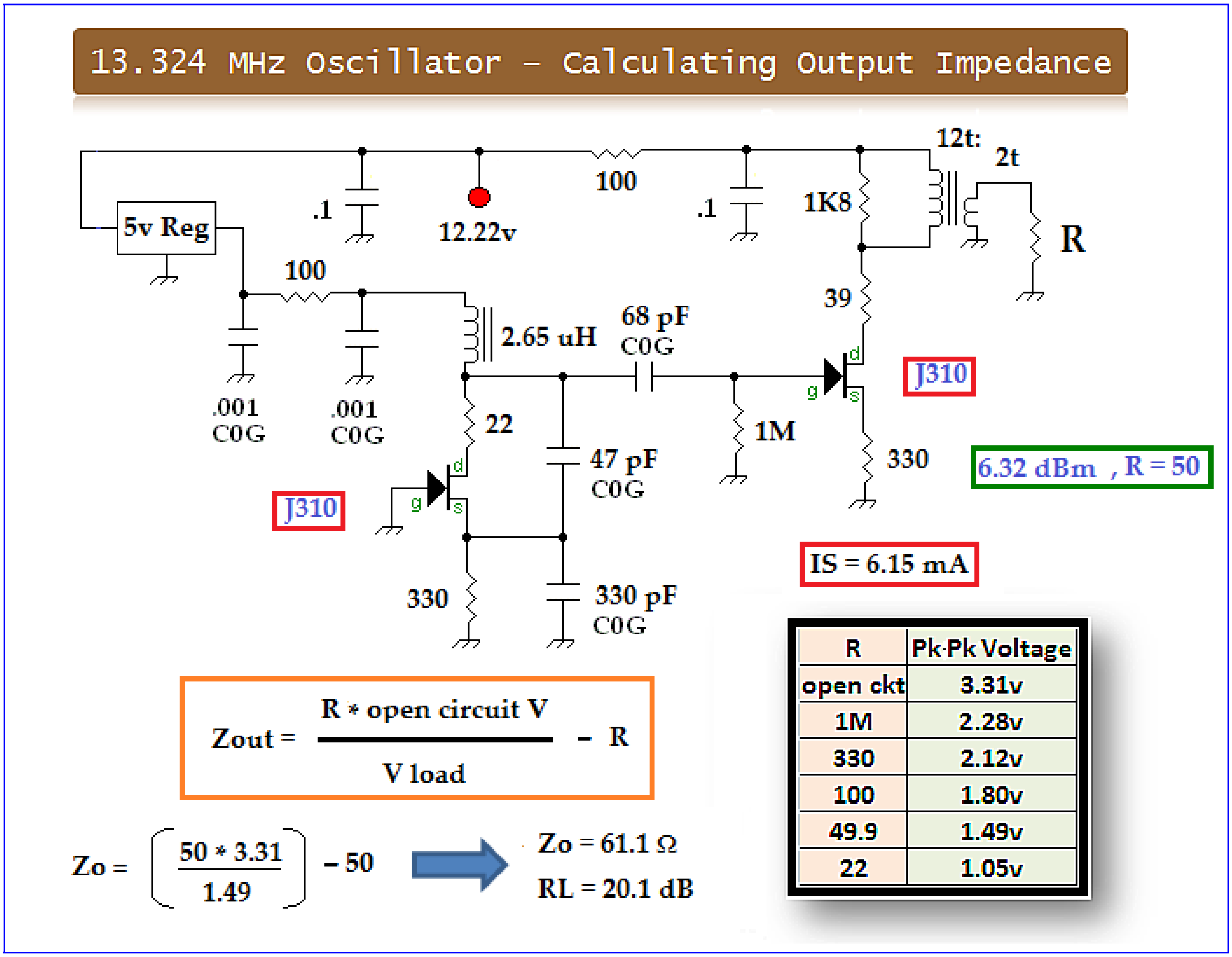

13.324 MHz Oscillator – Calculating Output Impedance

$$\text{Zout} = \frac{\text{R} * \text{open circuit V}}{\text{V load}} - \text{R}$$

R	Pk-Pk Voltage
open ckt	3.31v
1M	2.28v
330	2.12v
100	1.80v
49.9	1.49v
22	1.05v

$$\text{Zo} = \left(\frac{50 * 3.31}{1.49}\right) - 50 \Rightarrow \text{Zo} = 61.1\ \Omega$$

$$\text{RL} = 20.1\ \text{dB}$$

Above — One method of calculating output impedance. Running the output at open-circuit likely effects the oscillator by changing its load despite having the JFET buffer. Some builders use this equation for calculating the output impedance in their audio amplifiers. This amplifier **should** have a 50 ohm output impedance based upon the transformer turns ratio and the 1K8 resistor across transformer: 1800:50 ohms = a 36:1 impedance ratio and a 6:1 turns ratio.

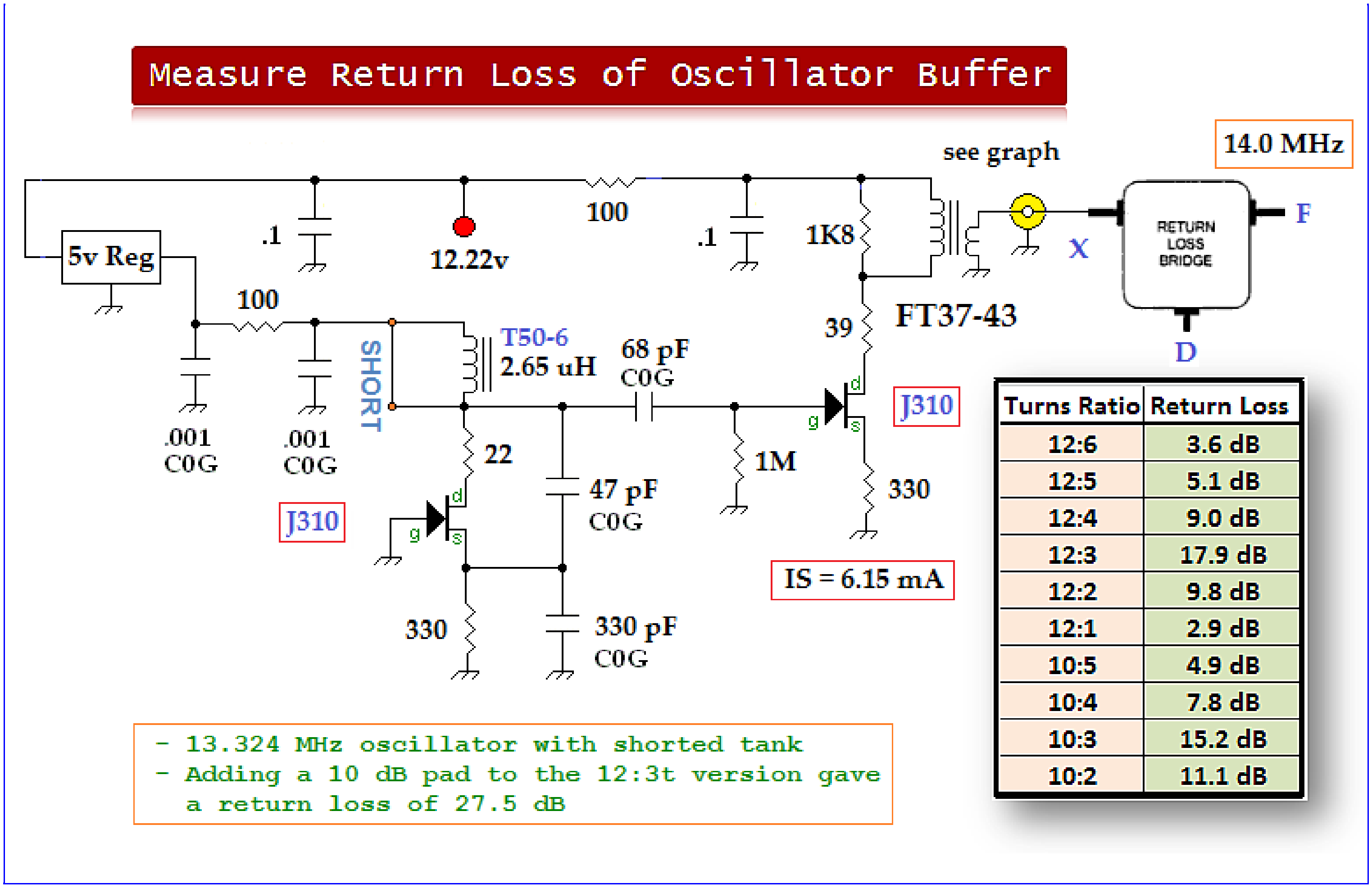

Measure Return Loss of Oscillator Buffer

see graph
14.0 MHz
5v Reg
.1
12.22v
100
.1
1K8
X
RETURN LOSS BRIDGE
F
D
FT37-43
100
39
SHORT
T50-6
2.65 uH
68 pF
C0G
J310
d
g
s
.001
C0G
.001
C0G
22
1M
330
J310
d
g
s
47 pF
C0G
IS = 6.15 mA
330
330 pF
C0G

Turns Ratio	Return Loss
12:6	3.6 dB
12:5	5.1 dB
12:4	9.0 dB
12:3	17.9 dB
12:2	9.8 dB
12:1	2.9 dB
10:5	4.9 dB
10:4	7.8 dB
10:3	15.2 dB
10:2	11.1 dB

- 13.324 MHz oscillator with shorted tank
- Adding a 10 dB pad to the 12:3t version gave a return loss of 27.5 dB

Above — A simple 13.3 MHz L-C oscillator was built and evaluated. After shorting the tank coil, return loss versus turns ratio was measured and tabled as shown. To my surprise, I observed the best match with a 4:1 turns ratio. This suggested that the transformer, wound on a ferrite FT37-43 toroid was exhibiting high resistance and far from the "ideal transformer". The inductance of my 12 turn transformer was 38.3 uH.

The initial secondary winding had 6 turns and then was reduced sequentially by 1 turn. After removing each turn, the 1/2 cm of increased wire length was cut off and the enamel scraped off of the new wire ending to ensure a short connection to the output jack. During measurement, unless the secondary transformer wires were kept tidy, a ~40 MHz oscillation occurred when the 1K8 resistor was disconnected. The 1K8 resistor prevented such oscillations and improved the return loss by 1-4 dB at the various turns ratios. Testing frequency was 14 MHz.

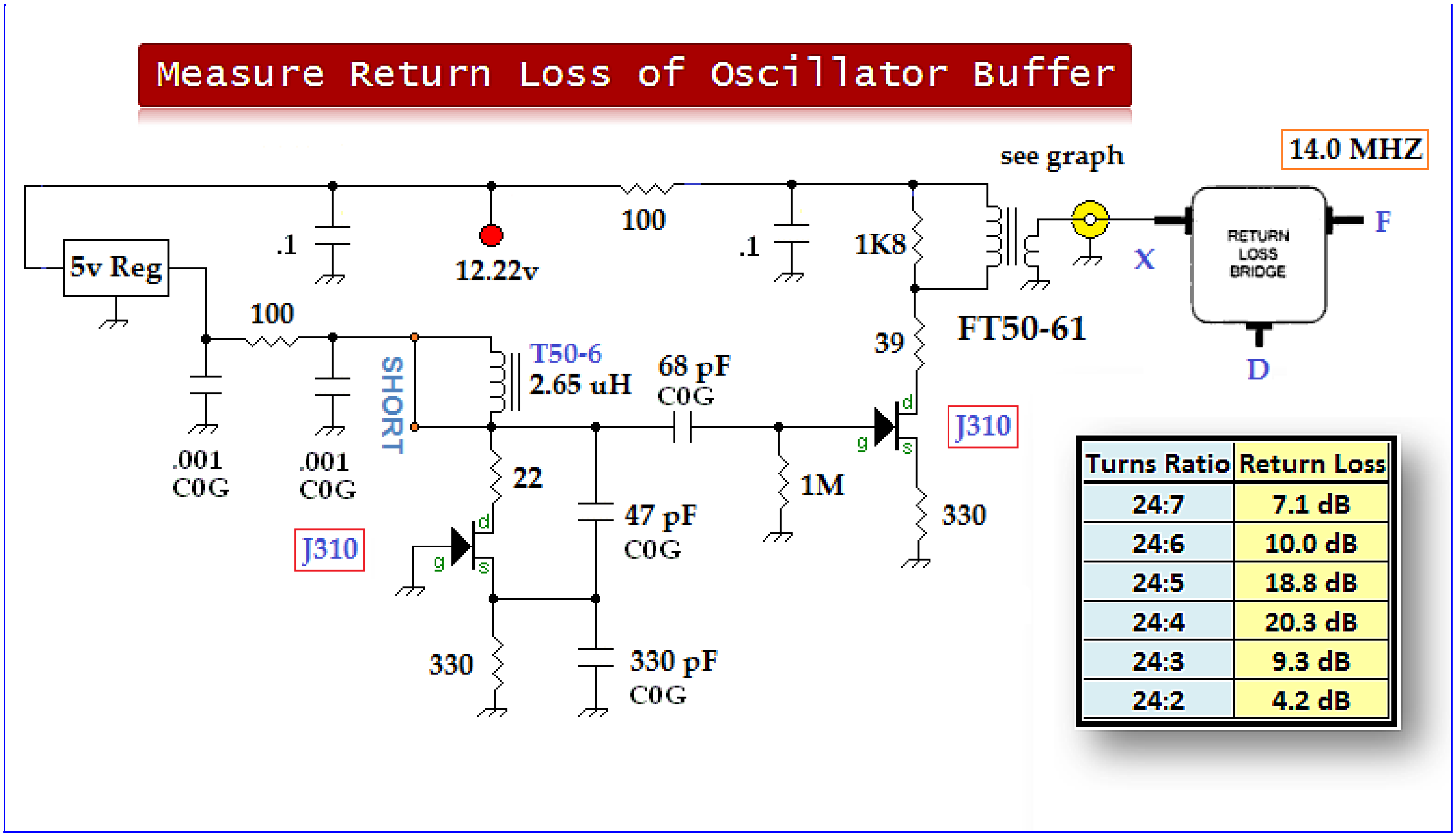
Measure Return Loss of Oscillator Buffer
see graph
14.0 MHZ
5v Reg
.1
12.22v
100
.1
1K8
X
RETURN LOSS BRIDGE
F
D
100
FT50-61
39
SHORT
T50-6
2.65 uH
68 pF
C0G
J310
g
d
s
.001
C0G
.001
C0G
22
1M
330
J310
47 pF
C0G
330
330 pF
C0G

Turns Ratio	Return Loss
24:7	7.1 dB
24:6	10.0 dB
24:5	18.8 dB
24:4	20.3 dB
24:3	9.3 dB
24:2	4.2 dB

Above — The same circuit with a lower-loss, FT50-61 ferrite transformer. I could have used a FT37-61, but prefer the 50-61 as the bigger core allows the use of heavier wire which provides some robustness when performing intensive experiments. The inductance of 24 turns on a FT50-61 measured 36.2 uH. Although lower permeability ferrite toroids require more windings, this transformer is closer to the "ideal transformer" than that wound on a FT37-43 ferrite core — a 6:1 turns ratio gave the best return loss; the output Z is pretty close to 50 ohms.

The information garnered during these tests proved enlightening and reinforces why bench measurement provides the greatest way to learn about and optimize your circuits. I hope this simple web page on return loss measurement fuels your own experiments — the most important experiments will be those *you* do on *your* bench.

Miscellaneous Figures and Photos

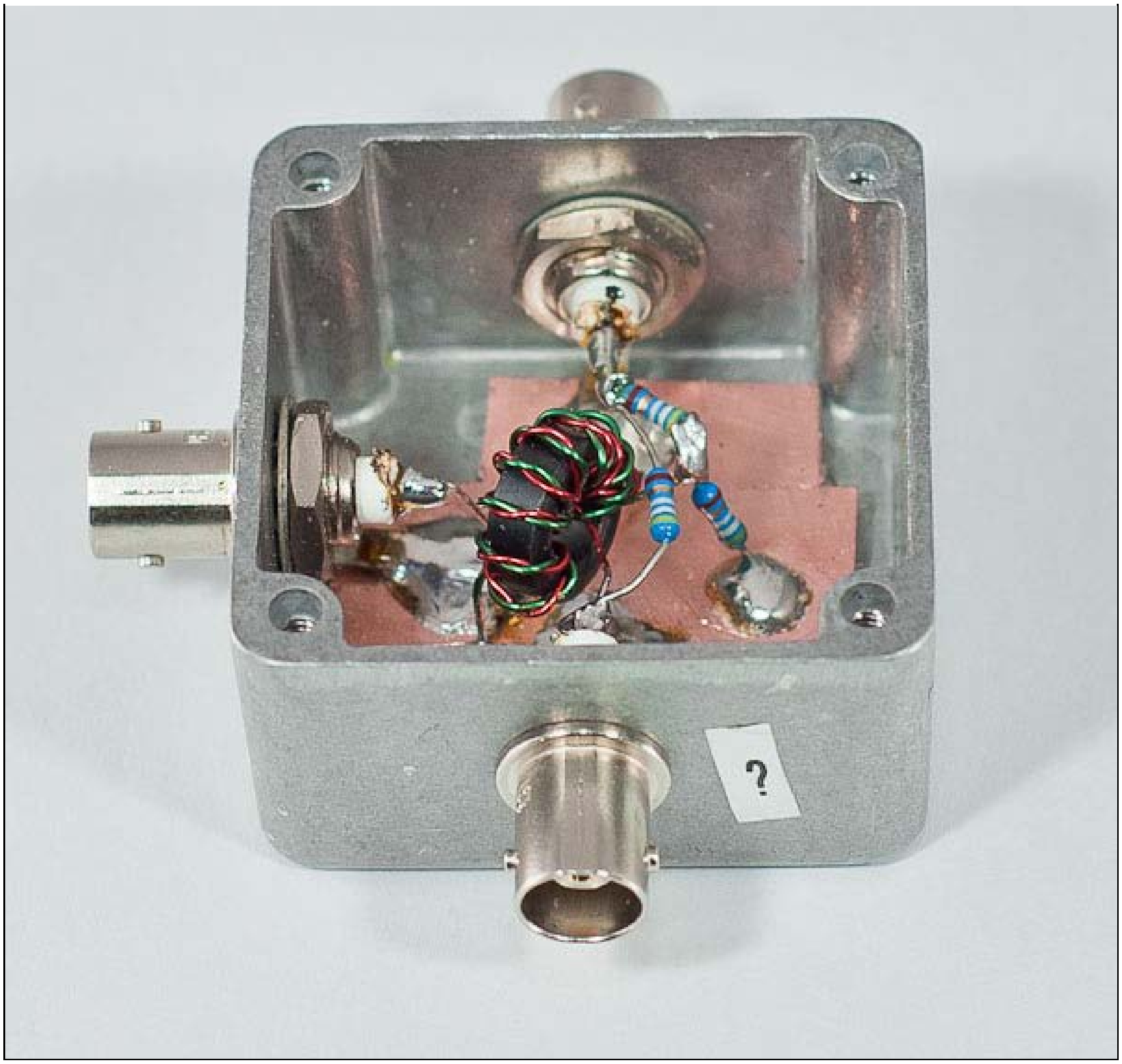

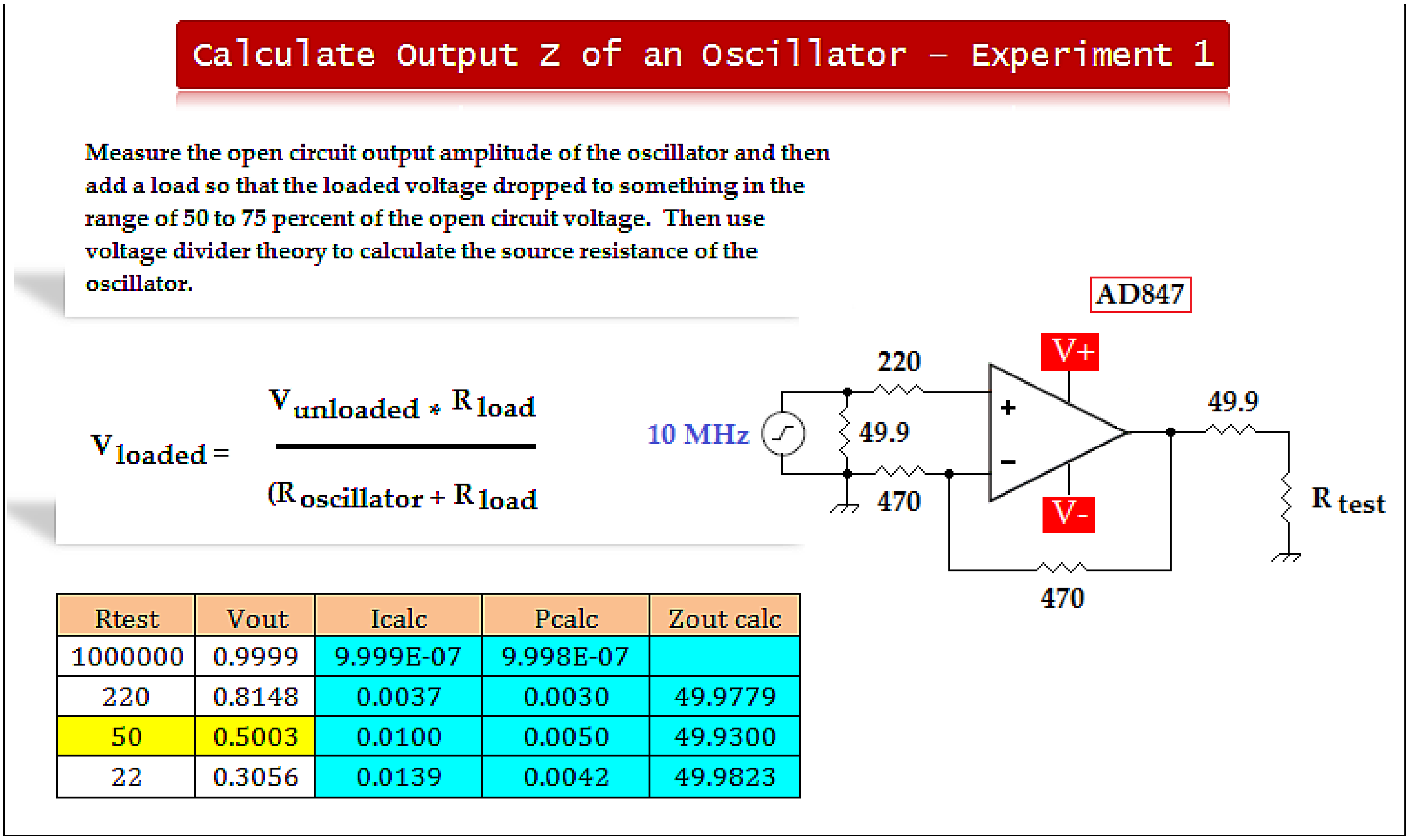

Calculate Output Z of an Oscillator – Experiment 1

Measure the open circuit output amplitude of the oscillator and then add a load so that the loaded voltage dropped to something in the range of 50 to 75 percent of the open circuit voltage. Then use voltage divider theory to calculate the source resistance of the oscillator.

$$V_{loaded} = \frac{V_{unloaded} * R_{load}}{(R_{oscillator} + R_{load}}$$

Rtest	Vout	Icalc	Pcalc	Zout calc
1000000	0.9999	9.999E-07	9.998E-07	
220	0.8148	0.0037	0.0030	49.9779
50	0.5003	0.0100	0.0050	49.9300
22	0.3056	0.0139	0.0042	49.9823

RF — Test and Measurement

Miscellaneous RF Topics 2011

Introduction

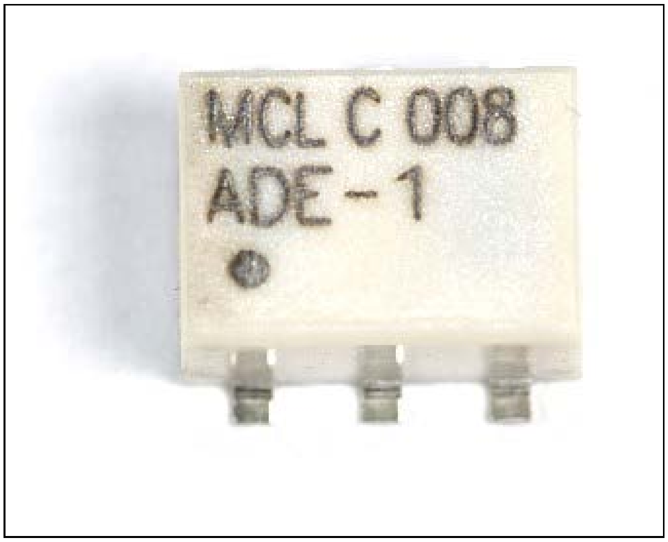

My basic goal for Fall and Winter 2010 was to fearlessly advance my RF design ability — pushing just beyond my comfort zone to impose the psychological stress that promotes focused learning. You may have experienced this in University or when working against a deadline. Cramming, "burning the midnight oil", or locked room brainstorming exemplify this approach.

These circuits feature carefully measured input and output impedances (nominal impedance = 50 Ω), plus voltage gain and DC current.

This web site spawns email with builders worldwide. Our interactions are varied; getting help, giving help — or just chat. On occasion, I design, build and/or test circuits to help struggling builders. After spending considerable time, I email them my work hoping it will help. Often enough, I never receive any acknowledgement from these readers — did the circuit work or did they appreciate I spent 1-2 hours researching their concern?. This is actually normal — we must constantly strive to overcome our innate, self-centered nature; lest it dominate our behavior. все нормальные.

To that point, I wish to gratefully acknowledge the people who support me in this hobby: Wes, Ken, Scott, Peter, Tom and the many others whose email advice and published and private work informs and inspires me.

Topics:

1. Transmit Mixer Experiments
2. Bipolar Transistor Feedback Amplifier Experiments
3. JFET Common Gate Transistor Amplifier Experiments

Navigation and Preamble:

This web page grew into a large monster — and includes a supplemental web page with numbered topics referenced in the text. I apologize for the navigation difficulties this web page poses. Equal time was spent experimenting with the circuit designs and circuit photography. I strive to provide a variety of bitmap and photographic image styles on this web site.

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1. Transmit Mixer Experiments

Since I've never experimented with transmit mixers, I didn't appreciate how much time goes into their design. Consider, for example, the LO system from the project entitled A Monoband SSB/CW Transceiver in Chapter 6 of EMRFD. The mega low (about -20 dBm) output from a diode ring mixing a VFO and crystal oscillator is triple tuned band-pass filtered and then amplified to +8 dBm. Continuing on, the transmitter chain features more mixing, band-pass filtering and voltage amplification by a feedback amplifier chain boosting the signal to around 300 mW. The circuits needed to mix, filter and amplify this RF chain would challenge most amateur designers — me included.

Contrast this with a typical first transmitter built by a new builder. Likely your first scratch homebrew transmitter consisted of a crystal oscillator, a keyed Class A buffer/amplifier and perhaps a Class C final amplifier. No mixer was needed for we obtained a crystal cut on the frequency of choice. Our focus was **power**— getting 0.25 to 1 watt into our antenna system! A good example was the Tuna Tin 2 transmitter by the late Doug DeMaw, W1FB that only used 2 stages. Although Doug wrote his 1976 article for Hams to build a transmitter from parts found at home, kitted versions are sold today.

Returning to transmit mixers — as amateur designers, we likely need to start on a small portion of the transmit chain and then after developing some competency, slowly extend our experiments all the way to the antenna port. In Fall 2010, I just examined some basic transmit mixing to get a feel for what's involved and what to expect. Mixing signals is a complex affair encompassing topics such as intercept point, conversion gain or loss, image noise suppression, noise figure, spurious/intermodulation products and port isolation. To keep things simple, only mixer port isolation and reducing spurious mixer products were examined.

Before beginning, I express the following concern: We experimenters, as stewards of the airwaves, must build exemplary transmitters with very low spurious outputs. I follow the example of Wes, W7ZOI and others — my transmit chains have spurious frequencies at least 50-60 dB down from the carrier (dBc). As a web author and radio amateur, I never want to directly or indirectly contribute to RFI and hope you agree.

Why Use a Transmit Mixer?

If you plan to design a superheterodyne based transceiver, you'll probably need to use a transmit mixer. Also mixing 2 frequencies permits using cheap microprocessors crystals to target a desired transmit frequency; separate crystal oscillators drive the RF and LO ports of the mixer. For added flexibility, the LO can be converted to a VFO once you have the basic design working well.

I purchased a bag of low cost crystals. By mixing 2 appropriate crystals, output on a Ham band is possible. For example, crystals at 2.048 + 5.0688 MHz = 7.117 MHz; 4.194 + 11.228 MHz = 7.034 MHz; and 3.932 + 11.046 MHz = 7.114 MHz. I frequently operate QRP on 40 Meters in the USA Novice band, so 7.114, or 7.117 MHz is okay. This helps CW operators avoid all the RTTY and QRM down in the traditional 40M band QRP frequency window.

Some Mixer Bullets

Mixers have 3 conventionally named ports; RF, LO (local oscillator) and IF (output).

The diode ring mixers presented are Level 7 mixers. Maximal LO power is 7 dBm.

Many builders limit the maximum RF power into a Level 7 diode ring transmit mixer RF port to between 0 to -3 dBm.

The term *isolation* refers to the amount of LO power that leaks into the RF or the IF ports.

Low-pass filtering the LO *can* significantly reduce harmonic products in a mixer

The top of the spectrum analyzer screen (always the top, and never the bottom) is called the reference level. That is the power at the top. If you have a signal generator with the output adjusted to be -27 dBm and pass this signal into the spectrum analyzer and adjust the attenuation in the analyzer to put that signal at the top of the screen, you then the reference level is -27 dBm. *(Pertains to examining a mixer output in a SA)*

Choosing a Mixer

A number of mixers were considered; passive, active, unbalanced, single-balanced and finally, double-balanced. The diode ring mixer is an obvious good choice commensurate with my goals of reducing spurs, LO feed through and achieving high port-to-port isolation. In future web pages, other mixers may be presented, however this page is focused on the diode ring mixer. Click for a file with a few scanned pages concerning mixers from my "ideas only" notebook from ~2002. I own over 30 notebooks now.

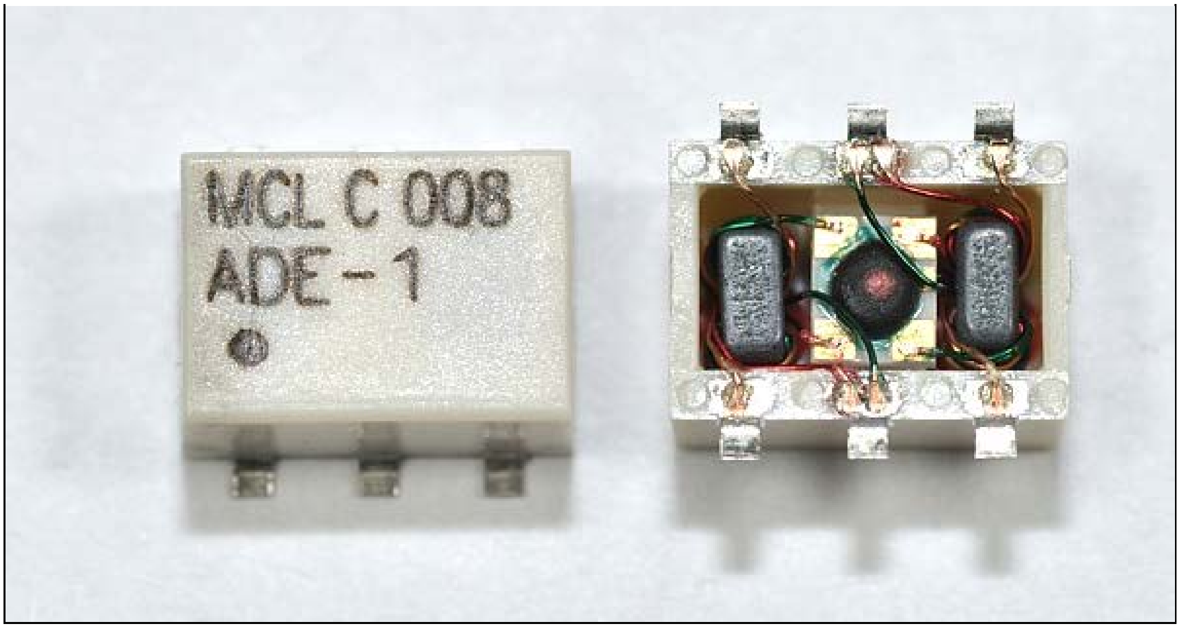
MCL C 008
ADE-1

Above — ADE-1 diode ring mixers. We're using these now as they're cheaper than the SBL-1, TUFF-1 etc. hole-though versions. Although SMT parts, they can be flipped over and wired "normally" with a little effort, steady hands and good vision. Mini-Circuits will sell them in small quantities to Hams; email them and enquire. I feel the diode ring mixer has been misunderstood by some amateur builders — lore and misperceptions that the 7 dBm LO port drive, the need for 50 ohm port terminations, a ~ 5 dB insertion loss and cost make them undesirable. Their excellent performance and design challenges are reasons why we use them; "the journey — not the destination" stuff.

In receiver applications, some builders and kit sellers seem more focused on features such low-battery indicators, digital displays, miniaturization and cost containment than basic receiver performance. Certainly keeping cost down down deserves consideration, however, good mixer performance is king. You'll have to decide what's affordable and important and build accordingly.

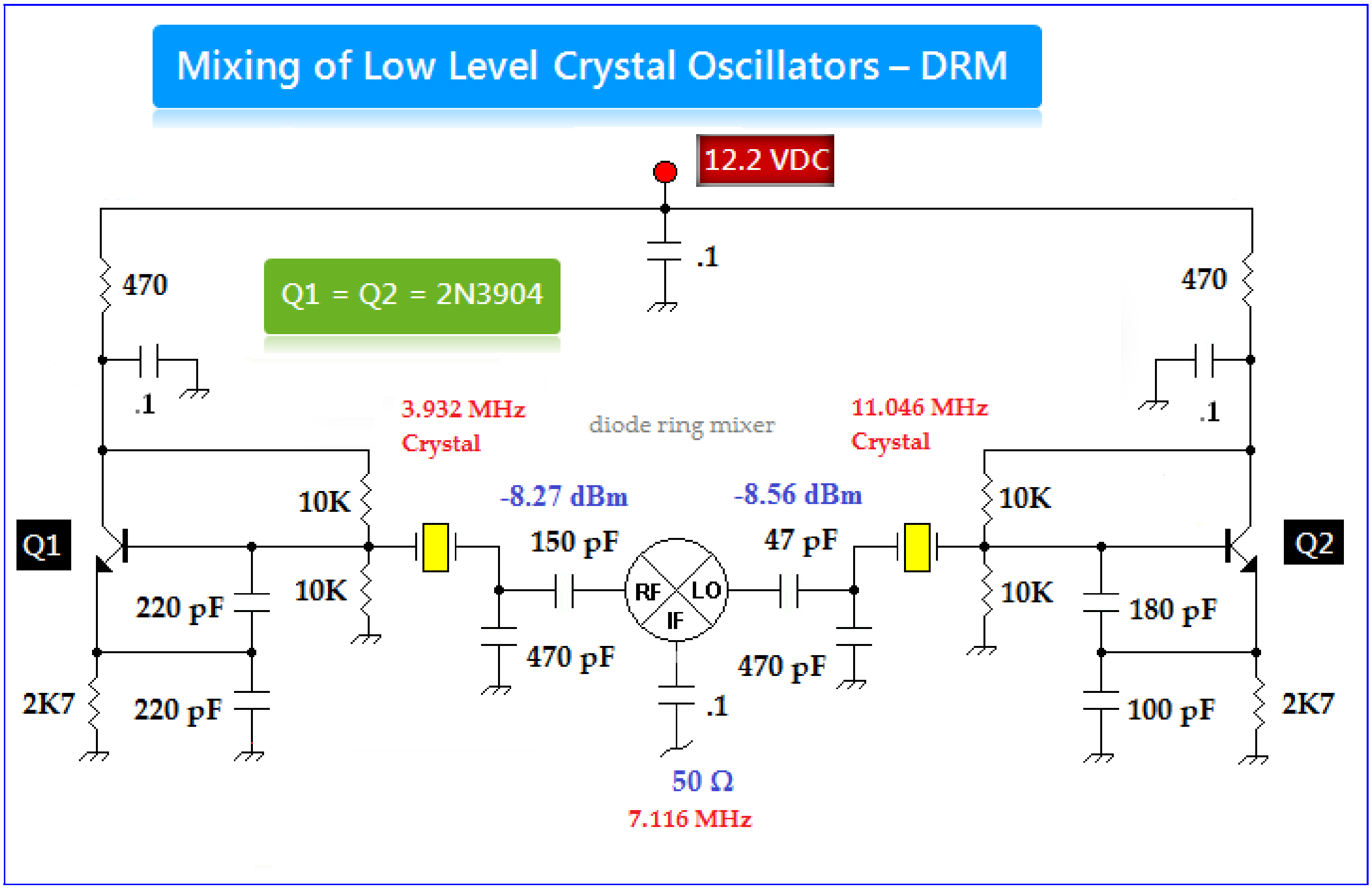
Mixing of Low Level Crystal Oscillators – DRM
12.2 VDC
.1
470
Q1 = Q2 = 2N3904
470
.1
.1
3.932 MHz
Crystal
diode ring mixer
11.046 MHz
Crystal
10K
-8.27 dBm
-8.56 dBm
10K
Q1
150 pF
47 pF
Q2
RF
LO
IF
10K
10K
220 pF
470 pF
470 pF
180 pF
2K7
220 pF
.1
100 pF
2K7
50 Ω
7.116 MHz

Above — My very first transmit mixer experiment. My hope was to build a transmit mixer possessing low spurious output to alleviate the need for stiff, post mixer band-pass filtering such as a triple tuned band-pass filter. Thus, low-level, low distortion output was taken from between each crystal oscillators' shunt capacitor and crystal. The desired output frequency is ~7.114 MHz to build a transmitter for the 40 Meter Ham band.

The mixer output to 50 MHz looked like this in a Spectrum Analyzer. The dominant frequencies are the **sum** and the **difference**: 11.046 **+** 3.932 MHz = **14.98 MHz**; 11.046 **-** 3.932 MHz = **7.114 MHz**. The frequencies realized are *slightly* different since the oscillator output is shifted by crystal variances and from circuit capacitance.

In the experiments that follow, I built some circuits to filter and/or amplify the output of the *above* mixer circuit.

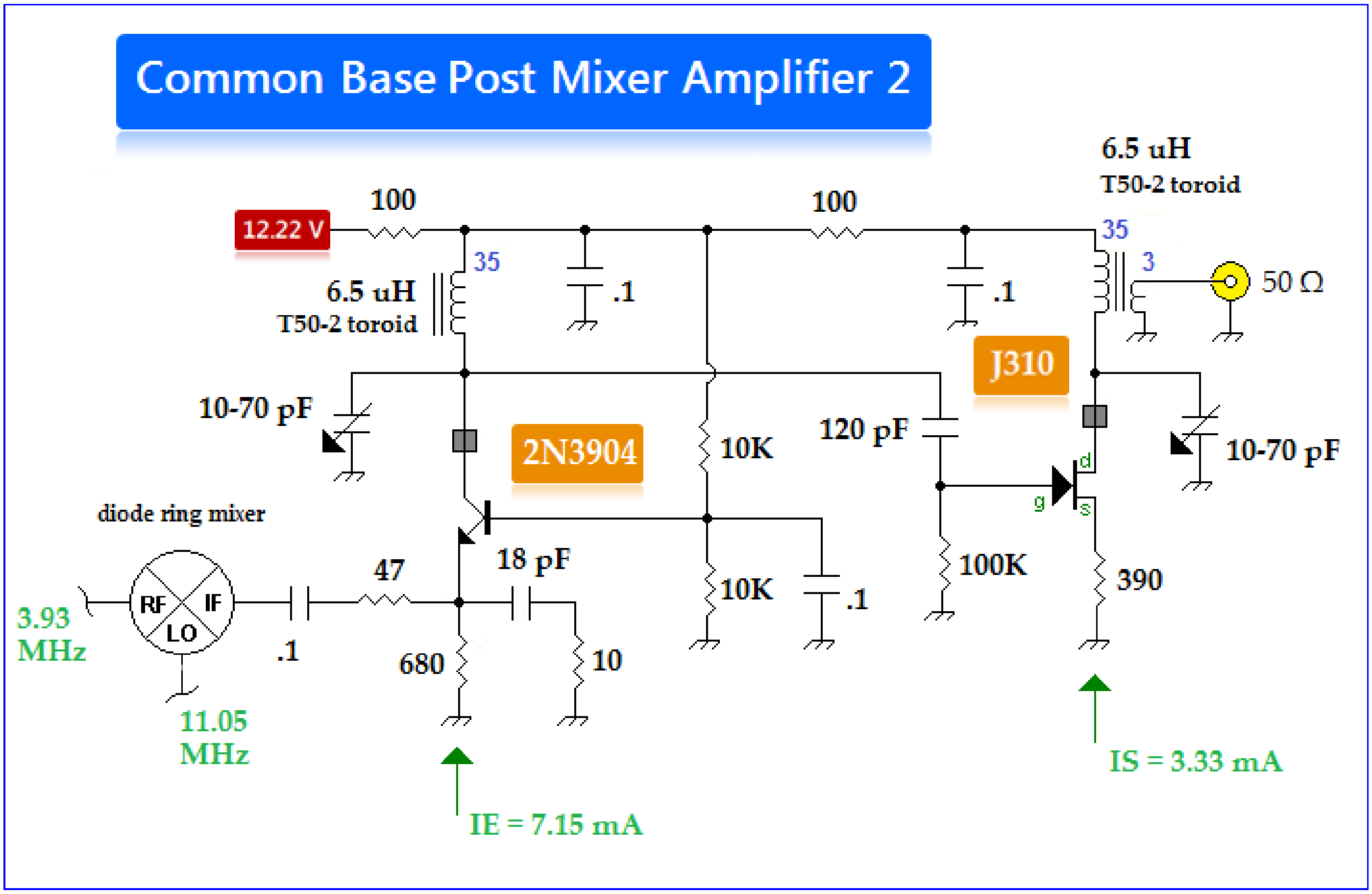

Above — The first post mixer amp; a common base input amplifier that's AC coupled to a common drain FET amp. I hoped that 2 tuned L-C tank circuits could substitute for a passive double or triple-tuned band-pass filter, plus provide some gain.

A broad-band, common base input amp was chosen to properly terminate the diode ring mixer and alleviate the need for a diplexer. A ~50 Ω input impedance is established by a 47 Ω series resistor since the 2N3904s input impedance is quite low due to the moderately high emitter current employed to boost gain and IMD performance.

This amplifier failed to reduce spurious output 50 dB down or greater — my design goal. Here are its scope and spectrum analyzer outputs; please observe that the unwanted 14.98 MHz signal is only 32 dB down from the desire IF of 7.114 MHz. An RC network consisting of a shunt 10 ohm resistor + an 18 pF cap provides additional low-pass filtering above 20 MHz. I attribute this simple filter to Dr. Ulrich Rohde as I have seen it in some of his post mixer, common base RF amplifier designs. Click for a brief supplement regarding his low-pass network ***(#2 RC Low-pass Network on the Supplemental Page)***

The amp design shown above was actually an improved version of this prototype. In the prototype amp, the mixer power at 14.98 MHz was only 23 dB down from the desired intermediate frequency of 7.114 MHz. You can't expect a single L-C tank to well filter a mixer output. Unfortunately, the 1K2 -12K resistor providing DC bias for the emitter follower lowers the Q of the common-base collector tank circuit. 12K is better than 1K2 in this regard. Poor performance sparked the design of the second common base amp shown above.

I use ferrite beads and 51 Ω resistors interchangeably on the collector/drains of amplifiers to snuff out UHF oscillations. According to my experiments, the resistors may work better. I purchased the ferrite beads from Diz. After the common base amplifiers shown above, I decided to try a tuned input + output common gate JFET amp:

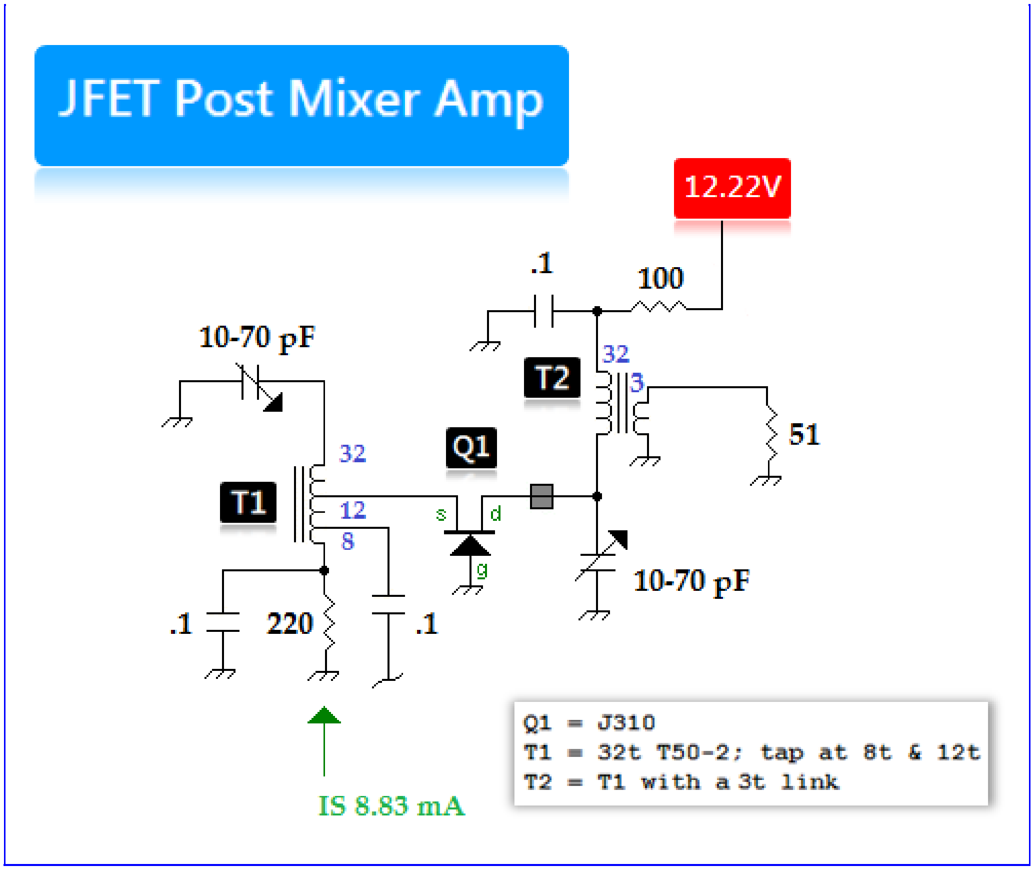
JFET Post Mixer Amp
12.22V
.1
100
10-70 pF
32
T2
3
51
Q1
32
T1
12
8
s
d
g
10-70 pF
.1
220
.1
IS 8.83 mA
Q1 = J310
T1 = 32t T50-2; tap at 8t & 12t
T2 = T1 with a 3t link

Above — A JFET common gate amp with tuned input and output built about 3 years ago. For spectrum analysis. I padded the amplifier output to provide a -28 dBm 7.116 MHz signal. The vertical resolution on the SA is the standard 10 dB/division. As shown, the 14.98 MHz signal is ~ 39 dB down; an improvement over the amplifiers shown previously. This narrow-band amplifier requires a diplexer. I wanted *better* filtering than that offered by amplified circuits with 2 tuned L-C circuits, so I halted this experiment and decided to try a triple tuned band-pass filter.

This JFET circuit experimentation spawned over 8 weeks of experiments concerning common-gate RF amps — some of them appear later.

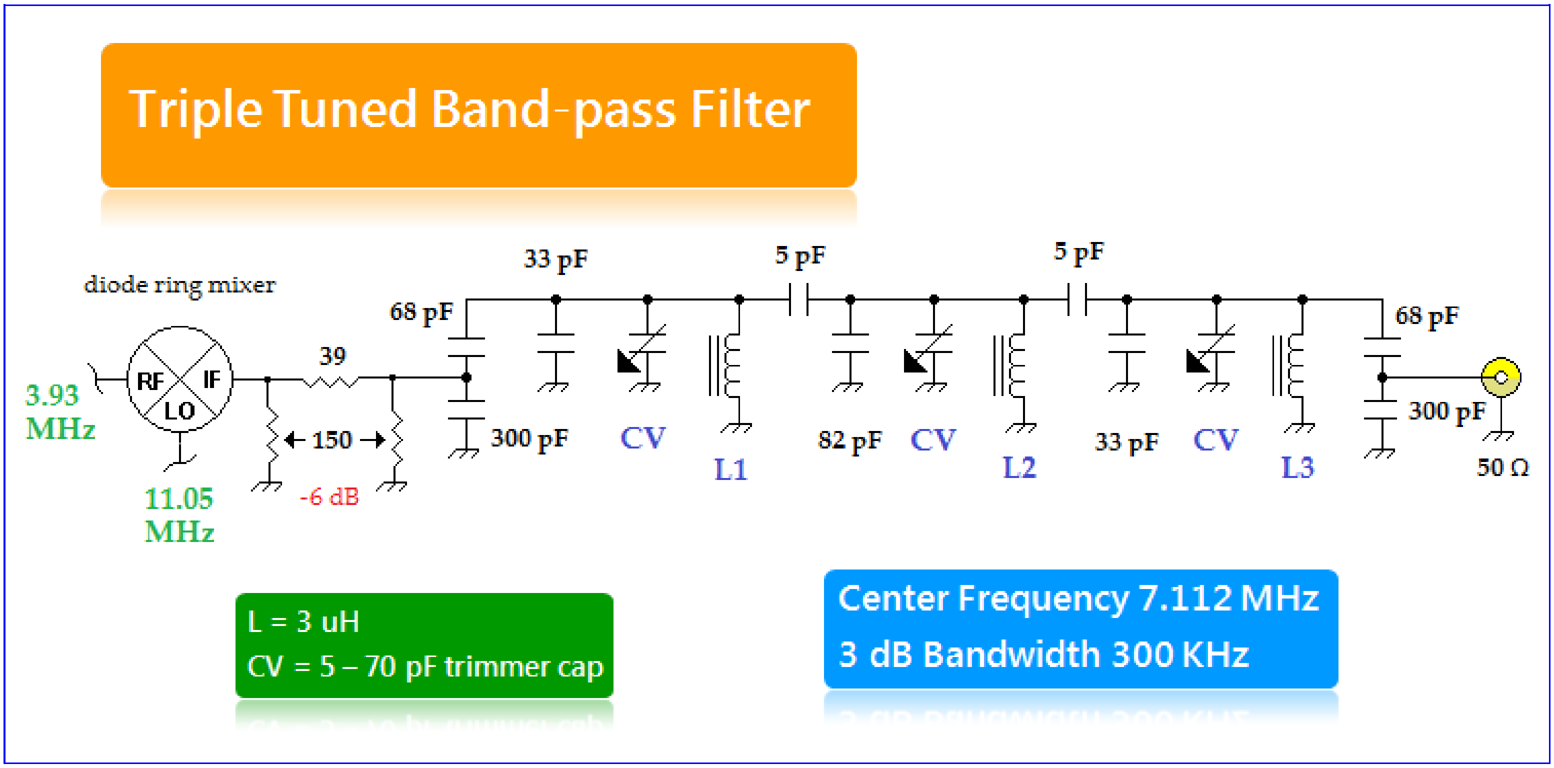
Triple Tuned Band-pass Filter
diode ring mixer
3.93 MHz
RF
IF
LO
11.05 MHz
39
150
-6 dB
68 pF
300 pF
33 pF
CV
L1
5 pF
82 pF
CV
L2
5 pF
33 pF
CV
L3
68 pF
300 pF
50 Ω
L = 3 uH
CV = 5 – 70 pF trimmer cap
Center Frequency 7.112 MHz
3 dB Bandwidth 300 KHz

Above — A triple tuned band-pass filter designed with software from EMRFD called TTC-08. Click for the breadboard photo. The diode ring was connected to the filter input via a 6 dB attenuator pad using short leads. Click for analysis in GPLA. All inductors are 3.0 uH — 23 or 24 turns on a T50-2 powdered iron toroid. I measured all the inductors and obtain the exact desired inductance by expanding or squishing the wire turns, or if necessary, adding (this means rewinding the entire coil) or removing a turn. If you lack an inductance meter, just winding the formula calculated number of turns will be close enough for most applications — I only got a good L- C meter in 2009 and somehow managed.

I learned that the ultimate way to peak a triple tuned filter is by tweaking the tuning capacitors while it's connected to a spectrum analyzer — what a thrill!

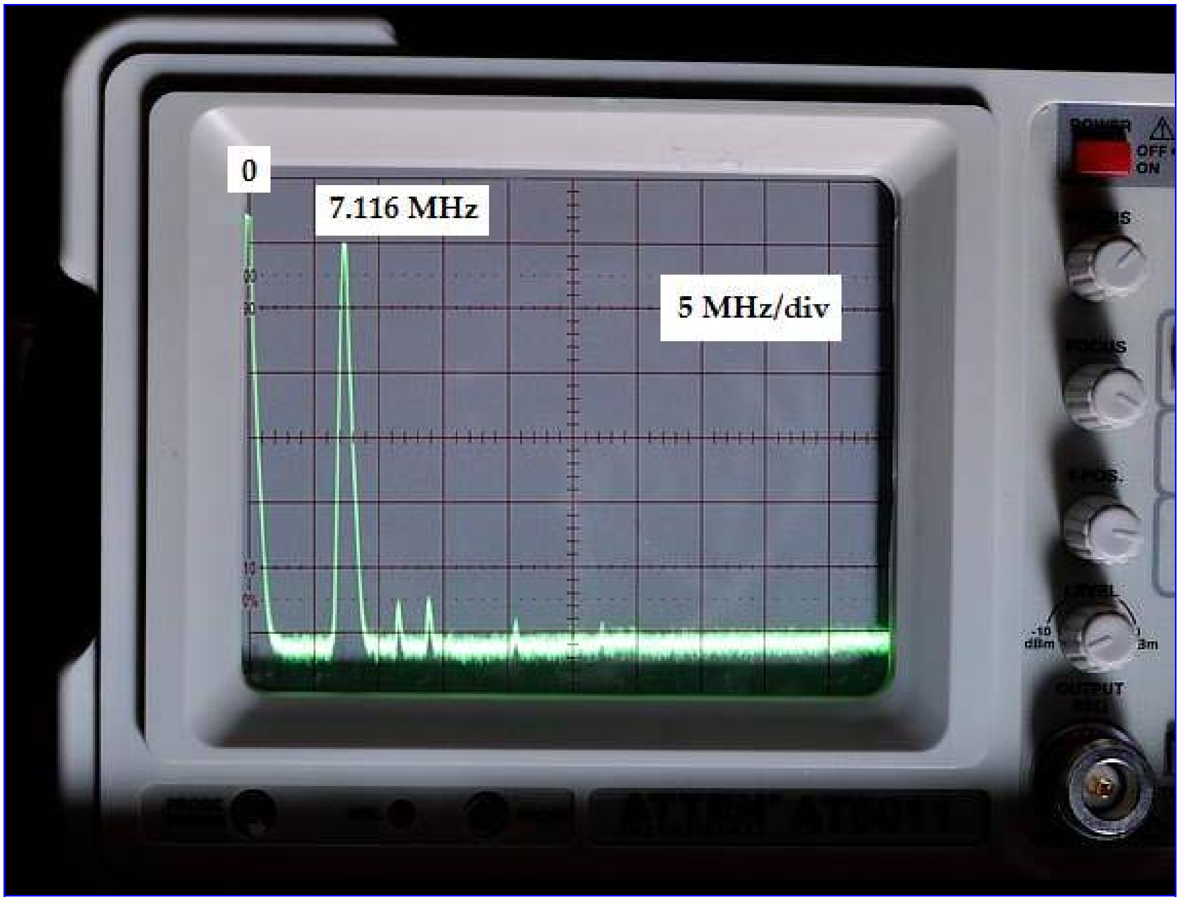

Above — While a little tedious to build and align, the triple tuned filter worked magnificently; the strongest spur is 54-55 dB down and the 14.98 MHz signal is gone. Insertion loss = 2.5 dB. This experiment provided a benchmark of what great post mixer filtering looks like. Post mixer filtering is an important topic worth studying further:

Why do we need filtering on a mixer output?

Let's examine mixer ports more closely. A port is just a pair of wires where signals are applied or removed. There are 2 kinds of mixer *outputs*: 1) the sum plus difference frequencies; 2) spurs.

Further, 2 kinds of spurs occur: One type is straight feed through where 1 signal from the 2 input ports makes it out to a 3rd port. Examples include LO feed through to the RF port, or LO feed through to the IF port.

The other type of spur is a mixing product such as a harmonic.

In general, the mixer output frequencies are numerically described by an equation:
IF (output) = N x L +/- M x R
N and M are both integers, 1, 2, 3, ... L = local oscillator frequency, R = radio frequency

A mixer is said to be balanced when you duplicate some of its functions and then combine them — usually with transformers. Consider, for example, the single diode mixer — they work, but the output contains ++ feed through and spurs. A mixer with 2 diodes or 2 FETs etc. can be much easier to use because the transformer combines the signals in a way that cancels some of the spurs and feed through. The double-balanced diode ring mixer uses four diodes and 2 transformers — producing even less feed through and harmonic output.

In a double-balanced diode ring mixer, the LO and RF ports are balanced and all ports of the mixer are isolated from each other. The double-balanced mixer greatly reduces, but does not stop all LO feed through at the RF and IF ports. A wideband match at 50 ohms is required to maintain mixer balance; hence you will often see attenuator pads on the LO, RF and *especially* the IF ports.

Let's focus on the IF port. Attenuator pads absorb any reflected mixer products and signals coming back into the IF port, thus increasing the match to the IF port. You may have noticed some builders use a diplexer on the IF port. The diplexer presents a wideband match to all IF port frequencies — passing the desired sum or difference frequency and absorbing the unwanted mixer products reflected back into the IF port by subsequent stages.

Since the IF output contains the sum and difference of the LO + RF, LO feed though, and other spurious energy, band-pass filtering is required to launder the IF signal into something useful. Following a transmit mixer, we filter with an L-C band-pass filter — after a receive mixer, crystal band-pass filters dominate. If you choose an unbalanced mixer or single-balanced mixer, filtering becomes more difficult than with a double balanced mixer. Unbalanced mixers are usually reserved for situations where high performance is being sacrificed for cost containment and/or want of a low parts count. There is no free lunch — you either alleviate as many mixer products as you can at a low-level with good practices, or have to deal with them down your signal chain while sacrificing optimal mixer performance.

Double balanced mixers are sensitive to non-resistive IF port terminations. When improperly terminated, the 2 transmission-line transformers work poorly — any reflected power generates high voltage across the diodes and degrades mixer performance. According to Dr. Ulrich Rohde, some proper ways to terminate the mixer include using a diplexer followed by a wideband 50 Ω feedback amp, or a common-gate JFET amplifier. *(Reference 1)*

Improved Local and RF Oscillators

In the earlier experiment, I really should have the run the LO port at 7 dBm. In order to improve my experiments, new crystal oscillators were designed with emphasis on correct LO output power and low harmonic energy.

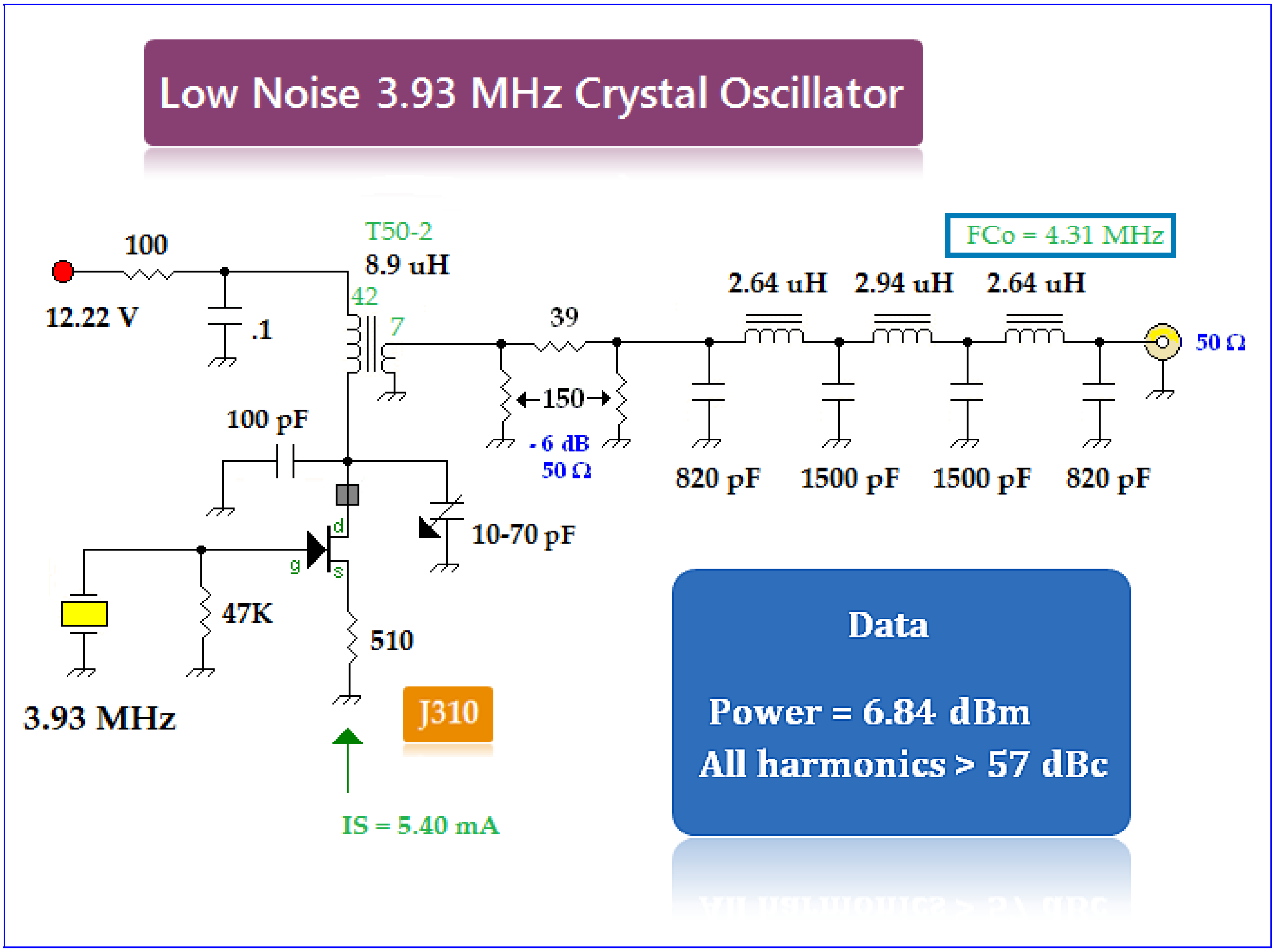

Above — The new LO; a 3.93 MHz crystal oscillator with stiff low-pass filtering. Admittedly, this 7 element Chebychev low-pass filter is overkill, however, I wanted to examine filtering and learn how much is required. On the bench — do whatever you like; even chasing crazy personal goals can be instructive and help you relate to information from texts and articles, or satisfy a whim. I can read something 100 times, but may not understand it well until I actually do it.

ECS V
3.93-17
CHINA

Above —The LO breadboard in close-up using a long focal length lens. Click for a wide angle photograph. The unsoldered end of the 100 Ω resistor in the close up photograph is where I connected the VCC.

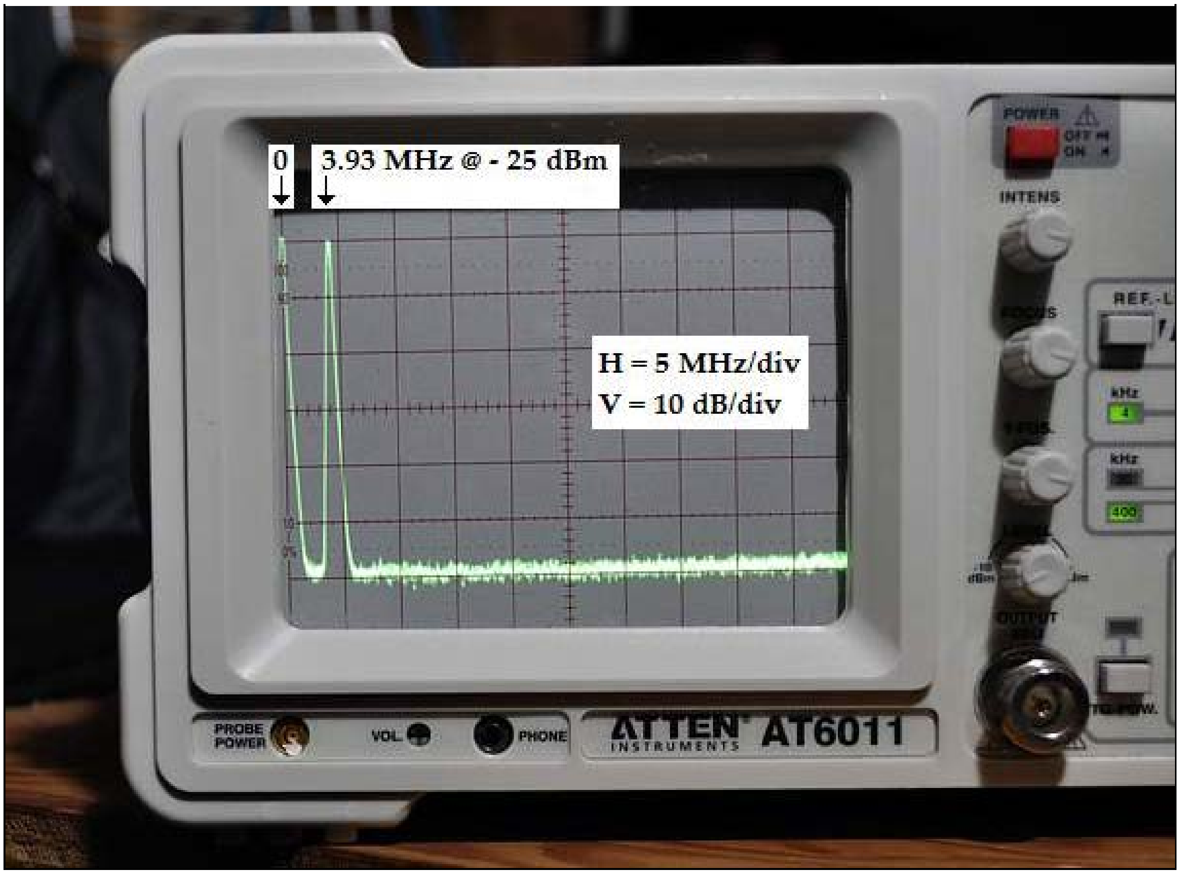
0
3.93 MHz @ - 25 dBm
H = 5 MHz/div
V = 10 dB/div
ATTEN AT6011
INSTRUMENTS
PROBE POWER
VOL.
PHONE
POWER
INTENS

Above — Spectrum analysis of the well-filtered 3.93 MHz LO. Not surprising, no harmonic energy is seen.

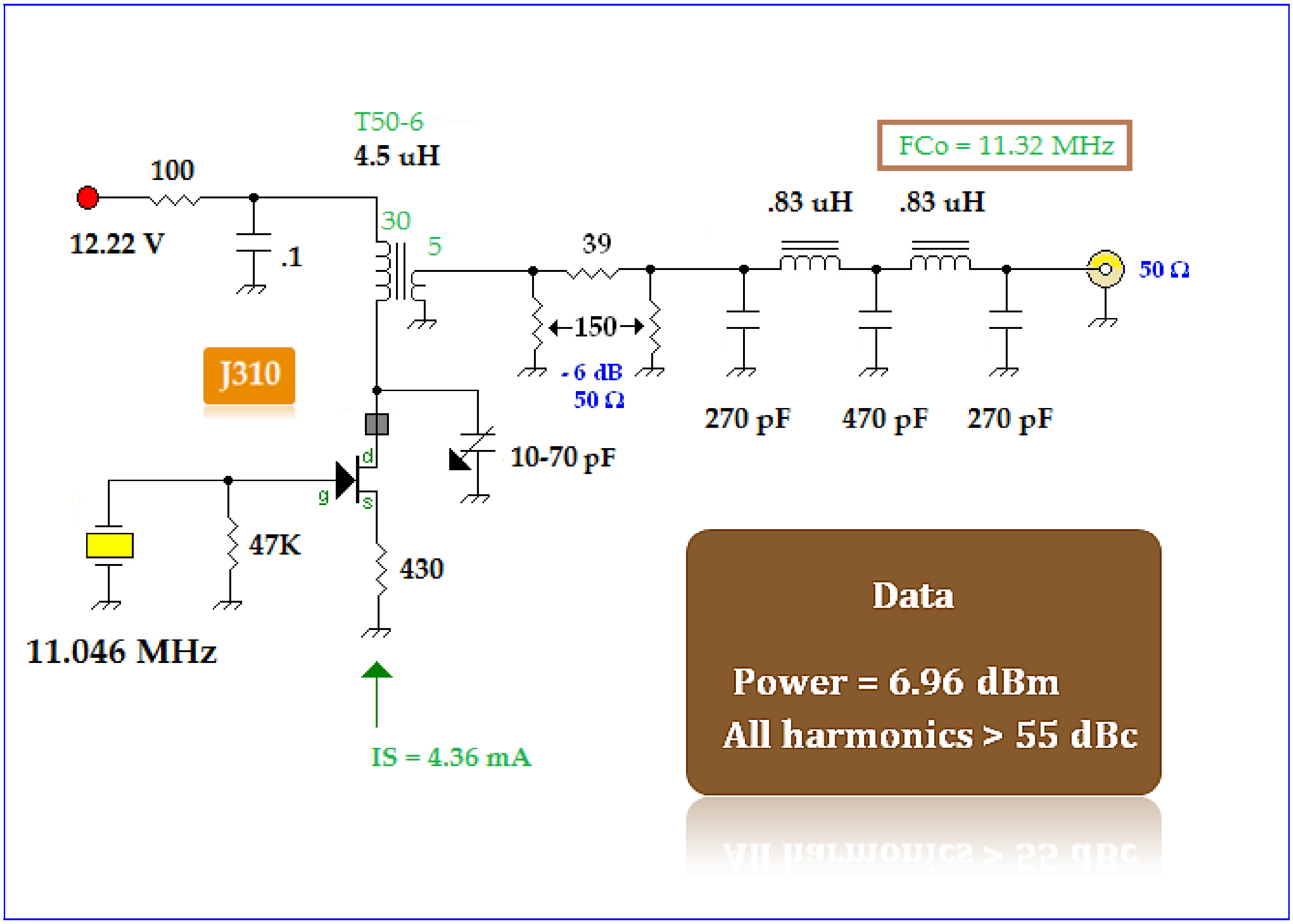
T50-6
4.5 uH
FCo = 11.32 MHz
100
12.22 V
.1
30
5
39
.83 uH
.83 uH
50 Ω
J310
←150→
- 6 dB
50 Ω
270 pF
470 pF
270 pF
d
g
s
10-70 pF
47K
430
11.046 MHz
IS = 4.36 mA
Data
Power = 6.96 dBm
All harmonics > 55 dBc

Above — The redesigned RF port oscillator. Clearly, the 7 element Chebychev low-pass filter isn't needed, so an N = 5 version was tried. Click for the spectrum analysis — again no harmonic energy was seen. In both the RF and LO signal generators, I tried to get as close to 7 dBm output power as possible.

To operate this oscillator at the desired RF port signal level; for example, between 0 and -10 dBm, you might just attenuate the output with a fixed pad or step attenuator. My conclusions echo the work of others experimenters; lowering the RF port down from 7 dBm to as low as - 10 dBm, lowered the amplitude of the spurious mixer products seen in the spectrum analyzer. Click for a sample. Refer to the QST Technical Correspondence citation in the references section for more information.

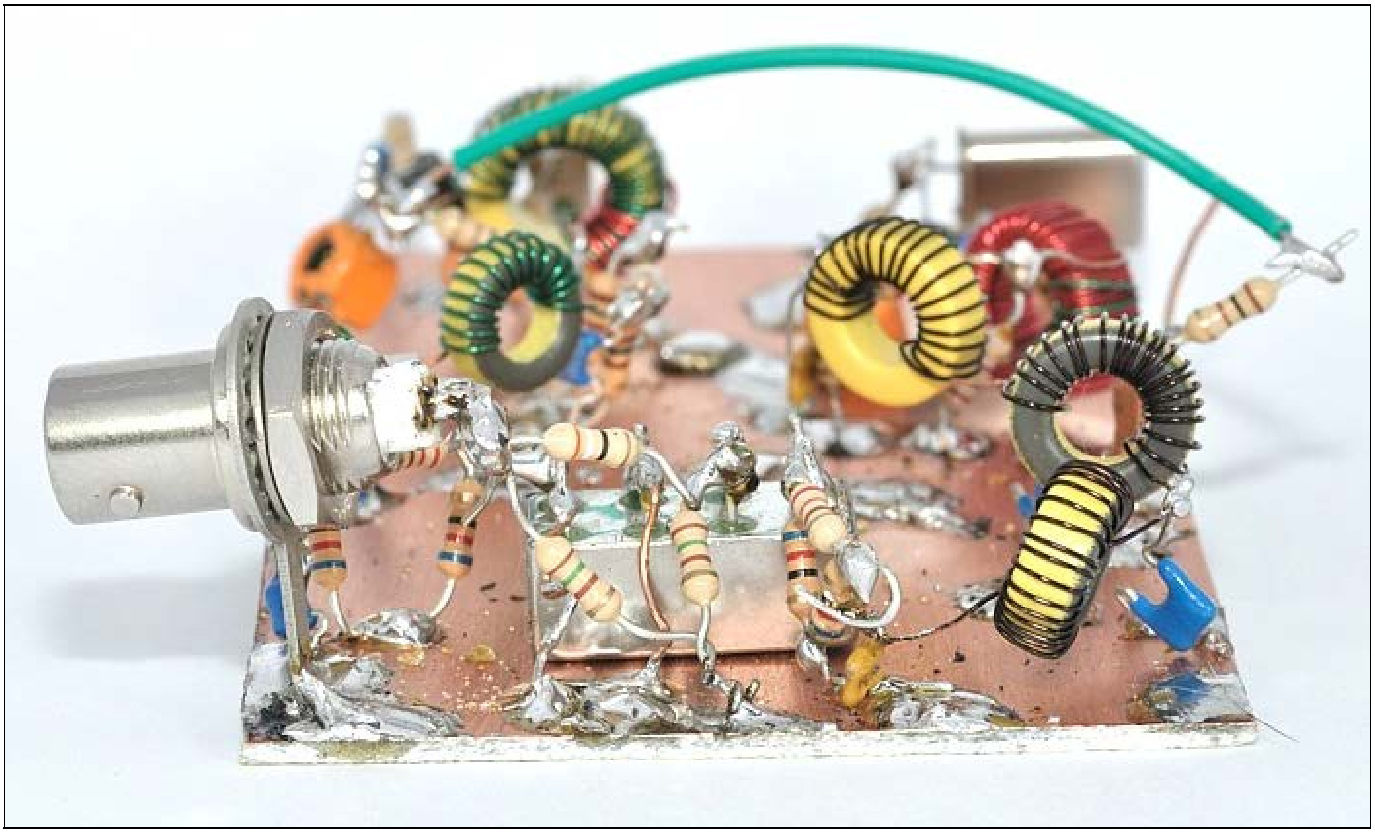

Above — The 2 re-designed oscillators wired up and connected to an SBL-1 mixer. I actually connected the attenuator pads after the low-pass filters as explained later.

Two different crystal oscillators were then built:

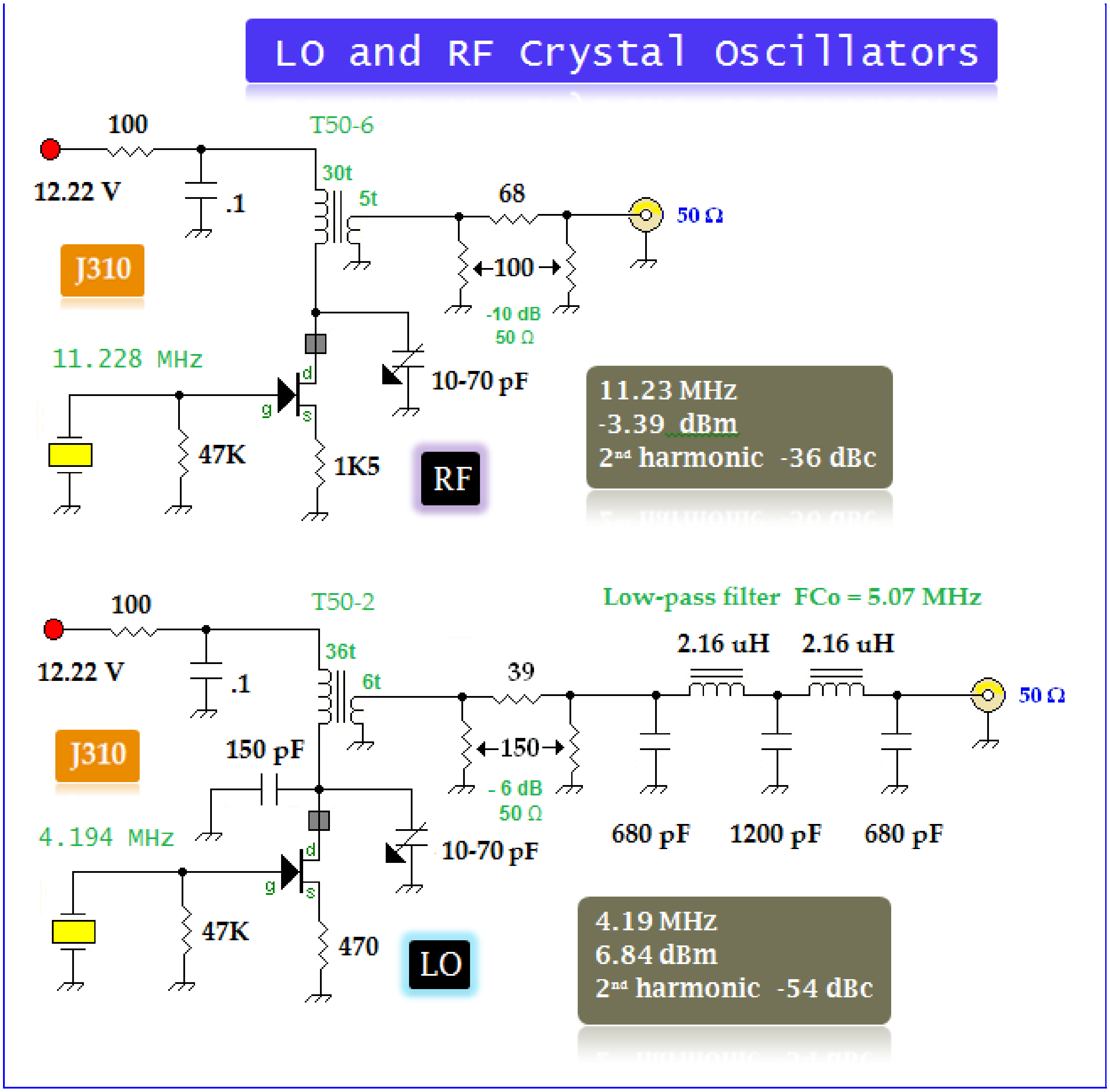
LO and RF Crystal Oscillators
100
T50-6
12.22 V
30t
5t
68
.1
50 Ω
J310
←100→
-10 dB
50 Ω
11.228 MHz
d
10-70 pF
11.23 MHz
-3.39 dBm
2nd harmonic -36 dBc
g
s
47K
1K5
RF
100
T50-2
Low-pass filter FCo = 5.07 MHz
12.22 V
36t
2.16 uH
2.16 uH
6t
39
.1
50 Ω
J310
150 pF
←150→
- 6 dB
50 Ω
4.194 MHz
d
10-70 pF
680 pF
1200 pF
680 pF
g
s
47K
470
LO
4.19 MHz
6.84 dBm
2nd harmonic -54 dBc

Above — Two different crystal oscillators targeting ~ 7.034 MHz were built. Click for the breadboard photo. You can see the crystal frequencies in this photograph. The RF port oscillator power was set to -3.39 dBm by choosing a low value JFET source resistor and attaching a 10 dB attenuator pad. Relatively low harmonic distortion prompted the exclusion of a low-pass filter on the RF oscillator. The LO output power was ~ 7 dBm.

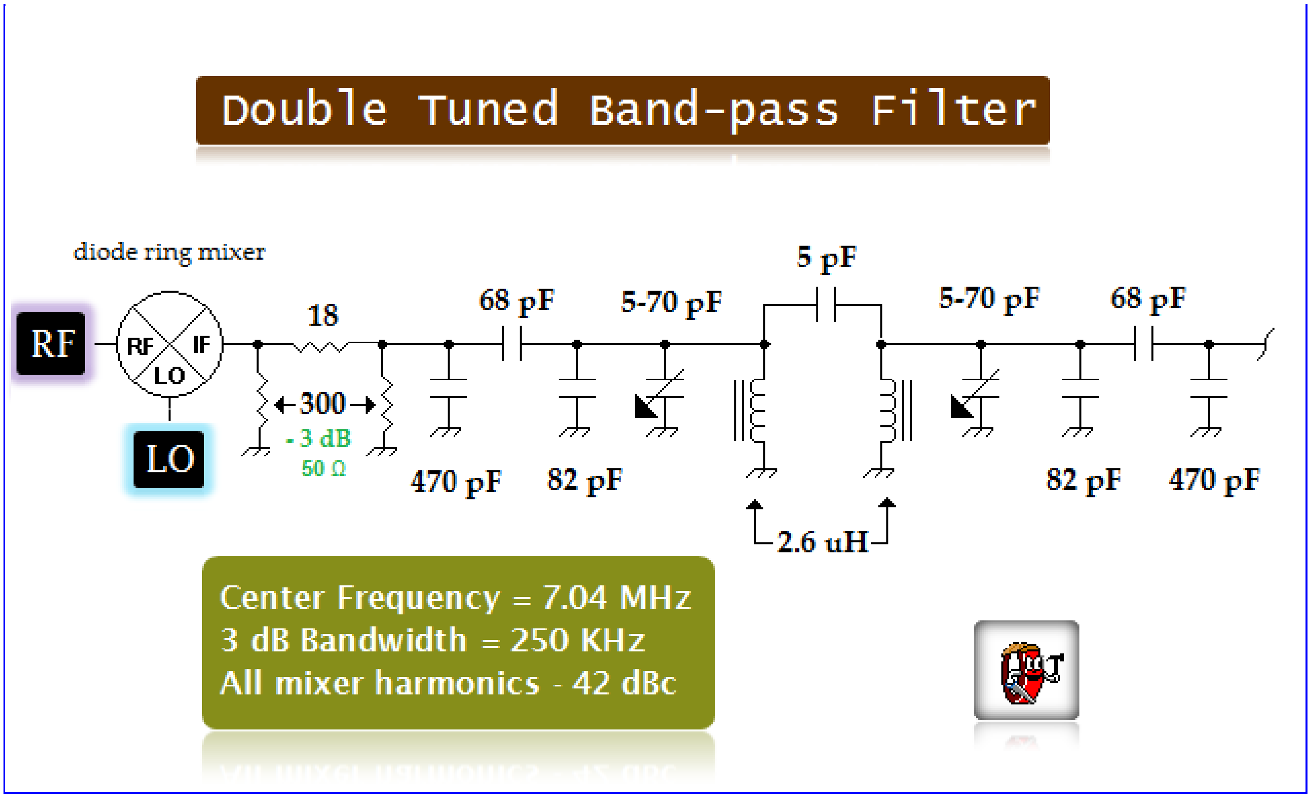

Above — The final experiment; placing a double tuned band-pass filter after the TUFF-1 diode ring mixer with the 2 latest crystal oscillators attached . This filter was in my junk box and I peaked it for the 7.034 MHz IF with a spectrum analyzer. The strongest spur was 42 dB down from the carrier — falling well short of the triple tuned band-pass filter presented before.

Clearly from all these experiments, a strong case for placing a triple tuned band-pass filter after a transmit mixer exists. If you use an unbalanced or single-balance mixer, a double balanced mixer might sufficiently not block feed through and spurious RF to keep your signal chain tidy. I enjoy studying the transmit chains of others to see how they filtered spurious and feed through RF. At the end of the day, as long as the output carrier spurs are low enough to meet your country's regulatory requirements, you're okay. Designing for low spurious emissions is an exciting challenge — one you'll miss if you don't try your hand with RF design.

A realization emerged following these experiments — I couldn't measure the return loss of the local oscillators! It technically could be done, but not by me. After 2 weeks of struggling, I engaged an American colleague with whom I occasionally build experimental circuits. After making some progress, we became stalled again. This time I asked Professor Ken Kuhn and Wes, W7ZOI for some ideas. Eventually a method to measure the RL of local oscillators came together along with enough material for another web page — RF Workbench 3.

When you do experiments, knowledge evolves as you go — for me, I learn mostly from making mistakes. I often think I should repeat most of my experiments over before presenting them, but this would consume too much time. However, footnotes can serve to steer readers for minor issues. If I had to re-build the crystal oscillators from Part 1, I'd build each crystal oscillator with a separate JFET buffer — then the return loss of the oscillator buffers could be measured as shown on RF Workbench 3 (with a shorted oscillator tank). Also, the pi attenuator pads on the crystal oscillators should follow the low-pass filters to garner the best output return loss. The good news is past experiments inform future experiments.

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2. Bipolar Transistor Feedback Amplifier Experiments

I love making signals bigger — especially while preserving fidelity. It would be nice to become a reasonably competent amplifier designer — hopefully by studying sound schematics, applying software, building circuits and measuring evermore parameters this might occur. The mathematical equations of RF amplifier design seem quite daunting; they're the fodder of electrical engineers with their Hewlett Packard scientific calculators, SPICE software and GHz F-t transistors. With most things technical, as you try to advance, more questions than answers cross your mind; however, somehow this is normal and may actually signal progress.

Abundant amplifier references exist; for example, EMRDF Chapter 2: Feedback Amplifiers. This is essential reading and I won't repeat this information. Rather, I'll just share some ideas developed or reinforced on my bench. In the past, I've preferred amplifiers with narrow-band (tuned circuits) in an attempt to reduce distortion and maximize gain. Now after critically examining these tuned amps with scope and spectrum analyzer, I better appreciate the significant intrinsic feedback of RF transistors ***(the tendency to oscillate)*** and broadband designs are sought. Often you'll spend more time taming a tuned amplifier than building one.

This section focuses on return loss, bias techniques and achieving linear amplification — for example; finding ways to apply negative feedback, match the input, or how to set the collector voltage. All my experiments and thoughts about RF amplifiers are from an amateur designers' perspective and I welcome your feedback. The first amplifier shown is a classic W7ZOI topology that I call the "Beaverton Special".

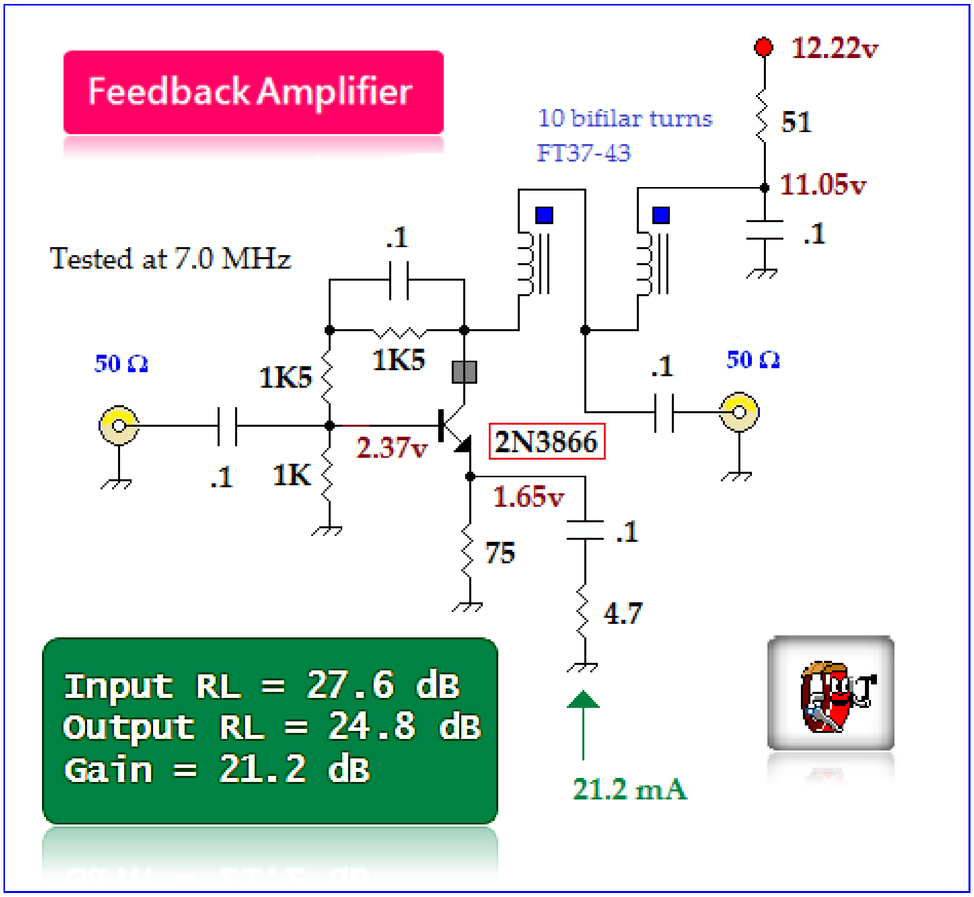

Above — A classic feedback amplifier popularized by Wes, W7ZOI in books like Solid State Design for the Radio Amateur and EMRFD. My respect for this humble design increased after building and testing 4 different versions to get a feel for amps with both shunt and series feedback. Of the 4 built, this particular version became my favorite — providing excellent input and output matching without crazy high emitter current. Employing a low noise / high F-t 2N3866 transistor is icing on the cake — an attempt to maximize impedance matching and performance using this standard, fits most transistors bias/feedback circuit. The humble 2N3904 also worked well in this slot. You don't need the ferrite collector bead with a 2N3904.

Other good experiments include trying different transistors and/or increasing the emitter current while being careful not to exceed the BJT's current rating (plus add heat sinking as required). You might also try the stage at different frequencies or perhaps sweep it to see at what frequency the gain starts to fall off.

Of the 4 BJT feedback amps shown in part 2, only this amp has a true broad-band input and output. What bothers me about broad-band linear amplifiers is that when you chain up 2 or more of them, signal fidelity generally degrades as it passes through each successive amp stage. Solutions include mopping things up with some low-pass filtering after the last stage, leaving it alone, or tuning the amplifiers (i.e. not using broadband stages).

The biggest caveat for feedback amps are variations in input and output impedance caused by source and load mismatches. For example, a 75 Ω resistor was connected to the output of the FBA above. The input return loss degraded to 16.8 dB. Further, the same 75 Ω load was removed and then connected to the input during output return loss measurement— this degraded the output RL to 23.4 dB. Clearly *load* mismatches upset return loss more than *source* mismatching. A 50 Ω attenuation pad should likely follow a feedback amp in situations where high input return loss are desired; for example, after a diode ring mixer.

Noticing a variation of the classis feedback topology in EMRFD Figure 6.140, I asked Wes, W7ZOI about it. It turns out there's another way to "skin the shunt feedback cat". The above RF amp uses a series connection of 2 feedback resistors (1K5 and 1K5 with a bypass cap across one 1K5). The result is a resistance at DC of 3K, but a resistance at RF of just 1K5. You could also use a 3K resistor directly from collector to base that is paralleled by a series connection of a 1K5 resistor plus a 0.1 uF capacitor. That network has the same impedance as my amp shown above. That is; the resistance would be 3K at DC, but 1K5 at RF.

This explanation fueled the next experiment — transistor amplifiers have 2 operating conditions; 1 at DC, the other at AC. Like a carpenter framing a house, you begin design by setting the DC bias — no small design task since bias concerns more than just establishing the base voltage and emitter current. For example, biasing may effect voltage gain, maximum signal handling capability, noise figure, impedance matching, class of operation, the operating point (sometimes called quiescent point or q-point), feedback and temperature stability. Biasing provides much to think about, however, a practical way to explore any topic is to chunk it into small, understandable pieces that become a stepping stone to advancement. Let's focus on biasing for temperature stability. The next amp uses the wrap-around PNP bias — an awesome technique.

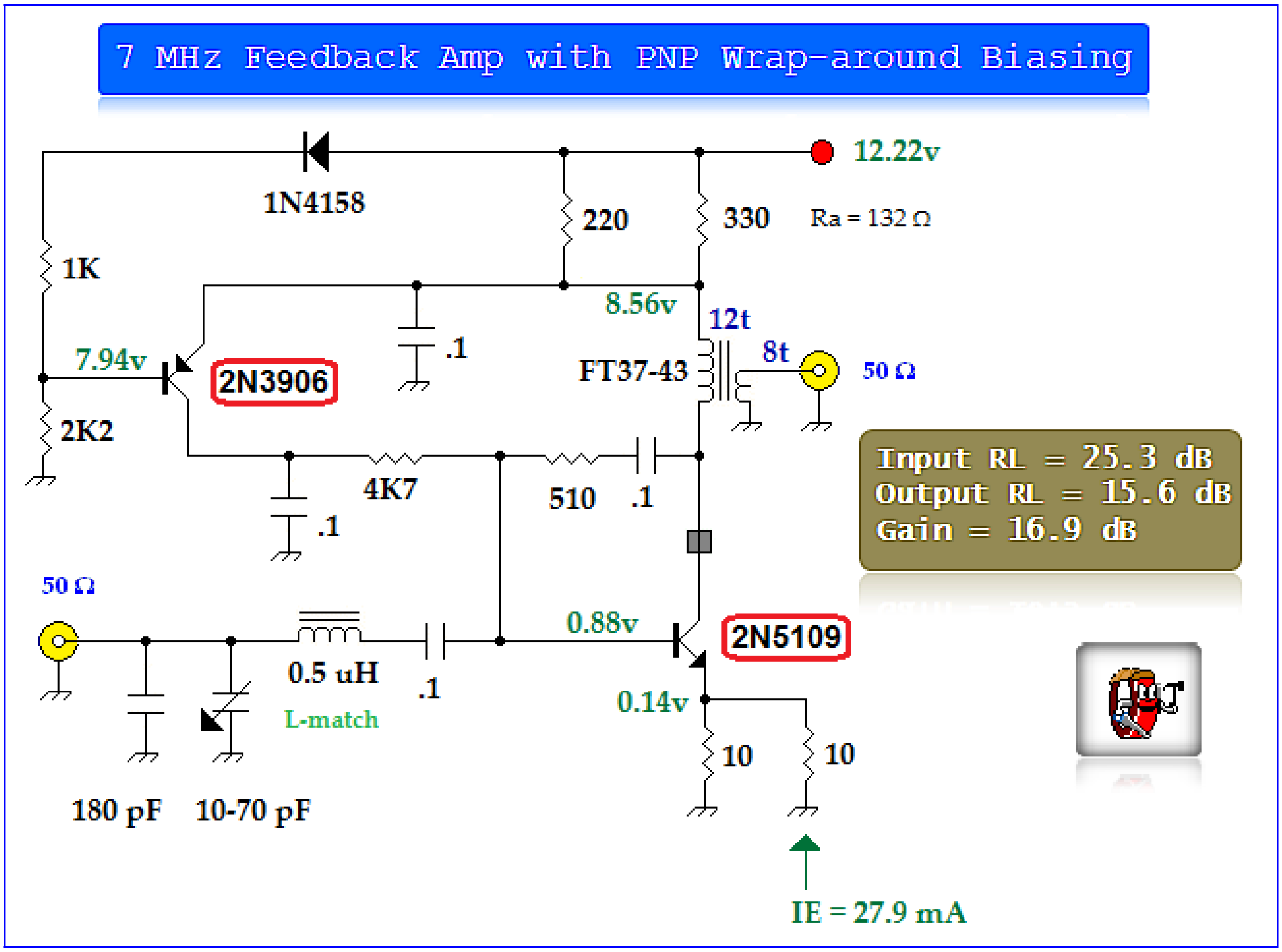

Above — A 7 MHz FBA using PNP wrap-around biasing. I learned about wrap-around biasing from Wes, W7ZOI and share a simple way for new builders to also learn this technique as the **#1 Design Center** on the supplemental web page. Click for a prototype breadboard photograph. This amplifier employs heavy shunt feedback from collector to base. Degenerative (series) feedback from the 2 parallel 10 ohm resistors also enhances temperature stability.
Expanded bias circuit temperature stability discussion follows amplifier number 4.

The wrap-around or feedback bias scheme is good because it's self stabilizing. The diode in the PNP bias network further ensures that the PNP bias remains constant with temperature changes. It really should be to glued to the NPN transistor (or its heat sink) to allow tracking of the NPN's temperature variations. This bias circuit doesn't load the NPN base input impedance. Another great virtue is that the emitter of the amplifying transistor can be directly connected to ground allowing better performance at VHF and UHF.

Noise from the PNP will be amplified by the NPN, so the low-pass network formed by the 0.1 uF capacitor and 4K7 resistor is essential. In some related circuits, you may see an RF choke used instead of a resistor.

The actual 2N5109 input impedance is probably around 40 ohms — easy matching with an L-match network.

Amplifiers with an L-match tuned input shouldn't follow a diode ring mixer unless preceded with a diplexer since the narrow-band L-match tunes only 1 frequency. L-match networks can make an impedance bigger or smaller depending how they're oriented and also provide some low or high-pass filtering depending on the configuration. I design my L-networks on the bench using experience plus trial and error — a better way is to use software. I recommend the program called Zmat08.exe that is included on the CD that accompanies EMRFD. The software will get you close, however, bench tweaking is required since you're often matching a complex impedance, comprised in part, of stray reactance.

Setting up an L-Network for an Input Match

A suggested bench method for optimizing input Return Loss (RL) using an L-Match network.

Your task is find the "perfect" L and C values to get a RL of 20 dB or higher. Start by soldering in an inductor calculated from Zmat08.exe or according to your wisdom. Set up the amplifier for input return loss measurement. The first chore is to find the nominal target capacitance that provides the best match at the design frequency. I use a big range, air variable capacitor for this — with the input circuit connected to a return loss bridge, connect up and tune the big variable capacitor to give the greatest RL. Remove the variable capacitor, measure it, and then solder in an equivalent trimmer capacitor, and as required, fixed capacitor(s) so you can tune at least 25 pF above and below the target capacitance. Often, the target C will be close to whatever the software recommends. In amplifier 2, my C values are the 180 pF + a 10-70 pF trimmer.

Next, determine the optimal inductor. On my bench, I keep a variety of pre-wound #6; and #2 material powdered-iron toroid inductors and choose one close to the calculated or a self-chosen L value. I start with an inductor wound with 4-5 more turns than needed. After soldering it in, the RL is checked. Remove 1 or 2 turns, tweak the trimmer capacitor and again check the RL. If after removing 1 or 2 turns, the RL is going up, you've determined there was enough inductance to get the best RL. *(If the RL goes down, you probably didn't start with enough L to get the best possible RL).*

You can also also squeeze together or spread apart the toroid windings to vary inductance — the maximal inductance variation varies due to factors including wire gauge and total turns. Compressing the windings with thumb and forefinger *increases* the inductance and widening the gaps between windings *reduces* inductance on a toroid.

Assuming the RL increased after removing 1 or 2 turns, remove another turn, tweak the trimmer capacitor and check the return loss, and so on. Repeat until your return loss starts to decrease. Then add back a turn or 2 to find the absolute best match. *This procedure allows you to find the optimum inductance in-situ.* Once, you've figured out the best inductance, cut the inductor leads short, solder it in, tweak the trimmer capacitor, and then consider further tweaking the coil by expanding or squishing the windings on the toroid while looking at the RL in a bridge detector.

In summary, to get the best possible RL — design a prospective L-match with software, and then bench test to determine the optimal in-situ L and C by using values above and below the calculated L and C values while observing the results in a return loss bridge. This method seems tedious, but emphasizes that repeated bench practice and patience pays off. You can always just use the calculated L-network values and/or develop your own method to set them up.

Consider mitigating the stray inductance caused by the long lead that occurs after removing wire turns by cutting the lead and scraping off the enamel insulation every couple of turns or so. This is a gamble — If you cut the lead and need to add back a turn, you'll have to rewind the coil from scratch, or add in and solder another turn (messy). I'm often able to get a L-network RL of 22-26 dB using my method and feel it's worth the the time and effort.

When bench tweaking the L and C values, your actually looking at the peak-to-peak AC voltage with the amp input connected to the unknown port of the RL bridge. Tune for the lowest, stable peak-to-peak voltage. Test it against the open circuit peak-to-peak voltage to calculate the RL. Since the open circuit doesn't change, you know the return loss is improving when the peak-to-peak voltage of the amplifier under test is going *down*. I store the open circuit voltage in my scientific calculator and calculate the RL from time to time as I'm tweaking the L and C values. After awhile, the whole procedure becomes automatic and quick. Once you 're done and everything's tidy, measure the open circuit and connected amp peak-to-peak voltages and calculate RL a final time. This is your reportable return loss.

You can scale matching networks from other builder's schematics by calculating the XL and XL and then applying these reactances to your desired frequency. Bench tweaking is still required. I also hope the person whom I'm copying didn't make a bench or drafting error. Be discerning about whatever your find on the Internet "Misinformation Highway" — this site included. Although I'm no philosopher, I know at least 3 things about people. They: 1. are often biased; 2. can lie; and 3. can make errors.

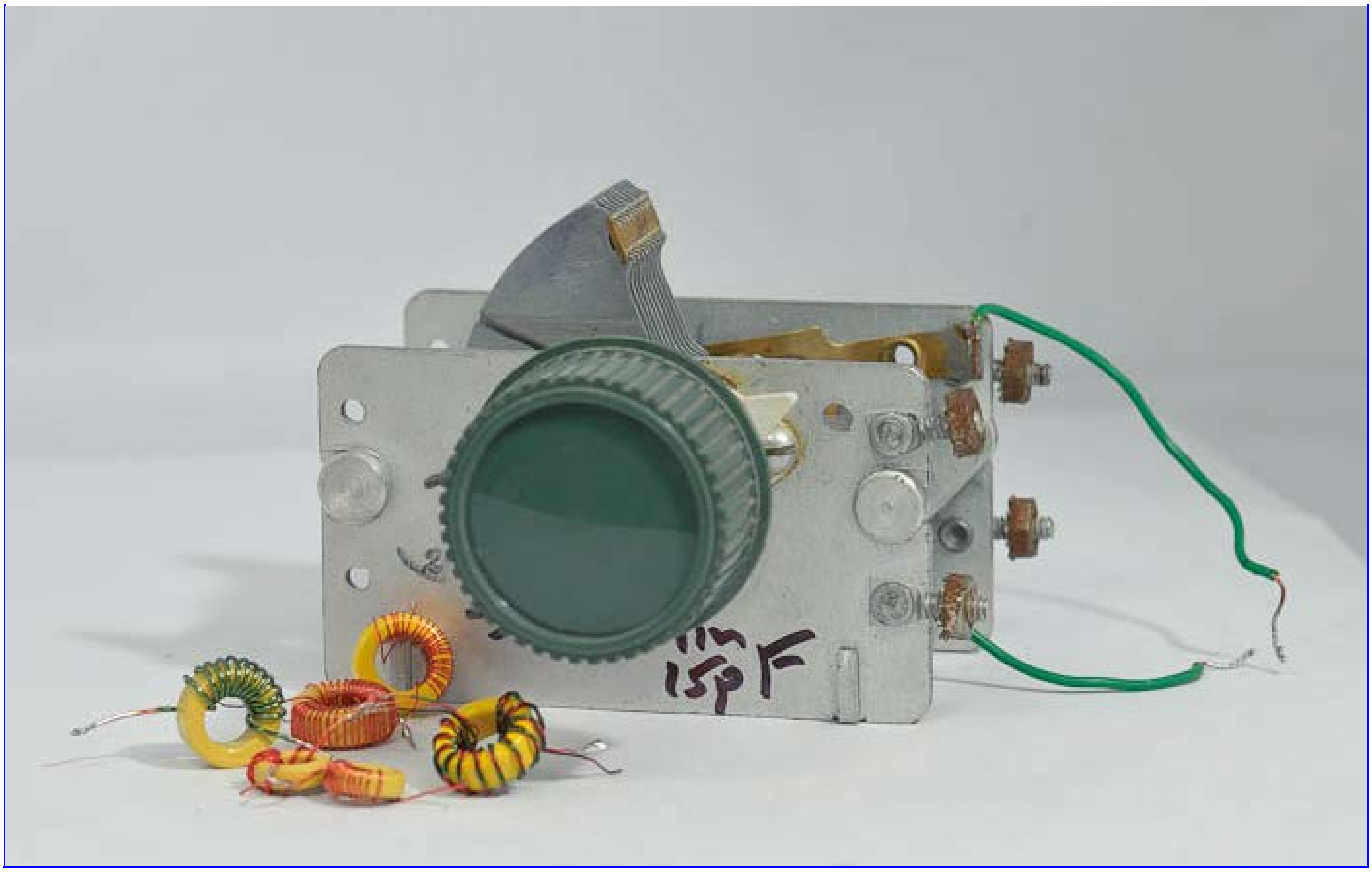

Above —Some toroids and the *air variable capacitor* I sometimes use to **coarsely** bench tune L-C circuits to determine the "ballpark" tuning capacitance. This capacitor features built-in reduction drive and varies from 15pF to 428 pF. When using an external capacitor connected to your circuit with short copper wires, expect some signal distortion and watch out for hand and body caused capacitance variations. The connecting wires also have reactance which won't be there when you swap in a small trimmer cap plus any fixed value capacitors.

Next up is a common emitter amp using "noiseless" feedback - this means the AC feedback is achieved with transformers instead of "noisy" resistors.

3

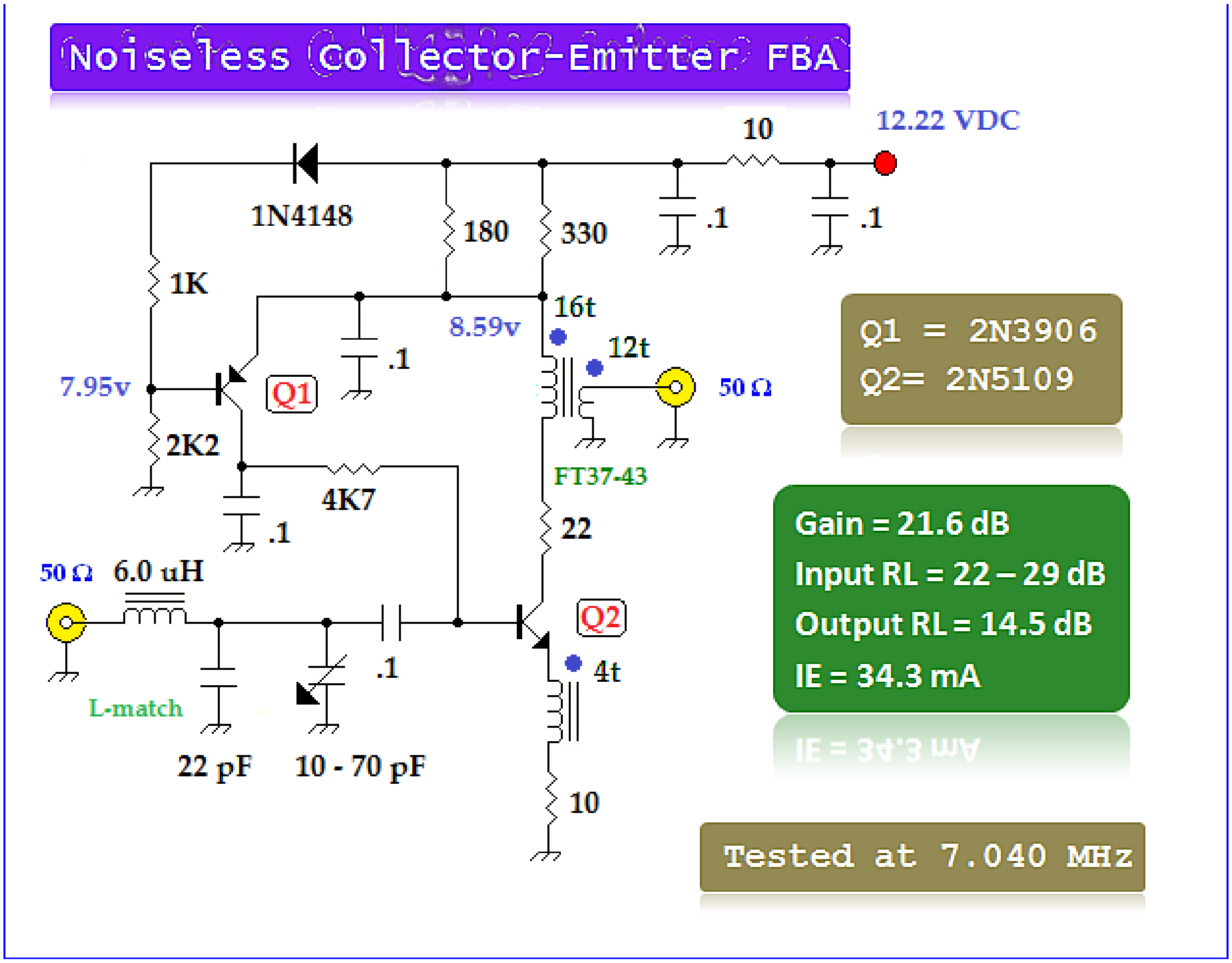
Noiseless Collector-Emitter FBA
10
12.22 VDC
1N4148
180
330
.1
.1
1K
16t
8.59v
12t
50 Ω
Q1 = 2N3906
Q2= 2N5109
7.95v
Q1
.1
2K2
4K7
FT37-43
.1
22
Gain = 21.6 dB
Input RL = 22 – 29 dB
Output RL = 14.5 dB
IE = 34.3 mA
50 Ω
6.0 uH
Q2
.1
4t
L-match
22 pF
10 - 70 pF
10
Tested at 7.040 MHz

Above — Schematic of a 7 MHz collector-emitter "Griffiths" feedback amp. I ran substantial emitter current through this NPN. RC = 116.5 ohms — I paralleled 2 resistors for RC because I lack resistors between 100 and 150 ohms. The basic design is by Bruce Griffiths, who has a great web site. I thought I put up *big* schematics!

The input L-network was designed on the bench and provides a good input match peaked at 7.040 MHz — this pumped up the gain 3-4 dB. In my amp, a T50-2 powdered iron toroid inductor forms the L-match coil. Matching for the best possible input return loss is touchy and best done on the bench. For example, if the 6 uH inductor is decreased to 5.8 uH, the match could fall by 2-4 dB. With patience and careful tweaking return losses approaching 29 dB are possible, but likely too time consuming for most builders. The procedure as described earlier is pragmatic: connect a RL bridge to the input and adjust the L and C values until the lowest return loss is discovered. Even squishing or expanding the toroidal inductor windings can squeeze out a final dB or so of input matching.

Output matching proved interesting. Although I tried, the best output RL I could muster was 14.5 dB. Lowering the 10 Ω degeneration resistor or increasing the current could increase the output return loss. An output attenuator pad might be considered — a 3 - 6 dB pad would increase the output RL to over 20 dB.

All 3 output transformer windings were wound on a FT37-43 with care to keep the phasing correct. Amplifier gain is not dependent on collector current. For example, substituting an Ra of 180 ohms (clipping out the 330 Ω resistor) yielded a gain of 19.5 dB, an emitter current of ~ 20 mA and an output return loss of 12.6 dB, while the input match changed very little.

The oscillation snuffer 22 Ω collector resistor was 15 ohms in another version, however, parasitic oscillations were discovered at ~175 MHz and snuffed out by raising this resistor from 15 to 22 ohms. I sometimes go as high as 51 Ω; especially in JFET circuits.

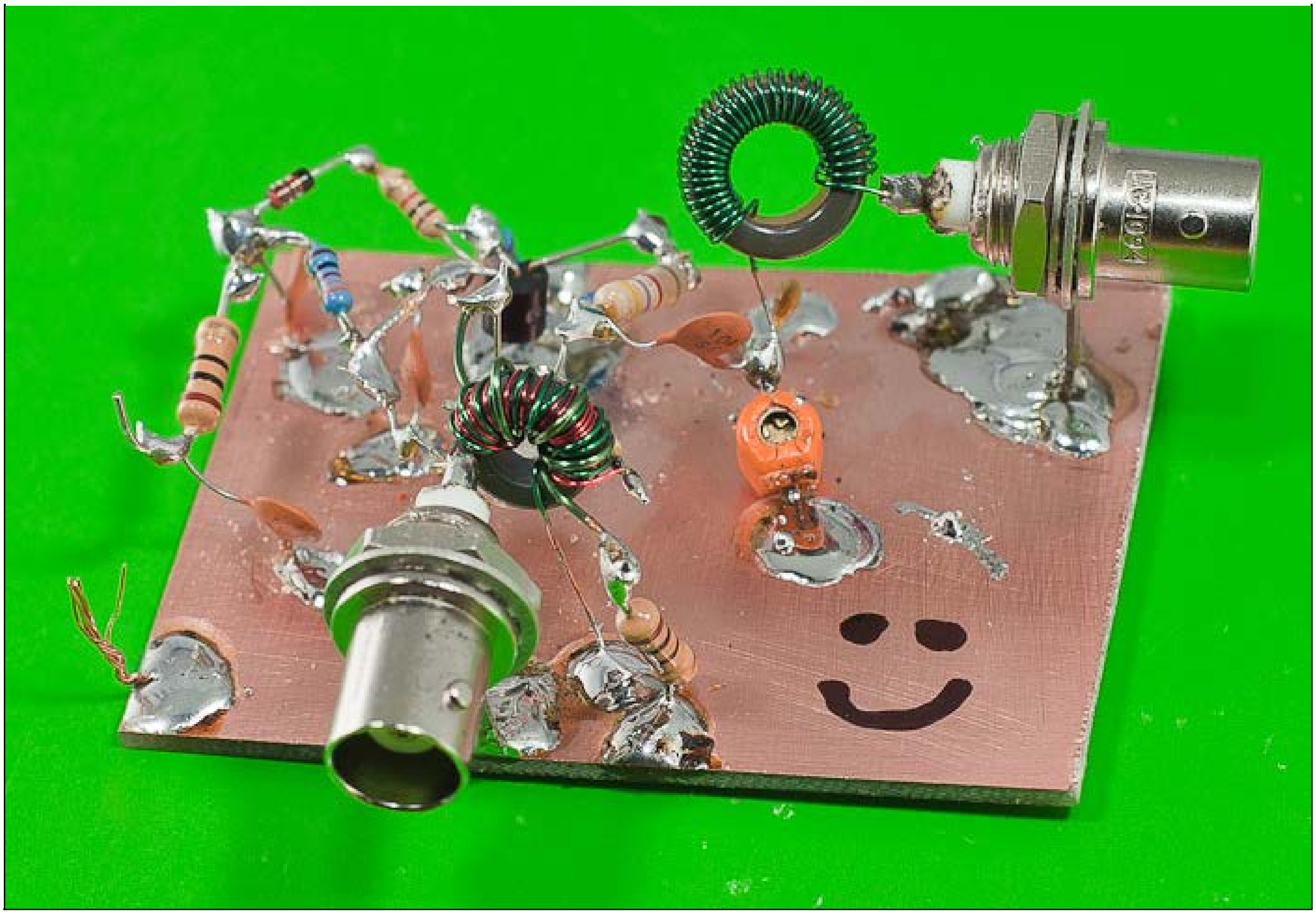

Above — The breadboard of the noiseless collector-emitter 7 MHz feedback amp. Click for a photo of another version. The hot "modern" replacement for the 2N5109 is this SMT part. I also like the BFG135 T/R BJT.

The final FBA experiments *below* use a standard voltage divider bias, tweaked for temperature compensation. The AC feedback is base to emitter — a rarely used topology in North America; although I'm not sure why.

4

Base-Emitter FBA -- DC Bias Using a 2N2222a

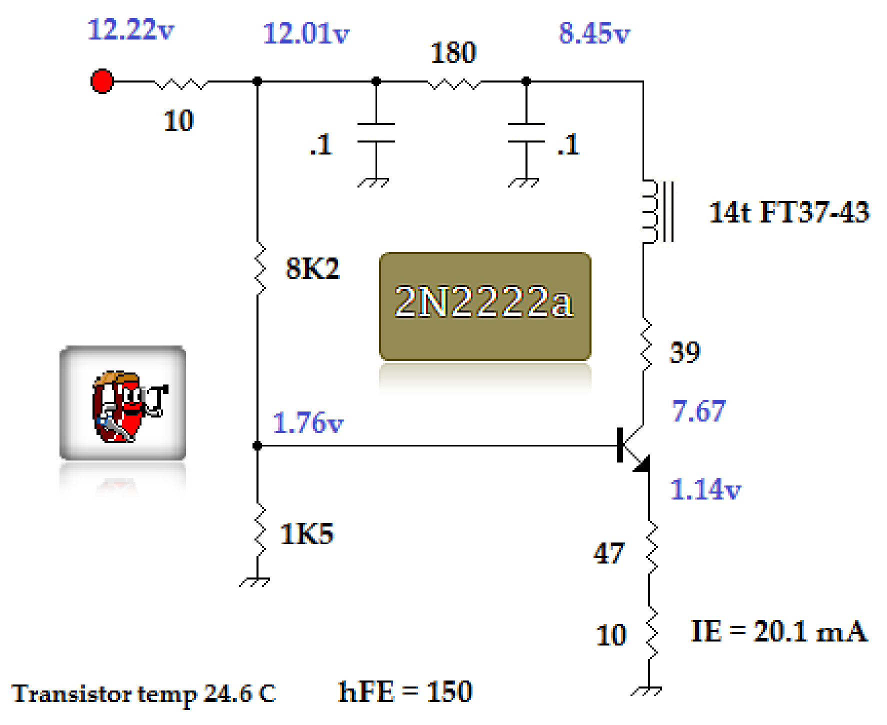
12.22v
12.01v
180
8.45v
10
.1
.1
14t FT37-43
8K2
2N2222a
39
7.67
1.76v
1.14v
1K5
47
10
IE = 20.1 mA
Transistor temp 24.6 C
hFE = 150

Above — The DC bias resistor values for a 2N2222a with a DC Beta or hFE of 150 and a emitter current of 20.1 mA. Almost every text author writes about voltage divider bias temperature stability, but some builders get bogged down in the details. Since the bipolar junction transistor is a voltage controlled device *(see section 4: QRP-POSDATA for an explanation)*, you must set up some DC voltages — I created a design center presenting an easy approach to design reasonably temperature stable BJT amps. See **#5 Design Center** on the supplemental web page. After getting the bias, the AC parts were added, and the completed schematic is shown below.

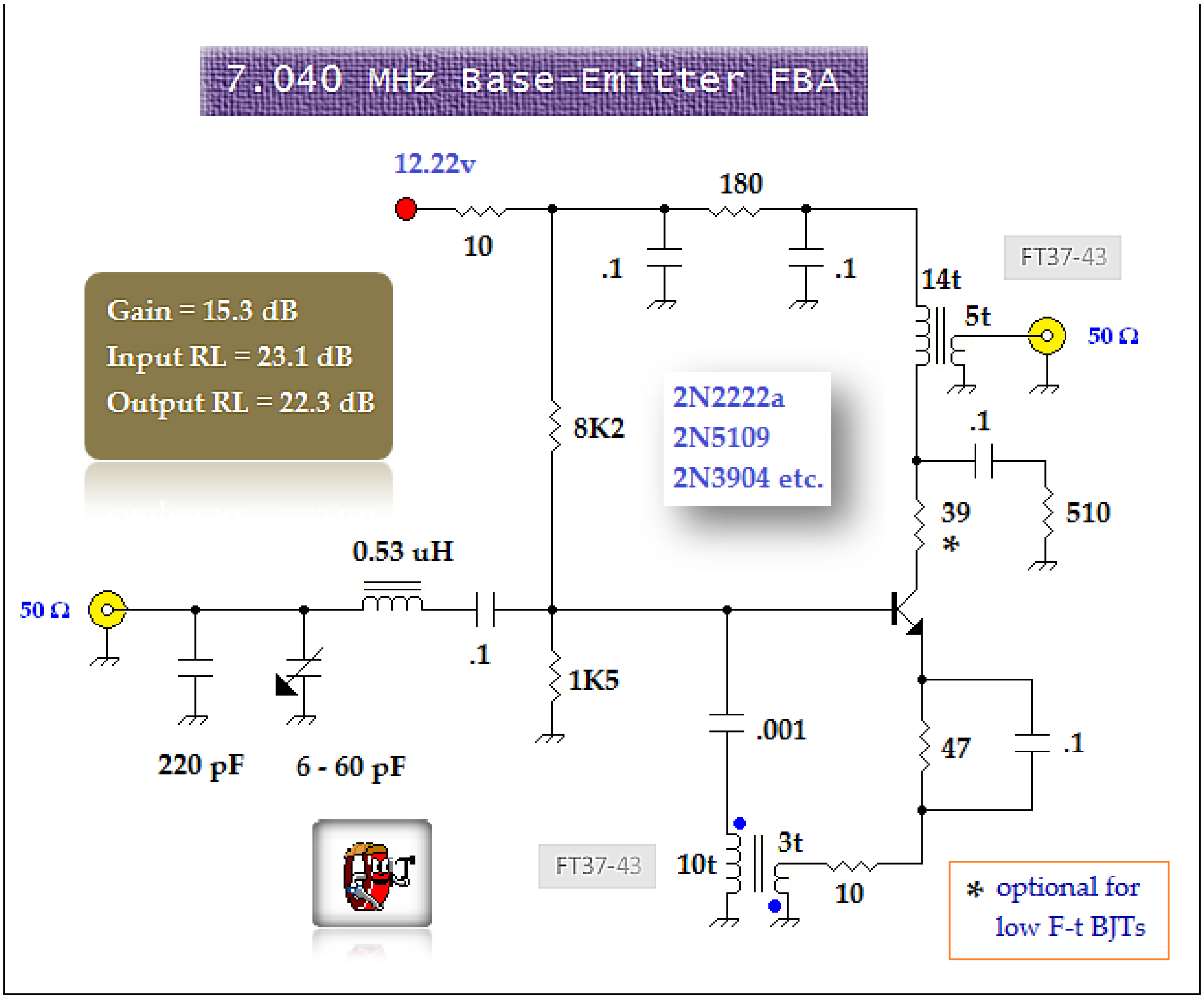

Above — A base-emitter feedback amp built Dec 21, 2010. I read about base-emitter feedback in Dr. Rohde's book *(Reference 1)*. He had some discussion, a small signal model and lots of difficult math, but no circuit examples. After searching on the web I found 1 example in the HBR-2000 transceiver; a project designed and built my respected Canadian colleague Marcus, VE7CA. Click for his web site. I decided to build my own design using a L-match to tune the input to 50 Ω.

The above amp was built around around a 2N2222a. The 39 ohm resistor is not really required with the 2N2222a. For high F-t transistors like the 2N3866, 2N5109 or microwave transistors, ferrite bead(s) or the resistor are *not* an option. Low F-t transistors like the 2N2222a or 2N3904 don't need the UHF oscillation snuffer resistor since they lack real gain at these frequencies. With the design center, you should be able to bias your own amp according to the emitter current you want — choose a BJT, measure or choose its hFE and then choose IE.

Missing from this web page is how to choose an operating point + discussion about DC load lines and related topics. I may tackle these topics on a future web page. I'm not sure anyone cares about this anymore.

The most difficult part was the output transformer. Lacking a base to collector connection, the collector impedance runs quite high and finding a good match into 50 Ω proved impossible — even with a shunt resistor across the primary coil. I saw a strategy in Marcus' amp; AC couple the collector to ground via a 510 Ω resistor. I did this. From then on, it was just trial and error to identify the optimum turns ratio for the collector transformer. An interesting experiment might be to figure out the turns ratio using a lower loss output transformer such as a FT-37-61.

The turns ratio of the various collector and drain transformers on most of these amplifier designs were determined by placing the amp in an output RL measurement setup and adding or removing secondary turns to get the highest possible RL. See the procedures for RL measurement on the RF Workbench pages.

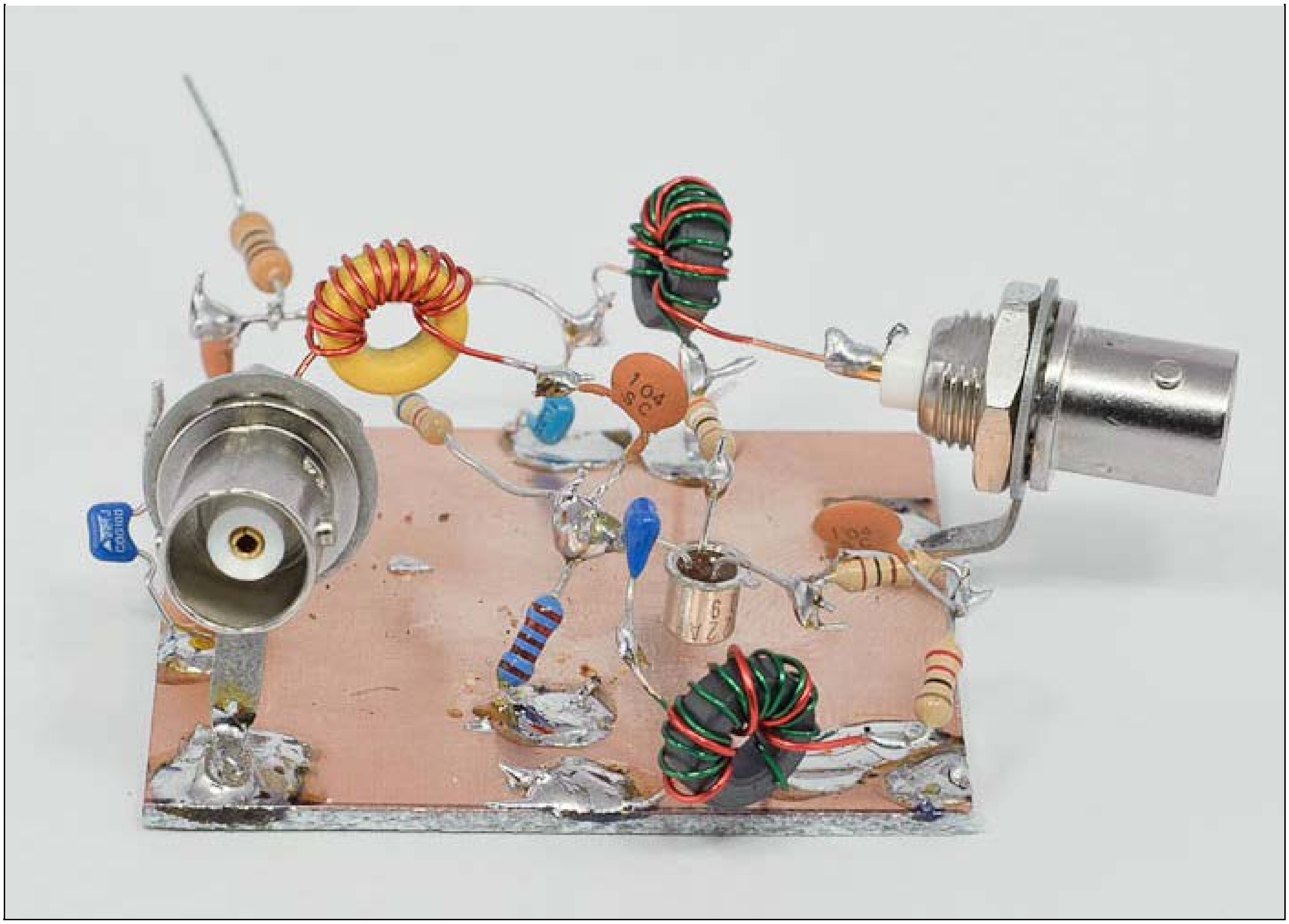

Above — The breadboard of the first version of the base-emitter FBA.

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3. JFET Common Gate (CG)Transistor Amplifier Experiments

These experiments focus on setting up a desired input return loss and getting a reasonable output return loss in the CG amplifier. My expectation of an easy set of experiments proved wrong — assumptions never substitute for actually building and measuring.

I like motorcycles. The difference between riding a motorbike versus *driving* a car parallels learning on the bench versus learning by just simulating or calculating component "ideal" values on paper or computer. In the car you're isolated from wind, smells, temperature changes and subtle road traction and camber differences that you fully sense on the motorcycle. Bench experiments prove equally visceral and experiential — the sensory input from learning as you build and test circuits imprints deeply in your mind.

1

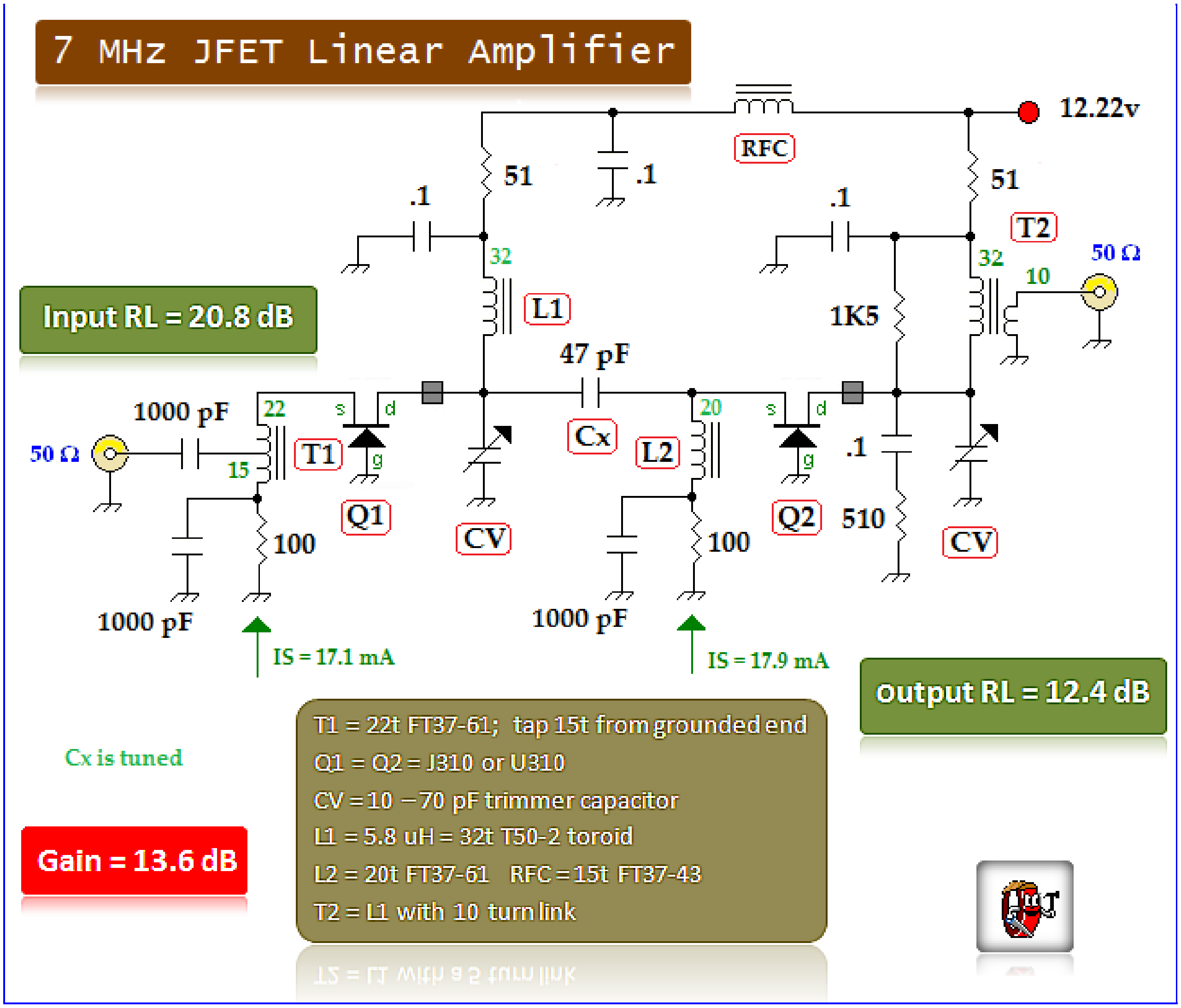
7 MHz JFET Linear Amplifier
12.22v
RFC
51
.1
.1
32
L1
51
.1
T2
32
10
50 Ω
1K5
Input RL = 20.8 dB
47 pF
1000 pF
22
s
d
50 Ω
T1
15
g
Cx
L2
20
s
d
g
.1
Q1
CV
100
Q2
510
CV
100
1000 pF
1000 pF
IS = 17.1 mA
IS = 17.9 mA
Output RL = 12.4 dB
Cx is tuned
T1 = 22t FT37-61; tap 15t from grounded end
Q1 = Q2 = J310 or U310
CV = 10 – 70 pF trimmer capacitor
L1 = 5.8 uH = 32t T50-2 toroid
L2 = 20t FT37-61 RFC = 15t FT37-43
T2 = L1 with 10 turn link
Gain = 13.6 dB

Above — A 7 MHz JFET "linear" amplifier built only for testing ideas — *do not build*. It went through several incarnations and prompted many experiments. The input return loss was deliberately set to 20.8 dB, although I set a RL from 10.0 - 28.6 dB during my experiments. Bypassing the JFET source resistor increases gain, but of course changes input RL.

The output transformer represents a terrible design, but shows the length I went to to try an obtain a decent output return loss. Working with this circuit, led me to abandon tuning the output transformer in situations where a high return loss was desired since the low value resistors required kill the tank Q significantly.

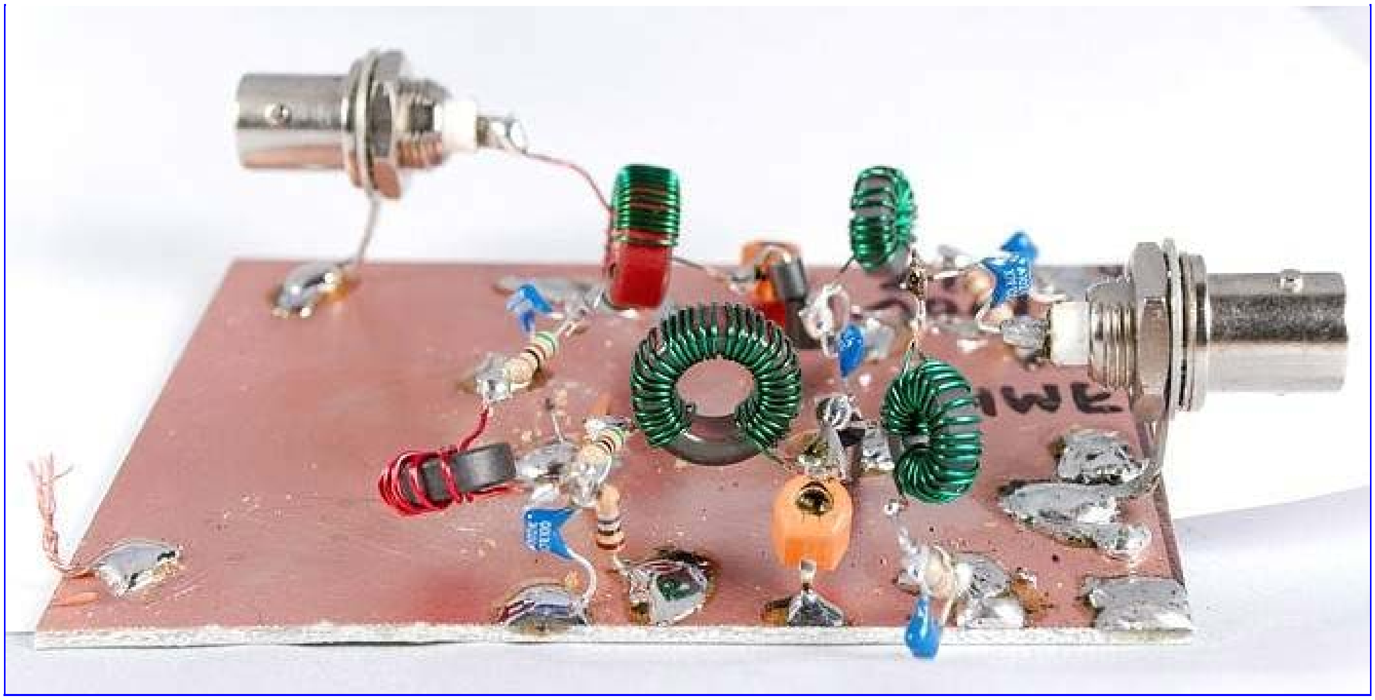

Above — Breadboard of 1 version of the prototype low-level JFET "linear" amplifiers for 7 MHz. Click Click . Cx is tuned with a variable cap and a nearest standard value substituted; in my case 46 pF was the measured value of the variable cap at point Cx.

Setting Input Impedance

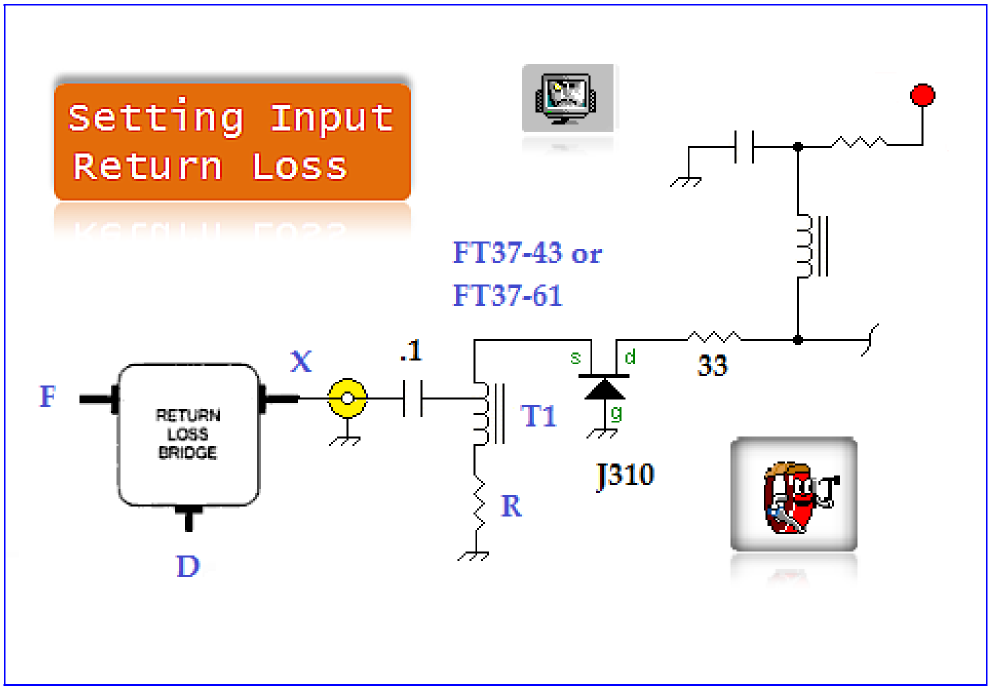

Above — The procedure used to set a desired CG amplifier input Return Loss. Numerous factors influence the input impedance and I discuss them in **#4 Some Factors Affecting Common-Gate Amplifier Input Impedance** on the supplemental web page. I keep some tapped inductors on my workbench such as this FT50-43 or these FT50-61 core inductors. To find the best return loss using such a coil, you can change tap points, remove windings and even wind more turns and solder the 1 end of your new windings to 1 end of the existing wire. Some builders omit inductor taps and manipulate the input return loss other ways as described in the supplemental article.

Normally we set the input match after establishing the output match since the output impedance dramatically affects the input impedance.

Further, you might notice that the tap point may vary between different JFETs. Most of my "real world" coils have at least 2 tap points and I choose the tap that gives the best return loss. More often than not, I bias for 14 - 18 mA and leave off the source bypass capacitor; it's your call.

The input return loss that gives the lowest noise figure is often chosen by engineers.

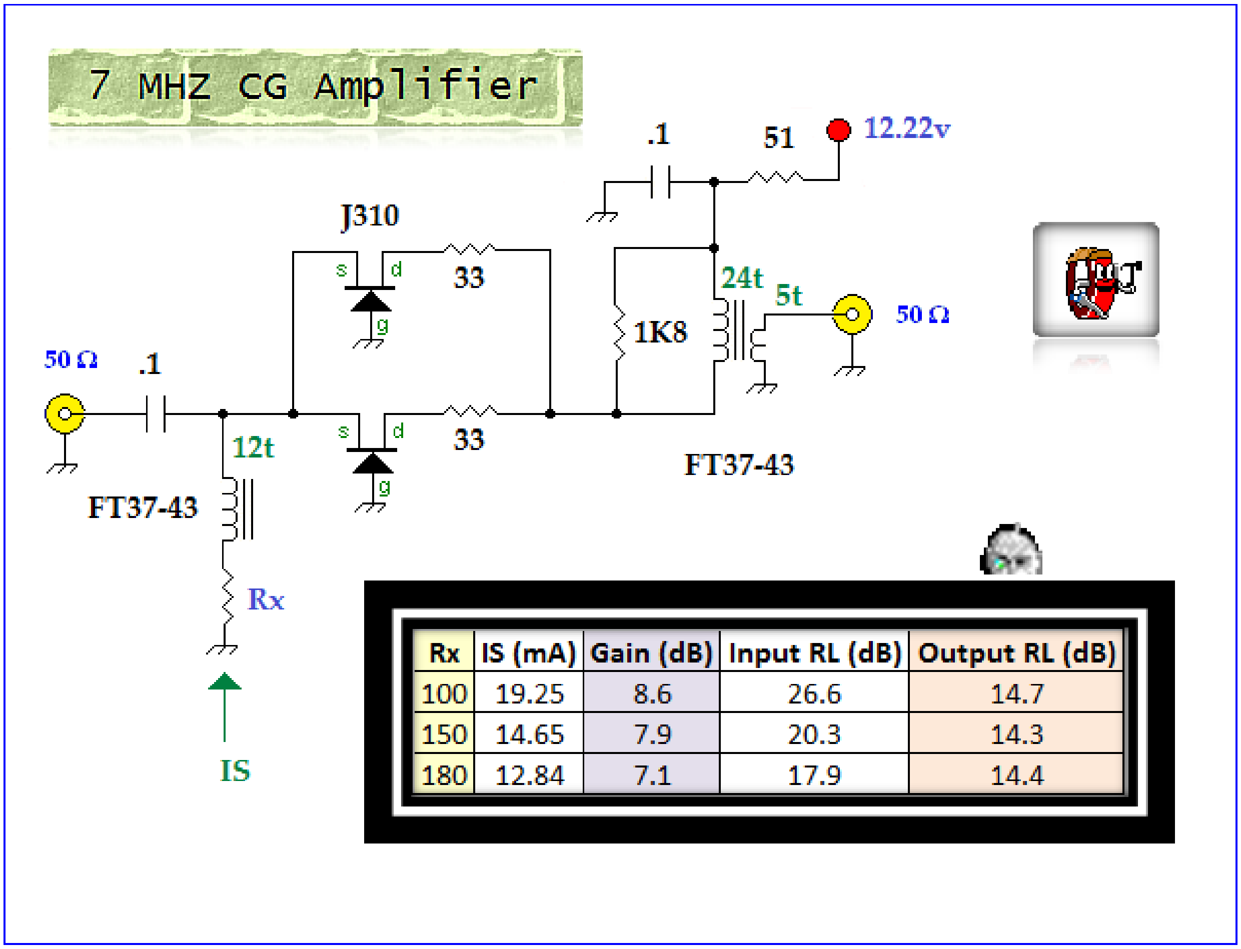

Rx	IS (mA)	Gain (dB)	Input RL (dB)	Output RL (dB)
100	19.25	8.6	26.6	14.7
150	14.65	7.9	20.3	14.3
180	12.84	7.1	17.9	14.4

Above — An experimental 7 MHz common gate amp designed to terminate a diode ring mixer. The best thing about using 2 JFETs is that you don't have to determine the tap point in the decoupling inductor (12 turns on a FT37-43 in this amplifier). I put up to 4 in parallel during my various experiments. It's faster to match just 2 JFETs, so 2 were favored.

The output RL wasn't great at ~ 14 dB, however is probably normal or better than most published amateur projects. I set the output match by adding a shunt 1K8 resistor across the primary winding and then finding the turns ratio to give the best output return loss. Without the resistor, the best output RL will be ~5 dB or worse. The resistor reduces power.

I learned that putting JFETs in parallel in a common gate amplifier reduced the output return loss in circuits using an output transformer like in the schematic above; this is unfortunate.

I wanted an output RL of 20 dB or greater — this is no small request; over a week was spent investigating transformer behavior and finding ways to improve output return loss when you really *want* to.

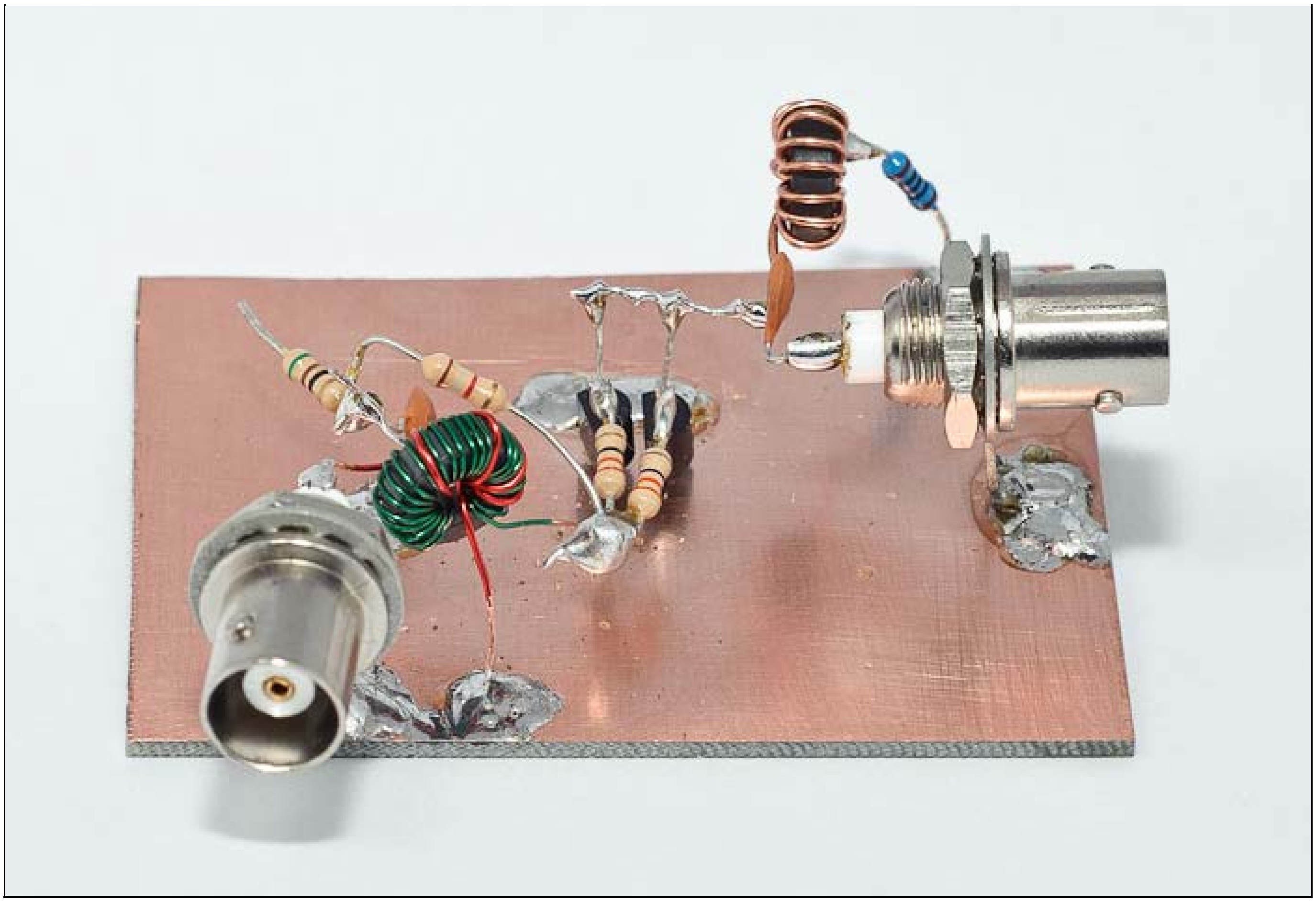

Above — The breadboard of the above 7 MHz CG amplifier.

3

Output Impedance Experiments

For some reason, I assumed that when using an arithmetically correct turns ratio, the output transformer will end up at 50 Ωs. For example, if I wish to transform 450 ohms to 50 ohms, I'd use a 9:1 impedance ratio (3:1 turns ratio) and get 50 ohms. Sadly, it isn't this simple — impedance transformation is complicated and whole books have been written about it. I'll share some of my experiments that might inform yours.

The first task was to built a simple jig to evaluate primary and secondary coupling, turns ratios and return loss.

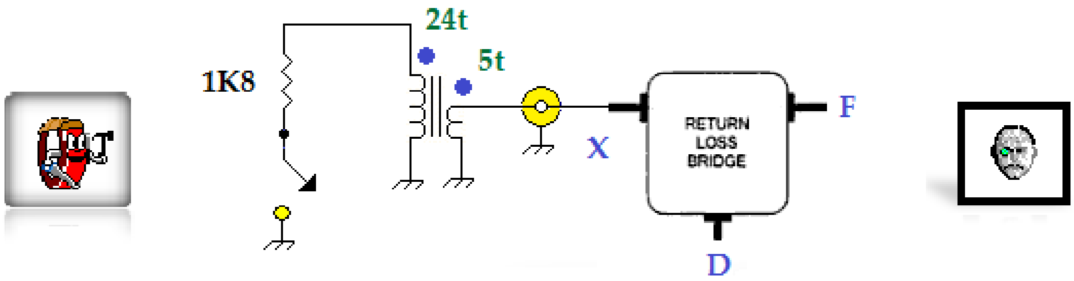
1K8
24t
5t
X
RETURN LOSS BRIDGE
F
D

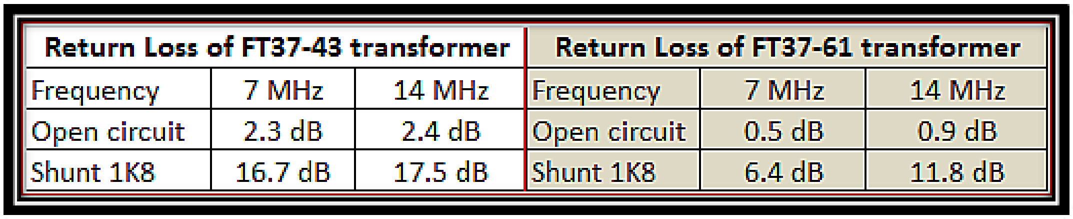

Return Loss of FT37-43 transformer			Return Loss of FT37-61 transformer		
Frequency	7 MHz	14 MHz	Frequency	7 MHz	14 MHz
Open circuit	2.3 dB	2.4 dB	Open circuit	0.5 dB	0.9 dB
Shunt 1K8	16.7 dB	17.5 dB	Shunt 1K8	6.4 dB	11.8 dB

Transformer Return Loss Tool

Above — The simple tool built to evaluate the return loss of a transformer out-of-circuit. In this case, I examined the 24t : 5t transformer of the 7 MHz CG amplifier shown earlier. The table shows the best possible return loss when the 1K8 resistor is across the primary coil. Additional experiments were completed and follow below.

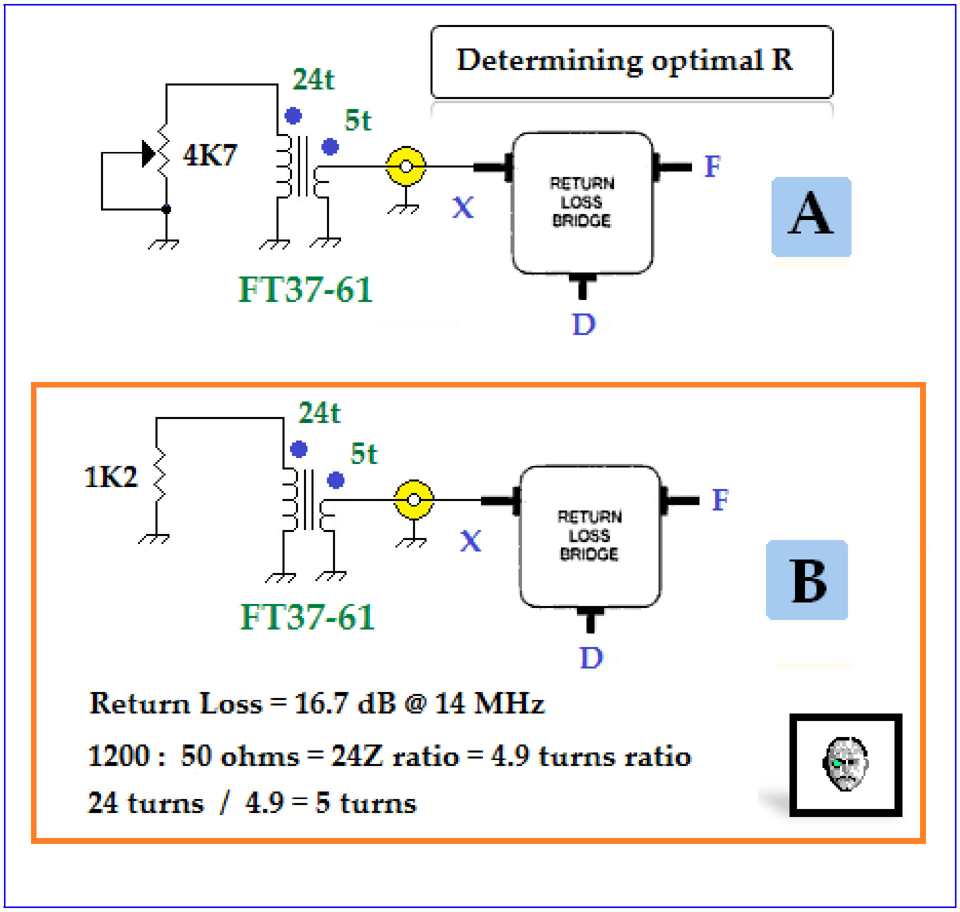
Determining optimal R
4K7
24t
5t
X
RETURN LOSS BRIDGE
F
D
FT37-61
A
1K2
24t
5t
X
RETURN LOSS BRIDGE
F
D
FT37-61
B

Return Loss = 16.7 dB @ 14 MHz

1200 : 50 ohms = 24Z ratio = 4.9 turns ratio

24 turns / 4.9 = 5 turns

Above — An experiment to see if changing the shunt resistor can improve return loss; yes it can. The shunt resistor was a 4K7 potentiometer — Using the potentiometer, I was able to determine the optimal resistance needed to increase the return loss @ 14 MHz of the **FT37-61** ferrite-base 24t : 5t transformer. The pot was removed, measured and replaced with the nearest standard value; a 1K2 resistor. The best possible RL was 16.7 dB using a 1K2 shunt resistor. At 7 MHz, the FT37-61 didn't work well. Five turns on a FT37-61 based transformer doesn't have enough inductive reactance to get a good return loss.

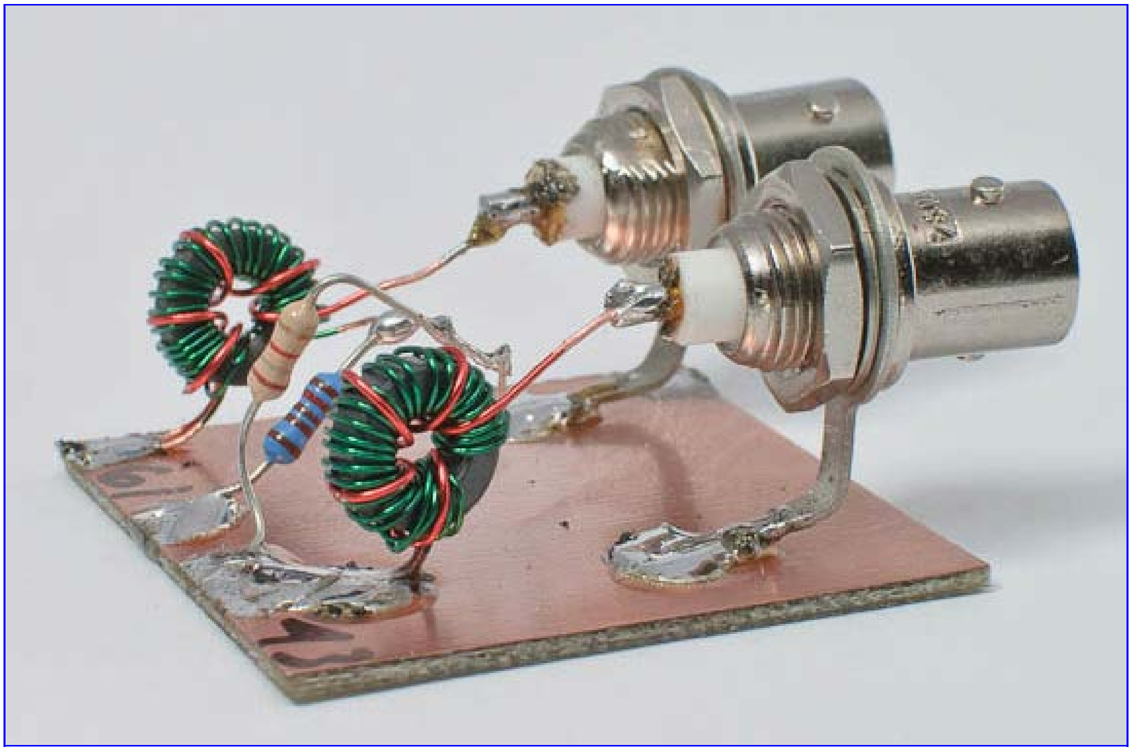

Above — The transformer testing jig. I omitted the switch shown in the schematic above and just soldered the shunt resistor across the primary winding.

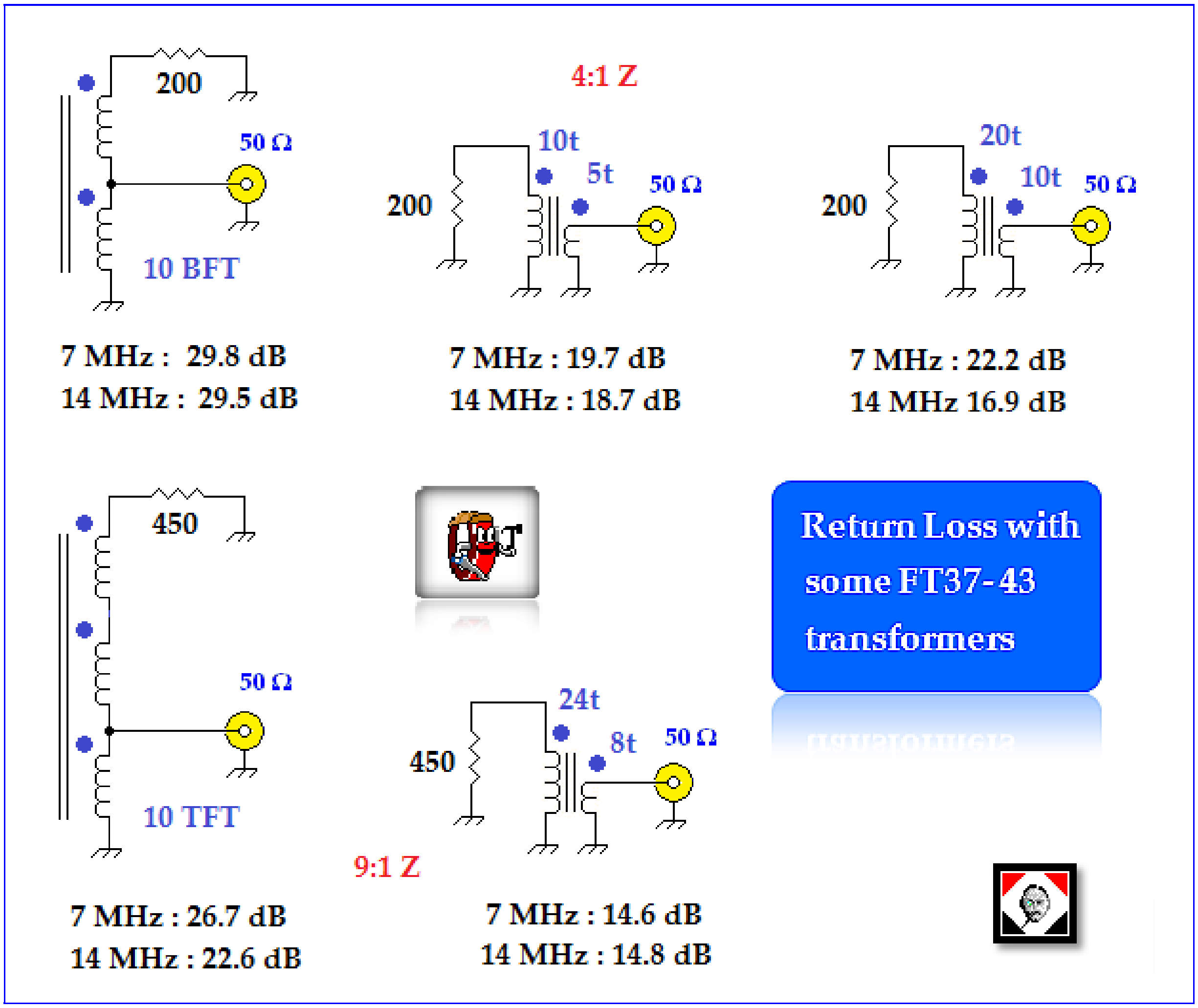
200
50 Ω
10 BFT
7 MHz : 29.8 dB
14 MHz : 29.5 dB
4:1 Z
10t
5t
200
50 Ω
7 MHz : 19.7 dB
14 MHz : 18.7 dB
20t
10t
200
50 Ω
7 MHz : 22.2 dB
14 MHz 16.9 dB
450
50 Ω
10 TFT
7 MHz : 26.7 dB
14 MHz : 22.6 dB
24t
8t
450
50 Ω
9:1 Z
7 MHz : 14.6 dB
14 MHz : 14.8 dB
Return Loss with some FT37-43 transformers

Above — Some of the outcomes using the transformer jig pictured above. While I basically understood that transformer efficiency tends to fall as the turns ratio increases, I never thought this would also happen with return loss. By *no* means do these crude experiments constitute science, but the following themes emerged:

1. The better coupling of transmission line transformers (bifilar, trifilar etc.) translates into improved RL over conventionally wound transformers
2. Limiting the turns ratio to 3:1 or less generally improved the return loss. As the turns ratio moves above 3:1, the best possible return loss tends to decrease.
3. The smaller or secondary winding should have 4-10 times the inductive reactance of the impedance it's connected to. For a 50 ohms impedance this means a minimal XL of 200 - 500 ohms. I noticed a weak trend towards better return loss with higher XLs. This means that to use a FT37-61 at 7 MHz, the secondary winding should be 9 -14 turns or so.

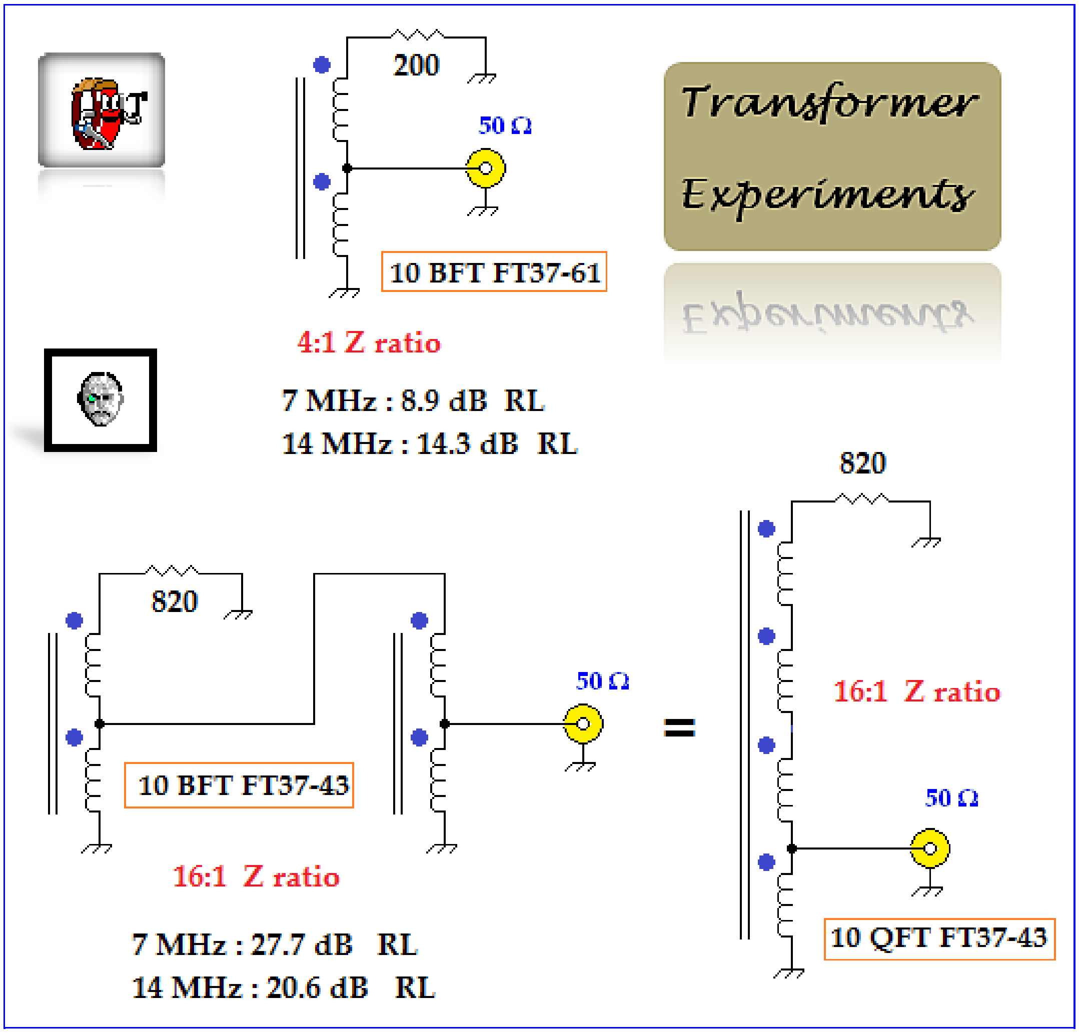
Transformer Experiments
200
50 Ω
10 BFT FT37-61
4:1 Z ratio
7 MHz : 8.9 dB RL
14 MHz : 14.3 dB RL
820
10 BFT FT37-43
50 Ω
16:1 Z ratio
7 MHz : 27.7 dB RL
14 MHz : 20.6 dB RL
=
820
16:1 Z ratio
50 Ω
10 QFT FT37-43

Above — Further transformer experiments. For a 4:1 impedance transformation at 7 and 14 MHz, a FT37-43 ferrite toroid gave a better out-of-circuit RL than the FT37-61 *The comparison transformer with a FT37-43 ferrite core was shown earlier*. It's possible to transform a big impedance such as 16:1 by cascading 2 bifilar transformers, or by using a quadrifilar transformer. I didn't build the quadrifilar transmission line transformer, but show it for completeness sake.

Of course, once you connect the transformers to a real circuit, things will change — still it's great to be able to examine transformer return loss in a controlled environment.

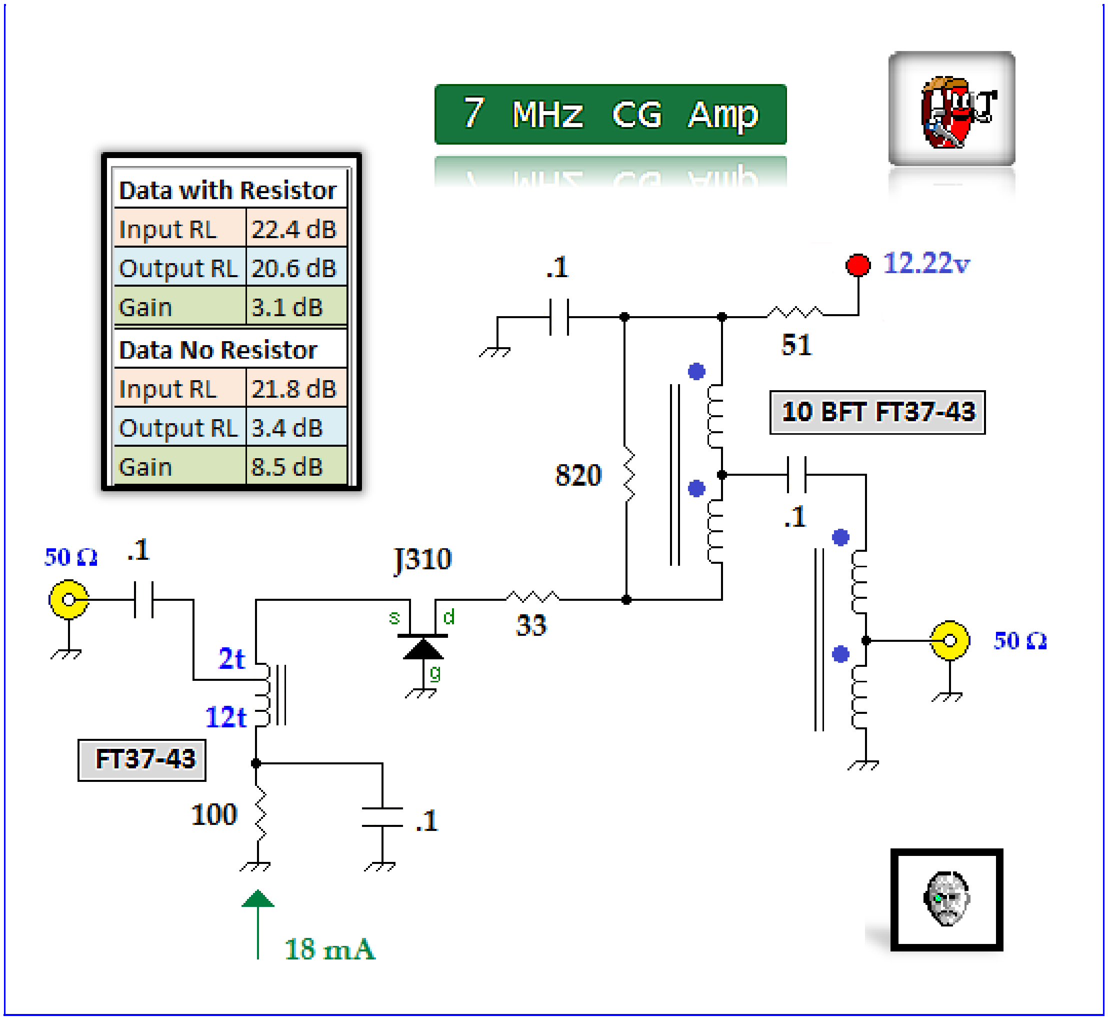

Data with Resistor	
Input RL	22.4 dB
Output RL	20.6 dB
Gain	3.1 dB
Data No Resistor	
Input RL	21.8 dB
Output RL	3.4 dB
Gain	8.5 dB

7 MHz CG Amp
.1
12.22v
51
10 BFT FT37-43
820
.1
50 Ω
.1
J310
s
d
g
33
2t
12t
FT37-43
50 Ω
100
.1
18 mA

Above — a common gate amplifier experiment using 2 cascaded 4:1 Z transmission line transformers. Data with and without the 820 Ω resistor shows that while the resistor gives a great output RL; it eats a lot of power. In cases where I've seen cascaded transmission line transformers used, the resistor was omitted. The Ugly Weekender transmitter by Wes, W7ZOI provides a good example.

In many cases, it's prudent to sacrifice gain for return loss, however, when you see a builder (like the former me), put a 32:3 turns ratio on a 5 MHz amplifier output transformer and label the secondary windings **"50 Ω",** we'll know better.

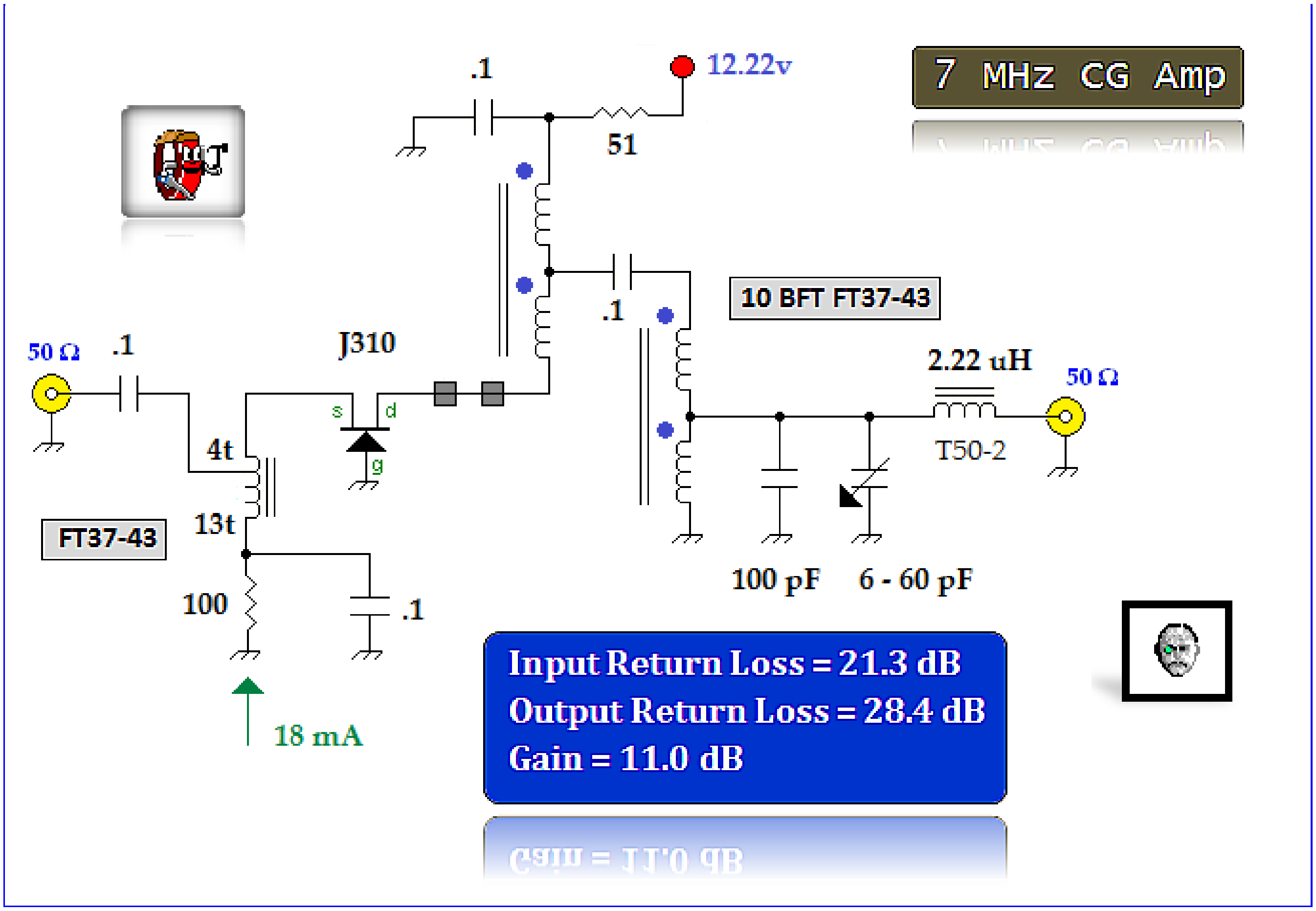

Above — An evolution of the amplifier above to get the best possible output RL. I omitted the 820 ohm resistor and matched the output with an L-network. The return loss on the output of the second transmission line transformer (measured before the L-match was added) was 3.4 dB.

The L-match values were *roughly* determined by using this chart (you can also do the math). According to the chart an *(output)* RL of 3.4 dB, is either 10 ohms or ~250 ohms or so. Ten ohms is unlikely, so I designed my L-match to match 250 to 50 ohms. This provided some starting values for the L and C parts and the rest was done on the bench using trial and error with an RL bridge. At the time, this was the highest output RL I'd ever achieved.

RF engineers use math to calculate impedance (they always do). I sent the schematic to Wes, W7ZOI for his analysis and summarize his return email comments as follows: At 7 MHz, the XL of the 2.22uH inductor is 97.6 Ω, therefore the impedance looking into that with 50 Ohms as the load is 50+j97.6. A complex inversion of this value gives a complex admittance that has a real part: 0.0041. Flipping that gives 240 Ω. The equivalent reactance is inductive with a value that would be tuned by a 184 pF capacitor; a bit more than you have there — so there is some reactance presented by the center tap of the second transformer. Neglecting these details, the L net generates about 240 Ohms. The two transformers then kick the Z up by 16 to 3856 Ohms.

I was pleased that my simple chart gave a value close to his calculation. Test it out — the chart may work okay for you.

The input match is over 20 dB and reasonable. More time could have been spent on the input autotransformer by tapping and such to increase the input RL, however, time is the 1 resource we all seem to lack.

4

The final amplifier experiments employ an L-match to set output return loss. When reading electrical engineering books you'll often see all sorts of matching networks on both the input and output of FETs and BJT amplifiers. The networks look simple, but in practice, aren't. They tune sharply, have a low bandwidth and in the case of the CG amp, harbor a big problem — tuning the output for the best output return loss, **dramatically** affects the *input* return loss and potentially, your return loss measurement by the reactance affecting the RF signal in your bridge.

When tuning the output, you're actually changing 2 complex impedances — this is not trivial.

Also if you're off by a few pF or tens of uH in your network C and L values respectively, you can wreak havoc with the measurements. At this point, I don't possess all the skills needed to tune both the output and the input network to a RL of 20 dB or greater; especially with a broadband input.

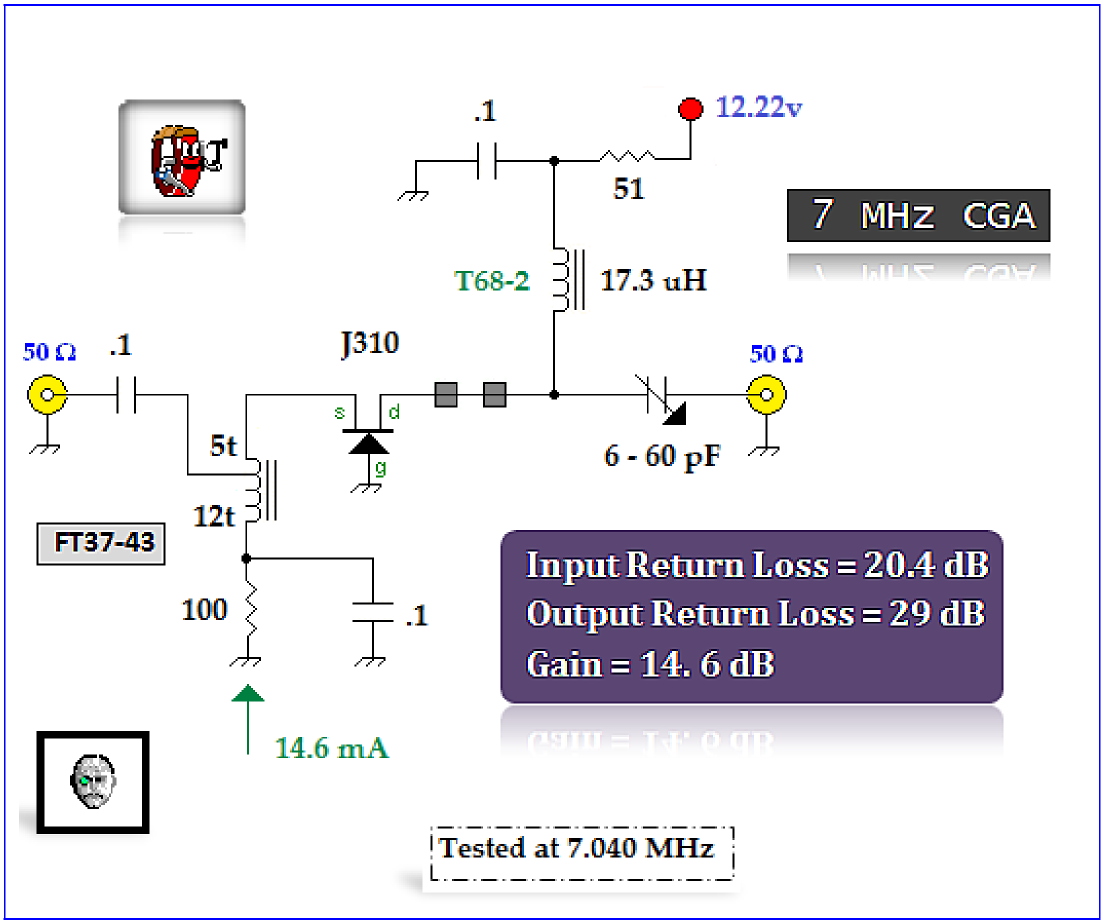

Above — A common gate amp employing a high-pass L-network to match the output. Miraculously after 2 hours of tweaking, I obtained a good input and output match; however this amp isn't reproducible. The inductor was wound on a T68-2 using 28 gauge wire — always a pain. Through trial and error, I learned that the output impedance of the drain was around 11800 ohms. Starting with 18.4 uH on theT68-2, I removed 2-3 turns at a time until a reasonably low return loss was obtained; then I removed 1 turn at a time. I went too far and had to add back a turn. I clipped the excess lead every second turn which made it tedious, but exacting. It seems that the L value is very critical – it would be nice to use a variable inductor to figure these things out. Compressing and expanding the windings also provided a simple way to vary inductance.

In several other circuits, the best possible input return loss was only 14 dB. Mistuning also caused oscillations to occur in one 14 MHz amp with an output network inductor of 7.4 uH. I also tried a 14 MHz amp with an L-match on both the input and output, however, was unable to match both the input and output due to the interplay between them.

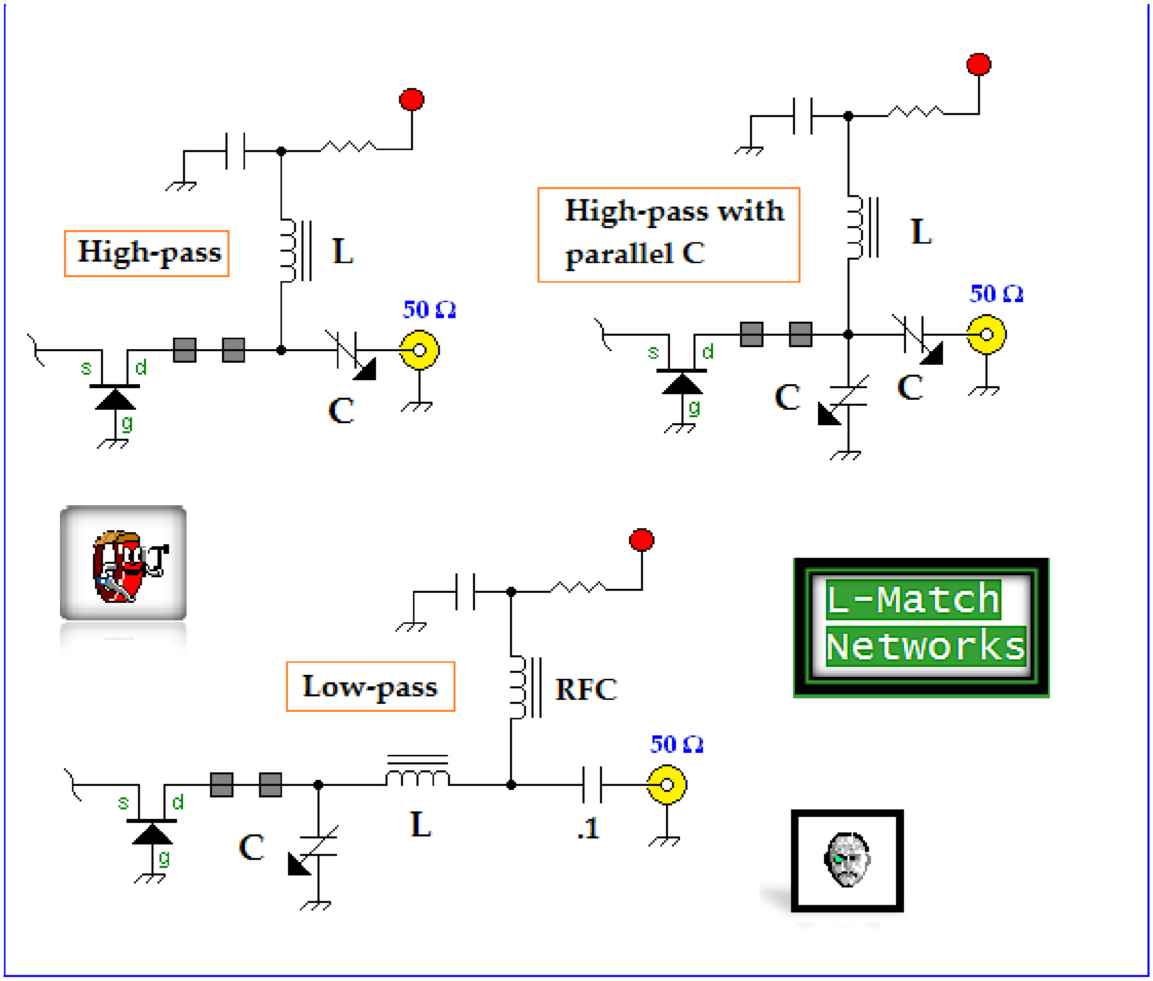
High-pass
L
50 Ω
s
d
g
C
High-pass with parallel C
L
50 Ω
s
d
g
C
C
Low-pass
RFC
50 Ω
s
d
g
C
L
.1
L-Match Networks

Above — Here are 3 possible L-network configurations for tuning a CG amplifier output. They can be used in other circuits and are worth studying. The L-match with 2 variable capacitors generally requires lower inductance than the others.

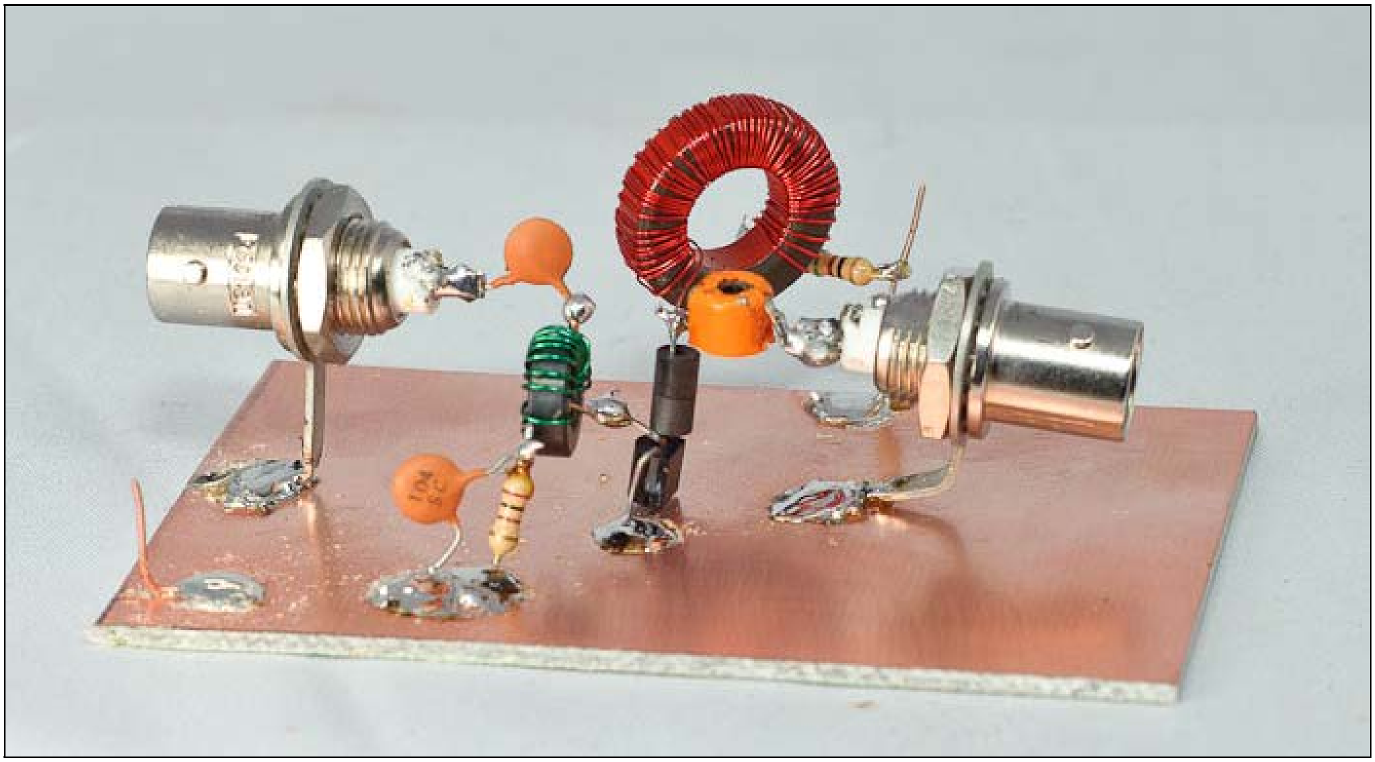

Above — A breadboard of 1 of the high-pass tuned CG amps. The gate lead on this transistor is too long — the inductance will likely cause UHF oscillations. 2 ferrite beads were placed on the drain to mitigate these, but a better construction technique is recommended and shown below.

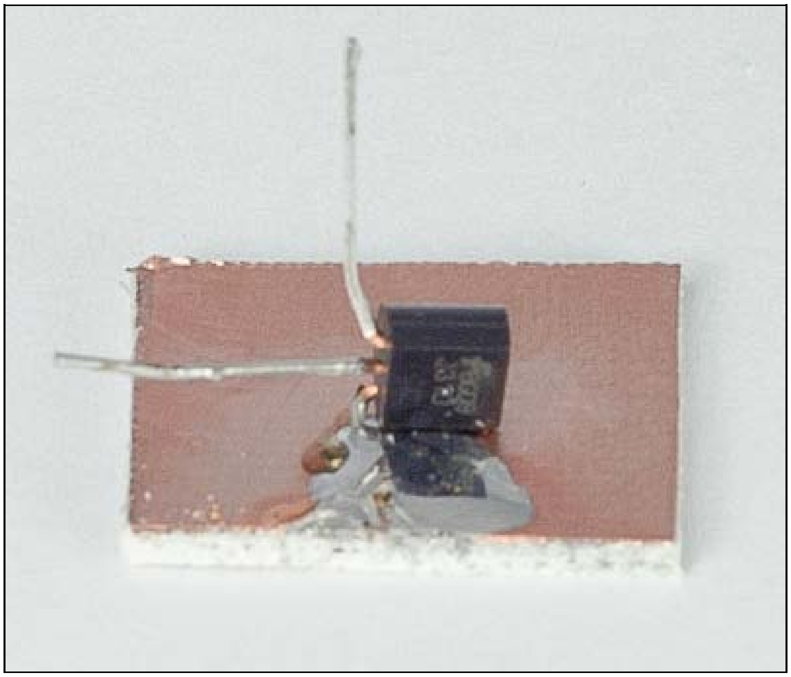

Above — the preferred way to ground the gate with the JFET on its side. The hole-through version of the U310 JFET has a metal case that is connected to the gate that makes it ideal for grounded gate amplifiers. Some suppliers only sell SMT versions of the U310 now.

4. QRP — Posdata for January 2013: Transistor Bias Model

This discussion concerns setting up the DC bias point for linear BJT operation.

Earlier I stated that a bipolar transistor is a voltage controlled device. A few readers thought I made a typo: something I frequently do, but not in this case, since I purposely made that statement. In reality, the argument could go either way since collector–emitter current is controlled by the base-emitter current (~a current controlled device) and by the base–emitter voltage (~a voltage controlled device).

Stated using the correct physical model, a transistor is a **current controlled current source**. With external circuitry we can manipulate this physical model into a voltage controlled current source, or a voltage controlled voltage source, or even a current controlled voltage source. Whether you model the transistor with current or voltage, the math tells the truth when properly examined.

Please view the following two 2N3904 SPICE models generated by Wes, W7ZOI for me many years ago when I began to learn small signal analysis using impedance and hybrid parameters, plus set out to learn ways to establish DC bias and temperature stability in BJTs.

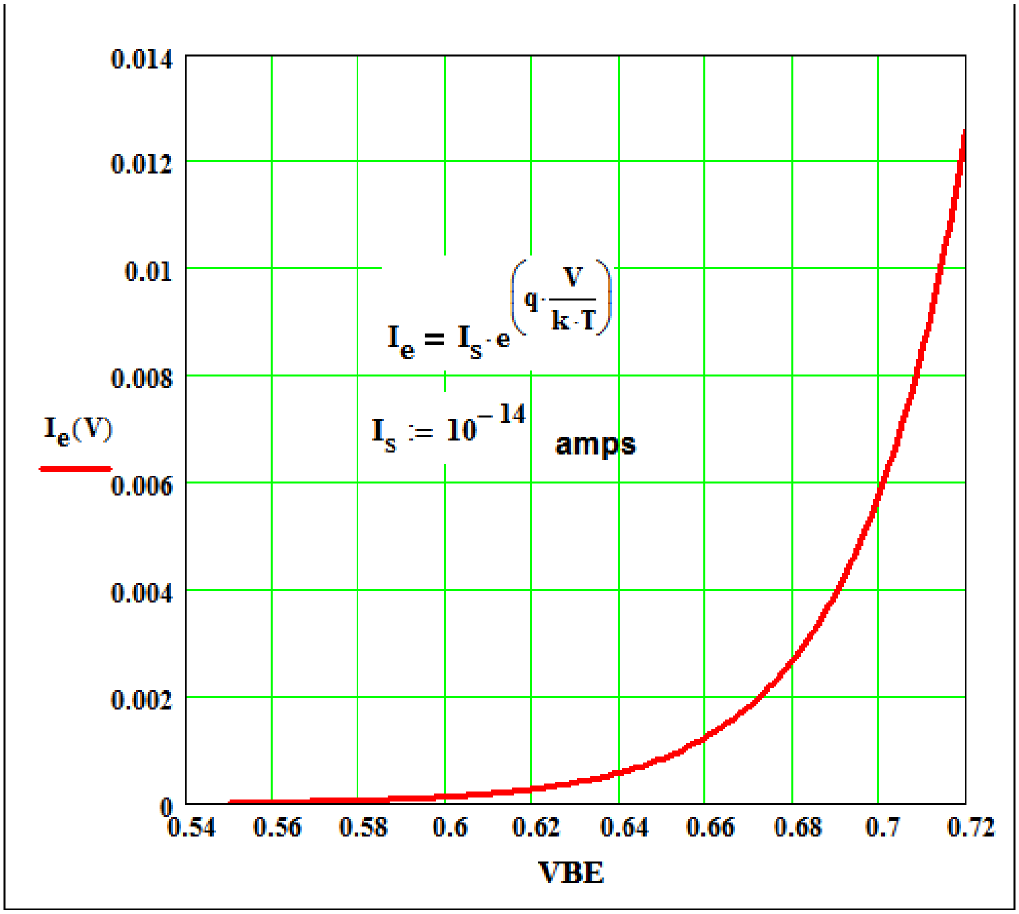

Above — the Y axis shows how changing base-emitter voltage or current changes the VBE. We tend to assume a VBE of 0.7, however, the math shows the truth. Whether we plot voltage or current for the Y axis data, the graph slope remains similar. The greater the applied DC voltage placed on the base-emitter port, the more current will flow.

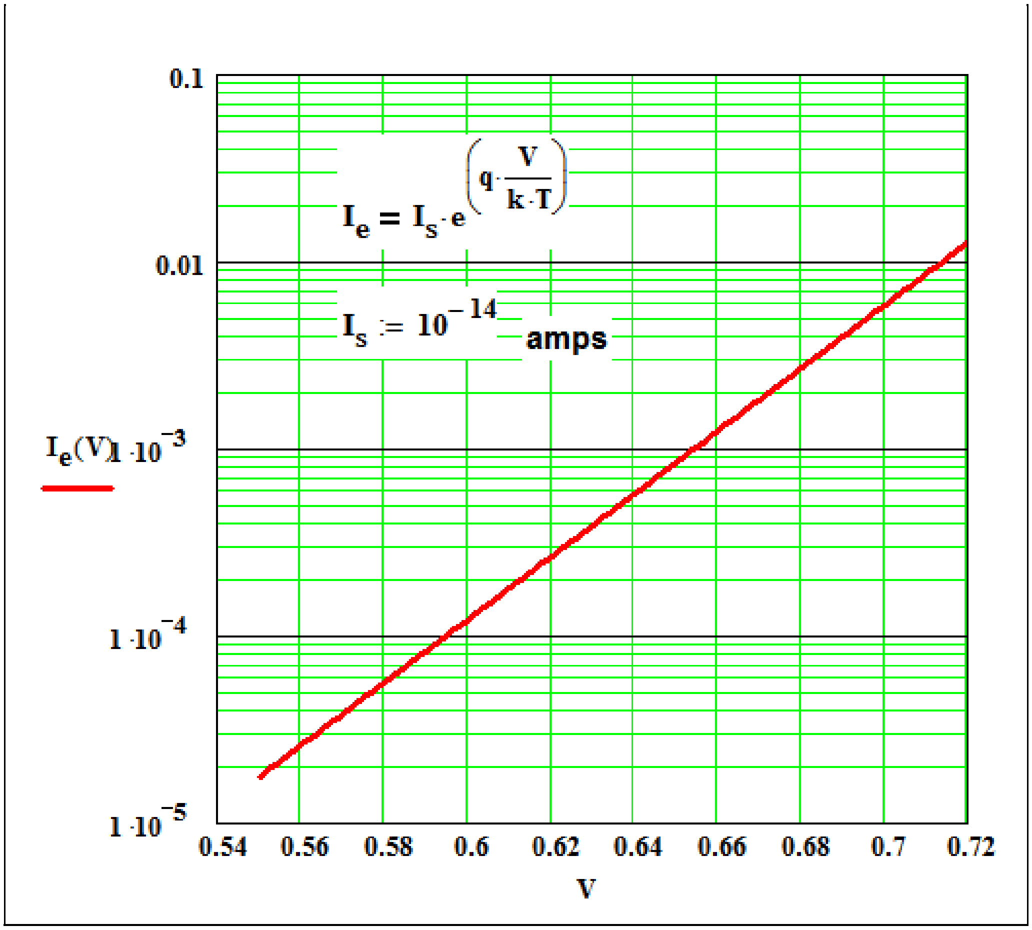

Above — Logarithimic base current plotted against VBE. If we want this current to increase, we need to put more DC voltage on the BE junction. On the bench, we may easily measure base voltage to confirm our calculations — measuring base current proves more difficult. Whether I'm setting up amplifer bias with voltage dividers, a current source, or even biasing it with a downstream AGC voltage, I prefer to think in terms of voltage control — although I get that V and I truly just coexist.

Current or voltage modelling — it's your choice and the math will guide you. Look for these equations on the Web, or in second hand bookstores. I've got 8 or 9 transistor theory books now and they're really timeless.

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5. Miscellaneous Figures and Photographs

ECS D
11.04-
KOREA

RF
Shunt Feedback
Decreases input Z
Affects current gain

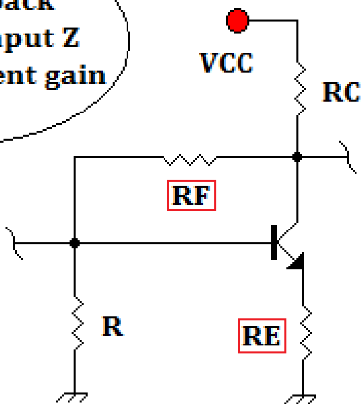

RE
Series Feedback
Increases input Z
Affects voltage gain
emitter degeneration

FBA

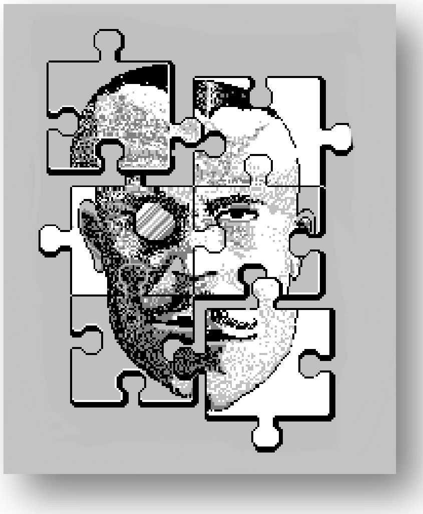

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6. References

1. Communications Receivers - Principles & Design. Rohde, L.R and Bucher, T.T.N. 1988. McGraw-Hill.
2. Technical Correspondence QST Magazine (ARRL) Aug 1990. Hayward W.
3. Experimental Methods in RF Design (ARRL) 2003. Hayward W. Campbell R. Larkin B.
4. Microwave Handbook Vol 1. Components and Operating Techniques. 1989 RSGB.
5. Emails with Wes, W7ZOI and Professor Ken Kuhn, Winter 2010-2011 — Thanks! Никогда не забуд.

RF — Test and Measurement

Hobby and Fun 2011

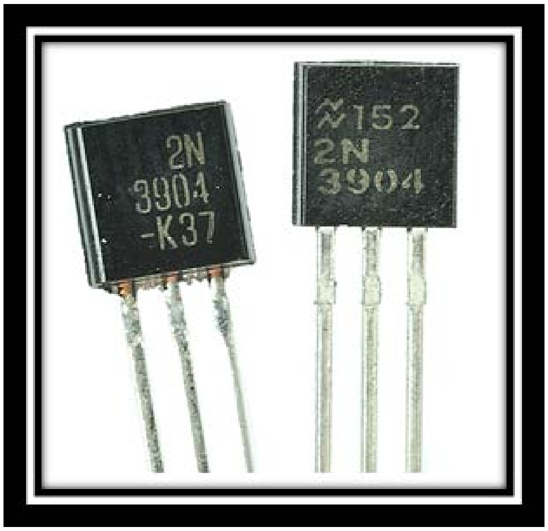

Introduction

Hobbies are supposed to be for recreation. Electronics should be fun, not stressful — heavy math, big parts counts and complexity are more likely to scare away experimenters than recruit them. This page avoids the measurement focus of my latest stuff and simply promotes fun and discovery.

You might be interested to know that my simple experiments/projects garner the most emails. Many wrote "I'm rediscovering electronics", or, "I want a simple and fun hobby". Hobby and fun are my goals too.

Simple Regenerative Receiver Experiments

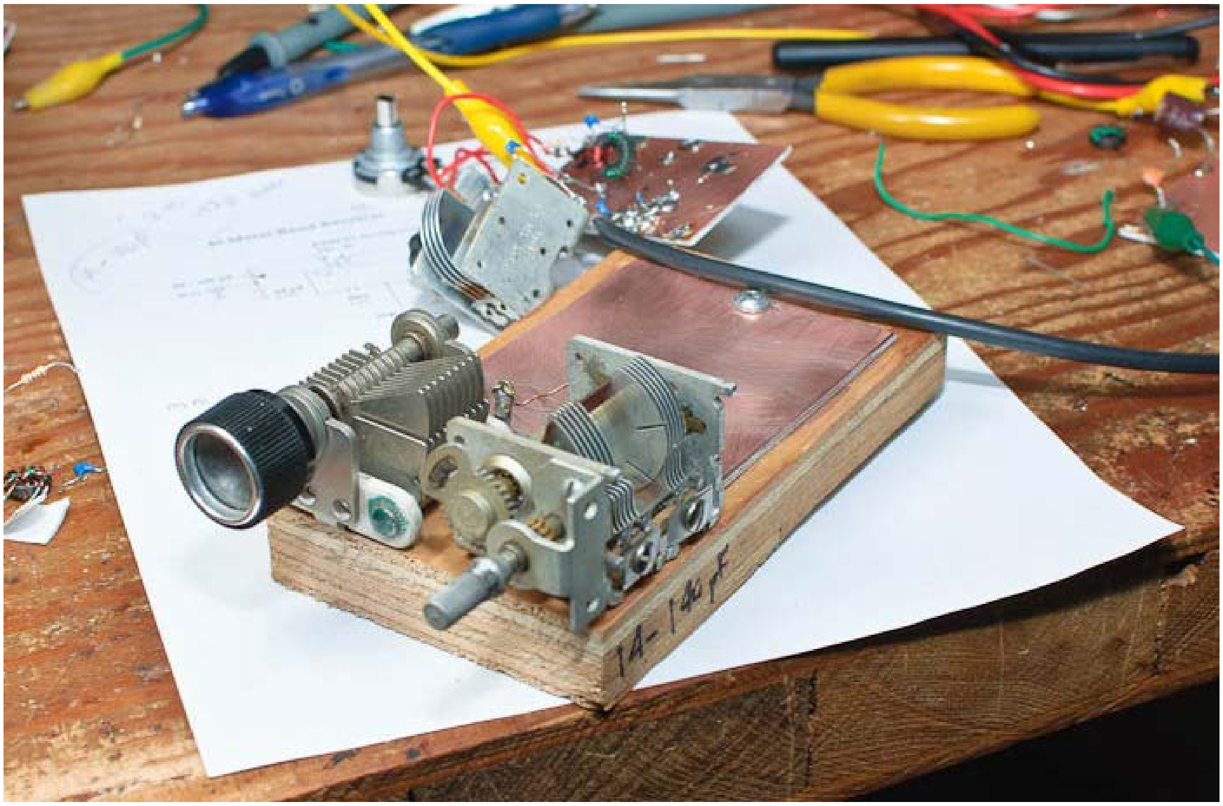

Above — 2 air variable capacitors and a copper clad board screwed onto a piece of wood for my bench musing. Regenerative receivers delight and amaze — some builders take them very seriously. I respect this, but to me; they should be as simple as possible. I wanted a 2 stage "genny" receiver for this page and present 2 different receivers; 1 is my design, the others is a JFET variant of a favorite W7ZOI circuit. Quoting Wes, W7ZOI "feedback your imagination".

Some builders place a simple common gate or a common base RF preamp on the input to boost gain and reduce antenna radiation of the RF oscillator, while others place an RF gain control on the input — usually a potentiometer; to prevent overloading the RF stage. I won't prescribe what to do — that's up to you. There are countless example of regenerative receivers on the web and you can many spend hours viewing them. Some of the most intriguing are those built by Russian speaking experimenters. Example link.

My circuit ideas are meant as fodder for your own experiments.

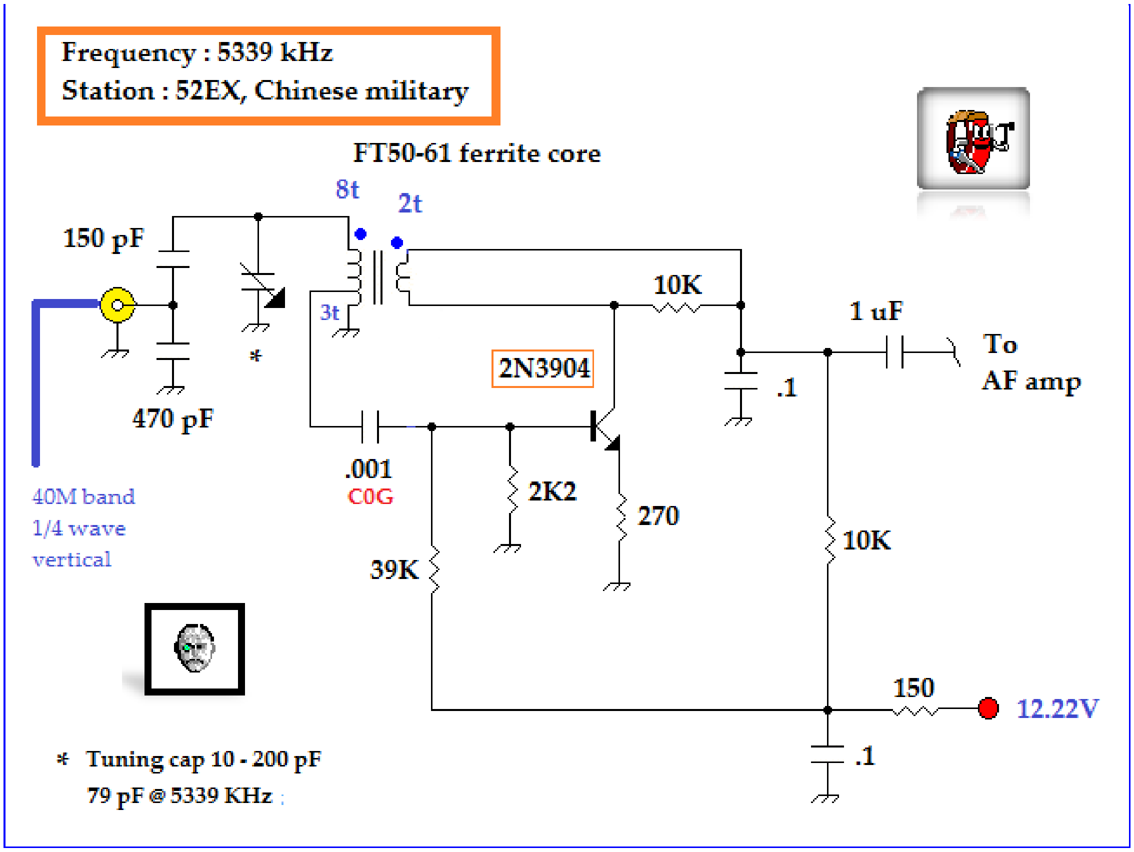
Frequency : 5339 kHz
Station : 52EX, Chinese military
FT50-61 ferrite core
8t
2t
3t
150 pF
470 pF
*
10K
2N3904
1 uF
To
AF amp
.1
.001
C0G
2K2
270
10K
39K
40M band
1/4 wave
vertical
150
12.22V
.1
* Tuning cap 10 - 200 pF
79 pF @ 5339 KHz

Above — An experimental, ultra-simple "CW" receiver. At 5339 KHz I hear strong Morse code each night. It's suggested to be from China, but I'm unsure. Connected to my 1/4 wave 40M band vertical - a simple matching network and trimmer tuning capacitor were fitted to the input. Here's some audio. I like the beat note of this receiver - it has no regeneration control and is fixed for CW. Minimalist circuits are fun — some hardcore regen builders might freak out; no voltage regulator (here's a version with that + a T68-6 inductor), no regeneration control (here's a version with that), a relatively low Q coil etc. I wanted to try my hand at design and not just copy someone else's receiver.

I call it the Stupid— Simple receiver and although it emits crisp, warm audio, some bench work is required to get the correct bias and appropriate amount of positive RF feedback — an experimenter's circuit that explores DC bias and AC feedback. The sort of thing a father can build with his son. We need more circuits fitting this profile.

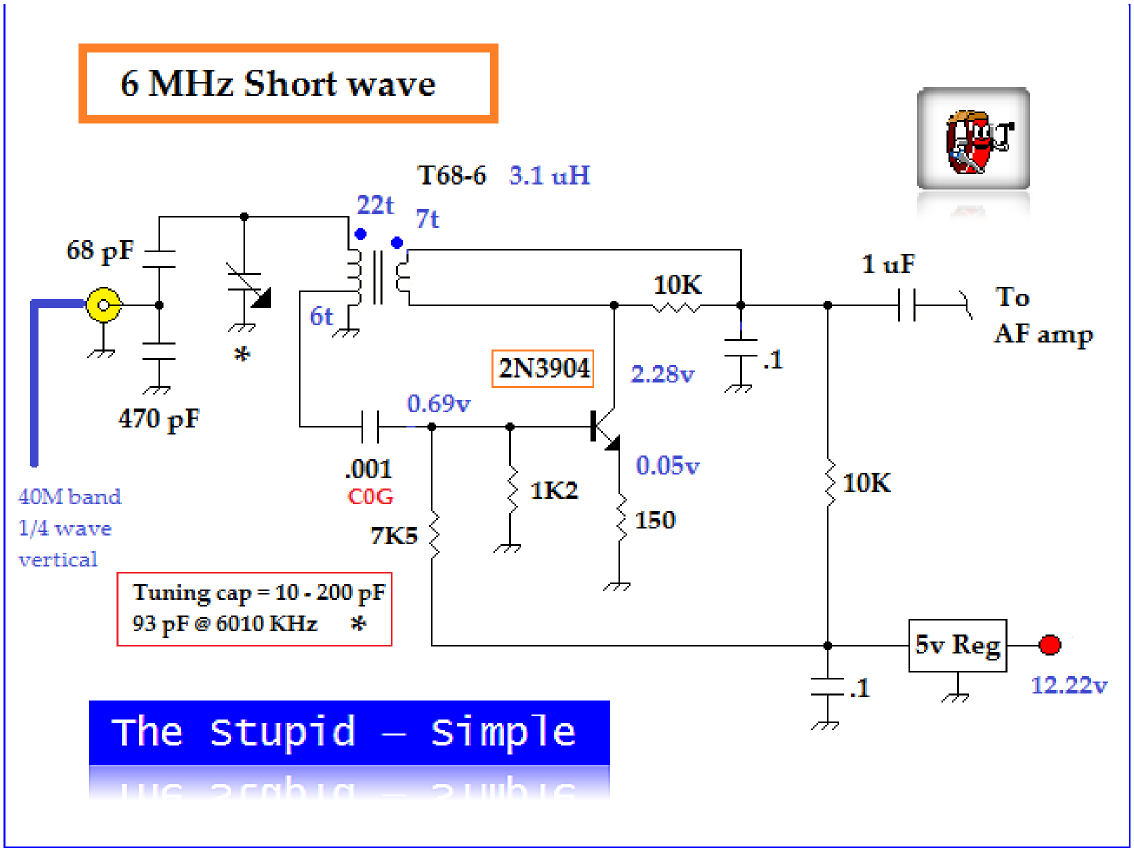
6 MHz Short wave
T68-6 3.1 uH
22t
7t
6t
68 pF
470 pF
*
40M band
1/4 wave
vertical
10K
1 uF
To
AF amp
2N3904
2.28v
.1
0.69v
.001
C0G
1K2
0.05v
150
7K5
10K
Tuning cap = 10 - 200 pF
93 pF @ 6010 KHz *
5v Reg
.1
12.22v
The Stupid — Simple

Above — The Stupid—Simple experimental receiver set up for ~6 - 7 MHz. 2011 marks the 50th anniversary of Radio Habana Cuba. We tune RHC at 6010 KHz, and as long as I've been listening to SW radio, I've tuned this station. Here are 3 sound bytes from around 6 MHz recorded from 2:30-2:40 GMT on Feb 28, 2011, including an old repeated episode of DX'ers Unlimited by Arnie Coro which had faded out by the time I located and turned on my audio recorder. Audio1 Audio2 Audio 3. The audio stage in these recording was a discrete transistor AF amp I designed, however, an LM386 was chosen for the final amp to keep the parts count and difficulty down. I got a little too close to the receiver a couple of times during the recording and made the open circuit breadboard squeal.

Arnie Coro talked about a "regenerodyne" receiver in Sound Byte *Audio3*. Very cool. Here's a link. Now this is radio!

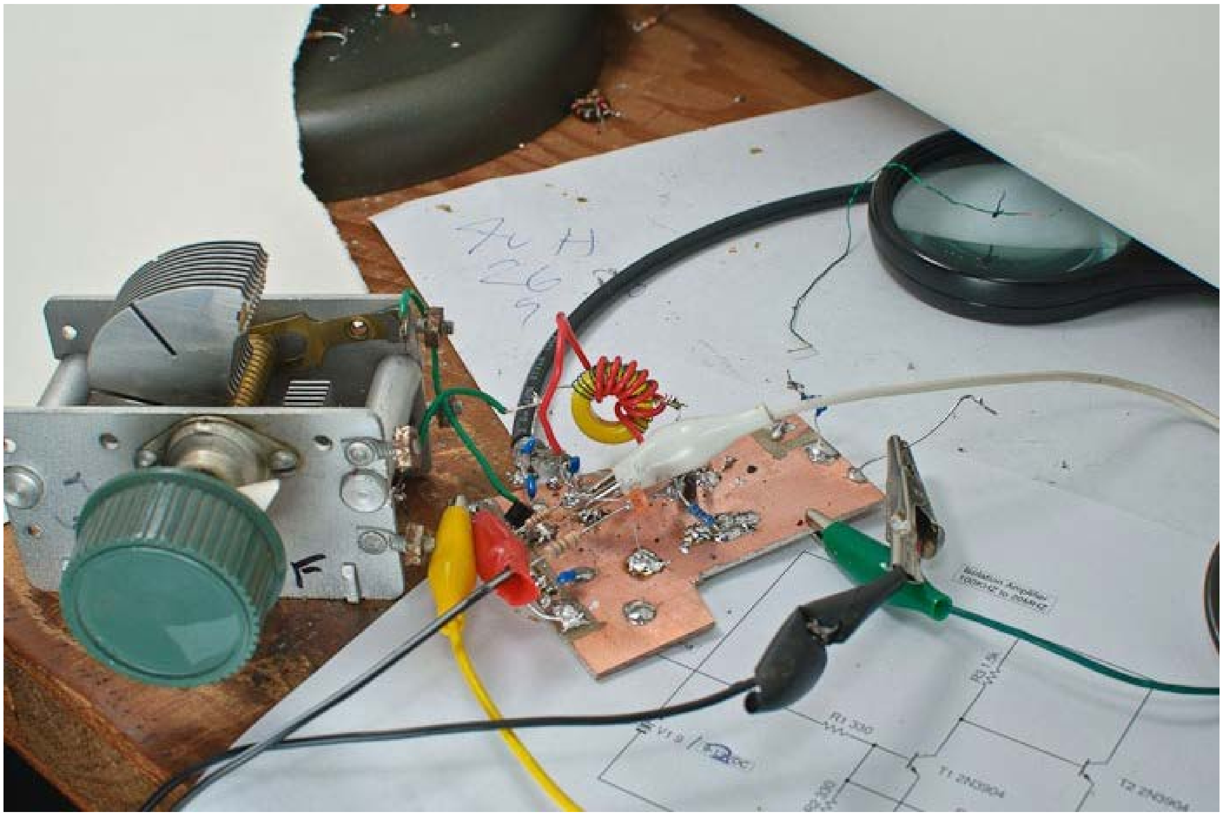

Above — The Stupid-Simple regenerative receiver breadboard for 6 MHz. You can see the T68-6 — the red secondary windings are wound in the same direction as the 22 turns of primary. I started with 9 turns and unwound a link and tested sequentially until I had the right amount of feedback for AM. I just used normal hook up wire for the secondary winding. The white colored cable goes to the audio amp. This is a prototype experimental layout — a regenerative receiver should have short connections around the tank circuit and be in metal box for best results.

On some stations, my little 1 RF + 1 AF stage receiver sounded better than my superheterodyne receivers. The 2N3904 is just barely turned on — I determined that a base bias of 0.66-0.69v provided maximal sensitivity. The 150 ohm emitter resistor can be a 500 ohm pot and used to fine tune the regeneration. 150 ohms gave the best compromise gain and feedback + current for the 2N3904.

Audio Amplifier

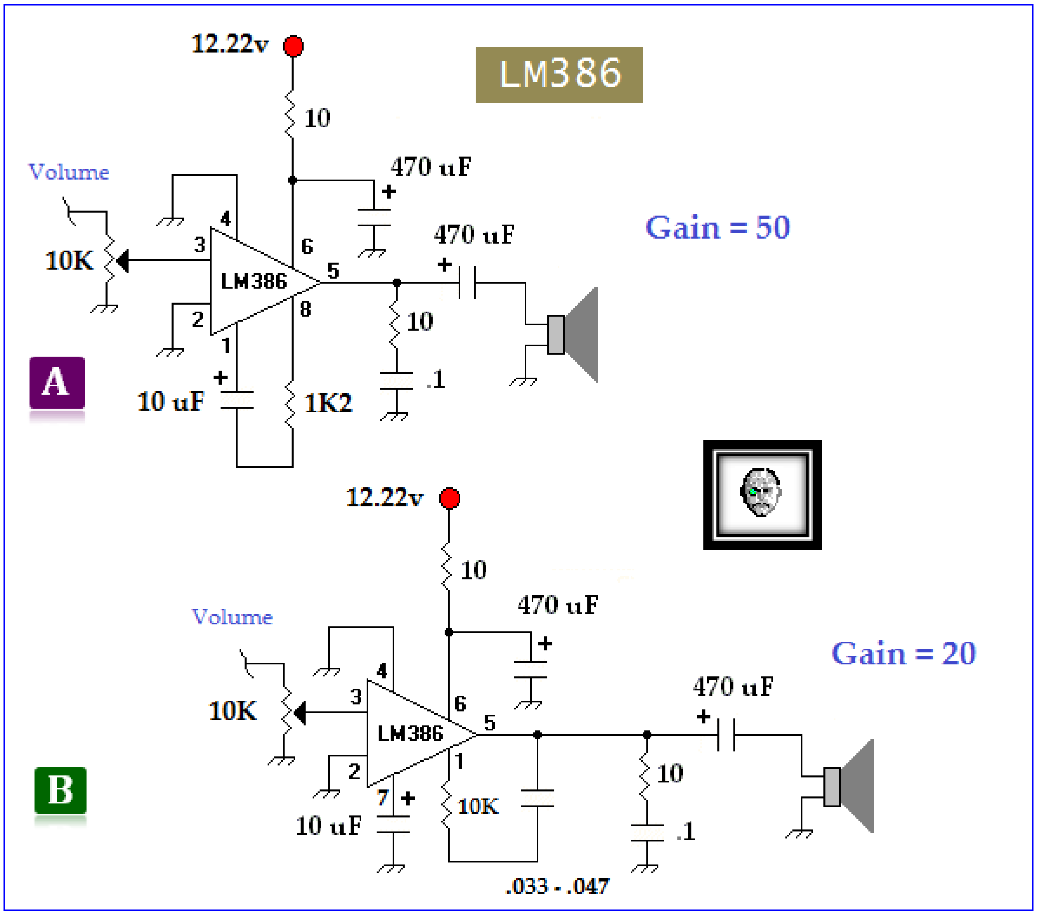

Above — I chose an LM386-N for my AF power amplifier. The LM386 exhibits less peak signal distortion when run in the low-power (X20) gain mode and a higher VCC such as 12 volts. My receiver used the schematic denoted B — a 10K and 0.033 to 0.047 uF RC network is used to reduce the amplifier high frequency response. Click for a sound byte of me tuning around 6 MHz with a 10K + 0.047 uF RC network between pins 1 and 5. Figure B is my favorite way to use the LM386 and comes right off the National Semiconductor LM386 data sheet. Look for this data sheet with your favorite search engine.

Because I have a big antenna, Figure B provides adequate volume to a speaker. Connecting pins 1 and 8 via a 10 uF capacitor bypasses some emitter resistance and gives X200 gain. A resistor in series with the capacitor pin 1 and 8 will reduce the gain. Figure A shows a gain = 50 configuration. You'll have to choose the LM386 set gain to suit your particular regenerative receiver, however, the greater the gain setting, the greater the chance of distortion, unwanted noise and audio feedback.

I generally build my audio power amps around op amps or discrete transistors, but the LM386 exalts this web page's theme. Distortion in all these small power amplifiers is dependent on input signal amplitude as much as anything else.

LM386 Motorboaters

Expect AF feedback motorboating via your DC power lines as you increase the AF gain pot in *many* LM386 circuits. If this happens, try better bypass and decoupling on the LM386 power line: 100 to 470 μF shunt bypass on the DC line + a 10-22 series decoupling resistor, plus 100 - 470 μF shunt bypass on pin 6. Click for 1 example. ypically 470 μF bypass is required if you suffer 60 hertz hum. You may model your simple RC filter with application E on the javascript applet page to see the 3 dB cut off frequency of your particular DC line low-pass filter.

Stupid—Simple Notes

The Stupid—Simple circuit really needs the adjustable 10K regeneration control if you wish to tune both AM and CW. The number of turns on the feedback winding varies with factors including transistor beta, how you wind the primary and secondary windings (greatly affects the coupling between the primary and secondary windings) and whether you want AM, or CW reception — or both. Experiment with the number of turns to figure it out.

You can try "matching" the tank circuit to your antenna by decreasing the 470 pF cap to as low as 68 pF. This will affect the tuning capacitor range. For an air variable tuning capacitor, use anything you can find. Consider connecting fixed parallel and/or series capacitors to reach or limit the desired capacitance. Many good examples are published on the web.

Some builders float the tuning capacitor across the inductor so the cap is ungrounded. The stator (body) of the capacitor should be connected to the circuit ground to help minimize the effects of hand capacitance. A grounded metal case further helps.

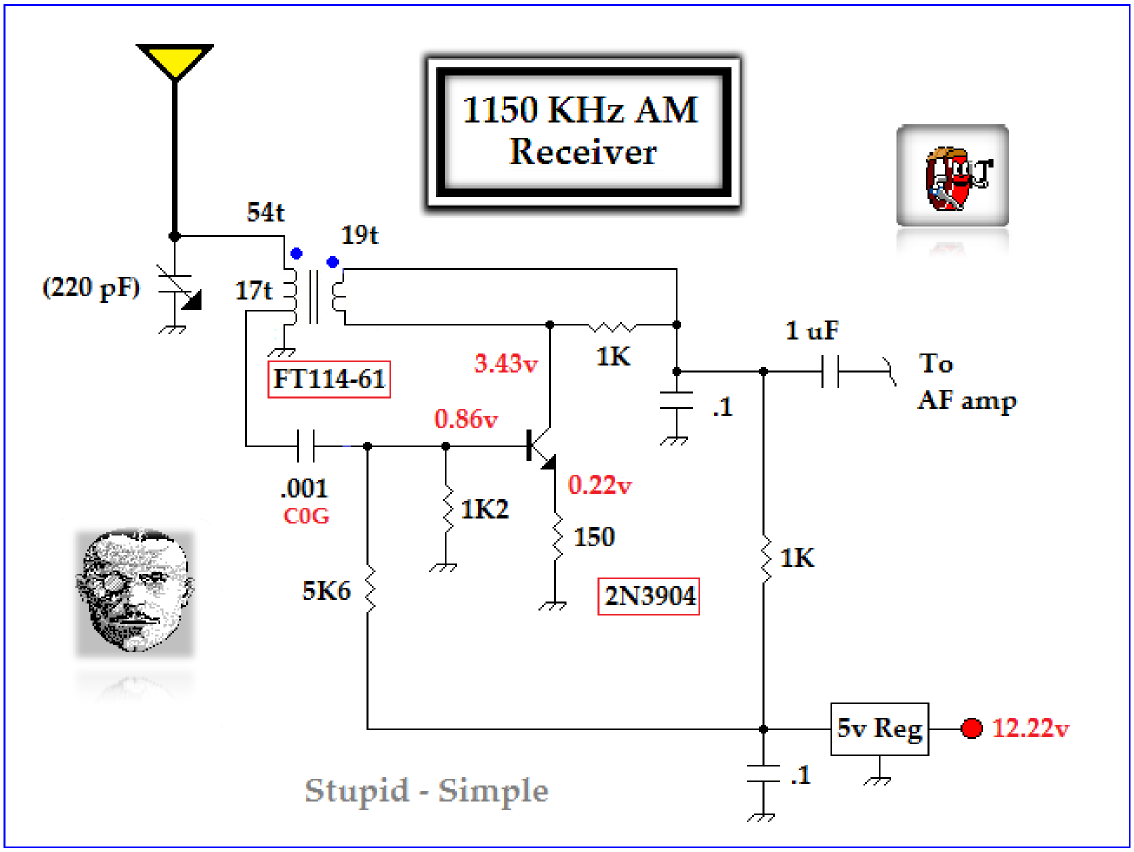

Above — My popcorn regenerative design "The Stupid-Simple" set up for broadcast band radio at 1150 KHz.

A reader from Brazil enquired about putting the Simple Stupid on MW. I had some time for a couple of experiments but only wanted 1 frequency — 1150 KHz, the local 10 KW sports radio station. Using 28 gauge wire, I wound 54 turns (about 230 uH) on a A FT-114-61. Most builders won't have this toroid, however ferrite rods from AM radios are plentiful and a great substitute.

This design relaxed the regeneration to improve audio quality (no whining or hissing). The bias and feedback loop were wound for the best sounding audio. For example, at the bias shown, if you increased the 19 turn link to 21 turns, the bass response increases; decreasing to 17 turns reduces the bass response.

As a result of lowered positive feedback, the selectivity is down, however, a variable capacitor is needed to peak the station. After peak tuning, I removed and measured the air variable cap at ~ 200 pF and then substituted a 220 pF fixed capacitor to simplify things.

For audio, I used a bench AF power amp into a speaker. It sounds nice for 1 transistor. Audio sample

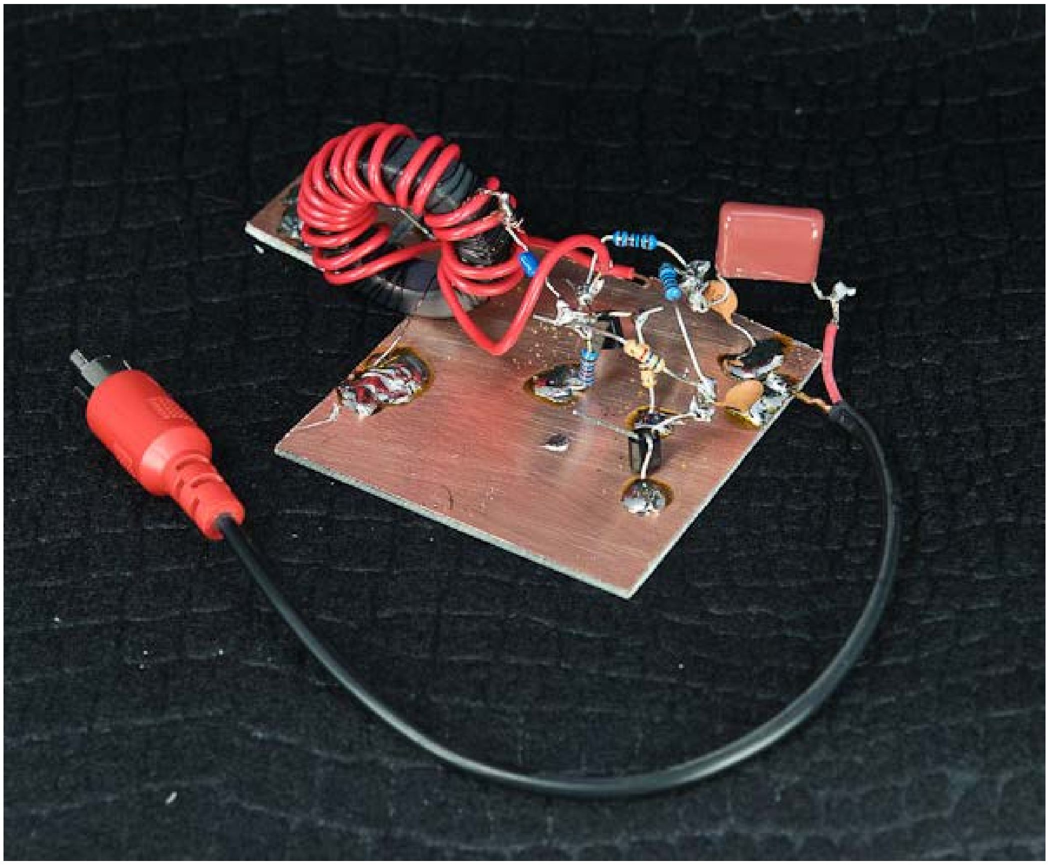

Above — The breadboard of the 1 channel receiver for my workshop - I'll use it to keep track of the Canadian Football League statistics. My test antenna was a long piece of outside wire. Red hook-up wire forms the 19 turn feedback winding.

For cities with multiple AM stations (AM stations are dying out in Canada), you'll have to add more regeneration and probably move to a better design. This radio is simple, but not extraordinary.

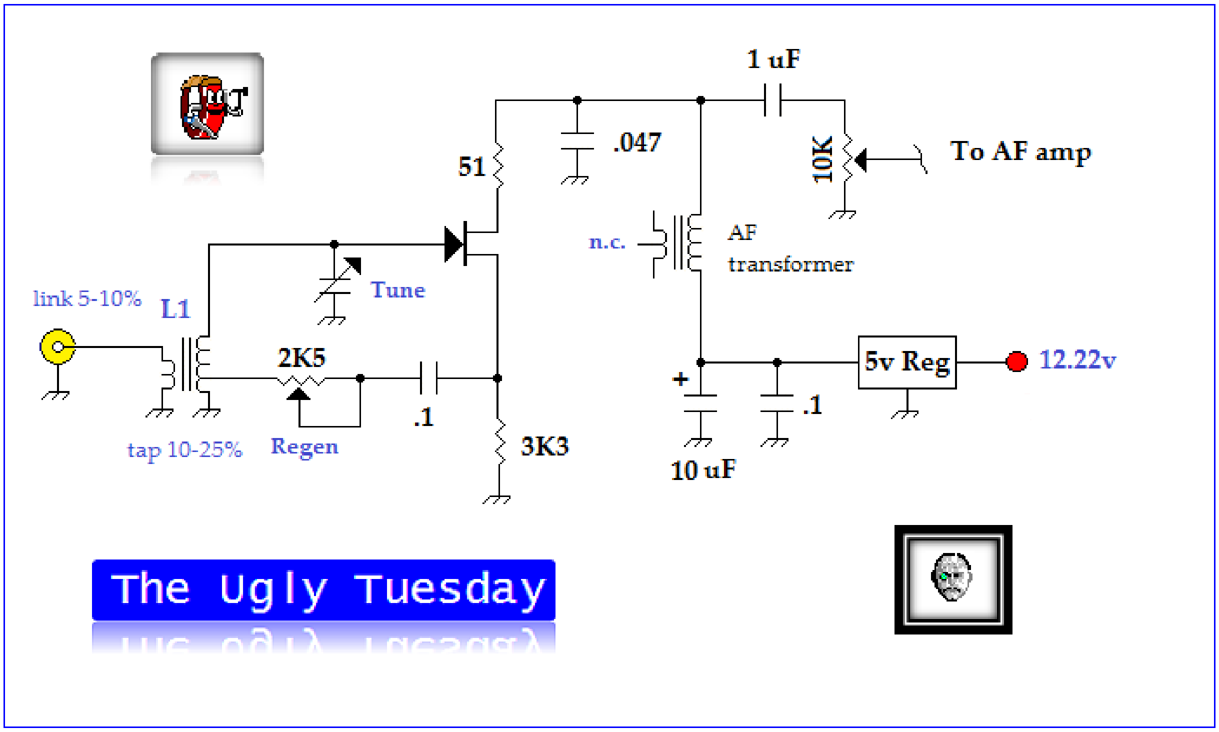

Above — Another regenerative design that tuned AM, SSB and CW from 5-11 MHz with different toroid coils wound on a T50-6. It's based on a favorite design by Wes, W7ZOI. I suggest tapping L1 at 10 - 25% of the total number of turns. The secondary link for the antenna connection depends on the impedance of the antenna, but 5 - 10% of the total number of L1 primary turns worked well at my QTH. Please experiment with the secondary link to determine the optimal coupling to your antenna. My L1 inductance ranged from 1.5 to 5.6 uH. You may have to add a fixed capacitor in parallel with your air variable capacitor when using low inductance coils such as 1.5 uH.

The 51 ohm resistor suppresses UHF parasitic oscillations. The AF transformer is a transistor radio output (1000 : 8 ohm) junk box special and serves as an RF choke. I tried various AF transformers harvested from old transistor radios in this slot and they all worked fine. Nothing's really critical on this receiver — that's why I like it. Truly junk box radio.

Simple Active Antenna Experiments

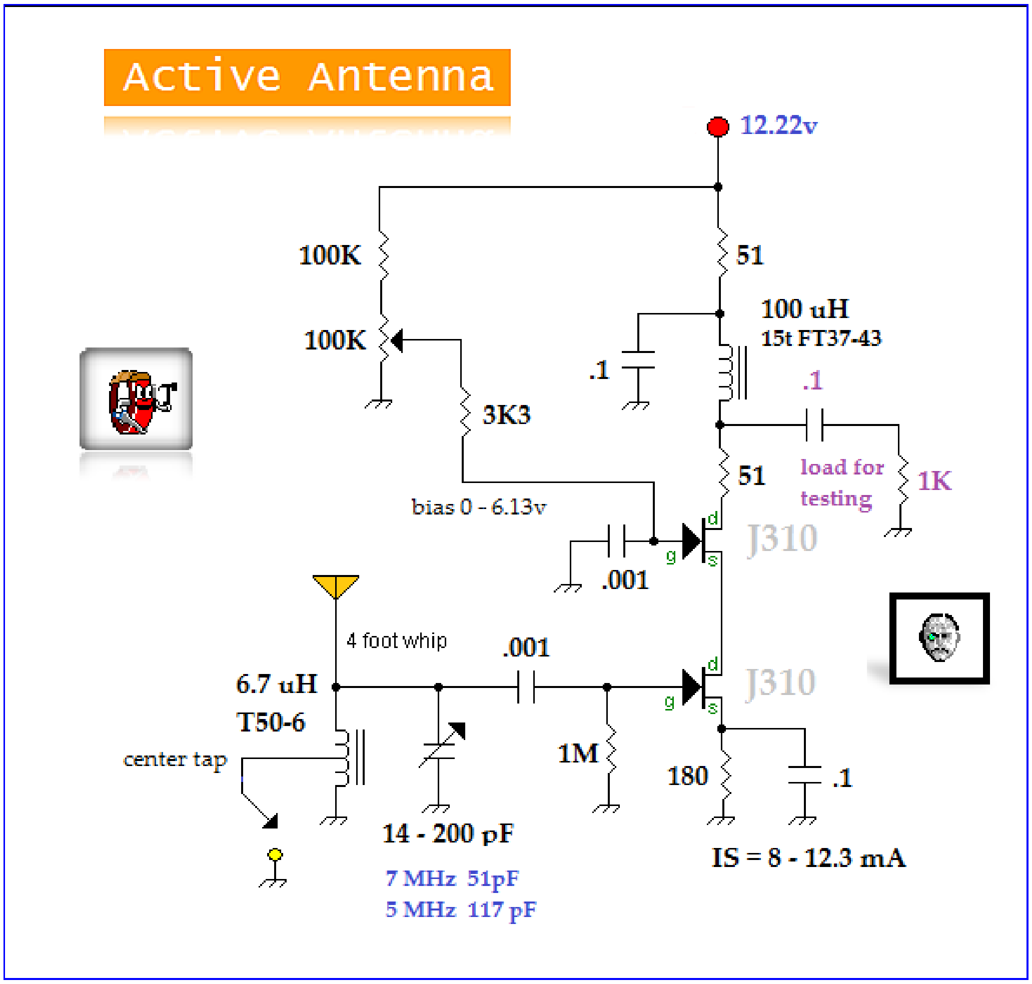

Above — A voltage probe or active antenna using a telescopic whip. It's been awhile since I built one in keeping with a minimalistic circuit theme. I tested this VPA from 5 to 14 MHz. The center tap on the coil allows the peaking at ~10 MHz and higher. The L value is non-critical; choose a value that will work with your tuning variable capacitor or varactor. The L - C values can be *roughly* determined from a chart like this, or just do the math (XL = XC at the desired frequency). Account for stray inductance. If you wish to perform return loss measurements on this circuit, you'll have to short the 6.7 uH inductor as the whip antenna can tune in RF from the RF signal generator used for the return loss bridge.

Without the 1K load, the circuit will oscillate. I thought about some ways to match the output transformer to a regenerative receiver tank circuit. The 100 uH drain choke could be replaced by a (bifilar) 2:1 transmission line transformer or two. Transformer experiments this Winter clearly illustrated the superior coupling of transmission line transformers and mandates using them over conventional transformers whenever possible.

Using a conventional transformer with a shunt resistor across the transformer would also work, but the resistor reduces gain. I built and tested this output circuit with an 8:1 transformation using two 2:1 transmission line transformers. The output impedance at the JFET drain is somewhere around 4300-4500 ohms at 7-14 MHz. The transformed output impedance is somewhere around 250-330 ohms at 7- 14 MHz. Connecting the VPA output to a tap in the regenerative main tuning inductor might work — being careful not to load down the regenerative tank coil.

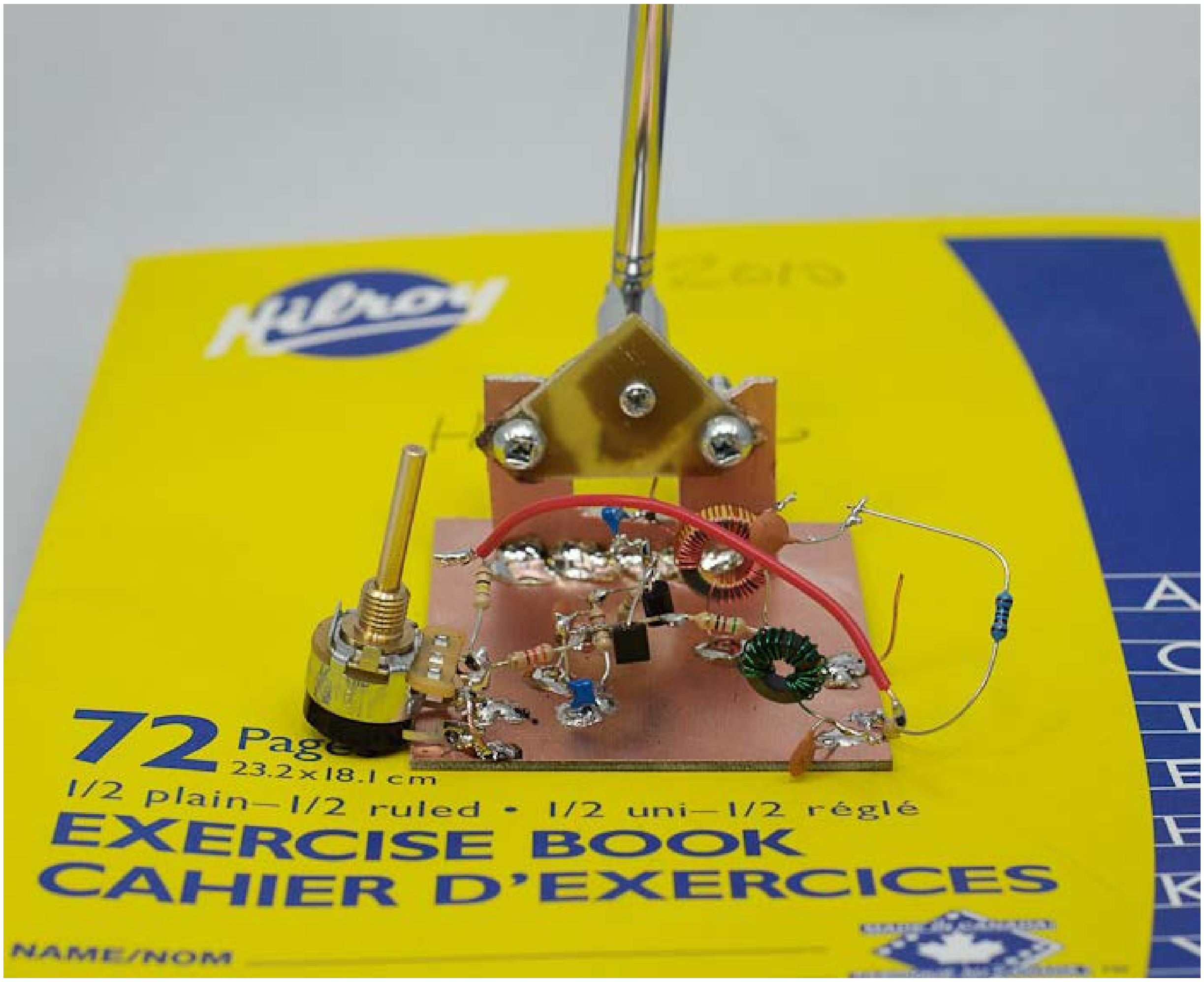
2010
Hilroy
72 Pages
23.2×18.1 cm
1/2 plain—1/2 ruled • 1/2 uni—1/2 réglé
EXERCISE BOOK
CAHIER D'EXERCICES
NAME/NOM

Above — The VPA breadboard on my latest notebook. The 100K pot sets the stage gain. While simple, it works okay.

Above — the VPA built March 12, 2011 (the 14-200 pF air variable cap is not shown). It took about 45 minutes to design, build and test it. The 1K load used for testing is the blue resistor to the extreme right.

Low-pass Filter for 21 MHz

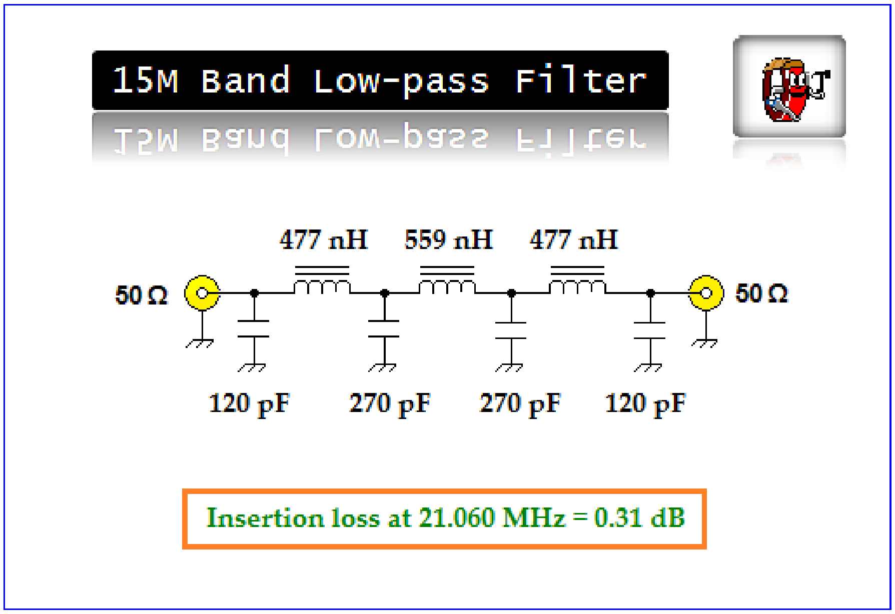
15M Band Low-pass Filter
477 nH
559 nH
477 nH
50 Ω
50 Ω
120 pF
270 pF
270 pF
120 pF
Insertion loss at 21.060 MHz = 0.31 dB

Above — A 7 element Chebyshev low-pass filter for the 15 Meters Ham band (fCo = 25.03 MHz to allow the use of standard value capacitors). A builder requested a band-pass filter design for his 15M band receiver. In order to accurately test my design, I decided to make a permanent, low-pass filter module to follow my signal generator. 15 Meters is a favorite Ham band, so I'm certain to use it in the future.

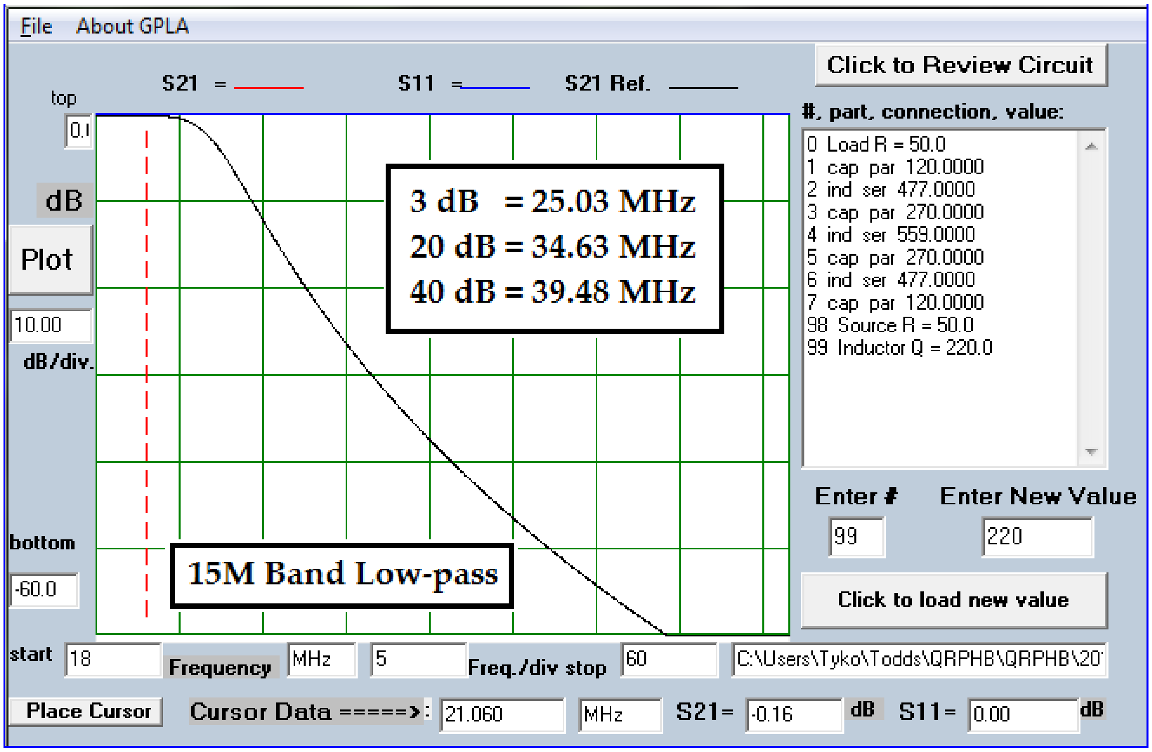
File
About GPLA
S21 =
S11 =
S21 Ref.
Click to Review Circuit
top
dB
Plot
dB/div.
bottom
Place Cursor
Click to load new value

3 dB = 25.03 MHz
20 dB = 34.63 MHz
40 dB = 39.48 MHz

15M Band Low-pass

#, part, connection, value:
0 Load R = 50.0
1 cap par 120.0000
2 ind ser 477.0000
3 cap par 270.0000
4 ind ser 559.0000
5 cap par 270.0000
6 ind ser 477.0000
7 cap par 120.0000
98 Source R = 50.0
99 Inductor Q = 220.0

Enter #: 99
Enter New Value: 220

top: 0.0
10.00 dB/div.
bottom: -60.0
start 18 Frequency MHz 5 Freq./div stop 60
C:\Users\Tyko\Todds\QRPHB\QRPHB\20

Cursor Data =====>: 21.060 MHz S21= -0.16 dB S11= 0.00 dB

Above — A GPLA plot of the filter. The frequency cut-off at -3, -20 and -40 dB are shown. Perhaps this filter is overkill, but I had all the parts on hand and love a serious low-pass filter. Click for the bread board photo.

Fine-Tuneable 1 KHz Wein Bridge Oscillator

FINE TUNING
AF GAIN

In 2010, I wanted a fine-tuneable Wien bridge oscillator to drive a notch filter in an AF distortion analyzer. Ken Kuhn drew me up a schematic on his coffee break and emailed it the same morning.

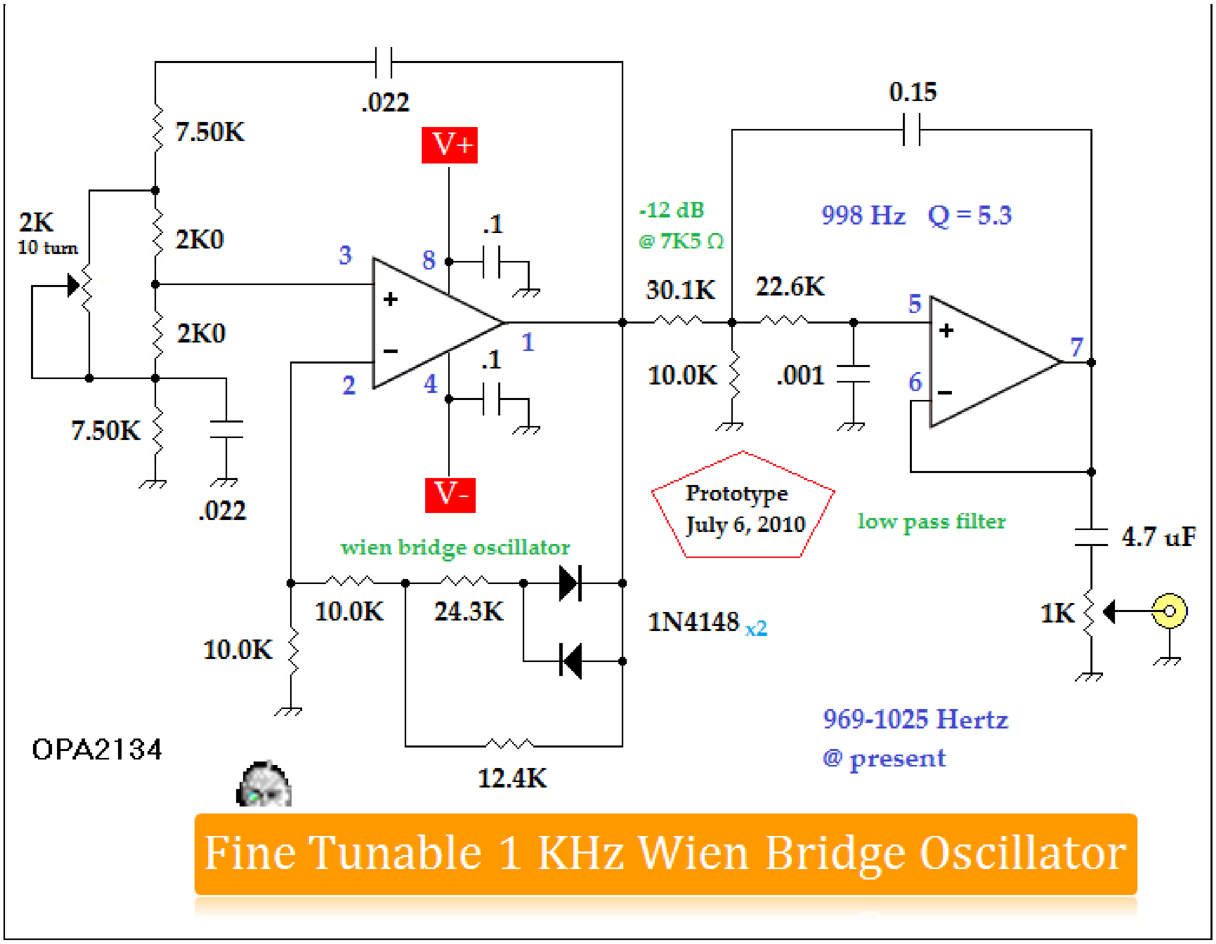
.022
7.50K
V+
2K
10 turn
2K0
.1
3
8
2K0
1
2
4
.1
7.50K
.022
V-
wien bridge oscillator
10.0K
24.3K
10.0K
1N4148 x2
12.4K
OPA2134
-12 dB
@ 7K5 Ω
30.1K
22.6K
0.15
998 Hz Q = 5.3
5
7
10.0K
.001
6
Prototype
July 6, 2010
low pass filter
4.7 uF
1K
969-1025 Hertz
@ present
Fine Tunable 1 KHz Wien Bridge Oscillator

I applied anti-parallel diodes instead of the classic incandescent bulb for amplitude stabalization in the feedback loop; probably a mistake leading to higher distortion. Ken's fine-tuning circuit works perfectly. I matched the 7K5 + 2K0 + 0.22 uF components on each filter half. 1% parts go in this circuit.

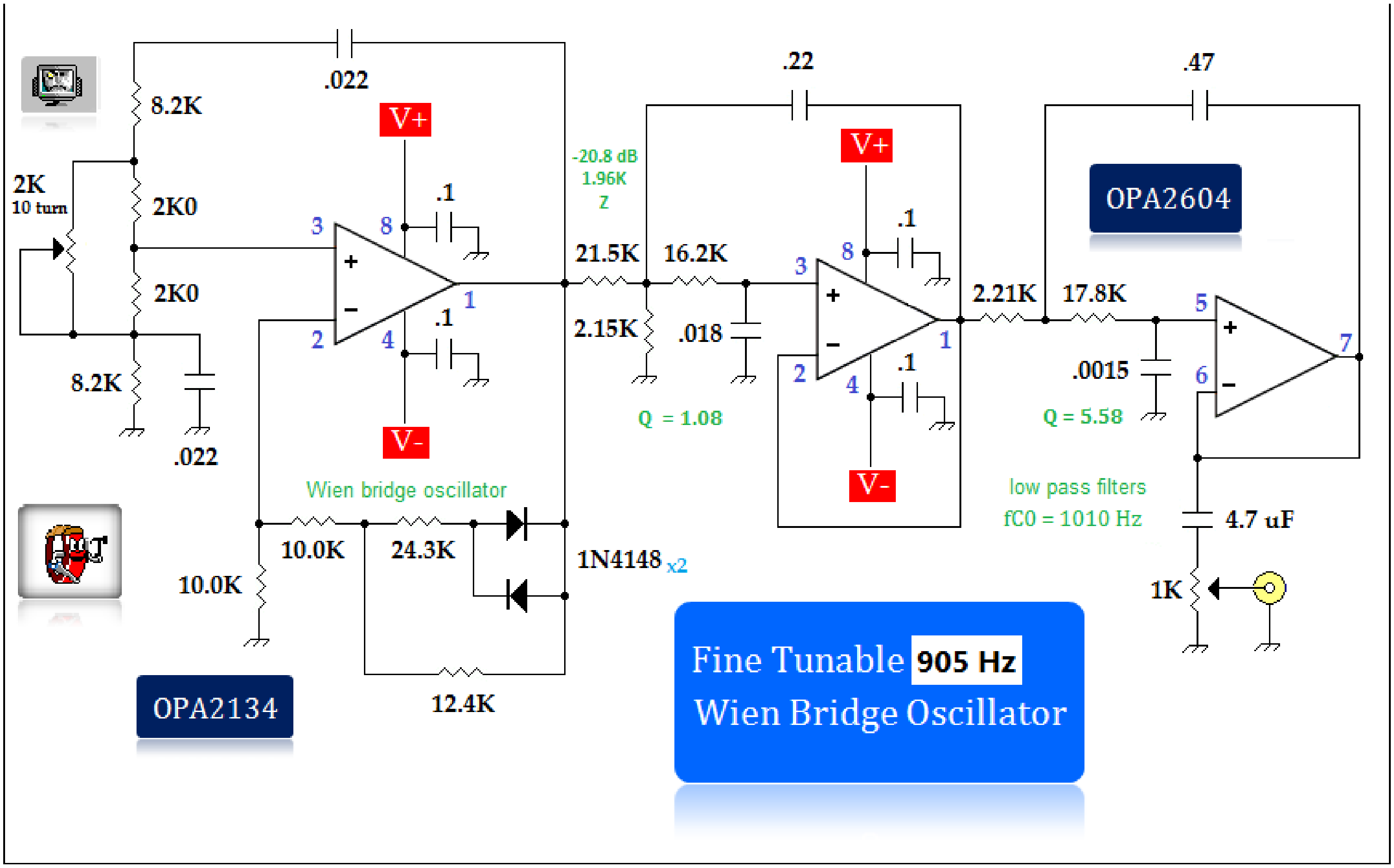
.022
8.2K
V+
2K
10 turn
2K0
3
8
.1
+
−
1
2K0
2
.1
4
8.2K
.022
V-
Wien bridge oscillator
10.0K
24.3K
10.0K
1N4148 x2
12.4K
OPA2134
-20.8 dB
1.96K
Z
21.5K
16.2K
2.15K
.018
Q = 1.08
.22
V+
.1
8
3
1
2
4
.1
V-
.47
OPA2604
2.21K
17.8K
5
7
.0015
6
Q = 5.58
low pass filters
fC0 = 1010 Hz
4.7 uF
1K
Fine Tunable 905 Hz
Wien Bridge Oscillator

A version for 905 Hertz built with crazy expensive op-amps. I chose 905 Hz to match my notch filter frequency.

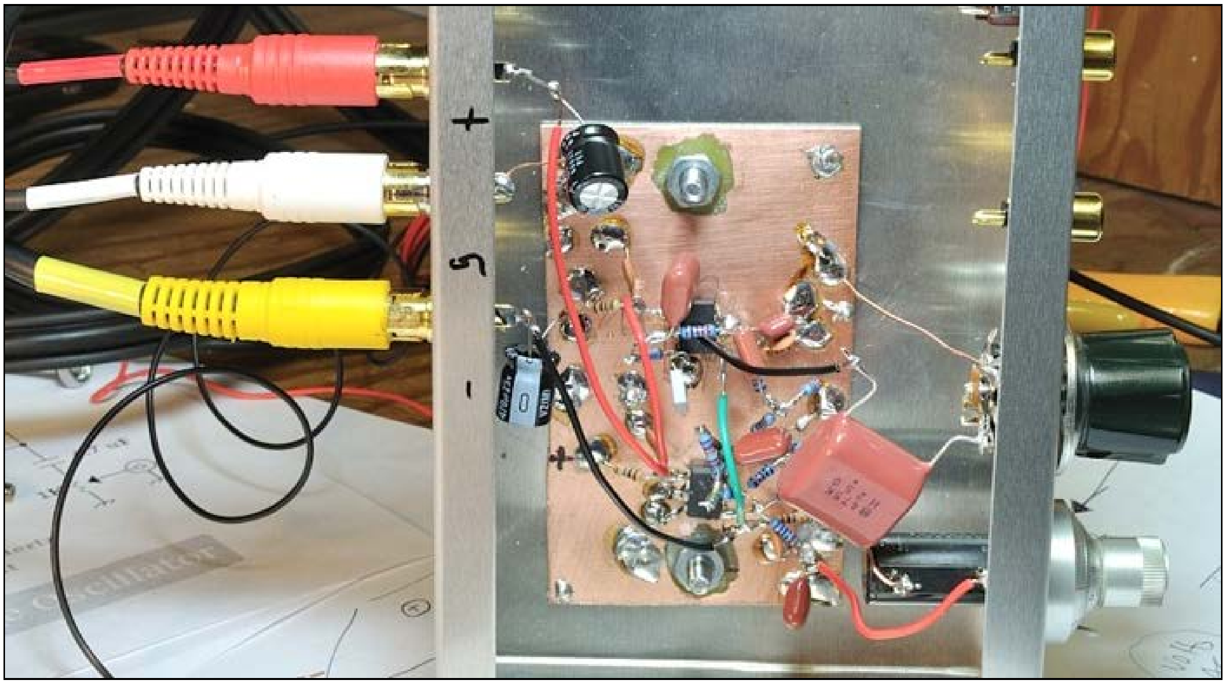

My breadboard.

RF — Test and Measurement

QRP Modules 2011

Introduction

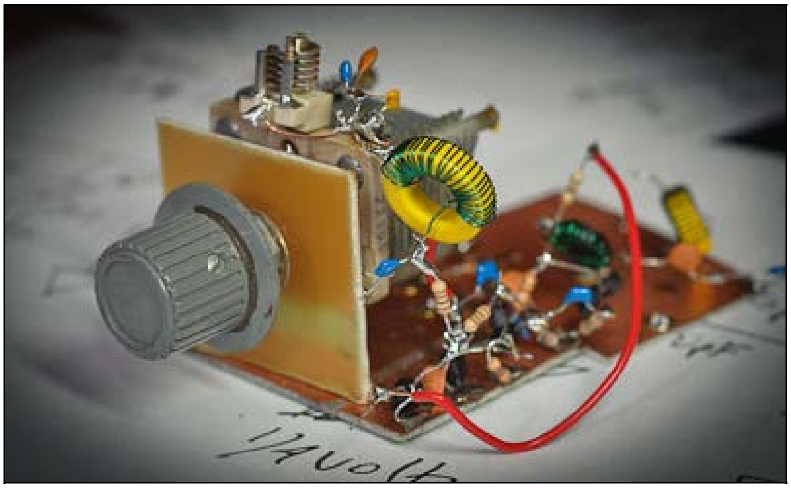

As experimenters, we rebuild core circuits over time. I decided to increase my collection of stock modular circuits to avoid re-inventing the wheel. This web page serves as a module repository for the website.

Since our needs differ, I've shared these circuits more for interest sake and really not as schematics to copy. All modules were carefully built and tested.

1 great virtue of the metal encased module is strong shielding. RF modules use a 50 ohm port impedance and BNC connectors. RCA jacks interface the AF modules.

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40 Meter Band-pass Filter

7 MHz Band-pass Filter

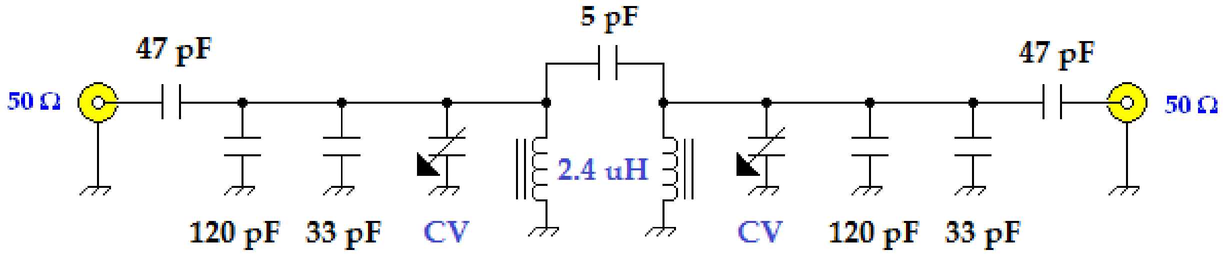

Qu = 220
FC = 7.040 MHz
BW = 237 KHz
IL = 2.1 dB
S11 = - 27 dB

CV = 2 - 20 pF

Above — A 40 Meter Ham band double-tuned band-pass filter. I designed this circuit using 2 programs that came with EMRFD and describe the process on this web page. The 2.4 uH measured coils were wound using #22 AWG wire on T68-6 powdered iron toroids and all fixed caps were ceramic C0G type. I centered my filter at 7.040 MHz. You should be able to peak it anywhere on the 40 Meter CW sub-band by tweaking the variable capacitors.

I peaked the trimmer capacitor while looking at the peak-to-peak voltage on a 50 ohm terminated oscilloscope. The filter input was connected to a 7.040 MHz signal generator with a 30 dB return loss, low harmonics (-55 dBc) and 50 ohm cables.

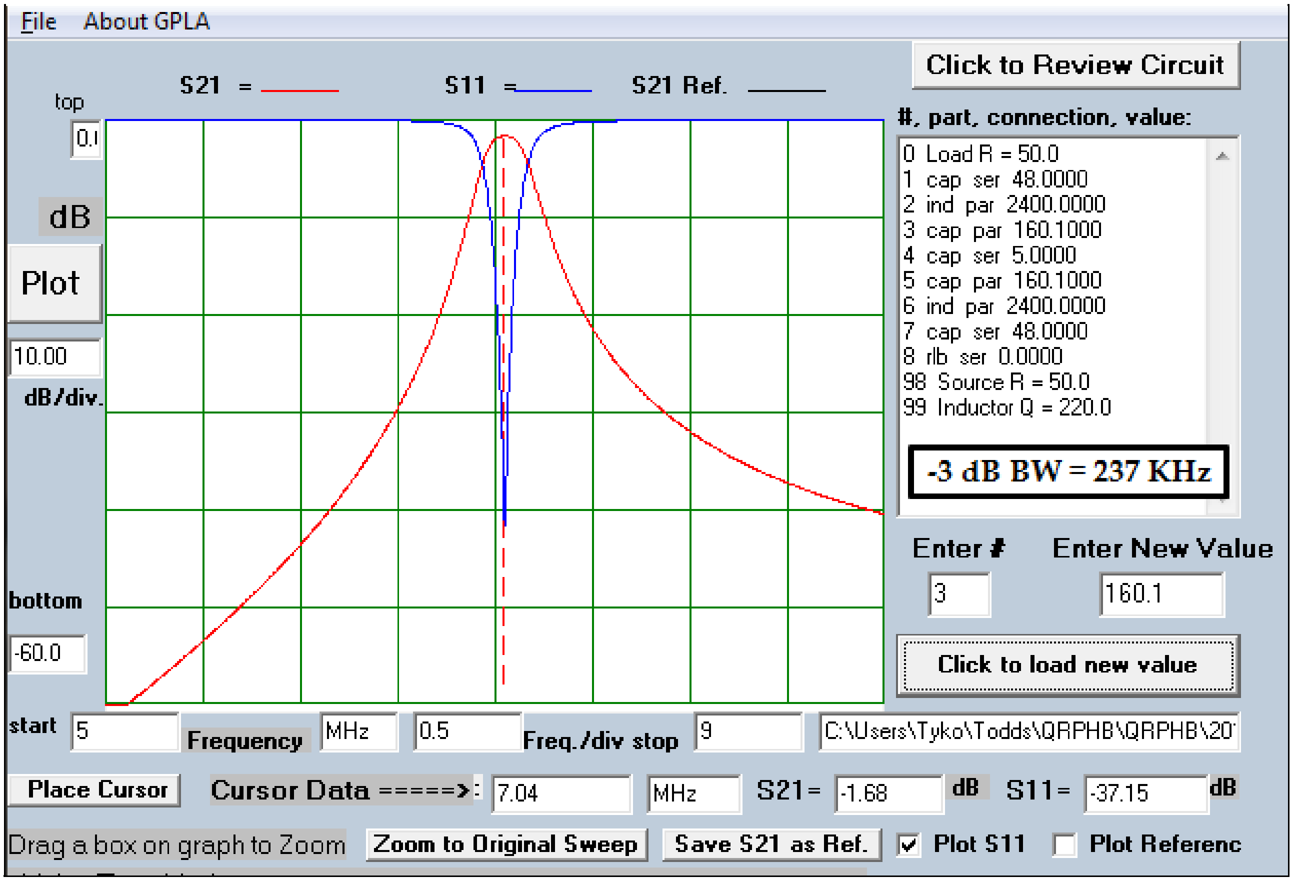
File
About GPLA
S21 =
S11 =
S21 Ref.
top
dB
Plot
dB/div.
bottom
start
Frequency
Freq./div stop
Click to Review Circuit
Click to load new value
Place Cursor
Cursor Data =====>
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.

#, part, connection, value:

0 Load R = 50.0
1 cap ser 48.0000
2 ind par 2400.0000
3 cap par 160.1000
4 cap ser 5.0000
5 cap par 160.1000
6 ind par 2400.0000
7 cap ser 48.0000
8 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 220.0

-3 dB BW = 237 KHz

Enter # 3
Enter New Value 160.1

top 0.(
10.00 dB/div.
bottom -60.0
start 5 MHz 0.5 Freq./div stop 9
C:\Users\Tyko\Todds\QRPHB\QRPHB\20
Cursor Data =====> 7.04 MHz S21= -1.68 dB S11= -37.15 dB
☑ Plot S11 ☐ Plot Referenc

Above — A simulation of my filter design in in GPLA08. The calculated IL was 1.68 dB, I measured the IL at 2.1 dB The calculated return loss or S11 was 37.2 dB; I measured 27 dB. A good filter.

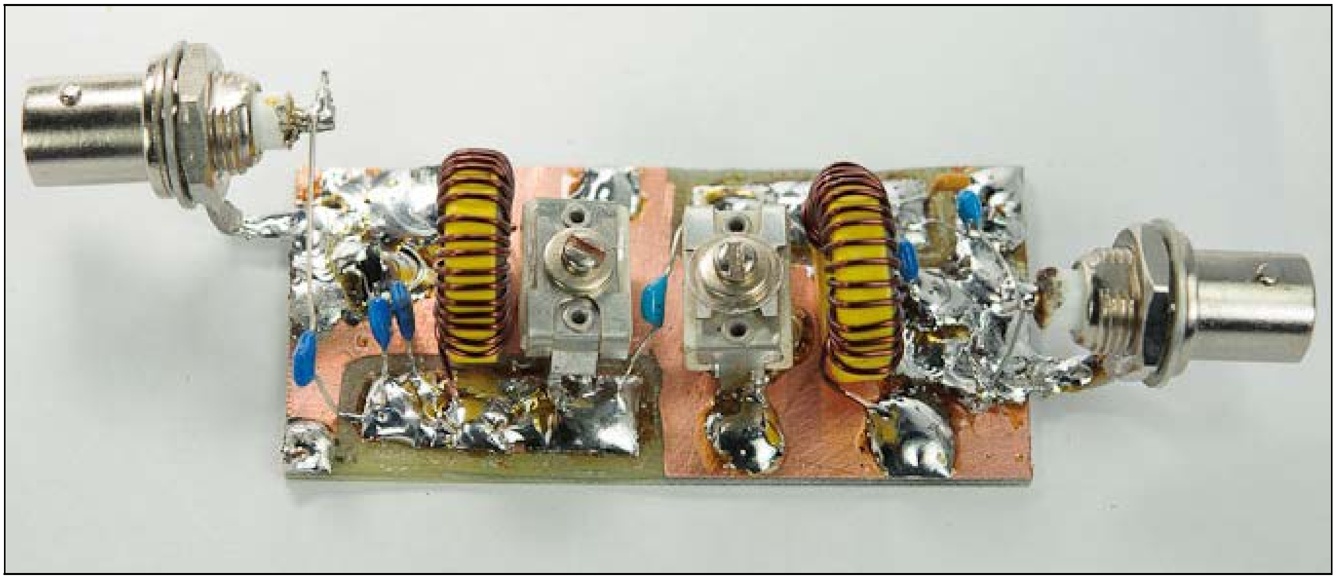

Above — the 40 meter double tuned band-pass filter breadboard with temporary BNC connectors and series caps. Since this filter will serve as my main front-end filter for all future 40M band receiver bench design, I blinged out and put in big toroids and high Q, air-variable trimmer capacitors. While I could have just use a single 150 pF tank capacitor and a wide range trimmer cap such as common, ceramic 10-70 pF, the small range, high Q trimmer capacitors offer better performance and fine tuning.

Click for a spectrum analyzer +tracking generator sweep where the center frequency = 7.040 MHz. Graticules: Horizontal = 1 MHz per division, Vertical = 10 dB per division. You can see why it tunes so sharply.

After testing the bread-board, I removed the temporary BNC connectors and series caps, I stuck it in a Hammond box and wired in permanent, short leaded 47 pF capacitors. Final testing in the sealed box varied minimally from the open bread board. This board looks especially ugly because it held a previous filter and contained lots of remnant solder.

Broadband Feedback Amp

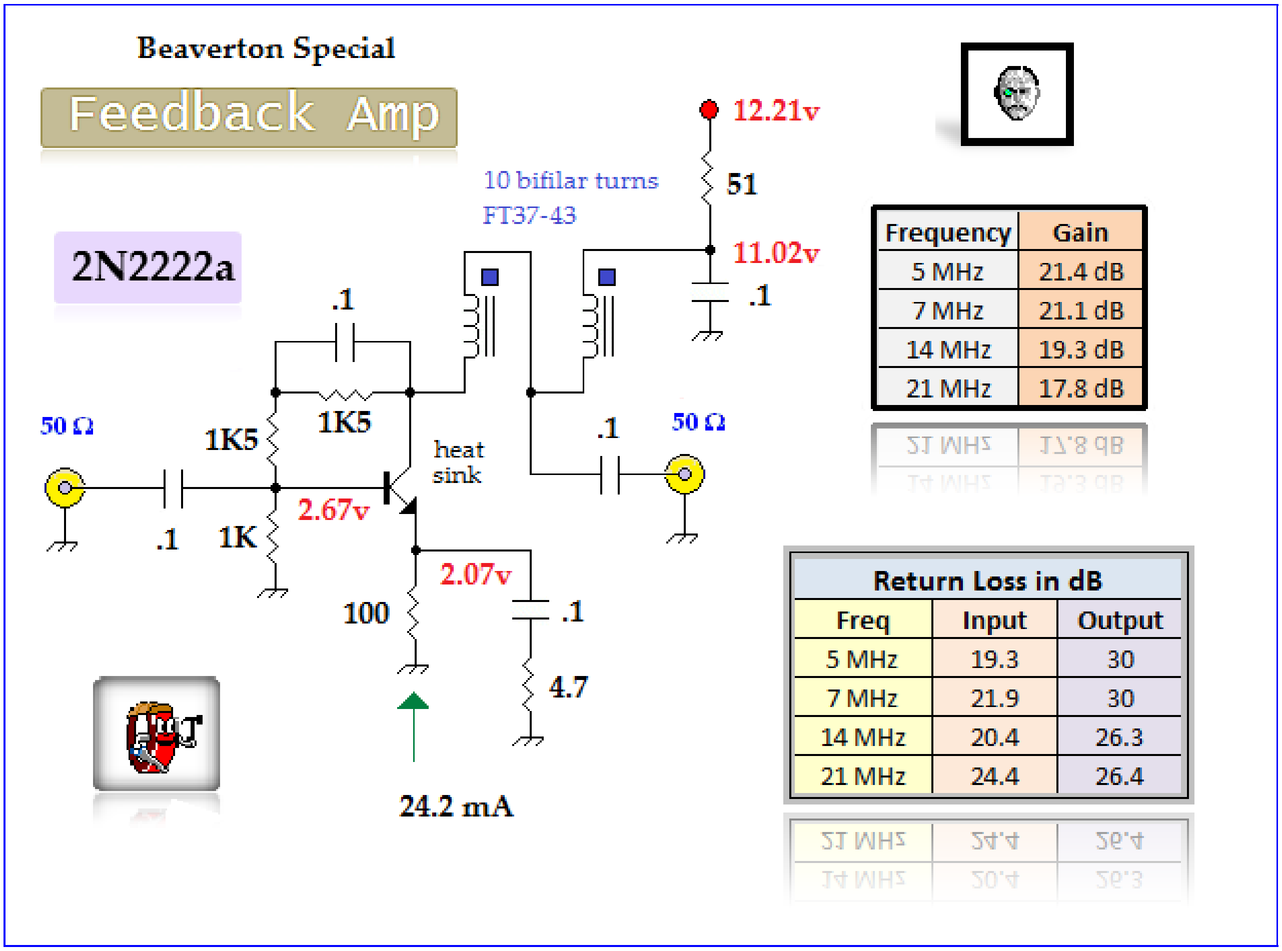
Beaverton Special
Feedback Amp
2N2222a
12.21v
51
10 bifilar turns
FT37-43
11.02v
.1
.1
1K5
1K5
50 Ω
50 Ω
.1
heat sink
2.67v
.1
1K
2.07v
100
.1
4.7
24.2 mA

Frequency	Gain
5 MHz	21.4 dB
7 MHz	21.1 dB
14 MHz	19.3 dB
21 MHz	17.8 dB

Return Loss in dB

Freq	Input	Output
5 MHz	19.3	30
7 MHz	21.9	30
14 MHz	20.4	26.3
21 MHz	24.4	26.4

Above — A "Beaverton Special" feedback amp with analysis. As experimenters, we often need a go-to, broadband 50 ohms input and output RF amplifier. This is it!

Popularized by Wes, W7ZOI and Doug DeMaw, W1FB, this amp has stood the test of time and fits perfectly into the 50 ohm module concept. A bevy of transistors were tried — a 2N4401, 2N5179, 2N3904, 2N3866 or 2N5109 all worked fine. For the greatest return loss and signal handling possible, current over 21 mA is required and thus a 2N3904 isn't the best choice. Collector current = heat, so heat sink the BJT as appropriate.

I found that a 2N2222a biased with over 22 mA emitter current gave a stellar output return loss and low distortion. Within reason, for different transistors, keep the bias and feedback resistors constant and change the emitter resistor (100 ohms in my amp) to set the current you want or need.

Many builders follow this amp with an attenuator pad to preserve the input return loss.

Diode Ring Mixer

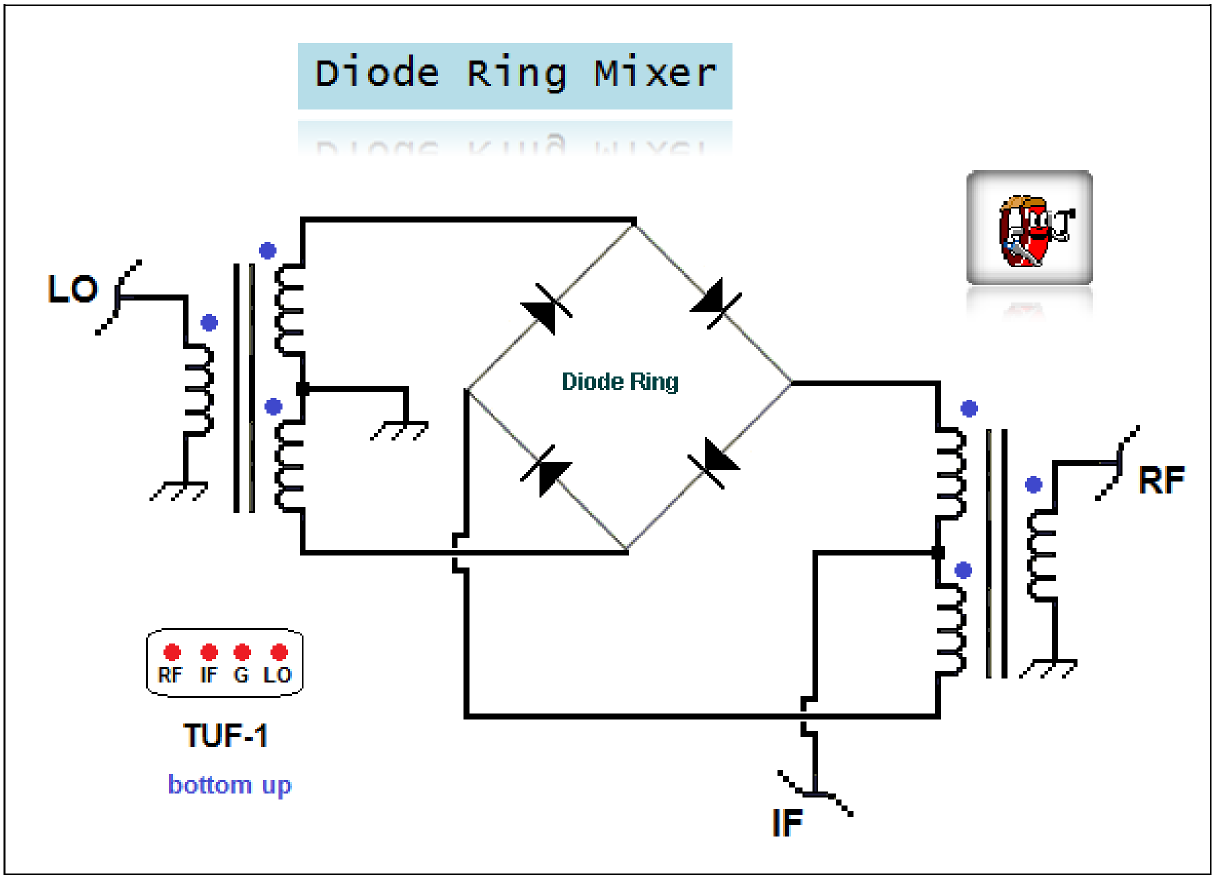
Diode Ring Mixer
LO
Diode Ring
RF
RF IF G LO
TUF-1
bottom up
IF

Above — A Minicircuits TUF-1 diode ring mixer was used in standard configuration. 7 dBm LO drive.

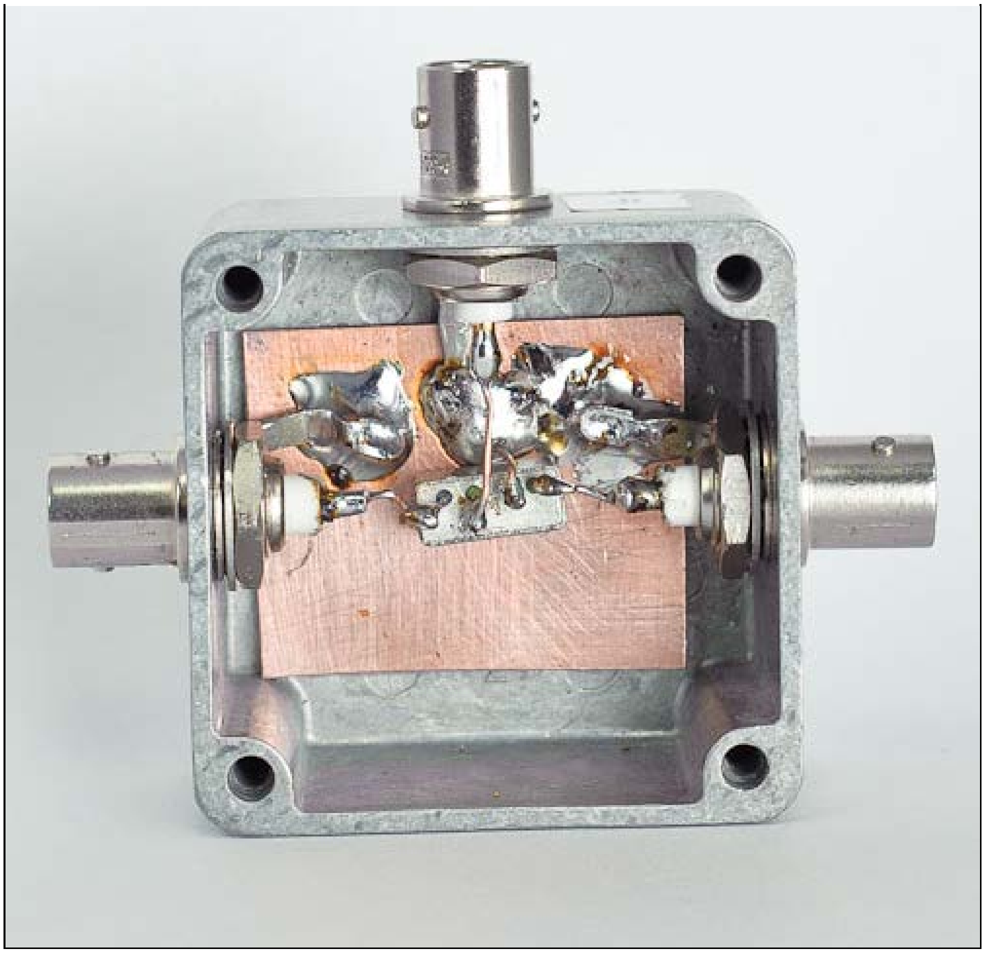

Above — The DRM module. It's hard to photograph inside a solder laden chassis. Connections are short.

Popcorn Audio Frequency Power Amplifiers

Popcorn Receiver Audio Amp

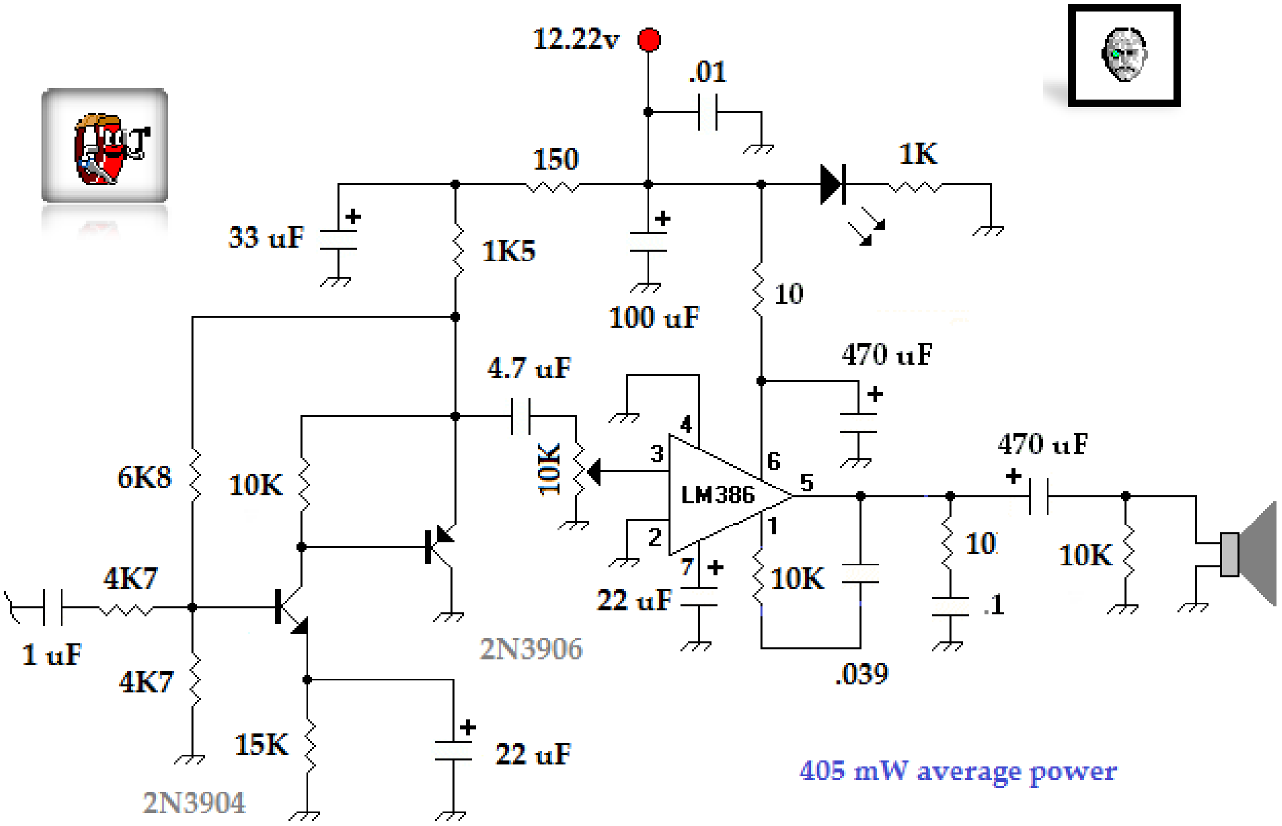
12.22v
.01
150
1K
33 uF
1K5
100 uF
10
470 uF
4.7 uF
6K8
10K
10K
4
3
6
5
LM386
470 uF
2
1
7
4K7
10
10K
22 uF
10K
.1
1 uF
4K7
2N3906
.039
15K
22 uF
2N3904
405 mW average power

Above — Popcorn receiver audio power amp. I wanted a simple audio stage for testing popcorn receivers (to follow a high output impedance preamp device). Completing this module means never having to build such an amp again. The voltage gain is provided by BJTs to keep the noise down, but the popcorn factor up. The preamp impressed me with its strong signal handling capacity via feedback and careful biasing. The NPN is center biased so that when its intentionally distorted during testing, the positive and negative halves of the AC waveform distort equally — it provides a nice, big, AC voltage swing. An LM386 in X20 gain mode with some bass boosting comprises a reasonable power amp section. The 10K resistor on the output discharges the 470 uF cap when no speaker is connected to avoid a loud pop. The 4K7 series input R can be lowered, or omitted for more sensitivity.

Some builders might employ the LM386 in a higher gain mode at the expense of fidelity, or just wire up a TDA7052. I think in popcorn circuits, what really matters is that you understand what you're doing and try to *design* rather than just copy the "usual circuits".

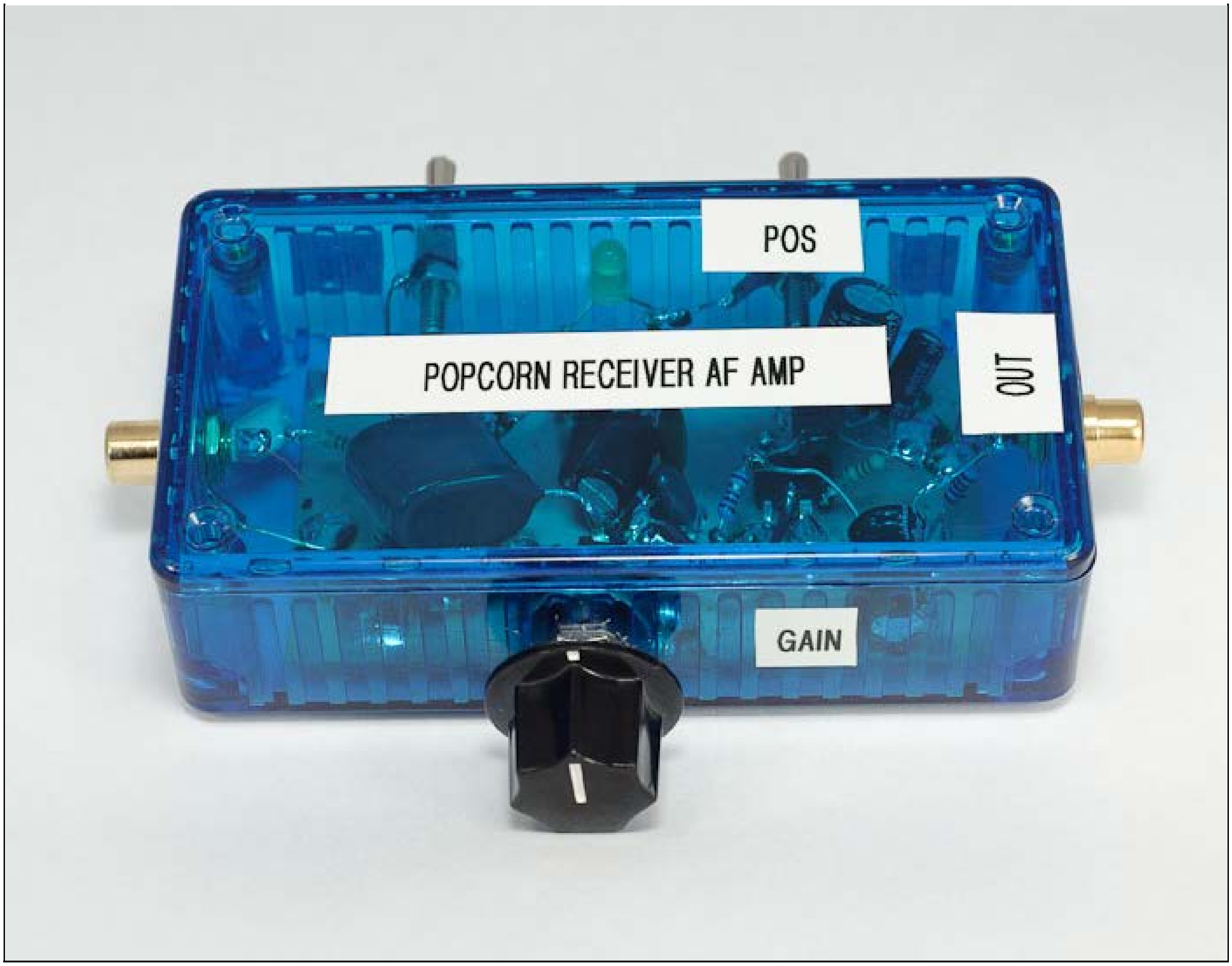

Above — The popcorn AF amp in a clear blue chassis. Phono jacks provided a connection for the input and output — they 're inexpensive and readily available. The DC supply is connected to uninsulated banana jacks on the rear; it's well decoupled (resistor) + bypassed (capacitor) to help stop parasitic AF feedback. This amp is pretty quiet, considering its junk box legacy.

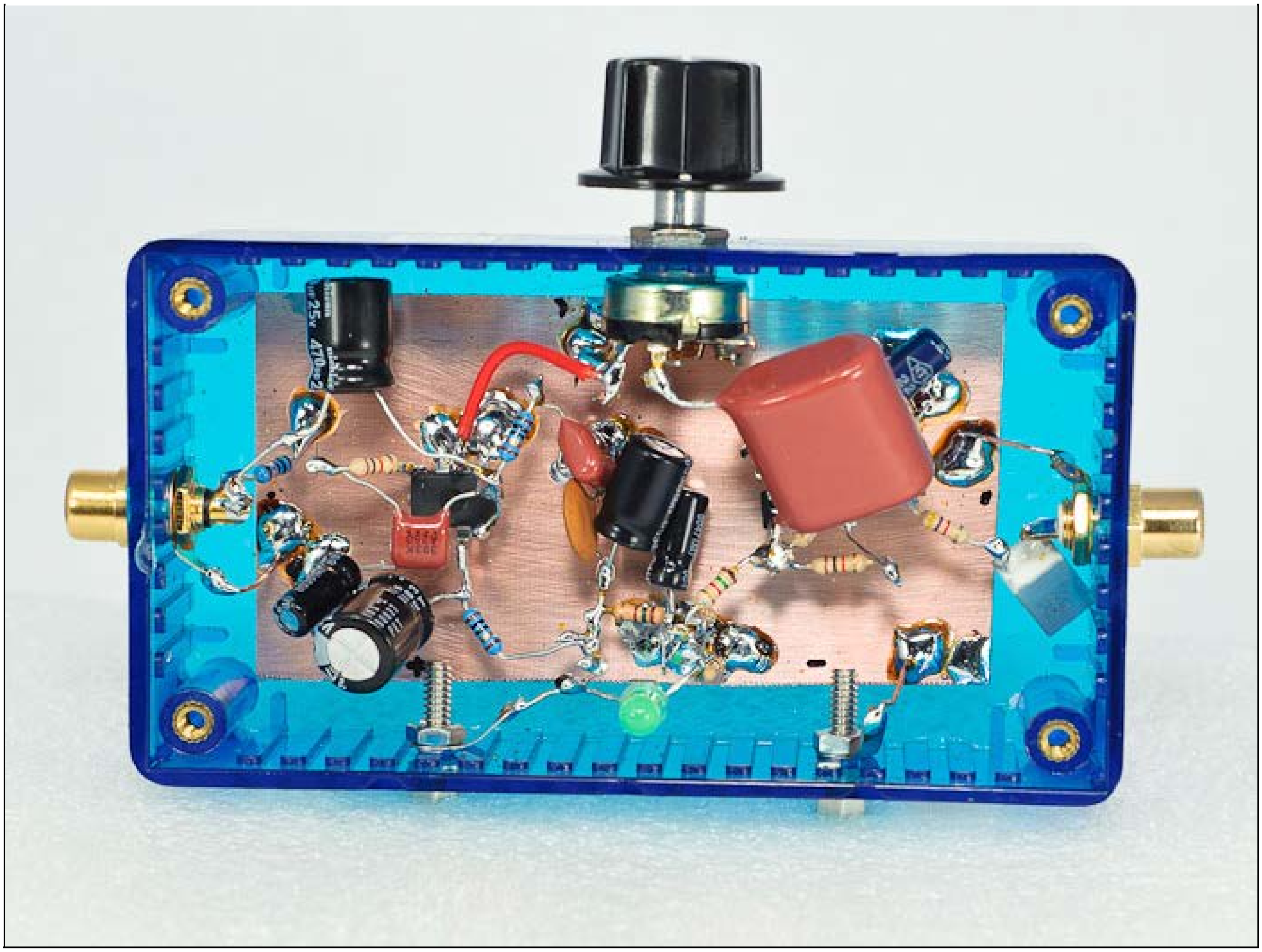

Above — The project with the top cover removed. The board is secured by the ground wires connecting it to the pot, jacks and DC voltage posts. The input is on the right.

I like a relatively simple, lower gain AF amp on the bench for receiver development. You can use such an amp to decide on how much overall AF gain is needed, how you'll distribute it, and not have to deal with unwanted AF feedback.

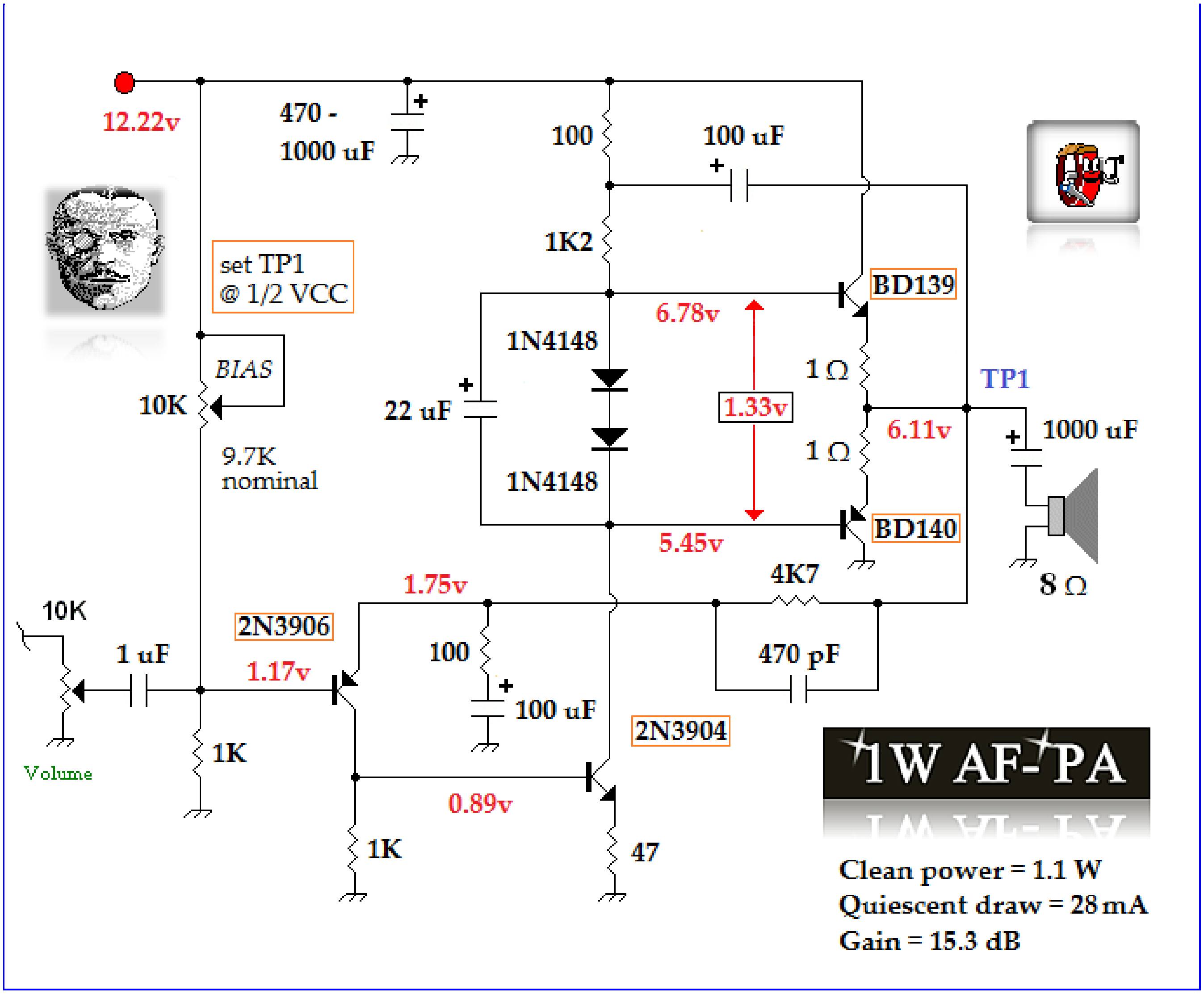
12.22v
470 -
1000 uF
100
100 uF
1K2
set TP1
@ 1/2 VCC
BD139
6.78v
1N4148
1 Ω
TP1
BIAS
10K
22 uF
1.33v
6.11v
1000 uF
9.7K
nominal
1N4148
1 Ω
BD140
5.45v
4K7
8 Ω
1.75v
10K
2N3906
1 uF
1.17v
100
470 pF
100 uF
2N3904
1K
Volume
1W AF-PA
0.89v
1K
47
Clean power = 1.1 W
Quiescent draw = 28 mA
Gain = 15.3 dB

Above — 1 watt popcorn audio power amplifier. Built around the BD139/140 complimentary pair - I achieved a clean I KHz sine wave at 1.1 Watts power after testing + tweaking my prototype design. I chose the familiar series diode pair to bias the power followers into Class A/B; an amplified diode (transistor level shifter) might be a better choice.

Bootstrapping the 2N3904 voltage amp pumps up the clean signal power capacity. The 2N3906 establishes the bias for the 2N3904 and the BD139-140 pair. Set the 10K bias pot so that the DC voltage at TP1 is 1/2 of the VCC. During testing, the AC voltage was centered perfectly between the DC rails and when pushed into clipping, the positive and negative AC waveform distorted nearly equally. Quiescent current = 28 mA ; not meant for a field-portable receiver.

Click for a photo of my breadboard. Copper clad board serves as heat sinks for the power followers. The BD139 and BD140 make great complimentary transistors for audio frequency power amplifiers. With an Ft of 190 MHz, the BD139 can work okay as a driver or even the final in modest power QRP transmitters.

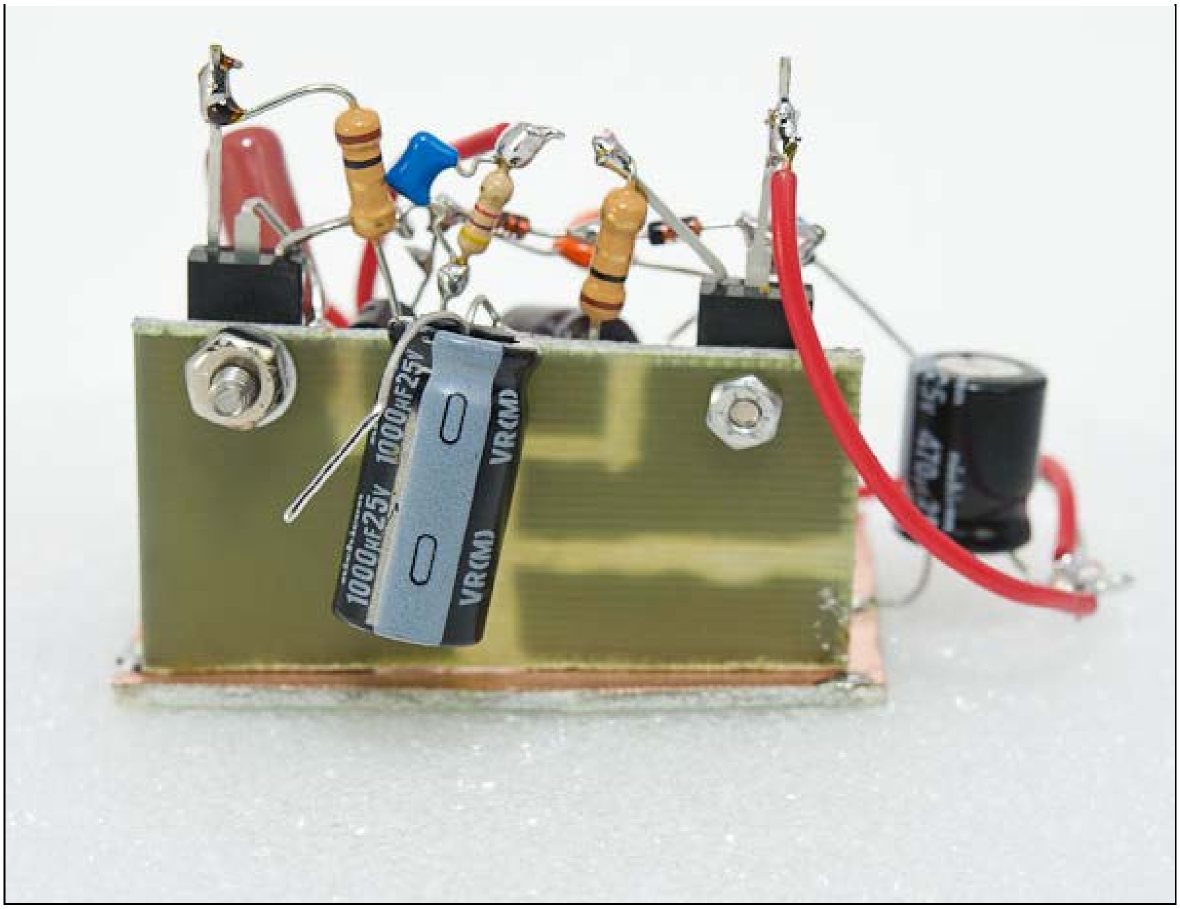

Above — 1 watt Audio PA (reverse view).

Pop DC2 — Popcorn Direct Conversion Receiver Main Frame

These circuits update the Popcorn DC receiver from 1998 and includes all components from the product detector through to the speaker, minus the VFO and band-pass filter.

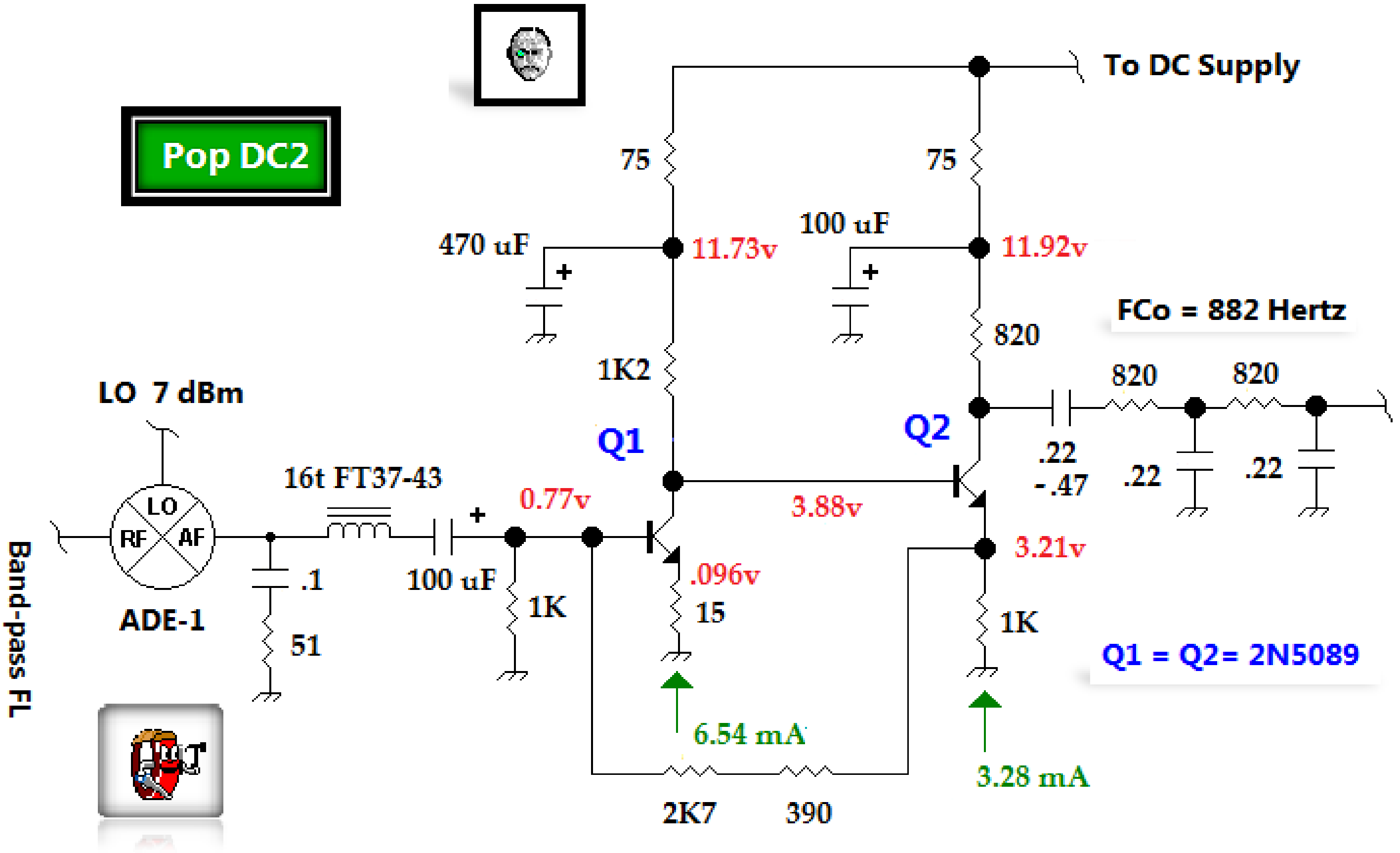
Pop DC2
To DC Supply
75
75
470 uF
11.73v
100 uF
11.92v
1K2
820
FCo = 882 Hertz
LO 7 dBm
820
820
Q1
Q2
.22
- .47
.22
.22
16t FT37-43
0.77v
3.88v
3.21v
LO
RF
AF
.1
100 uF
.096v
1K
15
1K
ADE-1
51
Q1 = Q2= 2N5089
Band-pass FL
6.54 mA
3.28 mA
2K7
390

Popcorn Direct Conversion Receiver Main Frame

Above — The mixer and first audio preamplifier The 0.22 uF to 0.47uF cap connecting Q2's collector to the low-pass filter network exerts a high-pass response to remove low frequency noise and potentially any hum. I heard no hum, although a 470 uF filter capacitor on Q1 helps ensure that. Increase the 100 uF filter capacitor filtering Q2 if you hear hum or motor boating. The diode ring mixer exhibits AF that's hard to beat — very dynamic, vibrant and lively. I enjoyed the low microphonics with the double balance + a return loss of over 25 dB on all of 3 of its ports. Alternate photo.

I've read negative comments about my use of "those big filter capacitors" — 1 thing radiophiles can learn from audiophiles is that to adequately decouple and bypass means we need to stop fooling around with the usual 22 - 47 uF capacitors and *really* bypass. Viewing well designed AF amplifiers informs us so; these designers *really* filter their amplifiers from the DC supply. You can always increase the decoupling resistor value to allow use of a smaller capacitor value, however, we only have a single power supply at around 12 VDC, and I dislike giving up too much of it for DC filtering purposes. Do what ever amuses you.

Click for some analysis of the preamp. The MPSA18 went obsolete in 2011, so I chose the low-noise 2N5089 for Q1 and Q2.

The Popcorn DC2 receiver keeps the format of the earlier version; discrete transistors for all but the power amp and R-C low-pass filtering. The filter still allows you to listen to SSB, as there aren't many poles and the cutoff is nearly 900 Hertz —it just removes the ice-pick in the ear often heard in unfiltered DC receivers. You can change the capacitor values for a different cutoff frequency. Applet E performs this function.

Second Preamplifier Stage with TDA7052 final

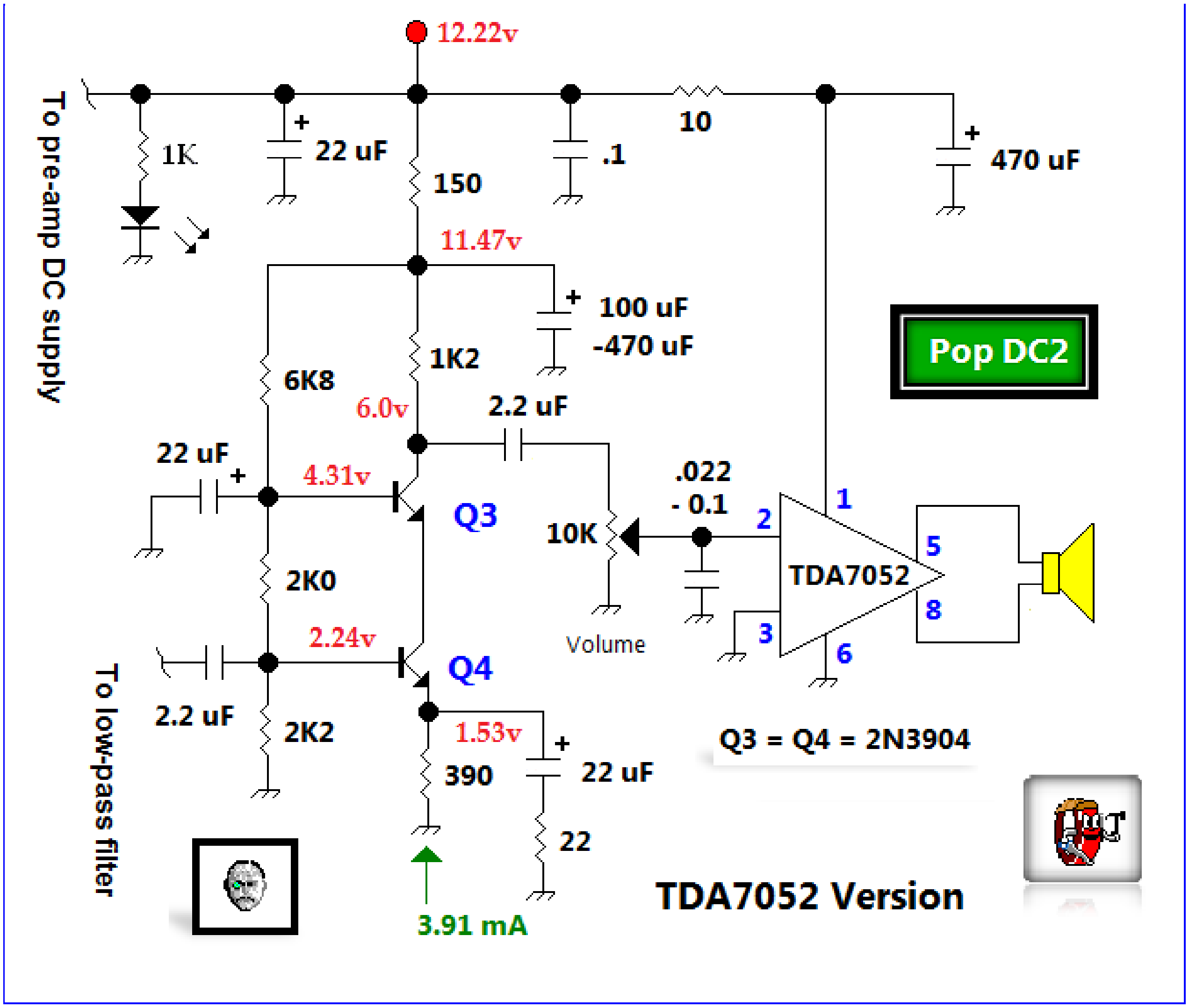

Above — The 2nd pre-amp and AF power amp. Experimenting with a number of audio stages, I decided on this cascode common emitter / common base amp biased to provide temperature stability, high gain, low distortion + proper termination of the low-pass filter. (The input Return Loss = 19 dB in my 820 ohm bridge set up). Increase the 100 uF filter capacitor on Q3 up to as high as 470 uF if you hear motor boating (low frequency thumping). This stage is prone to feedback since it's directly connected to the power amp. Photograph.

The simple and effective TDA bridged amp has a fixed gain of 40, so this receiver isn't crazy loud, however, it sounds okay. The bypass capacitor on Pin 2 filters hash noise and *can* remove some of the high frequency din from off frequency stations. Experiment to find the best value for your ears; even 0.015 uF might be your preference. I chose a 0.047 uF for my final version.

The 2 uF coupling caps between the power amp and Q3 can be lowered or raised to suit your parts collection. All the audio path coupling or bypass capacitors were "polysomething" types in my bread boards.

This is a base station receiver since the quiescent current draw listening to noise = 37 mA.

For low parts count or beginner's receivers, IC audio power amps make sense; 1 chip and you're done. Consider, for example, the TDA7052 — 2 bridged amplifiers supply reasonable power and headroom in an 8 pin DIP package. A good, but imperfect part. Depending on your goals and abilities, the limitations of the 7052's fixed 40 dB gain and/or the inability to drive grounded loads or insert additional feedback networks may constrain your designs.

Sound Bytes on 40 Meters:

I recorded these sound bytes prior to adding a 0.047 uF bypass capacitor to pin 2 of the 7052 chip and increasing the coupling cap on Q2 from 0.22 to 0.47 uF.

For a control — An ICOM superheterodyne receiver with digital IF filtering set to wide (2.2 KHz) was recorded immediately after recording the Pop DC2 receiver (although I pressed the middle (900 Hz) and narrow (600 Hz) filter selection briefly, but they made the noise worse), The antenna is a 1/4 wave vertical in a city lot with noisy conditions. I don't believe in artificially making my stuff sound better than real, and present warts-and-all audio files. I compressed these files heavily so you'll hear the noise phase shifting a little. Normally with this antenna, a "quiet" QRN level is S9; it doesn't bother me. Icom

Pop DC2 — I was tuning through a pile up to hear how the receiver copes with all the signals (twice as many with a DC receiver!)

Pop DC2 — More QRN, QSB and pile ups.

SSB - After this, I changed the .22 coupling cap between Q2 and the R-C filter .47 uF to add a little more bottom end.

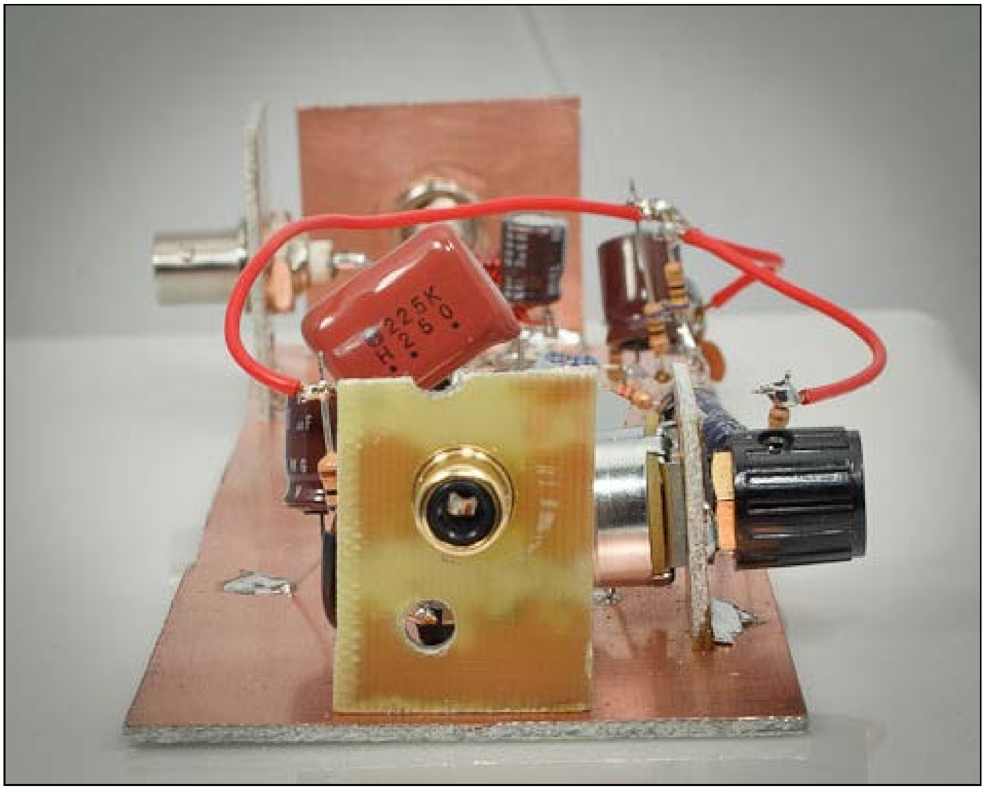

Above — Speaker terminal (an RCA jack isolated from ground on the TDA7052 version). Volume pot at right.

Second Preamplifier Stage with LM386 final

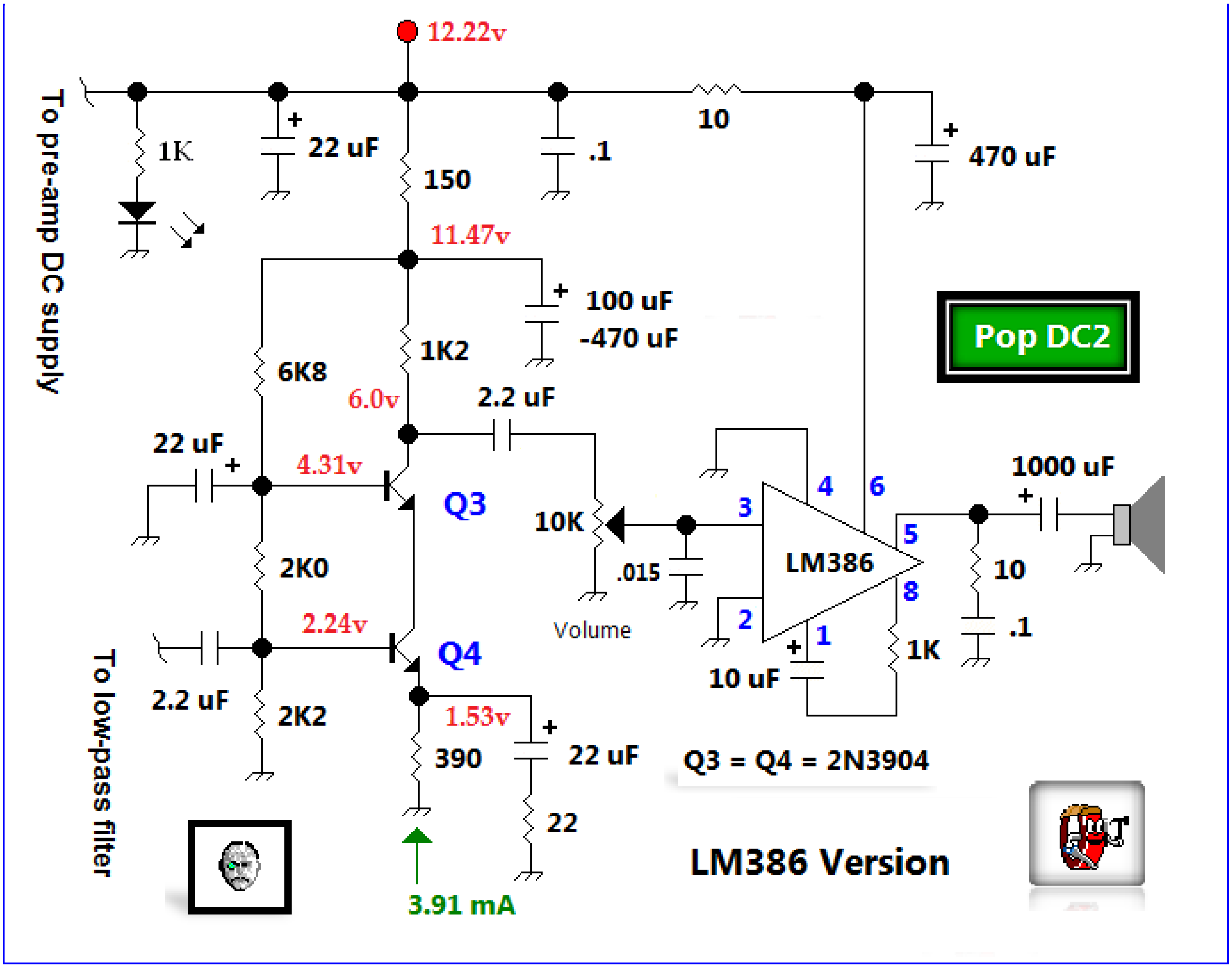
12.22v
To pre-amp DC supply
1K
22 uF
150
.1
10
470 uF
11.47v
100 uF
-470 uF
Pop DC2
6K8
1K2
6.0v
2.2 uF
22 uF
4.31v
Q3
10K
3
4
6
1000 uF
5
LM386
.015
10
8
2K0
2.24v
Q4
Volume
2
1
.1
1K
2.2 uF
10 uF
To low-pass filter
2K2
1.53v
390
22 uF
Q3 = Q4 = 2N3904
22
LM386 Version
3.91 mA

Above — The 2nd preamp and final with an LM386 set for just under a gain of 50. Click for a Canadian SSB sound byte.

Alternate Final Amp Stage that connects to the Q3 volume potentiometer

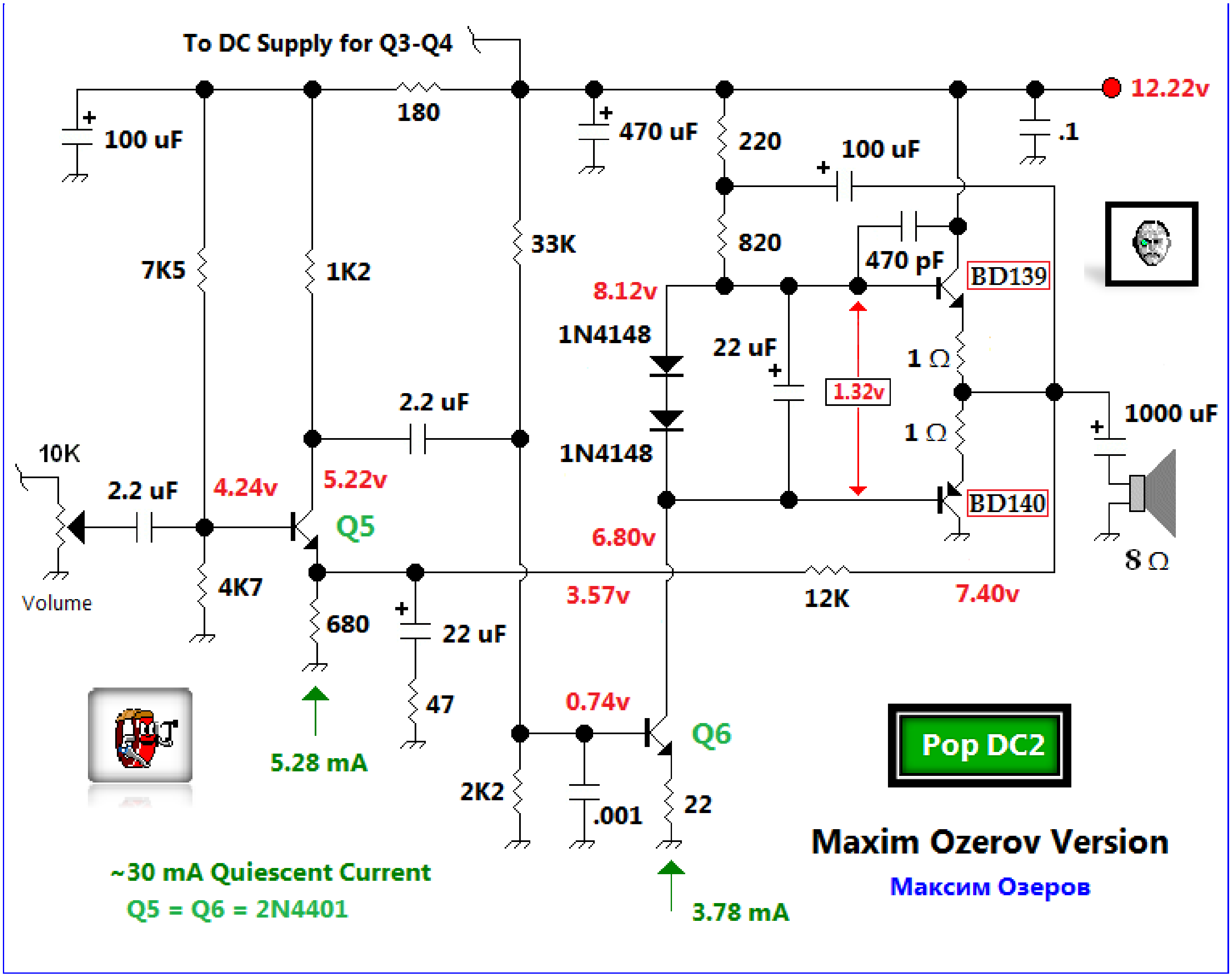
To DC Supply for Q3-Q4
12.22v
100 uF
180
470 uF
220
100 uF
.1
7K5
1K2
33K
820
470 pF
BD139
8.12v
1N4148
22 uF
1.32v
1 Ω
1 Ω
2.2 uF
1N4148
1000 uF
10K
2.2 uF
4.24v
5.22v
Q5
6.80v
BD140
8 Ω
Volume
4K7
680
22 uF
3.57v
12K
7.40v
47
5.28 mA
0.74v
Q6
Pop DC2
2K2
.001
22
Maxim Ozerov Version
Максим Озеров
~30 mA Quiescent Current
Q5 = Q6 = 2N4401
3.78 mA

Above — A reader called Maxim Ozerov requested a discrete semiconductor version of the power amp after I posted the 7052 version on my blog. Placing 2 voltage amps inside the negative feedback loop proved challenging, since I'm no expert and learn on the bench. The gain = ~42 and the maximum pure sine wave power before clipping begins to occur = ~625 mW. This amp is louder and sounds warmer than the 7052 version.

2N3904s work fine for Q5 and Q6, but I found that the 2N4401 had a consistently higher DC beta and this helps ensure the bias and collector resistors shown will provide the widest possible, pure AC signal swing.

This amp replaces the earlier IC power amps (connects to 10K volume pot after Q2, however a 2.2 uF coupling cap is required after the volume potentiometer). If you need more **voltage** gain, increase the value of the 12K negative feedback resistor. Above 75K, the gain will approach 50 and *greatly* increase the possibility of distortion.

My dummy load for development and testing = three 1/2 watt resistors in parallel: 75, 82 and 10 ohms.

Certainly you can craft better - louder - quieter audio stages with low noise op-amps, however, my readers write that they enjoy building up discrete transistor designs, and for popcorn receivers; I do too.

Sound bytes from November 1, 2011

40 Meters - QRN is lower tonight. Some audio from a lineout tape deck (no tone controls nor equalization). I have only 2 cassette tapes, This one is Russian language from 1983 - the 1 strong accented syllable generates good peaks for AF listening tests. Audio recorded from an 8 ohm, 18 cm (7 inch) speaker mounted in a wooden frame with no back. Speaker choice and cabinets are critical and often overlooked; again we may look to audiophiles for guidance

Click for some 50 ohm AF preamplifier experiments cut from this page.

7 MHz VCO Experiments

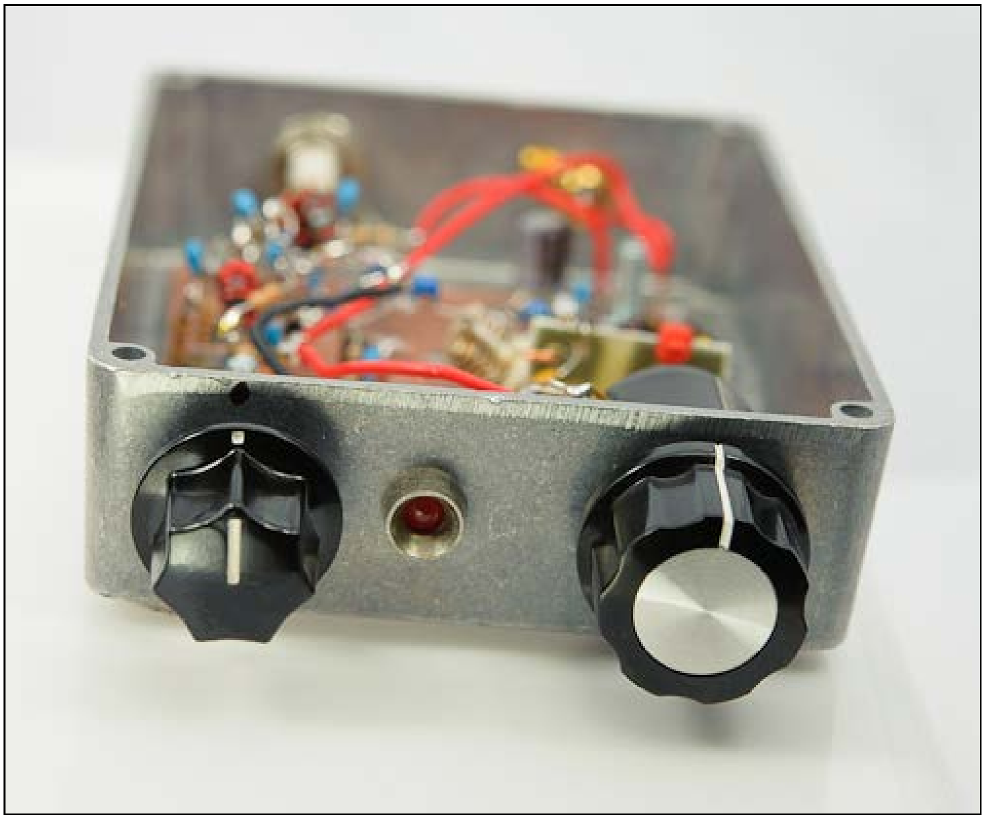

As RF designers and builders, we rely on signal generators for nearly every experiment. I sought a reliable 7 MHz voltage controlled oscillator and built 1 after some effort. I'll describe and critique a VCO I rapidly designed for a reader and then present a better VCO with some design ideas.

7 MHz VCO Experiments: A rapidly developed Popcorn 7 MHz VCO

A reader needed a 7 MHz VCO in a hurry (3 hours); he only had 1 MVAM109 varactor and wanted to cover the bottom 60 KHz of the 40 Meter Ham band using a linear taper 10K potentiometer for tuning. He planned to use a dual-gate MOSFET cascode buffer (good choice), so I didn't have to bother with a buffer.

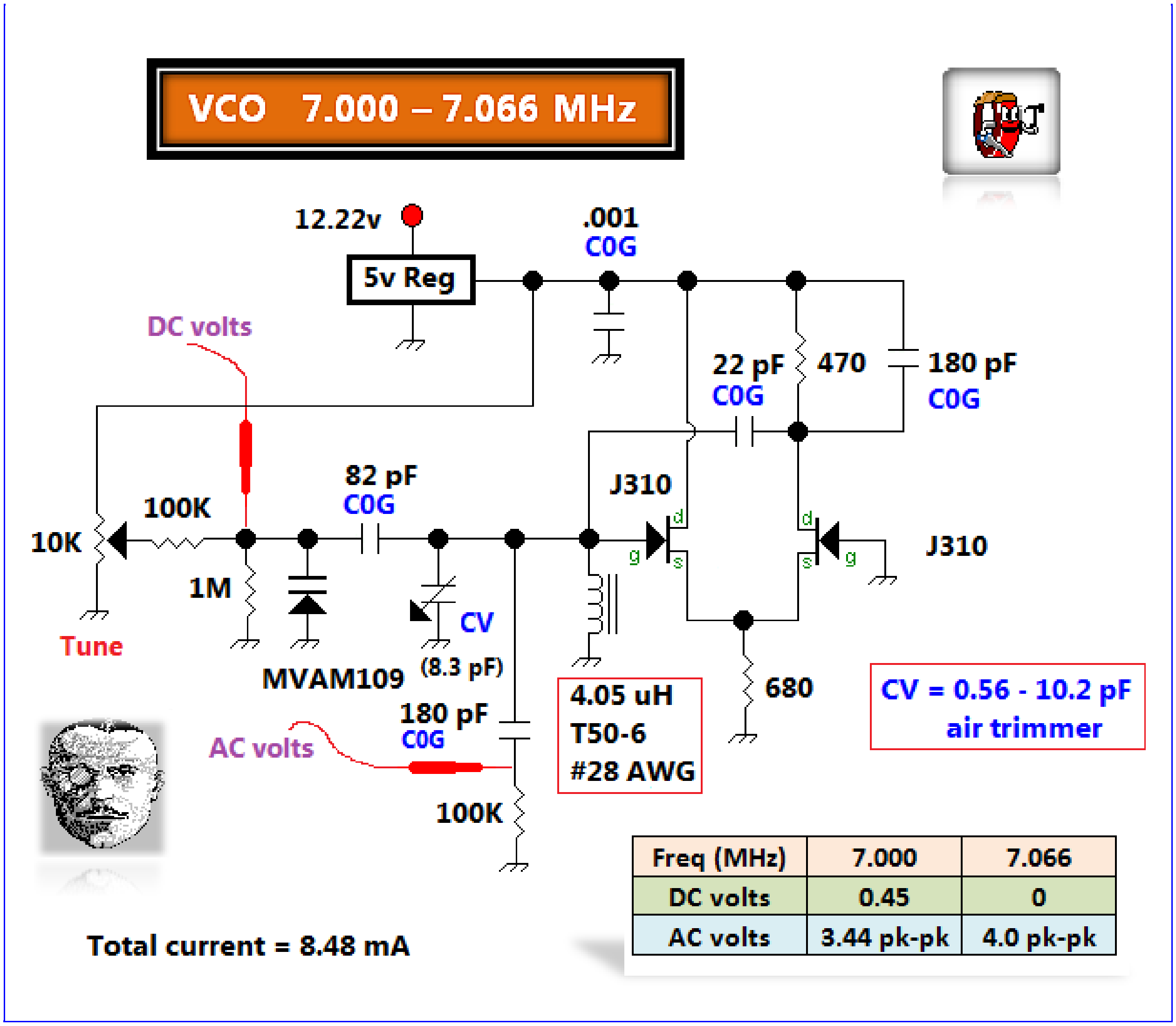

Freq (MHz)	7.000	7.066
DC volts	0.45	0
AC volts	3.44 pk-pk	4.0 pk-pk

Above — The VCO with a 100K resistor as the temporary buffer. He'll use a 100K resistor on G1 of the 2-gate MOSFET buffer. With a Q of 150 at 1 MHz; high noise level and a hyper-abrupt capacitance-versus-voltage curve designed for tuning AM radios, the MVAM109 varactor ranks poorly. The C of my MVAM109 with no reverse DC voltage was 725 pF.

Still, this VCO tuned in a linear fashion, showed a nice sinusoidal output and proved frequency stable. I wanted the AC voltage at the varactor anode at under 1 volt pk-pk (it was 752 mV) to help reduce forward conduction during the positive AC voltage swing. I was bad and ran the tuning DC voltage from 0 to 0.45 volts which greatly increases the potential for forward conduction in a varactor. To mitigate this somewhat, an 82 pF couples the varactor to the tank and drops the AC voltage and reactance seen by the varactor.

In VCOs on the web and print, you'll often see builders connect their varactor to a high Z, and high AC voltage point in the VFO tank; whoa!

At HF, if a varactor is forward biased by the positive half of the AC signal, varactor leakage current and voltage-source loading increases momentarily and lowers Q + broadens tuning. Further, serious harmonic energy and phase noise might be generated as the varactor is biased positive and negative alternately. You can sometimes see distortion in your scope during experiments with extreme AC voltage swings across the varactor. The varactor coupling capacitor should be as low as possible.

Balanced varactor tuning (anode to anode) provides another way to reduce AC signal effects at the cost of reduced maximum capacitance since the 2 varactors are in series. With back-to-back varactors, as the AC signal swings, the varactors are driven into high and low capacitance alternately, but the net capacitance remains constant. Thus applied reverse DC voltage sets the varactor capacitance rather than AC signal amplitude.

The reader for whom I made this impromptu circuit can lower the AC tank voltage by decreasing the VCC or increasing the 680 ohm source resistor after installing the buffer and tweaking things for a 7 dBm output voltage. This topology suffers from an amplitude versus frequency issue — at 7.0 MHz, the output = 3.44 volts pk-pk and at 7.066 MHz the output rises to 4.0 volts pk-pk.

Stuck with an MVAM109 constraint and 3 hours to design/build a VCO, I share this circuit as a raw experiment; not an example of good design because it is not. I took the signal off the gate to derive the best sine wave; this requires a lightly coupled, high impedance buffer with strong reverse isolation to prevent the pulling of the VCO frequency by downstream changes.

A lower L + higher C in the tank, and/or a higher Q varactor could turn this VCO into something reasonable. Popcorn versus high performance? You choose!

7 MHz VCO Experiments: A Suitable 7 MHz VCO

PART 1: Introduction

During my Fall 2011 VCO experiments I studied books including EMRFD and built versions of EMRFD Figures 4.33 and 4.34. Figure 4.33 is a common-base Colpitt's Oscillator using a hyperabrupt varactor. On Q1, the 33 ohm resistor in series with the 0.1 uF cap "de-Q" the 2N3904 to reduce UHF oscillations. Wes also employs current limiting with a 1K5 emitter resistor.

The temperature drift compensation circuit involving a temperature sensitive reference diode + op-amp fascinated me — astute temperature compensation design. I built and tested the whole circuit; the VCO has some amplitude versus frequency and phase noise issues, but it's okay for general use and *great* for varied environments. After tackling Figure 4.33, I built and tested the JFET Colpitts oscillator in Figure 4.34 and share my experiences developing this VCO with an alternate buffer.

These circuits are not cookie-cutter / carbon-copy: they show raw design ideas from the bench.

PART 2: The Voltage Controlled Oscillator

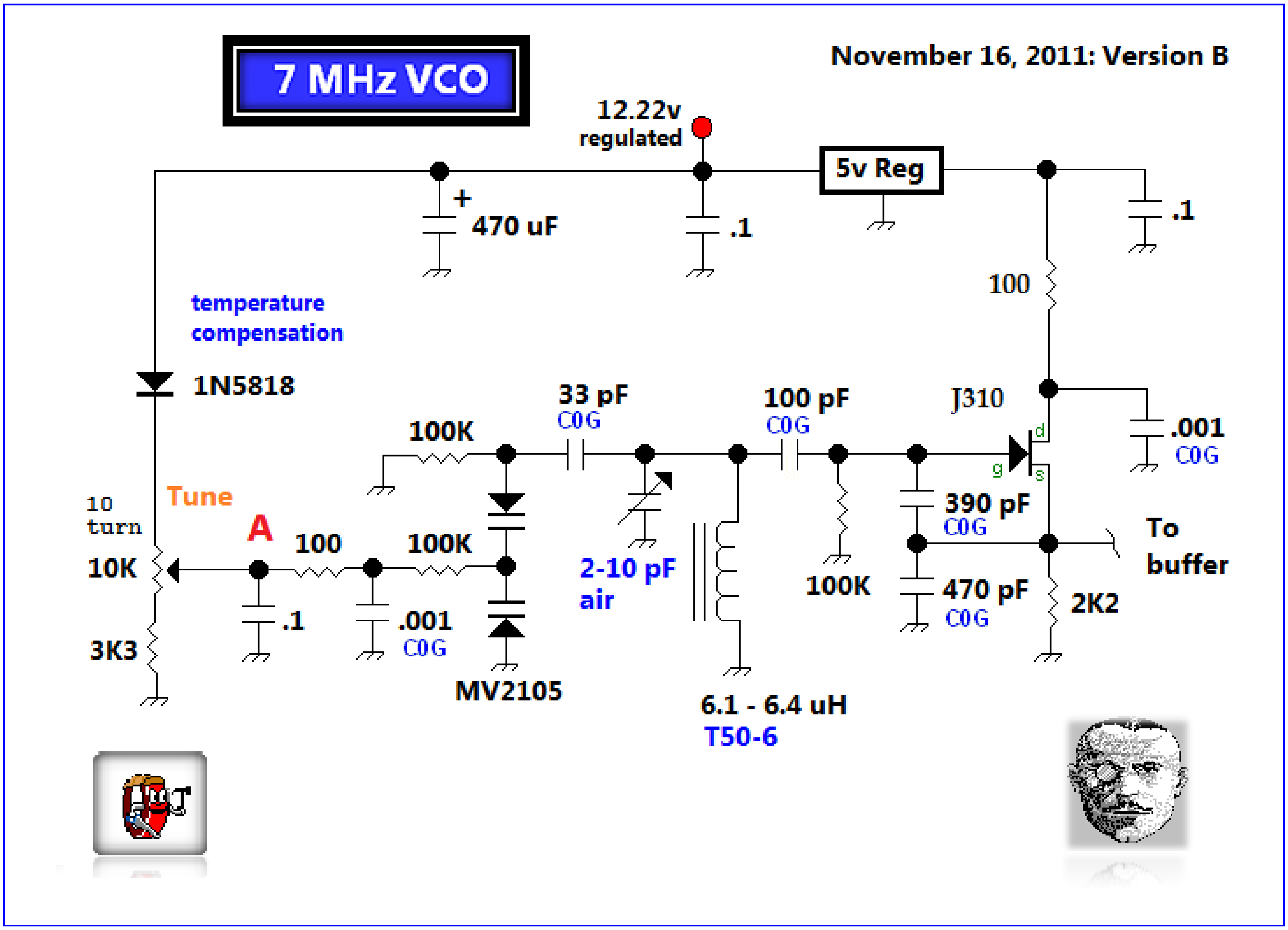
7 MHz VCO
November 16, 2011: Version B
12.22v
regulated
5v Reg
+
470 uF
.1
.1
100
temperature
compensation
1N5818
33 pF
C0G
100 pF
C0G
J310
100K
d
g
s
.001
C0G
10
turn
Tune
A
100
100K
10K
390 pF
C0G
To
buffer
2-10 pF
air
100K
470 pF
C0G
2K2
.1
.001
C0G
3K3
MV2105
6.1 - 6.4 uH
T50-6

Above — A JFET Colpitts VCO picked after after trying 5 different topologies. This VCO is my version of EMRFD Figure 4.34; originally designed by Wes, W7ZOI.

This JFET Colpitts oscillator exhibits a flat output versus frequency, low noise, scales easily to other frequencies and accomodates a wide variety of varactors. For example, you may scale it to other frequencies by changing the L and tweaking the "Colpitt's capacitors" up or down as needed.

I employed a small air variable trimmer capacitor to set the lower band edge and this meant experimenting with the inductor to find 1 that allowed me to set the band edge with such a small trimmer capacitor. I built 2 versions; in 1 the required L= 6.09 uH and in the other, L= 6.4 uH. It would be much easier to use a trimmer cap with a larger capacitance range as it makes chosing the inductor less exacting.

With the trimmer shown set to half its range, I started with a 6.6 uH coil and remove 1 turn at a time until the output in a counter was close to 7.00 MHz. After permanently fixing the inductor, I tweaked the trimmer cap so the lower band edge was 7.000 MHz with the chassis lid on.

To further drop phase noise, you could reduce the 33 pF coupling cap, add another pair of anti-parallel varactors, run a higher C to L ratio, or perhaps decrease the source resistor to increase the current limiting. Also low resistance, high Q, SMT varactors would help lower phase noise — SOD parts are tiny, but test your hand steadiness and vision.

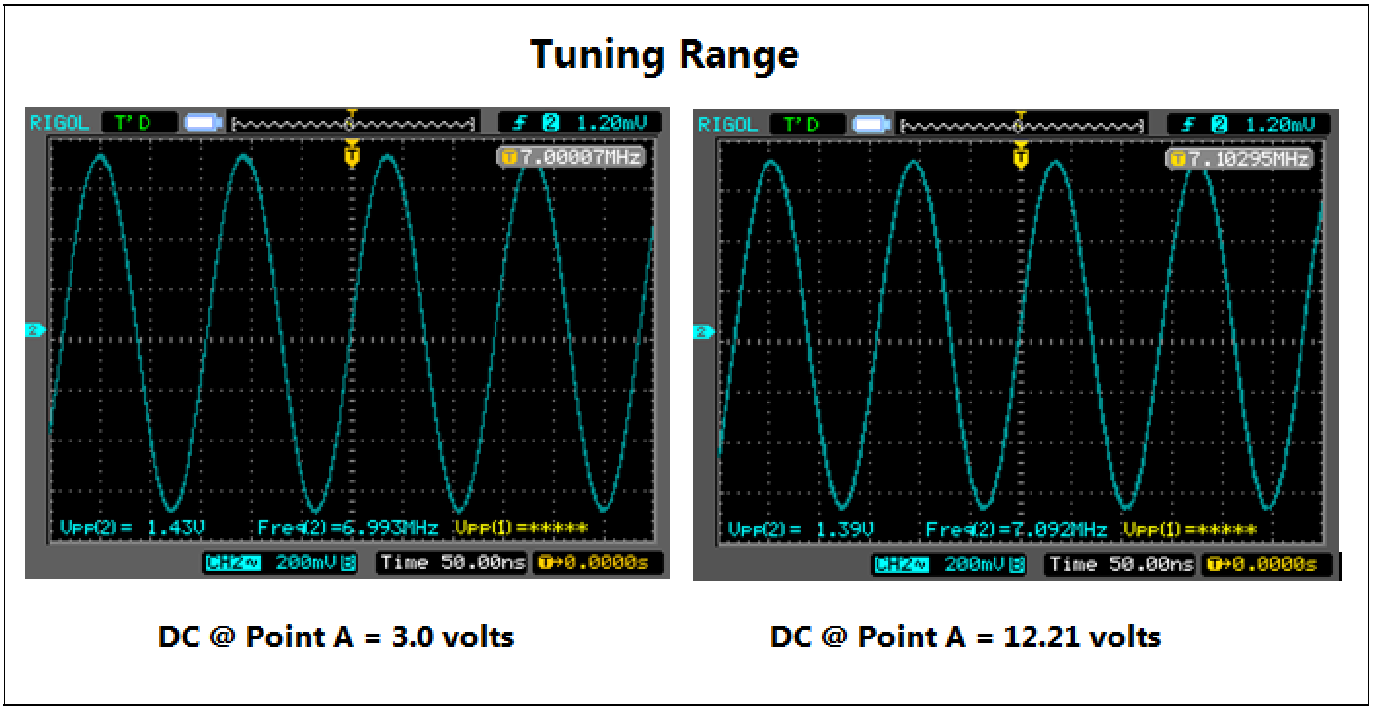
Tuning Range

RIGOL T'D
1.20mV
7.00007MHz
Vpp(2) = 1.43V
Freq(2) = 6.993MHz
Vpp(1) = *****
CH2 200mV
Time 50.00ns
0.0000s
RIGOL T'D
1.20mV
7.10295MHz
Vpp(2) = 1.39V
Freq(2) = 7.092MHz
Vpp(1) = *****
CH2 200mV
Time 50.00ns
0.0000s

DC @ Point A = 3.0 volts

DC @ Point A = 12.21 volts

Above — When tuning from the minimum frequency and tuning voltage (7.0 MHz / 3.0 VDC) to the maximum tuning voltage and frequency (7.103 MHz / 12.21 VDC) the signal amplitude only changes 0.04 volts peak-peak.

I kept a minimum of 3.0 VDC on the varactors at the minumum frequency to provide reasonably linear tuning, keep the applied reverse voltage away from 0, and improve temperature stability. All were bench determined and are not factors you can generalize to all VCO circuits. Change the minimum DC voltage on your VCO control by adjusting the resistor on the grounded end of the pot; 3K3 in my case.

Click for a moderate resolution photograph of the VCO and buffer prior to adding the temperature compensation parts.

PART 3: The Buffer/Amplifer

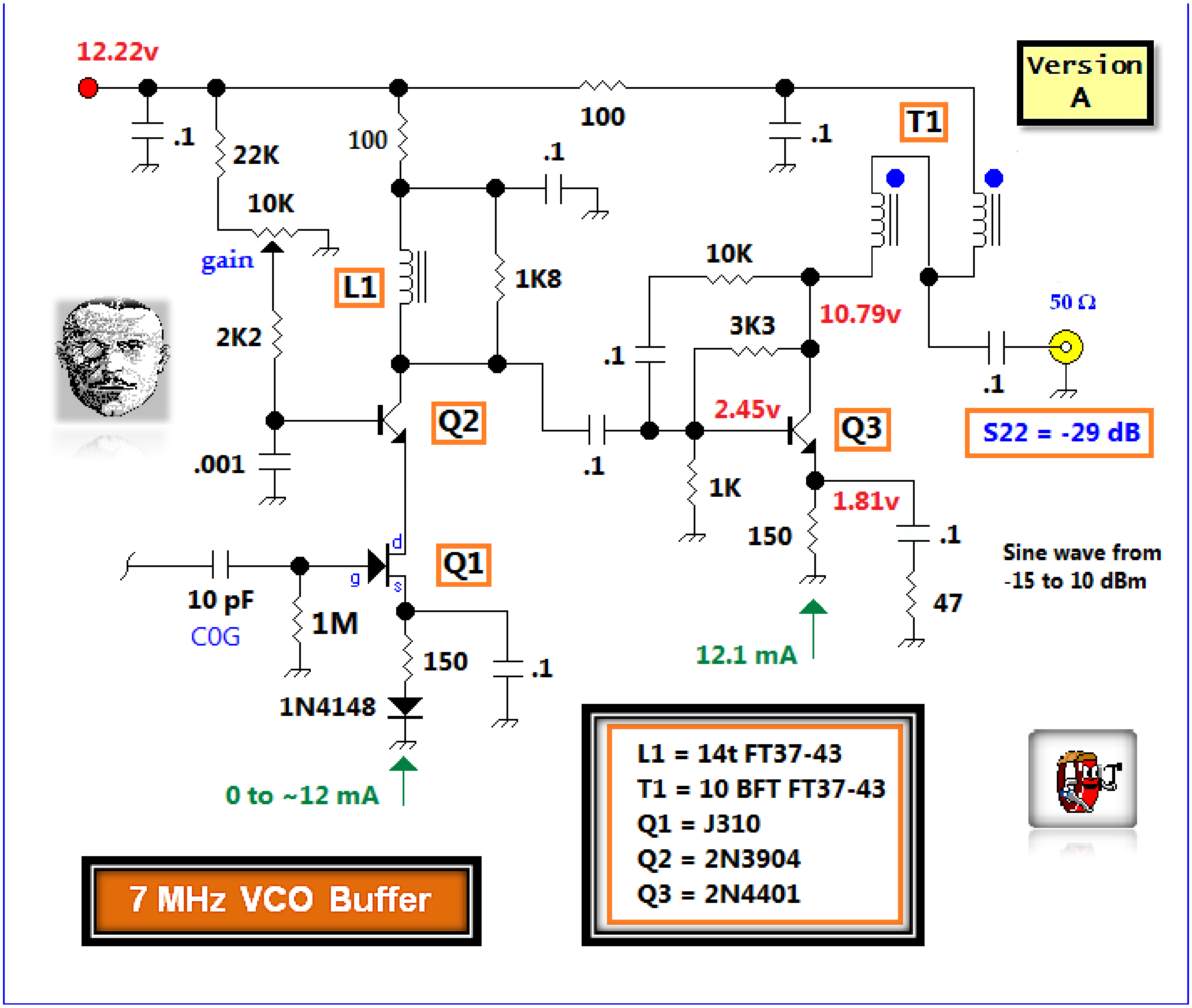
12.22v
.1
22K
100
100
.1
.1
T1
Version A
10K
gain
L1
1K8
10K
2K2
3K3
10.79v
.1
50 Ω
Q2
2.45v
Q3
.1
.001
.1
S22 = -29 dB
1K
1.81v
150
.1
d
Q1
g
s
Sine wave from -15 to 10 dBm
47
10 pF
C0G
1M
12.1 mA
150
.1
1N4148
0 to ~12 mA

7 MHz VCO Buffer

L1 = 14t FT37-43
T1 = 10 BFT FT37-43
Q1 = J310
Q2 = 2N3904
Q3 = 2N4401

Above — The Q1-Q2 hybrid-cascode amp gives strong reverse isolation (nearly 70 dB) and front panel gain control. You could also employ a dual gate MOSFET or JFET cascode with either fixed bias, front panel control, or a trimmer resistor to adjust the bias on Q2

I enjoyed designing the Q3 final amp amp and matching its input impedance to the output Z of Q2. One way to establish a fixed + known output impedance in order to to get a strong return loss without tuned circuits/networks is to feedback some signal from the collector to the base. The difficulty lies in finding how much negative feedback to apply, while still DC biasing the amplifier for good temperature stability. I set up a crude experiment to determine the Scattering Parameter S22. The goal is to set up a good Q3 output return loss using feedback + matching the Q3 input impedance by tweaking the inductor resistor across L1 and adjusting Q3's emitter degeneration.

The return loss in my first prototype without any attenuator pad = 29 dB; some of this was pure luck.

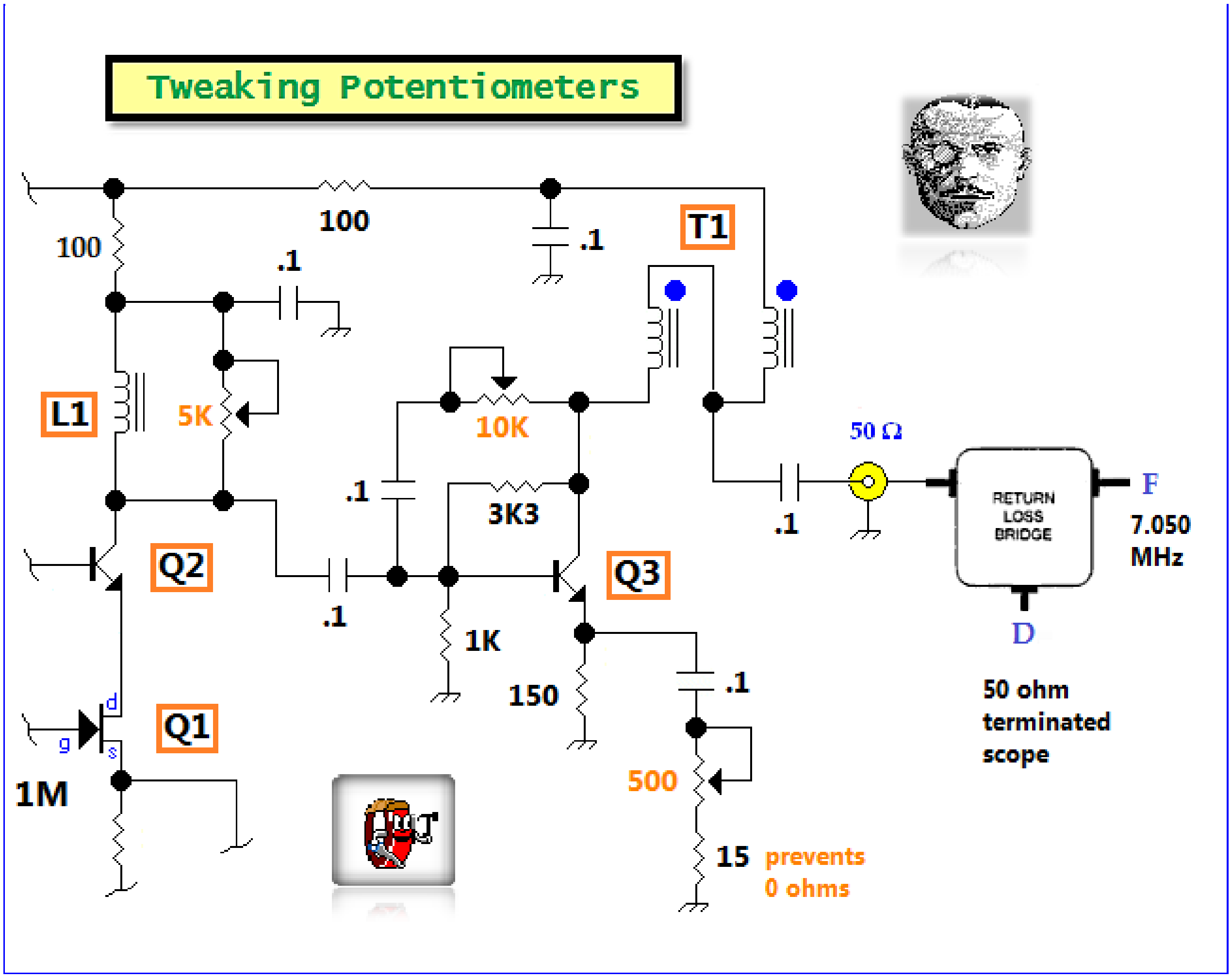
Tweaking Potentiometers
100
100
.1
.1
T1
L1
5K
10K
50 Ω
.1
3K3
.1
RETURN LOSS BRIDGE
F
7.050 MHz
Q2
Q3
.1
1K
D
150
.1
50 ohm terminated scope
d
Q1
g
s
1M
500
15 prevents 0 ohms

Above — Q2 and Q3 with 3 variable **orange colored** resistors in-situ and a Return-Loss bridge connected to the output. The potentiometers are tweaked while watching the detected output in an oscillocope. Adjust all the pots for the lowest peak-peak voltage and then carefully remove each pot and measure its resistance with an ohm meter. Replace all 3 pots with the nearest equivalent standard value resistor. Then measure and calculate the return loss (negative of S22). Watch the Q3 emitter resistance — too little R might bring distortion.

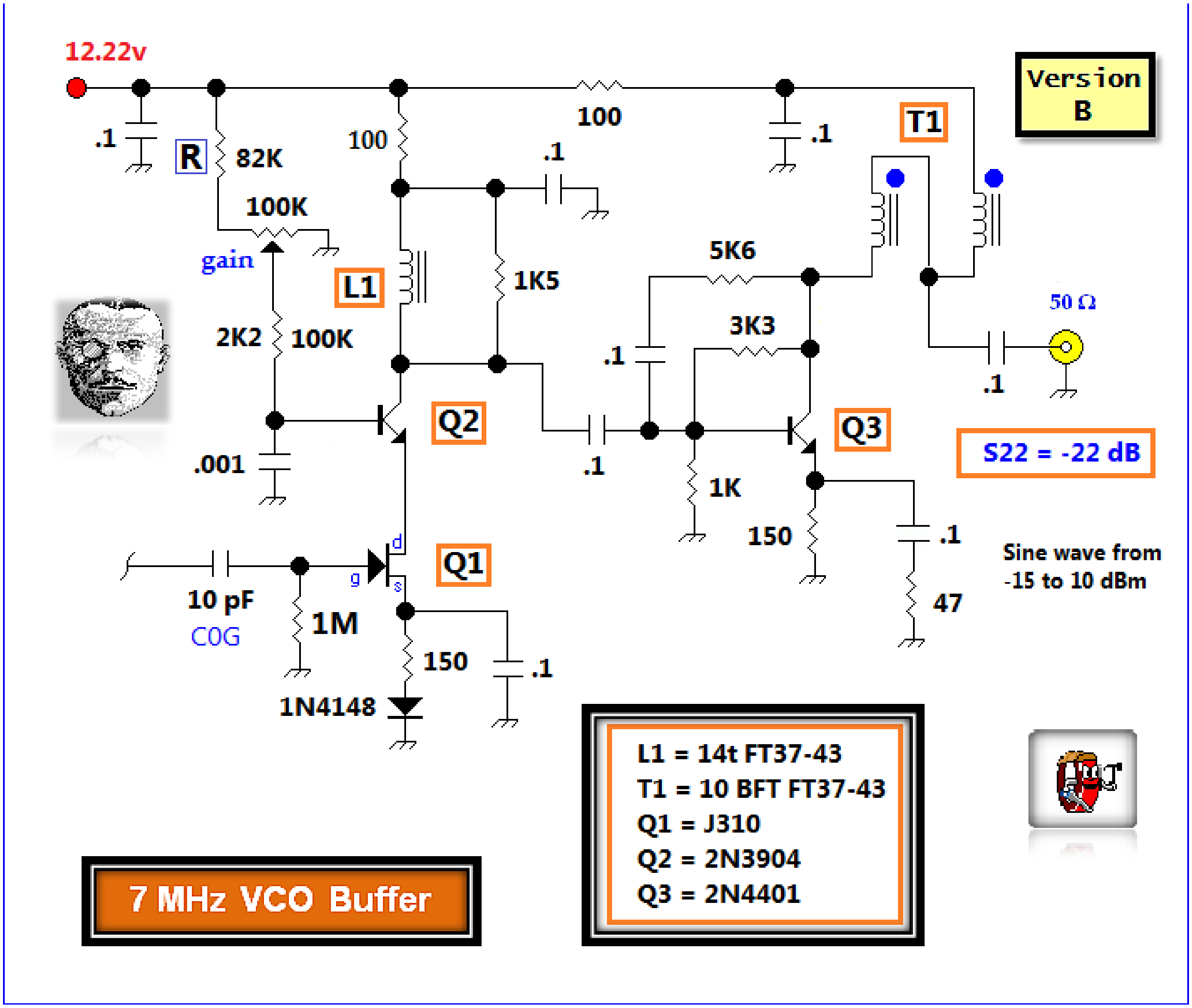
12.22v
.1
R
82K
100
100
.1
.1
T1
Version B
100K
gain
L1
1K5
5K6
2K2
100K
3K3
.1
50 Ω
.1
Q2
.1
Q3
S22 = -22 dB
.001
1K
150
.1
Q1
d
g
s
Sine wave from -15 to 10 dBm
10 pF
C0G
1M
47
150
.1
1N4148
L1 = 14t FT37-43
T1 = 10 BFT FT37-43
Q1 = J310
Q2 = 2N3904
Q3 = 2N4401
7 MHz VCO Buffer

Above — A seperate buffer built with 100% different parts that required different AC feedback plus shunt resistor across L1. The parts in this circuit weren't as hot as Version A, and the maximum output voltage was only 1.8 volts pk-pk. In order to get the AC output voltage to just above 2 volts, I had to tweak the resistor labelled **R**.

To keep the heat and current down in the final amp, I decided to keep the maximum clean output to 2 volts peak-peak (= 10 mW = 10 dBm) with an emitter current of ~ 12 mA. If you want higher clean output than 10 dBm, you'll have to run more Q3 emitter current and maybe choose a different BJT, plus apply a heat sink.

When cranked to maximum DC voltage, the Q2 gain pot allows a peak output AC voltage of ~2.2 volts pk-pk into 50 ohms and distortion is evident. At or below 2 volts pk-pk all is well — I'll use this VCO mostly from 0 to 7 dBm.

Since the circuits uses 2 BJTs and a JFET and many 5% tolerance resistors , the Q3 output will vary according to your parts. Tweak the resistor labelled **R** to provide a maximum AC signal just over 2 volts peak-peak into 50 ohms. This translates to around 3.8-5.5 volts DC bias for Q2 with your gain pot cranked fully clockwise.

Return loss variations. You probably noticed the return loss in Version B = 23 dB, while Version A = 29 dB.

Version B originally had the 1K8 shunt resistor across L1 and the 10K + 0.1 uF AC feedback arm just like version A and I measured a return loss of 22 dB. I stuck in 2 tweaking potentiometers (did not bother tweaking the the emitter series feedback element). After pot tweaking, the best return loss I could obtain with 5% tolerance resistors was 23 dB and this probably represents what the average builder will obtain. An S22 of - 22 to -23 dB works fine for the QRP work bench.

If you don't plan to do any potentiometer tweaking, I recommend building circuit A since it has a little more gain due to the slightly higher shunt resistor, and also I built 3 versions of Version A with an S22 of -22 dB or higher.

PART 4: Temperature Compensation

Before temperature compensation, my VCO slowly drifted down in frequency and was unusable.

If you look through the Ham Radio VFO/VCO literature, you will see that many builders use polystyrene caps as the Colpitt's capacitors, and/or in parallel with other NP0/C0G tuning capacitors. Negative temperature compensation caps like an N750, or the polystyrene types temperature compensated the oscillator. Negative temperature co-efficient caps are hard to obtain for many builders; especially in small quantities, however, they are worth their weight in gold.

Diode Compensation

Stabilize your VCO as much as possible with compensating capacitors and by following prudent temperature stability techniques before adding diode compensation. *See the VFO 2011 web page and EMRFD.* Temperature compensation is best performed in a homebrew oven (see EMRFD) and normally takes an incredible amount of time and patience.

Temperature compensating diodes are far from static — a diodes temperature co-efficient is dynamic and may vary with current and also unfortunately, with temperature and even while tuning your VCO !

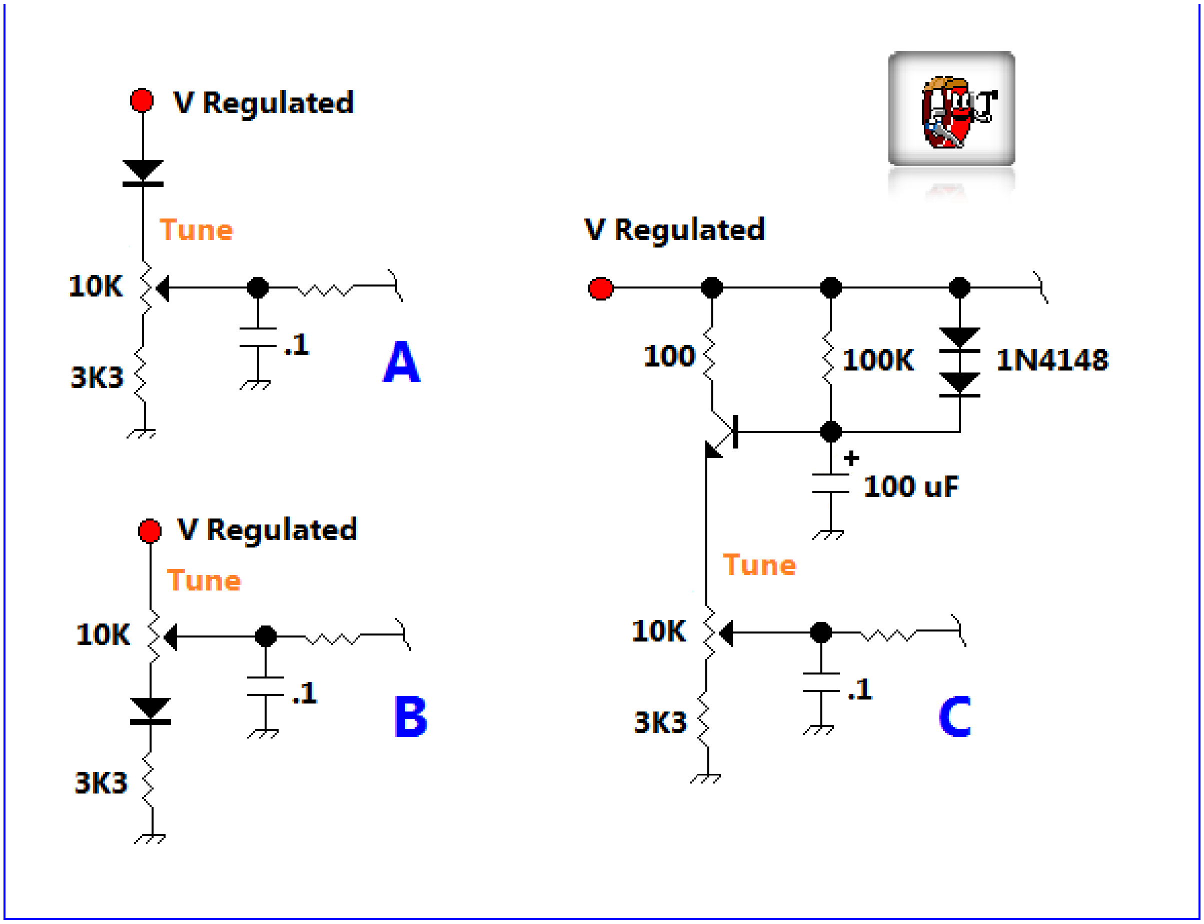

Above — Simplistic diode temperature compensensation schemes.

The late, great, Doug DeMaw advocated sticking a 2N3904 or 2N2222a (wired as a diode) between the control potentiometer and the varactor decoupling network since the forward biased P-N junction exhibits a negative temperature co-efficient and should stop the decrease in frequency. It can help, however, as you tune and swing the control DC voltage from minimum to maximum the forward bias on the diode increases and the diode temperature coefficient decreases.

I've never had success using a transistor in this way; the BJT caused the VCO frequency to increase in an erratic manner that varied along with the DC control voltage. When watching drift in a frequency counter set to sample every second or so, a stable design will slowly change frequency in 1 or occasionallly 2 Hertz increments — some people call this "linear drift". if you see your VCO dropping down frequency in 10 - 20 Hertz jumps per second, you'll have a bad time temperature compensating.

I experimented with the above 3 designs that keep a constant current on the diode. Figures A and B work. I tried both and confirmed that a given diode compensated slightly differently when in circuit A or B. This gives you a bit of a tweaking room for your chosen compensation diode. I tried Figure C, but it had too much negative temperature coefficient and sent the VCO drifting upward about 1-2 Hertz each second.

I settled on circuit A and then tried some diodes: the initial best was a grubby old Germanium from my junk box. The best choice turned out to be a Schottky barrier rectifier (1N5818). I connected the VCO to a receiver and could listen to CW QSOs without groaning. My VCO now drifted up in linear, 1 Hertz hops at about 105 Hz per hour. It took a long time to tack solder in and wait 10 or 15 minutes for each diode to stablize before I finally settled on the 1N5818.

The better solution is to choose a suitable diode and vary its current to tweak the temperature compensation. Wes did this in EMRFD Figure 4.33.

Advanced designs may use a reference voltage + a temperature dependent voltage that is applied to op-amps in a proportional way to temperature compensate the DC control voltage. Then, too, some builders ovenize their VCO container to maintain a very stable environmental temperature.

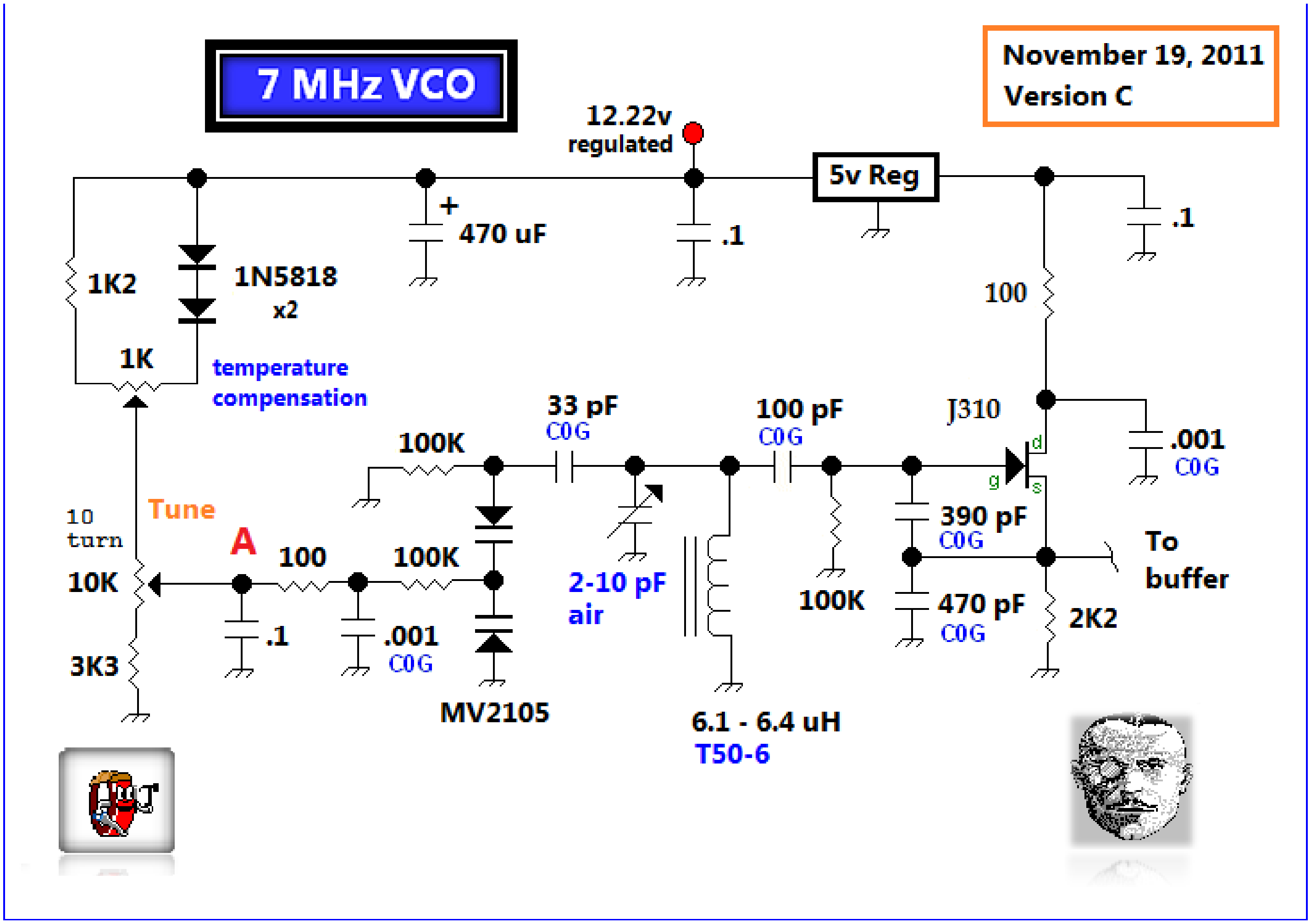
7 MHz VCO
November 19, 2011
Version C
12.22v
regulated
5v Reg
+
470 uF
.1
.1
100
1K2
1N5818
x2
1K
temperature
compensation
33 pF
C0G
100 pF
C0G
J310
100K
d
g
s
.001
C0G
10
turn
Tune
A
100
100K
390 pF
C0G
To
buffer
10K
2-10 pF
air
100K
470 pF
C0G
2K2
.1
.001
C0G
3K3
MV2105
6.1 - 6.4 uH
T50-6

Above — A simple and elegant diode compensation scheme proposed by Ken Kuhn. Basically, it lets you tweak the degree of compensation to what is really needed rather than accept what you get from a diode. Adding more diodes will increase the effect — but the 1.2 K resistor should be increased accordingly to roughly match the overall voltage drop of the diodes. Hopefully there is a point on the 1K potentiometer where temperature compensation can be very good at a tuning point of interest. The diodes should be located to thermally match the rest of the oscillator circuitry.

Set the band edge *after* finding the sweet spot on the 1K potentiometer since it will affect the tuning frequency. This experimental circuit cannot be casually copied and it took a while to converge to the desired operating point on the 1K potentiometer. Generally you start with the 1K pot towards the 1.2 K resistor and then adjust for the best stability after warm-up. Then repeat and adjust as necessary over time.

Temperature compensatiing an oscillator like this is a challenge as all parts have some temperature drift and it takes a lot of measurements (and often, some dumb luck) to determine the overall compensation curve that is needed.

My 1 hour drift up in frequency is now ~ 60 Hertz per hour at various tuning frequencies across the tuning range. I stuck with the 1N5818 diode, and probably should have tried other diodes and also changed the 1K2 resistor to observe any effects, however, I have spent an inordinate amount of time on this circuit and leave it to others, or future bench work to improve. *See QRP — Posdata below.*

7 MHZ VCO
GAIN
TUNE
G

Above — Version C of the VCO. When I built the first versions, I drilled a hole to accomodate a third potentiometer, but filled it with a LED holder that was temperature sealed with epoxy glue. The 1K pot *jus*t fit into my chassis.

QRP— Posdata for January 2012

In late 2011, I shopped on eBay to build up a small quantity of 10 - 270 pF polystyrene, plus some 56 pF N750 ceramic temperature compensation capacitors. After 2 simple, but time-consuming experiments, I temperature stablized my 7 MHz VCO frequency drift to under 10 Hz per hour in the relatively constant temperature of our basement.

I didn't feel like re-doing the whole resonator circuit and thus focused on the tank to FET coupling capacitor. Placing a N750 capacitor in parallel with a fixed NP0/C0G cap to make 100 pF resulted in over-compensation and no amount of tweaking on the "adjustable diode" circuit worked. A few hours late, I swapped in a 100 pF polystyrene capacitor and after further hours of waiting and tweaking, I nailed the frequency stability sought.

An oven provides the best way to temperature compensate, however, whether you choose the oven method, or the bench method like I did, great patience is required to see if a change to your TC circuitry works or not.

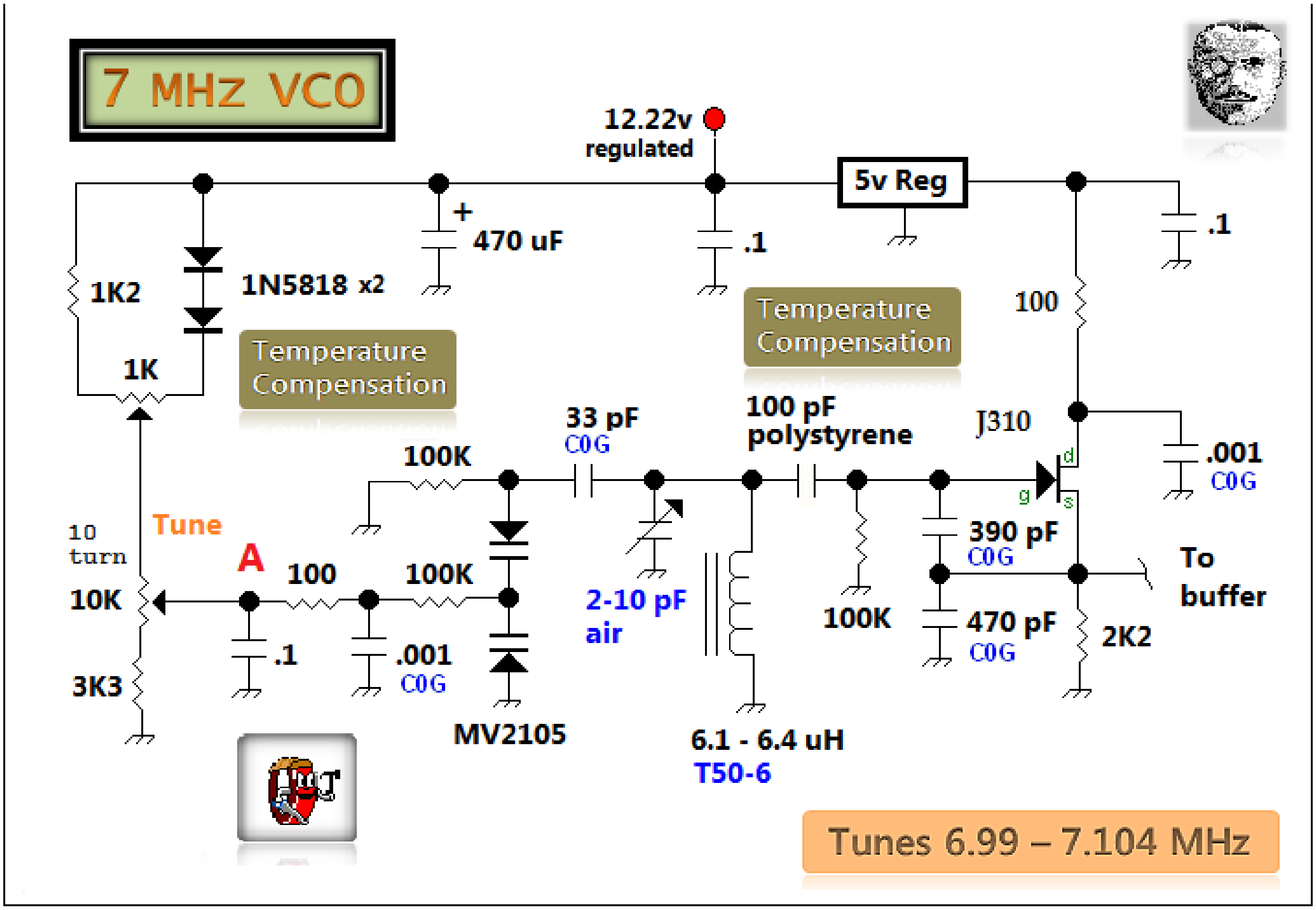
7 MHz VCO
12.22v
regulated
5v Reg
+
470 uF
.1
.1
1K2
1N5818 x2
Temperature Compensation
Temperature Compensation
100
1K
33 pF
C0G
100 pF
polystyrene
J310
d
g
s
.001
C0G
100K
10
turn
Tune
A
10K
3K3
100
100K
.1
.001
C0G
MV2105
2-10 pF
air
6.1 - 6.4 uH
T50-6
100K
390 pF
C0G
470 pF
C0G
To
buffer
2K2
Tunes 6.99 – 7.104 MHz

Above — Final version of the 7 MHz VCO. I changed the 100 pF capacitor coupling the JFET to the resonator circuitry from C0G to polystyrene and slowly tweaked the 1K temperature compensation pot to find the point of convergence.

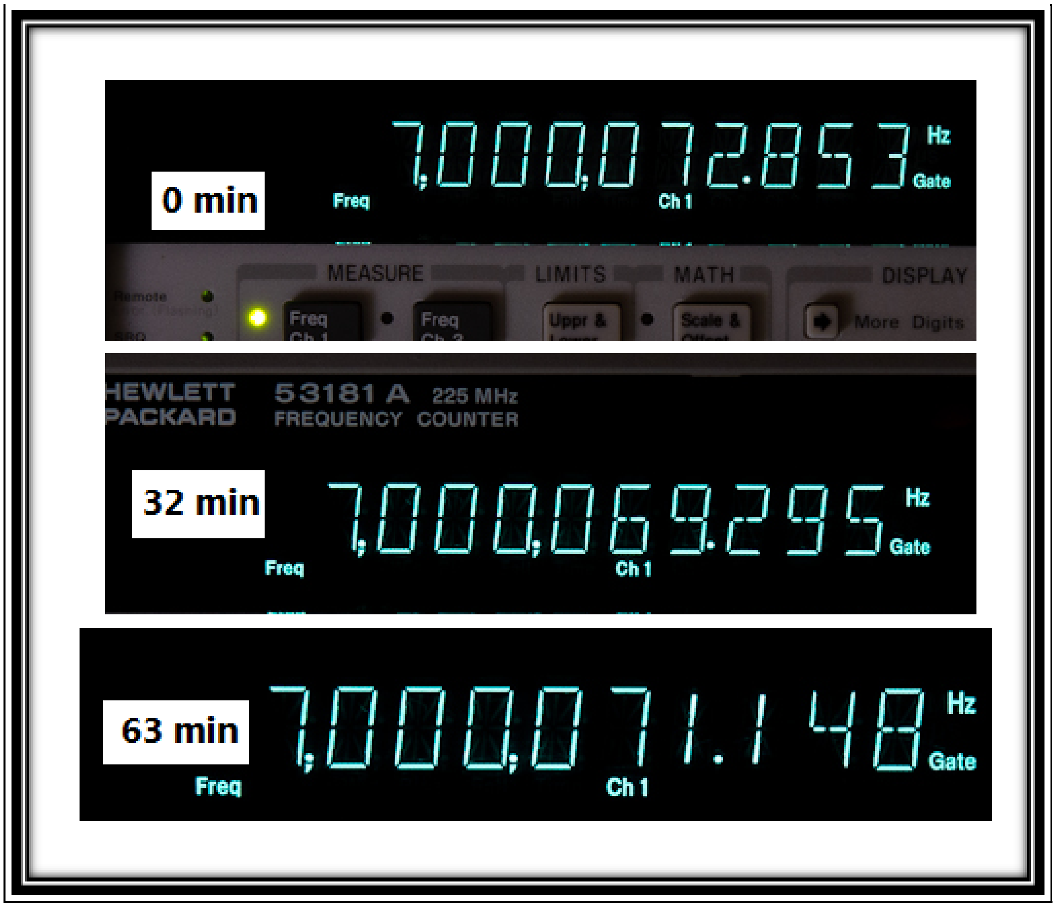
0 min
Freq
7,000,072.853
Hz
Gate
Ch 1
MEASURE
LIMITS
MATH
DISPLAY
Freq Ch 1
Freq Ch 2
Uppr &
Scale &
More Digits
HEWLETT PACKARD
53181 A 225 MHz
FREQUENCY COUNTER
32 min
Freq
7,000,069.295
Hz
Gate
Ch 1
63 min
Freq
7,000,071.148
Hz
Gate
Ch 1

Above — The ~1 hour drift after a 30 minute warmup period for the 7 MHz VCO. Love this.

TEMPCO
CAPS

Above — My new temperature compensation capacitor parts drawer. I'll keep an eye out for further bargain temperature compensation parts on eBay and at Ham Radio festivals.

Fearless Leader and Hero   Храбрый вождь и герой

Above — Professor Vasily Ivanenko ( ), fearless leader (ТЫ МОЙ ГЕРОЙ)

He's my hero because he's humble, fallible, well-intentioned and moral. Professor Ivanenko lives for learning — fame is filler — hollow and distracting. His current *ego* lags his voltage by 90 degrees. Is he part inductor / part human?

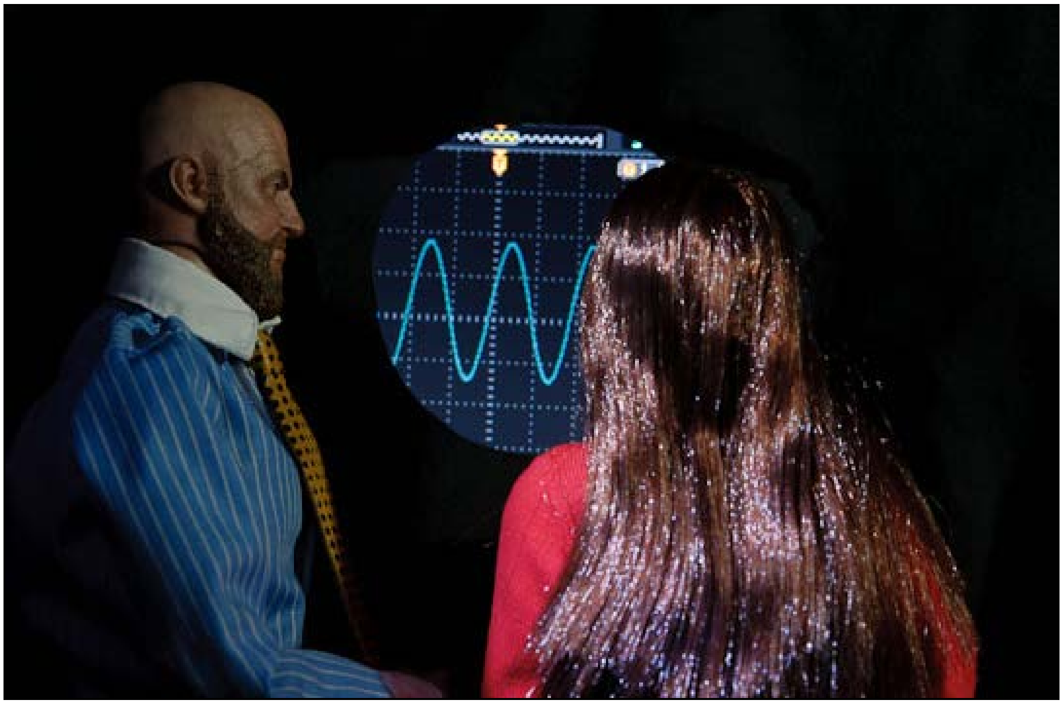

Miscellaneous Photos and circuits

Above — 3 types of adapters. A BNC male to SMA female, a BNC male to PL-259, and a BNC female to S0-239 allow the RF modules to be connected to a variety of equipment.

SPECTRUM ANALYZER CALIBRATOR
OHM TERMINATOR
SCOPE
RF
RF
RF
GAIN
D
4
-10
IN

Click

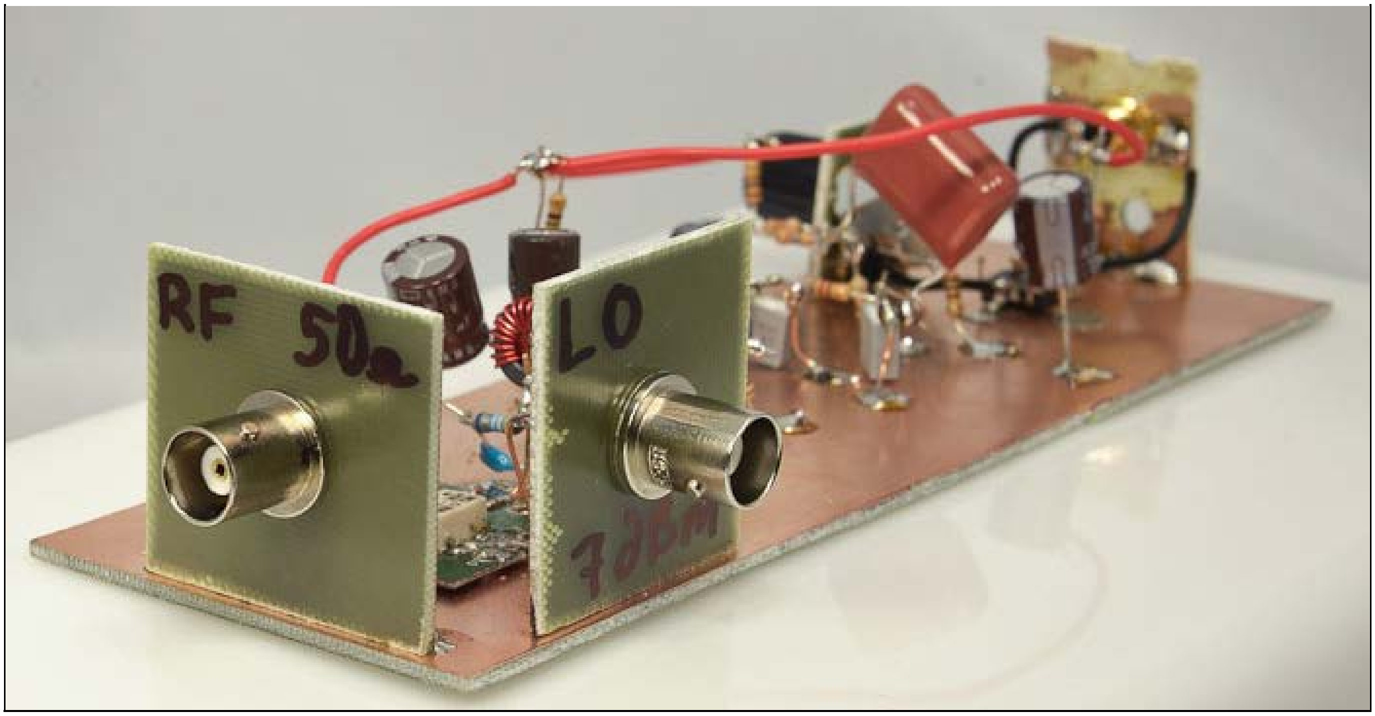
RF 50Ω
LO
7dBm

QRP SWL HOMEBUILDER

RF — Test and Measurement

Double Tuned Receiver Band-pass Filter Design Center

This web page is for builders who own EMRFD. Assisted by 4 of the Ladpac programs from the EMRFD compact disk, and the information presented in EMRFD Chapter 3, I share some experiments building popcorn receiver band-pass filters. Prior to diving into this material, please read the help file ***Ladpac2008 Manual.pdf*** and a file on the EMRFD compact disk called The Double Tuned Circuit: An Experimenter's tutorial by Wes, W7ZOI.

Preface

Derived from experiments, my web content reflects the efforts of a lay-person, hobby-level designer — I make mistakes. I say this not to make excuses or avoid accountability, but to share the truth. My hope is that my experiments inform yours and we all improve over time. I correct reported mistakes and rely on your eyes to see them.

Arduous and requiring good math skills, filter design is out of reach for many builders. Software changes this and learning to apply computer programs in real-world situations is part of our hobby. This web page shares some bench experiences, plus my thoughts about using some programs written by Wes, W7ZOI. I present suggestions and examples based more on empiricism and from reading about band-pass filter design than scientific methodology.

From email regarding my VFO and RF Workbench pages, I have become aware that I've lead many builders to think that a perfect sine wave and a high return loss are "must have" bench outcomes. This is false. A clean sine wave proves useful for accurate measurement, but is not a *de rigueur* bench outcome. A desire for high return loss reflects my own personal *obsession*; in simple QRP rigs, this may represent folly. Please don't overestimate the importance of return loss from my bias; decide for yourself.

Part 1: Experiments with 2 coupled L-C tanks.

Goal: A 15 Meter band band-pass filter with an insertion loss < 4 dB and a return loss of >= 20 dB.

Software: Ladbuild08 and GPLA08.

The simplest band-pass filter is an L-C tank. To get a decent stop band we generally couple 2 or 3 tanks together with series capacitor(s). Other filter topologies were ignored. In Part 1, I just connected up a couple of tanks on the bench without the use of software. Some attempts at impedance matching via transformer links were also trialed.

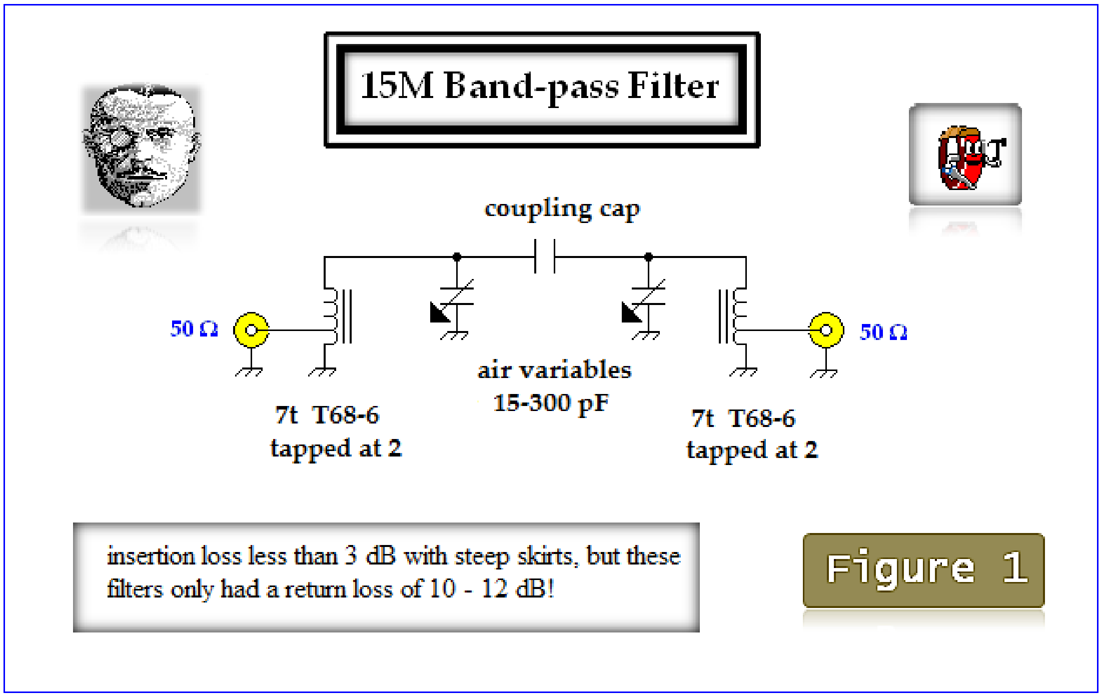
15M Band-pass Filter
coupling cap
50 Ω
50 Ω
air variables
15-300 pF
7t T68-6
tapped at 2
7t T68-6
tapped at 2
insertion loss less than 3 dB with steep skirts, but these filters only had a return loss of 10 - 12 dB!
Figure 1

Above — I built a 5 component filter for the base experiment. Inductors = 7 turns of #22 AWG on a T68-6; tapped at 2 turns from ground. The inductors turns were expanded or compressed until L= 300 nH. Tuning capacitors = large 15 to 300 pF air variable capacitors. Coupling capacitors trialed = 2 pF, 3.3 pF, 5 pF, and 7.5 pF.

After soldering in a coupling capacitor, each tank (also called resonator) was tuned to resonance by looking at the peak-peak output voltage in a 50 ohm terminated oscilloscope. After tuning, I measured insertion and return loss and then swept each filter with a tracking generator + spectrum analyzer. On the bench I determined that the greatest return loss occurred with 2 transformer taps from ground; the result — a dismal 10-12 dB.

What effect does changing the coupling capacitor have?

2 pF coupling capacitor

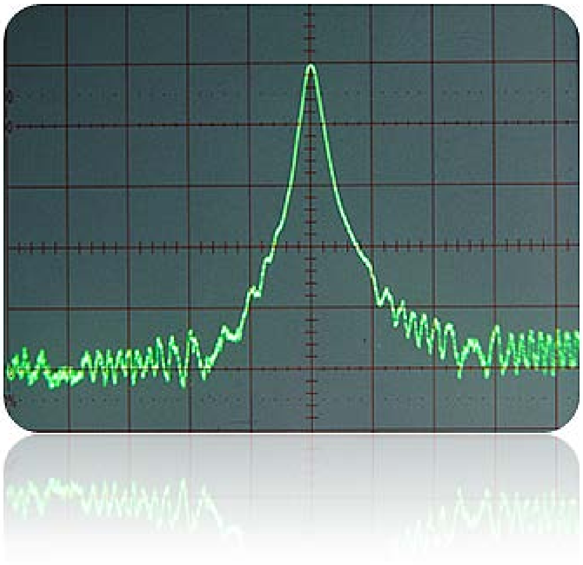

Above — A spectrum analyzer + tracking generator sweep of the filter response with a 2 pF coupling capacitor between the inductors. Graticules = 2 MHz per horizontal division and 10 dB per vertical division. Click on this zoom to better see the - 3 dB bandwidth. The sweep revealed a sharp peak response with steep skirts and a 3 dB down BW of ~220 KHz or so. Some of the noise arose from the big air variable caps connected to each tank with short hook up wires, plus no shielding.

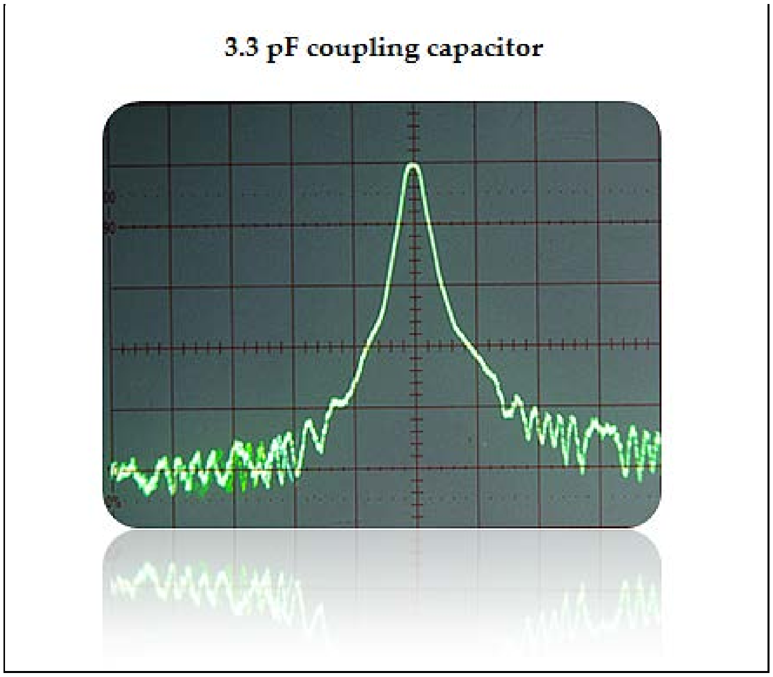
3.3 pF coupling capacitor

Above — The SA + TG sweep with a 3.3 pF coupling capacitor. The peak isn't as sharp, but still looks good. As shown, increasing the coupling capacitor value increases the 3 dB filter bandwidth with all other components equal.

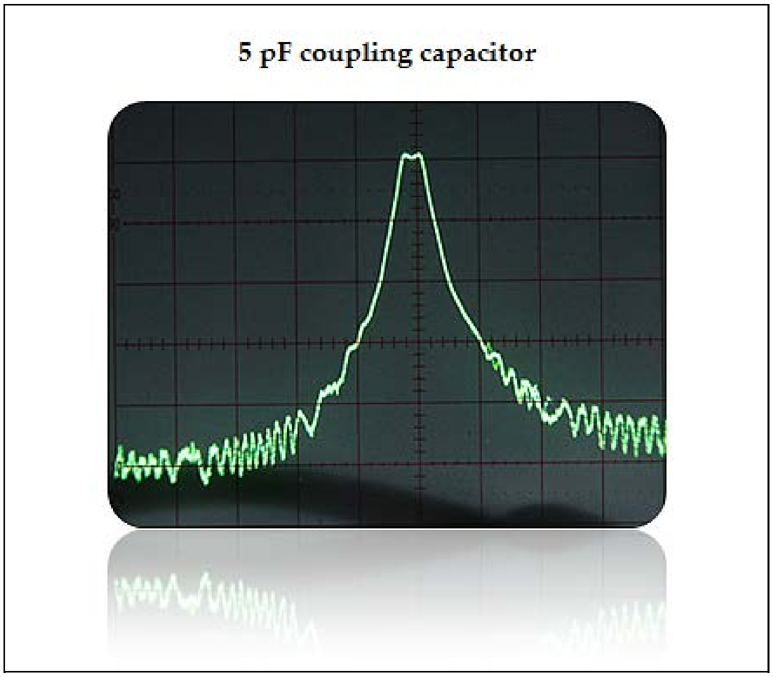
5 pF coupling capacitor

Above — With a 5 pF coupling capacitor, a double humped response appeared. The bandwidth further increases.

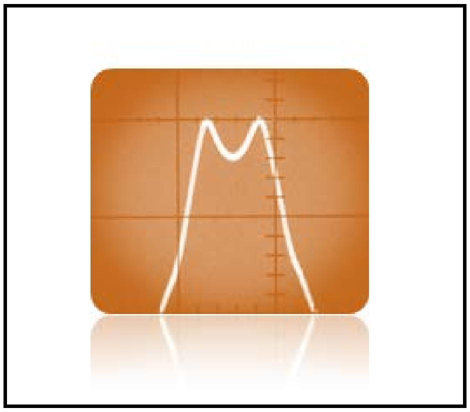

Above — A zoom of the double humped filter response employing a 7.5 pF coupling capacitor. Imagine the difficulty tuning this band-pass filter in a receiver by listening to band noise. Tuning in either peak skews the filter bandwidth. Additionally, the 3dB bandwidth now = ~ 1.6 MHz — Not a good filter!

Optimizing Return Loss

Despite trying, I could not obtain a better return loss than 10 -12 dB by changing the tap point on the 7 turn inductors. In part this was due to limited potential autotransformer ratios on a 7 turn coil. I emailed Wes, W7ZOI and he sent this file. I learned that adding a series capacitor to each end will tune the filter to 50 ohms impedance. What capacitor value should we use?

The answer can be found purely experimentally, or with Ladbuild08 to make a digital file of your filter and GPLA08 to analyze it.

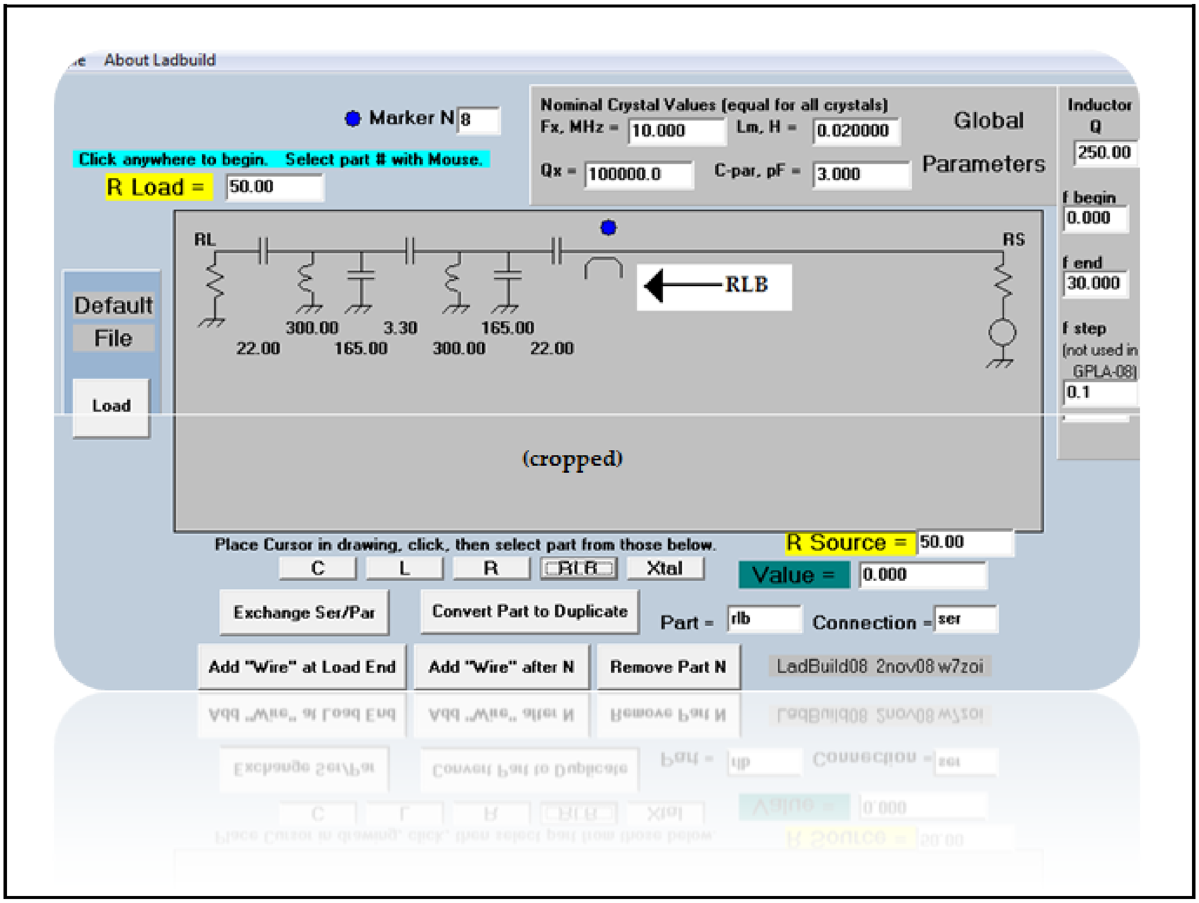

Click anywhere to begin. Select part # with Mouse.

Marker N 8

R Load = 50.00

Nominal Crystal Values (equal for all crystals)

Fx, MHz = 10.000

Lm, H = 0.020000

Qx = 100000.0

C-par, pF = 3.000

Inductor Q 250.00

f begin 0.000

f end 30.000

f step (not used in GPLA-08) 0.1

(cropped)

Place Cursor in drawing, click, then select part from those below.

R Source = 50.00

Value = 0.000

Part = rlb

Connection = ser

LadBuild08 2nov08 w7zoi

Above — I "built up" my Figure 1 filter in Ladbuild08 with a 3.3 pF coupling capacitor. Initially I guessed at the values for the series end capacitors and knew my tuning capacitor were ~ 165 pF because I removed and measured them from the peaked filter from Figure 1 and added a few pF for stray capacitance. Any of these values can be changed in GPLA, so educated guessing is okay.

For size 50 to 68 toroidal inductors, many builders choose a Qu value from 200 - 250 with # 6 material. Qu affects insertion loss and to some extent, return loss. Click for a tutorial from Wes', W7ZOI site and consult EMRFD for more information.
In order for GPLA08 to display an S11 plot (return loss), a return loss bridge (RLB) must be added as shown. Also check the **Plot S11** check box in GPLA08.

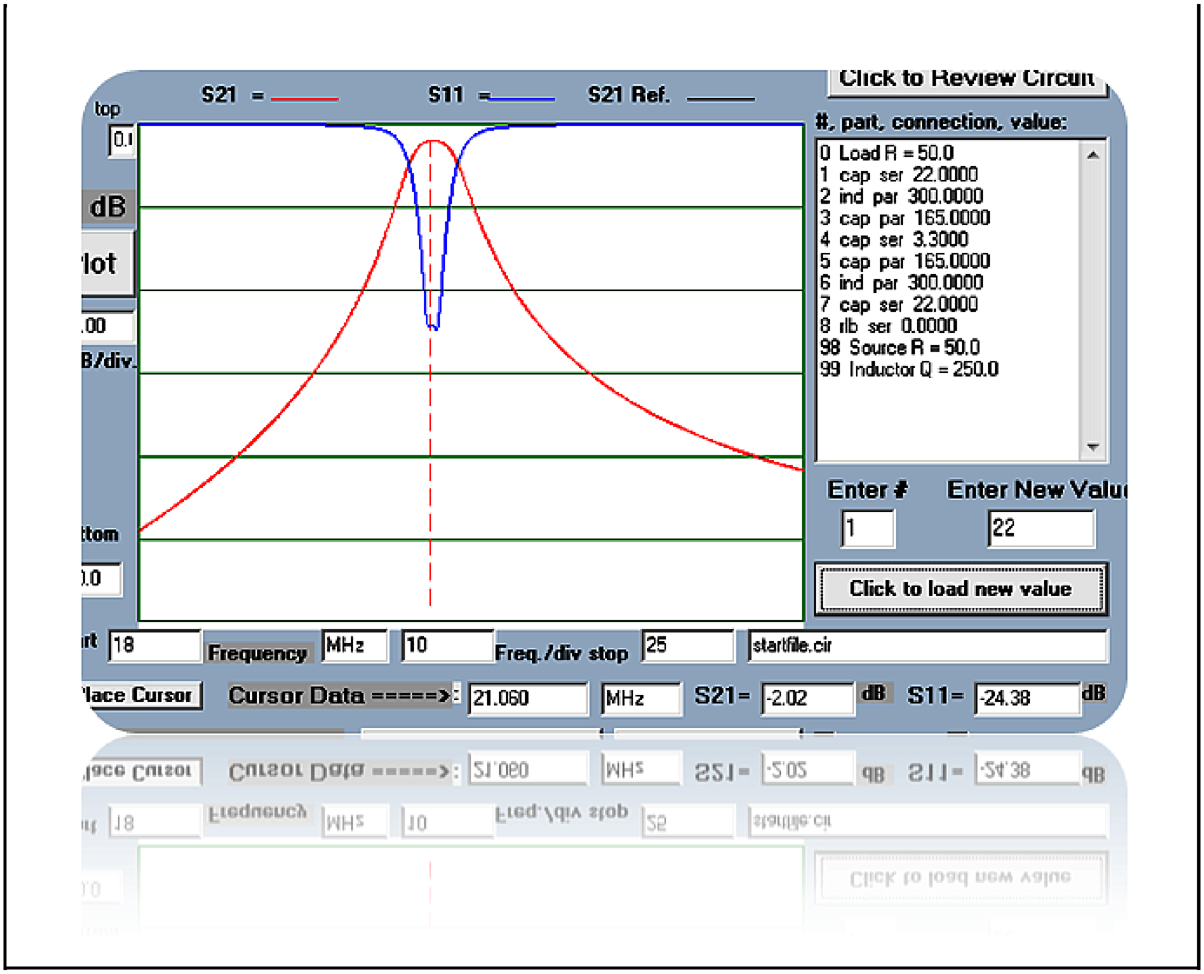
S21 =
S11 =
S21 Ref.
Click to Review Circuit
top
0.0
dB
Plot
10.00
dB/div.
bottom
-60.0
start
Frequency
Freq./div
stop
Enter #
Enter New Value
Click to load new value
Place Cursor
Cursor Data =====>
dB

#, part, connection, value:
0 Load R = 50.0
1 cap ser 22.0000
2 ind par 300.0000
3 cap par 165.0000
4 cap ser 3.3000
5 cap par 165.0000
6 ind par 300.0000
7 cap ser 22.0000
8 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 250.0

Enter #: 1
Enter New Value: 22

start: 18 MHz, Freq./div: 10, stop: 25, startfile.cir

Cursor Data: 21.060 MHz, S21= -2.02 dB, S11= -24.38 dB

Above — The GPLA 08 filter simulation of the filter "built" with Ladbuild08 above.

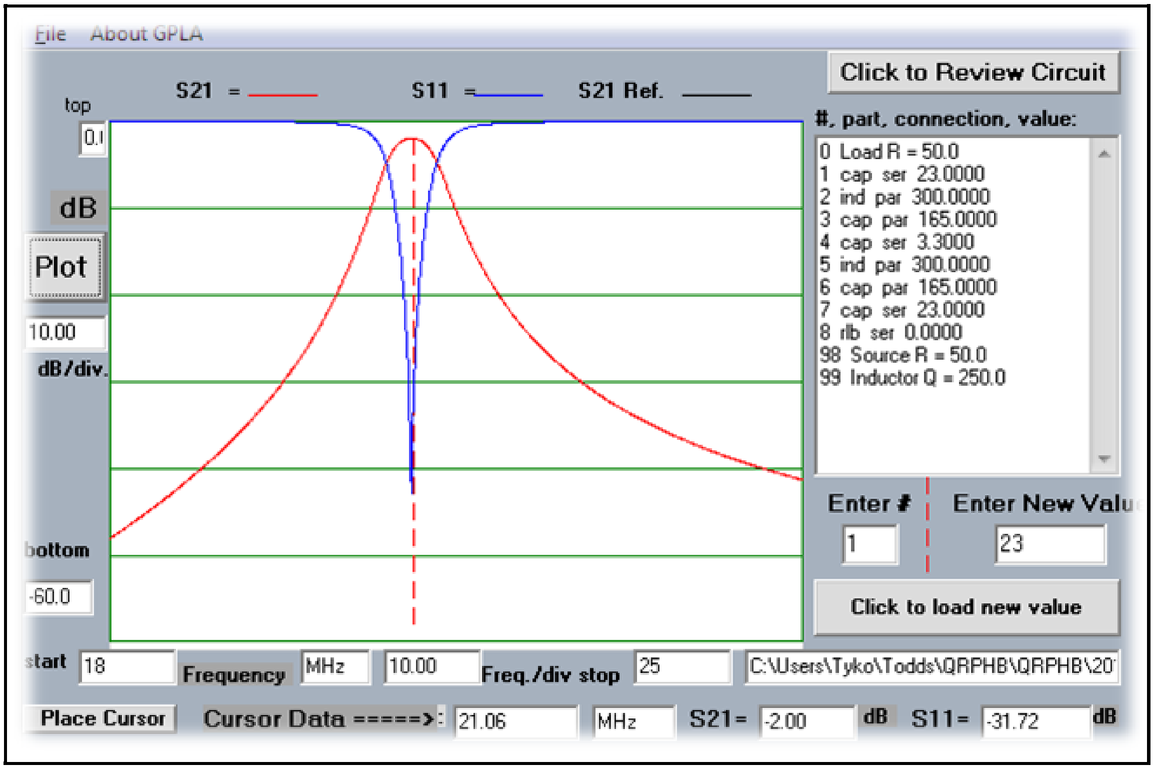
File
About GPLA
Click to Review Circuit
S21 =
S11 =
S21 Ref.
top
0.0
dB
Plot
dB/div.
bottom
start
Frequency
Freq./div
stop
Enter #
Enter New Value
Click to load new value
Place Cursor
Cursor Data =====>
dB

#, part, connection, value:
0 Load R = 50.0
1 cap ser 23.0000
2 ind par 300.0000
3 cap par 165.0000
4 cap ser 3.3000
5 ind par 300.0000
6 cap par 165.0000
7 cap ser 23.0000
8 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 250.0

top: 0.0, dB/div.: 10.00, bottom: -60.0

Enter #: 1
Enter New Value: 23

start: 18 MHz, Freq./div: 10.00, stop: 25, C:\Users\Tyko\Todds\QRPHB\QRPHB\20

Cursor Data: 21.06 MHz, S21= -2.00 dB, S11= -31.72 dB

Above — In this filter simulation, I tweaked the end capacitors (parts #1 and #7) from 22 to 23 pF and watched the return loss (S11) improve by 7.34 dB — if wanted, you can optimize the end capacitor values to improve the match into 50 ohms. To re-establish the center frequency, slight retuning of parallel capacitors #3 and 6 is required when changing the series end capacitors; although I specifically didn't change them for this example.

Increasing the 2 end capacitors to increase S11 renders an option only; you don't have to go for the best S11 in your filters. Increasing the series end capacitors to bump up return loss tends to increase the 3 dB bandwidth and reduce insertion loss.

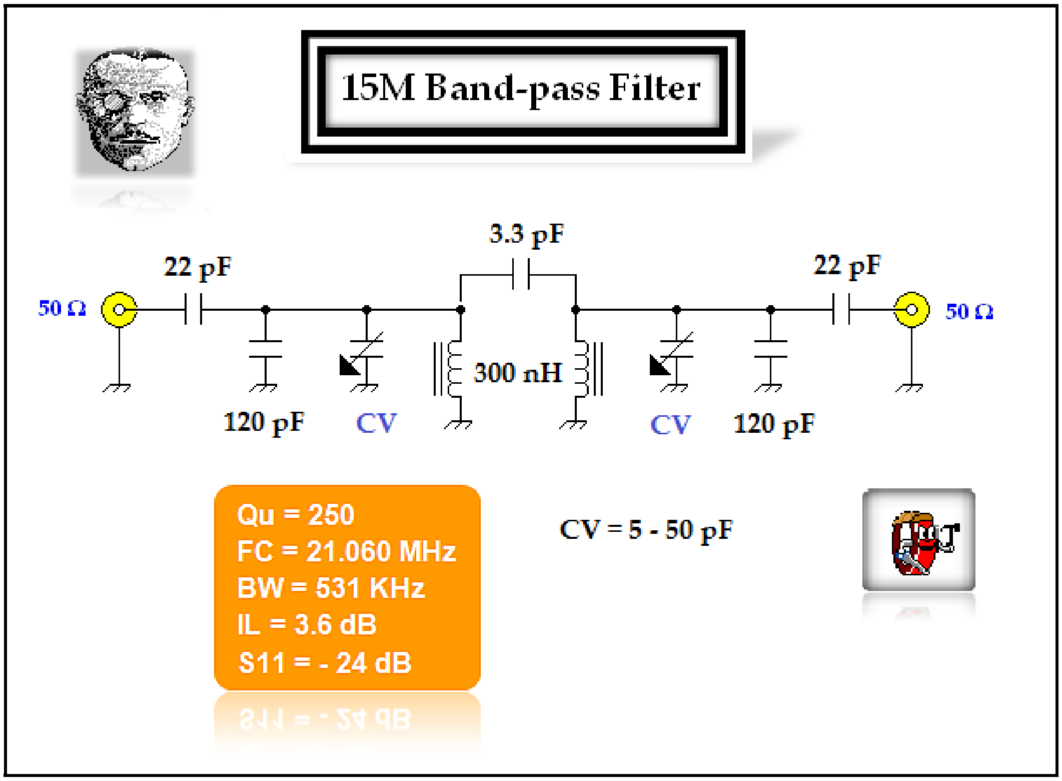

Above — I built and measured the filter with 22 pF end capacitors since these are common, standard values. In another experiment, a 1 pF cap was soldered in parallel with each series capacitor and the return loss increased by about 4 dB. Click for a bench photo of an alternate version of the above filter. Clearly, GPLA08 simulation furnishes us popcorn builders with a starting point to make top-notch band-pass filters.

Click for another simulation of a filter employing a 2 pF coupling capacitor, with the end capacitors tweaked for the best S11. *S-11 is just the negative of the return loss.* I would certainly use this filter in the front end of a popcorn direct conversion receiver.

An easier way to design your band-pass filters involves using DTC08 to design a raw filter and GPLA08 to substitute in standard value capacitors and tweak your filter. That's part 2. The material presented in this section supports the discussion in Part 2 and 3.

Part 2: Band-pass Filter Design using DTC08

Prior to using these Ladpac programs, some numbered design points and a preamble follow.

More than anything else, our parts collection dictates what filter parameters we choose and end up with. For example, if you want filters with a low bandwidth such as 150 KHz and under, you'll require inductors and capacitors that provide really high Q, or you might suffer from punishing insertion loss.

The following are general starting points only — *your* needs, parts and abilities drive *your* filter design. Example variances include: if a low noise amplifier follows a filter, a higher insertion loss might be okay; a high return loss is not always required for a low noise figure; especially in popcorn receivers. Also, it's a viable choice to trade off insertion loss for steep skirts in some filters.

1. A reasonable 3 dB bandwidth = 100 to 500 KHz, but this depends on the purpose of the filter.
Numerous considerations challenge us. Will this be a whole band (CW + SSB) filter, or a CW only filter? As a CW op who uses simple equipment, I tend to design moderate bandwidth (200-300 KHz) CW-only filters. If you need CW + SSB, then a bandwidth of 350 KHz or greater might suit you. It's really up to you.

Other factors affecting bandwidth choice include whether the filter drives a superheterodyne or a direct conversion receiver. In superheterodyne receivers, your intermediate frequency informs your filter bandwidth choice. Consider the following 2 diagrams:

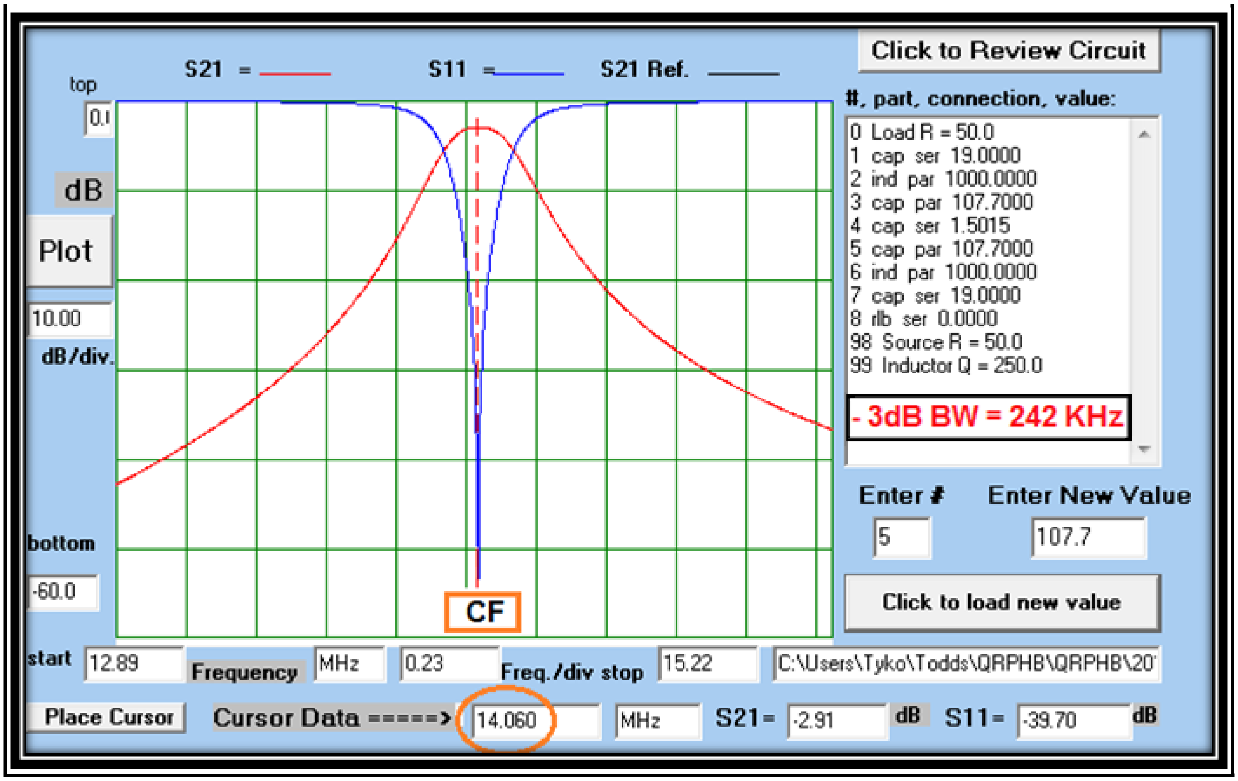
Click to Review Circuit
S21 =
S11 =
S21 Ref.
top
dB
Plot
bottom
CF
Place Cursor
Click to load new value

#, part, connection, value:

0 Load R = 50.0
1 cap ser 19.0000
2 ind par 1000.0000
3 cap par 107.7000
4 cap ser 1.5015
5 cap par 107.7000
6 ind par 1000.0000
7 cap ser 19.0000
8 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 250.0

- 3dB BW = 242 KHz

Enter # 5
Enter New Value 107.7

top 0.
10.00 dB/div.
bottom -60.0
start 12.89 Frequency MHz 0.23 Freq./div stop 15.22 C:\Users\Tyko\Todds\QRPHB\QRPHB\20
Cursor Data =====> 14.060 MHz S21= -2.91 dB S11= -39.70 dB

Above — Using DTC08 and GPLA08, I designed an example filter for the front end of a 14 MHz superheterodyne receiver with an 11 MHz IF. BW = 242 KHz. CF = 14.060 MHz; a frequency some QRP operators favor.

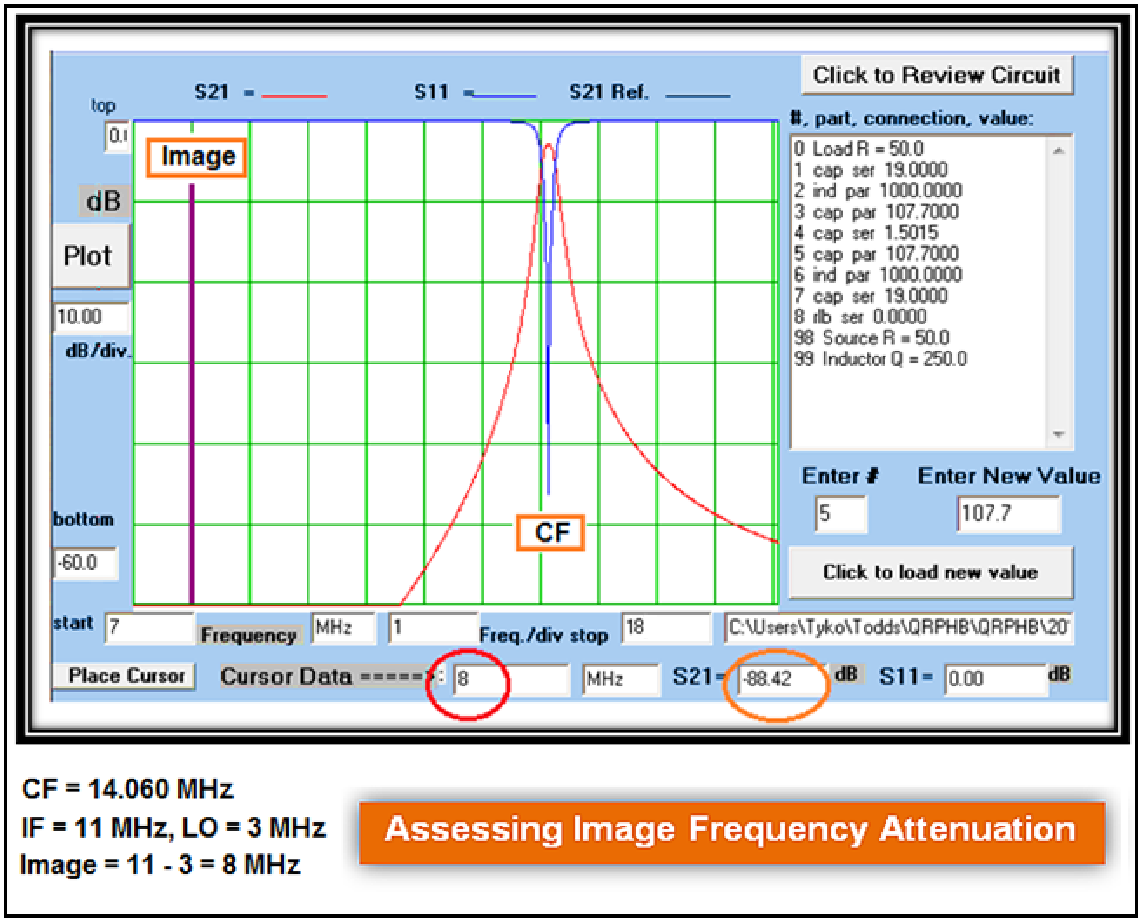
Click to Review Circuit
S21 =
S11 =
S21 Ref.
top
Image
dB
Plot
bottom
CF
Place Cursor
Click to load new value

#, part, connection, value:

0 Load R = 50.0
1 cap ser 19.0000
2 ind par 1000.0000
3 cap par 107.7000
4 cap ser 1.5015
5 cap par 107.7000
6 ind par 1000.0000
7 cap ser 19.0000
8 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 250.0

Enter # 5
Enter New Value 107.7

top 0.
10.00 dB/div.
bottom -60.0
start 7 Frequency MHz 1 Freq./div stop 18 C:\Users\Tyko\Todds\QRPHB\QRPHB\20
Cursor Data =====> 8 MHz S21= -88.42 dB S11= 0.00 dB

CF = 14.060 MHz
IF = 11 MHz, LO = 3 MHz
Image = 11 - 3 = 8 MHz

Assessing Image Frequency Attenuation

Above — Assessing filter attenuation at the image frequency using GPLA08. *To keep the arithmetic simple, I employed a frequency of 14 MHz for the image frequency calculation.* As shown, the simulated attenuation of my 8 MHz image frequency is 88.42 dB. Since I personally target an image frequency suppression of 60-70 dB; at 88 dB, if I wanted, I could increase the bandwidth of this filter for broader coverage and reduced insertion loss.

How much image frequency rejection is needed for superheterodyne receivers? I'm uncertain, for I have seen competent authors choose between 50 and 100 dB. I feel a good target = 60 - 70 dB, and 50 dB is the bare minimum. To realize image attenuation above 50 dB, shielding is usually required.

Three or more L-C tank band-pass filters may be required when your image frequency is close to the IF frequency. Choose both your intermediate frequency and your bandwidth wisely.

2. After selecting your bandwidth, *tweak the inductance* and only if necessary, make minor adjustments to your set 3 dB bandwidth to give standard, or near-standard value coupling capacitors that you *own.* Obviously, you can place fixed capacitors in series or parallel, or even couple your resonators with a variable capacitor.

3. I favor size 50 to 80 powdered iron toroids with number 2, 6, or 10 material for a reasonably high Qu.

4. I aim for an insertion loss of of 3-4 dB; especially above the 40 Meter band; *consider the variances discussed earlier*

5. I aim for a return loss of at least 20 dB; *consider the variances discussed earlier*

6. If you can, measure your bread boarded filter bandwidth to confirm or improve the GLPA simulation. Insertion and return loss are easily measured — see EMRFD and the RF Workbench web pages on this site for methods.

I provide no graphic tutorial of DTC08; however, some work flow suggestions follow:

Open up DTC08, choose your center frequency, Qu, inductance and bandwidth and then press the **Calculate** button. Adjust the L until you get close to a standard value coupling capacitor from your parts bin. If required, you may also tweak the bandwidth value to get the needed coupling capacitor. It's wise to change the L before BW since changes in inductance don't cause too many complications within limits.

Name and save your filter to a specific file system directory or folder; or simply save it as the default file.

Open GPLA08 and load your recently saved filter file. Press the **Plot** button and then the **Click to Review Circuit** button. In some cases, you will have to type the CF in the *Cursor Data* text box and press **Plot** to set the cursor at your center frequency.

Change the coupling capacitor(s) to a standard value using the **Enter New Value** data entry controls.

Adjust the series end coupling capacitors to standard values. and if S11 is an issue for you, tweak them up and down while observing S11. Re-establish your center frequency by tweaking the parallel tank tuning capacitors and then re-plot to ensure the CF is lined up with the center of the plot.

In Part 3, I provide 3 filter design examples. Your own filter designs will be the most important examples to study.

Part 3: Band-pass Filter Examples

Example 1: An 80 Meter Band Filter

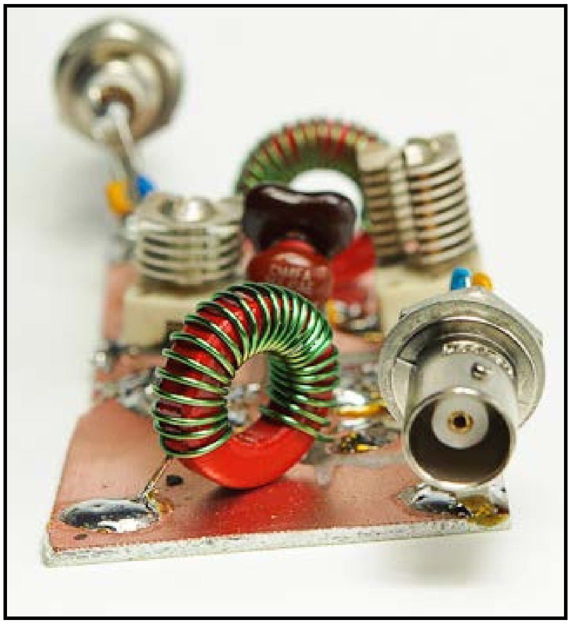

Above — Breadboard photograph of the 80M filter. This example filter may hit home for you — I like listening to CW at and below the 3560 KHz QRP calling frequency, however, another local Ham likes to talk on 75 meters SSB at or above 3790 KHz. This situation calls for a narrow band-pass filter. With my filter, the attenuation at 3790 KHz = ~ 24 dB; had I built a wide bandwidth filter, for example, 350 KHz BW; the attenuation at 3790 KHz, would only be ~4 dB. Perhaps a 3 resonator filter with even steeper skirts would be better?

I'll show the design process from start to test.

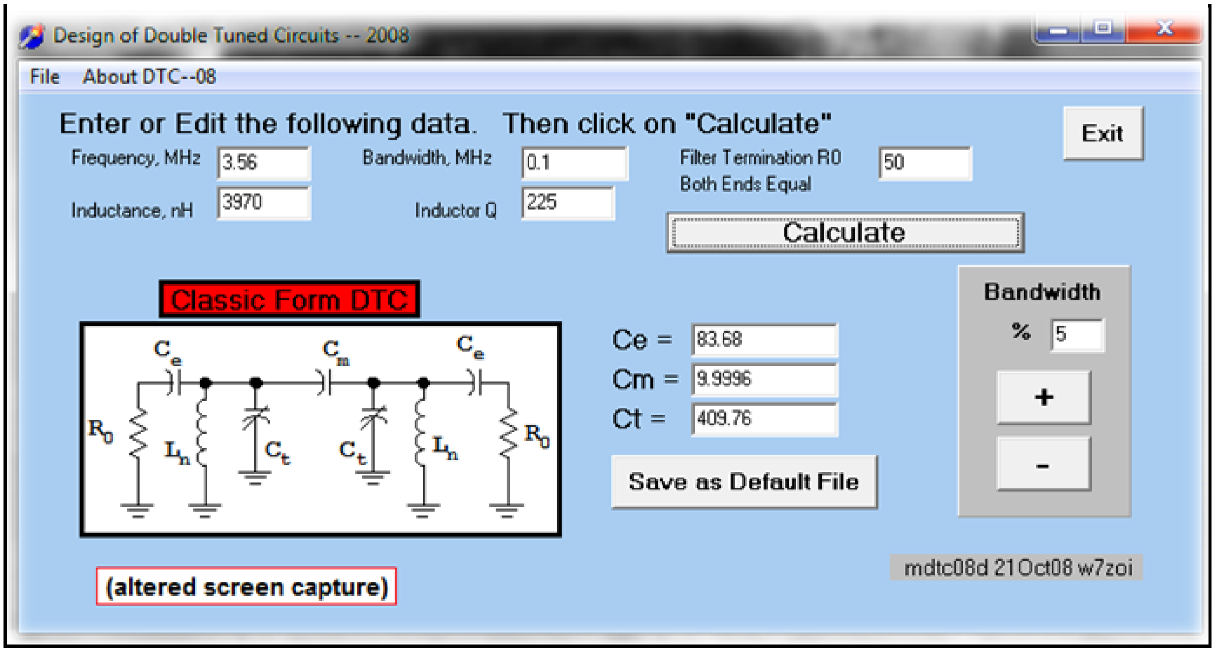
Design of Double Tuned Circuits -- 2008
File
About DTC--08
Exit
Calculate
Classic Form DTC
C_e
C_m
C_e
R_0
L_n
C_t
C_t
L_n
R_0
Bandwidth
+
-
Save as Default File
(altered screen capture)
mdtc08d 21Oct08 w7zoi

Enter or Edit the following data. Then click on "Calculate"

Frequency, MHz 3.56

Bandwidth, MHz 0.1

Filter Termination R0 Both Ends Equal 50

Inductance, nH 3970

Inductor Q 225

Ce = 83.68

Cm = 9.9996

Ct = 409.76

% 5

Above — The basic DTC08 data entry fields were populated. I chose a 100 KHz bandwidth and tried different L values until Cm = 10 pF, since I have a whole drawer of 10 pF capacitors. I believed my Inductor Q would be at least 225 and wound 25 turns of #22 AWG on a T68-2 toroid and expanded or contracted the windings until I measured 3970 nanohenries. In reality, we should measure the inductor Q and in future I will, however, my sense is that few builders do.

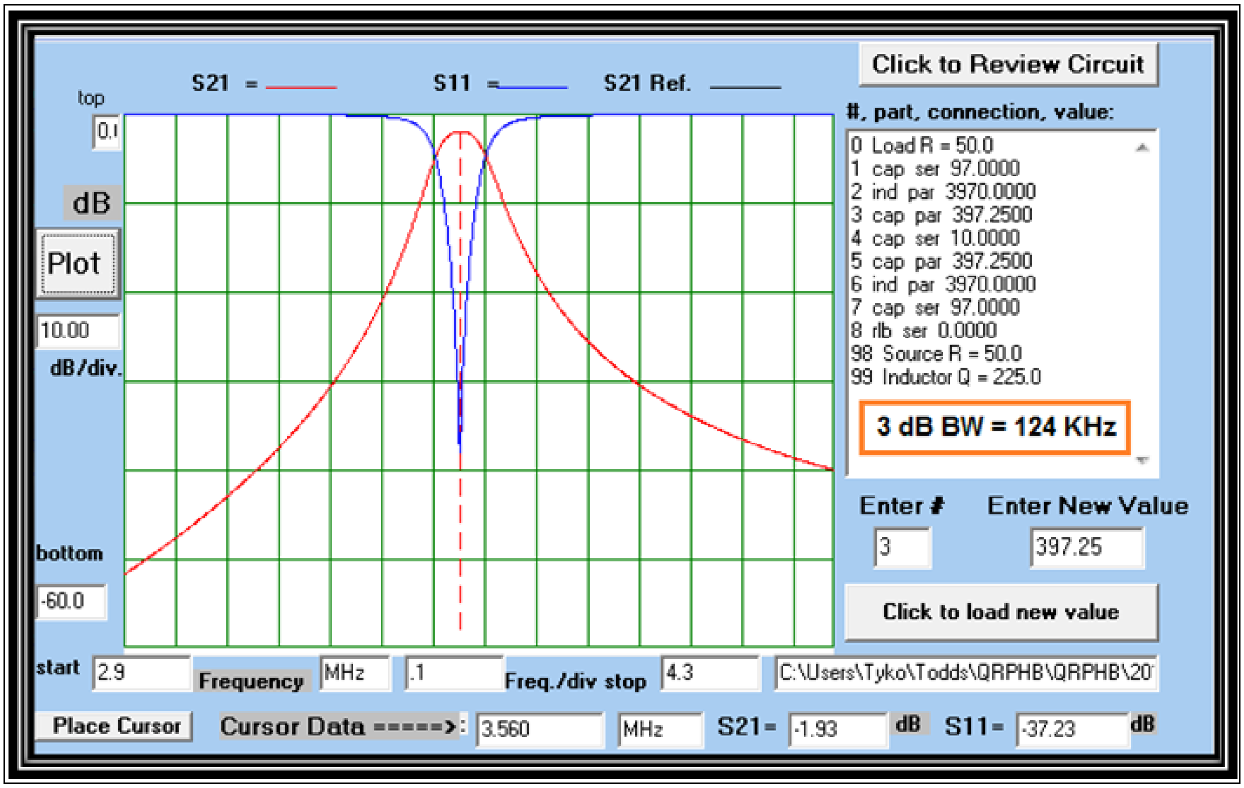
Click to Review Circuit
S21 =
S11 =
S21 Ref.
top
0.0
dB
Plot
dB/div.
bottom
start
Frequency
Freq./div
stop
Place Cursor
Cursor Data =====>:
Enter #
Enter New Value
Click to load new value

#, part, connection, value:

0 Load R = 50.0
1 cap ser 97.0000
2 ind par 3970.0000
3 cap par 397.2500
4 cap ser 10.0000
5 cap par 397.2500
6 ind par 3970.0000
7 cap ser 97.0000
8 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 225.0

3 dB BW = 124 KHz

Enter # 3

Enter New Value 397.25

10.00 dB/div.

bottom -60.0

start 2.9 Frequency MHz .1 Freq./div stop 4.3

C:\Users\Tyko\Todds\QRPHB\QRPHB\20

Cursor Data =====>: 3.560 MHz S21= -1.93 dB S11= -37.23 dB

Above — After saving my filter, I opened it up in GPLA08 as above. I replaced #4 with a standard 10.0 pF value, and started tweaking the end caps; parts #1 and #7 to gain a better S11 per my obsession with return loss. Retuning #3 and #7 re-establishes the center frequency and allows the S21 and S11 values to be interpreted. I settled on this filter and headed for the bench.

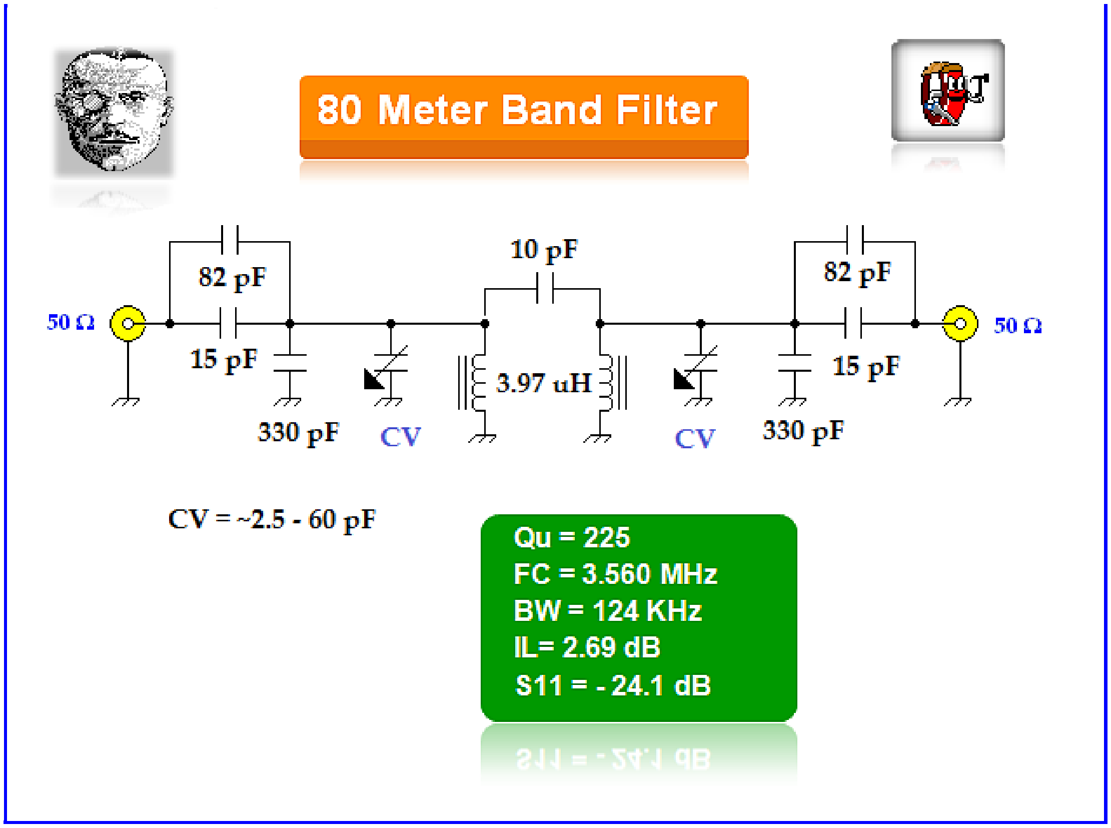

Above — Schematic and analysis of the breadboard. Click for another photograph. In reality, I bench determined the exact capacitance needed to tune each tank at 3.56 MHz with 2 large air variable capacitors that I removed and measured after peaking the filter. For each tank, I try to get just below this value with fixed value capacitors and add a small (2.5 - 22 pF, or so) air variable trimmer capacitor for peaking.

You need to test with capacitance under and over that required to ensure you properly tuned each L-C tank to resonance. Your parts collection, stray capacitance, mistakes or inductance variations in the toroids necessitate custom tuning of your tanks on the bench. I give capacitance values that should work, but it's up to you to ensure resonance of each tank. I find narrow BW filters require a steady hand to tune.

After peaking the tank in your oscilloscope, record the peak-to-peak voltage. Remove the filter and connect your signal generator to your scope with an RF barrel connector and again record the peak to peak voltage. The difference between the 2 is your insertion loss. You can calculate IL with Applet H on this page . Next, perform return loss measurements. If you can, determine the true 3 dB bandwidth of your filter by sweeping it with SA plus a generator. My filter 3 dB BW = 124 KHz.

Example 2: 20 Meter Band Superheterodyne Receiver Filter

A fictitious builder wants a superheterodyne receiver that covers 14.0 - 14.350. His IF = 2 MHz. The local oscillator = 12 MHz. The image frequency = (12 - 2) = 10 MHz. He centers his filter at 14.020 MHz. In this simulation-only example, we'll go from 1 resonator to 3.

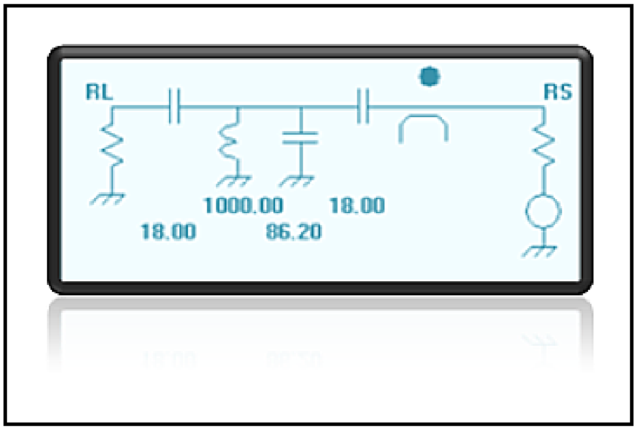

Above — A single resonator with series matching capacitors "built up" in Ladbuild08.

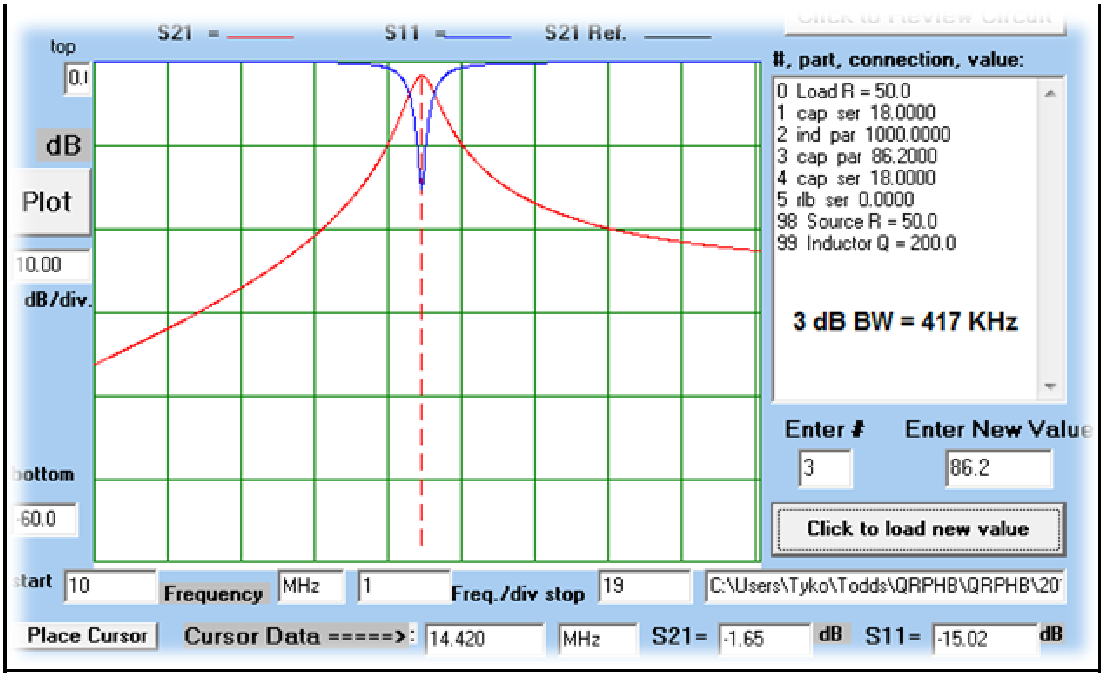
S21 =
S11 =
S21 Ref.
top
dB
Plot
dB/div.
bottom
start
Frequency
Freq./div stop
Enter #
Enter New Value
Click to load new value
Place Cursor
Cursor Data =====>

#, part, connection, value:
0 Load R = 50.0
1 cap ser 18.0000
2 ind par 1000.0000
3 cap par 86.2000
4 cap ser 18.0000
5 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 200.0

3 dB BW = 417 KHz

top 0.
10.00 dB/div.
bottom -60.0
start 10 Frequency MHz 1 Freq./div stop 19
C:\Users\Tyko\Todds\QRPHB\QRPHB\20
Enter # 3 Enter New Value 86.2
Cursor Data =====> 14.420 MHz S21= -1.65 dB S11= -15.02 dB

Above — The GPLA08 plot of the single tank filter. The bandwidth = 417 KHz. Increasing the end capacitors to 22 pF to try to increase return loss increases the 3 dB bandwidth as shown here, so we better stick with the original design.
In GPLA simulations with a perfectly centered filter, S21 = the insertion loss and S11 is negative of the return loss.

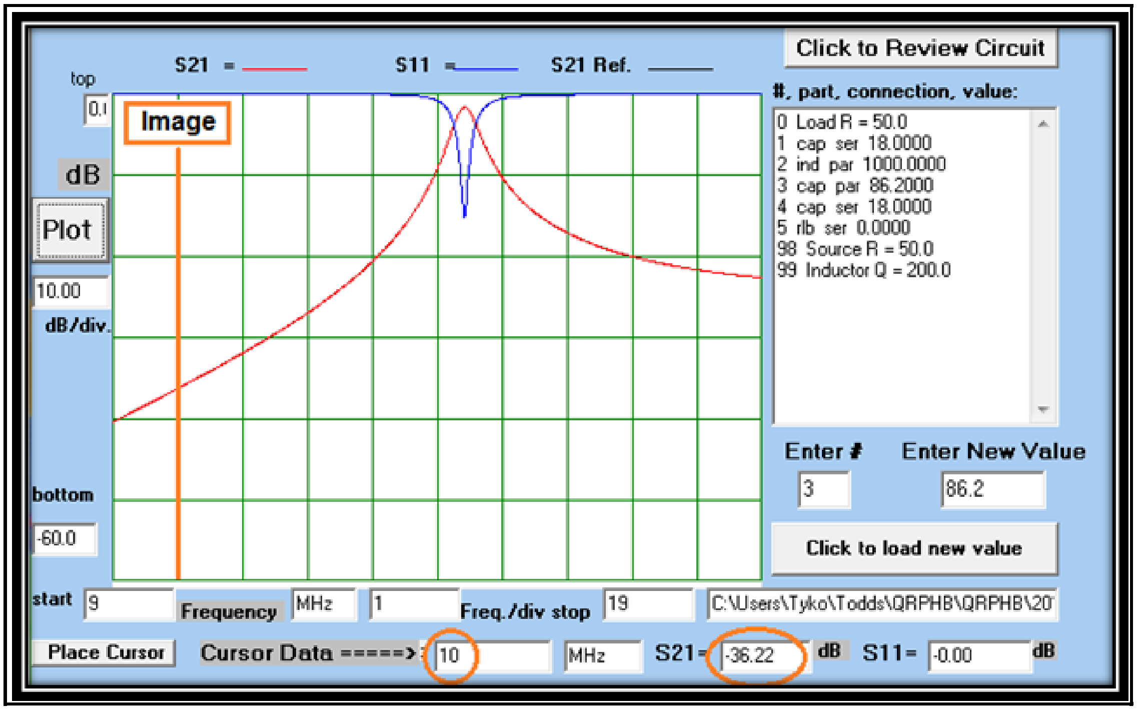
Click to Review Circuit
S21 =
S11 =
S21 Ref.
top
Image
dB
Plot
dB/div.
bottom
start
Frequency
Freq./div stop
Enter #
Enter New Value
Click to load new value
Place Cursor
Cursor Data =====>

#, part, connection, value:
0 Load R = 50.0
1 cap ser 18.0000
2 ind par 1000.0000
3 cap par 86.2000
4 cap ser 18.0000
5 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 200.0

top 0.
10.00 dB/div.
bottom -60.0
start 9 Frequency MHz 1 Freq./div stop 19
C:\Users\Tyko\Todds\QRPHB\QRPHB\20
Enter # 3 Enter New Value 86.2
Cursor Data =====> 10 MHz S21= -36.22 dB S11= -0.00 dB

Above — Assessing image frequency attenuation in GPLA08; this sucks — only 36.2 dB down. We need to add a tank.

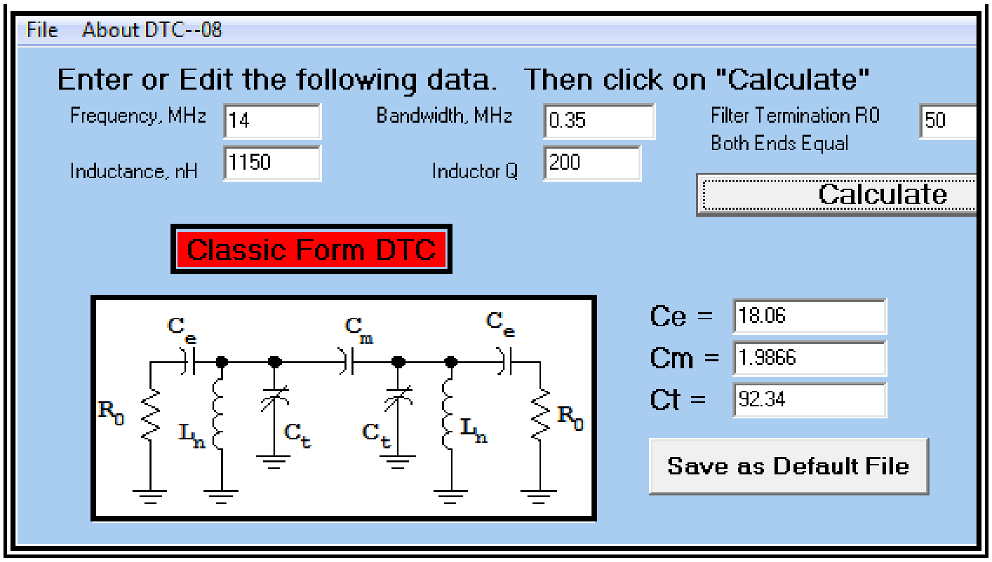
File
About DTC--08
Calculate
Classic Form DTC
Save as Default File
Ce
Cm
Ce
R0
Ln
Ct
Ct
Ln
R0

Enter or Edit the following data. Then click on "Calculate"

Frequency, MHz: 14
Bandwidth, MHz: 0.35
Filter Termination R0 Both Ends Equal: 50
Inductance, nH: 1150
Inductor Q: 200

Ce = 18.06
Cm = 1.9866
Ct = 92.34

Above — Building up a filter in DTC08, I increased the L from 1000 to 1150 nH to give a Cm near to a standard value.

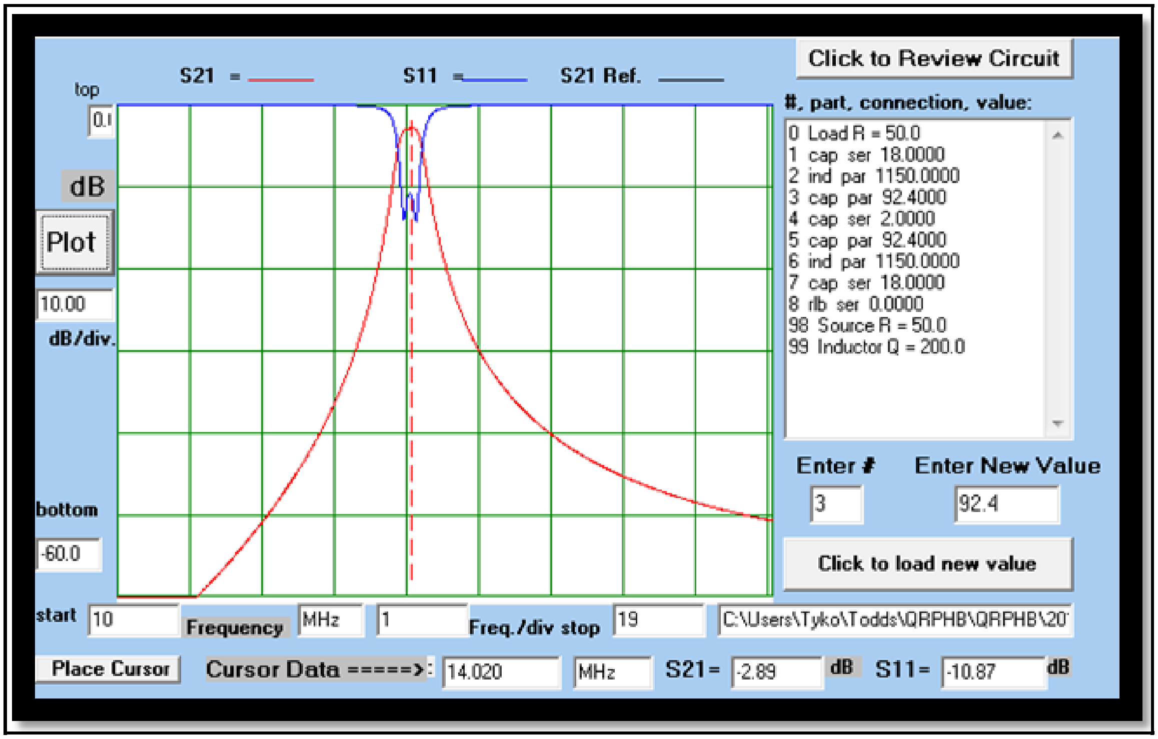
S21 =
S11 =
S21 Ref.
dB
Plot
Frequency
Click to Review Circuit
Click to load new value
Place Cursor

top: 0.
dB/div.: 10.00
bottom: -60.0
start: 10 MHz
Freq./div: 1
stop: 19
C:\Users\Tyko\Todds\QRPHB\QRPHB\20

#, part, connection, value:

```
0  Load R = 50.0
1  cap  ser  18.0000
2  ind  par  1150.0000
3  cap  par  92.4000
4  cap  ser  2.0000
5  cap  par  92.4000
6  ind  par  1150.0000
7  cap  ser  18.0000
8  rlb  ser  0.0000
98  Source R = 50.0
99  Inductor Q = 200.0
```

Enter #: 3
Enter New Value: 92.4

Cursor Data =====>: 14.020 MHz S21= -2.89 dB S11= -10.87 dB

Above — The GPLA08 plot of the double tuned filter. I set #4 to 2 pF and #1 and #7 to 18 pF (nearest standard values). #3 and #5 were slightly tweaked to center the filter. The simulated IL is only up 1.24 dB from the single resonator version. You are probably wondering why I didn't design the filter for a CF = 14.020 MHz in DTC08 above to keep consistency. I probably should have, but wanted to illustrate the versatility of GPLA08 to center filters "on the fly".

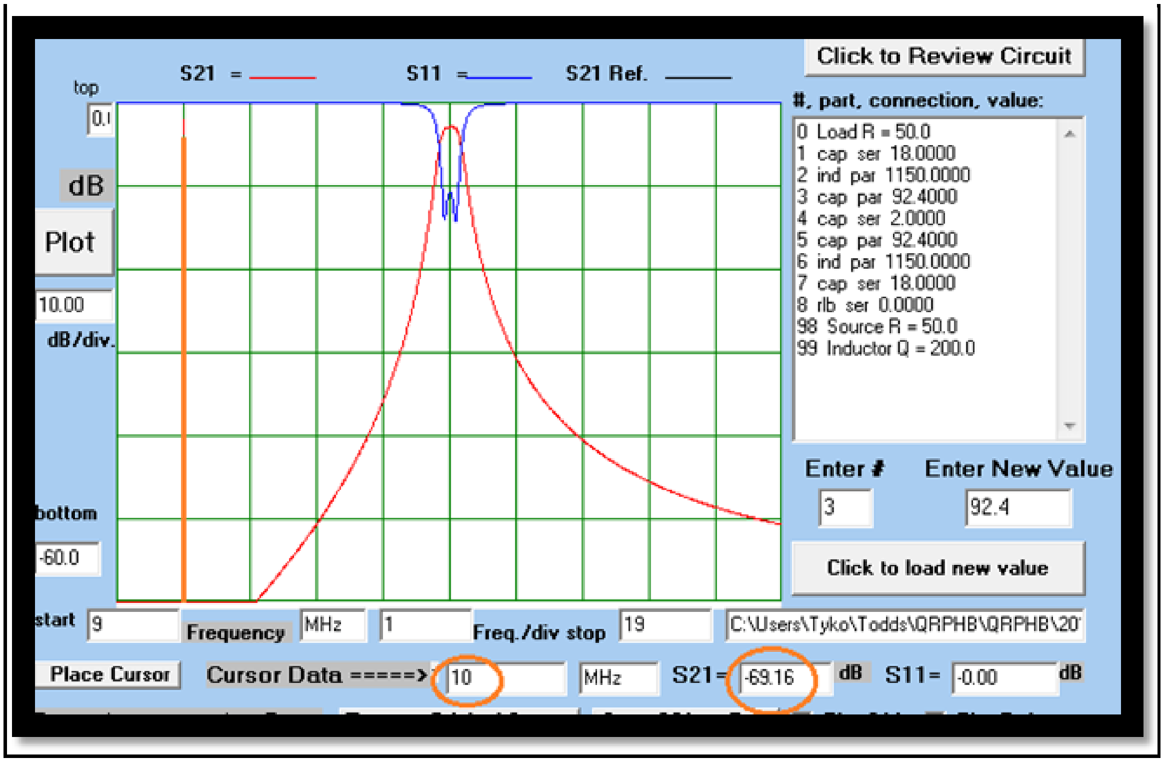
S21 =
S11 =
S21 Ref.
top
dB
Plot
dB/div.
bottom
Click to Review Circuit
Place Cursor
Click to load new value

0.\
10.00
-60.0

#, part, connection, value:
0 Load R = 50.0
1 cap ser 18.0000
2 ind par 1150.0000
3 cap par 92.4000
4 cap ser 2.0000
5 cap par 92.4000
6 ind par 1150.0000
7 cap ser 18.0000
8 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 200.0

Enter # 3
Enter New Value 92.4

start 9 Frequency MHz 1 Freq./div stop 19 C:\Users\Tyko\Todds\QRPHB\QRPHB\20

Cursor Data =====> 10 MHz S21= -69.16 dB S11= -0.00 dB

Above — Assessment of the 10 MHz image — now it's 69.2 dB down. Although this filter will work well for his particular receiver specifications, this fastidious builder wants even greater image attenuation and decides to add a third resonator!

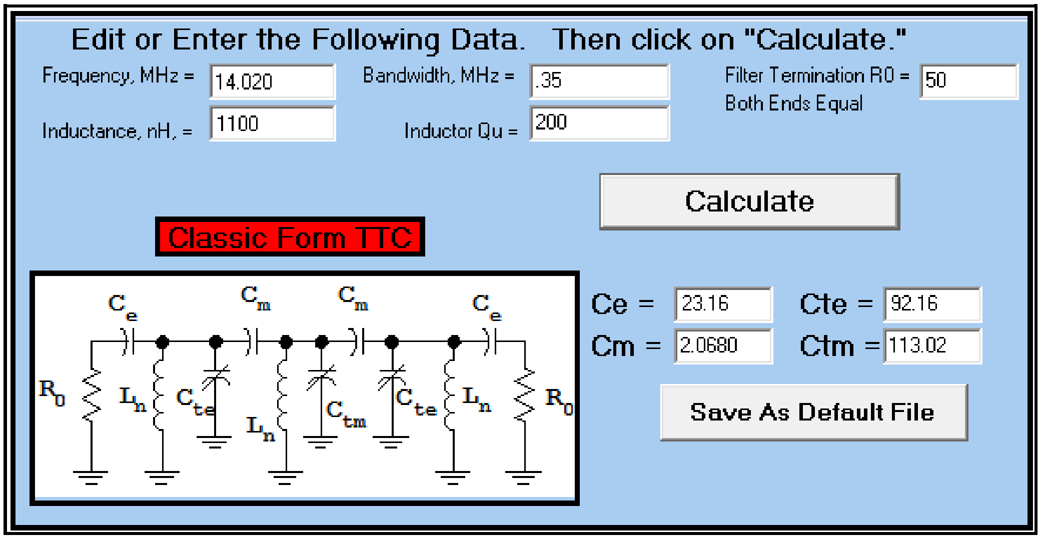
Classic Form TTC
Calculate
Save As Default File
C_e
C_m
C_m
C_e
R_0
L_n
C_{te}
L_n
C_{tm}
C_{te}
L_n
R_0

Edit or Enter the Following Data. Then click on "Calculate."

Frequency, MHz = 14.020
Bandwidth, MHz = .35
Filter Termination R0 = 50
Both Ends Equal
Inductance, nH, = 1100
Inductor Qu = 200

Ce = 23.16
Cte = 92.16
Cm = 2.0680
Ctm = 113.02

Above — Building up a filter in TTC08, I chose an L of 1100 nH to give a Cm close to a standard value.

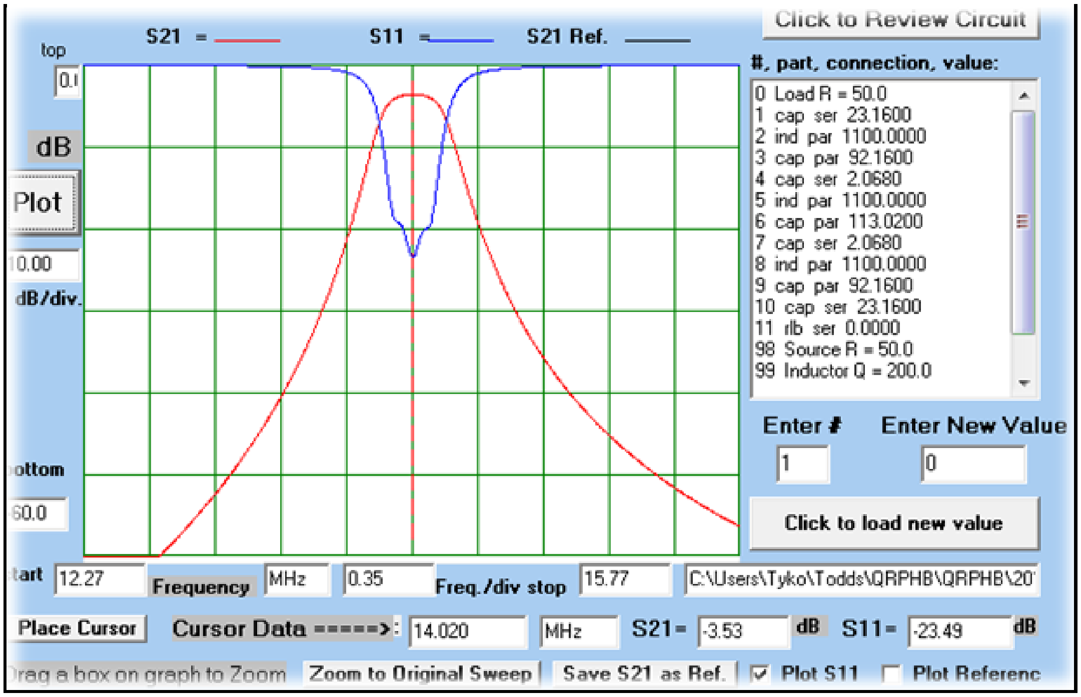
Click to Review Circuit
S21 =
S11 =
S21 Ref.
top
dB
Plot
dB/div.
ottom
Enter #
Enter New Value
Click to load new value
Place Cursor
Cursor Data =====>:
)rag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Plot Referenc

#, part, connection, value:
0 Load R = 50.0
1 cap ser 23.1600
2 ind par 1100.0000
3 cap par 92.1600
4 cap ser 2.0680
5 ind par 1100.0000
6 cap par 113.0200
7 cap ser 2.0680
8 ind par 1100.0000
9 cap par 92.1600
10 cap ser 23.1600
11 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 200.0

top 0.0
0.00 dB/div.
ottom 60.0
Enter # 1
Enter New Value 0
tart 12.27 Frequency MHz 0.35 Freq./div stop 15.77 C:\Users\Tyko\Todds\QRPHB\QRPHB\20
Cursor Data =====>: 14.020 MHz S21= -3.53 dB S11= -23.49 dB
☑ Plot S11 ☐ Plot Referenc

Above — The GPLA plot of the 3 tank filter. I performed no parts tweaking — it's up to you from here on in. The simulated IL remains quite reasonable.

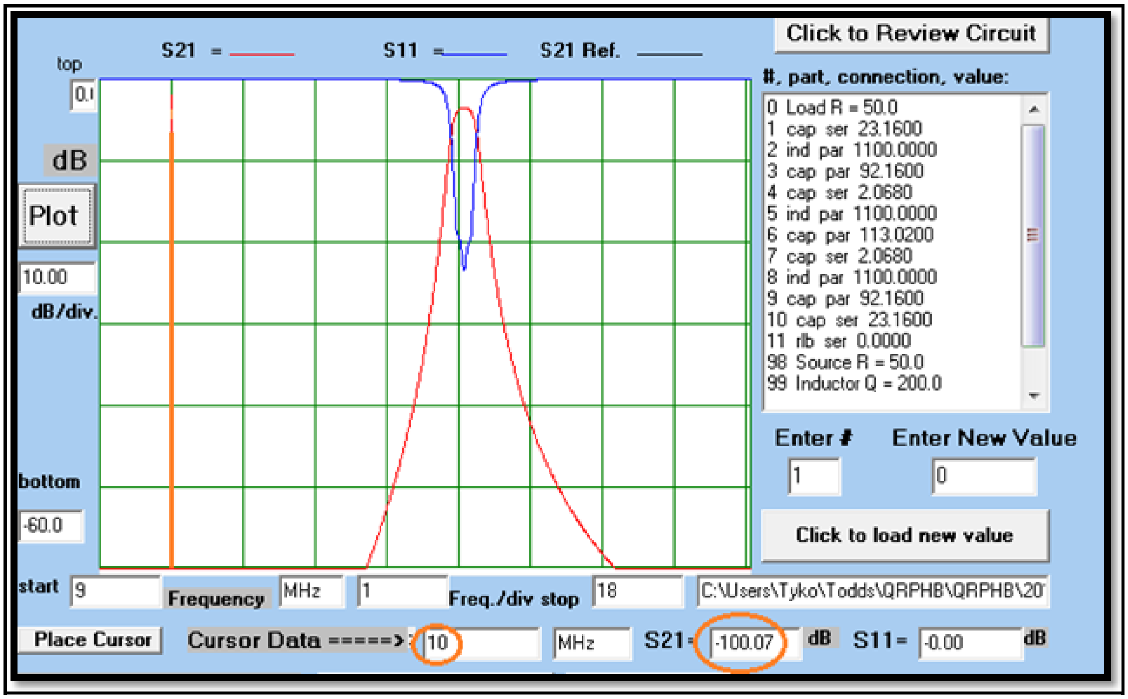
Click to Review Circuit
S21 =
S11 =
S21 Ref.
top
dB
Plot
dB/div.
bottom
Enter #
Enter New Value
Click to load new value
Place Cursor
Cursor Data =====>:

#, part, connection, value:
0 Load R = 50.0
1 cap ser 23.1600
2 ind par 1100.0000
3 cap par 92.1600
4 cap ser 2.0680
5 ind par 1100.0000
6 cap par 113.0200
7 cap ser 2.0680
8 ind par 1100.0000
9 cap par 92.1600
10 cap ser 23.1600
11 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 200.0

top 0.0
10.00 dB/div.
bottom -60.0
Enter # 1
Enter New Value 0
start 9 Frequency MHz 1 Freq./div stop 18 C:\Users\Tyko\Todds\QRPHB\QRPHB\20
Cursor Data =====>: 10 MHz S21= -100.07 dB S11= -0.00 dB

Above — The GPLA08 assessment of the 10 MHz image frequency. Now 100 dB down!

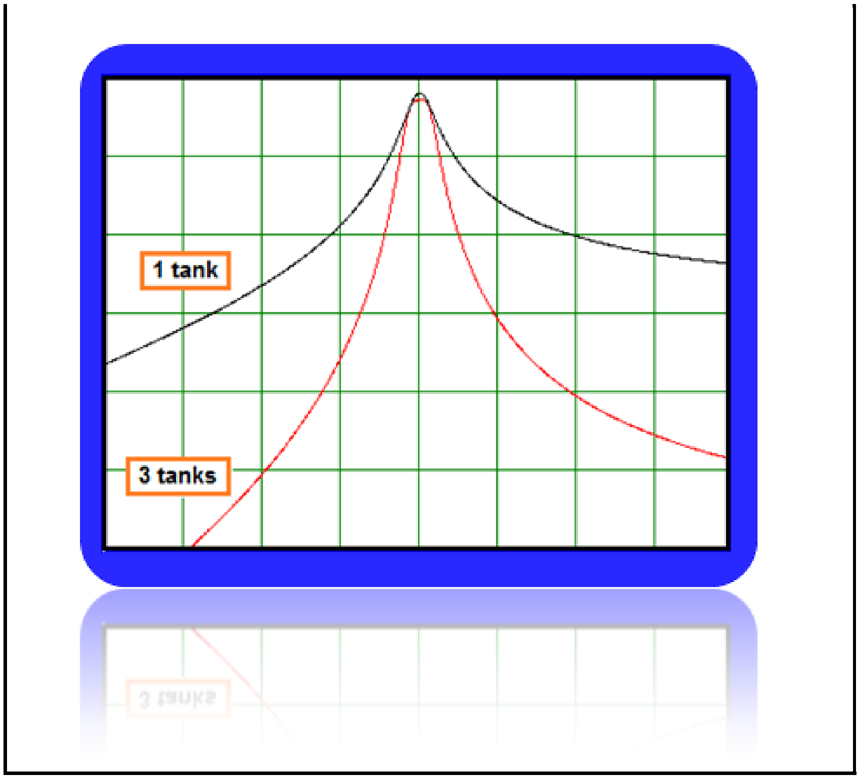

Above — The 1 tank and 3 tank filters superimposed to show the skirt action. The 3 dB bandwidth is the same!

Example 3: A 20 Meter Band-pass Filter for a Builder from Argentina

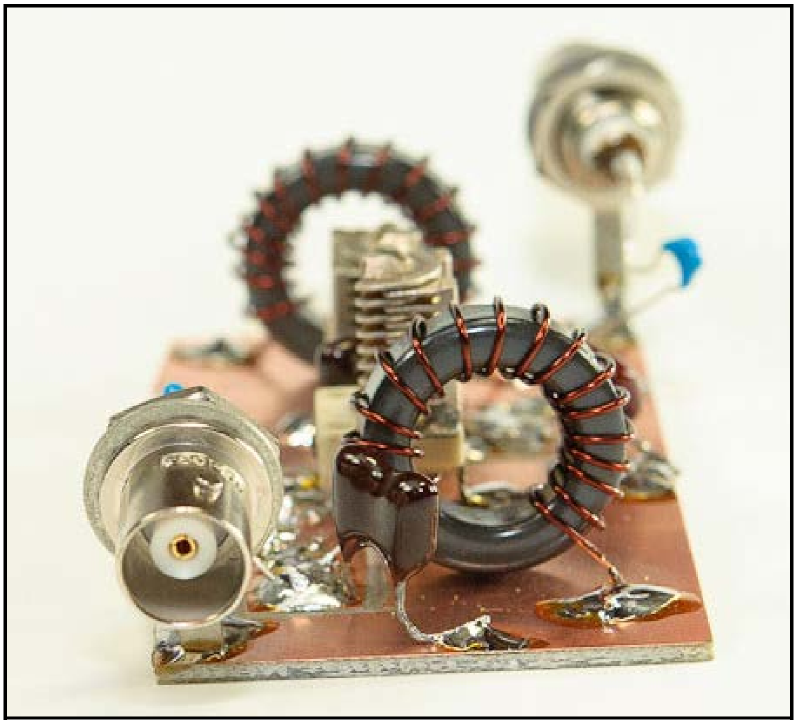

Above — An Argentinean builder emailed that he wanted a band-pass filter optimized for 14.070-14.095 MHz RTTY but also usable for the CW sub-band and lower SSB frequencies. He wanted a center frequency in the RRTY sub-band and I chose 14.079 MHz. Tuning this filter to a center frequency as low as 7.030 MHz for CW should be possible with the variable capacitor value shown, but as mentioned, you really need to do this carefully on your bench. I employed T80-10 toroids and scrunched or expanded the 16 turns of # 22 AWG wire until they measured exactly 1000 nH.

The best return loss will only occur when your filter is perfectly tuned to the test frequency, so tune carefully.

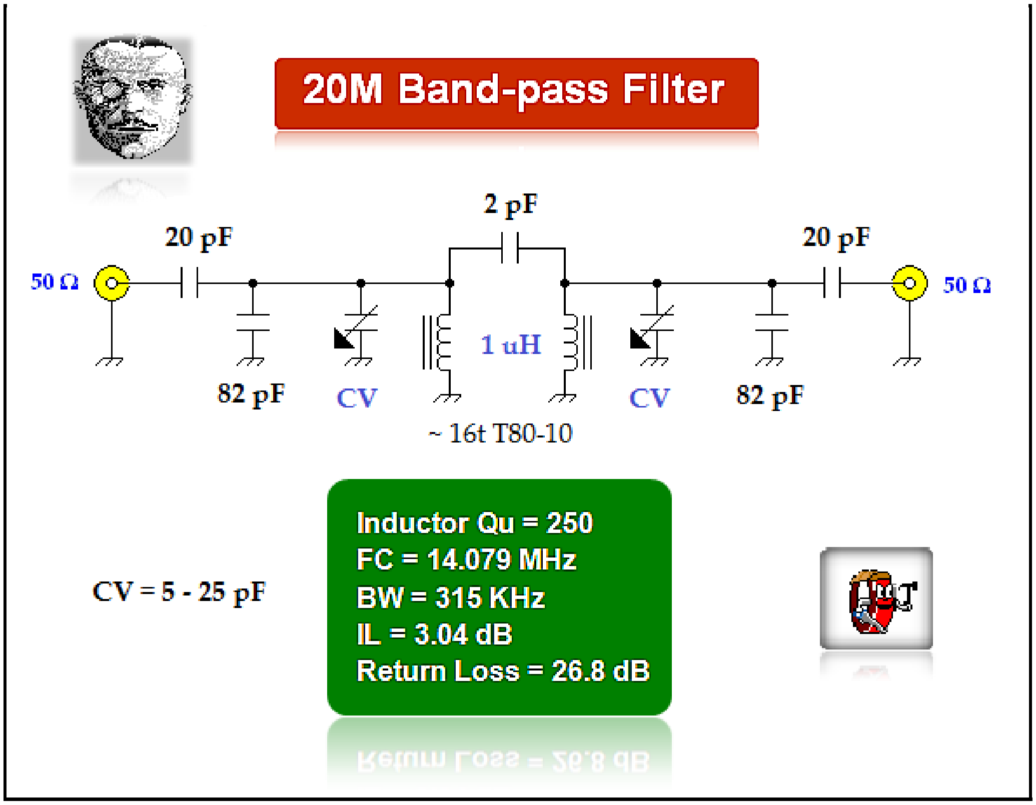

Above — The schematic + bench analysis for the 20 Meter band double tuned band-pass filter. My original design called for 22 pF series end capacitors to get a decent return loss. After building and measuring the circuit, the results were disappointing: insertion loss = 3.7 dB and a return loss = 17 dB. I wanted a better S11 and IL, so I decreased the end capacitors to 20 pF and savored the measured data shown in the schematic.

Simulating this tweaked design in GPLA08 unveiled a lower return loss than the original design simulation with 22 pF end capacitors; exactly opposite to my bench observations.

Bench work reveals the truth — The filter *you* get is dependent on factors such as parts types + tolerances, stray reactance, layout, test gear and any bench errors. For example, I don't know the Qu of my 1 uH inductors, but suspect that the Qu is greater than the 250 specified. Also my intended - 3 dB bandwidth was 350 KHz, yet my filter = 315 KHz; in part, because I lowered the series end capacitors, but also due to other fore mentioned factors.

Many popcorn builders can't easily measure their filter bandwidth. Does it really matter? Probably not, however, the big realization for me is that unless you measure, you won't actually know your data like insertion loss, return loss, or bandwidth — simulations are great, but don't obliterate the need for bench testing as possible.

Consider this; with the SPICE program you can design a circuit with a 2N3904 and run 400 mA of current through it — the transistor won't smoke 1 bit ! Project outcomes depend on understanding and employing best practices, experience and measurement on the bench. Finding best practices proves difficult in a day and time when general scientific literacy, the number of expert mentors and interest in analog electronics are all waning.

Click for another photo of the filter. On my actual filter, I used high Q, air variable trimmer caps that only had a capacitance variation of 15 pF or so. I soldered in fixed capacitors to get close to the capacitance needed to tune each tank. If possible, I think its better use smaller value trimmer caps because they permit finer tuning. The air variable trimmer offers high Q plus you can see when the capacitor is fully meshed (maximum C). This signals that you need to add more fixed capacitance to that tank for peaking.

Conclusion

To repeat; our parts collection dictates our band-pass filter outcomes. Size 50 to 68 #6 material toroids will work fine for most HF frequencies above 3 MHz. Don't stress out too much if your insertion or return loss is a little higher than you wanted; in all likelihood your filter will work fine and you'll be glad you didn't just copy some else's design and rob yourself of the design experience.

I am hopeful, this web page will inspire a few builders to experiment with band-pass filters for their receivers and other applications. My sincere thanks to Wes, W7ZOI for his guidance with filter design.

QRP — Posdata for August 2012 — NE612 Mixer Band-pass Filters

I designed some band-pass filters for NE612 based front-ends with LadBuild and GPLA and show my 75 Meter band filter design figures below. I'm not a fan of employing an NE612 as a receiver mixer since it easily overloads and spews harmonics when mixing strong input signals. The 1K

'RF gain' pot found in many receivers, or the more conventional switchable attenuator pad prove essential when receiving 'booming' signals with a NE602/NE612 mixer in your front-end.

Still, for field-portable tranceivers/receivers, the NE612 mixer keeps the current and radio size down nicely.

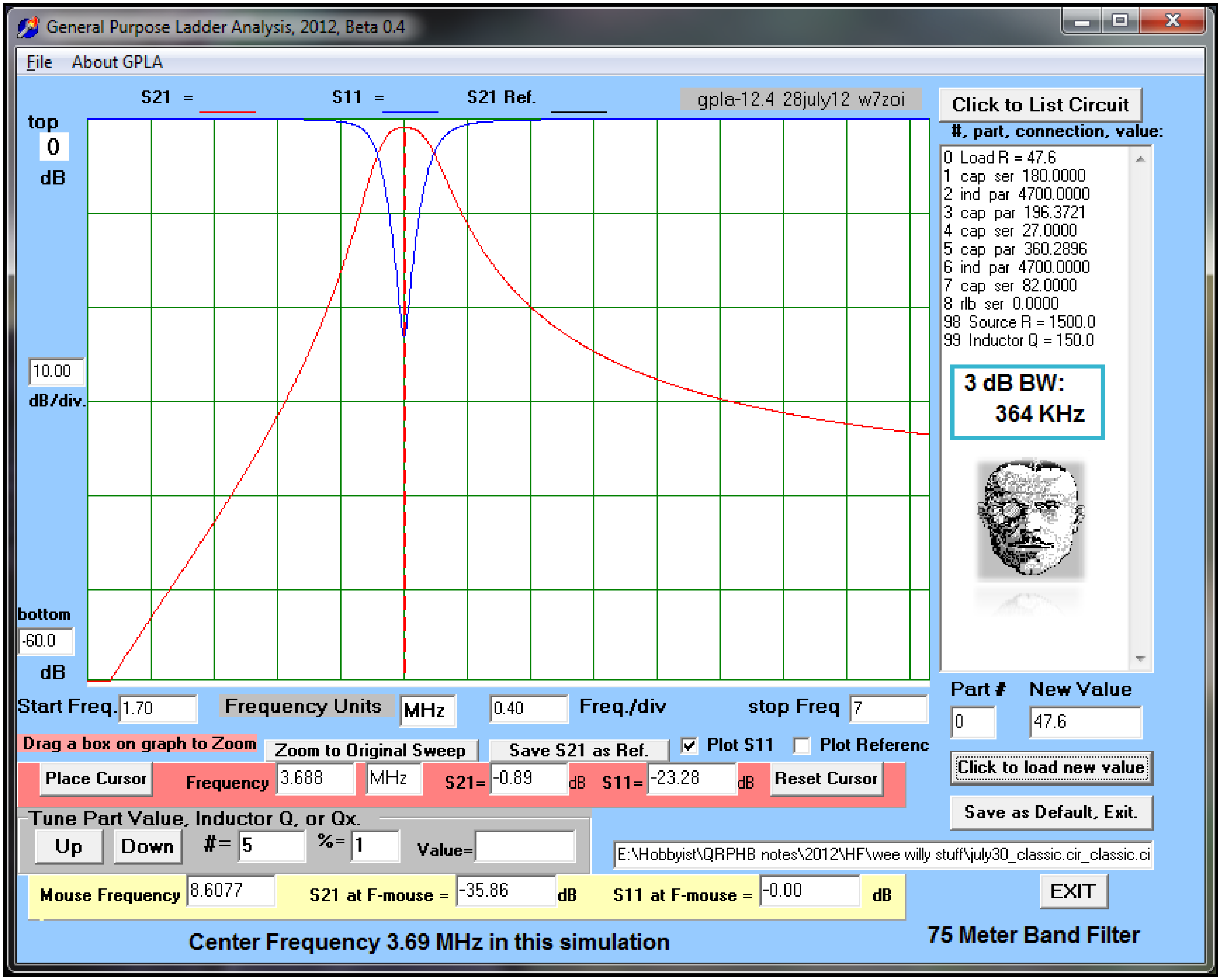
General Purpose Ladder Analysis, 2012, Beta 0.4
File
About GPLA
S21 =
S11 =
S21 Ref.
gpla-12.4 28july12 w7zoi
top
dB
dB/div.
bottom
dB
Click to List Circuit
#, part, connection, value:
Part #
New Value
Click to load new value
Save as Default, Exit.
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
☑ Plot S11
☐ Plot Referenc
Place Cursor
Reset Cursor
Tune Part Value, Inductor Q, or Qx.
Up
Down
EXIT

```
0  Load R = 47.6
1  cap  ser  180.0000
2  ind  par  4700.0000
3  cap  par  196.3721
4  cap  ser  27.0000
5  cap  par  360.2896
6  ind  par  4700.0000
7  cap  ser  82.0000
8  rlb  ser  0.0000
98  Source R = 1500.0
99  Inductor Q = 150.0
```

top 0 dB

10.00 dB/div.

bottom -60.0 dB

3 dB BW: 364 KHz

Start Freq. 1.70

Frequency Units MHz

0.40 Freq./div

stop Freq 7

Part # 0

New Value 47.6

Frequency 3.688 MHz S21= -0.89 dB S11= -23.28 dB

#= 5 %= 1 Value=

E:\Hobbyist\QRPHB notes\2012\HF\wee willy stuff\july30_classic.cir_classic.ci

Mouse Frequency 8.6077 S21 at F-mouse = -35.86 dB S11 at F-mouse = -0.00 dB

Center Frequency 3.69 MHz in this simulation

75 Meter Band Filter

Above — My filter centered at 3.69 MHz. I set the 3 dB bandwidth higher than my usual 200-300 KHz so I could tune a good chunk of the 80-75M band without losing too much signal.

To establish some starting L and C values, I built a classic form filter in DTC08 with a 50 Ω input and output impedance centered at 3.69 MHz. After some tweaking, I settled on L = 4700 nH, Ce = 148 pF, coupling capacitor Cm = 27 pF and about 220 pF (Ct) to resonate each tank.

Next I changed the termination R's to 1500 Ω in DTC08 to simulate the right half of the filter matched into the 1K5 input impedance of an NE612. This gave me some Ct and Ce values to start with. I started Ladbuild 08 and built up a schematic.

In a seperate experiment, I determined that the resonator Qu of a 3.7 MHz L-C tank with an L of 4700 nH wound on a T50-2 core, was ~150.

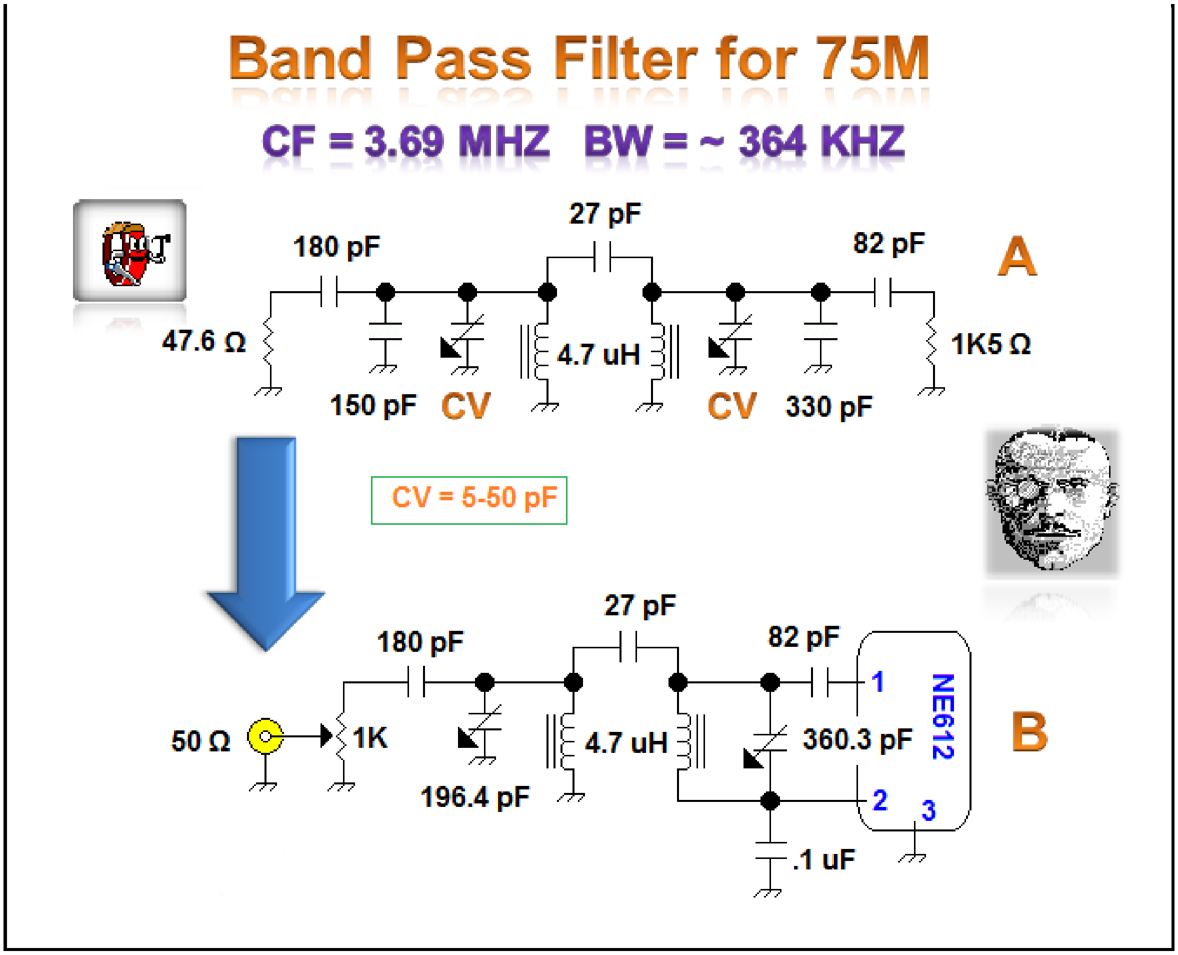

Above — The completed schematic. My filter exhibits an attenuation of ~70 dB at the top of the AM radio broadcast band (1500 KHz) providing I shield it in an RF-tight box. I took the 47.6 Ω input Z from the 1K pot and my 50 Ω antenna in parallel. An input Z of 50 Ω would work just as well in simulation and on-bench.

In Part A, I show a possible way to resonate each tank with 1 fixed C and a trimmer capacitor. In Part B, I omitted this detail and just show the calculated C needed for resonance as a variable capacitance.

To make this filter with GPLA, I tweaked the capacitor values to nearest standard value parts and tuned the filter with the GPLA Tune Part Value controls while looking at the waveform and my 3 dB bandwidth. I love tweaking values in GPLA and over the years have designed several hundred RF filters for readers.
The rubber hits the road on the bench however! You can get an E.E. degree without melting solder in this day and time — but only bench measurements tell the truth.

Please tune each tank carefully like I mentioned earlier... For example, say a tank needs 180 pF for resonance, *but you don't know this*. You solder in a 100 pF cap and a 5-50 pF *enclosed* ceramic trimmer capacitor into the L-C tank. While watching the 'scope this tank will "peak" since the tank will exhibit its highest peak-peak voltage when the trimmer cap is set to 50 pF and fall off as you decrease the C of the trimmer. You might think you peaked the tank, however you' re actually under by 30 pF!

While leaving the trimmer set to maximum C (peak-peak voltage) in this theoretical example, if you tack solder in another 10 pF cap your 'scope will show an even greater pk-pk voltage. , If you remove this 10 pF cap and then place in a 27 pF cap, the pk-pk voltage will go even higher since you're almost at the target 180 pF. If you removed the 27 pF cap and tack soldered in a 47 pF cap, the pk-pk voltage in the 'scope will go down since your now at 197 pF. Thus you know that resonance is somewhere between 177 and 197 pF.

Of course you could decrease the trimmer cap C and stil use the 47 pF cap, however, my description isn't a prescription to follow, just some things to think about. Sometimes I remove a trimmer cap and measure it to ensure the cap is not set to maximum C; that would tell me I need to add more fixed capacitor(s) to the tank. Air variable trimmer caps give visual indication since maximum C occurs with maximum mesh. Unfortunately they are rare and expensive.

On my bench I keep a pair of small 12 to 400 pF air variable caps and temporarily solder them into my tanks. After peaking, I remove and measure them — then I have a good idea of what capacitance is needed to resonate the tank at my test frequency.

It's all an experiment.

Click for another low loss, well matched example: CF = 5.17 MHz, 3 dB BW = 196 KHz. 50 ohm version. NE612 final version.

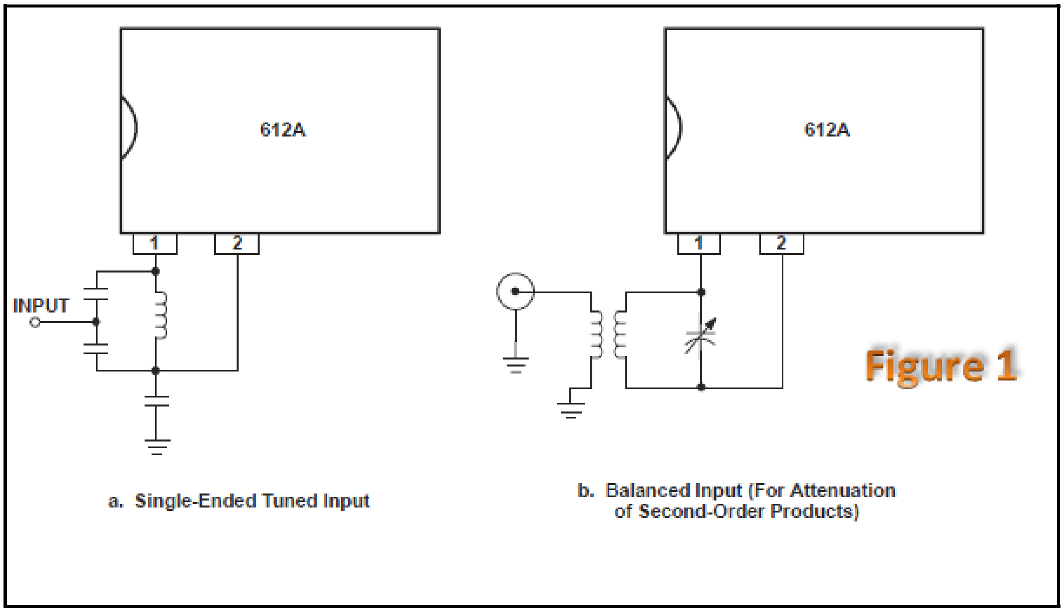
612A
612A
1
2
1
2
INPUT
Figure 1
a. Single-Ended Tuned Input
b. Balanced Input (For Attenuation of Second-Order Products)

Above — NE612 input circuits. The NE612 datasheet specifies a 3 pF input capacitance + a 1K5 input resistance.

If you look around the Web, many builders just run a single tank for band-pass filtering. While okay for novelty-grade rigs, the poor filter stopband may unleash some ugly problems in the mixer and on down the receiver chain.

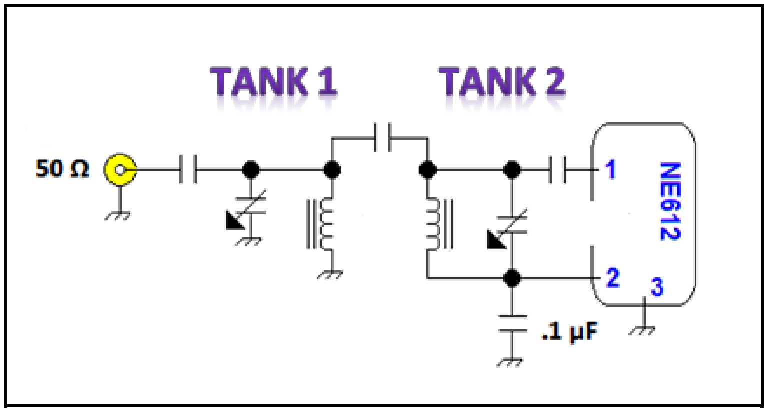
TANK 1
TANK 2
50 Ω
1
2
3
NE612
.1 µF

Above — A double tuned circuit with the L-C tanks named 1 and 2 and a series capacitor to match Tank 2 to the NE612.

Most builders match Tank 1 into its 50 Ω source with a capacitor divider, or a matching transformer. For Tank 2, some enthusiasts just connect the Tank 2 coil directly to pin 1 as shown in Figure 1a. Without the matching series capacitor, unfortunate side effects may arise...

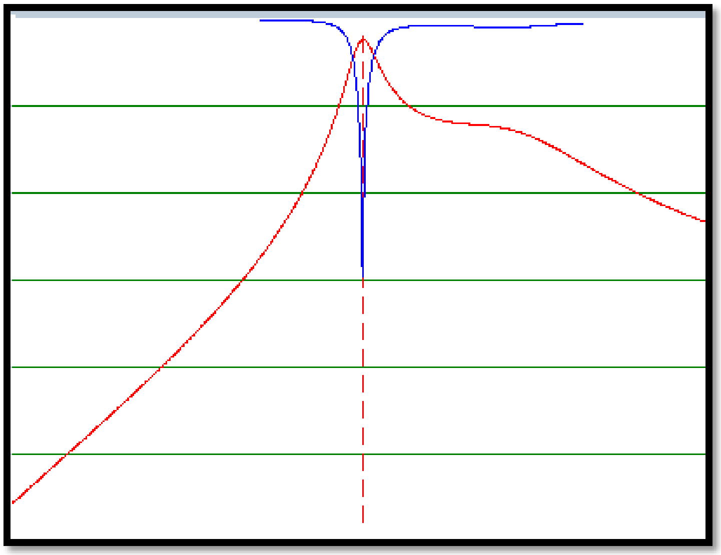

Above — The low-pass skirt of a double-tuned filter may attenuate higher frequencies poorly when no series capacitor (or other network) matches Tank 2 to the NE612 input. I perfectly matched Tank 1 to its 50 Ω source just connected Tank 2 to a 1500 Ω resistive load in this simulation. I wonder how bad things get in the real world when a complex impedance is involved?

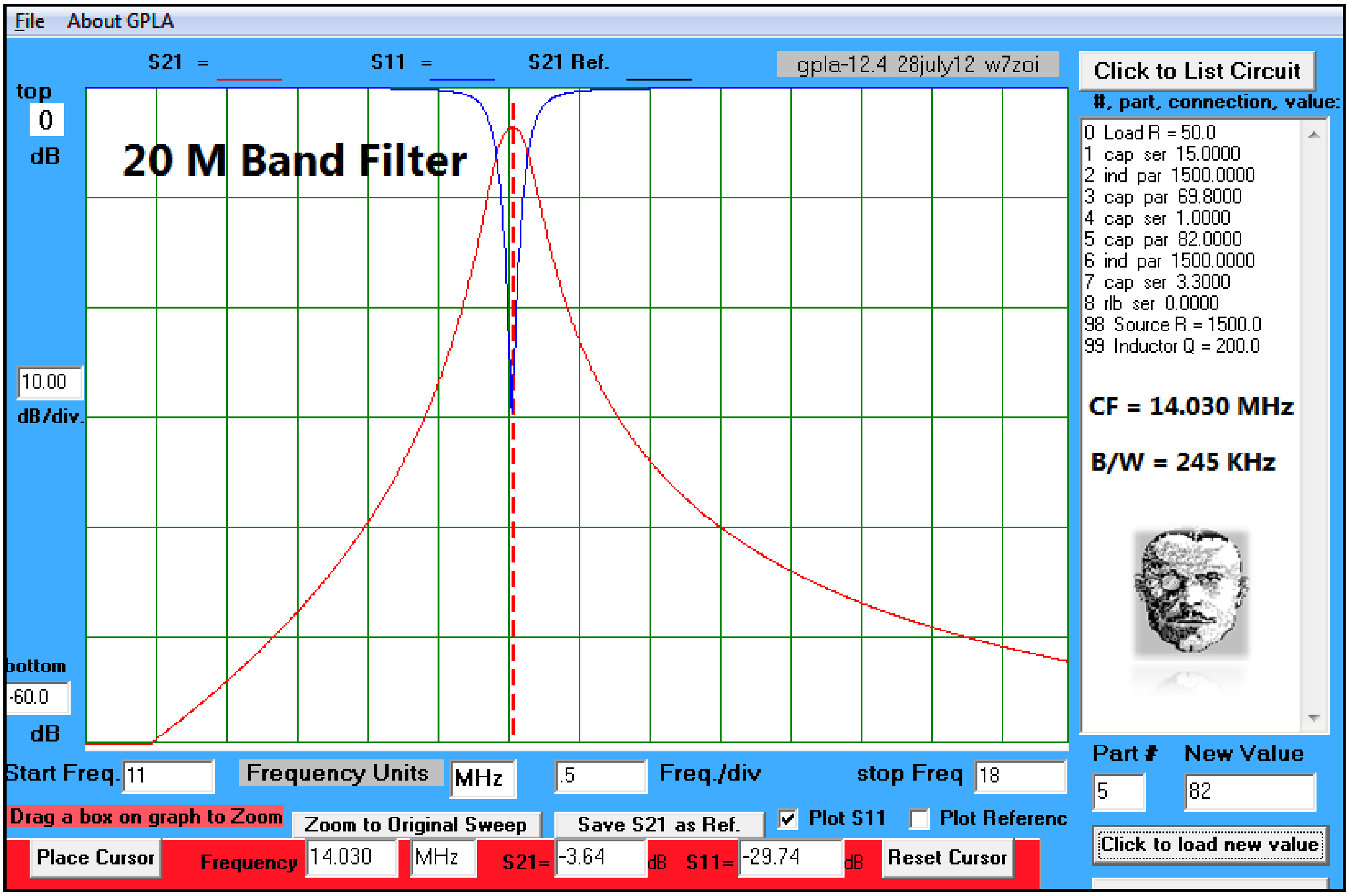
File
About GPLA
S21 =
S11 =
S21 Ref.
gpla-12.4 28july12 w7zoi
Click to List Circuit
#, part, connection, value:
20 M Band Filter
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Place Cursor
Reset Cursor
Click to load new value

```
0  Load R = 50.0
1  cap  ser  15.0000
2  ind  par  1500.0000
3  cap  par  69.8000
4  cap  ser  1.0000
5  cap  par  82.0000
6  ind  par  1500.0000
7  cap  ser  3.3000
8  rlb  ser  0.0000
98  Source R = 1500.0
99  Inductor Q = 200.0
```

CF = 14.030 MHz

B/W = 245 KHz

top 0 dB

10.00 dB/div.

bottom -60.0 dB

Start Freq. 11

Frequency Units MHz

.5 Freq./div

stop Freq 18

☑ Plot S11

☐ Plot Referenc

Part # 5

New Value 82

Frequency 14.030 MHz

S21= -3.64 dB

S11= -29.74 dB

Above — I designed a filter for a 20 Meter band CW receiver centered at 14.030 MHz with DTC and GPLA. The design 3 dB bandwidth = 245 KHz. NE612 filter design was discussed in QRP — Posdata 1.

I then breadboarded the filter with T68-6 inductors, but common lower Qu ceramic trimmer capacitors.

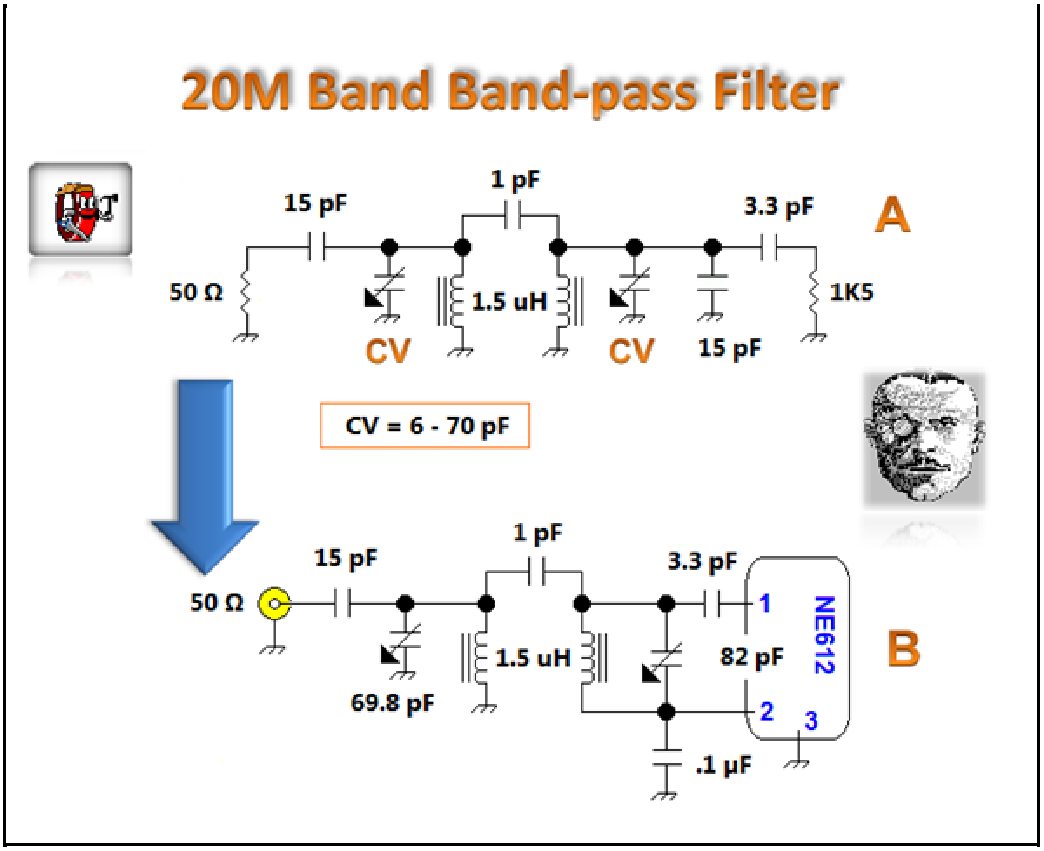
20M Band Band-pass Filter
A
15 pF
1 pF
3.3 pF
50 Ω
1.5 uH
1K5
CV
CV
15 pF
CV = 6 - 70 pF
B
1 pF
15 pF
3.3 pF
50 Ω
1.5 uH
82 pF
69.8 pF
.1 µF
NE612
1
2
3

Above — The DTC/GPLA filter design with Tank 2 evolved to provide single-ended input for the NE612.

I wanted to test 2 questions:

1. Does the 0.1 µF coupling cap connected to the cold end of Tank 2 and Pin 2 change the bandwidth or filter skirt shape?
2. Will the 3.3 pF cap really match the NE612?

I expect that worldwide, the NE612 input impedance may vary slightly from part to part; different breadboards will exhibit different reactances and that although the datasheet specifies 1500 Ω , we may be dealing with a complex impedance that varies with the aforementioned factors plus perhaps, input frequency. I simply want a good filter with clean skirts.

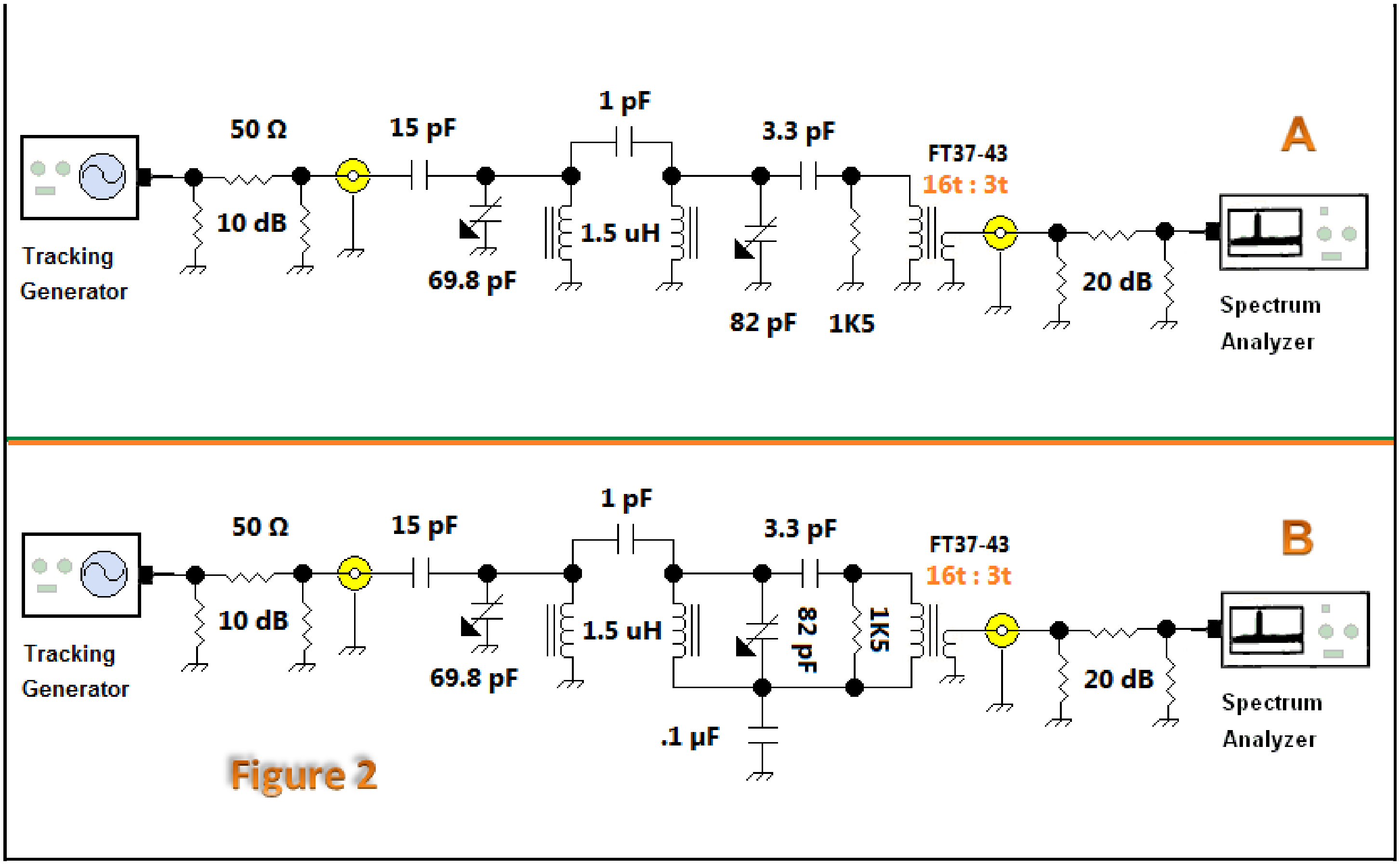
A
Tracking
Generator
50 Ω
10 dB
15 pF
69.8 pF
1 pF
1.5 uH
3.3 pF
82 pF
1K5
FT37-43
16t : 3t
20 dB
Spectrum
Analyzer
B
Tracking
Generator
50 Ω
10 dB
15 pF
69.8 pF
1 pF
1.5 uH
3.3 pF
82 pF
1K5
.1 µF
FT37-43
16t : 3t
20 dB
Spectrum
Analyzer

Figure 2

Above — Experiment #1. I compared spectrum analysis of circuit A with B. I built and measured A and then cut away some copper to isolate the copper board grounding the Tank B parts. This "island" was AC coupled to the rest of the ground plane with a short leaded 0.1 µF ceramic capacitor.

I saw no significant difference between Circuit A and B — it appears the 0.1 µF capacitor does not affect the filter parameters to any extent.

To simulate a NE612, I soldered a 1K5 Ω 5% resistor across Tank 2. Tank 2 was transformer coupled to the 50 Ω Z required for spectrum analysis. A 20 dB pad ensured a strong return loss and a safe input amplitude for the SA.

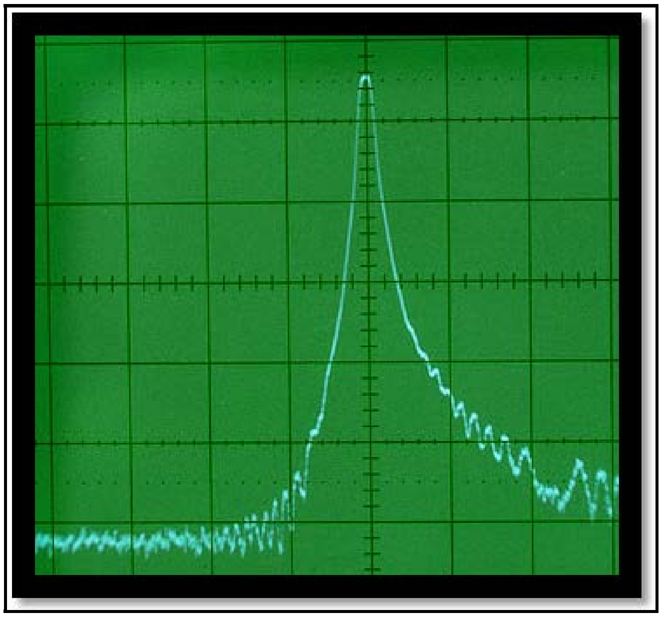

Above — Spectrum analysis of Figure 2A or B. I saw flat topping of the waveform – almost double humping with a higher than wanted 3 dB bandwidth; this bothered me. Fixing this problem was Experiment #2.

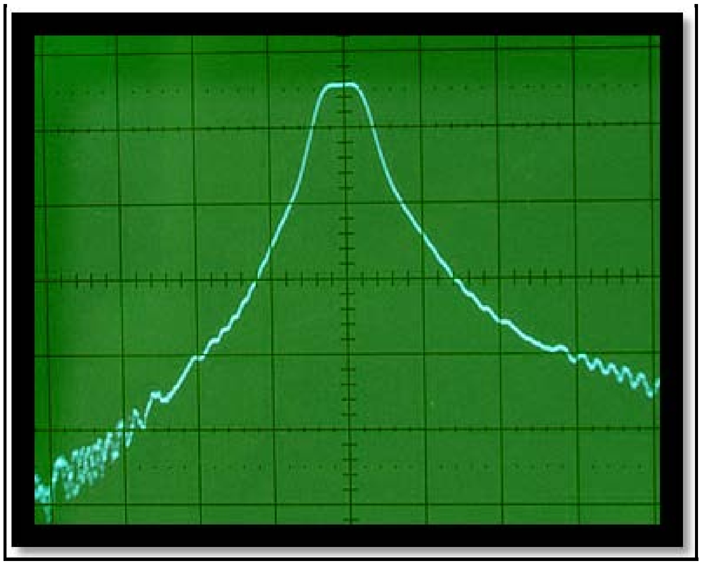

Above — A zoom of the poor coupling of Figure 2A or B. From my experience building filters, I suspected a termination resistance mismatch in Tank 2 ; exactly what I was trying to avoid!

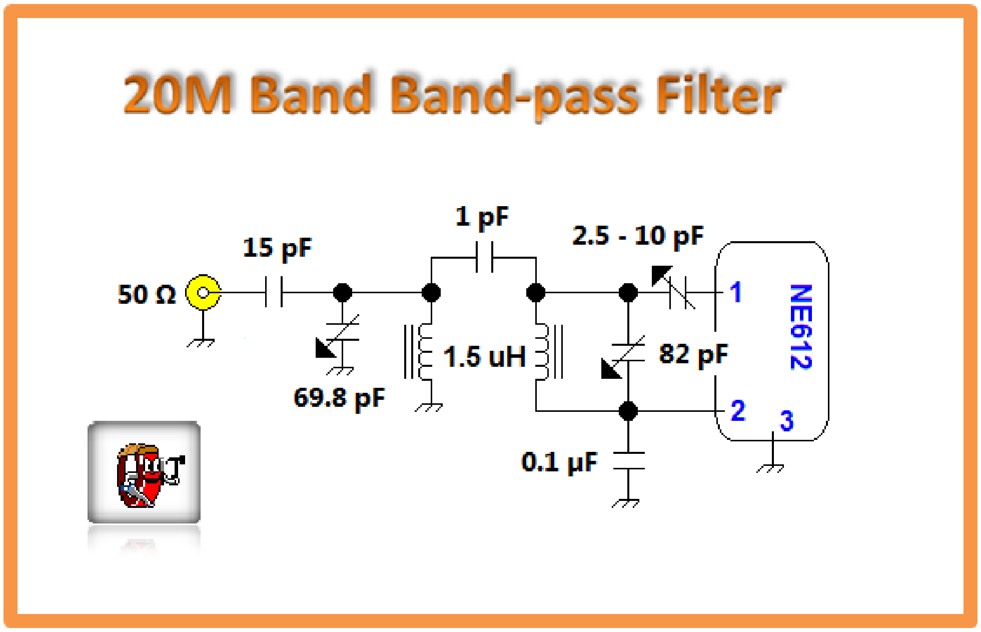
20M Band Band-pass Filter
50 Ω
15 pF
69.8 pF
1 pF
1.5 uH
2.5 - 10 pF
82 pF
0.1 µF
1
2
3
NE612

Above — I swapped a trimmer capacitor for the series 3.3 pF fixed cap in Tank 2. Then I reconnected the circuit into my test set up.

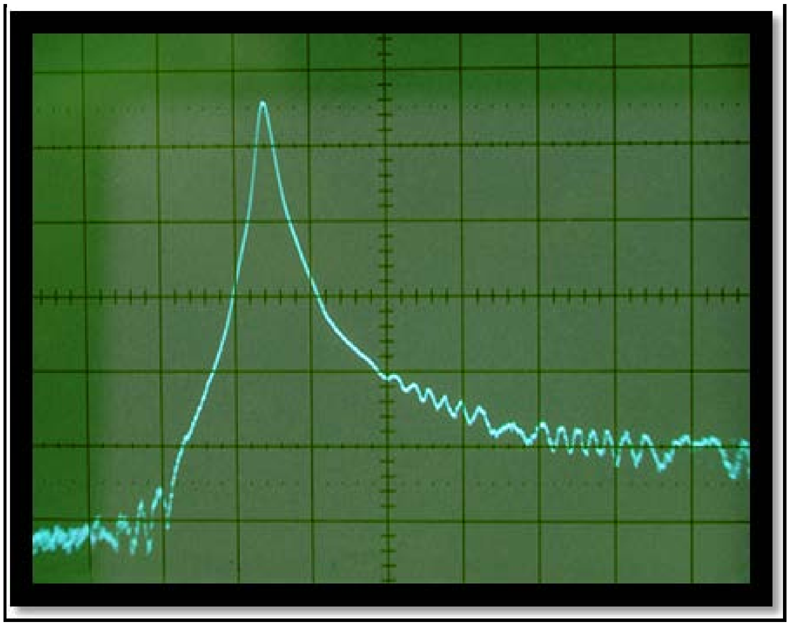

Above — A photo of my TG + SA measurement after tweaking the newly added trimmer capacitor and peaking each tank. I shifted the SA screen center over so the tracing could be seen without all the hash marks in the center. Wonderful.

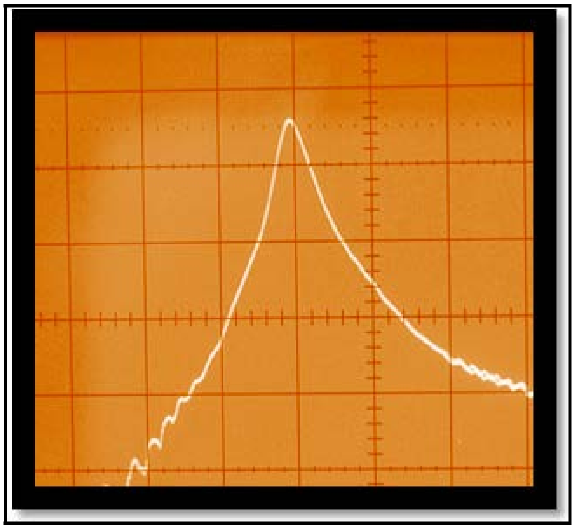

Above — A zoom of the now matched Tank 2. Due to the bench-altered Tank 2 match, my low-Q variable capacitors and other factors, the 3 dB bandwidth now is just over 300 KHz.

I'm not sure if these experiments reflect what actually happens with a NE612 input band-pass filter, however, I plan to match my second tank with a series trimmer capacitor in future NE602/NE612 work. I also want to explore balanced input.

RF — Test and Measurement

RF Workbench Page 4

The 4th installment of a QRP/SWL HomeBuilder series exploring *basic* RF measurement

Part 4 describes a method to calculate reverse isolation in the **50 Ω environment** after converting measured peak-to-peak AC voltages to dBm. I tested 2 common amps at ~7 MHz to show the concepts and calculations.

In this series, I gratefully borrow from the work of Wes, W7ZOI per correspondence, direct contributions and from EMRFD.

Tools Needed

1. 50 Ω terminated scope (or a spectrum analyzer) and a 50 Ω signal generator
2. 50 Ω RF cables with RF connectors (such as short cables with female BNC connectors)
3. 6 dB 50 Ω attenuator pad; plus an adjustable attenuator if you use a fixed output signal generator.
4. BNC through-response connector(s)

Procedure

1. Measure the amplifier forward power gain. This is S21.
2. Measure amplifier reverse power gain. This is S12. Like S11, express S12 as a negative value.
3. Reverse isolation using dB values = S21 - S12.

Step 1 : Measure the forward power gain

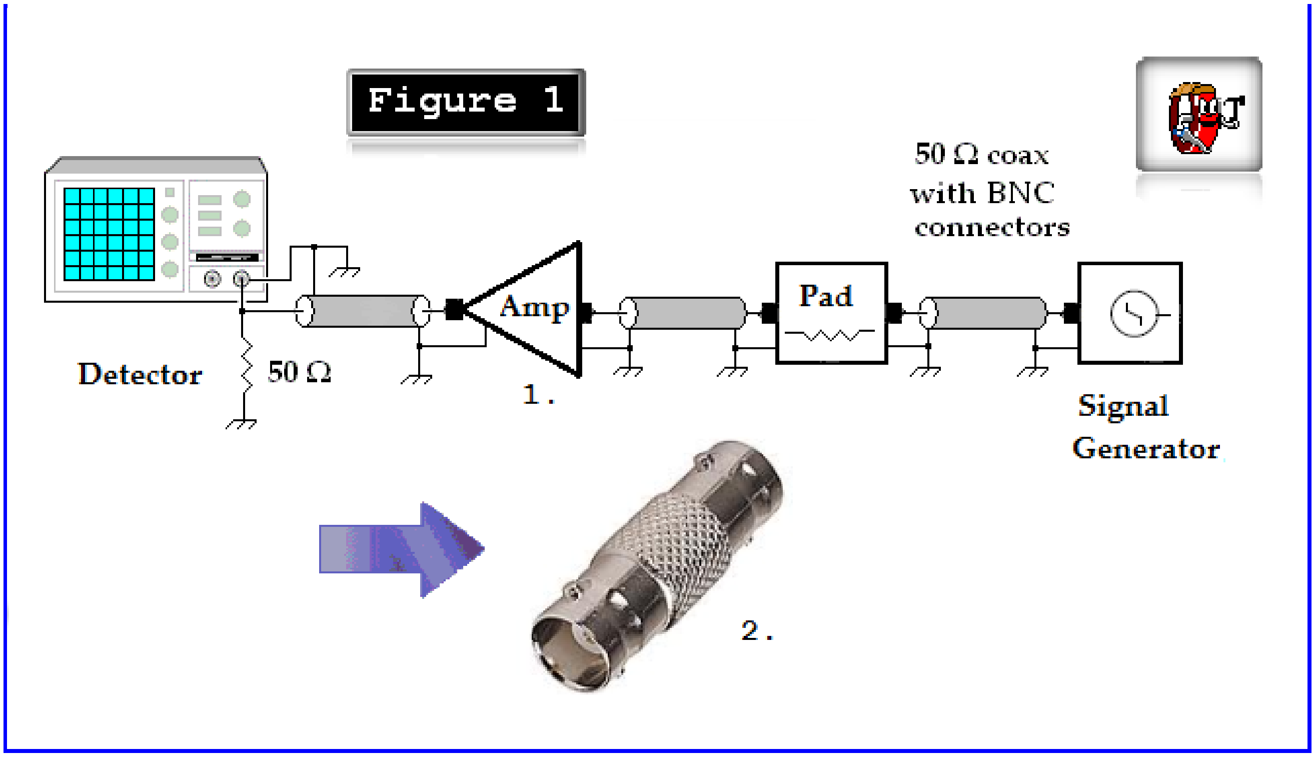

Figure 1

Figure 1 shows how to measure forward gain in a 50 Ω environment — **1**. Convert the measured AC voltage to dBm, **2**. Disconnect the amplifier, insert a through-response connector and convert this measured AC voltage to dBm. The difference between the 2 values = S21. Applet H will do these calculations from the peak-peak voltages. *The attenuation pad following the signal generator in Figures 1 and 2 signify that the signal generators have a 50 ohm output impedance and is optional.*

Choose a signal generator level that ensures the output of your amplifier is linear while providing a good signal to noise ratio for measurement. With an oscilloscope, I generally test amplifiers with an input power of between 0 and -11 dBm; although choose whatever level that works for you consistent with linear amplification.

After measuring the forward gain of your amp, a good way to test for linearity is to add a fixed 6 dB pad between your signal generator and your amplifier to drop the applied signal by half. *[A 6dB pad drops the peak-peak voltage by 1/2 . A 3 dB pad drops the power in dBm by 1/2]*. The power gain should be equal or nearly equal to the measured dB value obtained before you added the 6 dB pad. If they vary significantly, you are likely driving the amp too hard and causing some non-linear output products. S21 = complex *linear* gain.

Step 2 : Measure the reverse power gain

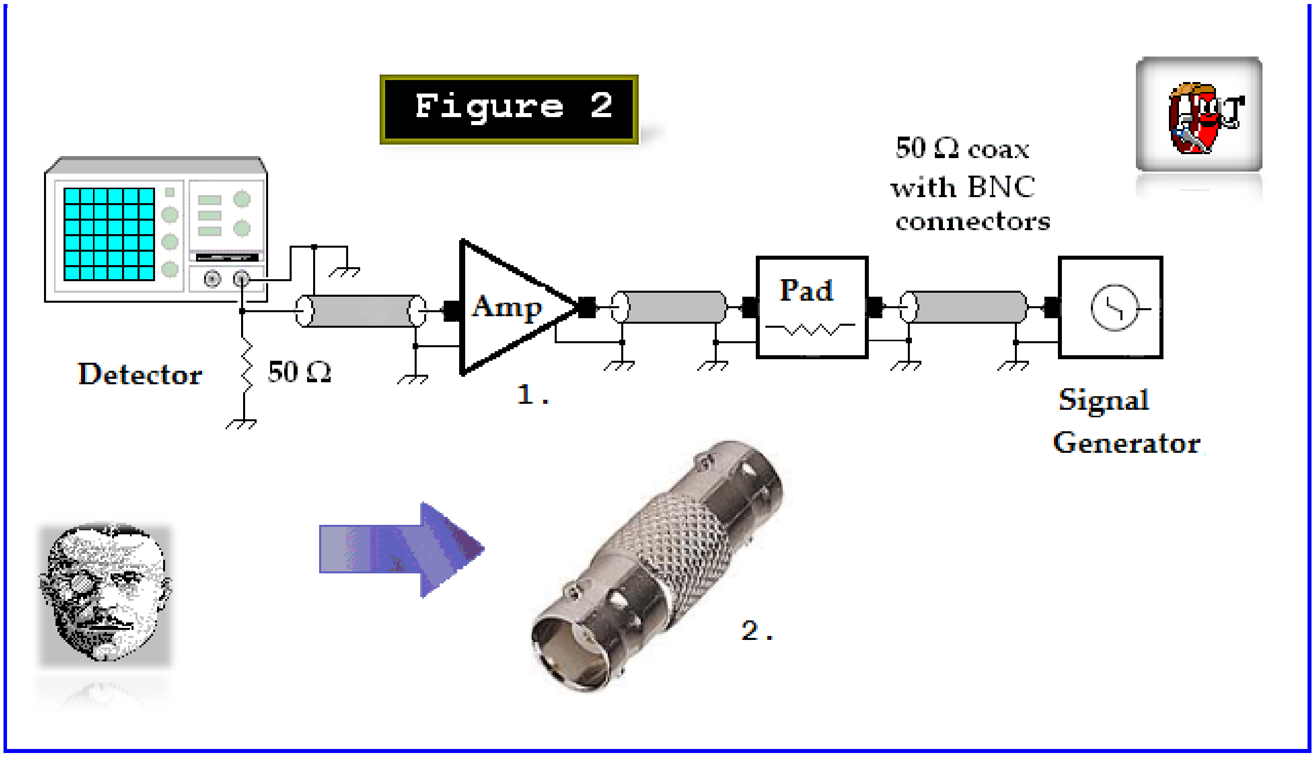

Figure 2 shows how to measure reverse gain in a 50 Ω environment — **1**. Convert the measured AC voltage to dBm, **2**. Disconnect the amplifier, insert a through-response connector and convert this measured AC voltage to dBm. The difference = S12. Ensure that you employ the same drive level used to measure the forward gain.

Measuring reverse gain may be tough. When the amplifier under test requires a low drive level and/or has strong reverse isolation, you may not have enough signal to accurately measure with your oscilloscope. The tool of choice for low reverse voltage measurment is a spectrum analyzer (SA) — a narrow band SA may be required to distinguish the weak signal from random noise with low signal voltages.

Summary

A **practical** bench work flow goes something like:

1. Measure the through-response peak-peak voltage.
2. Measure and record the peak-peak AC voltage while driving the amplifier input port (forward gain set-up).
3. Reverse the amp so you're driving the output port and then measure the peak-peak AC voltage (reverse gain set-up).
4. Calculate S21 and S12.
5. Calculate reverse isolation.

Example 1: Feedback amplifier

In the first example, I measure the reverse isolation of a Beaverton Special feedback amp. The schematic is shown below. Tested with a 7.039 MHz signal generator possessing a return loss of 30 dB.

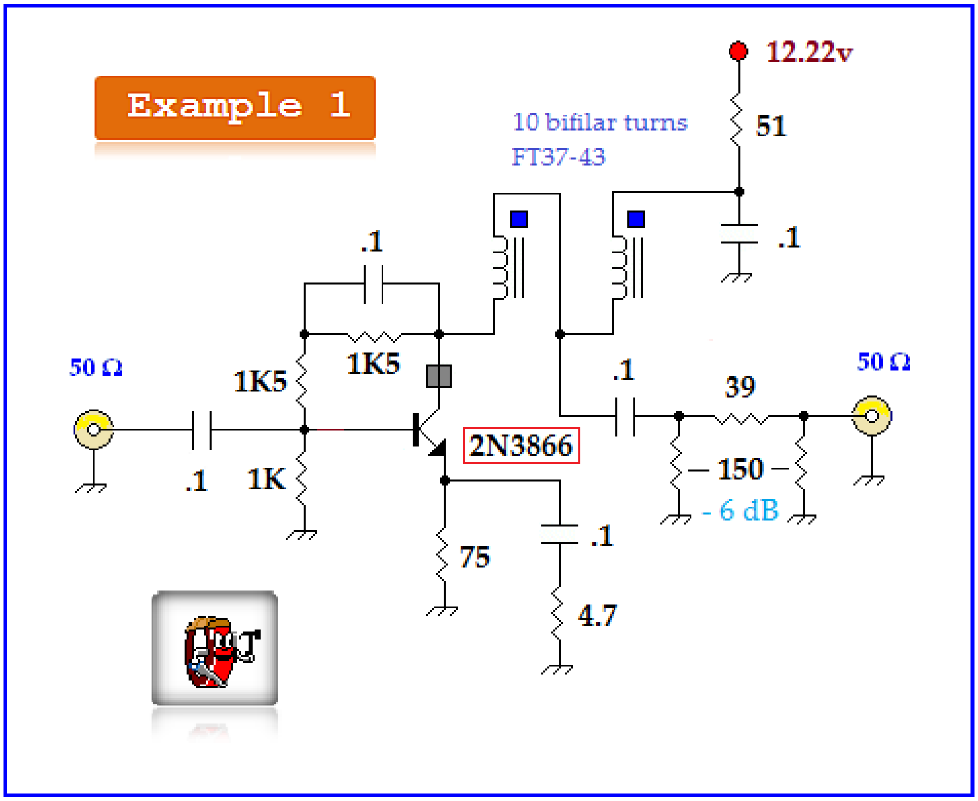
Example 1
12.22v
10 bifilar turns
FT37-43
51
.1
.1
1K5
50 Ω
1K5
.1
39
50 Ω
.1
1K
2N3866
150
- 6 dB
75
.1
4.7

50 ohm Voltage Measurements:

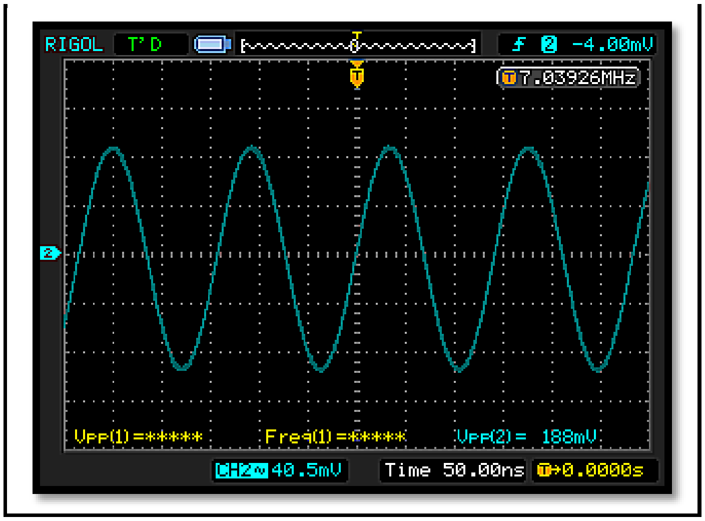

Above — AC voltage with a through-response connector in-situ: 188 mV pk-pk

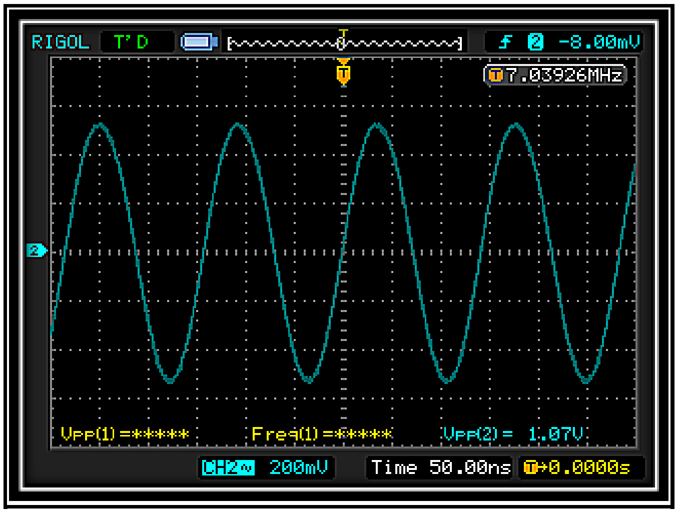

Above — AC voltage with forward gain set-up: 1.07 V pk-pk

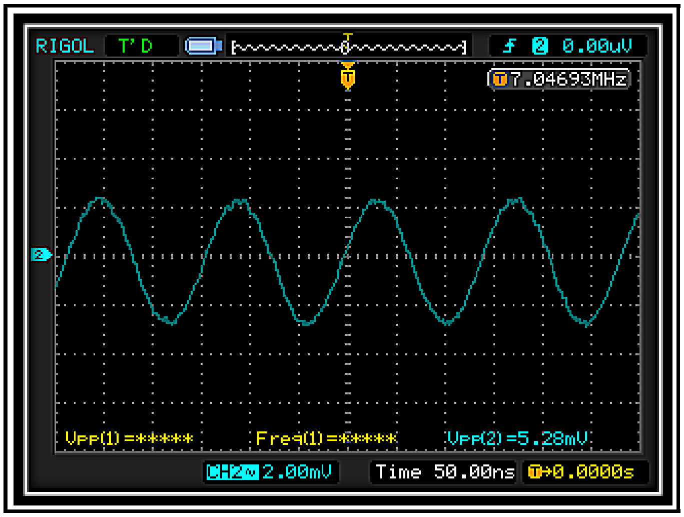

Above — AC voltage with reverse gain set-up: 5.28 mV pk-pk.

S21 = 15.1 dB. S12 = -31 dB. I tested my driven amp's linearity by adding a scrap, standard value 6 dB pad in between the signal generator and the amplifier — the S21 was 15.2 dB with the pad and 15.1 dB without the added 6 dB pad. It's linear.

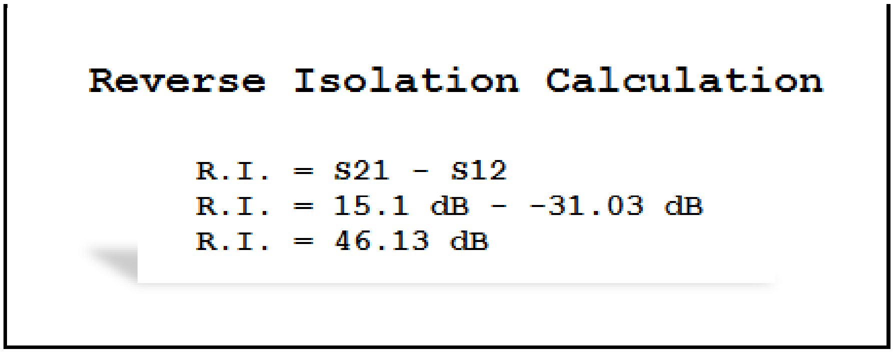

Reverse Isolation Calculation

R.I. = S21 - S12
R.I. = 15.1 dB - -31.03 dB
R.I. = 46.13 dB

Example 2: Common Base Amplifier

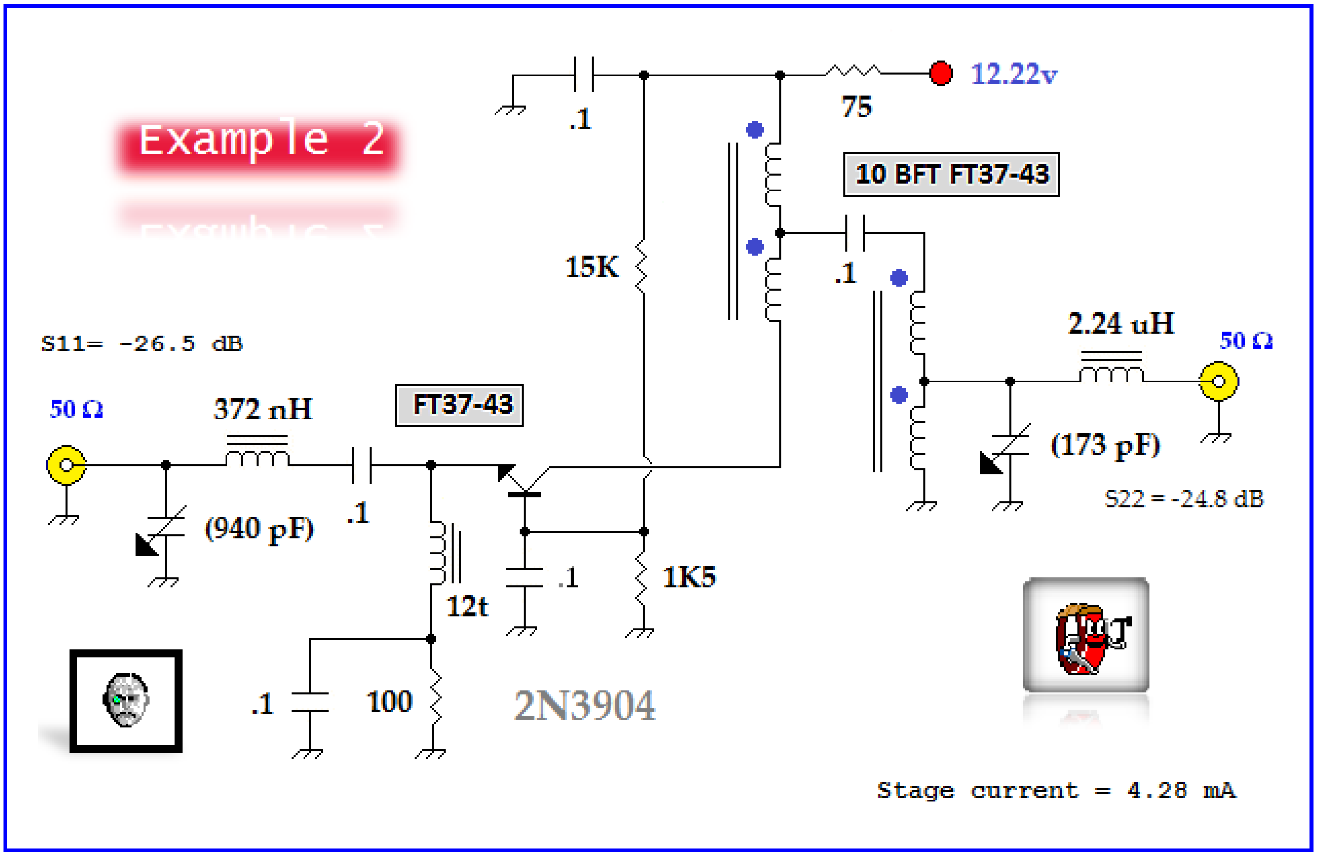
Example 2
.1
12.22v
75
10 BFT FT37-43
15K
.1
2.24 uH
50 Ω
S11= -26.5 dB
50 Ω
372 nH
FT37-43
(940 pF)
.1
(173 pF)
S22 = -24.8 dB
12t
.1
1K5
.1
100
2N3904
Stage current = 4.28 mA

Above — A common base amp employing L- networks for a strong return loss in and out at 7.039 MHz. S11 and S22 = the negative of return loss.

Through connector voltage = 192 mV peak-peak.

S21 = (1.88 volts peak-peak AC voltage) = 19.82 dB.

S12 = (1.68 mV peak-peak AC voltage) = -41.16 dB.

Reverse isolation at 7.039 MHz = (S21 - S12) = 61.42 dB

I confirmed the linearity of my S21 using the aforementioned 6 dB attenuator pad — I couldn't increase my signal generator output level above the indicated -10.35 dBm, since gain compression emerged in the common base amplifier (reduced AC voltage was measured).

My reverse AC voltage was under 2 mV; about the threshold where my oscilloscope waveform becomes rather ugly and sits in the noise. Clearly, the limitations of measuring reverse isolation with an oscilloscope must be factored. Still, you got to love 60 dB + of reverse isolation in a popcorn circuit.

1 local professional EE told me if you can measure it with a 'scope, you don't have spectacular reverse isolation - no doubt, a spectrum analyzer

pumps up the measurement quality in circuits with high reverse isolation, but more amateur designers have 'scopes than spectrum analyzers, so just do your best.

Involving Scattering Parameters as possible on your workbench can only lead to circuit improvement. You can't better your outcomes if you can't or don't measure them — applying and more importantly, understanding test equipment is just 1 component of our hobby. A hobby unto itself; test equipment activity complements amateur radio design. I have met test equipment focused builders who make radio gear just as an excuse to apply their test gear!

Improved bench practices are the corollary of striving to learn more about measurement techniques and increasing our collection of measurement devices.

QRP — Posdata 1: Hycas Amplifier

I love the hybrid cascode (hycas) as a general purpose RF amplifier. What's not to love about a using a common source FET followed by a common base bipolar amp? I attempted to measure the reverse isolation of a version just using an oscilloscope.

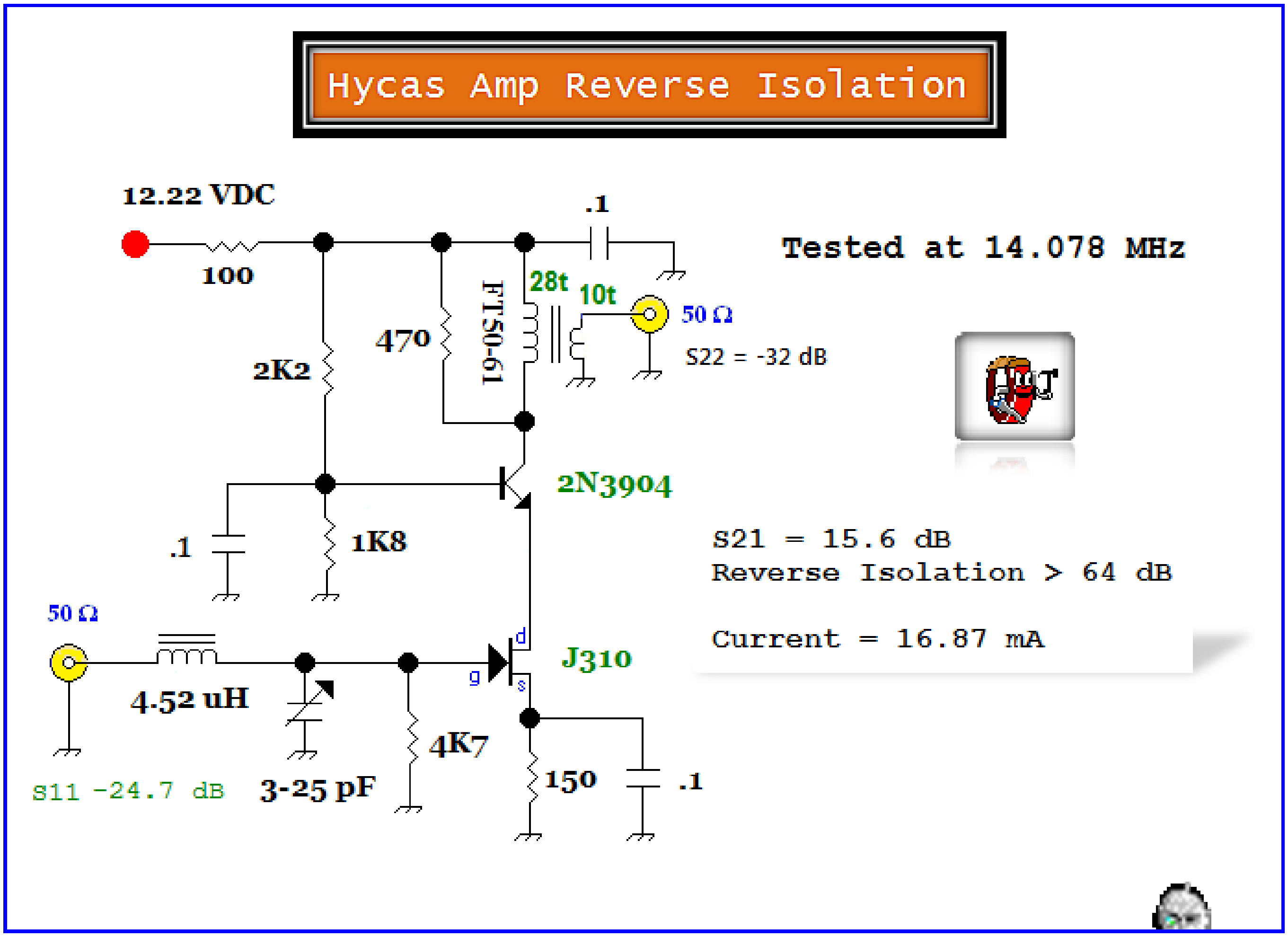

Above — A hycas amp set up for high return loss on both ends at 14.078 MHz. Too much current may cause gain compression and harmonic distortion, so please test your hycas amps for both. I tested using a signal generator with a 30 dB return loss driving a 50 Ω terminated oscilloscope. Since the hycas amp contain a high impedance input JFET and a common base amp, the reverse isolation should be reasonably high, or at least as good as a common base amplifier.

My testing failed — The reverse isolation was too high to measure with an oscilloscope. Using proper bench techniques (linear amplification + honest scope reporting), I determined the highest reverse isolation I could measure = 64 dB. In fact, injecting a whopping signal of 1.08 volts peak-peak into the hycas output port only gave an S12 of 1.84 mV — whoa!

The problem is such a strong signal (1.08 volts peak-peak) at the input port results in severe limiting and distortion; so valid reverse isolation measurement isn't possible. Even a 350 mV peak-peak signal may give some gain compression during S21 measurement depending on your matching. Thus, I can only accurately say that the reverse isolation of my hycas amp is greater than 64 dB.

Strong reverse isolation is 1 reason I favor hycas amps as VFO buffers. They make pretty good I.F. amps also.

The hycas IF amp system by Wes, W7ZOI and Jeff, WA7MLH offers amazing performance and features an excellent JFET bias scheme. I built 1 in 2008 — amazing design.

QRP — Posdata 2:   Doesn't S12 = Reverse Isolation?

Many web sites, books and people report that reverse isolation = S12, yet above, I depart from this argument. In truth, I think reverse isolation equals S12, but reverse isolation may also equal S21 - S12.

I'll let you decide what to do, but explain why I enjoy the latter.

S12 is a negative value.

I prefer to turn that negative value into a positive 1 — RF Workbench 4 concerns measuring and applying amplifiers with the goal of high reverse isolation and not just measuring S12.

The main purpose to quantify amplifer reverse isolation is to strive to *improve reverse isolation* and an amplifier is but 1 component in our 50 Ω block. I believe in a creative, systems approach; open minded and positive (pun intended).

The whole RF Workbench series attempts to present 50 Ω bench measurements in a vibrant way devoid of excessive + boring engineer-style content that could blank the eyes of the budding Hams/SWLs designers that visit my site. I imagine this web site bores more advanced RF designers *to tears*.

Our goal is to obtain high reverse isolation while applying a 50 Ω systems approach.

Break away from strict + "stodgy" math-driven methods to fuel creative thought and experimentation.

I posit that an appropriate figure of merit in a well designed isolation amplifier is the difference between S21 and S12; and therefore, the term reverse isolation can be more than just S12.

Ham/SWL component-level experimentation by commoners like me is ~~slowly~~ dying and being replaced by a new generation of skilled, code writing experimenters. Although, some builders just copy other people's code and then apply it to kitted hardware. Reverse isolation impacts both our analog and digital designs.

Please consider this example:

I'm switching a level 7 diode ring mixer with 12 MHz and per normal, create lots of internal harmonic energy. With my spectrum analyzer connected to the mixer RF port I measure my 12 MHz LO signal at 50 dB below a +7 dBm signal, or -43 dBm. That's a 50 over S9 signal — very high amplitude in context!

I require strong LO isolation in my circuit and thus stick in a 50 Ω input/output amplifier. I measure this amp: S21 = 15 dB and S12 = -31 dB.

So, the signal at the amplifier input is -43 dBm plus -31 dB = -74 dBm. But, alas, -74 dBm isn't good enough me — I want to use that amplifier to elicit greater isolation. However, I don't want any gain in my system, so I insert a 15 dB attenuator pad after the amplifier. For this pad, both S12 and S21 = -15 dB. For my amp, the net cascade is S21 = 0 and S12 = -46 dB.
Since S21 = 0, the block has 0 impact on the signal amplitude applied to the mixer, but the signal at the input of my isolation amplifier is -43 dBm plus - 46 dB, or -89 dBm. This isolation I like — it also illustrates a systems approach that gets you thinking about measurement in your own 50 Ω blocks.

The figure of merit for making a good isolation amplifier is now the difference between S21 and S12. If you want, go ahead and just use S12 for reverse isolation, but you'll probably measure S21 plus S12 anyway and that's what this web page is about! Onward.

QRP — Posdata 3

Comments From the Workbench

I'm no amateur electonics expert — I'd like to be one, but this is a tough field; RF and AF *design* is quite scientific, under-resourced and a bit overwhelming. How do we experimenters advance and stay motivated? Reading works by professionals like Chris Trask, N7ZWY, Bob Larkin, W7PUA, Doug Self, Rod Elliott and others may highlight our lack of knowledge and scientific methodology — a realization which can distress and demotivate us lay-designers. To a degree, this is irrational thinking; personal growth is always about hard work, problem solving and overcoming barriers.

Unlike the white belted Karate student, who studies and practices under the guidance of a master to attain black belt skill level, most amateur designers, excluding electrical engineering students, can't access good teachers. As a lay-person, with few face-to-face mentors (nobody in

Canada), I try to learn by experimenting and incorporating whatever knowledge, advice or schematics I can find. Fortunately, some Electrical Engineers give me advice by email and in turn I'm able to share this information via experiments on QRP / SWL HomeBuilder.

Our dusty, analog hobby fades palpably — the number of analog electronics gurus dwindles each decade and modern electronics embraces miniature circuitry often involving digital ICs controlled by lines of code.

Current electronics hobbyist magazines rightfully focus on topics that are contemporary or important to their advertisers; for example, promoting mixed-signal ICs, DSP, microcontrollers and the kits they describe and then sell for income. Nuts and Volts is 1 example. Both analog RF and AF design increasingly lies in the hands of a small group of specialists, enthusiasts and students.

Yet, we *persevere*. Sharing our knowledge, circuits, experiences and references on the Internet helps sustain our small global community. That's the site purpose— sharing the (warts and all) experiments + basic information of a lay-person.

The Emitter Choke in Common Base RF Amps

This web page covers reverse isolation — a really important topic. 2 principle amplifiers we employ for strong reverse isolation are the common base BJT and common gate JFET alone or in cascode with other amplifier topologies.

Some comments regarding using a radio frequency choke in the common base amplifier follow.

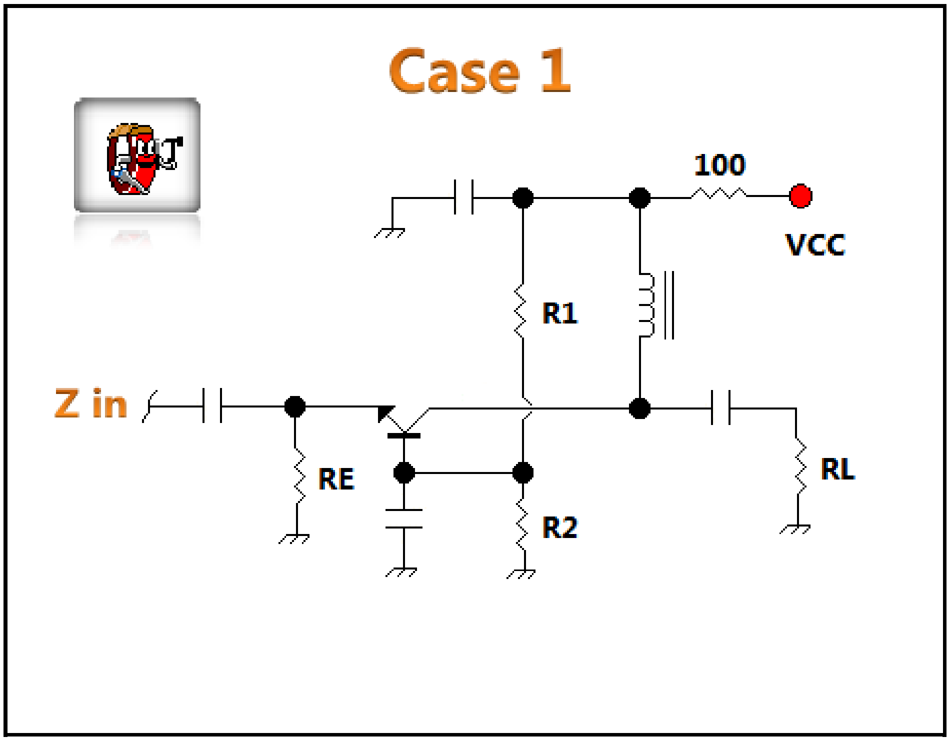

Above — Case 1: Emitter resistor only.

Apart from providing DC bias along with R1 and R2, emitter resistor RE plays another important role. Despending on its value, a portion of the input AC signal may pass through RE to ground instead of going through the transistor — degrading signal amplitude and noise figure. To minimize this, the resistor value should be many times (~10X or more) than the input impedance of the amplifier.

Although we might bias a common base amp to give an input Z of 50 Ω, often we'll choose a much lower input Z to get higher voltage gain. Input Z = 26 / Ie where Ie = mA; so if you bias for 5 mA, you are looking at an input Z of ~5 Ohms. In that case, a low value bias resistor such as 100 Ω won't shunt much of the input signal to ground, nor will it likely contribute much noise.

For most common base RF amps, a correctly chosen emitter resistor is all that's needed to decouple the AC signal and using an emitter choke proves hard to justify. However, it's important to understand how to apply an emitter choke since the basic principle also extends to the common gate JFET amplifer and other circuits.

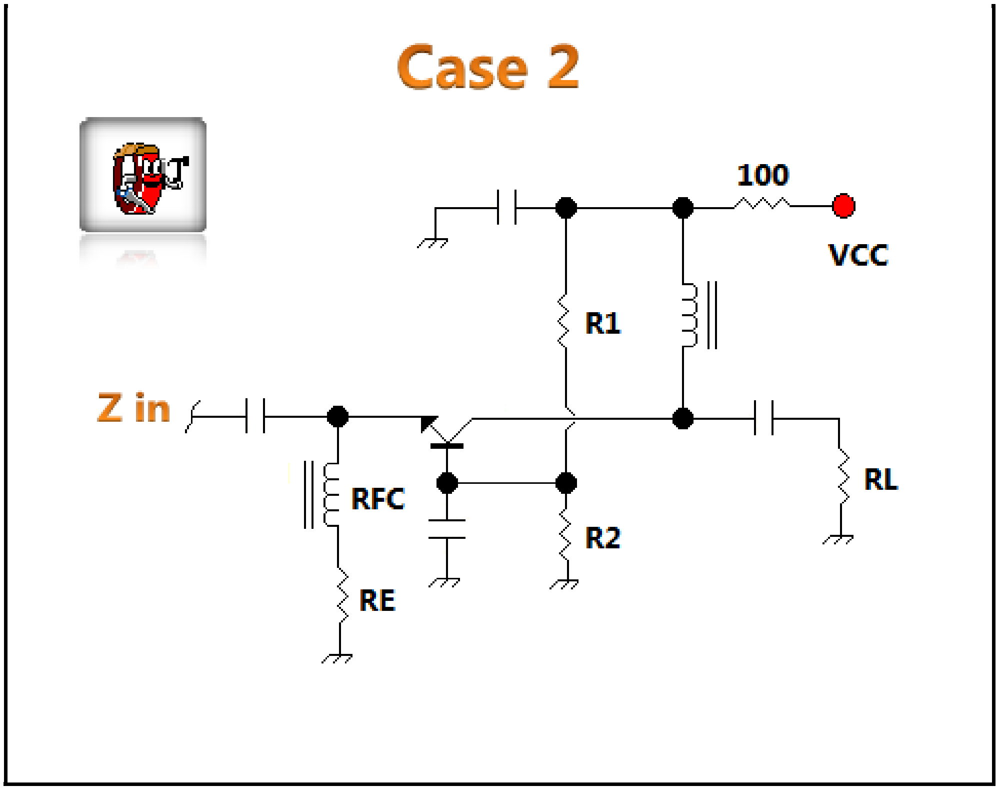

Above — Case 2: Emitter resistor plus a choke.

The choke’s main purpose is to block or choke RF from passing to ground. The ideal choke would present infinite impedance to AC signals, plus 0 resistance to DC voltage. In reality, "ideal" = fantasy electronics and you can simply estimate a choke's inductive reactance using the classic formula (XL =2*PI * Freq * L).

Using a coil (and not just a resistor) is generally better for decoupling — although how much better might be debatable. If the inductive reactance (XL) of the coil is significantly higher than the input impedance of the transistor, then all of the input signal power goes to the transistor.

By convention, a minimum choke XL should be at least 3 times the input resistance, however, the self-resonant frequency of the coil must be significantly higher than the applied frequency. Thus, an ideal range of inductive reactance exists, and too little or too much can degrade performance. Many builders target an XL around 10 times higher than the transistor input impedance at the lowest operating frequency.

Example: For a common base amp biased for an input Z of 50 ohms, the minimum inductive reactance (XL) for the choke = 500 ohms. To calculate the inductance of an emitter choke for this amp at 50 MHz, we re-arrange the formula to solve for L.

L = XL / 2* Pi * F
L minimum = 1.59 uH.
Winding the choke on a ferrite core, or possibly a bead for VHF often means less turns, less winding capacitance and a higher self-resonant frequency.

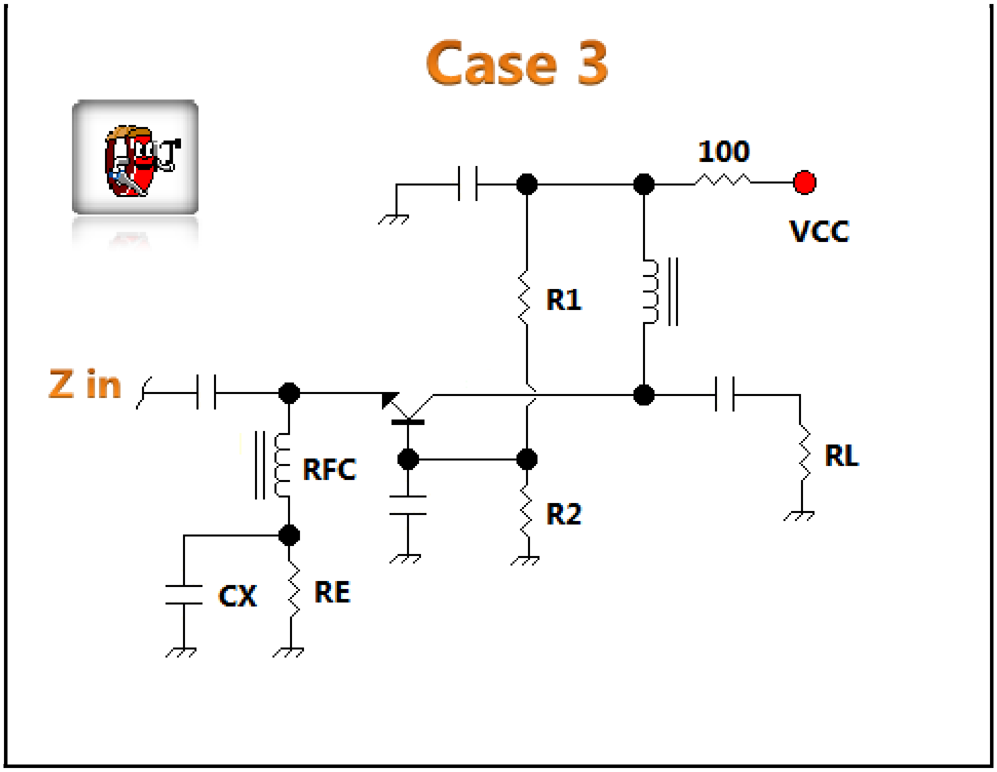

Above — Case 3: Bypassed emitter resistor plus choke.

The primary purpose of the capacitor across RE is to filter resistor noise — but that is only an issue well below the frequency of interest and it should not be relevant at high frequencies where the choke reactance is significant. There may be some useful effect if the self-resonant frequency of the capacitor Cx is above the frequency of interest.

You can only use bypass capacitor **Cx** when a choke is implemented.

A 0.1 uF may be useless at high frequency. In error, I've used this value previously on the site; after 14 years of experimenting, I've learned a lot from my design mistakes.

The case of the common gate JFET amplifier

This discussion also informs common gate JFET amplifer design. The JFET source requires signal decoupling similar to the emitter of the bipolar transistor discussed above.

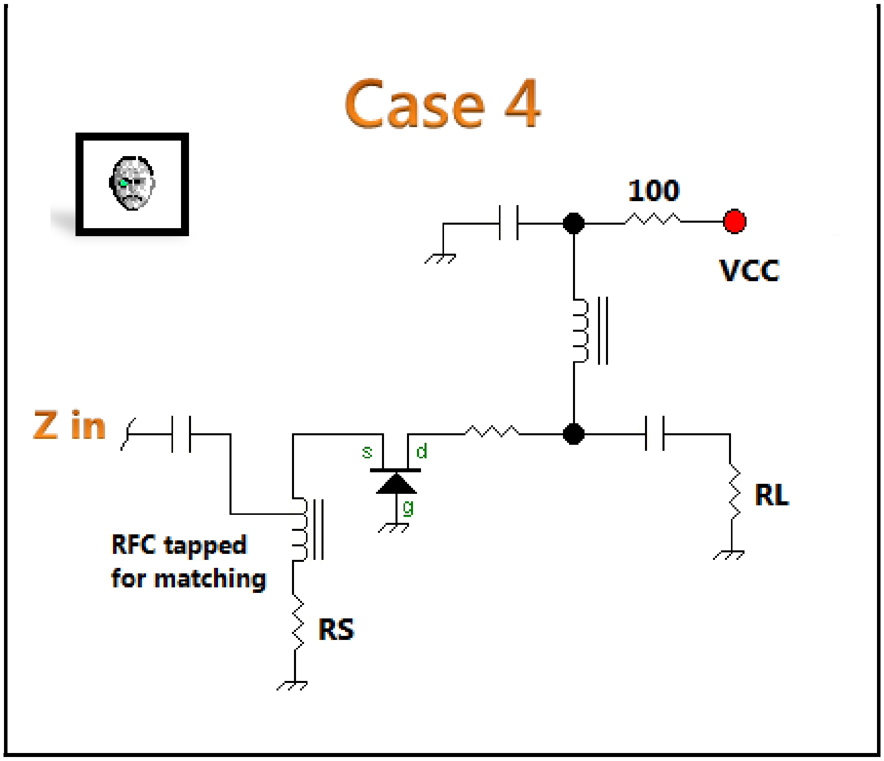

Above — Case 4: A choke plus source resistor will commonly be the "go to" design. Things get a bit more complicated with some, but not all JFET circuits — engineers often match the JFET input for a low noise figure rather than just the "correct" input impedance.

A good example follows: We might place a common gate JFET amp after a diode ring mixer because of the wideband load it presents to the mixer's RF port. The best noise match may occur with a hypothetical input Z of ~70 Ω (this argument represents an advanced topic).

After measuring the JFET pinchoff voltage and Idss, you would likely find that a source bias resistor of ~100 Ohms would be needed. This R value is so close to the JFET input Z that signal losses to ground would occur — demanding a choke for signal amplitude preservation, plus impedance and noise figure control.

RF — Test and Measurement

VFO - 2011

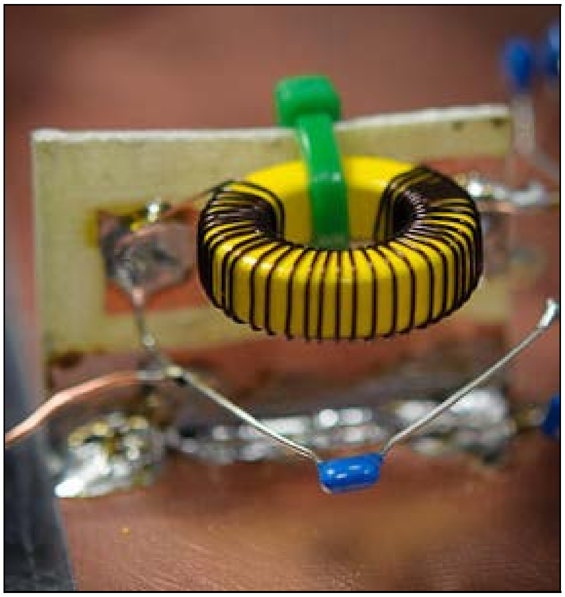

Building VFOs in 2011 might seem an irrelevant exercise given the move to and evolution of digital signal generators laden with bells and whistles like memories and audio or video frequency displays.

A successful L-C VFO requires skill, patience and some good parts to pull off — else, a "drift monster" may result. Despite their limitations, it's possible to build L-C VFOs with low frequency drift, distortion and phase noise; our typical VFO performance markers. L-C VFOs don't require programming skills or equipment to encode a microprocessor — making them a good choice for people who don't build or can't afford kit oscillators. Most of all, they kindle creativity, problem solving and pride when your oscillator actually works as planned. Junk box radio; my passion.

This material reflects lots of empiricism; not pure science. It's really *your* VFO design odyssey; a chance to think creatively and critically to sort out what works and what's folly.
Countless web pages discuss VFO design and I encourage you to search for and read them. Wes' EMRFD oscillator and temperature compensation notes = essential reading. Only your first 25 VFOs will prove difficult — it gets easier after that.

VFO 2011 Topics:

1. Frequency Stability Notes
2. Vackar VFO Experiments
3. HF Signal Generator
4. Miscellaneous Bits

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1. Frequency Stability Notes

Building an oscillator that stays on frequency purports our greatest challenge and goal in L-C VFO design. Since drifting VFOs pose a source of frustration, I cover some topics that may help your VFO stay on frequency — do they help?

What is good drift parameter?

I'm uncertain, for after warm-up, I've measured kits that drifted 50-150 Hertz per hour, built L-C VFOs that drifted under 20 Hz per hour and every once and a while, build a drift monster VFO that sweeps upward at 2 - 8 hertz per minute! Likely under 20 Hertz per hour after warm up = a gold standard to compare against. You should be able to listen to a 10-20 minute QSO with no re-tuning, however, this assumes the transmitting stations are locked on frequency.

1. Unloaded Q and Frequency Stability

The number 1 reason to employ high resonator Q in oscillators is to obtain low phase noise. Secondly, the very steep phase slope through high Q resonance minimizes the effect of amplifier phase shifts caused by temperature changes and this in turn, minimizes any amplifier-induced frequency instability.

Long term frequency stability is chiefly dependent on the temperature, environmental and age stability of the resonator components regardless of Q.

I often see designs featuring high Q inductors wound on powdered iron toroids complimented with trashy, low Q variable and/or fixed capacitors, If you design for a high Q tank to minimize phase noise, consider using a high Q coil plus appropriately temperature stable, high Q capacitors.

2. Temperature Stable Inductors

Knowing that I'm venturing into a topic of great debate and lore, the inductor is 1/2 of the VFO resonator and thus a major source of temperature drift in L-C VFOs. Since MF and some HF VFO designs *may* preclude using the *inherently more temperature stable air wound inductor*, powdered iron toroids dominate our evermore compact designs. Many builders choose #6 material, although the lower temperature coefficient of #7 material theoretically should be better — however, my experiments have failed to measure a significant difference between these 2.

Some builders prefer size 68 inductors, for the bigger core is less affected by heating than smaller size toroids. My experience suggests that providing the VFO amplifier current is kept low, both size 50 and 68 are both suitable and the inductance needed should inform the core size.

I used to think that heavier gauge wire created greater frequency stability than smaller gauge wire until Wes, W7ZOI, woke me up. As it turns out, smaller gauge wire is often better for thermal stability because smaller gauge wire lies closer against the toroid core. Winding stiffer, heavier gauge wire creates more air gaps than smaller gauge wire and air gaps expand and contract during temperature changes. Smaller gauge wire will have a reduced Q, but it won't be as significantly lower as you might guess. As possible, I prefer tightly wound number 28 wire. 26 gauge wire tends to be my maximum size wire for VFO coils, however I suggest you make your own conclusions.

Wash your hands before winding and use both hands to actively move both the toroid and wire for tight turns. Take your time, ensure steady wire pressure and avoid kinking your wire. Taps increase the likelihood for air gaps — mitigate this by stripping the 2 tap forming wires as close to the toroid as possible and twist them into 1 wire right down tightly to the toroid edge to reduce any air gap.

The thermal stability characteristics of wire can be mitigated somewhat by annealing the wire with temperature cycling or by dunking it in boiling water. Roy, W7EL first reported annealing coils in 1980 and this has been confirmed during experiments by builders using temperature controlled ovens. I don't boil my coils any more.

3. Double Stacked Toroids

I noticed a new trend in VFO design is to stack 2 powdered iron toroid inductors. This allows the builder to double the inductance per number of windings over a single toroidal inductor. In an L-C VFO, the goal of these builders possibly is to reduce heating effects, increase unloaded Q, or perhaps to reduce core magnet flux density. For me the goal is far simpler, I just want to make compact, large L value inductors for 3 MHz and less.

Above — A T68-6 hamburger. The two T68-6 cores were epoxy glued together and compressed lightly in a vice for several hours. One of the initial tests I performed was to see if boiling the stacked coil affected the epoxy glue. The glue was not effected by annealing wire on a stacked coil with 5 or even 10 minutes of boiling in water. As mentioned, I stopped boiling my VFO inductors as tightly winding them with 26 gauge wire seems to work well.

I hold concern that stacked toroids may create more wire-air gaps when compared to a single toroid and stay with 1 toroid as possible. In compact antenna tuners and other non VFO projects, this isn't an issue.

4. VFO Tank Capacitors

We choose VFO tank capacitors to avoid temperature change caused frequency drift, or to counter drift during our temperature compensation process.

Many authors have published guidelines for long term temperature stability. It's important to consider these guidelines, but also try whatever works. I believe the following arguments are accurate based upon my experiments:

1. Multiple NP0 or C0G (0 temperature-compensation) tank caps: Most builders minimally use 4 or more C0G or NPO capacitors to reduce heating effects and to average out temperature coefficient variations.

2. No VFO tank capacitors from online surplus parts stores; buy new stock from known and reputable manufacturers. Grab bags and musty, old, surplus parts can obviate good design.

3. Trimmer and tuning caps need to be temperature stable. Air variable capacitors = my favorite, as possible.

4. Varactor, or diode tuning generally = more drift and a greater need for temperature compensation.

5. Employ short, stiff capacitor leads. I use 100 volt or higher voltage C0G tank caps as they tend to have thicker leads that stay put — perfect for Ugly, Manhattan, or Chuck Adam's MUPPET construction.

5. Temperature Compensation

The goal of temperature compensation is to cancel the tendency of the VFO to drift in 1 direction — easier said than done + very time consuming. A web search for VFO temperature compensation will yield many good write-ups. I feel it's partly art, partly luck and partly science. Your net VFO temperature coefficient can be affected by so many variables, so no 1 recipe will ensure a low drift VFO. Experiment, allow a lot of time to assess your changes and be patient — you'll figure it out.

The simplest way to test for drift involves watching a frequency counter, but if you don't have one, you might use a commercial, frequency stable (synthesized) receiver set in the SSB/CW mode. I use both. Experienced builders often employ an oven to test their temperature compensation at different, controlled temperatures. Wes, W7ZOI employs a styrofoam cooler housing a light bulb heat source controlled by a Variac. See EMRFD for more details and a photograph.

In 2011, I decided to build up a supply of temperature compensation capacitors and keep them in their own parts bin.

TEMPCO
CAPS

Above — "Tempco caps". A parts drawer containing polystyrene capacitors from 10 to 270 pF plus some 56 pF ceramic N750 capacitors for negative temperature compensation. I purchased these capacitors on eBay.

For capacitors other than NP0 (which use 0 instead of a ppm value), the temperature coefficient = **P** for positive and **N** for negative, followed by a 3-digit value specifying ppm/°C. For example, N220 is - 200 ppm/°C. and P100 is +100 ppm/°C.

I use NP0 and C0G ceramic capacitors interchangeably for both tuning and RF bypassing the VFO tank resonator. For C0G/NP0 *temperature compensation bypass*, I normally apply 0.01 or 0.001 μF caps, however, the more expensive 0.1 μF COG ceramic capacitors are still sold if you need C0G/NP0 bypass <= 7 MHz.

If your VFO is drifting upward you might insert 1 or more positive coefficient capacitor(s). If your VFO drifts downward, then try using negative coefficient value(s). Sometimes just 1 capacitor will do the job.

Since I don't stock any positive coefficient capacitors for positive coefficient compensation, I might try a adding a silver mica capacitor. ***Caution*** silver mica capacitors are extremely non-predictable and can't be universally recommended in temperature compensation schemes. You might also try swapping out 1 or more of your main tank NP0 or C0G capacitors in case they are bad; sometimes it gets frustrating. I provide some temperature compensation examples on the QRP Modules 2011 web page in the 7 MHz VCO section.

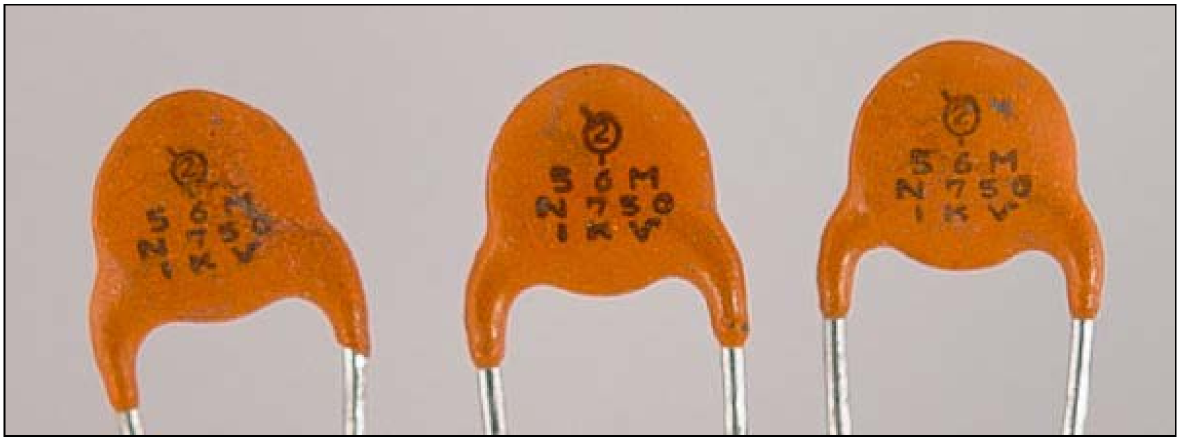

Above — 56 pF N750 ceramic capacitors rated at 1KV

6. Mechanical Rigidity

Movement of your VFO tank parts may lead to frequency instability. For example,

1. Well secure your single-sided only copper board. I use at least 4 number 8 bolts — 4-40 hardware is too light. Boards can warp over time if not lashed down properly. Aggressively bolt down any variable capacitors. No tank parts should move.

2. Anchor your inductor so it cannot budge: nylon bolts, zap-straps, glue - whatever.

3. Consider placing the VFO in a strong chassis with rubber feet.

4. Buss wires should be made from thicker gauge, well anchored wire.

7. Miscellaneous Points

1. Regulate the VFO amplifier DC voltage and wideband filter it. Voltage regulators require RF and often AF bypass to attenuate any noise or ripple riding on the DC.

> A decoupling resistor with a bypass cap on either side will widen your DC supply filtering bandwidth and deserves strong consideration. A poorly filtered DC supply can easily transmit the VFO tank energy to other stages along your DC lines and also may allow noise on the DC supply to modulate your VFO and increase phase noise.

2. You should have the buffer + a load resistor connected to your VFO when testing. **Do your temperature stability work after the buffer is built and the VFO is in its case.**

3.Stick your VFOs in an air tight, RF tight case to minimize air temperature changes and RF leakage respectively. Sometimes a VFO will drift once in a case because any radiated buffer amplifier heat will warm up the inside of the chassis. This usually levels off after warm up.

4. Modern voltage regulators may significantly reduce noise compared to a zener diode regulator. Specific low noise and low temperature coefficient voltage regulators are available, but maybe overkill for you. Whatever you use — filter it well —
The Micrel MIC5209-5.0BS in SOT223 sits in a couple of my reference oscillators.

5. JFET Gate clamping diodes may increase phase noise, but not prohibitively so in most popcorn designs.

6. When winding toroid inductors, wind 2 extra turns. When finished, unwind the first 2 turns since they are usually loosely wound and prime culprits for air gaps.

7. Since magnet wire comes off small spools, wire has a natural curve or radius — ensure you wind your coils according to the natural curve of the wire.

8. The need to secure powdered iron windings with dope, wax, goop, etc. is over-emphasized and usually unnecessary.

---

2. Vackar VFO Experiments

Some builders proclaim the Vackar as the "King of VFOs". I built a couple and became impressed by the low distortion and less than 5 Hertz per hour long-term drift achieved in my 2 designs. Inspired by work from Iulian, YO3DAC entitled Very Low Phase Noise Vackar VFO for HF Transceivers *(link and reference used by permission of Iulian)*, I crafted my version from his notes and schematic.

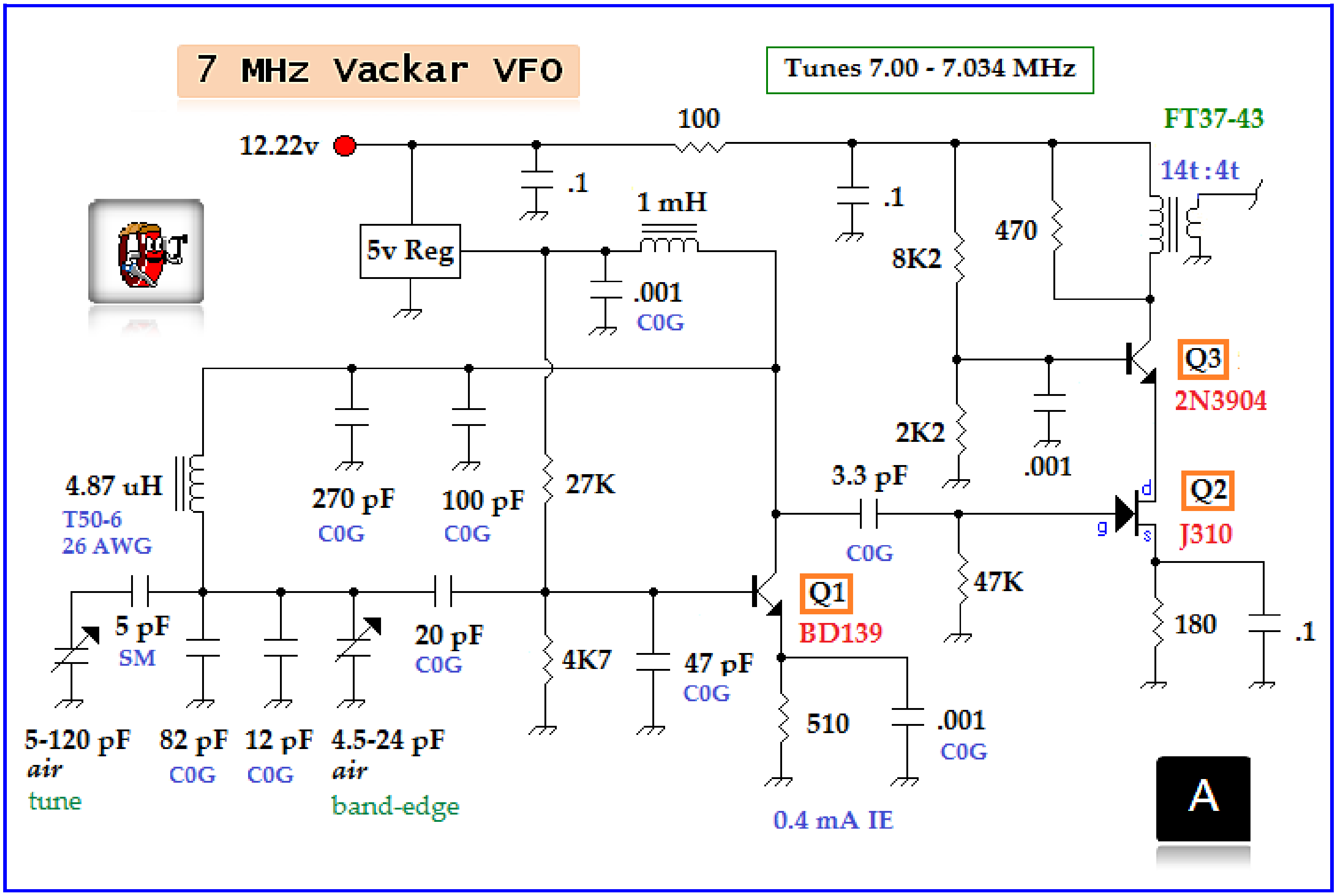
7 MHz Vackar VFO
Tunes 7.00 - 7.034 MHz
12.22v
100
FT37-43
14t : 4t
.1
1 mH
.1
5v Reg
470
8K2
.001
C0G
Q3
2N3904
4.87 uH
T50-6
26 AWG
270 pF
C0G
100 pF
C0G
27K
2K2
.001
3.3 pF
C0G
Q2
J310
d
g
s
47K
5 pF
SM
20 pF
C0G
4K7
47 pF
C0G
Q1
BD139
180
.1
510
.001
C0G
5-120 pF
air
tune
82 pF
C0G
12 pF
C0G
4.5-24 pF
air
band-edge
0.4 mA IE
A

Above — Schematic of the Vackar VFO employing a BD139 — a large area transistor, to reduce 1/f noise. Iulian shared many design pearls in his paper and I won't repeat them. I ran Q1 with 0.4 mA emitter current to reduce heating and flicker noise. It's difficult to measure flicker noise, so no objective comments can be made.

I limited the tuning range to 34 KHz since the tuning capacitor lacked reduction gear and I was born with fumble fingers. As a CW operator - you'll find me down at the bottom of the band away from the RRTY anyhow. Increasing the 5 pF cap coupling the tuning capacitor to the tank increases the tuning range as expected.

Temperature compensating my VFO with the 5 pF silver mica capacitor proved a gamble since SM caps are unpredictable and often best avoided. In *my* VFO, it worked perfectly, however. This circuit is difficult to replicate and *not recommended* for new builders. Temperature compensation provided the sublime frequency stability.

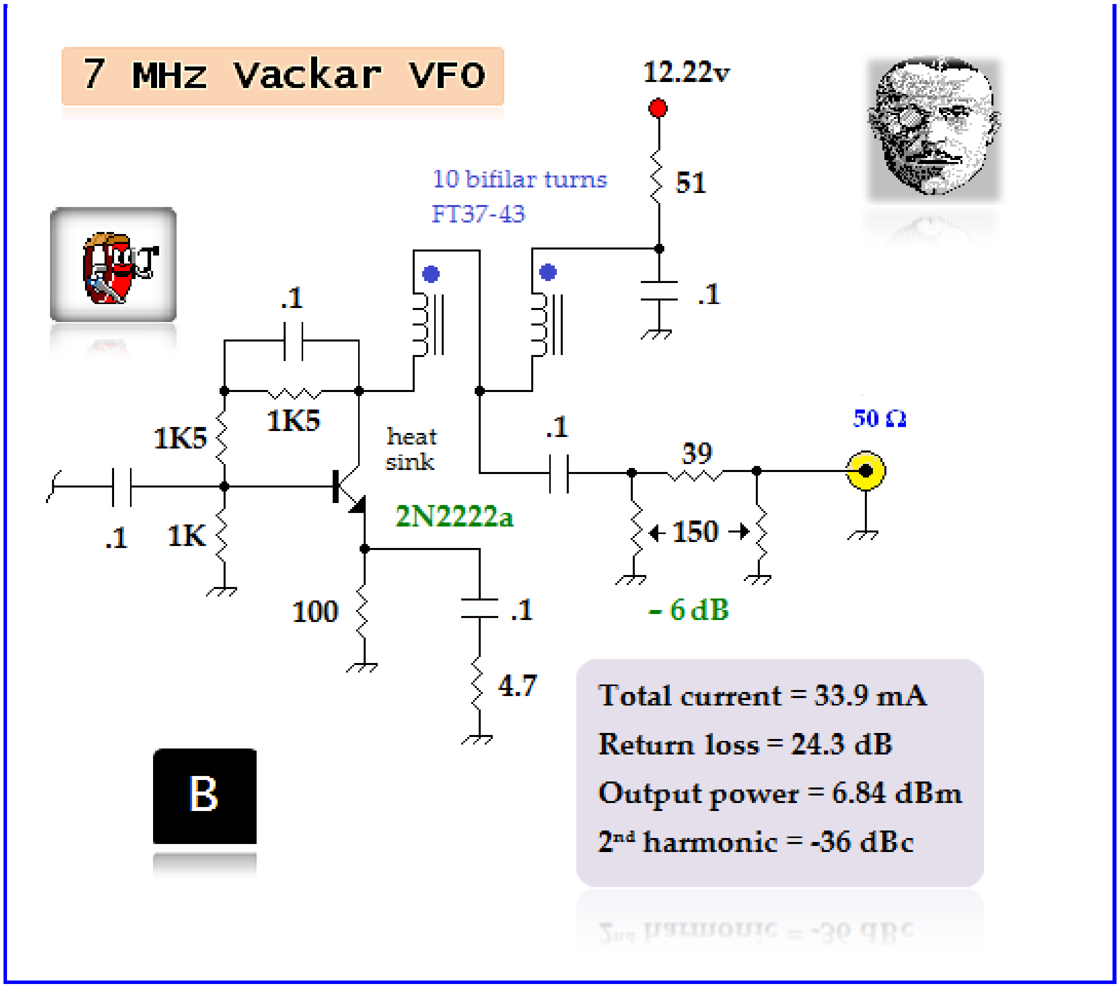
7 MHz Vackar VFO
12.22v
51
10 bifilar turns
FT37-43
.1
.1
1K5
1K5
heat
sink
.1
39
50 Ω
.1
1K
2N2222a
150
100
.1
- 6 dB
4.7
B
Total current = 33.9 mA
Return loss = 24.3 dB
Output power = 6.84 dBm
2nd harmonic = -36 dBc

Above — The final amp and measured output data. Measuring the 2nd harmonic 36 dB down without any tuned circuit or low-pass filter rocked. I ran nearly 22 mA of emitter current to bump up the return loss and spectral purity. A 2N5109 or 2N3866 would likely do a better job with less current. Total current = the entire VFO current. I glued a drilled copper penny on the 2N2222 to dissipate heat.

A photo of my version of a Vackar VFO. My design goals included low phase noise, low distortion, a return loss over 20 dB, good reverse isolation and ~7 dBm output power. I believe all VFOs are experimental; you build to suit whatever tuning capacitor or varactors you have, plus design around constraints such as total current, tuning range and other personal criteria.

Unlike harmonic distortion, oscillator phase noise, being close to the oscillation frequency, cannot be removed by filtering nor limiting — you must design for low phase noise. Modern digital VFOs are well harmonically filtered, and any phase noise depends on the DDS clock employed, so check the DDS specifications carefully if you go the DDS VFO route.

I'll be the first to state I'm no expert with VFOs, however, likely the only way to become expert is to build many and learn from your mistakes.

Above — A 7 MHz Vackar VFO with the lid off

Sound Test?

Although this technique raises the ire of some builders, I test my VFOs in a nearby receiver. The VFO output was terminated with a 51 ohm resistor that was also attached to my frequency counter via alligator clips and wire. I tuned a nearby CW superheterodyne receiver to 7.00 MHz with the audio beat note centered in its 600 hertz wide I.F. filter and watched the counter plus listened to the receiver.

Click for a 1 minute 32 second audio file of the result (it stayed perfectly on frequency for ~5 hours of testing before I got a bad headache from listening to it and shut it off). *You can initially hear a station in the back ground despite only having a 45 cm piece of wire as the receiver antenna.* The VFO slowly drifts down to 6999996 Hz and then slowly back up to 7000000 Hz. You can hear the signal amplitude decrease as the VFO drifts down. So it doesn't stay perfectly on frequency, but slowly cycles up and down a few hertz. This VFO is my lab temperature stability benchmark for an L-C VFO.

A badly drifting VFO will move out of the test receiver I.F. pass band and sound like a Theremin as it does. Testing in a receiver; places the VFO in the exact circumstance it will be used — beating RF to mix to another frequency; in this case, base band audio.

The temperature stability and compensation of any VFO schematic are rarely reproducible since there are just too many variables. Try your best to get the drift out of your VFO using low temperature coefficient capacitors (NP0/C0G) and then after that, temperature compensate. Even today, I occasionally build a drift monster VFO and become frustrated. VFO design is not for the faint of heart and it's no wonder that many builders make a VXO, or cave in and build or buy a DDS signal generator.

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3. HF Signal Generator

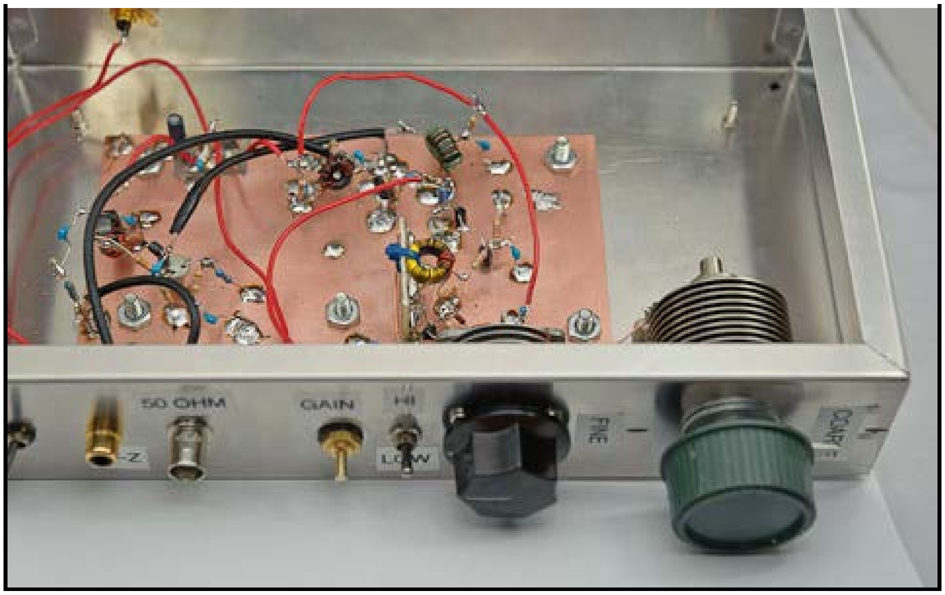

Above — I built a general purpose ~2.8 to 10.8 MHz signal generator (SG) for my lab in 2011. The first VFO topology tested was the Vackar. In my version, while employing a 100K ohm resistor as the buffer, the VFO only tuned from about 4 to 8 MHz and suffered from *extreme* amplitude variation as I changed the frequency across its range. For sweeping filters or measuring Q, a signal leveling circuit would be needed as normally we like our SG output to be flat across its frequency range. I later changed to a Hartley VFO because of its flatter output and the wider available frequency range with any given resonator.

This initial Vackar VFO experiment wasn't a total waste as I learned a way to accurately sweep a **D**evice **U**nder **T**est with an unlevel amplitude SG. Measure the peak-peak voltages of the DUT with a signal generator and an oscilloscope in the same manner we measure insertion loss or gain in a 50 ohm system: Measure the peak-to-peak voltage with the DUT in line; disconnect the DUT, insert a barrel connector and then re-measure.

The dBm difference between the 2 becomes the dB value to plot for *that* frequency. To a sweep a filter, say for example, a band-pass filter, find the center frequency and then sweep below and above that CF while plotting the dB versus frequency.
This "in and thorough" measurement described takes time, but resolves any frequency versus amplitude issues and can be used to test signal generators. We tend to ignore things like cable loss versus frequency and scope or spectrum analyzer ripple.

Still, it will be easier to just use a Hartley VFO where our sweeps are assumed to be level due to the flatness of the amplitude versus frequency for **small excursions** such as 3 dB band-pass filter sweeps. Do not expect amplitude flatness over wide excursions however — this requires additional circuitry.

To reduce noise and boost fidelity, this SG runs modest current and was not designed for battery use.

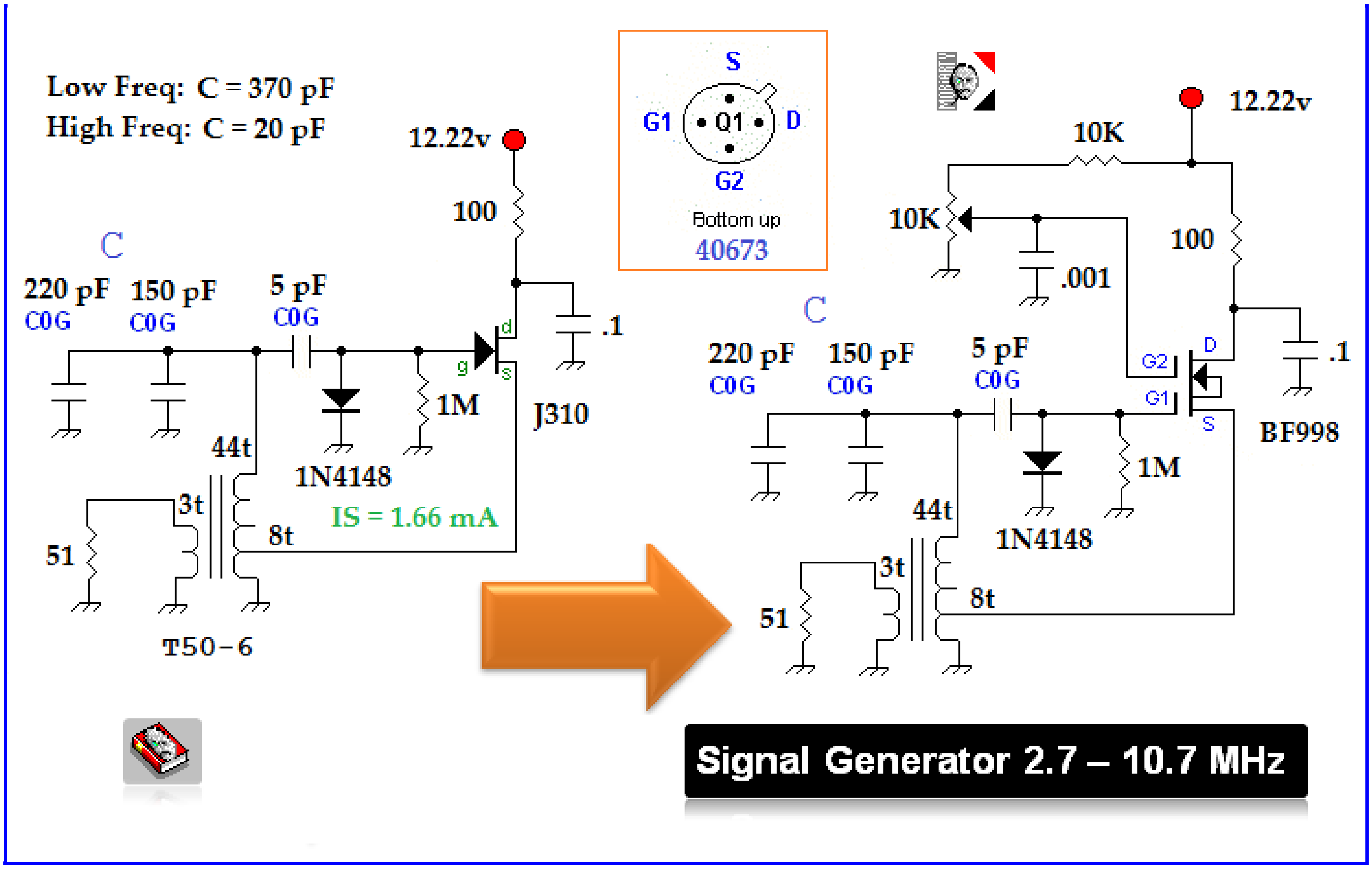
Low Freq: C = 370 pF
High Freq: C = 20 pF
12.22v
100
C
220 pF
C0G
150 pF
C0G
5 pF
C0G
d
g
s
.1
1M
J310
44t
1N4148
3t
IS = 1.66 mA
8t
51
T50-6
S
G1
Q1
D
G2
Bottom up
40673
12.22v
10K
10K
.001
100
C
220 pF
C0G
150 pF
C0G
5 pF
C0G
G2
D
G1
S
.1
BF998
1M
44t
1N4148
3t
8t
51
Signal Generator 2.7 – 10.7 MHz

Above — My Hartley VFO is morphed into a double-gate MOSFET VFO; this was a mistake and I make lots of them.

When venturing out, it's often best to confirm a proven design is working before morphing it to something untried. Shown above left is the Hartley oscillator from EMRFD Chapter 7 sans buffer. Fixed "tuning" capacitors; either 20 pF (not shown) or 370 pF (150 pF + 220 pF) represent the intended high and low frequency swing of my air variable tuning capacitors.

I wanted a variable amplitude VFO and thus replaced the JFET with a double-gate MOSFET using a simple variable voltage divider to control gate 2. I showed this to Wes, W7ZOI and he informed me that the flicker noise of MOSFETs precludes their use in oscillators. I have always wondered why I've never seen MOSFET VFOs in any radio literature.

Above — My project chassis fitted with hardware. I employed 2 air variable tuning capacitors — the fine tuning capacitor ranges 13.6 to 27.5 pF, features built in 6:1 reduction gear and was purchased from Doug DeMaw many years ago. I secured the main copper board with 6 number 8 bolts. Rubber feet provide a stable, shock resistant base for the sheet metal box.

Final Build

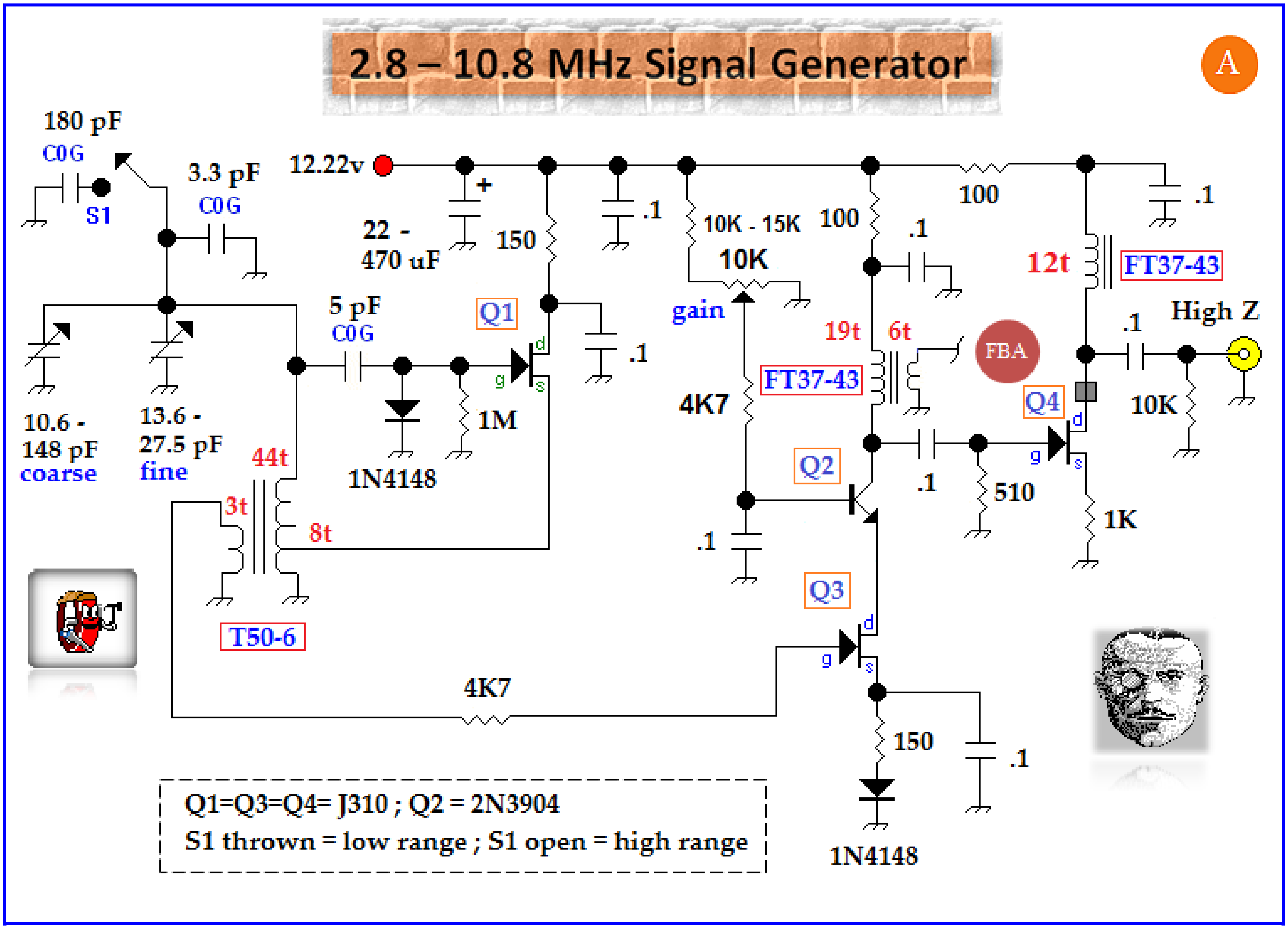
2.8 – 10.8 MHz Signal Generator
A
180 pF
C0G
S1
3.3 pF
C0G
12.22v
+
22 -
470 uF
150
.1
10K - 15K
100
100
.1
.1
12t
FT37-43
10K
gain
5 pF
C0G
Q1
d
g
s
.1
19t
6t
FBA
High Z
.1
10.6 -
148 pF
coarse
13.6 -
27.5 pF
fine
1M
4K7
FT37-43
Q4
d
10K
1N4148
44t
Q2
g
s
.1
510
1K
3t
8t
.1
Q3
T50-6
d
g
s
4K7
150
.1
Q1=Q3=Q4= J310 ; Q2 = 2N3904
S1 thrown = low range ; S1 open = high range
1N4148

Above — Oscillator + buffer schematics of the latest version of my signal generator. I spent 1 evening playing with VFO designs and settled on the simple Hartley from EMRFD, Figure 7 .27. The 3 turn link provided lower distortion than coupling the oscillator to its buffer by the JFET source or gate.

Regulated 12.2 VDC powers the oscillator; avoiding the typical 5-9 VDC voltage regulator we normally use. A 22 to 470 μF cap should be employed to filter any voltage regulator noise from our DC supply. Mine has a 470 μF capacitor.

1 hour drift lies under 40 Hertz when averaged from 15 different frequency points between minimum and maximum. The Q2/Q3, Q4 and Q5 transformer inductances were optimized to allow good signal and/or matching performance in the ~ 2.5 to 10.8 MHz frequency range.

A hybrid cascode (hycas) buffer with variable base bias on Q2 forms the amplitude control for both the high impedance and low impedance outputs. The 510 ohm gate resistance on Q4 terminates the hycas amplifier and sets up a known output impedance to drive the 50 ohm feedback amp. I measured a greater than 22 dB return loss on the output of the 19:6 turn transformer from 4 to 14 MHz — indicating it drives the feedback amp reasonably well.

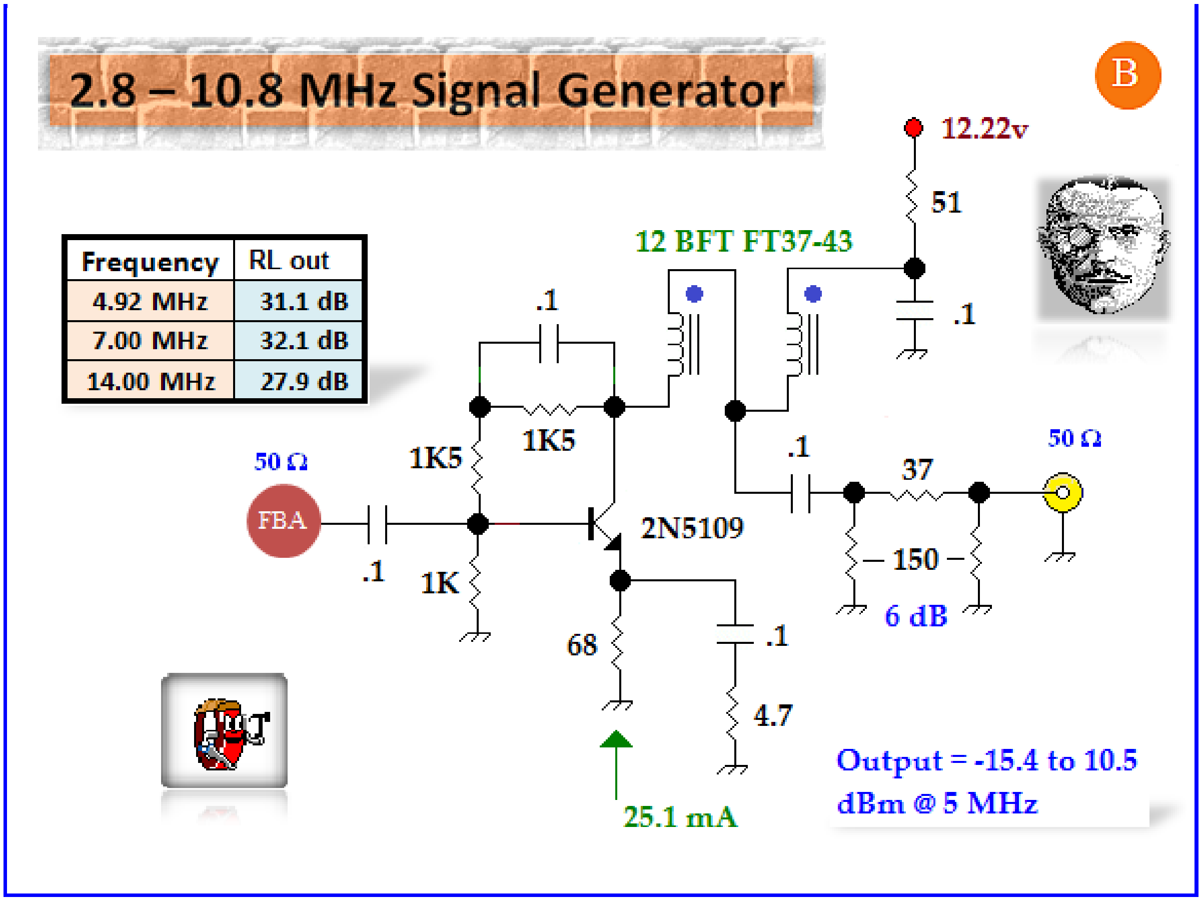
2.8 – 10.8 MHz Signal Generator
B
12.22v
51
12 BFT FT37-43
.1
.1
1K5
1K5
50 Ω
FBA
.1
1K
2N5109
68
.1
4.7
.1
37
50 Ω
150
6 dB
25.1 mA
Output = -15.4 to 10.5 dBm @ 5 MHz

Frequency	RL out
4.92 MHz	31.1 dB
7.00 MHz	32.1 dB
14.00 MHz	27.9 dB

Above — The 50 ohm impedance feedback amp. Running 25.1 mA current allowed a clean sine wave output up to 2.12 volts-peak to peak into a 50 Ω terminated oscilloscope, plus an output return loss of over 30 dB across the SG tuning range. 3 tabled output return loss measurements are shown; including an out-of-range 14 MHz measurement.

Two series resistors made up the 37 ohm "resistor" depicted in the 6 dB pad, although a 39 Ω resistor would work fine.

At low output amplitudes, I typically stick an external 6, 10 or 20 dB attenuator on the output since the hycas amp can distort the signal a little when the gain control is set to a really low bias voltage on Q2. Then I fine tune the output power with the gain control.

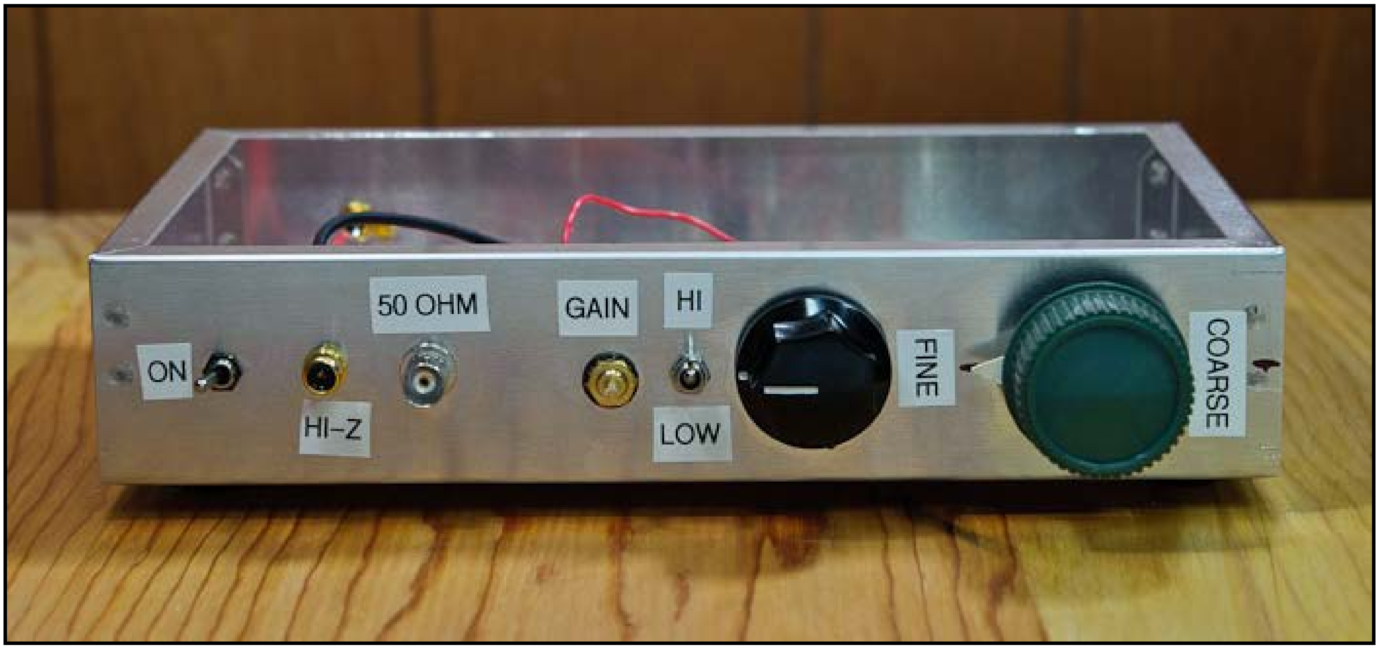
ON
HI–Z
50 OHM
GAIN
HI
LOW
FINE
COARSE

Above — A "lid off" front panel photograph. Click or click for other photos. I'm now using miniature pots with a shaft diameter of 3.18mm. The potentiometer shaft lacks a knob and I'll purchase some on my next parts order.

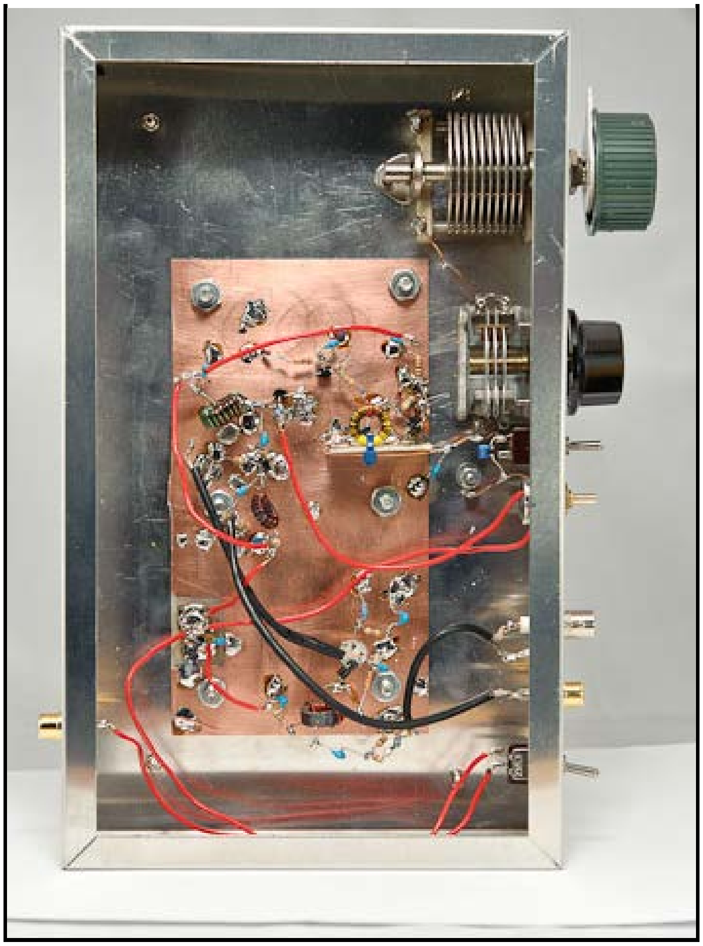

Above — The completed signal generator.

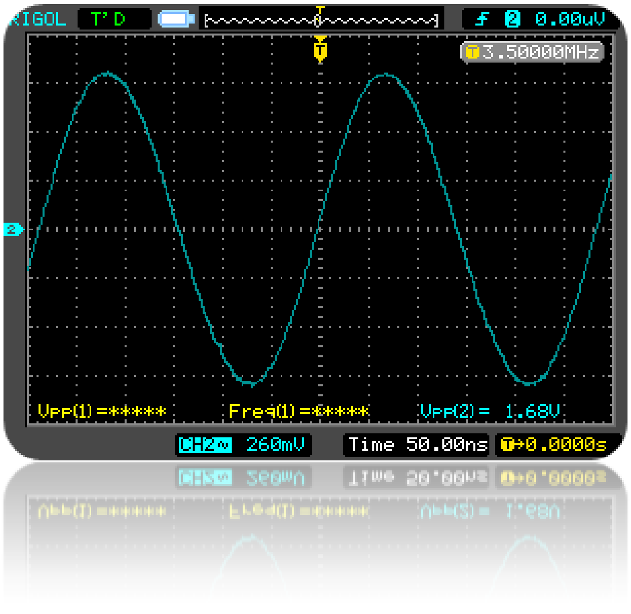
IGOL
T'D
2 0.00uV
T 3.50000MHz
2
Vpp(1)=*****
Freq(1)=*****
Vpp(2)= 1.68V
CH2 260mV
Time 50.00ns
T→0.0000s

Above — Signal generator output at 3.5 MHz.

I appreciate that the VFO tank would be difficult to replicate since the 2 air variable capacitors are unique, however this is true of most VFOs. Wes wrote some great notes in EMRFD Chapter 7 regarding copying signal generators and the versatility of the Hartley VFO. I hope this project furnishes some ideas that spawn you to build something better than I did. *(I've received over 350 related emails since posting this page in 2011* *and many readers have built really great VFOs — Way To Go !)*

QRP — PosData for December 17, 2013

I slightly boosted the tuning range from 2.8 to 10.8 MHz by dropping the 5 pF resonator capacitor to 3.3 pF in October 2013. The schematics now reflect this changes plus clarify 1-2 stumbling blocks readers had. For example: my use of a 100K gain pot plus a 150K maximum voltage limiting for the Q2 bias. My build still has these, however, I altered the schematic to show a common 10K gain pot, plus a fixed 10 to 15K resistor used to limit the Q2 bias to between 5 and 6 VDC maximum.

In reality, any reasonable pot and resistor will do since they function as simple voltage dividers. With a 12 volt supply, we don't want to drive the Q2 bias with more than ~ 5 to 6 VDC since this will just distort the AC signal as the hycas stage saturates. Measuring with a voltmeter, solder either a 10K, 12K, or 15K resistor to limit the maximum Q2 bias with the 10K potentiometer turned fully clockwise.

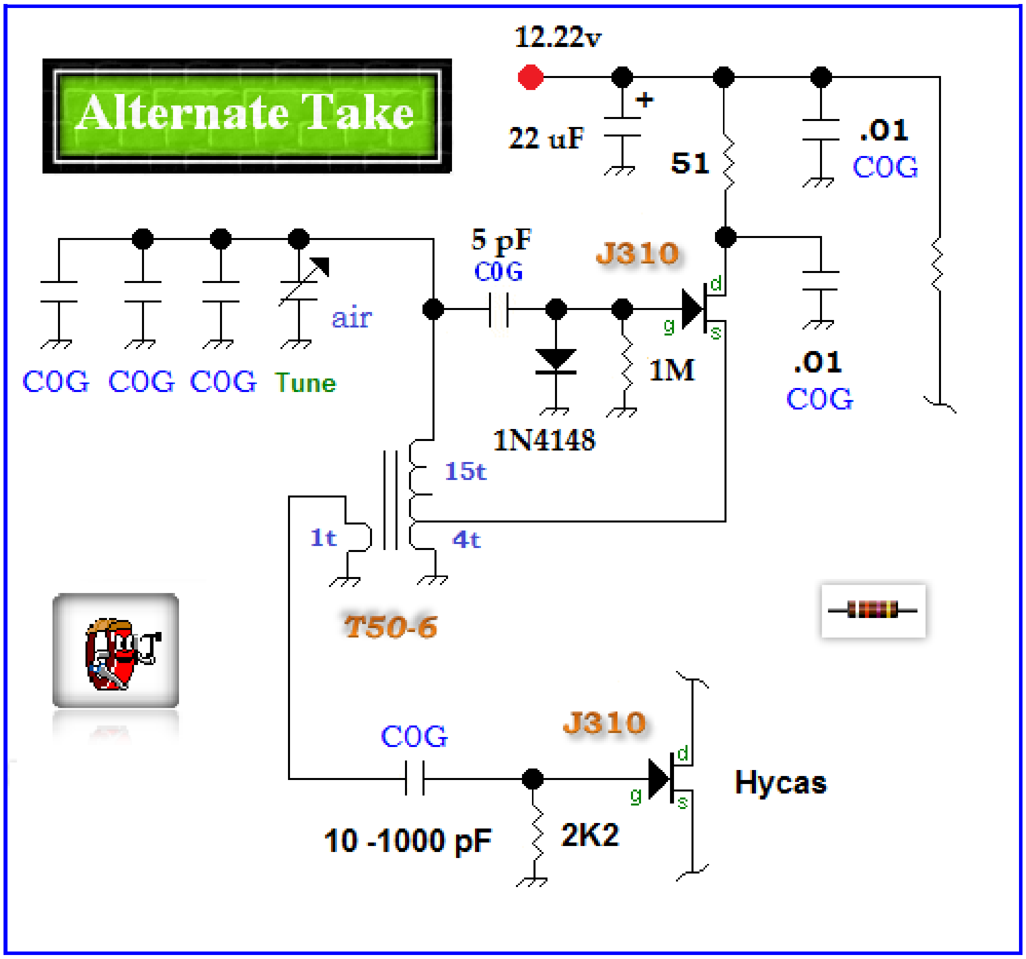

Above — Alternate way to couple the Hartley oscillator to the hycas buffer. Ground the JFET gate with a shunt resistor and lightly AC couple the JFET gate to the Hartley secondary coil with a series capacitor. You choose the capacitor value to limit the signal amplitude as needed. Our main goals are to lightly couple the Hartley tank to its buffer and avoid overdriving the hycas stage. Numerous examples of this "Alternate Take" circuit may be found on the QRP / SWL HomeBuilder web site.

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4. Miscellaneous Bits

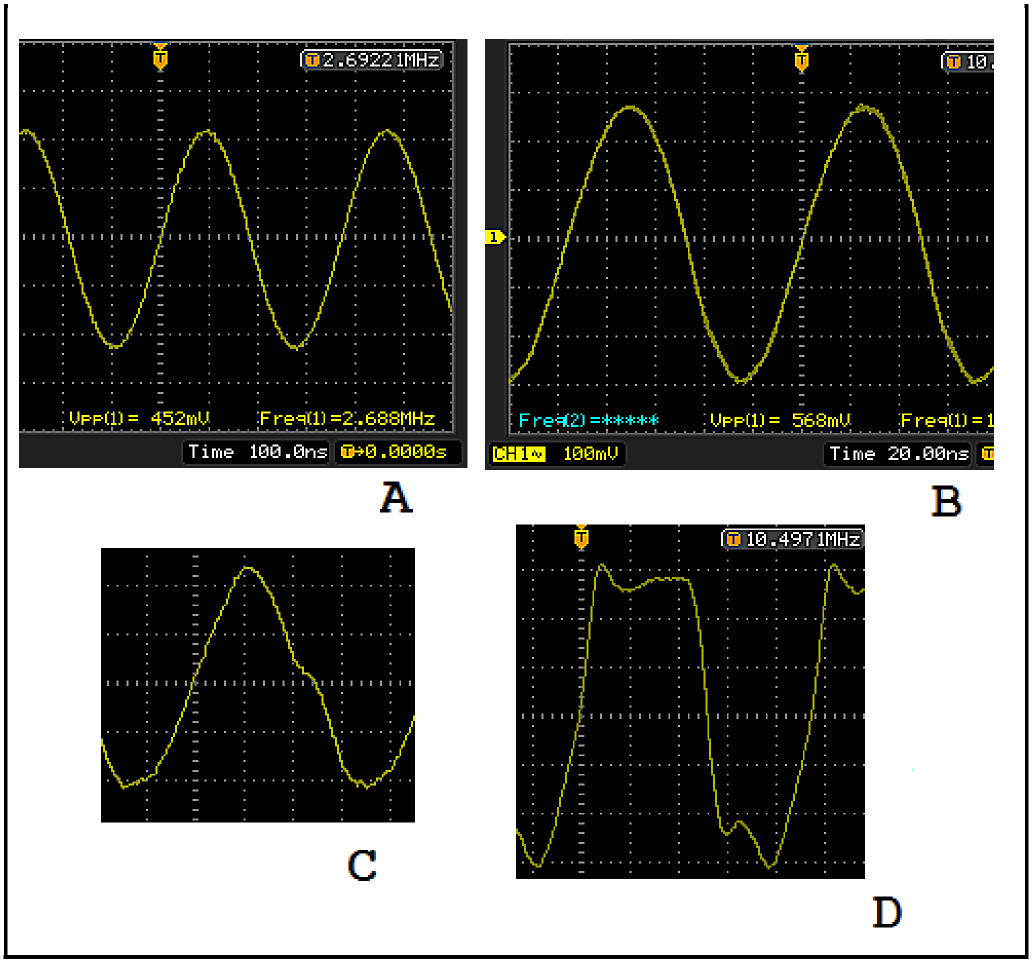
T 2.69221MHz
Vpp(1)= 452mV
Freq(1)=2.688MHz
Time 100.0ns
T→0.0000s
A
T 10.
1
Freq(2)=*****
Vpp(1)= 568mV
Freq(1)=1
CH1 100mV
Time 20.00ns
B
C
T 10.4971MHz
D

Above — Scope traces of an unbuffered Hartley oscillator with a X10 scope probe across a 51 ohm resistor across the 3 turn link. The unbuffered Hartley sine wave isn't harmonic free, but cleans up when properly buffered with a higher impedance amplifier. Figure A = the lowest frequency (2.7 MHz) — the distortion increased with frequency (Figure B was measured at 10.5 MHz). Figure C illustrates how slightly stronger output coupling with a 6 turn link trashes the output waveform — the strategy of using 2-3 links over the center of the main inductor works well.

Figure D is the 6 link coupled Figure C oscillator with the gate clamping diode removed; yikes! I spent 4 hours studying what different current, voltages, coupling and so forth do to the Harley oscillator. I recommend the Hartley topology because it's simple, always starts and versatile.

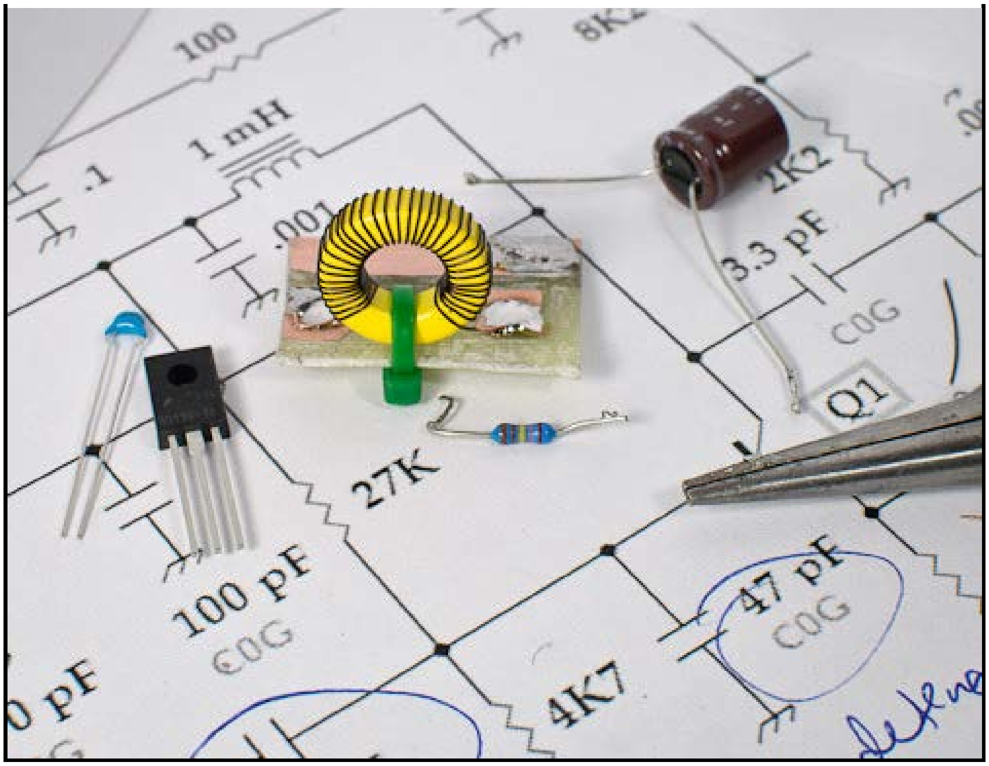
100
8K2
1 mH
.1
.001
2K2
3.3 pF
C0G
Q1
27K
100 pF
C0G
0 pF
4K7
47 pF
C0G

Above — In my various signal generator experiments, I zap strapped the toroid to a small piece of thick copper board that was later soldered to the main board. The L seems robustly secured.

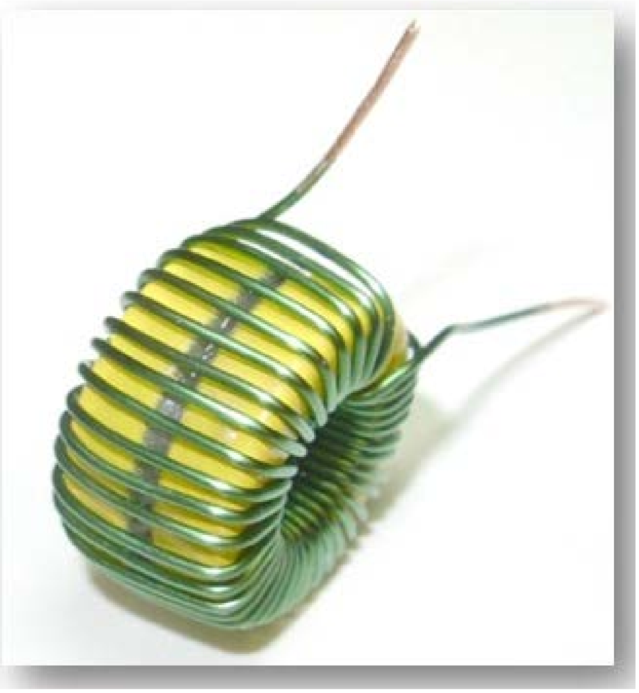

Above — A stacked toroid from the deleted VFO-2008 web page. I incorporated some of the information from the VFO-2008 page into this web page

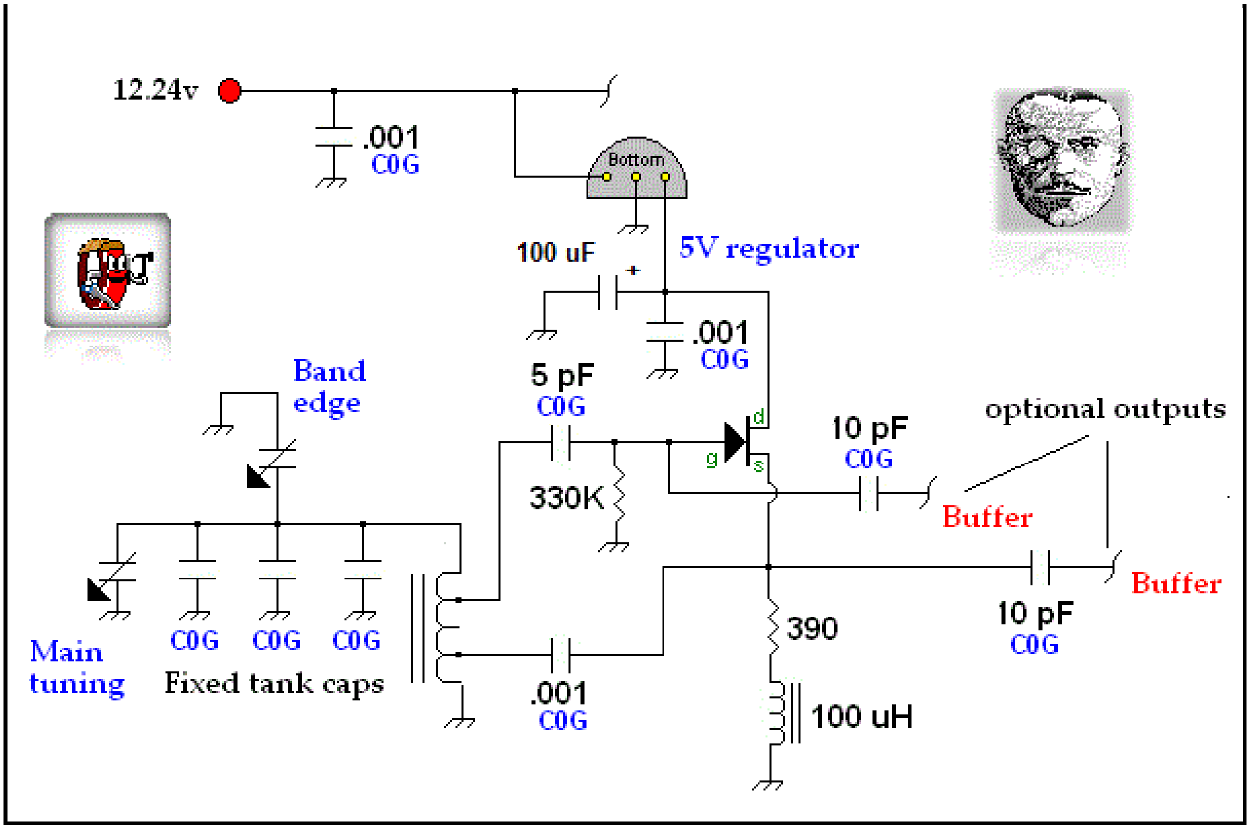
12.24v
.001
C0G
Bottom
100 uF
5V regulator
.001
C0G
Band
edge
5 pF
C0G
d
g
s
10 pF
C0G
optional outputs
330K
Buffer
Buffer
390
10 pF
C0G
Main
tuning
C0G
C0G
C0G
Fixed tank caps
.001
C0G
100 uH

Above — In order of preference, 3 ways to couple a Hartley oscillator to its buffer. From now on, I'll couple with a 1-3 turn link since it gave a lower distortion signal than with source or gate coupling. This figure omits the gate clamping diode seen earlier— tapping the inductor as shown keepings the FET gate AC voltage at a reasonable level when not using a gate clamping diode. Some builders leave off the gate clamp diode that clips positive signal peaks for lower phase noise. The diode acts as an AGC and offers benefit. Reverse biasing this diode was suggested by Dr. Ulrich Rohde: see — Key Components of Modern Receiver Design - Part 2: Dr. Ulrich Rohde, KA2WEU , QST for June 1994.

A formula to use for the inductor taps: Divide the total turns by 1.45 to get the first tap and by 7.25 to get the second tap (near ground link).

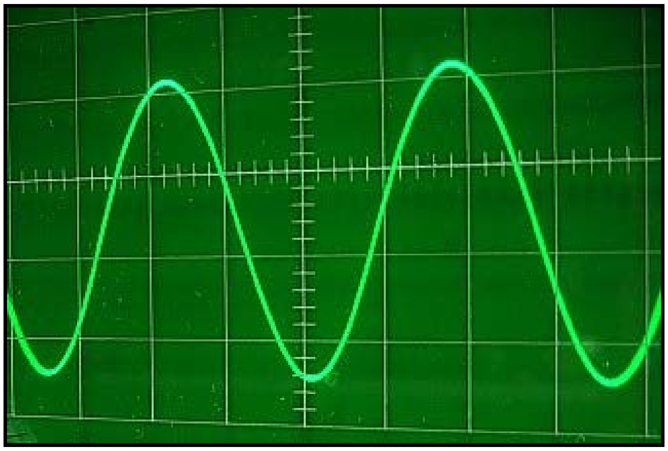

Enjoy your VFO experiments.

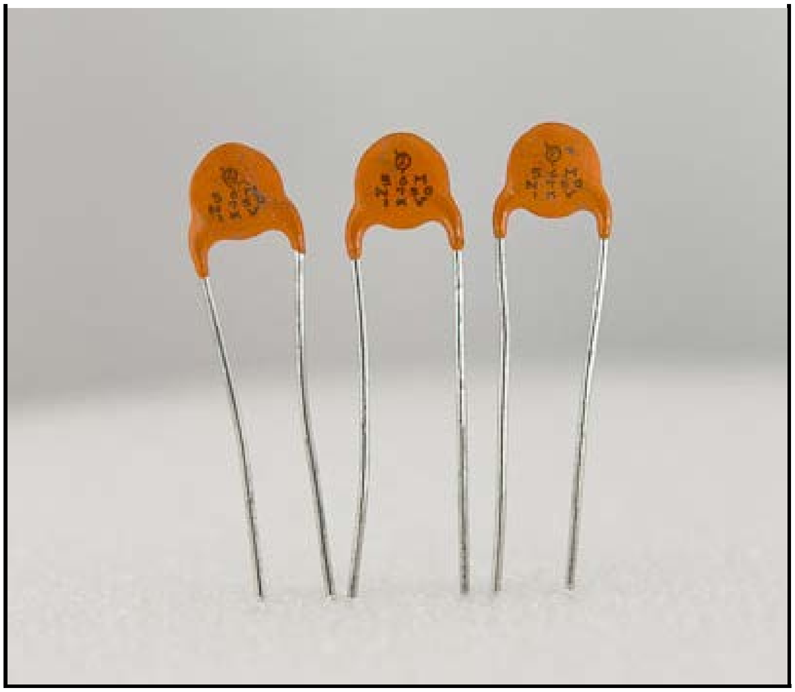

GAIN
HI
50 OHM
ON
HI-Z

QRP SWL HOMEBUILDER

RF — Test and Measurement

The Butler Did It ! - First VHF Experiments 2011

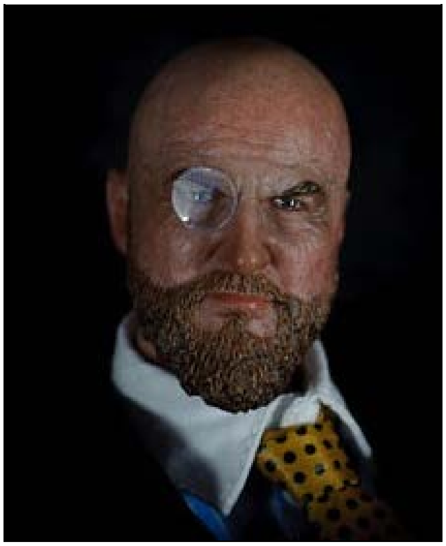

Venturing into VHF, I felt like a beginner with no experience or confidence — however, the excitement and allure of new parts and circuits kept me going.

After performing a literature review, talking to some colleagues and renovating my QRP work bench, my first tasks involved buying some VHF parts + exploring the Butler crystal oscillator. Specifically, I'll cover my experiences with the common base version of the Butler oscillator.

Like HF, the VHF knowledge base contains ever-present lore. Consider the Butler oscillator — I have read arguments stating that the emitter follower version of the Butler oscillattor is vastly superior to the common base version because the latter is prone to UHF and other spurs. These comments seem to have originated from a good book entitled Crystal Oscillator Circuits. *Revised Edition* by Robert J. Matthys published in 1992 by the Krieger Publishing Company.

While examining the schematics of professional/world class gear using a Butler, the common base version clearly dominates. Spectrum analysis and other measurements indicate that when common UHF oscillation management techniques are applied, common base Butler crystal oscillators work well.

Suppressing UHF oscillations with ferrite beads (and small value resistors), feedback, neutralization, limiting gain, etcetera are routine practices for us experimenters applying active devices that have strong gain into UHF on up. This is vanilla, or matter-of-fact construction for us; no worries. While fun and often convenient, lore ultimately stifles our progress.

Increasingly, I'm adopting the philosophy of Bob, K3NHI; "TMITK" — to measure is to know. Consider, too, you have to know what to measure and possess the required gear.

For BJTS, I purchased PN5179, MPSH10, 2SC3355, BF199, 2SC3357-RE, 2N5109/2N3866 and NE46134. The PNP part = MPSH81.

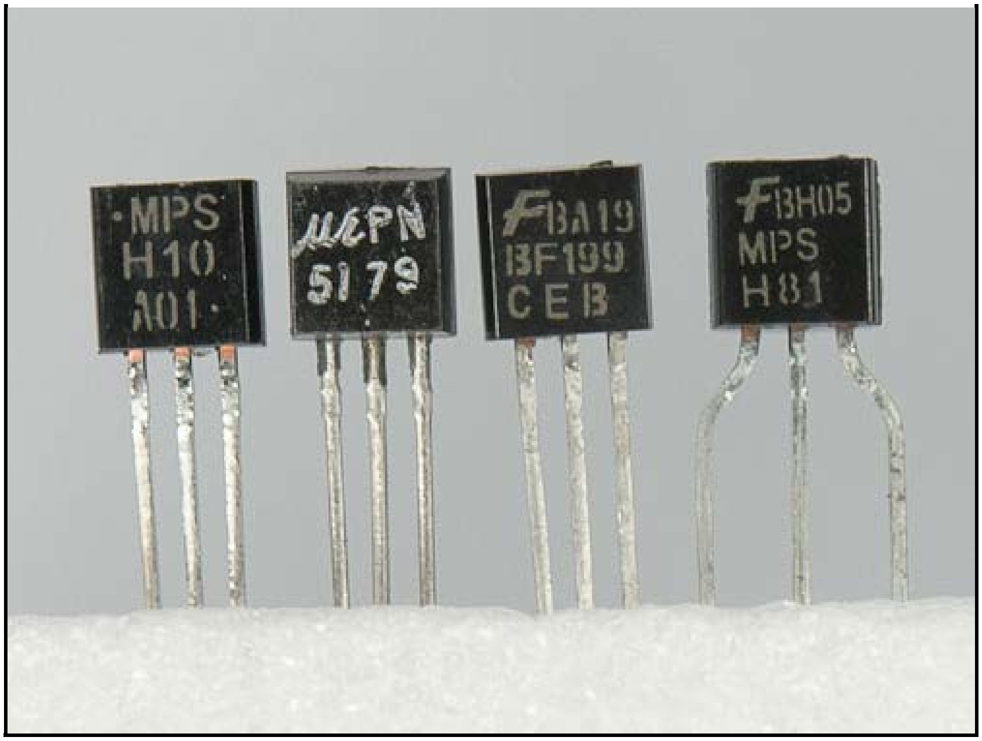

For JFETs, the J310 in TO-92 and SMT will remain my workhorse FET part along with a couple of other *low noise* JFETs and 2-gate MOSFETs. At VHF, the noise figure in a receiver chain is established by the first amplifier so a low noise preamp ranks important.

A collection of 100 volt NP0 capacitors ranging from 1 pF to 22 pF were added along with some chip and SMT caps as low as 0.5 pF. You might need a few air trimmer capacitors with a minimum capacitance ~ 2 pf — I applied 2 - 20 pF trimmer capacitors in most of the circuits that follow.

1. Experiments with a Butler Oscillator with a 23.3 MHz Fundamental Crystal

Fundamental Frequency

Long ago, I pulled a crystal marked 70.00000 MHz from a Drake Transmitter. I keep a fundamental oscillator based upon EMRFD Figure 4.23 on hand and verifed the fundamental frrequency at 23.3 MHz.

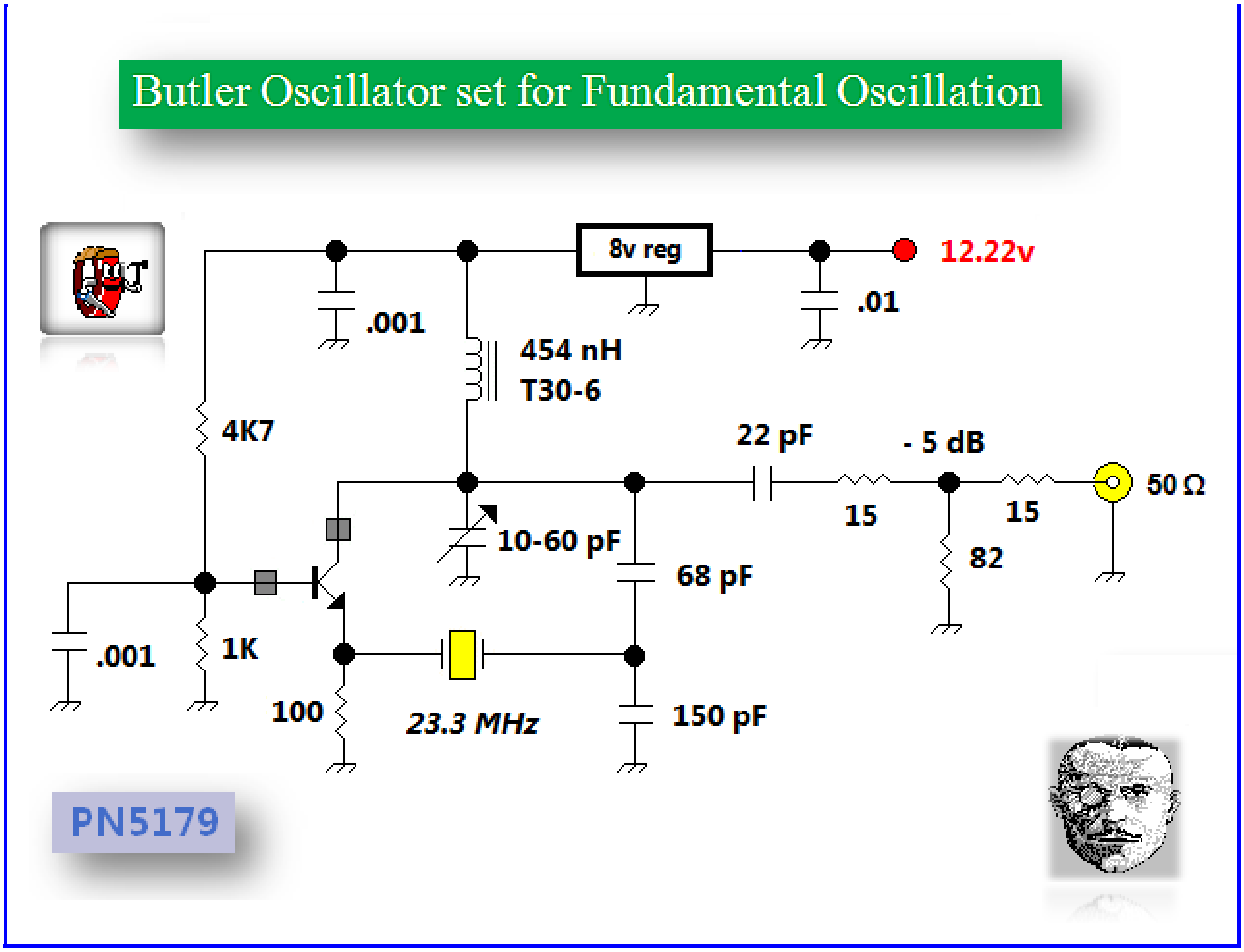
Butler Oscillator set for Fundamental Oscillation
8v reg
12.22v
.001
.01
454 nH
T30-6
4K7
22 pF
- 5 dB
15
15
50 Ω
10-60 pF
68 pF
82
.001
1K
100
23.3 MHz
150 pF
PN5179

Above — A Butler oscillator arranged for output at the fundamental crystal frequency. While commonly arranged as an overtone oscillator, the Butler is a good oscillator for any application. Consider, for example, EMRFD Figure 7.32. Wes applied the Butler at a 14 MHz fundamental because he wanted the lowest phase noise and IMD prone signal source possible. Tellingly, his buffer circuitry also conforms to this high standard.

My initial waveform looked distorted and prompted a solution. My experience yields that the L value needs to be adjusted for the best looking waveform in the Butler circuit. The inductor wire, wrapped around a T30-6 toroid was either scrunched to increase the inductance, or expanded to decrease the L while re-peaking the trimmer cap. Eventually, with patience, a beautiful sine wave emerged on my 'scope. I removed and measured the L with an ADE inductance meter. Consider all of my reported inductance values as nominal — gentle expansion or contraction of the inductor coils might be required to get an agreeable sine wave.

Click for the oscillocope tracing at 23.3 MHz.

The Butler at Overtone Frequencies

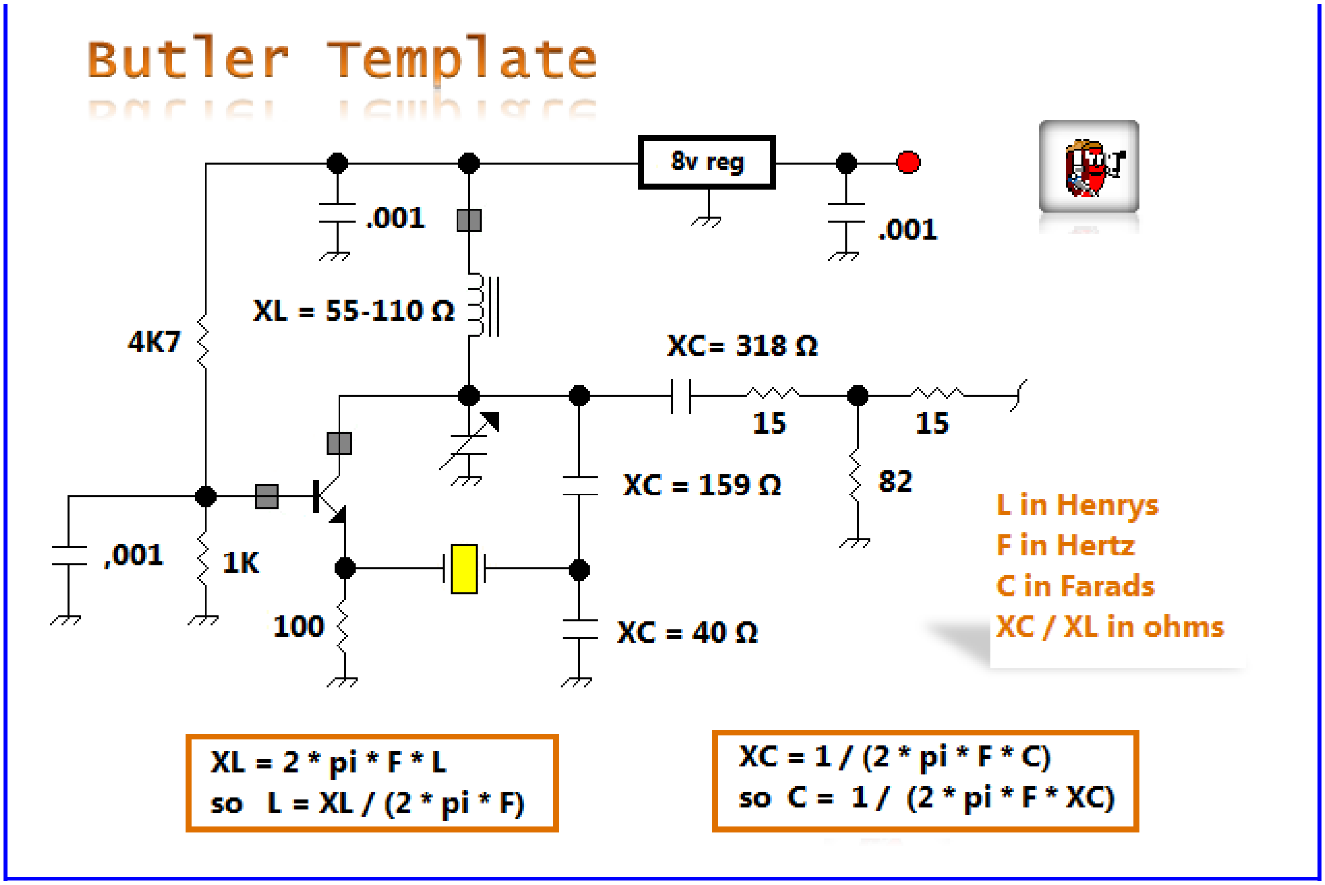
Butler Template
8v reg
.001
.001
XL = 55-110 Ω
4K7
XC= 318 Ω
15
15
XC = 159 Ω
82
,001
1K
100
XC = 40 Ω
L in Henrys
F in Hertz
C in Farads
XC / XL in ohms
XL = 2 * pi * F * L
so L = XL / (2 * pi * F)
XC = 1 / (2 * pi * F * C)
so C = 1 / (2 * pi * F * XC)

Above — A template (of sorts) for calculating Butler capacitor and coil values. The concept, rather than the absolute value matters most. I examined some well-designed Butler oscillators from professional equipment and determined their average XL and XC values. From the reactances shown, calculate the L and C values for the overtone frequency of interest with the 2 formulas in orange boxes. *Remember these XL or XC values just serve as starting values for experiments.*

For example : At 50 MHz with an XL of 108 Ω : L = 108 Ω / (6.28 * 50000000 Hz) = 0.000000344 H or 344 nH.

Fine tuning of the capacitor and inductor values might be required since factors including buffer input resistance +/- reactances, the overtone frequency and/or your breadboard layout may affect your Butler oscilator function.

In the experiments from the 3rd to 9th overtone frequency, the L = an air inductor wound with 21 to 22 AWG wire on a bolt.

Third Overtone Frequency

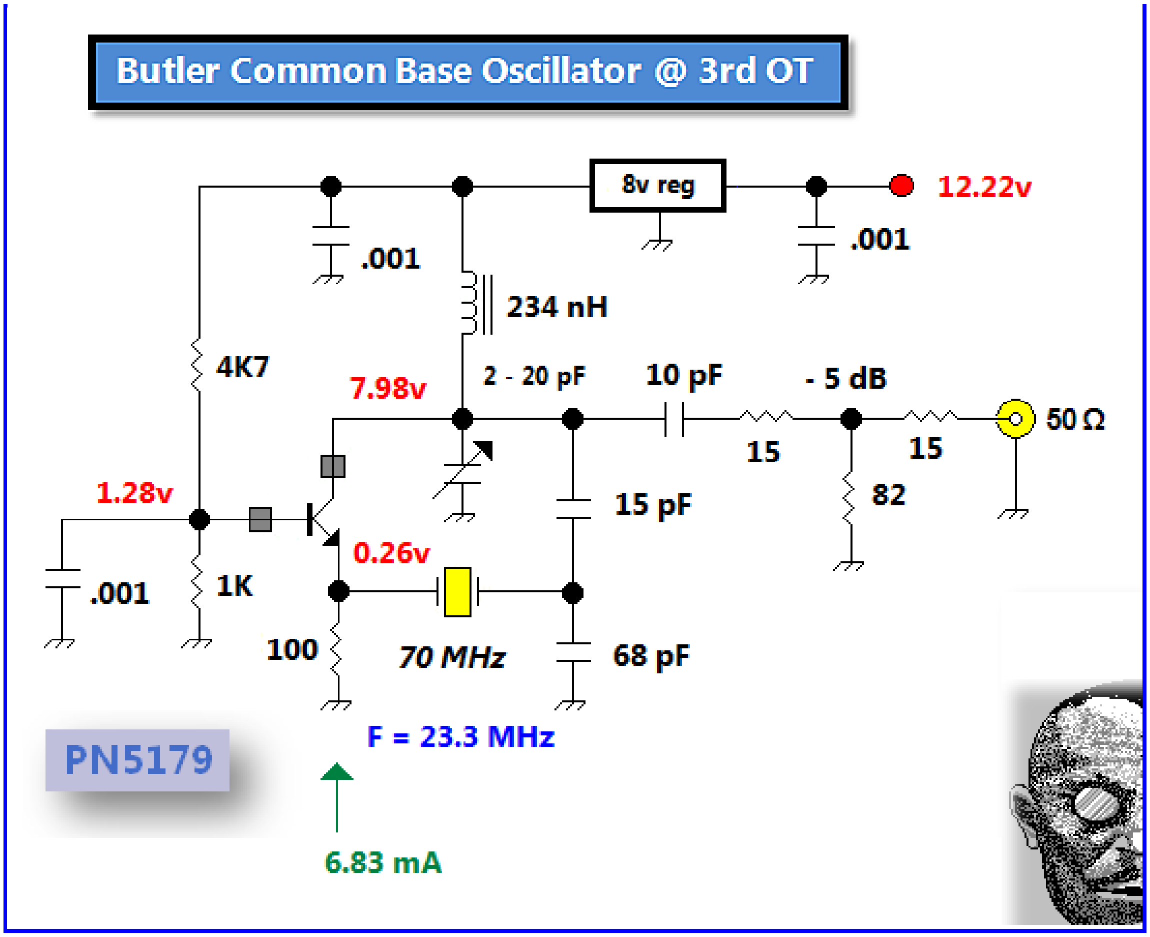
Butler Common Base Oscillator @ 3rd OT
8v reg
12.22v
.001
.001
234 nH
4K7
7.98v
2 - 20 pF
10 pF
- 5 dB
50 Ω
15
15
82
1.28v
15 pF
0.26v
.001
1K
100
70 MHz
68 pF
F = 23.3 MHz
PN5179
6.83 mA

Above — The Butler oscillator now arranged for output at the third overtone. Click and click for the 'scope outputs at the third crystal overtone. The first scope tracing was slightly mistuned. Once again, the inductor had to be gently squished or contracted to obtain a pristine sine wave.

Fifth Overtone Frequency

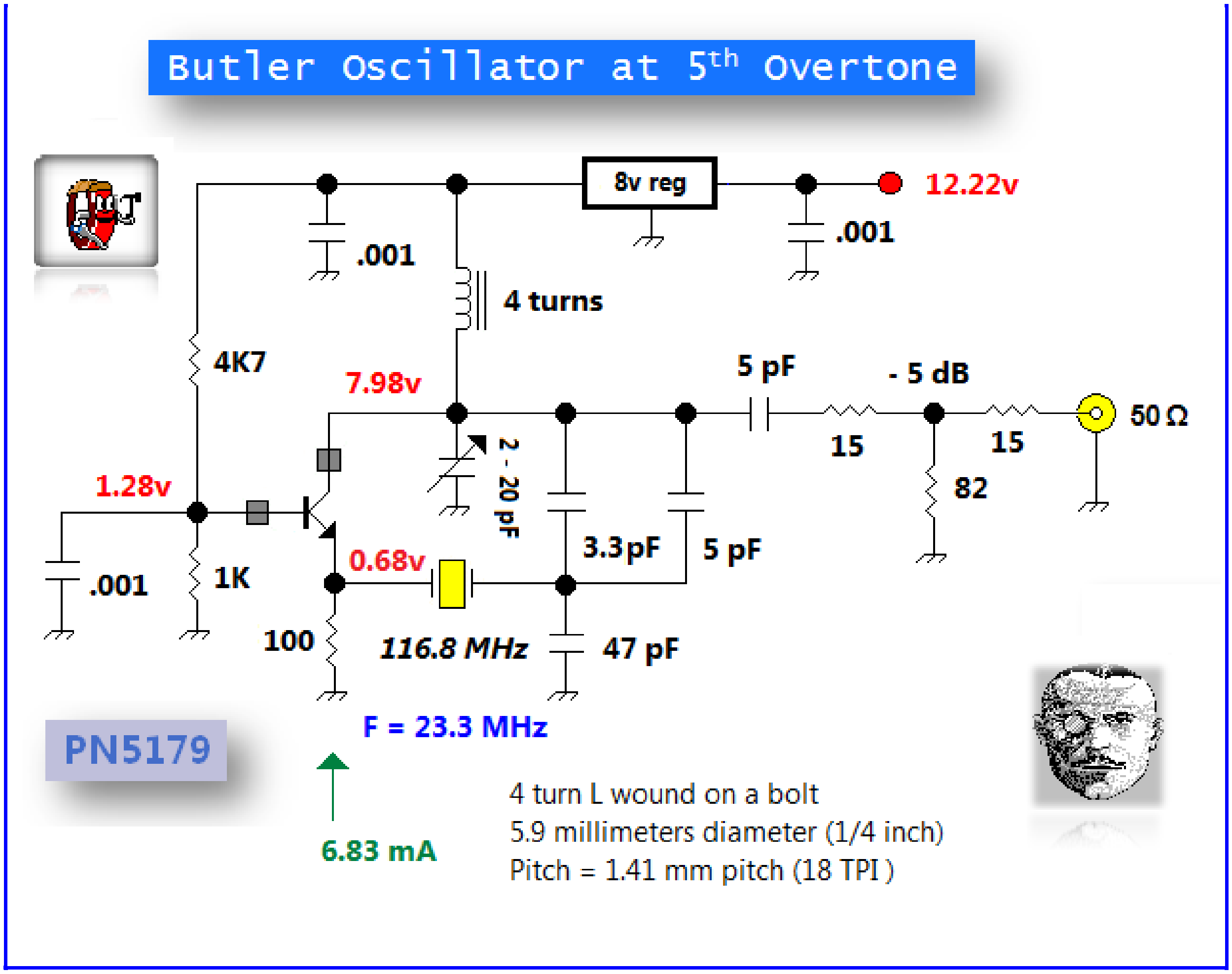
Butler Oscillator at 5th Overtone
8v reg
12.22v
.001
.001
4 turns
4K7
7.98v
5 pF
- 5 dB
15
15
50 Ω
82
1.28v
2 - 20 pF
3.3pF
5 pF
.001
1K
0.68v
100
116.8 MHz
47 pF
PN5179
F = 23.3 MHz
6.83 mA
4 turn L wound on a bolt
5.9 millimeters diameter (1/4 inch)
Pitch = 1.41 mm pitch (18 TPI)

Above — The Butler oscillator at the 23.3 Mhz crystal's 5th overtone. Here's the 'scope tracing and an Ugly Construction photograph. The output = 7 dBm — very cool.

Some authors directly connect the attenuated output to the Local Oscillator port of a diode ring mixer. The signal is adjusted to the desired 7 dBm power by tweaking the 50 Ω pad attenuation, and/or the NPN's current. A good example = Single-Conversion Microwave SSB/CW Transceivers by Rick Campbell in QST for May, 1993.

The circuit above was measured with a 50 Ω terminated oscilloscope however, I also tested it with a 10X probe attached to termination resistors from 51 to 1 Meg ohms. When changing the 51 ohm termination resistor to a higher value such as as 47K, a previously working Butler may stop oscillating. The buffer input impedance and capacitance greatly affected the oscillator in my experiments.

When I wired up a Butler, 1 of 3 things happened: it did not oscillate, it gave a distorted output waveform, or it wowed me with a nice sine wave. Tuning the L-C tank is critical + finicky and may test your patience.

Adding an Inductor Across the Crystal

Butler Oscillator at 5th Overtone

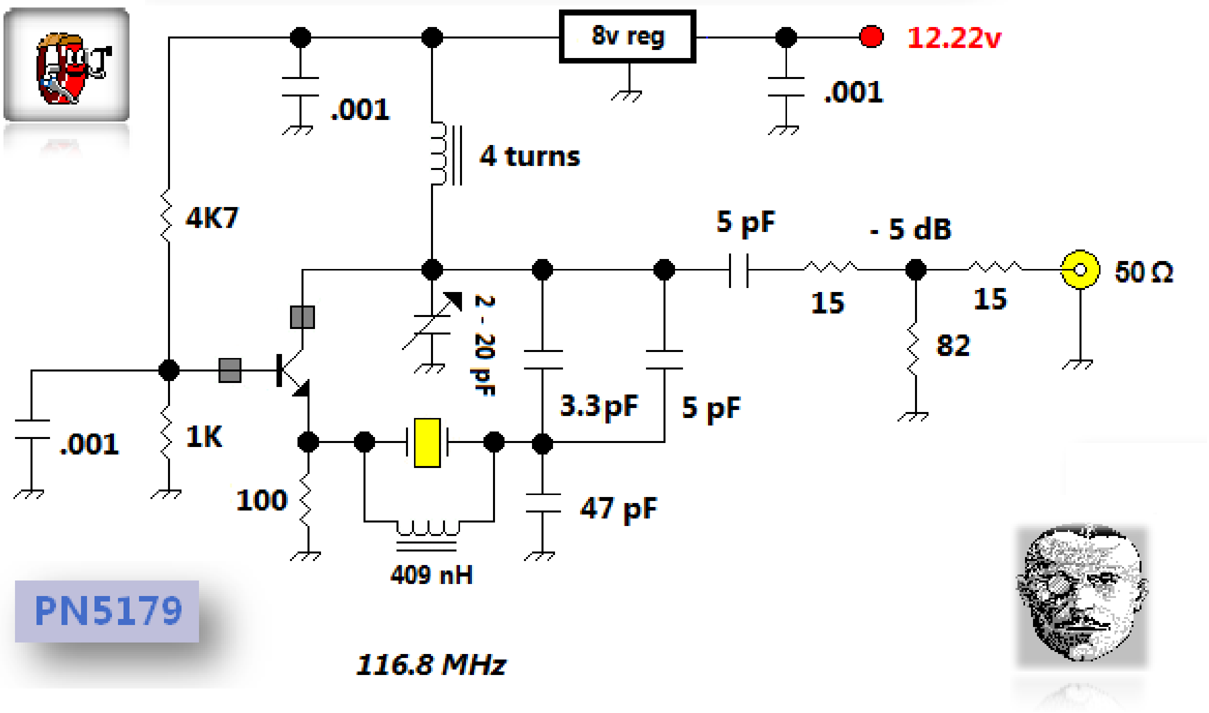
8v reg
12.22v
.001
.001
4 turns
4K7
5 pF
- 5 dB
15
15
50 Ω
82
2 - 20 pF
3.3pF
5 pF
.001
1K
100
47 pF
409 nH
PN5179
116.8 MHz

Above — The 5th overtone Butler with an inductor in parallel with the crystal

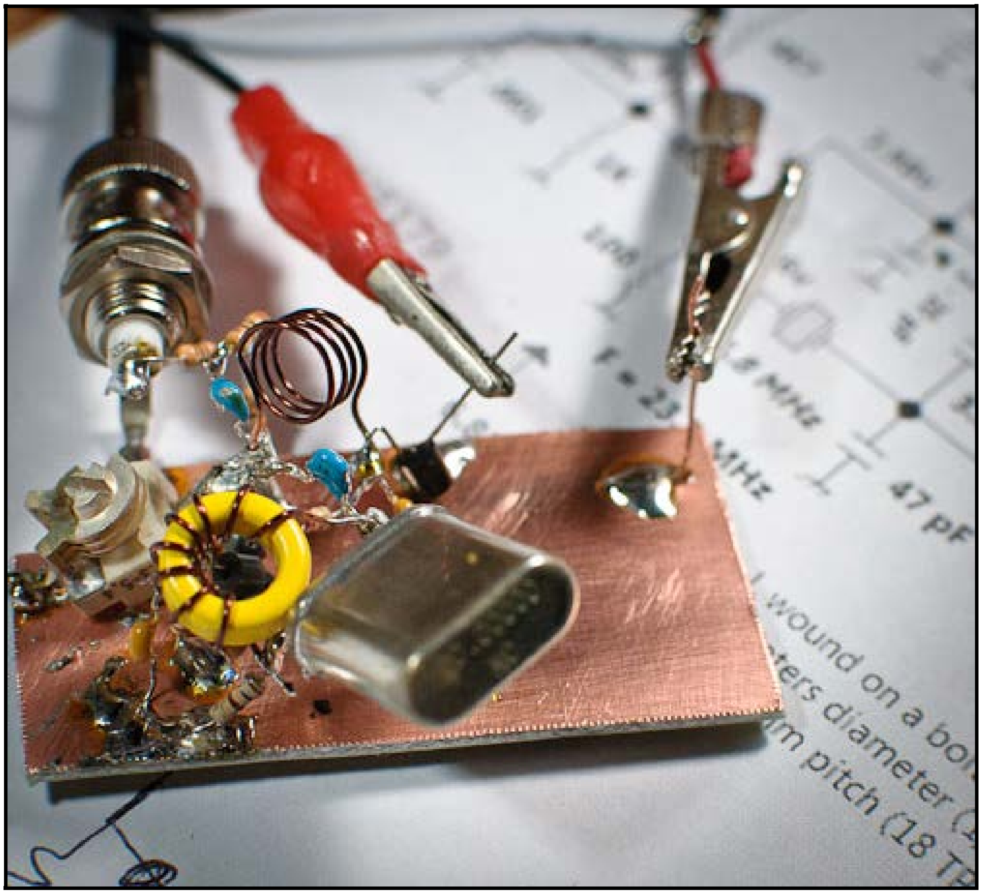

Above — My 116.8 MHz oscillator breadboard with an inductor wound on a T50-6 with wide spacing to allow scrunching and expanding of the windings across the crystal. I roughly determined my L should be ~ 400 nH and wound this on a # 6 toroid. While observing the output in my scope, I scrunched and then expanded its windings and adjusted the trimmer capacitor. The goal was to find a clean signal that snuffed out immediately when the trimmer cap was tuned off resonance. After finding the optimal L, I later removed and measured the coil. There is very little "wiggle room" — the oscillator tunes up and then dies very sharply as you tweak the trimmer cap. No sidebands were observed.

The inductor across the crystal is optional — some suggest it might only be needed above ~ 70 MHz.

At frequencies above ~70 MHz, the parallel capacitance of the xtal (C par) approaches the internal series resistance of the xtal and this provides an alternate path around the crystal for the signal and may short-circuit the crystal. The parallel inductor resonates with the crystal's parallel capacitance and tunes it out, so the crystal remains unbypassed.

Our teacher, Wes, W7ZOI published a document covering the Butler parallel crystal inductor here.

Simply put — the inductor allows clean tuning and output. That is, when you tune the trimmer to one side or another, the oscillator just dies and doesn't produce the sidebands that are shown in Wes' web article.

Since many of us choose computer, or other surplus crystals, a high C par + low Q crystal might give you tuning woes depending on your overtone frequency. In this case, adding the L to your circuit may improve tuning and ward off any unwanted sidebands.

With my particular crystal the parallel inductor is not needed, however, I can report that even slight mistuning just snuffed out my oscillator with the added inductor.

Seventh and Ninth Overtone Frequency

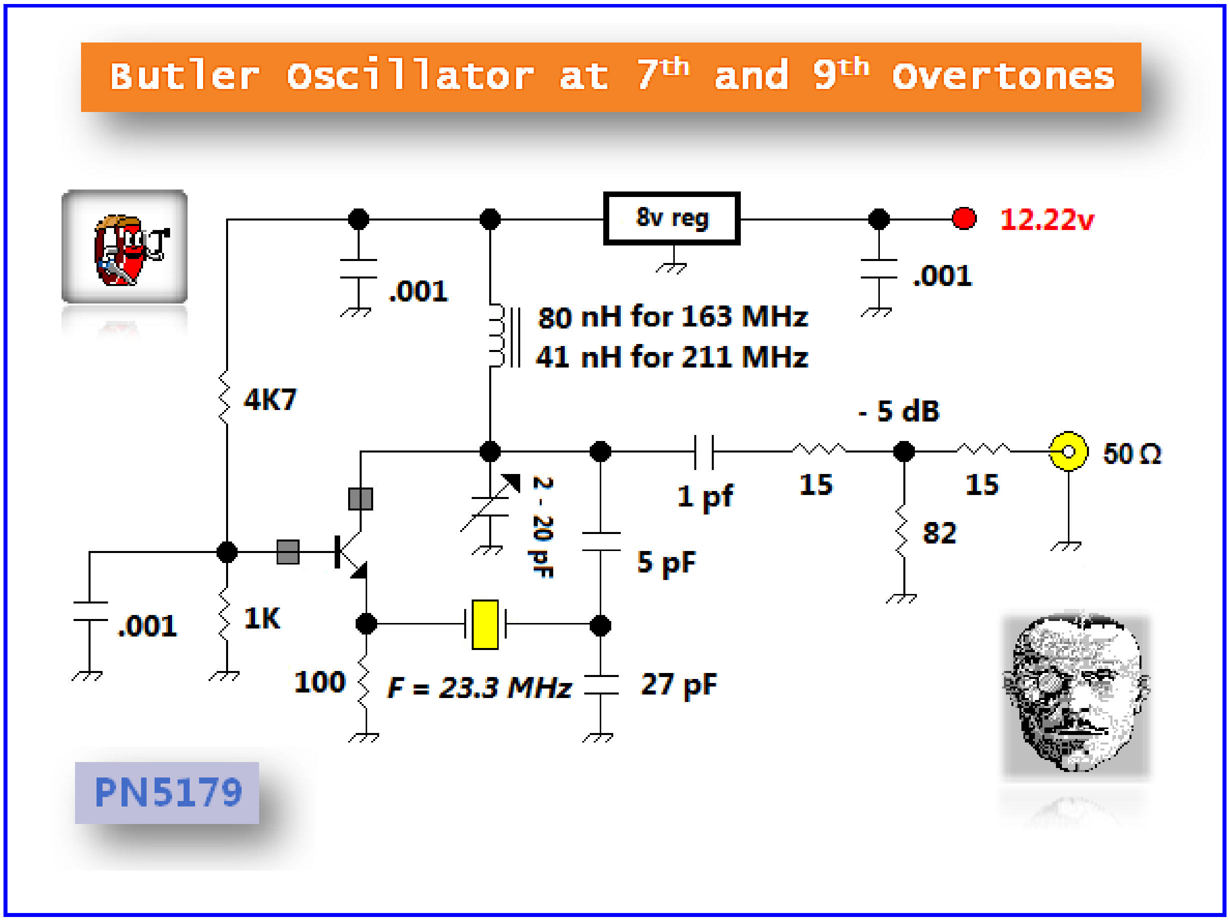

Above — I decided to take the Butler up to the 7th and 9th overtones. The 1 pF coupling capacitor proved the most critical part; for example, if I raised it to 5 pF, the oscillator would not tune above the 5th overtone. I wound the inductors on bolts and then compressed or stretched the links to get the perfect inductance. At these frequencies, stray inductance becomes quite significant and my coils were 1 to 1.5 turns less than indicated on a spreadsheet coil inductance calculator. Click for the seventh overtone 'scope shot. Click for the ninth OT 'scope tracing.

I'm confident that if my 'scope bandwidth was higher, I could have resonated the 11th overtone.

---

2. Butler Oscillator-based 50 MHz Signal Generator

Lacking a 6 Meter band signal generator, I decided to build a 1 frequency device employing a Butler oscillator. Some may laugh at a 1 frequency signal generator — I won't since I'll use it to design and align amplifers, filters, a new 6 Meter band VCO and measure scattering parameters. Besides, you can double, triple, VXO or mix single frequency generators with another variable oscillator — this web site has roots in humble, simple test equipment.

In my bag, I found a crystal labelled 50.0000 MHz and measured its fundamental at 16.67 MHz in a simple Colpitt's oscillator — perfect . Design goals included variable amplitude, strong reverse isolation + reasonable shielding and return loss. Since, I lack another 6 Meter band signal generator I could not measure return loss, however, choosing proven circuits + a terminal attenuator pad will help.

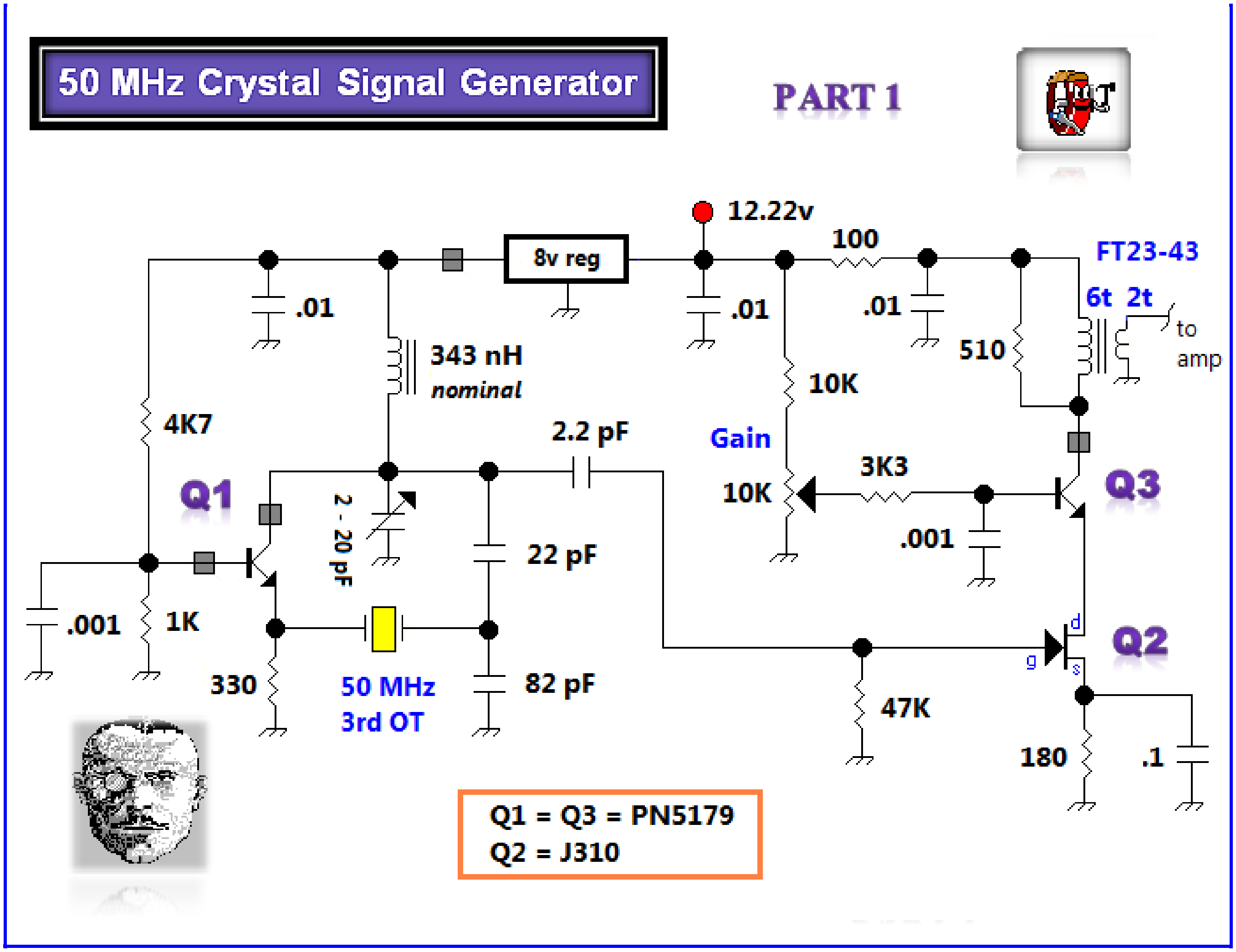
50 MHz Crystal Signal Generator
PART 1
12.22v
8v reg
.01
.01
100
.01
FT23-43
6t 2t
to
amp
343 nH
nominal
510
10K
4K7
2.2 pF
Gain
Q1
3K3
Q3
10K
2 - 20 pF
.001
22 pF
.001
1K
d
Q2
330
50 MHz
3rd OT
82 pF
g
s
47K
180
.1
Q1 = Q3 = PN5179
Q2 = J310

Above — Butler oscillator + hycas buffer. The 22 pF cap in the Butler was originally 15 pF, but when tested with various coils, oscillations proved a litle sluggish, so the 22 pF was substituted. I experimented with the coil, but ran out of time, so I wound a few turns of wire on a T50-10 toroid and soldered it in. After some careful manipulation of the windings, a glorious sine wave arose. I removed the L, measured it at 343 nH and then re-soldered it in place. An air coil or other size 6 or 10 powdered iron inductor should work fine.

Click for a moderate resolution photograph of the entire project.

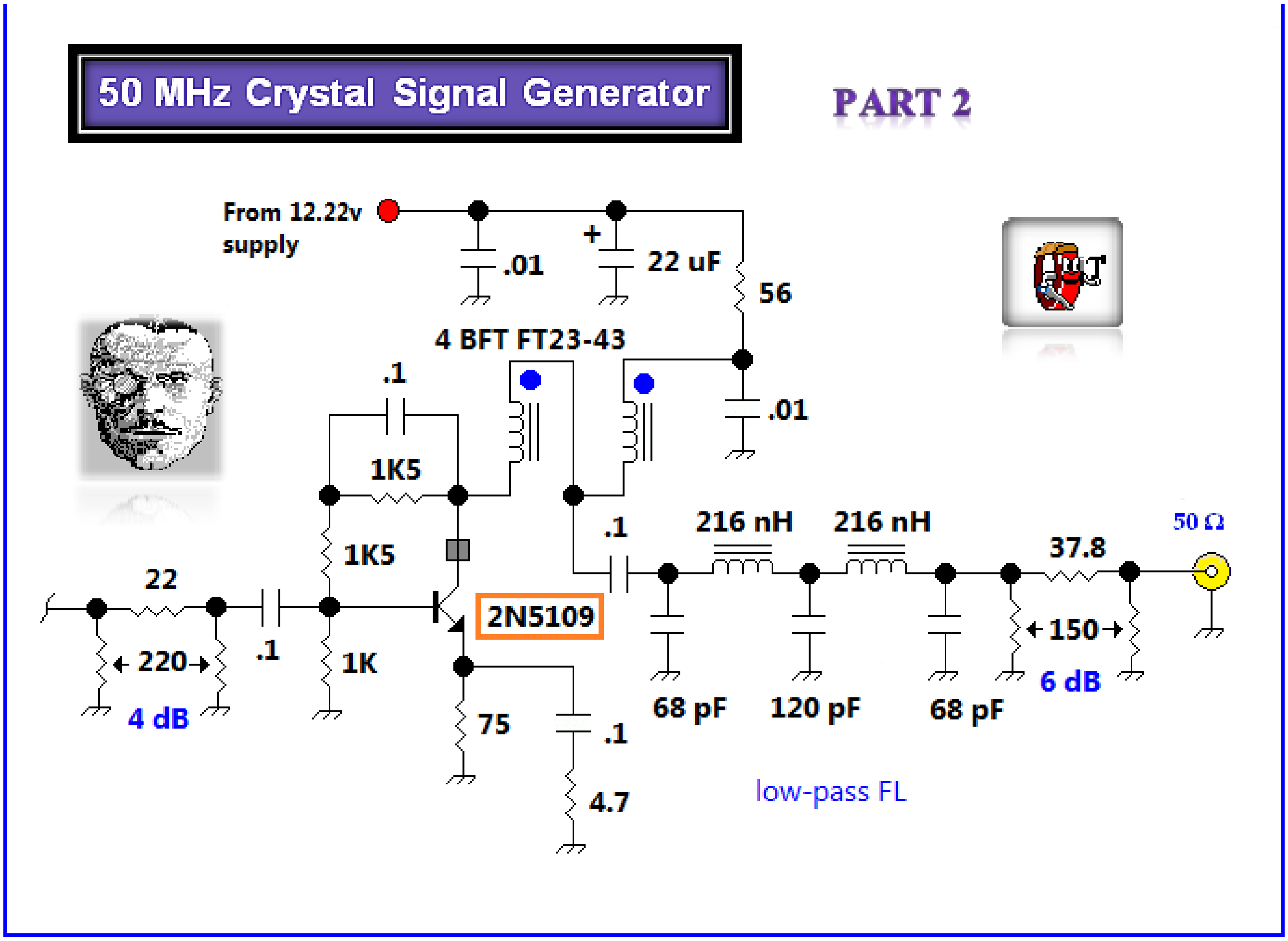
50 MHz Crystal Signal Generator
PART 2
From 12.22v supply
.01
+
22 uF
56
4 BFT FT23-43
.1
.01
1K5
1K5
.1
216 nH
216 nH
37.8
50 Ω
22
2N5109
220
.1
1K
150
4 dB
6 dB
75
.1
68 pF
120 pF
68 pF
4.7
low-pass FL

Above — The final amplifier and low-pass filter. The maximum output of the Q2/Q3 amp is hot and can overdrive the 2N5109, therefore a 4 dB pad was added. This pad also improves the input return loss of the 2N5109. An alternate technique might be to further reduce the maximal DC bias voltage into the Q3 base and remove the 4 dB pad.

Click for the minimum and maximum output voltage waveforms from my 'scope

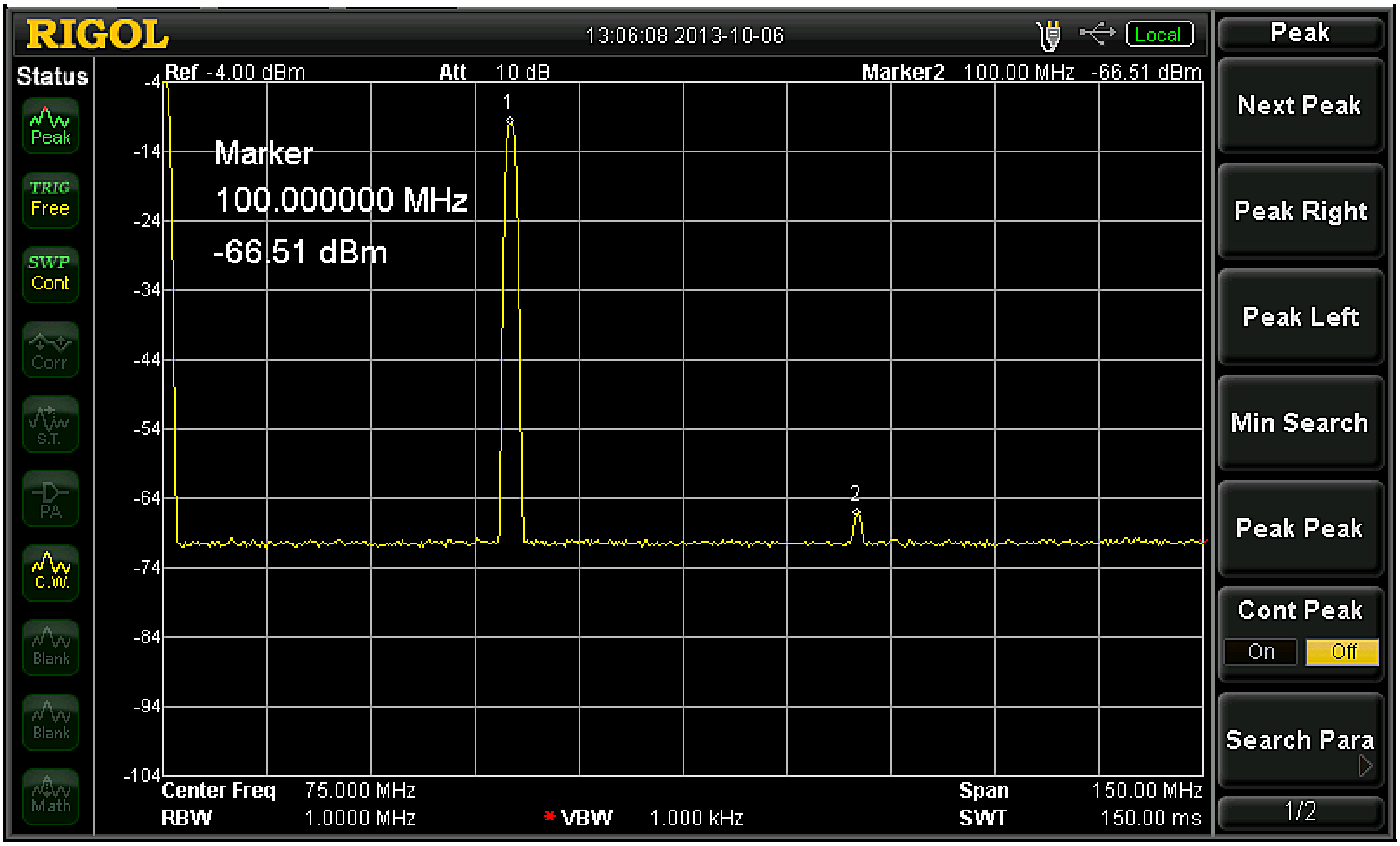
RIGOL
13:06:08 2013-10-06
Local
Status
Peak
TRIG Free
SWP Cont
Corr
S.T.
PA
C.W.
Blank
Blank
Math
Ref -4.00 dBm
Att 10 dB
Marker2 100.00 MHz -66.51 dBm
Marker
100.000000 MHz
-66.51 dBm
1
2
-4
-14
-24
-34
-44
-54
-64
-74
-84
-94
-104
Center Freq 75.000 MHz
RBW 1.0000 MHz
VBW 1.000 kHz
Span 150.00 MHz
SWT 150.00 ms
Peak
Next Peak
Peak Right
Peak Left
Min Search
Peak Peak
Cont Peak
On
Off
Search Para
1/2

Above — Spectrum analysis with the generator output at -10 dBm. I placed Marker # 2 on the 2nd harmonic peak (100 MHz) and measured the power. The low-pass filter only attenuates the 2nd harmonic by ~ 25 dB, however, with the nice sine wave from the Butler, the 2nd harmonic measured -66.51 dBm = -56.51 dBc.

The 37.8 resistance indicated in the pad = 2 resistors in series. Many just use a 37 or 39 Ω R.

I look forward to advancing my VHF skills with this little signal generator.

50 MHZ XTAL OSCILLATOR
PART 1
12.22v
100
.1
510
FT23-43
6t
2t
to amp
Q3
3K3
.001
Q2
47K
180

3. Doubler for the 50 MHz Signal Generator

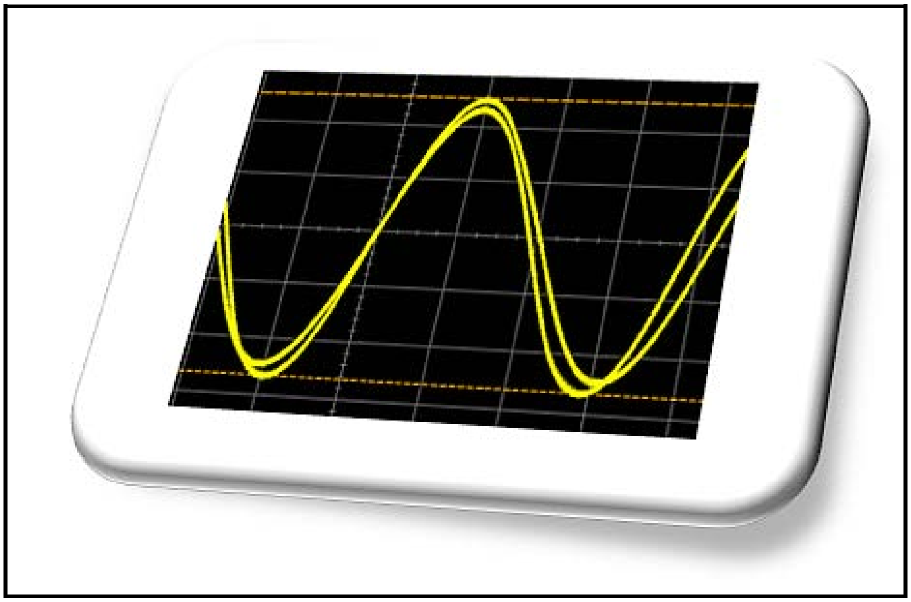

50 MHz Doubler Experiment

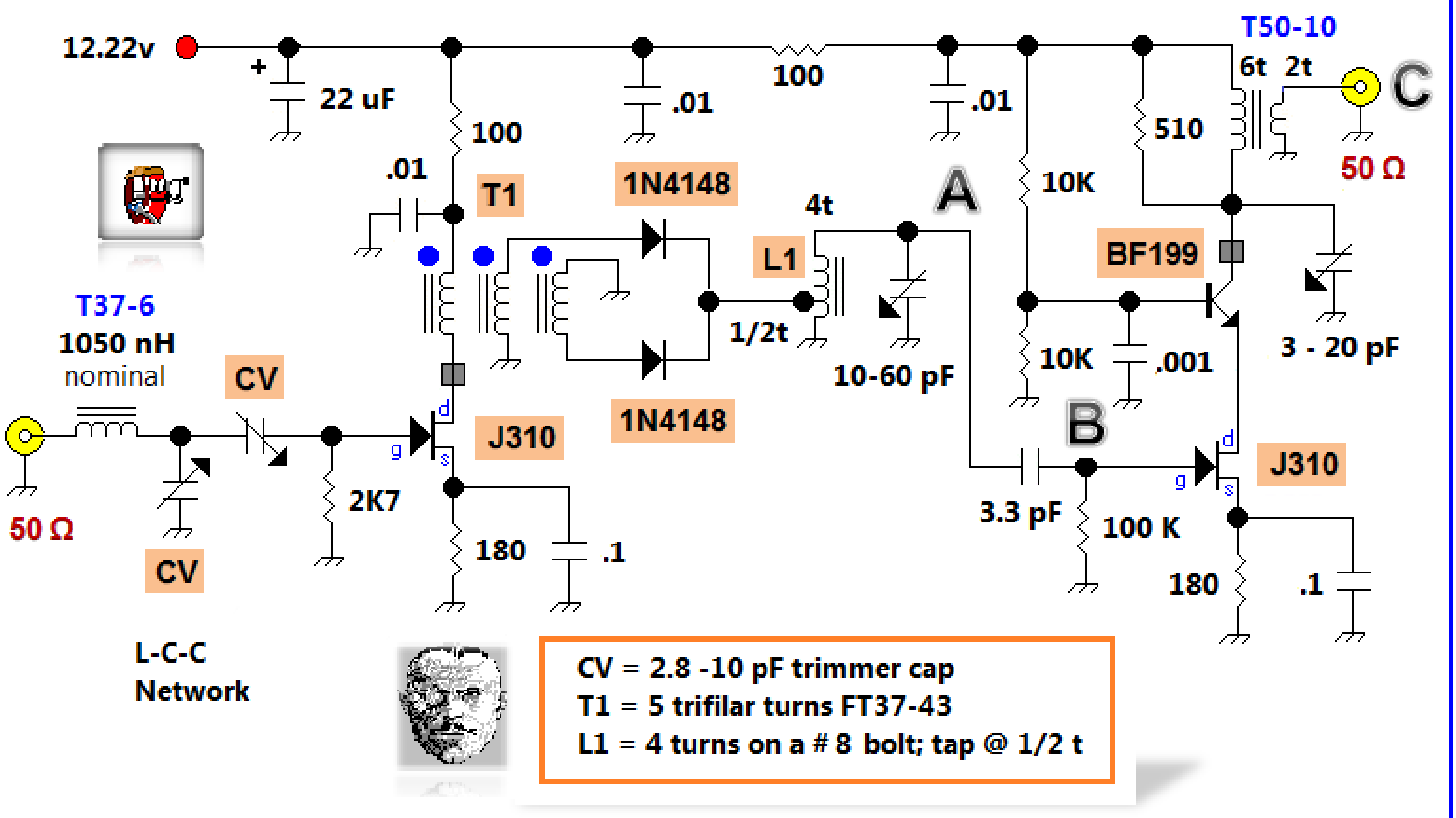

CV = 2.8 -10 pF trimmer cap
T1 = 5 trifilar turns FT37-43
L1 = 4 turns on a # 8 bolt; tap @ 1/2 t

Above — An experimental frequency doubler for the Butler Oscillator-based 50 MHz Signal Generator shown above.

After trying a few circuits, I settled on a simple full-wave doubler featuring matched 1N4148 diodes driven by a JFET amplifier. Chapter 3 of Solid State Design for the Radio Amateur by Hayward and DeMaw for the ARRL = my key reference. Matched diodes (and a little luck), may suppress the 50 MHz signal up to 60 dB so only a single-tuned circuit follows the diodes.

The first JFET amp drives the diodes to improve harmonics + output voltage — an L-C-C Tee network matches the 2K7 Ω input to the 50 MHz signal generator output. I designed this matching network on the bench with the 2 diodes disconnected to avoid distortion during signal measurements. Using a 10X probe, I peaked the capactors for the greatest signal amplitude after finding the optimal L by educated trial and error. The inductor wound on a T37-6 was scrunched a little to further peak the L-C-C network.

I wound L1 with bare copper 26 AWG wire on a #8 bolt with coarse threads. To make enough space to solder on the 1/2 turn tap, I stretched the last turn with the other 3 turns still on the bolt to prevent stretching these coils. Click for a 'scope tracing at Point A. My 10X scope probe has ~ 15 pF capacitance and this affected the tuning — you can see some harmonics in the signal. With the 10X probe at Point B, I was nearly able to turn the circuit to 100.0 mHz, but still the 10:1 probe upsets the circuit somewhat.

This L - C tank tunes sharply and best with a non-conductive screw driver. I final tuned the L1 tank when the hycas amp was completed and connected to a 50 Ω terminated 'scope — eliminating the earlier tuning problems caused by the 10X probe. It seems that VHF requires more thought and care than HF when tuning resonators (tanks).

Point C is the maximum output (10.34 dBm) into a 50 ohm terminated 'scope. The 100.0 MHz signal is okay, but some builders might want to add low-pass filtering +/- an attenuator pad; or perhaps drive another feedback amp?

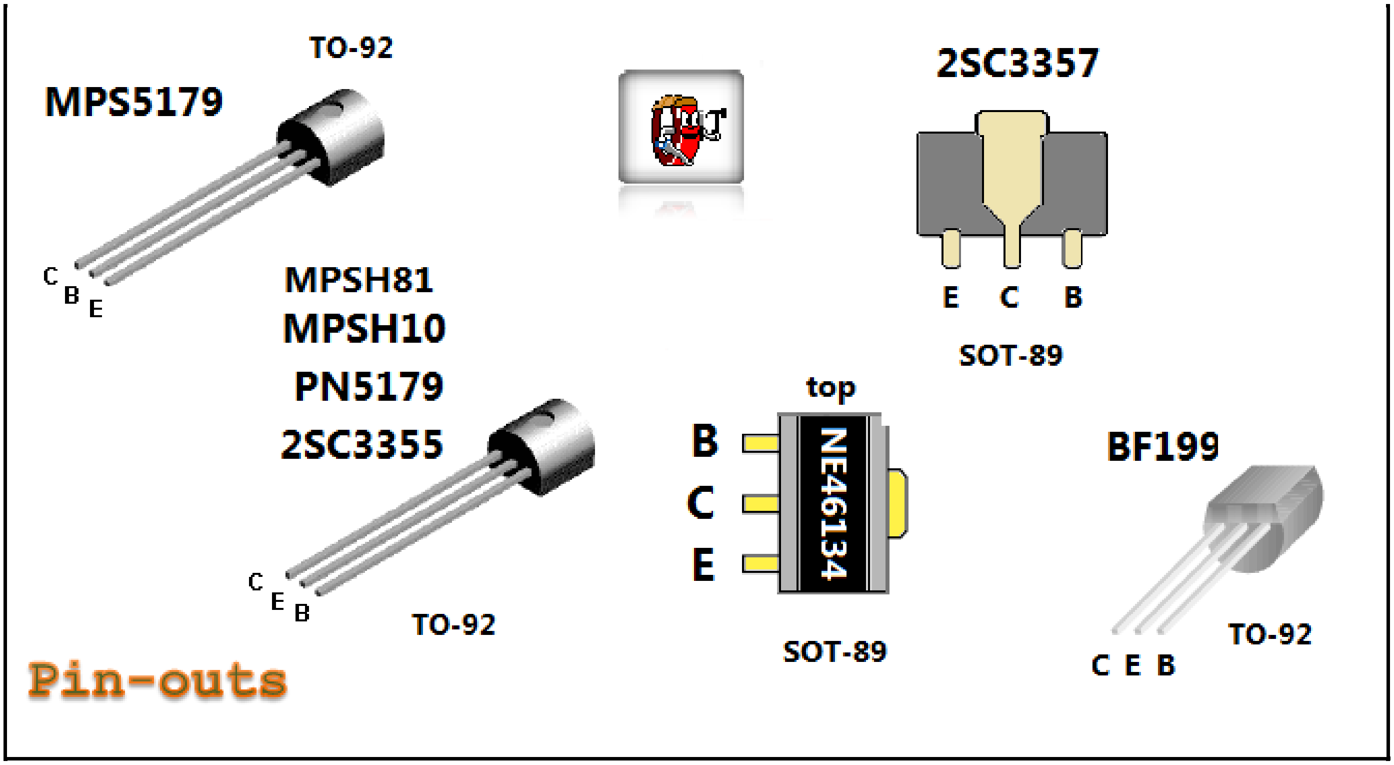
TO-92
MPS5179
C B E
MPSH81
MPSH10
PN5179
2SC3355
C E B
TO-92
2SC3357
E C B
SOT-89
top
B
C
E
NE46134
SOT-89
BF199
TO-92
C E B
Pin-outs

RF — Test and Measurement

VHF to the Max — Miscellaneous 2012 Experiments

As a VHF newcomer, I need to make lots of circuits, measurements, mistakes and maybe — I might advance. My literature review revealed a big gap between popular, "for-fun", novelty-grade projects and the blinged-out circuits such as ultra low-noise LNA's featuring GaAs, MESFET, and pHEMT devices. Where do we find the middle ground projects? Likely on our own RF work benches.

Numerous questions arose — Will Ugly Constuction work? Do I have the right test gear? Am I measuring the proper things? What about noise figure? All a bit overwhelming — but even improbable discoveries began as simple questions and observations. We solve far more difficult problems each day.

I'm learning that whether your a beginner, or a master, bench fundamentals rank supreme. Want to avoid oscillations in your high fT BJT VHF amplifier? Work towards high reverse isolation, strong S11 and S22, careful layout and employ techniques that suppress instability — nothing earth shattering huh? I'm told that acquiring the needed skills takes time and practice.

In early Winter 2011-2012, I built some VHF signal generators, amplifiers and a lots of junk. This web page documents a few of these experiments.

Section 1. Early MAX2606 VCO experiments
Section 2: A 2-band signal generator based upon the MAX2606 VCO
Section 3: 50 MHz VCO
Section 4: 50 MHz Receiver Pre-amp and Filter
Section 5: QRP — POSDATA: Z-Communications VCO Experiments

Section 1. Early MAX2606 Experiments

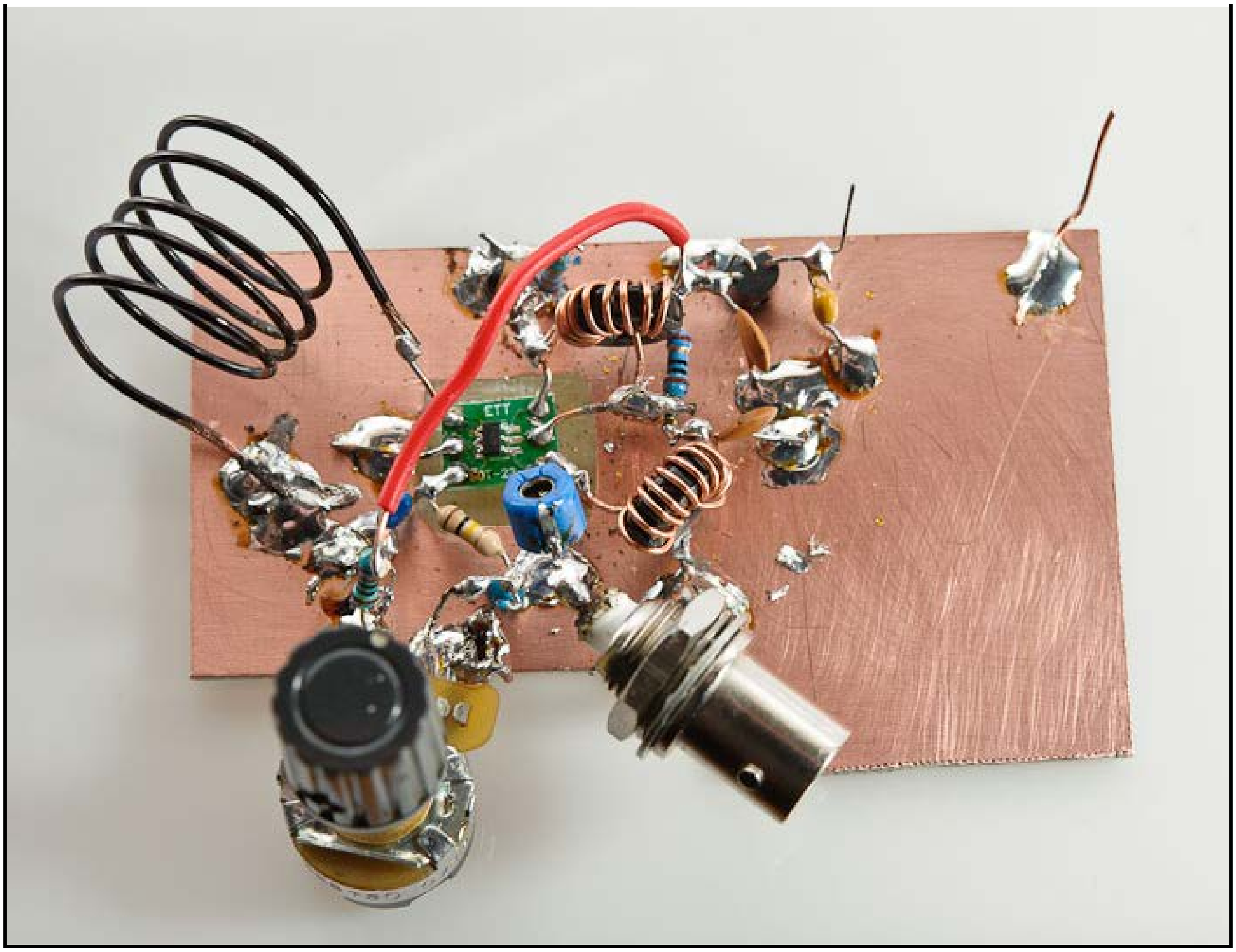

Above — My first of many MAX2606 VCO Experimental breadboards.

Maxim makes a series of cool SOT23-6 VCOs ranging from 45 to 650 MHz. Wanting a VCO to cover from ~100 to 106 MHz, I just had to try this chip. The datasheet provided all the online information I could find; save for a few homebrew, flea-powered FM transmitter projects that proved unhelpful.

After soldering the IC on a breakout (prototype) board using about 20X magnification, the proto-board was dropped onto a copper clad board with some of the copper ground away.

Max2606 VCO Experiments

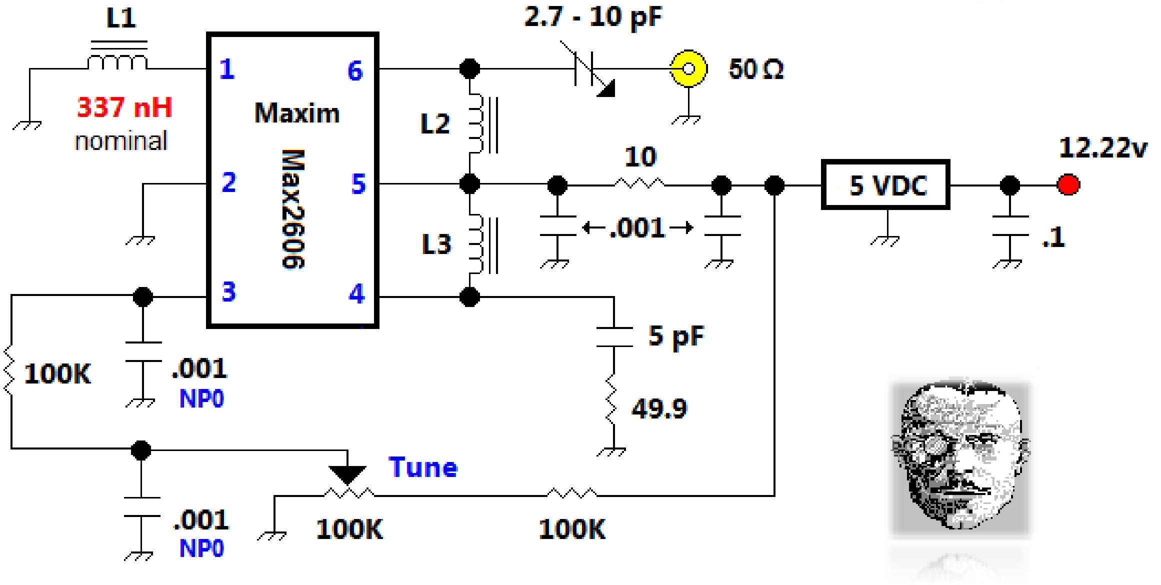

L1 = 5 turns on a 5/8 inch bolt (15.9 mm)
L2 = L3 = 411 nH

Above — My first MAX2606 VCO experiment. A coil lying on the workbench was soldered in as L1. I stretched it a little to set the lower band edge. Going from CCW to CW on the 100K tuning pot, I measured from 86.3 — 106.3 MHz. I'll write about L1 a little later, for making a good output network consumed my initial experiments.

The Maxim datasheet shows a simple output network consisting of 2 pull-up resistors with a maximum R of 1K. All the online FM transmitter designs I saw used 1K pull-up resistors and made no attempt at matching or even employing inductors in place of the resistors. I applied two 560 ohm pull-up resistors in place of L2 and L3 and the output looked distorted and low in amplitude. Click for a 50 Ω terminated 'scope tracing and click for a tracing with a 10X probe connected to a 10K load resistor. Unacceptable for even us scratch-builder RF experimenters.

Wanting to match the output into a 50 Ω load with high-pass L-network instead of just resistors, I calculated that an L of 250 to 800 nH, plus a capacitor from 2 to 10 pF might work, however, as a VHF newbie, my hopes weren't high. I went for a single-ended output and not knowing what to do, terminated the unused port with an AC-coupled 49.9 Ω resistor.

Choosing a 100 MHz test frequency (where I own a doubled 50 MHz xtal oscillator), I removed L1 to snuff the oscillator and measured an output return loss of ~ 17 dB with L2 = L3 = 298 nH and the variable cap set to 7.3 pF (I removed it and measured it). It took about 1 hour of trying different L values to get this return loss. I also learned that the L value and L to C ratio of L2 and its series capacitor greatly affects the purity of the output waveform.

Like all L-networks, the L and C *must* be correct to obtain a strong, clean output. Since C is variable, I tried various inductor values and further fine-tuned them by scrunching or expanding the L2 windings. *Compress or expand the L2 windings + trim the variable capacitor to peak the L-network at your desired frequency.*

From my experiments, the L3 inductance should be close to L2 for the best output voltage and symmetry, however, don't bother scrunching or expanding L3 because this won't greatly affect the output signal as long as the L3 inductance is close to L2.

Click or click for some 'scope captures of poorly matched output L-networks — low gain and/or distortion appeared with mistuning.

Click for the output where L2 = L3 = 298 nH. I had the tuning set to 100.6 MHz for this screen capture, however, you can see the nice waveform and strong peak-peak voltage when compared to the pull-up resistor only versions.

The problem with a high Q L- network = low bandwidth. I wound L2 and L3 on T37-10 powdered iron toroids and later tried T37-6 toroids. The higher Q of the number 10 material seemed to translate into higher output voltage, but narrower bandwidth over the number 6 material toroidal inductors. Alternate breadboard. When tuning the MAX2606, signal amplitude changes with tuning frequency and a single L-network peaked somewhere near the middle of the tuning range further worsens this amplitude issue.

The *unbuffered* VCO waveform distorts somewhat as you move farther away from the peak L-network frequency. After trial and error, I settled in a compromise of L2 = L3 = 411 nH. This gave the best overall signal purity + amplitude from about 98 to 106 MHz with a set peak at ~ 102 MHz. Tuning below 98 MHz tended to really distort the waveform. Click for the *unbuffered* minimum and maximum frequency 'scope tracings.

Placing an attenuator pad plus a buffer amp after the VCO dramatically reduced this distortion in my experiments, assuming the L-network components are correct and tuned.

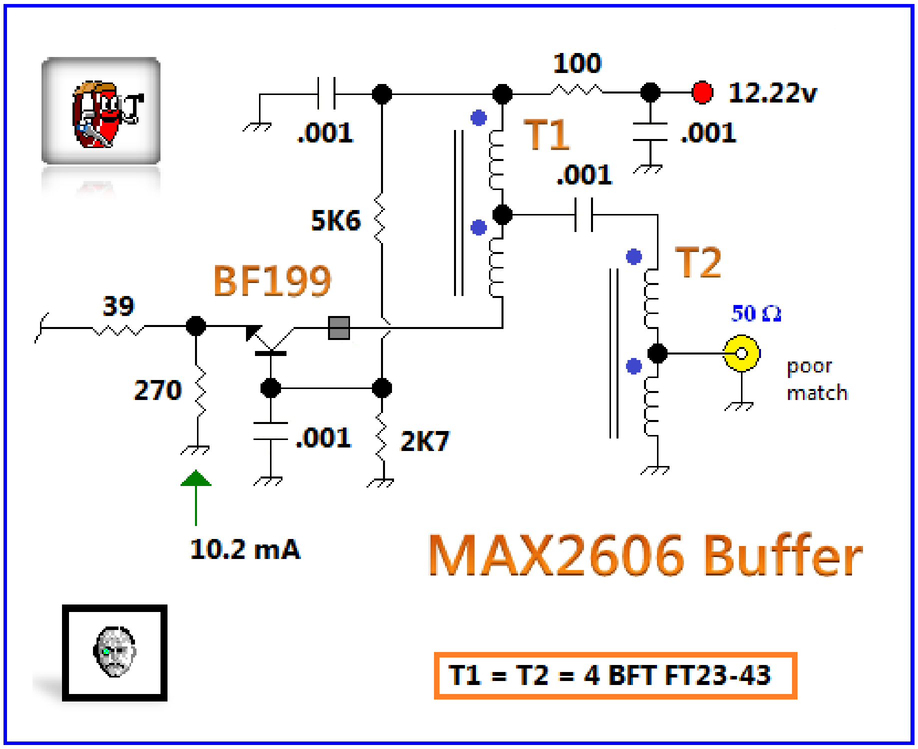

Above — A trial buffer first connected to output of the VCO schematic above. Two series-connected 2 transmission line transformers dropped the output impedance down for examination in my 50 Ω terminated scope — unfortunately the output return loss was poor (less than 10 Ω). Unlike the common base stage in a hybrid cascode amp, varying the bias to adjust gain worked poorly and lower applied bias caused distortion. I found it preferable to just fix the bias to get the greatest voltage gain + lowest harmonic distortion.

This buffer was discarded since the return loss was too low for my needs.

Testing a Hybrid-Cascode Buffer

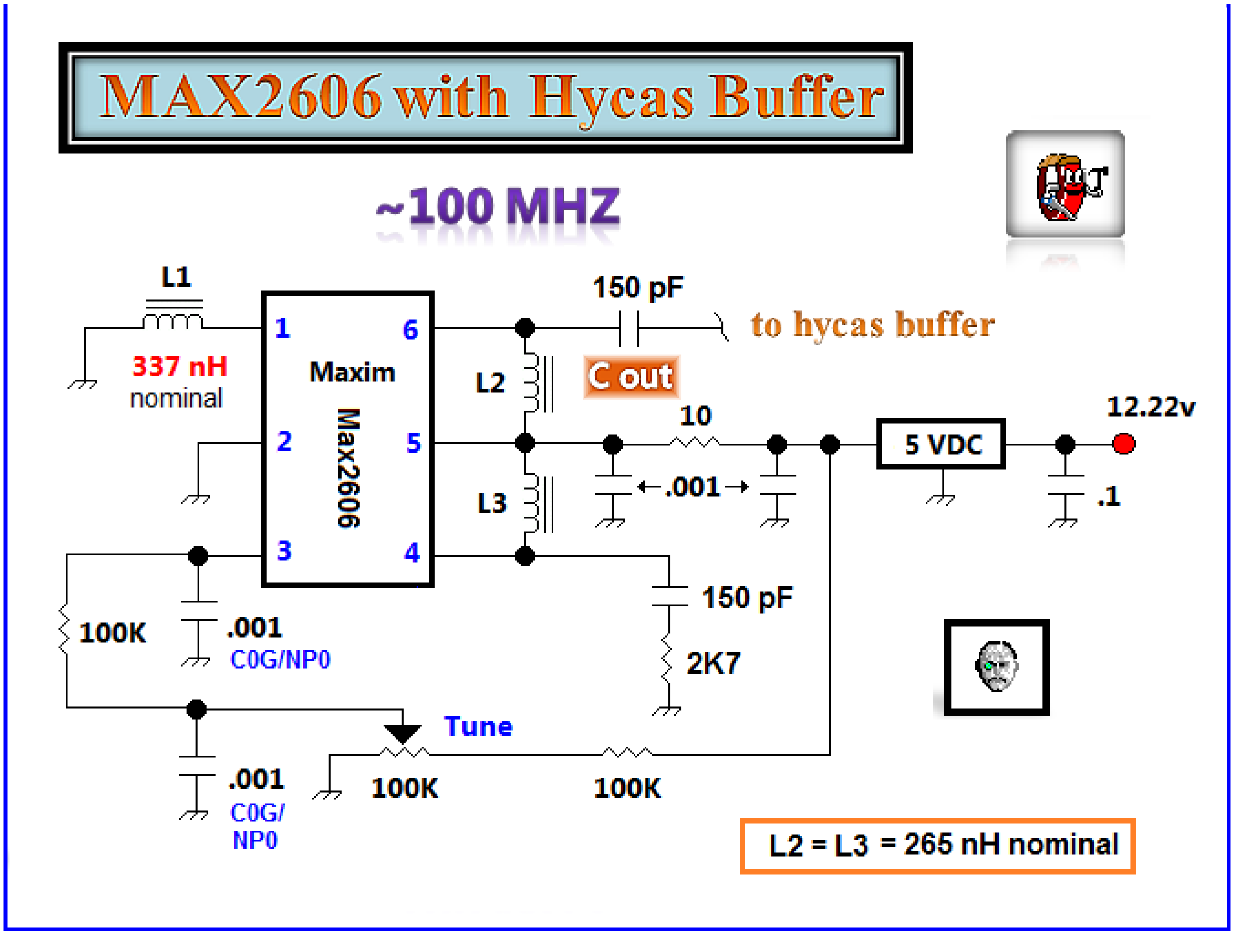
MAX2606 with Hycas Buffer
~100 MHZ
L1
337 nH
nominal
1
2
3
6
5
4
Maxim
Max2606
150 pF
to hycas buffer
L2
C out
10
12.22v
5 VDC
L3
.001
.1
150 pF
2K7
100K
.001
C0G/NP0
Tune
.001
C0G/
NP0
100K
100K
L2 = L3 = 265 nH nominal

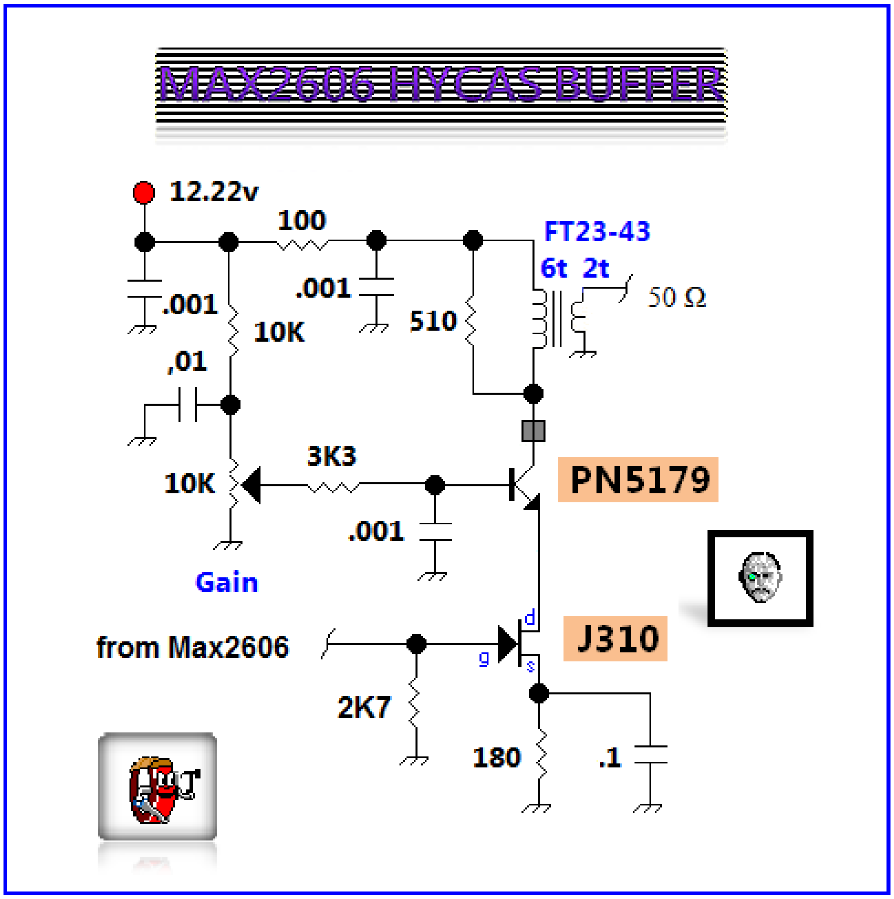
MAX2606 HYCAS BUFFER
12.22v
100
FT23-43
6t 2t
50 Ω
.001
.001
10K
510
,01
3K3
10K
PN5179
.001
Gain
d
J310
from Max2606
g
s
2K7
180
.1

Above — MAX2606 VCO into a hybrid cascode buffer at ~ 100 MHz. I also tried a buffer with a cascode of PN5179 transistors, however, the input Z of the buffer changed when adjusting the gain potentiometer and wrecked the input matching, so I stuck with the hycas buffer shown above.

L1 and L2 = ~ 265 nH wound on T37-10 toroids. To peak the L-match at ~102 MHz, I originally placed a 100 pF in parallel with a 10 - 70 pF trimmer cap for *C out*. After tuning, I removed, then measured these 2 caps to discover that *C out* = ~150 pF; so I just substituted a 150 pF capacitor. The L1 windings were expanded a little to re-peak the output network — expanding the coils raises fCo, while compressing the windings lowers the cut-off frequency. I don't recommend omitting a trimmer capacitor unless your confident with your measurements.

Click for the maximum power 'scope tracing of the hycas amp with the L-match peaked at 102.2 MHz (3.44 dbM)

Once again, I terminated the secondary output of the MAX2606 with an load resistance equal to the main output with an approximately equivalent fixed-value capactor — I'm not sure if it's needed, but it works okay and I stuck with it.

Up at ~ 144 MHz

Click for another experiment with the fore mentioned MAX2606 into the hycas buffer shown above at ~ 144 MHz. I peaked the L-match for 142.2 MHz and the output power = a surprising 7 dBm. The output is a clean sine wave from 135 to 169 MHz, although the signal amplitude varies widely. I also peaked it at ~144 MHz. I wound L1 - L3 with #21 AWG on a #10 bolt. Photo 1 Photo 2.

Let's build something useful with the MAX2606 based upon the experiments thus far...

Section 2.   A 2-band Signal Generator Based Upon the MAX2606 VCO

Above — My dual VCO based on the MAX2606. This general-purpose signal generator will start my VHF circuit development in these 2 frequency bands. The importance of owning good signal generators can't be overstated — while not engineer grade, this box features a clean sine wave, strong output return loss and 1 KHz or better tuning resolution.

The center ON-OFF-ON toggle switch only turns on 1 oscillator at a time. The top 2 (ten-turn) tuning potentiometers lack knobs *(I'll get some later)* and the black knobs below them are attached to *unused* potentiometers. Initially, I planned to employ front panel gain control and drilled holes and fitted 10K pots in the chassis — I later decided to control the output power with outboard variable attenuators and skipped front panel power control for simplicity sake. Click for a side view of the unfinished project. Click for an early photo of the VCO **A** breadboard — I attached a shield to the copper clad board to help isolate the 2 VCOs.

I chose the frequency band **A** (138.5 - 172 MHz) to include the Ham 2 meter band + local commercial/service VHF segment and band **B** (98.919 - 109.06 MHz) to capture the FM broadcast band above 98 MHz.

Band A: 138.5 - 172 MHz

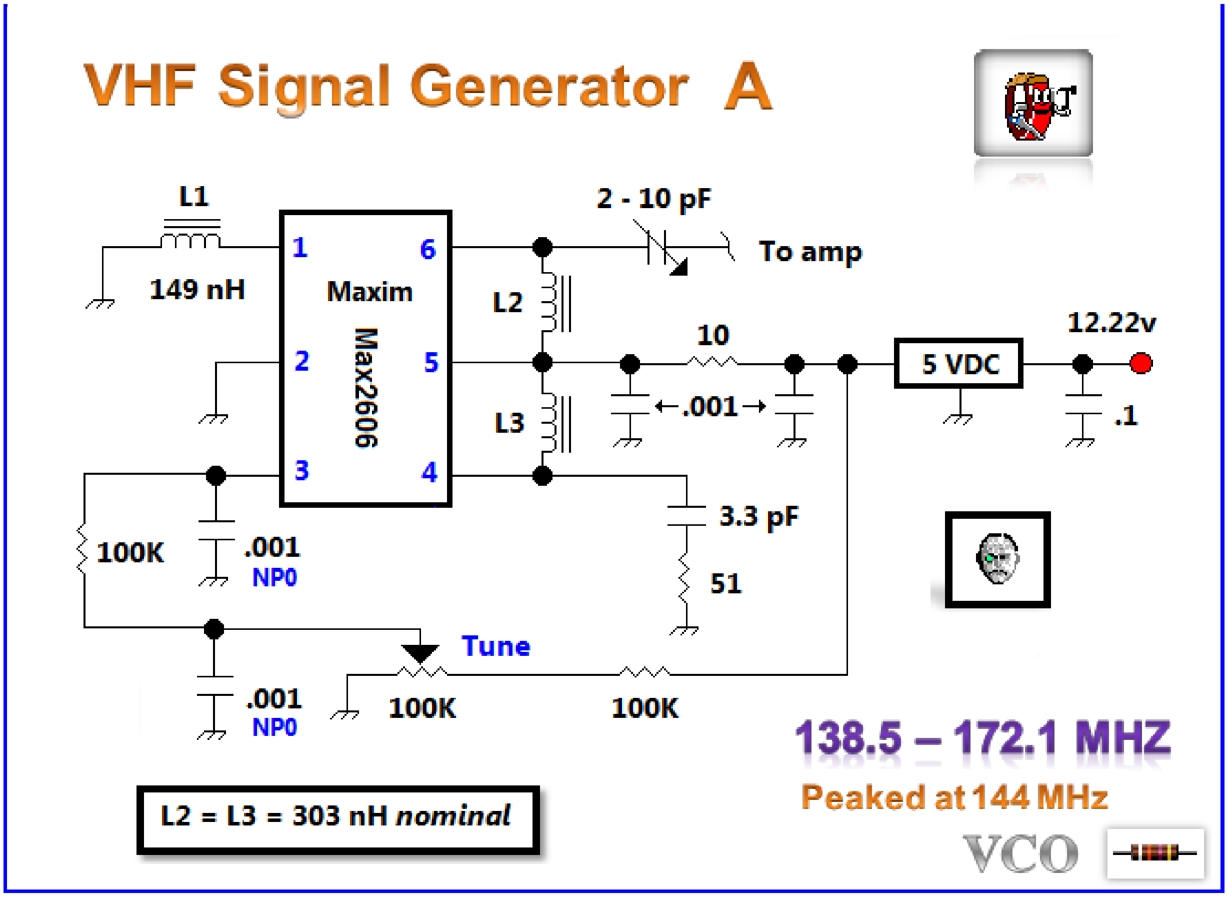
VHF Signal Generator A
L1
149 nH
Maxim
Max2606
1
2
3
4
5
6
2 - 10 pF
To amp
L2
L3
10
.001
12.22v
5 VDC
.1
3.3 pF
51
100K
.001
NP0
Tune
100K
100K
.001
NP0
L2 = L3 = 303 nH *nominal*
138.5 – 172.1 MHZ
Peaked at 144 MHz
VCO

Above — The VCO schematic **A**. An L-match peaks the output at 144 MHz into 50 Ω. The beauty of this circuit = simplicity; just 2 active devices give low distortion and a strong output return loss (S22) on the 2 Meter Ham band.

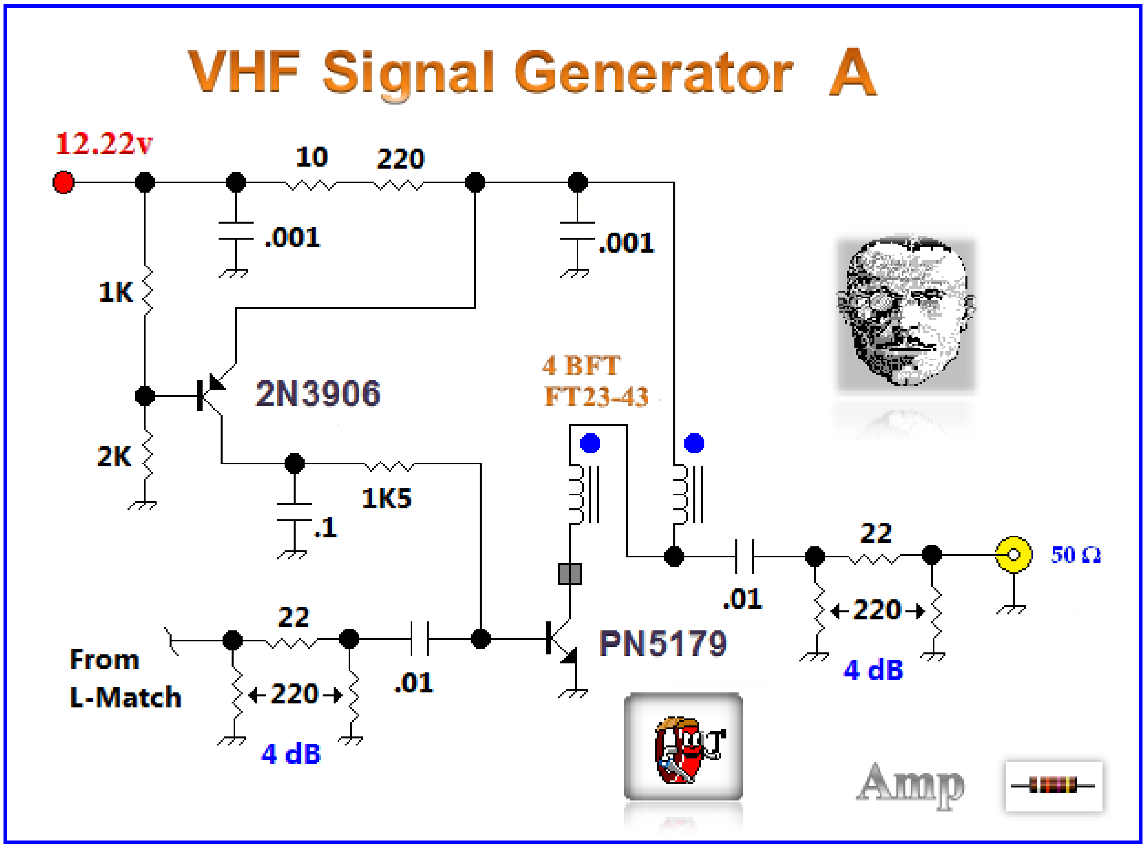
VHF Signal Generator A
12.22v
10
220
.001
.001
1K
2N3906
2K
.1
1K5
4 BFT
FT23-43
.01
22
50 Ω
220
4 dB
From
L-Match
22
220
4 dB
.01
PN5179
Amp

Above — The output amplifier for VCO "A". Click for a schematic with some analysis at 144 MHz (the frequency I'll use the most). I spent a lot of time trying to develop a 50 Ω output Z voltage amp up at ~ 144 MHz. My attempts to employ shunt and series feedback gave generally poor results — stray reactances plague the standard FBA designs that work great under ~70 MHz.

Since the MAX2606 has an output L-Match, getting a high output return was my only goal — grounding the PN5179 emitter, employing a 4:1 transmission line transformer and biasing for ~15 mA emitter current did the trick. A 4 dB pad on the NPN input further establishes a strong S22 (output return loss).

As possible, I attach additional 50 Ω outboard attenuators on my signal generators, however, the S22 on the stock generator should be okay across the VCO range due to the two 4 dB pads.

I measured the S11 on a prototype NPN amplifier by using the MAX2606 VCO shown to drive a MMIC with a 16 dB 50 Ω attenuator pad on the output and connecting it to the RF port of my return loss bridge. Thus, the actual VCO helped me design the final amplifier which buffers it in my final build. I kept the PN5179 and all other leads short as possible.

The output power looks like a sine wave when tuned from CCW to CW: With the 10-turn tuning potentiometer set to CCW [138.5 MHz], the output power ranges from -1.9 dBm; hits a peak of 0 dBm at 144 MHz and then gradually drops to -11.2 dBm at CW [172.1 MHz].

I moved away from the hycas buffer amp to simply my design and increase reproducibility. A MMIC might also work well, however the high current drain, potential for instability and biasing considerations introduce new problems — a simple wrap around PNP-biased NPN amplifier works okay. Sometimes the best solution = the simplest.

Band B: 98.919 - 109.06 MHz

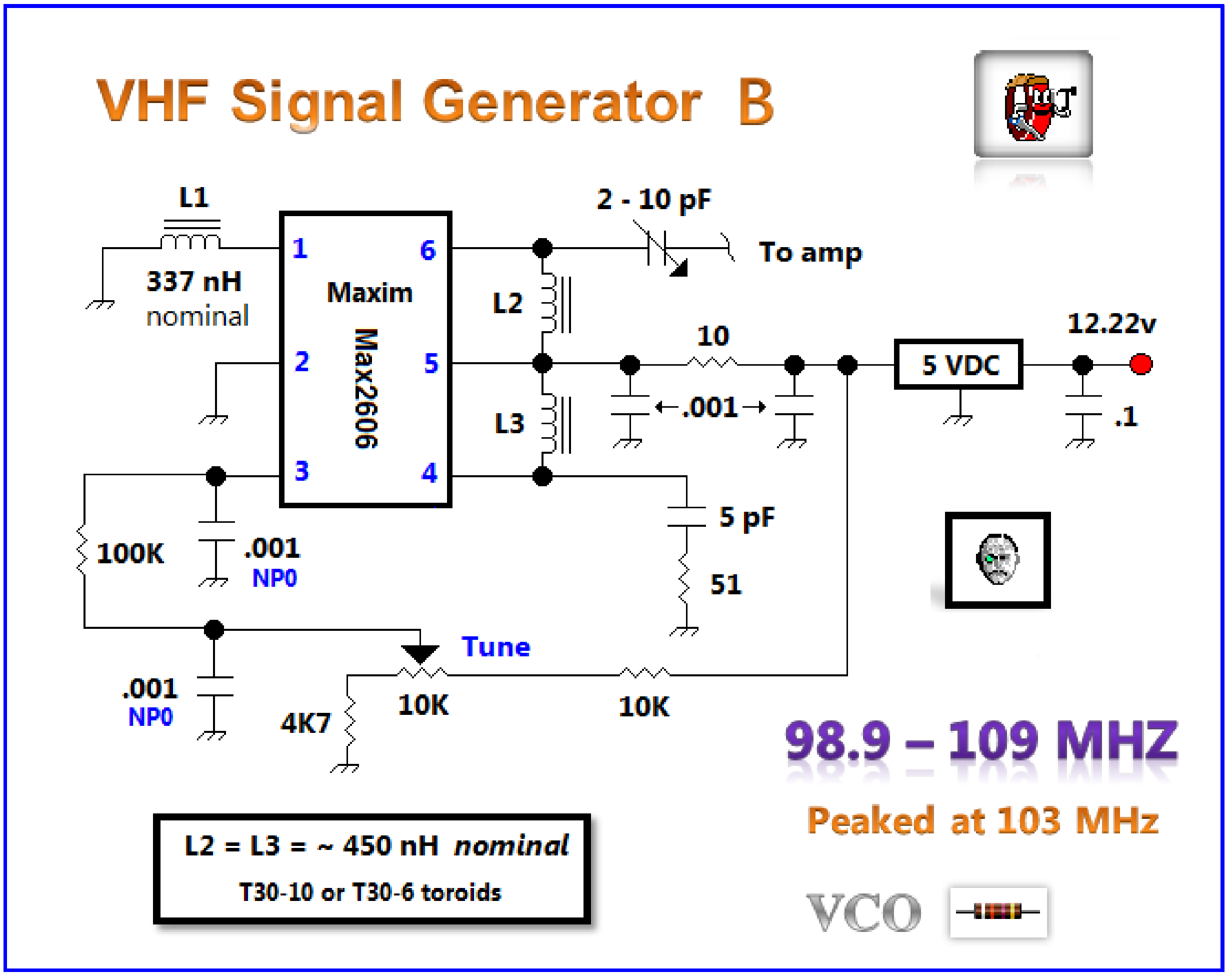

Above — The VCO schematic **B**. An L-match peaks the output at 103 Mhz, although compressing or expanding L2 and tweaking the 2 -10 pF capacitor can peak the L-network anywhere in the tuning range. I limited the tuning range by adding a 4K7 R to the tuning pot to enable better matching and fine tuning.

In all cases L1 = an air inductor wound on a coarsely threaded bolt using 20 or 21 guage enamel-coated magnet wire for mechanical stability. I set the lower band edge of the VCO by setting the tuning pot to CCW and compressing or expanding the L1 inductor to get the frequency shown.

For L1, I found that excessively long leads can create unwanted oscillations and my coils are just a few mm above the copper board. Some builders properly mount their coils in a upright "smokestack" fashion and/or well away from the nearby metallic chassis or copper PCB to minimize Q losses + inductance changes. My coils lie well away from the metal chassis walls.

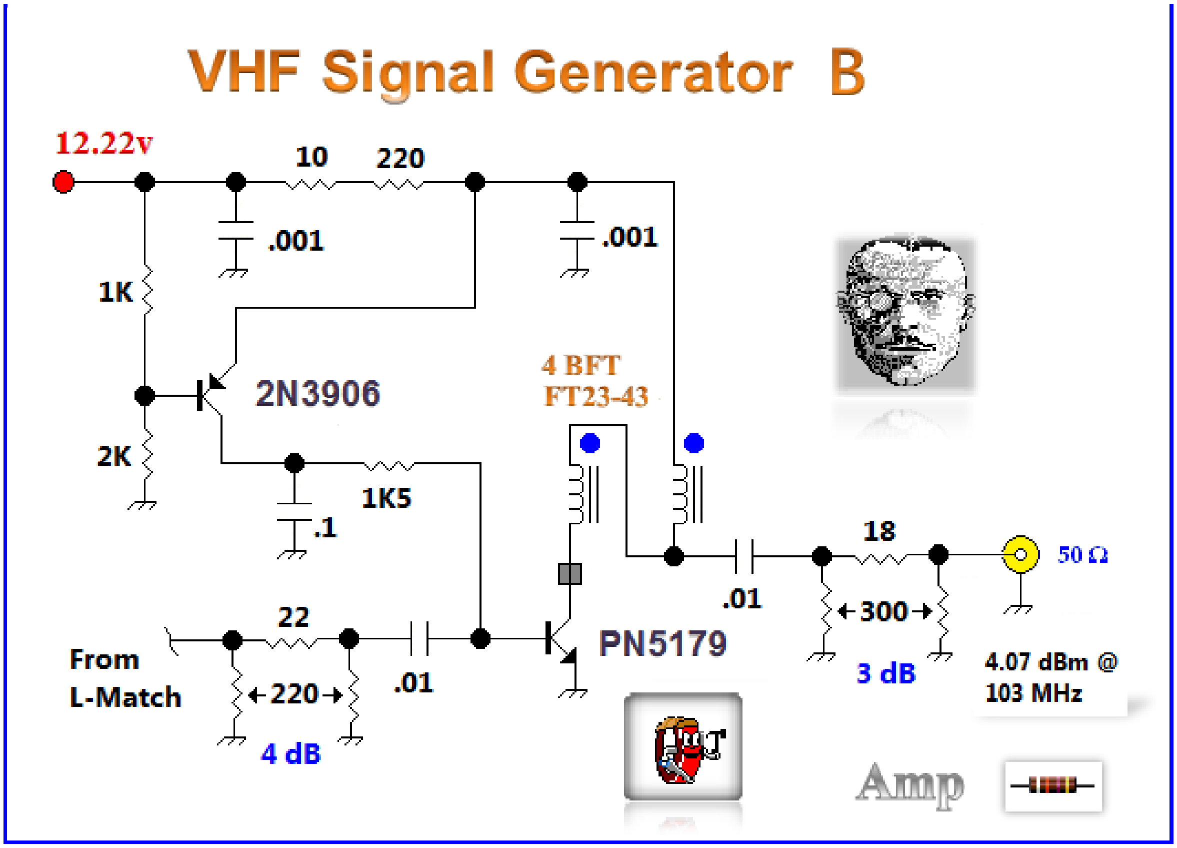
VHF Signal Generator B
12.22v
10
220
.001
.001
1K
2N3906
4 BFT
FT23-43
2K
1K5
.1
22
From
L-Match
220
.01
4 dB
PN5179
18
.01
300
3 dB
50 Ω
4.07 dBm @
103 MHz
Amp

Above — The VCO **B** buffer/amplifier schematic. A clean sine wave appears across the entire tuning range — output return loss tuning from minimum to maximum was > 21 dB before I added the 3 dB pad.

Click for a photo of the completed, partially labelled project during the final tune up with all the boards bolted in.

Section 3. 50 MHz VCO

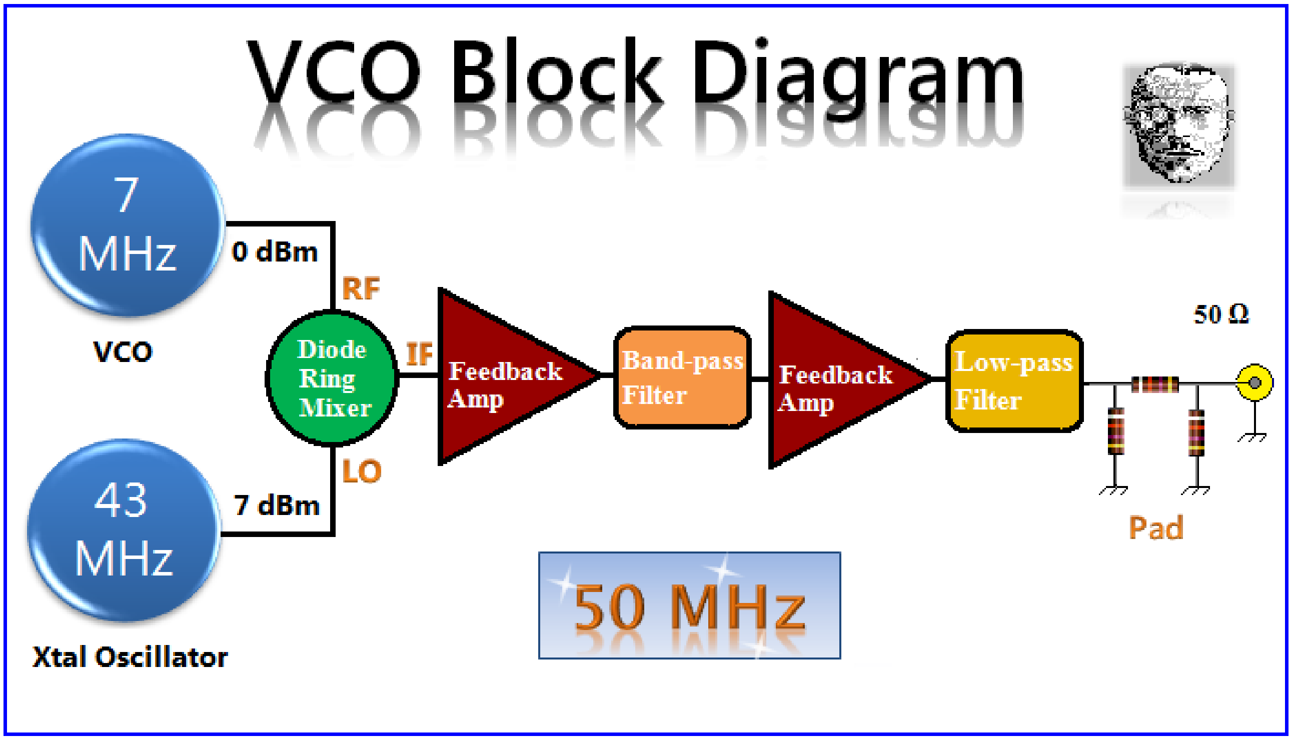
VCO Block Diagram
7
MHz
VCO
0 dBm
RF
Diode
Ring
Mixer
IF
LO
43
MHz
7 dBm
Xtal Oscillator
Feedback
Amp
Band-pass
Filter
Feedback
Amp
Low-pass
Filter
50 Ω
Pad
50 MHz

Above — Block diagram of the 50 MHz VCO I designed and built in February-March 2012. Click for a photo.

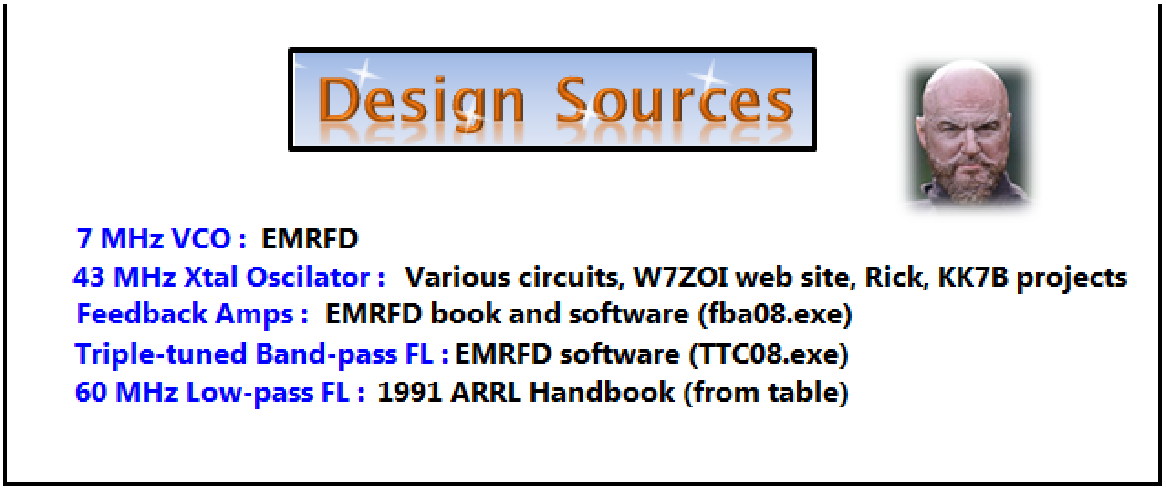

Design Sources

7 MHz VCO : EMRFD

43 MHz Xtal Oscilator : Various circuits, W7ZOI web site, Rick, KK7B projects

Feedback Amps : EMRFD book and software (fba08.exe)

Triple-tuned Band-pass FL : EMRFD software (TTC08.exe)

60 MHz Low-pass FL : 1991 ARRL Handbook (from table)

Above — Like most of you, I'm just an amateur designer who relies on others for example circuits, design procedures and inspiration. These cited references plus hard work drove my experiments. This project succeeds the Miscellaneous RF Experiments web page from 2011 — QRP SWL HomeBuilder evolves as I do.

7 MHz VCO + Buffer Amplifier [0 dBM output power]

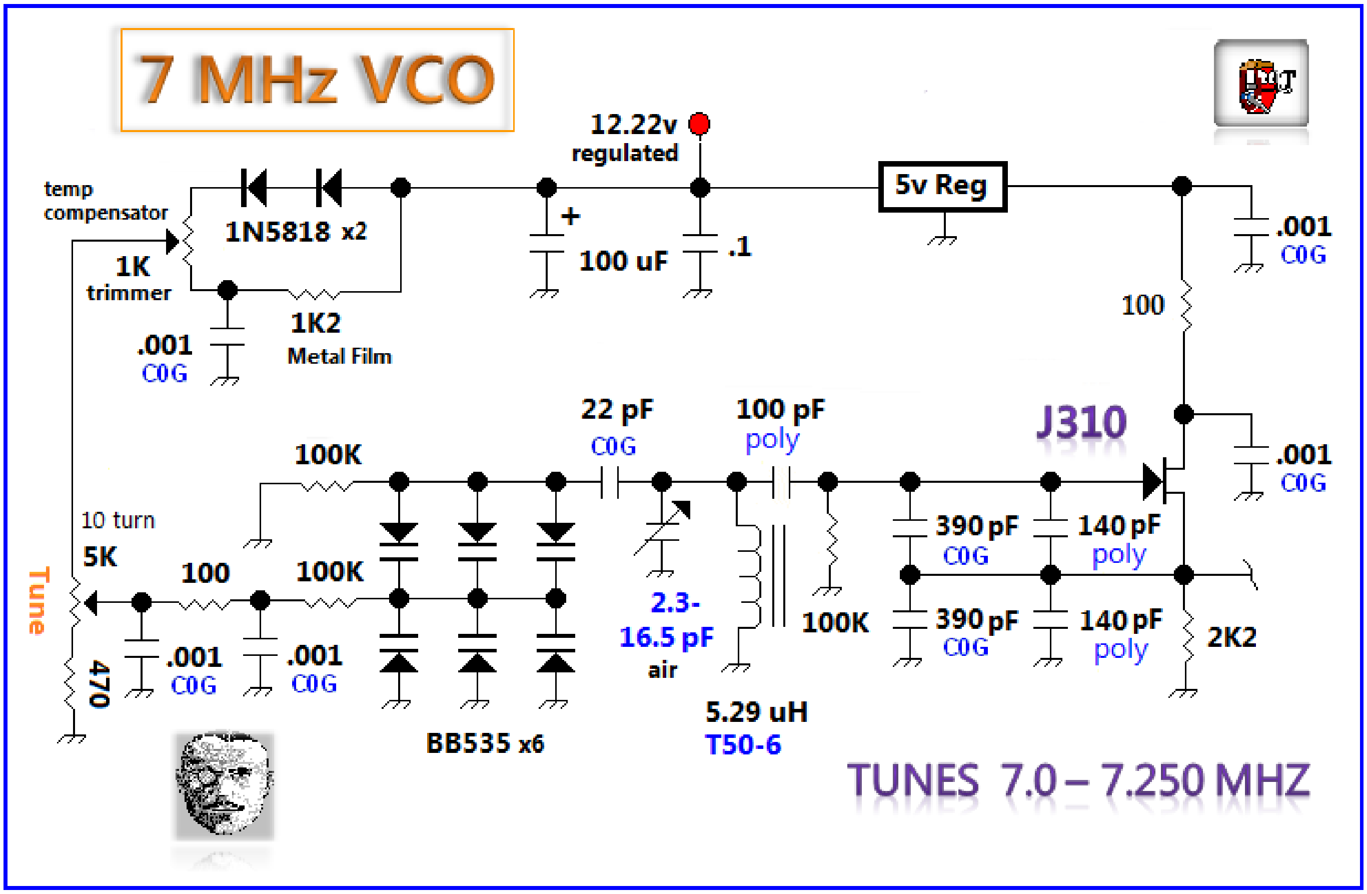
7 MHz VCO
12.22v
regulated
temp
compensator
1N5818 x2
+
100 uF
.1
5v Reg
.001
C0G
1K
trimmer
1K2
Metal Film
.001
C0G
100
22 pF
C0G
100 pF
poly
J310
.001
C0G
100K
10 turn
5K
Tune
100
100K
390 pF
C0G
140 pF
poly
470
.001
C0G
.001
C0G
2.3-
16.5 pF
air
100K
390 pF
C0G
140 pF
poly
2K2
BB535 x6
5.29 uH
T50-6
TUNES 7.0 – 7.250 MHZ

Above — 7 MHz Colpitts VCO schematic.

This VCO tunes ~7.00 to 7.250 MHz, although a wider tuning range occurs if you allow the tuning diodes to drop to 0 VDC with the 5K tuning pot cranked CCW. A 470 ohm resistor keeps about 1 VDC on the varactors at the lowest tuning frequency/applied reverse DC voltage.

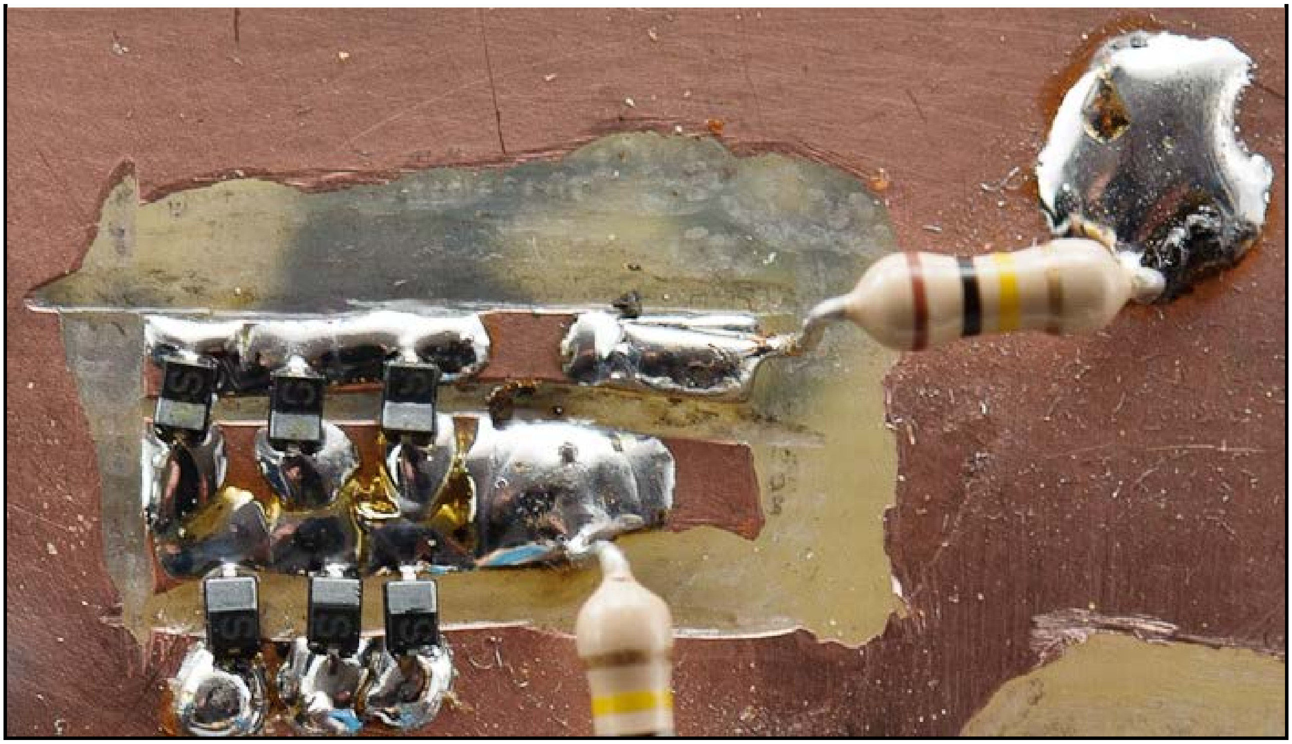

Above — A macro photograph of the six BB535 varactors soldered on the VCO breadboard. With 0 applied reverse DC voltage, their total C = 43.5 pF. I left room for up to 4 more diodes, but didn't need them.

Macro photography provides an excellent way to inspect SMT parts — apart from all the fiberglass dust on the board, no shorts or other problems arose when soldering. Next to pF-value chip capacitors, these SMD varactors proved the most difficult surface-mount parts I've breadboarded to-date. Using clear tape, I tape my SMT parts to the PC board when soldering. With tape, you can still make tiny device placement adjustments with a pick or tweezers and yet the device holds steady enough to solder. I recently obtained a microscope for SMT work, although didn't need it for these diodes.

Striving for lower phase noise meant properly applying high Q tank parts — I soldered in 3 pairs of high-grade BB535 varactors and arranged them anti-parallel to avoid forward conduction + even harmonics. I also limited the AC voltage swing they "see" by connecting them to the L with a 22 pF capacitor. Tight windings of #28 gauge magnet wire on a T50-6 toroid formed the inductor. 4 number 8 bolts anchor the 7 MHz VCO board to the chassis and prevent board warp + movement.

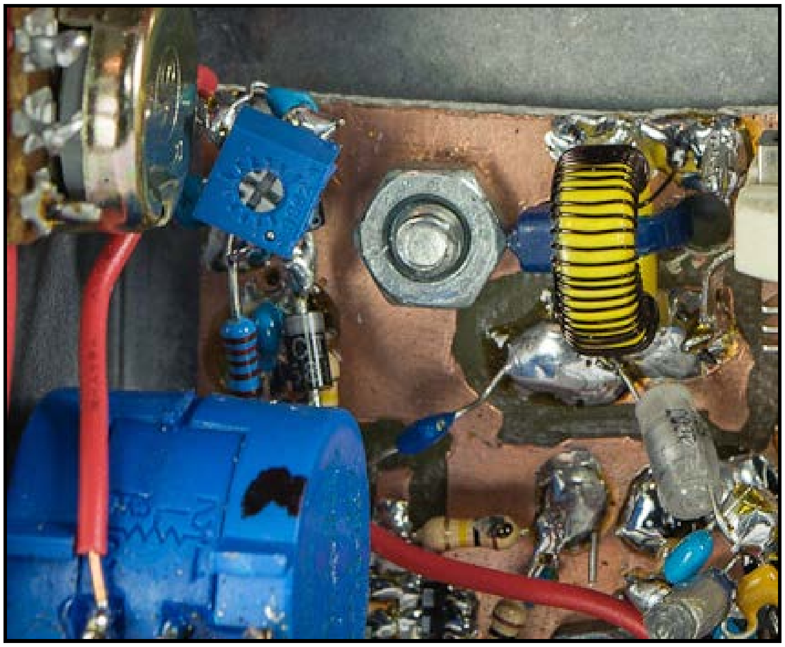

Above — a view of the square blue 1K temperature compensation (tempco) trimmer potentiometer.

To aid temperature compensation, I included 3 polystyrene capacitors in the base VCO — the tempco circuitry represents about 16 hours of work from December 2011. Click or click for photos of the bread board before the tempco parts were soldered on — the temporatry BNC connector lies in the background was removed after testing.

With care and patience my lid-on 1 hour temperature drift = ~10 Hz. My temperature compensation strategy worked because I took the time to measure and then determine how to cancel temperature drift in this 1 circuit — your results will vary and *experimentation* remains the key to temperature compensating VCOs and VFOs.

See EMRFD, and the VFO-2011 + QRP Modules 2011 web pages for more tempco information.

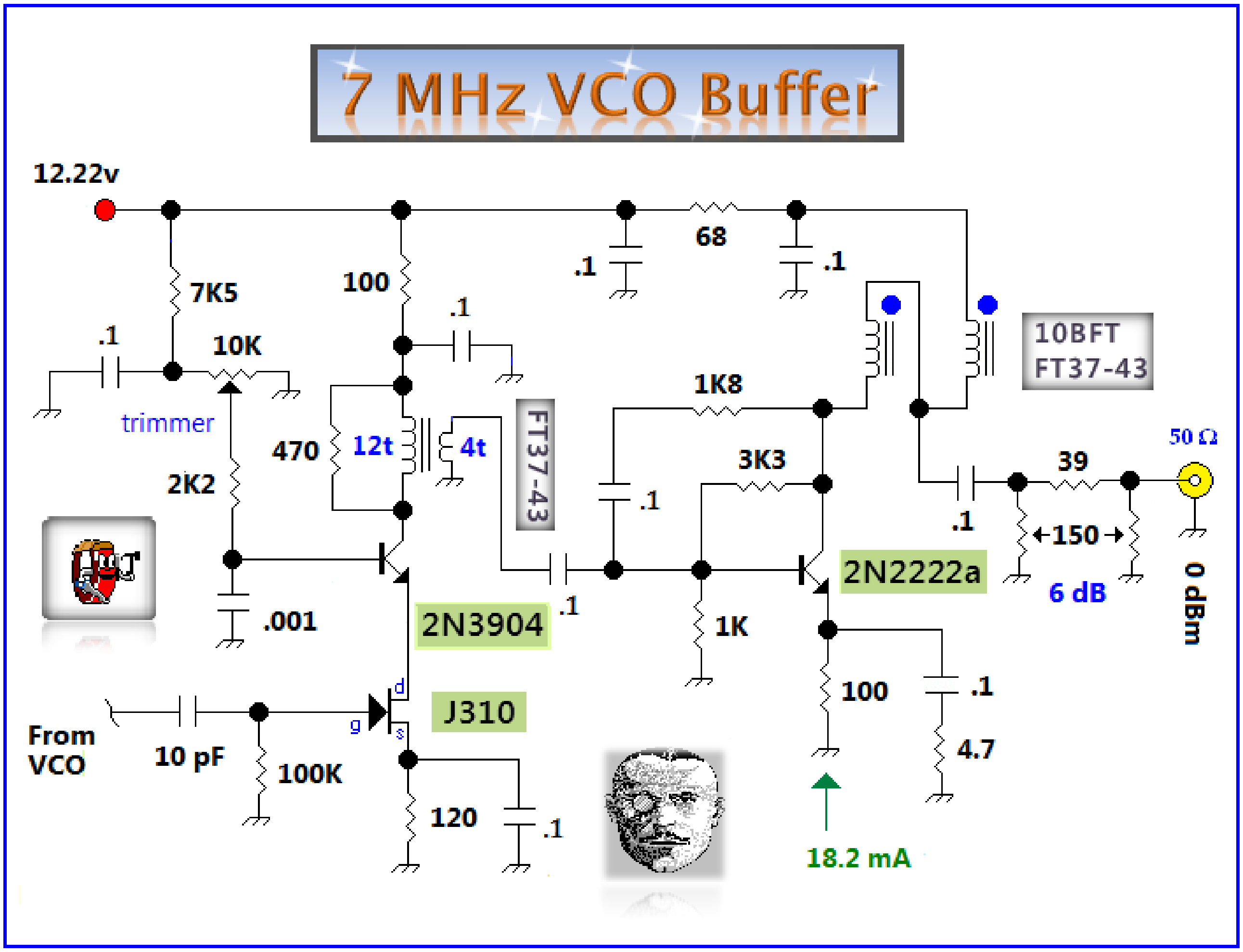
7 MHz VCO Buffer
12.22v
7K5
100
.1
68
.1
.1
10K
.1
trimmer
2K2
470
12t
4t
FT37-43
1K8
3K3
10BFT
FT37-43
.1
.1
39
50 Ω
←150→
6 dB
0 dBm
.001
2N3904
.1
2N2222a
1K
100
.1
4.7
From
VCO
10 pF
100K
d
g
s
J310
120
.1
18.2 mA

Above — 7 MHz VCO buffer/amplifier. I adjusted the 10K trimmer pot on the hycas buffer for exactly 0 dBm drive. Even before adding the 6 dB attenuator pad, the output return loss = 23.8 dB @ 7.0 MHz.

Originally, I wanted a VCO output of 7 dBm and applied ~18 mA emitter current in the final amp to preserve signal fidelity and eliminate the need for a low-pass filter. This buffer works great up to an output power of ~10 dBm: above 10 dBm or so, distortion occurs and you'll need to add a low-pass filter.

Adjust the hycas trimmer pot for whatever output power you seek, but If you're ever using this buffer for 7 -10 dBm output power, drop the 6 dB attenuator pad to 3 dB. This drops the drive level to maintain low harmonic distortion (2nd harmonic down > 35 dBc).

43 MHz Butler Xtal Oscillator [6.4 dBm output power]

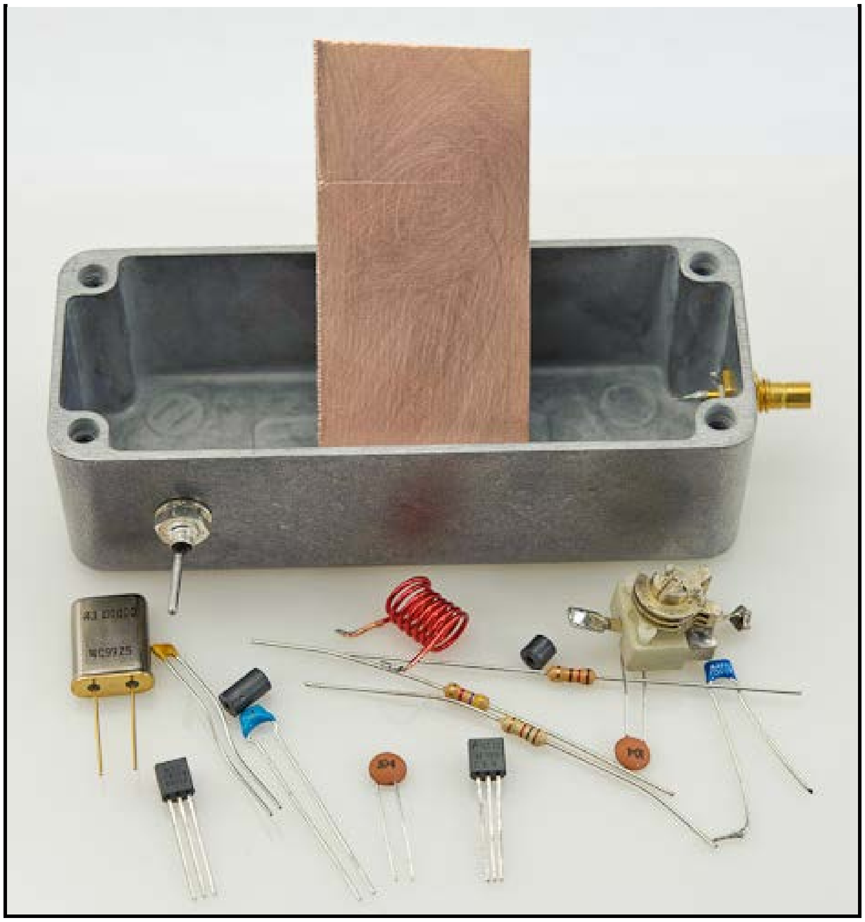

Above — Some Butler crystal oscillator parts prior to the build. Since this Butler will go inside a box containing a VCO and some high gain amplifiers, it would be foolish to not stick it in an RF-tight box. On the Hammond chassis above, you'll notice a feedthrough capacitor for the 12 VDC and an gold colored SMA connector for the output.

Since the required L = over 400 nH, I opted for a toroidal inductor wound on a T30-10 instead of the air coil shown in the photo.

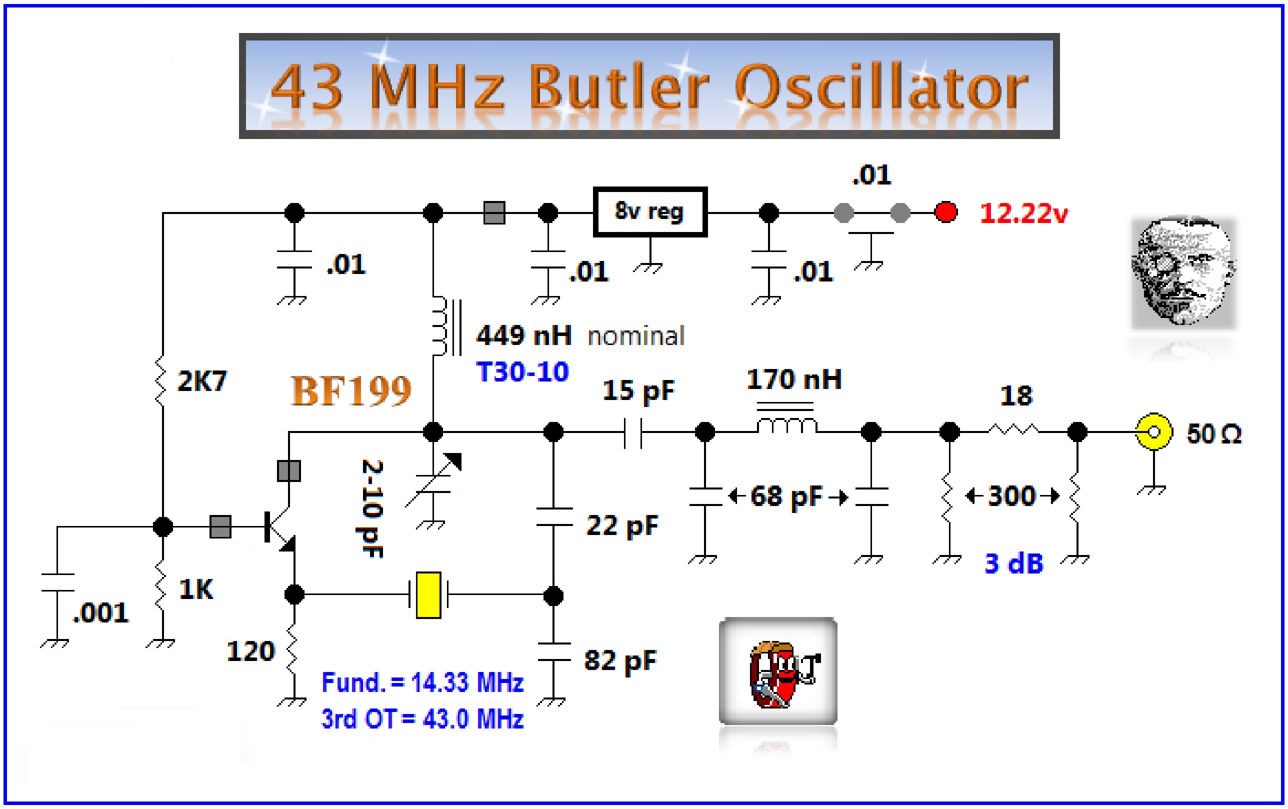
43 MHz Butler Oscillator
.01
8v reg
12.22v
.01
.01
.01
449 nH nominal
T30-10
2K7
BF199
15 pF
170 nH
18
50 Ω
2-10 pF
68 pF
300
22 pF
3 dB
.001
1K
120
82 pF
Fund. = 14.33 MHz
3rd OT = 43.0 MHz

Above — 43 MHz Butler overtone oscillator schematic. The highest power I could muster = 6.4 dBm (close enough to 7 dBM).

This Butler looks good on FFT. Click, Click or click for 3 'scope captures. Despite trying to milk maximal power, the 2nd harmonic is over 40 dBc down. Click for a snap shot of the completed oscillator.

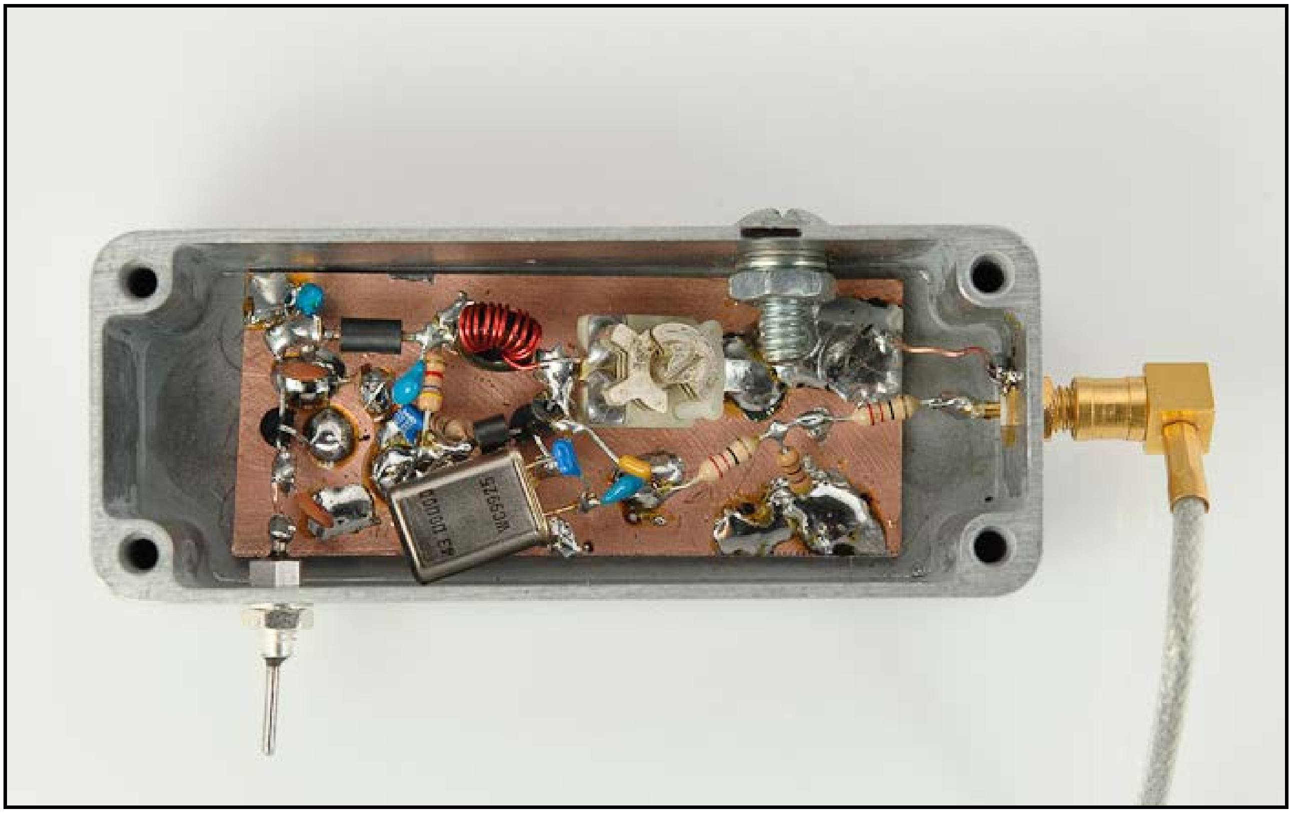

Above — The original Butler oscillator before adding the pi low-pass filter. The bolt (seen at top right) will also pass through the outer VCO chassis to hold this sub-chassis in place. Click for a bigger photograph.

Post-Mixer Amplifer and Triple-Tuned Filter

Post–mixer Amp and Band-pass Filter

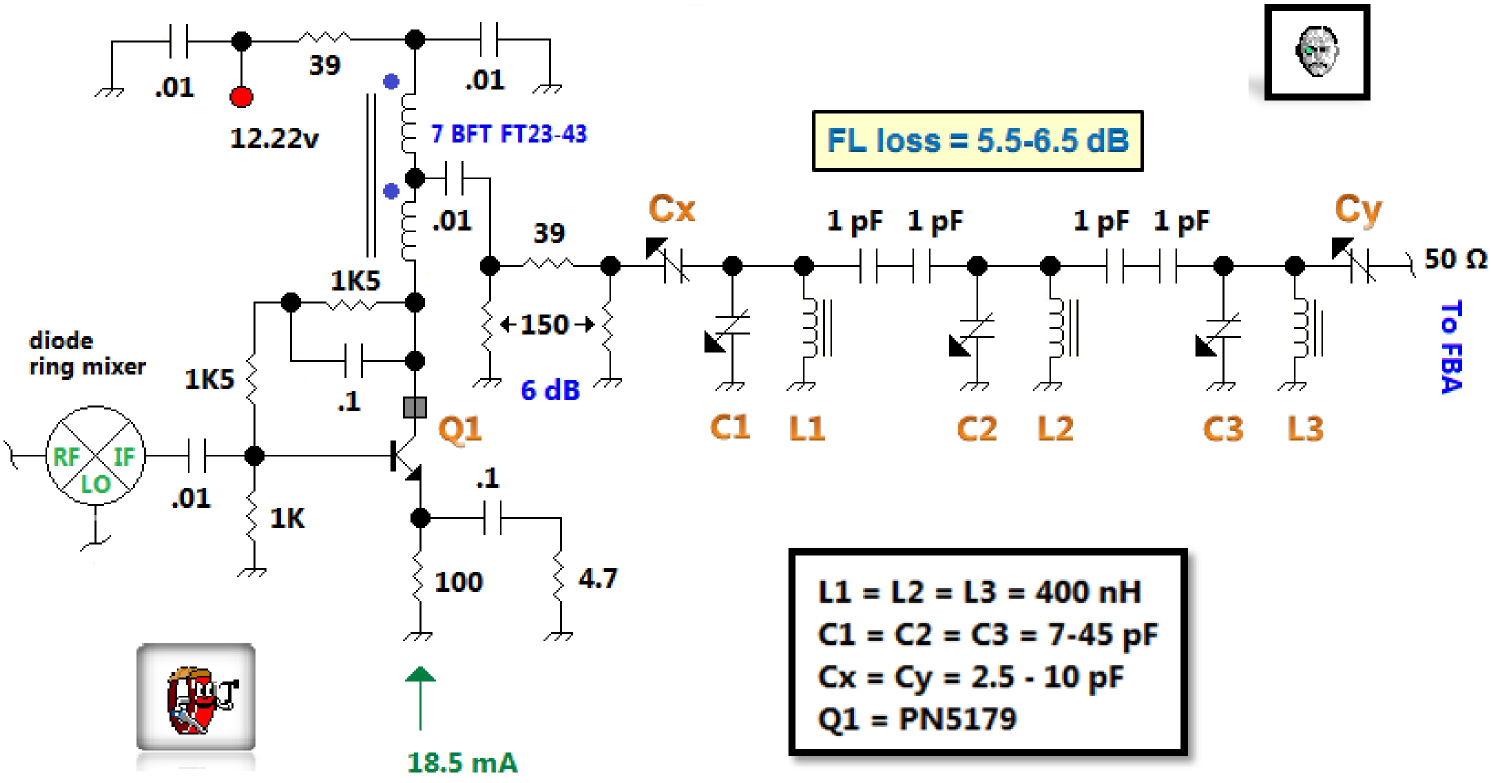

Above — Schematic of the diode ring mixer, Q1 feedback amp and the triple-tuned filter. *I used a MCL SBL-1 mixer*. L1 - L3 were wound on T30-10 toroids. I bought my #10 and some #12 toroids from the great folks at Debco Electronics.

The post-mixer feedback amp data at 50.0 MHz (isolated from the mixer and pad + filter) : Emitter current = 18.5 mA, S21 =18 dB, S11 = - 24.4 dB, S22 = - 21.5 dB. *(S21 = power gain; S11 = negative of the input return loss; S22 = negative of the output return loss).*

The 6 dB pad helps absorb signal reflections from the filter caused from stray reactance plus capacitance variations caused by coupling the 2 tanks with only 0.5 pF (2 series 1 pF capacitors with a +/- 0.25 pF tolerance!)

Preliminary filter alignment: Peak your filter however you want — but here's how I peaked my filter with a crystal controlled 50.0 MHz signal generator connected via a temporary BNC connector tack soldered onto the copper board and wired to the Q1 input. Terminate the filter with a ~50 Ω resistor, or a temporary BNC connector plugged with a 50 Ω resistive terminator.

Connect the signal generator to Q1 and peak C1, C2 and C3 (in that order) using a 10X 'scope probe. It's better measure with your probe at point C2 when tuning C1 since this reduces mistuning caused by probe capacitance — measure at point C3 when tuning C2 etc.

Then peak C3, Cx and Cy with the probe touching the terminating 50 Ω resistor. *It easier to perform the first tune-up with a 10X probe going sequentially from C1 to C3 since these peaking capacitors tune pin sharp.*

After the preliminary tune-up, if possible, connect a temporary BNC connector to the output and re-peak all the caps with a 50 Ω terminated scope; this boosts sensitivity and eliminates 'scope probe capacitance.

Perform pentultimate 50.0 Mhz alignment after you add the post-filter amp, low-pass filter and the 3 dB pad. Capacitor Cy critically sets the output return loss of Q2 and when properly matched, establishes a 50 Ω termination for the triple-tuned band-pass filter.

You can also match Cx by connecting a return loss bridge to the input of Q1 and terminating the RF chain with a 50 Ω resistor, although tuning Cx only changes the input S11 a little. In 1 experiment, I replaced Cx with 6 pF and it worked okay.

I wonder how I ever managed before making a return loss bridge: the workhorse of the QRP workbench.

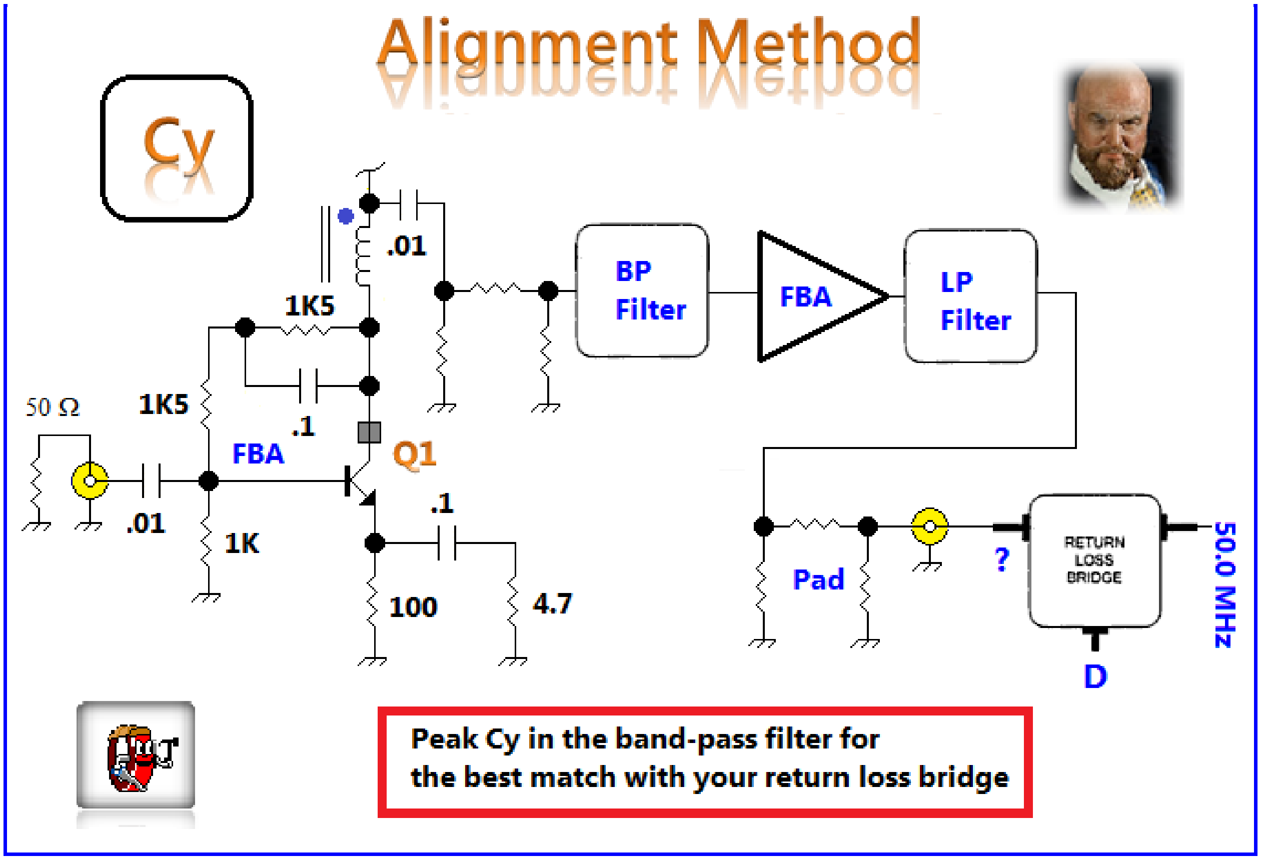
Alignment Method
Cy
50 Ω
1K5
.01
1K
1K5
.1
FBA
Q1
.01
.1
100
4.7
BP
Filter
FBA
LP
Filter
Pad
?
RETURN
LOSS
BRIDGE
D
50.0 MHz

Peak Cy in the band-pass filter for
the best match with your return loss bridge

Above — Schematic depicting how to tune up Cy.

Tuning Cy matches the band-pass filter output to the Q2 input impedance — it's fascinating to examine the interdependence of these 50 Ω stages. After setting Cy, I connected the 50 MHz signal generator to the Q1 input and a 50 Ω terminated 'scope to the output and re-peaked Cx, C1, C2 and C3 — finally I tweaked Cy 1 last time with the whole stage in a return loss measurement set-up.

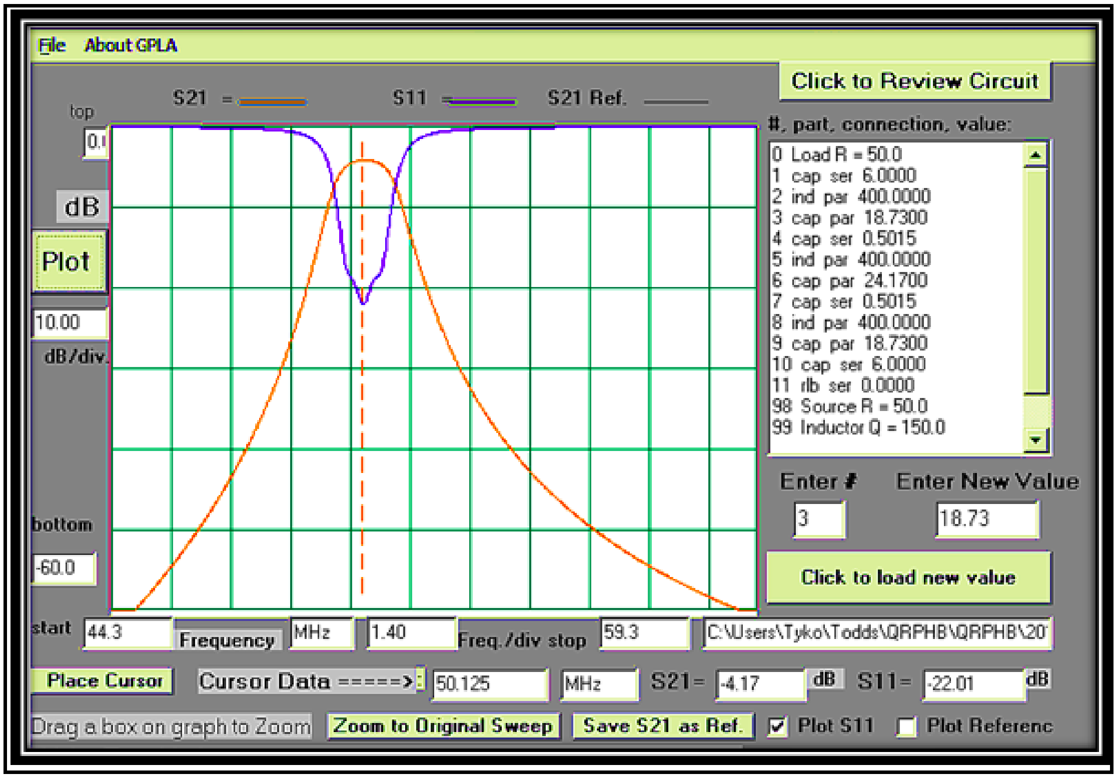
File
About GPLA
Click to Review Circuit
S21 =
S11 =
S21 Ref.
dB
Plot
Click to load new value
Frequency
Place Cursor
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.

#, part, connection, value:
0 Load R = 50.0
1 cap ser 6.0000
2 ind par 400.0000
3 cap par 18.7300
4 cap ser 0.5015
5 ind par 400.0000
6 cap par 24.1700
7 cap ser 0.5015
8 ind par 400.0000
9 cap par 18.7300
10 cap ser 6.0000
11 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 150.0

top 0.
10.00 dB/div.
bottom -60.0
Enter # 3
Enter New Value 18.73
start 44.3 MHz
1.40 Freq./div
stop 59.3
C:\Users\Tyko\Todds\QRPHB\QRPHB\20
Cursor Data =====> 50.125 MHz
S21= -4.17 dB
S11= -22.01 dB
☑ Plot S11
☐ Plot Referenc

Above — A GPLA simulation of the triple-tuned band-pass filter. CF = 50.125 MHz. I substituted 6 pF (the nominal value) for the 2 series end capacitors in my simulation. отлично!

Post-filter Feedback Amplifer, Low-pass Filter and Pad

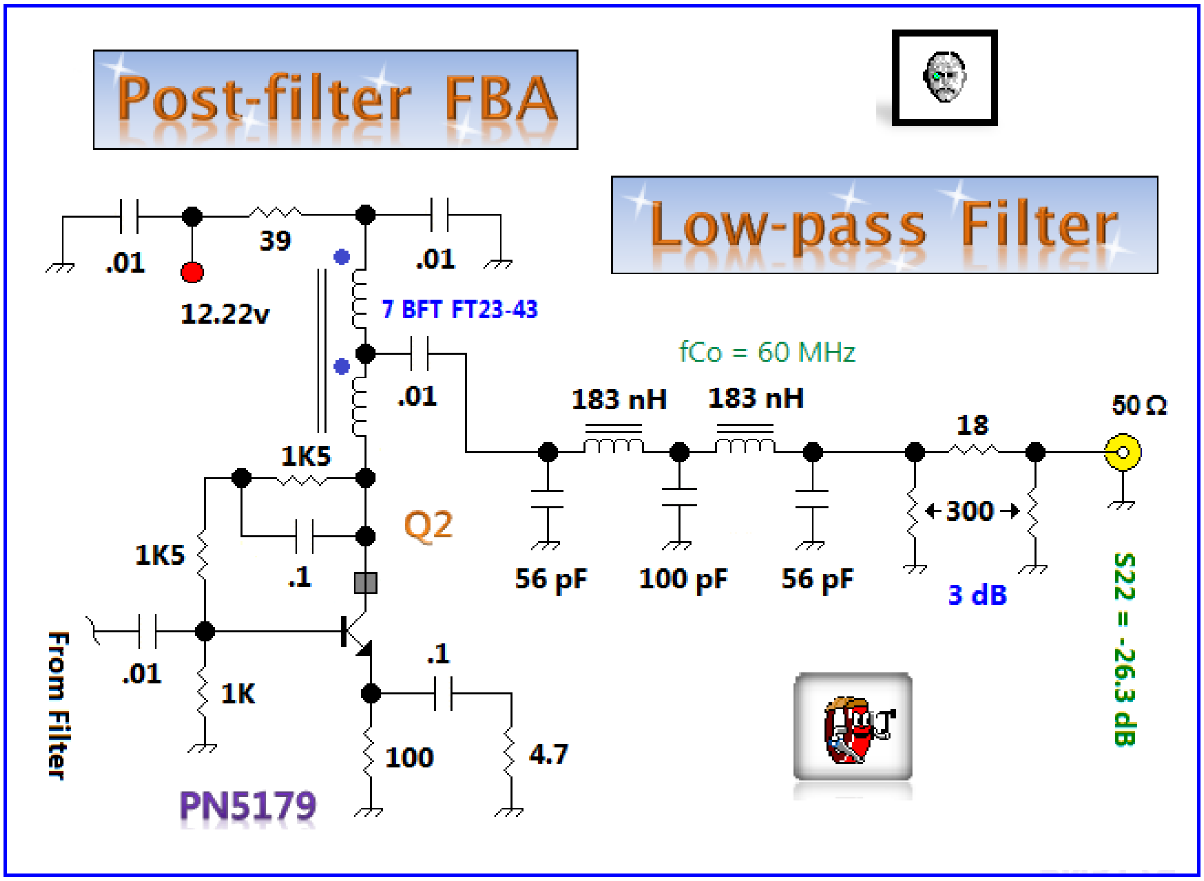

Above — Q2, the post filter feedback amp (FBA), an N=5 Chebyshev low-pass filter plus a 3 dB pad.

For Q2, I copied Q1 to deliver a strong input and output return loss. In many circuits employing cascaded FBAs, you increase emitter current in each successive FBA to reduce distortion, however, increasing emitter current affects both the input and output impedance and may trash your amplifier's S11 and S22.

I spent days studying, simulating + bench testing different amplifier designs in the Q2 slot — I generated enough material for another web page and plan to show this work in an update to my Popcorn superhet receiver some day.

It's possible to overdrive Q2 depending on your amplifer power and stage matching. If so, you might consider placing a 3-4 dB pad after the band-pass filter. Some might opt for a 7 element low-pass filter; experiment — as always.

Low-pass filter inductors = turns on T30-10 toroids, although #6 material toroids, or air coils will work fine.

Outputs

After bolting down the boards, wiring the DC and RF and confirming it worked, I finalized alignment. Using a frequency counter, I tuned the VCO to 50.125 MHz (the half-way point) and peaked C1, C2, C3 for the maximum peak-peak voltage into my 50 Ω terminated 'scope.

Click for the output at 50.125 MHz — 10.09 dBm. I normally hang an outboard 50 Ω attenuator on the output of my signal generators and keep 3 dB, 6 dB, 10 dB and 20 dB BNC-connected pads handy. With a 3 dB pad, the output power = 6.84 dBm — perfect for switching Level 7 diode ring mixers. Click for the 'scope shot with a 3 dB pad applied.

Click or click for an FFT of the output signal. The second harmonic is > 50 dB down. What fun!

The "vestigial" RF gain control shown on the chassis remains unused; wastage.

Miscellaneous Photos and Figures

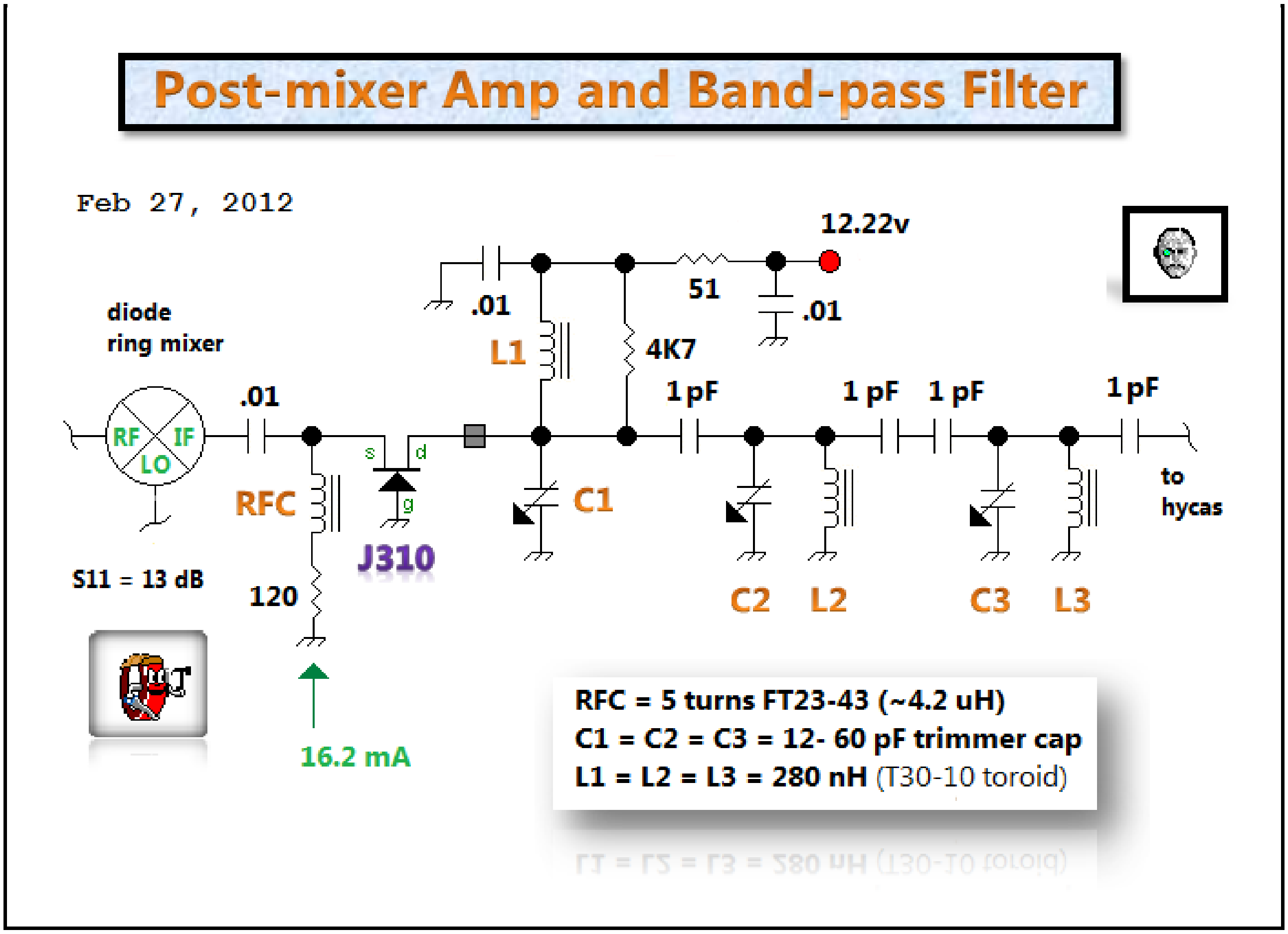
Post-mixer Amp and Band-pass Filter
Feb 27, 2012
12.22v
diode
ring mixer
.01
51
.01
L1
4K7
.01
1 pF
1 pF
1 pF
1 pF
RF
IF
LO
s
d
g
RFC
J310
C1
to
hycas
S11 = 13 dB
120
C2
L2
C3
L3
16.2 mA

RFC = 5 turns FT23-43 (~4.2 uH)
C1 = C2 = C3 = 12- 60 pF trimmer cap
L1 = L2 = L3 = 280 nH (T30-10 toroid)

Above — A **failed** experimental JFET post-mixer amp with tuned output driving a double-tuned filter.

Click for a GPLA simulation of the double-tuned filter. The common gate JFET amp provides a great way to terminate a diode ring and obviates the need for a diplexer network. Click for a breadboard photo of the above stage.

The amplifier input match @ 50 MHz is only ~ 13 dB, however, we're not interested in a narrow band match — the tuned output network makes strong input matching at 50 MHz impossible *(for me at least)* without additional L and C (narrow band components that we don't want!). I tried a few tapped inductor schemes, however, at VHF, adding turns added significant capacitance and things got ugly fast.

The common gate JFET amp/filter goof-up shattered my expectations. The 4K7 input/output impedance drove instability through unwanted coupling between the inductors. I learned my lesson: at or above 50 MHz, *stick to 50 Ω stages* for stability.

OFF
50
Ω
ON
GAIN
TUNE

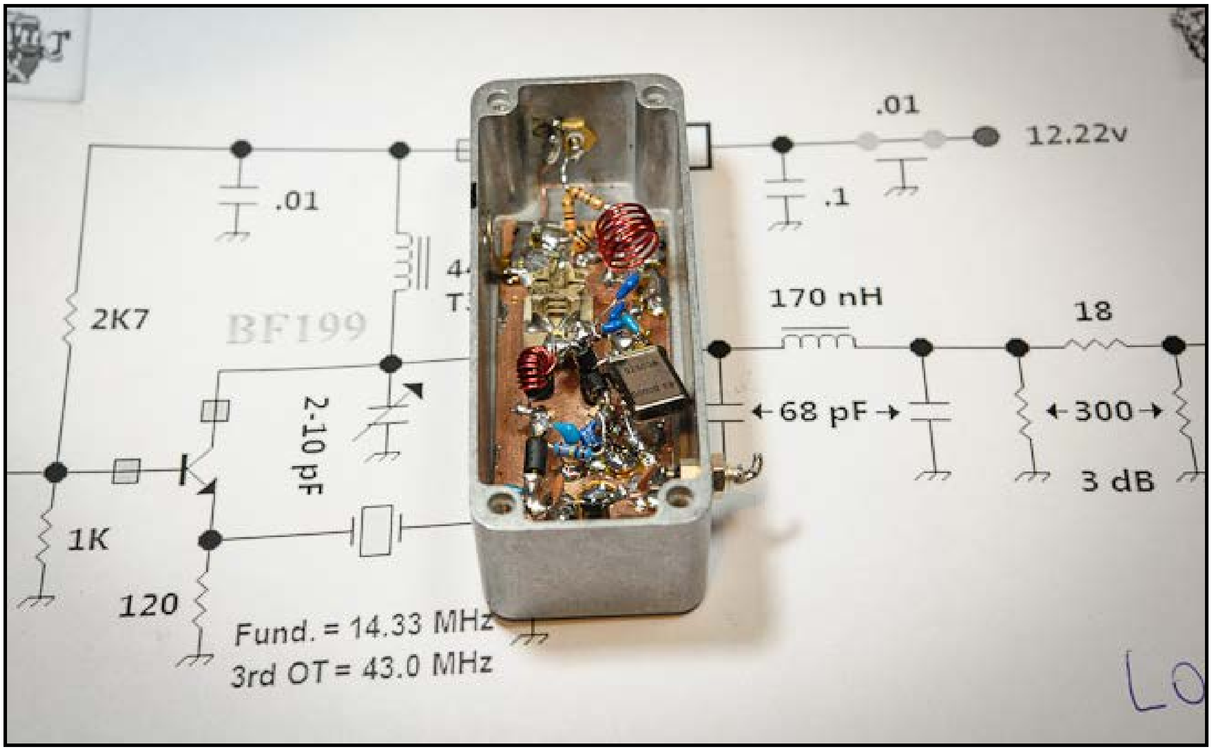
.01
12.22v
.01
.1
2K7
BF199
170 nH
18
2-10 pF
68 pF
300
3 dB
1K
120
Fund. = 14.33 MHz
3rd OT = 43.0 MHz
Lo

Section 4. 50 MHz Receiver Pre-amp and Filter

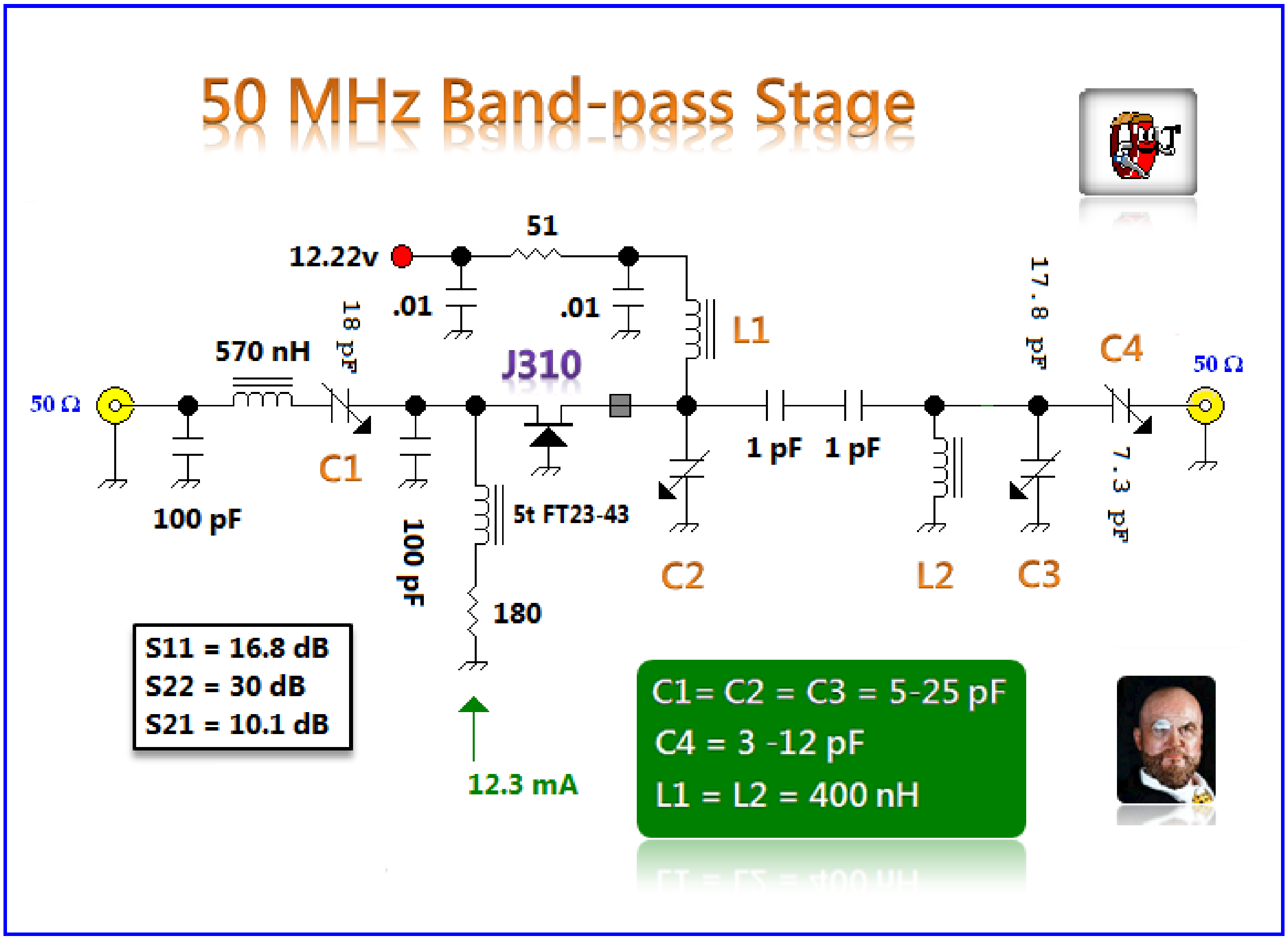
12.22v
51
.01
.01
18 pF
570 nH
L1
J310
17.8 pF
C4
50 Ω
50 Ω
C1
100 pF
100 pF
5t FT23-43
1 pF
1 pF
7.3 pF
C2
L2
C3
180
12.3 mA

50 MHz Band-pass Stage

S11 = 16.8 dB
S22 = 30 dB
S21 = 10.1 dB

C1= C2 = C3 = 5-25 pF
C4 = 3 -12 pF
L1 = L2 = 400 nH

Above — A 50 MHz receiver front end filter with embedded common gate amplifer.

Inspired by the General Purpose Monoband Receiver Front End from Figure 6.69 in EMRFD, I applied inductive and capacitive reactance modeling, DTC08, Ladbuild08 and GPLA08 from the EMRFD ladpac series and built a 50 MHz equivalent.

Connect an antenna to the input and a 50 Ω impedance mixer to the output.

I tested the stage at 50.0 MHz and wound my inductors on T30-10 toroids, although #6 material cores would work okay. You'll find all the measurement techniques in my RF Workbench series 1-4 available though the top-level menu.

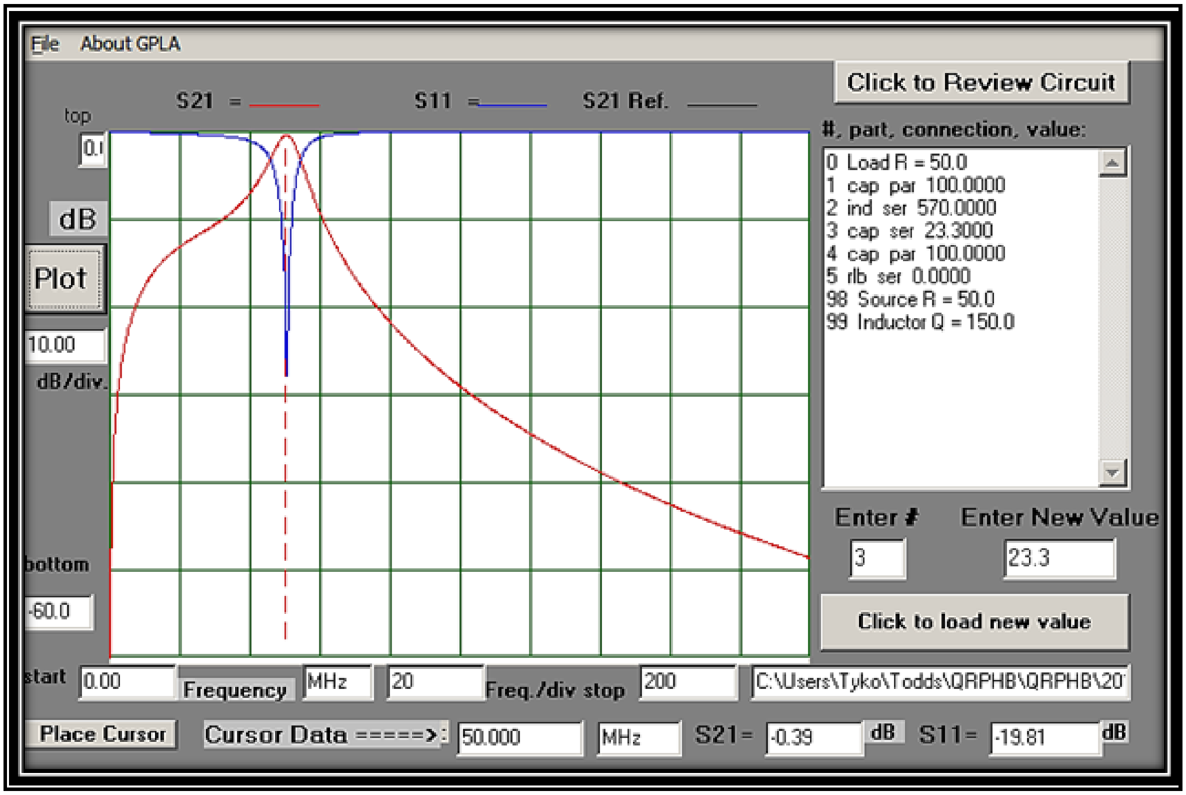

#, part, connection, value:
0 Load R = 50.0
1 cap par 100.0000
2 ind ser 570.0000
3 cap ser 23.3000
4 cap par 100.0000
5 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 150.0

top 0.(
10.00 dB/div.
bottom -60.0
Enter # 3
Enter New Value 23.3
start 0.00 Frequency MHz
20 Freq./div
stop 200
C:\Users\Tyko\Todds\QRPHB\QRPHB\20
Cursor Data =====> 50.000 MHz S21= -0.39 dB S11= -19.81 dB

Above — GPLA simulation of the peaked low-pass filter "built" in Ladbuild08.

Wes often employs a peaked low-pass filter and after studying his work, I can see why — way better attenuation than a simple 3 element low-pass filter. The FM broadcast band runs from about 87.5 to 108 MHz and in Russia, they call it "YKB" (Ультракороткие волны) or ultra-shortwave. At 87.5 MHz, attenuation = 25 dB; pretty good for such a simple filter. At 144 MHz, filter attenuation rises to ~ 40 dB.

This peaked low-pass filter acts as a preselector for the JFET amp that follows it. *Please read the text describing Figure 6.69 in EMRFD for some great notes by Wes.*

In the simulation above, a 50.0 MHz peak response occurred with C1 at 23.3 pF, while in my real circuit, the capacitor was set to ~ 18 pF. Stray L and C + the input Z of the JFET amp caused this variance, but assuredly; GPLA gets you close.

To peak the low-pass filter, I connected a return loss bridge to the input port and tweaked C1 for the lowest possible peak-peak voltage (tuned for the the best return loss which = 16.8 dB in my circuit). *You may also compress or expand the 540 nH inductor to aid tweaking.*

Since common gate amplifiers often exhibit a lower noise figure with a slight mismatch, an S11 of -16.8 dB works fine .I wish I had the gear to set the input match for the lowest possible noise figure — perhaps 1 day I will.

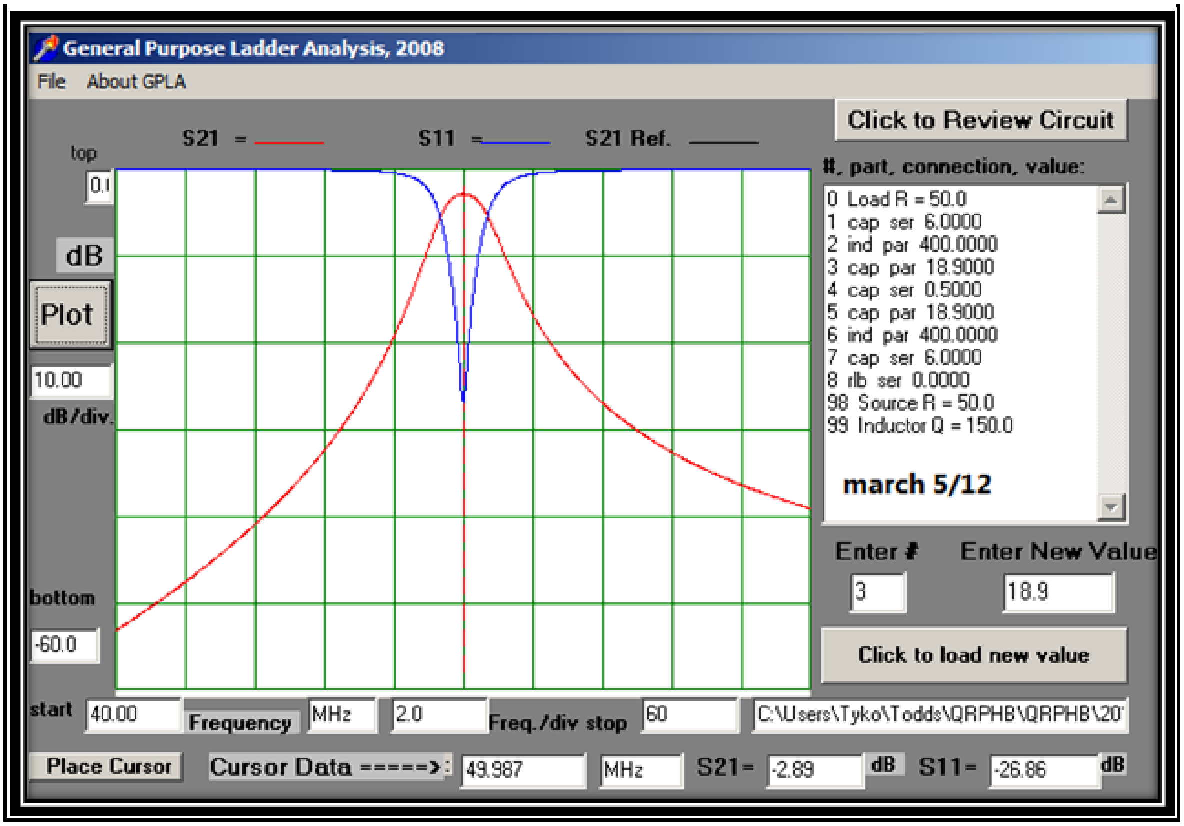
General Purpose Ladder Analysis, 2008
File
About GPLA
S21 =
S11 =
S21 Ref.
Click to Review Circuit
top
dB
Plot
dB/div.
bottom
Frequency
Freq./div
Enter New Value
Click to load new value
Place Cursor
Cursor Data =====>:

#, part, connection, value:

0 Load R = 50.0
1 cap ser 6.0000
2 ind par 400.0000
3 cap par 18.9000
4 cap ser 0.5000
5 cap par 18.9000
6 ind par 400.0000
7 cap ser 6.0000
8 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 150.0

march 5/12

top: 0.0
10.00 dB/div.
bottom: -60.0
start: 40.00 MHz
Freq./div: 2.0
stop: 60
C:\Users\Tyko\Todds\QRPHB\QRPHB\20
Enter #: 3
Enter New Value: 18.9
Cursor Data: 49.987 MHz
S21= -2.89 dB
S11= -26.86 dB

Above — A GPLA simulation of the 50 MHz double tuned band-pass filter "built" in DTC08. The bandwidth = ~1.8 MHz and varies slightly with the tuning of C4.

I peaked both C2 and C3 with a 50 Ω signal generator and a 50 Ω terminated scope connected to the input and output ports respectively.

Next, I connected my return loss bridge to the output and tweaked C3 and C4 for the lowest peak-peak voltage — the best return loss — and since you tweak 2 capacitors, a strong output return loss delights you.

Finally, I measured the peak-peak voltage with the amp in-line, and after removed the amp and reconnected the 50 Ω cables with a through-connector. Inputting the 2 pk-pk voltages into Applet H on the Design Center web page gave a gain *or S21* of 10.1 dB. I repeated all of the steps above a couple more times to ensure I had set C2, C3 and C4 perfectly.

I found tuning the resonators difficult due to the sharp tuning and wide capacitance range of C1-C3. Assuming your tanks are peaked, the best amplifier gain correlated to the highest input and output port return loss. Have I stressed the importance of a return loss bridge enough?

10.1 dB gain should be enough gain for listening to terrestrial 6 Meter band signals with my 5 element Yagi antenna.

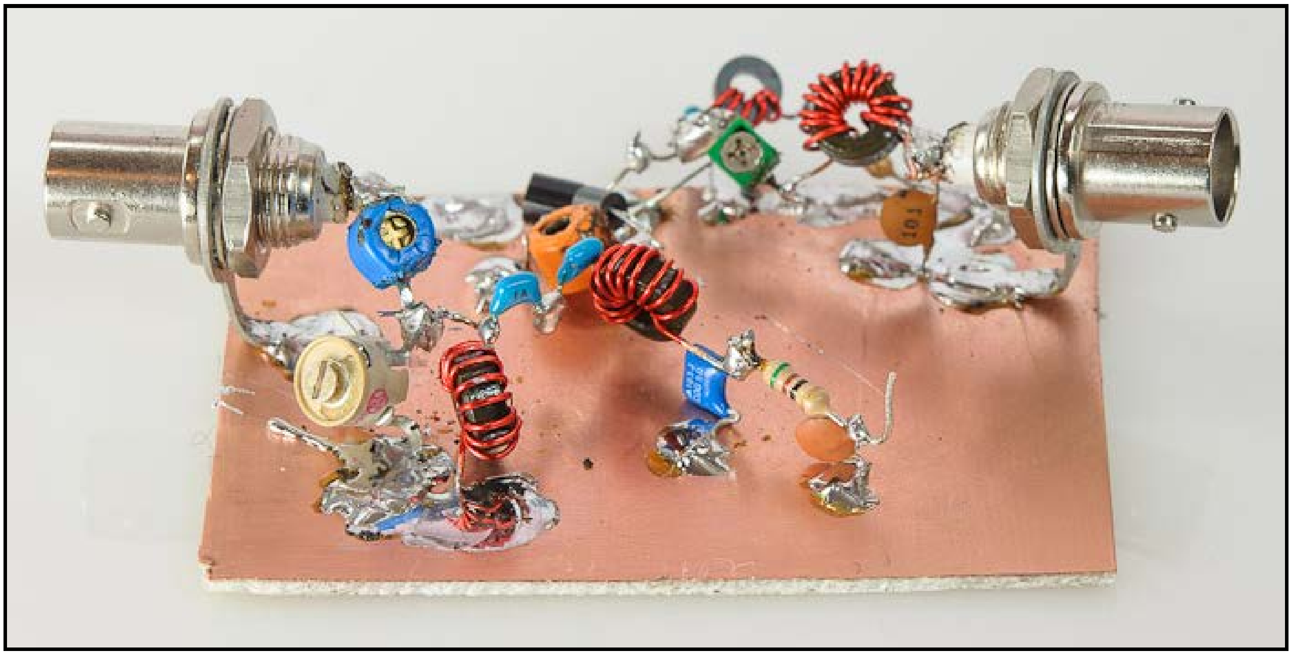

Above — A photo of my protoype 50 MHz pre-amp breadboard. In my "keeper" version, I'll swap in a U310 JFET and bias it for ~15 mA.

Section 5. QRP — POSDATA: Z-Communications VCO Experiment

Looking on eBay, sellers list numerous VCOs, although most are surface mount and go well above VHF. My favorite VCO comes from Mini-Circuits Labs: the POS series. Click for an example: the POS-75. These "plug- in" VCOs come in same package as the SBL-1 mixer and are likely obsolete, but still for sale. If you're building a frequency synthesizer with low phase noise requirements, MCL VCOs seem hard to beat. You can still order them from MCL, but the high product and shipping costs might alarm you.

I've looked for cheaper alternatives and the Z-Comm VCO raises 1 possibility. Last year, I purchased a V149MEM1 device for 5 dollars including shipping. Some experiments follow:

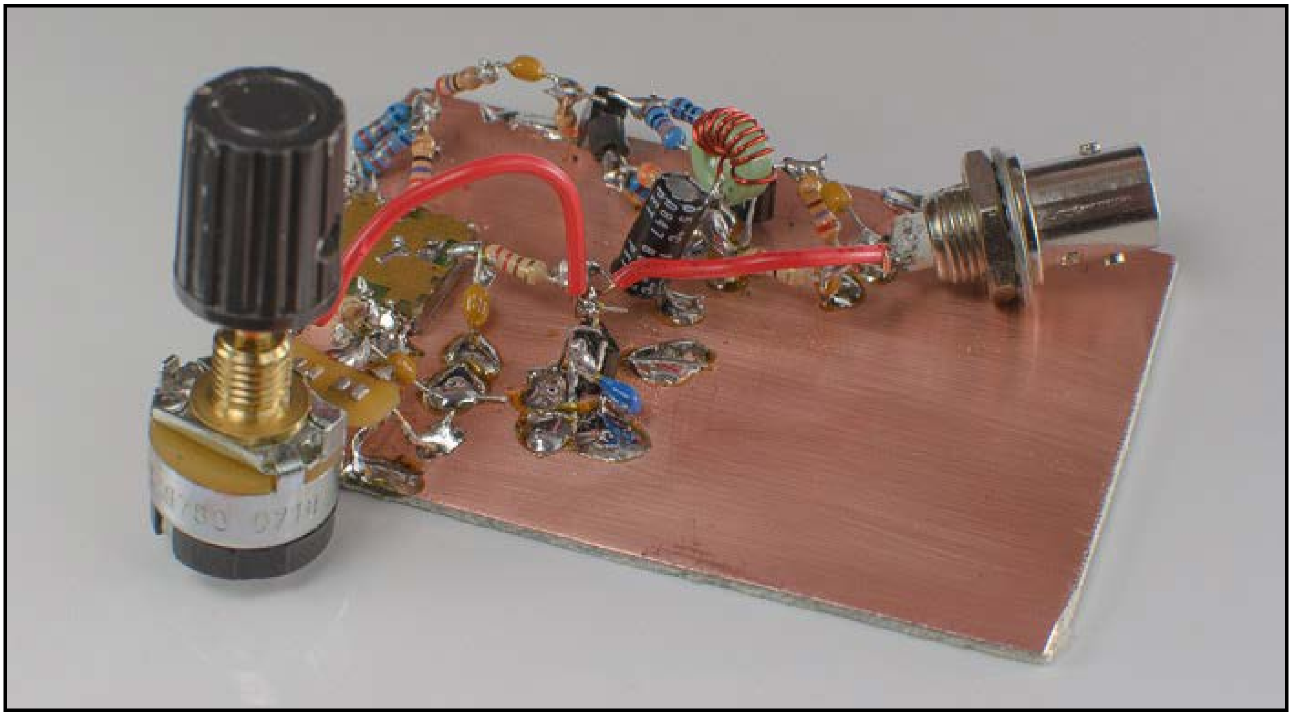

Above — My first breadboard. Lacking the MINI-16 receptable, like with MCL POS VCOs: I turned it upside down and soldered the metal case to my ground plane. If I were to keep this circuit. I wound solder all 4 sides to the copper clad board, plus run some copper de-soldering brade from the bottom to the ground plane, or even cut a square hole and flush mounted the VCO on is back.

While mounting it upside down deviates from the recommendations found on the Z-Comm mounting datasheet, I fiigured that for VHF at least, it might work okay. We desire low inductance grounding, but creativity might allow dead bug construction techniques to work.

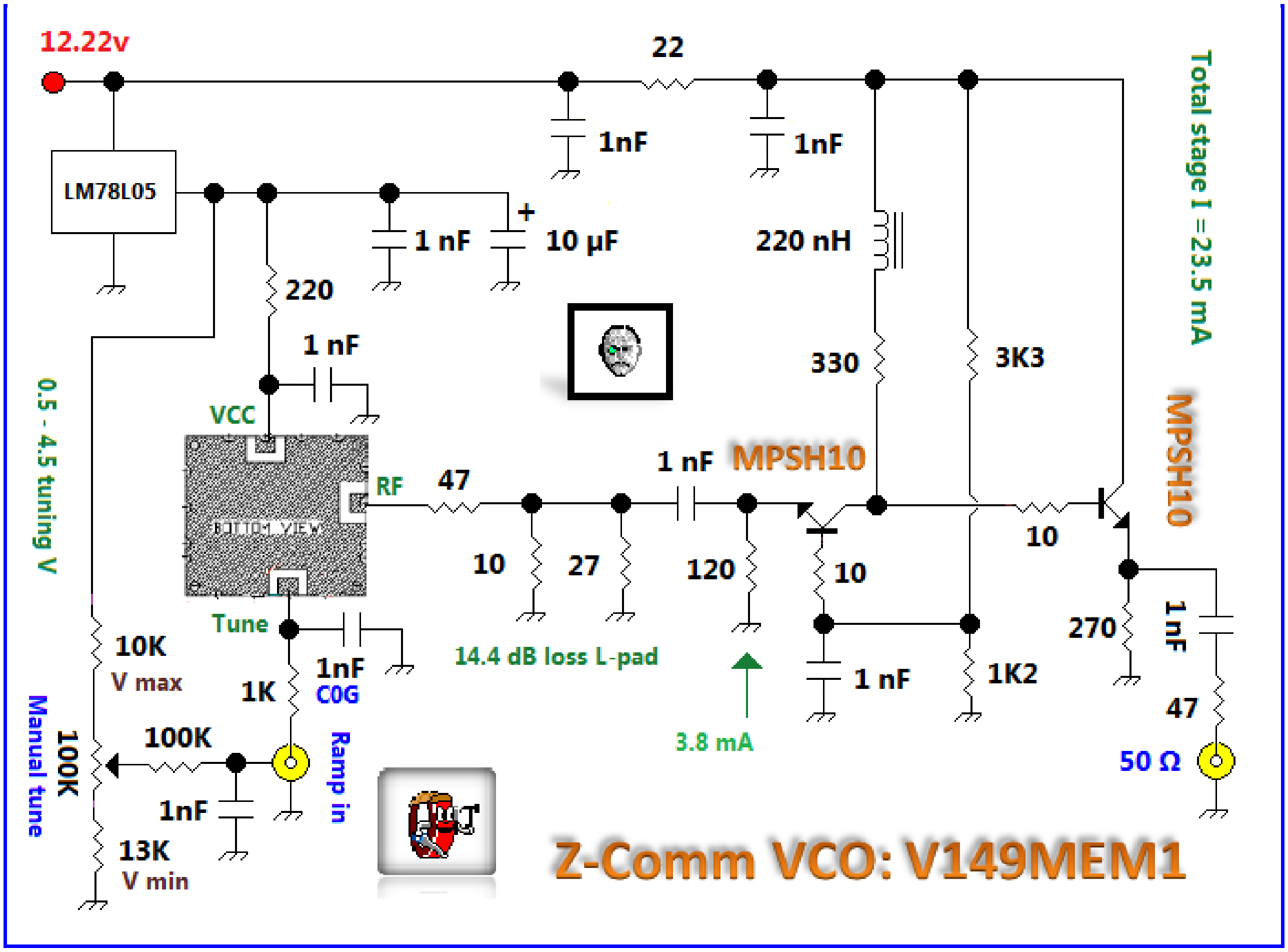
12.22v
22
1nF
1nF
LM78L05
+
1 nF
10 µF
220 nH
220
1 nF
330
3K3
Total stage I = 23.5 mA
0.5 - 4.5 tuning V
VCC
RF
47
1 nF
MPSH10
MPSH10
BOTTOM VIEW
10
27
120
10
10
Tune
10K
V max
1K
1nF
C0G
14.4 dB loss L-pad
1 nF
1K2
270
1nF
47
3.8 mA
100K
Manual tune
100K
Ramp in
1nF
50 Ω
13K
V min
Z-Comm VCO: V149MEM1

Above — My complete VCO. The Z-comm VCOs require at least a 10 dB pad on the output to keep port return loss high. Without a pad, you might see something like this plus boost the phase noise. In my circuit, I applied a resistor L-network with ~ 14.3 dB loss to pad the output and provide a match into a common base amp with an input impedance of ~ 6.8 Ω.

The 2-stage buffer is the brainchild of Bob, K3NHI and I love it. This buffer features a common base stage driving a emitter follower yielding high bandwidth and great reverse isolation. Normally, at VHF, the buffer is followed by more such stage(s), or a MMIC. The 220 nH inductor wound on a T30-12 toroid improves the high frequency response of the common base amplifer — experiment with this L to suit whatever VCO you wish to buffer. The gain of the 2 amp buffer is typically around 9 dB and the return loss at the input and output ports lies under 11 dB, so apply attenuator pads to boost S11/S22 as required.

Click for the scope tracing at 0.5 VDC tuning voltage. Click for the 4.5 VDC tuning voltage 'scope tracing. The harmonic distortion at the lowest tuning voltage = ~ -19 dBc and decreases to -28 dBc at the highest tuning voltage; better than specified. Notice that power decreases as frequency increases. All the commercial VCOs I tested do this. A higher fT amp like the PN5179 or other BJT might be a better choice to offset the power change versus frequency *contribution* of the buffer/amp.

For a sweep circuit, I would mix this VCO with another low level, single frequency VCO with its current controlled by a downstream leveling circut to derive a flat amplitude over the range of the VCO. I plan to try the Z- Comm V150S015 in such an arrangement to make a 70 - 150 MHz VCO for sweeping.

Please refer to the datasheet for the pin out on the Z-Comm VCO: I chose the pinout shown in the schematic to make an efficient drawing. The two 10 Ω resistors in the buffer/amp snub UHF oscillations first measured by Bob and confirmed by me. Ferrite beads might work as alternates.

Section 6. Miscellaneous Photos

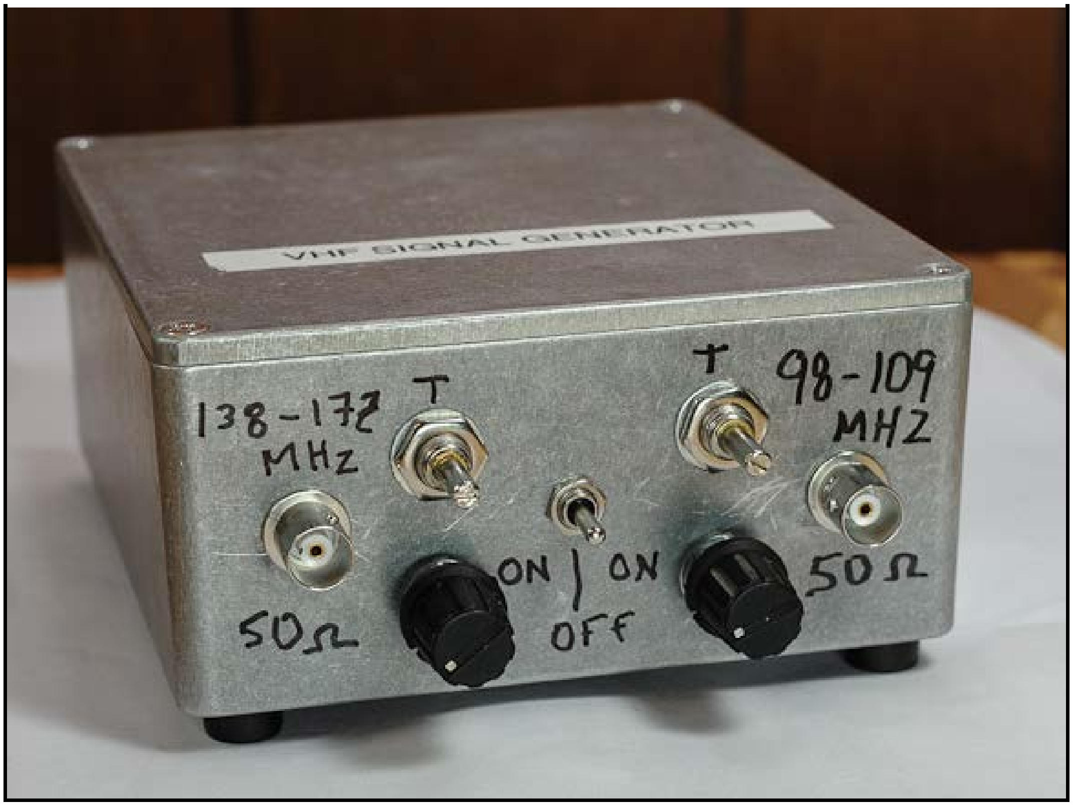
VHF SIGNAL GENERATOR
138-172 MHz
T
T
98-109 MHZ
ON | ON
OFF
50Ω
50Ω

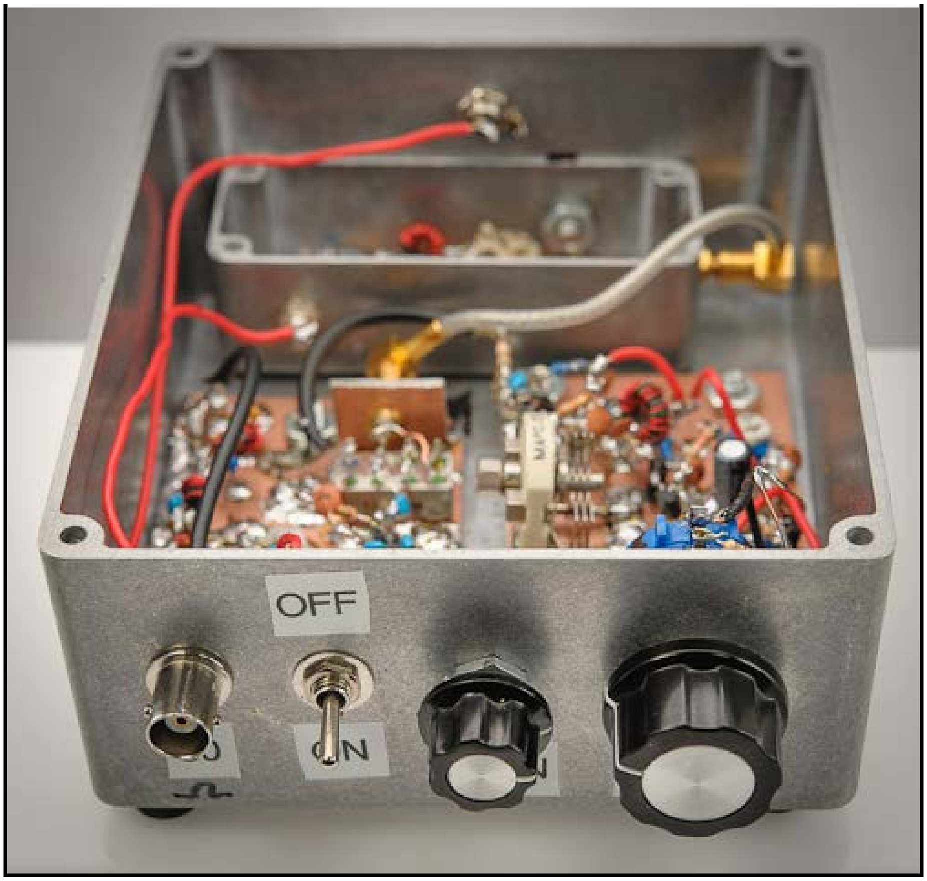
OFF
ON

MALE TERMINATOR 50Ω

RF — Test and Measurement

HF Ragbag

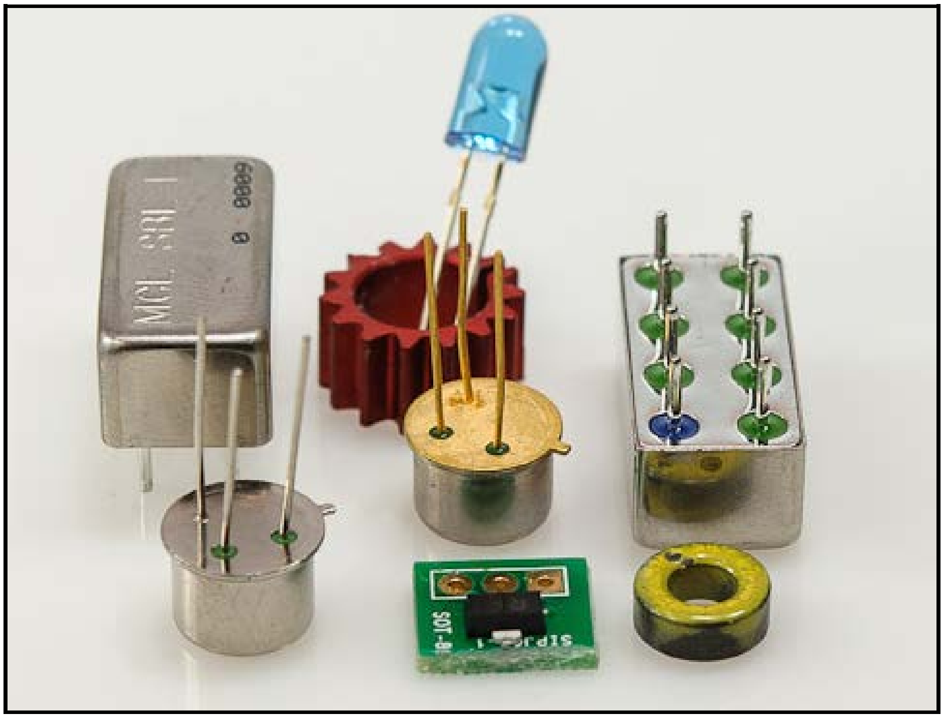

It's easier to present short topics on catch-all web pages — HF Ragbag shows some 2012 non-VHF experiments in no particular order. I also share thoughts on circuit building and writing: we can think and work better.

1. Comments from the Workbench - The Need for Clarity

On Building

In 2012, I boosted my circuit and writing quality to improve your experience: a genuine, return-to-basics approach in amateur, component-level electronic design. As possible, RF circuits will feature 50 Ω input and output ports — totally adopting a 50 Ω environment — for I'm convinced this is the best way to go. The 50 Ω building and measuring standard offers much: an easy-to-interface modular approach; 10 dB improved sensitivity over a 10X 'scope probe and if wanted, measurement with commercial or homebrew test equipment such as a spectrum analyzer, network analyzer or RF power meter.

Like many, I started out by collecting and copying circuits with little emphasis on true understanding. I wanted a completed circuit — quickly as possible — failing to develop my design skills. Without design skills honed by studying and properly measuring our circuits, we bide in hit-and-miss electronics — a frustrating repetition of trial and error, over and over again. We ought to adopt the attitude and thinking of engineers while keeping our design work —including the math — fun. However, embracing scratch-homebrew electronics with the overall goal of trying to understand each stage takes effort. "There is no substitute for hard work" wrote Thomas A. Edison. Scratch homebrew involves reading, simulating, collecting parts, mastering new techniques and building or buying test equipment.

This is more than knack, an abused noun that often means "hack". Our key tasks: to measure, analyze and understand the circuits we copy or create takes patience and practice. Dissecting circuits to understand their function means to hypothesize and reflect — to apply science on paper, with software, and finally, through careful bench experiments. Often we lack the math skills or test equipment to fully investigate some aspects of our circuits, but try our best: measure what we can measure, seek help and grow. I hope this site shows our hobby can be less about making stuff and more about the rewards of actual design: an authentic, personal journey to get better at something you love.

I've never been much of a kit builder; it's too much like Max Klein's Paint by Number for my tastes. But kits dominate HF QRP homebrew and may offer a cost effective way to make gear; especially test gear. Stuffing parts in a printed circuit board won't teach you much about design, but might get your feet wet. Some people remain perfectly happy building kits or madly copying circuits — all the power to you! Do whatever you want. One day you might awaken, but don't worry; I won't try to goad, or convince you.

My favorite builders include people over 50 who suffer the often crippling symptoms of 'appliance apathy' — an epiphany reminds them why they first got into radio: homebrew experiences. Maybe a crystal radio set, or a simple superhet receiver they breadboarded long ago. *Then they come back full circle*; like a loop antenna. Oh-boy — "Bob" rediscovered his radio roots and needs to unleash his creativity and passion to learn and improve. I write for people like Bob. Heck; I am Bob.

On Writing

You'll notice improved narrative writing too: I prefer to read and write crisp statements in short sentences and paragraphs. Brief, yet descriptive text accompanied by ample white space, clear headings and bulleted lists invites you to read on. Plain language writing — simple, clear, writing that is easy to read and understand — signals a refreshing move away from the turgid, word-filled claptrap I learned in grade school. Making your prose easier to read requires greater effort writing and re-writing. My first..to...fourth drafts always suck.

Passive verbs, or nouns and adjectives that function as verbs with no clear subject confuses readers and boosts wordiness: I employ active verbs to invigorate my writing — active verbs connote me or some else performing an activity you can visualize or feel. Actions that may inspire, persuade, or even vex you! Ours' is an emotional hobby.

RF electronics contains rich amounts of jargon. Of course, we must learn some jargon to communicate our ideas as hobbyists, but writing jargon to impress, or to place yourself above others lacks humility and alienates people. Do you know anyone who likes being talked down to? The first step towards becoming humble is to admit you're not humble and then work on it — and I'm working on it.

Although I enjoy writing about electronic experiments, I'm not sure it's worthwhile — Does anyone actually design circuits anymore? Well, back to my 1970's-style analog experiments...

2. Magnitude Only Scattering-Parameters

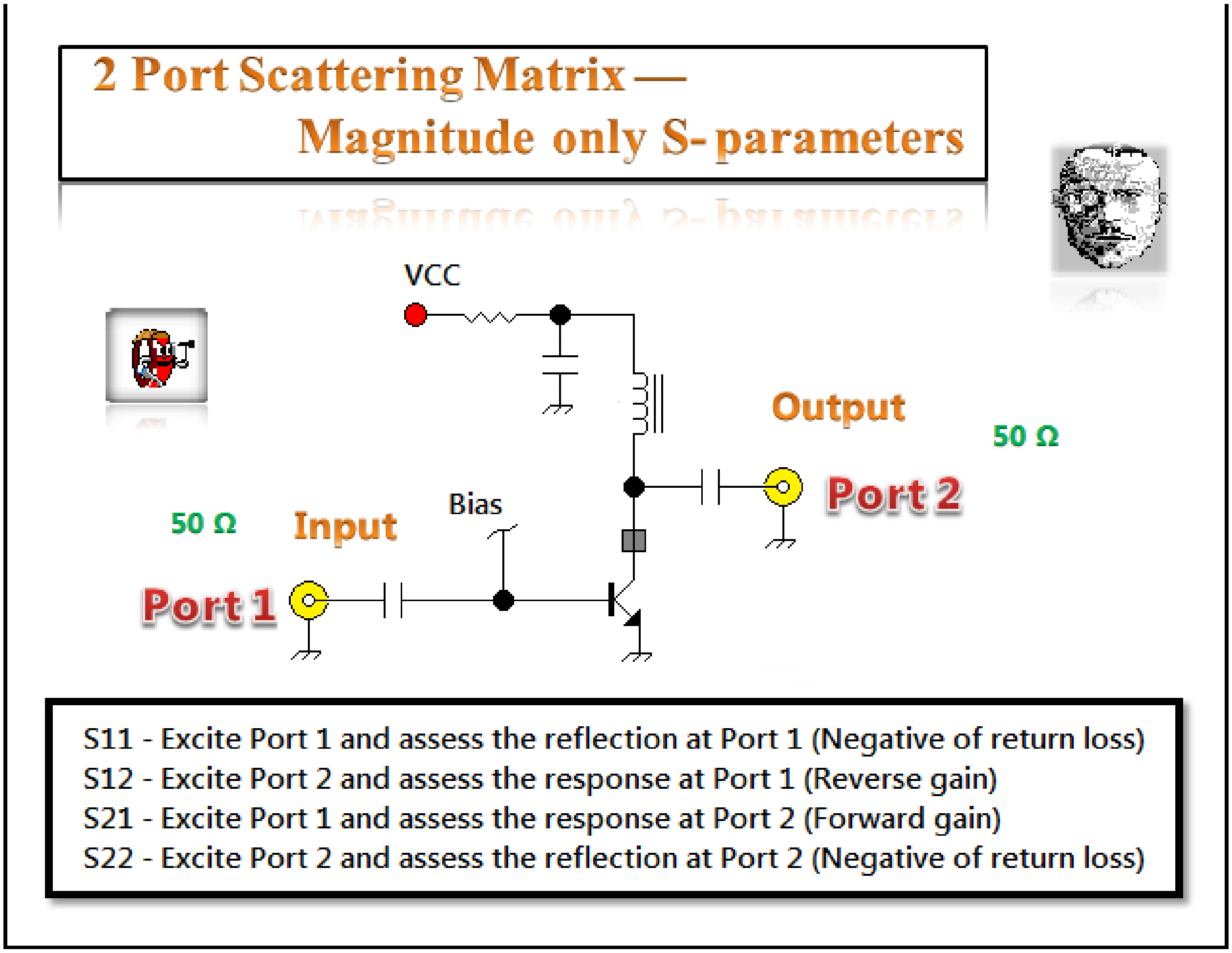

2 Port Scattering Matrix —
Magnitude only S-parameters

S11 - Excite Port 1 and assess the reflection at Port 1 (Negative of return loss)
S12 - Excite Port 2 and assess the response at Port 1 (Reverse gain)
S21 - Excite Port 1 and assess the response at Port 2 (Forward gain)
S22 - Excite Port 2 and assess the reflection at Port 2 (Negative of return loss)

Above — A simple model describing the S-parameters displayed on QRP / SWL HomeBuilder in a Class A amplifer with 50 Ω ports.

S-Parameters

Any device with 2 connectors may be modelled at AC for a specified frequency with just 4 scattering parameters: forward gain, reverse gain + input and output impedance (match or VSWR).

S-parameters address voltage ratios: comparing the amplitude of different signals at the 2 ports. For example, S21 is the magnitude of forward gain and equals the ratio of output voltage to input voltage.

S-parameters are vectors; a mathematical quantity that may be visualized as an arrow anchored at 1 end that pivots around its base. The length of the arrow represents magnitude while the angle it makes with another vector or its base line decribes its phase in degrees. In addition to phase and magnitude, S-parameters allow analysis of gain, stability, complex impedance (resistance + reactance), admittance and other vector quantities.

Measure S-parameters with all ports terminated in a 50 Ω impedance.

Some of us worry only about the gain, losses or "match" in our 50 Ω circuits and could care less how the signal phase changes as it passes through our amplifiers or attenuators. I express only S-parameter magnitude in logarithmic form (dB) and take this *Über simplified* approach because builders can easily measure S11, S12, S21 and S22 on a 50 Ω test bench with a small staple of bench accessories + a 50 Ω 'scope or detector.

Topics like matrix theory, vector math, the "jay" operator, converting S-parameters into other matrices, Smith charts etc. may turn *off* the average amateur designer. You advanced readers, may raise your 2 port network skills by visiting better web sites + reading books, simulating with SPICE, or better yet, measuring your port parameters with a vector network analyzer.

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3. More on Feedback Amplifiers (FBA)

Many builders (myself included) copy feedback amps rather than design their own. By tweaking the emitter current, shunt and series feedback while measuring S11 and S22, plus simulating with a program called FBA08.exe, I've learned it's possible to design good feedback amps FBA08 is 1 of the Ladpac programs that ships with EMRFD.

I wanted a FBA with ~35 mA emitter current for improved IMD and low distortion on strong signals. Such an amp might follow a diode ring mixer in a receiver I.F. chain.

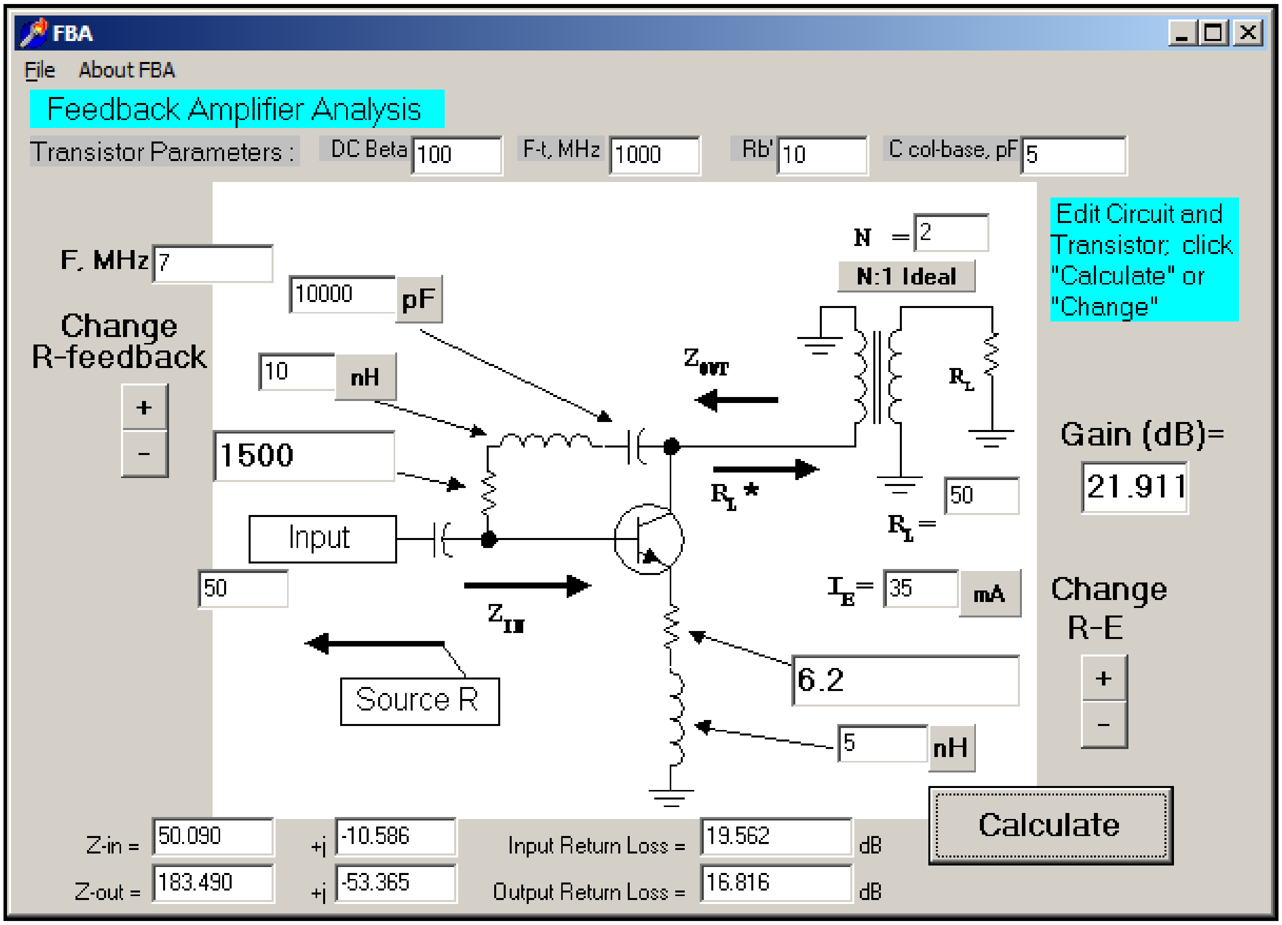
FBA
File
About FBA
Feedback Amplifier Analysis
Edit Circuit and Transistor; click "Calculate" or "Change"
Change R-feedback
+
-
Input
Source R
Z_{OUT}
Z_{IN}
R_L *
R_L
N:1 Ideal
Change R-E
+
-
Calculate

Transistor Parameters : DC Beta 100 F-t, MHz 1000 Rb' 10 C col-base, pF 5

F, MHz 7

10000 pF

10 nH

1500

50

N = 2

R_L = 50

I_E = 35 mA

6.2

5 nH

Gain (dB)= 21.911

Z-in = 50.090 +j -10.586 Input Return Loss = 19.562 dB

Z-out = 183.490 +j -53.365 Output Return Loss = 16.816 dB

Above — My 7 MHz FBA set up. Wes, W7ZOI suggested using 5 nH as the default emitter inductance and 10 nH for the default collector to base inductance in FBA08. These represent stray inductances in your circuit breadboard. Emitter inductance affects the input impedance more.

Zin = input impedance. Zout = output impedance.

Explore this program to learn how changing the emitter resistor, feedback resistor and emitter current affect the input and output return loss.

Adjusting the transformer N and load values only affect the calculations for Zin because this app wasn't really designed to crunch output transformer Z ratios for Zout manipulation. The default output Z = 200 Ω and thus for the N parameter with a 50 Ω RL, RL is multiplied by N^2 to set the amplifer load impedance.

From FBA08 simulations: with an emitter current of 35 mA, my series feedback = 6.2 Ω and shunt feedback = 1500 Ω.

I chose a simple voltage divider bias network to set up the ~35 ma and ensure reasonable temperature stability.

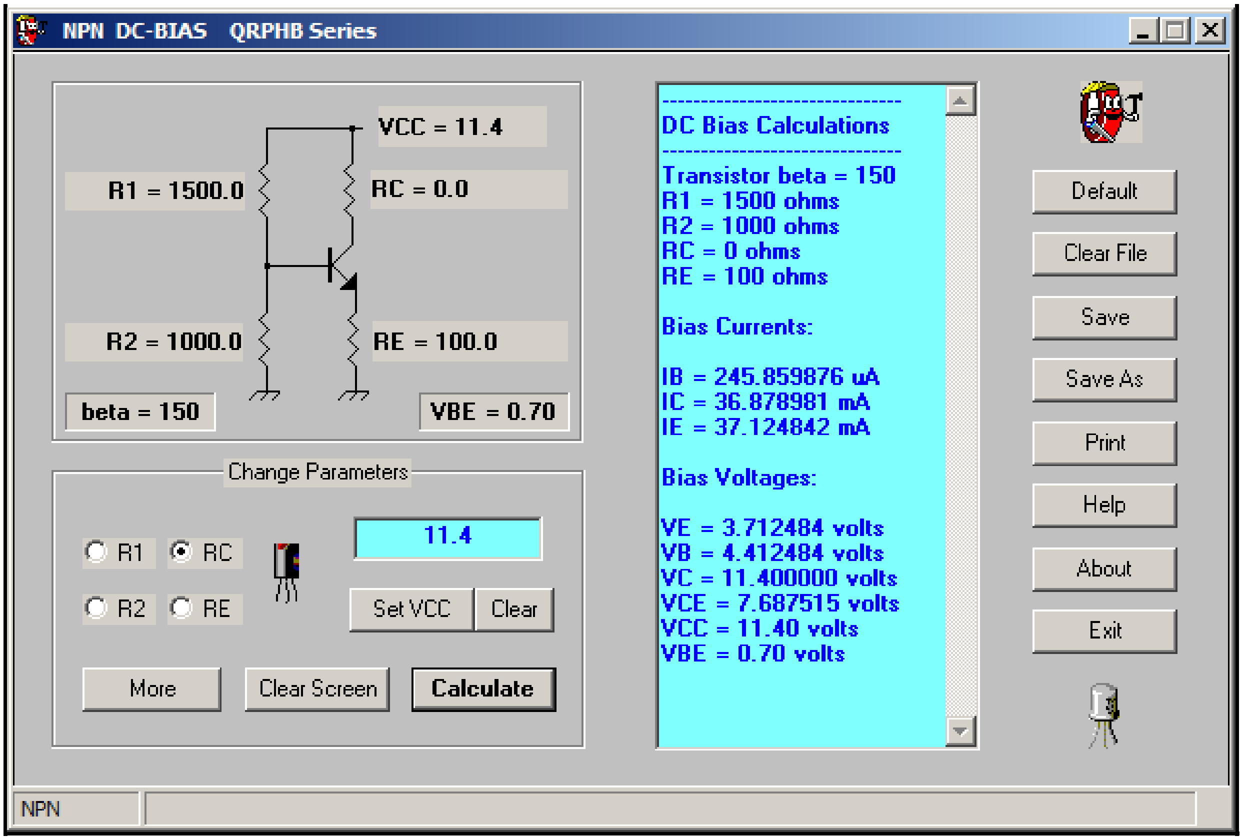

VCC = 11.4
R1 = 1500.0
RC = 0.0
R2 = 1000.0
RE = 100.0
beta = 150
VBE = 0.70

○ R1 ● RC
○ R2 ○ RE

11.4

```
--------------------------------
DC Bias Calculations
--------------------------------
Transistor beta = 150
R1 = 1500 ohms
R2 = 1000 ohms
RC = 0 ohms
RE = 100 ohms

Bias Currents:

IB = 245.859876 uA
IC = 36.878981 mA
IE = 37.124842 mA

Bias Voltages:

VE = 3.712484 volts
VB = 4.412484 volts
VC = 11.400000 volts
VCE = 7.687515 volts
VCC = 11.40 volts
VBE = 0.70 volts
```

Above — Choosing the emitter and nearest standard value bias network resistors to set up ~ 35 mA emitter current with a program. Actual biasing requires you to set up the correct emitter current + establish reasonable temperature stability.

Click and scroll to #5 for some basic transistor biasing notes. While this supplement shows a simple method for stable bias networks, it probably understates that **Beta** bias stabiility is a function of the ratio of RB to RE, where RB = the 2 base resistors in parallel. The lower the ratio the better, but then more input power is lost in those resistors. A higher ratio reduces stability but wastes less input power — another trade off we must negotiate! See Ken Kuhn's web site for thorough, expert-level information on voltage divider biasing your BJT amplifiers.

I use NPN DC BIAS, a program I wrote, however, Wes included 1 in the Ladpac software called Biasnpn08.exe that's also good. Determine the VC for the program by first multiplying the value of your decoupling resistor by the emitter current in Amperes to learn the voltage drop across the R. Then, subtract that voltage drop from your power supply voltage: 12.22V - (.0371 A X 22 ohms) = 11.4 VDC.

Our software allows you to pick approximate base and emitter resistor values to set up a desired current in your amplifier breadboard, but you must still choose reasonable values for temperature stability. Tweak them as needed, or choose some other bias method such as a current source. Let's move to the bench...

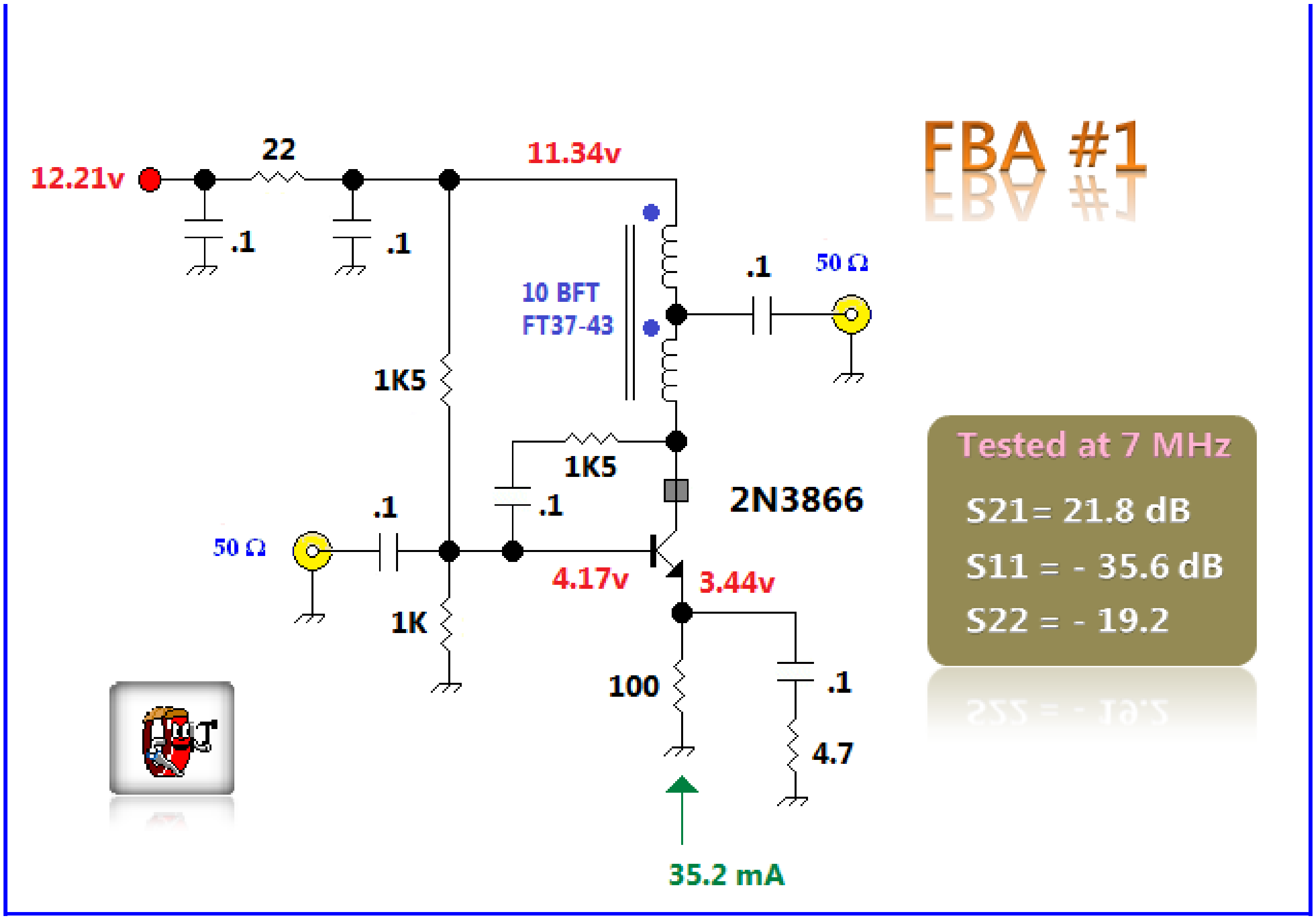
FBA #1
12.21v
22
.1
.1
11.34v
10 BFT
FT37-43
.1
50 Ω
1K5
1K5
.1
2N3866
.1
50 Ω
4.17v
3.44v
1K
100
.1
4.7
35.2 mA
Tested at 7 MHz
S21= 21.8 dB
S11 = - 35.6 dB
S22 = - 19.2

Above — My 7 MHz FBA with some measured S-parameters. On the bench, I lowered the 6.2 Ω series resistor to 4.7 Ω because the voltage divider bias network also affected Z in. I tried 3.3, 4.7 and 5.7 Ω resistors for series feedback and settled on 4.7 Ω since an S11 of -35.6 dB wins the prize!

The S22 of -19.2 dB bettered the value predicted by FBA and seems quite acceptable considering we normally follow a FBA with a 6 dB pad that raises the output return loss another 12 dB. FBA08 gets you close, however, only bench experiments will realize the amplifer you want, and sometimes, a decent S11 and/or S22 may elude you.

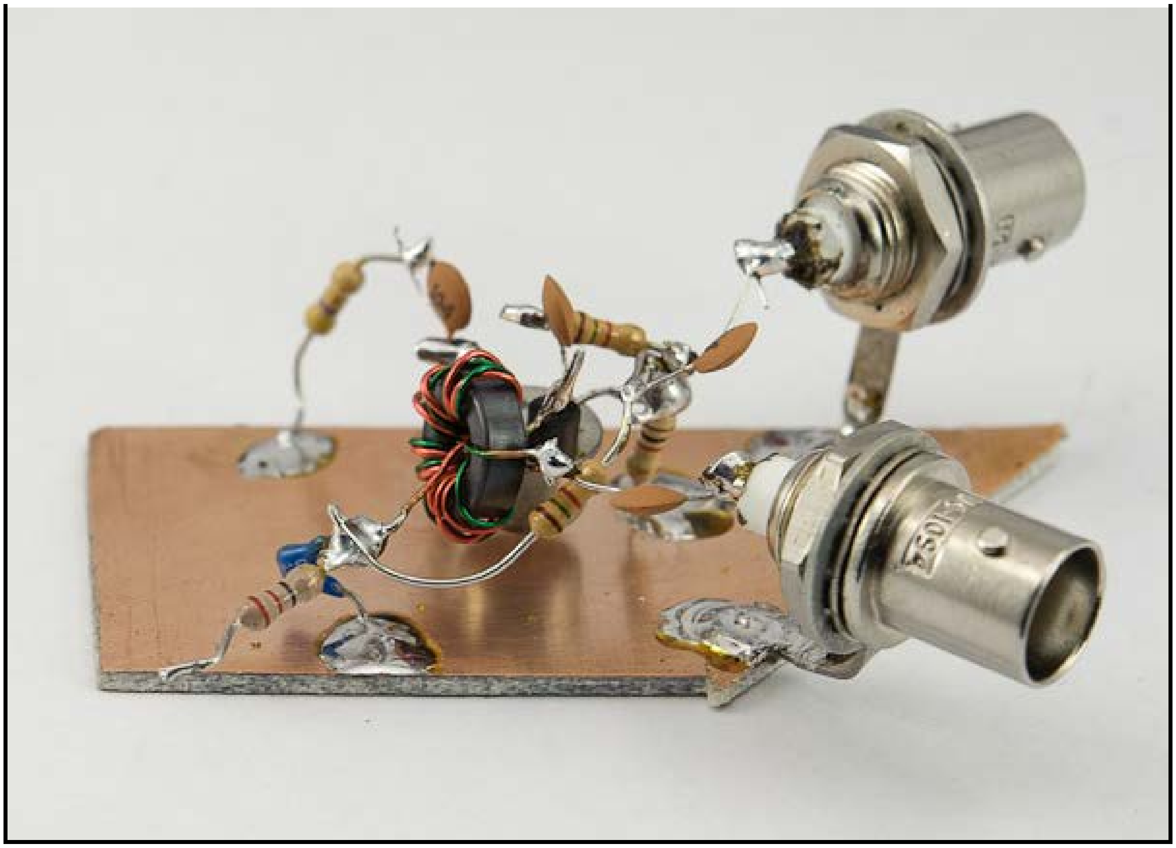

Above — A photo of the 35 mA feedback amp built on scrap of copper clad board.

Parallel Transistor Feedback Amp

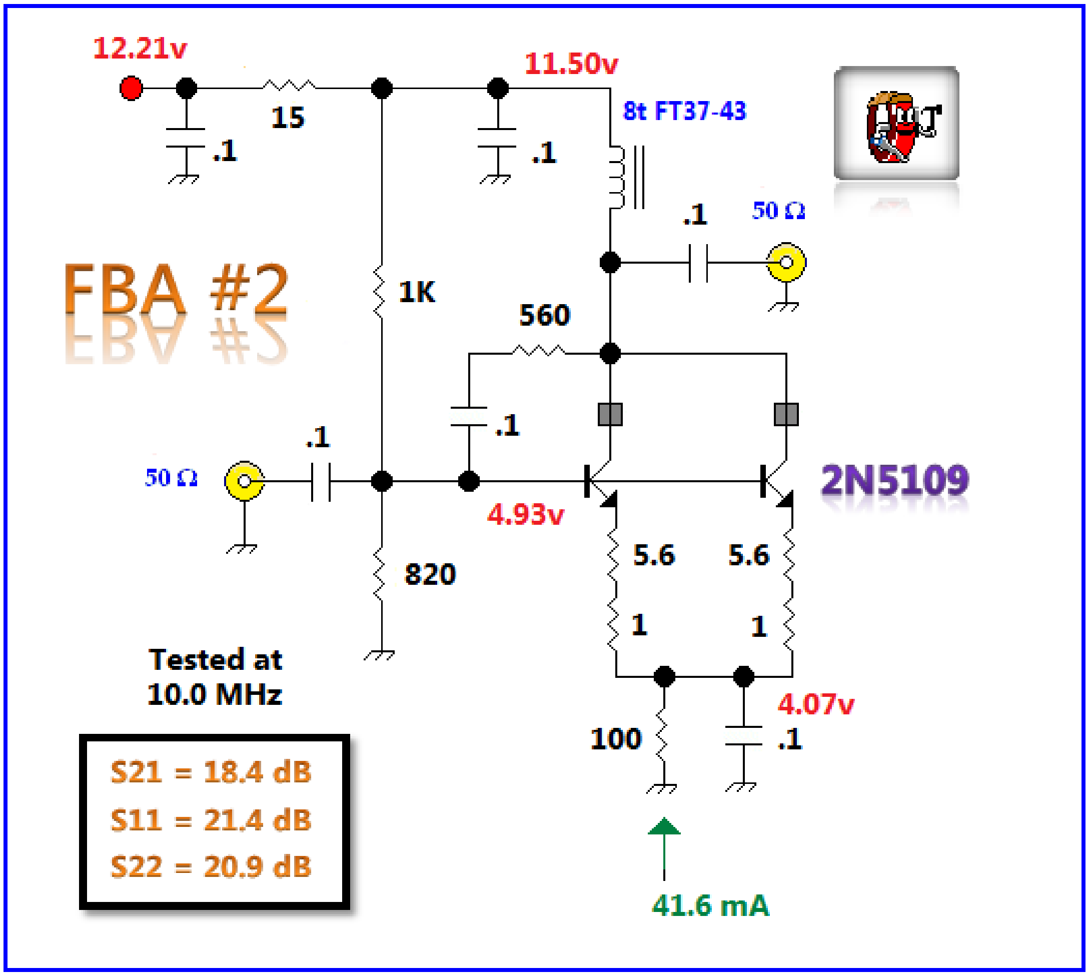
12.21v
15
.1
11.50v
.1
8t FT37-43
.1
50 Ω
FBA #2
1K
560
.1
50 Ω
.1
4.93v
2N5109
820
5.6
5.6
1
1
Tested at
10.0 MHz
S21 = 18.4 dB
S11 = 21.4 dB
S22 = 20.9 dB
100
4.07v
.1
41.6 mA

Above — A feedback amp with two 2N5109 transistors wired in parallel. Click for a photograph of this prototype. I lacked 6.8 Ω resistors and placed 1 Ω + 5.6 Ω to make the needed R for a strong S11.

Originally, I built FBA #2 with a 4:1 Z transmission line transformer, but measurements of S22 disppointed me. Later, a L wound with 8 turns around an FT37-43 ferrite toroid drove an S22 of 24 dB, but S11 was only 18.5 dB.

With the amp set up to measure return loss on the input port, I placed a 500 Ω potentiometer in series with a 100 Ω resistor between the collector and base terminals and tweaked the pot to obtain the lowest peak-peak voltage in my 'scope (lowest return loss). After, I removed the pot and measured its resistance at 572 Ω. Finally, I soldered in a 560 Ω resistor and re-checked S11. Perfect. With my goal of at least 20 dB for S11 and S22 obtained, I powered down my bench and took some photos.

Wes, W7ZOI displayed parallel transistor FBAs in EMRFD and other works and recently I noticed Lyle, KK7P employed a parallel NE46134 FBA as a post-mixer amplifer in the Elecraft K3.

Wes wired 2 parallel 2N3904s to avoid using an expensive medium power BJT like the 2N5109. Doing so splits the heat between 2 devices, but does not deliver better IMD performance beyond what is offered by increasing the emitter current. In a typical FBA bias setup, you may measure as much as 10 volts between the collector and emitter terminals and with a supply of 12 VDC + a standing current of 20 mA, the collector dissipation = ~200 mW. This is about maximum for a TO-92 device likes a 2N3904, but only half of maximal dissipation for 2 in parallel.

Then, too, the K3 applies 2 parallel medium power BJTs get power dissipation with an SMT transistor. For strong IMD performance, Lyle and crew are throwing 80 mA or so into the pair — hard to do with SMT parts, so they overcome heat and power dissipation issues with 2 devices. Cool (literally).

Heat sink BJTs when you crank up the emitter current.

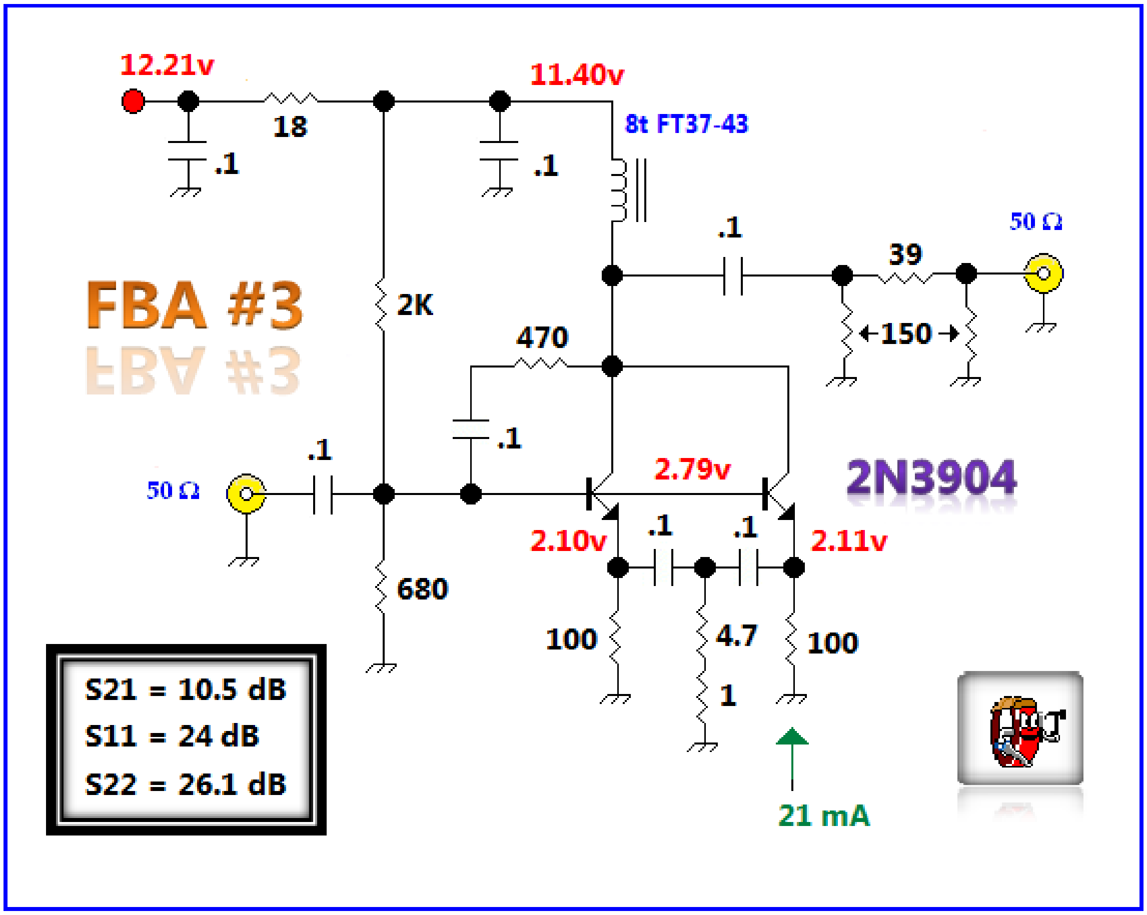

Above — An attempted 2N3904-based parallel feedback amp. Each BJT draws ~21 mA emitter current. Without the 6 dB output pad, the output return loss = 14 dB — I *failed* to realize both a strong (raw) S11 and S22.

The power gain including the 6 dB pad = 10.5 dB. I'll discard this design since it's substandard — without failures, victory may taste bland.

For bench designers, making a parallel FBA where both the raw S11 and S21 are > 20 dB is difficult and bench failures may either frusturate you, or enhance your resolve to succeed. With success, great satisfaction arises and I'm addicted to that feeling.

An FBA bench triumph means you managed to establish the perfect combination of series + shunt feedback, emitter current and the correct output transformer ratio for *that* transistor plus its biasing circuitry — no small task.

A well matched amplifier = a thing of beauty! The fetching trio of high S11, S22 and S21 rewards your efforts and boosts your confidence to experiment further. And so it goes...

Sadly, only a fraction of hobbyists create and evaluate their own circuits.

---

4. Microphonics in Direct Conversion Receivers

LO = local oscillator or VFO. DC Receiver = direct conversion receiver.

Microphonics are induced electrical responses that arise from a mechanical vibration on the DC receiver chassis or circuitry. The audio amp, acting like a transducer, makes a clicking, or popping noise when you do things like tap the chassis, or unplug components — the disturbance throws out a burst of DC voltage that's amplifed by the AF chain and pops the speaker.

We may read or hear inexperienced builders tell us to expect microphonics in our DC receivers — *de trop* folklore strikes again! As a student of EMRFD and those wise designers who live in and around Beaverton, Oregon, I share some of their best tips to decrease microphonics in your DC receiver projects. " Keep Your LO From Radiating to the Outside World and Keep Unwanted RF from the Outside World Getting Into Your Receiver" seems the appropos title for the bulleted notes that follow:

Read EMRFD pages 8.7 to 8.11 and then build or apply the presented examples. Wisdom is experiential; it comes by doing, not just reading. It's no accident that Chapter 8 author Rick, KK7B mentions microphonics and hum in the same section. I've never read more thorough notes regarding DC receiver nuances anywhere; for example, did you consider that an ungrounded air variable capacitor shaft poking outside the LO box will radiate LO signal per Figure 8.18 ? I didn't in my early days.

Stick your LO in a RF-tight enclosure with RF-grade connectors and coax to patch the AC signal to the product detector. Bypass RF with feedthrough capacitors on any DC voltage lines that pass through the LO chassis wall. Many enthusiasts have only operated kitted or homebrew DC receivers where the LO and receiver guts lie on the same circuit board — this *ensures* microphonics. Wes and Roger built the historic Ugly Weekender VFO, transmitter and receiver in seperate boxes — resulting in low microphonics and no pulling of the VFO when keying the transmitter. Nothing in that 2 part QST series was done by accident. Read these articles to "go to school".

Reciprocally important; keep unwanted outside world RF from getting inside your DC receiver! Apply resistors plus capacitors, or inductors plus capacitors to decouple and bypass RF from moving along on your DC voltage lines, key line, microphone cables etc.

Keep product detector port-to-port isolation high. Typically, we employ double balanced mixers to obtain high port-to-port isolation. I cover mixer balance on this page . For diode ring mixers, measure the return loss of the circuits that you connect to the product detector LO, RF and AF ports — I aim for 20 dB or greater return loss on my LO output, RF output and AF amp input circuits to help preserve the product detector balance and keep port isolation as high as possible. Along with 50 Ω amplifers, attach attenuator pads, AF diplexers, or whatever to help increase port return loss as required.

LO-RF port isolation: Consider a common gate amp with an output matching network to get a high output return loss (S22). The common gate amp provides strong reverse isolation without adding much noise.

Avoid end-fed wire antennas where there is a strong antenna field right next to your radio.

I favor sturdy chassis/cabinets with rubber feet. Homebrew copper clad board or die-cast aluminum cabinets may work best as joints and screwed connections won't corrode. *This is a weak recommendation.*

Double the LO frequency or apply a heterodyne VFO. Often microphonics arise in the VFO tank. EMRFD cover this well. If the VFO operates at a significantly different frequency than any of the signals reaching the balanced mixer, leaked LO won't cause as much havoc as when a LO tank is tuned to the mixer RF port frequency.

Despite proper techniques, RF can exit via the antenna port and make its back into our rig through power supply cables (often modulated by our house AC electricity). In some cases, we require special power supply decoupling to decrease hum and microphonics. We might need to add a common mode choke (+/- capacitors) for common mode noise suppression in addition to the usual differential mode choke(s) and capacitors. In my main shack power supply, I run a common-mode choke plus I soldered a 0.01 uF capacitor across each bridge rectifier diode to bypass RF.

Some radio operators just run battery power supplies.

Above — Feedthrough capacitors. I prefer hole mount over solder mount parts, however, quality feedthrough capacitors of any kind tend to be expensive. As a hobbyist, I'm constantly searching for bargains and when I find 1, I'll purchase a bunch to meet my current and future needs.

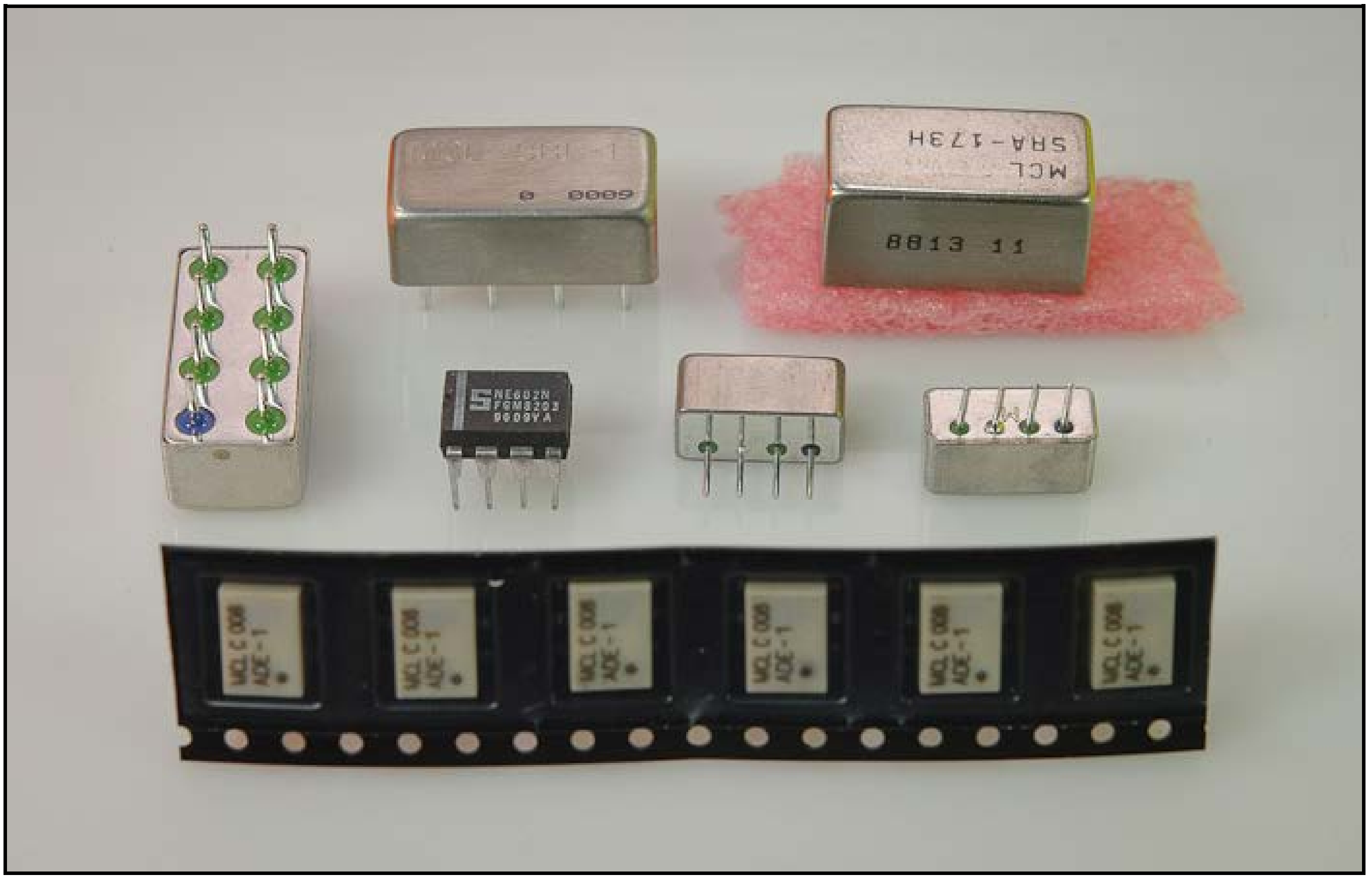
MCL SBL-1
6000 0
MCL SRA-173H
8813 11
NE602N
F6M8203
9000YA
1-30Y
00 J TDK

Above — Some double balanced mixers from my collection: ADE-1, NE602, TUF-1, TUF-2, SBL-1 and a SRA-173H; a MiniCircuit Lab's Level 17 diode ring mixer.

You owe it to yourself to listen to a DC receiver designed and built to reduce microphonics — music to our ears.

---

5. Some Experiments with RF Bypass Capacitors

Introduction

Bypass implies a low impedance path to ground for RF at 1 or more frequencies. After reading EMRFD pages 2.28 - 2.31, I decided to explore this subject for the first time. My bench measurements from Spring 2012 punctuated how little I knew about RF bypass and I share these notes as something for me and others to build on.

In these experiments, I

1. observed the self resonant frequency of MuRata RPE Series, 50v, 5% capacitors with X7R temp compensation at 0.1, 0.01 and 0.001 µF.
2. examined a wire short, plus 1 and then 2 Johanson Dielectric 0.01µF, 50v, X7R, size 1206 chip capacitors.
3. tested a 0.1 µF RF cap plus a parallel 2.2 µF electrolytic capacitor to look at parallel resonance side effects.
4. attempted to reduce the Q of some parallel capacitors to reduce unwanted high impedance peaks.

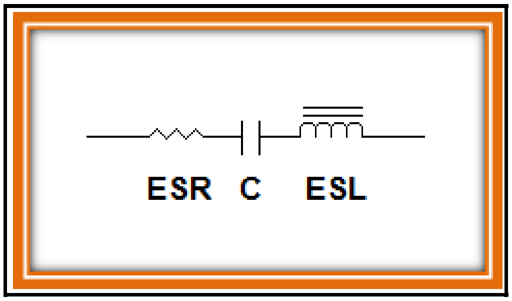

Above — The frequency dependent components of a capacitor are shown in this capacitor equivalent circuit schematic; essentially an RLC network. Engineers use mathematical formulae to describe the components of a capacitor along with reactance and with this math, you might derive an unknown variable from available data so it's worth diving into on your own.

ESR or equivalent series resistance = the sum of all of a capacitors' resistive components. Expressed in ohms, ESR acts like a resistor in series with the capacitor. Normally we desire capacitors with an ESR as low as possible. Consider reading the capacitor datasheets for those your stock and/or searching for information regarding low ESR capacitors on the Internet.

ESL refers to the equivalent series inductance; the sum of all the capacitor's inductive components. This includes lead length in hole-through parts.

In a given capacitor, the series resonant frequency is the frequency where the inductive reactance from the ESL = the capacitive reactance, but since the 2 reactances are 180 degrees opposite in phase, they cancel to drop the impedance to 0 and the capacitor acts like a resistor at its ESR.

The series inductance of a capacitor may be determined using a network analyzer and unfortunately this in unattainable by most average builders. When designing RF bypass with network analysis, we strive for a low impedance over a wide frequency range, although small ripples typically occur.

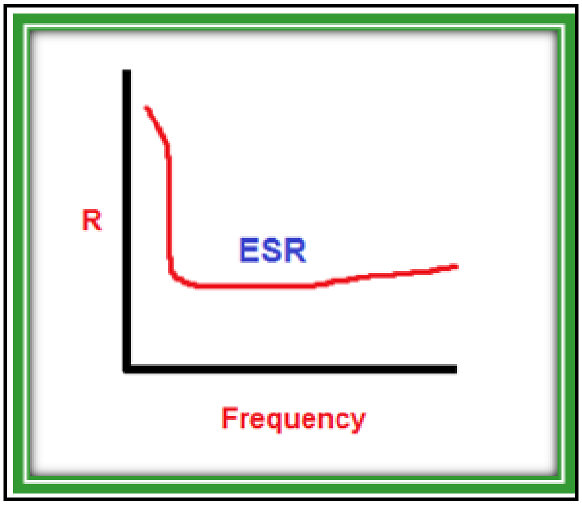

Above — A plot of equivalent series inductance. ESR tends to increase with frequency.

Methods

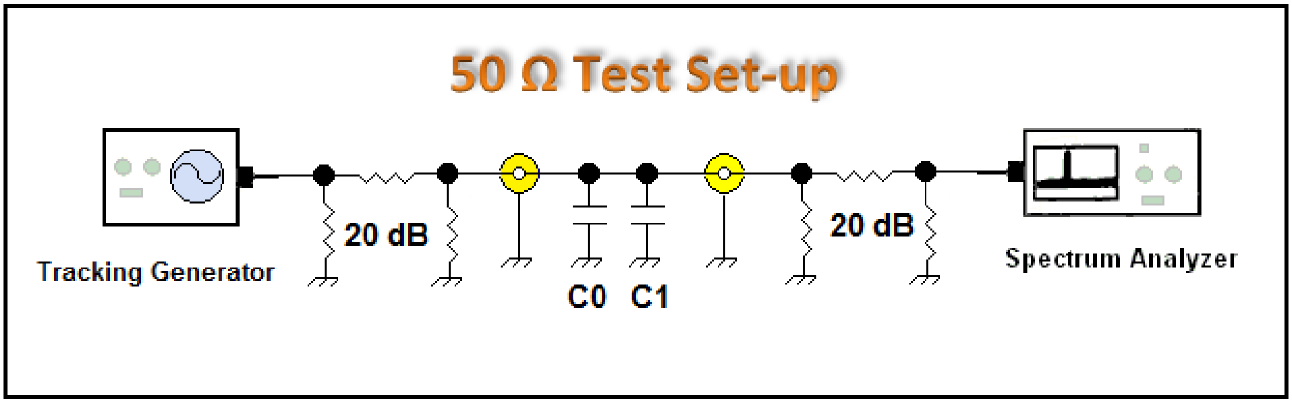

Above — My test set up. I performed all analysis with a tracking generator plus spectrum analyzer. The 50 Ω system used short coax patch cables fitted with BNC connectors with 20 dB attenuator pads before and after the capacitors under test. The capacitors shown as C0 and C1 were soldered on a copper board with short leads and BNC connectors. C1 is omitted when evaluating only 1 capacitor.

You may also perform capacitor self resonant frequency testing with a vector network analyzer, a signal generator plus a 50 Ω terminated scope, or with a sweep generator ramp-driving the oscilloscope X input while simultaneously driving a VCO with logarithmic output to the Y oscilloscope input. SPICE simulations may also yield insight.

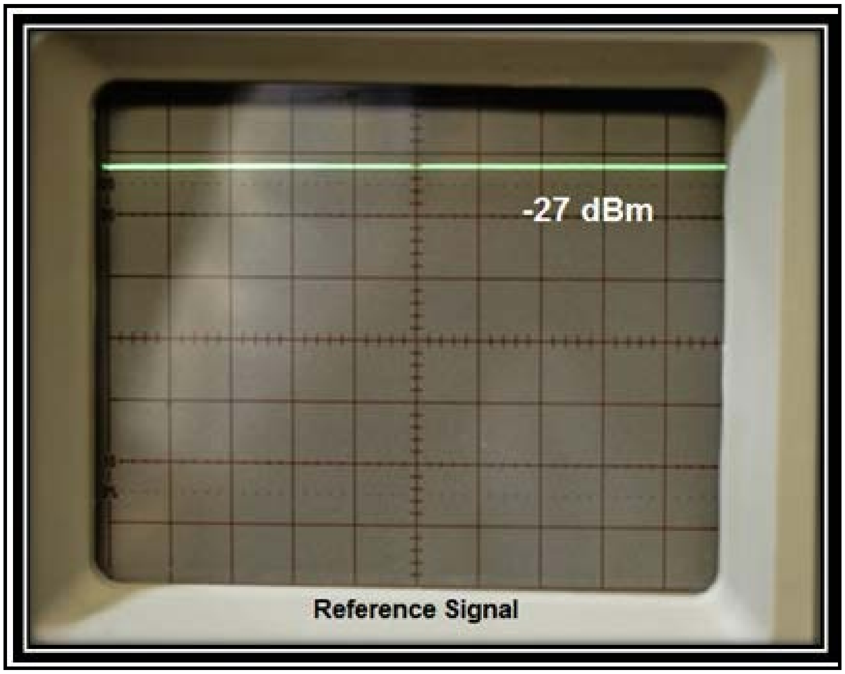

Above — The -27 dBm reference with a through-connector between my 2 coax patch cables (C0 + C1 board removed).
To save time I shot these SA photos handheld and prefer a slower shutter to capture a nice CRT tracing, so some of the photos show a little hand jitter.

Single Shunt Capacitors

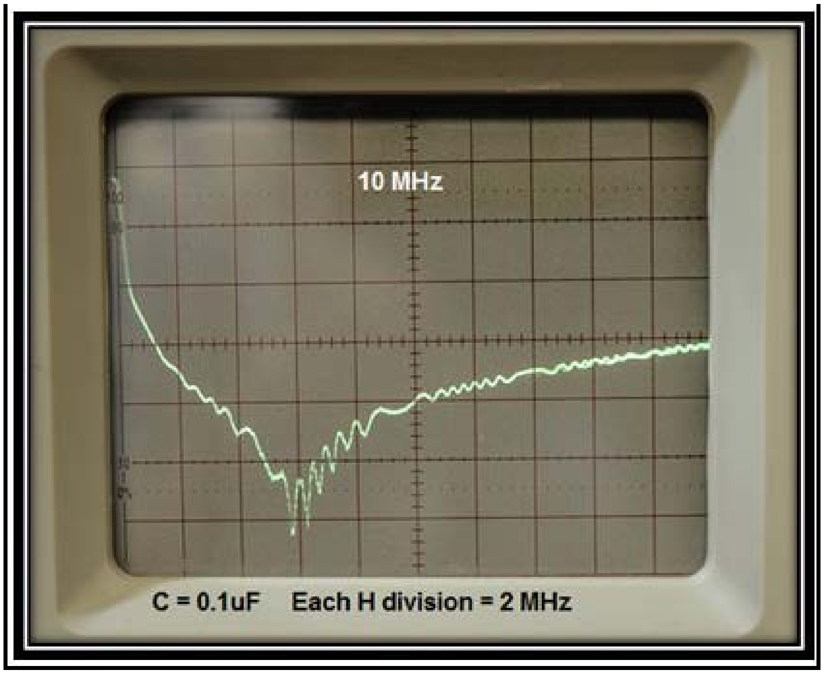

Above — C0 = 0.1 µF. I view the capacitor like a trap. At almost 5.8 MHz lies the peak attenuation, or lowest impedance — this is C0's self resonant frequency. The peak bypass frequency lies ~ 60 dB down. At 20 MHz, the attenuation is only ~ 30 dB.

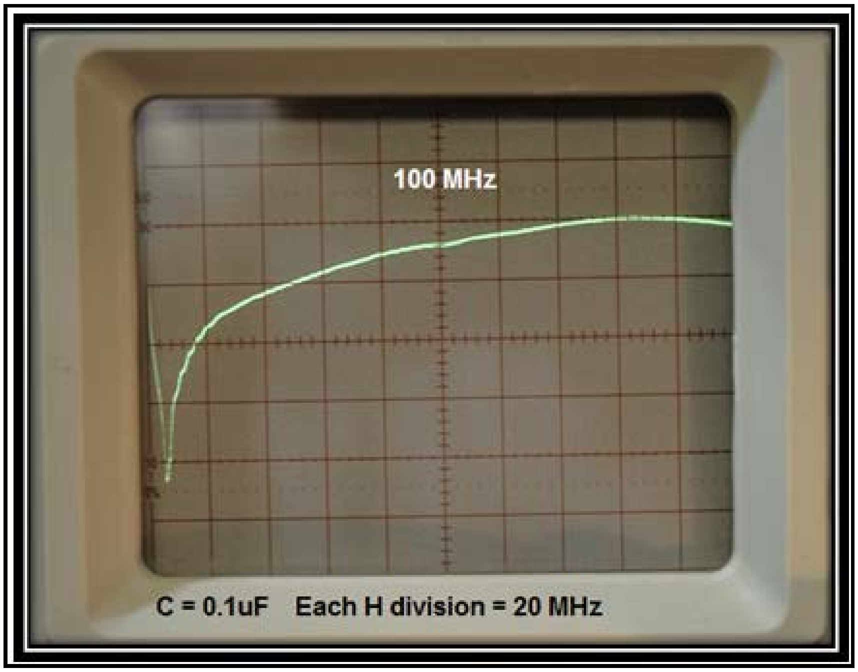

Above — Another shot of the 0.1 µF bypass cap with a 200 MHz span. At 50 MHz, the reference signal lies only ~ 17 dB down. At 100 MHz, the attenuation is only ~ 11 dB — this hardly qualifies as “bypass” much above the self resonant frequency. Above the self resonant frequency, a capacitor's XL affects impedance more than the ESR and XC of the capacitor.

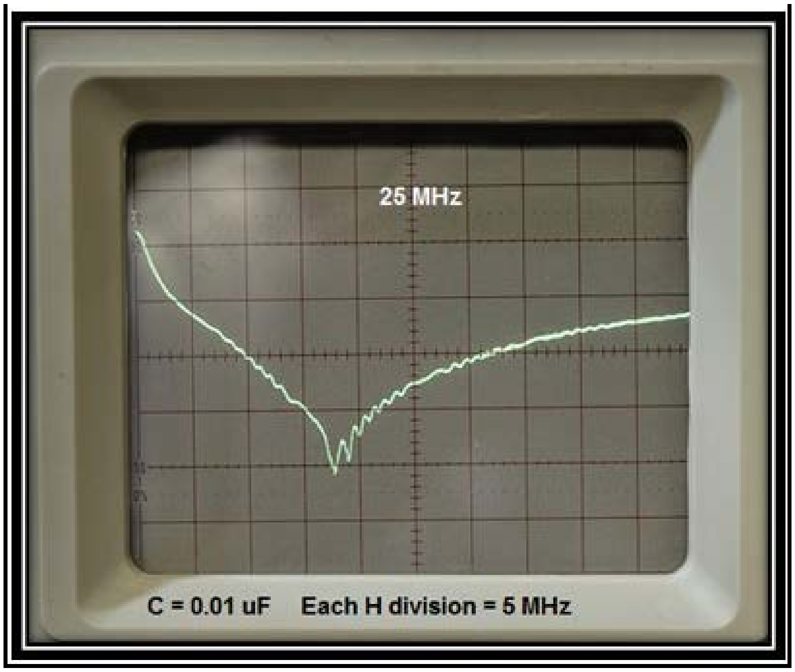

Above — C0 = 0.01 µF. The peak bypass frequency (capacitor self resonant frequency) is centered at 17.5 MHz and is ~ 50 dB down; not as deep as with the 0.1 µf cap. At 50 MHz, the attenuation is ~ 21 dB.

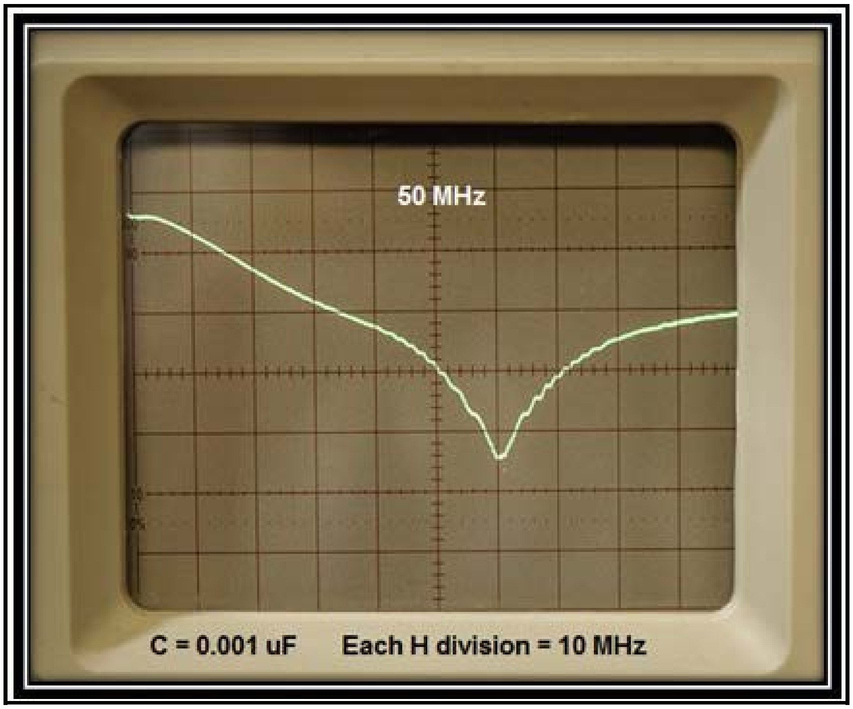

Above — C0 = 0.001. The response is peaked at 62 MHz with an attenuation of ~42 dB. At 100 MHz, the signal is 17 dB down. Again, the peak attenuation looks diminished compared to that of the 0.1 µF and the 0.01µF caps.

Capacitors in Parallel

Now I placed 2 caps in parallel (C0 + C1) as some builders do to try and garner a wider attenuation bandwidth.

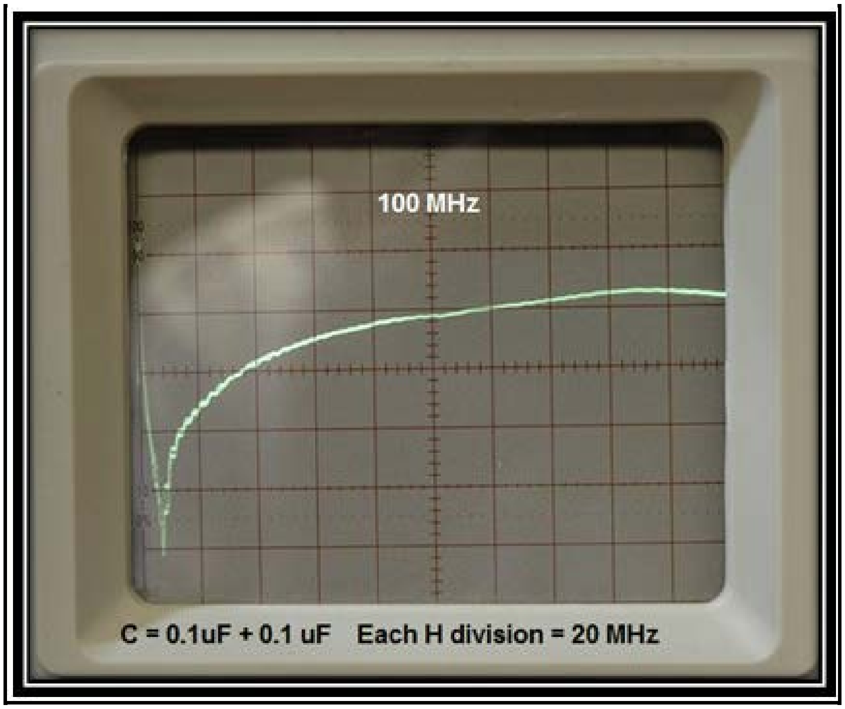

Above — C0 = 0.1 µF + C1 = 0.1 µF. The peak attenuation = 60 dB at 8 MHz; up 2 MHz from that of the single 0.1 µf capacitor. At 100 MHz, attenuation = ~ 19 dB — better than a single 0.1 µF but still low.

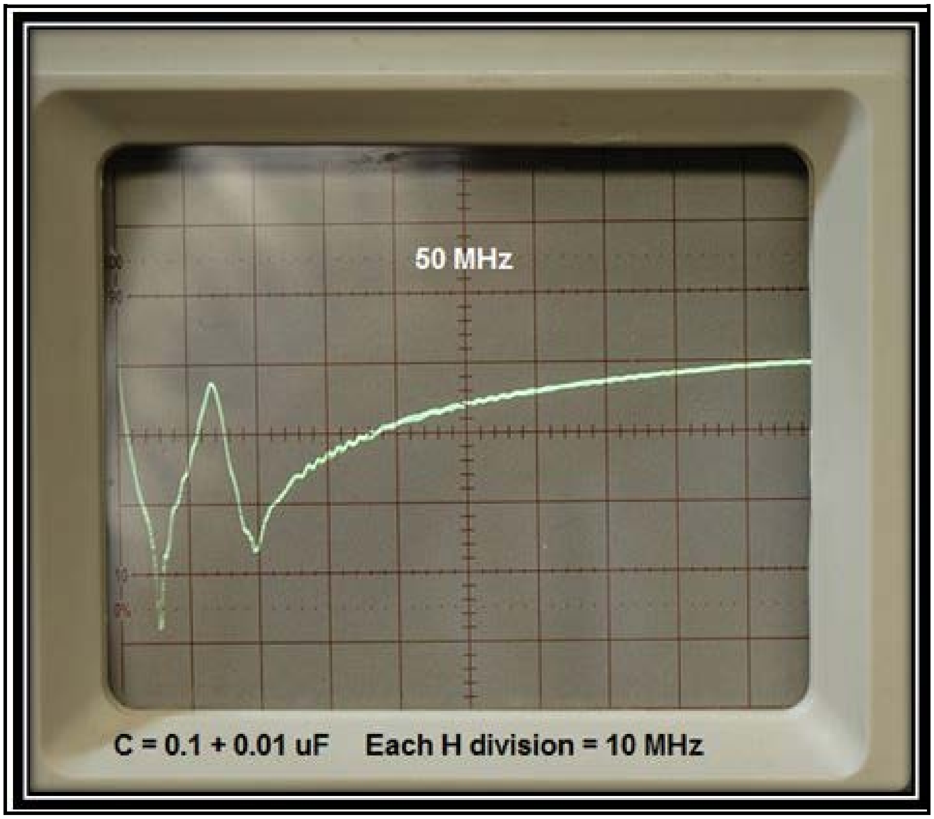

Above — C0 = 0.1 µF + C1 = 0.01 µF. Yikes! With the 2 different cap values, we get an unfortunate high impedance blip peaking at 13 MHz. Each capacitor exerts its self resonant frequency, but in between these self resonant frequencies, lies a disaster.
When placed in parallel, the inductance of 1 capacitor resonates with the capacitance of the other to form a parallel resonance — leading to a high impedance — that blocks RF bypass and peaks at a specific frequency.

But wait. Things can get worse:

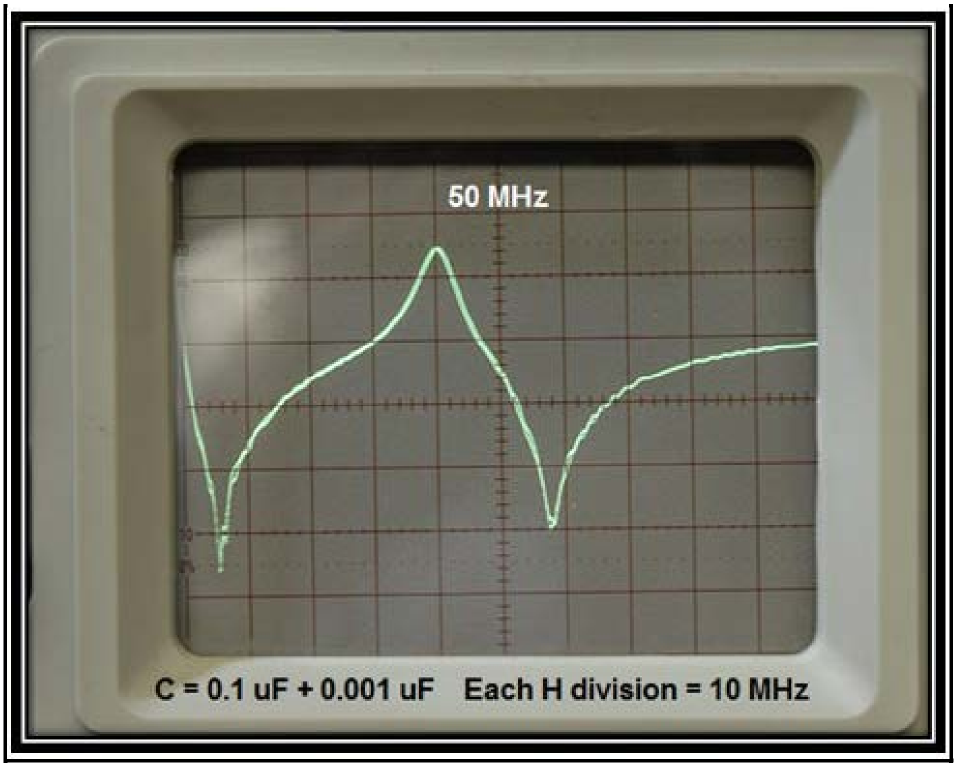

Above — C0 = 0.1 µF + C1 = 0.001 µF. The wide value variance between these 2 capacitors creates a huge, high impedance spike where the attenuation is only about 6 dB at 40 MHz. Catastrophic bypass indeed. катастрофа.

A 7 mm Length of Copper Wire

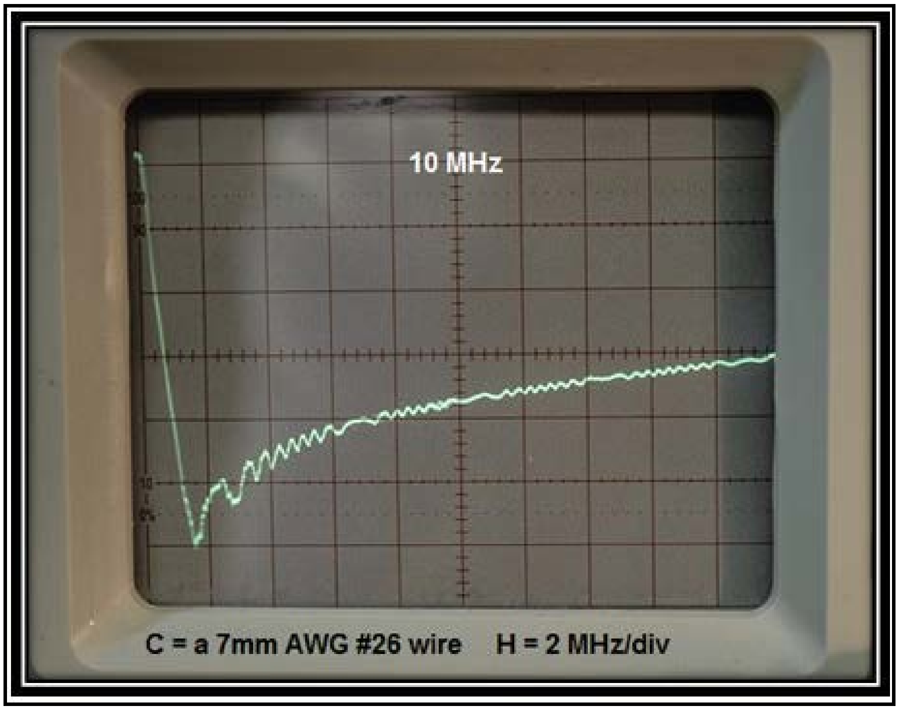

Above — A 7 mm piece of 26 gauge copper wire was shorted to ground instead of C0. This wire measured at ~7 nH of inductance and I saw that attenuation decreases with frequency from 62 dB at 8 MHz to ~33 dB at 20 MHz. Even a short piece of wire doesn't exhibit a flat, wideband bypass.

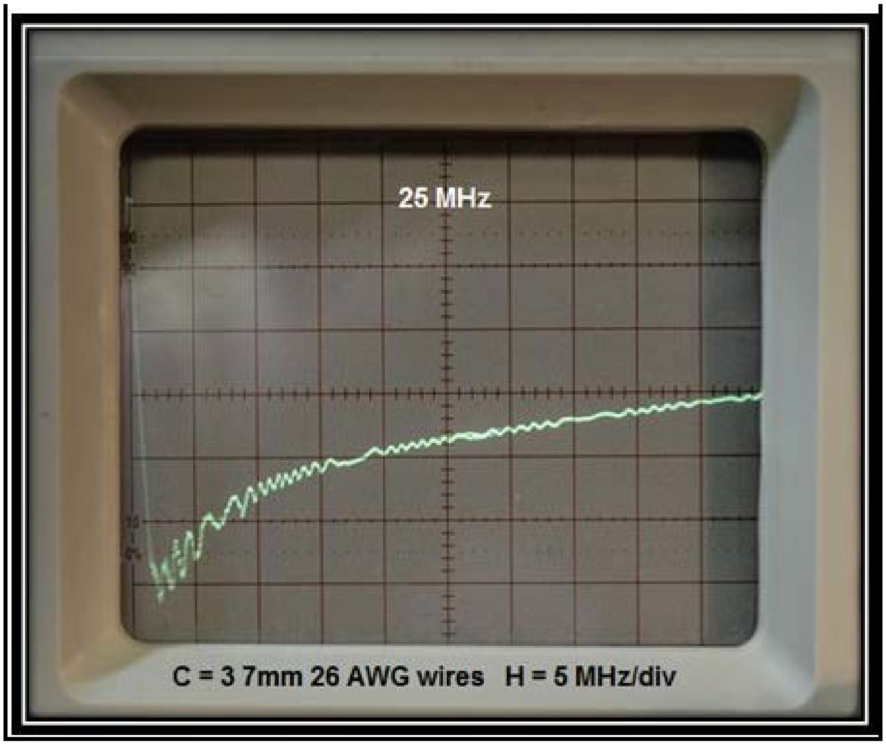

Above — This spectrum analysis shows three 7 mm wires shunted to ground – not much different than 1 wire.

0.01 µF Chip Capacitor(s)

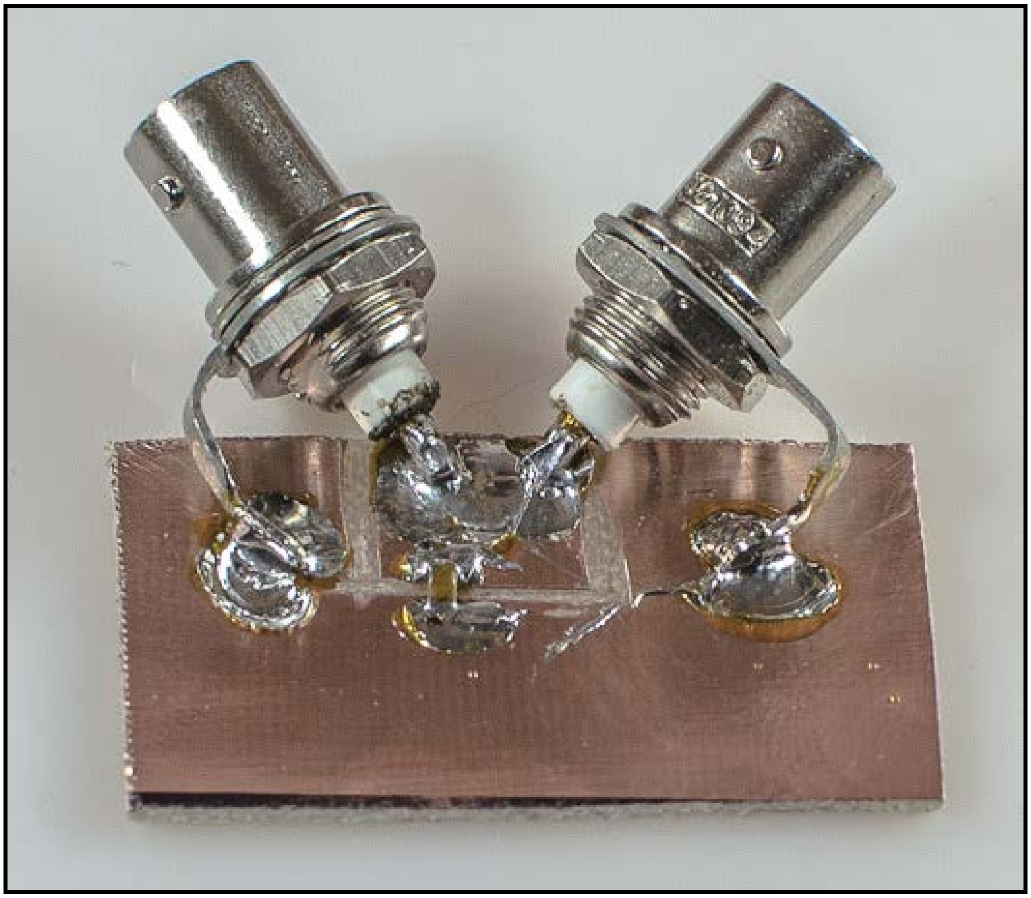

Above — The magnified copper board that I tested one or two 0.01 µF chip capacitors. You can see 1 capacitor soldered in.

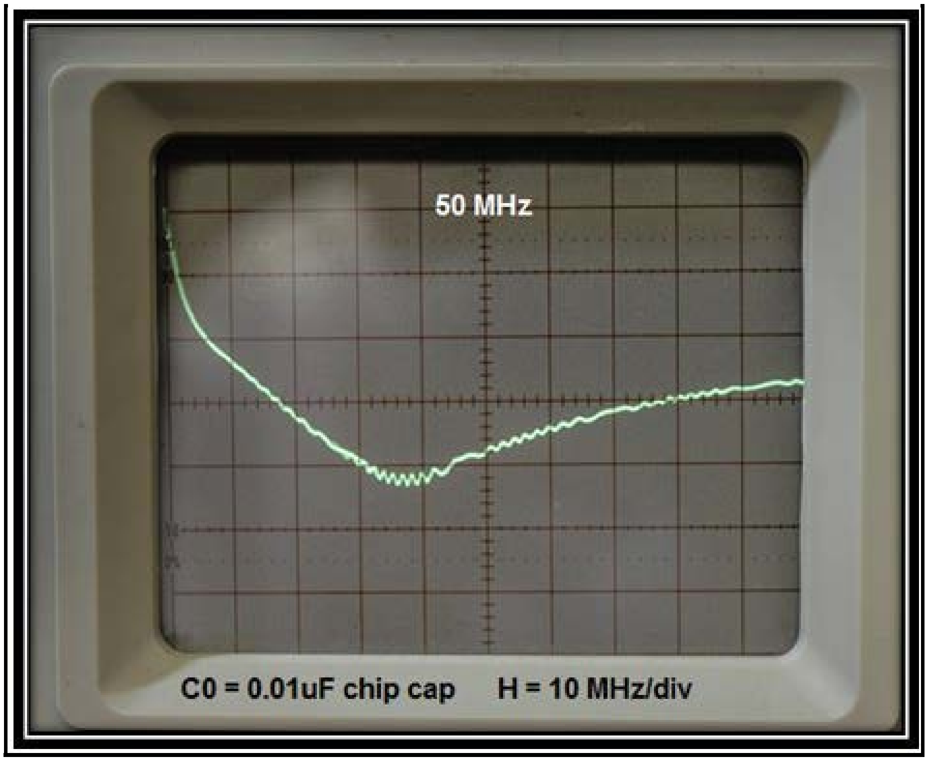

Above — C0 = 0.01 µF SMT cap. The SMT parts exhibited a peak attenuation of 45 dB at ~37 MHz. The attenuation dip lacks the sharp peak of the hole-through 0.01 µF cap shown eariler and exhibits a somewhat wider bandwidth. The self resonant frequency of the chip capacitor is 5 MHz higher than the particular hole-through capacitor I measured. Click for a side by side photo.

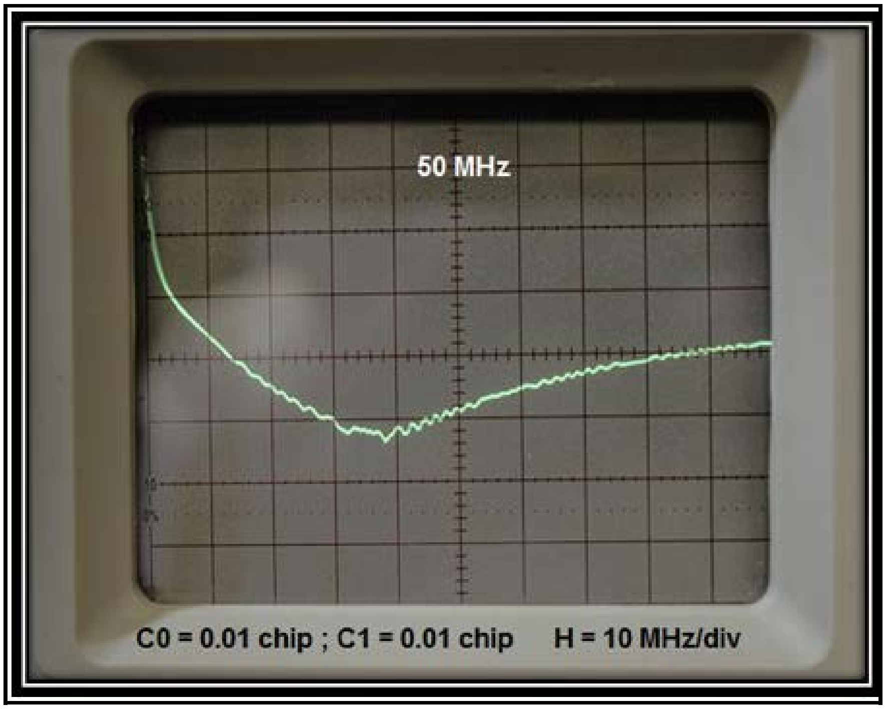

Above — C0 = 0.01 µF + C1 = 0.01 µF. The SMT parts exhibited a peak attenuation of 45 dB at ~37 MHz; similar to the single 0.01 µ F chip cap, but with a few more dB attenuation between 10 and 20 MHz.

0.1 µF Ceramic + a 2.2 µF Electrolytic Capacitor

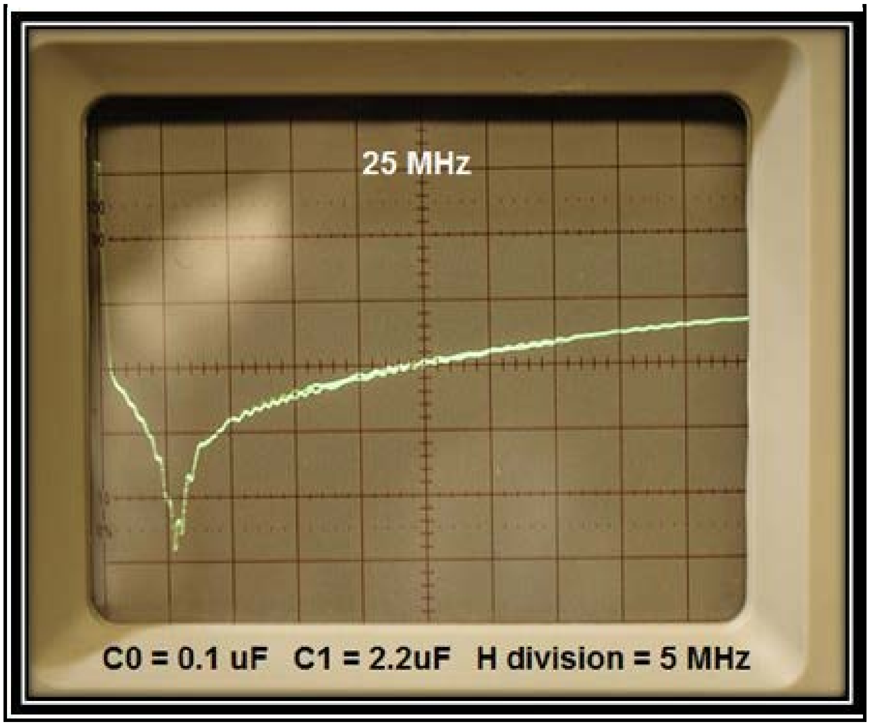

Above — C0 = 0.1 µF and C1 = 2.2 µF. The low Q 2.2 µF C1 electrolytic cap did not create the a parallel resonance with C0. Shaky photo — sorry. I also tested a 10 and 22 µF cap in parallel with C0 and saw no disturbance caused by a parallel resonance between a big AF capacitor and C0 (an RF value cap) with my RF spectrum analyzer.

Some additional experiments applying a low Q *A*F capacitor plus a ceramic *RF* capacitor for wideband bypass yielded some interesting results and I'll present these in a future project.

Capacitors in Parallel with a Series Resistor to Lower Q

In previous experiments, placing 2 RF capacitors in parallel led to the formation of a peaked high impedance blip between the low impedance peaks set by the self-resonant frequency of the 2 capacitors. If multiple capacitors are soldered in parallel, the series inductance of each capacitor will resonate with the capacitance of the next smaller C value.

One solution is to put a resistance in series with all but 1 of the parallel capacitors so that the Q of resonance formed by this capacitor's series inductance and the capacitance of the next smaller capacitor is low. If capacitors exhibited 0 inductance then putting capacitors in parallel would be fine, however, since capacitors exhibit inductance, a parallel resonant frequency may occur with capacitors in parallel.

I found applying a series resistance to lower Q may flatten the impedance versus frequency response of the bypass network, but didn't decrease the impedance at any 1 frequency. Optimal bypassing or achieving the lowest impedance over a wide frequency range presents a complex topic that might even challenge some engineers.

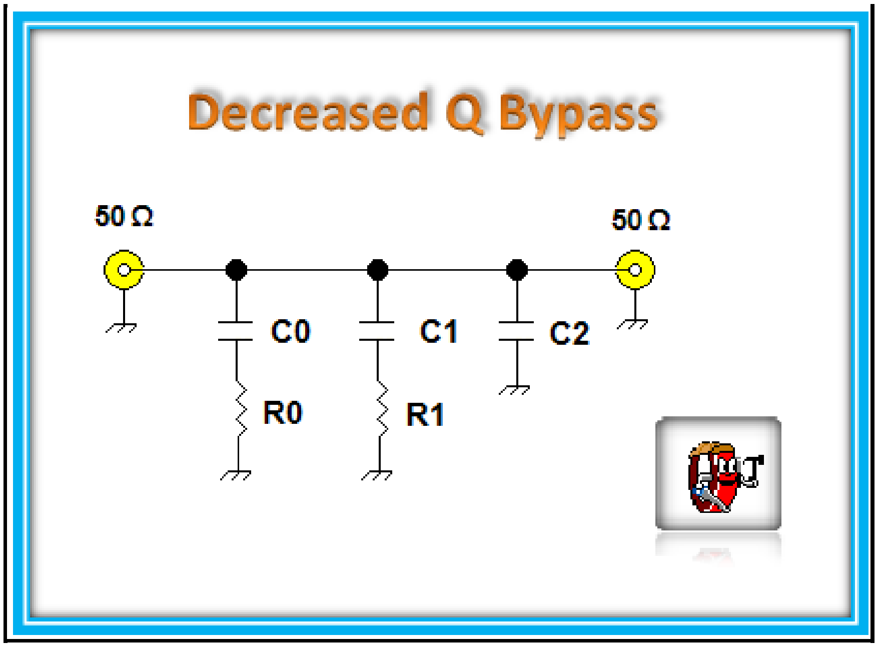

Decreased Q Bypass

Above — A method to exact wideband bypass.

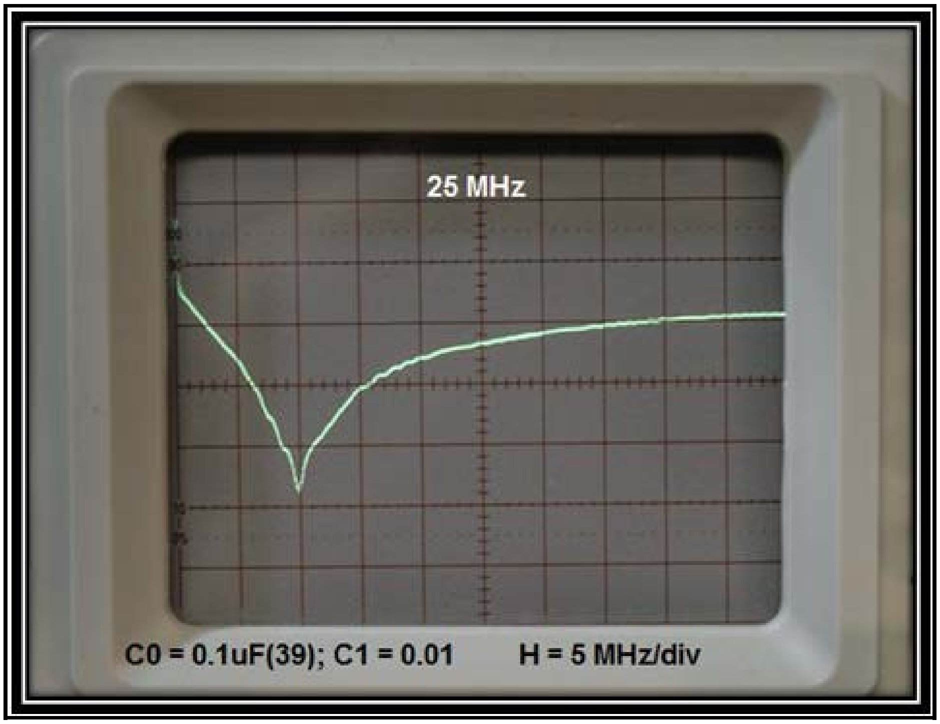

Above — My first try with C0 = 0.1 µF, R0 = 39 Ω and C1 = 0.01 µF. I arbitrarily placed the 39 Ω resistor in the R0 slot and saw that the high impedance peak seen earlier disappeared. This gave me the confidence to try 3 capacitors. I had no idea what R value to use and really just wanted to see what happens.

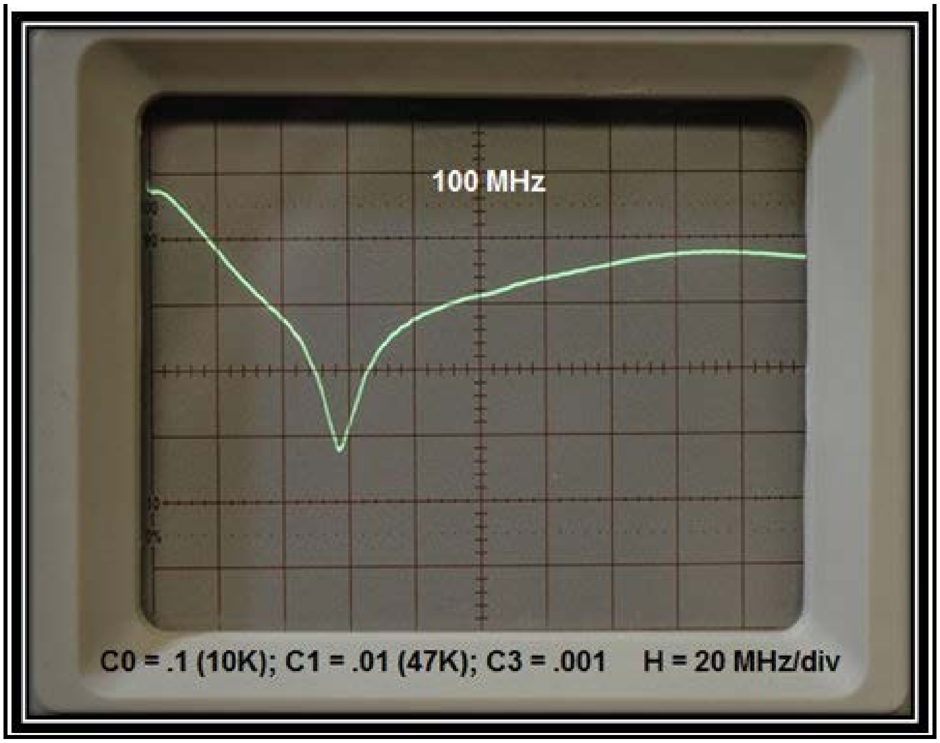

Above — The spectrograph with C0 = 0.1 µF, R0 = 10K, C1 = 0.01 µF, R1 = 47K and C3 = 0.001 µF.

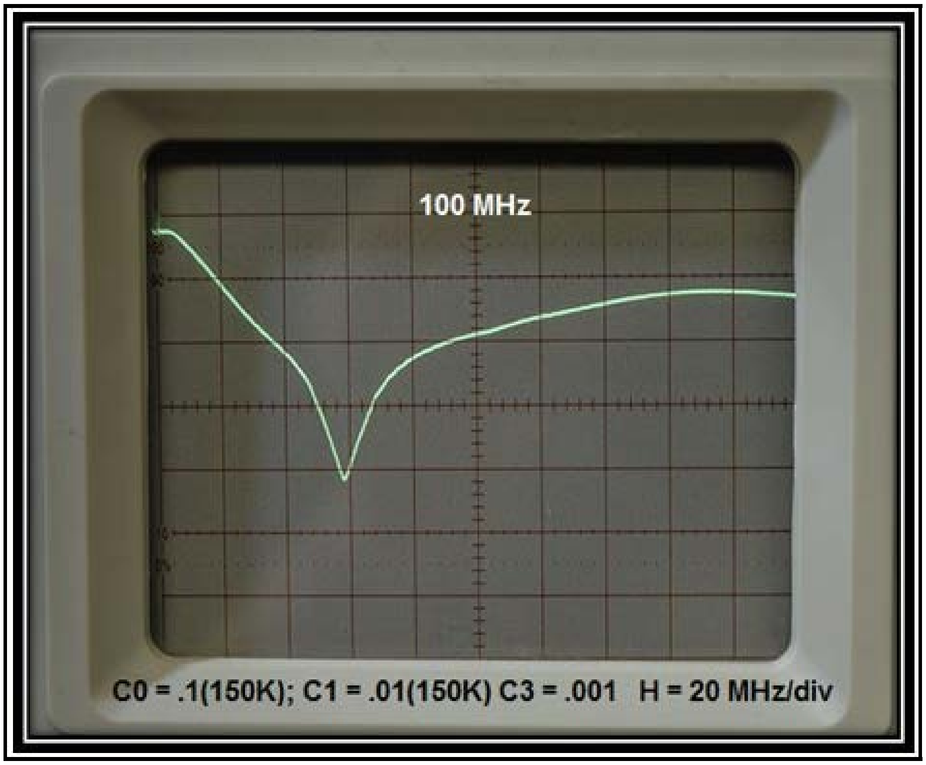

Above — C0 = 0.1 µF, R0 = 10K, C1 = 0.01 µF, R1 = 47K and C3 = 0.001 µF. Again, no high impedance peak response; the self resonant frequency is close to that measured with a single 0.001 uF earlier, however, the peak bypass frequency moved from to 57 MHz from 62 MHz. Changing the resistor values moved the self-resonant frequency and the peak attenuation value a little, but I fell kilometers short of setting a wide band bypass. My approach lacks any real science and I need to step it up.

I hope to learn what capacitor values and types, plus R values to apply. This sounds like a job for simulation as well as further on-bench experiments? After writing this material, I learned that Ken Kuhn wrote an Excel spreadsheet to examine the net impedance of up to 3 capacitors in parallel Click to download.

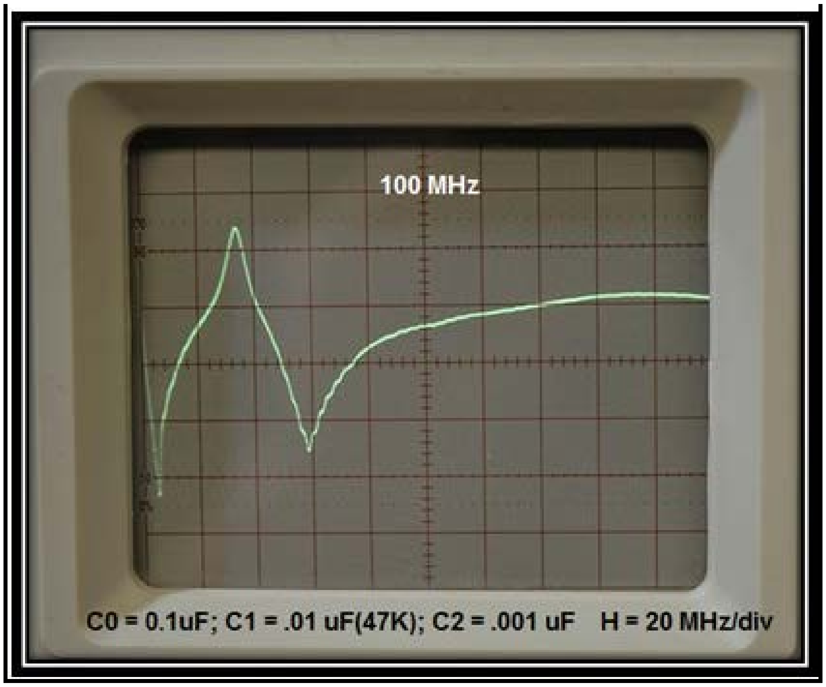

Above — Just as a gag, I removed R0 from capacitor C0 in 1 circuit and then hooked up the board. The high impedance peak re-emerged.

A Commerical Example

I found a wideband MMIC employing (R1 + C1 and C2) as part of a bypass strategy. Cick for the datasheet excerpt. Note the size of the SMD capacitors; 0603 — tiny caps! My experiments showed some high gain MMICs require careful low inductance grounding and correct part choices or crippling oscillations and other bypass issues might arise.

My Learnings

When we think bypass, we really should think frequency dependent attenuation. The bypass cap is actually a network where impedance versus frequency varies significantly. At its self resonant frequency, a capacitor will exhibit the lowest possible impedance making a single capacitor a relatively narrow-band bypass device. Intuitively, we might want to choose a capacitor with a series resonant frequency at the frequency we wish to bypass, however, if we require a wideband bypass, the need to evaluate our bypass capacitor(s) increases.

In short, above the series resonant frequency of a capacitor, its bypass is basically useless and we should likely ensure that the self-resonant frequency of the particular capacitor we're using is above the highest frequency to be bypassed.

Bypassing with 2 or more unmatched RF caps will lead to an attenuation gap with peak(s) determined by the parallel resonance of these capacitors. Going above a 10:1 capacitor ratio, for example, greater than a 0.1 and a 0.01 μf, may cause a **severe** gap in attenuation at the parallel resonant frequency generated by the 2 capacitors.

Mine and work from more reputable authors clearly shows we should avoid applying parallel **RF** bypass capacitors of *different* values unless we apply a Q-reducing resistor to the capacitor(s) in parallel with a given RF bypass capacitor. Please read EMRFD page 2.3 for more information and watch out for abundant folklore concerning RF bypass.

The need for measurement and analysis challenges us; in some cases, you may realize good attenuation in the radio band of interest, while poorly bypassing the frequencies above it and compromise an otherwise good design.

Capacitor lead length may affect self-resonance at RF.

Future Work

It would be awesome to learn more about getting a wide-band bypass. I want to order some low or ultra-low ESR caps and measure them. My MuRata RPE Series caps specify low inductance; low is relative — how low is low? Should we apply chip capacitors for bypass in our critical circuits such as low noise VHF amps or MMICs?. Am I fussing about nothing? Lots of questions that folklore just won't answer.

Per EMRFD page 2.3, bypass is only half the equation — we need to *decouple* + bypass to filter RF from moving along our DC lines and so forth.

---

6. Some Experiments with Chokes plus Decouple and Bypass Filters

Introduction

SRF = self resonant frequency; XL = inductive reactance; XC = capacitive reactance. L = inductor; C = capacitor; R = resistor.

Like the capacitor, inductors are networks with R, L and C and possess a SRF. R, L and C may vary with factors including the number of windings, frequency, or whether the L is wound on a ferromagnetic material, or air wound.

Considering R, L and C:

at frequencies below the SRF, XL dominates;
at frequencies above the SRF XC dominates;
at the SRF, the magnitude of XL and XC are equal but 180 degrees out of phase leaving resistance to dominate.

I encourage you to learn more by visiting the fabulous web site of David, G3YNH.

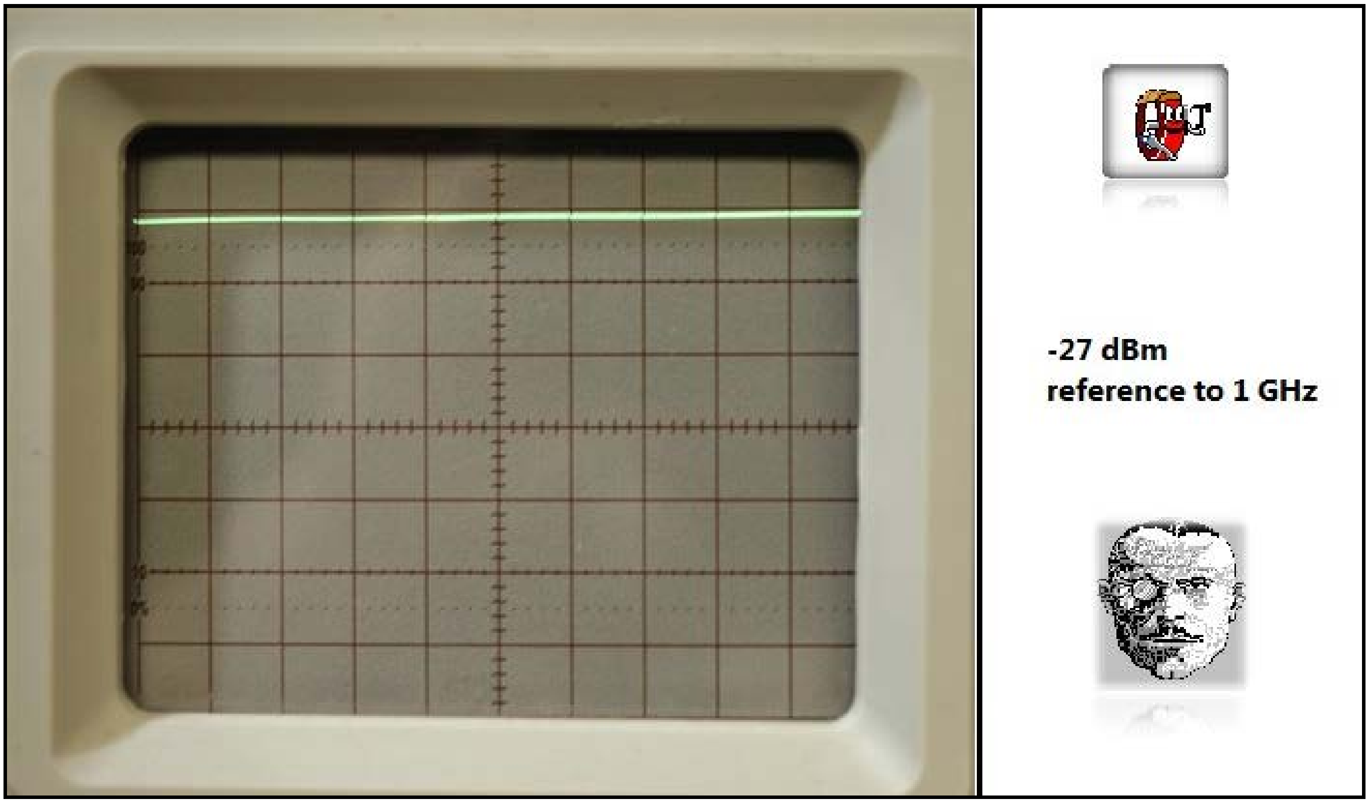

Above — Reference signal at -27 dBm. I used the exact test method shown in Section 5.

For those unaware, the spectrum analyzer screen is divided into 10 by 10 graticules. Each vertical division represent a 10 dB change; read down from the reference -27 dBm to measure the attenuation of the reference signal in dB. Horizontal divisions represent frequency; start at 0 on the left hand side and increment as specified on each figure.

A Few Inductors

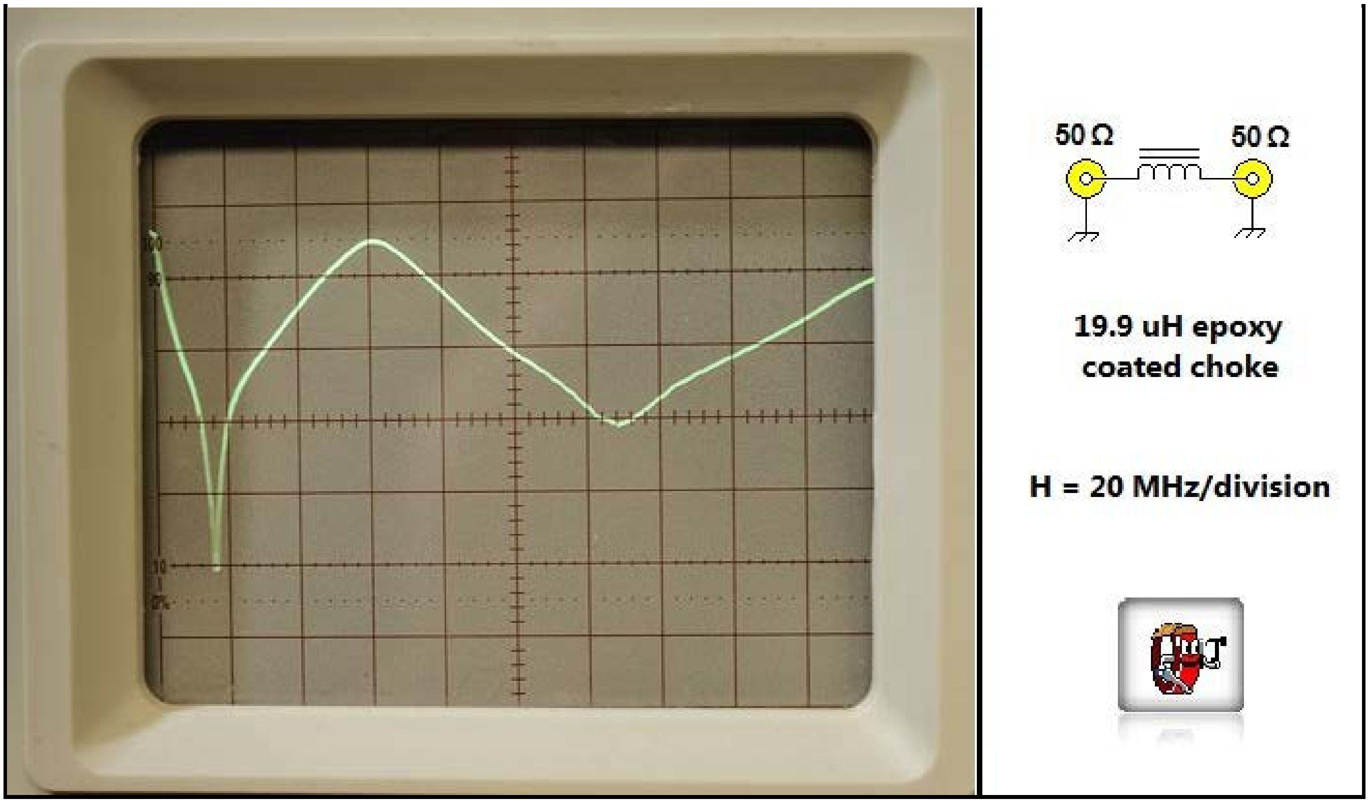

Above — A 19.9 uH epoxy coated choke that exhibits a primary SRF at 18 MHz and a second, smaller SRF at ~128 MHz. This wretched L gave me grief at 63 MHz. After measurement, I tossed it in the garbage can.

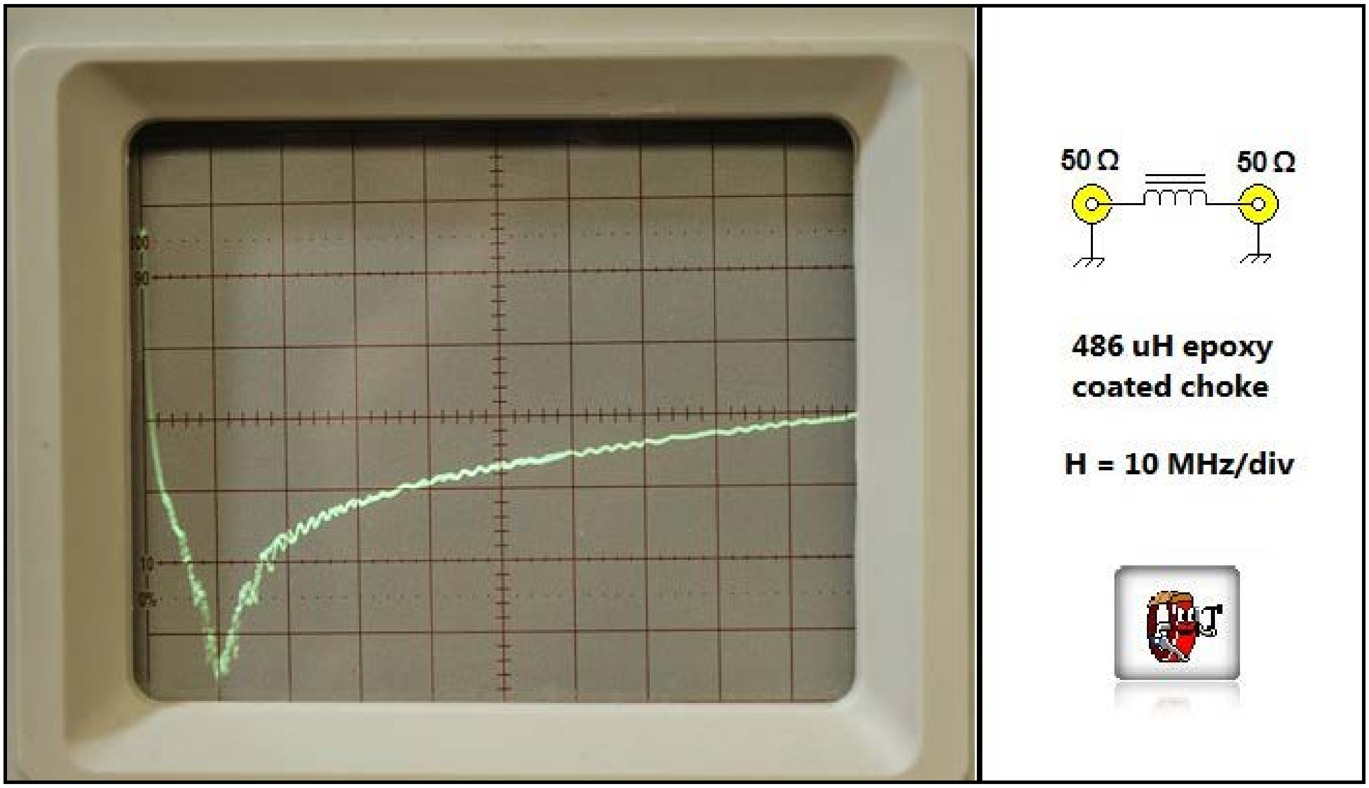

Above — A large, junk box choke with an SRF at about 10 MHz.

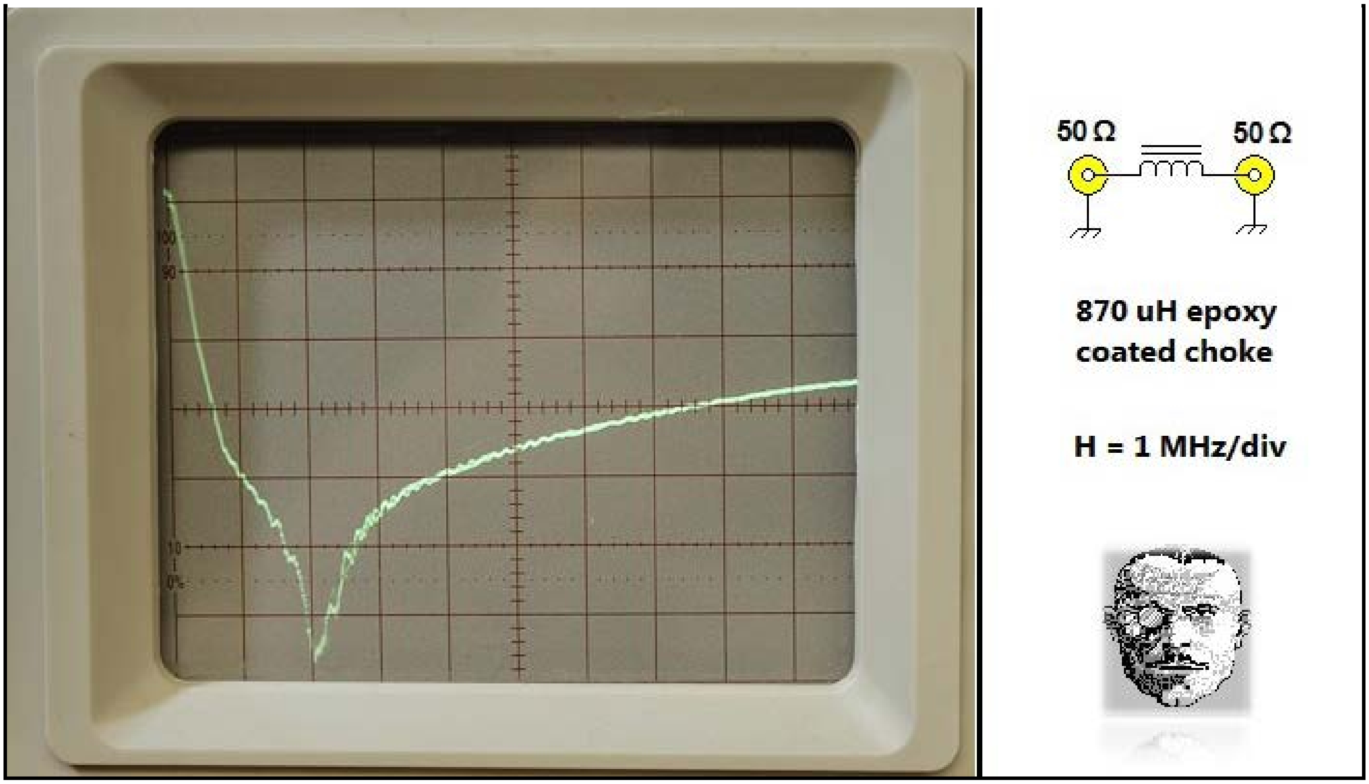

Above — I rarely use these big chokes: 870 µH with a SRF at about 2 MHz.

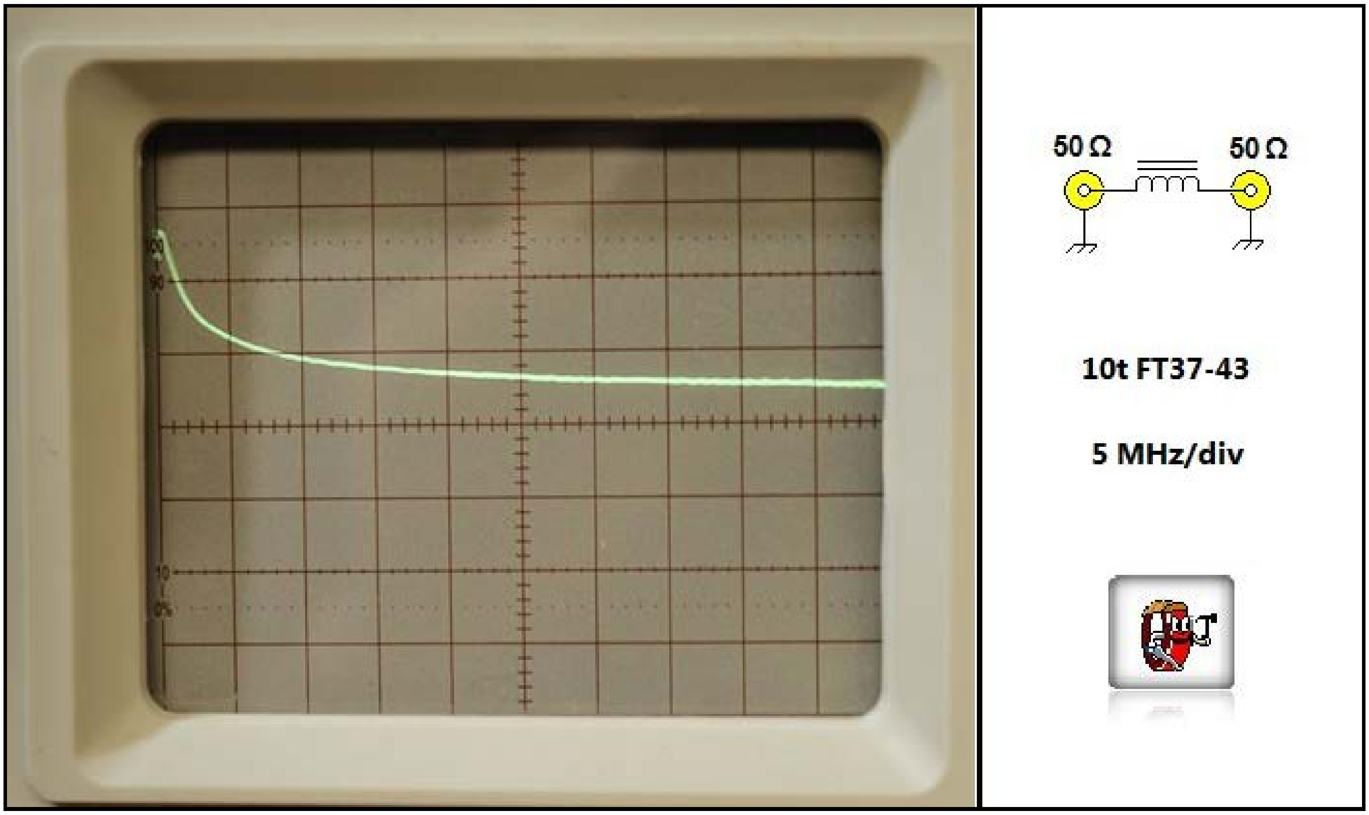

Above — A common L on our benches — 10 turns of #26 AWG on a FT37-43 ferrite toroid.

I couldn't measure the SRF with any span on my spectrum analyzer. I expect that a parasitic capacitance lies in parallel with the inductance, but the #43 material, with its low Q and high losses blankets the usual deep notch we see when the L exhibits a higher Qu.

10 Turns on a FT37- 43 with a Bypass Capacitor Shunting Each End

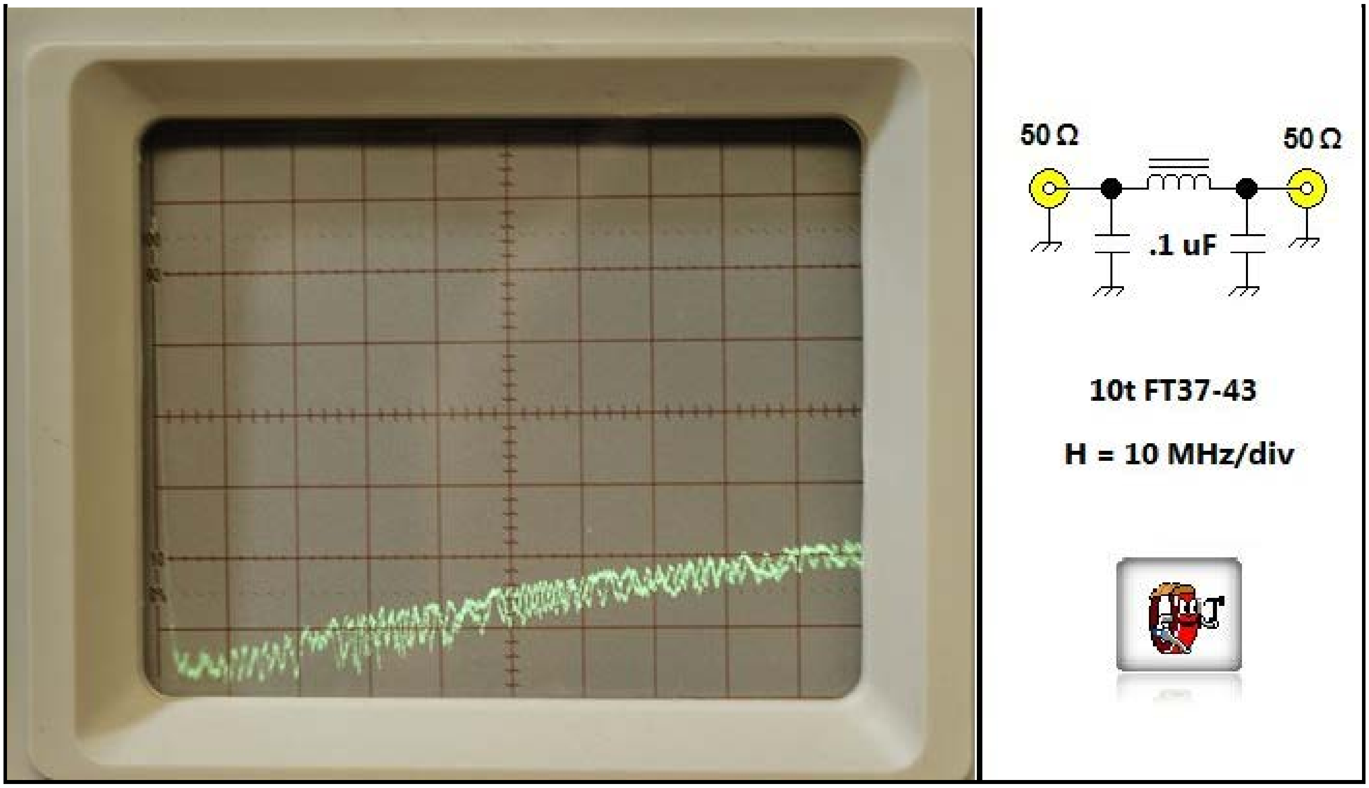

Above — Look at the big difference after adding shunt capacitors to a 10 turn FT37-43! Even at 100 MHz the attenuation lies nearly 50 dB down. Now I understand why Wes says **decouple plus bypass** when filtering our DC lines and so forth.

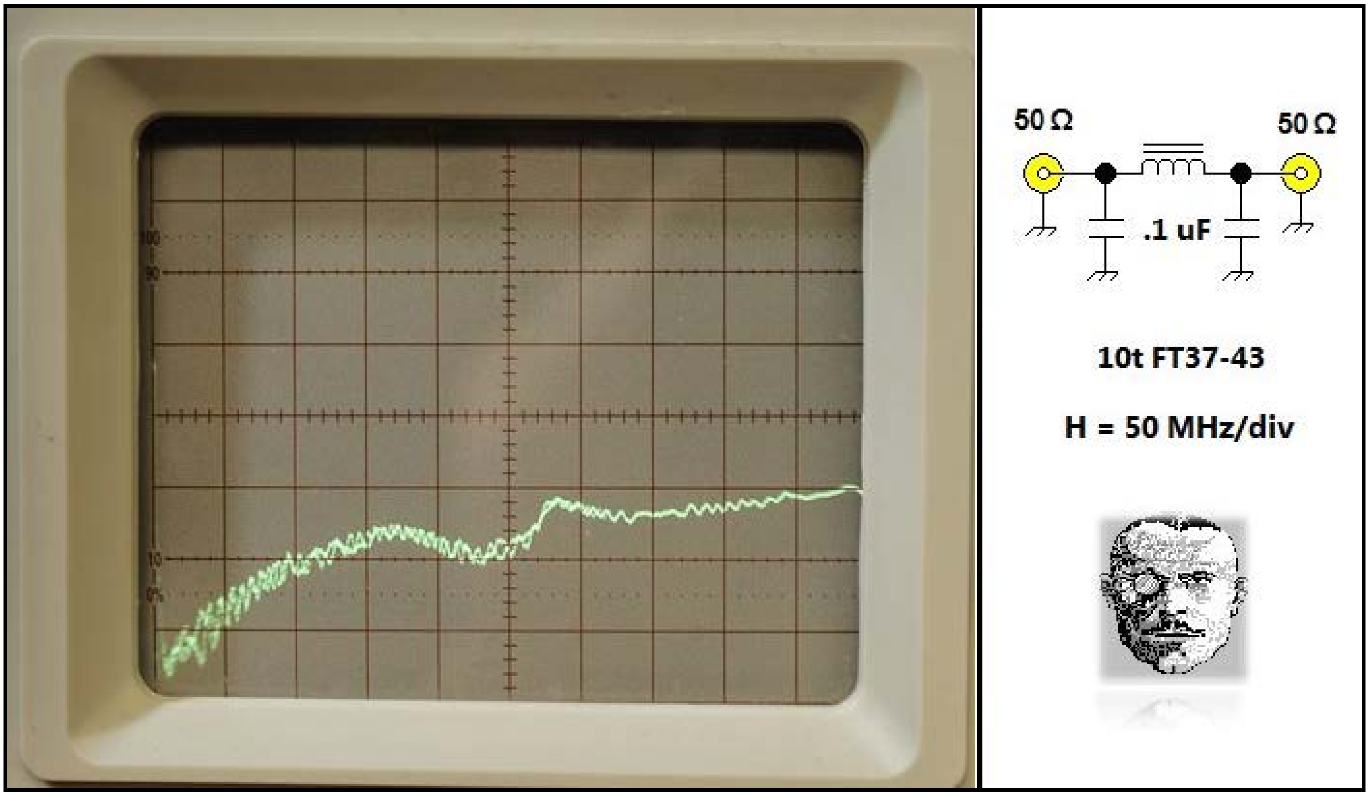

Above — The 10 turn FT37-43 coil with 0.1 μF shunt caps measured out to 500 MHz. Pardon the camera shake; I took all the photos hand held to save time.

A Resistor with a Bypass Capacitor Shunting Each End

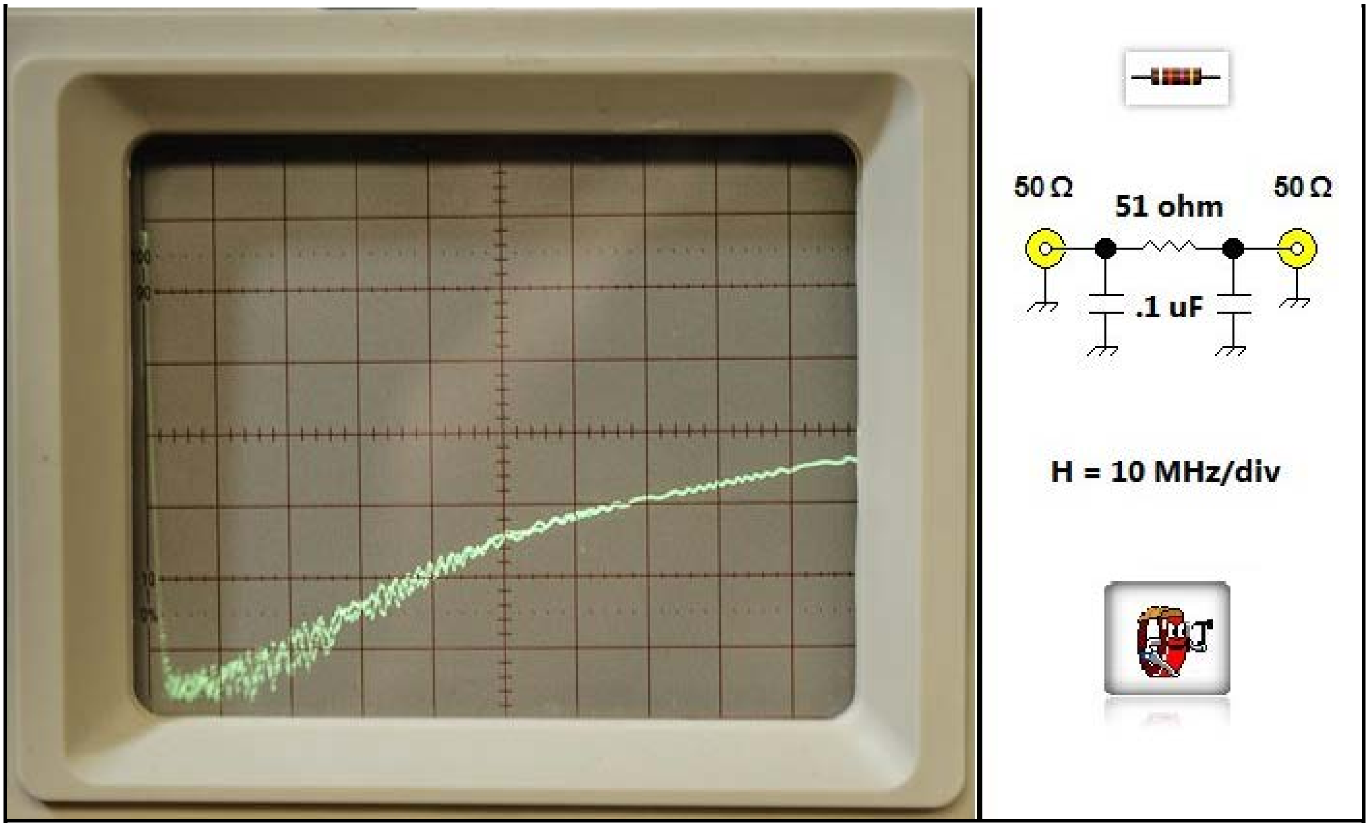

Above — A 51 Ω resistor bypassed with 0.1 µF capacitors at each end spanned out to 100 MHz. Even at 30 MHz, the attenuation looks stellar.

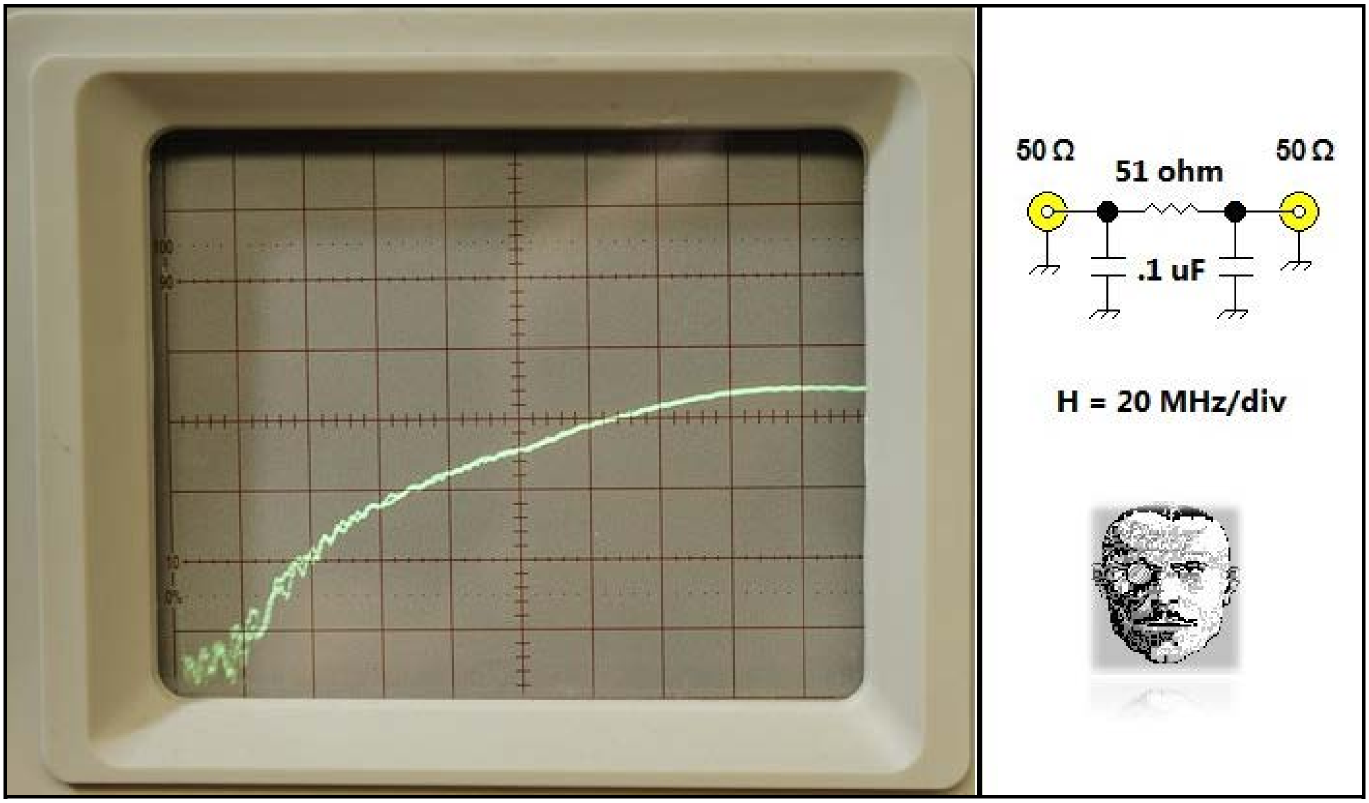

Above — The 0.1 µF bypassed 51 Ω resistor out to 200 MHz. I often use a 51 Ω decoupling resistor with appropriate capacitor values in active circuits that draw from 10 - 18 mA.

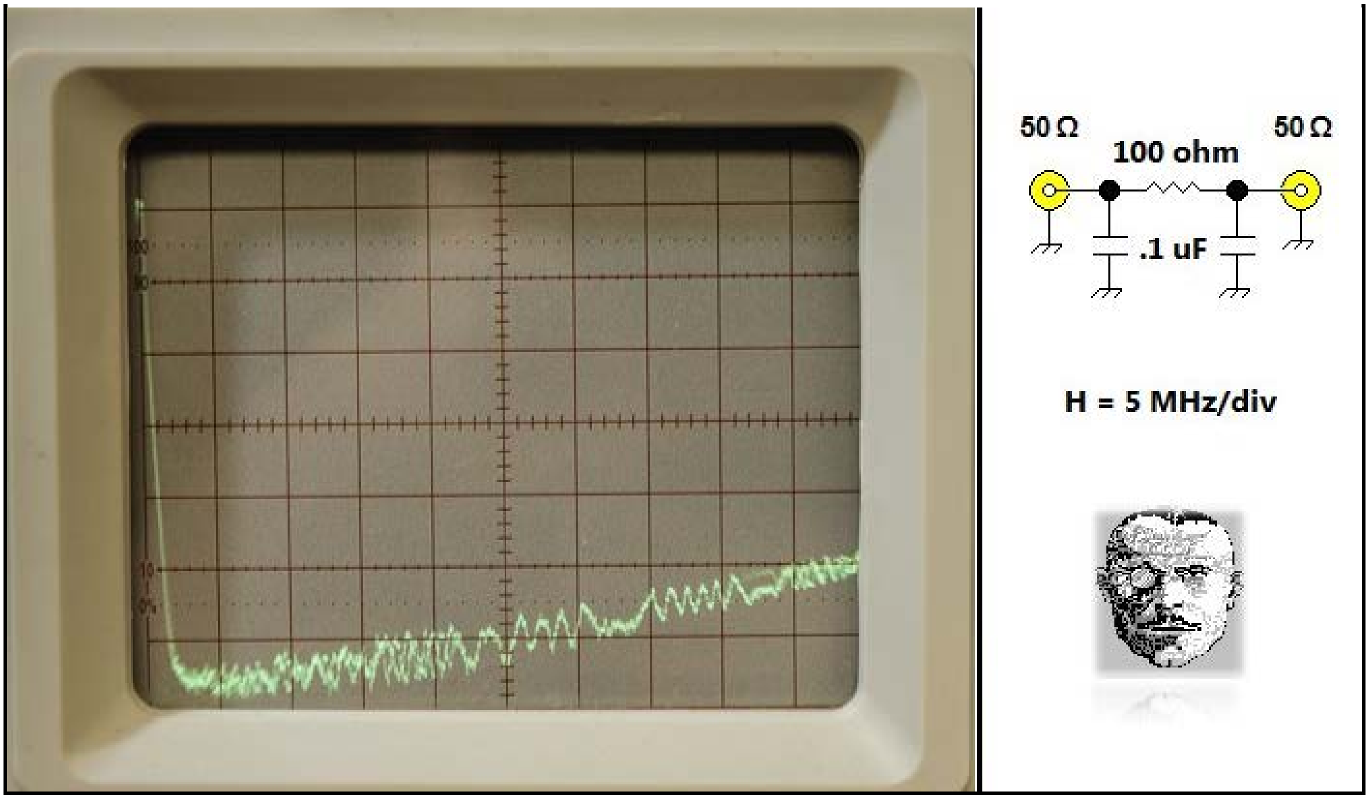

Above — The "bench standard"; a 100 Ω R with a shunt 0.1 μF at each end. We use this all the time. Even at 25 MHz, the attenuation looks around 55 dB down.

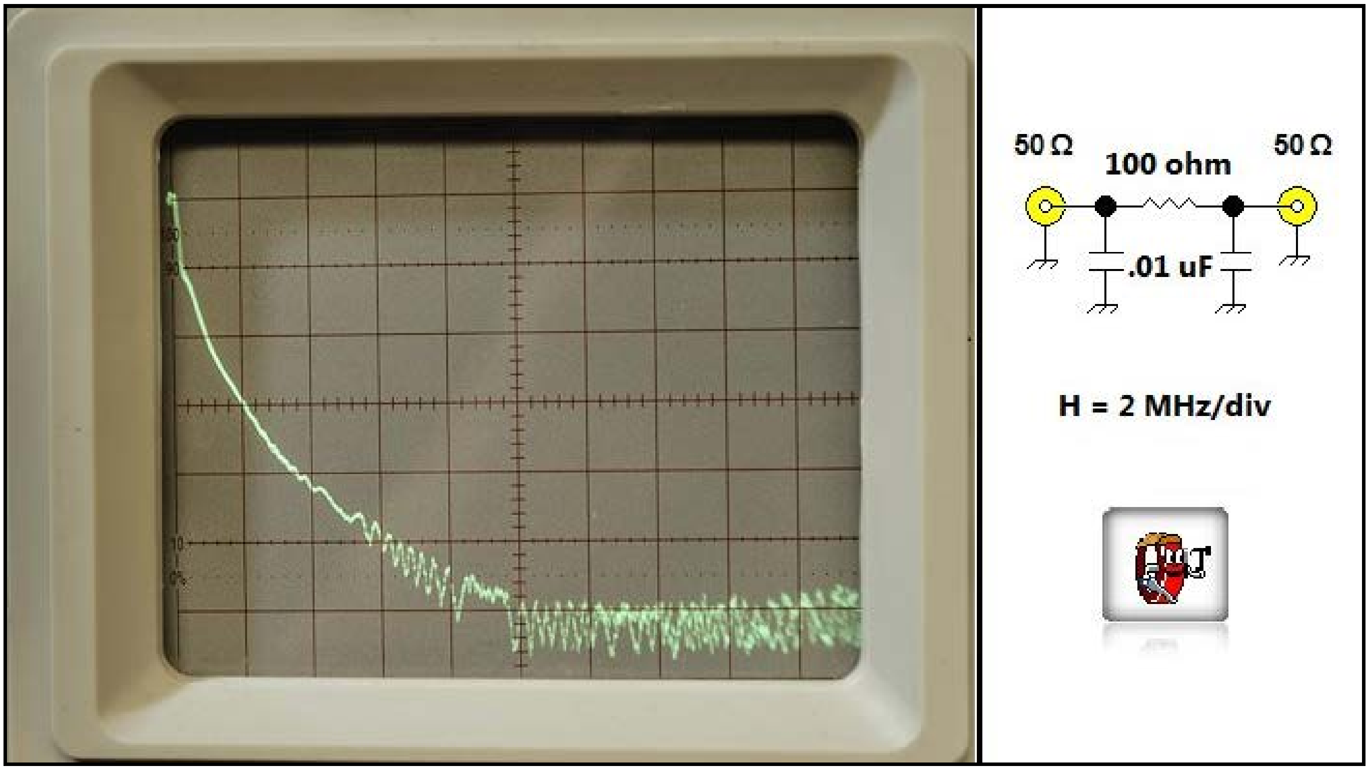

Above — The 100 Ω R with the shunt capacitors decreased to 0.01μF. At 6 MHz, we're about 50 dB down. From 10 to 20 MHz, the attenuation is about as high as I can measure.

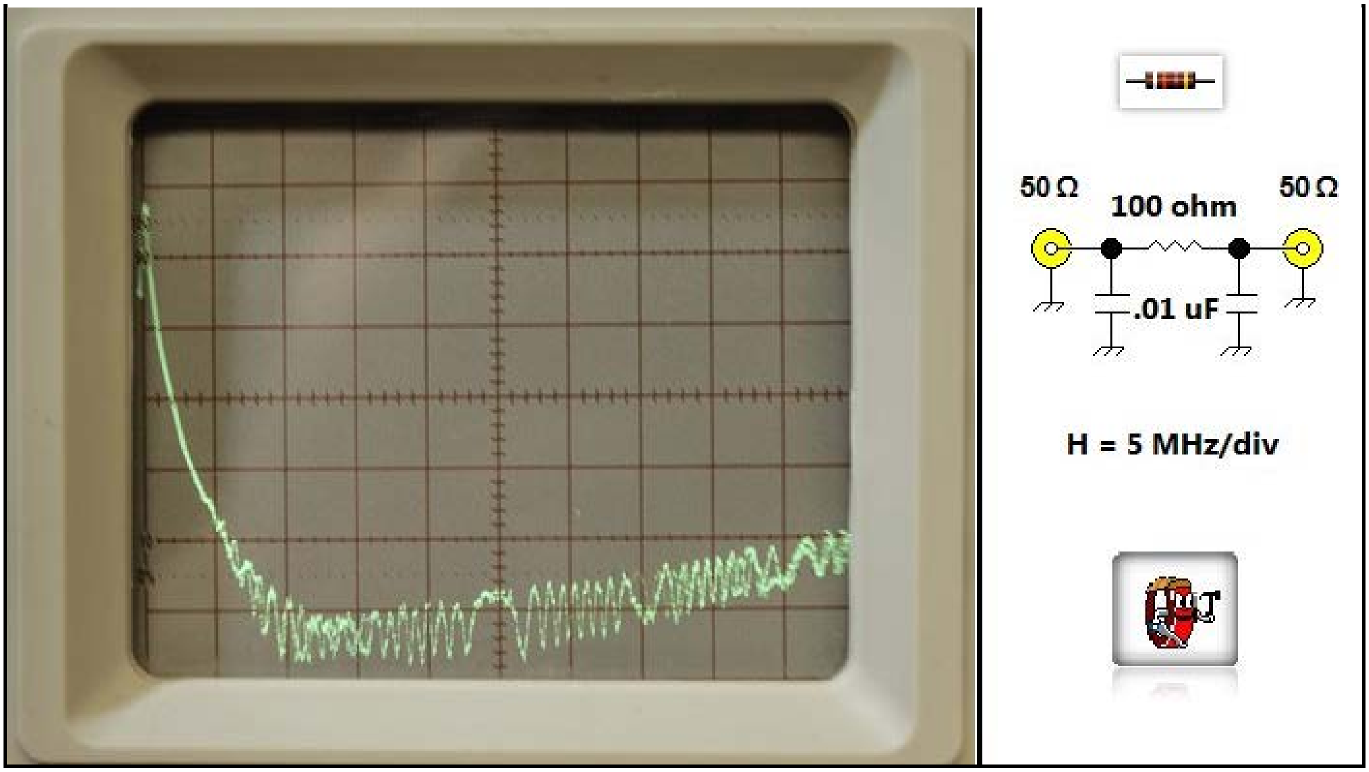

Above — 100 Ω R plus 0.01 μF caps out to 50 MHz. I've used this combination of R and C for filtering at 50 MHz a lot.

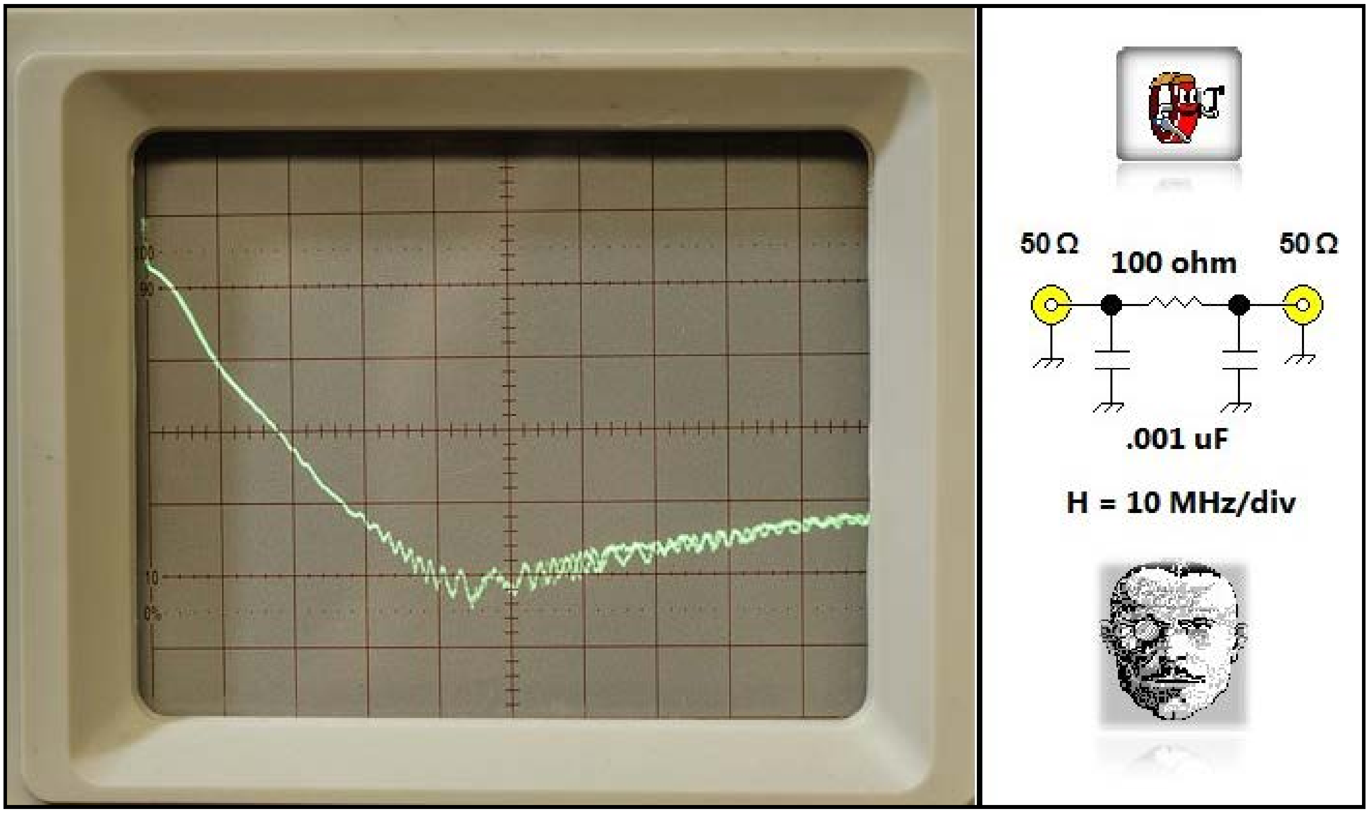

Above — 100 Ω R plus 0.001 μF capacitors out to 100 MHz. In my particular circuit, the attenuation at 50 MHz equals that of the 100 R + 0.01 μF C low-pass filter shown directly above.

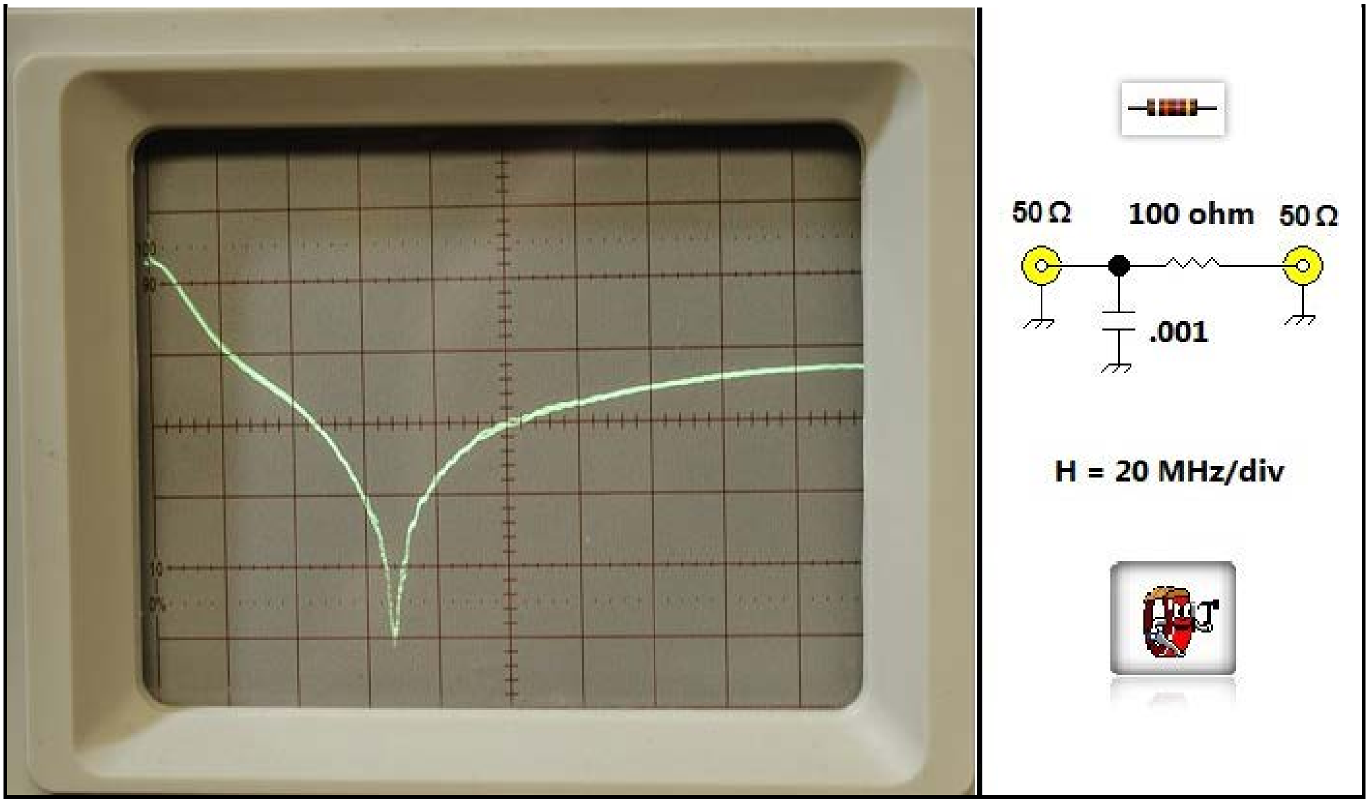

Above — A 100 Ω R plus a single 0.001 μF capacitor. If you leave off 1 capacitor, a serious notch appears at ~ 68 MHz. If you flip the filter around so the bypass cap is on the right hand side, the tracing appears the same. This problem occurred with all the filters tested in all experiments. As possible, solder a suitable bypass capacitor on *both* sides of the R or L.

I encourage you to experiment with the SRF of coils and wideband decouple + bypass filters on your own.

QRP Posdata for Oct 2013 — SRF of some common bypass capacitors

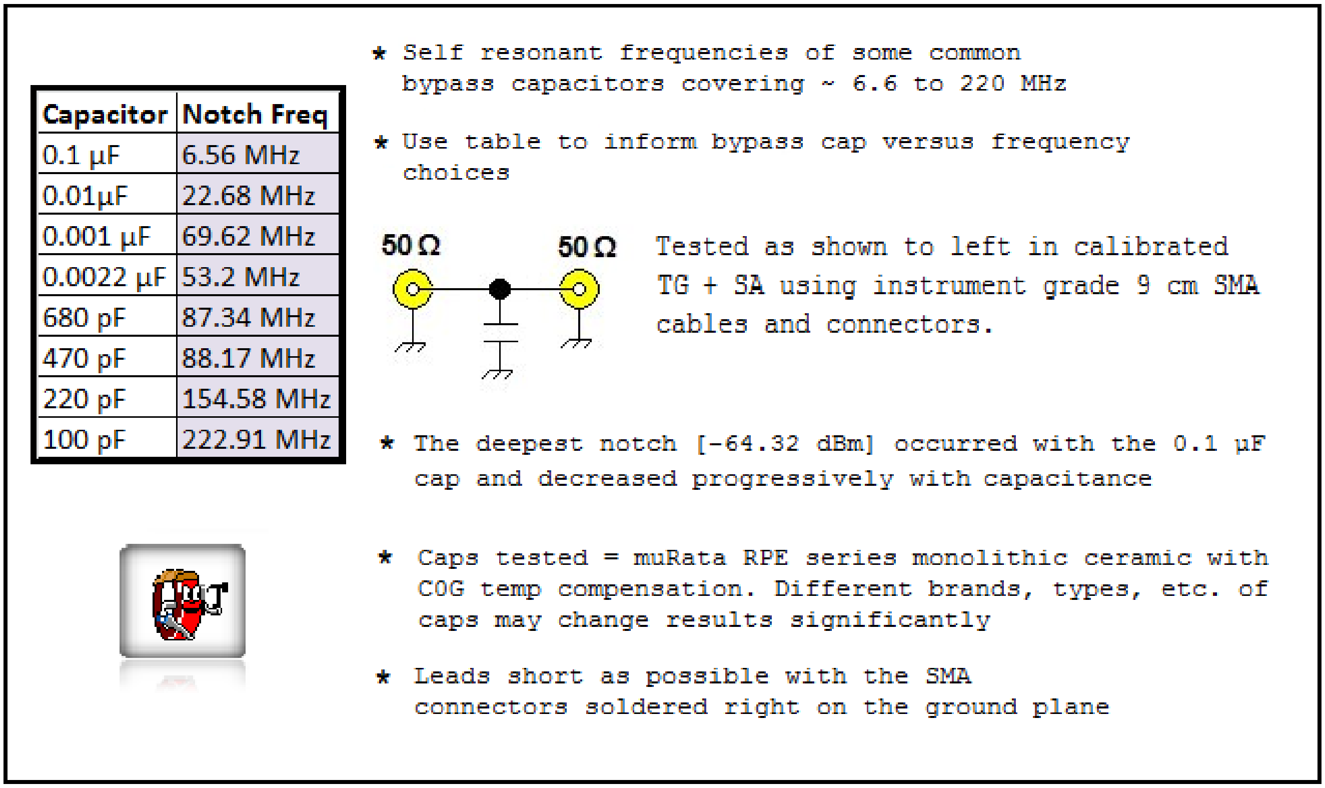

Capacitor	Notch Freq
0.1 µF	6.56 MHz
0.01µF	22.68 MHz
0.001 µF	69.62 MHz
0.0022 µF	53.2 MHz
680 pF	87.34 MHz
470 pF	88.17 MHz
220 pF	154.58 MHz
100 pF	222.91 MHz

* Self resonant frequencies of some common bypass capacitors covering ~ 6.6 to 220 MHz

* Use table to inform bypass cap versus frequency choices

Tested as shown to left in calibrated TG + SA using instrument grade 9 cm SMA cables and connectors.

* The deepest notch [-64.32 dBm] occurred with the 0.1 µF cap and decreased progressively with capacitance

* Caps tested = muRata RPE series monolithic ceramic with C0G temp compensation. Different brands, types, etc. of caps may change results significantly

* Leads short as possible with the SMA connectors soldered right on the ground plane

Above — A reference table showing the self resonant frequency of several comon value bypass capacitors in my parts collection. For example, if

I'm making a 21 MHz circuit, the best bypass capacitor choice from the table above = 0.01 µF. If possible, sweep the capacitors in your own collection to determine their SRF; or whether they're even suitable.

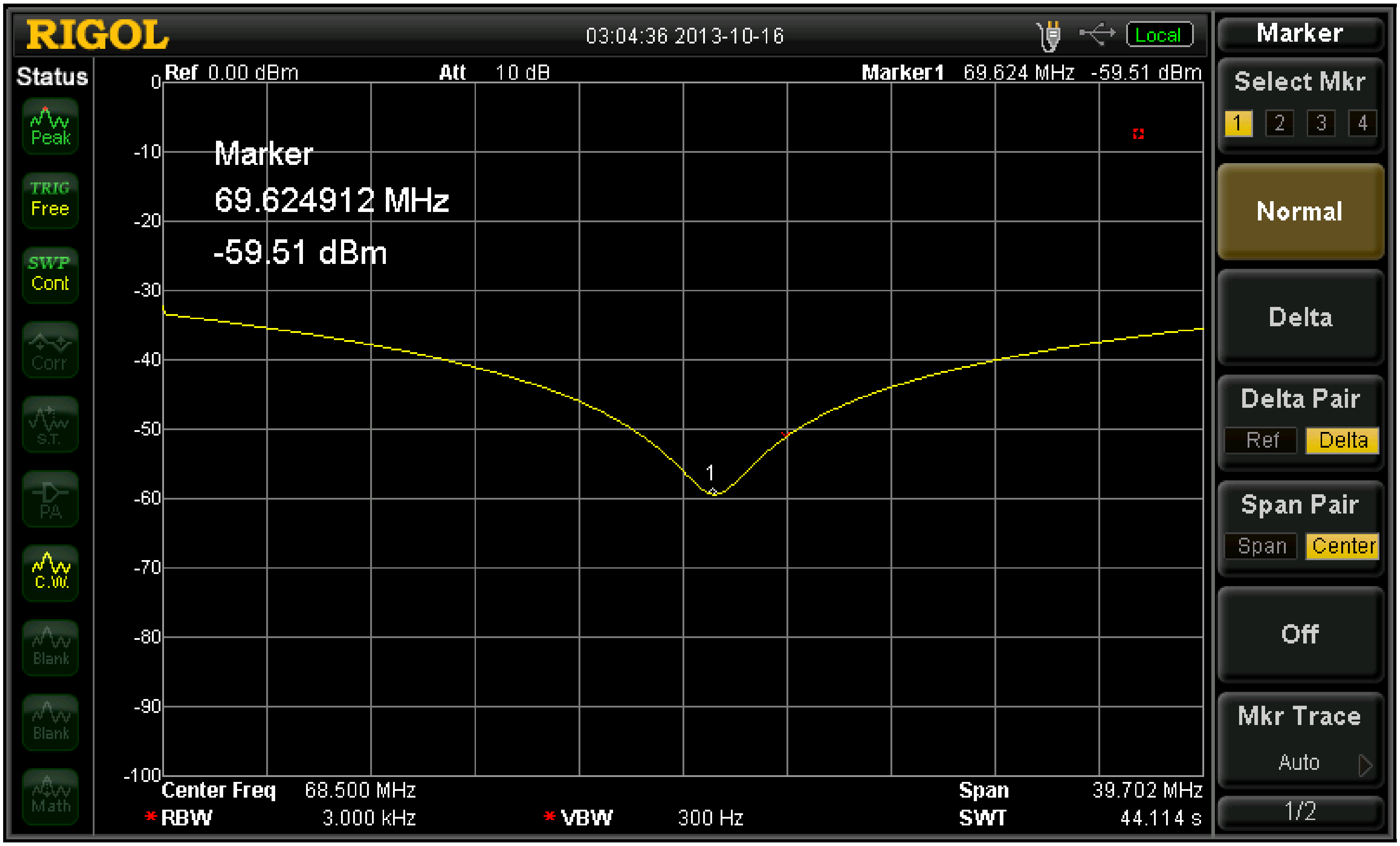

03:04:36 2013-10-16

Ref 0.00 dBm Att 10 dB Marker1 69.624 MHz -59.51 dBm

Marker
69.624912 MHz
-59.51 dBm

Center Freq 68.500 MHz Span 39.702 MHz
RBW 3.000 kHz VBW 300 Hz SWT 44.114 s

RIGOL
Local
Status
Peak
TRIG Free
SWP Cont
Corr
S.T.
PA
C.W.
Blank
Blank
Math
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
1
Marker
Select Mkr
1
2
3
4
Normal
Delta
Delta Pair
Ref
Delta
Span Pair
Span
Center
Off
Mkr Trace
Auto
1/2

Above — The close-in sweep of the 0.001 µF capacitor tabled above.

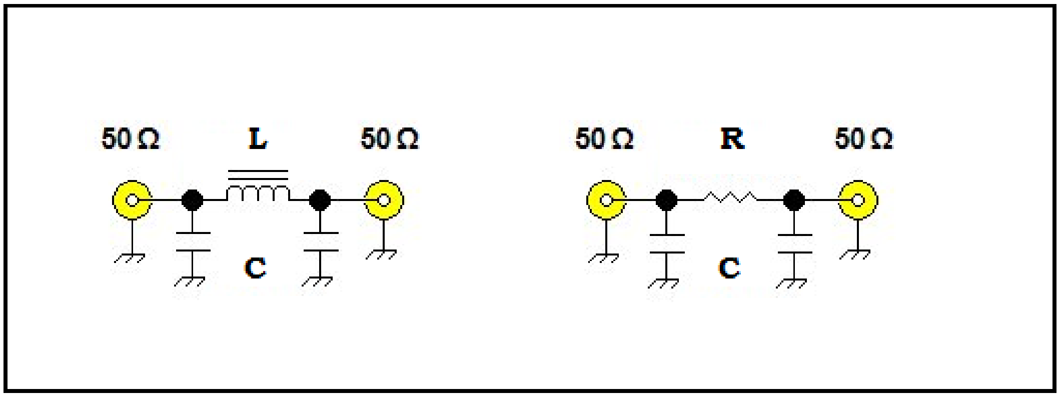

50 Ω
L
50 Ω
C
50 Ω
R
50 Ω
C

Above — As possible, stick 2 of your bypass cap values in a pi filter network with a series decoupling L or R to derive wideband filtration. For example, to filter your DC power lines.

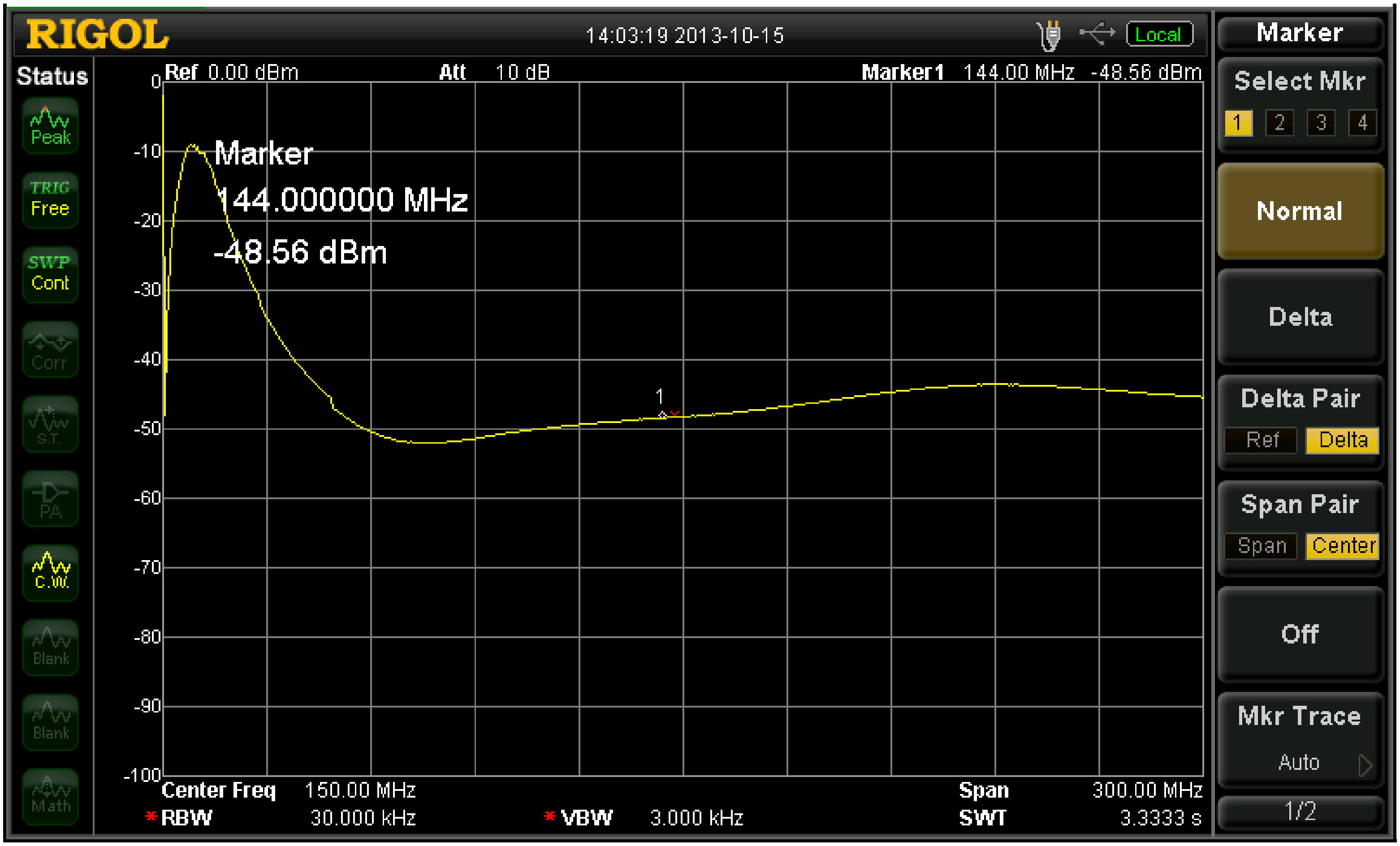
RIGOL
Local
Status
Peak
TRIG
Free
SWP
Cont
Corr
S.T.
PA
C.W.
Blank
Blank
Math
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
1
Marker
Select Mkr
1
2
3
4
Normal
Delta
Delta Pair
Ref
Delta
Span Pair
Span
Center
Off
Mkr Trace
Auto
1/2

14:03:19 2013-10-15

Ref 0.00 dBm **Att** 10 dB **Marker1** 144.00 MHz -48.56 dBm

Marker
144.000000 MHz
-48.56 dBm

Center Freq 150.00 MHz **Span** 300.00 MHz
*** RBW** 30.000 kHz *** VBW** 3.000 kHz **SWT** 3.3333 s

Above — A 300 MHz sweep of a pi filter [220 pF + 1.2 μH + 220 pF] for the DC supply line of a 150 MHz oscillator. The SRF peak lies at 76.69 MHz, but this filter works okay out to about 200 MHz. I placed a marker at 144 MHz and could use this filter for the 2M band as well.

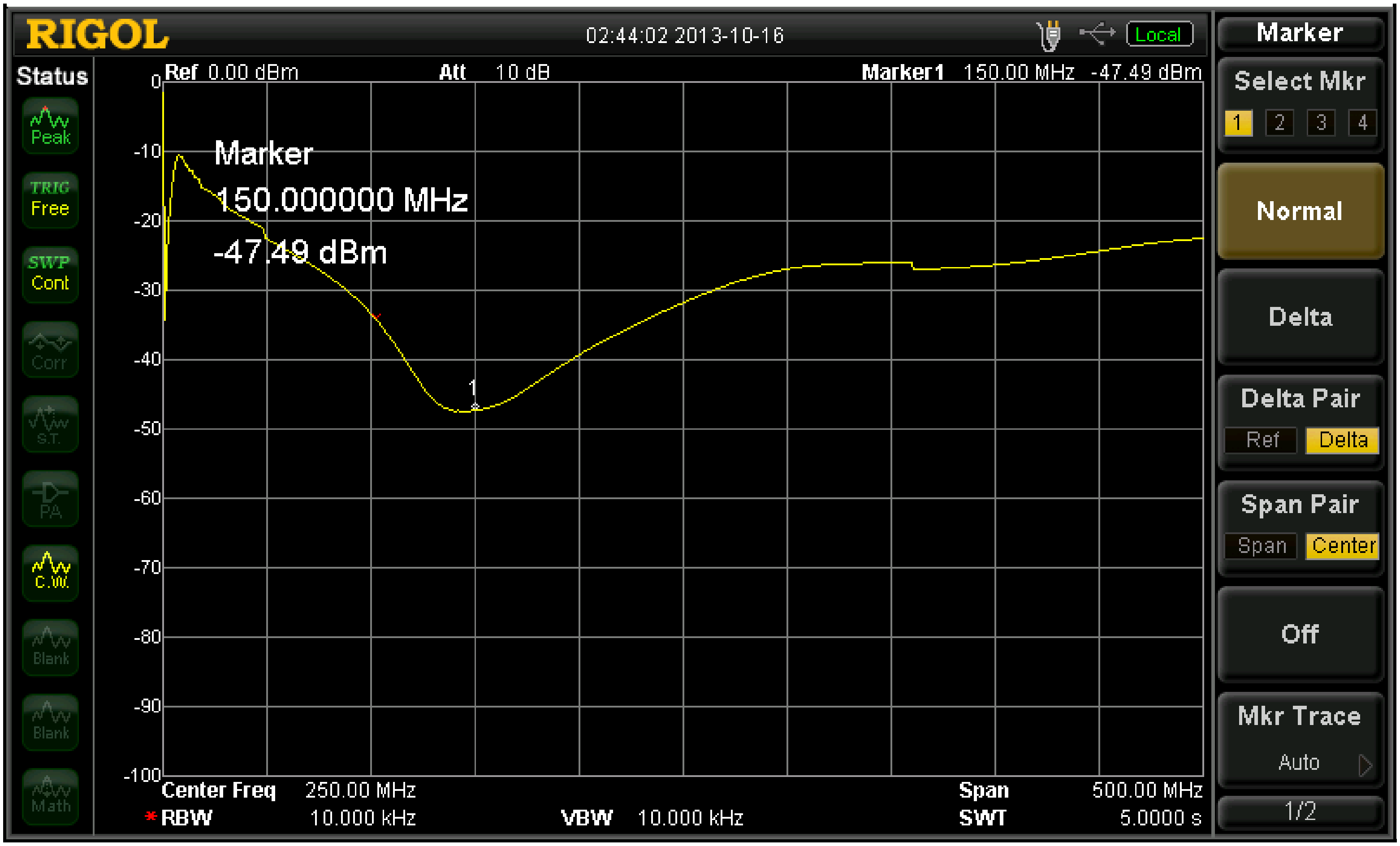
RIGOL
02:44:02 2013-10-16
Local
Status
Peak
TRIG Free
SWP Cont
Corr
S.T.
PA
C.W.
Blank
Blank
Math
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
1
Marker
Select Mkr
1 2 3 4
Normal
Delta
Delta Pair
Ref Delta
Span Pair
Span Center
Off
Mkr Trace
Auto
1/2

Ref 0.00 dBm Att 10 dB Marker1 150.00 MHz -47.49 dBm

Marker
150.000000 MHz
-47.49 dBm

Center Freq 250.00 MHz Span 500.00 MHz
RBW 10.000 kHz VBW 10.000 kHz SWT 5.0000 s

Above — The network described above, except I replaced the 1.2 µH L with a size 0805 10 Ω resistor [220 pF + 10R + 220 pF] and swept to 500 MHz. I set Marker 1 on 150 MHz; the frequency of the oscillator I wanted to DC powerline filter. The resistor gives a bit more filter bandwidth around 150 MHz. A 51 or 100 Ω resistor will further increase the bandwidth while decreasing the attenuation depth somewhat. Although resistors incur a DC voltage drop, they avoid the potential of an unwanted SRF in your filter arising from a renegade inductor— and so, a resistor may pose a better choice for pi filtering DC lines and so forth. It's your call.

At HF and lower VHF, I've found a hole-through capacitor may sometimes filter better than a "garden variety" SMT counterpart. Click for a graphic that shows this. Presumably, the SMT cap exhibited a lower Q than the equivalent hole-though part. At some frequency above 200 MHz, the lead inductance of the hole-through capactor may cause the opposite effect.

Further, on the VHF — Véronique web page, Section 6: I swept 3 capacitors including an ultra-high Q SMT part.

RF — Test and Measurement

RF Workbench Page 5

Welcome to part 5 of a web series exploring basic RF measurement and bench practices. This installment builds on the information from RF Workbench Parts 1 - 4.

In RFWB #5 I share a hodge-podge of thoughts and circuits concerning power measurement on the beginner-level RF workbench. Consult EMRFD for more support. Big thanks to my mentors: Wes, W7ZOI. Bob, K3NHI and John, K5IRK for their support as I advance to the basics.

Power Measurement Empowers You

Before embracing the 50 Ω RF environment, I misjudged the need to quantify small signal power — now I get that we measure lots of low-level signals on the 50 Ω RF workbench. Whether you're driving a mixer RF port with -30 dBm to reduce spurs, or tweaking an amplifer-under-test to exact the best S21, low-level RF power measurement is fundamental to fruitful RF design.

1 way to measure low-level RF power includes building a log linear RF power meter (PM) based on the Analog Devices AD8307. The basic circuit I show posits that most of you measure from MF to HF and don't need a PM that reads flat into UHF and further; a simple, 2 chip circuit might even prompt you to actually build a barebones PM for your QRP workbench.

Search for and download the Analog Devices AD8307 Revision D datasheet — it's definitely worth a read. Kudos to the design team that brought us a truly milestone device for low-cost power measurement.

Analog Devices offers a whole family of log-amps at different frequency ranges — for example, the AD8311 Log Amp/Detector covers from ~100 MHz to 2500 MHz. A sister product, the AD8302 2.7 GHz RF / IF Gain Phase Detector looks amazing.

1. A Barebones RF Power Meter

Lacks the usual input frequency compensation network needed to keep power measurement flat over several hundred MHz — since most input compensate by attenuating HF, this simple version offers stronger sensitivity at HF than usual.

Good from MF up to about 100 MHz.

4.5v B+ to eliminate power supply decoupling issues and to give greater battery life than a 9v battery.

Minimum input power about -70 dBm. Maximum input power +15 dBm. Requires a metal box.

Big thanks to Wes, W7ZOI for letting me present his simple RF power meter. I found *numerous* AD8307-based RF power meter designs in periodicals and on the web and the writers devised simple to elaborate input compensation networks to establish a flat response out to 500 MHz — involving parts such as nH-level inductors, chip resistors and capacitors. This PM goes the opposite direction; a plain circuit for you builders who measure under 100 MHz; particularly at HF.

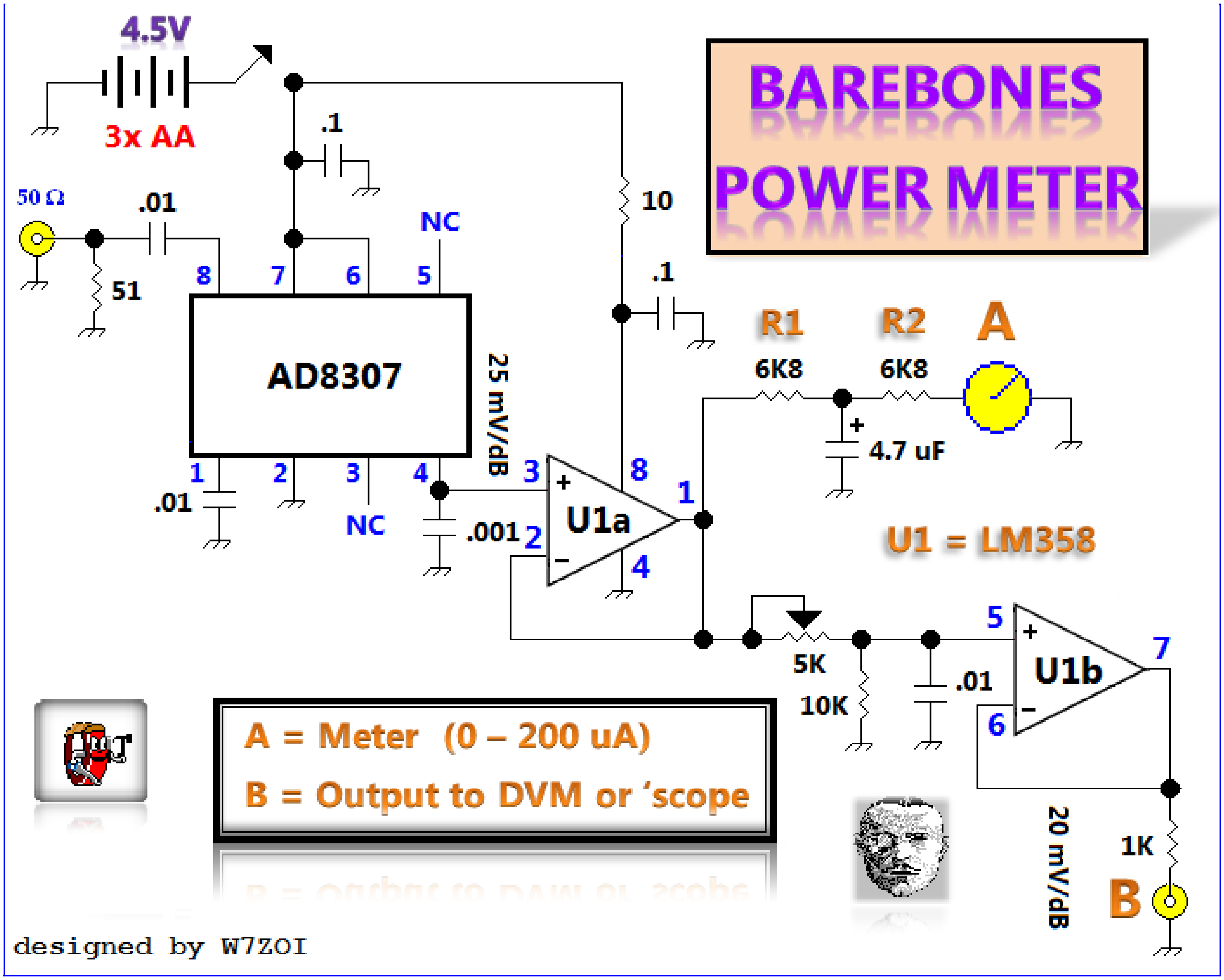
4.5V
3x AA
.1
50 Ω
.01
NC
10
51
8
7
6
5
.1
BARBONES
POWER METER
R1
R2
A
6K8
6K8
AD8307
25 mV/dB
4.7 uF
1
2
3
4
.01
NC
.001
3
+
U1a
2
−
8
1
4
U1 = LM358
5K
10K
.01
5
+
U1b
−
6
7
A = Meter (0 – 200 uA)
B = Output to DVM or 'scope
20 mV/dB
1K
B
designed by W7ZOI

Above — the complete Barebones PM schematic. Presented with the permission of Wes, W7ZOI.

AD8307 Input Pin 8: Some Graphs and Notes:

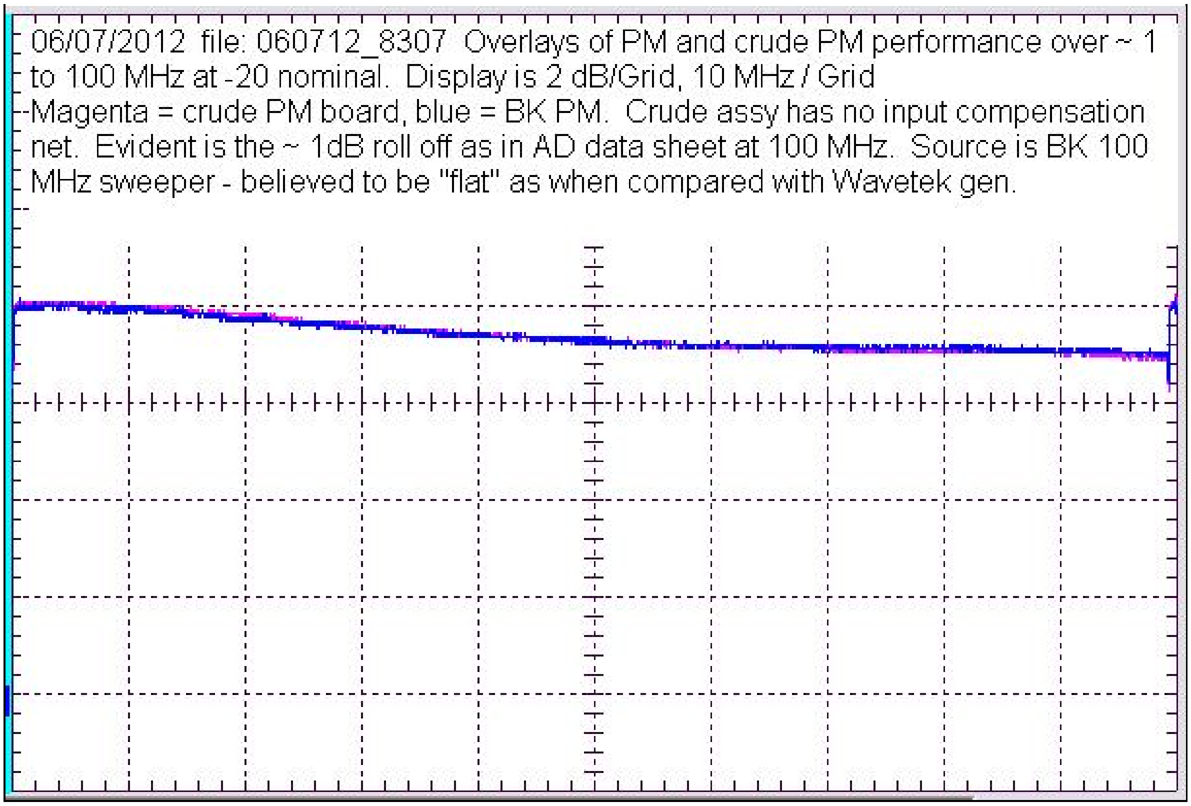

06/07/2012 file: 060712_8307 Overlays of PM and crude PM performance over ~ 1 to 100 MHz at -20 nominal. Display is 2 dB/Grid, 10 MHz / Grid
Magenta = crude PM board, blue = BK PM. Crude assy has no input compensation net. Evident is the ~ 1dB roll off as in AD data sheet at 100 MHz. Source is BK 100 MHz sweeper - believed to be "flat" as when compared with Wavetek gen.

Above — The lack of input compensation might raise a few eyebrows! A sweep of the Barebones PM by Bob, K3NHI shows a reasonably flat response out to 100 MHz that's comparible to some of the 0-100 MHz range of wider sweeps in the published compensated circuits I've read.

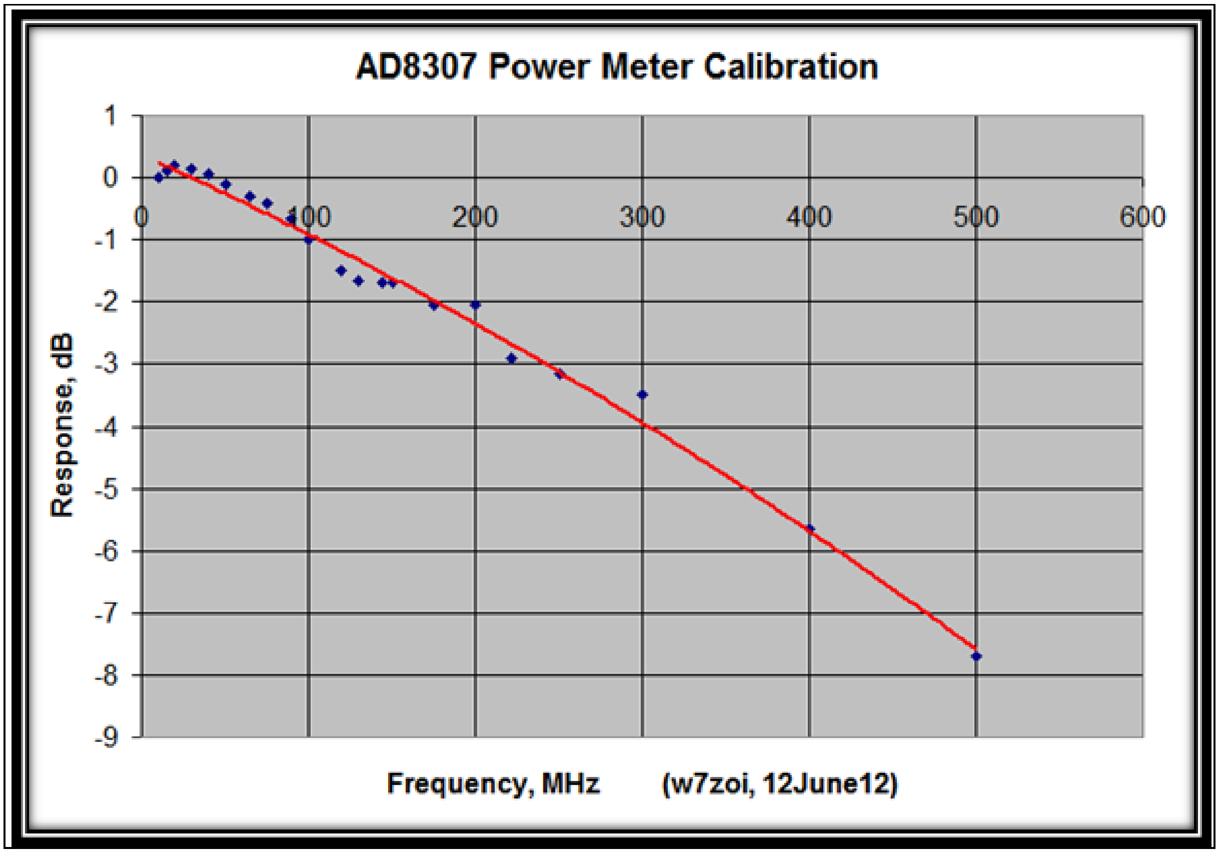

Above — A different Barebones PM plot from Wes, W7ZOI that goes out 500 MHz. For HF work, this power meter proves adequate for QRP HomeBuilders. By all means, add some input compensation if you want to — good circuit examples abound. For example, EMRFD Figure 7.13, or Bob Kopski's — An Advanced VHF Wattmeter referenced in Section 5.

AD8307 specifications allow a typical +/- 0.3 dBm "ripple" in the input to output transfer characteristic. Bob, K3NHI verified this ripple in his lab.

Therefore; depending on the position of a signal in the transfer curve, a move between 2 different power levels may yield as much as 0.6 db peak difference error. Figure 8 of the Rev D datasheet shows this. Figure 24 plus associated text tells why this occurs: the transfer characteristic is a chunk or segmented realization of a log transfer characteristic. It's really good — just not perfect.

If you consider the cost of thermal sensor power meters from Agilent, Techtronix, or even the Mini-Circuits PWR-6GHS, the AD8307 seems a bargain.

Measuring U1a Pin 1 With a Panel Meter

The first output at Pin 1 drives nearly any junkbox DC panel meter you might own The schematic specifies a 0-200 uA movement, however a 1 mA meter movement also works by tweaking R1 and R2 to establish the correct current. In the circuit shown the R = 13.6K. This R establishes the current required to drive the 200 uA meter Wes used in his design — nothing more. A wide variety of panel meters work because the drive current comes from an op-amp. Don't order an expensive panel meter just because you want to employ a 100 or 200 uA model — choose your meter because it affords good needle movement and resolution to allow accurate power measurement.

Although elementary for some, the following diagram shows you how to measure the maximum current for your meter: 100 uA, 200 uA, etc.

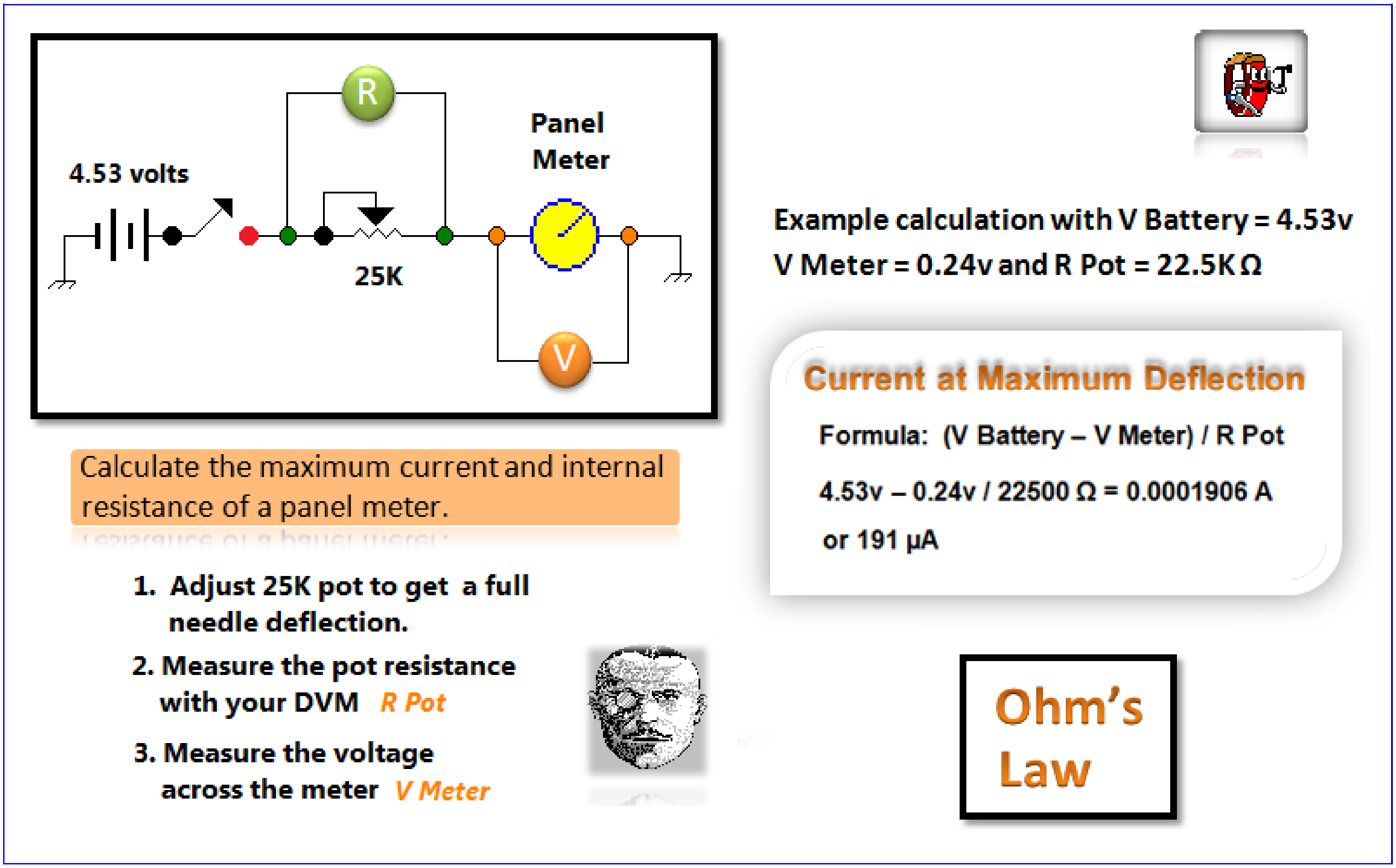

Calculate the maximum current and internal resistance of a panel meter.

1. Adjust 25K pot to get a full needle deflection.
2. Measure the pot resistance with your DVM *R Pot*
3. Measure the voltage across the meter *V Meter*

Example calculation with V Battery = 4.53v V Meter = 0.24v and R Pot = 22.5K Ω

Current at Maximum Deflection

Formula: (V Battery – V Meter) / R Pot

4.53v – 0.24v / 22500 Ω = 0.0001906 A

or 191 µA

Above — In my shoebox sat 4 different panel meters. I measured 1 meter and show the math above — a 191 µA meter.

DIRECT CURRENT
0
.2
.4
.6
.8
1
Simpson

Above — An antique 1 mA panel meter driven with 1 mA to achieve full deflection.

Meter resolution presents the biggest problem for junkbox panel meters and if you look around the web, you'll see some great examples how builders calibrated and/or marked the scale on their AD8307 circuit panel meters.

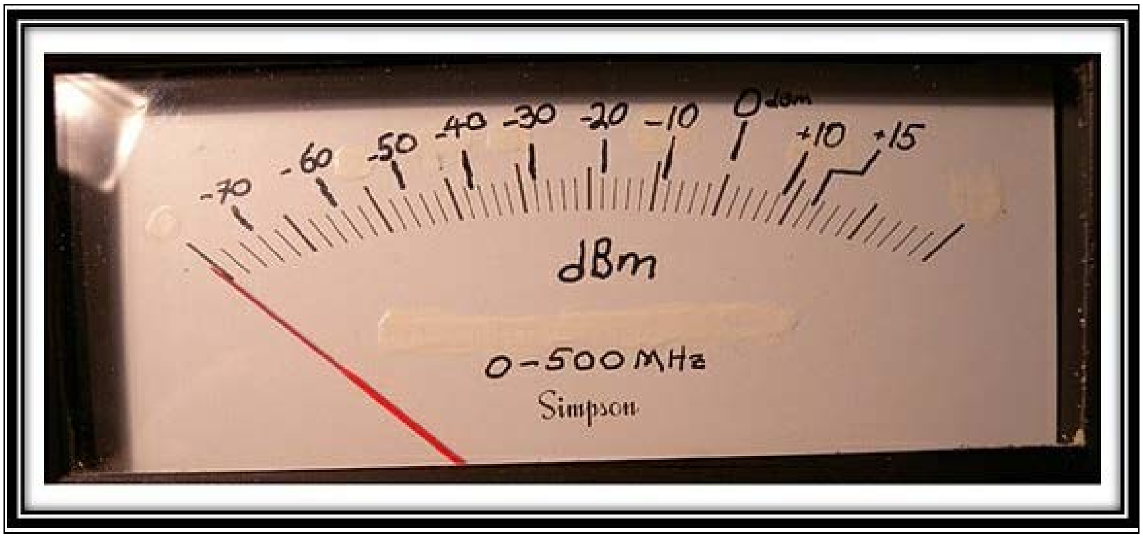

Above — Panel meter markings on my friend Peter's power meter.

I personally like my panel meters to read about 75% of full deflection at 7 dBm, but it's really your choice. Adjust R1 and/or R2 up or down to give the desired amount of meter deflection for whatever panel meter you own.

You may apply Ohm's law to figure out the maximum in-situ current for any panel meter. In the schematic the total R is 13.6K, so when you apply +10 dBm applied to the power meter input, the current in the panel meter will be 2.0v /13.6K = 147 uA. The maximum 200 uA will occur with a Pin 1 voltage of 2.72v. The op-amp won't go all the way to the positive rail, but If it did go all the way to 4.5v, you would hurl 331 uA into the panel meter. This exceeds the meter's uppermost scale, but likely won't destroy it.

The 4.7 uF cap can be any small uF capacitor value and low-pass filters the DC to smooth out the meter movement. I used a 10 uF in my breadboard.

I normally view the panel meter to tune resonant circuits and observe trends; but not to precisely measure power — it's often more accurate to quantify power readings at Port B since this eliminates panel meter resolution issues.

How to Measure Power at Port B

We measure the DC voltage at port B and use equations or graphs to translate this voltage into an actual power reading after reference calibration. U1a and U1b are unity-gain voltage followers to buffer the AD8307 output. U1B features a 5K potentiometer in series with a 10K shunt resistor to form a voltage divider that changes the 25 mV/dB AD8307 output to 20 dB/mV. Tweak the 5K pot to calibrate to get as close to 20 dB/mV as possible, although since the LM358 buffers just pass on the DC voltage changes of the AD8307, the pot does not technically alter log linearity.

Wes published some essential notes on his web site. On page 8, you find his formula to convert a measured DC voltage into dBm. I wrote a program that incorporates his formula: Applet L on my Design Center web page; except that it takes calibration power at -10 dBm and -20 dBm.

Let's run through 1 example:

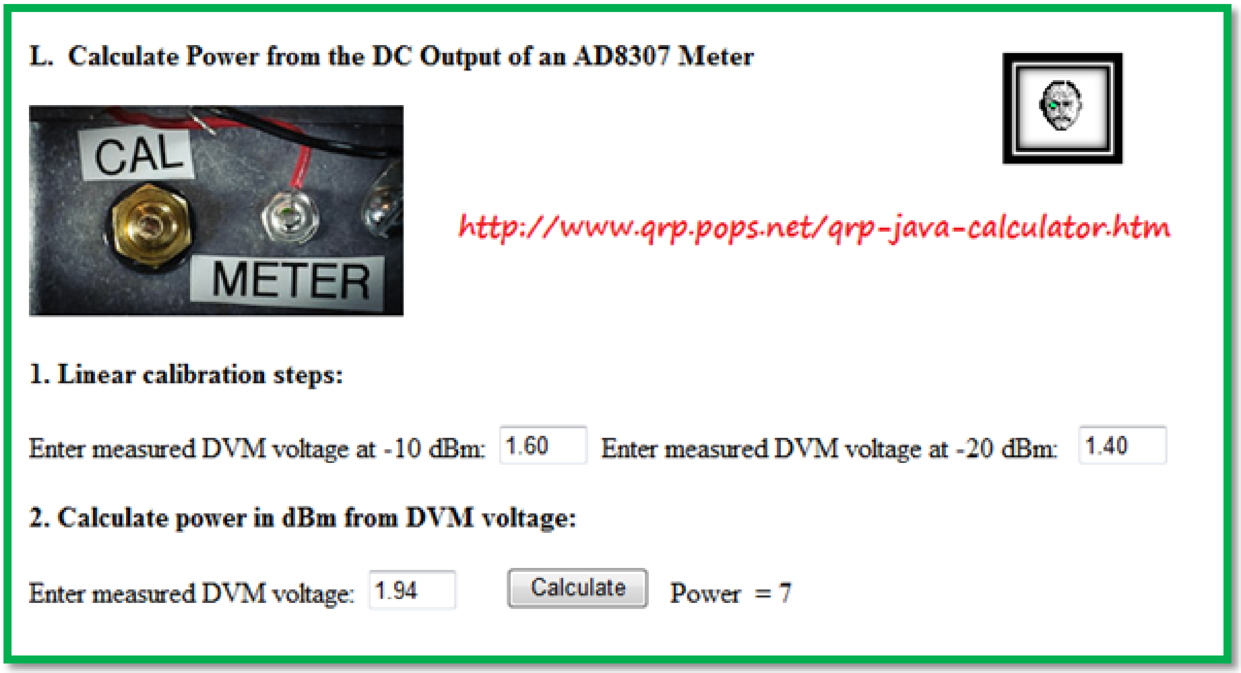

L. Calculate Power from the DC Output of an AD8307 Meter

http://www.qrp.pops.net/qrp-java-calculator.htm

1. Linear calibration steps:

Enter measured DVM voltage at -10 dBm: 1.60 Enter measured DVM voltage at -20 dBm: 1.40

2. Calculate power in dBm from DVM voltage:

Enter measured DVM voltage: 1.94

Power = 7

Above — A screen capture of JavaScript Applet L. I calibrated my instrument by connecting a 10.0 MHz sine wave calibrator to the 50 Ω input port of my PM. At -10 dBm input power, my Port B reading was 1.6 VDC; at -20 dBm, I measured 1.4v at Port B. These 2 points establish the log linearity per Wes' notes. After this calibration, I measured the output power of a 4 MHz sine wave VFO that I designed to run at 7 dBm output power to drive the LO port of a diode ring mixer. Port B read 1.94 volts and when I entered this into Applet L and pushed <<Calculate>>, the VFO output power was indeed 7 dBm. More on this later...

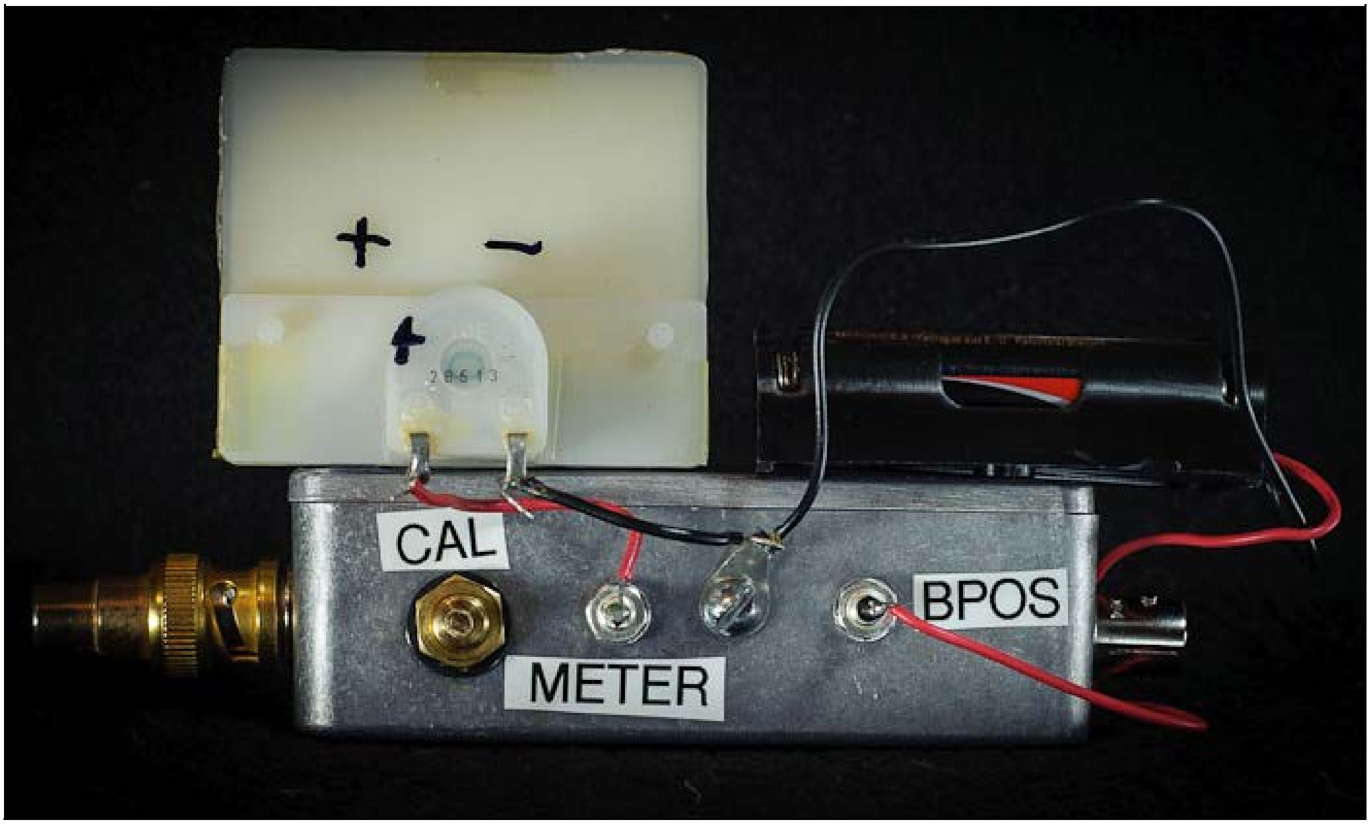

Above — My prototype RF-tight breadboard of the Barebones PM. I ran my 'trademark' die case box, BNC RF input and Port B connectors, a common ground lug and feedthrough capacitors for the B+ and panel meter connections. I placed a BNC to RCA adaptor on Port B to allow the insertion of a standard-type positive DVM probe. A black alligator clip terminates the distal end of the negative probe on all my DVMs. I just clip it onto the ground lug.

Above — A view of my breadboard showing my 100 uA panel meter and the 4.5v battery pack. I raised R2 in the original schematic up to 8K2 to set my preferred needle movement in this 100 uA panel meter. A meter with linear markings might be better?

Some Further AD8307 Notes

After power up, you'll notice a DC output voltage around 0.22v or so with no input signal; this arises from wideband noise caused by resistors and amplifiers in the AD8307— all normal.

If possible, verify a 25 mV per dB power change with a manual sweep using a sine wave signal generator on the input and a DVM to AD8307 Pin 4. If you don't have the test gear to perform this function check, no problem.

The AD8307 input resistance = 1100 Ω , so we must place a resistor in parallel with the input to establish 50 Ω. Many builders just shunt a short-leaded 51 Ω resistor from input to ground like Wes did, however, you might also see builders place a 1% tolerance 53.2 Ω R in that slot to derive an input Z of 49.9 Ω. I did this in another "blinged-out", frequency compensated AD8307 meter I built for future UHF circuit experiments.

With 20 and/or 40 dB taps, attenuator pads and some 50 Ω cables, a Barebones AD8307 PM can measure everything HF you might build or buy for your *QRP* workbench. I posit that a simple AD8307 power meter may form the heart of a basic, first QRP workbench. Lacking a oscilloscope when I started in radio electronics, I measured RF with a germanium diode RF probe and a DVM — I would have enjoyed a simple log power meter plus a basic calibrator, however, the AD8307 did not exist back then.

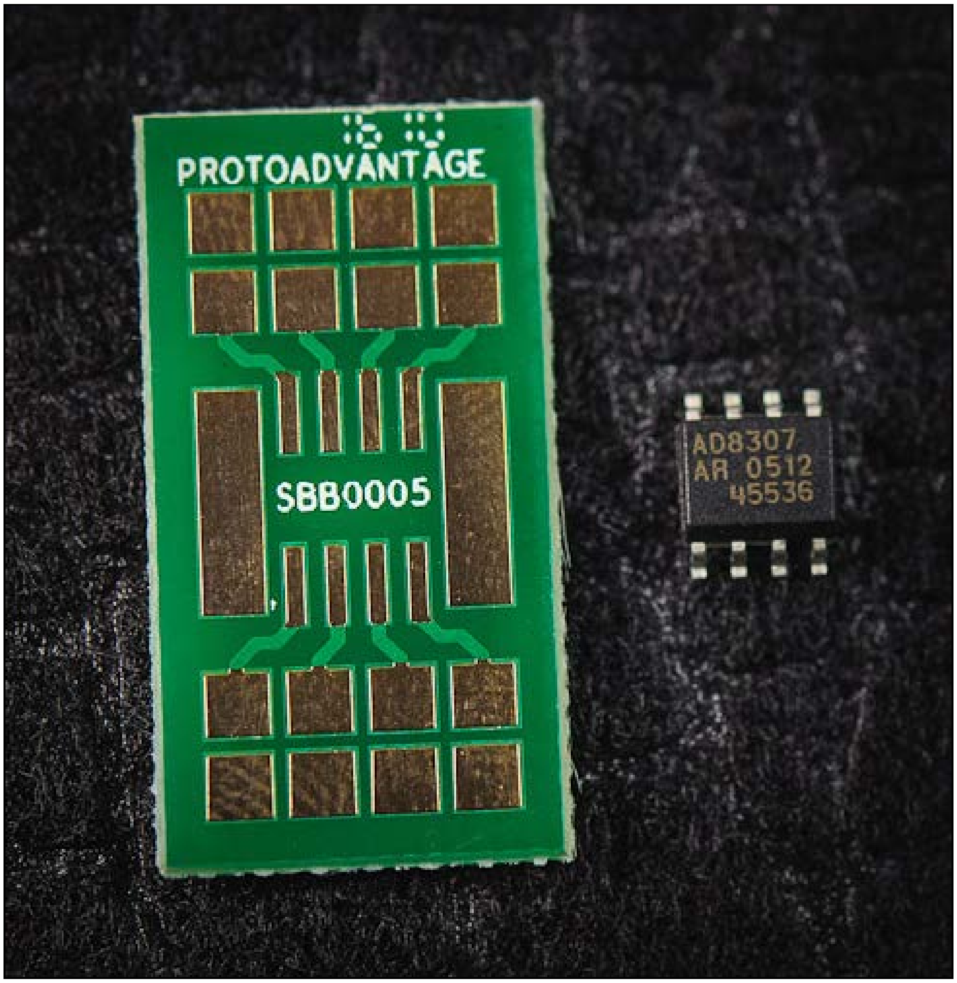

Above — Some builders lament because an AD8307 (in DIP) costs around $10.00. I bid for and bought the AR version chip shown above for $4.42 USD. The above green Proto Advantage breakout board cost $1.00. To compare; some people spend $5.00 for a boutique coffee in Canada — it's all good.

The SMD packaged AD8307AR may offer better performance above 100 MHz with its lower lead inductance.

QRP — PosData for Dec 3, 2013

Realize your bench acumen — adapt and build some test equipment to suit *your* needs. Steve, VK2SJA crafted a version of the AD8307 PM. Click for his beautiful box featuring a 1mA meter movement. Aided by the Tonne software "Meter" program and the AD8307 datasheet, his ranks among the best I've seen. Kudos Steve.

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2. Power Meter Calibrators

1. CMOS Clock Oscillator RF Calibrator @ -10 dBm

Bob, K3NHI designed a 10.0 MHz reference oscillator for -10 dBm that might help equip the beginner bench. This CMOS signal source does not need an AC power reference to calibrate it — just a DVM to make a DC measurement and your good to go!

In addition to calibrating an AD8307-based PM, you might use this -10 dBm reference to calibrate other gear including homebrew sine wave signal generators; that's what I'll do later.

MX045
10M0000
CTS 3C
1030 12A
MX045
10M0000
CTS 3C
1030 12A

Above — The recommended CMOS clock oscillator for the CMOS RF calibrator. Digi-Key part # CTX772-ND. Data sheet.
If you substitute another CMOS clock, it must swing nearly rail-to-rail for accuracy. Bob intended this calibrator for those who lack the bench instruments needed to precisely calibrate RF devices since only a DVM is needed for calibration. This generator also offers a range of calibrated harmonics as Bob described in his January-February QEX article A Simple RF Power Calibrator — great when you want to examine a spectrum analyzer over a limited span.

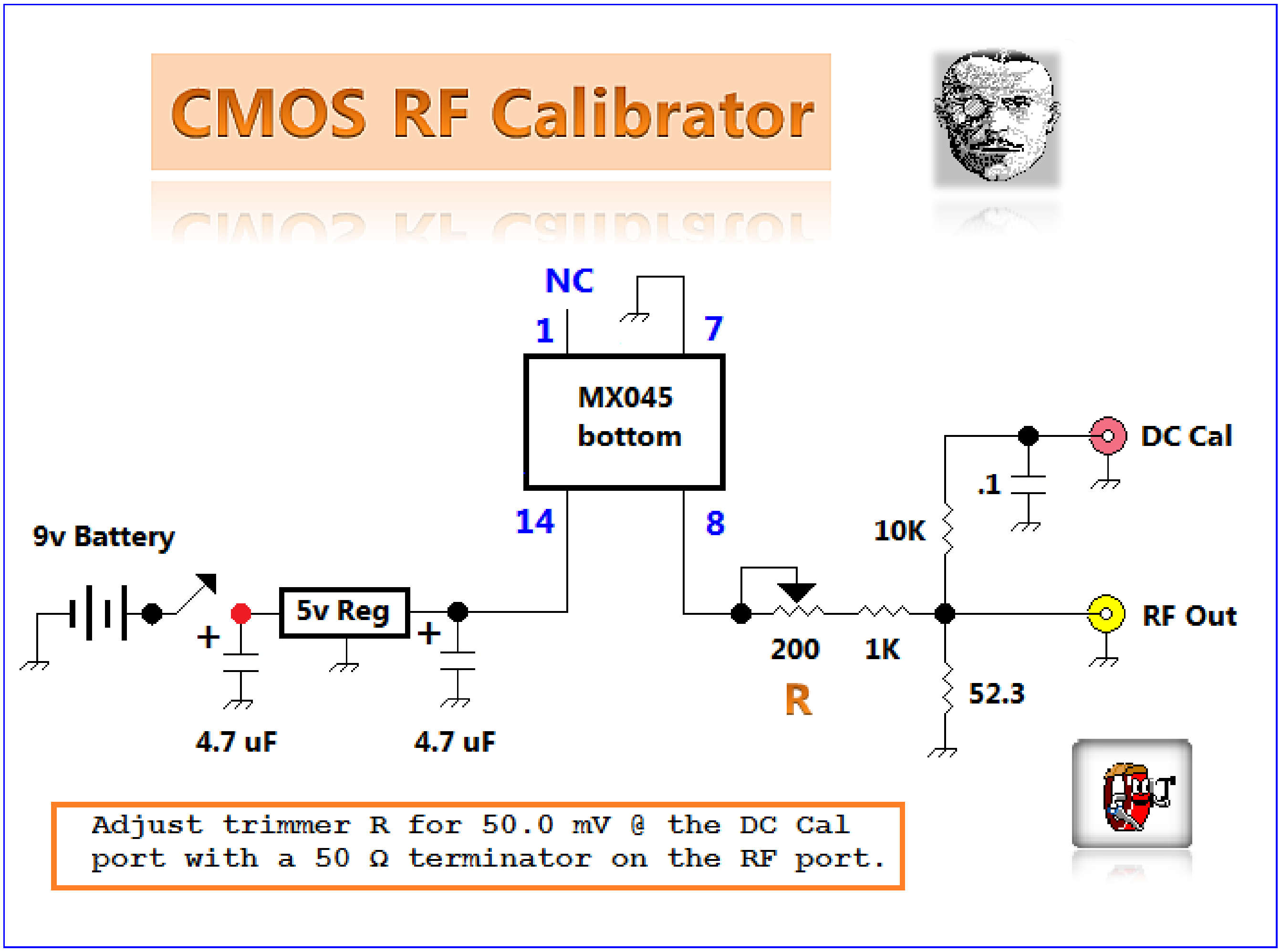
CMOS RF Calibrator
NC
1
7
MX045
bottom
14
8
9v Battery
5v Reg
4.7 uF
4.7 uF
200
R
1K
10K
.1
52.3
DC Cal
RF Out

Adjust trimmer R for 50.0 mV @ the DC Cal port with a 50 Ω terminator on the RF port.

Above — My version of the K3NHI CMOS signal source (presented with the permission of Bob, K3NHI). The 52.3 Ω resistor is a standard 1% part and I bought 5 for all my AD8307 projects and this little signal generator. In my first version, the trimmer resistor was 500 Ω and worked okay, but the 200 Ω trimmer improved calibration. I ordered 10 Bourns 200 Ω and 10 Bourns 500 Ω trimmers on eBay for a few dollars and after studying Bob's published work and applying his influences to my own, I now love to precisely calibrate or bias circuits with a 200 or 500 Ω trimmer R as appropriate.

QRP — PosData for November 22, 2012

If required, you may substitute a 49.9 to 51 Ω resistor for the 52.3 Ω specified.

Per Bob's QEX 2010 Tech Notes and his emails specifically about calibrating the AD8307 with a CMOS *square wave*: Modern AD8307 chips are better calibrated with a -10 dBM square wave. To test log linearity after CMOS signal generator calibration, apply a sine wave signal generator to your power meter and adjust its output to get the same power meter DC output voltage as with the CMOS generator. Then insert attenuator pads on the now calibrated sine wave generator to assess the mV/dB change with different power levels.

Bob's original CMOS calibrator outputted - 20 dBm, however, he updated it to output -10 dBm in 2010 as reported in his QEX 2010 Tech Notes.

Some readers have asked why calibrate the AD8307 at 10 MHz? Calibrate at whatever frequency you want, or more than one. However, at 10 MHz, the AD8307 exhibits its best log performance compared to other frequencies. Click or click for datasheet graphs.

EQUUS
#4320
.050
www.iequus.com
AUTOPOWER OFF
10 MegOhm Input Impedance
DCV
OFF
ACV
BAT.
OHM
DCA
mA
©IEC 2002

Above — The DVM calibration port reading (2 volt scale) from my CMOS clock calibrator after calibration. That was easy!

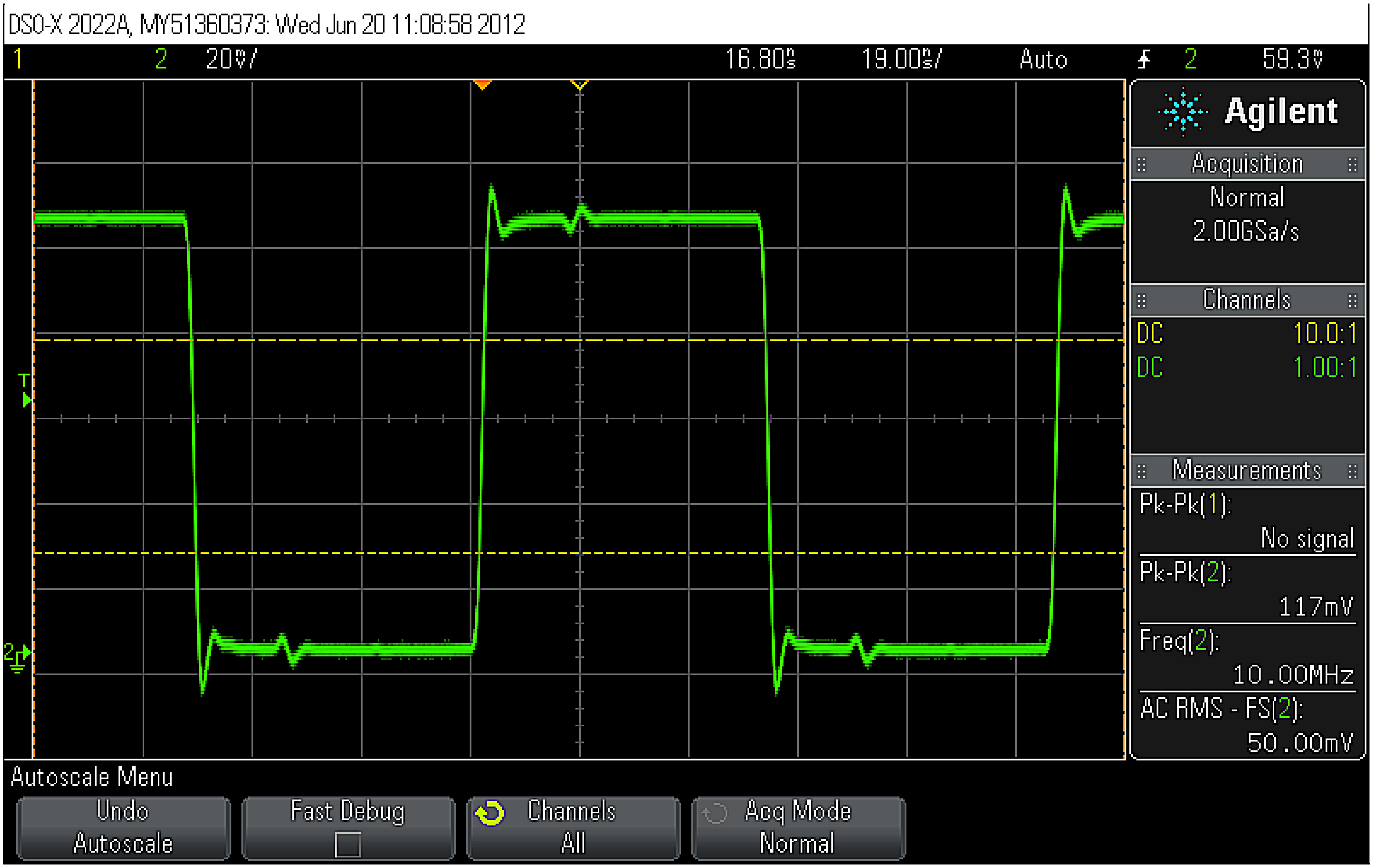

DSO-X 2022A, MY51360373: Wed Jun 20 11:08:58 2012

1 2 20mV/ 16.80ns 19.00ns/ Auto 2 59.3mV

Acquisition
Normal
2.00GSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Pk-Pk(1): No signal
Pk-Pk(2): 117mV
Freq(2): 10.00MHz
AC RMS - FS(2): 50.00mV

Agilent
T
2
Autoscale Menu
Undo Autoscale
Fast Debug ☐
Channels All
Acq Mode Normal

Above — The calibrated CMOS clock RF calibrator in my 50 Ω terminated scope.

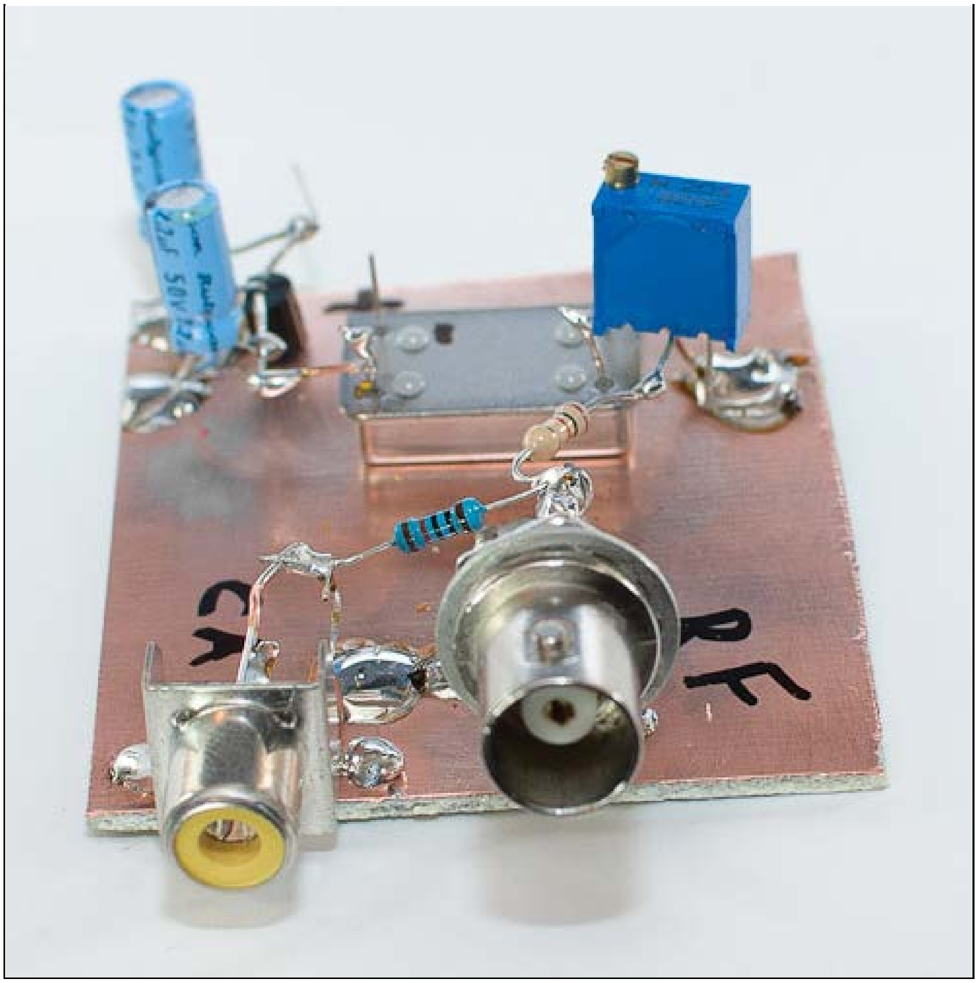

Above — The breadboard of my version of the K3HNI CMOS -10 dBm RF calibrator. For best results, stick it in a shielded box. When correctly calibrated, it outputs -10 dBm on an AD8307 PM, -14 dBm on a spectrum analyzer and -13 dBm on a conventional, thermal-sensor power meter.

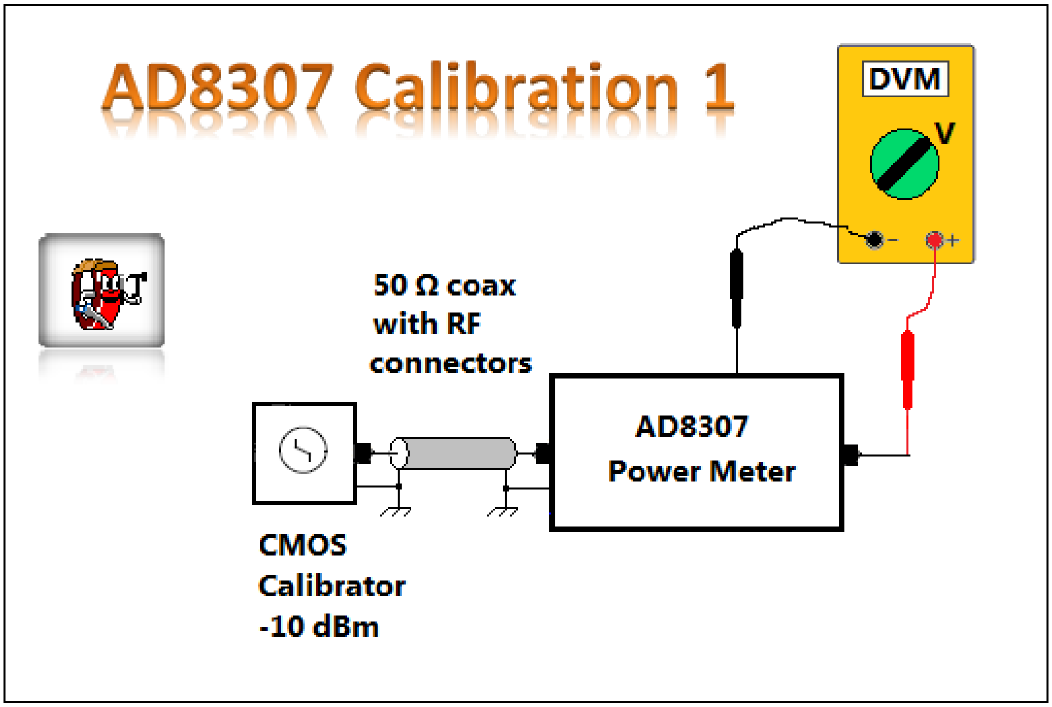
AD8307 Calibration 1
DVM
V
-
+
50 Ω coax
with RF
connectors
AD8307
Power Meter
CMOS
Calibrator
-10 dBm

Above — The procedure for calibrating an AD8307 PM with the -10 dBm square wave CMOS signal source.

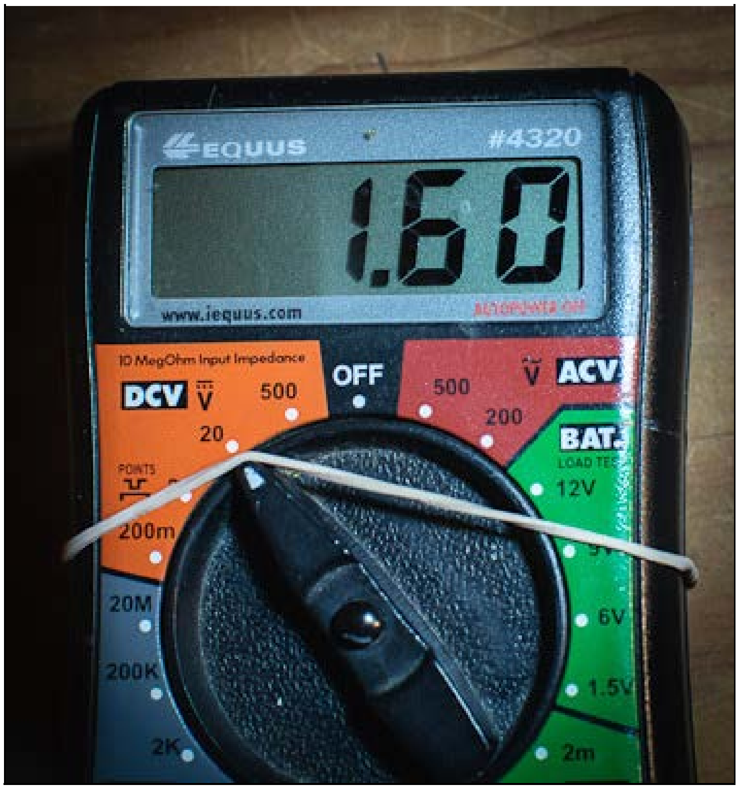

Above — When I connected the calibrated CMOS clock RF calibrator to my build of the Barebones PM, I measured 1.60v with my DVM; ***the -10 dBm reference voltage.*** Since the log-linear power changes 20 mV/dB; for my calibration reference voltage: 1.40v = -20 dBm, 1.20v = -30 dBm, 2.0v = 10 dBm etc.

Remember that the Barebones PM runs on a battery pack and over time the B+ will change. *Each tim*e I measure power with the meter I first calibrate it to establish the -10 dBm reference voltage.

Here's a simple formula that only works for 20 mV/dB @ my particular 1.60v calibration voltage, but gives you the general idea:

Power in dBm = 50 x (V - 1.8)

So if I measure 1.94v: 50 x (1.94 - 1.8) = 7 dBm.

2. Sine Wave Oscillator for Calibration @ -10 dBm and -20 dBm.

You may also calibrate your AD8307 PM with a calibrated sine wave signal generator. Advanced builders who own the gear needed to measure RF power tend to use a sine wave for calibration.

It's easy to calibrate the AD8307 with a sine wave signal source. Normally we calibrate our sine wave signal generators with instruments such as a 50 Ω terminated 'scope, a spectrum analyzer, a calibrated power meter, or a 49.9 to 51 Ω terminating resistor plus a 10X probe etc., but if you lack these instruments, your stuck.

No problem. You may calibrate any appropriate sine wave oscillator at -10 dBm with your Barebones PM and the CMOS RF Calibrator shown earlier. Let's examine the procedure:

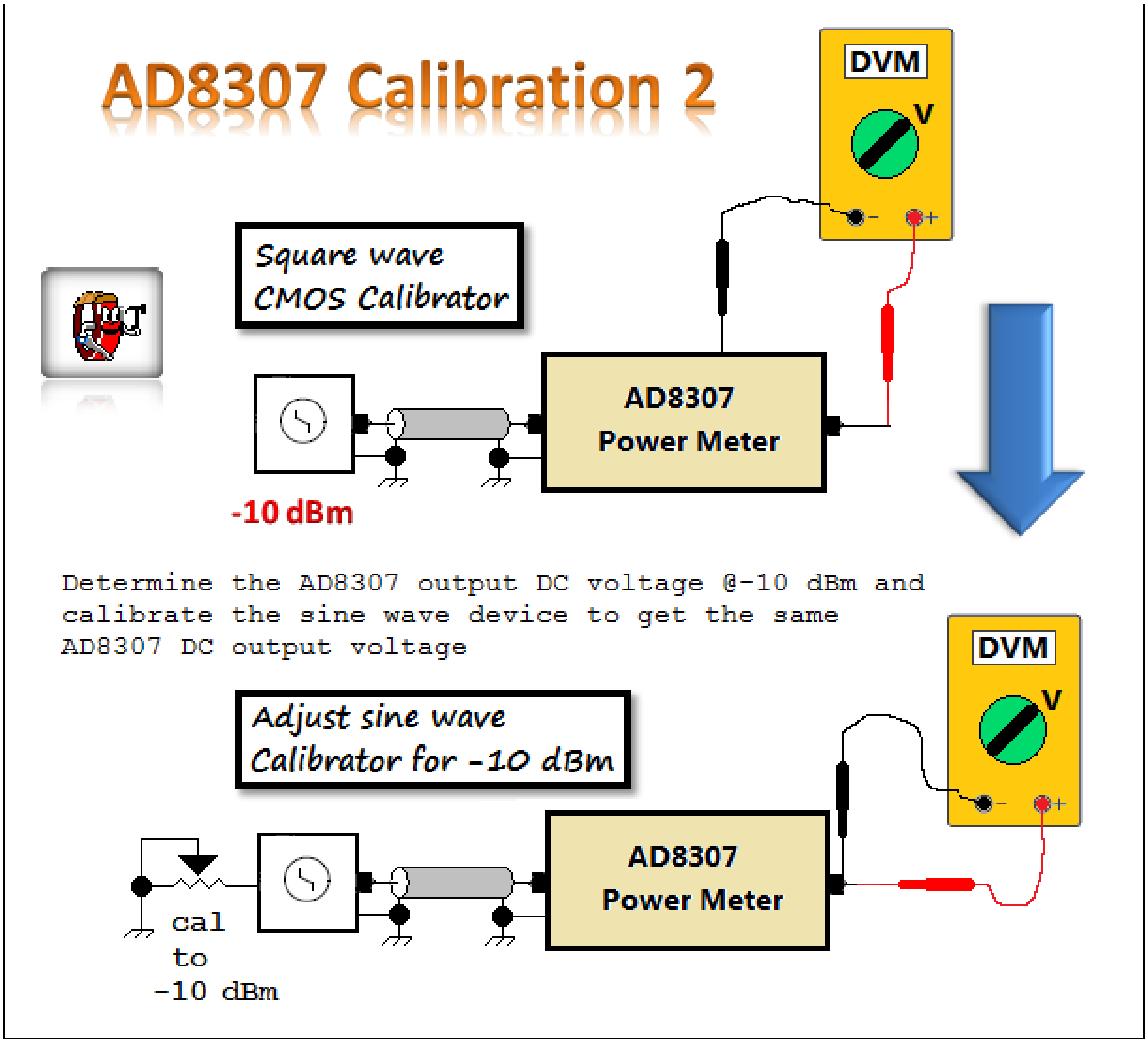

AD8307 Calibration 2

DVM
V
Square wave
CMOS Calibrator
AD8307
Power Meter
-10 dBm

Determine the AD8307 output DC voltage @-10 dBm and calibrate the sine wave device to get the same AD8307 DC output voltage

DVM
V
Adjust sine wave
Calibrator for -10 dBm
AD8307
Power Meter
cal
to
-10 dBm

Calibrate the AD8307 PM with the CMOS square wave reference and record the DC voltage at the output of Port B. Connect up your sine wave generator and adjust its output until you get the same Port B DC voltage as the reference CMOS RF signal generator — your sine wave oscillator should now be calibrated to -10 dBm.

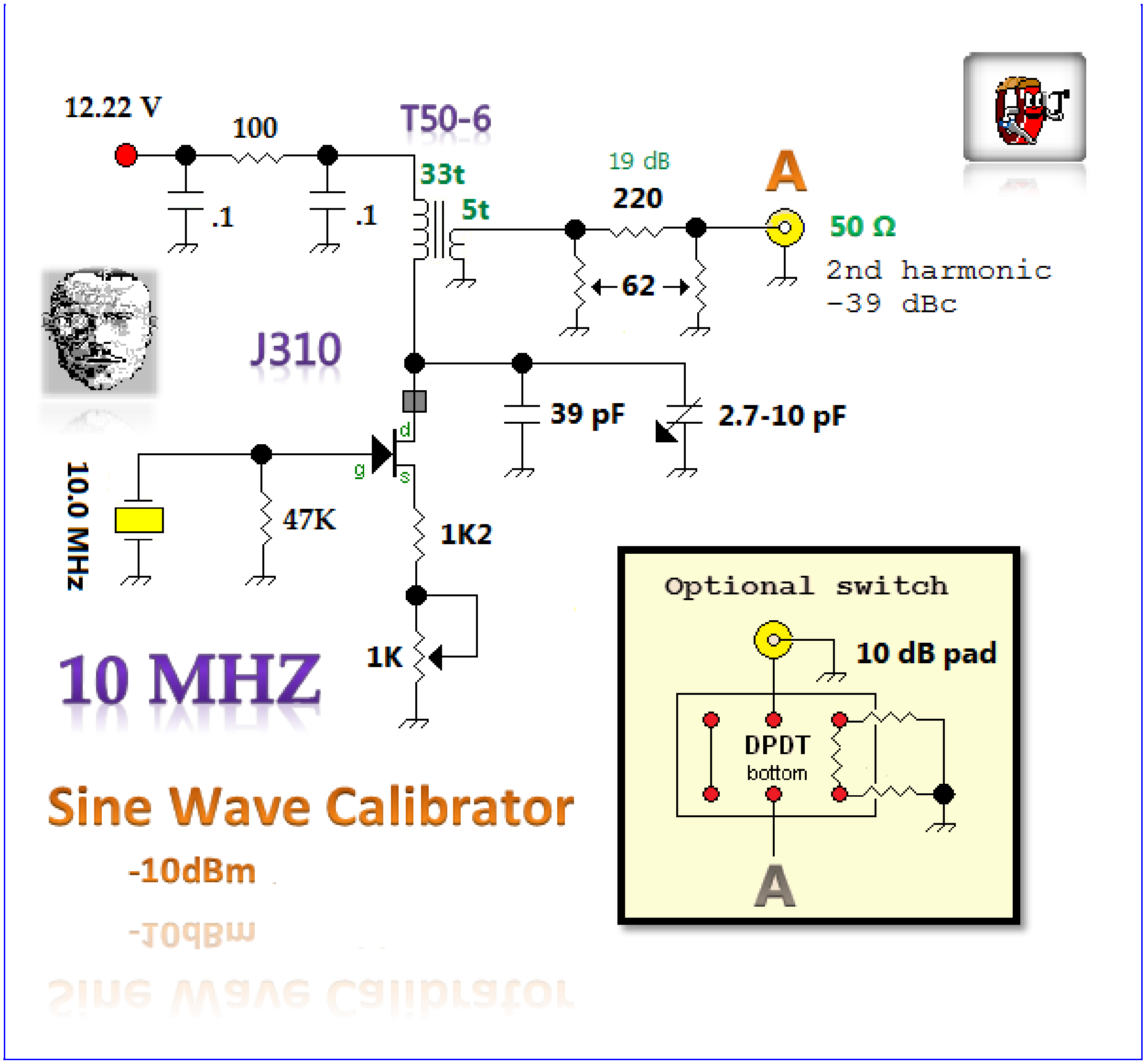
12.22 V
100
T50-6
33t
5t
.1
.1
19 dB
220
A
50 Ω
2nd harmonic
-39 dBc
←62→
J310
d
g
s
39 pF
2.7-10 pF
10.0 MHz
47K
1K2
1K
10 MHZ
Sine Wave Calibrator
-10dBm
Optional switch
10 dB pad
DPDT
bottom
A

Above — I designed this simple 10.0 MHz sine wave calibrator to evaluate Bob's CMOS square wave RF calibrator and serve as an example sine wave reference oscillator. When running a regulated VCC of at least 12v and the *tank is perfectly* tuned, low distortion arises. I measured the second harmonic @ 39 dBc down. The L with 33 turns = 4.43 uH.

The initial tuning procedure goes like this:

1. Terminate the output with a 50 Ω resistor terminator, or a 50 Ω terminated 'scope, or your AD8307 PM.
2. Connect an ammeter between the VCC node and the regulated power supply.
3. Adjust the emitter trimmer R so that the circuit draws around 2.7 mA — then disconnect the ammeter leads.
4. Adjust the trimmer cap for the highest pk-pk voltage (and/or or best looking waveform) in the 'scope, or highest power in the AD8307 PM. *Nominal total C to resonate my particular circuit was ~ 45 pF.*

If not already done, connect the tuned-up sine wave signal source to a AD8307 PM. Adjust the trimmer potentiometer so the Port B DC voltage = the reference voltage measured during your CMOS RF generator power meter calibration. Your sine wave signal source is now calibrated to -10 dBm.

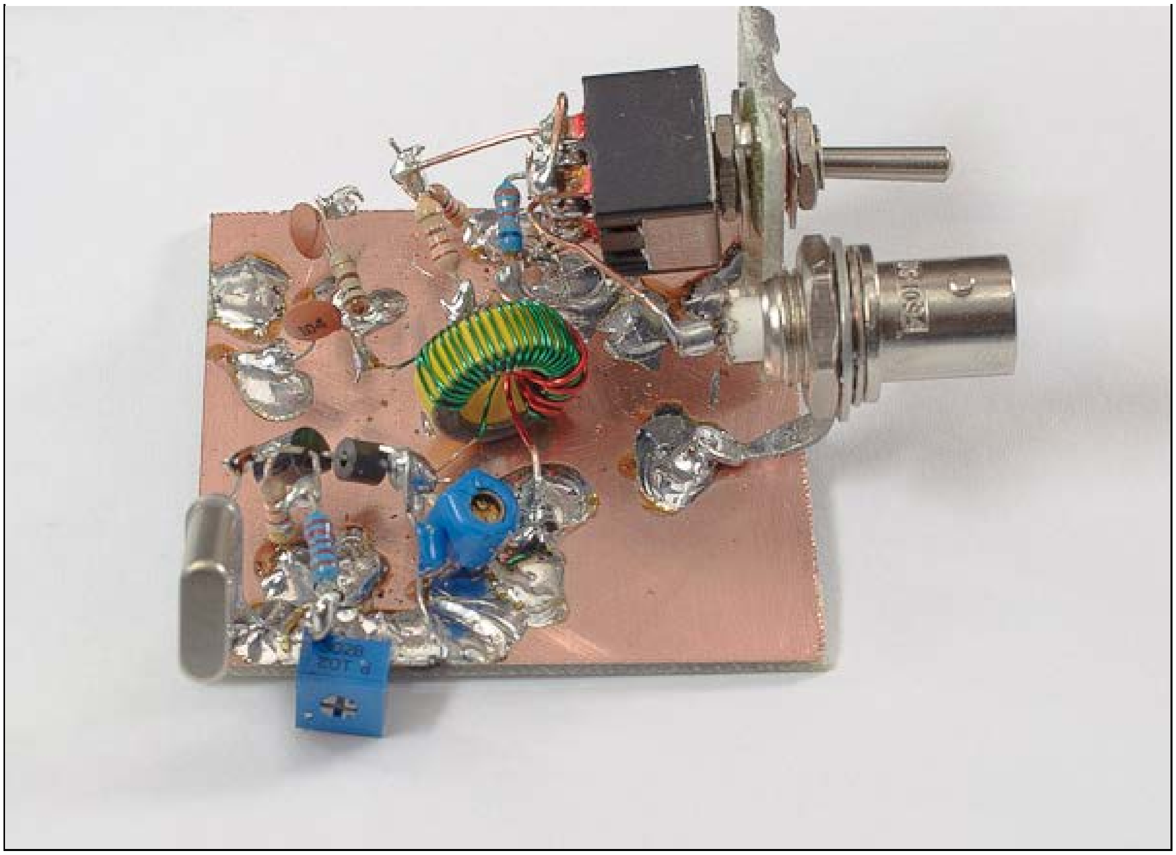

Above — The breadboard of my 10 MHz sine wave signal source. I included the optional switched 10 dB attenuator shown on the schematic inset. In the end I decided to just stick a removable **10 dB** pad like this 6 dB pad in-line for my -20 dBm measurement.

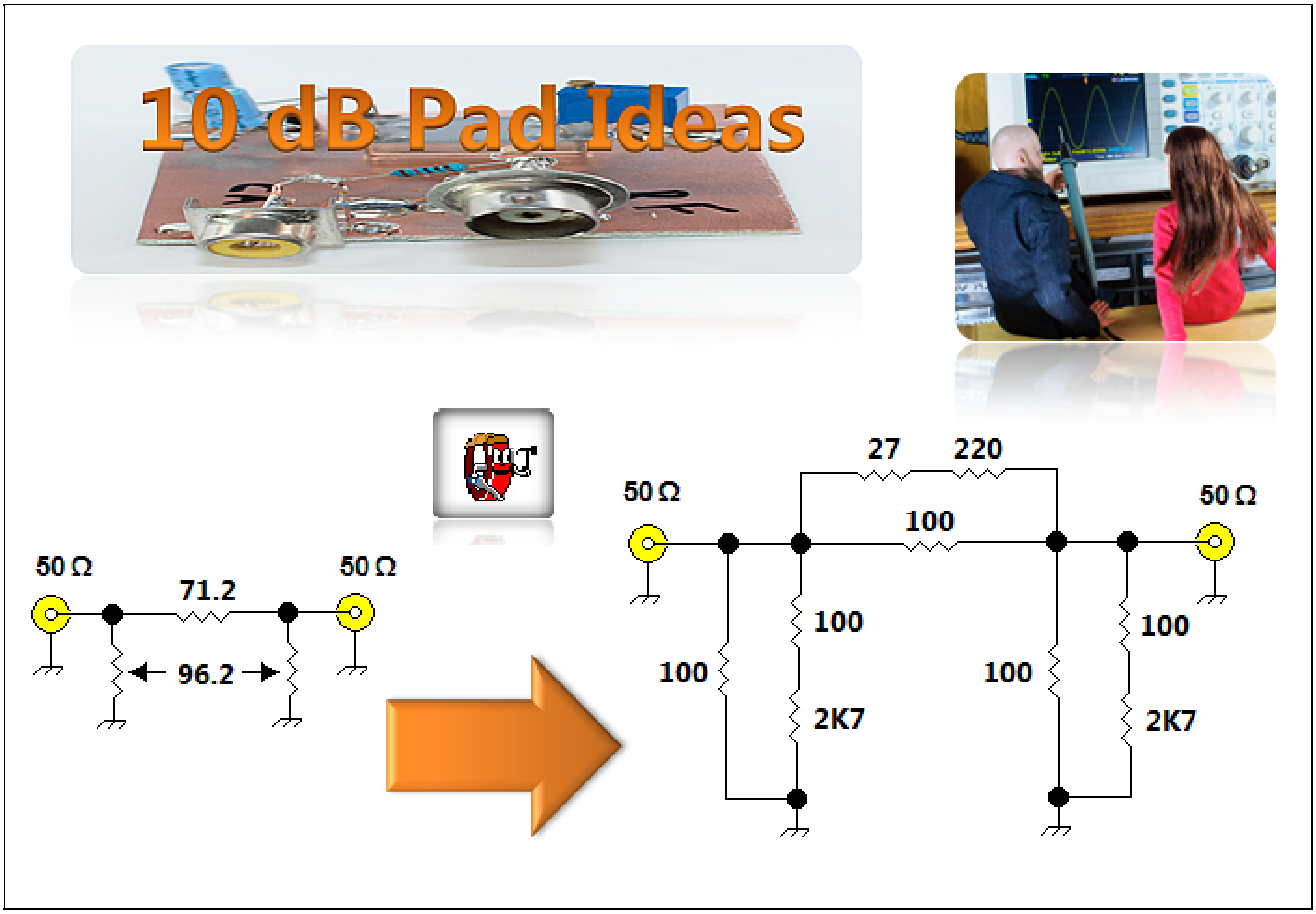
10 dB Pad Ideas
50 Ω
71.2
50 Ω
96.2
50 Ω
27
220
100
50 Ω
100
100
2K7
100
100
2K7

Above — Craft accurate attenuator pads with parallel + series resistors and some creative energy. Lacking the proper 1% parts, I hand selected some 5% resistors among the values shown to the right and built a pad that *precisely* gave a 10 dB power drop at 50 Ω.

Now let's check the calibration of this little sinusoidal RF generator...

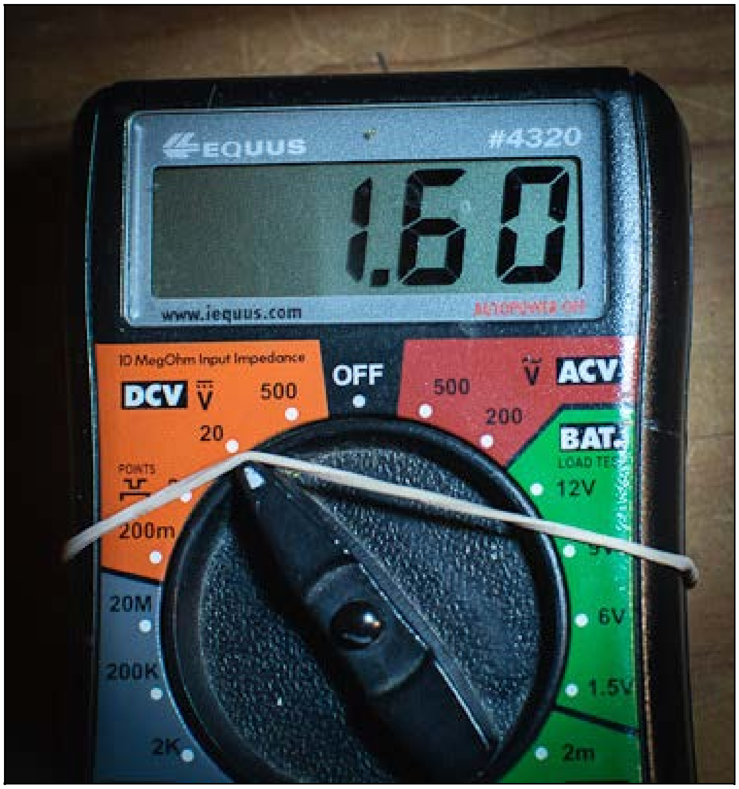
EQUUS
#4320
1.60
www.iequus.com
AUTOPOWER OFF
10 MegOhm Input Impedance
DCV
500
20
200m
OFF
ACV
500
200
BAT.
LOAD TEST
12V
6V
1.5V
2m
20M
200K
2K

Above — When connected to the Barebones PM, I calibrated the output power of the sine wave generator by tweaking the trimmer pot to give an output of 1.60v; the same Port B voltage yielded by the CMOS RF calibrator.

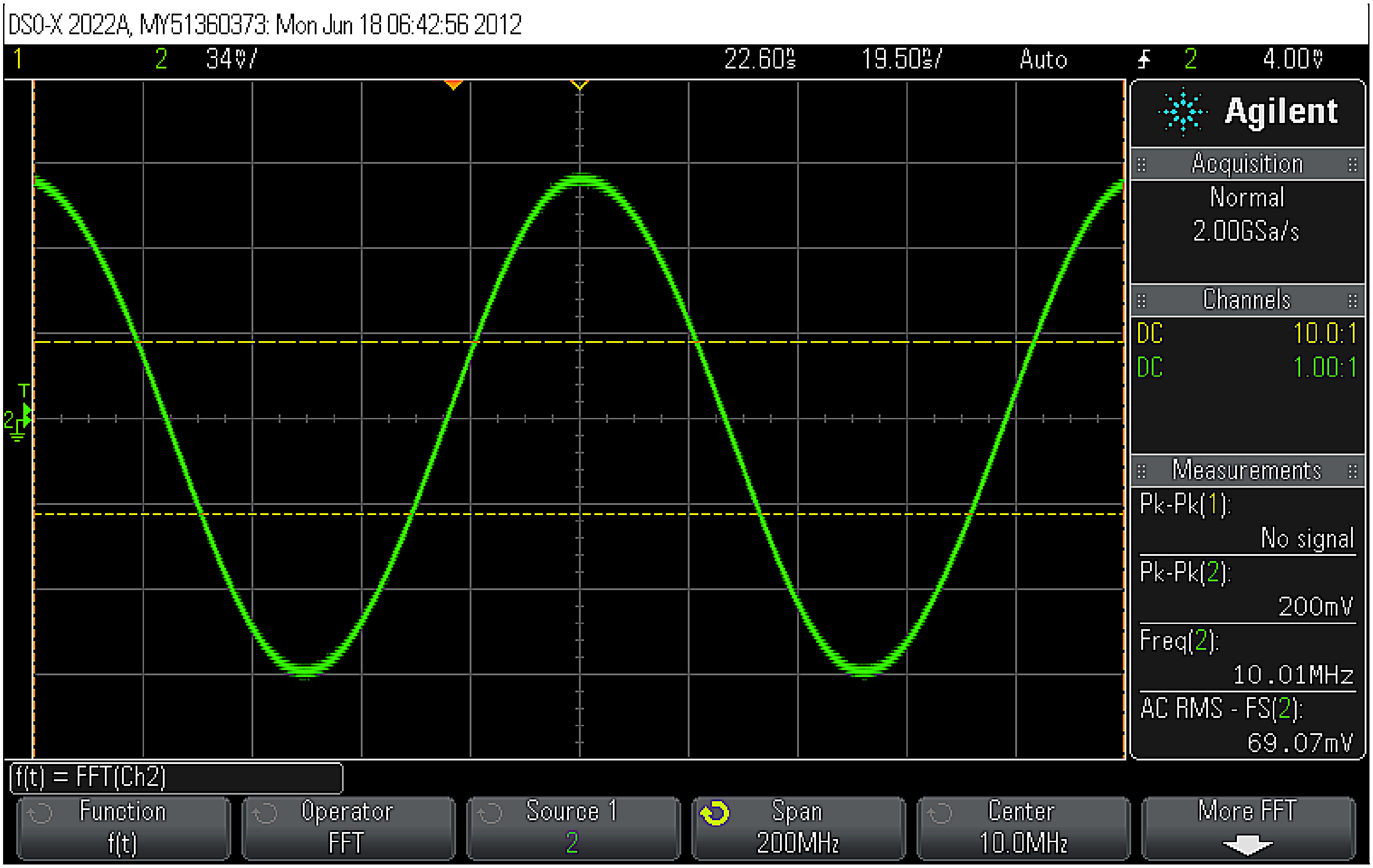
DSO-X 2022A, MY51360373: Mon Jun 18 06:42:56 2012

1 2 34mV/ 22.60ns 19.50ns/ Auto 2 4.00mV

Agilent

Acquisition: Normal, 2.00GSa/s

Channels: DC 10.0:1, DC 1.00:1

Measurements:
Pk-Pk(1): No signal
Pk-Pk(2): 200mV
Freq(2): 10.01MHz
AC RMS - FS(2): 69.07mV

f(t) = FFT(Ch2)

Function: f(t)
Operator: FFT
Source 1: 2
Span: 200MHz
Center: 10.0MHz

More FFT

Above — The 50 Ω terminated 'scope verification of my calibrated 10 MHz sine wave signal source: 200 mV pk-pk = -10 dBm. Wow, thanks for this Bob!

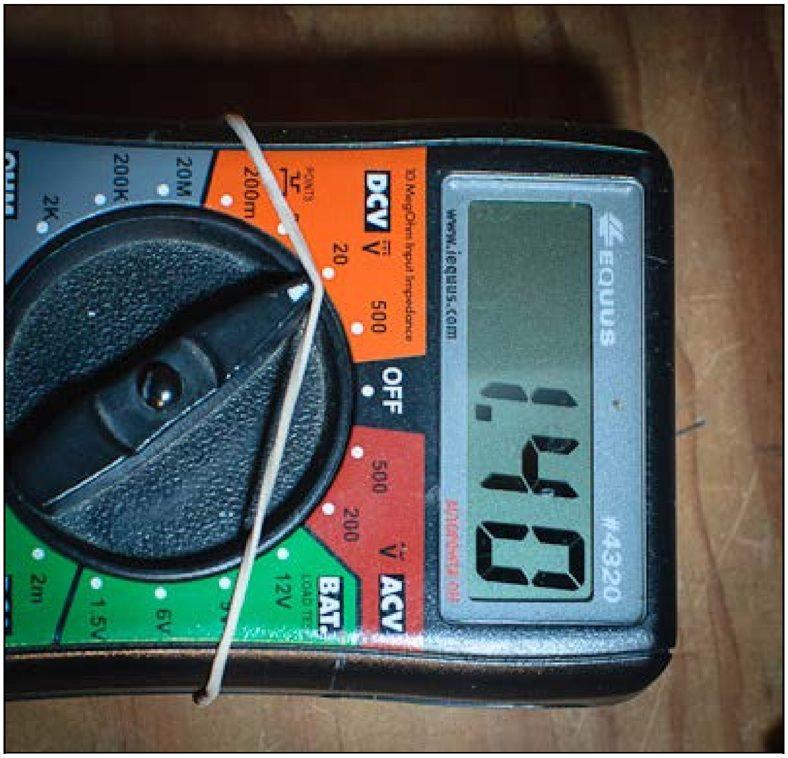
EQUUS
#4320
1.40
www.iequus.com
10 MegOhm Input Impedance
DCV
ACV
OFF
20
500
200
200m
20M
200K
2K
2m
1.5V
6V
12V
BAT

Above — The Port B voltage when a 10 dB attenuator pad was connected to the calibrated -10 dBm sine wave signal source: Measured power = -20 dBm. Notice the 20 mV/dB power drop — right on specification.

Refer to the section titled **<How to Measure Power at Port B>** Recall Wes' calculation needed 2 points to set the log linearity. I chose -10 dBm and -20 dBm instead of 0 dBm and -10 dBm so the CMOS RF calibrator could be used to calibrate any sine wave signal generators on hand.

The -10 dBm calibration reference power serves as 1 of the calibration points in Applet L while we derive the other by adding a 10 dB attenuator pad to a *sine wave* signal source output port. ***Don't connect an attenuator pad to the CMOS square wave calibrator —*** error in the AD8307 arises. Why? Analog Devices mysteriously changed the AD8307 at some point after 2004 and altered its crest factor — this disallows us performing log linearity calibration with a square wave.

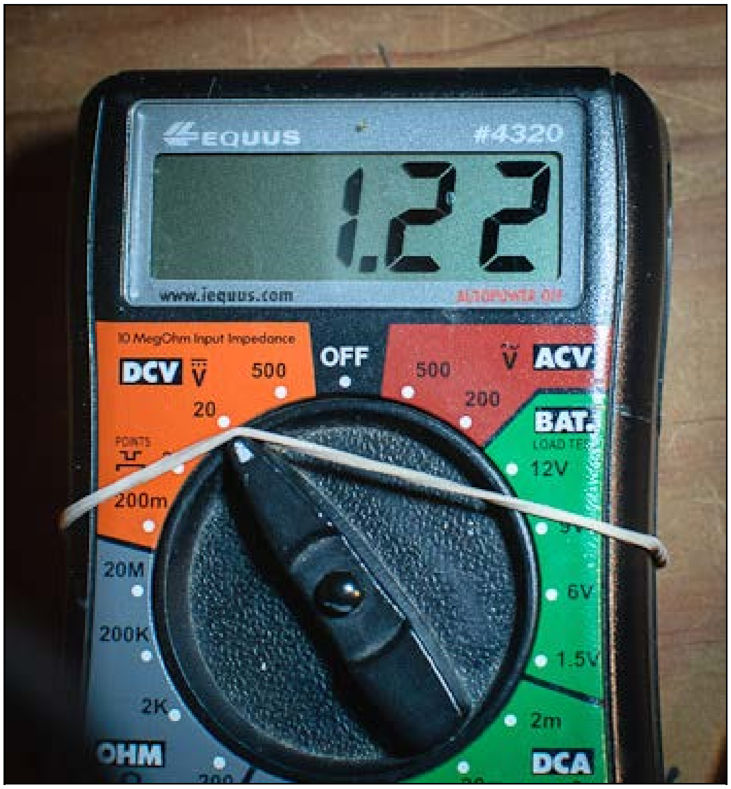

Above — A 20 dB pad connected to the -10 dBm sine wave signal source yielded 1.22v at Port B in the Barebones PM. See the power calculation with Applet L below:

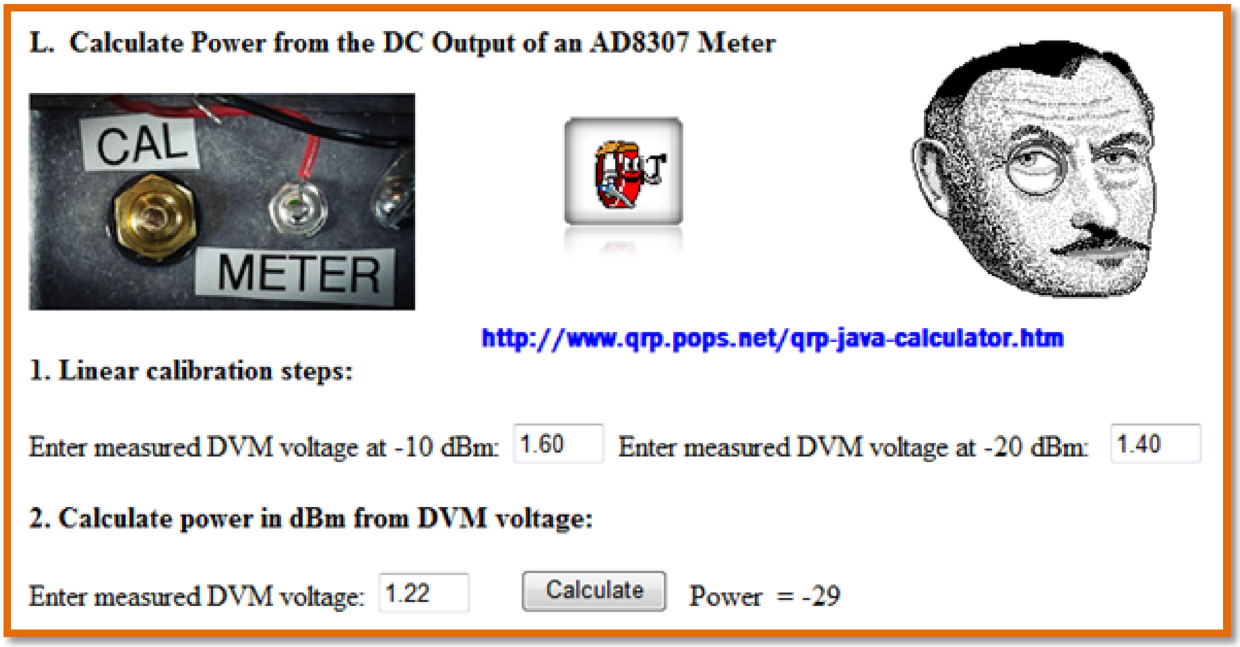

L. Calculate Power from the DC Output of an AD8307 Meter

http://www.qrp.pops.net/qrp-java-calculator.htm

1. Linear calibration steps:

Enter measured DVM voltage at -10 dBm: 1.60

Enter measured DVM voltage at -20 dBm: 1.40

2. Calculate power in dBm from DVM voltage:

Enter measured DVM voltage: 1.22

Power = -29

Above — The calculation of the output power with a 20 dB attenuator pad on the sine wave signal source output. We're off by 1 dB since it should have calculated a power of -30 dBm. Could this be error caused by my attenuator circuit, or non-linearity by the AD8307 PM, or a bit of both? We have to live with such problems. Still, the Barebones power meter seems quite impressive for a simple circuit that I scratch built and calibrated in about 25 minutes.

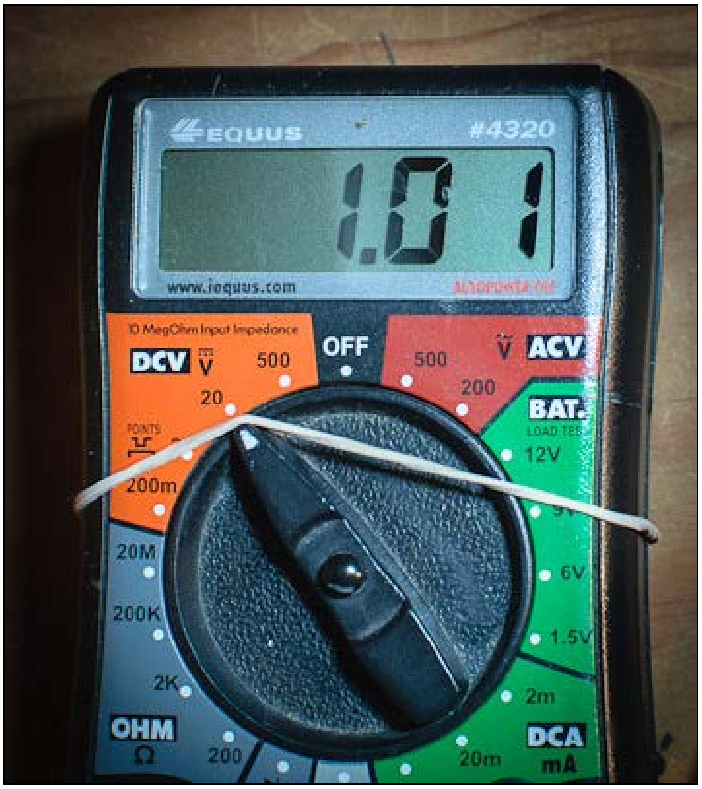

Above — The Barebones PM DC output voltage with a 30 dB attenuator pad on the output of my -10 dBm, 10 MHz sine wave signal generator: Measured power = -39.5 dBm. Again; a very good — but not perfect power meter.

A Barebones power meter allows builders with modest equipment to measure power, gain/loss, and with a return loss bridge, return loss at HF. I wish I owned this little gem back when I started out.

Richard, "Dick", N4HAY, posted some great notes on his blog. I recommend following his blog since he really digs deep and likes math — thanks Dick!

Best!

---

3. A Basic RF Workbench

Since January 2012, a handful of readers asked what I consider a good basic *RF* work bench. Again, I'm just an amateur hobbyist, so my opinion might show my ignorance.

A stand-alone 50 MHz oscilloscope with at least one 10X probe. *More bandwidth if you plan to work above 50 MHz*

If no oscillocope, an AD8307-based power meter *The modern version of the diode RF probe*.

3-4 50 Ω coaxial cables with BNC connectors; a 50 Ω scope feed-through terminator, *1-2* 50 Ω BNC port terminators, a though-connector and some BNC connectors to solder onto temporary circuit boards or mount in a chassis.

A homebrew return loss bridge.

3, 6, 10 and 20 dB BNC connector equipped attenuator pads, or a step attenuator.

Signal generator(s) that cover most of HF; +/- VHF signal generators described in the next section.

AADE L/C Meter IIB. Click

12 volt regulated power supply good for at least 1 amp.

Digital multimeter. *I use 2 and keep 1 set up for current measurement only.*

Frequency counter: homebrew or commercial. *I ran a 40 year old, ovenized, accurate HP counter until 2012.*

With these devices, as possible, you can work in a modular, 50 Ω environment and measure gain or loss in dB, return loss in dB and absolute power in dBm. Starting small and expanding your bench around 50 Ω input and output impedance devices will provide a lifetime of challenge and excitement in RF design.

Later, the big toys can follow: spectrum analyzers, VNAs, commercial signal generators and other lab quality stuff.

Equipping an RF bench presents quite a financial burden. I started small and slowly added pieces over time. Many pieces such as my L/C Meter IIB were gifts for holidays or my birthday. Other pieces were old, inexpensive equipment that I restored and calibrated.

3dB ATTE
FREQUENC
Mini-Circuits
15542
HAT-6

Above — RF tools of the trade. We're RF experimenters! As scratch homebrew builders, gear like BNC, SMA and through-connectors, 50 Ω terminators and inline attenuators lie scattered on our benches; our fodder. Alternate photo.

4. VHF Signal Generators

Having only started at VHF in November 2011, my knowledge suffers, however, a search for accessible, affordable, good quality VHF signal generators disheartened me. Ten year old or newer signal generators covering the VHF band work up to several GHz and cost a small fortune.

Lamenting old timers often recommend the vaccum tube HP-608 series that covered ~10-480 MHz. These heavy, glowing beasts sometimes come up in estate sales or on eBay for $200-400.

Then, too, the HP8640 series seems attractive, however, they are full of decaying parts. Ken Kuhn and others restore old HP gear as a hobby and this direction certainly gives us a valid option.

I've investigated 1 or 2 new, low-cost, commercial signal generators that work into VHF, but they failed to excite me; especially after I downloaded the schematics and sat in disbelief over their poor design.

Some minimum commercial signal requirements might include stable, linear tuning, a metal chassis, 50 Ω output with a return loss greater than 20 dB and low harmonic distortion at all frequencies. Like the rest of our lives, our budget usually determines what we buy.

I decided to build my own VHF signal generators and document them on this web site. I've learned that home building signal generators between 50 and 200 MHz requires skill and care, but can be done.

What about digital clocks?

At VHF, DDS spurs get extreme as you get closer to the maximum clock frequency .

The Si570 looks intriguing, however, still requires an MCU + components, I haven't read any lab quality evaluations of the Si570 as part of a engineer-grade VHF-UHF signal generator and if you know better, please email me.

5. L - C Meters

If you search for opinions about which L/C meter to get, you'll find an abundance of super write-ups including those that cover measuring with Kelvin probes, SMD tweezers; or statements suggesting that if you really need maximum accuracy, purchase a VNA. I encourage you to research this yourself and find the best L/C meter for *your* bench. Here are my 2 cents worth of opinion and please remember — I'm often wrong.

I use an AADE L/C IIB meter to test inductors and capacitors for HF and even some VHF work. Yes, the AADE L/C IIB doesn't measure large-value electrolytic caps and so forth, however, considering the cost versus performance — it's accurate enough for the popcorn RF workbench.

The AADE L/C meter uses the method described by William Carver, W7AAZ in an article called The LC Tester published in Communications Quarterly, Winter 2003 . EMRFD page 7.12 briefly examines Bill's circuit and shows his original oscillator along with an extended range Colpitts oscillator designed by Wes. For brevity sake, I'll just discuss inductance measurement with Carver-style meters. With care, an inductance resolution of 5 - 20 nH might be realized with such a device.

We normally don't consider that our inductor is actually a network with L, a parallel C and losses that might be modelled as R in series with the L, or a R in parallel with the C depending on our model. The inductor also exhibits a self-resonant frequency and for our design purposes, we usually *ignore* all these details and just consider it a "pure L". My L/C meter's oscillator runs from a few tens to a few hundred KHz and generally lies below the self-resonant frequency of the inductors I measure with it. I've learned by sweeping/analyzing my completed filters, that as long as you avoid the coil's SRF, *the low frequency* Carver-style meter proves a stalwart inductance meter for most HF and some VHF applications.

Often, we popcorn builders want to make a filter, an oscillator, or a pi, or L match and we apply software or tables to calculate the L and C values needed to resonate our filter tank(s) or matching networks, or to synthesize a low-pass filter. These math-driven programs/tables assume the *pure* "pixie dust" L described eariler — disregarding the stray C and R. So getting all worked up about whether our coil is 4.50 or 4.59 microHenries seems moot.

Further, we man-handle our inductors [changing the inductance somewhat] into a breadboard laden with 5% (or greater tolerance) capacitors, copper board pads/paths that exhibit C, active devices and so forth. Then, too, we connect these resonators, or filters to other blocks with sometimes reactive ports, plus or minus shielding. Despite all these variables, miraculously, we make the filter with our "measured" L work!

As we move up in frequency, the effects of stray L effect magnify and at some point our filter networks may behave poorly.

For band-pass filters with Carver-style device measured inductors, we need only adjust each trimmer capacitor to get the highest possible peak-peak voltage, or RF power with our filter between a signal generator and a 50 Ω terminated scope, power meter *respectively*, or whatever. After sweeping these peaked filters, rarely do I need to compress/expand, or add or remove windings to tweak the L get the desired filter response when the filter input and output ports are well matched.

In the case of single frequency matching networks like the L-match, we might need to tweak up or down the L to derive strong port matching. In all cases, our software and the L/C meter can get us into the ballpark, but in-situ bench measurement with other instruments will garner the home run.

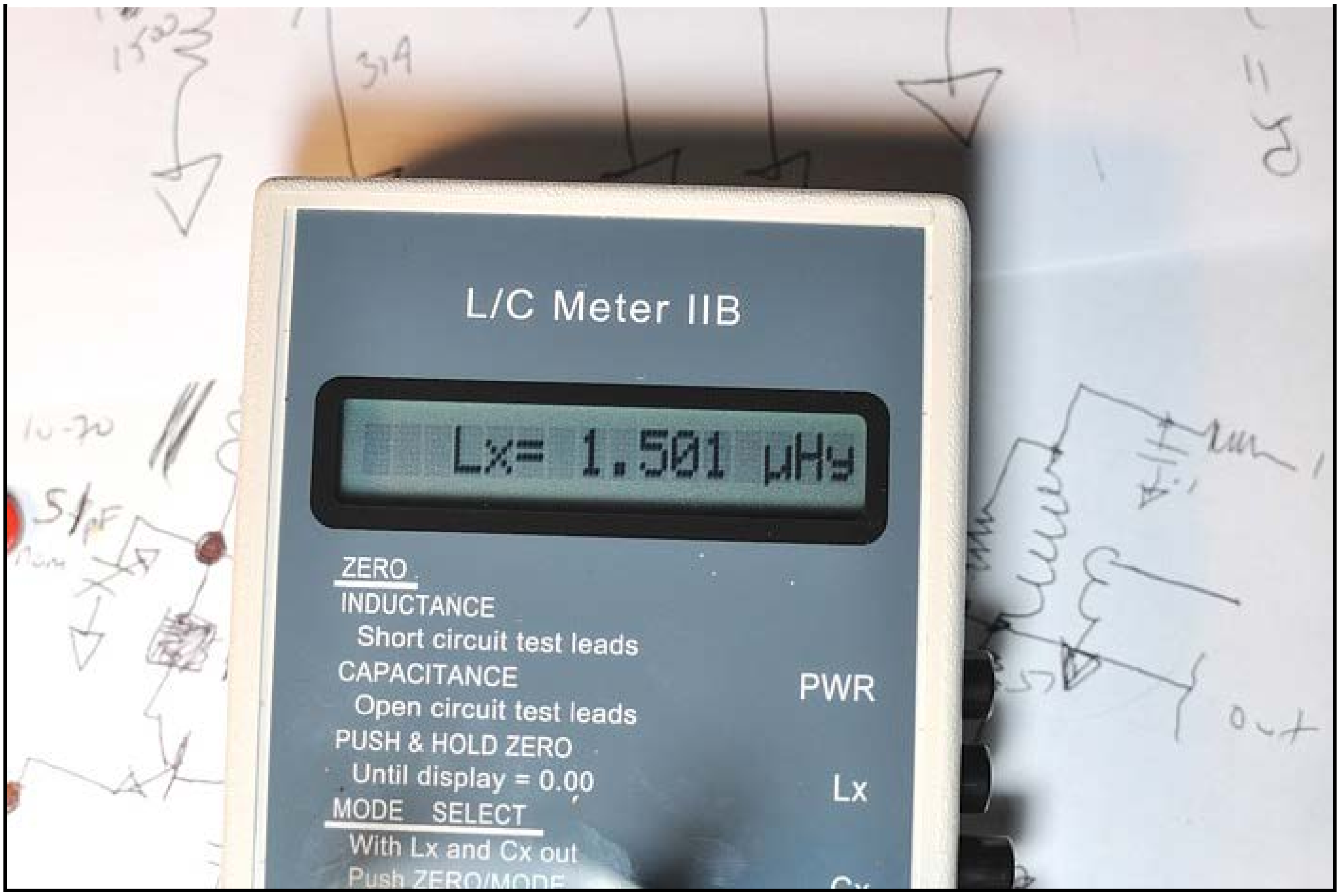
L/C Meter IIB
Lx= 1.501 µHy
ZERO
INDUCTANCE
Short circuit test leads
CAPACITANCE
Open circuit test leads
PUSH & HOLD ZERO
Until display = 0.00
MODE SELECT
With Lx and Cx out
Push ZERO/MODE
PWR
Lx

---

6. Bob, K3NHI — RF Power Meter Follow-on

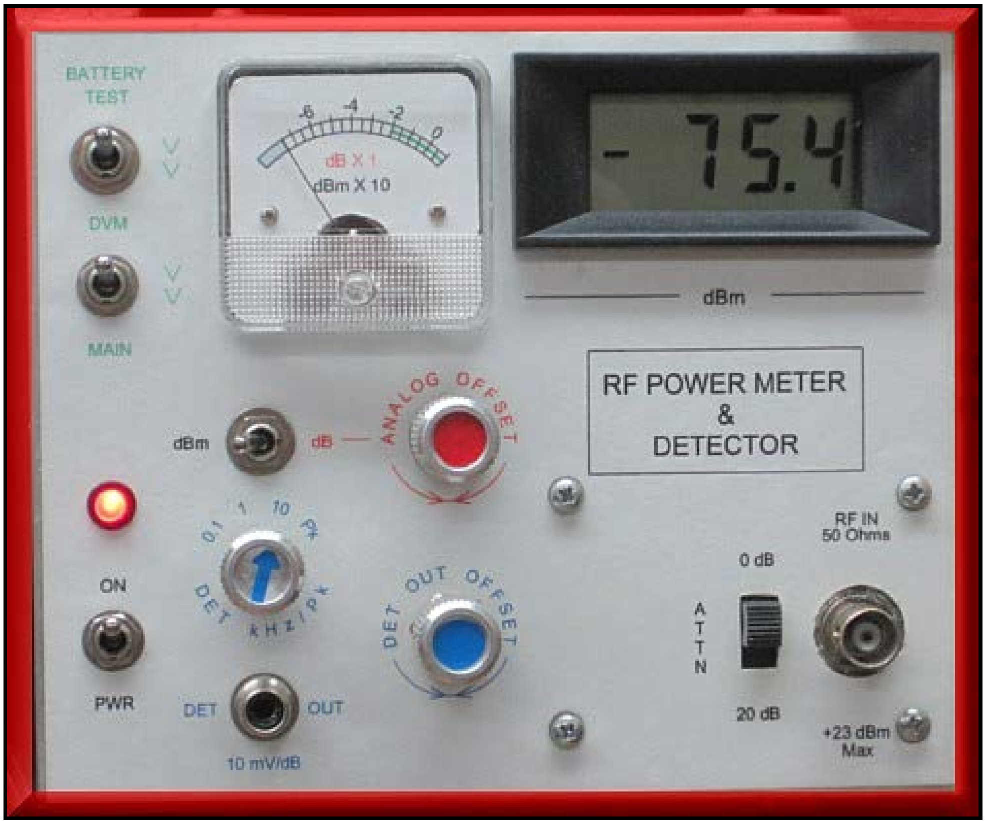
BATTERY TEST
DVM
MAIN
dB X 1
dBm X 10
-75.4
dBm
RF POWER METER & DETECTOR
dBm
dB
ANALOG OFFSET
ON
PWR
0.1 1 10 PK
DET kHz / Pk
DET OUT OFFSET
DET
OUT
10 mV/dB
RF IN 50 Ohms
0 dB
ATTN
20 dB
+23 dBm Max

Bob built a follow-on detector and power meter to his 2002 QEX power meter *[Reference 3 in Section 7].* Bob gave me the green light to share his creation on my site. Thanks awfully Bob!

Click for the schematic in pdf format. Per typical K3NHI fashion, it's laden with trimmer pots allowing precise calibration — Bob's stuff contains loads of tweaks and wiggles! The new PM offers more flexibility + features including bigger battery supplies that won't quickly die when you fail to turn it off. He also included a means to measure battery voltage on the analog meter. Click for a photo showing the batteries. Low noise, high-speed, rail to rail, CMOS op-amps for IC1 and IC3, allow you to capture PEP during sideband transmitter measurement with appropriate attenuation.

The TS922 op-amp might be hard to find in DIP since that package went obsolete, however, it's available in SMD. If you can't get any TS922, likely other modern, high speed, rail to rail, CMOS op-amps will work fine — consult datasheets to ensure you meet or beat the TS922's performance for IC1 and IC3. Some of the latest design op-amps offer truly sublime specifications and evoke joy in our breadboards.

Bob critically *isolated* the entire RF sub assembly **outlined in green on the schematic** with metal shielding and feed through capacitors for the B+ and DC output. This helps ensure stable and accurate AC voltage measurement. Click or click or click for more of Bob's photographs.

7. References

[1] Roger Hayward, KA7EXM — A PIC-based HF/VHF Power Meter, QEX May/June 2005

[2] Wes Hayward, W7ZOI, Bob Larkin, W7PUA, Simple RF-Power Measurement, QST, June 2001

[3] Bob Kopski, K3NHI — An Advanced VHF Wattmeter, QEX, May/June 2002.

[4] Bob Kopski, K3NHI — A Simple Enhancement for the Advanced VHF Wattmeter, QEX, Sept/Oct 2003.

[5] Bob Kopski, K3NHI — A Simple RF Power Calibrator, QEX, Jan/Feb 2004 **+** Tech Notes article, QEX, May/June 2010.

RF — Test and Measurement

VHF FM

Yes - I could purchase a FM radio-in-an IC for $2.00 and be done in 35 minutes, but what would I learn?

Repository for FM superhet receiver experiments conducted from 2012 to 2014.

1. 10.7 MHz IF Filter Experiments
2. A Basic Colpitts VCO
3. DC-DC Converter for VCOs
4. Supplemental Page #1 - it's time to make some receivers
5. Miscellaneous Photos or Figures

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1. 10.7 MHz IF Filter Experiments

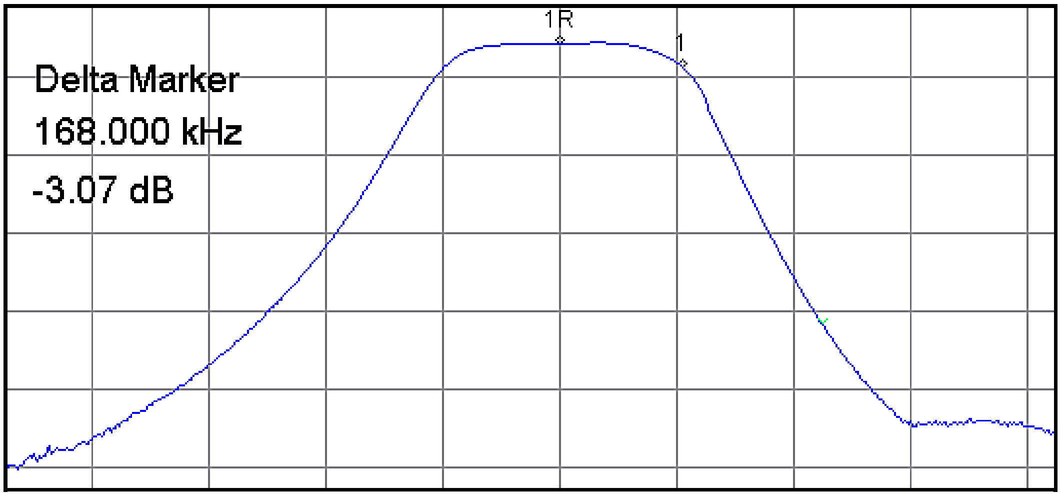

As a FM receiver design newbie, I read about and experimented with some 10.7 MHz IF filters to learn common practices, what's available and which measurements might help me to reach my goals. Over time, I've collected a variety of crystal and ceramic filters for hopeful future work. Click for 2 exotic examples. IF filters might be purchased at Ham festivals, surplus electronic parts stored and/or online. Prior to paying for a filter, I've found it useful to politely request a sweep of the filter, or, better yet, perform this task myself. To sweep a filter in your lab, you'll need a tool such as a spectrum analyzer with tracking generator, a VNA, or some other analog/digital sweep system.

I'll homebrew some crystal filters for narrow band FM in future installments — I ordered some 20 MHz xtals.

Sometimes a filter in your junkbox will state the IF and perhaps the 3 or 6 dB bandwidth, but not the input/output port termination impedance. How do we determine this impedance? I've learned we can figure this out by testing differerent termination resistors with this simple test jig:

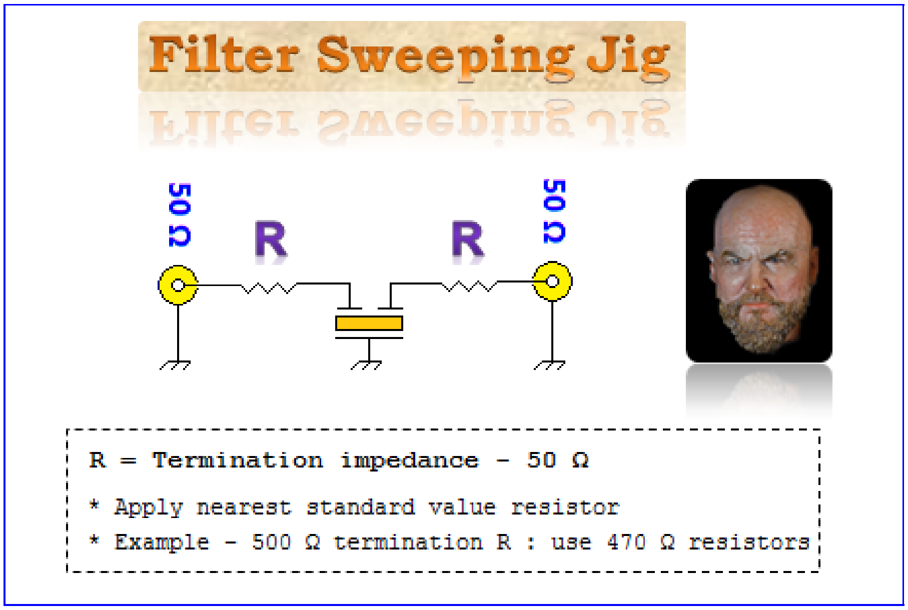

R = Termination impedance - 50 Ω

* Apply nearest standard value resistor

* Example - 500 Ω termination R : use 470 Ω resistors

Above — A simple crystal or ceramic IF filter sweeping jig. Since the series resistors attenuate the signal, losses occur; but the shape should look clean with minimal ripple. Normally, we builders will also place (or switch in) 50 Ω attenuator pads on both the signal source and detector within our sweep system to buffer impedance mismatch. Comparisons of this simple jig with more precise and complicated matching methods suggest that for many filter sweeps, it might work fine.

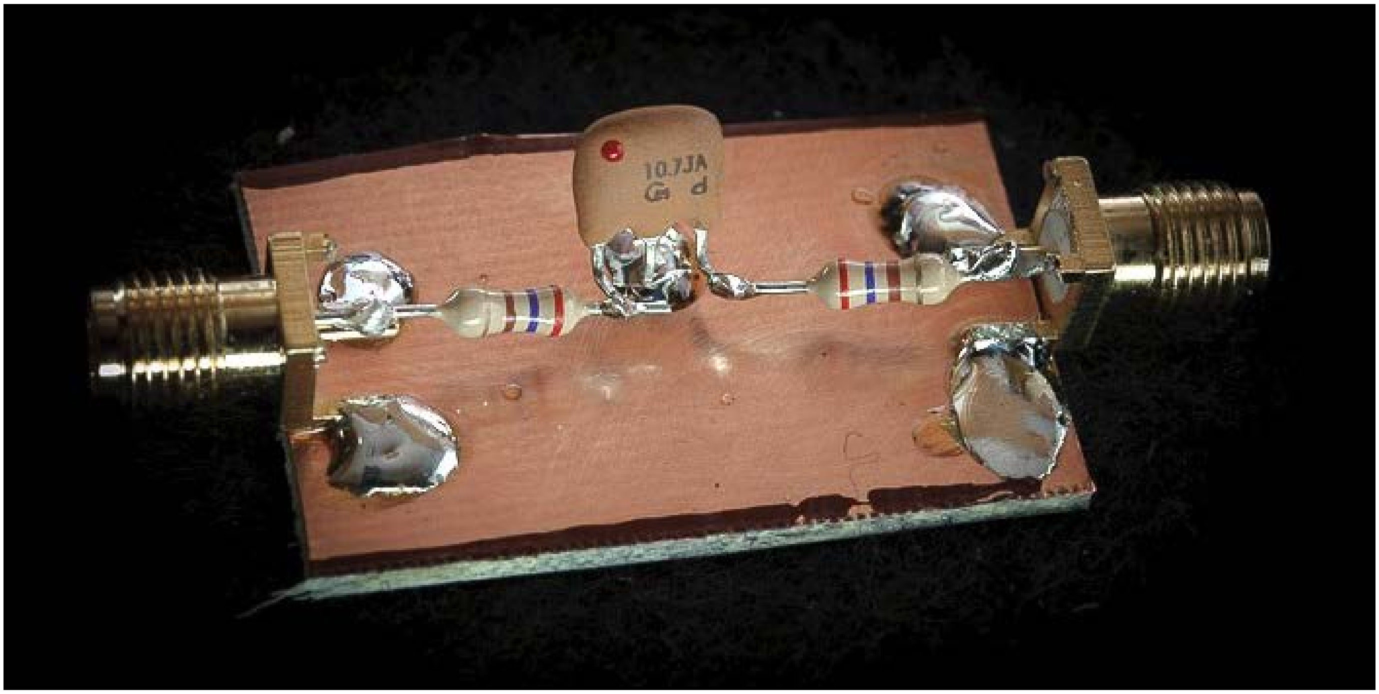

Above — My test jig with a Murata ceramic filter soldered in-situ. Keep the resistors *close* to the board. I've pretty much moved to SMA connectors in my lab: they're cheaper than BNC, plus we can buy a wide variety of quality 50 Ω patch cables donning various connectors for low cost. For example, a 30 cm cable with a male BNC and SMA connector on either end.

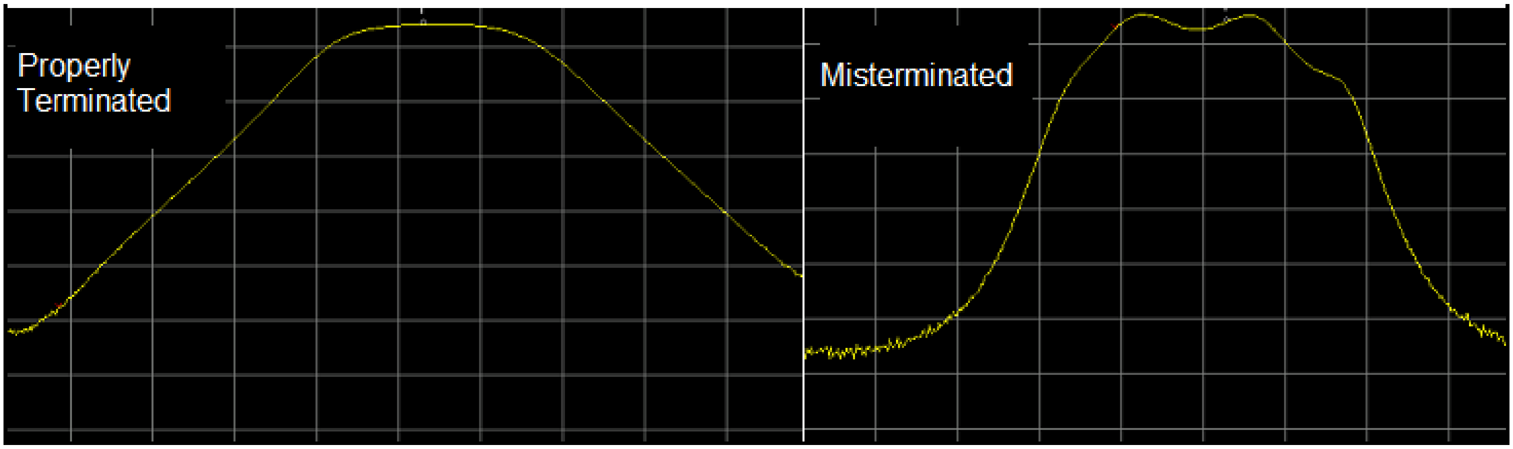

Above — A poor termination may result in improper bandwidth and ripple — easy to spot in this trace. Click for a trace from a 'gone bad' instrumentation crystal filter: 10.7 MHz @ 30 KHz with 2200 Ω Z in/out. Not really usable with ~ 10 dB ripple.

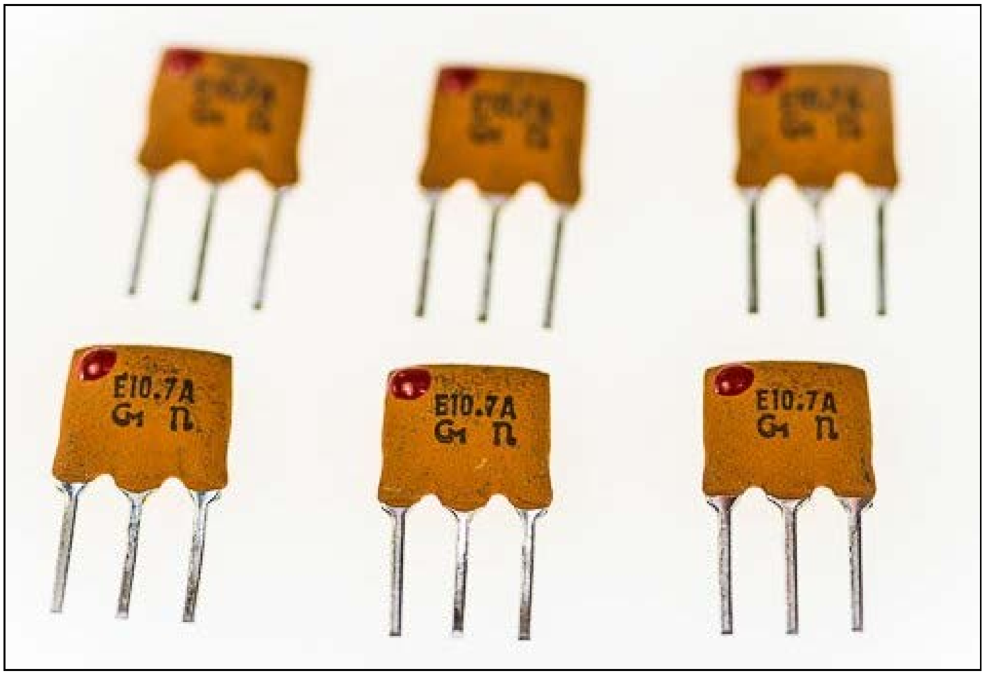

Above — Older 280 KHz Murata 10.7 MHz IF filters purchased long ago. Low cost = their main attraction, although they too will suffer total obsolescence and a price increase.

I bought some newer, lower insertion loss ceramic filters in the following bandwidths: 280 KHz, 230 KHz, 150 KHz, 25 KHz and 20 KHz. Check their datasheet — most Murata ceramic filters require a 330 Ω termination (preferably resistive) and I keep a filter sweeper jig with 270 Ω resistors as a regular bench tool. 280 KHz was a popular WBFM filter bandwidth in many older high-end FM receivers including my 1980's T-85 Yamaha receiver; my benchmark FM receiver.

Many of us hopeful FM builders, smitten by modern digital gear, fail to recognize the fantastic design achievements made by FM receiver engineers back in the day. All those air-variable, ganged band-pass preamp stages, low noise amplifers and often incredibly complicated and great sounding FM multiplex circuits just blow me away. Perhaps I'm a hopeless analog nostalgic? My T-85 sports 5 ceramic filters [280 KHz and 230 KHz B/W Muratas] and the narrow filters are listener switchable for narrow band Dx.

Ways to Match These Filters with Amplifers

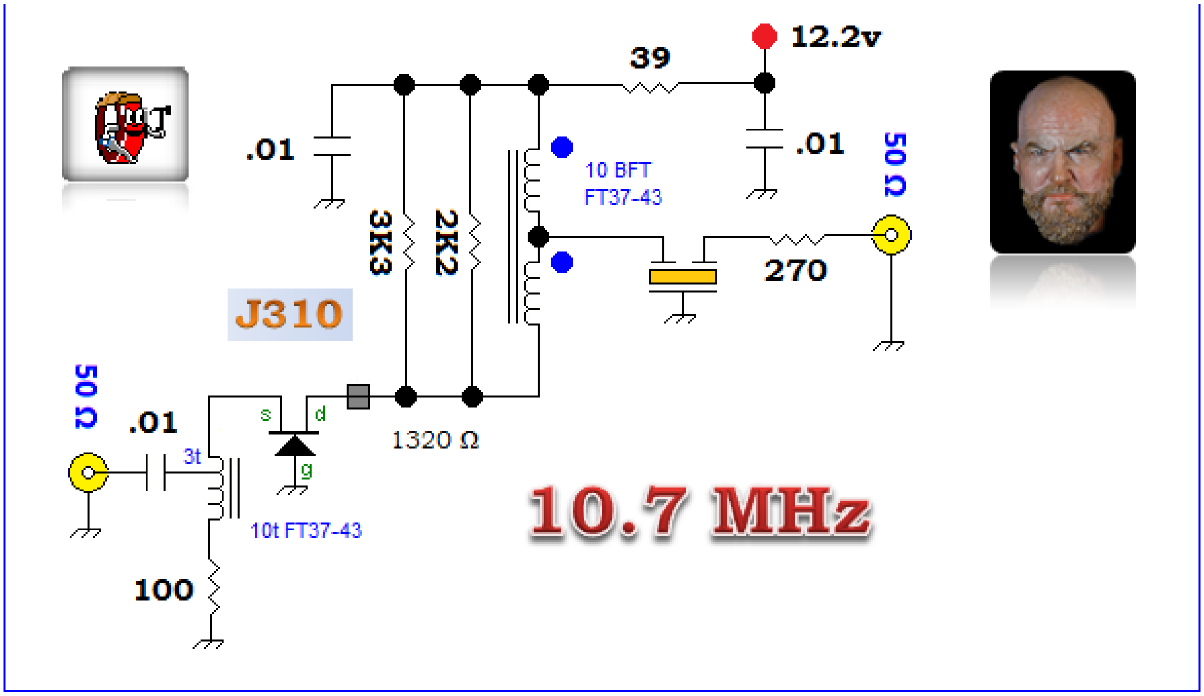
39
12.2v
.01
.01
50 Ω
10 BFT
FT37-43
3K3
2K2
270
J310
50 Ω
.01
3t
s
d
g
1320 Ω
10t FT37-43
100
10.7 MHz

Above — A common gate JFET amplifer drives a 330 Ω ceramic filter. I placed 2 resistors in parallel to get the needed shunt R of 1320; my 2 resistors measured 1316 Ω. The bifilar transmission line transformer provides the 330 Ω Z to drive the filter. Details of the JFET amp come in a later schematic, but the input return loss at 10.7 MHz = 23 dB. I swept this circuit and it looked similar to the tracing with the same ceramic filter in my 270 Ω filter sweeping jig. This particular filter exhibited 6.4 dB of insertion loss.

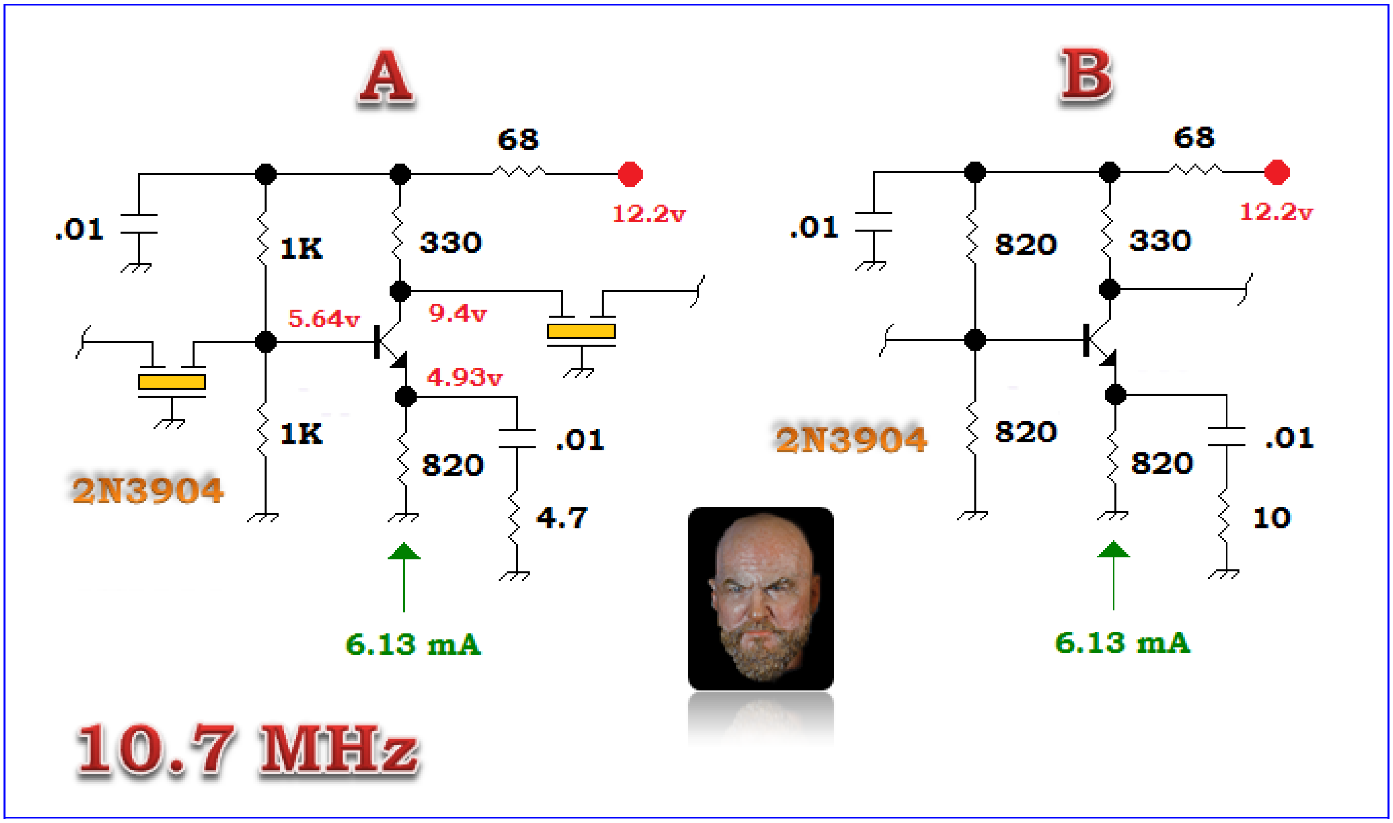
A
B
68
.01
1K
330
12.2v
5.64v
9.4v
4.93v
1K
820
.01
4.7
2N3904
6.13 mA
68
.01
820
330
12.2v
2N3904
820
820
.01
10
6.13 mA
10.7 MHz

Above — 2 versions of a BJT amp with a 330 Ω input and output impedance. If you read schematics of good FM receivers, often the designers drive the filter with a 330 Ω collector resistor. Click for an example. By keeping the bias and degeneration resistors low and the current moderate, an amplifer with 330 Ω input Z is easy to design [although the input Z will vary with Beta].

I felt surprised that version **A** exhibited a voltage gain of 11.7 despite those low bias and collector resistors. You can stick a filter on either side as shown. Murata recommends a buffer amp between cascaded ceramic filters and you'll see this often in FM receiver schematics from the 1980s or so. Resistors provide wideband termination. Version B is the same amp with a little more degeneration to lower the gain and serves as a design example. I've got the procedure documented here under '*Calculating the input resistance of a common emitter stage'.*

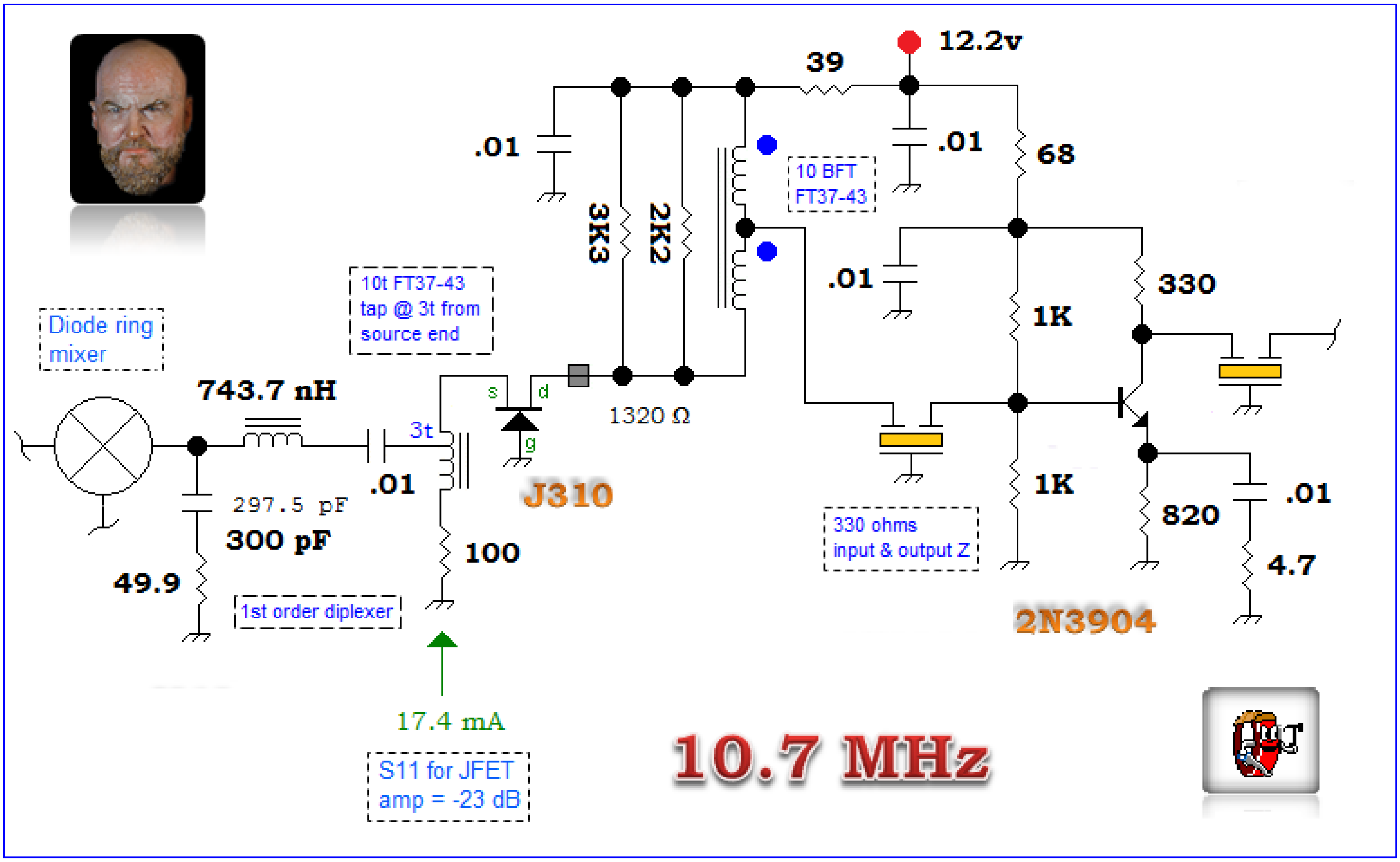
Diode ring mixer
743.7 nH
297.5 pF
300 pF
49.9
1st order diplexer
.01
3t
10t FT37-43 tap @ 3t from source end
100
17.4 mA
S11 for JFET amp = -23 dB
s
d
g
J310
.01
3K3
2K2
1320 Ω
39
12.2v
10 BFT FT37-43
.01
68
.01
1K
330
1K
330 ohms input & output Z
2N3904
820
.01
4.7
10.7 MHz

Above — An IF block using the designs shown earlier. I terminated this stage with a 270 Ω resistor and of course removed the mixer and diplexer. 2 sweeps lie below. I'm tempted to tune the JFET drain and couple the transformer with a few links as needed to get a 4:1 impedance ratio. Anyhow — food for thought.

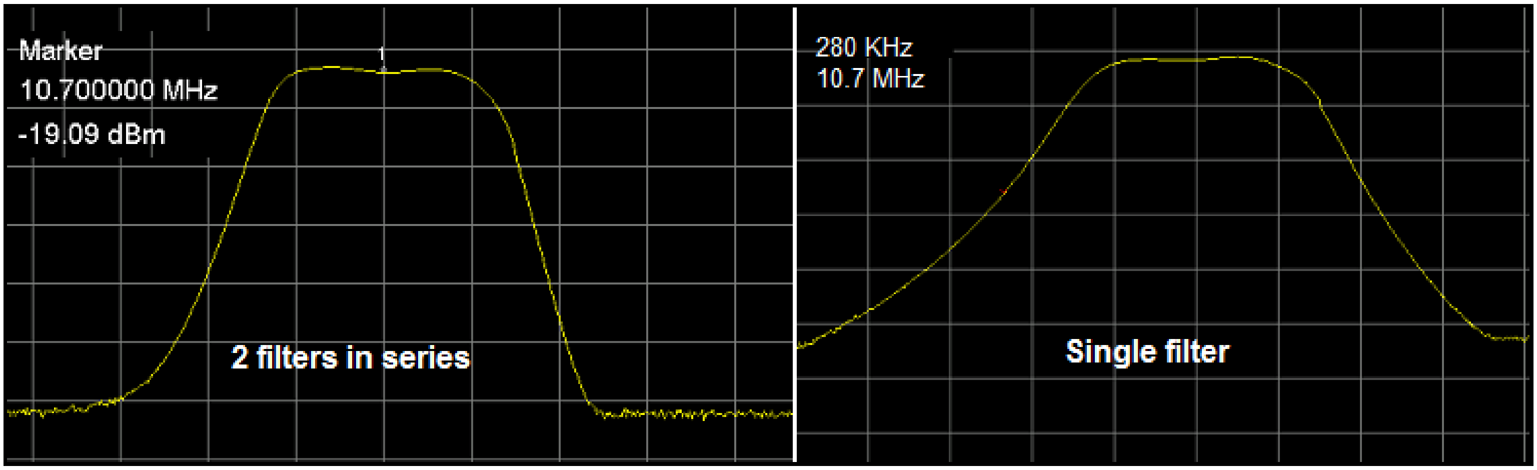

Above — A sweep of the IF block shown above left sans the mixer + diplexer (*two* 280 KHz ceramic filters). On the right lies the trace of the common gate amp driving a *single* 280 KHz filter with its output terminated with a 270 resistor. The advantages of 2 cascaded filters seems apparent, although the slight downward dimple at the center frequency might represent some capacitive loading at the output of the common gate amplifier.

I built a number of other amplifers and swept all of them Click or click for 2 early examples that use active devices instead of series matching resistors on the output. In these circuits, R Term was changed and then the circuit was swept. The tracings looked good.

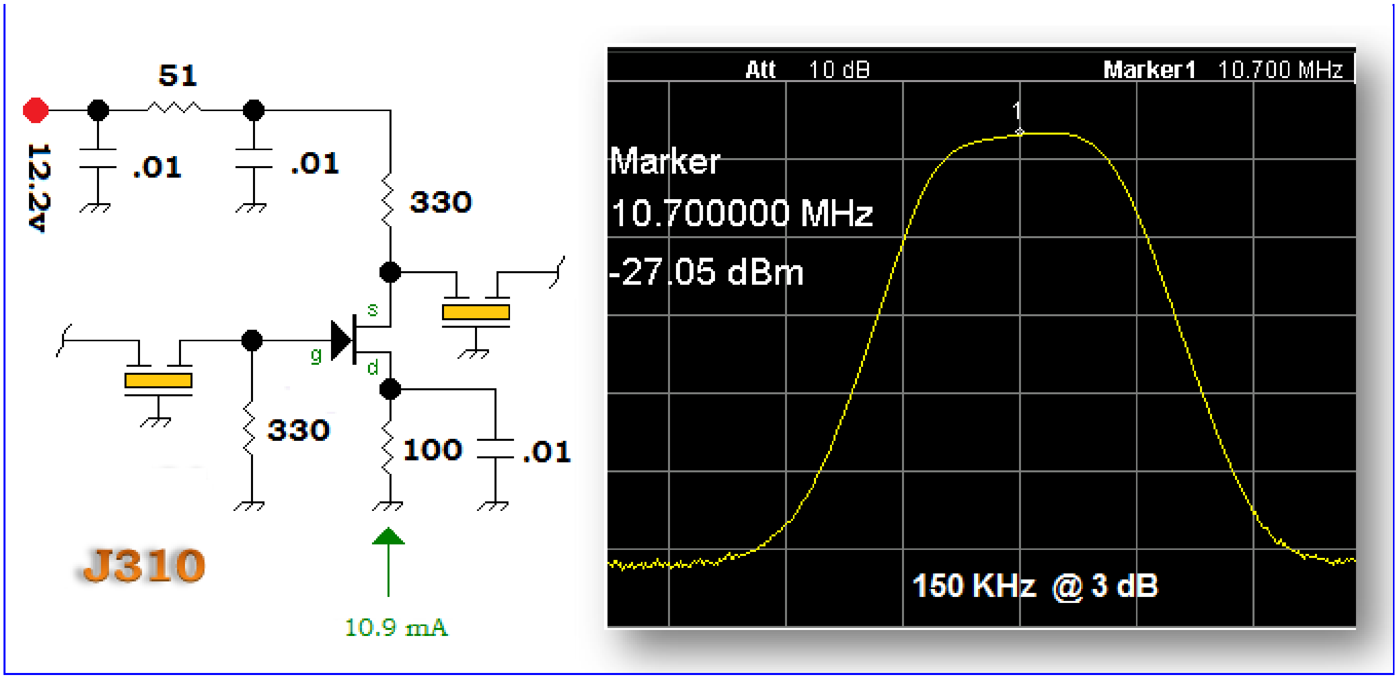

Above — I built Brian, K6STI's nJFET IF amp. He used it to offset the losses associated with 2 ceramic filters. Click for Brian's fabulous website. I placed 150 KHz 3dB BW filters before and after a J310 and swept — my circuit exhibited a 2 dB net loss which seems quite reasonable.

The 330 input resistor is a load/termination on the input filter and will dissipate some energy and lower the AC input voltage to the gate compared to the usual high Z input resistors we apply in our JFET common source amps — from open circuit to full termination would incur a 6 dB voltage drop. Still, for simplicity versus performance, Brian's circuit looks hard to beat.

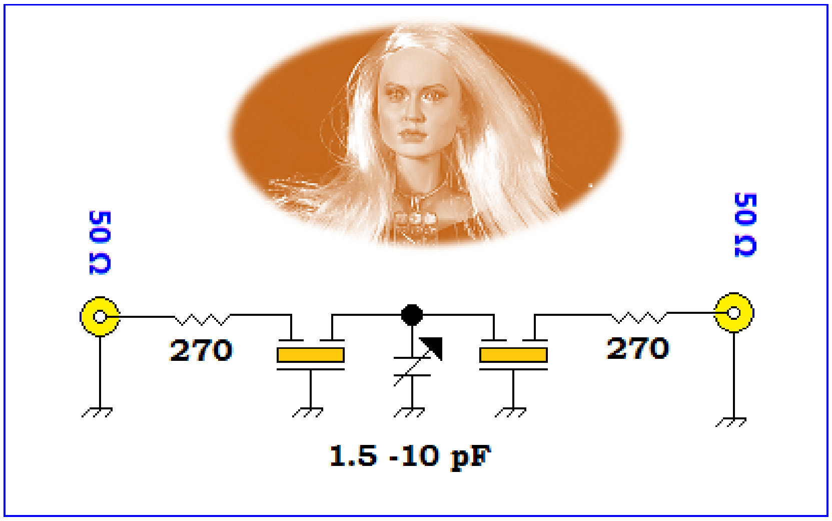

Above — 2 ceramic filters in series. I added a small trimmer between the pair in hopes to mitigate any filter skirt distress or ripple. Click for a tracing with and without the trimmer capacitor. You might experiment with the filter coupling and the filter block termination impedances to better their skirts and passband The losses of the above filter block may reach 12-14 dB.

If you don't have a sweep system, I was able to crudely test the amplifers + filters with my 10.7 MHz signal generator and a DSO.

Resistance Bridge

If you go with a BJT IF amplifer, it's possible to measure the input impedance with a bridge and tweak the emitter current and/or degeneration resistor to get very close to a 330 Ω Zin. I keep a drawer with through-hole resistors rated between 1 and 10 Ω for tweaking my emitter resistor values to change series feedback in my common emitter amps.

I first designed a simple 330 Ω bridge for measurement with my DVM. It worked, but the null lacked the depth and resolution we need. Later I improved the sensitivity by adding another coil and changing to a 'scope or SA detector, but after building EMRFD Figure 7.36, I abandoned my bridge. Figure 7.36 just blew me away. The null of a 330 resistor was only a few 10s of microvolts during calibration.

I placed a small 500 Ω pot in parallel with a 120 Ω resistor for the variable resistance. After some basic testing, I calibrated it with a 330 Ω resistor; adjusting the pot for the deepest null and just left it there for testing my 330 Ω IF amps @ 10.7 MHz.

I plan to make Figure 7.36 for VHF and maybe UHF with chip caps plus a small screwdriver adjustable trimmer pot [to get the lowest possible L] calibrate it and make it a part of my test bench arsenal. After getting a null, we measure the pot's resistance with an ohm meter to learn the impedance at the ? port

Considering that our predecessors measured just about everything RF with a bridge, this little circuit suddenly become relevant. A series L and C "add-on" circuit shown as Figure 7.39 may be placed in series with the ? port and device under test to deepen the null in the face of reactance. Bridge circuits form the very essence of RF measurement. Yes Bobby, we can measure impedance without a VNA.

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2. A Basic Colpitts VCO

FM TUNER VCO
TUNE

Above — My completed Colpitts VCO. *I installed the unlabelled, left-sided pot in case a potentiometer is required for future AFC circuitry changes. It's not hooked up.*

I reviewed some 1970's FM receiver schematics to learn that before PLL-locked VCOs dominated, often Colpitts VCOs were locked onto a strong frequency with Automatic Frequency Control (AFC). Local oscillators tanks often employed a inductor plus an air variable capacitor that tuned from ~77 to 119 MHz with a varactor for AFC. All the tuning and front-end filter air variable capacitors were ganged together and I'm sure alignment took some skill.

Some VCOs tuned with varactor(s) instead of an air variable cap — this is what I wish to do. Varactor tuned VCOs usually suffer more thermal drift than air variable capacitor versions.

AFC compensates for VCO thermal drift by a seperate varactor with its control voltage line DC coupled to the FM detector through an R-C low-pass filter. Any difference between the VCO frequency and the desired FM frequency produces a proportional DC voltage. The DC control voltage changes the oscillator to the desired frequency by re-tuning the AFC varactor within this feedback loop, albeit over a limited range. AFC is unsuitable for weak signal DXing, since it may pull the receiver onto a strong adjacent signal. Many 1970's FM receivers supplied an AFC defeat switch.

I remember 1 old FM receiver in my parent's home that stayed locked on 1 frequency for years thanks to AFC.

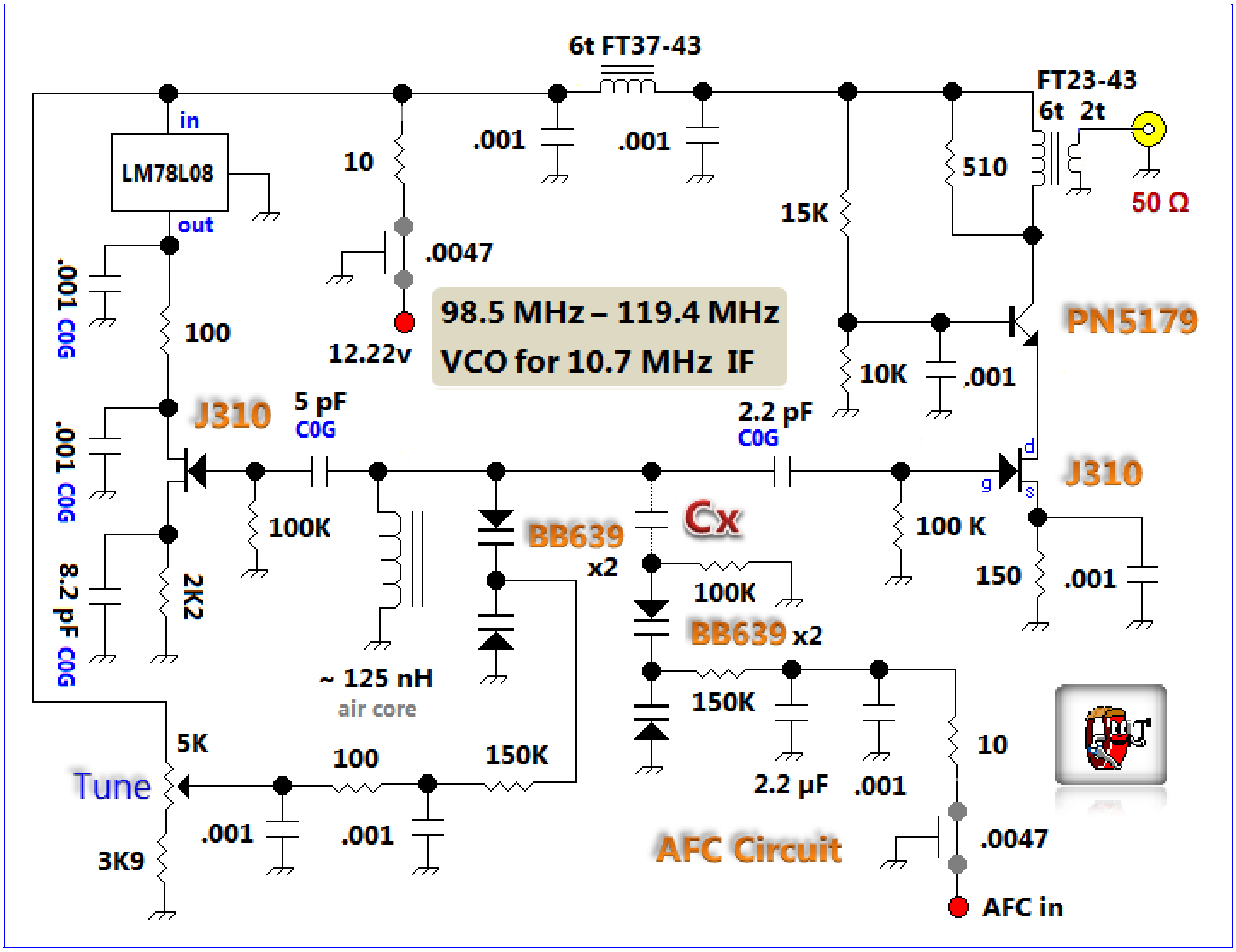
6t FT37-43
FT23-43
6t 2t
in
LM78L08
out
10
.001
.001
510
50 Ω
15K
.0047
.001 C0G
100
12.22v
98.5 MHz – 119.4 MHz
VCO for 10.7 MHz IF
PN5179
10K
.001
J310
5 pF
C0G
2.2 pF
C0G
.001 C0G
d
J310
g
s
100K
BB639
x2
Cx
100 K
8.2 pF C0G
2K2
100K
150
.001
BB639 x2
~ 125 nH
air core
150K
5K
100
150K
10
Tune
2.2 µF
.001
.001
.001
AFC Circuit
.0047
3K9
AFC in

Above — The schematic of my version of a JFET Colpitts VCO (with AFC) that lacks the standard gate to source feedback capacitor; the intrinsic capacitance from the J310 gate to source provides the feedback needed for oscillation.The 8.2 pF bypass cap was determined on the bench — too little, or too much C decreases output voltage, or snuffs out the oscillator.

I just couldn't bring myself to make a VCO with a BJT, since on my bench at least, they suffer more thermal drift than JFET-based oscillators. I built with a mixture of SMT and hole-through capacitors and resistors. The anti-parallel arranged hyperabrupt varactors were found on eBay. Click for a rear photo of the project chassis. The gold colored jack is an SMA connector.

I bench designed this VCO and it took many hours to find the correct amount of L and C for the resonator to give a low distortion, sine wave output across the ~21 MHz tuning range. This meant soldering in and removing these tank components frequently. Click for the lowest frequency output. Click for the highest.

In the example local oscillators I reviewed, the engineers made no attempt to level off the signal that normally increases in AC voltage as you increase frequency. I also ignored levelling. Presumably the designers didn't worry with leveling the oscillator output in their superhet receiver as long as the output voltage sufficiently drove the mixer into complete switching. Levelling would add cost and complexity. This isn't a lab grade RF signal generator — that's for sure.

At present, the AFC varactor pair is disconnected since I won't know how strongly to couple it with Cx until I have a working detector. Also I will need to experiment to determine the best R-C time constant for the low-pass filter; likely the 2.2 uF capacitor will need an increase in value.

With the 3K9 Ω resistor under the 5K tuning pot, I keep at least 5 VDC on the tuning varactors or the VCO would stop running as I tuned the pot towards CCW. The coil = about 3 turns of 16 gauge wire on a 5/8 inch bolt. (Despite Canada going metric in ~1975, they still sell nuts and bolts in inches at our hardware stores). The stiff wire prevents the inductor from turning into a "microphonic" spring when the VCO is bumped. Click for a photo. The nominal L = ~ 125 nH, although I bent and manipulated the coil so it sat attached to the copper clad board with no tension and then squished or expanded the turns to establish my lower band edge.

In many FM receivers, either a single or balanced dual-gate MOSFET mixer was driven by a high impedance buffer/amplifer. If I mix with a 2-gate MOSFET, I'll insert a common gate JFET amplifier on the IF strip to boost the LO output impedance and AC voltage.

The feedthrough capacitors are 0.0047 µF - they were on sale so I bought them. To prevent a parasitic high impedance when placed in parallel with my standard 0.001 µF bypass caps, I placed a series 10 Ω resistor.

I enjoyed this crazy design; trying to replicate a relic, but popular local oscillator idea from decades ago. Let's hope I did it justice. Perhaps future VHF stuff on the FM and even 2 meter band will involve an Si570 and PIC, Arduino or other microcontroller? This simple VCO will do for now. My greatest passion lies in designing and building the front end.

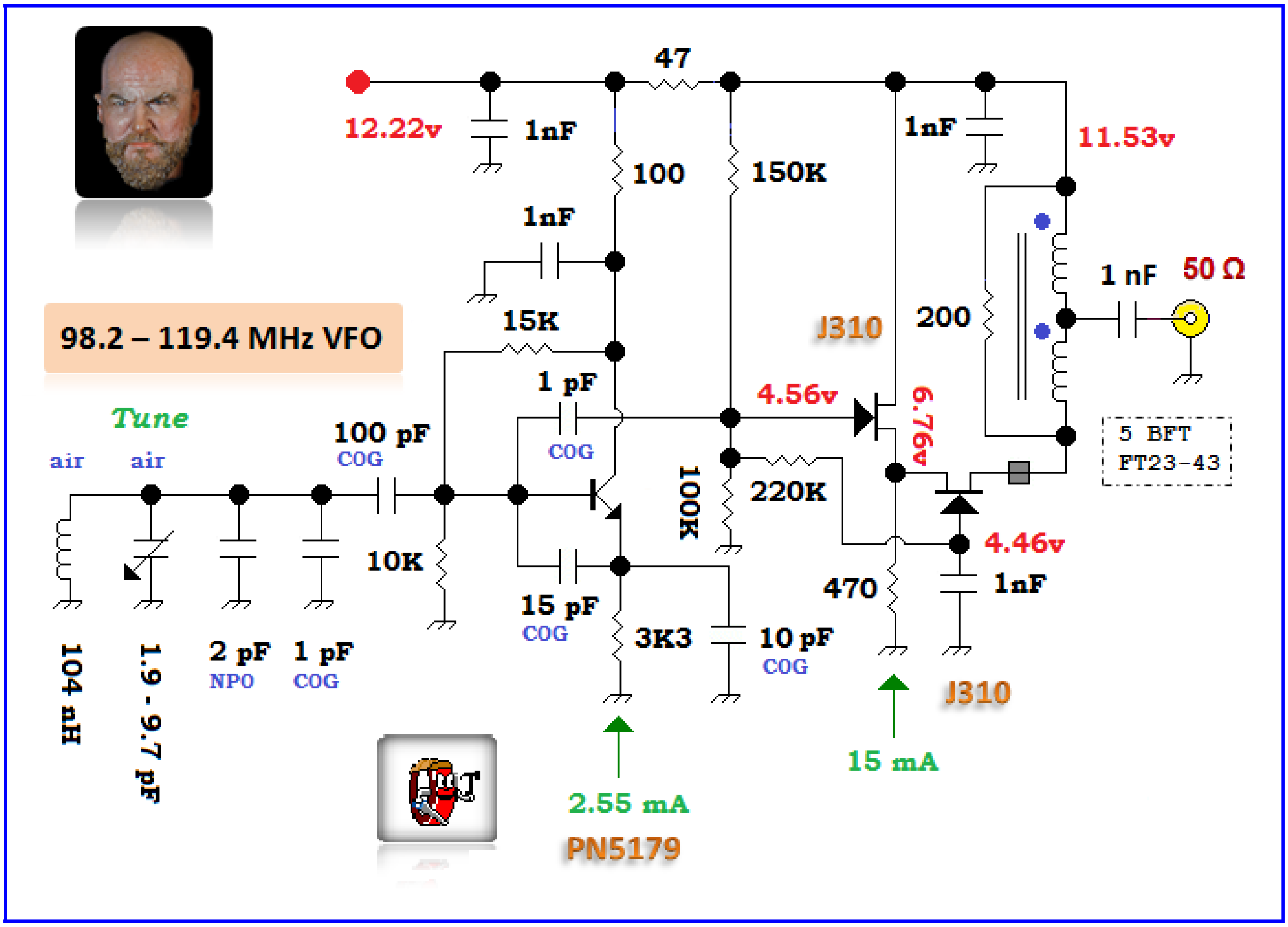
98.2 – 119.4 MHz VFO
12.22v
1nF
47
100
150K
1nF
11.53v
1nF
1 nF
50 Ω
15K
J310
200
1 pF
COG
4.56v
6.76v
Tune
air
air
100 pF
COG
100K
220K
5 BFT
FT23-43
10K
15 pF
COG
3K3
10 pF
COG
470
4.46v
1nF
104 nH
1.9 - 9.7 pF
2 pF
NPO
1 pF
COG
J310
15 mA
2.55 mA
PN5179

Above — A well-buffered, bench-module, high-side VFO I sometimes use for broadcast FM band mixing into a 10.7 MHz IF. The output at 98.5 MHz = -5.35 dBm, perfect for switching Gilbert cell mixers with a little padding or amplitude tweaking. Click for the output of the Colpitts only with a 10X probe @ 120 MHz. With care, you can see the second harmonic in the 'scope tracing — click for the SA tracing that shows the 2nd harmonic 27.5 dB down from the carrier. Click for a 'scope tracing with my MMIC bench module amplifier from VHF Veronica connected; the amp exerts some low-pass filtering that cleans up the signal somewhat.

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3. DC-DC Converter for VCOs

Until now, I ran a maximum reverse DC voltage of ~12 volts in my varactors. For wider VCO or L-C filter tuning, builders may chose 28 volt varactors such as the BB535 or BB149A and boost the 12v supply up to 28v with a DC-DC converter. Some build inductorless converters pulsed from 555 timers, or use CMOS voltage converters like the CL7662, or Si7661 to make a doubler. As an RF constructor, I like working with coils and built the following circuit:

DC–DC CONVERTER
SET DC
28V
OUT

Above — Bench module: 28v DC to DC converter. While containing no tuning control pot, my build places the zener diode regulator control potentiometer on the front panel to allow fast-tweaking of the output voltage from ~21-30 VDC depending on the load. Click for the breadboard photo.

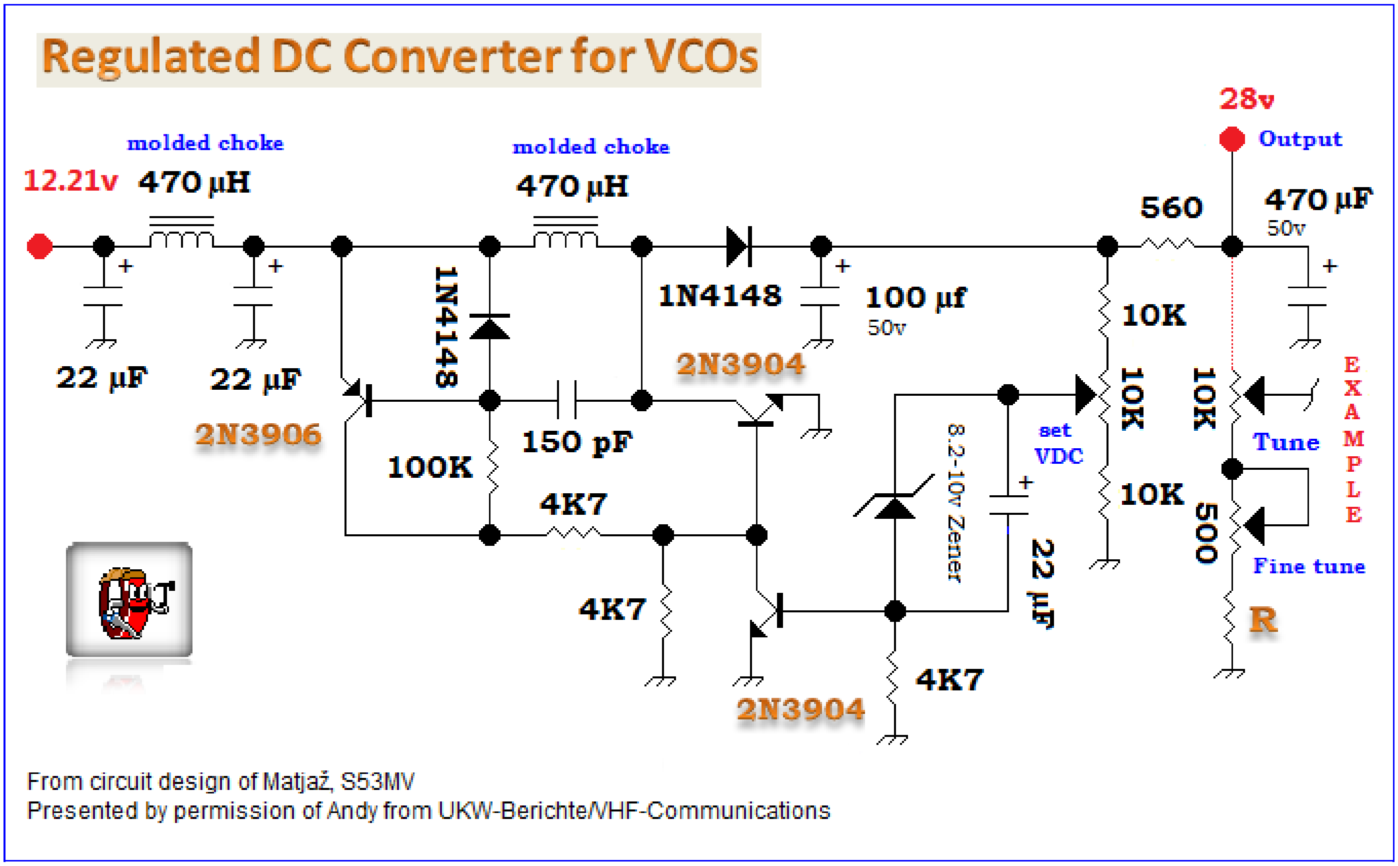
Regulated DC Converter for VCOs
12.21v
molded choke
470 µH
22 µF
22 µF
2N3906
100K
1N4148
molded choke
470 µH
150 pF
4K7
4K7
1N4148
100 µf
50v
2N3904
2N3904
4K7
8.2-10v Zener
22 µF
set
VDC
560
10K
10K
10K
28v
Output
470 µF
50v
10K
Tune
500
Fine tune
R
E
X
A
M
P
L
E

From circuit design of Matjaž, S53MV
Presented by permission of Andy from UKW-Berichte/VHF-Communications

Above — My regulated 28v converter for varactor tuning adapted from a design by Matjaž, S53MV. I pulled this circuit from his *amazing* 2-part article with circuits that span from 11 GHz RF to DC. *See the reference articles below*. I filtered heavily and at switch-on, my circuit draws ~ 50 mA, but then drops to ~ 11 mA after the capacitors charge. The 10K *[set VDC]* trimmer pot allows you to dial in your desired output voltage and thus this converter may work over a wide range of DC power supply voltages.

The tuning control(s) might be a single potentiometer, or even seperate pots for tuning 2 different VCOs. In the above schematic, I show 1 possible tuning scheme: a 10K coarse tuning in series with a 500 Ω fine tuning potentiometer. R keeps some minimal reverse DC on the varactor(s) and is optional. Again, my bench module DC converter omits any tuning controls — these are built into the circuit containing the varactor diode(s).

The oscillator frequency varies slightly with the set output voltage. Click for a screen capture at ~32 VAC with a 10X probe placed on the PNP emitter. In another test, with no load, I watched the coil's magnetic field collapse and ring in this cool 'scope capture. This is why I love deep memory DSOs so much.

VHF
COMMUNICATIONS

TV Satellite Receive System Part 1 : Low Noise 11 Ghz Down Converter ---- issue 4/86

TV Satellite Receive System, Part 2 : Indoor Unit ------- issue 1/87

http://www.vhfcomm.co.uk/

Above — Andy, G8ATD who owns VHF Communications magazine granted me permission to show the DC converter circuit. His magazine archives provide a treasure trove of useful circuits from VHF to Microwave and it's clear Andy passionately spent lots of time publishing the magazine until 2013, plus scanning and organizing the archived material.
Although VHF, UHF and microwave focused, much of the concepts and learning can also enrich your HF exploits.

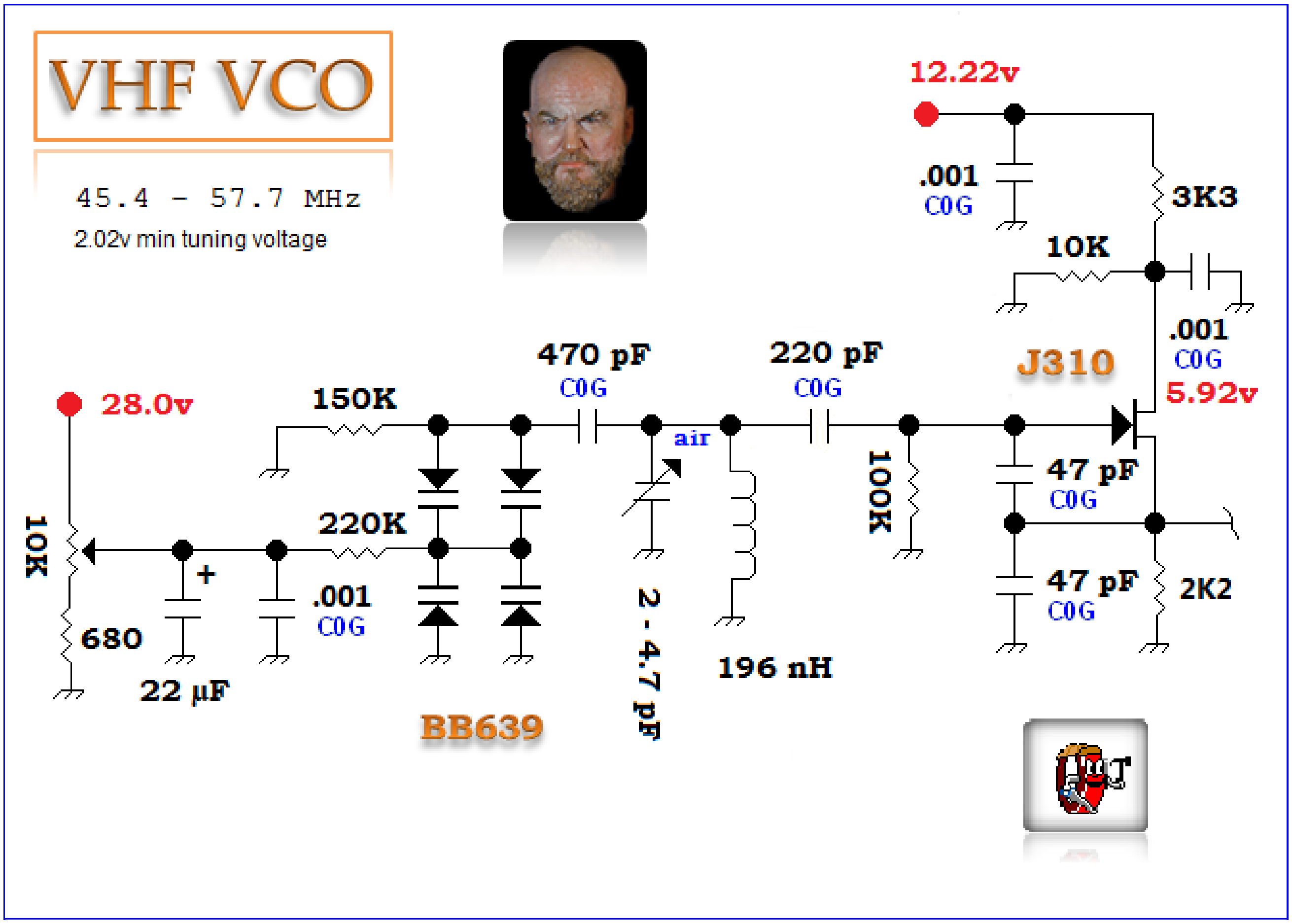
VHF VCO
45.4 - 57.7 MHz
2.02v min tuning voltage
12.22v
.001
C0G
3K3
10K
.001
C0G
J310
5.92v
28.0v
150K
470 pF
C0G
220 pF
C0G
air
100K
47 pF
C0G
10K
220K
+
.001
C0G
680
22 µF
2 - 4.7 pF
196 nH
47 pF
C0G
2K2
BB639

Above — A "quicky" VCO thrown together to test the DC-converter. Click and click for the output with the tuning pot set to fully CCW and then

CW. The 680 R keeps about 2 volts on the varactors with the tuning pot set to CCW.

In the reference articles cited above, you'll find 2 HF-VHF Hartley VFO designs that tune over a 20 MHz span thanks to 28 volt varactors and careful design. In yet another UHF circuit, a 1 octave tuning span is realized with the author's specially designed VCO. Truly hardcore design from a great teacher — I crave exposure to the work of such authors.

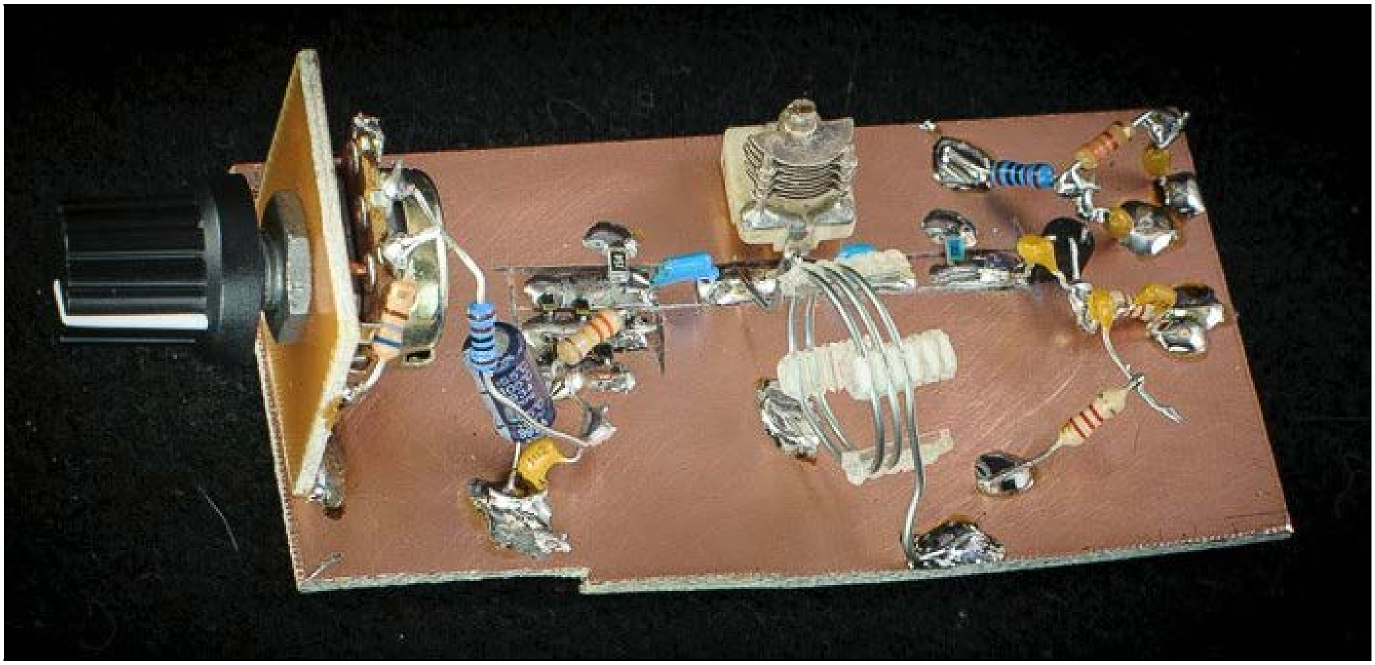

Above — A photo of my "quicky" VHF VCO. 73!

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4. Supplemental Web Page #1

Click for the first supplemental web page.

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5. Miscellaneous Photos or Figures

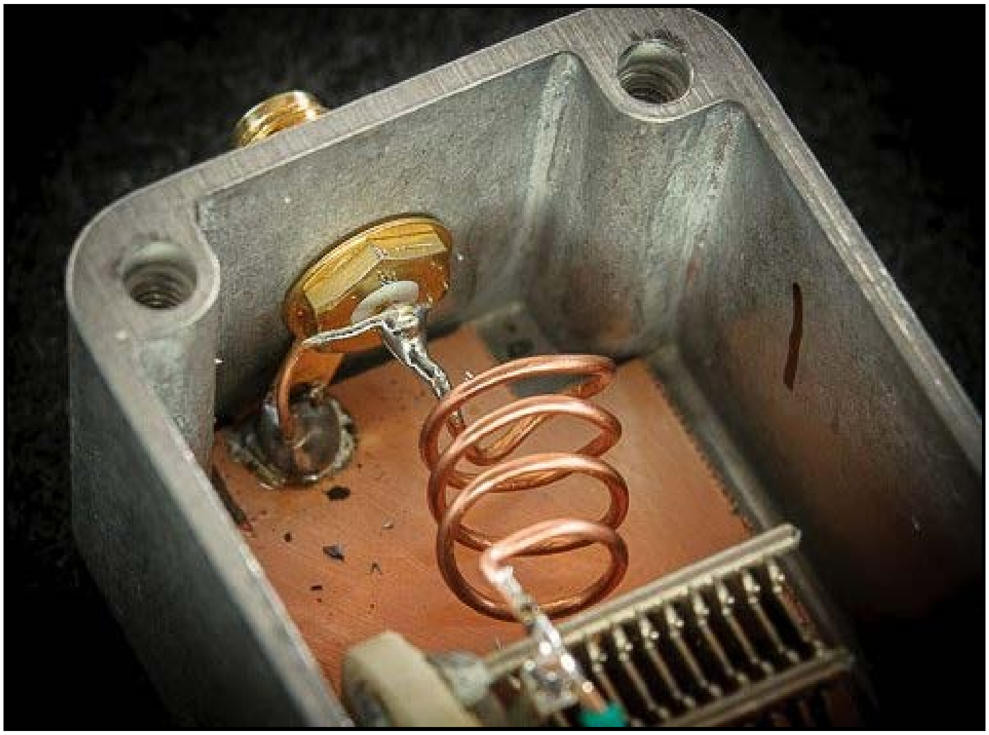

Regency
TRANS
OFF | VOL
SQUELCH
MIC
F1
F2
F3
F4
BTL-304
VHF-FM
IVER

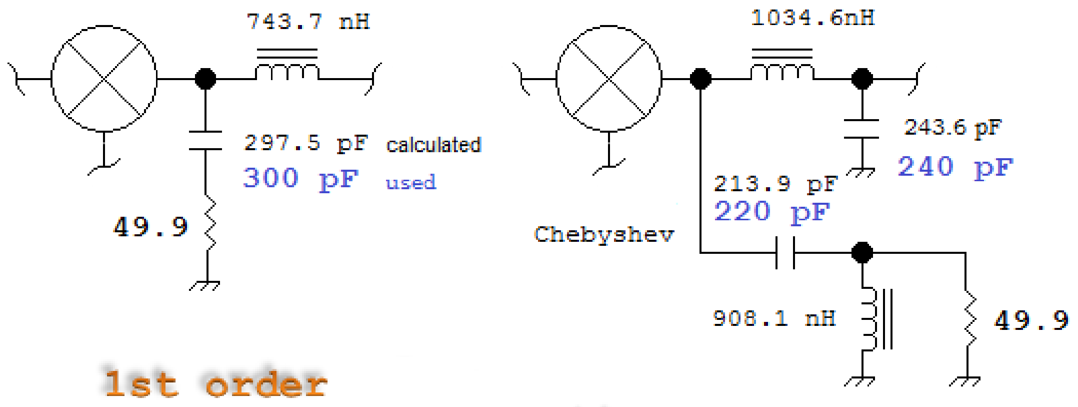
743.7 nH
297.5 pF calculated
300 pF used
49.9
1st order
1034.6nH
243.6 pF
240 pF
213.9 pF
220 pF
Chebyshev
908.1 nH
49.9

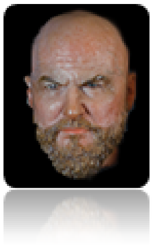

10.7 MHz IF Diplexer

2nd order

Oct 19, 2013

VE7BPO

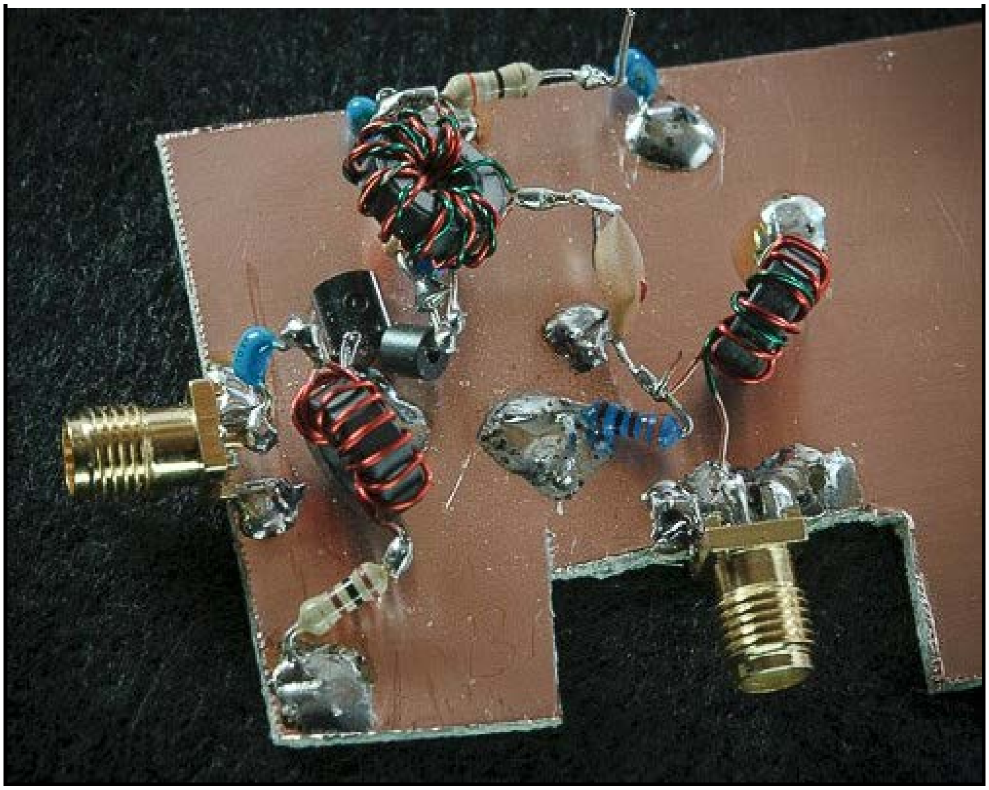

DELL

QRP SWL HOMEBUILDER

RF — Test and Measurement

Sundry Experiments 2012 - 2013

This page shows some of my better non-VHF experiments for 2012-2013.

Although VHF and UHF excite me greatly, It's always fun to build at HF, or even AF.

Section 1: I explain why you might see sweeps that look like oscilloscope tracings on QRPHB: they're devices swept with equipment designed by Bob, K3NHI. Bob's work simply amazes me — full-on, creative precocity.

Section 2: An LM1875 AF power amplifer test.

Section 3: Three Questions with Jason, NT7S.

Section 4: EMRFD Experiments — A 1-on-1 Tracking or Offset Phase-locked Loop.

Section 5: Boot-strapped Popcorn AF Feedback Pair.

Section 6: Non-Mechanical Iambic Paddle.

Section 7: A Journey Above HF.

Section 8: Popcorn AF Amplifier — Reprise

Section 9: The Progressive Receiver by John, K5IRK and Wes, W7ZOI

Section 10: Miscellaneous Pictures and Figures

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1. Analog Sweep System

Today, advanced experimenters might build a network analyzer/sweeper incorporating a microcontroller, a DDS, or Si570 based frequency synthesizer, plus the needed analog RF circuitry. I went another direction: the Bob Kopski, K3NHI sweep system — all analog, no lines of code and probably 4X the bench work. I show some photos, traces and text in hope it might inspire you to pursue your own sweep system — digital-based or otherwise.

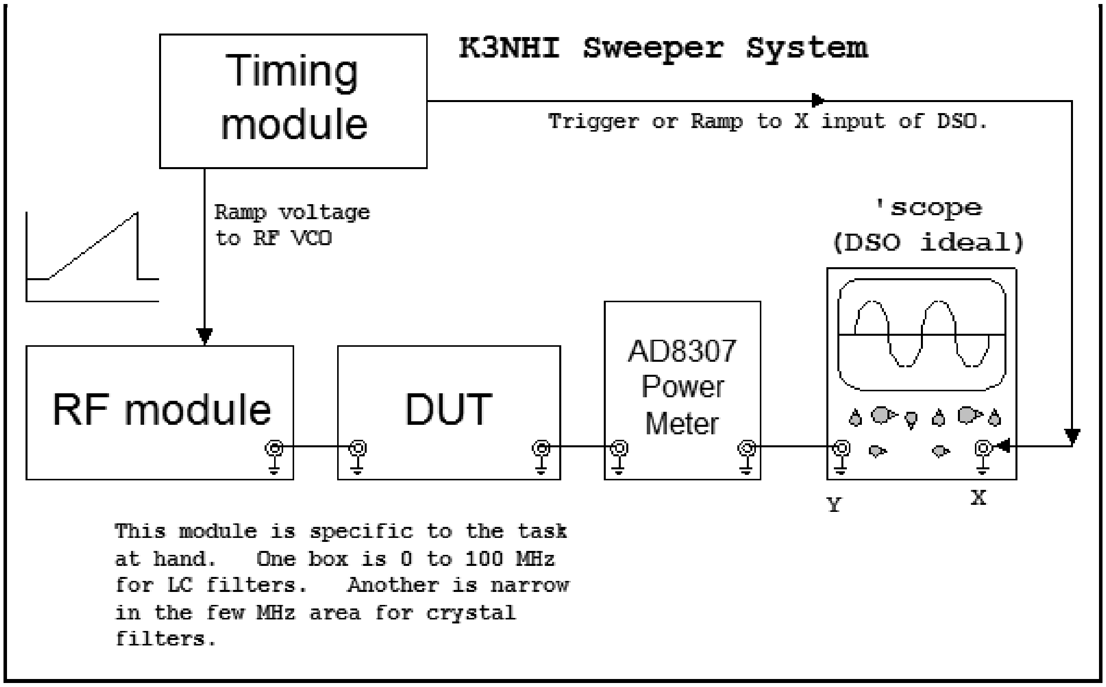
K3NHI Sweeper System
Timing module
Trigger or Ramp to X input of DSO.
Ramp voltage to RF VCO
'scope (DSO ideal)
RF module
DUT
AD8307 Power Meter
Y
X

This module is specific to the task at hand. One box is 0 to 100 MHz for LC filters. Another is narrow in the few MHz area for crystal filters.

Above — The K3NHI Sweep System macro diagram drawn by Wes. The resultant trace looks like the output of a tracking generator plus spectrum analyzer. What I like most is that I'm measuring with my "tough" 'scope and need not worry about input power and so forth like we do with expensive RF test gear. I simply love measuring signals with my oscilloscope. Testing circuits with Bob's sweep system compels me to treasure component-level analog design and renews my passion afresh.

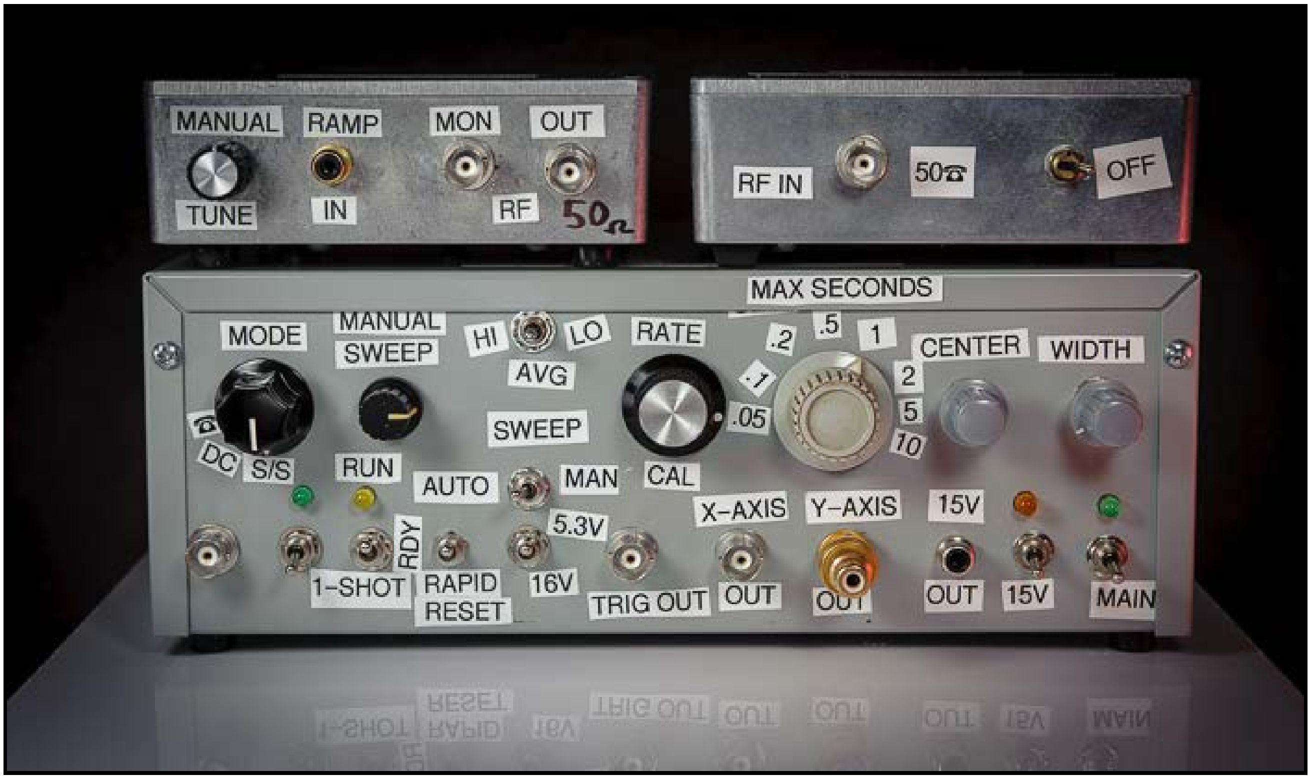
MANUAL
RAMP
MON
OUT
TUNE
IN
RF
50Ω
RF IN
50Ω
OFF
MAX SECONDS
MODE
MANUAL SWEEP
HI
LO
AVG
RATE
.2
.5
1
.1
.05
2
5
10
CENTER
WIDTH
SWEEP
DC
S/S
RUN
AUTO
MAN
CAL
RDY
5.3V
X-AXIS
Y-AXIS
15V
1-SHOT
RAPID RESET
16V
TRIG OUT
OUT
OUT
OUT
15V
MAIN

Above — 3 components of my K3NHI sweep system. Click for a higher resolution photo. To date, I've made the Utility Sweep Generator (time base) *on the bottom*, a 1-118 MHz VCO with clean and level output *top left*, an AD8307 power meter optimized for sweeps *top right* and a crystal filter VCO *shown later*.

Building Bob's Utility Sweep Generator proved difficult. Although technically just a ramp generator, this 1 is calibrated, provides high isolation between the X and Y channels and will sweep *anything*. The power supply has 8 different regulated DC voltages including ~ - 3V. I may use it as the time base for a spectrum analyzer project 1 day.
Bob gave me permission to post the schematics: One Two Three IC1-5 is an LM324 op-amp. Doc 1 Doc 2

Email me for some build notes.

Click, click, or click for photos of the 1- 118 MHz VCO. Click for the schematics. One Two

I show a bare-bones AD8307-based Power Meter (PM) on the **RF Workbench 5** web page, however, to augment the PM for sweeping, I added input compensation, plus some tweaks from Bob's QEX articles: Bob Kopski, K3NHI — An Advanced VHF Wattmeter, QEX, May/June 2002 *and* Bob Kopski, K3NHI — A Simple Enhancement for the Advanced VHF Wattmeter, QEX, Sept/Oct 2003.

I strongly recommend you build Bob's power meter (referenced above) if you're contemplating a power meter build.

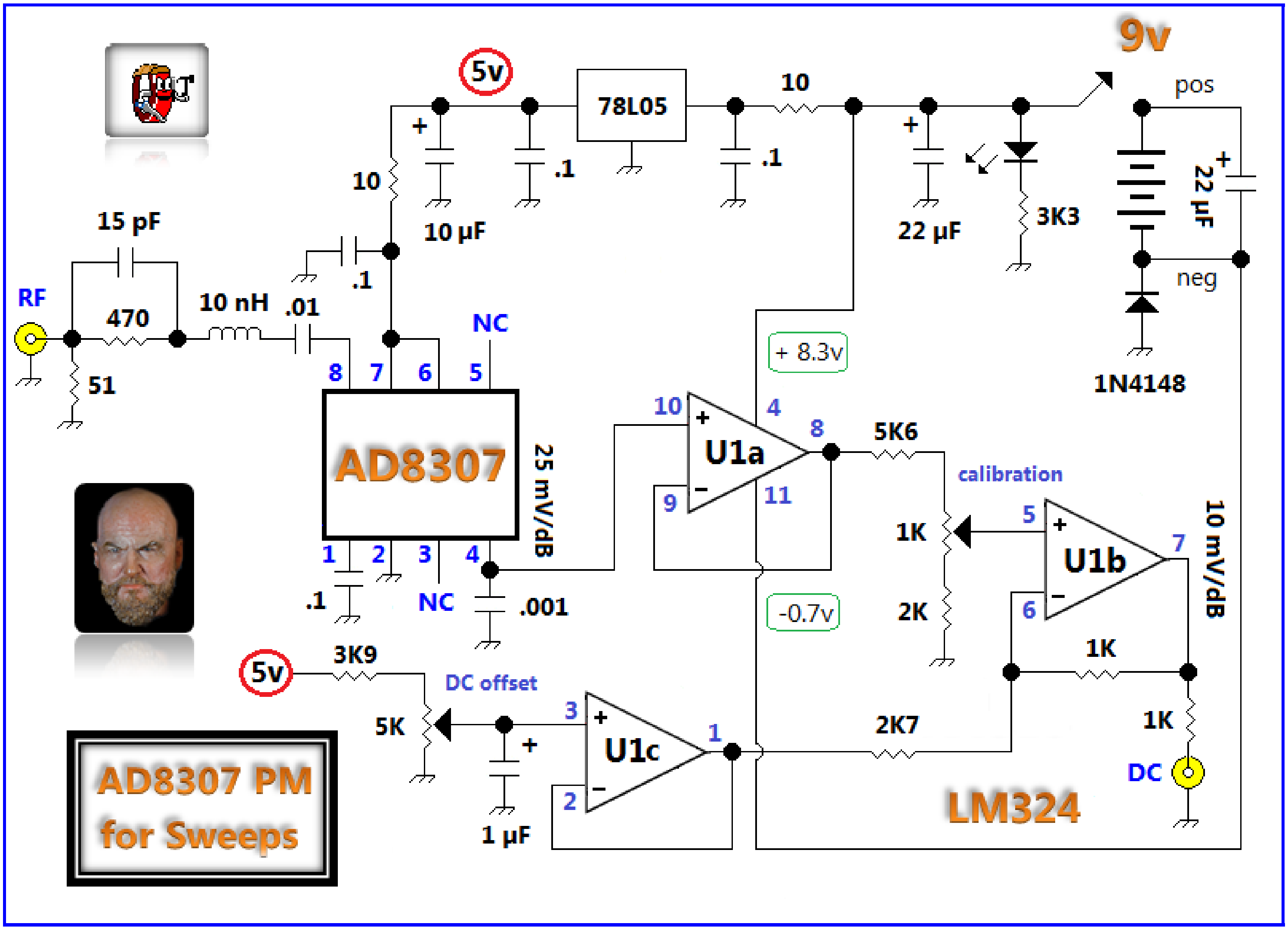
5v
78L05
10
9v
pos
+
.1
10
10 µF
22 µF
3K3
22 µF
15 pF
.1
neg
RF
470
10 nH
.01
NC
1N4148
51
8
7
6
5
+ 8.3v
AD8307
25 mV/dB
10
4
8
5K6
U1a
9
11
calibration
1K
5
U1b
7
10 mV/dB
1
2
3
4
.1
NC
.001
-0.7v
2K
6
1K
5v
3K9
DC offset
5K
3
U1c
1
2K7
1K
DC
2
1 µF
LM324
AD8307 PM
for Sweeps

Above — My AD8307-based power meter. Click for a photo of an early version lacking the level shifter. The level shifter, or DC offset control allows precise Y axis control to enable a resolution up to 1mV/dB when set up properly in the DSO. With this resolution, it's possible to see filter ripple.

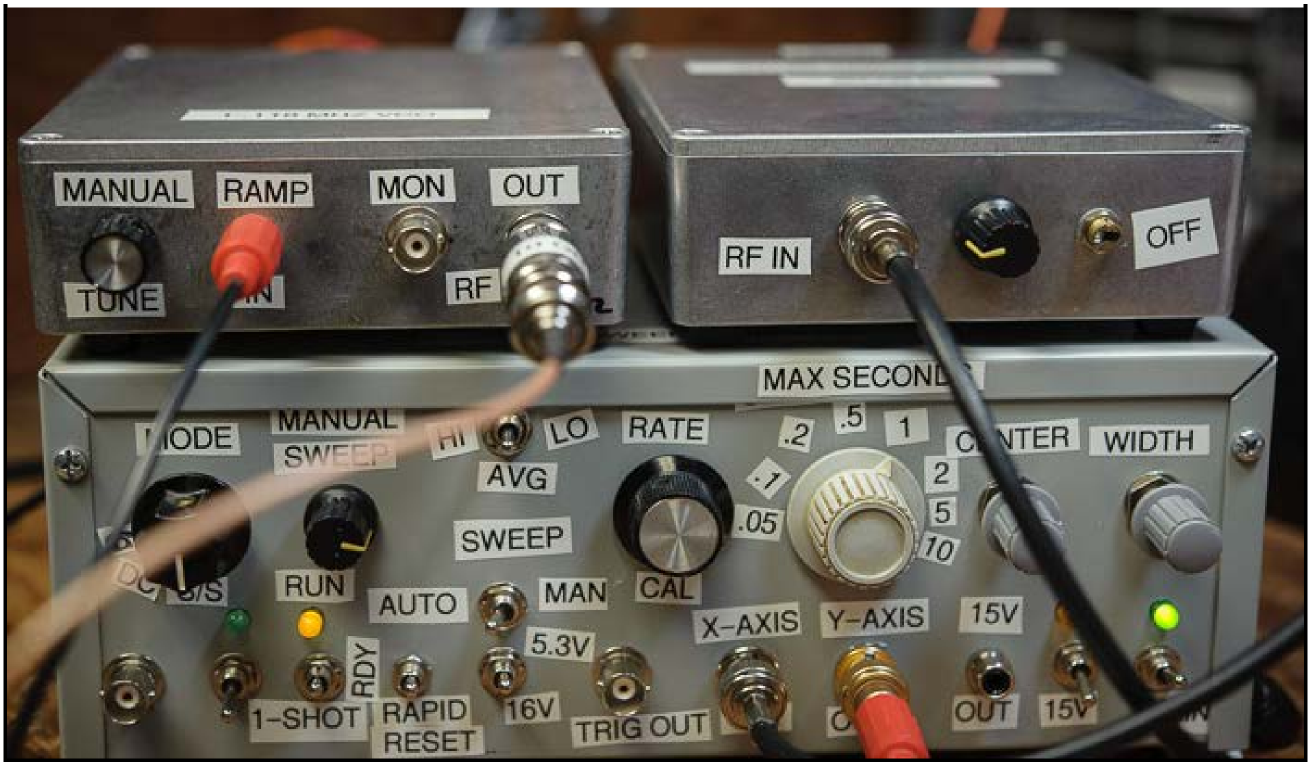
MANUAL
RAMP
MON
OUT
TUNE
RF
RF IN
OFF
MANUAL SWEEP
HI
LO
AVG
RATE
.2
.5
1
WIDTH
.1
2
.05
5
10
SWEEP
RUN
AUTO
MAN
CAL
X-AXIS
Y-AXIS
15V
5.3V
RDY
1-SHOT
RAPID RESET
16V
TRIG OUT
OUT
15V

Above — The K3NHI sweep system in action. This photo shows the power meter with the (later) added DC offset control. Using the offset control potentiometer, I'm able to examine the top of a signal peak at 1 dB per division with various spans.

7 MHZ BANDPASS
BW-237 KHZ IL-2.1 DB

Above — I swept a 7 MHz band-pass filter bench module.

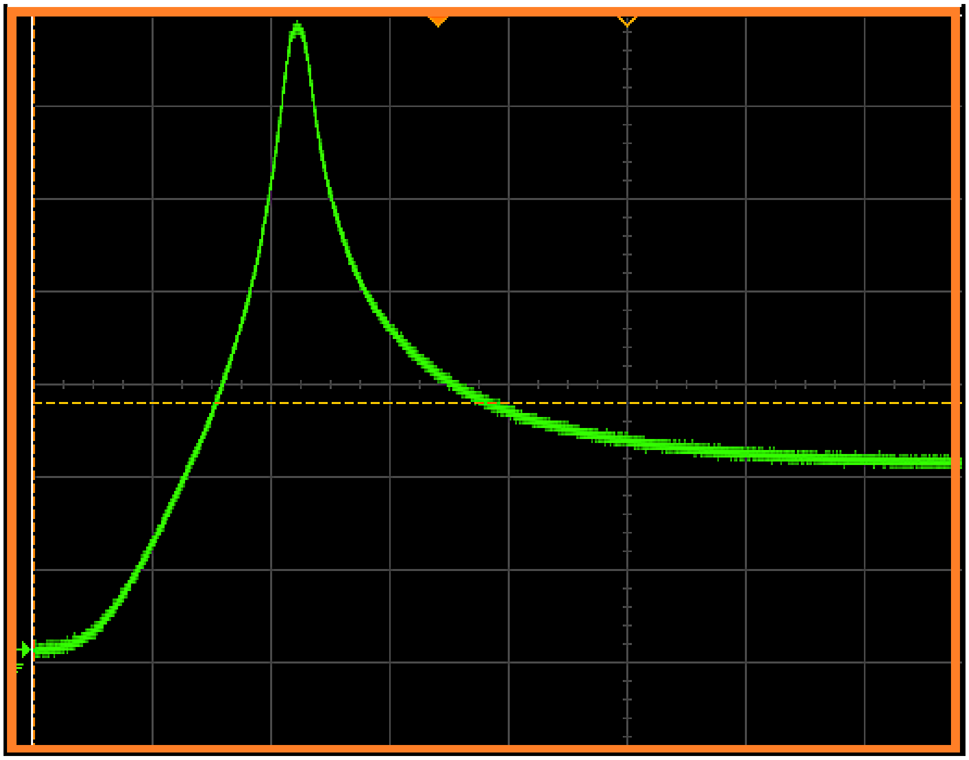

Above — A sweep of the above 7 MHz band-pass filter. At the time I was still learning system calibration and remember feeling blissful that I made such a cool sweep system.

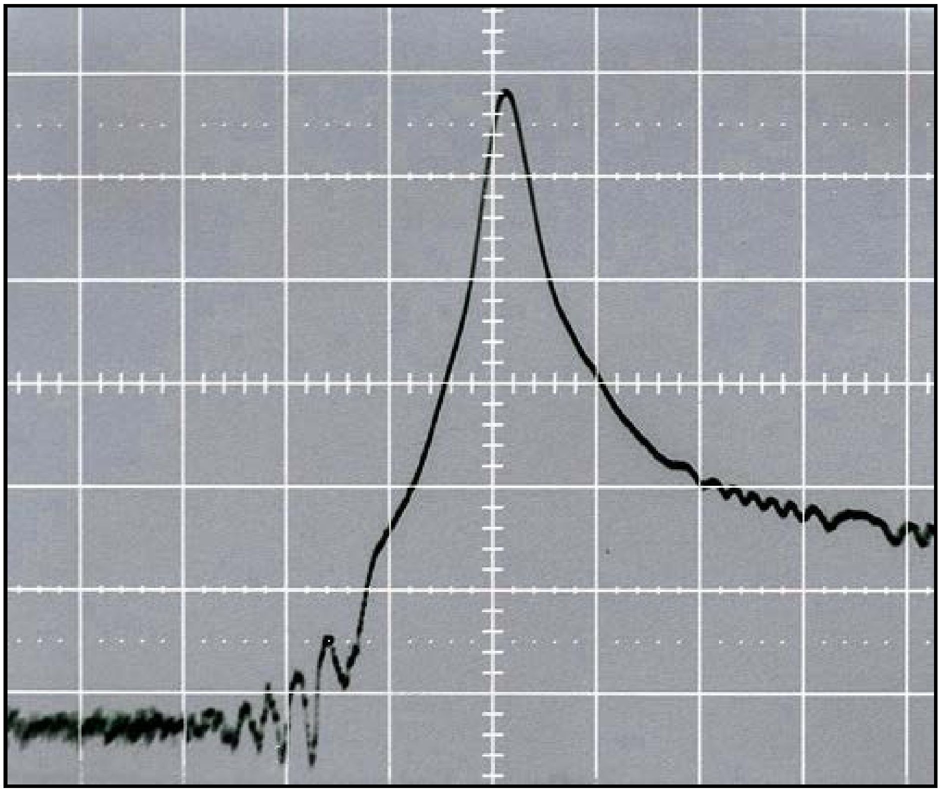

Above — A sweep of the 7 MHz band-pass filter with a tracking generator plus spectrum analyzer for comparison. The span differed from that used with the K3NHI sweep system, however, I'm sure I'll get better with the K3NHI system over time.

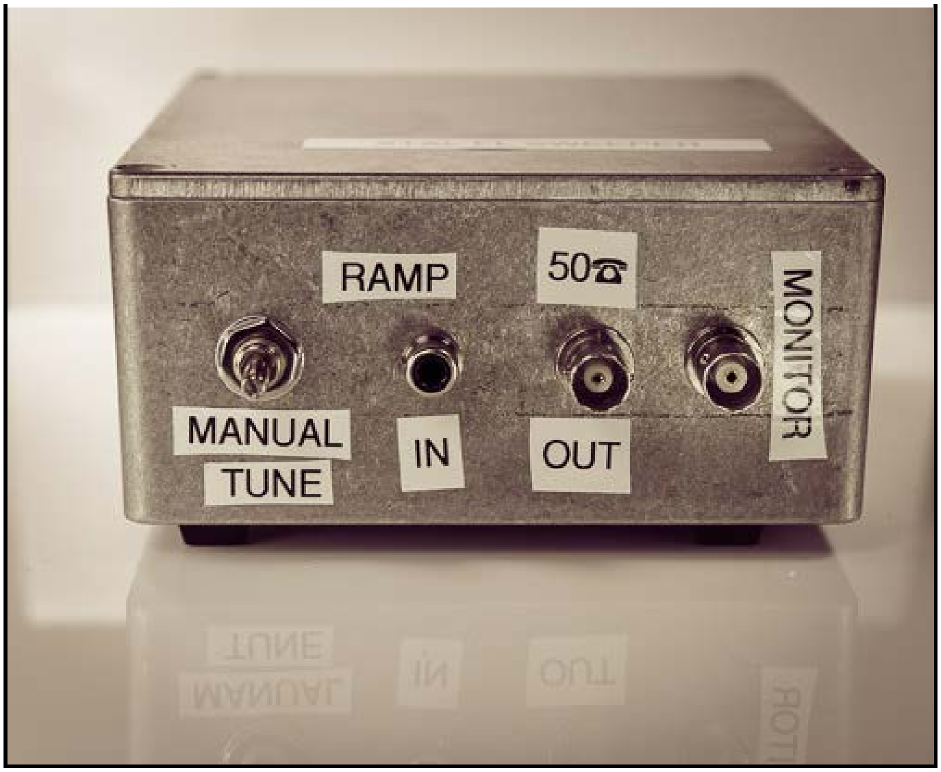

Above — My build of the K3NHI *Hartley* VCO for sweeping crystal filters. I ordered a 4 mm tuning knob for the 10-turn "Manual Tune" potentiometer used to help center the sweep in my 'scope. This 10-turn pot, a DIP switch with C's and a secondary L, plus two MV209 varactors allow narrow resolution sweeps (< 5 Hz nominal) within a ~2.5 - 18 MHz range.

I monitor the sweep frequency on a counter via the VCO monitor port and all the tweaks on this VCO and the Utility Sweep Generator allow easy filter centering. Click for a breadboard of the VCO with the first buffer and a temporary BNC connector for testing. Click for the whole project. The secondary wideband buffer provides strong signal fidelity, reverse isolation and output return loss (22.3 dB) — it draws 61 mA. Click for the VCO schematic courtesy of Bob, K3NHI. Click for a side-by-side of a xtal filter as measured with Bob's sweep system plus an N2PK VNA.

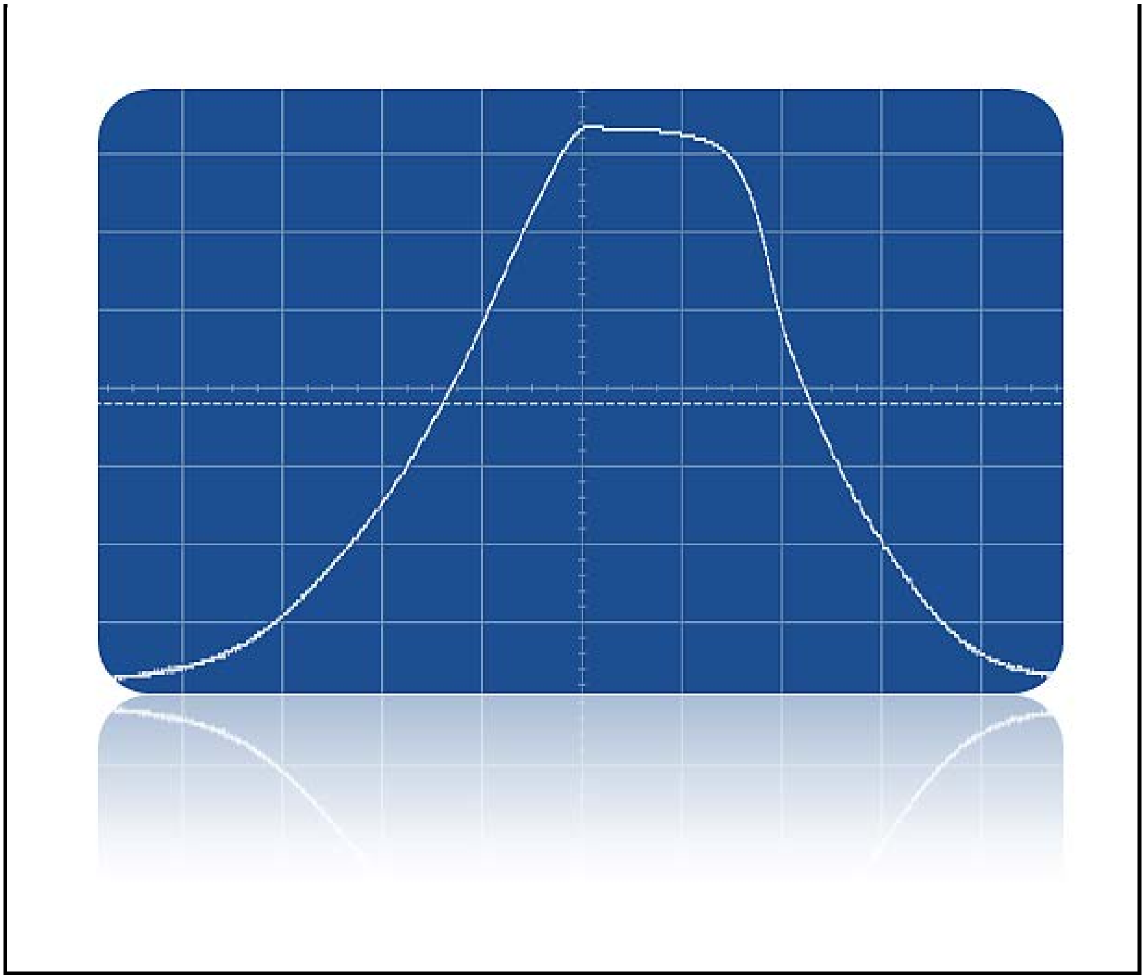

Above — I made and then swept a simple ~500 Hertz wide 4.9152 MHz Cohn or Min-Loss filter using 4 crystals.

So now, if you see sweeps on the site that look like oscilloscope tracings, you'll understand how they were created. I've learned so much from Bob's work and his mentorship last Spring. John, K5IRK coached me also.

QRP-POSDATA for October 2013

3 builders incorporated Bob's sweep system circuitry into projects including a receiver, a spectrum analyzer and the following build of the Utility Sweep Generator (USG) by Jay: Jay built some PC boards to simplify the wiring challenge this USG presents. Click 1 Click 2 Click 3. Great stuff — thanks for sharing.

QRP-POSDATA for March 2014 — Poor Hams Scalar Network Analyzer (PHSNA) —

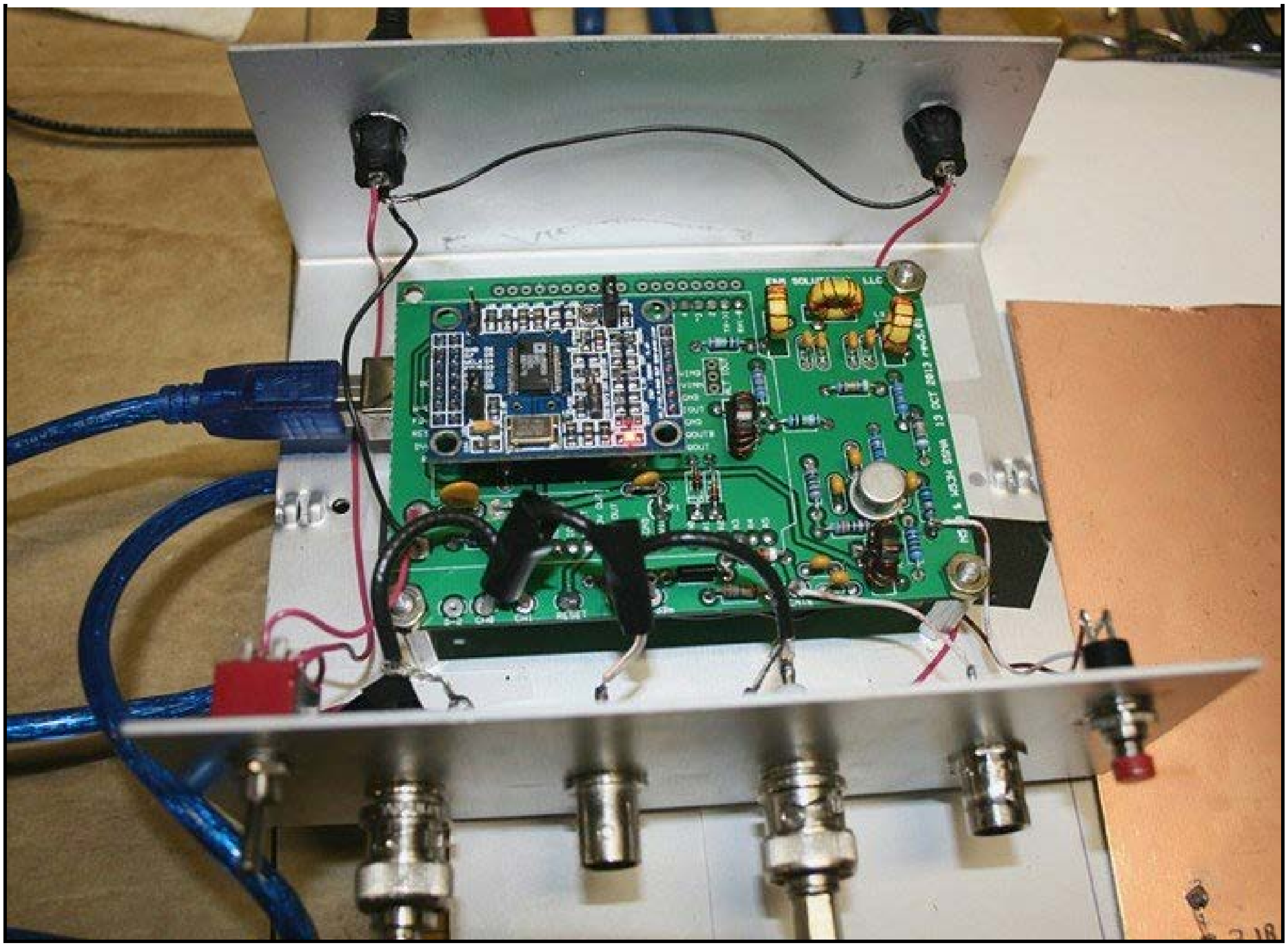

Above — The PHSNA built by Mikey, WB8ICN.

Jerry W5JH, along with Jim, N5IB and Nick, WA5BDU developed this low-cost sweeper/ lab toolkit.

The Poor Hams Scalar Network Analyzer consists of an Arduino UNO R3, plus an AD9850, or AD9851 DDS, a W7ZOI/W7PUA Power Meter and a MS Windows OS based computer. Builders can scan and plot L-C filters, crystal filters, RF amplifiers and such — much like Bob's sweep system — or an HF tracking generator + spectrum analyzer. The PHSNA also measures crystal parameters with little fuss. Connect a return loss bridge to easily sweep return loss measures of the input or output ports of filters, amplifiers, antennas and more. The total cost to build the PHSNA is approximately $50-60 USD.

Mikey graciously sent me some photographs of his PHSNA build. Complete system in his lab with the chassis lids removed for these photos. Monitor photo showing menu choices. Power meter. Mikey's jig to examine crystals with a 12.5 Ω termination. Once you own a calibrated sweep system, you'll wonder how you ever managed without 1.

Thanks again to Mikey for the photos. I built and tested the return loss bridge using the PCB from the PHSNA Yahoo group. Click for a 613 KB pdf file of my build. Nick, WA5BDU web site.

Hats off to Jerry and crew for this open-system project! A Yahoo group called PHSNA serves as the communications hub and houses superb, detailed documentation. You need to join Yahoo to access this group. Then search for PHNSA and while your at it, also sign onto the EMRFD group.

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2. LM1875 Audio Power Amplifier

I tested the LM1875 AF power amplifer because its specifications look great: 20 watts into a 4Ω or 8Ω load on ±25V supplies and a TO-220 package for easy heat sinking. Of course, for this web site, I tested it with a typical radio experimenter bench power supply; a single-supply at ~ 12 VDC.

This is probably not a great part for Ugly Construction and I *attempted* to return the load ground, the output Zobel RC filter network, feedback loop and input grounds to a central grounding point through separate paths cut paths into my copper board. A better breadboard method might include the so called "star grounding".

I saw RF oscillations on the 'scope and removed them by soldering a 0.001μF bypass capacitor across the input. A 470 pF bypass capacitor did not work well enough. The datasheet describes specific causes and cures for RF oscillations and I've learned they must be heeded. I once found similar problems with an LM380.

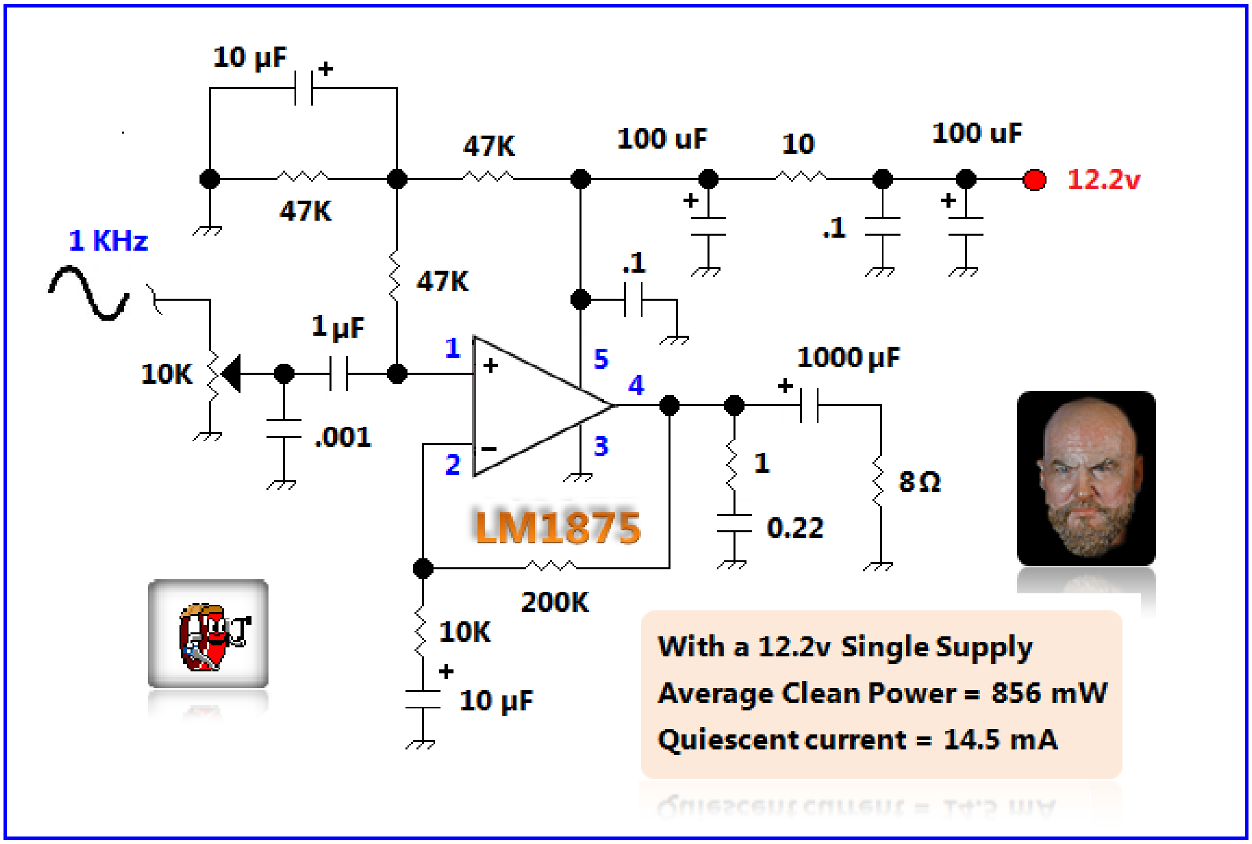
10 µF
+
47K
100 uF
10
100 uF
12.2v
47K
+
.1
+
1 KHz
47K
.1
1 µF
1
+
5
4
1000 µF
+
10K
.001
2
−
3
1
8Ω
0.22
LM1875
200K
10K
+
10 µF
With a 12.2v Single Supply
Average Clean Power = 856 mW
Quiescent current = 14.5 mA

Above — The LM1875 in the ~suggested datasheet, single-supply set up. This amplifer reminds me of setting up an op-amp. Unlike the LM380, within limits, you may choose the gain to suit your needs. As shown the gain = 25.6 dB. Dropping the feedback R to 100K dropped the gain down to 20.5 dB. For clean output power capacity; it blows away the LM380.

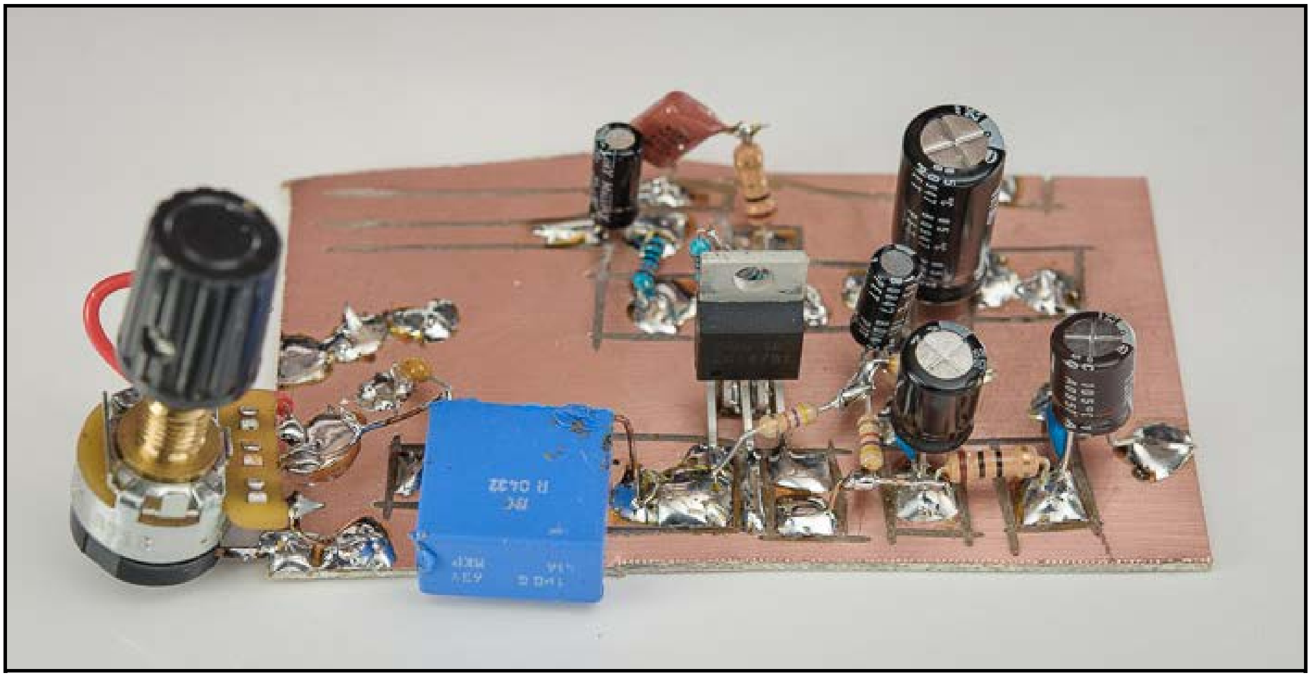

Above — My first LM1875 test breadboard. After the photo, I moved the 0.1 µF RF bypass cap right onto lead 5 — we should carefully RF bypass device power supply leads, but I got sloppy.

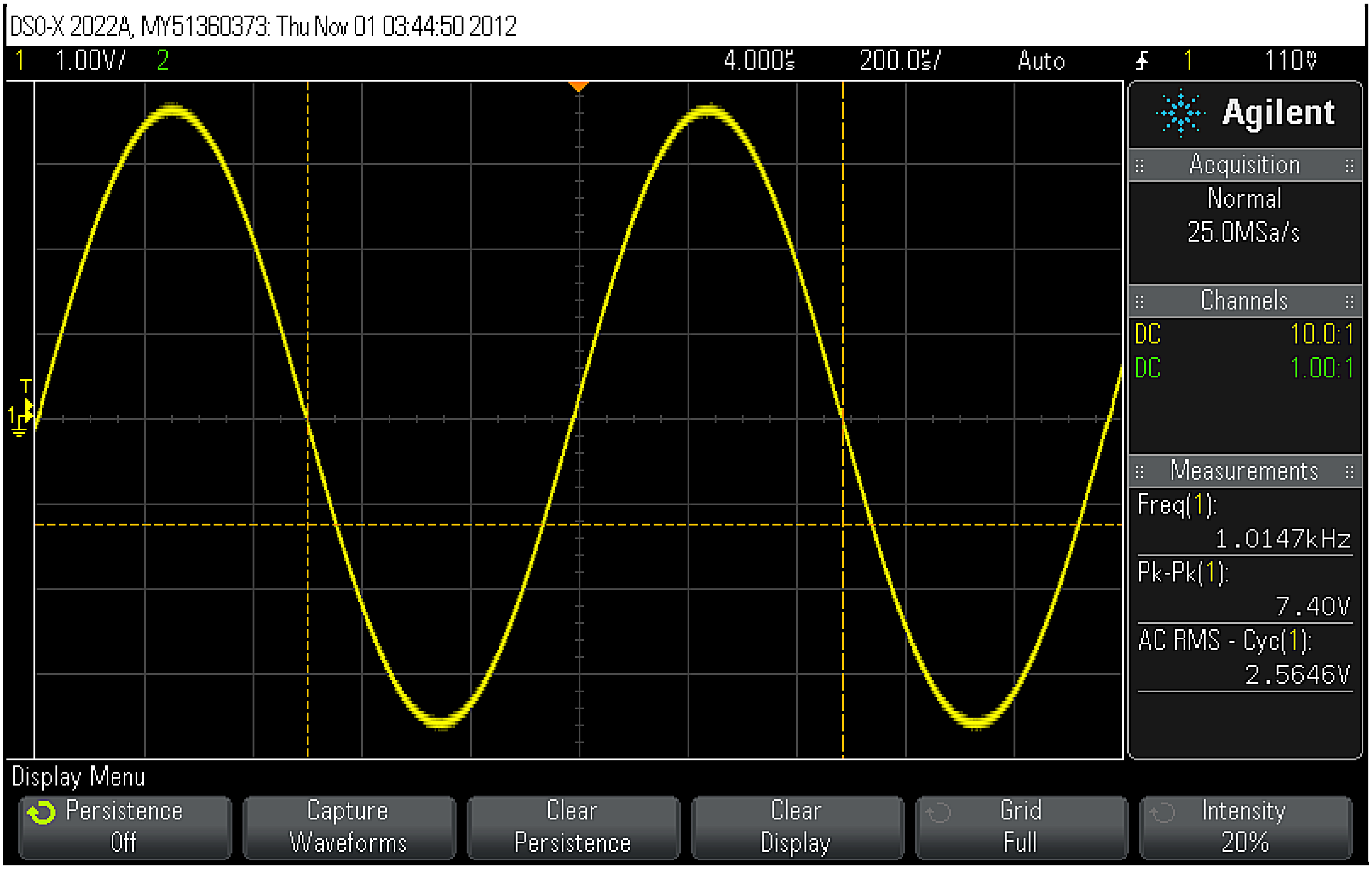

DSO-X 2022A, MY51360373: Thu Nov 01 03:44:50 2012

1 1.00V/ 2 4.000s 200.0us/ Auto 1 110mV

Acquisition
Normal
25.0MSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Freq(1): 1.0147kHz
Pk-Pk(1): 7.40V
AC RMS - Cyc(1): 2.5646V

Agilent
Display Menu
Persistence Off
Capture Waveforms
Clear Persistence
Clear Display
Grid Full
Intensity 20%

Above — At the maximum power before visible sine wave distortion appears; 856 mW. I listened to this amp while connected to a line-level tape player and an 8 Ω speaker load: very nice. I want to try it with a split +/-15 VDC supply and a star grounded breadboard since a 12v single-supply limits the output power so much. Still, at 12 volts single-supply, this IC yielded the highest clean, average output power of any AF Power chip I've tested: a worthy consideration for a high-grade receiver.

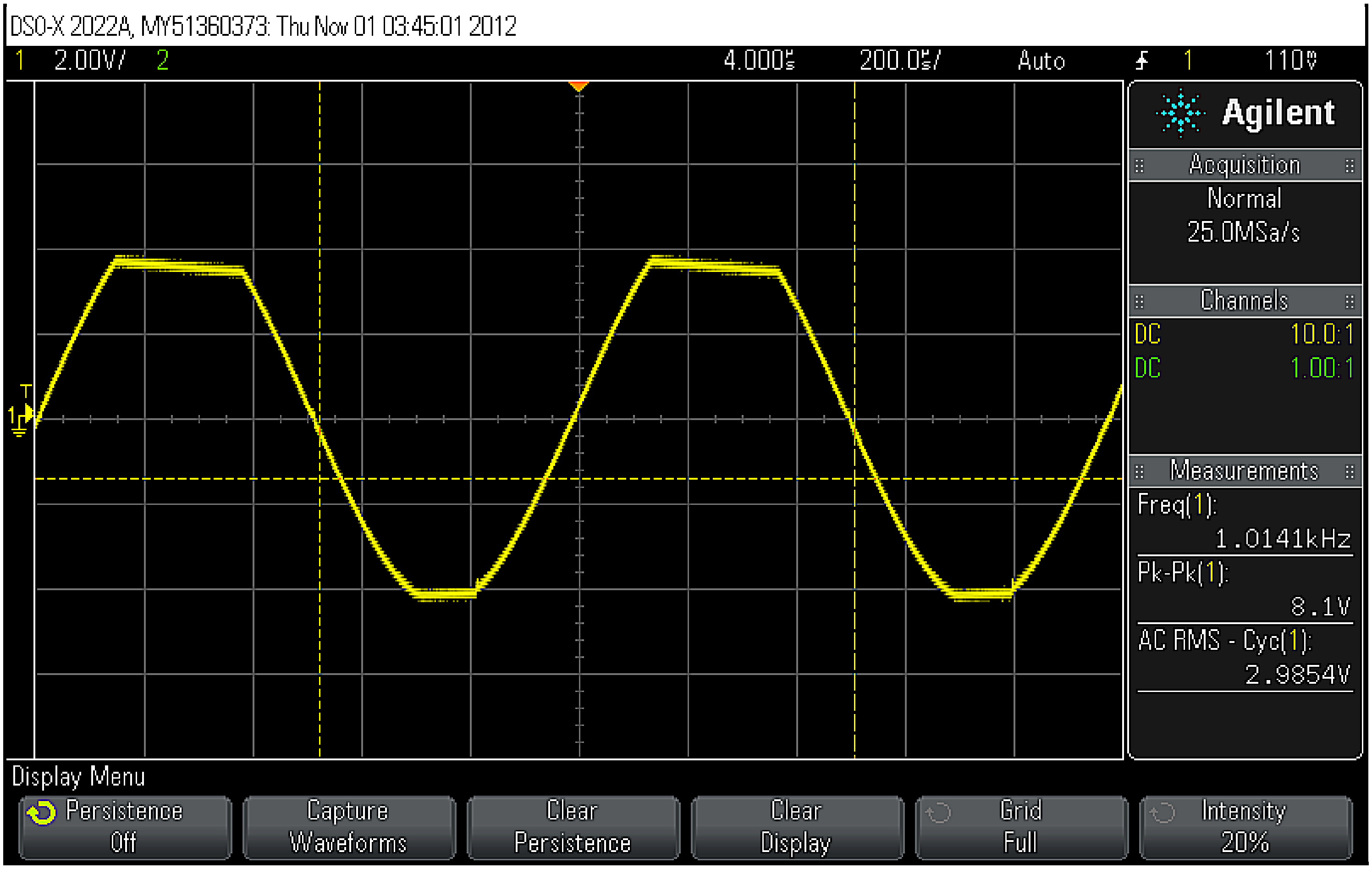

DSO-X 2022A, MY51360373: Thu Nov 01 03:45:01 2012

Acquisition: Normal, 25.0MSa/s

Channels: DC 10.0:1, DC 1.00:1

Measurements:
Freq(1): 1.0141kHz
Pk-Pk(1): 8.1V
AC RMS - Cyc(1): 2.9854V

Above — 'Scope tracing; I advanced the 10K volume pot to drive the amp into clipping.

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3. Interview — Three Questions with Jason, NT7S from Etherkit

I follow 2 English language amateur radio blogs — 1 is Ripples in the Ether by Jason, NT7S

Possessing a modern flare, Jason, the blogger, gently but resolutely challenges some of the cliquish, dogmatic thought and behavior that tarnishes amateur radio, or just blogs about fun stuff. He writes well — creating an emotional dialog that stimulates thought and reflection. We get a sense that he cares about our radio hobby and wants it to grow and improve.

Jason, the man behind Etherkit, champions a modern, open-source vision that I find both positive and refreshing.

1. Tell me about your decision to embrace the open source software philosophy for your hardware in a time where proprietary code, copyrights and patents still hold strong. How do Ham Radio equipment sellers benefit from code sharing?

I believe that the open sharing of knowledge has always been one of the cornerstones of our amateur radio community, going back to its earliest days. So the open source/open hardware ethos has always resonated with me in regard to our hobby. I started Etherkit with the intention of providing a small bit of income to my family and as a way to promote the idea of open hardware within the ham radio community at large. I have no illusions of becoming the next Elecraft, but I hope that I can build up a stable of affordable and fully-open ham radio kits that will be "hackable" and extensible for the motivated experimenter. I do this by providing the full source code for my microcontroller firmware, all of the PCB design files, Creative Commons licensed documentation, and programming ports for my products. I've already seen some neat examples of customers extending my first product (the OpenBeacon MEPT kit) by doing things such as adding in WWVB time discipline and pairing it up with a Raspberry Pi for cheap automation. I hope that others will take my code or my circuits and re-purpose them in their own work, even if they don't buy my products.

I am not an open source zealot and do not begrudge the large majority of vendors who choose to keep their intellectual property closed. However, most of what us smaller companies do is not on the cutting edge of radio. We leverage the knowledge and works of those who came before us. Perhaps if I created something wholly-new that would be patent worthy, I would consider keeping it closed, but that's not the kind of products that I'm able to develop as a one-man operation. We do not copy the designs of others, but we do take concepts that are for the most part well-tested and come with new ways to implement them. Because of that, it's my personal opinion that I have a duty to keep my designs open.

In the open hardware world at-large, there is a discussion about whether open source hurts your own business prospects. There are still some debatable points in that discussion, but I think it has been shown that if you look at the entire balance, open hardware is a good thing for smaller companies. One of the largest concerns is that under most open source licenses, a competitor can just clone your hardware and undercut your sales. That is a genuine concern, but I think that products such as Arduino have shown that if you make a quality product, most folks will recognize that quality and stick with the original.

Even if others buy a clone of your hardware, in all likelihood, that may be strengthening your brand identity (as long as that vendor isn't stealing your name). Another concern is that a customer can just copy your product for themselves. To that, I say good!. Because of the work and costs involved (economy of scale), it's going to be time and/or money consuming to make that copy. It's probably cheaper and faster to just buy the kit. The reason you copy it for personal use is because you love working with the technology. Which is exactly what I want to encourage. You may lose a small bit of sales, but I think it gives you more name recognition in the end.

2. What’s it like being a vendor at Dayton?

To be clear, I wasn't a vendor at Hamvention in 2012 (hopefully I will be there by 2014), but I was a vendor at Four Days In May at the Fairborn Holiday Inn. It was a wonderful experience to get to sit with the big names in the QRP world, selling my wares. I got the opportunity to meet tons of QRPers and build up some good relationships. Online sales are wonderful for the ultra-small operations such as myself, but nothing beats actually meeting your customers face-to-face, especially when you are at the world's most well-known QRP convention.

3. In industry, SMT parts are normal and hole-thru might better be called “hold-over”; what’s your view on kitting products with SMT parts?

We've seen some SMT kits within the QRP world, but they still are more of an oddity than anything else. I understand the concerns that people have with SMT assembly, but I think that there is still a lot of trepidation that builders needn't have. It's my opinion that SMT construction with "larger" components such 1206 or 0805 is well within the capabilities of the average kit builder. I also believe that once you are comfortable with SMT construction, it is probably faster and more efficient than through-hole construction.

OpenBeacon is a through-hole product, but I have had a QRP CW rig in development for the last two years that is a SMT design. In beta testing, I've found that one of the biggest challenges in kitting is that I have to clearly identify each and every component. With a through-hole kit, you can just throw all of the resistors or all of the capacitors together because they are clearly marked. Not so with SMT. You have to have a system to keep each value separated from the others and marked with a value. SMT resistors and semiconductors have a laser-etched value, but it's nearly impossible to see by naked-eye, and SMT capacitors generally have no markings at all.

So I have had to compartmentalize each strip of components of the same value cut from a reel, and mark them with a sticker. That is pretty costly and time-consuming. I'm hoping to find ways to streamline this process so that I can release SMT kits without the large time investment that it currently takes.

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4. EMRFD Experiments — A 1-on-1 Tracking Phase-locked Loop

I built the 1-on-1, or offset phase-locked loop circuitry described on EMRFD page 4.22 and share these schematics in faith you'll create your own. Rich with wisdom and reason, this section lies among the best topics from EMRFD. Please read Wes' notes since I won't repeat his narrative — only supply a few ideas and measurements. In the article closer, Wes suggests some modern parts to raise performance and I applied all of them with the exception of the 14 MHz VCO.

Rather than building the main VCO with divide by N circuitry to allow multiband use, I copied the original 14 MHz oscillator verbatim. Why? Well, I wanted to test this VCO: a design that wisely doesn't expose the varactor to high impedance or signal amplitude and thus avoids forward-biasing the single tuning diode. I've discussed this before on the QRP Modules 2011 web page under **7 MHz VCO Experiments**. Also, I really just wanted to learn about PLL circuitry. The Figure 1 macro schematic below illustrates this project.

In my circuit, a frequency stable 14 MHz VCO = **the goal**; the rest of the circuitry supports this.

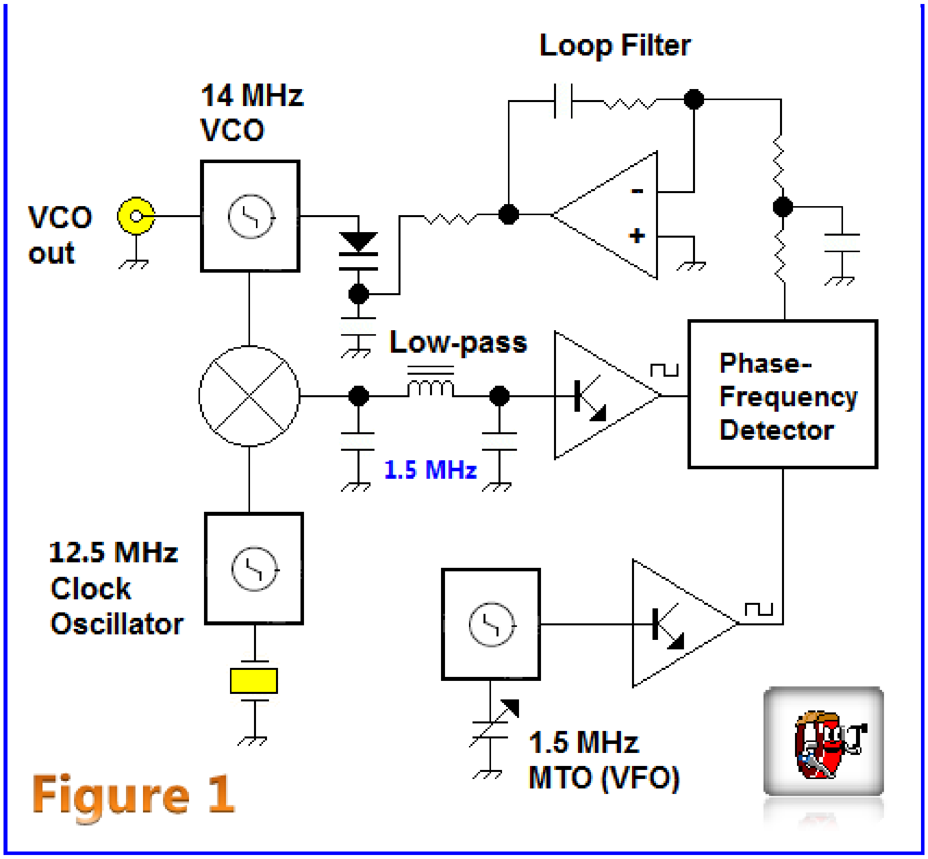

Figure 1

Loop Filter
14 MHz VCO
VCO out
Low-pass
1.5 MHz
Phase-Frequency Detector
12.5 MHz Clock Oscillator
1.5 MHz MTO (VFO)
-
+

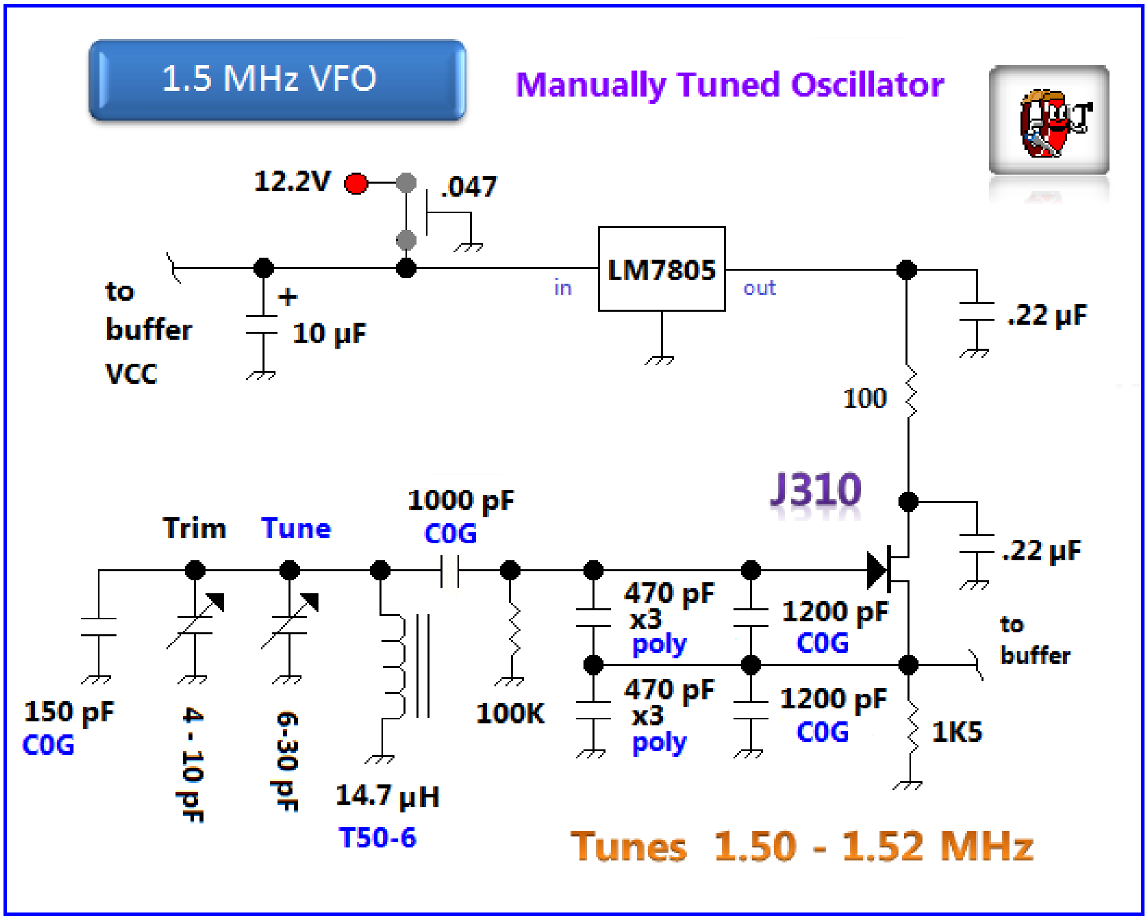

1.5 MHz VFO
Manually Tuned Oscillator
12.2V
.047
to buffer VCC
+
10 µF
in
LM7805
out
.22 µF
100
J310
.22 µF
to buffer
Trim
Tune
1000 pF
C0G
470 pF
x3
poly
1200 pF
C0G
470 pF
x3
poly
1200 pF
C0G
1K5
150 pF
C0G
4 - 10 pF
6-30 pF
14.7 µH
T50-6
100K
Tunes 1.50 - 1.52 MHz

Above — The 1.5 MHz VFO. In his modern writing, Wes calls this the MTO, or Manually Tuned Oscillator *in the context of a tracking PLL.* I wound the L with # 30 AWG wire on a T50-6 toroid.

My MTO exhibits a low tuning range (only 1.50 to 1.52 MHz) since I built in a box with a small air-variable capacitor that swung only 24 pF and I ran the "Colpitts capacitors" at 2610 pF to keep phase noise low. This box normally holds a VHF oscillator and I just removed the main board and swapped in a 1.5 MHz equipped copper board. I won't keep this PLL and thus sticking the 1.5 MHz MTO in an existing oscillator chassis with a grounded tuning shaft and feedthrough capacitor helped save money and time.

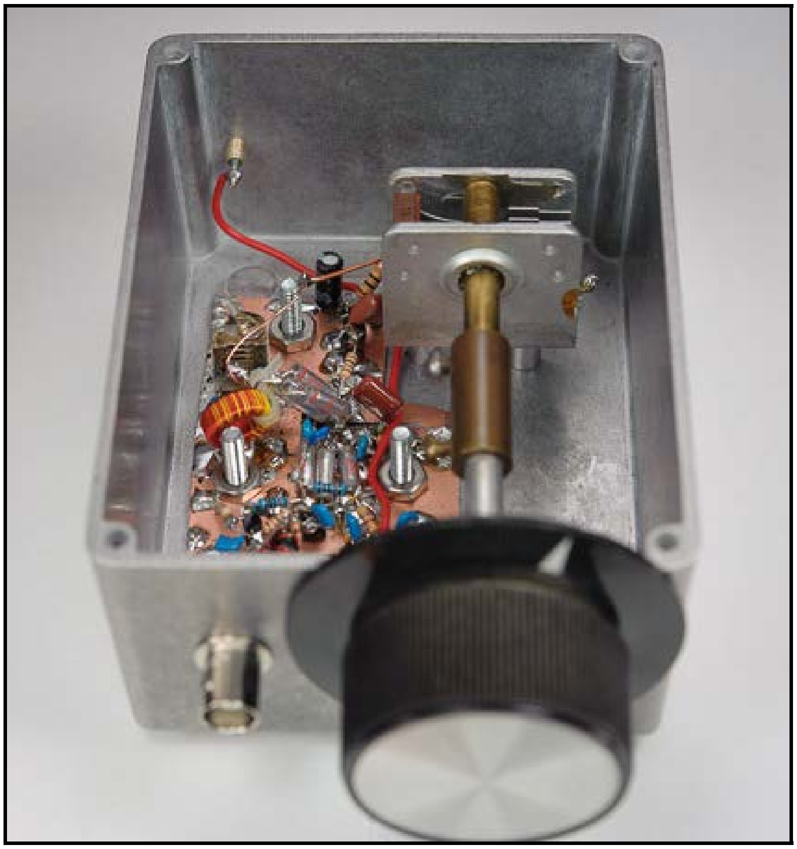

Above — The built 1.5 MHz MTO. With temperature compensation from 6 stiff-leaded, 600 VDC, 470 pF polystyrene capacitors, my frequency drift measured between 3 and 4 hertz per hour upward at room temperature. Properly designed + built + temperature compensated L-C oscillators at 1.5 to 3.5 MHz may exhibit stellar temperature stability. See the VFO - 2011 web page for some tips.

Since this VFO was sublimely frequency stable, I didn't possess the guts to change up the L-C ratio to garner a wider tuning range from the small air-variable tuning capacitor. A 100 pF, or greater delta-F air-variable tuning capacitor would stretch the VFO (MTO) tuning range nicely.

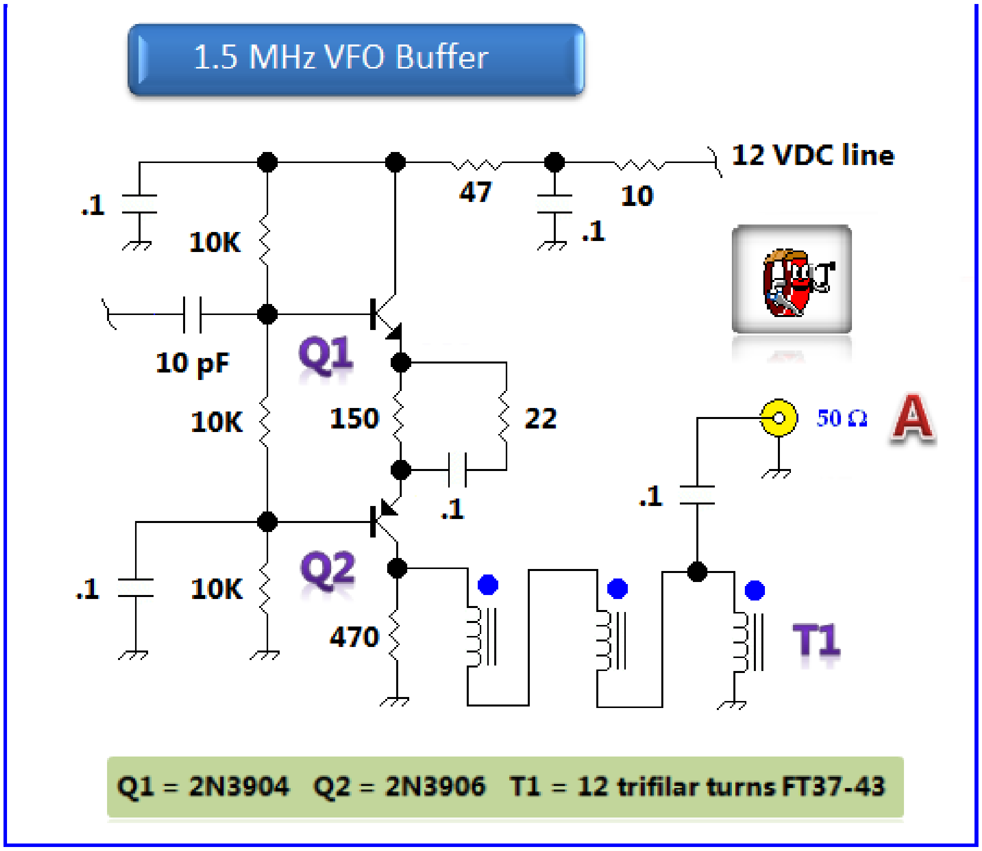
1.5 MHz VFO Buffer
12 VDC line
47
10
.1
.1
10K
10 pF
Q1
10K
150
22
.1
50 Ω
A
.1
.1
10K
Q2
470
T1
Q1 = 2N3904 Q2 = 2N3906 T1 = 12 trifilar turns FT37-43

Above — I designed this buffer last year and it's my new favorite. Click for the original. A 10 pF C0G/NP0 capacitor lightly couples the MTO output to the high impedance of Q1, an emitter follower. Further, a common base amp provides gain and *essential* reverse isolation. You may adjust Q2 gain by changing the degenerative feedback offered by the 22 Ω resistor and 0.1 µF capacitor. For example, decreasing the R to 18 Ω may provide 7 dBm output for a diode ring mixer.

MTO output power = 6.71 dBm.

I transformed the 470 Ω collector resistor impedance to 50 Ω with a transmission line transformer. Even though part of the PLL circuitry involves logic gates, or is at DC; as possible, my circuits employ a 50 Ω input or output impedance to allow measurement with my 50 Ω modules and/or instruments, plus transmission via 50 Ω cables.

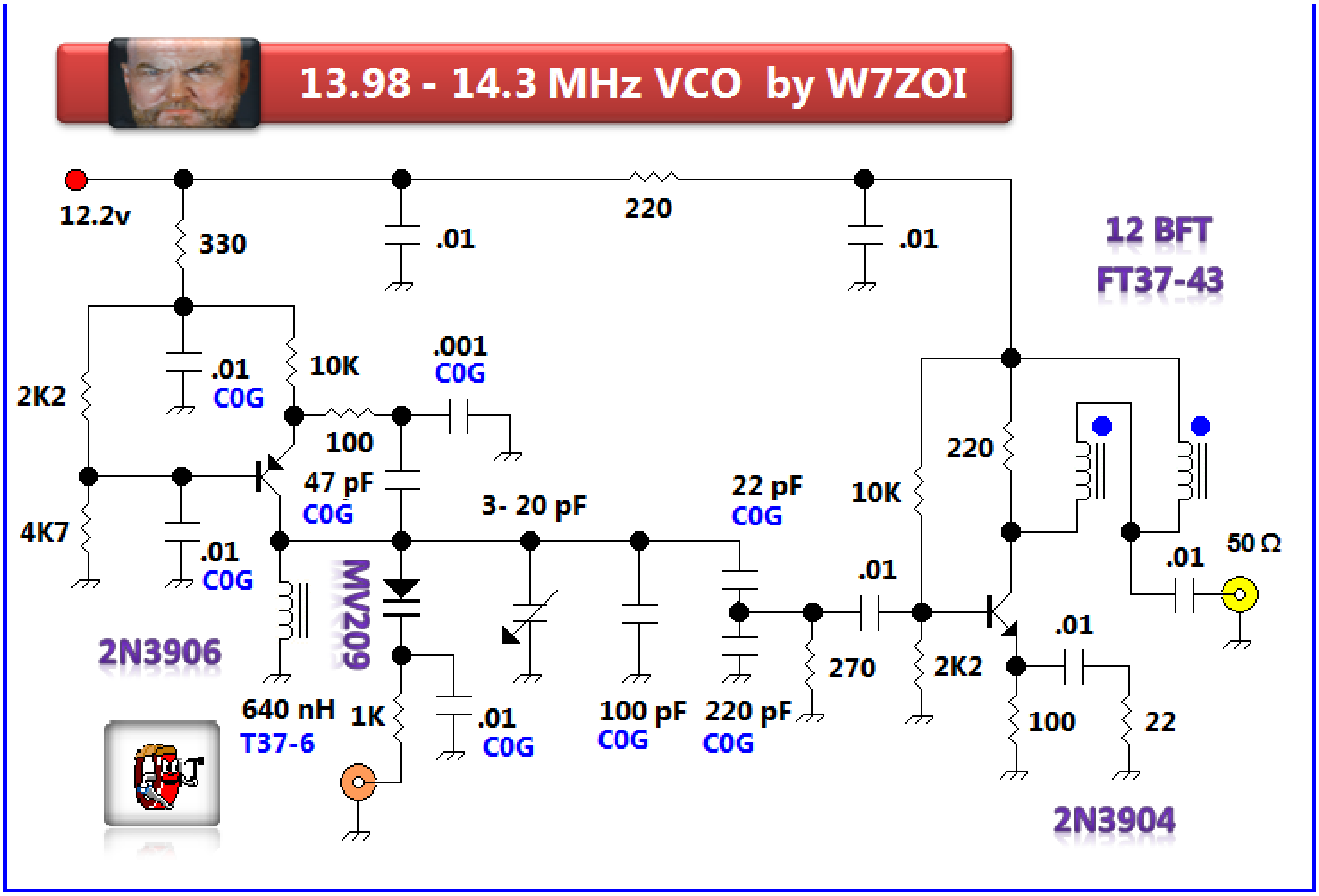
13.98 - 14.3 MHz VCO by W7ZOI
12.2v
330
.01
220
.01
12 BFT
FT37-43
2K2
.01
C0G
10K
.001
C0G
100
47 pF
C0G
3- 20 pF
22 pF
C0G
10K
220
4K7
.01
C0G
MV209
.01
50 Ω
.01
2N3906
270
2K2
.01
640 nH
T37-6
1K
.01
C0G
100 pF
C0G
220 pF
C0G
100
22
2N3904

Above — The 13.98 to 14.3 MHz VCO by Wes, W7ZOI (Figure 4.43 in EMRFD). The connector in series with the 1K varactor resistor was an RCA type. Output power = 1.62 dBm. I employed a 3 - 20 pF air variable for the trimmer.

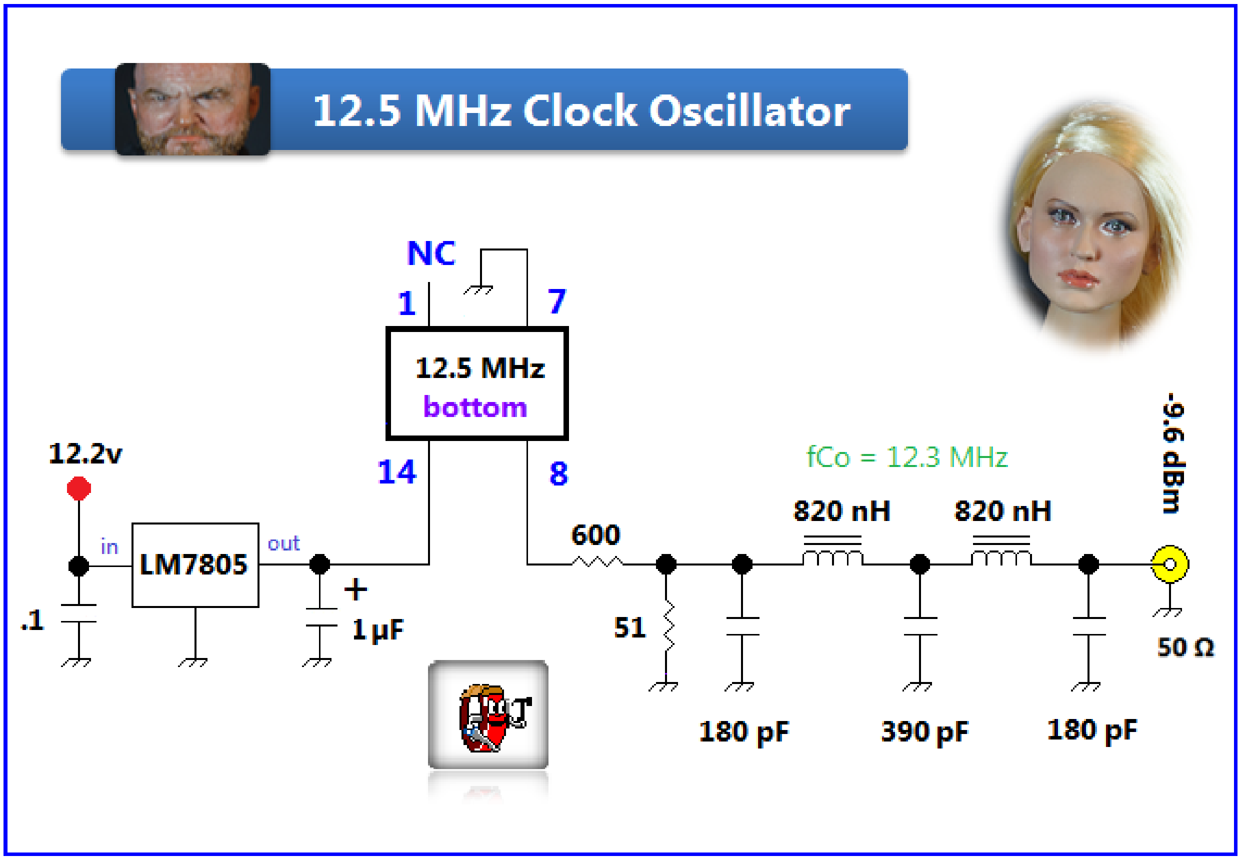
12.5 MHz Clock Oscillator
NC
1
7
12.5 MHz
bottom
12.2v
14
8
fCo = 12.3 MHz
-9.6 dBm
in
LM7805
out
600
820 nH
820 nH
+
1 µF
.1
51
50 Ω
180 pF
390 pF
180 pF

Above — In the original circuit, Wes built his 12.5 MHz crystal oscillator with a single 2N3904. Lacking a 12.5 MHz crystal, I built my xtal oscillator from an old, junkbox 12.5 MHz clock oscillator. A resistor L- matching network drove a low-pass filter to scrub off harmonics, Click for the clean output 'scope tracing at 211 mV pk-pk in my first version. Later, some tweaks gave a final power of -9.6 dBm (208 mV pk-pk). Many authors switch their NE612 mixers with a peak-peak voltage of ~200-300 mV. An AC-coupled 51 Ω resistor on the NE612 pin 6 properly terminates the oscillator to establish the desired drive power and filtering.

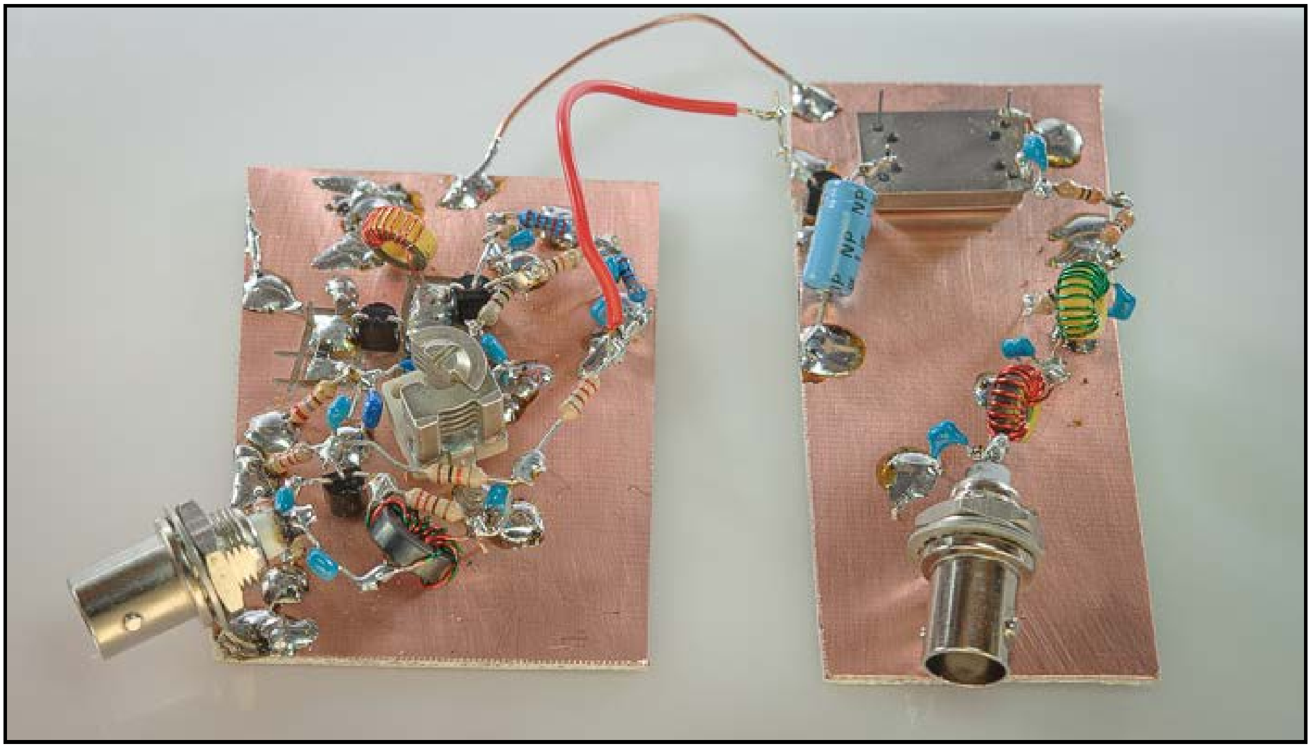
Above — Oscillator breadboards: 14 MHz VCO (left) and the 12.5 MHz clock oscillator (right).

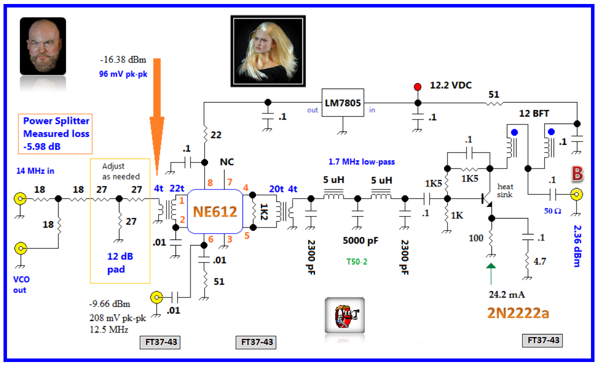
-16.38 dBm
96 mV pk-pk
Power Splitter
Measured loss
-5.98 dB
14 MHz in
18
18
18
27
27
27
Adjust
as needed
12 dB
pad
VCO
out
4t
22t
.1
22
NC
8
7
1
2
6
3
4
5
NE612
.01
.01
51
-9.66 dBm
208 mV pk-pk
12.5 MHz
.01
1K2
20t
4t
.1
out
LM7805
in
12.2 VDC
.1
51
12 BFT
.1
1.7 MHz low-pass
5 uH
5 uH
2300 pF
5000 pF
T50-2
2300 pF
.1
1K5
1K5
.1
1K
heat
sink
100
.1
4.7
24.2 mA
2N2222a
.1
.1
B
50 Ω
2.36 dBm
FT37-43
FT37-43
FT37-43

Above — Click to view the power splitter, mixer, low-pass filter and amplifier schematic. Click for an FFT of the clean 1.5 MHz output sine wave. At this point, the 14 MHz VCO has no DC voltage connected to its frequency compensation varactor. As shown, the mixer products are seriously attenuated by the simple, low-pass filter + keeping the mixer RF port signal amplitude low. The power splitter provides the input for the mixer and also the main output for the 14 MHz VCO. The main VCO output requires 50 Ω buffer/amplifer(s) to drive a receiver mixer, transmitter chain, or whatever.

I inserted the 12 dB attenuator pad to keep my mixer RF port signal low to drop the mixer products amplitude down; further losses occur in the transformer. You can change this pad to whatever is required. I belong to the camp of builders who drive their transmit mixers with low-level RF signals to avoid messy outputs at the IF port.

Click for a breadboard photo of my initial bench tests with the mixer board. A 50 Ω resistive terminator shunts the main VCO output port during this testing. I temporarily insert BNC connectors along my development breadboards to measure output signals with my 50 Ω terminated 'scope, spectrum analyzer, or power meters and *rarely* measure RF circuits with a 10X probe.

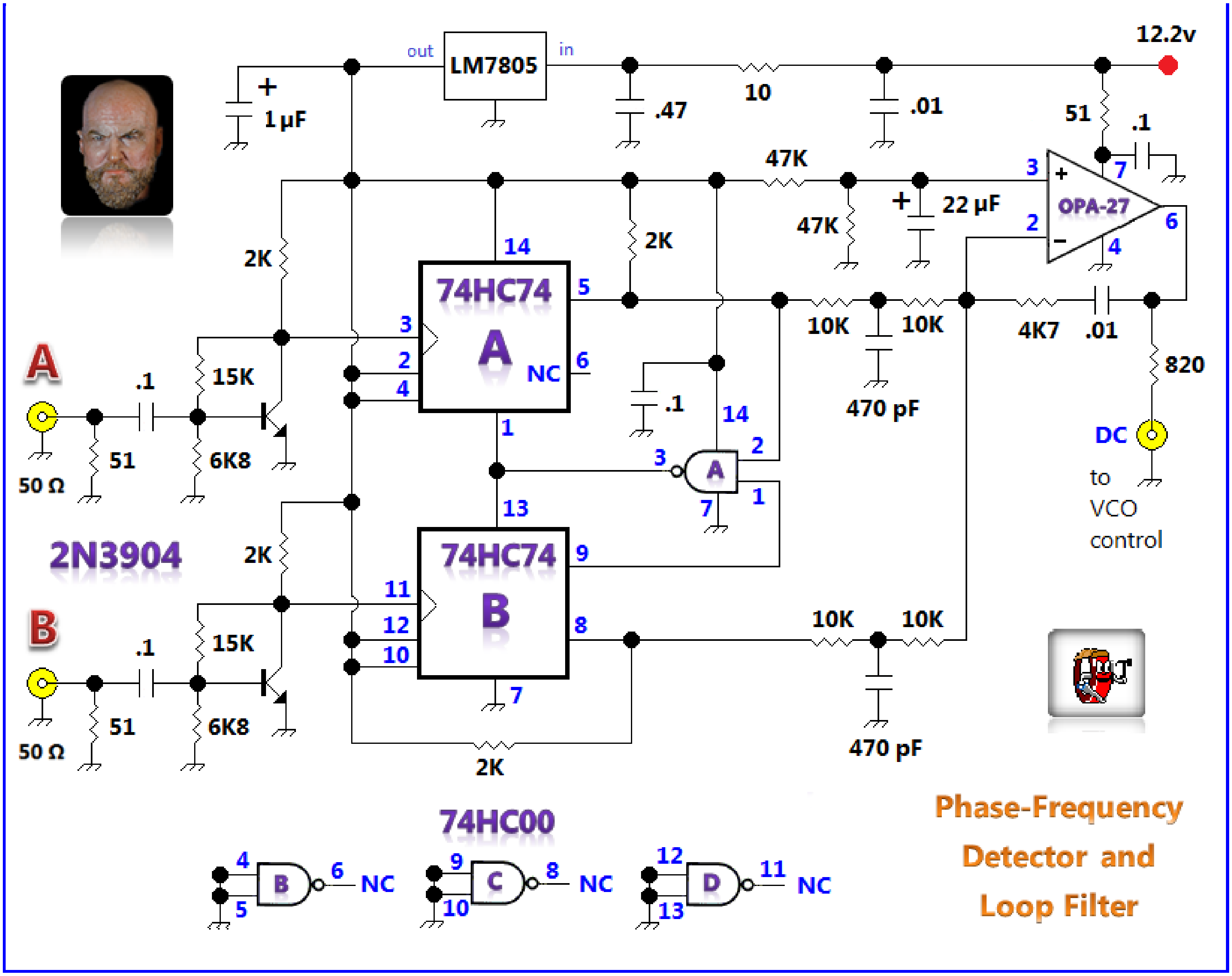
12.2v
out
LM7805
in
+
1 µF
.47
10
.01
51
.1
47K
47K
+
22 µF
3
+
7
OPA-27
2
−
6
4
2K
14
74HC74
A
5
2K
3
2
4
NC
6
1
10K
10K
4K7
.01
820
470 pF
.1
14
2
3
A
1
7
13
A
.1
15K
51
6K8
50 Ω
2N3904
2K
74HC74
B
9
11
12
10
8
7
B
.1
15K
51
6K8
50 Ω
10K
10K
470 pF
2K
DC
to
VCO
control
74HC00
4
5
B
6
NC
9
10
C
8
NC
12
13
D
11
NC
Phase-Frequency
Detector and
Loop Filter

Above — Phase-frequency detector and loop filter schematic. 51 Ω resistors terminate each 1.5 MHz input and drive two 2N3904 switches per EMRFD Figure 4.41. The loop filter design from EMRFD works as described, however, if you make a loop filter for a different circuit, casual copying goes out the window. Engineers design their loop filters according to factors including the crossover frequency, VCO gain, the N-division for the loop, etcetera *with software.* Some people and companies offer such software on the Web.

My loop filter 0.01 µF cap was a 1% polyester capacitor, although Wes specs a 10% tolerance in EMRFD. No cheapo ceramic bypass caps here please.

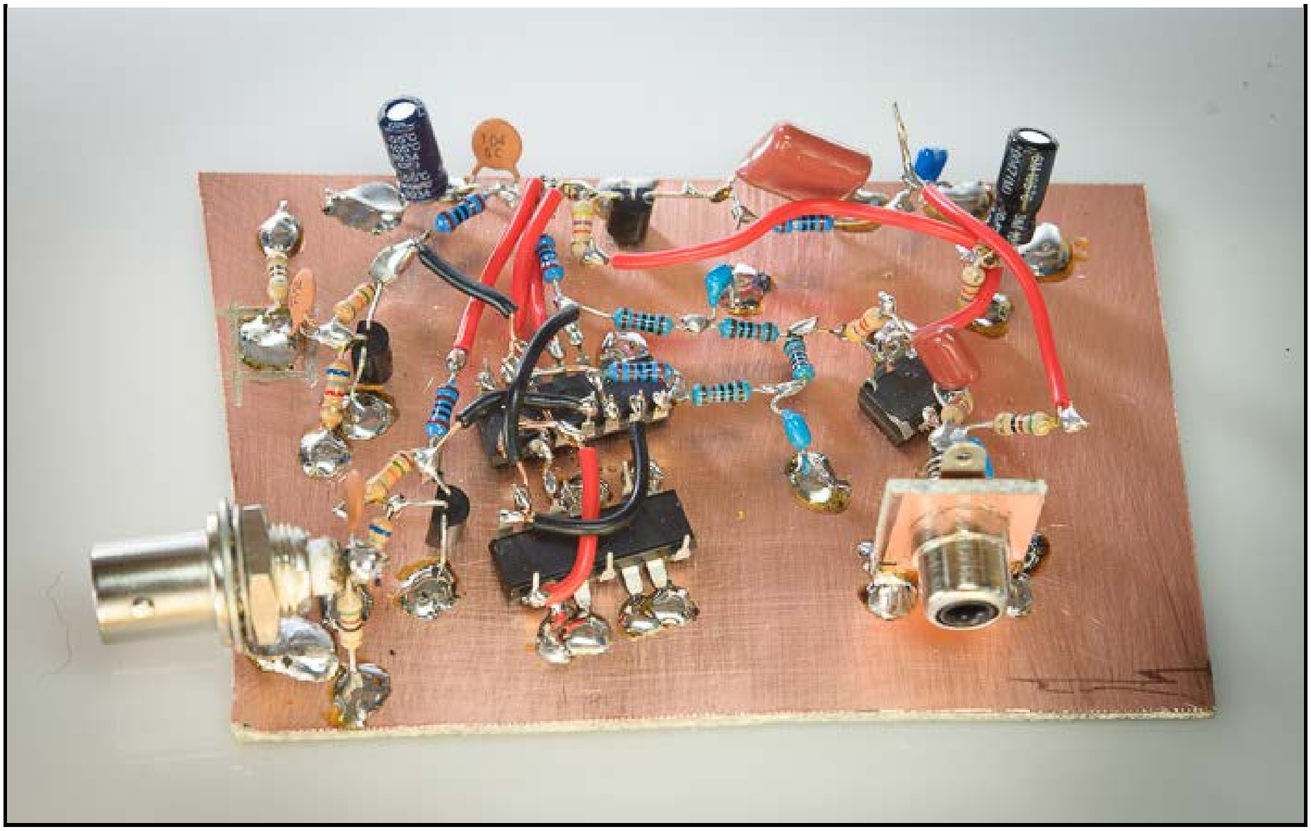

Above — Phase-frequency detector and loop filter breadboard. Click for a photo of the scattered, ugly, working boards on my workbench. Many prototypes look like this on our benches, however, sometimes, they work perfectly until we stick them in a box! Do you relate? Each oscillator belongs in its own metal box with strong bypass and decoupling networks (feedthrough caps reign supreme here) since the 3 oscillators might decide to party together and create havoc.

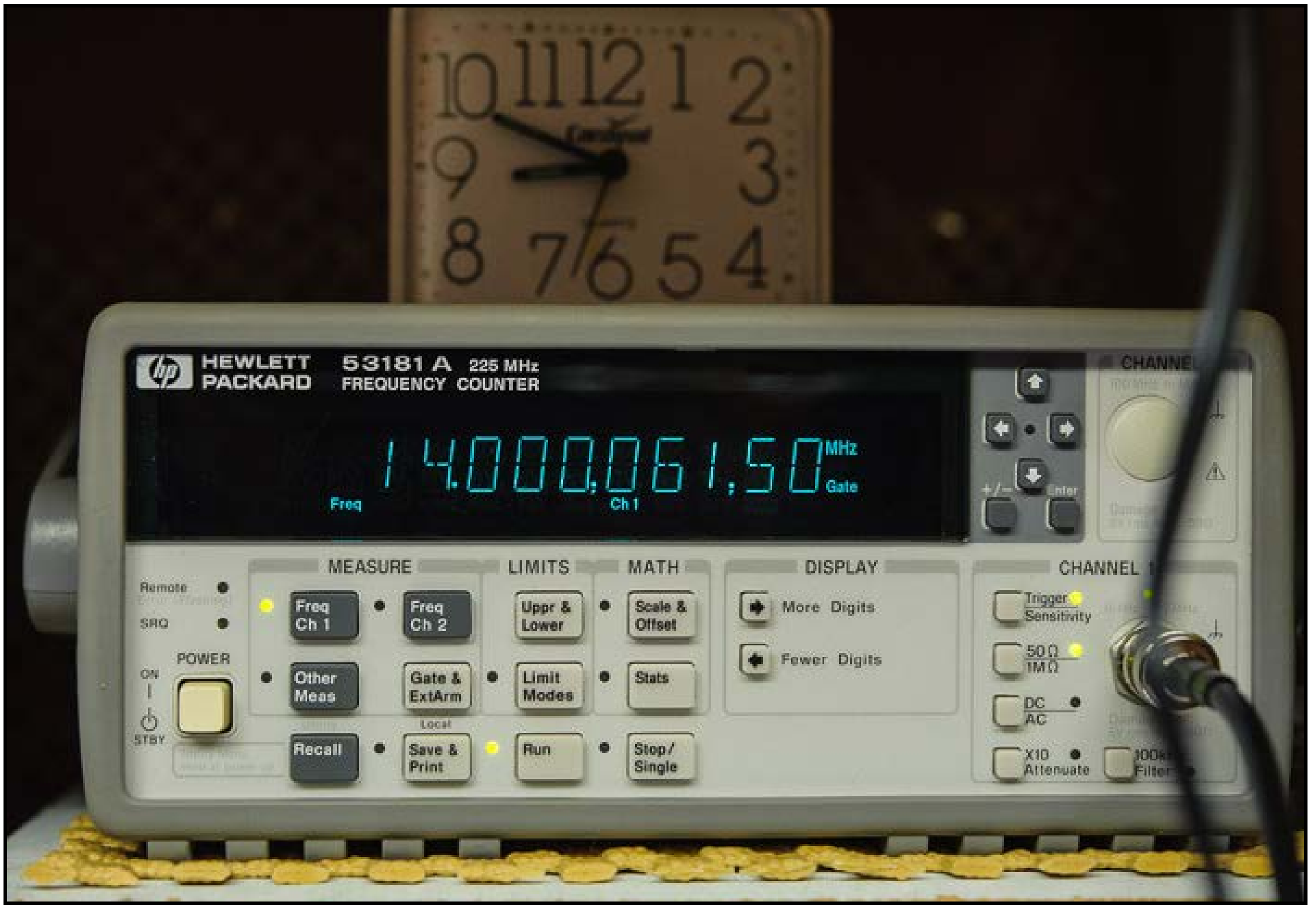
HEWLETT PACKARD
53181 A 225 MHz FREQUENCY COUNTER
14.000,061,50 MHz
Freq
Ch 1
Gate
MEASURE
LIMITS
MATH
DISPLAY
CHANNEL 1
Freq Ch 1
Freq Ch 2
Uppr & Lower
Scale & Offset
More Digits
Other Meas
Gate & ExtArm
Limit Modes
Stats
Fewer Digits
Recall
Save & Print
Run
Stop/ Single
POWER
Trigger Sensitivity
50 Ω 1M Ω
DC AC
X10 Attenuate

Above — My VCO frequency with the 1.5 MHz MTO set at full mesh. Since my MTO only tuned from 1.50 to 1.52 MHz, my VCO only tuned from

14.00 to 14.020 MHz, but that's easily fixed as I've stated. I'm very happy — it locked perfectly and my 14 MHz VCO stayed on frequency at the exact previously measured frequency drift of the 1.5 MHz MTO. When I connected the 14 MHz VCO to my counter without the PLL circuitry, it drifted willy-nilly.

Conclusion

The sense of awe and joy arising from locking a VCO on frequency won't be understood by many. The concepts and circuitry offers many possibilities. If the MTO and VCO exhibit low phase noise, short-term oscillator stability may be fantastic.

The 14 MHz VCO could be a 56 MHz VCO with sequential division by flip-flops to provide output at 28, 14 and 7 MHz with the 14 MHz portion going to the offset mixer. In EMRFD, Figure 4.44, Wes offers 14 and 7 MHz output by dividing the 14 MHz signal from the main power divider output port. The 7 MHz band is low-pass filtered to remove harmonic energy.

Wes extended this circuit by dividing the MTO by a hardware programmable frequency divider so that the difference from the mixer and low-pass filter is 170 kHz nominal. He uses this 'Almost Synthesizer' on the air for his QRP adventures.

While most builders will sensibly jump from an L-C VFO to a kit containing a programmed microcontroller plus a DDS or Si579, it's also fun to play with hardware to learn and ingrain synthesizer concepts + gain bench wisdom.

QRP — PosData for April 17, 2013

For a good read on the offset PLL, consider studying Wes' book **Introduction to Radio Frequency Design**, ARRL, 1994, page 320 and on. *This book is now out of print*. Wes ported the PLL active loop filter design program he wrote for IRFD from DOS to Windows in April 2013. Click and scroll for it. Thanks for this Wes!

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5. Boot-strapped Popcorn AF Feedback Pair

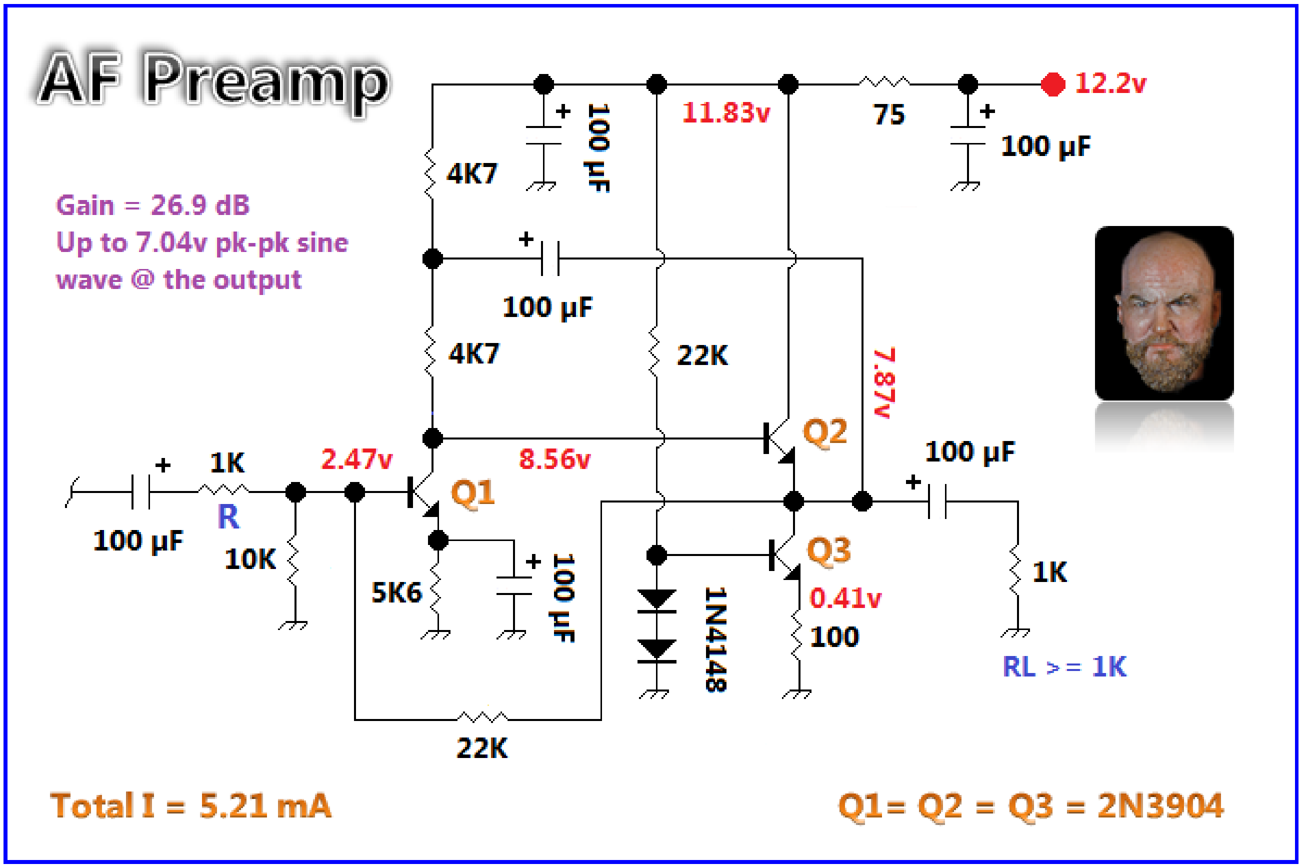

Above — I designed this AF stage for a builder from Indonesia; a popcorn AF shunt feedback amp based on the work of Douglass Self. Despite only drawing ~ 5 mA, this amp stayed clean until the output voltage exceeded 7.04 volts peak-peak on my test bench. Boot-strapping increases gain and lowers distortion in Q1.

Q2 buffers the Q1 voltage amp from external loading and increases gain.The Q3 current source boosts the load-handling capacity of the Q2 emitter follower. The input R can be raised to reduce sensitivity. The 1K output R could be a 5-10 K volume pot.

---

6. Non-Mechanical Iambic Paddle

Above — The very ugly development proto-board of my half-done non-mechanical Iambic paddle. At some point I'll build the other half (the dah paddle switch) and press it into service. You might also use this circuit as a non-mechanical straight key.

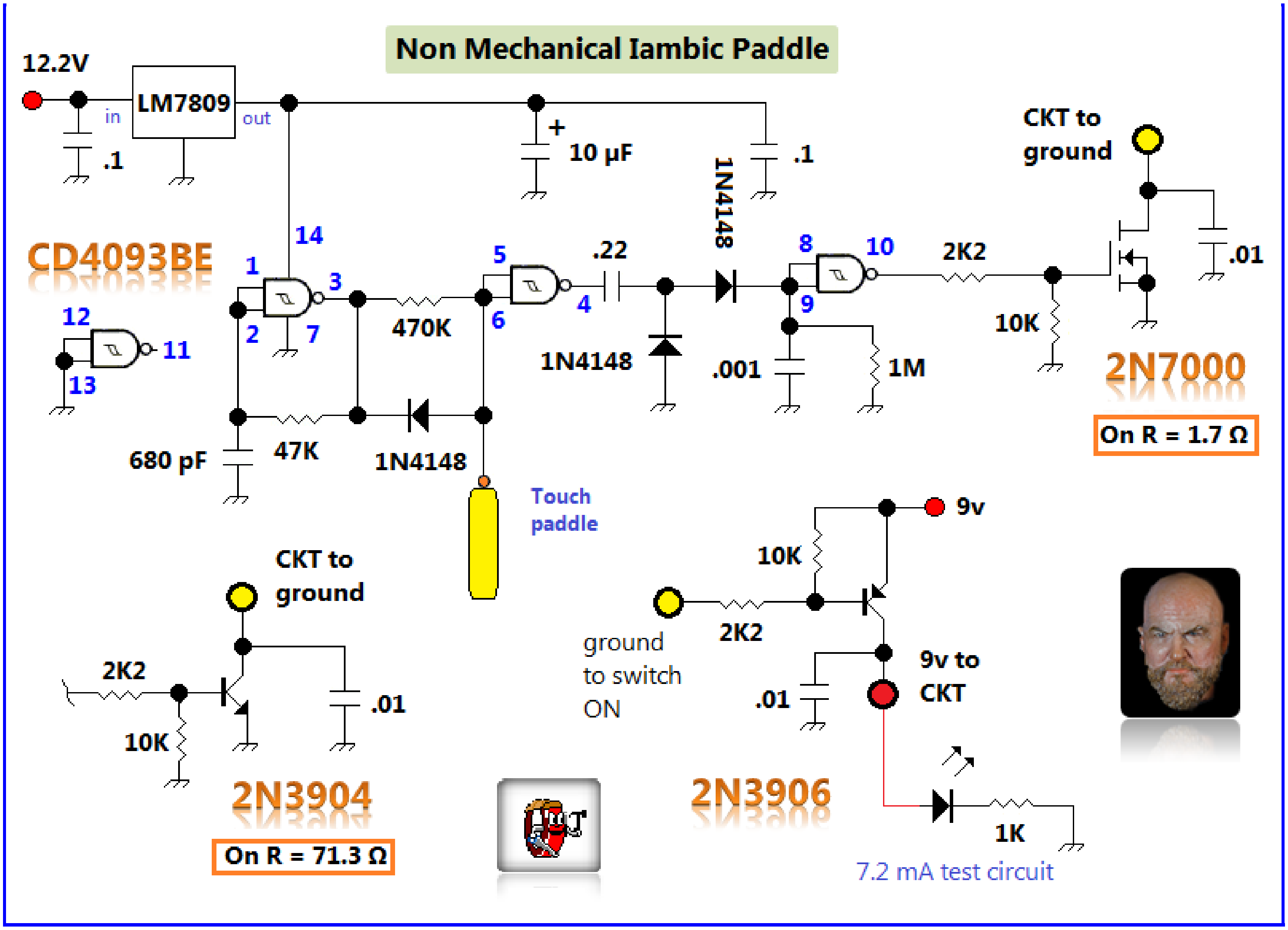
Non Mechanical Iambic Paddle
12.2V
in
LM7809
out
.1
+
10 µF
.1
1N4148
CKT to ground
CD4093BE
14
1
3
2
7
12
11
13
5
6
4
.22
470K
1N4148
8
10
9
.001
1M
2K2
10K
.01
2N7000
On R = 1.7 Ω
680 pF
47K
1N4148
Touch paddle
9v
10K
CKT to ground
2K2
.01
10K
2N3904
On R = 71.3 Ω
ground to switch ON
2K2
.01
9v to CKT
2N3906
1K
7.2 mA test circuit

Above — The schematic for 1 of the paddle circuits. I compared the ON resistance of the BJT switch with the enhancement mode FET and the 2N7000 won: only the FET could key the continuity tester on my DVM.

You may extend this circuit with a 2N3906 switch for paddle-switched 9 volts (or whatever VCC you want). In the bottom right, I connected the PNP collector to an LED and flashed it for fun. The 0.01 µF capacitor on the switch drain or collector bypasses any RF to ground. With higher power RF, you may have to place a similar bypass cap in parallel with the shunt 10K resistor on the 2N3904/2N7000 base and gate respectively.

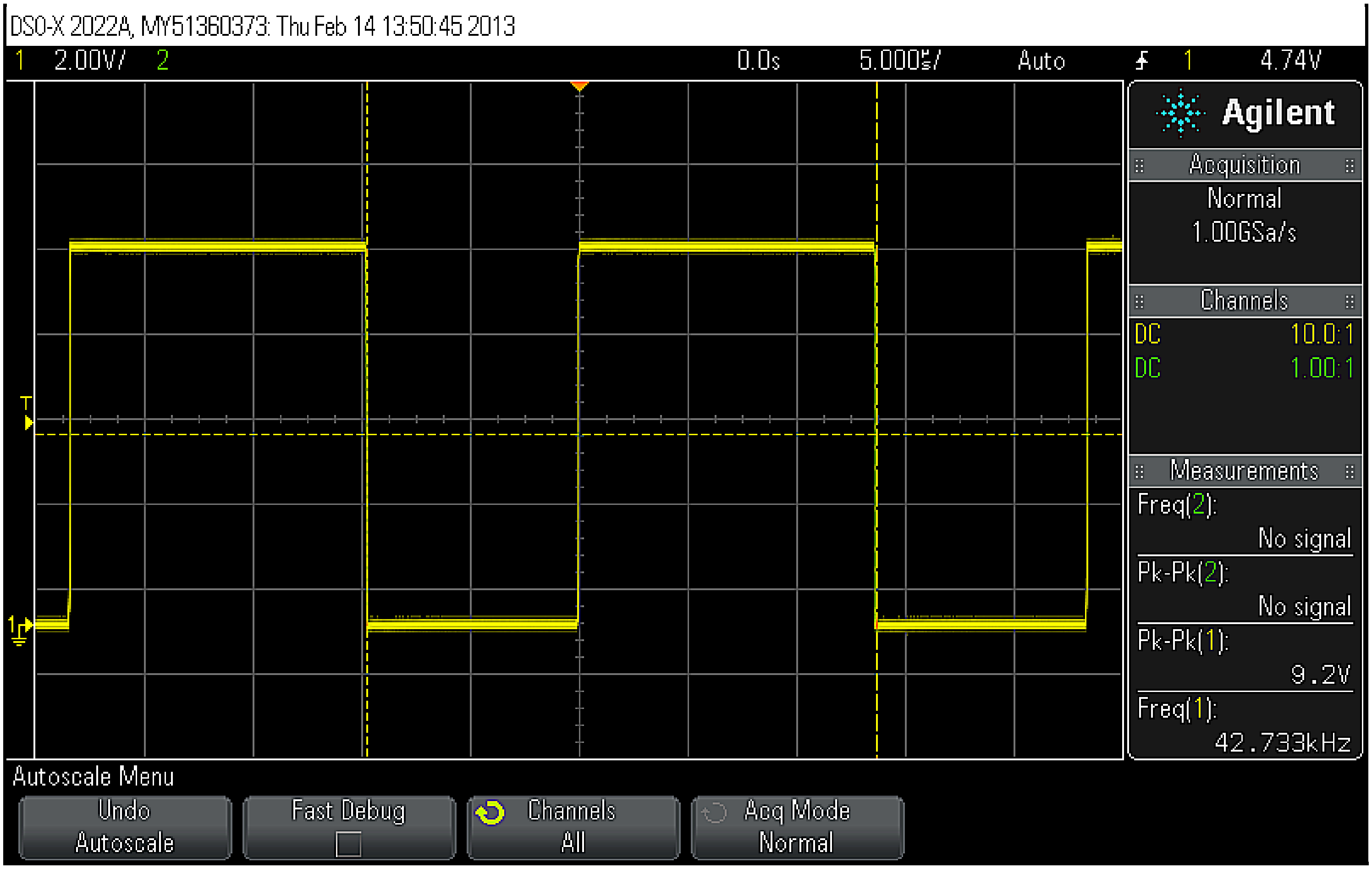
DSO-X 2022A, MY51360373: Thu Feb 14 13:50:45 2013

1 2.00V/ 2 0.0s 5.000㎲/ Auto ⨍ 1 4.74V

Acquisition
Normal
1.00GSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Freq(2):
No signal
Pk-Pk(2):
No signal
Pk-Pk(1):
9.2V
Freq(1):
42.733kHz

Agilent
T
1
Autoscale Menu
Undo Autoscale
Fast Debug ☐
Channels All
Acq Mode Normal

Above — A 'scope shot of the ~ 43 KHz oscillator generated in the first 4093 Schmitt trigger NAND gate.

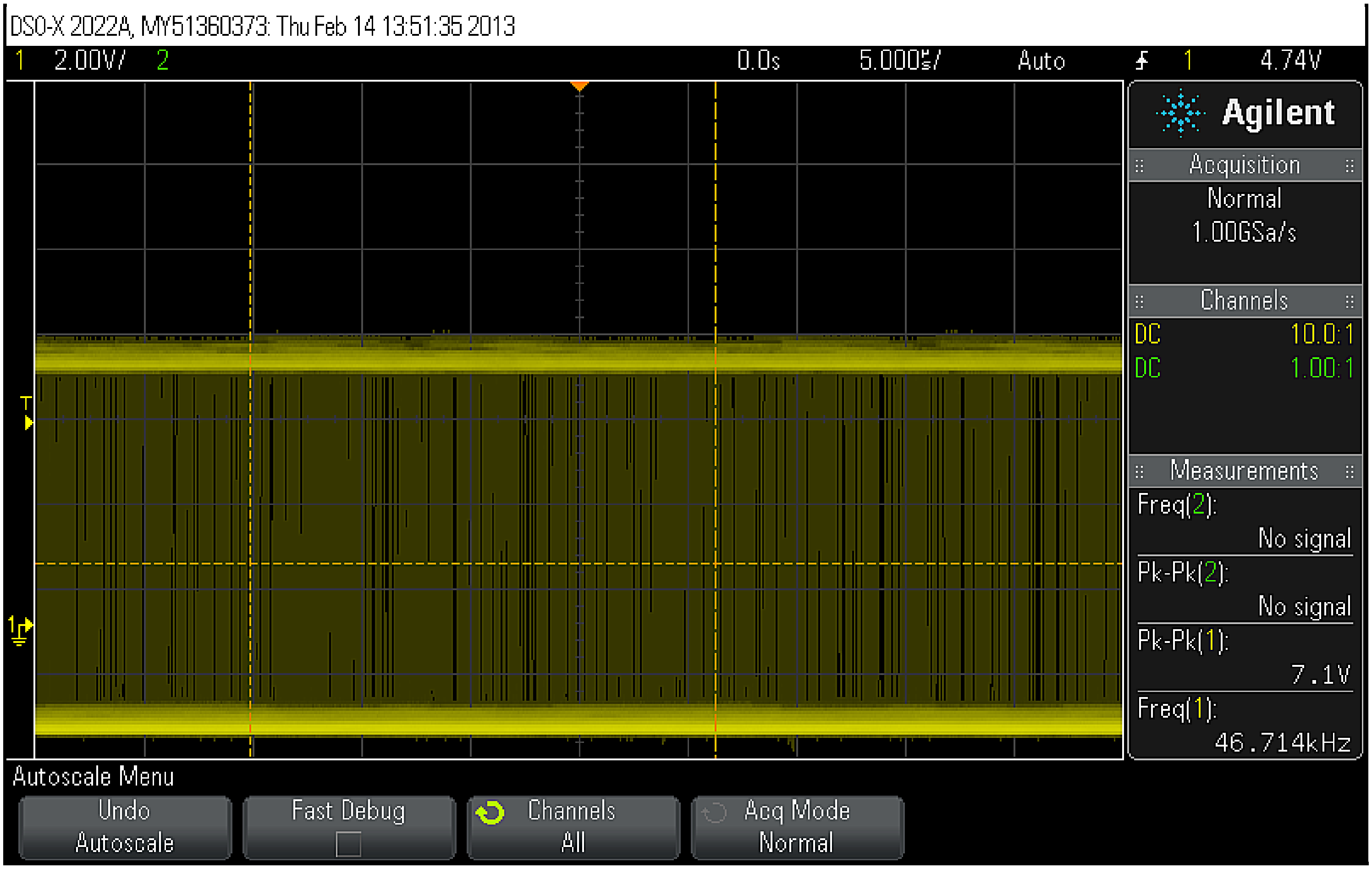
DSO-X 2022A, MY51360373: Thu Feb 14 13:51:35 2013

1 2.00V/ 2 0.0s 5.000s/ Auto 1 4.74V

Acquisition
Normal
1.00GSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Freq(2): No signal
Pk-Pk(2): No signal
Pk-Pk(1): 7.1V
Freq(1): 46.714kHz

Above — Here's the disturbed oscillator output *just* after the paddle is touched: this stops the signal at pin 5 and 6 of gate 2 and kills the AC output at pin 4. The DC voltage across the 0.001 µF cap discharges through the 1 megohm resistor pushing pin 10 HIGH to turn on the 2N7000 (or the 2N3904). Normally, pin 10 is LOW since the rectified output of the undisturbed ~43 KHz oscillator goes to both pin 8 and 9.

A fun circuit for a Saturday afternoon...

7. A Journey Above HF

This project began as a 14 MHz low-noise amplifier build, but ended up with me learning more about SMT breadboard techniques and suppressing spurs. A short exploratory/descriptive account of my bench journey plus some photos follow.

VAT–6
6 dB ATTENUATOR
50 OHM

Above — I'm slowly adding SMA connectors and pieces. Since modern consumer digital network engineers use them, they're abundant and often rated from DC to 18 GHz; more bandwidth than I'll ever need.

I'm also building with evermore SMT components and just love it. Through-hole (I prefer to say hole-through) stuff continues to disappear like lemonade on a hot August afternoon.

Above — The schematic of my version of Victor 4Z4ME's feedback amp (FBA) as tested at 14 MHz: he emailed me a paper and provided some online support. Click for another version from December 2012. Typical noiseless FBAs suffer from poor reverse isolation, however, Victor runs the collector to base feedback through an asymmetrical 3 dB power combiner/splitter that boosts port isolation, defines the gain, plus sets the input and output impedance.

Strong virtues of the asymmetrical power splitter — fully utilized in this design include a very low loss on the input side (the 1 turn side) and a much higher loss ont the feedback side that allows the feedback to defines the input impedance on one side while exerting a negligible impact on noise figure and dynamic range on the other side. Victor measured a noise figure of 1.5 dB using a MRF586 BJT. Thanks to Victor for the information and design.

For strong IMD properties, I ran 50.6 mA total stage current into a gorgeous, low-noise, NE46134 NPN transistor with a fT of 5.5 GHz. Using VHF-UHF techniques, I built with mostly SMT parts on 2–sided board using copper wire vias to connect the 2 copper surfaces. I discussed the wrap-around bias technique in 2011 as number 1.

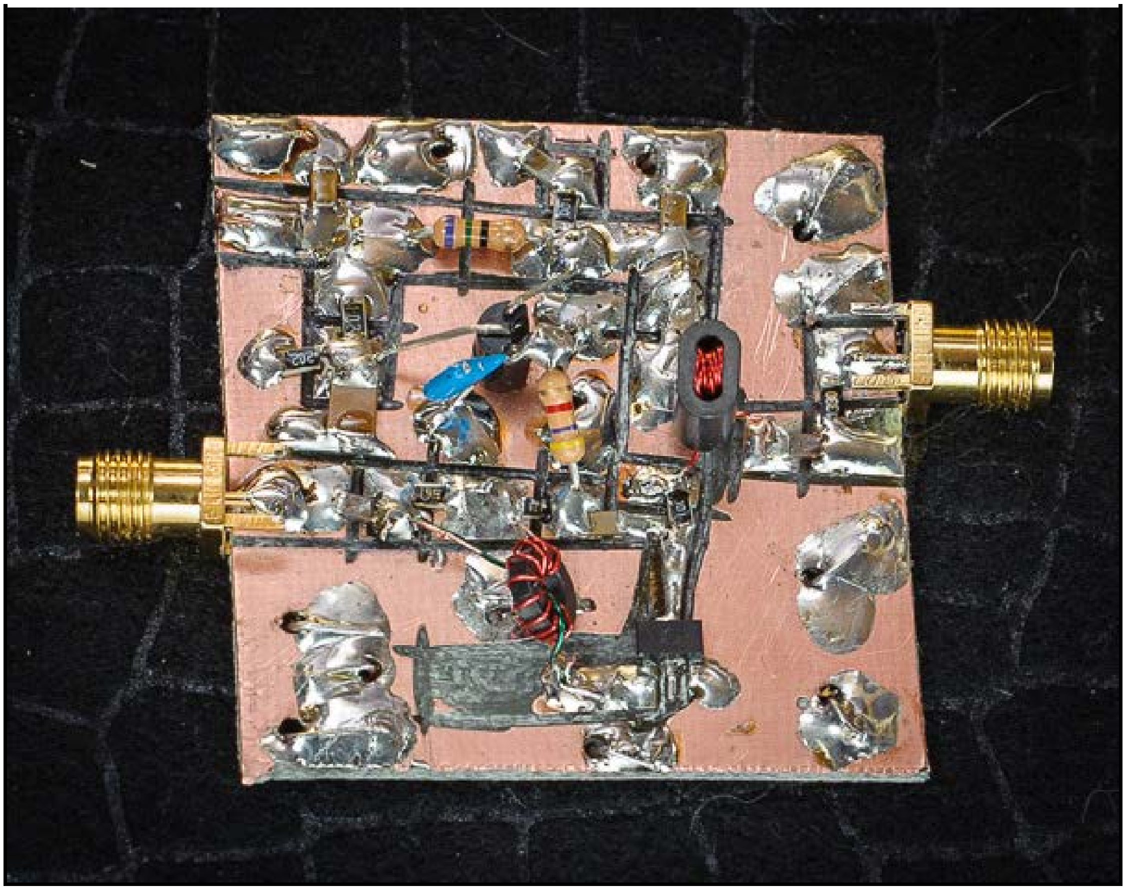

Above — My prototype breadboard with dremel cut islands for soldering the size 1206 or 0805 SMT parts, plus a few hole-through items. Carving an island for the SOT89 transistor package proved difficult, but even I (a challenged dremelist) did it.

Woe to Oscillations: Like misplaced car keys, oscillations may remain hidden unless you search for them. Often, the only difference between a proper oscillator and a regular amplifier is we *want* the former to oscillate. To check for instability, we might use our high bandwidth scope, or a spectrum analyzer, but many will have to find spurious RF with basic, DC - HF bandwidth test equipment. In any case, just do your best. To some extent, unwanted oscillations are the *elephant in the room* that few talk about. Well, it's okay to think, talk and feel some emotions about them.

Sure enough, when I connected a 14 MHz signal to the amp's input and a 50 Ω terminated 'scope to the output to measure gain, my sine wave had 2 or 3 others on top of it. In the 4Z4ME amp, the PNP bias transistor can be a source of AF to HF oscillations.

Victor wrote: "The circuit has a low frequency amplifying loop that goes through both transistors. The PNP transistor does not invert the signal (it is a common base amplifier) and the RF transistor inverts so it is a loop with 180 degrees phase shift (negative feedback). The various decoupling and RF coupling capacitors in this loop add phase shift on this low frequency loop. If the accumulated phase shift adds to an additional 180 degrees and gain is larger than 1 you have oscillations. The simplest way to solve it is to make one of the capacitors very large so it will add only 90 degrees phase shift but it will drop the gain at the higher frequencies where the other capacitors start to add phase shift to be less than 1 so there are no conditions for low frequency oscillations. This technique is called "Dominant Pole". That's the reason that I suggested to connect a very large capacitor to the PNP transistor".

I found my oscillations disappeared with a 0.1 μF collector bypass cap on the PNP (Cx on my schematic). The 0.1 μF cap on the PNP collector was critical – a 0.22 μF failed to work, as did a .001 μF --- but a 0.1 μF held it stable. In another 2N2222a-based 4Z4ME amp with 0.01 μF input and output caps, it took a 10 μF capacitor on the PNP collector to snuff out some ~766 Hz oscillations.

We don't use a wrap-around PNP bias with our RF oscillators — that's asking for trouble.

I aso measured oscillations at ~ 372 MHz with my spectrum analyzer. A collector 10 Ω R killed these UHF oscillations and after that I saw no spurs from .001 to 1 GHz. (I should have made the dremel cut right close to the NPN collector for the 10 Ω resistor. I hoped there were no oscillations above 1 GHz because I can't measure them.

Finding oscillations:

Many builders lack a spectrum analyzer, let alone 1 that goes up into UHF bandwidth. I'll share a few tips I've learned on the bench that don't require expensive test gear:

A 10X scope probe on the drain or collector of an amp may sometimes reveal oscillations up to the maximum 'scope bandwidth — set your 'scope vertical scale for high sensitivity. This provides direct measurment of oscillations.

Indirect methods to infer unwanted oscillations also lie in our armatorium. I learned this trick from Wes: Place the circuit under test in your normal gain measurement set up with an oscilloscope. Then vary the DC power supply voltage slowly and smoothly — your measured 'scope voltage changes should also track slowly and smoothly. You may see an AC voltage jump as the amplifier goes into and out of oscillation with the DC power supply tweaking. After finding this oscillation caused AC voltage spike, you work to remedy it with a variety of means such as better bypassing, changing bias voltages, shielding and locating breadboard errors.

Sometimes if you put your finger near the active part while watching the bias voltage or current you may see the bias jump around *if* oscillations are present.

My final indirect oscillation busting technique: If you measure the specified/expected gain and return loss on the input/output port, this *may* signal your device is stable — I've noticed this with MMICs where I saw oscillations on my SA, stabilized them and *only then*, measured the expected S21, S11 and S22.

Sometimes, eliminating a hot part proves the best fix! In 2012, a new builder wrote to say that he soldered in a Mini-Circuits DC - 6GHz MMIC; the ERA-2SM in SOT-86 as a buffer for his 3.5 MHz VFO. Anyhow, in the photo were long leads plus no decoupling resistors etc. It sounds like the circuit behaved hyperreactively and *vibrat*ed in spasm. The cure was to eliminate the microwave part and put in a hycas amp built with a J310 + a 2N3904 — we encounter risk when plying the latest, hottest, super-high fT amplifiers sold on eBay with casual abandon.

Practice makes perfect. if you believe learning is experiential and build to learn, you'll learn to build.

Finally, as an amateur, I struggled to choose a SMT ferrite bead and after reviewing many datasheets and application notes I ordered a size 0805, 800 mA part with 120 ohms Z at 100 MHz and its peak impedance at 340 MHz. I'll let you know how that works out.

RF Bypass on our DC lines: As possible, we ought to provide a broadband RF bypass to provide a low impedance to RF from low frequency up to the maximum frequency wherever our FET, BJT, MMIC, etc. operates. For example, you can't just swap a higher gain BF998 (1 GHz) for a 40673 (VHF) dual-gate MOSFET and expect the same stability and bypass requirements can you? At the very least, I bypass G2 of the BF998 with a size 0805 0.01 or .001 µF SMT capacitor and the drain with RF bypass good for 1 GHz.

Wideband RF bypass may solve oscillation issues too.

I tried to apply a broadband bypass in my breadboard, although it gets extremely difficult to think about bypassing RF at > 1 GHz for the QRP homebuilder. Our hobby should include reflection and proper intention at the very least.

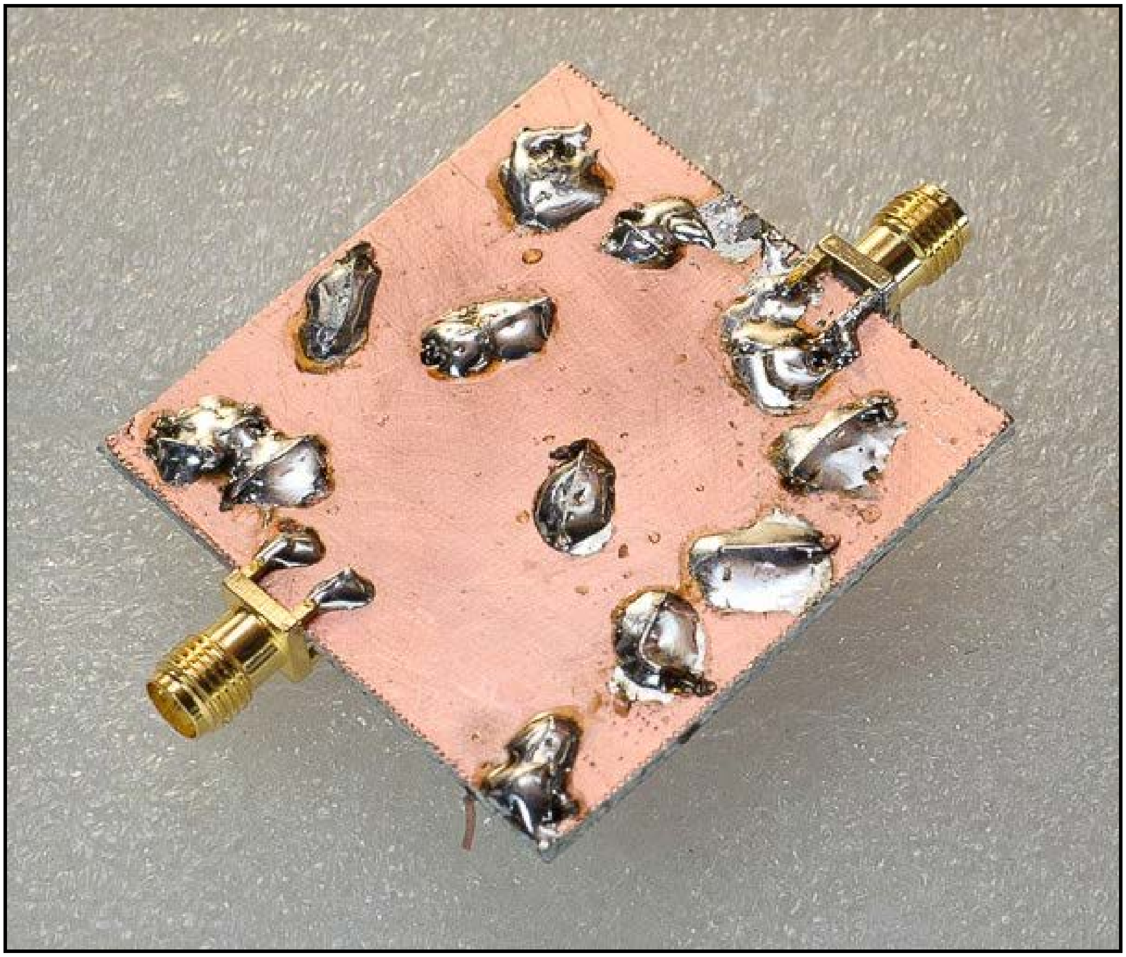

Above — A photo of the bottom of my breadboard showing the vias. I made mistakes: we should try to keep the via holes as close as possible to all bypass caps, my 10 Ω collector snubber resistor, collector port, or whatever we need to put at RF ground. The vias connect circuit areas to the large area, low impedance ground plane to minimize inductance. We should also try to place bypass capacitors as physically close to the pins of whatever we're bypassing.

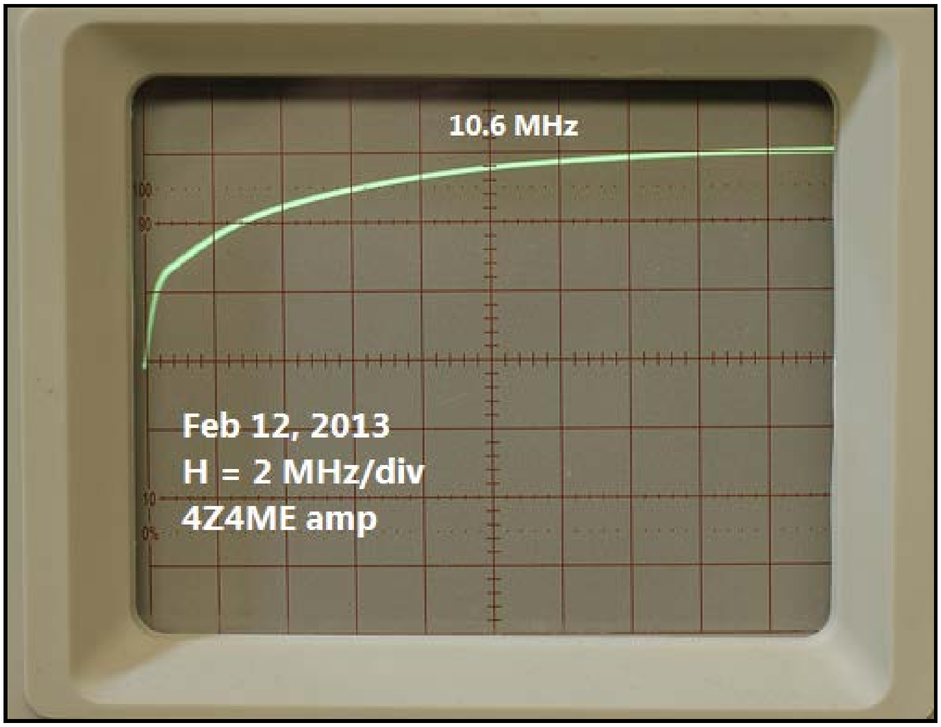

Above — A TG + SA sweep of the gain of my 4Z4ME NE46134 FBA from ~1 to 20.6 MHz. Each vertical quare denotes 10 dB. Each horizontal square = the value specified in the photo. In this case; 2 MHz per division. Maximum gain was ~16 dB.

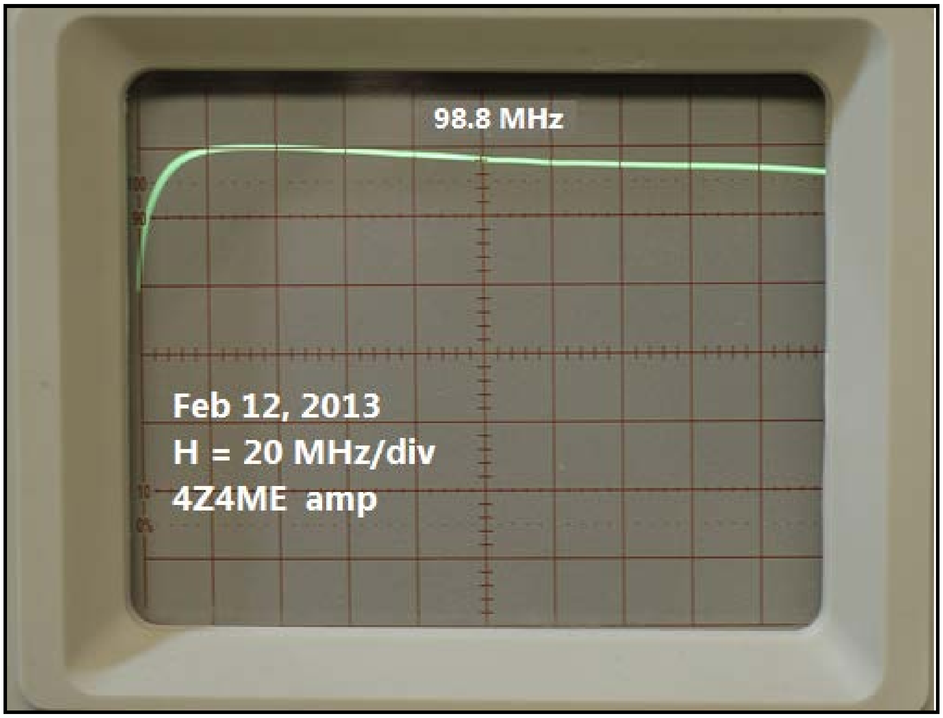

Above — A sweep from ~ 1 to 200 MHz. This would also make a good 6 meter band amplifer or ????.

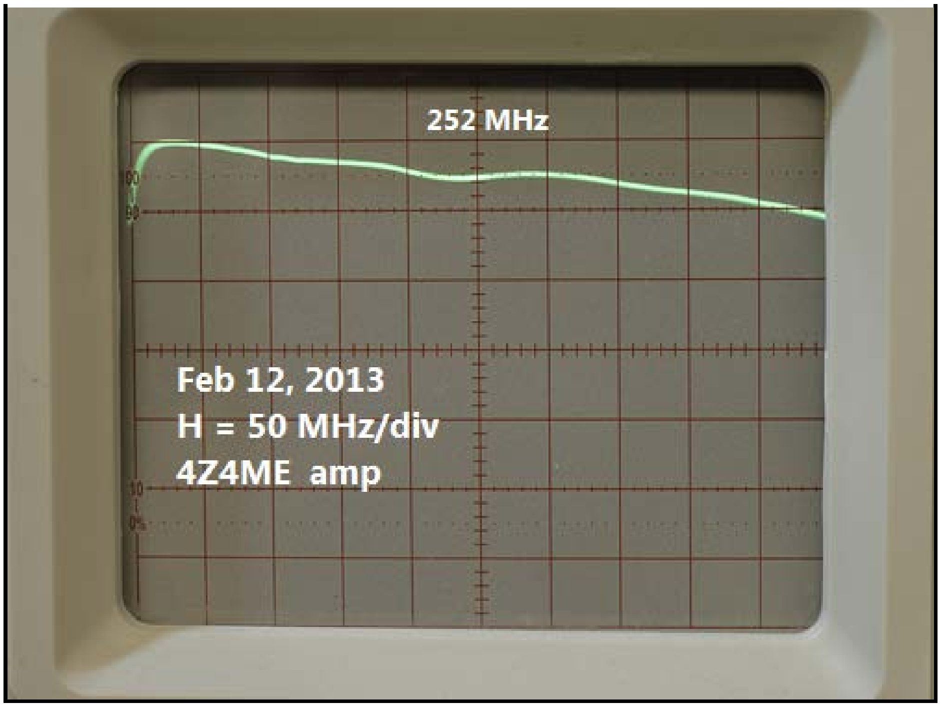

Above — A sweep from ~ 1 to 500 MHz.

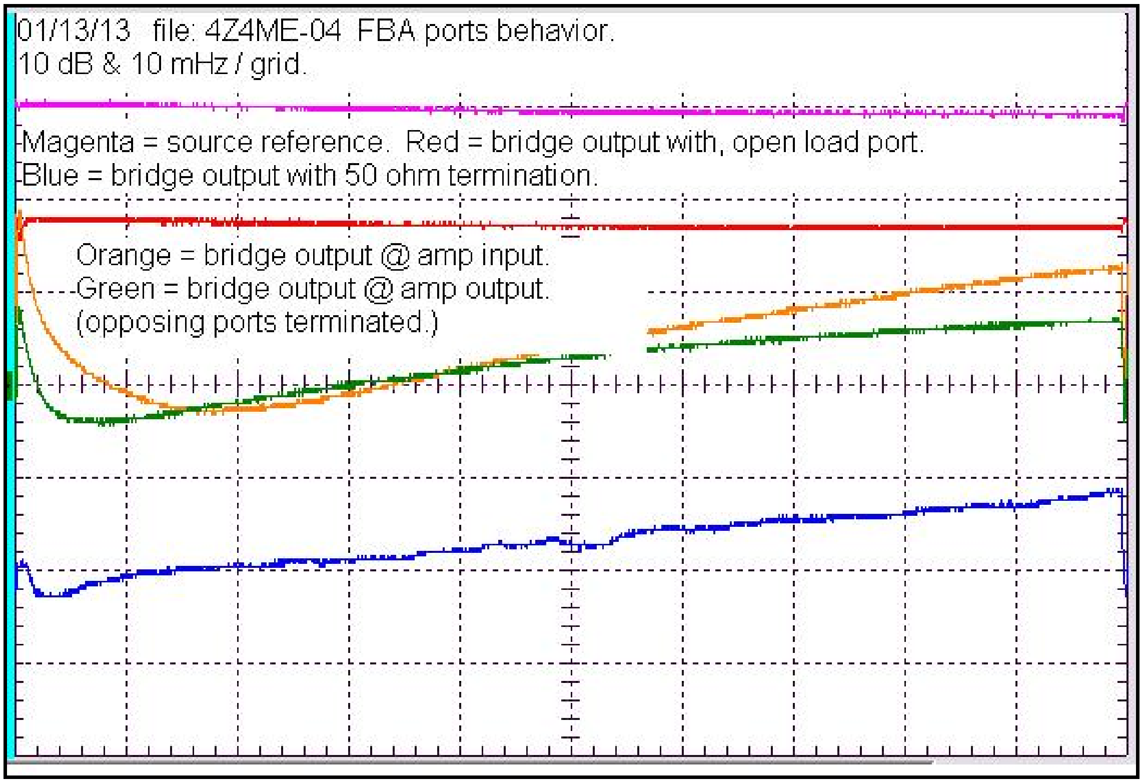

Above — Bob K3NHI made and swept a 2N5109 version of the 4Z4ME amp biased for ~47 mA emitter current. Here he swept return loss at the amp's input and output from about 1 to 100 MHz. The output return loss of my build was down, however, I didn't own many SMT resistors between 33 and 68 Ω. For example, if the output impedance at the collector is 10 Ω, then the series resistor should be 40 (39) Ω.

I've found that in my FBAs, changing the current and also the transistor type (2N5109 , 2N2222a etc.) also affects the input and output return loss. At HF, it's possible to measure RL with a simple bridge, so optimization is possible.

I learned a lot by building just 1 amplifer and discussing my findings by email with friends. Hopefully the next version I make will show improved understanding and skill.

---

8. Popcorn AF Amplifier for Receivers — Reprise

I've worked on a popcorn audio power amplifier (PA) since 2008 and offer my latest experiments. There's only so much you can do with a single-supply 12 volt AF power amp, but I enjoy improving my circuit.

My power measurement technique is shown as Figure 4 here. To enhance versatility, the following PA's may be coupled to whatever preamplifer you choose. In all cases, I drove the power amp stage with a 5532 op-amp voltage amplifer. The power followers were biased with a 2N3904 amplified diode (also called NPN shifter bias amplifier, or DC level shifter) rather than just a pair of series diodes, since this allows you to dial in just the right amount of bias as you watch the AC signal in your 'scope. I wrote a tutorial that explains how to bias complimentary-symmetry power followers in 2008: Click for the link.

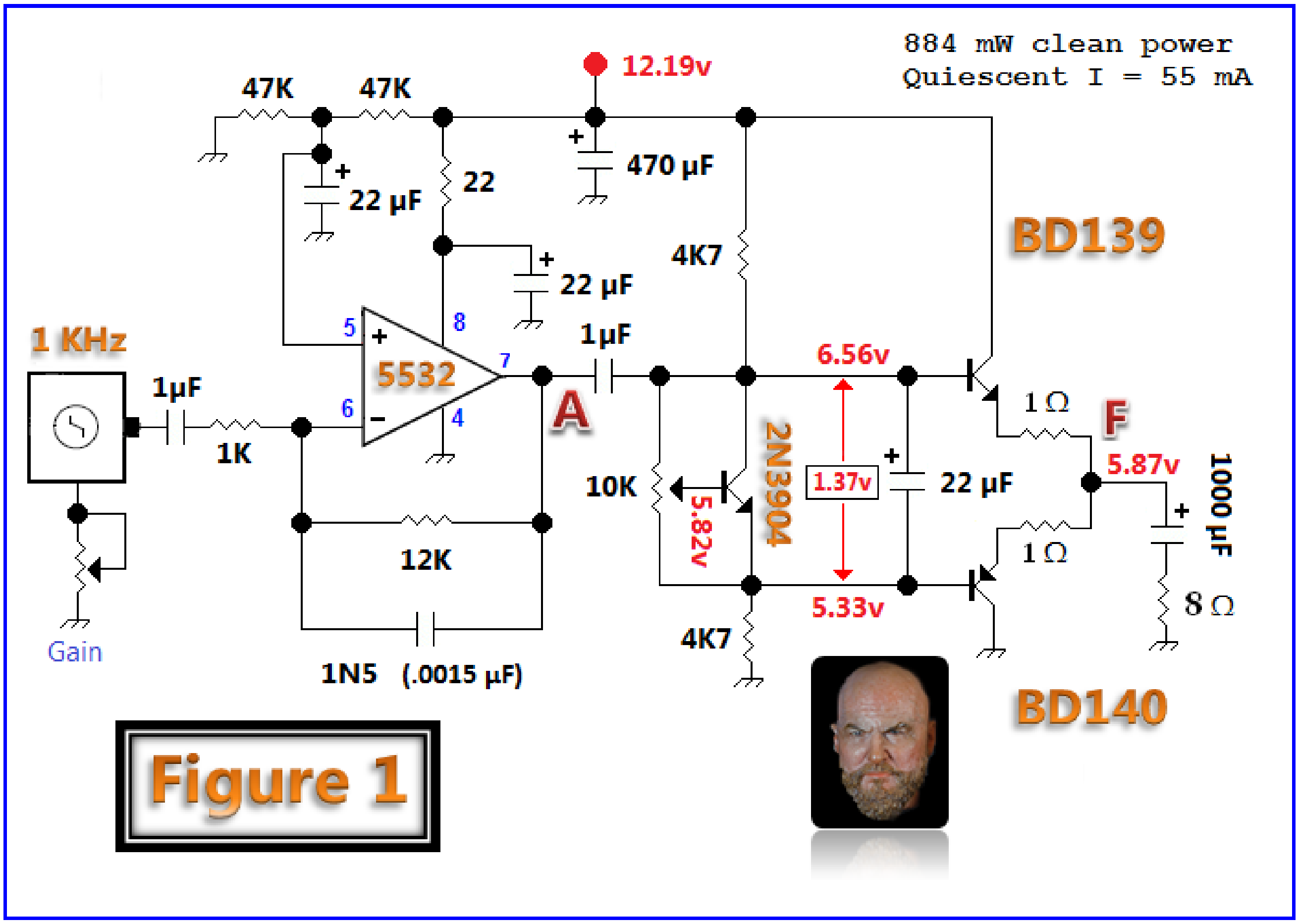
884 mW clean power
Quiescent I = 55 mA
12.19v
47K
47K
22 µF
22
470 µF
22 µF
4K7
BD139
1 KHz
5
8
5532
7
6
4
1µF
1µF
1K
A
6.56v
1 Ω
F
10K
2N3904
5.82v
1.37v
22 µF
5.87v
1000 µF
1 Ω
12K
5.33v
8 Ω
4K7
Gain
1N5 (.0015 µF)
BD140
Figure 1

Above — Figure 1: A popcorn AF power amplifer in full bench *test* mode. Measure the AC with a 10X 'scope probe across the 8 Ω resistor and the DC voltage and current with a multimeter. A distortion analyzer proves useful, but not essential for popcorn circuitry. I also listened to each amplifer connected to a line-level cassette player and an 8 Ω, 15 cm speaker. A 4 Ω speaker doubles the maximal clean power, but I don't own any and stuck to 8 Ω.

Containing no negative feedback, the power amplifer stage runs from the red-colored designator points **A** to **F**. You can AC or DC couple point F to your preamplifer stage as required to apply negative feedback.
As mentioned, you can use the 5532 preamp shown with any reasonable gain (i.e. change the 12K resistor), or opt to replace it with your own design. A low output impedance amplifer best drives the power stage.

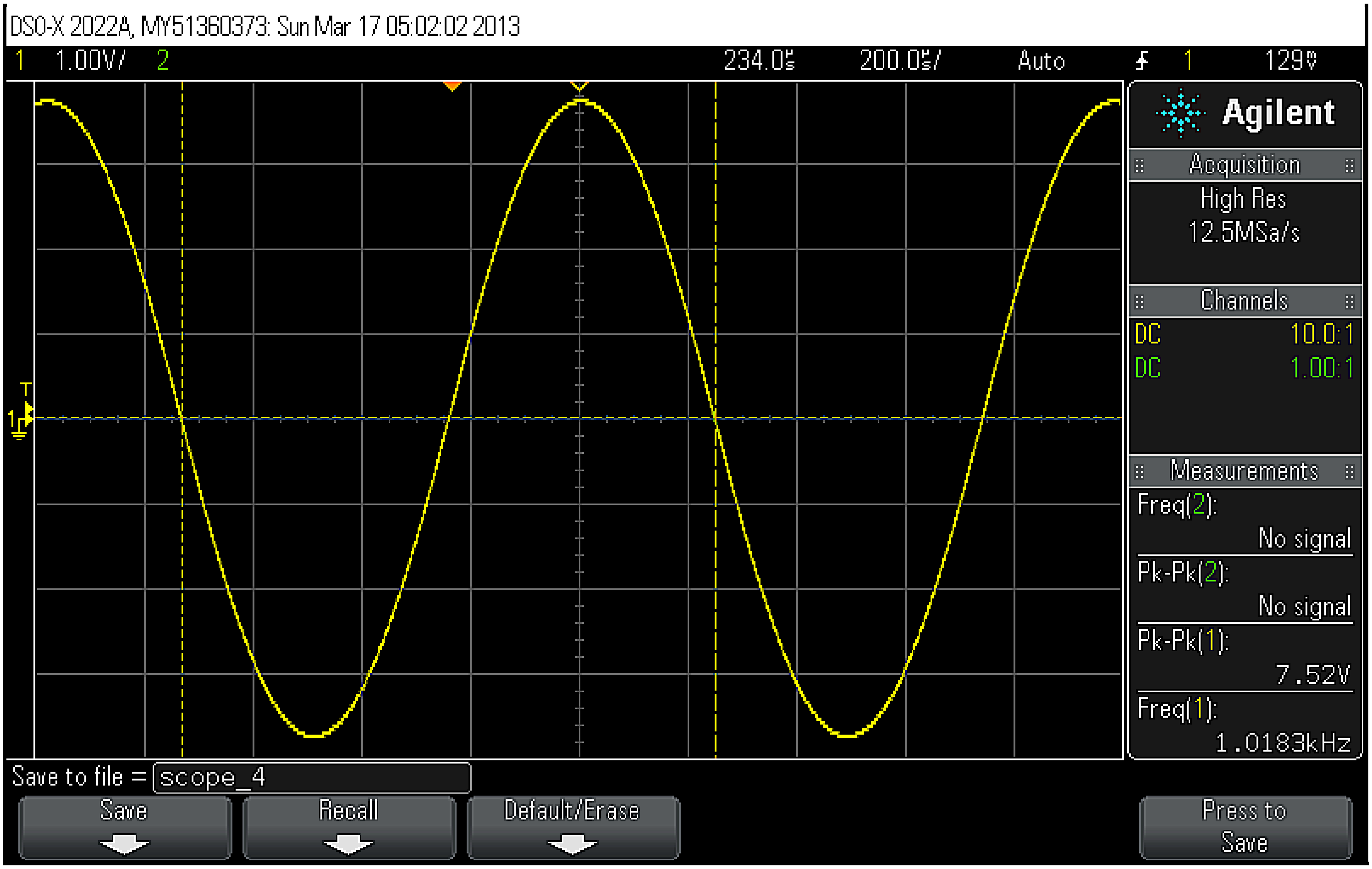

DSO-X 2022A, MY51360373: Sun Mar 17 05:02:02 2013

1 1.00V/ 2 234.0µs 200.0µs/ Auto 1 129mV

Acquisition
High Res
12.5MSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Freq(2): No signal
Pk-Pk(2): No signal
Pk-Pk(1): 7.52V
Freq(1): 1.0183kHz

Save to file = scope_4

Agilent
T
1
Save
Recall
Default/Erase
Press to Save

Above — The output of Figure 1 in my 'scope driven to the maximal pk-pk voltage just before distortion begins to appear. Obviously this task is somewhat subjective, however, allows comparison of the amps you build on your bench.

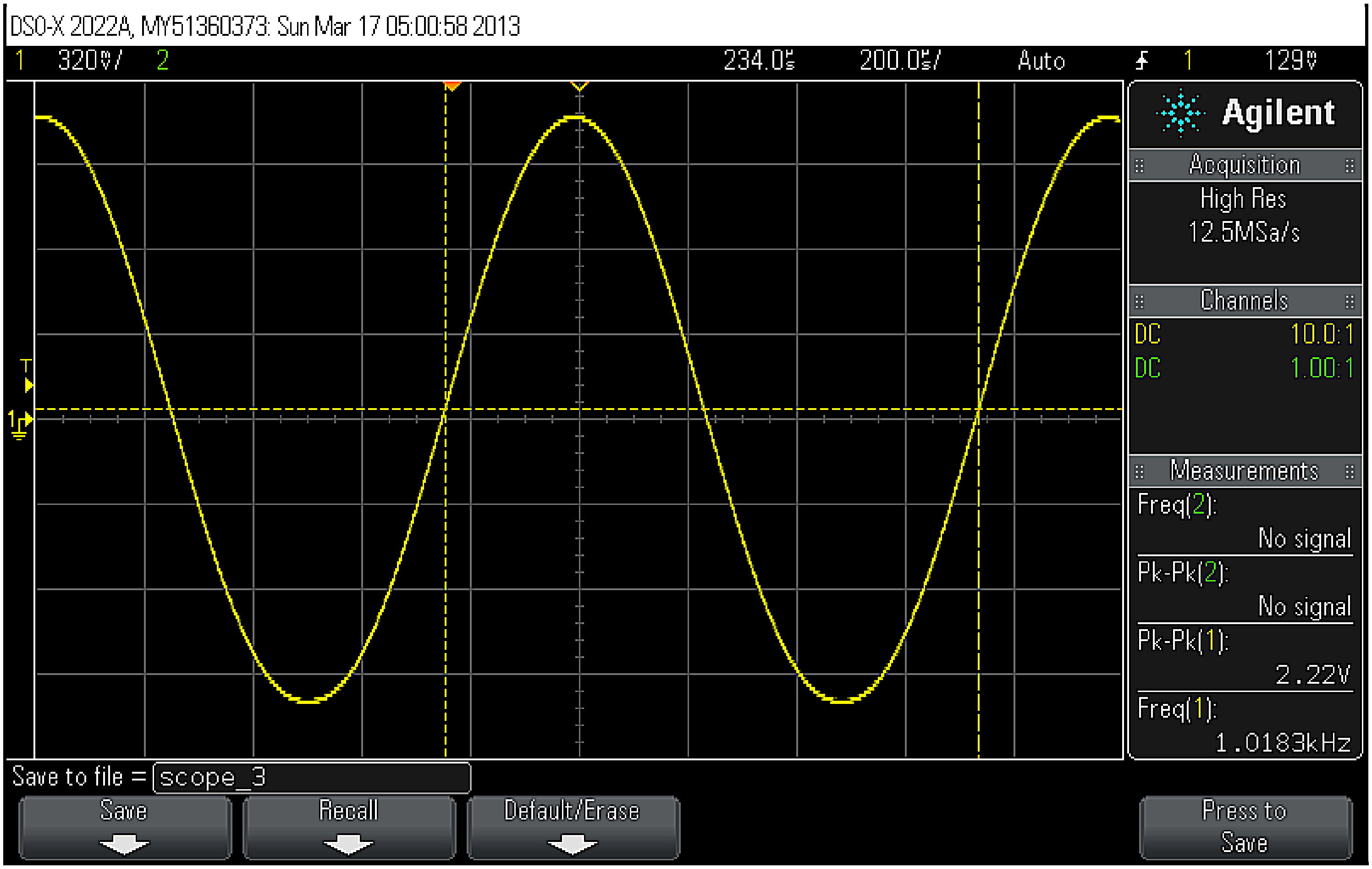

DSO-X 2022A, MY51360373: Sun Mar 17 05:00:58 2013

1 320mV/ 2 234.0us 200.0us/ Auto 1 129mV

Acquisition
High Res
12.5MSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Freq(2): No signal
Pk-Pk(2): No signal
Pk-Pk(1): 2.22V
Freq(1): 1.0183kHz

Save to file = scope_3

Above — A 'scope screen capture with the 22 µF level-shifter filter capacitor from Figure 1 removed. Look what happened; the maximum clean signal fell from 7.52v pk-pk to 2.22v pk-pk. That capacitor is essential to get the maximal possible headroom.

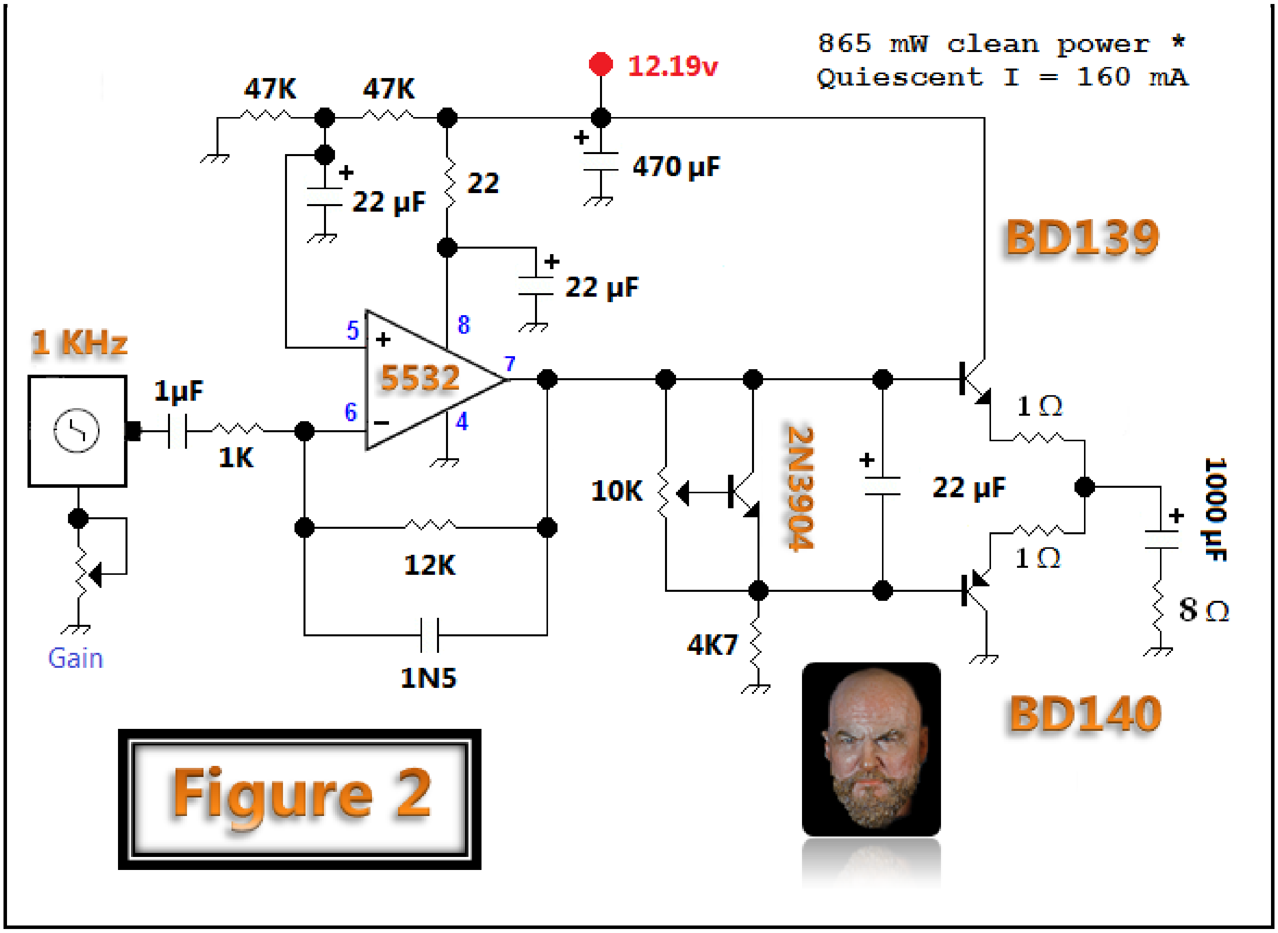
865 mW clean power *
Quiescent I = 160 mA
12.19v
47K
47K
22 µF
22
470 µF
BD139
22 µF
1 KHz
5
8
5532
7
6
4
1µF
1K
10K
2N3904
22 µF
1 Ω
1 Ω
1000 µF
8 Ω
12K
1N5
4K7
Gain
BD140

Figure 2

Above — Figure 2 is Figure 1 with the op-amp DC coupled to the level-shifter. I tested the circuit with and without the 4K7 resistor connecting the base of the 2N3904 to the DC supply: it didn't boost the amplifer headroom, nor reduced crossover distortion, so I removed that R.

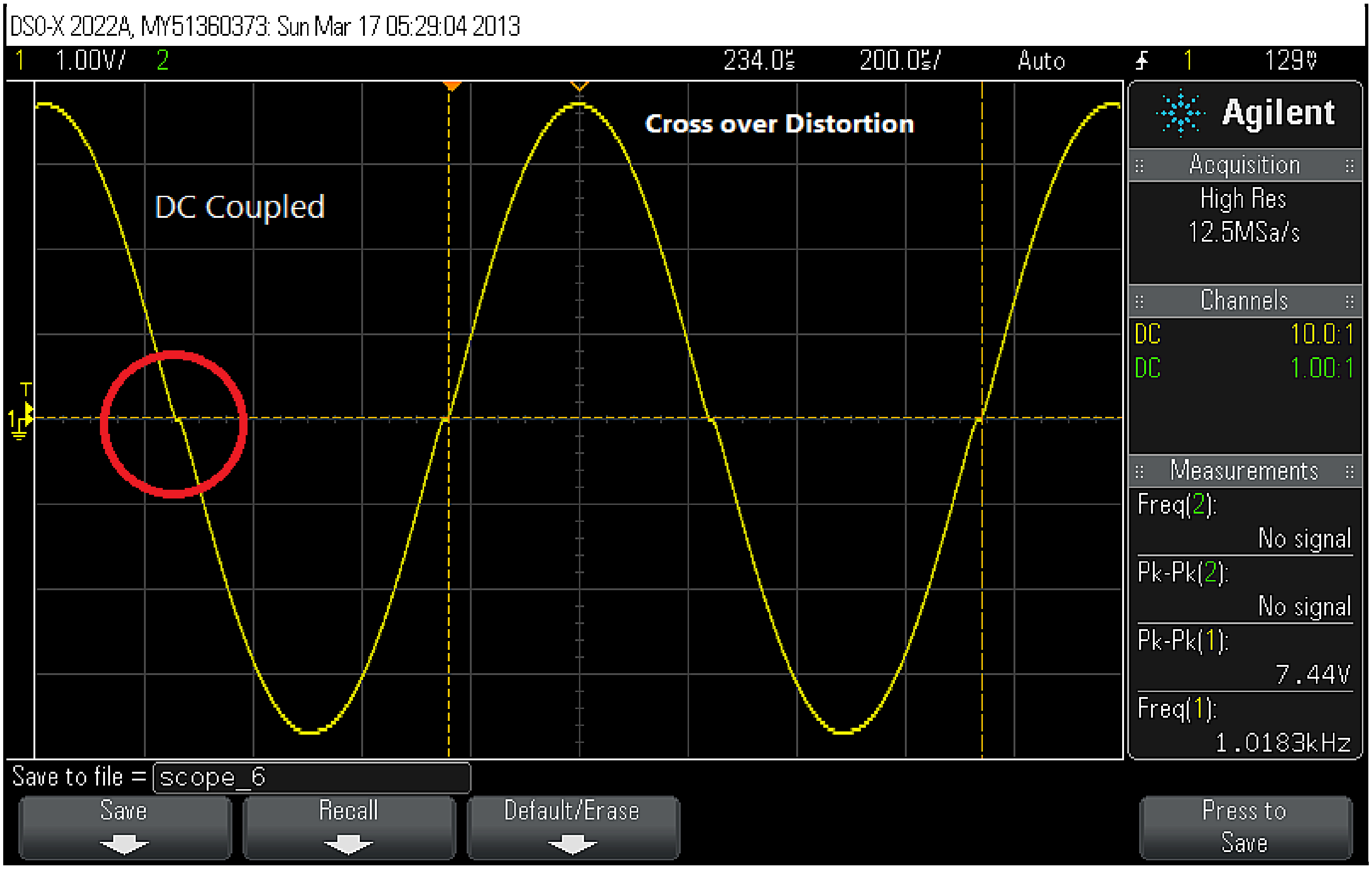
DSO-X 2022A, MY51360373: Sun Mar 17 05:29:04 2013
1 1.00V/ 2
234.0µs
200.0µs/
Auto
1
129mV
DC Coupled
Cross over Distortion
Agilent
Save
Recall
Default/Erase
Press to Save

Acquisition
High Res
12.5MSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Freq(2): No signal
Pk-Pk(2): No signal
Pk-Pk(1): 7.44V
Freq(1): 1.0183kHz

Save to file = scope_6

Above — The Figure 2 amplifer 'scope tracing. At *maximum power*, crossover distortion appeared and I've seen this before. Likely, there is not enough base drive to keep the power followers forward biased. By adjusting the level shifter, I almost removed the crossover distortion, but never eliminated it. This drove the quiescent current up to 160 mA. Yikes!

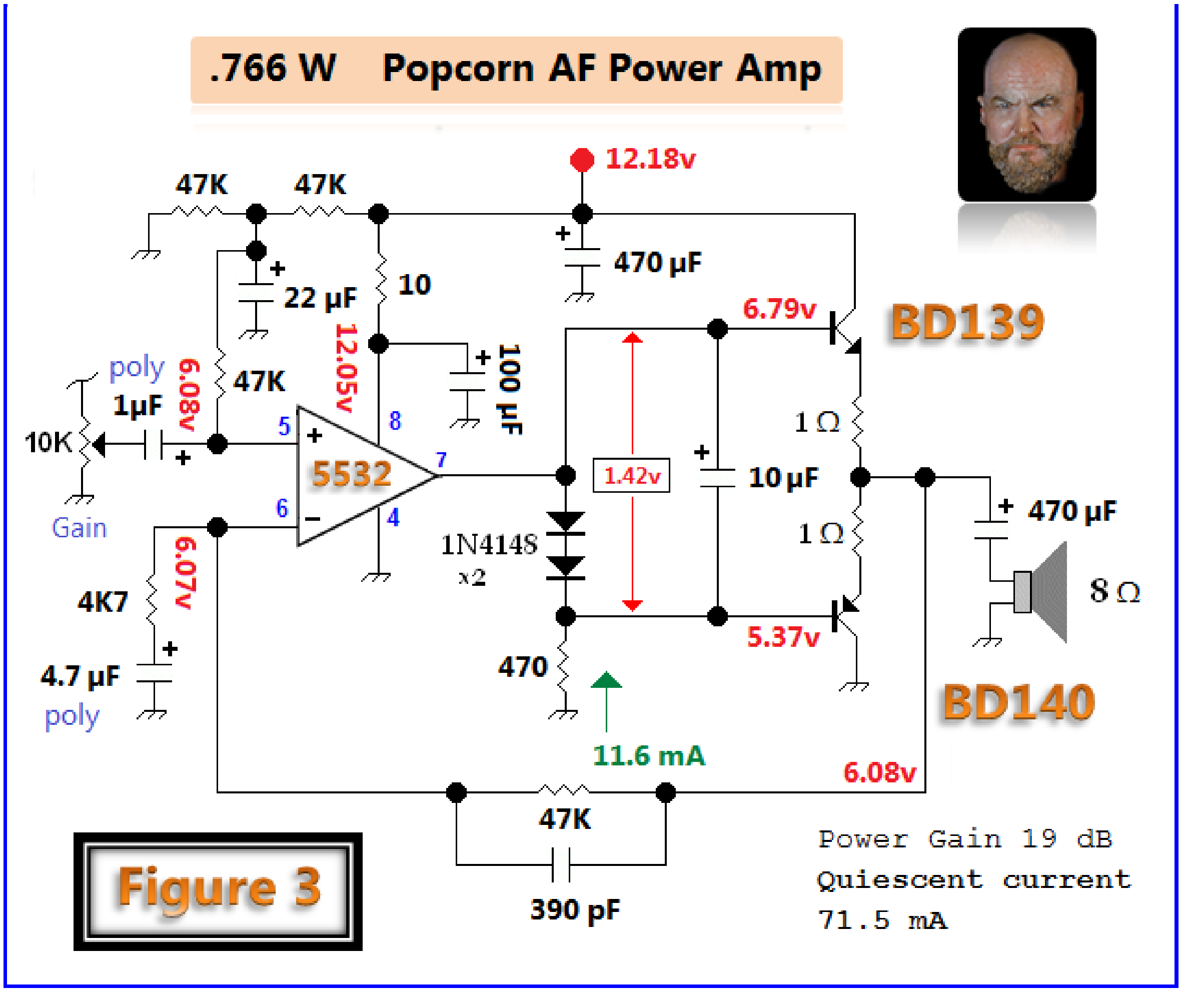
.766 W Popcorn AF Power Amp
12.18v
47K
47K
22 µF
10
470 µF
12.05v
100 µF
6.79v
BD139
poly
1µF
6.08v
47K
10K
Gain
5
8
7
6
4
5532
1 Ω
1.42v
10 µF
1 Ω
470 µF
8 Ω
1N4148
x2
4K7
6.07v
4.7 µF
poly
470
5.37v
BD140
11.6 mA
6.08v
47K
390 pF

Figure 3

Power Gain 19 dB
Quiescent current
71.5 mA

Above — A variation of Figure 2 employing diodes instead of an NPN level-shifter. To kill the cross-over distortion, I lowered the 4K7 resistor by a magnitude of 10. This gave a maximum clean power of 766 mW with a quiescent current of nearly 72 mA. Head room and quiescent current are inferior to the Figure 1 circuit.

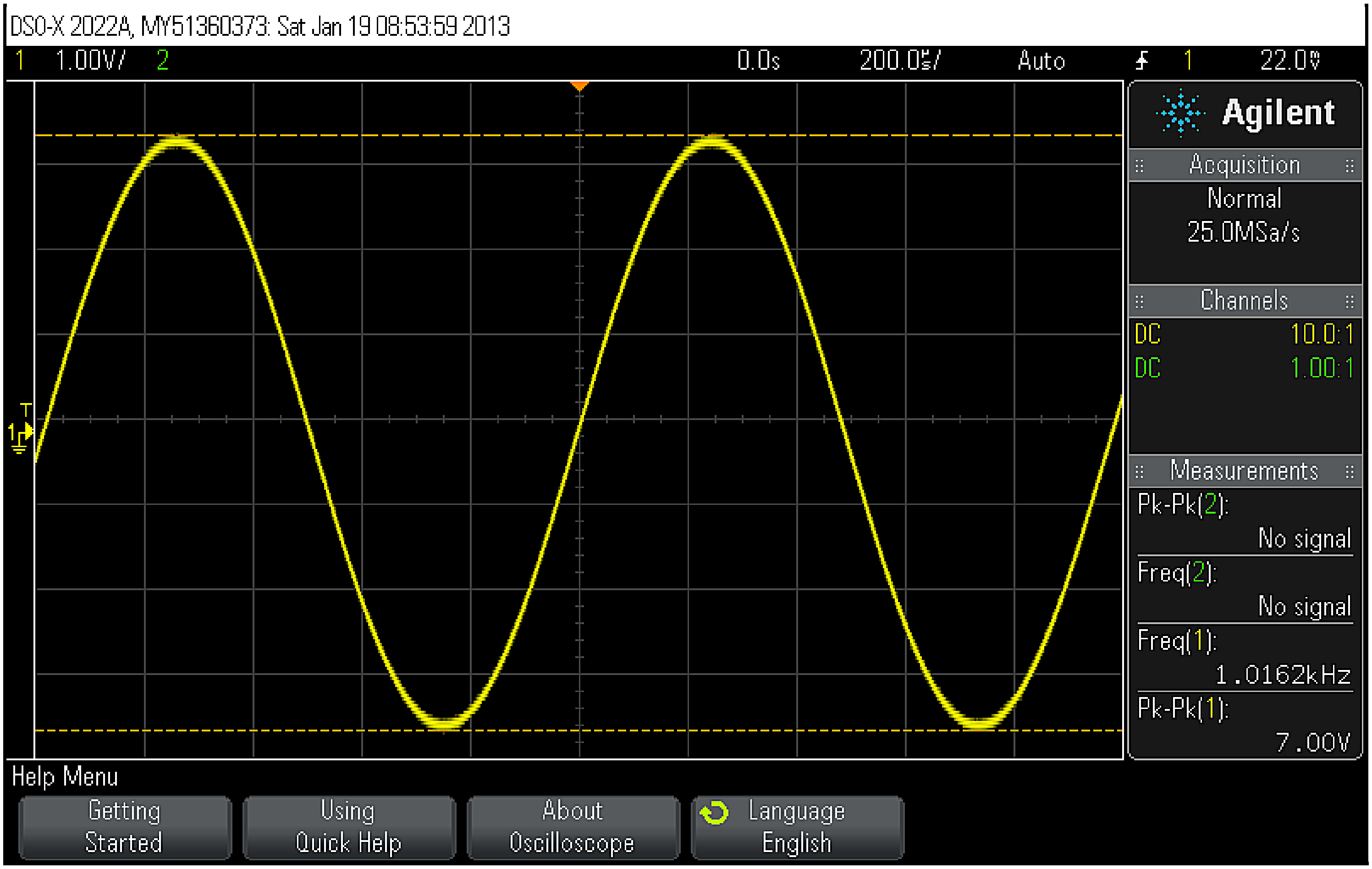
DSO-X 2022A, MY51360373: Sat Jan 19 08:53:59 2013

1 1.00V/ 2 0.0s 200.0us/ Auto 1 22.0mV

Acquisition
Normal
25.0MSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Pk-Pk(2): No signal
Freq(2): No signal
Freq(1): 1.0162kHz
Pk-Pk(1): 7.00V

Agilent
Help Menu
Getting Started
Using Quick Help
About Oscilloscope
Language English

Above — The Figure 3 'scope tracing. Click for a 'scope tracing with the signal generator amplitude increased *slightly* to push this amp into clipping.

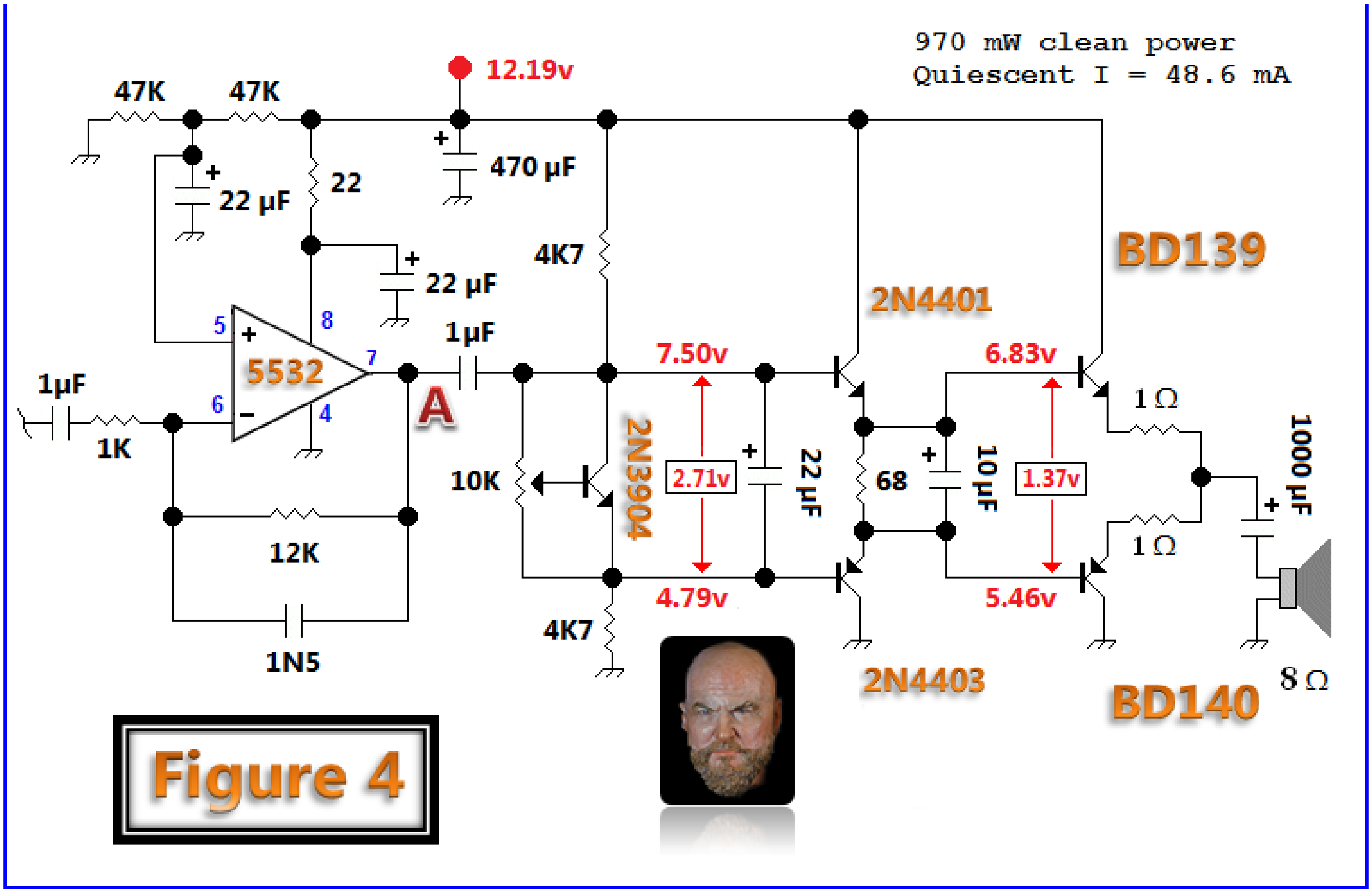
970 mW clean power
Quiescent I = 48.6 mA
12.19v
47K
47K
22
470 µF
22 µF
22 µF
4K7
BD139
2N4401
5
8
+
5532
7
6
−
4
1µF
1µF
1K
A
7.50v
6.83v
1 Ω
1000 µF
+
10K
2N3904
2.71v
22 µF
68
10 µF
1.37v
1 Ω
12K
4.79v
5.46v
4K7
1N5
2N4403
BD140
8 Ω

Figure 4

Above — Back to an AC coupled power amplifer like Figure 1. I added a set of intermediate followers built with a 2N4401/2N4403 pair. The clean output power now lies at 970 mW with a quiescent current under 50 mA. Adjusting the trimmer potentiometer on the level-shifter even a tiny amount may change the quiescent current dramatically.

I found a bias of 1.37v across the BD139/140 pair removed all trace of cross-over distortion at maximum clean signal power. Just tweak the 10K trimmer potentiometer while looking at your 'scope and decide what bias you prefer. I lower the bias until crossover distortion appears and slowly tweak it to find the sweet spot. Then measure the DC voltage across the power follower base terminals, plus the total stage quiescent current with the signal generator switched off. You might have to repeat this procedure a few times, since trimmer pot adjustment is quite sensitive.

Jerry, W5JH made a PC board. Click for front photo. Click for rear photo.

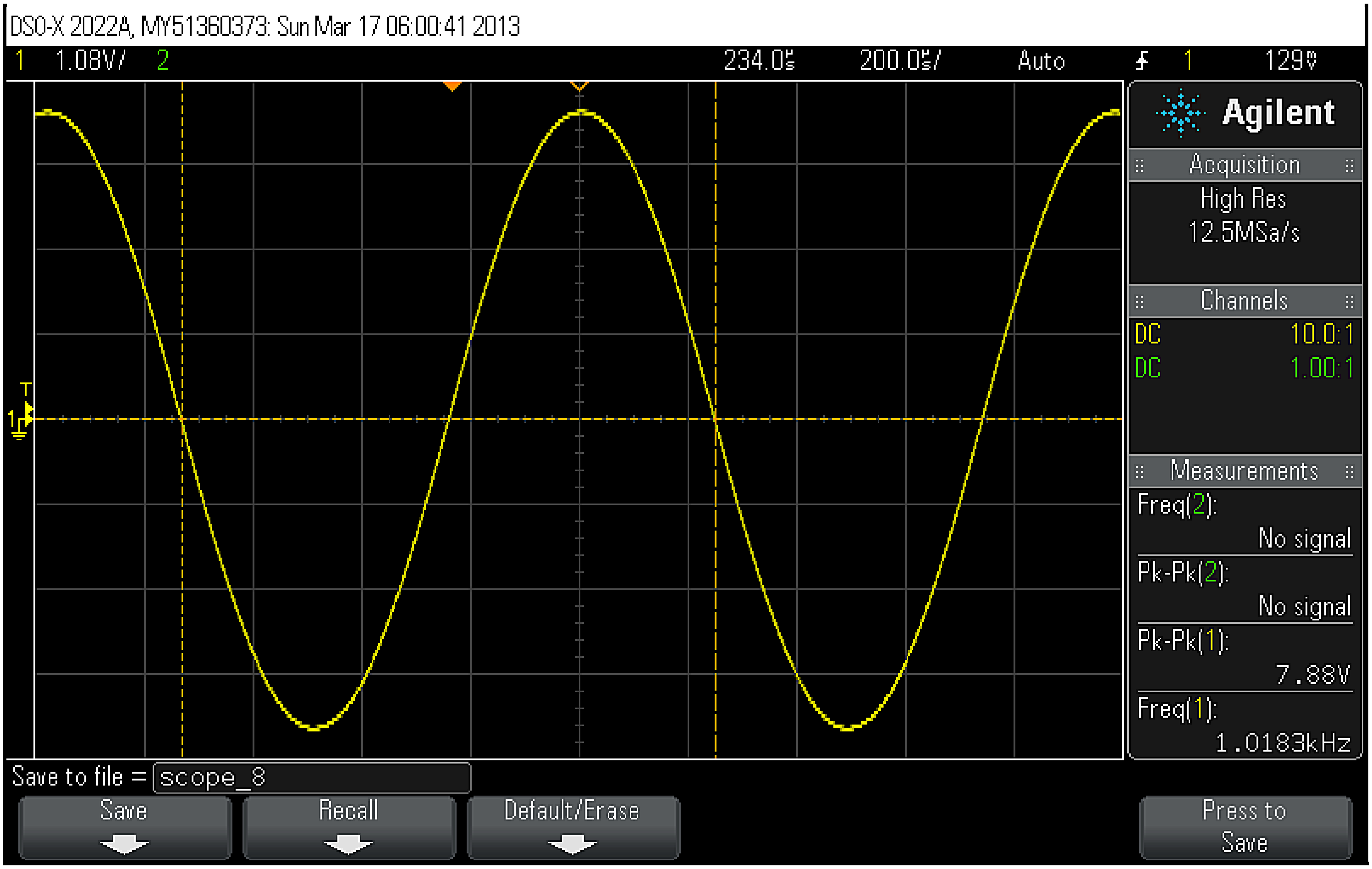
DSO-X 2022A, MY51360373: Sun Mar 17 06:00:41 2013

1 1.08V/ 2 234.0&#181;s 200.0&#181;s/ Auto 1 129mV

Acquisition: High Res 12.5MSa/s

Channels: DC 10.0:1; DC 1.00:1

Measurements:
Freq(2): No signal
Pk-Pk(2): No signal
Pk-Pk(1): 7.88V
Freq(1): 1.0183kHz

Save to file = scope_8

Agilent
Save
Recall
Default/Erase
Press to Save

Above — The Figure 4 'scope tracing.

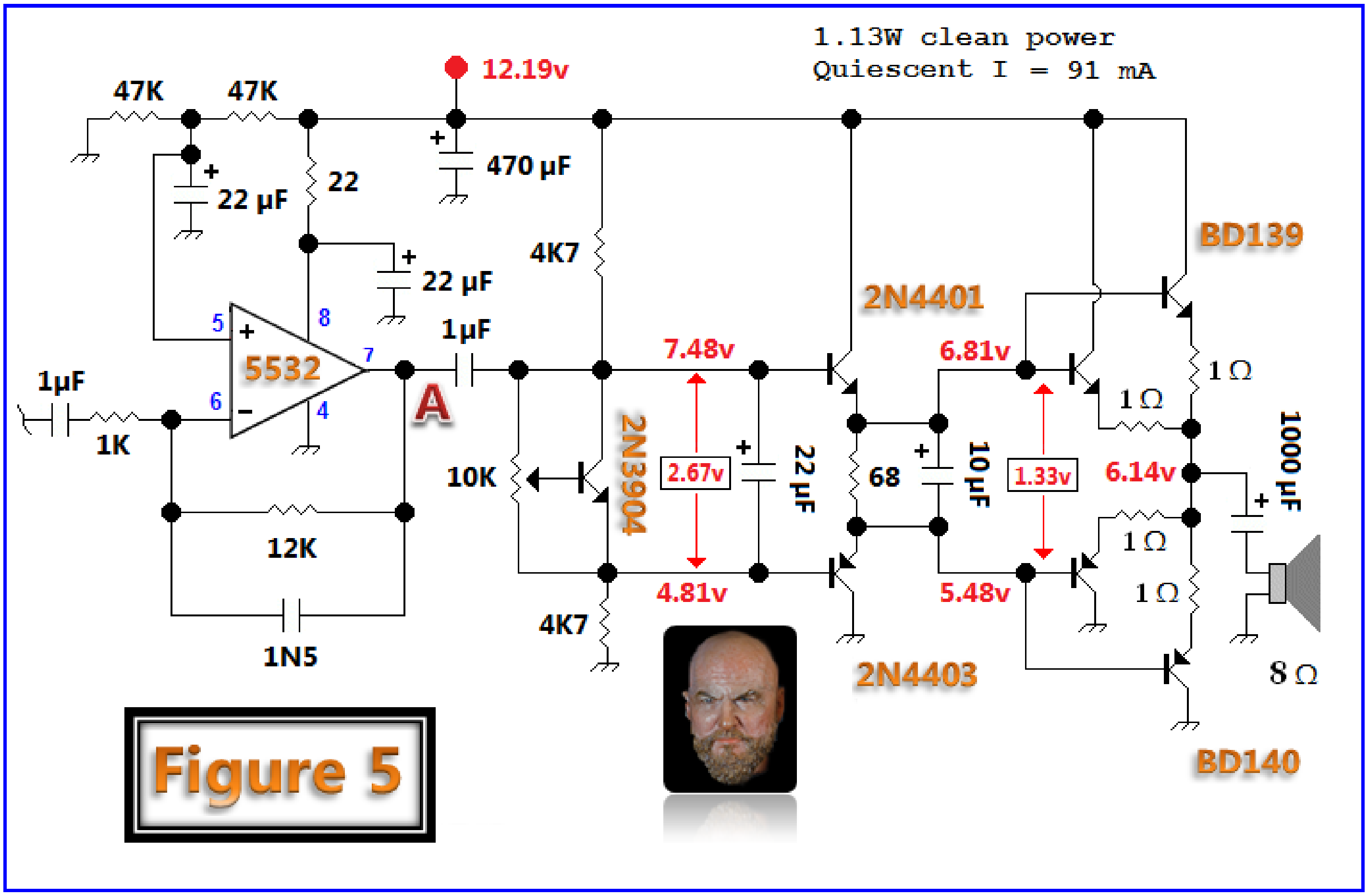
1.13W clean power
Quiescent I = 91 mA
12.19v
47K
47K
22 µF
22
470 µF
22 µF
4K7
2N4401
BD139
5
8
7
5532
6
4
1µF
1µF
1K
A
7.48v
6.81v
1 Ω
1 Ω
10K
2N3904
2.67v
22 µF
68
10 µF
1.33v
6.14v
1000 µF
12K
1 Ω
1 Ω
4.81v
5.48v
4K7
1N5
2N4403
8 Ω
BD140

Figure 5

Above — I added another BD139/140 power follower pair in parallel. The boost in headroom over Figure 4 was small, but it was nice to break the 1 Watt barrier. This amp sounded great and blew away an LM386 set up for a gain of 20 — more headroom, less noise and boosted warmth.

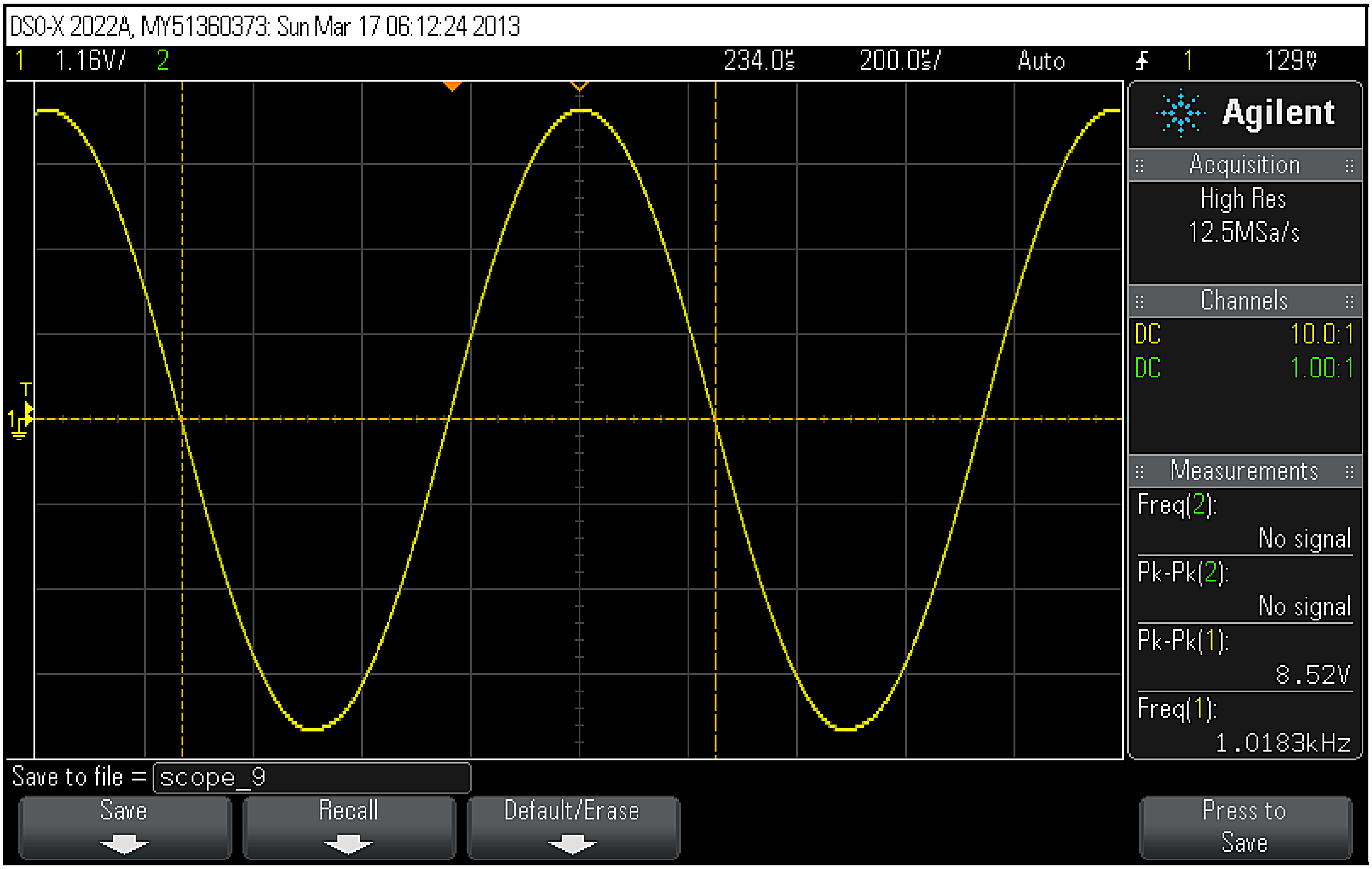

DSO-X 2022A, MY51360373: Sun Mar 17 06:12:24 2013

1 1.16V/ 2 234.0µs 200.0µs/ Auto 1 129mV

Acquisition
High Res
12.5MSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Freq(2): No signal
Pk-Pk(2): No signal
Pk-Pk(1): 8.52V
Freq(1): 1.0183kHz

Save to file = scope_9

Above — The Figure 5 'scope tracing.

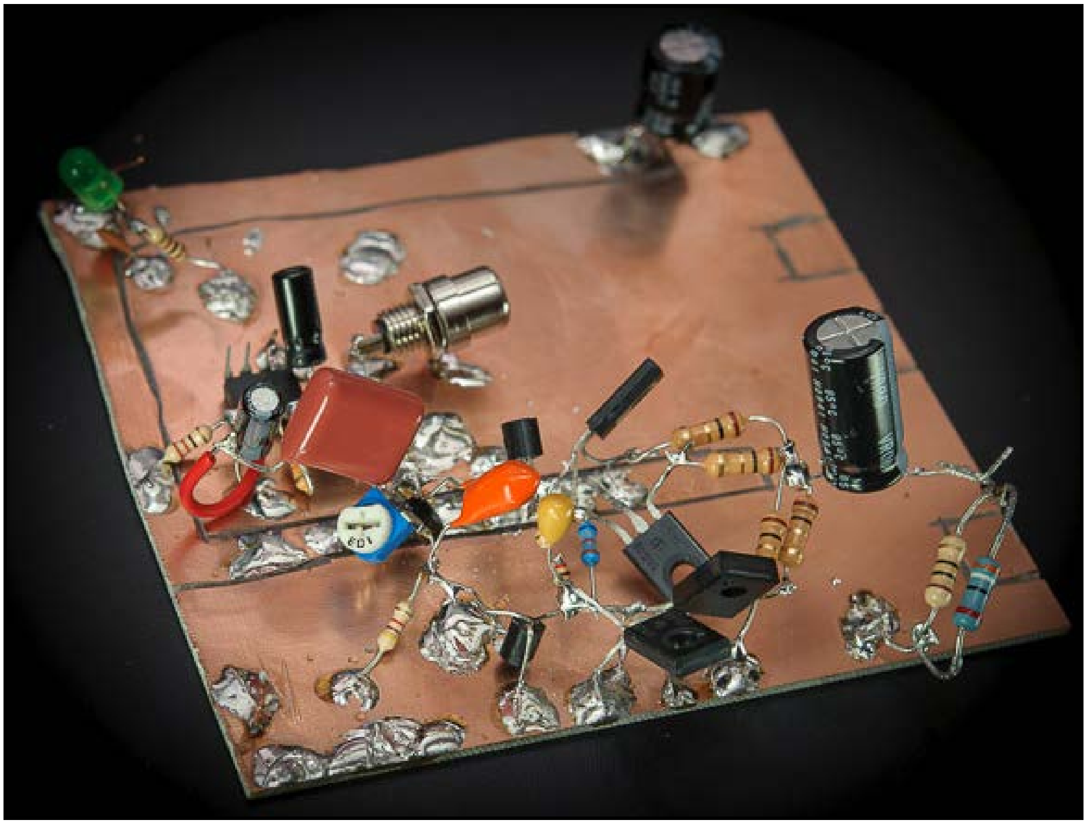

Above — The Figure 5 breadboard. I built all the AF power amps on this board. Signal caps <= to 1 µF were polyester film, while I employed 10 or 22 µF tantalum caps for the level shifters. Electrolytic caps work fine; especially for the level shifter capacitors. The green power indicator LED drew 10 mA and I subtracted this from the quiescent current measurements.

Depending on the AF gain of your receiver, you might wish to add the familiar Zobel filter; a 10 Ω R in series with 0.1 µF C from the positive end of the output capacitor to ground, or more AF bypassing/ decoupling to the circuitry.

No component values were critical — imbuing the spirit of homebrew radio, substitute parts and measure outcomes.

QRP — PosData for August 18, 2014

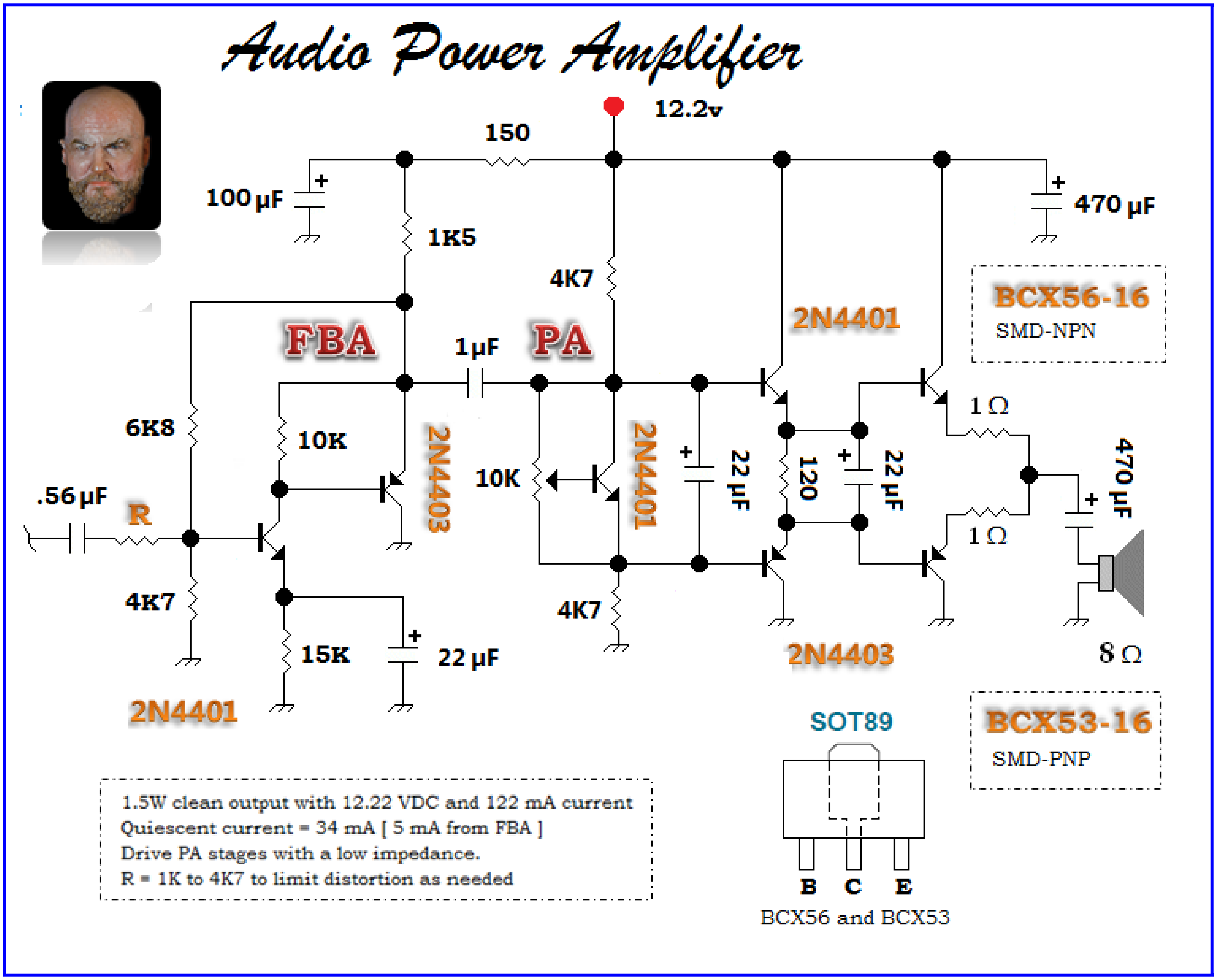

1.5W clean output with 12.22 VDC and 122 mA current
Quiescent current = 34 mA [5 mA from FBA]
Drive PA stages with a low impedance.
R = 1K to 4K7 to limit distortion as needed

Above — I built a 100% discrete version of Figure 4 power amplifer with a 2N4401/2N4403 feedback voltage amp that drives the PA stage with a low impedance. Without a low impedance drive, the PA [all the components right of the 1 µF capacitor where you see **PA**] the headroom of the PA section falls down. Thus an op-amp or emitter follower drive works great.

I moved to SMD power transistors: the NXP BCX56 + BCX53. These give a little more output than the BD139/140, and take much less board room. I ran no heat sink other than 8 mm by 4 mm PC board traces for the collectors. A better choice might be the related BCP56 + BCP53 pair in SOT223 since the bigger package of this version better sinks heat.

I determined the optimum emitter resistor for the 2N4401/2N4403 followers = 120 Ω [not 68 Ω as shown in Figure 4]. This drops the the PA quiescent current in half and yields the same performance. If you build Figure 4, change to 120 Ω.

I meant Figure 4 and the QRP POS-Data amp as easy-to-make power amplifiers with a *little* gain. You will have to add voltage gain in some AF projects. For Figure 4, it's easy to change up the 12K resistor, or apply the other half of the 5532. Decouple and bypass better if you get motor boating or hum. 73 de VE7BPO

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9. The Progressive Receiver by Wes, W7ZOI and John, K5IRK

When introduced in QST for November 1981, the Progressive Communications Receiver (PR) by Wes, W7ZOI and John, K5IRK set a dynamic range benchmark for dual-conversion homebrew receivers: 94 dB in CW mode. 31 years later, few other home-built radios have ever reached this benchmark.

The PR is a single conversion superheterodyne 80m receiver; or perhaps it's a direct conversion receiver with an extra mixer ahead of the product detector? It's both and that's the point. Further, Wes and John added other bands with another mixer, plus a crystal oscillator, RF filter +/- an RF amp for each band.

You'll see the PR listed as A High-Performance Communication Receiver in ARRL Handbooks from the early 90s or so. ARRL staffers built and enjoyed the PR in their test lab for many years.

After purchasing the 1991 ARRL Handbook and reading about this project, I slowly adopted and entrenched the PR's progressive (modular) approach. When I built and web published my 2 TRF WWV receivers with crystal IF filters, a couple of people wrote that I "grossly over-designed" them, however, other, more astute builders placed a mixer on the front end and turned their TRF into a multi-band superhet like I later did. These builders understood how progressive circuit building works — all PR inspired.

I hope my introduction renews your interest in the PR. Wes and John's article is thorough and complete — I can't add to it, however, I'll share my thoughts along with those from Wes and John all these decades later.

The IF Stage gain comes from 2 dual gate MOSFET amplifiers. The final MOSFET amp drives a BJT differential pair providing 9 MHz RF to the product detector at 50 Ω and signal for the AGC circuit. Wes recalls using a 3N211 in the original MOSFET slots since Doug DeMaw owned a pile of them and contributed some. In some areas, the 40673 was the dominant 2-gate MOSFET soldered by radio home builders back in the day.

An evolved version of the PR Intermediate Frequency stage appeared in EMRFD as Figure 6.50. Wes replaced the now hard-to-find and *expensive* leaded dual-gate dual gate MOSFET with a cascode of J310s. I built this stage and it performed well with my 12.2 VDC power supply.

Jeff, WA7MLH built the general purpose IF system and noticed if the power supply dropped below 12 VDC, the gain control and maximum gain fell off and he wrote to Wes about his findings. Wes later confirmed dysfunction with a lower DC supply. I asked him to recollect this time:

"…. Frankly I don't remember if I went immediately to computer simulations or if I built a single stage. I think I built. Anyway, Jeff was correct, depending upon the FETs that were used. Then I got to plowing into the details of the cascode, this time with SPICE. I was using PSPICE for some simulations, but was in the process of switching over to LT-SPICE. That makes no difference, for I used the same models in both.

Anyway, playing with a single stage showed that the mechanism for gain reduction was that when the voltage on the upper gate was reduced, it did nothing to the upper stage, but it compressed the supply on the lower FET. So far as signal goes, the upper part was nothing more than a common gate stage that passed whatever signal current was there in the drain of the lower part on into the source of the upper part.

But these were depletion mode FETs, the normal thing for most of the JFETs we use. As such, you have to get the gate down pretty low to get the source voltage low enough to be effective in reducing the gain of that lower FET. That's when it became clear that one could use other parts in the upper slot. An enhancement mode FET such as a MOSFET would work well. And just a common bipolar would do the job nicely too..."
Wes, W7ZOI per an email - January 2013.

In QST for 2007, a refined version of the EMRFD Figure 6.50 IF stage appeared with a hybrid cascode amplifier instead of the cascode JFETs (and the 2 original dual gate MOSFETs of the PR). Further, Wes added a third amplifier to widen gain control. The hybrid cascade stage has since gone in 100s of receivers across the globe; ensuring the PR legacy lives on as the modernized hycas version.

Roger, KA7EXM sold kits of the hycas amp for years, however, these kits sold out. PC boards may still be available via his web site. Roger received permission to publish the QST hycas article online:

Above — The now *sold out* hycas IF System kit once offered by Roger, KA7EXM.

To underscore my love of the original PR IF amp, I built a version using SMT dual gate MOSFETs in 2013 and feel the SMT version might be perfect for builders who prefer to manually control IF gain in most situations, but want AGC control now and then. Versions built with the BF998 MOSFET may suffer parasitic ocillations at UHF and so meticulous attention to decoupling and bypassing out to UHF and in some cases double-sided copper board may be required to prevent unwanted ringing at UHF.

If you build the entire PR with the BF998, the VFO output runs about 10 dBm and requires attenuation. Again, please consider UHF oscillation precautions.

Wes and others have built both leaded and all-SMT versions of the hycas amplifer.

John, K5IRK Recalls

I wanted John’s recollection of the PR design and build and received the following narrative in late March 2013:

“…One night in late 1979 I had telephoned Wes to chat about QRP and building rigs. During the conversation he told me he had a project and related QST article in mind and asked me if I wanted to participate. He was in the process of writing a book (IRFD) and didn’t have much free time, so he needed some help. I told him yes. A few weeks later I received the first schematics and began to gather parts.

Recall that the project started as direct conversion receiver. But it then progressed (hence the title of the article) to a superhet. I choose to build my superhet with a SSB filter as I had already built Wes' CW Competition Grade RX from SSD. During the next year he sent me schematics and a few critical parts thru snail mail. (The Internet and e-mail would come later.) I would build the circuits and report the results back to him. As I recall, we only had about three phone conversations throughout the whole project.

The design was an iterative process. For example, the IF circuitry began with a single 40673, but grew to include two stages. Wes bread boarded this in a mono band version of the receiver at his end. An early audio derived AGC system was replaced by the IF derived circuit that appears in the article. The VFO was also designed twice, as were the Front end Filters and the BFO. More is said below about the design procedure.

I designed the circuit board layouts. The traces on my boards were drawn by hand and etched at home. I sent hand drawn sketches of each of the boards to Doug DeMaw; Circuit Boards Specialists (CBS) then created the commercial boards for those folks who wanted boards. I recall that we sent out layouts to any readers for a SASE. All of my boards were designed and built on double sided PC material with the exception of the VFO board and the Audio Filter boards. This can be seen in the photos. The boards eventually sold by CBS were single sided. All layouts and functionality were confirmed prior to publication.

The traditional design process for a homebrew ham receiver in 1980 started with schematic sketches based upon the intuition and experience of the designer. The total circuit would then be built. Measurements were merely things that were done afterward, something to characterize the result. The PR was different. Individual stages were designed, built, and measured. Negative feedback was used in the critical amplifiers to guarantee that the gains were high enough for reasonable noise figure, but low enough to preserve input intercept.

Only after the individual stages were operational, were they assembled to form a working receiver. Some stages were further modified during system assembly and evaluation. We had no computers available for circuit simulation, although the gain distribution was optimized with a hand calculator. The goal was not just a receiver that sounded good, but a box with good two tone dynamic range.

Once my receiver was completed, I sent it to Wes for MDS and DR measurements. A goal was to compare these measurements with those already done in Oregon. Roger (KA7EXM) took many (if not all) of the photos. Wes then forwarded the receiver to ARRL. They returned it to me when they were finished. Wes refined the article during the final months of the project before it was finally published. I received copies of his drafts, and then offered my feedback.

We had hoped that a "few" experimenters would enjoy building the receiver, but had no idea that it would be as successful as it was. We eventually learned why this occurred: First, the receiver held up well when it was measured at ARRL Headquarters, exceeding the performance of most of the appliances being evaluated at the time. This prompted some League staff members to build the receiver for their own use. This, in turn, prompted them to include it in the Handbook for several years.

My original receiver plays as well today as it did in the beginning. The electrolytic caps on the audio board have been replaced, for they were beginning to go south on me, but that’s the only change. I do have a second version that is used for experiments..."

Some PR photos taken by John in March 2013

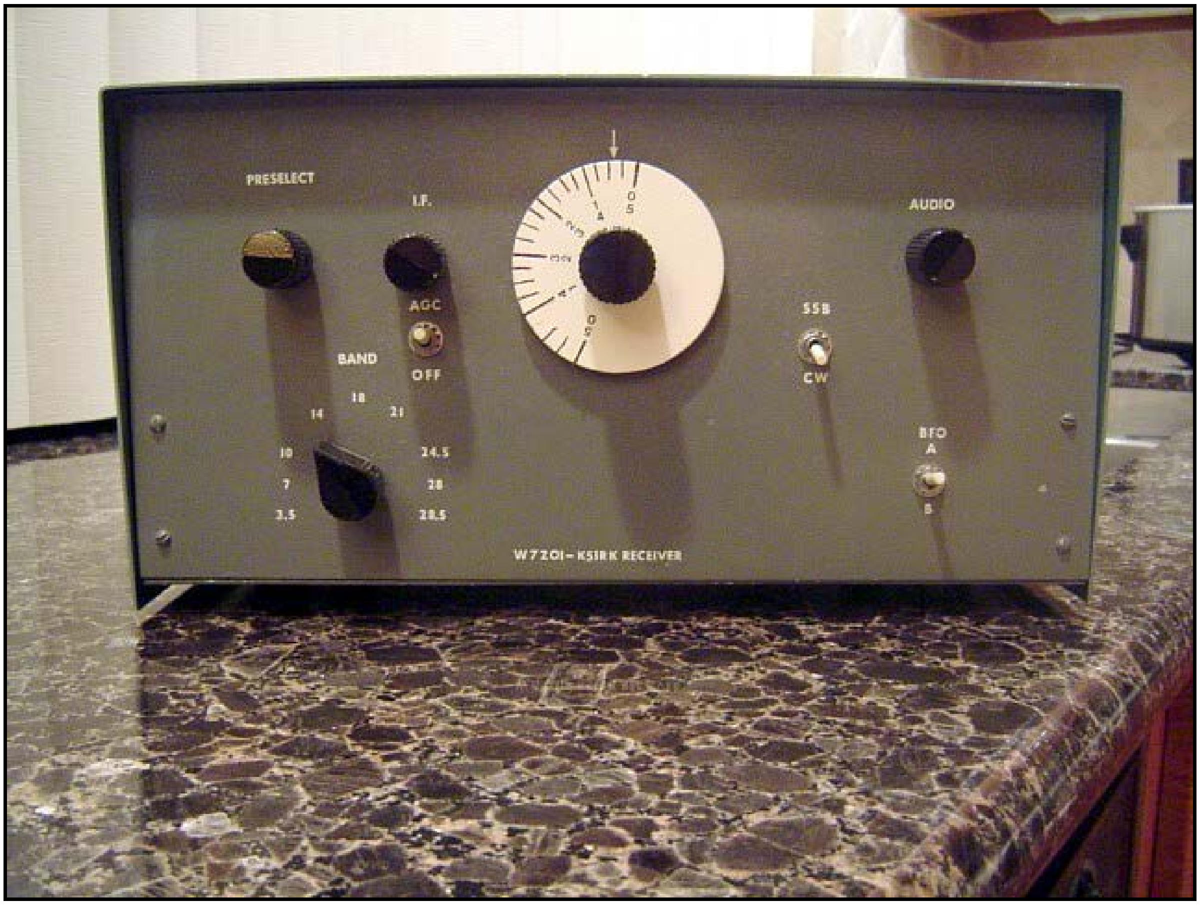

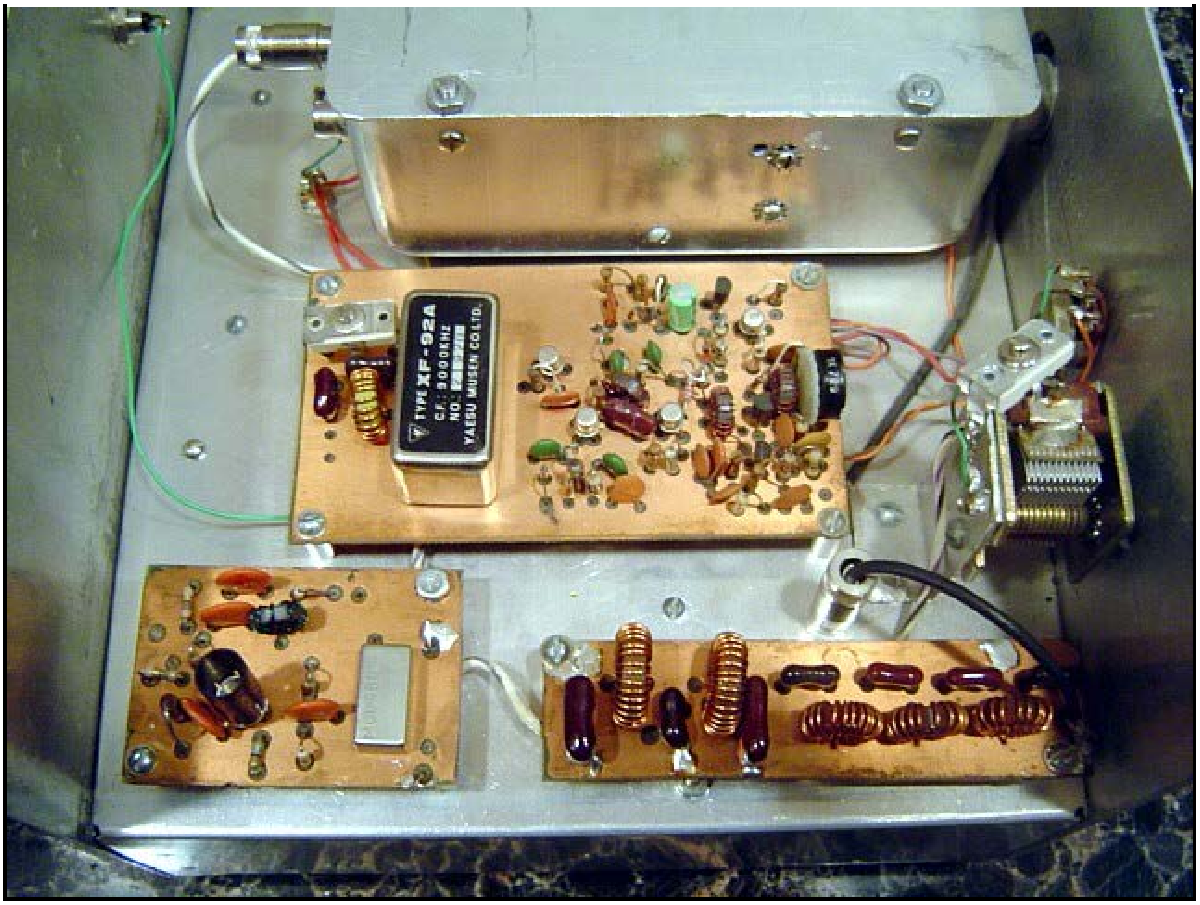
TYPE XF-92A
C.F.: 9000KHz
NO:
YAESU MUSEN CO.LTD.

"...You will notice a couple of things different in these photos than in the photos in the article. First, tacked on to the Front Panel 365 pF variable cap is a mica trimmer cap.....this is of no significance as I was just messing with lowering the BW upper and lower frequencies to see what difference it would make....None is the answer..." *John, K5IRK.*

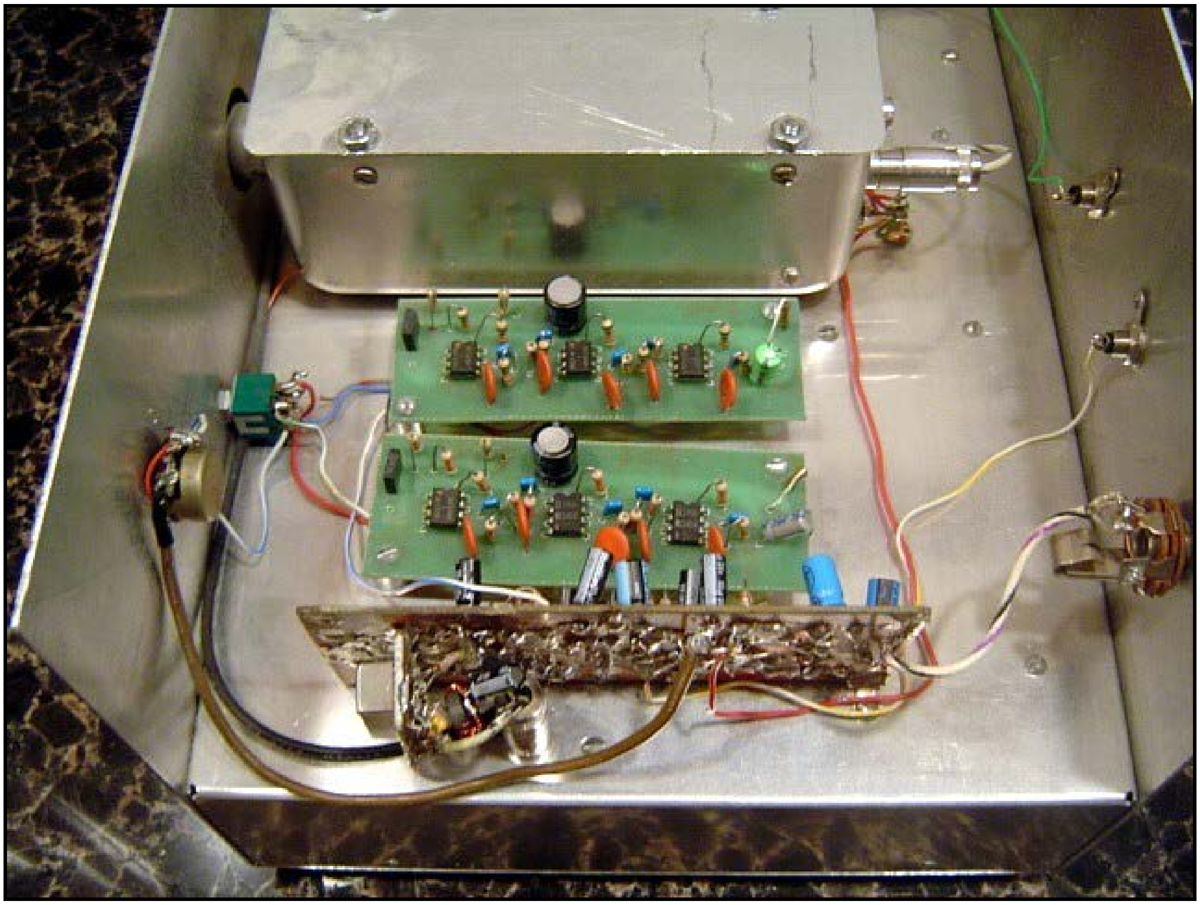

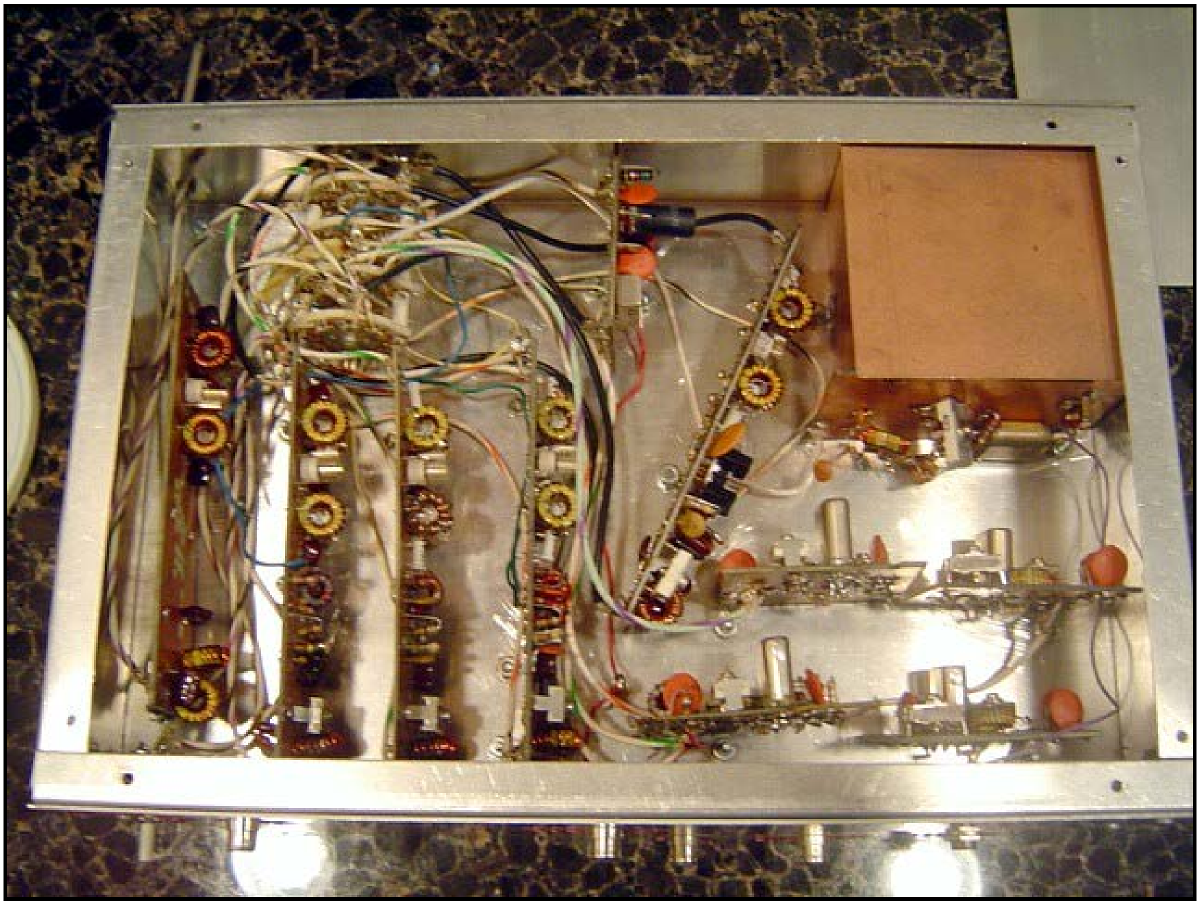

"...In the above photo you will see the addition of the 30 meter band to the RX with the diagonal front end filter board and the Xtal Oscillator attached to the BFO Box's wall that was added some years after the article was published…." *John, K5IRK.*

High-pass plus Peaked Low-pass Filter

If you know me, you know I love the peaked low-pass filter both at RF and AF. This adoration came from studying the PR and other work published and shared privately to me by Wes. *A good reference = The Peaked Lowpass: A Look at the ultraspherical filter by Wes for Ham Radio, June 1984.*

While the high-pass + peaked low-pass filter placed ahead of the second mixer in the PR wouldn't likely go in a modern W7ZOI design, its narrow-band LC filtration generates a roofing action when the receiver uses converters for bands other than 80 meters. The result is that much of the DR obtained in the single conversion version is retained in the dual conversion receivers.

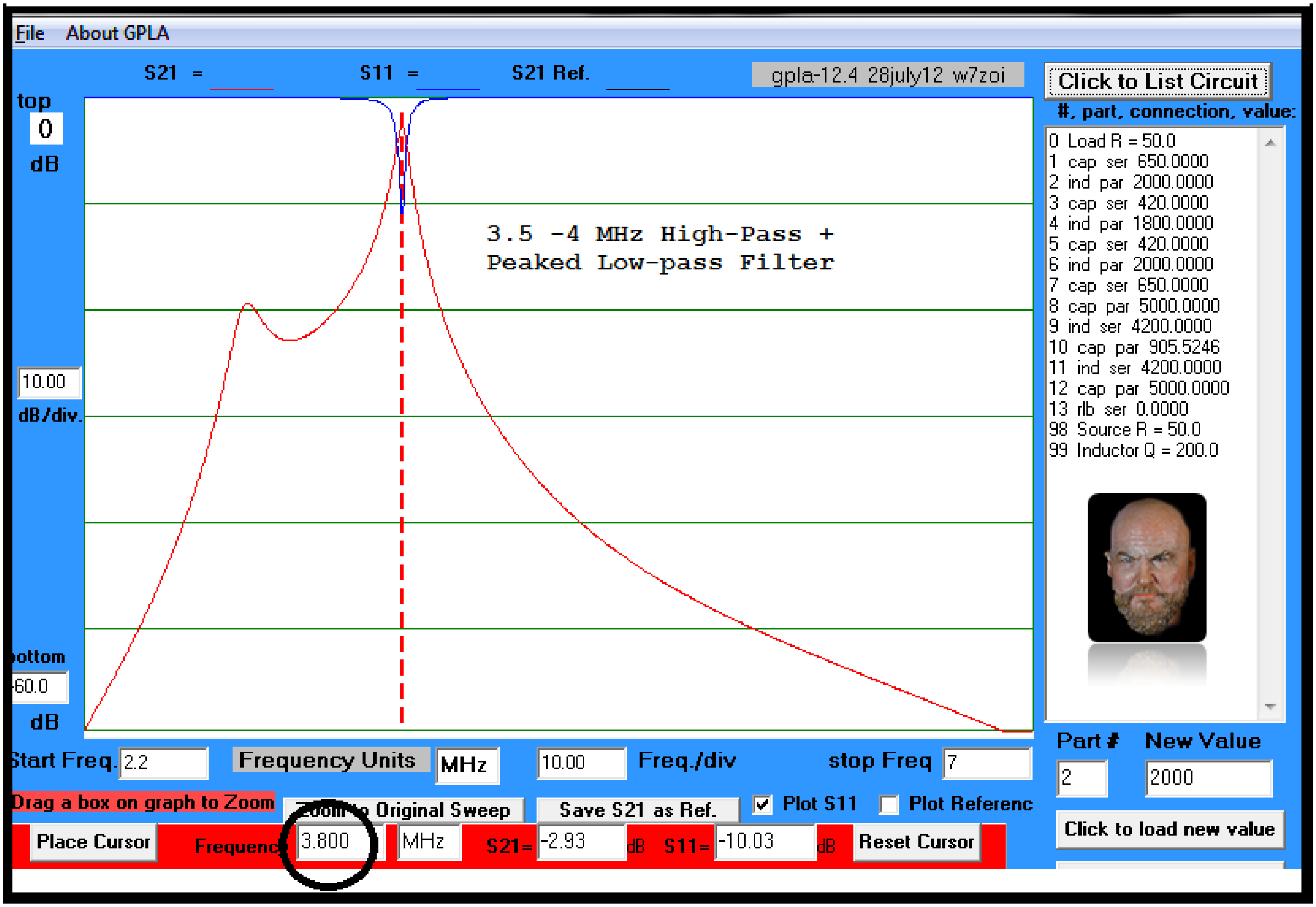
File
About GPLA
S21 =
S11 =
S21 Ref.
gpla-12.4 28july12 w7zoi
Click to List Circuit
top
dB
dB/div.
bottom
dB
3.5 -4 MHz High-Pass +
Peaked Low-pass Filter
Frequency Units
Freq./div
stop Freq
Drag a box on graph to Zoom
Zoom to Original Sweep
Save S21 as Ref.
Place Cursor
Reset Cursor
Click to load new value
Part #
New Value

#, part, connection, value:

0 Load R = 50.0
1 cap ser 650.0000
2 ind par 2000.0000
3 cap ser 420.0000
4 ind par 1800.0000
5 cap ser 420.0000
6 ind par 2000.0000
7 cap ser 650.0000
8 cap par 5000.0000
9 ind ser 4200.0000
10 cap par 905.5246
11 ind ser 4200.0000
12 cap par 5000.0000
13 rlb ser 0.0000
98 Source R = 50.0
99 Inductor Q = 200.0

top 0 dB
10.00 dB/div.
bottom -60.0 dB
Start Freq. 2.2
Frequency Units MHz
10.00 Freq./div
stop Freq 7
☑ Plot S11
☐ Plot Referenc
Frequency 3.800 MHz
S21= -2.93 dB
S11= -10.03 dB
Part # 2
New Value 2000

Above — A GPLA simulation of the front end high-pass/peaked low-pass filter centered for 3.8 MHz by tweaking capacitor #10 in the software. Click for another simulated filter that covers 3-4 MHz. Look at the sublime low and high-pass skirt action with a 3 dB bandwidth of 73 KHz. Love this!

Click for a screen shot of an entire 40 Meter band version shown with the low-pass filter section centered at 7.003 MHz. I also made 1 for WWV 10 MHz — by scaling the original version's XL and XC and tweaking with GPLA, you may build 1 for any HF band.

AF Amplifier

The post product detector AF chain sounds great. Many of us later replaced the Q5 mute switch with something quieter, however, even today — this AF block holds its own against most discrete component headphone-level circuits. I particularly love the crisp fidelity of the Class A feedback pair Q3 and Q4. Today, I would substitute a BD139 for Q4.

Wrap up

I could go on, but this web page is already too long. Studying + building stages from the PR; a receiver designed more than 3 decades ago, might raise your game today. Go team!

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10. Miscellaneous Pictures and Figures

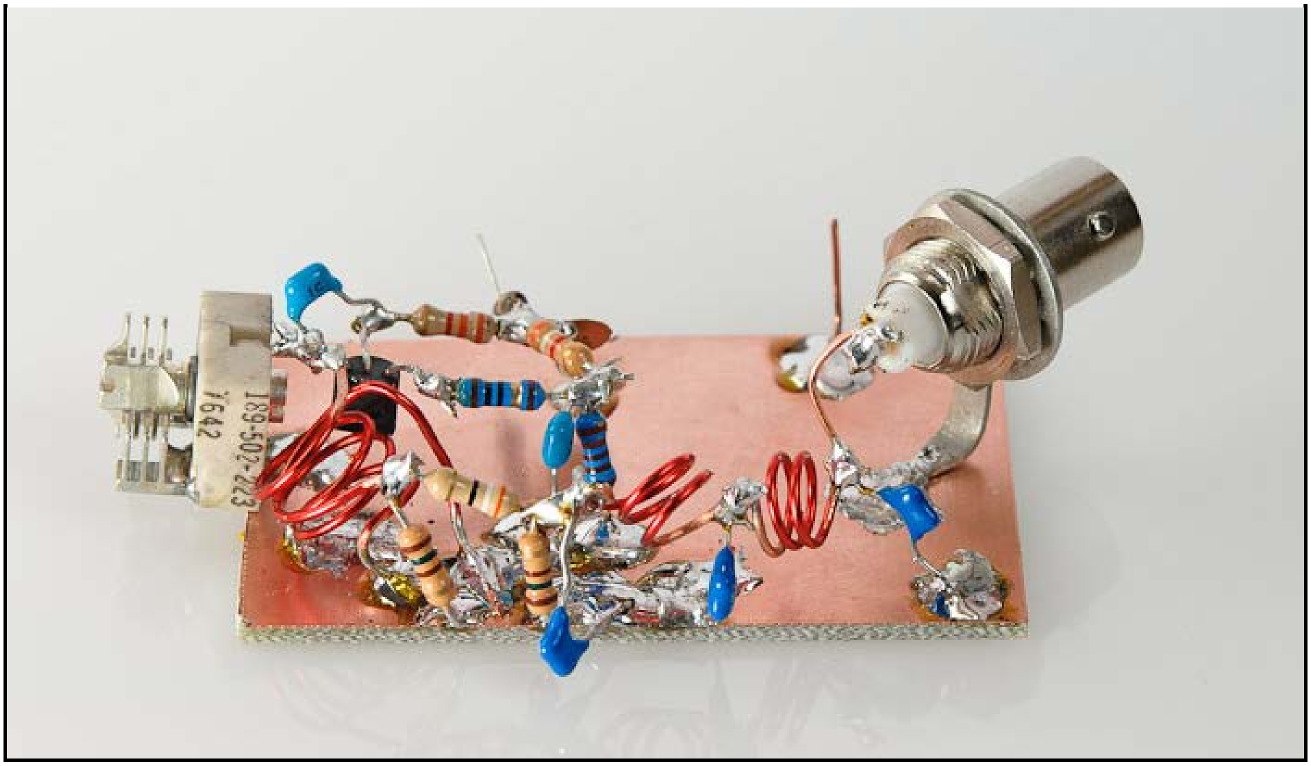

Above — I built a prototype 200 MHz oscillator with trailing low-pass filter before making the 210 MHz version placed in the 1-118 MHz VFO for the K3NHI sweep system. (Section 1). The secondary coil floats and may be positioned between any of the 4 primary links to change coupling and thus output power.

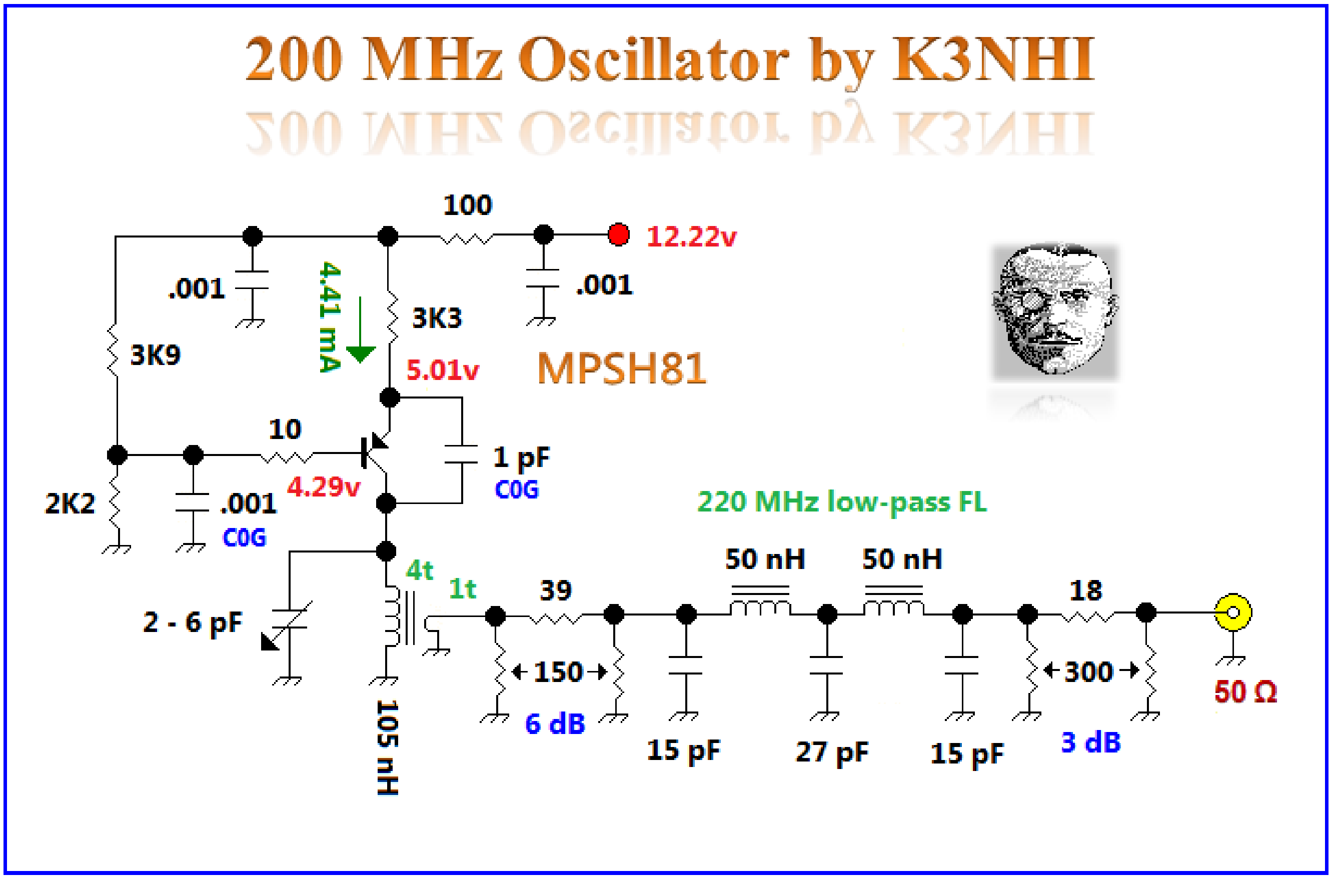
200 MHz Oscillator by K3NHI
100
12.22v
.001
.001
4.41 mA
3K3
3K9
5.01v
MPSH81
10
1 pF
C0G
4.29v
2K2
.001
C0G
220 MHz low-pass FL
4t
1t
39
50 nH
50 nH
18
2 - 6 pF
150
300
6 dB
3 dB
50 Ω
15 pF
27 pF
15 pF
105 nH

Above — The schematic of my 200 MHz local oscillator. Click for another version I designed that tuned from ~135-208 MHz.

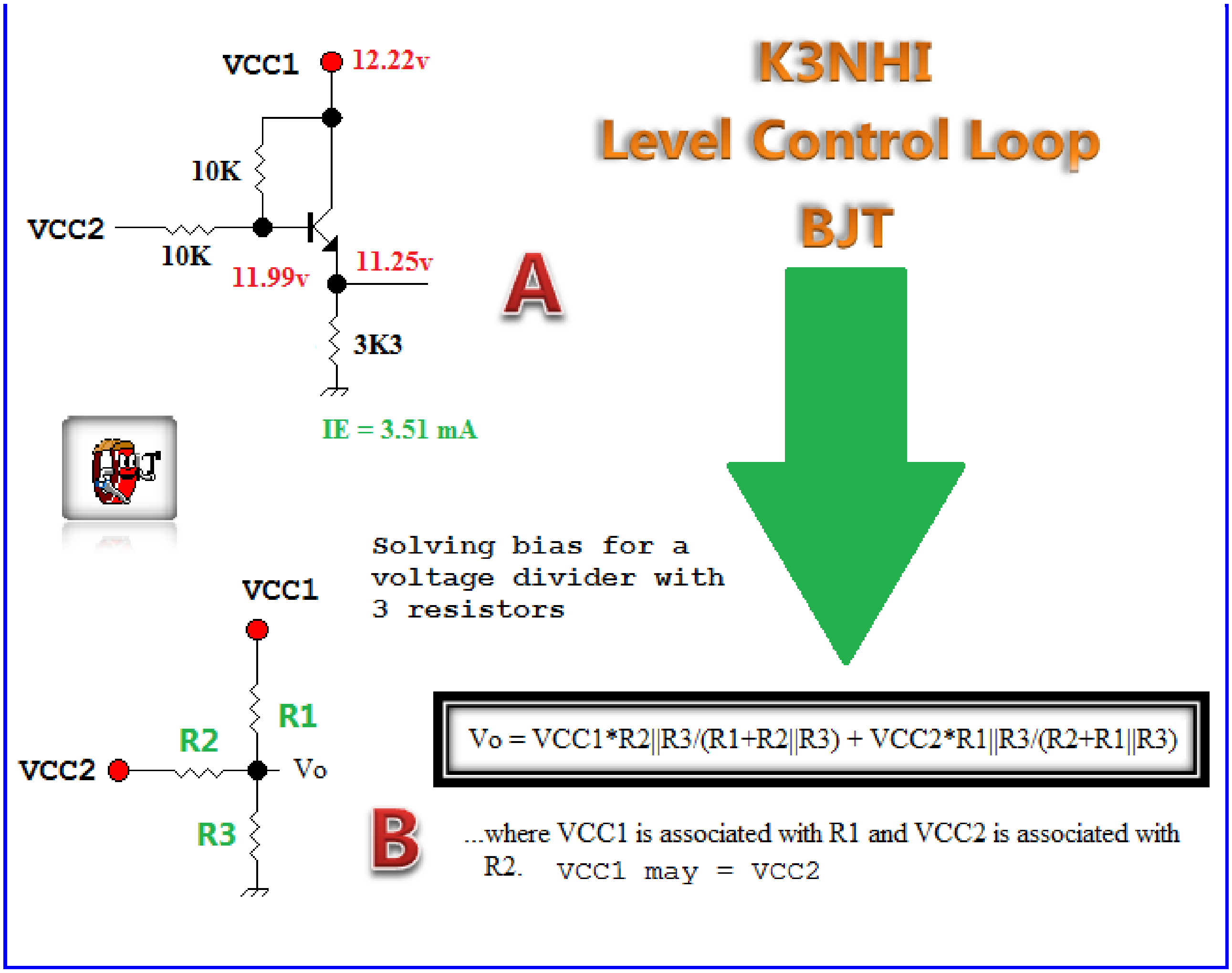
K3NHI
Level Control Loop
BJT
VCC1
12.22v
10K
VCC2
10K
11.99v
11.25v
3K3
IE = 3.51 mA
A
VCC1
R1
R2
VCC2
Vo
R3
B

Solving bias for a voltage divider with 3 resistors

$$Vo = VCC1*R2||R3/(R1+R2||R3) + VCC2*R1||R3/(R2+R1||R3)$$

...where VCC1 is associated with R1 and VCC2 is associated with R2. VCC1 may = VCC2

Above — In the K3NHI 1-118 MHZ VCO lies a fabulous leveling circuit that involves a CMOS rail-to-rail op-amp controlling a BJT level shifter. To understand the bias of this BJT, I made a breadboard (A) and then a simple model (B) and developed the equation shown that involves 3 bias resistors. Bias or Vo is determined by superposition. VCC1 and VCC2 may be equal or not. VCC2 comes from the op-amp. I also learned it's a good thing to surround myself with smart people.

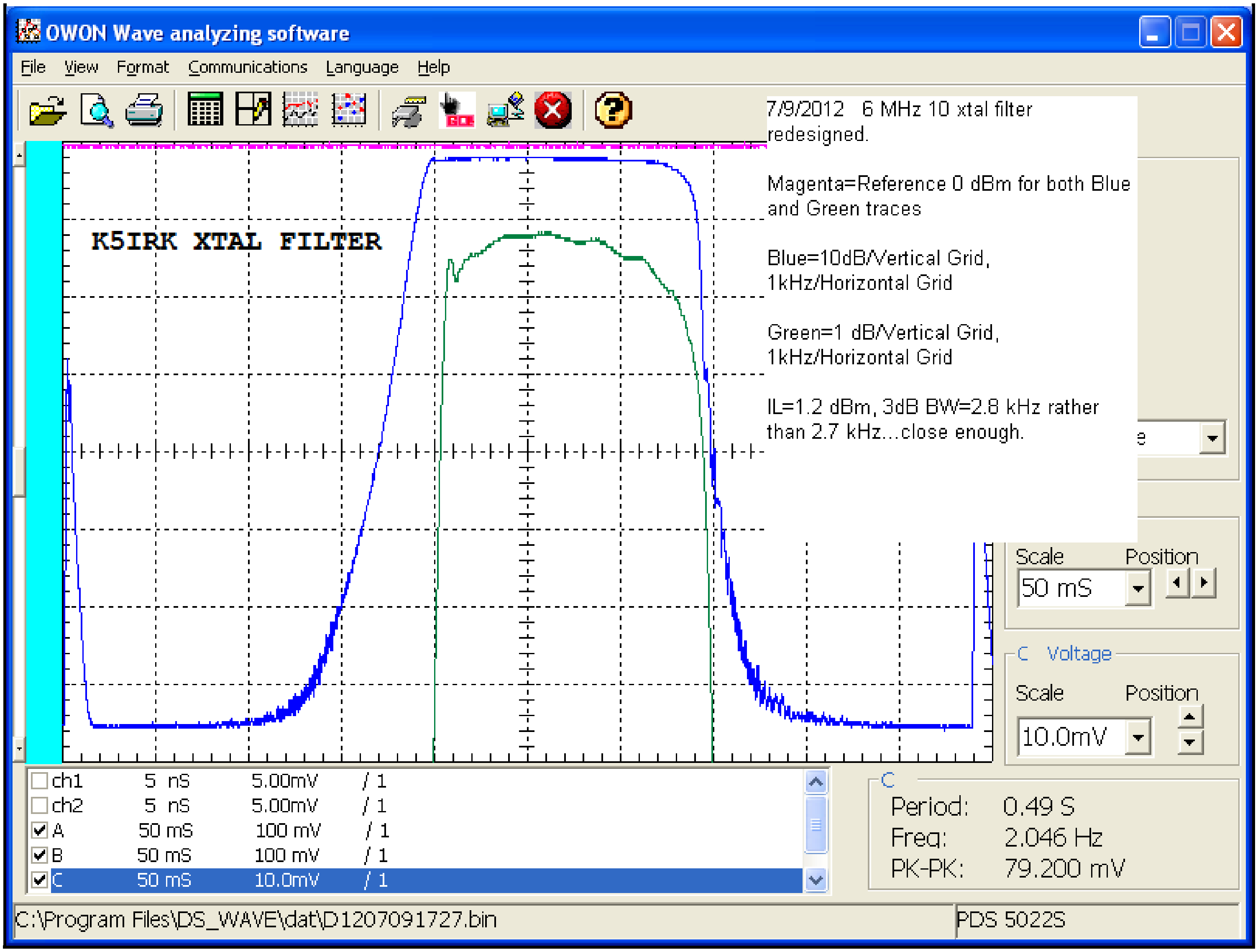
OWON Wave analyzing software
File
View
Format
Communications
Language
Help
K5IRK XTAL FILTER

7/9/2012 6 MHz 10 xtal filter redesigned.

Magenta=Reference 0 dBm for both Blue and Green traces

Blue=10dB/Vertical Grid, 1kHz/Horizontal Grid

Green=1 dB/Vertical Grid, 1kHz/Horizontal Grid

IL=1.2 dBm, 3dB BW=2.8 kHz rather than 2.7 kHz...close enough.

Scale 50 mS

C Voltage

Scale 10.0mV

☐ ch1	5 nS	5.00mV	/ 1
☐ ch2	5 nS	5.00mV	/ 1
☑ A	50 mS	100 mV	/ 1
☑ B	50 mS	100 mV	/ 1
☑ C	50 mS	10.0mV	/ 1

C

Period: 0.49 S

Freq: 2.046 Hz

PK-PK: 79.200 mV

C:\Program Files\DS_WAVE\dat\D1207091727.bin

PDS 5022S

Above — John, K5IRQ designed and swept a 10 crystal SSB filter with an insertion loss of 1.2 dB in the K3NHI sweeper that I just had to show you. Click for his build up in Ladbuild08 and then GPLA08 from the EMRFD CD. Bob's xtal sweeper from Section 1 and Wes' software arm us experimenters with solid tools. Nothing can replace measurement and reason.

RF — Test and Measurement

VHF — Véronique

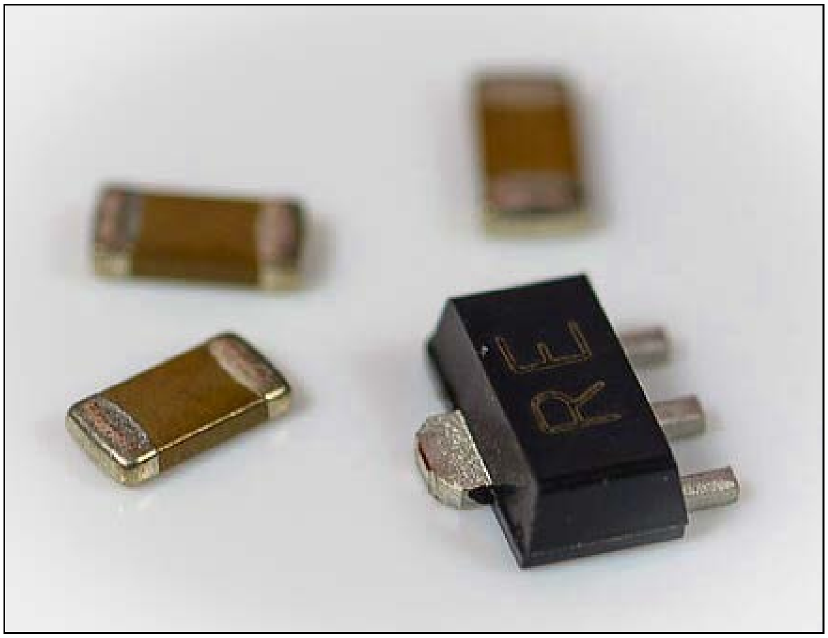

Repository for VHF experiments conducted in 2013 and 2014.

1. Ferrite beads
2. BFS17A transistor
3. 50 Ω MMIC Bench Amplifer
4. Breadboarding Double-Sided Copper Boards
5. Simple Preamp Filter
6. VHF Band-pass Filter Experiments
7. NE612 Mixer Diddy
8. Miscellaneous Photographs

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1. Ferrite Beads

I toiled to choose an SMT ferrite bead for my junk box. Selecting suitable chip beads not only troubles us, but even some engineers I've read — which to choose? Chip beads act as high frequency resistors that present a low impedance to DC plus our desired RF signal while impeding and dissipating UHF through resistive losses caused by minute heating of the ferrite material from eddy currents. SMT beads are typically rated by their maximum current, resistance at DC, and the impedance they present at 100 MHz.

Since a ferrite bead's impedance is essentially resistive to parasitic UHF oscillations, I remembered that the model for a bead is actually an inductor paralleled by a resistor. It's the "resistor" we're after, for that's the extra load that tends to stabilize the amplifier. From past success in UHF supression with low-value (10-51 Ω) resistors, I chose my SMT bead to have a relatively low Z at 100 MHz. Consider, too, that many chip beads sold today serve as RFI suppressors for high speed digital lines where the Z at 100 MHz and maximum current lie well above my requirements.

I found a chip bead that appealed to me on eBay and bought 50: size 0805; 800 mA; with a Z at 100 MHz of 120 Ω.

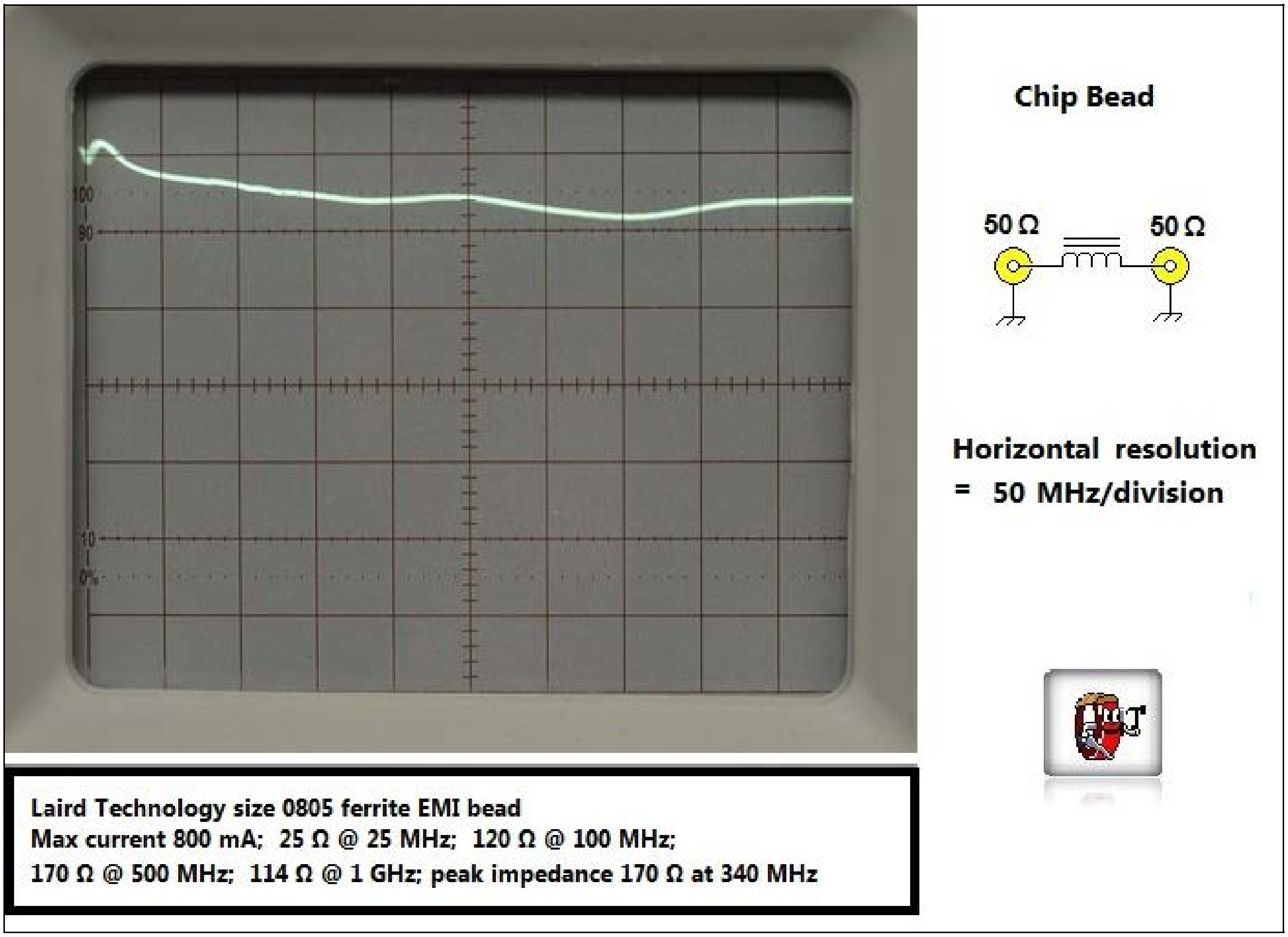

Laird Technology size 0805 ferrite EMI bead
Max current 800 mA; 25 Ω @ 25 MHz; 120 Ω @ 100 MHz;
170 Ω @ 500 MHz; 114 Ω @ 1 GHz; peak impedance 170 Ω at 340 MHz

Above — A sweep of my bead from 1- 500 MHz. Sadly, I did not perfectly center the sweep at 250 MHz, but the peak impedance occurred close to the specified 340 MHz.

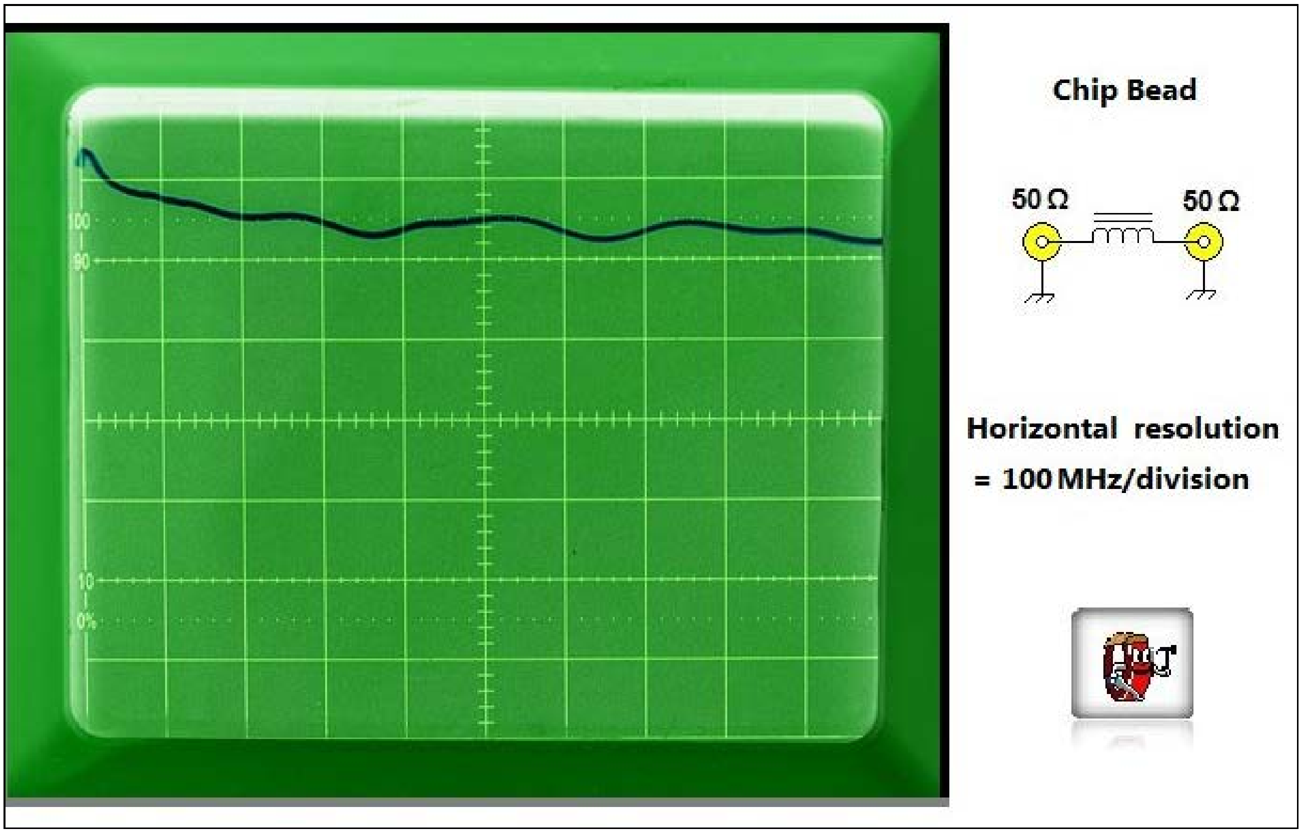

Above — I swept my Laird techlogies chip bead out to 1 GHz. Ultimately, I'll have to verify its function with in-situ experiments. For example, before and after chip bead analysis of a low noise amplifier that's oscillating at UHF.

FB43-101

If you sweep the floor under my QRP work bench, you'll find 2N3904s, J310s and a few FB-43-101s in the dust pan. In our hobby, FB-43-101s are common as fleas on a dog; many builders like to stick them on the drain, collector, or base/gate lead(s) of an active part to squash UHF oscillations. I've never seen a datasheet for this part and decided to sweep 1 for reference purposes.

2 sweeps of the FB-43-101 follow:

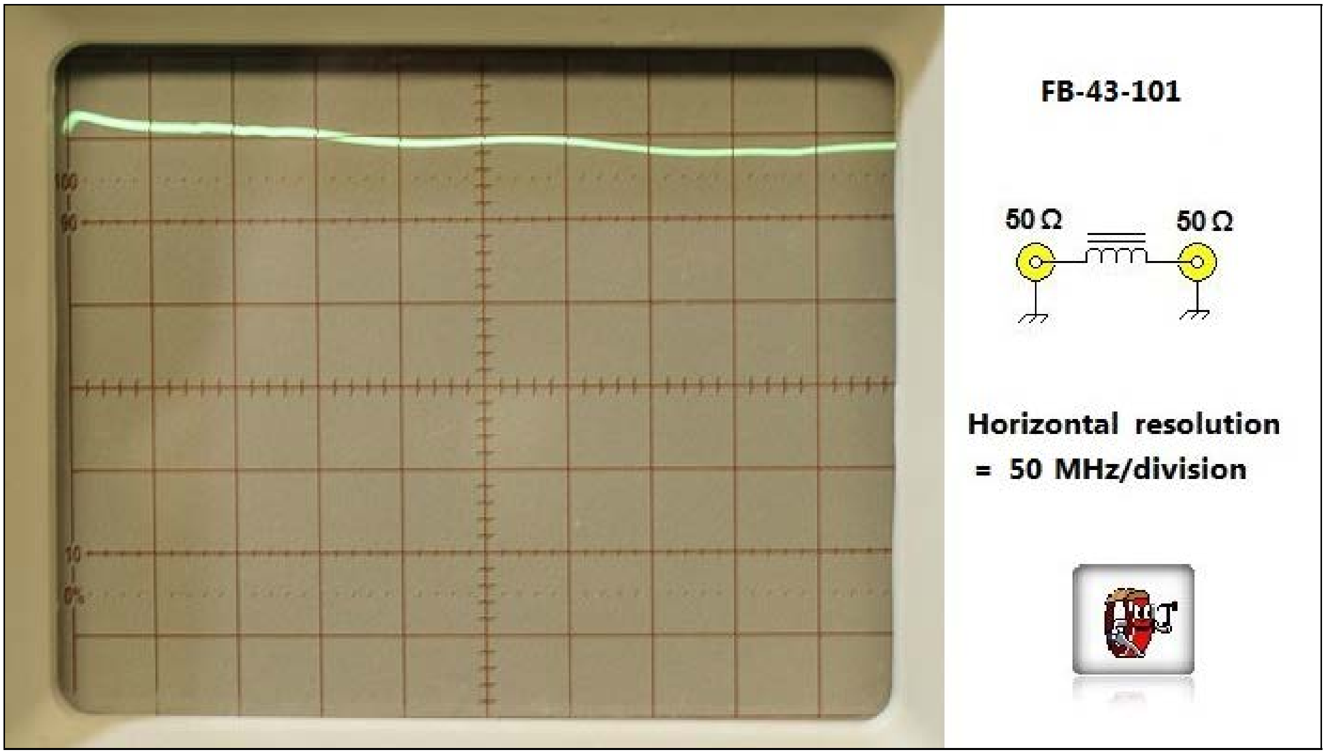

Above — A 1 - 500 MHz sweep of the FB-43-101 slide-on bead. This tracing shows very subtle attenuation that peaks between 400 and 450 MHz. Probably this minimal attenuation at UHF provides the reason we often need to put 2 on the drain or collector of our amplifiers?

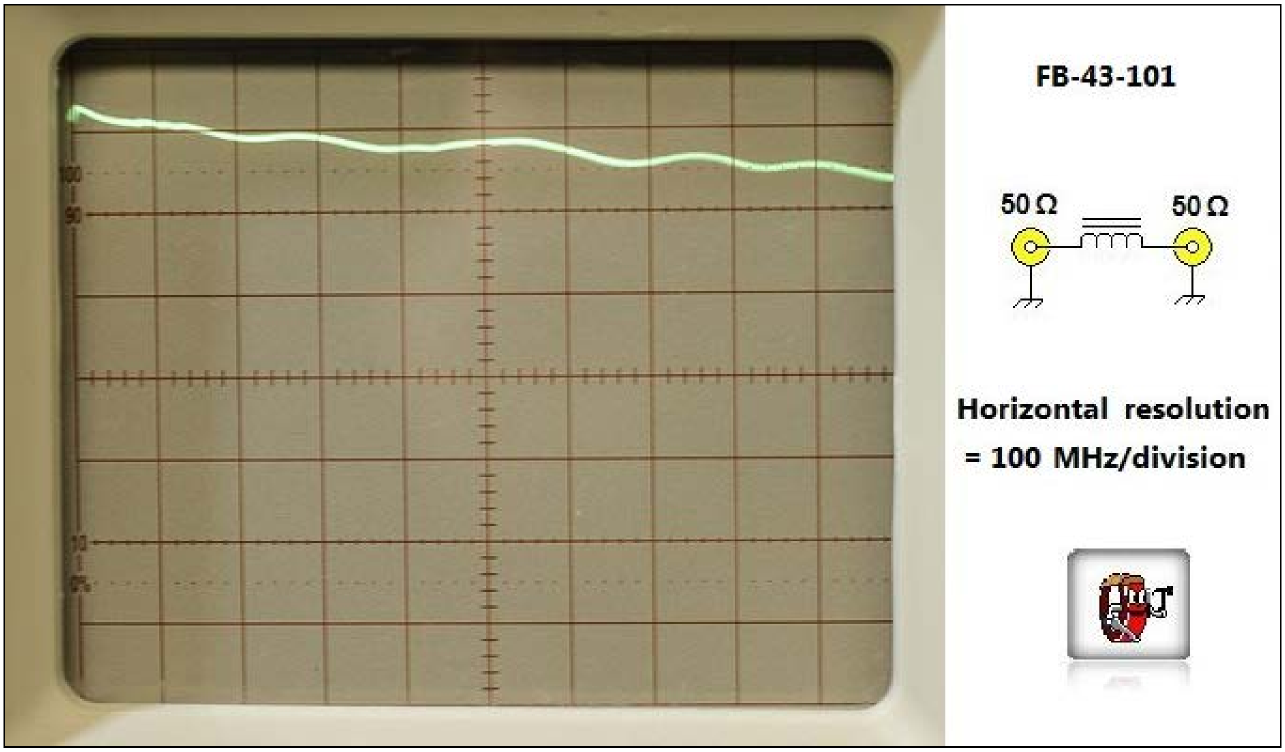

Above — A 1 - 1000 MHz sweep of the FB-43-101.

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2. BFS17A Transistor

I sought a surface mount NPN transistor to supplant my leaded transistors such as the PN5179, BF199 or MPSH10. Serving as a general purpose transistors biased for ~5 to 20 mA collector current — they'll work as buffers + oscillators + as the BJT for hybrid-cascode amplifiers built with a SMT J310 on the bottom.

My requirements were SOT-23 (3 well *seperated* leads allow easily carved islands in a copper board with a dremel tool); an fT that's not too high to help reduce higher UHF oscillations; and a noise figure < 3. Other factors included price and availability. We enjoy many choices with such criteria, but I settled on the BFS17A. Click for the data sheet . In summary, it's a 2.8 GHz part with a NF of 2.5 dB at 800 MHz.

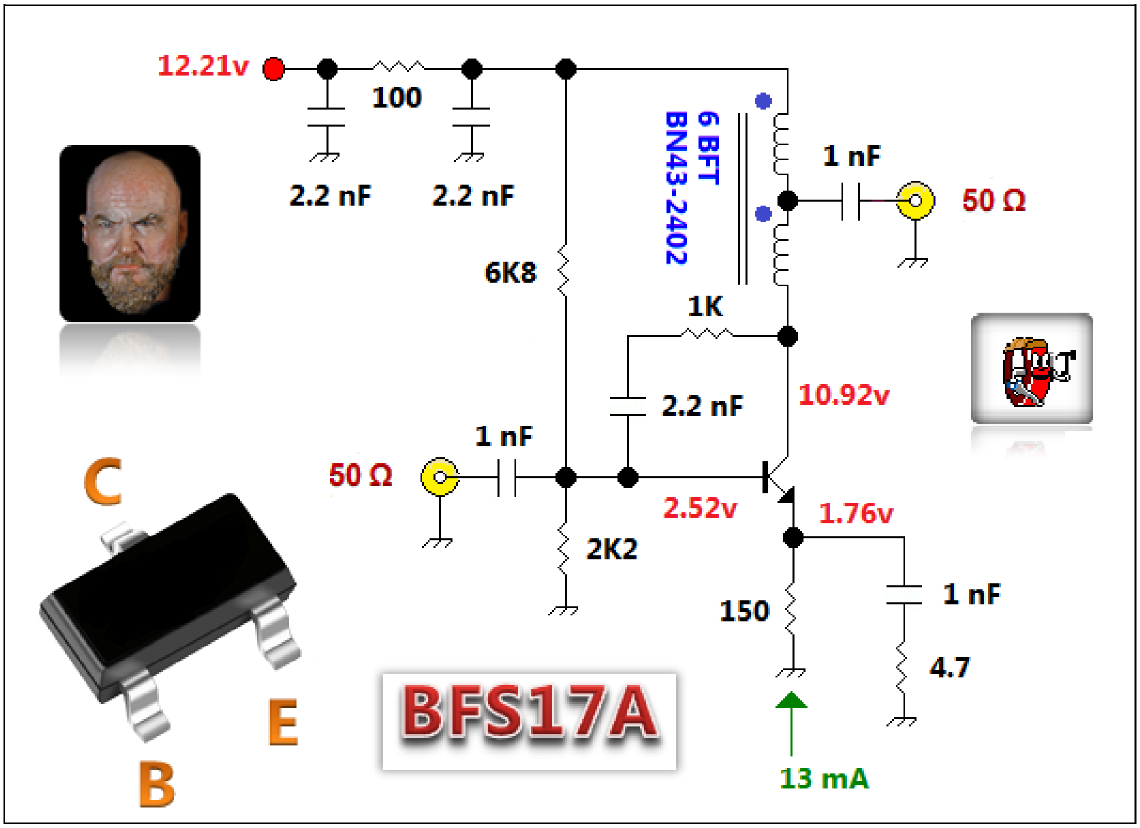

AAbove — My test schematic; a simple feedback amp with capacitors oriented to 50 MHz and above. A limited selection of SMT resistors constrained my experients, but the results seem okay. I strove for the best possible input and output return loss at 50 MHz. I wanted a emitter current of ~ 12 mA and got 13 mA with the bias resistors on-hand.

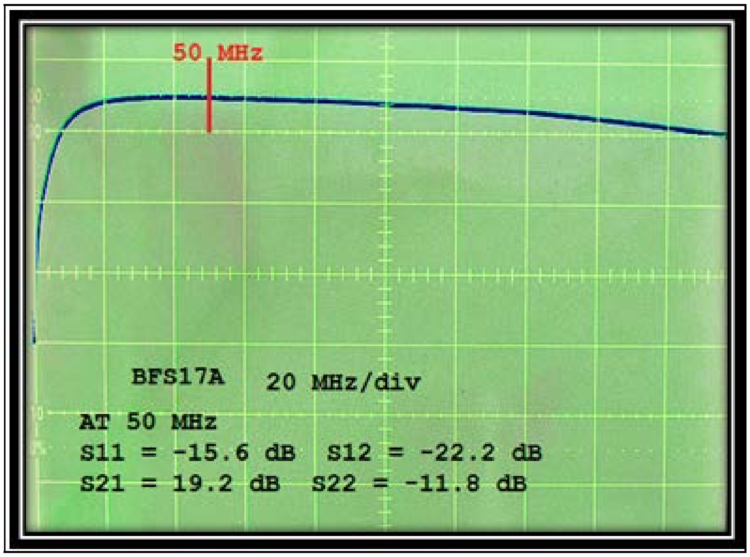

BFS17A 20 MHz/div

AT 50 MHz

S11 = -15.6 dB S12 = -22.2 dB

S21 = 19.2 dB S22 = -11.8 dB

Above — A 200 MHz wide sweep of my breadboard with tracking generator + spectrum analyzer. Please view the various 2-port measurements at 50 MHz in the lower half. Despite some input and output port mismatching, a gain of 19.2 dB was measured at 50 MHz.

I wound my output transformer within a BN43-2402 binocular ferrite, but ordered some #61 material equivalents for assessment at VHF.

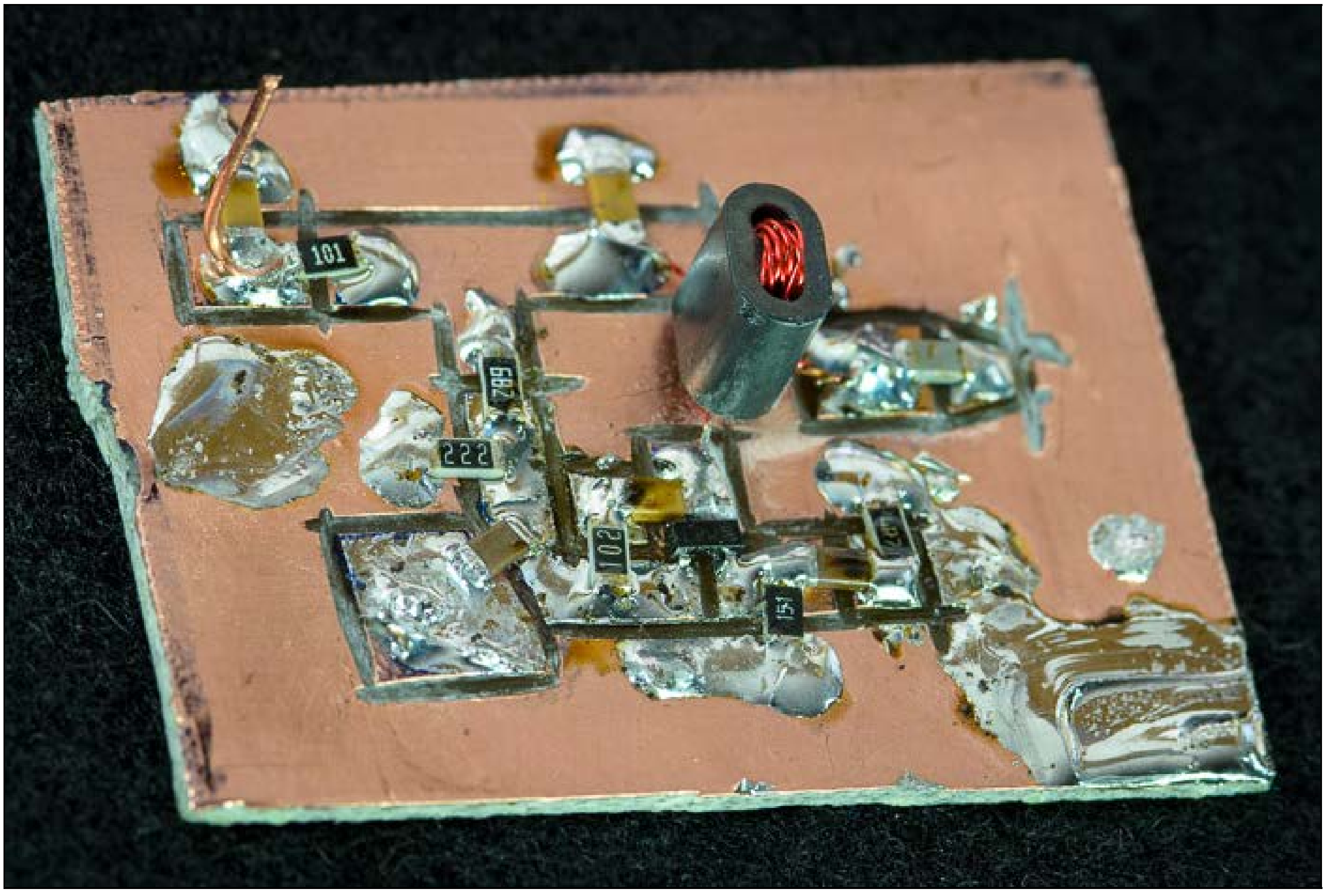

Above — My magnified breadboard looking messy after many parts substitutions from experiments to find the best possible S11 and S22. I removed the shiny RF connectors prior to photography since they often create blown highlights. Alternate image. Despite a limited RF bypass before and after the 100 Ω decoupling resistor + crude bread boarding, I measured no parasitic oscillations from 0.001 to 1 GHz — likely due to the heavy shunt feedback. I liked this transistor, found it easy to breadboard and ordered 100. You'll see the BFS17A in my experiments hereafter.

By all means, order whatever transistor *you* want. Past emailers wrote to say they enjoy reading how other experimenters think about and assess their parts such as RF beads or transistors.

Surface Mount Part Soldering

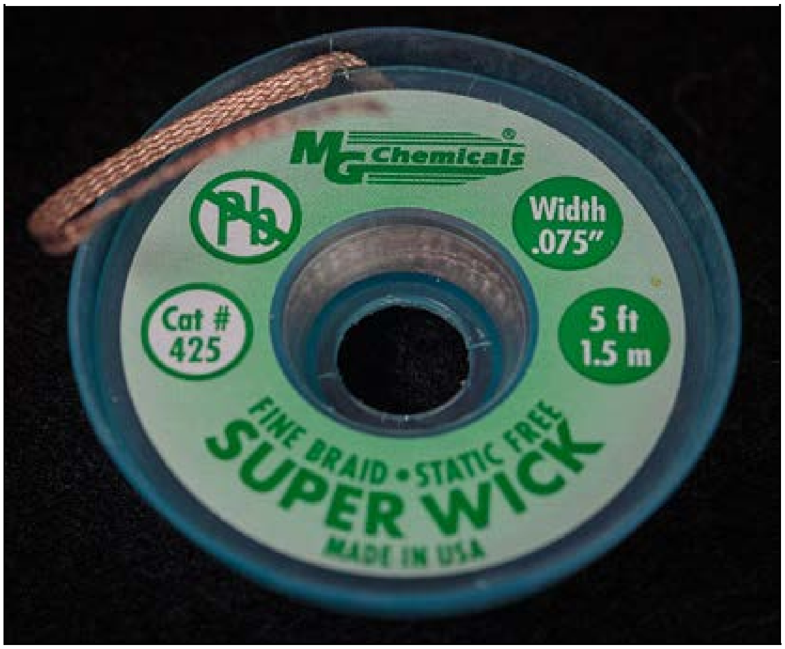

Above — Solder wick. On my SMT workbench, wick proves the most important tool period. A piece of desoldering wick can transform a monster mistake into a perfect circuit in under 2 seconds.

I've read many accounts of how builders anchor the parts they're soldering. We need to keep the SMT part flat on the board to avoid mechanical tension and poor solder joints — a system is required. For size 0805 and 1206 parts, I often just use my index finger fingernail to hold the part in place while I solder 1 lead with my other hand. After a few seconds of cooling, I solder the other lead and then usually touch up the first joint. For tricky formats like SOT-23, or SOT-143, I usually tape down the part while ensuring even pressure on all leads and just solder 1 lead. After cooling, I remove the tape and easily solder the other leads. Again, the intial lead may require some retouching.

SMT Size

Above — A 5X magnified roll of 50 BFS17A in SOT-23. Compact or what?

Above — BFS17A in SOT-23

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3. 50 Ω MMIC Bench Amplifer

To boost low-level signals during experiments, every 50 Ω workbench needs a utility RF amp module. With strong wideband gain + RF port return loss (S11 and S22), MMICs make a good choice. Since I own 15 pieces, I built an amp around the MCL MAR-3, a modest gain + noise figure, 2 GHz plastic part in the Micro-X package. We enjoy a bevy of MMICS to choose from and as they increase in fT and gain, so does the need for solid, low inductance grounding techniques.

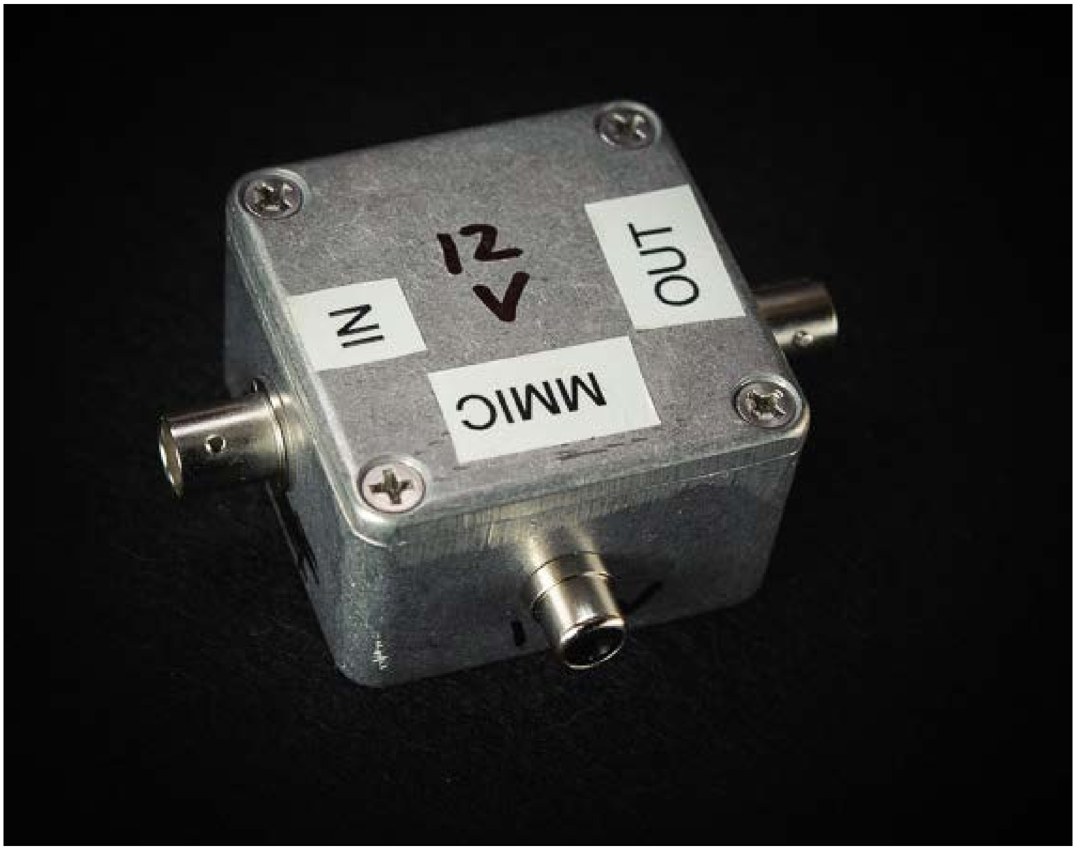

Above — The completed amplifer module in a Hammond box with an RCA jack for the DC voltage.

MMIC Bench Amplifier

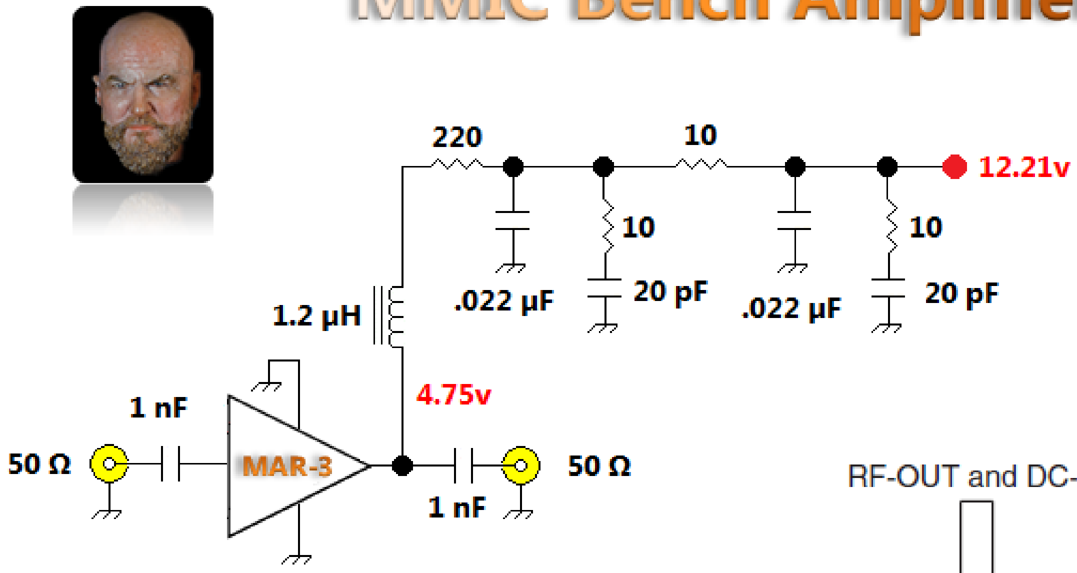

Frequency	S21
7 MHz	11 dB
14 MHz	11.2 dB
50 MHz	11.7 dB
100 MHz	12.1 dB
144 MHz	11.4 dB

I = 32.5 mA

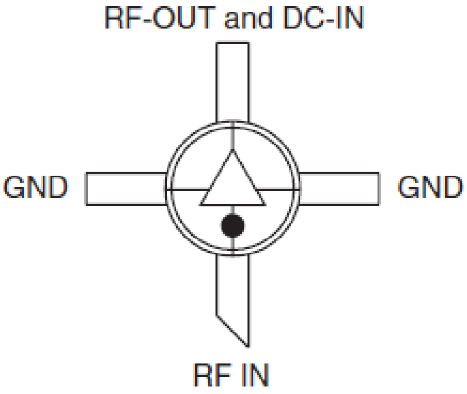

Above — Schematic with a table showing gain versus frequency. I built all SMT (size 0805 mostly) except for *short* leaded 1 nF input and output coupling capacitors. I applied sturdy wideband DC filtering since I can't risk RF flowing on my DC lines during bench experiments. I measured no oscillations from 100 KHz to 1.5 GHz.

I chose a 1.2 µH SMT choke in an attempt to boost gain from ~66 to 150 MHz. Many builders leave off the choke, but some RF will flow through the 220 Ω bias resistor to ground and thus, to get maximum gain, a high impedance RFC might help. Recall this RFC should exert an inductive reactance of at least 500 Ω (>= 10 X the load impedance) at the lowest amplifer operating frequency; in my case this occurs at ~66 MHz. A better choice for the RFC might be 1.6 µH which exerts ~ 500 Ω at 50 MHz, but I just own size 0805 1.0 and 1.2 µH chip inductors.

My particular amp delivers ~10 to 12 dB gain from about 5 to 180 MHz. Since the coupling capacitor value determines the low frequency response, if you want a MMIC amp for mostly HF, try reducing your input coupling caps from 0.001 to 0.01 µF or so. You mighty increase the RFC to say 10 µH as well — that's why we don't just build kits; design to suit *your* needs.

The 220 Ω bias resistor should really be 200 Ω for a VCC of 12.2v, however, I had to substitute the 220 Ω R due to a low selection of SMT parts. This dropped the current and also my gain at 100 MHz = 0.4 dB less than that specified in the MAR-3 datasheet — no big deal.

I built the bread board on 2-sided FR4 copper clad board. I soldered thin copper foil around all 4 edges to adjoin the top and bottom copper surfaces. Around each MMIC ground lead, I drilled 4 via holes and soldered copper wire from top to bottom. 2 vias were positioned near every bypass capacitor and all along the input and output paths. 23 total via wires.

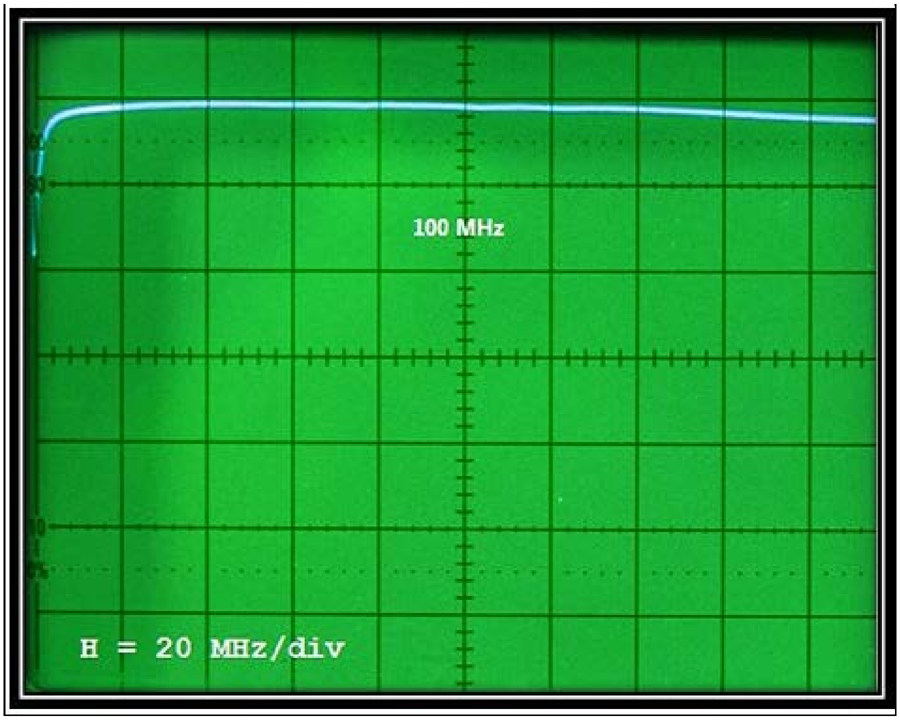

Above — Tracking generator plus spectrum analyzer sweep out to 200 MHz. Click for a sweep from 1 to 10 MHz showing a rapid fall off below 5 MHz. This little amp will serve me well for most HF and especially my VHF experiments. A UHF amplifier module is planned and all knowledge gained from VHF circuit building will flow forward.

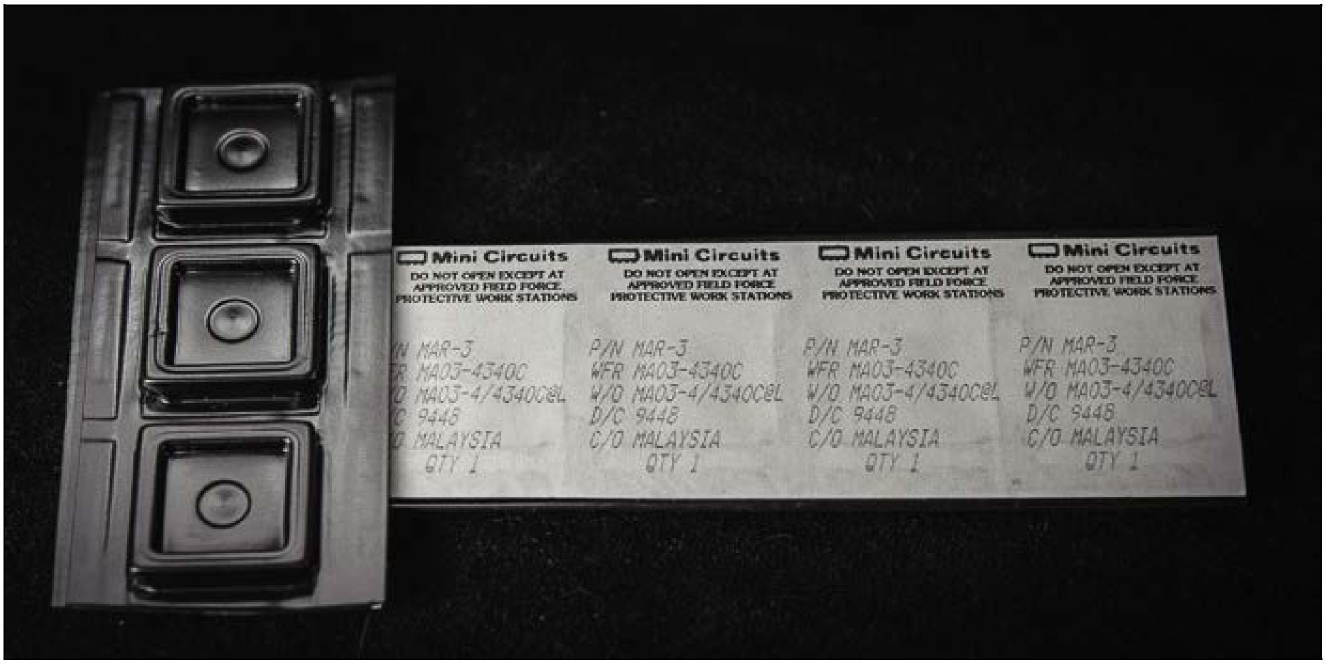
Mini Circuits
DO NOT OPEN EXCEPT AT APPROVED FIELD FORCE PROTECTIVE WORK STATIONS
P/N MAR-3
WFR MA03-4340C
W/O MA03-4/4340C@L
D/C 9448
C/O MALAYSIA
QTY 1

Above — Part of a strip of MCL MAR-3 amplifiers.

Feedback Amps (FBAs)

MMICs like the MAR-3 use a Darlington feedback pair. Still, too, we shouldn't write-off discrete component FBAs wielding transformers + shunt and series feedback at VHF. These amps; staples of countless W7ZOI and W1FB projects since the 1970s; evolved commercially into GaAs FBAs built on a tiny wafer by companies like TriQuint Semiconductor.

In broadband amplifiers, negative feedback permits a wideband (flat) gain response, reduces input and output VSWR (S21 and S22) and controls performance changes from S-parameter and other variations from transistor to transistor. In 2013, I needed an amp chain with >=25 dB gain at 144-165 MHz [~150 MHz mostly] for low level stuff : -25 to -10 dBm input power. Inspired by Wes' 144 MHz CW/DSB transmitter FBA chain *(**SSD** -- Chapter 8 -- Figure 30 in Solid Stage Design for the Radio Amateur; ARRL published in 1986 and out of print)*; I cascaded 3 PN5179 BJTs as FBAs:

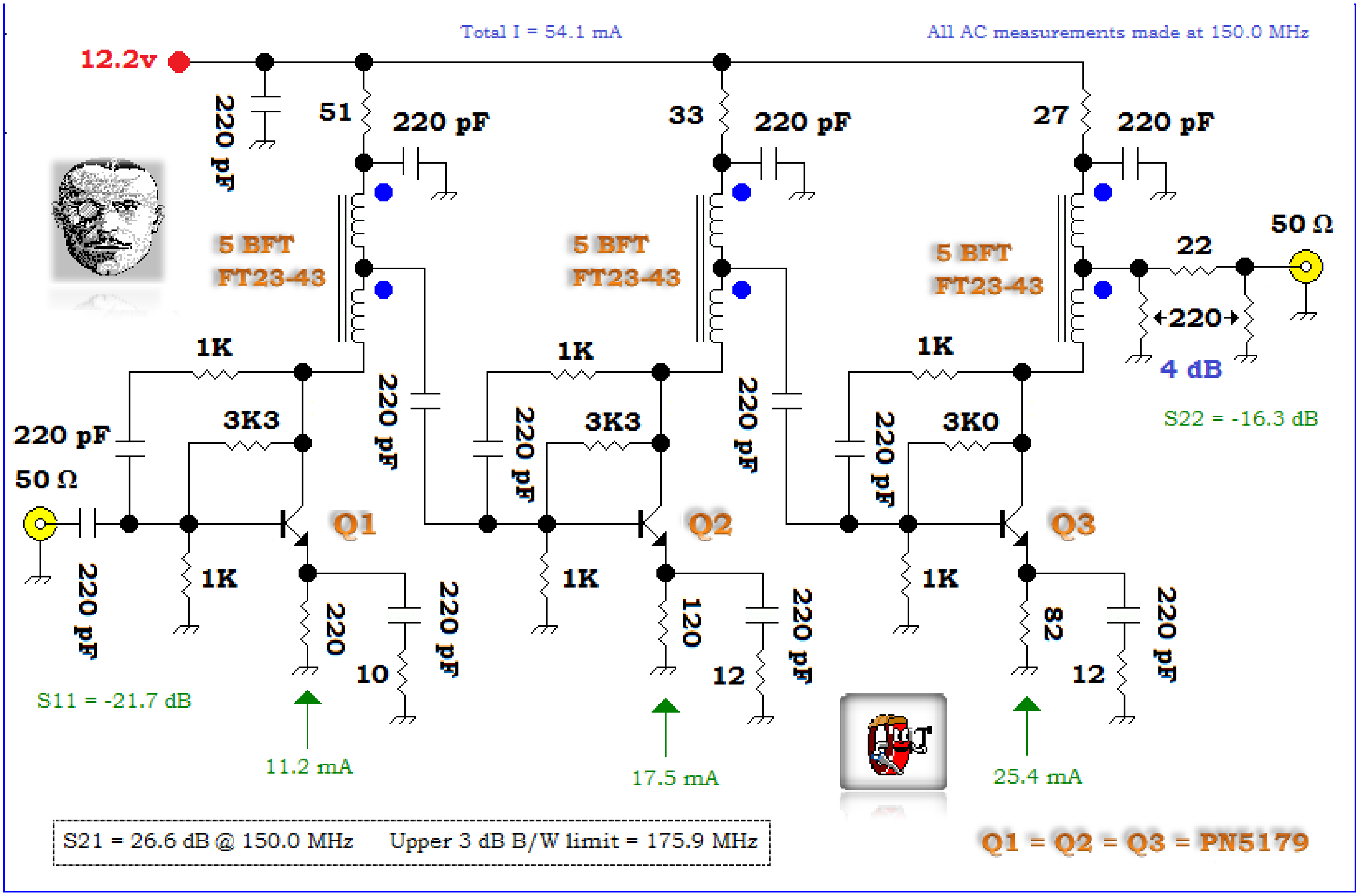
Total I = 54.1 mA
All AC measurements made at 150.0 MHz
12.2v
220 pF
51
220 pF
33
220 pF
27
220 pF
5 BFT
FT23-43
5 BFT
FT23-43
5 BFT
FT23-43
50 Ω
22
220
4 dB
S22 = -16.3 dB
1K
1K
1K
220 pF
220 pF
220 pF
220 pF
50 Ω
3K3
3K3
3K0
220 pF
220 pF
Q1
Q2
Q3
1K
1K
1K
220
120
82
220 pF
220 pF
220 pF
10
12
12
S11 = -21.7 dB
11.2 mA
17.5 mA
25.4 mA
S21 = 26.6 dB @ 150.0 MHz
Upper 3 dB B/W limit = 175.9 MHz
Q1 = Q2 = Q3 = PN5179

Above — My 150 MHz (design frequency) FBA module. Since the fT of the PN5179 = 900 to 2000 MHz @ a 100 MHz test frequency, gain drops steadily as we move up above 100 MHz. Centered at 150 MHz, my upper 3 dB drop off point was 175.9 MHz — thus this amp works okay from 144-165 MHz where I need it.

I built and tweaked each stage to derive the best S11 and S22 . *Click for a snapshot taken of my test of Q1 with a BNC connector attached to both ports — I did this for each stage.* It's a trade off since if you boost the emitter degeneration R, the S11 will improve but the gain decreases. Typical stage S11 = -18.5 dB and S22 = -17 dB. I progressively bumped up the current in each stage to reduce gain compression. I get ~12-13 dBm power out of the whole amplifer before compression/distortion occurs.

Securing the best S11 and S22 for each stages might seem silly, but invoked learning. The S11 and S22 of the *total amplifer* counts the most. An interesting thing happened to S22 – with a RF connector soldered right on the board without the pad, S22 = -23.8 dB. When I added the 4 dB pad and stuck it in the box and then ran a ~ 5mm copper wire to connect an SMA output jack, the S22 decreased to -16.3 dB! At 150 MHz — life differs from 7 MHz.

Placing the 4 dB pad between stage 2 and 3 will stabilize + enhance S22, gives a 4 dB higher 1 dB compression point and output intercept, which may make a FBA chain more useful for experiments like transmit driver applications. I can report I measured no oscillations out to 1.5 GHz and this amp works okay for my intended purpose with gain of 26.6 dB at 150 MHz.

I employed 220 pF caps because the plus the self resonant frequency of my 220 pF Murata caps = 154.6 MHz. Therefore, gain at lower HF is low.

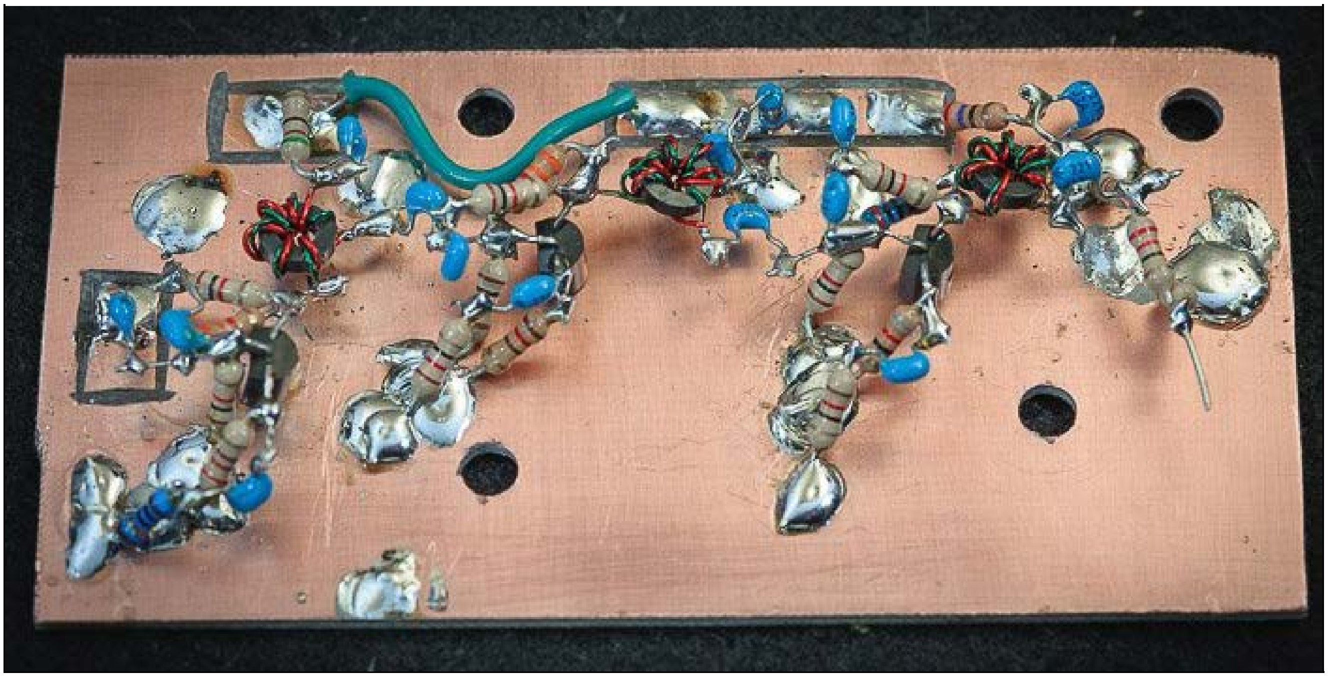

Above — FBA breadboard photograph.

QRP — Posdata for October 27, 2013

I first learned radio electronics from SSD, EMRFD and the ARRL Handbook and still remember the joy when my copy of SSD arrived in 1990. Feedback amplifiers litter this book — and for good reason — they offer stable 50 Ω blocks for building up our RF signal. Wes' 144 MHz CW/DSB transmitter still intrigues me and inspired the circuit shown above.

I asked Wes if he kept that 2M transmitter, and if so, could he snap a couple of photos for me? Wes opened it up to see that the VXO and the frequency multiplier chain were missing. Click Click Click . Thanks to Wes, W7ZOI for the photos.

---

4. Breadboarding Double-Sided Copper Boards

Seeking a low inductance AC ground for some of my VHF and UHF FR-4 prototype breadboards, I join the top and bottom copper surfaces with solder wick along its 4 edges and copper wire vias in the main board area.

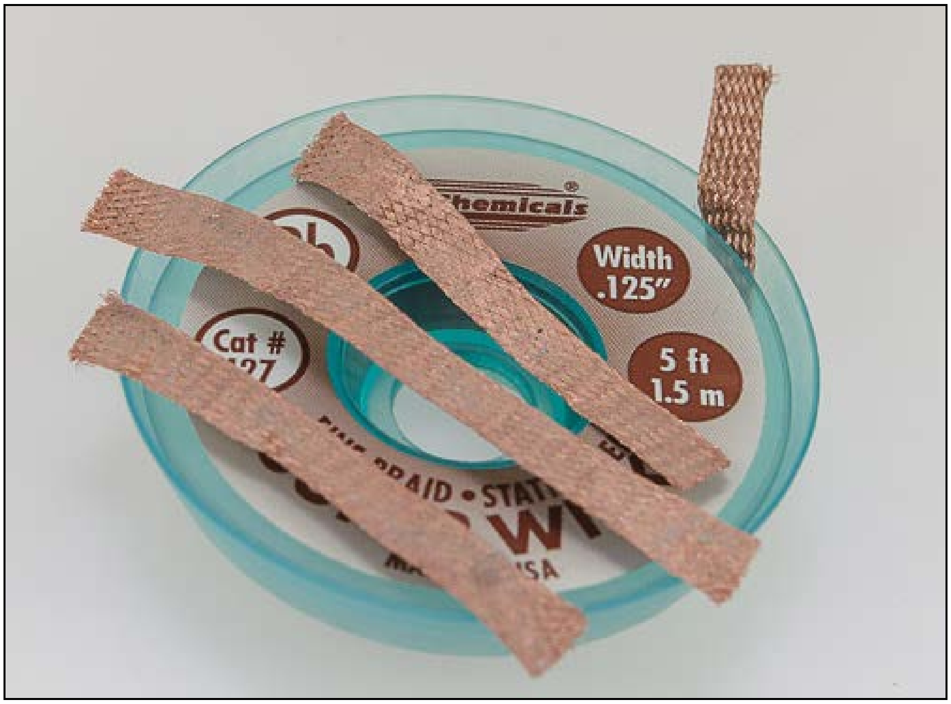

Above — A bench staple, solder wick, joins the 4 edges in true Ugy fashion. Many prefer copper foil for this task, but it's not cheap, nor readily available prompting a pragmatic approach. I take a hammer and pound the solder wick [0.125 inch minimum] so it becomes wider and thinner.

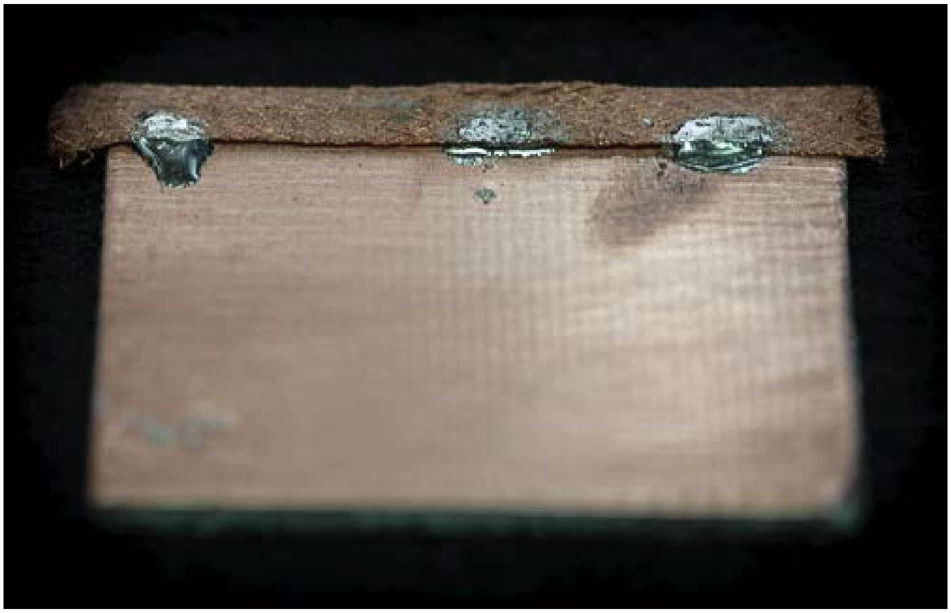

Above — Take a piece of wick and tack it in 2-4 places along the top surface of the copper board. The center solder shown above looks perfect — too much solder will flow into the wick and make a difficult bend job around the board edge. Tack just enough wick so you have enough left to go over the edge and to solder on other side of the copper board.

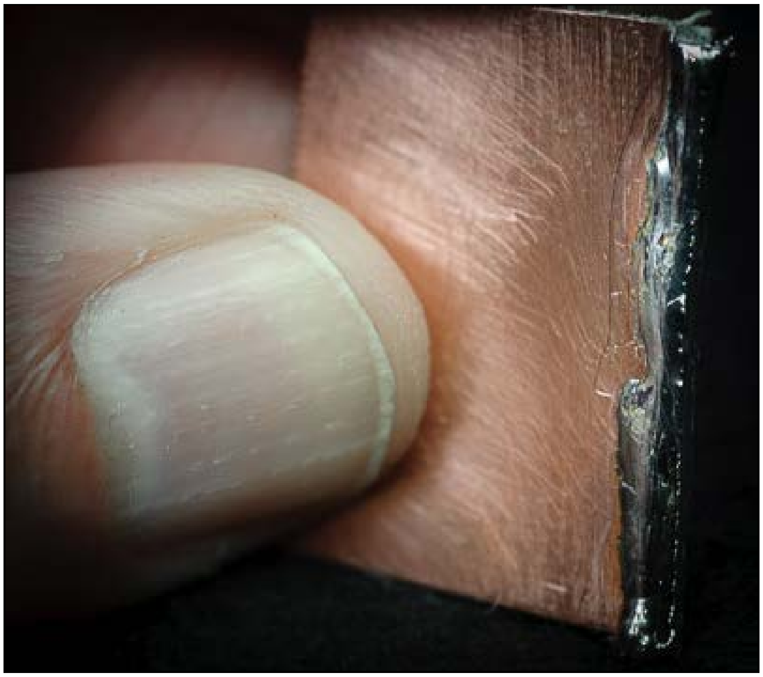

Above — With hand and/or pliers manipulate the wick around the other side to completely bridge the top to bottom. Finally, liberally solder the wick on both surfaces, move to the next board edge and repeat. Click for a rather messy UHF board with copper wick on 2 edges and numerous vias around a prescaler chip, some input + DC lines and a switch.

Above HF, most don't make pretty prototype boards to admire — rather, builders strive for good AC grounding and generally stick their board in a metal box for shielding and this hides the breadboard. No one's ever told me I make pretty circuits for any frequency and I'm okay with it.

Onto wire vias:

DRILLCO
Cutting Tools
Baton Rouge, LA
200A103 13 ~~12~~ Each
SIZE 3/64 JOBBER DRILL
GENERAL PURPOSE
DRILLCO
CUTTING TOOLS

Above — Your drill chuck will need to accommodate small bits such as those shown above (3/64 inches = 1.2 mm) . I keep these and others that vary from 0.5 mm to 1.2 mm for making via holes.

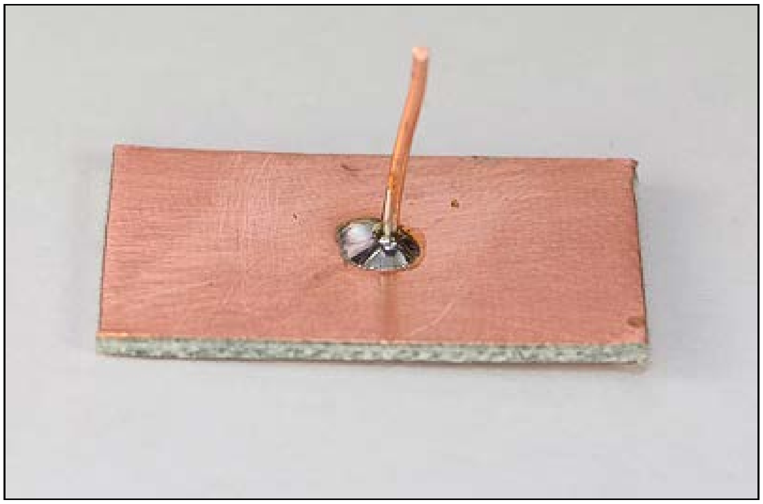

Above — Magnified via wire soldered at the top side. I found making a hole close to the same size of the via wire will hold the wire in place for rapid soldering. This wire is normally clipped flush at this point. Click for a photo of my flush cutters.

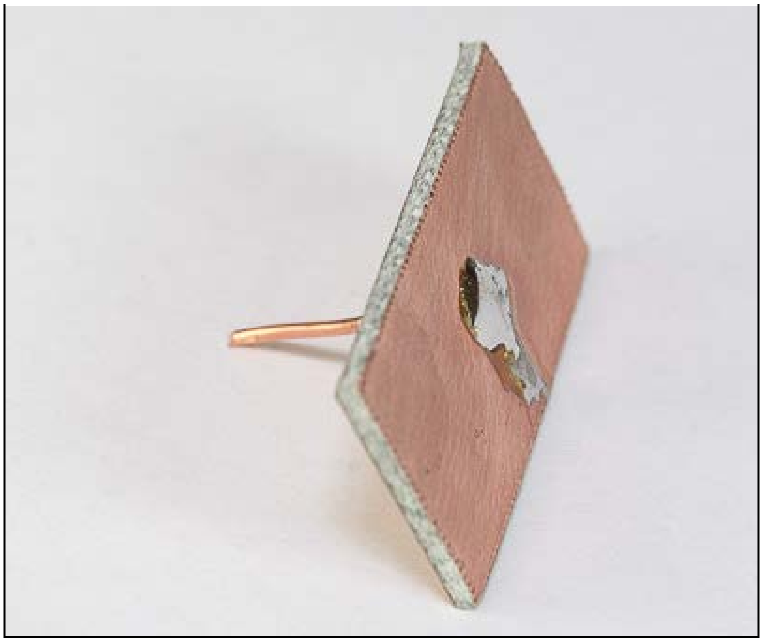

Above — The board shown above was flipped over to solder the bottom copper surface. I try to drill and solder in all vias prior to soldering active devices, since the board heat may damage some parts.

5. Simple Preamp Filter

Some RF filtering should proceed our receiver low noise amplifer (LNA) input — but what? Low-pass, high-pass, band-pass, 2 poles, many poles? Factors informing this decision might include our receive frequencies, QRM, selection of IF and thus our image stripping requirements, plus maximum tolerable signal loss before the LNA. We might not want image rejection from this filter since the post LNA filter can tackle this function.

I examined an input filter presented by Joe Reisert, W1JR in the November 1986 Ham Radio. Joe wrote a fantastic column called VHF/UHF World and his context was a high dynamic range 2M receive converter to a 28 MHz IF.

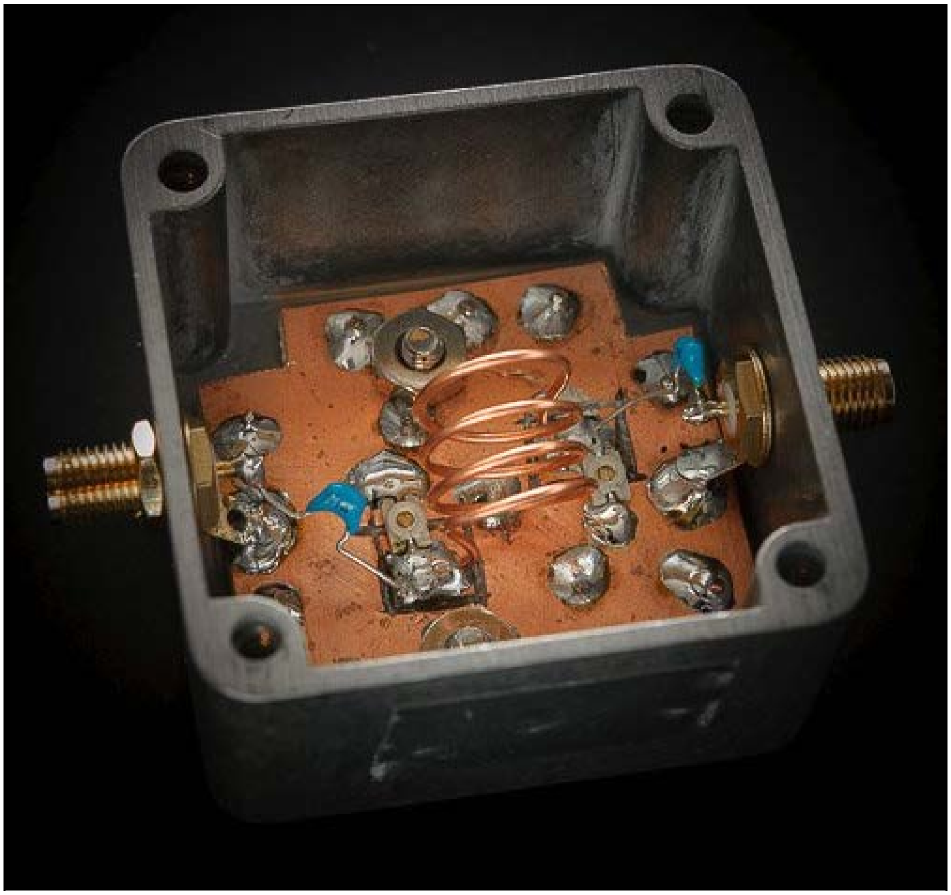

I'm uncertain how to classify this filter: it looks like a standard pi low-pass filter except the input and output series capacitors exert a high-pass skirt. Joe built his filter for 144 MHz. After "building" Joe's filter in Ladbuild08 I tweaked the filter in GPLA *[software from EMRFD]* to center it at our local NOAA weather channel: 162.55 MHz. Click for the GPLA plot.

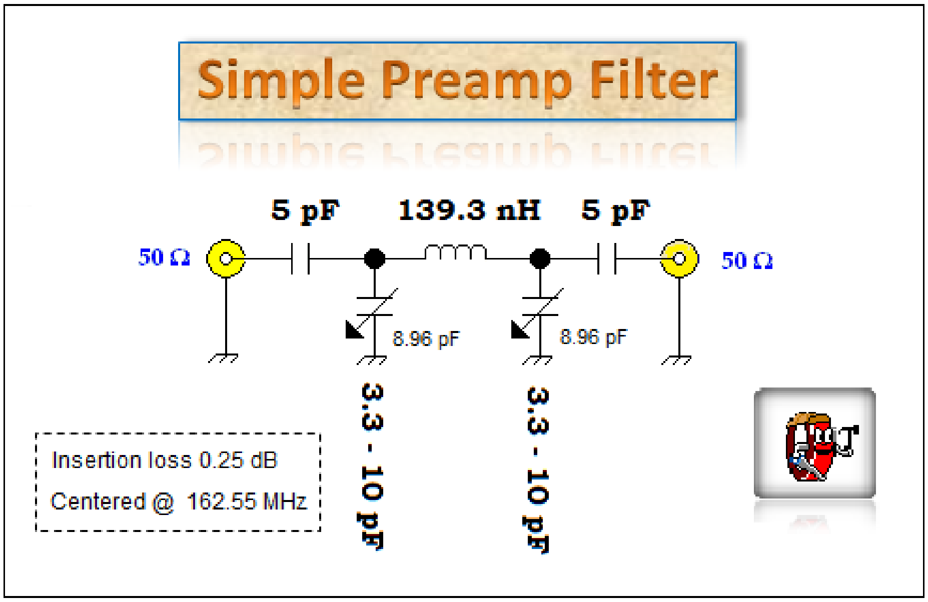
Simple Preamp Filter
5 pF
139.3 nH
5 pF
50 Ω
50 Ω
8.96 pF
8.96 pF
3.3 - 10 pF
3.3 - 10 pF
Insertion loss 0.25 dB
Centered @ 162.55 MHz

Above — Input filter schematic with values shown to center this rather symmetrical filter at 162.55 MHz. The half power (3 dB down) bandwidth = 18 MHz. You can easily scale it to other other frequencies — by tweaking the trimmer caps and perhaps squishing or expanding the inductor links some, this filter will tune widely including the 2 Meter Ham band. The IL blew me away (better than calculated) — the resonator Q was high due to the air wound L and Q >= 700 trimmer caps along with good port matching.

Click to view a larger photo of the breadboard. I wound the coil on a 3/8 inch diameter bolt but then spread the turns to get the L and length I wanted. Built on double-sided copper clad board, a few copper wire vias connect top to bottom. I joined the LC circuit to its ports with leaded 5 pF ceramic caps.

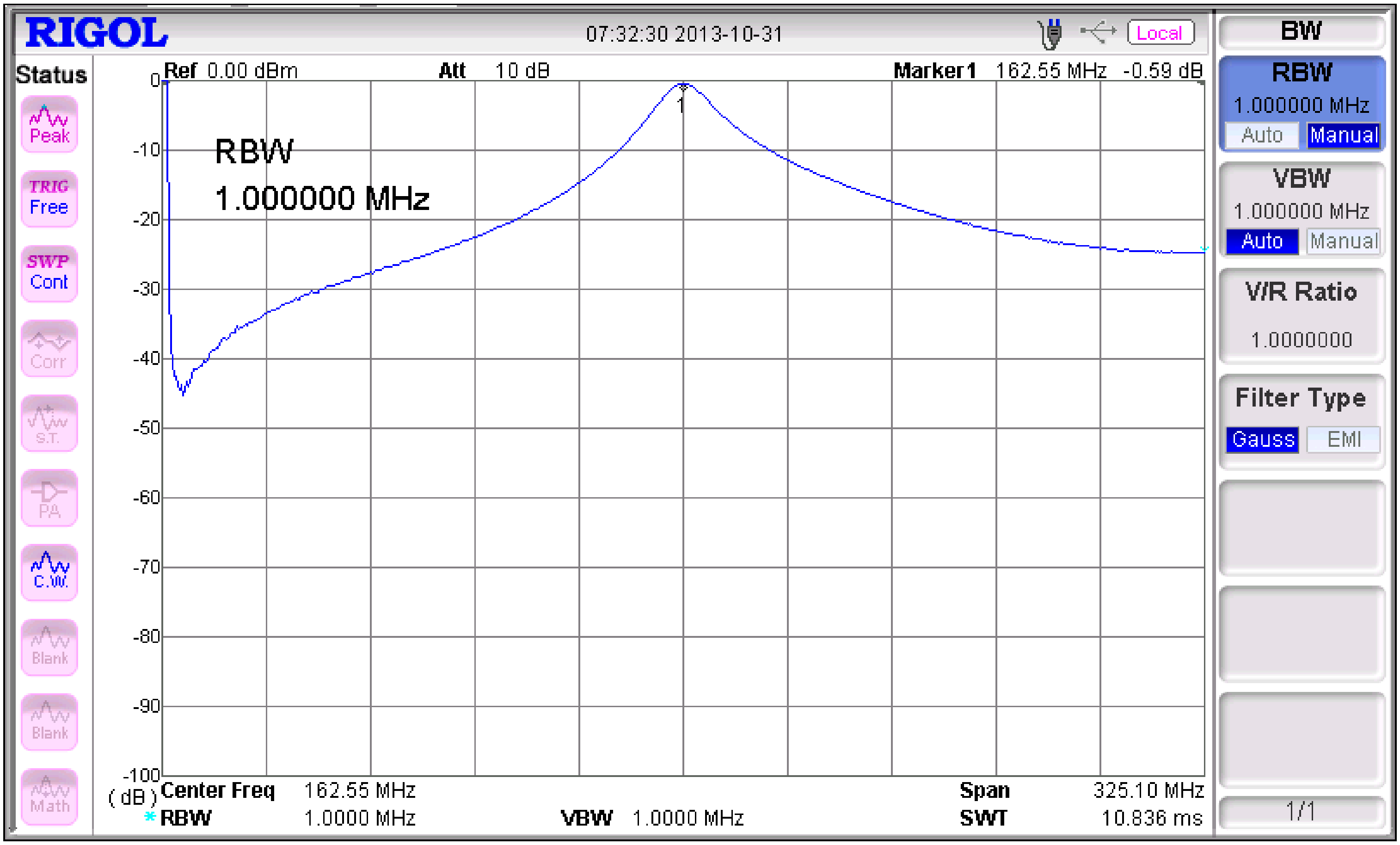
RIGOL
Local
Status
Peak
TRIG Free
SWP Cont
Corr
S.T.
PA
C.W.
Blank
Blank
Math
BW
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
(dB)
1
1/1

07:32:30 2013-10-31

Ref 0.00 dBm

Att 10 dB

Marker1 162.55 MHz -0.59 dB

RBW 1.000000 MHz

Center Freq 162.55 MHz

Span 325.10 MHz

RBW 1.0000 MHz

VBW 1.0000 MHz

SWT 10.836 ms

RBW 1.000000 MHz Auto Manual

VBW 1.000000 MHz Auto Manual

V/R Ratio 1.0000000

Filter Type Gauss EMI

Above — Tracking generator plus spectrum analyzer sweep. Under sweep set up, I minutely squished or expanded the L and tweaked the caps to peak the filter at 162.55 MHz while obtaining the lowest insertion loss. Further, I had to tweak the trimmer capacitors to center the filter with the Hammond lid on since putting the lid on changed the center frequency slightly. A *TG equipped* spectrum analyzer proves the ultimate bench tool for VHF and UHF in my humble opinion.

Almost All Digital Ele

Above — Zero calibration of my AADE L/C IIB meter. By sweeping numerous LC circuits after measuring the L with this tool, I've learned it's reasonably accurate with low inductance coils. I zero the meter prior to *each* measurement and zero calibrate it with the alligator clips butted end-to-end while gripping a small piece of copper wire. Try to keep the same relative alligator clip position during coil measurement. I'm uncertain if this is protocol, but it seems to work for me.

Thanks to Joe, W1JR for this circuit and the opportunity to learn more about component-level VHF design and construction.

---

6. VHF Band-pass Filter Experiments

Build Notes

1. All filters designed with the EMRFD ladpac programs DTC08, or TTC08 and then tweaked in GPLA.

2. Seeking a band-pass filter for my experiments with the local NOAA weather channel at 162.55 MHz, I designed, built and tested 3 filters. With a 10.7 MHz IF superhet receiver, the image frequency = 141.15 MHz.

3. My VHF sweep system = a tracking generator plus a spectrum analyzer.

Filter 1

To avoid the need for proper electromagnetic/electrostatic shielding, I kept my HF experimenter hat on and built my first filter with powdered iron toroids (T30-12) knowing I would pay a Qu penalty that may wreck filter insertion loss, bandwidth and port matching. I hoped that the passive electromagnetic shielding offered by toroidal inductors would reduce resonator coupling.

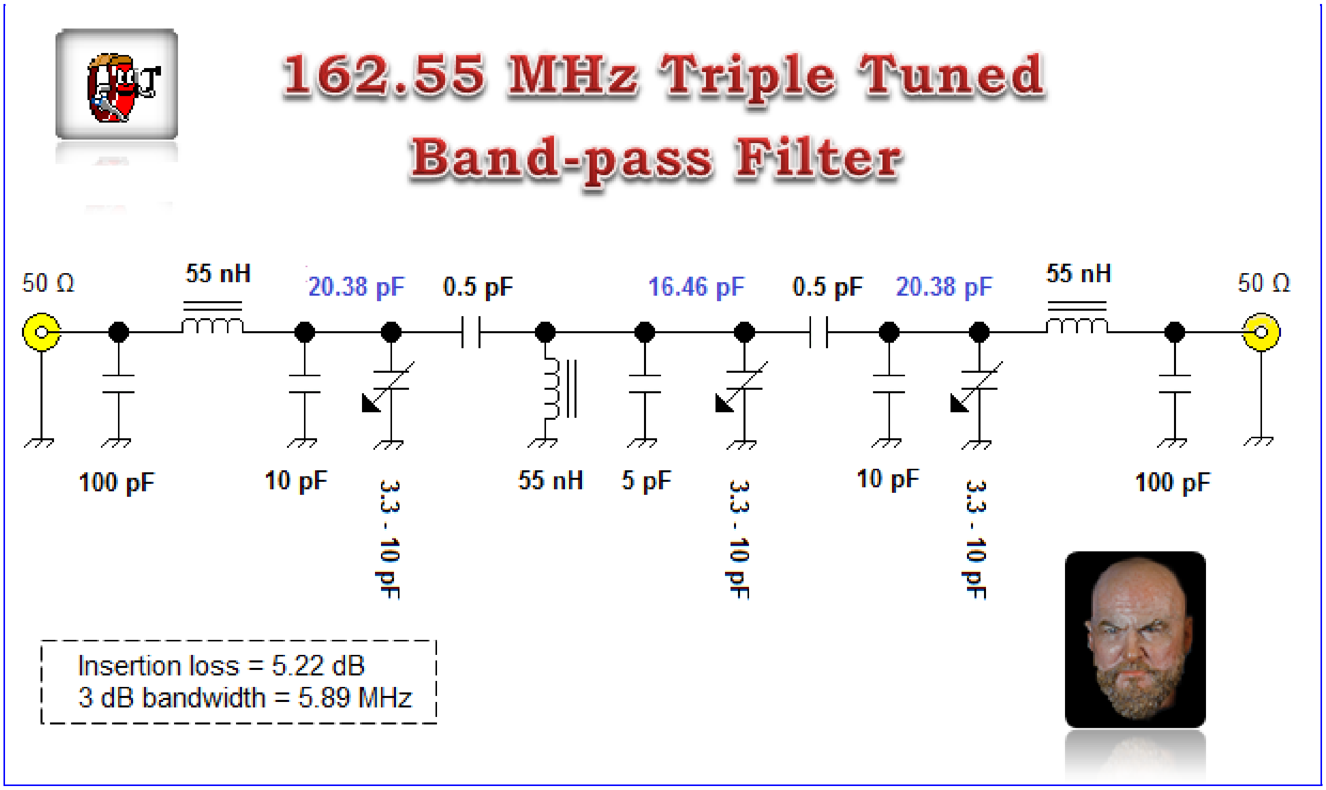
162.55 MHz Triple Tuned
Band-pass Filter
50 Ω
55 nH
20.38 pF
0.5 pF
16.46 pF
0.5 pF
20.38 pF
55 nH
50 Ω
100 pF
10 pF
3.3 - 10 pF
55 nH
5 pF
3.3 - 10 pF
10 pF
3.3 - 10 pF
100 pF
Insertion loss = 5.22 dB
3 dB bandwidth = 5.89 MHz

Above — Mixed-mode triple-tuned filter schematic. Click for the GPLA simulation. When we want to go up in frequency plus desire a narrow bandwidth, we face 2 options: reduce our inductance and/or coupling capacitor(s). This taxes our parts collection and breadboard skills since capacitors less than 1 pF are relatively uncommon and require SMD breadboard techniques. I adjusted my design bandwidth and inductance in TTC08.exe to allow the 0.5 pF capacitors plopped in my parts bin to work. For a change of pace, I chose a mixed-mode filter topology.

I strive to place a single high Q variable capacitor in my band-pass filter tanks, however, my Q = 700 SMD trimmers only ranged 3.3 to 10 pF so I stuck a leaded ceramic capactor in parallel with each trimmer.

Common SMD capacitors exhibit low to medium Q and I try to avoid them in my at HF band-pass filters: often I'll just solder a short leaded though-hole caps instead. I also applied this logic to my VHF filter, however, this might prove foolish at VHF since the self-resonant frequency of a given leaded cap is lower than that of an equivalent SMD cap and capacitor XL becomes more significant as we move up in frequency.

Click for a pdf file showing a simple experiment with 3 capacitors . I'll occasionally use ultra-high Q SMD caps in my future experiments based upon these results.

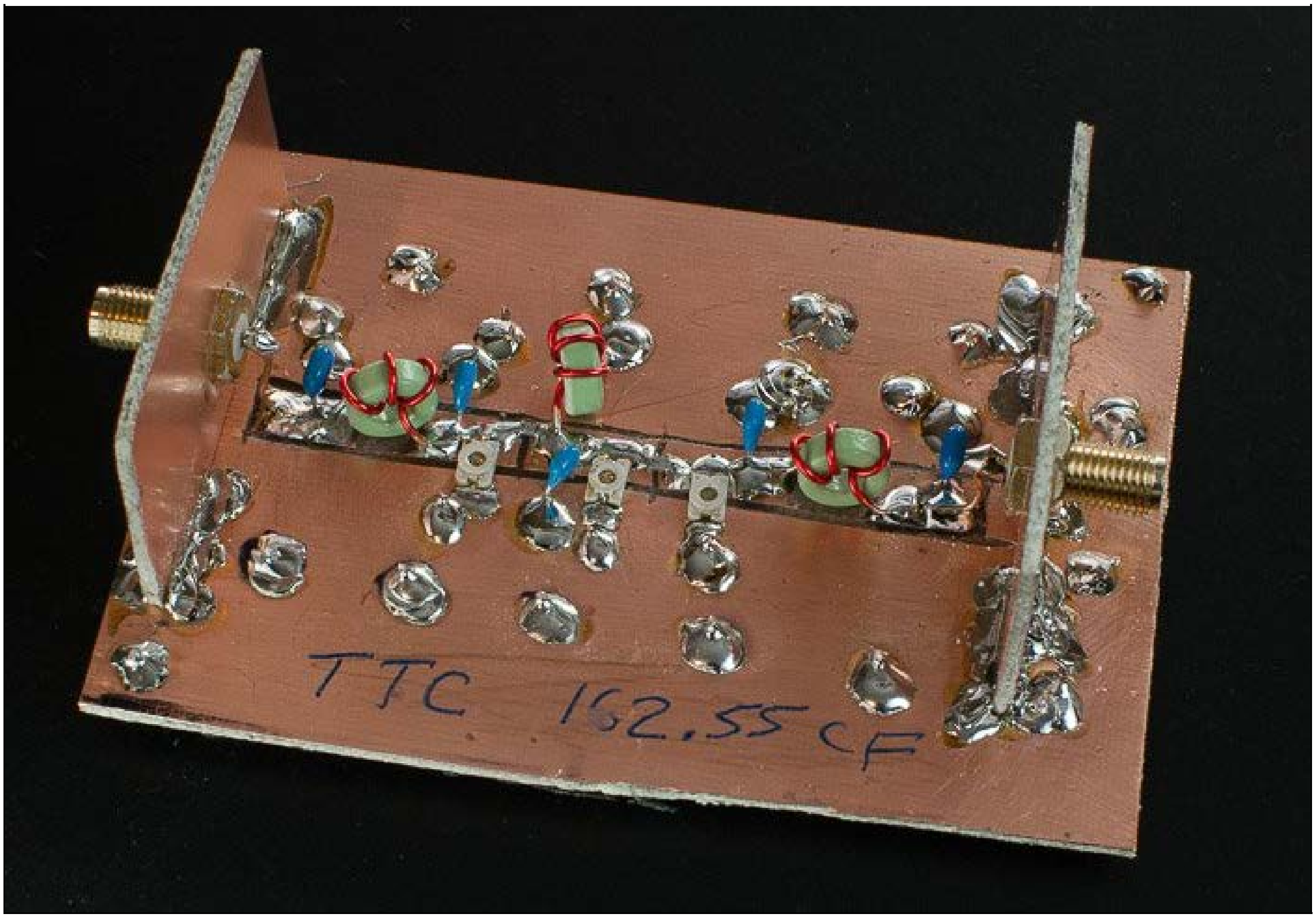

Above — My TTC breadboard. Click for a larger photo. Click for a bench sweep to view a feculent skirt peak in the filter spectogram. Some resonator coupling occurred despite spacing and placing the inductors at right angles. This circuit possessed 6 tweaks: the 3 trimmers and the 3 Ls — I just kept tweaking them until I got the best shape and lowest IL. That's 21 gauge wire on the toroids. My image frequency = 47.28 dB down. Since the sweep yielded such a wide discrepancy from my GPLA simulation, I discarded this filter and moved on to design #2.

Filter 2

Attempting to obtain a resonator Qu of at least 300-400, I moved to air core inductors wound with bare 22 gauge copper wire *plus* air-variable capacitors. Double-tuned classic topology. Without stout shielding, air wound inductors will couple and trash the stopband.

Create With Metal
Quality Metal Sheets
K-S
Metal edges may be sharp. Use gloves and safety glasses when handling. Children should have adult supervision.
6917 W. 59th St.
Chicago, IL 60638
773-586-8503
www.ksmetals.com

Above — Copper and brass sheets I bought for making filter boxes after Wes recommended using metal sheets or strips for shielding filters. In North America, builders can purchase a sheet metal hand brake plus a rotary cutter/shear for under $100 and make all sorts of boxes for radio gear. I'll equip my QRP workshop with such equipment over the next year. This was my first experience man-handling sheet metal or strips.

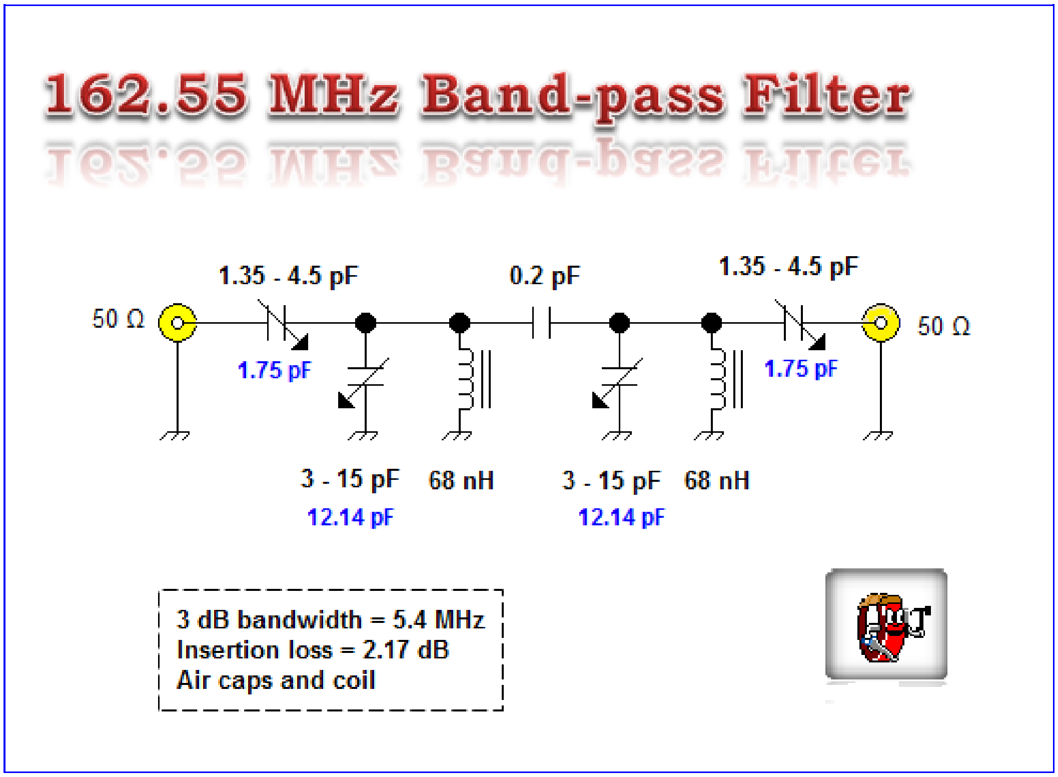
162.55 MHz Band-pass Filter
50 Ω
1.35 - 4.5 pF
1.75 pF
0.2 pF
1.35 - 4.5 pF
1.75 pF
50 Ω
3 - 15 pF
12.14 pF
68 nH
3 - 15 pF
12.14 pF
68 nH
3 dB bandwidth = 5.4 MHz
Insertion loss = 2.17 dB
Air caps and coil

Above — Schematic diagram of Filter #2 with tabled IL and half-power bandwidth. Click to view a macro photograph of the filter. I soldered the brass box onto a double sided copper-clad FR4 bread board laden with some copper wire vias to enhance the ground plane. The 0.2 μF coupling cap = an ATC microwave cap.

Click and click for the sweeps. Notice the splendid skirt symmetry at the filter top and also the fantastic peak attenuation in the low-pass skirt

(~81 dB from the filter peak to the lowest point in the low-pass filter skirt). I'd never seen deeper attenuation on my bench before: quite gratifying. My double-tuned filter had essentially matched the 3 dB BW of triple-tuned filter #1 with less insertion loss.

Not all appeared perfect however; attenuation of frequencies above the passband looked so-so and I was unable to get a lower 3 dB bandwidth by manipulating L and C in each tank.

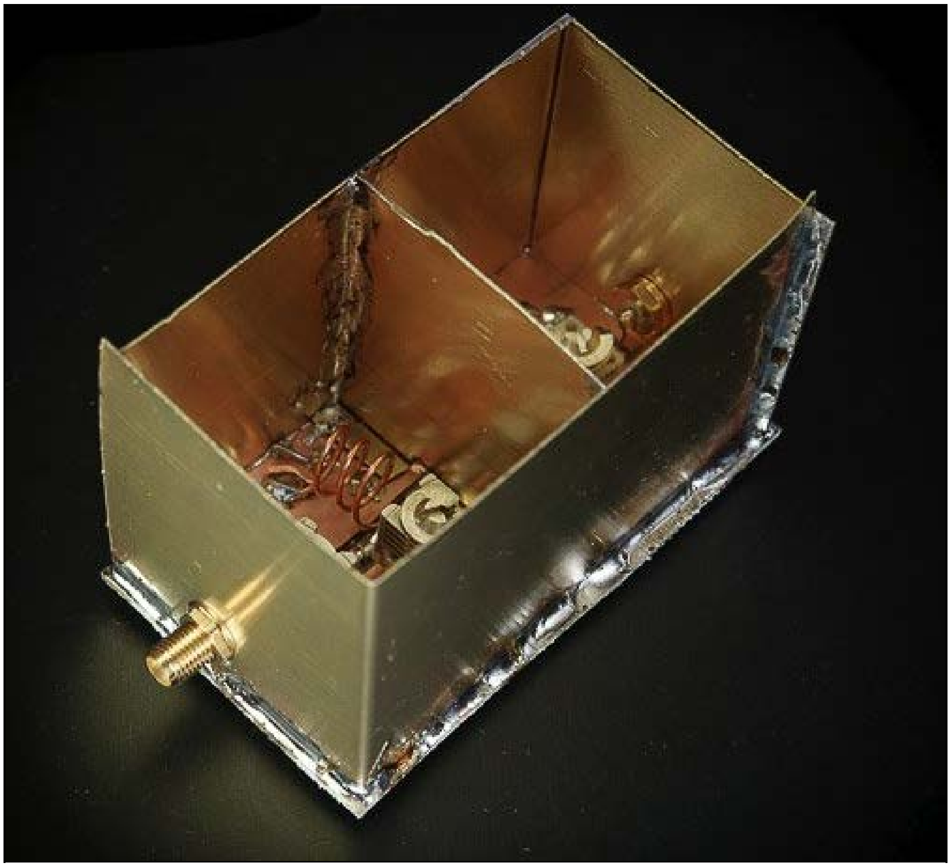

Above — My first ever brass box soldered on a 2-sided copper clad board: Filter #2. Lacking proper tools and also the knack for making beautiful chassis like Dave, AA7EE does, I just did my best. My only concern was getting tank isolation. I chiseled out a small cut in the center brass divider just high enough to clear the SMD 0.2 pF chip capacitor and center copper strip. Overlaps allowed soldering of brass walls After tweaking the L and C parts, I placed a brass lid on top during sweeps. Okay, onto filter # 3:

Filter 3

When coupling caps fall below 1 pF, some builders place their resonators in close proximity to couple the tanks, however, these usually involves slug-tuned powdered iron or ferrite inductors with a generally low Q. The coil consists of cup core and a threaded center core which combine to give a magnetic shield. A tin plated copper can surrounds the core for electrostatic shielding. I think after these experiments — placing each resonator in its own sealed box seems a better option.

I noticed another approach in The Double Tuned Circuit: An Experimenter’s Tutorial in QST for December 1991 by Wes, W7ZOI. Wes drilled a hole in the tank compartment divider and passed a wire soldered to 1 tank through the hole and positioned it near the variable capacitor of the other resonator. We change coupling by adjusting this wire.

The wire may be thought of a "tweakable" capacitor, however, the key point is we need to couple energy from 1 resonator to the next; whether by wire, capacitor or inductor, proper resonator coupling will give the required skirt shape within the the limits imposed by Q and the matching to the 50 Ω ports. When establishing a filter passband, the end Q and resonator coupling pretty much dictate the outcome.

Filter #3 involved more mechanics than electronics. I made a U shaped box from a small sheet of copper.

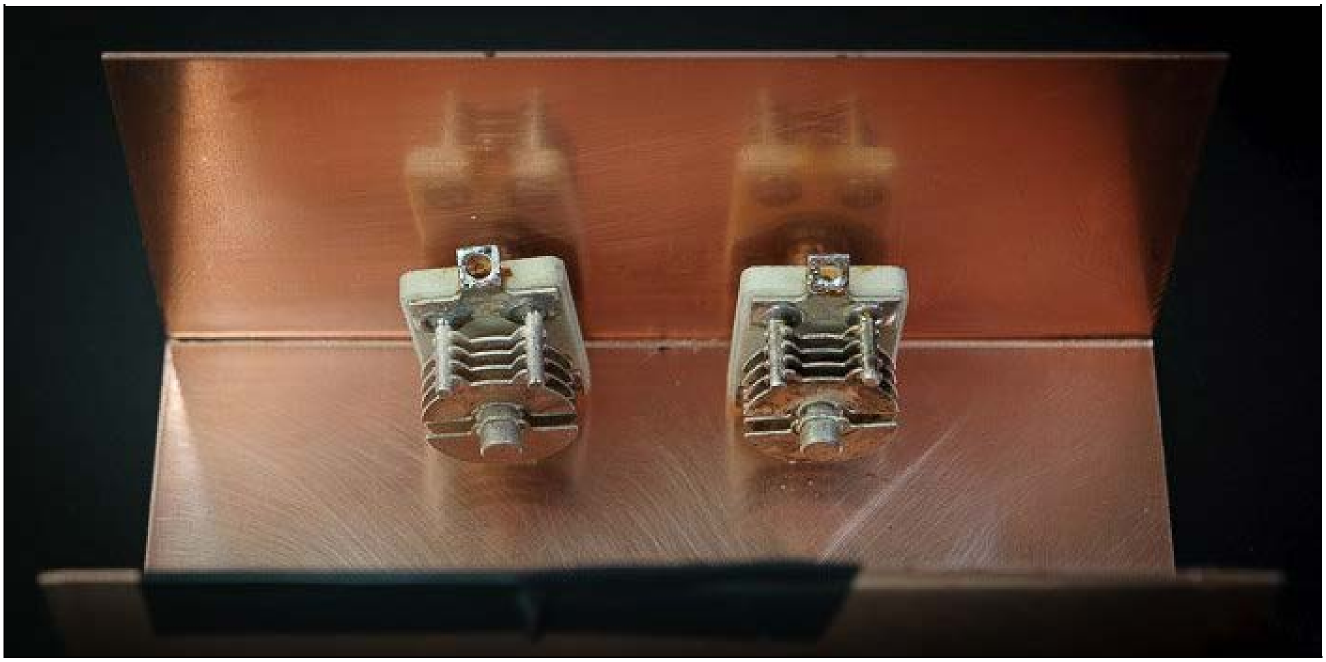

Above — My copper box drilled for the 2 air-variable tuning capacitors. I built the walls, top and divider from thinner gauge brass strips. Rosin flux aids soldering your metal sheets together — I soldered mine with a Weller 80 Watt iron and began with the center divider. Click for a side shot after completion.

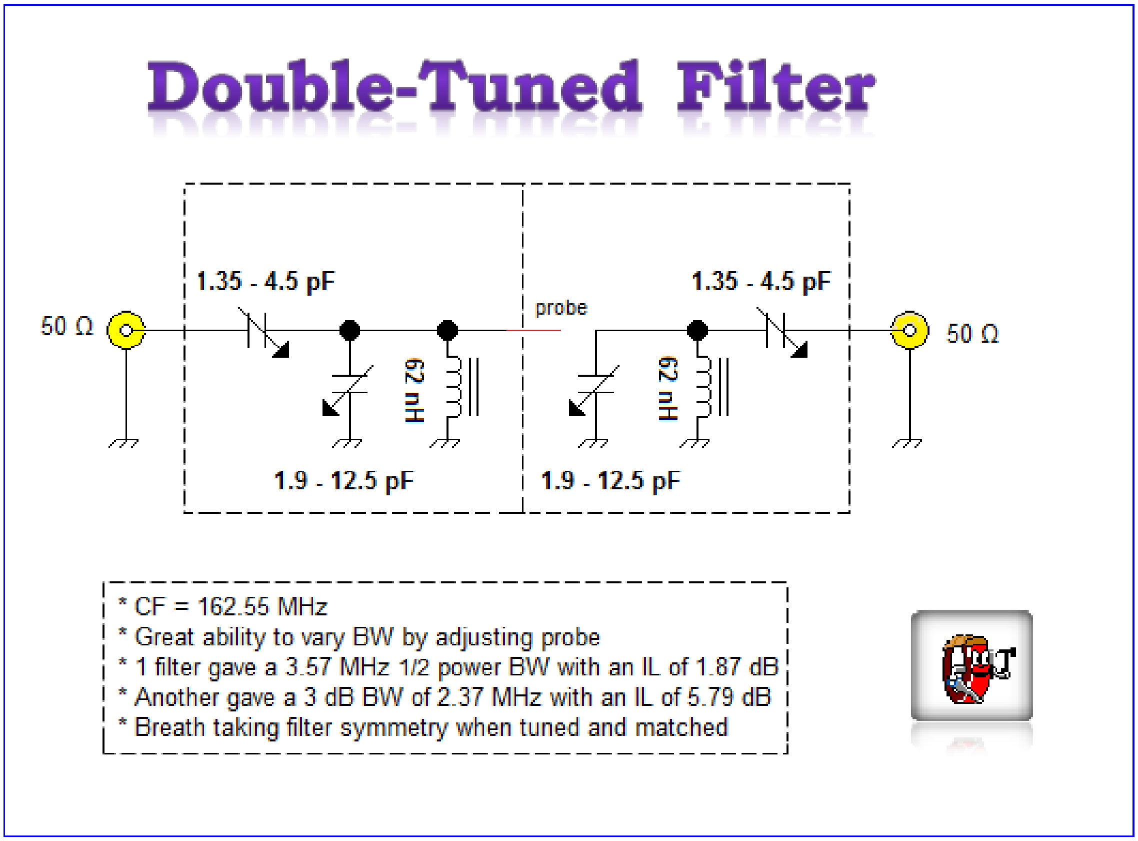

* CF = 162.55 MHz
* Great ability to vary BW by adjusting probe
* 1 filter gave a 3.57 MHz 1/2 power BW with an IL of 1.87 dB
* Another gave a 3 dB BW of 2.37 MHz with an IL of 5.79 dB
* Breath taking filter symmetry when tuned and matched

Above — My filter schematic with some tabled data. Click for a top off photograph where you can easily see the black wire probe. To change coupling, you change the wire length and/or its distance from the second tank capacitor. I really enjoyed moving the wire and watching the outcome on the screen. Per usual, I tweaked the coupling, Ls and end caps to derive many 3 dB bandwidths. In 1 arrangement with a 3 dB bandwidth of 3.57 MHz, the insertion loss was only 1.87 dB — I had evidently found a perfect ratio + combination of L and C yielding a low IL.

I'll increase the coil wire gauge in future experiments to lower solenoid resistance and try to garner even more Qu.

This is the *best* filter I've ever built. After peaking the tanks to 162.55 MHz, resonator adjustments weren't really needed. By moving the wire probe I saw that BW and IL change inversely. While tweaking the series caps and moving the probe, it felt like déjà vu from my experiences simulating these exact changes in GPLA over many years — except now they were alive and kicking. With some inductor manipulation (or as needed, changing the inductors) this filter can be centered from ~140 to well over 200 MHz. A high-octane, dramatic and versatile filter indeed.

Click for a sweep where I moved the wire very close to the neighboring tank capactor and over coupled the filter.

Click for a screen shot of another sweep.

Conclusion

With new awareness that resonator coupling and other issues may *also* occur in HF band-pass filters, making these 3 filters surely boosted my future band-pass filter construction standards at any frequency. Over the years, builders have emailed me sweeps of HF band-pass filters (usually VNA sweeps) with also sorts of extra resonances +/- poor insertion loss. Since I'm just an amateur, often nimrod RF enthusiast, I won't pretend I possess all the knowledge to critique their filter woes.

However, photos of their HF filters usually look messy and rushed: opposite to our needs — eschewing important factors like symmetrical layouts, inductor spacing, a first-rate ground plane, larger gauge + well spaced wire wound on big as possible toroid cores Yikes, I better stop now lest I venture into filter folklore.

Today, designing a filter with software is merely half the battle — construction poses the harder task. Unsurprisingly, measurement and experimental methods will elevate your outcomes.

Filter analysis with a sweep system is the ultimate, however I built and then tested many band-pass filters with a frequency counter, a signal generator, a 'scope and a return loss bridge during the first 12 years of my RF life.

Assuming you have a filter that peaks and isn't overcoupled: to measure the 3 dB bandwidth, first peak the filter to resonance for the highest peak-peak voltage in your 'scope. Here's the rest of the procedure:

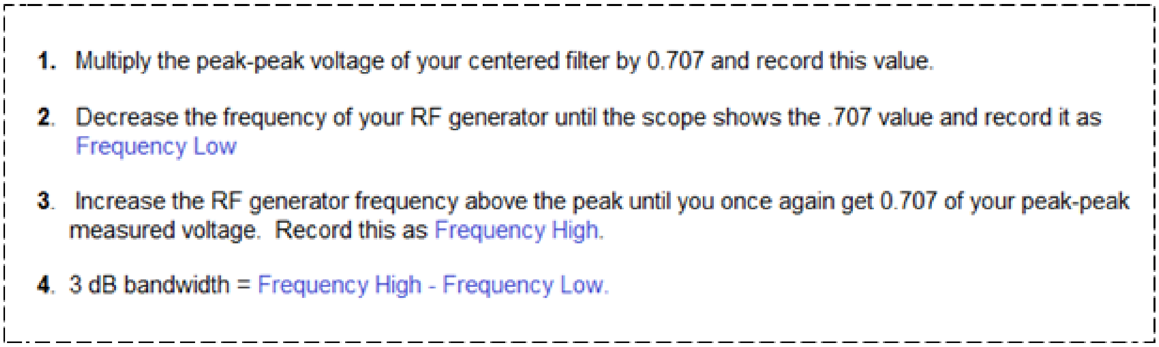

1. Multiply the peak-peak voltage of your centered filter by 0.707 and record this value.
2. Decrease the frequency of your RF generator until the scope shows the .707 value and record it as Frequency Low
3. Increase the RF generator frequency above the peak until you once again get 0.707 of your peak-peak measured voltage. Record this as Frequency High.
4. 3 dB bandwidth = Frequency High - Frequency Low.

You may also wish to measure the insertion and return loss as described in EMRFD, Radio Society Handbooks, or the RF Workbench series on this web site.

Whether you run superhet, low IF, SDR, or Zero IF (DC) receivers, or need to filter a transmit chain, well made band-pass filters just might boost your project performance. VHF poses additional challenges but offers great learning opportunities.

QRP — Posdata for Nov 12, 2013

A. Notes for Filter #2

Victor, 4Z4ME wrote to explain why the attenuation above the passband in Filter #2 looked mediocre. Filter topology and component values yielded the poor high-pass attenuation and not unwanted coupling as I originally shared.

Victor wrote: "The problem is that all the couplings are of one nature, in this case capacitive.
At very low frequencies the inductors short the signal to ground while the capacitors impedance gets higher so it is clear that the output signal goes to zero.

At high frequencies the inductors may be regarded as disconnected because their impedance get very high, however although the capacitors impedance get lower , you have them both at the series arms and at the parallel arms, so the signal gets to be attenuated by their impedance ratio and not get shorted to ground.

This can be shown in analytic calculation, or easier by simulation. See the attached file (LTSpice simulation). You can see that the filter (similar to your filter) gets closer to a finite attenuation at high frequencies, getting closer to the attenuation of a similar circuit with the inductors *removed*.

You can get better high frequency results by trading the center 0.2pF capacitor coupling to an inductive coupling. Remove the coupling capacitor and insert a wire through the center shield, ground its ends close to the main inductor. Shape the wire to a small loop near the grounded end of each of the resonator inductors to get small inductive coupling, and you get again a good BPF but with better high frequency attenuation. Instead of loops you can connect the coupling wire at a tap at the bottom of the main resonator inductors, close to the ground".

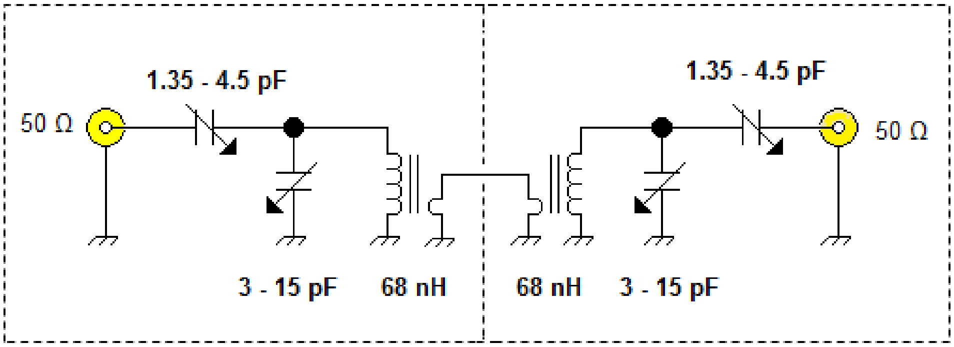

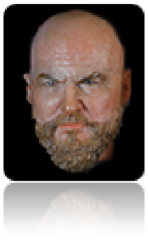

Filter 2 Pos-data Experiment

Above — Following Victor's suggestion, I inductively coupled the Filter #2 resonators with a wire looped near the grounded end of each tank inductor. Please view the schematic above. High-pass attenuation above the passband improved significantly. Click for a sweep out to ~ 511 MHz that shows the peak high-pass attenuation much closer to the low-pass skirt peak reponse.

At 2X center frequency (325.1 MHz) the high-pass skirt peak attenuation closed within 14 dB of the low-pass peak attenuation compared to the original Filter #2 response where the delta was around 30 dB. Further improvement occurs as we move above ~400 MHz. Big thanks to Victor for his support.

B. Sheet Metal Safety

A cut finger while working sheet metal prompted the following remarks: Jagged edges from cut sheet metal (especially brass stock it seems) may lead to deep cuts. Filing a burred edge with the metal clamped in a vice between some thicker metal stock with its raspy edge barely showing will reduce the "knife edge effect". When drilling, clamp the metal piece to your bench on a wooden backing board . If you jam your hand drill in an unclamped piece of metal it could spin and really gore you. Safety first.

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7. NE612 Mixer Diddy

The Signetics NE612 and ilk enjoys wide use by the amateur radio community in novelty-grade Ham band receivers, or in somewhat better receivers laden with abounding front end filters + *stout,* switchable RF attenuators. Do you think of the NE612 as an ersatz receiver mixer? Some only consider them for the transmit mixer slot. Read this link why.

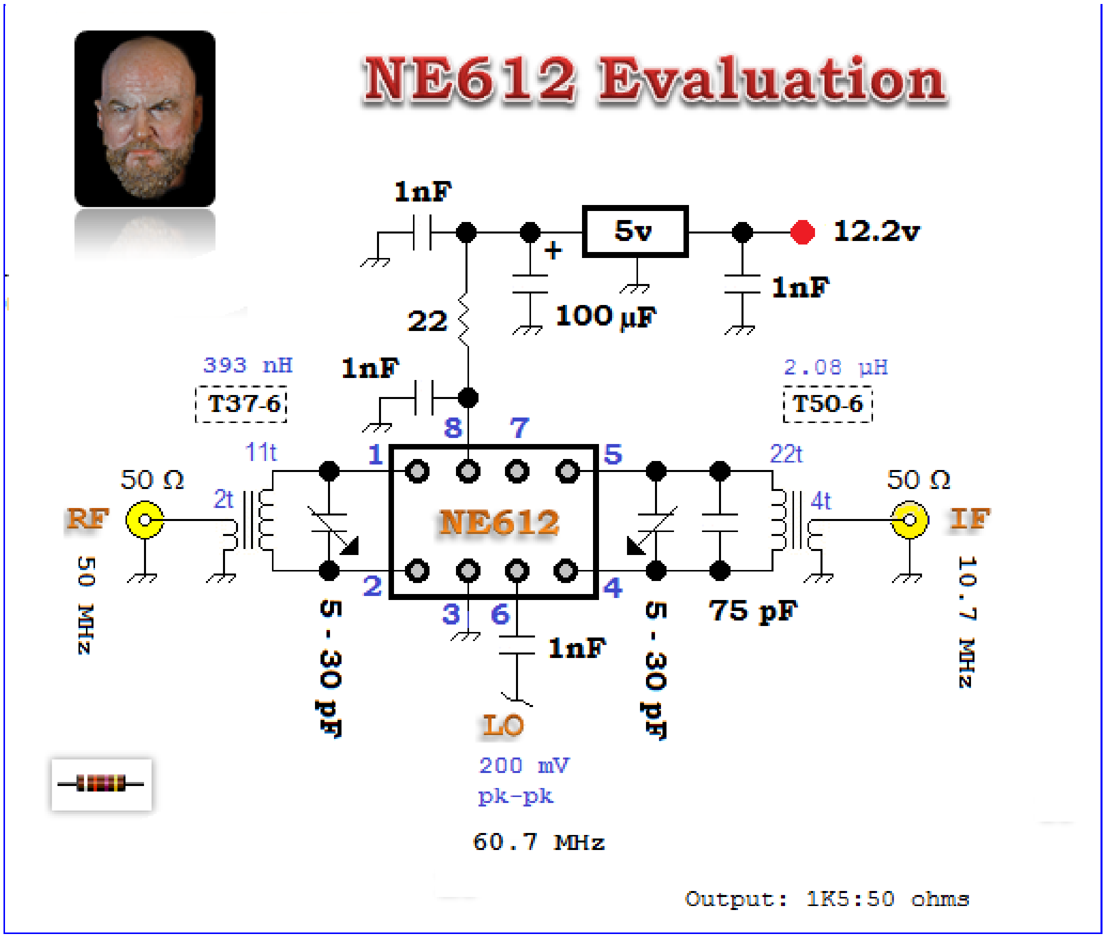
NE612 Evaluation
1nF
5v
12.2v
100 µF
1nF
22
393 nH
T37-6
1nF
2.08 µH
T50-6
8
7
11t
1
5
22t
50 Ω
2t
4t
50 Ω
RF
NE612
IF
50 MHz
2
4
10.7 MHz
3
6
5 - 30 pF
1nF
5 - 30 pF
75 pF
LO
200 mV
pk-pk
60.7 MHz
Output: 1K5:50 ohms

Above — My base schematic. I applied differential input to cancel 2nd order mixer products and balanced output to obtain maximum conversion gain. Click for the breadboard. Powdered iron toroids, Q = 1500 trimmers and a fixed C on the output formed the resonators. I chose a 10.7 MHz IF to drive low-cost ceramic filters in further (unshown) experiments. Normally, we don't bother tuning the input since our bandpass filter should launder the input signal sufficiently.

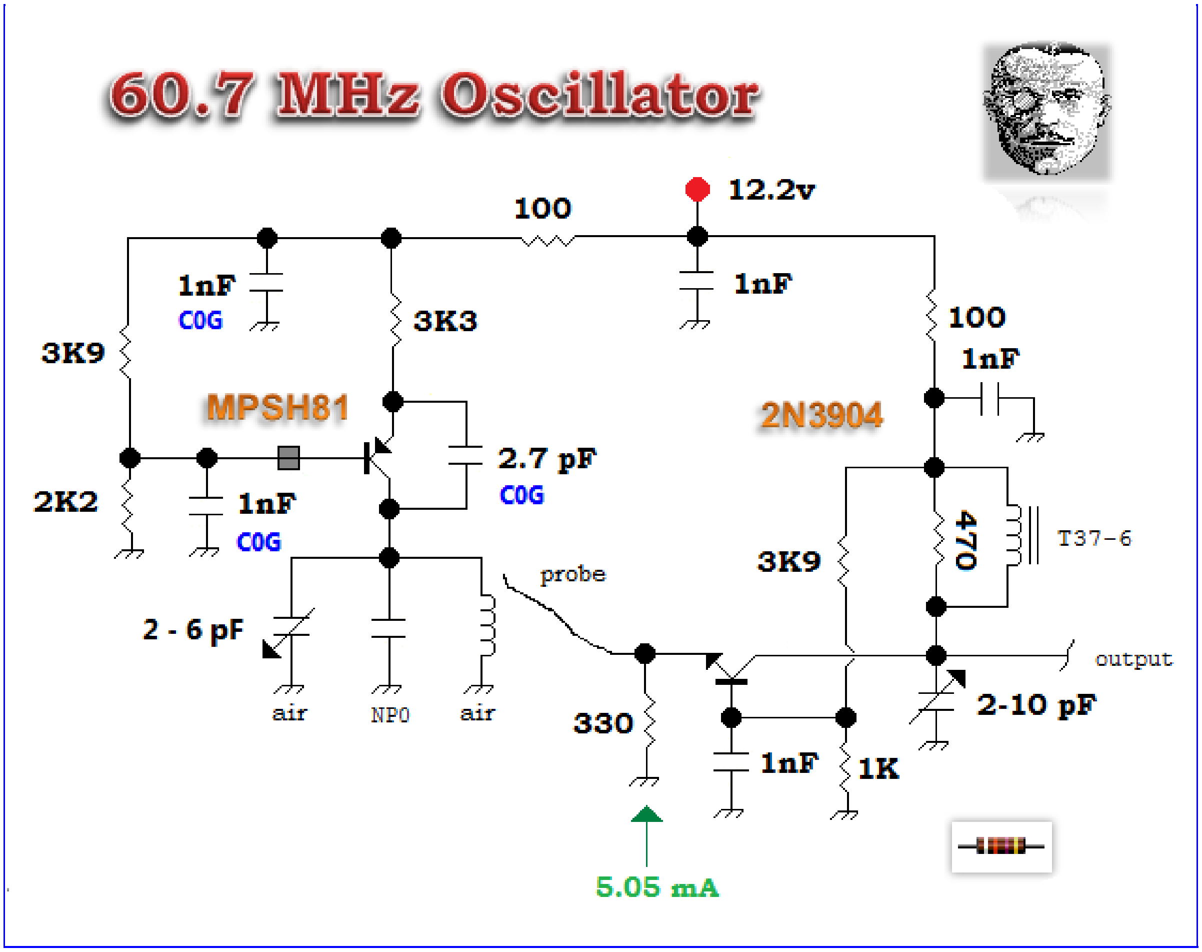
60.7 MHz Oscillator
12.2v
100
1nF
C0G
3K3
1nF
3K9
100
1nF
MPSH81
2N3904
2K2
1nF
C0G
2.7 pF
C0G
470
T37-6
3K9
probe
2 - 6 pF
air
NP0
air
330
1nF
1K
2-10 pF
output
5.05 mA

Above — My 'thrown together' 60.7 MHz local oscillator. A wire on the common base buffer amp input avoids the series R and C usually required and I moved the wire probe to set the output power between 180 and 250 mV peak-peak into a 1K resistor load.

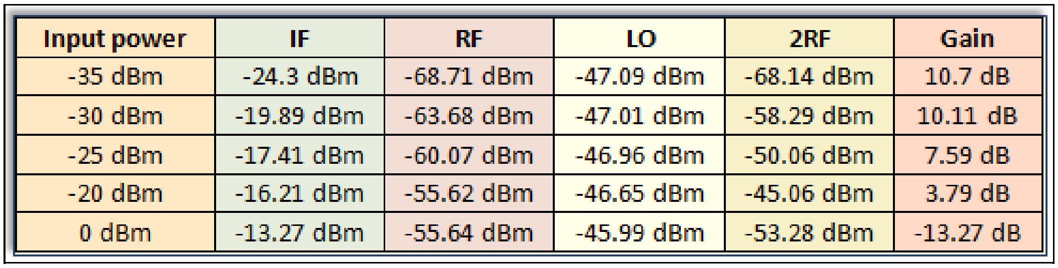

Input power	IF	RF	LO	2RF	Gain
-35 dBm	-24.3 dBm	-68.71 dBm	-47.09 dBm	-68.14 dBm	10.7 dB
-30 dBm	-19.89 dBm	-63.68 dBm	-47.01 dBm	-58.29 dBm	10.11 dB
-25 dBm	-17.41 dBm	-60.07 dBm	-46.96 dBm	-50.06 dBm	7.59 dB
-20 dBm	-16.21 dBm	-55.62 dBm	-46.65 dBm	-45.06 dBm	3.79 dB
0 dBm	-13.27 dBm	-55.64 dBm	-45.99 dBm	-53.28 dBm	-13.27 dB

Above — A table showing the mixer input, IF, RF, LO, 2xRF [the worst spur] power readings, plus calculated conversion gain. This table echos the datasheet + work by others — input power >= -25 dBm drives this mixer into compression. The NE612 runs low current plus low voltage across the output transistors — thus the maximum output power is limited to somewhere between +2 dBm to +5 dBm from my experiments.

Even with -35 dBm input power, I measured a conversion gain much lower than the typical 14-18 dB enjoyed by others who applied differential output at ~ 50 MHz. Turns out, I goofed — each output transistor contains a 1K5 Ω resistor, so when wired differentially, the output Z = 3K. Back to the bench!

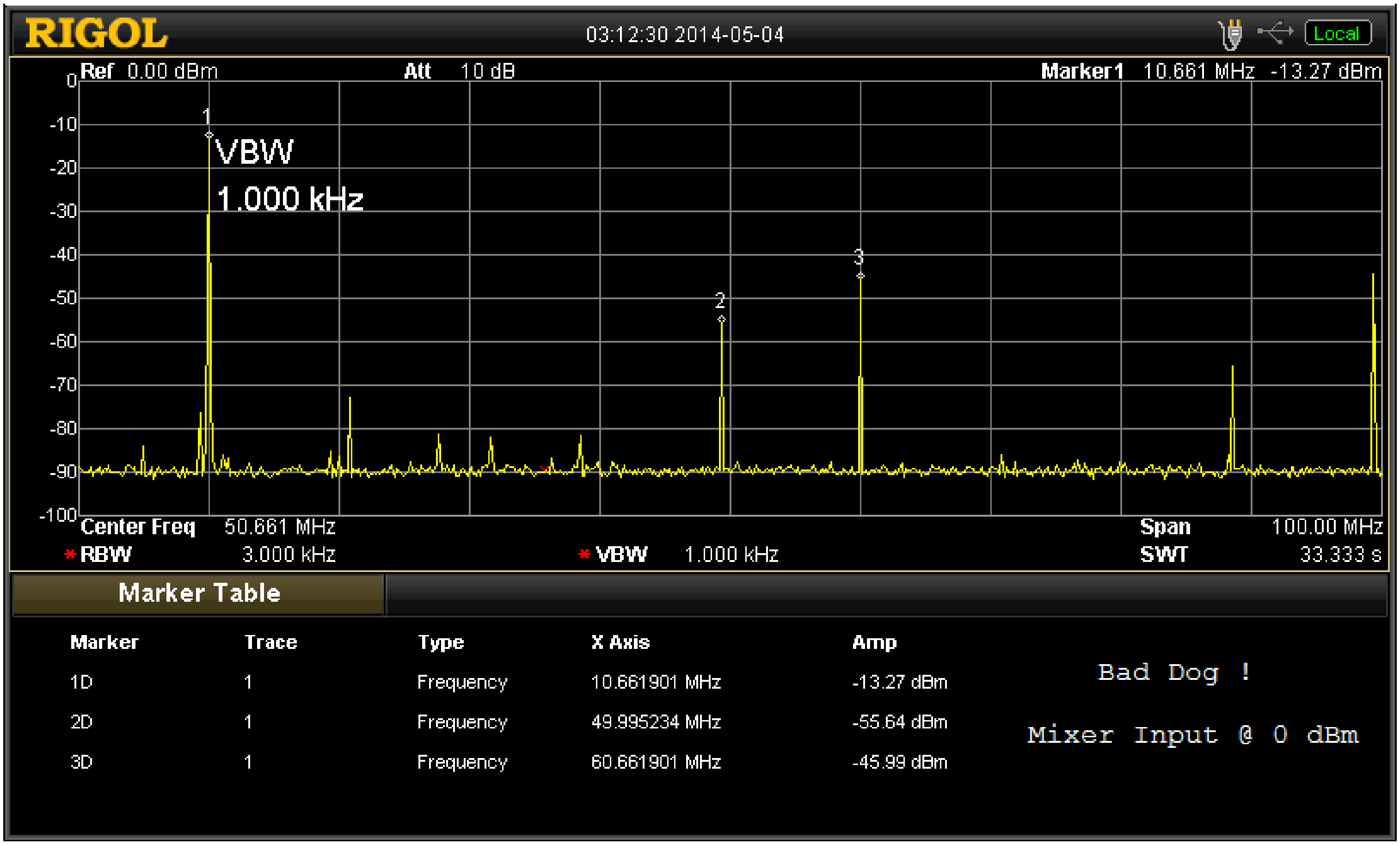

03:12:30 2014-05-04

Ref 0.00 dBm **Att** 10 dB **Marker1** 10.661 MHz -13.27 dBm

Center Freq 50.661 MHz **Span** 100.00 MHz

* **RBW** 3.000 kHz * **VBW** 1.000 kHz **SWT** 33.333 s

Marker Table

Marker	**Trace**	**Type**	**X Axis**	**Amp**
1D	1	Frequency	10.661901 MHz	-13.27 dBm
2D	1	Frequency	49.995234 MHz	-55.64 dBm
3D	1	Frequency	60.661901 MHz	-45.99 dBm

Bad Dog !

Mixer Input @ 0 dBm

Above — SA of the mixer output with 0 dBm RF input. Something we would never do in real-life, but I wanted to see the spurs with such a drive: the spurious output actually looks great! The NE602, NE612, MC1496 and SO42P [all Gilbert cell mixers] output cleanly; especially when compared to diode-based mixers.

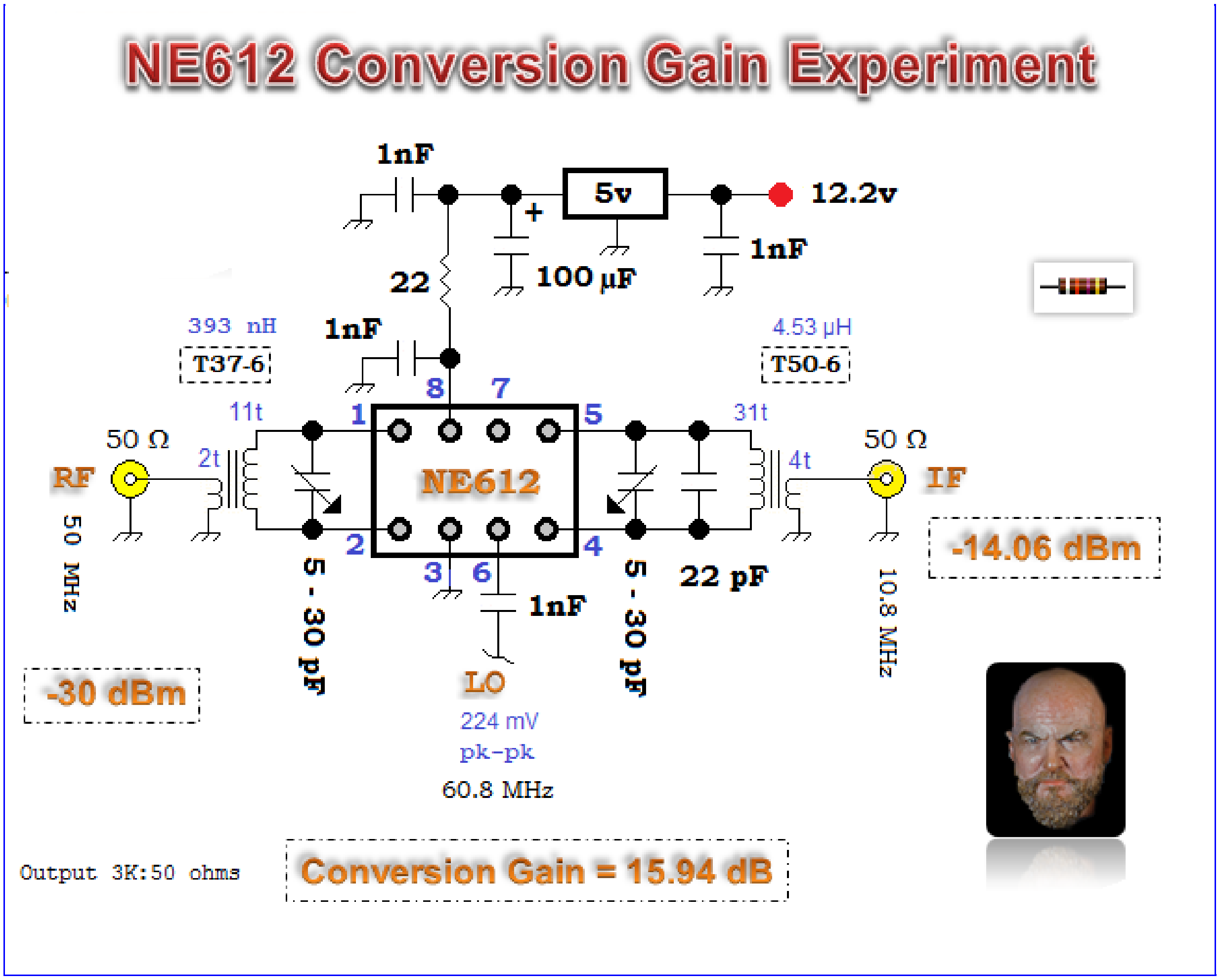
NE612 Conversion Gain Experiment
1nF
5v
12.2v
+
100 µF
1nF
22
1nF
393 nH
T37-6
4.53 µH
T50-6
11t
2t
31t
4t
50 Ω
50 Ω
RF
IF
50 MHz
10.8 MHz
1
2
3
4
5
6
7
8
NE612
5 - 30 pF
5 - 30 pF
22 pF
1nF
LO
224 mV
pk-pk
60.8 MHz
-30 dBm
-14.06 dBm
Output 3K:50 ohms
Conversion Gain = 15.94 dB

Above — My mixer with output Z corrected at 3K Ω. Wow, a conversion gain of 15.94 dB with -30 dBm drive. All good now. Click for the IF measurement on my SA. The LO had drifted up to 60.8 in this experiment, however, I left it and peaked the output resonator for maximum smoke. I also extracted another 0.5 to 0.8 dB gain by tweaking the LO drive. In my breadboard, a drive of 224 mV pk-pk gave the highest conversion gain.

Hereafter, I'll drive my NE612 transmit mixers with between -26 to -30 dBm on the RF port with differential input and output.

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8. Miscellaneous Photographs

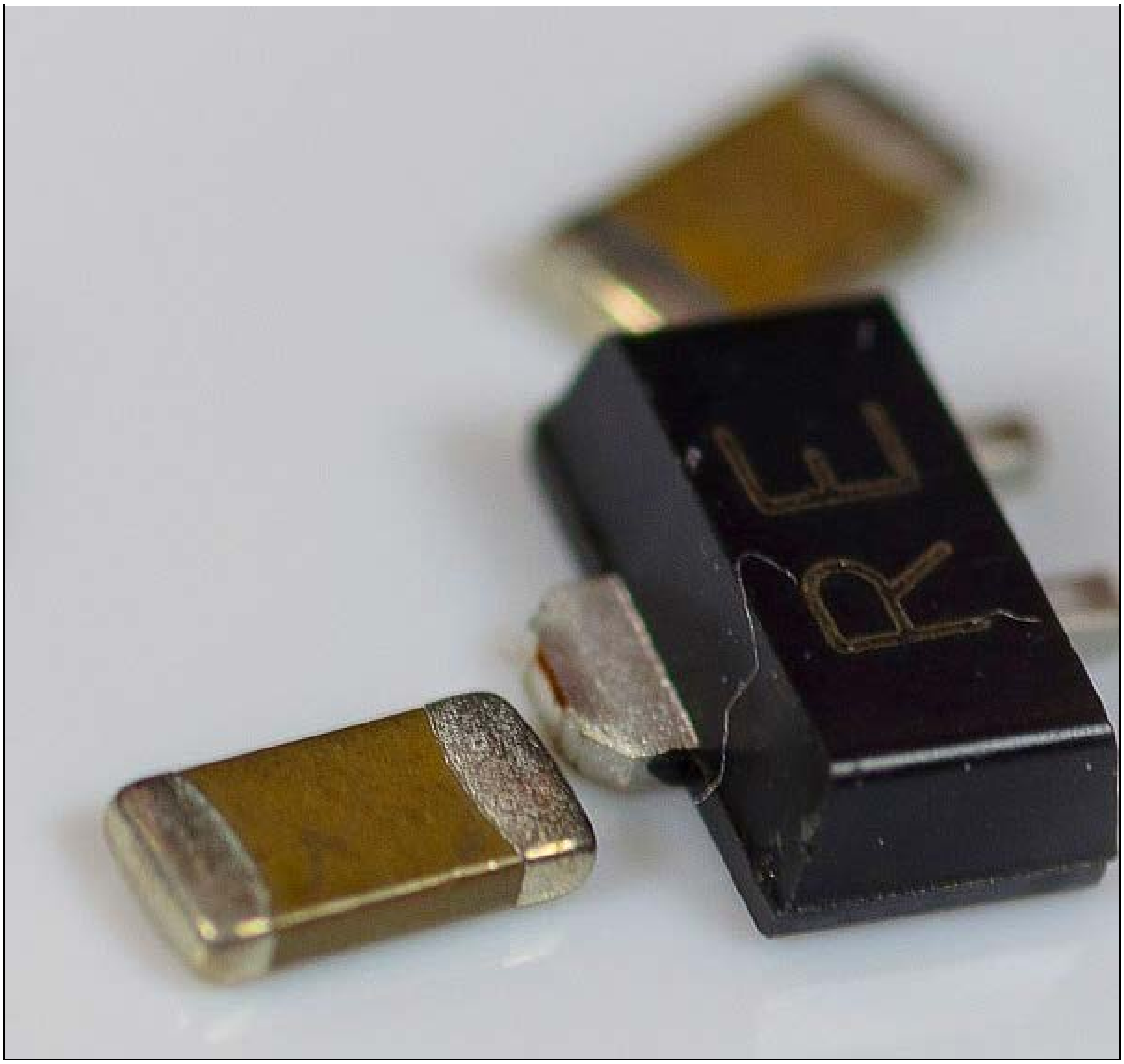

Above — Hair or lint in my SMT macro photo

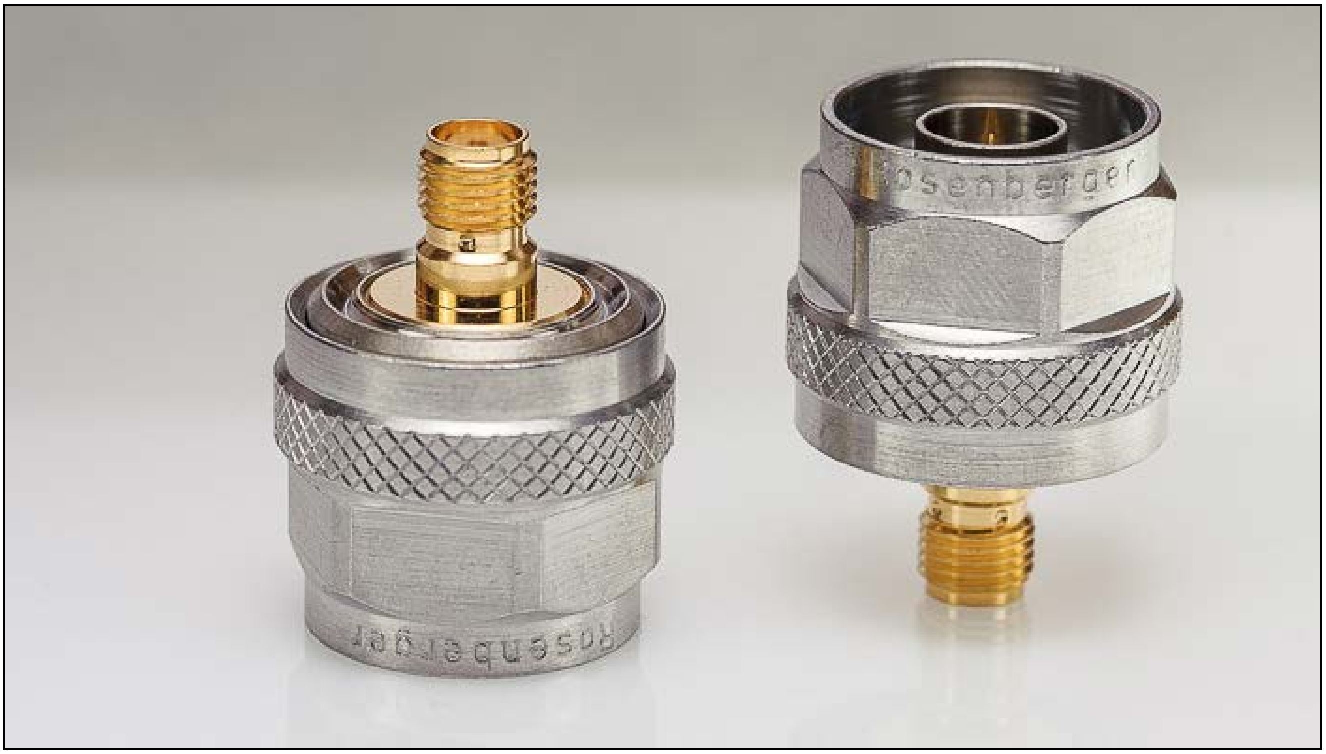
Rosenberger
Rosenberger

Above — Instrument grade N-male to SMA female

Above — Instrument grade N-male to SMA female; gorgeous machine work.

RF — Test and Measurement

RF Workbench Page 6 — QRP Transmitters

RF Workbench 6 explores some questions regarding basic transmitter power amplifer (PA) design. Since I write for both Ham and non-Ham readers, I feel badly that RF Workbench 6 excludes pure radio listeners; please consider getting your amateur radio licence to join the fun.

For Class A, AB and C transmitters in current source operation, radio builders knew most everything presented on this web page back in the 1980's — humbled and guileless, I've but a skosh of new ideas to further elevate this topic. Sometimes I feel bound in a creative straightjacket because puzzling design questions paralyze my understanding and progress. This web page explores a few transmitter questions born on my QRP work bench and I hope you'll relate and go design your own high-octane transmitters. As always, I hope to share insightful + actionable info for the DIY scratch builder; albeit from a lay-person perspective.

I borrow heavily from the work of Wes, W7ZOI per correspondence, direct contributions, from EMRFD and the references listed in Section 5. My sincere thanks to Wes for his support and inspiration.

Preface

You require an amateur radio operator licence to operate a radio transmitter and it's up to you to know and ensure your transmitter spurious emissions meet or beat the regulations in your country.

Although I measure my circuits with calibrated equipment, expect your measured voltage and current to differ from mine. **Why?** Variables may include your DC power supply voltage and current rating, dummy load resistance, stray L and C, cables and wire effects, bench errors, parasitic oscillations, temperature effects and parts tolerances.

I unabashedly declare my love for experiential learning: to build and measure, discover and develop — and best of all, to tune, tweak, and transform my RF power amps to unleash the "smoke" and power we all crave.

Contents

Section 1: 21.06 MHz Bipolar Transistor Transmitter in Class C: Dig out your old transistors and explore some Class C topics.

Section 2: PA Measurement with Examples: Measure collector V and I

Sections 3, 4: Incomplete and coming in 2013-14. I'll post any additions on the QRP Log -- Thanks

Section 5: I'll list all the references for this web page

Section 6: Photographs and Miscellany. I'm told at least ~~3~~ (now 4) people enjoy my photos.

Section 1: 21.06 MHz Bipolar Transistor Transmitter in Class C

Despite all the buzz about PA efficiency and the trend towards more efficient switched-mode power amplifiers, my email inbox fills with content regarding those Class A to C power amps. Consider too, most Hams, including QRP buffs, power their rigs with an AC connected DC supply that makes battery life moot. Perhaps our love of PAs in current source operation harkens from our historic tube days: do we simply enjoy making heat and wasting power? Like me, you might just love making and measuring bipolar transistor circuits.

A Class C power amplifer excited by a crystal oscillator offers both new and reawakening homebrewers the chance to make a simple but relatively powerful, 1 frequency transmitter with only 2 - 4 RF stages. Keying a Class-C PA embodies the Ham glory days: put some RF into the sky with basic, analog circuitry.

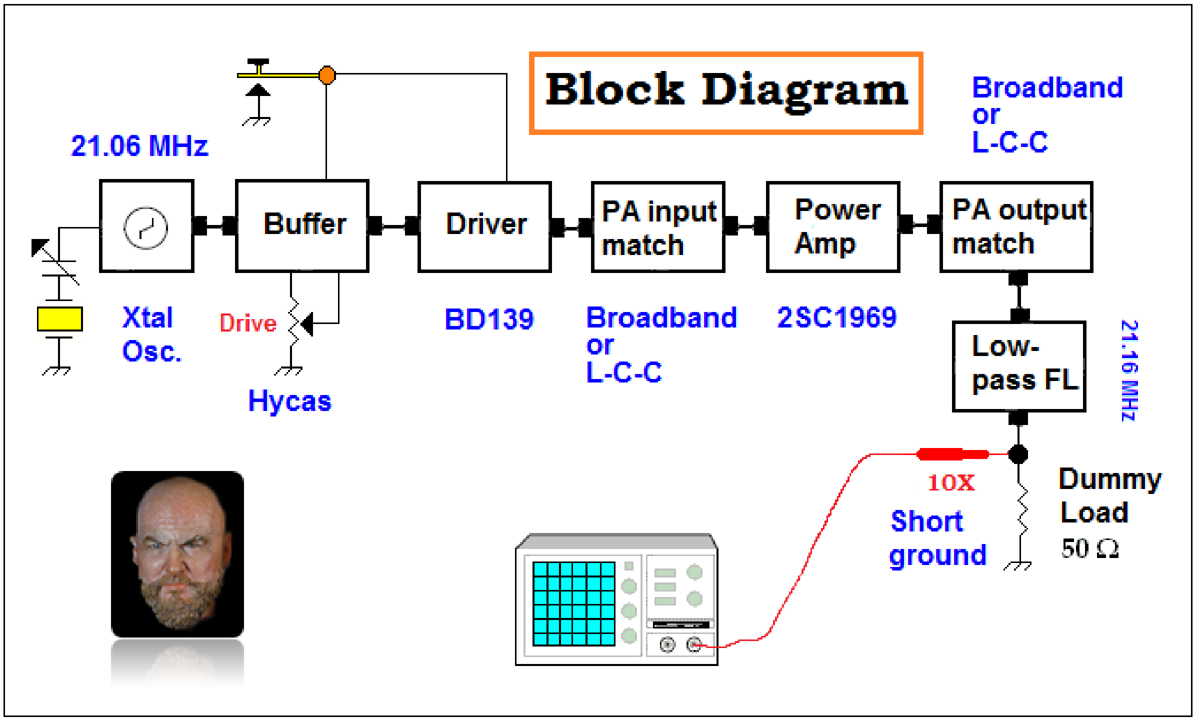
Block Diagram
21.06 MHz
Xtal
Osc.
Buffer
Drive
Hycas
Driver
BD139
PA input
match
Broadband
or
L-C-C
Power
Amp
2SC1969
PA output
match
Broadband
or
L-C-C
Low-
pass FL
21.16 MHz
10X
Short
ground
Dummy
Load
50 Ω

Above — The block diagram for all the experiments in Section 1. Each stage involving transistors was built and tested from left to right before making the next stage.

Crystal Oscillator, Keying Switch and Hycas Buffer Amplifer

As more a listener than a talker, I wanted a low-level crystal oscillator to keep my *key up* current draw low. In the class C power amplifers based on the above block diagram, I measured only 7.5 mA. *key up* and several hundred mA *key down*. I also wanted my back wave to be > 40 dB when I eventually converted the PA to Class AB during another set of experiments.

Design Question 1: What backwave should I strive for?

Backwave = the dB difference in output power between key up and down. Opinions differ and context may partly explain why. If you're working DX, backwave is less important than when your working nearby ops on 80 meters. From asking respected authors, experiments and operating, I feel 40 dB should be the minimal backwave to strive for. Operating Class C, your final(s) are turned off during key up and a >= 40 dB backwave proves an easy goal.

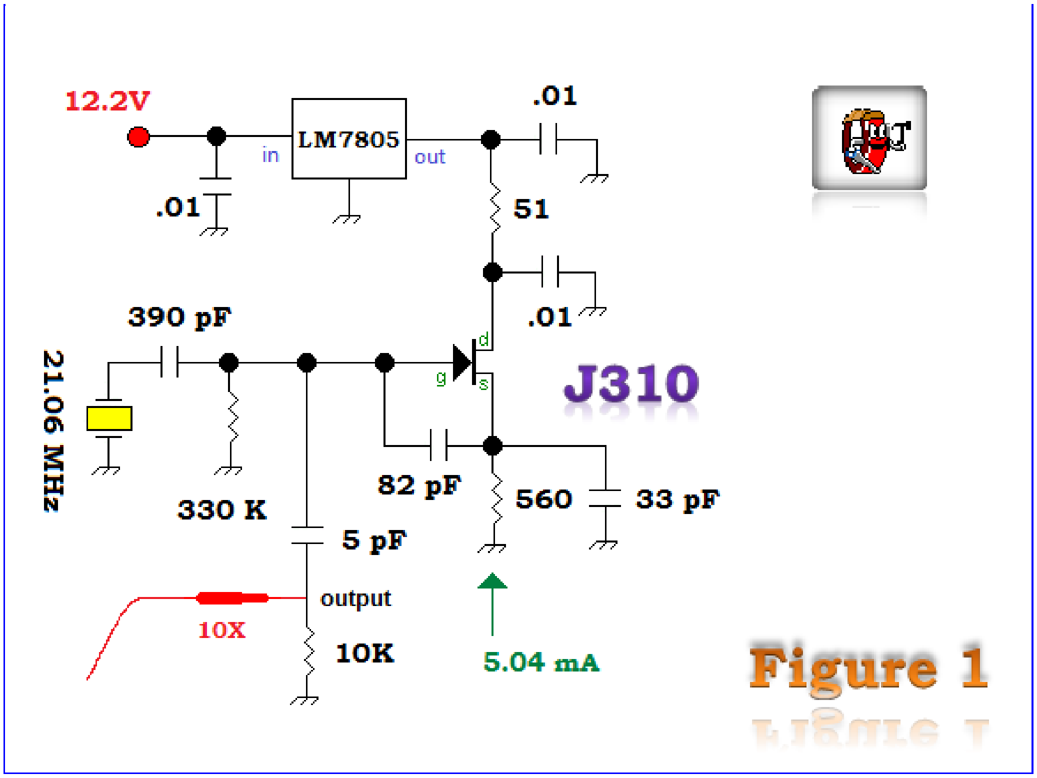
12.2V
LM7805
in
out
.01
.01
51
.01
390 pF
21.06 MHz
J310
d
g
s
330 K
82 pF
560
33 pF
5 pF
output
10X
10K
5.04 mA

Figure 1

Above left — The 21.06 MHz crystal oscillator. Click for the output voltage into 10K Ω. Click for the FFT. Seeking low distortion and output power, I placed variable capacitors in the feedback and source slots and also played with the 560 Ω source resistor. While watching in my 'scope and tweaking , I chose the the lowest distortion signal under 1 Vpp. The variable capacitors were removed, measured and replaced with nearest standard 5% parts. The 10K load of Figure 1 corresponds to the gate resistor of the hycas amplifer input.

21.0588241
MHz
Gate
Freq
Ch 1

Above — Without the 390 pF capacitor, the crystal oscillator vibrated at 21.058 MHz.

21.0603168
MHz
Freq
Ch 1

Above — The crystal oscillator measured frequency after experimentally adding a 390 pF cap. Should I have tried a 470 pF capacitor and attemped to get 21.0600 MHz?

My oscillator looks unconventional and in some cases you might want 1 with higher output voltage. Check EMRFD and the other W7ZOI references in Section 5 for xtal oscillator design ideas.

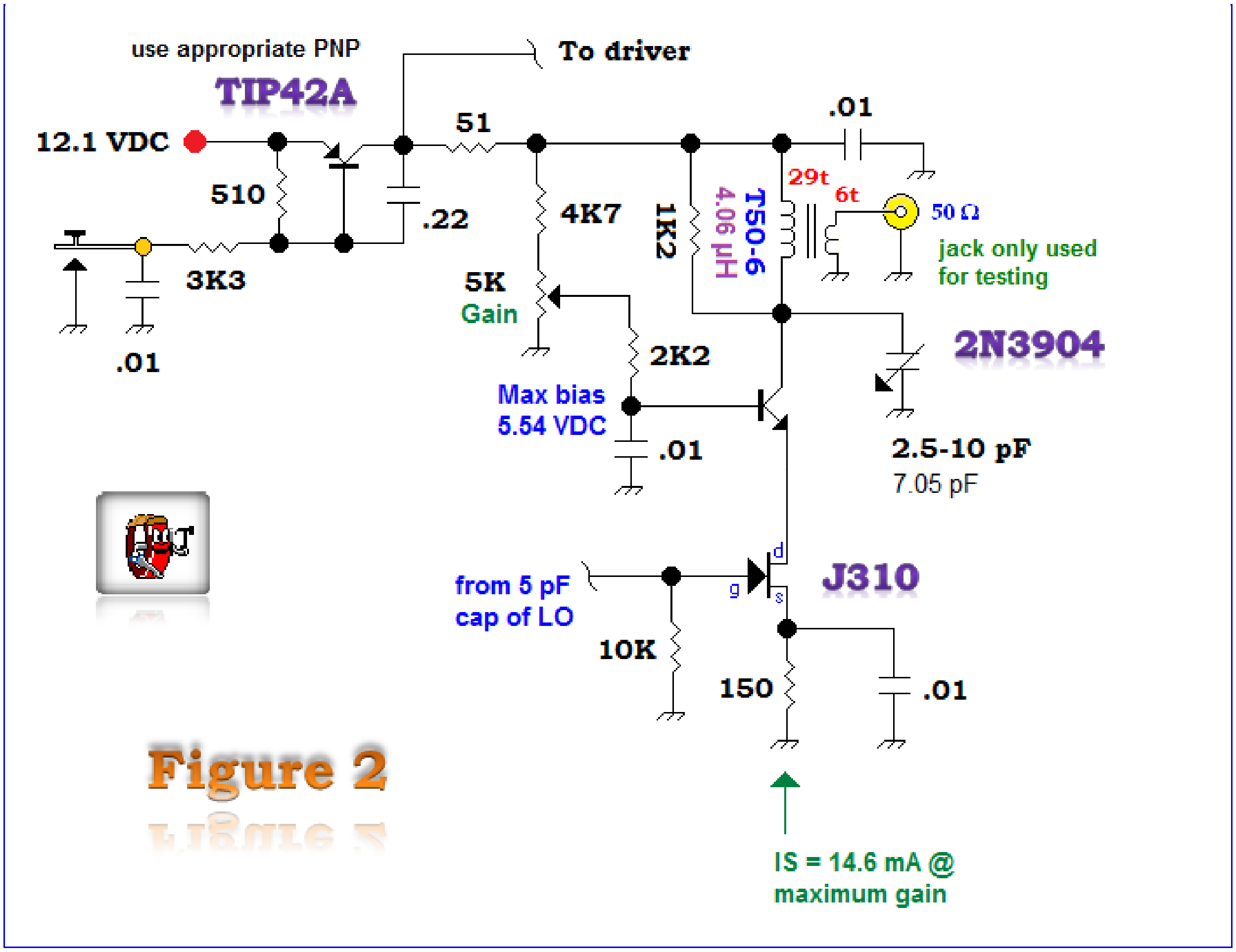
use appropriate PNP
TIP42A
To driver
12.1 VDC
51
.01
510
.22
4K7
1K2
T50-6
4.06 µH
29t
6t
50 Ω
jack only used
for testing
3K3
.01
5K
Gain
2K2
2N3904
Max bias
5.54 VDC
.01
2.5-10 pF
7.05 pF
d
J310
from 5 pF
cap of LO
g
s
10K
150
.01
IS = 14.6 mA @
maximum gain

Figure 2

Above — Figure 2, the hybrid cascode buffer. I've never tuned, nor keyed a hybrid cascode amp before and it works well. Click for the oscilloscope output. Click for the FFT measured with a long wire grounded 10X probe. I applied a junkbox TIP42A switch lying on my bench since I keyed a number of *unshown* high current stages during my experiments. Only about 10% of my experiments ever make it onto the QRP/SWL HB web site. For the PNP switch, just use whatever can handle the *measured* current with key down: 2N3904, 2N4403, 2N2907, BD140, etc.,etc..

Yes dear reader, measure everything.

The Driver Amplifer

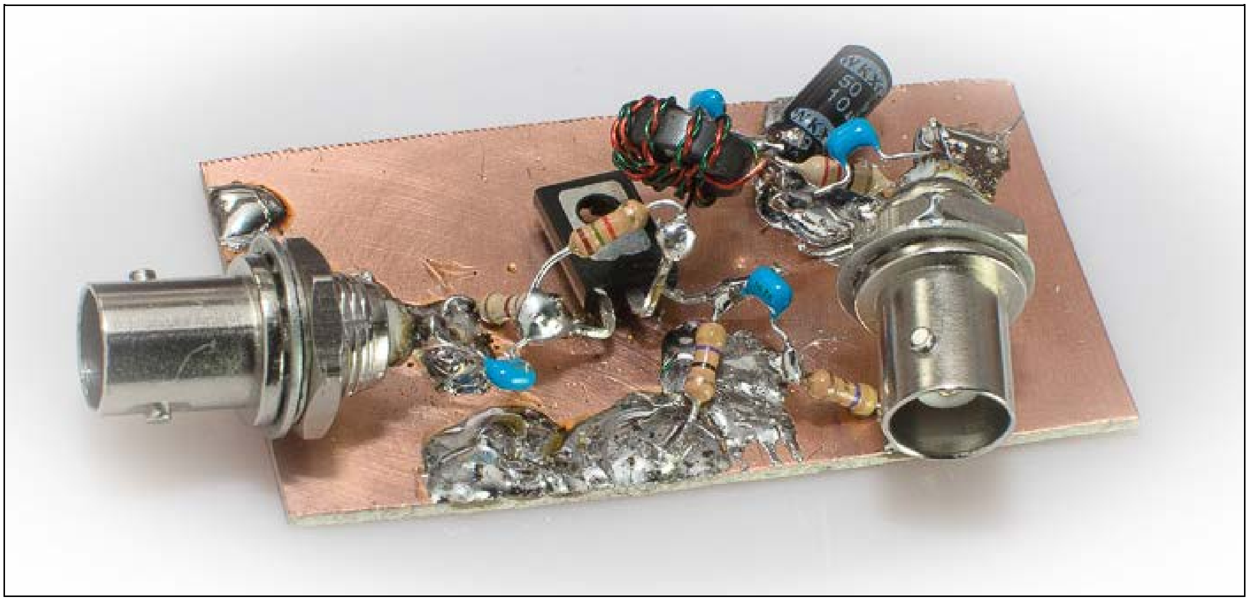

Above — A BD139 feedback amp breadboard. Click for the schematic. Wanting an output power of at least 22 dBm to drive my final, I built 3 varieties with both the BD139 and a 2N3866. Normally, for receiver amplifers, I focus on a strong input and output return loss and work hard to maintain linearity — but mostly keep the emitter current under 50 mA. At 21.06 MHz, the biggest *clean* signal I could muster with such a broadband feedback amp was +16 to +18 dBm — well short of my goal. Click for a DSO screen shot of the 41.3 mA amp at 6.42 Vpp or ~20.13 dBm power; quite distorted.

I needed to try something else and saw the Figure 3 amplifier in some of Wes' work; wielding bold emitter current to boost signal handling and power.

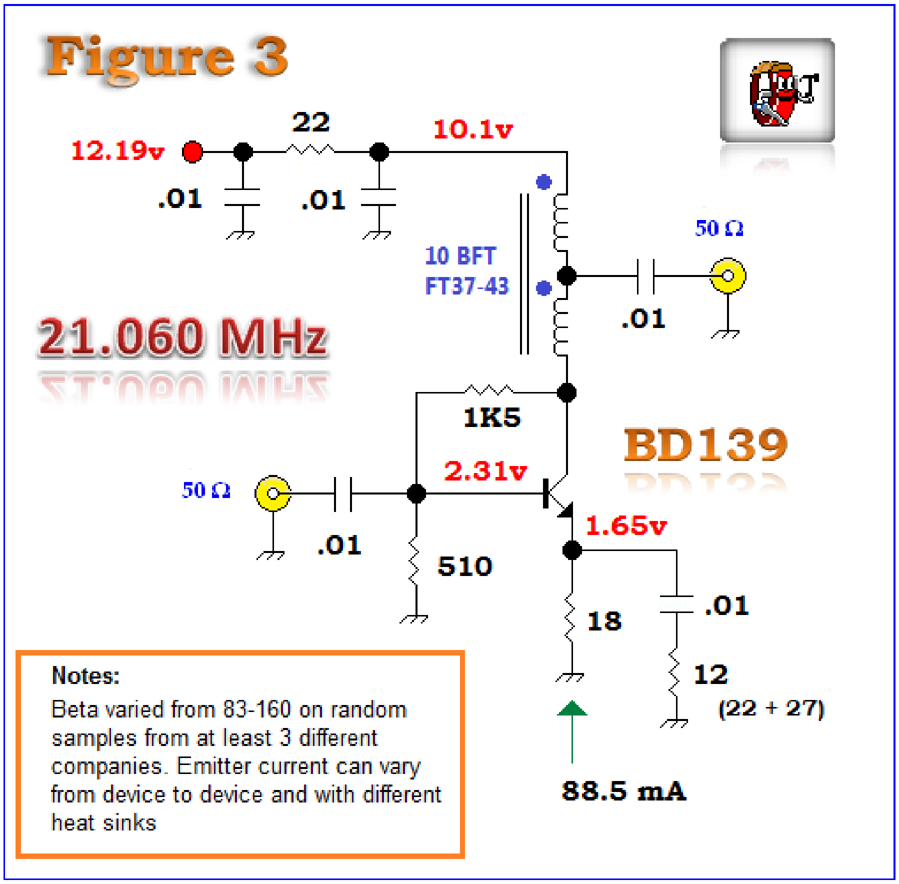

Figure 3

Notes:
Beta varied from 83-160 on random samples from at least 3 different companies. Emitter current can vary from device to device and with different heat sinks

Above — The W7ZOI designed feedback amp used for a driver in all Section 1 power amp experiments. Love it! Many builders feel tempted to abandon series and/or shunt feedback and just "go for gain". My experiments suggest this approach often leads to instability within the driver circuit and possibly on down the RF chain. We should strive for linearity and stability; 2 big reasons we apply feedback. Flirt with a driver *lacking* feedback if you dare.

Click for the maximum output power attained by turning my hycas bias pot fully clockwise: 7.77 Vpp, or 21.79 dBm. You can see distortion, but since this stage will drive a Class-C transistor PA (i.e. it will switch "a diode" on and off and generate clipping), I decided it will work fine. A VHF-UHF transistor such as the 2N3866 or 2N5109 may yield as much as 3-4 dBm more power, however, you'll see more clipping at higher driver levels. I stuck with the BD139 and tried several pieces from at least 3 different manufacturers (The BD139 was made by at least 10 companies at 1 point). A Philips version purchased in 2008 yielded the 21.8 dBm, so I bolted it to a home built copper clad heat sink and soldered it in place.

Calculating Transistor Output Power Off the Bench

Design Question 2: How do I mathematically estimate my Class A amplifier output power?

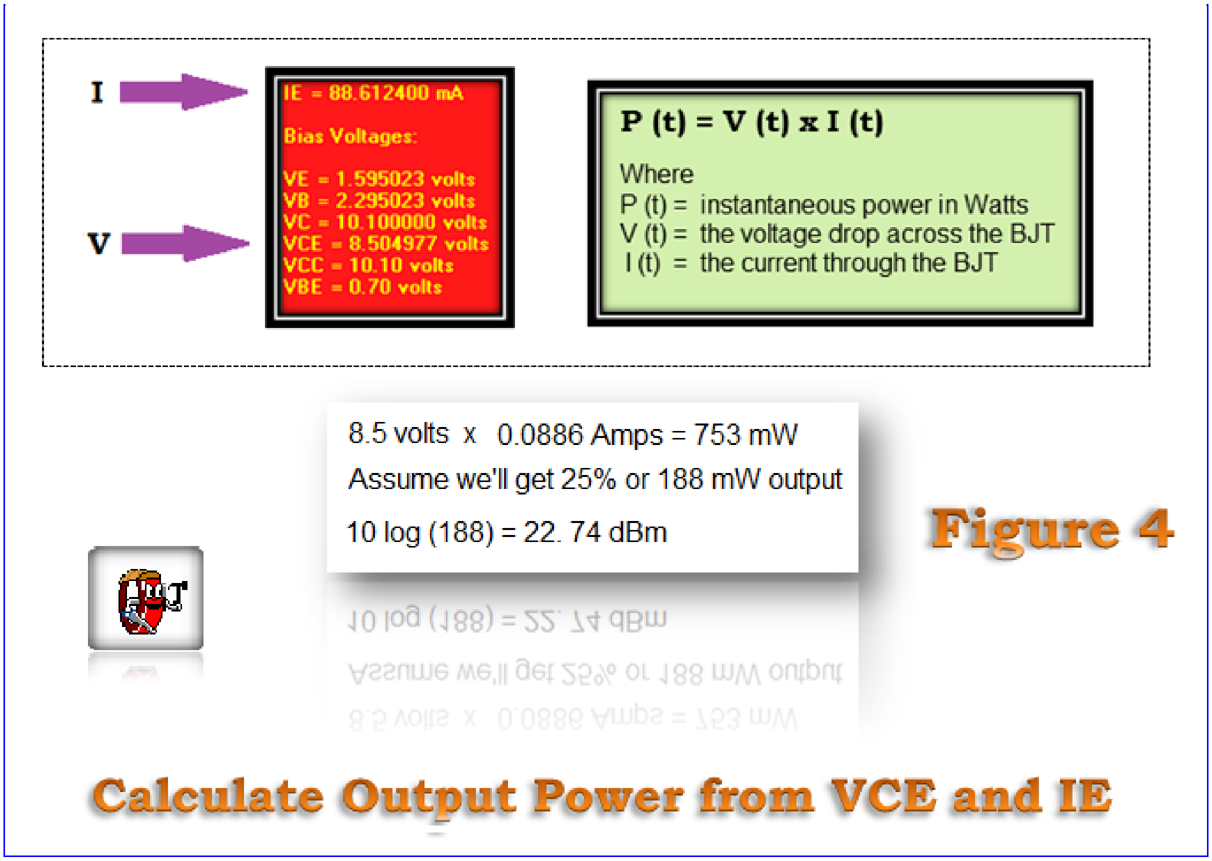

```
IE = 88.612400 mA

Bias Voltages:

VE = 1.595023 volts
VB = 2.295023 volts
VC = 10.100000 volts
VCE = 8.504977 volts
VCC = 10.10 volts
VBE = 0.70 volts
```

P (t) = V (t) x I (t)

Where
P (t) = instantaneous power in Watts
V (t) = the voltage drop across the BJT
I (t) = the current through the BJT

8.5 volts x 0.0886 Amps = 753 mW

Assume we'll get 25% or 188 mW output

10 log (188) = 22. 74 dBm

Figure 4

Calculate Output Power from VCE and IE

Above — Estimating output power from my Figure 3 amplifier. I measured a static DC Beta of 125 as shown in Section 5 on this page. Then I calculated VCE (the voltage across the transistor) and emitter current with my program NPN-DC Bias. Wes wrote a similar and likely better program called Biasnpn08.exe that's included on the EMRFD compact disk.
You may also measure your VCE and IE directly and improve the above calculation with measurements. I do this frequently.

Class A amps exhibit about 25% efficiency and also imagine that Figure 3 will bear some gain compression.

My measured power = 21.8 dBm — it amazes me how close a non-bench calculation using DC analysis can get to a AC bench measurement. The Figure 4 procedure is apparently a bread and butter RF design tool.

The Power Amplifier Input

Design Question 3: How do I match my driver output to the Class-C power amp input to maximize power?

This question provided a few nights of reading and experiments; time well spent. We have 2 main ways to match our driver output to the PA input: broadband or tuned. First, lets explore the problem theoretically:

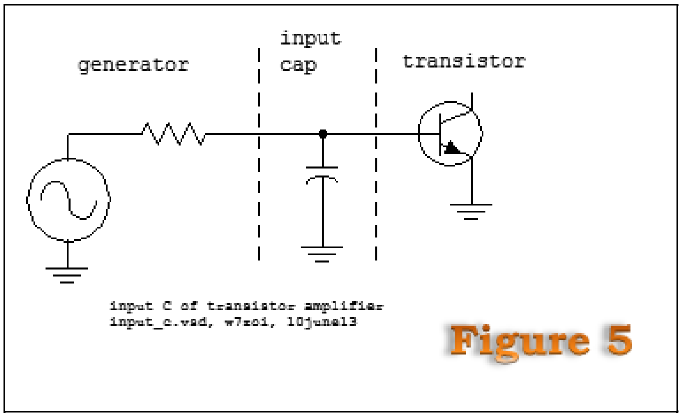

Figure 5

Above — A simple model sent by Wes: driving an amplifier with a power source. As amateur designers, simple models help us understand complex concepts.

A pure voltage source doesn't really exist. We don't apply a voltage to the base of the PA; rather, we apply a power source (our signal generator) — a signal voltage followed by a series impedance that's usually just a source resistance for a load. The power source + source impedance together *source* the load that includes the load capacitance represented as an input cap in Figure 5. You may wish to read about Thévenin's theorem and its dual, Norton's theorem to learn more about linear network analysis.

The load presents an impedance where the power is delivered and either dissipated in its resistance, or reflected back to the source when the load contains a reactance . At our PA input, this capacitive load reflects some of the signal back and induces a pole that corresponds to a "capacitor" time constant.

If you consider our power source, its source resistance, the PA input capacitance and just omit the effects of Q you'll see that the the voltage across the capacitor decreases as frequency increases. If you insert a 2:1 turns ratio transformer after the driver, you'll drop the AC voltage by 2 and its resistance by 4. For the same capacitance, the 3 dB cutoff frequency of this single pole filter increases. Also, the lower output impedance drops the driver amplifier voltage gain and may boost stability.

In short, we need a low driver source impedance since the Class C bipolar amplifier base-emitter junction has lots of capacitance To get current flowing into the PA base, we drop our driver output source impedance down *low*.

I thought — couldn't we just neutralize this capactance with an inductive output impedance? Thus our PA driver stage would drive a resistive load and everything would be "ducky". I consulted Wes, plus viewed some math and circuitry.

You can't effectively neutralize a bipolar transistor amplifier, since the capacitance isn't constant and behaves more like like a varactor diode rather than the C shown in Figure 5.. Even when forward biased, diode capacitance depends on the instantaneous voltage that appears across the diode. In contrast, 'FETs prove less troublesome and thus it's possible to achieve some neutralization with a 'FET amplifier. Please view the power stage from EMRFD Figure 11.14. Check out the push-pull pair of IRF511s. C5 and C6, at 22 pF each, are neutralizing capacitors.

In some cases, the capacitive reactance may be absorbed as part of a resonant circuit on the PA input. For example, a low-pass filter might soak up some of the C.

In all cases, our goal is drive in some power and switch the PA transistor solidly on and off (i.e. technically approaching class B but definitely class C because conduction will be less than 180 degrees) — a low output impedance can drive that input capacitance.

Driving final(s) with a very low output Z rings true even if your driving the latest (super-costly) ultra-low loss, high breakdown voltage, silicon GaN FETs to output >100 Watts at 1296 MHz in Class D, E, F, or Inverse Class F. Just get it done!

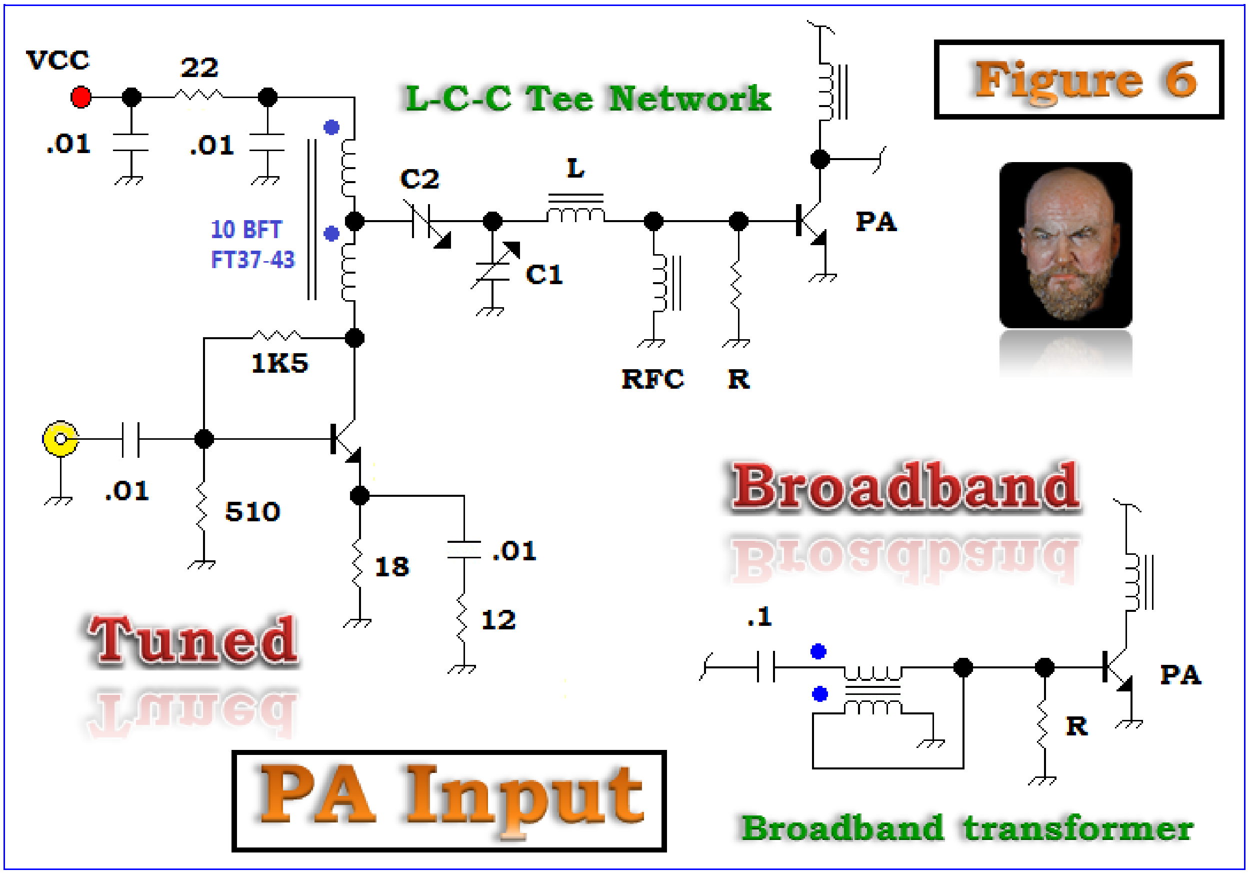

Above — Figure 6 shows 2 basic methods to drive the PA with a low impedance: single frequency network or broadband step-down transformer. I'll discuss both methods in detail later. Let's move away from theory and lighten things up for a couple of minutes.

Above — A short 10X probe ground lead boosts Tx measurement accuracy; in particular, for FFT analysis with your DSO. You can read or see **why** by searching the web for text and/or videos concerning oscilloscope probes.

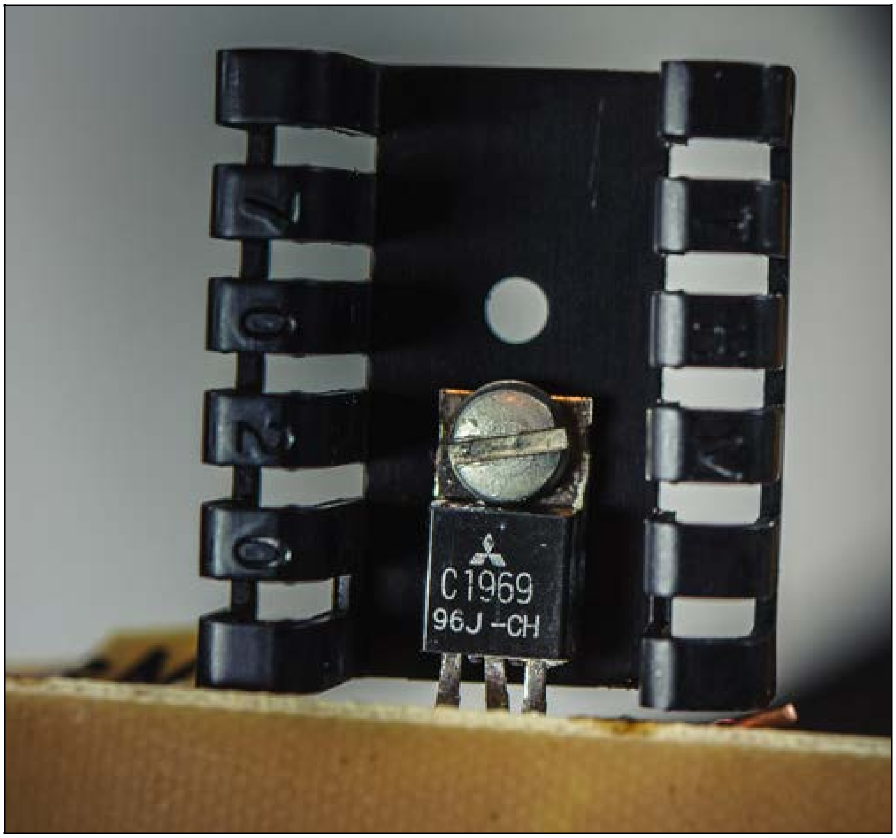

Above — The long gone 2SC1969 works great. Beware of counterfeits however.

Bipolar transistor selection troubles us since most of the 'old standbys' went obsolete way back when. I've been collecting dusty, old *QRP* driver and PA transistors for decades and my bag includes BD139, MJE181, 2SC2509, 2SC1969, 2SC2166, NTE123, 2N3053, 2N4037 and 2N2219A. For VHF, apart from the 2N5109/2N3866 standards, I've kept a few MRF607, 2SC1971 and 2N3553.

VHF/UHF transistors exhibit tremendous gain at lower HF, but they might oscillate without due care.

Some rules I've gleaned: The fT of a BJT should be at least 3-5 times the operating frequency; the VCEO should be at least double the VCC (more is better) ; don't exceed the maximum heat dissipation, nor maximum current. In short, read the datasheet. I won't cover heat sinking, nor gain compensation for multi-band amplifers on this web page; for it's been done by far better authors.

Lets make a basic Class C power amplifier based upon the RF blocks presented thus far.

Class C PA with Broadband Input and L-C-C Tuned Output

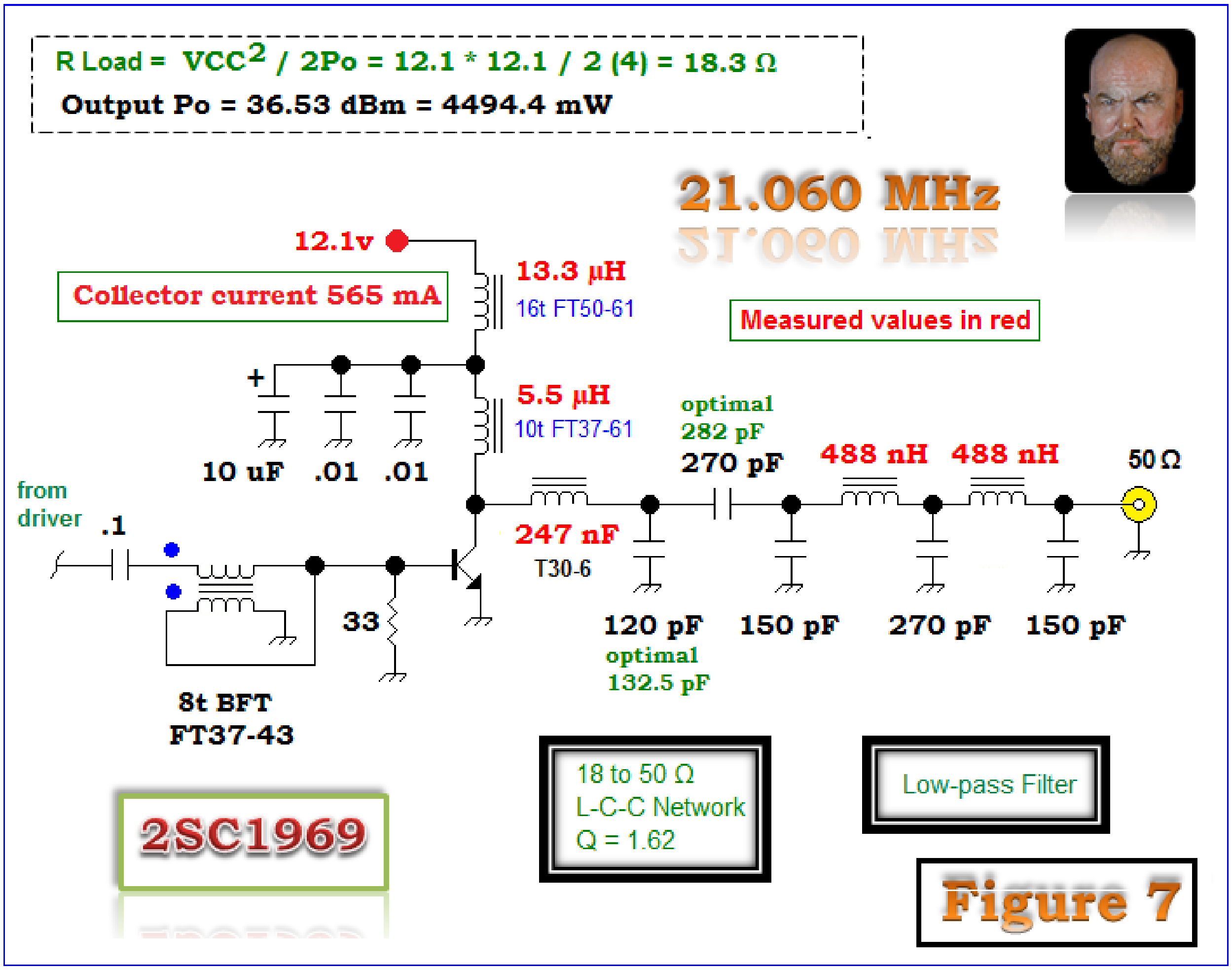
R Load = VCC2 / 2Po = 12.1 * 12.1 / 2 (4) = 18.3 Ω
Output Po = 36.53 dBm = 4494.4 mW
21.060 MHz
12.1v
Collector current 565 mA
13.3 µH
16t FT50-61
Measured values in red
+
10 uF
.01
.01
5.5 µH
10t FT37-61
optimal
282 pF
270 pF
488 nH
488 nH
50 Ω
from
driver
.1
247 nF
T30-6
33
120 pF
optimal
132.5 pF
150 pF
270 pF
150 pF
8t BFT
FT37-43
2SC1969
18 to 50 Ω
L-C-C Network
Q = 1.62
Low-pass Filter

Figure 7

Above — Input matched PA via a broadband transformer (a bifilar wound transmission line transformer with a 4:1 Z ratio). A great example of this design includes the Figure 2 of Ugly Weekender transmitter by Wes. The 50 Ω output Z of the driver is transformed to 12.5 Ω. to drive the PA input. While a conventional link-coupled transformer works okay, the closer coupling of a twisted wire transmission line transformer often affords a better impedance transform and lower losses. You might experiment with a 9:1 Z transformer instead of the 4:1 shown. Click for a highly compressed photo of 1 of the full breadboards.

The 33 Ω resistor helps lower gain and stabilize the amp. I ran 33 to 100 Ω applying experimental methods. Read more about the PA base resistor and coil XL requirements in the text following Design Question 6.

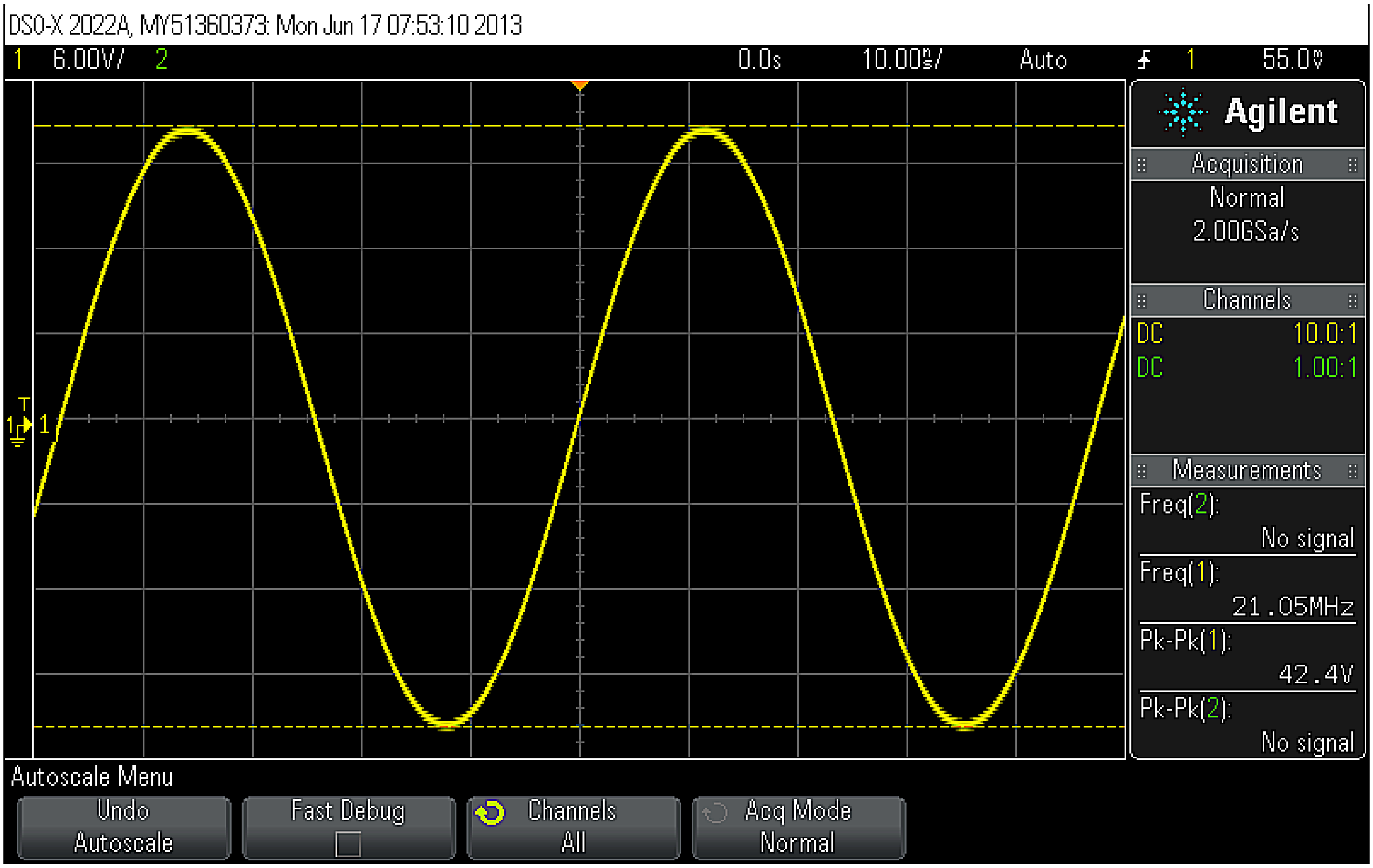
DSO-X 2022A, MY51360373: Mon Jun 17 07:53:10 2013

1 6.00V/ 2 0.0s 10.00ns/ Auto 1 55.0V

Acquisition
Normal
2.00GSa/s

Channels
DC 10.0:1
DC 1.00:1

Measurements
Freq(2): No signal
Freq(1): 21.05MHz
Pk-Pk(1): 42.4V
Pk-Pk(2): No signal

Above — The 'scope output from Figure 7. 42.4 Vpp = 36.53 dBm = 4.49 Watts.

L-C-C Output Matching Network

3 discussion points arise from Figure 7: [1] the output matching network. [2] the collector choke + decoupling circuitry, and [3] the low-pass filter. I'll discuss choosing a collector choke and decoupling in Section 2. We design our low-pass filters with tables or software; I used an old ARRL Radio Amateurs Handbook and then tweaked it in GPLA to get standard value capacitors. Click for a GPLA simulation of my filter. The L-C-C network also provides some low-pass filtering.

To calculate the collector output resistance, we use the formula R(load) = Vcc^2/ (2*Pout) as shown in Figure 7 for 4 Watts. For 1.5 Watts at 12 VDC --- R(load) = 12 * 12 / 2(1.5) = 48 Ω --- no output matching network is required; making 1.5 watts a popular transmitter power for new builders eager to learn about Class C.

Design Question 4: How do I make an L-C-C matching network?

Let's stick with 4W power and make an L-C-C Tee network for a 18 to 50 Ω transform. I prefer the L-C-C network over the L-network because you get 2 capacitors to tweak and I find it much easier to match a wide range of impedances compared to the L-network. Since we may pinch, or expand the inductor windings, in reality, the L-C-C gives you 2.5 possible tweaks.

Normally I wind the L on a number 6 powdered iron toroid with 26-28 gauge magnet wire in size T25, T30, T37, or T50. 26 gauge wire allows for good coil squishing and expansion with thumb and forefinger. For design cycle capacitors, I mostly solder in those horrible, low Q, orange, green, or red muRata trimmer caps such as the TZ03Z500F169B00. Although rare, ceramic-mica trimmers work well.

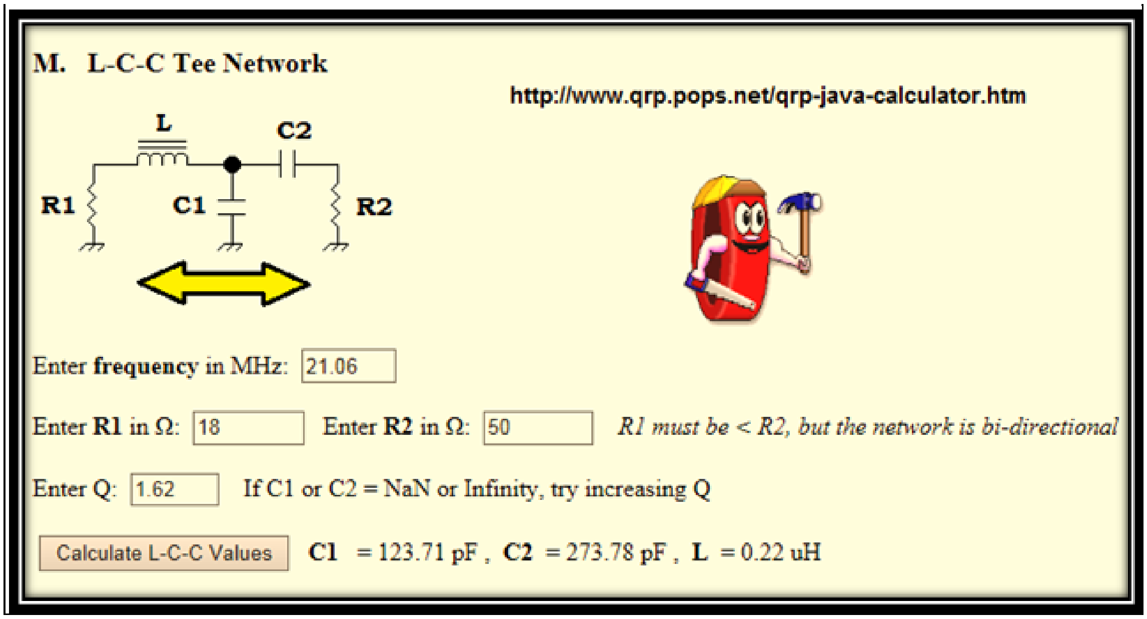

M. L-C-C Tee Network

http://www.qrp.pops.net/qrp-java-calculator.htm

Enter **frequency** in MHz: 21.06

Enter **R1** in Ω: 18 Enter **R2** in Ω: 50 *R1 must be < R2, but the network is bi-directional*

Enter Q: 1.62 If C1 or C2 = NaN or Infinity, try increasing Q

C1 = 123.71 pF , **C2** = 273.78 pF , **L** = 0.22 uH

Above — To calculate L, C1 and C2 we may employ software to obtain starting L and C values. I recommend Wes' ZMAT08.exe, a Ladpac program that ships on the EMRFD CD. I wrote my own java-script applet with less prompting and error checking and put in on the Design Center web page as **M**. Note I used 18 Ω as the load resistance in my calculations.

During actual bench assessment of your network, output your PA to a 50 Ω dummy load rated for that power and preferably measure the peak to peak voltage with a short-grounded 10X probe.

For Figure 7, I wound and tack soldered in a measured L of about 230 nH and placed a 100 pF cap plus 6-50 pF trimmer for C1 and a 220 pF + 22 pF cap + 6-50 pF trimmer cap for C2. The tuning procedure goes like this:

Tune the capacitors for maxmum power. Try squishing the L, then re-tweak C1 and C2 and see what happens. Did the Vpp go up or down? We want it to go up, so if the Vpp went up you needed more L, and perhaps still need more. If you squish the coil again (or remove it, add 1-2 turns and then replace it) and the Vpp goes down, you increased the L too much and need to go back down. If the original Vpp goes up when you expand the coils, you had too much L and need to do the opposite procedure just described. Re-tweak C1 and C2 after every inductance change and calculate the power in dBm and/or watts on your bench.

Through trial and error you'll find the optimal L. If nothing works, suspect a bench error, or device failure. Occasionally, I add too much, or too little fixed C in parallel with the trimmer cap. Another time, my transistor was fried.

Once you've extracted the maximum power, remove the cap(s) that make up C1 and measure them. Do the same for C2. I replace C1 and C2 with the nearest equivalent standard value capacitor or (parallel capacitors) and then repeat the tuning procedure to find the optimal L for these 2 new capacitors. Normally, after optimizing the Vpp, I'll remove and measure L to confirm my L-C-C network design. You can use the L just removed or make a tidier version to permanently solder in.

Once you solder in the "keeper" L, you'll need to expand or compress the links a tad to peak your Vpp once again. Although it sounds like a chore, I love measuring a higher Vpp with each successful manipulation of the L-C-C network; it's quite a rush actually.

In the end, my optimal measured values were: L = 247 nH, C1 = 132.5 pF and C2 = 282 pF. In my final, I substituted C1 = 120 pF and C2 = 270 pF as shown in Figure 7. Although I designed for 4W, I squeezed out 4.49W with my L-C-C network.

Design Question 4: How do I choose my L-C-C matching network Q?

The easy answer is the degree of impedance transformation sets the minimum Q and thus choosing the best Q becomes the central question.

The theory regarding loaded versus unloaded Q + network losses and such may bog down many, but in context, a lower Q leads to a more efficient network with less loss. Low Q values also means we tweak larger value capacitors that minimize the effects of stray capacitance. In the collector output network of Figure 7, the Q of 1.62 gave more power than an earlier Q = 5 network. Further, during design, I sometimes slightly adjust the Q in software so I get closer to standard value caps for C1 and C2.

Don't be afraid to remove C2 and just make an L-network. Again, just experiment on your bench to gain confidence.

I tried making this circuit with a BD139 in the PA slot and managed to squeeze a mere 3.1 Watts power at 12.1 VDC. Others, such as Wes and Jason, NT7S delivered more power into 50 Ω at and even above 21 MHz with a BD139 PA.

Factors such as transistor specifications, frequency, VCC, and driver power may affect the output power. In the end, the 2SC1969, a final I harvested from an old Cobra CB more than 20 years ago delighted me. I constantly scrounge for old driver and PA transistors in my travels. Sadly, many old CB radios given to me over time suffered from fried finals.
You might try checking eBay, but watch out for fakes.

The BD139 grew to notoriety because it's widely available, cheap and generally does the job at or below ~28 MHz, depending on what output power your seek. I found wide variation in Beta (or hFE) and fT in the random batch I tested. Also remember we're hitting them with lots of current and they heat up and specs change. At 7 MHz, the BD139 works great. The BD139 reminds me of the MPF102 JFET; you never know what your going to get. The best I've tested were Fairchild BD139s and woefully, they're all gone.

Class C Power Amp with Broadband Input and L-C-C Tuned Output

Let's make a PA with an L-C-C Tee network tuned input: Figure 8.

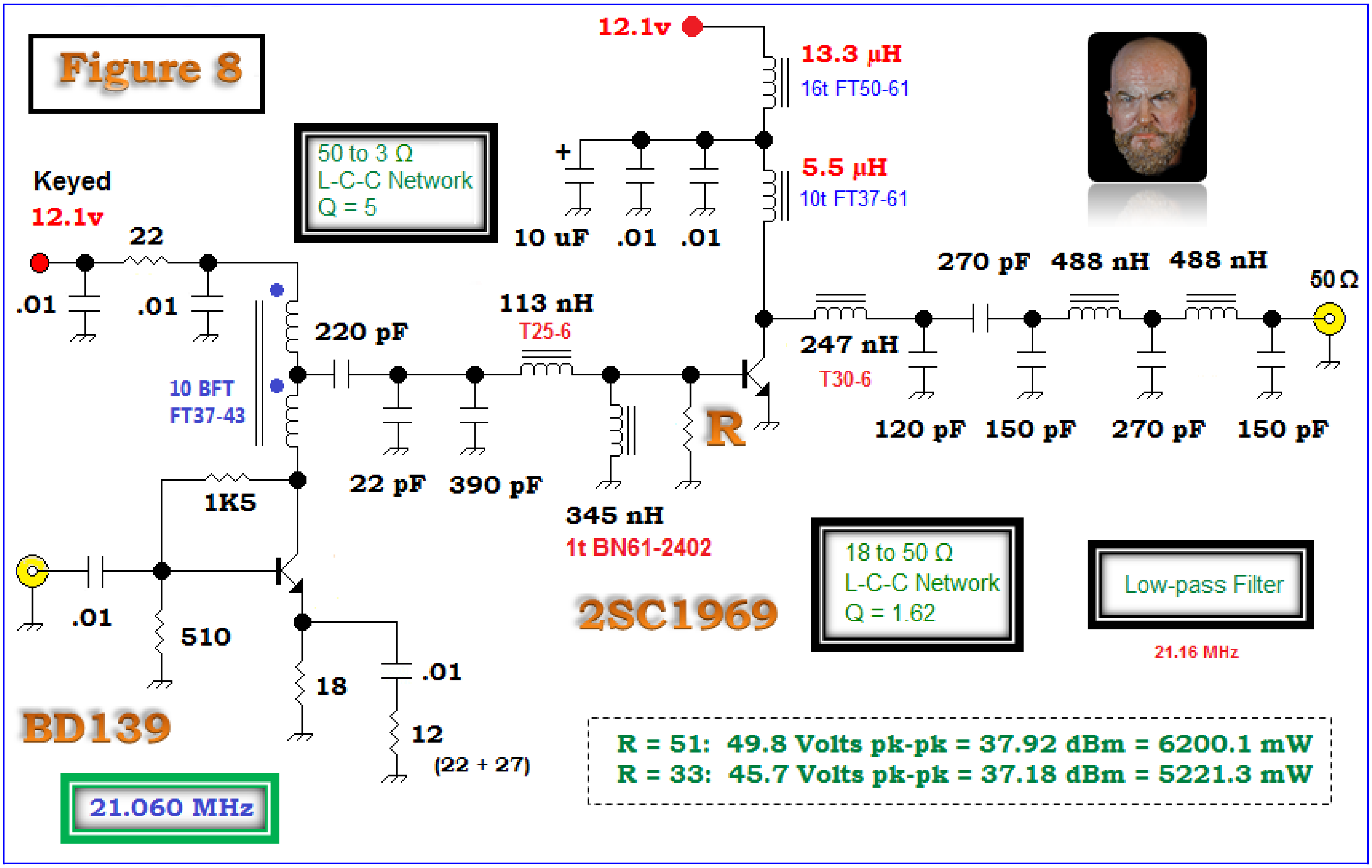
Figure 8
Keyed
12.1v
22
.01
.01
10 BFT
FT37-43
50 to 3 Ω
L-C-C Network
Q = 5
12.1v
13.3 µH
16t FT50-61
+
10 uF
.01
.01
5.5 µH
10t FT37-61
270 pF
488 nH
488 nH
50 Ω
220 pF
113 nH
T25-6
247 nH
T30-6
120 pF
150 pF
270 pF
150 pF
R
22 pF
390 pF
1K5
345 nH
1t BN61-2402
2SC1969
18 to 50 Ω
L-C-C Network
Q = 1.62
Low-pass Filter
21.16 MHz
.01
510
18
.01
12
(22 + 27)
BD139
21.060 MHz
R = 51: 49.8 Volts pk-pk = 37.92 dBm = 6200.1 mW
R = 33: 45.7 Volts pk-pk = 37.18 dBm = 5221.3 mW

Above — Figure 8. The Figure 7 PA with a tuned input network smashed my world with 6.2W power. Click for the FFT showing the second harmonic down at least 55 dB. I later confirmed this with spectrum analysis.

Design Question 5: How do I choose my PA input impedance?

PA Input Impedance

Calculating the input Z of a transistor with 100's of mA emitter challenges us.The familiar calculations like Zin = (Beta +1) x 26 /I e (mA) don't work out perfectly since our transistor is hot and Beta changes, and in my case I'm way up in fT. I asked Wes and he suggested I assume an input Z of 3 Ω (with about 200 pF of parallel C). Thus , I chose a 50:3 Ω transform to design my L-C-C network.

From my experiments, bench tweaking an L-network, or L-C-C network will accommodate anything even close to 3 Ω input impedance — 3 Ω seems quite actionable. Tune your L-C-C network in the manner described for the PA output match. Since your transforming 50 Ω to 3 Ω, the minimum Q will rise.

Design Question 6: How do I choose my PA input choke and resistor when fed with an L-C-C network?

The RFC serves as a DC return path for the PA base just like in the transformer in the wideband version. We normally apply a rule that the minimum inductive reactance of a choke should be 10x the impedance it's connected to, so that's 30 Ω XL.
Since F = 21.06 MHz, the minimum choke value will be 30 Ω / 21.06 MHz x 6.28) = 227 nH. In order to keep the SRF up and for ease, I ran a single turn of 26 gauge wire through a BN61-2402 binocular core and measured 345 nH. Good enough. The # 61 mix will exhibit some Q. Likely # 43 material will work fine too.

The resistor labelled R serves to reduce the Q of *my* particular RFC, lowers gain and boosts stability. With R = 33 - 51 Ω, the amp held stable, but if I tried to increase R above 51 Ω spasm erupted. The resistor affected output power as shown in Figure 8. Again the resistor should minimally be about 10X the input Z or so. I tried an R of 10 Ω and the output power dropped down to a little under 3W as more of my driver output just flowed through the resistor to ground.

To conclude, I executed the time honored tradition of choosing parts and circuits to extract power from a crystal oscillator-driven analog RF amplifer chain. Much of this information extends to linear operation (Class A, AB) and general RF design. Have fun designing your own transmitters and as always, apply experimental methods!

Section 2: PA Measurement with Examples

In this section, I posted some PA measurement ideas + experiments and comments about PA collector chokes.

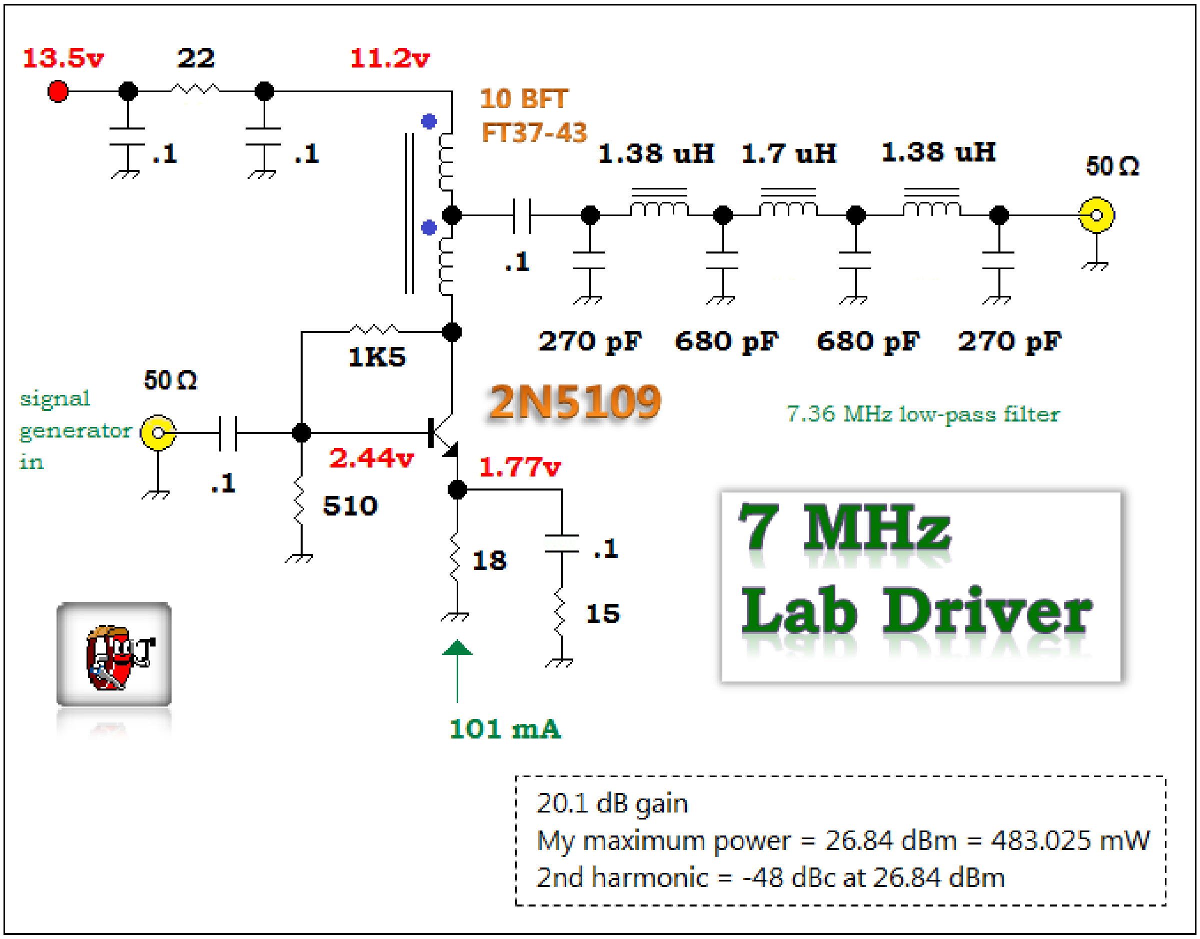
13.5v
22
11.2v
.1
.1
10 BFT
FT37-43
1.38 uH
1.7 uH
1.38 uH
50 Ω
.1
270 pF
680 pF
680 pF
270 pF
1K5
50 Ω
signal
generator
in
2N5109
7.36 MHz low-pass filter
.1
2.44v
1.77v
510
18
.1
15
7 MHz
Lab Driver
101 mA

20.1 dB gain
My maximum power = 26.84 dBm = 483.025 mW
2nd harmonic = -48 dBc at 26.84 dBm

Above — To boost my signal generator output for driving *any* experimental PA up to about ~20W output, I built a high-current, sine wave driver. I excite this amplifer with my variable gain homebrew HF signal generator — in the version shown above, a 7 MHz low-pass filter is soldered on the amplifier breadboard. I'll stick this amp in a metal box sans filter and then apply the correct bench module low-pass filter via a BNC connector. Click for a photo of 3 of my HF low-pass filter bench modules.

Normally the low-pass filter output is pad attenuated to buffer and reduce the output voltage since it's rare I need up to 483 mW drive on the QRP workbench.

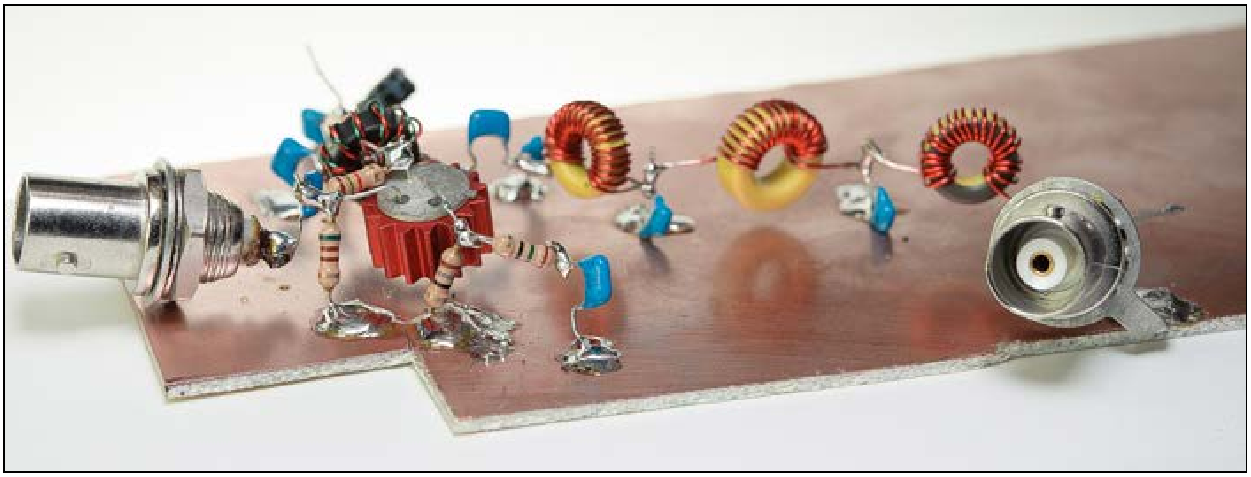

Above — A photo of the PA driver amplifer breadboard.

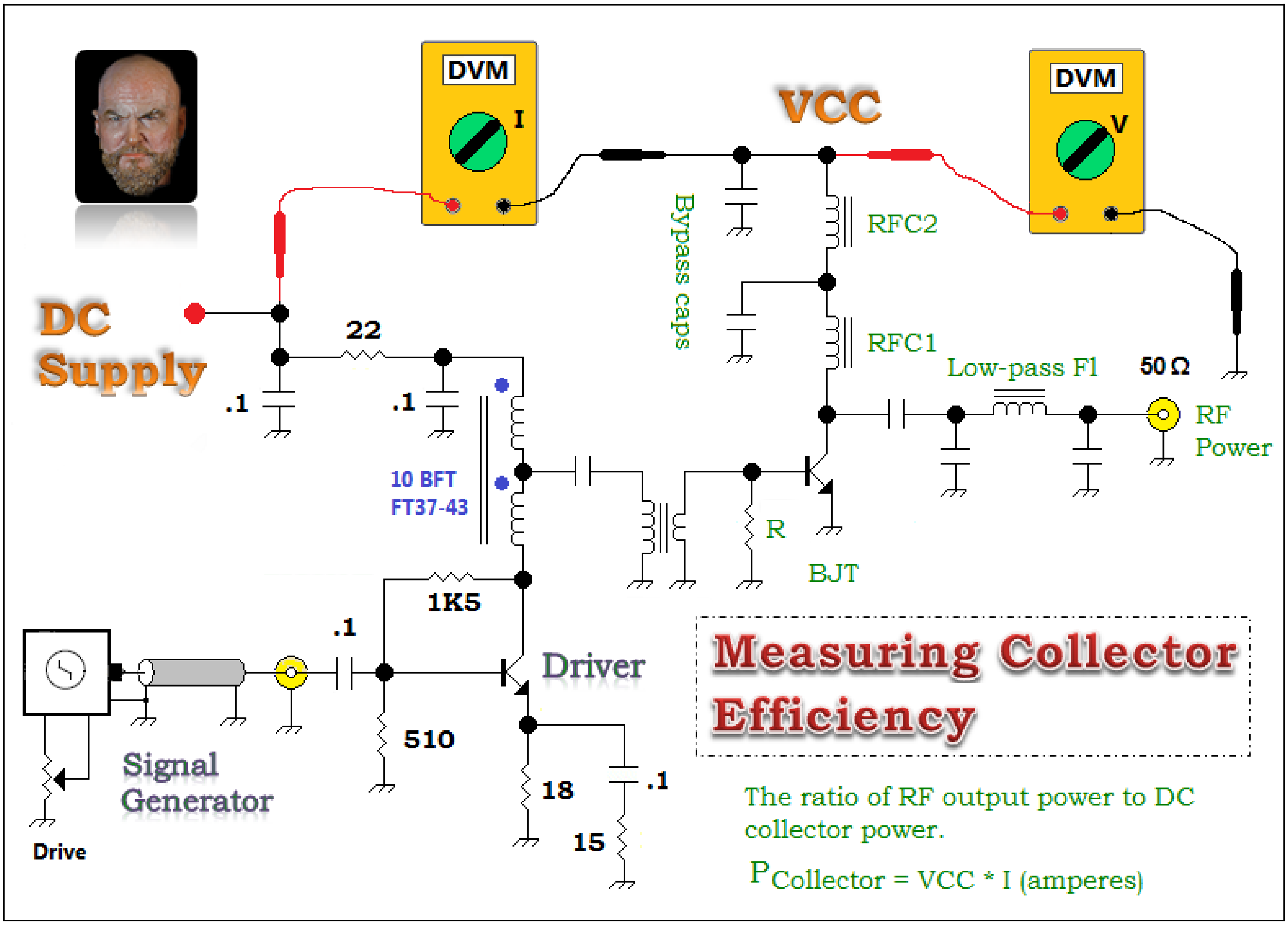
DVM
I
VCC
DVM
V
Bypass caps
RFC2
RFC1
DC Supply
22
.1
.1
10 BFT
FT37-43
Low-pass Fl
50 Ω
RF Power
R
BJT
1K5
.1
Driver
510
18
.1
15
Signal Generator
Drive
Measuring Collector Efficiency
The ratio of RF output power to DC collector power.
P Collector = VCC * I (amperes)

Above — A method to simultaneously measure collector **V** and **I** to calculate DC collector power. Two DVMs boost measurement fidelity since the current measuring ammeter's internal resistance will drop the DC supply ~ 0.2 to 0.5 volts depending on the device and current. Collector efficiency = RF output power / (V * I) .

This method provides a great excuse to purchase another multimeter.

Measure VCC where shown since the decoupling and bypass filters help prevent the AC signal from affecting the DC measurement. We only touch our 10X 'scope probe on the collector. Exert due care and wear eye protection in case you blow up the transistor and create shrapnel.

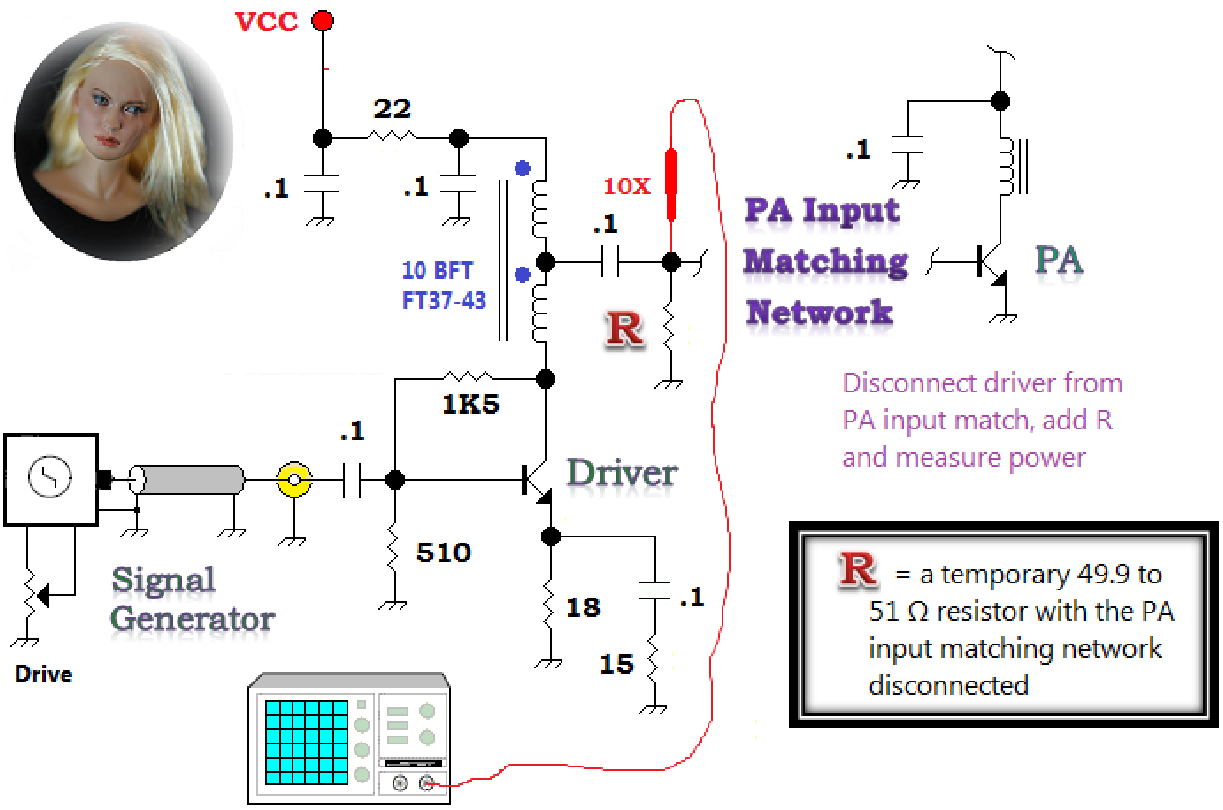
VCC
22
.1
.1
10 BFT
FT37-43
10X
.1
R
PA Input
Matching
Network
.1
PA
1K5
.1
Driver
510
18
.1
15
Signal
Generator
Drive

Disconnect driver from PA input match, add R and measure power

R = a temporary 49.9 to 51 Ω resistor with the PA input matching network disconnected

Measurement for 'Power Added' Efficiency

Above — Power Added Efficiency considers the base drive power in addition to the DC collector power. The formula = RF output power / (DC Power + RF drive power). Although uncommon, measuring drive power helps you to assess and compare both input matching and PA efficiency metrics.

At the very least — I like knowing my PA drive power and so employ driver amplifiers with 50 Ω output impedance to allow this power measurement. I often permanently solder a 49.9 or 51 Ω resistor to the breadboard ground plane and temporarily connect this R ; plus disconnect the input matching circuit to measure driver power when I've finished tweaking my collector to antenna port circuitry.

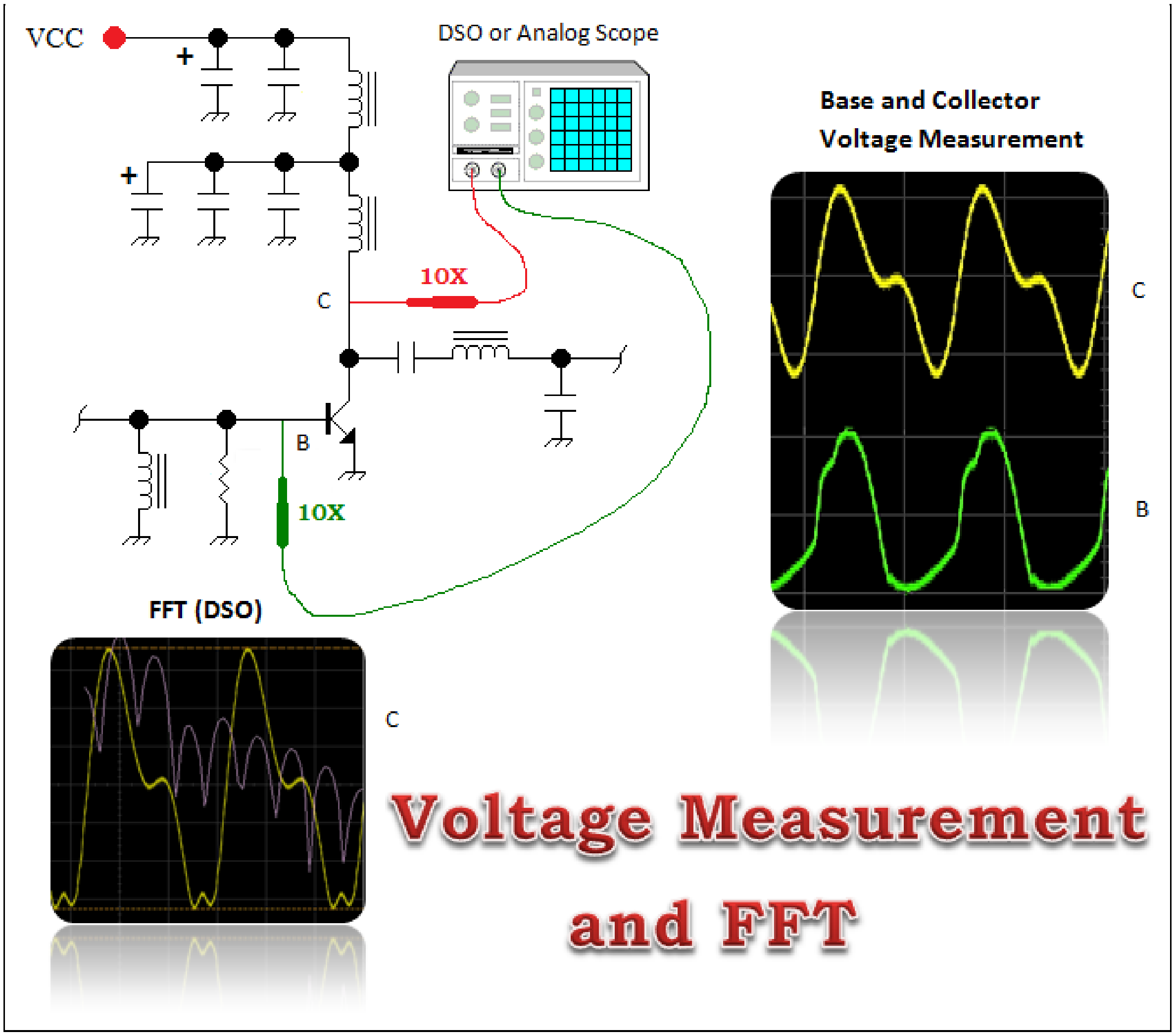
VCC
+
+
DSO or Analog Scope
Base and Collector
Voltage Measurement
10X
C
B
10X
C
B
FFT (DSO)
C
Voltage Measurement
and FFT

Above — Oscillocope measurements of the base and collector voltages. Most of us enjoy simultaneously running 2 channels on our 'scopes. With a good quality DSO, FFT analysis of the collector waveform may yield insight, however, this knowledge might also confound us since interpreting our measures is fully half of the task.

I often struggle to properly interpret measures. Some builders blog about or email me that they enjoy an innate gift at understanding electronic circuitry — I don't. I guess I lack the knack? For some of us, problems and complications block progress, but more often than not, we eventually cross the finish line.

Above — 1.5 Watt, Class C breadboard used for the experiments that follow. I changed the collector choke (RFC1) and applied various filters to examine some of the measurement techniques aforementioned. Click for a bigger photo.

The Collector Choke

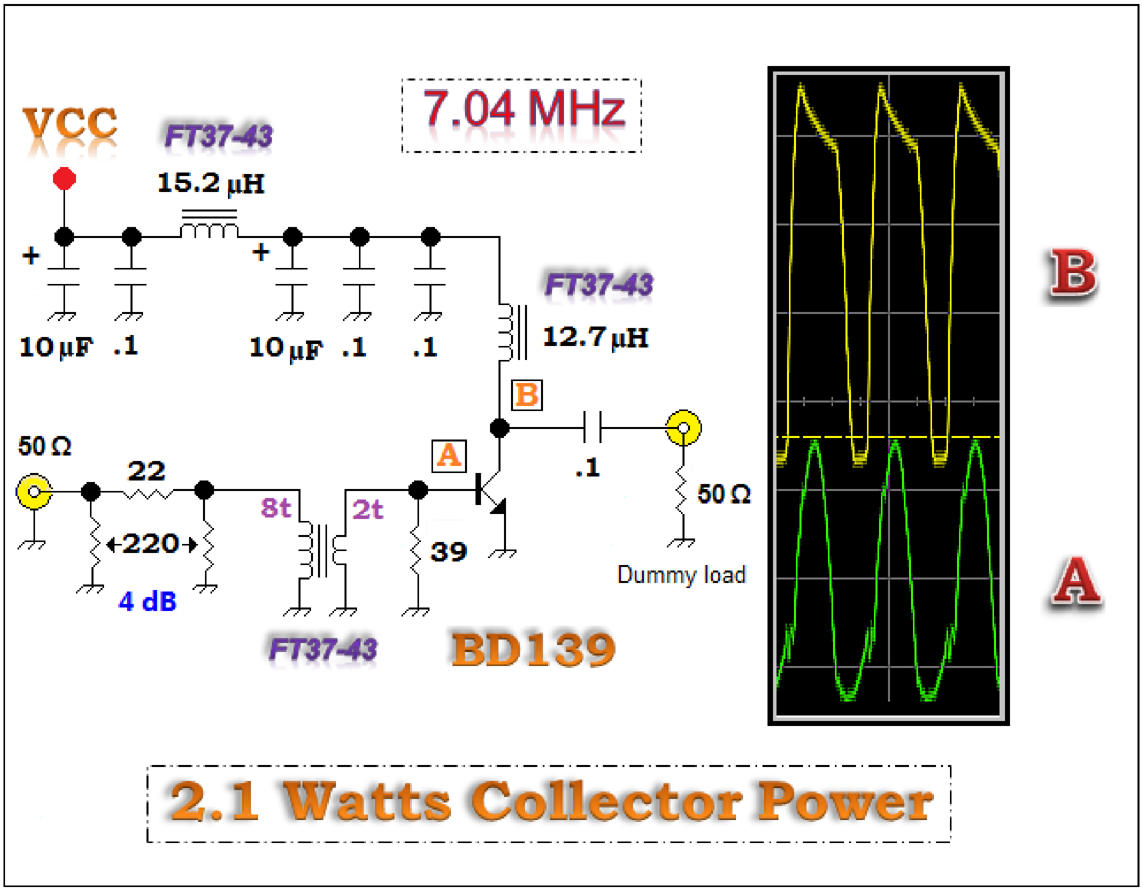

VCC
FT37-43
15.2 µH
7.04 MHz
+
10 µF
.1
+
10 µF
.1
.1
FT37-43
12.7 µH
B
B
50 Ω
22
A
.1
50 Ω
220
220
8t
2t
39
Dummy load
4 dB
FT37-43
BD139
A
2.1 Watts Collector Power

Above — A Class C amplifer with it's collector AC coupled to a 50 Ω resistor load. *No filter.*

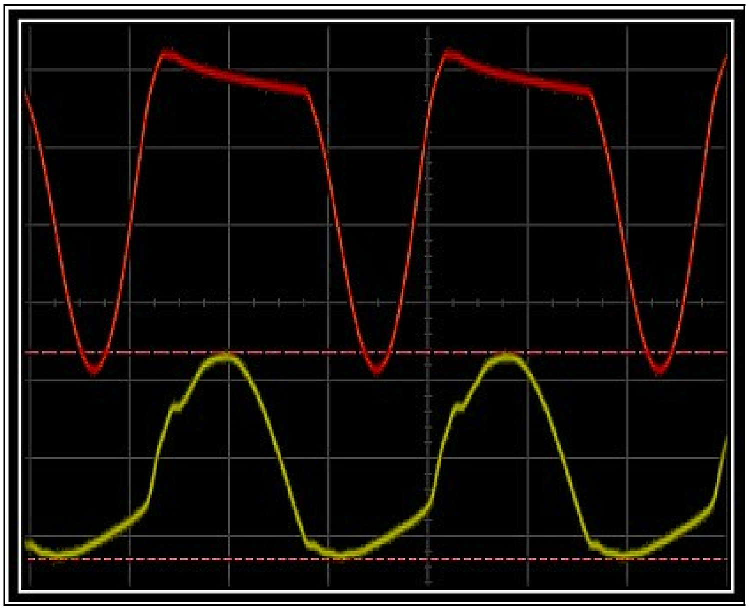

Above — Base and collector waveforms. The unfiltered collector waveform (top) rich in even and odd harmonics ~resembles a square wave. The maximum collector voltage occurs when the current is 0 and in concert, the maximum collector current flows where collector voltage falls to near 0. As the BJT shuts off, the collector circuit kicks and rings so that the DC collector voltage may rise as high as twice VCC.

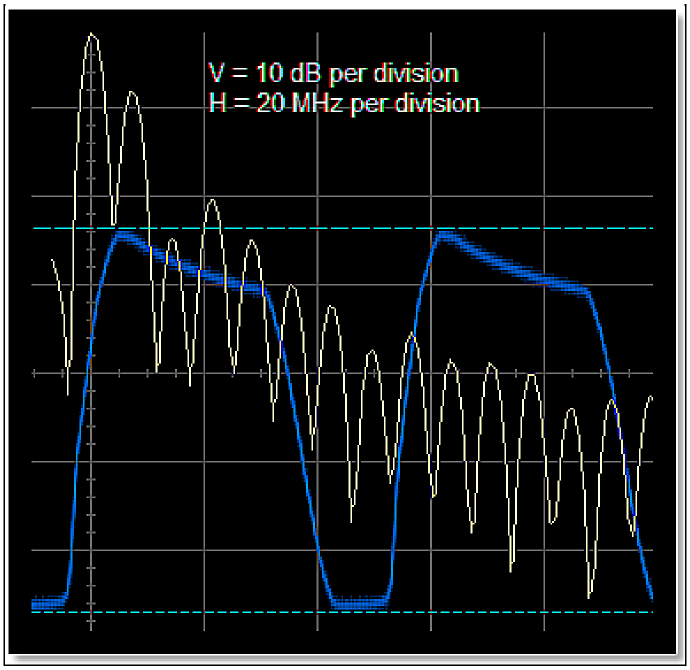

Above — An FFT of the unfiltered collector showing F1, F2, F3, F4, F5, etc. Distortion city!

The Collector Choke

I've read web pages suggesting we might boost PA efficiency by decreasing the collector choke inductance. While that's possible, in reality, it's not that simple. Experiments involving factors like collector load resistance, angle of conduction, RFC inductance/Q, matching networks, base drive configuration and output filtration are ripe with complicated math and theory that I struggle to understand — entire books and research papers explore these topics as author(s) configure their PA into Class D, E, etc. to boost efficiency. The published design work and PA devices out today are truly breath taking.

We should likely think of the BJT, collector current + voltage, the RFC, base drive and output networks as a system of parts that interact — changing 1 part might change collector current, impedance, efficiency, harmonics, etcetera. As such, the experiments that follow do not construe science; only some experiments by a neophyte to ponder and build on.

The ideal RFC passes only DC — i.e. exhibits infinite impedance to AC, but a short circuit to DC. The primary purpose of the choke is to block our high-power, distorted AC signal from flowing on our DC power lines. Some authors suggest that the minimum inductance for the inductor should be 5-10X the collector resistance and I'll leave that up to you. At HF, I wind my RFCs on #43 or #61 material ferrites while keeping the turns number low as I remember that the coil will exhibit a self resonant frequency that might cause problems if it lies near a frequency I need to filter.

1.5 Watt Amp with Three Different Collector Chokes

The 1.5 Watt obviates the need for a matching network since the collector load resistance = 48 Ω with a VCC of 12v. I rebelled and ran 13.5 V supply for a calculated 60.8 Ω collector load R. I probably should have this matched this collector load to 50 Ω at 13.5v, but wanted a "real world" amp without a matching network. At the very least, these amplifiers illustrate the PA measurement techniques shown above. I wound the RFC on a common FT37-43.

In all cases, I adjusted the base drive so that the sine wave PA output read ~24.5 Vpp while measuring collector V and I. I made DSO measures of the the base and collector voltage and collector FFTs, although forgot to save some of them as screen captures.

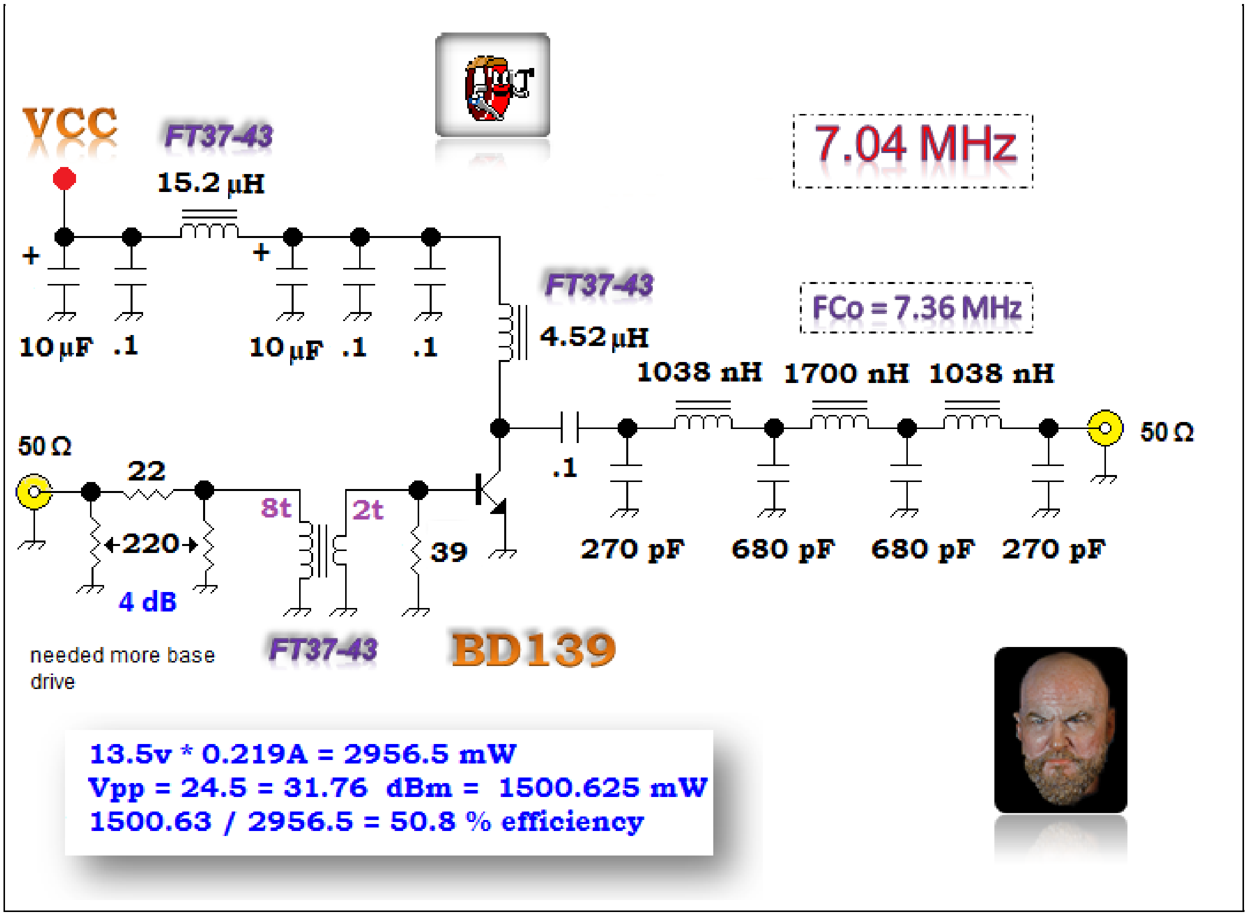
VCC
FT37-43
15.2 µH
7.04 MHz
+
+
10 µF
.1
10 µF
.1
.1
FT37-43
4.52 µH
FCo = 7.36 MHz
1038 nH
1700 nH
1038 nH
50 Ω
50 Ω
.1
22
8t
2t
39
+220+
270 pF
680 pF
680 pF
270 pF
4 dB
needed more base drive
FT37-43
BD139
13.5v * 0.219A = 2956.5 mW
Vpp = 24.5 = 31.76 dBm = 1500.625 mW
1500.63 / 2956.5 = 50.8 % efficiency

Above — The collector choke = 4.52 µH or an XL of ~ 200 Ω @ 7.040 MHz. My measurements indicate an efficiency of 50.8%. With a choke XL of only ~ 200 Ω, some of my collector AC might be flowing to ground through the bypass caps and that'll kill efficiency. Click for an FFT of the collector. This circuit required more base drive than the other 2.

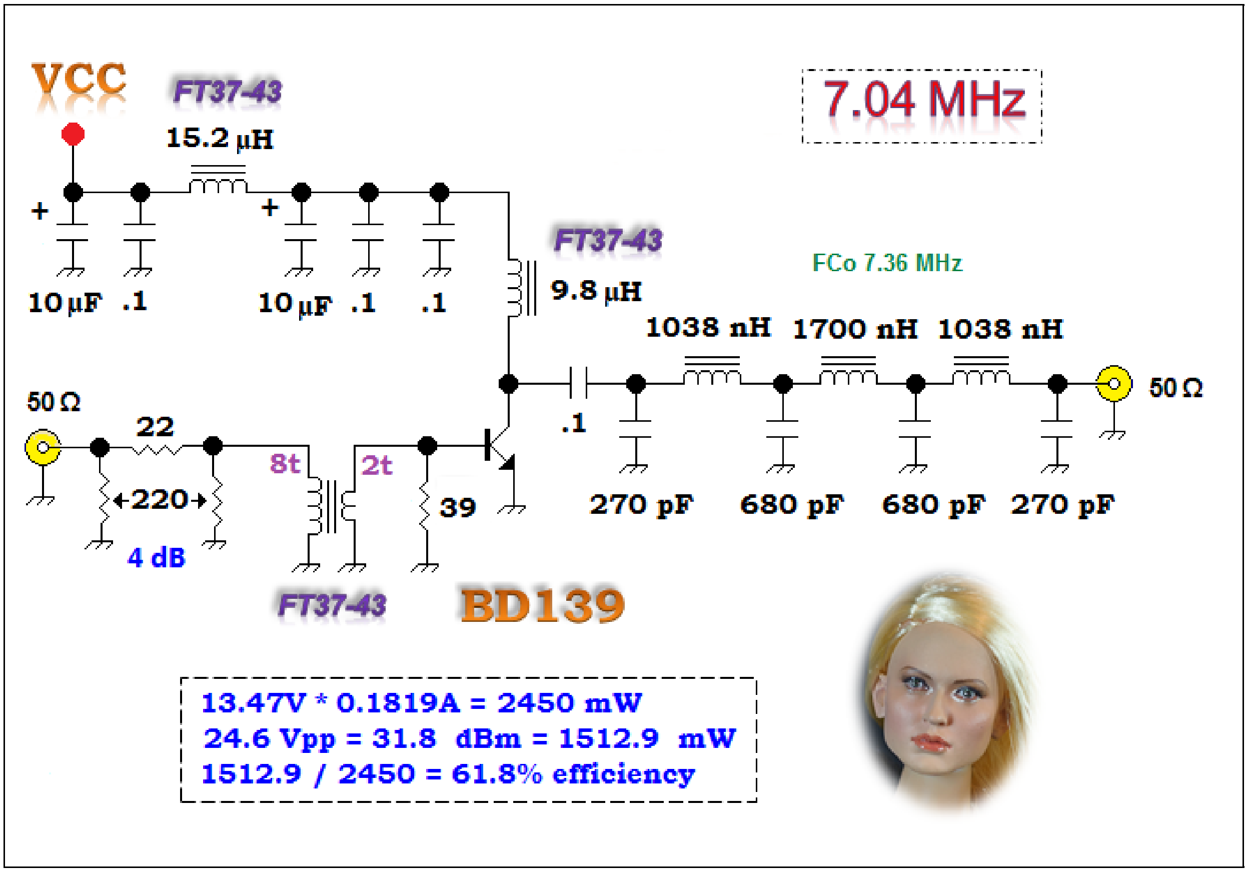
VCC
FT37-43
15.2 µH
7.04 MHz
+
+
10 µF
.1
10 µF
.1
.1
FT37-43
9.8 µH
FCo 7.36 MHz
1038 nH
1700 nH
1038 nH
50 Ω
50 Ω
.1
22
8t
2t
39
+220+
270 pF
680 pF
680 pF
270 pF
4 dB
FT37-43
BD139
13.47V * 0.1819A = 2450 mW
24.6 Vpp = 31.8 dBm = 1512.9 mW
1512.9 / 2450 = 61.8% efficiency

Above — The collector choke = 9.8 µH = an XL of ~ 434 Ω. Efficiency now 61.8%. Base and collector tracing. Collector FFT.

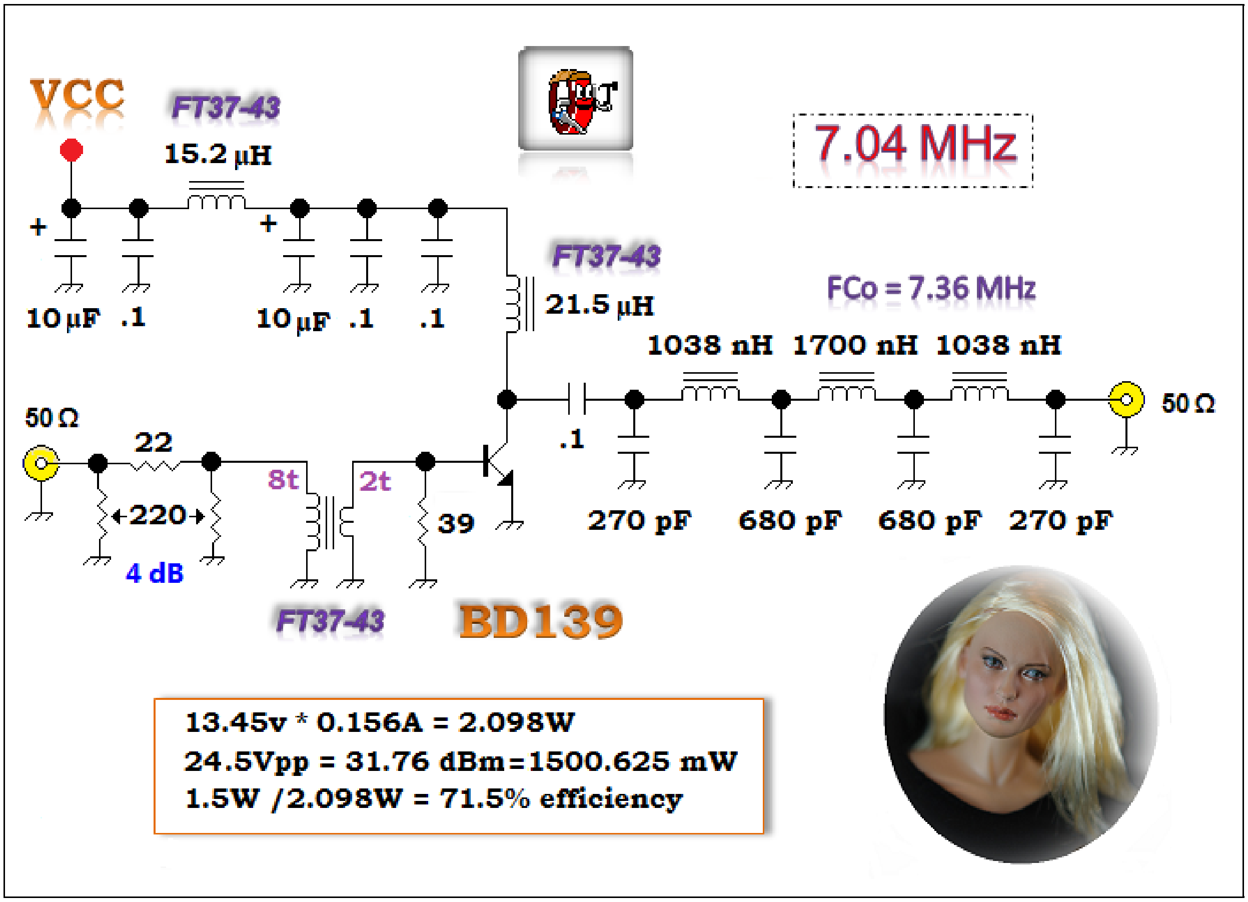
VCC
FT37-43
15.2 µH
+
+
10 µF
.1
10 µF
.1
.1
7.04 MHz
FT37-43
21.5 µH
FCo = 7.36 MHz
1038 nH
1700 nH
1038 nH
50 Ω
50 Ω
22
8t
2t
.1
39
220
4 dB
270 pF
680 pF
680 pF
270 pF
FT37-43
BD139
13.45v * 0.156A = 2.098W
24.5Vpp = 31.76 dBm=1500.625 mW
1.5W /2.098W = 71.5% efficiency

Above — The collector choke = 20.5 µH = an XL of ~ 951 Ω. 71.5% efficiency. Base + collector. Collector FFT. Sine wave FFT. To date, 71.5% is the best Class C efficiency I've measured.

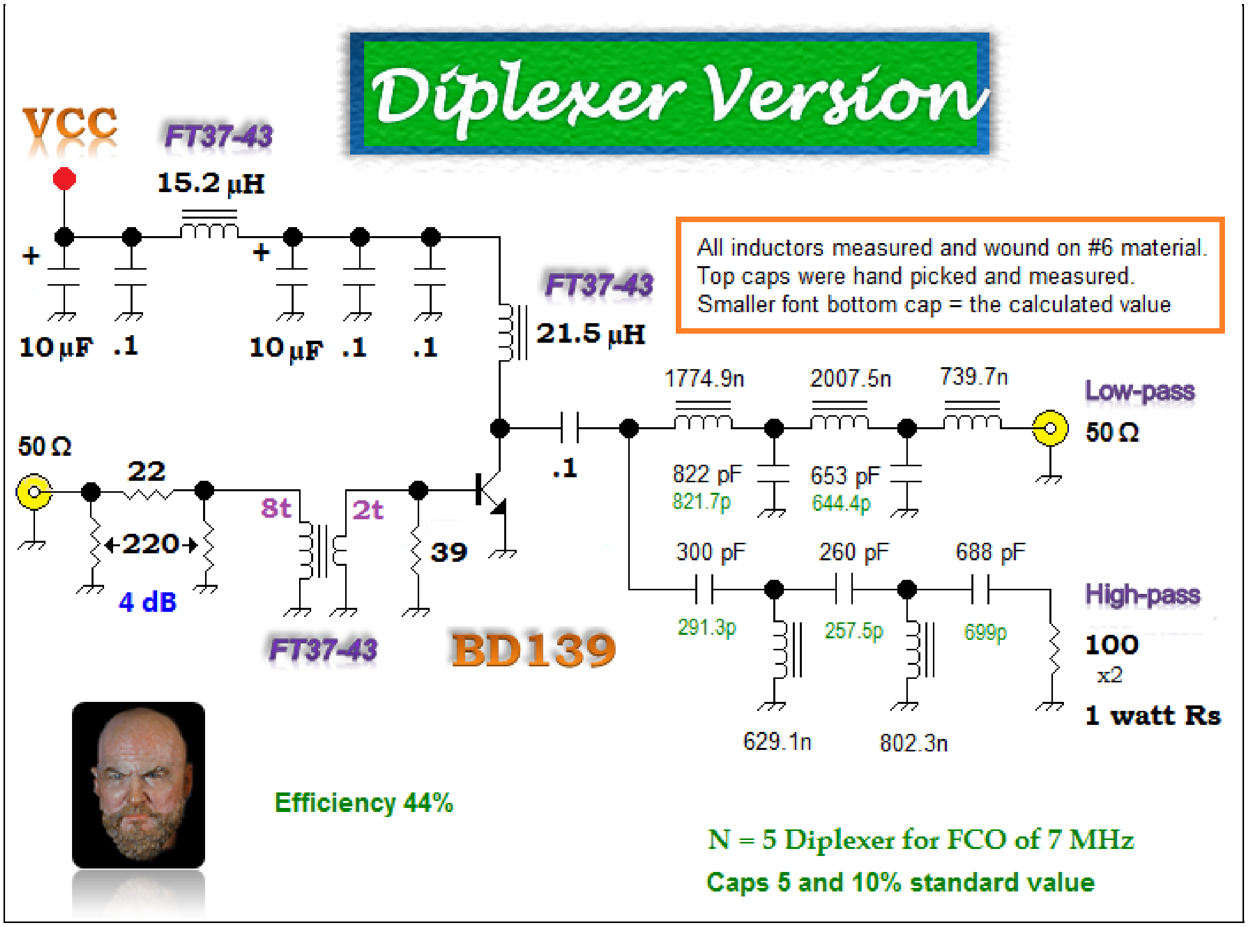
Diplexer Version
VCC
FT37-43
15.2 µH
+
10 µF
.1
+
10 µF
.1
.1
All inductors measured and wound on #6 material.
Top caps were hand picked and measured.
Smaller font bottom cap = the calculated value
FT37-43
21.5 µH
1774.9n
2007.5n
739.7n
Low-pass
50 Ω
50 Ω
22
.1
822 pF
821.7p
653 pF
644.4p
+220+
8t
2t
39
300 pF
260 pF
688 pF
High-pass
4 dB
291.3p
257.5p
699p
100
x2
1 watt Rs
FT37-43
BD139
629.1n
802.3n
Efficiency 44%
N = 5 Diplexer for FCO of 7 MHz
Caps 5 and 10% standard value

Above — A PA terminated in a N= 5 diplexer for 7 MHz. Click for the FFT of the collector. The collector waveform looks telling — resembling the 50 Ω resistor terminated version shown earlier. Unshown; I lowered the signal generator to 6.99 MHz and drove it to a sinusoidal 1825 mW to obtain a true 50 Ω collector load resistance plus get the greatest low-pass output signal and efficiency (44%) . Although diplexers will 50 Ω terminate the collector at all frequencies, they don't afford high collector efficiency.

Rogues Gallery

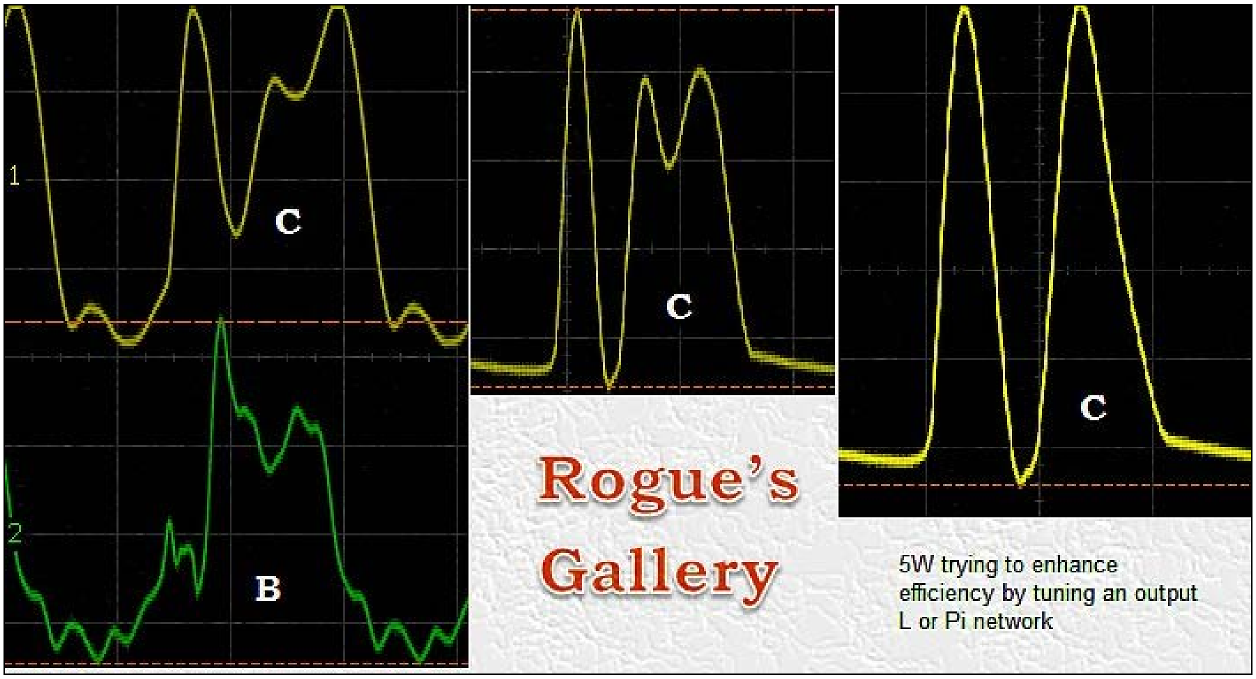

Above — Some 5W CW amplifier collector waveforms as I tried to boost efficiency by manipulating a matching network to drive up the ringing; all failures. These seemingly simple Class C PA's aren't so simple after all. Although failures — I felt thrilled by these experiments and vow to get better at it.

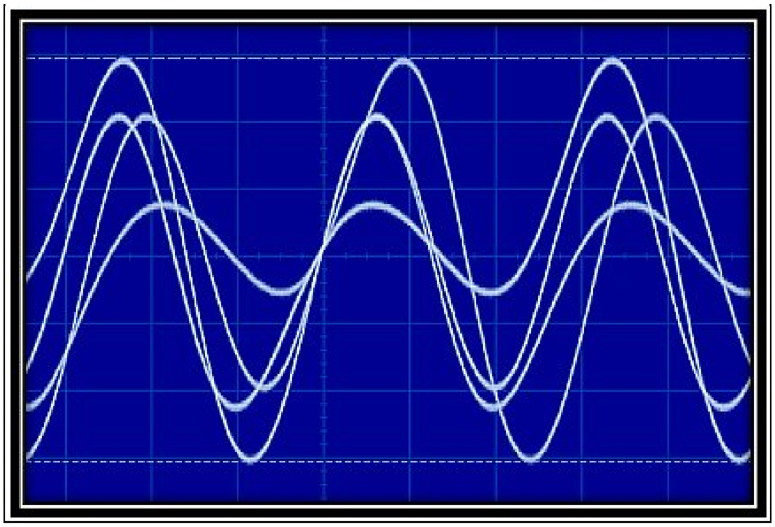

Above — A sine wave output of a very unstable PA.

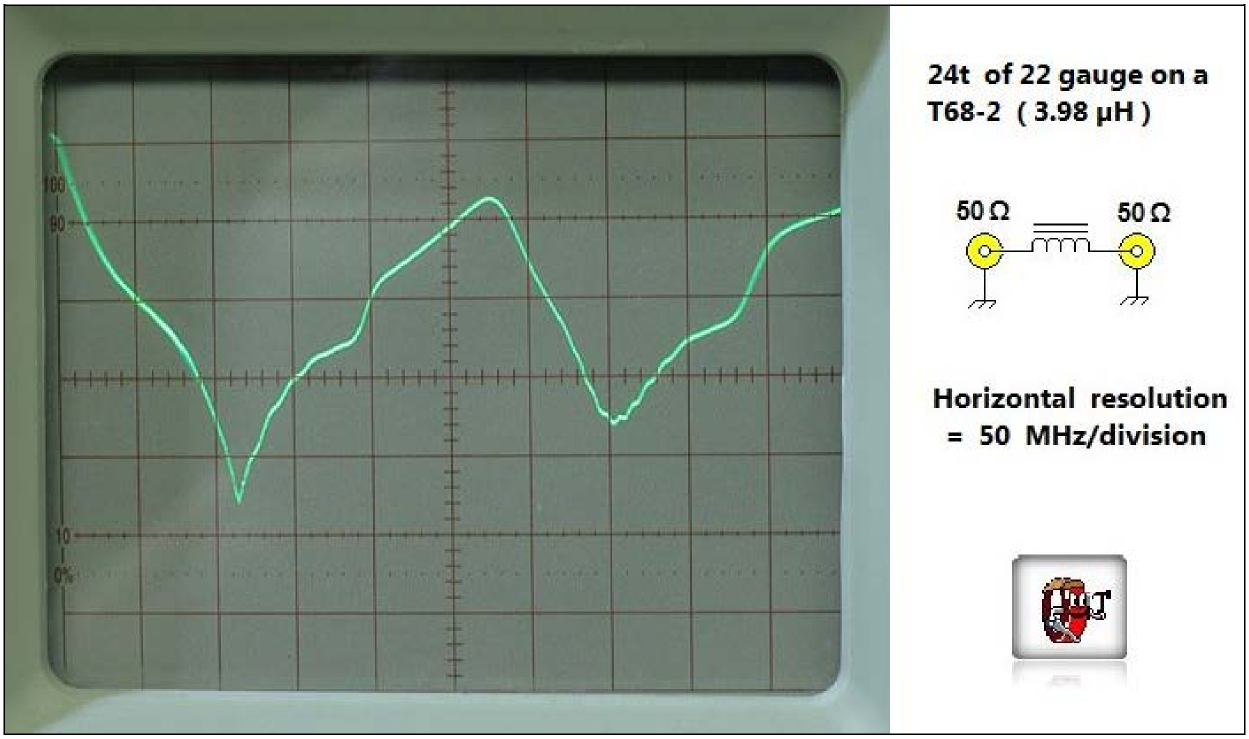

Above — To observe a renegade series resonant frequency, I wound a choke for a 21 MHz amplifer on a T68-2 powdered iron toroid: a casual 24 turns of wire. Sweeping it shows 2 SRFs at roughly 115 and 350 MHz. 2 SRFs jarred me.

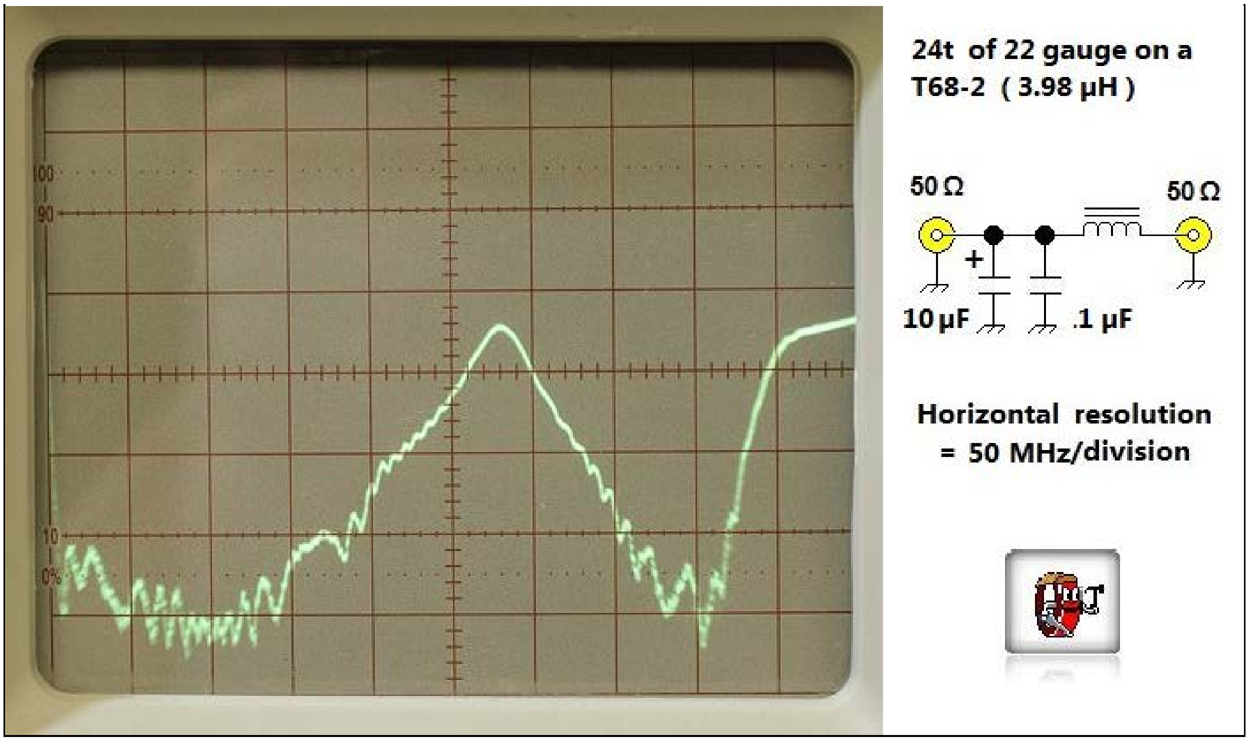

Above — I placed a couple of caps on the cold side like we normally do for our PA chokes. Likely I should have used a 0.01 µF cap instead of the 0.1 µF shown for 21 MHz, but the result would be the same: 2 SRFs remain and poor wideband bypass arises. We clearly need to consider SRF in our chokes and how it might affect our PA function and DC line filtering.

Conclusion to PA Measurement

With an oscilloscope and 2 DVMs you can easily explore boosting your Class C PA efficiency. I've seen precious little info on this topic in the amateur RF experimenter literature. 1 reputable reference = a section in EMRFD called **A Look at Some High Efficiency Amplifers**. For now, I'll temporize. Likely you'll advance faster than me, since I'm more a receiver guy and don't devote enough time to study transmitter design.

The math and concepts of efficient PA design within Class C - E flummox me. Most have just switched to driving FETs with a square wave built up from parallel inverters (high-speed logic gates in the now obsolete 74AC series) — but hopefully our experiments tweaking BJTs in Class C will carry us forward into other Tx modes.

Measuriing collector power with 2 DVMS while watching the sine wave output in your 'scope gives you incredible feedback: you can even observe thermal runaway. After purposely advancing the base drive to "heat up" a BJT, I saw the Vpp progressively drop in the 'scope, the DC voltmeter drop somewhat and then the DC current meter 'take off' : 400, 500, 890, 1200 mA and suddenly, poof, the BJT was on fire, exploded and flung 2 leads into the air. Normally, they just smoke and stink up your lab. I put a picture of a couple of blown BD139s in the photo section below. Expect to burn up some BJTs during experiments and please work safely.

Section 4: Class E Amplifier

This section unposted.

Section 5: References

1. Solid State Design for the Radio Amateur by Wes Hayward, W7ZOI and Doug DeMaw W1FB. American Radio Relay League 1986.

2. An Updated Universal QRP Transmitter by Wes Hayward, W7ZOI. American Radio Relay League: QST for April 2006.

3. Class E Amplifiers Part 1: Class E Basics. Dan Tayloe, N7VE / Ozarkcon Class E Presentation, 1994. *Search for it online*

4. The Handiman's Guide to MOSFET "Switched Mode" Amplifiers by Paul Harden, NA5N Part 1 Introduction to Class C,D,E and F. First Published in the journal "QRPp". Paul's Site

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Section 6: Miscellaneous Figures and Photos

B 39

JE181
8047
C3039
M0H4

2N3553
K0350
2N3553
K0350

2I D600D
WC9838

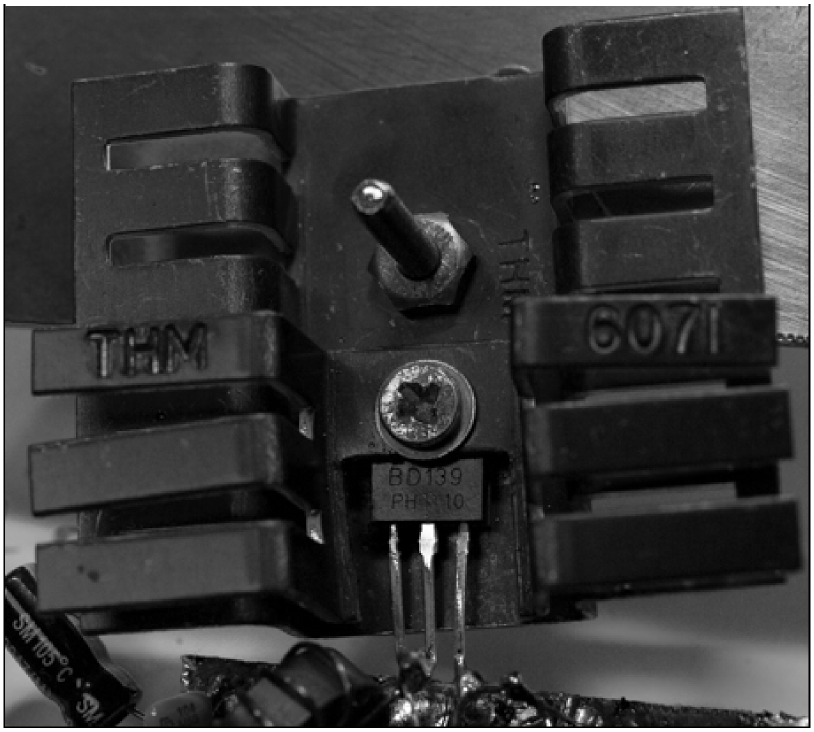
THM
6071
BD139
SM 105°C

RF — Test and Measurement

HF - Embarcadero

Respository web page for HF experiments performed in Fall 2013 and Winter 2014.

1. IMD Oscillator Quest
2. Almost Popcorn Superhet — an older, variant and incomplete HF project added for sake of interest
3. VXO — VCXO Notes
4. Funster Line — A Simple 40M Band QRP Trans-receiver.
5. Miscellaneous Photos and Figures

1. IMD Oscillator Quest

To measure IMD and calculate IP3 in receivers and components, we need 2 oscillators that typically lie 20 KHz apart, although some apply other frequency spacings. We join these oscillators with a 6 dB (or 3 dB) hybrid combiner and often follow the combiner with an RF attenuator and/or low-pass filter before connecting to a DUT and detector. I sought an oscillator possessing low phase noise, low distortion, strong return loss + high reverse isolation and documented my experiments to fuel your own. Nestled half-way within the HF band, 14 MHz is a popular IMD oscillator frequency choice. I chose 14.0 MHz and 14.020 MHz for classic 20 KHz spacing.

Wes, W7ZOI well covers intercept measurements in EMRFD and in part, popularized receiver DR measurements with his QST article entitled Defining and Measuring Receiver Dynamic Range in QST for July 1975. Click for the article header only. After publishing his article, receiver DR testing by the major Ham transceiver manufacturers became standard.

If you own 2 crystals spaced 20 KHz apart, you're set. A Butler oscillator set up for vibration at the xtal fundamental frequency works well. See EMRFD Figure 7.32 for a great example — A Butler carefully biased to stand reasonable current for low phase noise with a low impedance in the Colpitt's tank. Wes placed a 100 Ω resistor on the link between base terminals of the differential pair. The low impedance and the bias levelling provides current limiting and prevents the oscillator BJT from going into saturation.

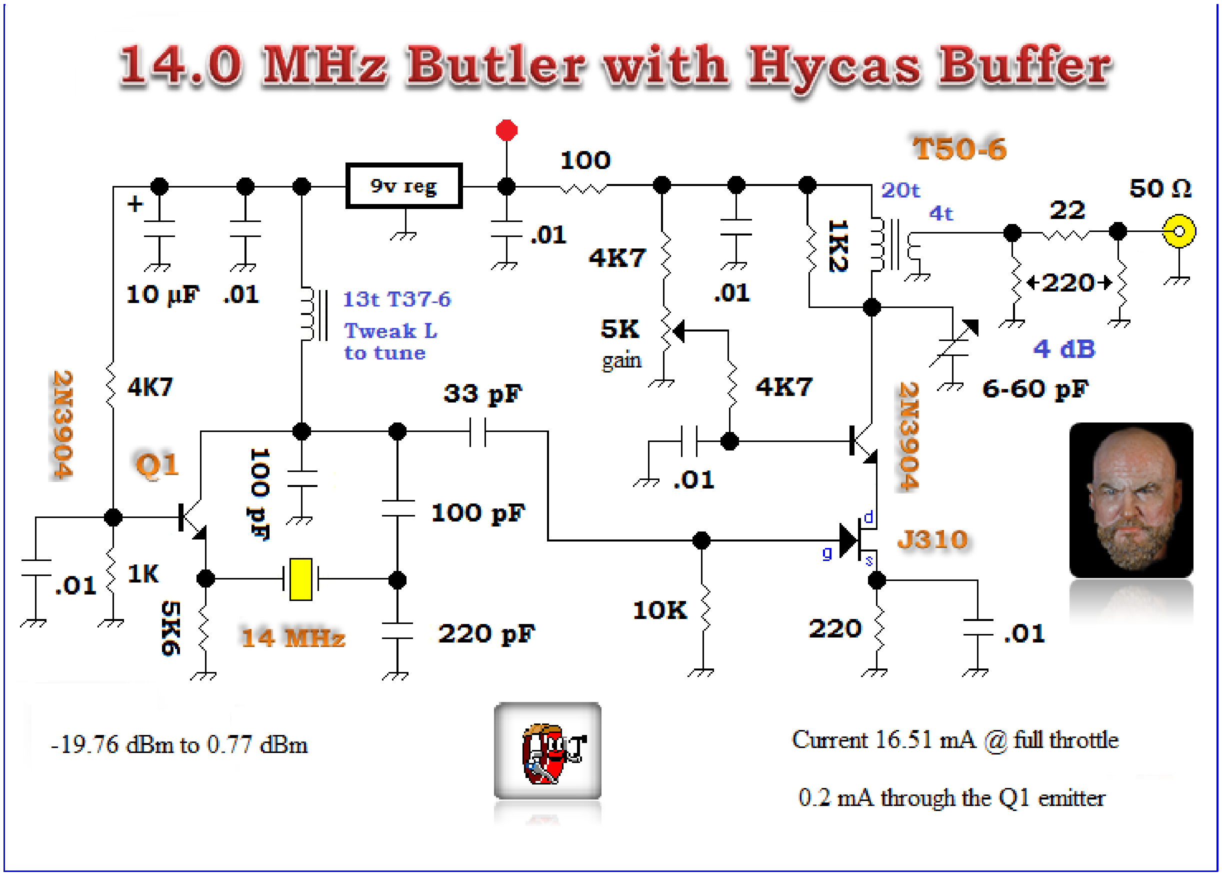
14.0 MHz Butler with Hycas Buffer
9v reg
100
.01
T50-6
20t
4t
22
50 Ω
+
10 µF
.01
13t T37-6
Tweak L
to tune
4K7
.01
1K2
220
220
4 dB
5K
gain
6-60 pF
2N3904
4K7
Q1
33 pF
4K7
100 pF
2N3904
.01
100 pF
d
g
s
J310
.01
1K
5K6
14 MHz
220 pF
10K
220
.01
-19.76 dBm to 0.77 dBm
Current 16.51 mA @ full throttle
0.2 mA through the Q1 emitter

Above — A fundamental frequency Butler with hybrid-cascode (hycas) buffer I built for 14.0 MHz some years ago. Rather than tuning the oscillator tank with the usual low-Q trimmer capacitor, I designed for a fixed C of ~100 pF and thumb and finger tuned the tank to preserve the Q.

Alternately, a standard Colpitt's crystal oscillator with the crystal connected to ground via a shunt capacitor of >= 200 pF provides a great way to get a low phase noise, low distortion oscillator. Take the oscillator output from the junction of the xtal and shunt capacitor and ensure you lightly load this node. See EMRFD Figure 4.24 or my Low Noise Crystal Oscillator web page for examples.

A problem arose. I couldn't find 2 crystals 20 KHz apart, so running 2 fundamental Butler or Colpitts oscillators for IMD measurement seemed out of reach. A web search yielded 1 solution; pull the xtal oscillators to a desired spacing around 14 MHz and crystal filter the output to drop phase noise.

My next experiments mirrored the work of Christian, DL9NL on this web site. It appears he based his design on that of Stuart, KI6QP who authored A Precision Two-Tone RF Generator for IMD Measurements for QEX for April 1995. Stuart used crystals cut 20 KHz apart to make 2 Colpitt's oscillators running moderate current with output filtering by 1 xtal filter tuned to the oscillator frequency to reduce phase noise.

In his project, Christian, DL9NL wired up two 14.318 MHz microprocessor filters in a super VXO topology to cleverly move the xtals 5 or 20 KHz apart. He also output filtered his 2 oscillators with a xtal filter.

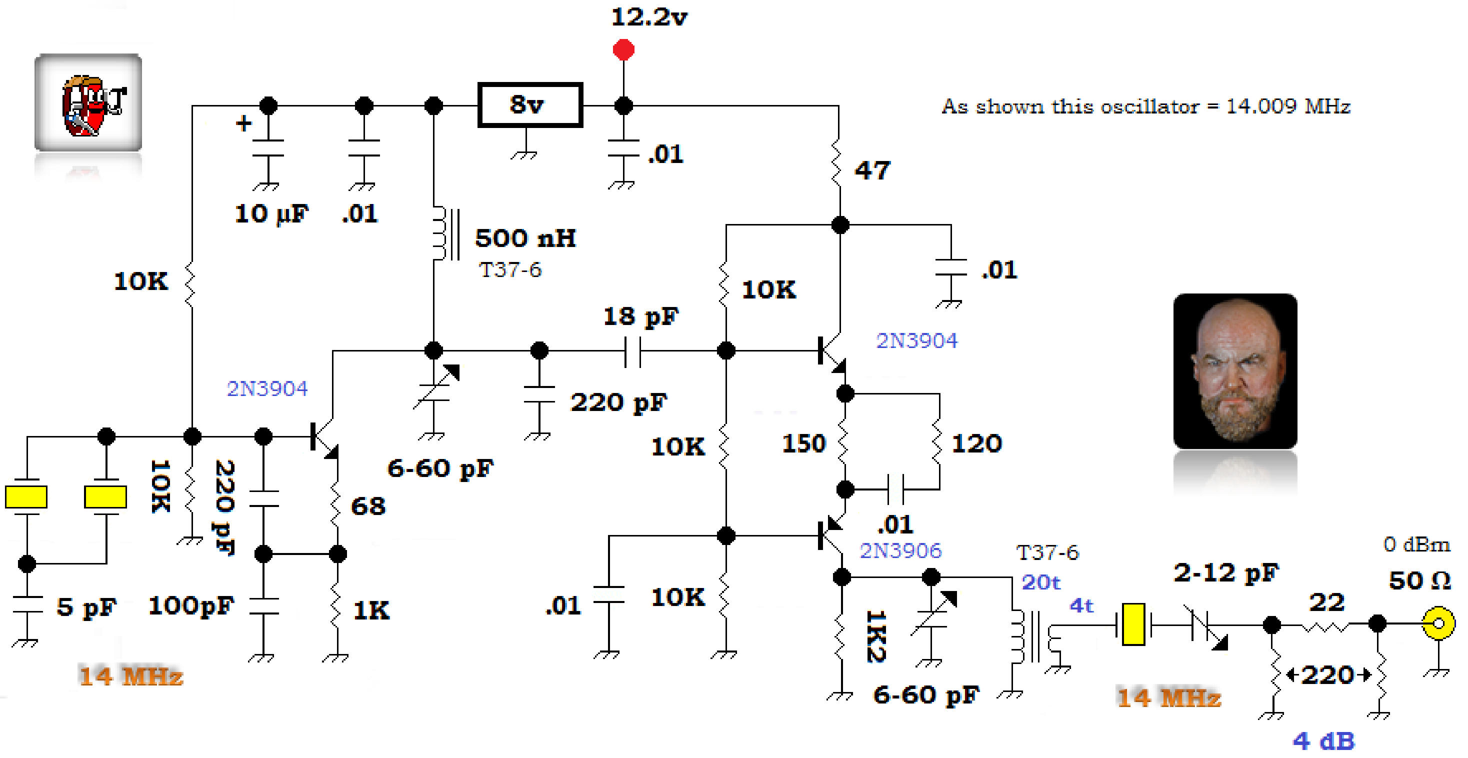
12.2v
8v
.01
47
+
10 µF
.01
500 nH
T37-6
10K
.01
10K
18 pF
2N3904
2N3904
220 pF
6-60 pF
10K
150
120
10K
220 pF
68
.01
2N3906
T37-6
20t
4t
0 dBm
50 Ω
2-12 pF
22
5 pF
100pF
1K
.01
10K
1K2
6-60 pF
220
14 MHz
14 MHz
4 dB

As shown this oscillator = 14.009 MHz

General Idea:

1. Use a super VXO with added L and/or C on 2 different oscillators to pull them 20 KHz apart
2. Apply an external xtal filter to lower phase noise

Above — 1 of my rudimentary experiments involving a super VXO plus output xtal filter. Not a great design. In this experiment, the 2 crystals were connected to ground via a 5 pF capacitor to yield 14.009 MHz. I learned that xtal frequency and xtal parameters determined the available frequency spread and output filter function.

After thought and the above bench work, and also because I need to make oscillators for IMD measurements at 50-100 MHz, I decided to go with an LC oscillator. They work fine for IMD measures with proper design and construction. For example, the signal generator shown in EMRFD Fig 7.27 sports a phase noise approaching -140 dBc/Hz @ a 10 kHz spacing; getting awfully close to the cherished vintage HP-8640B signal generator.

With LC oscillators, I learned that a metal enclosure with a feedthrough capacitor for the DC line proved important.Strong reverse isolation also ranks 'very important'. A case in point follows:

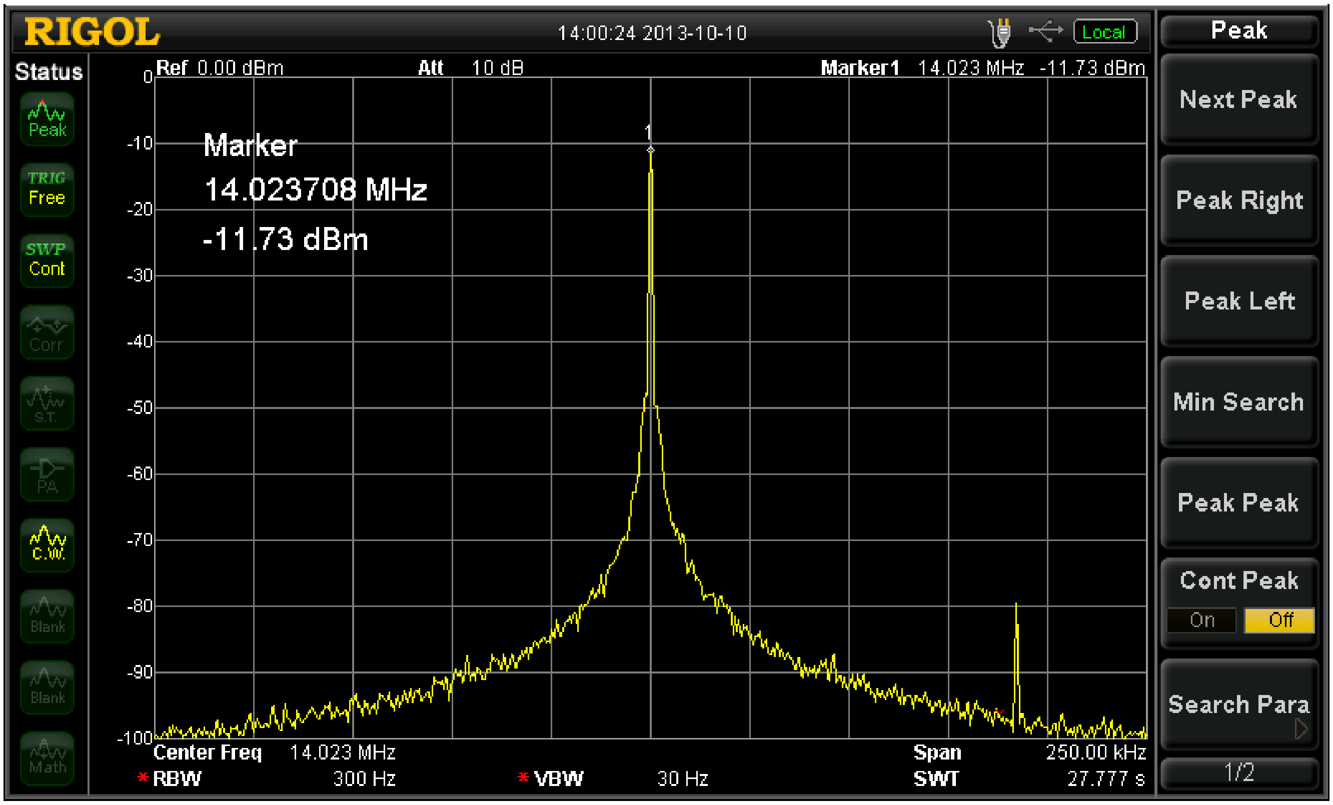

14:00:24 2013-10-10

Ref 0.00 dBm

Att 10 dB

Marker1 14.023 MHz -11.73 dBm

Marker
14.023708 MHz
-11.73 dBm

Center Freq 14.023 MHz

RBW 300 Hz

VBW 30 Hz

Span 250.00 kHz

SWT 27.777 s

RIGOL
Local
Status
Peak
TRIG Free
SWP Cont
Corr
S.T.
PA
C.W.
Blank
Blank
Math
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
1
Peak
Next Peak
Peak Right
Peak Left
Min Search
Peak Peak
Cont Peak
On
Off
Search Para
1/2

Above — A close-in spectrum analysis of 1 of my 14.02 MHz LC oscillators. Span = 250 KHz; RBW = 300 Hz and my video bandwidth = 30 Hz to "cut the grass". You can see a spur about 92 KHz right of center; a signal from my SA or environment is getting back into my VCO and low-level modulating it. Yikes! Another RF-tight LC oscillator with a common-base isolation amp showed no such spur.

Close in spectrum analysis may allow you to measure phase noise with your spectrum analyzer, however the wide-range, first oscillator of a Rigol spectrum analyzer operates in the range of 2- 4 GHz and is varactor tuned; as such, the best phase noise we can measure with it = -88 dBc/Hz @ 10 KHz spacing.

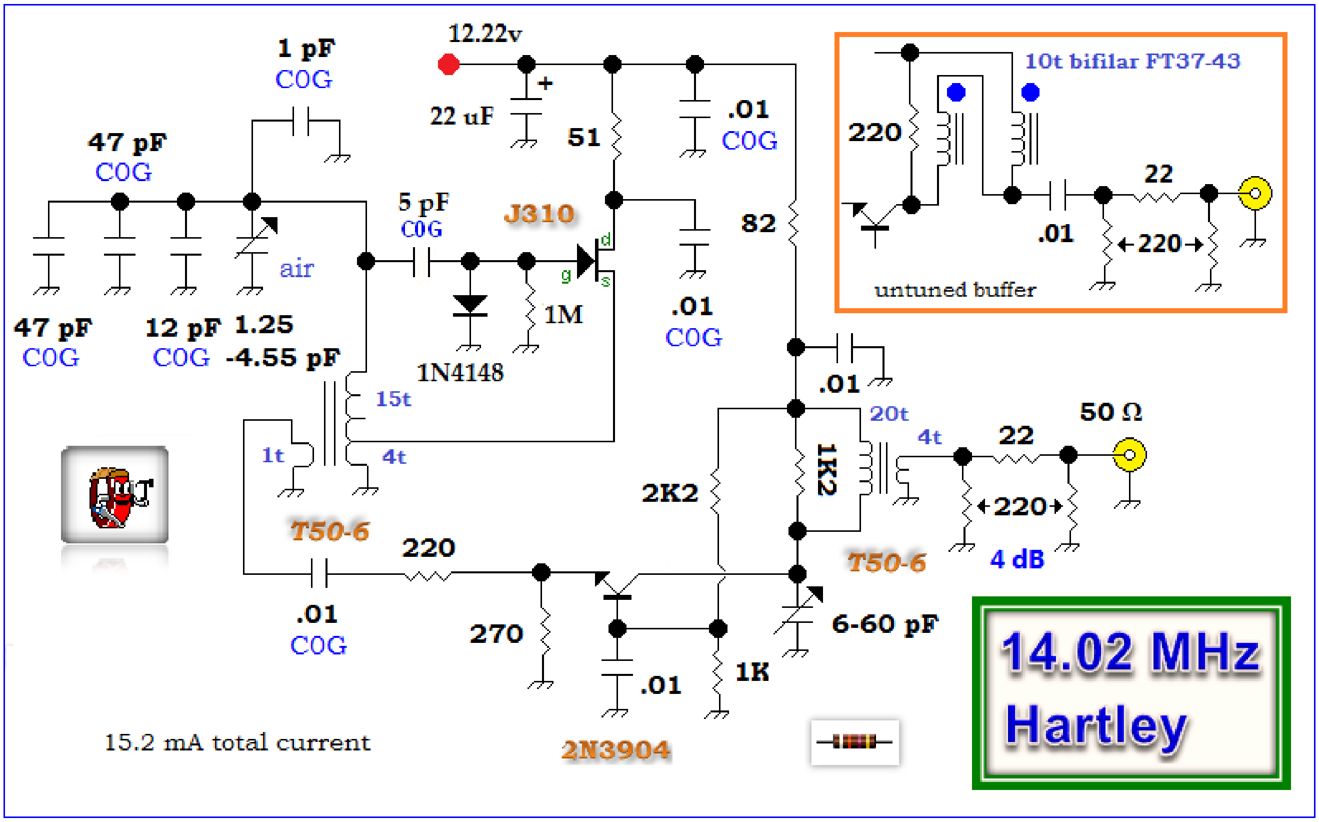
1 pF
C0G
12.22v
22 uF
51
.01
C0G
47 pF
C0G
5 pF
C0G
J310
82
air
d
g
s
1M
.01
C0G
47 pF
C0G
12 pF
C0G
1.25
-4.55 pF
1N4148
15t
1t
4t
T50-6
220
.01
C0G
270
.01
2N3904
1K
2K2
1K2
20t
4t
22
50 Ω
220
4 dB
T50-6
6-60 pF
.01
15.2 mA total current
10t bifilar FT37-43
220
22
.01
220
untuned buffer
14.02 MHz
Hartley

Above — 1 of my experiments: a Hartley with common-base buffer amp right out of EMRFD Figure 7.27 sans the final amp. I made 2 versions: 1 with a tuned buffer amp and another with a wideband output (see orange inset). The output power of the tuned amp and wideband amp = -6.7 dBm and -11.7 dBm respectively.

You may want to add a final amplifer — I've got a couple of amplifer modules if I need to get to 0 dBm or above. Prior to tweaking the lid-on frequency to 14.02 MHz, I measured the 2nd harmonic at 55 -dBC in the tuned output version— yay! Building with solid temperature drift techniques, the frequency drift in my counter went just a few hertz *up* over time. The Figure 7.27 oscillator remains a go-to circuit for us builders.

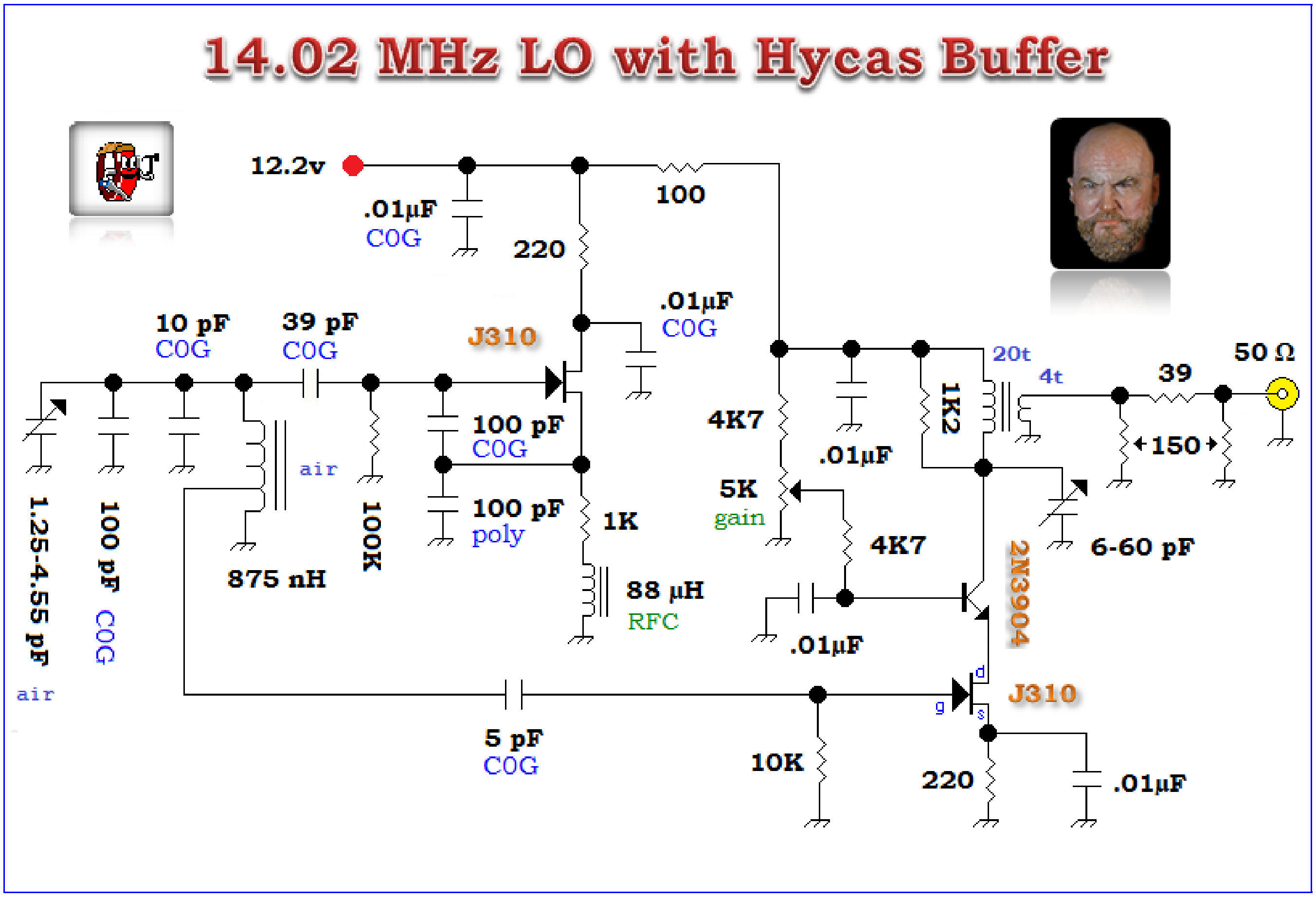
14.02 MHz LO with Hycas Buffer
12.2v
.01µF
C0G
220
100
J310
.01µF
C0G
10 pF
C0G
39 pF
C0G
100 pF
C0G
100 pF
poly
1K
88 µH
RFC
air
875 nH
100K
1.25-4.55 pF
air
100 pF C0G
4K7
5K
gain
.01µF
1K2
20t
4t
39
50 Ω
150
6-60 pF
4K7
2N3904
.01µF
5 pF
C0G
10K
d
g
s
J310
220
.01µF

Above — A Colpitts with hycas buffer allowing variable power output. During measurement of IMD, the 2 oscillators need to exert the same amplitude, so only 1 needs to have variable output power. A wideband bench generator plus a 1 frequency oscillator like this might be all you need.

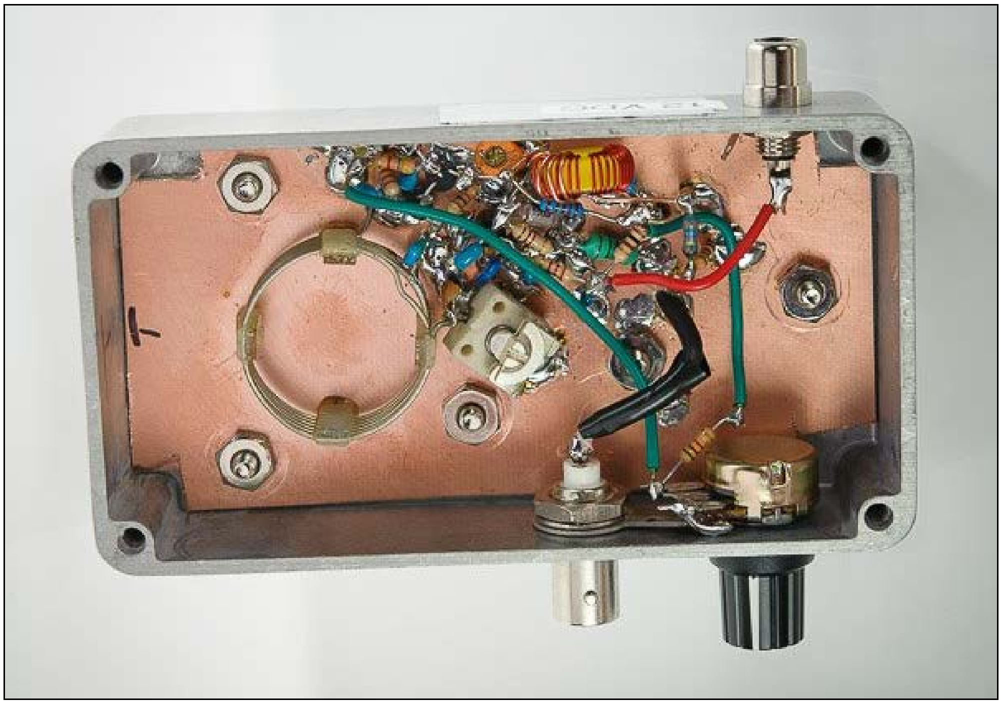

Above — A photo of the completed Colpitts LC oscillator. Running a phono jack for the DC input was a mistake. A feedthrough capacitor = the best choice. The epoxy glued air wound coil and air trimmer cap plus the regular temperature stability techniques and a 100 pF polystyrene capacitor yielded a temperature drift under 40 Hertz per hour. 5 bolts anchor the copper clad board.

I connected the 5 pF coupling cap to the lowest turn on the air coil. Mounting an air coil (solenoid) in smokestack fashion over a copper board probably upsets its Qu, but it worked okay.

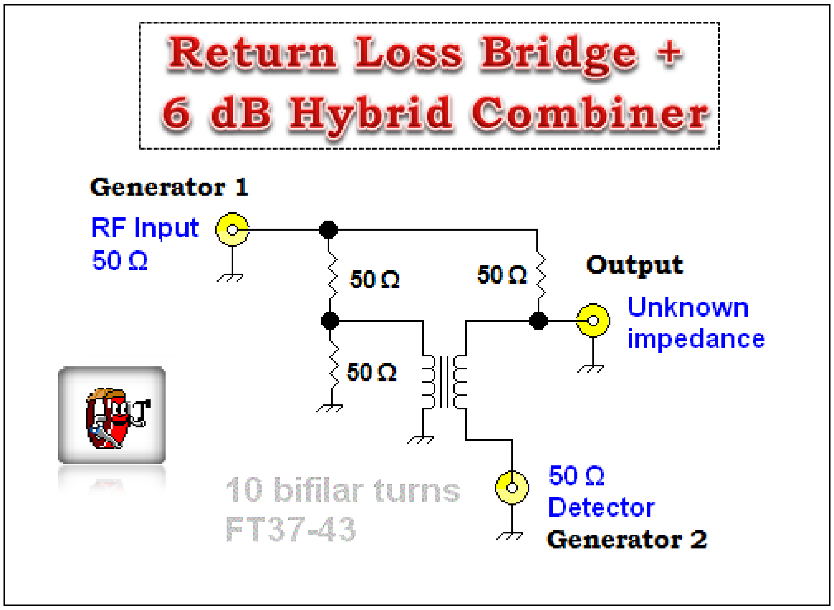

Above — Our old friend the Return Loss Bridge is also known as a 6 dB hybrid combiner and 1 serves double-duty on your QRP workbench as an isolator and a return loss bridge.

Phase Noise and Commercial Signal Generators

The worst of today's ham transceivers transmit a CW carrier with noise that is down by 117 dBc/Hz @ 10 kHz spacing. This is bad enough that if you had a Ham operating this rig 0.8 km away you would hear this noise, even with a perfect receiver. In a typical oscillator, the phase noise @ 100 kHz spacing lies ~20 dB lower than @ 10 kHz out to a noise floor that is around -140 dBm/Hz or better. The Elecraft K3 impresses us with phase noise at -138 dBc/Hz @ 10 KHz [Sherwood].

We either build, borrow or buy our signal generators. Second hand commercial products range from good old HP/Agilent gear or LC boxes once used by TV/FM receiver repairmen. The TV service equipment covers ~300 kHz to 150 MHz and tends to be inaccurate with a limited output amplitude range, while the vintage HP stuff often is heavy, decaying and crowds your bench.

Most of hobbyists can't afford nor justify spending $8-18k on boxes that go down to -127 dBm amplitude and -146 dBc phase noise at 1 GHz @ 20 kHz offset [Agilent N5181B MXG X-Series RF Analog Signal Generator]. These generators feature components like a YIG oscillator phase locked to an ovenized crystal reference. Professional, high-end gear.

Another choice = the Arbitrary/Function Generator or ARB that sell for a fraction of the cost of the aforementioned boxes. A few friends own them, in particular, products made by Rigol and GW Instek. These DDS generators range in frequency and price: higher price generally = better phase noise.
For example, the popular Rigol DG1022A phase noise = -108 dBc/Hz @ 10 KHz offset and the DG4162 = ≤-115 dBc/Hz @ 10 KHz offset; not good. Often ARBs will feature a host of modulation functions, sweeps, frequency counters and the 2 output channel models may offer I/Q outputs and the ability to perform 2-tone IMD tests. Search around the T Equipment website to read some equipment datasheets

My question to 2 informed EEs — Is the phase noise of a -115 dBc/Hz ARB *good enough* to reliably measure IMD? Their answer: yes, if you have a high end, modern spectrum analyzer with a minimum RBW of 100 Hz, deft analyzer skill and understand the measurement. Often us hobbyists have to make due with whatever test equipment we can build or buy.

You might just build a low noise oscillator with a crystal at 14.0 MHz and provide the other tone with your bench signal generator or some other combination of 2 devices. This is test equipment junkie fodder — band-of-brother's stuff. Thanks for reading.

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2. Almost Popcorn Superhet

I published this rogue web page with hope you might find it interesting. It houses notes and photos for an incomplete update to my 1998 Popcorn 7 MHz, CW, superhet receiver.

Click for the Almost Superhet web page.

Click for the Almost Superhet Supplement page

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3. VXO — VCXO Notes

VXOs and VCXOs provide a useful main or reference oscillator for HF and when multiplied, in VHF-UHF designs. Ignorant of such circuits, I executed some crude experiments to discover how they work and find ways to improve my designs. Increasingly clinical on my bench, I'm losing patience with the radio mystique — although the limits of my lab equipment, brain power and bench skills humble and tumble me into deeper understanding why educated people might submit to electronics folklore and go in blind faith.

I'm not sure my bench work accomplished much, but if I can add 1 factoid to the RF enthusiast VXO knowledge base, then, I'll feel happy. I'm officially adopting **System D**; the slang term that originated in the French-speaking African continent and Caribbean Plate. In Down and Out in Paris and London, George Orwell called these System D practitioners "débrouillards" — low-level kitchen help, who achieve culinary success in the worst of circumstances. Television hero MacGyver practiced System D.

System D in the context of the QRP Homebuilder describes an effective, practical and resourceful builder who skillfully adapts to any situation and *gets it done*. System D builders don't just kludge together crap — these science-informed débrouillards innovate and shine. Sounds hopeful doesn't it?

Nearly all my bench adventures begin with a web search and the key word *VCXO* yielded many espléndido files + presentations by people and companies who passionately share their knowlege and experiences. Thanks to all!

Experiments

It started with an email from Paol — what's the S12 of the source follower in his 14 MHz VXO buffer amplifier? I built 1 for 10 MHz and tested it since I didn't know.

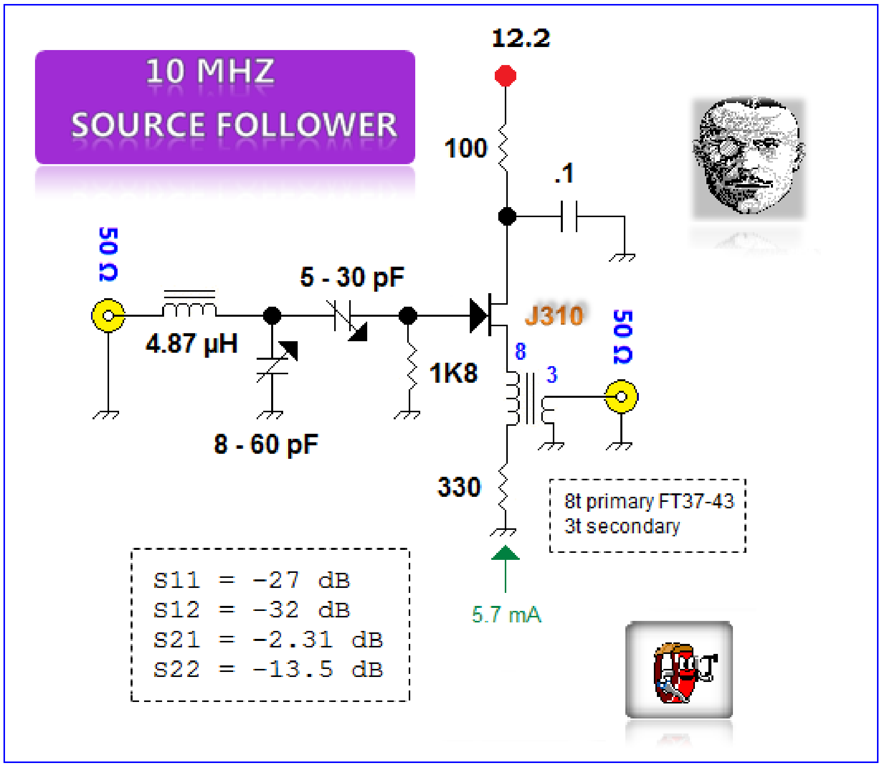

Above — Device Under Test. Paol copied a source follower he found on a web site (complete with an über kitsch 1 mH choke on the source). I tweaked the current and replaced that big, old MF choke with a tapped FT37-43 giving an output return loss of ~ 13.5 dB. Although mediocre, it's probably better than the match provided by the series resistor we typically stick between the JFET source and its 50 Ω load. Further, for my S12 measurement, I matched the input with a L-C-C network to get a strong return loss @ 27 dB. Measured with a spectrum analyzer, S12 = -32 dB; paltry reverse isolation. The matching networks incurred some losses but raised measurement fidelity.

-32 dB — not great, but okay if followed by another amp. For a diode ring mixer, I might couple it to a common base amp, or eliminate the source follower altogether and replace it with a hycas buffer amp. Paol drove a NE612 transmit mixer with his VXO + a source follower and it worked okay in his bare-bones TX. He AC-coupled a 51 Ω resistor to ground on pin 6 of the NE612 that well terminated the LP filter. Intrigued, I then helped him with his VXO.

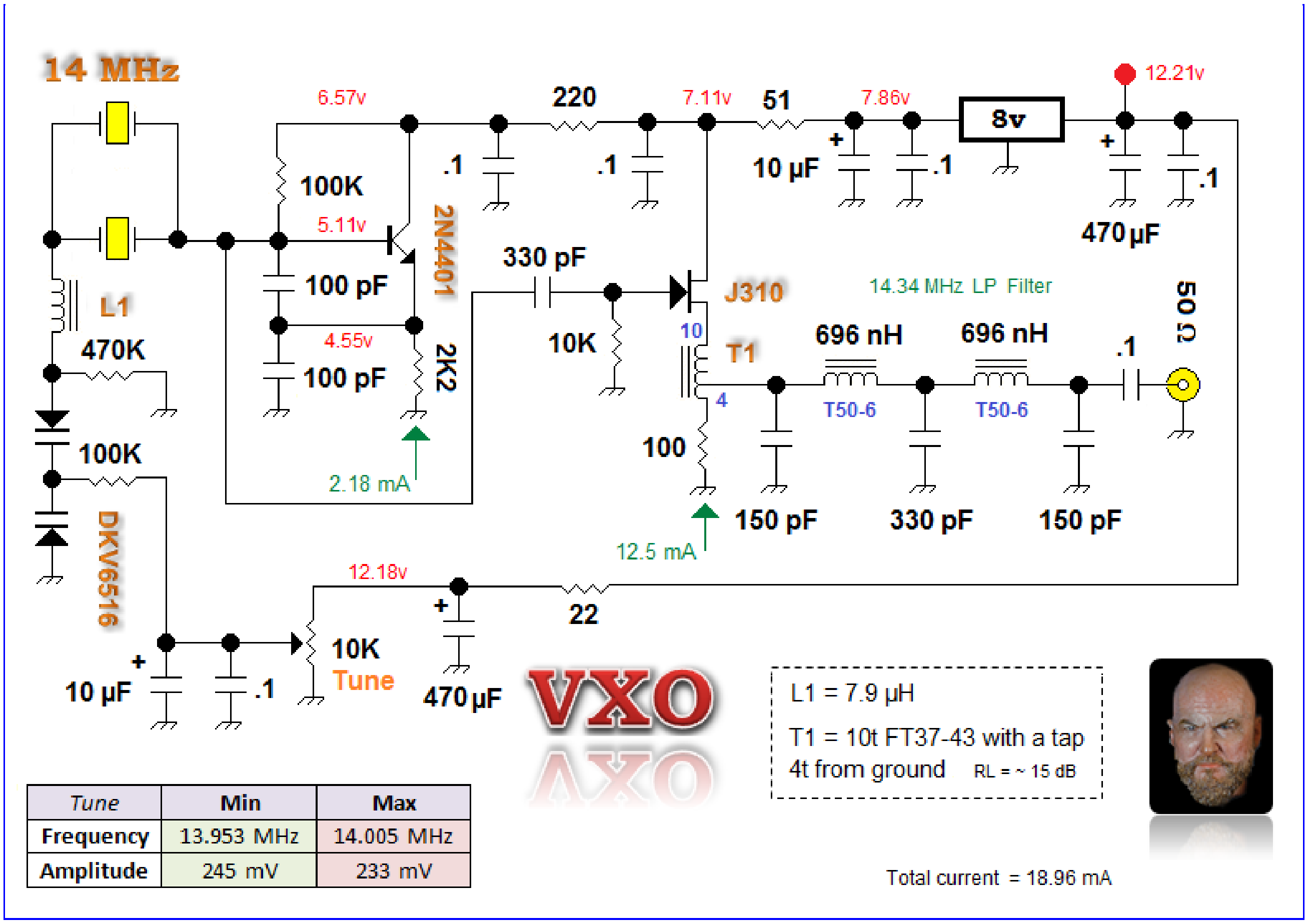
14 MHz
6.57v
220
7.11v
51
7.86v
8v
12.21v
100K
.1
.1
10 µF
.1
470 µF
.1
5.11v
2N4401
L1
100 pF
330 pF
J310
14.34 MHz LP Filter
50 Ω
470K
4.55v
100 pF
2K2
10K
10
T1
696 nH
696 nH
.1
4
T50-6
T50-6
100K
2.18 mA
100
DKV6516
150 pF
330 pF
150 pF
12.5 mA
12.18v
22
10K
Tune
470 µF
10 µF
.1
VXO

Tune	Min	Max
Frequency	13.953 MHz	14.005 MHz
Amplitude	245 mV	233 mV

L1 = 7.9 µH

T1 = 10t FT37-43 with a tap 4t from ground RL = ~ 15 dB

Total current = 18.96 mA

Above — My first VXO experiment with varactors instead of an air variable cap that technically creates a voltage-controlled crystal oscillator (VCXO). The tabled values were measured with L1 wound on a FT50-61 ferrite toroid.

Paol had varactors but no air-variable capacitors. Both of us owned some Q = 200, DKV6516 silicon varactor diodes that with a reverse DC voltage of 2 to 10 volts give a nice tuning range of 18 to 140 pF for a single diode. We cheated and ran the reverse DC voltage from 0 to 12.2 volts, although later increased the 22 Ω R to limit the peak tuning voltage to 10v. Paol also put a fixed resistor on the cold end of his 10K tuning pot to keep a minimum 2 VDC on the varactors: I didn't bother, since my "this is only a test" breadboard will be dismantled and junked.

Above — DKV6516

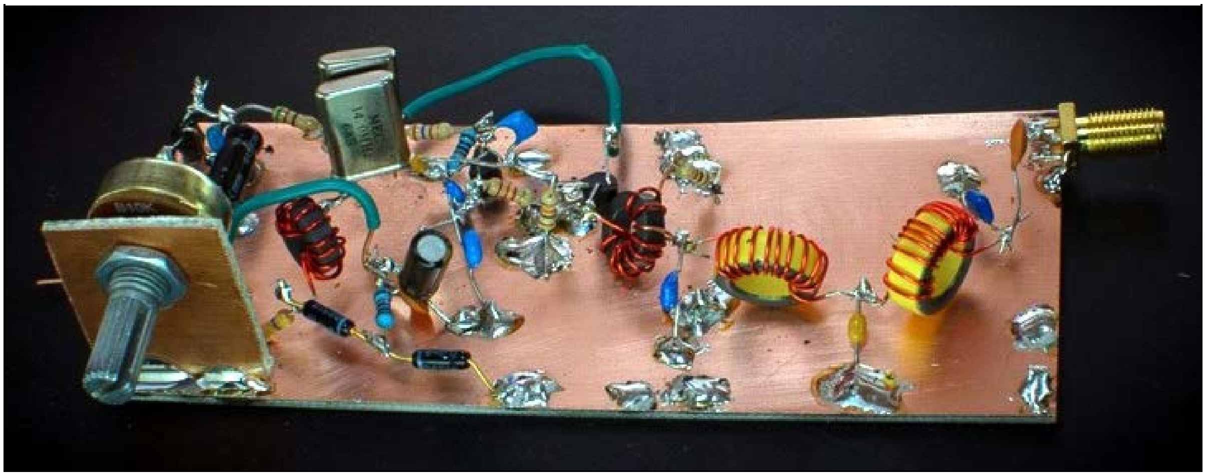

Above — VCXO breadboard. Paol and I each made a VCXO and he with 14.060 MHz crystals. Lacking these, I just used 2 junk box 14 MHz crystals with a measured Qu of ~80K. The tapped FT37-43 gave an output return loss of ~ 15 dB thus providing a reasonable match into a simple 50 Ω low-pass filter. Click for a sweep showing the 2nd harmonic suppression.

My initial build didn't contain the two noise filtering 470 µF caps on the 12 volt supply: I originally soldered a solitary 22 µF cap cap close to the 8 volt voltage regulator input. My 12.2 volts comes from a regulated DC supply. More on filtering noise later.

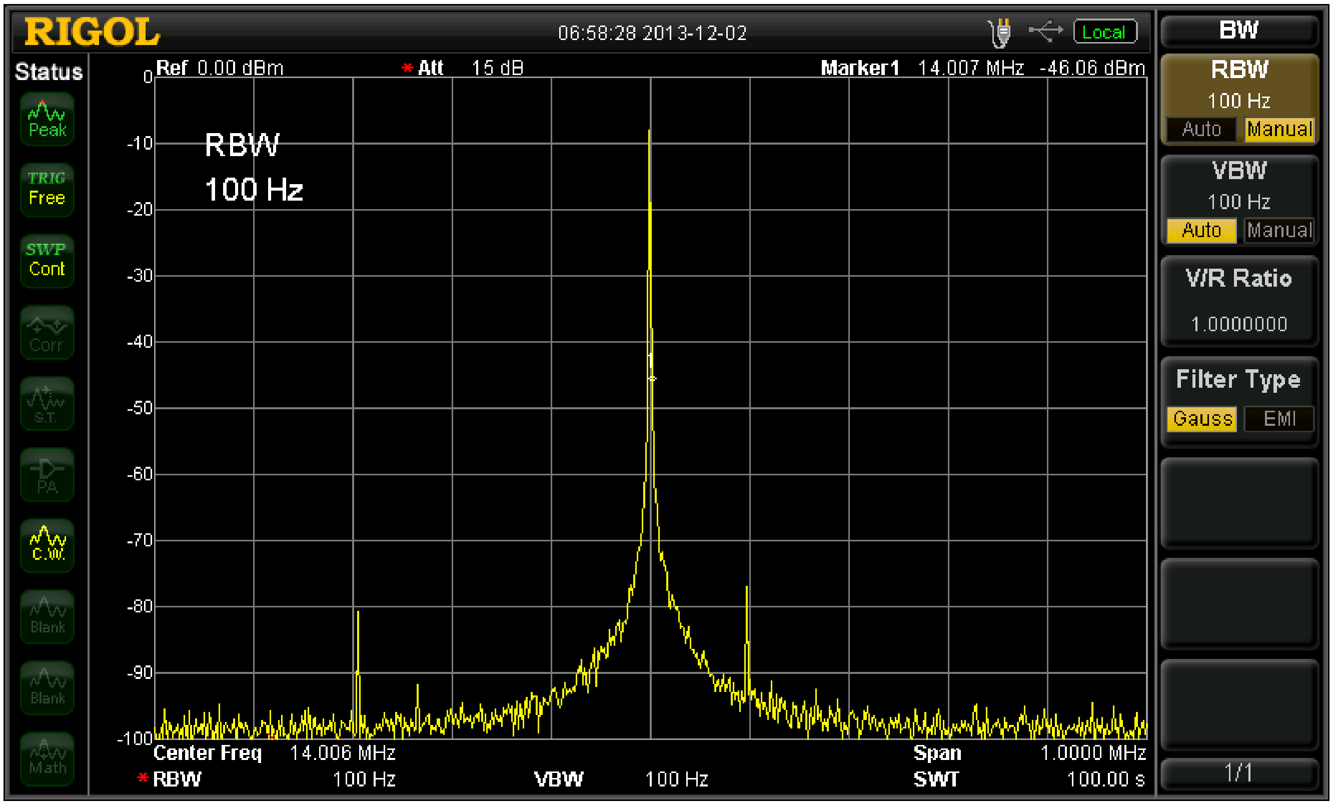

RIGOL 06:58:28 2013-12-02 Local

Ref 0.00 dBm *Att 15 dB Marker1 14.007 MHz -46.06 dBm

RBW 100 Hz

Center Freq 14.006 MHz Span 1.0000 MHz

*RBW 100 Hz VBW 100 Hz SWT 100.00 s

BW

RBW 100 Hz Auto Manual

VBW 100 Hz Auto Manual

V/R Ratio 1.0000000

Filter Type Gauss EMI

Above — My VCXO spectrogram showed 2 big spurs: 300 KHz down and 100 KHz up from center frequency (CF). I exchanged the varactors with an elegant, Q >= 1000 air variable, plus changed to a higher Q inductor, but could not get rid of these spikes. I assumed these spurs came from the crystals, or the BJT. Then, too, might they arise from my spectrum analyzer?

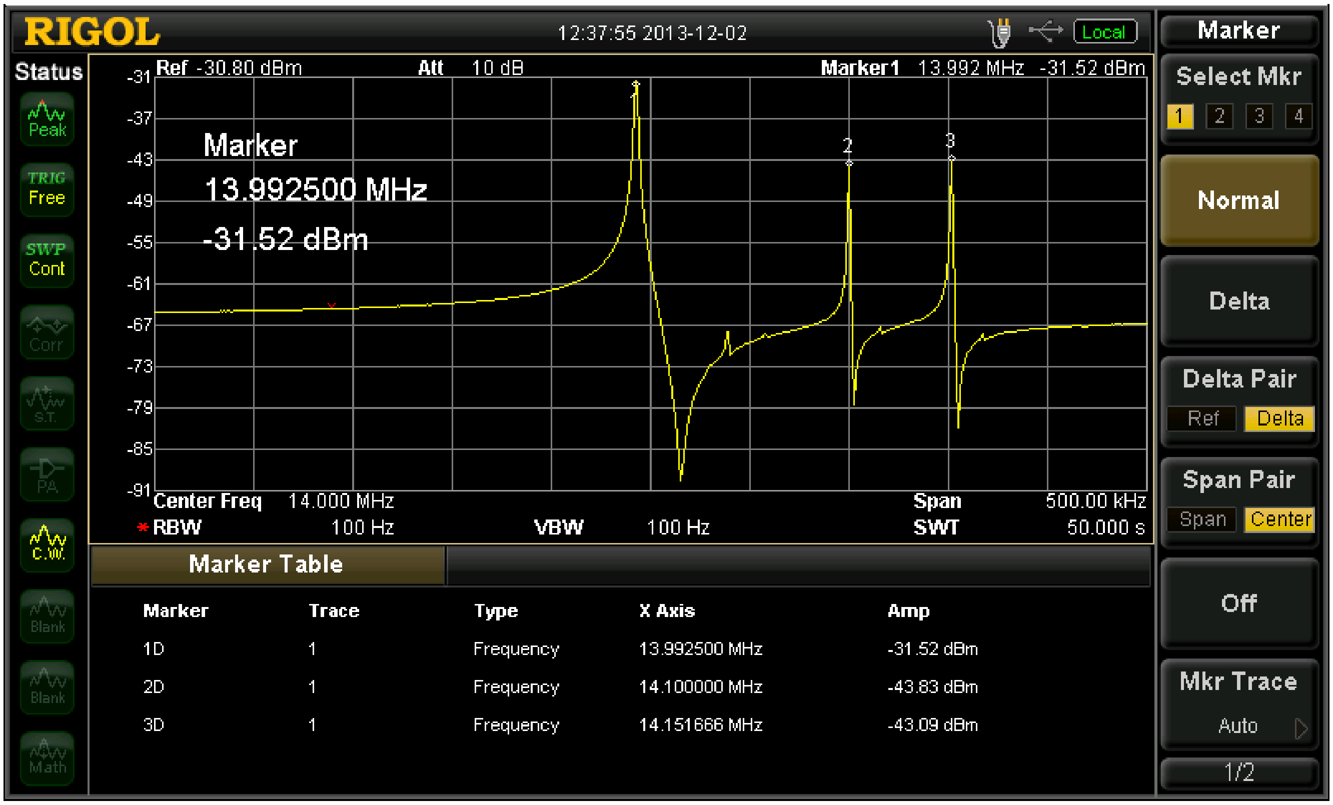
RIGOL
Local
Status
Peak
TRIG
Free
SWP
Cont
Corr
S.T.
PA
C.W.
Blank
Blank
Math
-31
-37
-43
-49
-55
-61
-67
-73
-79
-85
-91
2
3
Marker
Select Mkr
1
2
3
4
Normal
Delta
Delta Pair
Ref
Delta
Span Pair
Span
Center
Off
Mkr Trace
Auto
1/2

12:37:55 2013-12-02

Ref -30.80 dBm Att 10 dB Marker1 13.992 MHz -31.52 dBm

Marker
13.992500 MHz
-31.52 dBm

Center Freq 14.000 MHz Span 500.00 kHz
RBW 100 Hz VBW 100 Hz SWT 50.000 s

Marker Table

Marker	Trace	Type	X Axis	Amp
1D	1	Frequency	13.992500 MHz	-31.52 dBm
2D	1	Frequency	14.100000 MHz	-43.83 dBm
3D	1	Frequency	14.151666 MHz	-43.09 dBm

Above — 14 MHz crystal sweep spectogram. To find out why these spurs occurred, I swept 1 crystal at a time from my batch and saw spurs on all of them. However, after some reading, I discovered that the mere presence of a crystal spurious response doesn't signal causality since this is almost a normal happening. Wes, W7ZOI explains this on this web page. Crystals usually have a spurious response and from Wes, the spur is more often than not about 80 or 100 kHz above the main signal. This happens with fairly good crystals, less so with crappy, cheap crystals and even less often with good quality crystals. Since many of us buy computer-grade crystals from Mouser-Key, or online auction sites, who really knows what we're getting? 1 day I hope to test a Q = 1 million crystal — that will be fun.

However, renograde crystals could still be the cause. Sometimes when pulling a crystal(s), we're living on the edge — the main resonance is pulled so far that the circuit balks at the resonant frequency, or lies near the edge of such behavior and spurs start to show up. *Back to System D*. Simple substitution with 2 other crystals from another batch could tell me if these particular crystals were behaving poorly. It turns out, they were.

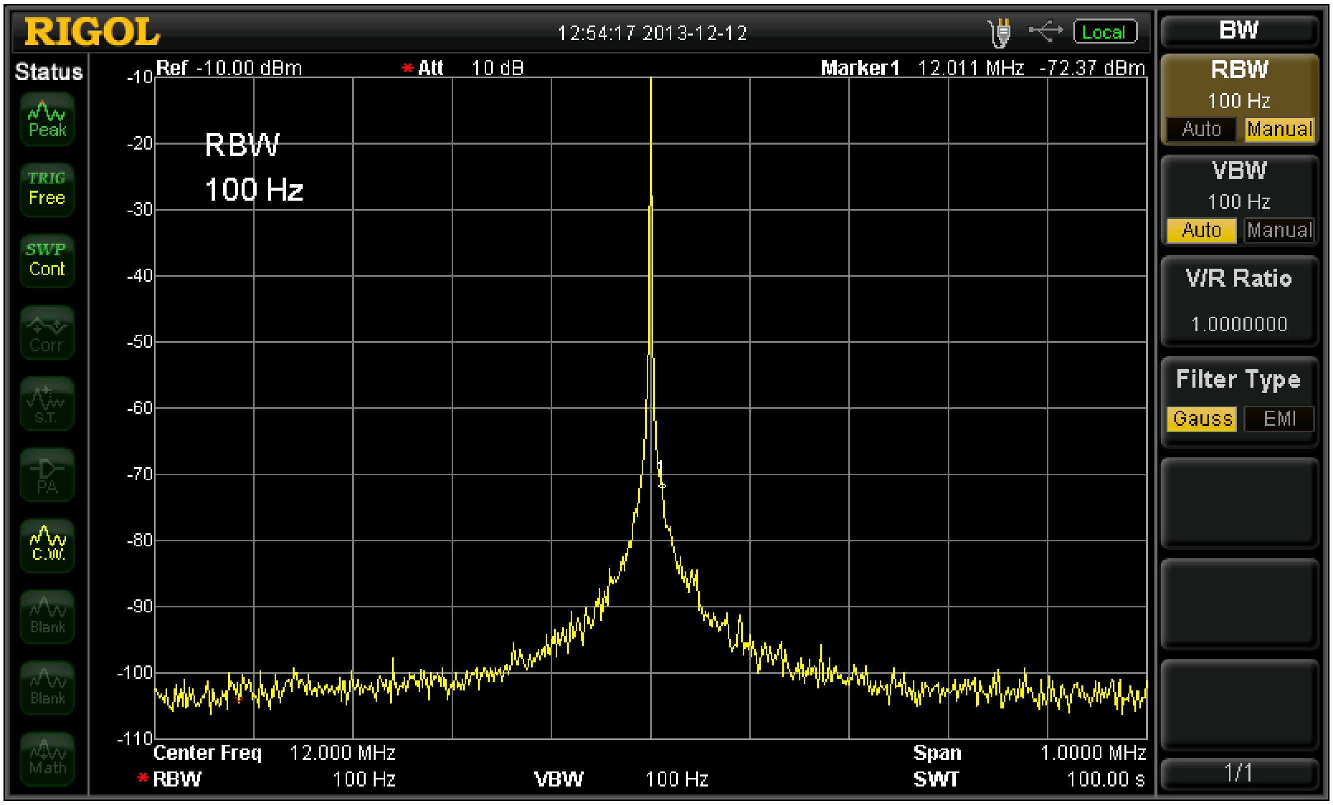
RIGOL
Local
Status
Peak
TRIG
Free
SWP
Cont
Corr
S.T.
PA
C.W.
Blank
Blank
Math
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
BW
Auto
Manual
Auto
Manual
Filter Type
Gauss
EMI
1/1

12:54:17 2013-12-12

Ref -10.00 dBm Att 10 dB Marker1 12.011 MHz -72.37 dBm

RBW
100 Hz

Center Freq 12.000 MHz Span 1.0000 MHz
RBW 100 Hz VBW 100 Hz SWT 100.00 s

RBW 100 Hz
VBW 100 Hz
V/R Ratio 1.0000000

Above — Spectogram of the VCXO with 12 MHz crystals. I wanted to try other 14 MHz crystals, but didn't own any. My nearest value crystals were 12 MHz jobs with a Qu of 120K. Eh voila! No spurs — yay! Let's talk about noise:

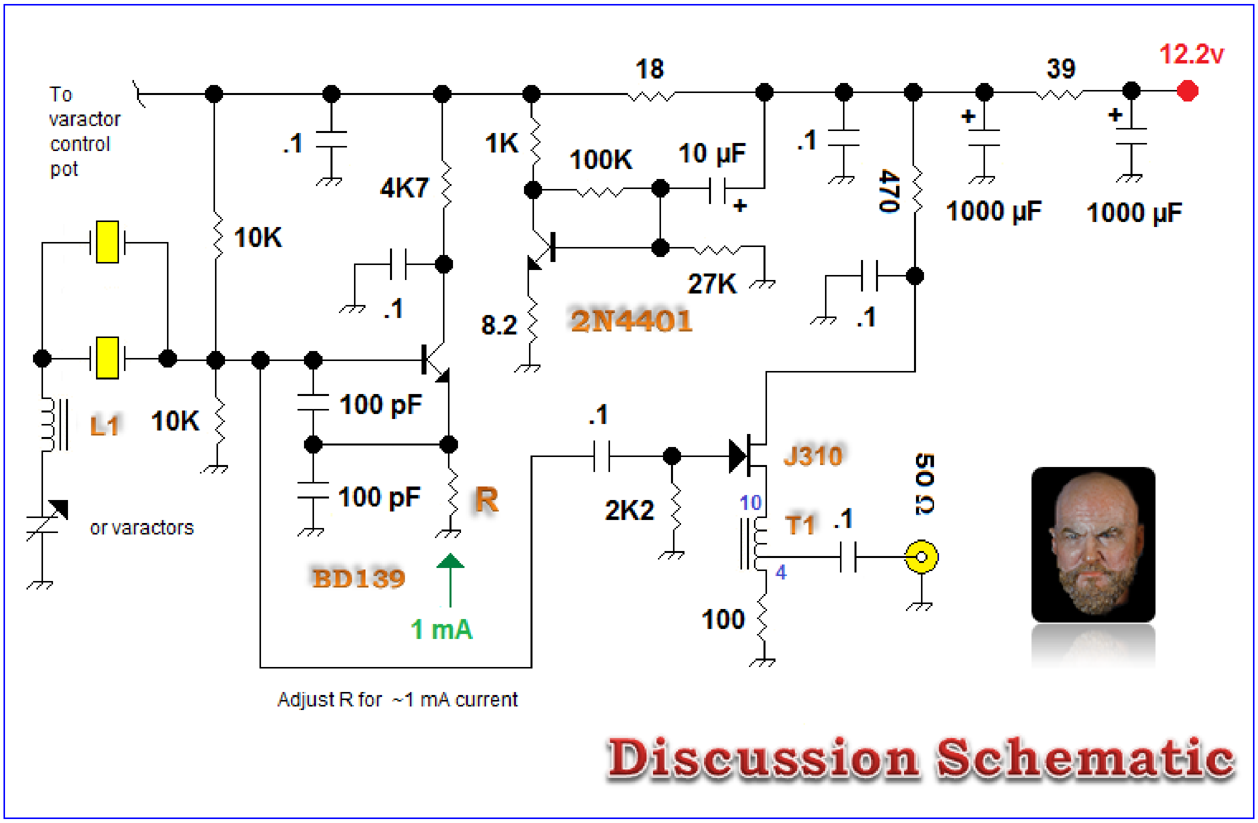

Above — Schematic for sideband noise discussion

System D design poses a real challenge with repect to noise. Measuring noise proves an advanced technique beyond the scope of this popcorn RF web site. We can't measure noise with our spectrum analyzer since the oscillator in the analyzer usually exhibits more noise than the VXO we want to test.

On page 4.12 of EMRFD version 1 is a small photo of 2 spectograms that show a clean crystal trace contrasted with a really bad oscillator trace. Baffled, because I could not replicate this experiment, I emailed Wes and asked him how he did it. Wes wrote we're able to see the noise in those traces because his SA featured a multiple pole, wideband filter with steep skirts that allows us to see the baseline noise close-in to the carrier. In contrast, most modern SAs feature synchronously tuned resonator type, or digital filters that produce a narrow peak with skirts that spread way out. The noise gets swept under the skirts.

By all means, advanced builders may apply notch filter techniques to measure oscillator sideband noise down low, however, a consideration for others might be to apply techniques proven to reduce noise and spurs — and just build the best oscillator possible plus measure what you can.

Some basic techniques to make a low-noise VCXO are well described elsewhere and may include: a high Q resonator, high Q varactors [with low series resistance], low power supply noise [including varactor tuning voltage], a low flicker noise amplifer, avoid overdriving the crystal and try to swing the highest AC voltage in the tank without reaching saturation and/or causing reverse breakdown in the varactor(s). Even the ratio of the Colpitts capacitors can affect phase noise, but without a method to measure phase noise, this gets esoteric. Some of these techniques also apply to VXOs.

Power Supply Noise

Bob, K3NHI and others have measured significant noise from the LM317 or related voltage regulators that we amateurs typically use. Power supply noise can FM our resonator and boost oscillator sideband noise. We may filter power supply noise with *large* value capacitors plus/minus series decoupling. See the work of Leif, SM5BSZ on this web page under the heading "The +12V supply is carefully decoupled like this". In addition, Charles Wenzel, published this web page.

I employed both techniques in my discussion schematic above. I went with the pi filter shown above 1000 µF - 39R - 1000 µF at the voltage input. A inductor might be used instead of the R if the voltage drop is too high for you. The Wenzel circuit fascinates me. The series resistor (18 Ω in my version) samples the current that flows into the oscillator. A voltage is then developed that is applied to the amplifier to generate a voltage that is out of phase with the noise current.

With good DC noise filtering I could measure small improvements in sideband noise in my SA despite only able to measure down to -88 dBc/Hertz at 10 KHz offset. In contrast, you rarely ever see even 1 electrolytic capacitor in the VXO schematics featured on many Ham radio builder sites.

Another trick is to avoid a regulator altogether. Since my DC supply already has a voltage regulator set to 12.2v, placing a second 5 to 8 volt regulator after it might just add another noise source.

Overdriving the Crystal

I heed the advice of Konstantinos, SV3ORA. He found that gently driving his crystal generated less noise and spurs compared to overdriving the crystal. Thus I adjusted my emitter resistor to about 1 mA current. For the schematic above, a typical emitter resistor starting value = 1K8. Just measure your emitter current.

I employed a large area, slower BJT, the BD139 to hopefully drop flicker noise. Expensive, super high Q crystals (Q = 500K to 1 million) may be driven with up to several mA of current, however, it's likely not so for the computer-grade xtals we typically use. I can't measure the outcome of these interventions, but System D thinking might just prevail.

Varactors

Varactors tend to be low Q and their Q deteriorates as we go up in frequency. I've seen very low phase noise VCXOs employing varactors, however, these were engineering marvels. Still, as a VHFer and hopeful UHF enthusiast, this is the direction I wish to go. We ideally need to keep some reverse DC voltage on the varactors at all times and not go to 0 — this also limits tuning range in our simple 12v supply radios. Read your datasheet. Air variable capacitors (a VXO) might be a better solution for your application.

How Does a VXO work?

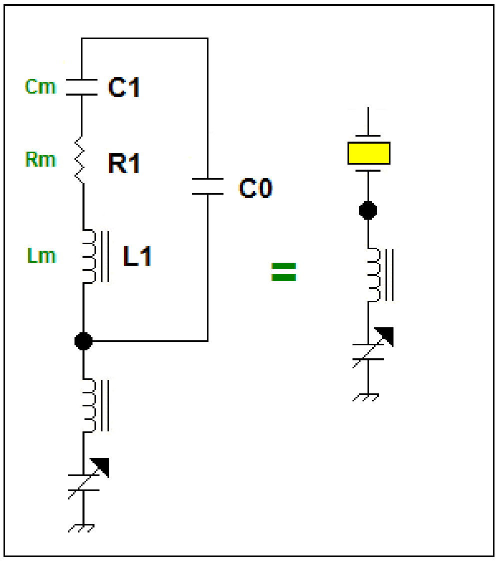
Cm
C1
Rm
R1
Lm
L1
C0
=

Above — The crystal equivalent electrical circuit has 2 arms: The impedance of the motional arm Zm lies in parallel with Zo, the impedance resulting from the parallel capacitance C0 (formed by the 2 crystal leads.) We measure and/or calculate these parameters when designing our crystal filters. In the above schematic I added the external L and C used to move the crystal's series resonant frequency around in our VXO, VCXO, or Super VXO circuits.

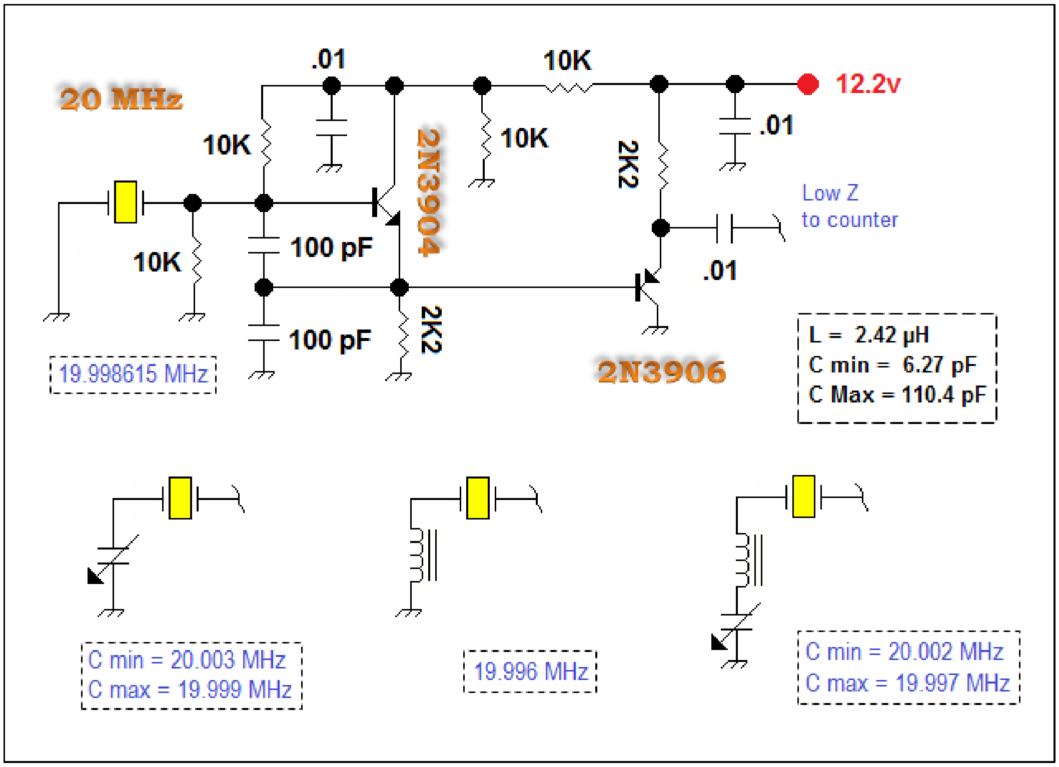
20 MHz
.01
10K
12.2v
10K
10K
2N3904
2K2
.01
Low Z
to counter
10K
100 pF
.01
100 pF
2K2
19.998615 MHz
2N3906
L = 2.42 µH
C min = 6.27 pF
C Max = 110.4 pF
C min = 20.003 MHz
C max = 19.999 MHz
19.996 MHz
C min = 20.002 MHz
C max = 19.997 MHz

Above — I made some simple experiments to explain why we place both a L and C in series with the crystal and how it changes the crystal frequency in our oscillator. From these experiments, some theory from EMRFD and wisdom from Ken Kuhn, I made the following simple conclusions:

Electrically a crystal looks like a large inductance in series with a small capacitance and in parallel with C0. An external inductor adds to the crystal's series inductance and *lowers* the resonant frequency.

The external variable capacitor adds in series with the crystal internal capacitance to lower the net capacitance and *raise* the resonant frequency.

The purpose of adding an external inductor is so that we can tune both lower and higher than the natural crystal frequency. In contrast, if we only apply an inductor, the oscillator frequency would always be lower and if we just apply a capacitor, the oscillator frequency would always be higher.

Since the external inductance has much lower Q than the effective internal inductance, it adds to noise and signal losses. The same goes for the external C.

As we raise the inductance ever higher to boost the delta F, at some point, the parallel C of the crystal resonates with this "too high" L and the series resonant frequency has nothing to do with the series resonance of the crystal. This kills the normally sublime frequency stability of a crystal-based oscillator.

Q of the VXO/VCXO Inductor

I experimented to learn that the Q of that L doesn't need to be that high to allow the frequency to be moved up or down by an air variable cap or varactor.

For example, if I wound a coil on a T68-2 and shunted it with a resistor no less than 1K8 — it worked fine (sometimes the frequency shift would even improve 2-3 KHz for a given L). A #61 ferrite toroid wound inductor also worked well and requires much less turns allowing thicker wire for mechanical stability. Also, the lower number of turns helps avoid significant SRFs. Temperature stability remains a question with the this and all ferrites.

An FT37-43 or FT50-43 ferrite inductor worked poorly – I measured high signal losses plus the maximum frequency swing dropped when compared to the same inductance value wound on a T-68-2, or FT-50-61. Avoid #43 ferrites in any resonator circuit unless you're purposely building a noisy oscillator for learning purposes.

Some guys use those little molded chokes with a Q of ~ 50 for the L and they also work well. Predictably, as I lowered the Q of the external L, or went from an air variable C to a varactor, signal losses increased resulting in lower signal output amplitude.

Decreasing resonator Q increases phase noise. For a popcorn radio, I'm not sure the change in phase noise would be a deal breaker in some homebrew projects, but as possible, I think it's wise to employ high Q resonator components: crystal, inductor and the variable capacitance. Thus I'll wind my VXO/VCXO inductors on powdered iron toroids hereafter.

Since a quartz crystal resonator is driven by the piezoelectric effect, fundamental plus overtone frequency modes (3/5/ 7/11) may be derived. I unbypassed the collector and placed a collector choke on it to examine the output with my 'scope. The waveform rung with many harmonics. Lots to learn.

Go débrouillards!

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4. Funster Line — A Simple 40M Band QRP Trans-receiver

Click for the Funster transmittter notes.

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5. Miscellaneous Photographs and Figures

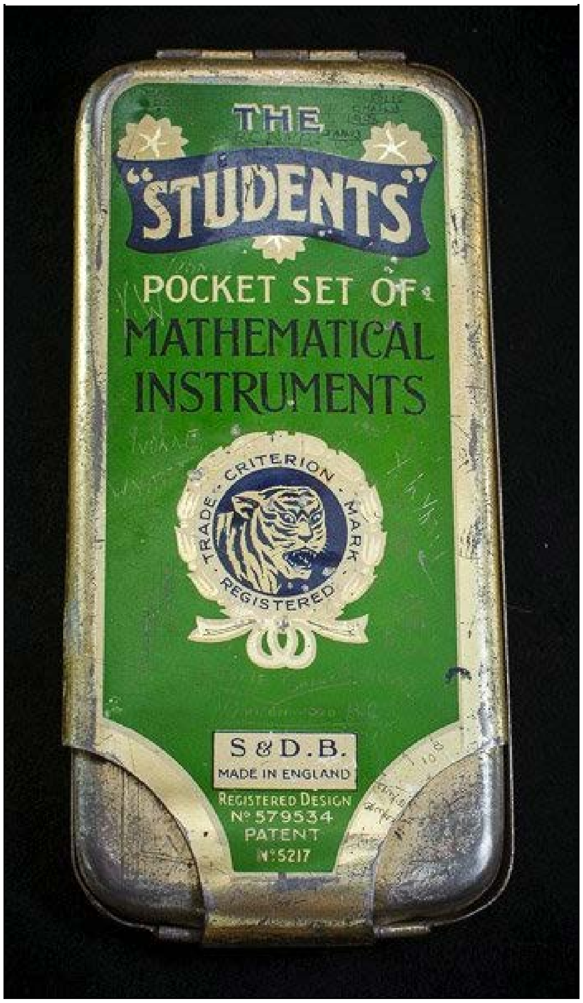

Above — My handed-down geometry set — purchased in 1938. Click for larger picture.

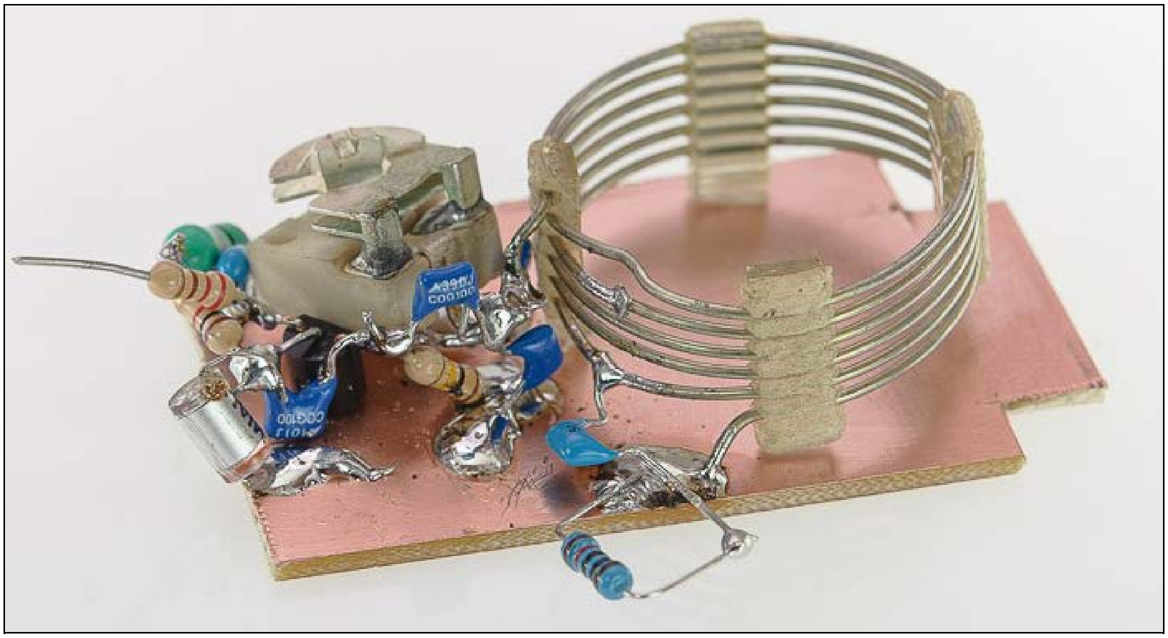

Above — My prototype Colpitts LC oscillator with only a 10K resistor as the load.

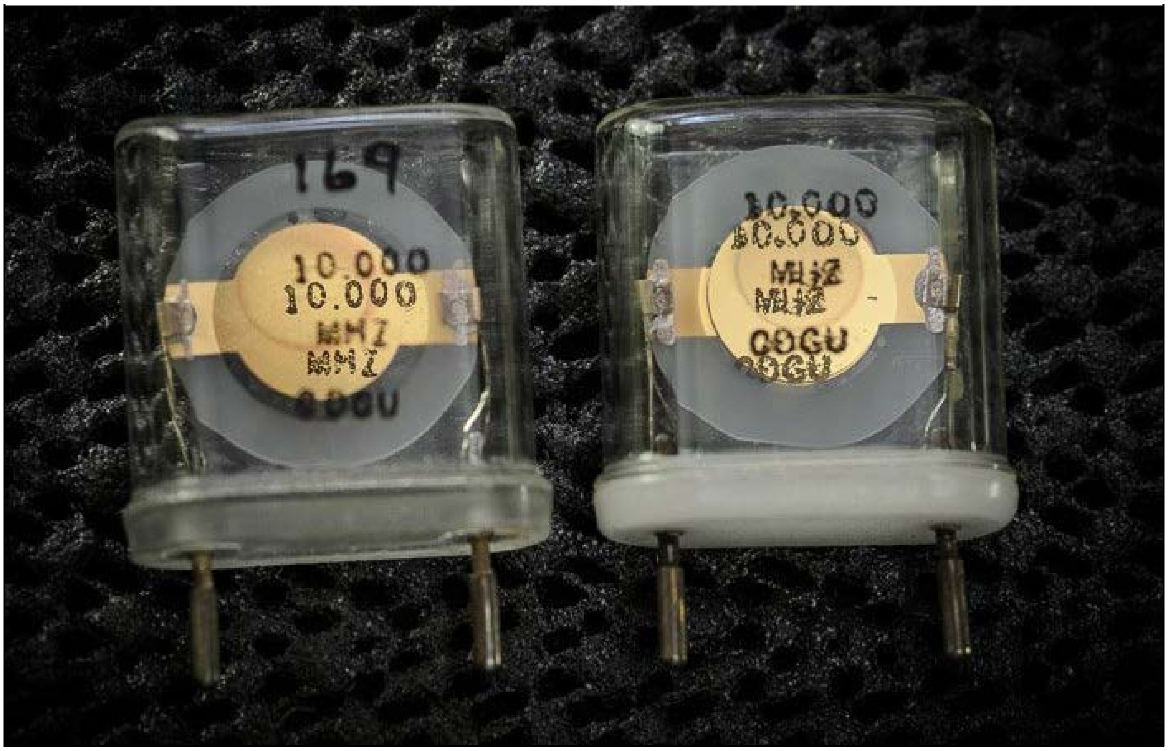
169
10.000
10.000
MHZ
MHZ
CQGU
10,000
10.000
MHZ
MHZ
CQGU
CQGU

Above — Hi Q glass encased crystals. Click for another photo.

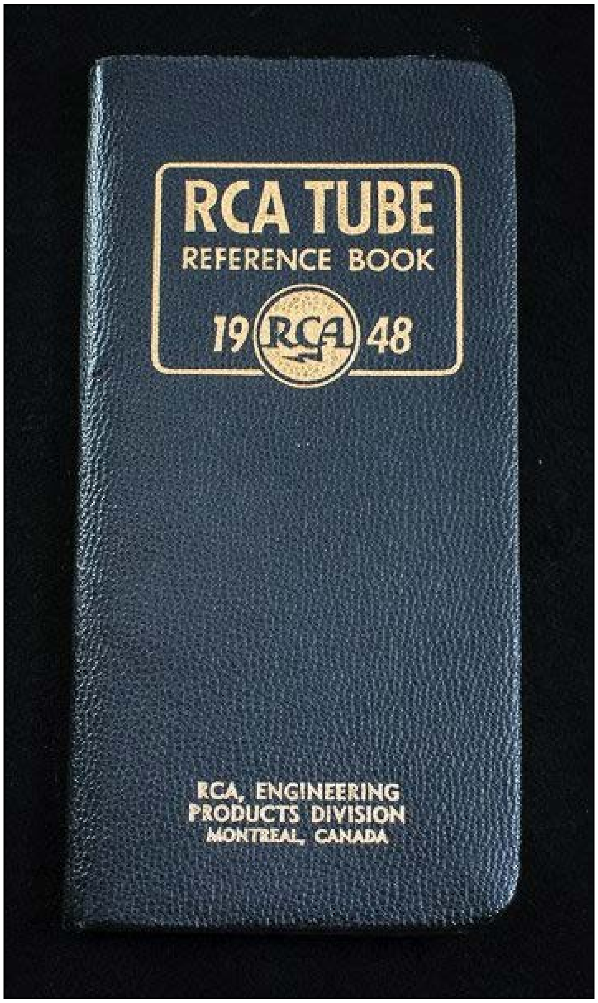
RCA TUBE
REFERENCE BOOK
19
RCA
48
RCA, ENGINEERING
PRODUCTS DIVISION
MONTREAL, CANADA

April 2014: New player on the scene — Bar Bar Kitty — chief science officer and QC consultant.

April 2014: Other new pet: Munchkin. Clear-spoken and direct — pet me, or feed me... and oh yah, Q2 is oscillating.

MP143
CTS5C0315

RF — Test and Measurement

Caitlyn 310 — UHF Beginnings

Marker
7.070000 MHz
-1.42 dB

Respository web page for beginner UHF experiments in 2014-2015.

1. References
2. Transistors, RFCs, Capacitors and a 50 Ω Detector
3. Return Loss Bridge Experiments
4. VCO Experiments
5. Frequency Counter Kit

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1. References

After a modest quest, I found an excellent microwave primer called Microwaves Made Simple. Principles and Applications by W. Stephen Cheung and Fred H. Levien. Published in 1985, the authors brilliantly teach the basics in plain language (no small task). My copy was printed in December 2013 by Artech House who print single copies of many classic texts on demand. Click for a photo of my book.

The ARRL published 2 UHF compendium books entitled: The ARRL UHF / Microwave Experimenters Manual [1990] and The ARRL UHF / Microwave Projects Manual [1994]. While out of print, used copies seem prevalent and might serve as good resources for builders who hunger for circuits and Ham-related UHF circuit building information. Click and click for photos.

Instrument companies provide continuing education and materials to educate & support their customers. With luck you'll find helpful free application notes and other tools. Two recent RF library additions include an Agilent CD containing all their current application notes and webcasts [my image is truncated and the CD includes applying SA's, 'scopes and signal generators], and this old Spectrum Analyzer Fundamentals booklet by Tek.

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2. Transistors, RFCs, Capacitors and a 50 Ω Detector

I want to grasp circuits from 300 to 1296 MHz. This meant acquiring some UHF parts, making some bench tools and buying a 50 Ω detector to sweep and/or measure power in my UHF stages. Click for a snapshot of some of my parts cabinets.

BJTs

I'll employ the BFR93A, 2SC3356, and 2SC3583 as my mainstay NPN bipolars; at least to start with. Numerous transistors will work — price, availability, NF and shipping costs informed my choice. I'd also feel happy with MRF901, BFR92 and BFR96 NPNs and it's always fun reading datasheets. My PNP choice = BFT93 by NXP. Later on, I'll add in discrete GaASFET and other non-BJT species. Only 2 MMICs lie in the parts cabinet: MAR-3 and MGA-61563.

Radio Frequency Chokes (RFC)

Although, I'll also wind, or perhaps ply carefully dimensioned copper board traces to make RF chokes, I built up a stock of lower Q chip inductors in size 0805 and 0603. These include 8.2 nH, 33 nH, 68 nH, 220 nH, 330 nH, 470 nH and a few other values. For RFCs we need to consider L, tolerance, SRF, Q , maximum current and temperature stability — it's probably better to only buy clearly specified parts so you can study their datasheet to glean this information. I've swept nearly all my RFCs and recorded their SRF.

Choosing RFCs — SRF (series resonant frequency)

An RF choke exerts its greatest impedance at its SRF and in the case of a first-order RFC such as a single inductor, we should aim the SRF at or near the frequency we wish to attenuate the most. Consider a choke in the emitter lead of a BJT Colpitts oscillator with a frequency range from 375 to 400 MHz: The choke's ideal SRF should lie somewhere above 400 MHz. As possible, the SRF of a first-order RFC should exceed the operating frequency of the device it's choking.

In higher-order filter applications such as a C-L or C-L-C (pi filter) applications, engineers tend to target the choke's SRF to >= 10 times the operating frequency. Challenges such as limited inductor choices, needing to match stages, or coping with stray reactances will arise, however, as amateur UHFers, we just try our best to fit an RFC.

UHF Capacitors

I swept numerous size 0805 + some 0603 and 1206 capacitors in a microstrip line jig to determine their SRF. Math formulas enable us to calculate and plot attentuation, Q and ESR at self-resonance if we wish. Click for 1 example. Although we rarely apply capacitors at their SRF in practical circuits, considering Q, ESR and attenuation gets us thinking that capacitor SRF is a dynamic value that may vary widely with part size, capacitance and datasheet specified Q.

For instance, if you take a size 1206 capacitor, measure its SRF and then replace it with a same-value size 0805 capacitor, the SRF of these two caps might vary by as much as 200 MHz or more. Size does matter! Even the same value capactor by a different manufacturer may be a SRF game changer. Bob, K3NHI tells it correctly: to measure *is* to know.

Datasheet specified capacitor Q is usually measured at a low frequency like 1 MHz. Since Q decreases as frequency increases, a capacitor that specs a Q of 2500 at 1 MHz may only sport a Q of 87 at its SRF way up at 512 MHz. During sweeps, I measured a deeper attenuation notch and often a higher SRF for "very high Q" caps when compared to the common, low-medium Q, popcorn caps sold as mystery parts by online stores or auctions. I'm now hypervigilent about finding very high Q SMD capacitors for sale at a low price.

I wrote the SRF of all my SMD caps in my notebook and use this data to inform my capacitor choice for RF bypass and tuning. Click for a photo of 3 UHF parts drawers. I've pretty much gone to size 0805 caps to try and garner a higher SRF at VHF and UHF. Still, too, we might have to solder down 0603 parts up above 1 GHz. Yikes!

Did you notice that when you drop a 0805 part on the floor, you never ever find it again? Even a little cough can expunge a size 0603 part from your QRP workbench.

50 Ω Detector

From 0.5 - 200 MHz, my 50 Ω terminated input DSO forms the heart of my test bench. An analog, or digital storage oscillocope with a bandwidth >= 1 GHz, plus a suitable wideband probe costs dearly and for many, won't be an option. UHF bandwidth, thermistor-based 50 Ω power meters are also expensive and lack signal viewing.

Thus, a spectrum analyzer seems the best choice for the amateur UHF enthusiast. A spectrum analyzer with a built-in tracking generator adds serious value — giving us a MF-UHF sweep system with profound utility. One popular, modern TG + SA choice is the Rigol DSA-815. I'm fortunate to have access to gear that measures up to 3 GHz.

3. Return Loss Bridge Experiments (RLB)

I'd be lost without a return loss bridge at UHF. Directivity marks the touchstone of a return loss bridge — and up at UHF grabbing a minimum 20 dB directivity may pose quite a challenge. Experiments to find a bridge with good directivity from 250 to 1750 MHz follow:

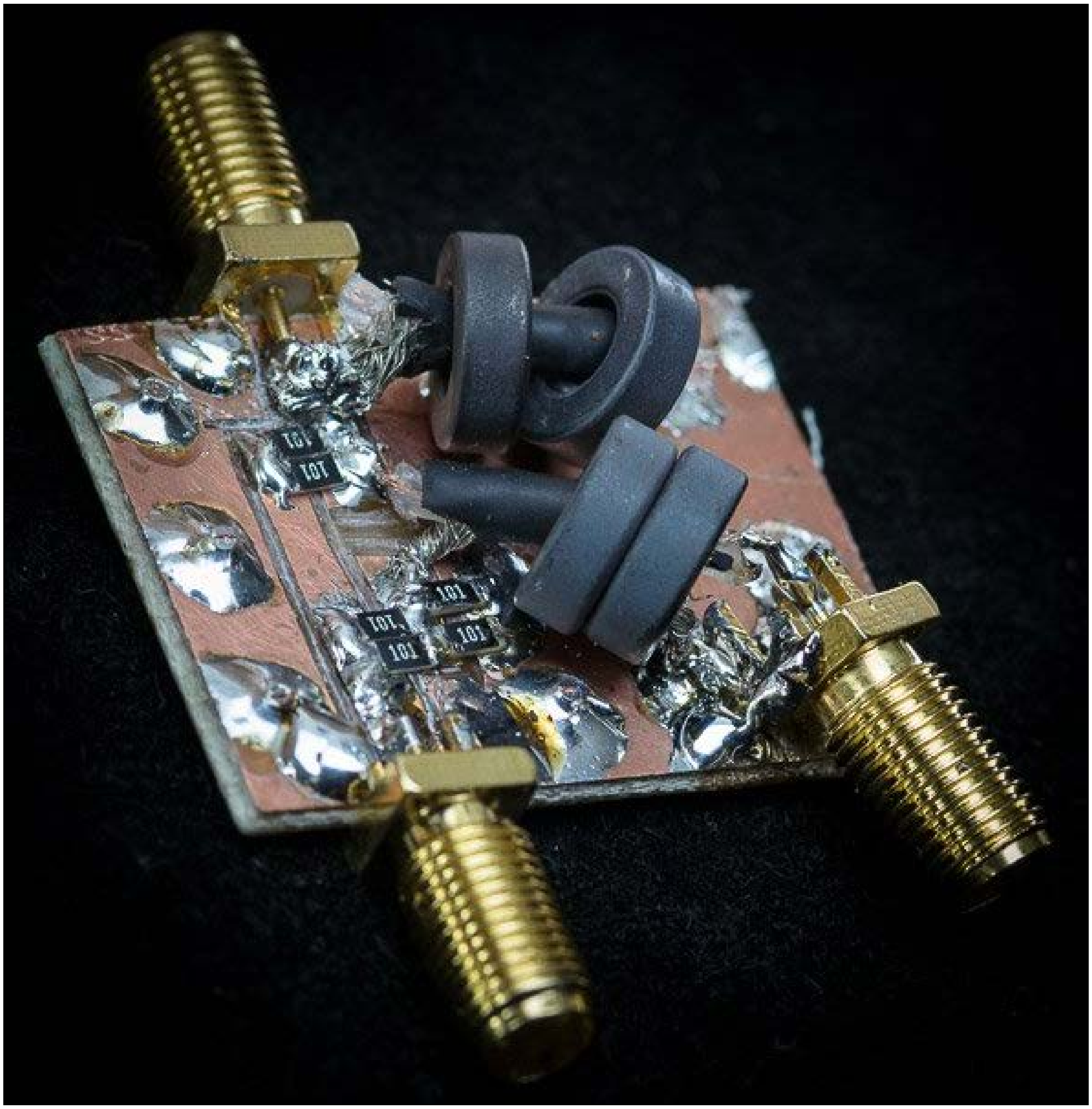

Above — A macro photo of RLB#1: 1 of the 3 "string of pearls" type return loss bridge built this Winter. I tried different numbers, sizes and mixes of ferrites. This particular bridge had 3 and then 2 FT37-61 toroids as shown, although I did not shorten the RG-174 coax when reducing to 2 toroids. The 61 mix gave poor directivity and was abandoned.

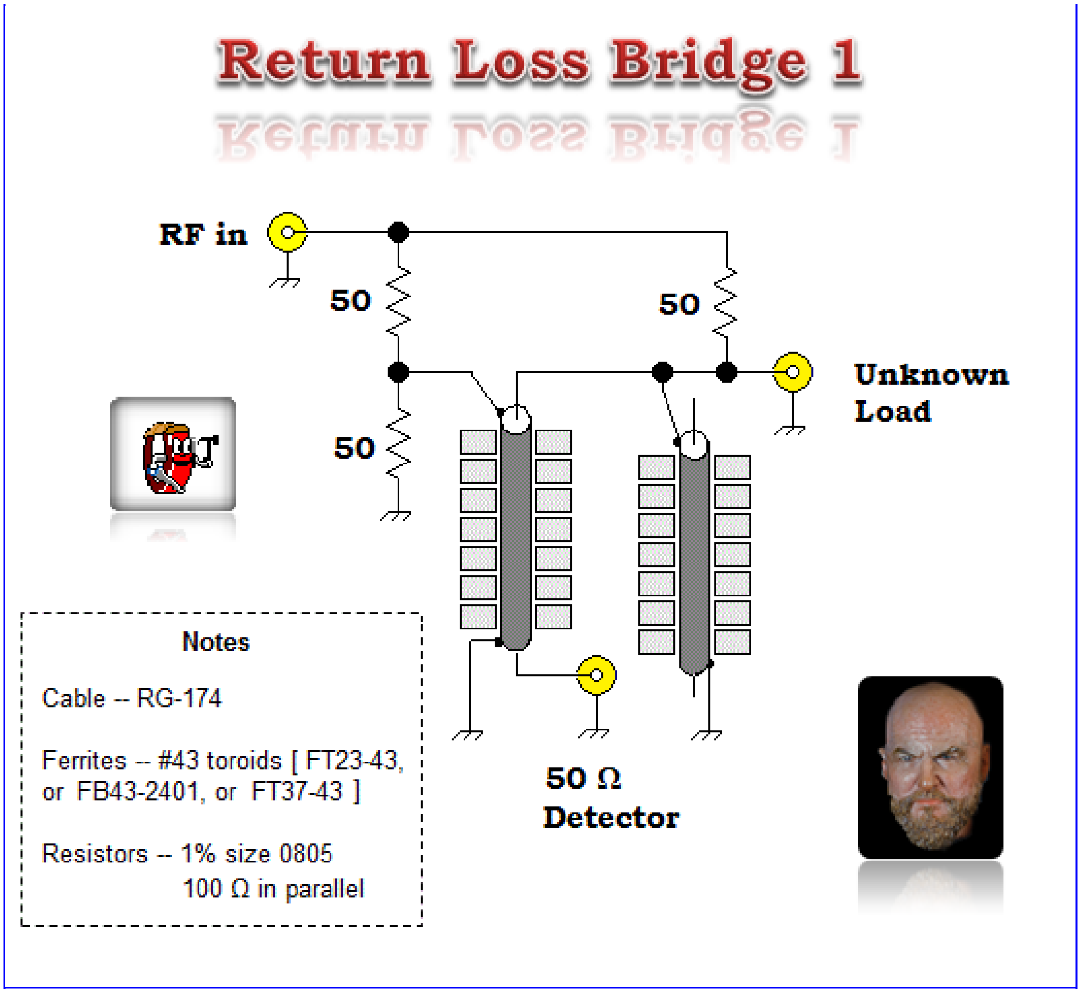

Notes

Cable -- RG-174

Ferrites -- #43 toroids [FT23-43, or FB43-2401, or FT37-43]

Resistors -- 1% size 0805
100 Ω in parallel

Above — Return loss bridge #1: the "string of pearls" variant. Several web sites feature great "string of pearls" RLB experiments for you to review and many place enough ferrite to extend from HF to UHF. I swept each of my builds in a Rigol tracking generator + spectrum analyzer with 4 frequency markers set. I made an open-circuit sweep [nothing on the unknown impedance port] followed by a sweep with a Mini-Circuits Labs DC - 18 GHz, 50 Ω load threaded on the unknown Z port. The difference between the open-circuit and 50 Ω measurement = the directivity at that frequency.

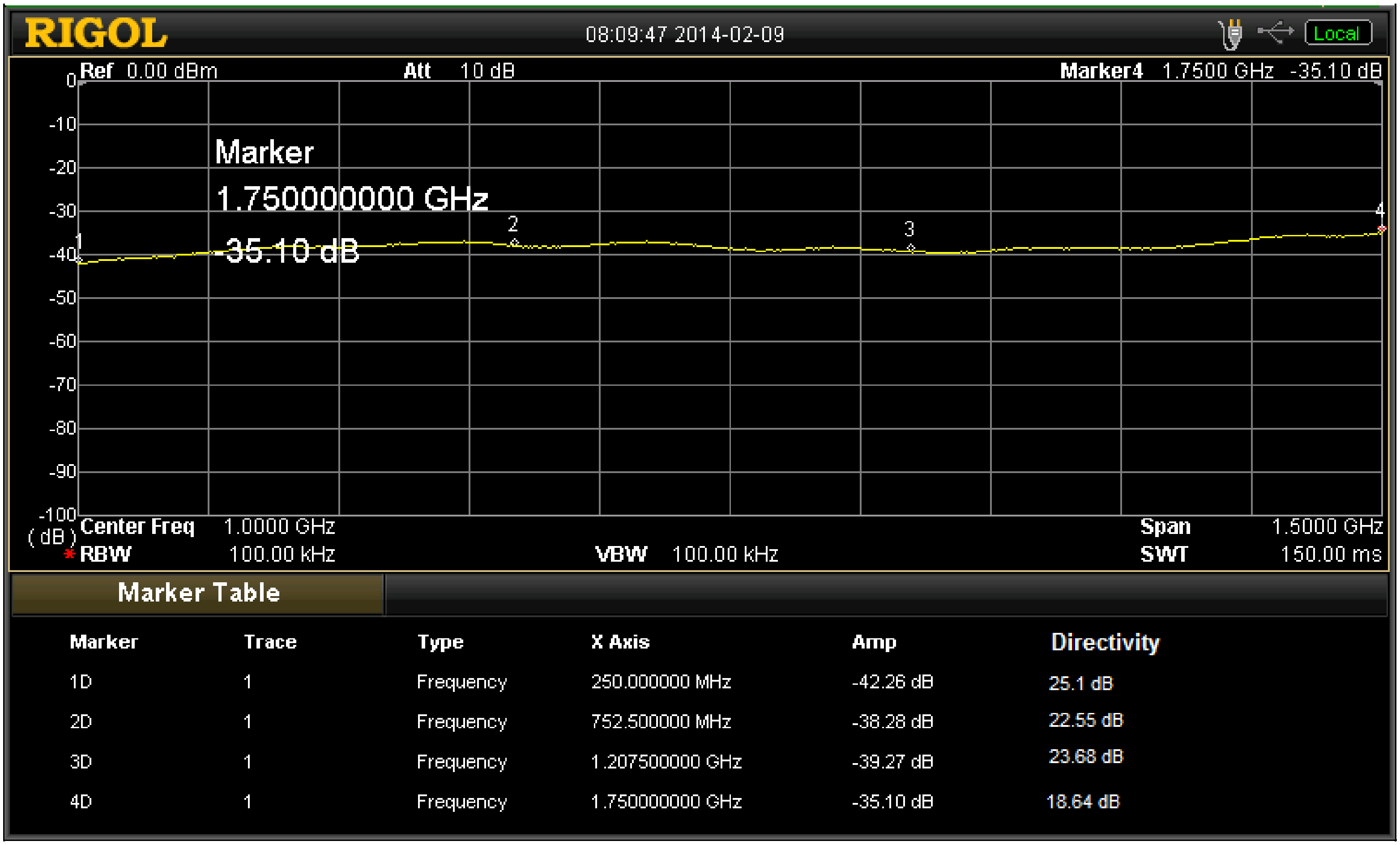
RIGOL
08:09:47 2014-02-09
Local
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
(dB)
Marker
1.750000000 GHz
-35.10 dB
1
2
3
4

Ref 0.00 dBm **Att** 10 dB **Marker4** 1.7500 GHz -35.10 dB

Center Freq 1.0000 GHz **Span** 1.5000 GHz

RBW 100.00 kHz **VBW** 100.00 kHz **SWT** 150.00 ms

Marker Table

Marker	Trace	Type	X Axis	Amp	Directivity
1D	1	Frequency	250.000000 MHz	-42.26 dB	25.1 dB
2D	1	Frequency	752.500000 MHz	-38.28 dB	22.55 dB
3D	1	Frequency	1.207500000 GHz	-39.27 dB	23.68 dB
4D	1	Frequency	1.750000000 GHz	-35.10 dB	18.64 dB

Above — The sweep of my best "string of pearls" bridge from 250 MHz to 1.75 GHz showing the directivity at 4 frequency points. Click for the open circuit sweep. I felt encouraged by this sweep with five FB43-2401 beads over each piece of coax cut just long enough to fit the beads. I built on 2-sided FR4 copper clad board with at least 6 via wires connecting the 2 copper surfaces.

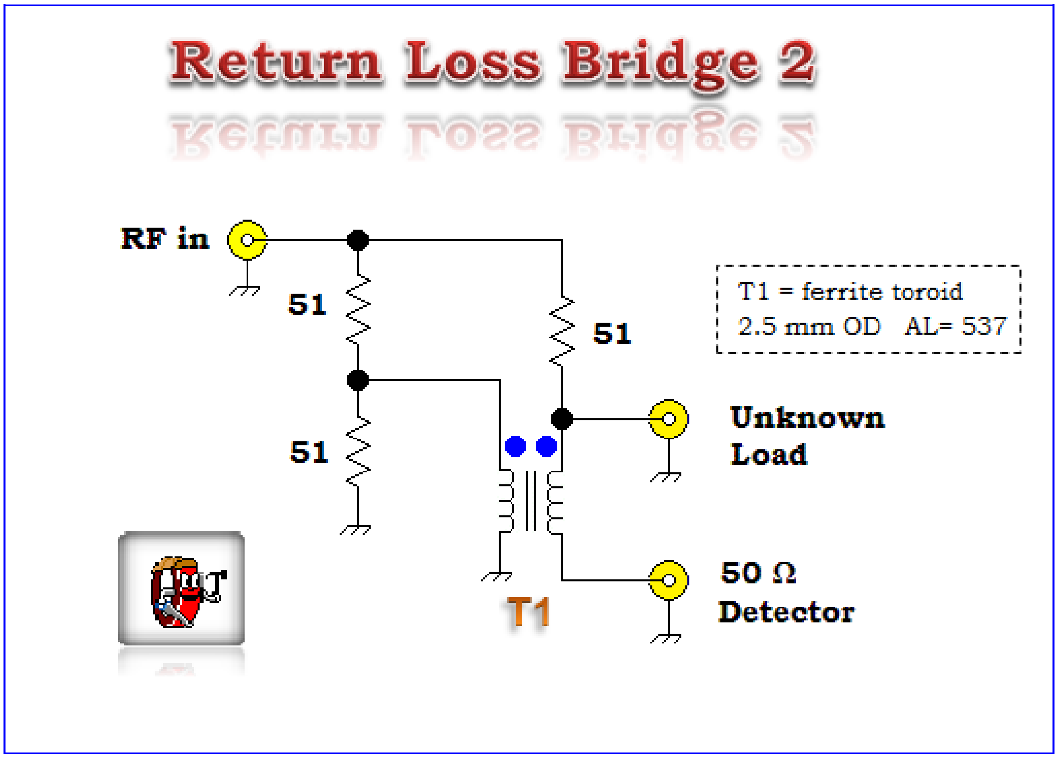
Return Loss Bridge 2
RF in
51
51
51
T1 = ferrite toroid
2.5 mm OD AL= 537
Unknown
Load
50 Ω
Detector
T1

Above — Schematic of RLB #2: the bridge topology featured in EMRFD. T1 = 5 bifilar windings of 32 gauge wire wound on a *tiny* ferrite toroid boasting a strong AL. I pulled this ferrite from a blown up mixer removed from an old 1.5 GHz spectrum analyzer. I started with 5 toroids, but during winding, got spastic and dropped 2 of them on the floor and concluded that the SMD part gnome who lurks beneath my bench swallowed them up, since I couldn't find them after an intensive search.

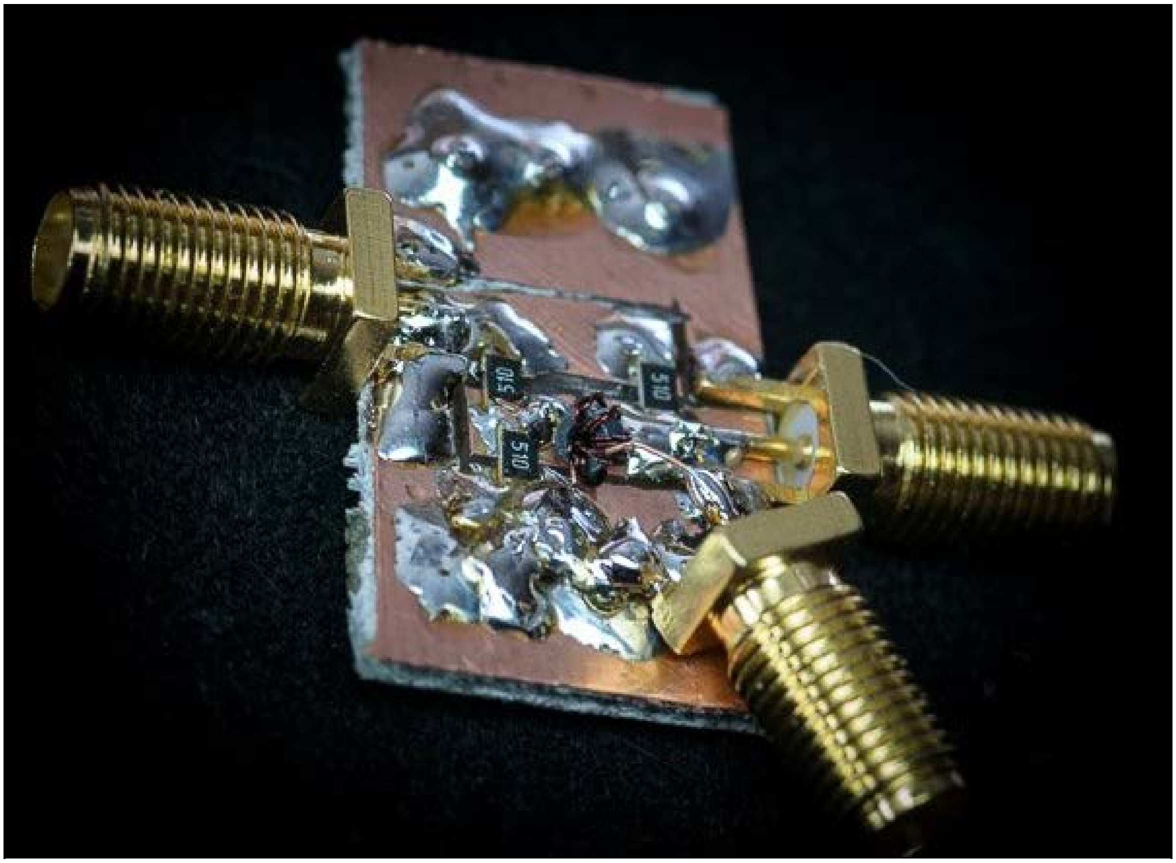

Above — Magnified return loss bridge #2 breadboard. Serious UHF enthusiast Paul Wade, W1GHz found that the smaller your breadboard, the better the UHF directivity in his bridge experiments: My findings support his. In RLB #2, I went with plain, size 1206, 5% resistors. I just ordered some size 0603 49.9 Ω 1% resistors for future experiments in my quest to make my ultimate UHF RLB.

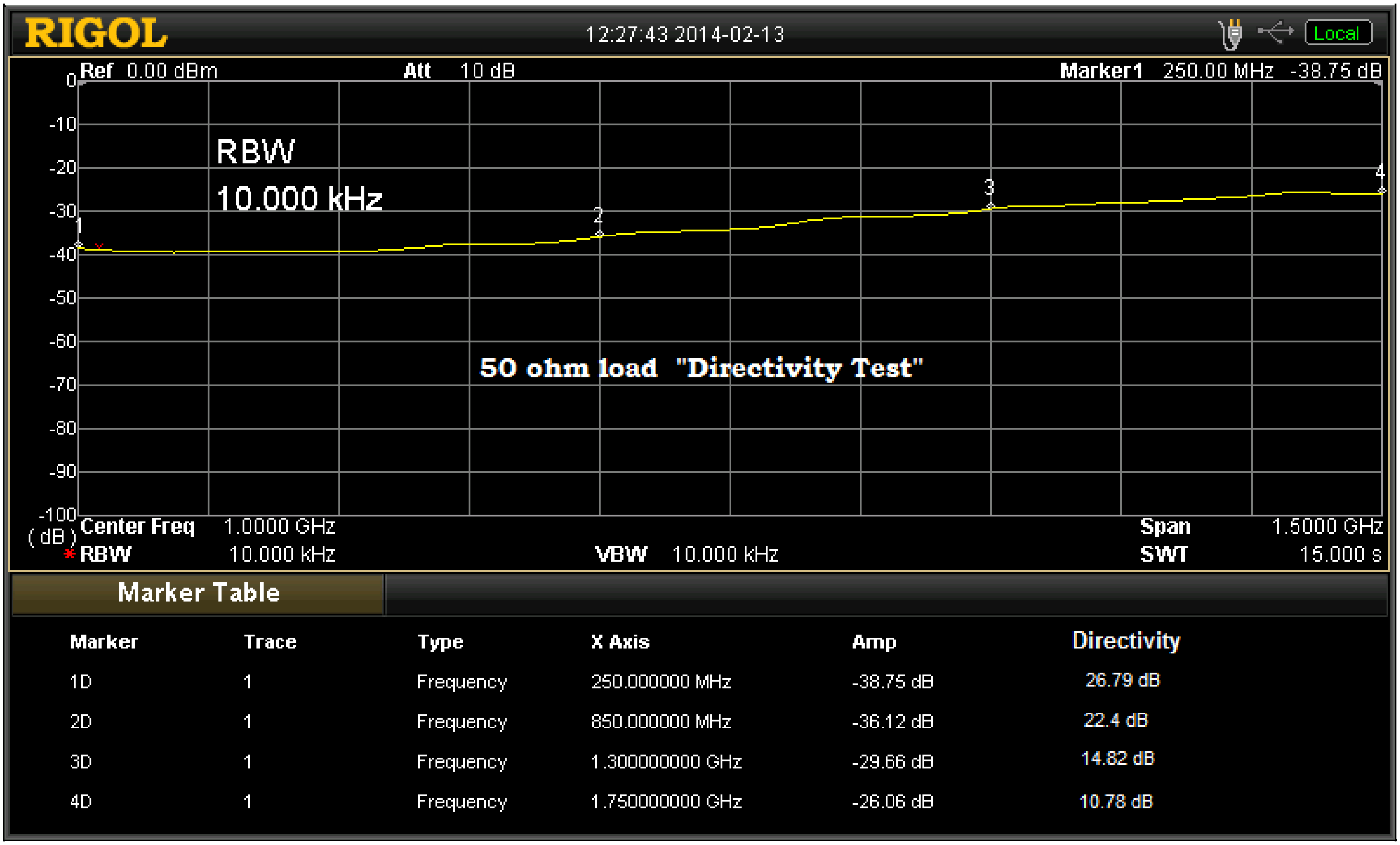
RIGOL
12:27:43 2014-02-13
Local
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
(dB)
RBW
10.000 kHz
50 ohm load "Directivity Test"
1
2
3
4
Marker Table

Ref 0.00 dBm
Att 10 dB
Marker1 250.00 MHz -38.75 dB
Center Freq 1.0000 GHz
Span 1.5000 GHz
RBW 10.000 kHz
VBW 10.000 kHz
SWT 15.000 s

Marker	Trace	Type	X Axis	Amp	Directivity
1D	1	Frequency	250.000000 MHz	-38.75 dB	26.79 dB
2D	1	Frequency	850.000000 MHz	-36.12 dB	22.4 dB
3D	1	Frequency	1.300000000 GHz	-29.66 dB	14.82 dB
4D	1	Frequency	1.750000000 GHz	-26.06 dB	10.78 dB

Above — The sweep of RLB #2 from 250 MHz to 1.75 GHz showing the directivity at 4 frequency points. Above ~900 MHz, directivity falls right off, so this bridge won't cut it for a serious UHF bench. I tried reducing T1 to 3 bifilar windings but this worsened the directivity. Click for a different sweep of RLB # 2 from 50 MHz to 1.5 GHz. Directivity = 27.5 dB at 50 MHz, so this bridge would work great for VHF. I imagine that SMD 49.9 Ω 1% resistors might boost directivity a little.

Of course, we're always impressed by the work of Kostas , SV3ORA.

Return Loss Bridge 3

Some experiments with the 3-bead RLB from Sam Wetterlin follow:

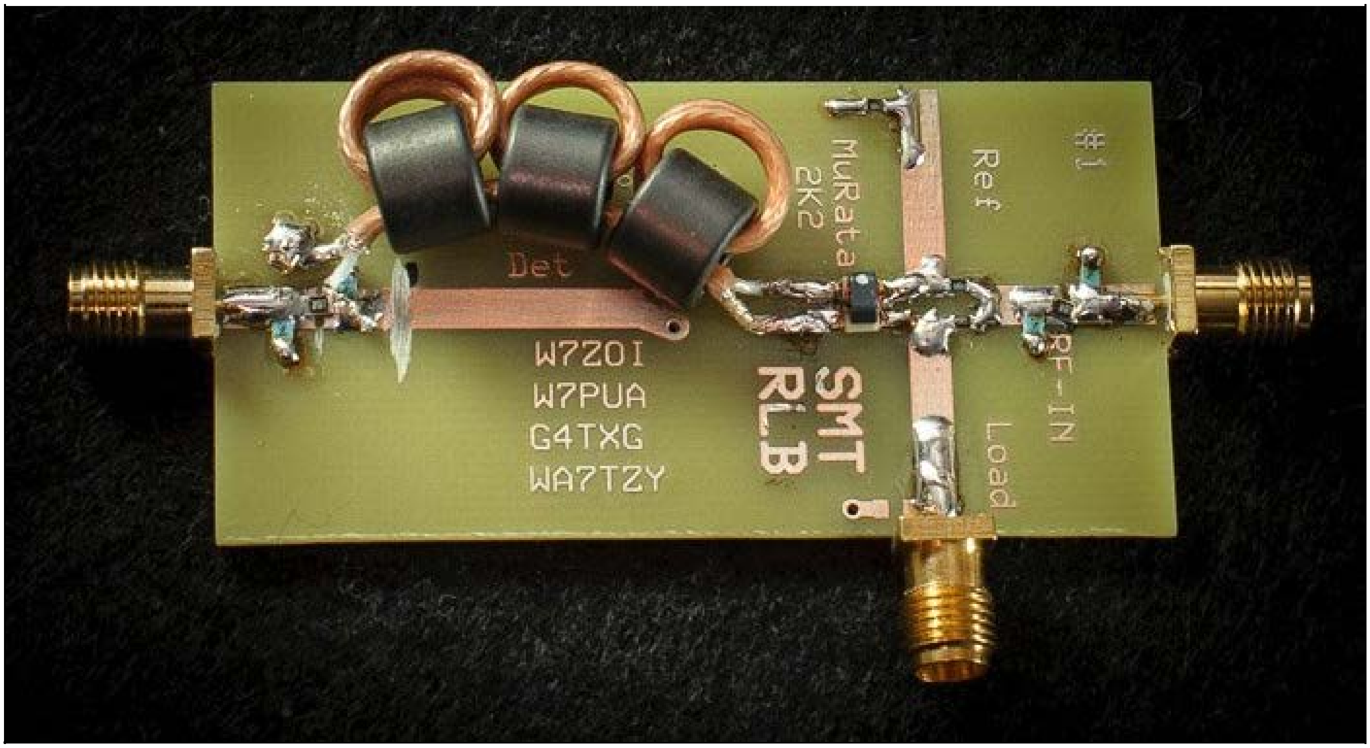
MuRata
2K2
Ref
#1
Det
W7ZOI
W7PUA
G4TXG
WA7TZY
SMT
RLB
RF-IN
Load

Above — My build of the Wetterlin 3-bead return loss bridge. This PC board was the only 1 left over from a 2006 joint project between the 4 Hams whose calls are etched on the PCB. Wes sent me this board and some of the parts and I'm grateful. My 3 dB pads = 294 Ω 1% resistors plus an 18 Ω 5% in size 0805. My 49.9 Ω 1% resistors = size 0603. The transformer = a Minicircuits Labs TC1-1-1-13M+. Click for the ferrite description. I used 24 gauge copper via wires to connect grounded nodes to the ground plane on the back of the PC board. I chose to permanently solder a 49.9 Ω resistor on the reference port.

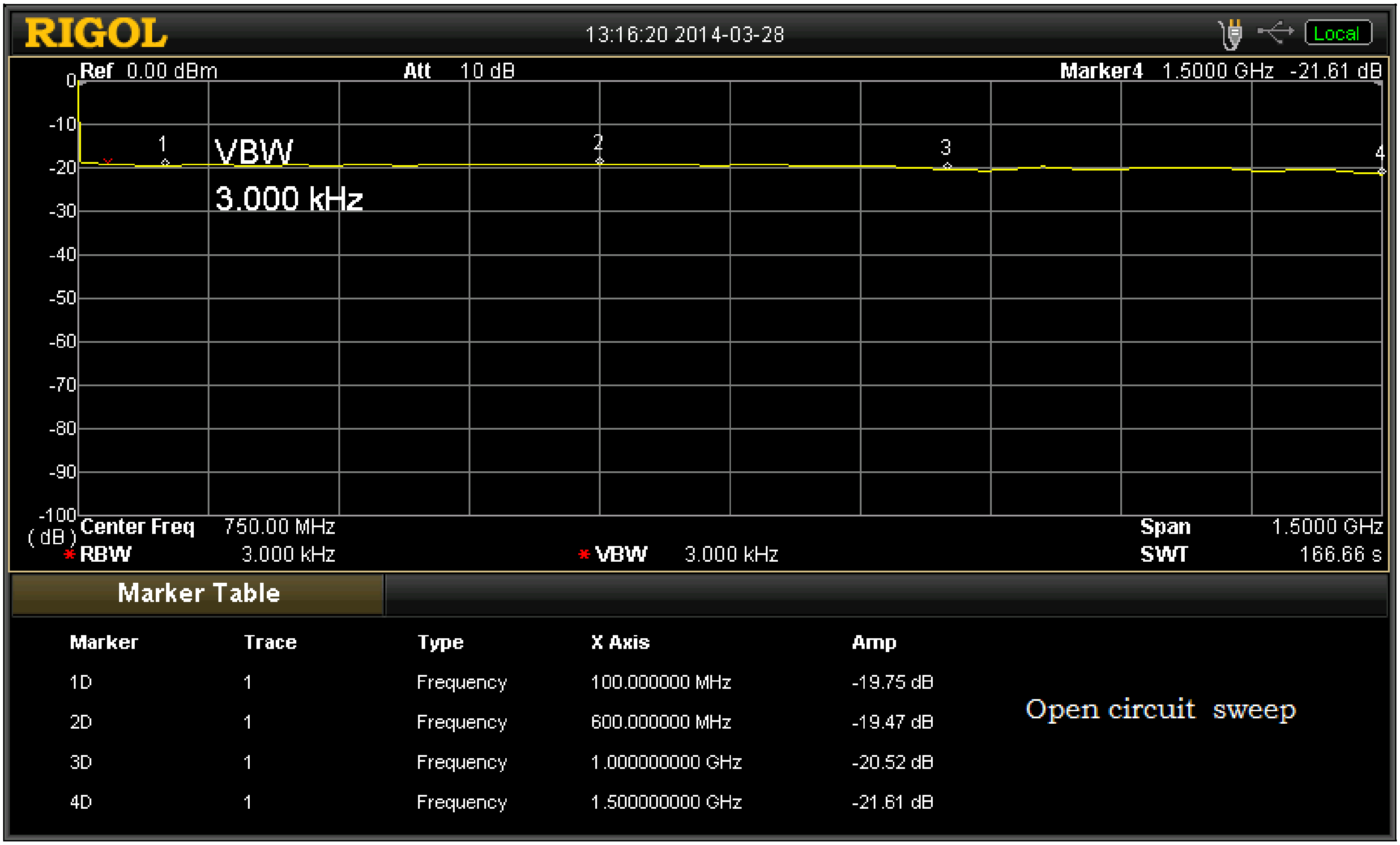
RIGOL
Local
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
(dB)
1
2
3
4
VBW
3.000 kHz

13:16:20 2014-03-28

Ref 0.00 dBm
Att 10 dB
Marker4 1.5000 GHz -21.61 dB

Center Freq 750.00 MHz
Span 1.5000 GHz
RBW 3.000 kHz
VBW 3.000 kHz
SWT 166.66 s

Marker Table

Marker	Trace	Type	X Axis	Amp
1D	1	Frequency	100.000000 MHz	-19.75 dB
2D	1	Frequency	600.000000 MHz	-19.47 dB
3D	1	Frequency	1.000000000 GHz	-20.52 dB
4D	1	Frequency	1.500000000 GHz	-21.61 dB

Open circuit sweep

Above — Open circuit sweep with 4 markers set. Span = 1.5 GHz.

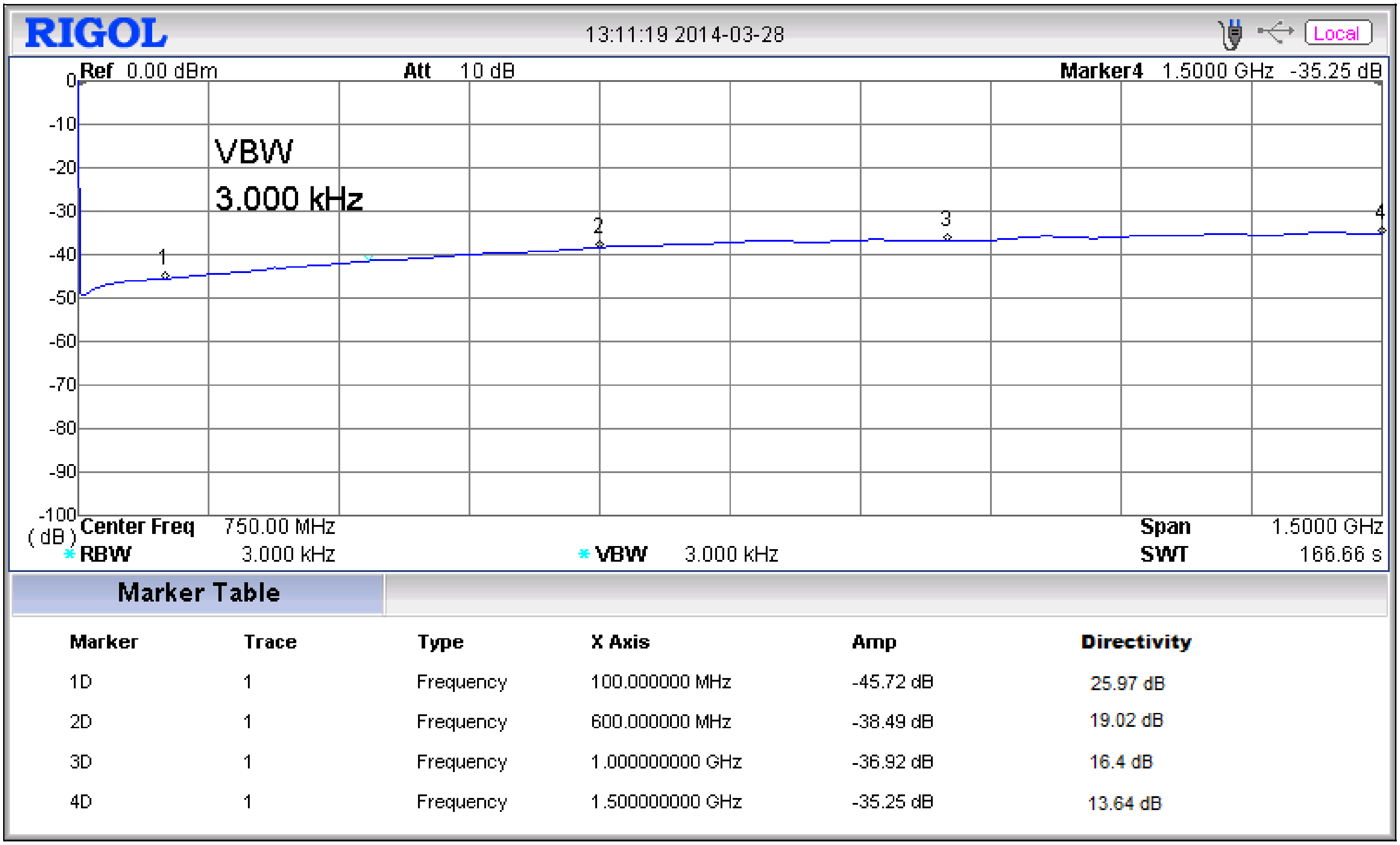
RIGOL
Local
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
(dB)
1
2
3
4

13:11:19 2014-03-28

Ref 0.00 dBm Att 10 dB Marker4 1.5000 GHz -35.25 dB

VBW
3.000 kHz

Center Freq 750.00 MHz Span 1.5000 GHz
RBW 3.000 kHz VBW 3.000 kHz SWT 166.66 s

Marker Table

Marker	Trace	Type	X Axis	Amp	Directivity
1D	1	Frequency	100.000000 MHz	-45.72 dB	25.97 dB
2D	1	Frequency	600.000000 MHz	-38.49 dB	19.02 dB
3D	1	Frequency	1.000000000 GHz	-36.92 dB	16.4 dB
4D	1	Frequency	1.500000000 GHz	-35.25 dB	13.64 dB

Above — 50 ohm load termination sweep with calculated directivity. Click for the 50 Ω sweep where the span = 200 MHz. I was disappointed with the UHF directivity in *my* build.

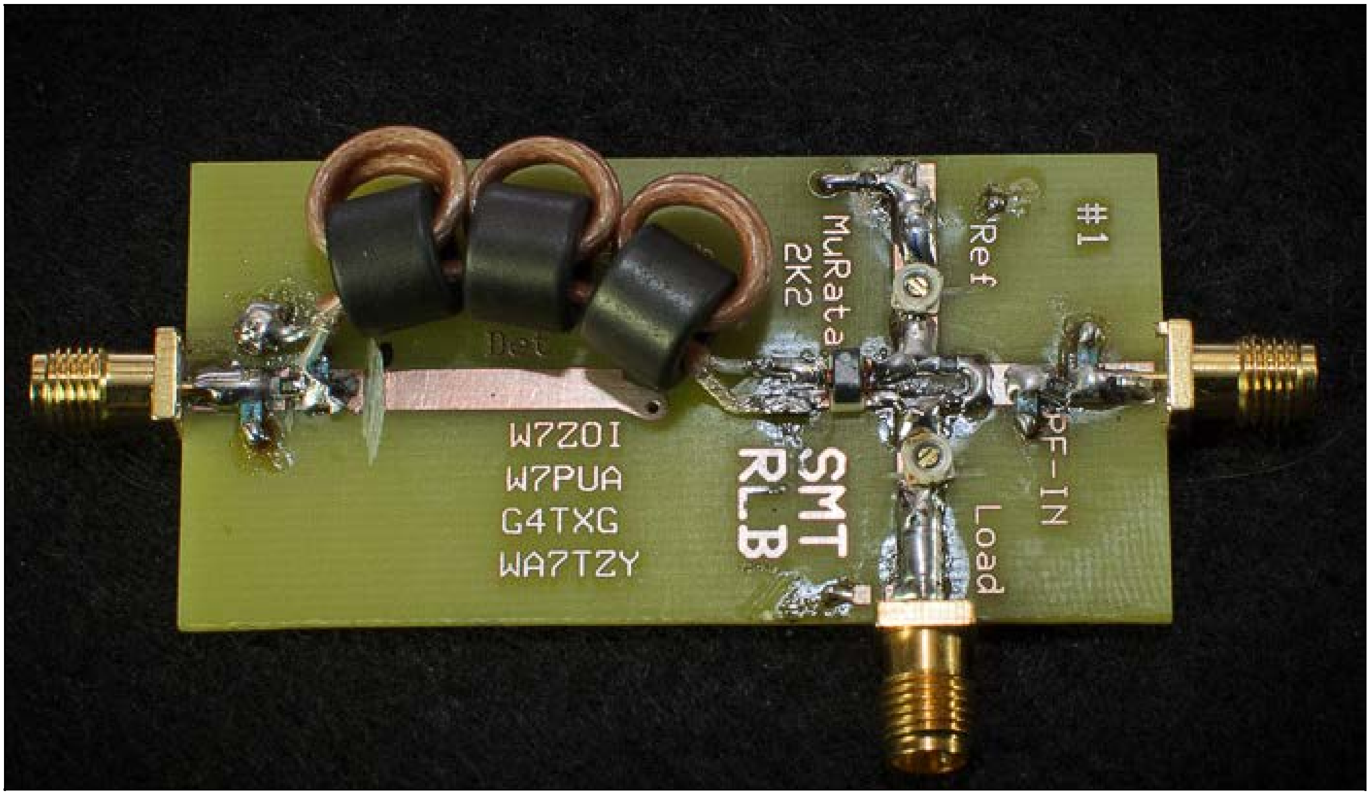
MuRata
2K2
Ref
#1
Det
W7ZOI
W7PUA
G4TXG
WA7TZY
SMT
RLB
RF-IN
Load

Above — The 3-bead RLB with added series trimmer capacitors on the load and reference ports. SMT trimmer caps = Voltronics JR300 5.5-30 pF with a Q of 1500. I tried both shunt and series caps to try and boost UHF directivity.

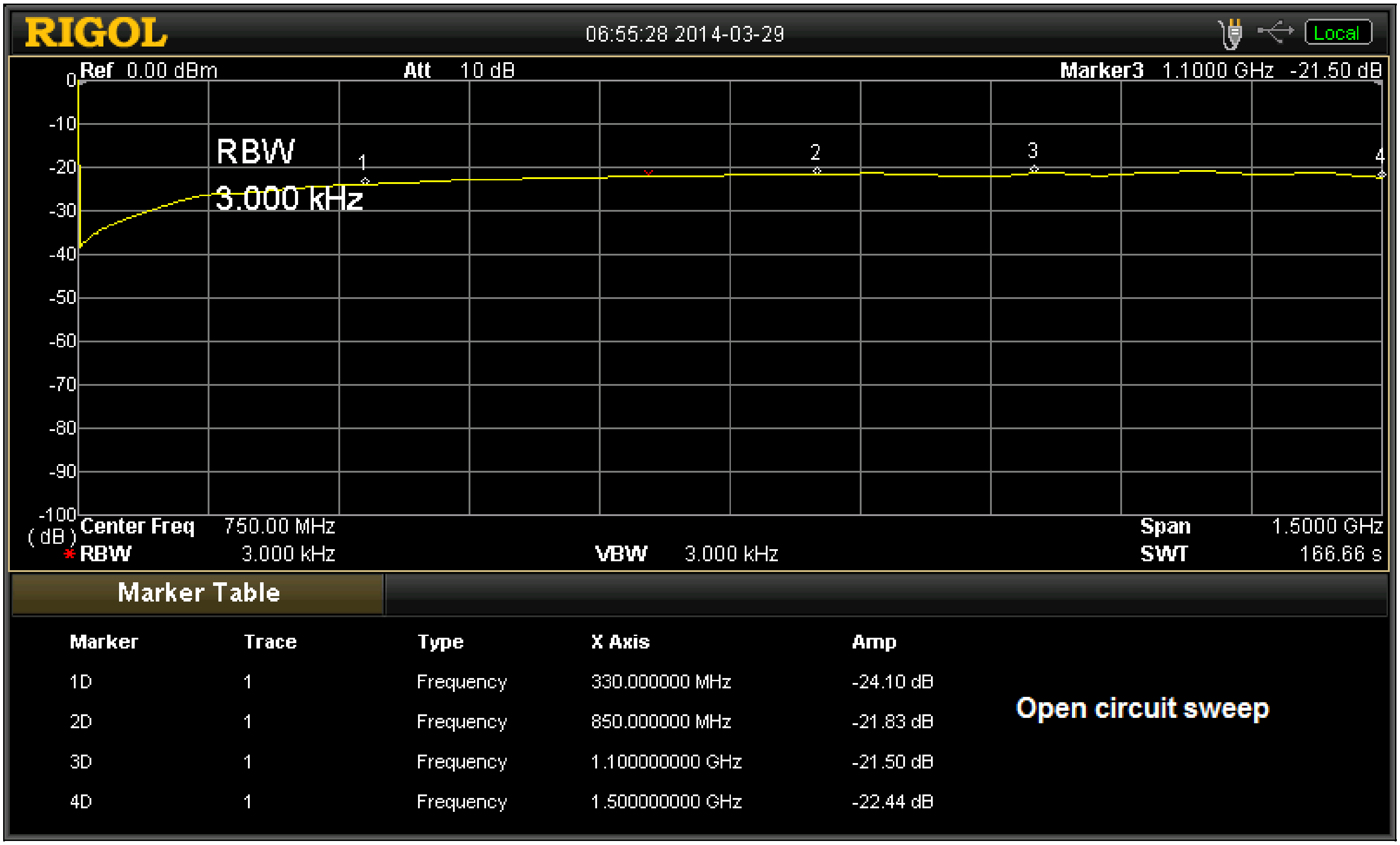
RIGOL
06:55:28 2014-03-29
Local
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
(dB)
RBW
3.000 kHz
1
2
3
4

Ref 0.00 dBm
Att 10 dB
Marker3 1.1000 GHz -21.50 dB
Center Freq 750.00 MHz
Span 1.5000 GHz
RBW 3.000 kHz
VBW 3.000 kHz
SWT 166.66 s

Marker Table

Marker	Trace	Type	X Axis	Amp
1D	1	Frequency	330.000000 MHz	-24.10 dB
2D	1	Frequency	850.000000 MHz	-21.83 dB
3D	1	Frequency	1.100000000 GHz	-21.50 dB
4D	1	Frequency	1.500000000 GHz	-22.44 dB

Open circuit sweep

Above — Open circuit sweep of the 3-bead bridge with series capacitors on the load and reference ports.

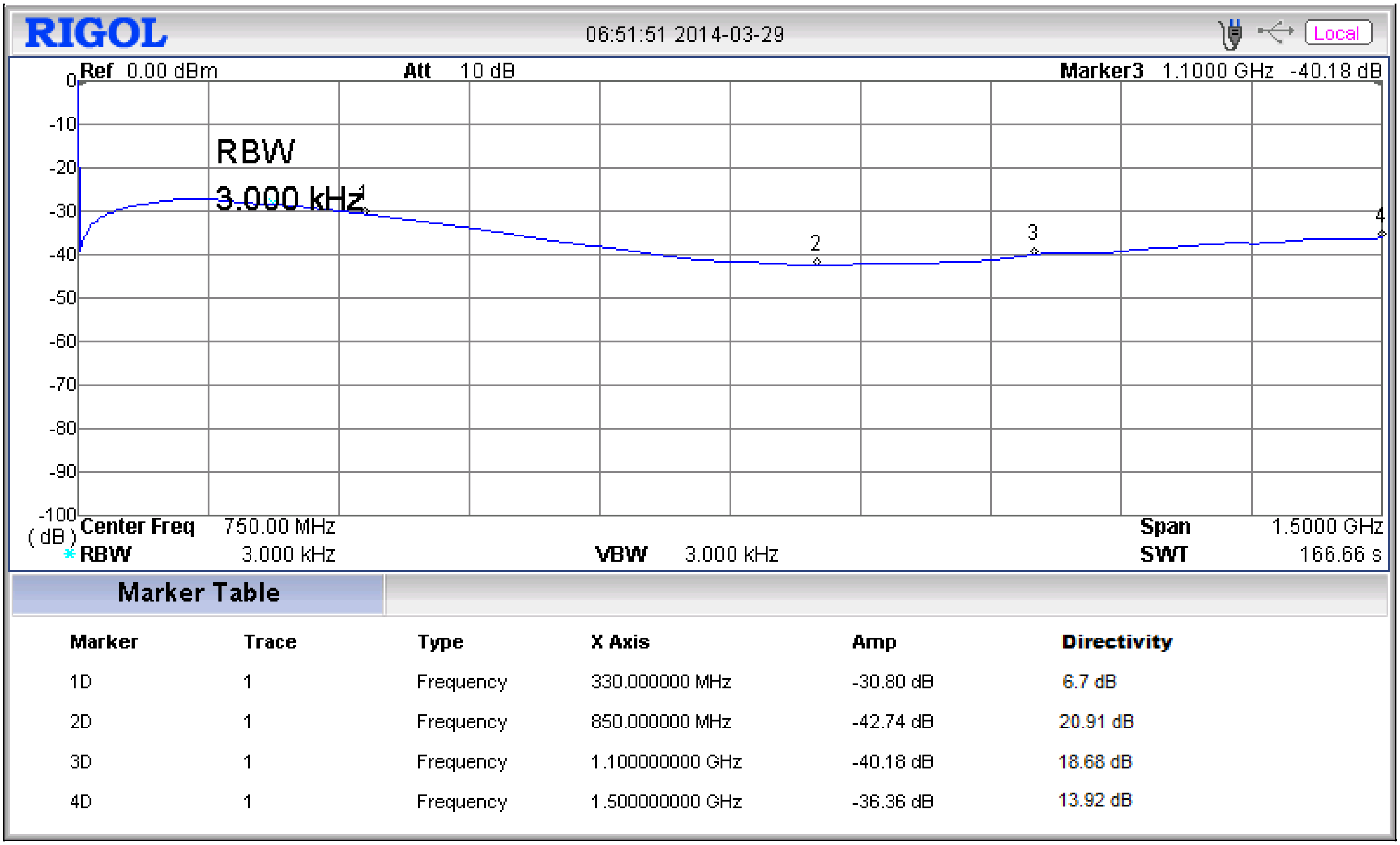

06:51:51 2014-03-29

Ref 0.00 dBm **Att** 10 dB **Marker3** 1.1000 GHz -40.18 dB

Center Freq 750.00 MHz **Span** 1.5000 GHz

RBW 3.000 kHz **VBW** 3.000 kHz **SWT** 166.66 s

Marker Table

Marker	Trace	Type	X Axis	Amp	Directivity
1D	1	Frequency	330.000000 MHz	-30.80 dB	6.7 dB
2D	1	Frequency	850.000000 MHz	-42.74 dB	20.91 dB
3D	1	Frequency	1.100000000 GHz	-40.18 dB	18.68 dB
4D	1	Frequency	1.500000000 GHz	-36.36 dB	13.92 dB

Above — 50 Ω load sweep. By carefully tweaking the 2 trimmer caps, I set the deepest NULL at ~ 850 MHz; although it's not as deep as I want. Low end directivity was compromised.

Return Loss Bridge 4

Since my bench experiments with the "string of pearls" (SOP) return loss bridge showed promise, I kept going and eventually built a version closer to my goal: A bridge for 300 MHz to 2 GHz with decent directivity.

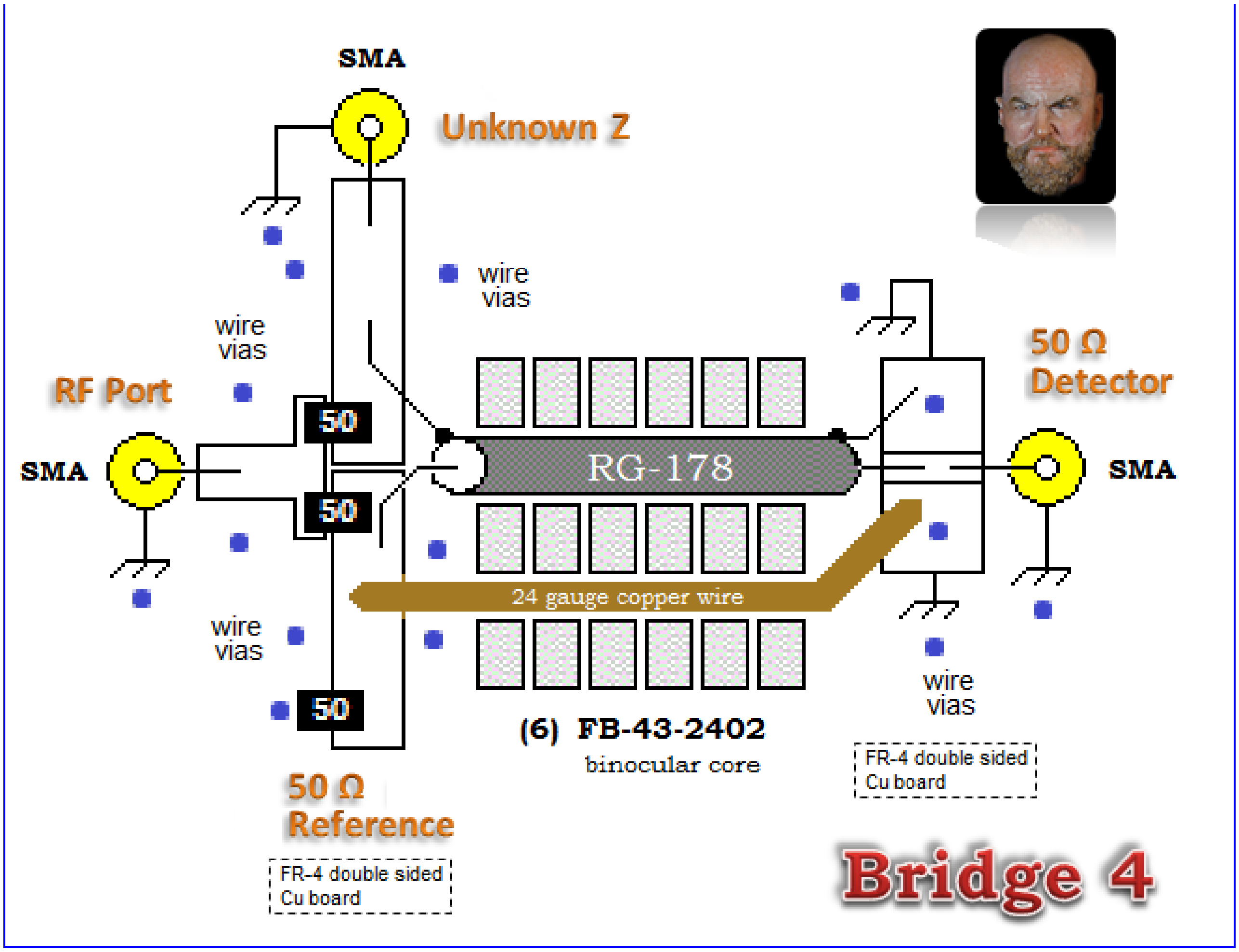
SMA
Unknown Z
wire vias
wire vias
RF Port
SMA
50
50
RG-178
50 Ω Detector
SMA
24 gauge copper wire
wire vias
50
wire vias
(6) FB-43-2402
binocular core
FR-4 double sided Cu board
50 Ω Reference
FR-4 double sided Cu board
Bridge 4

Above — My SOP build diagram of Bridge #4. I cut traces in 2-sided FR-4 Cu board to make the needed microstripline paths.The two 49.9 Ω 1% bridge resistors = size 0603, however, my reference port 49.9 Ω, 1% resistor was size 1206. The braid of the coax goes to the unknown impedance port and the center core to the reference port. Six FB-43-2402 binocular cores just passed the diameter of the RG-178 coax and binocular ferrites boosted balance compared to seperate beads in my experiments.

Rather than run coax through the remaining hole in the ferrite string, I just used a 24 gauge piece of Cu wire for balun symmetry. I left the green insulation on the wire to help keep it in place during soldering — I used the same wire spool to make the via wires.

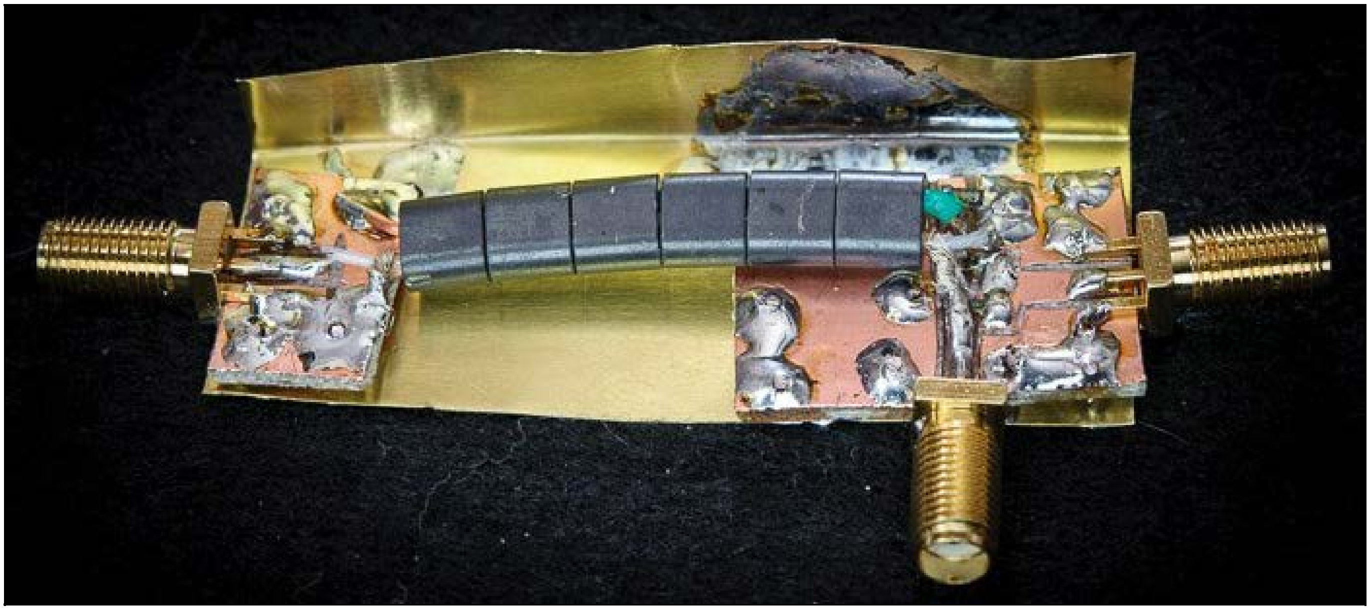

Above — Breadboard photograph. Click for a larger photo. I soldered some thin brass sheet metal to electrically join the ground planes of the 2 carved boards [represents the normal RF-tight metal chassis we apply].The brass sheet boosted directivity 8 dB by improving balun function.

Comments by a prominent figure in our hobby ....."and the thing is 'ugly to the core'. Way to go."

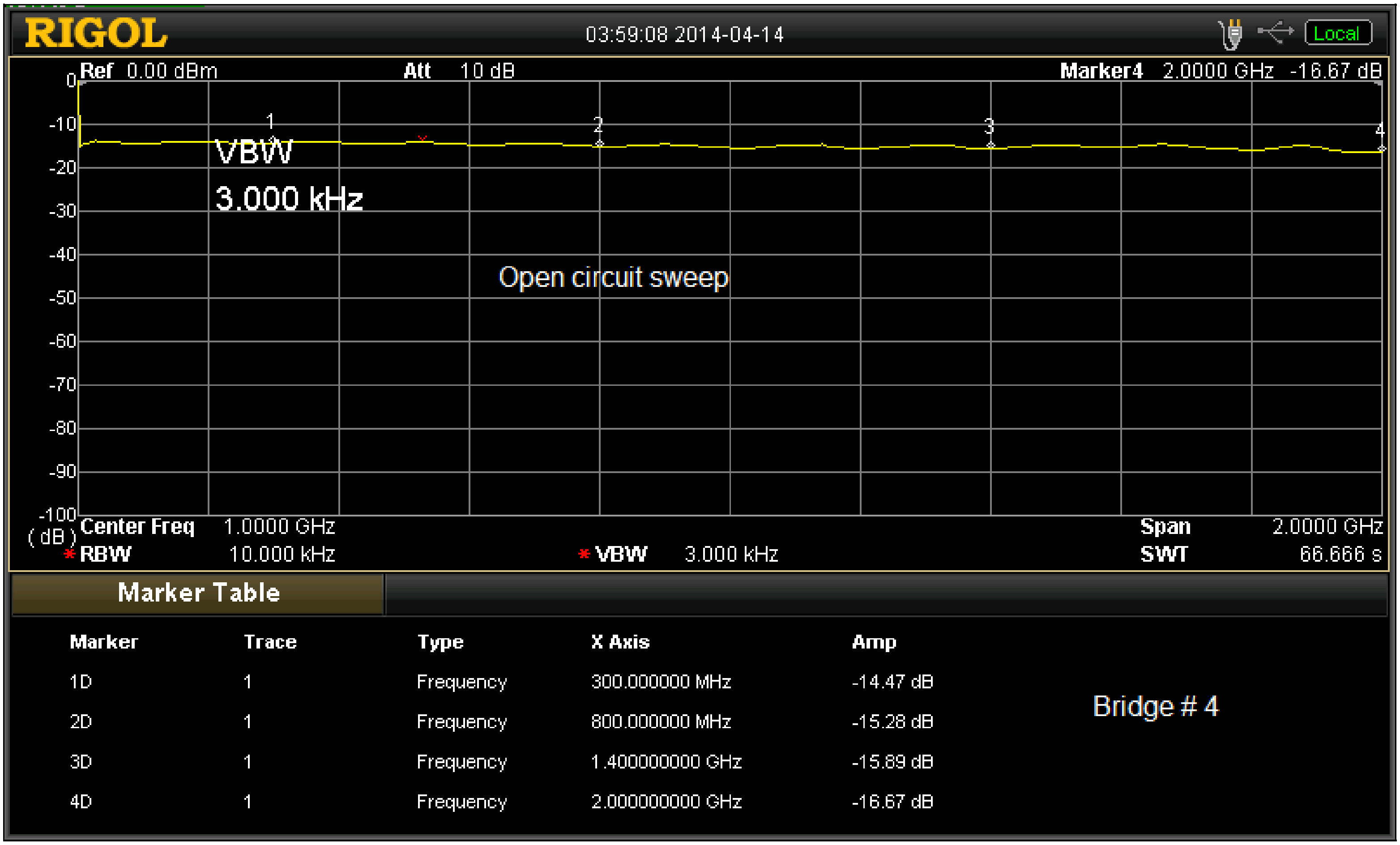
RIGOL
03:59:08 2014-04-14
Local
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
(dB)
1
2
3
4
VBW
3.000 kHz
Open circuit sweep
Marker Table
Bridge # 4

Ref 0.00 dBm
Att 10 dB
Marker4 2.0000 GHz -16.67 dB
Center Freq 1.0000 GHz
Span 2.0000 GHz
* RBW 10.000 kHz
* VBW 3.000 kHz
SWT 66.666 s

Marker	Trace	Type	X Axis	Amp
1D	1	Frequency	300.000000 MHz	-14.47 dB
2D	1	Frequency	800.000000 MHz	-15.28 dB
3D	1	Frequency	1.400000000 GHz	-15.89 dB
4D	1	Frequency	2.000000000 GHz	-16.67 dB

Above — Open circuit sweep with a 2 GHz span and center frequency of 1 GHz.

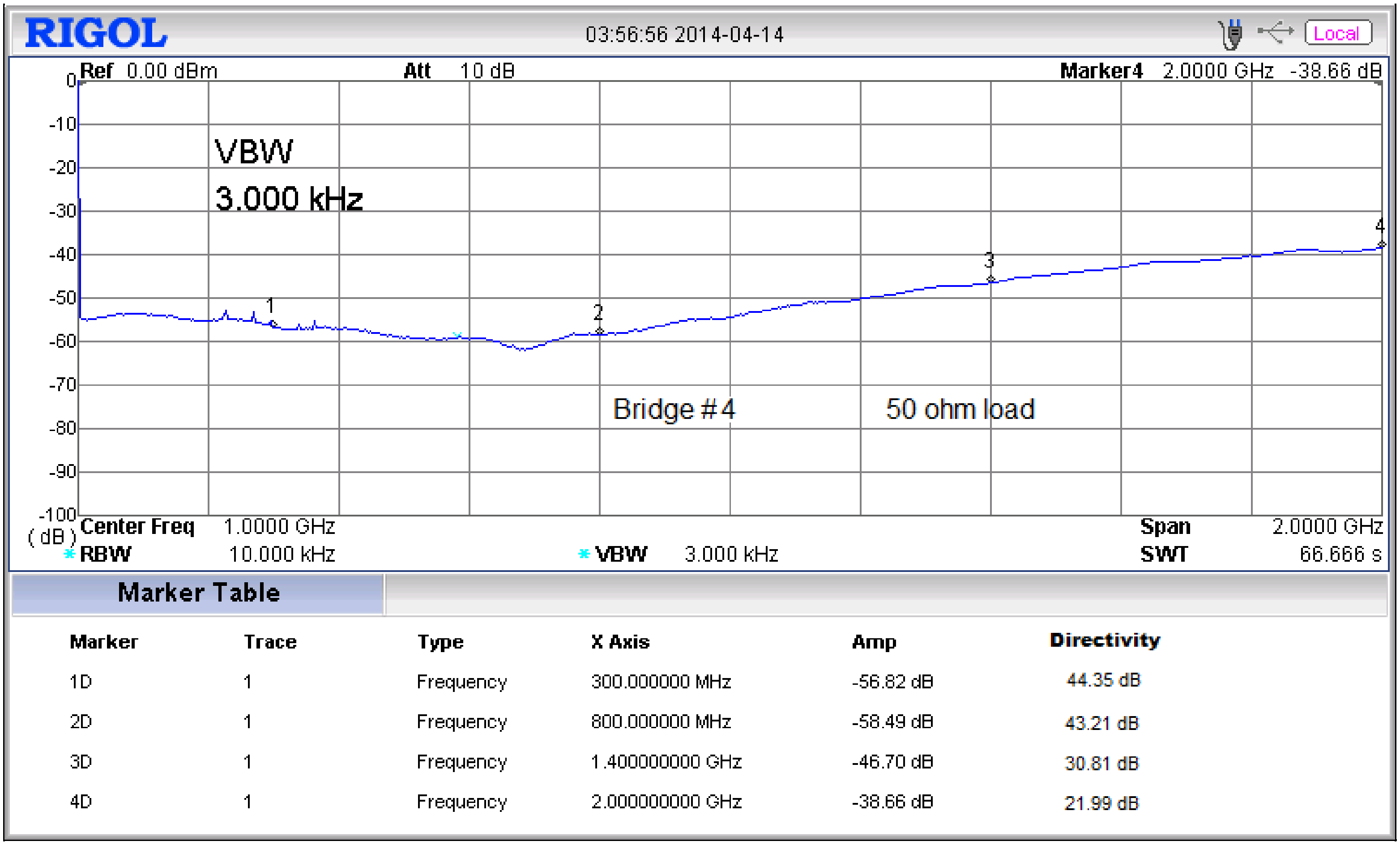
RIGOL
Local
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
(dB)
1
2
3
4
VBW
3.000 kHz
Bridge #4
50 ohm load

03:56:56 2014-04-14

Ref 0.00 dBm **Att** 10 dB **Marker4** 2.0000 GHz -38.66 dB

Center Freq 1.0000 GHz **Span** 2.0000 GHz

* **RBW** 10.000 kHz * **VBW** 3.000 kHz **SWT** 66.666 s

Marker Table

Marker	Trace	Type	X Axis	Amp	Directivity
1D	1	Frequency	300.000000 MHz	-56.82 dB	44.35 dB
2D	1	Frequency	800.000000 MHz	-58.49 dB	43.21 dB
3D	1	Frequency	1.400000000 GHz	-46.70 dB	30.81 dB
4D	1	Frequency	2.000000000 GHz	-38.66 dB	21.99 dB

Above — Sweep with a 50 Ω load threaded on the unknown impedance port and 4 markers showing directivity at those 4 frequencies. Yay — this is much better! I wanted at least 30 dB directivity at 1296 MHz and got it.

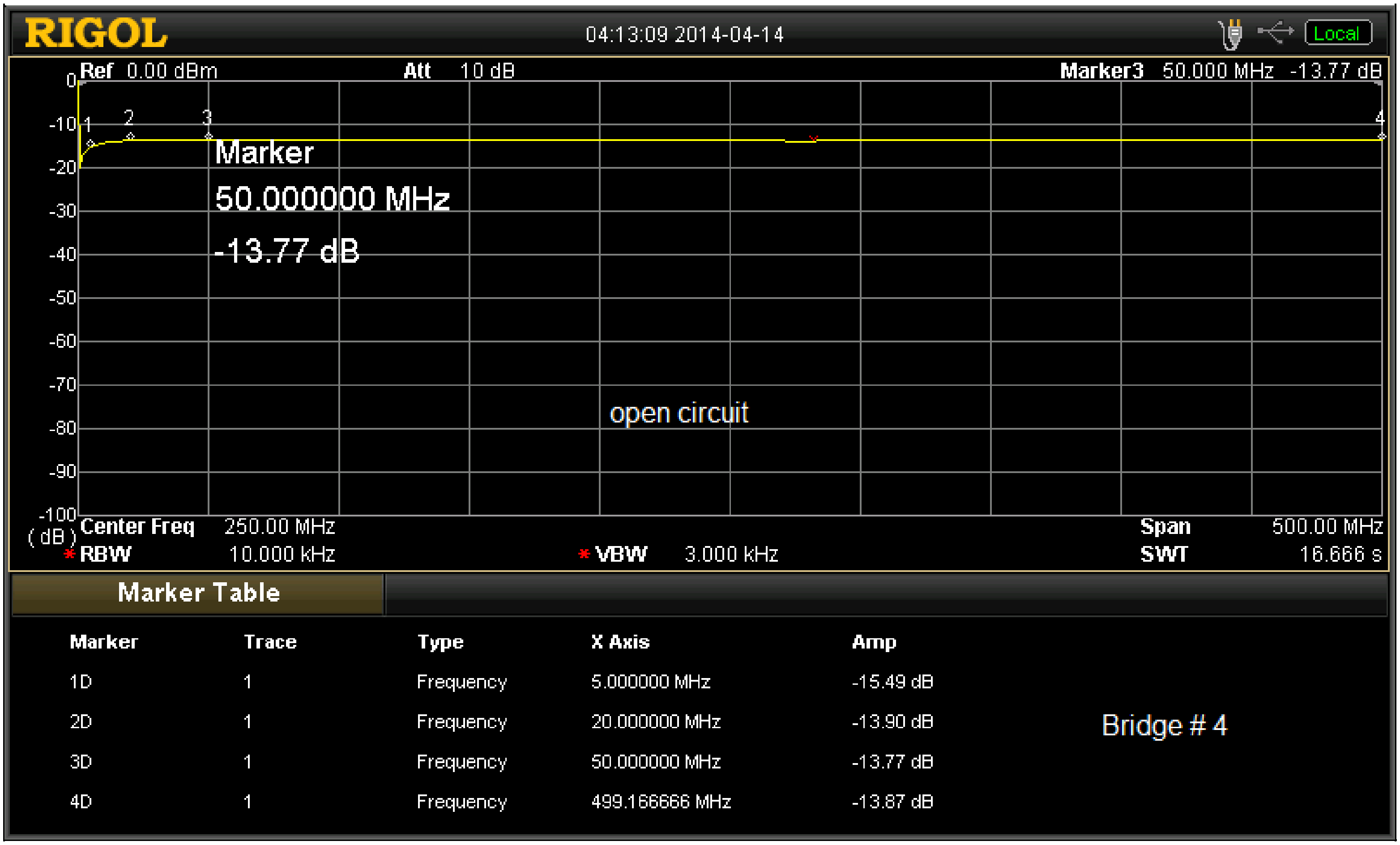
RIGOL
04:13:09 2014-04-14
Local
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
(dB)
1
2
3
4
open circuit
Bridge # 4

Ref 0.00 dBm **Att** 10 dB **Marker3** 50.000 MHz -13.77 dB

Marker
50.000000 MHz
-13.77 dB

Center Freq 250.00 MHz **Span** 500.00 MHz

RBW 10.000 kHz **VBW** 3.000 kHz **SWT** 16.666 s

Marker Table

Marker	Trace	Type	X Axis	Amp
1D	1	Frequency	5.000000 MHz	-15.49 dB
2D	1	Frequency	20.000000 MHz	-13.90 dB
3D	1	Frequency	50.000000 MHz	-13.77 dB
4D	1	Frequency	499.166666 MHz	-13.87 dB

Above — Open circuit sweep with a 500 MHz span and center frequency of 250 MHz. I set 2 of the markers to evaluate the directivity at HF.

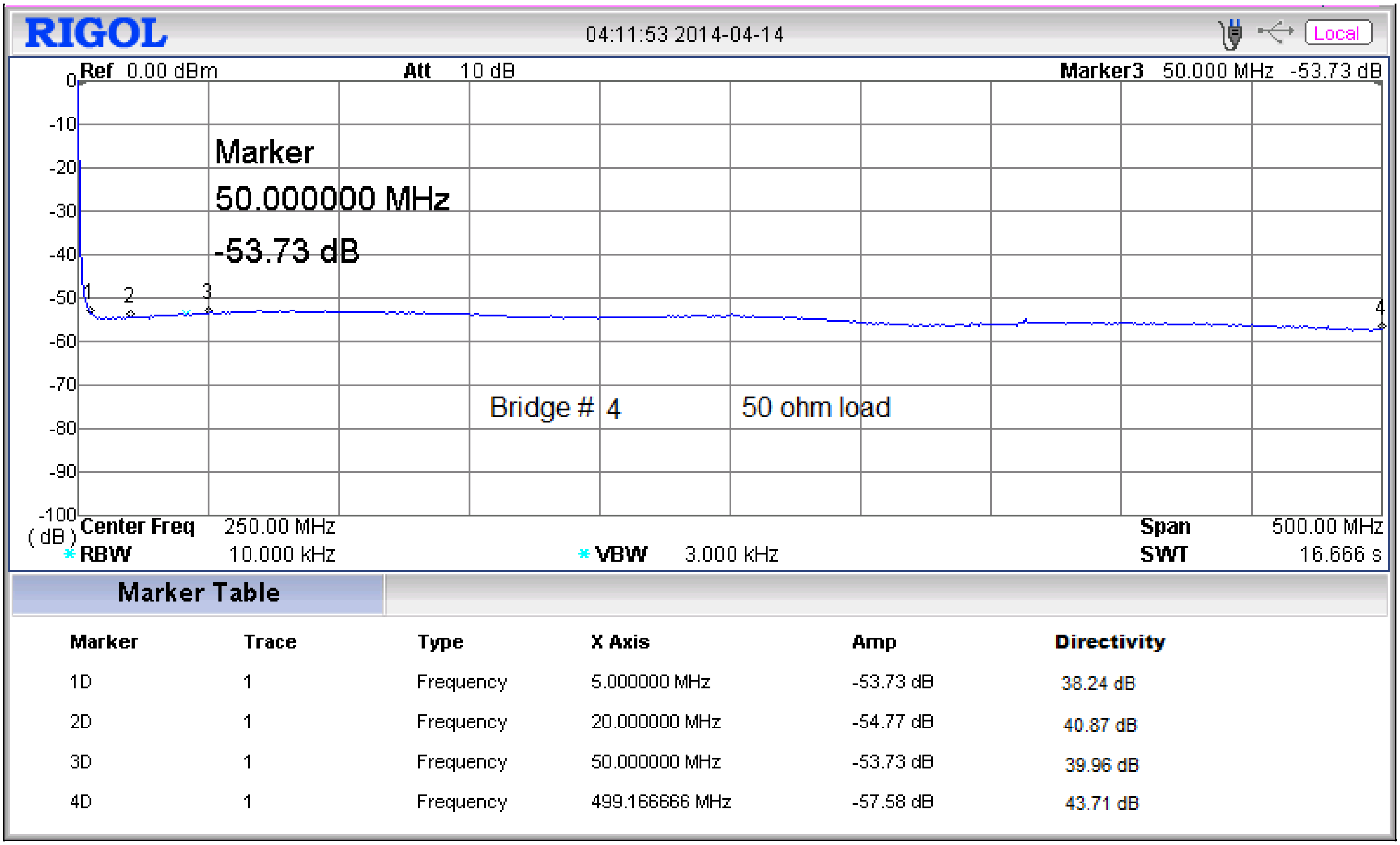

Ref 0.00 dBm **Att** 10 dB **Marker3** 50.000 MHz -53.73 dB

Marker
50.000000 MHz
-53.73 dB

Bridge # 4 50 ohm load

Center Freq 250.00 MHz **Span** 500.00 MHz
RBW 10.000 kHz **VBW** 3.000 kHz **SWT** 16.666 s

Marker Table

Marker	**Trace**	**Type**	**X Axis**	**Amp**	**Directivity**
1D	1	Frequency	5.000000 MHz	-53.73 dB	38.24 dB
2D	1	Frequency	20.000000 MHz	-54.77 dB	40.87 dB
3D	1	Frequency	50.000000 MHz	-53.73 dB	39.96 dB
4D	1	Frequency	499.166666 MHz	-57.58 dB	43.71 dB

Above — 500 MHz sweep of Bridge #4 with a 50 load on the unknown impedance port. The directivity at HF surprised me. Although better suited for VHF-UHF, this bridge will work okay from 5 MHz to ~1.5 GHz.

4. VCO Experiments

Ask experimenters about homebrew RF oscillators and you might hear about a pleasing paradox — vexing and satisfying in the same breath! At UHF we usually make a VCO and keep it on frequency by phase/frequency locking to a xtal oscillator reference. I sought some wideband, free running VCOs in hopes I'd inch up the learning curve.

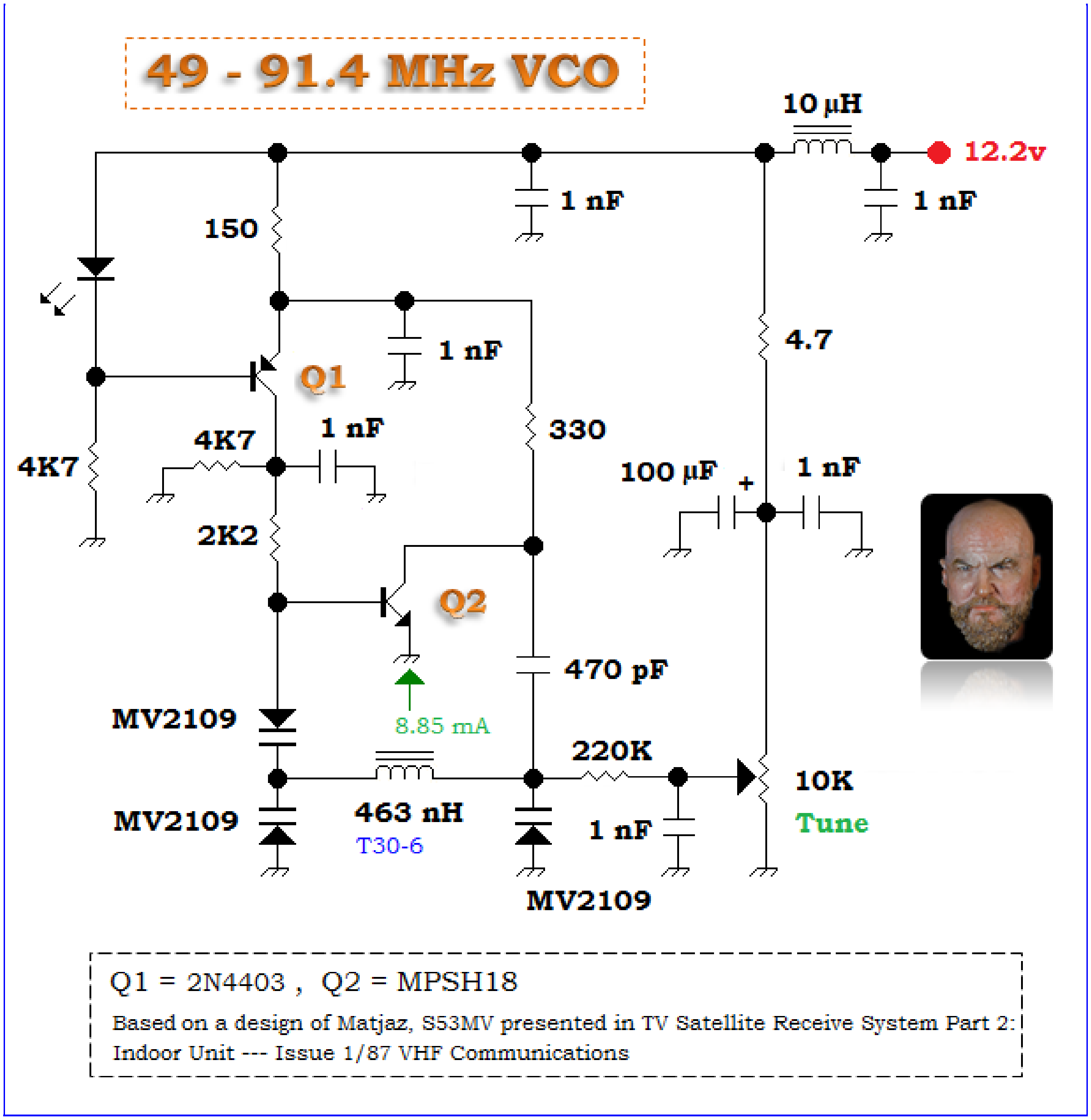

Q1 = 2N4403 , Q2 = MPSH18

Based on a design of Matjaz, S53MV presented in TV Satellite Receive System Part 2: Indoor Unit --- Issue 1/87 VHF Communications

Above — My first attempt at a VCO circuit described by Matjaž, S53MV in a 2-part article published in VHF Communications magazine. The original circuit contained a tunable RF filter, mixer, buffer amplifer + more and I recommend you purchase the 2 articles for your own analysis. Shown with permission from Andy Barter of VHF Communications magazine, I ordered all issues from the 1980s which came on this DVD.

With 28v varactors, this VCO will tune 1 octave minimum.

To bench investigate this stunning common emitter Colpitts variant, I first built it at VHF using through-hole parts with a standard 12 volt tuning voltage that tuned from 49 to 91.4 MHz. The output came from 1 link around the 463 nH inductor terminated in a 1K resistor at the hot end + ground at the cold end to allow 10X probe measurement with my DSO.

Matjaž, S53MV describes his circuit function here. A variable C on the base in combination with the input capacitance of Q2 operates as a tuned impedance matching network and preserves a steep phase slope (which means you have higher Q) — a requirement for low phase noise. In essence, the inductor with a varactor at each end forms an adjustable pi-network to provide correct phase shift tracking.

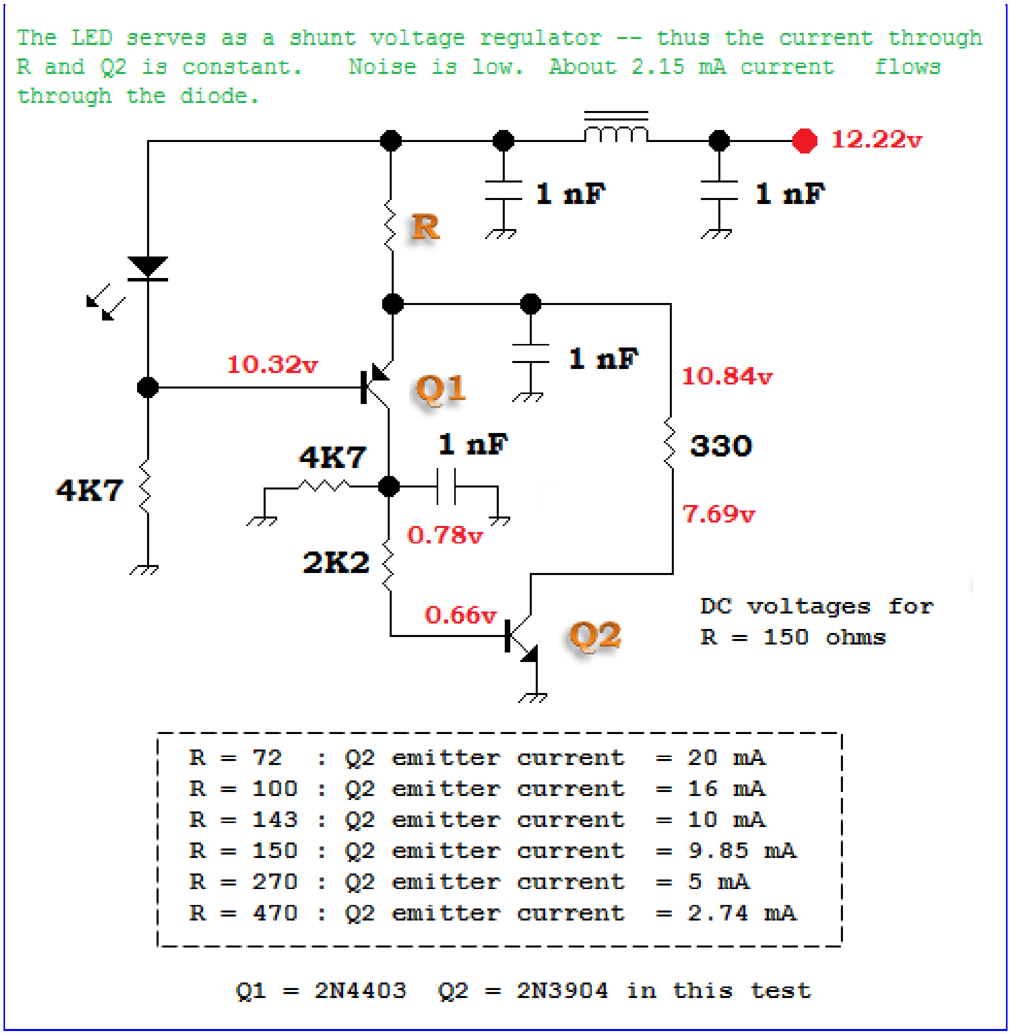
12.22v
1 nF
1 nF
R
1 nF
10.32v
Q1
10.84v
4K7
1 nF
330
4K7
0.78v
7.69v
2K2
0.66v
Q2

The LED serves as a shunt voltage regulator -- thus the current through R and Q2 is constant. Noise is low. About 2.15 mA current flows through the diode.

DC voltages for
R = 150 ohms

```
R = 72  : Q2 emitter current  = 20 mA
R = 100 : Q2 emitter current  = 16 mA
R = 143 : Q2 emitter current  = 10 mA
R = 150 : Q2 emitter current  = 9.85 mA
R = 270 : Q2 emitter current  = 5 mA
R = 470 : Q2 emitter current  = 2.74 mA
```

Q1 = 2N4403   Q2 = 2N3904 in this test

Above — I built the low-noise, temperature-stable, PNP current source using though-hole parts. R provides a convenient way to vary collector current, although changing the PNP base bias also works.

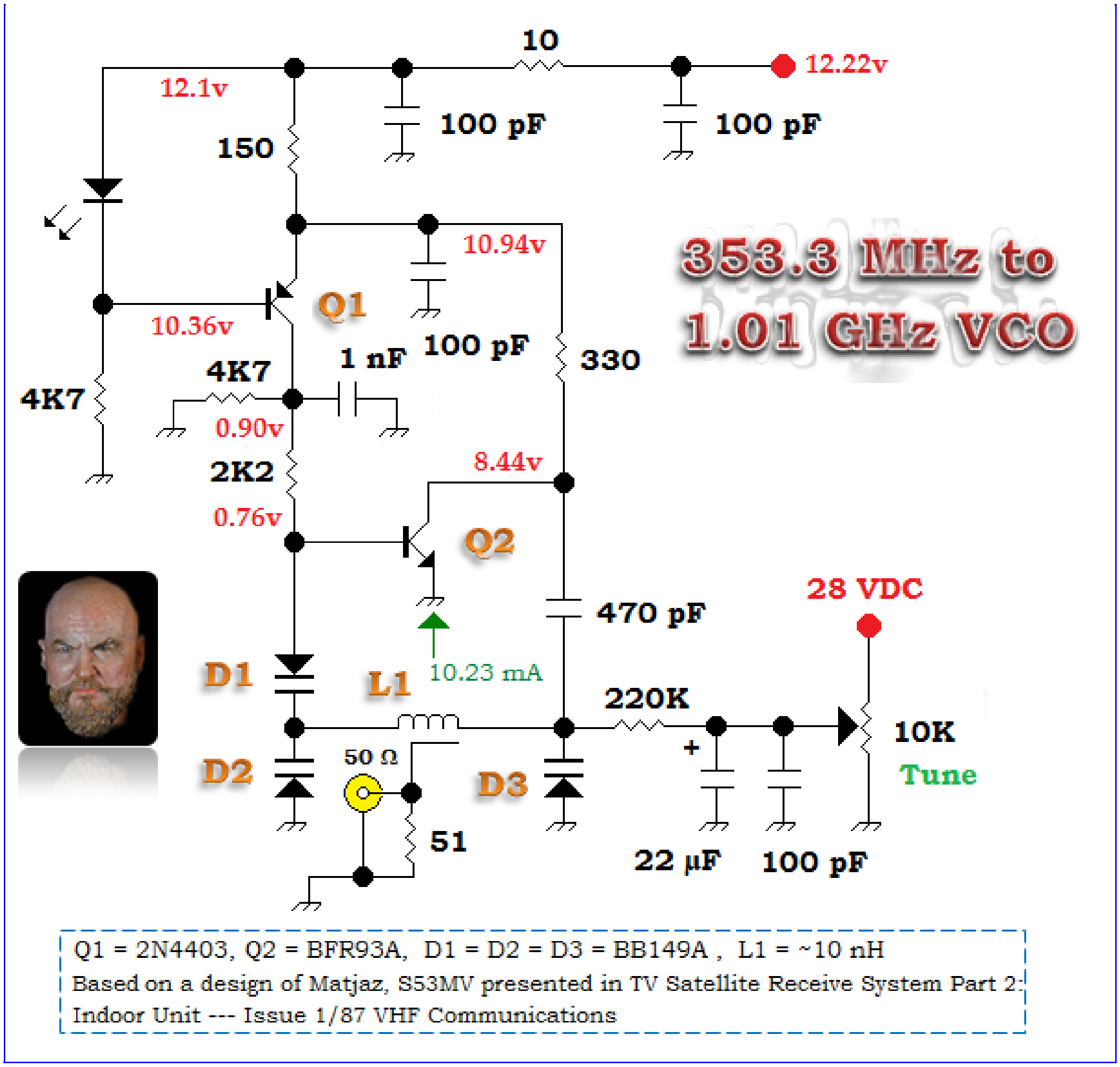

Q1 = 2N4403, Q2 = BFR93A, D1 = D2 = D3 = BB149A , L1 = ~10 nH
Based on a design of Matjaz, S53MV presented in TV Satellite Receive System Part 2:
Indoor Unit --- Issue 1/87 VHF Communications

Above — My UHF VCO schematic. Click for the breadboard photo. A wire positioned near L1 provided the output into my spectrum analyzer. Click for a sweep with the reverse DC voltage set at 0v. Click for the a sweep with the tuning at 28v to establish the lowest possible varactor capacitance. Markers indicate the carrier frequency. As shown, a common emitter VCO exhibits rich harmonic energy and viewing the second harmonic at 2 GHz felt really cool in the 28v sweep. Not to worry — the tracking generator in the Rigol TG + SA units also exhibit strong harmonics and work fine for sweeping.

Click for a pdf file showing how I laid out my board. I cut traces on the top of 2-sided FR4 board and connected any grounded points on top to the bottom ground plane with a 24 gauge copper via wire. A 28v DC-DC Converter to supply the varactors lies on VHF-FM.

I varied L and even tried a 3 mm by 8 mm copper sheet metal inductor but this failed to oscillate. In the end, a single wire with ~10 nH inductance worked to give me the tuning span shown. L1's distance above the ground plane was determined by tuning the VCO for the smoothest transistion across its range. This circuit begs further experiments including Q2 current, L1 and the 470 pF fixed feedback capacitor.

---

5. Frequency Counter Kit

A sensitive UHF bandwidth frequency counter makes an important tool for the UHF homebrew experimenter. With a search engine, you'll find commercial and kit counters for sale along with DIY projects for builders handy with microcontrollers.

If you already own a decent counter, then a crude prescaler tool employing an IC like the MC12079 might work okay if you can tolerate or manage modulus division by 64, 128, or 256. The MC12079 requires an RF signal between -17 dBm to +3 dBm to count properly, so many builders place amplifier(s) along with anti-parallel clamping diodes before the digital IC. The Motorola datasheet shows a basic circuit to build off.

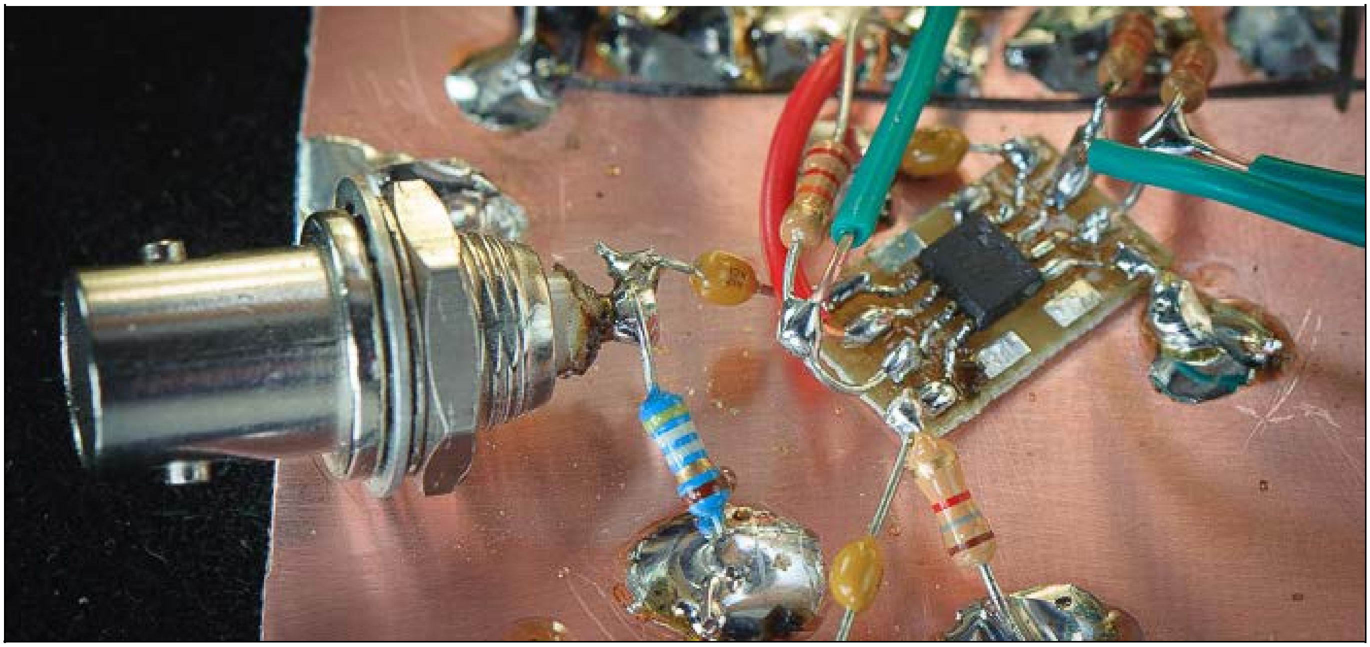

Above — My first UHF counter experiment involved the Motorola MC12079 and 12080 prescalers. Eventually I made a proper double-sided copper board device with anti-parallel diodes, a MMIC, the MC12079 and some 74AC series logic — it worked okay for casual use. The 2 big drawbacks were MC12079 self-oscillation with 0 applied input signal and having to remember to multiply measures by my set prescaler division integer. I sought a long-term solution.

A Solution Appears

In 2012 I bought a second-hand, calibrated HP 53131A with the optional A6 High Stability Timebase from an EE for ½ the going price at the time. 225 MHz bandwidth poses its only limitation; it even came with the original spiral bound manual.

This summer, Shahriar from TheSignalPath.com reviewed a Chinese kit to take the HP 53131A to 3 GHz with a clone of the original HP OPT30 Channel 2 kit. Based on his quantitative review and warm thoughts of using my sturdy HP counter at UHF, I got 1. Mine sold on eBay for $87 Canadian including shipping. Click for TheSignalPath.com video. Click for a larger photo of the kit I bought.

53181A 225 MHz
FREQUENCY COUNTER
CHANNEL 2
MEASURE
LIMITS
MATH
DISPLAY
CHANNEL 1
Freq Ch 2
Uppr & Lower
Scale & Offset
More Digits
Fewer Digits
Trigger Sensitivity
Gate & ExtArm
Limit Modes
Stats
50Ω 1MΩ
DC AC
Local
Save & Print
Run
Stop/ Single
X10 Attenuate
100kHz Filter
+/-
Enter

Above — My HP counter with the kit installed as Channel 2.

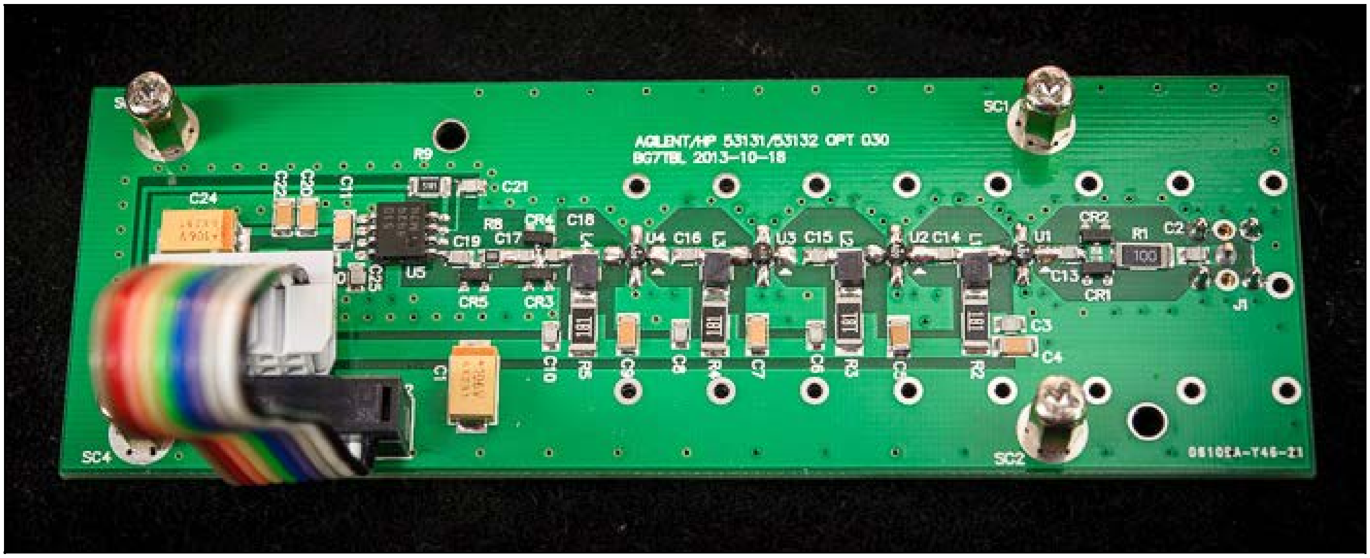
AGILENT/HP 53131/53132 OPT 030
BG7TBL 2013-10-18

Above — Top of the circuit board. Anti-parallel diodes, 4 MMICS, passives and then even more anti-parallel diodes go before the prescaler chip.

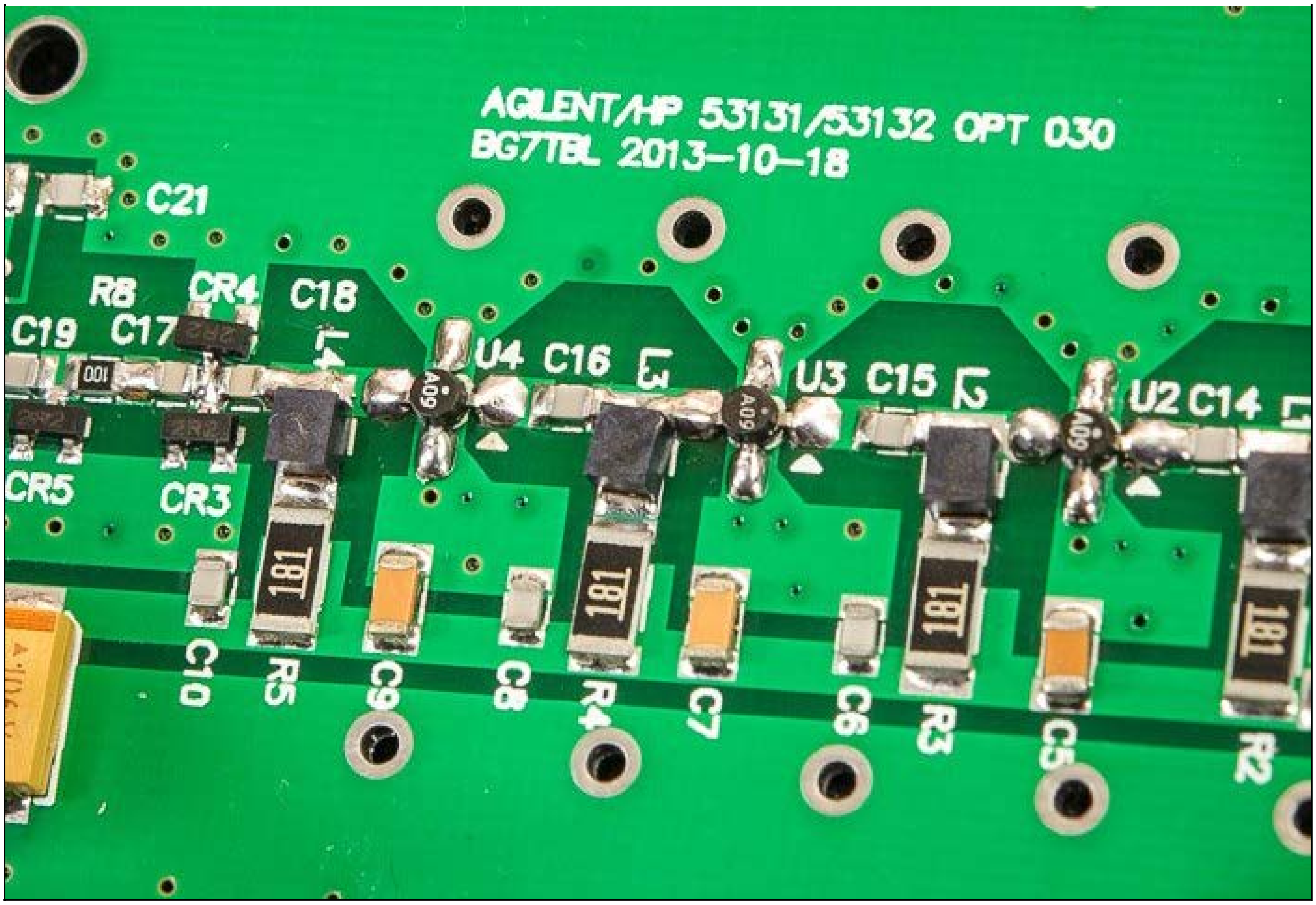
AGILENT/HP 53131/53132 OPT 030
BG7TBL 2013-10-18
C21
R8
CR4
C18
C19
C17
U4
C16
U3
C15
U2
C14
CR5
CR3
C10
R5
C9
C8
R4
C7
C6
R3
C5
R2

Above — Close up of SMD circuitry.

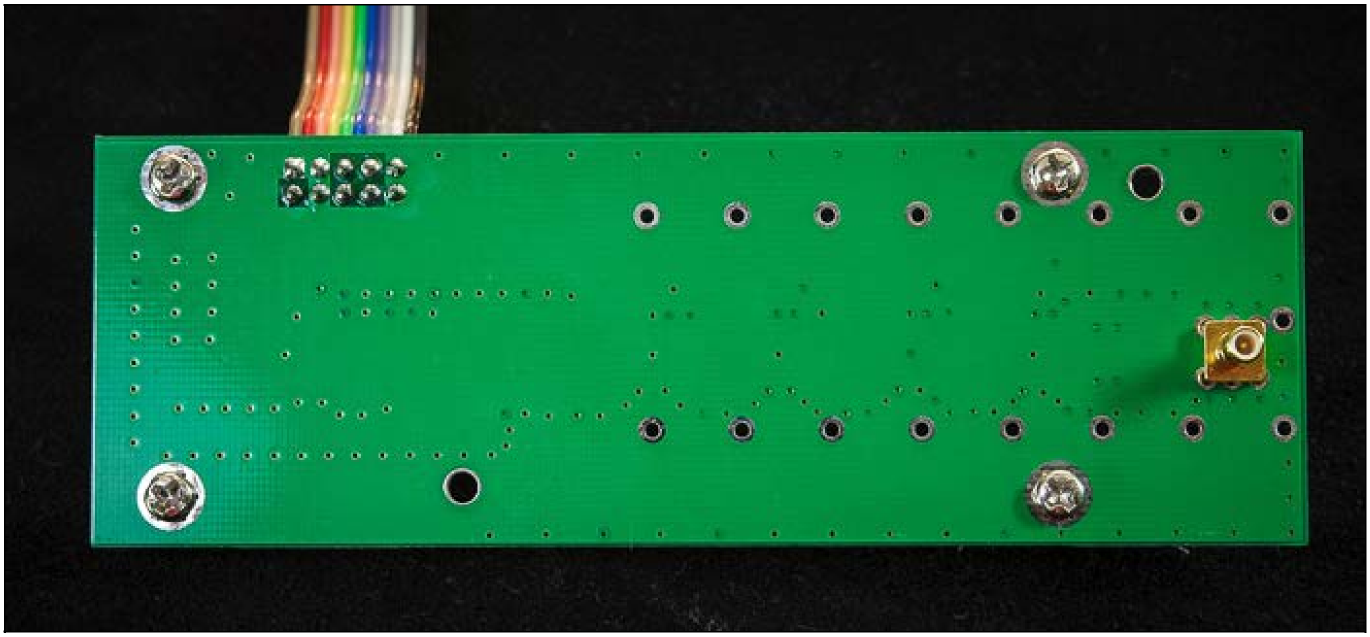

Above — Rear view of the circuit board showing stiching vias that join the top ground plane to the bottom ground plane along the signal path. My tests showed that it works okay to 3.1 GHz. Click for a picture of the installed board. I'm very happy with my HP counter's boosted bandwidth.

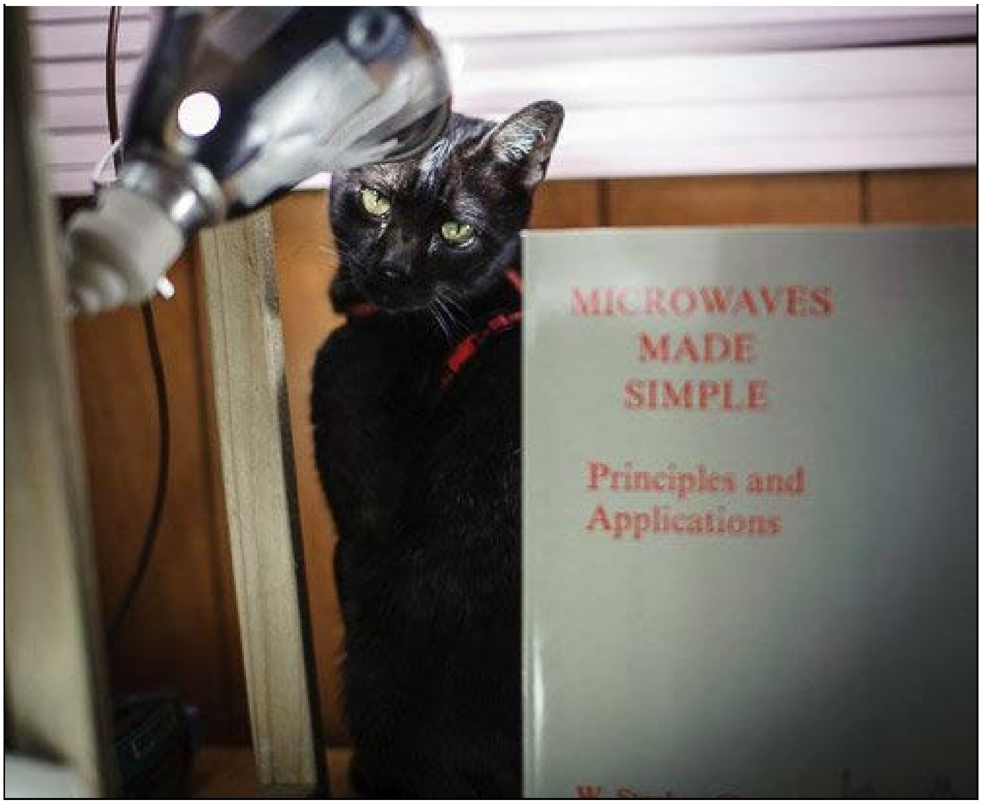
MICROWAVES
MADE
SIMPLE
Principles and
Applications

RF — Test and Measurement

Funster Line — Transmitter

Funster Line
VFO IN
FO
RF GAIN
KEY
XTAL
POWER

Menu Item 4 on the HF Embarcadero web page. Click here to go back.

The receiver will go on its own page and hopefully I'll complete and write it up this Fall.

1. Transmitter
2. References

Introduction

I began the Funster transceiver line in 1995 and show the 2014 version [now back to a CW trans-receiver on the 40M band]. Judging by reader feedback, plus analog scratch-homebrew threads in social networks, email lists and print, many of us feel a nostalgic pull towards old-school radio. Me too.

Now at version 8 — Funster shares my joy in making a simple, old-style radio with all discrete parts. In some ways, this radio set is a twisted version of Wes and Roger's Ugly Weekender from QST for August 1981.

1. Transmitter

Summary

Variable power: 128 to 3312 mW @ 13.6 VDC. Switchable 7.04 MHz xtal oscillator or external VFO input port. Solid state transmit/receive [T/R] circuit with PIN diode. External continuous and switched 12 VDC power jacks. Single-ended BJT Class C power amplifier with 67% efficiency.

Note: I state 12 VDC in my DC circuits, however, this nominal value might better be termed 12 -13.6 VDC.

Key up power current draw @ 13.6 VDC = 17 mA. Key down current @ 3W RF power with 13.6 VDC = 420 mA.

DC Circuitry

It's fun to march off the signal path and focus on DC circuitry — switching, regulating and filtering the DC voltage feeding our RF or AF stages with finesse. Trans-receivers contain DC, RF, AF and external patch cords that benefit from mindful DC line filtering + selective high-isolation amps in the signal path to prevent RF flowing where it's unwanted. You'll see heaps of decoupling with RF + AF bypass and a few strong reverse-isolation amplifers in this radio set.

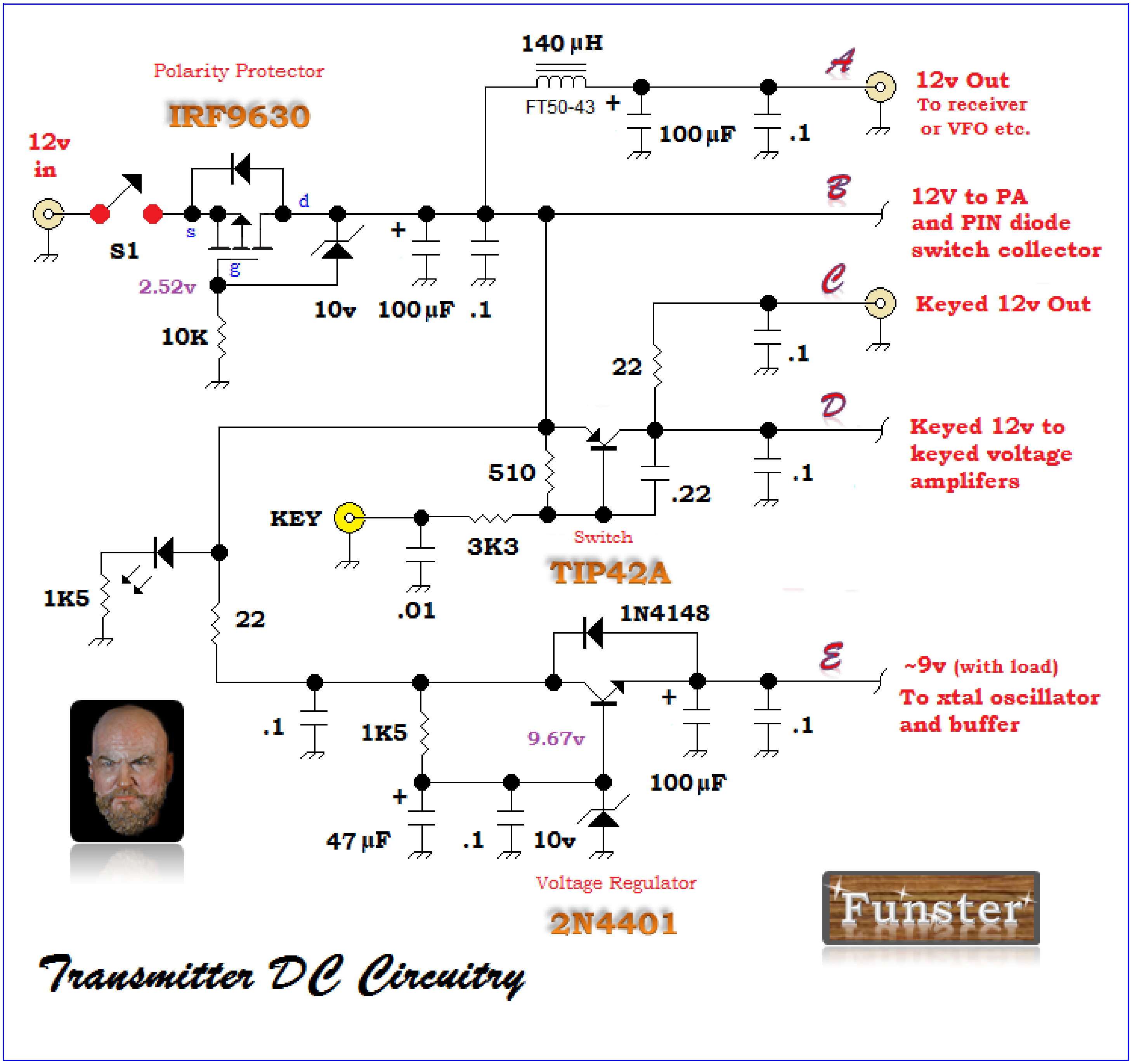
140 µH
FT50-43
Polarity Protector
IRF9630
12v in
S1
s
d
g
2.52v
10K
10v
100 µF
.1
100 µF
.1
A
12v Out
To receiver
or VFO etc.
B
12V to PA
and PIN diode
switch collector
C
Keyed 12v Out
22
.1
D
Keyed 12v to
keyed voltage
amplifers
510
.22
.1
KEY
3K3
.01
Switch
TIP42A
1K5
22
1N4148
E
~9v (with load)
To xtal oscillator
and buffer
.1
1K5
9.67v
100 µF
.1
47 µF
.1
10v
Voltage Regulator
2N4401
Funster
Transmitter DC Circuitry

Above — The DC circuit board. Click for the breadboard photo. A reader sent me 2 IRF9630 power MOSFETS: avoiding the voltage drop of the usual single rectifier diode, I employed 1 as a reverse polarity protector. Another reader sent me a long strip of 2N4401 BJTs, so I ran them instead of the equally good 2N3904. Thanks for the parts guys!

A simple series voltage regulator with a zener diode reference supplies DC to the crystal oscillator and its buffer. The base-emitter voltage drop of the 2N4401 emitter follower lays in series with the load, so load current changes alter the regulator output voltage. Vout = Vzener - VBE : so the regulated voltage is roughly 9 VDC.

Oscillator Circuitry

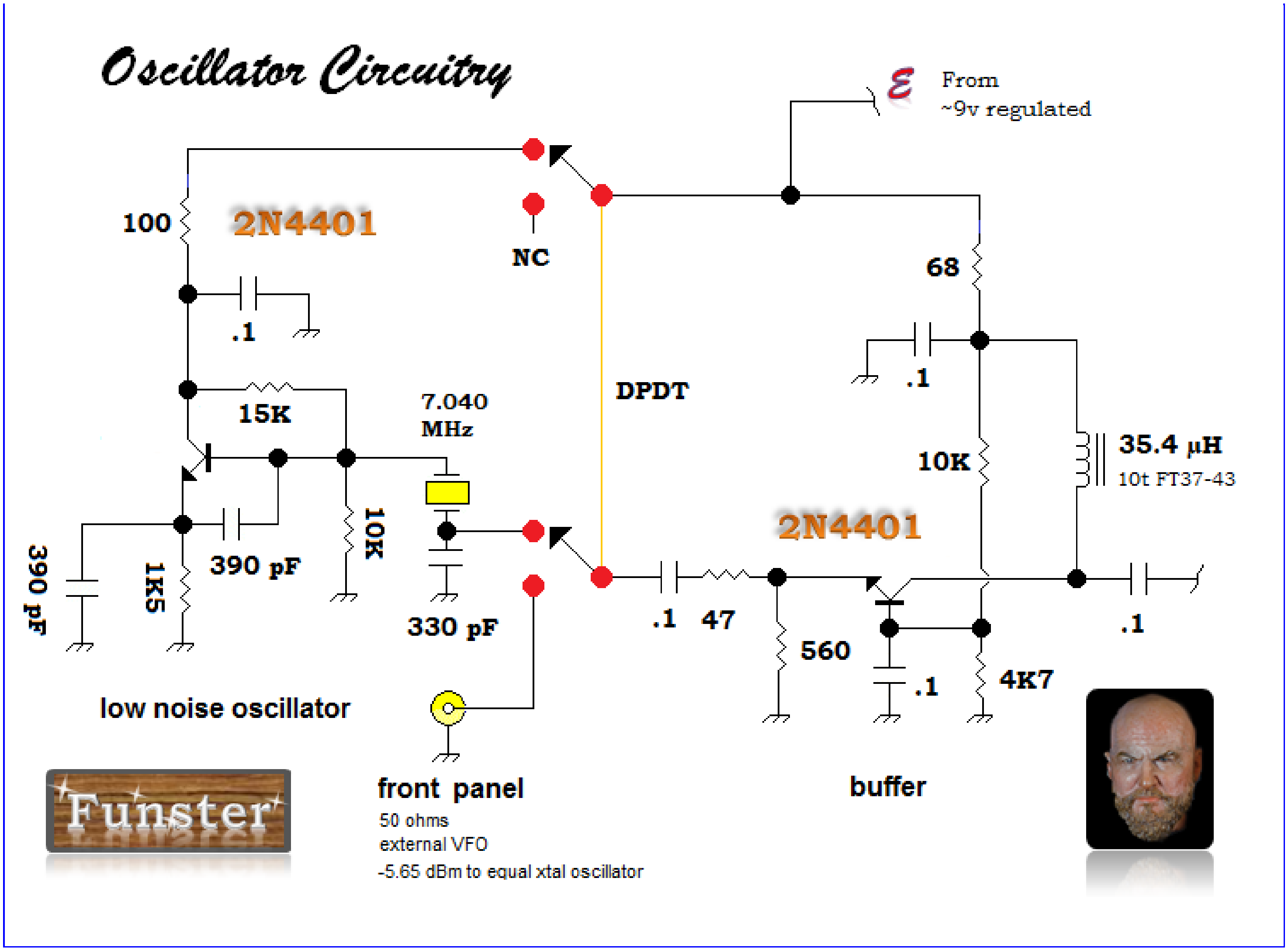
Oscillator Circuitry
From
~9v regulated
100
2N4401
NC
.1
15K
7.040
MHz
DPDT
68
.1
10K
35.4 µH
10t FT37-43
10K
390 pF
1K5
390 pF
330 pF
2N4401
.1
47
560
.1
4K7
.1
low noise oscillator
Funster
front panel
50 ohms
external VFO
-5.65 dBm to equal xtal oscillator
buffer

Above — Oscillator circuitry. I soldered my oscillator circuitry on the DC control board. Click for the breadboard. Click for a close-up of the old NorCal crystal supplied by NT7S — thanks Jason! To equilibrate to the xtal oscillator AC output voltage, the VFO input port should run about -5.65 dBm. I might stick a 6 dB attenuator pad on the front panel switch and use a 7 MHz VFO with 0 dBm output power.

Keyed Voltage Amps

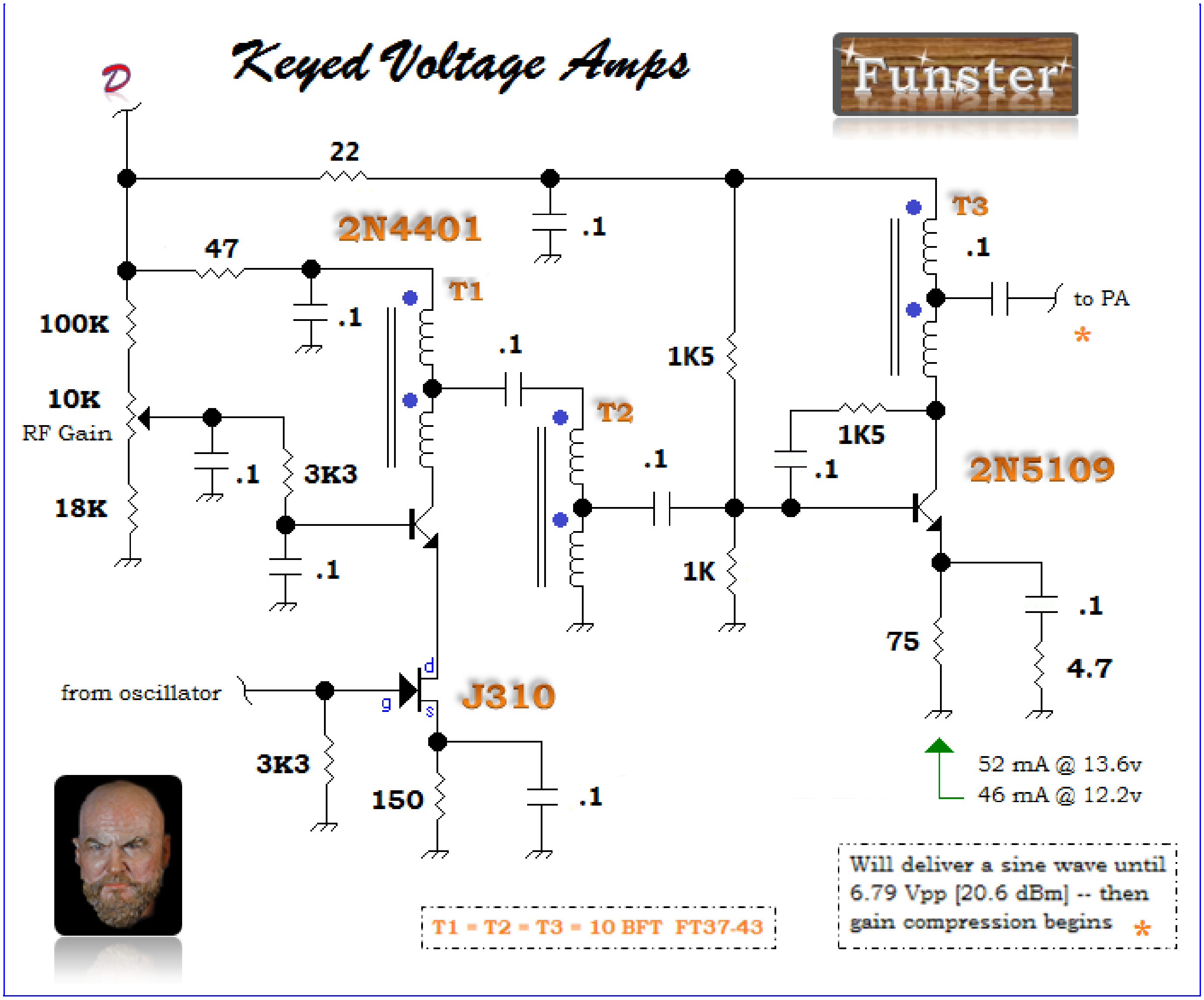
Keyed Voltage Amps
D
Funster
22
2N4401
.1
T3
.1
47
.1
T1
to PA
*
100K
.1
1K5
10K
RF Gain
T2
1K5
.1
.1
2N5109
.1
3K3
18K
.1
1K
.1
75
4.7
from oscillator
d
g
s
J310
3K3
52 mA @ 13.6v
46 mA @ 12.2v
150
.1
Will deliver a sine wave until 6.79 Vpp [20.6 dBm] -- then gain compression begins *
T1 = T2 = T3 = 10 BFT FT37-43

Above — The 2 keyed voltage amplifers. Click for a breadboard photograph. I set the value of the RF gain pot series resistors by placing a 100K pot before and after the 10K gain pot and tweaked them back and forth to find close to 3W maximum and 125 mW minimum RF power with the gain pot set @ CW and CCW respectively. The 100K pots were removed, measured and nearest standard value resistors substituted: 100K and 18K.

By carefully choosing the 75 Ω emitter resistor, the 2N5109 feedback amp output remains a sine wave at the drive levels needed for a PA output at 3 Watts. At 3 Watts PA output, the feedback amp output voltage = 5.91 volts pk-pk [19.4 dBm]. The emitter current shown will cleanly drive a PA for more power if desired. Boost it as needed.

Power Transistor and T/R Switching

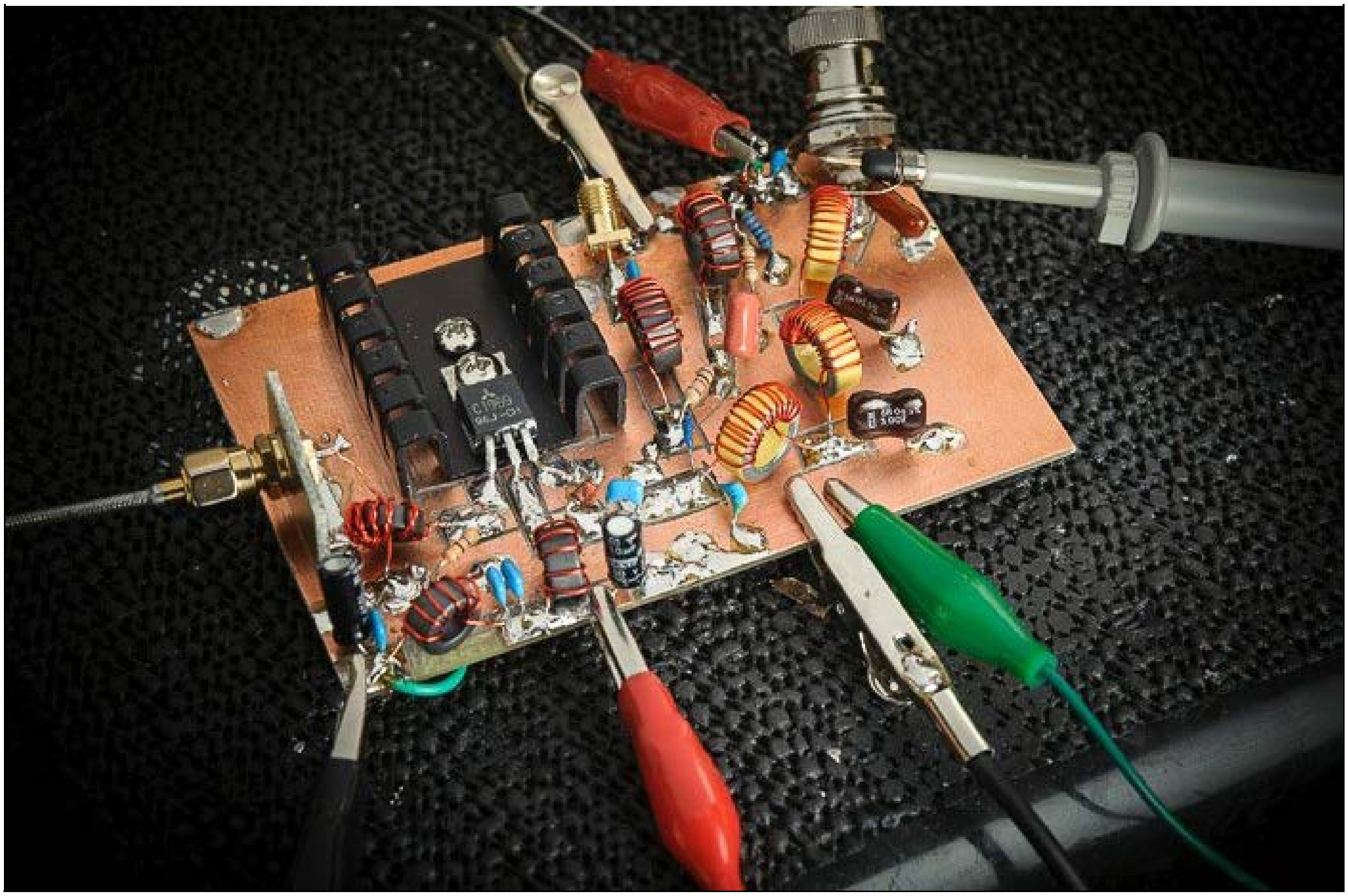

Above — Final testing the PA and T/R circuitry before installing it into the Hammond chassis. Click for a bigger photo of my test setup.

Three temporary RF connectors were soldered on this board for bench measurement. I connected the (SMA) receiver port to Channel 1 of my 50 Ω terminated 'scope to measure the RF not getting shunted to ground by the PIN diode. The SMA cable/connector to the far left is a temporary cable connected to the keyed voltage amp board output in the Tx chassis — thus I tested the PA stage with its own xtal oscillator and RF amplifers. The right-sided BNC RF port connects the PA low-pass filter to a 10W, 50 Ω dummy load via a 22 cm 50 Ω patch cable.

Further, I measured collector voltage + collector current with 2 DVMs and also PA output power in my oscillocope (DSO) Channel 2 with a 10X probe employing a tiny ground lead.

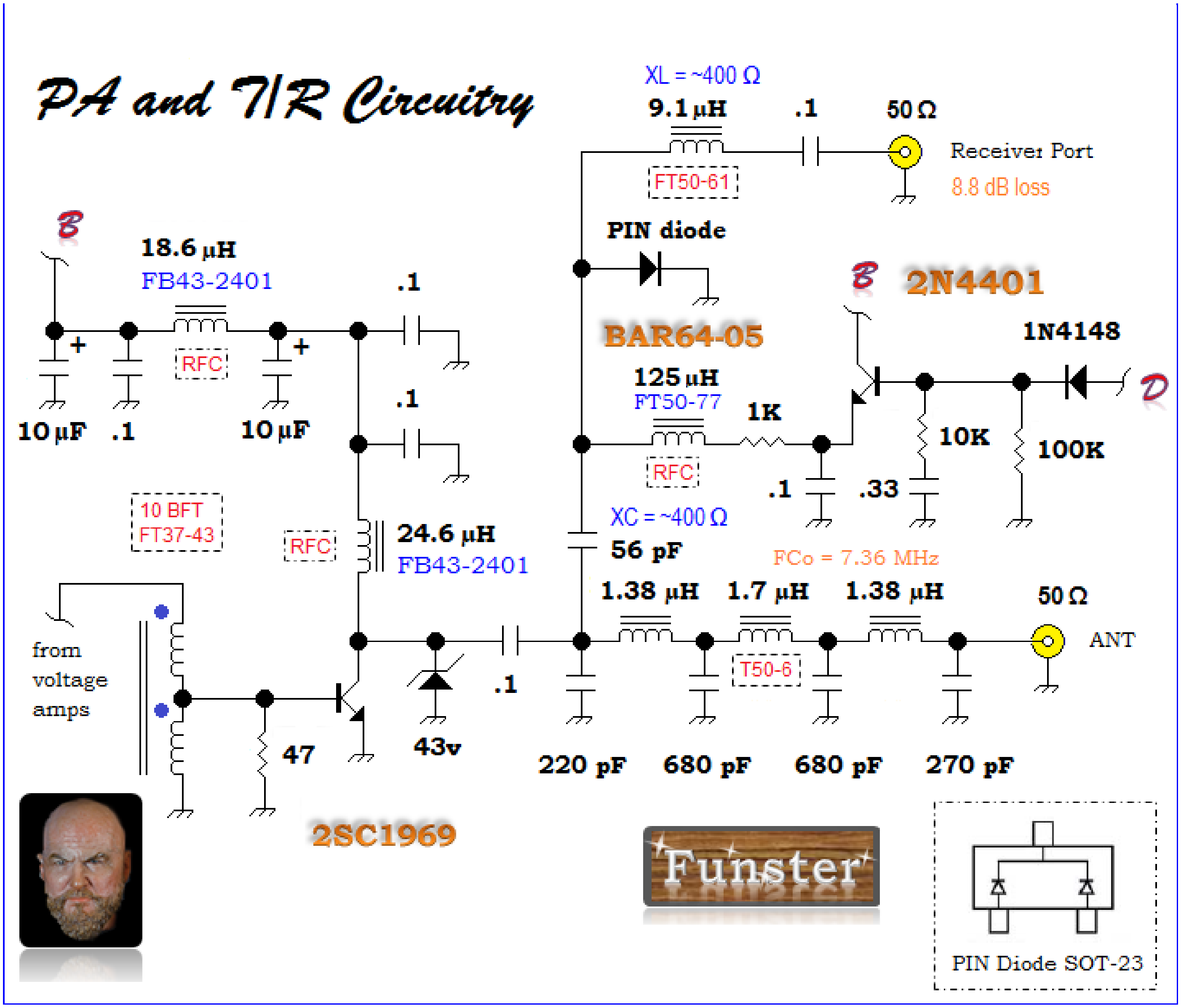
PA and T/R Circuitry
XL = ~400 Ω
9.1 µH
.1
50 Ω
Receiver Port
8.8 dB loss
FT50-61
PIN diode
B
2N4401
BAR64-05
1N4148
D
B
18.6 µH
FB43-2401
.1
+
+
RFC
125 µH
FT50-77
1K
10K
100K
10 µF
.1
10 µF
.1
RFC
.1
.33
10 BFT
FT37-43
RFC
24.6 µH
FB43-2401
XC = ~400 Ω
56 pF
FCo = 7.36 MHz
1.38 µH
1.7 µH
1.38 µH
50 Ω
ANT
from
voltage
amps
T50-6
.1
47
43v
220 pF
680 pF
680 pF
270 pF
2SC1969
Funster
PIN Diode SOT-23

Above — PA and T/R circuitry schematic. Click for another breadboard photograph taken before the 2N4401 switch was added. Although we might run a BD139 or other cheap BJT for the final, I chose my favorite HF classic, the 2SC1969. This transistor will survive a high VSWR, however a 43 volt - 500 mW zener diode further protects it from such.

In 1 version with a 1:4 Z collector matching network and no zener diode, I measured 6.25W RF power after tweaking the 100K and 18K RF gain limiting resistors in the preceeding hycas voltage amp to drive the PA harder. At ~3W maximum power in my final experiment, the 2SC1969 barely warms up.

Collector Matching

After a number of experiments, I learned that from tens of mW up to ~ 3.3 Watts RF power, we may omit collector matching and still get reasonable efficiency if you run a collector choke >= 15 µH. Thus, I made the maximum power ~ close to 3W — easy peasy.

Ask QRP enthusiasts what QRP is all about and they might extol the thrill of exacting the most kilometers per Watt — in keeping with that spirit, I love turning down my Tx power and the Funster front panel RF gain control makes it a breeze.

The PA circuit is standard fodder. I wound the 24.6 µH and 18.6 µH RFCs on FB43-2401 ferrites [a single hole bead that looks like a fat FT37-43]. An FT37-43 or FT50-43 makes a great substitute.

PA Measures

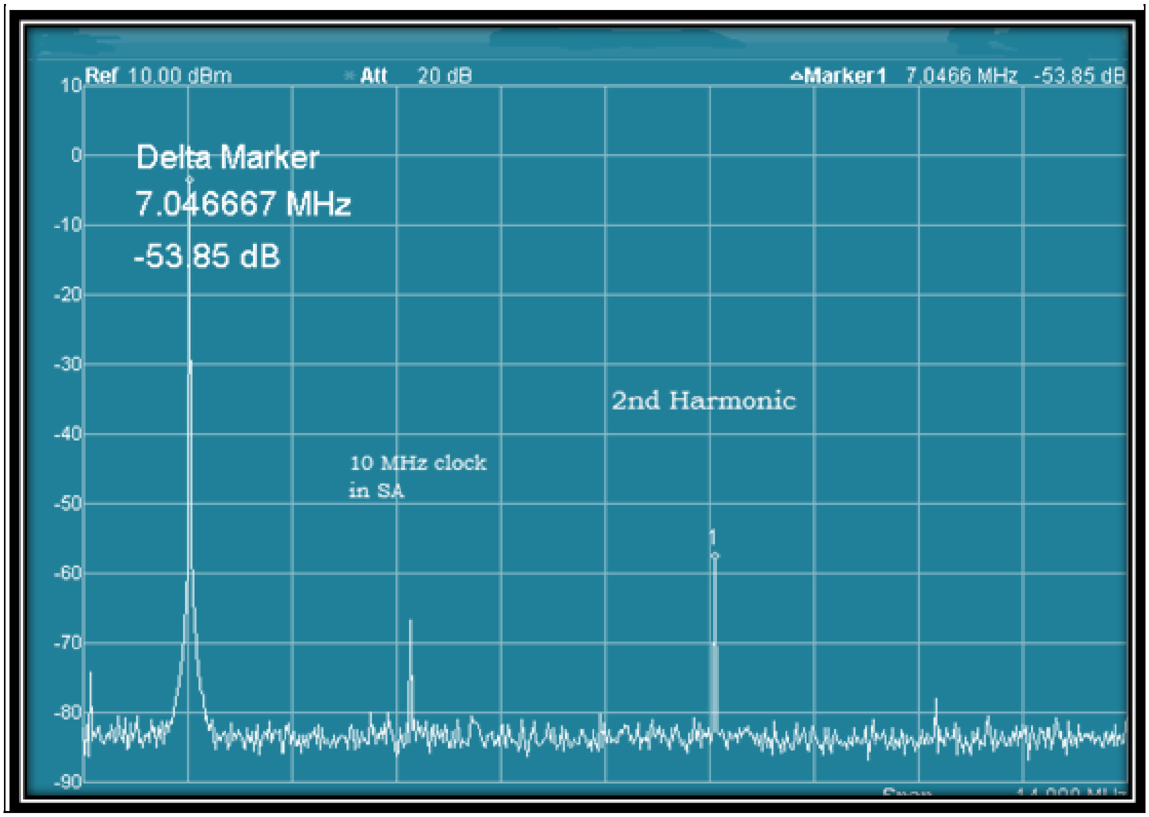

Above — Spectrum analysis of the Tx output. The 10 MHz clock signal from my spectrum analyzer lays between the fundamental and 2nd harmonic. The 2nd harmonic = -53.85 dBc @ 3W power output.

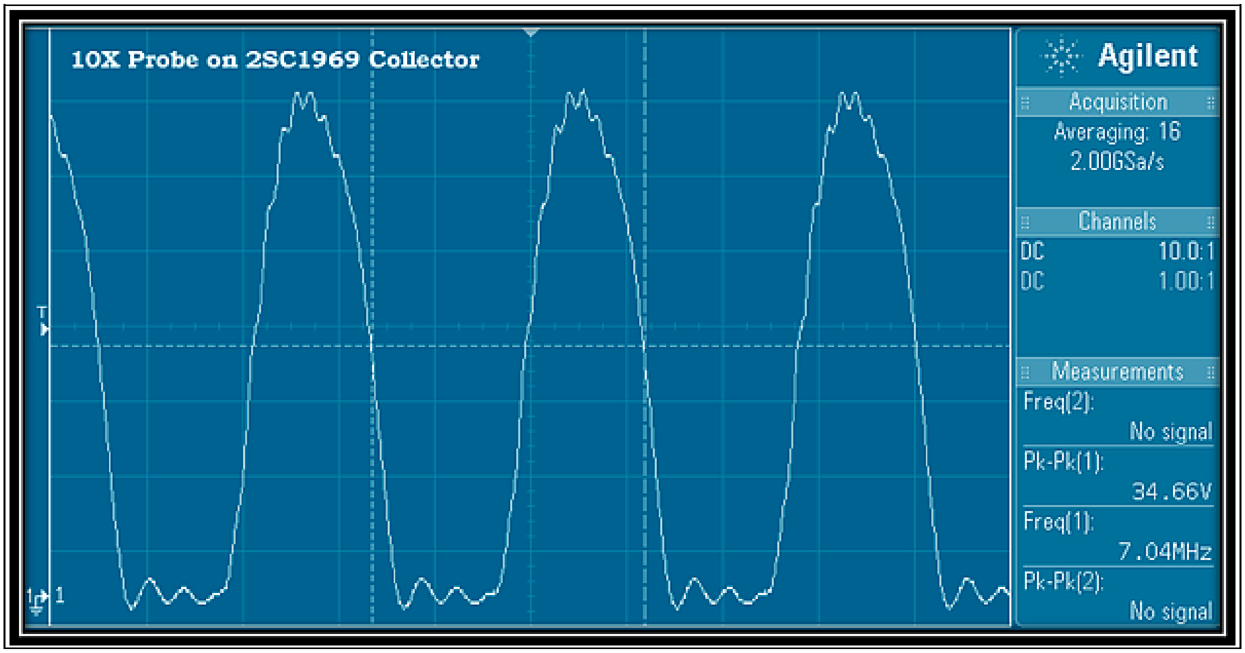
10X Probe on 2SC1969 Collector
Agilent
Acquisition
Channels
Measurements
T
1

Averaging: 16
2.00GSa/s

DC 10.0:1
DC 1.00:1

Freq(2): No signal
Pk-Pk(1): 34.66V
Freq(1): 7.04MHz
Pk-Pk(2): No signal

Above — PA collector waveform at 3W output measured with my DSO's 10X probe.

VICHY
VC99
APO
DC
0.331
AUTO
A
MAX/MIN
Hz/DUTY
REL
HOLD
RANGE
DC/AC
Hz
°C
hFE
EQUUS
#4320
13.58
DCV
OFF
ACV

Above — Set your meters on stun! DC measures to calculate PA efficiency [See RF Workbench 6]: DC power = 13.58V x 0.331A = 4.49W. RF power = 3W. Efficiency = RF power / DC power = 3W / 4.49W = 66.8%.

T/R Discussion for Single Band Transceivers

Previous Funsters ran a simple QSK T/R circuit developed by Wes, W7ZOI in the early 1980s: a series X = 500 Ω resonator with anti-parallel diodes between the L and C. The series capacitor presents 500 Ω reactance to the 50 Ω transmit line so that only a small portion of the transmitter power flows to ground via the diodes and even less reaches the receiver input. In short, the 500 Ω capacitive reactance + clamping action of the anti-parallel diodes protect the receiver front end.

For 1 band, this simple circuit sizzles. Two potential concerns:

~6-9 dB loss of the receive signal making it better for lower HF, although I've seen builders add a receive preamp and use this T/R system on 12 and 10 meters. Since both band noise and signals get attenuated simultaneously, I've rarely had readability issues on 160-30 meters in my popcorn transceivers.

The anti-parallel diodes may cause IMD. The intercept for the 500 Ohm series reactances with shunt diodes is around +6 or +7 dBm. This might exert problems in a high performance receiver front end, but poses a non-issue with typical NE612 front ends. Many builders, including Wes, reduce IMD potential with 2 or 3 series diodes on each leg. Another solution includes running a PIN diode as the shunt element. That's what I did.

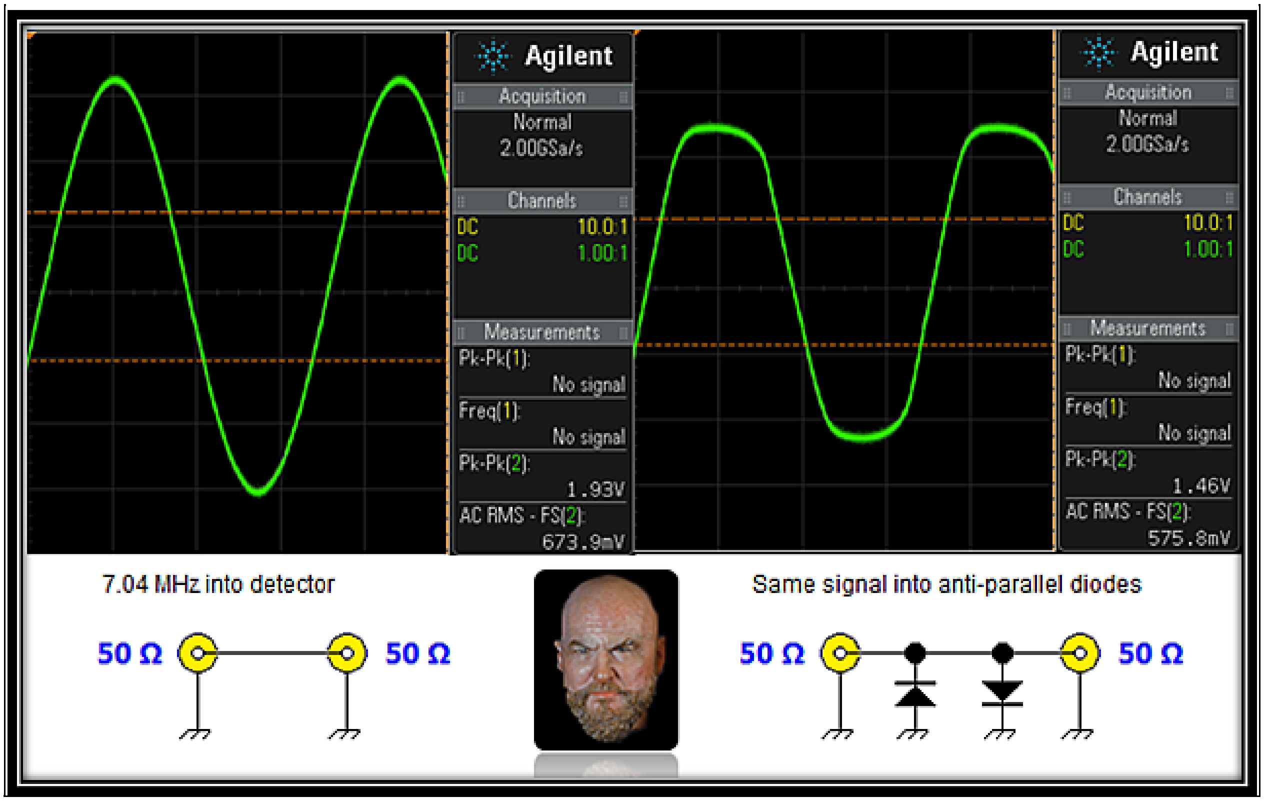
Acquisition
Normal
2.00GSa/s
Channels
DC 10.0:1
DC 1.00:1
Measurements
Pk-Pk(1): No signal
Freq(1): No signal
Pk-Pk(2): 1.93V
AC RMS - FS(2): 673.9mV

Acquisition
Normal
2.00GSa/s
Channels
DC 10.0:1
DC 1.00:1
Measurements
Pk-Pk(1): No signal
Freq(1): No signal
Pk-Pk(2): 1.46V
AC RMS - FS(2): 575.8mV

Above — The DSO tracing of an experiment showing the before and after effect of 2 anti-parallel diodes. The voltage across a silicon diode varies with the current going through it. Silicon diodes don't conduct much current until the voltage across them reaches a threshold [typically ~0.6 to 0.7 volts].

In situ, the forward threshold voltage of each diode limits the circuit voltage by clipping off AC voltage above its threshold. Clamping refers to the limiting of voltage in *2* directions using anti-parallel pair(s) of clipping diodes. For example, if a negative-going AC dips more than 1 diode drop below ground, the left hand diode will begin to conduct and clip off any voltage above its threshold. This, of course, describes the "ideal diode" — in real life, factors like switching speed, current-handling and temperature are all in play.

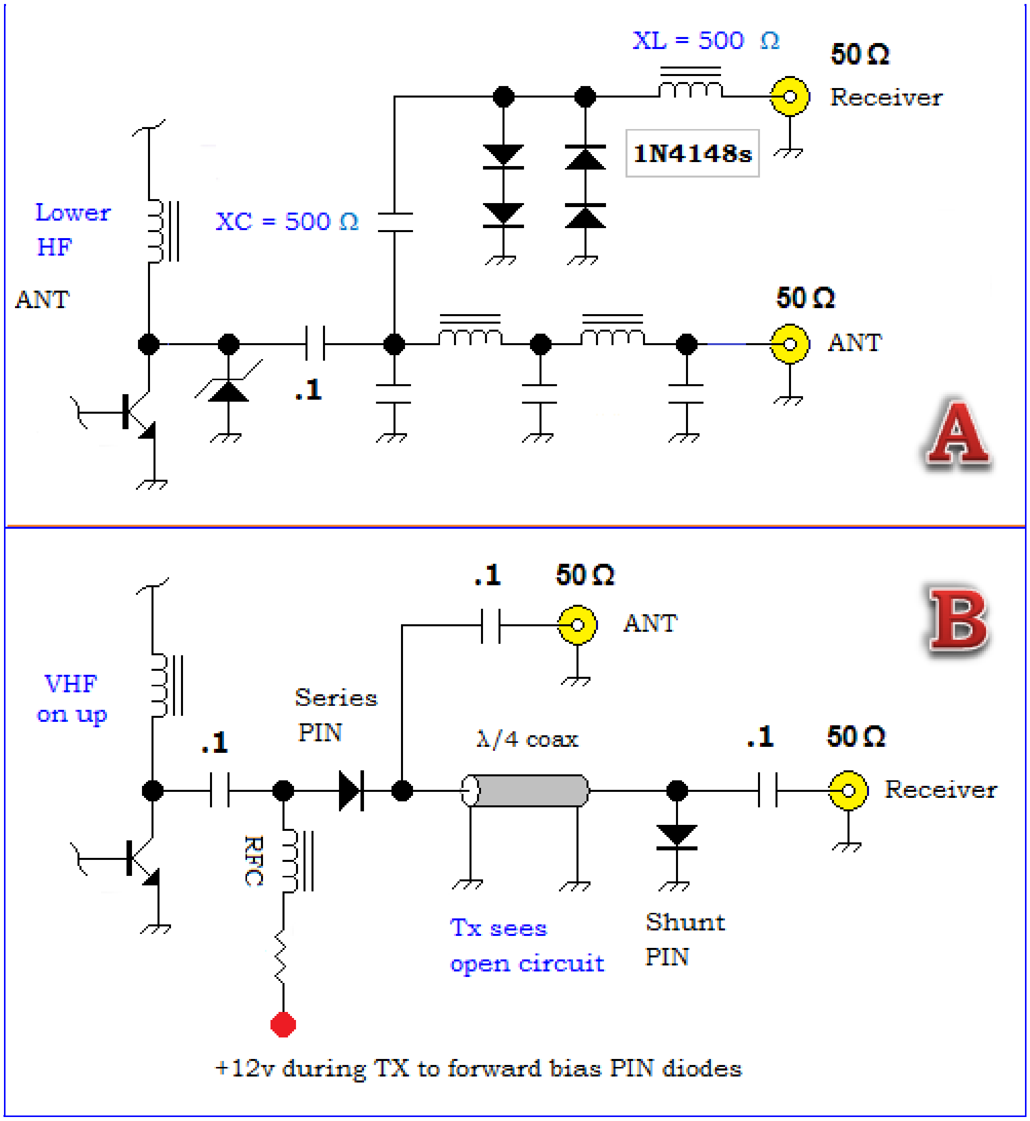

Above — 2 possible T/R schemes. Figure A shows the classic W7ZOI T/R system with 2 diodes per leg. See EMRFD Fig 2.112, for an example with 3 diodes per leg. For 1 band, it's often our go-to circuit.

Figure B shows a scheme well suited for VHF on up: Both PIN diodes get forward biased during transmit mode, however, a 1/4 wave transmission line lays between the series and shunt PIN diode. 1/4 wave transmission lines exert magic [actually it's pure physics that may be verified with a Smith chart]. When the shunt PIN diode gets biased *on* and grounds the receiver port end of the transmission line, the other end looks like an open circuit and thus power flows to the antenna port and not into the forward biased shunt PIN diode to ground. I hope to apply this system in future VHF and UHF projects and sadly, it's impracticable at HF.

Funster Version 8 T/R

As it happens, I seek experience with PIN diodes and therefore shunted a PIN diode instead of running anti-parallel diodes in the classic W7ZOI T/R scheme. This meant adding a transistor switch to quickly bias on the PIN diode @ *key down* and run a little hang time @ *key up*.

Please refer to the PA-T/R schematic. During key down, keyed 12 volts saturates the 2N4401 switch and 11 ma current biases *on* the PIN diode. At key up, the BJT switch's base voltage is held on by the 10K plus series 0.33 μF capacitor just long enough to allow the stored energy in the large PA collector choke to collapse — protecting the receiver.

Feel free to experiment with the timing capacitor value. Previously, Wes, W7ZOI suggested connecting the T/R receiver port to a 50 Ω teminated 'scope for general measurement and also for clocking up RC time constants in DC switching circuits. With a 2 channel 'scope you can monitor the receiver port switch function in 1 channel while watching the PA collector AC voltage in the other. Now that's experimenting! Click for a sample from my QRP workbench.

I chose an XC / XL of 400 Ω for the series L-C network. The 9.1 μH coil shouldn't be wound on a 43 material ferrite [the Qu is just too low]: a bigger powdered iron toroid like size 68, or even a 61 ferrite material toroid works okay from my experiments [Q's as high as 162 were measured on a FT50-61 @ 1 MHz in 2013]. Although this coil tunes coarsely, try tweaking the 9.1 μH inductor with thumb and forefinger during actual signal testing in a receiver.

I wound the 125 µH choke connected to the pin diode cathode on a 77 material ferrite toroid to get it done with just a few turns and avoid a self resonant frequency close to 7 MHz.

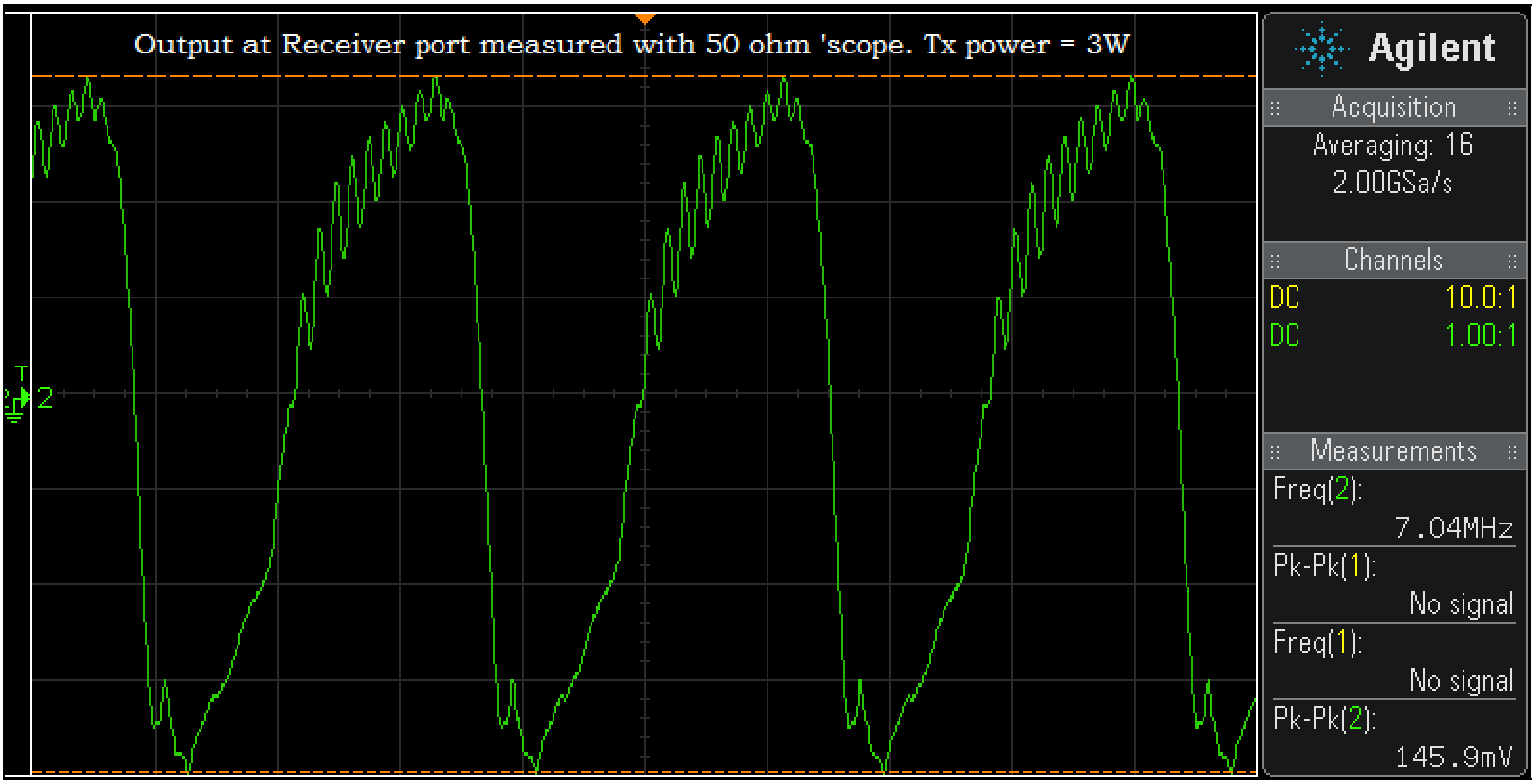
Output at Receiver port measured with 50 ohm 'scope. Tx power = 3W

Averaging: 16
2.00GSa/s
DC 10.0:1
DC 1.00:1
Freq(2): 7.04MHz
Pk-Pk(1): No signal
Freq(1): No signal
Pk-Pk(2): 145.9mV

Above — 50 Ω terminated DSO measurement of the receiver port @ 3W transmitter power. Theoretically all power should shunt to ground through the PIN diode, however, the diode exhibits a little resistance and the series L-C circuit contains reactance, so isolation is never perfect.

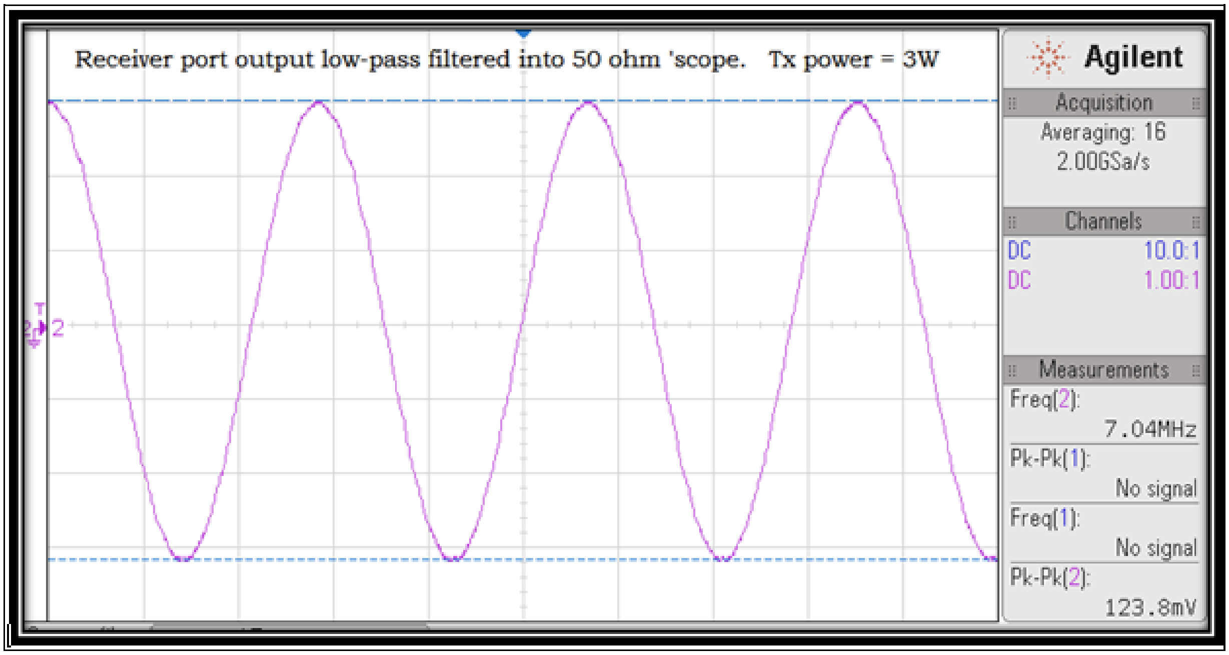
Receiver port output low-pass filtered into 50 ohm 'scope. Tx power = 3W

Averaging: 16
2.00GSa/s
DC 10.0:1
DC 1.00:1
Freq(2): 7.04MHz
Pk-Pk(1): No signal
Freq(1): No signal
Pk-Pk(2): 123.8mV

Above — A low-pass filtered measure of the receiver port while in transmit mode. The beauty of a 50 Ω measurement environment shines: I placed a 7.36 MHz-bench module low-pass filter between the receive port and my DSO to quantify the leaked power to the receiver port as -14.17 dBm when the transmitter delivers 3W. Safe for my receiver.

My sincere thanks to those who offered advice and feedback during the build of this transmitter.

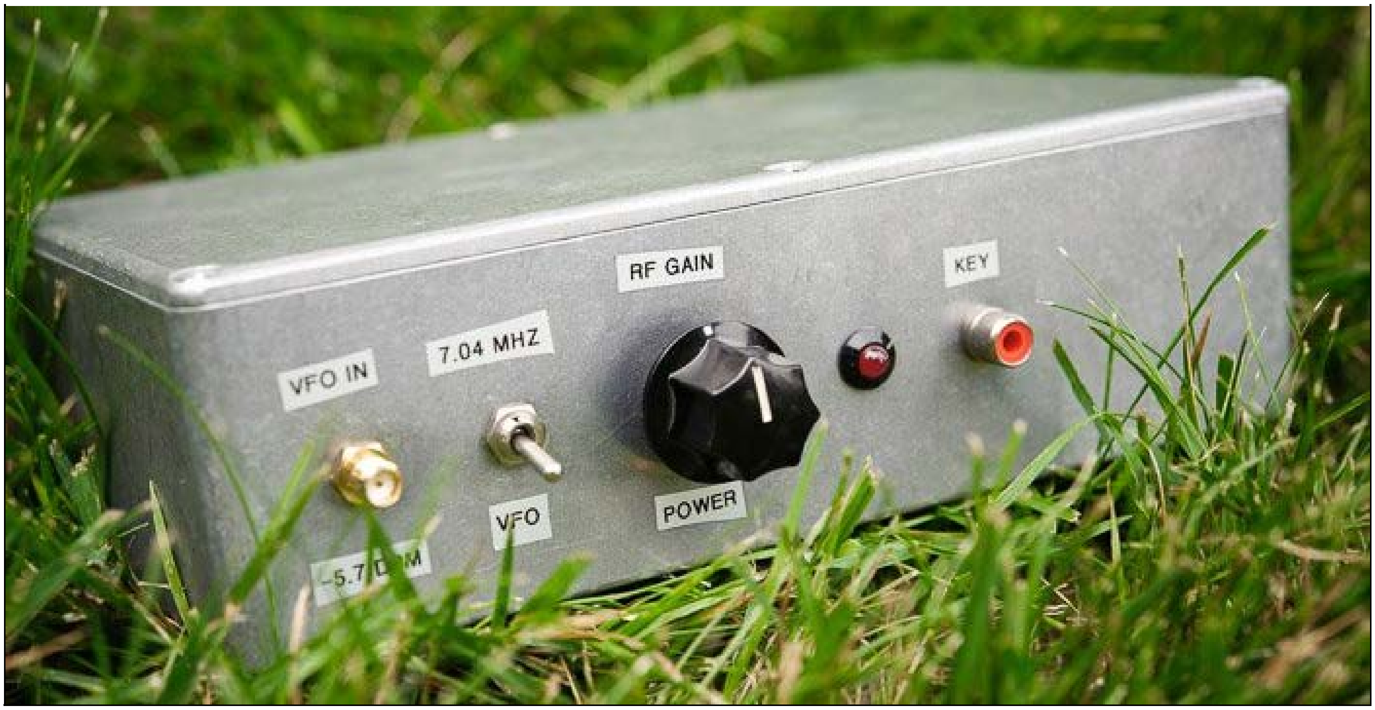
VFO IN
7.04 MHZ
RF GAIN
KEY
-5.7 DBM
VFO
POWER

Above — Funster in the field.

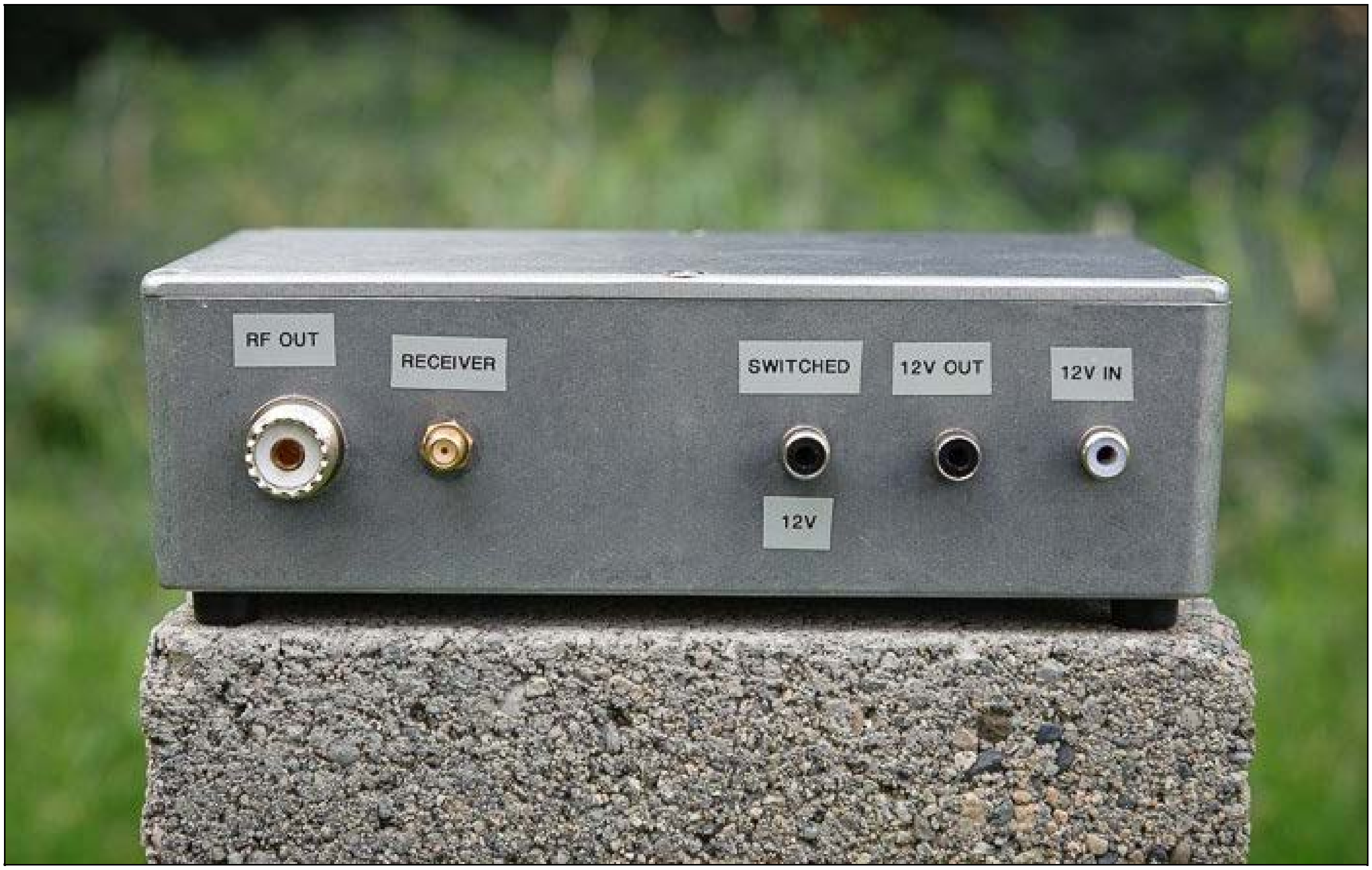
RF OUT
RECEIVER
SWITCHED
12V
12V OUT
12V IN

Above — Rear view of the Funster Tx.

VFO IN
VFO
XTAL
RF GAIN
POWER
KEY

---

2. References

T/R References

Perfecting a QSK System. QEX for Mar/Apr 2006. Markus, VE7CA. Click for pdf.

Electronic Switching and How it Works, QST for September 1984. Doug, W1FB

7 MHz receiver -- discussion begins on page 215 -- On page 214 in Fig 1 see the 33 pF input cap plus receiver protecting anti-parallel diodes. Also view the 555 timer and other T/R control circuitry in Figure 2 on page 215. *This receiver realizes the first-ever printed version of the W7ZOI T/R system described earlier.* Solid State Design for the Radio Amateur. ARRL,1986 [out of print] by Wes, W7ZOI and Doug W1FB.

Transmit - Receive Antenna Switching. EMRFD. First published by the ARRL in 2003. Page 6.68.

Schematic for the 30-W, 7 MHz power amplifier. Figure 2.112 [page 2-42] EMRFD. Design by Wes, W7ZOI

QRP SWL HomeBuilder

RF — Test and Measurement

VHF FM — Supplement 1

This page supplements VHF FM

1. 10.7 MHz IF Strip - with example broadcast band FM receiver
2. NOAA Receiver Experiments @ 162.55 MHz

---

1. 10.7 MHz IF Strip

I'm inexperienced with making FM receivers and lack confidence. I began with a utility module to allow basic assessment of the circuit gain required for different detectors, ceramic filter bandwidths, and more so — to get something working to boost my confidence.

The FM receiver 10.7 MHz IF standard began soon after World War 2 and 10.7 MHz still makes sense for the primitive radio builder — surplus IF filters still seem available in a variety of bandwidths. Although vexxing, if we suffer from receiver images at 10.7 MHz, we can always filter the input better, or jump up the IF and make a crystal filter for say 20 MHz. Above 20 MHz good, inexpensive, fundamental-mode crystals get hard to find.

Mixer

I chose a diode ring mixer; again. After trying other mixers such as balanced FETs, or an NE612 , I kept coming back to the diode ring. Partly I'm biased and partly it's from from measures like this one. Although the oscillators weren't perfectly set for a 10.7 MHz IF, the LO and RF signals are both > 40 dB down from the desired IF — love this.

Since I designed a 50 Ω bench module, the IF output contains a source follower to drive the IF port. In an actual "keeper" receiver, you probably wouldn't bother since you might just directly drive the detector, or perhaps another 330 Ω input/output IF amp before the detector.

Although I humbly build simple/primitive circuits, my design goal is never for a *low parts count* — each part serves its purpose. A low parts count ideology plus minimalism exploits the frugal and primitive homebrew nature of our brother hobbyists, however, often gets out of hand. Some builders just cite a low parts count *design goal* to rationalize a poor design. Worse yet, inexperienced minimalists often exclude vital parts such as DC supply decoupling and bypassing, temperature stablizing bias networks, or adequate band-pass filtering. To each his own. Please discern all you see or read in homebrew radio; we're builders, not lemmings.

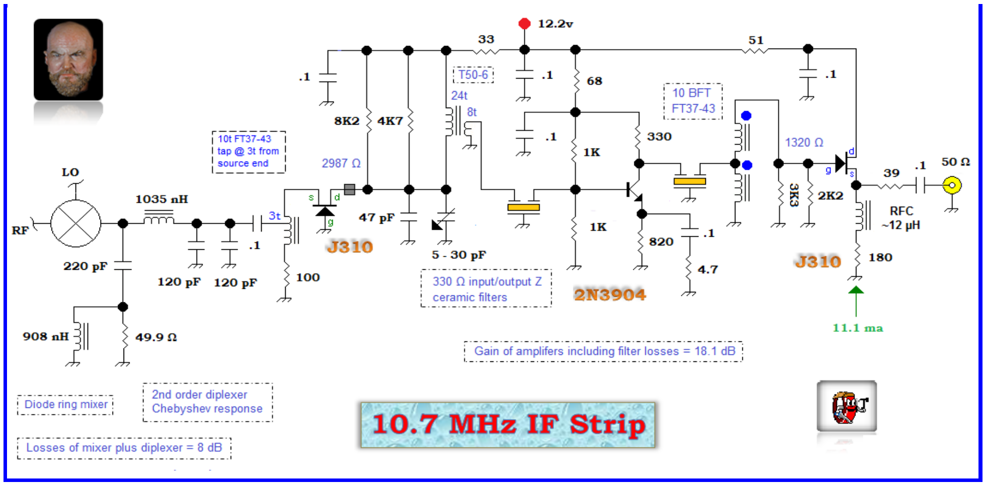
12.2v
33
51
.1
.1
68
.1
T50-6
24t
8t
10 BFT
FT37-43
8K2
4K7
.1
330
1K
1320 Ω
10t FT37-43
tap @ 3t from
source end
2987 Ω
LO
1035 nH
RF
3t
s
d
g
47 pF
J310
.1
5 - 30 pF
1K
820
.1
4.7
3K3
2K2
39
.1
50 Ω
RFC
~12 µH
J310
180
220 pF
120 pF
120 pF
100
330 Ω input/output Z
ceramic filters
2N3904
11.1 ma
908 nH
49.9 Ω
Gain of amplifers including filter losses = 18.1 dB
Diode ring mixer
2nd order diplexer
Chebyshev response
10.7 MHz IF Strip
Losses of mixer plus diplexer = 8 dB

Above — Click on the IF strip schematic to view it. Most all the stages were discussed on VHF-FM. My net module gain = 10.1 dB. The 2 ceramic IF filters = 230 KHz Muratas with a measured average loss of 6.15 dB each.

LO
RF
10.7 MHZ IF
STRIP

Above — The boxed up circuit contains 3 SMA jacks. Click for a photo of the completed breadboard.

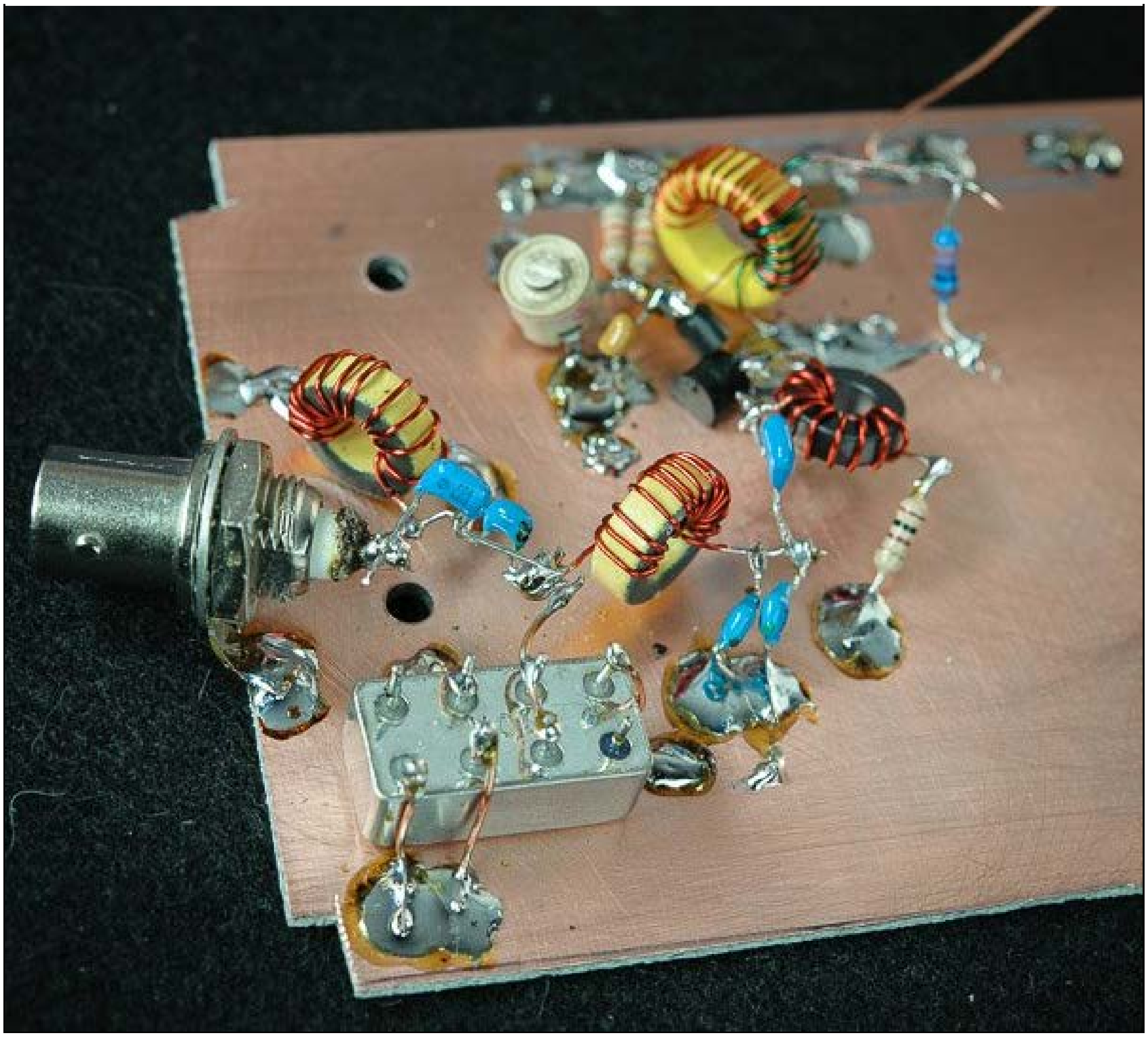

Above — A close up of the mixer, diplexer and JFET amp, although the SBL-1 mixer is disconnected. This board contains a temporary BNC jack to allow testing of the non-mixer parts such as JFET gain, diplexer loss, return loss, to confirm the tuning cap choice and also to look for any UHF oscillations eminating from the FET, a UHF part. Click to zoom in on the common gate amplifer with its gate lead soldered as close to the plastic case as possible.

Detector

I tried to homebrew my first IF amp +/- limiter and detectors , but felt unhappy with their performance, failures, circuit complexity and/or noise issues. Click click or click for 3 raw, miserable design examples from Winter 2014. Discouraged; after 2 months of lamenting, I opted for an IC detector subsystem. 3 relic part choices might include the CA3089, SA604A or LA1150.

In my case, the CA3089 suited me best and offers a lot: a double-balanced quadrature FM detector with limiter + IF ampifiers; squelch, AFC, AGC, AF preamp and the potential for high-fidelity FM reception. All that's required is an outboard detector resonator — easy to build with a powered iron toroid plus a fixed + trimmer cap.
Price + shipping varies widely, but last year, I got 5 shipped to me from Europe for $7.25 USD and these will make 5 receivers — not bad at all. What hobby isn't expensive?

I've even read that some builders used the CA3089 for an S-meter amplifer, although its logarithmic compliance is far from stellar. You'll need to download the CA3089 datasheet.

Let's build a receiver:

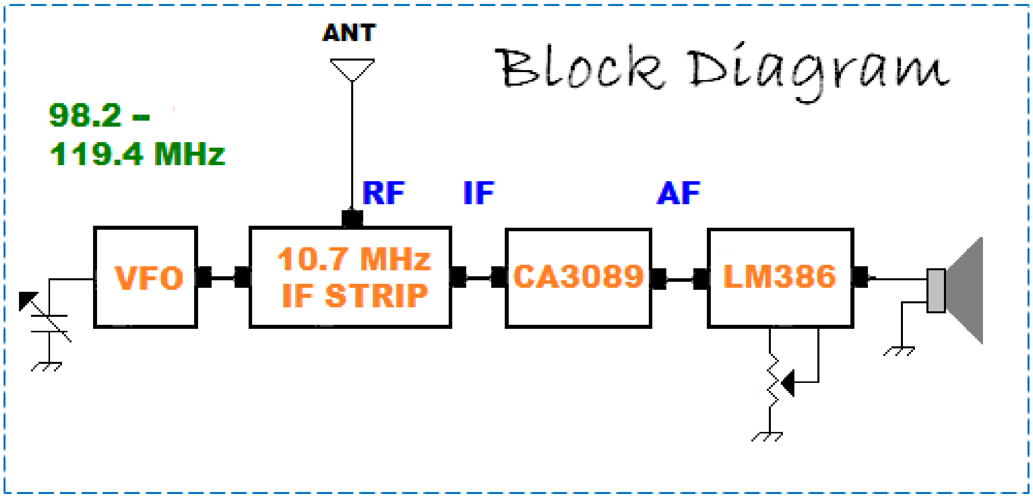
Block Diagram
ANT
98.2 –
119.4 MHz
RF
IF
AF
VFO
10.7 MHz
IF STRIP
CA3089
LM386

Above — The block diagram. The antenna = 1 meter piece of wire soldered to a SMA jack that was threaded into a brass sheet to fashion a crude ground plane. No LNA or input band-pass filtering was employed.

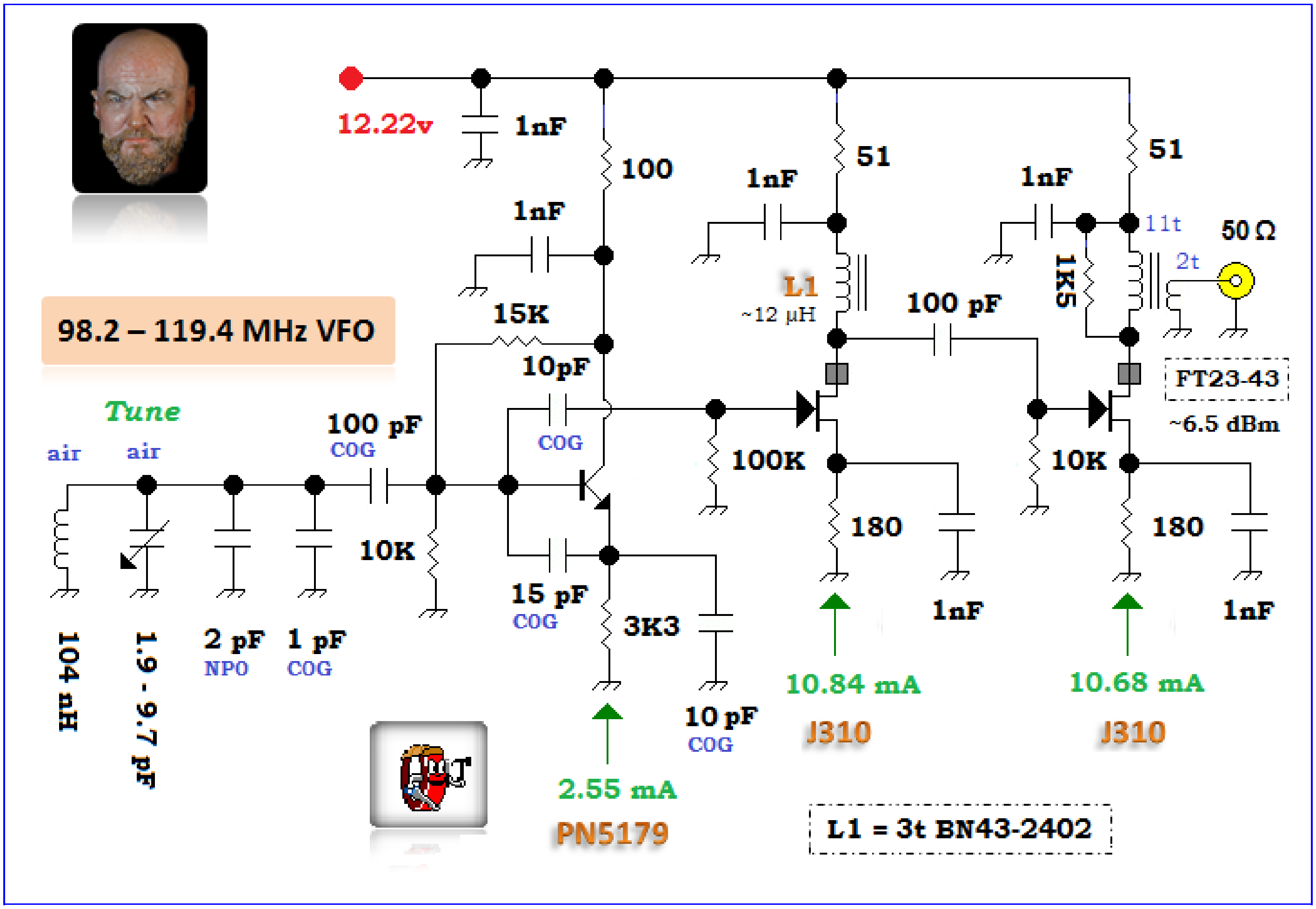
12.22v
1nF
100
1nF
15K
10pF
COG
98.2 – 119.4 MHz VFO
Tune
air
air
100 pF
COG
10K
15 pF
COG
3K3
10 pF
COG
104 nH
1.9 - 9.7 pF
2 pF
NPO
1 pF
COG
2.55 mA
PN5179
51
1nF
L1
~12 µH
100 pF
100K
180
1nF
10.84 mA
J310
51
1nF
11t
2t
50 Ω
1K5
FT23-43
~6.5 dBm
10K
180
1nF
10.68 mA
J310
L1 = 3t BN43-2402

Above — The temperature compensated, free running VFO. Normally we should run a VCO-PLL, digital contraption, or a VFO/VCO with ALC feedback, but this thing worked fine to learn on.

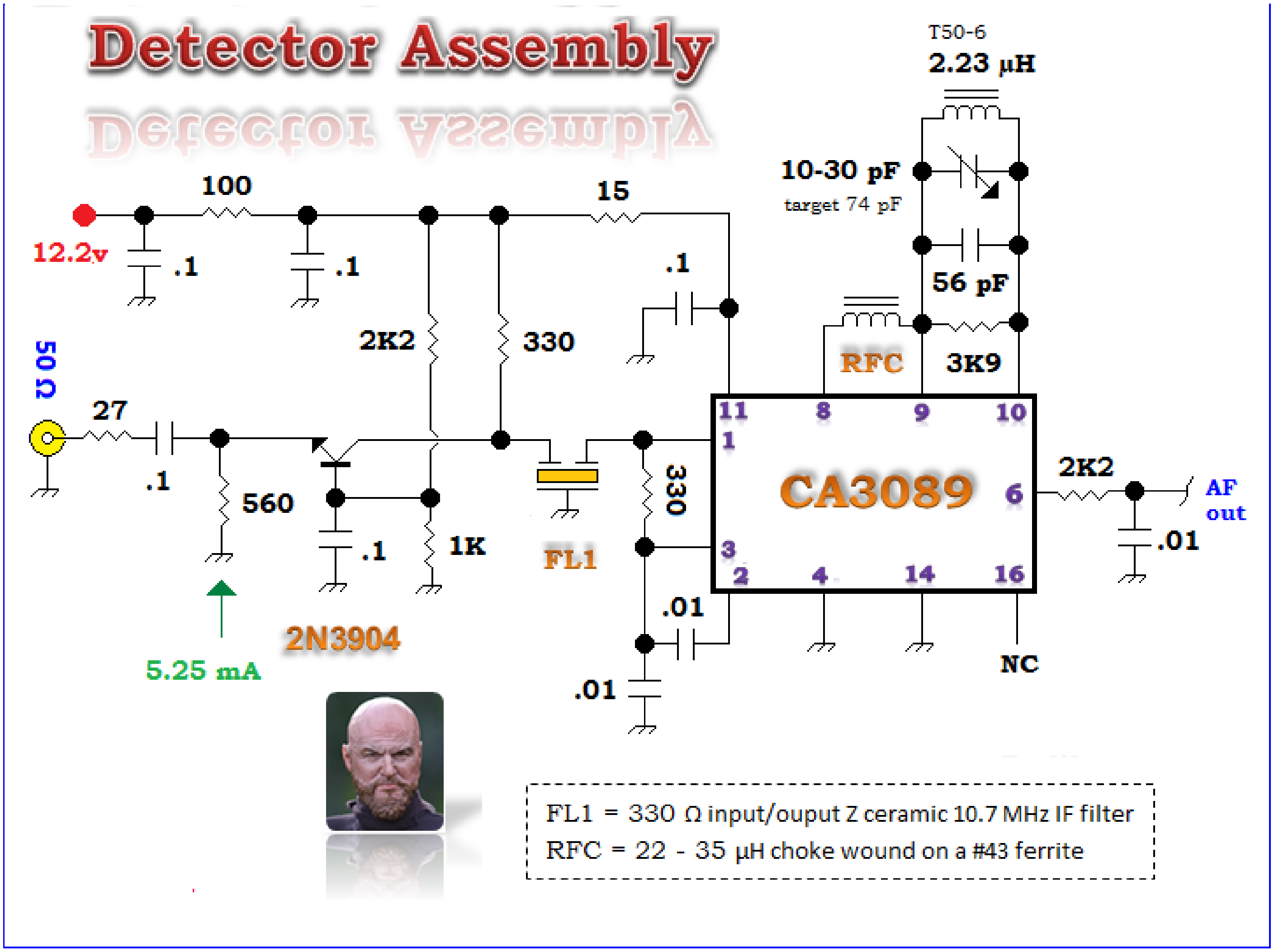

FL1 = 330 Ω input/ouput Z ceramic 10.7 MHz IF filter
RFC = 22 - 35 µH choke wound on a #43 ferrite

Above — The detector assembly. To match to the 50 Ω IF strip port, I employed a common base amp with a 330 Ω collector resistor driving a final 230 KHz wide "tail end or mop up" filter. In many designs you could simply drop this amp as the gain isn't really needed. On the other hand, the CA3089 contains a limiter and it won't hurt at all.

To make the detector coil, a small square island was carved on the copper clad board. The island was bisected so that pin 9 soldered to 1/2 the island and pin 10 to the other half. The 3K9 R, 56 pF C and a small, high Q SMT trimmer capacitor bridged the 2 islands. Finally, a 2.23 µH, T50-6 toroidal inductor was soldered across the 2 islands.

Tune a station and peak the trimmer cap for the most crisp sounding audio — it's set and forget. When driven with enough signal for full quieting, the CA3089 delivers very low distortion — the FM receiver in my truck sounds worse.

An RFC provides a DC short across pin 8 to 9 and keep ~5.5 VDC bias on the pin 9 transistor base. The minimum inductance should be 10X the detector coil. I wound my RFC with 6 turns on a BN43-2402 [35 µH] , but any old #43 ferrite wound choke >= 22 µH should work. For my chokes, I prefer a low # of turns on a binocular core to avoid any SRF issues.

Since the CA3089 contains a powerful audo preamplifer, only an AF power amplifer with low gain is required. I opted with the old LM386, but in future, better, "keeper rigs" I'll add an op-amp tone control stack driving a pair of power followers for good measure.

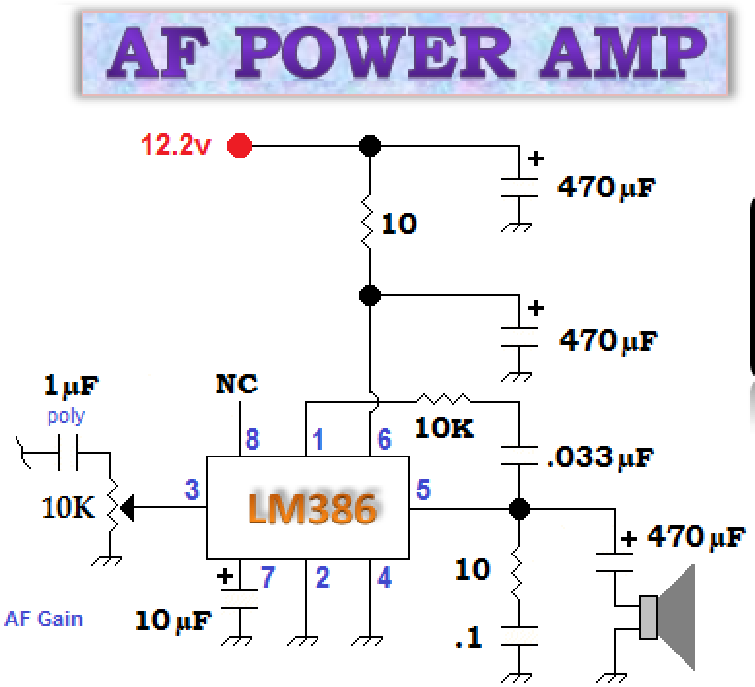

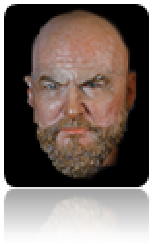

Above — Final audio power amp: an LM386 set for a voltage gain of 20 with some low-pass filtering and stout DC line filtering.

Click for a photo of the detector and LM386 assembly. Click for a better view of the outboard resonator and nearby RFC.

Outcomes

After connecting the VFO, antenna, IF strip, detector assemby, speaker and powering them up, loud FM radio blared through the loudspeaker. I tuned every local FM station with full quieting and felt surprised that despite no band-pass filtering, plus no RF preamp, it worked and sounded so well.

Further experiments showed that inserting as much as 15 dB attenuation between the IF stip and the detector assembly still kept full quieting on all the stronger stations. In some cities with multiple, strong FM stations, input band-pass filters will be needed. I'll cover that in a later installment.

I connected this VFO to the IF strip and tuned in my local NOAA weather station at 162.55 MHz. Click for a photo of the VFO built on a piece of bent copper sheet metal.

Future experiments may include changing ceramic filter bandwidth, trying different mixers, applying varactor-tuned input band-pass filters for strong FM environments and for FM Dxing. Finally, I'll design a low-noise preamp with a common gate JFET and/or a dual-gate MOSFET. Utimately, I hope to make a dedicated NOAA weather receiver, a broadcast FM Dx receiver and then some narrow band FM jobs for 2M or 6M. The future looks good.

Audio sample one : a few local stations [mostly recorded before I added the negative feedback on the LM386]
Audio sample two: a weak signal [our provincial Highway Report] that doesn't reach full quieting.

Thanks.

2. NOAA Receiver Experiments @ 162.55 MHz

I document some *raw* experiments and hopefully 1 day will make a good receiver for my local NOAA FM broadcast.

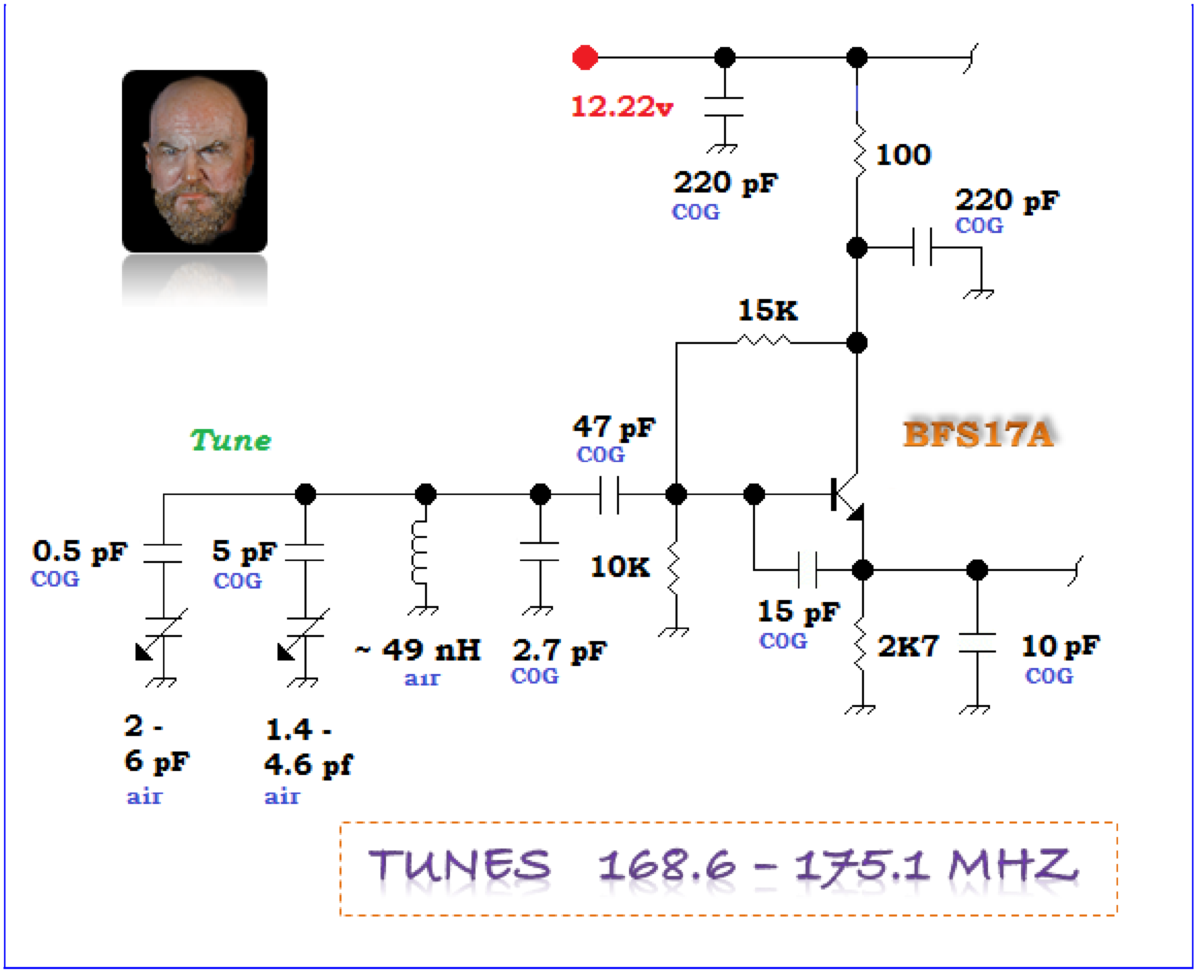
12.22v
220 pF
COG
100
220 pF
COG
15K
BFS17A
Tune
47 pF
COG
0.5 pF
COG
5 pF
COG
10K
15 pF
COG
~ 49 nH
air
2.7 pF
COG
2K7
10 pF
COG
2 -
6 pF
air
1.4 -
4.6 pf
air
TUNES 168.6 – 175.1 MHZ

Above — I built a VFO for 173.25 MHz with fine tuning for my local, NOAA weather report receiver @ 162.55 MHz. The fine tuning 2- 6 pF variable capacitor in series with an ATX 0.5 pF chip cap resolves 10's of kilohertz to permit tuning narrow band signals. You'll especially need fine resolution tuning when applying ceramic IF filters <= 150 KHz.

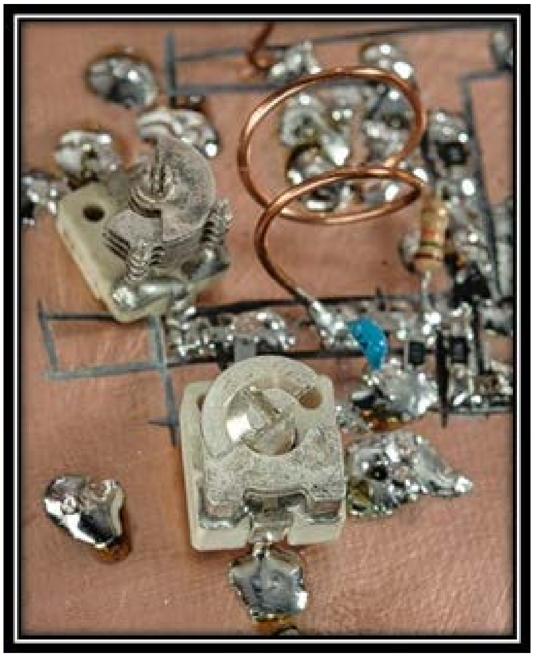

Above — The 2 VFO air variable tuning capacitors. Click for the circuit breadboard with a tuned, common emitter buffer, that I'd rather not show [because it sucks]. I ran the VFO into a bench module to boost the power up between 5 and 10 dBm in my experiments.

Since @ VHF, my VFO went on 2-sided FR4 board with several wire vias joining the 2 surfaces. We normally avoid double sided boards for VFOs since doing so makes a low Q, potentially moisture absorbant, undefined temperature coefficient "capacitor" that may worsen temperature drift. For bench learning and in particular, FM reception, temperature stability tested adequate and I can listen for hours without retuning.

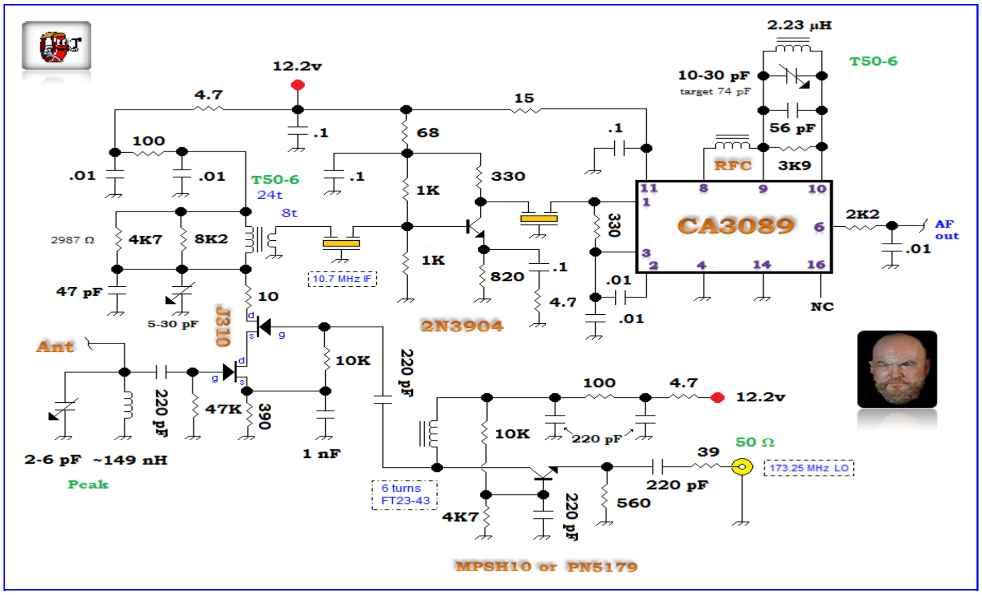
2.23 µH
T50-6
12.2v
10-30 pF
target 74 pF
4.7
15
56 pF
100
.1
68
.1
.01
.01
T50-6
24t
8t
.1
1K
330
RFC
3K9
11
8
9
10
1
CA3089
6
2K2
AF
out
2987 Ω
4K7
8K2
330
3
2
4
14
16
.01
10.7 MHz IF
1K
820
.1
.01
4.7
.01
47 pF
5-30 pF
10
J310
d
s
g
NC
2N3904
Ant
d
g
s
10K
220 pF
220 pF
47K
390
100
4.7
12.2v
10K
220 pF
2-6 pF
~149 nH
1 nF
50 Ω
39
173.25 MHz LO
Peak
6 turns
FT23-43
220 pF
560
4K7
220 pF
MPSH10 or PN5179

Above — The entire receiver with a cascode mixer from EMRFD. In experimenter's mode; I tried out many ideas. For example: different bandwidth IF filters [settled on 230 KHz] , 1 versus 2 ceramic filters, or eliminating the 2N3904 amp [2 better drove the CA3089]. One salient learning — IF filters may possess a wide variation in center frequency and thus if you have a sweeper, matching them might be useful. In this receiver topology, you don't need to match 230 KHz or 280 KHz ceramic filters; the mismatch became noticeable with a <= 150 KHz 3 dB filter bandwidth.

I boosted the VFO signal with a common base amp — I varied the power into this LO amplifier by applying different strength attenuator pads. Between 1.5 to 2 Vpp on the mixer gate gave a reasonable compromise of conversion gain, noise and easy-to-get VFO power. From EMRFD, maximum conversion gain occurs when driven with 5 Vpp.

This unbalanced mixer worked fine, however, without a metal case, I heard a little hum from my DC supply and noises from household appliances such as the clothes washer and fridge. This receiver suffered from microphonics as well. The AF amp was a LM386 set for gain = 50.

A simple LC resonator tuned the mixer RF input and proved essential. I tried different ways to couple a 25 cm long wire antenna such as tapping the coil and an L- network, however, my main antenna peeve was severe hand capacitance effects. Although this receiver does not require a preamp for RF gain, the isolation seems needed. If you put your hand near the telescopic whip antenna of my Realistic Pro 2020 scanner, no noise or RF disturbance arises.

From studying scanner and FM receiver schematics, most rigs contain a dual-gate MOSFET preamp for a low noise figure and high input isolation. These MOSFET amplifiers feature input and output tuning, although with slug-tuned inductor cans and the oh-so-typical varactors, the resonator Q runs low.

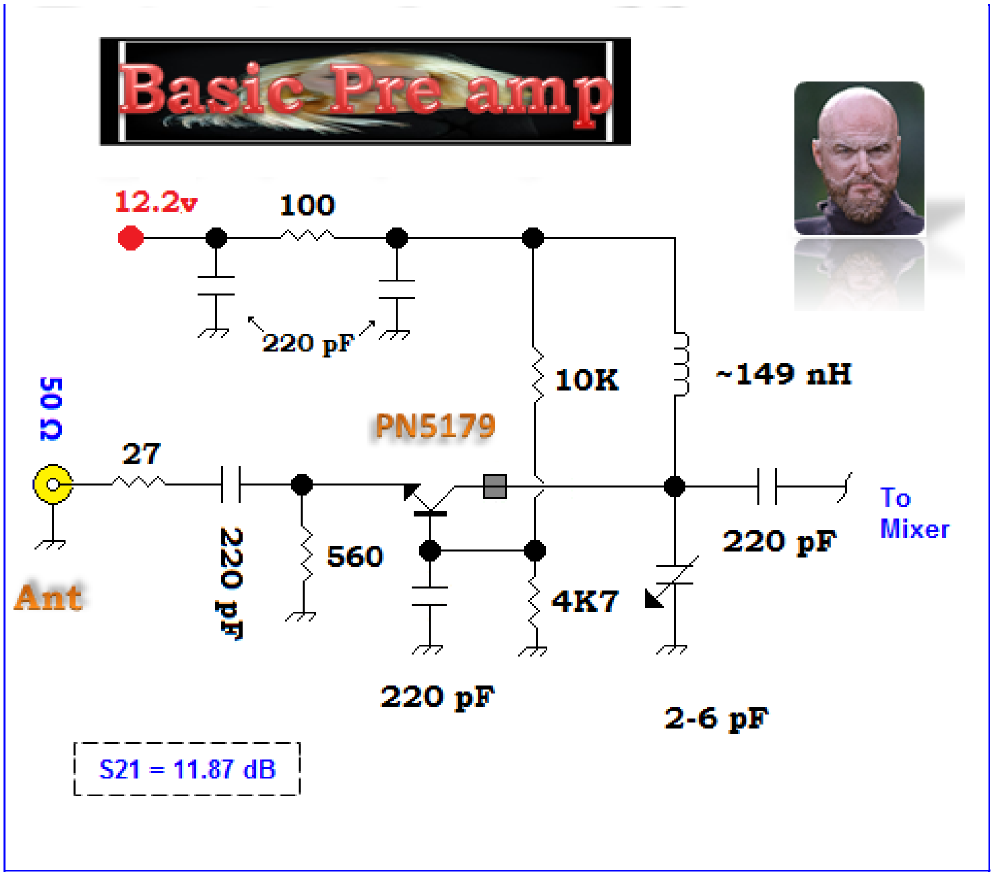
Basic Pre amp
12.2v
100
220 pF
10K
~149 nH
50 Ω
PN5179
27
To Mixer
220 pF
560
220 pF
4K7
Ant
220 pF
2-6 pF
S21 = 11.87 dB

Above — I quickly built a tuned-output common base amp to study front end isolation. I removed the existing resonator and connected this to the JFET mixer gate. It eliminated antenna hand capacitance effects. Click for a sound byte of the receiver with this preamplifier and a 20 cm wire antenna attached to its input. [206 KB download]. I reckon some of my receiver problems arose from the mess of unshielded boards, modules and wire on my bench.

Tuned Input with a 2-Gate MOSFET [162.55 MHz]

A dual gate MOSFET preamp concluded this day's experiments. Tests of a simple input network follow:

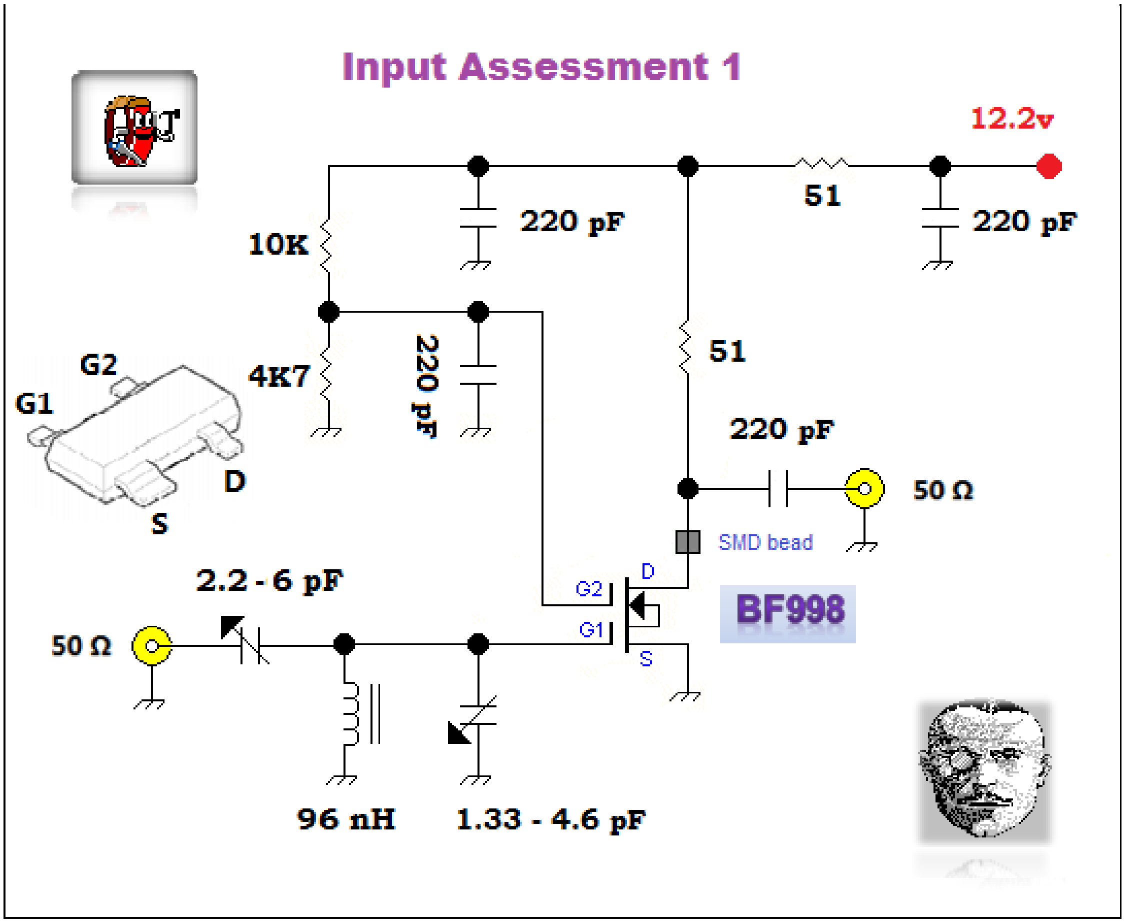
Input Assessment 1
12.2v
51
220 pF
220 pF
10K
4K7
220 pF
51
220 pF
50 Ω
G2
G1
D
S
SMD bead
2.2 - 6 pF
50 Ω
D
G2
G1
S
BF998
96 nH
1.33 - 4.6 pF

Above — Input Assessment 1. To examine the input without any output network effects, I loaded the BF998 drain with a 51 Ω resistor and matched the input parallel resonator for the greatest input return loss [-S21] by tweaking the series SMD trimmer capacitor. After setting the best input return loss [21 dB], I swept this amp.

The XL of the 96 nH air wound coil = 98 Ω and the XL and XC of this tank may be scaled to other frequencies by keeping the reactance values shown or choosing your own. For example; a coil for 50 MHz where XL = 98 Ω = ~312 nH. I discussed and swept the ferrite bead soldered on the FET drain in Section 1 of the VHF Veronica web page.

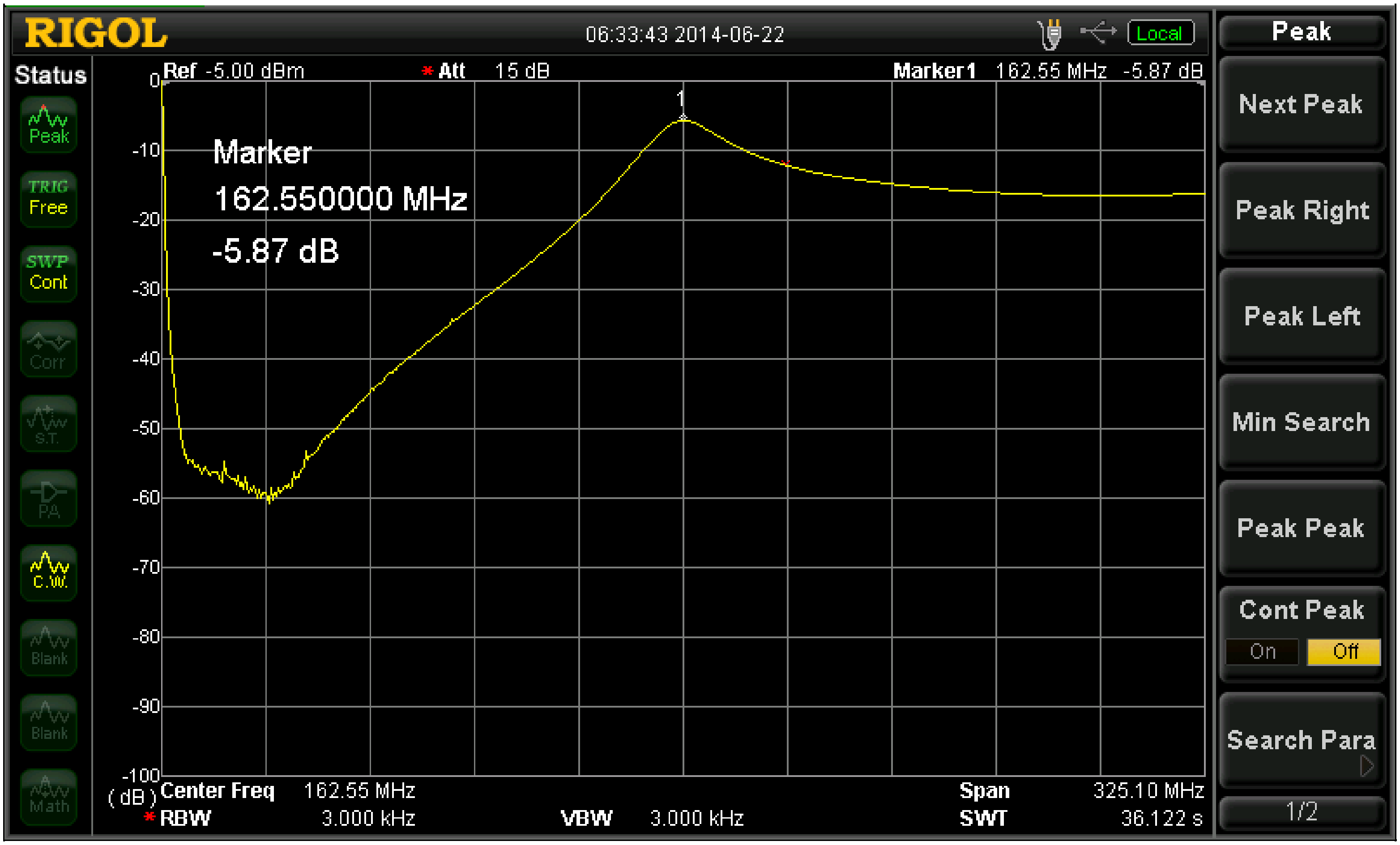
RIGOL
Local
Status
Peak
TRIG Free
SWP Cont
Corr
S.T.
PA
C.W.
Blank
Blank
Math
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
(dB)
1
Peak
Next Peak
Peak Right
Peak Left
Min Search
Peak Peak
Cont Peak
On
Off
Search Para
1/2

06:33:43 2014-06-22

Ref -5.00 dBm
*Att 15 dB
Marker1 162.55 MHz -5.87 dB

Marker
162.550000 MHz
-5.87 dB

Center Freq 162.55 MHz
Span 325.10 MHz
*RBW 3.000 kHz
VBW 3.000 kHz
SWT 36.122 s

Above — A sweep of the Input Assessment 1 amplifer. Although easy peasy to adjust, series matching the resonator to its input load results in a slipshod right-hand [low-pass] skirt. Click for a screen shot showing the amp's 3 dB bandwidth.

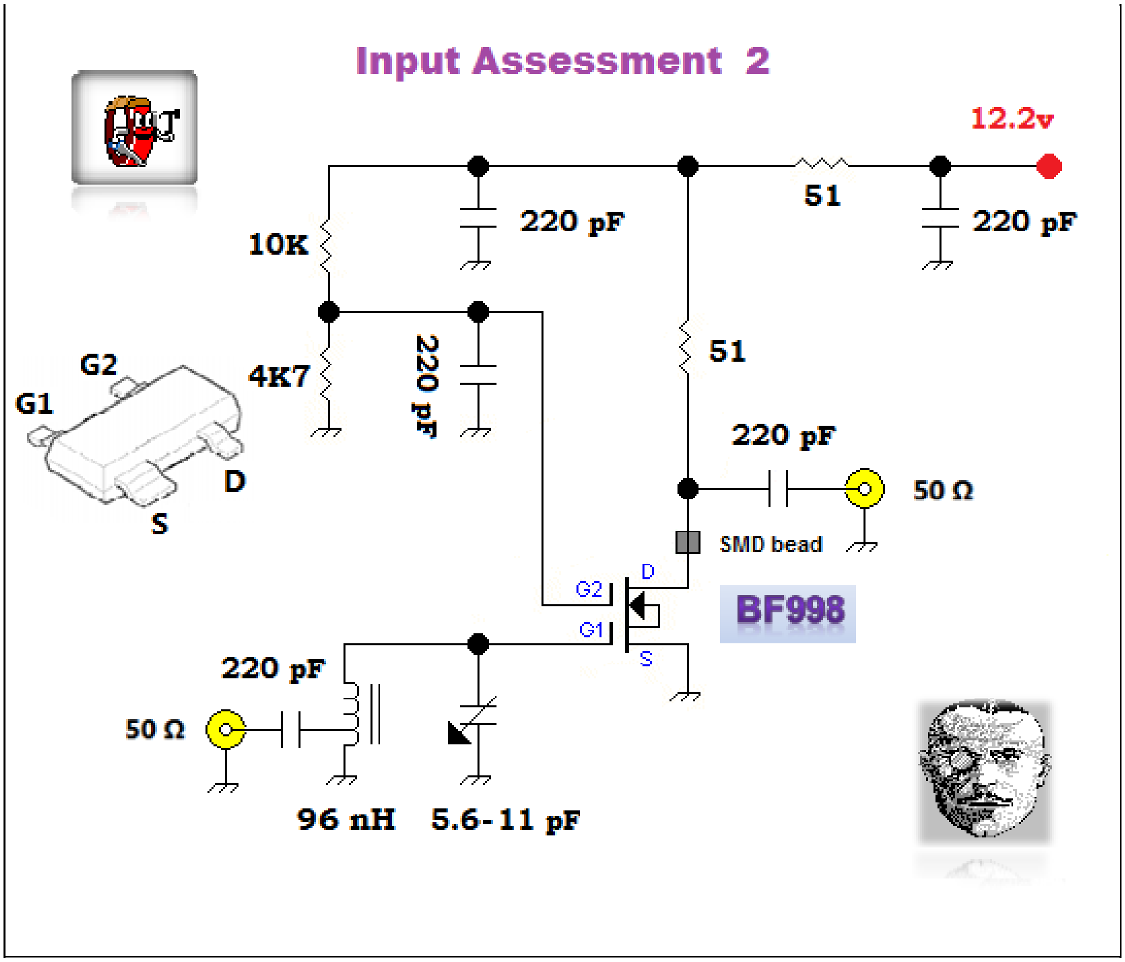
Input Assessment 2
12.2v
51
220 pF
10K
220 pF
G2
G1
4K7
220 pF
51
D
S
220 pF
50 Ω
SMD bead
D
G2
G1
S
BF998
220 pF
50 Ω
96 nH
5.6-11 pF

Above — Input Assessment 2. After measuring a poor low-pass skirt in Input Assessment # 1, I opted for the conventional tapped transformer to steepen the low-pass skirt response versus frequency. My sweeps *did* show a better low-pass skirt shape . Finally, I built a "real" amp and soldered in a broadband output network, tweaked the bias scheme + limited the VDD with a series 150 Ω resistor. A higher value input resonator trimmer cap is required for this amplifier versus that in Input Assessment # 1.

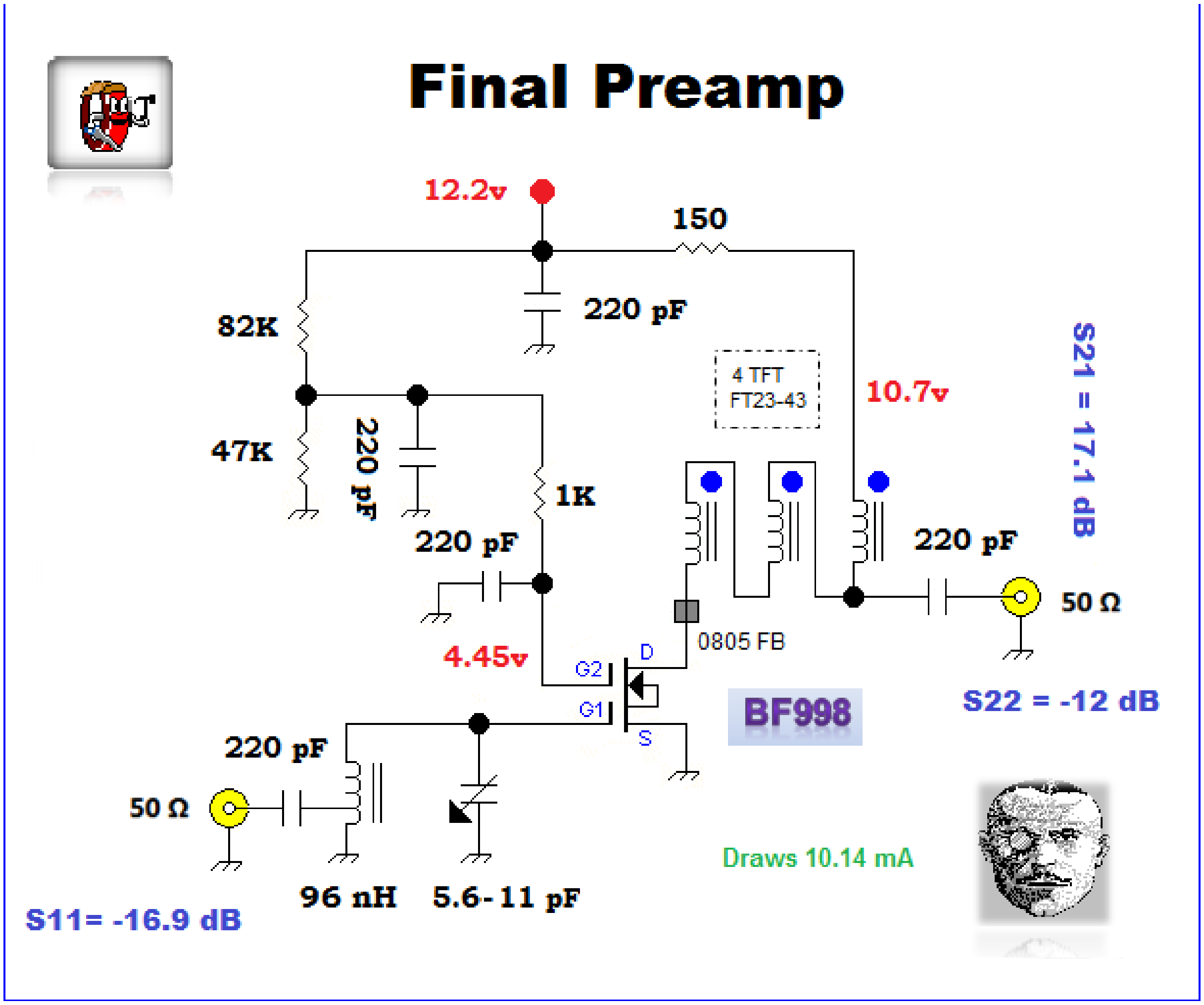

Above — The final 162.55 MHz preamp schematic + some measures. Click for a breadboard photo. Click for the gain measurement with a TG & SA. I measured the same S21 [within 0.3 dB] using my VHF signal generator plus my 50 Ω input DSO. I didn't push too hard with the gate bias or VDD, since neither maximal gain nor parasitic oscillations were sought. Click for a zoom of the filter peak response. Click for a wider sweep to see the right-hand skirt response.

Built on 2-sided FR4 with short cut paths to fit mostly size 0805 SMD parts, I placed via wires on every ground point and detected 0 unwanted oscillations from HF to 3 GHz.

A bare copper wire coil allows us to set the input impedance tap point anywhere along the wire — unlike the *integer only* tap points provided by magnetic toroid-based transformers. In LNA design, many builders set the input tap point for the lowest NF with the amp in noise figure test mode. Another vanilla flavored option is to set the tap with the amplifier input connected to a return loss bridge while adjusting the tap point for the best input return loss — that's what I did. My S11 = - 16.9 dB with my final tap around 1.2 turns of the total 7 links on my 96 nH coil.

The output transformer presents a poor match to 50 Ω with a S22 of just -12 dB. I plan to put a 4 dB pad after it for my NOAA receiver, so it's okay. Some might chase a better output return loss and also perhaps tune the output for better band-pass filtration.

Your FM receiver preamp might need better input filtration, however, if a simple design works, then simple rules! Have fun with *your own* experiments.

473
270
472

RF — Test and Measurement

Pin Outs

Mini-Circuits Labs SBL-1 and TUF-1 diode ring mixers

...more later

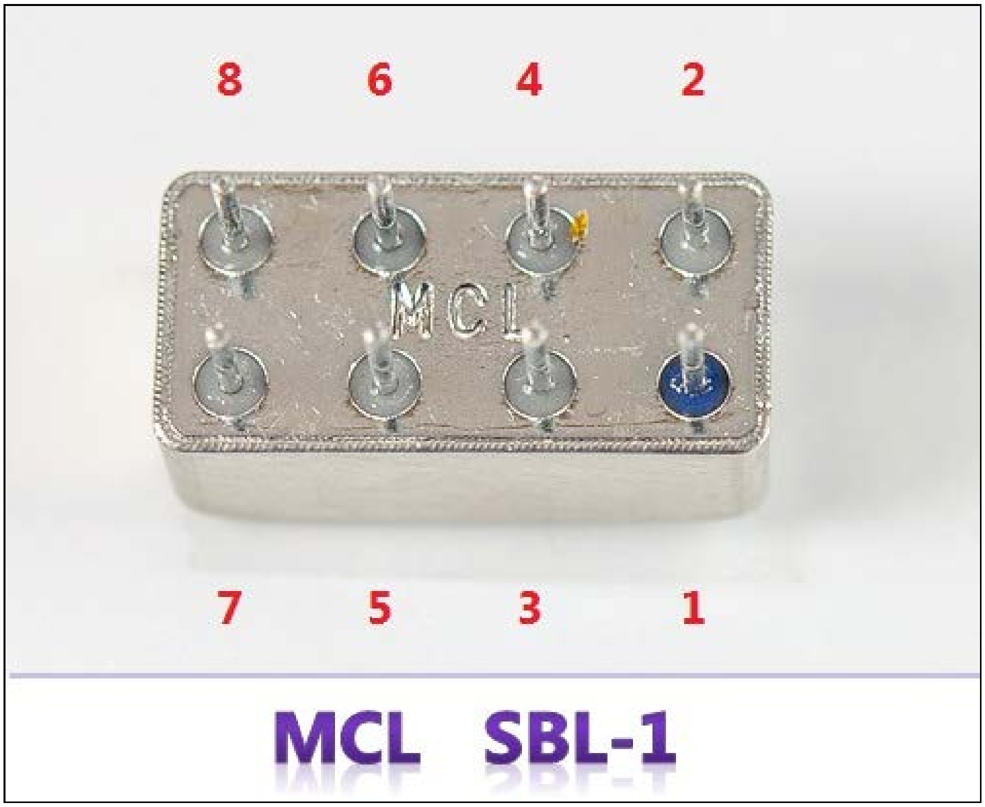
8
6
4
2
MCL
7
5
3
1
MCL SBL-1

Above — Normal set-up: **Ground** -- Pins 2, 5, 6 and 7. **LO** -- Pin 8, **IF** -- Pins 3 and 4, **RF** -- Pin 1

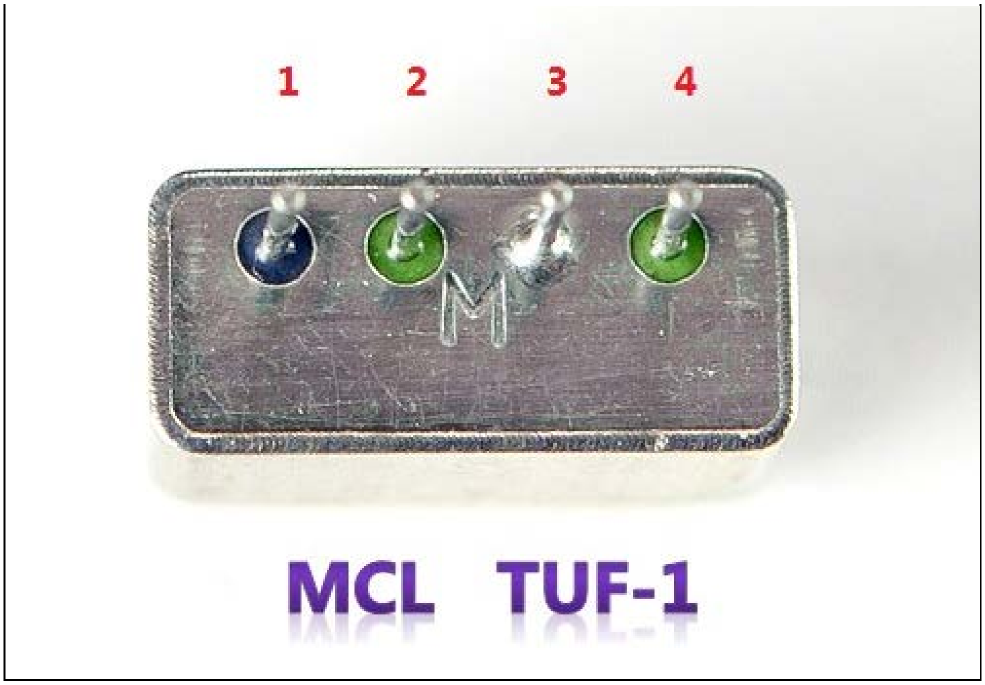
1
2
3
4
M
MCL TUF-1

Above — **RF** -- Pin 1, I**F** -- Pin 2, **Ground** -- Pin 3, **LO** -- Pin 4.

RF — Test and Measurement

VHF-FM Supplement — Amplifiers

Deleted October 26, 2013

Amateur Radio Electronic Design

KL7R Memorial Receiver Experiments

Introduction

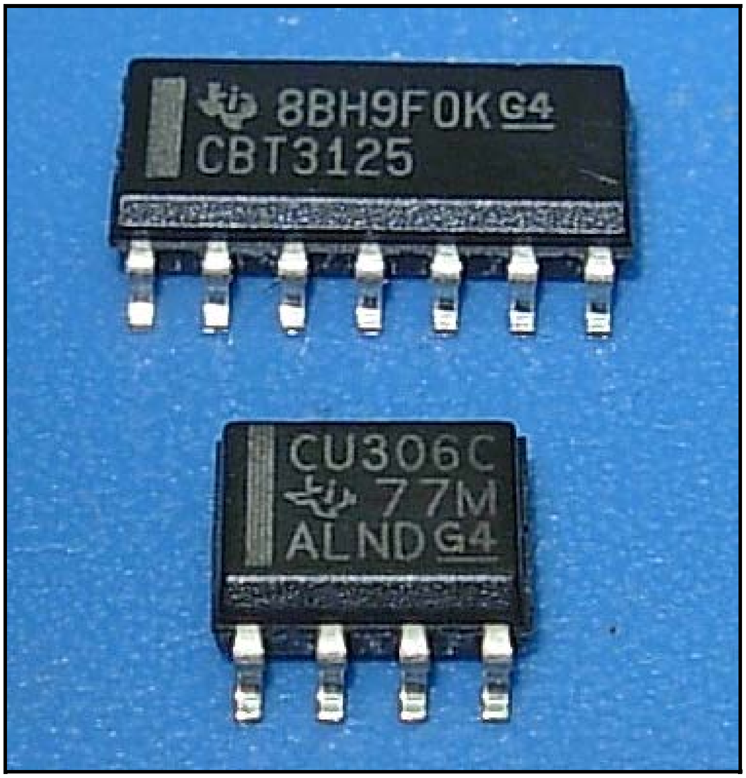

This web page is a memorial to Mike Caughran, KL7R, who died suddenly in January 2007. Mike was a passionate experimenter who was embraced by the homebrew radio electronics community. He was best known as the co-creator of and sidekick to Bill Meara, M0HBR on the podcast Solder Smoke. Mike was a hardcore science and technology buff. His knowledge of general science and curiosity about minimalist RF designs was amazing. I worked Mike on 40 and 80 meter CW and later by voice on eQSO. Mike was the first person to refer to this web site as the "popcorn site". He held an interest in digital circuits. In tribute to Mike, a series of receiver experiments which includes some digital circuits are presented. Mike Caughran will be remembered as a remarkable, kind and passionate homebuilder.

Navigation

There are 3 linked web pages associated with this KL7R tribute web page.

1. Mike's personal web page His own web page memorializes him best
2. Supplemental web page Additional schematics and photos which supplement this main web page
3. VFO web page Describes the VFOs used for these experiments

My special thanks to Wes, W7ZOI for his coaching and suggestions to improve many of the circuits on this web page. This web page borrows heavily from his designs as presented in EMRFD.

Receiver Description

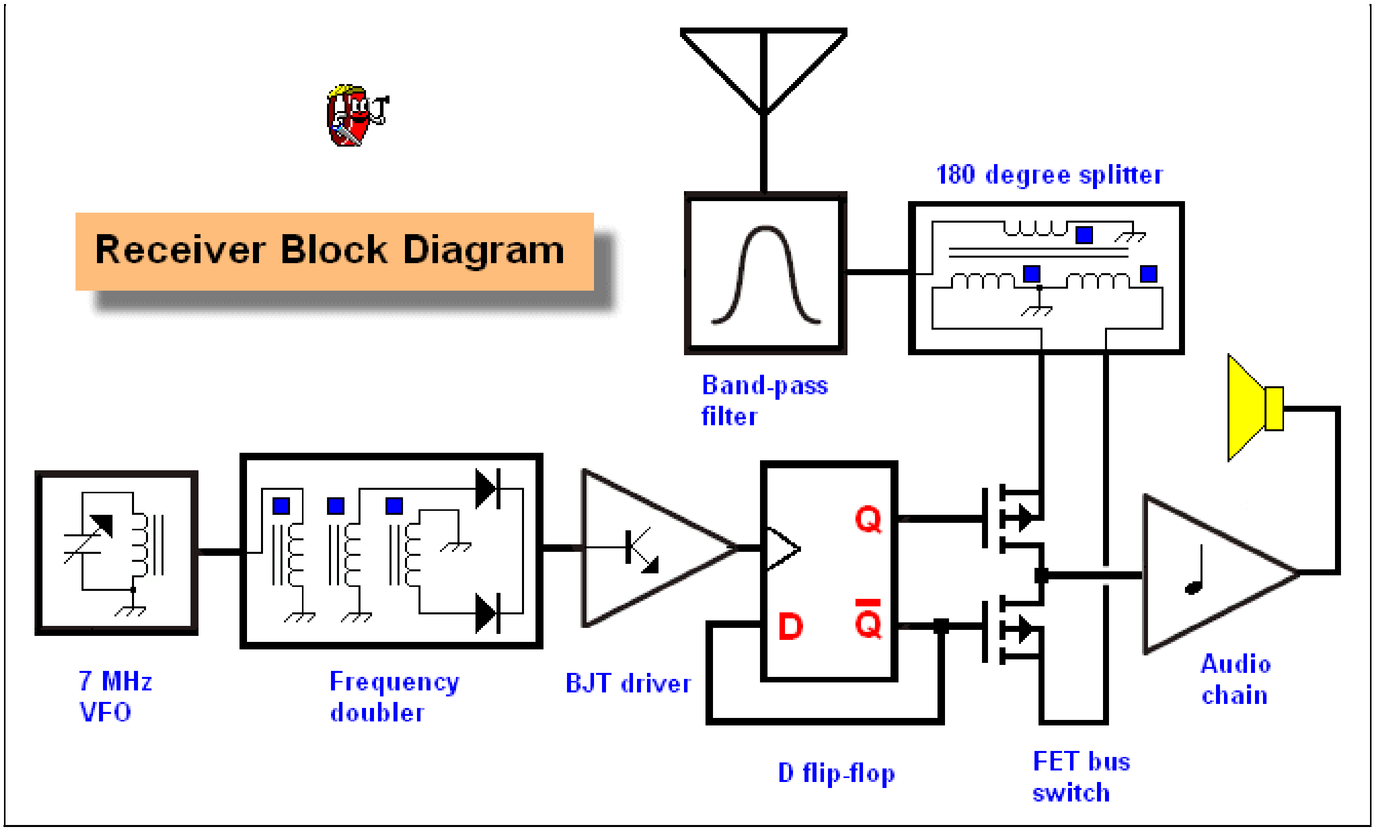
Receiver Block Diagram
180 degree splitter
Band-pass filter
7 MHz VFO
Frequency doubler
BJT driver
Q
D
Q̄
D flip-flop
FET bus switch
Audio chain

Shown above is the receiver block diagram. The KL7R memorial receiver depicted on this web page is the final output of many hours of experimentation. Most of the circuits or circuit ideas originated in EMRFD.

From our conversations, Mike was always challenging himself; experimenting, testing and pushing his knowledge threshold. The joy of discovery motivated him. Fired by his spirit of inquiry, I explored methods to build a receiver containing at least 1 digital circuit. On many days, I accomplished nothing. The circuits did not work and little to no progress was made. These were the difficult dry spells all experimenters must endure. Design and circuit failures can be very disheartening. I also wasted a lot of parts. However, I kept going and slowly successes occurred and my confidence rose. The end result was a little more knowledge and a cool, popcorn, direct conversion receiver which I hope will provide ideas and inspiration for your own experiments.

Double Tuned Band-pass Filter

Figure 1

40 Meter Band-pass Filter

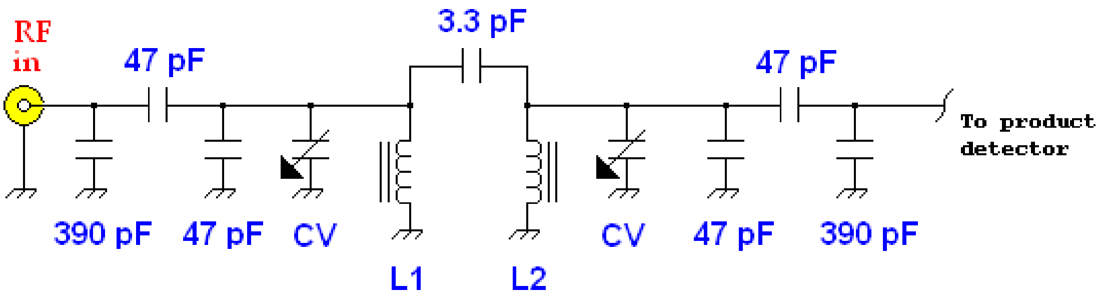

CV = 6.0 - 50 pF trimmer cap
L1 = L2 = 3.4 uH = 29 t #24 AWG on a T50-6 toroid
Input and output impedance = 50 ohms
-3 dB bandwidth = .220 MHz
Insertion loss = 2.3 dB

Figure 1 shows the front end band-pass filter. If you can't obtain a 3.3 pF coupling capacitor, try this other 7 MHz band-pass filter circuit or perhaps just design your own. See the Webmaster's page for information concerning many of the parts used on this web page.

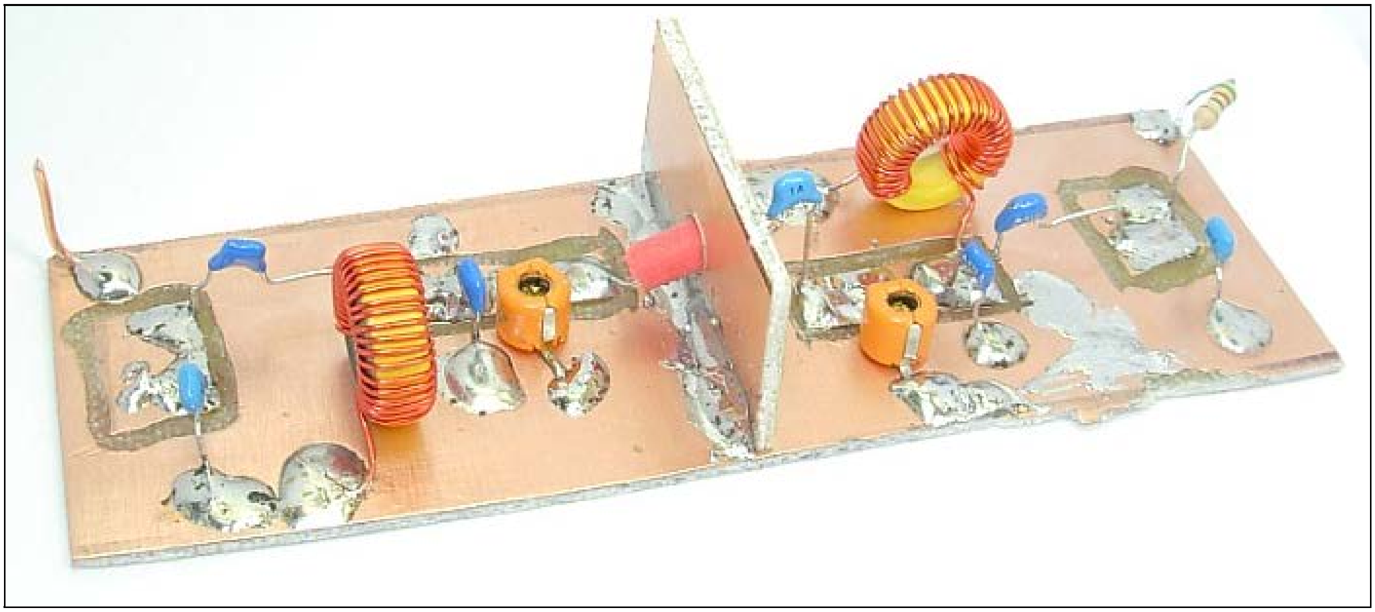

Shown above is a photograph of the Figure 1 breadboard. The inductors were spaced apart at right angles to reduce unwanted coupling. The copper clad board L-C tank divider is not necessary. The 51 ohm load resistor seen to the right was removed after testing.

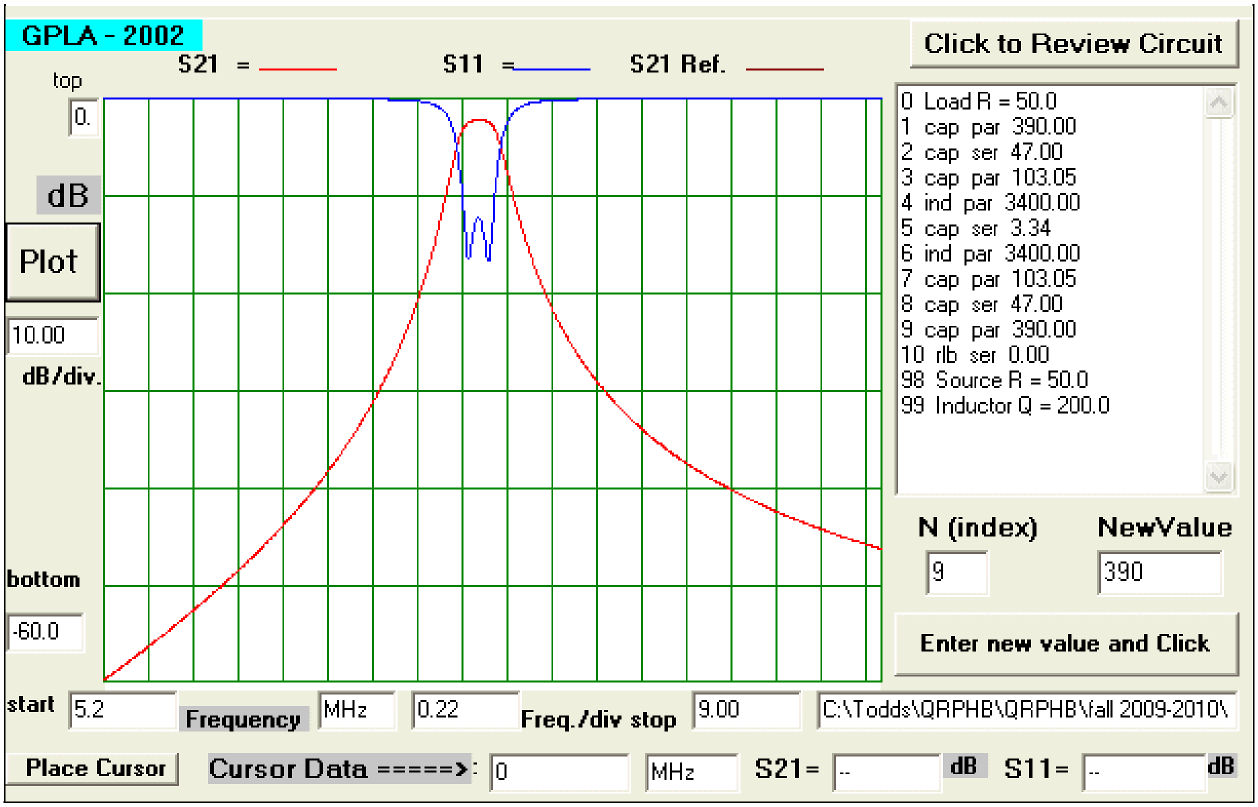
GPLA - 2002
S21 =
S11 =
S21 Ref.
Click to Review Circuit
dB
Plot
Frequency
Place Cursor
Enter new value and Click

```
0  Load R = 50.0
1  cap  par  390.00
2  cap  ser  47.00
3  cap  par  103.05
4  ind  par  3400.00
5  cap  ser  3.34
6  ind  par  3400.00
7  cap  par  103.05
8  cap  ser  47.00
9  cap  par  390.00
10  rlb  ser  0.00
98  Source R = 50.0
99  Inductor Q = 200.0
```

top 0.

10.00 dB/div.

bottom -60.0

start 5.2 MHz

0.22 Freq./div

stop 9.00

C:\Todds\QRPHB\QRPHB\fall 2009-2010\

N (index) 9

NewValue 390

Cursor Data =====>: 0 MHz S21= -- dB S11= -- dB

Shown above is a GLPA simulation of the Figure 1 band-pass filter. Хорошо.

Product Detector Experiments

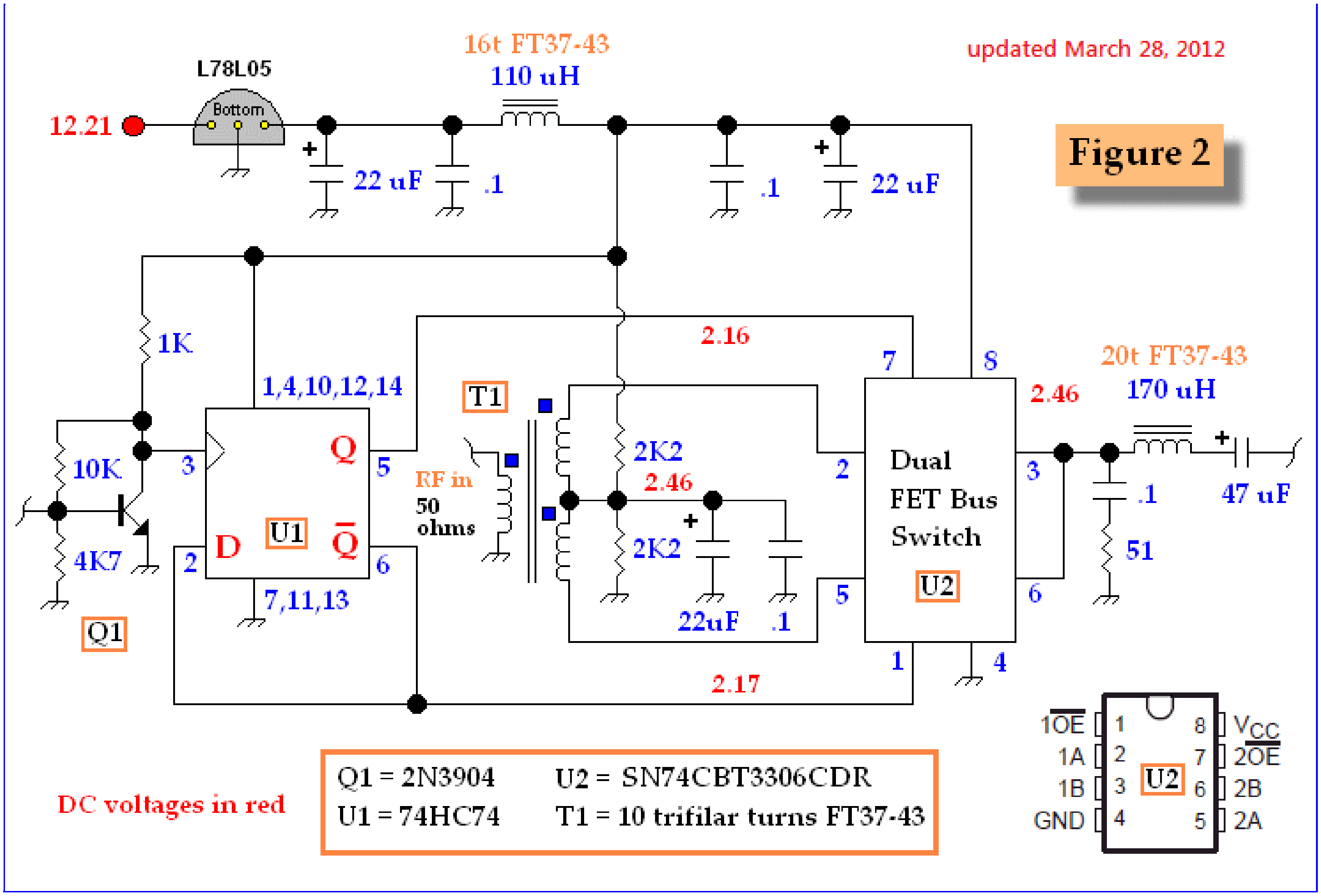
updated March 28, 2012
L78L05
Bottom
12.21
16t FT37-43
110 uH
22 uF
.1
.1
22 uF
1K
10K
4K7
Q1
3
1,4,10,12,14
Q
5
U1
D
2
Q̄
6
7,11,13
T1
RF in
50 ohms
2K2
2.46
2K2
22uF
.1
2.16
7
8
2
5
1
4
3
6
2.17
Dual FET Bus Switch
U2
2.46
20t FT37-43
170 uH
.1
47 uF
51
DC voltages in red
Q1 = 2N3904
U1 = 74HC74
U2 = SN74CBT3306CDR
T1 = 10 trifilar turns FT37-43
1OE
1A
1B
GND
1
2
3
4
8
7
6
5
VCC
2OE
2B
2A
U2

Figure 2

Shown above in Figure 2 is the BJT driver, D flip-flop and the CMOS switch product detector. The 14 MHz VFO connects to Q1 via a 0.1 uF coupling capacitor that is shown on the VFO schematic. A dual FET bus switch (CBT3306) serves as the product detector. The on-resistance of this switch is only around 3 ohms! If you are ambitious, you might try using a 14 pin SOIC switch such as the QUAD FET SN74CBT3125DR with 2 pairs of the 4 switches wired in parallel. I tried 3 different CMOS switches in the U2 slot. The other switches were the MAX4066CPD and a 74HC4053 (wired up appropriately using their datasheets). The insertion loss and performance of these 2 switches was disappointing. My bench standard for comparison was a 7 dBm diode ring mixer. Numerous experiments were performed. For example, I tried running the 4066 at 12 volts VCC to minimize its on-resistance and had to modify most of Figure 2 as well. Being new to digital, blending 5 volt and 12 volt logic IC required great effort to get it working properly. These experiments consumed the better part of 2 days. My conclusion was that if you are going to go to the trouble of make a CMOS switch work, you might as well use a part that has a low on-resistance. Hence, I have since abandoned using DIP IC CMOS switches (4053, 4052, 4066 etc.) as mixers and product detectors. They may still be a good choice in your own context.

The CBT3306 is outstanding and very similar to the diode ring mixer with respect to insertion loss and audio quality as a product detector. There are some other good CMOS switches you might try. I chose the CBT3306 because it was SOIC (the largest of the common SMT topologies), costs only 77 cents (Canadian dollars) and only has 8 pins to deal with. Pragmatism on the workbench is always good!

SMT versus VE7BPO

The difficulty with using the CBT3306 was that I had to learn about and equip for SMT. I ordered the switches and after their arrival, hesitated to do anything with them for 5 days. I managed to borrow a magnifier and bought a SOIC prototype board and some flux. Still, I seemed to be paralyzed with fear about soldering U2. I was stuck. For inspiration, I went back to Mike's web site and found this web page. Here Mike was working with a 18 pin SOIC chip and I was worried about a mere 8 pin IC! Part of the problem was my relatively poor eyesight. I learned this can be managed with a magnifying visor. I bought mine here , but only after U2 was soldered in. The borrowed table magnifier was okay, but constrained arm movement and reduced lighting. The visor seems to be a better choice.

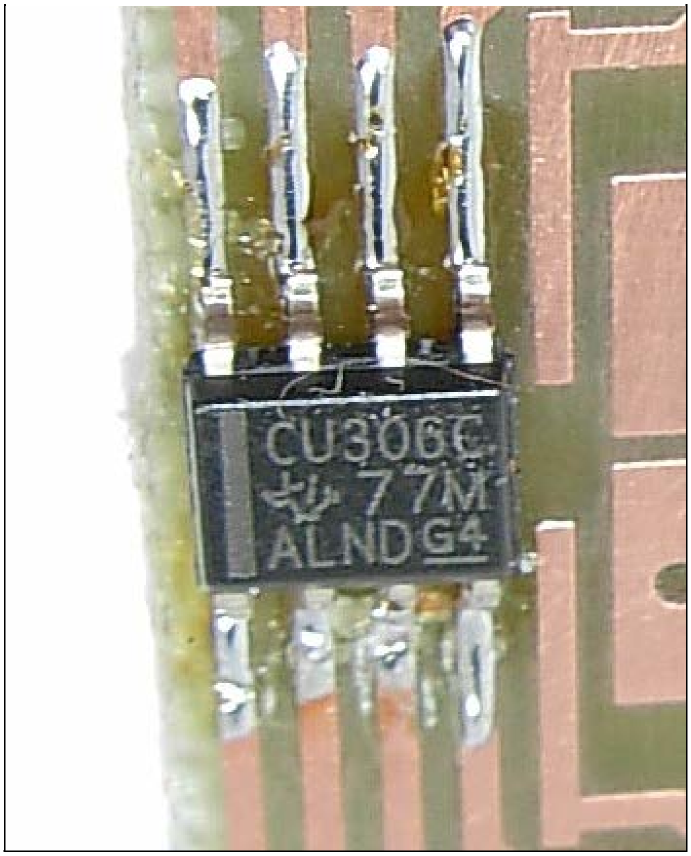

Shown above is the CBT3306 soldered on my prototype board. I put flux on the board traces and then tinned them. Following that, I lined up U2s leads on the traces and began soldering. The bottom pins (pins 1-4) did not go well, but they were soldered all the same. Following that, the soldering of pins 5-8 went very well. I was very happy; the SMT monster had been tamed! It was learned from Wes, W7ZOI that many builders use Surfboards for SOIC applications. I will get some for future SMT IC work. Using SMT parts in your Ugly Construction allows you to use parts which are unavailable otherwise. Increasingly, good old DIP ICs are disappearing from catalogs and some new parts are appearing as SMT only. It makes sense to jump in and use SMT parts when it is advantageous for spec reasons, or if miniaturization is required.

With some effort, the Figure 2 circuit could be morphed into Colin, G3SBI's H-mode mixer format. Not on this web site though! If you Google "H-mode mixer" , many good websites will be returned.

The product detector's baseband audio output is at the 47 uF capacitor which connects to Q1 of Figure 3. A simple 51 ohm, low pass network is used to terminate U2. This is from W7EL's An Optimized QRP Transceiver from QST for Aug 1980. I have some more information regarding AF termination circuits on this web page. You may wish to increase the 170 uH inductor value somewhat to get more low pass filtering. The product detector circuit is the number one potential source of hum and noise in this receiver. Take the time to plan your layout to minimize wire length and crossing and provide some physical symmetry. Decouple well.

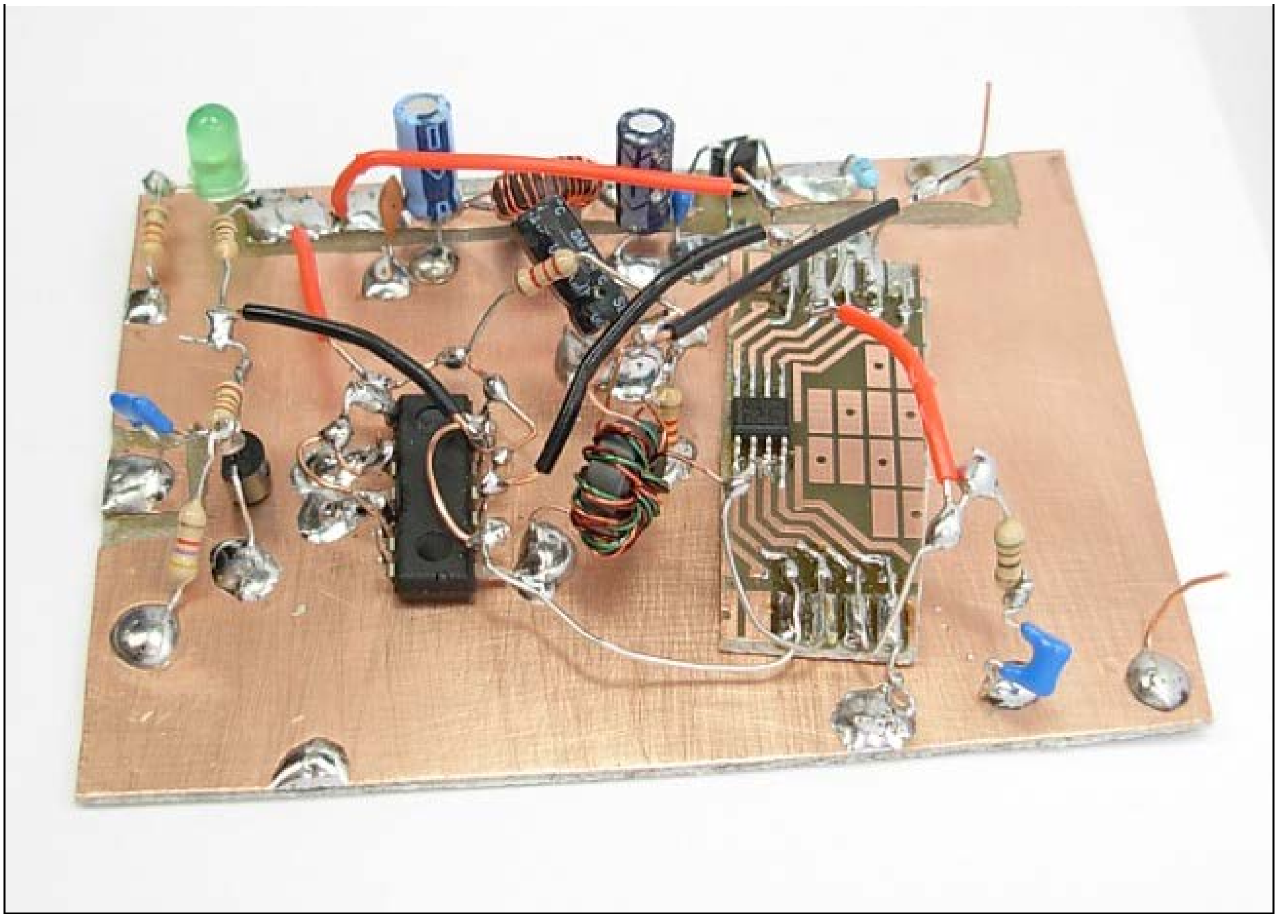

Shown above is the product detector. At this point, I had not decide how to terminate U2 and had soldered a shunt 0.1 uF cap and 51 ohm resistor to the switch output. U2 is dwarfed by the FT37-43 toroid; a part we normally think of as small in size.

Figure 3

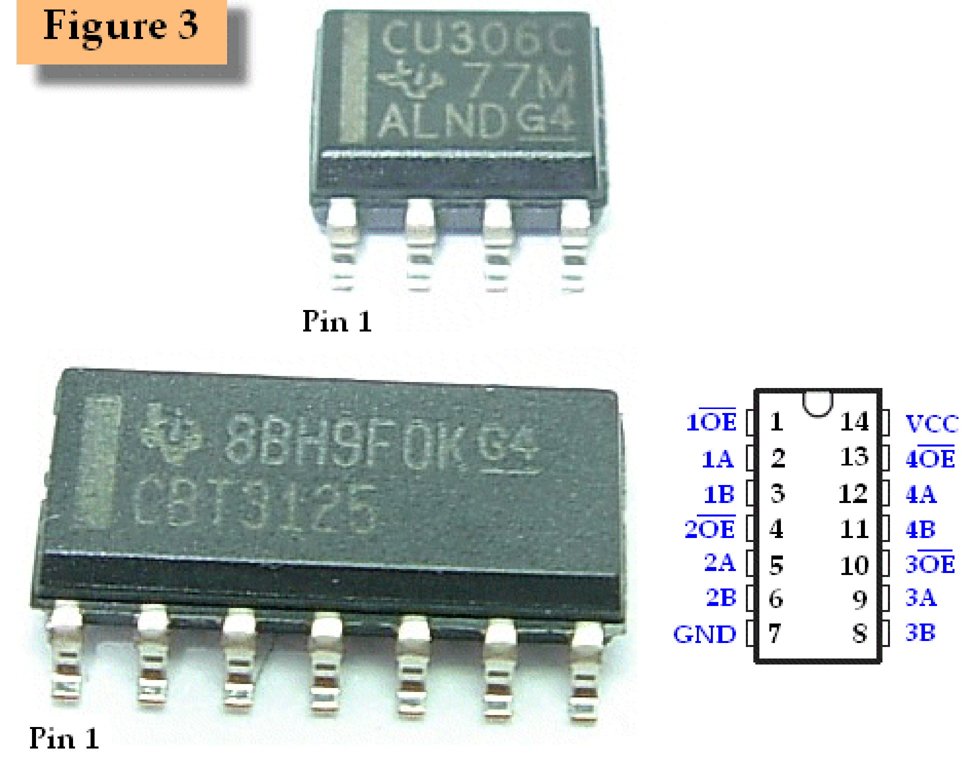
CU306C
77M
ALND G4
Pin 1
8BH9F0K G4
CBT3125
Pin 1
1$\overline{OE}$ 1 14 VCC
1A 2 13 4$\overline{OE}$
1B 3 12 4A
2$\overline{OE}$ 4 11 4B
2A 5 10 3$\overline{OE}$
2B 6 9 3A
GND 7 8 3B

Figure 3. Photographs of the FET bus switches I have in my collection and the pin-out for the 14 pin CBT3125

A diode ring mixer was used as a reference mixer in the product detector experiments.

Audio Amplifier Chain

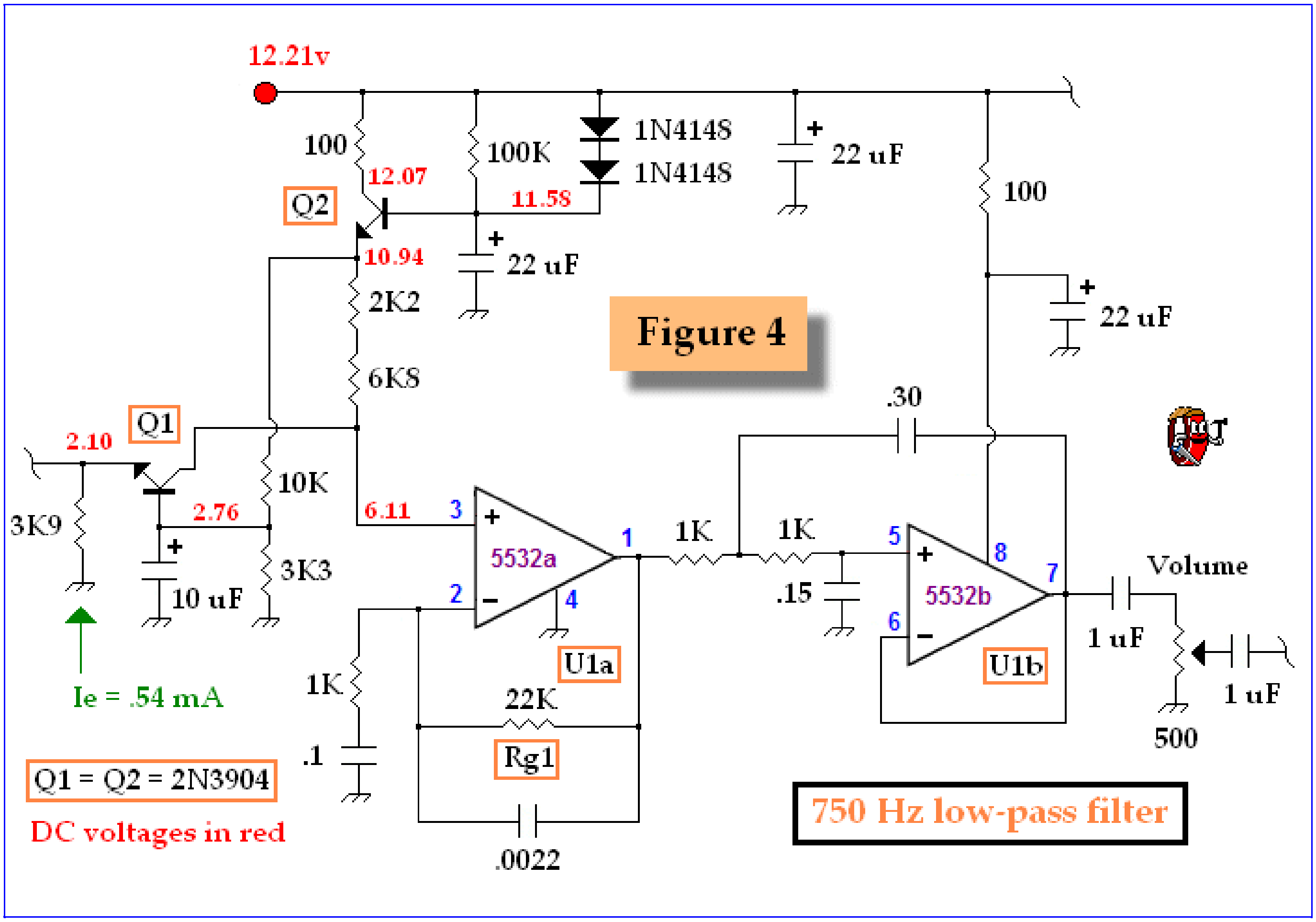
12.21v
100
100K
1N4148
1N4148
22 uF
12.07
11.58
Q2
10.94
22 uF
100
2K2
6K8
22 uF
Figure 4
.30
Q1
2.10
10K
3K9
2.76
6.11
3
+
5532a
1
1K
1K
5
+
5532b
8
7
Volume
3K3
10 uF
2
–
4
.15
6
–
1 uF
U1a
U1b
1 uF
Ie = .54 mA
1K
22K
500
.1
Rg1
Q1 = Q2 = 2N3904
750 Hz low-pass filter
DC voltages in red
.0022

Shown in Figure 4 is the audio preamp and first low pass filter. Direct conversion receivers are all about audio. High performance DC receivers have become more common since Rick, KK7B unleashed his R1 on the world in 1992. High performance receivers are out of scope for this popcorn website, however, this design is welcome. The entire audio chain uses low-cost 5532 op amps, cheap BJTs, plus fairly common resistor and capacitor values. Poly"something" capacitors were used for all audio AC coupling and shunting capacitors of 4.7 uF or less.

For hum immunity, the familiar BJT capacitive multiplier popularized by Roy, W7EL was used at Q2. Using a high-end spectrum analyzer, Wes, W7ZOI demonstrated that this circuit can oscillate. He detected oscillations at UHF. Thus, Wes recommended using a 100 ohm snubber resistor on the Q2 collector to alleviate these parasitic oscillations. Additionally, 2 diodes were added in parallel to the 100K base resistor. This provides an instant-on feature for the audio preamp, as normally there is a time-constant delay when you switch on the receiver. I like this feature, but it is purely optional.

Q1 is a common base amp biased for 0.54 mA. Therefore, the input impedance is 26/0.54 or about 48 ohms. The 6K8 + 2K2 collector resistors were paralleled so that the quiescent collector voltage was close to 6.1 volts. You could also substitute a single 9K1 resistor, although this is an uncommon value. This voltage provides the approximate VCC/2 bias needed for U1a and U1b. Connecting the Q1 collector directly to the pin 3 op-amp input allows the exclusion of a coupling capacitor and the usual VCC/2 resistor network used to bias the 5532 op-amp from a single power supply. I borrowed this from EMRFD.

The gain of U1 is set by the resistor labeled Rg1. If after testing, the AF gain is too high (for example if this AF stage was used in a superheterodyne receiver), simply lower this resistor value. I chose a 22K ohm resistor to allow enough gain for weak signal listening. On louder stations, you will need to lower the volume control to prevent distortion in the stages that follow as overall, there is a lot of gain in this AF chain. Adjust the Rg1 value to suit your needs. If you use a switch such as a 4052 for U2, or your receive antenna is small, you may want to increase this resistor a little for more gain. This is an experimenter's receiver after all. The 0.0022 uF capacitor in the op-amp feedback loop provides a single pole of low pass filtering. I ran this capacitor as high as 0.0082 uF. This gave a theoretical 3 dB cutoff frequency of ~ 880 Hz, but the receiver lost its sizzle. Experimentally, I learned that using a 0.0022 uF feedback capacitor on both U1A and U2A dropped some of the high frequency noise while preserving some sparkle in the received audio.

The audio preamp chain is concluded with a 750 Hz low-pass filter. Resistor values were kept low to minimize noise. All the active low pass filters are low Q, Sallen-Key designs with a Butterworth response. They are stable, easily scalable and brain-dead simple. These filters are fatigueless due to their gentle cut off slope. I actually had a 0.30 uF capacitor in my parts collection, although it was a 600 volt rated part from my tube amp parts bag. You could use two 0.15 uF capacitor in parallel or just substitute a 0.33 uF capacitor. If you can't find a 500 ohm volume control potentiometer, swap in whatever you have, but try to keep the resistance low.

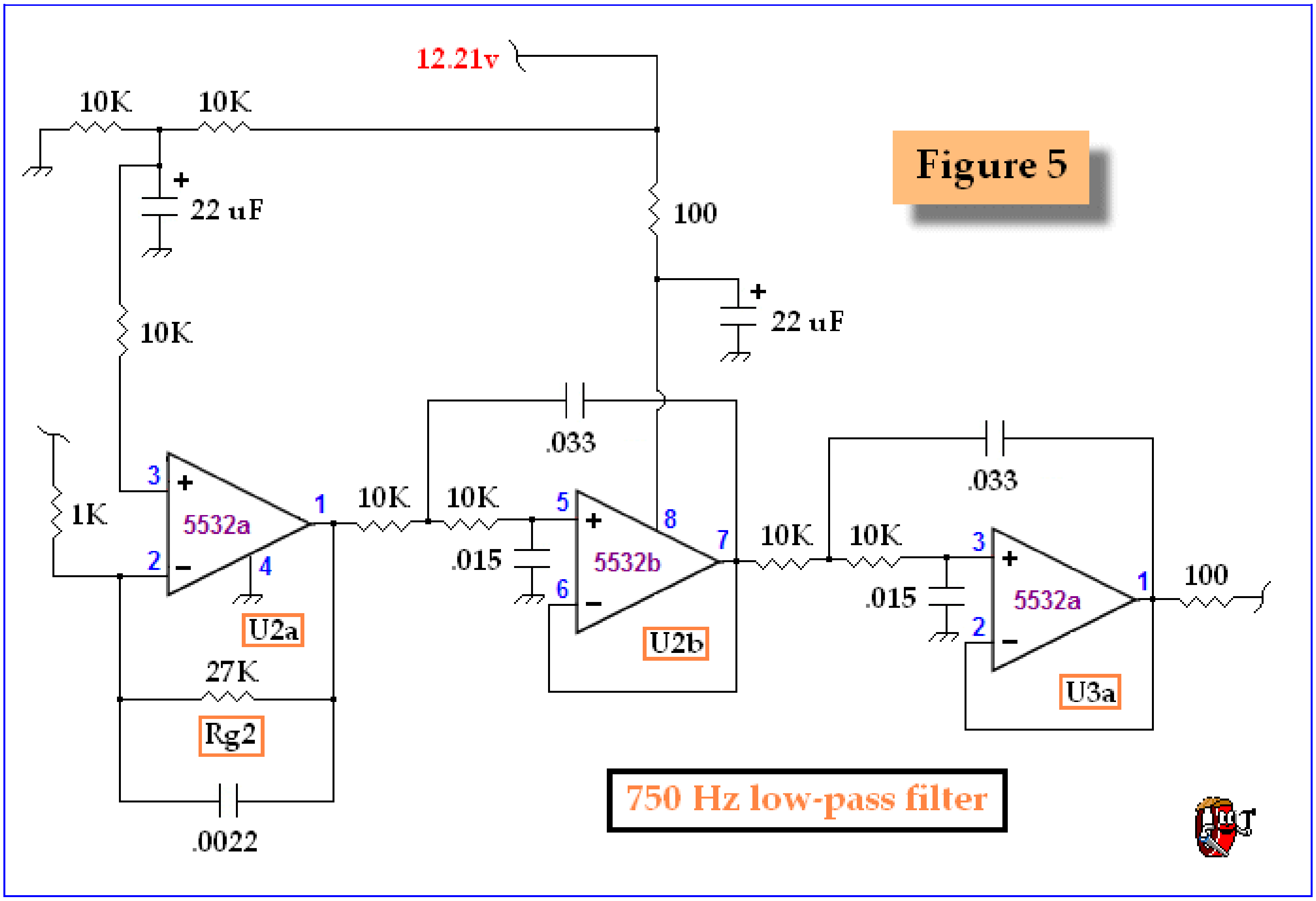

In Figure 5, the remaining preamplifier stage and low-pass filters are shown. Rg2 was chosen for the same reason as Rg1 in Figure 4. Please experiment with these values. The low pass filter stages are scaled up by a factor of 10 as resistance values are less critical at this point in the audio chain. You could use the same resistor and capacitor values used in the first low-pass filter or use the Figure 5 values for all of the low-pass filters. Very often, our parts collections dictate how we experimenters design and build circuits.

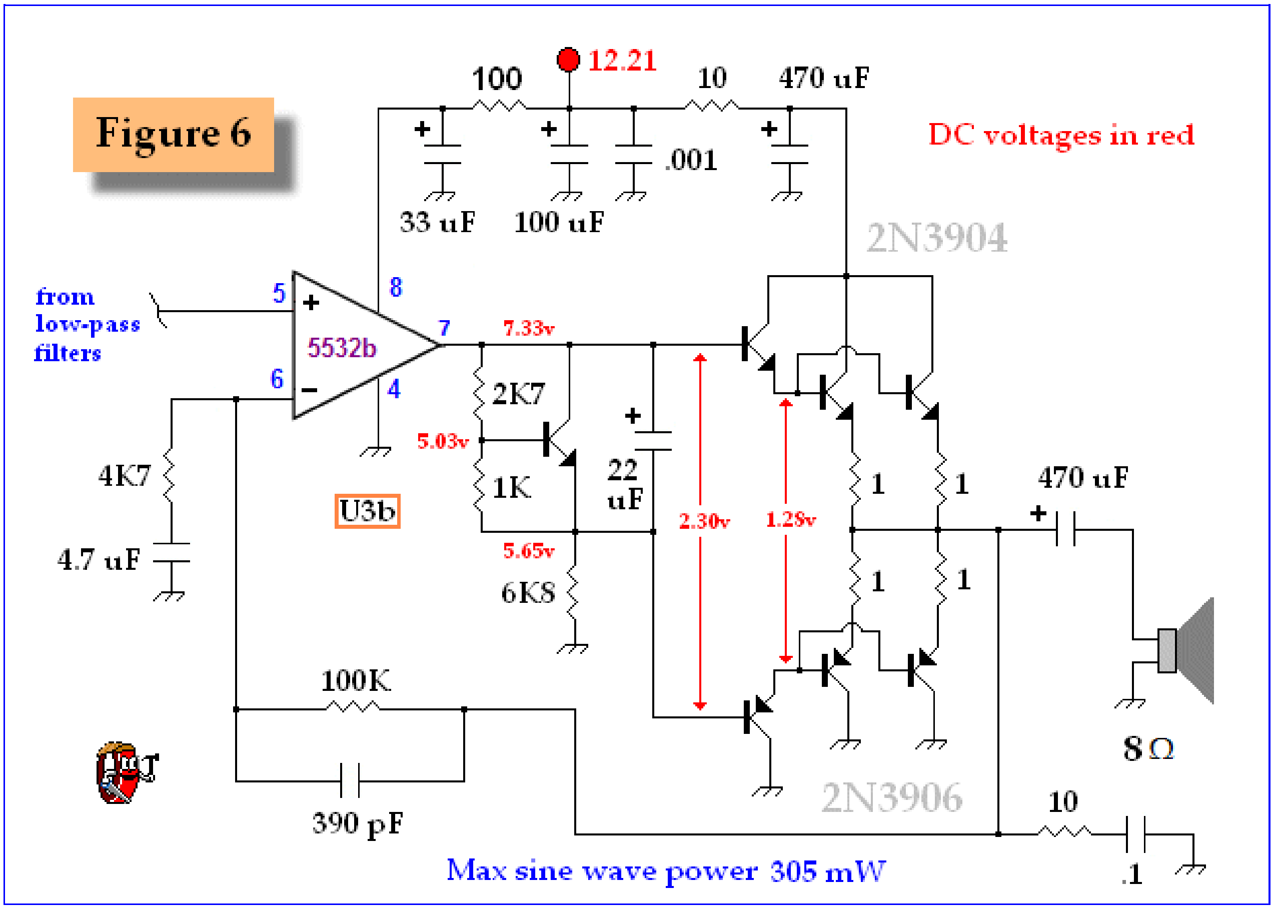
Figure 6
12.21
100
10
470 uF
DC voltages in red
+
.001
33 uF
100 uF
2N3904
from
low-pass
filters
5
+
5532b
−
6
8
7
4
7.33v
2K7
5.03v
1K
+
22
uF
U3b
4K7
4.7 uF
2.30v
1.28v
1
1
470 uF
+
5.65v
6K8
1
1
8 Ω
100K
390 pF
2N3906
10
.1
Max sine wave power 305 mW

Figure 6 is the power amplifier schematic. Apart from field portable transceivers where headphones are used to save battery power, I exclusively listen to my receivers via a loudspeaker. This safely allows the exclusion of AGC circuits. You may have noticed that AGC circuits have not been presented on this web site. I rarely use them. The extensive VCC decoupling in Figure 6 is needed in this high gain AF chain. The 1 ohm emitter resistors in the finals invite instability, but were tamed with the 10 ohm / 0.1 uF low pass filter. My original design called for 2.2 ohm emitter resistors, but none were available. This final amplifier is moderately loud and very quiet. When it was first built (the AF chain was built backwards), you could not tell it was on when no signal was applied. With no antenna connected to this receiver and the volume on full, there is only a little noise. This is a good way to test a receiver AF chain for noise. Speaker choice is also important. Speakers of a greater power rating and size sound better; especially when mounted in a wooden cabinet.

Biasing power amps has been discussed extensively on this web site. Ensure you measure and record your quiescent DC voltages as shown in Figure 6. If you hear cross over distortion or the quiescent voltage between the bases of the paralleled final transistors is less than 1.25 volts, try decreasing the 6K8 resistor to 5K6 ohms.

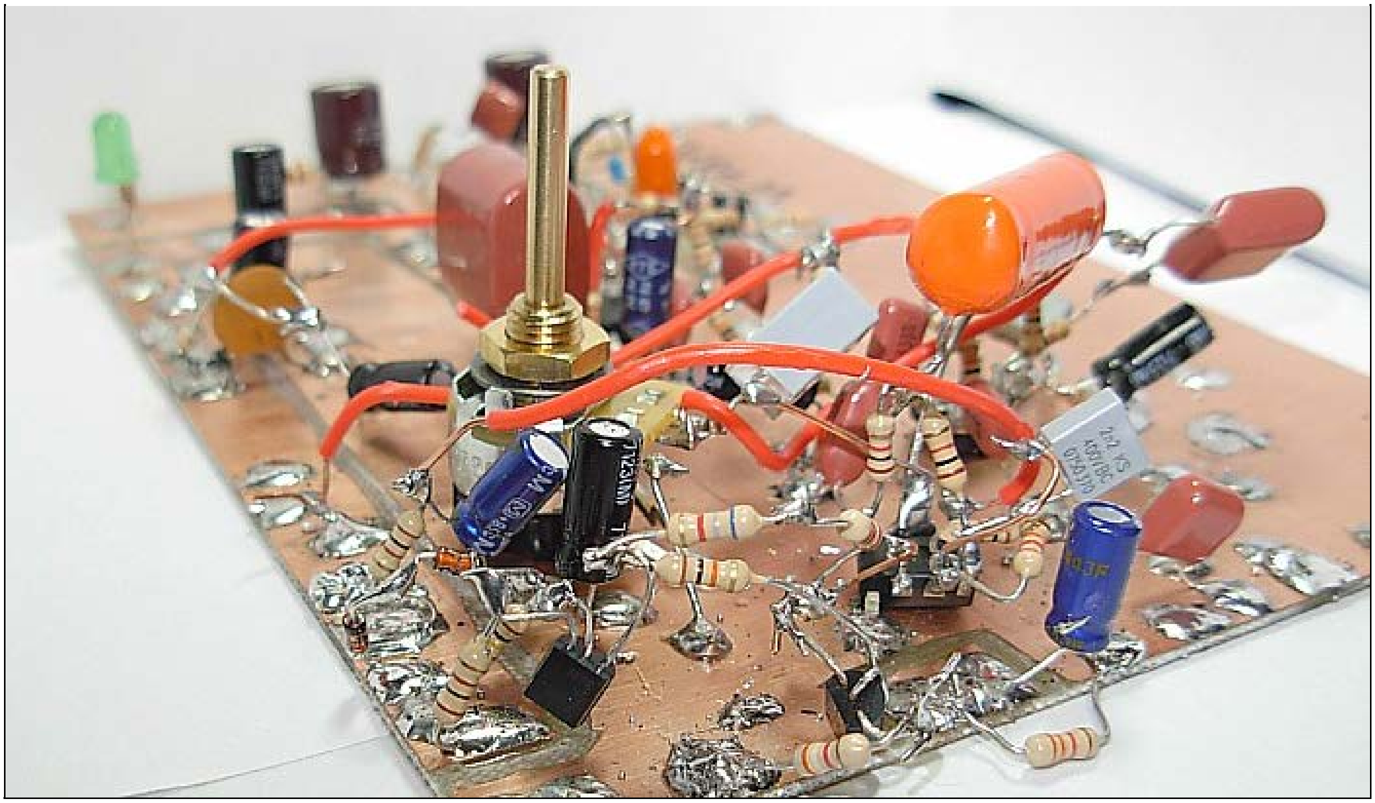

The final preamp breadboard is shown above. You can tell by all the grunge and the solder marks, that many different configurations were trialed. Despite looking haggard, the AF chain is quiet and does not hum nor detect broadcast radio.

Shown above is an early breadboard of Figure 6. In this version, the volume control was at the input and a voltage divider network was wired to pin 5 to provide VCC/2 bias. Testing with an audio signal generator, a tape player and other sources were performed. Later, the biasing resistors and the potentiometer were removed and the Figure 5 stage was added to the copper clad board and tested.

Final Thoughts

We are remembered best by those whom we affect. Certainly Mike's unique perspective and enthusiasm inspired me to dig deeper into this hobby. I asked Bill, M0HBR, for a quote to conclude this web page. Bill wrote this: "Just last week somebody was asking me for background info on Mike's DSB modification of the Heath HW-8... I think it is a real tribute to Mike that years after his passing, hams around the world are still talking about him fondly, still visiting his web site, still following his lead on homebrew radio projects. Certainly among the 3,000 + listeners of the SolderSmoke podcast, Mike is present in spirit every time a soldering iron is heated up." Thank you Bill.

My heartfelt regards to Mike's family.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

VFO Experiments 2009

Amateur and Short Wave Radio Electronics Experimenter's Web Site

Supplement to the VFO 2009 Web Page

This web page is a supplement to the VFO 2009 Web Page

Figure 10 Bipolar Transistor Notes

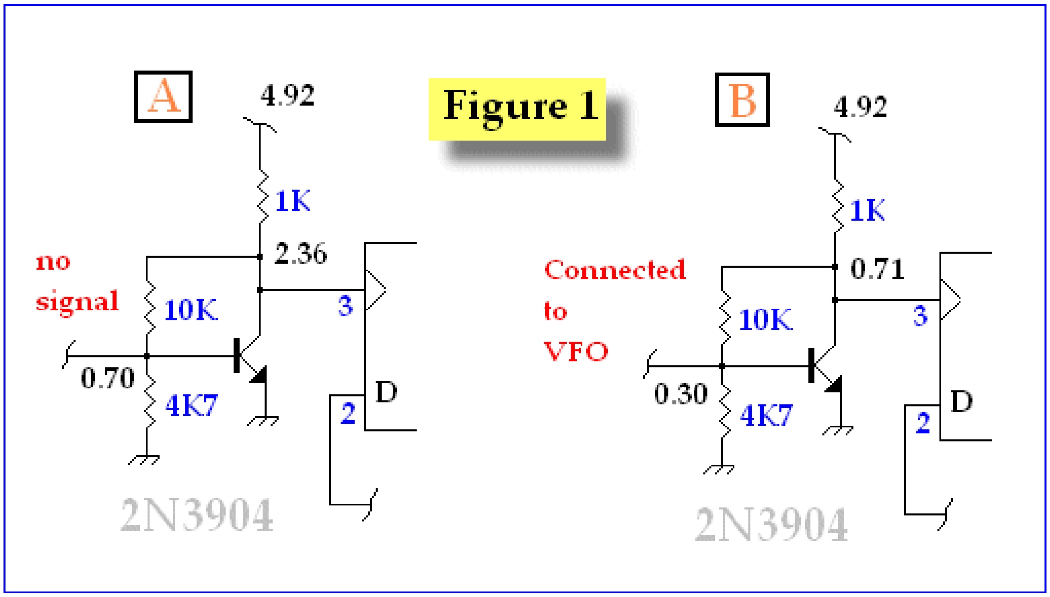

This circuit is from EMRFD and is an analog to digital interface for the VFO. I did not understand the circuit, so I asked Wes, W7ZOI to explain his design criteria and the basic circuit function. This transistor circuit is a driver. The purpose of this transistor driver is to positive edge trigger a D flip-flop. The paramount criterion was that the transistor collector has a quiescent bias voltage that fell between the minimal acceptable logic high and logic low DC voltages on the 74HC74 clock input. See this chart for details about this topic. The correct DC collector voltage is set via feedback from a voltage divider (in this case, a 10K and 4K7 resistor). The collector DC voltage (shown above in Figure 1A) was 2.36 and lies perfectly between the logic low and high state of the 74HC device that it drives.

This transistor circuit is also a high gain amplifier, however, its primary function is a driver. Refer to figure 1B. When connected to the VFO output, the base voltage drops to 0.30 volts. This is an average DC voltage because it fluctuates as the AC waveform swings up and down. More or less AC drive on the input will change this DC voltage.
When connected to the VFO output, the collector voltage dropped to 0.71 VDC. Again, this is just an average, as when the AC swings positive, the the collector voltage will drop down to saturation (where collector voltage is less than base voltage) and then increase towards the positive supply. It does not have to go into cutoff; just to 3.2 volts or so. It also does not have to go into saturation; just to below the 1.3 volts or so. Thus, the transistor remains between cutoff and saturation when appropriately driven with a sine wave.

Our VFO serves as the clock and data on the D flip-flop inputs are only transferred to the flip-flop's outputs on the positive edge of a clock pulse. Positive edge triggering means that the output only responds to the input changes when the clock signal transitions from logic low to logic high. What a fantastic little circuit! You can find additional information and some practical examples in EMRFD. My special thanks to Wes, W7ZOI for helping me to better understand his design.

Positive Edge Triggering

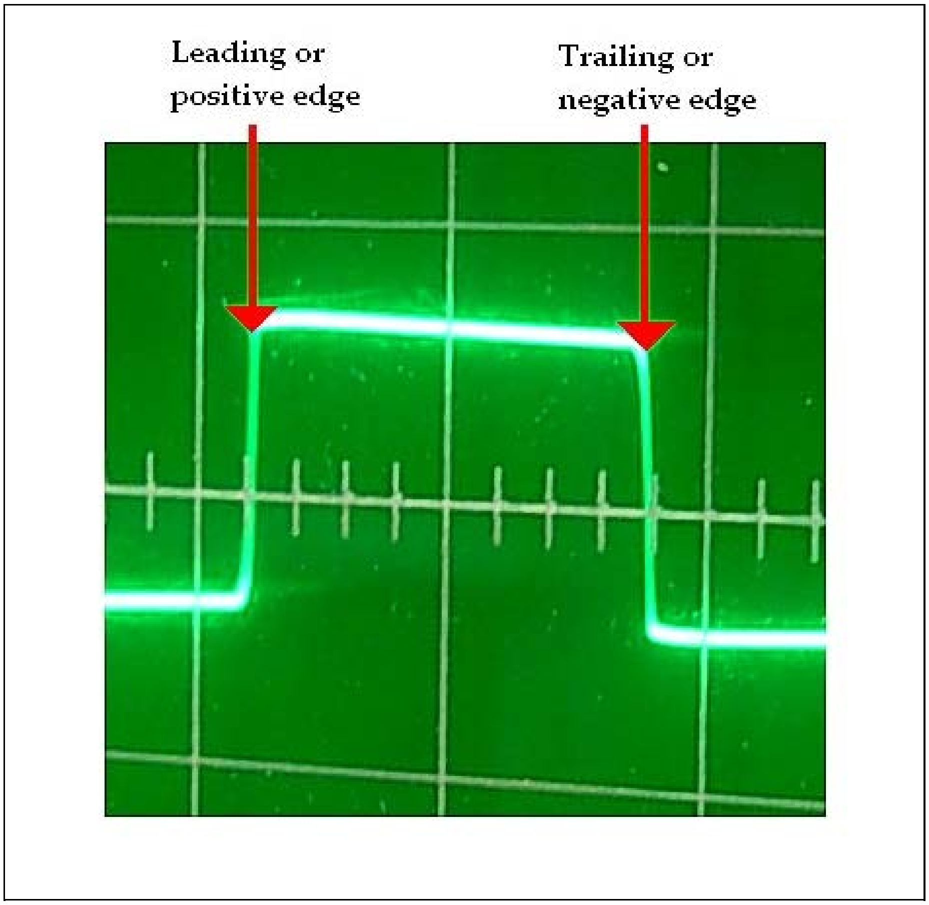

The triggering of a positive edge triggered flip flop is better understood viewing a graphic like above. The instant the waveform goes positive, the flip flop is triggered. It is easy to understand why a square wave is desirable for clean triggering.

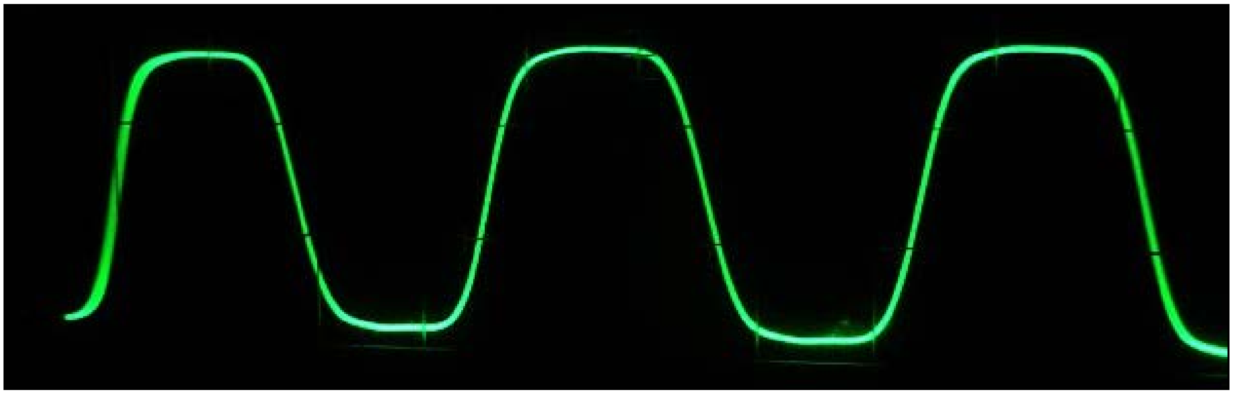

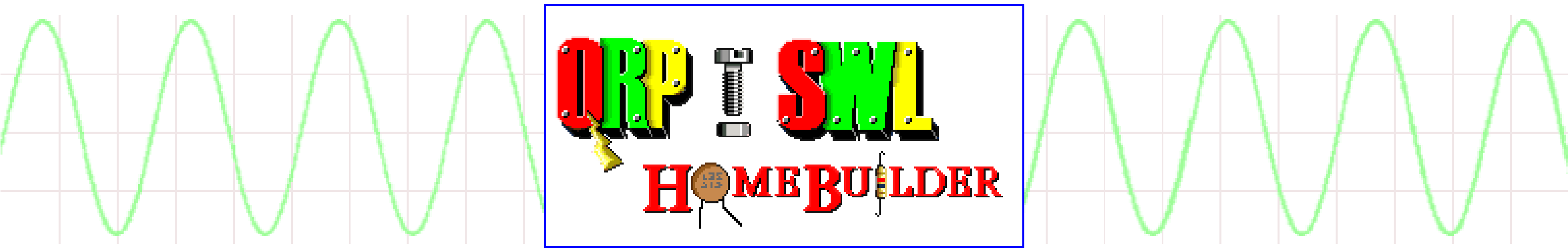
QRP SWL
HOMEBUILDER

Amateur and Short Wave Radio Electronics Experimenter's Web Site

Radio Amateurs of Canada Support Page

Commentary for Canadian Radio Amateurs

A significant number of licensed Canadian amateur radio operators do not support their national amateur radio society: Radio Amateurs of Canada Typically support is by membership, but may also include volunteering time to perform the various functions required to run a large, non-profit organization. It has been demonstrated repeatedly, that a small percentage of people are doing most of the work in modern volunteer organizations.

Some thoughts concerning volunteerism

- Volunteerism is down in many sectors including service clubs, meal delivery programs, church groups, volunteer firefighters radio clubs, etc. etc.
- The population is aging and our current volunteers are retiring; Younger folks have so many distractions and things they can do today. We now live in a world with 200 plus TV channels! The spirit of volunteerism seems to be decreasing in the western world.
- There is some evidence that people who donate their cash to charities also tend to participate in groups, associations and organizations. Is this a characteristic or trait?
- People volunteer for causes they believe in. What do people believe in now? Is our culture too self-absorbed, individualistic and focused on our own personal agendas and pleasure?
- Economics. Are young to middle aged people less able to volunteer and contribute because they are spending more of their time working?

RAC Membership

If you haven't, please consider joining the RAC. I joined out of respect to the many RAC volunteers who have devoted their personal time and continue to toil to keep amateur radio viable in Canada. We cannot take our currently allocated radio frequency bands for granted. There are groups who for profit, want to apply technologies which will consume or interfere with the radio frequency bands we enjoy. Canadian amateur radio needs a strong, united voice to survive into the future.

Apathy and lack of awareness may significantly decrease the rights and privileges we enjoy as radio amateurs today. The least we can do is support our national amateur radio society. It would be even better if more of us contributed by volunteering our personal time towards our wonderful radio hobby and serving the RAC.

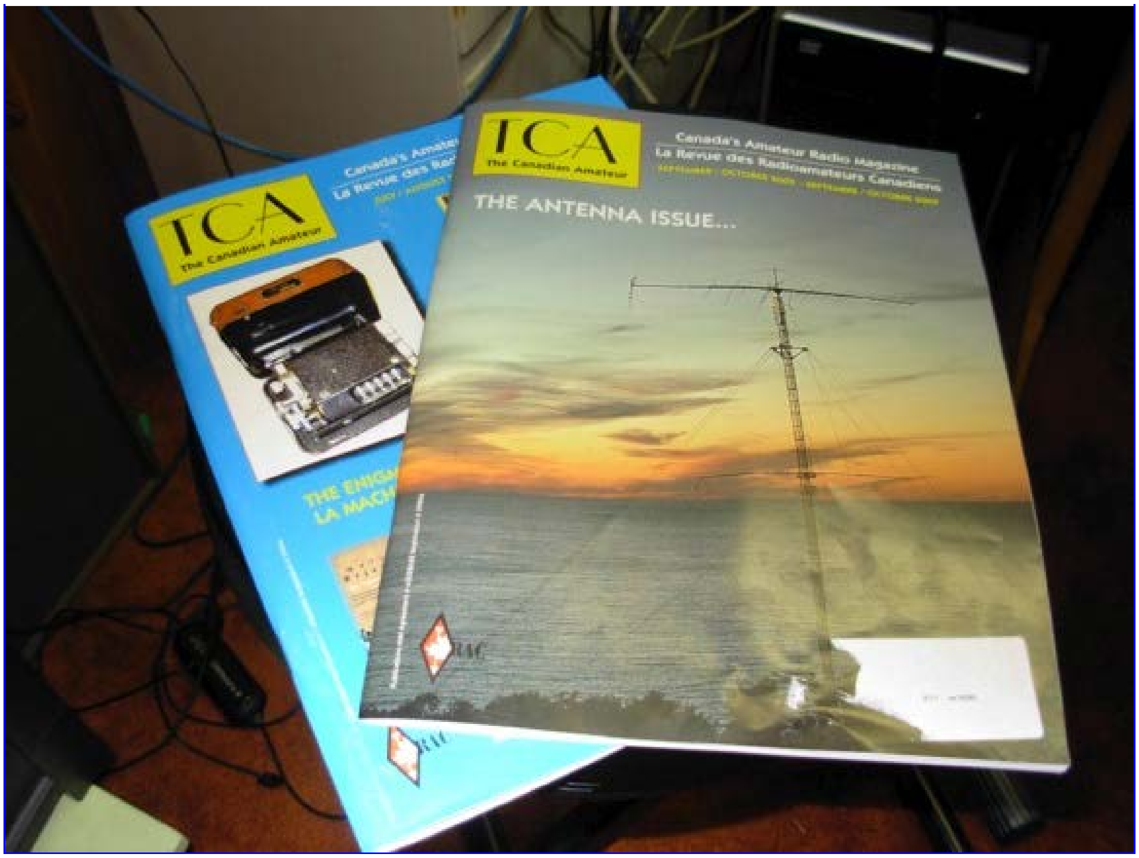
TCA
The Canadian Amateur
Canada's Amateur Radio Magazine
La Revue des Radioamateurs Canadiens
THE ANTENNA ISSUE...
THE ENIGM
LA MACH

The RAC Journal The Canadian Amateur is an excellent resource. Sept-Oct 2009 marked the first ever antenna issue.

Old QRPHB Web site graphics...

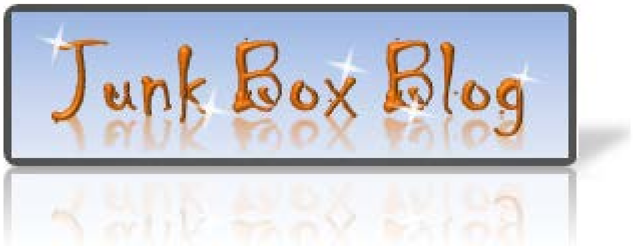
Junk Box Blog

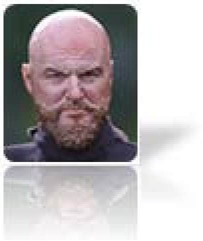

QRP
HOME BUILDER

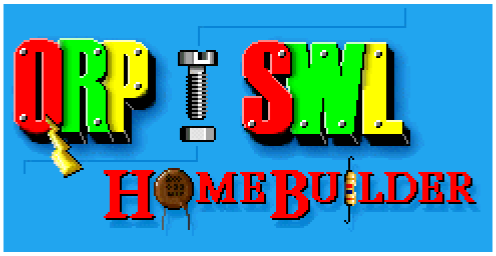
QRP
SWL
HOME BUILDER

QRP
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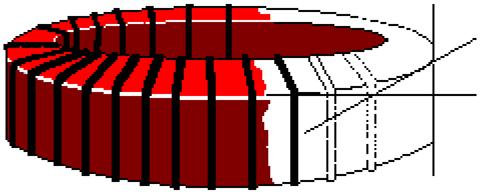

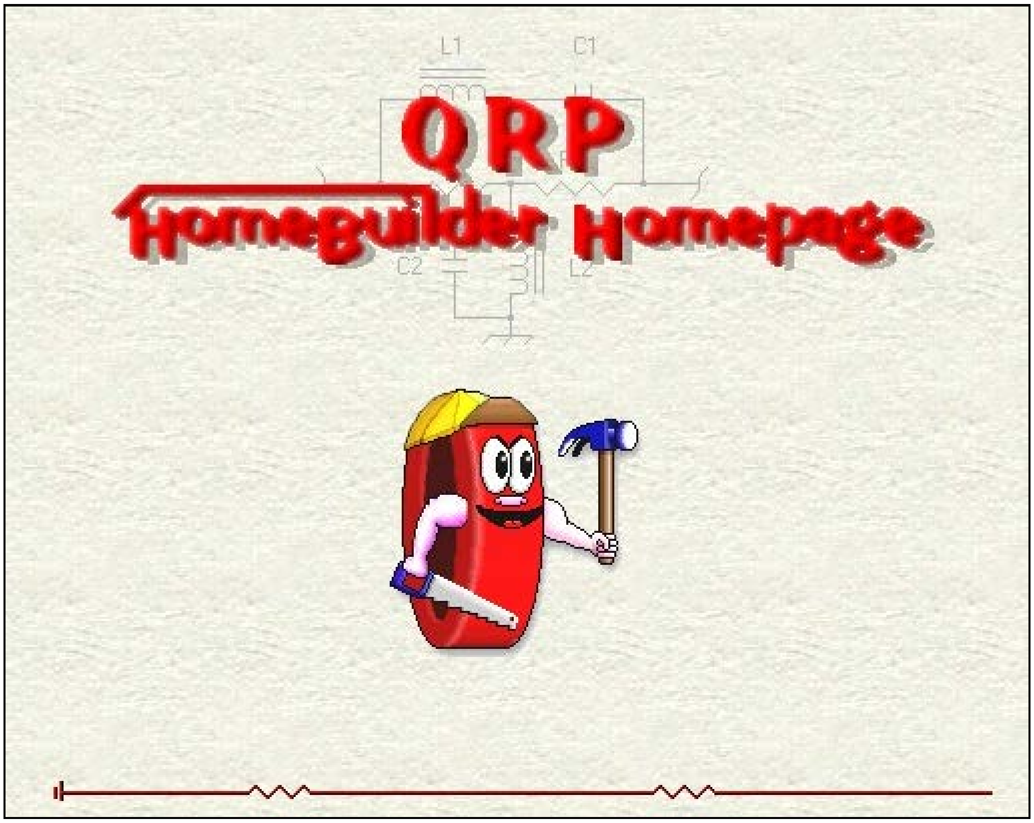
L1
C1
QRP
Homebuilder Homepage
C2
L2

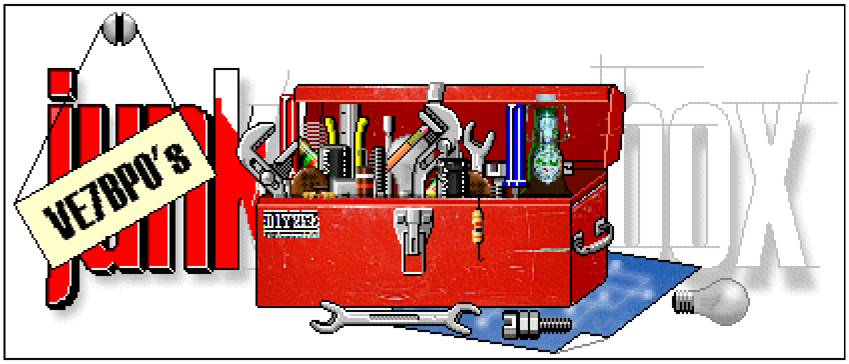
VE7BPO's
junk box

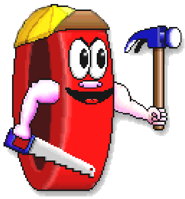

This page last updated: September 21, 2013

Info on the Popcorn Superhet RF Amp

Discussion

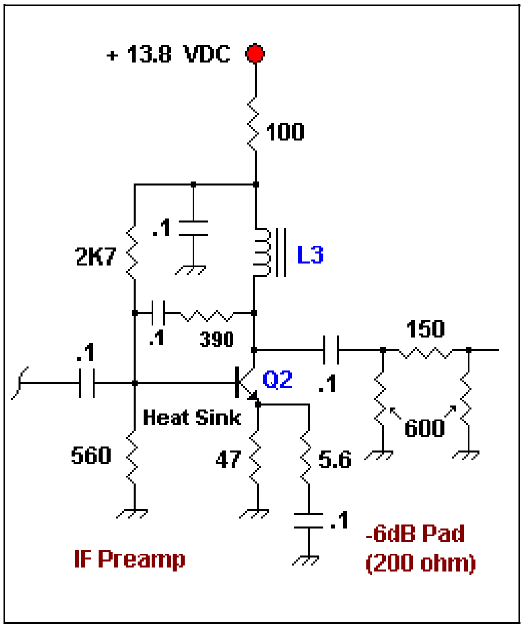

I have received a lot of emails regarding this RF amp from the popcorn superhet receiver. This amp was designed using a calculator and as it turns out, my input and output impedance was off by several ohms from the target 50 ohms input Z and 200 ohms output Z. Today we have computer programs to calculate the resistor values, so crunching the math is not a factor any more. This RF amp is preceded by a 50 ohm diplexer and followed by a 200 ohm pad, so it actually matches the preceding and following stages very well considering that it is clearly depicted to be a popcorn receiver. If I had to redesign this amp in 2008, I would use software to design a CE amp using "noiseless" Norton feedback, Still, this was a good sounding receiver at the time.
Probably the weakest section of this receiver is the audio preamp from Q5 on through to the LM386. I would likely never use these noisy stages in 2008-9. Instead I would use low noise op amps. This web site like my own abilities has grown over time. In the following section, I have paraphrased some writing from Wes, W7ZOI concerning the Q2 RF amp.

An Analysis by W7ZOI

The input impedance of a common emitter bipolar transistor amplifier is related to the standing current, the emitter degeneration resistance, the transistor beta, the F-t, and the operating frequency. Most of those details can be well modeled with the hybrid pi model. If you put quite a bit of emitter degeneration in such an amplifier, the gain drops while the input impedance increases. However, it is much less dependent upon beta and frequency. The emitter degeneration is one form of negative feedback. But now we introduce a second form of negative feedback by applying some of the collector voltage to a resistor that generates a current that is fed back to the base. This feedback tends to reduce gain just as does emitter degeneration. But it also tends to reduce input impedance. By playing a careful balancing act, you can design an amplifier that has a 50 Ohm input and output impedance with a reasonable amount of gain. This particular circuit has a gain of 21.7 dB at 10 MHz and an input return loss of 14 dB. The output return loss is even better at 18.6 dB. Z-in is 39-j14 while Z-out is 172-j34.

These are calculated values using that hybrid pi model. I have devoted a few pages to a discussion of this feedback amplifier topology in the ARRL 2003 book, Experimental Methods in RF Design. This was co-authored by KK7B and W7PUA. You can get the book on line from the ARRL. The book includes computer programs that will handle the design chores. One deals with bias issues while another does the RF design and analysis.

The RF amplifier under discussion may be found on this web page

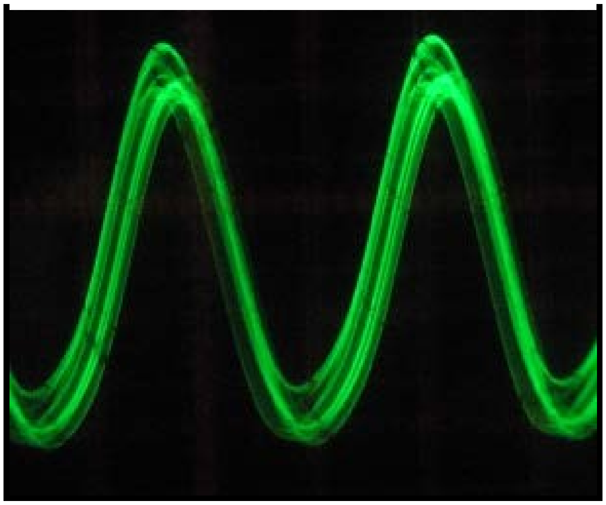

Amateur and Short Wave Radio Electronics Experimenter's Web Site

3 MHz VFO for 40M Popcorn Superhet Receivers

Discussion

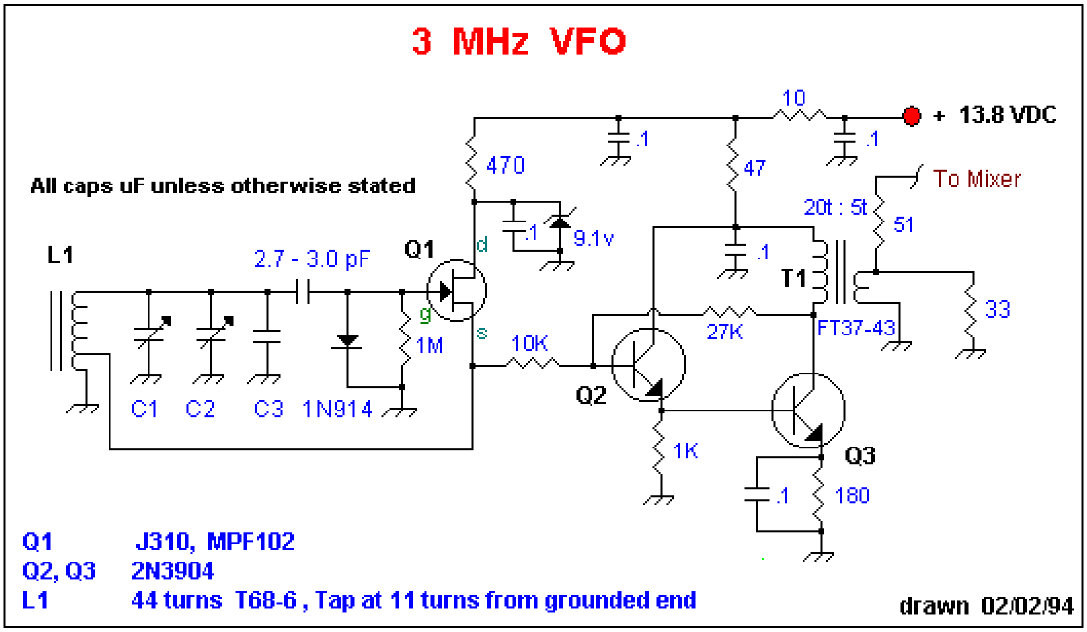

This VFO was first popularized by Roy Lewallen, W7EL and has been used in countless homebrew and commercially sold QRP rigs. For the 40 meter ugly super hets, you have a choice of a VFO frequency of 3 MHz or 11 MHz and I chose the former for this website. For L1, you can use the T68-6 as shown or redesign your own inductor using a T50-6 core. The T68-6 core allows the builder to wind the coil using # 24 AWG wire for enhanced Q and stability. The main tuning capacitor, C1 that was used had a built in reduction drive and went from 4 - 19 pF. If you use a tuning capacitor with a greater capacitance swing, you may have to connect it to the top of L1 via a small-value NP0 capacitor to reduce the tuning frequency range. This can be done using math or by just plain experimentation. C2 is a small ceramic air-variable trimmer from my junk box used to set the lower band edge of the VFO. It can be omitted if the user wants to go frugal and experimentally set the lowest frequency of the VFO using small-value ceramic NP0 caps. Air variable caps for C1 and C2 are mandatory for minimal drift VFO operation. C3 actually refers to 4 NP0 ceramic caps which were used to place the VFO on the correct frequency. Four caps were used to minimize heating and thus drift in the VFO. For the prototype VFO which tunes something ~ 3.00 to 3.67 MHz , I used the mentioned air-variable, four NP0 ceramic caps (20pF,100pF,5pF,100pF) and C2 the trimmer cap that went from 2 - 50 pF. These values should be used only as a guide for prospective builders as there are many variables at play. Following a 10 minute warm up period, the VF0 frequency stability is excellent. Again, keeps all component leads as short as possible. T1 is a broadband transformer wound by using 20 turns of # 26 AWG over a FT37-43 toroid core and then distributing 5 secondary turns spaced evenly over the primary windings. Do not omit the 33 ohm load resistor. The 2.7 to 3.0 pF coupling cap should also be of the NP0 ceramic type. Q1 can be the J310 (my favorite) , 2N4416 , MPF102 or other correct substitutes.

This VFO should be in a separate sealed, shielded box from the rest of the receiver

.

VFO Stability Hints

Numerous tips for enhancing VFO stability have been generated from Wes Hayward, W7ZOI, Roy Lewallen, W7EL, Doug DeMaw, W1FB and others. Here are a few summarized:

1. Use air wound or powdered-iron toroidal inductors made from number 6 material.
2. Use the heaviest gauge of wire possible to wind your inductor.
3. Anneal the inductor by boiling it in water for around 5 minutes after winding.
4. Use ugly construction above a SINGLE-SIDED copper side up ground plane.

5. Capacitors in the L-C circuit should be NP0 ceramic type.
6. Use air variable capacitors for tuning that have double bearings and no backlash.
7. The VFO should be operated at a lower regulated voltage.
8. Do not use cheap low-Q trimmer caps.
9. Completely encase the VFO to prevent RF leakage and to minimize environmental temperature changes.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

4 MHz BFO for 40M Popcorn Superhet Receivers

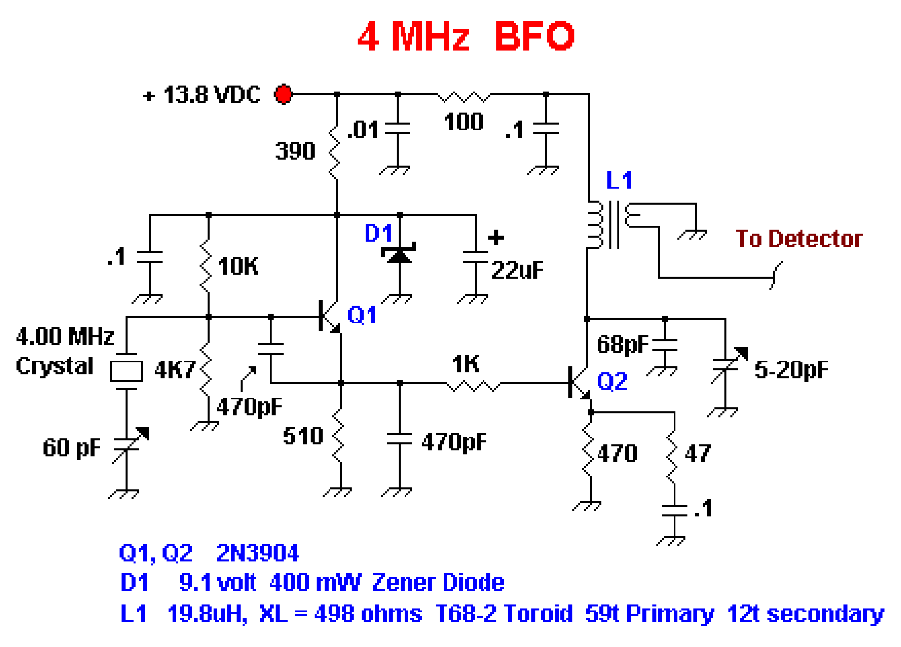
4 MHz BFO
+ 13.8 VDC
.01
100
.1
390
L1
To Detector
D1
+
22uF
.1
10K
Q1
4.00 MHz
Crystal
4K7
470pF
1K
Q2
68pF
5-20pF
60 pF
510
470pF
470
47
.1
Q1, Q2 2N3904
D1 9.1 volt 400 mW Zener Diode
L1 19.8uH, XL = 498 ohms T68-2 Toroid 59t Primary 12t secondary

Discussion

Shown is a 2 stage BFO for use with the Ugly 40 meter superhets with a 4.00 MHz IF. This is a design by W7ZOI which I have used from 3.5 to 9 MHz by only changing the crystal and the Q2 output coil and capacitor values to suit the frequency of choice. The output coil is 59 primary and 12 secondary windings on a T68-2 toroid core. You will need in the order of 79 pF to resonate this coil, thus a 68 pF plus a 5-20 pF variable works well. If you do not have a T68-2 core, a T50-2 could be used with 30 AWG wire which is a bit difficult so you could opt for an XL of 200 ohms which would be 40 primary and 8 secondary turns on a T50-2 core. You would need ~200 pF to resonate such a coil and the BFO would have reduced output power, but would still work okay. If you design your own tank, you probably should not use an XL/XC less than 190 ohms for the output stage at 4 MHz. Use a 5:1 turns ratio for primary to secondary windings.

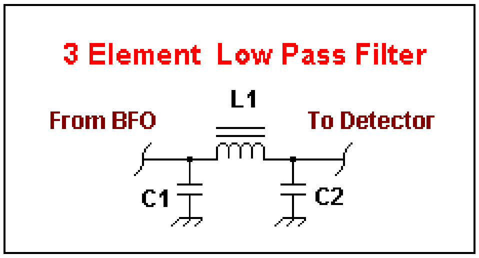
3 Element Low Pass Filter
L1
From BFO
To Detector
C1
C2

It wouldn't hurt to follow the Popcorn Superhet BFO with a low pass filter. A simple pi-type 3 element filter is suitable. Since I had a couple of 470 pF caps left over, I made a low pass filter using a 6.8 MHz cutoff frequency with a 1.17 uH inductor. A 1.17 uH inductor using a T37-2 core requires 17 turns while on a T50-2 core requires 15 turns. Caps were inexpensive monolithic ceramics from Digi-Key. The filter is shown below, L1 = 1.17uH , C1 and C2 = 470 pF. If you want, you may use other cutoff frequencies to suit any junk box caps you have on hand and use an XL/XC of 50 ohms.

Construction

Keep component leads as short as possible to promote stability. Do not omit the zener diode D1. I thought of using a small ferrite bead on the base of Q2 and will try it on the next version of this BFO that I make. The BFO, if unstable can break into all sorts of weird AF sound effects that are very annoying. The BFO should ideally be in a shielded box, but many amateurs have good results by just placing the BFO strategically in the receiver chassis. When winding L1, make sure you wind the secondary coil so that the secondary's grounded end is on the cold side of the primary coil that connects to the 100 ohm resistor and positive voltage. I just pick one end of the primary coil and close wind the secondary coil from this point in the same direction for the correct number of windings. Then the starting point of the secondary can be grounded and the other end connected to the detector or a low pass filter. After building the coil, temporarily place a 51 ohm resistor from the secondary output lead to ground. Then you can test and peak the tuning of the output tank into a load. Leave the resistor in place for all your testing work such as crystal matching or RF stage testing until you are ready to connect it to the product detector. The 60 pF variable cap connected between the crystal and ground is used to set the beat frequency of the BFO. Adjust it to get a good sounding beat note when listening to a station. You will notice that the beat frequency can be tuned roughly by just listening to 40 meter band noise in the headphones and then tweaked on an active QSO.

QRPHB Archive Schematics

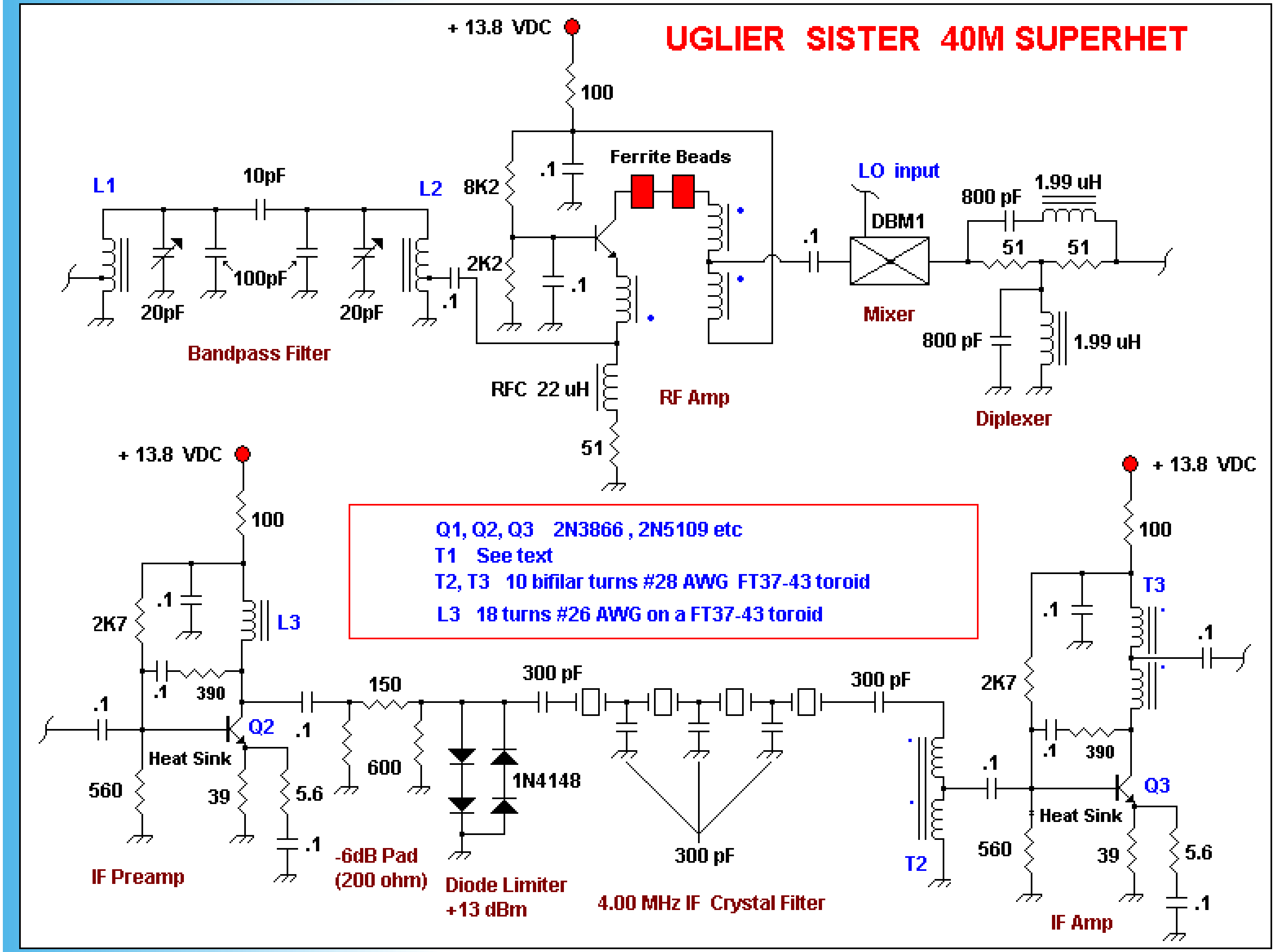
UGLIER SISTER 40M SUPERHET
+ 13.8 VDC
100
8K2
.1
Ferrite Beads
L1
10pF
L2
20pF
100pF
20pF
2K2
.1
.1
Bandpass Filter
RFC 22 uH
51
RF Amp
LO input
DBM1
Mixer
.1
800 pF
1.99 uH
51
51
800 pF
1.99 uH
Diplexer
Q1, Q2, Q3 2N3866 , 2N5109 etc
T1 See text
T2, T3 10 bifilar turns #28 AWG FT37-43 toroid
L3 18 turns #26 AWG on a FT37-43 toroid
+ 13.8 VDC
100
2K7
.1
L3
.1
390
.1
Q2
.1
Heat Sink
560
39
5.6
.1
150
600
-6dB Pad
(200 ohm)
300 pF
1N4148
Diode Limiter
+13 dBm
300 pF
300 pF
4.00 MHz IF Crystal Filter
T2
.1
+ 13.8 VDC
100
T3
.1
.1
2K7
.1
390
Q3
Heat Sink
560
39
5.6
.1
IF Amp
IF Preamp

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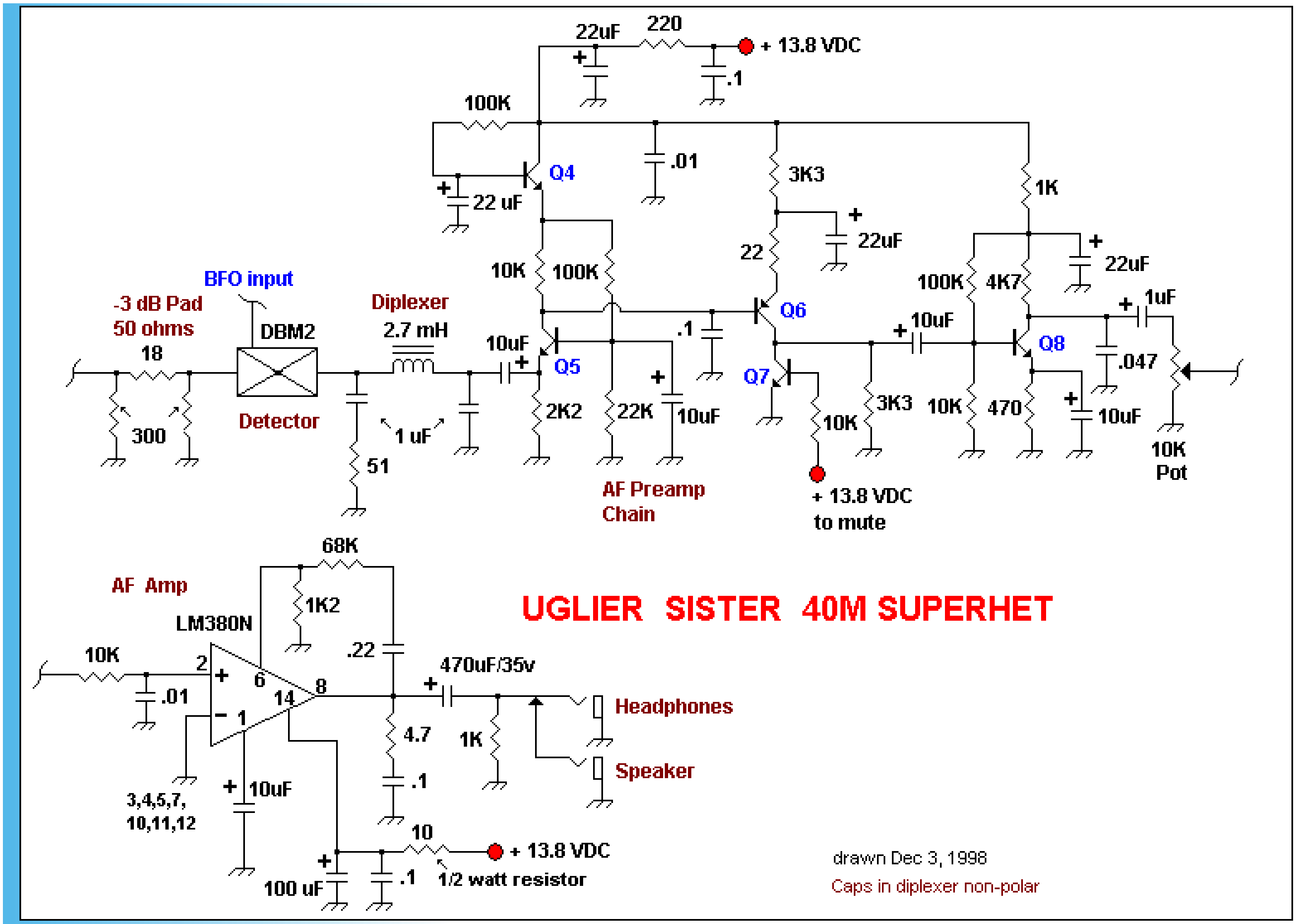
22uF
220
+ 13.8 VDC
.1
100K
Q4
.01
3K3
1K
22 uF
22uF
22
22uF
100K
4K7
10K
100K
BFO input
Q6
1uF
-3 dB Pad
50 ohms
Diplexer
10uF
Q8
DBM2
2.7 mH
.1
18
10uF
.047
Q5
Q7
300
Detector
1 uF
2K2
22K
10uF
10K
3K3
10K
470
10uF
10K
Pot
51
AF Preamp
Chain
+ 13.8 VDC
to mute
68K
AF Amp
1K2
UGLIER SISTER 40M SUPERHET
LM380N
10K
2
6
.22
.01
14
8
470uF/35v
Headphones
1
4.7
1K
.1
Speaker
3,4,5,7,
10,11,12
10uF
10
+ 13.8 VDC
100 uF
.1
1/2 watt resistor
drawn Dec 3, 1998
Caps in diplexer non-polar

<\p>

Uglier Sister Superhet Receiver

This is a 40 M superhet that I built a few years ago. While I was happy with this receiver, it has been discontinued from the main listings on the QRPHB website. I have had a couple requests for this schematic, so I have created this archival web page.
I stood a lot of current in the IF preamp and main IF amplifiers, which is not really necessary, particularly in the case of the post-filter amp. Of course raising the emitter resistor values is easy to do in these amps if you do wish to lower the current. There also is no audio filtering in the AF preamp stages, which is something that I often use in better quality receivers that I build now.

VFO and BFO

VFO schematic
BFO schematic

Construction Information

Refer to this web page for details on the xtal filter, diplexer and construction information.

The Norton RF preamp is discussed on the RF Preamp web page.

Return to the QRP HomeBuilder Homepage

Amateur and Short Wave Radio Electronics Experimenter's Web Site

Diplexer Supplemental Page

More Information on the Bridge-Tee Diplexer

Introduction

No web page on the QRPHB web site has furnished more email and controversy than the Diplexer Web page. This page has received much work to improve its content and accuracy and the email received has been greatly appreciated. Presented is the detailed math and some information regarding the Bridge-Tee Diplexer by Helmut Strickner, VK4STR and Wes Hayward, W7ZOI.

VK4STR

The T-bridge diplexer math calculation (also known as the W1JR diplexer)

The formulae presented and used in the program for the Bridge-T Diplexer uses a Q of 1. Using a Q = 1 resonator is not optimal because we don't want a "broad peaking response" of the series LC resonator in the T-bridge diplexer. Our goal should be to only let the desired IF frequency pass and attenuate all other frequencies as much as possible by properly terminating them into 50 Ohms in the diplexer.

The optimal Q for HF frequencies is around 10, less for higher frequencies. The higher Q of the series resonator effectively increases the attenuation of undesired harmonic frequency components from the mixer IF-port, and the reflected products from the crystal back to the IF-port. The IM performance (IP3) of the receiver is improved.

The possible improvement in IP3 depends mainly on the following stages. The post-mixer amplifier following the diplexer has to handle huge impedance variations at the input of the crystal filter. Crystals do not absorb but reflect any products they cannot handle. These products are then reflected back to the IF-port of the mixer deteriorating the IM performance.

A low Q diplexer lets these reflections from the crystal pass unhindered and most mixers will react with degraded intermodulation performance. It is also important to note that a good termination insensitive post-mixer amplifier should follow the diplexer.

The best results for a high intercept (IP3) receiver can be obtained by choosing:

1. High level mixer
2. T-bridge diplexer with optimised Q (Q=10 for HF)
3. Termination insensitive post-mixer amplifier (see N6NWP - QEX July 1995)

I believe that the intermodulation performance of many receivers can be improved by some simple measures like a properly designed diplexer. The T-bridge diplexer from W1JR is the best one around, go for it.

A brief example of the calculation for a 10.7MHz diplexer follows in Figure 1. The value of K should be 10 for short wave and 2 to 4 for VHF (2 meter band). K is the ratio of L to C.

I hope that you can use this example to calculate the values for other diplexer frequencies.

To fully understand the basis of this calculation please refer to Meinke/Grundlach: "Taschenbuch der Hochfrequenztechnik", Springer-

Verlag Berlin/Heidelberg. Page 127.

$$K = \frac{1}{Z} \cdot \sqrt{\frac{L}{c}} \quad (K = 10) \qquad \omega_r = 67\,196\,000$$

$$L_1 = \frac{K \cdot Z}{\omega_r} = \frac{10 \cdot 50}{2 \cdot 3{,}14 \cdot 10{,}7 \cdot 10^6} = $$
$$= 7{,}44 \cdot 10^{-6} \approx 7{,}5\ \mu H$$

$$C_1 = \frac{1}{\omega^2 \cdot L_1} = \frac{1}{(2 \cdot 3{,}14 \cdot 10{,}7 \cdot 10^6)^2 \cdot 7{,}44 \cdot 10^{-6}} =$$
$$= 29{,}7 \cdot 10^{-12} \approx 30\ pf$$

$$L_2 = C_1 \cdot Z^2 = 29{,}7 \cdot 10^{-12} \cdot 50^2 =$$
$$= 7{,}42 \cdot 10^{-8} \approx 74\ nH$$

$$C_2 = \frac{L_1}{Z^2} = \frac{7{,}44 \cdot 10^{-6}}{50^2} =$$
$$= 2{,}97 \cdot 10^{-9} \approx 3\ nF$$

Figure 1

73!
Helmut VK4STR

W7ZOI

Attached are some outputs from Mathcad, Version 7.0. The "proper" equations are derived, along with some other results. Feel free to put these on the web, although this is mathematics rather than the usual "formulas" and there might not be any interest in such stuff.

As it turns out, the formula that Todd presented in completely accurate for the case of Q=1. That is, both the series and parallel tuned circuits have inductors and capacitors with reactance of 50 Ohms. Evaluation then shows that S11=0 for all frequency, while S21 peaks broadly at the resonant frequency. If you pick a higher Q, the inductor in the series tuned circuit increases by Q and the capacitor in the parallel one increases by Q. Resonance is maintained in both. Again, you then get a perfect match at all frequencies and a S21 peak at resonance. But I don't know if this is what Joe had in his original work.

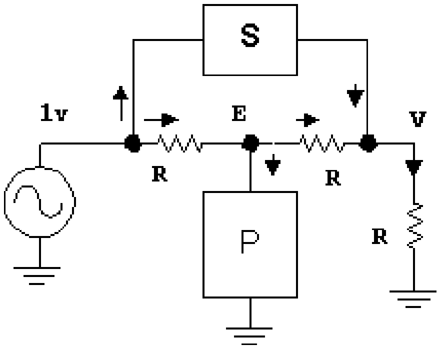

Shown is a general bridge T type network with series impedance S and parallel impedance P. We wish to find the input impedance seen by the generator. But to do this, we need to know the input current. The input voltage is set at 1, so Zin=1/Iin. To calculate this, we must know E and V. These are obtained with a nodal analysis.

We write the nodal equation at E :

$$\frac{(1-E)}{R}=\frac{E}{P}+\frac{(E-V)}{R}$$

We solve this for E:

$$\frac{(1-E)}{R}=\frac{E}{P}+\frac{(E-V)}{R}\ \text{solve},E\ \rightarrow \frac{-\left(\frac{1}{R}+\frac{1}{R}\cdot V\right)}{\left(\frac{-2}{R}-\frac{1}{P}\right)}$$

We now write the equation at V and solve it for E:

$$\frac{(1-V)}{S}+\frac{(E-V)}{R}=\frac{V}{R}\ \text{solve},E\ \rightarrow -\left(\frac{1}{S}-\frac{1}{S}\cdot V-\frac{2}{R}\cdot V\right)\cdot R$$

We now equate the two expressions for E to each other and solve that for V.

$$-\left(\frac{1}{S}-\frac{1}{S}\cdot V-\frac{2}{R}\cdot V\right)\cdot R=\frac{-\left(\frac{1}{R}+\frac{1}{R}\cdot V\right)}{\left(\frac{-2}{R}-\frac{1}{P}\right)}\ \text{solve},V\ \rightarrow \frac{-\left[\frac{-R}{S}+\frac{1}{\left[\left(\frac{-2}{R}-\frac{1}{P}\right)\cdot R\right]}\right]}{\left[\frac{R}{S}+2+\frac{1}{\left[\left(\frac{-2}{R}-\frac{1}{P}\right)\cdot R\right]}\right]}$$

which simplifies to $V = \dfrac{\left(2\cdot R\cdot P+R^2+P\cdot S\right)}{\left(2\cdot R\cdot P+R^2+3\cdot P\cdot S+2\cdot S\cdot R\right)}$

We now take one of the expressions for E and put V in it to obtain a complete solution.

$$E = 2\cdot P\cdot\frac{(R+S)}{\left(2\cdot R\cdot P+R^2+3\cdot P\cdot S+2\cdot S\cdot R\right)}$$

The next chore is to evaluate the input impedance, Zin. We get this by calculating the input current. The input voltage is set at 1, so Zin=1/ i-in.

$$i\ in = \frac{(1-V)}{S}+\frac{(1-E)}{R} \qquad \text{So } Z = \frac{1}{\left[\frac{(1-V)}{S}+\frac{(1-E)}{R}\right]}$$

which simplifies to $Z\ in = \dfrac{-1}{(-R+R\cdot V-S+S\cdot E)}\cdot S\cdot R$

But to get a meaningful expression, we must sub V and E into this. When we do so, we get

Figure 2

$$Z\text{ in} = \frac{\left(2\cdot R\cdot P + R^2 + 3\cdot P\cdot S + 2\cdot S\cdot R\right)}{\left(2\cdot R\cdot P + 3\cdot R^2 + P\cdot S + 2\cdot S\cdot R\right)}\cdot R$$

This is now a useful result. We can, for example, let S, P, and R be resistor values. We can then design bridge T attenuators. But let's continue with the analysis. Let's ask the question "What are the conditions that will provide an input impedance of R?" We merely set the Zin expression equal to R, and then solve that equation for S or P. We will solve for P.

$$\frac{\left(2\cdot R\cdot P + R^2 + 3\cdot P\cdot S + 2\cdot S\cdot R\right)}{\left(2\cdot R\cdot P + 3\cdot R^2 + P\cdot S + 2\cdot S\cdot R\right)}\cdot R = R \text{ solve}, P \rightarrow \frac{R^2}{S}$$

Hey, that's a cool result, and it's even rather simple. This is an expression for P in terms of S. If we use it for attenuators, it says that our pad is matched with these conditions. We can combine these results with the equation for V to get the attenuation. A couple of interesting matched pads are shown:

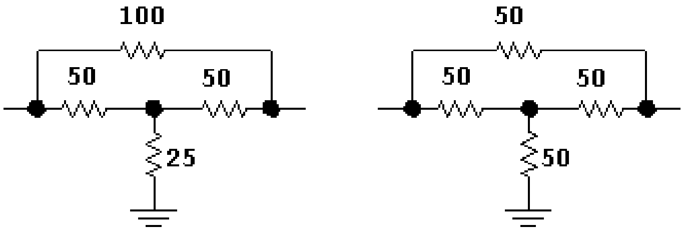

Figure 3

The expression for V was $\frac{\left(2\cdot R\cdot P + R^2 + P\cdot S\right)}{\left(2\cdot R\cdot P + R^2 + 3\cdot P\cdot S + 2\cdot S\cdot R\right)}$ But the conditions for a match were

$P = \frac{R^2}{S}$ So, we put this in for P.

$$\frac{\left(2\cdot R\cdot P + R^2 + P\cdot S\right)}{\left(2\cdot R\cdot P + R^2 + 3\cdot P\cdot S + 2\cdot S\cdot R\right)} \text{ substitute}, P = \frac{R^2}{S} \rightarrow \frac{\left(2\cdot\frac{R^3}{S} + 2\cdot R^2\right)}{\left(2\cdot\frac{R^3}{S} + 4\cdot R^2 + 2\cdot S\cdot R\right)}$$

which simplifies to $V = \frac{R}{(R+S)}$ So the two pads have voltage outputs of 0.5 and 0.333 and the resulting attenuations are 6 and 9.54 dB.

But enough about the attenuators. Let's get back to the original question, that of the diplexer. The circuit of interest is one where the series network is a series tuned circuit while the parallel one is a parallel tuned circuit. But we want to know the conditions that will generate a perfect match. With such a circuit, it is clear that a match will exist at resonance so long as both circuits are resonant at the same frequency. The impedance of the series tuned circuit goes to zero while that of the parallel TC becomes infinite (neglecting loss.)

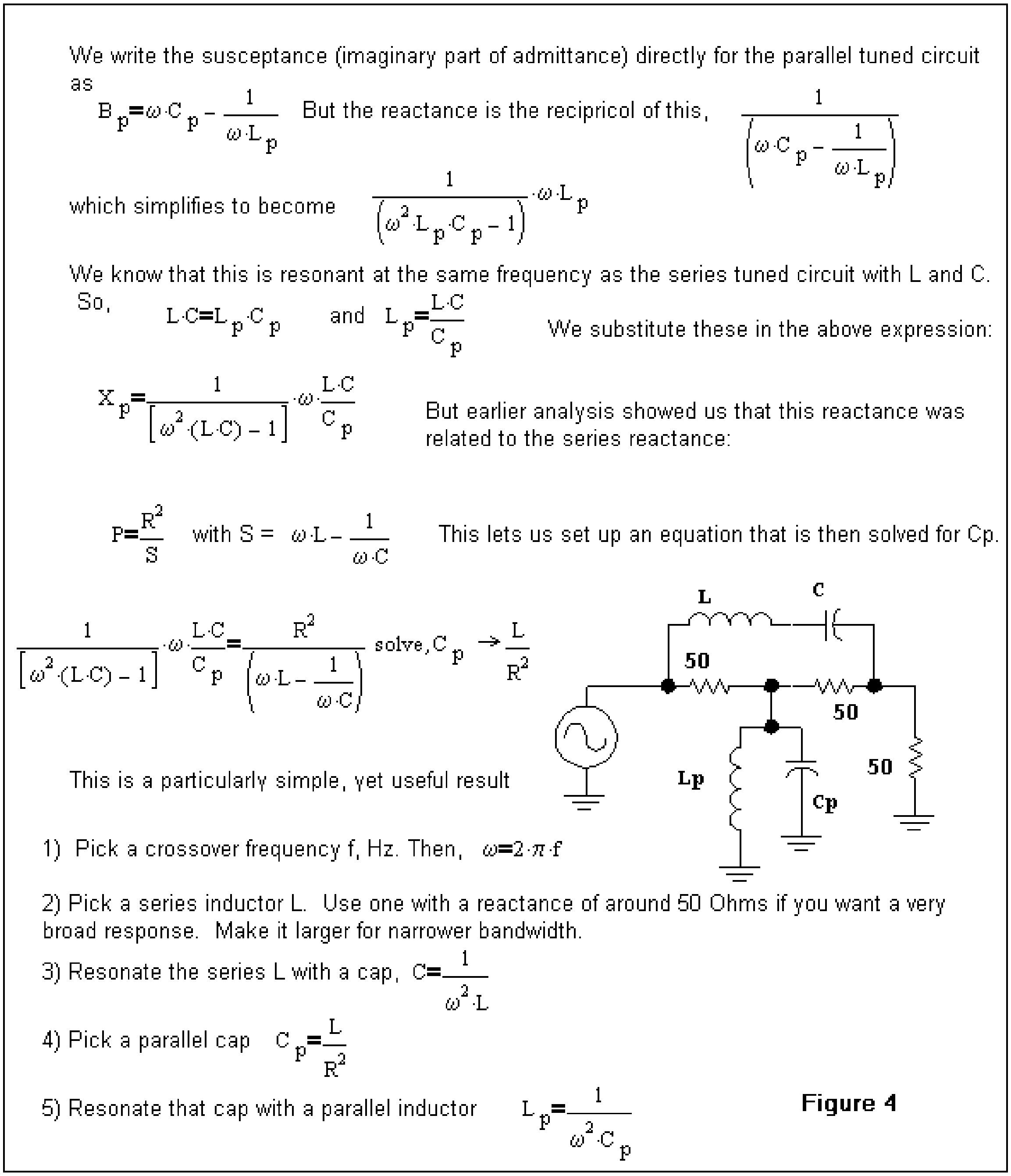

We write the susceptance (imaginary part of admittance) directly for the parallel tuned circuit as

$B_p = \omega \cdot C_p - \frac{1}{\omega \cdot L_p}$ But the reactance is the reciprical of this, $\frac{1}{\left(\omega \cdot C_p - \frac{1}{\omega \cdot L_p}\right)}$

which simplifies to become $\frac{1}{\left(\omega^2 \cdot L_p \cdot C_p - 1\right)} \cdot \omega \cdot L_p$

We know that this is resonant at the same frequency as the series tuned circuit with L and C. So, $L \cdot C = L_p \cdot C_p$ and $L_p = \frac{L \cdot C}{C_p}$ We substitute these in the above expression:

$X_p = \frac{1}{\left[\omega^2 \cdot (L \cdot C) - 1\right]} \cdot \omega \cdot \frac{L \cdot C}{C_p}$ But earlier analysis showed us that this reactance was related to the series reactance:

$P = \frac{R^2}{S}$ with S = $\omega \cdot L - \frac{1}{\omega \cdot C}$ This lets us set up an equation that is then solved for Cp.

$$\frac{1}{\left[\omega^2 \cdot (L \cdot C) - 1\right]} \cdot \omega \cdot \frac{L \cdot C}{C_p} = \frac{R^2}{\left(\omega \cdot L - \frac{1}{\omega \cdot C}\right)} \text{ solve}, C_p \rightarrow \frac{L}{R^2}$$

This is a particularly simple, yet useful result

1) Pick a crossover frequency f, Hz. Then, $\omega = 2 \cdot \pi \cdot f$

2) Pick a series inductor L. Use one with a reactance of around 50 Ohms if you want a very broad response. Make it larger for narrower bandwidth.

3) Resonate the series L with a cap, $C = \frac{1}{\omega^2 \cdot L}$

4) Pick a parallel cap $C_p = \frac{L}{R^2}$

5) Resonate that cap with a parallel inductor $L_p = \frac{1}{\omega^2 \cdot C_p}$

Figure 4

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Amateur and Short Wave Radio Electronics Experimenter's Web Site

Astable Multivibrator Projects

Discussion:

Astable or free-running multivibrators have been used in home-built amateur radio equipment for many years. The basic circuit is a two stage amplifier with AC-coupled feedback from output to input. One transistor stage is on (conducting current) while the other is off (not conducting current) until the stages switch conducting states repeatedly at a specific frequency. The oscillation frequency is set by the resistor and capacitor values connected to the base terminal of each stage. This RC network determines how long the transistor stays in the off position.

Presented are two projects which utilize astable multivibrators built using the ubiquitous 2N3904 BJT. The first project is a code practice audio-frequency oscillator while the second is a simple , no-frills electronic keyer for keying a transmitter. Either circuit would be a great first project to learn how to build circuits using Ugly Construction.

Code Practice Oscillator

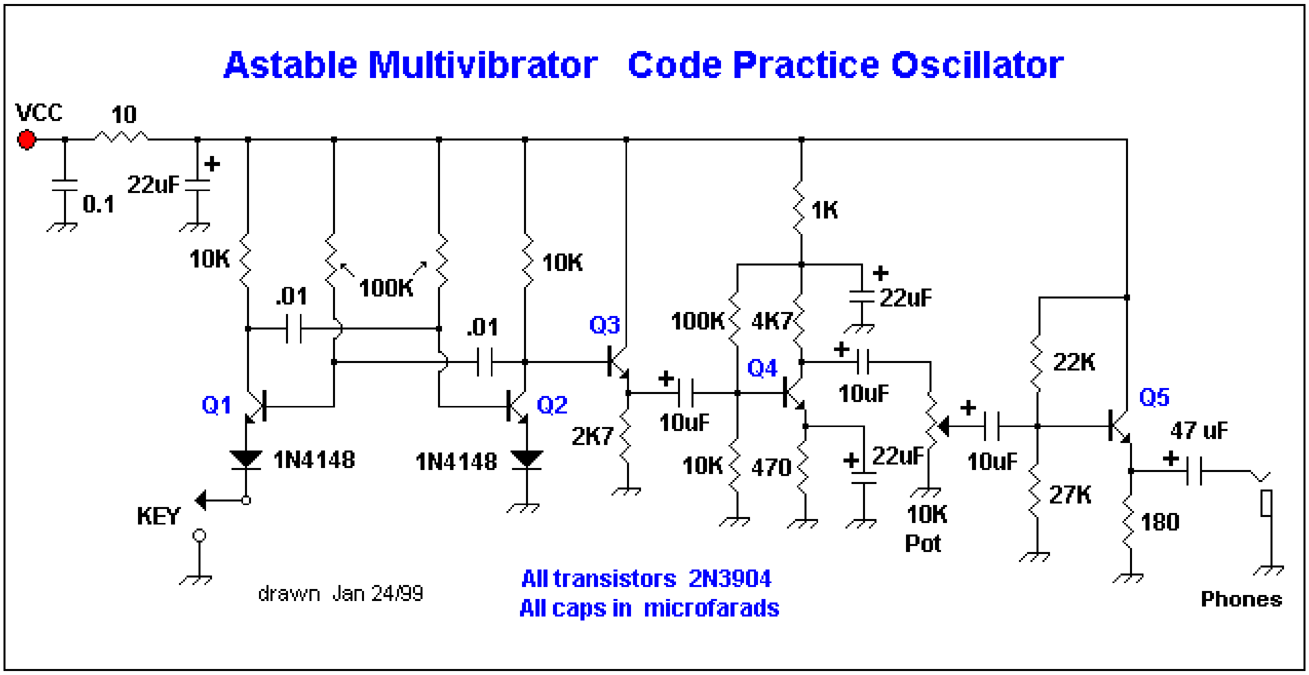
Astable Multivibrator Code Practice Oscillator
VCC
10
0.1
22uF
10K
.01
100K
.01
10K
Q1
Q2
Q3
1N4148
1N4148
KEY
2K7
10uF
100K
4K7
1K
22uF
Q4
10uF
10K
470
22uF
10K Pot
10uF
22K
27K
Q5
180
47 uF
Phones
drawn Jan 24/99
All transistors 2N3904
All caps in microfarads

Above is the schematic for a simple Morse code practice oscillator. This circuit was originally built with 2N3904 transistors, however many different NPN transistors could be substituted as required.

Tracing the circuit from left to right first brings us to the multivibrator circuit which is composed of Q1 and Q2. The oscillation frequency of the multivibrator is ~ 700 hertz and is set by the RC network formed by the 100K resistor and the 0.01 uF capacitor connected to each transistor base terminal. The approximate time off for each transistor is given by the following formula:

[Time 0ff = 0.7 * R * C] with R in ohms and C in farads.

It maybe more practical to leave the resistance value fixed and vary the capacitor value to obtain a desired oscillation frequency. Rearranging the above formula allows this :

[Total Time Off = 1 / Frequency] with Total Time Off being the total number of seconds that both transistors are off and Frequency is in hertz.

Once the total time off is known, you must divide that answer by 2 as each transistor is off half of the total time off in this symmetrical circuit. Then you simply solve for the capacitor value:

[Time Half = Total Time Off / 2]
[Capacitor = Time Half / (0.7 * R)] with Capacitor answer in farads.

Lets run the numbers to solve for the capacitor values in the schematic;
R = 100K, desired frequency = 700 hertz.
Total Time Off = 1 / F ----> 1 / 700 = 0.00143 seconds.
Time Half = Total Time Off / 2 ----> 0.00143 / 2 = 0.00071 seconds.
Capacitor = Time Half / (0.7 * R) ----> 0.00071 / (0.7 * 100000) = 0.0000001 farads = 0.01 microfarads.

For 600 hertz, the capacitors would be 0.012 uF and for 400 hertz, 0.018 uF.

As you can see it is maybe necessary to adjust the base resistor value to achieve a specific oscillation frequency. The rule of thumb is that the base resistor should be ~ten times the value of the collector resistor assuming the base-bias resistor is connected to VCC as shown.

The output of the multivibrator is buffered by the high input impedance of an emitter follower Q3. This serves to prevent the oscillation frequency from changing when the output load is changed. The AF stage connected to the emitter-follower is a standard high gain common-emitter amp that has been used in many of the projects on this web site. As the multivibrator is buffered by 2 amplifier stages, good frequency stability is realized and frequency changes are negligible when turning the volume control pot. The final stage is a common-collector amplifier which can drive low impedance headphones with reasonable volume.

Code Practice Oscillator Project Notes

The voltage / time output waveform of the astable multivibrator is largely a square wave which some people find harsh. Many users prefer listening to a sine wave although that is beyond the scope of this web page. The multivibrator shown has real advantages in that, it is both dependable and tolerant with respect to parts substitutions. Keying the oscillator as shown practically guarantees that the multivibrator will start running each time you hit the key.

VCC can be 9 to 13.8 volts DC and the larger the voltage the greater the volume in the headphones. The B+ decoupling circuit at the top left can be omitted for battery operation or if you prefer not to bother with it. The basic multivibrator and emitter-follower circuit can be used in a transceiver as a sidetone for monitoring keying. A series resistor from the emitter-follower maybe necessary to attenuate/match the sidetone to the transceiver's AF amp.

If you desire speaker level output, the Q5 common-collector final can be omitted and the circuit shown below used. This circuit uses the LM386N and provides up to ~ 0.5 watts into an 8 ohm speaker. Connect the Figure 1 circuit as shown to the 10 uF coupling capacitor connected to the collector of Q4. Do not connect the 10 ohm half-watt resistor to the decoupled VCC shown in the schematic. The power supply to the LM386N AF amp should be directly connected to the VCC, not like the common-collector AF stage shown in the schematic to the right.

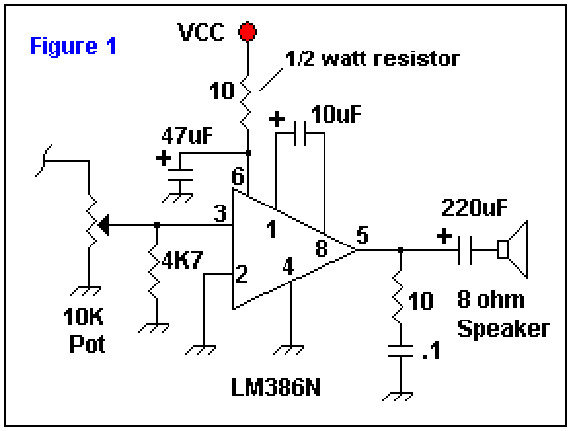

Simple Electronic Keyer

A simple keyer suitable for a popcorn QRP transmitter can be built around an astable multivibrator and an example of such is shown above. The basic design of this keyer is from notes, however the original author of the circuit is unknown. The notes were written in 1973 . I modernized the circuit, added a variable speed control and designed an additional output driver stage.

Keyer Operation

Keying this circuit generates either dits and spaces or dahs and spaces. When the keyer is idle, Q1 is on and Q2 and Q3 are switched off. When the user sends code, Q1 turns off and Q2 and Q3 switch on and in turn key any device appropriately connected to the collector of Q3. The off-time of Q1 sets the on-time of Q2 and Q3. The off-time of Q2 and Q3 is set by the 22K Q2 base resistor. This off-time is the set time of the spaces and is constant.

The 68K resistor on the base of Q1 is about three times the resistance of the 22K base resistor on Q2 and consequently dahs are ~ three times the length in duration than dits. Spaces and dits are of the same length of time because when sending dits, the 68K base resistor is paralleled with the 33K resistor and effectively the resistance is ~22K ohms. If the optional relay driver transistor Q4 is used instead of Q3, the theory is the same, just substitute Q4 wherever you see Q3.

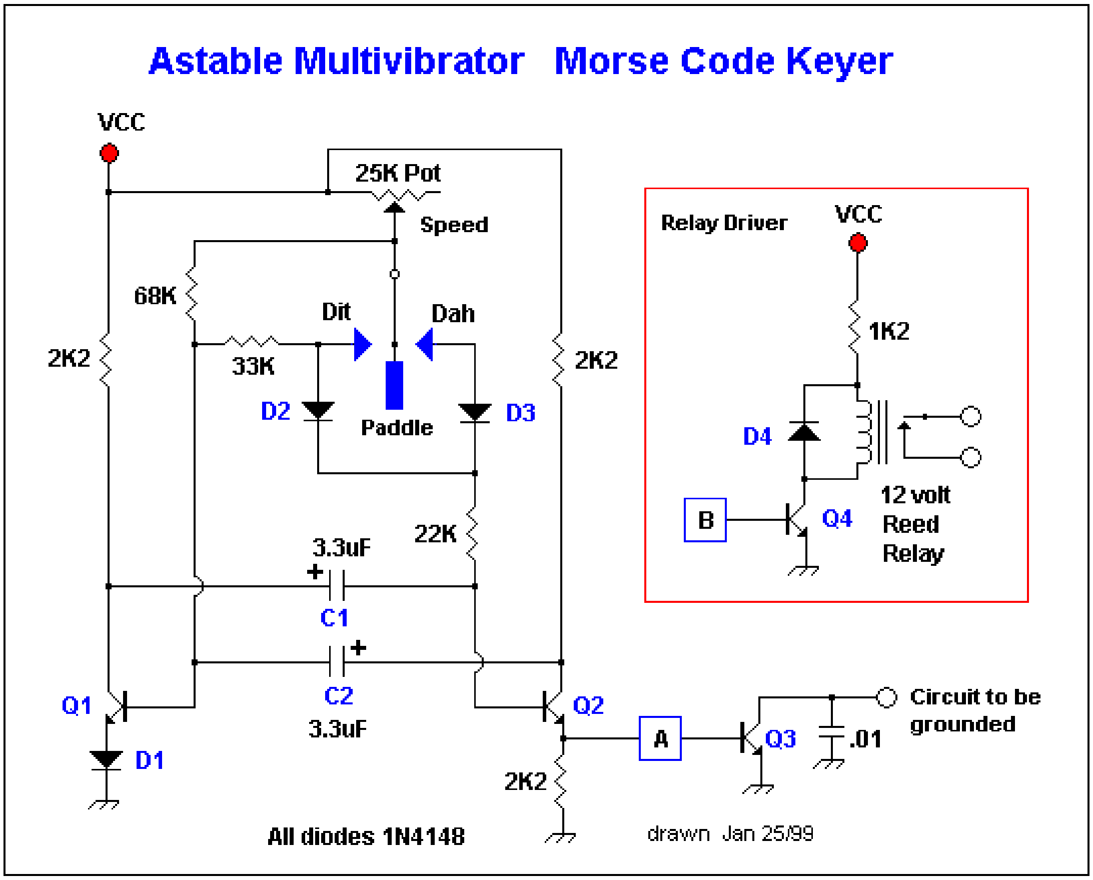

Keyer Speed

The keyer speed is very sensitive to the power supply voltage and any keyer speeds mentioned are ball-park values. Your results may vary depending on your VCC and component tolerances. If the 25K speed control pot is turned to minimum resistance, the actual power supply voltage will be present on both the paddle common and the top end of the 68K base resistor. This will be the maximum speed for the keyer. In fact, the speed control pot could be omitted if you want to economize and the keyer will run at the maximum speed as determined by C1 and C2. If you do not want the speed control feature, connect the paddle common and the 68K resistor to the VCC supply. Another alternative is to build a two speed keyer by using a switch to switch in or out a fixed resistor to vary the voltage instead of using a potentiometer. A trimmer resistor may also be used for "lid-off" speed adjustments.

Varying the base-bias voltage with a pot changes the charging rate on capacitors C1 and C2. Although, I experienced no problems be careful with some resistances/VCCs as the circuit may be unable to provide enough current to saturate the transistors when the base-bias voltage is at its minimum setting (pot set to maximum resistance). Smaller pots such as 10K can also be used with a more limited ability to reduce the keyer speed below the maximum rate.

To set the maximum rate for the keyer, it is necessary to vary the value of C1 and C2. For this circuit to function correctly, C1 must equal C2. An experiment was conducted with the 25K pot removed and the paddle common and the supply end of the 68K resistor connected to the main B+ terminal. VCC was measured at 13.8 volts. C1 = C2. The words per minute were counted for four different standard capacitance values and the results were as follows:

2.2 uF = 27 WPM
3.3 uF = 23 WPM
4.7 uF = 17 WPM
10 uF = 9 WPM

For this project, I settled with the 3.3 uF value, although personally, I use a 2.2 uF capacitor for C1 and C2. Sending speed can be reduced with the speed control pot or by increasing the time interval between characters and words. With 3.3 uf caps for C1 and C2, turning the 25K speed control pot to maximum resistance dropped the sending rate down to 12 words per minute. If you needed to slow down below 12 WPM, an amateur could send code using the Farnsworth method as mentioned above. At any rate this circuit allows you to determine the maximum speed rate by choosing the C1 and C2 capacitance value to suit your needs.

Q3, Q4 Output Stages

Two different output stages maybe used with this keyer and they will be referred to as the Q3 or Q4 stage.The Q3 stage is a simple transistor switch which will ground any component(s) connected to its collector when turned on during code sending. A variety of transistors maybe used here and care must be taken to ensure that you do not exceed the maximum dissipation of a given BJT.

The Q4 stage is a relay driver. The 12 volt relay used during bench testing was a Radio Shack reed relay that I had in my parts collection. Specifications were SPST 1A @ 125 VAC , 1050 ohms DC coil resistance, part number 275-233. My VCC was 13.8 volts so a 1K2 current limiting resistor was placed between the relay and supply voltage. The relay has suffered no harm despite significant torture but be careful when you are using a VCC greater than 12 volts. This resistance may be dropped down to 470 ohms or omitted if you are using lower voltages. Any relay with a DC coil resistance of 500 to 3000 ohms should work in this circuit.

I have never used this keyer with the Q4 relay driver for QRP operation as I prefer solid-state switching. The Q3 stage in turn can be connected to trigger a PNP transistor switch to supply DC voltage to a keyed transmitter driver and/or to pull a VFO to its offset frequency. A great example of PNP transistor switches can be found in The Ugly Weekender article by KA7EXM and W7ZOI. This article is referenced in the recommended reading list on this web site. Another bonus of the Q3 stage is that it draws less current than the Q4 stage.

Sending Code

If you are used to a deluxe iambic keyer, this keyer will take some getting used to. The dahs in particular can be problematic as they do not self-complete like they do on my station homebrew TTL iambic keyer. After some practice, however most people should be able to send some good morse code with it despite the lack of iambic luxury.

Miscellaneous

When you power up this keyer, it sends a dit. In one version of this keyer, used in a 40M transceiver, I had a 10K pot for the speed control with a built-in switch on the 10K pot to turn the keyer on or off during station setup.

The diodes D1 - D4 can be any common switching diode such as the 1N914. Q1 to Q4 can be any NPN transistor with a Beta greater than 50 such as the 2N3904 or 2N2222. In the test keyer, all BJT's were 2N3904.

For fun, I connected the multivibrator code practice oscillator to the keyer and gave the keyer a workout. They both work great together and are very complimentary. Have fun with astable multivibrators !

Update Oct 2007:

Giovanni, IW7EHC has posted a great web page on this schematic including PCB layout files in FidoCAD format

Check out his excellent Italian and English language web site

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Amateur and Short Wave Radio Electronics Experimenter's Web Site

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Supplemental Page for the 10 MHz WWV TRF receiver

I have received a tremendous amount of feedback regarding the 10 MHz WWV TRF receiver. Many builders have constructed their own versions and have improved it. This captures the spirit of the QRP/SWL Homebuilder web site; take an idea and evolve it into something better on the bench.

I will post some of the feedback as well as provide additional comments and images regarding the 10 MHz WWV project on this supplemental web page. Please continue to provide project feedback and help me to improve the QRP/SWL HomeBuilder web site.

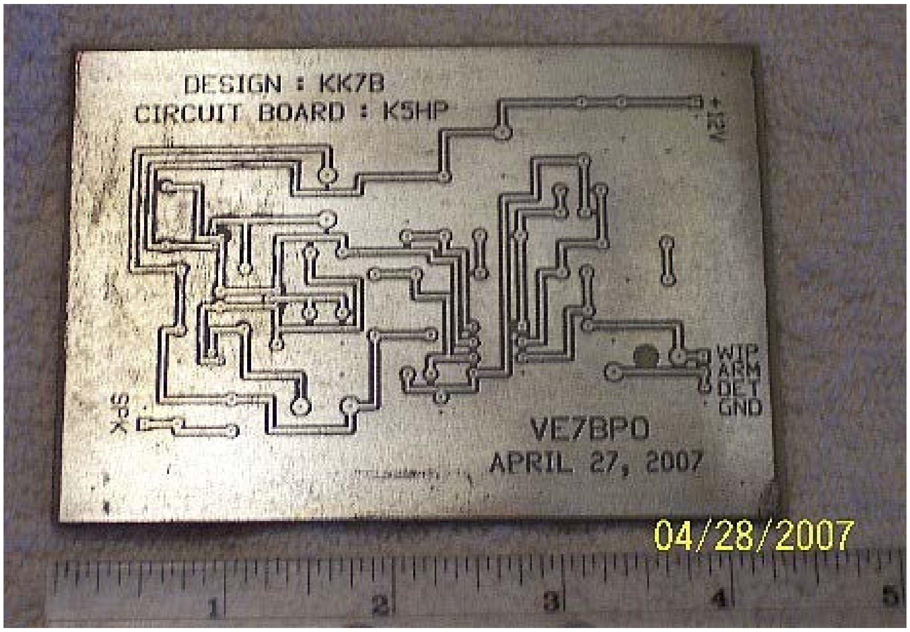

Above. Etched Audio amplifier PC board from K5HP.

Terry, K5HP
Hi Todd,

I have just finished (few days ago) your design for the 10 MHz WWV Receiver. I reduced you schematic diagrams to CirCad schematics, drug out the rat-net, positioned and connected everything, and etched the boards. I'll include a photo of the 4 finished boards. They are very roomy for extra tinkering. Except for two solder bridges on two very big pads on the tweeker capacitors in the front end, it all worked perfectly first try. Hmmm, I cannot say that for all my projects in the past. After repairing the two shorts to ground of the RF path, the front end then tuned and worked perfectly also.

I have not taken the project out to the Lab (barn) and put it on my Motorola Service monitor, but the input to the filter board is roughly 500 uV. It can easily hear WWV at this level with a decent antenna connected to the filter input when WWV is fairly strong at my location. Not bad, considering the mismatch at that location.

Have you or someone else tinkered with an AGC/AVC circuit? At one time I had a nice circuit using an National chip (don't remember the number) which is no longer available that was easy to build and easy to retro-fit into something. It was an AVC which they called an audio AGC.

When I built out the boards I placed proper credit to you and the other developers mentioned on the boards. Should you want my work product it's free for the asking. I'll be glad to send it to you. CirCad in ver 4 is a fairly

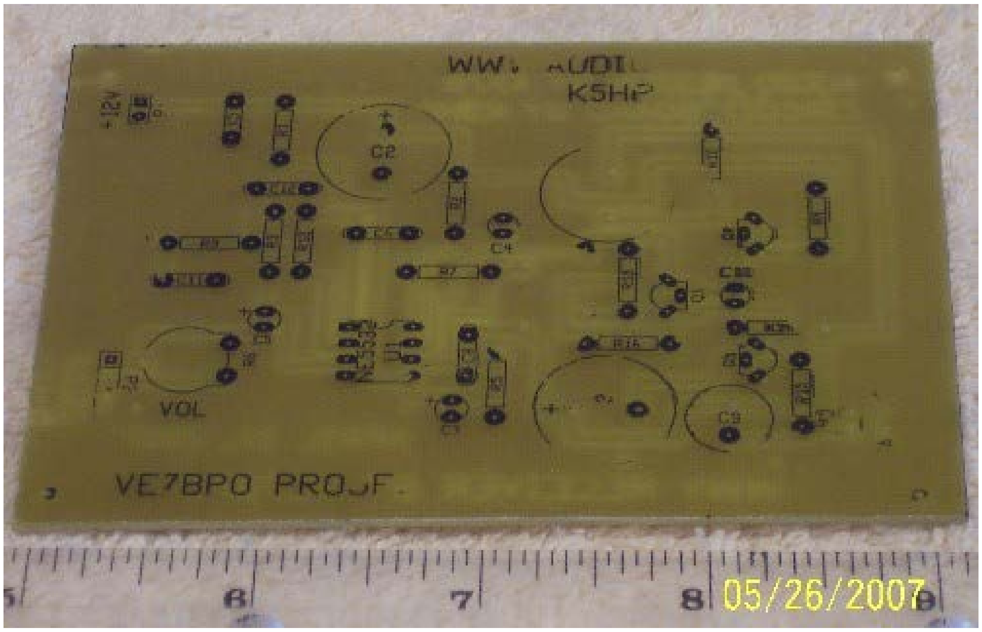

Above. Audio amplifier PC board overlay for parts placement from K5HP.

complete PCB cad program and it's free too. There is a version 5, but I have not tried it out yet.

My sincere congratulation for producing and error free web article. That is a heck of a more than you can say about many other projects in the past. Most of those in the past had errors a plenty, and some just did not flat work as described. Someone just thought they would as it turned out. Thanks for the fine article and I'll check your site over for more interesting thing to build or learn from. Best wishes and good luck.

Above. A layout of the 4 completed boards by K5HP.

"I use the CirCAD to produce the artwork, then take the laser printer output and bond the plastic toner onto the PCB. Works good most of the time. Sure easier than trying to do photo etch, and silk screening is pretty expensive. The bottom copper is viewed as you would look down onto the top of a circuit board, through to the copper side. The side you are seeing is bonded to the copper surface. Print one out, hold it up to a light source looking through non printed side and it becomes apparent."

Terry designed and built printed circuit boards. His photographs, etching and overlay files are all bundled together in convenient zipped files which can be downloaded below.

Download the front end zip file

Download the Crystal filter zip file

Download the Detector zip file

Download the AF amp zip file

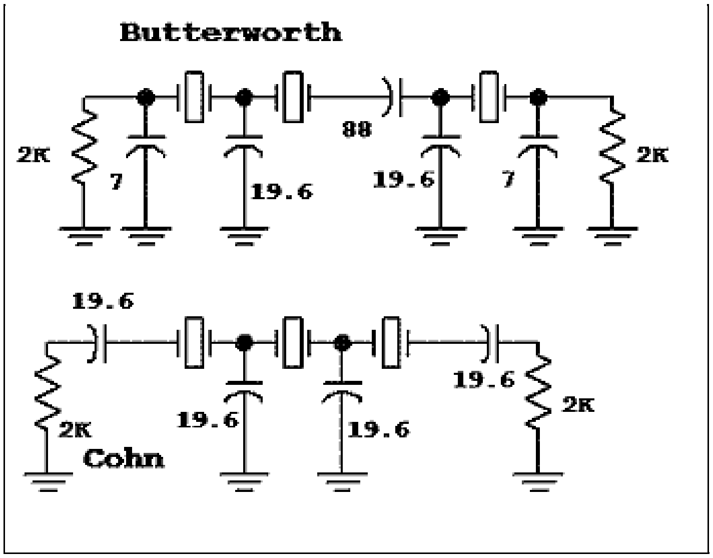
Butterworth
2K
7
19.6
88
19.6
7
2K
19.6
19.6
19.6
2K
Cohn
19.6
19.6
19.6
2K

Above. Schematics diagrams of 10 MHz crystal filters by Wes, W7ZOI. I did not experiment with the Butterworth type filter.

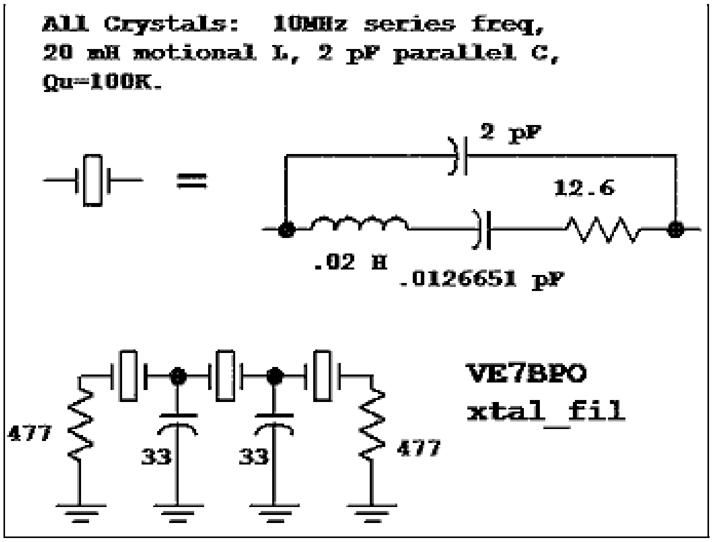
All Crystals: 10MHz series freq, 20 mH motional L, 2 pF parallel C, Qu=100K.
=
2 pF
12.6
.02 H
.0126651 pF
477
33
33
477
VE7BPO
xtal_fil

Above. Schematics diagrams by Wes, W7ZOI.
A schematic representation of the 10 MHz xtal is shown along with the "popcorn" 10 MHz xtal filter I designed.

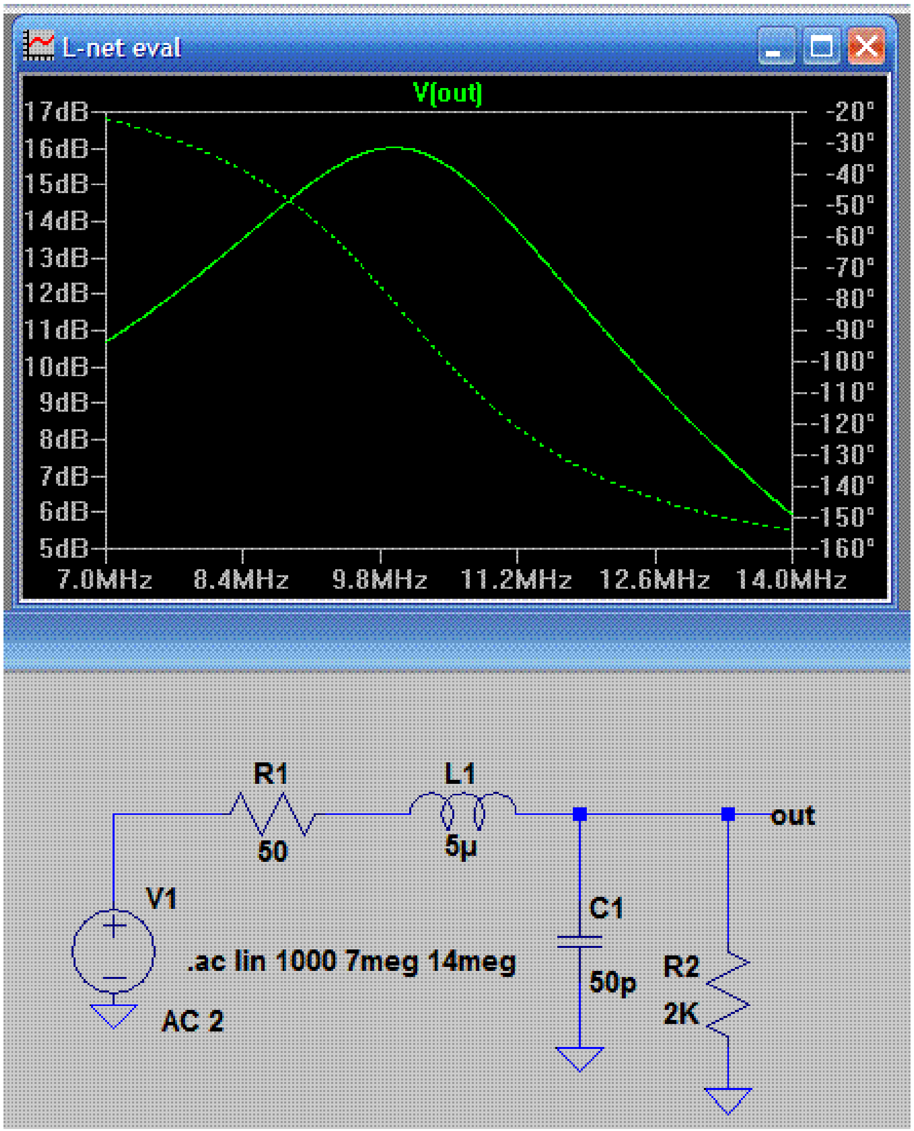
L-net eval
V(out)
17dB
16dB
15dB
14dB
13dB
12dB
11dB
10dB
9dB
8dB
7dB
6dB
5dB
-20°
-30°
-40°
-50°
-60°
-70°
-80°
-90°
-100°
-110°
-120°
-130°
-140°
-150°
-160°
7.0MHz
8.4MHz
9.8MHz
11.2MHz
12.6MHz
14.0MHz
R1
50
L1
5µ
out
V1
C1
50p
R2
2K
AC 2

```
.ac lin 1000 7meg 14meg
```

Above. A simulation of an L network depicted in the L-Match and AM Detector schematic for those interested in driving this detector with a 50 ohm output impedance.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

MF TRF Receiver Supplemental Page

Click here to go to the main project web page This supplemental page is under construction

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5532 Op amp Pin Out

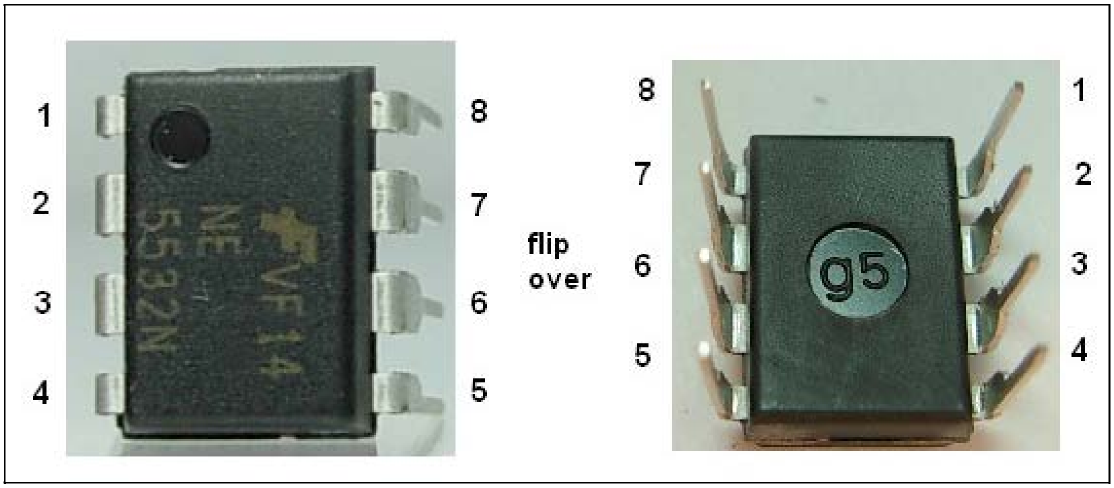

A Version of the Receiver Using Just L1 and C1 as the band pass filter

You can see a red LED and current limiting resistor in the photos. This is a power on indicator. The telescopic whip antenna can be seen in the lower photo.

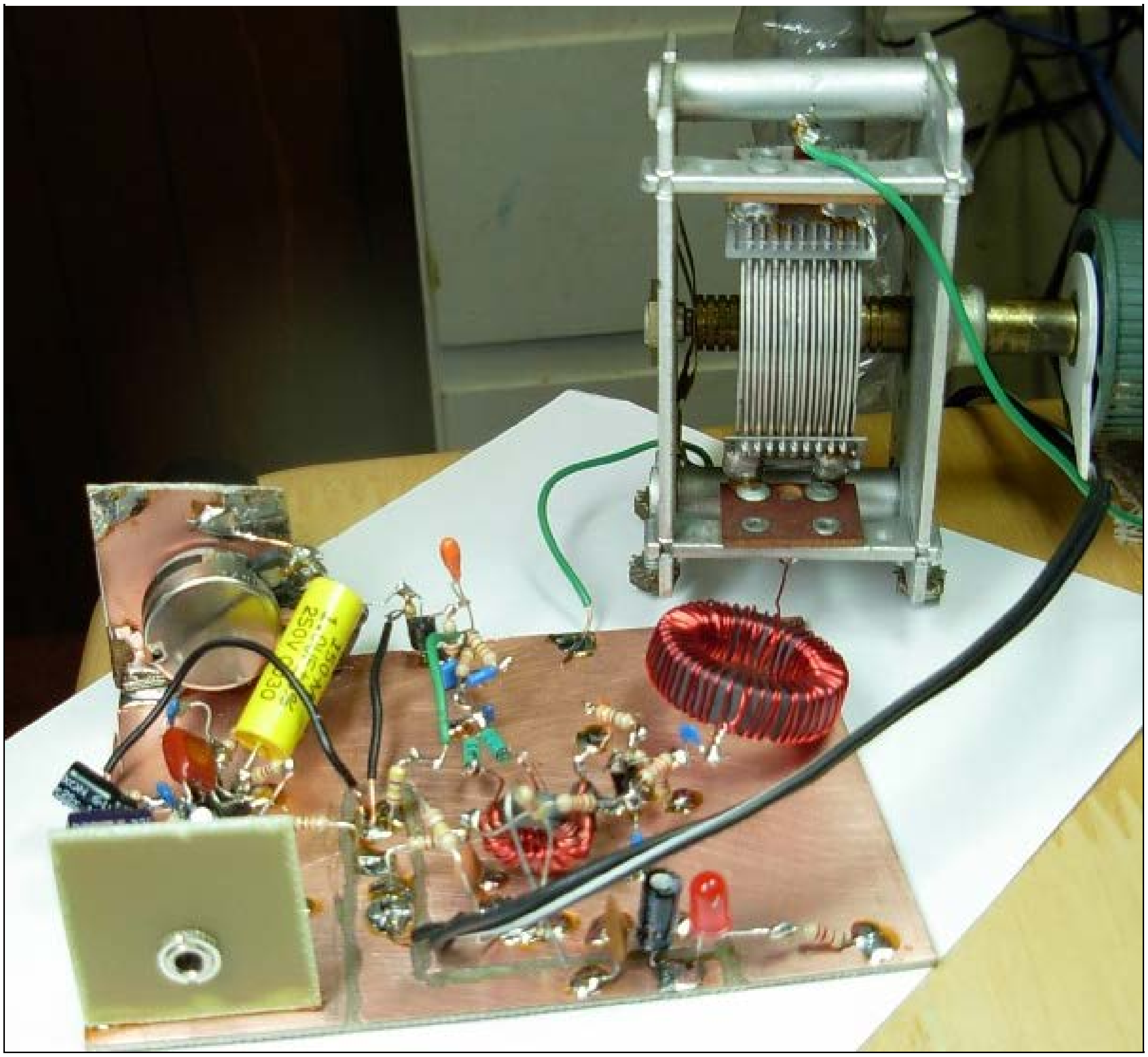

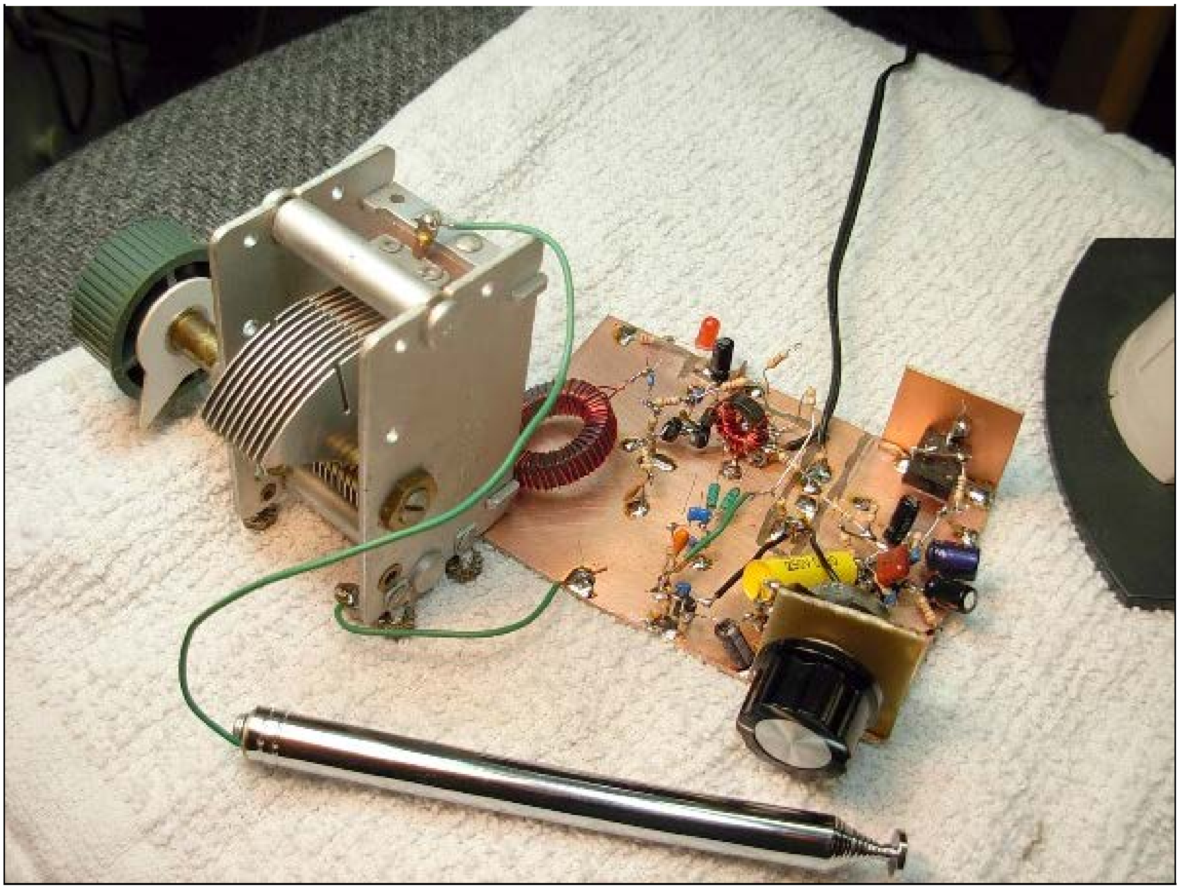

Early Versions of the Project Front End

In section A of the schematic below, a dual-ganged 365 pF air variable capacitor was used for tuning. CV, a small compensating capacitor may be required to adjust for the capacitive differences of the 2 L-C tanks in the front end filter. It may have to be placed on the L1 side of the filter (opposite to what is shown). A JFET source follower was used for Q1 but discarded because stage gain was insufficient with a short whip antenna.

In the version depicted as section B, two 12-110 pF air variable capacitors were used along with switchable 270 pF capacitors to provide 2 ranges of tuning. Although this worked, the switching mechanism was found to degrade selectivity somewhat. The JFET was reconfigured as a common source RF amp. This amp caused some distortion of the RF signal on stronger stations unless the gate resistor was lowered to 47K or less. Ultimately a cascode BJT RF amp was chosen for the project. A photograph of the section A breadboard is shown below the schematic.

Broadcast Radio Band Front End

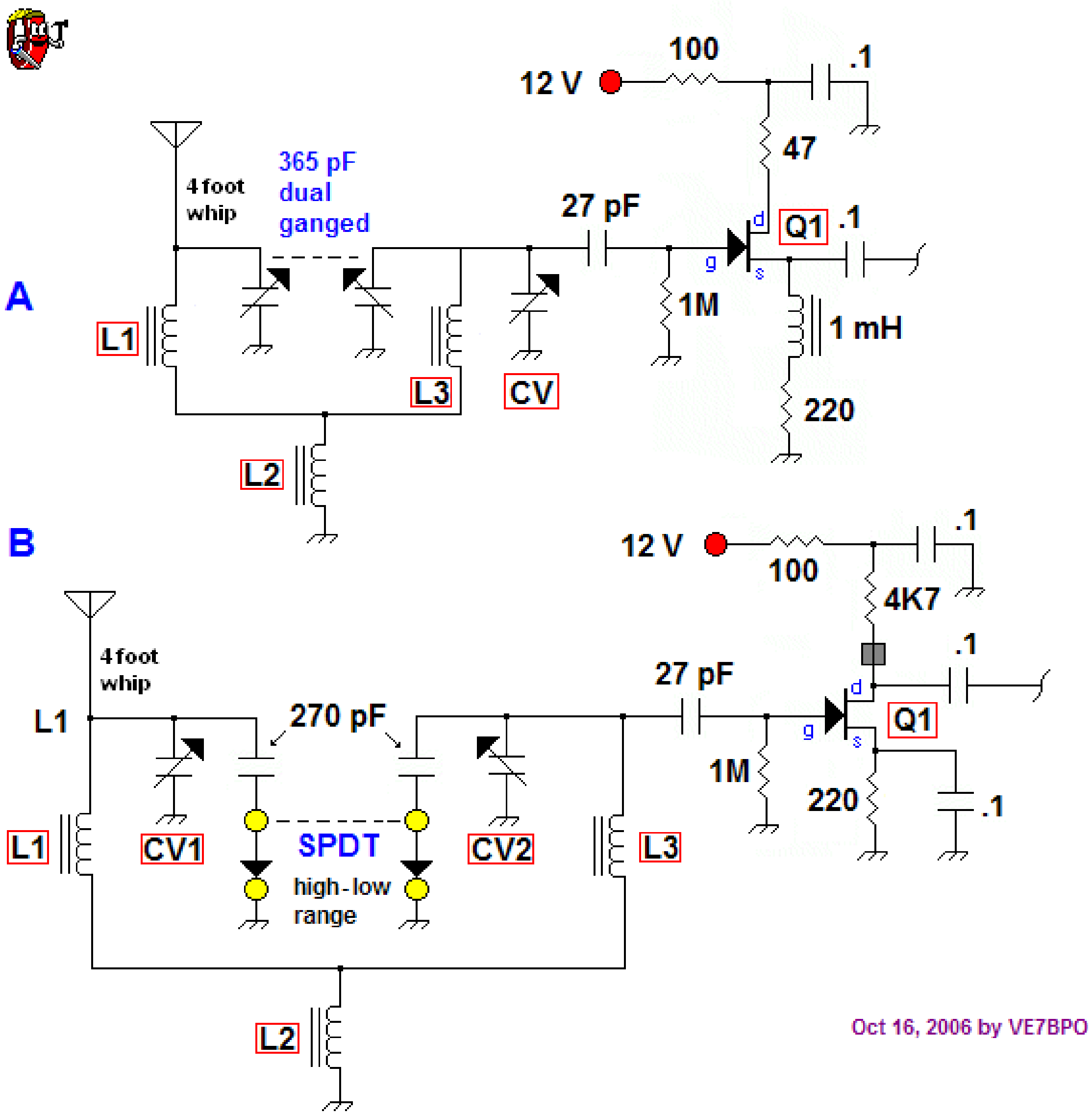
A
12 V
100
.1
47
4 foot whip
365 pF dual ganged
27 pF
d
Q1
.1
g
s
1M
1 mH
L1
L3
CV
220
L2
B
12 V
100
.1
4K7
.1
4 foot whip
27 pF
d
Q1
L1
270 pF
g
s
1M
220
.1
L1
CV1
SPDT
high-low range
CV2
L3
L2

Oct 16, 2006 by VE7BPO

L1 = L3 = 200 uH or 55 turns #28 AWG on a FT50-61 ferrite core
L2 = ~ 5 uH = 9 turns #22 AWG on a FT50-61 ferrite core
CV = small value trimmer capacitor for tracking - 4.5 - 20 pF
CV1 = CV2 = 12 - 110 pF air variable capacitor
Q1 = nJFET; MPF102 or J310

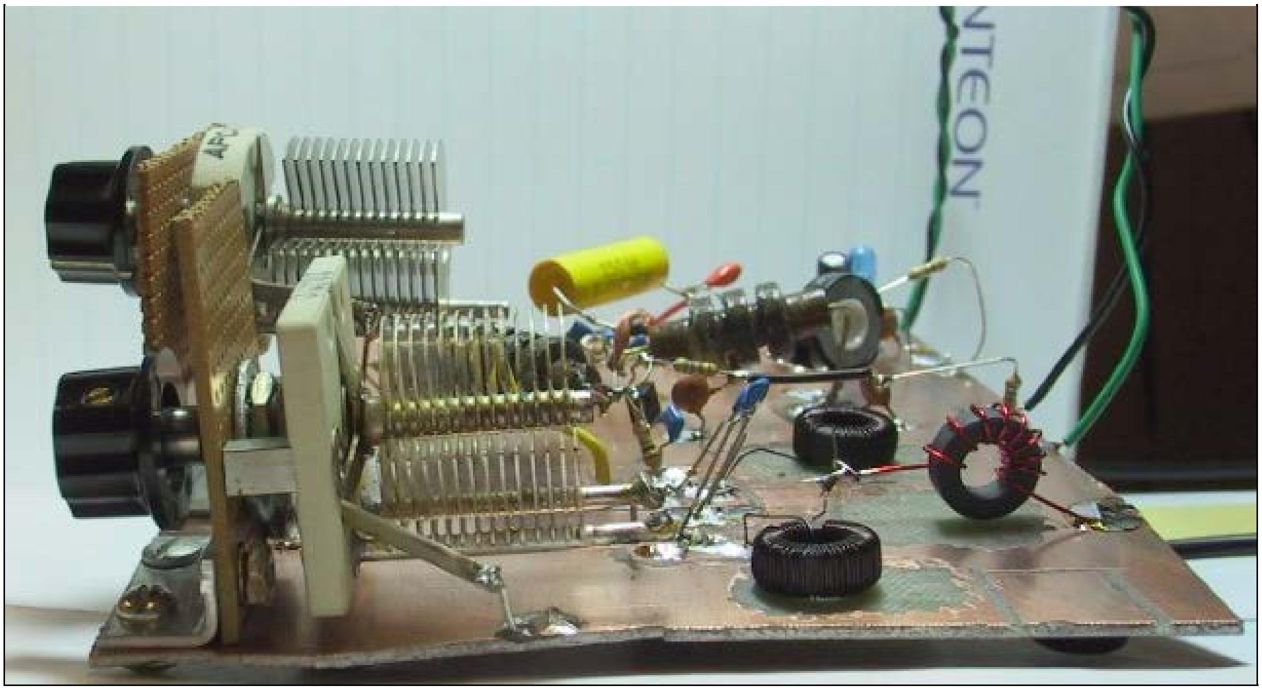

The inspirational detector schematic used for motivation to develop the full wave detector

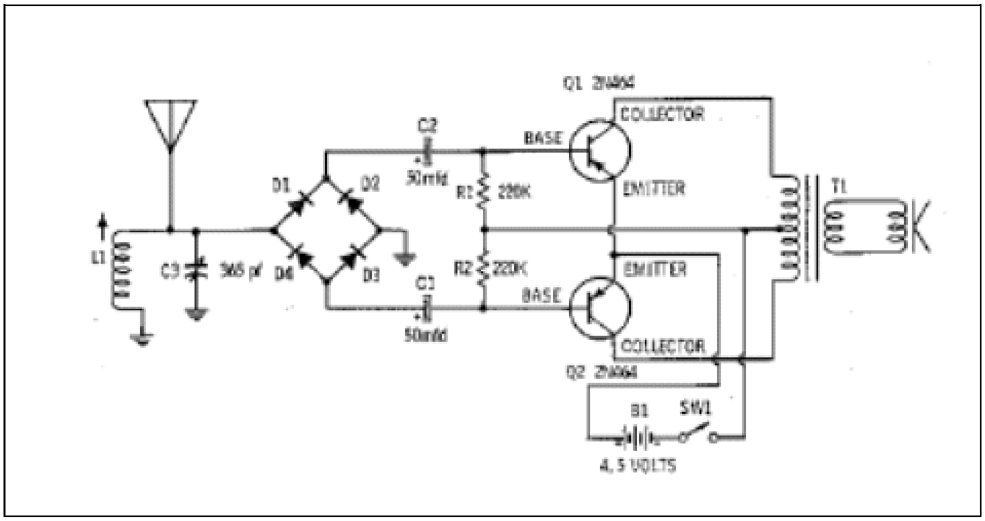
Q1 2N464
COLLECTOR
BASE
EMITTER
C2
50mfd
D1
D2
R1
220K
T1
L1
C3
365 pf
D4
D3
C1
R2
220K
EMITTER
BASE
50mfd
COLLECTOR
Q2 2N464
B1
SW1
4, 5 VOLTS

Varactor Tuned Front-end Band pass Filter

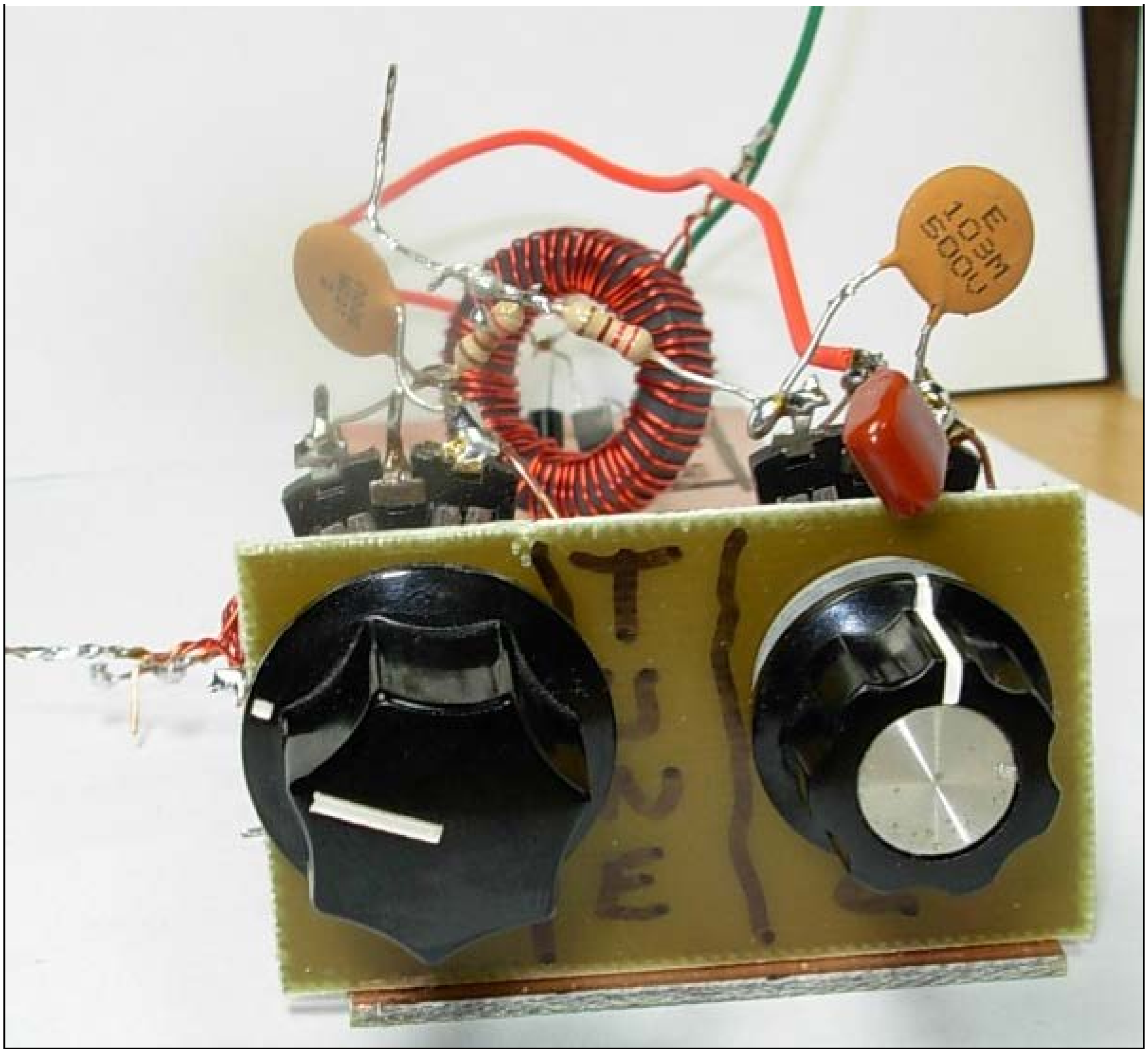
E
103M
500V
TUNE

Above photo. The 2 potentiometer varactor controlled band pass filter.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

Supplemental to the Cascode Hybrid 5 MHz WWV Receiver

DC Voltages of the Cascode Hybrid Amp

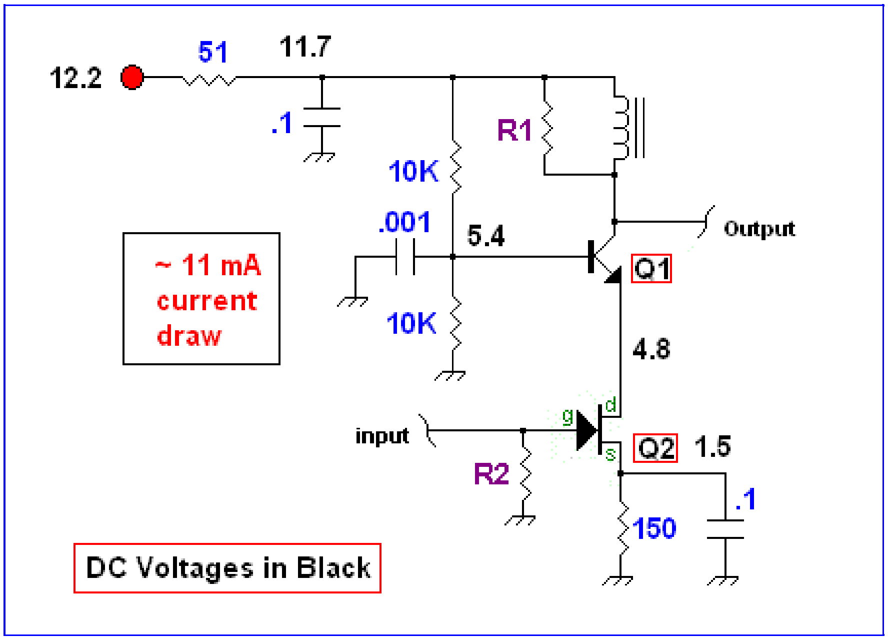

On the right is the basic hybrid cascode amplifier schematic. Note that the Q1 voltage divider bias has two 10K resistors as compared to the 12K and 10K combination used in the final project. A slightly lower Q1 bias voltage was ultimately chosen along with a 150 ohm Q2 source resistor to enhance stability. Early bread boards of this amplifier used a 47 - 100 ohms Q2 source resistor along with the slightly higher Q1 bias, but suffered from parasitic oscillations.

The DC voltages are rounded to 1 decimal point. These are ball park values for reference purposes. The typical stage current draw was around 11 mA. R1 sets the output impedance and is optional. R2 sets the input impedance. This amp is very versatile in that it can be used to match a wide variety of input and output impedances.

The **main 5 MHz WWV receiver web page** which this web page supplements is here.
Click here for a recording of 5 MHz WWV made with the Icom R-75 receiver using the 6 KHz AM filter and the stock speaker. You may wish to compare it to the recorded 5 MHz WWV receiver project audio files linked here , here and here.

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10 MHz Components

For those who wish to experimentally develop a 10 MHz version, I have included some potential band pass and crystal filter schematics you may wish to consider. In addition, my preliminary experiments indicated that another RF amplifier stage might be necessary for 10 MHz WWV. During development of these band pass and crystal filters, 10 MHz WWV reception was very poor and due to lack of time and the poor conditions, further experimentation was abandoned.
To the left is a 10 MHz band pass filter schematic with a -3dB bandwidth of around 100 KHz.

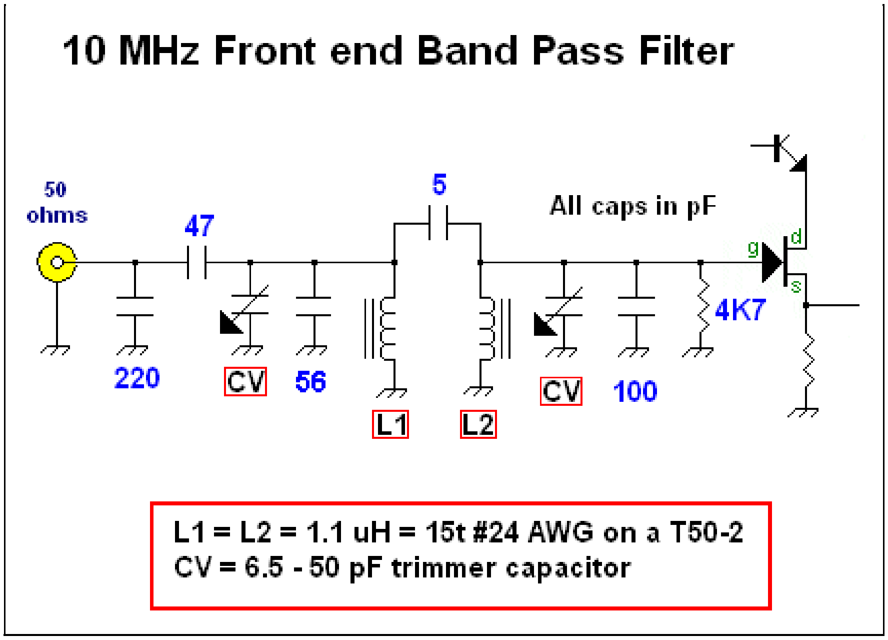
10 MHz Front end Band Pass Filter
50 ohms
47
5
All caps in pF
g
d
s
4K7
220
CV
56
L1
L2
CV
100
L1 = L2 = 1.1 uH = 15t #24 AWG on a T50-2
CV = 6.5 - 50 pF trimmer capacitor

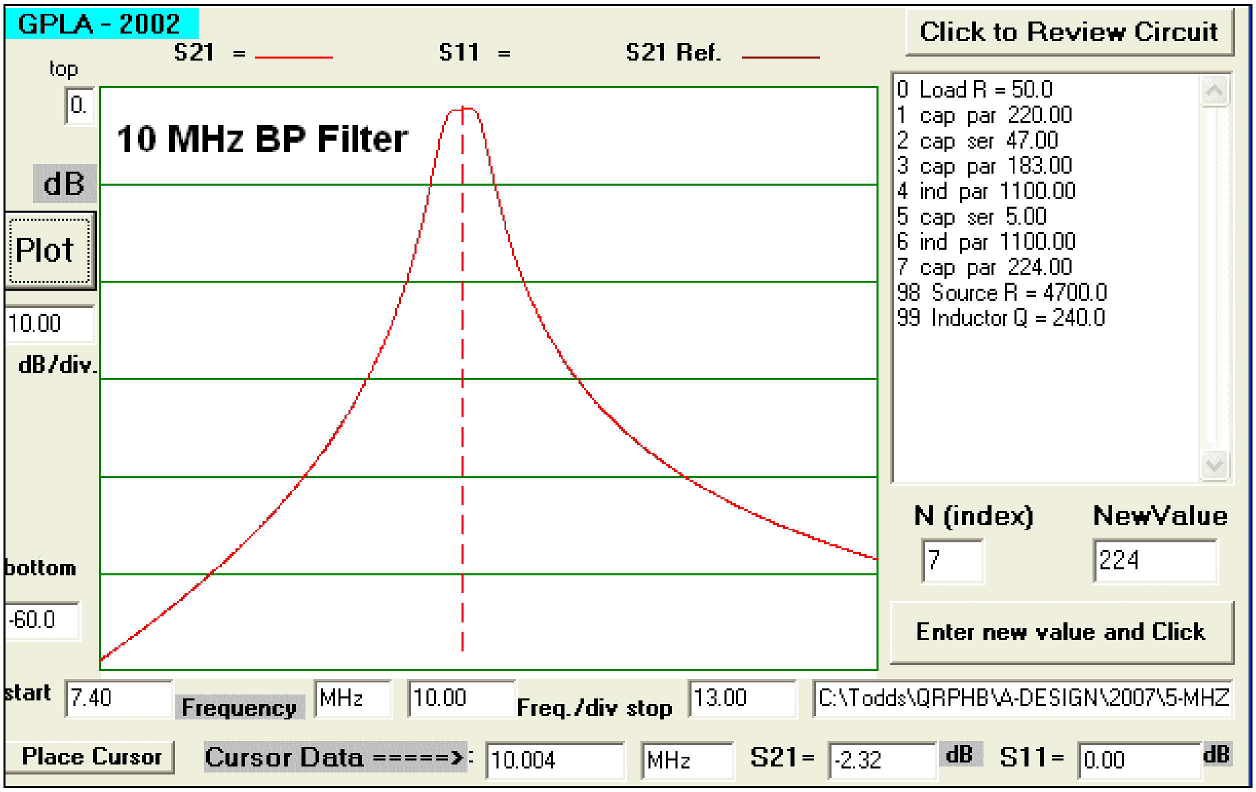
GPLA - 2002
S21 =
S11 =
S21 Ref.
Click to Review Circuit
top
dB
Plot
dB/div.
bottom
10 MHz BP Filter
N (index)
NewValue
Enter new value and Click
start
Frequency
Freq./div stop
Place Cursor
Cursor Data =====>:

```
0  Load R = 50.0
1  cap  par  220.00
2  cap  ser  47.00
3  cap  par  183.00
4  ind  par  1100.00
5  cap  ser  5.00
6  ind  par  1100.00
7  cap  par  224.00
98  Source R = 4700.0
99  Inductor Q = 240.0
```

top: 0.

dB/div.: 10.00

bottom: -60.0

N (index): 7

NewValue: 224

start: 7.40 MHz

Freq./div: 10.00

stop: 13.00

C:\Todds\QRPHB\A-DESIGN\2007\5-MHZ

Cursor Data =====>: 10.004 MHz S21= -2.32 dB S11= 0.00 dB

The GPLA simulation of the 10 MHz front end band pass filter. Tuning is very sharp with this filter.

To the left is a crystal filter design for 10 MHz. The realized bandwidth of these simple min-loss crystal filters is dependent on your crystal parameters.

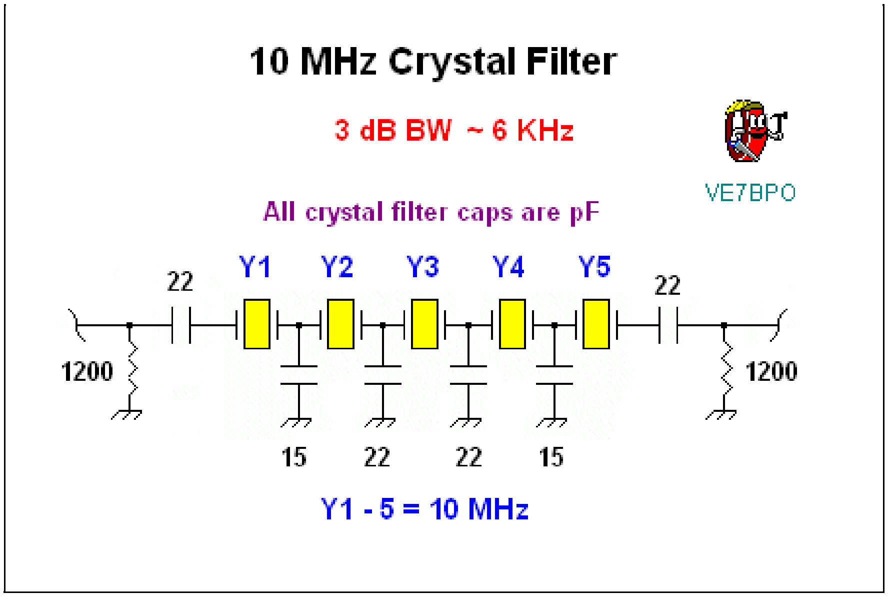
10 MHz Crystal Filter
3 dB BW ~ 6 KHz
VE7BPO
All crystal filter caps are pF
22
Y1
Y2
Y3
Y4
Y5
22
1200
1200
15
22
22
15
Y1 - 5 = 10 MHz

A photograph of the experimental 10 MHz crystal filter is shown to the right. Leads were kept long so that parts could be reused in future experiments.

CRYSTEK
10.000
CY12A

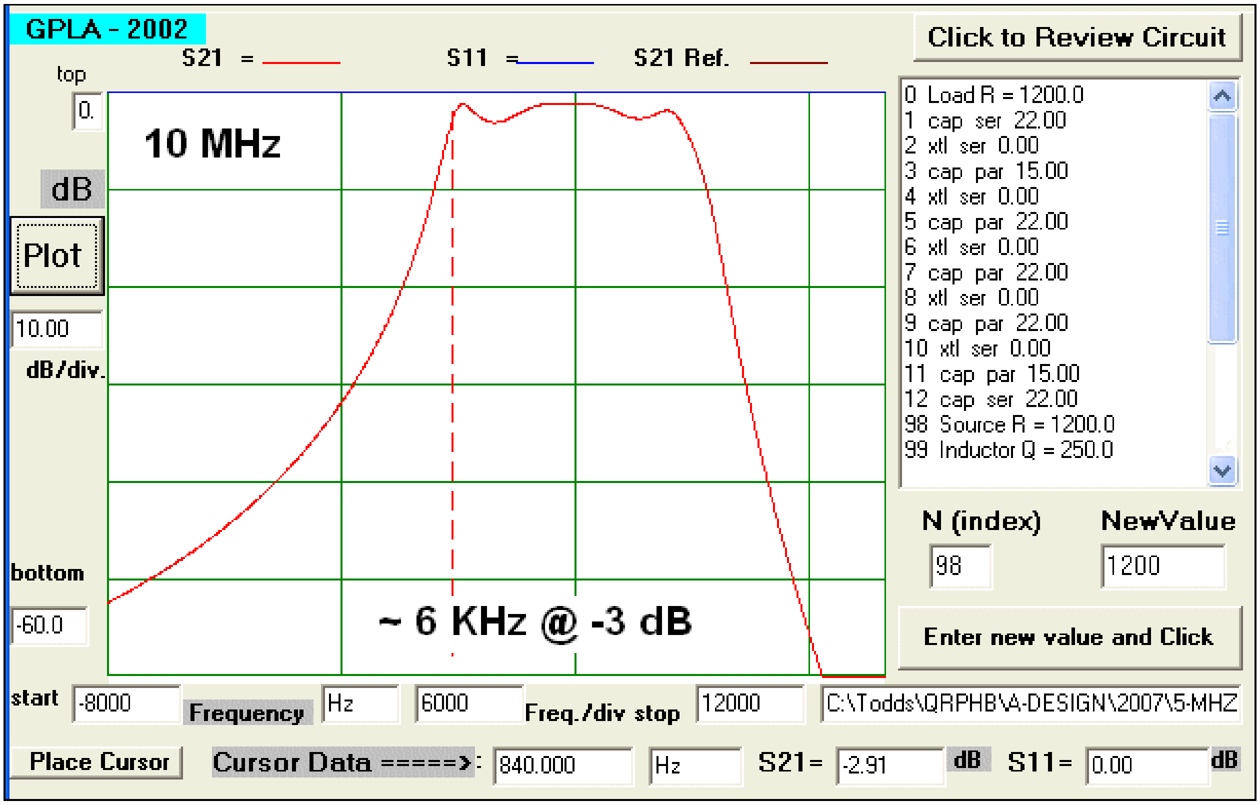
GPLA - 2002
S21 =
S11 =
S21 Ref.
Click to Review Circuit
top
0.
dB
Plot
10.00
dB/div.
bottom
-60.0
10 MHz
~ 6 KHz @ -3 dB
N (index)
NewValue
Enter new value and Click
Place Cursor
Cursor Data =====>
Frequency
Freq./div
stop
start

0 Load R = 1200.0
1 cap ser 22.00
2 xtl ser 0.00
3 cap par 15.00
4 xtl ser 0.00
5 cap par 22.00
6 xtl ser 0.00
7 cap par 22.00
8 xtl ser 0.00
9 cap par 22.00
10 xtl ser 0.00
11 cap par 15.00
12 cap ser 22.00
98 Source R = 1200.0
99 Inductor Q = 250.0

N (index): 98
NewValue: 1200

start: -8000 Hz
Freq./div: 6000
stop: 12000
C:\Todds\QRPHB\A-DESIGN\2007\5-MHZ

Cursor Data =====>: 840.000 Hz
S21= -2.91 dB
S11= 0.00 dB

Above. The GPLA simulation of the 10 MHz crystal filter.

---

6 MHz Components

Since it is easy to find 6 MHz crystals and Radio Habana Cuba is on 6.0 MHz, band pass and crystal filters were designed for reference purposes. To the right is the front end, band pass filter schematic.

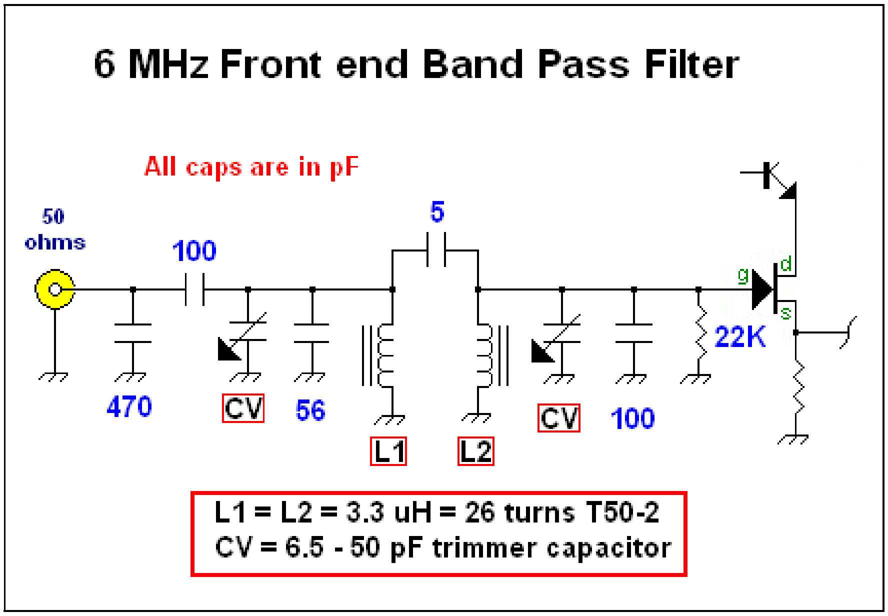
6 MHz Front end Band Pass Filter
All caps are in pF
50 ohms
100
5
470
CV
56
L1
L2
CV
100
22K
g
d
s
L1 = L2 = 3.3 uH = 26 turns T50-2
CV = 6.5 - 50 pF trimmer capacitor

To the left is a potential crystal filter for 6 MHz AM reception. The bandwidth is ~ 5 KHz which is starting to get too narrow for some listeners, however, your crystal parameters will determine your filter's actual bandwidth.

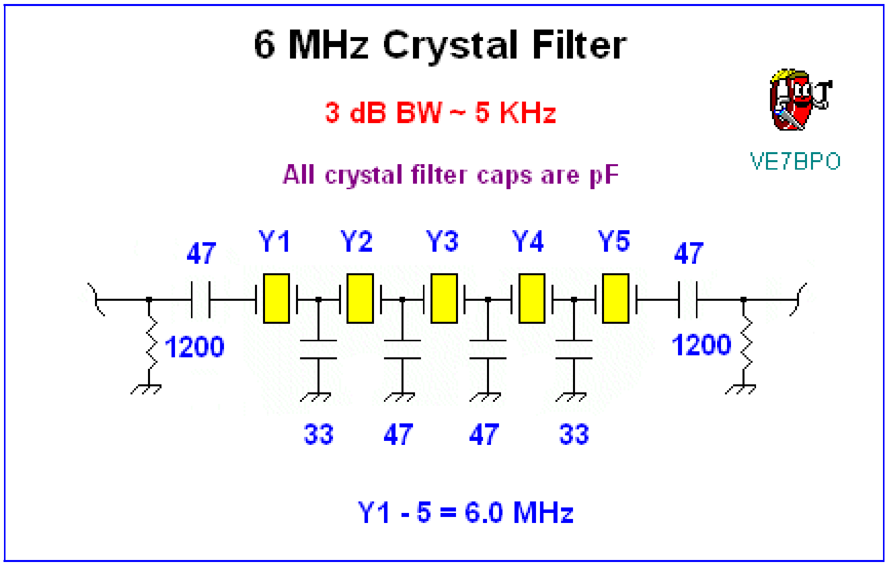
6 MHz Crystal Filter
3 dB BW ~ 5 KHz
All crystal filter caps are pF
VE7BPO
47
Y1
Y2
Y3
Y4
Y5
47
1200
1200
33
47
47
33
Y1 - 5 = 6.0 MHz

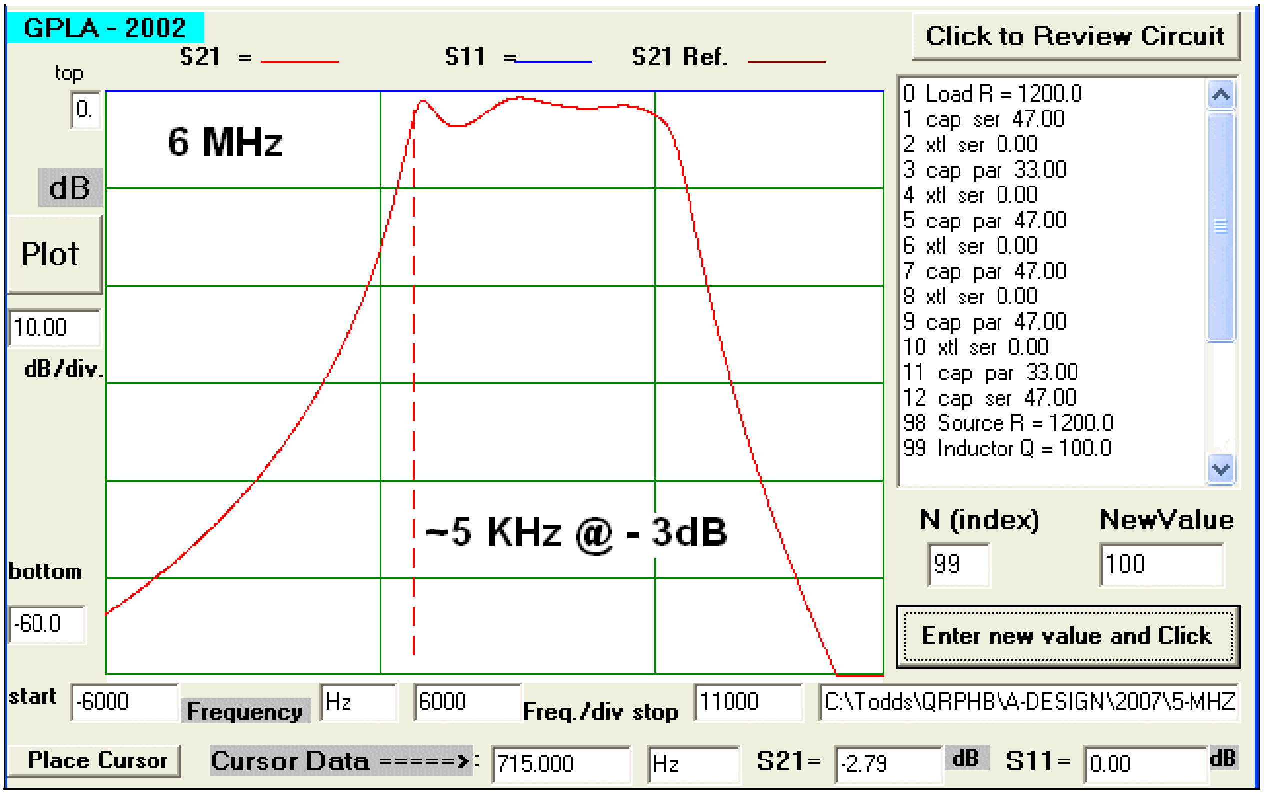
GPLA - 2002
S21 =
S11 =
S21 Ref.
6 MHz
~5 KHz @ - 3dB
dB
Plot
Click to Review Circuit
Enter new value and Click
Place Cursor

top 0.

10.00 dB/div.

bottom -60.0

0 Load R = 1200.0
1 cap ser 47.00
2 xtl ser 0.00
3 cap par 33.00
4 xtl ser 0.00
5 cap par 47.00
6 xtl ser 0.00
7 cap par 47.00
8 xtl ser 0.00
9 cap par 47.00
10 xtl ser 0.00
11 cap par 33.00
12 cap ser 47.00
98 Source R = 1200.0
99 Inductor Q = 100.0

N (index) 99

NewValue 100

start -6000 Frequency Hz 6000 Freq./div stop 11000 C:\Todds\QRPHB\A-DESIGN\2007\5-MHZ

Cursor Data =====>: 715.000 Hz S21= -2.79 dB S11= 0.00 dB

The GPLA simulation of the crystal filter using the parameters from the 6.0 MHz crystals I had in my parts collection.

VE7BPO Envelope Detector

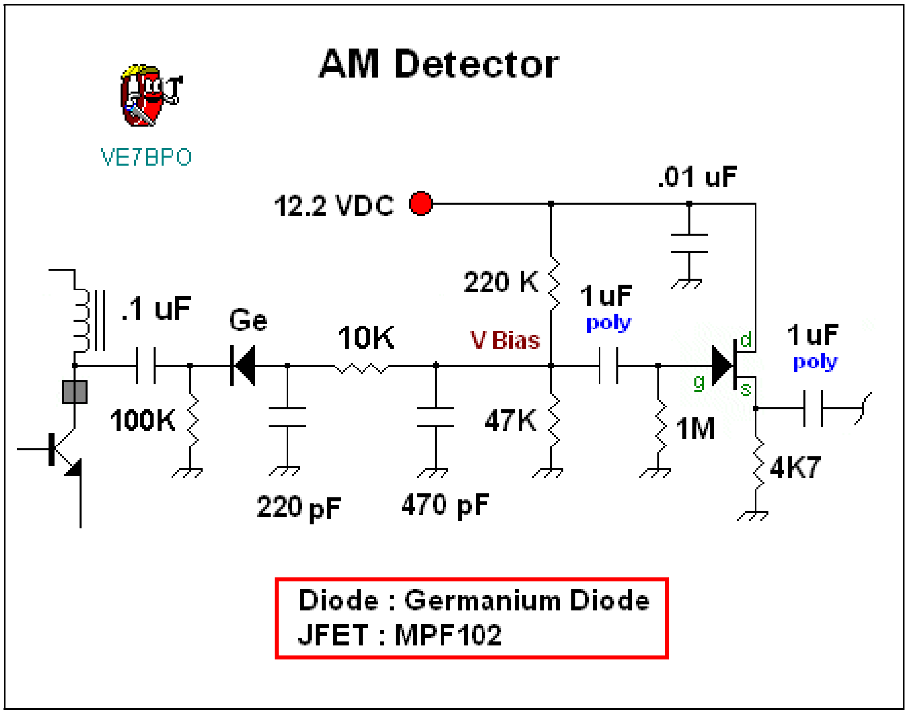
AM Detector
VE7BPO
12.2 VDC
.01 uF
220 K
1 uF
poly
.1 uF
Ge
10K
V Bias
d
g
s
1 uF
poly
100K
47K
1M
4K7
220 pF
470 pF
Diode : Germanium Diode
JFET : MPF102

To the left is the schematic of another detector experimentally developed for the 5 MHz WWV receiver. The germanium diode has incredible sensitivity when biased, although noise tends to increase with applied DC voltage. This basic design also worked well with a hot carrier diodes, although had less sensitivity. V bias can be changed by adjusting the 220K, 47K and 100 K resistor values. Note diode polarity.

Miscellaneous Photos and Circuits

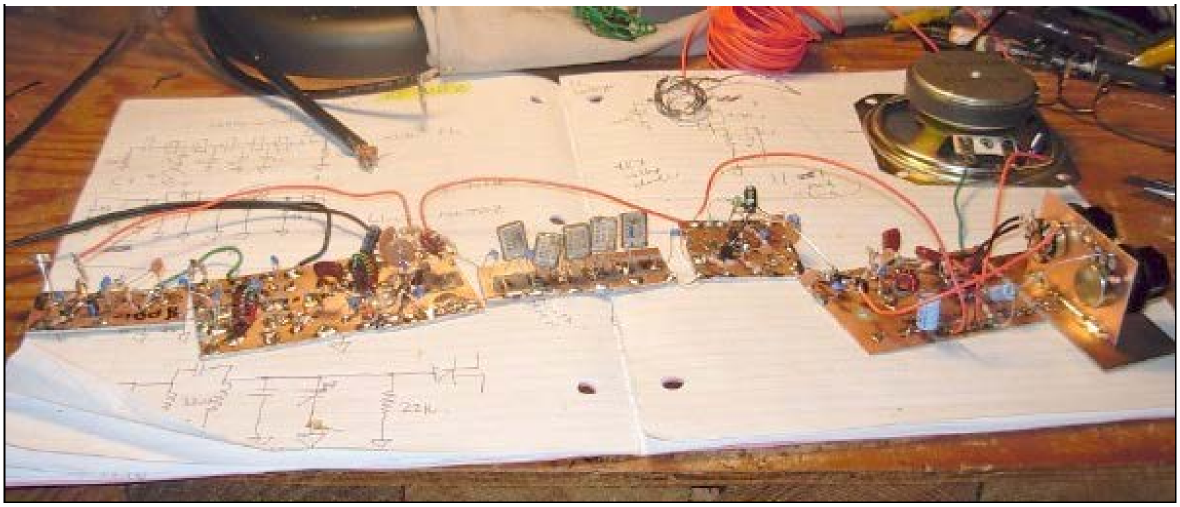

Above. A work bench version of the basic receiver bread board built in distinct stages from the antenna input to the speaker.

Above, A breadboard of the KK7B audio stage which is preferred to the LM386 stage used in the 5 MHz WWV receiver. The LM386 does take up less room and certainly increases the popcorn factor.

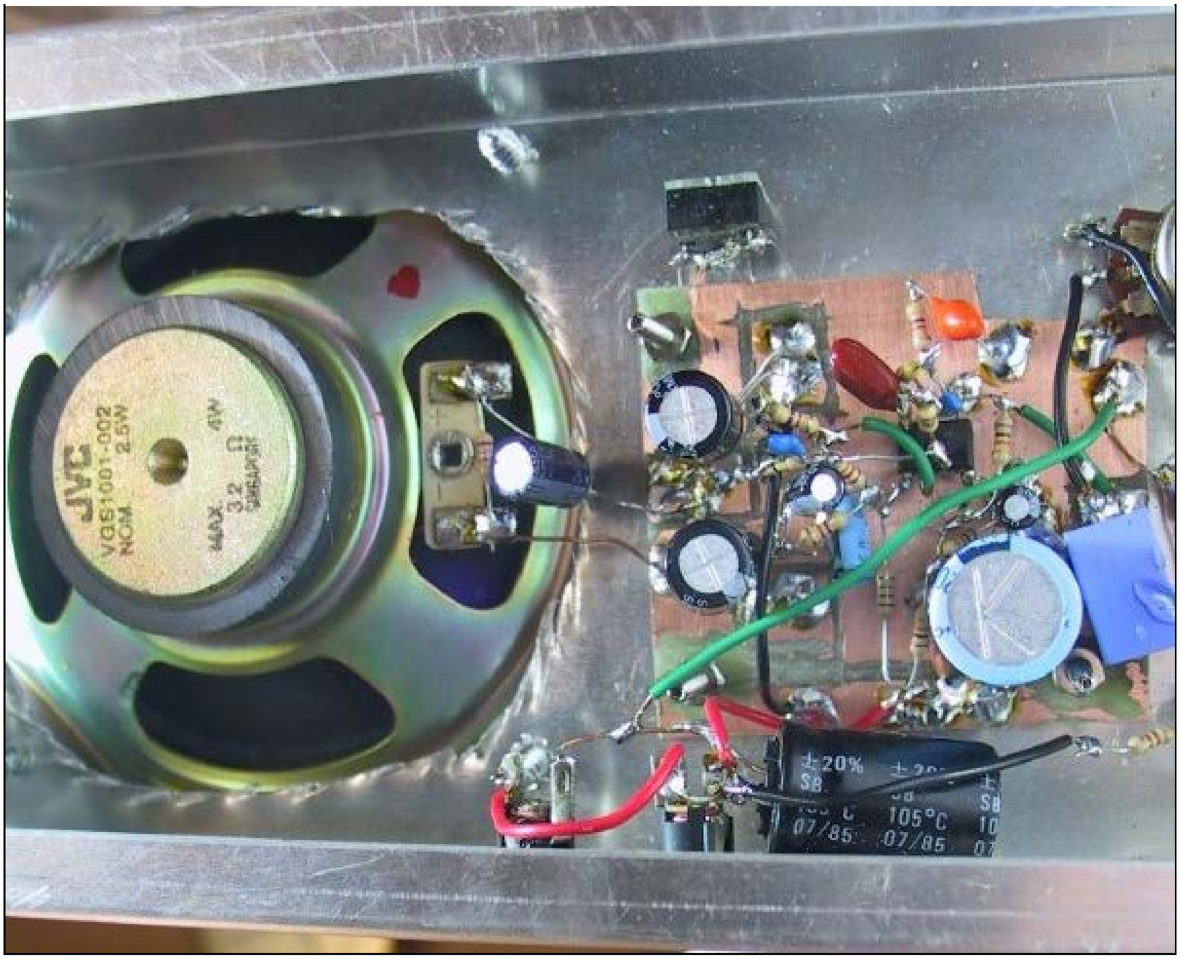
JVC
VGS1001-002
NOM. 2.5W
MAX. 4W
3.2 Ω
±20%
SB
105°C
07/85

Above. The AF stage shown above in a chassis containing a speaker. This is my lab AF amp for testing receivers on my work bench.

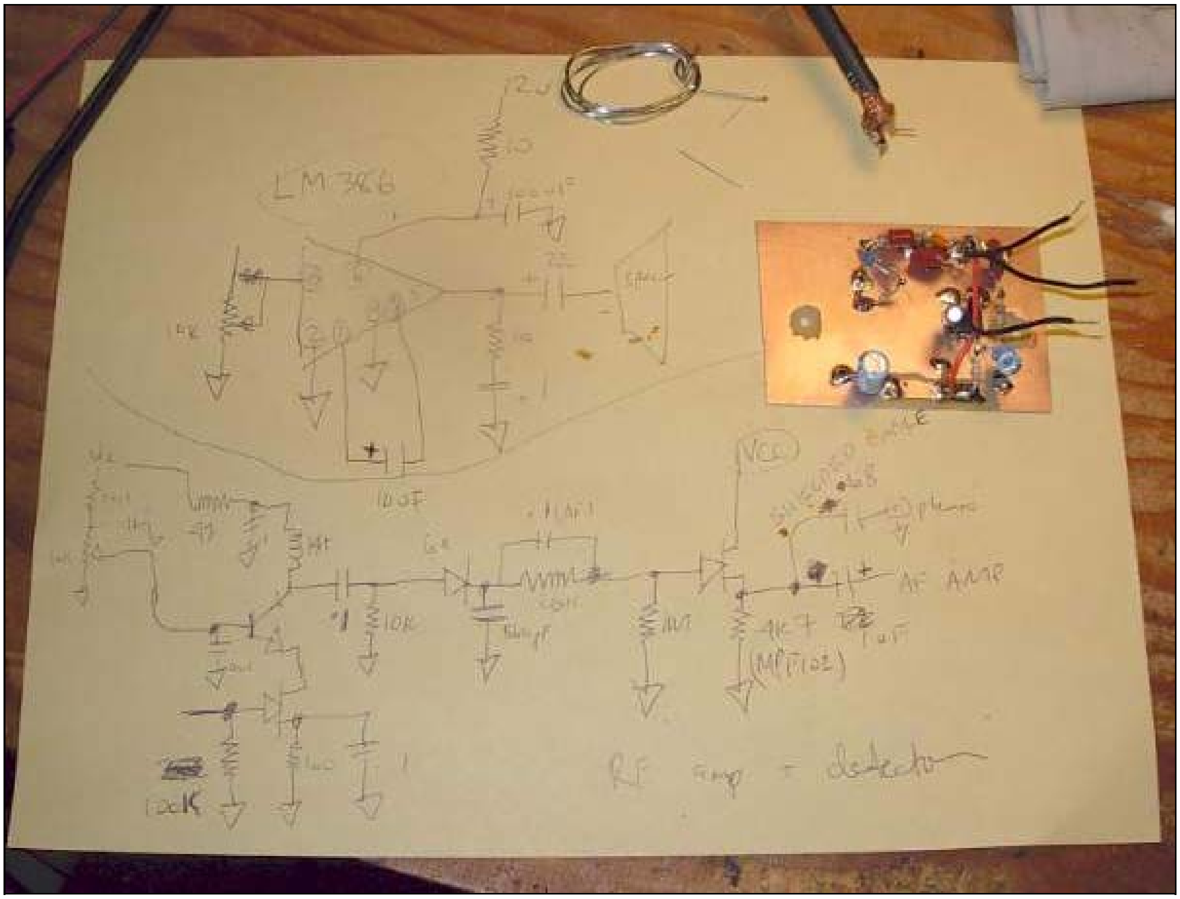
12V
10
LM386
1000uF
22
14K
.1
100uF
.1
10K
1N
22K
4K7
(MPF102)
VCC
AF AMP
1uF
100K
RF amp + detector

A work bench photo of the first version of the W7ZOI detector built in October 2007 is shown above.

RF — Test and Measurement

My Links

Greetings! I enter the QRPHB / SWL HomeBuilder site here and linked a few of my favorite tools, part suppliers and URLs I like and wish to remember. This page might feel intransigent.

In the following section called **Graphics**, I show the odd newer schematic or photo unpublished as permanent site content. A schematic might just represent my mistaken notion or whimsy: a sense of what's caught my fancy — not that my opinion is better than anyone elses.

Quick Navigator

Graphics

Russian giant sunflower — grew to over 3 meters tall

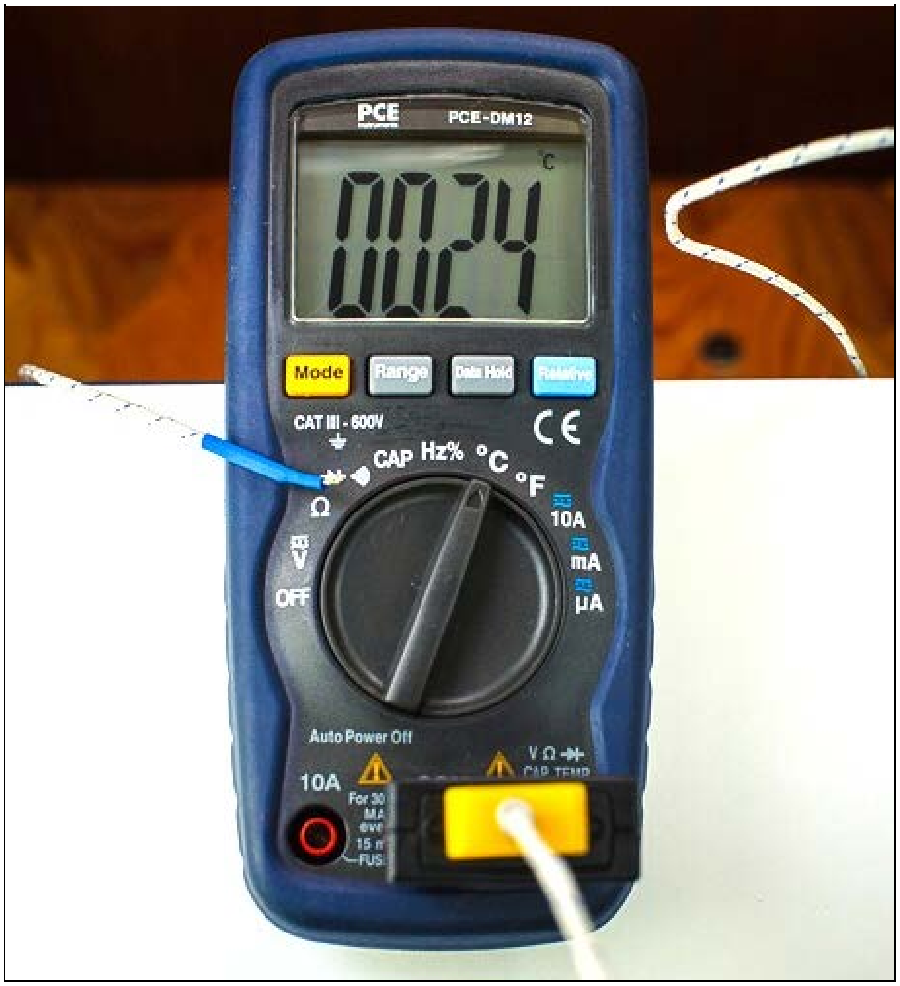

My gorgeous new PCE multimeter just in time for Season 16 experiments starting October 3. Click for another photo. Click for the PCE website — test equipment galore.

RF Transistor Data Spreadsheets

FET

BJT

Test Equipment

Test equipment

USA Rigol Dealer T Equipment

Online Tools and Publications

Standard resistor and cap values

Smith Chart information

Good inductive/capacitive reactance calculator other tools available

Resistive pad attenuator calculator

Ohm's Law 1 pager

VHF Communications website UKW-Berichte/VHF-Communications

The Signal Path EE video blog They review and show the DSA1030A SA + TG

DUBUS Technical magazine for 50 MHz and above

Favorite Experimenters

Esteemed QRP homebrew mentor - Wes Hayward's, W7ZOI web site

🍁 Iulian, YOUDAC-VA3IUL Comprehensive design information and amazing circuits web site

🍁 Markus Hansen, VE7CA A venerable Room 19 Radio School graduate. He has authored for QST. See his receiver featured in QST for March 2006

🍁 Blog of fellow VE7-land experimenter Steve, VE7SL. Look for a link to Steve's web site on his blog

Professor Ken Kuhn's web site. Perhaps start on his site map. A treasure trove of useful information

Ripples in the Ether An always interesting blog from our friend Jason who runs Etherkit

SV3ORA's Site Friend Konstantinos from Greece. Design info galore. Check out his microwave links.

FM Tuner Site Vintage FM Tuner Information

Paul, KE7HR Caver website

Matjaž, S53MV Microwave and RF. My favorite microwave designer. See this page for some inspiration

Paul Wade, W1GHZ authors my favorite QST column *Microwavelengths* His site

Jacques, VE2AZX web site Retired EE with great ideas

Michigan QRP Club Publish *The 5 Watter* Quarterly

Website of Michel, **F6FEO** from France. F6FEO project pages: click and click

Roland, a retired EE who lives in France keeps this wonderful test equipment page

JF1OZL Mega site that first inspired me years ago. He once wrote me a letter - great guy

Brian, K6STI 88-108 MHz web site.

Leif, SM5BSZ Amazing work

KA7OEI Microwave Page web site

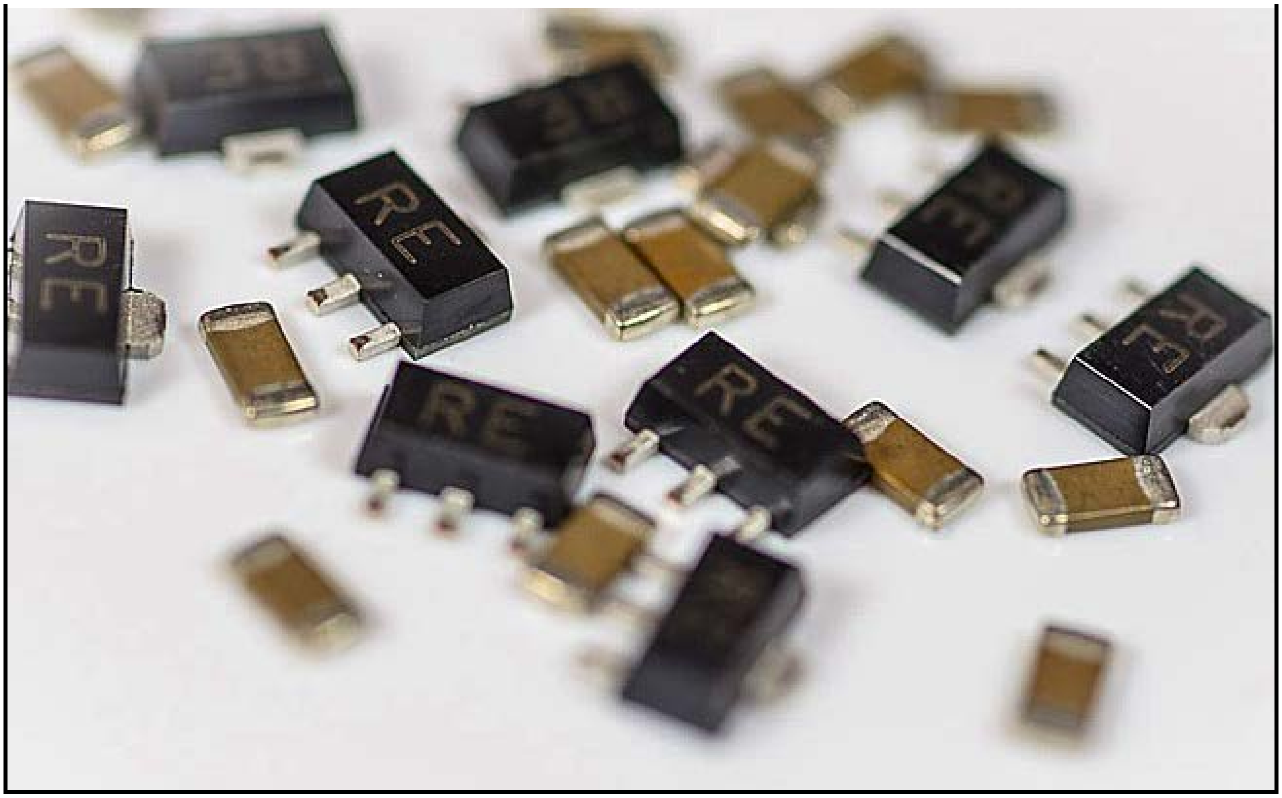
RE

ТЕЛЕГРАФНЫЙ КЛЮЧ
СОЛДАТЫ РОА!
ПОЧЕТНАЯ ГРАМОТА ЦК ВЛКСМ

Memorial Museum of the Leningrad Siege, St. Petersburg, Russia
Государственный музей обороны и блокады Ленинграда

VE7BP0 photos 2006

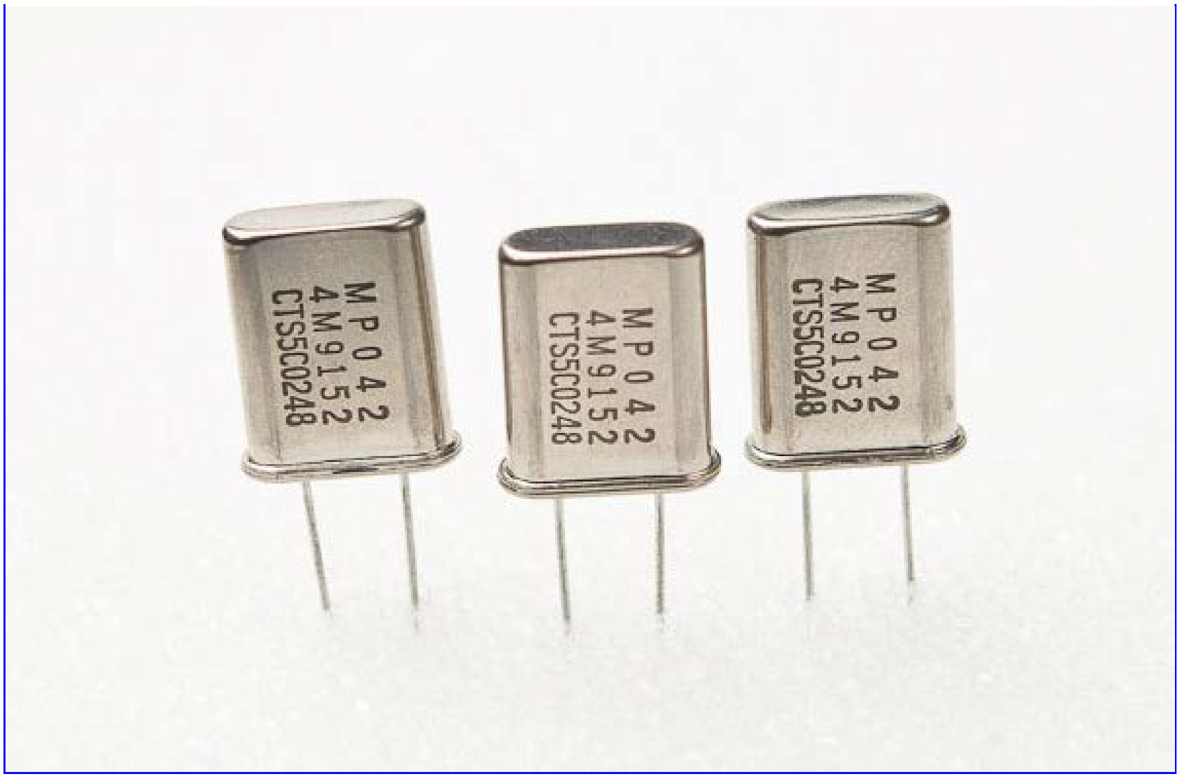
MP042
4M9152
CTS5C0248
MP042
4M9152
CTS5C0248
MP042
4M9152
CTS5C0248

RF — Test and Measurement

RF Workbench Page 1 - Case Study Answers

This web page supplements RF Workbench Page 1

Answers:

1. Calculate the power in dBm at point B **= 13.75 dBm**
2. Calculate the power in dBm at point C **= 10 dBm**
3. What is the attenuation in dB of the 50 ohms attenuator pad? **= -3.75 dB**
4. What is the output power in mW of this stage? **= 10 mW**

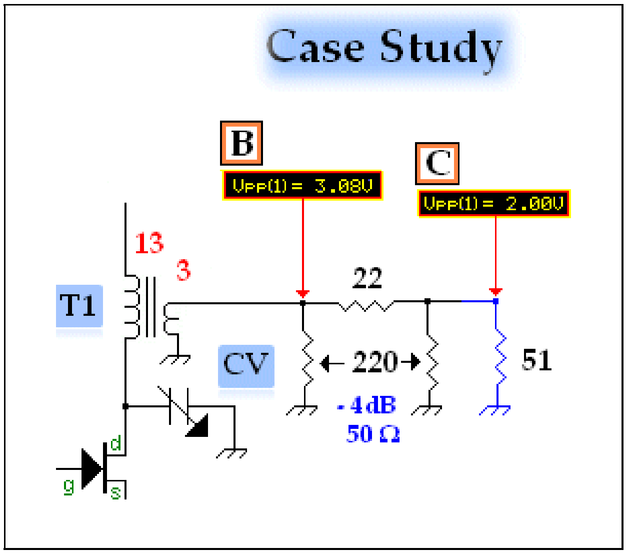
Case Study
B
Vpp(1)= 3.08V
C
Vpp(1)= 2.00V
13
3
T1
22
CV
← 220 →
51
- 4 dB
50 Ω
d
g
s

The design contained a "theoretical" - 4 dB, 50 Ω attenuator pad using standard value resistor substitutions

RF — Test and Measurement

50 Ohms Attenuator Pads

This web page supplements RF Workbench Page 2

Table For Pi and T- type pads

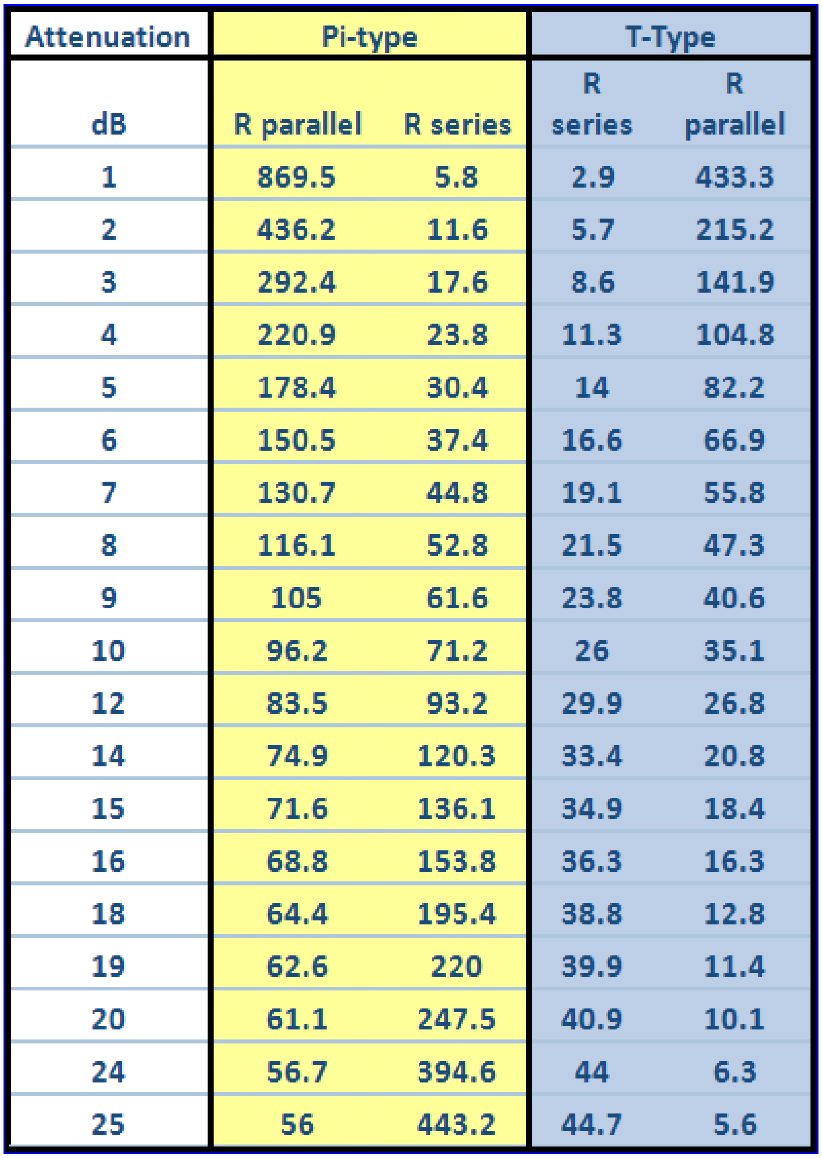

Attenuation	Pi-type		T-Type	
dB	R parallel	R series	R series	R parallel
1	869.5	5.8	2.9	433.3
2	436.2	11.6	5.7	215.2
3	292.4	17.6	8.6	141.9
4	220.9	23.8	11.3	104.8
5	178.4	30.4	14	82.2
6	150.5	37.4	16.6	66.9
7	130.7	44.8	19.1	55.8
8	116.1	52.8	21.5	47.3
9	105	61.6	23.8	40.6
10	96.2	71.2	26	35.1
12	83.5	93.2	29.9	26.8
14	74.9	120.3	33.4	20.8
15	71.6	136.1	34.9	18.4
16	68.8	153.8	36.3	16.3
18	64.4	195.4	38.8	12.8
19	62.6	220	39.9	11.4
20	61.1	247.5	40.9	10.1
24	56.7	394.6	44	6.3
25	56	443.2	44.7	5.6

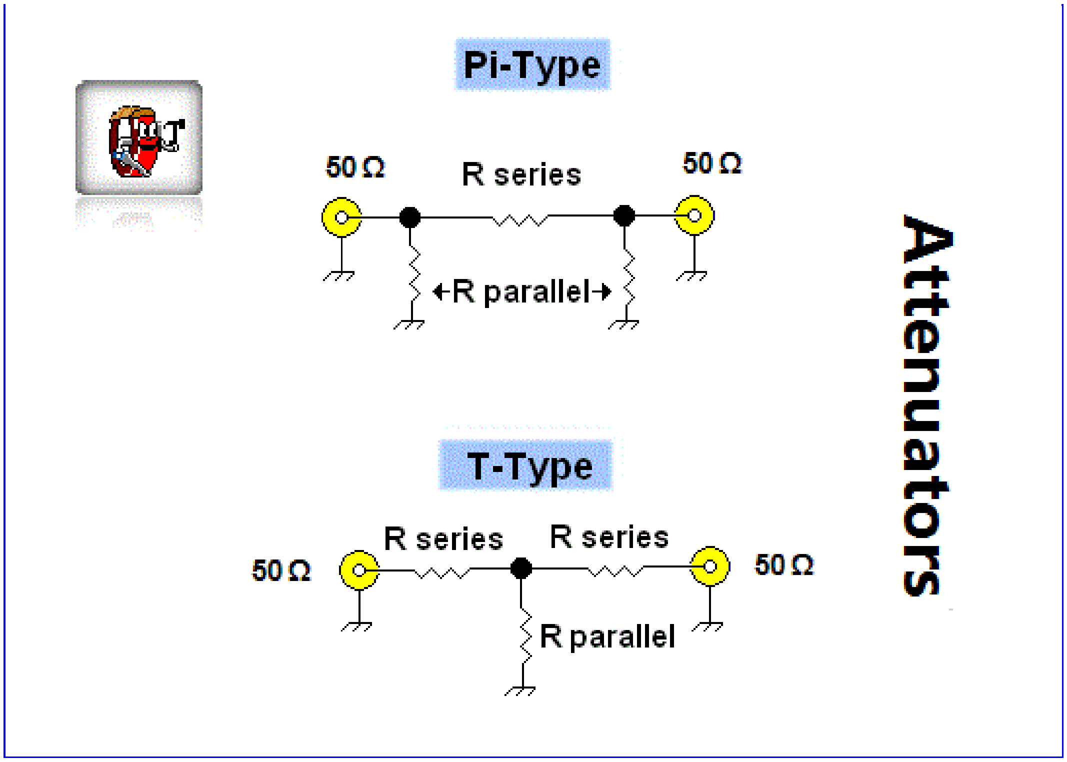
Pi-Type
50 Ω
R series
50 Ω
R parallel
T-Type
R series
R series
50 Ω
50 Ω
R parallel
Attenuators

To build attenuator networks, we normally choose use nearest standard resistor values, or parallel/series 2 or more resistors from our resistor collection to approximate the tabled R. If you're building with 5% parts, consider measuring a few resistors with an ohmmeter to find the best match to the tabeled R.

Resistors in the 8 dB T-type or the 4, 14 and 19 dB Pi-type networks are close to 5% standard resistor values.

RF — Test and Measurement

Expected Return Loss Table (50 ohm bridge)

This web page is a supplement to Transistor Input Impedance Experiments

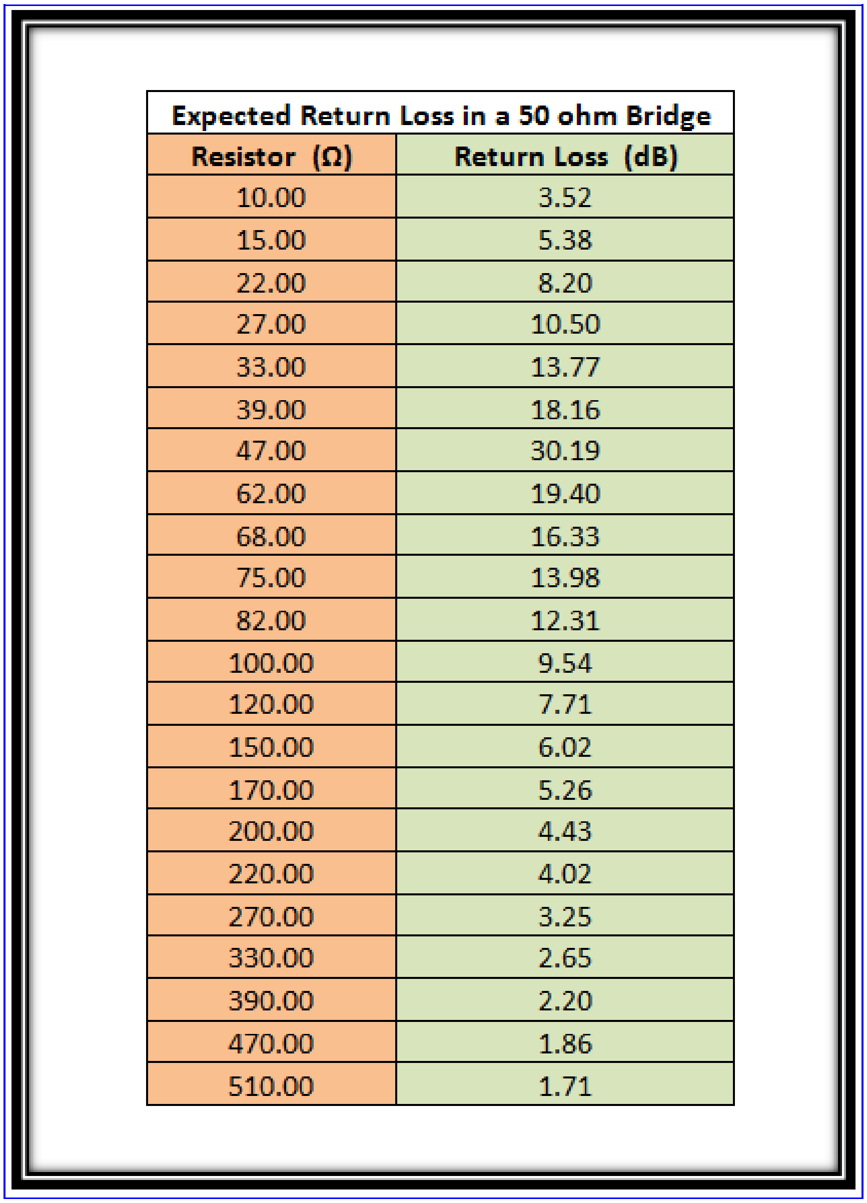

Expected Return Loss in a 50 ohm Bridge

Resistor (Ω)	Return Loss (dB)
10.00	3.52
15.00	5.38
22.00	8.20
27.00	10.50
33.00	13.77
39.00	18.16
47.00	30.19
62.00	19.40
68.00	16.33
75.00	13.98
82.00	12.31
100.00	9.54
120.00	7.71
150.00	6.02
170.00	5.26
200.00	4.43
220.00	4.02
270.00	3.25
330.00	2.65
390.00	2.20
470.00	1.86
510.00	1.71

QRP SWL HOMEBUILDER

RF — Test and Measurement

Miscellaneous RF Topics 2011 Supplement

Introduction

This web page supplements the Miscellaneous RF Topics 2011 web page.

1. Design Center - Wrap Around Bias

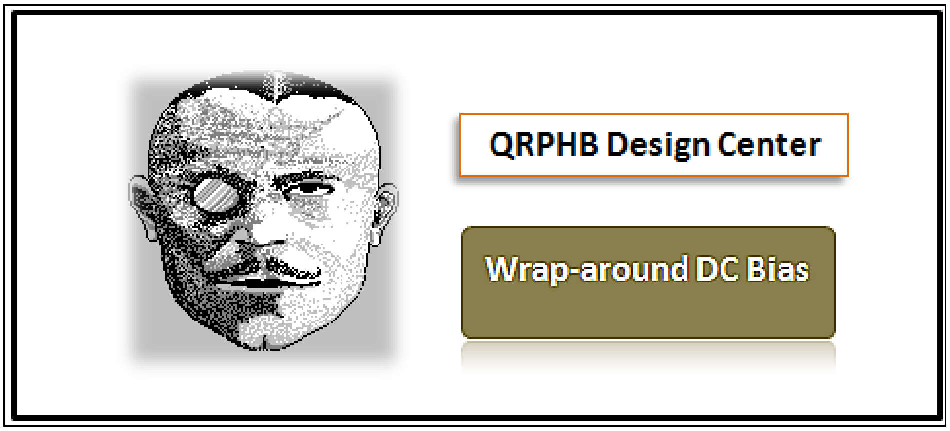

PNP Wrap-around Bias for an NPN RF Amp

There are entire books written on RF power amps. I don’t pretend to be an expert and offer a simple approach to help move novice builders up the learning curve. Big thanks to Wes, W7ZOI for the theory and explanation for EMRFD Figure 2.16; the wrap-around PNP bias of an NPN transistor with grounded emitter. This bias circuit is fantastic and helps prevent you from burning up too many expensive medium power transistors such as the 2N3866 or 2N5109 during experiments and operation. From our emails, the following experiments were performed and information gleaned.

Since the NPN emitter terminal is grounded or near to ground on my web page examples, the current can really run high — Don't forget to use heat sinks and appropriately rated resistors on the NPN circuit when you really go for power.

Wrap Around PNP Bias

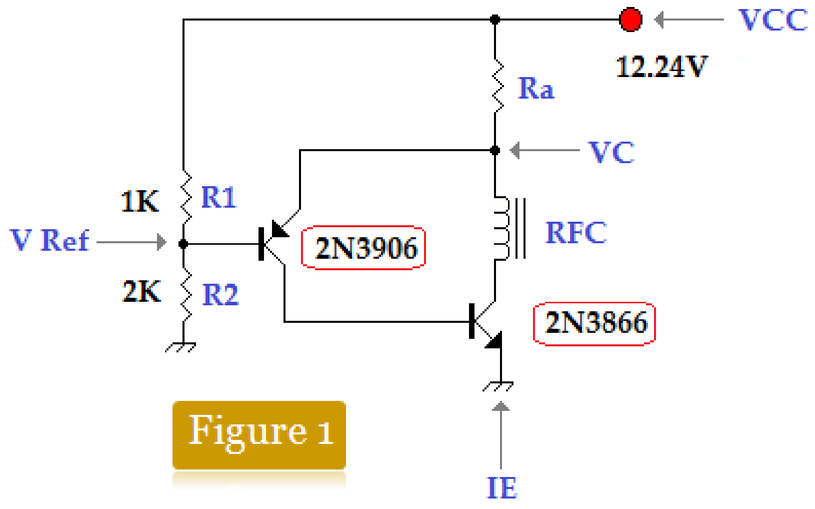

Figure 1

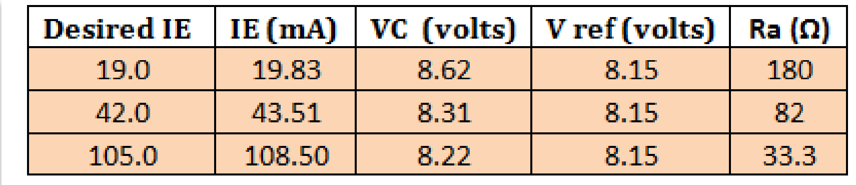

Desired IE	IE (mA)	VC (volts)	V ref (volts)	Ra (Ω)
19.0	19.83	8.62	8.15	180
42.0	43.51	8.31	8.15	82
105.0	108.50	8.22	8.15	33.3

Above — The schematic and data table from some biasing experiments. The normal decoupling parts were removed to isolate the biasing circuitry. All voltage and current values were measured. Another photo. A folded piece of paper is under the wire connecting the NPN emitter to the copper clad board. This is how I measure emitter current. The paper acts as an insulator and allows you to press hard with the ammeter probe to ensure good contact. After current measurement, the paper was discarded and the emitter soldered to the copper ground plane.

Biasing Procedure

Step 1: Choose a Target VC

Using collector resistor Ra, we want to drop about 2/3 of the power supply voltage across the NPN transistor. For a 12 volt supply or VCC, this is 8 volts VC. The formula is Target voltage = VCC x 0.66. Why choose 2/3 VCC instead of ½ VCC like we do for Class A audio amplifiers? In audio amps we just use a resistor as the load and the collector voltage can't go above the power supply unless we insert some reactances in the circuit. In simple AF voltage amps, the half VCC supply allows the greatest undistorted, peak-to-peak AC signal swing.

In RF power amps, a transformer or RFC lies on the collector terminal, so the instantaneous collector voltage (sum of the supply voltage plus the peak AC voltage) can go well above the supply voltage. If you have 8 volts on the collector, VC can easily rise to 16 volts or so on signal peaks. It's often prudent to choose a VC closer to VCC than the classic ½ VCC of audio amplifiers.

Hereafter, Target VC is referred to as **VRef**

Step 2: Choose R1 and R2 to bias the PNP @ VRef

Choose the PNP biasing transistors R1 and R2 so that the PNP bias = VRef. The formula follows:

$$\text{VRef} = \frac{\text{VCC} \times \text{R2}}{\text{R1} + \text{R2}}$$

I wrote a Java Applet that does the math Applet A ; just plug in a VCC and play with the resistor values until you get your target VRef with the resistors from your parts collection. Try to get a bias as close as possible to the targeted VRef, but don’t stress out over it.

Step 3: Choose Ra to give (VRef + 0.6)

Ra = VCC – (VRef + 0.6) / desired current in amperes. Use or make up Ra with nearest standard resistor value(s) with an appropriate power rating. In a PNP, the emitter terminal is 0.6 VDC higher than the base, so need to we add that to VRef. The desired current is any reasonable current that you want to set up; for example 25 mA or 75 ma.

Example Calculation

I wanted a emitter current of 105 mA from the Figure 1 circuit. VCC = 12.24. Let's run through the steps.

Step 1: Choose a Target VC

Target voltage = 12.24v x 0.66 = 8.1 VDC -> Now called VRef

Step 2: Choose R1 and R2 to bias the PNP at VRef

I just plugged some resistor values into Java Applet A. R1 is normally lower than R2.

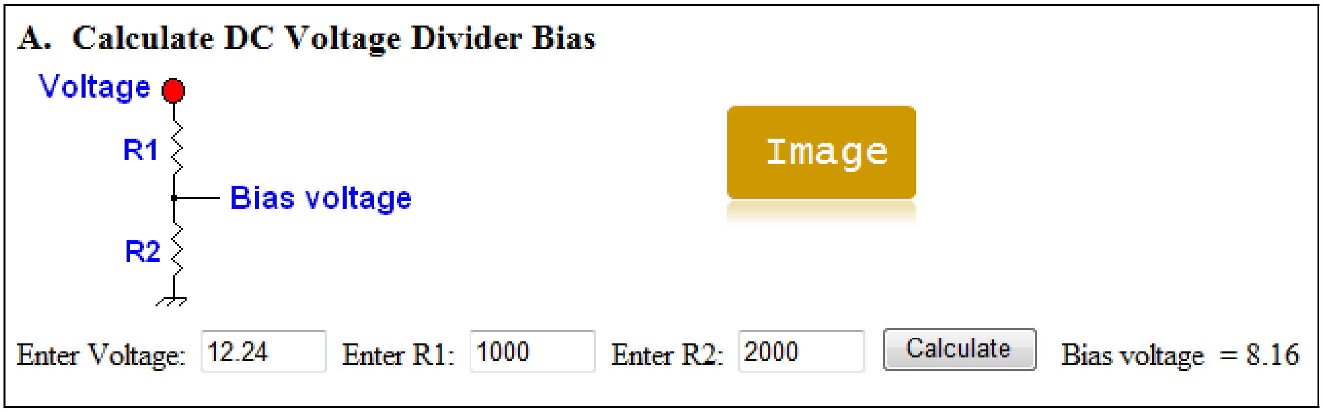

A. Calculate DC Voltage Divider Bias

Enter Voltage: 12.24 Enter R1: 1000 Enter R2: 2000 Bias voltage = 8.16

Above — A practical bias network. I have lots of 1 and 2K resistors. 8.16 v is close to my target VRef.

Step 3: Choose Ra to give (VRef + 0.6)

12.24v – (8.16v + 0.6v) / 0.105 A desired = 33.1 ohms. I put three 100 ohm ½ watt resistors in parallel for Ra. Click for lateral view photo showing the 3 resistors.

The exact measurements of this example and 2 other (19 and 42 mA) are tabled in Figure 1. I used an 82 ohm 1/2 watt resistor for Ra in the 42 mA version. The bench values closely approximate the calculated values. This circuit is quite instructive. In a real circuit (Figure 2) we add in the decoupling parts. Ra performs double duty as the decoupling resistor as well as the current regulator resistor.

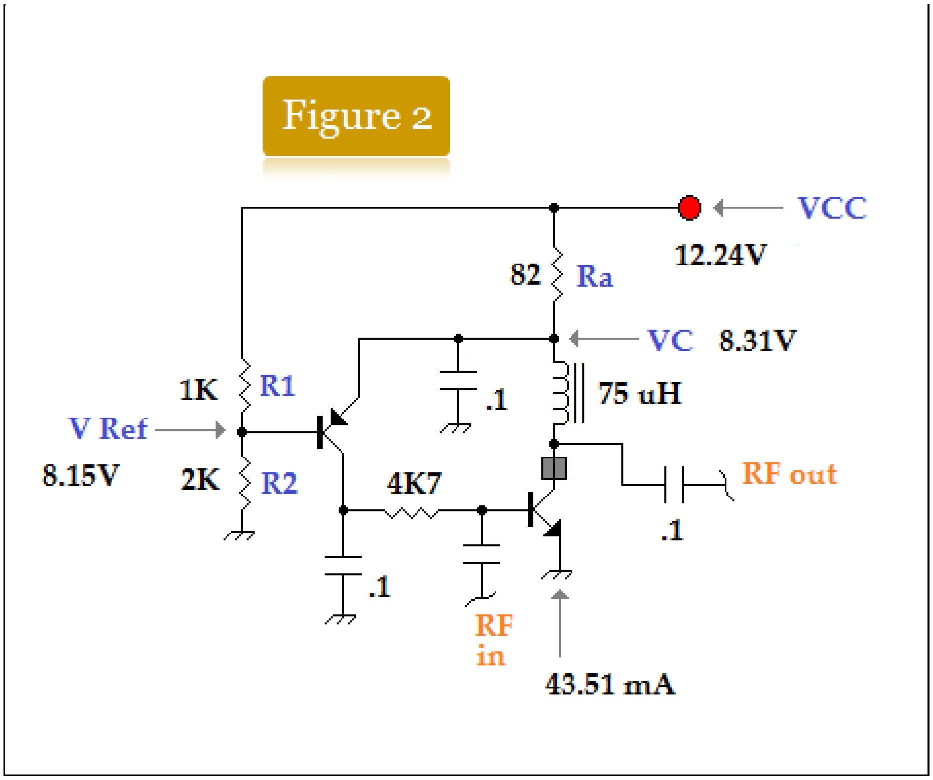

Above — A working version of the desired 42 mA medium power amp from Figure 1. Refer to EMRFD Chapter 2 for further information.

How does the PNP wrap-around bias loop work?

Using the sample conditions from Figure 2: VC = 8.16v calculated, Desired IE = 42 mA and VCC = 12.24v
The main decoupling/current limiting resistor Ra is established at 12.24v – (8.16v + 0.6v) / 0.042 mA = 82.9 Ohms.

No matter what, the PNP VRef = 8.16 volts. All of the desired conditions are established and the current is flowing in the NPN. Let's change these conditions and see what happens.

First, instead of 42 mA, assume that the NPN current drops to something less. Hence, there will not be as much of a drop across Ra. This will cause VC to increase. This is the voltage on the PNP emitter. When this voltage increases, there is more voltage between the base and the emitter of the PNP, which will make it draw **more** current. That current comes out of the PNP collector runs to the base of the NPN. This causes the NPN to draw more current (beta times) which increases its collector current and causes the collector voltage to drop because of the I x R drop in Ra. It drops until it reaches the 8.16 volt level.

Let's now assume the opposite. The NPN draw too much current, more than the desired 42 mA. This means that there is too much I x R drop in Ra and VC goes **below** 8.16 volts. This tends to turn the PNP off. The PNP collector current drops, so the NPN base current also drops, causing the NPN collector current to drop. This causes VC to again increase to reach 8.16 volts. Is this cool or what?

---

2. RC Low-pass Network

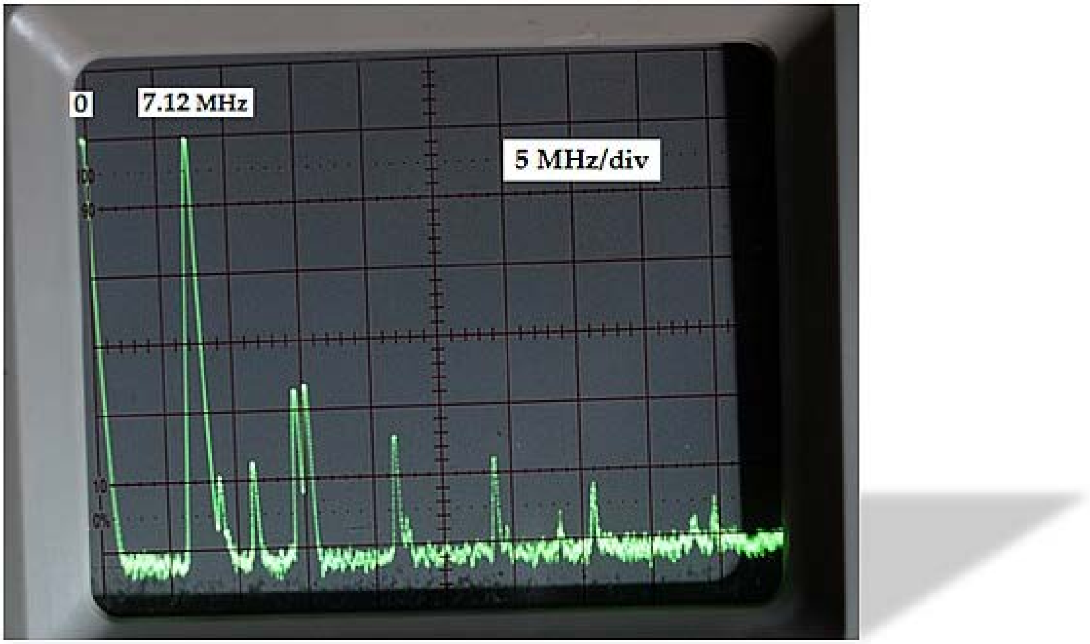

Above — Spectrum analysis without the RC low-pass filter.

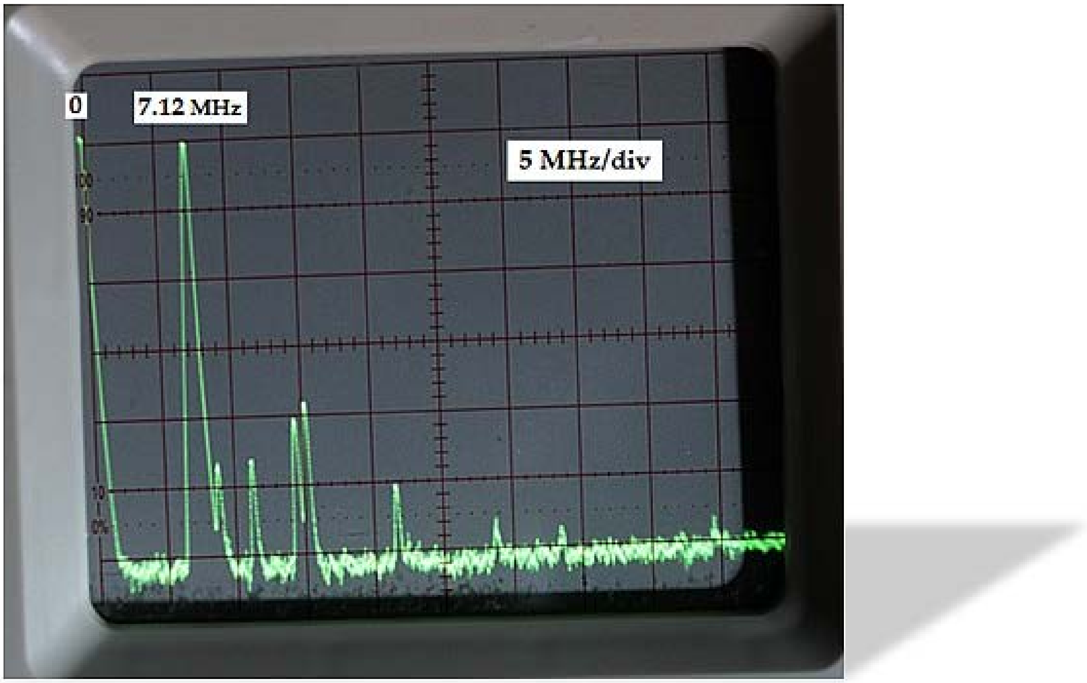

Above — Spectrum analysis with the RC filter in-situ. Above 20 MHz, the spurs are ~5-6 dB down.

3. Transistor Power Dissipation in the 2N3904

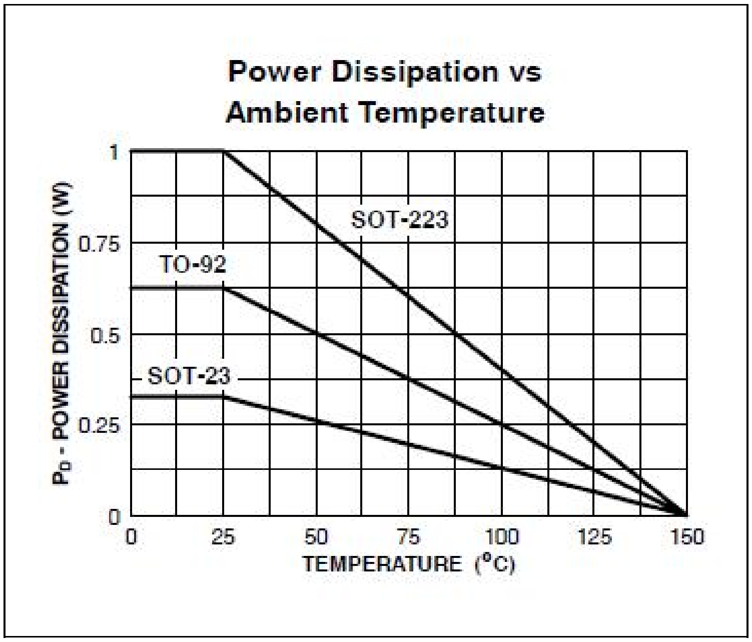

Above — Power Dissipation versus Temperature for the 2N3904 in 3 packages.

Power dissipation in the collector resistor

For example, VC (the voltage across the transistor) = 10 volts and the emitter current = 20 mA

P = I x E = .020 amps x 10 volts = 200 mW

Power dissipation in the emitter resistor

P = I x E = .020 amps x the measured emitter voltage

or P = I x I x R

For example, emitter current = 20 mA with a 5 ohm emitter resistor; P = .020 amps x .020 amps x 5 ohms = 2 mW

We assume IE = IC in the above examples. At 200 mW collector dissipation, the 2N3904 temperature temperature climbs to about 65 C. A metal can transistor such as 2N2222 has more surface area and better heat dissipation. A heat sink also improves heat dissipation. Temperature dissipation charts are referenced to ambient temperature which may be dependent on the air circulation around the transistor. If you plan on running 200 mW or so collector dissipation with a 2N3904, glue on a heat sink. A pinch of the finger and thumb, or a infrared thermometer are the most common popcorn ways to test for the need for more heat sinking, or a part with better power dissipation.

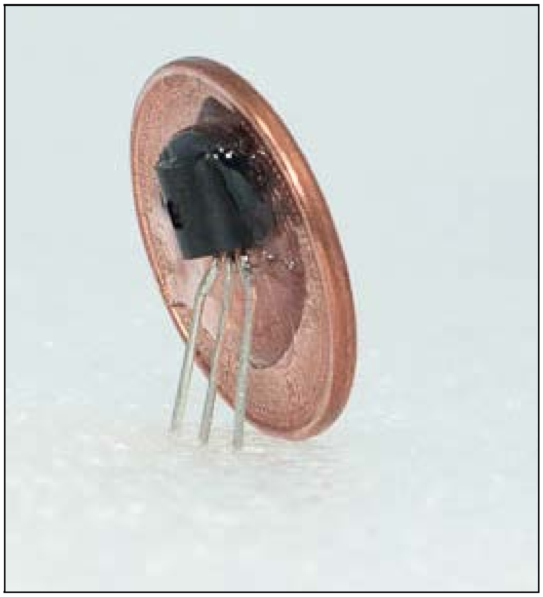

Above — I learned this from a Russian builder. 100 heat sinks for a dollar. Typically, a small blob of epoxy with the transistor positioned to the lower edge of the penny works best. I used too much epoxy and didn't wait for it to completely dry before taking this photograph — the penny slid down.

---

4. Some Factors Affecting Common-Gate Amplifier Input Impedance

A question arises: with all the devices and topologies available, why build a common-gate JFET RF amp in 2011 and on? For the J310 JFET at least: they're cheap, the input impedance is close to 50 ohms and wideband, the amp demonstrates good stability, signal handling capability and linear performance — all without running mega-current. Мне нравится. Many authors state the common-gate noise figure is inferior to that obtainable with the common-source topology, but for the popcorn builder, the common-gate noise figure is probably reasonable.

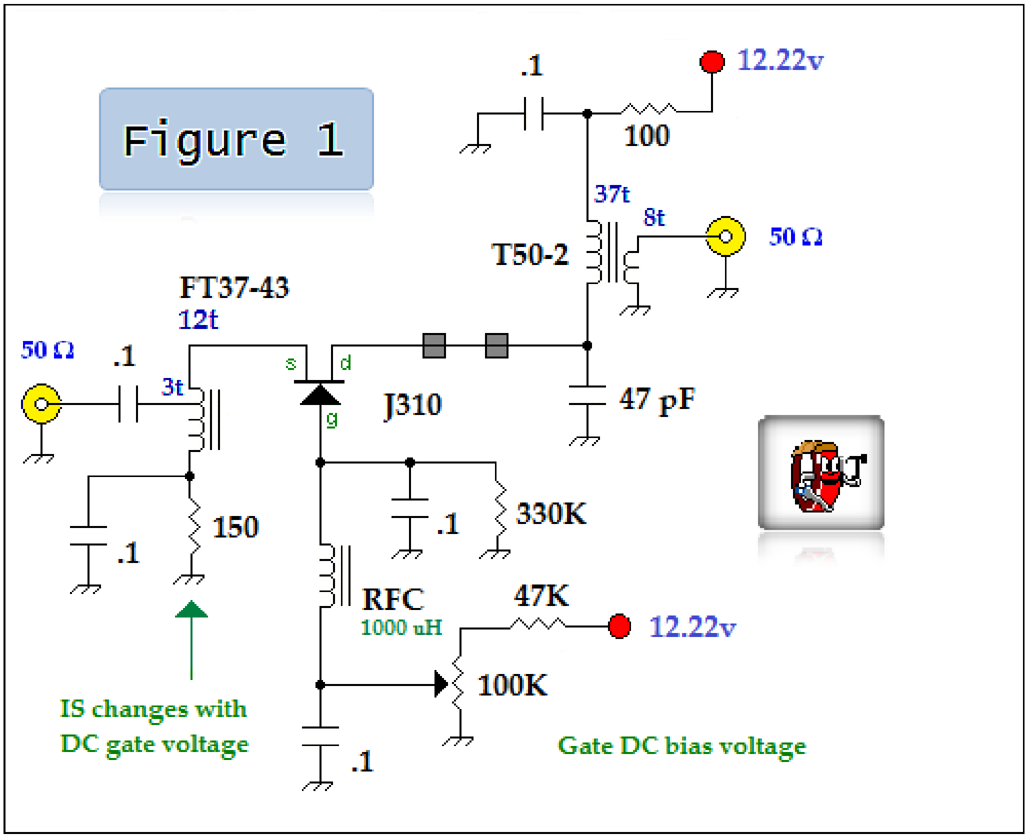
Figure 1
.1
12.22v
100
37t
8t
50 Ω
T50-2
FT37-43
12t
50 Ω
.1
3t
s
d
J310
g
47 pF
150
.1
.1
330K
RFC
1000 uH
47K
12.22v
100K
IS changes with DC gate voltage
Gate DC bias voltage
.1

Above — A JFET gate biasing experiment. Here I applied 0-7 volts DC to the gate of a common-gate FET amp. The results proved interesting; see the graph below. The drain was tuned with a fixed 47 pF cap and manually "scrunch tuned" by pinching the T50-2 toroid with fingers and thumb. The input RFC serves to decouple the DC from the AC signal and the tap is used to improve the input impedance match.

Figure 2

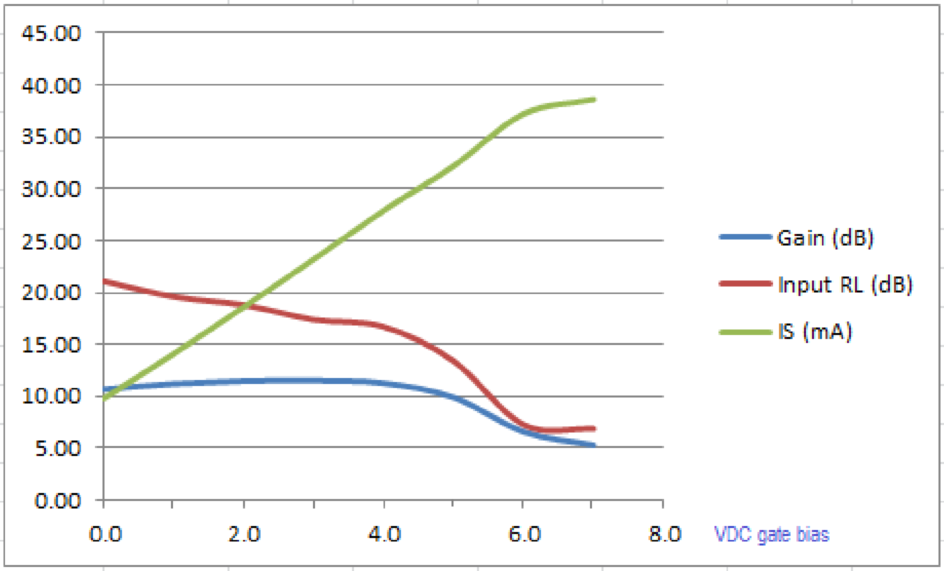

Above in Figure 2 — A graph of the DC gate voltage versus gain, input return loss and source current from Figure 1.

Increasing the DC gate voltage increases the source current as shown in the graph — ranging from 9.8 to 38.6 mA. From a DC gate voltage of 0 to about 4 volts, amplifier gain changes very little. Technically, the gain of this amplifier should increase along with drain current, however, the input resistance simultaneously goes down, creating greater voltage division loss at the input plus reduced return loss from impedance mismatch. This tends to cancel the increased gain as the plot shows.

The AC signal current injected into the FET comes out of the drain with power gain because that same current is now flowing into a higher impedance. The gain is dependent on the ratio of the impedance at the drain to that at the source. Click for a SPICE plot of DC gate voltage versus source current for 0 - 5 volts from Wes, W7ZOI.

From experiments, I learned that at least 6 things effect input return loss: the source resistor value, stacking or paralleling JFETS, the gate DC voltage(all which change current and/or transconductance), whether or not you bypass the source resistor, negative feedback and also the tap on the input RFC. Like other amps, the impedance of the device before and after the JFET amp can also change the input match, but those are external and normal considerations.

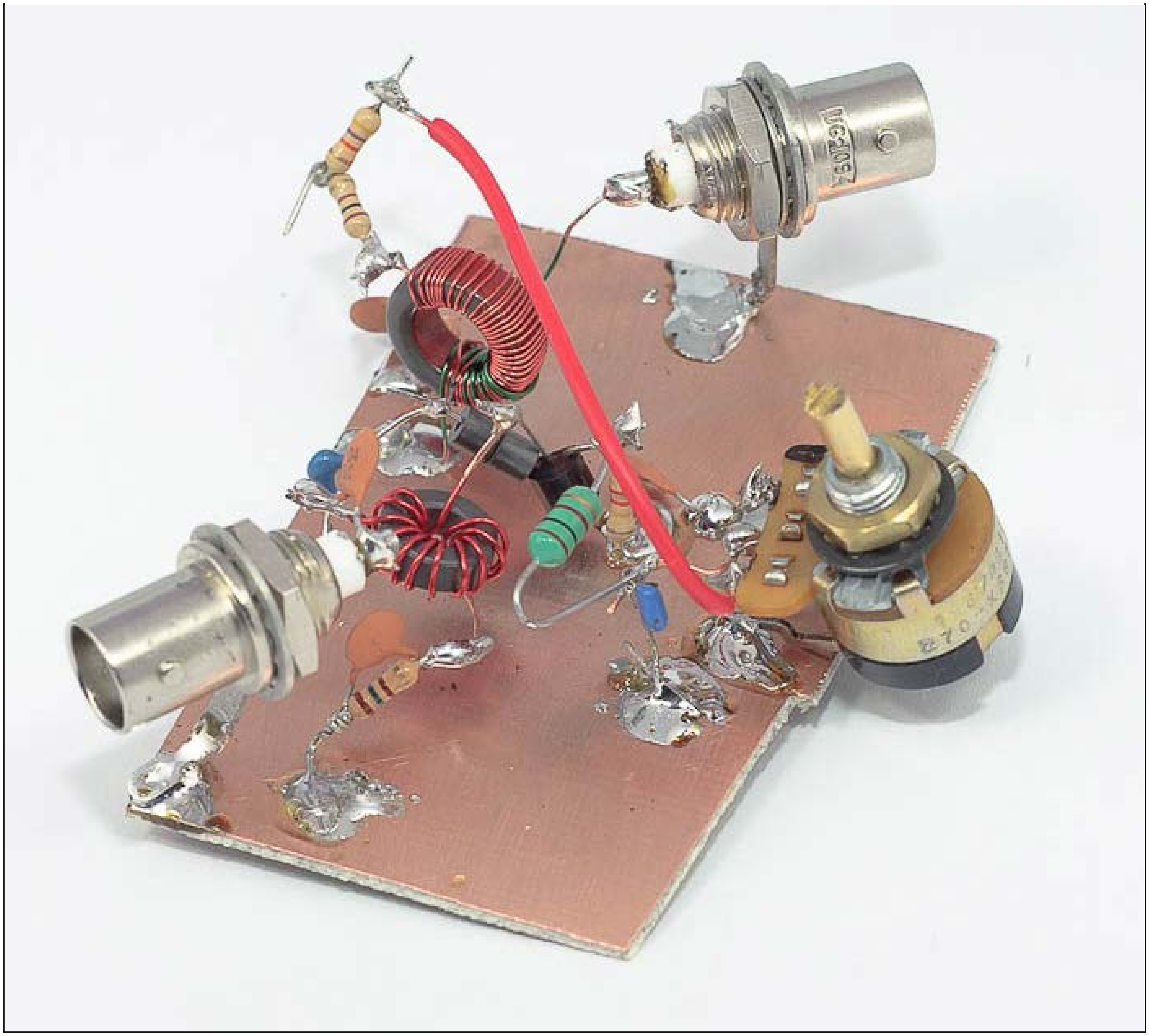

Above — Breadboard of the DC gate bias experiments of Figure1. Properly biased JFETs act like a current source where drain current is controlled by the gate-to-source DC voltage. The input impedance of the common gate amp is the reciprocal of the transconductance. Ken Kuhn posted some great JFET design notes in the yellow JFET section on his web site. EMRFD provides another essential reference for RF JFET design.

Noise Figure and the Common Gate Amplifier

Noise figure is important in low-level RF amplifiers such as a preamp or post-mixer amp because noise generated by these amplifiers contributes to the overall noise figure of a receiver. The input impedance an amp like the common-gate is considered an *active* impedance. Often, with active impedances, obtaining the maximum power transfer and lowest noise figure don't occur simultaneously. That is, the optimum input impedance match for gain is not the optimum input match for low noise performance. With pure resistances, the best noise figure possible is 3 dB; however, when using an active impedance, it's possible to achieve a noise figure less than 3 dB by applying negative feedback or other techniques to manipulate the JFET active input impedance and lower its voltage noise.

A stellar example by Bill, W7AAZI employs DC gate bias, noiseless negative feedback and paralleled JFETs to achieve a noise figure in the 1.2-1.5 dB range. This mind-boggling circuit is described in EMRFD as Figure 6.94. I wanted to explore this topic: can amateur builders design *common-gate* amplifiers for a lower noise figure? The answer is perhaps, however, unfortunately, there is no cookie-cutter approach.

Low noise amplifier design imposes an advanced topic and many builders lack the math skills and/or test equipment to design and generate results. Each design must be approached on a case-by-case basis, although similar fundamentals apply to all cases — using active impedance manipulation techniques and paralleling up JFETs while paying attention to all the resistances in a circuit — even loss resistance in the inductors. I learned from Professor Ken Kuhn that when amplifiers are paralleled the output signal power adds linearly, whereas the internal noise adds statistically (square root of the sum of the squares) and thus noise figure improves. In short, paralleling JFETs reduces voltage noise, but only to a point, as input capacitance also increases which can degrade high frequency performance and noise figure. Ideally, the JFETs paralleled should be matched for IDSS and VP.

Further, all devices have a voltage noise specifications (in volts per root Hz) and a current noise specifications (in amperes per root Hz). The source impedance that produces the lowest noise is the ratio of the two — derived from Ohm's law. The input impedance of the device may be higher or lower; thus the optimum source impedance for low noise is not necessarily the optimum source impedance for maximum power transfer. It's unlikely that these two impedances differ widely, however, only careful bench measurements or closely copying proven designs will ensure the desired results.

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5. Design Center - Temperature Stable Voltage Divider Bias

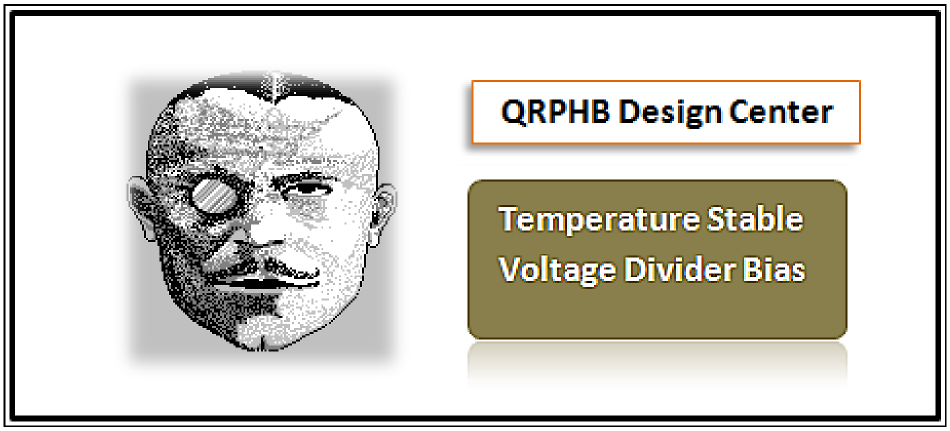

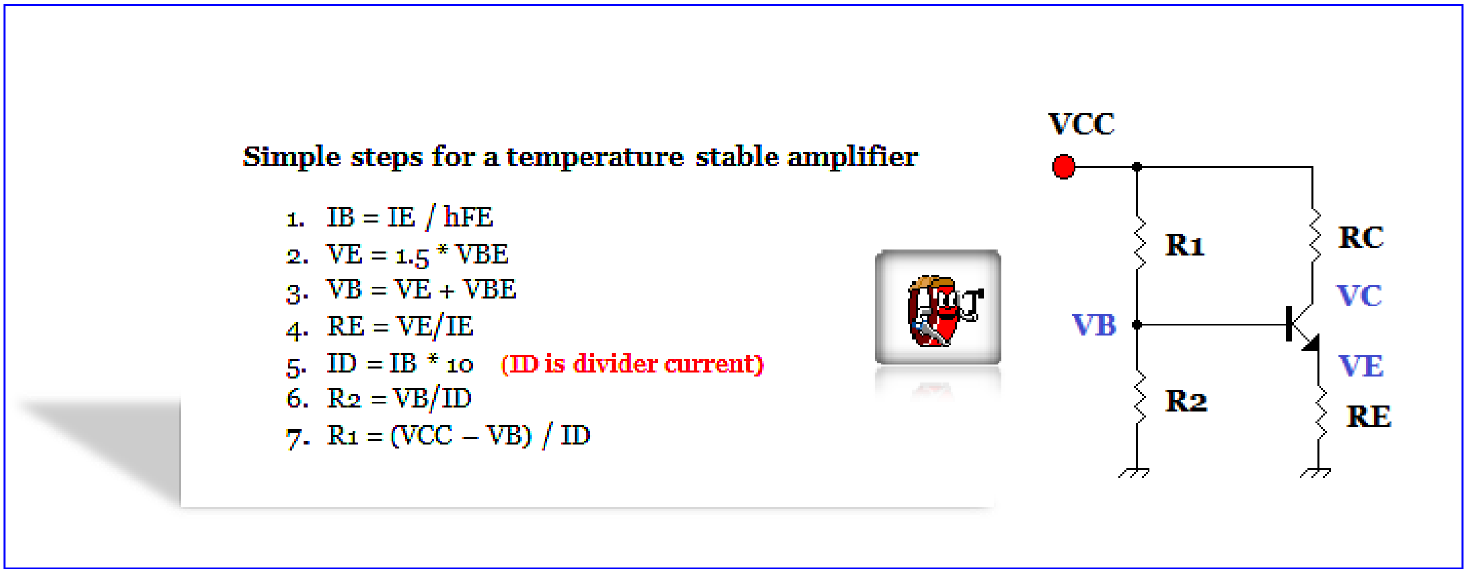
Simple steps for a temperature stable amplifier

1. IB = IE / hFE
2. VE = 1.5 * VBE
3. VB = VE + VBE
4. RE = VE/IE
5. ID = IB * 10 (ID is divider current)
6. R2 = VB/ID
7. R1 = (VCC – VB) / ID

Above — A simple way to design a temperature stable BJT voltage divider bias. Assumes that IC = IE. You specify IE.

I sought to develop a simple way for builders to design a temperature stable BJT amp using voltage divider bias. It wasn't so easy. Here is the full math from Ken Kuhn. As shown, it gets complicated and over-the-head of the target readers of this web site.

My simple approach makes assumptions, and certainly an astute builder could improve my algorithm - I developed other formulae, however settled on this one because it well fits the scope of the QRP/SWL HB web site. Most engineers design their bias networks in SPICE and I recommend this.

To choose a Beta or hFE, you can measure the Beta or use the transistor datasheet Beta near to the emiiter current you intend to apply. Many builders debate this and even go as far to state that spec sheet Beta values are useless. This may be true, but you *have* to decide on some approach. Ultimately, you will build the amplifier and can tweak 1 or more of the bias resistor values to set your bias voltage (emitter current). Click for a snippet from a 2N3904 datasheet showing hFE at a range of currents.

Biasing BJTs is a great example of building to suit your design requirements. The average reader likely operates their radios at room temperature where a minimum temperature stability factor is needed. On the other hand, you may operate field portable, or use a crammed chassis where transistors heat threatens stability. As always, your design choices must fit your needs, parts and abilities.
The above 7-step method forms a simple **QRPHB Design Center** method to achieve a reasonable temperature stability factor at normal

operating temperatures. I considered 2 factors: VBE and Beta (hFE) changes.

VBE

We normally attribute the voltage difference from base to emitter (VBE) as 0.7 volts for silicon transistors. VBE changes inversely with temperature and at AF to HF, we mitigate VBE creep by applying an emitter resistor to increase the emitter voltage VE. The emitter resistor provides a feedback loop so as collector current starts to increase due to a rise in temperature, the voltage drop across RE also starts to increase. This voltage tends to reverse bias the base-emitter junction. The net effect is decreased collector current.

How do I choose an emitter resistor value for VBE bias stability asked the little grasshopper (novice)?

The VE value should typically be about 10 to 25% of VCC. VE recommendations really vary from author to author — some say VE should be at least 5X VBE while other authors suggest 2-4 volts as the minimum acceptable VE value for bias stability in typical AF-HF amplifiers. I use 1.5 * VBE (0.7) = a VE of 1.05 volts, but it's up to you. Since you know IE for your transistor, calculate the resistor RE to provide the target VE using ohm’s law: RE = VE/IE.

At VHF on up, emitters are typically directly connected to ground since that path must have as near zero inductance as possible. In these amps, the bias is derived by a feedback circuit that controls the base current to stabilize the collector current at a specific level. Inductance in the emitter lead causes significant loss of gain at higher frequencies and also upsets the input impedance to the base. Similar effects occur in JFETs and even vacuum tubes. 10s of nH of inductance at 144 MHz represents a reactance of 10s of ohms. At UHF on up this becomes very serious — that's why construction methods are so critical for these builders.

In conclusion; to influence VBE stability against temperature changes and to some extent leakage current, at AF- HF, apply series feedback to a raise emitter voltage (VE). Accounting for variations arising from 5% tolerance parts, I chose a minimal VE of 1.05 volts (equation 2 of 7 in my "Simple Steps..." algorithm).

A tradeoff challenges us — increasing the emitter resistance, increases AC degeneration, lowers AC signal gain and raises the transistor input impedance. Bypassing all or part of the emitter resistance offsets these problems.

Beta

Beta variation arising from temperature changes must be mitigated. I briefly discuss the factors that change Beta in the bullets under the #5 Bipolar Junction Transistor Beta Tester on this page.

To design "beta independent amplifiers", the builder alters the resistance ratio RB/RE. Decreasing this ratio improves the Beta stability while decreasing the amplifier current gain. The ratio can be confusing, so the Design Center equations 5, 6 and 7 just make the current in the divider 10X the base current. It's simple — you're done. Feel free to choose whatever ratio you think is best. Good values for the RB/RE ratio lie in the 12 - 20 range.

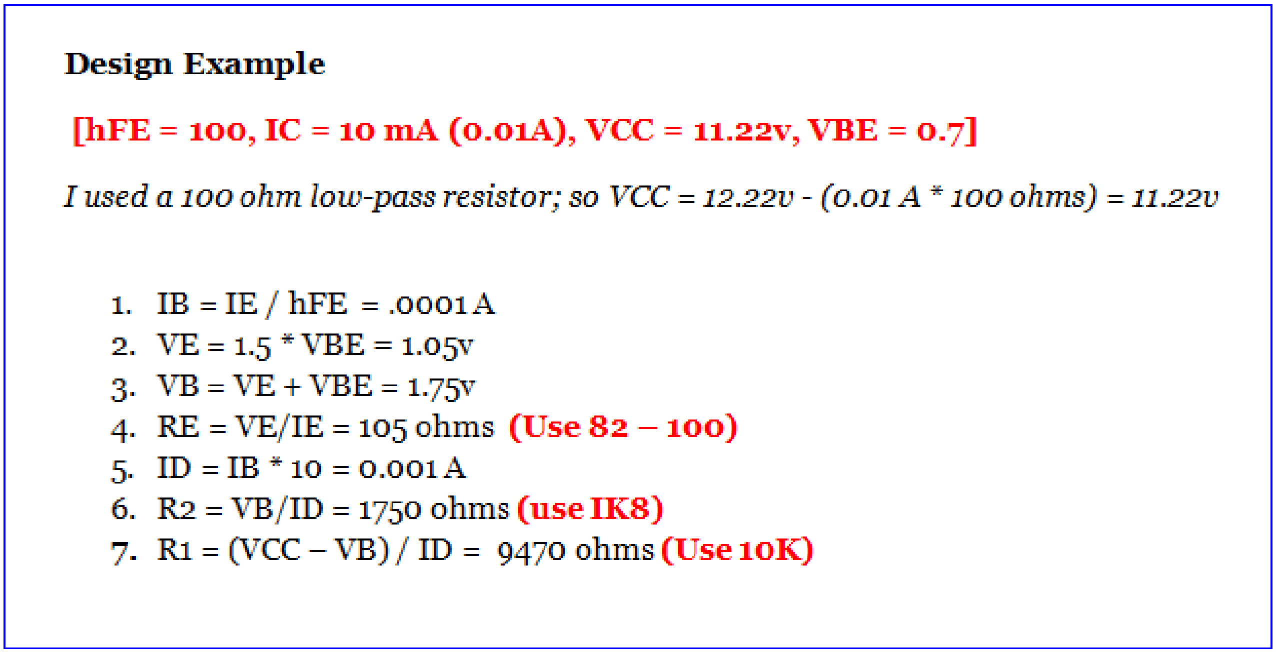

Design Example

[hFE = 100, IC = 10 mA (0.01A), VCC = 11.22v, VBE = 0.7]

*I used a 100 ohm low-pass resistor; so VCC = 12.22v - (0.01 A * 100 ohms) = 11.22v*

1. IB = IE / hFE = .0001 A
2. VE = 1.5 * VBE = 1.05v
3. VB = VE + VBE = 1.75v
4. RE = VE/IE = 105 ohms **(Use 82 – 100)**
5. ID = IB * 10 = 0.001 A
6. R2 = VB/ID = 1750 ohms **(use IK8)**
7. R1 = (VCC – VB) / ID = 9470 ohms **(Use 10K)**

Above — A design example employing my "Simple steps for a temp stable amp" bias algorithm. My VCC = 12.22 volts, but, as always I decoupled and bypassed the VCC — in this case, I applied a 100 ohm /0.1 uF network. At 10 mA emitter current, the voltage drop across the 100 Ω resistor results in a VCC of 11.22 volts.

Big thanks to Wes, W7ZOI and Professor Ken Kuhn for helping me with my math problems and to better understand biasing concepts.

A friend made a Design Center spread sheet for MS Excel. In this application you enter the desired IC rather than IE.

QRP SWL HOMEBUILDER

Amateur Radio Electronic Design

50 Ohm Common Emitter Audio Preamp Experiments

Introduction

This page supplements the Pop DC2 Receiver Experiments from this web page.

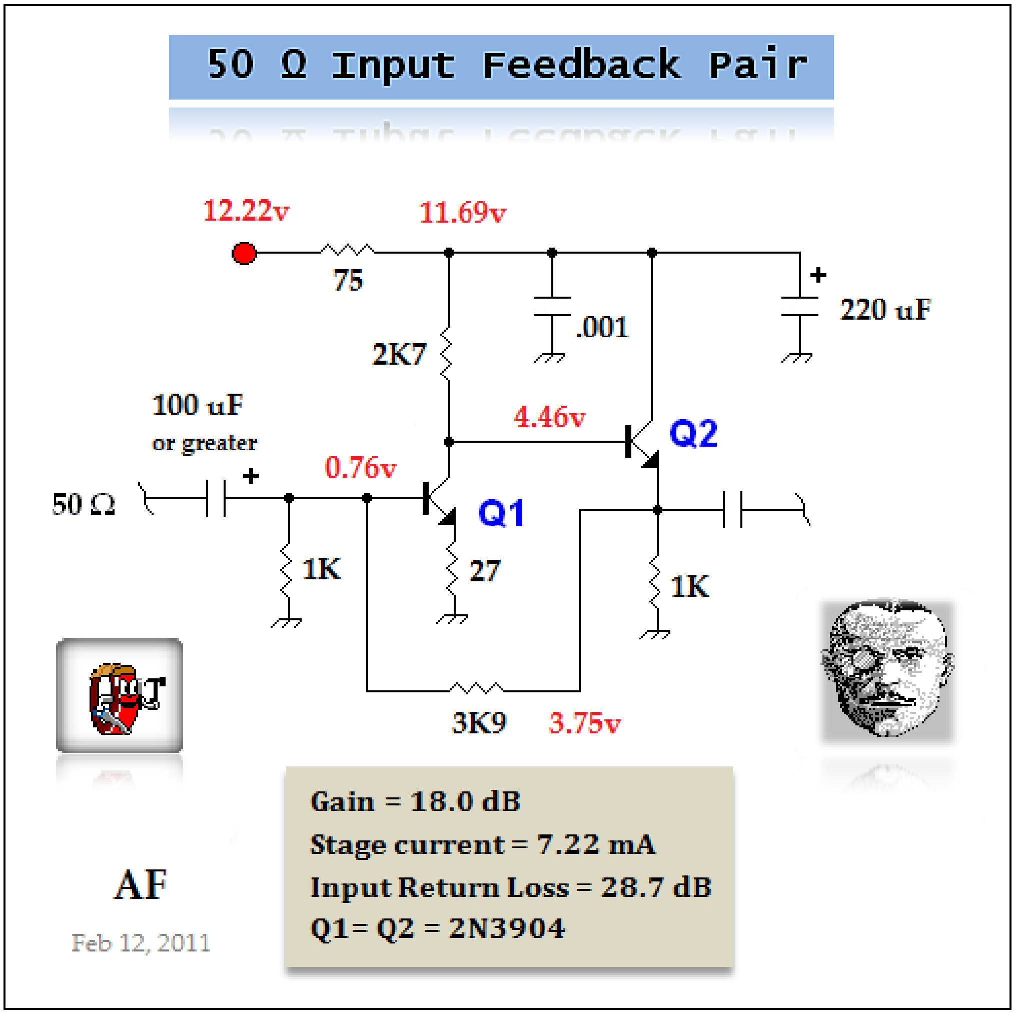

50 Ω Input Feedback Pair

Gain = 18.0 dB
Stage current = 7.22 mA
Input Return Loss = 28.7 dB
Q1= Q2 = 2N3904

Above — A 50 ohm audio preamp to follow a diode ring product detector.

Many seek an alternative to the common base AF preamp that typically follows a diode ring product detector. Winter experiments yielded some possible ideas. The simplest is shown above.

Using all different parts, I built and measured another version to ensure reproducibility of the input return loss while just using standard 5% resistor values. The second amp proved similar: 18.4 dB gain, 7.27 mA stage current (3 .8 mA is consumed by the emitter follower), a return loss of 27.6 dB and a nice sine wave output. A 2K2 resistor AC coupled to the emitter follower provided a load. Note in the photo, I used 1% resistors in some slots, but the values were standard 5% and not unusual values like 15.4 K etc.. The 3K9 feedback R is the most critical value — it's a 5% part.

About 1/4 of my resistor collection are 1% metal film, as I don't like stocking both 5% and 1% tolerances of the same R value. I envision this amp driving a 5532 amplifier/low-pass filter built with 5% resistors with the op-amp output connected to a 1-10K volume control potentiometer.

The amp above is pure popcorn fluff, yet represents over 8 hours of reading, calculations and bench discovery. In another version, I soldered in low noise transistors (MPSA18 for example) and 1% metal film resistors to try and drop the noise figure. Yet another stage had Q1 collector bootstrapping (3 layers of feedback). I'm not sure what I'll do with these experiments, however, at least 1 of these will end up on the module page as the update to the popcorn DC receiver mainframe.

Glenn, VE7DNL built a landmark common emitter preamp with parallel 2N4401s, shunt feedback and some 1% bias resistors. I built a version of his pre-amp without the diplexer. The input return loss in my version was only 5 dB — likely the diplexer network helps establish the input match. It appears Glenn's goal was low NF and the best match and noise figure don't always correlate. I matched Q2 and Q3 as well as I could since only 6 were available. An Hfe of 220- 240 is not uncommon for the 2N4401 — a good part.

Here's a SPICE plot of the amp performed by Wes, W7ZOI. The two plots are S21 and S11. S21 is the forward gain in dB. S11 is the input reflection coefficient, which is just the negative of the return loss. At 1 kHz, the calculated gain = just under 42 dB and the input match = ~17 dB return loss.

To improve return loss in my breadboard, I need to tweek Q2 and Q3 bias (lower the 6.04K resistor), plus add some emitter degeneration. Emitter degeneration (series feedback) would worsen the noise figure. The 100 uF emitter caps offer some series feedback and capacitor values like 1000 uF are needed if "true" AF bypass is wanted.

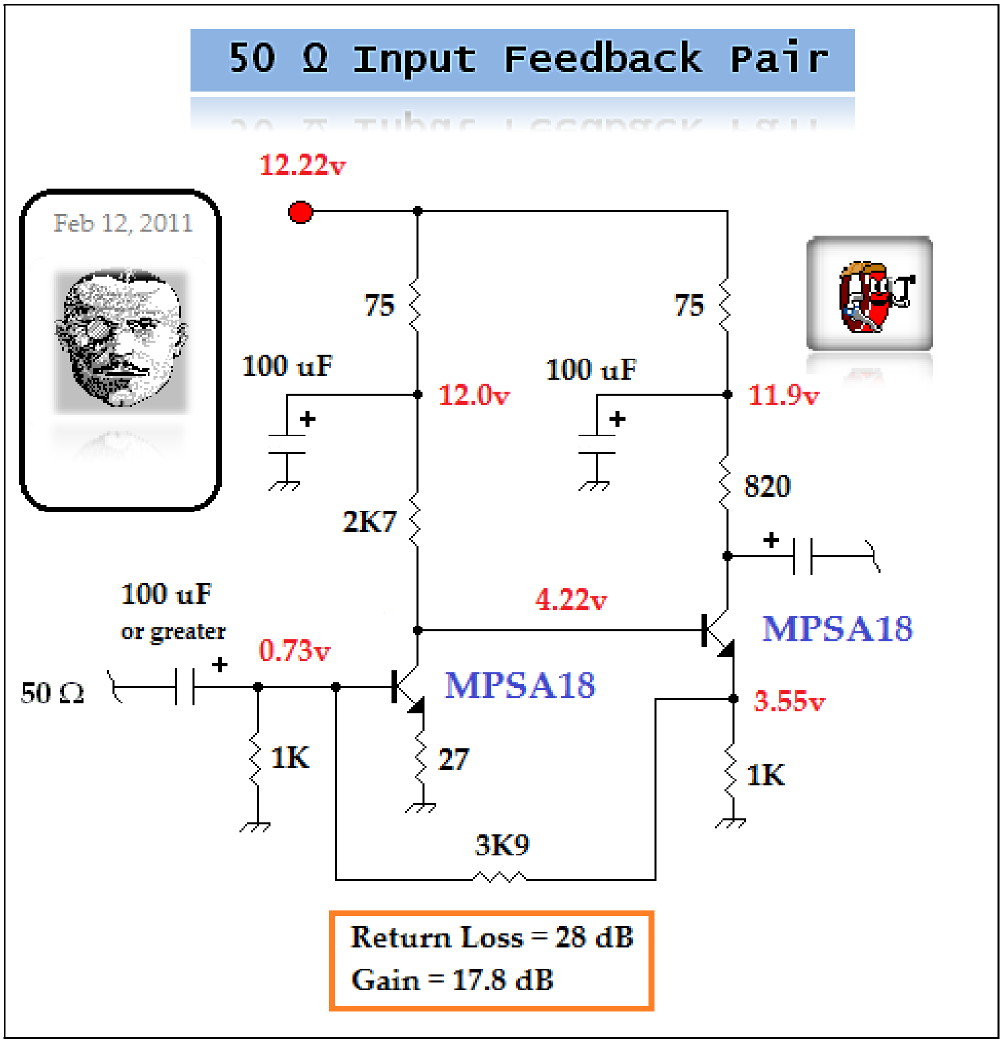

Above — Alternate experimental 50 ohm audio preamp to follow a diode ring product detector. The high impedance output enables small value output coupling capacitors for pseudo high-pass filtering. I simply added a collector resistor plus a decoupling network to Q2. The low noise MPSA18 BJT is a favorite and predictable part. The 2N3904, 2N4401 and others should work fine.

Don't even think about using an input capacitor less than 100 uF at 50 ohms — you'll trash the input Return Loss. I measured the highest Return

Loss with a 470 uF coupling capacitor, but the 100 uF cap shown worked almost as well.

I'm currently decreasing the (Q2) 1K emitter resistor with hopes of squeezing out a little more gain while trying to preserve strong signal handling capacity. I've found that heavy feedback is your friend.

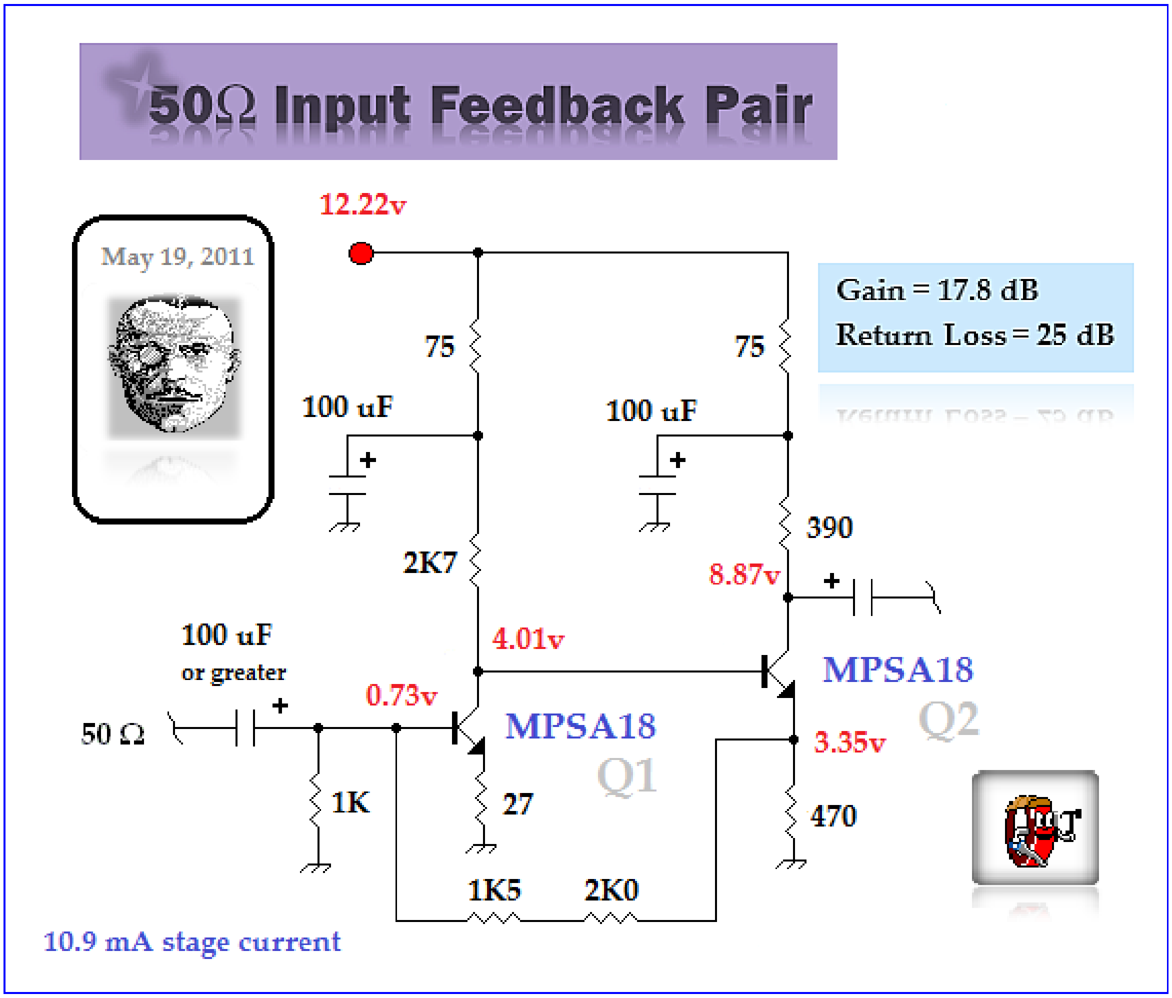
50Ω Input Feedback Pair
May 19, 2011
12.22v
Gain = 17.8 dB
Return Loss = 25 dB
75
75
100 uF
100 uF
+
+
390
2K7
8.87v
+
100 uF
or greater
4.01v
MPSA18
0.73v
+
50 Ω
MPSA18
Q2
3.35v
Q1
1K
27
470
1K5
2K0
10.9 mA stage current

Above — Another version; trying to increase stage gain. The Q2 collector resistor dramatically affects clean signal handling — lowest distortion occurred with a 367 ohm collector resistance. I substituted a 390 ohm collector R. This dropped the gain a little, but increasing distortion over gain is never my goal.

During experiments, dropping the the Q2 emitter resistor below 470 ohms made the other biasing resistors more critical, decreased return loss and invited distortion. The best return loss occurred when critically biasing with 1% resistors — I'm avoiding that!

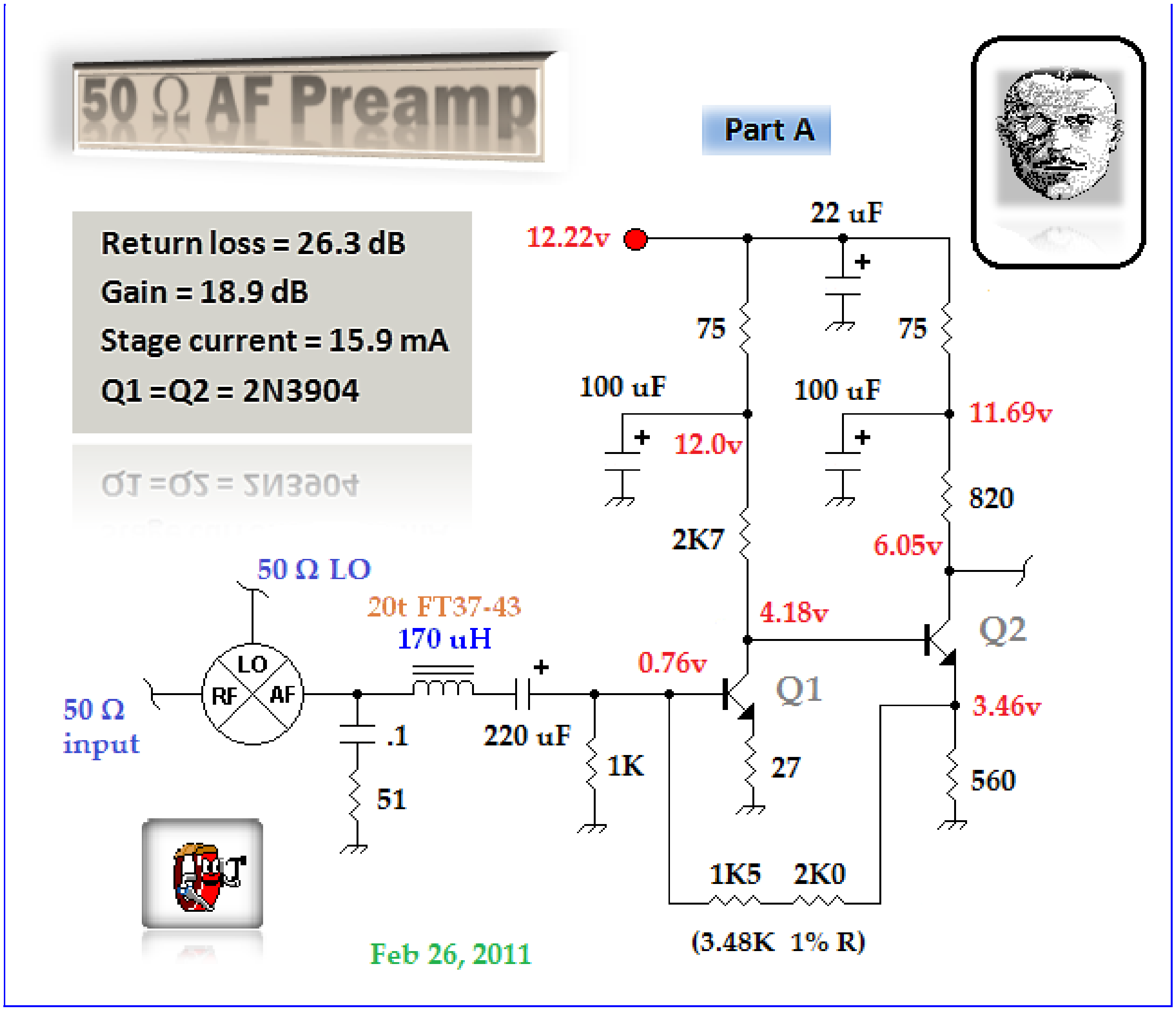
50 Ω AF Preamp
Part A
Return loss = 26.3 dB
Gain = 18.9 dB
Stage current = 15.9 mA
Q1 =Q2 = 2N3904
12.22v
22 uF
75
75
100 uF
100 uF
12.0v
11.69v
820
2K7
6.05v
4.18v
Q2
Q1
0.76v
3.46v
50 Ω LO
20t FT37-43
170 uH
LO
RF
AF
50 Ω
input
.1
220 uF
1K
27
560
51
1K5
2K0
(3.48K 1% R)
Feb 26, 2011

Above — Another popcorn part experiment from February. A low-pass network terminates a diode ring mixer and drives a 50 ohm input feedback pair arranged so the Q2 collector DC voltage is approximately 1/2 VCC — this provides the DC bias for a 5532 op-amp low-pass filter arranged in the Sallen-Key topology.

The Q2 collector voltage removes the need for a separate single supply op-amp bias network and an AC coupling cap. I didn't try this circuit in a receiver; arranging the feedback network and testing the possibility of such a design drove this experiment. A perfect 1/2 VCC Q2 collector voltage might be obtained with a standard 1% value 806 ohm R. I lack this part.

RF — Test and Measurement

Almost Popcorn Superhet

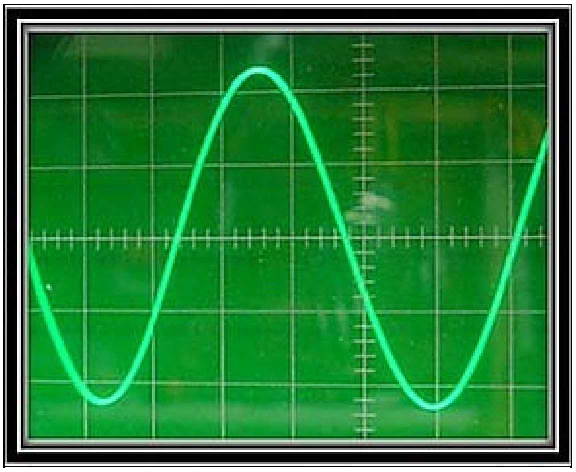

1. Receiver Concept and Macro Diagram

Not done.

Maybe a flight-of-fancy that never crosses the finish line? This page seems to repeatedly find the back burner; a good intention that never sees completion. Sadly this is normal for some of us builders — how many incomplete projects adorn your home and workshop? Still, this web page might fuel your *own* experiments.

For years, I've attempted to update my Popcorn Superhet from 1998 but always seem to lose interest from numerous distractions such as VHF and UHF experiments and other non-radio stuff. So here it is so far — raw and unrefined: more experiments from my analog-centric workbench. To clarify — I love the new digital radio stuff, but that's well covered on the net by numerous code writers and those bleeding edge, frontier-pioneer types. I prefer a 50 Ω lab with all the visceral enjoyment and learning it has to offer. To each his own.

This web page remains unlisted on the main top level menu — and for good reason.

Click for some supplemental lab notes.

2. N = 4, Gaussian-to-6 dB Crystal Ladder Filter

I frequency matched four 11.0592 crystals, characterized them and took an average of those crystal parameters plus some data from Zverev and inputted this into xlad08.exe, a program that ships with EMRFD.

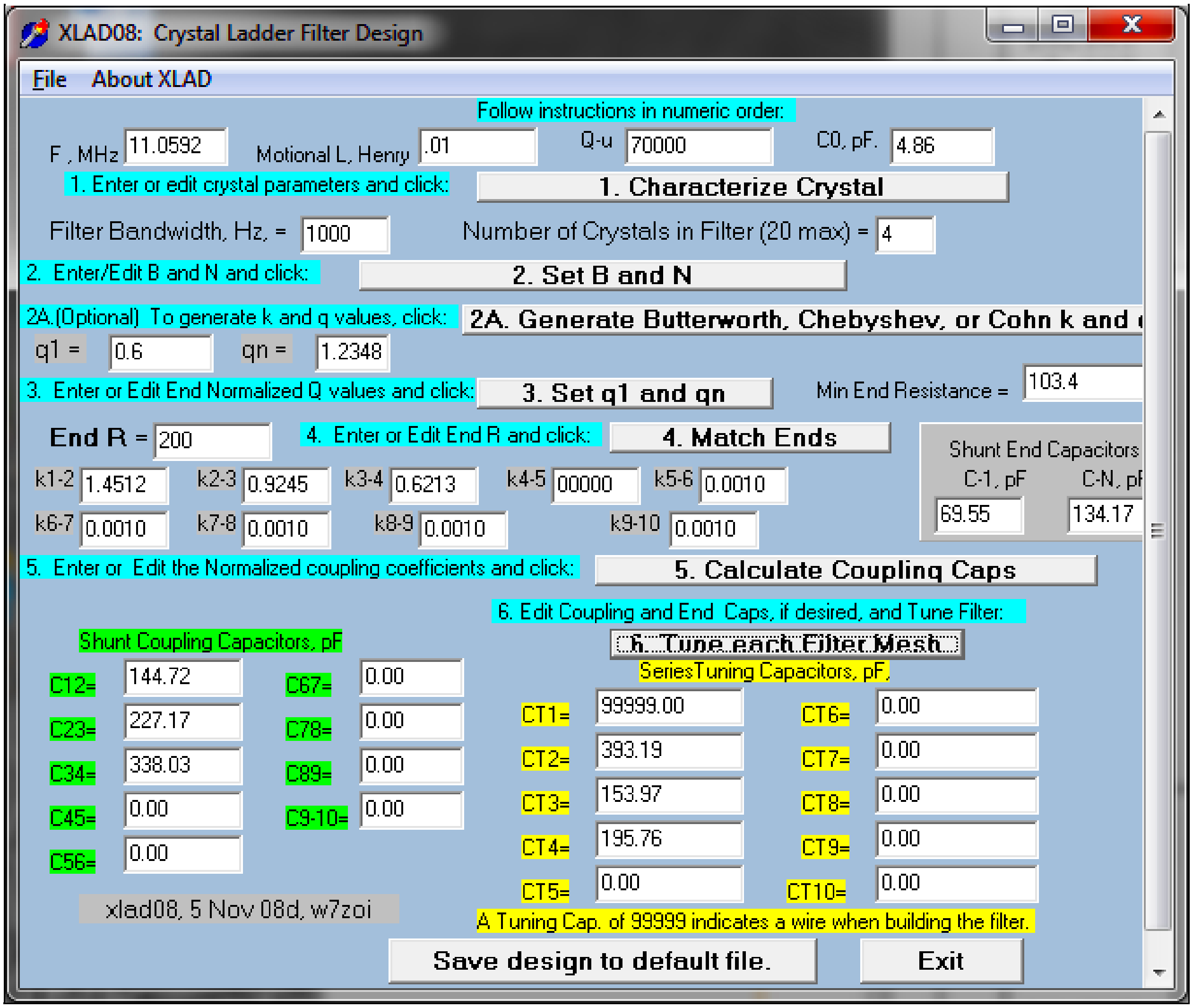
XLAD08: Crystal Ladder Filter Design
File
About XLAD
1. Characterize Crystal
2. Set B and N
2A. Generate Butterworth, Chebyshev, or Cohn k and
3. Set q1 and qn
4. Match Ends
5. Calculate Coupling Caps
6. Tune each Filter Mesh
Save design to default file.
Exit

Follow instructions in numeric order:

F , MHz 11.0592
Motional L, Henry .01
Q-u 70000
C0, pF. 4.86

1. Enter or edit crystal parameters and click:

Filter Bandwidth, Hz, = 1000
Number of Crystals in Filter (20 max) = 4

2. Enter/Edit B and N and click:

2A.(Optional) To generate k and q values, click:

q1 = 0.6
qn = 1.2348

3. Enter or Edit End Normalized Q values and click:

Min End Resistance = 103.4

End R = 200

4. Enter or Edit End R and click:

Shunt End Capacitors

C-1, pF	C-N, pF
69.55	134.17

k1-2 1.4512
k2-3 0.9245
k3-4 0.6213
k4-5 00000
k5-6 0.0010
k6-7 0.0010
k7-8 0.0010
k8-9 0.0010
k9-10 0.0010

5. Enter or Edit the Normalized coupling coefficients and click:

6. Edit Coupling and End Caps, if desired, and Tune Filter:

Shunt Coupling Capacitors, pF

C12=	144.72	C67=	0.00
C23=	227.17	C78=	0.00
C34=	338.03	C89=	0.00
C45=	0.00	C9-10=	0.00
C56=	0.00		

SeriesTuning Capacitors, pF.

CT1=	99999.00	CT6=	0.00
CT2=	393.19	CT7=	0.00
CT3=	153.97	CT8=	0.00
CT4=	195.76	CT9=	0.00
CT5=	0.00	CT10=	0.00

xlad08, 5 Nov 08d, w7zoi

A Tuning Cap. of 99999 indicates a wire when building the filter.

Above — Xlad08.exe screen shot.

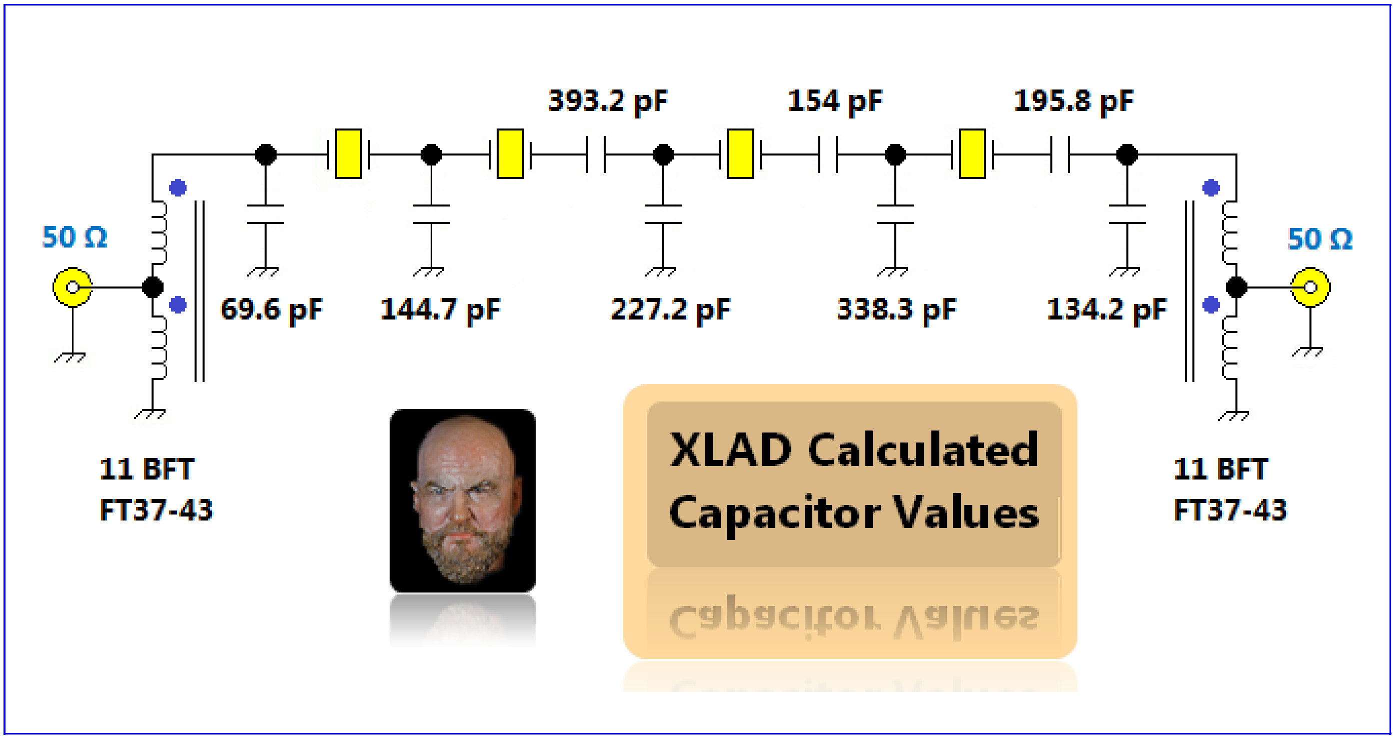
393.2 pF
154 pF
195.8 pF
50 Ω
50 Ω
69.6 pF
144.7 pF
227.2 pF
338.3 pF
134.2 pF
11 BFT
FT37-43
11 BFT
FT37-43
XLAD Calculated
Capacitor Values

Above — The xlad filter expressed as a schematic. Click for a GPLA plot of the filter.

I built and hand tuned this crystal filter with my analog sweep system. Click for a photo of the optimized filter breadboard — I used 1 or 2 parallel capacitors to tune each capacitance to derive the best possible skirt shape. Click for a sweep of this optimized filter in my 'scope. 2 bifilar transmission line transformers provided the required 200 Ω port termination in my 50 Ω sweep system.

I sought a crystal filter based on the xlad08 calculated values using only 1 nearest standard value in each capacitor slot.

Transitional filters like the G-to-6 dB, are generally tolerant of part substitutions and thus I sought a filter with only 1 nearest 5% standard-value capacitor in *every* slot instead of 2 sticking 2 close in value parallel caps to make up the needed capacitance as needed.

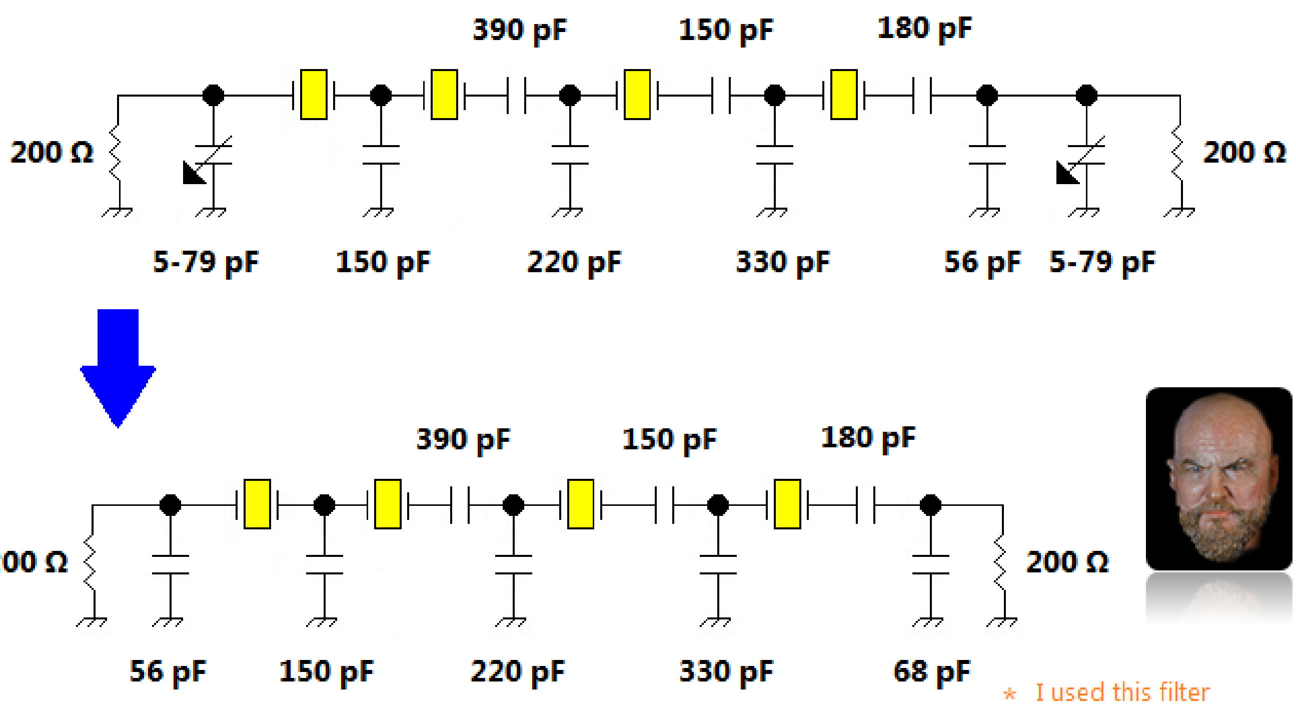

IF = 11.0592 MHz, Lm = 0.01, Qu = 70K, C0 = 4.86 pF, BW = 1KHz Q1= 0.6, QN = 1.2348, R = 200 ohms, K1-2 = 1.4513, K2-3 = 0.9245, K3-4 = 0.6213

N=4 Gaussian-to-6 dB

Above —The 2-step transition to a 1 capacitor, nearest standard value in each capacitor slot. In the top diagram, I placed a trimmer cap on each end to allow filter tweaking while looking at the swept filter in my 'scope. I've learned that adjusting the parallel cap nearest to each port a simple way to tweak a G-to-6 dB filter. After setting the best looking skirt, I removed and measured the end parallel capacitance and substituted the nearest standard fixed capacitor. Manipulating the capacitors values will change filter bandwidth and return loss.

You might compare the lower filter to the xlad calculated values to see how tolerant the circuit is.

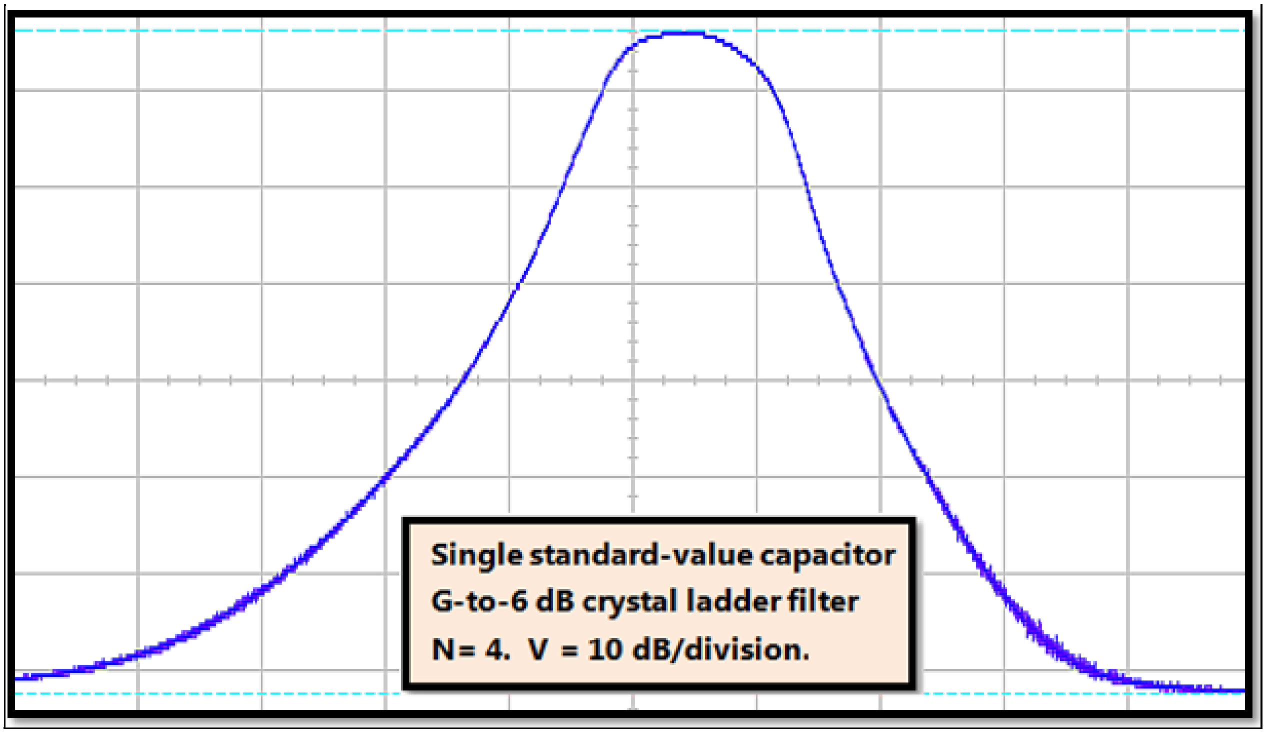

Above — A sweep of the single value capacitor version that's used in the Almost Popcorn receiver. While the 1 KHz filter skirt isn't perfect, it's reasonable. Click for the test bench breadboard. This particular filter measured 1/2 power bandwidth = 1227 KHz and the insertion loss was ~3.6 dB.

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3. IF Amplifier

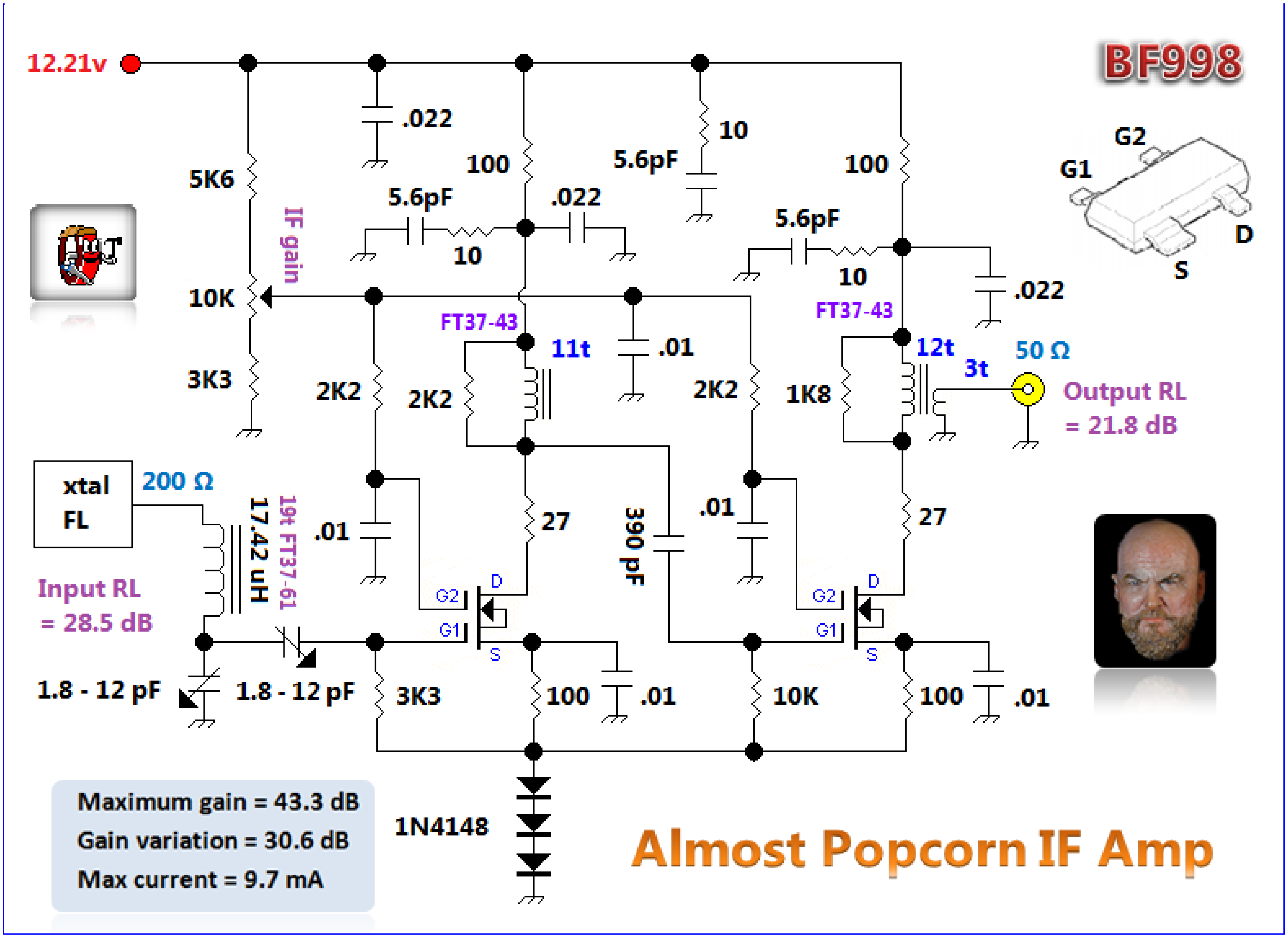
12.21v
BF998
.022
10
100
5.6pF
100
G2
G1
D
S
5K6
5.6pF
.022
5.6pF
IF gain
10
10
10K
FT37-43
FT37-43
.022
11t
.01
12t
3t
50 Ω
3K3
2K2
2K2
2K2
1K8
Output RL
= 21.8 dB
xtal
FL
200 Ω
17.42 uH
19t FT37-61
.01
27
390 pF
.01
27
Input RL
= 28.5 dB
G2
D
G1
S
G2
D
G1
S
1.8 - 12 pF
1.8 - 12 pF
3K3
100
.01
10K
100
.01
Maximum gain = 43.3 dB
Gain variation = 30.6 dB
Max current = 9.7 mA
1N4148
Almost Popcorn IF Amp

Above — Version 2 of a popcorn IF amplifer idea with BF998s. IF = 11.0572 MHz.

I have no use for AGC in my personal receivers since I listen through a speaker and *always* ride the RF gain control with my finger. Since the BF998 has gain into UHF, wideband decoupling + bypass SMT R-C networks filter each MOSFET in case of oscillations. Click and click for photos. This circuit will operate fine with just 0.022 µF bypass caps.

A network matches the 200 Ω xtal filter output impedance to the 3K3 input Z of the IF amp cascade. The L-C-C network has become a favorite matching weapon — 2 tweaks is often better than the 1 offered by a garden variety L-network. The product detector that follows this stage is a Level 7 diode ring mixer soldered onto the audio preamp board. This receiver will feature some modish circuits aimed at low noise + high fidelity but still stay "almost popcorn". Anyhow, that's my hope.

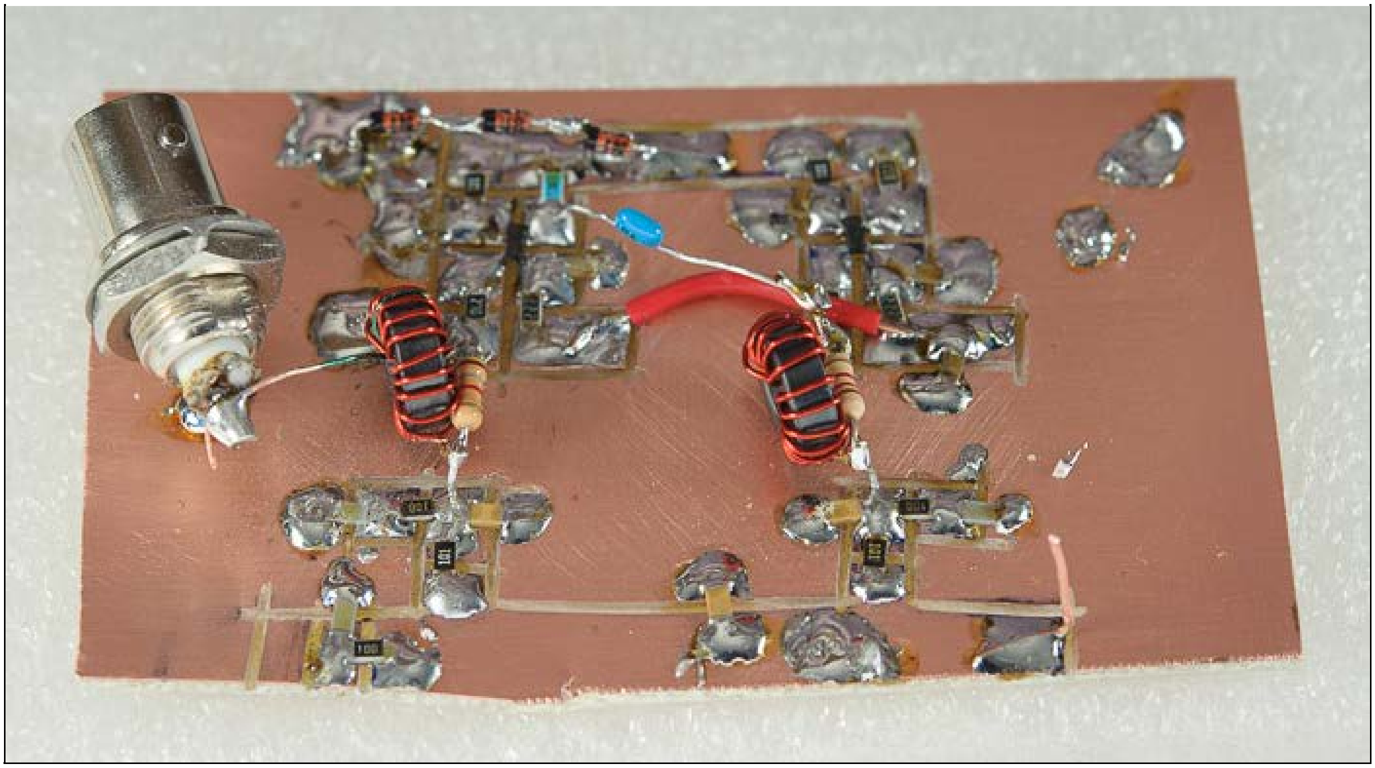

Above — A breadboard of the Popcorn IF amp sans the input network. I tested this stage using an oscillator with a 3K3 output impedance and liked what I saw. Click for a reverse angle view. After this build, I ordered some SMT versions of the 1N4148 diode. The BNC connector was only soldered on the board for testing purposes.

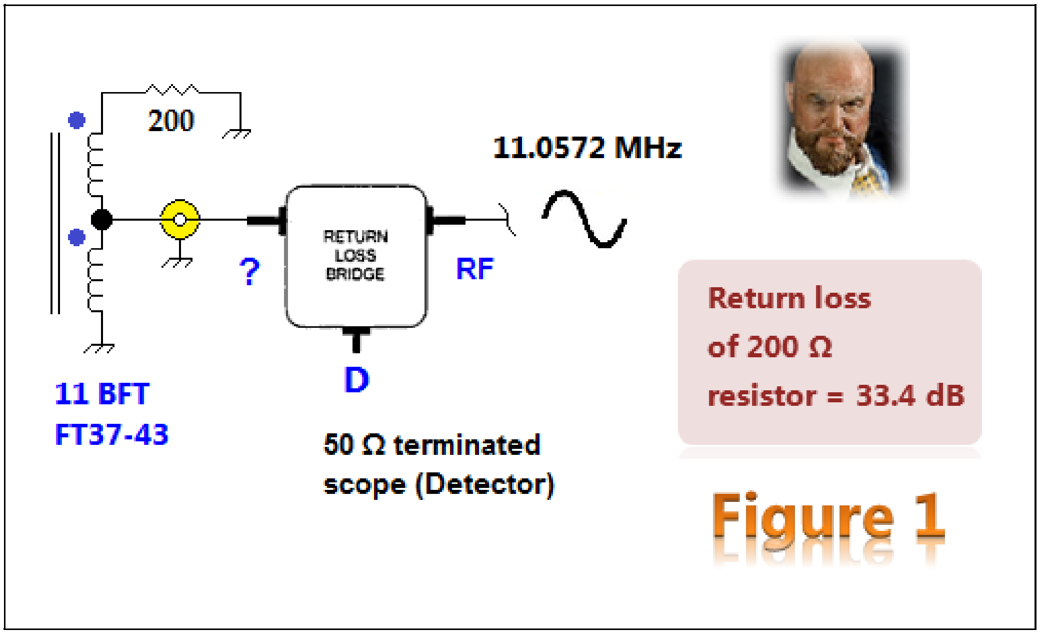

Above — Setting up to measure the return loss of the 200 Ω input Z of my popcorn IF amp. 1 difference between scratch homebrew and kit building is all the measurements you need to make to optimize your scratch receiver. A joie de vivre stems from our descriptive/exploratory analysis before and after making our breadboard. We just learn from mistakes and move forward to improve both our knowledge and gear.

I chose a 200 Ω input impedance for a reason — it's easy to apply a standard 50 Ω return loss bridge via a 4:1 transmission line transformer to establish the correct input impedance for the single frequency matching network.

From the set-up shown above, I found that with a 200 Ω resistor, my return loss at 11.057 MHz = 33.4 dB. This signals the very best we can achieve with our network: directivity. Click for a photo of the above experiment breadboarded on a scap of copper clad board.

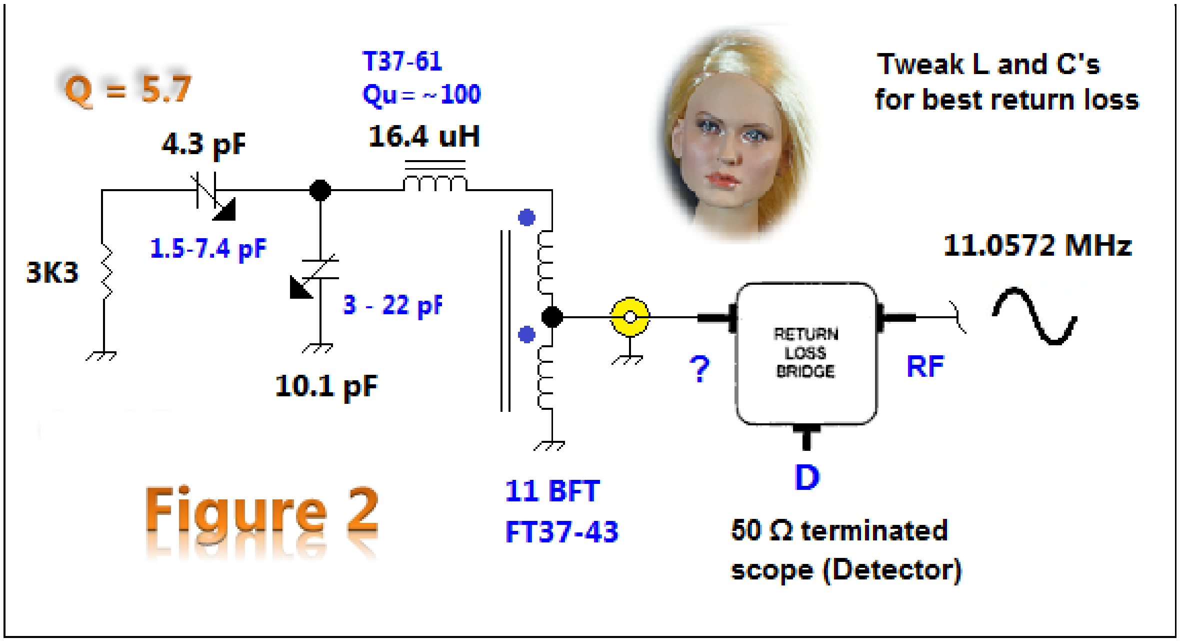
Q = 5.7
T37-61
Qu = ~100
16.4 uH
4.3 pF
1.5-7.4 pF
3K3
3 - 22 pF
10.1 pF
Tweak L and C's
for best return loss
11.0572 MHz
RETURN LOSS BRIDGE
?
RF
D
11 BFT
FT37-43
50 Ω terminated
scope (Detector)

Figure 2

Above — The schematic of my 200 to 3K3 Ω matching network. I designed it with zmat08.exe, a program by Wes that I first used as a console app since the days of DOS. *Zmat08 program comes with EMRFD.* Click for a screen shot of from Zmat08.
The calculated values from Zmat08 only consider a pure resistance and not a complex impedance, so on-bench adjustments of the design L and C values are normally required and fun to do. Variable trimmer caps make tweaking the C easy.

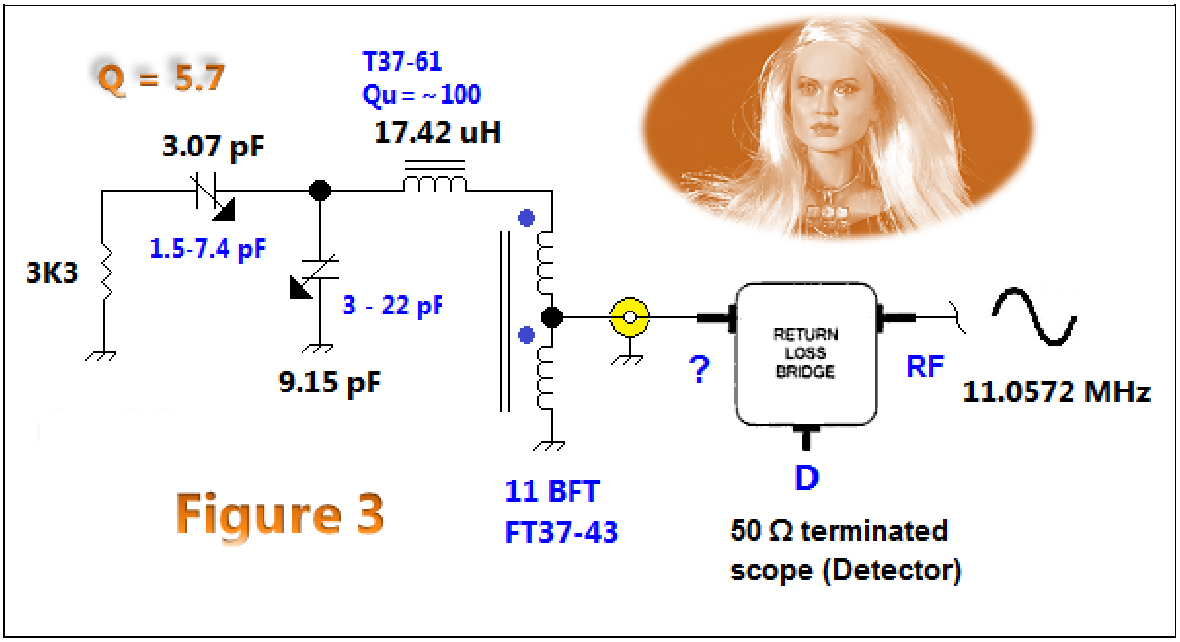
Q = 5.7
T37-61
Qu = ~100
17.42 uH
3.07 pF
1.5-7.4 pF
3K3
3 - 22 pF
9.15 pF
RETURN LOSS BRIDGE
?
RF
11.0572 MHz
D
11 BFT
FT37-43
50 Ω terminated
scope (Detector)

Figure 3

Above — The final— *measured* schematic — While watching the peak to peak voltage on my 50 Ω terminated scope, L and both capacitors were tweaked until I found the highest return loss. L is tweaked by scrunching or expanding turns, or adding/removing turns as needed: in this case, I added a turn and expanded the windings slightly. With the L-C-C match, a return loss greater than 25 dB may arise plying good bench practices — mine measured a lovely 29.2 dB. I removed and measured the inductor plus 2 capacitors to get the values shown **black** in Figure 3.

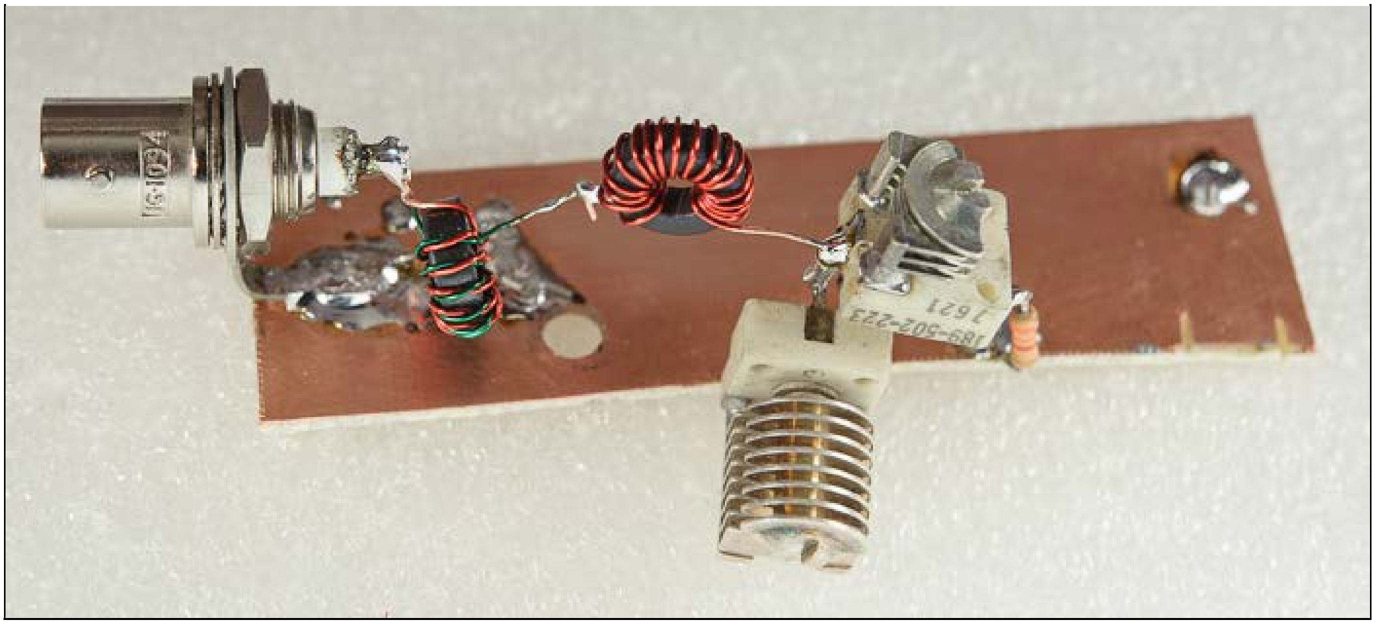

Above — A breadboard of the Figure 3 network before I experimented to find the best L (and shortened its leads).

After I making and tweaking the Figure 3 network, I took the coil along with 2 cheaper trimmer caps and added them to my IF amplifer breadboard. While measuring the return loss of the IF strip input, I had to expand a couple of links on the inductor, but after tweaking the L and the 2 trimmer caps, I measured a 28.5 dB return loss. This ensures my crystal filter will see close to a 200 Ω termination at the IF input. I love well matched stages!

Further, I made a L network and then a L-C-C network to match the output port, however, UHF oscillations erupted. I then went back to a simple broadband transformer and measured a RL of 21.8 dB with a 12:3 turns ratio. Done.

---

4. Mixer and Post-Mixer Amplifer

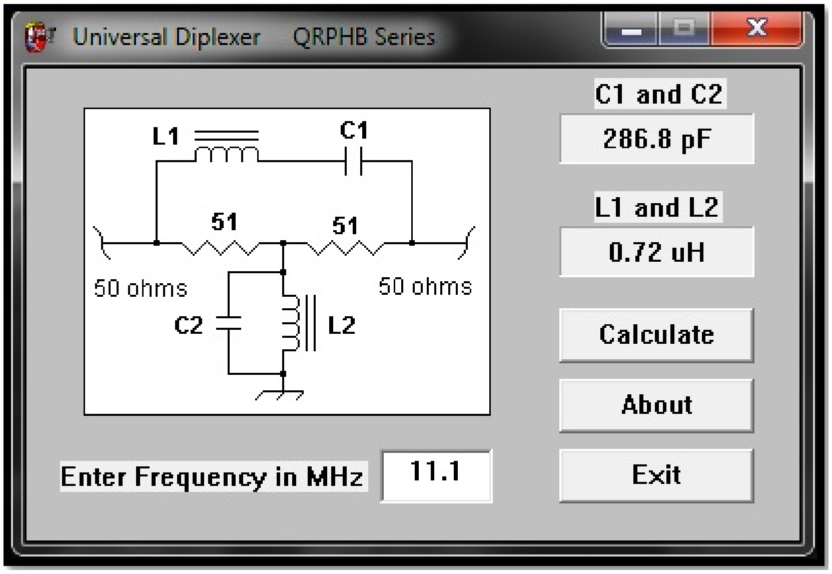

Universal Diplexer QRPHB Series

C1 and C2: 286.8 pF

L1 and L2: 0.72 uH

Enter Frequency in MHz: 11.1

Above — I tested the W1JR (Joe Reisert) bridged-tee diplexer against another design used by Ten-Tek. I'll show the outcomes on the Almost Popcorn receiver page some day, but the W1JR better fullfills its purpose; termination from DC to daylight at the mixer IF port. I calculated the L and C values for a 11.0592 MHz IF with my Universal Diplexer application from many moons ago.

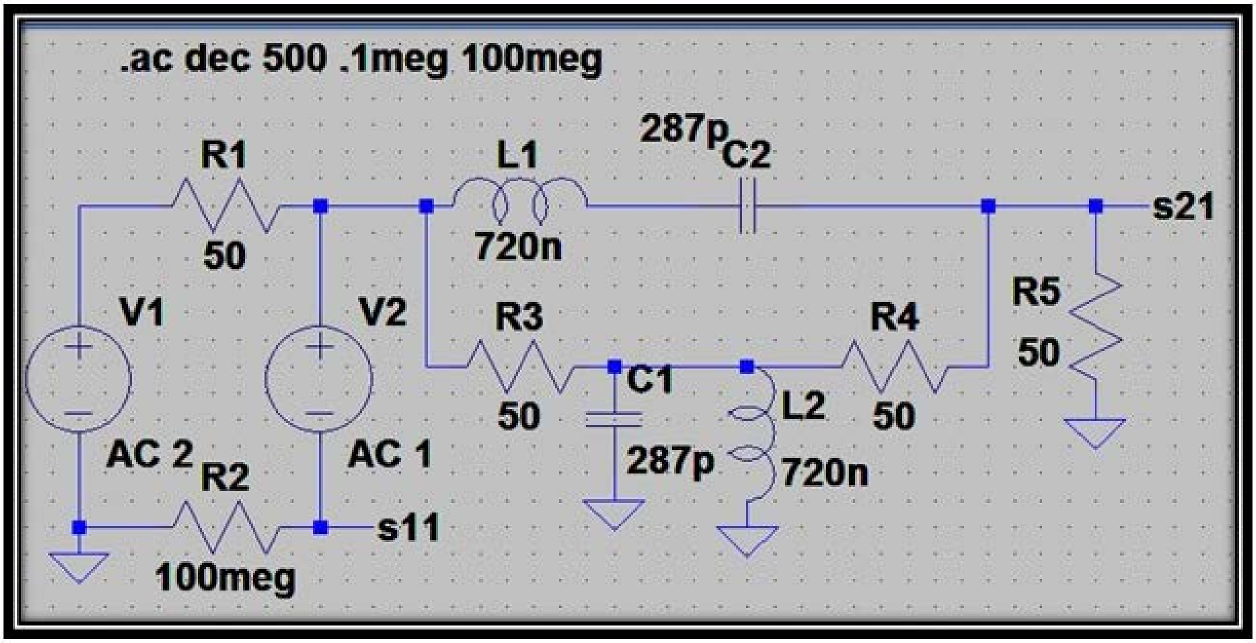
.ac dec 500 .1meg 100meg
R1
50
L1
720n
287p
C2
s21
V1
V2
R3
50
C1
287p
L2
720n
R4
50
R5
50
AC 2
AC 1
R2
100meg
s11

Above — SPICE provides a great way to assess a diplexer since you can plot both S21 and S11 against frequency.

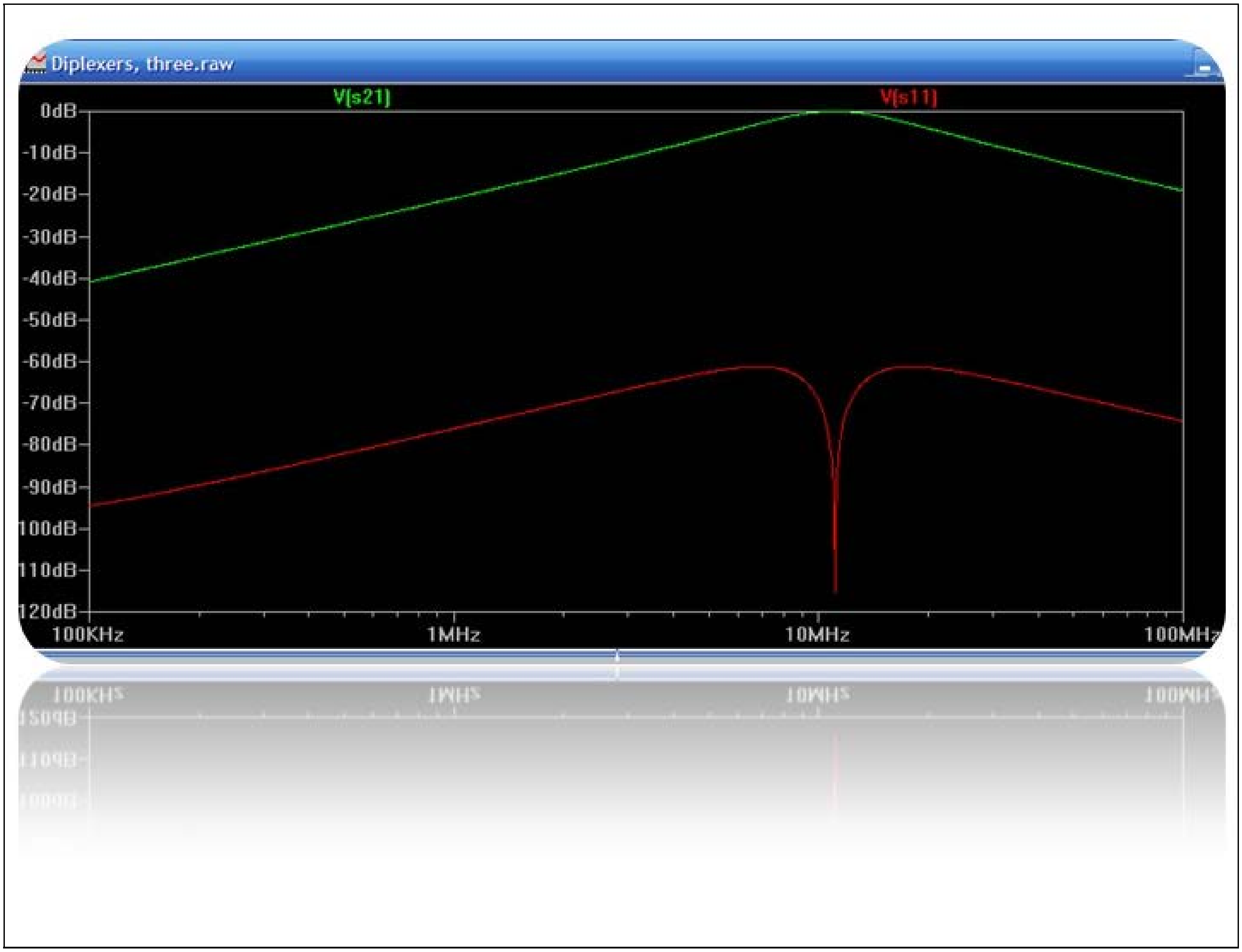

Above — A fantastic match! Thanks Joe for the design and to **Wes, W7ZOI** for his help with diplexers and the SPICE plots through many years of related experiments. Since web publishing the diplexer page, at least 500 diplexer-related emails have come in. Human translated versions of the web page exist in at least 3 languages.

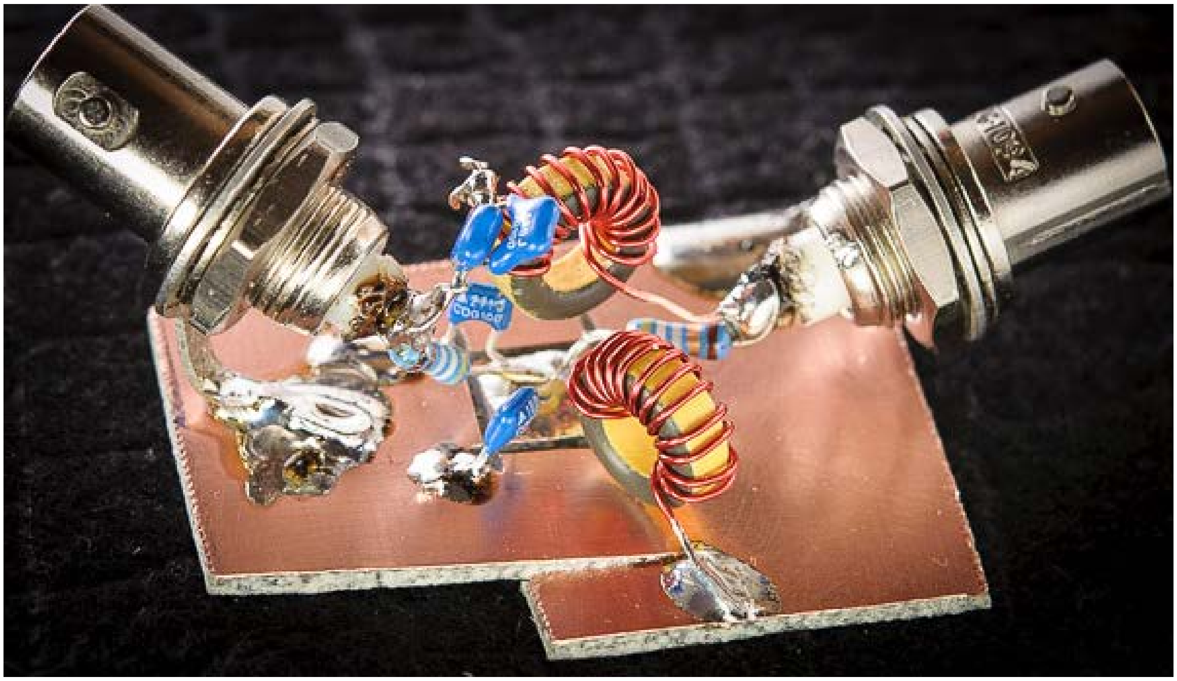

Above — The evaluation breadboard of my W1JR diplexer. Those are T30-6 toroids but they look huge in this photo.

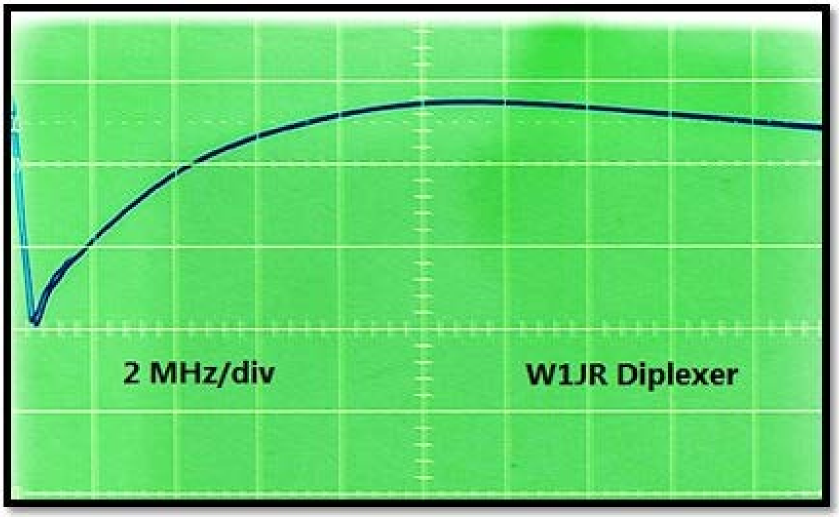

Above — Tracking generator plus spectrum analysis sweep. SPICE does a better of examining the high-pass side.

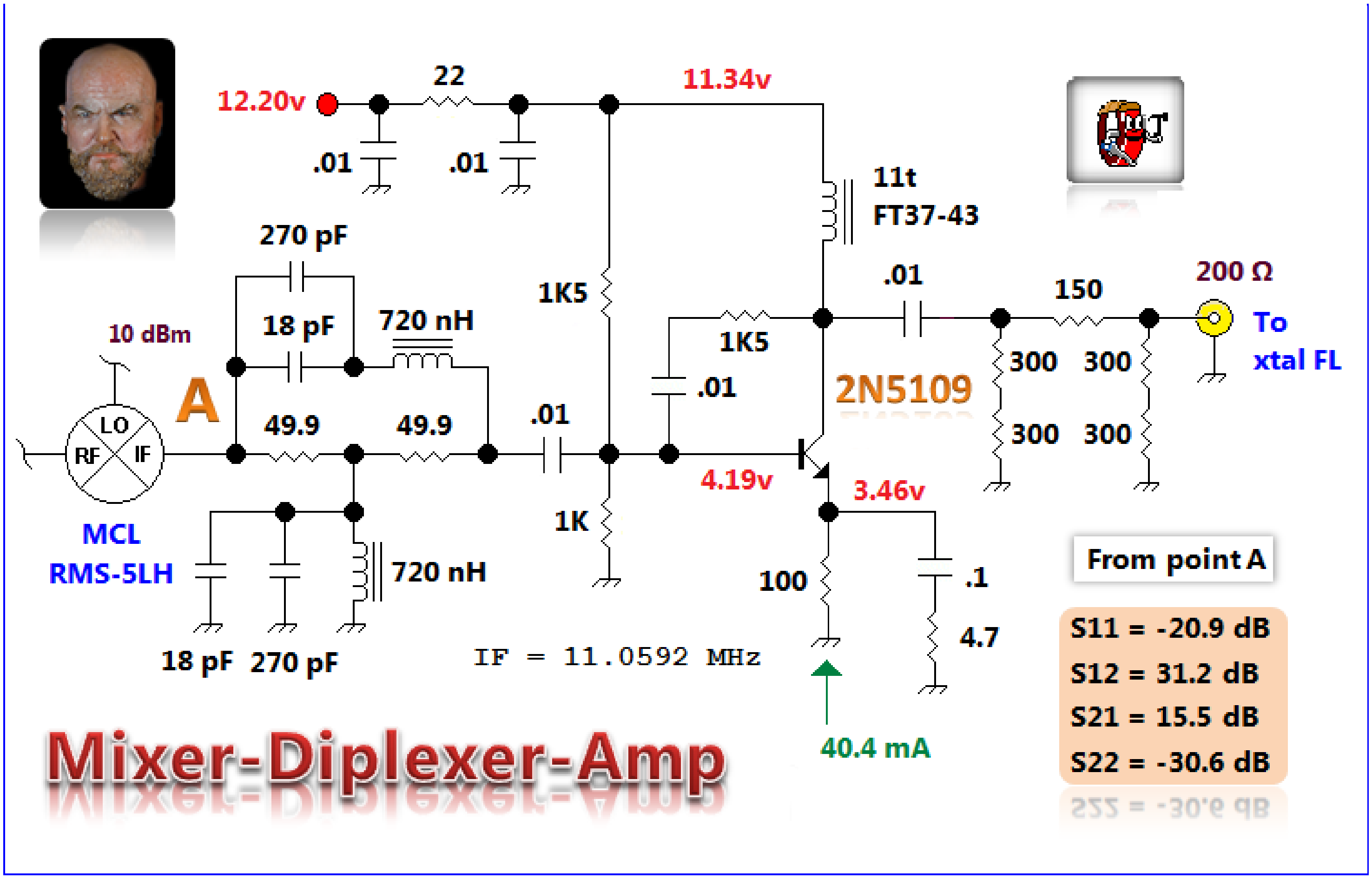
12.20v
22
11.34v
.01
.01
11t
FT37-43
270 pF
1K5
.01
150
200 Ω
To
xtal FL
10 dBm
18 pF
720 nH
1K5
300
300
A
.01
2N5109
LO
RF
IF
49.9
49.9
.01
300
300
4.19v
3.46v
MCL
RMS-5LH
1K
720 nH
100
.1
From point A
4.7
S11 = -20.9 dB
S12 = 31.2 dB
S21 = 15.5 dB
S22 = -30.6 dB
18 pF
270 pF
IF = 11.0592 MHz
40.4 mA
Mixer-Diplexer-Amp

Above — A look at the diode ring mixer, diplexer and post-mixer amp from the latest version of my Almost Popcorn Receiver. I tested the diplexer and RF amp with pad as one unit (see the S-values).

It did not make sense to use a transmission line transformer to get 50 Ω on the amp collector and then use another transformer to build it back up to the needed 200 Ω impedance for the crystal filter, so I just employed a single choke driving a 200 Ω Z attenuator pad.
S parameters are 50 Ω values, thus S22 = the 200 Ω transformed into 50 Ω. After terminating the stages 200 Ω output with a 4:1 Z transmission line transformer, I tested it like any other 50 Ω circuit andmeasured S22 as -30.6 dB — my xtal filter input Z is well established.

Even with the 6 dB *(200 Ω)* attenuator pad and losses from the diplexer, the stage gain from point A = 15.5 dB. Click for to view a bigger picture of the breadboard. Losses from a diode ring mixer are typically 5 - 7 dB.

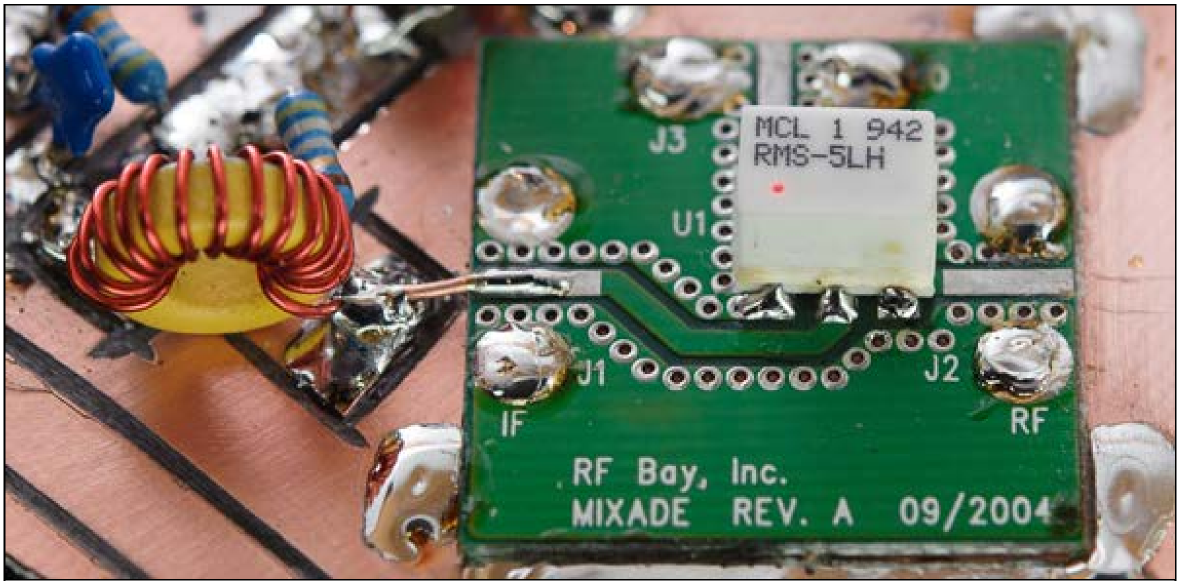
J3
MCL 1 942
RMS-5LH
U1
J1
J2
IF
RF
RF Bay, Inc.
MIXADE REV. A 09/2004

Above — Mixer and diplexer assembly. The RMS-5LH takes 10 dBm LO drive.

5. Product Detector and Post Product Detector AF Amplifer

I kept the diode ring for a product detector: an SBL-1 driven with a xtal oscillator (BFO).

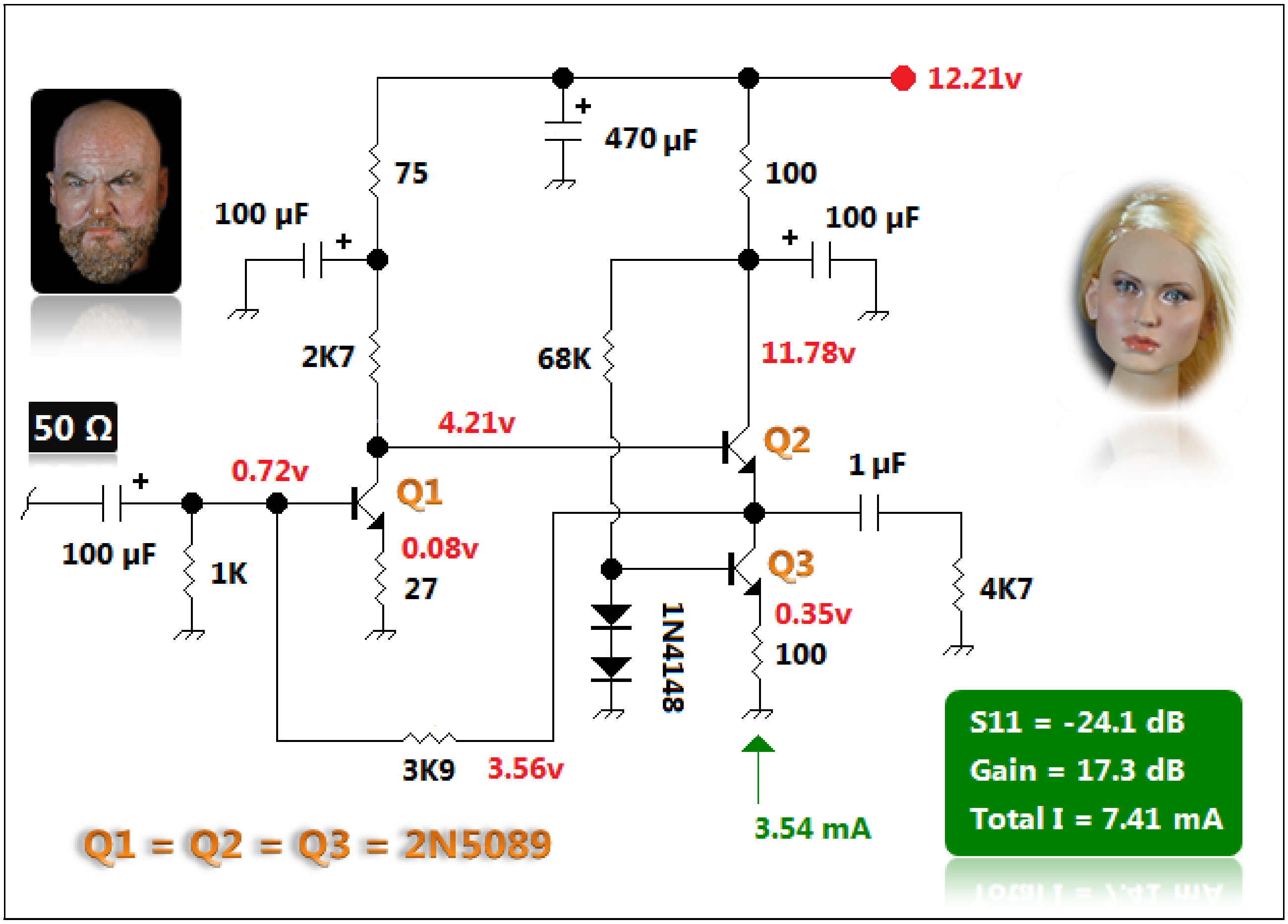
12.21v
470 µF
75
100
100 µF
100 µF
2K7
68K
11.78v
50 Ω
4.21v
Q2
1 µF
0.72v
Q1
0.08v
100 µF
1K
27
Q3
4K7
0.35v
1N4148
100
S11 = -24.1 dB
Gain = 17.3 dB
Total I = 7.41 mA
3K9
3.56v
3.54 mA
Q1 = Q2 = Q3 = 2N5089

Above — My post-product detector amplifier: a common emitter/ emitter follower pair arranged for a 50 Ω input impedance with shunt and series feedback. Getting the biggest, clean sine wave in and out posed my only goal — the 3.54 mA current source on the follower helps that cause. The input Z tested quite insensitive to output load variations and the (S11) return loss = 24.1 dB.

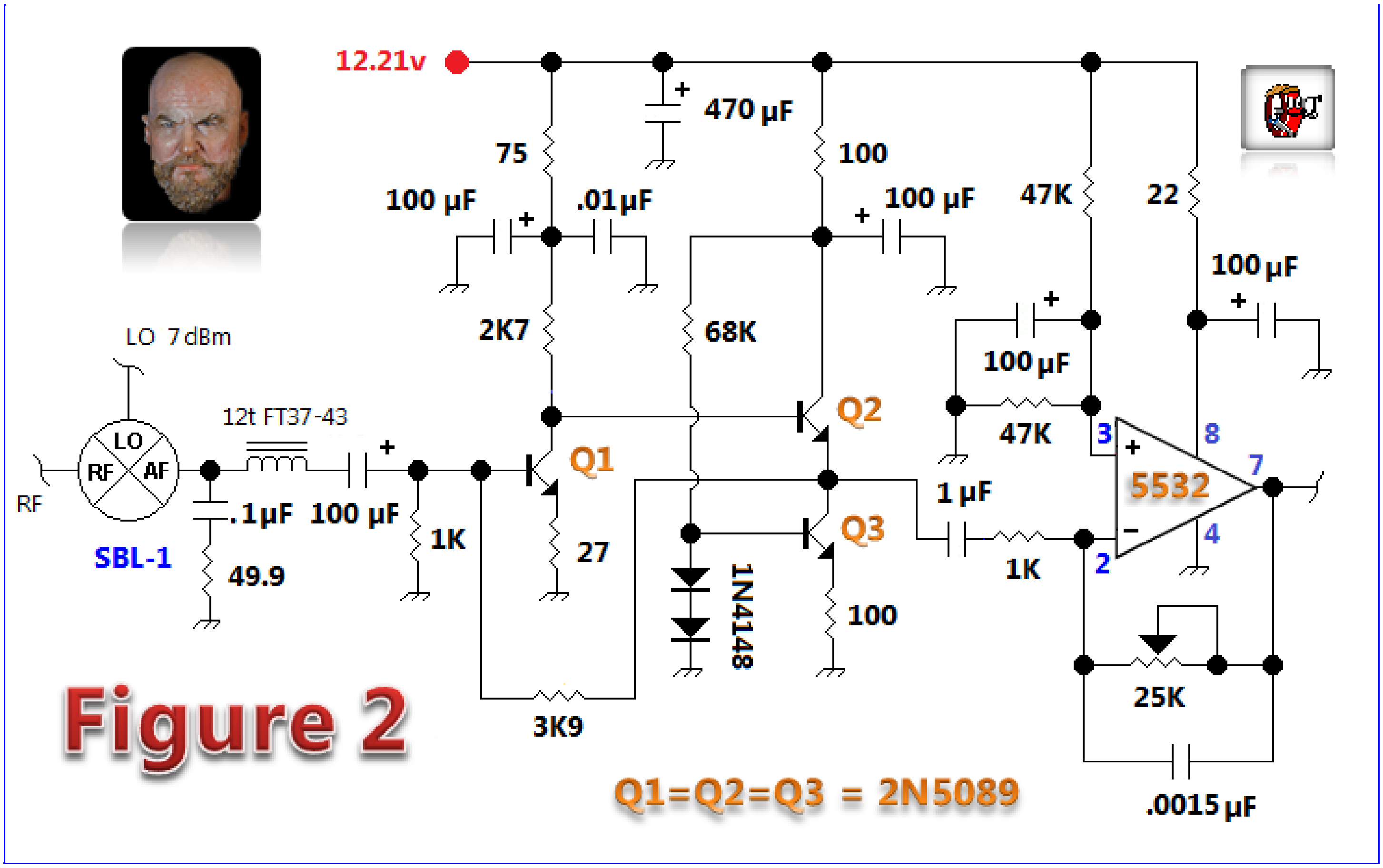
12.21v
470 µF
75
100
100 µF
.01µF
100 µF
47K
22
100 µF
2K7
68K
100 µF
LO 7dBm
47K
Q2
12t FT37-43
LO
RF
AF
Q1
3
8
+
7
5532
RF
1 µF
.1µF
100 µF
1K
-
SBL-1
27
Q3
1K
2
4
49.9
1N4148
100
25K
3K9
Q1=Q2=Q3 = 2N5089
.0015 µF

Figure 2

Above — The "Full Monty product detector to AF preamp". A MCL SBL-1 diode ring mixer drives the 50 Ω input Z feedback pair and finally a 5532 op-amp with adjustable gain. The 25K gain trimmer pot allows the builder to accommodate factors such as whether the stage is a DC receiver, or an RF-AF block for a superheterodyne receiver like in this radio. I'll set the gain as low as possible and hope to build up my AC voltage with active, gain producing low-pass filter op-amp stages.

The output t pin 7 is directly coupled to an op-amp AF filter. With software we can easily design a myriad of audio filters: band-pass, low-pass, high-pass, all-pass etc. I only run low-pass filters in this slot and even here we must decide whether to make our reponse Gaussian to 6 dB (or 12 dB), Bessel, Butterworth, or a Chebyshev with some degree of ripple. I'm testing out a few designs with an eye towards simplicity and 10% parts.

Spurred on by curiosity, with my ears as the main evaluation tool; I currently have a 5532 paper design to deliver 20 dB gain with a 500 Hz pass-band, Gaussian to 12 dB low-pass response. Click for schematic, I chose a 500 Hz cut off frequency since the skirt shape by definition is subtle and the Q low. This trick should better roll off the AF above 1 KHz a little faster without the ugly group delay associated with steeper filters employing more poles. We shall see!

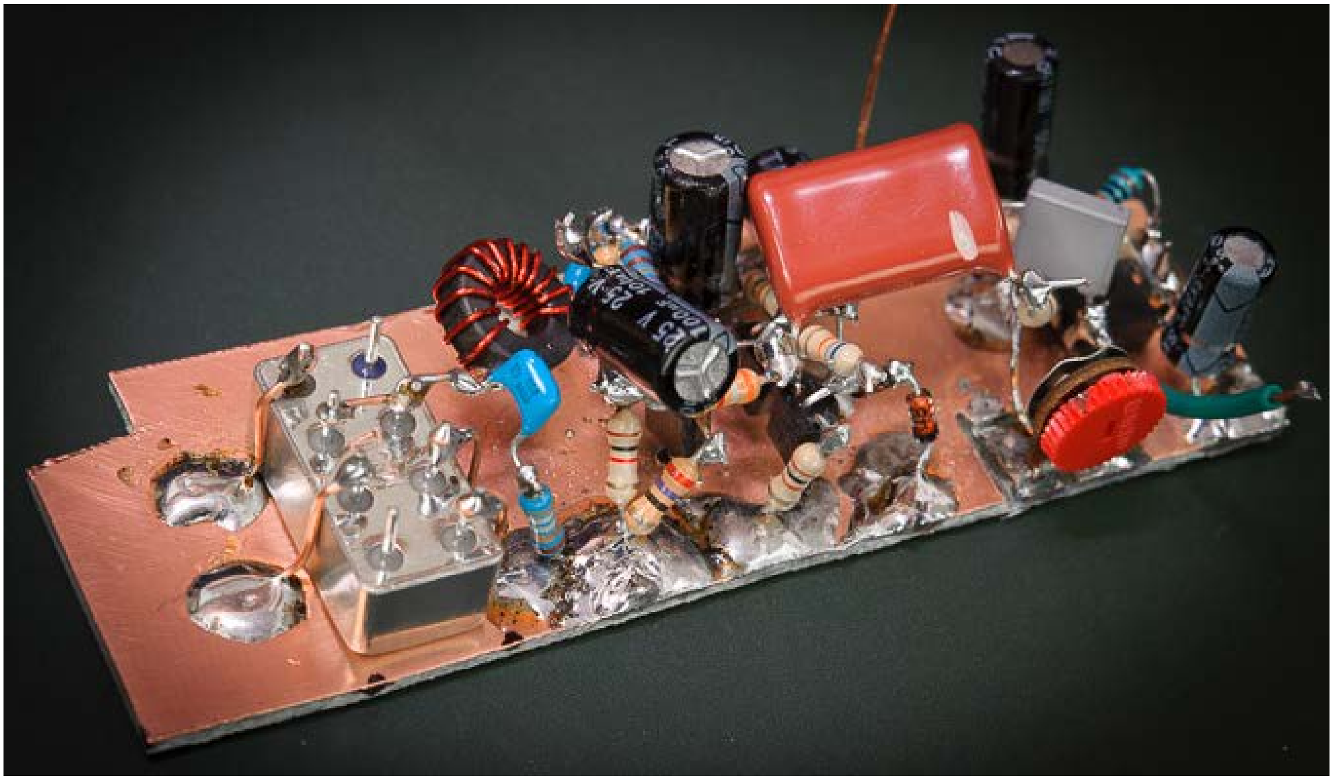

Above — The compact breadboard of Figure 2.

Audio filters and AF power amp are incomplete.....

RF — Test and Measurement

Almost Popcorn Superhet — Supplemental Lab Notes

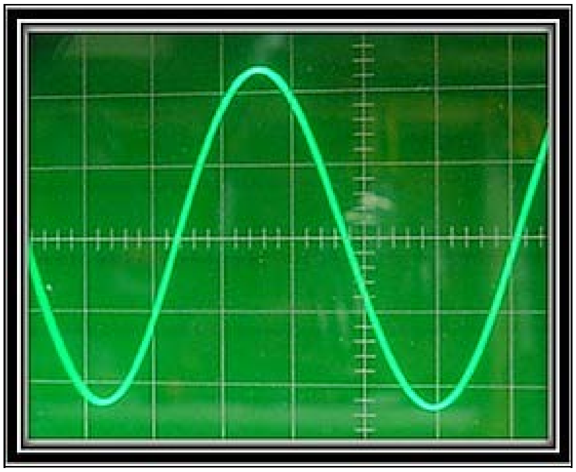

These lab notes supplement the Almost Popcorn Superhet Receiver Web page which has remained incomplete for greater than 10 years. I'm sorry for the rough writing and procrastination.

N = 3 Gaussian-to-6 dB Crystal Ladder Filter

I spent a pleasant Saturday afternoon designing, building and testing Gaussian-to-6 dB crystal filters. I inputted some xtal parameters + constants from Zverev into Xlad08.exe from EMRFD. Here's the N = 3 version

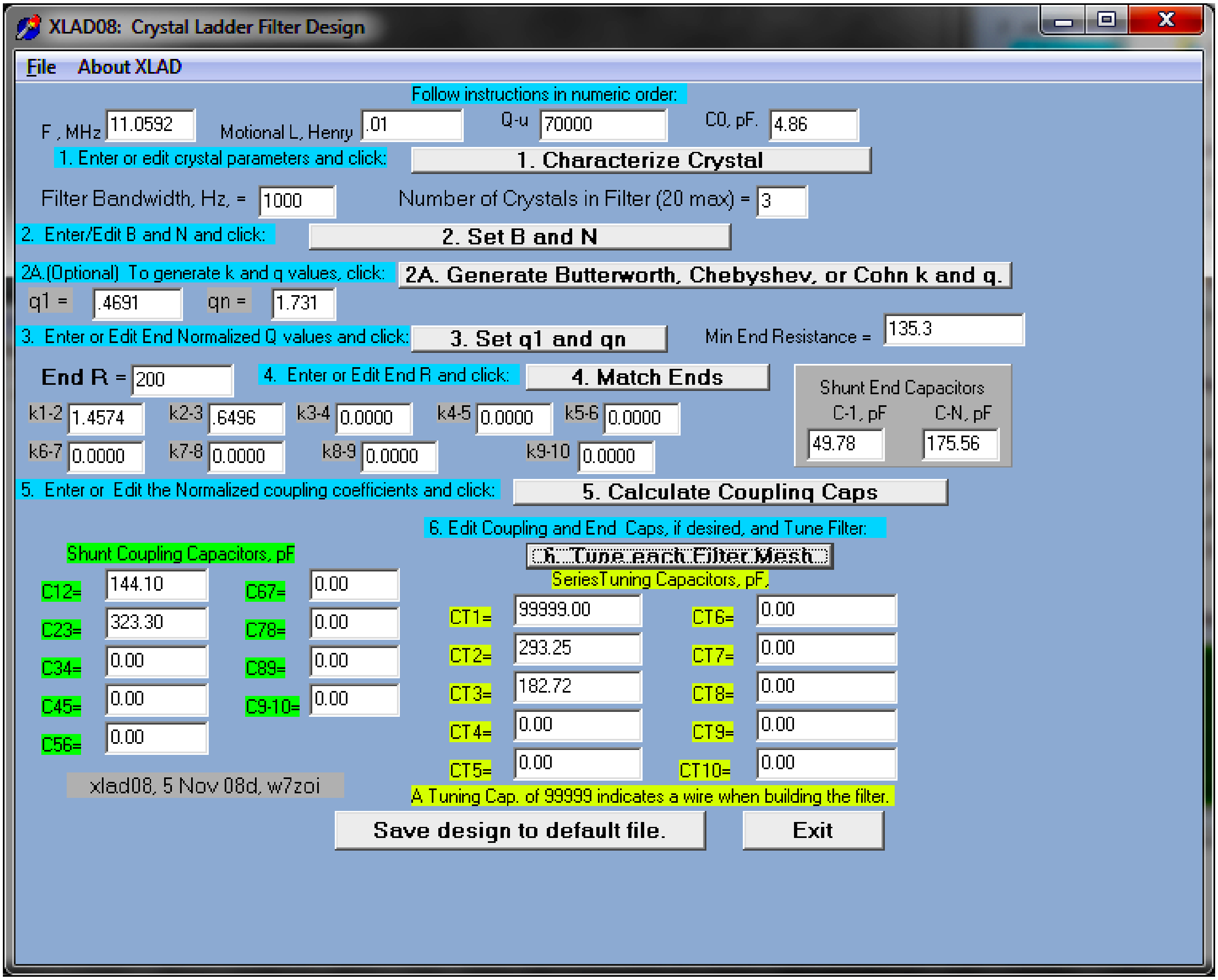
XLAD08: Crystal Ladder Filter Design
File
About XLAD
1. Characterize Crystal
2. Set B and N
2A. Generate Butterworth, Chebyshev, or Cohn k and q.
3. Set q1 and qn
4. Match Ends
5. Calculate Coupling Caps
6. Tune each Filter Mesh
Save design to default file.
Exit

Follow instructions in numeric order:

F , MHz 11.0592
Motional L, Henry .01
Q-u 70000
C0, pF. 4.86

1. Enter or edit crystal parameters and click:

Filter Bandwidth, Hz, = 1000
Number of Crystals in Filter (20 max) = 3

2. Enter/Edit B and N and click:

2A.(Optional) To generate k and q values, click:

q1 = .4691
qn = 1.731

3. Enter or Edit End Normalized Q values and click:

Min End Resistance = 135.3

End R = 200

4. Enter or Edit End R and click:

Shunt End Capacitors

C-1, pF 49.78
C-N, pF 175.56

k1-2 1.4574
k2-3 .6496
k3-4 0.0000
k4-5 0.0000
k5-6 0.0000
k6-7 0.0000
k7-8 0.0000
k8-9 0.0000
k9-10 0.0000

5. Enter or Edit the Normalized coupling coefficients and click:

6. Edit Coupling and End Caps, if desired, and Tune Filter:

Shunt Coupling Capacitors, pF

C12= 144.10
C23= 323.30
C34= 0.00
C45= 0.00
C56= 0.00
C67= 0.00
C78= 0.00
C89= 0.00
C9-10= 0.00

SeriesTuning Capacitors, pF.

CT1= 99999.00
CT2= 293.25
CT3= 182.72
CT4= 0.00
CT5= 0.00
CT6= 0.00
CT7= 0.00
CT8= 0.00
CT9= 0.00
CT10= 0.00

xlad08, 5 Nov 08d, w7zoi

A Tuning Cap. of 99999 indicates a wire when building the filter.

Above — A screen capture from Xlad. This app allows skilled builders to depart from the typical Cohn (Min-Loss) filter and tune filter poles to derive beautiful skirt shapes and low insertion loss if wanted. I'm not a great crystal filter designer, but I've seen work from friends who have a knack for it: imagine making a N= 8 to 10 crystal CW filter with just ~1 dB insertion loss like these builders! Click for the GPLA simulation.

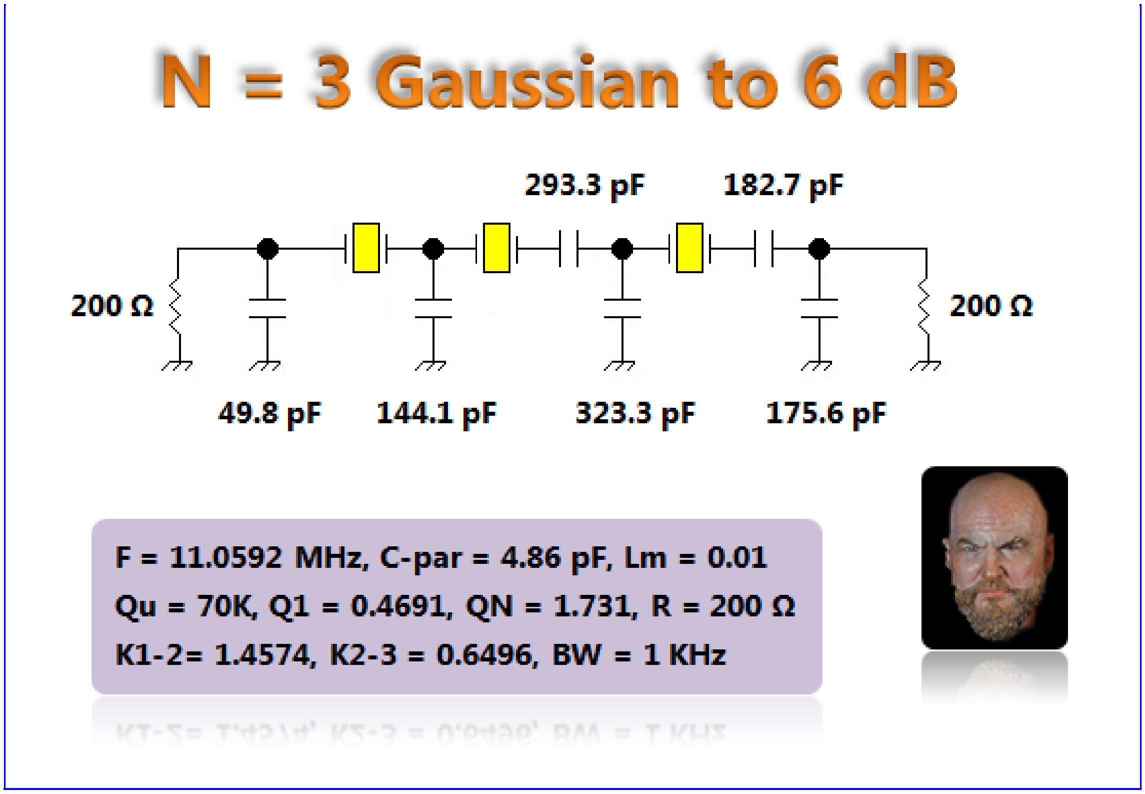
N = 3 Gaussian to 6 dB
293.3 pF
182.7 pF
200 Ω
200 Ω
49.8 pF
144.1 pF
323.3 pF
175.6 pF
F = 11.0592 MHz, C-par = 4.86 pF, Lm = 0.01
Qu = 70K, Q1 = 0.4691, QN = 1.731, R = 200 Ω
K1-2= 1.4574, K2-3 = 0.6496, BW = 1 KHz

Above — Gaussian-to-6 dB xtal filer schematic where N = 3.

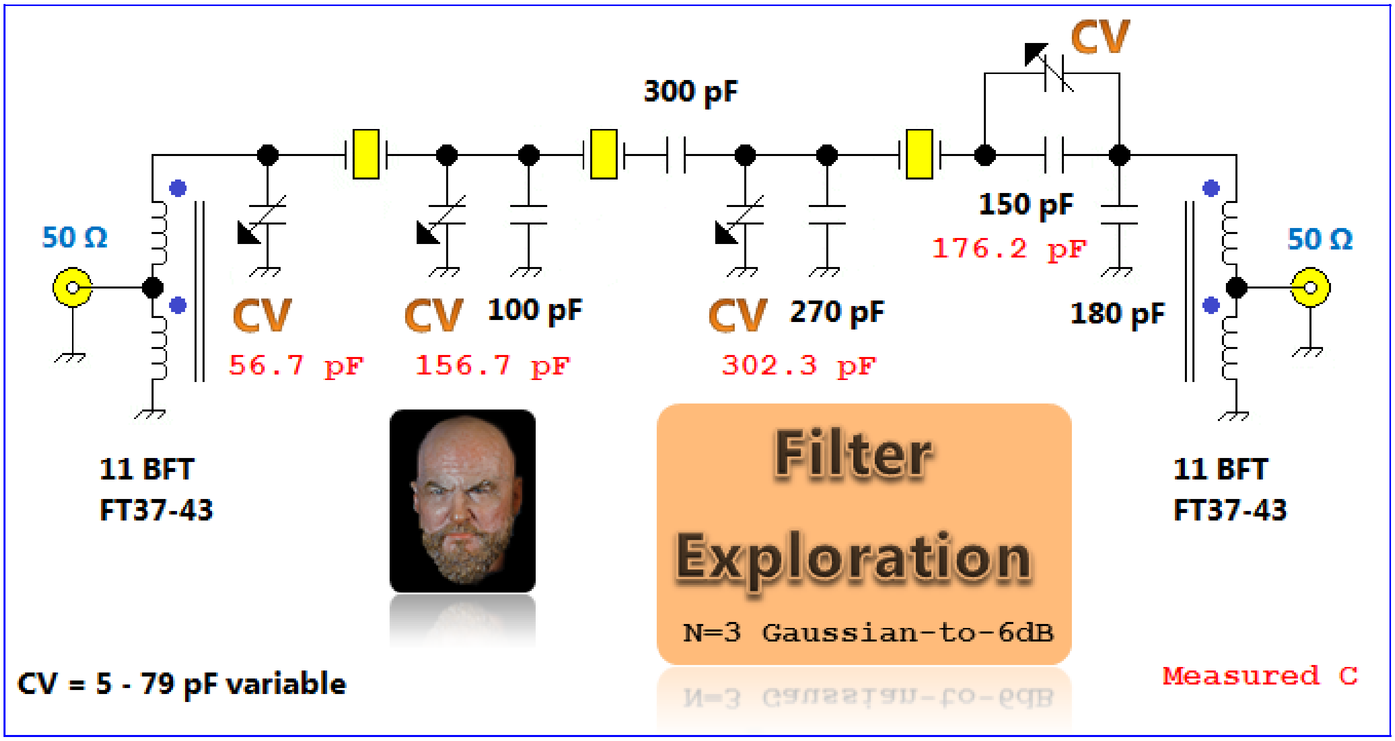
CV
300 pF
150 pF
176.2 pF
50 Ω
50 Ω
CV
56.7 pF
CV
156.7 pF
100 pF
CV
302.3 pF
270 pF
180 pF
11 BFT
FT37-43
11 BFT
FT37-43
Filter
Exploration
N=3 Gaussian-to-6dB
CV = 5 - 79 pF variable
Measured C

Above — Circuit to allow evaluation of the filter in my 50 Ω sweep system. Transmission transformers provide the needed 200 Ω filter termination. I inserted 4 trimmer caps to permit tweaking of the filter under test to establish the very best filter shape. With trimmer capacitor adjustment, I was able to trash the filter or peak it well. Click for 3 different swept bandwidths: Sweep-1 Sweep-2 Sweep-3.

After peaking, I removed *all* the caps and measured them as shown in **red font**. I'll replicate these values with nearest standard-value fixed capacitors. The trimmer caps nearest to the ports proved more sensistive compared to the 2 middle trimmers capacitors during tuning.

This might be the coolest thing I've ever done on my test bench.

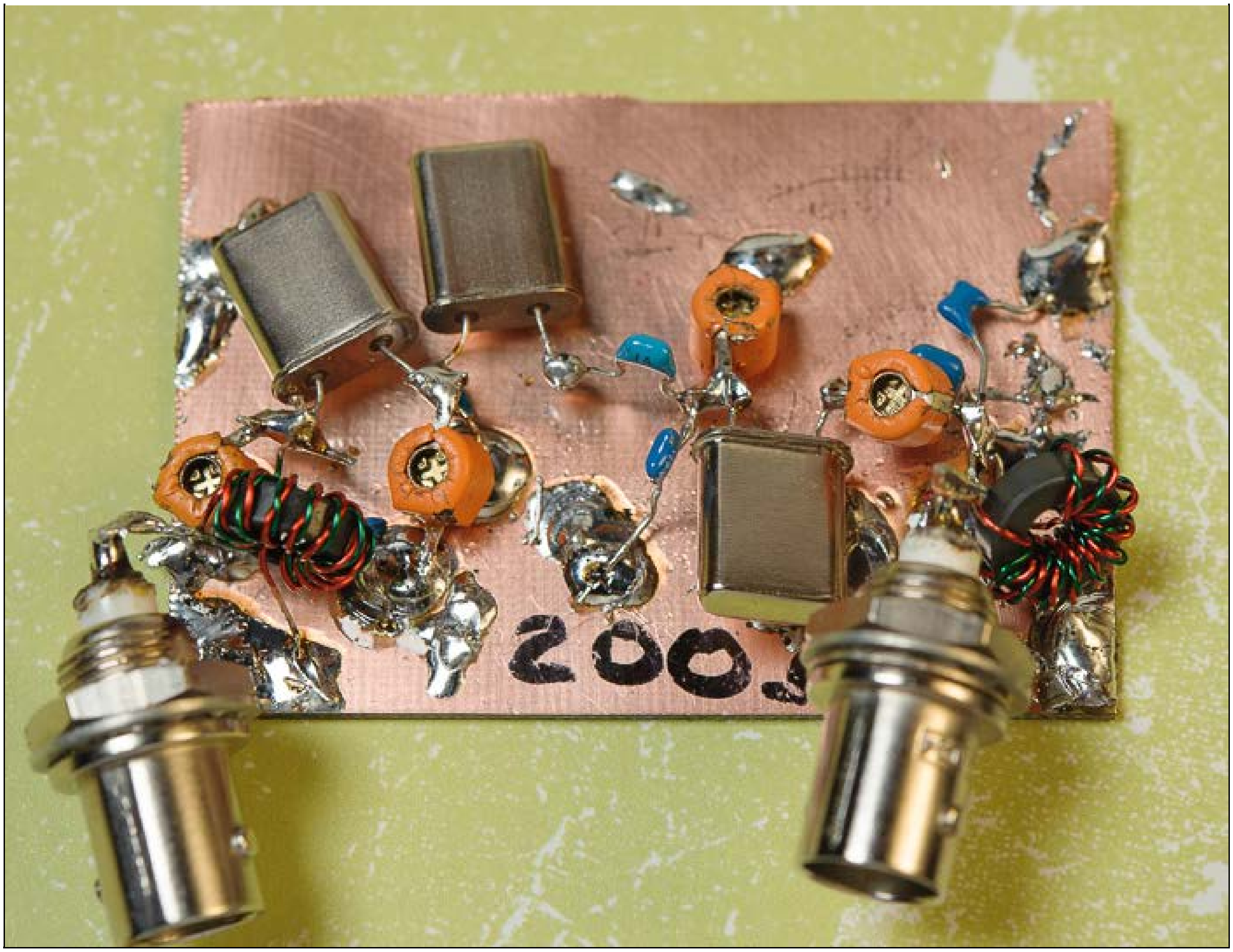

Above — My N = 3 filter breadboard. I left the capacitor leads long for re-use. I consume huge numbers of parts and recycle as possible to keep costs down.

Mixer and Post Mixer Amplifer Development

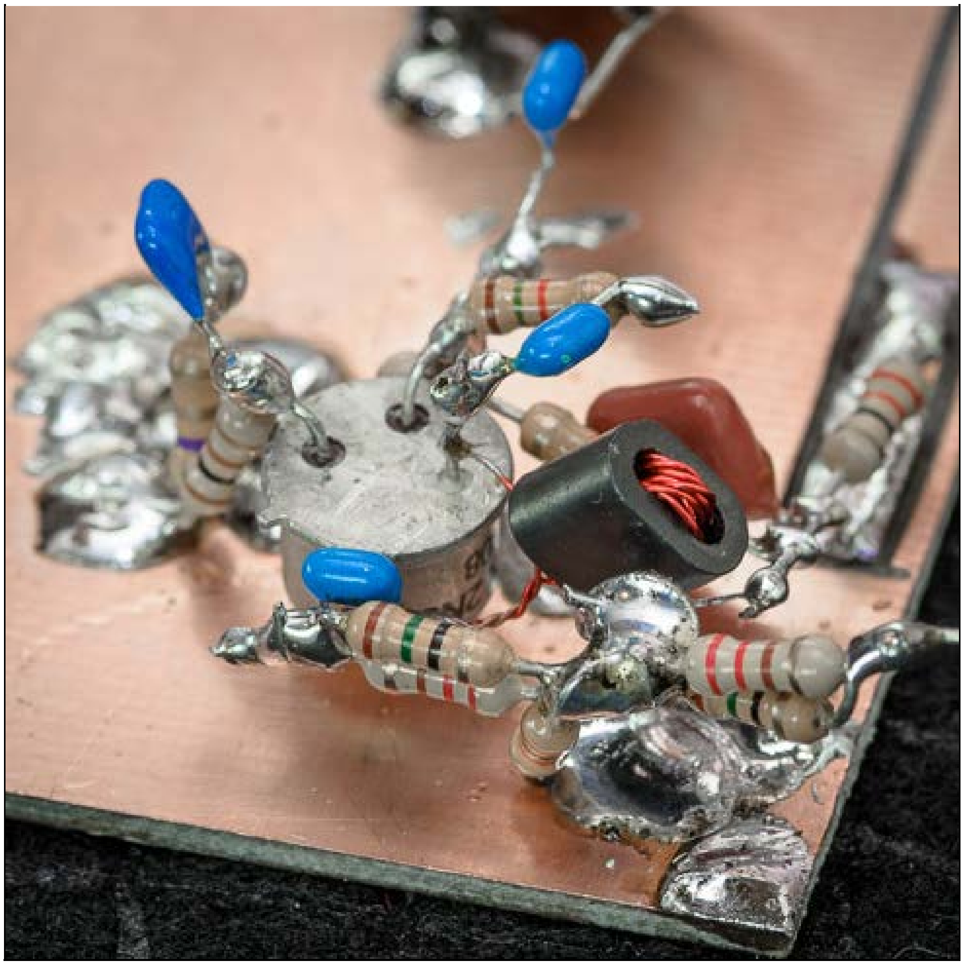

Above — Ugly breadboard shot with my ancient 105 mm lens for a change. It's a Beaverton Special feedback amp (FBA) biased for ~40 mA. For my post-mixer amp. If you need a stout RF amp, this one will do in a storm.

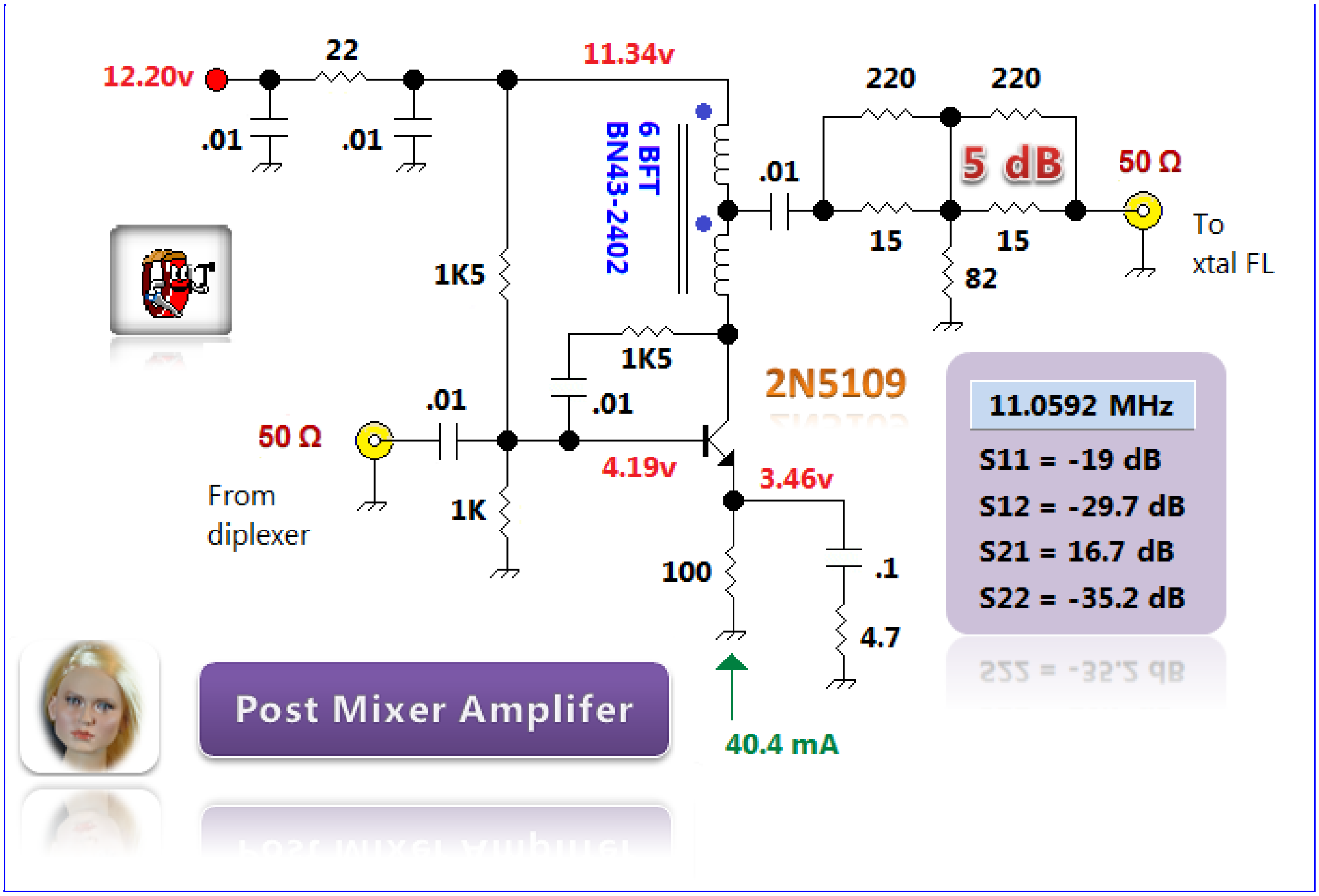
12.20v
22
11.34v
.01
.01
6 BFT
BN43-2402
220
220
5 dB
50 Ω
.01
15
15
82
To
xtal FL
1K5
1K5
2N5109
.01
.01
50 Ω
From
diplexer
4.19v
3.46v
1K
100
.1
4.7
40.4 mA
11.0592 MHz
S11 = -19 dB
S12 = -29.7 dB
S21 = 16.7 dB
S22 = -35.2 dB
Post Mixer Amplifer

Above — The Beaverton Special feedback amp biased for ~40 mA with a 50 Ω output Z. The FBA with no 5 dB pad: S11 -18.5 dB; S12 -34.6 dB; S21 22.1 dB and S22 -31.8 dB. I love this FBA for its simplicity and well defined port impedance. My IF = 11.0592 MHz. Click for a discarded (but cool) photo.

To drive the 200 Ω input Z of my xtal filter I later converted the output to 200 Ω by changing the collector transformer and pad.

Frequency Synthesizers and Logic

I've spent a great deal of time reading about & playing with some HC series logic I bought in 2011-2012. I even purchased a few 74AC74, a D flip-flop you can clock up to 160 MHz or so. Most of my reading concerned frequency synthesizers: PLLs, dividers, prescalers, etc. Since most modern devices run a clock at GHz frequencies, the evolution of frequency synthesis technology from around the mid 1970's to now makes for a fascinating read.

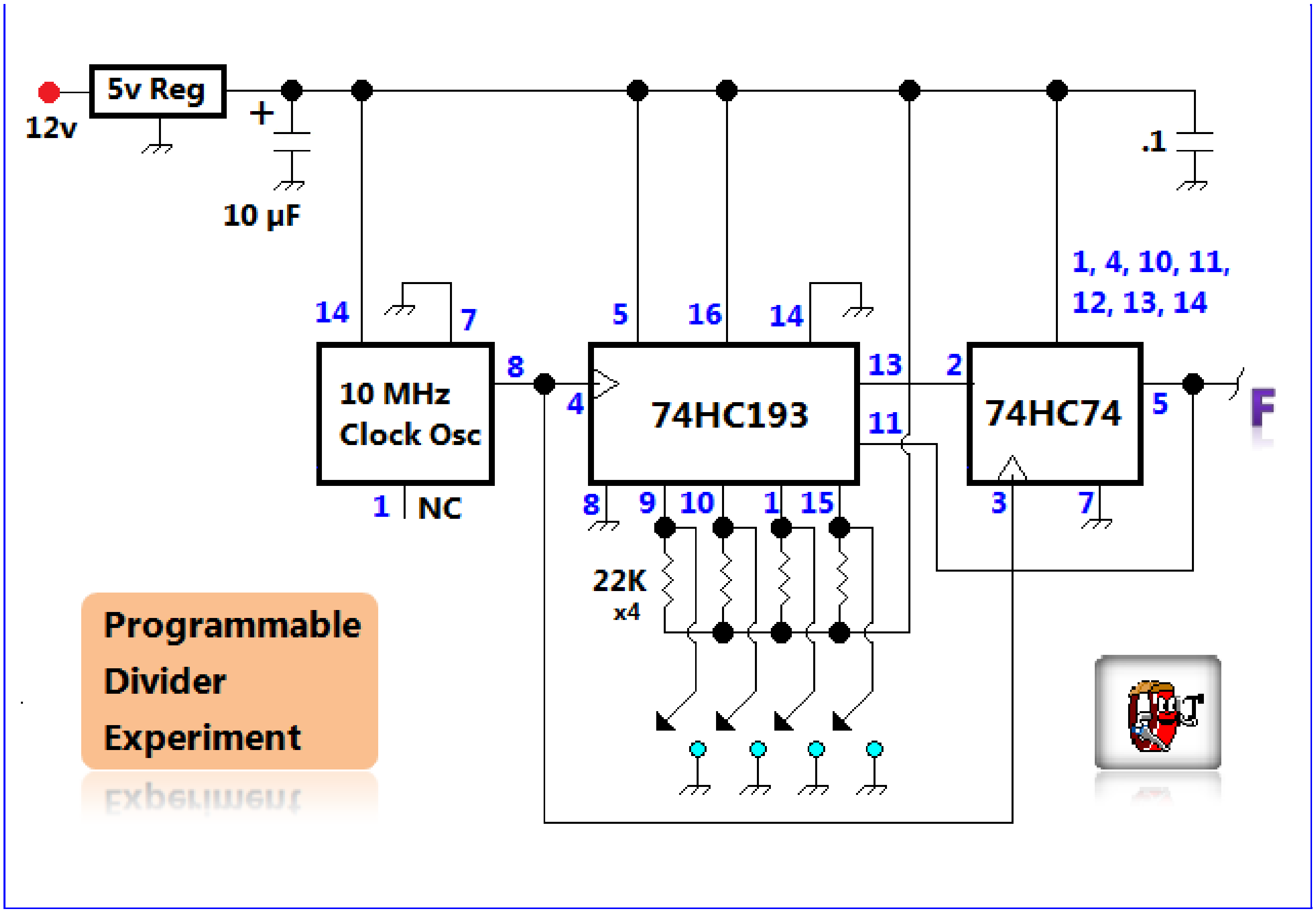
5v Reg
12v
+
10 µF
.1
1, 4, 10, 11,
12, 13, 14
14
7
5
16
14
8
10 MHz
Clock Osc
4
74HC193
13
2
74HC74
5
F
11
1
NC
8
9
10
1
15
3
7
22K
x4
Programmable
Divider
Experiment

Above — Using a CMOS 10 MHz clock oscillator, I tested out a positive edge-triggered programmable frequency divider designed by Wes, W7ZOI in 2011. It works perfectly.

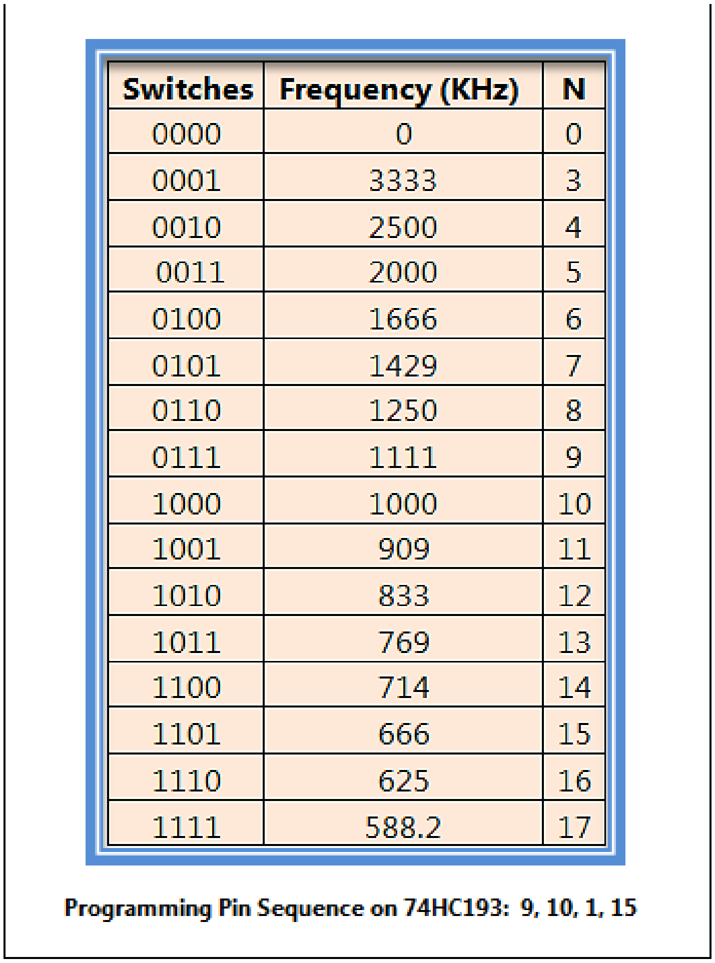

Switches	Frequency (KHz)	N
0000	0	0
0001	3333	3
0010	2500	4
0011	2000	5
0100	1666	6
0101	1429	7
0110	1250	8
0111	1111	9
1000	1000	10
1001	909	11
1010	833	12
1011	769	13
1100	714	14
1101	666	15
1110	625	16
1111	588.2	17

Programming Pin Sequence on 74HC193: 9, 10, 1, 15

Above — A test of all 16 combinations of the 4 programming switches with the 10,000 KHz input. I show the measured output frequency in KHz and the integer generated by dividing the output F into 10,000 KHz. You may leave pin 9 HIGH and just run it as a divide by 10 to 17 counter with 3 panel mounted programming switches — that's what I hope to do.

While working at Tektronixs, Wes designed the frequency synthesizer for the 492 Spectrum Analyzer; a portable SA that went to 21 GHz or so. His experiences informed the design of this simple, low-cost, edge-triggered divider.

Here, Wes applies the 74HC193 as a down counter where a number is loaded and then it count downs until zero is reached. The number gets boosted by 2 — 1 comes from the 74HC74 D flip-flop, while the other arises from the phasing of the signals. The 74HC74 makes the overall output coherent with its clock and avoids the flicker noise that otherwise might be generated in the long divider chain of the ripple counter.

The standard binary to decimal conversion is altered in this circuit.

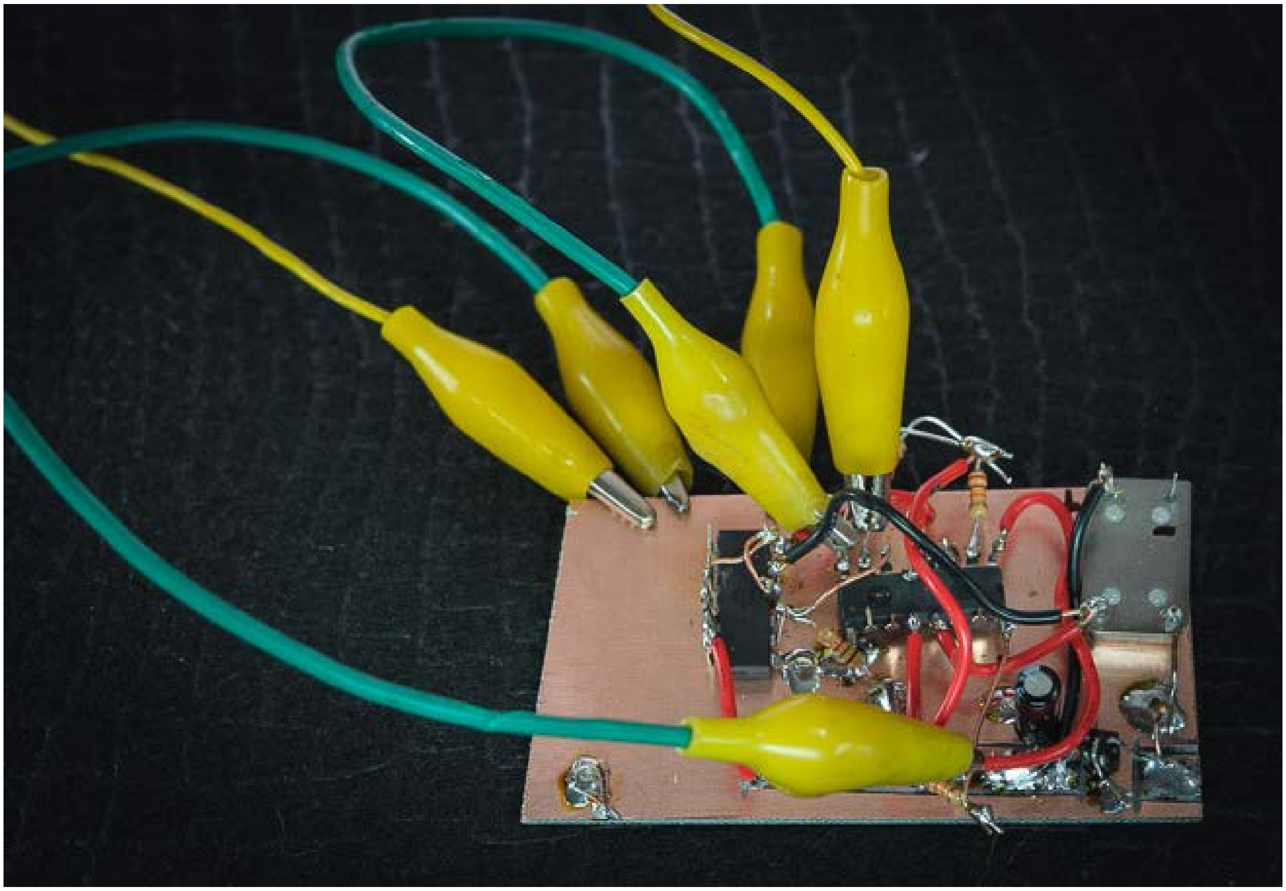

Above — My ugly breadboard. Instead of switches, I relied on bench jumpers to set a pin LOW.

Check out the standard binary switch combinations on this cool website: Math Is Fun. I also enjoyed their hexidecimal drum machine tool - Click. Actually, the whole web site looks great and I will recommend it to our friends with children and maybe even a few radio enthusiasts.

The Local Oscillator

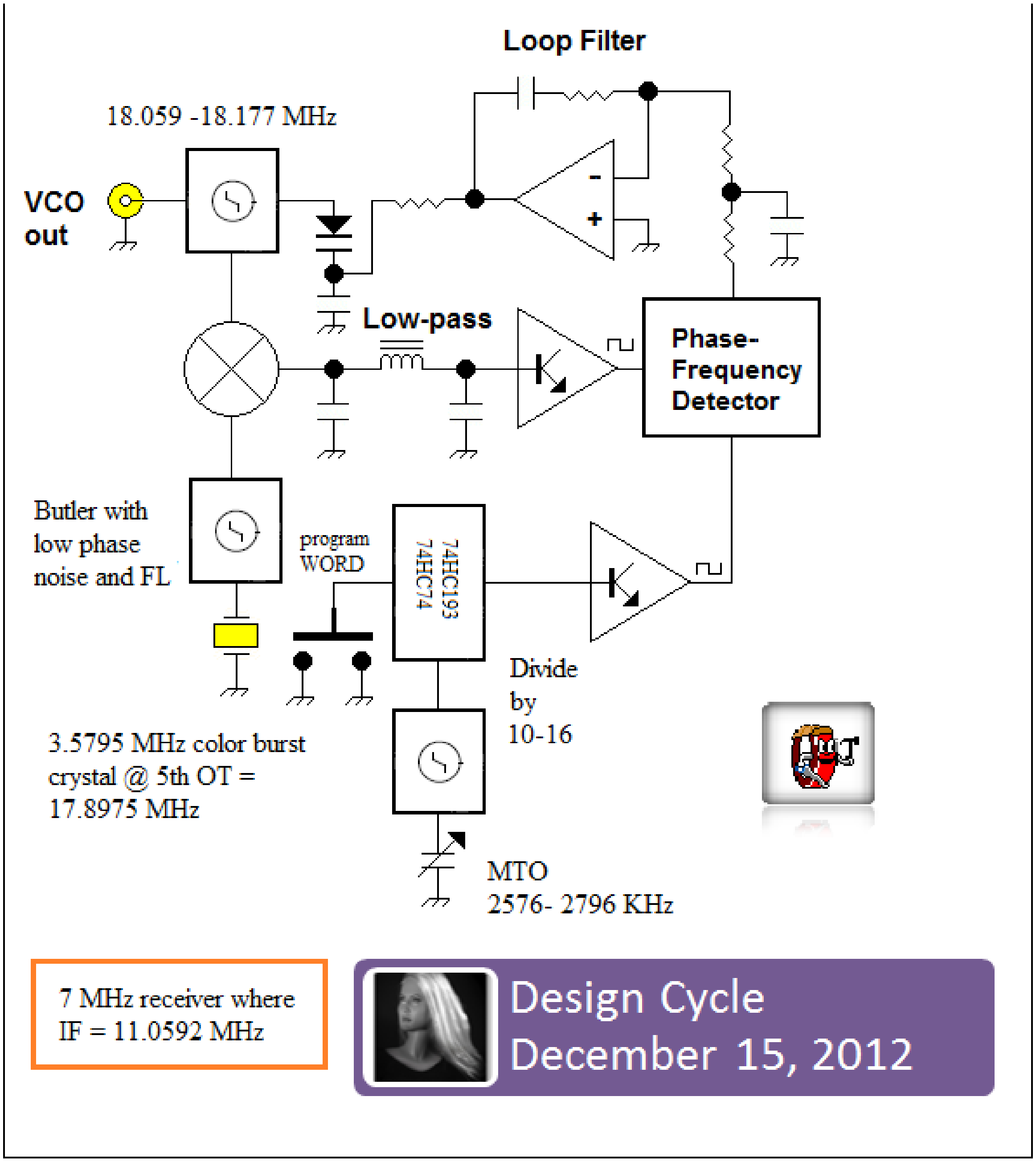
Loop Filter
18.059 -18.177 MHz
VCO
out
Low-pass
Phase-
Frequency
Detector
Butler with
low phase
noise and FL
program
WORD
74HC193
74HC74
Divide
by
10-16
3.5795 MHz color burst
crystal @ 5th OT =
17.8975 MHz
MTO
2576- 2796 KHz
7 MHz receiver where
IF = 11.0592 MHz
Design Cycle
December 15, 2012

Above — An Almost Synthesizer based upon the design currently in use at W7ZOI.

I picked the MTO, xtal oscillator and VCO frequencies and will design the loop filter once I get the parts and a few small die-cast boxes on hand. The MTO division integer is low and quiet — plus this scheme enhances MTO frequency stability and spectral purity. A 4-bit ripple counter + flip flop perform the division where N = 10 - 16. I might go higher with N , but don't want to get too greedy. For CW, I'm generally in the bottom 20 KHz of the band anyway.

The MTO tunes about a 13-14 KHz range and the N gives 6 different tuning ranges (with some overlap) to span a total range of ~118 KHz. The 4-bit WORD is changed by 3 chassis-mount toggle switches and give a PLL reference of ~~175 to 280 KHz.

This almost synthesis seems a little crude in a time when people use microcontrollers to input a WORD into a chip with with the simple turn of a rotary controller, however this set-up fosters learning, huge fun, and when the oscillators plus loop filter are well designed; low phase noise and reciprocal mixing.

The Crystal Filter

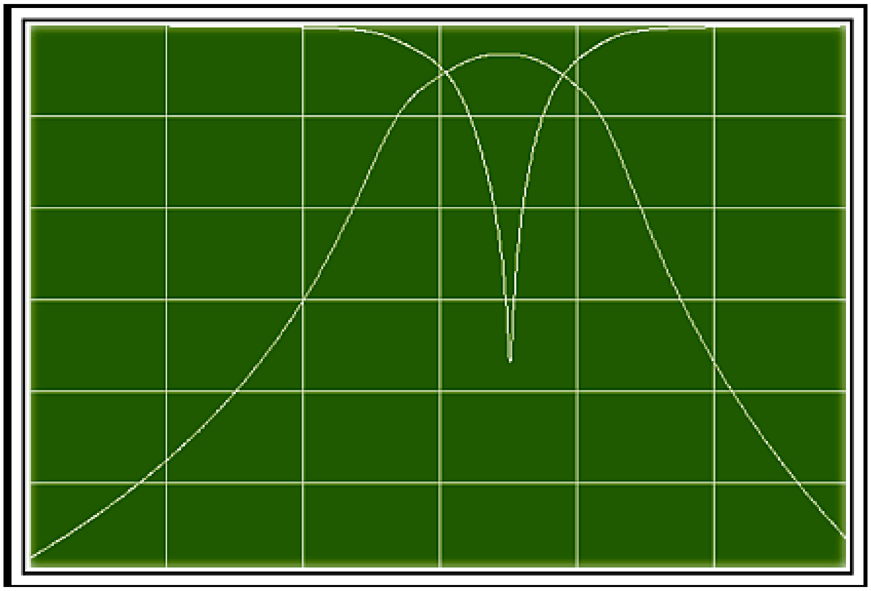

Above — A GPLA sweep of my 4 crystal filter where C parallel = 4.86 pF, Lm = .01 H, IF = 11.0572 MHz, BW = 1 KHz and R term = 200 ohms. This Gaussian to 6 dB filter design was chosen for speaker audio that sounds full + dynamic without the hollow ringing so often heard in homebrew receivers. I filter in my brain and first learned to copy CW across a room while listening to a speaker.

My code mentor Doug, could make coffee, walk around the room, talk to us and still 100% copy CW at 40 WPM. He taught us the ear to brain bandwidth is ~ 100 Hz when copying weak signal CW through a sideband crystal filter. To this day, I prefer listening through wider CW filters with brain band-pass filtering.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

KL7R Memorial Supplemental Page

This web page is a supplement to the K7LR Memorial Receiver Experiments Web Page

Audio Preamplifier Focus

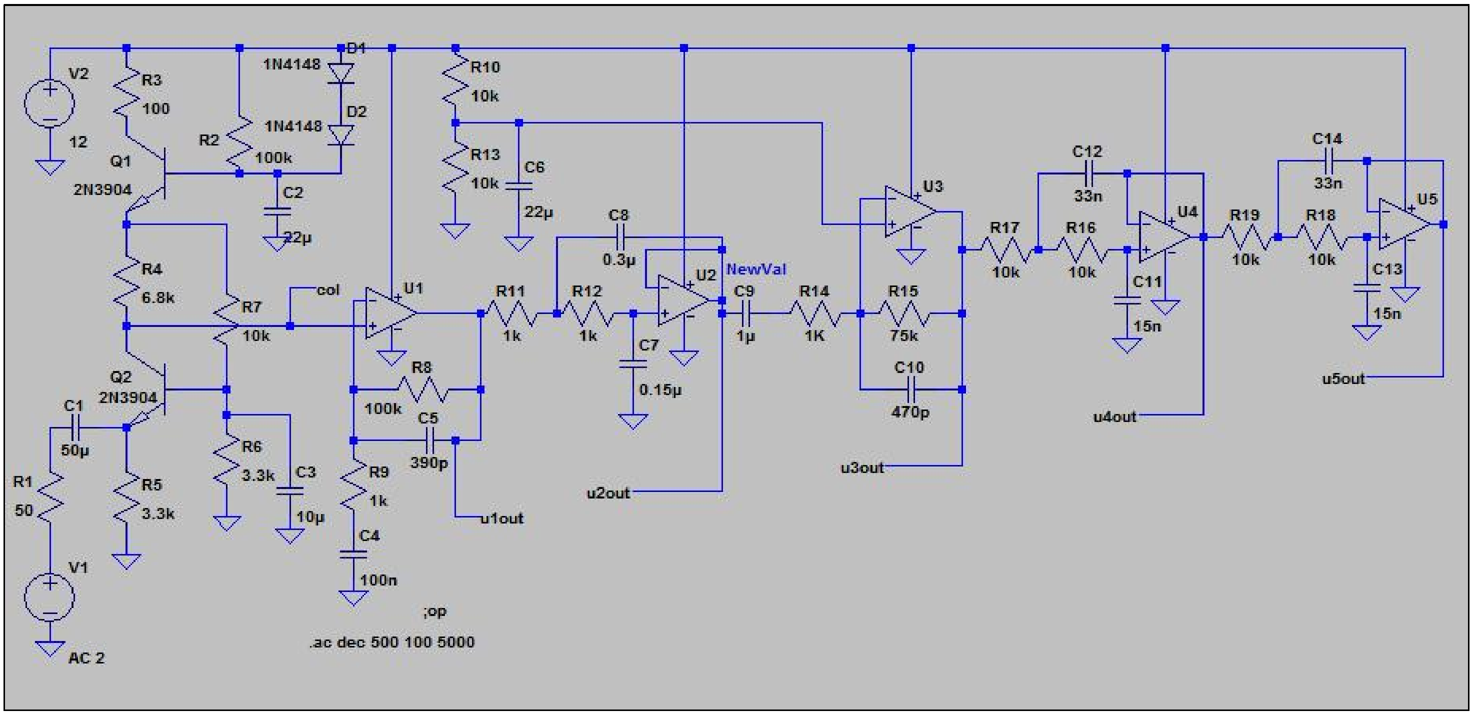
V2
12
R3
100
Q1
2N3904
R2
100k
1N4148
D1
1N4148
D2
C2
22µ
R10
10k
R13
10k
C6
22µ
R4
6.8k
R7
10k
col
U1
R11
1k
R12
1k
C8
0.3µ
U2
NewVal
C9
1µ
R14
1K
R15
75k
C10
470p
U3
R17
10k
R16
10k
C12
33n
C11
15n
U4
R19
10k
R18
10k
C14
33n
C13
15n
U5
Q2
2N3904
C1
50µ
R1
50
R5
3.3k
R6
3.3k
C3
10µ
R8
100k
C5
390p
R9
1k
C4
100n
C7
0.15µ
V1
AC 2
u1out
u2out
u3out
u4out
u5out
;op
.ac dec 500 100 5000

Shown above is a SPICE build of an earlier prototype of the audio preamp chain which was ultimately used in this receiver. This SPICE work was performed by Wes, W7ZOI. Note that at this point, I had 100K plus 390 pF feedback in U1 and a 75K plus 470 pF feedback resistors in the op-amp amplifiers (really massive gain). I spent 4-5 days trying different audio stages before settling on the circuits shown.

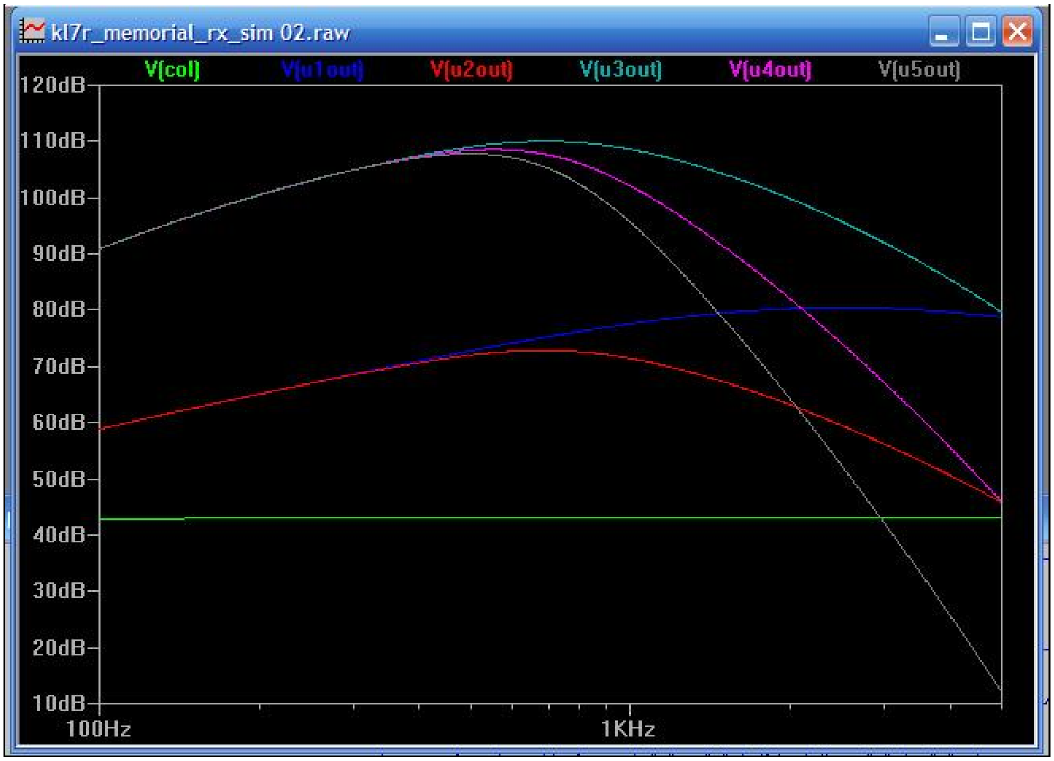

Shown above is the voltage versus frequency plot from a SPICE run of the schematic shown above. The gentle slope (decibels per octave) of the low pass filters can be seen. Certainly Chebychev filters with 1-2 dB of ripple would have provided steeper filtering, but the filters would have odd resistor values and be less easily modified or reproduced by popcorn builders. The V(u5out) shows a reasonable low pass response for the AF preamp.

Audio Power Amp

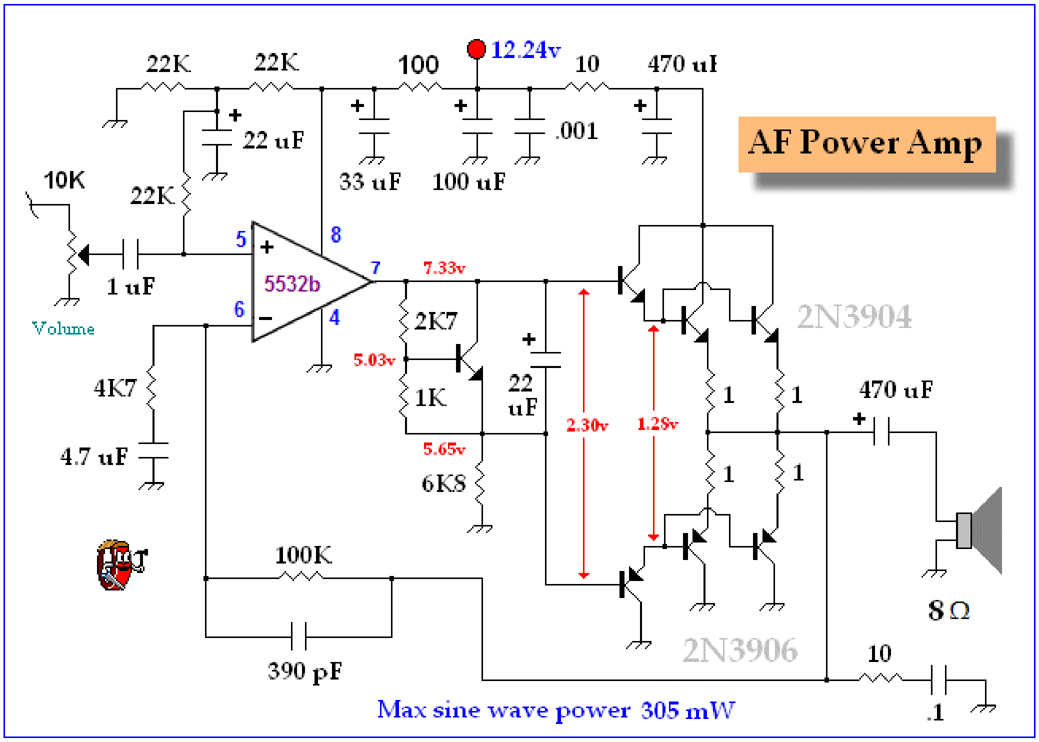
22K
22K
100
12.24v
10
470 u
22 uF
33 uF
100 uF
.001
AF Power Amp
10K
22K
Volume
1 uF
5
8
6
4
7
5532b
7.33v
5.03v
2K7
1K
22 uF
5.65v
6K8
2.30v
1.28v
2N3904
1
1
1
1
470 uF
4K7
4.7 uF
100K
390 pF
2N3906
8 Ω
10
.1
Max sine wave power 305 mW

This schematic shows a stand-alone version of the audio power amp. If only 1/2 of the 5532 is used, connect pins 3 and 2 of the unused op-amp to the point where all the 22K resistors connect (VCC/2 bias point).

Product Detector Notes

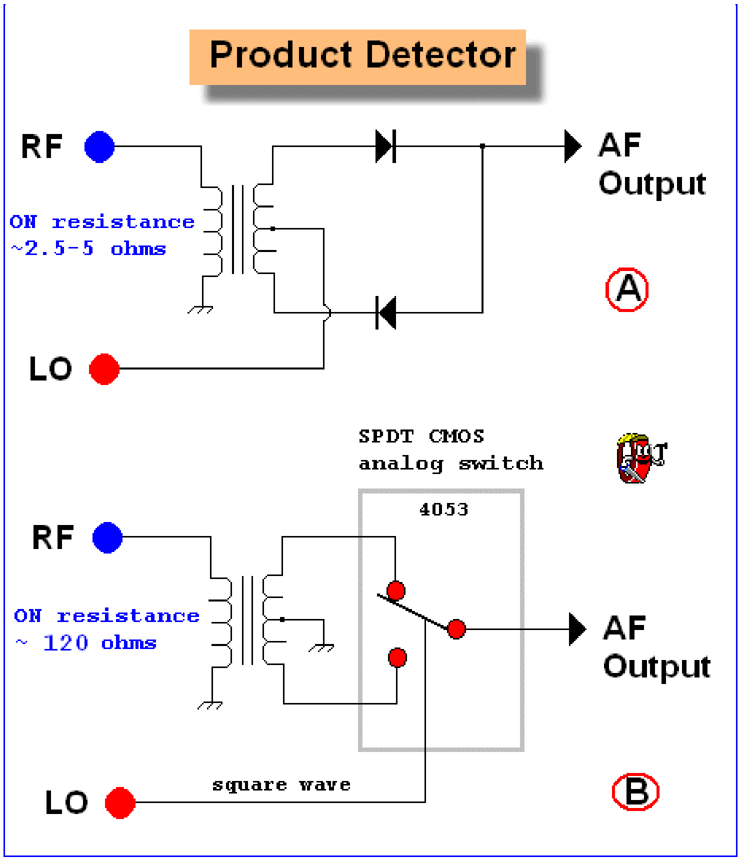
Product Detector
RF
ON resistance
~2.5-5 ohms
LO
AF
Output
A
SPDT CMOS
analog switch
4053
RF
ON resistance
~ 120 ohms
AF
Output
square wave
LO
B

Shown above is the analogy between an SPDT CMOS switch and a single-ended, diode product detector. In both cases (A and B), the LO causes 1 diode (switch) to conduct, while the other is OFF. Then, on the other half cycle, the other diode (switch) conducts. If you wish to actually using the product detector/mixer depicted as "A" go with Figure 5.19B in EMRFD which has the LO applied to the transformer primary. As shown, "A" has poor LO to RF isolation, but it helps model the CMOS SPDT analog switch function. Function and performance are completely different topics... The on-resistance of the 4053 is much higher and thus performance is not identical.

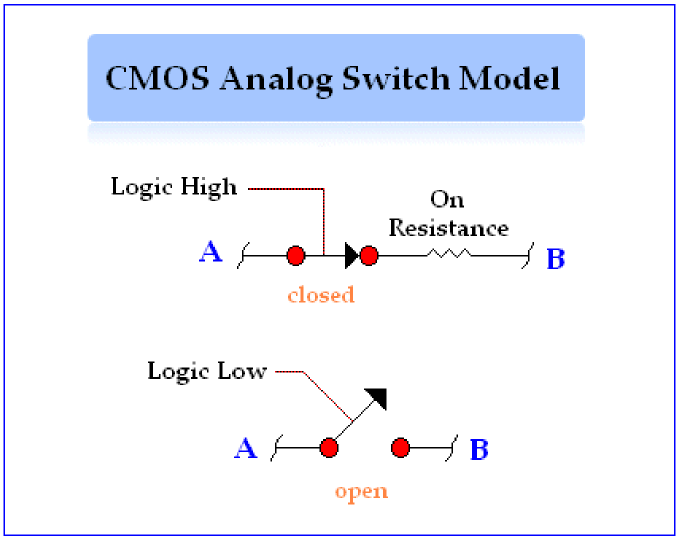
CMOS Analog Switch Model
Logic High
On
Resistance
A
B
closed
Logic Low
A
B
open

CMOS analog switch model. A or B are bidirectional and can be used interchangeably for the input or output. Ideally the on-resistance should be low to reduce propagation delay of digital signals plus resistance and perhaps distortion of analog signals. They can be used to switch digital bus data or analog signals. CMOS switches can replace mechanical reed switches in some low power circuits.

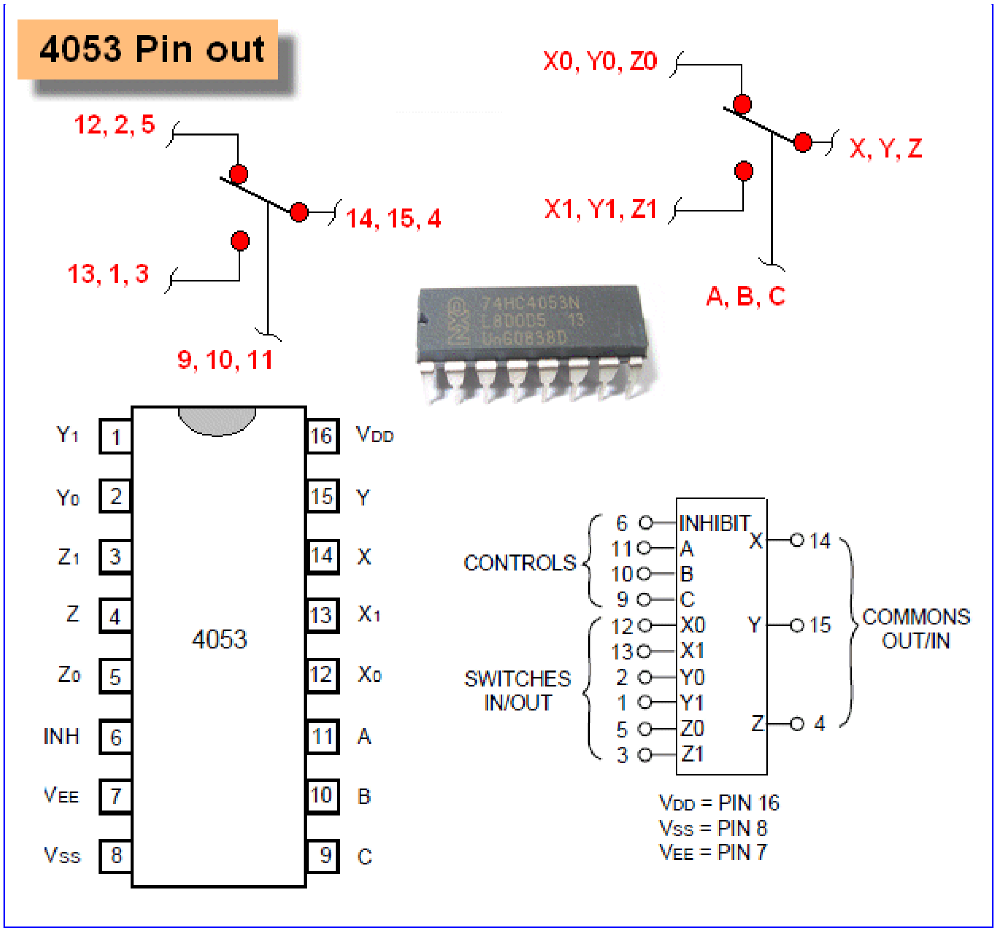
4053 Pin out
12, 2, 5
14, 15, 4
13, 1, 3
9, 10, 11
X0, Y0, Z0
X, Y, Z
X1, Y1, Z1
A, B, C
74HC4053N
L8D0D5 13
UnG0838D
Y1 1
Y0 2
Z1 3
Z 4
Z0 5
INH 6
VEE 7
VSS 8
16 VDD
15 Y
14 X
13 X1
12 X0
11 A
10 B
9 C
4053
CONTROLS
6 INHIBIT
11 A
10 B
9 C
SWITCHES IN/OUT
12 X0
13 X1
2 Y0
1 Y1
5 Z0
3 Z1
X 14
Y 15
Z 4
COMMONS OUT/IN
VDD = PIN 16
VSS = PIN 8
VEE = PIN 7

The CD4053BC is a triple 2-channel multiplexer having three separate digital control inputs; A, B, and C, and an inhibit input. Each control input selects one of a pair of channels which are connected in a single-pole double-throw configuration. A high on resistance makes the 4053 a compromise part for RF mixing. It might be perfectly okay for your design.

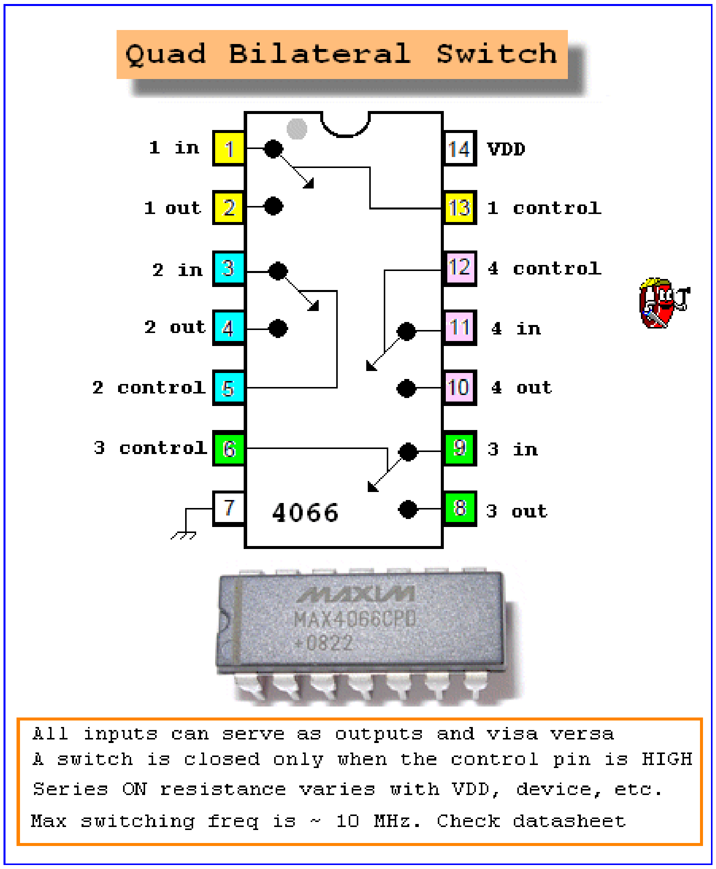
Quad Bilateral Switch
1 in 1
1 out 2
2 in 3
2 out 4
2 control 5
3 control 6
7
14 VDD
13 1 control
12 4 control
11 4 in
10 4 out
9 3 in
8 3 out
4066
MAXIM
MAX4066CPD
+0822

All inputs can serve as outputs and visa versa
A switch is closed only when the control pin is HIGH
Series ON resistance varies with VDD, device, etc.
Max switching freq is ~ 10 MHz. Check datasheet

The 4066 is more easily understood when drawn in a semi-schematic. The on-resistance of this MAXIM version is better than the usual HC4066. About 45 ohms with a VCC of 12 or so.

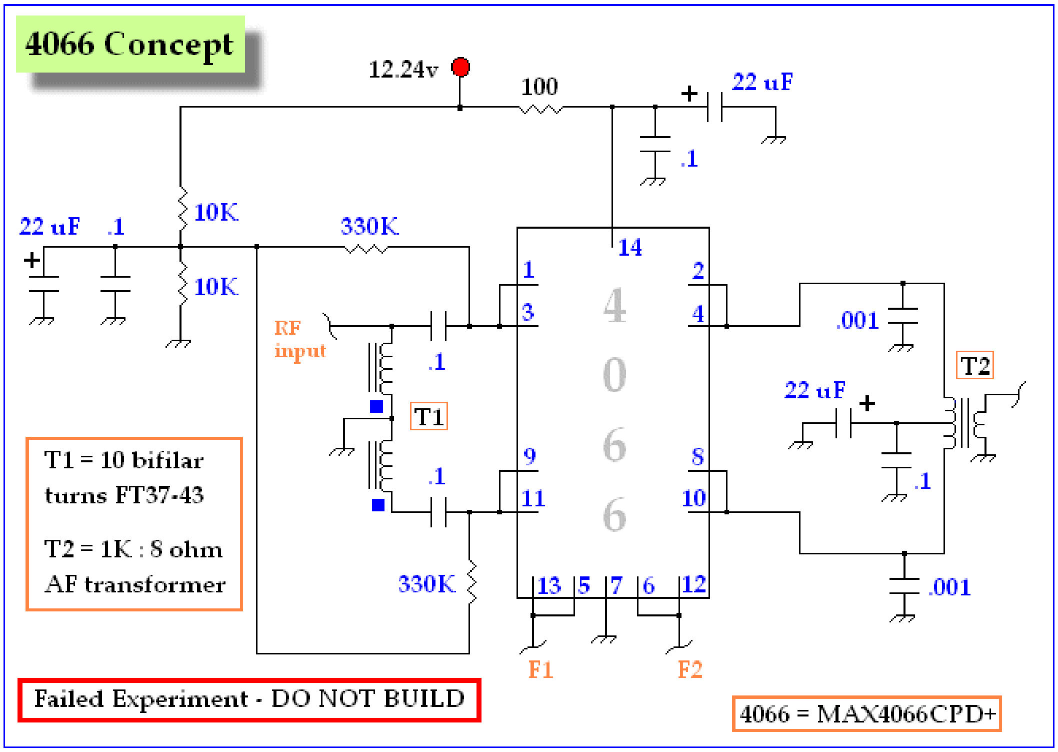
4066 Concept
12.24v
100
22 uF
.1
22 uF
.1
10K
10K
330K
14
1
2
3
4
4
0
6
6
RF
input
.1
T1
.1
.001
T2
22 uF
.1
9
8
11
10
330K
13
5
7
6
12
.001
F1
F2
T1 = 10 bifilar turns FT37-43
T2 = 1K : 8 ohm AF transformer
Failed Experiment - DO NOT BUILD
4066 = MAX4066CPD+

A 4066 experiment that was a total failure. It is both humbling and useful to show your failures and not just the good fruit. This circuit had hum, noise and low output. The input transformer was a bifilar type, which was really cool.

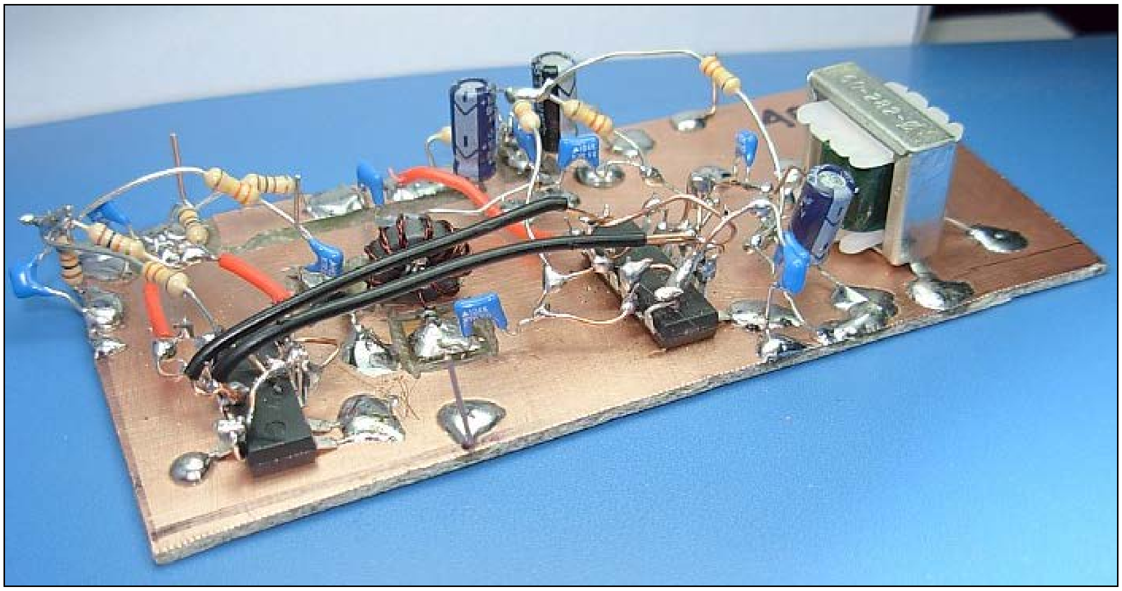

The breadboard of the 4066 Concept schematic shown above.

74HC4053N
L8D0D5 13
UnG0838D
MAXIM
MAX4066CPD
+0822

The DIP IC switches used as product detectors in the K7LR memorial receiver experiments.

My work bench during some final experiments for this project.

Amateur and Short Wave Radio Electronics Experimenter's Web Site

K7LR MEMORIAL RECEIVER VFOs

This web page is a supplement to the [K7LR Memorial Receiver Experiments Web Page]()

14 MHz VFO Circuit

Figure 1

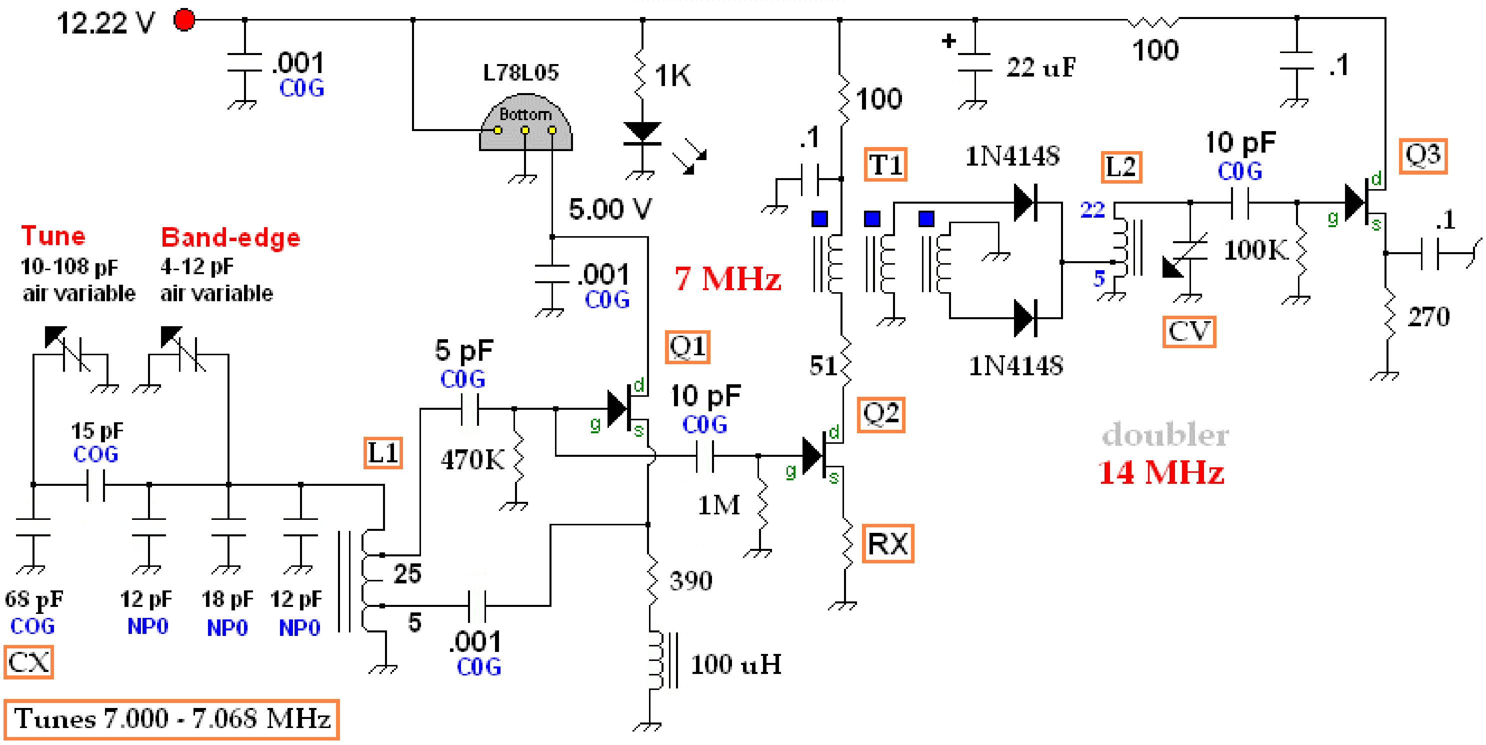
12.22 V
.001
C0G
L78L05
Bottom
1K
5.00 V
.001
C0G
100
.1
+
22 uF
100
.1
T1
1N4148
L2
10 pF
C0G
Q3
22
5
100K
CV
.1
270
1N4148
7 MHz
Tune
10-108 pF
air variable
Band-edge
4-12 pF
air variable
5 pF
C0G
Q1
51
10 pF
C0G
Q2
470K
L1
15 pF
C0G
1M
RX
doubler
14 MHz
25
5
390
.001
C0G
100 uH
68 pF
COG
12 pF
NP0
18 pF
NP0
12 pF
NP0
CX
d
g
s

Tunes 7.000 - 7.068 MHz

L1 = 6.1 uH = 36t on a T68-6 toroid. Tap at 25 and 5 turns. (used 26 AWG)
Q1 = Q2 = Q3 = J310
100 uH RFC that I used was wound as follows: 38t on a FT50-61 ferrite toroid
T1 = 10 trifilar turns on a FT37-43 L2 = 2 uH = 22t on a T50-6; tap @5t
CV = 6.0-50 pF trimmer capacitor
RX = 470 ohms

Figure 1 is the 14 MHz VFO used to switch (clock) the CMOS switch product detector. The tuning range can be easily changed by adjusting capacitor CX. As shown, the the tuning capacitor has a frequency range of about 68 Hz. If you decrease CX to 47 pF, the tuning range increases to around 99 Hz. Increasing CX to 100 pF gave about a 40 Hz tuning range. When you use a larger tuning range, fine tuning can become difficult. A geared reduction dial is one possible solution. For simplicity, I prefer to just keep the tuning range low as reasonably possible and use a big knob on the main tuning variable capacitor. Even the 68 Hertz tuning range shown can prove difficult for fine tuning. As experimenters, we are continually problem solving. Choose the tuning range and/or methods which suit your personal needs.

The base 7 MHz oscillator is doubled since a D flip flop is used to clock the CMOS switch product detector. This oscillator has low harmonic content and this is important for suppressing the 7 MHz fundamental frequency and its harmonics in the frequency doubler. Some astute builders may even match the two diodes used in the doubler. Diode matching is discussed on this page. CV tunes very sharply and the output at Q3 is a clean sine wave. This in turn provides a well balanced square wave at each output of the D flip-flop. The Q3 output voltage was measured at -0.46 dBm (0.6 volts peak to peak into 50 ohms).

Choosing Capacitor Values

There are a number of ways to determine the capacitor values required to tune your VFO L-C tank circuit. It is pretty much essential to have a frequency counter and nice perhaps, to own a capacitance meter. Main tuning capacitors are typically harvested from an old radio or from the junk box. Its tuning range could be anywhere from 30 to 300 pF, or more. To limit the tuning range of this variable capacitor, normally you parallel a fixed-value capacitor and then series connect it to the top of L1 with a small, fixed-value capacitor. I performed this task entirely by trial an error using a frequency counter connected to the collector of Q2. Some fixed value NP0 or C0G capacitors plus a small trimmer capacitor are also required for tuning and to set the lower band edge respectively. Finding the right combination of capacitor values is painstaking, but with practice, gets easier. Once you have the basic capacitor values sorted out and your tuning range set, frequency stability experiments are then performed. This is known as VFO temperature compensation. Some times temperature compensation can be achieved by finding the right combination of NP0 and C0G capacitors. Additionally some negative or positive temperature coefficient capacitors may have to be soldered in and tested. Your final capacitor leads should be short as practically possible to reduce stray lead capacitance and for mechanical rigidity. Temperature compensation is discussed on this web page.

A 7 MHz VFO Circuit for Diode Ring Product Detectors

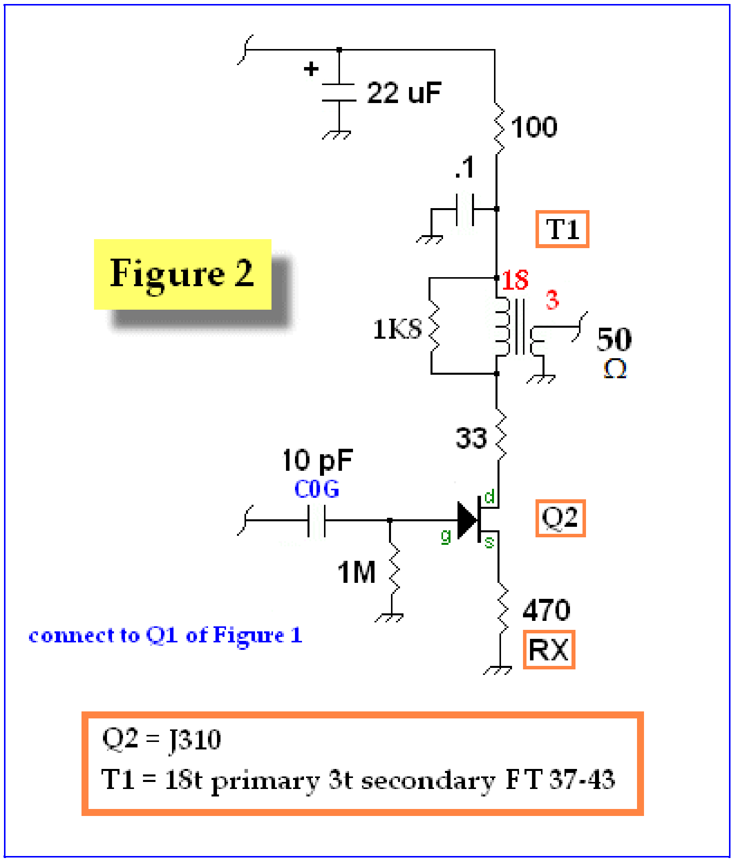
+
22 uF
100
.1
T1
Figure 2
18
3
1K8
50
Ω
33
10 pF
C0G
d
g
s
Q2
1M
470
RX
connect to Q1 of Figure 1
Q2 = J310
T1 = 18t primary 3t secondary FT 37-43

If you want to build a simpler version of the K7LR memorial receiver, a diode ring mixer may be substituted for the digital switch. The VFO requires modification as it will be run at 7 MHz. A different buffer is used and the Q2 to Q3 frequency doubler circuit is excluded. The diode ring product detector version is very nice. You could use a Mini-circuits TUF-1 , SBL-1 or alternate, or perhaps homebrew your own.

In Figure 2 is a VFO buffer configured to drive a 50 ohms input impedance, 7 dBm level, diode ring mixer. Change Rx to change the output voltage. With RX at 470 ohms, the output was somewhere around 5 dBm. This is useable for many situations. If you want exactly 7 dBm, the AC peak to peak voltage with a **51** ohm load resistor connected to the 3 turn link should be 1.43 volts. Adjust RX to achieve this voltage in your oscilloscope.

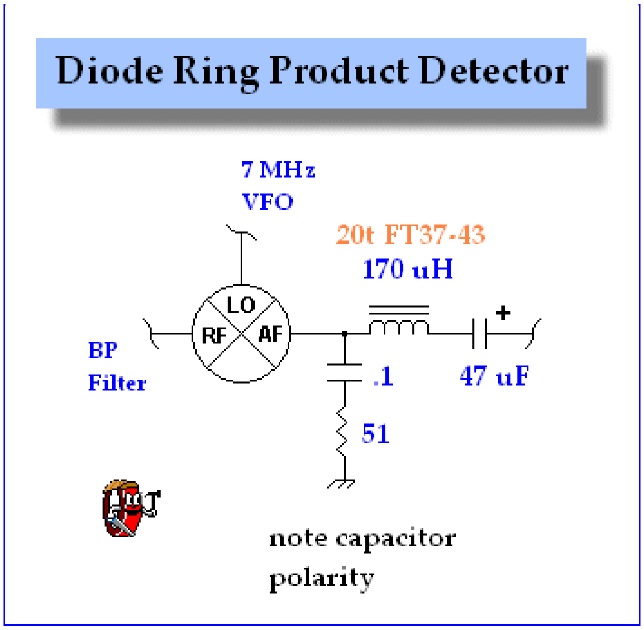
Diode Ring Product Detector
7 MHz
VFO
20t FT37-43
170 uH
LO
RF
AF
+
BP
Filter
.1
47 uF
51

note capacitor polarity

Note that if you build a diode ring product detector receiver version using the simple W7EL low pass termination network, the polarity of the 47 uF electrolytic capacitor will need to be changed as shown.

Key goals of this website include providing ideas, basic support and encouragement. I am delighted when builders make their own stuff and not copy my circuits. This is why we homebrew; to create, explore and share. Mike, K7LR did all of these very well.

QRP SWL
HOMEBUILDER

Amateur and Short Wave Radio Electronics Experimenter's Web Site

Photography Links

Nikkor 50mm lenses

HENRI CARTIER-BRESSON - shot a lot with 50mm - video to watch over and over

The genius of photography -- BBC4 series about the history of photography

http://www.freestylephoto.biz

Radio and Electronics Cookbook

Radio and Electronics Cookbook

Edited by
Dr George Brown, CEng, FIEE, M5ACN

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British Trust for Conservation Volunteers
FOR EVERY TITLE THAT WE PUBLISH, BUTTERWORTH-HEINEMANN WILL PAY FOR BTCV TO PLANT AND CARE FOR A TREE.

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Preface

Although we are surrounded by sophisticated computerised gadgets these days, there is still a fascination in putting together a few resistors, capacitors and the odd transistor to make a simple electronic circuit. It is really surprising how a handful of components can perform a useful function, and the satisfaction of having built it yourself is incalcuable.

This book aims to provide a wide variety of radio and electronic projects, from something that will take a few minutes to a more ambitious weekend's worth. Various construction techniques are described, the simplest requiring no more than a small screwdriver, the most complex involving printed circuit boards.

Originally published by the Radio Society of Great Britain, the projects were all chosen to be useful and straightforward, with the emphasis on practicality. In most cases the workings of the circuit are described, and the projects are backed up by small tutorials on the components and concepts employed. In the 21st century it may seem strange that few of the published circuits use integrated circuits (chips). This is intentional as it is much easier to understand how the circuit works when using discrete components.

Anyone buying the *Radio and Electronics Cookbook* will find that it will lead to hours of enjoyment, some very useful and entertaining gadgets, and increased knowledge of how and why electronics circuits work, and a great sense of satisfaction. Beware, electronic construction is addictive!

WARNING: This book contains construction details of transmitters. It is illegal to operate a transmitter without the appropriate licence. Information on how to obtain an Amateur Radio Licence can be obtained from the Radiocommunications Agency, tel. 020 7211 0160.

1 A medium-wave receiver

Introduction

Let us start off with something that is really quite simple and yet is capable of producing a sense of real satisfaction when complete – a real medium-wave (MW) radio receiver! It proves that receivers *can* be simple and, at the same time, be useful and enjoyable to make. To minimise the confusion to absolute beginners, *no* circuit diagram is given, only the constructional details. The circuits will come later, when you have become accustomed to the building process. In the true amateur spirit of ingenuity and inventiveness, the circuit is built on a terminal strip, the coil is wound on a toilet roll tube (as amateur MW coils have been for 100 years!), and the receiver is mounted on a piece of wood.

Putting it together

Start by mounting the components on the terminal strip as shown in **Figure 1**, carefully checking the position and value of each one. The three capacitors are all the same, and so present no problem. They (and the resistors) may be connected either way round, unlike the two semiconductors (see later). The resistors are coded by means of coloured bands. You can refer to Chapter 7 if you have difficulty remembering the colours and their values.

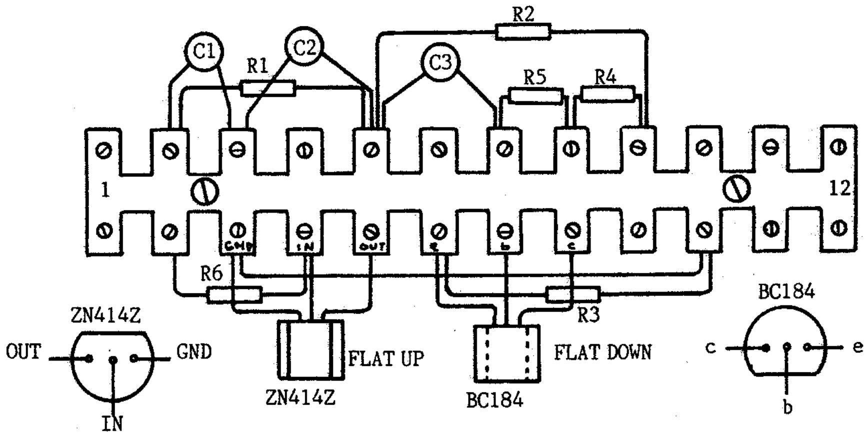

Figure 1 Terminal strip – position of components

1. Brown, Black, Yellow	100 000 ohms	(R1, R5, R6)
2. Green, Blue, Brown	560 ohms	(R2)
3. Red, Violet, Brown	270 ohms	(R3)
4. Brown, Black, Orange	10 000 ohms	(R4)

The integrated circuit (the ZN414Z) and the transistor (the BC184) *must* be connected correctly. Check Figure 1 carefully before fitting each device.

Now wind the coil. Most tubes are about 42 mm diameter and 110 mm long. Don't worry if your tube is slightly different; it shouldn't matter. Make two holes, about 3 mm apart, about 40 mm from one end, as shown in **Figure 2**. Loop your enamelled wire into one hole and out of the other, and draw about 100 mm through; loop this 100 mm through again, thus anchoring the wire firmly. Now wind on 80 turns, keeping the wire tight and the turns close together but not overlapping. After your 80th turn, make another two holes and anchor the wire in the same way as before. Again, leave about 100 mm free after anchoring. Using another piece of enamelled wire (with 100 mm ends as before), loop one end through the same two holes which contain the end anchor of the last winding, wind two turns and anchor the end of this short winding using another pair of holes. Figure 2 shows the layout.

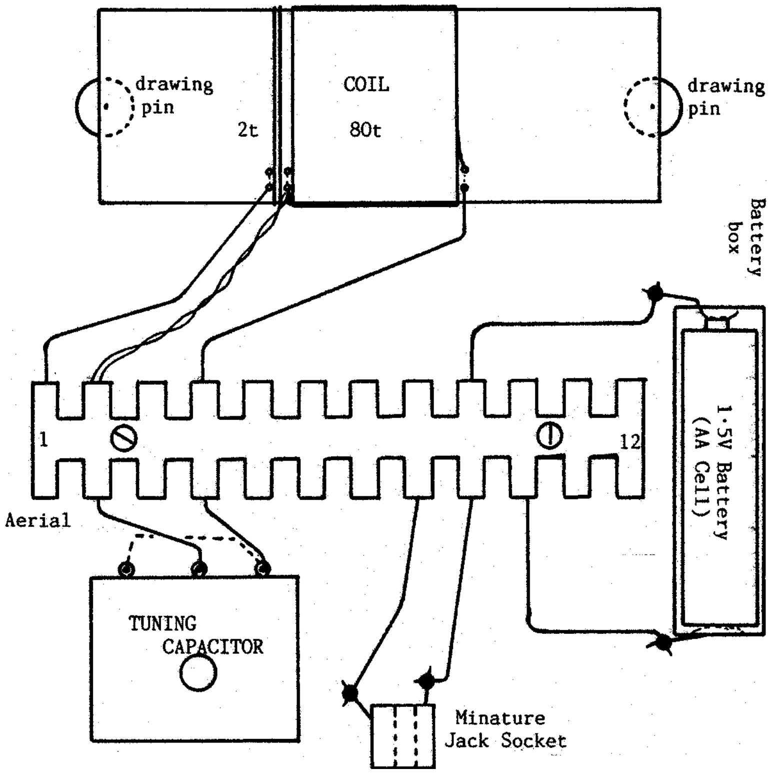

Figure 2 The layout of the parts on the wooden base

With some glass paper, remove the enamel from the ends of both pieces of wire which go through the same holes (i.e. the bottom of the large coil and the top of the small coil), then twist these bare ends together. Remove the enamel from the remaining ends of the coil. The coil is now finished!

The baseboard can be any piece of wood about 150 mm square. Fix the coil near the back edge using drawing pins and connect the wires from the coils to the terminal strip as shown in Figure 2. Using short pieces of PVC-insulated wire (and with assistance if you have never soldered before), solder one piece across the two outer tags of the variable capacitor, shown by the dotted line in Figure 2, and then two longer pieces to the centre tag and one outside tag. Connect these to the terminal strip. Then solder two more insulated wires on to the jack socket (into which you will plug your crystal earpiece), the other ends going to the terminal strip. The last two wires (one must be red) need to be soldered on to the battery box, their other ends going to the terminal strip also. Make sure the red wire goes to the *positive* terminal on the battery, and is connected to terminal 9. The other connection to the battery goes to terminal 10.

Attach the terminal strip to the baseboard with small screws or double-sided sticky tape. The other parts can be mounted the same way.

Listening is done ideally with the recommended crystal earpiece. Don't be tempted to use your Walkman earpieces; they are not the same and will not perform anything like as well. The receiver should work without an extra aerial, but one can be attached to terminal 1 if necessary. A long piece of wire mounted as high as possible is ideal. The *Audio-frequency Amplifier* project will enable you to use a loudspeaker with your receiver, using the signal from the jack socket. No circuit modifications will be needed!

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1, R5, R6	10 kilohms (kΩ)
R2	560 ohms
R3	270 ohms
R4	10 kilohms (kΩ)

Capacitors

C1, C2, C3	100 nanofarads (nF)
	500 picofarads (pF)

Semiconductors

ZN414Z, BC184

Additional items
- 12-way 2 A terminal strip
- 22 metres of 28 SWG enamelled copper wire
- A few short pieces of coloured PVC-insulated wire
- Crystal earpiece
- 3.5 mm jack socket
- 1.5 V AA-size battery and box
- Toilet roll tube
- Double-sided sticky tape or selection of screws

Tools required

Small screwdriver, soldering iron.

2 An audio-frequency amplifier

Introduction

This simple amplifier can be built by anyone who is able to solder reasonably well. It doesn't require any setting up and, provided our instructions are followed exactly, will work very well. The circuit diagram is included for the benefit of our more advanced readers, but it is not needed in the construction process. Please practise your soldering before you start, and don't use a printed circuit board (PCB) until you are confident that your soldering is up to scratch.

The amplifier can be used with other projects; it will provide plenty of sound from the MW Radio or from the Morse Sounder projects. It will usually be built into other pieces of equipment, so a box is not supplied with the kit. There is no reason why it shouldn't be put into a box and used as a general-purpose amplifier to help test other projects.

The components

Before you start, you should check that you have *all* the components to hand. A list and some helpful hints are given below.

1. PCB. The plain side is the *component side* and the soldered side is the *track side*. **Figure 1** shows the track side full size. Make the PCB from the pattern given in Figure 1. Otherwise, build the circuit on a matrix board.
2. Three resistors. Locate the gold or silver band around the resistor, and turn the resistor until this band is to the right. There are three coloured bands at the left-hand end of the resistor. Find the resistor whose colours are YELLOW, VIOLET, RED, and look at the resistor colour code chart which you will find in Chapter 7. From this, you will see that YELLOW indicates the value 4, VIOLET the value 7, and RED the value 2. The first two colours represent real numbers, and the last value is the number of zeros (noughts) which go *after* the two numbers. So, the value is 47 with two zeros, i.e. 4700 ohms. In this way, the resistor coloured BROWN, GREY, BROWN has a value of 180 ohms, and the last one, BROWN, RED, GREEN, has a value of 1 200 000 ohms. The ohm (often written as the Greek letter omega (Ω)) is the unit of resistance. If you do not yet feel confident in identifying resistors by their colours, use the Resistor Colour Codes given in Chapter 7.
3. Four capacitors. The two small 'beads' are tantalum capacitors and will be marked 4.7 μF or 4μ7, with a '+' above one lead. A tubular capacitor with wires coming from each end should be marked 220 μF, with one end marked '+' or '–'. This is called an *axial* capacitor because the wires lie on the axis of the cylinder. This is in contrast to the final capacitor, where both wires emerge from the same end. This is a *radial* capacitor, and will be marked 47 μF. Again, one lead will be marked '+' or '–'. Capacitors marked like this are said to be *polarised*, and it is vital that these are placed on the PCB the right way round, so take notice of those signs!
4. Two diodes. These are tiny glass cylinders with a band around one end, and may be marked 1N4148; this is their type number. Like polarised capacitors, they *must* be put on the PCB the correct way round!

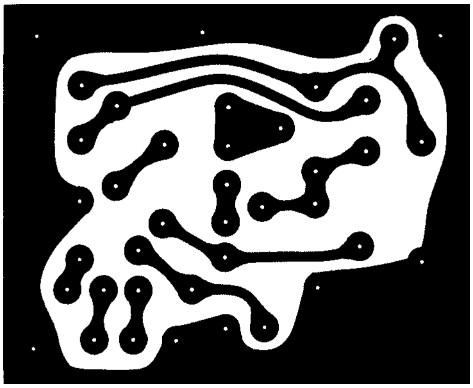

Figure 1 The toil pattern of the PCB – looking from the track side

5. Three transistors. One should be a BC548 (or a BC182), the other two should be BC558 (or BC212).
6. One volume control with internal switch.
7. One loudspeaker. This is quite fragile – don't let anything press against the cone.
8. One PP3 battery clip with red and black leads.

Putting it together

Lay the PCB on a flat, clean surface with the track side downwards. It is always useful to compare the layout with the circuit diagram, given here in **Figure 3**. Although you can't see it, the D-i-Y Radio sign should be at the top. Compare the hole positions with those shown in **Figure 2**. Bend the resistor wires at right angles to their bodies so that they fit cleanly into the holes in the PCB. Push each resistor towards the board so that it lies flat on the board. Then supporting each one, turn the board over and splay out the wires *just* enough to prevent the resistor falling out. Then, solder each wire to its pad on the PCB, and cut off the excess wire. When you have more confidence, you can cut of the excess wire *before* soldering; it often makes a tidier joint.

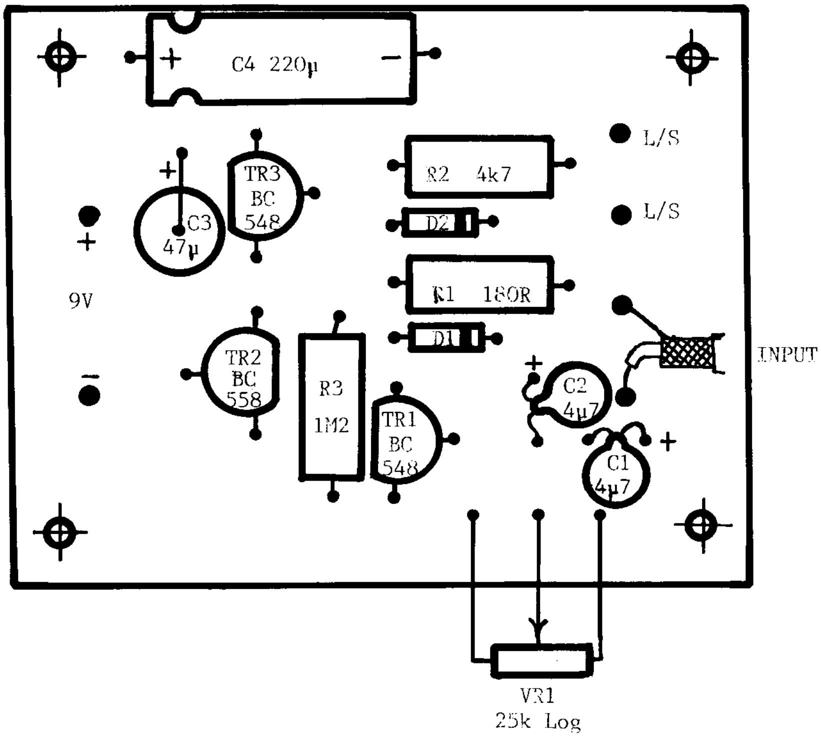

Figure 2 Positions of the components on the printed circuit board (PCB)

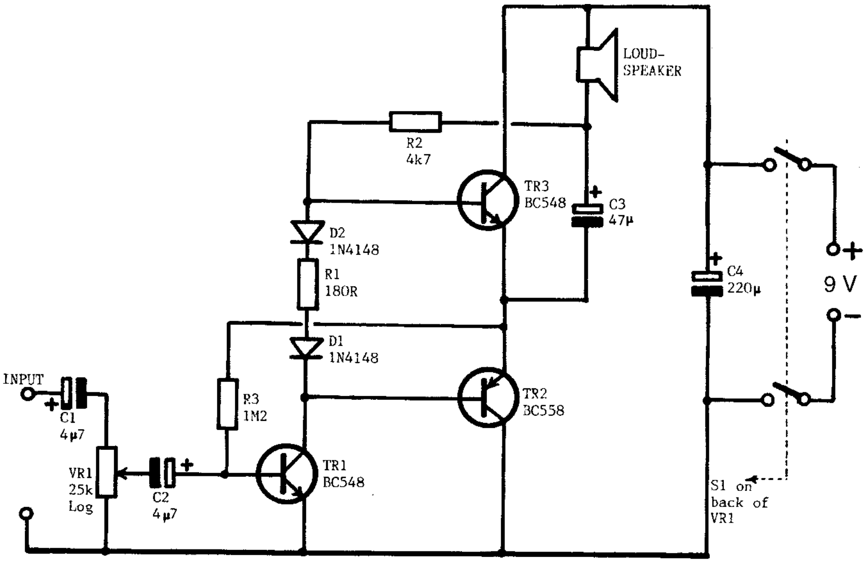
LOUD-SPEAKER
R2
4k7
TR3
BC548
C3
47µ
D2
1N4148
R1
180R
C4
220µ
9 V
D1
1N4148
INPUT
C1
4µ7
R3
1M2
TR2
BC558
VR1
25k
Log
C2
4µ7
TR1
BC548
S1 on back of VR1

Figure 3 The amplifier's circuit diagram

Now fit the four capacitors. Each must be connected the right way round, so look at each component, match it up with the diagram of Figure 2, bend its wires carefully and repeat the soldering process you performed with the resistors, making sure that the components are close to the board and not up on stilts! Fit the two diodes the correct way round, and solder then as quickly as you can – they don't like to be fried!

Mount the transistors about 5 mm above the PCB. Make sure the correct transistors are in the correct places, and that the flats on the bodies match up with those shown in Figure 2.

Mount the volume control so that the spindle comes out from the front of the board. Use a piece of red insulated wire to the pad marked + on the PCB, and a black piece to the pad marked –, and solder these to the tags on the back of the control, as shown in **Figure 4**. Connect the two leads from the battery clip to the other tags on the switch; Figure 4 will help you. Finally, use two pieces of insulated wire about 100 mm long, twisted together, to connect the loudspeaker to the PCB.

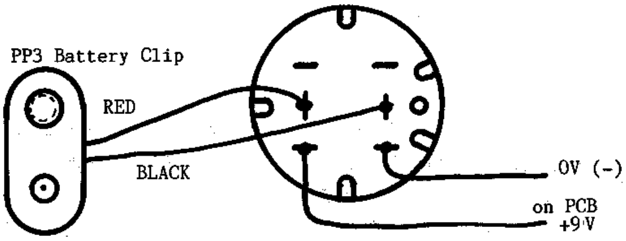
PP3 Battery Clip
RED
BLACK
0V (-)
on PCB
+9V

Figure 4 Connections to switch on back of VR1

Box clever!

If you wish to put the amplifier into a box, there is no problem; almost any box that is big enough will do. All that is needed is one hole big enough to accept the bush of the volume control; the PCB will be supported by the volume control. The prototype was not fitted into a box, but mounted on an odd piece of aluminium, bent into an L-shape and screwed on to a wooden base. The loudspeaker was mounted on the aluminium panel by two small pieces of aluminium with 3 mm holes drilled in them, which acted as clips around the edge of the speaker. Drill a few holes in the panel in the position of the speaker to let the sound get out!

Your input signal can be connected to the amplifier with two short pieces of wire, but if the connection needs to be long, use screened cable, with the braid connected as shown in Figure 2.

If you decide to use a different loudspeaker, make sure that its impedance (the resistance value marked on the back of the magnet) is at least 35 ohms. Anything lower may damage TR2 and TR3, and will certainly run down your battery very quickly. You will be surprised at the uses you can find for this little amplifier!

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	180 ohms (Ω)
R2	4.7 kilohms (kΩ)
R3	1.2 megohms (MΩ)
VR1	25 kilohms (kΩ) log with DPST switch

Capacitors: all rated at 25 V minimum

C1, C2	4.7 microfarads (μF)
C3	47 microfarads (μF)
C4	220 microfarads (μF)

Semiconductors

TR1, TR3	BC548 npn
TR2	BC558 pnp
D1, D2	1N4148

Additional items

- PCB
- Speaker >35 ohms
- PP3 battery clip and battery

3 A medium-wave receiver using a ferrite-rod aerial

Introduction

This design came from the Norfolk Amateur Radio Club, and enables you to build a simple Amplitude Modulation (AM) receiver for frequencies between 600 kHz and 1600 kHz. It should take you around 2 hours to build, and can be used with Walkman-type earpieces. **Figure 1** shows the circuit diagram.

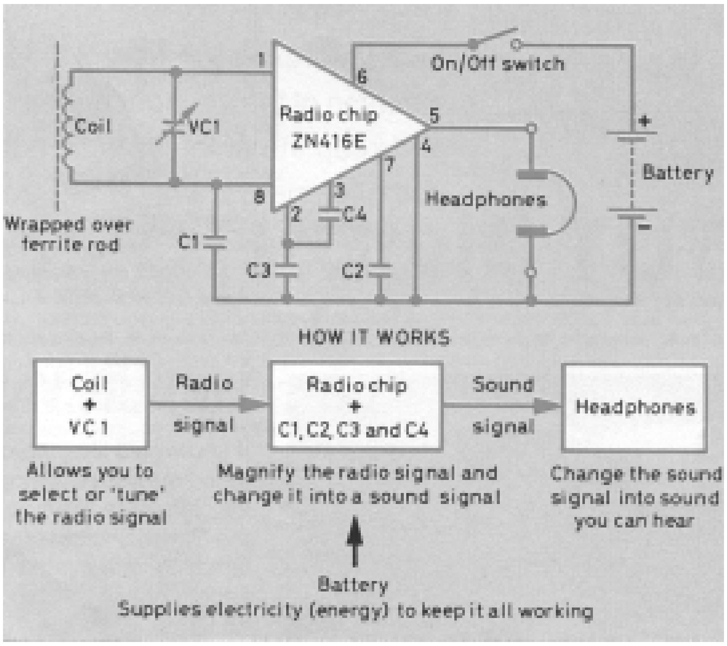
On/Off switch
Coil
VC1
Radio chip
ZN416E
1
6
5
4
7
3
8
2
C4
Headphones
Battery
+
−
Wrapped over ferrite rod
C1
C3
C2
HOW IT WORKS
Coil + VC 1
Radio signal
Radio chip + C1, C2, C3 and C4
Sound signal
Headphones
Allows you to select or 'tune' the radio signal
Magnify the radio signal and change it into a sound signal
Change the sound signal into sound you can hear
Battery
Supplies electricity (energy) to keep it all working

Figure 1 Circuit and block diagrams of the radio

Description

The whole circuit is built on a 50 mm by 50 mm printed circuit board (PCB) designed to fit on the inside of the lid of a plastic box, and is stuck there using sticky pads, the shaft of the variable capacitor going through a hole in

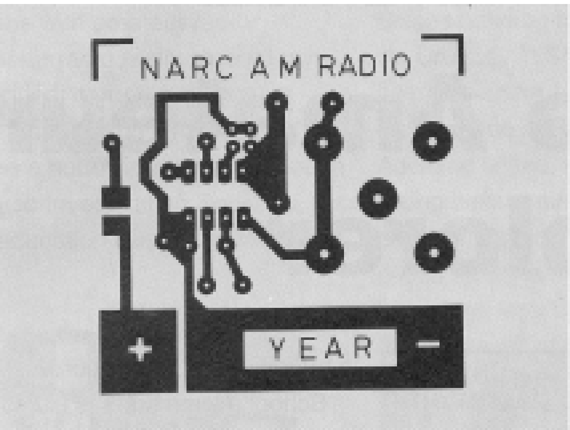

Figure 2a The PCB, solder side

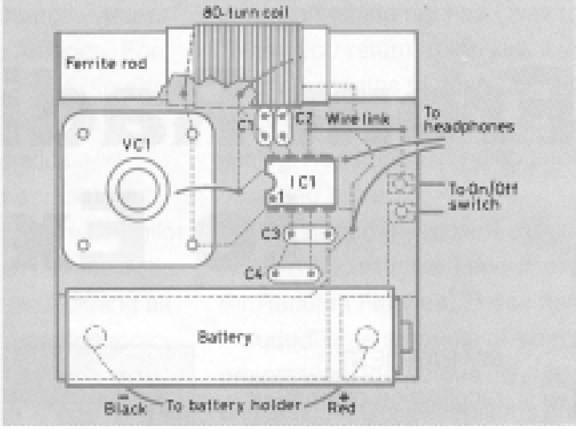

Figure 2b The PCB, component side

the lid. Only two pairs of leads are soldered to the board – one pair goes to the 1.5 V battery in its holder, and the other to the earphone socket. **Figures 2a** and **2b** show the printed circuit and the component layout double size for clarity. You are not obliged to build the circuit on a PCB.

Building it

1. **Check and identify components**. Tick the parts list.
2. **Carefully unwind the wire.** Use paper to make an insulating tube (called a 'former') around the centre of the ferrite rod and secure it with Sellotape. Now, close-wind *all* the wire (leave no gaps between adjacent turns) around the paper former. Secure the winding with more Sellotape, leaving 50 mm of wire free at each end for connection to the circuit. See **Figure 3a.**
3. **Solder in VC1.**
4. **Solder in the integrated circuit holder.** There is a notch in one end of the holder; this should face VC1. Solder also the wire link and the capacitors. Be careful to avoid solder 'bridges' between adjacent tracks on the PCB.
5. **Solder the battery leads.** These must be connected properly – the red battery lead to the + (positive) area and the black lead to the – (negative) area.
6. **Strip bare 1 cm of insulation from the ends of two wires**. Solder them between the PCB and the headphone socket (see **Figure 3b**). Use the end tabs on the socket. Using another pair of insulated wires connect the ON/OFF switch to the PCB tabs shown in Figure 2b.

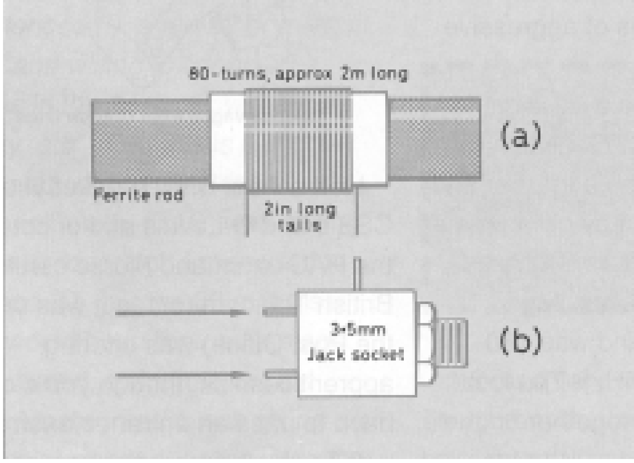

Figure 3 Details of coil and headphone socket

7. **Fix the elastic band.** This goes through the holes at the top of the PCB, with the ferrite rod being slipped through the two end loops. (Note: although the coating on the copper wire is designed to melt away during soldering, it is quite common for difficulty to be experienced in obtaining a good soldered joint; to be on the safe side, remove the coating *before* soldering (with a small piece of sandpaper).) Carefully place the wire ends of the coil through the PCB just above VC1, and solder on the track side.
8. **Fit IC1 into its holder.** This should be done carefully, making sure that *all* the pins are located above their respective clips *before* applying any pressure! Make sure also that the notch on the IC (as shown in Figure 2b) matches the notch in the holder, and faces VC1.
9. **Put battery in its holder.** Listen for some noise in the headphones as VC1 is rotated. Make sure the headphone plug is fully inserted into its socket.
10. **Fix the working board to the lid.** Use the sticky pads and apply *gentle* pressure. Fit the tuning knob, the ON/OFF switch and the earphone socket.
11. **Test again.** If all is still working, fit the lid screws and admire your completed radio!

Parts list

Capacitors	
C1, C2	0.01 microfarad (μF)
C3, C4	0.1 microfarad (μF)
VC1	500 picofarads (pF)
Semiconductor	
IC1	ZN416E

Additional items
- Plastic box (recommended size 76 × 64 × 50 mm internal)
- 8-pin DIL socket for IC1
- Printed circuit board
- Tuning knob for VC1
- Wire link for PCB
- 2 m of 30 SWG copper wire, self-fluxing
- Piece of paper 25 × 50 mm, to make the coil former
- Ferrite rod 70 mm long by 10 mm diameter, approximately
- Battery, AA size 1.5 V, with holder and attached wires
- Miniature earphone socket (3.5 mm stereo jack)
- ON/OFF switch (push-button SPST latched or slide switch)
- 4 off 100 mm insulated connecting wires, for jack socket and ON/OFF switch
- Pair Walkman-type earphones
- Elastic band, to attach ferrite rod to PCB
- 4 off sticky pads for securing PCB to box lid

Kits

Ready-made PCBs may be available from Alan J. Wright, G0KRU, Hewett School, Cecil Road, Norwich NR1 2PL.

4 A simple electronic organ

Introduction

This project has nothing to do with radio but, let's admit it, *any* electronics project is good experience! Why not build this little organ – it will keep the children amused at least! It uses the popular NE555 integrated circuit, which contains a circuit which will periodically switch the voltage on the output pin between the supply voltage and zero. Just how frequently this switching occurs depends upon the components external to the integrated circuit. If this switching occurs several hundred or thousand times a second, the change in voltage produced will generate a musical note when connected to a small loudspeaker. The circuit is shown in **Figure 1**.

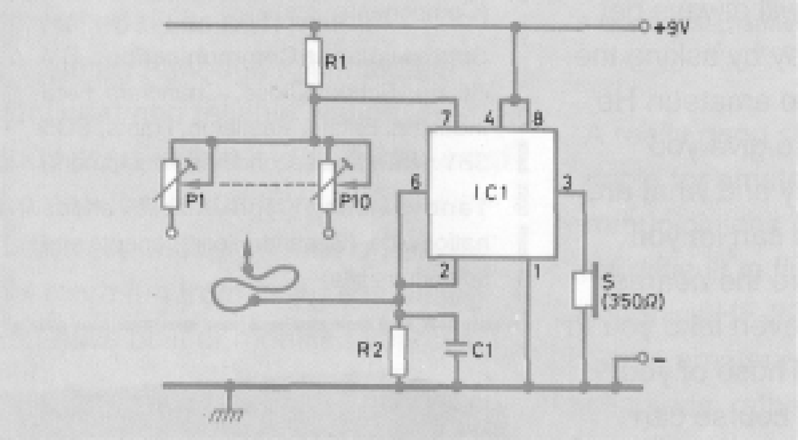
+9V
R1
7
4
8
P1
P10
6
IC1
3
2
1
S
(350Ω)
R2
C1
-

Figure 1 Circuit diagram

Putting it together

(a) Using a PCB. The job is very simple. The placement of components on the unsoldered side of the board is shown in **Figure 2** and the design on the copper track is illustrated in **Figure 3**. Put each component, in turn, on the board, making sure that it lies flat on the board with its tags or wires going cleanly through the holes provided for it; then, solder the wires to the board, cropping them before or after the soldering,

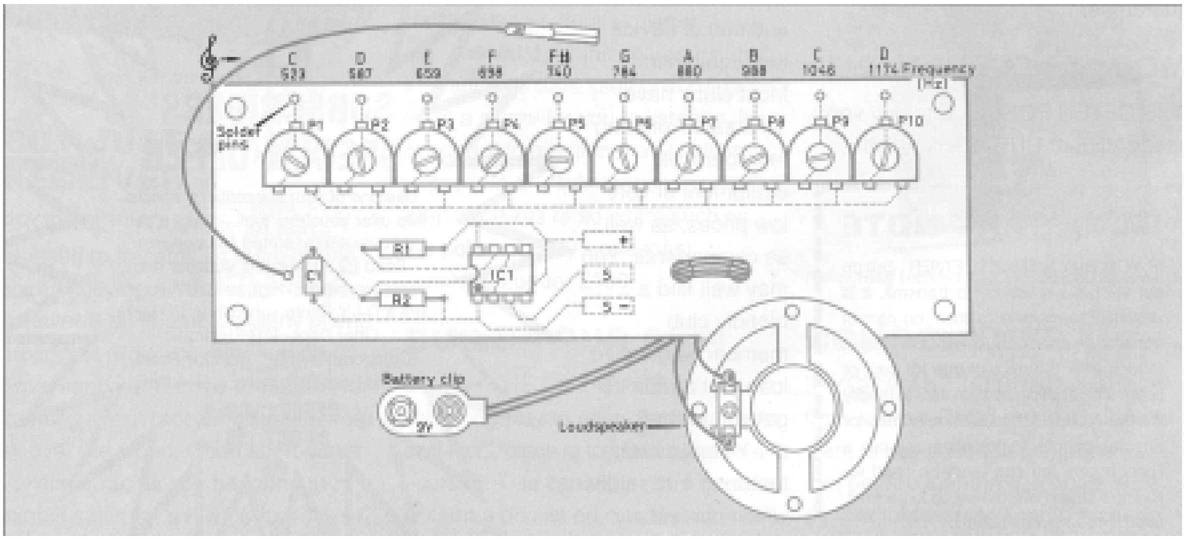
C 523
D 587
E 659
F 698
F# 740
G 784
A 880
B 988
C 1046
D 1174
Frequency (Hz)
Solder pins
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
R1
R2
IC1
C1
+
S
S -
Battery clip
9V
Loudspeaker

Figure 2 Position of components on the printed circuit board (PCB)

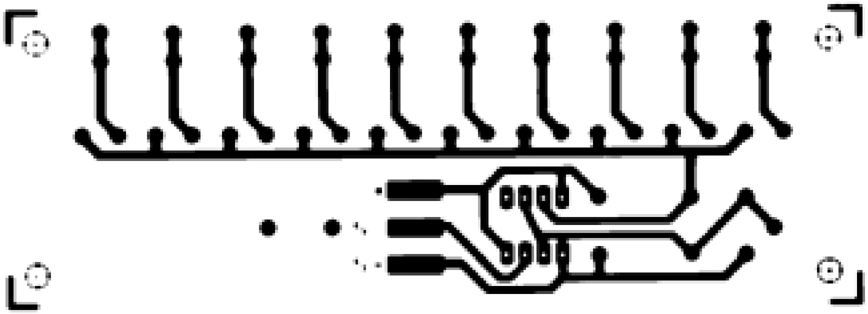

Figure 3 The connections

depending on your preference. If you choose to use a holder for your integrated circuit (highly recommended if your soldering is less than perfect), make sure that the end with a notch in it faces R1 and R2, as shown in Figure 2. Solder the two leads to the speaker to the tabs marked S (either way round), having looped them through the two holes to the right of the tabs in Figure 2. Looping them through the holes acts as a strain relief, ensuring that the soldered joints are not subjected to pulling and bending as you move the wires about. Do the same with the battery leads, the red lead going to the + tab and the negative lead to the – tab (which also has one speaker lead already attached to it). **Figure 4** shows this in detail. Treat the loudspeaker with care – the cone is quite fragile and must not be touched.

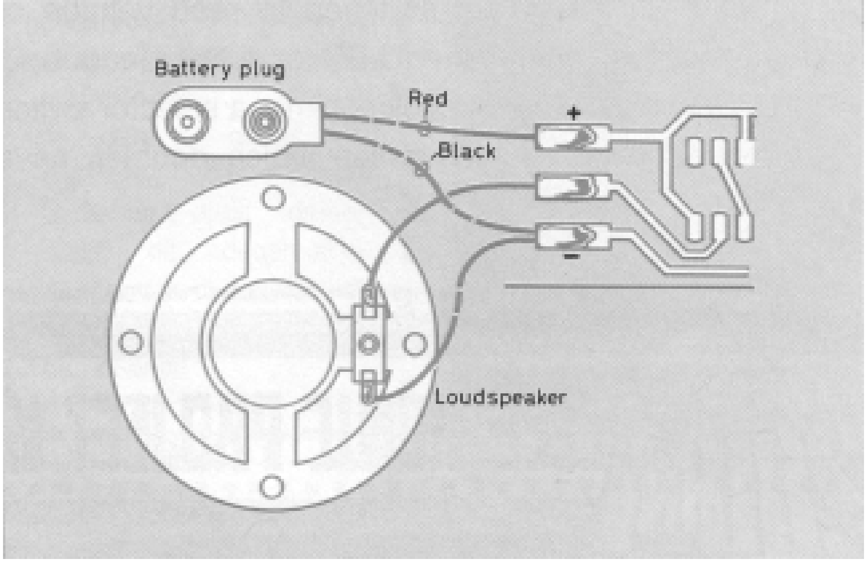

Figure 4 Battery plug and loudspeaker connections

(b) Without a PCB. This is more difficult, and you may need to enlist some help. Using some matrix board (such as Veroboard) is probably the best way of replacing the PCB. You could arrange your circuit in exactly the same way as in the PCB in Figure 3, using wires to replace the copper track.

A simple ‘keyboard’

The keyboard is a row of solder pins along the rear edge of the PCB, one for each note covering the range shown in Figure 2. A flying lead with a small spade on it is provided to touch any of the pins in turn, producing any one of ten different notes.

Testing

Check first that each component is in the correct place. When inserting the NE555 chip, first make sure that the end carrying the notch lies over the end of the holder with the notch; then, make sure each pin of the chip lies directly above the hole into which it fits, before pressing *gently* to insert the chip into the socket. Make sure the battery connections are correct, and insert the battery into the clip. Nothing should happen, except for a click from the loudspeaker; touching the spade on any of the pins should produce a coarse note from the speaker. If nothing happens, check everything again; don’t *assume* that wires go where you think they go!

After you get the first note, all the others should work, too, but they will sound off-tune at first. The organ needs tuning up by adjusting the 10 preset variable resistors P1 to P10. The approximate frequency to which each note should be tuned is given in Figure 2; if you can beg, borrow or steal a frequency counter, setting up is easy. If you have a piano, the organ can be tuned by comparison of the notes with those on the piano. The frequencies are given in Hertz (abbreviation Hz), and represent the number of times the IC switches on and off every second. If the sound coming from the loudspeaker is too loud or very distorted, then try putting an 330 Ω resistor (colour code orange, orange, brown) in series with the loudspeaker. This is done by taking the resistor and cutting its leads to about 5 mm; then, disconnect one speaker lead from the tab on the PCB (it doesn’t matter which). Solder one end of the resistor to the vacated speaker tab, and the free speaker lead to the other end of the resistor. This will limit the volume of sound from the speaker, and lengthen the life of your battery. If it is still too loud, try a resistor of a larger value, or use a smaller resistor to make it louder.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	2.7 kilohms (kΩ)
R2	1 Megohm (MΩ)
P1–P5	Preset resistor 100 kilohms (kΩ)
P6, P7	Preset resistor 50 kilohms (kΩ)
P8	Preset resistor 25 kilohms (kΩ)
P9, P10	Preset resistor 10 kilohms (kΩ)

Capacitor

C1	100 nanofarads (nF) or 0.1 microfarad (μF)

Integrated circuit

IC1	NE555 timer chip

Additional items

S	Loudspeaker >60 ohms (Maplin)
	1 off battery clip (for PP3 battery)
	1 off spade terminal
	12 off solder pins 'Veropins'
	3 off 10 cm lengths of 'hook-up' wire

(This article is based on projects originally designed by Radio Scouting, Netherlands.)

5 Experiments with the NE555 timer

Introduction

Several of the projects in this book use the NE555 timer, an integrated circuit which is at the heart of many circuits whose processes are determined by time intervals. **Figure 1** shows the circuit diagram of an audio oscillator using the 555. The timing voltages (governing the frequency of oscillation) are produced by R1, R2 and C2; a voltage appears at pin 3 which ‘switches’ at this frequency between zero and a voltage close to the supply voltage, which in this case can be anywhere between 6 V and 14 V. The output current, when applied through R3 to a small loudspeaker, produces an audible tone, provided that there is a DC path between the two test leads.

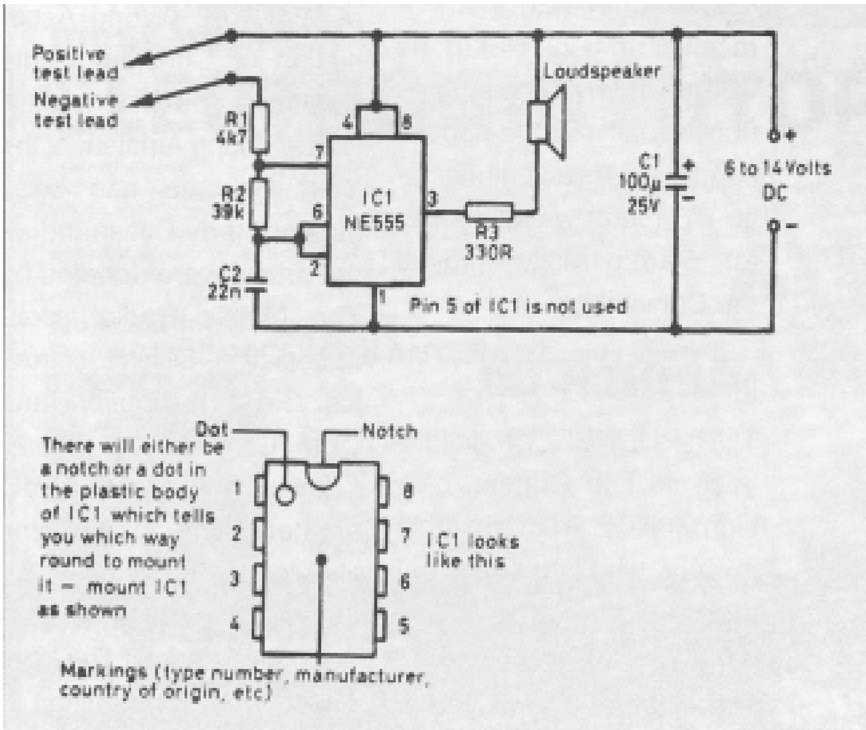
Positive test lead
Negative test lead
R1 4k7
R2 39k
C2 22n
4
8
7
6
2
1
3
IC1 NE555
R3 330R
Loudspeaker
C1 100µ 25V
+
−
6 to 14 Volts DC
+
−
Pin 5 of IC1 is not used
Dot
Notch
There will either be a notch or a dot in the plastic body of IC1 which tells you which way round to mount it – mount IC1 as shown
1
2
3
4
8
7
6
5
IC1 looks like this
Markings (type number, manufacturer, country of origin, etc)

Figure 1 The circuit diagram

Construction

The simplest way to mount the components is on a piece of matrix board (Veroboard), available from any of the good suppliers. The prototype of this circuit used the type of board with copper strips along the underside; these strips are used like the copper tracks on a PCB, to join components together. Firstly, cut the four strips between the positions of the pins of the IC socket, as shown in **Figure 2**. You can buy a tool for this purpose, but a small twist drill (about 3 mm diameter) is just as good. Turn it between your fingers – if you use a drill you will end up with holes right through the board! Then solder in the IC socket (with the notch in the position shown), followed by the four links made with single-conductor insulated wire. Put in each component as shown, ensuring that C1 (an *electrolytic* or *polarised* capacitor) is connected correctly. When all the components have been soldered in, take the 555 chip and lay it on its socket, with its own notch lying above that of the holder. Then, making sure that each pin lies *directly* above its corresponding socket, press down *gently* on the chip, with the board supported on a flat surface.

Testing

Connect the circuit to a battery or small power supply, ensuring that the positive and negative leads are the right way round. Always use red and black leads here, then you are less likely to get it wrong! Switch on. Nothing

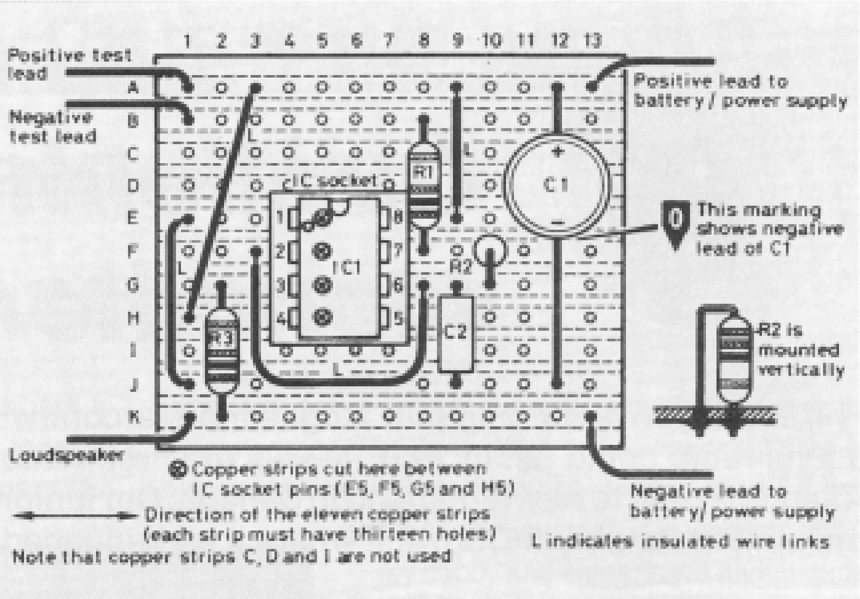
1 2 3 4 5 6 7 8 9 10 11 12 13
A B C D E F G H I J K
Positive test lead
Negative test lead
Loudspeaker
IC socket
1 2 3 4 5 6 7 8
IC1
R1
R2
R3
C1
C2
+
−
L
Positive lead to battery / power supply
This marking shows negative lead of C1
R2 is mounted vertically
Negative lead to battery/ power supply
⊗ Copper strips cut here between IC socket pins (E5, F5, G5 and H5)
Direction of the eleven copper strips (each strip must have thirteen holes)
Note that copper strips C, D and I are not used
L indicates insulated wire links

Figure 2 Veroboard layout. If you can read a circuit diagram, the project can be built using other methods

should happen until you short together the two test leads, when there should be a note from the loudspeaker. If this doesn't happen, switch off, disconnect the circuit and check your wiring and soldering. Is it exactly like Figure 2? Are the soldered joints round and shiny? If any are dull, then 'sweat' them briefly with a hot soldering iron until the solder runs, remove the iron, and check that they are as shiny as the rest. Check that there are no solder 'bridges' between adjacent tracks by holding your board up to a strong light. Then, reconnect, switch on and touch the test leads together. All should now work!

Uses of your circuit

1. As a Morse practice oscillator. Simply connect the two test leads to your key and, each time the key is pressed, you should hear a note from the speaker. The frequency of the note may be altered by putting a resistor in series with the key. To do this, remove one test lead from the key and select a resistor; connect one end of the resistor to the free test lead and the other to the empty terminal on your key. Selecting the value of resistor that you need will be a useful experiment in itself.
2. As a continuity tester. You can check fuses and lamp bulbs by connecting them across your test leads. If the speaker remains silent, the fuse or bulb has blown.
3. To indicate changes of resistance. Hold the ends of the test leads in each hand; you should hear a low note, because of the high resistance of your body. Squeeze the ends harder, and the frequency of the note should rise, because you are now making better contact. Repeat this with damp hands and the frequencies will be higher still.
4. As a thermometer. Connect the test leads to a thermistor (a device whose resistance changes with temperature) and warm it with a hair-dryer, or even in your hands, and you will hear the pitch changing with the temperature of the thermistor. A suitable 'bead' thermistor is available from Maplin (order code FX21).
5. As a diode tester. Use any diode, and connect the negative test lead to the end of the diode marked with the ring. This is the cathode of the diode. The other end, the anode, should be connected to the positive test lead, and a note should be heard from the speaker. This does not necessarily mean that the diode is working – yet. Reverse the connections and *nothing* should be heard. If this is the case, the diode *is* working.
6. As a light meter. Use a photoconductive cell (a device whose resistance changes with light intensity) connected between the test leads. A note should be heard. Shading the device with your hand will increase its resistance and the note should decrease in frequency. A suitable device is the ORP12 cell from Maplin (order code HB10).

There are many more applications. **Do not connect the test leads to other circuits that are switched on.** Your circuit, or the circuit you are connecting it to could be damaged. Think of a *passive* device or circuit (i.e. one *not* requiring a power supply or battery) where changes of resistance occur, and you have found another application!

Parts list

Resistors: all 0.25 watt carbon film types

R1	4.7 kilohms (kΩ) – yellow, violet, red
R2	39 kilohms (kΩ) – orange, white, orange
R3	330 ohms (Ω) – orange, orange, brown

Capacitors

C1	100 microfarads (μF) 25 V radial electrolytic
C2	22 nanofarads (nF) or 0.022 microfarad (μF) polyester type with 10 mm lead spacing

Integrated circuit

IC1	NE555

Additional items

Miniature loudspeaker (preferably 35, 40 or 80 ohm)
8-pin DIL socket for IC1
0.1 inch Veroboard (‘stripboard’), size 11 strips by 13 holes
PVC-covered stranded wire for test leads, loudspeaker and battery connections
PVC-covered solid wire for links on the board
A power source of between 6 V and 14 V, such as a 9 V battery (PP3)

Component sources

Cirkit
Tandy – many high street shops

6 A simple metronome

Introduction

A metronome is a device used by musicians to indicate the tempo of a piece of music. Until electronics came on the scene, this ‘beating of time’ was achieved in much the same way as a clock keeps time, i.e. with a pendulum device, the clicking of the escapement indicating the beats of the music.

Those of you who have already built the Morse Key and Buzzer from the designs in this book, will recognise the circuit of this metronome – it is exactly the same as was used to produce the note of the buzzer. This circuit is shown in **Figure 1**.

The circuit

Three components determine the speed at which the circuit oscillates – the speaker (LS), the resistors (VR1 + R1) and the capacitor (C1). VR1 is a variable resistor, so that the speed at which the oscillator operates can be varied. Compared with the component values of the Morse Buzzer (which operated at around 800 Hz), these components now give an oscillation frequency of around 1.25 Hz, which is far too low to be heard as a note. What we *do* hear, however, is a series of clicks, as the voltage across the speaker changes quickly from 0 to 9 V and back again.

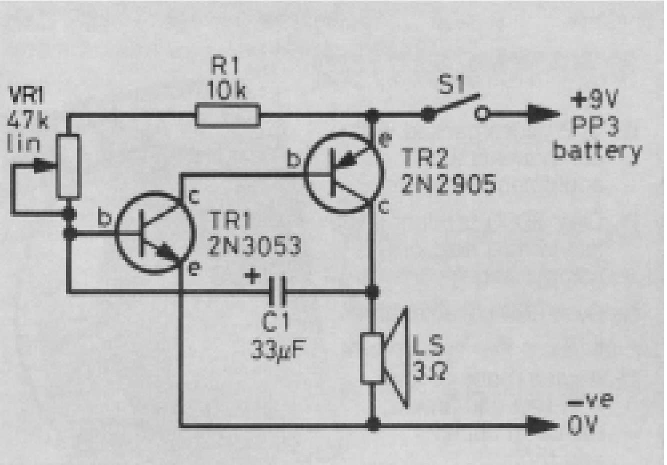

Figure 1 The metronome circuit is rather like the Morse oscillator

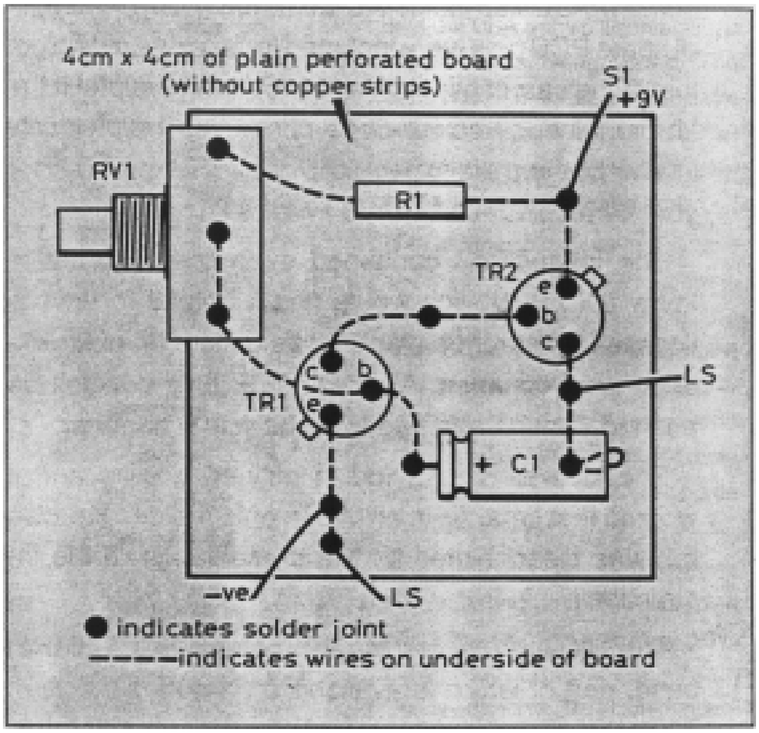
4cm x 4cm of plain perforated board
(without copper strips)
S1
+9V
RV1
R1
TR2
e
b
c
LS
c
b
TR1
e
+ C1
–ve
LS
● indicates solder joint
– – – –indicates wires on underside of board

Figure 2 The component wires are pushed through holes in the circuit board and joined together underneath

Variation of speed could be achieved by varying resistance or capacitance. However, as you may already know, variable capacitors have values in the picofarad range, not the tens of microfarads used here, so it is very simple to employ a variable resistor (potentiometer) to control the oscillator. You could use a multi-way switch to switch in one of several capacitors, as well as having the variable resistor, but this was found to be an unnecessary complication. This design operates between about 100 clicks per minute and 200 clicks per minute.

Making the prototype

A single piece of plain matrix board (no copper strips) measuring about 40 × 40 mm is sufficient to hold all the components except the potentiometer and switch (see later). The case can be plastic or aluminium, and one measuring 65 × 100 × 50 mm is about right. Make sure there are holes in the case beside the speaker cone to let the sound out, and larger holes for the potentiometer and switch. If a potentiometer is used with a combined ON/OFF switch, then the extra hole for the switch is not necessary! It is advisable to construct the circuit *before* putting it in the box, so that it can be tested to ensure that everything is working. If it is, then you can exercise your ingenuity in mounting the speaker, battery and board inside the box. A final test can be made before starting the calibration process.

Calibration

There is no 'easy' way to do this. The frequencies involved are too low to be measured with the average frequency counter, so you will need to resort to using a stopwatch and counting the number of clicks per minute.

Parts list

Resistors: 0.25 watt, 5% tolerance		
R1	10 kilohms (kΩ)	
VR1	47 kilohms (kΩ) linear potentiometer	
Capacitor		
C1	33 microfarads (μF) electrolytic	
Transistors		
TR1	2N3053	npn
TR2	2N2905	pnp
Additional items		
S1	SPST	ON/OFF switch
LS	3 ohms (Ω)	loudspeaker
	Knob with pointer for VR1	
	PP3 battery and connector	
	Aluminium case, 65 × 100 × 50 mm	
	Matrix board (plain), 40 × 40 mm	

7 What is a resistor?

Introduction

Materials that carry electricity easily are called **conductors**. They include all metals and salt water, for example. We use wire as a conductor, and the ease with which it passes an electric current depends upon the material, its thickness and its length. Silver (symbol Ag), gold (Au), copper (Cu) and aluminium (Al) are the best metallic conductors. Most wires are made of copper, although the best conductor, weight for weight, is aluminium.

Materials that *don't* carry current (or, at least, do so very badly) are called **insulators**, and they include dry wood, rubber, plastic and glass among their number. Wires are often coated with a layer of insulator to prevent adjacent wires touching and causing an accident.

Resistors

If there wasn't such a thing as resistance, the subject of electronics wouldn't exist; only infinite currents would flow and voltages wouldn't exist either! We need to reduce the flow of current if we are to make current do something useful for us. Components that resist the flow of current are called **resistors**, and they are said to have a **resistance** which is measured in ohms (Ω), named after Georg Ohm, who formulated the law (also named after him) by which the voltage and current through a conductor are related. His law gave rise to the formula *everyone* remembers:

$$I = \frac{V}{R},$$

where I is the current flowing, measured in amps,
V is the voltage across the conductor, and
R is the resistance of the conductor, measured in ohms.

From this equation, you can see that, for a constant value of voltage, V, if the resistance goes up, the current will go down, and vice versa. The circuit symbols for resistors are shown in **Figure 1**. You will find the upper symbol in older magazines; it is still preferred by many engineers. The lower symbol is the prevalent standard symbol.

Resistors are made in several ways, the cheapest using carbon; another type is usually made from a ceramic cylinder (used only as a support) on which

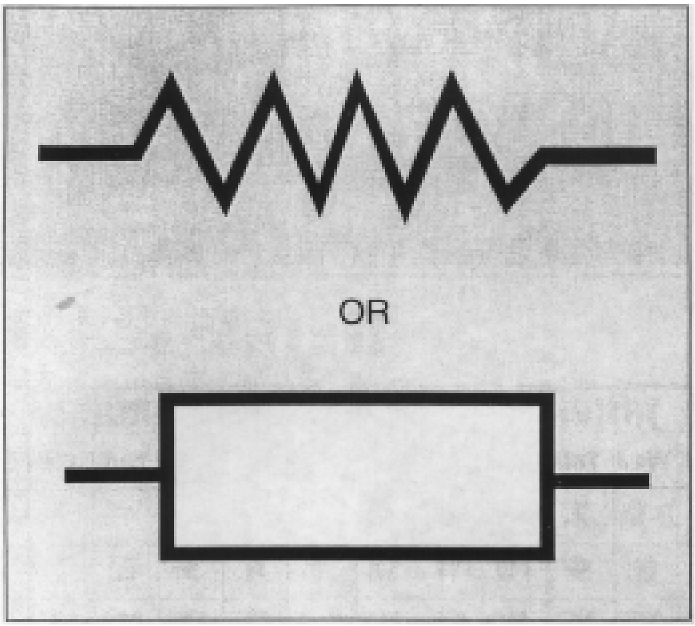

Figure 1 Circuit symbols for resistors

is placed a very thin film of metal – the thinner the film, the greater the resistance. All resistors are coated with a thin film of insulation, for the same reason we discussed earlier.

The colour code

Each resistor has coloured bands on it which enable us to see what value of resistance it has. There are normally three (but sometimes four) at one end, and a single one at the other (see **Figure 2**). The colours indicate figures, according to the list below.

Colour	*Value*	*Colour*	*Value*
Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Grey	8
Yellow	4	White	9

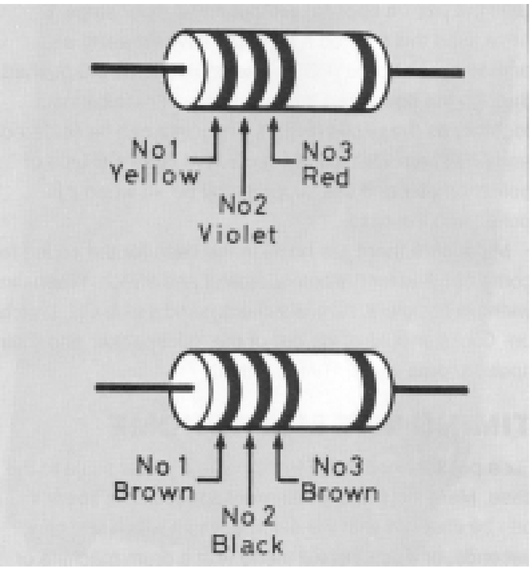

Figure 2 Some examples of resistor colour codes; top 4700 Ω (4.7 kΩ) and bottom 100 Ω

Using the colour codes is easy, once you see the logic behind it. Hold the resistor so that the single band is towards the right. The three colours on the left are read in the normal order from left to right. The first two bands *always* indicate numbers; the third band gives the number of zeros to add to the right of these two numbers. So, looking at the top resistor in Figure 2, yellow, violet, red means 4, 7, and two zeros, giving 4700 ohms! Looking at the lower resistor, brown, black, brown means 1, 0, and one zero, giving 100 ohms.

Remembering the order of the colours may be difficult at first. The colours from red to violet are the colours of the rainbow, in order, so if you know those, you're almost there! Around those colours are black and brown below the red, and grey and white above the violet, which you can imagine as getting brighter from black to white (well, almost!). It won't be long before you don't need to remember them at all.

The isolated band on the right-hand side is not part of the resistor's value; it indicates its *tolerance*, i.e. how close it might be to the indicated value. A brown band indicates ±1%, a red band ±2%, a gold band ±5% and a silver band ±10%. For example, a resistor marked as being 100 ohms with a ±5% tolerance will have an *actual* value somewhere between 95 ohms and 105 ohms.

8 Waves – Part 1

Introduction

Waves are responsible for most of the processes in life where energy is transferred from one place to another. Heat and light energy from the sun, for example, come to us as *electromagnetic waves*. Sound travels through the air as a wave; it is not the same sort of wave as light or heat, but it obeys many of the same properties. Damage is caused to coastal margins by the waves of the sea – again, another type of wave, but still obeying many of the same properties. Radio waves are of the same type as heat and light waves, as are gamma rays, X-rays, ultra-violet waves and infra-red waves. So, once we begin to understand what radio waves do, we are also learning about a huge chunk of physics at the same time! All these waves are part of the *electromagnetic spectrum*. The word 'spectrum' simply means a 'range', so what we have is a range of electromagnetic waves – that's all!

Sensing things

Light waves are invisible, but our eyes can detect the *effect* they have on different materials because the waves produce an effect on the retina of the human eye which the brain can interpret. We cannot see heat waves either, but we can feel the *effect* they have on our skin. Gamma rays and X-rays are also invisible, but their detrimental *effects* on human tissue are well known. It is not surprising, then, that we cannot see radio waves. We cannot sense them, either, until we produce a device upon which they have an *effect*. That device is a **radio receiver**; it is able to process certain characteristics of radio waves, and make these characteristics audible by generating sound waves from the loudspeaker or headphones. Other characteristics of the same waves may be turned into light as a TV picture on a cathode-ray tube, or as a fax image on a sheet of paper.

Visible waves

Let's start our description with some waves that we can actually see! When a small stone is thrown into a pond, we see circular water waves *radiating* from the point where the stone fell into the water, as **Figure 1** shows. (Notice that we use the word *radiating*, even with water waves; it is not a radio term, but one which describes any motion where the *radius* of a circle is increasing. In this case, it is the radius of the circular waves which is

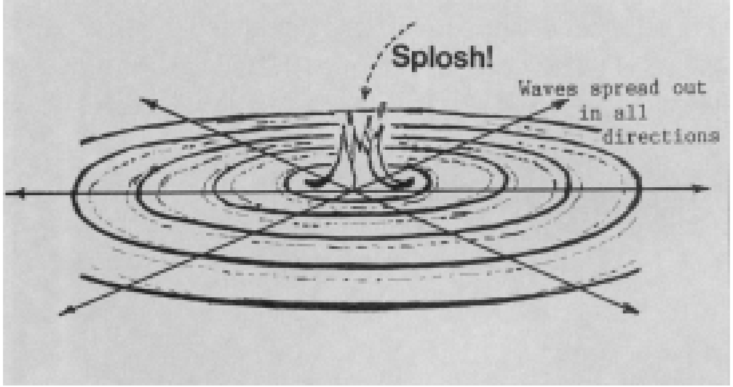

Figure 1 The waves move out from the point where the stone landed

increasing.) If you were to watch the water waves down at the water level, perpendicular to the direction in which they are travelling, you would see something like the illustration in **Figure 2**.

The horizontal line represents the water level before the wave started, and the vertical line represents the direction in which the water is displaced at any instant.

All waves are described in the same way

'Freezing' the motion of the water in this way allows us to define two very important characteristics of a wave, characteristics which we talk about every day – *wavelength* and *amplitude*. The wavelength of a wave is simply the distance (measured in metres) from any point on one wave to the same point on the adjacent wave. Look at the diagram and you will see what is meant by 'the same point on the adjacent wave'. The amplitude of a wave

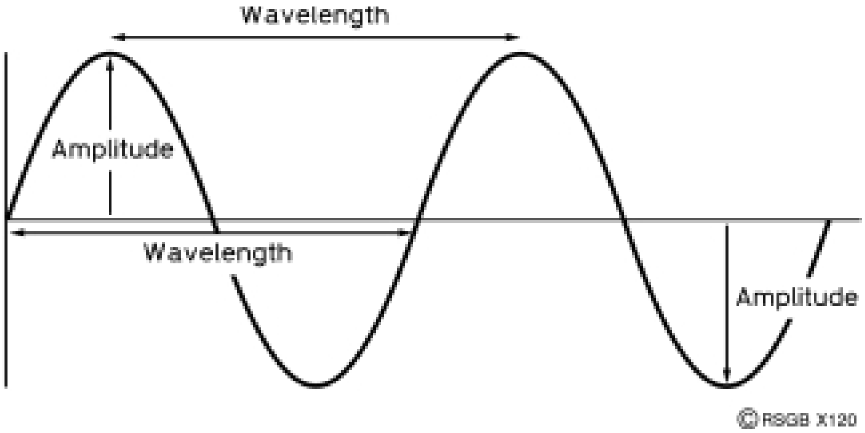

Figure 2 A water wave, viewed in cross-section

is always measured from the centre (undisturbed) position of a wave to the peak (or the trough) of the wave. Both these positions are shown, the arrow indicating that the measurement is taken *from* the centre *to* the peak or trough. The amplitude of a wave is defined as the maximum displacement of the wave from the centre position – the direction (up or down) of that displacement does not matter. Waves of greater amplitude carry more energy with them.

If we now 'unfreeze' the wave, we will see it travel from left to right (or right to left, depending on where we are looking). The speed at which it moves is called its *velocity*, and is measured in metres per second.

Another useful word is *propagate*; it means *travel*. We talk about radio waves propagating from a transmitter to a receiver. This velocity of propagation (for electromagnetic waves) is very fast indeed – they will cover 300 million metres in one second. This is virtually incomprehensible, so think of a radio wave travelling around the earth – it can travel 7½ times round the earth in one second! We use the symbol *c* for the velocity of radio waves (which is the same as the velocity of light, of course – all electromagnetic waves travel at this speed through air and space).

The last thing we need to know about the wave is its *frequency*. Imagine a cork floating on the water in the path of the wave; it will bob up and down. If we were able to count the number of times it went through its highest position in one second, then that number would be its frequency. Any periodic motion like this is said to go through one *cycle* each time one complete wave passes a point (in this case, our cork). We are thus counting the number of cycles per second of the cork's motion. The unit of frequency is thus 'cycles per second'; this unit is now named after Hertz, a radio pioneer, and is abbreviated to Hz.

Our description of the wave is now quite simple – we need only four quantities:

(a) **Frequency** symbol f – unit, hertz (Hz)
(b) **Wavelength** symbol λ (Greek letter lambda, pronounced 'lamb-da') – unit, metre (m)
(c) **Amplitude** symbol a – unit depends on application
(d) **Velocity** symbol c – unit, metres per second (m/s or ms^{-1})

The basic formula

Whatever may happen to a wave while it travels through different media (vacuum, air, brick, wood, etc.), one thing and **only** one thing remains constant – its frequency. Its wavelength, amplitude *and* velocity may change, but its frequency never does. Three of the four characteristics already identified are connected by the simple relationship

$$c = f \times \lambda.$$

Remember that *c* is constant if the wave travels in air or in a vacuum. This means that waves having higher frequencies (*f* large) must have smaller wavelengths (λ small) and vice versa. You can imagine frequency and wavelengths being on opposite ends of a see-saw!

Divisions of units

Because the frequencies of radio waves are so high (despite them having the lowest frequencies in the electromagnetic spectrum!) we have a problem with writing them down. Do you write in your log book that you have just heard a station on 14 100 000 Hz? Of course not, you write it as 14.1 MHz, knowing that the prefix mega (M) means 'one million'. The prefixes which you need to know (when applied to frequency) are:

kHz	kilohertz	meaning	1000 Hz
MHz	megahertz	meaning	1 000 000 Hz
GHz	gigahertz	meaning	1 000 000 000 Hz.

Notice that the 'k' in kilohertz is a lower case letter. It is **incorrect** to write it as an upper case letter. 'K' is a computer-related prefix meaning **not** 1 000 but 1 024!

When we come on to discuss heat and light waves, we will use wavelengths rather than frequencies, because of the see-saw effect – as the frequencies get larger and larger, the wavelengths get smaller, and hence are numbers which are more manageable, both to talk about and to write down!

Bands

Gamma rays, X-rays, ultra-violet waves, light waves, infra-red waves are all part of the electromagnetic spectrum, but we divide them up because they have different properties. This is why we divide up our radio frequencies into different bands. The radio waves of top-band signals (around 2 MHz) have completely different properties compared with those in the 20 metre band, so we are dividing up the *radio spectrum* in the same way – by property.

9 A beat-frequency oscillator

Introduction

Many readers will know that, although they have a short-wave radio which covers at least one of the amateur bands (e.g. 7 MHz or 14 MHz), they are unable to listen to SSB or Morse signals. This is because the receiver lacks a Beat-Frequency Oscillator (BFO). We need the 'carrier' frequency of a BFO to replace the carrier that has been removed from the signal at the transmitter. When listening to Morse signals, the BFO signal 'beats' with the incoming signal to produce a note in the loudspeaker. If you are a musician, you will be familiar with the method of using 'beats' to tune one musical instrument from another; in the BFO, the beat frequency produced is the tone signal you hear.

In the more complex amateur radio receiver, a BFO is incorporated as part of the whole system. In our model, it is an external circuit that sits alongside your radio. The circuit diagram is shown in **Figure 1**.

Construction

Built on a small piece of matrix board about 80 × 50 mm, the circuit can be fitted inside a small plastic box. For once, we *don't* want to screen the circuit to prevent it interfering with other equipment; we *want* it to interact

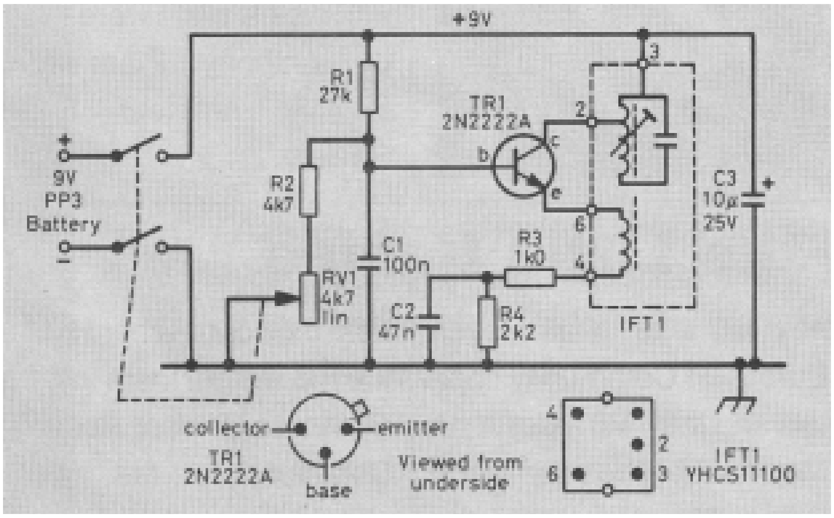
+9V
R1
27k
TR1
2N2222A
b
c
e
2
3
6
4
+
9V
PP3
Battery
−
R2
4k7
C1
100n
R3
1k0
C3
10µ
25V
+
RV1
4k7
lin
C2
47n
R4
2k2
IFT1
collector
emitter
base
TR1
2N2222A
Viewed from
underside
4
2
6
3
IFT1
YHCS11100

Figure 1 Circuit diagram of the BFO

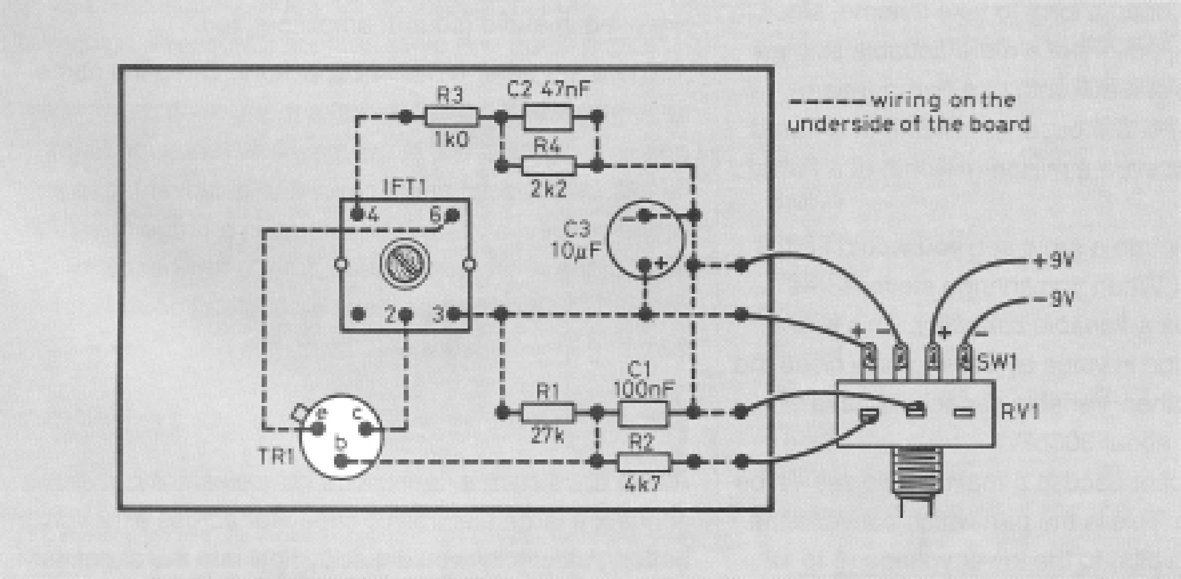

Figure 2 Matrix board layout shown from the component side. Adjust IFT1 carefully for the best results

with our receiver! This is why we use a plastic box. Maplin Electronic Components supply a suitable box, complete with the matrix board to fit inside (order code YU46).

Look at **Figure 2** carefully before you start to build the circuit, so that you can position the components correctly. Firstly, inspect the intermediate frequency (IF) transformer, IFT1, and remove its metal screening can very carefully. Again, this is to allow some signal to escape from our circuit and enter our radio. Having done this, solder the components, using the matrix board as a support. Underneath the board, the components are linked by single-conductor, insulated wire. Take particular care with the polarity of the electrolytic capacitor, C3, and the connections to the transistor, TR1 (see Figure 1).

The variable resistor, VR1, has a switch mounted behind the control itself, and the insulated leads to it from the battery should be about 10 cm long. Connect these before fitting VR1 into the case, so that the BFO can be calibrated (adjusted) correctly.

Calibration

After a final check that all the components have been fitted and soldered correctly, connect the battery, switch on, and hold the transistor between your fingers, to check that it is not getting hot. Place the circuit close to your receiver, and set RV1 to mid-position. Tune your receiver to find an amateur SSB transmission; the frequencies listed below will help you in knowing where to look. It may sound very strange, but don't worry. *Slowly* turn the core of IFT1 with a small, non-metallic screwdriver or with the correct 'trimming tool'. The core into which the blade fits is very fragile, so attempt this process with care. When the speech sounds as natural as you can get it, leave the core at this position, and use RV1 to make the speech sound natural.

Using the BFO

For best results, you may have to move the BFO nearer or further away from your radio. At the lower end of most bands (for instance just above 7.000 MHz or 14.000 MHz) you should be able to resolve Morse code (CW) signals. If you find that the BFO signal is a little weak, solder a 15 cm length of insulated wire to pin 2 of IFT1, and place it alongside your radio. This should improve signal intelligibility. When you are happy with the performance, switch off, drill a 10.5 mm hole in the box and fit RV1, followed by the matrix board assembly. Screw the base to the box, fit the knob, and the BFO is complete!

Where to listen

Band	**Frequencies (MHz)**
15 m	21.000–21.450
17 m	18.068–18.168
20 m	14.000–14.350
30 m	10.100–10.150
40 m	7.000–7.100
80 m	3.500–3.800

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	27 kilohms (kΩ)
R2	4.7 kilohms (kΩ)
R3	1 kilohm (kΩ)
R4	2.2 kilohms (kΩ)
VR1	4.7 kilohms (kΩ), linear, with DPST switch

Capacitors

C1	100 nanofarads (nF) or 0.1 microfarad (μF), ceramic
C2	47 nanofarads (nF) or 0.047 microfarad (μF), ceramic
C3	10 microfarads (μF), 25 V radial, electrolytic

Additional items

TR1	2N2222A npn
IFT1	Toko type YHCS11100
Box	plastic, approximate size 100 × 70 × 45 mm
Board	matrix, to fit inside the box
Connector	for PP3 battery
Knob	for RV1

10 What is a capacitor?

Introduction

A capacitor is a device that stores energy in the form of electricity. Much less energy than a battery, and for a shorter time, however. The simplest form of capacitor takes the form of two flat metal sheets separated by air; connections are made to each plate, as **Figure 1** shows. If you imagine a pair of these plates, 30 cm square and separated from each other in air by 1 mm, the capacitance of this device would be almost exactly 80 picofarads (pF), i.e. 80 million-millionths of the unit of capacitance, the farad. Now this is quite a small value, you will agree, and it comes about because the farad is such a large unit. Nevertheless, as you will probably know, we may have capacitors of value 10 000 microfarads (μF) in our radio equipment, and they can be smaller than your little finger, so they are obviously not made the same way!

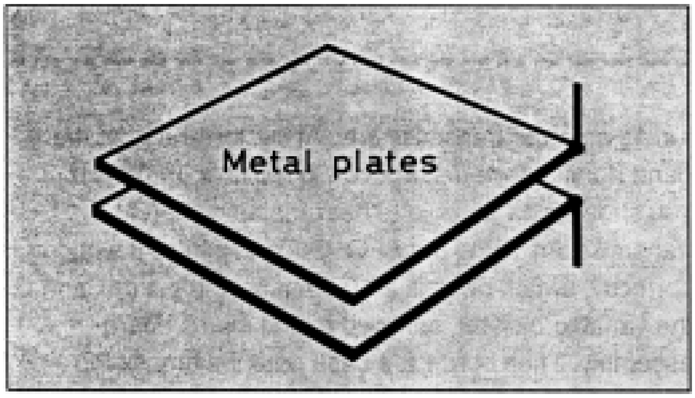

Figure 1

Large and small

We cannot go into the manufacture of capacitors here – after all, we are users of the devices, not the designers! First of all, beware of incorrect statements; the words ‘capacitor’ and ‘capacitance’ are *not* the same. For example, a large capacitor would be a description of one the size of a toilet roll. It need not have as large a capacitance as one the size of your little finger. A ‘large capacitor’ is one which is physically *big*, a ‘large capacitance’ refers to a capacitor which can store a larger amount of energy when a certain voltage is applied between its plates. The capacitors in a mains power supply are usually big **and** have large capacitances. High-power RF amplifiers may have large capacitors with small capacitances!

Electrolytics . . .

Electrolytic capacitors usually have capacitances of 1 μF or above. They differ from other capacitors in that they **must** be connected the right way round (i.e. they have positive and negative connections, just like a battery). They may explode if the connections are reversed!

. . . and the others

Other capacitors may be connected either way round, despite their names. We have *polystyrene*, *ceramic*, *silver-mica* and *tantalum*. Each has its own advantages and disadvantages, and the parts list for a project will always tell you which type is best.

Storing energy

If you were to connect a large capacitance across a 12 V power supply, nothing would appear to happen. Removing the capacitor from the supply and connecting it to a voltmeter would show that the capacitor has 12 V between its ends. This shows that, while the capacitor was connected to the supply, energy flowed from the supply into the capacitor. We say that the capacitor was *charged up* by the supply. If you are using an *analogue* voltmeter (i.e. one with a meter and pointer), you will notice that the indicated voltage slowly drops until, eventually, there is no voltage across the capacitor. This is because the capacitor has *discharged* its energy into the voltmeter. If you had used a smaller capacitance, the same would happen, except that the voltage would drop to zero more quickly – the capacitor stores a smaller amount of energy because its capacitance is smaller. Capacitors behave like other things in life – a small car can move more quickly than a large bus – a small piccolo emits a higher note than a flute – the voltages in a circuit containing a small capacitance will change more quickly than those in a circuit with large capacitance.

Varying the capacitance

Some capacitors are capable of having their capacitance changed manually; these are called *variable capacitors*. They work like the basic capacitor of Figure 1. Imagine moving the top plate of the pair a little to one side; the capacitance is determined, not just by the size of the two plates, but by their *area of overlap*. As this decreases, so does the capacitance. Such devices are limited in their capacitance, about 500 pF being the maximum value.

AC and DC

Because the plates of a capacitor do not touch each other, a direct current (DC) cannot pass between them. However, an alternating voltage on one plate can induce an identical alternating voltage on the opposite plate, and thus a capacitor appears to pass an alternating signal, even though currents as such, do not pass between the plates. This property of passing AC and not DC is very important, and a capacitor used in this way is called a *DC blocking capacitor* or, simply, a *blocking capacitor.* A blocking capacitor can be used at the same time, to couple a signal from one circuit to the next; here it would be known as a *coupling capacitor. Decoupling capacitors* are to be found where the capacitor is employed to remove an AC signal while retaining a DC component.

Finally . . .

Unlike resistors, the manufacture of capacitors renders them susceptible to excess voltage, so if you find a capacitor labelled 10 μF 16 V, it means that operating it above 16 V may fatally damage the device (and the circuit around it). This voltage is called the *working voltage* of the capacitor; on some electrolytics, you may find it expressed as *volts working* (i.e. 8 μF 450 V WKG).

Many smaller capacitors have their properties marked on them in a colour code, like resistors. **Figure 2** shows these codes, and their meaning, and the table below summarises the values of the colours.

Table 1

Colour	*Value*	*Voltage (tantalum capacitor)*	*Voltage (polyester capacitor)*
Black	0	10	–
Brown	1	–	100
Red	2	–	250
Orange	3	–	–
Yellow	4	6.3	400
Green	5	16	–
Blue	6	20	–
Violet	7	–	–
Grey	8	25	–
White	9	3	–

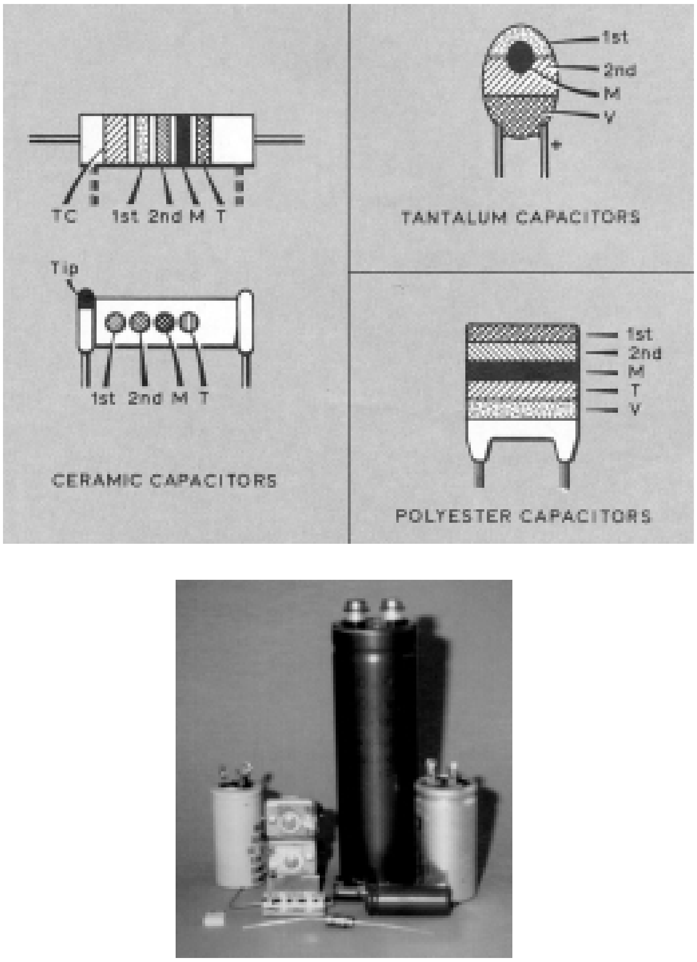
TC
1st
2nd
M
T
TANTALUM CAPACITORS
1st
2nd
M
V
+
Tip
1st
2nd
M
T
CERAMIC CAPACITORS
1st
2nd
M
T
V
POLYESTER CAPACITORS

Figure 2 Some capacitors have coloured bands or stripes, rather like resistors. The colour code, which is the same as the resistor code, is shown in Table 1. The band shown on the chart as ‘1st’ is the first number of the capacitor’s value in pico-Farads, ‘2nd’ is the second number and ‘M’ is the Multiplier or number of noughts. For example, a capacitor reads from the top: Brown, Black, Yellow, Black, Red. Its value is One, then Nought, then Four more noughts = 100 000 pF (also referred to as 0.1 μF or 100 nF). Its tolerance (Black) is 20% and the working voltage (Red) is 250 V. The ‘V’ means the maximum working voltage. The band marked ‘T’ shows the tolerance, just like resistors, and the one marked ‘TC’ is only used on special capacitors designed to change their value with temperature

11 Waves – Part 2

Introduction

We left Part 1 with the concept that radio waves are divided up into bands which have different properties. Not *all* the properties are different, though. We need to discuss several wave properties, so we will start with what happens to waves as they propagate over long distances.

Getting weaker

Imagine a torch battery connected to a bulb by wires about 1 metre long. The bulb lights normally. If we now take the bulb 100 metres away from the battery and wire it up, we would expect the bulb to be somewhat dimmer, which is exactly what would happen. It happens because of the resistance of the wires – the wires do not form a perfect conductor. A similar situation occurs with radio waves.

All waves suffer from *attenuation* – they get weaker the further they travel. In cases of extreme attenuation, we need to apply some *amplification* before the attenuated wave can be used in a receiver.

Carrying information

When we speak over the telephone, the range of frequencies in our voices extends from very low frequencies up to about 15 or 20 kHz. In audio terms, this is quite a large *bandwidth* (meaning a wide band of frequencies). For communications purposes, however, most of this bandwidth is not needed, and in the telephone system (and in our transceivers), this is cut down so that it extends from about 200 Hz to 3 kHz, a reduction in bandwidth from 20 kHz to about 3 kHz. A bandwidth of 3 kHz has been found to be sufficient to convey speech intelligibly which, after all, is just what we need!

The radio waves coming from an amateur transmitter convey our speech signals over long distances. By themselves, the speech signals do not travel very far, so they have to be combined with a radio signal that *will* travel long distances. This extra signal is called the *carrier wave* (or just the *carrier*), because its job is to *carry* the speech signals along with it! The process of combining the speech (or Morse code) with the carrier is called *modulation*.

Wider and wider

Sending Morse code is achieved simply by switching (or *keying*) the carrier on and off. The bandwidth of the transmitted signal is only about 100 Hz. Speech, with its reduced bandwidth of 3 kHz, will produce a *single-sideband* (SSB) transmitted signal with a bandwidth of 3 kHz. If the same speech signal were used to produce an *amplitude-modulated* (AM) signal from the transmitter, it would have a bandwidth of about 6 kHz. Perhaps you can now understand why the bandwidths needed to produce hi-fi broadcasts need to be so large. TV signals need bandwidths running into tens of megahertz!

Waves need aerials

Radio waves are produced whenever changing currents flow through a wire, and when that wire is made in such a way as to maximise the *radiation* from the wire, it is called an *aerial* or *antenna*. The same piece of wire will receive radiation from other aerials; an aerial will transmit and receive. This is an important property of the aerial: when a current flows through it, electromagnetic waves are launched into the air; when electromagnetic waves in the air encounter the aerial, currents are produced in it.

From the simplest transmitting aerial, waves travel in all directions, like the waves on the pond that we considered in Part 1. They will travel a long way through air and space before they become too week to be received. They won't travel very far into the earth, however! The earth will *reflect* some of the wave and will *absorb* the rest. That portion of the wave which is reflected will again travel through air and space until it is totally attenuated.

Look at **Figure 1**; A represents a radio transmitter, with B1, B2 and B3 being receiving stations. The two arrows pointing 'downwards' from A represent two of the waves from A which just graze the earth's surface. Waves above

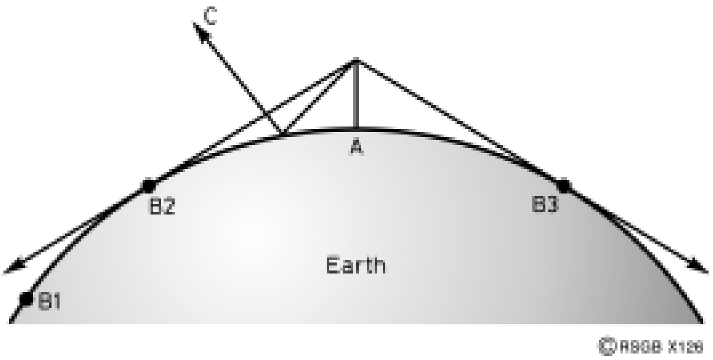

Figure 1 Stations between B2 and B3 receive the *ground wave*

these will travel on into space; waves below them will either be absorbed and reflected by the earth or received by aerials. B1 will not receive any signals from A, because it is below A's horizon. B2 and B3 can receive A's signals because they are *just* on A's horizon. Any stations between B2 and B3 will also receive A's signals, which are known as *ground-wave signals*. The wave at C represents one which is reflected by the ground and travels into space.

This description begs the question of how signals are received from stations well beyond the ground-wave range.

Mirrors in space

Suppose that there was something, out in space, that would reflect radio waves. Waves from A that travel out into space could be reflected off it and return to earth, enabling stations such as B1 to receive A's signals. The situation just described is illustrated in **Figure 2**.

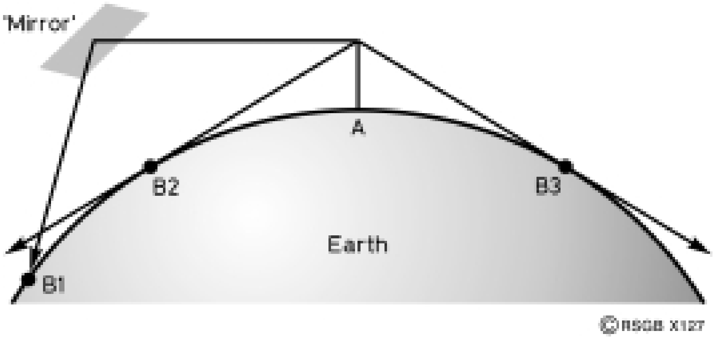

Figure 2 Reception of A's signals at B1 using the *sky wave*

Just such a mirror in the sky really *does* exist. It is not man-made, of course! The earth is surrounded by the atmosphere, a mixture of many gases, such as nitrogen and oxygen. The energy contained in the radiation from the sun is more than sufficient to *ionise* these gases, thus making them into electrical conductors. When a gas is ionised, some of its electrons are physically stripped out of the atoms and are free to move about, just as the electrons of a metal do in a wire. Consequently, we can regard this part of the atmosphere (the part illuminated by the sun) as acting like a sheet of metal, which *reflects* radio signals! It is not a perfect reflector, but is sufficient to produce long-range (DX) radio propagation via the *sky wave* under the right conditions. (A more down-to-earth example of ionised gases conducting electricity can be found in the fluorescent tube and the neon sign – many gases glow when they are continuously ionised.)

This conducting region at the extremity of the atmosphere is called the *ionosphere*, and it exists in layers between 60 km and 700 km above the earth's surface. When the ionosphere is sufficiently ionised, it glows; this is the natural phenomenon known as the *aurora borealis*, or the *northern lights*.

The property of the ionosphere that enables radio waves to be reflected does not act in a uniform way; it is very selective about which waves it reflects, and which waves go straight through it and into outer space. In general, it reflects only those waves with frequencies below about 30 MHz – the HF bands!

In Part 3 we will look at families of waves.

12 An LED flasher

Introduction

The LM3909 is an integrated circuit (IC) which will flash a light-emitting diode (LED). Using only two extra components and a battery, the circuit is cheap and has a very low current drain from a 1.5 V cell. The circuit can be used as a novelty flasher, an indicator for a dummy alarm bell box, or it could be attached to a torch so that it could be found easily in the dark! The simple circuit is shown in **Figure 1**.

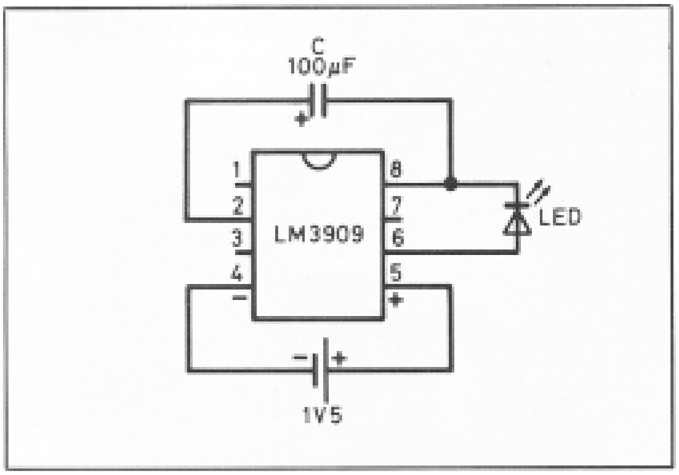

Figure 1 Circuit diagram of the LED Flasher. Pins 1, 3 and 7 of the IC are not used

Assembly

The circuit can be built on a small piece of Veroboard (the piece shown in **Figure 2** measures 15 holes by 10 strips). Using such a board, follow these instructions.

1. Depending on how far away you want the LED from the circuit board, solder a length of insulated wire to each lead of the LED. Use different colours of insulation – say, red and black, connecting the *red* lead to the *anode* (a) lead (the longer one) of the LED, and the black one to the *cathode* (k). Figure 2 shows these leads.
2. Cut the copper tracks as shown in Figure 2, using a 3 mm (⅛ inch) diameter drill, rotated between thumb and forefinger, or use the proper tool. Make *absolutely* sure that the tracks are completely broken!
3. Fit the IC holder in the correct position, using the cut tracks as guides, and make sure the small notch is facing towards the top of the board. Solder the pins to the copper tracks.
4. Mount the capacitor, positive end to the left, so that the positive lead is soldered to track F, which connects it to pin 2 of the IC; the negative lead is soldered to the right-hand side of track E, this being connected to pin 8 of the IC.
5. Solder on the battery leads, positive to the right, and the extended LED leads, positive downwards.

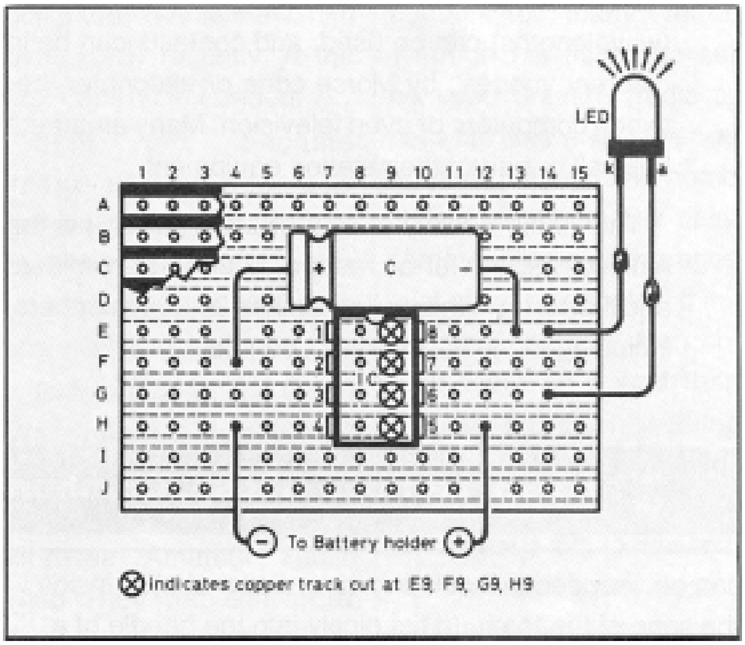

Figure 2 Board layout viewed from the component side. The tracks are cut under the board where shown

6. Check the circuit, and hold up the board to a bright light and look carefully for solder bridges between the tracks and pieces of copper swarf which may have escaped your inspection in 2 above! Remove whatever you find.
7. When all seems well, put the IC into the socket, ensuring that the notch or dot on the upper surface of the IC lines up with the notch on the holder. Line up each pin on the IC with the hole below it before pressing *gently* on the IC with the board supported on a firm surface.
8. Connect the battery; the LED should start to flash. The circuit is complete and working!

If you prefer, the whole circuit (battery included) can be mounted in a small plastic box, with the LED mounted on a clip and protruding through the panel. There are many other possibilities, and it is up to you to find an application for your own use.

Parts list

		Maplin code
LM3909	Integrated circuit	WQ39N
IC socket	8-pin DIL	BL17T
LED	5 mm diameter	WL27E
100 microfarad (μF)	Electrolytic capacitor (10 V)	FB48C
Battery holder	For AA-size cell	YR59P
Battery	1.5 V AA cell	

Small piece of Veroboard (15 holes by 10 strips)
Small plastic box (if required)
LED clip (if required)
Two lengths of coloured, insulated wire for LED (as required)

Availability

All parts can be obtained from Maplin Electronics Ltd.

13 Waves – Part 3

Introduction

When we talk about the spectrum being divided up into bands, this is just for our convenience; there are no natural divisions although, as we have seen, some of the properties of different bands really *are* different! Let's look at **Figure 1**, and see how the frequencies are divided up.

The divisions

- **Very low frequencies** (VLF) cover the range from a few kilohertz up to 30 kHz. Very long-range communication is possible, but at *very* small bandwidths. It is used for special purposes.
- **Long waves** (LW) are used for medium-distance commercial broadcasting and have frequencies from 30 kHz to 300 kHz.
- **Medium waves** (MW) are used for commercial broadcasting, and use frequencies from 300 kHz to about 1.5 MHz (1500 kHz). Typical range is about 200 km.
- **Short waves** (SW) encompass both the low-frequency (LF) and high-frequency (HF) amateur radio bands. There are nine narrow amateur bands in the SW spectrum between 1.8 MHz and 30 MHz. Some of these bands give round-the-world communication.
- **Very high frequencies** (VHF) span the range between 30 MHz and 300 MHz. Relatively short-range communication is possible. They were once used for broadcast TV before it moved to UHF. There are now three

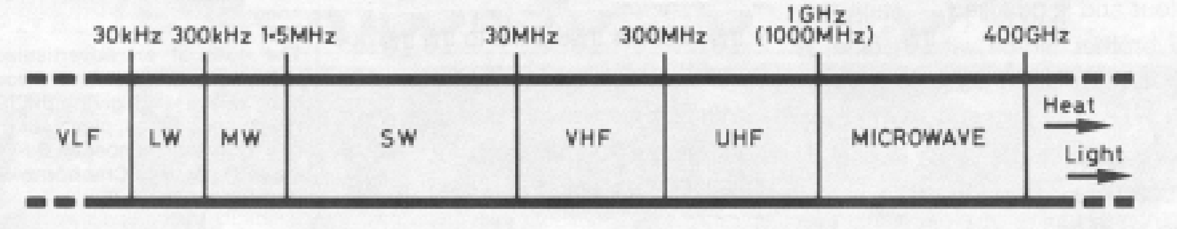

Figure 1 Diagram of radio frequency spectrum

amateur bands here – 6 m, 4 m, and 2 m. Repeaters are used to extend the usable range of mobile stations. VHF waves are not usually reflected by the ionosphere, but when they are, ranges of several thousand kilometres are possible. Weather affects these waves on a regular basis, however. In addition to amateur users, the VHF part of the spectrum is also used by the police, the fire and ambulance services, weather satellites, and many others,

- **Ultra-high frequencies**, sometimes called *centimetre waves*, cover the range from 300 MHz to 1000 MHz (or 1 GHz). The only amateur band in this range is the 70 cm band, and we share it with radar, TV and cellular telephone users as well.
- **Microwaves** begin at 1 GHz and extend to about 400 GHz. They are *never* reflected by the ionosphere, are partially attenuated by buildings, and are reflected from aircraft and cars. Microwave absorption in the atmosphere is quite significant, and rain and fog can attenuate microwaves quite heavily.
- **Heat, light** . . . Above 400 GHz we run into the infra-red bands and on into the visible light and ultra-violet bands. We generally take 400 GHz as being the limit of what we class as radio waves.

Bandwidth again

Complex signals need more bandwidth than simple signals. Even if it were possible, we would not be able to transmit a single television channel in the whole of the MW broadcast band! When TV used part of the VHF band, only five channels were possible in the range from 45 MHz to 68 MHz. By moving TV to the UHF band, we now have 47 channels between 470 MHz and 855 MHz!

It's your choice!

The number of permutations you have amongst all the modes and all the bands is enormous! Only you can decide what you are interested in and what you want to learn about. That is the attraction of amateur radio!

14 Choosing a switch

Simple, but be careful!

A switch is the simplest electronic component, but care is needed in choosing the correct one for the job. Here is a list of the main characteristics of a switch, which will help you to select what you want.

1. **Rating**. This gives the maximum voltage and current that a switch can handle. For example, a 250 V 1.5 A switch will switch mains voltage at a current not exceeding 1.5 A. If the current is greater than 1.5 A, the switch may get hot and fail. If the voltage is too great, the switch may arc each time it is switched off, thus wearing away the contacts.
2. **Number of poles**. A single switch can control many circuits; the number of poles tells you *how many* different circuits it can handle. See **Figure 1**.
3. **Number of throws**. This tells you the number of positions each pole can have. This is best illustrated in Figure 1. The simplest ON/OFF switch is a Single-Pole, Single-Throw (SPST) switch. A Single-Pole,

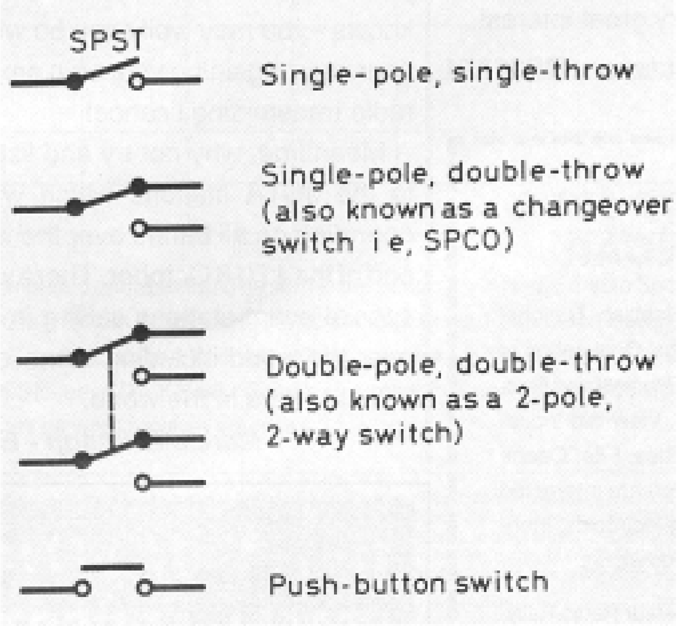
SPST
Single-pole, single-throw
Single-pole, double-throw (also known as a changeover switch i e, SPCO)
Double-pole, double-throw (also known as a 2-pole, 2-way switch)
Push-button switch

Figure 1 Some circuit symbols for different types of switch

Double-Throw (SPDT) switch may also be used as an ON/OFF switch, but is used mainly to change between two parts of a circuit, and is commonly known as a Single-Pole Change-Over (SPCO) switch. Two or more SPCO switches can be operated at once; Figure 1 shows an example. The two switches are said to be *ganged*. See also 'Types of switch' below.

4. **Number of ways**. When a switch has more than one throw, we tend to use the word 'ways' instead. This means that if a switch has one pole and six throws, we would normally call it a '1-pole 6-way' switch. Such switches tend to be rotary switches, as are described below.

Types of switch

(a) **Push-button**. These are found on calculators, telephones, electronic games and most equipment with a digital display.

(b) **Rotary**. These are switches controlled by a knob, and are turned instead of moved up and down. **Figure 2** shows the rear of such a switch and its circuit symbol. The commoner types of rotary switch are: 1-pole, 12-way; 2-pole, 6-way; 3-pole, 4-way; 4-pole, 3-way; 6-pole, 2-way. All these switches have 12 click positions, as you may have guessed, but each one comes with an adjustable end-stop so that you can set the correct number of ways according to the contacts on the switch.

(c) **Slide**. This switch is common on the cheaper types of radio, mainly as an ON/OFF or band-changing switch. They are not very rugged, but are small and cheap to produce. Very small types are manufactured for use on PCBs.

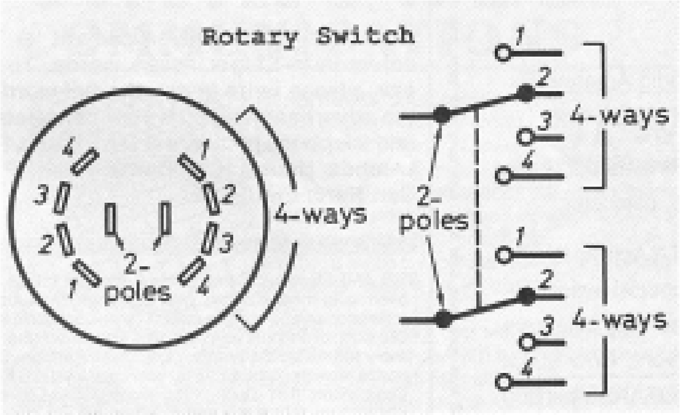

Figure 2 The rotary switch can select several different circuits at once

(d) **Toggle**. Available as two-way types or three-way, with a centre-off position. Can be manufactured to handle very high currents.

(e) **Micro-switch**. These are devices which are usually operated indirectly, such as when the cover is removed from a high-voltage power supply, or when the door of a fridge is opened. The 'micro' part of the name doesn't refer to the size of the switch, but to the *small* movement that is required to activate it.

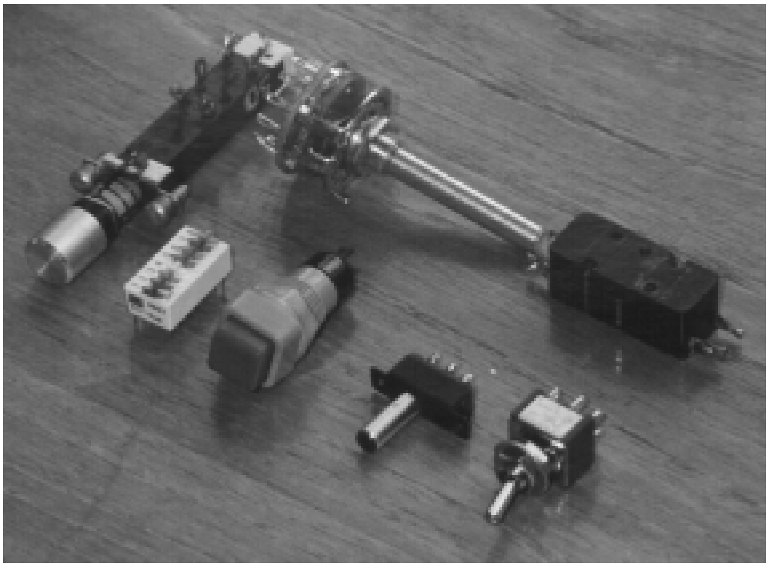

15 An aerial tuning unit for a receiver

Introduction

Any length of wire will act as an antenna (or aerial) but, to get the best results from a transceiver or receiver, an aerial tuning unit (ATU) is required. This matches the *impedance* of your aerial to the impedance at the aerial socket of your radio. Impedance is like resistance, and is measured in ohms, but it is used for alternating currents, and hence is common in audio and RF engineering. Most receivers have an impedance at the aerial socket of about 50 ohms (Ω); aerial impedance, on the other hand, can be anywhere between 20 Ω to over 1000 Ω, depending on its length and its height above ground.

Fortunately, you don't *need* to be able to calculate your aerial's impedance; all you need is a device that will perform the matching operation for aerials with a large range of impedances, and this is exactly what is described here! The subject of *matching* is a complex one, but all you need to know is that most signals will become clearer, and that there will be less noise and interference. Stations will become louder, so you will probably be able to reduce the setting of your RF gain control (always a good thing to do).

This design of ATU covers all amateur and broadcast bands from 10 m (28 MHz) to 80 m (3.5 MHz), and is very easy to build. The circuit is shown in **Figure 1**.

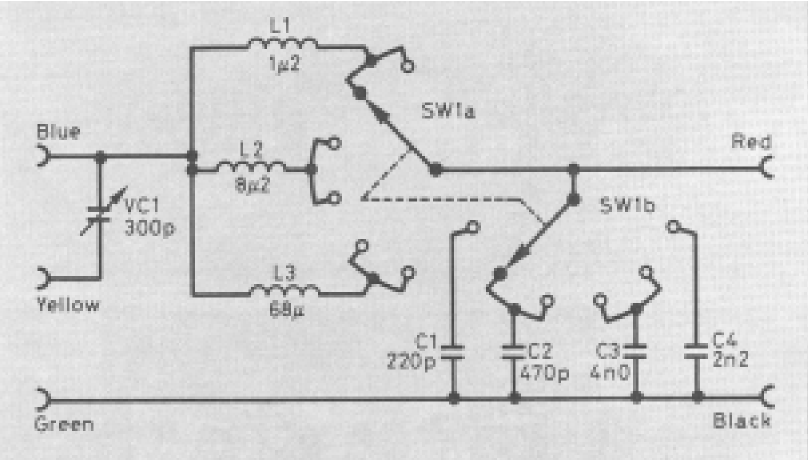

Figure 1 Circuit diagram of the Antenna Tuning Unit, showing the use of a 2-pole, 6-way rotary switch to select inductors (L) and capacitors (C)

Construction

1. Firstly, you will need a simple plastic case in which to house the ATU. The size should be approximately 85 × 145 × 50 mm.
2. Start by drilling two 10.5 mm holes in the front of the case; these are for the 6-way switch and the tuning capacitor.
3. Drill three 8 mm diameter holes in the left-hand side of the box, for the three sockets, coloured blue, yellow and green.
4. On the right-hand side of the box, drill two 8 mm diameter holes for the red and black sockets.
5. Now, fit the 6-way switch (SW1), the tuning capacitor (VC1), and all the sockets to the case. Check that the vanes of the capacitor rotate smoothly when the shaft is turned.
6. Wire up the inductors (coils). Figure 1 and the wiring diagram of **Figure 2**, will help with this. As you can see, each one side of each coil is connected to two switch connections, the other end going to VC1.
7. Solder in the fixed capacitors. One end of each goes directly to the ground socket (black), and the other end goes to the switch.
8. Solder a wire between the green and black sockets. The output from the ATU comes from the red socket, and this is connected to the two tags in the centre of the switch, as Figure. 2 shows clearly.
9. Finally, connect the blue and yellow sockets to the tuning capacitor, and the ATU construction is complete.

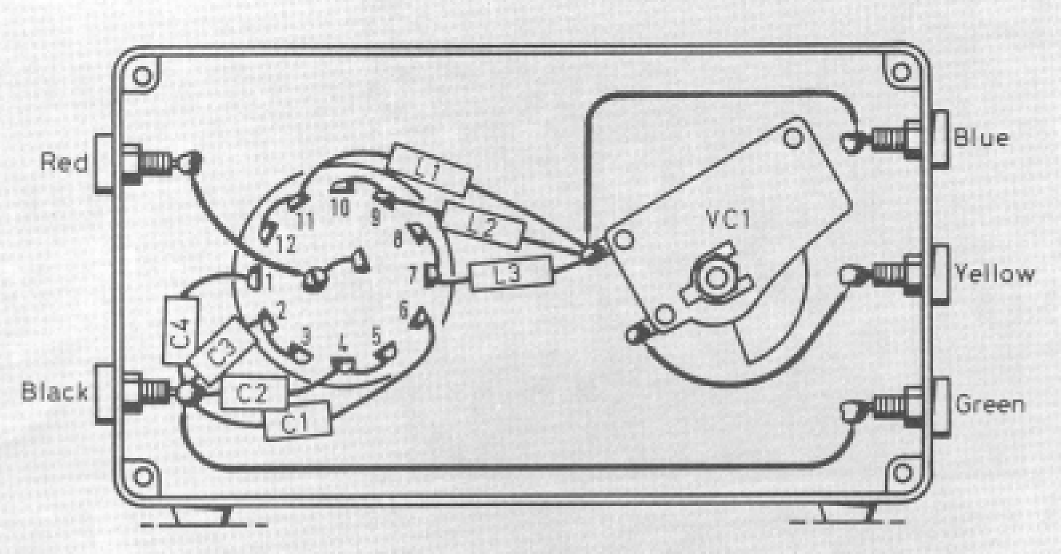

Figure 2 The internal view of the case shows the main tuning capacitor, VC1. This is a solid dielectric type, which has adjustable brass plates

In practice . . .

Figures 3 and **4** show two different ways of connecting your aerial to your ATU. In each case you will need to select each switch position in turn, and rotate the tuning capacitor through its full range while listening to a station. You should find that one switch position enables VC1 to produce a peak in the signal strength in the loudspeaker. At this point, your aerial and receiver are said to be *matched*. Stations in the same band will probably peak with VC1 at the same setting of SW1, but different bands will almost certainly require different positions of SW1.

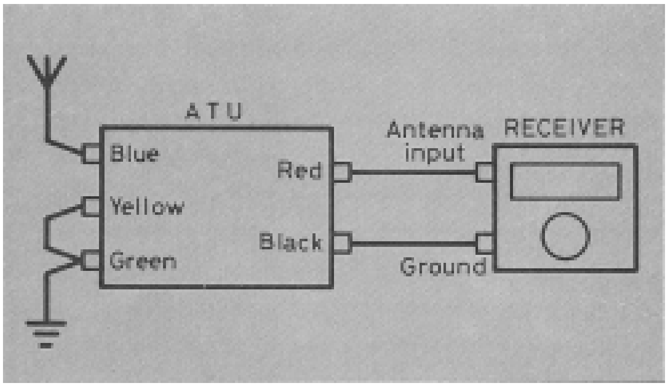
ATU
Blue
Yellow
Green
Red
Black
Antenna input
RECEIVER
Ground

Figure 3 You may find that parallel tuning gives best results with your antenna

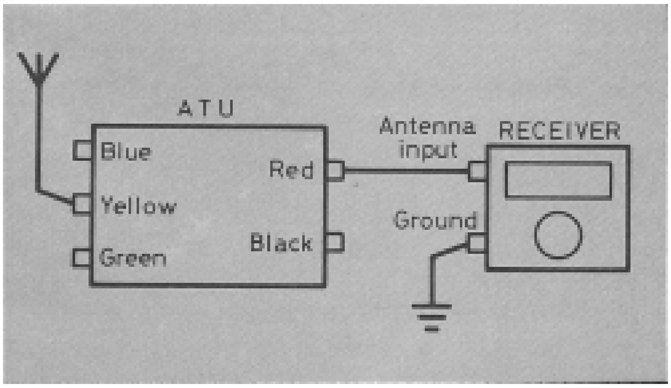
ATU
Blue
Yellow
Green
Red
Black
Antenna input
RECEIVER
Ground

Figure 4 In other cases, series tuning could be the most effective arrangement

Parts list

Capacitors (all rated at 16 V or more)

C1	220 picofarads (pF) polystyrene
C2	470 picofarads (pF) polystyrene
C3	1000 picofarads (pF) or 1 nanofarad (nF) polystyrene
C4	2200 picofarads (pF) or 2.2 nanofarads (nF) polystyrene

Inductors

L1	1.2 microhenries (μH)
L2	8.2 microhenries (μH)
L3	68 microhenries (μH)

Switch

SW1	2-pole 6-way rotary

Sockets

4 mm type, one each of red, black, yellow, blue, green

Additional items

Plastic or metal case, e.g. Maplin type YU54
Two large knobs for SW1 and VC1

16 A simple 2 m receiver preamplifier

Introduction

Designed specifically to complement the modified air-band portable (also described in this series), this can be used with some success on many receivers suffering from 'deafness' on VHF.

The circuit

An RF preamplifier is a device which improves the input signal to an existing receiver, enabling it to work more effectively. Because of the noise which is added to the signal by the preamplifier, *very* weak signals may not be usefully enhanced, but stronger signals will be improved considerably.

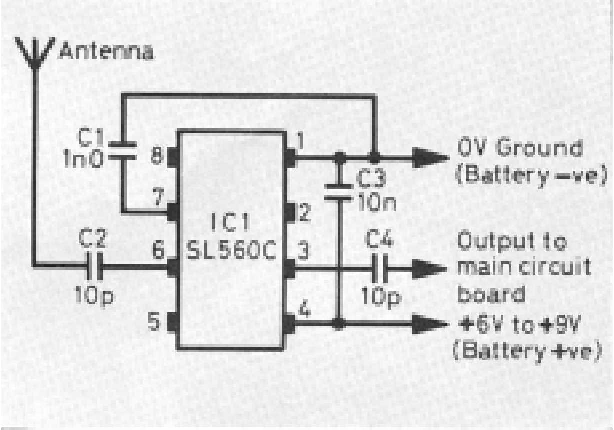

Figure 1 The integrated circuit is mounted upside down. Make sure you identify pin 1 which has a small dot next to it

This little circuit (shown in **Figure 1**) uses a GEC/Plessey integrated circuit type SL560C. With the addition of four capacitors, it is used between your aerial and the aerial input of the radio's PCB.

Putting it together

1. Use a small piece of prototype (matrix) board about 25 mm square. Use an 8-pin DIL socket for the integrated circuit (don't risk soldering the chip – it is seldom a risk worth taking). Figure 1 shows the connections to the socket, *looking from underneath*.
2. Make special note of the pin numbers, so that you know how to put the chip into the socket when you have finished. The positive and negative connections to the circuit are taken from the main PCB *after* the ON/OFF switch – so that the switch operates the preamplifier, too.
3. Unsolder the lead to the radio's telescopic aerial and connect it to the free end of C4, as shown. Then solder a short lead between the telescopic aerial and C2.
4. Sometimes it is possible to cajole your little preamplifier into the radio's plastic case, provided there is room and that you make sure that none of the soldered joints on your little board touch any of the metal inside the case when you replace the back and screw it on again.
5. If there is not enough room inside, then put the preamplifier into its own box, with battery and switch, and its own aerial. Keep the lead from the preamplifier to the aerial connection of the radio as short as possible – perhaps using screened cable.

Because your preamplifier is untuned, you will find not only that it helps with reception on 2 metres, but also that reception on the FM broadcast band is improved!

Parts list

Integrated circuit	
IC1	GEC/Plessey SL560C
Capacitors	
C1	1 nanofarad (nF) ceramic
C2, C4	10 picofarads (pF) ceramic
C3	10 nanofarads (nF) ceramic
Additional item	
Prototype broad approx. 25 × 25 mm	

17 Receiving aerials for amateur radio

Introduction

For any radio receiver to work well, it must have some form of antenna, or aerial. In almost all domestic transistor radios, the aerial is built into the set, either as a ferrite rod (which looks like a rod of dark grey metal) on which are wound coils of wire, or as a chromium-plated telescopic metal rod. Some radios have both forms of aerial, using the ferrite rod aerial for long waves (LW) and medium waves (MW) and the metal rod for very high-frequency (VHF) stations using frequency modulation.

There's broadcast reception . . .

No aerial is perfect, and these two types are *far* from perfect! As in most mass-produced equipment, *they serve their purpose*, which is not critical, and they allow the radio to be carried around easily, because they are not big and bulky. The broadcast stations are very powerful, usually quite close, and the circuits in the radio are quite sensitive, so the need for large aerials disappears.

. . . and there's amateur DX

Here we have an application which, in comparison with the broadcast situation, couldn't be much more different. The stations do not use much power, they may be half the world away, and the requirement for good aerials and very sensitive receivers is paramount. The aerials must be large and they must be as high as possible, away from buildings and trees, which cause reduction in signal strength, and away from man-made sources of interference.

You may not have thought about this but, in general, the larger an aerial becomes, the longer the cable (or 'feeder') must be in order to reach your shack and the receiver inside it. Cables reduce the received signal, so what your aerial gains by being large, the feeder (if you're not careful) will lose!

A simple aerial . . .

We now know that a 'good' aerial is essential. But what is a 'good' aerial? It depends on your purse, your property and your enthusiasm! One of the simplest (and, incidentally, one which is *not* subject to the cable loss problem discussed above) is the **Long Wire**, shown in **Figure 1**. This is, quite literally, a long piece of wire going from a chimney stack to a tree or pole

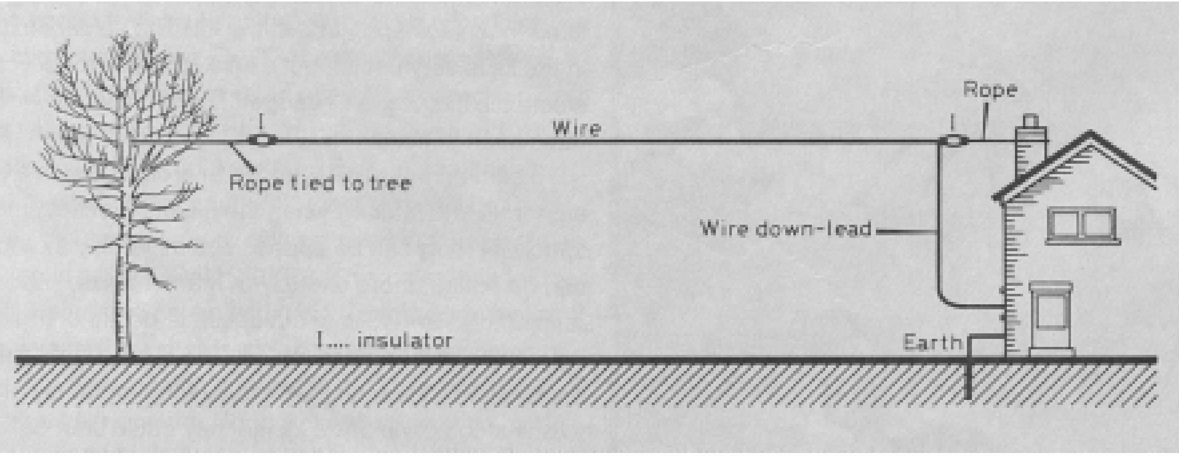

Figure 1 A tree at the bottom of the garden can provide a useful antenna support. Insulators can usually be obtained from Tandy stores or TV aerial suppliers

at the end of the garden. The longer it is, the better. Notice that the wire itself is *not* used to loop around the tree or chimney. Rope is used for both, and is secured to the end of the wire using an insulator of the 'dog bone' or 'egg' variety, to be found in profusion at rallies.

The wire is brought into the house through a window into the shack where the receiver is situated. The long wire aerial is best used with an aerial tuning unit (ATU), which is also described in this book. One of the advantages of the long wire is that it can be used on several frequency bands.

. . . and more complicated ones

Next up the ladder of complexity is the **dipole** (meaning two poles, or two elements). One form of dipole for lower frequencies would take the same basic form as the long wire, except that the feed to the receiver is taken, not from the end, but from the centre. The wire is essentially cut into two halves, and the two ends at the centre are connected to one end of a coaxial cable, which is then taken to the receiver. A smaller form of this is shown in **Figure 2**, which is conveniently mounted in a house loft. Aerials should always be mounted outside for best results, but will work when mounted inside, and the loft space is the logical situation.

The total length of the dipole should ideally be one-half of the wavelength of operation – hence the term 'half-wave dipole'. For example, a dipole for use on 20 m should be about 10 m long. Dipoles are thus 'single-band' aerials. They can be modified for use on several bands, and then become known as 'trapped dipoles', having coils and capacitors at certain points along their lengths.

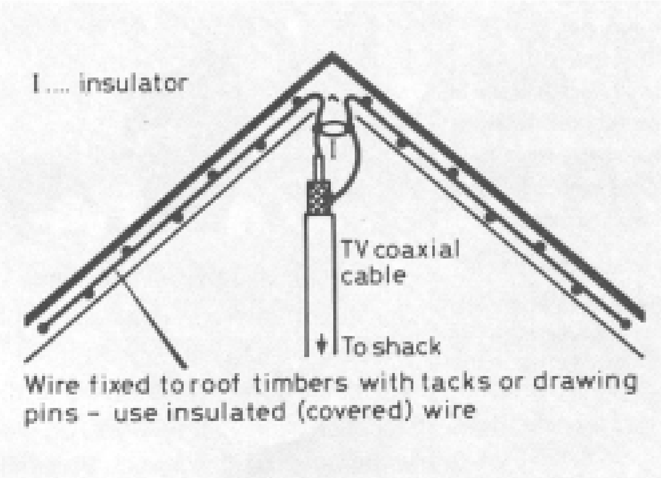
I.... insulator
I
TV coaxial cable
To shack
Wire fixed to roof timbers with tacks or drawing pins – use insulated (covered) wire

Figure 2 An indoor antenna should be mounted as high as possible

Indoor aerials

For flat- or apartment-dwellers, an indoor aerial is often the only solution, in which case the dipole of Figure 2 may be of great use. Other popular types include the **loop aerial**, of which several types are shown in **Figure 3**. The shape of the loop is of secondary importance, but it should be as large as possible.

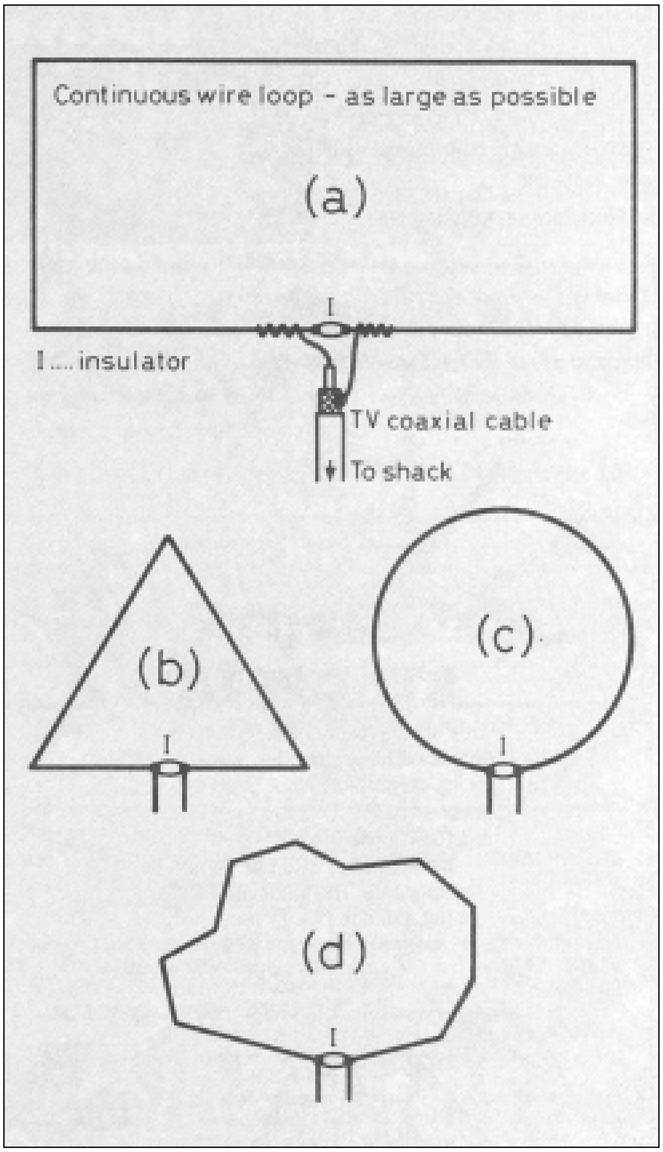
Continuous wire loop – as large as possible
(a)
I
I .... insulator
TV coaxial cable
To shack
(b)
I
(c)
I
(d)
I

Figure 3 Try different shapes of loop antenna to see which works best

Ingenuity is called for when considering indoor aerials. A dipole can be mounted along a picture rail or pelmet. A vertical loop of aluminium foil can be stuck to an inside wall and covered with wallpaper! The designs are limited only by your imagination, and will give you hours of listening pleasure

Outdoor aerials

If you want to venture beyond the simple long-wire discussed earlier, then the erection of outdoor aerials can be a bit tricky; they can be more than a one-man job, and can involve seeking planning permission. Get some help advice from someone who has done it before – what about your local radio club? Plenty of designs for aerials appear in *RadCom*, so you should never be short of ideas!

18 The Colt 80 m receiver – Part 1

Introduction

This is the first of four parts detailing the design and construction of a simple radio capable of good reception of amateur radio signals on the 80 metre band. If you can solder and have some basic hand tools, at the end of Part 4 you will have a working receiver, in which you can take pride, and start some serious listening on 80 m! For testing, all you will need is another receiver and a multimeter.

Description

The radio will be built in three modules, or stages, as illustrated in **Figure 1**. Each of these is built on a printed-circuit board (PCB) or matrix board and can be tested in its own right. The case will need some holes drilled, and care will be needed to mount the PCBs in the case.

Get to it!

Surprisingly enough, when you are building a radio section by section (which is *always* the best way), it is easiest to start at the output and work

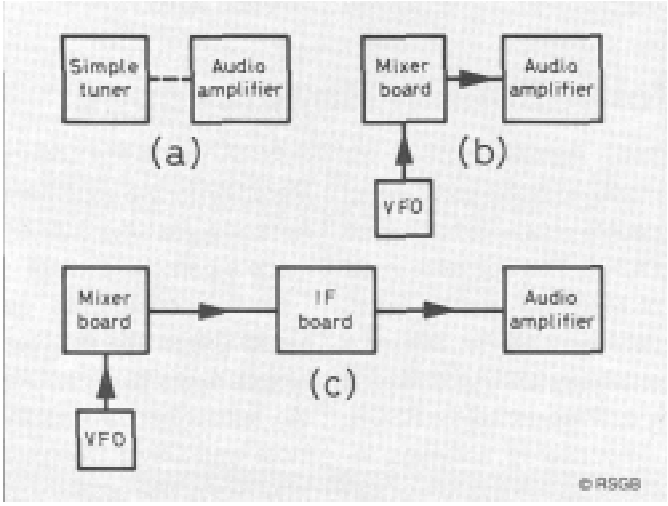
Simple tuner
Audio amplifier
(a)
Mixer board
Audio amplifier
VFO
(b)
Mixer board
IF board
Audio amplifier
VFO
(c)
© RSGB

Figure 1 Build your Colt and watch it grow. A simple crystal set (a) becomes a direct conversion receiver (b) and finally an 80 metre amateur band superhet (c)

towards the input, and you can test what you have done stage by stage. You will see what this means as you progress with your construction.

Every receiver needs some audio frequency (AF) amplification to make the sound signals big enough for you to hear. The circuit for the AF amplifier is shown in **Figure 2**. It uses the TDA7052 integrated circuit (IC) plus a handful of extra components. R1 in conjunction with C2 and C3 *decouple* the battery supply, preventing any audio signals getting through to it and affecting other parts of the radio, when they are connected. C1 acts to prevent high frequencies (above the 3 kHz bandwidth) going into the amplifier input. A volume control, VR1, is connected across the amplifier input, so that the amplifier can accept signal inputs over a wide range. **Figure 3c** shows the connections, which are made with screened cable. The

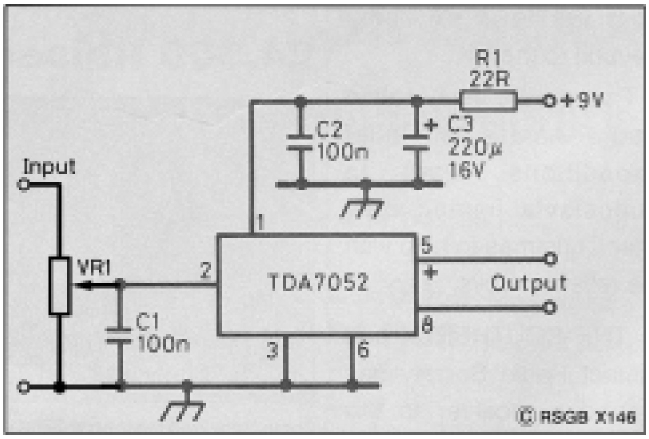
R1
22R
+9V
C2
100n
+ C3
220µ
16V
Input
1
5
VR1
2
TDA7052
+
Output
C1
100n
8
3
6
© RSGB X146

Figure 2 The Philips TDA7052 integrated circuit (IC) used in the audio amplifier needs very few extra components. It has a signal voltage gain of 100 times and the output is suitable for a loudspeaker or headphones

centre conductor of the left lead goes to the point marked ‘input’ in Figure 2, the braid being connected to the amplifier earth (0 V) tag. The right lead to VR1 goes to whatever signal source you have for testing – see later. VR1 is *not* mounted on the PCB.

The circuit is constructed on a small PCB or matrix board. Make sure that the electrolytic capacitor, C3, is soldered into the board the correct way – its positive and negative connections are shown in **Figure 3b** for reference. If you are **at all** concerned about soldering the IC into the board, enlist some help, *or*, obtain an 8-pin DIL socket, which you can solder in and then carefully insert the chip into the socket, making sure that is the correct way round. The markings on the chip are shown in **Figure 3a**.

The output leads from the amplifier go to a plastic 6.3 mm (¼ inch) mono jack socket, so that *neither* output lead is connected to the metal case. The amplifier will drive a pair of headphones or a small 8 Ω loudspeaker.

The battery leads must be the right way round also; the battery itself can be a PP3 or PP9, or you can use a small DC power supply.

Testing

First, check that all the components are in the right places, that your soldering is good, and that you have headphones or a loudspeaker connected. Set VR1 about halfway along its travel. Connect the battery.

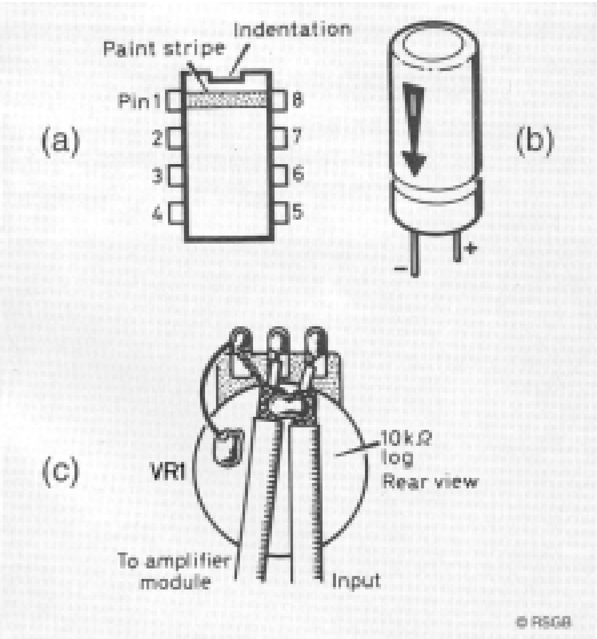

Figure 3 It is important to check the component connections carefully. The diagram shows (a) top view of the IC, (b) electrolytic capacitor and (c) volume control (VR1) connected across the input of the amplifier

A slight hissing noise should be heard; touching the input lead to the amplifier (the centre of the three connections on VR1) should produce a loud buzz. Touching the shaft at the same time will make the buzz quieter. This is the quickest way of confirming that your amplifier *seems* to be working. The only real test is to give it something meaningful to amplify! See the design of our *Crystal Radio Receiver* for full details.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	22 ohms (Ω)
VR1	10 kilohms (kΩ) log

Capacitors

C1, C2	0.1 microfarad (μF)
C3	220 microfarads (μF) electrolytic 16 V

Integrated circuit

IC1	TDA7052 audio amplifier

Additional item

PCB	(see below)

Component suppliers:
Maplin

The next part . . .

The metal case will be marked out ready to receive the completed modules.

19 A crystal radio receiver

Introduction

Here's a quick project to fill in a winter's evening! It was originally designed as a piece of test gear for the *Colt* receiver, but can be successfully used by anyone as a first radio project. Another use for it would be as test gear for any audio amplifier project requiring an audio input for test purposes; this is ideal, as it does not require any power supply!

Details

The initial rough-and-ready test for the audio amplifier of the *Colt* receiver will have whetted your appetite; you will want to prove more conclusively that your amplifier works, and in a way that others in the household will appreciate. Buzzing noises are not convincing in this respect! You are going to put together a simple crystal set – the simplest type of radio that there is – and use it as a signal injector for your amplifier. In this way, you build a real medium-wave (MW) receiver which drives a loudspeaker, as an intermediate product of the construction of an 80 metre amateur band receiver!

The circuit diagram is shown in **Figure 1**. It has a 60-turn coil mounted on a small piece of paper or card wrapped round a ferrite rod. The coil has a connection made to its centre-tap (the middle turn of the coil). The tuning capacitor, VC1, is the most expensive part of the circuit but don't worry, it will be used in the final design of the receiver also! Connect the diode, D1, from the centre-tap to the input to the potentiometer of the amplifier circuit of the *Colt*. Be careful to connect the aerial to the *vanes* of VC1, and not to its *frame*, or you will experience some strange effects when you are tuning. If your amplifier is working correctly, you should be able to receive local stations on medium-waves quite well.

If you think the crystal set will be of use to you in the future as a signal injector, all you will need will be another variable capacitor! If you do not intend to use the amplifier, a small crystal earpiece will allow you to listen. Walkman-type headphones will *not* work!

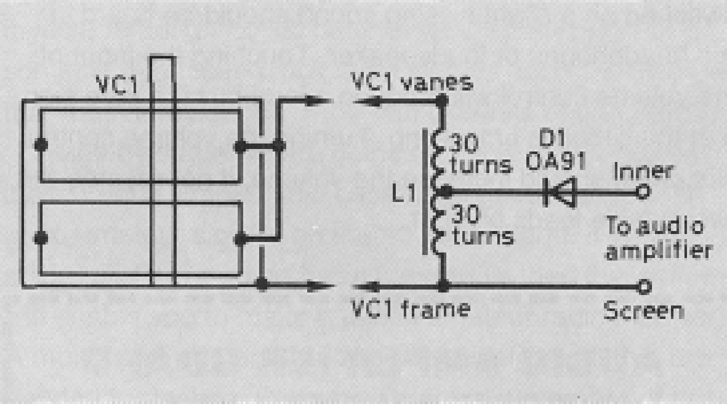
VC1
VC1 vanes
30 turns
D1
OA91
Inner
L1
30 turns
To audio amplifier
VC1 frame
Screen

Figure 1 Both sets of moving vanes are joined as shown. L1 is wound on a ferrite rod with 32 SWG wire and centre-tapped. A single winding (no tap) can be used, joining D1 to the top of the winding

Parts list

Variable capacitor	
VC1	125 + 125 picofarads (pF) twin-gang
Ferrite rod	
About 100 mm to 140 mm long	
Diode	
D1	OA91 germanium diode
Additional items	
Wire	2 m of enamelled copper wire, between 23 SWG and 32 SWG
Earpiece	High-impedance crystal type (only needed if you are not using the amplifier)

20 The varactor (or varicap) diode

Introduction

Many of the circuits for receivers and transmitters presented in this series rely upon the variable capacitor as a means of tuning. Another method of varying capacitance (without any moving parts) is provided by the *varactor diode*, sometimes called a varicap diode. This is a component which changes its capacitance as the voltage across it is varied.

The details

Figure 1 shows how a varactor diode might be connected to demonstrate its operation. Its symbol is that of an ordinary diode, with a capacitor symbol next to it. A variable voltage is applied across it in such a way that the diode is *reverse-biased*. This means that virtually no current passes through it – the positive voltage is applied to the cathode. Varactors are cheaper than variable capacitors, and they are tiny in comparison, very suitable for today's miniature circuits. If A and B were connected across the tuning coil in a simple receiver (with a series capacitor to block the DC from the battery reaching the coil), the tuning operation would be accomplished by turning the knob on the 10 kilohm potentiometer.

Varactors are available with different values, from less than 20 picofarad (pF) for VHF applications to 500 pF for medium-wave radios. They are

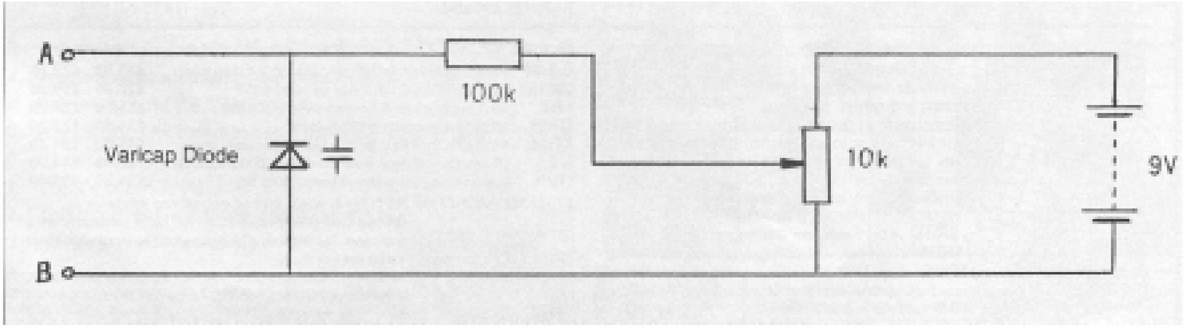

Figure 1 The capacitance of the varicap diode (between A and B) increases as the voltage is reduced, using the variable resistor

tuned usually by voltages between 2 V and 9 V. For a real application of varactors, you should consult the circuit diagram of the *Yearling* 20 metre receiver, elsewhere in this book.

In some circuit designs, several circuits are all tuned to the same frequency in order to improve the overall *selectivity* (the ability of the circuit to reject signals very close in frequency to the wanted signal). Special dual- and triple-varactors are available for circuits like this. Having been made at the same time from the same materials makes their individual characteristics virtually identical. Like all other diodes, they must be correctly wired into the circuit – their *polarity* is important.

Changes in temperature will cause the capacitance to change which, if it were part of an oscillator circuit, would cause the oscillator to drift – you would have to keep retuning the radio! This can be corrected by using a special integrated circuit called a *phase-locked loop* (PLL). Modern TV sets and satellite receivers use varactors and PLLs in this way.

Some useful varactor types

Type No.	*Tuning range*		*Description*
	pF/V	*pF/V*	
BB204B	42/2.0	15/12	Dual VHF
BB212	560/0.5	22/8	AM tuning
KV1235	450/2.0	30/8.5	Triple AM
KV1236	450/2.0	30/8.5	Dual AM
MV1404	120/2.0	9/10.0	HF tuning

21 A portable radio for medium waves

Introduction

The ZN415E integrated circuit (IC) can be used to make a very efficient AM portable MW broadcast radio with a built-in loudspeaker. Here's how!

The circuit

Figure 1 shows the circuit diagram of the portable radio. It's not as complicated as it may appear, especially after you have got started. L1 is a coil of wire mounted on a ferrite rod, acting as an aerial; VC1 is a variable capacitor which works, with L1, to tune in different stations. IC1 contains circuits of its own which boost the selected signal and it includes a *detector* which extracts the audio signal from the incoming RF signal. Earphones could be connected to the output of IC1 (between pins 4 and 5), but the output would not be powerful enough to drive a loudspeaker.

More sound

This is where IC2, an LM386 comes in. This is a small audio *power* amplifier which produces audio signals with enough power to drive a small

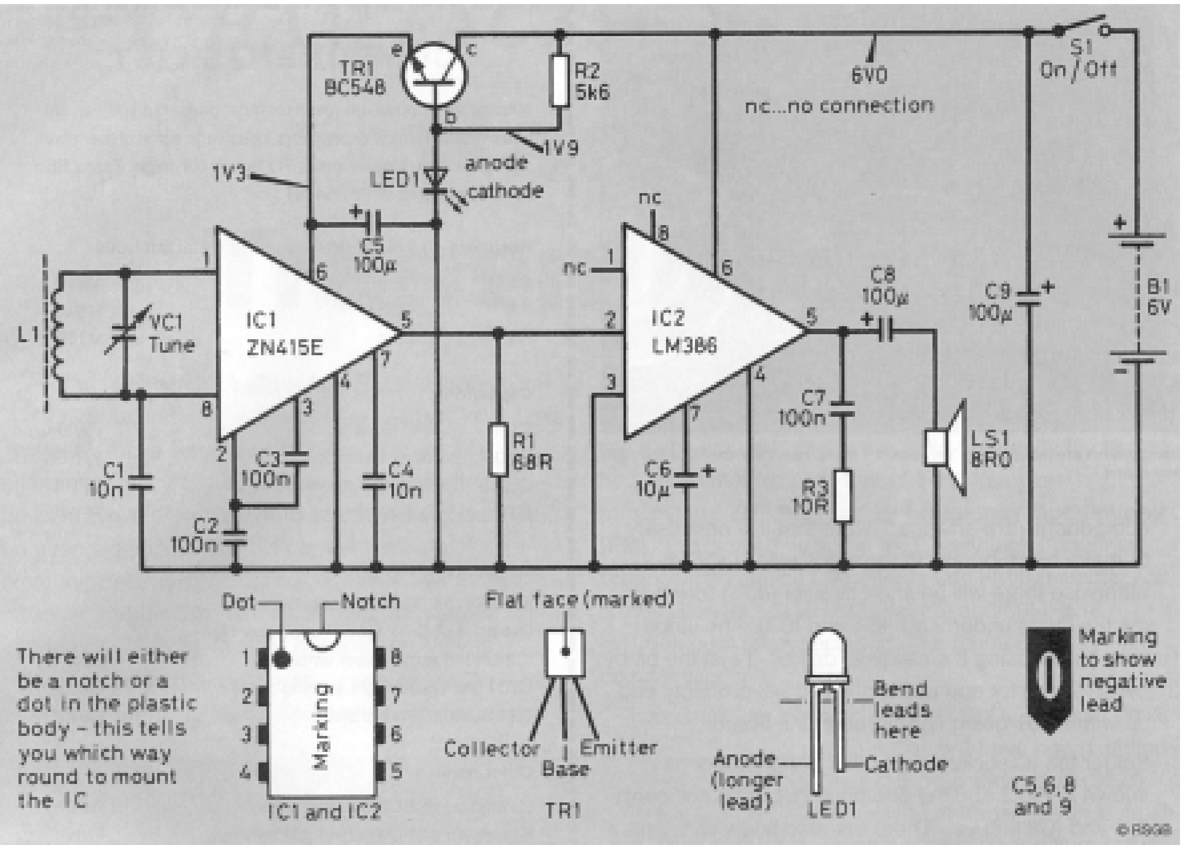
TR1
BC548
e
c
b
R2
5k6
6V0
nc...no connection
S1
On / Off
1V9
1V3
LED1
anode
cathode
C5
100µ
nc
8
nc
1
6
IC1
ZN415E
5
7
4
3
8
2
1
L1
VC1
Tune
C1
10n
C3
100n
C2
100n
C4
10n
R1
68R
IC2
LM386
2
3
6
5
4
7
C6
10µ
C8
100µ
C7
100n
R3
10R
LS1
8R0
C9
100µ
B1
6V
+
-
Dot
Notch
1
2
3
4
8
7
6
5
Marking
IC1 and IC2
Flat face (marked)
Collector
Base
Emitter
TR1
Bend leads here
Anode (longer lead)
Cathode
LED1
Marking to show negative lead
C5, 6, 8 and 9
©RSGB

There will either be a notch or a dot in the plastic body – this tells you which way round to mount the IC

Figure 1 The circuit diagram of our easy-to-build portable radio. Take care to mount the ICs and LED the correct way round

loudspeaker, LS1. The radio uses a 6 volt battery, which is made by connecting four 1.5 volt AA cells in series (4 × 1.5 V = 6 V) using a battery holder designed for this purpose. Although a 6 V supply is ideal for IC2, it is far too great for IC1, which needs only about 1.3 V. This lower voltage is provided from the 6 V supply by TR1 (an npn transistor), R2 and LED1 (a light-emitting diode). When current passes through an LED (see the description of the LED in this series) a reasonably constant voltage of 1.9 V appears between the anode and the cathode. Because of the voltage (0.6 V) that *always* exists between the base and emitter of a working transistor, the voltage on the emitter is about 1.9 V – 0.6 V = 1.3 V, and this is used as the power supply for IC1.

To keep the radio as simple as possible, no volume control has been fitted. Instead, you can use the directional properties of the ferrite rod aerial (see the information on ferrites in this book) to reduce the volume by rotating the set about a vertical axis using the handle provided.

Putting it all together

1. Start by covering the ferrite rod with Sellotape, or alternatively wrap a piece of paper tightly around it, and secure it with Sellotape. Then, with at least 2 metres of 24 SWG enamelled copper wire, wind 75 turns tightly around the rod. To be safe, leave about 50 mm of wire at the ends of the coil, then wrap the whole coil with Sellotape to hold the turns in place, leaving only the ends free. Then, using a small piece of sandpaper, remove the enamel from the last centimetre of each end of the coil.
2. Most of the components are mounted on a piece of Veroboard (the type with parallel copper strips on one side). The piece used on the prototype measured 32 holes by 10 strips, as **Figure 2** shows. Before you start fitting components, cut the copper strips as shown. It is easier to do it now than when the board is littered with components! The strips may be cut with a 3 mm (⅛ inch) twist drill rotated between thumb and forefinger. Resist the temptation to use a hand drill – the idea is just to cut the copper, **not** to drill right through the board!
3. Solder the IC sockets and the other components on the board as shown in Figure 2. Make sure that the IC sockets are fitted with their notches towards the *top* of the board, as viewed in Figure 2. Do not insert the chips yet. Always keep the wires left over from cropping resistors and capacitors, they will come in handy at times like this: make the wire links that are clearly shown in Figure 2. Connect the electrolytic capacitors (C5, C6, C8 and C9), the transistor and the LED the correct way round; then check it again when you have done it!
4. Finally, solder lengths of stranded insulated wire to act as 'flying leads' for future connection to L1, VC1, LS1, S1 and the battery connector.
5. Apart from the battery holder, everything is mounted on the case *lid*. This makes assembly and testing much easier, and eases fault-finding if

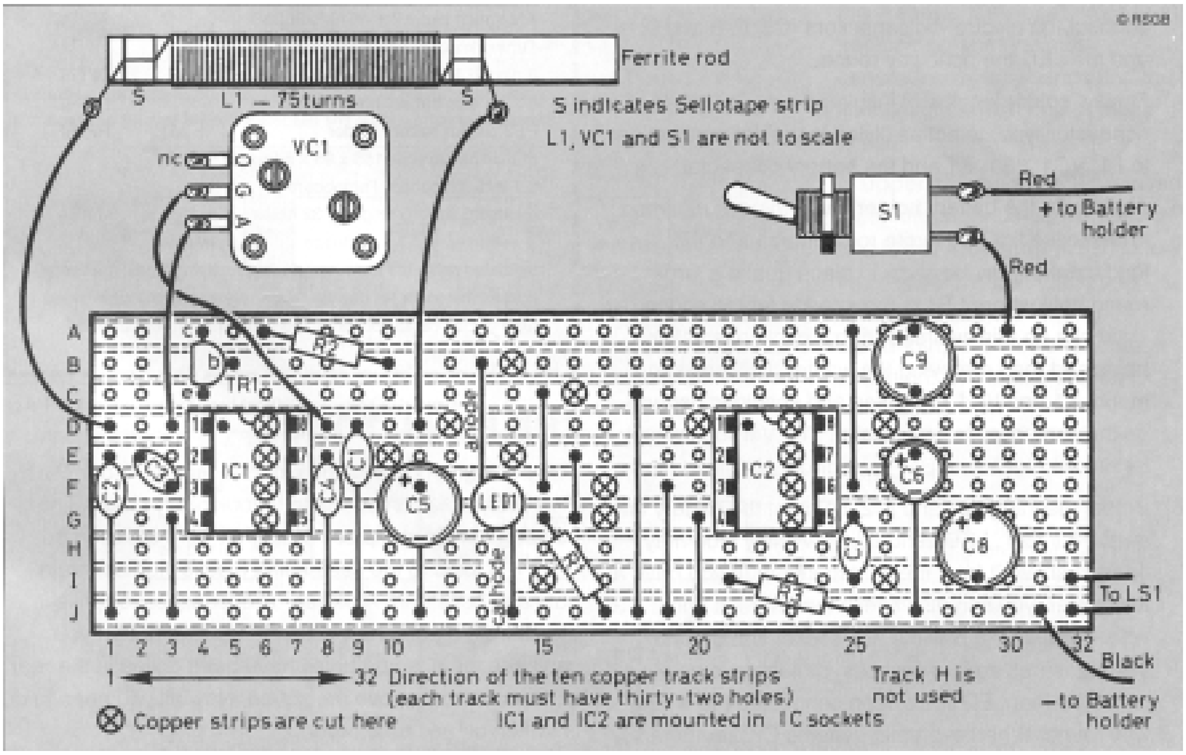
© R508
Ferrite rod
S
L1 — 75 turns
S
S indicates Sellotape strip
L1, VC1 and S1 are not to scale
VC1
nc
O
G
A
S1
Red
+ to Battery holder
Red
A
B
C
D
E
F
G
H
I
J
c
b
e
TR1
R2
IC1
C2
C3
C4
C1
C5
anode
cathode
LED1
R1
IC2
C9
C6
C7
C8
R3
To LS1
1 2 3 4 5 6 7 8 9 10 15 20 25 30 32
1 → 32 Direction of the ten copper track strips (each track must have thirty-two holes)
Track H is not used
Black
− to Battery holder
⊗ Copper strips are cut here
IC1 and IC2 are mounted in IC sockets

Figure 2 Veroboard layout for the Portable Radio. Make sure that all the wire links are included

the need arises! At the speaker position, make one large hole or a series of small holes to let the sound out. The ferrite rod may be stuck to the lid, as may the loudspeaker. Drill holes of the correct size to fit the particular types of variable capacitor (VC1) and switch (S1) that you are using. The Veroboard may be held in position by Blu-Tack or double-sided sticky tape.

6. Before inserting IC1 and IC2, connect the battery and switch S1 on. The LED should glow dimly (you may have to shield it with your hand in order to see it). If you have a test meter, check that there is about 1.3 V between pins 6 and 4 of IC1. If the reading is around 6 V or there is no glow, you may have connected the LED the wrong way round! When everything seems normal, switch off and disconnect the battery. Insert IC1 and IC2, making sure that the pins are straight and lie immediately above their corresponding holes in the sockets, and that the notches line up with the notches in the holders. Then push *gently* downwards on each IC in turn until the chip is firmly seated in its socket.
7. Switch on! By rotating the tuning capacitor, VC1, you should now be able to tune in many stations, rotating the radio to give you some volume control.

Final touches . . .

The handle was made with part of an old leather belt, secured to the case with ‘number plate’ nuts and bolts from Halfords. The loudspeaker grille is the lid from a *pot-pourri* container, and some extra holes were drilled in the back to improve the sound. See what you can find to finish off your radio!

Parts list

Maplin order codes are given for most of the parts, but you should get used to using the ‘beg, borrow or steal’ technique, or to use your ever-expanding junk box.

		Maplin code
Resistors: all 0.25 watt, 5% tolerance		
R1	68 ohms (Ω)	M68R
R2	5.6 kilohms (kΩ)	M5K6
R3	10 ohms (Ω)	M10R
Capacitors		
C1, C4	10 nanofarads (nF) or 0.01 microfarad (μF) ceramic	BX00A
C2, C3, C7	100 nanofarads (nF) or 0.1 microfarad (μF) ceramic	YR75S
C5, C8, C9	100 microfarads (μF) electrolytic, at least 10 V	FF10L
C6	10 microfarads (μF) electrolytic, at least 25 V	FF04E
Semiconductors		
IC1	ZN415E radio chip	
IC2	LM386 audio power amplifier	UJ37S
LED1	3 mm green LED	WL33L
TR1	BC548 npn transistor	QB73Q
Additional items		
LS1	Miniature 8 ohm loudspeaker	WB08J
S1	Miniature SPST toggle switch	FH97F
Ferrite rod	Length approx. 100 mm	YG20W
	24 SWG enamelled copper wire	BL28F

Additional items (*continued*)

VC1	Tuning capacitor 140 to 300 picofarads (pF)	FT78K
	Tuning knob	FK41U
	8-pin DIL IC sockets (two required)	BL17T
	4 × AA-size battery holder (long)	HF94C
	PP3-type clip for battery holder	HF28F
	Plastic box approx. 158 × 95 × 54 mm	LH51F
	0.1 inch Veroboard, min. size 32 holes × 10 strips	JP46A

Plus

- Stranded insulated conductor for flying leads
- Multicore solder
- Materials for handle and speaker grille
- Double-sided sticky tape or Blu-Tack
- Sellotape
- Glue
- Four AA-size 1.5 V batteries

22 The Colt 80 m receiver – Part 2

Introduction

In Part 1 we constructed the audio amplifier module for the system and tested it in a very simple way. If you did what was suggested and built the simple Crystal Set to use as a signal source, you will know just how well the amplifier works.

The case

Metal cases for the project are available from Maplin, telephone 01702 554 161 (code XB67). From the photograph on p. 72 you can see the way the components are mounted. The audio amplifier is seen at the top right of the base, to the right of the tuning capacitor VC1. The next in this series will deal with the variable-frequency oscillator (VFO) and VC1. The current part deals with preparing the case to receive the components.

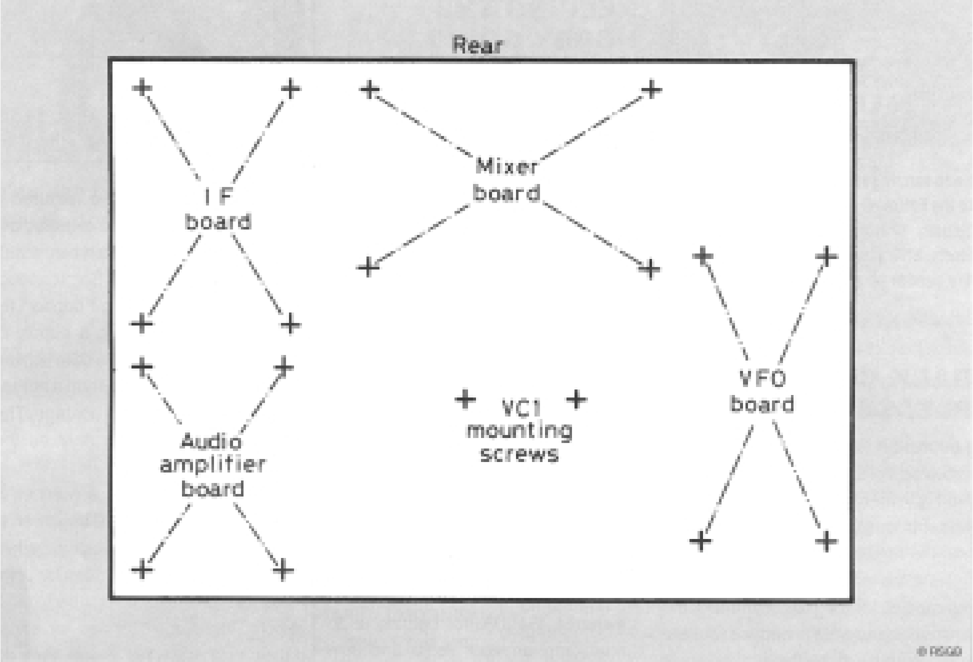
Rear
I F board
Mixer board
VFO board
Audio amplifier board
VC1 mounting screws
© RSGB

Figure 1 Fixing holes for each module are best measured from each printed circuit board or matrix board

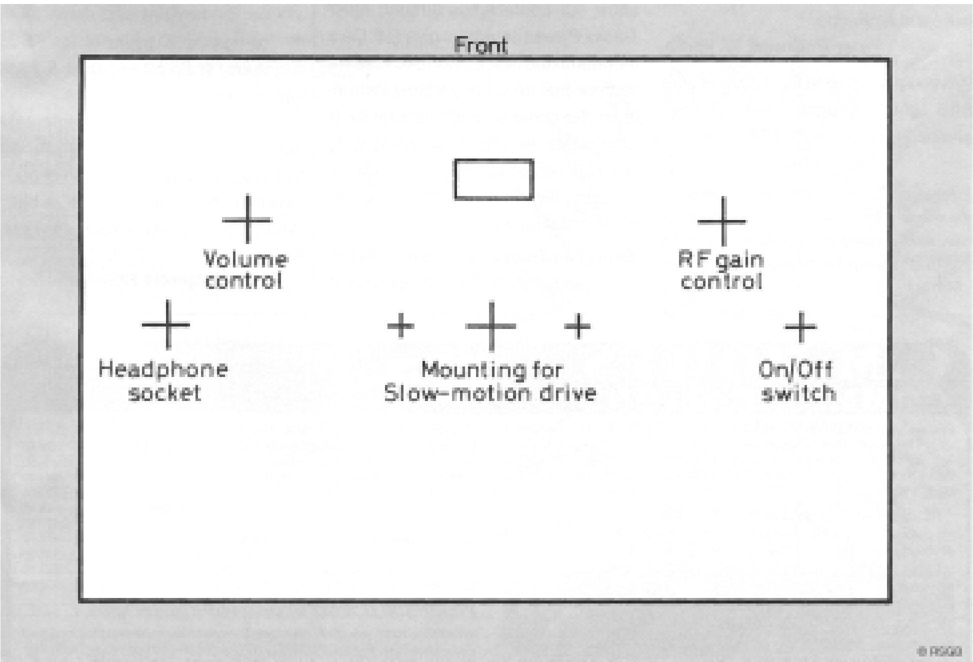
Front
Volume control
RF gain control
Headphone socket
Mounting for Slow-motion drive
On/Off switch
© RSGB

Figure 2 Position the slow motion drive to allow viewing of the tuning dial

Figures 1 and **2** show the markings for preparing the front panel and base. All the circuit boards and the tuning capacitor are mounted on the base using 10 mm stand-off pillars with 6BA bolts. The board locations are shown in Figure 1. The front panel control positions are shown in Figure 2, together with the small rectangular hole for viewing the tuning dial.

The best way to mark out the holes for the boards is to lie the boards flat on the base (before you've started soldering the components in) and marking the base through the holes in the boards. This minimises the scope for errors!

A *reduction drive* is used between the tuning knob and the capacitor shaft. This is simply a gear mechanism that slows down the capacitor shaft by a factor of six compared with the tuning knob, and makes tuning very much easier. The recommended variable capacitor also has a pulley wheel mounted on the shaft. Glued to this wheel will be a scale marked with frequency and is visible through the rectangular hole in the front panel.

The next part . . .

The variable-frequency oscillator and mixer will be added to the project.

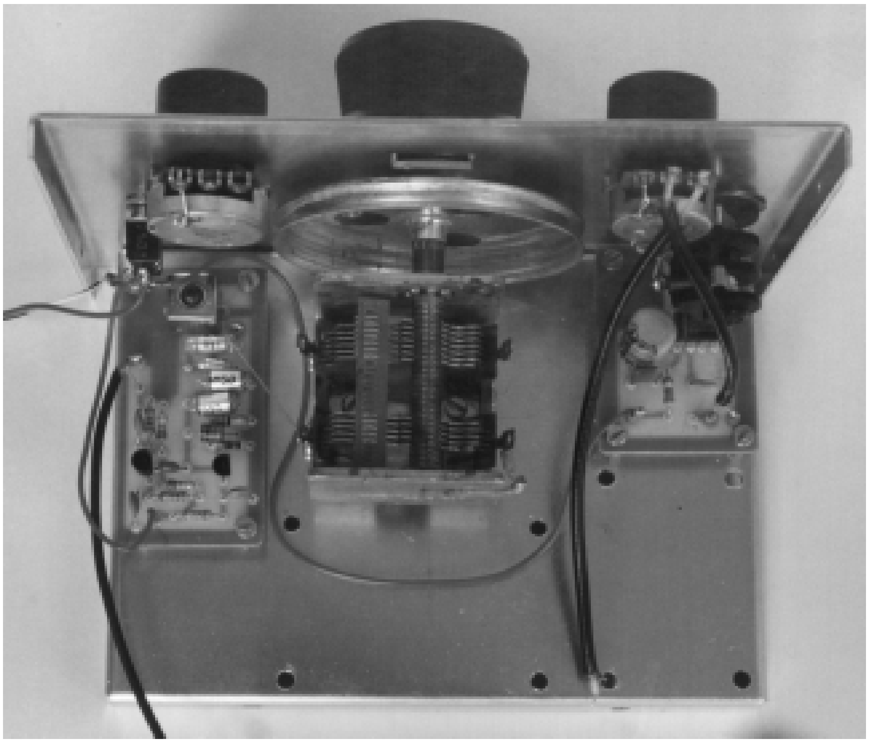

23 A simple transistor tester

Introduction

Although transistors aren't used as much as they were before integrated circuits came along, a transistor tester is still a useful piece of test equipment to have around the shack. This design is about the simplest possible and will produce an indication of whether a transistor is giving any current gain; this does not necessarily mean that the transistor is perfect but that it is working to a certain extent. This tester will **not** test field-effect transistors (FETs). If you buy a bag of transistors at a rally, this tester is useful for giving a yes/no indication of which ones go straight in the bin and which are kept for further use.

How it works

Figure 1 shows the simple wiring circuit. In order to explain the working of the circuit, a circuit diagram is shown in **Figure 2**, with the npn transistor, TR1, under test shown as part of the circuit. The pnp/npn selector switch, SW1, is omitted for clarity.

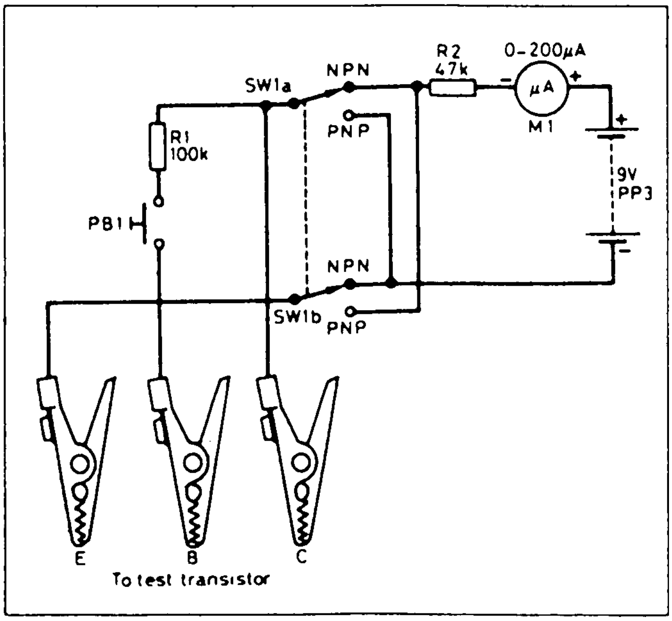

Figure 1 Circuit diagram of the transister tester

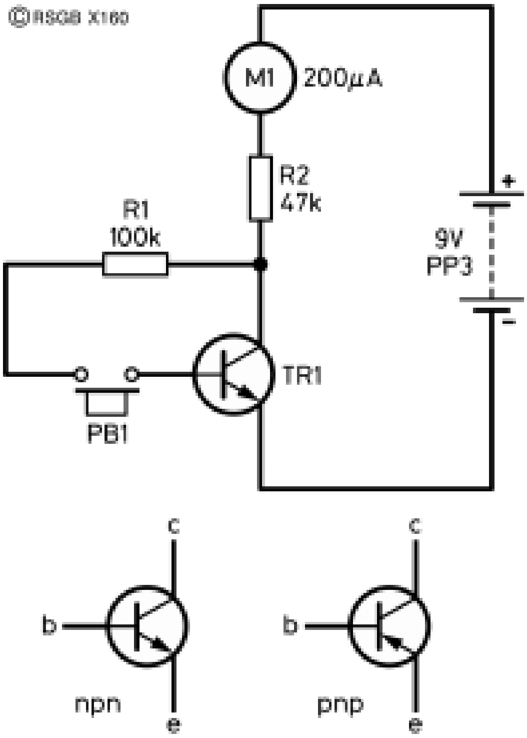

Figure 2 Testing an npn transistor

Any current that flows through the transistor, TR1, must flow from the battery, through the meter, M1, and through the protective resistor, R2. R2 prevents excessive current flowing through the meter and damaging it. Even if there is a short-circuit between emitter and collector, the maximum current that will flow is given by the simple equation

$$I = \frac{V}{R},$$

where I is the current flowing in amps,
V is the battery voltage, and
R is the total circuit resistance in ohms.

Putting in the correct values, gives

$$I = \frac{9}{47\ 000} = 0.000191 \text{ A, or 191 microamps } (\mu\text{A}).$$

The resistance of the meter, M1, will cut this down a little more, but it is within the indicating range (200 μA) of the meter.

As shown, with the push-button switch, PB1, *open*, a good transistor will not draw any current from the battery, and M1 will thus remain at zero. When PB1 is *pressed*, a *very small* current is injected into the base of the transistor. If the transistor is working, it will produce a much larger current between the collector and emitter, and this current will also flow through M1 and R2, giving a significant reading on M1, showing that all appears to be well. If an appreciable current flows when PB1 is *open*, then your transistor is suspect.

Don't be put off by the apparently complicated switch, SW1. It is there to allow the other type of transistor, the pnp type, to be tested. All it does is reverse the battery connections, so that the emitter goes to the *negative* battery terminal for testing an npn transistor, and to the positive terminal for a pnp type!

Most transistors in common use are of the npn type, which is why Figure 2 shows the testing of an npn type. The connections to the different transistor *encapsulations* (shapes) are given in any good component catalogue. Avoid the trial-and-error method to discover the connections to a transistor. This is unscientific, and can be very frustrating, particularly if the transistor is faulty in the first place!

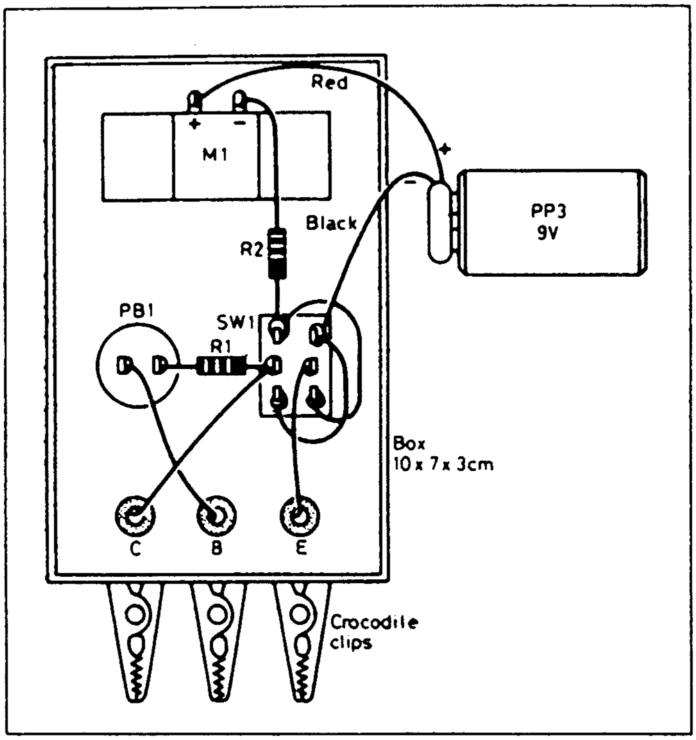

Figure 3 This shows how to wire up the tester

Construction

The unit can be built into a small plastic box, the components being soldered directly to the fixed terminals of the meter and the two switches; no circuit board is necessary! Use different colours of wire for the three test leads, and make sure you know which is which! Check the connections against the wiring diagram of **Figure 3**. When you are confident that all is correct, connect the battery and make sure there is no reading on the meter when nothing is connected to the crocodile clips!

Find any transistor for which you know the connections and the type (npn or pnp). Set the npn/pnp switch accordingly. Connect the three clips, making sure that they do not touch each other. A small reading on the meter at this stage means the transistor is suspect; a large reading means it is not working and should be thrown away! Press PB1 and watch the meter; a reading greater than half of full-scale indicates a good transistor. If it is less than half, you may have a transistor with ‘low gain’; it may be usable for non-critical applications, but if you are in any doubt – throw it away!

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	100 kilohms (kΩ)
R2	47 kilohms (kΩ)

Additional items

PB1	Push-button switch
SW1	DPDT (double-pole double-throw) switch
M1	Micro-ammeter – *not* less than 200 μA full-scale deflection
	Crocodile clips (3 needed)
	PP3 battery and connector
	Plastic box about 10 × 7 × 3 cm

Common types of transistor

BC108, BC109, 2N2369A

These are small-signal npn types, used in audio amplifiers. They are in metal cases (called TO18) and have a tab next to the emitter lead. Common types have a B or C suffix (e.g. BC109C). The C suffix indicates a higher current gain than those with a B suffix. The 2N2369A is specially designed for radio use at high frequencies.

2N3703, BC212L, BCY71
These are pnp transistors, and so must be used with the collector and base *negative* with respect to the emitter. These three types are used in small amplifiers and audio oscillators. The first two have plastic encapsulations (TO92), while the BCY71 has a metal case (TO18).

BFY50, BFY51, BFY52
For slightly higher powers, these are ideal. They have been used in novice transmitters up to 600 milliwatts (mW). The TO5 case is a scaled-up version of the TO18 case. They are all npn types.

2N3055, 2N3773, TIP35C
These are high-power transistors in bigger encapsulations. The thick metal TO3 case of the 2N3055 and 2N3773 is designed to bolt to a heat sink, a large piece of metal which conducts the heat into the air more rapidly than the transistor itself can. The TIP35C is made of plastic but has a thick metal tab by which it, too, can be bolted to a heat sink.

24 An introduction to transmitters

Introduction

We usually think of a transmitter as being a 'black box'. However, that is the form a transmitter takes for our use on the amateur bands. Many electrical circuits are transmitters, even though transmitting may not be their primary function!

Anything that emits electromagnetic energy at *any* frequency is a transmitter, from radio at the low-frequency end of the spectrum, to gamma rays at the high-frequency end. We all know that a magnet will attract certain metals and that a comb rubbed on your coat sleeve will pick up small pieces of paper. The former is an example of the effect of a magnetic field, the latter of an electric field. Electromagnetic fields are combinations of both types of field, and are produced whenever an electromagnetic wave is transmitted.

What frequency?

Many everyday objects have a natural frequency of oscillation. This is called their *resonant frequency*. A wine glass will ring when struck gently; an empty wine bottle will sound if you blow across the top; a guitar string will vibrate when plucked. These are all examples of resonance, and the resonant frequencies will **not** change unless the objects themselves are changed physically in some way. These are resonances in *sound*; we are primarily interested in electrical resonances.

The basic electrical resonant circuit is the combination of an inductor (coil) and a capacitor, as shown in **Figure 1**.

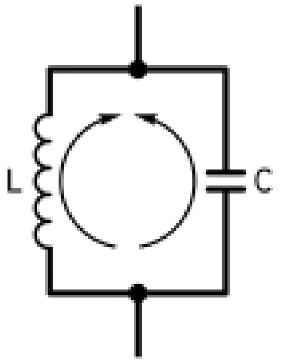

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Figure 1 The basic electrical resonator. The energy in the circuit alternates between the inductor and the capacitor

A pulse of energy applied to this *tuned circuit* will make it *ring* (oscillate) at its resonant frequency. The energy in the circuit transfers between the inductor and the capacitor every cycle of the oscillation. Just like the wine glass, its oscillation dies away because it is losing some energy to its surroundings – it is transmitting! The frequency of the resonance depends on the values of L and C.

Keeping it going

If we want to keep the circuit oscillating, rather than having it die away, we must supply the circuit with just enough energy to replace the energy lost both by radiation and by losses in the circuit itself. Because of this, you will find in all oscillator circuits, a transistor, valve or FET working with the tuned circuit to provide this extra energy.

As it stands, of course, even with its transistor, our oscillator will not radiate very far. Connecting an aerial to it, and a Morse key to interrupt the power supply, it would become a very low-power CW transmitter. Add a couple more transistors to form a radio-frequency (RF) amplifier, and you have the basis of a simple low-power (QRP) transmitter.

Resonant circuits can also be made using quartz crystals; these work at the crystal frequency only, and this is marked on the crystal case.

A tiny spark transmitter

This is a simple piece of test gear that will increase your knowledge and understanding of resonance. You can use it to estimate the resonant frequency of most of the inductor/capacitor (LC) tuned circuits that you build. The circuit is shown in **Figure 2**. It operates around a relay. Any relay that operates from a 6 V to 9 V source and has contacts which are normally closed (i.e. closed when the battery is not connected). Fit the relay, a toggle switch and the battery in a metal box, and connected up as shown in the diagram. Some foam rubber inside the box may help to reduce the escaping noise of the relay. A small hole in the side of the box enables the 2-turn loop to emerge. This should be about 40 mm diameter, made with insulated wire. Switch on; there should be a loud buzzing noise from the relay. If not, you have probably chosen the wrong contacts on the relay!

When it is working, bring the loop close to the aerial of a radio – it should produce a loud noise from the speaker!

How it works

When you switch on, current flows through the relay contacts and through the relay coil. The relay operates and opens the contacts, causing the relay to 'drop out'. When it does, the circuit is completed again and the contacts are opened, and the cycle repeats. Each time the relay contacts open, there is a small spark between them, causing very rapid current surges through the wire loop. This makes the loop transmit RF energy, very briefly. In the early days of radio, this type of circuit was known as a *spark transmitter.*

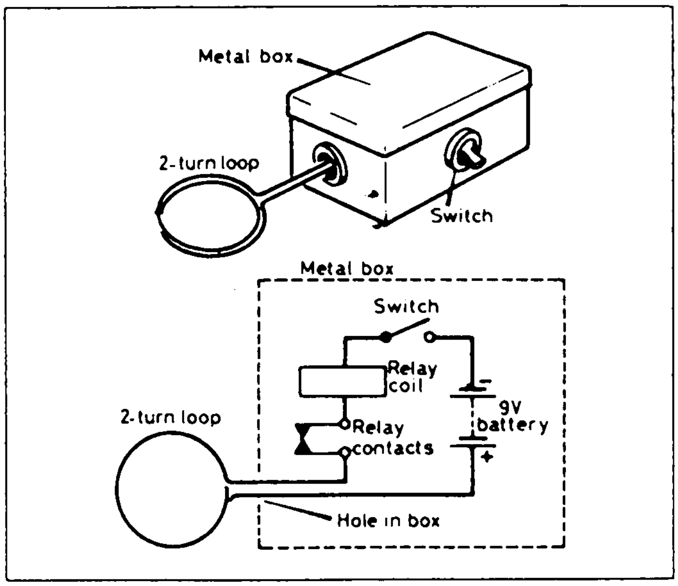

Figure 2 The current path is interrupted when relay is energised as shown above

Make a tuned circuit

Use a discarded toilet-roll centre, and wind about 10 turns of enamelled copper wire round it, keeping each turn close to the next. Scrape off the enamel for about 1 cm at each end, and solder a 100 picofarad (pF) capacitor (or a variable capacitor of about the same value) between the ends. The resonant frequency should be about 10 MHz. If you have used fewer turns or a smaller capacitor, the frequency will be higher.

Measuring the resonant frequency

Set up the buzzer as shown in **Figure 3**, with the loop around one end of your coil. Then make a similar loop, solder it to the end of a piece of coaxial cable going to the aerial socket of a calibrated receiver. Set the buzzer going, tune the receiver around 10 MHz, and search for the maximum noise level from the speaker. When you have found it, move the two loops as far away as possible from the main coil. This is called reducing the *coupling* between the coils, and it may result in a slightly different, but more accurate, resonant frequency.

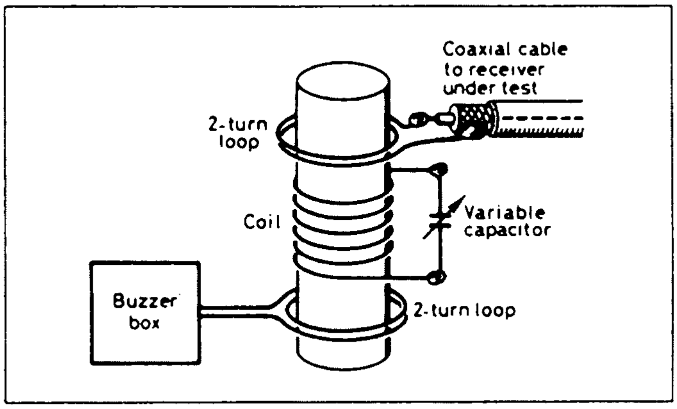

Figure 3 Experiment with the spacing between the loop and the tuned circuit

Parts list

Any small relay which operates between 6 V and 9 V
Metal box – do not use a plastic box!
9 volt battery and connector
On/off (SPST) toggle switch
Plastic foam, as required

25 The Colt 80 m receiver – Part 3

Introduction

In Part 2 we marked out the case ready for installation of the modules when they are completed. In this part, the building of the variable-frequency oscillator (VFO) and mixer will be described. This will produce a type of receiver known as *direct-conversion*, because it converts the radio-frequency (RF) signal directly into an audio-frequency (AF) signal which we can hear in a loudspeaker after amplification. A block diagram of the system is shown in **Figure 1**. The modifications needed to make a full superheterodyne receiver will be left until later.

The direct-conversion receiver covers the 80 metre amateur band and will receive both Morse (CW) and speech (SSB) signals. The audio amplifier was covered in Part 1, so your *Colt* is rapidly taking shape! By the time your construction has reached the end of this part, you will have a receiver ready to use, even if the project is not yet complete!

The direct conversion process

Like most things in radio, the principles of direct conversion are not difficult. From the aerial, the signal we want to hear is selected by the *tuned filter*, which rejects the signals we don't want. The signal then enters the

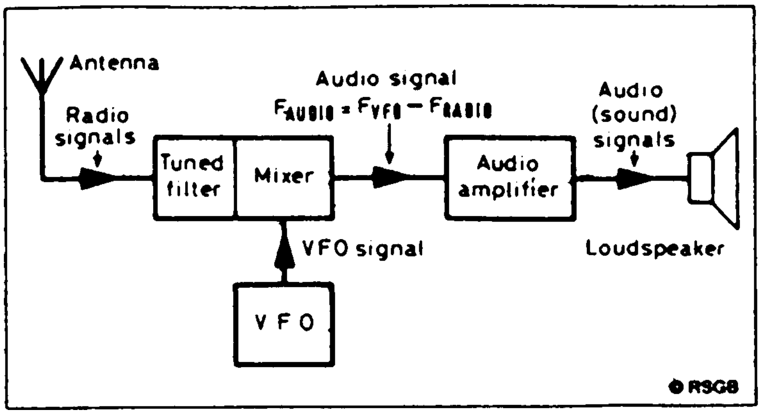
Antenna
Radio signals
Audio signal
$F_{AUDIO} = F_{VFO} - F_{RADIO}$
Audio (sound) signals
Tuned filter
Mixer
Audio amplifier
VFO signal
Loudspeaker
VFO
© RSGB

Figure 1 Stages of direct-conversion receiver

mixer, along with the signal from the *VFO*. The VFO produces a sine wave whose frequency can be varied across the whole of the 80 metre amateur band (3.5–3.8 MHz), by turning the knob on the tuning capacitor, VC1. The mixer produces, at its output, *two* signals; one signal is at the frequency of the **sum** of the signal and VFO frequencies, the other is at the **difference** of the two frequencies. It is the latter that we want. Let's look at the numbers involved. If the signal is at 3650 kHz and the VFO is at 3651 kHz, then the sum frequency is 7301 kHz, and the difference frequency is 1 kHz. If we feed the output of the mixer into our audio amplifier, the 7301 kHz signal is automatically removed (it is far too high to be considered an audio signal!) and the resulting 1 kHz signal is amplified and fed to the speaker, producing a note which we can hear!

Building the VFO

Figure 2 shows the circuit of the VFO. It is a tried and tested circuit, and should work first time. It uses a *field-effect transistor* (FET) for TR1, the oscillator itself. RFC is a *radio-frequency choke*, a coil of wire which will pass a direct current (DC) but which will prevent radio-frequency (RF) signals getting through.

All VFOs have a tuned circuit which, in this case, is formed by the coil L1 and the capacitors C1 and VC1. The frequency will also be affected to some extent by C2, C3, C4 and C5. Transistor TR2 is an *emitter follower*, a stage which gives no voltage gain but provides a good *buffer* stage, isolating the VFO from the effects of the stages that follow it. When building a VFO, the

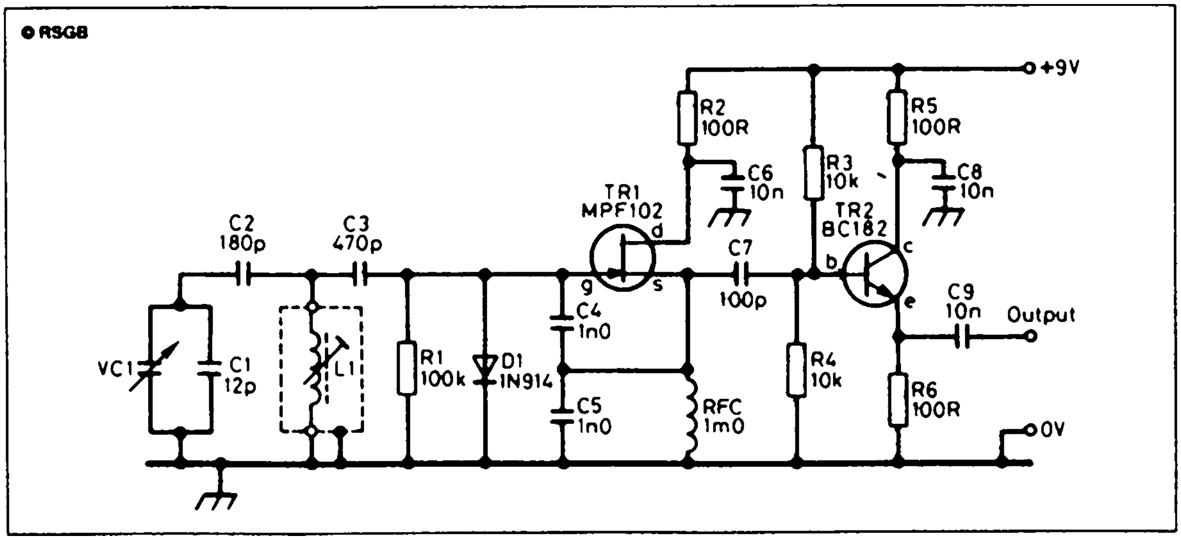

Figure 2 The variable-frequency oscillator uses a field-effect transistor (FET)

parts must be securely mounted. If components move, so does the frequency! At worst, the oscillation will become unstable and the VFO will be useless. Keep the component leads as short as possible – this improves their mechanical stability as well as their electrical stability!

Mount the parts on the printed-circuit board (PCB) or matrix board and, when completed, the VFO should look like the one shown on the left in the photograph on p. 72. Make sure that TR1, TR2 and D1 are the right way round.

On completion, check the component positions then mount it in the case as shown in the photograph, to the left of the tuning capacitor when viewed from the rear. The VFO coil, L1, will need some adjustment, but that will have to wait until the mixer is built. Connections to the other boards are made with screened cable.

The mixer board

So far, we have an audio-frequency (AF) amplifier and a VFO; the addition of a mixer board gives us a complete direct-conversion receiver for 80 m. The mixer circuit diagram is shown in **Figure 3**. Let's follow the signal path.

- From the aerial, the RF signal goes to the gain control potentiometer, RV1. This reduces very strong signals, to prevent them overloading the mixer.
- To select the required band of signals, a *bandpass* filter is made up of RF transformers T1 and T2; these are tuned by C1 and C3, and are coupled together by C2.

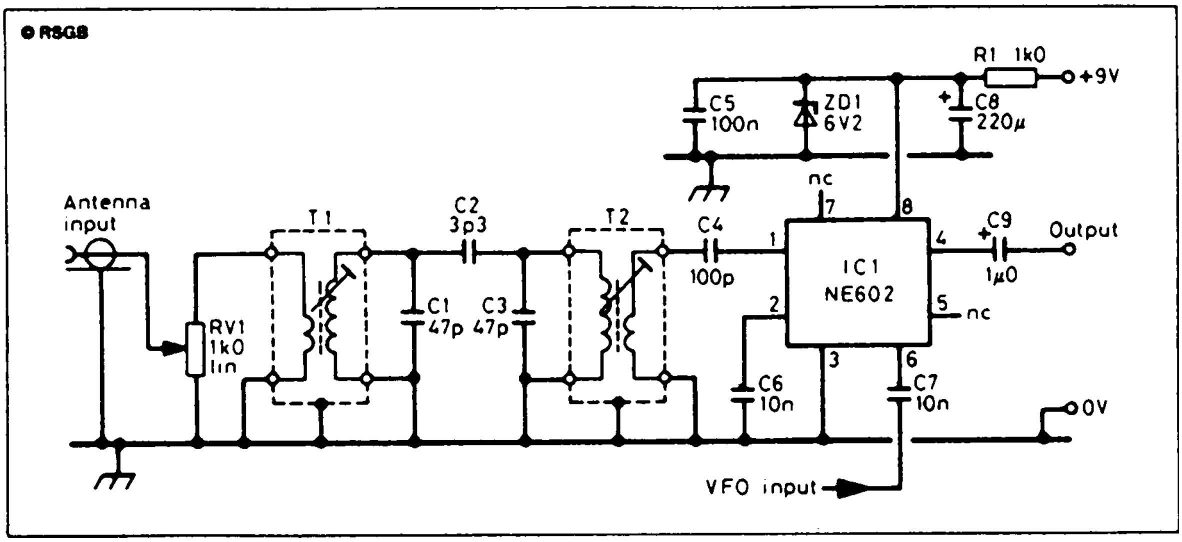

Figure 3 The mixer board has a bandpass filter and stabilised supply

- After the filter, the signal is coupled into the integrated circuit (IC) mixer type NE602, by the capacitor C4. Capacitors C5 and C8 *decouple* the supply line, to prevent unwanted signals on the supply from disturbing the VFO operation. The use of the term *decouple* is exactly the opposite of *couple*; when two circuits are *coupled* together, the signal passes from one to the other; when two circuits are *decoupled*, signals **cannot** pass from one to the other.
- The NE602 works with a 6 V supply; it is produced here from the 9 V supply by the *Zener diode* ZD1 and the resistor R1. ZD1 operates at 6.2 V, and gives a steady output for the mixer. The audio output from the mixer appears at pin 4 or IC1. This is taken to the audio amplifier board via C9 and the volume control (see Part 1).

Care must still be taken to insert some components the right way round. These are the electrolytic capacitors, C8 and C9, the Zener diode, ZD1, and the integrated circuit, IC1. Check all component positions and make sure all your soldered joints are bright and shiny.

Putting it together

The interboard wiring, shown in **Figure 4**, uses screened cable; ideally, this should be thin coaxial cable, but screened microphone cable is suitable. The diagram shows how the two controls, the RF Gain and Volume, are connected to the boards. The leads marked '+9 V' are all connected to the battery supply via a miniature on/off toggle switch. Double check all connections before connecting the battery.

Setting the VFO

Very little adjustment is needed to get the receiver going. Firstly, the VFO must be adjusted to cover the required band, in this case 3.5–3.8 MHz.

If you have a frequency counter, connect it to the output of the VFO. If you haven't, read this part anyway so you understand the process, then another means of setting the VFO will be given especially for you! Rotate VC1 until the vanes are fully meshed. Very carefully, adjust the core of the VFO coil (L1) with a plastic trimming tool so that the frequency approaches and settles at 3.500 MHz. When you rotate VC1, the frequency should increase to **at least** 3.800 MHz at the far end of its travel.

In the absence of a frequency counter, borrow a communications receiver, set it for SSB reception (USB or LSB) on exactly 3.500 MHz. Set VC1 with the vanes fully meshed and turn the core of L1 in both directions until you hear a whistle in the communications receiver. Rotate the core so that the whistle reduces in frequency. It will eventually fade out at around 200 Hz;

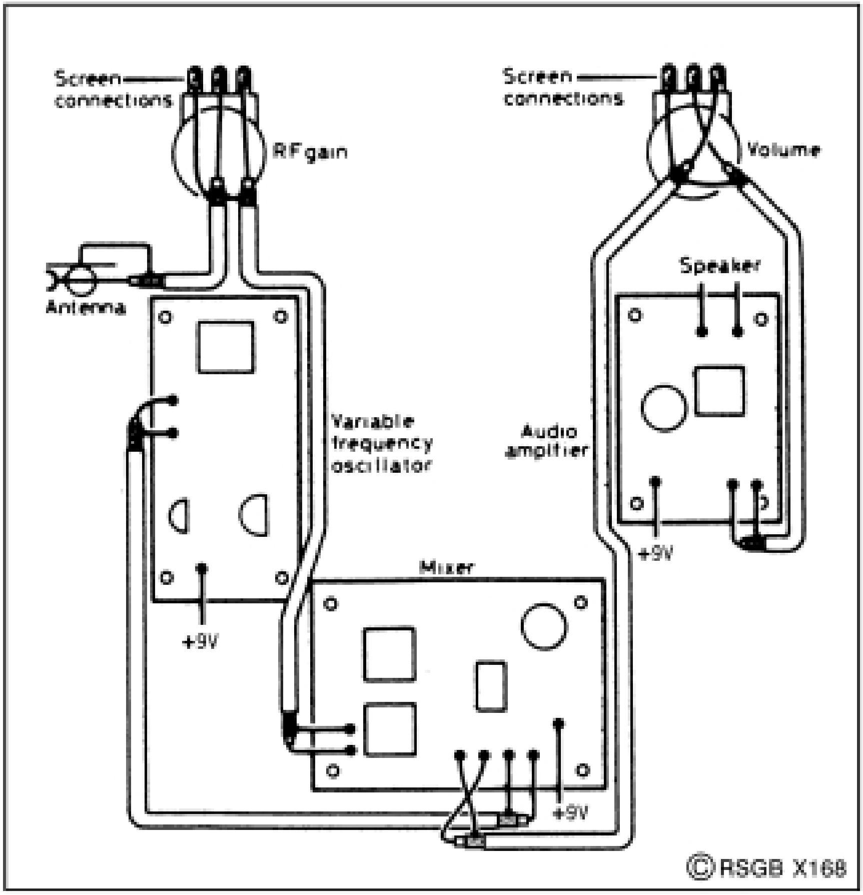
Screen connections
RF gain
Antenna
Variable frequency oscillator
+9V
Screen connections
Volume
Speaker
Audio amplifier
+9V
Mixer
+9V
© RSGB X168

Figure 4 Make sure that interconnections between the boards are correct, including cable screens

turn the core a little further and then leave it at that position. Rotate VC1 right to the other end of its travel, and search for the whistle with the tuning knob of the communications receiver. Check that the VFO frequency is at least 3.800 MHz.

Then, whichever method you are using for frequency measurement, mark the dial with frequency steps of 50 kHz. Setting and calibration are finished!

Setting the mixer

Again, there are various ways of doing this. If you have a signal generator, inject a signal at a frequency within the 80 m band, and adjust the cores of T1 and T2 sequentially for maximum output.

If you haven't a signal generator, connect an aerial to the mixer input, set the RF Gain to maximum (fully clockwise), and find a consistent signal. Adjust the volume control to a comfortable level. Rotating the core of T2 with your trimming tool, maximise the output. Then do the same with T1, although this will have much less effect. Find another station, and check that the positions of the cores aren't too different for a maximum signal.

You may find that your receiver benefits from the insertion of an aerial tuning unit (ATU) between the aerial and the input, to compensate for the impedance of your aerial not being 50 Ω. A design for such an ATU is presented in another part of this series. If the signals are still weak, connect the ATU to the junction of C1 and C2 via a 100 pF capacitor.

Try listening!

Remember that 80 m is a variable band. During daylight hours, your will hear Morse signals at the lower end of the band, and some British and closer continental stations between 3.7 and 3.8 MHz. In the evenings, stations up to 1000 miles away should be heard. Look for Novices around 3.7 MHz!

Parts list – VFO board

Resistors: all 0.25 watt, 5% tolerance		
R1	100 kilohms (kΩ)	
R2, R5, R6	100 ohms (Ω)	
R3, R4	10 kilohms (kΩ)	
RV1	1 kilohm (kΩ) linear	
Capacitors		
C1	12 picofarads (pF) polystyrene	
C2	100 picofarads (pF) polystyrene	
C3	470 picofarads (pF) polystyrene	
C4, C5	1 nanofarad (nF) polystyrene	
C6, C8, C9	10 nanofarads (nF) polystyrene	
C7	100 picofarads (pF) min. ceramic	
VC1	140 + 140 picofarads (pF) variable	
Semiconductors		
TR1	MPF102	FET
TR2	BC182	npn
D1	1N914	silicon
Inductors		
L1	Toko KANK3334	
RFC	1 mH	RF choke

Parts list – mixer board

Resistors: 0.25 watt, 5% tolerance

R1	1 kilohm (kΩ)
VR1	1 kilohm (kΩ) potentiometer (linear)

Capacitors

C1, C3	47 picofarads (pF) min. ceramic
C2	3.3 picofarads (pF) min. ceramic
C4	100 picofarads (pF) min. ceramic
C5	100 nanofarads (nF) min. ceramic
C6, C7	10 nanofarads (nF) min. ceramic
C8	220 microfarads (μF) electrolytic 16 V
C9	1 microfarad (μF) electrolytic 16 V

Integrated circuit

IC1	Philips NE602 or NE602A

Additional items

T1/T2	Toko KANK3333
	On/off switch
	Miniature toggle switch

The next part . . .

The IF amplifier and the Beat-Frequency Oscillator will be added to convert the *Colt* into a superheterodyne receiver.

26 A two-way Morse practice system

Introduction

It is said that the pleasure of sending and receiving Morse code more than compensates for the learning effort needed. Transmitters for Morse code can be much simpler than those needed for any of the speech modes.

Many people choose to learn sending and receiving on their own. It can be much more fun if you have someone to learn with you, and it is for this reason that the following project arose. It comprises just one small circuit, and you build an identical circuit for each of the people who want to learn with you. All the individual circuits are connected with their output leads in *parallel*, as the two-way circuit of **Figure 1** shows.

A simple circuit

This diagram shows two identical circuits, as would be used if two people wanted to learn together. The circuit centres around our old friend the NE555 integrated circuit (IC). As it is connected here, it works as an *astable multivibrator*, a daunting name for what is essentially an oscillator. Each circuit is self-contained, having its own battery, Morse key, sounder and

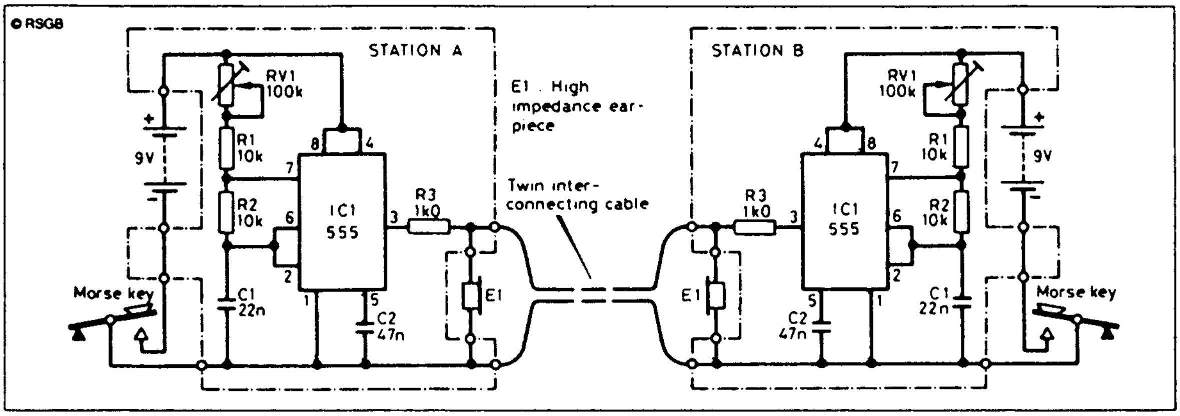
© RSGB
STATION A
RV1
100k
R1
10k
R2
10k
9V
+
−
Morse key
C1
22n
8
4
7
6
2
1
5
3
IC1
555
R3
1k0
C2
47n
E1
E1 . High impedance ear-piece
Twin inter-connecting cable
STATION B
RV1
100k
R1
10k
R2
10k
9V
+
−
4
8
7
6
2
5
1
3
IC1
555
R3
1k0
C2
47n
C1
22n
E1
Morse key

Figure 1 The circuit diagram shows two stations, but you could connect several more if needed

plastic box. The Morse key makes and breaks the power supply to the circuit, thus turning on and off the note emitted by the earpiece. The frequency of the note is controlled by the variable resistor RV1, resistors R1 and R2, and the capacitor C1. The range given by RV1 is approximately from 500 Hz to 2200 Hz.

R3 protects the output of the IC against accidental shorting either to the 0 V or to the 9 V supply rails. For best results, a crystal earpiece or high-impedance headphones should be used. You could try Walkman-type headphones, but the volume may be too low for you.

The units may be interconnected with thin twin cable (the sort used for wiring doorbells) and can be comfortably separated by 25 m, more than enough to communicate between rooms, or even with a neighbour!

In use

When an operator presses his key, the note is heard by himself and by everyone else who is connected. If more than one key is pressed at the same time, two or more notes are heard by everyone! It helps if each person adjusts his own potentiometer, RV1, to give a note which is different from the others. When one operator stops sending, the other can start immediately, without pausing to change from transmit to receive. In practice, this technique is known as *full break-in*.

The current drawn by the circuit is only 10 milli-amps (mA) when the key is down, meaning that the life of a typical PP3 battery will be virtually its shelf-life! No switch is needed, because the key acts as the switch. The current drain will be even less if the NE555 is replaced by an ICM7555 IC. It has exactly the same pin connections as the NE555, so no circuit modifications are needed.

The circuit board

The circuit is constructed easily on a small piece of Veroboard of the copper-strip type. **Figure 2** shows the layout of the prototype, the board measuring 18 holes by 10 strips. **Be aware that there is no row 'I' when you are transferring mental images of where the parts are to real positions on the board!** Break the copper tracks where shown with a 3 mm ($\frac{1}{8}$ inch) twist drill, rotated carefully between thumb and forefinger. Hold the board up to a bright light to make sure that the tracks are completely broken and that there are no fragments of copper swarf shorting adjacent tracks. Then, solder in the wire links shown in Figure 2, followed by the resistors, RV1, and the capacitors, C1 and C2. Solder the battery connector leads to tracks A and G, G being positive. Use insulated wire to connect from the board to the jack sockets used as connectors for the key and the earphones. If you use

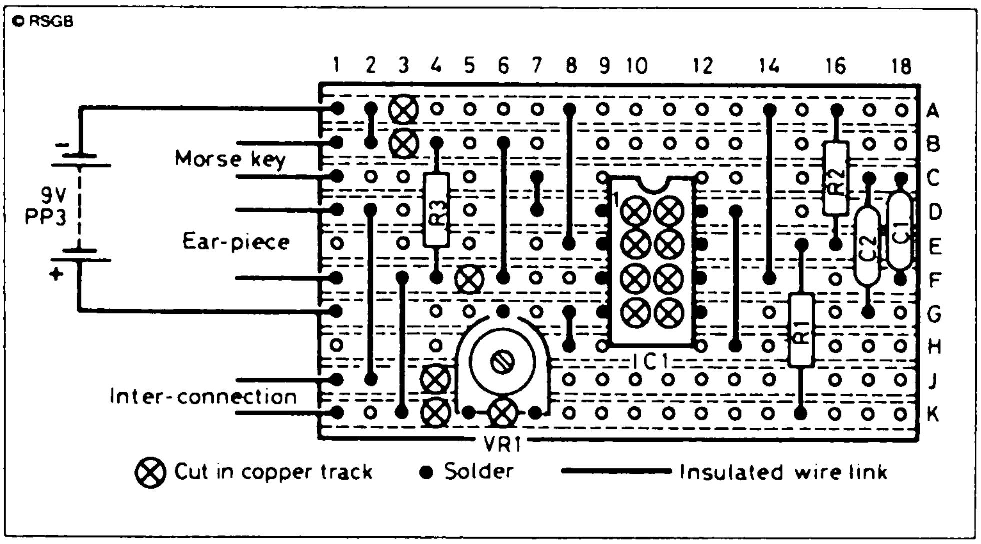
© RSGB
1 2 3 4 5 6 7 8 9 10 12 14 16 18
A B C D E F G H J K
9V
PP3
Morse key
Ear-piece
Inter-connection
R3
R2
R1
C1
C2
IC1
VR1
Cut in copper track
Solder
Insulated wire link

Figure 2 The Morse Duet is an easy project to build on stripboard (Veroboard)

different sized jack sockets (i.e. 2.5 mm and 3.5 mm) you won't plug the earphones into the key socket! A two-screw terminal strip is useful to connect the cable runs between operators.

The key

The circuit is designed to be used with a *straight key* (one that moves up and down). It is a requirement of the UK Morse test that a straight key is used, so it is very sensible to learn sending with a straight key before you try anything more complex! You will find many to choose from at rallies.

Parts list

		Maplin order codes
For each board, you will need:		
Resistors: all 0.25 watt, 5% tolerance		
R1, R2	10 kilohms (kΩ)	M10K
R3	1 kilohm (kΩ)	M1K0
RV1	100 kilohm (kΩ) min. preset (horizontal mounting)	UH06G
Capacitors		
C1	22 nanofarads (nF) ceramic, 25 V	WX78K
C2	47 nanofarads (nF) ceramic, 25 V	RA47B

Integrated circuit	
IC1 NE555	QH66W
Additional items	
8-pin DIL socket	BL17T
Jack plug and socket 2.5 mm	HF76H, HF78K
Jack plug and socket 3.5 mm	HF80B, HF82D
Battery type PP3	
Battery connector	HF28F
Plastic box with lid 114 × 76 × 38 mm	LH14Q
Veroboard 0.1 inch with copper strips 18 holes × 10 strips	JP46A
Terminal strip (two section)	FE78K
Crystal earpiece	LB25C
Morse key	

27 The Colt 80 m receiver – Part 4

Introduction

In Parts 1 to 3 of this series, the design of an 80 metre direct-conversion receiver has been described. In this final part, we are going to change the circuit to operate as a superheterodyne receiver, or *superhet*. Most radio receivers are superhets, and they change the incoming signal to another frequency, known as the *intermediate frequency*, or IF, before producing an audio signal. The use of a superhet in a good receiver is mandated by the requirements for good *sensitivity* and *selectivity.*

Sensitivity and selectivity

Figure 1 shows the block diagram of the receiver. If you look closely, you will see that it is two similar circuits, one after the other. The incoming

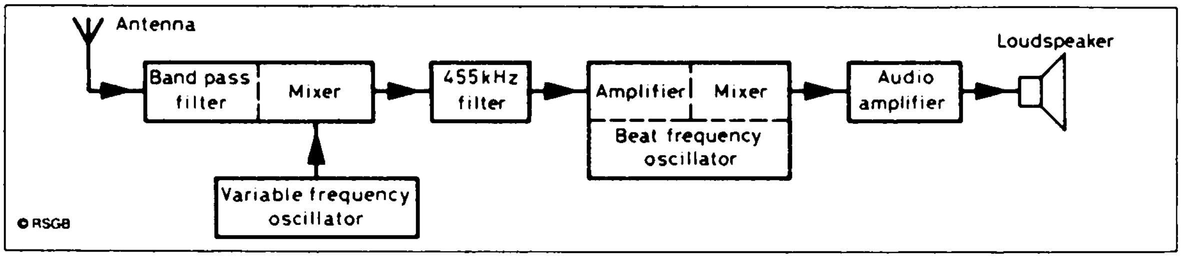

Figure 1 This is how the different stages of the Colt go together to make a superhet receiver

signal is filtered and fed to a mixer where it is combined (mixed) with the signal from the variable-frequency oscillator (VFO). This oscillator operates at a frequency which is 455 kHz higher than the incoming signal from the aerial, and the mixer output is therefore at a frequency of 455 kHz. If you are not sure about this, please refer to the section 'The direct conversion process' in Part 3 of this project. This new frequency is called the *intermediate frequency*, or IF. This frequency doesn't change; the tuning is accomplished by the VFO, and the mixer output is *always* at 455 kHz. The extraction of the audio signal from the IF signal is identical with the direct conversion process which is used in your existing receiver.

This may seem a long-winded way of doing things, but it has its advantages. A receiver must have a good *sensitivity*, or gain, so that it can receive very weak signals. In very general terms, it is easier to handle low-frequency signals than it is to handle high-frequency signals. We are changing our signal frequency from around 3.6 MHz down to 0.455 MHz (455 kHz), which is much lower and can be filtered and amplified relatively easily. A second advantage is that it is easier to provide gain at a fixed frequency than at a variable frequency. Remember that the IF is fixed, and providing gain is, again, relatively simple.

Our receiver also needs good *selectivity*, the ability to separate (or select) one station from another very close to it in frequency. This requirement is significantly simplified by the fact that the IF is fixed, and a good filter in the IF circuits can do wonders for the rejection of adjacent-frequency stations! Several stages of IF amplification and filtering are possible in more adventurous designs.

The filtered signal at 455 kHz passes to another mixer which has an associated oscillator, usually called a *beat frequency oscillator* (BFO). When receiving CW (Morse) signals, the BFO is usually tuned about 1 kHz above or below the IF (i.e. at 454 or 456 kHz) to produce a 1 kHz beat note as the audio signal. This signal is then amplified and fed to a loudspeaker or headphones.

The circuit

Figure 2 shows the circuit of the IF section shown in the photograph on p. 94; this section is added to the existing circuit to make it a superhet. The existing mixer board (described in Part 3) is used as the first mixer. Between it and the audio amplifier is connected the new IF board.

The signal output from the first mixer (at 455 kHz IF) is fed into a *crystal filter*, the most expensive part in the whole receiver. It provides the selectivity which makes the Colt such a good receiver. Another NE602 mixer/oscillator chip follows the filter. The oscillator section is controlled by the tuned circuit in T1, the frequency of which can be altered by rotating the core inside the coil. Once set, it remains fixed.

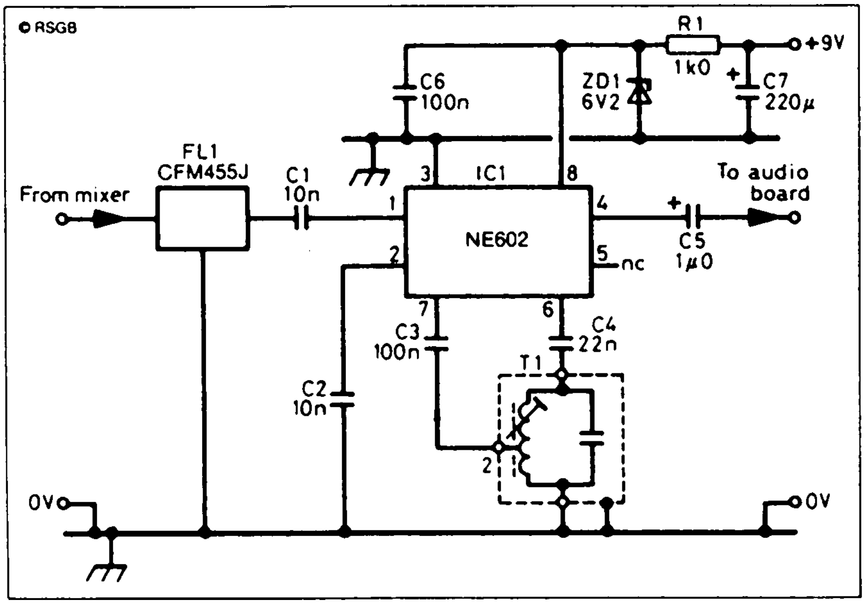

Figure 2 The IF board is connected between the mixer and audio amplifier

At this stage you should have built the first mixer and the audio amplifier, and proved that they *both* work by using the circuit as a direct-conversion receiver. When you have finished constructing and checking the IF board, you will need to add it to your existing circuits.

Adjusting and testing

There are three pairs of connections to the IF board – the 9 V supply leads, the input leads and the output leads. The IF board should be mounted on the metal baseplate, along with the other boards. **In making the following connections, make absolutely sure that the braid of each piece of coaxial**

cable is soldered to the correct connection on each board. The same applies to the polarity of the 9 V leads. Disconnect the screened lead which presently goes from the first mixer board to the AF amplifier at the amplifier end. Connect it instead to the *input* of the IF board. Connect a new piece of screened cable from the IF output to the vacated AF input. Now connect the 9 V supply leads to the same points as the supply leads from the other boards. Check these newly made connections.

You should have confidence at this point that things should be right. After all, you *have* tested the direct-conversion process and you *know* it works. All that you are now testing is the IF board. This is the attraction of building a receiver in modules, working from the speaker backwards, and testing as you go!

The VFO and BFO need to be correctly adjusted. Mesh the vanes of the tuning capacitor and, using the same frequency measurement method as you did originally, set the VFO frequency to 3.955 MHz (which is 3.500 MHz + 0.455 MHz, if you hadn't guessed!). The BFO can be set using a frequency counter, but it is just as good to set it by listening to SSB or CW signals. A high-pitched hissing sound should be heard in the speaker. As you rotate the core, the pitch should reduce, go through a minimum, then increase again. Set the core at the minimum pitch position. You may want to readjust the two cores a little as your listening skills improve but, once you are happy, they will never need to be altered again!

In conclusion . . .

You should now have built a superhet receiver capable of excellent results. It uses the same type of circuit as that found in far more advanced receivers.

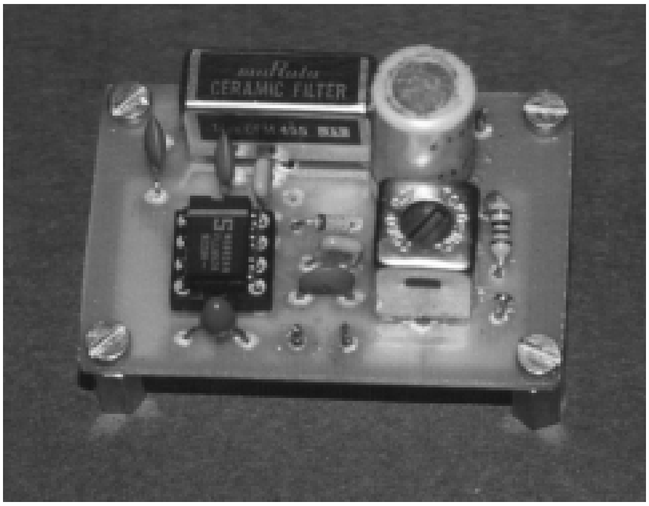

The superhet is far more sensitive than the direct-conversion type, and can weed out those elusive DX stations. You may have found that a station will appear at two places on the dial of the direct-conversion receiver; you will have no such problem with the superhet.

Parts list

Resistor

R1	1 kilohm (kΩ), 0.25 watt, 5% tolerance

Capacitors

C1, C2	10 nanofarads (nF) min. ceramic
C3, C6	100 nanofarads (nF) min. ceramic
C4	22 nanofarads (nF) min. ceramic
C5	1 microfarad (μF) 16 V electrolytic
C7	220 microfarad (μF) 16 V electrolytic

Integrated circuit

IC1	NE602

Additional items

ZD1	Zener, 6.2 V 0.5 watt
FL1	Crystal filter, Murata CFM455J
T1	Tuned inductor, Toko YHCS11100AC

28 A simple crystal set

Introduction

There are many designs of crystal set – they are all ‘simple’, and even the most seasoned radio amateur will build one of these every so often because it is something that never ceases to amaze! Although using modern components, the design is a period piece!

Design and construction

The circuit diagram of **Figure 1** shows the simplicity of the circuit. The prototype was constructed on a wooden baseboard with an aluminium front panel, although this could be made of wood if you prefer.

Winding the coil always causes the most groans but when finished, gives the most satisfaction. The construction of the coil is detailed in **Figure 2**. A discarded toilet roll centre is an ideal *former* on which to wind the coil. The coil will take up about 7 cm of the length of the tube, so assuming the tube is about 11 cm long, the ends of the coil will be about 2 cm in from each end of the tube.

The aerial coil, the *primary winding* of this radio-frequency (RF) transformer, is made from about 30 turns of 26 SWG enamelled copper wire, wound on the matchstick ribs. These ribs should be about 2 cm long, and are glued on **top** of the end of the secondary coil *after* the secondary coil has been wound. The *secondary winding* has 140 turns with *taps* every 10 turns for 70 turns. This coil covers most of the length of the cardboard tube. To make your coil-winding easier, here are some tips for completing the coil and still having some hair left at the end!

- Support the reel of wire on a dowel rod or pencil, clamped in a vice or held rigid in a vertical position by some other means. Don't leave it to trail around on the floor.
- Have a small piece of sandpaper handy to remove the enamel from the copper wire, starting with the end coming from the reel. Remove about 1 cm only, until the shiny copper is visible all round the end of the wire.

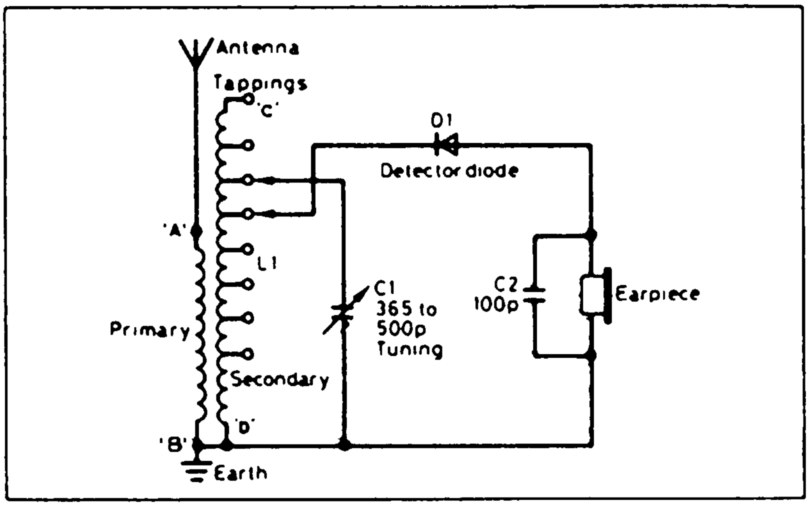

Figure 1 Circuit diagram of the crystal set

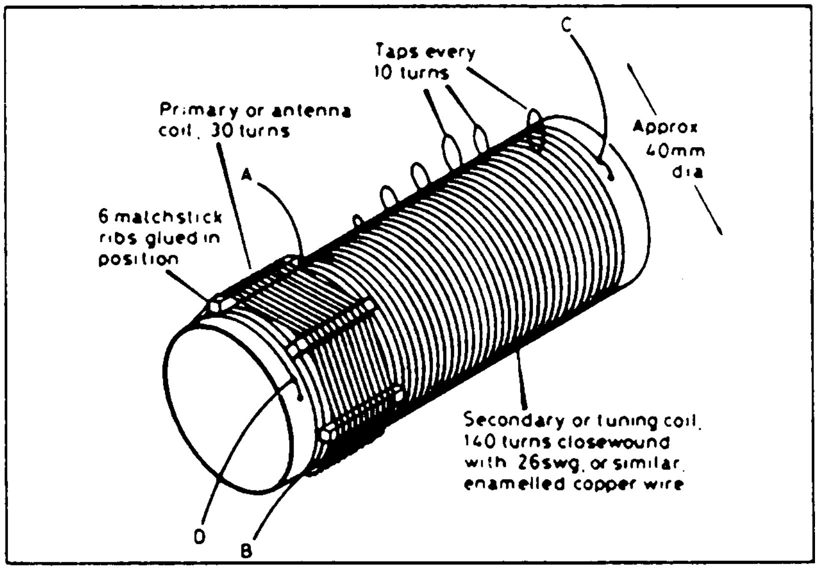
C
Taps every 10 turns
Primary or antenna coil, 30 turns
Approx 40mm dia
A
6 matchstick ribs glued in position
Secondary or tuning coil, 140 turns closewound with 26swg. or similar, enamelled copper wire
D
B

Figure 2 The coil is mounted on a cardboard tube as shown. Exact size is not too important. Try different taps for best results

- This part is the most difficult of all. Seasoned coil winders may have their own favourite ways of doing this, but for first-timers, play it safe and do it this way! Have a second bobbin (or a piece of stout card) ready, on which you will need to wind the wire loosely while you prepare the taps. Then, starting from the free end of the wire, measure 125 cm and, at this point, remove about 2 cm of the enamel with the sandpaper. Bend the wire firmly back on itself in the middle of the bared area, and *tin* (cover with solder) the exposed copper. This is your first tap. Then repeat this six more times at 125 cm intervals, thus giving you seven taps; wrap the wire as you go, on to the second bobbin or piece of card. After the seven taps, you are half-way down your coil so, to begin winding it in earnest, wind the wire carefully from the second bobbin or card **back** on to the original reel of wire.
- Looking at Figure 2, make two small holes about 3 mm apart, about 2 cm down from the top of the tube, where wire C will be entering. Poke the end of the wire into one hole, then bring it out again through the other; leave about 10 cm of wire on the free end. Loop this wire in and out once more, thus anchoring the wire firmly.
- Then, begin winding; keep the wire tight and make adjacent turns touch neatly. As you pass each tap, make sure it sticks outwards while avoiding flexing the wire too much; the wire is inherently weak at each tap.
- When you reach the last 10 cm of wire, stop. Put two more holes, like the first, beside your stopping point, and anchor the end, D, of the coil in the same way as you did with end C. The secondary winding is complete. Take a break *after* you have completed the next step!

- Prepare the six matchsticks for supporting the primary coil and glue these every 60 degrees around the end of the coil at D. Remove the enamel from the free end of the new copper wire on your reel and, using your favourite quick-drying cement, put a drop over the wire on one of the matchsticks, leaving 10 cm free as before. If you are using 26 SWG enamelled copper wire, its diameter is 0.46 mm, so 30 turns should occupy 14–15 mm of the 20 mm matchstick length. This will allow you to position the glued point such that the coil will be roughly in the centre of the matchsticks. When the glue has set, wind the 30 turns and anchor this end of the coil in the same way. Then remove the enamel at the end of the 10 cm lead.

Assembly

The coil former can be screwed to the baseboard at each end, *before* the front panel is screwed to the baseboard! As the photograph on the next page shows, the tuning capacitor is mounted in the centre of the front panel. Five solder tags (or drawing pins as a last resort) should be screwed into the baseboard. The two to the left of the photograph are the connections to the earphones, the two along the rear edge have the diode, D1, soldered to them. One end of the diode (and, for once, you can connect the diode either way round!) is connected to one earphone tag. The other end has a flying lead of about 10 cm attached to it and terminated in a crocodile clip which is used to connect to one of the taps on the coil. The fifth tag secures the end, A, of the primary coil, to which you will attach the aerial. The earth tag on the tuning capacitor, C1, serves as an anchor point for the ground connections to B and D and to the other earphone tag.

Use

The longest piece of wire you have available to use as an aerial should be connected to the aerial tag just mentioned. If you can connect the earth tag of the tuning capacitor to a good electrical earth, this will help also. You should be able to hear something as you turn the tuning knob. Try adjusting the tapping connections on the coil – change only one at a time, or you will never find the optimum positions. You now have a fully operational crystal set!

Simple it may be, but this circuit illustrates some important principles which are used even in the most expensive receivers. Firstly, the coil, L1, and the capacitor, C1, form a *tuned circuit* which *resonates* at the frequency of the station you have tuned in. This *selects* the signal you want to hear. The *modulation* on this signal is removed by the *detector*, D1, and fed to the earphones, which act as *transducers*, turning the electrical energy into sound energy which you can hear. It doesn't need a battery or other power supply either!

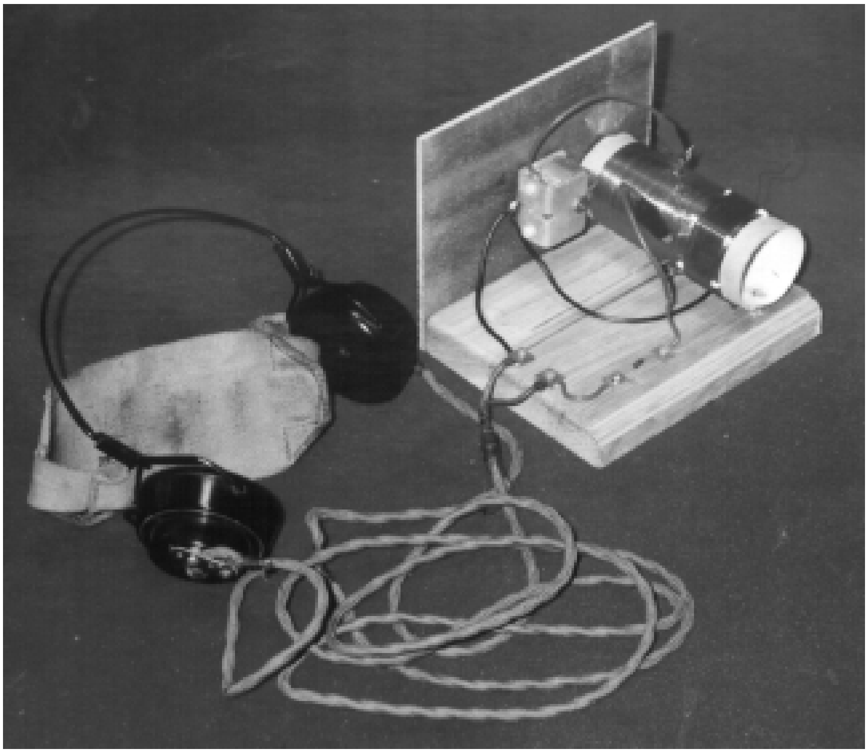

Parts list

Capacitors	
C1	Variable capacitor of between 200 and 500 picofarads (pF) maximum
C2	100 picofarads (pF) min. ceramic
Additional items	
D1	Germanium, type OA47 or OA90
	High impedance crystal earphone (not Walkman type)
	Tuning knob
	Wooden base, approx. 110 mm square
	Aluminium (or wood) front panel, approx. 80 × 100 mm
	Cardboard tube (toilet roll centre), about 110 mm long, 40 mm diameter
	Reel of 26 SWG enamelled copper wire for both windings of L1

29 A crystal calibrator

Introduction

A crystal calibrator is a device that produces oscillations of a precise frequency which are rich in *harmonics*. A harmonic is an integer multiple of the fundamental frequency; for example, if our fundamental frequency was 100 kHz (as it is in this circuit), there would be harmonics of this frequency at 200 kHz, 300 kHz, 400 kHz, and so on. These harmonics can be used, when picked up by any receiver, to calibrate that receiver, as the harmonics are quite accurate in frequency (see later for an assessment of accuracy). However, a gap of 100 kHz between harmonics is rather wide for most purposes, so we reduce this frequency to 25 kHz, so that the harmonics are then 25 kHz apart, thus producing a much more useful set of *marker points*. A calibrator such as this is often called a *crystal marker*, producing these marker points from 25 kHz to beyond 30 MHz.

The circuit

The circuit diagram is shown in **Figure 1**. The circuit around TR1 is the fundamental oscillator, and its frequency is controlled by the quartz crystal, X1. Even crystal oscillators are not 100% accurate, and the small trimmer capacitor, TC1, is able to 'pull' the frequency to one which is nearer the

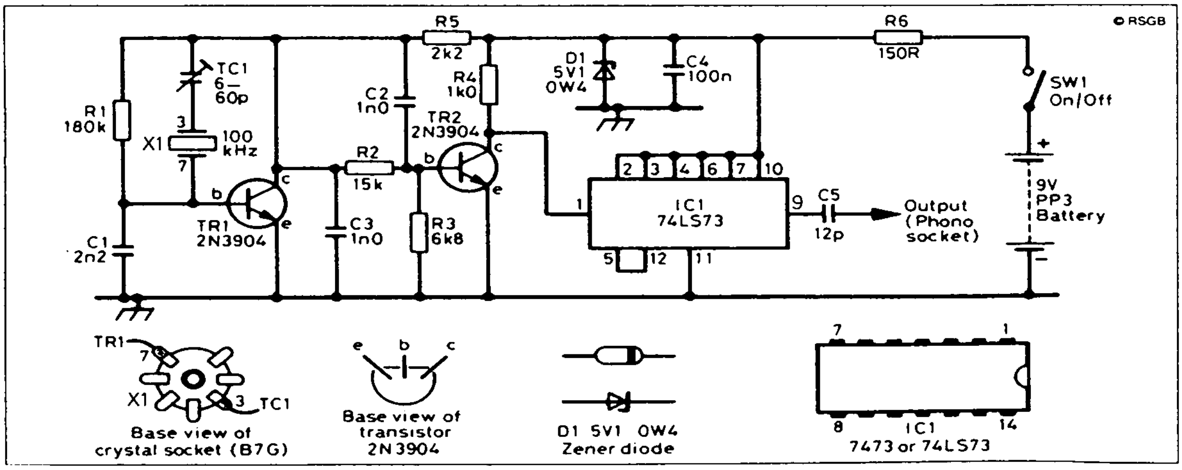
© RSGB
R5
2k2
R6
150R
TC1
6–
60p
R1
180k
X1
3
7
100
kHz
C2
1n0
R4
1k0
TR2
2N3904
D1
5V1
0W4
C4
100n
SW1
On/Off
R2
15k
b
c
e
TR1
2N3904
C1
2n2
C3
1n0
R3
6k8
2 3 4 6 7 10
1
IC1
74LS73
9
C5
12p
Output
(Phono
socket)
+
9V
PP3
Battery
–
5 12 11
TR1
7
X1
3
TC1
Base view of
crystal socket (B7G)
e b c
Base view of
transistor
2N3904
D1 5V1 0W4
Zener diode
7
1
8
IC1
14
7473 or 74LS73

Figure 1 Circuit diagram of the calibrator which uses easily obtainable components

correct one. TR2 is a *buffer* stage, which isolates the oscillator from the rest of the circuit. It acts as a switch, and applies a good signal (switching between 0 and 5 V) to the input of IC1.

IC1 is an integrated circuit which can be connected to do several things. It is connected here to divide the incoming frequency by a factor of 4, producing on pin 9 an output frequency of 25 kHz.

The combination of R6, C4 and D1 produces a supply of 5 V for IC1; it would be damaged if the battery voltage were applied to it. You will no doubt be ready to assemble the circuit, so here is some information for you.

Construction

If possible, always build a circuit in individual stages, which you can test as you go along. It is not always easy in small projects like this, but even the crystal calibrator can be split into two for construction and testing.

It is an ideal project for assembly on Veroboard of the copper-strip type; the prototype layout is shown in **Figure 2**, on a board measuring 11 holes by 24 strips. First of all, remove the copper strip at the locations shown, using a 3 mm drill rotated between the fingers. Hold the board up to the light to ensure that there are no pieces of copper swarf bridging adjacent strips, and that the copper is completely removed where it should be! Assemble the circuit from left to right, but do not wire up anything around IC1. Be aware that the diagram shows the board *from the component side*. Although you

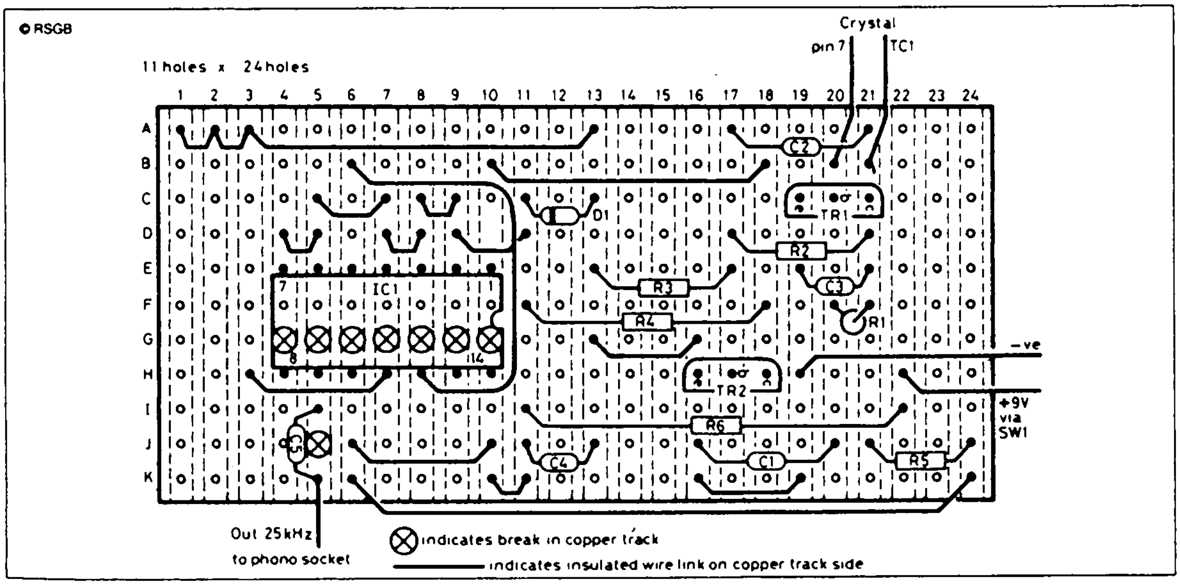
© RSGB
Crystal
pin 7
TC1
11 holes x 24 holes
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
A B C D E F G H I J K
C2
TR1
D1
R2
IC1
7
8
14
R3
C3
R4
R1
TR2
R6
C4
C1
R5
−ve
+9V via SW1
Out 25kHz to phono socket
indicates break in copper track
indicates insulated wire link on copper track side

Figure 2 Stripboard, such as Veroboard, should be cut as shown to approx. 62 × 28 mm

can use virtually any kind of crystal, you will need to mount it firmly. If you use a small one, it can be soldered directly in position on the board. With one in a valve envelope, you will need a B7G valveholder. Be prepared to mount the circuit in a **metal** container; the prototype used an (empty) tin of tuna! The valveholder mounts well on any metal case.

Disconnect the aerial of your receiver, and replace it with about 30 cm of wire laid near your oscillator circuit. Connect the battery and switch on. Tune the receiver around until you can hear a whistle on SSB. Rotate the tuning knob to reduce the frequency of the whistle and, as the whistle becomes too low to hear, you have reached one of the calibration markers, and your frequency will be an integer multiple of 100 kHz. If you are already using a calibrated receiver, you will be able to verify this. Going up or down in frequency should locate another marker 100 kHz away, and so on right through the receiver's tuning range. If the signals coming from the circuit are very weak, switch off the calibrator and connect another 30 cm piece of insulated wire to the collector of TR2, and lay it close to (but *not* touching) the wire from the aerial connector. Switch on an try again; you should not now have a problem! If you have access to a multimeter, check that the voltage at the collector of TR1 is very close to 5 V. If it is close to 9 V, you have connected the diode, D1, the wrong way round!

Having verified that the oscillator is working, you can now wire up the integrated circuit socket, being careful to put the notched end of the socket pointing towards R4, the collector resistor for TR2.

Check your connections around IC1, and when you are satisfied that they are correct, line up IC1 with its socket, making sure that the notched ends are together, and press down *gently* to insert the IC into its socket. Insert the 30 cm piece of insulated wire into the output socket, connect the battery and switch on. You should still hear whistles in your receiver, but now they should be 25 kHz apart, rather than 100 kHz apart.

All that now remains to be done is to mount the circuit rigidly inside whatever casing your have chosen. Make sure that none of the connections under the board touch the metal case, and secure the valveholder, on/off switch and output connector to the case. You now have a completed crystal calibrator.

Calibration

The simplest way to calibrate your circuit is with a frequency counter. Most clubs will have one of these and, if not, will know someone who has! Connect it to the collector of TR2, where the frequency should be 100 kHz. Do *not* connect it to any part of the circuit around TR1, or you may alter the frequency you are trying to measure! If the frequency is not exactly 100.000 kHz, rotate TC1 until it is (or is as close as you can get it). Now your calibrator is as accurate as the counter with which you have calibrated it.

Accuracy

Despite your best efforts at calibration, by whatever means, your crystal will *never* have a constant frequency. Such a thing is a scientific impossibility. It is usual to express the accuracy of a crystal in parts-per-million (ppm), and it is governed by many things, principally its temperature. You will be *very* fortunate if your circuit maintains an accuracy better than about ±10 ppm. Expressed in figures, it means that the true frequency can be anywhere between 99.999 kHz and 100.001 kHz, i.e. within 1 Hz of the correct frequency.

Although this may seem more than adequate, it is as well to remember that the accuracy degrades as the frequency increases. At 1 MHz the error will be ±10 Hz and at 10 MHz it will be ±100 Hz. At 30 MHz it will be 300 Hz. Even so, this should be acceptable for most non-critical applications.

Parts list

Resistors: all 0.25 watt, 5% tolerance		**Maplin code**
R1	180 kilohms (kΩ)	M180K
R2	15 kilohms (kΩ)	M15K
R3	6.8 kilohms (kΩ)	M6K8
R4	1 kilohm (kΩ)	M1K0
R5	2 kilohms (kΩ)	M2K0
R6	150 ohms (Ω)	M150R
Capacitors		
C1, C2, C3	1 nanofarad (nF) or 1000 picofarads (pF)	WX68Y
C4	100 nanofarads or 0.1 microfarad (μF)	YR75S
C5	12 picofarads (pF)	WX45Y
TC1	60 picofarads (pF) trimmer	WL72P
Semiconductors		
TR1, TR2	2N3904 npn	QR28F
IC1	7473 or 74LS73N dual JK flipflop	YF30H
D1	5.1V 500 mW Zener	QH07H
Additional items		
100 kHz crystal		
B7G valveholder (found at most rallies)		
14-pin DIL IC socket		BL18U
Phono socket		YW06G
PP3 battery connector		HF28F
PP3 battery		
On/off switch		FH00A
Veroboard		JP47B
Metal case as required		

30 A simple short-wave receiver – Part 1

Introduction

No apologies for yet another design of short-wave radio. This is the beauty of our hobby – there is always something new to try. Not all circuits operate in the same way; not all circuits work equally well; sometimes a simple design suits the operator better than a complicated design. So here is another one for your consideration; it's a good project for a novice, *and* a good one-evening project for someone more experienced.

A basic description

Figure 1 gives the block diagram of the receiver, which employs a *regenerative detector*, one of the earliest techniques by which excellent *selectivity* (the ability to separate two stations very close in frequency) could be combined with good *sensitivity* (the ability to pick up very weak stations) using a very simple circuit. The receiver falls into the category known as *tuned radio frequency* (TRF), meaning that the whole circuit (prior to the extraction of the modulation from the carrier) operates at the incoming radio frequency. In other words, it is *not* a superhet.

As you can see, the regenerative detector has what is called a *feedback loop*, which feeds a small amount of the output signal back to the input. You have heard the effects of feedback with a public address system, when the microphone gain is too great – everything becomes very loud and then bursts into a deafening squeal! This is exactly what the feedback does here, except that it is carefully controlled, thus providing both gain and selectivity. The resulting audio is then amplified for use with headphones.

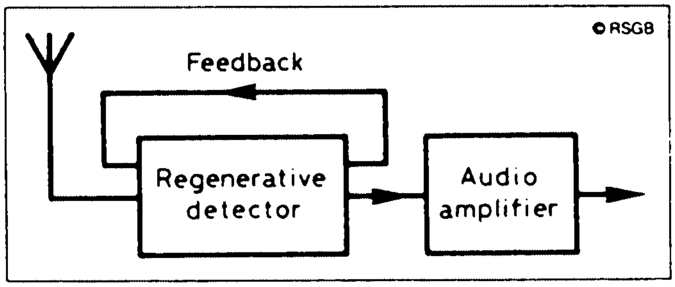

Figure 1 Just two simple stages make up the circuit

The circuit

The circuit of **Figure 2** shows the complete system. TR1 is an untuned *field-effect transistor* (FET) stage, and is used to match the aerial to the next stage. Occasionally, a regenerative detector produces unwanted signals, and TR1 also prevents them from reaching the aerial and being transmitted! The smaller of the two windings on T1 (the *primary* winding) will match a low-impedance aerial, the capacitor input matching a high-impedance aerial.

Ignore TR2 for the moment – the next stage in the signal path is TR3, the detector, using another FET. The tuned circuit is formed by T2, VC1 and VC2 (remember TR1 is untuned). The primary winding on T2 taking the output from TR1. The reason for having two variable tuning capacitors, one large, the other small, is that the large capacitor is the main tuning capacitor, while the small one is used as a *bandspread* control (for very fine tuning). The tuned signals are then detected (converted to audio frequencies) by TR3.

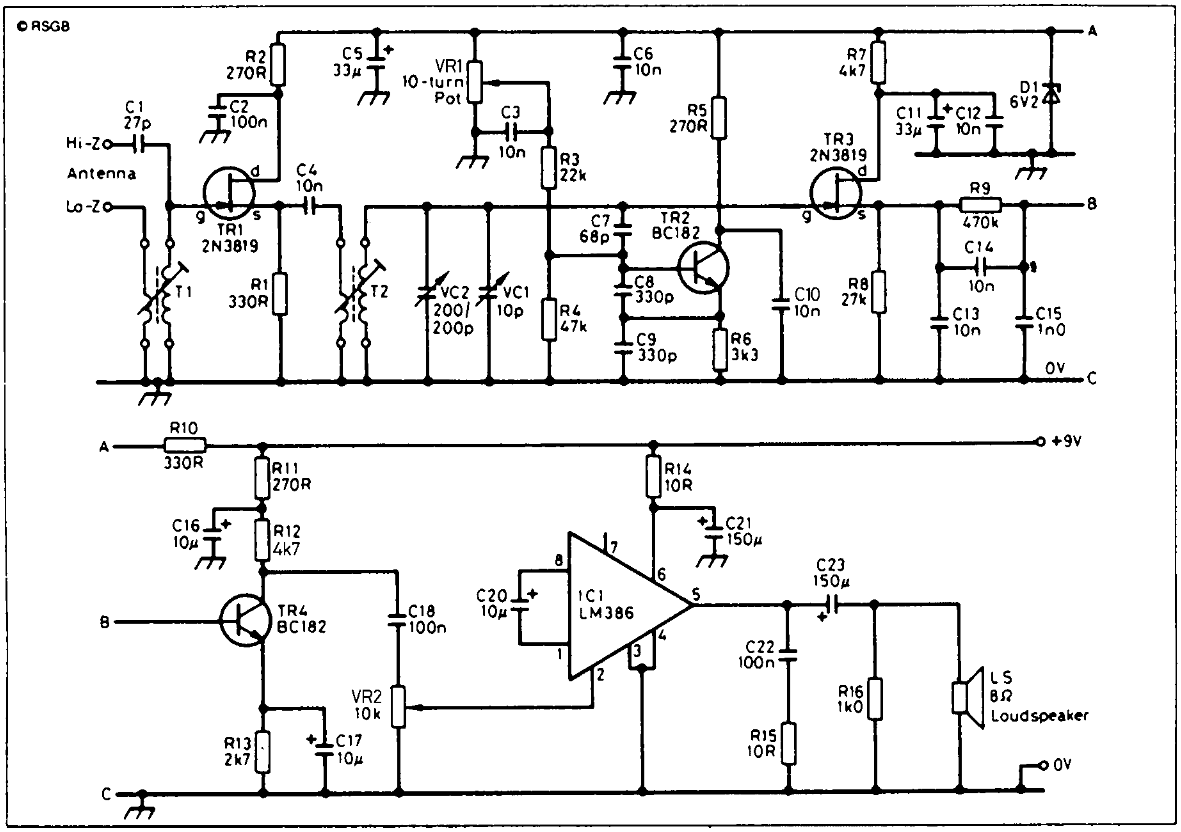
©RSGB
R2 270R
C5 33µ
VR1 10-turn Pot
C6 10n
R7 4k7
A
C1 27p
Hi-Z
Antenna
Lo-Z
C2 100n
C3 10n
R5 270R
C11 33µ
C12 10n
D1 6V2
C4 10n
R3 22k
TR3 2N3819
d
g
s
R9 470k
B
TR1 2N3819
C7 68p
TR2 BC182
C14 10n
T1
R1 330R
T2
VC2 200/200p
VC1 10p
R4 47k
C8 330p
C9 330p
R6 3k3
C10 10n
R8 27k
C13 10n
C15 1n0
0V
C
R10 330R
+9V
R11 270R
R14 10R
C16 10µ
R12 4k7
C21 150µ
C23 150µ
TR4 BC182
C18 100n
C20 10µ
IC1 LM386
1
2
3
4
5
6
7
8
C22 100n
R16 1k0
LS 8Ω Loudspeaker
VR2 10k
R15 10R
R13 2k7
C17 10µ
0V

Figure 2 The circuit diagram showing the 10-turn potentiometer VR1. This is the regeneration control for the circuit

TR2 is a *Q-multiplier* stage. It is a Colpitts-type oscillator which uses C8 and C9 to give feedback and produce the oscillation. C7 couples the tuned circuit (and the input to TR3) to TR2. The tuned circuit thus controls the frequency of oscillation of TR2 and the signal passed on to TR3.

The secret of the ease of operation of this receiver is VR2, a 10-turn potentiometer (or *helipot*). The resistance wire is wound in the form of a helix, giving a much greater wire length than in a normal potentiometer, and the shaft must be turned ten times to cover the whole length. Helipots are very useful when very fine adjustments have to be made. Here, VR2 sets the regeneration (or *reaction*) level, depending on the type of signal you are receiving, as will be discussed in Part 2.

TR4 provides the first stage of audio amplification and, after the volume control, VR2, the audio amplifier integrated circuit, IC1, will drive a small loudspeaker or headphones.

In Part 2, the construction will be discussed, together with the choice of aerial, the parts list, and advice on using the receiver.

31 A fruit-powered medium-wave radio

Introduction

This is a one-evening project that will result in a working medium-wave (MW) radio, and will also teach you a little about the way electricity can be generated from the right metals and a little (safe) acid. All you need are three lemons or other citrus fruit, three pieces of copper and three pieces of zinc (or galvanised metal) for your power supply.

Construction

Figure 1 shows the circuit and **Figure 2** its layout on a simple ‘plug-in’ prototype board. The six pieces of metal are connected as shown, to wire the three lemons in series; use ordinary wire between each lemon and the next. If you have a meter to measure the total voltage, it should be about 1.8 V. Use a standard ferrite rod, and wind on it about 40 turns of single-conductor PVC-insulated wire.

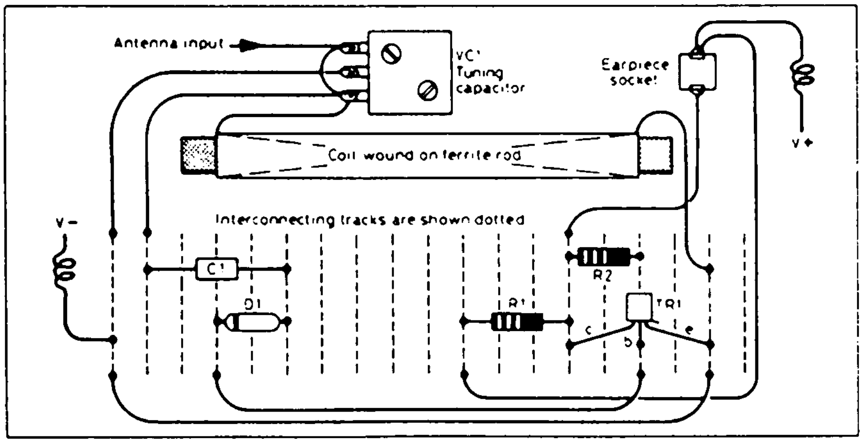
Antenna input
VC1
Tuning
capacitor
Earpiece
socket
V+
Coil wound on ferrite rod
V–
Interconnecting tracks are shown dotted
C1
D1
R1
R2
TR1
c
b
e

Figure 1 Most parts are plugged into the board as shown – soldering is not required

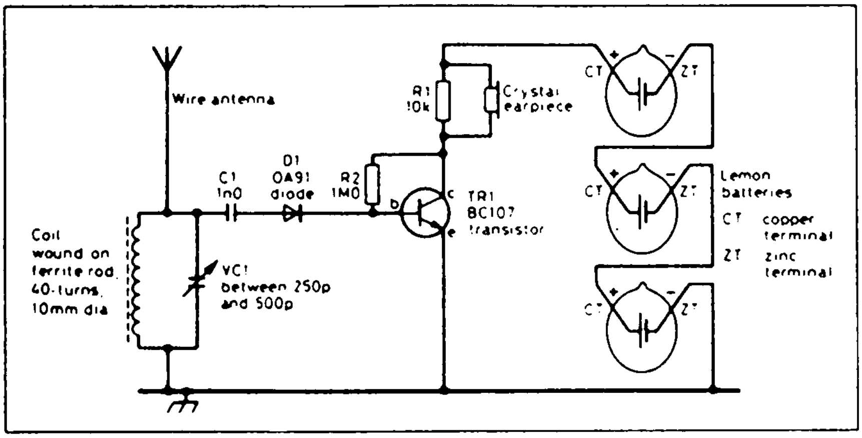
Wire antenna
Coil
wound on
ferrite rod.
40-turns,
10mm dia
C1
1n0
D1
OA91
diode
R2
1M0
VC1
between 250p
and 500p
R1
10k
Crystal
earpiece
b
c
e
TR1
BC107
transistor
CT
ZT
+
–
Lemon
batteries
CT copper terminal
ZT zinc terminal

Figure 2 Three lemons power the radio, which gives good results for such a simple circuit

Wire up the circuit on the board as illustrated in Figure 2. Soldering is not required with this type of board – just plug in the components and the wires. Only one transistor is needed. The tuning capacitor, VC1, selects the station you want to hear, and D1 helps to remove the carrier from the RF signal. The resulting audio signal is fed to TR1, a small transistor audio amplifier, which makes the signal big enough to drive a crystal earpiece comfortably. Walkman-type earphones will not work, so invest in a crystal earpiece which you can use in several other projects, too! If you use a smaller capacitor than that specified for VC1, you will need more turns on the aerial coil.

Tests on the prototype indicated that the radio will run for about a week on three lemons!

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	1 megohm (MΩ)
R2	10 kilohm (kΩ)

Capacitors

C1	1 nanofarad (nF) min. ceramic
VC1	250–500 picofarad (pF) variable

Semiconductors

TR1	BC107 npn (or BC108, BC109C)
D1	OA90, OA91 germanium (not silicon)

Coil

L1	2 metres of single-conductor insulated wire on a standard ferrite rod

Additional items
- Plug-in prototype board, e.g. Maplin YR84F
- Wire aerial at least 3 m long
- Crystal earpiece
- Three juicy fruits

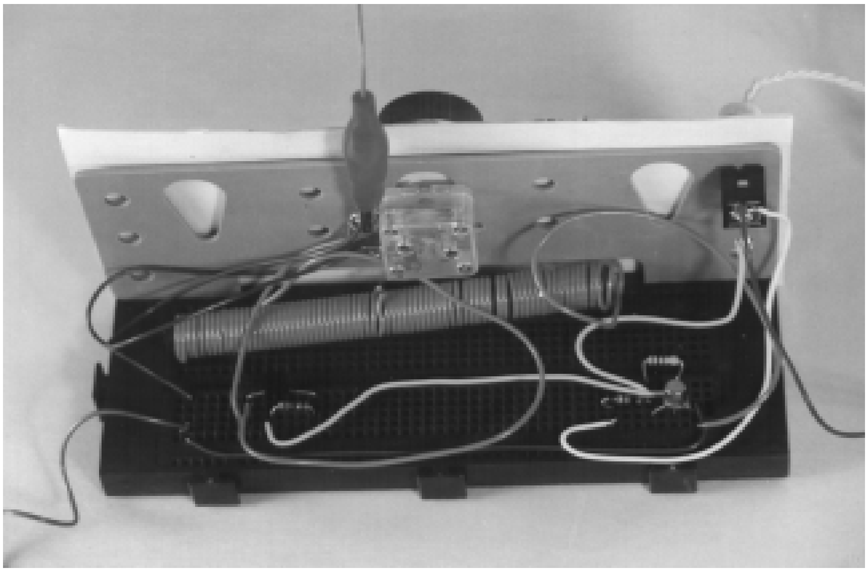

32 A capacitance bridge

Introduction

It is always valuable to have a means of measuring capacitors amongst your test gear. Universal LCR bridges (i.e. systems that can measure inductance, capacitance and resistance) can be found at most rallies, and you can work your way up to owning one of these. In the meantime, a piece of home-made equipment gives you experience as well as resulting in a useful measuring instrument.

The circuit described here is called a *capacitance bridge*, because it balances the effects of one resistor/capacitor pair against another; if one capacitor has an unknown value, then the other can be calculated. The basic bridge circuit is shown in **Figure 1**. To avoid having calculations to perform, this instrument will be calibrated by using capacitors of known values. The bridge is a useful way of performing measurements, because a knob is turned until there is a null in the signal from an earpiece or loudspeaker. The ear is very precise in being able to perceive nulls, which makes the bridge easy to use and reasonably accurate. At the null, the bridge is said to be *balanced*.

How does it work?

Figure 2 is the circuit diagram for this capacitance bridge. Transistors TR1 and TR2 form an oscillator. This is the audio oscillator shown in Figure 1, and produces an alternating voltage which is fed to the bridge. RV1 (in the collector lead of TR2) replaces both R1 and R2 in Figure 1 – that part of

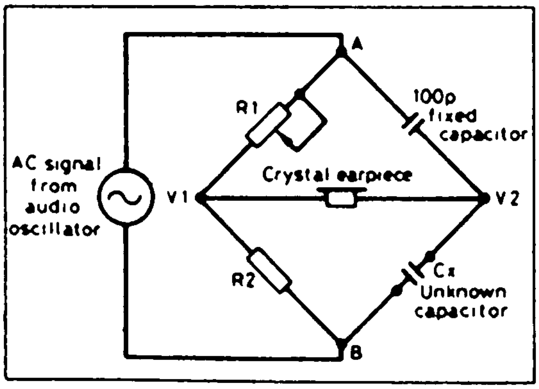

Figure 1 Simplified circuit of a capacitance bridge. R1 is adjusted for minimum sound

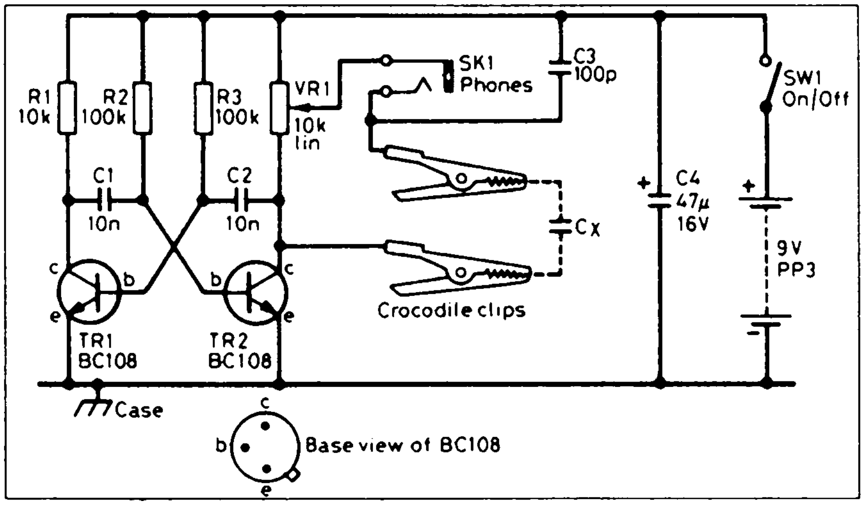
R1
10k
R2
100k
R3
100k
VR1
10k
lin
SK1
Phones
C3
100p
SW1
On/Off
C1
10n
C2
10n
C4
47μ
16V
Cx
9V
PP3
c
b
e
TR1
BC108
TR2
BC108
Crocodile clips
Case
Base view of BC108

Figure 2 Transistors TR1 and TR2 give an audio signal which is adjusted by variable resistor RV1

RV1 *above* the wiper represents R1, while that part *below* the wiper represents R2. The voltage on one side of the earpiece is determined by the ratio of these values, and is adjusted by rotating RV1. The voltage on the other side of the earpiece is determined by the ratio of C3 to Cx, where Cx is the unknown-valued capacitor. When these two voltages are the same, the bridge is balanced and there is no current through the earpiece.

Figure 3 shows the layout of the components on the matrix board of the prototype. It measures 10 holes by 14 holes, and is of the plain type, i.e. no copper strips. All earth connections are taken to a single solder tag. When

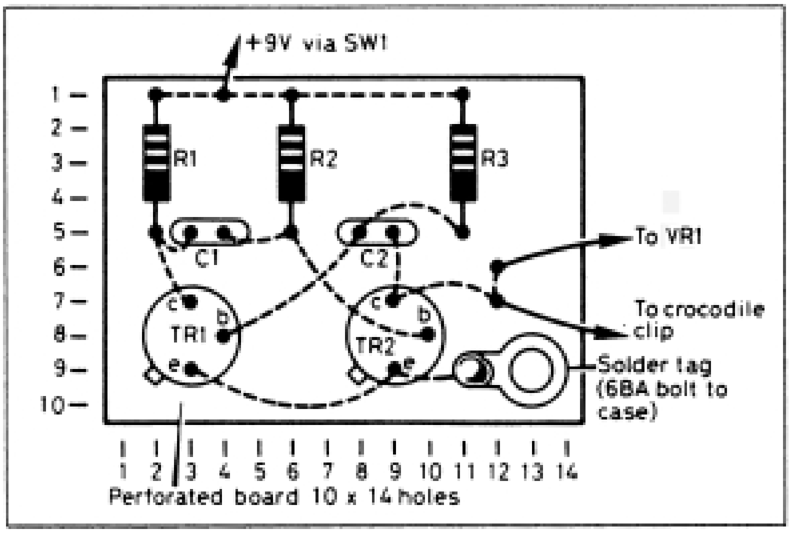
+9V via SW1
1
2
3
4
5
6
7
8
9
10
R1
R2
R3
C1
C2
To VR1
To crocodile clip
TR1
TR2
c
b
e
Solder tag (6BA bolt to case)
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Perforated board 10 x 14 holes

Figure 3 Components are soldered together on a small prototype board

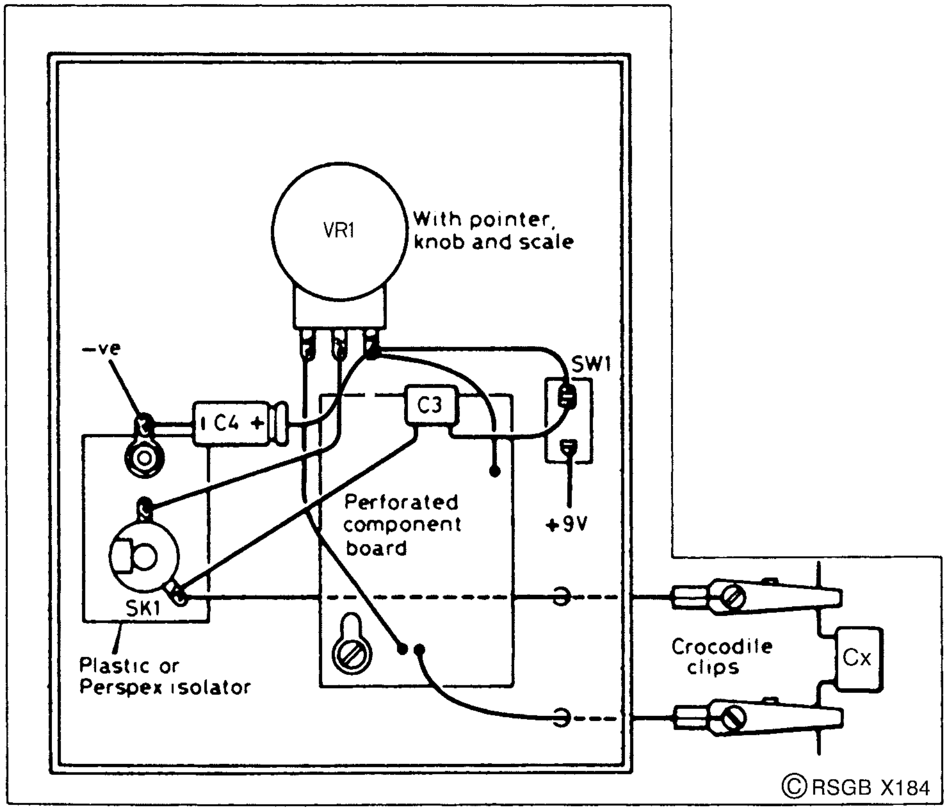
VR1
With pointer, knob and scale
–ve
C4
C3
SW1
+9V
Perforated component board
SK1
Plastic or Perspex isolator
Crocodile clips
Cx
©RSGB X184

Figure 4 Layout of the parts inside an aluminium box. The earpiece socket is insulated from the case

mounting the board inside a metal box, a long screw is used with extra nuts, to earth the board to the case while providing a stand-off, thus preventing any unwanted short-circuits between the board connections and the case. Be aware that a *crystal* earpiece must be used; low-impedance headphones of the Walkman type are not satisfactory. Solder two flying leads as shown in **Figure 4**, about 15 cm long, terminated in small crocodile clips for attaching to the unknown capacitor.

Calibration

After checking the circuit carefully, attach the battery and switch on; a buzzing noise should be heard in the earpiece. This is the first sign that everything should be OK. If there is no buzz, switch off and recheck the connections.

You will now need a range of close-tolerance (1%) silver-mica capacitors covering the range 10 to 1000 picofarads (pF). Arrange the capacitors in ascending order and connect them to your bridge in sequence. After having prepared a neat piece of card or paper mounted behind the knob on the front panel, mark the dial at the positions of the nulls for all the capacitors. You have now calibrated your capacitance bridge. If you are more likely to want to measure larger capacitors, replace C3 by a 1 nanofarad (nF) capacitor, and the bridge will measure up to 10 nF approximately.

Parts list

Resistors: all 0.25 watt, 5% tolerance	
R1	10 kilohms (kΩ)
R2, R3	100 kilohms (kΩ)
RV1	10 kilohms (kΩ) linear
Capacitors	
C1, C2	10 nanofarads (nF) ceramic
C3	100 picofarads (pF) silver mica or polystyrene
C4	47 microfarads (μF) 16 V electrolytic
Semiconductors	
TR1, TR2	BC108 npn
Additional items	
SW1	SPST on/off switch
	Battery connector, PP3 type
	Earpiece, crystal type
SK1	3.5 mm jack socket for earpiece
	Battery, 9 V PP3
	Matrix board, approx. 10 holes by 14 holes
	Aluminium case, approx. 10 × 8 × 5 cm

33 A simple short-wave receiver – Part 2

Introduction

In Part 1, the design of this receiver was discussed in some detail. Now we are going to put it all together and see how it works. The receiver is laid out on a printed-circuit board (PCB) or on a matrix board.

Construction

The layout of the components is shown in **Figure 1**. Identify each part separately, insert it into the holes in the board and solder carefully. Long leads may be cropped before or after soldering, depending on your skill and preference. All electrolytic capacitors, T1, T2 and IC1, must be connected correctly. The front-panel controls are connected to the PCB terminals shown in Figure 1.

The layout of the controls and the placing of the board inside the case are matters of personal preference. The size of the prototype front panel is shown in **Figure 2**. The prototype had a slow-motion drive fitted to VC2, the main tuning capacitor. This required the capacitor to be fitted on its own small panel. The bandspread control does not need any form of

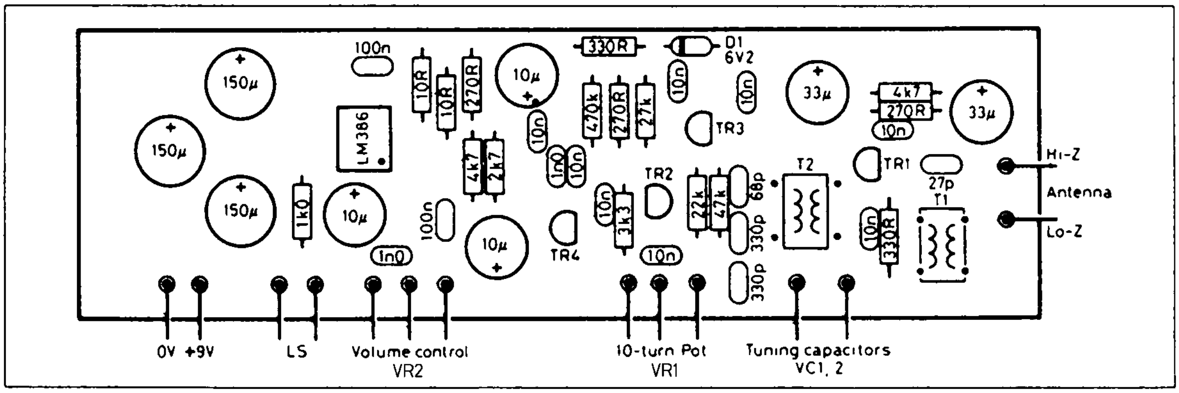
150µ
150µ
150µ
100n
LM386
1k0
10µ
1n0
100n
10R
10R
270R
4k7
2k7
10µ
10µ
10n
1n0
10n
330R
470k
270R
27k
D1
6V2
10n
10n
TR3
TR4
10n
3k3
TR2
10n
22k
47k
68p
330p
330p
T2
33µ
4k7
270R
10n
TR1
27p
T1
10n
330R
33µ
Hi-Z
Antenna
Lo-Z
0V +9V
LS
Volume control
VR2
10-turn Pot
VR1
Tuning capacitors
VC1, 2

Figure 1 Layout of the receiver circuit board

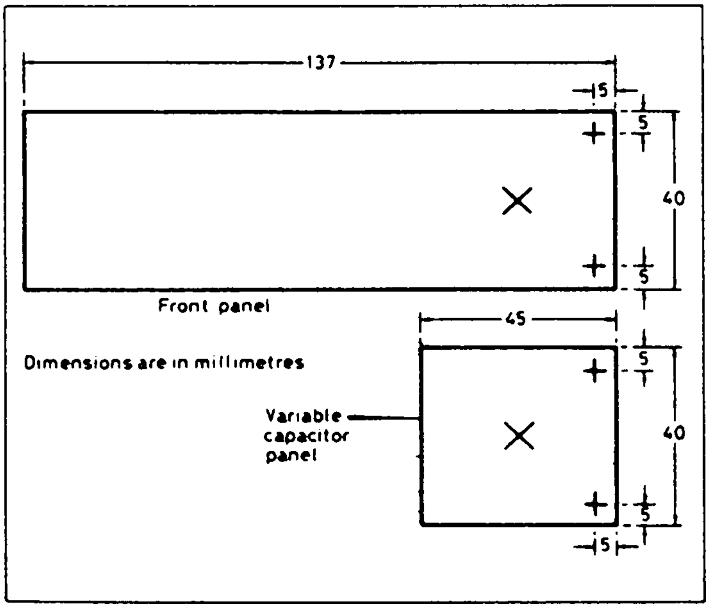

Figure 2 The case can be metal or made from PCB material

slow-motion drive. A tuning dial may be fitted behind the tuning knob on VC2 if required. The volume control, VR2, has its own on/off switch for the battery, which can be mounted behind the back panel, on which are mounted the aerial input sockets and the headphone/speaker socket. Check your soldering carefully, together with all the wiring between the board, the potentiometers and variable capacitors. When you are confident that everything is perfect, connect the battery and switch on.

The first tests

If you have a good aerial and are using an aerial tuning unit (ATU), use the low-impedance input. Excellent results are possible, though, with about 3 metres of wire connected to the high-impedance input. Set the volume control to give a gentle hiss in the headphones or speaker. Advance the reaction control to give a definite hiss. As you tune in an AM station, the hiss will change to a whistle; back off the reaction until the oscillation *just* stops. The receiver is now correctly set for AM reception.

On the amateur bands, the stations will be SSB or CW, and the reaction needs to be set *just above* the oscillation point, and will need slight adjustment from time to time for different qualities of signal. Juggling with the volume, reaction and tuning is part of the pleasure of using regenerative receivers!

In action

Practice is needed for best results. The regenerative receiver is renowned for its versatility in being able to be set up *exactly* for all types and strengths of signal. The basic receiver tunes from 6.5 MHz to 11 MHz approximately; this includes two amateur bands at 7.0 MHz and 10.1 MHz and two broadcast bands.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1, R10	330 ohms (Ω)
R2, R5, R11	270 ohms (Ω)
R3	22 kilohms (kΩ)
R4	47 kilohms (kΩ)
R6	3.3 kilohms (kΩ)
R7, R12	4.7 kilohms (kΩ)
R8	27 kilohms (kΩ)
R9	470 kilohms (kΩ)
R13	2.7 kilohms (kΩ)
R14, R15	10 ohms (Ω)
R16	1 kilohm (kΩ)
VR1	10 kilohm (kΩ) linear 10-turn potentiometer
VR2	10 kilohm (kΩ) log potentiometer

Capacitors

C1	27 picofarads (pF)
C2, C18, C22	100 nanofarads (nF)
C3, C4, C6, C10, C13, C14	10 nanofarads (nF)
C5, C11	33 microfarads (μF) 16 V electrolytic
C7	68 picofarads (pF)
C8, C9	330 picofarads (pF)
C15	1 nanofarad (nF)
C16, C17, C20	10 microfarads (μF) 16 V electrolytic
C21, C23	150 microfarads (μF) 16 V electrolytic
VC1	10 picofarads (pF) variable
VC2	200 picofarads (pF) variable

Semiconductors

TR1, TR3	2N3819
TR2, TR4	BC182
IC1	LM386
D1	6.2 V 0.5 W Zener

Inductors

T1	3 turns primary, 15 turns secondary, wound on 2-hole ferrite bead, with 28 SWG wire
T2	2 turns primary, 17 turns secondary, wound on a T68-2 toroidal former, with 28 SWG wire

Additional items
- Printed-circuit board
- Battery connector
- PP3 battery
- 8-pin DIL socket
- 8 ohm speaker or headphones (Walkman type)
- Case to suit

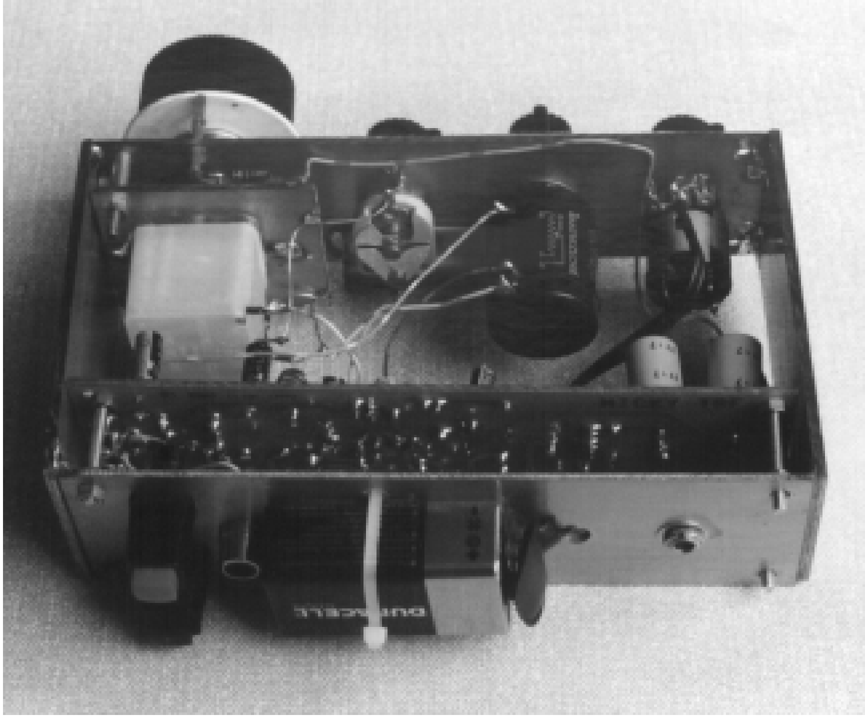

34 A basic continuity tester

Introduction

This little device can be built on a plug-in breadboard, and is ideal for testing fuses and cables, as well as doubling as a signal source for testing amplifiers, etc. It can even be used for testing npn transistors by replacing either of the transistors in the circuit, and seeing if the circuit still works!

Simple and quick to build

Using a plug-in breadboard, this circuit is so simple it could almost be built when you need it, and then dismantled again! If you want the circuit to make a different sound, the components to change are R2, R3, C1 and C2. Always make sure that R2 = R3 and C1 = C2, or the sound may be excessively ‘edgy’ and lacking in volume.

Basically, the circuit is an oscillator which drives a little loudspeaker directly. The fuse or cable you are testing is connected between the crocodile clips. If there is a current path between the two clips, the current also flows through the circuit, thus operating the oscillator and producing a sound from the loudspeaker.

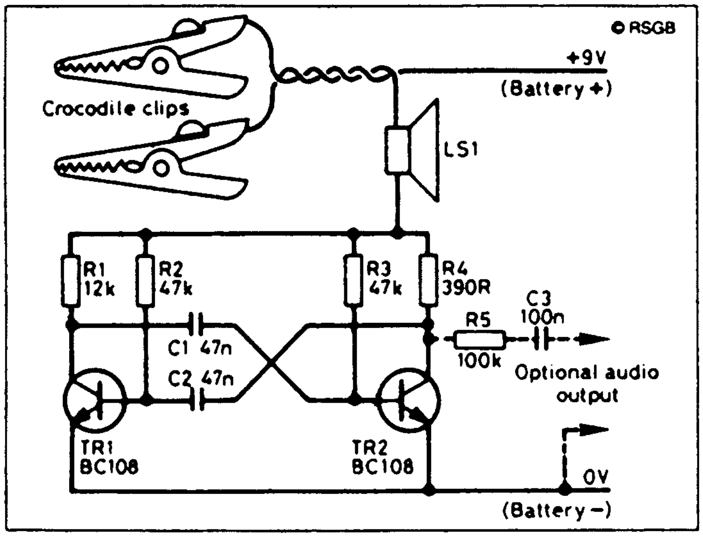
© RSGB
+9V
(Battery +)
Crocodile clips
LS1
R1 12k
R2 47k
R3 47k
R4 390R
C3 100n
R5 100k
C1 47n
C2 47n
Optional audio output
TR1 BC108
TR2 BC108
0V
(Battery –)

Figure 1 The circuit diagram of the continuity tester

If you want to use the circuit to produce a signal to test an amplifier, for instance, connect the croc clip which comes directly from the battery to the junction of R1, R2, R3 and R4. This supplies current to the circuit while, at the same time, bypassing the loudspeaker. Use the two components R5 and C3 between the oscillator and your amplifier. The loudspeaker is bypassed because you will want to listen to the output from your amplifier, *not* from the oscillator!

Remember, NEVER test any equipment which is still connected to the mains electricity supply. Avoid testing anything which is switched on and has its own power supply. You may damage both your tester ***and*** the circuit you are 'testing'!

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	12 kilohms (kΩ)
R2, R3	47 kilohms (kΩ)
R4	390 ohms (Ω)
R5	100 kilohms (kΩ) optional

Capacitors

C1, C2	47 nanofarads (nF) ceramic
C3	100 nanofarads (nF), 0.1 microfarads (μF) ceramic optional

Semiconductors

TR1, TR2	BC108 npn

Additional items

LS1	Loudspeaker (8 Ω)
	2 crocodile clips
	Prototype circuit board
	PP3 battery connector
	PP3 battery

35 A charger for NiCad batteries

Introduction

The cost of replacing dry batteries can be alleviated to a great extent by the use of rechargeable batteries such as those containing nickel and cadmium (called *NiCads*). They are more expensive than the batteries they replace, but they can be charged hundreds of times and thus prove cheaper in the long run.

NiCads produce only 1.2 V per cell, compared with the 1.5 V of ordinary cells, so before you rush out and buy lots of these, please make sure that the equipment on which you plan to use them will work on the reduced voltage! For example, if you are using four cells to give you a 6 V supply, NiCads will give you only 4.8 V, which is quite a reduction. Using six cells to replace a 9 V battery will give you only 7.2 V. Not all equipment is happy with these reductions!

However, we all use them when we can, and they save substantial amounts of money. Here is the circuit of a charger to keep them in prime condition.

Charging NiCads – the ampère-hour

NiCads require charging at constant current, which means that connecting one across a normal power supply (constant *voltage*) is useless and can destroy it. They need pampering to the extent of needing a long charge (around 16 hours) at a rate dependent upon the *capacity* of the battery. By the capacity of a battery, we mean how much energy it can store. You will probably know that energy is measured in joules. For the purposes of storing energy in batteries, the joule is *not* the ideal unit, so we use one that is! This unit is the ampère-hour (Ah), and must be interpreted with some realism. For example, if the battery is rated at 2 Ah, it will deliver a current of 0.5 amp for 4 hours, or 0.25 amp for 8 hours. Provided the current is not too high, the product of the current (in amps) and the time for which it will flow (in hours) before the battery is flat will always be around 2 Ah. A workable ‘rule of thumb’ for calculating the charging current is that its value should be around one-tenth of the numerical value of the capacity; so, for our 2 Ah battery, a charging current of around 200 mA ($2 \div 10 = 0.2$ A or 200 mA) would be used.

Constant voltage to constant current

Many integrated circuit (IC) chips are available for use as voltage regulators, i.e. they supply a constant voltage. Most of these can be persuaded to become constant current supplies with one external resistor!

The voltage regulator IC usually has only three connections – 'input', 'output' and 'common'. It is designed (in the case of the LM7805) to produce a constant 5 V output between the 'output' and the 'common' connections, at currents of up to 1 A. If a resistor is connected between these, the IC will maintain 5 V across it. If you look at **Figure 1**, you will see the circuit performing this conversion.

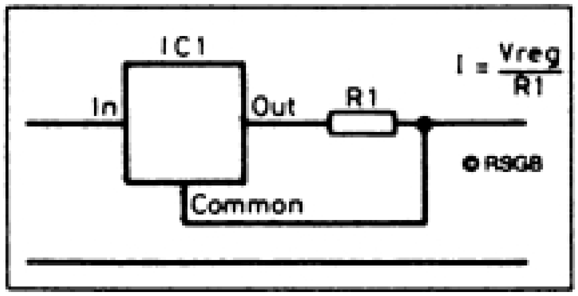

Figure 1 Voltage regulator arranged to produce a constant current

For the previous example, we derived a charging current of 200 mA, so we now need to calculate the value of resistor that will produce this current. Using the equation which is derived from Ohm's law:

$$I = \frac{V}{R}, \text{ from which } R = \frac{V}{I},$$

where R = R1, the resistance in ohms that we are calculating,
V is the voltage across R1 (5 V), and
I is the current flowing (200 mA).

So,

$$\text{R1} = \frac{5}{0.2} = 25\,\Omega.$$

25 ohms is not a 'common' or 'preferred' resistor value, so we must choose the next *largest* value, which is 27 Ω. This reduces the current, but only slightly – it is now 185 mA. When calculating resistor values in power supply circuits, we must *always* check the power that they dissipate and make sure we specify and fit a suitable resistor.

Power (in watts) is the product of the voltage across and the current through a device, so in this case it is given by:

$$\text{Power} = V \times I = 5 \times 0.185 = 0.925\,\text{W}.$$

Rather than use a 1 watt resistor operating very near its limit, it is safer to use a 2 watt resistor operating well within its limits.

Looking again at Figure 1, we now have a constant-current source producing 185 mA, when R1 is a 27 Ω, 2 W resistor. For use with NiCads requiring charging currents other than 200 mA, you will need to repeat the two equations above, using a new value for *I*.

The full circuit and its assembly

This is shown in **Figure 2**, and can be broken down into two parts. The first is the AC to DC conversion produced by the mains transformer, T1, the bridge rectifier, BR1, and the smoothing capacitor, C1. The second is the constant-current section already discussed.

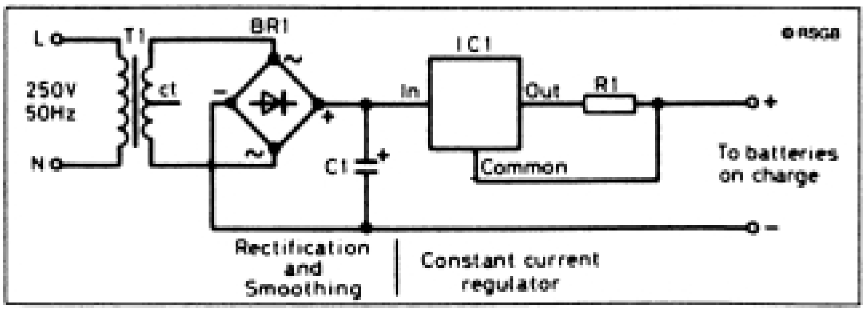

Figure 2 The complete circuit including mains components

The prototype was assembled on matrix board measuring 18 holes by 12 strips, although, as **Figure 3** shows, this is much larger than is strictly necessary. No strip cutting is needed, but make sure that IC1 and C1 are inserted correctly.

Warning! Before you attempt to wire up the transformer and the bridge rectifier, be aware that you will eventually be connecting the circuit to the mains supply, so there are three possibilities for you: (1) get a qualified friend to supervise your completion and testing of the circuit; (2) get your qualified friend to complete and test the circuit for you; (3) replace the transformer and bridge rectifier with a mains adapter.

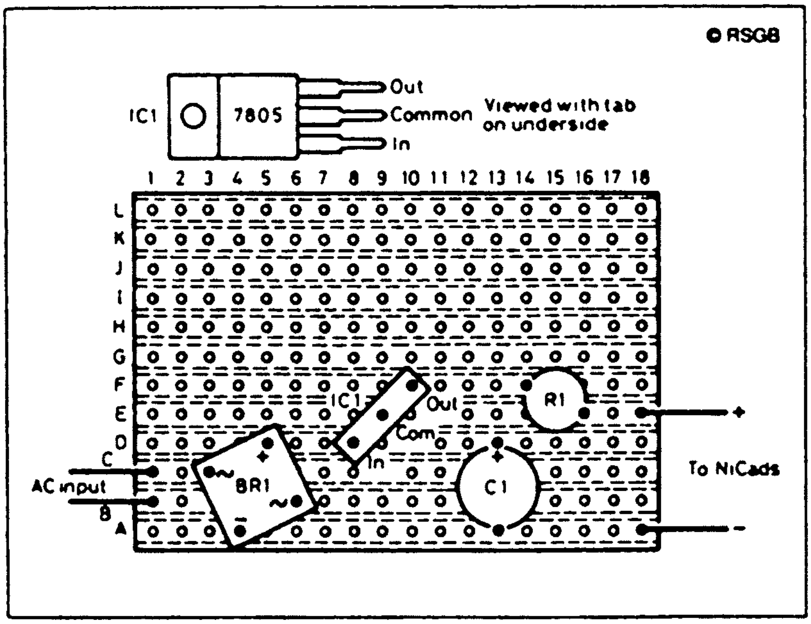

Figure 3 The charger can be built on Veroboard

If you decide to use the mains adapter, its output is connected directly across C1, because T1 and BR1 are now no longer needed. Make sure the polarity (positive and negative) is correct and that the adapter output is set to 12 V.

A quick test

If you have built the mains version, make sure all connections are correct, and that there are no soldered joints which will touch other parts of the circuit. The box must be securely closed before tests begin. The RSGB cannot be held responsible for damage to equipment or batteries! The version using the mains adapter need not be closed during tests.

Switch on. With nothing connected to the output, the unit should run cold. If this is not the case, switch off and recheck your circuit. If all is well, switch on again and connect a DC multimeter (on the current range) across the output. It should indicate only a slight difference from the calculated value of 185 mA. You can now charge your NiCads!

Other charging currents can be set by having different values for R1, perhaps selectable by a rotary switch. Remember to make sure that the values of both resistance *and* power dissipation are correct, and don't exceed the 250 mA rating of the transformer (or the 1 amp rating of the IC if you are using a bigger transformer).

Parts list

		Maplin code
Resistor		
R1	As required – see text	
Capacitor		
C1	1000 microfarads (μF) 35 V electrolytic	FF18U
Semiconductors		
IC1	LM7805 5 V, 1 A regulator	CR14Q
BR1	W005 50 V, 1 A full-wave rectifier	QL37S
Transformer		
T1	9–0–9 V, 250 mA sub-min. transformer	YN15R
Additional items		
Case		FG41U
Veroboard, 18 holes by 12 strips		
Plug to suit NiCads		
Double-sided sticky tape as required		
Insulated wire for battery connections		

36 An 80 metre crystal-controlled CW transmitter

Introduction

A simple transmitter is ideally suited to anyone venturing into our marvellous hobby for the first time. If you are put off by the complexities and prices of the 'black boxes' then this is the transmitter you've been looking for!

The circuit

The complete circuit is shown in **Figure 1**. It is a single-transistor crystal oscillator which is *keyed* (switched on and off) by the Morse key in the +12 V supply rail. The circuit first appeared in *QST* (the American equivalent of *RadCom*) in 1982, and has since appeared in a modified form in the *ARRL Handbook*. The circuit can produce about 2 watts on 80 m, and can be constructed on a piece of plain matrix board; the prototype board measured 7 cm by 3 cm, and its layout is shown in **Figure 2**.

Note that a bare copper wire runs along the bottom edge of the board to act as an earth wire for the relevant components. The only 'difficult' part of the construction is the winding and wiring of T1. The main winding is 38 turns of 26 SWG enamelled copper wire, and there are two link windings of four turns each. Make sure that all windings are wound the correct way round the toroid – Figure 1 shows this and should be studied carefully. If the windings do not have the correct *sense* (i.e. a clockwise coil has been wound anticlockwise, or vice versa), or have been connected incorrectly to the rest of the circuit, the oscillator will not work!

When putting components on the board, wire in the crystal socket *without the crystal in it*. Crystals do not like to be subjected to the horrors of a soldering iron, so keep your crystal to one side during the construction process!

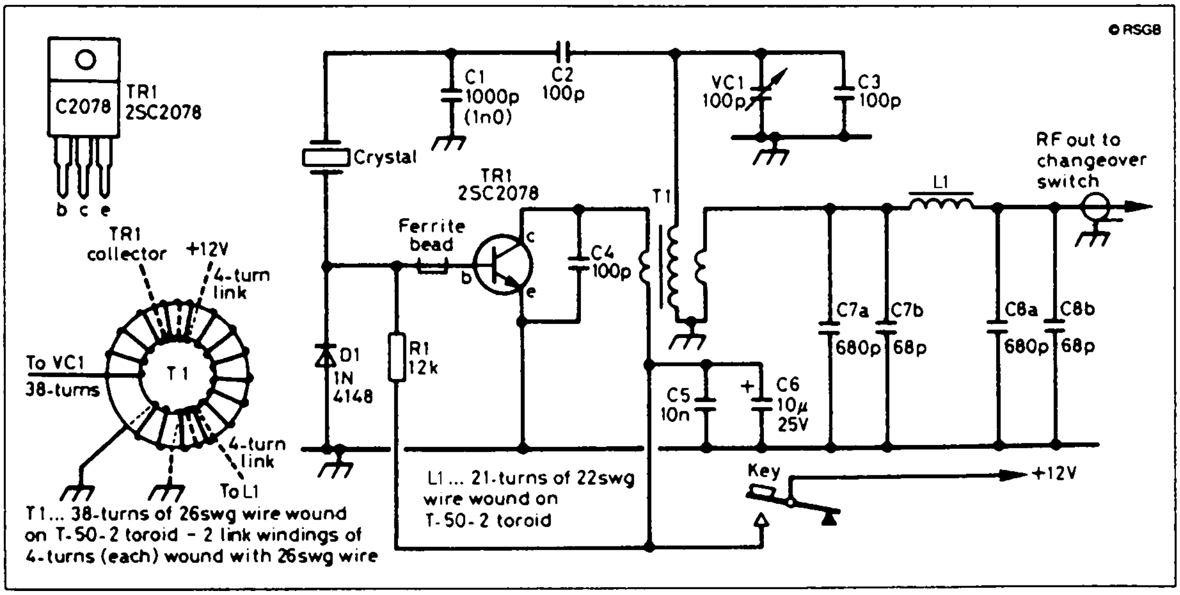
© RSGB
C2078
TR1
2SC2078
b c e
TR1
collector
+12V
4-turn
link
To VC1
38-turns
T1
4-turn
link
To L1
T1... 38-turns of 26swg wire wound
on T-50-2 toroid – 2 link windings of
4-turns (each) wound with 26swg wire
C1
1000p
(1n0)
C2
100p
Crystal
TR1
2SC2078
Ferrite
bead
b
c
e
C4
100p
D1
1N
4148
R1
12k
L1 ... 21-turns of 22swg
wire wound on
T-50-2 toroid
VC1
100p
C3
100p
T1
C5
10n
+
C6
10µ
25V
C7a
680p
C7b
68p
L1
C8a
680p
C8b
68p
RF out to
changeover
switch
Key
+12V

Figure 1 The simplest form of transmitter is a keyed crystal oscillator. Note that L1, C7 and C8 make up a *low-pass filter* which reduces unwanted *harmonics* (outputs at the transmitter frequency multiplied by 2, 3, 4, etc.)

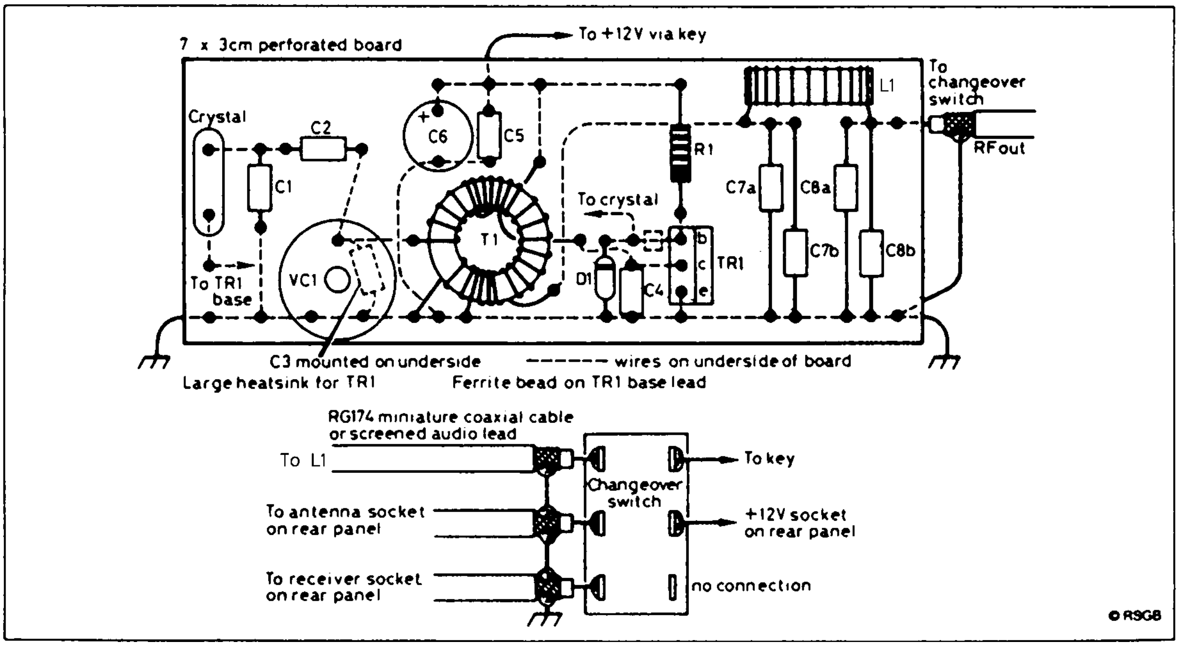
7 x 3cm perforated board
To +12V via key
Crystal
C2
C1
C6
C5
R1
L1
To changeover switch
RFout
C7a
C8a
C7b
C8b
To crystal
T1
TR1
b
c
e
D1
C4
VC1
To TR1 base
C3 mounted on underside
wires on underside of board
Large heatsink for TR1
Ferrite bead on TR1 base lead
RG174 miniature coaxial cable or screened audio lead
To L1
To antenna socket on rear panel
To receiver socket on rear panel
Changeover switch
To key
+12V socket on rear panel
no connection
© RSGB

Figure 2 Component layout is straightforward on a 'matrix board' (it has holes but no copper strips). The dotted lines are the connecting wires. The lower part shows the connections for the transmit/receive switch

The output filter, which comprises C7, C8 and L1, is a *low-pass* filter, which helps reduce any *harmonics* present in your signal. Harmonics are integral multiples of your transmitter frequency, so if you are transmitting on a frequency, *f*, harmonics will be present at frequencies 2*f*, 3*f*, 4*f*, . . . and so on. L2 is another inductance using 22 SWG enamelled copper on a ferrite toroid. The changeover switch is external to the transmitter board, and is used to switch your aerial between the transmitter and the receiver; its wiring is shown in Figure 2.

Use a dummy load

A dummy load enables you to test your circuit without actually transmitting a signal. If you haven't such a thing already, it is easy to construct one to use with this transmitter. Don't use it for transmitters of more than 2 watts output, though. Use two 100 ohm, 1 watt resistors, connected in parallel across the end of a short piece of coaxial cable, terminated in a BNC, PL259 or N-type free plug, as shown in **Figure 3**. Plug this into the aerial socket on your transmitter, plug in your crystal and connect the transmitter to a 12 V supply. Have another receiver switched on and tuned to the crystal frequency. Although the radiation from your dummy load is minimal, it will

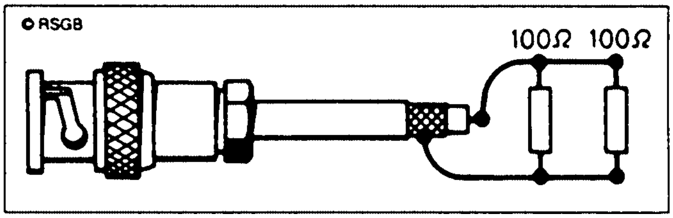

Figure 3 A simple 2 W dummy load can be made from two 100 Ω (ohm) resistors in parallel. The plug should match the socket on your transmitter

be enough to be picked up by a receiver in the same room. Send dashes with the Morse key, and adjust VC1 until the received note is *clean*. It should not sound rough, or have a *chirp* (change its frequency during a dash or dot). Avoid tuning for maximum power; this is seldom the correct setting!

You will need to put your completed transmitter in a metal box, using sockets for the power supply, aerial, receiver and Morse key. The sockets can be chosen to match your existing equipment.

Figures 4–7 are taken from the RSGB book *Practical Antennas for Novices*, and may give you some ideas on the type of aerial to be used with your transmitter.

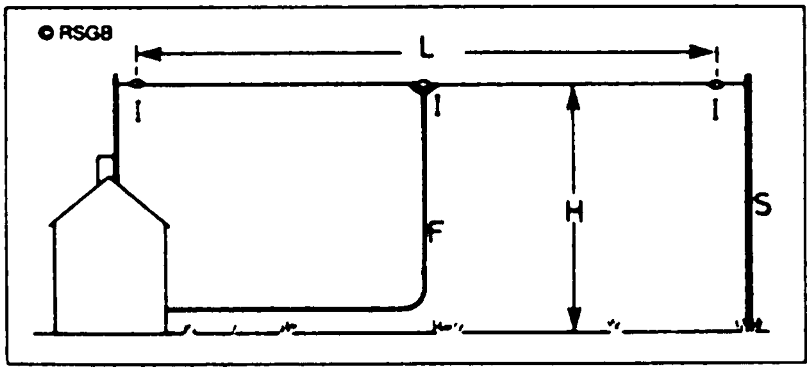

Figure 4 A simple dipole can be very effective. For the 3.5 MHz band, length L is 40 metres and height H should be as large as possible. The far support S can be a tree, pole or building. Insulators I may be home made from strong plastic and the feeder F should be 50 Ω (ohm) coax cable

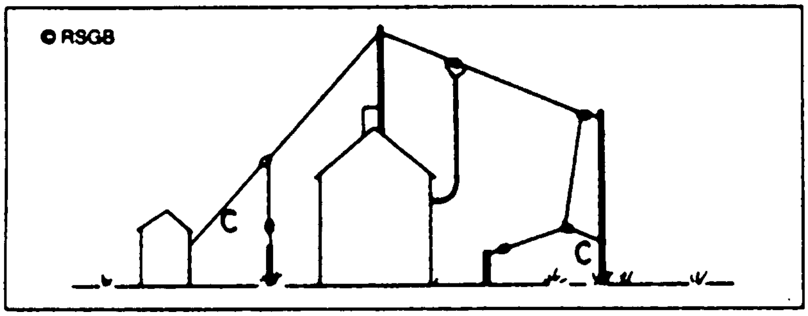

Figure 5 Your signal is radiated mostly from the centre of the dipole so the ends can droop or even be bent but the length may need shortening by a few centimetres because the ground and the bends will detune the dipole. Cords C are best made from strong plastic rope from a sailing or camping shop

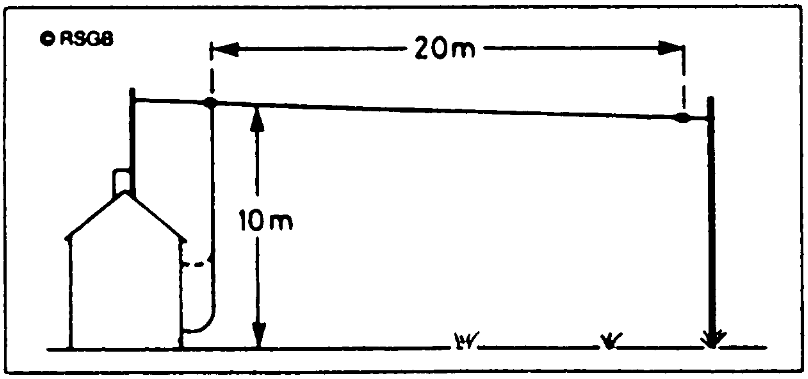
© RSGB
20m
10m

Figure 6 An 'inverted-L' takes up less space than a dipole and doesn't need coax cable. Like the dipole, the end can droop or be bent to save space as in this case most of the radiation comes from the area around the top of the vertical part

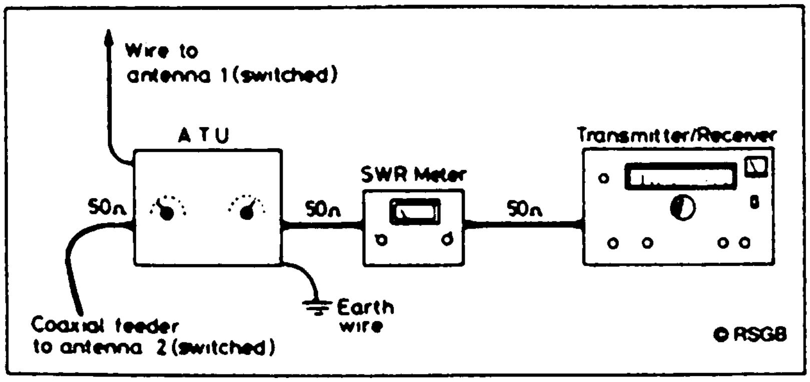
Wire to
antenna 1 (switched)
ATU
SWR Meter
Transmitter/Receiver
50Ω
50Ω
50Ω
Earth
wire
Coaxial feeder
to antenna 2 (switched)
© RSGB

Figure 7 Almost any length of wire more than 10 m or so long will work (though it will work better the longer and higher it is) but an Aerial System Tuning Unit (ASTU or ATU) will be needed

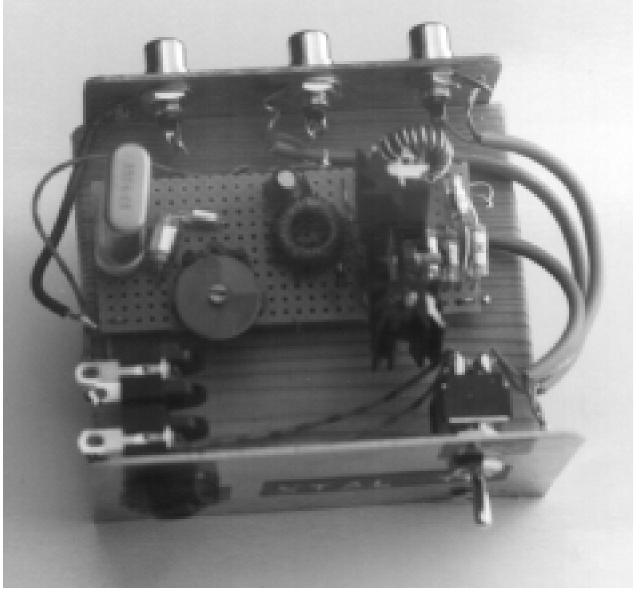

Parts list

Resistor

R1	12 kilohms (kΩ), 0.25 watt, 5% tolerance

Capacitors

C1	1000 picofarads (pF) polystyrene
C2	100 picofarads (pF) polystyrene
C7a, C8a	680 picofarads (pF) polystyrene
C7b, C8b	68 picofarads (pF) polystyrene
C3, C4	100 picofarads (pF) ceramic
C5	10 nanofarads (nF) polyester
C6	10 microfarads (μF) electrolytic 25 V
VC1	100 picofarads (pF) trimmer

Semiconductors

D1	1N4148
TR1	2SC2078 (see sources list)

Inductors

T1	38 turns 26 SWG enamelled copper on T–50–2 toroid, with two link windings of four turns
L1	21 turns 22 SWG enamelled copper on T–50–2 toroid

Additional items

- Ferrite bead
- Crystal (e.g. 3.579 MHz) and holder
- Metal box
- Socket for Morse key.
  This must be totally isolated from the metal of the box, as *both* connections can be at +12 V.
- Sockets for 12 V supply, aerial and receiver
- Switch – DPDT
- Heat sink for TR1
- RG174 miniature coaxial cable for signal leads (see Figure 2)

Component sources

Special components

2SC2078	Cricklewood Electronics Ltd, 40 Cricklewood Broadway, London, NW2 3ET.

37 A solar-powered MW radio

Introduction

What could be more ecologically friendly than a radio powered by the sun's energy? This design is quite standard, and if you have built any of the other medium-wave radios in this series, then this one should present few problems.

The solar panel

The solar panel is to the solar cell as the battery is to the cell; in other words a solar panel is several solar cells connected in series. The solar panel quoted for this radio will generate about 9 V at a current of around 30 mA on a sunny day. The circuit will operate on a supply of around 2 V, so bright sunshine is *not* necessary for satisfactory operation. The volume will be less, of course.

The circuit

The radio uses the ZN415E integrated circuit (IC), connected as shown in **Figure 1**, the complete circuit diagram. The signal is tuned in by the combination of L1 and VC1. L1 is made by winding about 35 turns of 24 SWG enamelled copper wire on a ferrite rod. A standard ferrite rod of 10 cm length and 1 cm diameter is used.

Signals selected by the tuned circuit are passed to IC1, which amplifies the signals and removes the audio component, which is then amplified further by IC2 for driving a small loudspeaker. The removal of the audio component is the process we call *detection*. In addition to this, IC1 provides *automatic gain control* (AGC), which helps to keep the audio signal constant, even when the incoming RF signal may vary due to fading.

The prototype board

Veroboard (also known as matrix board or stripboard) is ideal for the construction of the radio. The layout is shown in **Figure 2**. The board size is 11 strips by 30 holes (**please note that there is no row 'I', so take care with your counting!**). Using a 3 mm ($\frac{1}{8}$ inch) twist drill rotated between

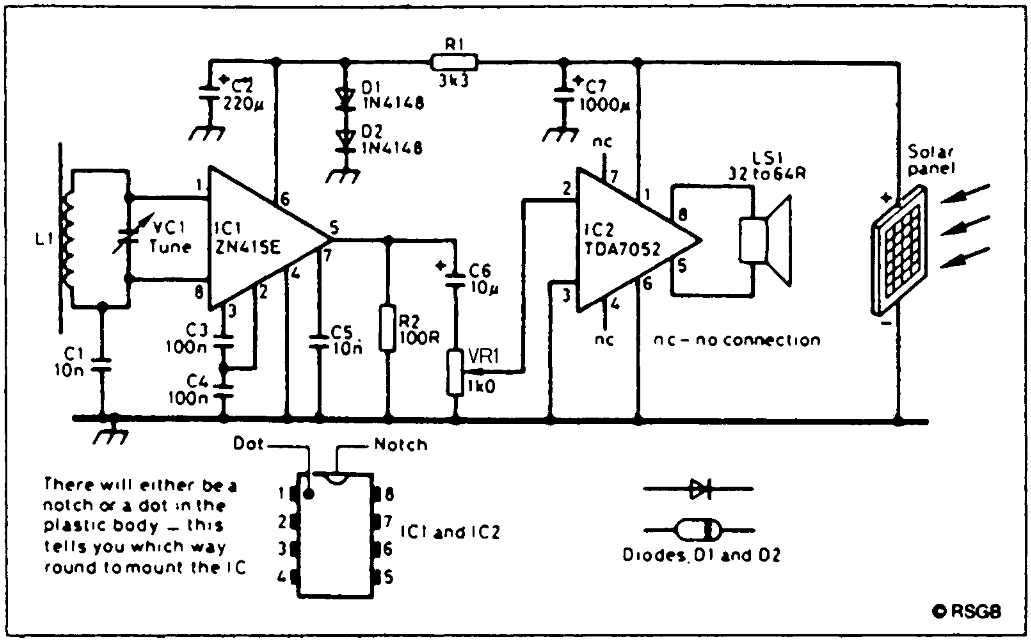
R1
3k3
C2
220µ
D1
1N4148
D2
1N4148
C7
1000µ
nc
LS1
32 to 64R
Solar panel
L1
VC1
Tune
IC1
ZN415E
IC2
TDA7052
C1
10n
C3
100n
C4
100n
C5
10n
R2
100R
C6
10µ
VR1
1k0
nc – no connection
Dot
Notch
There will either be a notch or a dot in the plastic body – this tells you which way round to mount the IC
IC1 and IC2
Diodes D1 and D2
© RSGB

Figure 1 The radio uses just two integrated circuits (chips) and operates at any voltage from 2 to 9 V

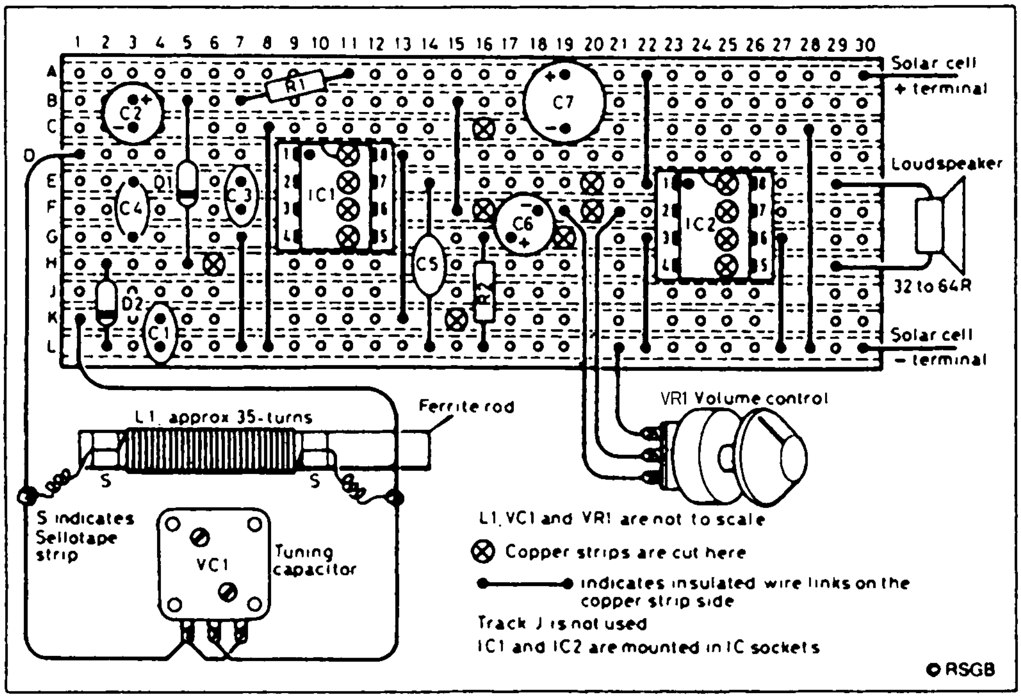
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
A
B
C
D
E
F
G
H
J
K
L
R1
C2
C7
D1
C4
C3
IC1
C6
IC2
C5
R2
D2
C1
Solar cell + terminal
Loudspeaker
32 to 64R
Solar cell – terminal
L1 approx 35-turns
Ferrite rod
S
VR1 Volume control
S indicates Sellotape strip
VC1
Tuning capacitor
L1, VC1 and VR1 are not to scale
⊗ Copper strips are cut here
●——● indicates insulated wire links on the copper strip side
Track J is not used
IC1 and IC2 are mounted in IC sockets
© RSGB

Figure 2 Follow the layout carefully, making sure that all connections are neatly soldered

your thumb and forefinger, break the strips at the points marked with a cross inside a circle. Hold the board up to the light to ensure that the tracks *have* been broken and that there is no copper swarf shorting tracks together.

Firstly, solder in the 8-pin DIL sockets for the ICs, making sure that the notches in the sockets are facing upwards, as shown on the diagram. Then, solder in the wire links, resistors, capacitors and diodes, making sure that the electrolytic capacitors (C2, C6 and C7) and the diodes (D1 and D2) are connected the correct way round. Use different colours of wire for the connections to the volume control, VR1, to avoid incorrect connections. Note the wiring of the tuning capacitor (VC1) shown in Figure 2; a two-section type is used, and both sections are wired in parallel to give twice the capacitance of a single section.

There is no on/off switch – just turn the volume down when you are finished using the set! The solar panel can be mounted parallel to the top of the case, or angled to receive the maximum energy from the sun, as shown in the photograph. You could have a battery available as a standby source to use the radio after dark; any battery of between 6 V and 9 V will do. Wire it with a simple changeover switch, so you can switch between solar and battery power. Ask a friend for help with this if you are not sure how to do it.

You may need to adjust the number of turns on L1 to get the best results, but it should be possible to receive at least five stations at good volume with your sun-powered radio!

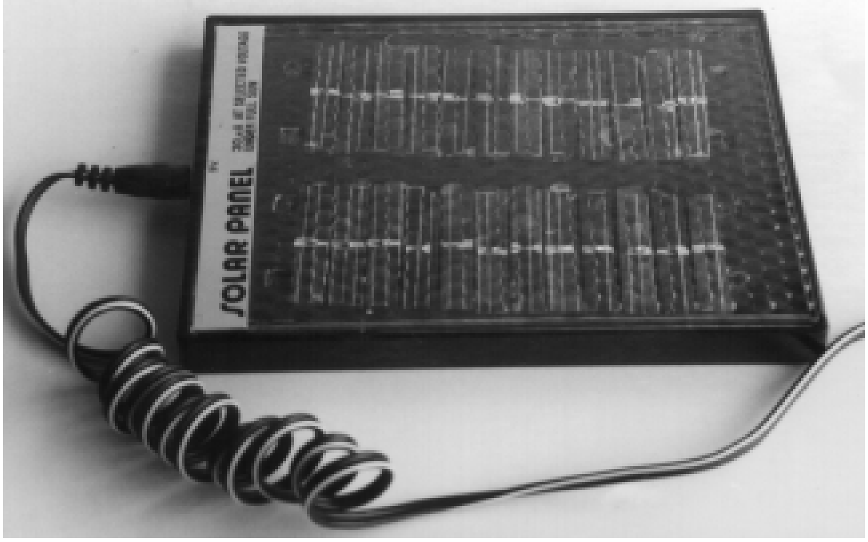

Parts list

		Maplin code
Resistors: 0.25 watts, 5% tolerance		
R1	3.3 kilohms (kΩ)	M3K3
R2	100 ohms (Ω)	M100R
VR1	1 kilohm (kΩ) log	FW21X
Capacitors		
C1, C5	10 nanofarads (nF) ceramic	BX00A
C2	220 microfarads (μF) electrolytic (10 V)	FB60Q
C3, C4	100 nanofarads ceramic	YR75S
C6	10 microfarads (μF) electrolytic (10 V)	FB22Y
C7	1000 microfarads (μF) electrolytic (10 V)	FB81C
VC1	140–300 picofarads (pF)	FT78K
Semiconductors		
IC1	ZN415E (or ZN416E)	UR70M
IC2	TDA7052	UK79L
D1, D2	1N4148	QL80B
Solar panel	9 V at 50 mA	RK23A
Additional items		
LS1	32–64 ohm miniature loudspeaker	YT28F
	Ferrite rod	YG20W
	24 SWG enamelled copper wire	BL28F
	Plastic box, approx. 220 × 140 × 70 mm	YN39N
	Veroboard, cut to size	JP47B
	8-pin DIL sockets, 2 required	BL17T
	Knobs, 2 required	FD67X
	Material for speaker grille	
	Connecting wire	

38 A receiver for the 7 MHz amateur band

Introduction

Listening on the 40 metre band (from 7.0 to 7.1 MHz) can be very rewarding – it is a popular haunt for HF Special Event stations, and at night there are signals to be heard from all over Europe. This receiver is designed purely for the 40 m band, and is ideal for those who have built the simpler receivers and are looking for something a little more challenging. The more experienced constructor may prefer to build this on prototype board.

The circuit and its construction

Figure 1 shows the circuit diagram. The receiver will work well with headphones or loudspeaker. Walkman-type headphones and speakers are ideal for use here.

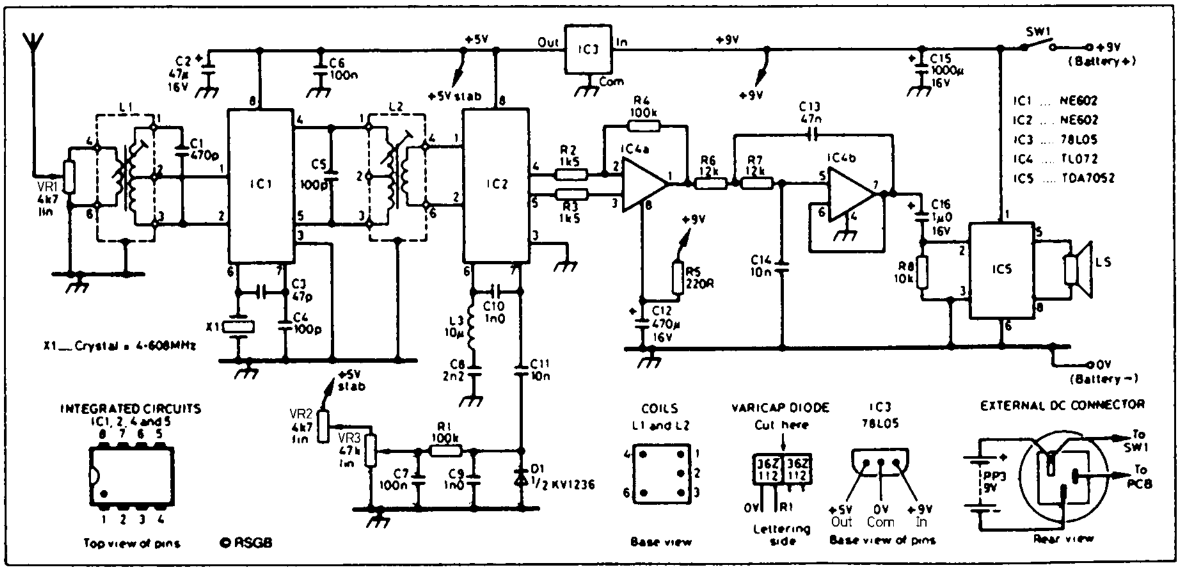
C2 47µ 16V
C6 100n
+5V
Out
IC3
In
Com
+5V stab
+9V
C15 1000µ 16V
SW1
+9V (Battery+)
L1
L2
C1 470p
VR1 4k7 lin
IC1
C5 100p
IC2
R2 1k5
R3 1k5
R4 100k
IC4a
R6 12k
R7 12k
C13 47n
IC4b
C16 1µ0 16V
IC1 ... NE602
IC2 ... NE602
IC3 .... 78L05
IC4 .... TL072
IC5 .... TDA7052
R5 220R
C14 10n
R8 10k
IC5
LS
C12 470µ 16V
0V (Battery −)
C3 47p
C4 100p
X1
X1 __ Crystal = 4·608MHz
C10 1n0
L3 10µ
C8 2n2
C11 10n
+5V stab
VR2 4k7 lin
VR3 47k lin
R1 100k
C7 100n
C9 1n0
D1 1/2 KV1236
INTEGRATED CIRCUITS
IC1, 2, 4 and 5
8 7 6 5
1 2 3 4
Top view of pins
© RSGB
COILS
L1 and L2
Base view
VARICAP DIODE
Cut here
36Z 112
36Z 112
0V
R1
Lettering side
IC3
78L05
+5V Out
0V Com
+9V In
Base view of pins
EXTERNAL DC CONNECTOR
To SW1
To PCB
PP3 9V
Rear view

Figure 1 The receiver gives good performance on the 7 MHz amateur band as well as being simple to construct and align

Signals arriving at the aerial are coupled into IC1 via gain control VR1, which also functions as the on/off switch. Tuning is provided by varying the voltage on the *varactor diode* (or varicap), D1. VR3 is the main tuning control, and VR2 is the *bandspread* (fine tuning) control. The varactor diode is supplied as a dual device, which must be cut down the middle *carefully* with a sharp knife; with the lettering upwards, the ground lead (0 V) is on the left-hand side, as Figure 1 illustrates.

Solder in the IC sockets first, followed by the coils. After this come the links, resistors, capacitors and varactor diode. Ensure that IC3, the voltage regulator, is wired correctly, and check the polarity of the electrolytics. The crystal, X1, is very fragile, so take extra care with it. The wiring of the three controls is shown in **Figure 2**.

Before putting the ICs in their sockets, connect up the battery and check the following voltages with the negative voltmeter lead connected to the negative terminal of the battery:

Pin 8	IC1	5 V
Pin 8	IC2	5 V
Pin 8	IC4	9 V
Pin 1	IC5	9 V

When all these have been found to be correct, switch off and put the ICs carefully into their sockets. Use wire of different-coloured insulation to wire up the front-panel controls.

The case can be a small plastic box of size 22 cm by 15 cm by 8 cm, with three 10.5 mm holes drilled in the front and two 8 mm holes in the side for the aerial and earth connections. On one side are a 6 mm hole for the speaker socket and an 11 mm hole for the optional external power supply.

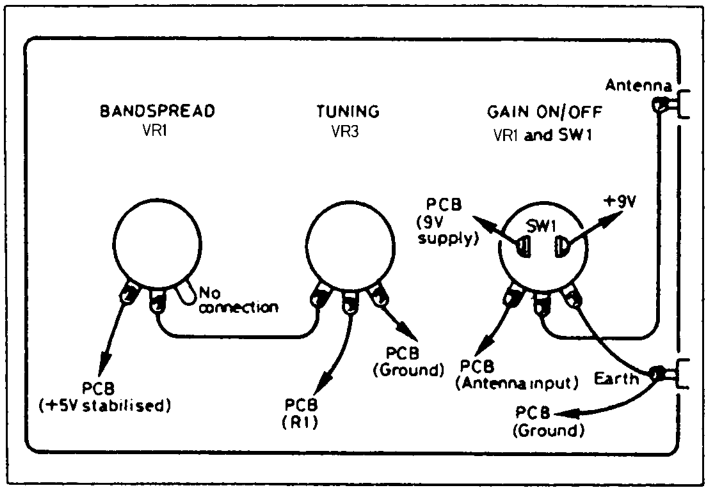

Figure 2 Rear view of the variable resistors. Check the connections carefully to make sure the wires are fitted correctly

Testing and tuning

The aerial for the receiver should be between 30 and 70 feet of wire, mounted as high as you can make it, away from trees and buildings if possible. Connect the battery and switch on. Adjust L1 and L2 for the best results. Tune slowly with VR3; you should find CW stations at the lower end of the band (anticlockwise) and SSB stations at the upper end (clockwise). You may find that it is easiest to make these adjustments *before* mounting the board in the case with double-sided sticky tape or pads. If you are planning to use an external DC supply, make sure it is a safety approved stabilised 9 V type, and **disconnect the battery before you use such a supply!**

If you suspect that the tuning doesn't quite cover the lower CW end of the band, try increasing C9 to 1200 pF. If it is the upper SSB end which is missing, decrease C9 to 820 pF.

It is always advisable to use an aerial tuning unit (ATU) between your aerial and the receiver. A suitable design of ATU is included as a project in this book.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1, R4	100 kilohms (kΩ)
R2, R3	1.5 kilohms (kΩ)
R5	220 ohms (Ω)
R6, R7	12 kilohms (kΩ)
R8	10 kilohms (kΩ)
VR1	4.7 kilohms (kΩ) linear, with SPST switch
VR2	4.7 kilohms (kΩ) linear
VR3	47 kilohms (kΩ) linear

Capacitors: all rated 16 V or more

C1	470 picofarads (pF) polystyrene 5%
C2	47 microfarads (μF) electrolytic
C3	47 picofarads (pF) polystyrene 5%
C4, C5	100 picofarads (pF) polystyrene 5%
C6, C7	100 nanofarads (nF) ceramic
C8	2.2 nanofarads (nF) polystyrene 5%
C9, C10	1 nanofarad (nF) polystyrene 5%
C11, C14	10 nanofarads (nF) ceramic
C12	470 microfarads (μF) electrolytic
C13	47 nanofarads (nF) ceramic
C15	1000 microfarads (μF) electrolytic
C16	1 microfarad (μF) electrolytic

Inductors

L1	Toko KANK3335R
L2	Toko KANK3333R
L3	10 μH 5%, e.g. Toko 283AS–100

Semiconductors

IC1, IC2	NE602 or NE602A
IC3	78L05 5 V, 100 mA
IC4	TL072
IC5	TDA7052

Additional items

D1	Toko KV1236 cut into two sections (one half used)
X1	4.608 MHz (available from Cirkit)
	3 × silver knobs, one with pointer
	Plastic case approx. 22 × 15 × 8 cm
	Speaker 8–32 Ω, or headphones
	4 × 8-pin DIL sockets for IC1, IC2, IC4, IC5
	2 × 4 mm sockets (red and black) for aerial and earth
	3.5 mm chassis-mounting jack socket for speaker
	DC power socket for external supply (if required)
	Prototype board

Kits

A complete kit is available from JAB Electronic Components.

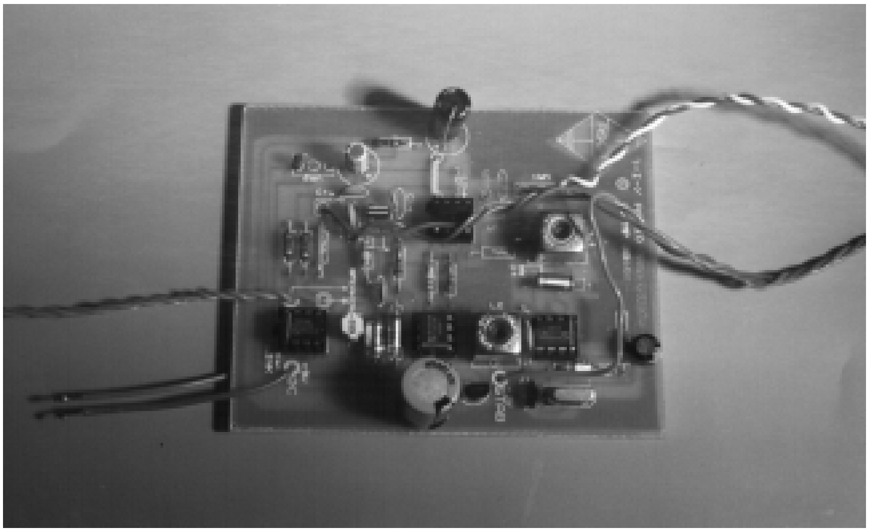

39 Diodes for protection

Introduction

Many semiconductor devices can be destroyed in an instant if their supply is reversed. With the use of batteries as power sources, it is quite common for the battery to be connected ‘the wrong way round’, and the scope for damaging equipment is significant and very real. Diodes can protect equipment in several ways, and you may do worse than to consider one of these approaches to protect your next expensive project.

Choose wisely!

All the diode circuits given here are so simple as to invite calamity. The circuits are not foolproof but, with a little care, will work first time. Remember that a semiconductor diode has a forward voltage drop of between 0.5 V and 0.7 V, depending on its type and the current flowing. This will be mentioned later.

The first thing you need to do is to insert a good multimeter *in series* with the circuit you want to protect; set the range to Amps DC, and switch on. Check that the circuit works properly. Then, decrease the current range on the meter until a good reading is indicated. Make a note of this current, as it is the normal running current of your circuit.

To choose a diode, you must consult the catalogues or data sheets and find one where the quoted *maximum forward current* exceeds the current you have measured; preferably it should be at least twice your measured current. Secondly, the diode will have a *peak inverse voltage* (PIV); this is the maximum voltage it can withstand when the cathode is made positive with respect to the anode, i.e when it is *reverse-biased* and not conducting. This voltage must be greater than your battery voltage, again by a factor of about 2. Except in the case of the bridge rectifier (see later), these criteria will enable the selection of a suitable diode to be made easily.

The series diode

The simplest and most obvious way to protect equipment is to insert a diode in the positive supply lead, as shown in **Figure 1**, with the diode passing current *only* when the supply is of the correct polarity. Because of the 0.6 V that exists across the diode, your equipment will normally operate on a

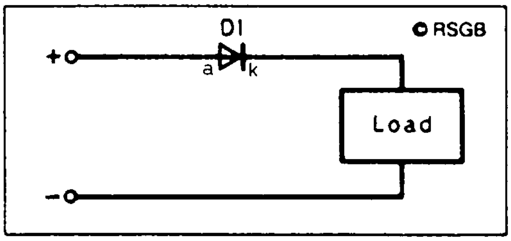

Figure 1 Series diode protection

slightly lower voltage. If you imagine reversing the supply to this circuit, you will see that the negative terminal of the battery is connected to the anode of the diode; the diode becomes reverse-biased and will not conduct any current, thus protecting the load. Your equipment will not operate when the battery connections are reversed.

The parallel diode

The circuit of **Figure 2** overcomes this voltage drop. It places the diode in parallel with the load (your equipment) but in a normally reverse-biased condition so that it draws no current when the battery is correctly connected. Reverse the battery connections, however, and a very large current will flow through the diode, thus blowing the fuse! For this technique to work successfully, the current drawn by the diode when the battery connections are reversed *must* be much greater than the maximum current drawn by the equipment, in order to blow the fuse. This is usually not a problem, however.

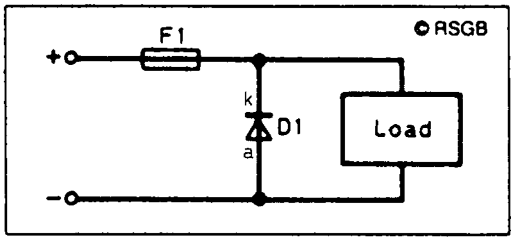

Figure 2 Parallel diode and fuse

The diode bridge

For sheer elegance, the circuit of **Figure 3** takes the biscuit! It uses four diodes connected in the form known as a *bridge rectifier.* Such rectifiers exist, and do not have to be made up from four discrete diodes.

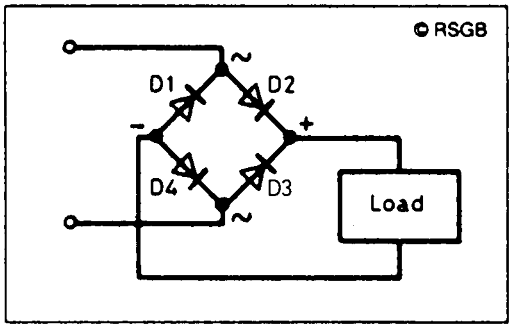

Figure 3 The diode bridge

Follow the current round the circuit from the supply, assuming initially that the top wire is positive and the bottom wire negative. It flows from the positive supply

(a) through D2
(b) through the load (top to bottom)
(c) through D4

and back to the negative of the supply.

Now assume that the bottom supply lead is positive and the top lead negative. The current flows from the positive supply

(a) through D3
(b) through the load (top to bottom)
(c) through D1

and back to the negative of the supply.

So, whichever way round the battery is connected, the current will *always* flow the same way through your equipment!

The circuit does have a drawback, however. Whichever way round the battery is connected, there are always **two** diodes conducting the current at any time. In the first case it is D2 and D4; in the second case, D1 and D3. This means that there is a total voltage drop of about 1.2 V. If your equipment can tolerate that reduction in voltage, then you will not have a problem.

Decoupling

Whenever the supply rail to a piece of equipment, or even to an individual stage of a circuit, is broken for the insertion of a device that will drop voltage, strange things can happen. This is because the supply for any circuit is assumed to have a low resistance to DC and a low *impedance* to AC. (Impedance is the AC equivalent of DC resistance.) These two are not the same, and the insertion of a diode or diodes is certain to make a big difference to them both. To overcome any irregularities in the operation of the circuit you are protecting in any of the ways described previously, the protected supply needs to be *decoupled* with a capacitor.

If the circuit handles audio frequencies only, placing an electrolytic capacitor directly across the load in all three circuits should solve the problem. The parallel circuit of Figure 2 is less at risk than the other circuits. The size of the capacitor will be determined by the current taken by the circuit, and may need to be chosen within the range 100 µF to 10 000 µF, with a working voltage greater than the supply voltage.

If the circuit is mainly handling RF currents, placing a capacitor of 0.01µF across the load should prevent any problems. A second capacitor, also across the load, of between 10 µF and 100 µF may be needed. Again, the parallel circuit of Figure 2 is less at risk than the other two.

Don't be afraid to experiment, but confine your experimenting (at first) to small equipment and low currents, until you get a 'feel' for the technique.

40 An RF signal probe

Introduction

A radio-frequency (RF) diode probe is a simple device which, when used with a conventional multimeter, enables the measurement of RF voltages in a circuit. When constructed, this will be one of the most useful pieces of test equipment for the experimenter who revels in the construction of transmitters and receivers.

The circuit

Figure 1 shows the simple circuit diagram. It is *almost* the same as a common diode rectifier circuit, but with a simple change to make it more sensitive. The circuit is known as a *voltage-doubler*, and is often found in high-voltage supplies, with beefier capacitors and diodes, of course! Because we are dealing with high frequencies and smaller voltages, the diodes and capacitors can be physically very small. The diode circuit of D1 and D2 *rectifies* or *detects* the RF from the probe, and any remaining AC is removed (short-circuited to ground) by C2. This produces, at the output, a constant voltage proportional to the peak-to-peak RF voltage present at the input; the output voltage is fed to an ordinary multimeter (on a voltage range).

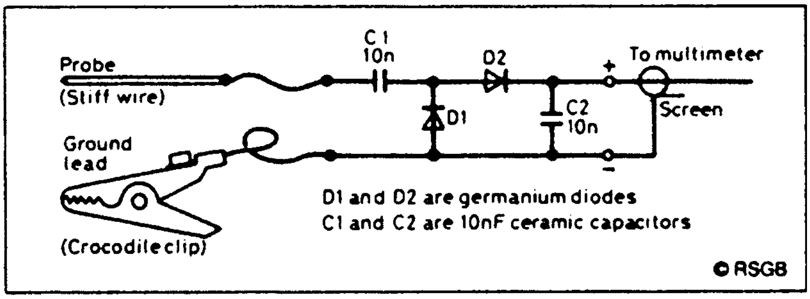
C1
10n
D2
Probe
(Stiff wire)
D1
C2
10n
+
To multimeter
Screen
Ground
lead
−
(Crocodile clip)
D1 and D2 are germanium diodes
C1 and C2 are 10nF ceramic capacitors
© RSGB

Figure 1 The diode probe can be made from four electronic components

Construction

Although the circuit layout is not critical, a description of the prototype is given here for your information. **Figure 2** has the details. The components are soldered to square pieces of copper-clad printed-circuit board (PCB) glued to a larger piece of PCB. The larger piece serves as a ground connection. Use a stiff copper wire as the probe, and an insulated flexible wire with a crocodile clip to connect the probe to the ground of the circuit under test.

Cut a piece of plain PCB, 30 mm by 45 mm and another of 15 mm by 45 mm. Cut the smaller piece into three measuring about 15 mm square. Stick the three small pieces to the larger piece, ensuring that there are small gaps between each, as Figure 2 shows. Solder the components in place. The connection to the multimeter should be thin coaxial cable or screened microphone cable. If you use unscreened cable, there may be RF pickup here which can lead to false readings.

Simple to use

Using the probe is simple. Connect it to the multimeter and set the meter to around 10 V DC – you may need to reduce this, depending upon the magnitude of the RF voltage you are trying to measure. Hold the probe by

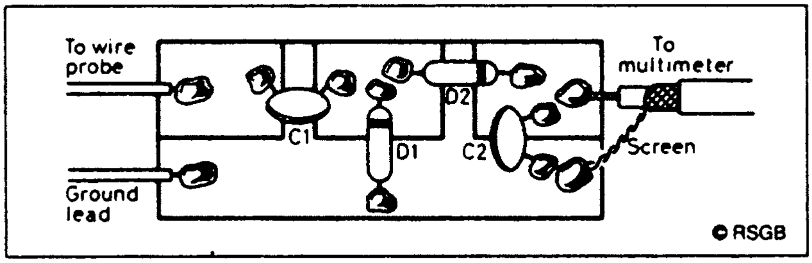
To wire
probe
Ground
lead
C1
D1
D2
C2
To
multimeter
Screen
© RSGB

Figure 2 The components are mounted on a copper-clad PCB

its base, being careful *not* to touch any of the components. Connect the croc clip to a ground point on the circuit and touch the probe on the circuit point to be tested. If an RF signal is present, there should be a reading on the multimeter. That's all there is to it!

Parts list

Capacitors

C1, C2	10 nanofarads (nF), or 0.01 microfarad (μF) ceramic

Semiconductors

D1, D2	Any *germanium* signal diode, e.g. OA91 or AA119

Additional items
- Stiff copper wire
- Insulated flexible wire
- Copper-clad PCB
- Crocodile clip
- Coaxial or screened cable

Source

All components are available from Maplin.

41 An RF changeover circuit

Introduction

The simplest entry route to operating an HF station is to buy or build a receiver, and to add a simple CW (Morse) transmitter. In theory, this sounds so simple, yet in practice there is one significant hurdle to be overcome. How can they both share the same aerial? A manually operated changeover switch is the obvious solution, but it takes time to perform the switching operation, by which time someone else has squeezed in before you and contacted the DX station! This small circuit accomplishes the changeover automatically, as soon as the transmitter is keyed.

How it's done

The circuit is shown in **Figure 1**, and uses the signal from the transmitter to operate a relay. A relay is a switch which is operated electrically in the following way. A coil of wire with an iron core is used as an electromagnet. When current flows through the coil, it produces a magnetic field which, in turn, is used to pull a set of switch contacts. These contacts will be used to switch the aerial from transmitter to receiver and vice versa. The relay used here has a double-pole changeover (or DPDT, or DPCO) switch. If you are confused by the different types of switch, look at the basic descriptions elsewhere in this book. The *pole* of a switch is the part that doesn't move; in Figure 1, one pole is connected to L1 and the other to the aerial output. In a circuit diagram, the switch contacts are always shown in their *normal* state, i.e. when *no* current flows in the relay coil. The changeover switch is normally in the receive position, so we say the receive switch is *normally closed*, and the transmit switch is *normally open*. We choose to have the circuit in the receive position normally, because everyone spends a lot more time receiving than transmitting. The relay is energised only when you are transmitting.

There are three RF sockets – one for the transmitter, one for the aerial, and one for the receiver. When the transmitter is not in use, there is a direct connection (via the Rx normally closed contacts of the relay) between the aerial and the receiver. The transmitter (which is not keyed at this time) is connected to a 50 ohm dummy load, R1.

When the transmitter is activated by pressing the Morse key, an RF signal appears at the transmitter socket. The wire carrying the signal to the relay

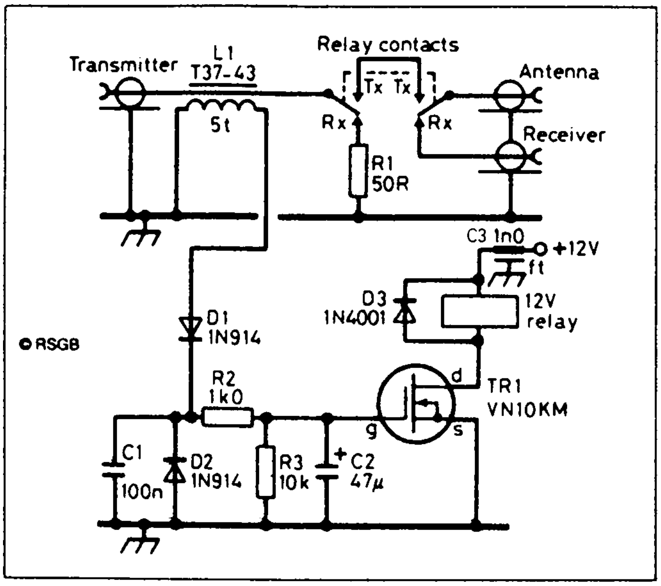

Figure 1 RF activated relay

Tx contacts passes through a toroid (a ferrite coil former, looking like a black Polo mint), which has a five-turn coil wrapped around it. This five-turn coil picks up the signal, which is then detected by D1 and D2, and converted to a steady voltage. C1 removes any remaining RF and C2 provides *hang*. Without it, the circuit would detect the gaps between every dot and dash being sent, and switch the aerial over very rapidly and very frequently! This is *not* what we want. We need the relay to remain in the transmit condition at normal Morse keying speeds, and then return to receive when the sending is complete. The combination of C2 and R3 achieves this.

The voltage appearing across C2 is fed to a VMOS field-effect transistor (FET), TR1, which acts as an electronic switch. When a voltage appears across C2, the FET switches on and passes a current through the relay coil, changing the contacts from receive to transmit. The diode, D3, across the relay winding protects the FET from being damaged by the large reverse-voltage spike which occurs across the coil when the FET switches off.

Construction

This is very simple – a circuit board is not required. The prototype was built into an old 50 g tobacco tin. All ground leads are soldered directly to the tin, thus supporting the components automatically. Phono sockets were used for the aerial, receiver and transmitter; you could use whatever connectors matched the rest of your station. The 12 V supply is fed through the tin using a 1000 pF feed-through capacitor, C3.

The 'dummy load', R1, must be able to withstand the RF output power of the transmitter. For novice use, 4 watts is adequate. Two suggestions for making up R2 from standard resistors are shown in **Figure 2**. Six 330 ohm, 1 watt resistors in parallel have a combined resistance of 330/6 = 55 Ω at 6 W. Two 100 ohm, 2 watt resistors in parallel have a combined resistance of 100/2 = 50 Ω at 4 W.

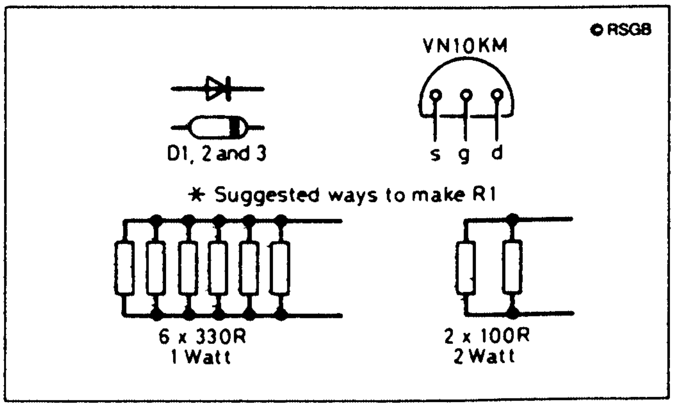

Figure 2 Component details

Make sure all the contacts to the relay are correct; also ensure that TR1, C2, D1, D2 and D3 are correctly wired.

Winding the toroid, L1, is very simple. It is made from PVC-insulated hook-up wire. Each time the wire passes through the centre of the toroid counts as one turn. The wire from the transmit socket to the relay simply passes through the centre! Use thin 50 Ω coax for the leads to the three sockets.

What happens to the receiver?

On transmit, the receiver is not connected to the aerial, but is only the separation of the switch contacts (about 0.5 mm!) away from the transmit lead. The receiver *will* pick up the transmitted signal, and there is a possibility that this signal will be enough to damage the receiver's sensitive input circuits. This can be prevented with the simple addition shown in **Figure 3**. Two diodes are connected back to back across the receiver socket. These act as a *limiter*, reducing the amount of signal that can enter the receiver. Solder these directly between the receiver socket and the tin.

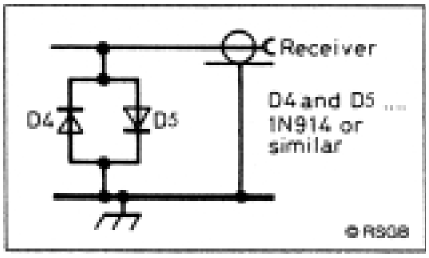

Figure 3 Receiver input protection

Warning

The wiring **must** be thoroughly checked. If the relay switch connections are wrong, there is a **great probability** that the full RF power will be applied to your receiver! You can check these connections as follows. With the 12 V supply connected, check that the relay energises (clicking sound heard) when the FET drain (d) is shorted to earth. Check the aerial and receiver connections with an ohmmeter or continuity tester. Disconnect the 12 V supply, and check that there is continuity between the centre pins of the aerial and receiver sockets. Reconnect the 12 V supply, short the FET drain to earth again (this will not damage the FET) and check that there is continuity between the centre pins of the aerial and transmitter sockets. If these tests show correct operation, disconnect the drain shorting wire (*most* important!) and your aerial auto-changeover is ready for use! Avoid using the device without the lid fitted.

Parts list

Resistors: 0.25 watt, 5% tolerance, unless otherwise stated

R1	50 ohms (Ω) – see text and Figure 2
R2	1 kilohm (kΩ)
R3	10 kilohms (kΩ)
Capacitors	
C1	100 nanofarads (nF), 0.1 microfarad (μF)
C2	47 microfarads (μF) 15 V electrolytic
C3	1000 picofarads (pF) feedthrough
Semiconductors	
D1, D2, D4, D5	1N914
D3	1N4001
TR1	VN10KM
Additional items	
L1	T37–43 toroid
	Relay 12 V DPDT (DPCO) relay
	Three sockets to suit (phono, SO239, etc.)
	Thin coax cable and hook-up wire

42 A low-light indicator

Introduction

This is a simple one-evening project that can be built for the pure fun of it, or to use as the basis of a more complex project to switch your shack lights on when it gets dark! In its prototype form, it simply flashes an LED when the ambient light level drops to a preset point.

Operation

The heart of the circuit shown in **Figure 1** is a *photo-conductive cell*, also called a *light-dependent resistor* (LDR), a device whose resistance changes according to the amount of light falling on it. In bright light, the resistance is low (about 1 kΩ), whereas in the dark, its resistance is very high (up to 10 MΩ). The cell is made from a semiconducting material known as cadmium sulphide (CdS), and is enclosed in a small plastic container. The semiconductor is laid on a flat insulating surface in the form of a small flat ribbon. The ribbon construction gives a good area of surface for a given

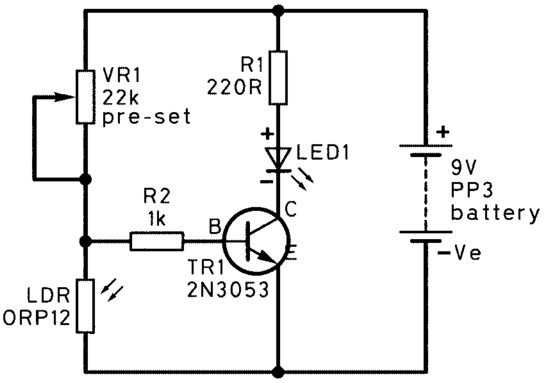
VR1
22k
pre-set
R1
220R
+
LED1
−
+
9V
PP3
battery
−Ve
R2
1k
B
C
E
TR1
2N3053
LDR
ORP12

Figure 1 Circuit diagram

©RSGB DY107

length of ribbon, and the length of the ribbon is maximised by laying it out in a zig-zag pattern, as can be seen diagrammatically in **Figure 2**. In the dark, CdS is an insulator; when light falls on it, electrons are released inside the CdS, making it conduct. The more light there is, the more electrons there are, and the resistance falls.

In this circuit, the LDR is connected across the 9 V supply in series with a variable resistor, VR1. In this arrangement, the voltage that exists across the LDR will be determined by the light level. As the light intensity increases, the resistance of the LDR falls, dropping a smaller voltage across it. The

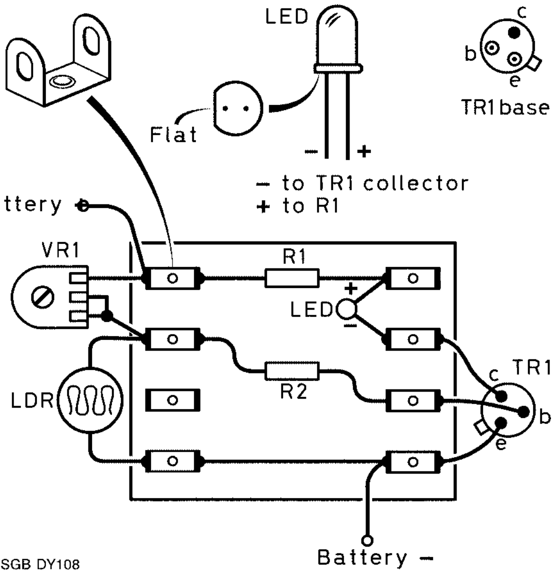
LED
Flat
− +
− to TR1 collector
+ to R1
c
b
e
TR1 base
Battery +
VR1
R1
+
LED
−
TR1
c
b
e
LDR
R2
Battery −

Figure 2 Component layout on tagstrip

©RSGB DY108

reverse happens when the light intensity falls – the voltage across the LDR increases. This voltage is used to drive an npn transistor, TR1, connected as an electronic switch. As the voltage on the base (B) rises, it will reach a point where TR1 will suddenly start to pass current, just as an ordinary switch does when pressed. The current flowing through TR1 also flows through a flashing light-emitting diode (LED), D1 and its series resistor, R1. D1 can be a steadily glowing type, if preferred. If you want to make the circuit switch the LED on at a different ambient light level, adjust VR1.

Construction

The prototype was made on an eight-tag tagboard (Figure 2). The resistors R1 and R2 can be laid on the tagboard for soldering, the rest of the components lying above or to the side of the board. Check the circuit after you have soldered everything on, then connect the battery. The LED should flash if you put your hand over the LDR, and VR1 can be adjusted to vary the point at which the LED lights. The project can be housed in a small plastic box with holes provided for the LDR and LED and an on/off switch if you want one.

Parts list

Resistors: all 0.25 ohm, 5% tolerance

R1	220 ohms (Ω)
R2	1 kilohm (kΩ)
VR1	22 kilohms (kΩ) linear pre-set

Semiconductors

LDR	ORP12
TR1	2N3053 npn
LED1	Flashing LED

Additional items

Plastic box
Tagboard with 8 tags
PP3 battery connector

43 A J-pole aerial for 50 MHz

Introduction

For FM communication (i.e. voice and data) on the VHF bands, a vertical aerial is used to give all-round (non-directional) coverage. This is a half-wave aerial which can be fed at the end, thus removing the principal problem with the conventional vertical centre-fed half-wave dipole, which is that the feeder should leave the dipole at right angles. This is no problem when the dipole is horizontal, but can be difficult for the vertical dipole.

Basic facts

A feeder must be connected to an aerial at a point where the *impedance* (AC 'resistance') of the aerial closely matches that of the feeder. The difference between the two impedances gives rise to the voltage standing-wave ratio (VSWR), which is unity only when the two impedances are the same. With 50 Ω feeders, the feed point of a half-wave aerial is at the centre, where the aerial impedance is around the same value. At the end of a half-wave aerial, the impedance is high, so it is *not* a suitable point to connect a 50 Ω feeder.

Connection at this point can be effected using an RF transformer. RF transformers act in the same way as ordinary transformers, except that they are much smaller, and usually comprise wires of particular lengths adjacent to each other. **Figure 1** is a good starting point. It shows the aerial in its diagrammatic form. Notice that the aerial is in the form of an elongated letter 'J'; this shape gives rise to its nickname – the *J-pole*. The quarter-wave RF transformer is the lower 'U' section below the half-wave element. At the bottom of the U section, the impedance is zero (this may become clearer later) and at the top of the U section it is high, thus matching the aerial impedance. The coaxial feeder cable is connected part-way up the U section, where the impedance is around 50 Ω.

The practicalities

Figure 2 shows the aerial as constructed. As it is about 4.5 metres high, it may be too high for the average house loft, but is ideal for mounting outside, supported by a non-metallic pole or hung from a tree branch. The upper half-wave section is made from 1.5 mm insulated copper wire, as used in domestic mains wiring. The quarter-wave transformer below the half-wave section is made from 300 Ω balanced line ('ribbon cable'). The

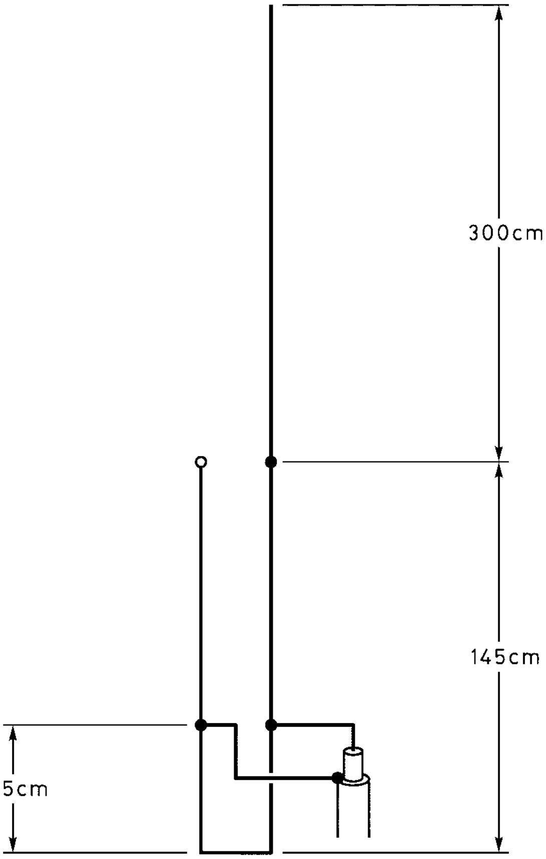

Figure 1 Overall dimensions of the 6 metre J-antenna

wires at the bottom of the transformer section are stripped of their insulation, twisted and soldered. At the upper end, only one wire of the balanced line is soldered to the bottom of the half-wave section. The other wire of the pair is not connected and is left insulated.

At the feed point of the transformer, the insulation needs to be carefully stripped from the balanced line. You will need a standing-wave meter (VSWR meter) in the coaxial line between your transmitter and the aerial, and you will need to adjust the position of the feed point. 45 cm from the bottom was the best point on the prototype, but this position is dependent upon the immediate surroundings of the aerial, and *must* be done when the aerial is in its final operating position. **Warning: *Never* make adjustments to the feed point when the transmitter is on. Make a VSWR measurement, switch off, move the feed point, switch on again, make another measurement, and so on.** You will need to aim for the lowest VSWR you can – certainly better than 2:1. Having found the best position, wrap all the exposed wires with self-amalgamating tape, to seal them against the ingress of moisture.

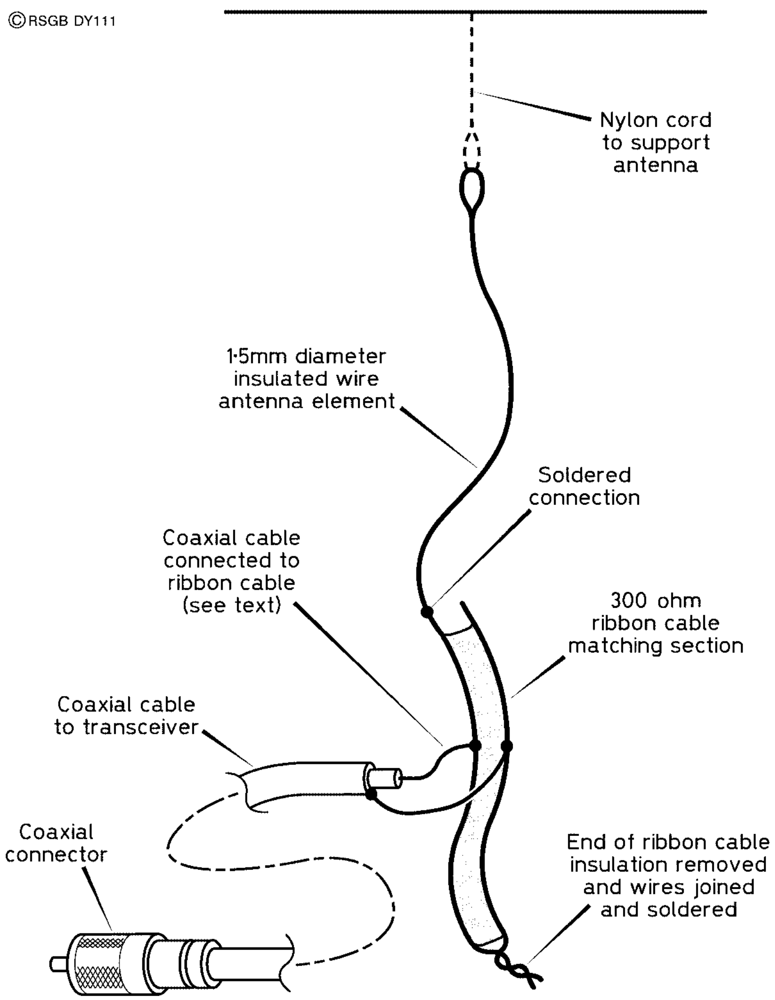
©RSGB DY111
Nylon cord to support antenna
1·5mm diameter insulated wire antenna element
Soldered connection
Coaxial cable connected to ribbon cable (see text)
300 ohm ribbon cable matching section
Coaxial cable to transceiver
Coaxial connector
End of ribbon cable insulation removed and wires joined and soldered

Figure 2 Construction details

How it performs

Figure 3 shows a computer prediction of how the J-pole radiates. It is called a *polar diagram*, and shows the distribution of your transmitted power when viewed 'from the end of your garden'. Most of your signal is sent at a fairly small angle to the horizontal; very little signal goes upwards, which is a good thing, of course. This also shows why the J-pole (or any other vertical aerial) should not be called 'omnidirectional', which means it radiates in all directions. It is omnidirectional *only* in the horizontal plane.

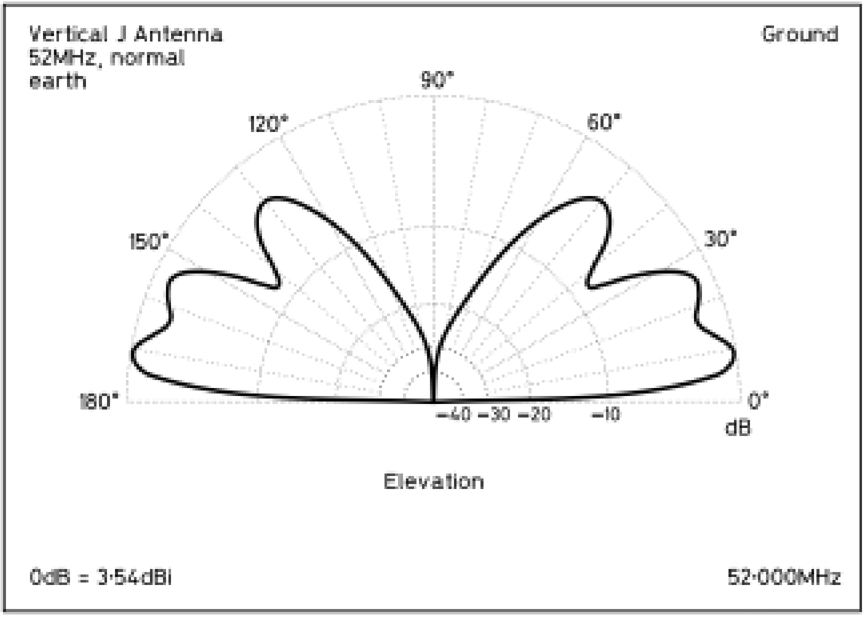

Figure 3 This polar diagram computed for the J-pole

©RSGB X210

Safety

Where you mount your aerial is a matter of personal preference and the restrictions of height and space, but the following safety rules *must* be applied.

1. Never fix an aerial where it may come into contact with power lines or telephone lines.
2. When climbing a ladder to put up an aerial outside, make sure the ladder is safe and that it is secured.
3. Don't do this alone. Preferably have someone with you. If this is not possible, make sure someone knows where you are.

Parts list

3.00 metres	1.5 mm insulated copper wire
1.50 metres	300 ohm balanced line
As required	50 ohm coaxial cable
As required	Self-amalgamating tape

44 Measuring light intensity – the photometer

Introduction

Before the days of automatic 'point-and-shoot' cameras, a photographer would use a light meter or *photometer* to measure the light level, then manually convert this reading into shutter speed and lens aperture settings to ensure a correctly exposed negative. Modern cameras have quite sophisticated photometers, which control the shutter speed and iris settings automatically.

A short explanation

A simple photometer circuit is shown in **Figure 1**, and is based on a device called a *light-dependent resistor*, or LDR. As its name tells us, its resistance depends upon the amount of light falling on it. In bright light, the resistance is relatively low (about 1 kΩ), whereas in the dark, its resistance is very high (up to 10 MΩ). The cell is made from a semiconducting substance known as cadmium sulphide (CdS), and is enclosed in a small plastic container. The semiconductor is laid on a flat insulating surface in the form of a small flat ribbon. The ribbon construction gives a good area of surface for a given length of ribbon, and the length of the ribbon is maximised by laying it out in a zig-zag pattern. In the dark, CdS is an insulator; when light falls on it, electrons are released inside the CdS, making it conduct. The more light there is, the more electrons there are, and the resistance falls.

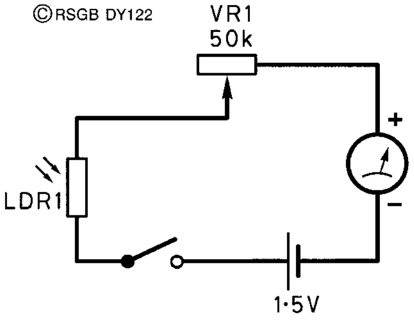

Figure 1 Circuit diagram of photometer

The photometer circuit

The circuit is simply a series connection of four things – the battery, the LDR, a variable resistor and a meter. A switch is also provided. The combination of the LDR resistance and that of VR1 determines the current flowing, which is indicated on the meter. Altering the resistance of VR1 sets the *sensitivity* of the photometer – you may want full-scale deflection of the meter needle for a bright light, or for a dim light.

It is simple to make, and a plug-in type matrix board is ideal to test the circuit, so that you can decide if you want to make a permanent version. Connect all the components in series; the only change you may want to make is the connection to VR1. If you find that the sensitivity control seems to work 'backwards', simply unsolder the wire from the end tag of VR1 and solder it to the opposite end tag. Problem solved!

In use

As soon as you connect up the battery, you will probably have a meter reading because of the daylight falling on the LDR. Shading it with your hand should reduce the reading. If the meter needle is hard over against the end-stop, turn VR1 until it indicates about half-scale. The LDR is very sensitive, and will read zero only in a dark room. If you put on a torch to see what the meter reading is, the LDR will detect the torch light, and will give a reading!

Here is a simple project where you can use the photometer in an experiment which has an analogy in radio. Draw a circle on a large (A3 or bigger) sheet of paper and divide it up into 30-degree sectors, as shown in **Figure 2**. Draw a series of smaller circles which divide the maximum radius into five. Look at the figure if you're not sure about this. Bring the LDR away from the circuit by using two long, flexible wires. The experiment must be performed in a darkened room (preferably in total darkness). Prepare a table with two columns, the left-hand one headed 'Angle (degrees)' and the right-hand one 'Meter reading'. Fill in the left-hand column 0, 30, 60 . . . and so on up to 360°.

Place the torch in the position shown, with its lens at the centre of the circle and pointing along the 0° line; switch it on. Place the LDR facing the torch and adjust VR1 until you have full-scale deflection of the meter needle. Suppose the meter indicates 10 units at this point. Enter this into your table in the 0° row. Keeping the torch the same distance from the circle centre, and pointing at it, move the LDR round all 30° positions and record the meter readings. Switch off the torch and take the sheet of paper and your tabulated results into daylight!

Lay the large sheet of paper on a table with your results beside it; then, at each 30° interval, plot the point along the radius corresponding to the meter

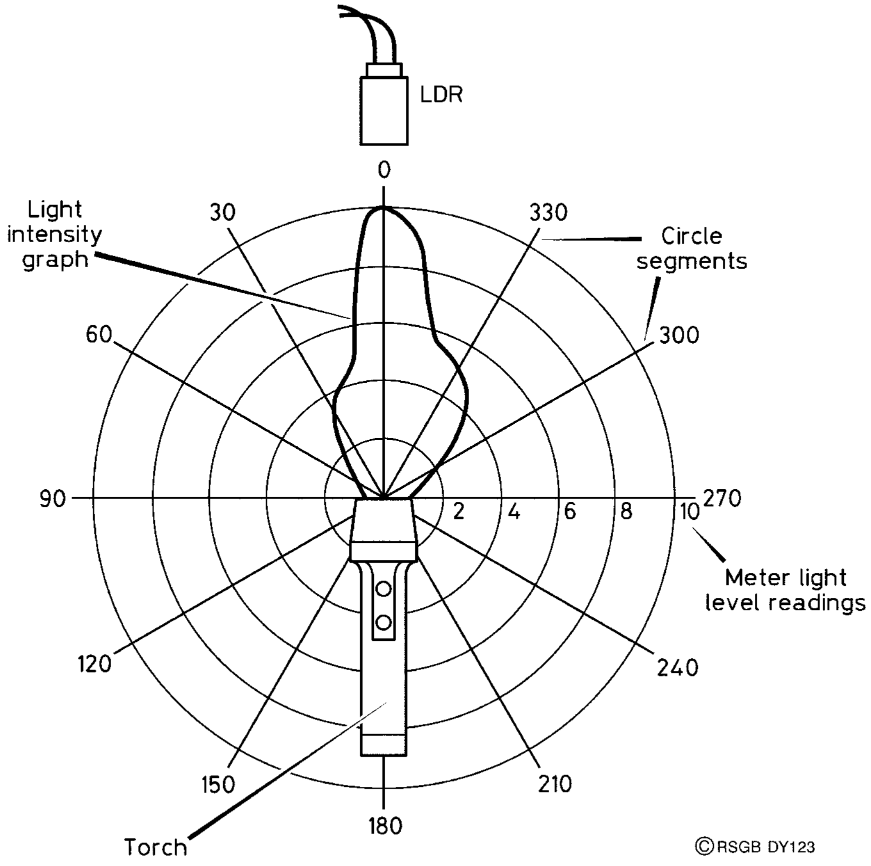

Figure 2 Torch light intensity pattern plotted at RSGB HQ

reading. Then, join up all the points and you have what is called a *polar diagram* of light intensity. The use of the word 'polar' implies that the readings have been taken in a circle and plotted that way.

Light waves and radio waves are both examples of *electromagnetic radiation*. The torch is designed to 'beam' its radiation in a particular direction, just like an aerial does. Hence the use of the word 'beam' for a directional aerial. If a similar polar diagram is drawn for a Yagi-type aerial, it will show the same general characteristics as does Figure 2, namely a main direction (or 'lobe') where most of the energy is concentrated, with evidence of *sidelobes*, indicated by 'lumps' on the otherwise smooth main lobe.

Also in this book you will find a project for the construction of a UHF field-strength meter, which you could use to carry out a measurement of the polar diagram of a UHF aerial.

Parts list

Resistor

VR1	50 kilohms (kΩ) linear

Semiconductor

LDR1	ORP12

Additional items
Meter, 50 or 100 μA
Battery clip for single AA cell
AA cell

45 A 70 cm Quad loop aerial

Introduction

This is a description of how to make an aerial for the 70 cm band which has gain compared with the ‘rubber duck’ or the dipole aerial. It can easily be dismantled and reassembled, making it ideal for contest use.

The principles

Most aerials which comprise several similar *elements* arranged along a *boom* are variations of the design originated by Yagi and Uda, and which takes the name (for historical reasons) of the former, and is know as the Yagi array. Let us suppose we have a Yagi aerial beaming left to right in front of us. The elements get progressively shorter from the left (look at almost any TV aerial to see this). All the elements on a Yagi aerial are classified as follows:

- The *reflector* – the leftmost element as we look at the array. It is the longest. Next to it is:
- The *driven element* – this is the element connected to the feeder, which in turn runs down to the transceiver. It is slightly shorter than the reflector.
- All the elements beyond the driven element are called *parasitic elements*, or *directors*. They are shorter than the driven element and usually get progressively shorter as we progress to the right along the boom. The directors are mainly responsible for the *directivity* (or *beamwidth*) of the array.

The progression from a simple dipole (a driven element in isolation) to a Yagi array is simple, but is nevertheless important. To make an aerial of two elements, a reflector (*not* a director) is added to the driven element. For three or more elements, directors are added to the two-element design. Adding more and more directors soon becomes impractical, the reduction in beamwidth (such as it is) does not warrant the extra expense, weight and wind resistance that is incurred.

Instead of using linear (straight) elements, as in the generic Yagi, this design uses loops. Designs using squares of wire instead of loops are known as *Quad* aerials, and HF designs require large X-shape frames to support the large squares of wire. At 70 cm, however, the use of wire loops is easier, and they are self-supporting.

Construction

This is quite simple. Any type of material (metal, plastic, wood) can be used for the *boom* (the support for the elements) and for the mast. The elements are made from 14 SWG enamelled copper wire. 16 SWG hard-drawn aerial wire, which is not enamelled, has also been used with success. Thinner wire might result in a rather ‘floppy’ aerial! The separate parts of the aerial are held together with *jubilee clips* (hose clips).

The driven element is secured to the boom with a jubilee clip and a three-connector plastic connector block as shown in detail in **Figure 1**, and in the photograph. Cut the wire for the driven element 70 mm longer than the 700 mm indicated in Figure 1. Then, using sandpaper, remove the enamel from one end to a distance of 20 mm, and from the other to a distance of 50 mm. After forming the loop of the driven element, bend both stripped ends through 90°, and insert them into the first to holes of the plastic connector block (Figure 1). Do not tighten the screws yet. Push both ends into the block as far as they will go, then bend the 50 mm end back on itself and pull the ends back through the connector block so that the end you have just bent goes into the third hole in the block. Now tighten the screws in the block and in the jubilee clip.

Each director and the reflector should be made 40 mm longer than the circumferences shown in Figure 1. Strip the enamel, as before, from the last 20 mm at each end. Form the wire into the loop, slip the ends under the jubilee clip (Figure 1) and tighten it. You may find that it helps to solder the stripped ends together before securing the jubilee clip.

The boom is fixed to the mast using jubilee clips and wire, as shown in Figure 1. Solder the feeder cable to the driven element, with the braid soldered to the end of the driven element which is connected to the boom (this applies to metal booms; with plastic or wooden designs, the feeder connections are not critical).

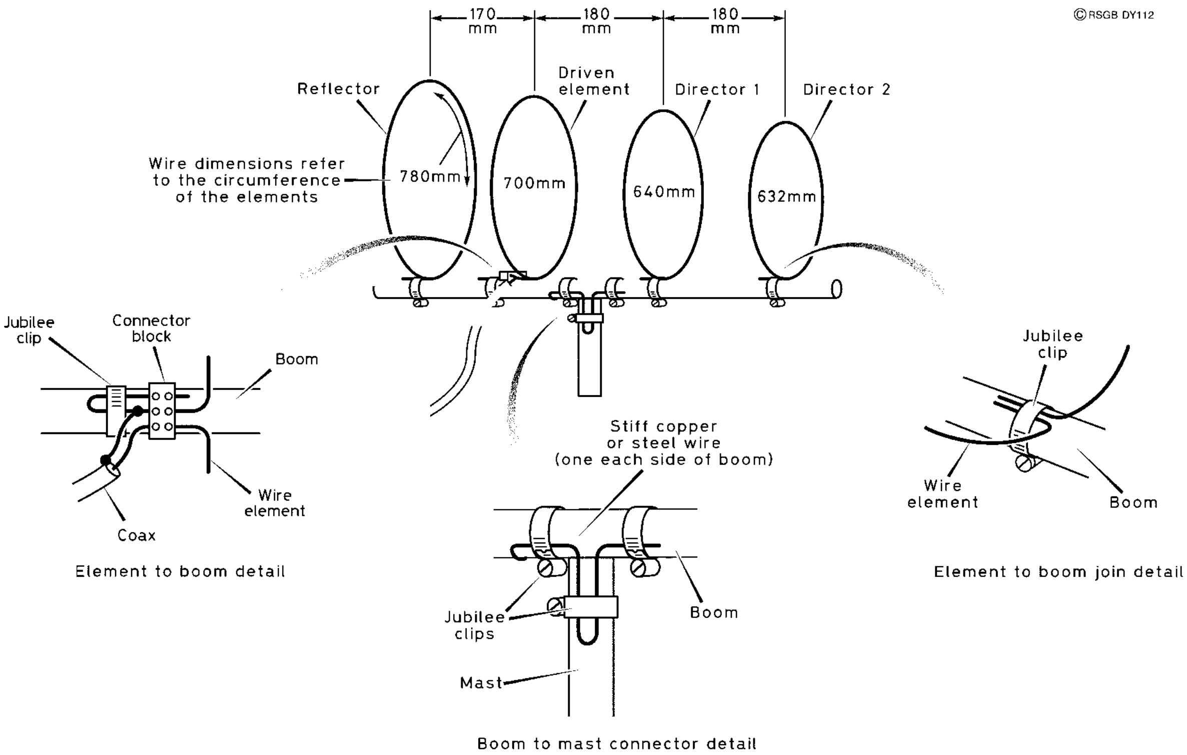
170 mm
180 mm
180 mm
©RSGB DY112
Reflector
Driven element
Director 1
Director 2
Wire dimensions refer to the circumference of the elements
780mm
700mm
640mm
632mm
Jubilee clip
Connector block
Boom
Wire element
Coax
Element to boom detail
Stiff copper or steel wire (one each side of boom)
Jubilee clips
Boom
Mast
Boom to mast connector detail
Jubilee clip
Wire element
Boom
Element to boom join detail

Figure 1 70 cm 4 element quad construction, with detail of how hose clamps are used in the construction

You will need a plug on the shack end of your feeder to suit the transceiver, aerial tuning unit (ATU) or the standing-wave meter (SWM) you are using. Always connect these in the order: transceiver – SWM – ATU – aerial.

Testing

Always test aerials outside and away from buildings (if possible!). This avoids getting misleading results.

Use a rubber duck, or whatever aerial you usually use, and tune around to find a repeater or beacon signal which is consistent. Note the reading on the S-meter. Then, connect your new Quad loop. Rotate it to give the strongest S-meter reading (don't forget it is directional). Verify that the meter reading varies as you rotate it. How does the S-meter reading compare with the original reading? Much depends on the siting of your original aerial; if you are comparing your Quad loop at ground level with a vertical on the chimney, you wouldn't expect your new aerial, even with its gain, to outperform a vertical which is well elevated!

Now a test on transmit is called for. The use of an SWR meter is essential here. Find a clear frequency and check that it *really is clear* before announcing your presence and carrying out the test. A reading of 1:1 is excellent, but any value less than about 1.8:1 would be acceptable. You can measure the directivity of your aerial using the field strength meter, also described in this series.

Materials

4 metres of 14 SWG enamelled copper wire
Material for boom and mast
15 amp connector block
7 Jubilee clips

The enamelled copper wire is available from AA&A Ltd, Sycamore House, Northwood, Wem, Shropshire SY4 5NN. Everything else is available from most hardware stores.

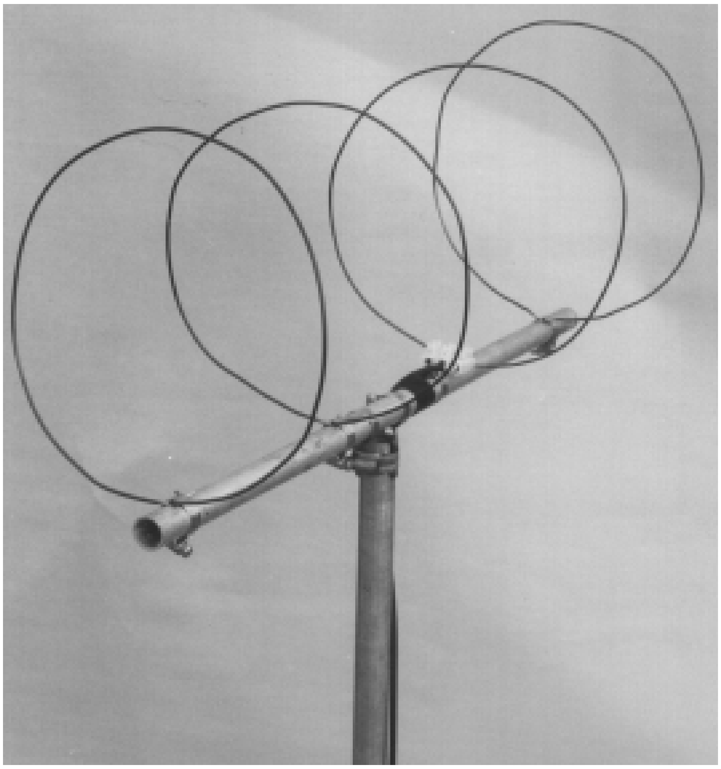

46 A UHF field strength meter

Introduction

It is always interesting, and often useful, to know just *where* the radiation is going from your aerial. How much of your radiated energy is going in the general direction of the station you are in contact with, and how much is being effectively wasted? Some of these questions can be answered with the use of a *field strength meter.* A field strength meter is simply a receiver, stripped down to its bare essentials, such that it responds only to the magnitude of the carrier. The use of a field strength meter assumes that the aerial under test is radiating a continuous carrier. Don't forget to find a clear frequency and identify your transmissions at least every quarter-hour, in order to comply with the terms of your licence.

Description

Two types of field strength meter are shown in **Figure 1**. You will recognise both circuits (Figure 1b particularly) as being types of 'crystal set' with a meter replacing the headphones. Figure 1a is a broad-band HF design (there is no tuning provision) and Figure 1b is tuned in the same way as the crystal set; with a loop of wire as an aerial, it will perform well in the VHF/UHF range.

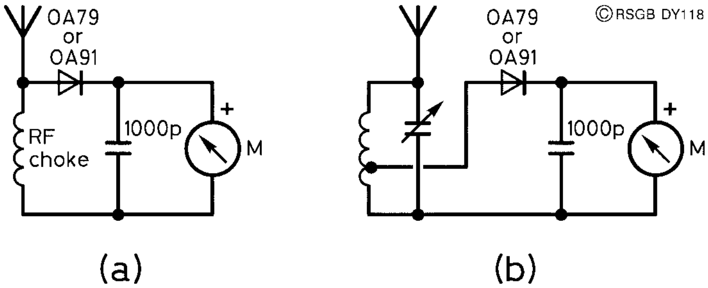

Figure 1 Construction of the UHF field strength meter

A tuned field strength meter also doubles as an *absorption wavemeter* if it is well calibrated. Such devices are useful for detecting transmitter harmonics also. This design is intended for use in the UHF band, so it will have to be sensitive around 432 MHz.

Construction

The field strength meter comprises a loop of wire, 600 mm long, which acts both as aerial and as the tuning inductance, a diode, a capacitor, a connector block, a meter and a length of twin wire. All the components, with the exception of the meter, are fixed to a pole with a jubilee clip, as shown in **Figure 2**. The meter should have a sensitivity of between 50 µA and 100 µA, or a multimeter can be used. The multimeter is more flexible, as you can select different current ranges, giving you a range of sensitivities.

Using the field strength meter

Connect your meter to the ends of the twin wire from the pole. Place a hand-held transceiver about 2 metres away, and press Transmit. If there is no meter reading switch off the transmitter and check the wiring. If the needle attempts to go negative, simply reverse the wires to the meter. If the reading is too high, either move the transmitter further away, or increase the current range on the multimeter. Try changing the orientation of the transmitter aerial, and note how the signal varies.

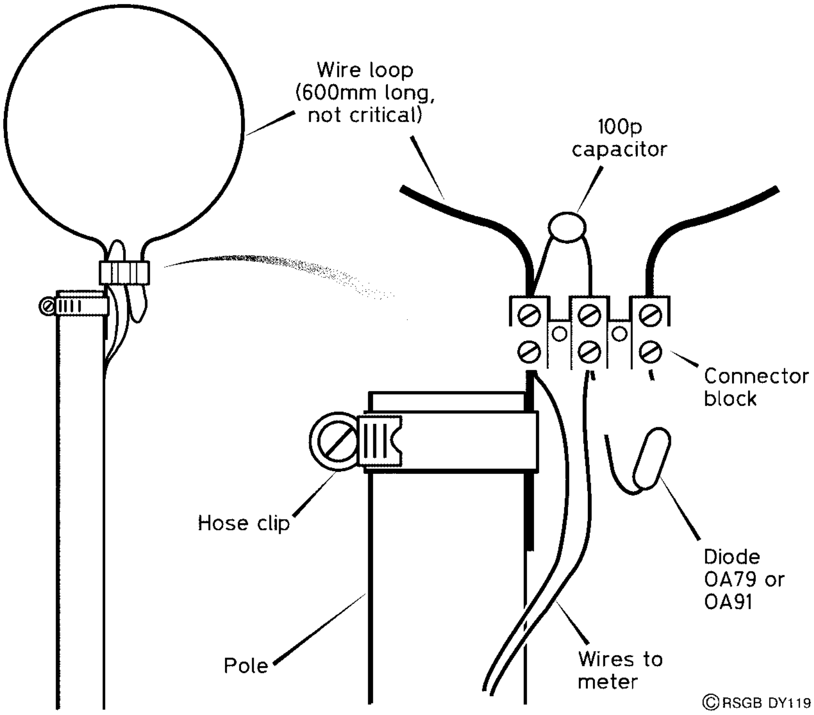
Wire loop
(600mm long,
not critical)
100p
capacitor
Connector
block
Hose clip
Diode
OA79 or
OA91
Pole
Wires to
meter
©RSGB DY119

Figure 2 Assembly of the field strength meter

To measure the *polar diagram* (a graph of the signal strength against the angle between the aerial boom and the field strength meter, plotted on polar axes) of a beam aerial, mount the loop as far away from the aerial as you can, preferably at the same height, and rotate the aerial, say 15 degrees at a time, and record the signal strength, until the aerial has been turned through 360 degrees. If you need help plotting the graph, enlist the help of a friend who has done it before, or one who knows about polar graphs! If you have already built the Photometer project, you will have measured and plotted the polar diagram of the light intensity from a torch. Now you will see the great similarity!

Parts list

Capacitor	100 picofarads (pF)
Diode	Germanium, OA79 or OA91
Connector block	10 A, 3-way
Wire	600 mm of 16 SWG enamelled copper Length of twin cable for meter connection
Clip	Jubilee (hose) clip

47 Christmas tree LEDs

Introduction

A novelty ideal for the festive season, this circuit causes one LED at a time to light up around a small cardboard Christmas tree.

Warning

This circuit uses members of the integrated circuit family known as CMOS (complementary metal-oxide semiconductor). These use very little current and can be completed destroyed if they come into contact with the magnitudes of static electricity that most of us carry about when we walk on carpets and wear rubber shoes. You will never know if this wanton destruction has happened – all you will discover is that your circuit doesn't work and that you have tested *everything*. To avoid this problem do the following things:

1. **Before you open the little packet in which each IC is supplied, touch something which you *know* to be earthed – the metalwork of any equipment which is mains-earthed, for example. Then open the packet.**
2. **Let the IC fall gently on the bench – don't pick it out with your fingers. Touch your earthed metalwork again. Pick up the IC and insert it gently into its holder.**
3. **Repeat the process with the second IC.**

The circuit is safe from destruction while it is connected to the battery. However, when the battery is removed, the same care should be exercised with its handling, because there are no supply decoupling capacitors across each IC.

Description

Figure 1 shows the layout, and how the wires are connected from the circuit board to the LEDs around the tree. The circuit, shown in **Figure 2**, is quite complicated, so you need to be confident in your logical approach to circuit-building before you attempt this one! It uses two common integrated circuits (ICs). IC1 is simply an oscillator which provides timing pulses for IC2, which 'counts' up to a maximum of 10. The outputs of the counter are indicated by light-emitting diodes (LEDs); red, orange, yellow and green are common colours which you can use.

The circuit is built on a single piece of Veroboard measuring 29 holes by 12 strips. **Be aware that there is no strip labelled 'I', so don't make mistakes in your counting!**

First of all, cut the tracks in the positions shown in Figure 1 using a 3 mm ($\frac{1}{8}$ inch) twist drill rotated between thumb and forefinger. Then, solder in the IC sockets, the notches facing row M. Wire up and solder in the links and then the Veropins for the connections to the LEDs and battery. Having done this, the resistors and the capacitor should be fitted. When wiring the LEDs, each cathode (the lead adjacent to the 'flat' on the LED encapsulation) is connected to R4, and the anodes go to separate pins on IC2.

Testing

Hold up your circuit board to the light and check carefully for solder bridges between adjacent tracks. Then check again that the wiring is correct. Place the ICs in their holders, with the notched ends lining up with those on the holders. Connect the battery, and the LEDs should illuminate in sequence.

If you have no success, you are now wishing you had checked the circuit more carefully! Learn something from your mistake and it will not have

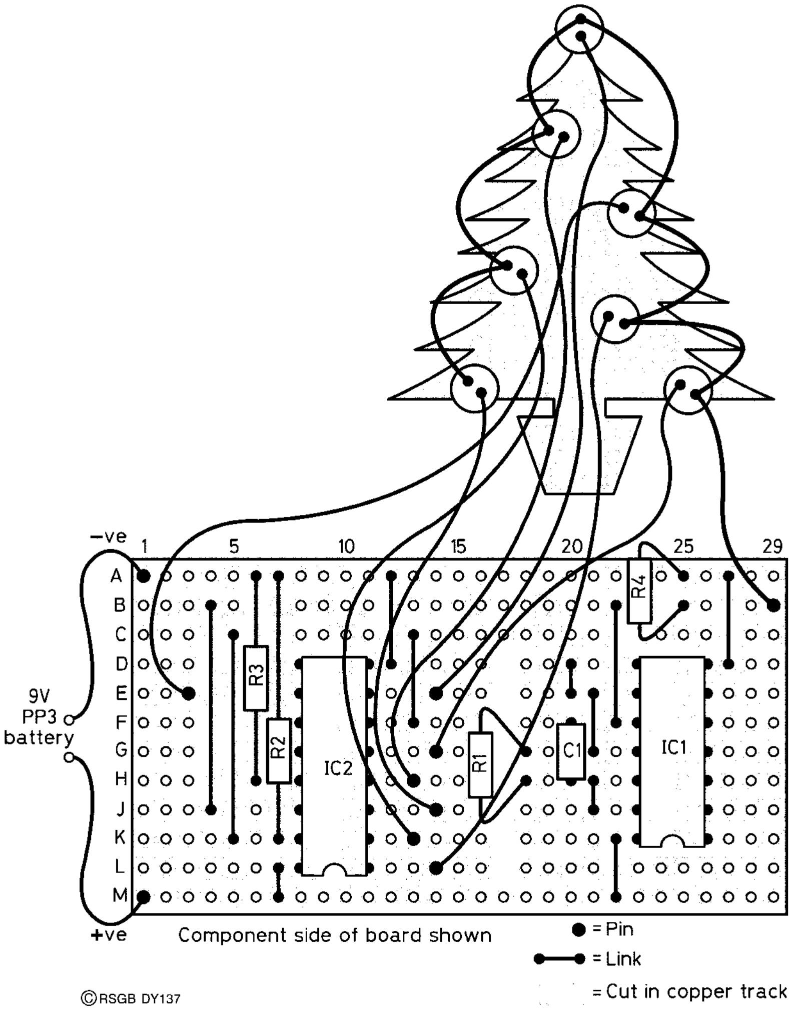
−ve
1
5
10
15
20
25
29
A
B
C
D
E
F
G
H
J
K
L
M
9V
PP3
battery
+ve
R3
R2
IC2
R1
C1
IC1
R4
Component side of board shown
● = Pin
●—● = Link
= Cut in copper track
©RSGB DY137

Figure 1 Christmas tree, component layout

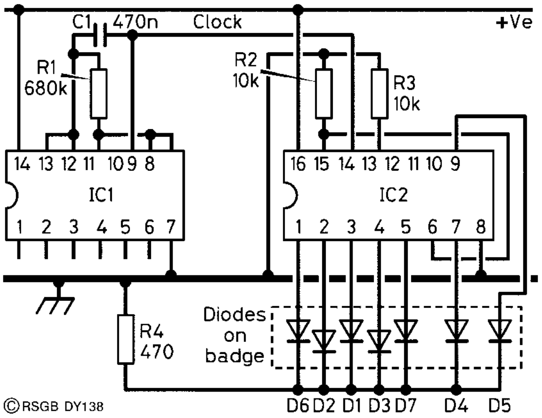
C1
470n
Clock
+Ve
R1
680k
R2
10k
R3
10k
14 13 12 11 10 9 8
IC1
1 2 3 4 5 6 7
16 15 14 13 12 11 10 9
IC2
1 2 3 4 5 6 7 8
R4
470
Diodes on badge
D6 D2 D1 D3 D7 D4 D5
©RSGB DY138

Figure 2 Christmas tree, circuit diagram

been in vain! The first thing to check is that the LEDs are the correct way round. If that is OK, then check the positions where the tracks are broken (intentionally!). After that, are the wire links in the right places – had you forgotten there is no row ‘I’? Check *all* the wiring, then check *again* for solder bridges, and switch on again. One of these tests should have revealed a fault. If it *still* refuses to work, perhaps one (or both) of your ICs were damaged by static electricity, despite your precautions – or did you choose to ignore them?

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	680 kilohms (kΩ)
R2, R3	10 kilohms (kΩ)
R4	470 ohms (Ω)

Capacitor

C1	0.47 microfarad (μF) min. metallised polyester film

Semiconductors

IC1	4011
IC2	4017

Additional Items

D1–D7	5 mm LEDs in choice of colours
	14-pin DIL socket for IC1
	16-pin DIL socket for IC2
	PP3 battery clip and battery
	Veroboard, Veropins
	Insulated wire for links

48 An audio signal injector

Introduction

An audio signal injector is a device used to test audio frequency circuits. It is simply an oscillator running at a frequency in the audio range, so that when its output is fed to the input of an amplifier, it will produce a sound in the loudspeaker if the amplifier is working. The oscillation is so rich in harmonics that the signal can also be heard (sounding rather different) when injected into an RF circuit.

The design

The circuit is shown in **Figure 1**, and is a basic *astable multivibrator*, a free-running oscillator producing a roughly rectangular-wave output. The two transistors, TR1 and TR2, operating as switches, switch on and off alternately at a frequency around 500 Hz. The prototype was constructed on plain matrix board (no copper strips), as illustrated in **Figure 2**.

Both transistors are type BC108, which are only a few pence each new, and can be found at almost any rally. You can add an on/off switch, or simply disconnect the battery when you are finished using it. To make the unit in one piece, the battery can be taped to the board, as the diagram shows.

The probe itself is made from a short piece of stiff insulated wire, soldered to a tag on the board; an earth lead is also soldered to the board, and terminated in a crocodile clip to attach to the ground lead of the equipment under test.

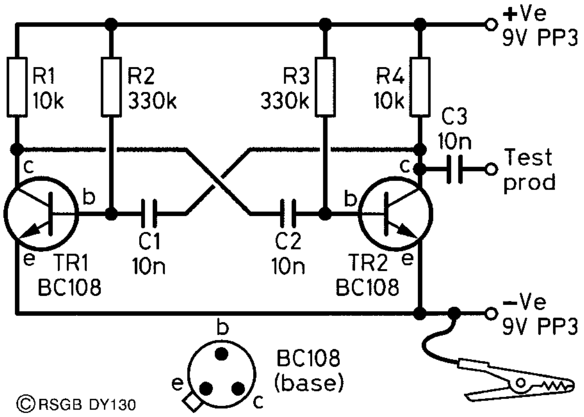

Figure 1 Circuit diagram of the signal injector

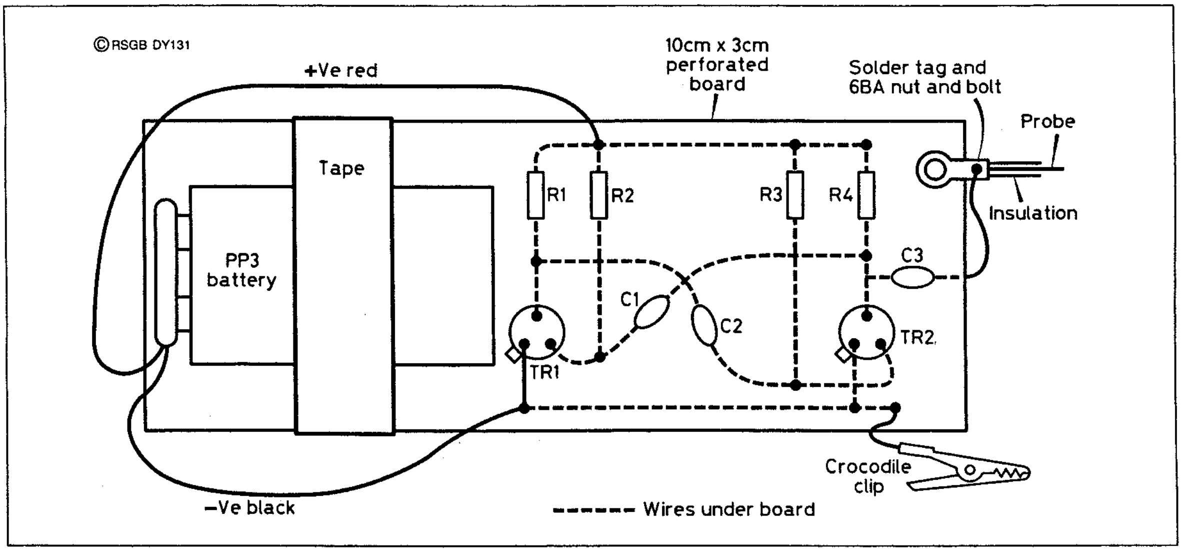
©RSGB DY131
+Ve red
10cm x 3cm perforated board
Solder tag and 6BA nut and bolt
Probe
Tape
PP3 battery
R1
R2
R3
R4
Insulation
C3
C1
C2
TR1
TR2
Crocodile clip
–Ve black
------ Wires under board

Figure 2 Component layout of the signal injector

Using it

After checking the wiring of the circuit, connect the battery. Find a transistor radio that is known to work. Carefully remove the case, switch on and apply the probe to the centre tag of the volume control. A *very* loud buzz should be heard from the speaker, indicating that the audio circuits of the radio are working. Using the injector to fault-find equipment you have made yourself is rather more instructive and rewarding, because you *know* where to inject the signal, and you should *know* what to expect when you do.

Warning

Do *not* work on any equipment connected to the AC mains. Work only on battery-powered circuits, for your own safety.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1, R4	10 kilohms (kΩ)
R2, R3	330 kilohms (kΩ)

Capacitors

C1, C2, C3	10 nanofarads (nF) or 0.01 microfarad (μF) ceramic

Semiconductors

TR1, TR2	BC108

Additional items
- PP3 battery and connector
- Matrix board 10 cm by 3 cm
- 6BA solder tags
- Thick insulated wire for probe
- Crocodile clip

49 Standing waves

Introduction

Everyone has, or *should* have, a standing-wave ratio (SWR) meter as part of his/her array of test gear. Most people know how to use it, but what does it really do?

Before attempting to answer that question, we need to look at some aerial fundamentals. An aerial is a *transducer*, the word meaning 'to lead across'. We use it whenever one form of energy is converted into another form. A bulb is a transducer; it converts electrical energy in the filament to radiated heat and light energy. **Figure 1** shows the situation.

An aerial, or antenna, is also a transducer; it converts radio-frequency (RF) energy in the feeder (or *transmission line*, to give it its proper name) into radiated electromagnetic energy, in the manner shown in **Figure 2**. The aerial has resistance, just like the bulb filament, and if the filament had zero resistance, there would be no radiated energy. In the same way, if the aerial had no resistance, there would be no radiation from it.

Transmission lines should convey RF energy from transmitter to aerial with the minimum power loss. A common form of transmission line is the *coaxial*

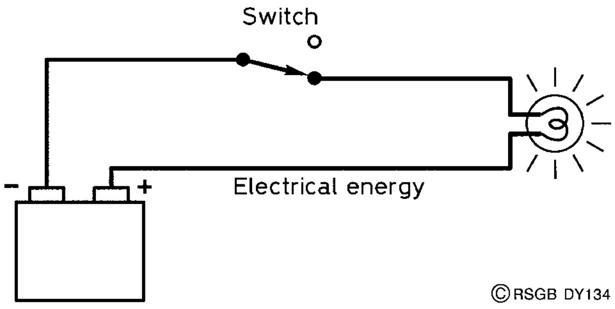

Figure 1 The light bulb converts electrical energy to electromagnetic light energy

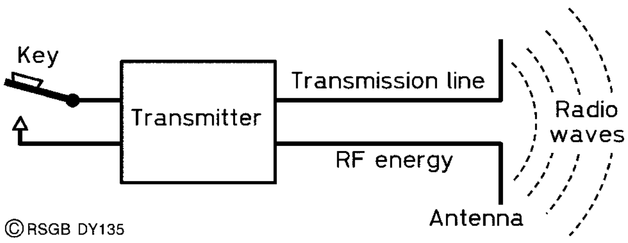

Figure 2 The antenna converts RF current to electromagnetic radio waves

cable. As you might expect, any feeder cable has a DC resistance caused by the resistance of the copper wire from which it is made. It also has an AC resistance, caused by the capacitance between the centre conductor and the braid, and by the inductance of the cable itself. This means that the feeder has an *impedance*, which is constant for the particular type of cable. This is what we call the *characteristic impedance* and, for the cables used in most amateur radio applications, it is 50 Ω.

If this impedance can be made the same as that of the aerial (it is already the same as the impedance of the transmitter output), then the transfer of energy will occur with minimum loss. If the aerial and cable impedances are *not* the same, then there is a *mismatch*, which causes some of the RF energy to be reflected back towards the transmitter. We now have a situation where RF energy is flowing along the cable from the transmitter to the aerial (the *forward* wave) and, at the same time, flowing from the aerial to the transmitter (the *reflected* wave). The two waves interact along the cable and form a stationary pattern of voltage and current. The pattern is known as a *standing wave*, and can be visualised from the waveforms in **Figure 3**. The ratio of the maximum voltage to the minimum voltage on a given wave defines the *voltage standing-wave ratio* (VSWR), or just *standing-wave ratio* (SWR) for short.

The SWR meter is easy to use. It is positioned in the feeder between the transmitter and the aerial tuning unit (ATU) if there is one, or between the transmitter at the aerial otherwise. Most meters have a single meter and a four-position switch. The transmitter is first keyed and, with the switch in

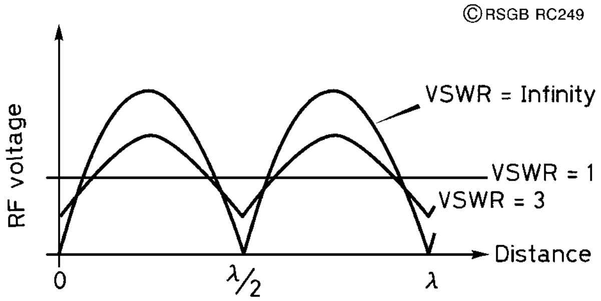

Figure 3 Standing waves on a transmission line

the ‘calibrate’ position, the sensitivity control is adjusted to give full-scale deflection on the meter. The switch is then changed to ‘forward’ to read the forward power, to ‘reflected’ to read the reflected power, and to ‘SWR’ to read the value of the standing-wave ratio. When there is no reflection (see Figure 3), the meter should read 1:1 or, simply, 1.

Most SWR meters remain in the feeder line while the transmitter is operating, so the condition of the aerial and feeder can be constantly monitored. Problems with the aerial (such as water entering the feeder at its junction with the driven element) are immediately shown up. Without the use of the SWR meter, the situation would slowly deteriorate over several months and you would be left wondering why so few stations were answering your calls!

50 A standing-wave indicator for HF

Introduction

The standing-wave ratio (SWR) meter shows how well the aerial system, including the feeder, is *matched* to the output of the transmitter. This design does not *measure* SWR, but it gives an indication of when the SWR is minimum for a given system of aerial and feeder. The design is usable on the HF bands from 1.8 to 28 MHz, and can be used at 50 MHz with reduced sensitivity.

How it works

There are two types of wave in any feeder: the *forward* wave, which travels from the transmitter to the aerial; the *reflected* wave, which travels back to the transmitter from the aerial. The presence of a reflected wave is evidence that some of your transmitted power is not being radiated, but is being returned to the transmitter to be lost as excess heat. When aerial and feeder are perfectly matched, there is *no* reflected wave, and all the power from the transmitter is radiated.

Referring to the circuit of **Figure 1**, a tiny fraction of the signal is removed by the transformer, T1, and by the capacitors, VC1 and C1. It is then detected by the germanium diodes, D1 and D2, and any residual RF removed by the capacitors, C2 and C3. The currents through the diode and meter (depending on the position of switch, S1) represent the forward and reflected signals. VR1 acts as a sensitivity control for the meter.

It pays to shop around for a suitable meter. Surplus types from tape recorders and hi-fi equipment are usually ideal for this purpose. A new one would cost several pounds. The more sensitive the meter, the more sensitive your indicator will be. Meter sensitivity is given by the current required to give full-scale deflection (FSD) of the pointer. One with an FSD of between 50 and 200 micro-amps (μA) is suitable for this circuit. The higher the FSD, the less sensitive the circuit.

Construction

The meter circuit and the sampling transformer (see **Figure 2**) are built and mounted on Veroboard of the copper-strip variety. It simplifies construction

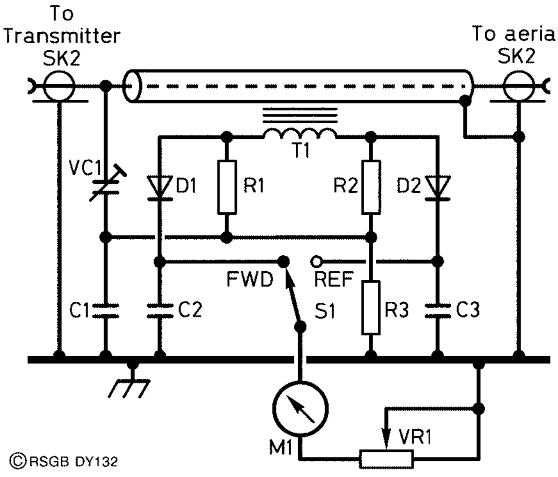

Figure 1 Circuit diagram of the SWR meter

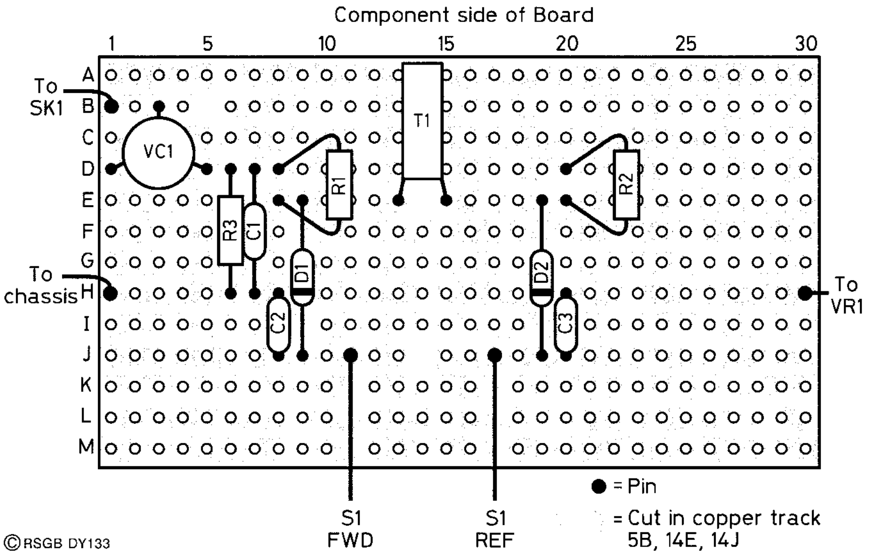

Figure 2 Component layout of the SWR meter

but reduces the operational range of the meter to below 30 MHz because of the capacitive coupling between strips. The board has 13 strips by 30 holes, although you can reduce this if you have a smaller case.

Firstly, cut the tracks at the three points shown. Then insert and solder Veropins for connections to the external components, the switch, variable resistor and the meter. Solder in the components starting with the resistors and followed by the capacitors and the diodes, ensuring that the diodes are inserted correctly.

Now you have to wind the transformer, T1, on a small toroidal ferrite core. Wind the secondary with 15 turns of 36 SWG enamelled copper wire, spaced evenly over about two-thirds of the former. The turns should not overlap, and considerable care must be taken; the wire is very thin, will kink easily and will break if you apply too much tension. The 'primary' is an 8 cm length of 50 Ω coaxial cable which passes through the toroid on its way between the input and output connectors. The braid of the cable is connected to the case at only *one* of the connectors (see Figure 1); this prevents the screen and the metal case between the two sockets forming a single, shorted turn.

The ends of the secondary winding must be carefully stripped of their enamel with sandpaper, before attaching the toroid to the board with cotton or nylon fishing line. On no account must wire be used for this!

Solder the secondary connections of T1 to the board and thread through the coaxial cable ready for soldering to the connectors.

The case used was an aluminium box (Maplin LF02C), but any suitable metal box could be used. Aluminium is preferable, as it is easily drilled with simple tools. Use standoff insulators to mount the board in the case. Once this has been done, the leads from the board to the chassis-mounted components can be soldered. So can the coaxial cable passing through the toroid. Make the lead from the input socket to VC1 as short as possible.

Setting up

You will need a 50 Ω dummy load and a transmitter to set up your indicator. Connect the transmitter to SK1 and the dummy load to SK2. Set the toggle switch, S1, to *forward* and the sensitivity control, VR1, to mid-travel. Switch on the transmitter, and set VR1 for maximum meter deflection. Switch to *reflected* and adjust VC1 until the reading is minimum (ideally zero). This completes the setting up!

Using the indicator

For setting up an aerial, connect your circuit between the transmitter and the cable leading to the aerial. With S1 in the *forward* position, key the transmitter and adjust VR1 for maximum reading on the meter. Switch to *reflected*, and then adjust your ATU to give minimum reflected power. If your adjustments are to be made to the aerial itself, to give minimum reflected power, you must make a note of the reflected reading, switch off the transmitter, make a change to the aerial, key the transmitter, and note whether the reflected power is greater or less than before. Then, make more changes to the aerial. **Never adjust your aerial with the transmitter on**. Make your adjustments on an unused frequency, and do it as quickly as possible, thus avoiding (or minimising) interference to other stations.

Parts list

Resistors: all 0.25 watt, carbon 5% tolerance
(or Maplin 0.6 watt metal film)

R1, R2	27 ohms (Ω)
R3	2.2 kilohms (kΩ)
VR1	10 kilohms (kΩ) linear

Capacitors

C1	220 picofarad (pF) disc ceramic 50 VDC
C2, C3	0.1 microfarad (μF) disc ceramic 50 VDC
VC1	20 picofarad (pF) trimmer

Semiconductors	
D1, D2	OA91 germanium
Additional items	
S1	Single-pole changeover (SPDT or SPCO)
SK1, SK2	Coaxial sockets to suit station standards
	Veroboard – 13 strips by 30 holes
	Veropins (7 off)
	Amidon FT 50–43 ferrite toroid
	Meter, less than 200 μA FSD
	36 SWG enamelled copper wire
	Short length of UR43 or RG58 coaxial cable
	Insulated stranded wire
	Aluminium box
	Standoff insulators for mounting the board
	Knob for the sensitivity control

51 A moisture meter

Introduction

Dry rot (*Merulius Lacrymans*) can strike havoc in buildings, causing the timbers to decay and crumble to dust – hence the term *dry rot*. Wood is attacked only if its moisture content rises above 20%.

Construction

The circuit of the moisture meter is shown in **Figure 1**. The two probes touch the wood, and the current that flows between them depends on the moisture content of the wood. If the moisture is sufficiently high, the current, after amplification, will be enough to light the LED.

The meter can be made on a piece of plain matrix board (no copper strips), as **Figure 2** shows. The board is big enough (10 cm by 2.5 cm) to accommodate the PP3 battery, taped on. No case is needed, unless you want

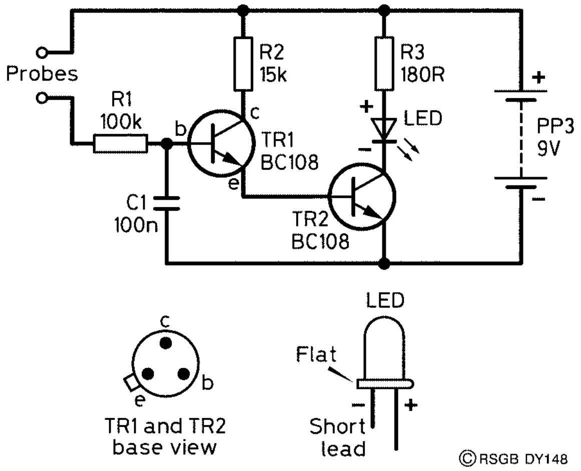
Probes
R1
100k
b
R2
15k
c
TR1
BC108
e
C1
100n
R3
180R
+
LED
−
TR2
BC108
+
PP3
9V
−
c
e
b
TR1 and TR2
base view
LED
Flat
−
+
Short
lead

©RSGB DY148

Figure 1 Circuit diagram of a moisture meter

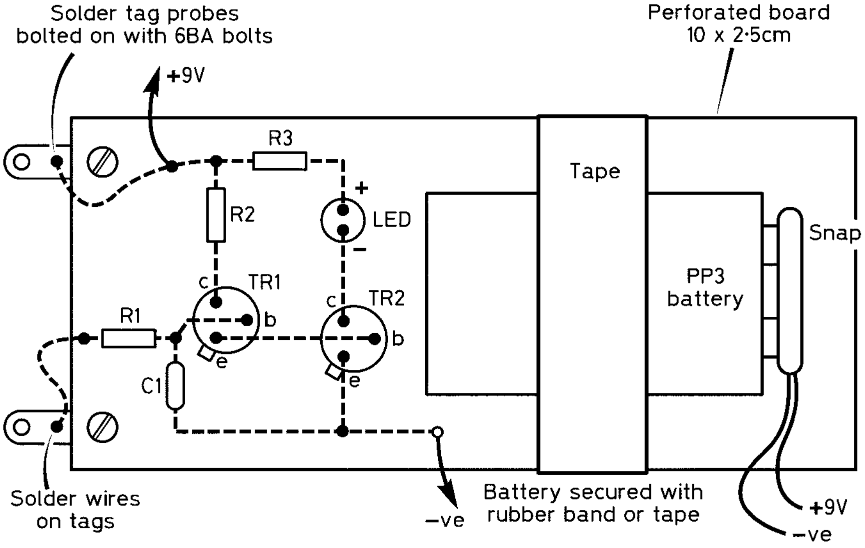
Solder tag probes
bolted on with 6BA bolts
+9V
R3
+
LED
−
R2
c
TR1
b
e
R1
C1
c
TR2
b
e
Tape
PP3
battery
Snap
Perforated board
10 x 2·5cm
Solder wires
on tags
−ve
Battery secured with
rubber band or tape
+9V
−ve

©RSGB DY149

Figure 2 Moisture meter, component layout

to leave the meter in a damp location for a protracted period! Make sure that the transistors and LED are mounted correctly. In Figure 2, the connections as shown to TR1 and TR2 are illustrated as if the transistors were transparent. An on/off switch is not really necessary, as only a very small current flows when the probes do not touch anything. Use solder tags, screwed to the board, to act as probes.

After the assembly is completed, check your circuit one final time, and then connect the battery. Nothing should happen at first. If you lick your forefinger and hold it across the probes, the LED should light.

Using it

The prototype was compared with a commercial moisture meter, and the LED lit when the moisture was around 20%. This was quite fortuitous, as the point at which the LED lights depends both on the separation of the probes and on the gain of the two transistors.

In addition to searching for dry rot, the instrument may be used to monitor the moisture in the soil of household plants. In this case, probes made of 16 SWG copper (*not* enamelled) should be soldered on to the two tags, and should penetrate the soil to a depth of several centimetres, and R1 may require adjusting so that the LED extinguishes if the soil is too dry, and lights if the soil is sufficiently moist. If you wanted to leave the meter with the probes in the soil, an on/off switch *would* be necessary.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	100 kilohms (kΩ)
R2	15 kilohms (kΩ)
R3	180 ohms (Ω)

Capacitor

C1	0.1 microfarad (μF) polyester

Semiconductors

TR1, TR2	BC108
LED	Any shape or colour will do

Additional items
- PP3 battery and connector
- Solder tags (2 off) for probes
- Matrix board 10 cm by 2.5 cm

52 Simple aerials

Introduction

The performance of *any* receiver or transceiver, no matter how expensive it is, is limited by the aerial that feeds it. Two of the most frequently asked questions are:

- Which is the best sort of aerial to use?
- Where is the best place to locate an amateur radio aerial?

To answer these questions, you must ask yourself what sort of operation you want to do. Are you interested in local, chatty contacts on the lower bands or VHF, or are you more disposed towards long-distance (DX) contacts, and on what band?

A house with a moderately sized garden is assumed in the diagrams here, to illustrate the configurations of some simple aerials. You would not need all these aerials festooned around your house, because one or two would be sufficient for your needs. The problems incurred by properties with more restricted space will be covered later.

VHF aerials

For VHF operation, the aerial should be mounted as high as possible, either on a mast or on a chimney. For all-round coverage on FM and the local repeaters, a vertical colinear is a good choice. For SSB and CW DX operation, a horizontal rotatable beam is needed. If satellite working is envisaged, you will need to contemplate mounting an elevator on top of your rotator, so that your beam can point in *any* direction, including vertically upwards! An advantage of satellite working is that the aerials do not *necessarily* have to be up in the air, provided you have a relatively uncluttered site. Your rotator and elevator can be at ground level, which is good!

If the VHF aerial is mounted on the chimney, use a double mounting bracket, particularly if you have a beam and rotator. Keep the TV, broadcast FM and amateur aerials as far apart as possible, and keeping the feeders separated is also a good plan.

The dipole aerial

One of the simplest types of aerial for single-band operation is the half-wave dipole. (The name ‘dipole’ simply means ‘two poles’ or ‘two elements’, and

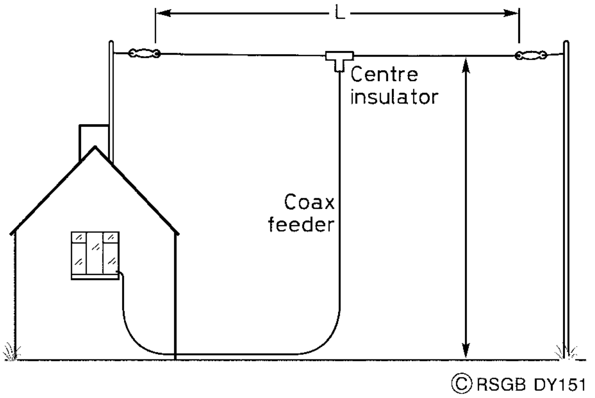

Figure 1 Layout for a dipole aerial

in this case the total length of the dipole is approximately half a wavelength at the operating frequency.) It is usually fed in the centre by coaxial cable as shown in **Figure 1**. The length of the dipole for the lowest frequency in each band is shown in **Table 1**. Normally, the length of the aerial will be 'trimmed' to be tuned to the centre frequency of the part of the band in which you will operate. This is done using the data in the right-hand column of Table 1. As an example, suppose you wanted your aerial to be resonant at 3.7 MHz. The table gives an overall dipole length of 42.86 m for 3.5 MHz. To resonate the aerial 200 kHz *higher*, then this length must be shortened by 2 × 0.595 m = 1.190 m. Your dipole would thus be 41.67 m long. Remember to allow extra wire for fixing the dipole ends to the insulators.

Table 1 Dipole lengths for lowest frequency of each band and the length to be trimmed from each to raise the resonant frequency by 100 kHz

Band (MHz)	*Dipole length (m)*	*Trim each end (mm/10 kHz)*
1.8	83.33	2190
3.5	42.86	595
7	21.43	150
10	14.85	70
14	10.71	35
18	8.33	20
21	7.14	15
24	6.03	12
28	5.36	10
50	3.00	6

On the lower-frequency bands, the lengths become rather large. In this case, you can 'bend' your dipole, as illustrated in **Figure 2**. The length of wire required to give an acceptable value of SWR (less than 2:1 on transmit) may need to be different from the calculated value, so be prepared to experiment!

Dipoles are single-band aerials, although they will often work acceptably on the third harmonic of their design frequency: a 7 MHz dipole often operates reasonably well on 21 MHz. It is possible to operate several dipoles in parallel, as **Figure 3** shows. Interaction between the elements can occur if the spacing between them is less than about 10 cm. A multi-band dipole, as shown in Figure 3, has the elements separated with plastic spacers, and drooping ends to produce maximum spacing between the elements' ends.

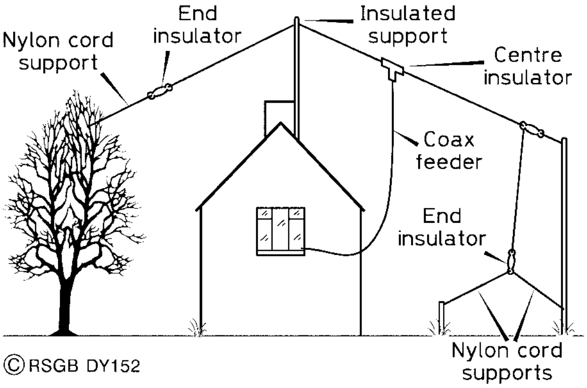
End insulator
Insulated support
Nylon cord support
Centre insulator
Coax feeder
End insulator
Nylon cord supports

©RSGB DY152

Figure 2 Possible layout for a dipole aerial in a confined space

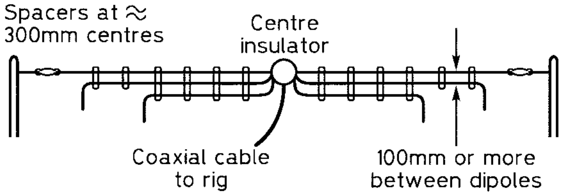
Spacers at ≈ 300mm centres
Centre insulator
Coaxial cable to rig
100mm or more between dipoles

©RSGB DY153

Figure 3 Multi-band dipole aerial

The long-wire aerial

This aerial is simple, cheap, easy to erect, and suits most houses and gardens, as **Figure 4** shows. Using an aerial tuning unit (ATU), an end-fed long wire can function on several bands when used with a set of radials or a counterpoise. **Figure 5** illustrates the setup. The length of the aerial will determine the bands which will be covered.

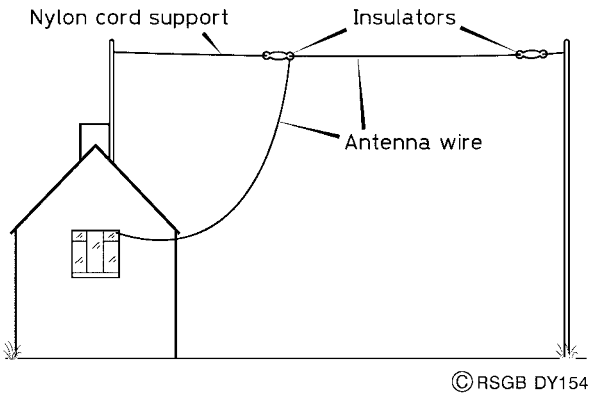
Nylon cord support
Insulators
Antenna wire
©RSGB DY154

Figure 4 Long-wire or inverted-L aerial

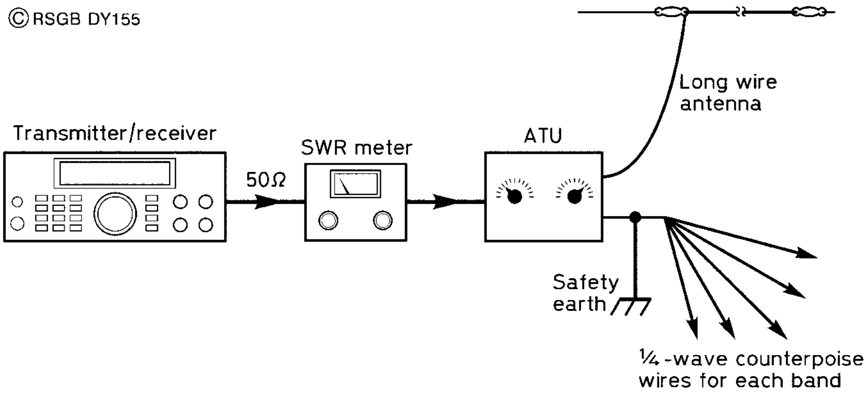
©RSGB DY155
Long wire antenna
Transmitter/receiver
SWR meter
ATU
50Ω
Safety earth
¼-wave counterpoise wires for each band

Figure 5 How to connect a radio to a long-wire aerial

A wire length of 10.5 m will work on the 40, 30, 17, 15 and 12 m bands.

A wire length of 15.5 m will work (with an ATU) on the 80, 40, 20 and 12 m bands and possibly (depending on your ATU) on the 17 and 15 m bands.

A wire length of 26.5 m will operate on all bands, but may be difficult to load on 10 m.

The wire lengths given here may need some adjustment because of the geometry of your particular house and garden. For receive-only purposes, the lengths are far less critical.

In general, you cannot get a good radio-frequency (RF) earth from a first-floor (or higher) shack. Unless a good RF earth exists within a small fraction of a wavelength of the transceiver, an *artificial ground* comprising a single $\frac{\lambda}{4}$ radial or counterpoise will be needed. You will need one counterpoise for each band you intend to use, and the wire can be concealed around the skirting-board of the shack, or under the carpet. Make sure that the free end

Table 2 Lengths of elements for vertical antennas, radials for verticals and counter-poises for end-fed long wire antennas

Band (MHz)	*Element length (m)*
1.8	39.66
3.5	20.40
7	10.20
10	7.14
14	5.1
18	3.96
21	3.4
24	2.95
28	2.55

of each counterpoise is well insulated; this point can carry a *very high voltage* when you transmit; anyone coming into contact with this can suffer very severe RF burns. Counterpoise lengths can be read from **Table 2**.

The vertical aerial

The single-band vertical aerial is sometimes used by DX operators because it has a low angle of radiation, which favours long-distance propagation. However, it must be sited clear of obstructions and must have a *good* counterpoise or radial system. Illustrations of the vertical aerial are shown, and the lengths of the vertical and radial sections are given in Table 2. The centre of the coaxial feeder is connected to the vertical section, and the braid to the counterpoise or radial system, which is made up of four or more wires buried just below the surface and joined together near the base of the aerial.

Cable entry to the house

Bringing coaxial cable into the house by an open window must be regarded as a temporary measure. Wooden window frames can be drilled, one hole for each feeder. Make the holes slope downwards from inside to out to prevent rain entering, and treat these with wood preservative. Leads from long-wire and inverted-L aerials should be kept separate from other cables.

Alternatively, a plastic pipe large enough to take all your feeders could be fitted into the brickwork (again, sloping downwards towards the outside). You may want to let a friendly builder do this for you.

53 A breadboard 80 m CW transmitter

Introduction

In the early days of radio, many circuits were built on a wooden baseboard, the parts being screwed down on the board. This was called breadboard construction, because it was a breadboard that was frequently commandeered for the process! Wives have always been generous in this respect, it appears!

This circuit was originally designed by GM3OXX, and became known as the *Oner*, because it was built on a circuit board one inch square! The circuit appeared in the G QRP Club journal *Sprat* and, since that time, many hundreds of *Oner* circuits have been built and used on the air. It is a well-proven circuit.

The transmitter has no tuned circuits in the power amplifier (PA) and thus has a rather high *harmonic* content. It **must** be used with the ***low-pass filter*** described elsewhere in this book. Without the low-pass filter, interference will be caused to other stations.

Simple aerial changeover switching is provided, which allows this circuit to be used with any of the 80 m receivers, such as the *Colt*, described in this book. It can also be used with any kit or commercial receiver for the 80 metre band.

The circuit

The transmitter circuit is shown in **Figure 1**. TR1 is a crystal oscillator, the frequency of which is controlled by crystal X1. A small trimmer capacitor, TC1, is added to allow the frequency of X1 to be varied by a small amount. If adjustment of this trimmer is made possible from the front panel, it is useful to adjust the transmit frequency to avoid other stations already on the crystal frequency. The collector load resistor, R2, of the oscillator transistor, TR1, determines the power output; a value of 3.3 kΩ seems to work well in producing an output of 3 watts.

TR1 is directly coupled to TR3, a VMOS transistor (a type of field-effect transistor (FET)). This acts as the power amplifier (PA) stage. TR3 should

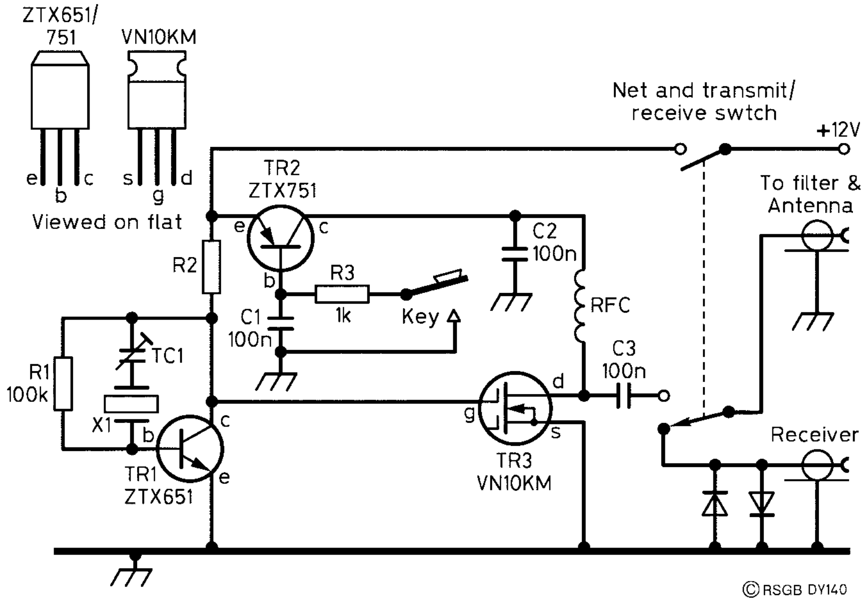
ZTX651/
751
VN10KM
e
b
c
s
g
d
Viewed on flat
Net and transmit/
receive swtch
+12V
TR2
ZTX751
To filter &
Antenna
e
c
C2
100n
R2
b
R3
RFC
C1
100n
1k
Key
C3
100n
R1
100k
TC1
X1
d
g
s
c
b
TR1
ZTX651
e
TR3
VN10KM
Receiver
©RSGB DY140

Figure 1 Circuit diagram of the breadboard transmitter

give about 3 W output, which is then coupled to the output by C3. The radio-frequency choke (RFC) providing the drain load of TR3 is simply a few turns of wire on a ferrite bead.

TR2 is an interesting addition to the circuit. It is used as a switch to 'key' the PA, TR3. The transmitter *could* be built without TR2, just placing the Morse key between the top of the RFC and the 12 volt supply. Adding TR2 is helpful, because it means that one side of the Morse key can be grounded (always a good thing), and some degree of *shaping* of the output RF waveform is provided by R3 and C1. This makes the transmission sound a little better and reduces the possibility of spurious frequencies being generated and transmitted. TR2 is a pnp transistor; note that it is the *emitter* of this transistor which is connected to the positive side of the supply.

Some form of changeover switching is needed for the aerial. A double-pole changeover toggle switch can be used. See the chapter on switches, later on in this book. One pole is used to switch the aerial between transmitter and receiver; the other pole is connected in the 12 volt supply line, and is labelled RECEIVE/TRANSMIT – NETTING. Its use will be described later. In this simple circuit, the PA cannot work when the key is open, because the key breaks its supply (via the RFC). When the key closes, TR2 switches on and applies the 12 volt supply to the top of the RFC. C2 is a *decoupling* capacitor, which prevents any residual RF signals at the top of the RFC reaching TR2.

Building

The prototype was put together as follows. Take a piece of plain printed-circuit board (PCB) measuring 5 cm by 4 cm. Then, with a *new*, *sharp blade* in a junior hacksaw, draw the blade horizontally across the surface of the copper in order to make a pattern of 6 squares along the 5 cm side and 5 squares along the 4 cm side. No more pressure should be applied than is necessary to cut through the copper! All the parts will be soldered on these pads in a form of surface-mount construction. To do this, each active pad (i.e. one that is going to have a component soldered to it) needs to be *tinned*. This means coating the pad's surface with solder, and is carried out as follows. Place the hot tip of the soldering iron on to the pad, and hold it there for a second or so. Then, with the tip still in place, touch the end of your reel of solder *on the pad*, not the tip of the iron. The solder should flow evenly all over the pad, and you can remove the iron. The solder should solidify in a rounded, shiny blob! This provides a good surface for making soldered joints.

To join component leads to the pads, cut each lead about 1 cm long, and then bend the last 2 mm at right angles to the rest of the lead. As you did before, tin the 2 mm length of each lead. Place the tinned portion on to the pad, and place the tip of your iron *on the pad*, close to the lead. The solder on the pad and on the lead will melt and run together; remove the iron and *hold the component still* until the solder solidifies. When the joint has cooled, give the lead a gentle tug to make sure you have a good joint (a good *mechanical* joint is usually a good *electrical* joint, too!). Each transistor straddles three pads, so the centre lead will need to be shorter than the other two. Take care here to get the lead lengths right – if you do, you will be surprised how much more firmly the transistor is held than if you just botched the lead lengths by bending them to fit! Make sure the connections to the transistors are correct.

Winding the RFC is quite simple. Seven (or more) turns of thin (32 SWG) enamelled copper wire are threaded through a small ferrite bead. This requires care, because the bead is small and the wire is thin. Trim the ends to within about 1 cm of the bead, remove the enamel carefully with sandpaper and tin the bare ends, prior to soldering the choke to the board.

After completion of the wiring, check the circuit against Figure 1. Bread-boarding a circuit like this has its advantages, but it can have disadvantages, too. One of these disadvantages is that it can make circuit checking difficult. For a simple circuit like this, it is not too bad! Check that no solder has run between the pads. Plug in your crystal for the 80 m band, and connect up the 12 V power supply. Do not connect the Morse key yet and do not switch on the power.

Testing and operating

Clear your workbench of all metallic objects, slivers of copper, bits of wire, etc., switch on your power supply. With an external receiver, listen on and around your crystal's frequency for a signal. Remember that the oscillator runs all the time and, because you haven't yet connected the Morse key, your receiver is close enough to pick up the signal from the oscillator. This confirms that your oscillator is running. Switch off.

Connect the station aerial to the transmitter's aerial socket, and the receiver to the transmitter's receiver socket. Connect the Morse key, put the Receive/ Transmit–Netting switch in the receive position and switch on. You should be able to hear stations in the normal way. Now put the switch in the Transmit–Netting position. Signals in the receiver should almost disappear, as the circuit has disconnected the receiver's aerial.

Tune the receiver until you can hear your own crystal oscillator signal. This is known as *netting*, tuning your receiver and transmitter to the same frequency. Pressing the key will now transmit your signals when the switch is in the Transmit–Netting position; switch back to the receive position to listen for stations answering your call. As soon as you are happy that your circuit is functioning properly, **you must build the low-pass filter circuit** before using the transmitter regularly.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	100 kilohms (kΩ)
R2	See text
R3	1 kilohm (kΩ)

Capacitors

C1, C2, C3	100 nanofarads (nF), or 0.1 microfarad (μF)
TC1	3–60 picofarads (pF) trimmer

Semiconductors

TR1	ZTX651
TR2	ZTX751
TR3	VN10KM

Additional items

RFC	7 turns of 32 SWG enamelled copper on a ferrite bead
Switch	Double-pole changeover (DPDT or DPCO) toggle
Crystal	For 80 m band
Crystal holder	HC25 type
Sockets	According to station fittings

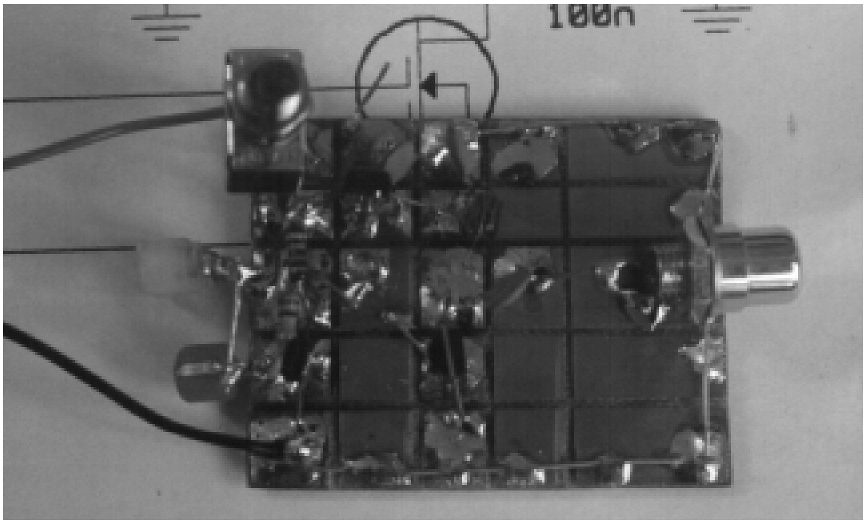

54 A 7-element low-pass filter for transmitters

Introduction

The simpler the transmitter, the more likely it is to radiate *harmonics* of its fundamental frequency. Harmonics are integral multiples of the frequency on which the transmitter is *designed* to operate. If you think you are transmitting on a frequency, *f*, for instance, you will also be radiating the harmonics of *2f*, *3f*, *4f*, . . . and so on. This results in your signals being heard on *several frequencies*, spread over a very wide frequency range. You are also contravening the terms of your licence. To avoid this, it is always advisable to use a *low-pass* filter between your transmitter and aerial. This is a filter which will *pass* your signal frequency, *f*, and all frequencies *below* it, but will *not pass* (attenuate) frequencies above *f* to any significant extent. The value of *f* is known as the *cutoff frequency* of the filter.

A design of 7-element low-pass filter

A 7-element low-pass filter (LPF) is so called because it has seven components, as the circuit diagram of **Figure 1** shows. Filters containing any odd number of elements are possible: a 3-element filter would

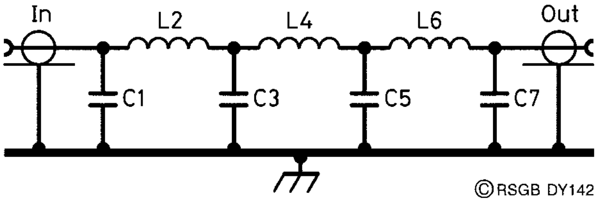

Figure 1 Circuit diagram of filter

comprise C1, L2 and C3 only, and is sometimes called a pi-network because the element disposition resembles the Greek letter pi (π); a 5-element filter would comprise C1, L2, C3, L4 and C5 only, and so on. In general, the more elements the filter has, the more effectively it attenuates signals above *f*.

The circuit of Figure 1 is designed to have an input and an output impedance of 50 Ω, which means that it can be placed in the aerial feed of any common transmitter. Filter design is a very complex business, and is best left to the experts. One such expert is W3NQN, who produced a number of computer designs of LPF using commonly available (*preferred value*) capacitors, and aimed specifically for use on amateur frequencies. The results of this work are condensed into **Table 1**. The inductors are wound on standard toroidal cores, and their details are included in the table.

Table 1 Filter component values for each brand

Band metres	*C1,7 pF*	*C3,5 pF*	*L2,6 turns*	*L4 turns*	*Core type*	*Wire SWG*
80	470	1200	25	27	T37-2	28
40	270	680	19	21	T37-2	26
30	270	560	19	20	T37-6	26
20	180	390	16	17	T37-6	24
15	82	220	12	14	T37-6	24
10	56	150	10	11	T37-6	22

Making the filter

The filter was made originally as an adjunct to the *Breadboard 80 m CW transmitter*, which you will also find in this book. It uses the same constructional technique, based on a single piece of plain, copper-clad

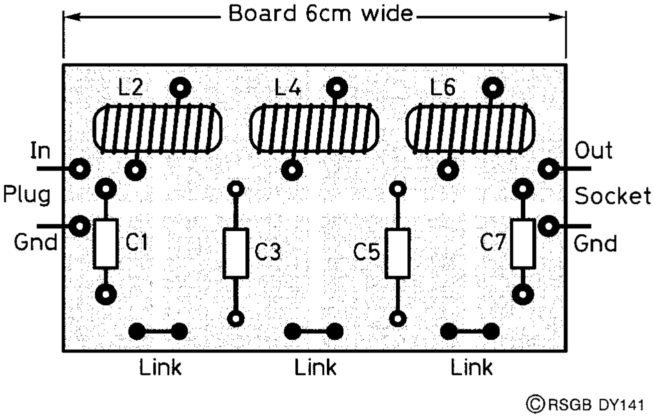

Figure 2 Layout and construction of filter

PCB, with 'pads' created by using a sharp blade in a junior hacksaw. The cuts in the copper are shown in the layout diagram of **Figure 2**. There are two ways of mounting the components: the first way is to drill small holes in each pad, as shown in Figure 2, and mount the components through the holes in the normal PCB manner; the second way is to solder the components directly to the pads, in the way that was described for the *Breadboard transmitter*.

Winding the inductors is quite simple. All you need to remember is that each time the wire passes through the core counts as one turn. Cut off the spare wire at each end of each coil to about 1 cm, scrape off the enamel with sandpaper, and tin the exposed copper. See the transmitter description if you are unsure of how to do this. Note the wire links between each of the lower pads, forming a solid 'ground' for the elements. The prototype had a plug and socket on the ends, to match the transmitter and aerial terminations.

The type of capacitor used in the design is not critical; the polystyrene type works well.

55 Radio-frequency mixing explained

Introduction

Mixers find widespread use in electronic circuitry. Many of the projects in this book, together with every TV set and radio in the home, contain mixer circuits – a good indication of their usefulness.

Confused?

Audio mixers (as used in recording studios and radio broadcast stations) are used to **add** or ‘balance’ the signals from various sources such as microphones, CD players, etc. These have nothing whatsoever to do with radio-frequency (RF) mixers, and should never be confused with them.

RF mixers and beat frequencies

Instead of **adding** signals (as in the audio mixer), the RF mixer **multiples them together**. As you might expect, this has an entirely different effect. The two signals entering the mixer *beat* or *heterodyne* with each other to produce *signals on other frequencies*. One example of this occurs in sound, when two musical notes of almost the same frequency are heard together. Instead of hearing two separate notes, the listener hears one note whose *intensity* (*loudness*) appears to increase and decrease. This intensity variation is called a *beat*, and its frequency is equal to the difference in the frequencies of the two original notes. The technique is used by musicians to tune their instruments. If one note is known to be a correct frequency, the other can be tuned to it by making the beat frequency as close to zero as is possible.

Multiplying together

The process of mixing presupposes that we have a device which will automatically multiply two signals together. Fortunately, this is easy; so easy, in fact, that it often occurs when we do not want it! Multiplying is achieved by any device which is *non-linear*; this means a device whose output is not a constant factor larger than its input, something that can be achieved by many electronic devices and circuits.

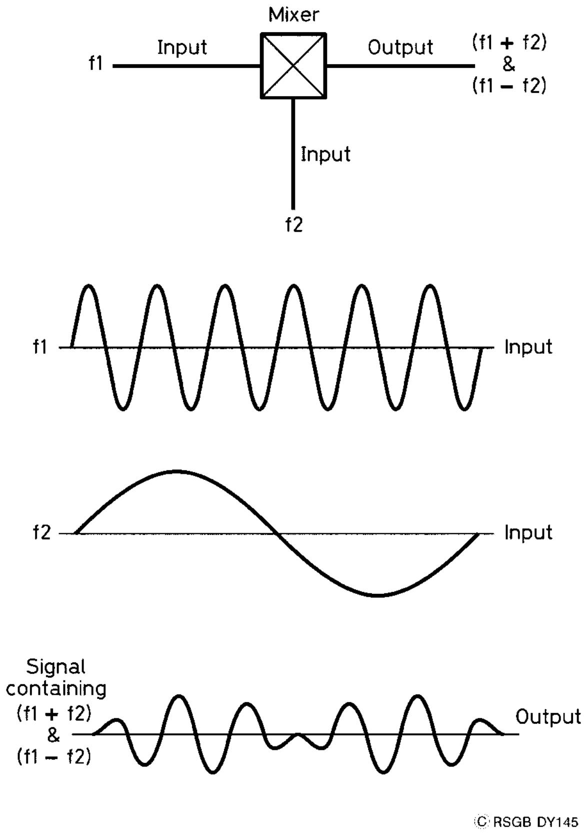

Figure 1 The effect of multiplying (or mixing) two signals together

Let us look now at what a mixer does in concrete terms. Suppose two signals, of frequencies *f*1 and *f*2 go into our mixer. These signals are shown in **Figure 1**. Putting numbers in, to make the situation clearer, suppose *f*1 is 1.000 MHz and *f*2 is 160 kHz. The beat frequency is the *difference* of these: 1.000 MHz – 0.160 MHz = 0.840 MHz, or 840 kHz. A mixer *also* produces an output at the *sum* of these frequencies; in this case the new frequency would be 1.000 MHz + 0.160 MHz = 1.160 MHz.

Suppose you fed the output of your mixer, operating with these input frequencies, into a receiver and tuned around to find what frequencies were present. You would find two signals, one at 840 kHz and one at 1.160 MHz, showing that the two 'new' frequencies were very real!

In addition to drawing out the waveform of the resultant signal, as in Figure 1, we can draw the inputs and outputs on a frequency axis, to form a *spectrum* of the signal components. This is done in **Figure 2**. The top two diagrams show the input signals at *f*1 and *f*2. The bottom diagram shows the output signals in relation to the input signals. Depending on the type of mixer used, one or both of the input signals would be removed.

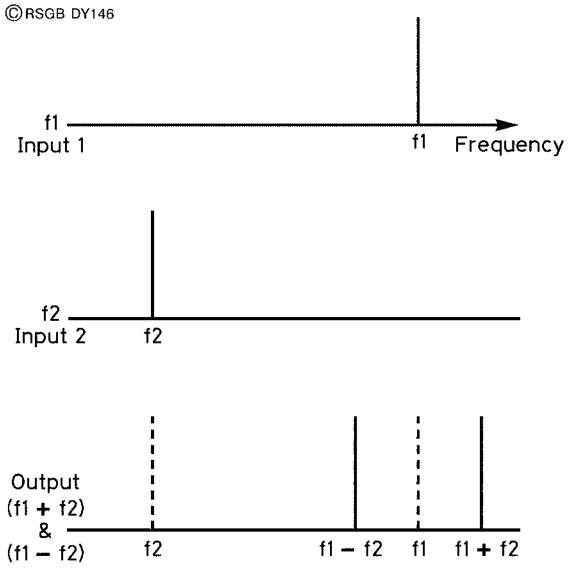
©RSGB DY146
f1
Input 1
f1
Frequency
f2
Input 2
f2
Output
(f1 + f2)
&
(f1 − f2)
f2
f1 − f2
f1
f1 + f2

Figure 2 The result of multiplying or mixing two signals together as seen on a spectrum analyser

A mixer in every radio

Basically, a mixer is used to change a signal from one frequency to another, something it does without altering the characteristics of the incoming signal. If the incoming signal is amplitude modulated (AM), then the frequency-changed signal would be AM also. The same applies to FM, SSB, CW, and all other modulation forms you can think of. This explains why mixers are often called *frequency changers*.

Frequency changing is the key process in the type of radio known as a *superheterodyne* (or *superhet*). By mixing the incoming signal with a variable-frequency *local oscillator* as **Figure 3**, shows, the signal can be converted to the fixed frequency of a filter and amplifier. This is useful

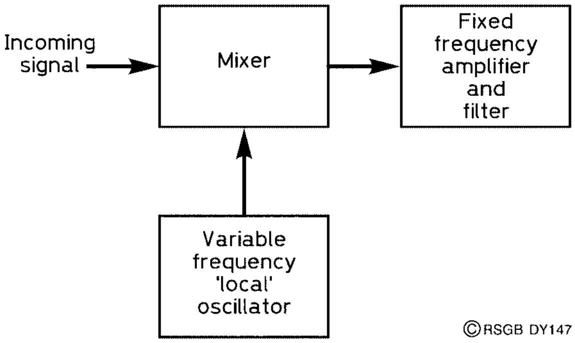
Incoming signal
Mixer
Fixed frequency amplifier and filter
Variable frequency 'local' oscillator
©RSGB DY147

Figure 3 The basic idea of a superhet receiver

because it is easier to make a very high-quality filter and amplifier at a single fixed frequency, than at a variable frequency.

All TV receivers and virtually all radio receivers (and transmitters) use mixers. Both the *Yearling* and *Colt* receivers (see the relevant projects) are superhets, and use mixers.

56 A voltage monitor for a 12 V power supply

Introduction

If for any reason, the stabilisation of your main 12 volt power supply unit (PSU) breaks down, it is possible that a voltage much higher then the nominal 13.8 V will be applied to your precious equipment. If you would like to know the instant that this occurred, and hence be able to switch things off before it was too late, then this circuit is what you need. It will give audible *and* visual indications if the voltage rises above 14.4 V, and a visual indication only if the voltage is reduced.

The circuit

The circuit uses three ICs and is shown in **Figure 1**. The circuit is powered by the PSU whose output is being monitored, and the circuit's immunity to supply line variations is secured by the 6 volt regulator, IC1. The heart of the circuit is IC2, an LM3914; it is a *bargraph driver*, which operates ten LEDs in a display resembling a thermometer – the string of lit LEDs increases in length as the voltage on pin 5 increases.

The input voltage range on pin 5 is 1.2 V maximum, making each LED correspond to one-tenth of this, which is 0.12 V, the *step size*. R1 and R2 act as a voltage divider, so that voltages of up to the maximum of 14.4 V may be applied to R1 without exceeding 1.2 V at pin 5. R3 sets the brightness of the LEDs and R4 determines the step size.

IC3 is an *opto-isolator*, a device containing an LED and a phototransistor in one package. This enables the piezoelectric sounder to operate without affecting the operation of the bargraph driver. The input to IC3 is provided by the voltage on D8, so that if any of the LEDs at or above D8 are lit, the

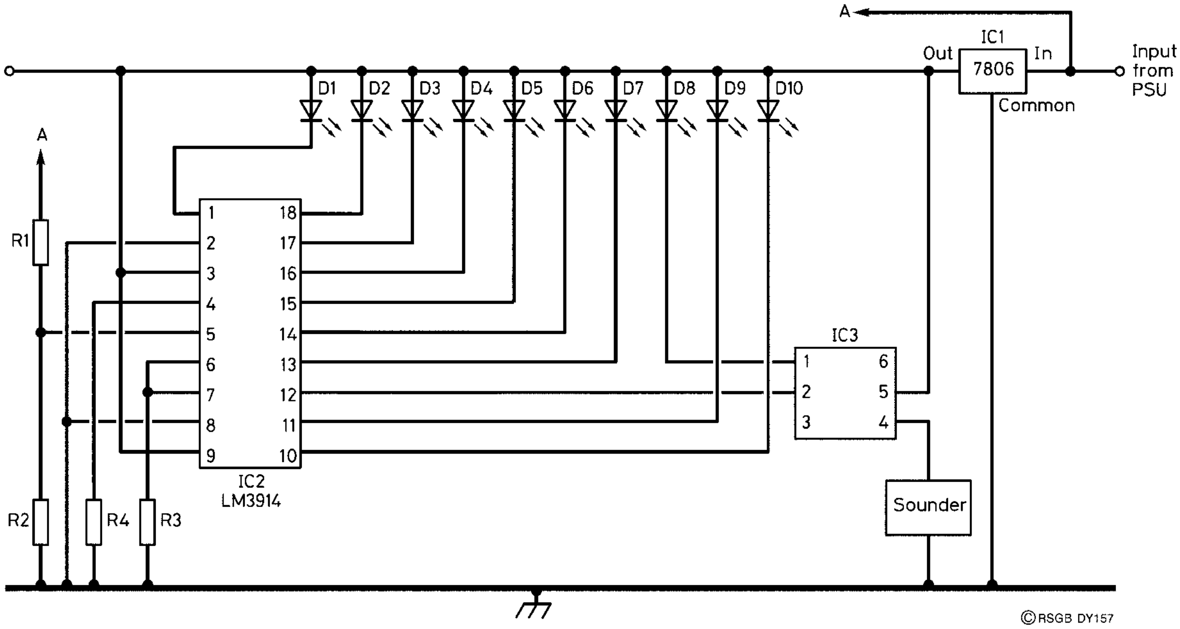
A
IC1
Out
In
7806
Input
from
PSU
Common
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
A
R1
1
2
3
4
5
6
7
8
9
18
17
16
15
14
13
12
11
10
IC2
LM3914
IC3
1
2
3
6
5
4
Sounder
R2
R4
R3
©RSGB DY157

Figure 1 PSU monitor, circuit diagram

sounder will operate, indicating overvoltage. Despite the fact that some of your other equipment might be damaged by this overvoltage, the monitor circuit itself is unaffected.

Construction

The prototype was built on two pieces of Veroboard of the copper-strip variety. The main (circuit) board measured 15 strips by 25 holes, and the display (LED) board measured 4 strips by 30 holes. Track cuts are necessary in each board. The correct places are shown for the main board in **Figure 2**, but there is sufficient flexibility in the layout of the display board for a prescriptive layout not to be needed. All the anodes of the LEDs are connected to the same strip, which makes things comparatively simple!

For the main board, insert the Veropins and the wire links first, and solder them to the copper strips. Then fit the IC holders and the resistors. Fit the IC holders with their notches towards the top of the board. When fitting the voltage regulator, IC1, note than the centre lead (the 'common' lead in Figure 1) does *not* go to position A3; the track should be cut at A3, and the common lead soldered at B3. This is indicated in Figure 2.

Wire up the LED board with its ten LEDs and 11 connecting wires, each about 10 cm long. This length depends on how far away from the main

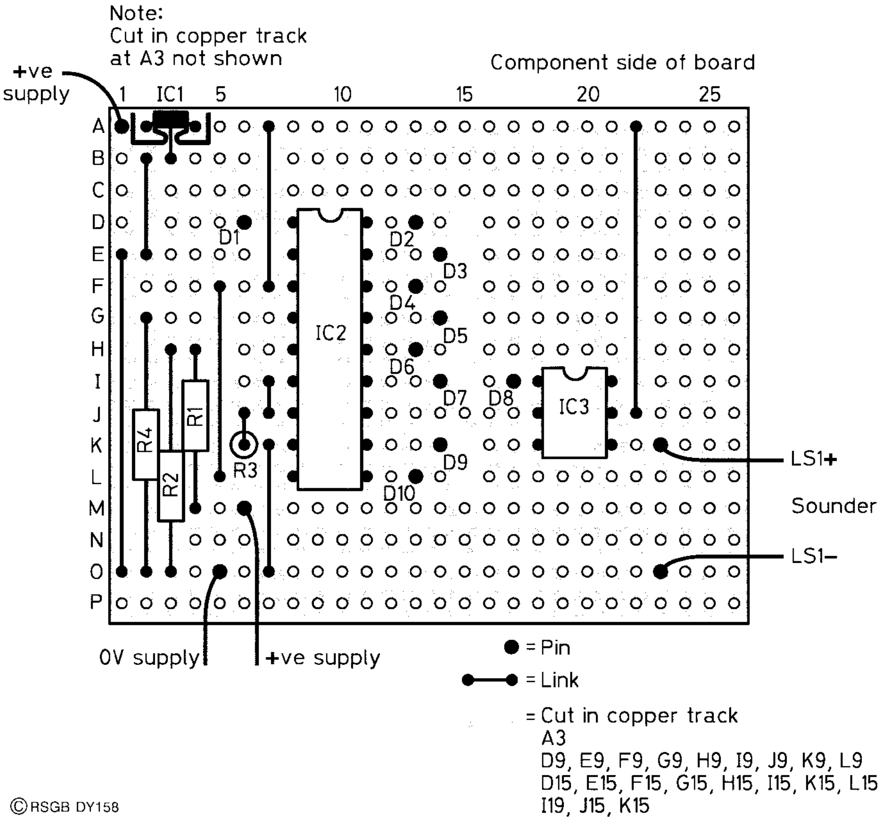
Note:
Cut in copper track
at A3 not shown
Component side of board
+ve supply
1
IC1
5
10
15
20
25
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
IC2
IC3
R1
R2
R3
R4
LS1+
Sounder
LS1−
0V supply
+ve supply
= Pin
= Link
= Cut in copper track
A3
D9, E9, F9, G9, H9, I9, J9, K9, L9
D15, E15, F15, G15, H15, I15, K15, L15
I19, J15, K15

Figure 2 PSU monitor, PCB layout

©RSGB DY158

board you are planning to mount the display. The LEDs should have different colours: three orange, four green and three red, to indicate ‘low’, ‘medium’ and ‘high’ voltage.

Now solder the other ends of these leads to the Veropins on the main board, making sure that the order is correct. Finally, connect the piezoelectric sounder to the main board; the polarity is important, so make sure the red lead goes to pin 4 of IC3 and the black lead to the ground rail. If you were careful to fit the IC holders with their notches in the correct positions, match these up with the notches on the ICs before pushing home the ICs *gently*. Check your circuit for solder bridges and unwanted pieces of copper swarf before screwing the small heat sink to the voltage regulator, IC1.

Testing

(a) **With a variable-voltage PSU**. Set the PSU for 10 V, connect the circuit and switch on. Increase the voltage slowly, and check that each LED lights up after the one before it. As the voltage exceeds about 14.4 V, the first red LED should light and the sounder should operate. If an LED does not illuminate, you should immediately suspect either a dry joint or an incorrect LED polarity. The voltage at which the first red LED lights can be adjusted by varying R1; increase R1 if the LED comes on too early; decrease R1 if the LED comes on too late.

(b) **Without a variable-voltage PSU**. For your 'variable supply', you can use several AA-type 1.5 V cells (or 1.2 V NiCad cells) in series. The voltages produced by a range of cells is shown in **Table 1** – because of the lower voltage of NiCad cells, more of them are needed to produce a given voltage.

Once the operation of the circuit has been checked, it can be fitted into a plastic or metal box. Only two connections are needed for the PSU. You may want to drill some holes in the case to increase the apparent loudness of the sounder.

Table 1 Test voltages available from batteries in series

No. of batteries	*Voltage, nicads*	*Voltage, dry cells*
7	8.4	10.5
8	9.6	12
9	10.8	13.5
10	12	15
11	13.2	–
12	14.4	–
13	15.6	–

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	11 kilohms (kΩ) – see text
R2	1 kilohm (kΩ)
R3	1.2 kilohms (kΩ)
R4	18 kilohms (kΩ)

Semiconductors

IC1	L7806
IC2	LM3914
IC3	Opto-isolator – Maplin code WL35Q
D1–D3	3 mm LED, orange
D4–D7	3 mm LED, green
D8–D10	3 mm LED, red

Additional items

LS1	Piezoelectric sounder, wire leads
	6-pin DIL socket for IC3
	18-pin DIL socket for IC2
	Veroboard – two pieces for main and display boards, see text for sizes
	Veropins
	Heat sink for IC1
	Single-core insulated wire for links
	Insulated stranded wire for interconnecting the boards
	Case as required

57 A 1750 Hz toneburst for repeater access

Introduction

Repeaters across the UK and much of Europe need an access tone to switch the transmitter from standby ready for use. Commonly, this is a 1750 Hz tone of duration no greater than half a second. Although many UK repeaters may now be accessed using the *continuous tone-coded squelch system* (CTCSS – see the *RSGB Yearbook*), you may wish to access a repeater whose CTCSS frequency you don't know; in this case, using the universal 1750 Hz tone will gain you access. Commercial transceivers are usually fitted with an automatic toneburst, but if you are using a home-made design, then you may want to incorporate this little circuit.

Warning

This circuit uses a member of the integrated circuit family known as CMOS (complementary metal-oxide semiconductor). These use very little current

and can be completed destroyed if they come into contact with the magnitudes of static electricity that most of us carry about when we walk on carpets and wear rubber shoes. You will never know if this wanton destruction has happened – all you will discover is that your circuit doesn't work and that you have tested *everything*. To avoid this problem do the following things:

1. **Before you open the little packet in which the IC is supplied, touch something which you *know* to be earthed – the metalwork of any equipment which is mains earthed, for example. Then open the packet.**
2. **Let the IC fall gently on the bench – don't pick it out with your fingers. Touch your earthed metalwork again. Pick up the IC and insert it gently into its holder.**

The circuit is safe from destruction while it is connected to the battery.

Circuit description

The circuit is shown in **Figure 1**. The tone is generated by an integrated circuit oscillator (IC1), whose frequency is controlled by a *ceramic resonator*, XL1. Its frequency is very high, and is divided down to the 1750 Hz needed by the same chip. The ceramic resonator is designed to operate at 455 kHz, the intermediate frequency of many receivers. Because all divider circuits use powers of 2, we need the oscillator to run at 448 kHz so that when it is divided by 256 ($256 = 2^8$), we end up with 1750 Hz. Try it on your calculator:

$$\frac{448\ 000}{256} = 1750.$$

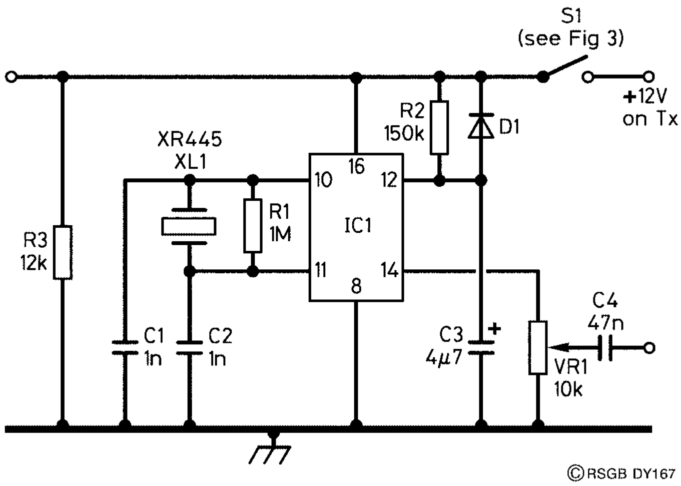

Figure 1 Toneburst module, circuit diagram

We use C1, C2 and R1 to *pull* the frequency of the oscillator away from 455 kHz to 448 kHz. The divider chain has eight *counters* in it, and each counter divides the frequency of the signal it sees by two, giving the final division of 256.

This counting process can be stopped at any time by taking the voltage on the *reset* pin (pin 12) up to the supply voltage. When the circuit is switched on by closing S1, pin 12 is at 0 V because C3 is discharged. The oscillator runs, producing the output frequency of 1750 Hz. As time progresses, C3 charges up through R2 and the voltage on pin 12 rises. When this has risen sufficiently, and in a time determined by the values of C3 and R2, the counter resets and stays in the reset state; no division takes place and there is no output. The duration of the toneburst is thus governed by C3 and R2.

When S1 is opened, the circuit is switched off, and C3 is discharged through D1 and R3, ready for the next toneburst. If you have used a repeater, you will know that a toneburst is needed **only** to activate a repeater in the standby condition; it is not needed once a contact has been established.

VR1 adjusts the amplitude of the tone fed to the microphone, and C4 prevents any voltage that may be present on your microphone connector from damaging the integrated circuit.

Construction

The prototype circuit was built on Veroboard of the copper-strip variety, measuring 20 holes by 14 strips. The layout is shown in **Figure 2**. Make the track cuts first, and check that there are no slivers of copper wedged between adjacent tracks. Then, solder in the IC socket (with the notched end

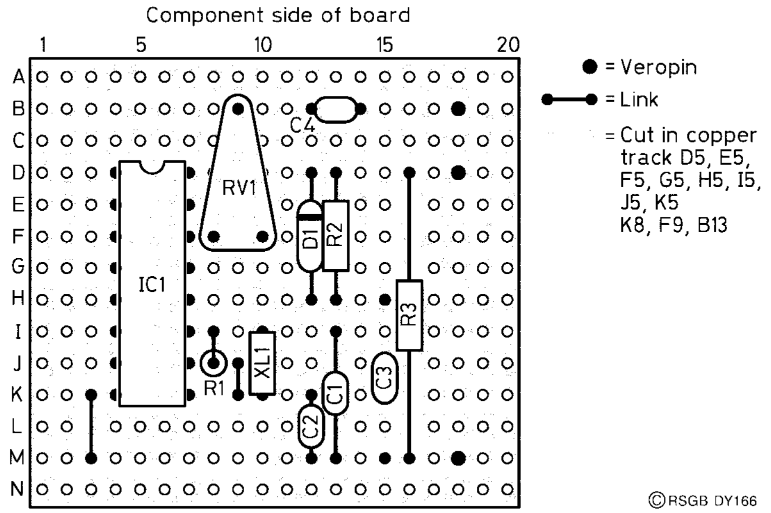

Figure 2 Veroboard component layout

facing towards track A), the wire links and the three Veropins. Having done this, solder in the resistors, capacitors and diode, making sure that D1 and C3 are the right way round! Using your best soldering technique, solder in the ceramic resonator quickly, to prevent heat damage. Recheck your circuit, check for solder splashes and bridges, and then gently insert IC1 into its socket, matching up its notch with that of the socket.

Testing

Set VR1 to half-way and connect a crystal earpiece to the output; apply power to the circuit. You should hear the tone, lasting for about half a second. If there is no tone, disconnect your circuit from the power supply, and check for dry joints in the vicinity of pin 12. Is the diode, D1, the correct way round? Is C3 the correct way round? Did you choose to ignore the CMOS safety precautions given earlier?

Once the circuit is working, you need to decide how you are going to connect it to your transmitter. Two options are shown in **Figure 3**. If you have access to a point in your transmitter circuit that has between 9 V and 12 V positive on it during transmit, you can use this to power your circuit. As the toneburst is needed only for repeaters, the switch, S1, disconnects it when not needed, as shown in Figure 3a. If you want the circuit to be self-powered, then a 9 volt PP3 battery may be used; Figure 3b shows this configuration.

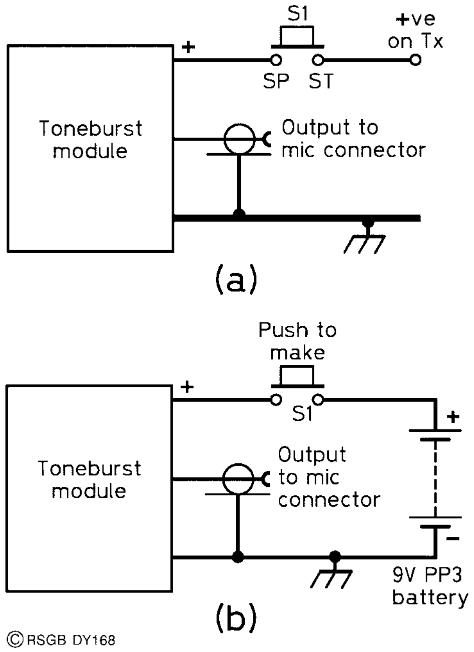

Figure 3 Toneburst module: two alternative switching arrangements

The output from the circuit board is fed directly into the microphone socket, in parallel with the microphone itself; use thin coaxial or screened cable for this lead, or you may induce hum into the microphone circuit and suffer from RF breakthrough into the audio circuits. To adjust the setting of VR1, start with it at the zero output position and connect a dummy load to your transmitter. Slowly, increase the output while monitoring your transmitted signal on another nearby receiver. Make sure you do **not** increase the output so far that the signal sounds distorted. If you would prefer that the tone was on continuously while you made this adjustment, simply connect a wire across C3 remembering, of course, to remove it as soon as you have completed the test!

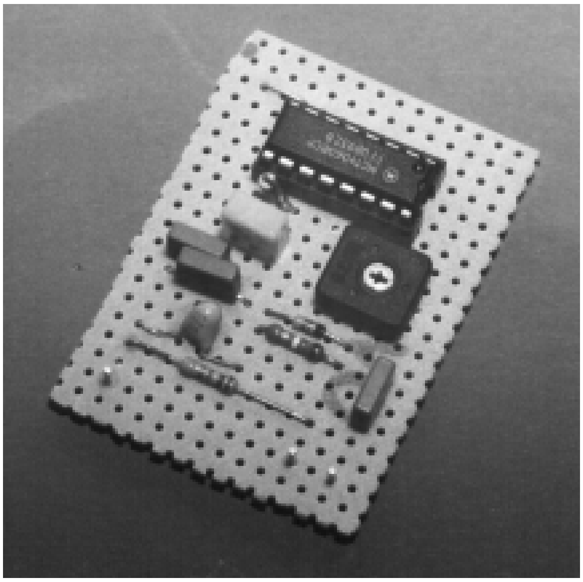

Parts list

Resistors: all 0.25 watt, 10% tolerance (or better)

R1	1 megohm (MΩ)
R2	150 kilohms (kΩ)
R3	12 kilohms (kΩ)
VR1	10 kilohms (kΩ) horizontal preset

Capacitors: all 16 V WKG or higher

C1, C2	1 nanofarad (nF) disc ceramic
C3	4.7 microfarad (μF) tantalum bead
C4	47 nanofarads (nF) disc ceramic

Semiconductors	
IC1	4060
D1	1N4148
Additional items	
XL1	XR455
	Veroboard (see text for size)
	Veropins (3)
S1	Switch (momentary action push-to-make SPST)
	16-pin DIL socket for IC1
	Single-core insulated wire for links
	Coaxial or screened cable for microphone connection

58 A circuit for flashing LEDs

Introduction

There are many occasions when one's attention needs drawing to the fact that something important has happened. A single red light coming on is seldom sufficient to attract attention, particularly if it is surrounded by other lights and indicators. The eye is known to be very sensitive to *changes* in its peripheral vision; such changes can be brought about by movement or by differences in light level – a flashing light, for example. So, a circuit that flashes a single LED or a pair of LEDs finds plenty of uses in the amateur station.

Warning

This circuit uses a member of the integrated circuit family known as CMOS (complementary metal-oxide semiconductor). These use very little current and can be completed destroyed if they come into contact with the magnitudes of static electricity that most of us carry about when we walk on carpets and wear rubber shoes. You will never know if this wanton

destruction has happened – all you will discover is that your circuit doesn't work and that you have tested *everything*. To avoid this problem do the following things:

1. **Before you open the little packet in which the IC is supplied, touch something which you *know* to be earthed – the metalwork of any equipment which is mains earthed, for example. Then open the packet.**
2. **Let the IC fall gently on the bench – don't pick it out with your fingers. Touch your earthed metalwork again. Pick up the IC and insert it gently into its holder.**

The circuit is safe from destruction while it is connected to the battery. However, when the battery is removed, the same care should be exercised with its handling, because there is no supply decoupling capacitor across the IC.

Basic description

LEDs can be made to flash (switch on and off) by driving them from sources that switch on and off. Such a source is an *astable multivibrator*. If you have built or read about *A basic continuity tester*, elsewhere in this book, you will have come across such a beast before. That circuit used an astable multivibrator made from two transistors. This new circuit achieves the same behaviour from a single integrated circuit, the CMOS 4011. To give it its full description, the 4011 is a *quad 2-input NAND gate*. Quite a mouthful, but all it means is that inside the chip are four NAND gates, each with two inputs.

A NAND gate needs a positive voltage (known as a *logic 1*) on *both* inputs in order to produce zero volts (known as *logic 0*) at the output. Two NAND gates can be connected, as are A and B in **Figure 1**, to make our astable multivibrator. The combination of A and B has been described as the most perverse circuit in electronics; as soon as the output goes to logic 1, the circuit decides that it would prefer to have a logic 0 there, and switches over. With logic 0 at the output, the circuit now prefers to have logic 1 there, and so it goes on! We are going to use this continuous switching backwards and forwards to flash two LEDs. The rate at which A and B 'change their minds' is the frequency at which our LEDs will flash, and is controlled by the charging and discharging times of C1 through R2 and C2 through R1. As the values of R1 and R2 are the same, and those of C1 and C2 are the same, the ON and OFF states of the circuit are the same.

Gates C and D do not contribute to the flashing action; they act as *buffers* to isolate the LEDs from the multivibrator circuit itself. You will find in electronics that an oscillator is seldom used to drive another device *directly*; there is usually a buffer between it and the stage it drives.

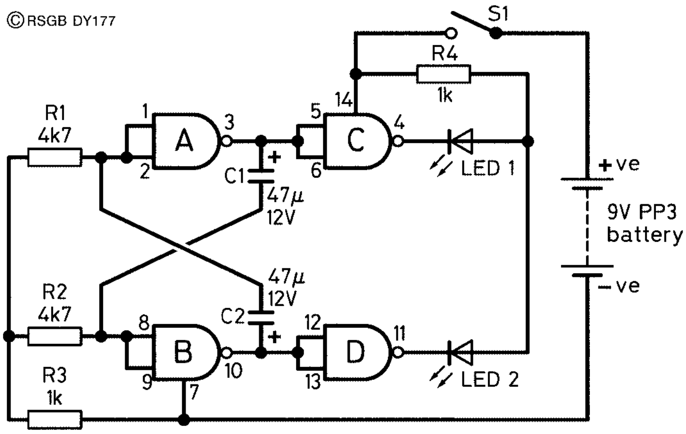

Figure 1 Flashing LEDs, circuit diagram

A characteristic of all multivibrators, astable or not, is that they have two outputs. In this case, those outputs are at pins 3 and 10, which are then buffered and appear at pins 4 and 11, respectively. When one output is at logic 1, the other is at logic 0, and vice versa. This means that LED1 is off when LED2 is on, and LED1 is on when LED2 is off, the two states switching backwards and forwards at the frequency of the oscillator.

Construction

Read the warning at the beginning of this article again. It is not intended to scare you off from building this, but is a genuine piece of advice which can save you time and irritation when all your labours result in a circuit that doesn't work! That extra bit of care can make all the difference!

Veroboard (the copper strip type) is used for the layout, shown in **Figure 2**. It measures 20 holes by 12 strips. **Be aware that there is no row 'I' in the layout, so don't miscount when you are placing components on the board!**

Firstly, cut the tracks using a 3 mm (⅛ inch) twist drill held between thumb and forefinger; check that there are no slivers of copper bridging any of the tracks, and that the tracks have been completely cut by the drill. Solder in the components carefully. Leave the IC in its carrier for the time being, and solder in the IC socket, with the notched end facing row A. On completion, check the circuit carefully. If you are happy that it is correct, follow the instructions given earlier and fit IC1 into its socket, matching up the two notches. Connect the battery and switch on. The two LEDs should flash on and off alternately. If only one LED flashes, you have probably connected the other one the wrong way round. Switch off, check and correct if necessary. If neither LED flashes, you must have a significant error in your circuit, which will need checking *again*! Or did you choose to ignore the handling precautions for the CMOS chip?

Figure 2 Flashing LEDs, component layout

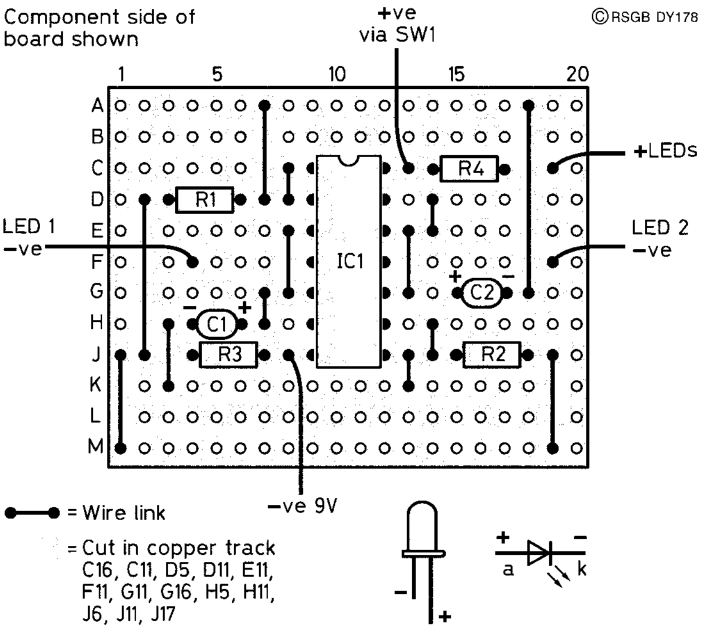
Component side of board shown
+ve via SW1
©RSGB DY178
1
5
10
15
20
A
B
C
D
E
F
G
H
J
K
L
M
R1
R2
R3
R4
C1
C2
IC1
+LEDs
LED 1 −ve
LED 2 −ve
−ve 9V
= Wire link
= Cut in copper track C16, C11, D5, D11, E11, F11, G11, G16, H5, H11, J6, J11, J17
−
+
a
k

The board can be mounted near to the point where you want your flashing LEDs to be seen, although long leads to the LEDs are acceptable. The LEDs can be different colours – it's all up to you now!

Parts list

Resistors: all 0.25 watt, 10% tolerance or better	
R1, R2	4700 ohms (Ω)
R3, R4	1 kilohm (kΩ)
Capacitors	
C1, C2	47 microfarads (μF) 12 V WKG
Semiconductors	
IC1	4011
Additional items	
LED1, LED2	Any size of LED, any colour
S1	SPST on/off
	Plastic box if needed, 8.5 by 5 by 2.5 cm

Source

Components are available from Maplin.

59 Digital logic circuits

Introduction

Logic circuits form the backbone of even the most advanced computer, yet their basic operation can be demonstrated by a couple of switches, a battery and a bulb.

Logic using switches

Everyone reading this article will look at **Figure 1** and know immediately how it works and be able to write down something like ‘When switch A and switch B are closed, the light will come on’. Without knowing it, you have written down a logic statement involving the so-called **AND** operation; the light comes on only when switches A **AND** B are ON. Below the circuit in Figure 1, is a table showing the only possible positions of the two switches and the state of the bulb for each position. This is called a *truth table*, and is frequently used in logic analysis.

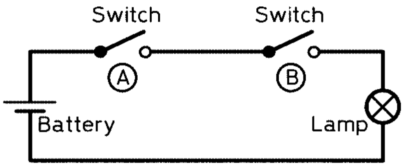

A	B	Lamp
Off	Off	Off
On	Off	Off
Off	On	Off
On	On	On

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Figure 1 Switches and lamp AND gate

Figure 2 shows a different circuit. Here, the two switches are in parallel rather than in series, as was the case in Figure 1. Again, if you analyse the circuit in words, you would say that the light will be on when switch A **OR** switch B is ON. This is an example of the **OR** operation, and its truth table is shown in Figure 2. The statement above is not complete, however; can you see why? The truth table will show you. The light comes on if A is ON, **OR** if B is ON, ***OR*** if A **AND** B are both ON. That third condition is easy to miss, but don’t worry about it!

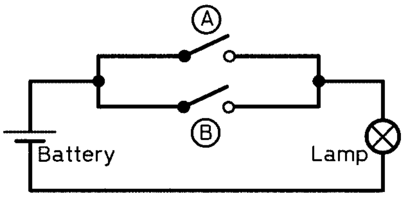

A	B	Lamp
Off	Off	Off
Off	On	On
On	Off	On
On	On	On

©RSGB DY184

Figure 2 Switches and lamp OR gate

Believe it or not, some very complicated logic is possible (in theory) using switches and lights, but it is highly impractical and would be very slow. This is where electronic logic circuits come in.

Switches with no moving parts

You may have come across projects in this book where a statement is made such as '. . . the transistor is being used as a switch . . .'. Transistors *can* be used as switches, as were thermionic valves in the world's first programmable computer *Colossus*, at Bletchley Park. However, technology has moved on from valves, through transistors to *logic gates*, combinations of electronic switches designed specifically to perform logic functions.

These act on voltage levels as their inputs and produce changes in voltage levels as their outputs. A positive voltage is called *logic 1*, and corresponds to a switch being ON in our previous descriptions; a zero voltage is called *logic 0*, and corresponds to a switch being OFF. The output from a logic gate (normally labelled Q) is also logic 1 or logic 0, corresponding to our light being ON or OFF, respectively, in our switch analogy.

Many logic devices operate from a stabilised 5 V supply, and this determines the *ideal* voltages corresponding to the two logic states:

logic 0 ≡ 0 V,

logic 1 ≡ 5 V.

The world isn't an ideal place, so the *real* voltage ranges used by the logic gates are:

logic 0 ≡ 0.0 to 0.4 V,

logic 1 ≡ 3.0 to 5.0 V.

The **AND** circuit of Figure 1 is now called an **AND gate**, and requires logic 1 inputs on A **AND** B to produce a logic 1 at the output. **Figure 3** shows this. The truth table is identical with that of Figure 1 – logic 1 replaces ON and logic 0 replaces OFF. Now compare Figure 2 with **Figure 4** – circuits and truth tables for the **OR** function. Again, we have exact similarity.

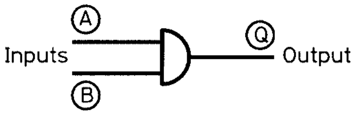

Inputs		Output
A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

©RSGB DY183

Figure 3 Electronic AND gate

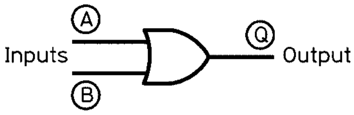

Inputs		Output
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

©RSGB DY190

Figure 4 Electronic OR gate

There is another very common logic gate, which performs the **NOT** function. It is easy to understand. Just ask yourself the question 'What is **NOT** logic 0?', and the answer is obviously 'logic 1'. Similarly, logic 0 is **NOT** logic 1. A **NOT** gate simply changes the logic state of the input; it is also known (because of this behaviour) as an *inverter*. Its symbol and truth table can be found in **Fig 5**. Note the little circle on the output of the gate in Figure 5. In logic circuits, this symbol always implies inversion, or the presence of a **NOT** gate. Keep an eye open for it!

So far, the logic functions we have discussed have all been words which we use in everyday language, which has made the electronic interpretation of them relatively easy. Now we must introduce a function for which there is *no* analogy in normal speech – the **NAND** function. This means a

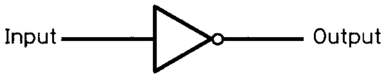

Input	Output
1	0
0	1

©RSGB DY185

Figure 5 Electronic NOT gate

combination of an **AND** gate and a **NOT** gate, and the sharp-eyed reader will have spotted the little circle added on to the normal **AND** gate symbol in **Figure 6**!

To make things easier to understand, the truth table in Figure 6 has four columns, not three as in previous tables. The third column is the standard **AND** output – compare it with the third column in Figure 3. That is the output from the **AND** gate *before* it encounters the little circle that inverts it, so the final output from the **NAND** gate is the output of the **AND** gate, inverted! The third and fourth columns are the inverse of each other.

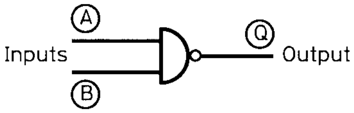

Inputs		and	Output
A	B		Q
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

©RSGB DY186

Figure 6 Electronic NAND gate

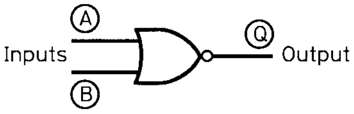

Inputs		or	Output
A	B		Q
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

©RSGB DY187

Figure 7 Electronic NOR gate

We can add the inverting operation to the output of an **OR** gate also, producing a **NOR** gate! The symbol and its truth table are shown in **Figure 7**. Again, notice that the final output is that of the ordinary **OR** gate, inverted!

These new functions of **NAND** and **NOR** are used more than the **AND** and **OR** functions because it makes other circuits easier to design using combinations of these gates.

A taste of Boolean algebra

The design of circuits using combinations of logic gates usually begins with a little mathematics, where the functions to be implemented are analysed. The mathematics used is surprisingly simple, and is a slightly changed version of ordinary algebra called *Boolean algebra*, which allows manipulation of logic functions to be made. Normal algebra has operations in it such as addition, subtraction and multiplication and division. The mathematician Boole found that the logical **AND** operation could be handled by the algebraic operation of *multiplication* (symbols × or •), and the **OR** operation by the algebraic operation of *addition* (symbol +). The **NOT** operation involved a new symbol, that of a bar over the input being inverted, such as A.

So, our five basic logic operators can now be written in a mathematical form:

AND	$Q = A \times B$
OR	$Q = A + B$
NOT	$Q = \overline{A}$
NAND	$Q = \overline{A \times B}$
NOR	$Q = \overline{A + B}$.

Using logic operations in a mathematical form enables the most complex logic to be designed, simplified and converted into circuit diagram form in a very efficient and rapid way. There are more logic operators than the five we have considered here but, in general, they can all be broken down into combinations of these gates alone!

60 A resistive SWR indicator

Introduction

When a transmitter produces some output power, we want to make sure that as much as possible of this power is radiated by the aerial. This often requires the use of an *aerial tuning unit* (ATU), which matches the aerial impedance to that of the transmitter.

How do you know when this matching has been achieved? The most usual way is to use a *standing-wave ratio* (SWR) indicator. If the impedance of the aerial does not match that of the transmitter output, some of your transmitter power (also known as the *forward* power) is reflected back along the aerial feeder and back into the transmitter, where it causes excess heating. The forward and reflected waves interact along the feeder to produce a wave whose position remains constant, and which is therefore called a *standing wave* or a *stationary wave*. An SWR meter simply indicates forward power and reflected power, and adjustments are made to your ATU until the reflected power is as small as possible (ideally zero, of course). If there is no reflected power then, by a process of elimination, all your forward power is reaching the aerial!

Sampling the RF

Whatever type of SWR indicator you use, it must use some sort of sampling circuit to pick up the forward and reflected waves. The project *A standing-wave indicator for HF*, elsewhere in this book, uses a toroidal transformer to separate the readings for the forward and reverse waves. This design differs in that it measures the voltages across resistors through which the RF current is passing. Its advantages are:

(a) it uses cheap parts – four resistors, two capacitors and a diode, together with a rotary switch, a surplus meter, a preset potentiometer and two sockets;
(b) within this SWR indicator, there is always a resistive path for the RF current from the transmitter, formed by R1, R2 and R3; this can prevent damage to simpler home-made transmitters, which may be damaged during adjustment of the ATU when using more conventional SWR indicators.

The only disadvantage of this form of indicator is that it must be switched out of circuit once the ATU has been adjusted for a particular band.

Construction

The SWR indicator is very simple to build, as most of the components can be mounted on the back of the 3-way rotary switch. This is shown in **Figure 1**. The switch is a 4-pole, 3-way rotary type, of which only two poles are used.

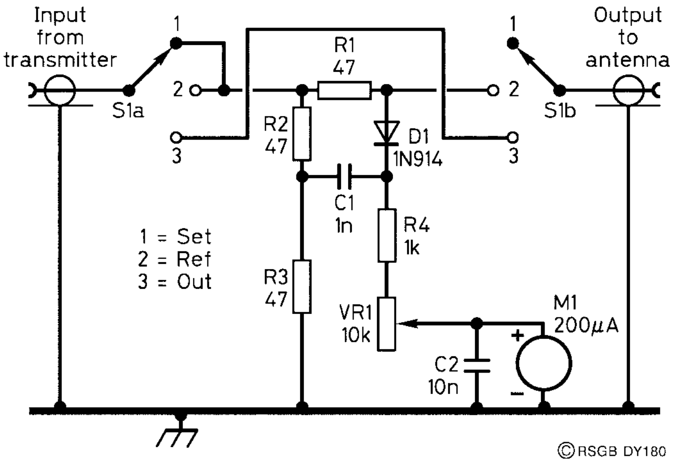

Figure 1 Resistive SWR meter, circuit diagram

Because the other switch contacts are not being used, they can be employed as support tags for other components. The ground wires are all soldered on to the metal frame of the switch. If your switch frame is of all-plastic construction, then a 12 SWG copper wire run around the switch will make a good earth connection to the metal case for the leads shown in Figure 1. The preset potentiometer used to control the sensitivity of the circuit can be mounted directly on the meter tag.

Resistors R1, R2 and R3 handle the RF power during the tuning-up process. If you have them, use 1 watt resistors; otherwise, you can use two 100 ohm half-watt resistors in parallel for each of R1, R2 and R3. The meter, M1, can be any DC type of sensitivity around 200 μA.

In use

First, find a clear frequency, and without the indicator in circuit, check that the frequency really *is* clear by asking and identifying yourself. If it is, connect the indicator between the transmitter and the ATU which, in turn, is connected to your aerial. Turn SW1 to the SET position and key the transmitter. Adjust VR1 until the meter reads full scale. Switch off the transmitter. Turn SW1 to the REF position and key the transmitter again. Adjust the ATU until the lowest reading is obtained on the meter. Switch off the transmitter. For the chosen frequency, you have adjusted your ATU for minimum reflected power and hence the lowest SWR. You will need to repeat the process when you change bands, and possibly when you change frequency within the same band. Switching SW1 to the OUT position, you are ready to transmit. You may have noticed that it is good practice to switch the transmitter off when operating SW1. Get into that habit!

Parts list

Resistors	
R1, R2, R3	47 ohm (Ω) 1 watt (or 2 × 100 Ω, ½ watt, see text)
R4	1 kilohm (kΩ) 0.25-watt
VR1	10 kilohms (kΩ) preset
Capacitors	
C1	1 nanofarad (nF)
C2	10 nanofarads (nF)
Semiconductors	
D1	1N914 or similar
Additional items	
SW1	4-pole 3-way rotary switch, of which only 2 poles are used
M1	200 μA DC
	Case

61 An audio filter for CW

Introduction

This is a simple passive circuit (it has no power supply) that adds some audio selectivity for Morse code reception and also includes a very simple noise limiter that gives a visual indication of when noise spikes are being removed!

The circuit

Figure 1 shows the complete circuit. The tuned circuit of C1 and L1 resonates very close to 800 Hz, so initially you will have to tune a signal in carefully until it sounds loudest – you will soon be able to do this without thinking. The two LEDs connected back to back across the signal path act as a noise limiter, reducing the amplitudes of static crashes and noise from car ignition systems, etc. The LEDs blink when they conduct – this is not necessary to the operation of the circuit, but adds a little colour to your listening! The noise limiter *does* make listening more comfortable, though.

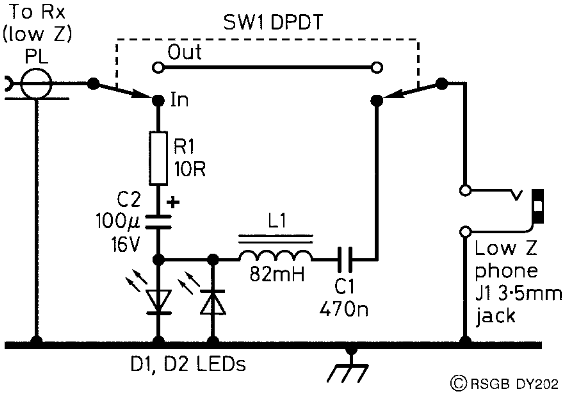

Figure 1 CW filter, circuit diagram

Construction

The circuit layout is shown in **Figure 2**. Point-to-point wiring is used, with a small tag-strip being the only item used for the extra support of C2 and R1. The LEDs and SW1 support the other components. An aluminium box (**Figure 3**) is used to make the circuit tidy and usable.

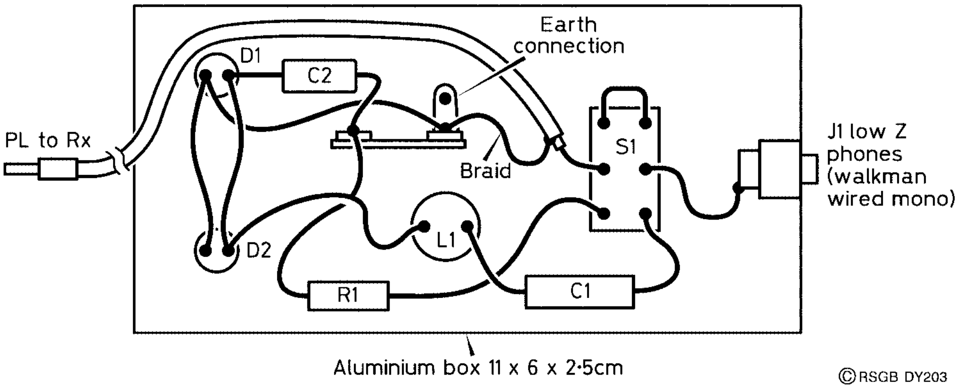
Earth connection
D1
C2
PL to Rx
S1
Braid
J1 low Z phones (walkman wired mono)
L1
D2
R1
C1
Aluminium box 11 x 6 x 2·5cm
©RSGB DY203

Figure 2 CW filter, component layout

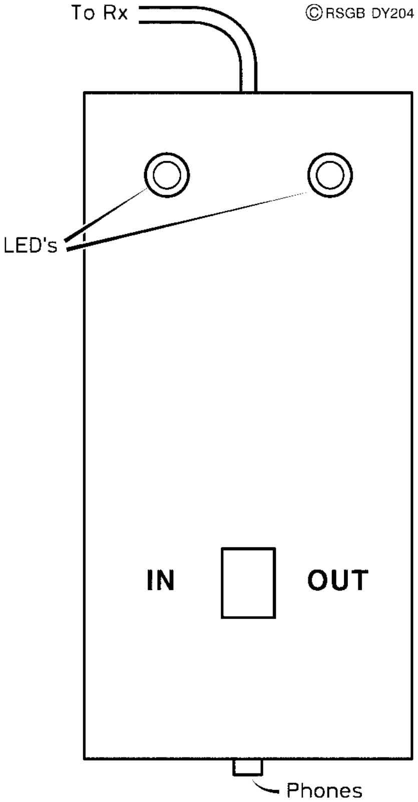
To Rx
©RSGB DY204
LED's
IN
OUT
Phones

Figure 3 CW filter, front panel

You must use low-impedance headphones for the circuit to perform properly. Plug the completed unit into the headphone socket of your receiver and adjust the volume so that the LEDs are just *not* blinking on normal audio. The unit should be switched out of circuit for speech listening; this is the purpose of the toggle switch, SW1.

Parts list

Resistor	
R1	10 ohms (Ω), 0.25 watt, 10% tolerance
Capacitors	
C1	470 nanofarads (nF)
C2	100 microfarads (μF) electrolytic, 16 V WKG
Inductor	
L1	82 millihenries (mH)
Semiconductors	
D1, D2	LEDs
Additional items	
SW1	DPDT
J1	3.5 mm jack socket
PL	Jack plug to suit receiver
	Aluminium box, approx. 11 by 6 by 2.5 cm

Source

Components are available from Maplin.

62 An electronic die

Introduction

Throwing a die is a venerable way of generating a ‘random’ number between 1 and 6. A die is easy to lose, so here is an electronic die-throwing circuit which brings the technique up to date and serves as another application of logic circuits. If you need a reminder of the basics of logic, refer to *Digital logic circuits*.

Warning

This circuit uses members of the integrated circuit family known as CMOS (complementary metal-oxide semiconductor). These use very little current and can be completed destroyed if they come into contact with the

magnitudes of static electricity that most of us carry about when we walk on carpets and wear rubber shoes. You will never know if this wanton destruction has happened – all you will discover is that your circuit doesn't work and that you have tested *everything*. To avoid this problem do the following things:

1. Before you open the little packet in which the IC is supplied, touch something which you *know* to be earthed – the metalwork of any equipment which is mains-earthed, for example. Then open the packet.
2. Let the IC fall gently on the bench – don't pick it out with your fingers. Touch your earthed metalwork again. Pick up the IC and insert it gently into its holder.

The circuit is safe from damage while it is connected to the battery.

Description

The circuit is shown in **Figure 1**. IC1a and IC1b form an *astable multivibrator*, similar to that used in 'An LED Flasher' also in this book. It runs constantly, and its output is fed to IC2 via a single NAND gate, IC1c. The other input of IC1c is held at 0 V by R3 and C3. Whenever one input of a NAND gate is logic 0 (or 0 V), there can be *no output* from the gate, irrespective of what is happening at other inputs. So, despite the fact that the oscillator (or *clock*) is running all the time, its square-wave output never

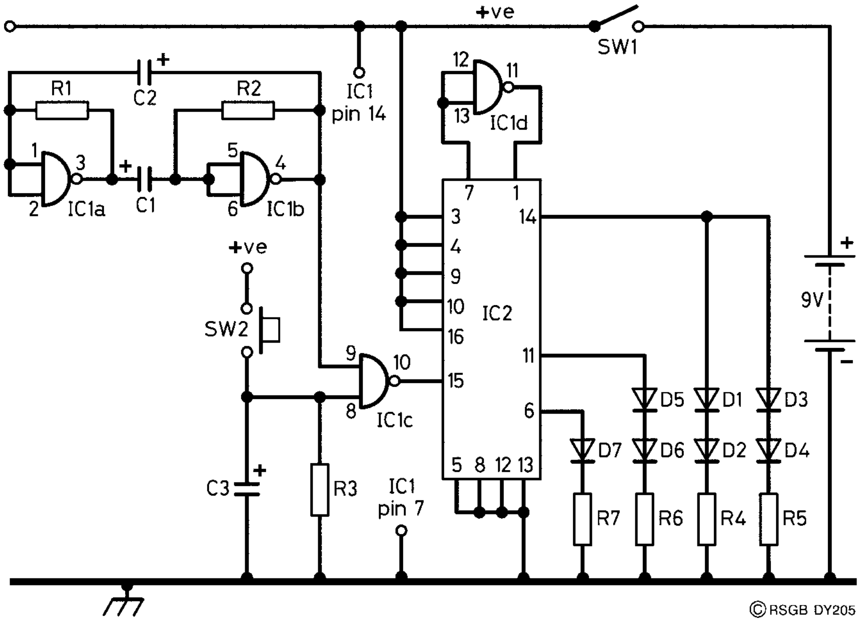
+ve
SW1
R1
C2
R2
IC1 pin 14
12
11
13
IC1d
1
3
IC1a
2
C1
5
4
6
IC1b
+ve
SW2
7
1
3
14
4
9
10
16
IC2
11
15
6
5 8 12 13
9
10
8
IC1c
C3
R3
IC1 pin 7
D5
D1
D3
D7
D6
D2
D4
R7
R6
R4
R5
9V
©RSGB DY205

Figure 1 Electronic dice, circuit diagram

reaches IC2 until the ‘other’ input of IC1c is brought away from logic 0. This happens when SW2 is pressed. Pressing SW2 momentarily, as is normally done, charges up C3 to 9 V, putting a logic 1 on the second input of IC1c and allowing the clock signal through to IC2. As the switch is released, C3 begins to discharge through R3, gradually lowering the voltage on pin 8 of IC1c. As this voltage crosses 4.5 V (half the supply voltage), IC1c then treats this input as logic 0, which cuts off the clock signal from IC2 again. Thus, when SW2 is momentarily pressed, the clock signal is fed to IC2 for a short interval of time, before being blocked again.

IC2 is a binary counter, and the outputs that concern us are from pins 14, 11 and 6. Pin 14 is the *most significant bit* and pin 6 the *least significant bit*. See the panel for an explanation of what happens here.

To understand these outputs, you should be able to count in binary, using three bits. At the start of the counting process, all the bits have zero values, i.e. 000. The left-most bit is called the *most significant bit*, and the right-most bit is called the *least significant bit*. (When we write numbers normally, a number 1 in the left-hand position represents one hundred, 1 in the middle column represents ten, while the number 1 in the right-hand position means one. One hundred is a more significant number than one, hence the nomenclature.)

The three bits of our binary number have values, from left to right, of 4 (=2^2), 2 (=2^1) and 1 (=2^0). This means that a number 1 in the left-hand column signifies the normal number four, in the middle column it would represent two, and in the right-hand column, it would represent one. This should help you understand the patterns of bits which emerge as the clock waveform is counted, as the next paragraph explains.

As each cycle of the clock enters IC2, it increments its internal counter and the values of that counter are shown by the states of pins 14, 11 and 6. After the first pulse, these three pins would have states corresponding to 001; after the second, 010; after the third, 011; after the fourth, 100; after the fifth, 101; after the sixth, 110. This sequence of 3-bit numbers represents a binary count from 1 to 6 in ‘normal’ parlance. These six states are used to illuminate the conventional pattern of dots on a die, using LEDs.

As the clock cycles are counted, the LEDs flicker as the die is ‘rolled’. Resistors R4 to R7 are used to limit the current through the LEDs. When the counter stops, it can be in any of the positions shown in **Table 1**. Because of

Table 1 Dice number relative to counter output

Step	*Pins*			*Dice number*
	14	*11*	*6*	
1	0	0	1	4
2	0	1	0	2
3	0	1	1	6
4	1	0	0	1
5	1	0	1	5
6	1	1	0	3

the way in which the dots are grouped on the faces of a die, the wiring of the LEDs is simpler than it might otherwise be. You can see from Figure 1 that there are really only three sets of connections to the LEDs – one from each bit of the counter output. When pin 14 is at logic 1, four LEDs are lit, corresponding to the number four. For the number five, pins 14 and 6 will be at logic 1. For the number one, only pin 6 is at logic 1. For three, pins 11 and 6 are at logic 1, for six, pins 14 and 11 are at logic 1, and for two, only pin 11 is at logic 1. These conditions are summarised in Table 1.

Construction

Two pieces of Veroboard (of the strip type) are needed – one for the main circuit (**Figure 2**) and the other for the display LEDs (**Figure 3**). The display board is easier to build, so we will do that first. It measures 20 holes by 18 strips.

Cut the tracks as shown in Figure 3, using a 3 mm (⅟inch) twist drill rotated between thumb and forefinger. Insert and solder the Veropins, resistors and the wire links. Then solder the LEDs in place, making sure their polarities are correct. The LEDs are mounted proud of the board (**Figure 4**, which will help when you come to fix the board into a case.

The main board measures 32 holes by 18 strips. As before, remove the tracks in the places shown in Figure 2. Note that track 'L' is *not* broken under the position for IC2. Solder in the IC holders and the links. Solder in R1 and R2 vertically, and R3 horizontally. Then solder in C1, C2 and C3; these all being electrolytics, check their polarities. Solder in the Veropins and prepare the connections to those components not on the main board, using stranded, insulated wire. Check the circuit carefully, and read the handling precautions given earlier before carefully inserting the two ICs.

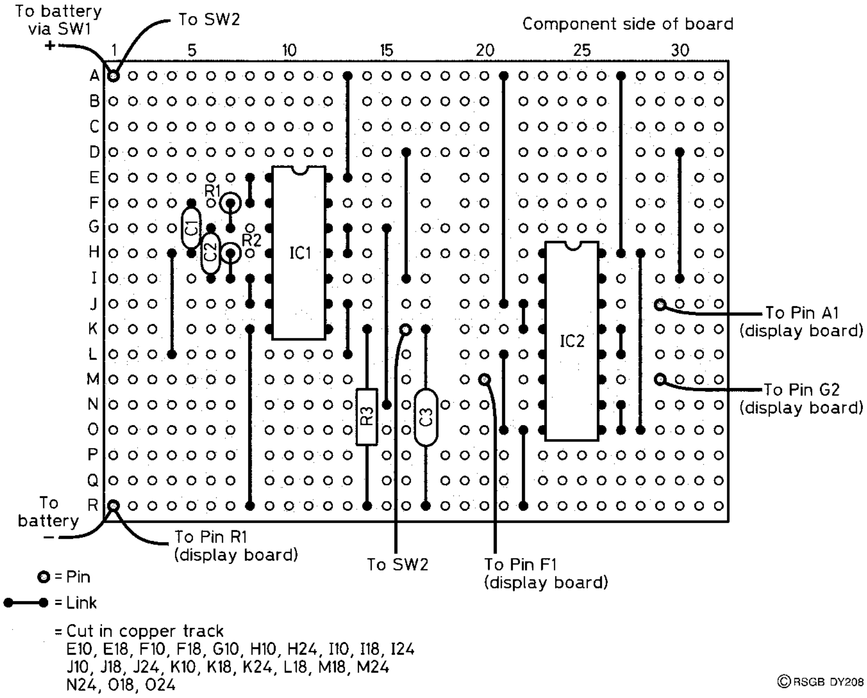
To battery
via SW1
+
To SW2
Component side of board
1
5
10
15
20
25
30
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
R1
R2
C1
C2
IC1
IC2
R3
C3
To Pin A1
(display board)
To Pin G2
(display board)
To
battery
−
To Pin R1
(display board)
To SW2
To Pin F1
(display board)
= Pin
= Link
= Cut in copper track
E10, E18, F10, F18, G10, H10, H24, I10, I18, I24
J10, J18, J24, K10, K18, K24, L18, M18, M24
N24, O18, O24
©RSGB DY208

Figure 2 Main board, component layout

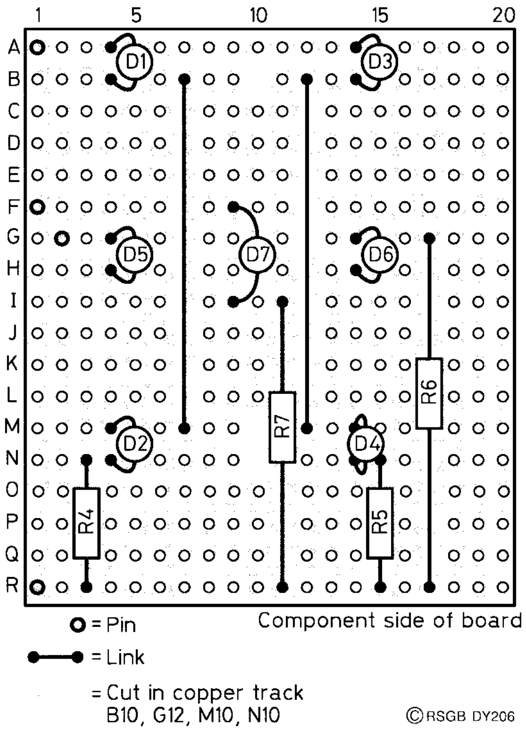
1
5
10
15
20
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
D1
D3
D5
D7
D6
D2
D4
R4
R5
R6
R7
= Pin
Component side of board
= Link
= Cut in copper track
B10, G12, M10, N10
©RSGB DY206

Figure 3 Board for the six LEDs

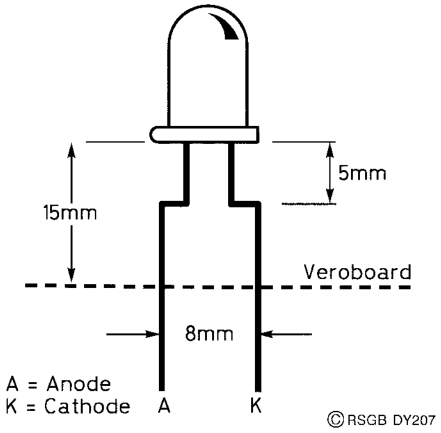

Figure 4 D7 lead bending

Testing and use

When the circuit is switched on, it is likely that the centre LED only will be lit. Press SW2, the 'throw' switch. All the LEDs should flicker, even after the switch is released, but only for a second or so. Then a standard pattern should show, signifying numbers between one and six. If this does not happen, switch off and check your circuit again. Are there any missing links? Are there any obvious dry joints (usually dull instead of shiny)? Can you see any solder bridges between tracks? Did you choose to ignore the handling precautions? If none of these results in a working circuit, try some fault-finding.

- Disconnect the lead to D7 on the main board (marked 'to pin F1' on Figure 2). Touch the lead on to the positive supply rail. D7 should light. Now transfer this lead on to pin 4 of IC1. If it flickers, then the oscillator is running (which it should).
- Transfer this lead to pin 10 of IC2. D7 should flicker when SW2 is pressed, but should be on permanently when it is released. This means that the correct signals are reaching IC2 from IC1.
- If one of the chains of LEDs (i.e. D1 and D2, D3 and D4, D5 and D6) does not light, you may have one *or both* LEDs the wrong way round.

When the die is working, you may care to experiment with the values of R1 and R2, but you should keep their values the same, i.e. R1 = R2. The larger the values of these, the more slowly the die will appear to 'roll'.

Finishing touches

On completion of the project, you will want to mount it in a smart case; any plastic box is suitable for this, with the display board mounted so that the

LEDs protrude through the top and are fixed to it using LED clips. The way in which you mount both boards to the case is entirely up to you.

Parts list

Resistors: all 0.25 watt, 10% tolerance, or better

R1, R2	5600 ohms (Ω)
R3	15 kilohms (kΩ)
R4–R7	470 ohms (Ω)

Capacitors

C1, C2	1 microfarad (μF) electrolytic, 16 V WKG
C3	68 microfarads (μF) electrolytic, 16 V WKG

Semiconductors

IC1	4011
IC2	4029
D1–D7	LEDs, any size and colour

Additional items

SW1	On-off switch SPST toggle
SW1	Push-to-make, non-latching
	Veroboard, 2 pieces, see text for sizes
	Veropins, 10
	Stranded insulated wire for general wiring
	Single-core insulated wire for links
	PP3 battery clip
	PP3 battery
	Plastic box to suit
	LED mounting clips (7)
	Means of mounting boards to box

Source

Components are available from Maplin.

63 The absorption wavemeter

Introduction

The purpose of the absorption wavemeter is to check that a transmitter is radiating within the correct waveband, and to detect any spurious *harmonic* emissions. A harmonic frequency is an integral multiple of the carrier frequency – e.g. if the carrier is at a frequency *f*, the harmonics are at frequencies 2*f*, 3*f*, 4*f* . . . and so on.

It can also be employed as a relative field-strength indicator, being used in experimentation with aerials. What it *cannot* do is to measure the transmitted frequency accurately; all it can do is to place the signal within a particular band, say the 7 MHz or the 18 MHz band (or their harmonics).

How it works

You may recognise the circuit of **Figure 1** as a crystal set with a meter replacing the headphones. It is simply the parallel combination of an inductance with a variable capacitance, which constitutes a resonant circuit with a variable frequency. A dial on the variable capacitor can be roughly calibrated with frequency. The fixed capacitor across the meter helps to improve the meter reading by making it read the peak value of the carrier wave rather than the average value.

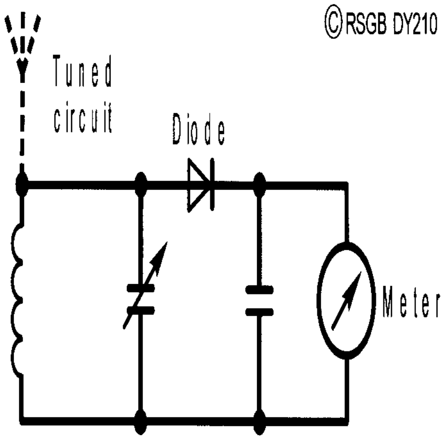

Figure 1 Absorption wavemeter circuit

When the wavemeter is situated in the vicinity of a relatively strong radio-frequency (RF) field, the inductor absorbs a small amount of energy from that field. If the circuit is resonant at the same frequency as that of the transmitter, an RF voltage is produced across the coil and is proportional to the strength of the RF field. The RF voltage is *rectified*, or *detected* (turned from AC into DC) by the diode and the second capacitor, and is displayed by the meter.

The tuned circuit

The formula for calculating the resonant frequency of a coil and capacitor is relatively simple. It is

$$f = \frac{1}{2\pi\sqrt{LC}},$$

where f is the resonant frequency (Hz),
L is the inductance (H), and
C is the capacitance (F).

If this formula puts you off, there is this slightly easier version:

$$f = \frac{159}{\sqrt{LC}},$$

where f is the frequency in **MHz**,
L is the inductance in **microhenries** (**μH**), and
C is the capacitance in **picofarads** (**pF**).

When a variable capacitor is specified, it is usual to quote its maximum capacitance, i.e. the value when the vanes are fully meshed. When the value of the capacitor is small, it is usual to quote its minimum capacitance also, the value when the vanes are fully open. If you use a variable capacitor of 10–100 pF with a 100 μH inductor, you will use the value of 10 pF to calculate the maximum resonant frequency, and the value of 100 pF to calculate the minimum resonant frequency, giving a tuning range of 1.6 MHz to 5 MHz. Check it yourself!

64 An HF absorption wavemeter

Introduction

An absorption wavemeter is basically a simple tunable detector circuit, such as would be used in a crystal set, but with the headphones replaced by a meter, in order to indicate the strength of the received signal.

The circuit

Figure 1 shows the circuit of the wavemeter. It is designed to cover all the HF bands from 1.8 MHz to 28 MHz in four switchable ranges. There is no built-in method of amplification, so a sensitive meter is needed in order to indicate sufficiently using the available absorbed energy. The meter does not need calibrating, it serves to produce only an indication of the absorbed power, *not* its absolute value.

An absorption wavemeter does not have outstanding selectivity, mainly because of the loading effect of the meter. This problem is ameliorated here (but only slightly) by the inclusion of R1 in series with the meter. It gives

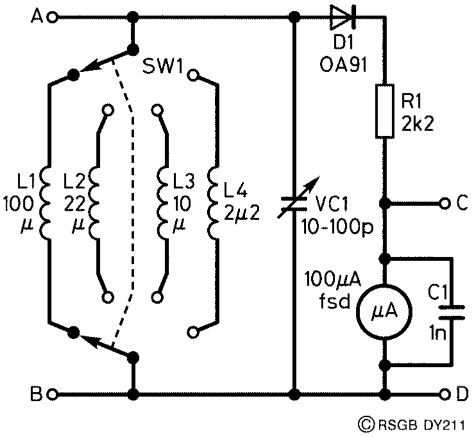

Figure 1 HF absorption wavemeter, circuit diagram

improved selectivity at the expense of a slight loss of sensitivity. The appearance of capacitor C1 across the meter is discussed in *The Absorption Wavemeter*, in the previous section.

Coils

These can be purchased (see the parts list) or hand-wound on short lengths of PVC water pipe or conduit, and the coil-winding details are given in **Table 1**. In theory, the 100 pF tuning capacitor would cover all the HF bands with only three coils, omitting the 22 μH coil. Sample calculations are explained in the previous article. However, its inclusion avoids the common problem of having some bands cramped at the extreme edges of the tuning scales.

Table 1 Close-wound coil values

L (μH)	No of turns	Span (mm)	SWG
PVC FORMER OF OUTSIDE DIAMETER 25 mm			
2.2	9	9	20
10	24	24	20
22	44	44	20
100	110	60	26
PVC FORMER OF OUTSIDE DIAMETER 20 mm			
2.2	10	10	20
2.2	9	5	26
10	32	32	20
10	24	12	26
22	63	62	20
22	41	21	26
100	134	70	26
PVC FORMER OF OUTSIDE DIAMETER 19 mm			
2.2	11	11	20
2.2	9	5	26
10	35	34	20
10	25	13	26
22	68	67	20
22	44	22	26
100	157	79	26

Construction

Hand-wound coils, using 19–25 mm PVC formers, have single-layer windings, with their ends secured by threading the wires through two small holes drilled in the formers at each end of each winding.

You may have wondered about the use of the two-pole switch SW1, as all the lower ends of the coils are grounded anyway. The answer lies in the ease of construction. Each coil can be mounted on the tags of the switch for support. If you are using the commercial coils, they are small enough to be accommodated on a miniature rotary switch; a larger rotary switch is required for hand-wound coils. The specification of a 6-way switch allows for the addition of extra frequency ranges at little extra cost. Rotary switches such as the 2-pole, 6-way variety have an adjustable end-stop which allows the number of ways to be set anywhere between 2-ways and 6-ways. Remove the nuts from the switch, and a ‘washer’ will fall out. It is not a washer, really, and has a little piece of metal bent over at right angles to the washer. This fits into one of 12 holes in the body of the switch, and prevents the shaft from turning through 360° and selecting the number of ways.

Calibration

This process needs a commercial amateur-bands transceiver, if it is to be done quickly and accurately.

- Connect the transceiver to a dummy load, and connect a piece of flexible wire from point A in Figure 1 and wrap two or three turns around the cable between the transceiver and the dummy load.
- Turn the transceiver power level control to minimum, and set the frequency at 1.81 MHz and the mode to FM or AM. Switch to transmit.
- With the wavemeter set to its lowest frequency range (i.e. 1.8–3.5 MHz), rotate the tuning capacitor until maximum deflection is obtained from the meter needle. Write the frequency on the inner ring of the wavemeter scale at that point.
- Switch off and retune the transmitter to 3.5 MHz. Repeat the above process.
- Repeat, using switch range 2 for 3.5, 7 and 10 MHz, range 3 for 7, 10 and 14 MHz, and range 4 for 14, 18, 21, 24 and 28 MHz.

An alternative source of calibration signal could be an HF signal generator, with a single-turn loop of wire at the remote end of its cable, and the wire from the wavemeter brought close to the loop.

Remember that the marks on the scale represent frequency *bands*, not precise frequencies.

Extending the range

If you would like to experiment with increasing the range to the lower VHF band, then 50 MHz should be achievable with an additional self-supporting coil (no former). Try three turns of 20 SWG enamelled copper wire of 25 mm ID (internal diameter). Wind it on some 25 mm PVC pipe, as before, then slide out the pipe! The same result could be achieved with four turns of 19 or 20 mm ID, or 12 turns of 7.1 mm ID.

Parts list

Resistor	
R1	2200 ohms (Ω) 0.25 watt, 10% tolerance
Capacitors	
C1	1 nanofarad (nF) min. ceramic
VC1	100 picofarad (pF) variable
Inductors	
L1	100 microhenries (μH)
L2	22 microhenries (μH)
L3	10 microhenries (μH)
L4	2.2 microhenries (μH)
Semiconductors	
D1	Germanium OA91 or 1N4148
Additional items	
SW1	Rotary 2-pole, 6-way
	Moving-coil meter, 50 or 100 μA FSD (any meter of this sensitivity will do)
	Plastic box, approx. 150 by 80 by 50 mm
	Connecting wire, coloured

65 A vertical aerial for 70 cm

Introduction

If the range of your hand-held transceiver is very limited, what you need is a vertical aerial mounted outside. This design is a half-wave dipole fed at the end instead of the middle. Because the impedance of the dipole is high at its ends (and low in the centre), a matching circuit is needed so that this high impedance can be matched to that of the low-impedance coaxial cable. All that is needed is a coil, which increases the *electrical length* of the aerial to ⅝-wavelength. (Note that the *electrical* length (i.e. the length as it appears to an RF signal) is not necessarily the same as the *actual* length.)

Construction

The aerial element and the coil are made from a single piece of 1.5 mm welding (brazing) rod, and the dimensions are given in **Figure 1.** Wind the coil around a 4 mm rod or the shank of a twist drill. The lower end is filed to a point and then soldered into the centre conductor of a 4-hole panel-mounting BNC socket. (Try to obtain a good-quality BNC socket with PTFE insulation – the insulation of cheaper sockets is easily damaged.) Trim the element to 427 mm (top of element to top of coil) *after* the wire has been soldered to the socket.

The base coil causes the aerial to be rather ‘whippy’, so a piece of 5 mm plastic knitting needle can be cut to the length of the coil and then forced into it.

The radials are made from four lengths of 3 mm welding rod. These are bent and soldered into the four mounting holes of the socket, and then cut to the lengths shown in Figure 1.

Testing

Using a standing-wave-ratio (SWR) meter connected between your aerial and the transceiver, measure the SWR (or obtain some indication of the reflected power) on transmit. If it is greater than 1.5, switch off the transmitter, trim about 3 mm off the end of the element, and try again. Repeat the process until the measured SWR (or the reflected power) is as low as you can get it.

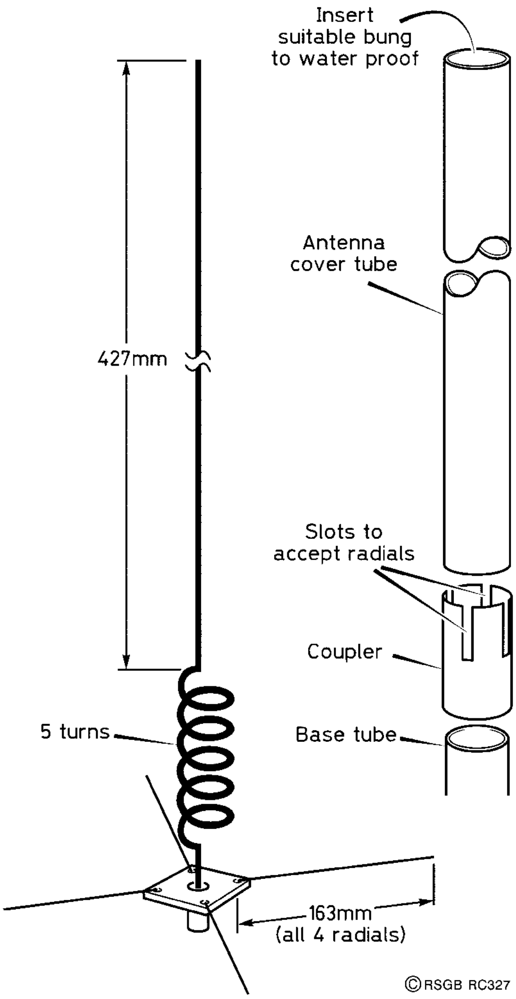
Insert suitable bung to water proof
Antenna cover tube
Slots to accept radials
Coupler
Base tube
427mm
5 turns
163mm (all 4 radials)
©RSGB RC327

Figure 1 Construction of the 70 cm antenna

Installation

The aerial is made waterproof by enclosing it in a 22 mm diameter PVC waste water pipe. It is 'weldable', and available at plumbers' merchants, usually by the metre. A coupler is slotted to take the radials (Figure 1). File the BNC socket as required, so that it slides inside the coupler until the radials poke out of the slots. Cut a length of plastic tubing which is 30 mm longer than the aerial, and push it into the coupler. You will then need a plastic bung or screw-top to waterproof the top end.

Plastic welding solution is now applied to the joints, sealing the aerial inside the tube. The coupler has been weakened as a result of making the slots, so it is worthwhile applying PVC tape around this joint until the welding solution sets.

A support for the aerial is made from an off-cut of tube pushed into the lower end of the coupler and held with a self-tapping screw.

Parts list

1	4-hole panel-mounting BNC socket
1 m	3 mm brazing rod (may be available from a small garage)
1 m	1.5 mm brazing rod
1 m	22 mm PVC waste water pipe
1	22 mm straight coupler
	Plastic welding solution

66 A UHF corner reflector aerial

Introduction

The corner reflector is a well-known design and is capable of good performance on the VHF and UHF bands. At UHF, the practical implementation of the corner reflector is an ideal constructional project.

Some details

Expressed quite simply, the aerial consists of a $\frac{\lambda}{2}$ dipole (where λ is the standard symbol for wavelength, making a '$\frac{\lambda}{2}$ dipole' a half-wave dipole).

Nothing new in that, you might say. However, the interesting feature is the reflector, which is not the usual single element, but a 90° metal 'corner', acting rather like a parabolic dish as used for satellite signal reception. The wind resistance of this type of reflector makes it impractical so, to reduce the 'windage' quite significantly, we make the 'corner' from closely spaced rods, as illustrated in **Figure 1**.

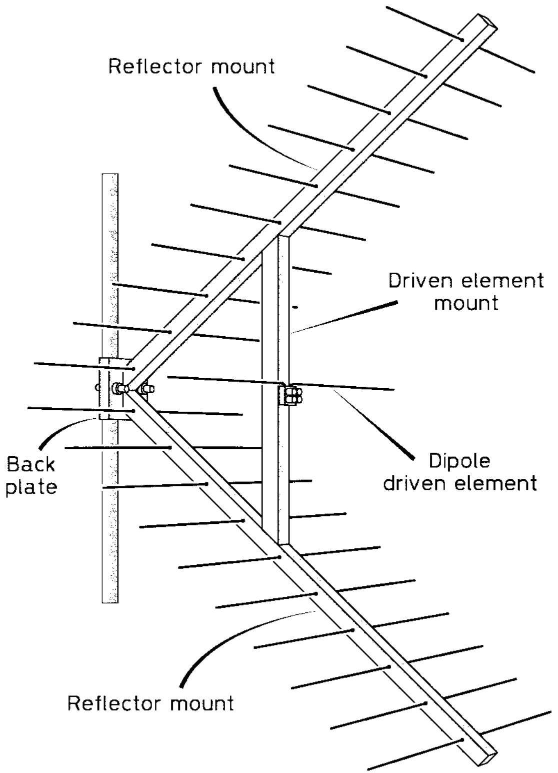

Figure 1 70 cm corner reflector antenna

©RSGB DY215

The reflector consists of a number of 0.6λ rods, spaced from each other by 0.1λ. The aerial frame can be made of metal or wood, but wood is easier to work with, and mounting the elements to the frame is simpler. The prototype was made with wood of 20 mm by 15 mm cross-section, as **Figure 2** shows. The wood was varnished for protection. The elements were made from 1.5 mm diameter copper wire, because a large reel of the wire happened to be available. The wire diameter is not critical; tubing could be used just as successfully. 14 SWG hard-drawn copper aerial wire would be even better than that used in the prototype.

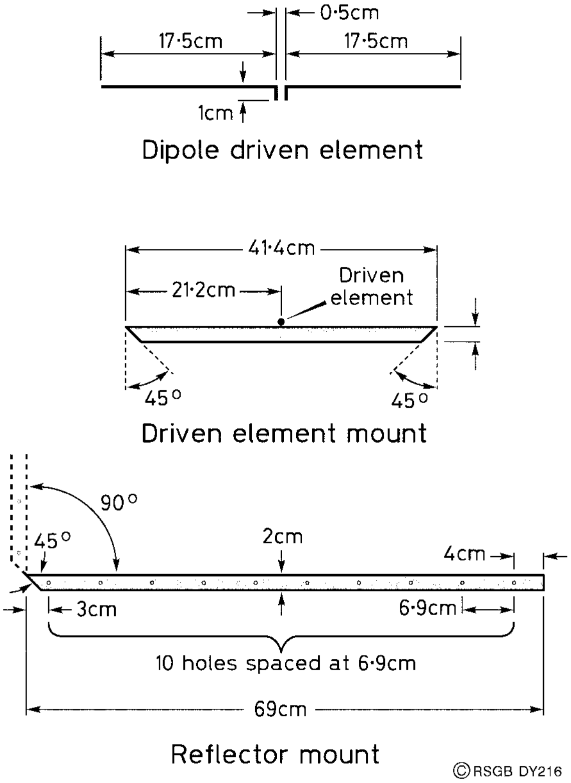
0·5cm
17·5cm
17·5cm
1cm
Dipole driven element
41·4cm
21·2cm
Driven element
45°
45°
Driven element mount
90°
45°
2cm
4cm
3cm
6·9cm
10 holes spaced at 6·9cm
69cm
Reflector mount
©RSGB DY216

Figure 2 Driven element dimensions, together with boom dimensions for driven element and reflectors

Construction

This project is just as much a woodworking project as a radio project! Follow the instructions carefully, and you should have little trouble.

- Cut the booms for the reflectors, as shown in Figure 2. A mitre block is invaluable here in producing the 45° corners.
- Using the dimensions given on the diagram, mark the hole positions for the reflector elements, and then drill holes of a size which holds the elements firmly.
- Cut the driven element boom according to the diagram, and mark the point midway along the longer side, which will assist you later in positioning the driven element.
- Cut the back plate to size (about 120 mm by 80 mm). You may need to alter this size depending on the size of the U-bolt you will be using to clamp the aerial to the mast.

- If you want to be extra cautious in your construction, use the belt-and-braces approach, commonly known as 'screw-and-glue' to fix the booms to each other and to the back plate.
- Fix the reflector booms to the back plate first, then slide in the driven-element boom until it will go no further, then apply the wood glue and screw the two ends tightly to the reflector booms. Leave for the period prescribed by the glue manufacturers for the glue to harden.
- Varnish the whole structure.
- Cut the driven element to the correct size plus a couple of centimetres (the reason for this will be evident in the *Testing* section), and fix it to the centre of its boom (at the position you marked earlier) with a 'chocolate block' connector to which the coaxial feeder cable will eventually be connected.
- Cut and fix the reflector elements in place. If you find that these are a loose fit in the holes then, *for each element*, drill a pilot hole through the boom to intersect the hole for the element. File off the point of a woodscrew, and screw it gently into the pilot hole until it meets the element and grips it in place. You will now see why the point was filed off! Alternatively, you can glue the elements in place.

Testing

Place the aerial on a mast, clear of obstructions. Connect it to a transceiver with a length of coaxial cable, with a standing-wave-ratio (SWR) meter in circuit. Find a clear frequency, identify your transmission and ask if the frequency *really is* clear. If so, key the transmitter again and note the SWR. **Do not stand in front of any aerial when it is radiating!** The length of the driven element must be adjusted to obtain an SWR of less than 2. If you have to shorten the dipole, bend the ends over rather than cut them off. That way, if you go too far, your can lengthen them again! The dipole was initially cut too long intentionally, to allow for adjustment here! Bending the ends over also reduces the risk of physical damage to clothing, skin and eyes. You may like to consider applying the same technique to the reflector elements for that reason alone.

Moving on . . .

Once you have warmed to the idea of the corner reflector as an aerial, you might like to ring the changes regarding the reflector. How about replacing the 20 reflector elements with a wire mesh, such as garden centres sell as 'chicken wire'? Choose the finest mesh if there is a choice. Some extra support may be needed around the edges of the mesh, but you could go on to make a comparison of aerial gain between the two types, using the *UHF Field Strength Meter* described elsewhere in this book.

Materials

Stiff wire or thin-walled tubing for dipole and reflector
Frame – wood, 15 mm by 20 mm cross-section, lengths given in text
Back plate – stout plywood, dimensions given in text
U-bolt to suit mast
Wood screws
Wood glue
50 W coaxial cable for feeder
2-terminal ‘chocolate block’ for dipole connection to feeder
Varnish

67 A switched dummy load

Introduction

A dummy load is a pure resistor of value 50 ohms which can replace your transmitting aerial and enable you to operate the transmitter for test purposes without radiating a signal. It sounds simple enough, but there are two main problems. Firstly, it is impossible to delve into your junk box and emerge with a resistor that will dissipate 100 W PEP and still retain its marked resistance value. Secondly, a ‘pure resistance’ is very difficult to achieve. A pure resistance is a device which has resistance but no reactance. All common resistors have significant reactance at radio frequencies, particularly the wire-wound varieties, which have a helical (i.e. wound like a coil) construction. This is particularly annoying, because wire-wound construction is normally used for large-wattage resistors.

Although all resistors have *some* reactance, not all are quite as bad as the wire-wound type. Carbon film resistors are made by depositing a thin film of carbon on the surface of a small, hollow ceramic cylinder, the thickness of the film of carbon determining the value of the resistor. Provided the lead lengths are kept short, these resistors have a tolerably small reactance, and will be used in this project.

Bearing the load

A 2 W carbon film resistor is hardly going to withstand our 100 W PEP of SSB, so it is obvious that the design of our dummy load must be a little more complex than a single resistor and a switch, despite what **Figure 1** might suggest! In fact, it uses 20 resistors, each of value 1000 Ω (1 kΩ). How does this solve our problem?

Perhaps a little theory is in order here, but no more than is required by the Radio Amateurs' Examination.

When two *equal* resistors of value *r* are combined in parallel (i.e. side by side), the total resistance, R_T, is given by:

$$\frac{1}{R_T} = \frac{1}{r} + \frac{1}{r}.$$

Adding 1/*r* to 1/*r* gives 2/*r*, therefore:

$$\frac{1}{R_T} = \frac{2}{r}, \quad \text{i.e. } R_T = r/2.$$

So, by connecting *two* equal resistors in parallel, we get a combined resistance which is *half* the individual resistances. If we combine *three* in parallel, we get a *third* of the resistance, and so on.

Here, we are connecting *20* resistors of 1 kΩ in parallel, so we will produce an overall resistance of *one-twentieth* of the individual resistance, i.e. 1000/20 = 50 Ω, which is what we set out to achieve!

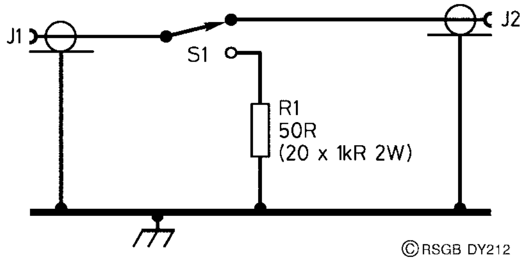

Figure 1 Basic circuit diagram

This is not the only advantage, though. Each resistor is capable of dissipating 2 W, so 20 of them will safely dissipate 40 W, for short periods at least. This power dissipation is approximately the same as 100 W PEP of normal speech, so the design should be capable of use in an 'average' amateur station. The power-handling ability of any dummy load can be improved by providing a 'heat sink' which helps to conduct the heat energy away from the resistors, thus lowering their temperature. One popular heat sink is a can of transformer oil, into which the resistors are immersed. This design uses a rather more mundane heat sink, but which is adequate for the job in hand.

Figure 2 PCB resistor supports

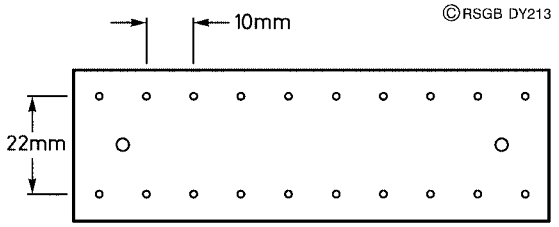
10mm
©RSGB DY213
22mm

2 PCBs (single sided) 100 x 35mm, 20 holes
1 'earth' PCB with two 3mm holes

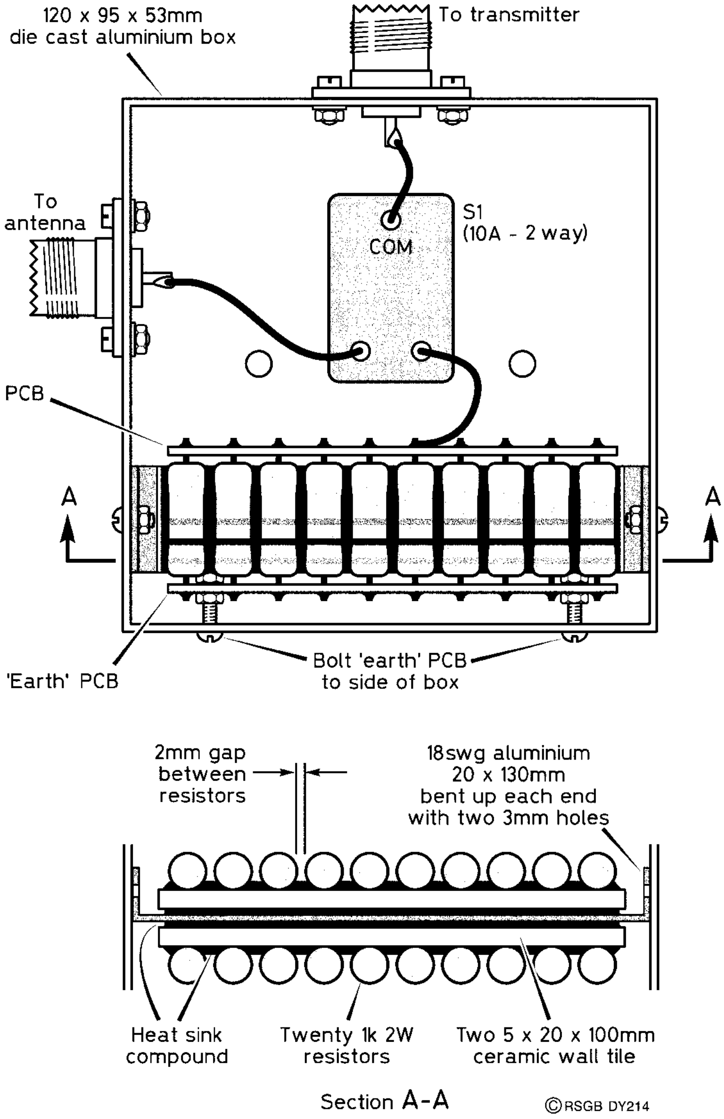
120 x 95 x 53mm
die cast aluminium box
To transmitter
To
antenna
S1
(10A - 2 way)
COM
PCB
A
A
'Earth' PCB
Bolt 'earth' PCB
to side of box
2mm gap
between
resistors
18swg aluminium
20 x 130mm
bent up each end
with two 3mm holes
Heat sink
compound
Twenty 1k 2W
resistors
Two 5 x 20 x 100mm
ceramic wall tile
Section A-A
©RSGB DY214

Figure 3 Switched dummy load, component layout

Pouring the heat away

Two basic PCBs are needed, the details being given in **Figure 2**. Both measure 11 × 35 mm. Each has a set of 20 holes of diameter about 1 mm to take the ends of the resistors. Only one of them has two 3 mm holes which are used for mounting the completed load. **Figure 3** shows how the heat sink is assembled. Solder one end of each resistor into the 'earth' PCB, and then mount this to the box using the two bolts as shown in the diagram. Between each rank of resistors is a 'sandwich' consisting of an aluminium strip and two pieces of ceramic wall tile, to act as a heat sink for the resistors. Heat sink compound is used to provide good thermal contact between the resistors and the tiles, and between the tiles and the aluminium strip. This is shown in the lower part of Figure 3. Thread the loose wires of the resistors through the holes in the second PCB, solder into place, and crop the protruding wires.

Switching

A changeover switch must be used so that the transceiver can be switched between the dummy load and the aerial without unscrewing connectors. For most purposes, an ordinary 10 A 230 V changeover switch will suffice, as found in many electrical shops and DIY stores.

Wire this into the circuit as shown in Figure 1 and Figure 3. Check your wiring. Put S1 in the 'dummy load' position. If you have a multimeter which includes an ohmmeter, measure the resistance across the socket, J1, before connecting it to the transceiver. It should be very near 50 Ω. With S1 in the 'aerial' position, there should be an infinite resistance across J1. Move your ohmmeter to read the resistance across J2. It should be infinite for both positions of S1. If all seems correct, close the box and your dummy load is ready for use!

Parts list

Resistors
  1000 Ω (1 kΩ) 2 W carbon film, 20 required
Additional items
  10 A 230 V changeover (SPDT) switch
  SO–239 sockets, 2 required
  Aluminium box 120 × 95 × 53 mm or similar
  Ceramic wall tile cut as required
  Aluminium strip, 18 SWG
  Nuts and bolts as required

68 A simple Morse oscillator

Introduction

This is an excellent project which uses the ‘junk box’ as its source of components. If you have trouble in finding the bits for this one, a good source of the components for this and many other similar projects is to be found with the parts list at the end of the project.

The circuit

This is shown in **Figure 1**, and uses an ‘unknown’ Plessey chip, which makes the overall circuit extremely easy to build. A 0.1 μF capacitor is connected between pins 7 and 8, a speaker (in the popular 8 to 25 Ω impedance range) is connected between pins 8 and 9. If a 9 V battery is connected with its positive terminal to pin 8 and its negative terminal to pin 1, 3 or 5, a tone will be produced in the speaker.

To make this circuit into a good Morse practice oscillator, it is necessary only to insert a Morse key into the supply rail from the battery.

However, there is another refinement which you may care to build into the circuit. The tone from the loudspeaker is different, depending upon which of pins 1, 3 or 5 you use. In the prototype, a single-pole changeover switch was used to select the tones from pin 1 or pin 3, and the Morse key would be connected to the circuit via a small jack socket. There is no need for an on/off switch, as the Morse key performs that function. The switch and the jack socket can be seen in the photograph.

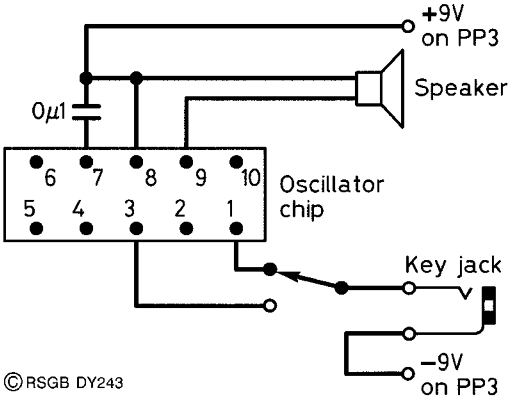

Figure 1 Morse oscillator, circuit diagram

The case

Almost any small loudspeaker will do; the higher the impedance the better. The 'impedance' is the figure usually printed on the rear of the speaker magnet. It is a value given in ohms (Ω). For simple circuits like this, you will usually find that the higher the impedance (within reason), the louder the sound it will produce. Speakers from old transistor radios will work, although their impedances can be rather low sometimes.

Any case big enough to house the components and the battery will be suitable. The prototype used a 'Walkman'-type speaker and case, and is shown in the photograph.

To use the circuit, simply attach a 3.5 mm jack plug to your Morse key, and insert it into the socket. Nothing should happen until you press the key, when a tone should be heard from the loudspeaker.

Another application

Try soldering the two wires of a 'twisted pair' to the 3.5 mm jack plug. Touching the wires together produces a tone from the speaker. This simple circuit can then be used as a 'continuity tester'. Touch the two wires to the ends of a fuse. If there is no sound, then the fuse is blown. There are many other such tests you could perform with this device – to check whether there really *is* a connection between one end of a wire and the other, for example.

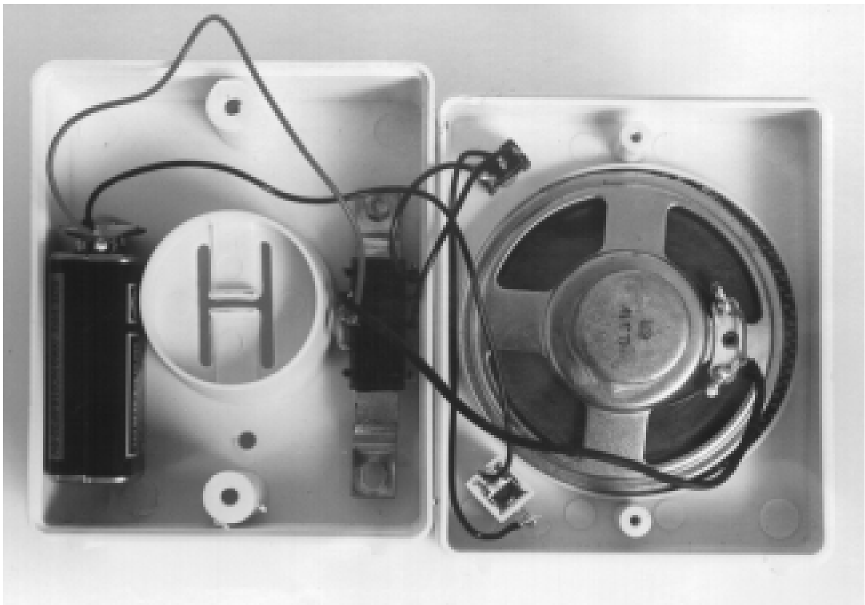

Warning

You must **never** make such tests on any equipment which is connected to the mains supply, even if it is switched off. If you want to make any such tests, make sure you are supervised by someone who understands what you are doing and is competent to advise and supervise you.

Parts list

Plessey oscillator chip
0.1 μF capacitor (disc ceramic)
Loudspeaker 8 to 25 Ω
3.5 mm jack socket (and 3.5 mm jack plug if needed)
Single-pole changeover switch

The Plessey oscillator chip is available from J. Birkett, 25 The Strait, Lincoln LN2 1JF, tel: 01522 520 767.

John Birkett may also provide a kit of parts (the chip, capacitor and loudspeaker).

69 A bipolar transistor tester

Introduction

This is a circuit which will test normal transistors, i.e. npn or pnp. It has the advantage of being able to test devices while they are still connected in their original circuits. However, when such tests are made, **the circuit containing the transistor under test must not be switched on**.

The circuit and how it works

The circuit runs from a 9 V battery such as a PP3 or six AA-type 1.5 V cells. Alkaline cells are to be preferred, as their electrolyte leakage properties are better. The circuit shown in **Figure 1** uses a single CMOS integrated circuit type 4001 or 4011. CMOS circuits require special handling precautions which are described in the project *Christmas Tree LEDs*, elsewhere in this book.

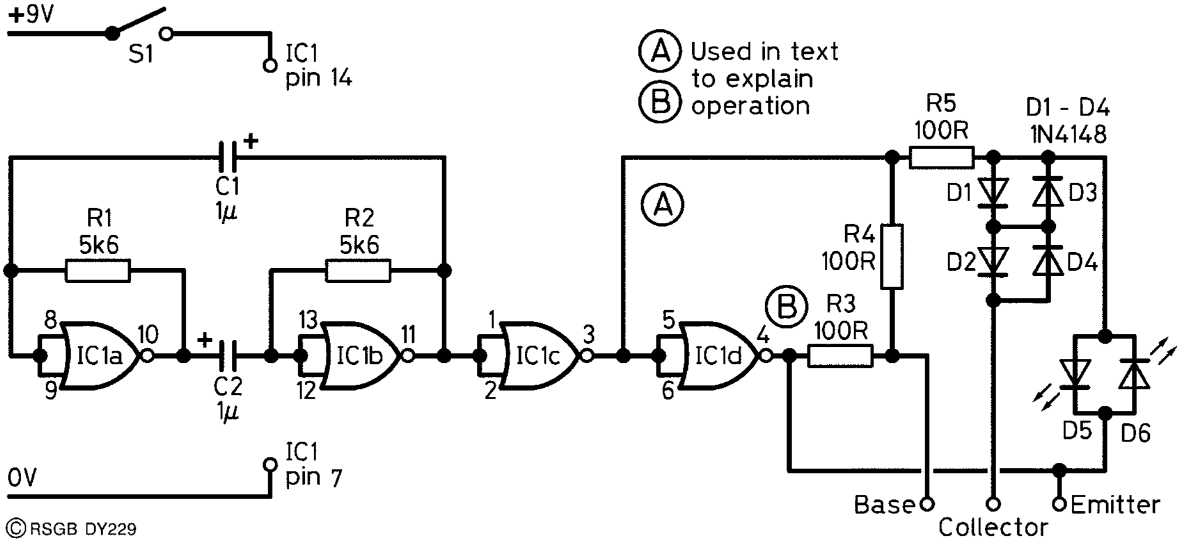
+9V
S1
IC1 pin 14
A Used in text
B to explain operation
C1 1µ
R1 5k6
R2 5k6
IC1a
IC1b
IC1c
IC1d
8
9
10
13
12
11
1
2
3
5
6
4
C2 1µ
IC1 pin 7
0V
A
B
R3 100R
R4 100R
R5 100R
D1 - D4 1N4148
D1
D2
D3
D4
D5
D6
Base
Collector
Emitter
©RSGB DY229

Figure 1 Transistor tester, circuit diagram

Inside the IC are four logic gates (see *Digital Logic Circuits*) which are all connected as inverters, which means that the output signal is always the logical 'opposite' of the input. The first two gates are connected as an oscillator; the circuit being the same as that used in *An Electronic Die*.

The output of the oscillator, at pin 11, is connected to the input of a buffer stage, IC1c, which helps to isolate the oscillator from the circuit that follows it. The buffer output appears on pin 3, which we shall label as *test point A* for future use. Another inverter, IC1d, follows this, its output at pin 4 being labelled *test point B*.

There are two LEDs connected back to back at the circuit output. These are D5 and D6, D5 being red and D6 being green. Whatever the output of the oscillator at any instant, one of the LEDs must be lit and the other unlit. With point A positive and point B zero, the red LED is lit, when A is zero and B is positive, the green LED is lit. Because the oscillator output is repeatedly switching from one polarity to the other, the lit LED is alternately red and green. They switch between the two colours much faster than we can see, so what we think we see are both LEDs lit together.

The two 100 ohm resistors, R3 and R4, provide the bias to the base of the transistor under test. When A is positive and B is zero, the base-emitter junction of the transistor will be forward-biased, and the transistor will switch on (if it is a working npn type). When the transistor is on, it effectively short-circuits D5 (the red LED) and it extinguishes. When point A is zero and B is positive, an npn transistor will be switched off and the green LED (D6) will light. Thus, for a working npn transistor, only the green LED is lit.

If the transistor under test is a pnp type, it will switch on when A is zero and B positive, thus short-circuiting the red LED (D6). When A is positive and B zero, the transistor is off and the red LED (D5) is lit. Thus for a working pnp transistor, only the red LED is lit.

To summarise, the states of the LEDs indicate the following conditions:

- Both LEDs apparently lit: no transistor connected, or transistor permanently open circuit.
- Neither LED lit: a collector-emitter short-circuit is almost certain.
- Red LED alone: pnp transistor in working order.
- Green LED alone: npn transistor in working order.

Construction

The prototype tester was built on a piece of Veroboard measuring 15 strips by 18 holes. Cut the tracks using a track-cutting tool or a 3 mm (⅛ inch) twist drill, as shown in **Figure 2**. Notice that, in this diagram, there is no

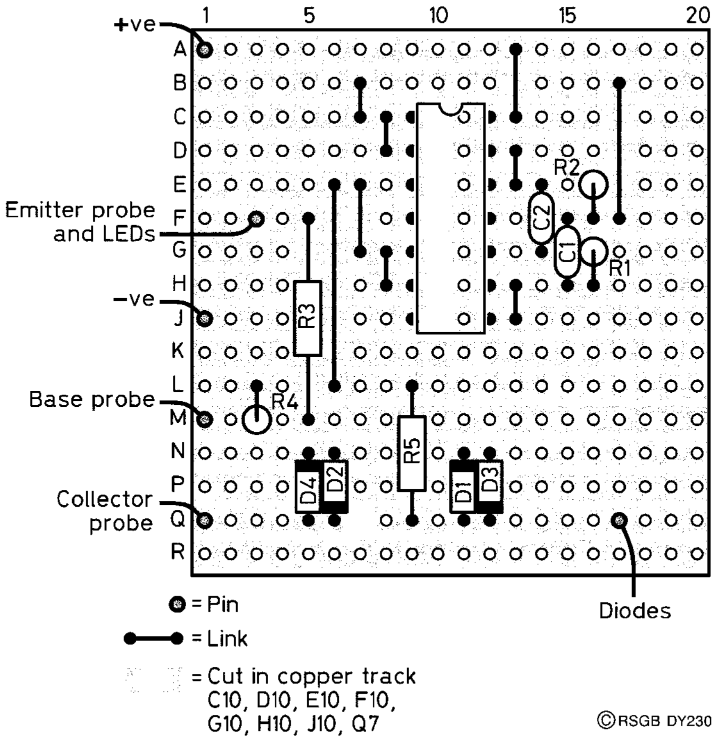
+ve
1
5
10
15
20
A
B
C
D
E
F
G
H
J
K
L
M
N
P
Q
R
Emitter probe and LEDs
−ve
Base probe
Collector probe
R1
R2
R3
R4
R5
C1
C2
D1
D2
D3
D4
Diodes
= Pin
= Link
= Cut in copper track C10, D10, E10, F10, G10, H10, J10, Q7
©RSGB DY230

Figure 2 Transistor tester, component layout

track ‘I’, so try to avoid miscounting when you translate diagram positions to real positions on the board. Hold the board up to a strong light to ensure that there is no copper swarf shorting adjacent tracks together, and that you have made the cuts in the correct places.

Having done this, insert and solder Veropins for all the connections to be made to components not on the board itself. Then solder in the IC holder and the wire links. Then insert the other components in the order resistors, capacitors and diodes D1–D4. Some resistors are mounted vertically so that their connections are on adjacent tracks. Double check the diode polarities – it is easy to make a mistake when wiring diodes in anti-parallel! Next, connect up the off–board components, again making sure that the LEDs have the correct polarity. The probe leads for the emitter, base and collector should be made from different colours of wire and terminated in probe clips (small insulated crocodile clips).

Check carefully for dry joints and errant blobs of solder. Plug the IC into its holder, ensuring that it is inserted the right way round, as shown in Figure 2.

Testing

Without a transistor in circuit, and the battery connected, both LEDs should be lit. Connect a known good npn transistor and verify that the green LED lights. Now simulate two transistor faults: disconnect the base lead and both LEDs should light; remove the transistor and connect the emitter and collector leads together. Neither LED should light.

Repeat the tests with a known good pnp transistor. The results should be the same, except that the correct indication should now be a lit red LED. On your computer, make a small label of the bulleted list above, to fit on your tester showing the states of the LEDs and what they mean. It will act as a useful *aide mémoire* when you use the tester in future.

Using

The circuit will test transistors in isolation or in an existing circuit, i.e. prior to use. You can check the lead identifications in component catalogues such as the Maplin catalogue. The tester is ideal for going through the large bags of unmarked transistors that you can buy for a song at rallies. You can sort them into three piles – npn, pnp and dud!

Parts list

Resistors: all 0.25 watt, 10% tolerance or better

R1, R2	5600 ohms (Ω)
R3, R4, R5	100 ohms (Ω)

Capacitors

C1, C2	1 microfarad (μF) electrolytic, 16 V WKG

Semiconductors

D1–D4	1N4148 general-purpose silicon diodes
D5	Red LED
D6	Green LED

Integrated circuit

IC1	CMOS 4001 or 4011

Additional items

- Veroboard, 15 strips by 18 holes
- Veropins
- PP3 battery and connector (or 6 × AA cells in PP3 clip holder)
- Switch, SPST
- Connecting wire
- One each of known working npn and pnp transistors for test purposes.

Source

Components are available from Maplin.

70 The ‘Yearling’ 20 m receiver

Introduction

Published to celebrate the first anniversary of *D-i-Y Radio*, this excellent receiver design forms a suitable ‘second receiver project’ for those who have successfully completed the MW receivers earlier in this series. The receiver is powered from a PP3 battery or from a mains adaptor, and can be built with the help of an experienced constructor, on a prototype board. The circuit diagram and some of the components used are shown in the separate diagram. Headphones or a loudspeaker can be used and, once the radio is completed, a few simple adjustments will make the *Yearling* spring to life!

Building the receiver

Before starting the constructional process, start by identifying all the parts. One by one, tick them off against the parts list. Are their values correct? The varactor diode is a twin type (see circuit diagram overleaf), and must be cut *carefully* down the middle, producing two devices, D1 and D2, with two wires each.

First, solder the IC sockets, followed by the coils (inductors); L1 is pink inside the top, and L2 is yellow inside. Then, solder in the varactors; the lettering on D1 should be next to coil L1, and the lettering on D2 should face resistor R7. After those, the capacitors, wire links and resistors should be soldered to the board. Take care to wire the voltage regulator, IC3, correctly. Solder in the crystal X1 as quickly and deftly as you can – crystals do *not* take kindly to having their leads bent and being fried with a soldering iron! Make sure that the electrolytic capacitors C2, C12, C15 and C16 are fitted the right way round. Most electrolytic capacitors have only the negative lead marked.

Figure 1 shows the rear of the front panel, illustrating the connections from the board and antenna socket to the controls. All normal connecting wires are 22 SWG or thereabouts, with insulation. Their lengths should be about 15 cm, except for the battery lead to the switch, which is about 8 cm. It is recommended that you use different-coloured wire for each connection to a control. **Figure 2** shows this. The variable resistor section of VR5, the AF gain control, uses single screened cable connected to 0 V (ground) at the

Amateur Radio

D-i-Y

Year

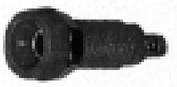
Antenna Socket

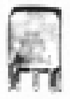
Variable Inductor

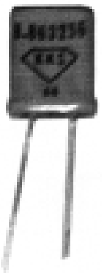
Crystal

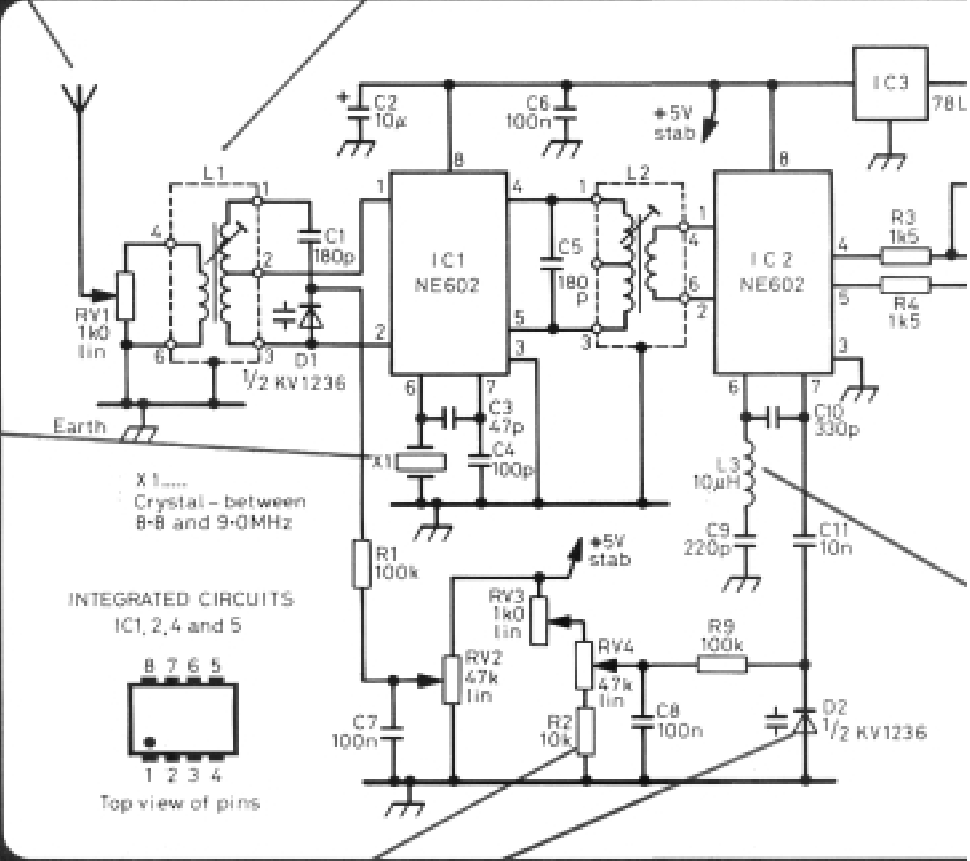
C2
10µ
C6
100n
+5V
stab
IC3
78L
L1
1
4
2
6
3
C1
180p
RV1
1k0
lin
D1
½ KV1236
Earth
8
1
2
4
5
3
6
7
IC1
NE602
C5
180
P
L2
1
3
4
6
2
IC2
NE602
8
4
5
3
6
7
R3
1k5
R4
1k5
C3
47p
C4
100p
X1
C10
330p
L3
10µH
C9
220p
C11
10n
X1.....
Crystal - between
8·8 and 9·0MHz
INTEGRATED CIRCUITS
IC1, 2, 4 and 5
8 7 6 5
1 2 3 4
Top view of pins
R1
100k
+5V
stab
RV3
1k0
lin
RV4
47k
lin
R9
100k
RV2
47k
lin
C7
100n
R2
10k
C8
100n
D2
½ KV1236

Resistor

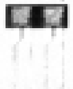
Varicap Diode

Most radio amateurs enjoy building part
is Do-it-Yourself (D-i-Y) Radio, and it is
successfully built yourself. Licensed
allowed (by the Government) to use ho
can see how radio components are dra
circuit diagram for the

D-i-Y Radio, RSGB, Lambda House, Cra

– Do It Yourself

RADIO

rling

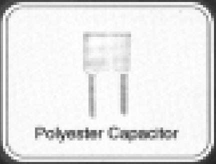
Polyester Capacitor

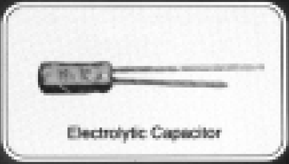
Electrolytic Capacitor

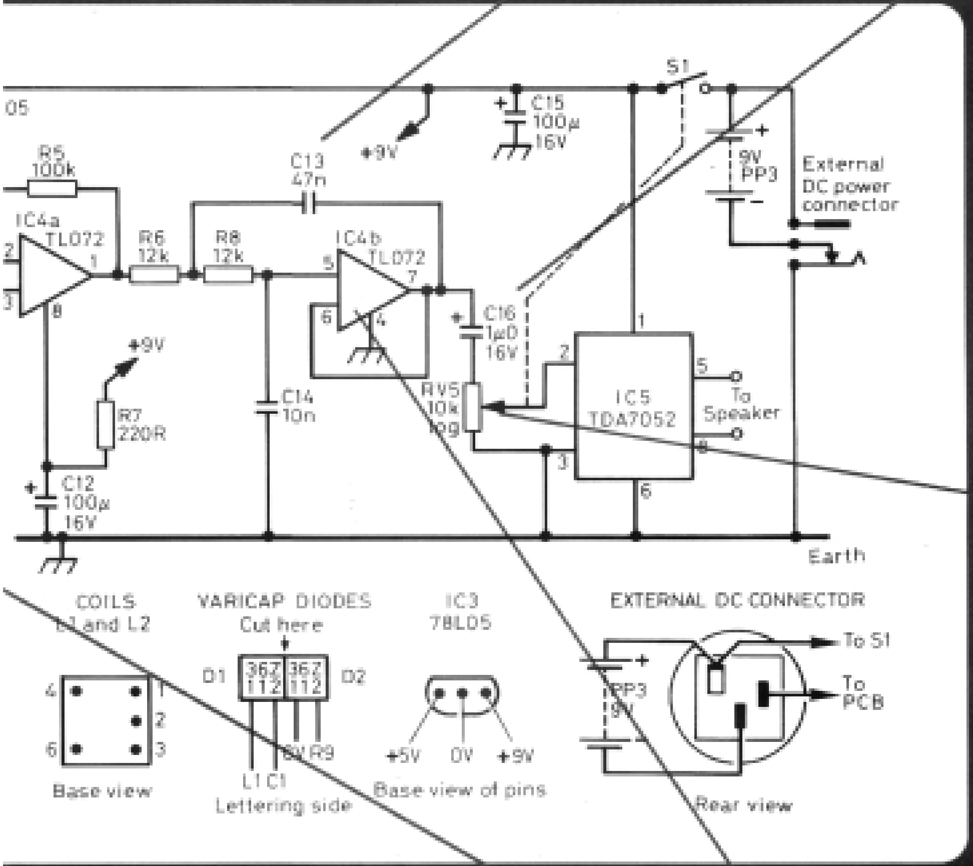
05
R5
100k
IC4a
TL072
2
3
1
8
R6
12k
R8
12k
C13
47n
+9V
IC4b
TL072
5
6
7
4
C15
100μ
16V
S1
9V
PP3
External
DC power
connector
C16
1μ0
16V
RV5
10k
log
IC5
TDA7052
1
2
3
5
6
8
To
Speaker
+9V
R7
220R
C14
10n
C12
100μ
16V
Earth
COILS
L1 and L2
4
1
2
6
3
Base view
VARICAP DIODES
Cut here
D1
367
112
367
112
D2
0V
R9
L1
C1
Lettering side
IC3
78L05
+5V
0V
+9V
Base view of pins
EXTERNAL DC CONNECTOR
PP3
9V
To S1
To
PCB
Rear view

AF Gain Control

Fixed Inductor

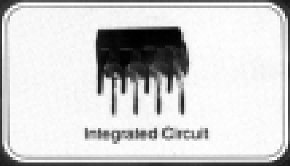
Integrated Circuit

of their radio stations themselves, this
very satisfying to use a radio you have
d radio amateurs are the only people
me-built transmitters. On this page you
wn on a circuit diagram. This is the full
D-i-Y Radio Yearling.

nborne Road, Potters Bar, Herts. EN6 3JE

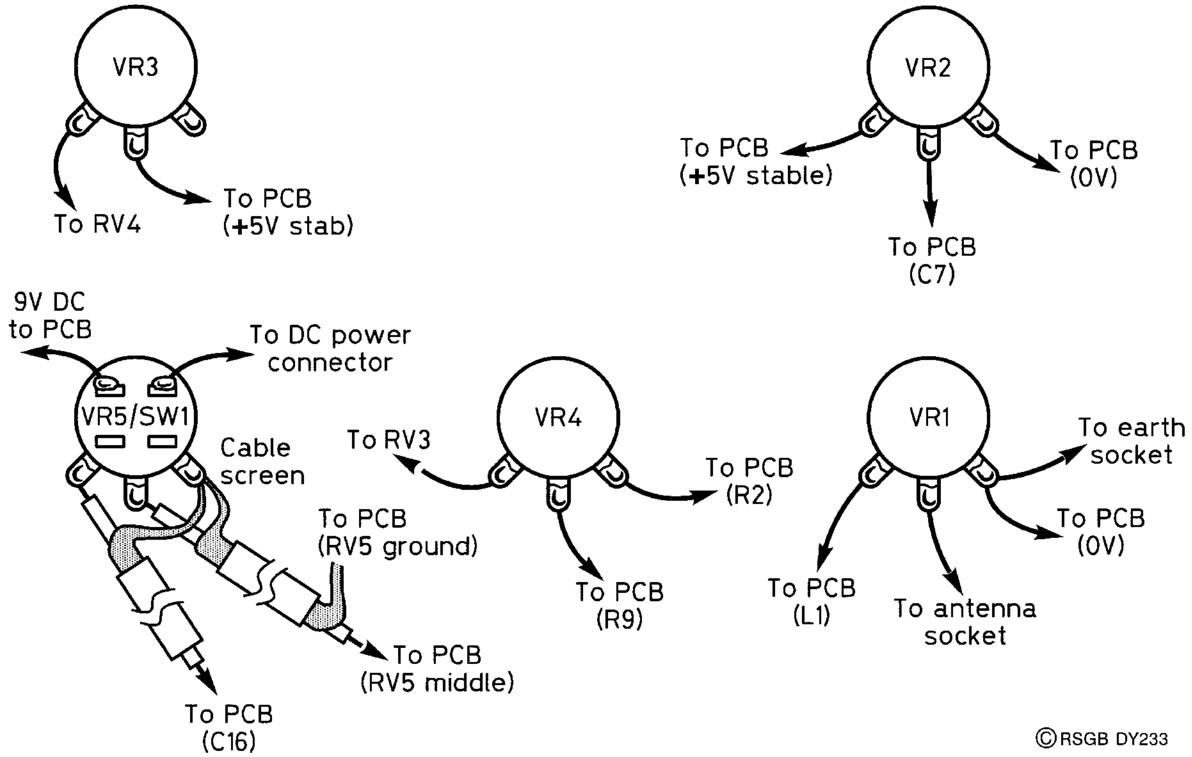
VR3
To RV4
To PCB
(+5V stab)
VR2
To PCB
(+5V stable)
To PCB
(0V)
To PCB
(C7)
9V DC
to PCB
To DC power
connector
VR5/SW1
Cable
screen
To PCB
(RV5 ground)
To PCB
(RV5 middle)
To PCB
(C16)
VR4
To RV3
To PCB
(R2)
To PCB
(R9)
VR1
To earth
socket
To PCB
(0V)
To PCB
(L1)
To antenna
socket
©RSGB DY233

Figure 1 Rear view of the variable resistors. Check the connections carefully to make sure the wires fit the correct holes

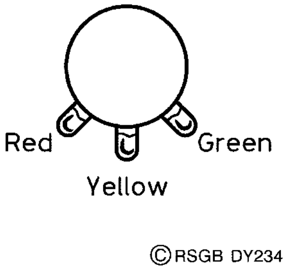
Red
Yellow
Green
©RSGB DY234

Figure 2 It is helpful to use different colour insulated connecting wires. Wires between each variable resistor and the board should be twisted together to give a neat wiring outfit.

board end. Now fit the ICs into their sockets. Make sure that they are the right way round (see circuit diagram) and that each pin lies directly above its corresponding socket before applying *gentle* pressure with the back of the board firmly supported.

Check that all the connections are correct (don’t *assume* this – check the ends of each wire against the circuit diagram) and that all your soldered joints are shiny. Lastly, drill the five 10.5 mm diameter holes for the main controls. On the side of the case, a 6.3 mm diameter hole is needed for the speaker socket, and 8 mm holes for the antenna and earth sockets. The external power socket requires an 11 mm diameter hole.

Adjusting it

Before you can make adjustments, and in order to hear *anything* on your *Yearling*, you will need to connect an antenna (aerial) to the antenna socket. About 8 metres of wire, preferably outdoors and as high as possible, is all you need to connect to the socket. Connect the 3.5 mm jack socket for the speaker, and a 3.5 mm jack to your speaker leads. Connect a battery and switch on.

1. Using a very small screwdriver or, better still, a non-metallic ‘trimming tool’, *gently* screw in the core of L2 as far as it will go, but *don’t force it*. Then unscrew it by three turns anticlockwise.
2. Set VR1, VR2 and VR4 to mid-position and rotate the core of L1 anticlockwise until the hissing noise you hear reaches a maximum intensity. Then adjust L2 for maximum noise.
3. If you now tune carefully with the main tuning control, VR4, you should hear some amateur Single-Sideband (SSB) speech signals. You may have to adjust the bandspread (fine tuning) control, VR3, to make the speech sound normal.
4. Having verified that everything is working, switch off and mount the controls on the front panel and the sockets on the side. To do this, it is much safer to disconnect all the controls and sockets, mount them in their final positions, and then wire them up again.
5. Fit the front panel knobs, connect your aerial and switch on again, checking that everything is working. Then, locate the cluster of CW (Morse) signals to be found at the bottom of the 20 metre band, set the bandspread control to mid-position and slacken off the main tuning knob. Turn the knob (but *not* the control!) until the pointer lies a little clockwise of 14.0 MHz. The SSB signals should now lie roughly between the dial centre and 14.35 MHz. Tighten up the knob.
6. Finally, fix the board to the rear panel, and secure the battery (if you are using one). Attach the rear panel to the back of the box, and you are finished!

Listening!

Make a habit of keeping the bandspread control in its centre position when searching for stations; then you can adjust it either way to make the signals readable. Unless you have a very big aerial, it is best to have the 'RF Gain' control, VR1, at maximum. Use the 'Antenna Tune' control, VR2, to give the best signal, and control the volume with the 'OFF/AF Gain' control. You will find some excellent DX stations with your *Yearling* receiver, and it will serve you well.

Parts list

Resistors (all 0.25 W, 5%)

R1, R5, R9	100 kilohms (kΩ)
R2	10 kilohms (kΩ)
R3, R4	1.5 kilohms (kΩ)
R6, R8	12 kilohms (kΩ)
R7	200 ohms (Ω)

Capacitors (all rated at 16 V or more, tolerance *at least* what is quoted)

C1, C5	180 picofarads (pF) polystyrene 5%
C2	10 microfarads (μF) electrolytic
C3	47 picofarads (pF) polystyrene 5%
C4	100 picofarads (pF) polystyrene 5%
C6, C7, C8	100 nanofarads (nF) or 0.1 microfarad (μF) ceramic
C9	220 picofarads (pF) polystyrene 2%
C10	330 picofarads (pF) polystyrene 2%
C11, C14	10 nanofarads (nF) or 0.01 microfarad (μF) ceramic
C12, C15	100 microfarads (μF) electrolytic
C13	47 nanofarads (nF) or 0.047 microfarad (μF) polyester, 5%
C16	1 microfarad (μF) electrolytic

Variable resistors

VR1, VR3	1 kilohm (kΩ) linear
VR2, VR4	47 kilohms (kΩ) linear
VR5	10 kilohms (kΩ) log with switch

Inductors

L1	Toko KANK3335R
L2	Toko KANK3334R
L3	10 microhenries (μH), 5%

Semiconductors

IC1, IC2	Philips/Signetics NE602 or NE602A
IC3	78L05 5 V 100 mA regulator
IC4	TL072 Dual Op-Amp
IC5	Philips TDA7052 audio amplifier

Additional items

D1, D2	Varactor diode Toko KV1236 (cut into two sections – see text)
X1	Crystal 8.86 MHz type (from Maplin, etc.)
4 off	8-pin DIL sockets for IC1, IC2, IC4 and IC5
2 off	4 mm sockets aerial (red) and earth (black)
1 off	3.5 mm chassis-mounting speaker jack socket
1 off	DC power socket for external supply (if required)
4 off	Red knobs with pointers
1 off	Tuning knob with pointer (e.g. 37 mm PK3 type)
1 off	Printed-circuit board or prototype board
1 off	Plastic case approx 170 × 110 × 6 mm (e.g. Tandy number 270-224)
1 off	Speaker 8–32 Ω impedance (or headphones)

71 Adding the 80 metre band to the Yearling receiver

Background

You will have noticed that your *Yearling* receiver has a dial which shows coverage of the 80-metre amateur band (3.5–3.8 MHz). This band is used for local contacts during the day, and contacts up to about 1600 miles in darkness. Longer distances are possible, particularly in the middle of winter.

The modifications

Only a few extra parts are required, as you may have noticed from the parts list. A low-pass filter, FL1 (one which passes low frequencies and rejects higher frequencies), is switched into the circuit on 80 m. The circuit of the

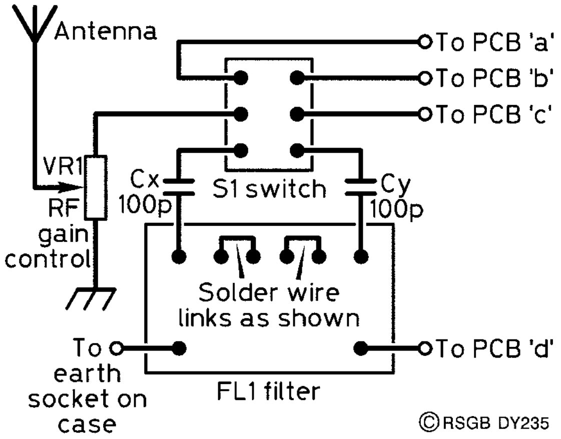
Antenna
To PCB 'a'
To PCB 'b'
To PCB 'c'
VR1
RF
gain
control
Cx
100p
S1 switch
Cy
100p
Solder wire
links as shown
To
earth
socket on
case
To PCB 'd'
FL1 filter
©RSGB DY235

Figure 1 The circuit diagram shows the extra components for 80 m operation. Note the connections to the PCB 'a', 'b', 'c' and 'd'

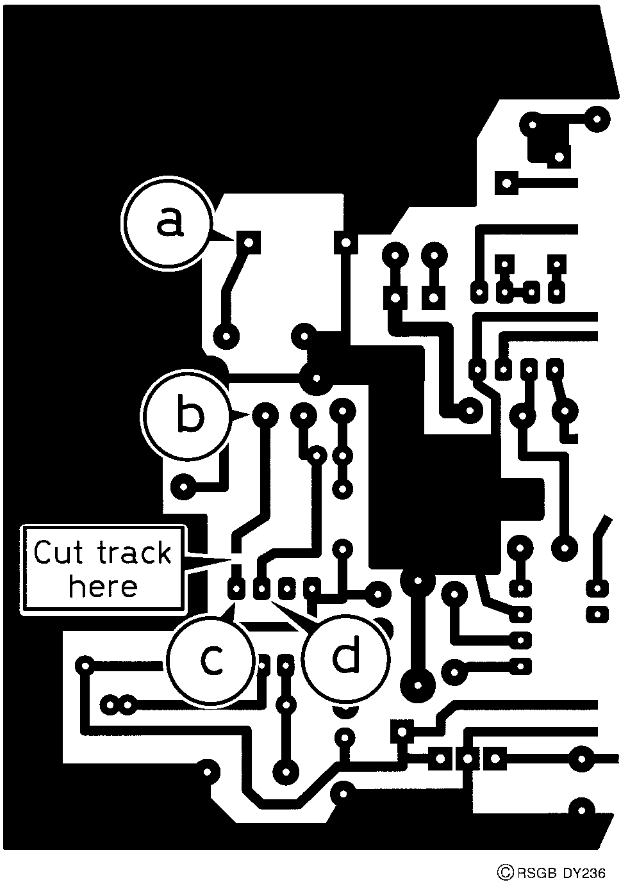
a
b
Cut track
here
c
d
©RSGB DY236

Figure 2 The underside of the PCB. Wires are connected from the switch and filter as shown

switch and its connections is shown in **Figure 1**. Before making the modifications, dismantle the receiver so that you have easy (and safe) access to the case and the track side of the PCB.

1. The first thing to do is to drill a 6.5 mm diameter hole in the side of the case into which the switch fits.
2. Then, using a sharp Stanley knife or scalpel, carefully cut the track on the PCB as shown in **Figure 2**, making a gap about 1 mm wide.
3. Using 10 cm lengths of different-coloured insulated wire, make the four connections, a, b, c and d, to the PCB, as shown in Figure 2.
4. Solder the two links on the filter, and then make the connections to the switch, capacitors and PCB. You will have to disconnect the existing wire between the RF gain control, VR1, and pin 4 of L1 on the PCB.
5. Lastly, check your new connections carefully, then mount the switch in the new hole and fix the filter to the bottom of the case with a little glue, as shown in **Figure 3**. Reassemble the circuit, and replace the back of the case.

More testing!

Firstly, switch your new switch, S1, into the 20 m position, to check that the original circuit still works! If you find that the ‘Antenna Tune’ control peaks at a slightly different position, don’t worry.

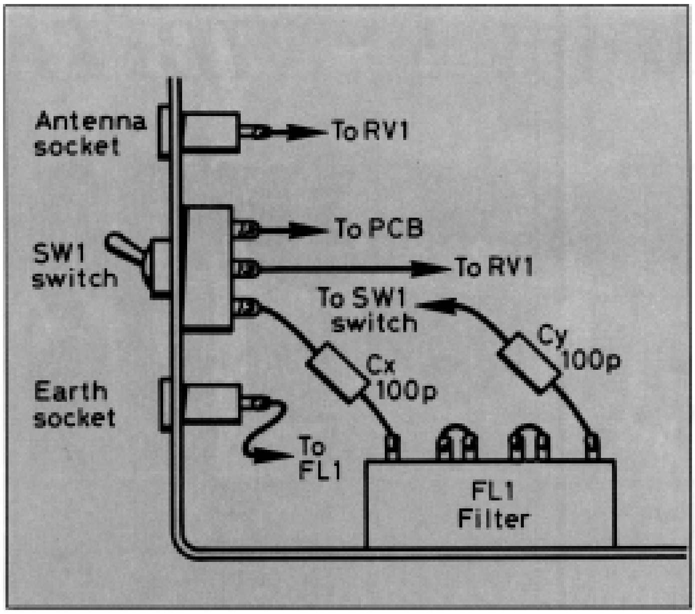

Figure 3 Internal view of the Yearling case. The filter FL1 is attached to the base with glue

Now switch to 80 m, and tune around the anticlockwise end of the dial; you should hear some SSB stations, particularly in the evenings and at weekends, when may people are on the air. At the other end of the travel of the tuning control, you should hear CW (Morse) stations.

The Radio Society of Great Britain broadcasts amateur radio news every Sunday morning on or about 3.65 MHz; the table below has the details. Finally, a good antenna is more important than ever for 80 metre reception – aim for more height and length, and then consider the project concerned with making an Antenna Tuning Unit (ATU)!

Parts list

Capacitors (all rated at 16 V or more, tolerance 10% or better)

Cx, Cy	100 picofarads (pF) polystyrene

Filter

FL1	Toko 237LVS1110 low-pass filter

Additional items

SW1	2-pole 2-way (changeover) toggle switch
7 off	Short lengths of insulated wire of different colours

The RSGB news broadcasts, GB2RS – Sunday mornings

Frequency (MHz)	*Local time*	*Reception area*
3.650	0900	SE England
3.650	0930	Midlands
3.650	1000	SW England
3.650	1100	Yorkshire
3.640	1130	Aberdeen
3.660	1130	Glasgow

The Midlands transmission is repeated at 1800 (6pm) local time on 3.650 MHz. All frequencies are approximate in order to avoid interference, and use lower sideband (LSB). If you also have a 40 metre receiver, there are GB2RS news broadcasts on 7.048 MHz at 0900 local time from Northern Ireland and from 1100 local time from the north midlands.

72 How the Yearling works

Introduction

The *Yearling* was designed to provide an introduction to *Amateur Radio* on the 20 m amateur band. Let's look at how the different sections (or 'stages') of a radio work, and how they fit together to form a complete receiver. **Figure 1** shows a block diagram which you can follow and compare with the circuit diagram of your *Yearling* receiver.

The antenna (or aerial)

Connected to your receiver, it will pick up not only amateur signals, but all other signals as well! This means that the receiver has to select the one signal that interests you, while rejecting all the others. The following stages do just that.

The RF filter

This stage (centred around L1) selects the band of radio frequencies (RF) containing the signal you want, in this case, those having wavelengths around 20 m. Signals from the 40 m band, for example, would not get through.

The crystal oscillator

This is an oscillator circuit designed around a quartz crystal (X1), and has a very stable frequency. It produces a single, very pure frequency to feed into the mixer. A crystal having a frequency between 8.800 MHz and 9.000 MHz is suitable for this circuit. The oscillator and mixer functions are both carried out inside IC1.

The first mixer

Yes, this stage 'mixes' two signals together. In this case, the two signals are (i) from the aerial via the RF Filter, and (ii) from the crystal oscillator. Two

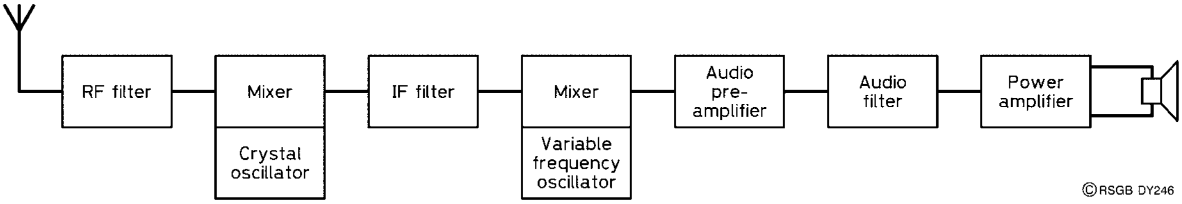

Figure 1 Block diagram of the Yearling, showing how the various stages fit together to make a complete radio receiver

bands of signals emerge from the mixer. The first is centred upon a frequency equal to the incoming signal frequency **added** to the crystal frequency, and the second is centred upon a frequency equal to the incoming signal frequency **subtracted** from the crystal frequency. Look at an example – if the signal is at 14 MHz and the oscillator at 9 MHz, then the mixer outputs will be 14 + 9 = 23 MHz and 14 – 9 = 5 MHz.

Intermediate frequency (IF) filter

It is the purpose of the IF filter (centred around L2) to select only one of these two bands of frequencies emerging from the mixer. In this case, it is the lower band of frequencies (around 5 MHz) which we select. This is because, in general, lower frequencies are easier to handle than higher ones.

Variable-frequency oscillator (VFO)

The VFO (part of IC2) enables us to tune into a particular station, and operates over a band of frequencies between 5 MHz and 5.35 MHz in this receiver. You will notice that IC1 and IC2 are the same type of chip, so that you will be expecting another mixer stage to be associated with the VFO. You are quite right!

The second mixer

This mixer obeys exactly the same rules as those of mixer 1. Sum and difference frequencies are produced, like this. Mixing is between the incoming IF signals (around 5 MHz) and the VFO signals (around 5 MHz), producing output frequency bands centred upon 10 MHz and 0 MHz. The use of the words ‘band of frequencies’ throughout this explanation is intentional. If all the signals were pure, there would be no bands; the bands are produced because of one thing – the modulation imposed on the pure frequencies at the transmitter. So, the 'bands' contain the one thing that we want to extract from the signal, and that is the speech or Morse code that the signal contains. The band of frequencies at 0 MHz is just that – the audio frequencies we want in the loudspeaker. Because of this, the audio frequency output of the second mixer is selected and passed on for amplification.

The audio preamplifier

Preliminary amplification of the minute audio signal which emerges from the second mixer is provided by IC4a, which will respond only to audio signals, automatically rejecting the 10 MHz signal.

The audio filter

The bandwidth of normal speech when transmitted by an amateur station is around 3 kHz, so there is no advantage to be gained in amplifying frequencies greater than this. IC4b is known as a low-pass filter, because it passes (lets through) lower frequencies and rejects higher ones.

The power amplifier

IC5 produces the final audio amplification and provides enough power (about 350 milliwatts (mW) to drive a small speaker.

How does it work on 80 m?

If you have fitted the 80 m modification to your receiver, you are probably wondering how the circuit works at this different frequency. Firstly, the filter which you fitted selects the 80 m band instead of the 20 m band. The only other slight difference lies in the way the first mixer stage works. Its job is to produce sum and difference frequencies from the incoming signal and crystal frequencies. On 20 m, it did this by subtracting the crystal frequency (9 MHz) from the incoming frequency (14 MHz) to produce an IF output of 5 MHz. On 80 m, the incoming frequency (3.5 MHz) is subtracted from the crystal frequency (9 MHz) to produce an IF output of 5.5 MHz, which is still within the tuning range of the VFO in the next stage.

73 A field strength meter

Introduction

Having a reliable field strength meter is always useful. There are two basic types – the tuned variety (also known as an absorption wavemeter) and the broad-band variety. A project centred on the tuned variety can be found in this book (*An HF absorption wavemeter*), and the way it works is also presented (*The absorption wavemeter*). This project describes an untuned or broad-band type which is every bit as useful as the tuned type, when it is the level of RF in which you are principally interested.

With the possible exception of the meter, you may have all the parts needed in your junk box. The prototype was distinguished by its meter, found at a rally, and marked 'Safe', 'Dangerous' and 'Explosive' on its scale.

How it works

The basic field strength meter uses the circuit of a crystal set, but with a meter replacing the headphones. A better design, which is used here, is that of a voltage doubler, giving more sensitivity. **Figure 1** illustrates the voltage doubler circuit.

The AC input shown will be our RF input, which will be explained soon. Diode D1 will pass the positive half of the signal and use it to charge up C1 to the peak value of the signal. D2 uses the negative half of the signal to charge up C2 to the same value. Because C1 and C2 are in series, the peak voltage appearing across *both* of them (which is the DC output voltage) is equal to *twice* the peak input voltage, hence the name voltage doubler. If you're wondering why DC is present at the output when AC comes in at the

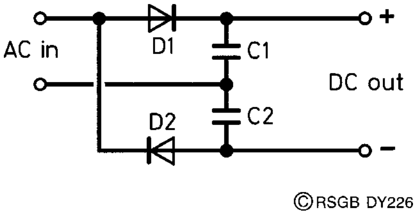

Figure 1 Voltage doubler circuit

input, remember that capacitors pass AC (RF) but block DC; thus the RF is shorted out through C1 and C2, but the steady voltage (DC) remains across the two capacitors. The voltage is thus proportional to the size of the RF signal applied at the input.

The circuit

The voltage doubler is converted into a field strength meter using the circuit of **Figure 2**. A piece of wire serves as the aerial to provide an RF signal across the radio-frequency choke (RFC). A choke is an inductor which is large enough to prevent the RF passing through it – it 'chokes' the RF. This produces the maximum RF signal at the input to the voltage doubler, and the DC output from it is measured on the meter.

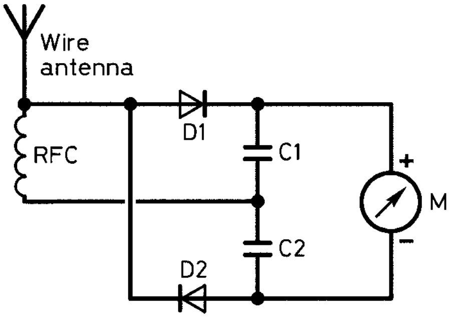

Figure 2 Field strength meter

©RSGB DY227

The parts used are not very critical. The RF choke can have any value between about 1 mH and 2.5 mH. Almost any common diode such as the 1N914 or 1N4148 can be used for D1 and D2. The two capacitors could be any value between 1 nF and 100 nF (0.001 μF and 0.1 μF). The meter should be reasonably sensitive, with a full-scale deflection (FSD) in the range 50 μA to 100 μA. Look for VU meters at rallies – these are ideal.

Construction

The prototype circuit was made on matrix board. If you don't want to use pins with the board, simply push the component leads through the holes and make the connections on the underside of the board, either with the excess component leads themselves, or with ordinary connecting wire.

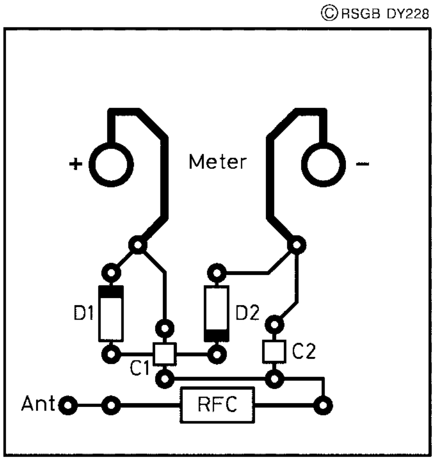

Figure 3 Board layout and interconnections

Component side of board shown.
All connections are under board

Figure 3 shows how the parts are placed and connected. The matrix board can be mounted directly on the meter using its terminal bolts!

In use

Needing no power supply other than an RF signal, just connect it all up and leave it to work! A short length of insulated wire is enough to pick up some RF and display it on the meter. Using a 200 μA meter, about 3 metres of wire gave a good deflection on the meter. To increase deflection, the wire can be wrapped around the aerial lead, provided that the wire is PVC covered and doesn't come into contact with the aerial wire.

This requires a little experimentation. Try a long piece of wire first and adjust its position until the meter needle kicks whenever there is a transmission. It is very reassuring to see the meter moving during a transmission. Although SWR meters also indicate power, they are usually set to read reverse power, and show little or no movement during transmission.

Parts list

D1, D2	1N914, 1N4148 or similar
C1, C2	10 nF disc ceramic
RFC	Miniature axial choke (1 mH)
Meter	Surplus VU meter or similar
Matrix board or similar	

Components are available from Maplin.

74 Preselector for a short-wave receiver

Introduction

A preselector is a simple RF tuned amplifier which is inserted between the aerial and the receiver. It provides some extra gain and may improve the overall performance of the receiver. This project uses a Field-Effect Transistor (FET) amplifier in grounded-gate mode.

The design has a tuned circuit at both the input and output which, with excessive gain and poor construction, would produce only one thing – oscillation! So, to avoid this happening, we will have only a low gain, and use a circuit which provides good isolation between input and output. The grounded-gate FET amplifier fulfils both these criteria. It will also cover a frequency range from about 7 to 30 MHz, which includes most of the HF amateur bands.

The circuit

This is shown in **Figure 1**. The signal from the aerial arrives at an RF transformer, the secondary of which is tuned with capacitor VC1a. The output from the tuned circuit is taken from a tap on the secondary to the source of the FET. The gate is grounded (earthed) and the amplified signal appears at the FET drain, which is then fed to the primary of another RF transformer, which is tuned by VC1b. The output to the receiver comes from the secondary of the RF transformer.

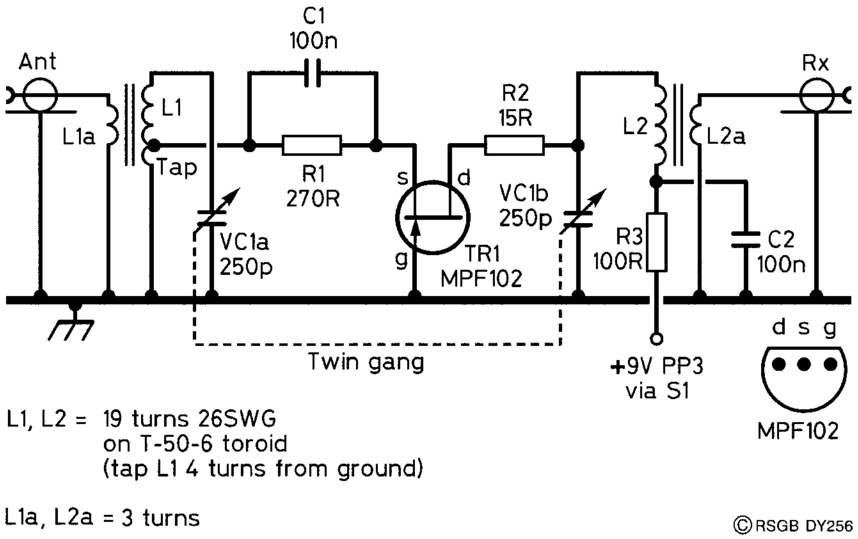
C1
100n
Ant
Rx
L1
L1a
Tap
R2
15R
L2
L2a
R1
270R
s
d
VC1b
250p
VC1a
250p
g
TR1
MPF102
R3
100R
C2
100n
Twin gang
+9V PP3
via S1
d s g
MPF102
L1, L2 = 19 turns 26SWG
on T-50-6 toroid
(tap L1 4 turns from ground)
L1a, L2a = 3 turns
©RSGB DY256

Figure 1 HF preselector, circuit diagram

Notice that the two RF transformers are identical, but they are used 'back to back', with the secondary of the first and the primary of the second being tuned. They are tuned with identical capacitors, fitted on the same shaft of a variable capacitor. We say that the two capacitors are 'ganged'. Because L1 and L2 are the same, and VC1a and VC1b are the same, both RF transformers should be resonant at the same frequency, no matter what that frequency is.

Construction

The final layout should look something like that shown in **Figure 2**. The external connectors and controls being two SO-239 sockets for connection to your receiver and aerial, a tuning control and its associated scale, and an on/off switch.

The circuit can be put together on a plain matrix board, using pins to anchor the components, or simply by pushing the component leads through the board and making connections on the underside. The layout of the prototype is shown in **Figure 3**. Mounting the board to the aluminium box is accomplished with bolts, solder tags and stand-off insulators.

Check your construction against the circuit diagram and against the layout diagram. Wire in the PP3 battery clip, put the switch in the 'off' position, and fit the battery. Testing can be carried out without fitting the top of the box.

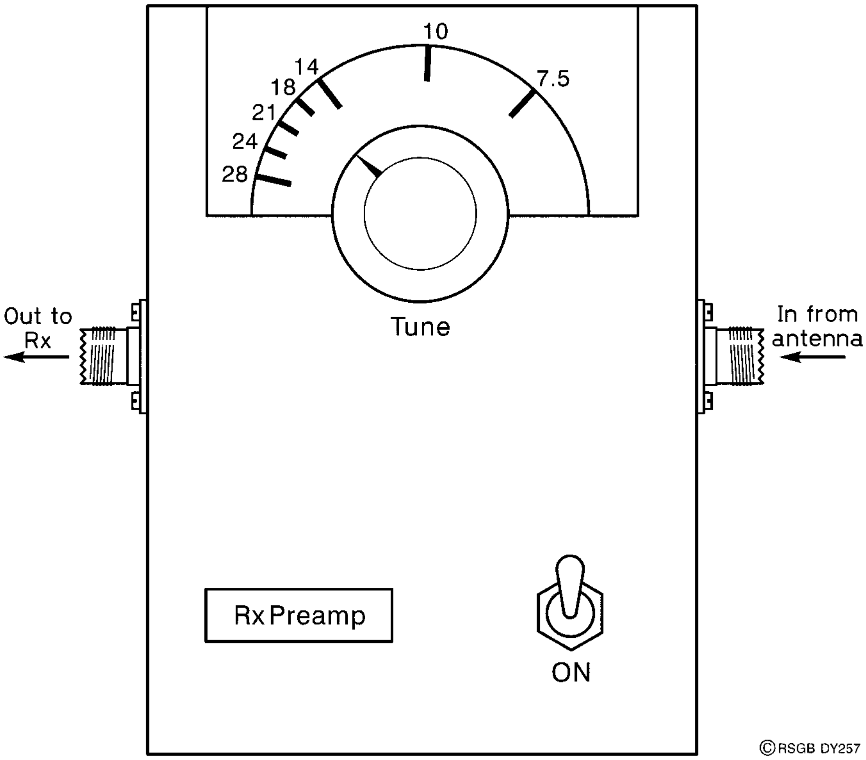

Figure 2 HF preselector, front panel layout

Testing

Don't fit your preselector yet. Tune your radio to a broadcast station, preferably a fairly weak one. Disconnect the aerial and fit your preselector between the aerial and receiver. Switch it on and rotate the tuning knob slowly. You should find a position where your original station is received more clearly than before. If it doesn't work at all, recheck your wiring. Is there a positive voltage on the drain of the FET? If not, work back towards the positive battery terminal. Is there a voltage at the junction of L2 and R2? Is there a voltage at the junction of L2 and R3? Is there a voltage at the junction of R3 and the battery lead? If there isn't a voltage at that point, then you have probably mounted your switch upside down, and it is off, not on! It's a common mistake.

Calibration

This is not obligatory, surprisingly enough. However, if having a frequency scale appeals to you, then using an RF signal generator (or using the services of a friend who has one) is the simplest solution. Feed in a weak modulated

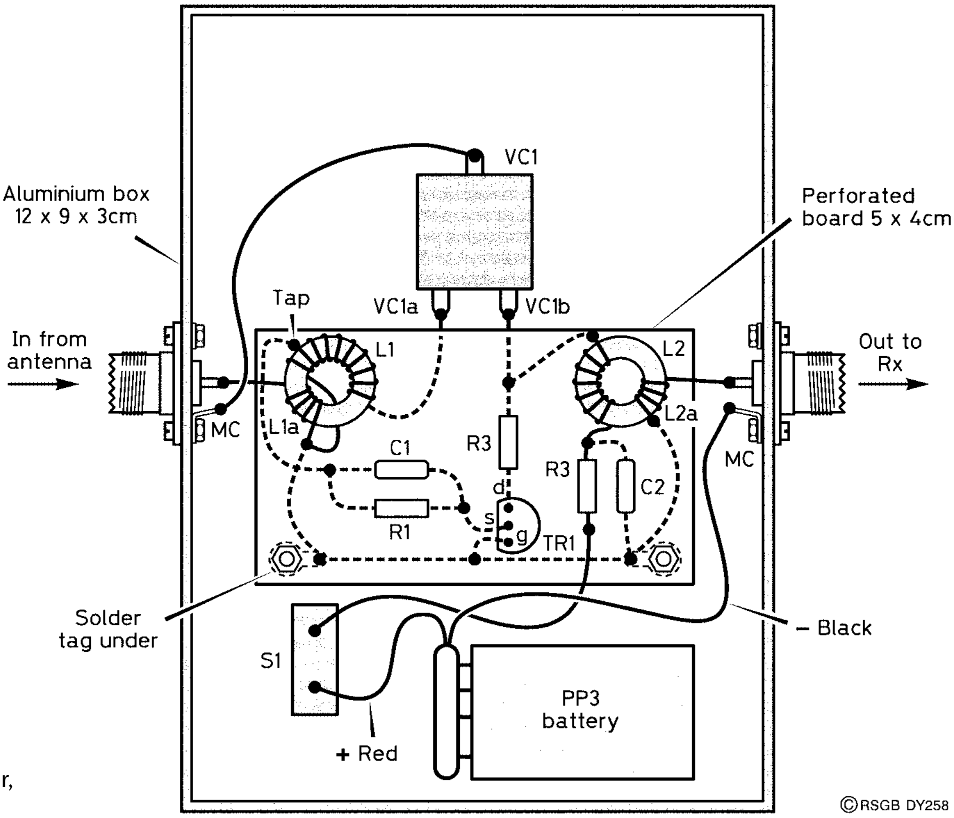
VC1
Aluminium box 12 x 9 x 3cm
Perforated board 5 x 4cm
Tap
VC1a
VC1b
In from antenna
L1
L2
Out to Rx
MC
L1a
L2a
C1
R3
R3
C2
MC
d
s
g
R1
TR1
Solder tag under
– Black
S1
PP3 battery
+ Red

©RSGB DY258

Figure 3 HF preselector, component layout

signal from the generator to the preselector, and rotate VC1 until the signal is maximum. Mark this frequency on your dial. Repeat the process for the frequencies shown on the dial in Figure 2.

If you have a commercial transceiver, feed its output into a dummy load (such as the type described in *A Switched Dummy Load*, elsewhere in this book) using a distinctive modulating signal such as an idling RTTY signal. Set the receiver to the same frequency with the preselector out of circuit. Insert it into the aerial lead, and search for the signal with VC1 until it gives the maximum deflection on your S-meter, then mark the frequency on your dial.

Parts list

Resistors: all 0.25 W carbon film or better

R1	270 Ω
R2	15 Ω
R3	100 Ω

Capacitors

C1, C2	100 nF (0.1 μF) ceramic
VC1	250/250 pF polyvaricon

Inductors

L1, L2	19 turns 26 SWG enamelled copper on T.50.6 toroid L1 has a tap 4 turns from ground end L1a and L2a – 3 turns wound over previous winding

Semiconductors

TR1	MPF102 FET

Additional items

Matrix board	To fit aluminium box (see Figure 3)
Aluminium box	12 × 9 × 3 cm
Battery and connector	PP3 9 V
S1	SPST on/off switch
Knob	As required
SO239	Sockets – 2 required

75 An audible continuity tester

Introduction

This is not the only continuity tester in this book. This alone attests to their use, so you may well want to experiment with several designs, then come up with one of your own! The very simplest form of continuity tester is probably a battery and a bulb in series, with the circuit being closed by connecting it to a fuse or other object being tested for continuity. The bulb could be replaced by a buzzer to give an audible indication. The current taken by the buzzer could damage some components, however. An ohmmeter can also be used, and is very popular for the purpose, as it indicates whether the circuit is low, medium or high resistance. This project has the advantages of indicating whether there is no continuity, some resistance or good continuity, and making an audible sound, so that you don't have to move your eyes from the circuit while making the test.

The circuit

Using only one integrated circuit, four components and a battery, this is a particularly simple circuit, as **Figure 1** shows. IC1 is usually used to flash an LED from a 1.5 V source, and to have a low current consumption. By changing the component values, IC1 is made to oscillate at audio frequencies, and we can hear these through the loudspeaker, LS1. Low-impedance speakers can be used, but result in an increased current drain, so the higher the impedance, the better.

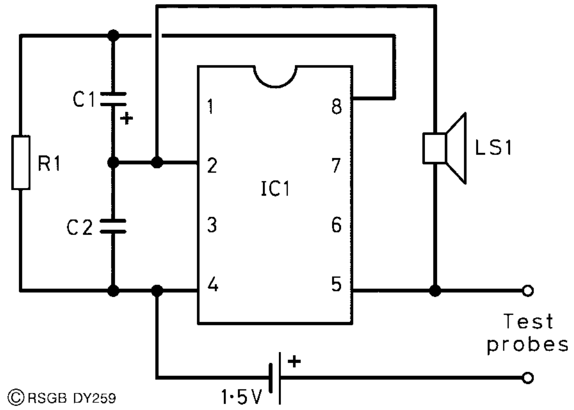

Figure 1 Continuity tester, circuit diagram

Construction

The layout of the circuit on Veroboard measuring 7 strips by 15 holes is shown in **Figure 2**. Start by making the four track cuts which will lie underneath the IC. Use a track cutter or a 3 mm ($\frac{1}{8}$ inch) twist drill rotated between thumb and forefinger for this. Solder the Veropins in place, followed by the wire link. Then solder in the IC holder, the resistor and the capacitors, making sure that the electrolytic capacitor, C1, is connected the correct way round.

Check, with the board against a bright light, that there are no shorted tracks, either by large blobs of solder or by copper swarf from the track-cutting process. Then insert IC1 into its holder the right way round. The probes can be ordinary connecting wire, the free ends being tinned with solder to prevent wire whiskers from touching components other than the one you are testing.

If you are happy that the circuit and the wiring appear to be correct, fit the battery into its clip. Nothing should happen until the probes are touched together, when you should hear a note from the loudspeaker. If nothing happens, all you can do is to recheck your circuit, as there is nothing else to go wrong!

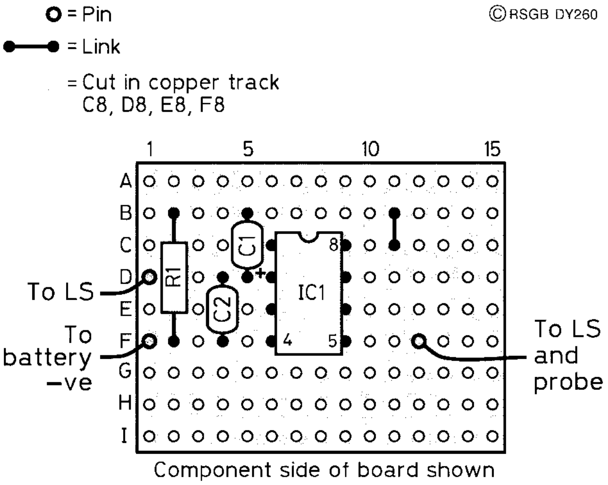
= Pin
= Link
= Cut in copper track
C8, D8, E8, F8
©RSGB DY260
1
5
10
15
A
B
C
D
E
F
G
H
I
R1
C1
C2
IC1
8
4
5
+
To LS
To battery −ve
To LS and probe
Component side of board shown

Figure 2 Continuity tester, component layout

Any box can be used; there is no justification for a metal case, unless you want to make use of something, which is to hand, such as a tobacco tin. Alternatively, any suitable plastic box will do.

Use

The tester will give different pitch notes for resistances of different values. The higher the resistance, the higher the pitch from the speaker. Try it with small inductors, and you will learn to recognise the different tones produced by the IC.

Safety notice

Using the continuity tester on components *in situ* is not advisable, as the results could be misleading. It can be dangerous to make measurements *in situ* on equipment, which is operating. If you must make such tests, always disconnect the equipment form its power source first.

Parts list

Resistor	
R1	1000 Ω (1 kΩ), 0.25 W carbon, 10% or better
Capacitors	
C1	10 μF electrolytic, 16 V
C2	0.1 μF subminiature polyester or ceramic

Integrated circuits	
IC1	LM3909N
Additional items	
	Veroboard 7 strips by 15 holes
LS1	64 Ω miniature loudspeaker
	IC holder
	Veropins
	Connecting wire
	Test leads
	1.5 V AA alkaline battery

76 An experimental 70 cm rhombic aerial

Introduction

Most commonly used aerials can be classed as *resonant* or *standing-wave* aerials. There is another class known as *non-resonant* or *travelling-wave*. Resonant aerials, such as the dipole, are narrow-band; this occurs because resonance occurs only over a narrow band of frequencies. Travelling-wave aerials, on the other hand, can operate over a wide band of frequencies.

The *rhombic* is an example of a non-resonant or travelling-wave aerial. It is often employed for fixed commercial and military short-wave radio links. Made with wire, it has a diamond shape when looking down on it from above. The four corners are supported on four masts. It is a very effective aerial, and has good gain, a quality which can be judged from the *polar diagram* shown in **Figure 1**. This has been obtained from a computer program, and so is the perfect shape for a rhombic aerial.

Theory (but only a little)

A polar diagram shows graphically the ability of an aerial to radiate (or receive) more effectively in one direction at the expensive of the radiation in other directions. Figure 1 shows the polar diagrams of two aerials, a simple 70 cm dipole and the rhombic described in this project. The dipole has the

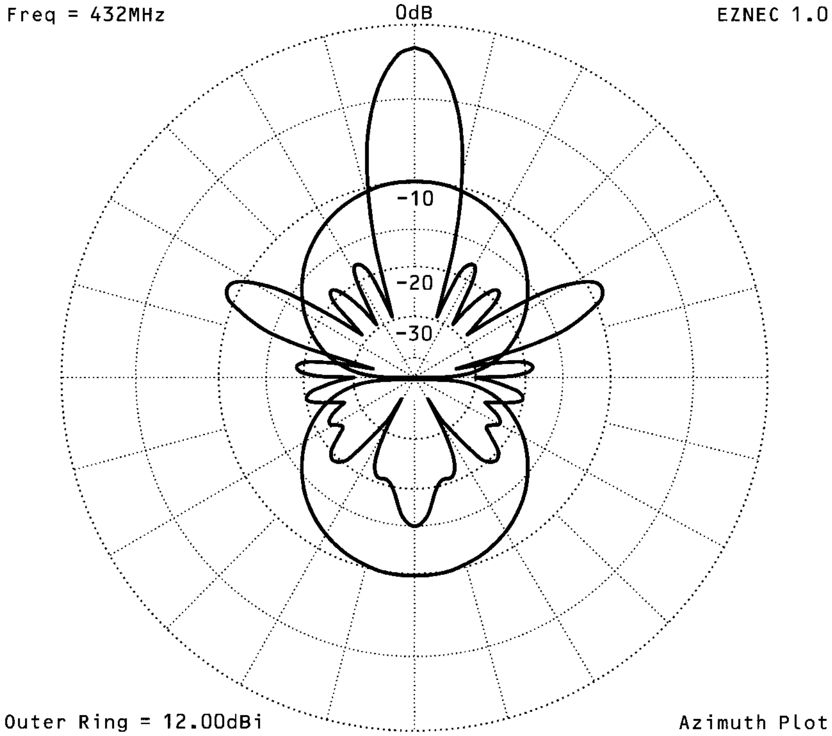

Figure 1 The horizontal polar diagrams of the small rhombic antenna and a dipole compared

©RSGB DY262

well-known figure-of-eight shape, showing a symmetrical angular behaviour about the direction of the aerial and about a direction perpendicular to the aerial. That of the rhombic, on the other hand, is quite irregular by comparison, but is still symmetrical about one axis only, not two. It's this asymmetry that gives the rhombic its gain, by virtue of its *front-to-back ratio*. This is the ratio of the power radiated forwards to that being radiated backwards. Notice the large *lobe* (lump) at the top of the polar diagram; this is the direction in which the aerial transmits best. The lobe in the opposite direction has been reduced significantly, allowing more power to be directed forwards, not backwards

Problems

The rhombic is not found in every amateur's back garden, despite its attractions. To work best each edge of the diamond shape should be about two wavelengths long. Hence, a rhombic for the 20 metre band could be about 80 m from tip to tip! Another disadvantage is that, because of its size, it cannot be rotated.

It will operate well over a range of frequencies. An HF rhombic could work on the 7, 10, 14, 18, 21 and 28 MHz bands. One for the lower VHF frequencies could operate on the 50, 70 and 144 MHz bands.

Its large size is less of a problem at UHF. A portable rhombic can be made for 70 cm which can be used with a hand-held transceiver. The aerial design to be described here will give a gain of up to 9 dB relative to a dipole. This is written as 9 dBd, the second ‘d’ meaning ‘relative to a dipole’. This is equivalent to improving your signal by 1.5 S-points at the receiver or (and you may be surprised by this) by fitting a linear amplifier to your transceiver that would take 5 W input and produce 40 W output to a normal dipole! Consider the relative costs of the two approaches to producing the same received signal. You will also receive everyone else’s signals 1.5 S-points better than before!

Unlike the popular Yagi aerial, this design has no critical dimensions and can be folded up for transport by car or bicycle. It has a fairly high input (or feed) impedance, being fed usually by balanced twin feeder. To feed it with standard 50 Ω coaxial cable, a matching transformer in the form of a *balun* is required. A balun will convert the *bal*anced (symmetrical) aerial impedance to the *un*balanced and lower impedance of the coaxial cable. The details of how to build the balun, which in this case is a half-wave transformer, are included in the constructional details.

Construction

The aerial frame is made up of 1 cm × 2 cm strips of wood fixed to a plywood centre using 30 mm long M4 bolts, as shown in **Figure 2a**. The outer bolts fixing the front and side supports can be removed for folding prior to transportation, as shown in **Figure 2b**.

The wires are fixed to the front and rear supports using screw connectors, sometimes called ‘chocolate block’ connectors. Detail X and Y of Figure 2 show how this is done. The side supports have holes in the ends through which the wire is threaded.

The aerial must be mounted in the horizontal plane using a small shelf bracket attached to the centre plate, using the same bolts that hold the rear support. The other half of the bracket may be mounted to a vertical mast using screws or jubilee clips (hose clips).

The balun

Cut a 23 cm length of coaxial cable; this is to be our half-wave transformer. Cut and remove 2 cm from each end of the sheath. Make the braid into a pigtail at each end. Cut and remove 1 cm of the inner insulator from each

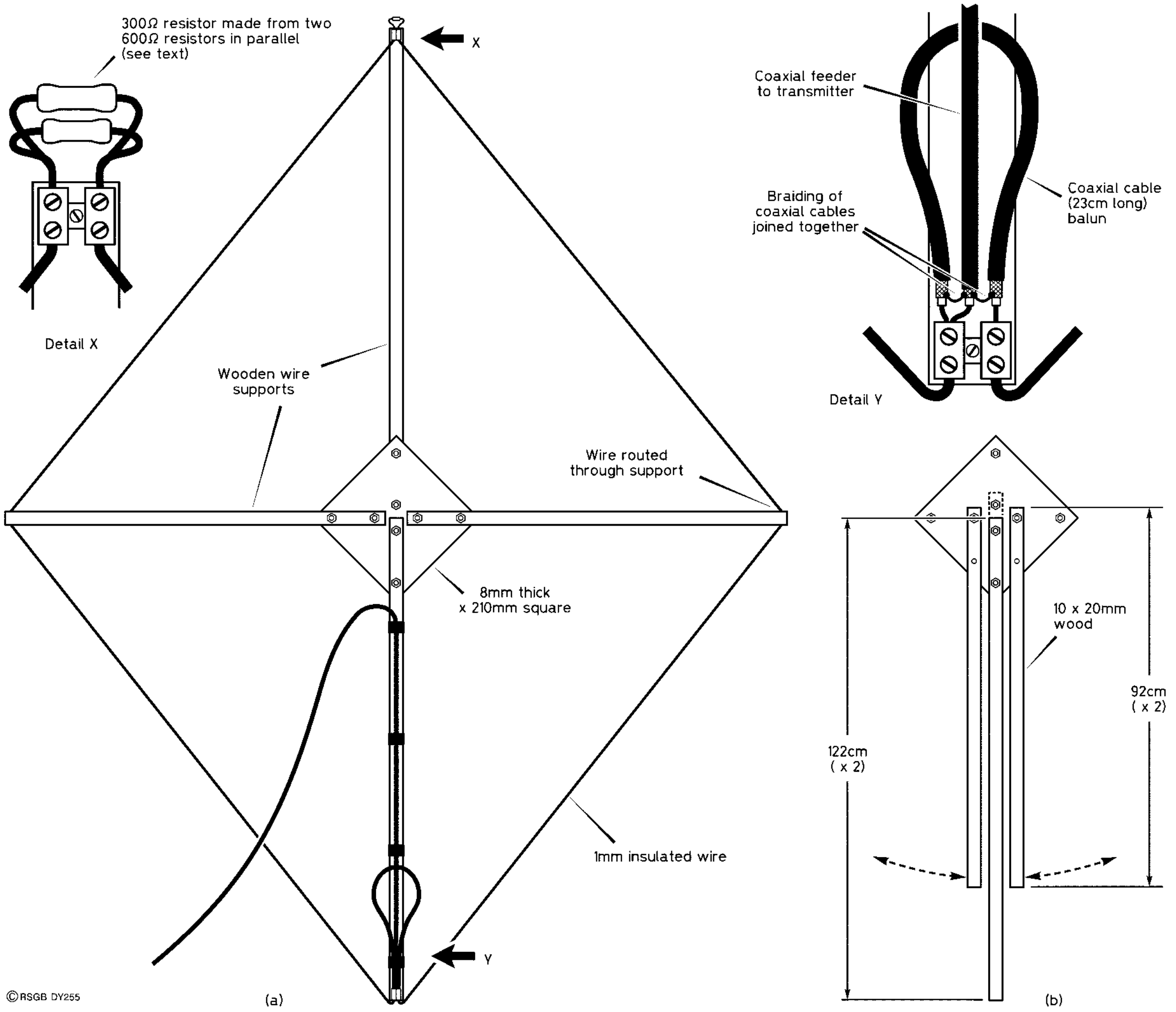
300Ω resistor made from two 600Ω resistors in parallel (see text)
X
Detail X
Wooden wire supports
Wire routed through support
8mm thick x 210mm square
1mm insulated wire
Y
©RSGB DY255
(a)
Coaxial feeder to transmitter
Braiding of coaxial cables joined together
Coaxial cable (23cm long) balun
Detail Y
10 x 20mm wood
92cm (x 2)
122cm (x 2)
(b)

Figure 2 Construction of the UHF rhombic antenna

end, leaving 1 cm of the centre conductor exposed. Fasten this piece of cable to the chocolate block connector together with the coaxial feeder cable as shown in Detail Y of Figure 2. The braids of all three prepared ends are soldered together, but are not connected to anything else. The inner conductor of the feeder from the transceiver is soldered to one end of the centre conductor of the 23 cm piece, and is connected to one end of the rhombic by one side of the chocolate block. The other end of the half-wave transformer also goes to the chocolate block, where it is connected to the other side of the rhombic loop.

The opposite corner of the rhombic, as shown in Detail X of Figure 2, shows that the loop is broken at the chocolate block, and is ‘terminated’ by two 600 Ω resistors in parallel. This makes the aerial a broad-band travelling-wave device, and gives it its directivity and gain. There is a rule of thumb, which includes a safety factor, which says that the terminating resistor must be able to absorb one-half of the maximum transmitter output power. So, if you use two 2 W 600 Ω carbon resistors (*not* wire-wound resistors) in parallel, you can use a transmitter with an output of 8 W, which is more than adequate for 70 cm hand-helds.

Using the rhombic

Fit the aerial to a pole or mast in the horizontal plane, if you intend to use CW or SSB, but in the vertical plane if you want to concentrate on FM work. In the latter case, a wood or fibreglass pole is mandatory. Tune to a local repeater, whose signal strength you know. Rotate the aerial to face the repeater, and you should see that the signal strength is greatly improved! Verify the directional properties of the aerial by rotating it and observing the changes in signal strength on your S-meter.

77 Water level alarm

Introduction

This is a simple device which, when you have built it, you begin to wonder how you ever managed without it! It will sound a buzzer when the level of water reaches a particular point, which you can set and vary at will.

Detecting water

Water is not too difficult to detect electrically, because it is a conductor of electricity. Not a good one, but sufficiently so to carry enough current to control a warning circuit.

The circuit is shown in **Figure 1**. If you imagine a resistor placed between the ends marked ‘water detector’, the circuit is then recognisable as a transistor used as an electronic switch. Whether the switch is off or on depends on the value of this resistor. If the resistance is low, the transistor switches on and the buzzer sounds. If the resistance is high, the transistor switches off and the buzzer stops.

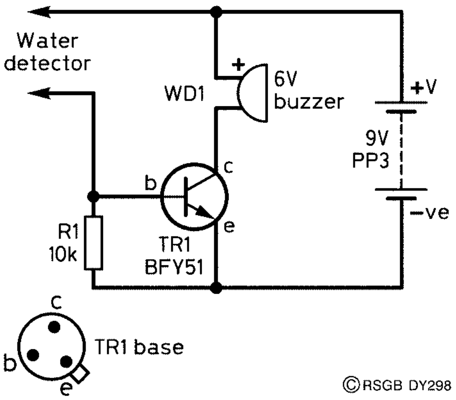
Water
detector
WD1
+
6V
buzzer
+V
9V
PP3
−ve
b
c
e
R1
10k
TR1
BFY51
c
b
e
TR1 base
©RSGB DY298

Figure 1 Circuit diagram of the water level detector

Construction

The unit is made in two separate sections – the detector board (**Figure 2**) and the main board (**Figure 3**). The main board is plain perforated board (without copper strips). The components are pushed through holes in the main board and connected together on the underside. The battery is held on with sticky tape. No on/off switch is used, as the circuit consumes virtually no current when it is not sounding the buzzer.

Unlike some buzzers, this type is polarised, and the red lead must go to the supply as shown in Figs 1 and 3.

The detector board is a piece of standard matrix board – the type with copper strips along one side. It measures 9 strips by 15 holes, and is wired in such a way that alternate strips are connected together, as Figure 2 shows. This gives a greater surface area for the water to touch, thus increasing the sensitivity of detection.

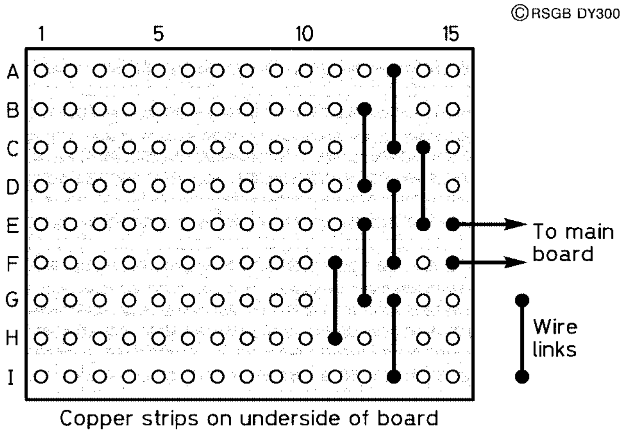
©RSGB DY300
1
5
10
15
A
B
C
D
E
F
G
H
I
To main
board
Wire
links

Copper strips on underside of board
Component side of board shown

Figure 2 Layout of the main board

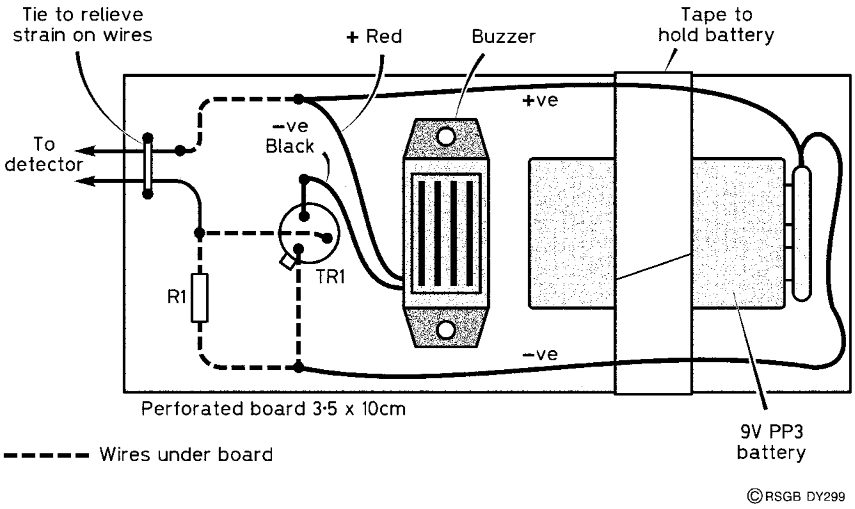
Tie to relieve strain on wires
+ Red
Buzzer
Tape to hold battery
To detector
−ve Black
+ve
TR1
R1
−ve
Perforated board 3·5 x 10cm
9V PP3 battery
----- Wires under board
©RSGB DY299

Figure 3 Water detector constructed from stripboard

The two boards are connected by ordinary twisted pair, enabling the detector to hang over the edge of the water container, with the buzzer circuit safely out of the way. When positioning the detector board, the left-hand edge (as shown in Figure 2) should face downwards, with the connecting-wire edge facing upwards. When the water level rises, the water causes current to flow between adjacent strips, and the higher the water, the lower the resistance between them. Eventually, the resistance will be low enough to turn on the transistor and sound the alarm.

Parts list

Resistor

R1	10 000 Ω (10 kΩ), 0.25 W

Semiconductor

TR1	BFY51

Additional items

WD1	6 V miniature buzzer (polarised)
	Battery PP3
	Battery connector
	Strip board 9 strips by 15 holes
	Perforated board 3.5 × 10 cm

78 A delta loop for 20 metres

Introduction

HF aerials take up a lot of room when they are straight. Space can be saved by bending them and, at the same time, giving them properties which are quite different from their original linear forms. The delta loops shown in the accompanying diagrams have the shape of the Greek upper-case letter delta (Δ) upside down. It can be upright, except that it is more practical to have the feed point at the bottom than at the top.

Putting the loop together

This is the design for a loop to be used on the 20 metre band. It is a very popular band and carries most of the amateur radio DX traffic. The aerial is light in weight and operates best if the top section is at least 30 ft above the ground, with the feeder point being about 6 ft above ground. All you need is some good wire, some polypropylene rope, some insulators and a method of matching the output of this 75 Ω balanced aerial to the 50 Ω unbalanced coaxial input of your transceiver or receiver.

Each of the three sides must be 7.2 m long. Using tent pegs or six-inch nails, mark out the three corners on the lawn, making sure that each pair of pegs or nails is exactly 7.2 m apart. Put the wire around the nails, together with two insulators on the wire for the two top corners. These insulators can be of the ‘dog bone’ variety, or of the home-made type, using a piece of flat plastic with holes in each end. The use of these is shown in **Figure 1**. Located at the positions of two of the tent pegs or nails, they must be secured at those points by any convenient means.

Now attach a support rope to the free end of each of the insulators, ready for suspension, as shown in the diagrams, from any convenient supports (house, tower, tree, etc.). The top section of the loop could be taped to a continuous piece of rope between the two supports. You might like to try this if you think it is easier. Then, when you find some dog-bone insulators, you can change the design and see if there is any noticeable change of performance.

Connecting to the radio

If you are the proud possessor of an aerial tuning unit (ATU) with a balanced output, all you will need is a length of twin cable soldered to the

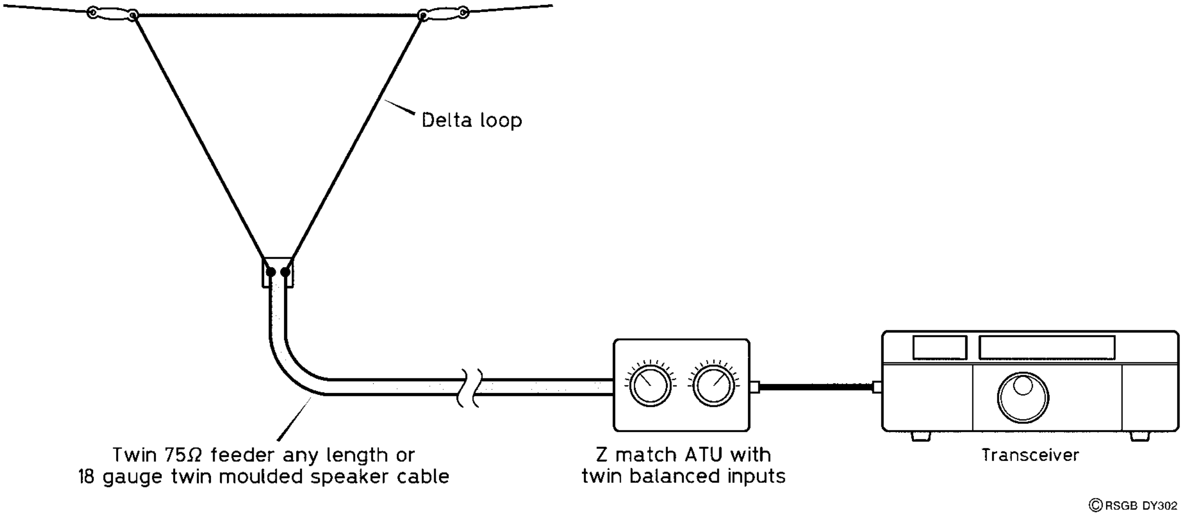
Delta loop
Twin 75Ω feeder any length or
18 gauge twin moulded speaker cable
Z match ATU with
twin balanced inputs
Transceiver
©RSGB DY302

Figure 1 Multiband version of the delta loop connected to the ASTU using 75 Ω twin feeder

ends of your delta loop and connected to the balanced output terminals on the ATU, as Figure 1 shows.

Another way is to buy a ferrite-cored 1:1 balun, and use it as indicated in **Figure 2**. This produces an aerial which will operate over the whole range of amateur and commercial short-wave frequencies, when used with an ATU.

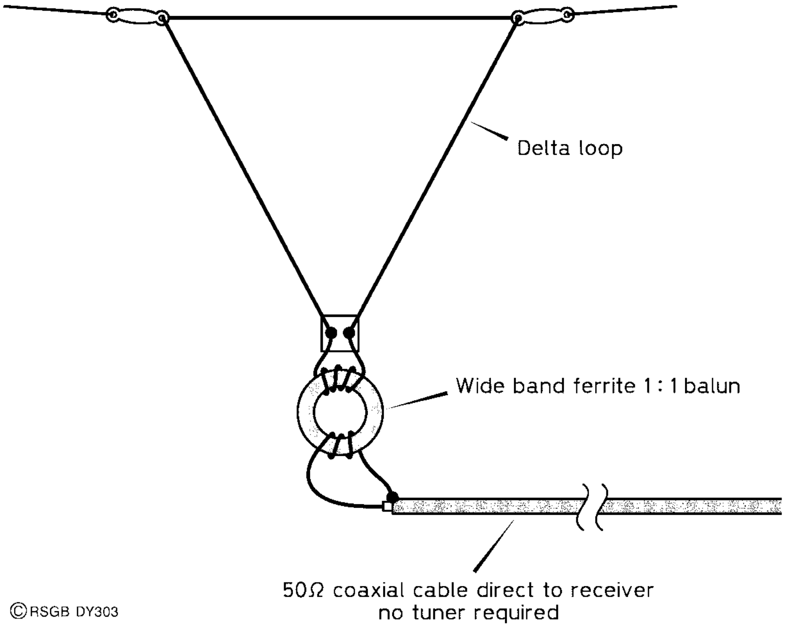
Delta loop
Wide band ferrite 1 : 1 balun
50Ω coaxial cable direct to receiver
no tuner required
©RSGB DY303

Figure 2 Multiband version of the delta loop using 75 Ω coaxial cable. This arrangement requires an ASTU if used with a multiband antenna

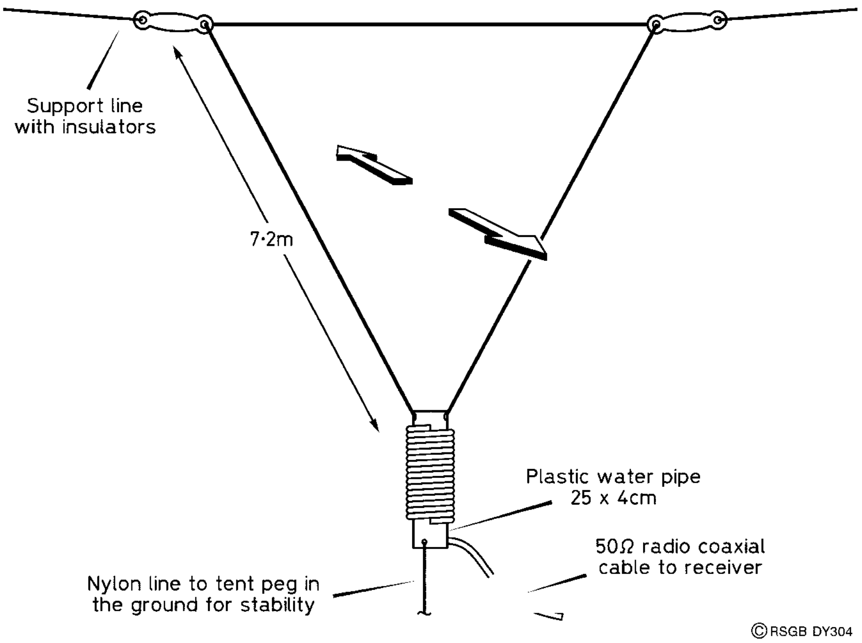

Figure 3 Single band version of the loop antenna using a coaxial balun. The direction of maximum signal strength is indicated by the arrows

However, since this aerial is designed to be a single-band type, there is a simpler answer to the problem of matching the aerial to your 50 Ω coaxial cable – **Figure 3** shows this. Make a tuned balun with a length of plastic water pipe, 25 cm long and 4 cm diameter and a piece of good-quality TV aerial cable. TV aerial cable has a characteristic impedance of 75 Ω, compared with the 50 Ω of the coaxial feeder that we usually use with amateur radio equipment. Use the type with a brown sheath and a closely knit earth braid, not the type having an earth foil inside the sheath.

The length we need for the balun is 3.8 m, but always allow between 3 and 4 cm extra for preparing the ends. Drill two small holes diametrically opposed in the top of the tube; these will be used to anchor the two ends of the delta loop, as shown in Figure 3. Drill another single hole in the bottom end of the tube, which will be used to anchor a nylon line going to the ground to add stability to the loop. Then, after drilling a pilot hole, drill a 5 or 6 mm hole near the top end of the tube, as shown in **Figure 4**. Prepare both ends of the coaxial cable, then feed one end into the tube, far enough for its ends to be soldered to the ends of the loop when the assembly reaches that stage.

Now, close-wrap the cable around the tube until only about 3 cm remain. Holding the cable tightly, drill another 6 mm hole beside the free end of the cable and feed it into this hole. At this point, feed the two ends of the loop into the top two holes and twist it back on itself. Figure 4 shows how this is done. Then, solder the ends of the coaxial balun to the ends of the loop.

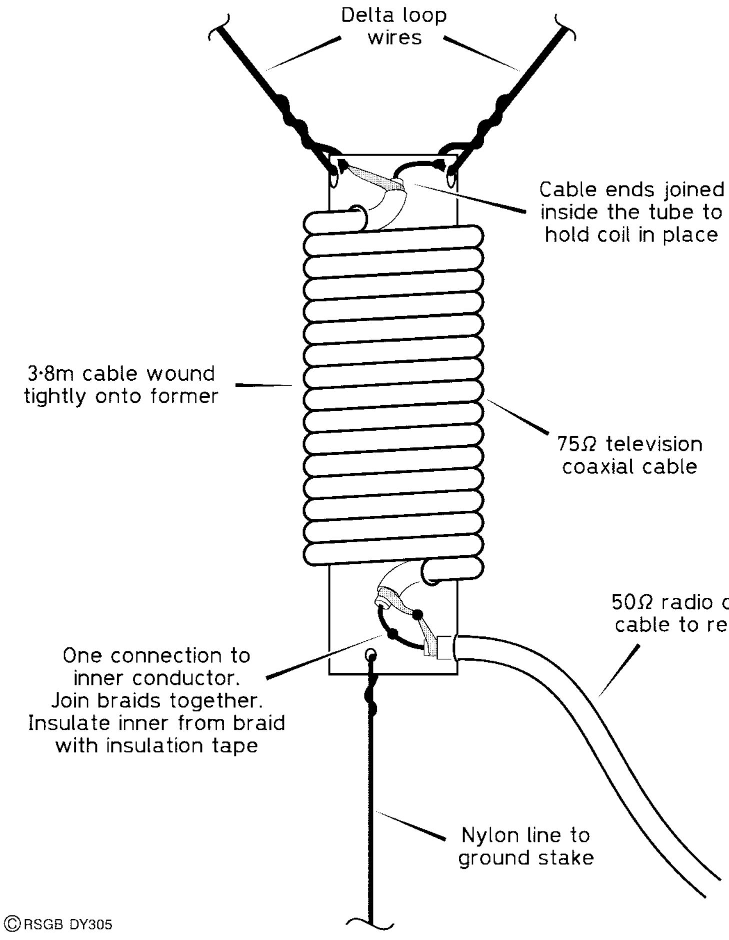
Delta loop wires
Cable ends joined inside the tube to hold coil in place
3·8m cable wound tightly onto former
75Ω television coaxial cable
50Ω radio coaxial cable to receiver
One connection to inner conductor. Join braids together. Insulate inner from braid with insulation tape
Nylon line to ground stake
©RSGB DY305

Figure 4 Construction of the balun

The bottom ends of the balun are then soldered to the 50 Ω coax which goes to your shack and to the transceiver.

Hoist the aerial into position carefully, being careful not to pull too hard on the support lines. Then, take the nylon line from the bottom of the balun to a peg in the ground. This adds stability to the aerial.

Using the delta loop

It is a directional aerial, as Figure 3 shows. It produces maximum power (and has maximum receive sensitivity) along a direction perpendicular to its own plane. Don’t be too concerned with which direction it is pointing at first. Give it a try ‘on the air’ and see how it performs. Then you can contemplate how to point it in your favourite direction, to the USA, or Australia, for example.

Experimenting

You may want to enclose the balun in some sort of weatherproof container. Plastic ice cream containers are favourites for this sort of job. Seal all the holes where wires enter it with silicone sealant or self-amalgamating tape.

If you have used ordinary single-strand or multi-strand wire for your aerial, it will stretch over time under its own weight and that of the balun. Its operating frequency will fall slightly as a result. If you notice a significant difference, then dismantle it, remeasure and fix the sides and erect it again, perhaps facing a different direction. You can buy pre-stretched or hard-drawn wire for such purposes, if you feel that periodic tweaking of your aerial is a chore.

You can make a delta loop for different frequencies simply by scaling the lengths of wire for the loop and for the balun according to the design frequency. If your maths isn't quite up to this, enlist the help of someone well versed either in maths or aerial design!

79 A simple desk microphone

Introduction

A hand-held transceiver is usually the first type used by most novices. It is ideal when used out of doors, in the shack or mobile. However, using one in the shack with an outside aerial is not the best of solutions.

This article describes the design of a desk microphone which can be used either for transceivers using a common microphone and push-to-talk (PTT) line, or for those using a separate PTT line.

It is a simple design, using the barrels of two plastic pens, the lid of an old coffee jar, and the plastic sheath of a DIN plug.

Construction

The end caps and the ink tubes should be removed from two ball-point pens, leaving only the two plastic shells. One of them is used for the vertical microphone support, while the other is used to hold the microphone element.

The vertical support should have the pointed end shaped so that it holds the microphone support at a convenient angle, as **Figure 1** shows.

The base should be prepared next – see **Figure 2**. Four holes are required. Two, A and B, are small holes for the cable to be fed through. A third, C, is slightly larger and is used to take one of the plastic end caps. The fourth hole, D, is determined by the type of switch that you want to use for the PTT function.

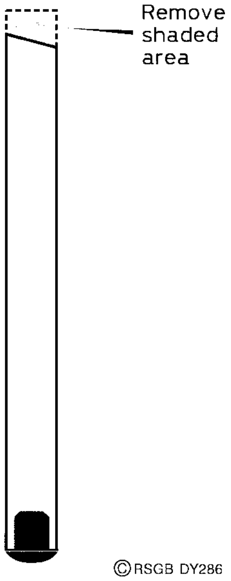
Remove
shaded
area
©RSGB DY286

Figure 1 Vertical support made from ball-point pen shell

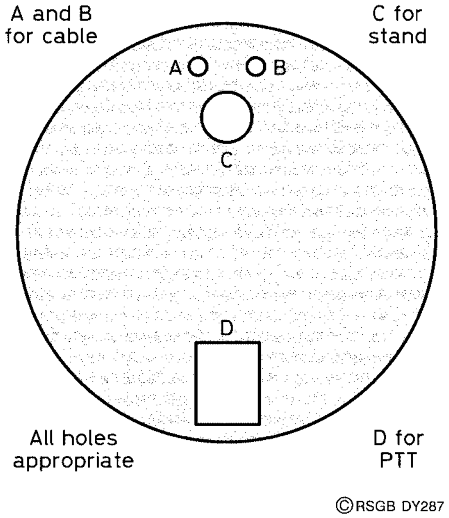
A and B
for cable
C for
stand
A
B
C
D
All holes
appropriate
D for
PTT
©RSGB DY287

Figure 2 The microphone stand base

Some epoxy resin such as Araldite Rapid is used to mount the separate parts. Mix only a small amount at a time, and glue each part of the base assembly and allow to harden before moving on. Be sure to read and follow the instructions for the use of the glue to prevent accidents.

Firstly, glue the end cap to the base, feeding it underneath and pushing it up through hole C. Then, the vertical pen body is placed over the protruding end cap and glued into place, making sure that the top (shaped) end is pointing in the right direction to hold the other plastic tube carrying the microphone. While the glue hardens, place the DIN plug sheath on the second pen body. Place and glue this pen body on the shaped top of the vertical support, making sure that the whole assembly is supported while the glue sets. What you should have now ought to resemble **Figure 3**, but without the microphone and wiring. Leave everything to set for 24 hours.

Any switch of the press-to-make variety can be used for your PTT switch, but choose one which does not apply too much force to operate! If you find the whole assembly is too light and slides over your table, some plasticine can be pushed into the base when all the wiring has been completed.

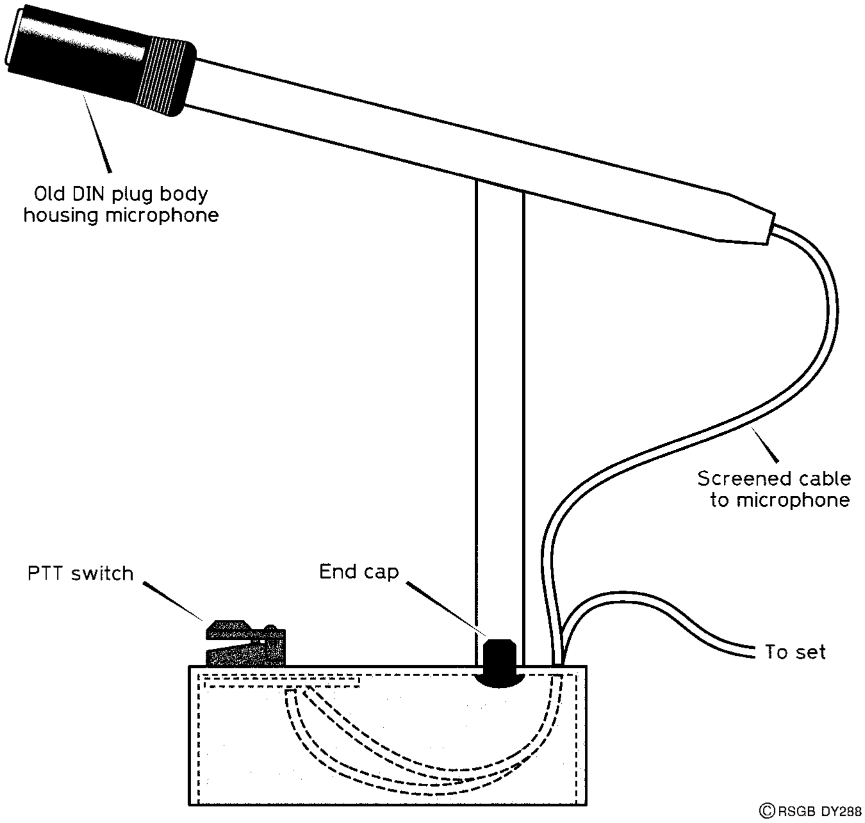
Old DIN plug body housing microphone
Screened cable to microphone
PTT switch
End cap
To set
©RSGB DY288

Figure 3 Complete microphone stand assembly

The circuit

A small electret condenser microphone is used, powered by a DC supply. Most hand-held radios use a single screened lead for both the PTT line and the microphone audio lead. In such cases, the circuit of **Figure 4** will operate the PTT function. Note that the PTT switch is in series with the audio lead from the microphone. If you find that the PTT switch does not switch your radio into transmit, reduce R1 from its normal value of 33 kΩ to 27 kΩ. You should find that the original value works with most hand-helds.

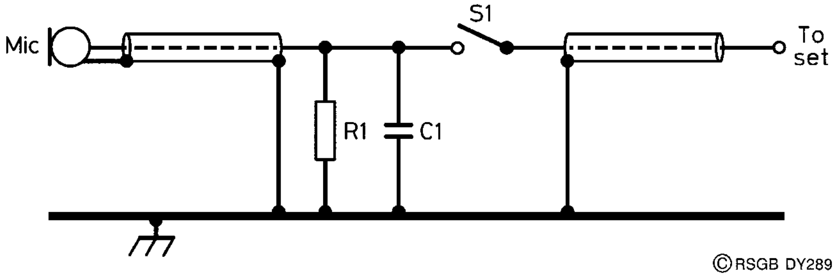

Figure 4 Wiring diagram for hand-held radios

For radios with a separate PTT lead, the circuit of **Figure 5** is used. However, a power supply is needed for the electret microphone. This can be a PP3 battery, or can (in most cases) be derived from the microphone socket on the transceiver. You will need to consult the makers' handbook for this information. Figure 5 shows the PTT switch wired in a 'ground-to-transmit' configuration, which is correct for most base-station transceivers. If you're in any doubt about what your radio needs, consult an experienced friend.

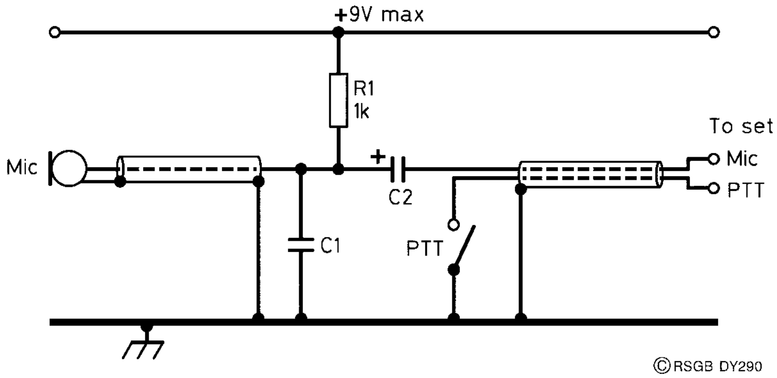

Figure 5 Wiring diagram for radios which use separate PTT lines

The last connections

The microphone element should be connected with screened cable. Tape (masking or insulating) should be wound around the electret insert until it is a snug fit inside the DIN plug sheath. Feed the screened cable through the barrel of the pen until it emerges from the far end. Poke it through hole B and make the connections under the coffee jar lid. The components can all be mounted on the PTT switch or on a small piece of Veroboard mounted under the top surface. The output lead emerges through hole A and is of sufficient length to reach your transceiver. A suitable plug needs to be fitted to it.

Parts list

Resistors: all 0.25 W carbon, 5% tolerance

R1 (Figure 4)	33 000 Ω (33 kΩ)
R1 (Figure 5)	1000 Ω (1 kΩ)

Capacitors

C1 (Figure 4 and 5)	0.1 microfarads (0.1 μF) disc
C2	10 microfarads (10 μF) electrolytic

Additional items

S1	Push-to-make
Mic	Electret microphone (Maplin type FS34W)
Screened cable	As required
Plug	As required by your radio
Veroboard	If required
PP3 battery and clip	If required

Two old plastic ball-point pens
Lid of coffee jar
Plastic sheath from DIN plug
Araldite or similar epoxy resin glue

80 Morse oscillator

Introduction

This is not the simplest Morse oscillator to build, but it differs from the simple circuits in that it produces a pure note, not a coarse, rasping sound. People who have practised Morse using a non-sinusoidal oscillator sometimes find that they have trouble copying Morse code with a pure tone. As the pure tone is the correct way to receive Morse code, it is important that you should learn to listen to the code from a pure oscillator – so here's one!

The twin-T

There are many oscillator circuits, and there are many variations of the twin-T oscillator that we are going to use. **Figure 1** shows one version of a very useful circuit. All oscillators must have positive feedback in order to work. The feedback determines the frequency of the note produced by the oscillator.

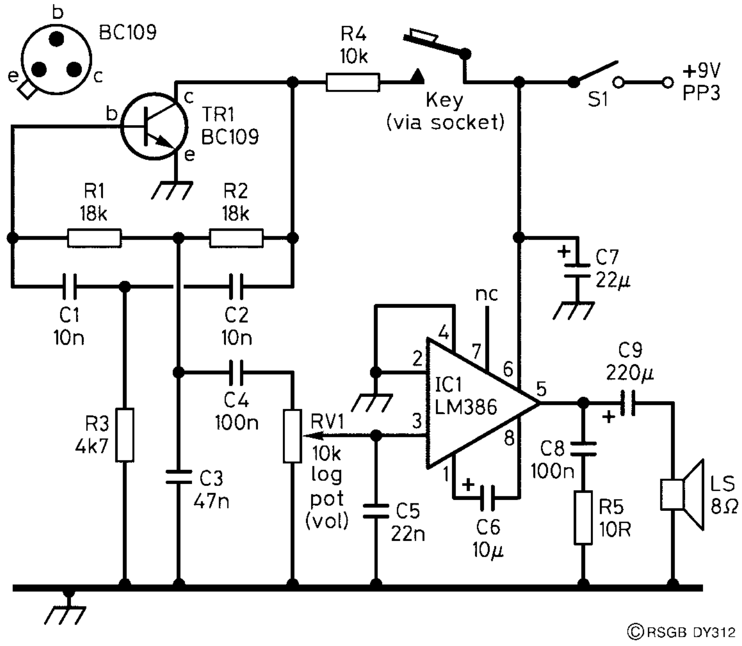
b
e
c
BC109
R4
10k
Key
(via socket)
S1
+9V
PP3
c
b
e
TR1
BC109
R1
18k
R2
18k
C1
10n
C2
10n
C7
22μ
nc
4
7
6
2
5
3
8
1
IC1
LM386
C9
220μ
+
+
+
R3
4k7
C4
100n
RV1
10k
log
pot
(vol)
C3
47n
C5
22n
C6
10μ
C8
100n
R5
10R
LS
8Ω
©RSGB DY312

Figure 1 Circuit diagram of the sinewave oscillator and amplifier

Here, the feedback circuit looks like two letter Ts. If you look at Figure 1, one T is formed by R1, R2 and C3, the other by C1, C2 and R3 – hence the name ‘Twin-T’. Notice that the two Ts are connected in parallel between the collector and base of TR1, so any signal appearing at the collector is fed into both Ts. What emerges is then fed back into the base, producing in turn a signal at the collector. And so it goes on, producing a sine wave output.

The oscillator output is fed into an integrated circuit amplifier for output via a small loudspeaker.

Putting it together

The prototype was constructed on plain matrix board (the type *without* the copper strips), as shown in **Figure 2**. The components have their leads pushed through the holes in the board, and connections are made underneath.

Build the amplifier circuit first, using a socket for IC1. Connect the 9 V supply and touch pin 3 with an ordinary piece of wire. If a buzz is heard from the speaker, all should be well. If not, check your circuit and make changes until it does.

Build the oscillator circuit, and connect its output to the volume control VR1 via C4. Set VR1 half-way along its travel and switch on. A note should be heard from the speaker when the Morse key is depressed. The component values making up the twin-T determine the frequency of the note. Try varying them if you think your note is too high or too low. Whatever changes you make, either to the resistors or the capacitors, always ensure that R1 = R2 and that C1 = C2.

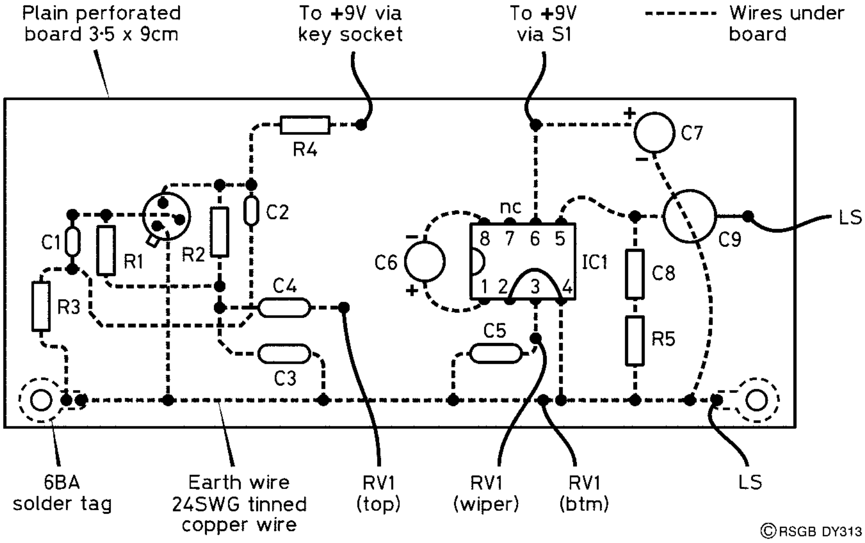
Plain perforated board 3·5 x 9cm
To +9V via key socket
To +9V via S1
------- Wires under board
R4
C7
+
−
C2
C1
R1
R2
nc
8 7 6 5
1 2 3 4
IC1
C6
−
+
C8
C9
LS
R3
C4
C5
R5
C3
6BA solder tag
Earth wire 24SWG tinned copper wire
RV1 (top)
RV1 (wiper)
RV1 (btm)
LS

©RSGB DY313

Figure 2 Component layout and interconnection diagram

Parts list

Resistors: all 0.25 W carbon film

R1, R2	18 000 ohms (18 kΩ)
R3	4700 ohms (4.7 kΩ)
R4	10 000 ohms (10 kΩ)
R5	10 ohms (10 Ω)

Capacitors

C1, C2	10 nF (0.01 μF)
C3, C8	47 nF (0.047 μF)
C4	100 nF (0.1 μF)
C5	22 nF (0.022 μF)
C6	10 μF electrolytic, 16 V WKG
C7	22 μF electrolytic, 16 V WKG
C9	220 μF electrolytic, 16 V WKG

Semiconductor

TR1	BC109

Integrated circuit

IC1	LM386

Additional items

VR1	10 kΩ log potentiometer with switch
LS	8 Ω loudspeaker

Matrix board 3.5 × 9 cm
Small jack socket for key input
Box
PP3 battery and clip

81 A simple 6 m beam

Introduction

The attraction of building your own aerials is an abiding feature of our hobby. You can *buy* almost any shape or size of aerial, but one you have made yourself can often work every bit as well as a commercial device costing ten times as much.

The design

This aerial, designed for use on the 6 m band, is essentially a two-element Yagi, with the elements bent in order to reduce the physical size. It is known

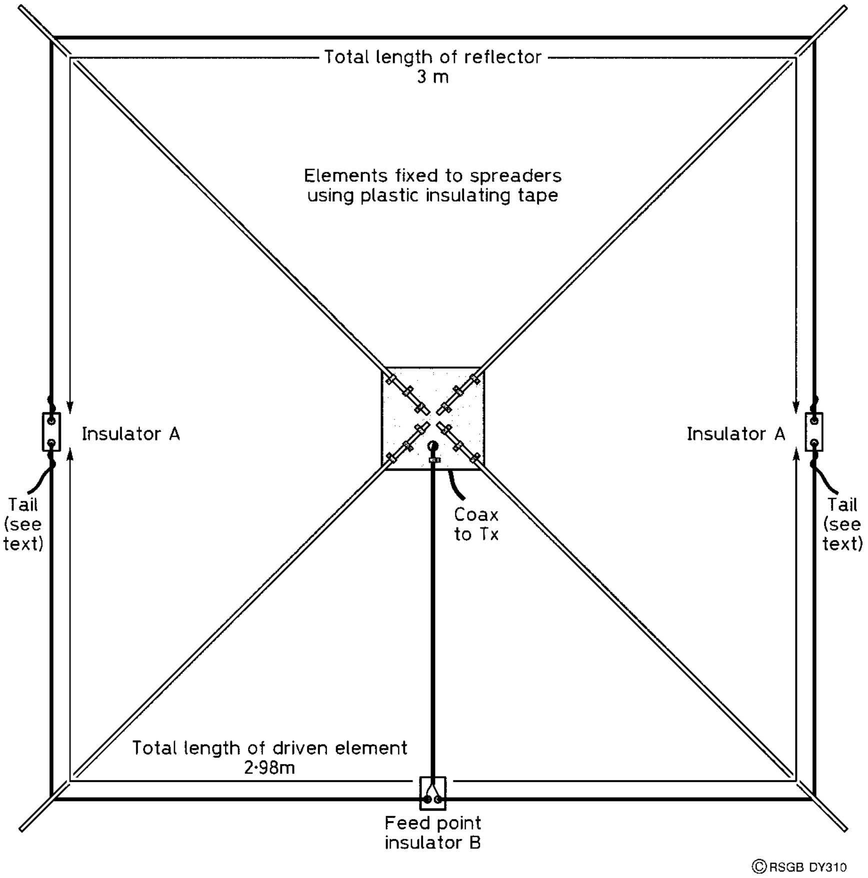
Total length of reflector
3 m
Elements fixed to spreaders
using plastic insulating tape
Insulator A
Insulator A
Tail
(see
text)
Tail
(see
text)
Coax
to Tx
Total length of driven element
2·98m
Feed point
insulator B
©RSGB DY310

Figure 1 Plan view of the complete 50 MHz VK2ABQ antenna

as the VK2ABQ beam, and was designed originally for the 20, 15 and 10 m bands, principally because of its space-saving qualities. It is made using a wooden frame and wire elements, and is ideal for portable operation.

Tools ready?

The beam is shown in **Figure 1**. The driven element is the one whose centre is fed by the coaxial cable, and lies between the two insulators marked A and the feedpoint at B. The reflector is also anchored at the points A, and lies over the upper half of the frame.

The wooden centrepiece is used to support the cross-pieces and to mount the aerial on the mast, using a common shelf bracket. The cross-pieces, known as *spreaders*, can be wooden canes or dowelling, and are mounted to the centrepiece using cable clips and adhesive. **Figure 2** shows how this is done.

If the aerial is to be a permanent installation, the spreaders should be weatherproofed using a good-quality exterior varnish. The wire elements are PVC covered and fed through holes in the spreaders.

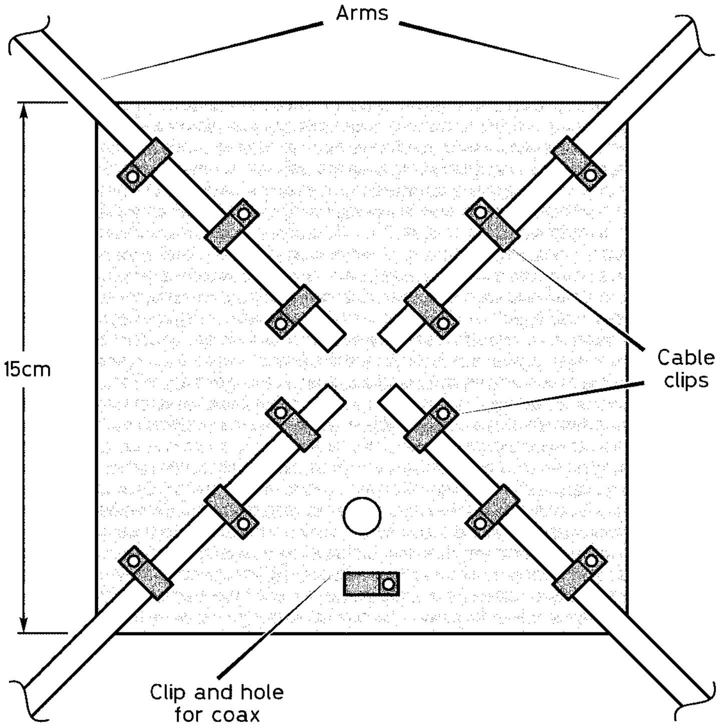

Figure 2 Centre support piece

©RSGB DY309

The end insulators are made of drilled perspex, and the wire passed through the two holes and twisted, as shown in **Figure 3**.

Note: if you have not drilled holes in perspex before, take care! The drill bit must be well-lubricated because it generates a lot of heat (enough to melt the perspex and jam the drill). Never turn the drill for more than a few seconds at a time, and moisten the bit in between. Start with a pilot hole and use bits of increasing size until the hole is the size you want.

Another perspex insulator is used to secure the feeder to the aerial, as shown in Figure 3. The feeder then passes directly to the centrepiece, where it is fastened with a cable clip and then passes down the mast.

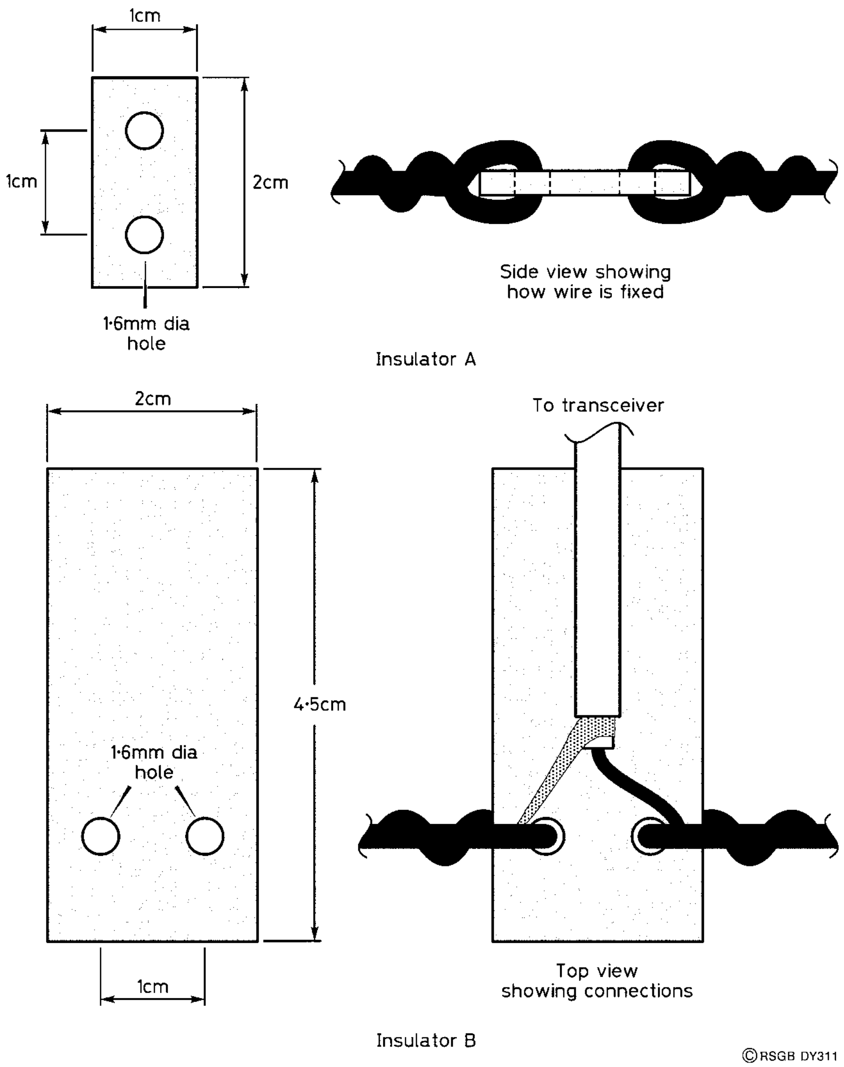
1cm
1cm
2cm
1·6mm dia hole
Side view showing how wire is fixed
Insulator A
2cm
To transceiver
4·5cm
1·6mm dia hole
1cm
Top view showing connections
Insulator B
©RSGB DY311

Figure 3 Details of insulators

Adjustment

The driven element (A–B–A) in Figure 1 is fixed to the end insulators in such a way as to have 'pigtails' which are about 10 cm long. Using an SWR meter between the aerial and the transmitter, trim the pigtails equally at each end for minimum SWR in that portion of the 6 m band in which you plan to work. Make sure that the transmitter is off when you trim the ends, as high voltages can be present there. Always listen on the frequency before you transmit and, when you do, ask if the frequency is in use and identify yourself. Use as little power as possible.

The prototype had an SWR of 1.2 at 50.2 MHz and performed well. If you look at Figure 1, which is a view of the aerial from above, you will immediately see that when the aerial is horizontal, it radiates with horizontal polarisation in a direction from the top of the page to the bottom. A metal pole or mast can be used for horizontal polarisation, but if you intend to use the aerial for vertical polarisation, it is much better to use a wooden or fibreglass pole.

Portable use

If you plan to operate portable with this aerial, the only real modifications you need are to the centrepiece and how it supports the spreaders. Instead of using glue and cable clips, nuts and bolts through the spreaders and centrepiece would allow the spreaders to be 'hinged' closed for transport.

Materials

Centrepiece	Hardwood, 15 × 15 × 25 mm
4 spreaders	110 cm long (cane or 6 mm dowel)
Wire	1.5 mm PVC-covered copper
50 Ω coaxial cable	RG58 or similar
Cable clips	6 mm (12 off)
Varnish	Polyurethane for waterproofing
Tape	Self-amalgamating, to waterproof all soldered joints
Insulators	See text

82 An integrated-circuit amplifier

Introduction

A simple audio-frequency amplifier is a very useful building-block in many more advanced electronic circuits. It is also a very useful piece of test equipment. To have one spare in the shack can be a life-saver at times.

Planning

Get into the habit of planning your project. How do you want it to look when it is finished. Do you want it in a box? Do you want it 'open-plan', with all the components on view?

The 'minimalist' approach to any project is simply a front panel and a baseboard, on to which all the components are fitted. In this case, the front panel would accommodate the loudspeaker, the volume control and the input and output jack sockets, and the baseboard would support the circuit board. Once you have decided these things, and know the size of the board, speaker and volume control, you can decided how big the panel and baseboard should be.

The amplifier

Instead of building the amplifier from discrete components (i.e. transistors), as was done in the project *An audio-frequency amplifier* (which you will find elsewhere in this book), we are going to use an integrated-circuit (IC) amplifier. External resistors and capacitors are still needed but, compared with the number of components *inside* the chip, these are very few indeed!

The IC we are going to use is the TBA820M. The circuit may look complicated, but with the use of a matrix circuit board it becomes quite simple. **Figure 1** shows the circuit diagram and **Figure 2** the layout on the board. The external connections to the PCB are shown in **Figure 3**.

To avoid having a separate switch to switch off the power supply when the amplifier is not being used, a volume control which incorporates a switch is used.

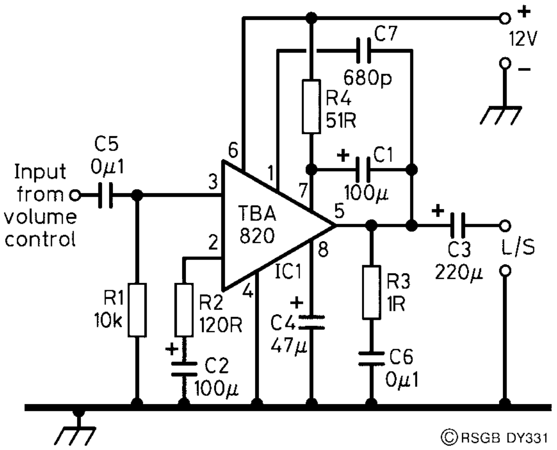
+
12V
−
C7
680p
R4
51R
C5
0µ1
Input
from
volume
control
6
3
1
7
TBA
820
5
2
8
IC1
4
+
C1
100µ
+
C3
220µ
L/S
R1
10k
R2
120R
+
C2
100µ
+
C4
47µ
R3
1R
C6
0µ1

©RSGB DY331

Figure 1 Audio amplifier, circuit diagram

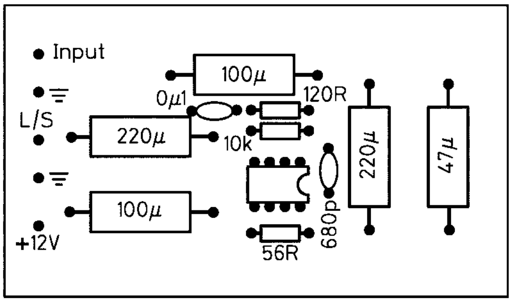
Input
L/S
+12V
100µ
0µ1
120R
220µ
10k
100µ
56R
680p
220µ
47µ

©RSGB DY332

Figure 2 Audio amplifier, component layout

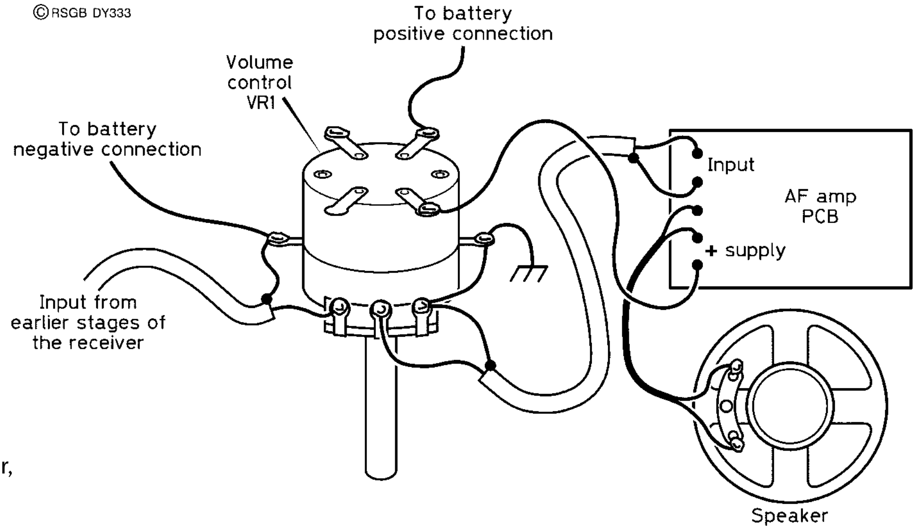
To battery
positive connection
Volume
control
VR1
To battery
negative connection
Input from
earlier stages of
the receiver
Input
AF amp
PCB
+ supply
Speaker

©RSGB DY333

Figure 3 Connecting the circuit board to the speaker, volume control/switch and battery

What power supply?

If the amplifier is to be used only for short periods, as a test instrument, for example, then it can be run from a PP3 battery, which can be mounted on the baseboard. If you intend to use it often, then a connection to an external power supply is preferable. For this option, you may want to consider fixing two terminals to the baseboard for this connection.

83 A novice ATU

Introduction

Having an aerial tuning unit (ATU) is always useful. It is used for adjusting the aerial impedance, as 'seen' by the transceiver, to be the same as that of the transceiver itself, usually 50 Ω. This process is called *matching*, and ensures that the receiver and the power amplifier (PA) stage of the transmitter work efficiently.

This design is due to the late Doug DeMaw, W1FB, and uses readily available components. It will handle up to about 5 W, and operates over the frequency range 1.8 to 30 MHz.

Circuit evolution

The basic circuit of one type of ATU is shown in **Figure 1**. On transmit, the input signal at L1 is coupled into L2, which forms a resonant circuit with C1. The signal across the resonant circuit is fed to the aerial by C2. The combination of L2 and C1 helps to remove signal harmonics, because they are not at the resonant frequency and are shunted to earth. On receive, only those signals which are within the pass-band of L2 and C1 will pass into the receiver. This improves receiver performance by rejecting many out-of-band signals which the simpler receiver doesn't like.

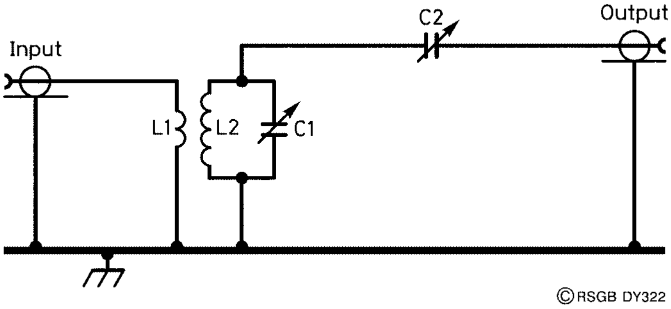

Figure 1 Basic circuit of the ATU

For this design, the all-important resonant frequency is chosen to be in the 80 metre band. If we want to make the circuit operate on other bands, we need to change either L2 or C1. It is easy to change L2 by using a set of switched inductors (L3–L5) as shown attached to S1 in **Figure 2**. Forget about S2 and L6 for the moment.

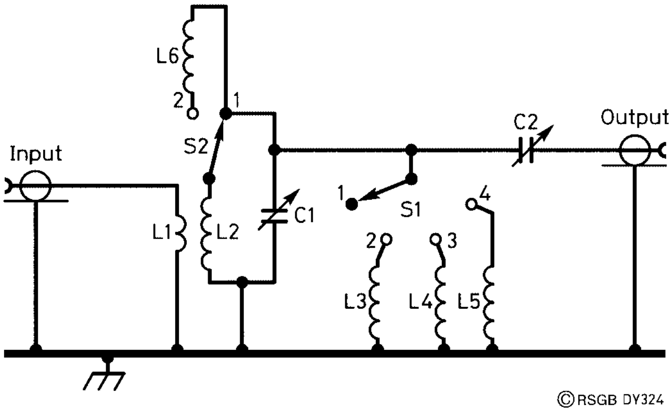

Figure 2 L6 added for 160 m

When S1 is in position 1, the circuit reverts to that of Figure 1. S2 should be brought into circuit only when S1 is in position 1. Looking at the way the circuit is drawn, you can see that when S2 is in position 2, we have two coils in series, which is equivalent to adding more turns to L2. More turns means more inductance, which lowers the resonant frequency still more, and gives coverage of the 160 m band.

Rather than having to remember to flick S2 to the correct position *and* move S1 to position 1 when we want to operate on 160 m, both functions can be combined into one rotary switch with two wafers. This circuit is shown in **Figure 3**.

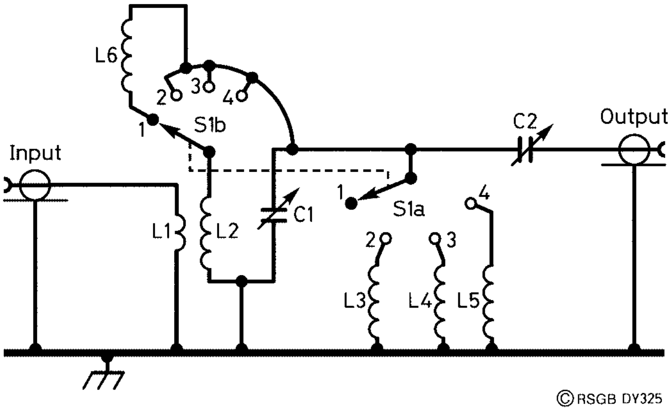
L6
2
3
4
1
S1b
Input
L1
L2
C1
C2
Output
1
S1a
4
2
3
L3
L4
L5
©RSGB DY325

Figure 3 Two-pole switch for all bands

In all positions of S1a *except* position 1, the extra coil, L6, is shorted out. The two halves of the switch, S1a and S1b, move together, as the shaft is turned, so both halves are in position 1 at the same time, position 2 at the same time, and so on. The two switches, S1 and S2, are said to be *ganged*.

Construction

L1 is formed by winding four turns of 22 SWG enamelled copper wire over L2, as in **Figure 4**. L2 already exists on the purchased former. After scraping the enamel off the ends of the wire (with a sharp knife or sandpaper), one end of L1 must be soldered to one end of L2, as shown in Figure 4. The free end of L1 goes to the transceiver aerial socket.

All components except the capacitors are assembled on the switch. Note that the rotor of C1 is earthed, but neither side of C2 is earthed. This means that the metal shaft of C2 is not earthed, and touching it will detune the ATU. Using a plastic knob for C2 will minimise this effect. If you decide to use a metal box, take precautions to ensure that no part of C2 is in electrical contact with the box.

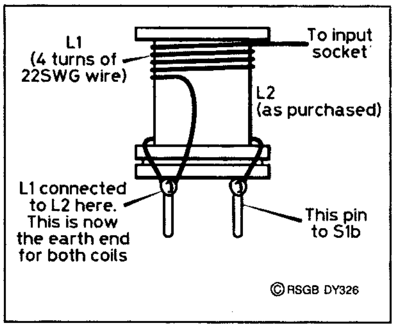
L1
(4 turns of
22SWG wire)
To input
socket
L2
(as purchased)
L1 connected
to L2 here.
This is now
the earth end
for both coils
This pin
to S1b
©RSGB DY326

Figure 4 L1 is wound over L2 as shown

The capacitors are mounted using M2.5 screws. Make sure that the screws do not foul the vanes of the capacitor. If your screws are too long, a few washers between the box and the capacitor will solve the problem!

In use

The best indication of a good match is obtained with a standing-wave meter between the ATU and the transceiver. The controls are adjusted alternately to ‘feel’ your way to a better and better match.

For receive-only use, the same alternate adjustments are used, watching for the maximum signal strength on the S-meter or, for a very weak signal, making the signal from the loudspeaker as large as possible.

Parts list

Capacitors	
C1, C2	350 pF variable
Inductors	
L1	See text
L2	27 μH
L3	10 μH
L4	2.2 μH
L5	1 μH
L6	65 μH
Additional items	
SO239 sockets (2 off)	
S1	2-pole 6-way rotary
Box	as required
Plastic knobs (2 off)	
Stick-on feet (4 off)	
M2.5 screws for capacitors	
Screws, nuts and washers for mounting the input and output sockets.	

84 CW QRP transmitter for 80 metres

Introduction

This is a relatively simple transmitter design having an output of 1 W. The design is not new, having been described before in other amateur radio publications. The components are all available new and the total cost should not exceed £15.

The circuit

Like other simple transmitters (see *An 80 Metre Crystal-Controlled CW Transmitter* and *A Breadboard 80 m CW Transmitter* elsewhere in this book) this one is crystal controlled. This assures frequency stability, but limits the usefulness of the transmitter. The key to increased frequency coverage without a conventional Variable Frequency Oscillator (VFO) is the use of a low-cost 3.58 MHz *ceramic resonator*. The 'pulling' range of a 3.58 MHz ceramic resonator covers the UK novice 80 m sub-band and some of the CW segment below 3.525 MHz.

A ceramic resonator is like a crystal, but not quite as stable in frequency. Its main advantage is its large pulling range.

The block diagram is shown in **Figure 1**. It is very similar to a crystal-controlled transmitter, and includes an oscillator, buffer and final amplifier.

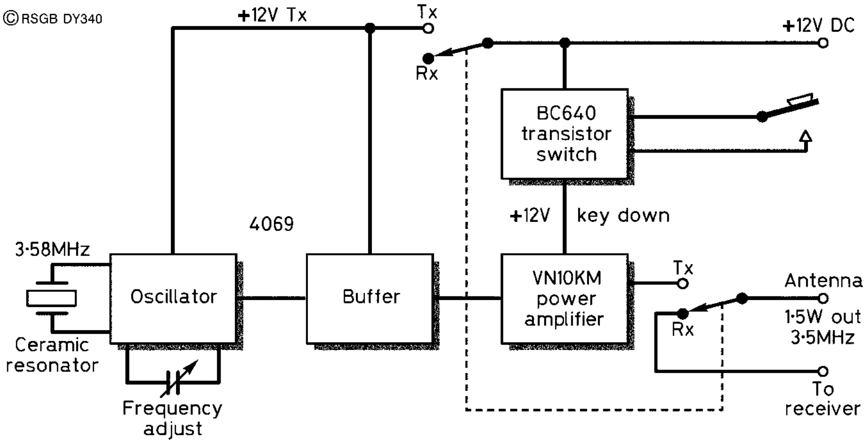
©RSGB DY340
+12V Tx
Tx
Rx
+12V DC
BC640 transistor switch
+12V
key down
4069
3·58MHz
Ceramic resonator
Oscillator
Buffer
VN10KM power amplifier
Frequency adjust
Tx
Rx
Antenna
1·5W out 3·5MHz
To receiver

Figure 1 Block diagram of the ceramic resonator controlled 80 m CW transmitter

This amplifier is keyed, the oscillator remaining running all the time. This improves frequency stability because the oscillator is not being continuously stopped and started by the key. It is switched off while receiving, though, to avoid interference with the received signal. Transmit/receive switching is accomplished by a panel-mounted switch controlling both the aerial, oscillator and buffer switching.

Figure 2 shows the transmitter circuit diagram. An unusual aspect of this transmitter is the use of a digital CMOS integrated circuit (IC) type 4069 for the buffer and oscillator stages. The IC houses six inverters, four of which are used in the circuit. One is used as the oscillator, two are used for the buffer stage, and the fourth provides an output for a direct-conversion receiver, should one be added at a later date.

The frequency of the oscillator is changed by varying the capacitance in the ceramic resonator circuit. This is provided by VC1.

The power amplifier (PA) is a small MOSFET (metal oxide semiconductor field-effect transistor), TR1. This is capable of providing an output power of 2 W but, in this circuit, it is run conservatively to give 1.5 W. The output can be varied by changing the resistance (R5 + R6) in the gate circuit. Attempts

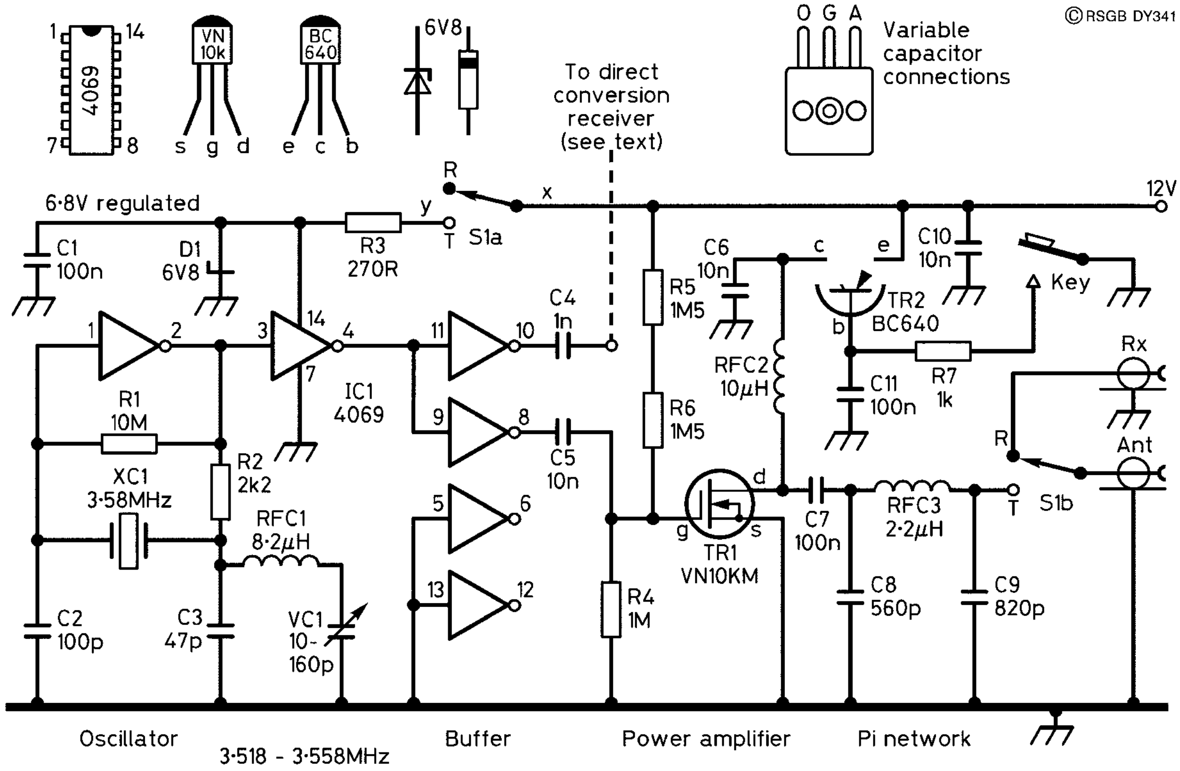
©RSGB DY341
1
14
4069
7
8
VN
10k
s g d
BC
640
e c b
6V8
To direct
conversion
receiver
(see text)
O G A
Variable
capacitor
connections
6·8V regulated
C1
100n
D1
6V8
R3
270R
y
T
S1a
R
x
12V
C6
10n
c
e
C10
10n
Key
R5
1M5
C4
1n
TR2
BC640
b
1
2
3
14
4
7
11
10
IC1
4069
9
8
C5
10n
R1
10M
XC1
3·58MHz
R2
2k2
RFC1
8·2µH
C2
100p
C3
47p
VC1
10-
160p
5
6
13
12
R6
1M5
R4
1M
RFC2
10µH
d
g
s
TR1
VN10KM
C7
100n
C11
100n
R7
1k
Rx
R
Ant
RFC3
2·2µH
T
S1b
C8
560p
C9
820p
Oscillator
3·518 - 3·558MHz
Buffer
Power amplifier
Pi network

Figure 2 Circuit diagram of 80 metre transmitter

to raise the output power by decreasing the values of these resistors may result in immediate MOSFET failure.

A pi-network (C8, RFC, C9) provides impedance matching to 50 Ω, together with harmonic suppression. Like all inductors in this transmitter, the pi-network inductor is a pre-wound RF choke. A pi-network is so called because the components are arranged in the shape of the Greek letter pi (π).

Keying is carried out by a pnp transistor switch, TR2. Closing the key earths the base and supplies 12 V to the collector of TR2 and to the drain of the MOSFET, TR1, allowing the PA to operate.

Construction

You must house your transmitter in a metal box, to avoid hand-capacity effects and the radiation of spurious frequencies. Size is not important, provided it is large enough to accommodate the transmitter without cramping the components. You may want to allow space for future additions such as a direct-conversion receiver, break-in keying, sidetone or a small power amplifier. A good size is 5 × 15 × 15 cm. You can make your own box, buy it, or even use a biscuit tin!

Front and rear panel connectors can be fitted first. The choice of these is a personal matter, but a good working choice would be:

(a) Power socket – 2.1 mm panel socket – centre pin positive.
(b) Key socket – ¼ inch jack socket.
(c) Aerial and receiver connectors – panel-mounting SO239 type.

Particular attention must be paid to the mounting of the variable capacitor, VC1. Make sure the hole for the shaft is amply big enough, and if you use screws to mount the capacitor on the front panel, then make sure they are not too long, otherwise they will touch the vanes of the capacitor! Mounting can be by means of glue, sparingly applied and kept well away from the shaft.

A board size of about 6 × 10 cm is adequate. Component layout on the board is suggested in **Figure 3**. The prototype used ordinary matrix board, which is preferable to stripboard for a design like this; stripboard has undue capacitance between adjacent strips. Component leads are fed through holes in the board and are connected underneath. Make sure that leads and connections are rigid because, if they can move, there is always the danger of short-circuiting, and capacitance changes.

To facilitate construction, servicing and testing, it is advisable to use Veropins for connections to the variable capacitor, transmit/receive switch,

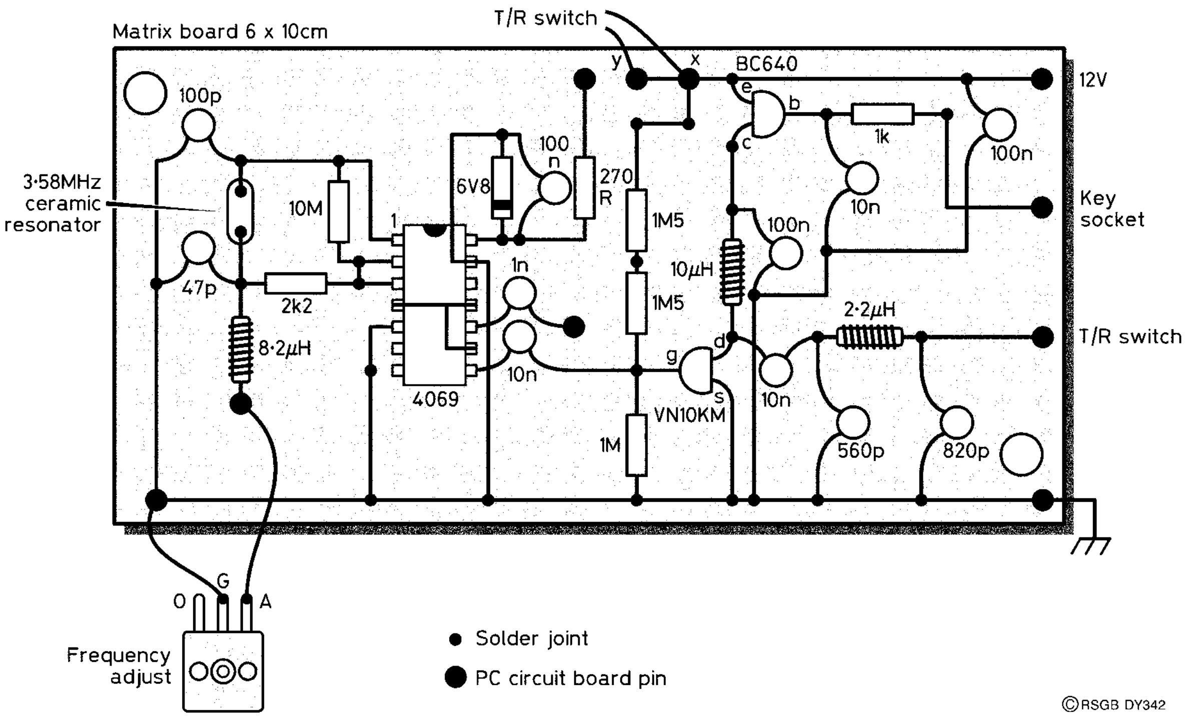
Matrix board 6 x 10cm
T/R switch
y
x
BC640
e
b
c
12V
100p
3·58MHz
ceramic
resonator
10M
1
6V8
100
n
270
R
1M5
1k
100n
10n
Key
socket
100n
10μH
47p
2k2
1n
1M5
2·2μH
T/R switch
8·2μH
4069
10n
g
d
s
VN10KM
10n
1M
560p
820p
O
G
A
Frequency
adjust
● Solder joint
● PC circuit board pin
©RSGB DY342

Figure 3 Component layout of the 80 metre transmitter. The transmit/receive switch is not mounted on the board and is not shown in this diagram

aerial and power sockets. Use screws and spacers to mount the circuit board to the box. Mounting the board horizontally assists troubleshooting.

Use a socket for the IC, and observe the CMOS handling precautions given in *An Electronic Die*, elsewhere in this book. When soldering the leads to the ceramic resonator, do it quickly – excessive heat damages the device. The earth lead running acoss the bottom of the board must be connected to the metal case by a short length of stout wire.

Testing

After carefully checking your wiring, both against the circuit diagram and the layout diagram, it is time to test your circuit. You will need a multimeter, an 80 m SSB receiver and a 50 Ω dummy load. A good design of dummy load can be found in the project *A Switched Dummy Load*, also in this book. An RF power meter and frequency counter will also be useful, although if your receiver has a digital frequency readout and S-meter, the latter two items are not really necessary. You will also need a 12 V 1 A power supply unit (PSU) to power the transmitter.

Switch the transmitter to receive and switch on the transmitter. No current should be consumed. Switch to transmit and check that pin 14 of IC1 is 6.8 V positive. With the dummy load connected to the aerial socket, press the key. The voltage on TR2 collector should now be 12 V, dropping to zero when the key is released.

Now check the operation of the oscillator. In transmit mode, you ought to be able to find a strong carrier signal with the receiver, even though the dummy load is connected. Adjusting the variable capacitor should change the frequency. At the lower end of the frequency range, you may find that the oscillator is unreliable in starting, because the circuit is attempting to pull the resonator too low in frequency. If this is the case, set the trimmer at the back of VC1 to minimum capacitance. If your version of VC1 has two trimmers, and you don't know which one to set, set them *both* to minimum capacitance. If there is still a problem, reduce the value of RFC1 to 6.8 or 4.7 μH.

In all probability, the unmodified circuit of Figure 2 will not require any of the changes outlined here. A coverage of 3.518 to 3.558 MHz should be possible, while preserving good frequency stability and reliable oscillation.

A signal probe (see *An RF Signal Probe*, elsewhere in this book) is useful for checking the operation of the oscillator and PA. Alternatively, an RF power meter or the receiver's S-meter can be used. With the PA running, the unit should draw between 200 and 300 mA. If TR1 becomes too hot to touch after a few seconds of transmitting, increase R5 or R6 to limit the transistor's heat dissipation. A small 6.3 V bulb connected across the aerial output is a simple way to check that the PA is working. An orange/white glow when the key is pressed is indicative of correct operation.

The final test is to monitor keying 'quality'. With your dummy load connected, press the key and listen to the note on the receiver's loudspeaker. Then operate the key, sending a string of dits, for example. What you hear should be free of chirps and clicks, as well as being stable in frequency. This test is sometimes better performed with no aerial connected to the receiver, thus preventing receiver overload and its associated plops. No problems should be encountered here.

Frequency tuning

A peculiarity of ceramic resonators is that, every now and again, their frequency changes abruptly by 100 Hz or so, then remains stable for some time. This is certainly noticeable in the received signal, but does not detract from the QSO and no characters are lost as a result. Try to keep the area around the ceramic resonator cool, to avoid temperature variations.

Parts list

Resistors: all 0.25 W, 5% tolerance

R1	10 megohms (MΩ)
R2	2200 ohms (2.2 kΩ)
R3	270 ohms (270 Ω)
R4	1 megohm (1 MΩ)
R5, R6	1.5 megohms (1.5 MΩ)
R7	1000 ohms (1 kΩ)

Capacitors

C1, C7	100 nF
C2	100 pF
C3	47 pF
C4	1 nF
C5, C6, C10	10 nF
C8	560 pF
C9	820 pF
VC1	10–160 pF variable

Inductors

RFC1	8.2 µH
RFC2	10 µH
RFC3	2.2 µH

Semiconductors

IC1	4069
TR1	VN10KM
TR2	BC640
D1	6V8 Zener

Additional items

- Matrix board (see text)
- 14-pin DIL socket
- Pointer knob
- Sockets (see text)

85 An audio booster for your hand-held

Introduction

The audio output from many hand-held transceivers and receivers usually leaves much to be desired, so this little amplifier was designed to increase the output at minimal expense.

All that is needed is a separate amplifier and bigger loudspeaker. This is accomplished using a single integrated circuit (IC), a few components, and a loudspeaker from the junk box. This circuit will enable the output from your hand-held to be heard easily in a car.

The circuit

This is shown in **Figure 1**. It uses only those components necessary to operate the IC amplifier. VR1 is the preset volume control, and varies the signal coming from the 'External speaker' jack on the hand-held before feeding it into the IC for amplification. C1 blocks any constant voltage present on the input.

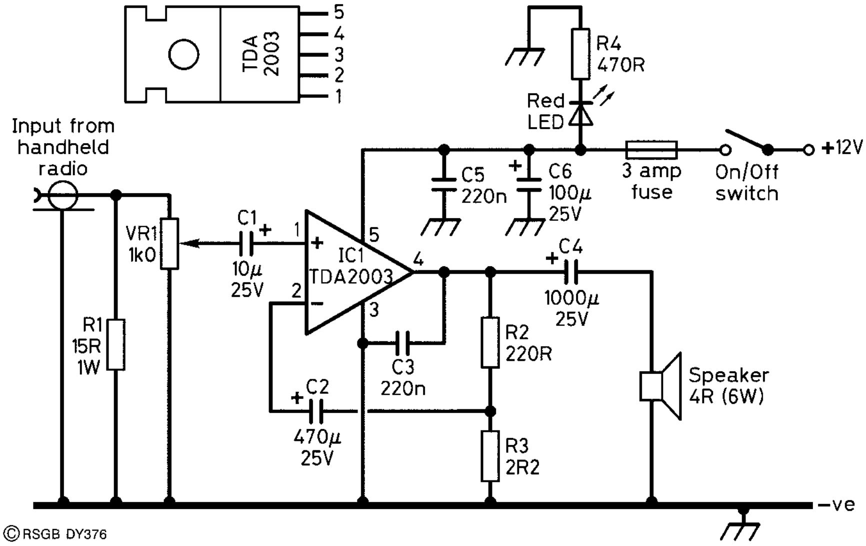
TDA 2003
5
4
3
2
1
R4
470R
Red LED
+12V
Input from handheld radio
C5
220n
C6
100µ
25V
3 amp fuse
On/Off switch
VR1
1k0
C1
10µ
25V
1
2
IC1
TDA2003
5
4
3
C4
1000µ
25V
R1
15R
1W
R2
220R
C3
220n
C2
470µ
25V
Speaker
4R (6W)
R3
2R2
−ve

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Figure 1 Circuit diagram of the audio amplifier. The power is derived from the cigarette lighter socket and the fuse is in-line with the lead

The IC output comes from pin 4 and is fed via the electrolytic capacitor, C4, to the loudspeaker. The circuit is provided with an on/off switch, fuse and LED to indicate when the circuit is switched on.

Construction

The box is made of aluminium. This is necessary to help to dissipate some of the heat generated by the IC. Do not build the circuit inside a plastic box unless you take special precautions! The IC has a metal mounting tab with a hole, specifically designed to be mounted to a metal box or other metal heat sink. Apply plenty of heat sink compound between the tab and the box, tighten the nut and bolt, and then wipe off any excess compound. The box will get slightly warm in operation.

The size of the box is not specified. You may want to decide on this when you find a loudspeaker. Choose one which will be able to handle 6 W

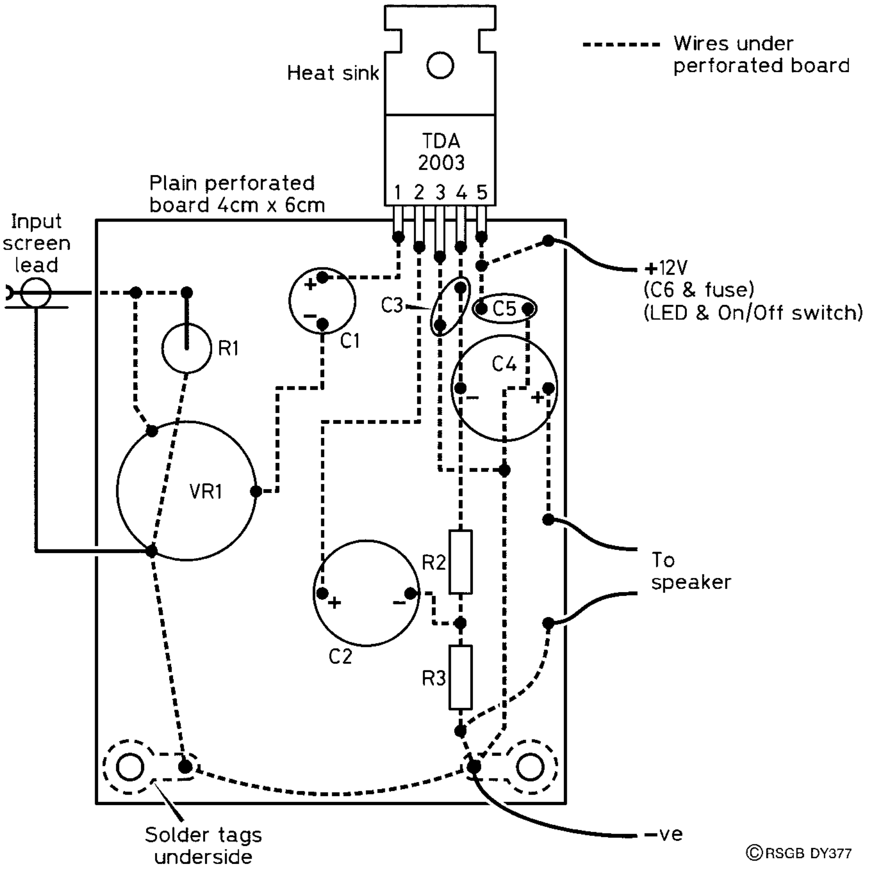
Heat sink
TDA 2003
1 2 3 4 5
Wires under perforated board
Plain perforated board 4cm x 6cm
Input screen lead
R1
C1
C3
C5
C4
VR1
R2
C2
R3
+12V
(C6 & fuse)
(LED & On/Off switch)
To speaker
Solder tags underside
−ve
©RSGB DY377

Figure 2 Layout of the components within the box

output. Drill all the holes in the box first. Holes for the speaker, input phono socket and the LED. The amplifier can be constructed on ordinary matrix board, which can be mounted inside the box with screws and spacers.

The layout is shown, for your guidance, in **Figure 2**. The components are mounted by pushing their leads through the holes in the board and making connections on the underside. The preset volume control, VR1, is set such that the hand-held's volume control is sufficient to control the final output over a good volume range. Use a screened lead from the 'External speaker' jack socket to the phono plug.

An external power supply is needed for this circuit. The normal dry battery which we usually use for small projects in this book will *not* work here, so you will need a proper mains power supply producing a stabilised 12 V. If you are going to use the unit principally in a car, then the cigar lighter socket can supply this voltage easily. Do make sure that the polarity is correct before you switch on!

When you plug the jack plug from your booster into the 'External speaker' socket on your hand-held, its internal speaker will be muted, so don't think that something dire has gone wrong! Adjust VR1 for a good volume range on your booster, when the volume control is turned on the hand-held.

Parts list

Resistors: all 0.25 W, 5% tolerance, unless otherwise stated

R1	15 ohms (15 Ω) 1 W
R2	220 ohms (220 Ω)
R3	2.2 ohms (2.2 Ω)
R4	470 ohms (470 Ω)
VR1	1000 ohms (1k Ω)

Capacitors

C1	10 μF 25 V
C2	470 μF 25 V
C3, C5	220 nF (0.22 μF) Mylar
C4	1000 μF 25 V
C6	100 μF 25 V

Semiconductor

LED	5 mm Red

Integrated circuit

IC1	TDA2003

Additional items
  Heat sink compound
  Nuts and bolts
  Loudspeaker 4 Ω 6 W
  3 A fuse
  On/off switch (SPST)
  Matrix board 4 × 6 cm
  Solder tags
  Plugs and screened cable for connecting lead
  Aluminium box

86 A grid dip oscillator

Introduction

When an inductor and a capacitor are connected, whether in series or parallel, they form a circuit with a natural (or *resonant*) frequency. The circuit stores energy, and this energy is being constantly shifted from the inductor to the capacitor and back again.

The dip oscillator is a simple instrument used to measure the resonant frequency of a tuned circuit without having to make any direct connection to the circuit. The circuit is more commonly known as the *grid dip oscillator* (GDO), from the days when the active device in the circuit was a valve. The FET or Field-Effect Transistor operates in a way which is very similar to that of the valve, so it is not quite a misnomer to call this instrument a grid dip oscillator, too.

The circuit

The GDO uses a calibrated, tunable FET oscillator in the circuit of **Figure 1**. It has a frequency range of 1.6 to 35.2 MHz in four ranges using a set of plug-in coils, shown in **Figure 2**. When the oscillator coil, L1, is placed near an external resonant circuit, some of its RF energy is coupled into the external circuit. A gain in energy of the external circuit must mean a loss of energy in the GDO circuit, resulting in a change of current through TR1, which is measured by the meter, M1.

The current through TR1 is of the order of 5 to 8 mA, but the change of current may be only a few microamps. To measure a very small

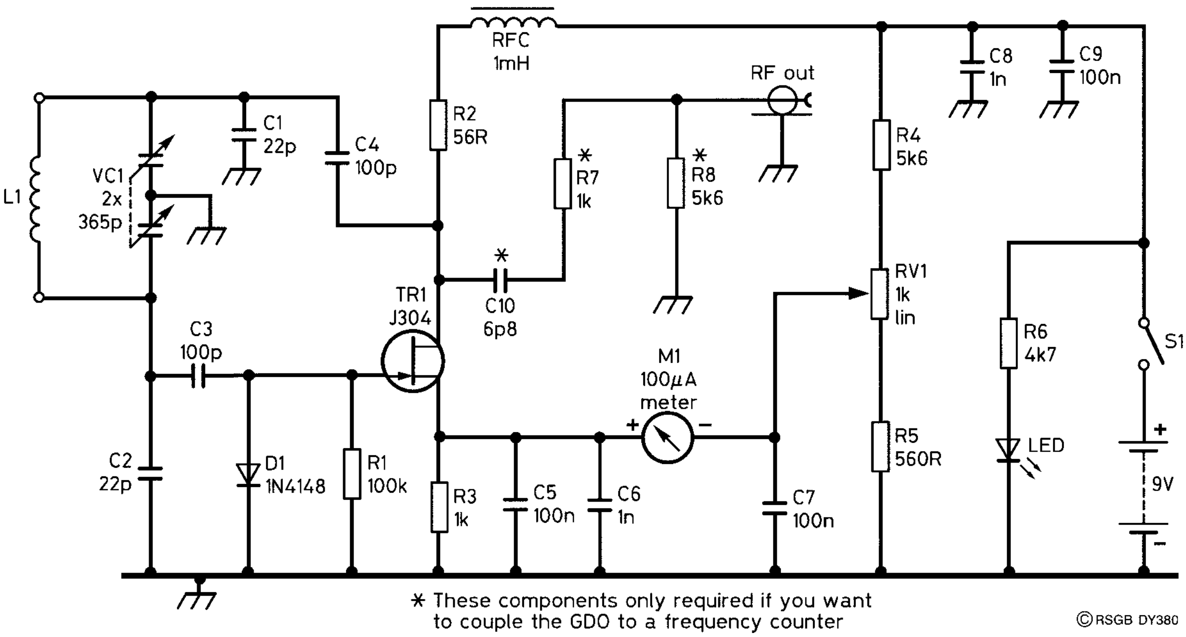
RFC
1mH
RF out
C8
1n
C9
100n
L1
VC1
2x
365p
C1
22p
C4
100p
R2
56R
*
R7
1k
*
R8
5k6
R4
5k6
RV1
1k
lin
R6
4k7
S1
TR1
J304
C10
6p8
*
C3
100p
M1
100μA
meter
+
–
C2
22p
D1
1N4148
R1
100k
R3
1k
C5
100n
C6
1n
C7
100n
R5
560R
LED
+
9V
–

* These components only required if you want to couple the GDO to a frequency counter

©RSGB DY380

Figure 1 Circuit of an FET GDO. The coils are wound on DIN speater plugs, which provide both a plug-in base and a coil former

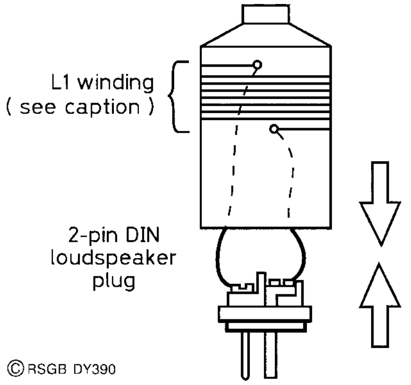
L1 winding
(see caption)
2-pin DIN
loudspeaker
plug

©RSGB DY390

Figure 2 Details of coil construction:
Range 1: 1.6–4.0 MHz 55 turns of 30 SWG
Range 2: 3.3–7.9 MHz 27 turns of 30 SWG
Range 3: 6.3–4.0 MHz 14 turns of 26 SWG
Range 4: 11.9–4.0 MHz 7 turns of 24 SWG.

change superimposed on a much larger standing current, the method of *offset* can be used.

One connection to the meter goes to the source of the FET, while the other goes to a variable offset voltage set by VR1. M1 has a full-scale deflection (FSD) of 100 μA. If the current through TR1 changes, the voltage across R3 changes. When there is no resonance, the voltage at the wiper of VR1 is set to be very slightly greater than that across R3, and there is a 75% FSD meter deflection. When the voltage across R3 decreases very slightly, due to external circuit resonance, a significant 'dip' in the meter deflection is produced, hence the name of the instrument.

The circuit is not difficult to make on standard matrix board. Provided you can follow a circuit and translate it into a good component layout, then this project is probably only an evening's work.

The most important part of the GDO is the tuning capacitor and its associated frequency-calibrated dial. New, air-spaced tuning capacitors can cost you up to £20, so it is worth delving around in junk boxes, or scouring the tables at a local boot sale or rally. The tuning capacitor from an old transistor radio should be perfect. It may even have a slow-motion drive and a dial which can be remarked for the project.

Choose a coil plug and socket arrangement that is practical. Think about crystal holders or phono plugs and sockets. The prototype shown in Figure 1 and Figure 2 used 2-pin DIN plugs, with the coil wound on the outside of the plastic plug cover. Figure 2 shows the coil construction and the winding details.

If you use a variable capacitor, VC1, with a value different from that shown in the parts list, then the frequency ranges will be different. This does not matter, as it will be taken into account during calibration.

Position VC1 so that the dial will be easy to see and to operate, while locating the coil socket as close to it as possible. **Figure 3** shows the traditional layout of the GDO.

Calibration

Because the GDO also radiates a very small amount of energy, a general coverage receiver can be used to calibrate the dial. Don't try to aim for great accuracy and clutter the dial with marks and figures! If you include C10, R7 and R8 in your circuit, you can connect a frequency counter directly to the GDO and leave it in circuit all the time.

The GDO in use

Always try to place the external tuned circuit with its coil coaxial with the plug-in coil, as shown in Figs 1 and 3. If the coils are at right angles, the GDO may not produce any resonance. Set the offset control to give about 75% FSD and slowly tune L1 through its whole range. If no dip occurs, you may have the wrong coil plugged in. When you eventually find a dip, move the external coil further away until only a minute dip is seen. You may have to retune the dip meter as you do this, but it gives a much more accurate reading of frequency.

Remember that you cannot 'dip' a coil by itself – there must always be a capacitor present.

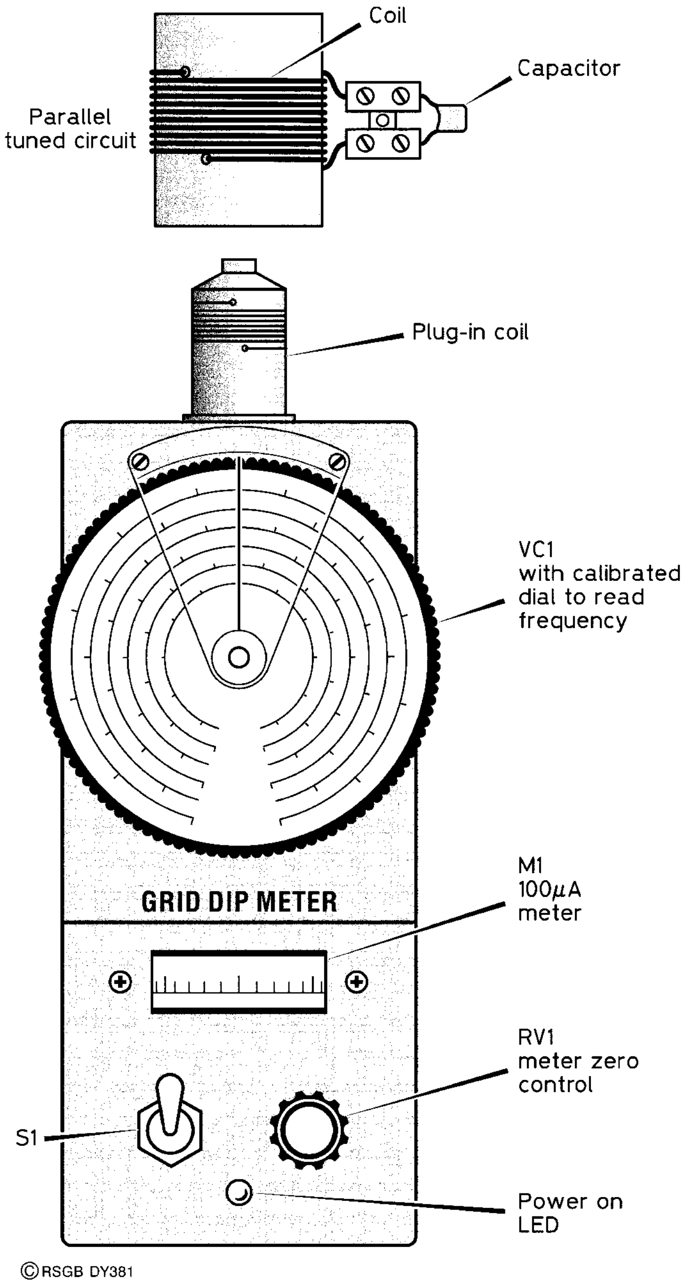
Coil
Capacitor
Parallel tuned circuit
Plug-in coil
VC1 with calibrated dial to read frequency
GRID DIP METER
M1 100μA meter
RV1 meter zero control
S1
Power on LED
©RSGB DY381

Figure 3 Layout of a typical GDO. The dial, meter and the location of the coil to the circuit under test can all be viewed at the same time. It is shown measuring resonance of a tuned circuit

Aerial resonance

Figure 4 shows how to check the resonance of a dipole aerial. Disconnect the coax feed at the aerial and place a short piece of wire, terminated with crocodile clips, across the centre insulator to short together the two ends of the aerial. By placing the GDO close to the shorting link, a dip should be seen on the meter while VC1 is turned. Alternatively, a loop in the element can be made around the coil, as in Figure 4, or the shorting link can be made long enough to loop over the coil. The latter method does not require tampering with the mounting and tensioning of the dipole wires.

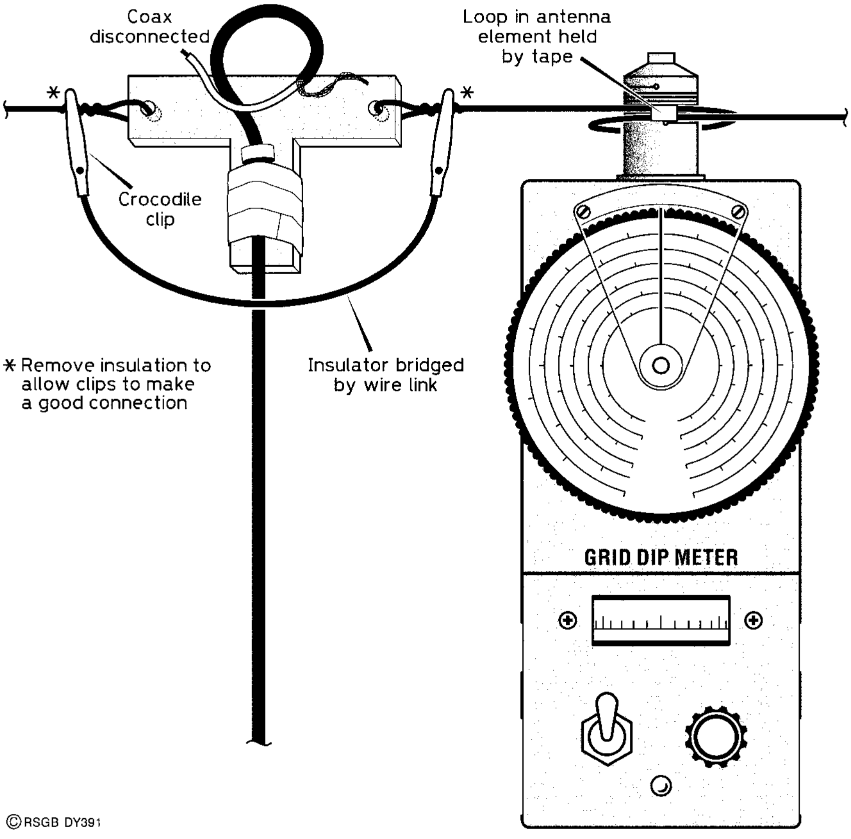
Coax
disconnected
Loop in antenna
element held
by tape
*
*
Crocodile
clip
* Remove insulation to
allow clips to make
a good connection
Insulator bridged
by wire link
GRID DIP METER
©RSGB DY391

Figure 4 A wire antenna element can be looped into a single turn coil for increased coupling to the GDO

Parts list

Resistors: all 0.25 W, 5% tolerance

R1	100 000 ohms (100 kΩ)
R2	56 ohms (56 Ω)
R3	1000 ohms (1 kΩ)
R4	5600 ohms (5.6 kΩ)
R5	560 ohms (560 Ω)
R6	4700 ohms (4.7 kΩ)
R7	1000 ohms (1 kΩ)
R8	5600 ohms (5.6 kΩ)
VR1	1000 (1 kΩ) linear

Capacitors

C1, C2	22 pF
C3, C4	100 pF
C5, C7, C9	100 nF (0.1 μF)
C6, C8	1 nF (1000 pF)
C10	6.8 pF
VC1	2 × 365 pF

Semiconductors

TR1	J304 or similar
D1	1N4148
LED	

Additional items

L1	See Figure 2
RFC	1 mH
S1	SPST
M1	100 μA

Source

Components are available from Maplin.

87 A CW transmitter for 160 to 20 metres

Introduction

This very small transmitter is designed to work on any band from top band (160 m) to 20 m, with an RF output of 1 W. It will work on higher frequencies but with a reduced output.

The circuit

The three-transistor circuit is shown in **Figure 1**. It comprises a crystal oscillator using a BC182 transistor which drives a 2N3866 power amplifier (PA) keyed by a ZTX750 PNP transistor. The oscillator and PA are coupled by a capacitor and resistor; this provides a very small amount of positive bias to the PA.

The oscillator can be used as a basic crystal oscillator but, by including a variable series capacitor as shown in Figure 1, the crystal frequency can be 'pulled' slightly, making the oscillator a *variable crystal oscillator* (VXO).

Construction

The PCB layout is shown in **Figure 2** and in the photograph. Although the prototype was built around a PCB, this circuit is equally amenable to

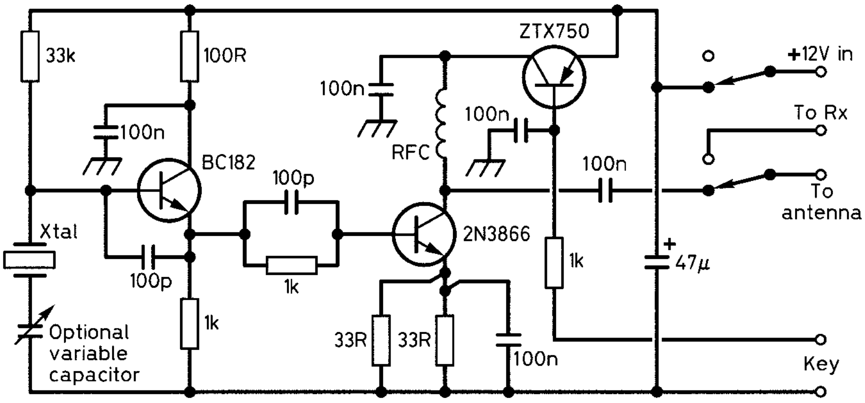
33k
100R
100n
BC182
100p
Xtal
100p
1k
1k
Optional
variable
capacitor
ZTX750
100n
RFC
100n
100n
2N3866
33R
33R
100n
1k
+
47µ
+12V in
To Rx
To
antenna
Key

©RSGB DY396

Figure 1 Transmitter circuit diagram

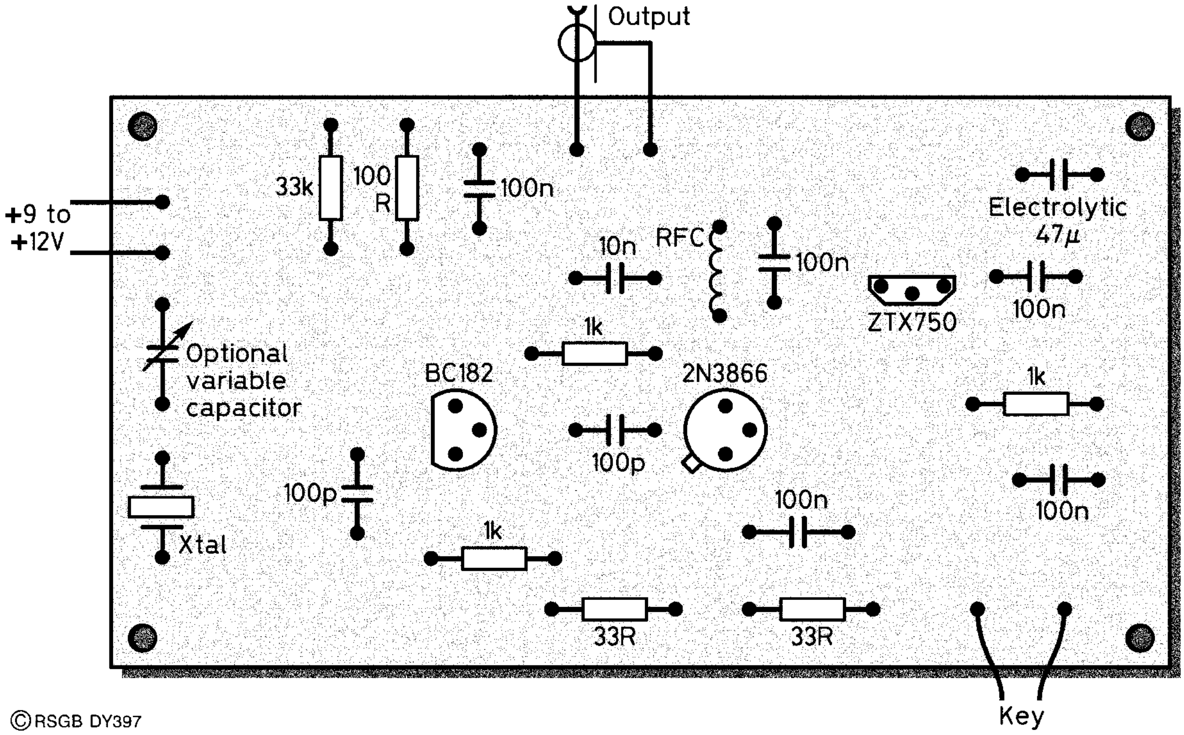
Output
+9 to
+12V
33k
100
R
100n
10n
RFC
100n
Electrolytic
47µ
100n
ZTX750
1k
Optional
variable
capacitor
BC182
2N3866
1k
100p
100p
Xtal
100n
100n
1k
33R
33R
Key
©RSGB DY397

Figure 2 Component placing on the PCB. The external connections are also shown

construction on a matrix board. Populating the PCB is very simple, and you can expect to be able to do this in about one hour. The radio-frequency choke (RFC) is made by winding 10 turns of 33 SWG wire on a ferrite bead. The enamel coating of the wire is intended to vaporise when soldered into the board, thus obviating the need to remove the enamel manually with a knife or sandpaper. However, if you do have problems with the PA either not working or keying intermittently, it is suggested that you investigate the RFC connections immediately!

If you decide to make the VXO version, you will have to cut the track between the crystal and earth, and connect the variable capacitor (250 pF) across the break.

In use

After performing the usual checks on the accuracy of your circuit building and the wiring of the external components, it is time to connect a 12 V battery between the points shown in Figure 2. Do not switch on yet. An aerial needs to be connected to the output via an ATU and a crystal, of frequency matching that of the aerial, fitted. The variable capacitor should give you a tuning range from about 14.058 to 14.064 MHz. 'Netting' (the process of tuning your transmitter to the same frequency as that of a received station) is achieved simply, because the oscillator is always running, and the leakage of the signal (despite the fact that the PA is not powered) is sufficient to bring the two frequencies to zero beat.

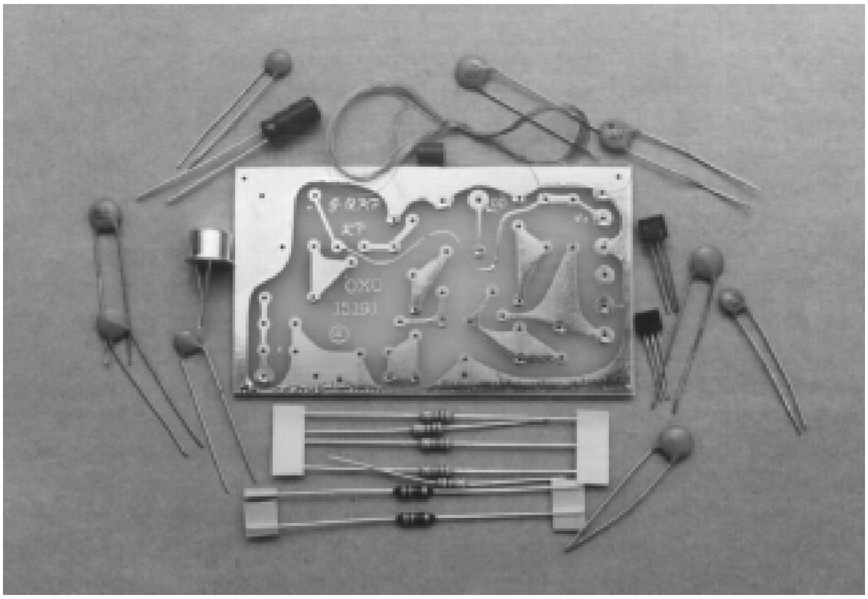

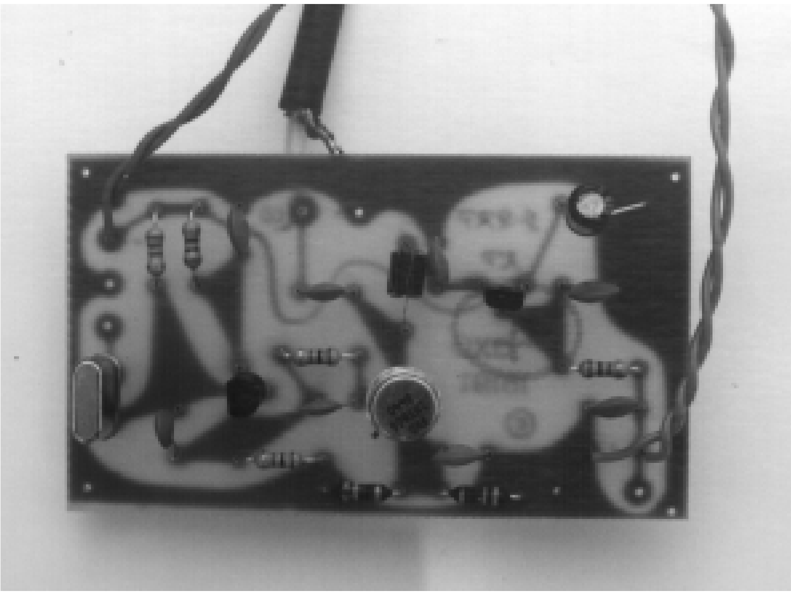

Warning

Note that the transmitter has no filtering; harmonics are not suppressed. It is strongly recommended that you use this transmitter in conjunction with the excellent low-pass filter described in the project *A 7-element low-pass filter for transmitters*, described elsewhere in this book.

88 Matching the end-fed random-wire aerial

Introduction

Many amateurs who do not have the space (or money) for a multi-band beam aerial, make use of the simplest possible alternative – the longest piece of wire that they can erect, with its end connected to the transceiver or receiver by an aerial tuning unit (ATU).

The length of the wire is not of major importance. Any length between 10 m and 80 m, with bends if necessary, will suffice. A good earth connection to the radio is just as important. Bends in the aerial wire can have some interesting effects on the directional properties of the aerial; V- or L-bends, or even a square shape are permitted. The only thing *not* permitted is to fold the wire back on itself in a tight hairpin bend!

Longish wire aerials

The term ‘long wire’ is usually used (incorrectly) to describe an end-fed aerial. How long is a piece of string? It depends what you mean by ‘long’. In aerial parlance, it means ‘long with respect to one wavelength’. Again, this depends on the band you are using. A long wire at 20 m is somewhat different from a long wire at 160 m. However, if you have sufficient real estate for a long wire on the 160 m band it must, by definition, be a long wire on all the other bands, too!

This should put you on your guard when analysing published data about feed-point impedance and the directional properties of a long wire aerial. Such theoretical data relate to a *real*, *ideal* long wire which is straight, horizontal, very high above perfect (conducting) ground, and not obstructed in any way. So your aerial doesn't quite match these criteria? Join the club!

Don't let this dampen your ardour when it comes to evaluating what the longish wire can do for you. The following should explain why.

Feed-point impedance

The impedance at the end of a longish-wire aerial can vary from a few tens of ohms to several thousand ohms, depending on the frequency in use and the wire length. It is also affected by factors such as bends, height above ground, proximity to buildings and wire diameter.

The actual value doesn't matter, provided we can make the aerial *appear* to have a 50 Ω impedance at the aerial socket of the transmitter. This process is what we call *impedance matching*, or simply *matching*. It maximises the power transfer from the transmitter to the aerial, and from the aerial to the receiver.

That is why an aerial tuning unit, or ATU, is almost (but not necessarily) obligatory.

The ATU

Many commercially produced HF receivers and transceivers have single 50 Ω coaxial sockets as their one and only means for connecting an external aerial. This means that an external aerial should have a 50 Ω feed impedance if it is to work efficiently, and it rules out most of the aerials being used by amateurs on the HF bands. Some means is necessary to change the aerial feed impedance to 'match' that of the transceiver. Such impedance-matching, or Z-matching (because Z is the symbol for impedance, just as L is the symbol for inductance) is the rôle of the ATU.

These can be bought and will accommodate either an end-fed or a coax-fed aerial. They can be bought ready for use or in kit form. Whether you want one for receiving only, or for use with a low-power (QRP) or high-power (QRO) transmitter, will determine what you need and how much you pay.

A simple single-band ATU

The simplest form of ATU is shown in **Figure 1**. It is simply a parallel LC (coil and capacitor) circuit, resonant at the chosen frequency, with taps on the coil for the aerial and the coaxial feed to the transceiver. If we assume the circuit is resonant, a high impedance exists at the top of the coil, and a low impedance at the bottom.

We said earlier that the end-fed longish wire presented an impedance which was high (or at least higher than 50 Ω). This explains why the aerial is tapped to the coil near the top, where the impedance is high, and the 50 Ω coax is tapped near the bottom, where the impedance is low.

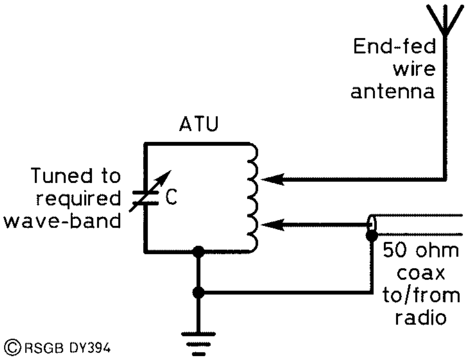

Figure 1 Parallel tuned circuit as single-band ATU for end-fed longish-wire antenna

Because the feed-point impedance of the aerial changes with frequency, so must the point at which the aerial is tapped to the coil to achieve impedance matching. The value of C must be changed also, to ensure that the circuit is resonant, and the 50 Ω tap will require tweaking also.

Setting up an ATU is quite simple. Make up an LC parallel-tuned circuit consisting of 50 turns of enamelled copper wire on an empty 35 mm film plastic container (or similar), tuned with a 500 pF variable capacitor. Make sure the enamel is removed from the ends of the wire before soldering.

Solder the inner wire of the coaxial cable from the radio to the first or second turn of the coil from its grounded end. Then solder the braid to the grounded end. Connect the aerial about one-third of the way down the coil from the top, removing the enamel at the connection point.

Adjust the variable capacitor for maximum noise or signal strength in the receiver. Then, try different tapping points from the aerial, to maximise the signal again. This matches the aerial impedance to that of the tuned circuit. Repeat the process with the coax tap, thus matching the impedance of the radio and the cable to that of the tuned circuit.

You will no doubt find that the tapping process on the coil was not easily accomplished, especially when the enamel must be removed at each tapping point without shorting adjacent turns together. It is therefore logical to produce a design where the taps have been prepared during the winding of the coil, and are selected with a rotary switch. To this end, the following multi-band design is described.

A multi-band ATU

The same type of coil design around a 35 mm film container is used (see **Figure 2**). The tapping points can be prepared in advance by a little judicious planning. Dismantle your original coil and measure the length of wire on it. It will be a little more than a calculation of $50 \times \pi D$ would suggest (where D is the diameter of the film container), due to the lack of tension in the coil and the wire diameter itself. You will need aerial tapping points at turns 1, 2, 3, 5, 10, 15, 20, 25, 30, 35, 40 and 45, corresponding to all the bands from 28 MHz to 1.8 MHz. The coaxial cable tap is fixed at turn 2 (an acceptable compromise). All the turns are counted from the earthy end.

Cut another piece of enamelled copper the same length as you used originally. Then, with the aid of an ordinary calculator, work out the positions of the points where the enamel must be removed for the taps. For example, turn 15 will have to be made $\frac{15}{50}$ of the way along the wire, turn 20 tap made at $\frac{20}{50}$ of the way along. So, if the length of wire is, say 4.7 metres, the two taps in question will be made at $\frac{15}{50} \times 4.7 = 1.41$ m and $\frac{20}{50} \times 4.7 = 1.88$ m from one end. This must be repeated for each of the tap positions, and the enamel removed ready for the wire to be soldered to it. With a

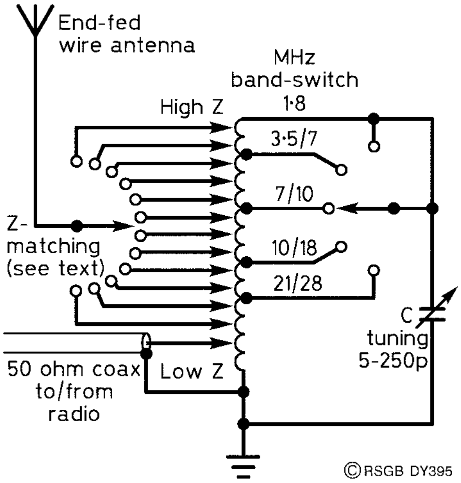

Figure 2 Simple multi-band ATU for end-fed longish-wire antennas

soldering iron, tin each tap point while the copper is shiny, thus ensuring a good, low-resistance connection. Do not solder on the taps yet.

The coil can now be wound as before. The taps can be soldered on, taking the lead from each one to the wafer of a single-pole 12-way rotary switch, the pole being connected to the aerial.

The tuning of the ATU is carried out by the same 250 pF capacitor, with a single-pole 5-way rotary switch used to select the band. Its tapping points will need to be chosen manually, using the method described earlier. Don't attempt to make new tapping points on the coil for this – use the taps available on the wafer of the other rotary switch, and find which is optimum for each band.

Notes

- For the aerial, use PVC-covered stranded tinned copper, of size 16/0.2 mm or 24/0.2 mm.
- Make the wire as long as possible, but anything over 10 m should be OK.
- Keep the wire as high as you can, in the clear and away from obstructions.
- Don't worry about bends, but don't use hairpin bends.
- Use a good insulator to attach your aerial – anything plastic will do.
- Anchor the wire near the point of entry to the building, but use a U-bend to prevent ingress of water.
- The wire can be brought in through the corner of a window, the PVC acting as an insulator. If you must drill a hole in the brickwork, make sure it slopes upwards from outside, so that water is deterred from entering.
- Use a good RF earth (as opposed to an electrical earth) such as half a dozen bare copper wires buried under the lawn in a fan shape. They should be joined together at the point of the fan and strapped to the earth connector of your ATU.

PART II— BUILDING AND USING BALUNS AND UNUNS

Chapter 7

The 1:1 Balun

Sec 7.1 Introduction

In this chapter I will introduce the most popular broadband Balun in amateur radio use—the 1:1 Balun. This topic been discussed in the amateur radio literature since the publication of Turrin's 1964 article.[8] Although Turrin's Balun is really a version of Ruthroff's, which was introduced in his classic 1959 article,[9] the real beginning of the broadband 1:1 Balun dates back to Guanella's classic paper of 1944.[3] Guanella's objective was to design a broadband 16:1 Balun to match the balanced output impedance of 960 ohms of a push-pull, 100-watt vacuum-tube amplifier to the unbalanced load of a matched 60-ohm coaxial cable. Use of his approach for 1:1, 4:1, and 9:1 Baluns has produced the designs of choice. They are presently called current or choke Baluns.

This chapter begins with an introduction to the technology of transmission line transformers. Other topics discussed include: 1) when to use a Balun; 2) highlights of significant articles in the professional and amateur radio literature; 3) high-power, medium-power, and low-power designs; and 4) isolation transformers. The latter is presented here for the first time. The chapter closes with a brief summary of the significant points included within.

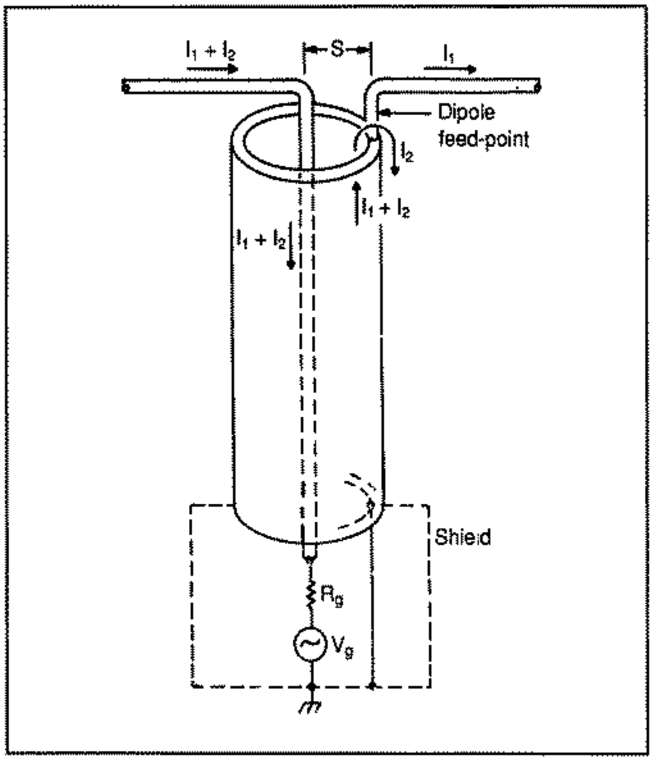

Figure 7-1. *An illustration of the various currents at the feedpoint of a dipole. I_1 is the dipole current and I_2, the inverted L (imbalance) current.*

Sec 7.2 When to Use a Balun

Baluns have taken on a more significant role in the past few decades with the advent of solid-state transceivers and Class B linear amplifiers with unbalanced outputs. That is, the voltage on the center conductor of their output chassis connectors varies (plus and minus) with respect to ground. In many cases, coaxial cables are used as the transmission lines from these unbalanced outputs to antennas like dipoles, inverted Vs, and Yagi beams that favor a balanced feed. In essence, they prefer a source of power whose terminals are balanced (voltages being equal and opposite) with respect to actual ground or to the virtual ground that bisects the center of the antenna. The question that is asked most frequently is whether a 1:1 Balun is really needed.

To illustrate the problem involved and to give a basis for my suggestions, I refer you to **Figure 7-1**. Here we have, at the feedpoint of the dipole, two equal and opposite transmission line currents with two components each—I_1 and I_2. Also shown is the spacing, s, between the center conductor and the outside braid. Theoretically, a balanced antenna with a balanced feed would have a ground (zero potential) plane bisecting this spacing. However, because a coax-feed is unbalanced and the outer braid is also connected to ground at some point, an imbalance exists at the feedpoint giving rise to two antenna modes. One lies with I_1, providing a dipole mode; the other lies with I_2, providing an inverted L mode.

If the spacing, s, is increased, the imbalance at the feedpoint becomes greater—giving rise to more current on the outer braid and a larger imbalance of currents on the antenna's arms. Several steps can be taken to eliminate or minimize the undesirable inverted L mode (that is, eliminate or minimize I_2). The obvious choice is to use a well-designed Balun that not only provides a balanced feed, but also minimizes (by its choking reactance) I_2—if the coaxial cable does not lie in the ground plane that bisects the center of the dipole. The other step is to ground the coaxial cable at a quarter-wave (or odd-multiple thereof) from the feedpoint. This discourages the inverted L mode because any radiating element will want to see a high impedance at these lengths instead of the low impedance of a ground connection.

I conducted experiments with Baluns on a 20-meter half-wave dipole at a height of 0.17 wavelengths, which gave a resonant impedance of 50 ohms. VSWR curves were compared under various conditions. When the coaxial cable was in the ground plane of the antenna (that is, perpendicular to the axis of the antenna), the VSWR curves were identical with or without a well-designed Balun—no matter where the outer braid was grounded. A significant difference was noted only when the coaxial cable was out of the ground plane. When the cable dropped down at a 45-degree angle under the dipole, a large change in the VSWR took place. This meant that the inverted L mode was appreciable.

It should also be mentioned that the direction of I_2, the imbalance current, can depend upon the side on which the coaxial cable is out of the ground plane of the dipole. For example, if the cable comes down under the right side in **Figure 7-1** (that is, the angle between the horizontal arm and the coax is less than 90 degrees on the right side and more than 90 degrees on the left side), then the direction of I_2 can be reversed by the imbalance in the induced currents on the outside of the braid. By the same token, by having the coaxial cable coming down on the other side, the value of I_2 is only increased in magnitude.

However, feeding a Yagi beam without a well-designed 1:1 Balun is a different matter. Because most Yagi designs use shunt-feeding (usually by hairpin matching networks) in order to raise the input impedance close to 50 ohms, the effective spacing (s) is greatly increased. Furthermore, the center of the driven element is actually grounded. Thus, connecting the outer braid (which is grounded at some point) to one of the input terminals, creates a large imbalance and a real need for a Balun. An interesting solution, which would eliminate the matching network, is to use a step-down Balun designed to match 50-ohm cable directly to the lower balanced-impedance of the driven element.[2]

In summary, if you concur with the theoretical model of **Figure 7-1**, my experiments performed on 20 meters, and the reports from radio amateurs using dipoles and inverted Vs without Baluns, then it appears that 1:1 Baluns are really needed for: a) Yagi beam antennas where severe pattern distortion can take place without one, and b) dipoles and inverted Vs that have the coaxial cable feed lines out of the ground plane that bisects the antennas, or that are unbalanced by their proximity to manmade or natural structures. In general, the need for a Balun is not so critical with dipoles and inverted Vs (especially on 40, 80, and 160 meters) because the diameter of the coaxial cable connector at the feedpoint is much smaller than the wavelength.

If my model, which assumes that a part of the problem when feeding balanced antennas with coaxial cable is related to the size of the spacing, s (shown in **Figure 7-1**), then the possibility exists for using Ununs for matching into balanced antennas with impedances other than 50 ohms and with small values of s. For example, half-wave dipoles at a height of about a half-wave, quads, and center-fed 3/2-wave dipoles—which all have impedances close to 100 ohms—could very well be matched to 50-ohm cable by a 2:1 Unun. As I will show, they are considerably easier to construct than 2:1 Baluns. Furthermore, Genaille[10] has recently shown considerable success using Ununs in this kind of application.

To wind up this section, I would like to comment on an article published by Eggers,[11] WA9NEW, concerning the use of a Balun with a half-wave dipole. While at North Carolina State University, he conducted an experimental investigation of pattern distortion without a Balun at 1.6 GHz in an RF anechoic chamber (which simulates "free space"). Briefly, his results showed that, with a Balun (bazooka type), the antenna radiation pattern compared very favorably with the classic "figure-eight." Without the Balun, the radiation pattern was severely distorted.

Even though the author expressed difficulty in obtaining accurate measurements at this very high frequency, I have a question regarding the validity of performing the experiment in the first place. From the photograph in the article, it appears that conventional coaxial cable and connectors were used in the experiment. If we assume an effective diameter of 0.375 inches for these components, then scaling up to 3.5 MHz (457.14 fold) results in a coaxial cable with a diameter of 14.28 feet! I am quite sure that the large spacing, s, of 7.14 feet would bring about a noticeable imbalance resulting in appreciable pattern distortion even at 3.5 MHz.

Sec 7.3 Highlights of Significant Articles on 1:1 Baluns

Although there have been many articles on 1:1 Baluns published in the professional and amateur literature, I have selected for review a few that I believe have had the most impact on 1:1 Baluns for amateur radio use. As you will see, even though I consider some of the amateur articles significant, their impact upon the use and understanding of these devices has not always been positive. In fact, in some cases, the opposite has been true.

In the professional literature

There are actually only two significant articles in the professional literature that provide the fundamental principles upon which the theory and design of this class of transformers are based. It can be said that succeeding investigators simply extended the works of the authors of these two articles.

The first presentation on broadband matching transformers using transmission lines was given by Guanella in 1944.[3] He coiled transmission lines forming a choke such that only transmission line currents were allowed to flow, no matter where a ground was connected to the load. His single, coiled transmission line resulted in a 1:1 Balun. It is shown schematically in **Figure 7-2A**. Prior to this, RF Baluns were achieved by the use of quarter and half-wave transmission lines, and as a result, had narrow bandwidths. Guanella then demonstrated broadband Baluns with impedance transformations of $1{:}n^2$ where *n* is the number of transmission lines he connected in a series-parallel arrangement.

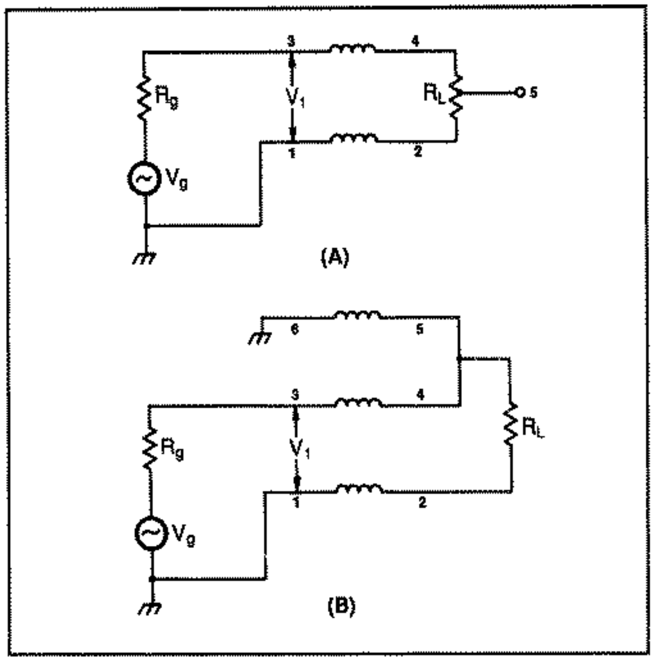

Figure 7-2. *Two versions of the 1:1 Balun: (A) the Guanella Balun and the basic building block; (B) the Ruthroff Balun as originally drawn.*

Several important points should be made regarding Guanella's 1:1 Balun shown in **Figure 7-2A**. With sufficient choking reactance, the output is isolated from the input and only flux-canceling transmission line currents are allowed to flow. With matched or very short transmission lines, the grounding of terminal 5 (actually or virtually like the center of a dipole) results in terminal 4 becoming $+V_1/2$ and terminal 2 becoming $-V_1/2$—creating a balanced output. This type of Balun has lately been called a "current" or "choke" Balun. A significant feature of this model is that a potential gradient of $-V_1/2$ exists along the length of the transmission line. This gradient, which exists on both conductors, accounts for practically all of the loss in these transformers because the loss mechanism is voltage dependent (a dielectric-type loss). All transmission line transformers have some sort of voltage gradient along their transmission lines and are, thus, subject to the same type of losses. Furthermore, the theory and loss mechanism is the same whether the transmission lines are coax or twinlead, or coiled around cores, or threaded through ferrite beads. Additionally, it was shown[2] that higher-impedance Baluns or Baluns subjected to higher VSWRs have more loss because the voltage gradients are also larger.

The second significant article on broadband transmission line transformers was published by Ruthroff.[9] His 1:1 Balun, which is shown as originally drawn in

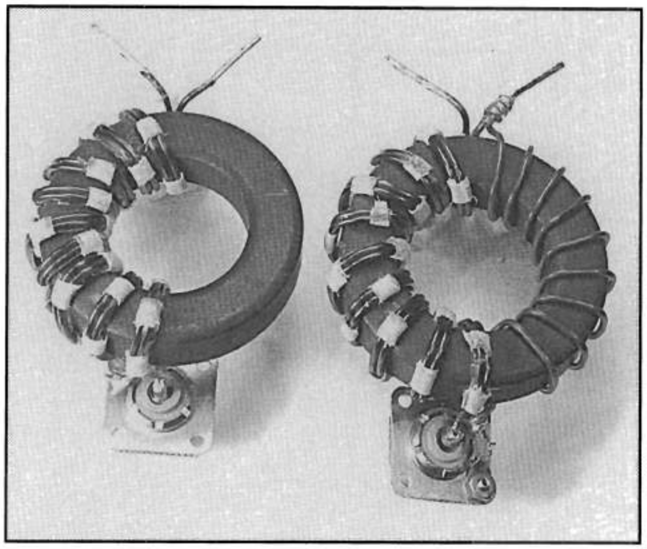

Photo 7-A. *The two basic forms of the 1:1 Balun that first appeared in the professional literature. The two-conductor Guanella Balun is on the left and the three-conductor Ruthroff Balun is on the right.*

Figure 7-2B, used an extra winding to complete (as he said) the path for the magnetizing current. Even though his schematic drawing appeared to look like a trifilar winding, his pictorial in the article clearly showed that the third winding (5-6) was on a separate part of the toroid. With an equal number of turns, it forms a voltage divider with winding (3-4) placing terminal 4 at $+V_1/2$ and terminal 2 at $-V_1/2$. In his classic paper, Ruthroff also presented his form of the 4:1 Balun (which is also different from Guanella's), a 4:1 Unun, and various hybrids. **Photo 7-A** shows the two basic forms of the 1:1 Balun that first appeared in the professional literature. The two-conductor Guanella 1:1 Balun is on the left and the three-conductor Ruthroff Balun is on the right. As was mentioned before, the Guanella Balun has also been called a "current" or "choke" Balun.

Before moving on to the significant articles in the amateur radio literature, some mention should be made of the differences between the two basic forms shown in **Photo 7-A**. Guanella's 1:1 Balun came to be known as the *basic building block* for this whole class of broadband transformers. This term was coined by Ruthroff as he showed its 1:1 Balun capability when the load was grounded at its center (terminal 5), and as a phase-inverter when the load was grounded at the top (terminal 4). By connecting terminal 2 to terminal 3 and connecting the bottom of the load to ground, Ruthroff demonstrated his very popular 4:1 Unun. I call this type of arrangement the bootstrap connection. By grounding terminal 2, there is no potential drop along the transmission line and, therefore, no need for magnetic cores or beads. This arrangement, which turns out to be an important function for extending the high frequency performance of this class of transformers, I call the "phase-delay" connection.

Thus, with the flexibility shown by Guanella's basic building block, a 1:1 Balun is now realized that not only presents a balanced power source to a balanced antenna system, but can also prevent an imbalance current (an inverted L antenna current) by its choking reactance when the load is unbalanced or mismatched or when the feedline is not perpendicular to the axis of the antenna.

Interestingly enough, except at the very low end of the frequency response of the Ruthroff 1:1 Balun where autotransformer action can take place, his Balun takes on the characteristics of the Guanella Balun. The reactance of the third winding becomes great enough to make it literally transparent. This is not the nature of the trifilar-wound (voltage) Balun, which is sensitive to unbalanced and mismatched loads over its entire passband because it is actually two tightly coupled transmission lines. This distinction was not recognized by most of those who published in the amateur radio literature.

In the amateur radio literature

R. Turrin, W2IMU—1964

The first presentation in the amateur radio literature on 1:1 Baluns using ferrite cores was by Turrin in 1964.[8] Turrin, who was a colleague of Ruthroff's at Bell Labs, took his small-signal design (which used No. 37 or 38 wire on toroids with ODs of 0.25 inches or less) and adapted it to high-power use. This was done by using thicker wire, larger cores, and (very importantly for high efficiency[2]) low permeability ferrite. Ruthroff used lossy manganese-zinc ferrites with permeabilities of about 3000 because efficiency was not a major consideration.

Figure 7-3 is a pictorial and a schematic of Turrin's design. As you can see, the third wire (winding 3-4) is placed between the two current-carrying wires (windings 1-2 and 4-5). **Photo 7-B** shows (on the left) his actual design using a ferrite core; a popular design (on the right) using a powdered-iron core is available in kit form from Amidon Associates, Inc. Both Baluns use 10 trifilar turns of a single-coated wire like Formex™ or Formvar™ on a toroid. Turrin's design

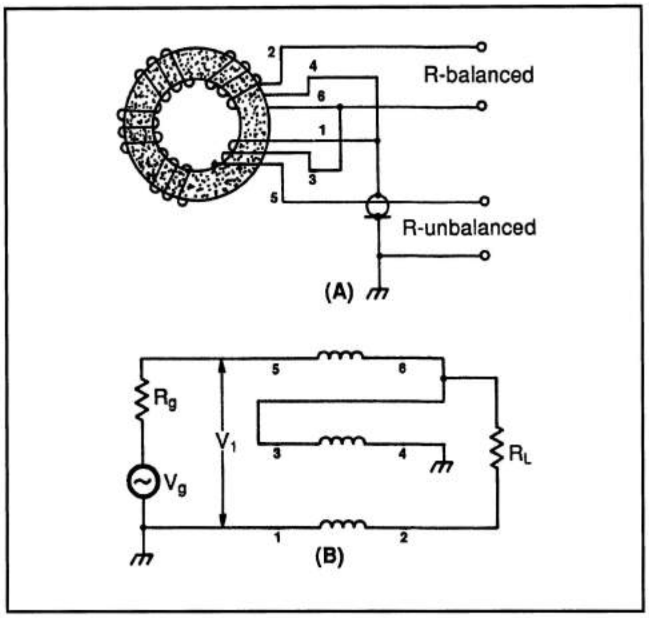

Figure 7-3. *(A) A pictorial of Turrin's 1:1 Balun, and (B) a schematic of his Balun.*

uses a ferrite toroid with an OD of 2.4 inches and a permeability of 40. The Amidon Associates' Balun uses a powdered-iron toroid with a 2-inch OD and a permeability of only 10. Both Baluns are specified to handle 1000 watts of power from 1.8 to 30 MHz.

Figure 7-4 shows the response curves for these two Baluns when terminated with 50-ohm loads. The response curve for a popular 1:1 rod-type Balun that uses the same schematic and wire is also shown. It has 8 trifilar turns, tightly wound on a rod of 0.5-inch diameter, 2.5 inches long, and with a permeability of 125. The rod-type Balun is shown in **Photo 7-C**.

Several important features should be brought out regarding the results shown in **Figure 7-4**. They are:

1. All Baluns had insufficient choking reactance and, hence, poor low-frequency responses. The powdered-iron version was especially poor. They all showed a drop in the input impedance and an inductive component at 2 MHz. This meant flux in the cores and an undesirable condition—especially for ferrite, which is a nonlinear material. Ferrite cores could not only suffer damage, but they could also generate spurious frequencies under these conditions. In fact, the same condition could occur at 4 MHz with a VSWR of 2:1! Therefore, I don't recommend any of these Baluns for use on 160 or 80 meters.

2. The major problem at the low-frequency end is the role of the third winding (3-4) in **Figure 7-3B**. It has been claimed[12] that the third winding improves the low-frequency response (over the two-conductor Guanella 1:1 Balun) because it enables autotransformer action at the low end. However, recent measurements I have made on two-conductor Guanella Baluns and three-conductor Ruthroff (or Turrin) Baluns, with loads grounded at their centers, show insignificant differences. This type of load approximates the actual condition when feeding a balanced antenna system. The negative feature of the third winding (3-4) is that, at the low-frequency end, there can be insufficient reactance to prevent harmful flux in the core because of a direct shunting path to ground. With the two-conductor 1:1 Balun, the only flux-inducing current is that of the imbalance current (the inverted L mode), which is usually far smaller.

3. Another important feature of the curves shown in **Figure 7-4** is the effect of the characteristic impedances of the coiled transmission lines. For example, a bifilar winding (wires tight together) on a toroid with spacing between adjacent bifilar turns exhibits a char-

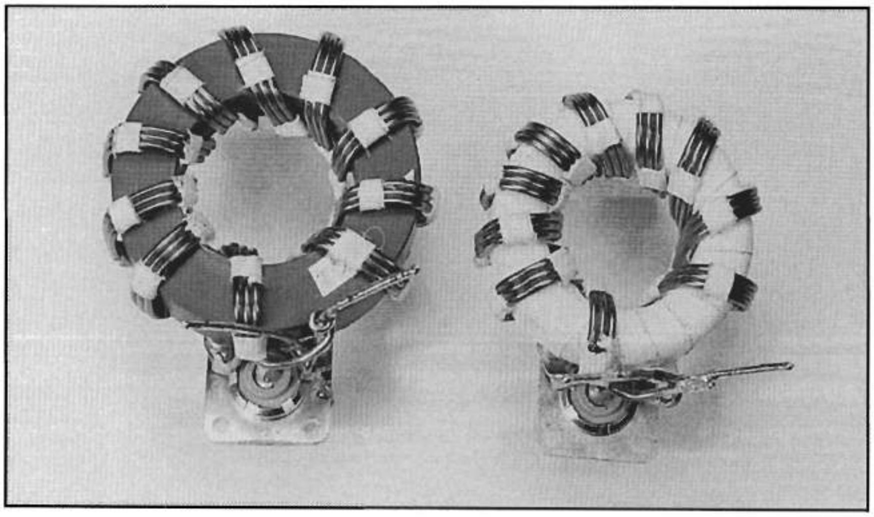

Photo 7-B. *Two versions of Turrin's design: On the left, the 1:1 Balun that has appeared in the amateur radio literature; on the right, a 1:1 Balun that has been readily available in kit form from Amidon Associates, Inc.*

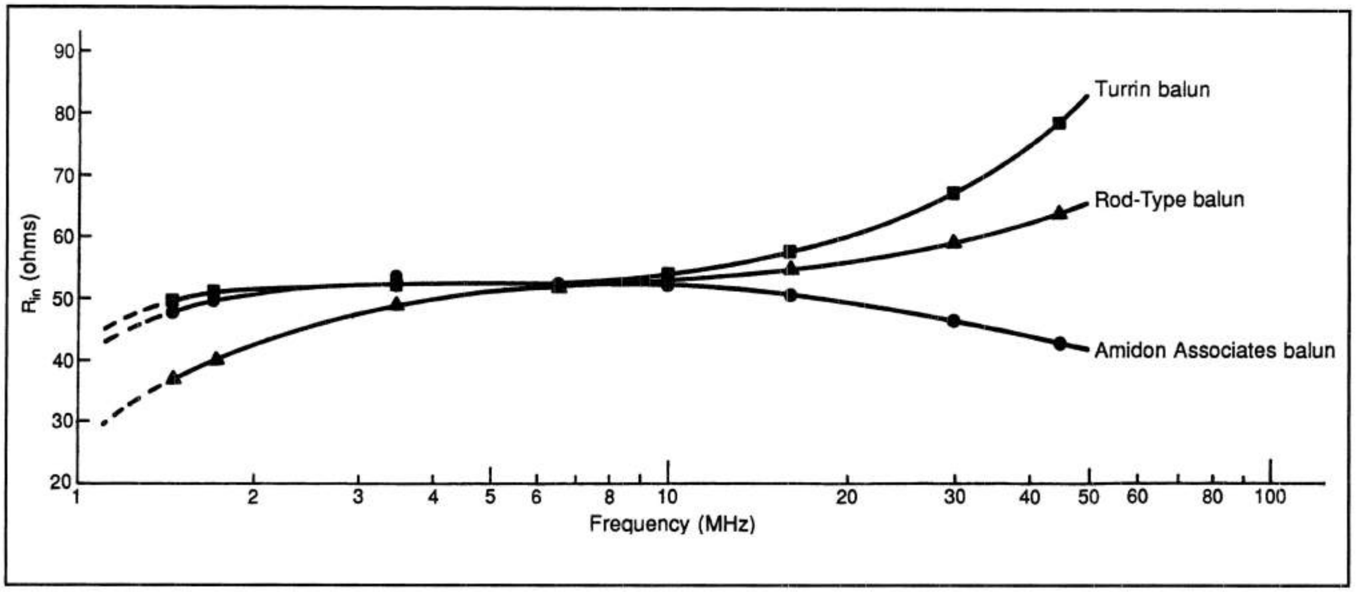

Figure 7-4. *The input impedance versus frequency, when terminated with 50 ohms, for the Turrin, typical rod-type, and Amidon Associates 1:1 Baluns.*

acteristic impedance of about 45 ohms. When wound on a rod with no space between adjacent bifilar turns, the characteristic impedance drops to about 25 ohms. With the third winding (3-4) between the other two as shown in **Figure 7-3B**, the characteristic impedance is raised to approximately 70 ohms in the toroidal case and to about 47 ohms in the rod case. If the toroidal Baluns were terminated in 70 ohms and the rod Balun terminated in 47 ohms, the high-frequency responses would be practically flat to at least 30 MHz. The difference in high-frequency response between the two toroidal Baluns (with 50-ohm loads) is due to the differences in the lengths of their transmission lines. The transmission line on the powdered-iron core is appreciably less because the OD, as well as the cross-sectional area, is smaller.

4. The trifilar-wound form of the 1:1 Balun also has an additional undesirable property. Its high frequency response is sensitive to unbalanced and mismatched loads. This is because the third wire now forms two tightly coupled transmission lines. It is unlike the Ruthroff version shown on the right in **Photo 7-A**. In his second article,[12] Turrin pointed out this important distinction.

J. Reisert, W1JR—1978

The next significant article on 1:1 Baluns was published by Reisert in 1978.[7] Reisert proposed winding some of the smaller (but still high-powered) coaxial cables around a 2.4-inch OD ferrite toroid with a permeability of 125. The windings also included a crossover, which is shown in **Figure 7-5** and **Photo 7-D**. In addition, he recommended various numbers of turns, depending upon the low-frequency requirement. For example, he suggested 12 turns to cover 3.5 MHz, 10 turns for 7 MHz, 6 for 14 MHz, and 4 for 21 and 28 MHz. Because the characteristic impedance of the coaxial cable is the same as the coax feedline, the Balun only introduces a foot or two of extra length to the feedline. This is true in the HF and VHF bands. The coaxial cables recommended in the article were RG-141/U, RG-142/U, and RG-303/U.

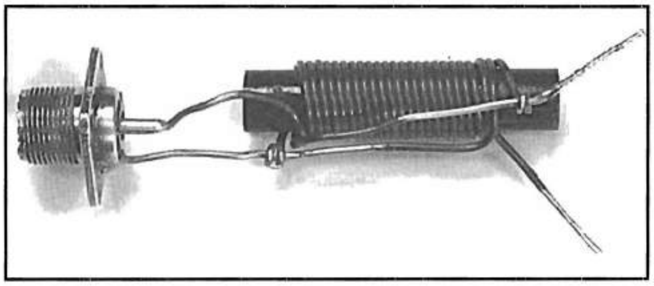

Photo 7-C. *A typical rod-type Balun.*

From the articles that followed in the amateur radio literature, it became apparent that few recognized all of the important features of Reisert's Balun. They are listed below.

1. An efficient, low-loss ferrite was used.

2. The Baluns had sufficient choking reactances for the various low-frequency requirements.

3. The characteristic impedance of the coiled transmission line was the same as that of the feedline, thus eliminating the extra transformer action of a length of transmission line with a different characteristic impedance.

4. The Balun is a form of Guanella's two-conductor 1:1 Balun, which is not prone to core flux and, hence, saturation and the generation of spurious frequencies. It is also not susceptible to mismatched and unbalanced loads as are the Turrin and "voltage" Baluns.

After constructing several of Reisert's Baluns and comparing them with other Guanella designs, I found that the crossover winding had virtually no effect up to 100 MHz (the limit of my equipment). In regards to Reisert's VSWR comparison with a rod-type Balun when feeding a triband Yagi beam on 20 meters, I found that his Balun had a lower VSWR (practically 1:1) at the best match point. The rod-type Balun had a best VSWR of about 1.3:1, but at a slightly higher frequency. He attributed the higher (and somewhat flatter) VSWR curve of the rod-type Balun to its greater ohmic loss. Because the rod-type Baluns I have investigated used the same low-loss ferrite that Reisert's did, I suspect that the differences in the VSWR curves were mainly due to the mismatch loss introduced by the rod-type Balun.

G. Badger, W6TC—1980

Badger published an in-depth, two-part series[13,14] in *Ham Radio* magazine in 1980 on air-core Baluns and Ununs. I am sure it was instrumental in advancing the technology of this class of wideband transformers. An article by Orr[15] also shows that there are many other radio amateurs who see the advantages of air-core transformers.

What are the claims for air-core Baluns over their ferrite-core counterparts? First and foremost, proponents of air-core Baluns claim they don't suffer the consequences of saturation that leads to spurious frequencies, heating, and ultimate damage. Secondly, it's said that they are not subject to arcing from the windings to the core.

What are the claims for the ferrite-core Baluns over their air-core counterparts? Simply put, they have wider bandwidths and are more compact.

After reading Badger's two-part series, I found that my curiosity was piqued by his experimental data on harmonic distortion due to saturation in a ferrite-core 1:1 Balun. Although many have expressed concerns regarding saturation in ferrite-core Baluns, Badger's data could very well provide the only results available. He used the two-tone test method, which combined two RF sources of 2.001 and 2.003 MHz, amplified it to 2 kW PEP and then fed it through a commercial 1:1 rod-type ferrite Balun. The data showed considerable distortion in the 3rd order and 9th order distortion products. In other words, appreciable nonlinearity took place at this high power level.

Several questions come to mind regarding these measurements. What was the low-frequency response of the commercial 1:1 rod-type Balun Badger used? From my measurements on a rod-type Balun (**Figure 7-4**), I found a drop in the input impedance and an inductive component at 2 MHz. This indicates flux in the core and a problem when using this Balun at 2 MHz. Because many rod-type 1:1 Baluns have been used over the years, it would have been instructive if he had also made these measurements at 4 and 7

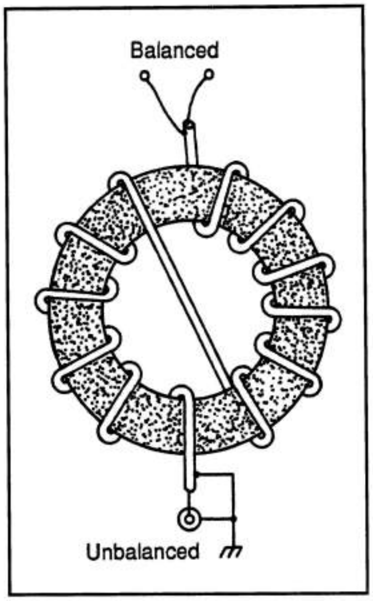

Figure 7-5. *A pictorial of the crossover used in Reisert's 1:1 Balun.*

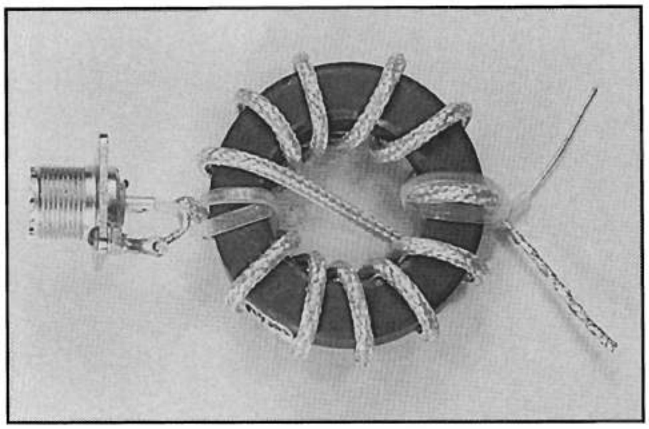

Photo 7-D. *A Reisert, W1JR, 1:1 Balun.*

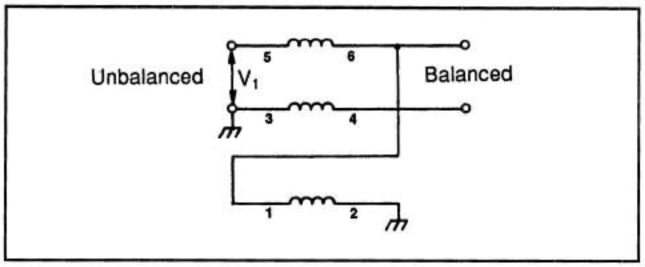

Figure 7-6. *Schematic of Badger's 1:1 Balun with a compensating winding (1-2). Winding (3-4) is the outer-braid of the coax and winding (5-6) is the inner conductor.*

MHz. They would have given the readers a safe lower-frequency limit for these Baluns.

I wondered why Badger didn't make similar measurements on Reisert's 1:1 Balun, which he included in his articles. As noted earlier, I consider Reisert's 1:1 Balun a very good design! I am sure that no distortion products would have been found at 2 MHz with this Balun. The end result is that Badger chose a poor ferrite-core design for making his comparisons. This helped to contribute to an undeserved reputation for the ferrite-core Balun.

Badger also suggested placing an insulated wire in parallel with the coax winding on Reisert's 1:1 Balun. He called this a compensating winding, which provided a superior balanced output. The third winding (1-2) is shown **Figure 7-6**. Winding (5-6) is the inner conductor and winding (3-4), the outer braid. Later experiments by myself and others have shown that a well-designed two conductor (Guanella) 1:1 Balun has a completely satisfactory balanced output for antenna applications. Furthermore, it does not suffer from an unbalanced and/or mismatched load and core saturation. Incidentally, Badger's schematic of **Figure 7-6** now adds up to four different versions of the 1:1 Balun. They are the two-conductor version of Guanella's and the three, three-conductor versions of Ruthroff's, Turrin's, and (now) Badger's.

Badger and Orr also mentioned the Collins Balun in their articles. This Balun is comprised of a dummy length of coax wound as a continuation of the original coiled coax winding. Interestingly, it is connected as a Ruthroff 1:1 Balun (**Figure 7-2B**), which also uses a third winding. Because there is appreciable coupling between the two coiled windings, the Collins Balun should also be susceptible to mismatched and/or unbalanced loads. Badger claimed it was, by far, the best 1:1 Balun he had ever used. Again, it would have been very informative if he had compared it with the Reisert Balun (without the compensating third wire).

M.W. Maxwell, W2DU—1983

One of the more significant articles on 1:1 Baluns was published by Maxwell[4] in 1983. Maxwell introduced, what he called, the "choke" Balun. It was formed by placing high-permeability ferrite beads over about one foot of small (but high-powered) coaxial cables similar to the ones used in the Reisert Balun. **Photo 7-E** shows the W2DU "choke" Balun removed from its plastic enclosure.

Maxwell compared his Balun with (what he termed) a "transformer-type" Balun by measuring the input impedances versus frequency when the outputs were terminated in 50 ohms. The "transformer-type" Balun didn't yield a true 1:1 impedance transfer ratio, which he claimed was due to losses, leakage reactance, and less than optimum coupling. Because Maxwell gave no description of the "transformer-type" Balun, I assumed it was the popular rod-type Balun shown in **Photo 7-C**. As you can see in **Figure 7-4**, this Balun has a poor low-frequency response. Furthermore, it is really optimized for a load of 47 ohms and not 50 ohms.

What Maxwell failed to realize was that his Balun was a form of Guanella's two-conductor type. That is, it is both a choke (a lumped element) and a transmission line (a distributed element). Additionally, Guanella's theory applies whether the transmission lines are coiled (about a core) or beaded, twin-lead or coaxial cable. From Ruthroff's classic paper,[9] which extended Guanella's work,[3] we became aware of the

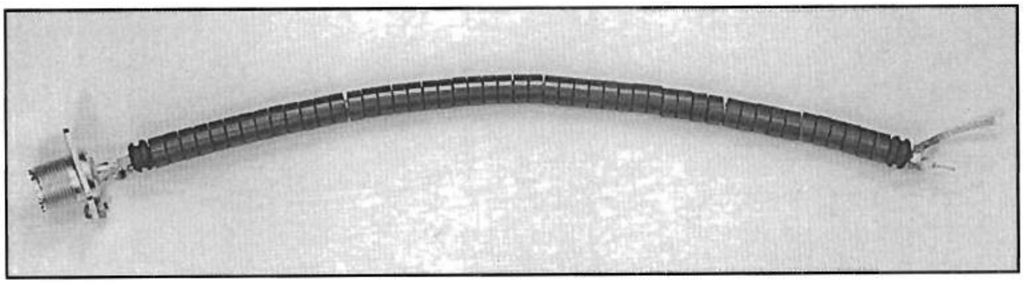

Photo 7-E. *The Maxwell, W2DU, "choke" 1:1 Balun.*

voltage drops along the lengths of the transmission lines. From very accurate insertion loss measurements,[2] we learned that the losses were mainly in the magnetic medium—and that they were related to the voltage levels and the permeabilities. Maxwell didn't take into account these latter findings. He used lossy high-permeability beads (2500) and assumed that the main loss was in the transmission line. He claimed that the CW power-handling capability of his Balun was 3.5 kW at 50 MHz and 9 kW at 10 MHz—the same as the coaxial cable itself. I seriously question these power ratings. Ironically, it is very likely that Maxwell's Balun had more real loss than the so-called "transformer-type" Balun!

R.W. Lewallen, W7EL—1985

There is very little doubt that Lewallen's interesting article[6] in 1985 contributed significantly to the better understanding and design of 1:1 and 4:1 Baluns. In it, he coined the (now very popular) terms "voltage" and "current" Baluns. The "voltage" Balun, a three-conductor type, has output ports which have voltages that are balanced to ground. It is brought about (see **Figure 7-6**) by the voltage-divider action of windings (5-6) and (1-2). Because we have two tightly coupled transmission lines in the passband with the same potential gradients, terminal 6 is at $+V_1/2$ and terminal 4 at $-V_1/2$ where V_1 is the input voltage. The "current" Balun, on the other hand, is a two-conductor Balun that produces equal and opposite currents on the output ports for any form of load impedance.

Lewallen conducted a series of experiments on 10 meters to compare the performances of "voltage" and "current" Baluns under balanced and unbalanced conditions. In the unbalanced (nonsymetrical) condition, the dipole was lengthened by five inches on one side and shortened by five inches on the other side. He then obtained a figure of merit for both Baluns (as well as for the case without a Balun) defined as the ratio of the average magnitude of the currents at the feedpoint over the magnitude of the imbalance (the inverted L) current. The magnitudes of the currents were obtained by current-probe toroids. Measurements were made at the antenna feedpoint and at a half-wave (physically) from it.

The "current" Balun consisted of 15 turns of very small RG-178/U coax on an FT82-61 core (a ferrite toroid with an OD of 0.825 inches and a permeability of 125). The "voltage" Balun had 10 turns of RG-178/U coax with a No. 26 wire in parallel (closely coupled) on the same toroid. The schematic is shown in **Figure 7-6**.

Lewallen concluded (and I agree) that his experiments clearly showed that the "current" Balun gave superior performance at every measured point in each experiment. However, the "voltage" Balun still improved the balance over the no-Balun case. He also concluded that other experiments should be performed in order to better compare the two forms of the Balun. One is to ascertain the difference when the feedline is placed nonsymetrical with respect to the antenna (to induce an imbalance current into the feedline). Others include determining the optimum point in the feedline to place the Balun, and testing the various kinds of core and beaded Baluns.

Although Lewallen's article pretty much speaks to Badger's proposal of adding a third wire to Reisert's Balun for better balance (i.e., avoid it), there are some comments and questions I have regarding his experiments and findings. They are:

1. Why didn't Lewallen use Reisert's Balun as the "current" Balun and Badger's suggested third-wire design as the "voltage" Balun? These would have been more realistic designs for comparisons. Instead, he used very small structures (which will only find use in QRP operations) and, as such, have higher frequency capabilities. Also, because the "voltage" Balun only had 10 turns (and hence a shorter transmission line and a poorer low-frequency response), it was favored in the comparisons on 10 meters. Had Lewallen used transmission lines of equal lengths on Reisert's cores, the differences between the two Baluns would have been even more dramatic.

2. It would also have been very useful if Lewallen had made comparisons between a "current" Balun that could handle the full legal limit of amateur radio power (again like the Reisert Balun) and "voltage" Baluns using Turrin's schematic (**Figure 7-3**) with rod and toroidal cores which have been readily available for nearly three decades.

3. Additionally, comparisons should not only be limited to 10 meters. Because 1:1 "voltage" Baluns are configurations of coupled transmission lines with various characteristic impedances, their performances with mismatched and unbalanced loads are more sensitive to the higher frequencies than their "current" Balun counterparts. Therefore, making similar measurements on 20 meters would also provide more useful information.

4. Even though Ruthroff's classic 1959 paper[9] has been the industry standard over the years, his 1:1

Balun design has been practically nonexistent in the amateur literature. Turrin mentioned its advantage over his first design in his second article.[12] But Turrin's first design has prevailed in our amateur literature. Because Ruthroff's design has the third conductor on a separate part of the toroid, it has the balanced output mentioned by Badger,[13] but still retains the flexibility of the Guanella[3] Balun. In other words, as the frequency is increased, the choking action of the third wire makes it practically transparent. This enables it to handle any form of load impedance. It would have been informative if Lewallen had pointed this out and also noted that Ruthroff's 1:1 Balun, although looking like a "voltage" Balun, is really a "current" Balun.

5. Lewallen and the others who have published in the amateur radio literature have failed to reference the first presentation on what are now known as "current" or "choke" Baluns, made by Guanella[3] in 1944. Even though Guanella used coiled transmission lines without a magnetic core, his theory on how these devices work is still applicable today.

J.S. Belrose, VE2CV—1991

The last article on 1:1 Baluns I considered worth mentioning was written by Belrose[5] in 1991. In it, he described the W2DU Balun by Maxwell and how his technique of threading coaxial cable through ferrite beads could be easily applied to 4:1 and 9:1 Baluns.

What immediately grabbed my attention in this article was the *deck head* (the editor's comments), which included highly complimentary remarks regarding the beaded-coax Balun. In essence, it said, "In this breakthrough article, W2DU's peerless 1:1 current-Balun design serves as the basis for excellent ferrite-bead-choke current Baluns capable of 4:1 and 9:1 impedance transformation."

However, if one reads the article carefully, it becomes apparent that this is not what Belrose said. His words were, "The *current Balun* of the *type* developed by Walt Maxwell, W2DU—a Balun consisting of ferrite beads slipped over a length of coaxial cable—is the best so far devised (italics mine)." He did not say that W2DU's Balun was "peerless." In fact, in the article he said just the opposite. He pointed out that the W2DU Balun's main disadvantage is that the beads are lossy at HF and heating becomes a concern when the transmitting power exceeds 125 watts! For high power (that is 1-kW CW), Belrose recommended Roehm's[16] designs, which use lower permeability (850) beads nearest the Balun's balanced output (where most of the heating takes place).

However, I do question two of the advantages he claims for the W2DU Balun. They are:

1. Its excellent power-loss and impedance-versus-frequency characteristics are much superior to those of a bifilar current Balun wound on a ferrite toroid.
2. It has excellent power-handling capability, and can function quite satisfactorily when working into highly reactive loads. This is so because the magnetic flux produced by currents flowing on this Balun's wires cannot saturate its ferrite beads.

Belrose obtained evidence for advantage number 1 by comparing the input impedance and power loss versus frequency of the W2DU Balun with a commercial Balun when they were terminated in 50 ohms. The commercial Balun was a bifilar wound toroidal type used in a differential-T tuner. What Belrose failed to realize was that the commercial Balun had heavily insulated wires, resulting in a characteristic impedance greater than 100 ohms. Thus, he was actually comparing a 50-ohm transmission line with a longer line that had a characteristic impedance in excess of 100 ohms! As expected, his input impedance versus frequency curve for the commercial Balun was even more severe than that of the Turrin Balun shown in **Figure 7-4**.

Advantage number 2 is based upon the premise that the magnetic flux produced by currents on the W2DU Balun's wires cannot saturate the ferrite beads, while the windings of a bifilar wound toroidal current Balun can. This is an incorrect assumption because the magnetic flux of a two-conductor type Balun, like the beaded-coax or the bifilar-wound toroidal Balun, is generated by the imbalance (inverted L) current and hence is *much* lower than the transmission line currents. This is especially true with sufficient choking reactances. The perception that the toroidal type Balun still transmits the energy to the output circuit by flux linkages, could very well lead to this mistaken impression.

For high power beaded-coax Baluns, Belrose referred to designs by Roehm,[16] who increased the power capability of this type of Balun by using lower permeability beads near the balanced output. He also increased the length considerably. For operation from 80 meters to 10 meters, Roehm used 28 inches of beaded coax. For 160 meters to 10 meters, he used 36 inches of beaded coax. Belrose's suggestion of connecting beaded coaxes in parallel on the low-imped-

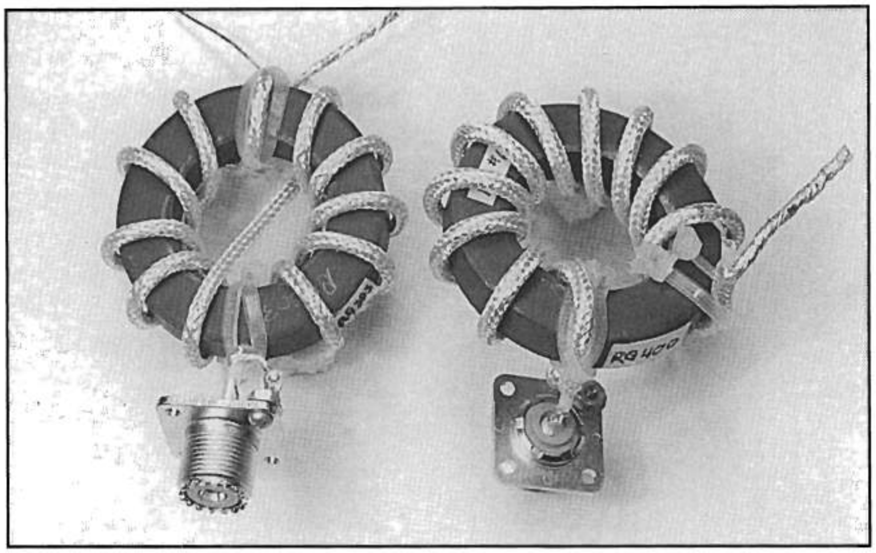

Photo 7-F. *Two versions of Reisert's 1:1 Balun. The Balun on the left uses the crossover shown in Figure 7-5. The Balun on the right is continuously wound. Both have the same electrical performance in the HF band.*

ance side and in series on the high impedance side to obtain a broadband 4:1 transformation ratio would require transmission lines with characteristic impedances of 100 ohms. This means, for a high power 4:1 Balun using beaded transmission lines, about 56 inches of beaded line would be required for the 80-meter to 10-meter operation and 72 inches for the 160-meter to 10-meter coverage. For a 9:1 Balun, it would be necessary to increase these lengths by 50 percent!

It remains to be seen what Belrose would have said or done if he had compared the W2DU Balun of Maxwell's with the W1JR Balun of Reisert's. He certainly couldn't claim the advantages listed in his article for the W2DU Balun. Would he still have claimed that the type of Balun developed by Maxwell is the best so far devised? Given the evidence, I doubt it.

Sec 7.4 High-, Medium-, and Low-power Designs

In this section I'll present my latest 1:1 Balun designs. Except for one Balun that appeared in the June 1993 issue of *CQ*, the others appeared for the first time in the magazine's April 1994 issue. Because I have favored Reisert's design throughout this chapter, the first Baluns described here are my versions of his technique of coiling small (but high power) coaxial cable around a low-permeability ferrite toroid. For my wire versions, I could have used all sorts of adjectives to describe them like Guanella, two-conductor, choke, and current. However, in the process of writing this section, I thought Belrose's adjectives were the most direct. Using his words, I call my wire versions of the 1:1 Balun simply—*bifilar toroidal Baluns*.

Photo 7-F shows two versions of Reisert's Balun. The one on the left uses the crossover shown in **Figure 7-5**. Because no difference in performance at HF was noticed without the crossover, a continuous-wound version is also shown on the right. The main advantage in the HF band with the crossover winding is purely mechanical. Having the input and output connections on opposite sides of the toroid is not only more convenient, but it also offers a much stronger method of mounting.

For operation from 1.8 to 30 MHz, 10 turns of small coax like RG-303/U, RG-142B/U, or RG-400/U are wound on a 2.4-inch OD ferrite toroid with a permeability of 250. If the use is limited from 3.5 to 30 MHz, then a permeability of 125 is recommended because it would yield a slightly higher efficiency at the high end. If one wants the highest possible efficiency and limits the operation from 14 to 30 MHz, then a permeability of 40 is recommended. With loads grounded at their centers, these conditions were found to give ample margins (handle a VSWR of 3:1 without any appreciable flux) at their low frequency ends.

For ease of winding, I found TY-RAP™ Cable Ties *very* useful. Two were used at each end. Removing the covering on the outer braid also helps. Because about 24 inches of cable is wound on the toroid, I recommend you start with at least 32 inches. Of the three cables noted above, I found RG-303/U cable the easiest to wind and connect. Although it only has a single-thickness braid (the others have double-thickness braids), its power rating is still the same—9 kW at 10 MHz and 3.5 kW at 50 MHz.

The next high power design is shown in **Photo 7-G** mounted in a 4 inch long by 3 inch wide by 2.25 inch

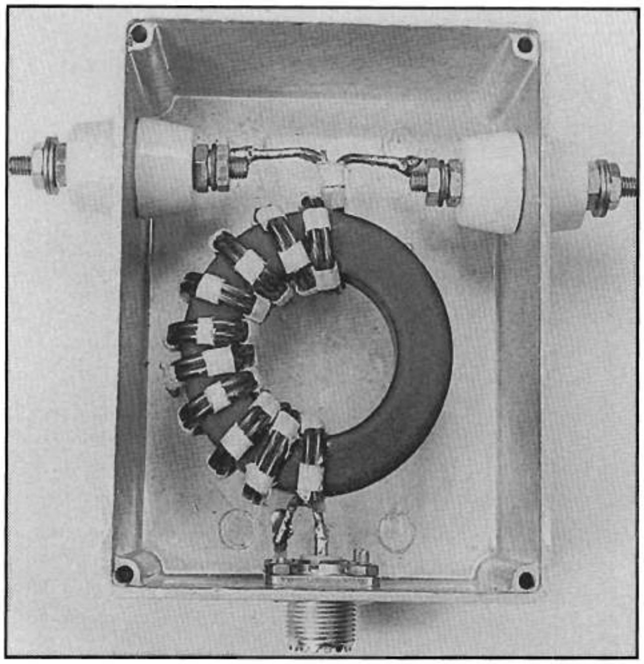

Photo 7-G. *My high-power design of a bifilar toroidal (Guanella/current) 1:1 Balun mounted in a 4 inch long by 3 inch wide by 2.25 inch high Bud aluminum box.*

high Bud CU 234 aluminum box. It has 10 bifilar turns of No. 12 H Thermaleze wire on a 2.4-inch OD ferrite toroid. As with the Reisert versions, a permeability of 250 is recommended for 1.8 to 30 MHz, 125 for 3.5 to 30 MHz, and 40 for 14 to 30 MHz. One wire is also covered with two layers of Scotch No. 92 polyimide tape in order to raise the characteristic impedance to 50 ohms. With this added insulation, the voltage breakdown of this twin-lead transmission line compares very favorably with RG-8/U cable (4000 volts). In order to preserve the spacing, the wires are also clamped together about every 1/2 inch with strips of Scotch No. 27 glass tape 3/16 inches wide and a little over 1 inch long.

Two "economy" versions of the high power bifilar toroidal Balun are shown in **Photo 7-H**. The one on the left shows the windings crowded on one-half of the toroid. The one on the right provides the same positions of the input and output connections by using the crossover. Their performances are identical. Both Baluns have 10 bifilar turns of No. 14 H Thermaleze wire on a 2.4-inch OD ferrite toroid. The choices of permeability, which trade off bandwidth for efficiency, are the same as those used in the two previous high power designs. The word "economy" here refers to economy in labor—this Balun is actually very easy to construct.

This "economy" Balun, which also handles the full legal limit of amateur radio power, has a small tradeoff in high frequency response. Because no extra insulation is used, the characteristic impedance of two tightly clamped No. 14 H Thermaleze wires is 45 ohms. With one layer of Scotch No. 92 tape, it increases to 50 ohms. But for most of the HF band, the difference in performance between Baluns using transmission lines of 45 and 50 ohms should be negligible. Even without the extra insulation, the voltage breakdown should compare very favorably with the smaller, high-power coaxes used in the Reisert versions (1900 volts).

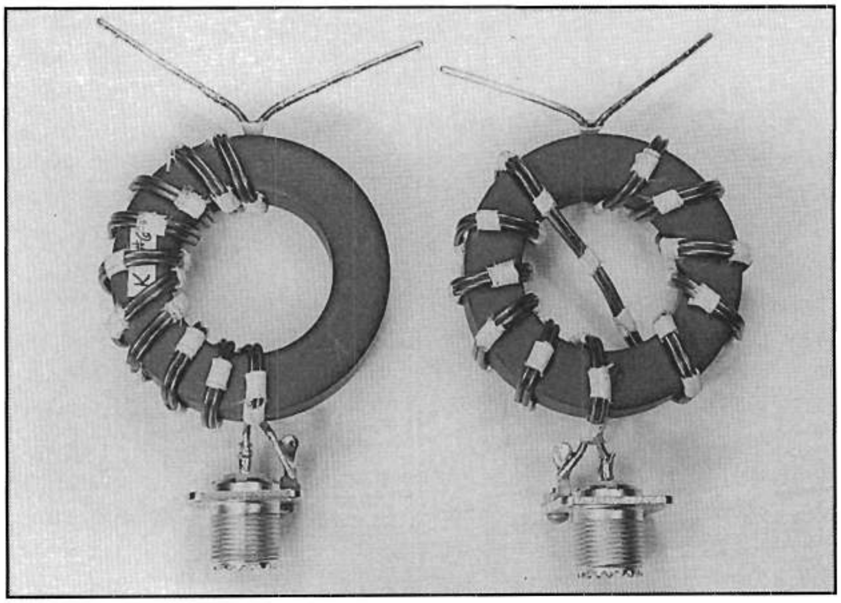

Photo 7-H. *Two "economy" versions of the high-power bifilar toroidal (Guanella/current) 1:1 Balun. The one on the right uses Reisert's crossover technique.*

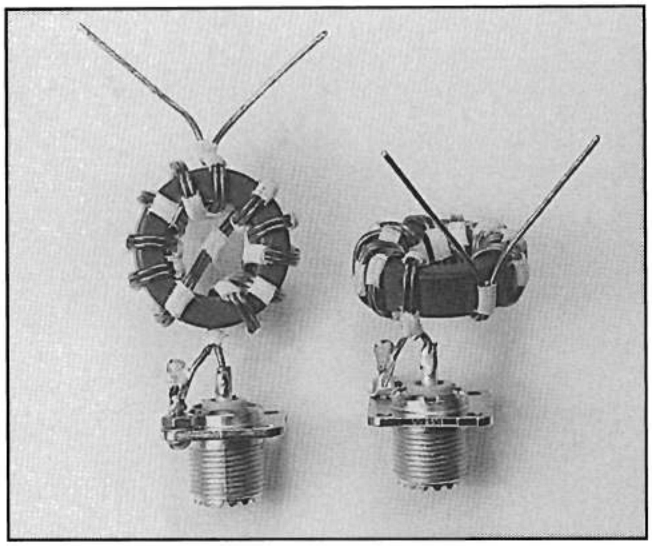

Photo 7-I. *Two low-power versions of the bifilar toroidal (Guanella/current) 1:1 Balun capable of handling the output of practically any HF transceiver. The Balun on the left has the crossover.*

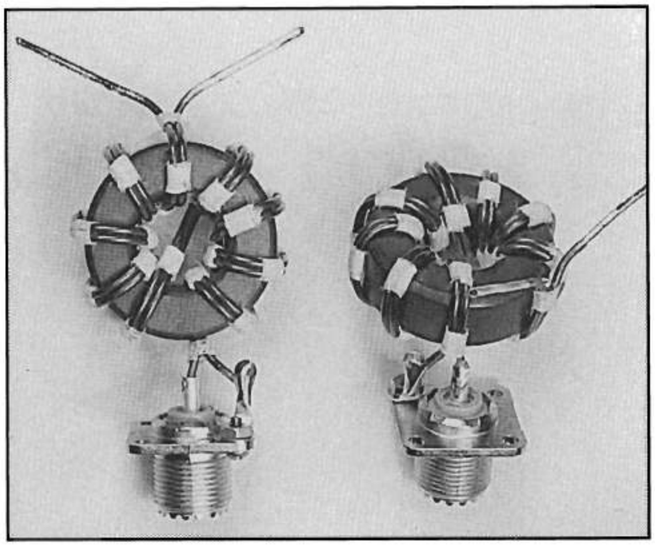

Photo 7-J. *Two medium-power versions of the bifilar toroidal (Guanella/current) 1:1 Balun capable of handling the full legal limit of amateur radio power when the VSWR is less than 2:1. The Balun on the left has the crossover.*

Photo 7-I shows two low-power versions of a bifilar toroidal Balun capable of handling the output of practically any HF transceiver. One has a crossover winding and the other, a continuous winding. They both have 10 bifilar turns of No. 16 H Thermaleze wire on a 1.25-inch OD ferrite toroid with a permeability of 250. Since efficiency is not a major problem in low-power use, I found no reason to suggest the other two versions, which use lower permeabilities. It is also interesting to note that two tightly clamped No. 16 H Thermaleze wires have a characteristic impedance close to 50 ohms. Therefore, this small Balun (particularly with its short leads) has a very good high frequency response.

Photo 7-J shows two medium-power versions of a bifilar toroidal Balun capable of handling the full legal limit of amateur radio power under controlled conditions—when the VSWR is less than 2:1. Being smaller than its larger (2.4-inch OD) counterpart, its heat-sinking capability and, hence, power rating is less. As before, one Balun uses a crossover while the other doesn't. Each has 8 bifilar turns of No. 14 H Thermaleze wire on a 1.5-inch OD ferrite toroid. The ferrite permeabilities and expected bandwidths are the same as the other high-power Baluns. Because the average magnetic path length in the core is about two-thirds that of the 2.4-inch core, only 8 bifilar turns are required in order to produce a similar low-frequency capability. Even though the characteristic impedances of their bifilar windings are 45 ohms, their responses on 10 meters should be somewhat better than the "economy" models because the lengths of their transmission lines are shorter (18 compared to 24 inches).

And now a few words on what sort of efficiency one can expect in trading-off low frequency response by using lower permeability ferrite cores. From earlier studies,[2] it was found that the efficiency (with sufficient choking, so only transmission line currents flow) is related to the permeability, the voltage drop along the length of the transmission line, and the frequency. The higher the permeability and/or voltage drop, the greater the loss. Additionally, the higher the permeability, the greater the loss with frequency. It was also found that a permeability of less than 300 was necessary in order to obtain the very high efficiencies of which these devices are capable.

Here are some efficiencies that might be expected from ferrites under matched conditions, based on the results of the studies:

1. With 250 material, an efficiency near 99 percent at 1.8 MHz and 97 percent at 30 MHz.
2. With 125 material, an efficiency near 99 percent at 3.5 MHz and 98 percent at 30 MHz.
3. With 40 material, an efficiency of 99 percent at 14 MHz and at 30 MHz.

When a Balun is exposed to a high impedance resulting in a VSWR of 2:1, the voltage, and hence loss, increases by about 40 percent. With a VSWR of

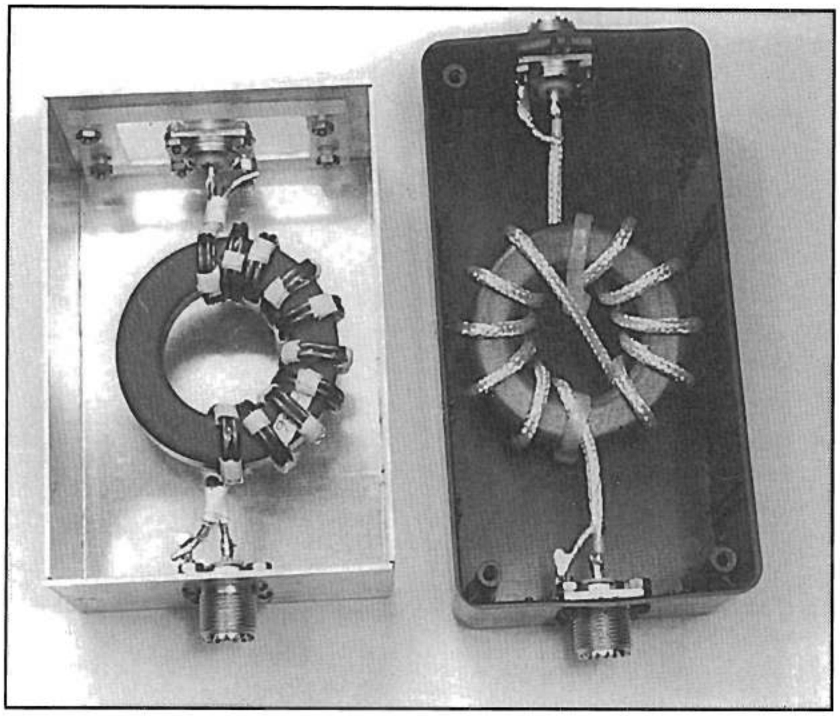

Photo 7-K. *Two examples of mounting the high-power 1:1 Guanella Balun in enclosures that allow isolation transformer operation.*

4:1, the loss doubles. With a VSWR of 10:1, the loss is more than three-fold. Since limited data was obtained in this study,[2] these increases in losses with increases in VSWR could very well be even greater.

Sec 7.5 Isolation Transformers

As was shown in the preceding sections, the 1:1 Guanella (current/choke) Balun is in reality a two-conductor RF choke, or an isolation transformer. However, practical Balun designs don't usually lend themselves to isolation use for mechanical reasons. They cannot be conveniently inserted into a coaxial cable system. Therefore, the objective is to mount the "Guanella Baluns" in enclosures that will allow them to perform as isolation transformers.

Photo 7-K shows two examples of enclosures that should accomplish the mission. The example on the left shows one of the high-power units mounted in a 5 inch long by 3.5 inch wide by 2.25 inch high aluminum enclosure. The output connector (on the top) is insulated by a 0.125-inch-thick piece of plastic. The one on the right shows another high-power unit mounted in a 6 inch long by 3 inch wide by 2 inch high plastic enclosure, which is available from Radio-Shack. The descriptions of the high-power units are given in the preceding section.

These isolation transformers can be used as Baluns when inserted in a coaxial cable one-half wavelength (physically) from a half-wave dipole[6] or between a coaxial cable and a balanced L-C tuner.[16] They should never be inserted in a coaxial cable system that presents a high impedance and, consequently, a high voltage. This could be harmful to the unit.

Note that the high-power unit on the left in **Photo 7-K** can also be used as a filament choke in a Class B linear amplifier. Its low-frequency response is much better than any rod-type, assuring 160-meter operation. Obviously, it would not be mounted in the aluminum enclosure shown in the photo. In addition, the two layers of Scotch No. 92 tape would not be required because the characteristic impedance of the winding is unimportant and the voltages involved are quite low.

By the way, the designs discussed above can be used as phase-inverters. Simply connect the hot lead on one side to the ground on the other side.

Sec 7.6 Summary

In investigating the 1:1 Balun, I was quite surprised to see the ferrite- and powdered-iron-core designs that have been available in the literature and off-the-shelf since 1964. They not only had poor low- and high-frequency responses, but they were also susceptible to flux in the cores at their low-frequency ends. Furthermore, since they only used single-coated wires, they were also prone to voltage breakdown. No doubt, these designs are responsible for the poor reputation that the Balun has had for many years.

It wasn't until 1978, when Reisert published his article, that a Balun which had all of the attributes of a good design became available. Namely:

a) It is efficient because it uses a low-permeability core.

b) It has sufficient choking reactance to meet its low-frequency requirement.

c) It is not prone to flux in the core (and, hence, saturation) because it has no third winding.

d) It has a 50-ohm characteristic impedance and maintains a 1:1 transformation ratio with a 50-ohm load.

e) It has a good voltage breakdown capability (1900 volts).

f) It can handle a mismatched and/or unbalanced load.

However, succeeding investigators failed to see the advantages of Reisert's design and proposed their own. Surprisingly, they belonged to two distinct groups. One group favored "air-core" Baluns and the other, "choke" (beaded-coax) Baluns.

The main argument given by the "air-core" followers was that their Balun would never experience problems with saturation, while the "ferrite-core" Balun would. However, the Reisert Balun is a current/choke type Balun that could only have flux in the core due to the imbalance (inverted L) current, which is much smaller than the transmission line currents. In fact, with any degree of choking reactance by the coiled transmission line, the imbalance current is essentially negligible. Therefore, saturation is not a concern with a Balun like Reisert's. In all fairness, it should be noted that it is a different story with the 4:1 current/choke and voltage Baluns. All three of these types of Baluns have a "magnetizing inductance" in their low-frequency models and hence a possibility of saturation with a poor design.

The advocates of the "choke" 1:1 Balun claim that their beaded-coax Balun can't saturate while the bifilar (current) toroidal Balun can. This is untrue; they are basically the same kind of structure, and neither has a third conductor which could allow a flux-causing current at the very low-frequency end. But of all of the attributes listed above for the Reisert Balun, the first one has the "choke" Balun at a disadvantage in the HF band. Because its transmission line is not coiled about a toroid, it does not have the multiplication factor of N^2 (due to mutual coupling), where N is the number of turns, while the toroidal Balun does. Therefore, higher-permeability beads are required in order to obtain sufficient choking reactance. This results in lower efficiency.

Finally, it should be pointed out that the 1:1 Balun using the small, but high-power, coaxial cable is capable of 5-kW operation in the HF band. Because of current crowding, the bifilar toroidal Balun, even with No. 12 wire, has shown excessive wire heating at this level. Therefore, No. 10 or No. 8 wire, with added layers of Scotch No. 92 tape in order to obtain a 50-ohm characteristic impedance, is recommended.

Chapter 8

The 4:1 Balun

Sec 8.1 Introduction

Chapter 7 in this book discussed the most popular of all Baluns—the 1:1 Balun designed to match 50 ohms unbalanced to 50 ohms balanced. It not only gave a review of the history, theory, and design of these broadband transformers, but also my viewpoint on published articles advocating later designs using coaxial cable wound around a toroid, threaded through ferrite beads, or just plain coiled in air (an air-core Balun). As was noted, I am in considerable disagreement with many of the claims advanced for these later 1:1 Baluns.

Chapter 8 deals with the next most popular Balun —the 4:1 Balun designed to match 50 ohms unbalanced to 200 ohms balanced. Baluns matching 50 ohms unbalanced to 12.5 ohms balanced are also included. It begins with a little information on the history and design of these Baluns, followed by high- and low-power designs and comparisons with other Baluns that have been on the market or in the amateur literature. Guanella's approach to the design of a 4:1 Balun is particularly noteworthy. It not only yields an excellent Balun design, but also an Unun (unbalanced-to-unbalanced transformer) with practically the same performance. His design could very well be called a *Balun/Unun*. As in the first chapter, this one also closes with a brief summary of the significant points.

Sec 8.2 A Little History and Design Information

There are really only two classic papers that have established the principles upon which the transmission line transformer (the Balun being a subset thereof) is based. The first one was written by Guanella in 1944. Guanella proposed the idea of coiling a transmission line to isolate the input from the output, resulting in the (now popular) *current* or *choke* Balun.[3] The second was by Ruthroff in 1959, whose analysis of these transmission line transformers is the present industry standard.[9] Ruthroff also introduced the Unun and the hybrid transformer.

Interestingly enough, both Guanella and Ruthroff had different approaches to their 1:1 and 4:1 Balun designs. Guanella used a two-conductor 1:1 Balun design, while Ruthroff used a three-conductor design. Ruthroff's third conductor (which was said to increase the low-frequency response over the two-conductor Balun[12]) lay on a separate part of a toroidal core. Investigators who followed failed to recognize this fact. Their comparisons were made with a three-conductor Balun that had the third wire in parallel with the other two, which then formed two coupled transmission lines. This gave rise to the term *voltage* Balun—an inferior design.[6]

However, the differences between Guanella's and Ruthroff's approaches to 4:1 Baluns were even more striking. Guanella connected coiled transmission lines in a parallel-series arrangement, so in-phase voltages were summed at the high impedance side. His Balun has been called a *current* Balun.[6] Ruthroff, on the other hand, obtained a 4:1 transformation ratio by summing a direct voltage with a delayed voltage that traversed a single transmission line in a phase-inverter connection (see **Chapter 7**). His Balun has been called a *voltage* Balun. The distinction between the operation of these two Baluns was also overlooked by practically everyone who followed.

This section reviews the two different approaches taken by Guanella and Ruthroff in obtaining 4:1 Baluns. Of particular importance are the descriptions of the potential drops along the lengths of the transmission lines when the loads are grounded at various points. These voltage drops are not only relevant to the ohmic losses in the Baluns, but also to their electrical performances. These descriptions were quite

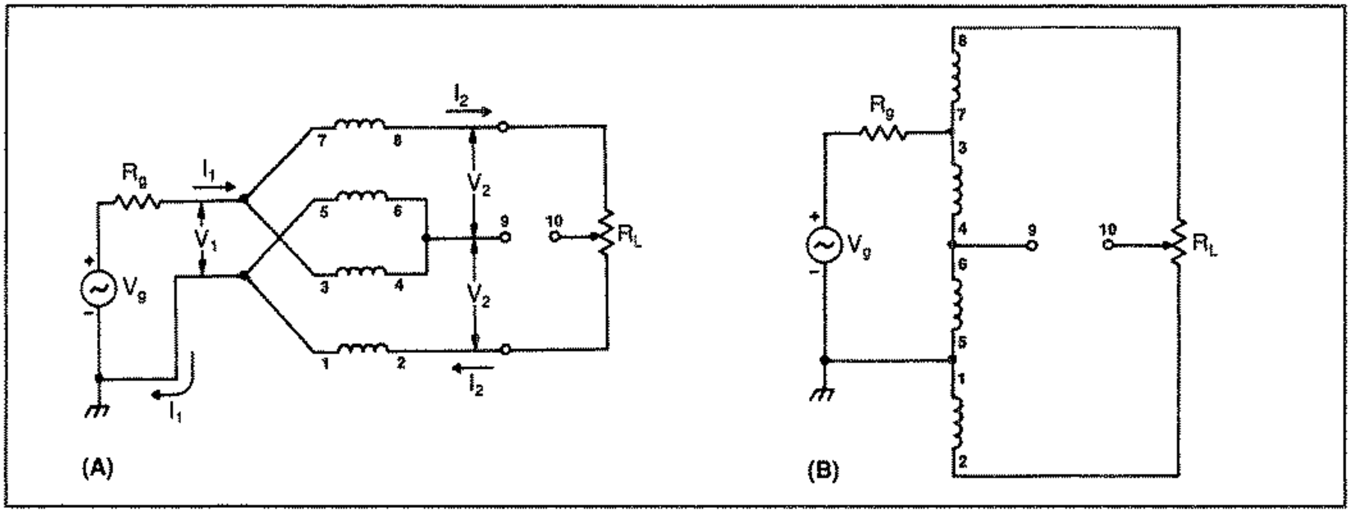

Figure 8-1. *Electrical models of the Guanella 4:1 Balun: (A) high-frequency, (B) low-frequency.*

possibly presented for the first time in the second edition of my book *Transmission Line Transformers.*[2]

Sec 8.2.1 Guanella's 4:1 Balun

Figures 8-1A and **B** show the high- and low-frequency models of Guanella's method of connecting transmission lines in parallel-series to obtain a 4:1 Balun. The high-frequency model (**Figure 8-1A**) assumes that the choking reactances of the coiled (or beaded) transmission lines are sufficient to isolate the input from the output, so only transmission line currents are allowed to flow. This occurs when the reactance of windings 3-4 and 5-6 (which are in series) is much greater than R_g (at least by a factor of ten.[2] If two cores are used, the reactance is the sum of the reactances of windings 3-4 and 5-6. If a single core is used, the reactance is twice as large because of the mutual coupling between the windings. The other advantage of Guanella's method (besides only using one core) is that shorter transmission lines can be used, resulting in better high-frequency performance.

As with all transmission line transformers, the objective is to have the transmission lines see loads equal to their characteristic impedances, resulting in "flat lines." This yields the highest frequency response. Because each transmission line in **Figure 8-1A** sees one half of the load, R_L, the optimum value of the characteristic impedance is $R_L/2$. Consequently, the input impedance, V_t/I_1, is simply the impedance of two identical transmission lines connected in parallel. It follows that the impedance transformation ratio is the load, R_L, divided by the input impedance.

Because the Guanella 4:1 Balun sums voltages of equal delays from identical transmission lines, his Balun is only limited in high-frequency performance by the deviation of the characteristic impedance of the transmission lines from the optimum values and the parasitics not absorbed into the characteristic impedance of the lines. I (and practically everyone else) had overlooked the simple and important statement, "a frequency independent transformation," which appeared in Guanella's 1944 article[3]—a fact that is evidenced by the scarcity of his designs in the literature. Another interesting aspect of the Guanella 4:1 Balun is the analysis of his Balun when the load is floating or grounded at different points. This leads to the determination of the voltage gradients that exist along the transmission lines and the various functions of which his 4:1 design is capable. Assuming a matched load or very short transmission lines resulting in $V_2 = V_1$, they are as follows.

Floating Load

With terminal 10 (which is at the center of R_L) floating, the potential gradient along the top transmission line in **Figure 8-1A** (windings 5-6 and 7-8) is $-1/2V_1$; along the bottom transmission line (winding 1-2 and 3-4) it's $-3/2V_t$. The voltage to ground on terminal 9, V_{90}, is $-1/2V_1$. Because the bottom transmission line (in **Figure 8-1A**) has a voltage drop along its length three times greater than the top transmission line, it results in three times more loss because losses in transmission line transformers are voltage dependent (dielectric-type losses).[2]

Even though a single-core Guanella 4:1 Balun maintains the voltages (stated above) when feeding a folded dipole (of about 200 ohms) which has a virtual-ground potential at terminal 10, it still feeds equal currents to each side of the antenna because of the series-connection at its output. Since the output voltages are not balanced to ground, a reactive component is probably introduced into the input impedance. Additionally, the choking reactance of the windings also prevents antenna currents from flowing on the outside of the coaxial cable feedline.

Load Grounded at Center

When two cores are used and terminal 10 (the center of R_L) is grounded, the voltage gradient along the top transmission line in **Figure 8-1A** is zero, and along the bottom transmission line it is $-V_1$. The voltage to ground on terminal 9 (V_{90}) is also zero. In fact, the core for the top transmission line isn't needed. It merely acts as a mechanical support for the top transmission line, which now only operates as a delay line. Also, all of the loss now occurs in the core of the bottom transmission line where a longitudinal potential gradient exists. Furthermore, the low-frequency response, as seen from **Figure 8-1B**, is now determined by the reactances of windings 1-2 and 3-4. This means that the low-frequency response with a floating load is better by a factor of two over the case where the load is grounded at its center.

But the single-core case is a different matter. Since the potential at terminal 9 (V_{90}) wants to be at $-1/2V_1$, connecting a ground directly to the center of R_L causes an imbalance that renders the single-core Balun unusable. If the ground were placed at a point 25 percent below terminal 8 (50 ohms from terminal 8 with a 200-ohm load), no difference would be noted from a floating load. This condition also exists when two cores are used.

Load Grounded at the Bottom

It is when the load is grounded at the bottom (at terminal 2), that we have what is probably the most interesting case. The 4:1 Balun (with two cores) is now converted into a very broadband Unun (unbalanced-to-unbalanced transformer). Because the bottom transmission line in **Figure 8-1A** has no potential drop along its length, it only acts as a delay line. The voltage to ground at terminal 9 (V_{90}) is $+V_1$, and the voltage gradient along the top transmission line is $+V_1$. This results in a voltage of $2V_1$ across the load. The low-frequency response is now determined by the reactances of windings 5-6 and 7-8. This is just the opposite of the Balun case when the center of the load was grounded. A single-core 4:1 Guanella Balun can also be converted to an Unun by putting a 1:1 Balun (for isolation) in series with the 4:1 Balun.[2]

There is a reason for claiming a very broadband response for a Guanella Unun (converted from his Balun)—the two in-phase voltages are now summed at the high-impedance side. The only other competition for a 4:1 Unun design is that of Ruthroff's,[9] where a direct voltage is summed with a delayed voltage that traversed a single transmission line (and, hence, had a built-in, high-frequency cut-off). In fact, very little information can be found in the literature on a *Guanella 4:1 Unun*.

Sec 8.2.2 Ruthroff's 4:1 Balun

Figures 8-2A and **B** show the high- and low-frequency models of Ruthroff's approach for a 4:1 Balun. The high-frequency model (**Figure 8-2A**) assumes that the

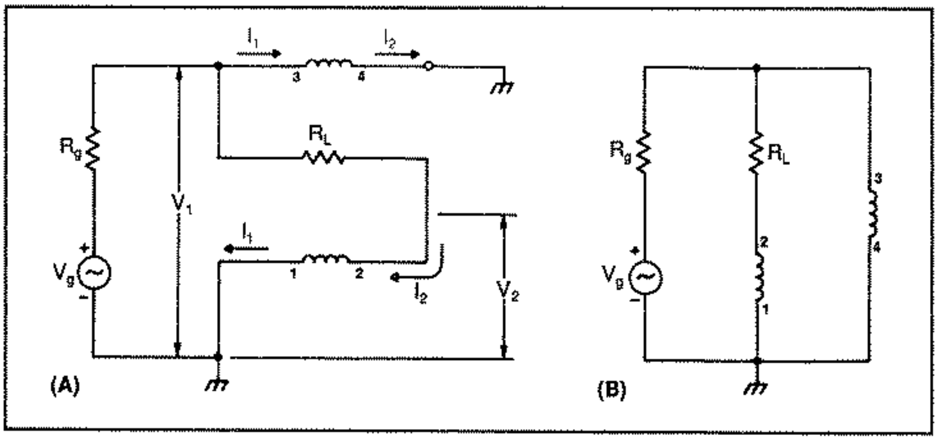

Figure 8-2. *Electrical models of the Ruthroff 4:1 Balun: (A) high-frequency, (B) low-frequency.*

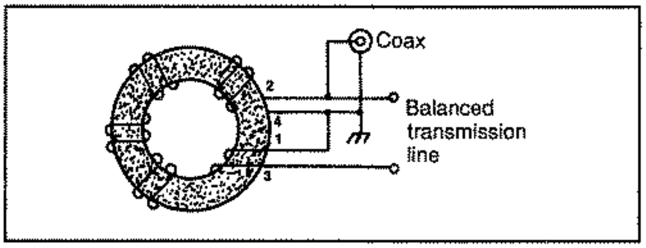

Figure 8-3. *A pictorial of the connections for a 4:1 Ruthroff (voltage) Balun.*

choking reactance of the coiled (or beaded) transmission line is sufficient to isolate the input from the output, so only transmission line currents are allowed to flow. This occurs when the reactance of winding 3-4 (or 1-2, because they are the same) is much greater than R_g (at least by a factor of ten^2).

As **Figure 8-2A** indicates, the transmission line is connected in a *phase-inverter* function (see **Chapter 7**). That is, a $-V_1$ voltage gradient now exists along the length of the transmission line. Therefore, the voltage across R_L now becomes $V_1 + V_2$. Although Ruthroff analyzed his 4:1 Unun in his classic paper,[9] his results also apply to his Balun with a floating load, because both devices sum a direct voltage with a delayed voltage. In essence, he used loop equations on the input and output and transmission line equations to eliminate one set of variables (I_2 and V_2). Ruthroff also used a maxima technique (setting a derivative to zero) to solve for the optimum characteristic impedance of the transmission line. As in the Guanella case, he found the optimum value to be $1/2R_L$.

An inspection of **Figure 8-2A** shows that the left side of R_L (terminal 3) has a direct voltage (V_1) to ground, and the right side (terminal 2) a delayed voltage ($-V_2$) to ground, which traveled the length of the transmission line. Also note, that if the line is electrically one-half wavelength long, the output is *zero.* As a result, Ruthroff's design (which has a built-in cut-off) is sensitive to the transmission line length.

I have recently unearthed another interesting aspect of Ruthroff's design.[2] If the center of the load is grounded, the high-frequency performance is vastly improved. The built-in high-frequency cut-off is eliminated and the Balun appears to take on the character of a Guanella Balun that sums voltages of equal delays. A closer inspection reveals that the input impedance now consists of two impedances in parallel: one consisting of $R_L/2$, and the other of a "flat line" terminated by $R_L/2$. As a result, the currents are not in phase!

Surprisingly, when matching into a folded dipole with an input impedance of 200 ohms, Ruthroff's Balun exhibits a high frequency response that is much greater than expected (see later sections). Because the folded dipole has a *virtual* ground at its center, the Balun could very well be summing voltages of equal phases.

Sec 8.2.3 Amateur Radio History and Design

Looking back at old issues of amateur radio handbooks (I don't have a complete set), I found that the first presentation on broadband 4:1 Baluns appeared in the 1955 edition of *The ARRL Handbook.* The section was called "Coil Baluns." The schematic diagram was that of Guanella's, shown in **Figure 8-1A**. What surprised me was that this section appeared to use many of the important words contained in Guanella's article.[3] It mentioned that the choking action of the coiled transmission lines should be great enough to isolate the input from the output at the lowest frequency of interest. It also included the requirement on the characteristic impedance of the coiled transmission lines; namely, that the characteristic impedance should be equal to $R_L/2$, where R_L is the load.

However, the section also included two other statements which are not correct in light of today's design practices. One recommended that the length of the winding in each coil be equal to about a quarter wavelength. The other stated that the principal application is in going from a 300-ohm balanced load to a 75-ohm coaxial line. With magnetic cores, the lengths of the windings are now considerably shorter than a quarter wavelength, and the applications include a host of different impedance levels.

Recent issues of the handbooks now include the 4:1 broadband *coil Balun* (along with the same write-up that appeared in the 1955 issue), and one with windings on ferrite cores. They are now called 4:1 air-core current Baluns and "just plain" 4:1 current Baluns (ferrite cores being assumed). Unfortunately, what is lacking in the description of the 4:1 current Balun is information on the importance of the characteristic impedance of the windings and the value of the permeability of the ferrite cores. The literature states that 8 to 10 turns (of No. 14 Formvar-coated, close-spaced—I guess) on a toroidal core or 10 to 15 turns on a rod are typical values for the HF range. Ferrites with permeabilities from 850 to 2500 are also suggested. Nothing is mentioned regarding the dimensions of the cores.

In essence, there's very little information available today in our handbooks that would help one understand and construct the "popular" *current* Balun. Even the choices of recommended ferrites to be used are found wanting. Accurate loss measurements[2] have shown ferrites with permeabilities of 850 to 2500 to be lossy in Balun and Unun applications. Only when the permeabilities of ferrites are 300 or less will Baluns and Ununs exhibit the very high efficiencies of which they are capable.

Even though the 4:1 *voltage* Balun has actually had a shorter history than the *current* Balun, considerably more construction detail (including an actual photograph) has been available in the amateur radio handbooks. As far as I can tell, the first presentation took place between 1965 and 1968. In looking through succeeding issues (including the 1993 issue), I find the write-up hasn't changed much (if any) over the years. The 4:1 Balun from the handbooks and a commercial rod-type are described and compared with my designs in the succeeding sections.

Sec 8.3 4:1 Ruthroff Balun Designs

As mentioned above, the schematic of Ruthroff's Balun is shown in **Figure 8-2A**. A pictorial representation is shown in **Figure 8-3**. **Photo 8-A** (on the left) shows my construction of a design close to the one shown in the handbook's photographs. It has 10 close-spaced, bifilar turns of No. 14 Formvar-coated wire on a 2.4-inch OD ferrite toroid with a permeability of 40. **Figure 8-4** shows a plot of the input impedance versus frequency when the 200-ohm load is center-tapped-to-ground (which is close to the actual case when matching into balanced antenna systems). As you can see, when compared to a design that has the proper characteristic impedance of the winding and sufficient choking, the response is very poor. Although this Balun has been rated at 1000 watts of RF power from 1.8 through 60 MHz, I would suggest it not be used below 6 MHz for fear of excessive flux in the core (especially when the magnitude of the load is greater than 200 ohms). Also, above 14 MHz, the transformation becomes considerably greater than 4:1.

My design, on the right in **Photo 8-A**, has 14 bifilar turns of No. 14 tinned copper wire on a 2.4-inch OD ferrite toroid with a permeability of 125 or 250. The wires are threaded through No. 13 Teflon tubing with a wall thickness of 20 mils. As you can see by its excellent high frequency response in **Figure 8-4**, the characteristic impedance of the bifilar winding must be very close to the ideal value of 100 ohms. **Photo 8-B** shows two different views of my design mounted in a 4 inch long by 3 inch wide by 2.25 inch high Bud CU 234 aluminum box. The Balun, which is placed equidistant between the top, bottom, and sides of the enclosure, is securely mounted by soldering its leads to the two feedthrough insulators and the SO-239 chassis connector.

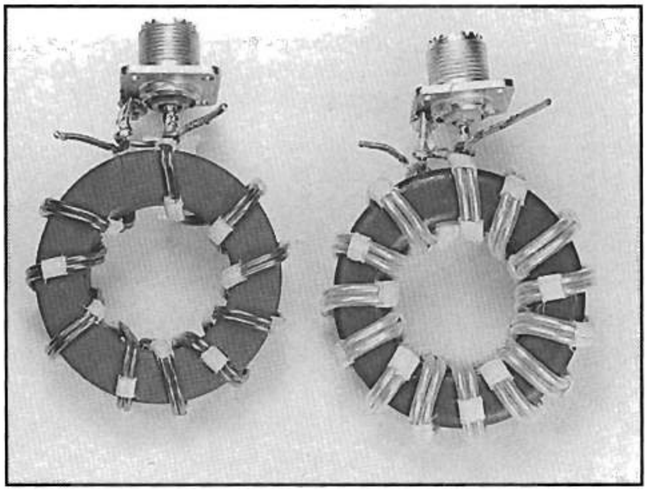

Photo 8-A. *Two designs of the 4:1 Ruthroff (voltage) Balun. The one on the left is taken from the amateur radio handbook. The one on the right is my improved version.*

It should be mentioned that if the Balun is to be used mainly on the lower portion of the HF band (including 160 meters), then the 250 permeability ferrite is recommended. Even though the difference in low frequency response between permeabilities of 125 and 250 doesn't show up in **Figure 8-4**, the 250 permeability would provide an extra safety margin (from flux in the core) at the low frequency end. The trade-off lies in giving up a little in efficiency (about 1 percent) for an increase in the safety margin (a factor of 2) at the low end.

Incidentally, the handbooks also state that the Balun can be used between a balanced 300-ohm point and a 75-ohm unbalanced line. Because I suspected this statement as well, I again measured the input impedances versus frequency of both Baluns when terminated in a 300-ohm center-tapped-to-ground load. **Figure 8-5** shows the deterioration that takes place, especially at the high end. Even a Balun that is well designed for a 50:200-ohm impedance level is not recommended

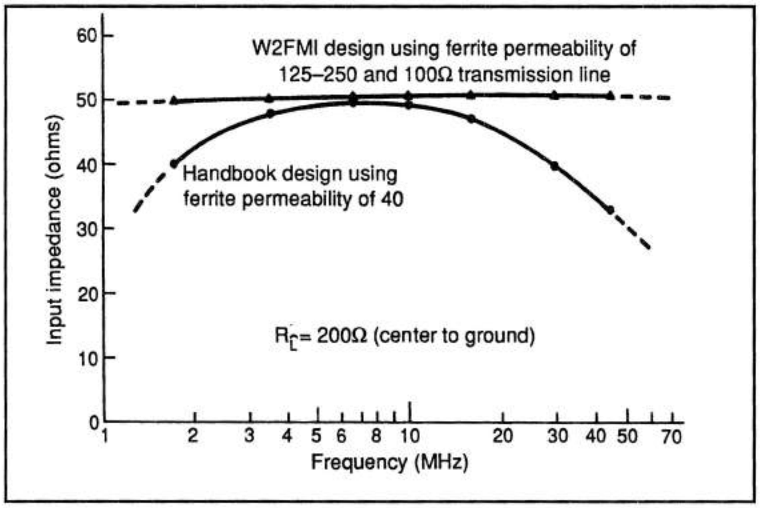

Figure 8-4. *The input impedance versus frequency for a 4:1 Ruthroff (voltage) Balun design from the amateur radio handbook and one optimized for the 50:200-ohm level. The load is grounded at its center.*

for the 75:300-ohm level. Because the length of the transmission line becomes significant beyond 10 MHz, standing waves then change the impedance ratio due to the mismatch with the Balun's transmission line. My design also shows more safety margin at the low end. I'm surprised that these simple measurements weren't made many years ago.

However, the Balun shown in the handbook does have one interesting feature. It uses a very low permeability ferrite (40), which has been shown by very accurate insertion loss measurements[2] to yield efficiencies in Baluns (and Ununs) of *99 percent* at the

Figure 8-5. *The input impedance versus frequency for the two Ruthroff Baluns of Figure 8-4, but with a 300-ohm load. Note the deterioration of the W2FMI design, which was optimized for the 50:200-ohm level.* ↓

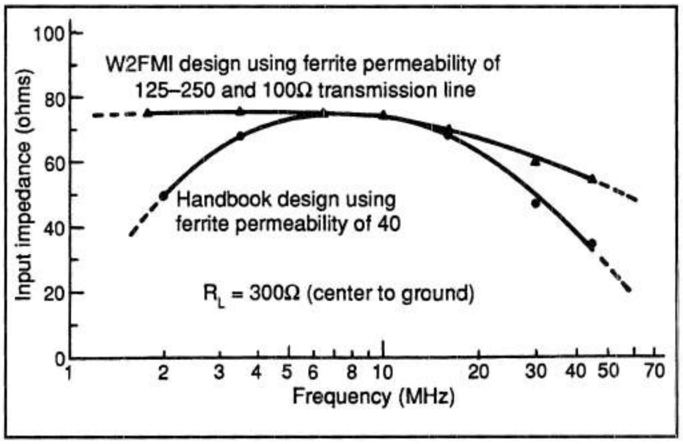

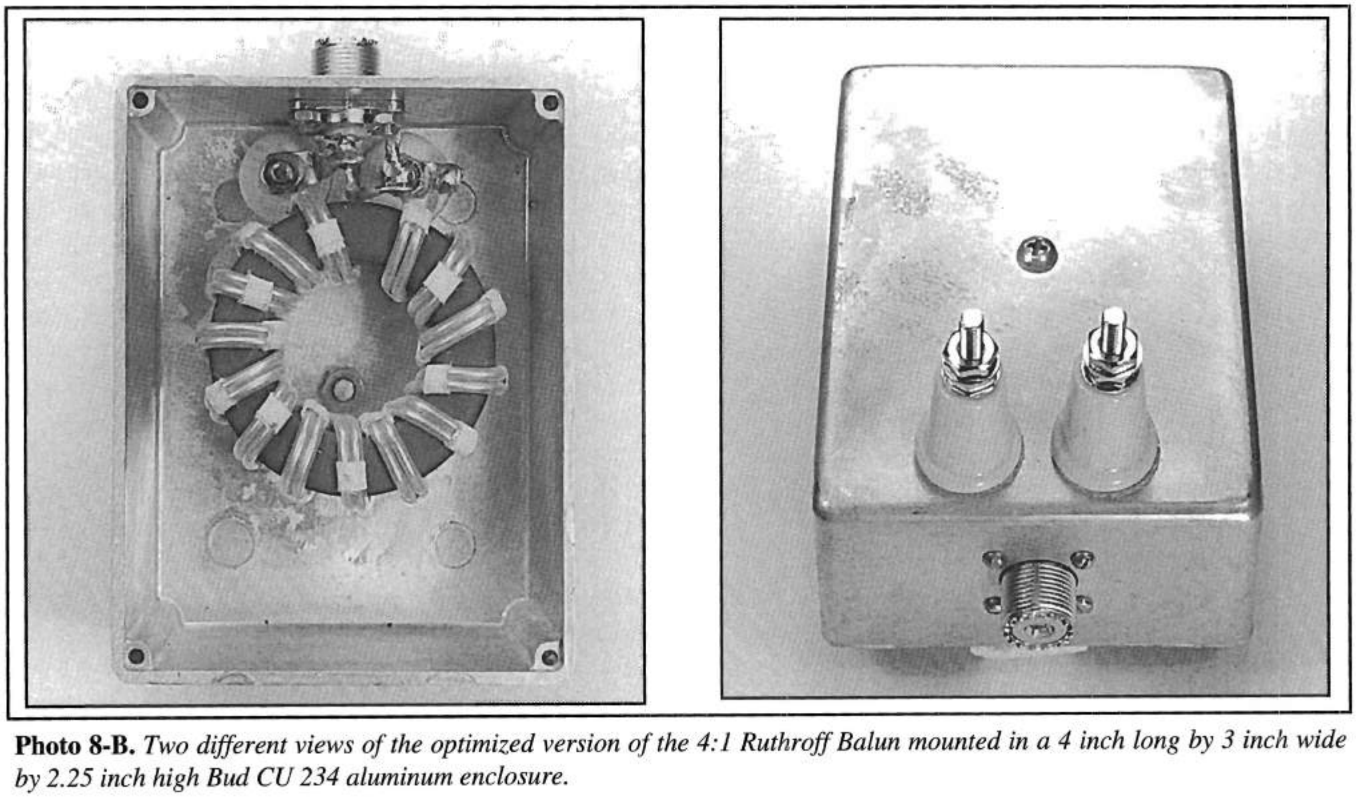

Photo 8-B. *Two different views of the optimized version of the 4:1 Ruthroff Balun mounted in a 4 inch long by 3 inch wide by 2.25 inch high Bud CU 234 aluminum enclosure.*

50:200-ohm impedance level! This is even a percent or two better than the ferrite with a permeability of 125. Because this ferrite permeability is so low, the major problem lies in obtaining sufficient choking reactance at the lowest frequency of interest, so that only transmission line currents are allowed to flow.

The design chosen (in order to exploit this very high efficiency) is shown **Photo 8-C**. It uses 14 bifilar turns of the same wire, as with my previous Balun shown on the right in **Photo 8A**, on two 2.4-inch OD cores (bound together with No. 27 glass tape) with permeabilities of 40. The unmounted view shows how the two cores are bound together by glass tape. The other views attempt to give an example for mounting the Balun. The Balun is supported by two acrylic end pieces which are, in turn, held fast to the enclosure by a long bolt. The Balun is placed equidistant between the top, bottom, and sides of a 5 inch long by 3.5 inch wide by 2.25 inch high aluminum enclosure. A few washers at the point where the bolt comes through the enclosure help to position the Balun between the top and bottom.

When matching 50 ohms (unbalanced) to 200 ohms (balanced), the response of this Balun is practically the same as mine, shown in **Figure 8-4** using a single core. From 1.7 to 30 MHz, it can certainly handle the full legal limit of amateur radio power with an efficiency close to 99 percent. However, if the operation of this Balun is restricted to the HF band only (that is, from 3 to 30 MHz), then it could be rated conservatively at 10 kW of peak power and 5 kW of average power. It would be an ideal Balun for a log-periodic beam antenna.

Finally, **Photo 8-D** shows three different views of a low power 4:1 Ruthroff (voltage) Balun designed to handle the output power of any HF transceiver easily. It has 10 bifilar turns of No. 18 hook-up wire on a 1.5-inch OD ferrite toroid with a permeability of 250. The enclosure is a 2.75 inch long by 2.125 inch wide by 1.625 inch high CU 3000-A minibox.

Section 8.4 4:1 Guanella Balun Designs

Photo 8-E shows two high-power Guanella 4:1 Baluns designed to match 50-ohm coaxial cable to loads of 200 ohms. They both use No.14 H Thermaleze wire with a covering of Teflon tubing giving characteristic impedances very close to 100 ohms (the objective). Their responses are flat from 1.5 MHz

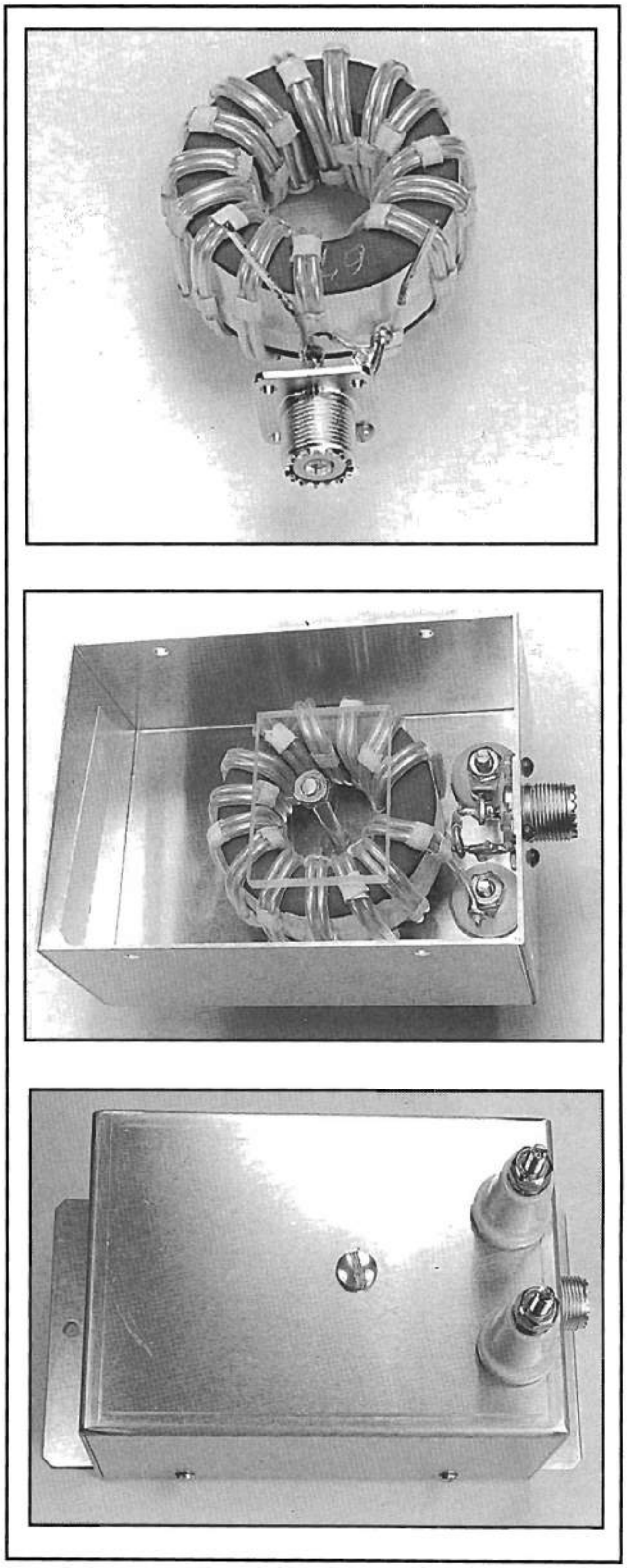

Photo 8-C. *Three views of the very high-power 4:1 Ruthroff Balun using two low-permeability (40) ferrite cores. Dimensions of the aluminum enclosure are: length, 5 inches; width, 3.5 inches; height, 2.25 inches.*

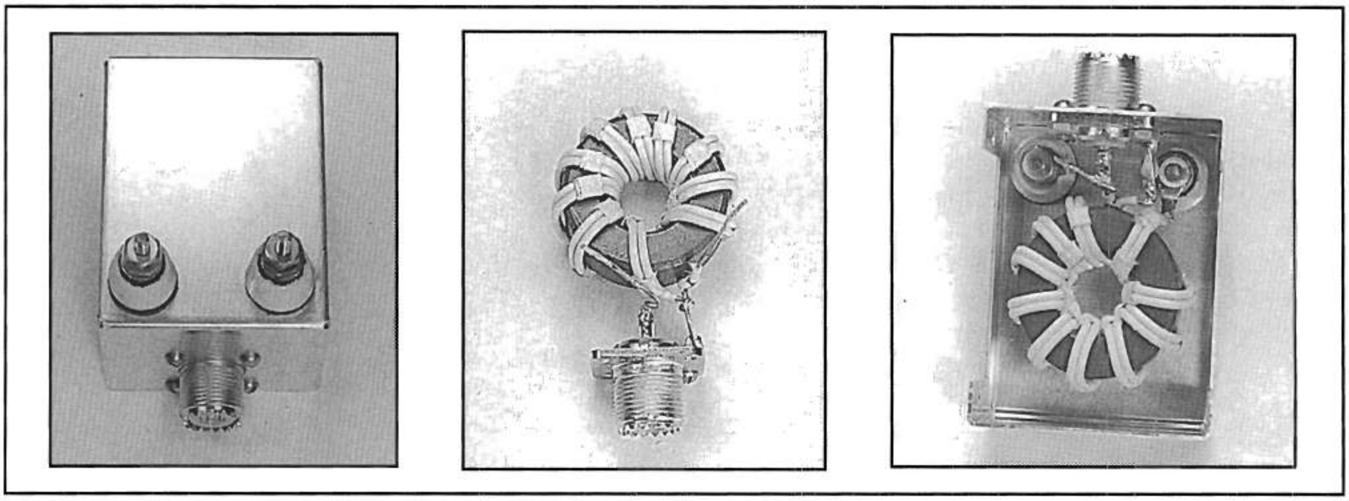

Photo 8-D. *Three views of the low-power 4:1 Ruthroff Balun designed to handle the output of any HF transceiver. The aluminum enclosure is a 2.75 inches high by 2.125 inches wide by 1.625 inches high CU 3000-A minibox.*

to well beyond 30 MHz. Both can easily handle the full legal limit of amateur radio power.

The single-core version (on the left) has 8 bifilar turns on each of its two transmission lines. The dual-core version (on the right) has 16 turns on each core. The wires are clamped together with strips of Scotch No. 27 glass tape placed about every 3/4 inch. The cores are 2.4-inch OD ferrite toroids with a permeability of 250. The connectors are on the low-impedance sides. For ease of connection, the dual-core version has one winding clockwise and the other, counterclockwise. Also, in the dual-core case, the spacing between the two cores (which isn't critical) can be as small as 1/4 inch.

These transformers can also be wound with ordinary No. 14 (solid) house wire. The several samples I tried yielded characteristic impedances close to 100 ohms (and, thus, were acceptable). The major difference lies in the voltage-breakdown capability. Units wound with Teflon-sleeved No. 14 H Thermaleze wire have been reported to withstand 10,000 volts without breakdown! Obviously, this is beyond the capability of ordinary house-wire.

Photo 8-F shows a Guanella (current) 4:1 Balun mounted in a 5 inch long by 4 inch wide by 3 inch high CU 3005-A minibox. It has 14 bifilar turns of No. 14 H Thermaleze wire on each of the two 2.4-inch OD ferrite toroids with permeabilities of 250. Each wire is covered with Teflon tubing, resulting in a characteristic impedance close to 100 ohms (the optimum). The windings also employ a crossover after the seventh turn, as shown in **Figure 8-6**. For ease of con-

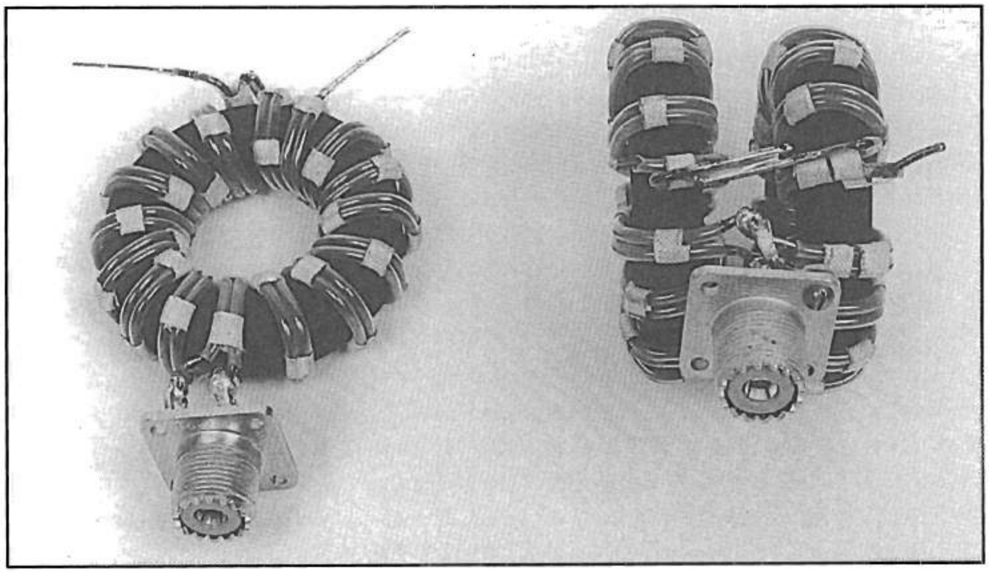

Photo 8-E. *Two high-power versions of the Guanella 4:1 Balun. The Balun on the left uses a single core while the one on the right uses two cores. The connectors are on the low-impedance sides.*

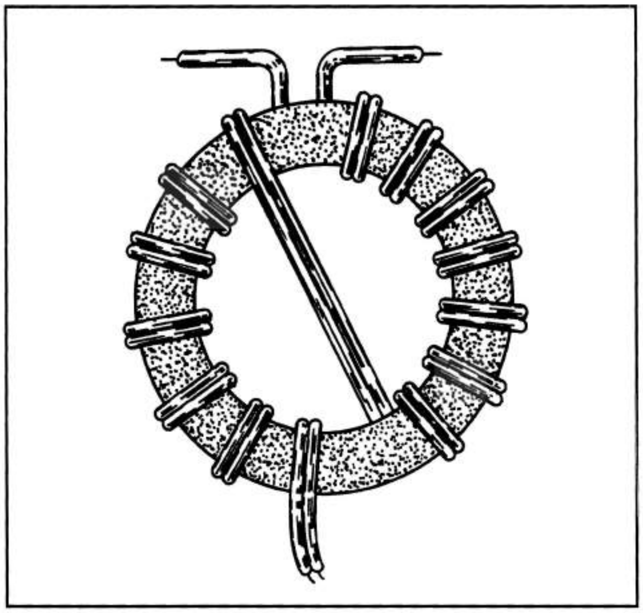

Figure 8-6. *Construction of a crossover placing input and output connections on opposite sides of the toroid.*

nection, one toroid is wound clockwise and the other, counterclockwise. The spacing between the toroids can be between 1/4 and 1/2 inch.

When matching 50-ohm cable to a balanced load of 200 ohms, the transformation ratio is constant (within 2 percent) from 1.5 to 45 MHz. This Balun can also handle the legal limit of amateur radio power. It would probably perform satisfactorily if wound with ordinary No. 14 house wire (solid), or with Teflon-covered No. 14 tinned wire. However, the design in **Photo 8-F** has withstood peak pulses of 10,000 volts! Considering this fact, it might be worthwhile to take the extra effort and use Teflon-covered No. 14 H Thermaleze wire.

A single-core version using two coiled transmission lines on a single core looks interesting and should be investigated. It results in balanced currents and unbalanced voltages. I would use two coiled transmission lines with 7 bifilar turns of the same wire on the same core as above.

Photo 8-G shows two low-power Guanella 4:1 Baluns designed to match 50-ohm coaxial cable to loads of 200 ohms. They both use No. 20 hook-up wire (solid) giving a characteristic impedance very close to the objective of 100 ohms. Their responses are flat from 1.5 MHz to well beyond 50 MHz. They are conservatively rated at 150 watts of continuous power and 300 watts of peak power. They have been exposed to 500 watts of continuous power (in a matched condition) for a considerable length of time with virtually no rise in temperature.

The single-core version (on the left) has 7 bifilar turns on each of its two transmission lines, while the dual-core version (on the right) has 14 turns on each core. The wires are clamped together about every 1/2 inch with strips of Scotch No. 27 glass tape. The cores are 1.25-inch OD ferrite toroids with a permeability of 250. The connectors are on the low-impedance sides. As above, the dual-core version has one winding clockwise and the other, counterclockwise.

Photo 8-H is a step-down version of the Guanella 4:1 Balun and uses two ferrite rod-cores 3/8 inch in diameter and 3.5 inches in length. Core permeabilities are 125. It uses the schematic of **Figure 8-1A,** but with the generator (which is grounded) on the right side and the load (ungrounded) on the left side. This 4:1 Balun is designed to match 50-ohm coaxial cable (on the right side) to a balanced load of 12.5 ohms. Each rod has 13.5 bifilar turns of No. 14 H Thermaleze wire. Again, for ease of connection, one rod is wound clockwise and the other, counterclockwise. The response is flat from 1.5 MHz to well over 30 MHz. This Balun is fully capable of handling the legal limit of amateur radio power. The connector is on the high-impedance (50 ohms) side. Beaded versions of Guanella's step-down 4:1 Balun also look very promising for operations on the VHF and UHF bands. The technique requires minimizing the parasitics in the interconnections. Some examples will be shown later.

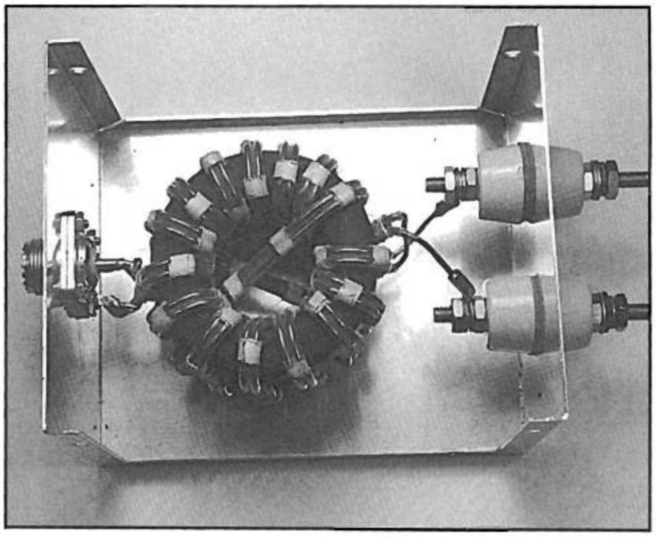

Photo 8-F. *A 4:1 Guanella Balun using the crossover connection of Figure 8-6 and mounted in a 5 inch long by 4 inch wide by 3 inch high CU 3005-A minibox.*

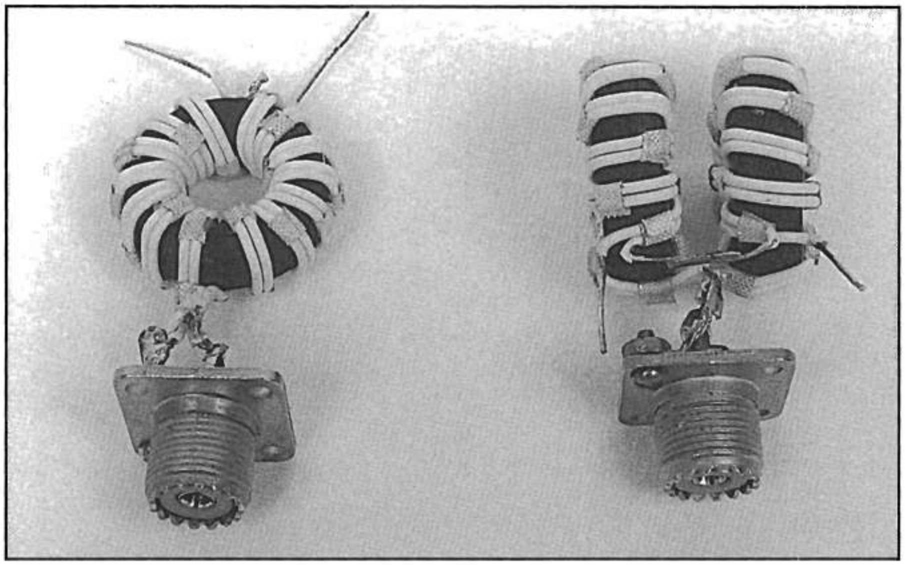

Photo 8-G. *Two low-power versions of the Guanella 4:1 Balun. The Balun on the left uses a single core while the one on the right uses two cores. The connectors are on the low-impedance sides.*

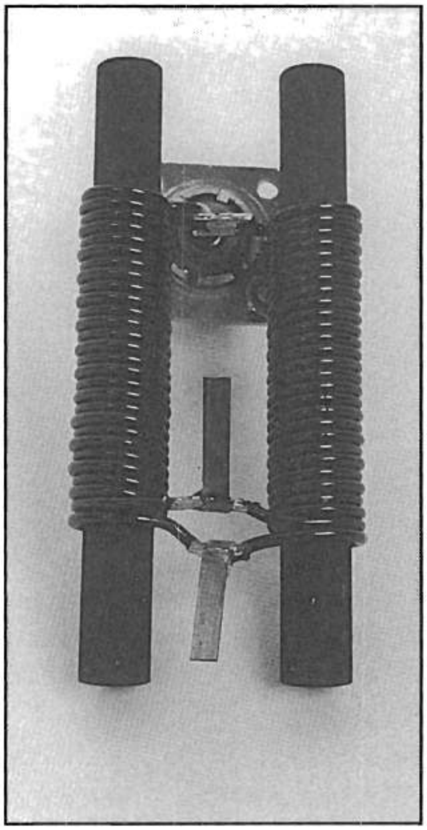

Photo 8-H. *A dual rod-core 4:1 Guanella step-down Balun designed to match 50-ohm cable to a balanced load of 12.5 ohms. The connector is on the 50-ohm unbalanced side.* ⟶

It should be mentioned again that the three dual-core Baluns above also make excellent broadband Ununs. They only sacrifice a little in low-frequency response. However, because of their conservative designs, they can still handle the 160-meter band.

Sec 8.5 Comparisons with Other Baluns

After completing the study on 4:1 Baluns, I thought it would be interesting to characterize other Baluns that are commercially available, or that have been recently described in the amateur radio literature. My findings are as follows.

The 4:1 Rod-type Ruthroff Balun

Photo 8-I shows a photograph of the typical rod-type 4:1 Balun, which was practically the only one available for the past three to four decades. The Balun in the photograph is the **HI-Q Balun.** It is the Ruthroff design (now called a *voltage* Balun[6]) with 10 bifilar turns of No. 14 wire on a 1/2-inch diameter ferrite rod 2 inches in length. In terminating this Balun with 200 ohms, the useful range was found to be from 7 to 15 MHz. Below 7 MHz, the input impedance showed a considerable inductive component—indicating autotransformer action and flux in the core (which could be harmful). Above 15 MHz, the transformation ratio increased and became complex. The optimum impedance level was found when matching 100 ohms to 25 ohms (indicating a characteristic impedance of the windings of only 50 ohms). The useful frequency range at this impedance level increased to 3.5 MHz to 30 MHz.

When matching 50-ohm coaxial cable to a 20-meter folded dipole at a height of 0.17 wavelengths (resulting in a resonant input impedance of 200 ohms), the VSWR curve was indistinguishable from that of the best Guanella 4:1 (current) Baluns.[6] This Balun also presented no difficulty in handling the full power limit. However, on 10 meters, the difference due to a very low characteristic impedance of the coiled transmission line became evident. **Figure 8-7** shows the poor VSWR curve of the rod-type Balun when compared to other Guanella and Ruthroff Baluns with characteristic impedances close to the optimum value of 100 ohms. The rod-type Balun with all of its inadequacies, which include voltage-breakdown, is certainly *not* recommended.

The high-power Ruthroff Balun is close to McCoy's design.[17] It uses 11 bifilar turns of No. 14 H Thermaleze wire on a stack of three T200-2 cores. The wires

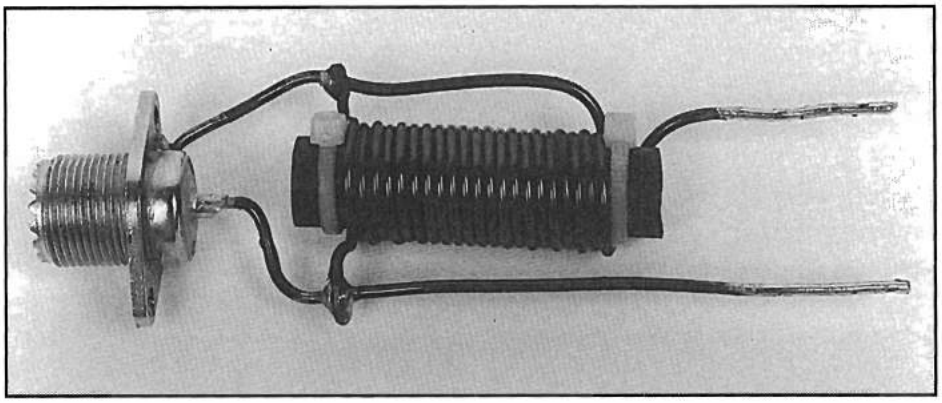

Photo 8-I. *A typical 4:1 rod-type Ruthroff (voltage) Balun (HI-Q).*

are also covered with 20-mil wall Teflon tubing yielding a characteristic impedance close to 100 ohms. I differ with McCoy's design because I feel the characteristic impedance of his transmission line could be closer to 50 ohms. His Balun and others that use powdered-iron cores will be described further in the next chapter on Baluns for antenna tuners.

The low-power units in **Figure 8-7** used 14 bifilar turns of No. 18 hook-up wire on 1.25-inch OD ferrite toroids with a permeability of 250. The transmission lines of the low-power Baluns were just under 20 inches, while those of the high-power Balun were 50 inches in length.

As can be seen in **Figure 8-7**, there are **very** small differences between the VSWR curves of the two low-power Baluns and the high-power Ruthroff (voltage) Balun. The differences could very well be attributed to the small variations in the characteristic impedances of the windings. Very likely, the most important information gleaned from **Figure 8-7** is that, when feeding a balanced dipole with a virtual ground-plain bisecting it, the Ruthroff Balun takes on the character of a two-core Guanella Balun. In other words, the Ruthroff Balun loses its built-in high-frequency cut-off!

4:1 Current Baluns

I also characterized several so-called *current* Baluns^6 that recently appeared on the market. These are my findings:

a) They are the dual-core (toroids) version of the Guanella Balun, which sums voltages of equal delays.

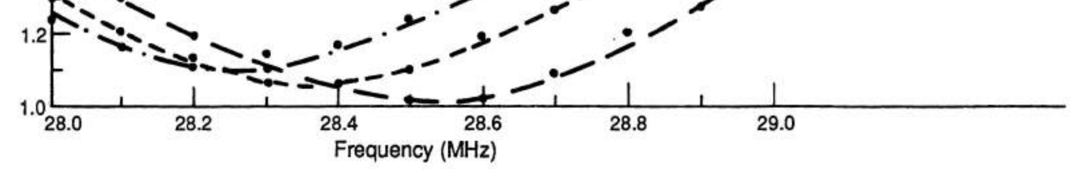

Figure 8-7. *Plots of VSWR curves on 10 meters for four different 4:1 Baluns. The high-power Ruthroff Balun is actually McCoy's design with a 100-ohm characteristic impedance winding (and is described in the next chapter). The Hi-Q Balun is shown in Photo 8-I. The comparisons show the importance of having the optimum value of the characteristic impedance of the windings and that the high-power Balun with its much longer transmission line indicates a Guanella-type operation.*

b) The electrical performances of these Baluns are vastly superior to the rod-type Balun described earlier.

c) These Baluns should meet their electrical and power-rating specifications.

d) My only criticism is that they could have more of a safety margin at the low-frequency end, where excessive core flux (due to higher than expected impedances) could take place. More inductance in the windings is recommended.

The Beaded-coax 4:1 Balun

A design in an amateur radio journal[5] advocated using beaded coaxial cable (of 100 ohms) in a 4:1 Guanella design. Various claims were advanced for this approach. I constructed one of these Baluns using No.14 wire with Teflon sleeving, resulting in the required 100-ohm characteristic impedance. Here are my findings:

a) The Balun had excellent margins at both the high- and low-frequency ends. The performance of this Balun verified the analysis (expressed earlier) with the high- and low-frequency models and the subsequent voltage gradients. In fact, the high-frequency performance exceeded the capability of my simple test equipment.[2]

b) The major disadvantage is in efficiency. Because high-permeability (2500) beads are required in order to obtain the required choking reactance in the HF band, this Balun had considerably more loss than coiled-type Baluns using low-permeability (less than 300) ferrite toroids.[2] A soak-test[2] (transformers connected back-to-back and about 500 watts applied into a dummy load) with the dual-core low-power unit in **Photo 8-G** showed that the smaller Balun ran considerably cooler! The beaded transmission line technique is recommended mainly for Baluns (and Ununs) operating at low impedance levels or on the higher-frequency bands.

Sec 8.6 Summary

Unlike the 1:1 Balun, the 4:1 Balun matching 50 ohms unbalanced to 200 ohms balanced has had no real standard for comparison in the amateur radio literature. As **Chapter 7** showed, Reisert's Balun in his 1978 article[7] had all of the attributes of a good 1:1 design. Therefore, he set a legitimate standard for others to follow or even attempt to exceed. Also shown were some of my variations in his design for increased efficiency and ease of construction.

However, **Chapter 8** has illustrated that the designs in the amateur literature (particularly the handbooks) are found lacking in bandwidth, or efficiency, or both. Even the 4:1 Baluns on the commercial market can be improved. This is *especially* true of the rod-type Balun that has been available for decades!

In the process of investigating the 4:1 Balun for my series of articles in *CQ* and *Communications Quarterly*, I have arrived at some designs that could provide the beginnings of standards for this device. They are included in this chapter and are:

1. For *balanced* applications like matching 50-ohm cable to the 200-ohm balanced input impedance of folded-dipole or log-periodic antennas, I recommend the single-core, Ruthroff design of **Photo 8-A**. It is capable of handling the full legal limit of amateur radio power. For a higher-power capability and a little less bandwidth, I recommend the Ruthroff design shown in **Photo 8-C**. These designs are presently called *voltage* Baluns.[6]

2. For unbalanced applications like the OCFD (off-center-fed dipole), or a dipole that could be unbalanced by surrounding structures or by construction errors, I recommend the two-core Guanella design of **Photo 8-E** or **Photo 8-F**. It is a much more flexible unit that can operate successfully as a Balun when the load is grounded at its center (**Figure 8-1A**), or as an Unun when the load is grounded at the bottom. Although not shown, it can even be grounded at the top, yielding a 4:1 phase-inverter.

3. For low-power 4:1 Baluns, there really have been no designs in the literature for comparisons. Therefore, by default, the designs in this chapter are suggested as standards. Applications of the single-core Ruthroff Balun and the two-core Guanella Balun are the same as their higher-power counterparts.

I am sure there are some who don't agree with the recommendations proposed above. The Guanella (current) Balun appears to be the main Balun of choice. The question is: Why use a two-core Guanella (current) Balun when a single-core Ruthroff (voltage) Balun will do? They both have the same power ratings! For those who disagree with my views, designs, or recommendations, I encourage them to (as the classic TV commercial used to say) *put it in writing*. Then we will all benefit from the new information.

Chapter 9

Baluns for Antenna Tuners

Sec 9.1 Introduction

The 4:1 Balun, matching 50 ohms (unbalanced) to 200 ohms (balanced), has found its most popular use in antenna tuners. Because the Balun rarely sees a resistive load of 200 ohms in this application, the primary objective is to take the balanced impedance (with respect to ground) of the input to an open-wire (or twin-lead) feedline and transform it into an unbalanced impedance which has one side grounded and can be transformed into 50 ohms by an L-C matching network. This was well described in two *CQ* articles by McCoy.[17,18]

As **Chapter 8** has shown, there are two different forms of the 4:1 Balun. One uses two transmission lines wound on separate cores (or threaded through ferrite beads in some cases) and connected in parallel at the 50-ohm side and in series at the 200-ohm side. This design was first presented by Guanella in 1944,[3] and is presently called a *current* Balun.[6] The other design, using a single transmission line wound around a core and connected in a phase-inverter configuration, was introduced by Ruthroff in 1959.[9] This design, which has recently been called a *voltage* Balun,[6] is now perceived as the inferior design.

This chapter presents another view of the 4:1 Balun. It not only includes the optimum design considerations for antenna tuner use, but also the design parameters for multiband antenna systems using center-fed dipoles with open-wire or twin-lead feedlines. Also included are my views on the G5RV antenna, the tuner using a 1:1 Balun before the L-C matching network, and the special cases of Ruthroff's 4:1 design matching into a load that is actually or virtually grounded at its center.

Sec 9.2 The Two Forms of Antenna Tuners

Three of the more common items in amateur radio jargon are VSWR, antenna tuners, and multiband antennas (especially the G5RV). These have appeared upon the scene because of the ease at which bands can now be changed and the narrow limits in the range of matching impedances with modern rigs.

The concept of using a wire antenna on many different bands isn't new. Designs have been around for more than six decades. In fact, satisfactory circuits have also been available which couple transmitters to balanced lines that present loads different than the transmitter output impedance. These were known as series and parallel-tuned circuits.[19] The transforming of a balanced impedance to an unbalanced impedance was accomplished by the isolation provided by magnetic coupling. Energy was transmitted from one circuit to the other by either having two coils in close proximity or by "link" coupling. However, these methods of coupling have fallen by the wayside, together with rock-bound rigs, plug-in coils, separate

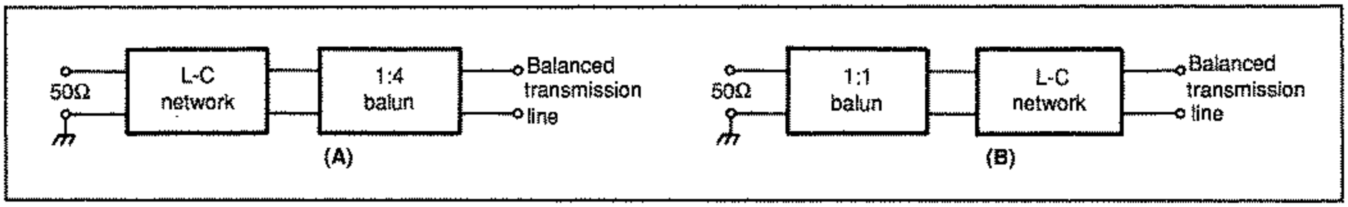

Figure 9-1. *The two basic forms of the Transmatch (antenna tuner): (A) the more popular design using an unbalanced L-C network and a 1:4 Balun; (B) a 1:1 Balun and a balanced L-C network.*

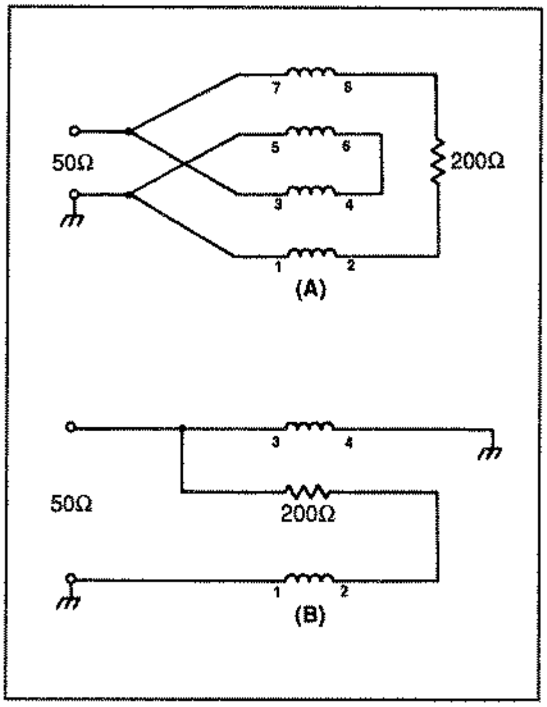

Figure 9-2. *The two basic forms of the 1:4 Balun: (A) the Guanella (current) Balun; (B) the Ruthroff (voltage) Balun.*

Figure 9-3. *The frequency response of a 4:1 Ruthroff (voltage) Balun with the load floating and with its center grounded. In the grounded case, the high-frequency response is similar to that of a 4:1 Guanella (current) Balun.*

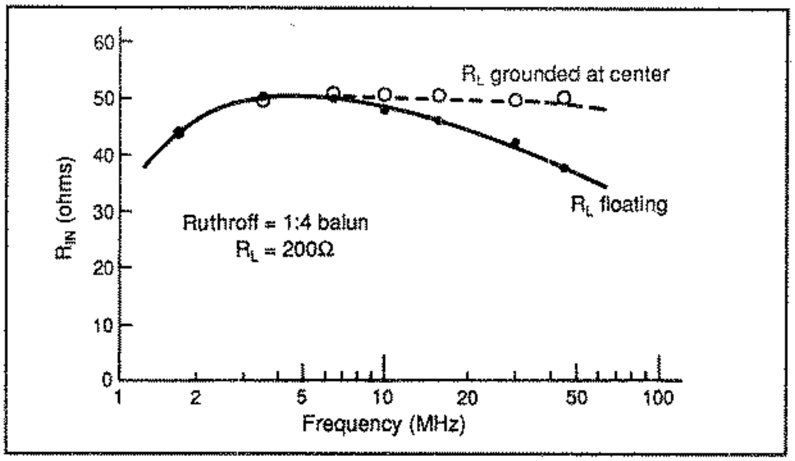

receivers and transmitters, and (sad to say) the exciting flashing of mercury-vapor rectifiers.

Today, the *transmatch* is most often used to convert the reactive/resistive load presented by an antenna system to a nonreactive, grounded 50-ohm load. The transmatch is also commonly known as an antenna tuner. The isolation role, that of converting a balanced impedance to an unbalanced one, is now provided by the Balun transformer.

There are two basic forms of the transmatch, and they are shown in **Figure 9-1**. **Figure 9-1A**, which shows a 4:1 Balun between the L-C network and the balanced transmission line, has been the most popular. In some designs, a 1:1 Balun has been used. In either case, this form of antenna tuner places the burden on the Balun, not on the L-C network. Depending upon the dimensions of the antenna and open-wire (or twin-lead) transmission line, the Balun can see very high impedances that may be harmful. In turn, the L-C networks are simple because of their unbalanced nature. Among the most popular networks are L, pi, T, Ultimate, and SPC types.[20–23] An added advantage to this approach is that the Balun can be placed outside the operating area and connected to the L-C network by a coaxial cable.[17,18]

On the other hand, **Figure 9-1B** takes the complexity out of the Balun and places it on the L-C network. With a balanced network, the 1:1 Balun should see a lower voltage drop along the length of its transmission line (and, hence, less loss[2]) because its load is always close to 50 ohms. Additionally, the choking requirements of a 1:1 Balun are considerably less than that of the 4:1 Balun in **Figure 9-1A**.

Roehm has addressed the problems related to this form of transmatch in an article.[16] In fact, he suggests a design using an unbalanced T network and a 1:1 beaded-coax Balun. Although a balanced L-C network is inherently more complex and costly, it would be interesting to see its comparison with Roehm's unbalanced design. Additionally, a comparison with a 1:1 Balun using 50-ohm twin-lead or coaxial cable wound around a ferrite toroid with a permeability of less than 300 would also be useful. Because the 1:1 beaded-coax (choke-type) Balun requires ferrite beads with permeabilities considerably greater than 300, it has more loss.[2]

In any event, the basic form of the transmatch using the design in **Figure 9-1B** looks promising and merits further investigation.

Sec 9.3 Another View of the 4:1 Balun

This section presents my views and the results of my work on a 4:1 Balun designed for use in the very popular "antenna tuner" shown in **Figure 9-1A**. Because the Balun may be exposed to harmful high voltage conditions in this application, the efficiency and

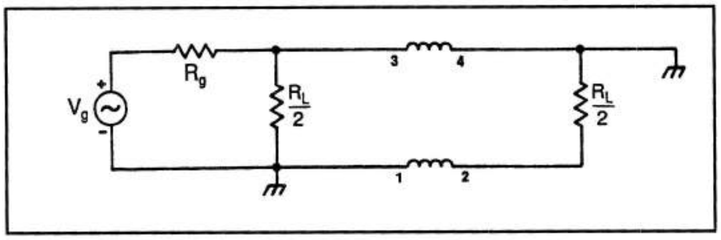

Figure 9-4. *Suggested model of the 4:1 Ruthroff (voltage) Balun when the load, R_L, is grounded at its center.*

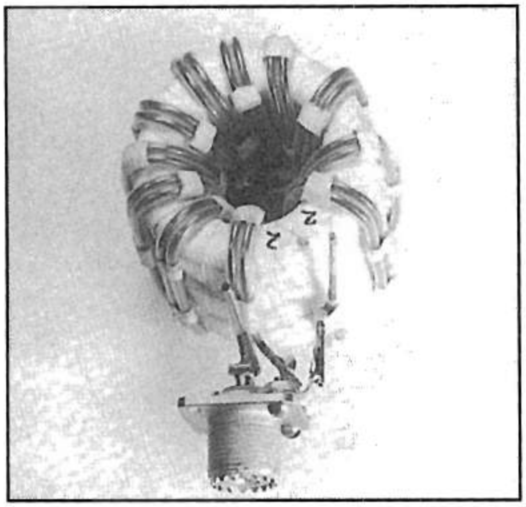

Photo 9-A. *The high-power Ruthroff 4:1 Balun used in the comparison with other Baluns (see Figure 9-7, and Figure 8-7 of Chapter 8). Except for some difference in the characteristic impedance of the bifilar winding, it is essentially the McCoy 4:1 Balun.*

ruggedness of the core materials are important considerations. Experiments have shown that losses in Baluns are related to the impedance level[2] (and, hence, voltage level), and the permeability of the materials. Therefore, the losses are of a dielectric-type and not of a current-type, as in conventional transformers. Moreover, it is well known that powdered-iron is a more rugged and linear material than ferrite. A very important question to ask is which form of the 4:1 Balun should be used in this application—Guanella's or Ruthroff's? My conclusions may surprise many readers.

As was mentioned at the beginning of this chapter and above, there are two basic forms of the 4:1 Balun. They are shown in **Figure 9-2A** and **B**. **Figure 9-2A** is Guanella's approach. It uses two coiled transmission lines (on separate cores) connected in parallel on the 50-ohm side and in series on the 200-ohm side. This has recently been called a *current* Balun.[6] In order to have "flat" transmission lines and obtain the highest frequency response, the characteristic impedance of the coiled transmission lines should be equal to the loads they see—namely, $1/2R_L$ and, in this case, 100 ohms.

As Guanella said in his classic paper,[3] this Balun is literally "frequency independent." At the low frequency end, the reactance of the coiled transmission line should be much greater than 100 ohms (in this case) in order to assure that the energy is transmitted from input to output by an efficient transmission line mode. Beaded transmission lines aren't recommended for use on the HF band at these impedance levels because of excessive dielectric loss.

Figure 9-2B shows Ruthroff's approach, which uses a single transmission line connected in the phase-inverter configuration (see **Chapter 7**). By grounding terminal 4, a voltage drop of $-V_1$ appears across the length of the transmission line. As a result, terminal 3 is at $+V_1$ and terminal 2 is at $-V_1$—a 4:1 transformation ratio.

It is when the load is actually grounded at its center that we see a very interesting feature of this approach. A simple impedance measurement will show that the high frequency response is *vastly* improved and that the Ruthroff (voltage) Balun appears to take on the character of a Guanella (current) Balun! **Figure 9-3** illustrates the measurements of the input impedance of a Ruthroff 4:1 Balun with the load floating, and when it is grounded at its center. These measurements (with a simple resistive bridge) were made on my design using a powdered-iron core, which will be described later.

A model for the Ruthroff 4:1 Balun, when the load is grounded at its center, is provided in **Figure 9-4**. If the characteristic impedance of the transmission line in the 4:1 Balun is 100 ohms (the optimum value if the load is 200 ohms), then the generator sees $R_L/2$ in parallel with a $R_L/2$ from a "flat" line. As a result, the generator sees its match of 50 ohms—even though the currents in the loads are not in phase!

However, when the Balun is connected to a center-fed, folded dipole, or log-periodic beam antenna with 200-ohm input impedances, the virtual ground-plane bisecting the antennas presents an interesting case. Because there is no metallic connection to the center of the load, the currents in both halves of the antennas are in phase. This is unlike the situation in **Figure 9-4**, where the current in the load on the right is delayed compared to the current in the load on the left. As is evident in **Figure 8-7** of **Chapter 8**, the VSWR curve

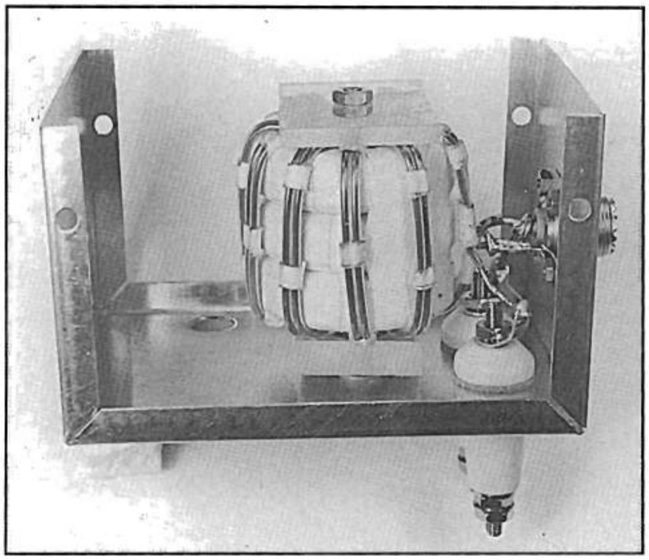

Photo 9-B. *The Balun of Photo 9-A mounted in a 5 inch long by 4 inch wide by 3 inch high minibox.*

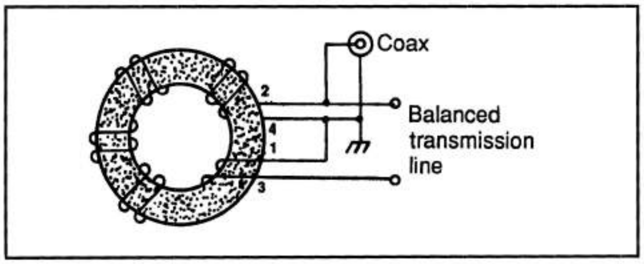

Figure 9-5. *A pictorial of the connections for a 4:1 Ruthroff (voltage) Balun.*

for the high-power Ruthroff Balun has practically the same shape as those of the two lower-power units—even though its transmission line is more than two and one half times longer.

Because the high-frequency response of a Ruthroff 4:1 Balun with a floating load is highly dependent upon the length of the transmission line, **Figure 8-7** suggests that, in the virtual ground case, the Balun acts as a Guanella Balun which sums voltages of equal phases. It also suggests that the effective electrical length of the transmission line is one-half of its actual length. I am quite sure that this model of Ruthroff's Balun was not proposed by him or by others that followed. However, it should be remembered that this condition only exists in the *balanced* case. With an unbalanced load, the Balun should introduce a reactive component that will limit the high frequency response. In the unbalanced case, the Guanella Balun with two cores is the Balun of choice.

Sec 9.4 Some "Hardy" 4:1 Designs

Photos 9-A and **9-B** show two views of a Ruthroff 4:1 Balun, much like McCoy's design, which has been used in his highly popular transmatch.[22] **Figure 9-5** shows a pictorial representation of the connections. It has 11 bifilar turns of No. 14 H Thermaleze wire on three (stacked) T200-2 cores. The cores are powdered-iron material with a permeability of 10. The OD

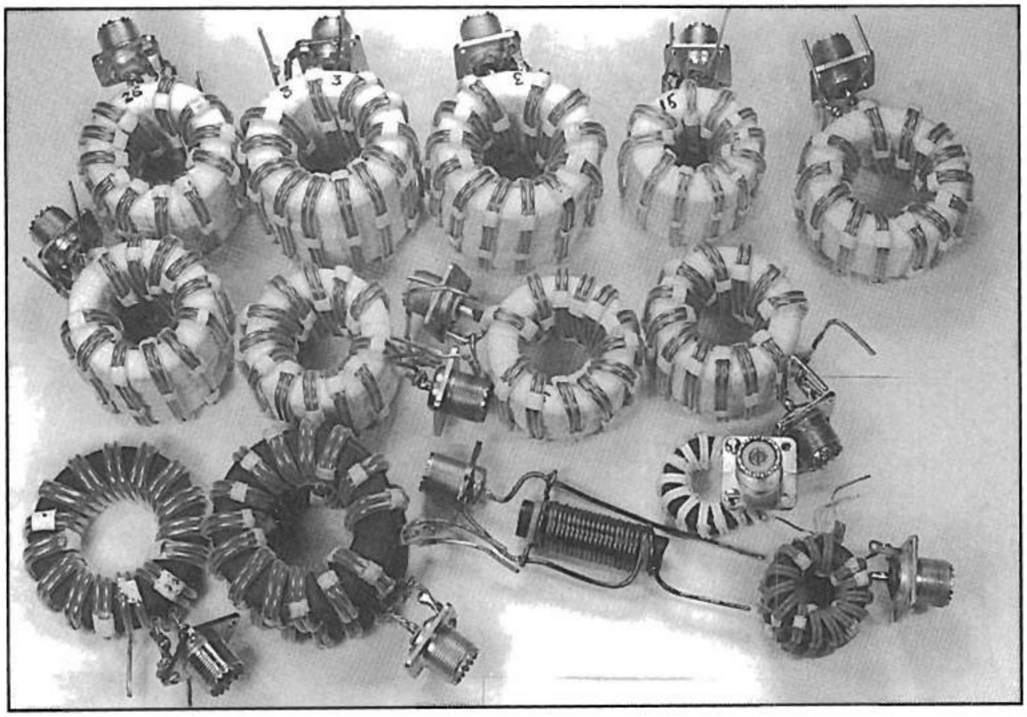

Photo 9-C. *The various Baluns used in the study of 4:1 Baluns for antenna tuners.*

is 2 inches. The wires are also covered with a 15-mil wall Teflon tubing, yielding a characteristic impedance close to the optimum value of 100 ohms.

I differ with McCoy's design here, because the characteristic impedance of his Balun could be closer to 50 ohms. **Photo 9-B** shows the Balun mounted in a 5 inch long by 4 inch wide by 3 inch high minibox. Because McCoy didn't use a thickly insulated wire, he wound a layer of Scotch No. 27 glass tape on each toroid before stacking. This was followed by another layer in the stacking process. With Teflon sleeving over the wire, the extra insulation provided by the glass tape could be dispensed with.

In order to improve the low-frequency response of McCoy's Balun, I made a study of higher permeability powdered-iron cores. **Photo 9-C** shows the various Baluns used in the study. The object of this study was to determine the best core material for a 4:1 Balun to be used in antenna tuners where they can be exposed to high impedances (and, hence, hostile environments). I knew, as the result of very accurate insertion loss measurements[2] that loss with ferrite materials was related to the voltage drop along the length of the transmission line and to the value of the permeability. Permeabilities of 40 (No. 67 ferrite) exhibited the lowest loss. The results taken on a single powdered-iron material—No. 2 material with a permeability of 10—also showed the very same low loss. Because powdered-iron material has been known to be more rugged and linear than ferrite material, this suggested that other powdered-irons with greater permeabilities should also be investigated.

I investigated four other powdered-irons with permeabilities of 20, 25, 35, and 75. Their designations were Nos. 1, 15, 3, and 26, respectively. Comparisons were made on input impedances (with the outputs terminated in 200 ohms) and temperature rises (when handling 500 watts of power). The power test showed, convincingly, that No. 26 material was not to be used because it showed a definite rise in temperature while the other three didn't. However, all four materials showed a definite lower input impedance than the No. 2 material, which has a permeability of 10. As expected, the higher the permeability, the larger the difference with No. 2 material. Although an input impedance measurement does provide some indication of loss because it appears as a shunting path to ground, a very accurate insertion loss measurement would provide a more precise indication of the trade-off that can be made in efficiency for low frequency response.

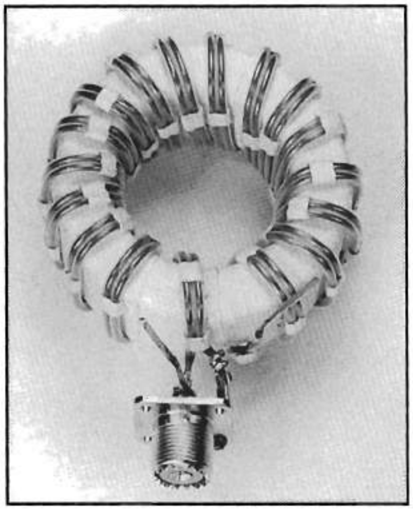

Photo 9-D. *An improved 4:1 Ruthroff design for antenna tuners.*

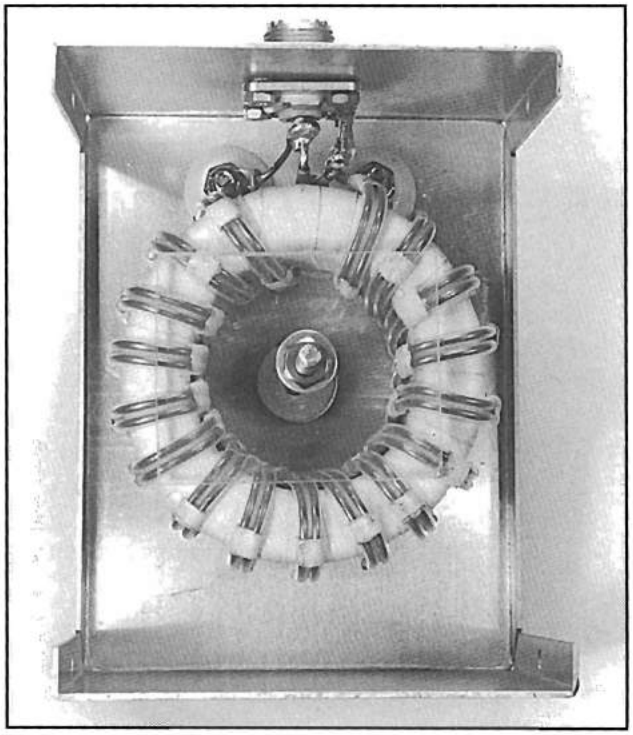

Photo 9-E. *The improved 4:1 Ruthroff Balun mounted in a 5 inch long by 4 inch wide by 3 inch high minibox.*

Because my simple loss measurements indicated that the higher permeability powdered-irons had more loss than the No. 2 material, I decided to design a 4:1 Ruthroff Balun using this material—but with a larger core and more turns than the McCoy[17,18] Balun. Although McCoy's design has enjoyed considerable success over the years, I felt that a larger inductive reactance was desirable in order to assure better performance on the lower frequency bands (particularly 160 meters).

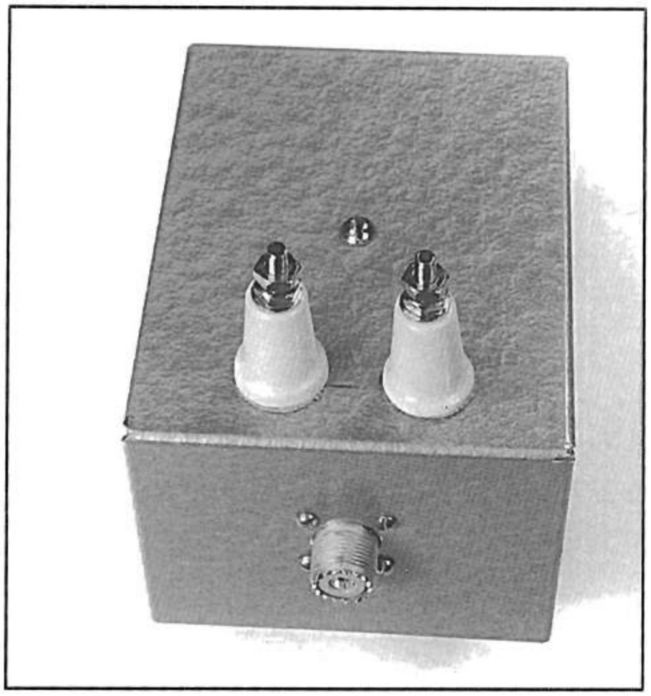

Photo 9-F. *The top view of the 4:1 Balun of Photo 9-E.*

The specific design is shown in **Photo 9-D**. It has 17 bifilar turns of No. 14 H Thermaleze wire on a T300A-2 powdered-iron core, which has an OD of 3 inches and a permeability of 10. With this number of turns and a larger cross section than the three T200-2 cores, the low frequency response improved by a factor of about two over the McCoy Balun, which has 10 to 12 turns on a stack of three T200-2 cores. Furthermore, the wires are also covered with 15-mil wall Teflon tubing, resulting in a characteristic impedance of 100 ohms (the objective). This well-insulated transmission line has been reported to handle 10,000 volts without breakdown. **Figure 9-3** illustrates the performance of this Balun (under a matched condition) when the load is floating and when it is center-tapped-to-ground. **Photo 9-E** shows the Balun mounted in a minibox 5 inches long by 4 inches wide by 3 inches high. **Photo 9-F** shows the top view of the mounted Balun.

Because the Balun with the larger core and more turns showed an improvement by a factor of two in the low-frequency response over the McCoy Balun, I constructed an even larger design. This is shown in **Photo 9-G**. It has 21 turns of the same wire on a T400A-2 core with an OD of 4 inches and a permeability of 10. Even though **Photo 9-G** shows the toroid wrapped with Scotch No. 27 glass tape, as mentioned earlier, this extra insulation isn't required because the wires are covered with Teflon sleeving.

Figure 9-6 shows the comparisons in the input impedances versus frequency of these three "hardy" Baluns when they are terminated in 200-ohm loads grounded at their centers. As can be seen, the low-frequency response of the Balun with the most turns and largest core is the best. Even though the Balun with the 3-inch core has a poorer low-frequency response, it is an improvement over the McCoy Balun and should find considerable use in transmatches. **Figure 9-6** also shows that the high frequency responses of these Baluns with the loads grounded at their centers are remarkably similar. This is especially interesting, as the length of the transmission line on the larger

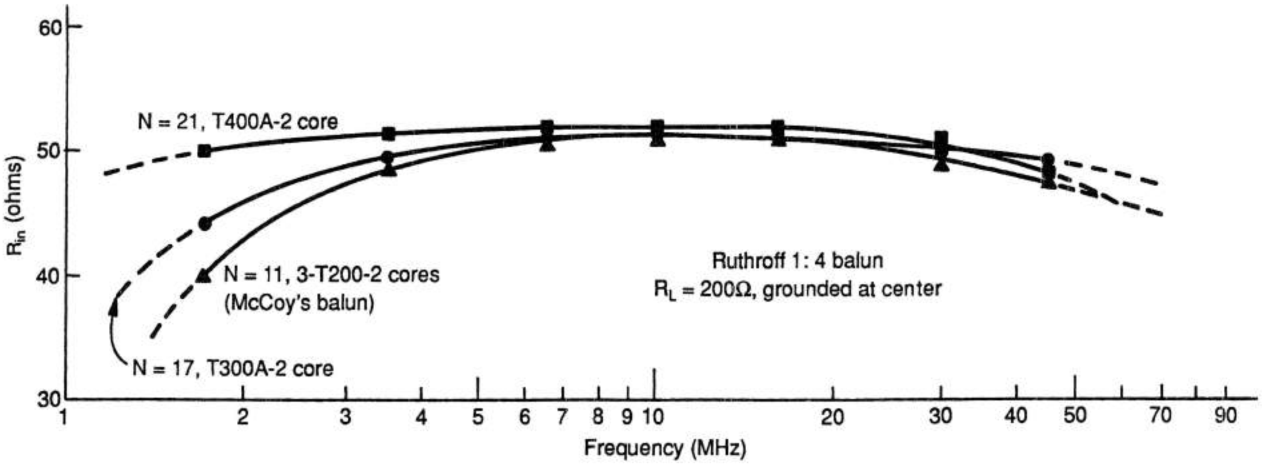

Figure 9-6. *A comparison of the performance of the McCoy 4:1 Balun with Baluns having larger cores and more turns.*

Balun (with the T400A-2 core) is more than twice as long as the other two (115 inches compared to 50 and 55 inches). If it is correct that my model of a Ruthroff (voltage) Balun feeding a balanced antenna or transmission line takes on the character of a Guanella (current) Balun because of the virtual ground, then this large Balun could have many applications.

Sec 9.5 Multiband Dipoles

Antenna tuners have been known to work well for some radio amateurs and not for others. This is due to the differences in the dimensions of their antenna systems. With high impedances seen by the 4:1 Baluns in the antenna tuners, the Baluns not only fail to provide a good balanced-to-unbalanced conversion, but they can also be damaged by excessive heating. The high current, low impedance condition seen by the Balun isn't a problem. Therefore, the object in multiband antenna design is to provide the most favorable impedances for the Baluns, especially on the three lowest frequency bands—40, 80, and 160 meters. Usually on the higher frequency bands, the impedances seen by the Baluns are not as high and the Balun's choking reactances are greater (assuring balanced-to-unbalanced conversion). This section discusses three cases of multiband center-fed dipole designs. They are 1) the "worst case" design, 2) a smaller design—the G5RV, and 3) a larger design. Others may have better designs for multiband operation, but it's clear that the "worst case" design ought to be avoided. **Figure 9-7** shows the symbols for the dimensions of the center-fed dipoles.

Sec 9.5.1 The "Worst Case" Design

Apparently, an 80-meter dipole with a quarter-wave open-wire (or twin-lead) feedline is a logical design for a multiband dipole. In **Figure 9-7** this would mean that $L_1 = L_2 = 59$ to 67 feet, depending upon the favorite operating frequency. If one were to use 450-ohm twin-lead with "open windows," L_2 would be diminished by 10 percent; with 300-ohm TV twin-lead, it would be diminished by about 20 percent. This would make a good antenna system on 160 meters. Because $L_1 + L_2$ is close to a quarter-wave, the current at the input to the feedline is at its highest value and the impedance at its lowest—a very favorable condition for the Balun. In fact, a 1:1 Balun at the feedpoint would probably do a good job.

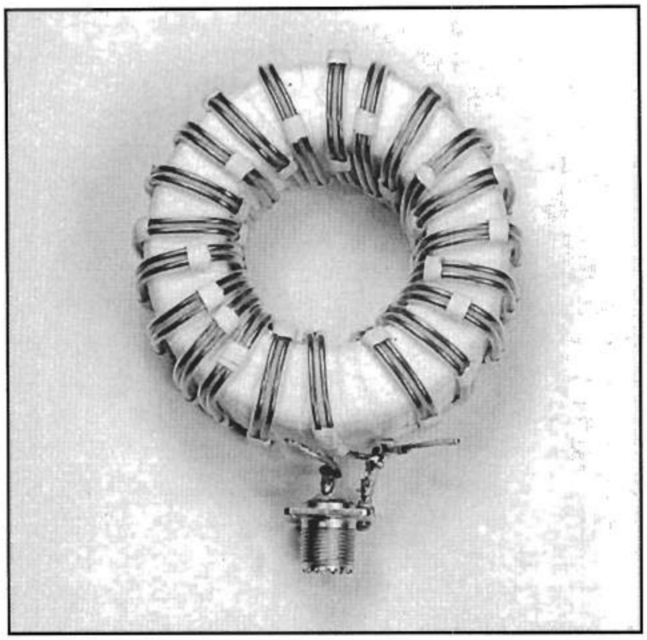

Photo 9-G. *A large 4:1 Ruthroff design using a 4-inch OD powdered-iron core and 21 bifilar turns.*

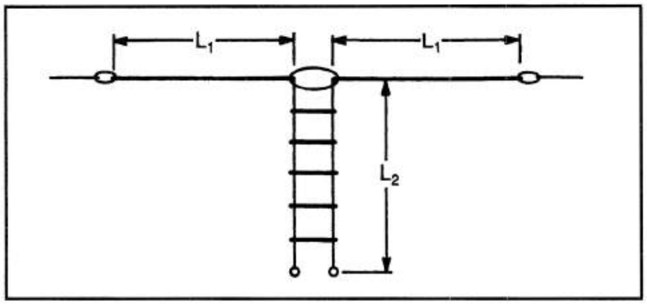

Figure 9-7. *The symbols used for the dimensions of a center-fed dipole with open-wire feeders (or twin-lead with appropriate consideration of velocity factors).*

However, what does the input to the feedline look like on 80 meters? If 450-ohm feedline is used, the 4:1 Balun sees a quarter-wave 450-ohm feedline terminated in approximately 50 ohms. Transmission line theory tells us that the Balun would see 4050 ohms—an impossible condition for most Baluns. The situation becomes worse on 40 meters, where we may have a center-fed, full-wave dipole with a half-wave transmission line (a 1:1 matching transformer). In this case, the Balun could see an impedance approaching 10,000 ohms—a more than impossible condition! Although high impedances would also be seen on 10, 15, and 20 meters, the conditions are not quite as severe because the Balun's choking reactances are usually greater and the impedances lower. In essence, the "worst case" design for a 4:1 Balun is the "best case" design (except for 160 meters), if one still uses inductive coupling to a parallel-tuned circuit.[19]

Sec 9.5.2 A Smaller Design—The G5RV

Varney,[24] G5RV, designed a multiband center-fed antenna system capable of operation on all HF bands from 3.5 to 30 MHz. In contrast to multiband antennas designed as half-wave dipoles on 80 meters (the "worst case" design), the full-size G5RV antenna was designed as a three-half-wave antenna on 14,150 MHz with a 1:1 transmission line matching transformer. It was possible to accomplish this using the dimensions of 51 feet for L_1 and 34 feet for L_2. For 450-ohm twin-lead with "windows," L_2 would he 31 feet; for 300-ohm TV ribbon, L_2 would be 28 feet. Consequently, the input impedance at the hase of the matching transmission line was about 100 ohms on 14,150 MHz, and a manageable impedance for 50 or 80-ohm coaxial cable.

However, with a total length for $L_1 + L_2$ of 85 feet, the impedances at the input to the transmission line on 40, 80, and 160 meters are also manageable. Even though they have a reactive component on these bands, they aren't so high that a well-designed 4:1 Balun in an antenna tuner can't handle them easily. Varney also showed that the highest impedances occurred on the 18-, 21-, and 28-MHz bands. However, this doesn't present a problem with the design shown in **Photo 9-D** because it uses an efficient core material, and it also has the highest reactances of its windings at these frequencies.

Varney[24] also wrote, at considerable length, on the unsuitability of a Balun being used to connect the base of the 34-foot open feeders to a coaxial cahle feedline. He stated that if a Balun is connected to a reactive load with a VSWR of more than 2:1, its internal losses would increase. Varney also mentioned heating of the wires and saturation of the core. Evidently Varney was not familiar with McCoy's design, which uses a powdered-iron core (with a permeability of 10) that can withstand VSWRs considerahly greater than 2:1—without showing any temperature rise. Furthermore, the wire doesn't heat up; however, the core itself does via dielectric heating. Additionally, with sufficient choking reactance, Baluns can handle (equally) the resistive and reactive components of an impedance.

Finally, after observing the voltage and current distributions on all of the bands, it appears that a 2:1 (100:50-ohm) Balun might he an interesting one to try on the G5RV antenna. It could he that many of the bands would not require the added matching of an antenna tuner. If some of the bands require an antenna tuner in order to be used, then I would suggest using a "hardened" Balun. That is what I call McCoy's approach, which uses efficient and hardy powdered-iron cores. A 2:1 Balun, comprised of a 1:2 Unun in series with a 1:1 Guanella (current) Balun, could be easily designed and built (see **Chapter 10**).

Sec 9.5.3 A Larger Design

Even though the G5RV antenna can be made to operate on 160 meters with a suitable antenna tuner, an antenna system larger than the "worst case" design can provide better operation on the 40-, 80-, and 160-meter hands. As you might expect, an antenna system about twice as large as the G5RV offers these advantages. Suggested dimensions are L_1 = 80 feet and L_2 = 100 feet. If the feedline is 450-ohm twin-line with "windows," then L_2 = 90 feet. If it is 300-ohm TV ribbon, then L_2 = 82 feet. As with the G5RV, it's the total length of $L_1 + L_2$ that presents favorable or unfavorable impedances to the 4:1 Balun in the antenna tuner. Therefore, L_1 and L_2 could hoth be 90 feet, as well. Only very small differences in performance would be noticed between these two systems, particularly on the lower-frequency bands. Obviously, other combinations totaling 180 feet are also possible. In the G5RV case, it's 85 feet.

Sec 9.6 Summary

After reading this chapter, one might think that I have set this technology back a few years by advocating voltage Baluns and powdered-iron cores. I have even questioned the professional literature. However, my conclusions were based upon three experimental results. These were: 1) measurements with my resistive bridge on input impedances of 4:1 Ruthroff (voltage) Baluns with loads floating and center-tapped-to-ground, 2) VSWR measurements on folded dipoles with various 4:1 Baluns (large and small and, therefore, with many different lengths of transmission lines), and 3) McCoy's success with his 4:1 Balun. Also, as this chapter points out, it helps to have the dimensions of a multiband, center-fed dipole, and feeders favor the operation of a 4:1 Balun in antenna tuners. And, *yes*, there is a "worst case" antenna design!

As in many investigations, supplying answers to some questions can lead to others that appear to be important. Specifically, for powdered-irons, how would permeabilities in the 20 to 35 range perform? Simple impedance measurements showing lower values on input impedances, indicate that there is more loss than with a permeability of 10; but accurate insertion loss measurements are needed in order to tell the complete story—the trade-off in efficiency for low-frequency response.

Finally, low permeability ferrite-like No. 67 material with a permeability of 40 looks interesting for use in Baluns for antenna tuners. Accurate insertion loss measurements[2] have also shown the very same high efficiency that was exhibited by powdered-iron having a permeability of 10. With a sufficient number of turns on an appropriate size core, a Balun made of this material could be practical. Even though the amateur radio literature still refers to the problem of core saturation, there has been only one recorded case. This was on 2 MHz with a rod-type 1:1 Balun where insufficient choking reactance exists.[13,14]

Chapter 10

1.5:1 and 2:1 Baluns

Sec 10.1 Introduction

There are many applications for broadband Baluns with impedance transformation ratios close to 1.5:1 and 2:1. Two applications involve matching 50-ohm cable to balanced loads of 75 or 100 ohms, which are the input impedances of a half-wave dipole at heights of 0.22 or 0.34 wavelengths above ground. Another, is the matching of 50-ohm cable to the 100-ohm input impedance of a quad antenna. An interesting, and somewhat unexpected, application is the matching of 50-ohm cable directly to the input impedance of the driven element of a Yagi beam antenna of 33 or 25 ohms. This would eliminate the common hairpin matching network presently used to raise their input impedances to 50 ohms.

There are many versions of these two Baluns. They include: 1) high- and low-power designs, 2) designs matching 50-ohm cable to higher or lower impedances, 3) series- or parallel-type designs, 4) single- or dual-core designs, 5) dual-ratio designs, and 6) HF and VHF designs. The series-type Baluns use an Unun (unbalanced-to-unbalanced transformer) in series with a Guanella (current) Balun. More details on these Ununs are provided in later chapters. In this chapter, you'll read about many high-power designs capable of handling the full legal limit of amateur radio power. They are optimized for sufficient margins in choking reactance at their low frequency ends, and in efficiency throughout their passbands. Two of the 2:1 Baluns are specifically designed for 2-meter operation.

Sec 10.2 1.5:1 Baluns

In this section, I'll present two series-type 1.5:1 Baluns (actually 1.56:1, which should be close enough). They both use 1.56:1 Ununs in series with Guanella 1:1 Baluns. **Figures 10-1A** and **B** show their schematic diagrams. **Figure 10-1B** has an extra input (to a tap), which provides another ratio of 1.33:1.

The left-hand side of **Photo 10-A** shows a design using **Figure 10-1A** mounted in a CU 3006 minibox 5.25 inches long by 3 inches wide by 2.25 inches high (RadioShack has carried a similar enclosure). The 1:1.56 Unun has 4 quintufilar turns on a 1.5-inch OD

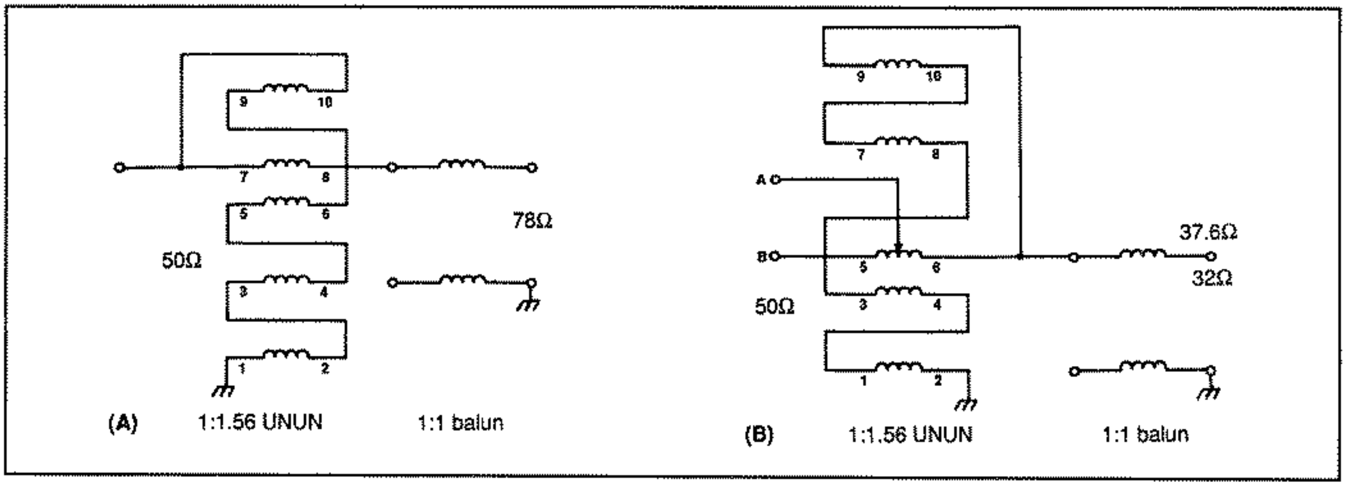

Figure 10-1. *Schematic diagrams of two 1.56:1 Baluns: (A) step-up, 50:78 ohms; (B) step-down, 50:37.6 ohms—connection A, 50:32 ohms—connection B.*

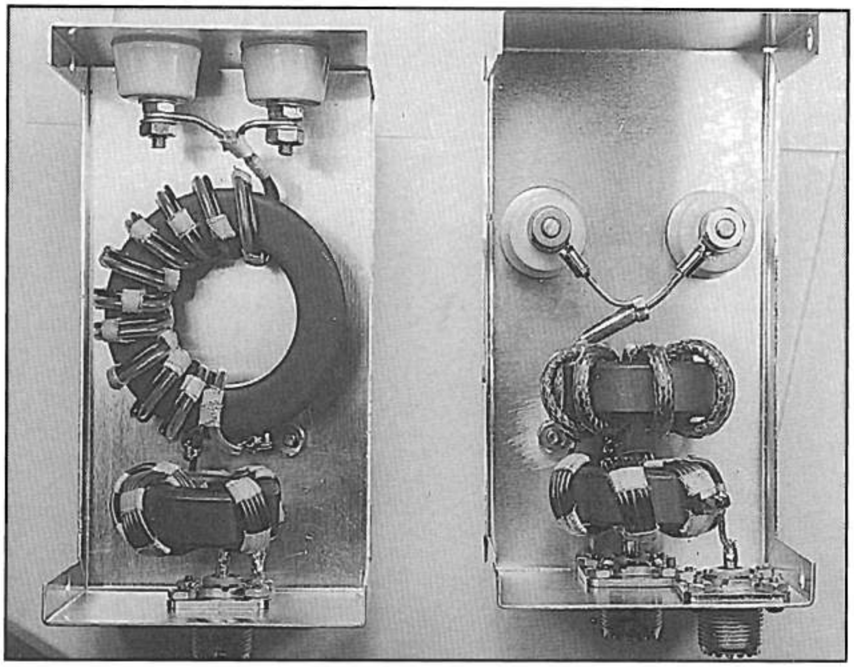

Photo 10-A. *Baluns using the schematic diagrams of Figure 10-1. Balun on the left matches 50-ohm cable to a balanced load of 78 ohms. Balun on the right matches 50-ohm cable to balanced loads of 37.6 or 32 ohms.*

ferrite toroid with a permeability of 250. Winding 7-8 is No. 14 H Thermaleze wire and the other four are No. 16 H Thermaleze wire.

The 1:1 Guanella Balun has 11 bifilar turns of No. 14 H Thermaleze wire on a 2.4-inch OD ferrite toroid with a permeability of 250. One wire is covered with Teflon tubing, resulting in a characteristic impedance very close to 78 ohms (the optimum value).

When matching 50-ohm cable to a balanced load of 78 ohms, the impedance transformation ratio is literally flat (within a percent or two) from 1.5 MHz to 40 MHz! You might be interested to know that (separately) the 1:1 (75:75-ohm) Balun would make an excellent isolation transformer for 75-ohm hardline, and the 1.56:1 (78:50-ohm) Unun an excellent match between 75-ohm hardline and 50-ohm cable.

The right-hand side of **Photo 10-A** shows a design using **Figure 10-1B** mounted in a similar enclosure. The 1.56:1 Unun has 5 quintufilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 5-6 is No. 14 H Thermaleze wire and is tapped at one turn from terminal 5. The other four wires are No. 16 H Thermaleze.

The 1:1 Guanella Balun has 7 turns of homemade coaxial cable on a 1.5-inch OD ferrite toroid with a permeability of 250. The inner conductor is No. 14 H Thermaleze wire and is covered with Teflon tubing. The outer braid, which is from a small coaxial cable or from 1/8-inch tubular braid, is also tightly wrapped with Scotch No. 92 tape to preserve the low characteristic impedance.

In matching 50-ohm cable to a balanced load of 37.6 ohms (connection A), or to a balanced load of 32 ohms (connection B), the response is essentially flat (within a percent or two) from 1.5 to 30 MHz.

Sec 10.3 2:1 Baluns

The 2:1 Balun lends itself to more choices in design than the 1.56:1 Balun. This is especially true because the parallel-type design, which provides a 2.25:1 Balun with the widest possible bandwidth, can easily be employed. The 1.56:1 Balun is at a disadvantage here. This section presents many Baluns using both series and parallel-type designs.

Sec 10.3.1 Series-type Baluns

Figure 10-2 shows circuit diagrams for two versions of the series-type Balun. **Photo 10-B** shows a design using **Figure 10-2A** mounted in a CU 3005-A minibox 5 inches long by 4 inches wide by 3 inches high. The 1:2 Unun has 7 trifilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. The output tap is located 6 turns from terminal 5. Winding 5-6 is No. 14 H Thermaleze wire and the other two are No. 16 H Thermaleze wire.

The 1:1 Guanella Balun has 14 bifilar turns of No. 14 H Thermaleze wire on a 2.4-inch OD ferrite toroid with a permeability of 250. Both wires are covered with Teflon tubing, which results in a characteristic impedance of 100 ohms (the optimum value). A crossover, placing 7 turns on one side of the toroid

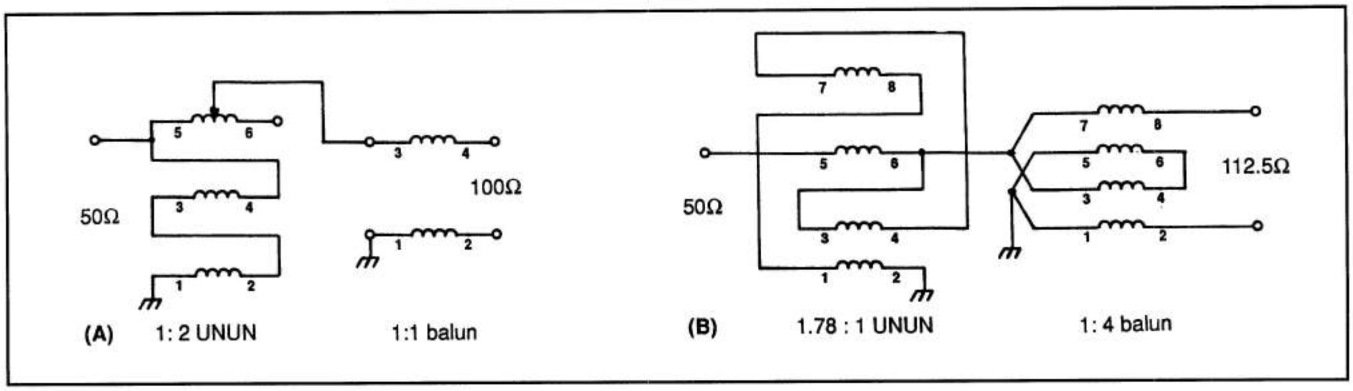

Figure 10-2. *Schematic diagrams of two versions of the series-type Balun: (A) 1:2 (50:100 ohms) Balun; (B) 1:2.25 (50:112.5 ohms) Balun.*

and 7 turns on the other, is used so the output and input are on opposite sides of the toroid. **Figure 10-3** is a drawing of the crossover. Although this technique has no electrical advantage at HF, the mechanical advantage is obvious.

When matching 50-ohm cable to a balanced load of 100 ohms, the response is literally flat (within 2 to 3 percent) from 1.5 to 30 MHz. By connecting the output of the Unun to terminal 6 instead of to the tap, the Balun would match 50-ohm cable to a balanced load of 112.5 ohms with about the same response.

Photo 10-C shows two slightly different versions of series-type 2.25:1 Baluns using the circuit of **Figure 10-2B**. Both have the same 1.78:1 step-down Unun, which has 5 quadrifilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 5-6 is No. 14 H Thermaleze wire, and the other three are No. 16 H Thermaleze wire. Each version also has 8 bifilar turns of No. 14 H Thermaleze wire on both of the 1.5-inch OD ferrite toroids, with a permeability of 250.

The differences are: 1) the Balun on the left in **Photo 10-C** has one layer of Scotch No. 92 tape on one of the wires in each bifilar winding and a crossover after the fourth turn, and 2) the Balun on the right has two layers of Scotch No. 92 tape on one of the wires on one toroid and no extra insulation on the wires of the other toroid. Therefore, one of the windings in the 1:4 Guanella Balun has a characteristic impedance a little less than 50 ohms and the other a little greater than 50 ohms, resulting in a canceling effect. Furthermore, the crossover isn't used in this design. The Balun on the left is mounted in a CU 3006 minibox 5.25 inches long by 3 inches wide by 2.25 inches high. The Balun on the right is mounted in a CU 3015-A minibox 4 inches long by 2 inches wide by 2.75 inches high.

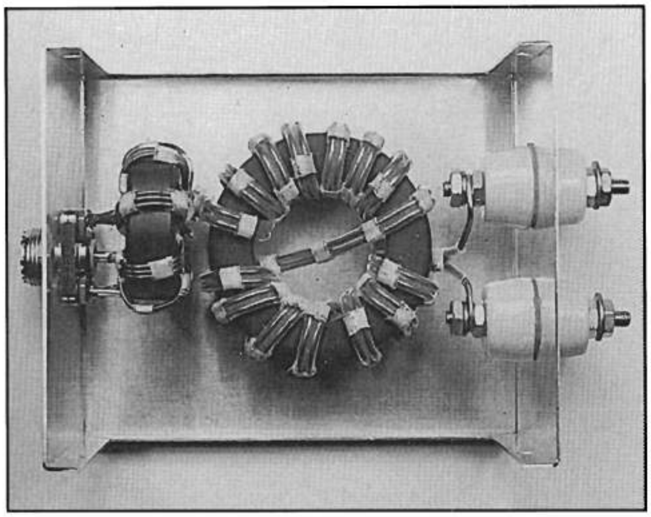

Photo 10-B. *A series-type Balun using the schematic diagram of Figure 10-2A designed to match 50-ohm cable to a balanced load of 100 ohms.*

The performance of these two Baluns is essentially the same. When matching 50-ohm cable to balanced loads of 112.5 ohms, the responses are essentially flat (within 2 to 3 percent) from 1.5 to 30 MHz.

From preliminary measurements on series-type 2:1 Baluns, the Balun in **Photo 10-B** is the one I'd recommend for matching 50-ohm cable to balanced loads of 100 ohms, while the Baluns in **Photo 10-C** would be best for matching to balanced loads of 112.5 ohms. Also, by replacing the 1.78:1 Unun in **Figure 10-2B** with a 2.25:1 Unun, and not adding any extra insulation to the windings of the 1:4 Balun, it's possible to obtain an excellent Balun matching 50-ohm cable to a balanced load of 89 ohms.

Figure 10-4 shows the schematic diagram of a series-type Balun designed to match 50-ohm cable to balanced loads of 25 or 22.22 ohms. **Photo 10-D**

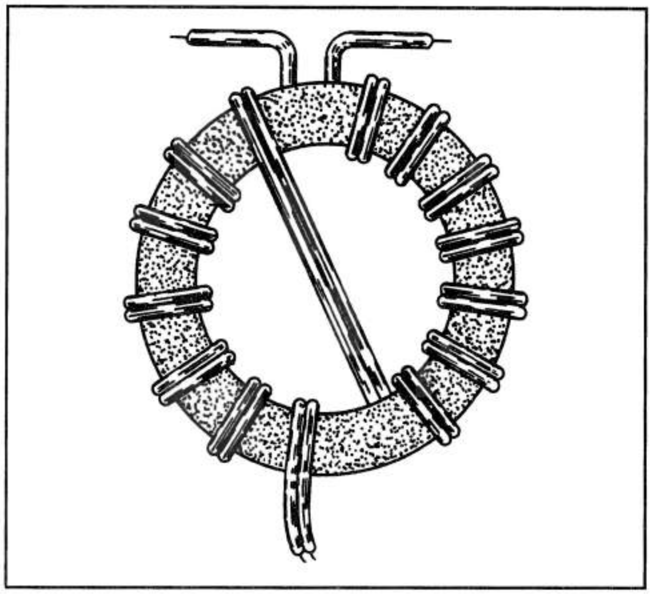

Figure 10-3. *Construction of a 1:1 Guanella Balun with a crossover placing the input and output terminals on opposite sides of the toroid.*

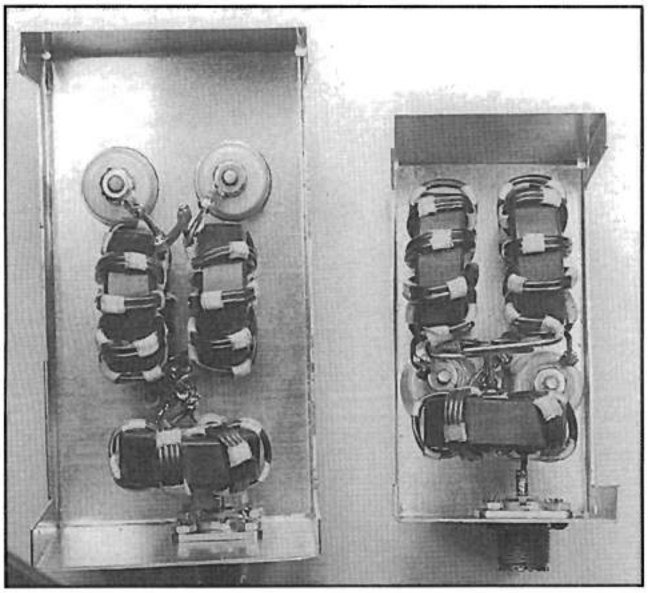

Photo 10-C. *Two series-type Baluns using the schematic diagram of Figure 10-2B designed to match 50-ohm cable to balanced loads of 112.5 ohms.*

shows two versions of this dual-ratio Balun. The Balun on the left, for its Unun, has 6 trifilar turns of No. 14 H Thermaleze wire on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 3-4 is tapped one turn from terminal 3, yielding the 2:1 ratio. The 1:1 Guanella Balun has 6 turns of homemade coaxial cable on a similar toroid. The inner conductor is No. 12 H Thermaleze wire and is covered with Teflon tubing. The outer braid, from a small coax or from 1/8-inch tubular braid, is tightly wrapped with Scotch No. 92 tape to preserve its low characteristic impedance.

In matching 50-ohm cable to balanced loads of 25 ohms (connection A) or to 22.22 ohms (connection B), the response is essentially flat (within a percent or two) from 1.5 to 30 MHz.

The Balun on the right in **Photo 10-D** has similar windings on a single 2.4-inch OD ferrite toroid with a permeability of 250. Its performance is quite comparable to the Balun on the left.

Sec 10.3.2 Parallel-type Baluns

As you saw in the previous section, the series-type Baluns presented here are combinations of Ununs with ratios of 1.33:1, 1.78:1, 2:1, and 2.25:1 in series with Guanella 1:1 or 4:1 Baluns. The Ununs, which are really an extension of Ruthroff's[9] bootstrap technique for obtaining a 4:1 Unun, sum direct voltages with delayed voltages that traverse a single transmission line. Therefore, the Unun eventually limits the high-frequency response of the series-type Balun.

On the other hand, the parallel-type Balun is an extension of Guanella's technique of summing voltages of equal delays. Instead of simply connecting transmission lines in parallel-series, the parallel-type Balun connects Guanella Baluns in parallel-series. As I noted in **Reference 25**, two 4:1 Guanella Baluns can be connected in parallel-series, yielding very broadband ratios of 6.25:1. This section shows how a 1:1 Guanella Balun can be connected with a 4:1 Guanella Balun in parallel-series, yielding a very broadband ratio of 2.25:1.

Figure 10-5 is the schematic diagram of the high-frequency model of a 2.25:1 Unun which is used for analysis purposes. Because the current through the load is $3/2I_1$, the transformation ratio is $(3/2)^2$, or 2.25:1. Therefore, if the impedance seen on the left side is 50 ohms, a matched impedance on the right side is 22.22 ohms. Because two thirds of the 50 ohms appears across the input of the Guanella 1:1 Balun, its optimum characteristic impedance is 33.33 ohms. Similarly, this is also the value of the optimum characteristic impedance for the windings of the 4:1 Balun. Because the 1:1 Balun wants to see 33.33 ohms on its output (a matched condition) and the 4:1 Balun wants to see 66.66 ohms, placing these two values in parallel results in the confirming value of 22.22 ohms.

If the 50-ohm generator is placed on the right side in **Figure 10-5**, the circuit becomes a step-up Unun matching 50 ohms to 112.5 ohms (on the left). If the ground is removed on the left side, the transformer becomes a Balun. A similar analysis as above, shows that the optimum characteristic impedance of the three bifilar windings now becomes 75 ohms.

Photo 10-E shows a parallel-type 2.25:1 Balun designed to match 50-ohm cable to a balanced load of 112.5 ohms. It has 9 bifilar turns of No. 14 H Thermaleze wire on each of the three toroids that have a 1.5-inch OD and a permeability of 250. Also, one of the wires on each toroid is covered with Teflon tubing, resulting in a characteristic impedance of 75 ohms (the optimum value). When operating as a Balun, the response is essentially flat from 7 MHz to over 45 MHz. As an Unun, the flat response is broadened from 1.5 MHz to over 45 MHz.

Because the coiled wire, parallel-type Balun didn't provide any real advantage over the series-type Balun (in fact, the low-frequency response was poorer), I investigated the beaded transmission line version for possible use in the VHF band. **Figure 10-6** shows a schematic diagram of one using coaxial cable. Obviously, twin lead could be substituted for the coaxial cable. **Photo 10-F** shows both versions.

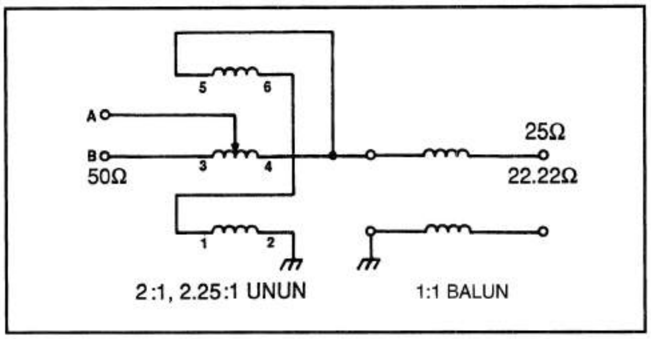

Figure 10-4. *Schematic diagram of a dual-ratio series-type Balun. Connection A matches 50-ohm cable to a balanced load of 25 ohms. Connection B matches 50-ohm cable to a balanced load of 22.22 ohms.*

The top design in **Photo 10-F** has 4 inches of 3/8-inch OD ferrite beads with a permeability of 125 on each of the three 75-ohm transmission lines. It is designed to match 50-ohm cable on the right to a balanced load of 112.5 ohms on the left (with the ground on terminal 1 removed). The transmission lines consist of two No. 14 H Thermaleze wires separated by the Teflon tubing covering one of them. When matching 50-ohm cable to a balanced load of 112.5 ohms, the response is essentially flat from 30 MHz to over 100 MHz (the limit of my bridge).

The bottom design in **Photo 10-F** also has 4 inches of 3/8-inch OD ferrite beads with a permeability of 250. However, they are now threaded by homemade coaxial cable with a characteristic impedance of 33.33 ohms. It is designed to match 50-ohm cable on the left to a balanced load of 22.22 ohms (with the ground on terminal 2 removed). The inner conductor of the coax is No. 14 H Thermaleze wire and is covered with

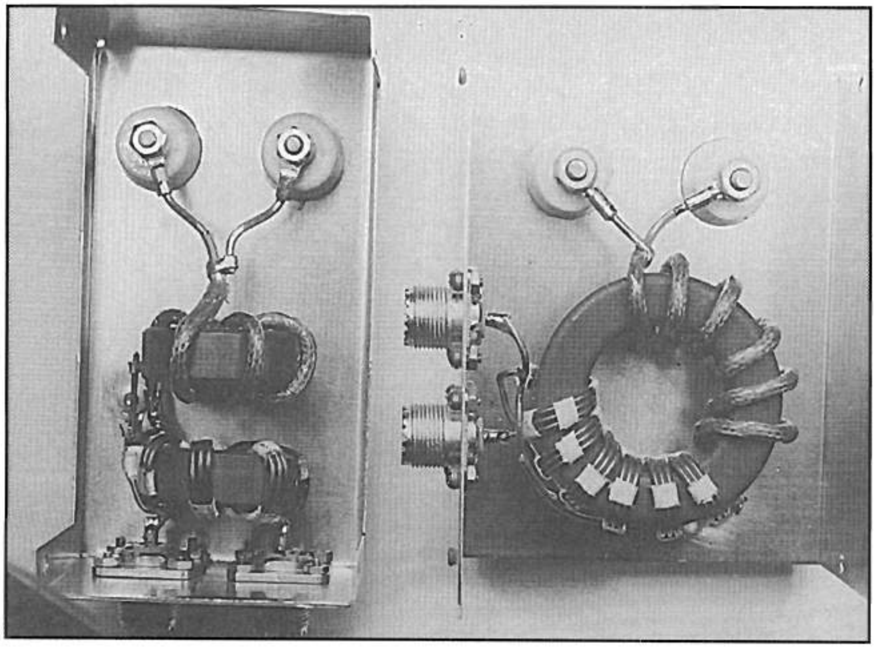

Photo 10-D. *Two series-type Baluns using the schematic diagram of Figure 10-4 designed to match 50-ohm cable to balanced loads of 25 ohms or 22.22 ohms.*

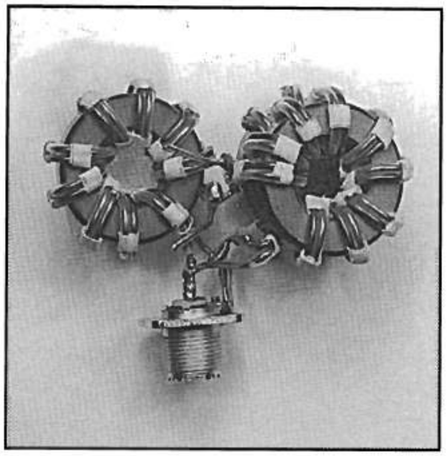

Photo 10-E. *Parallel-type 2.25:1 Balun matching 50-ohm cable to a balanced load of 112.5 ohms.*

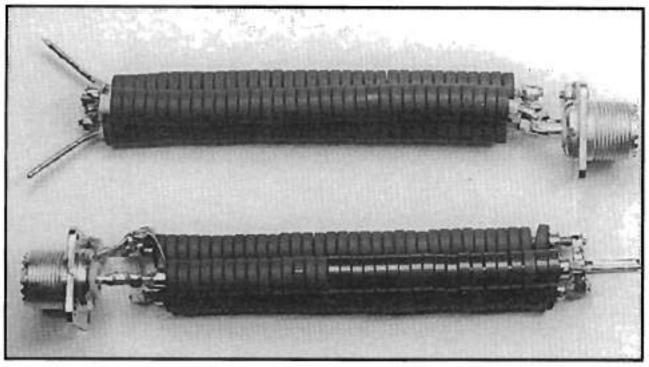

Photo 10-F. *Beaded transmission line versions of the 2.25:1 parallel-type Balun for operation in the VHF band. The top Balun matches 50-ohm cable to a balanced load of 112.5 ohms. The bottom Balun matches it to a balanced load of 22.22 ohms.*

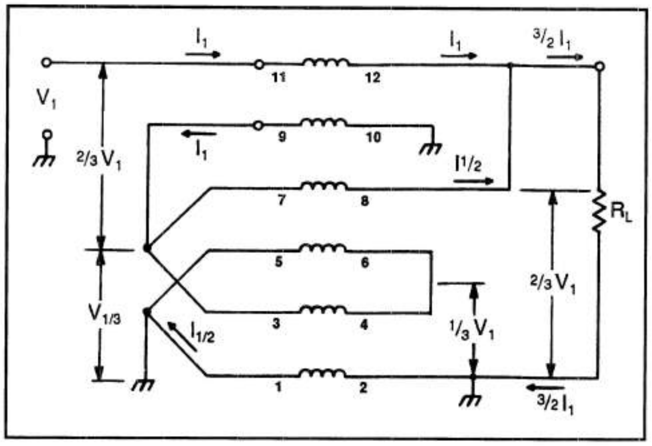

Figure 10-5. *High-frequency model of the parallel-type 2.25:1 transformer. Connections shown are for Unun operation.*

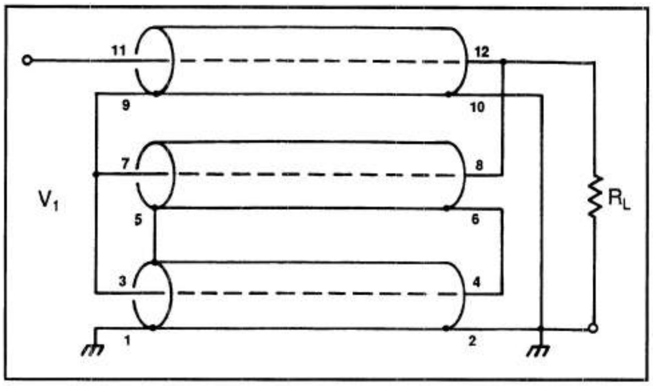

Figure 10-6. *The coaxial cable version of the parallel-type 2.25:1 transformer of Figure 10-5.*

Teflon tubing. The braid is from small coaxial cable or from 1/8-inch tubular braid. The braid is also tightly wrapped with Scotch No. 92 tape in order to preserve the low characteristic impedance. When matching 50-ohm cable to a balanced load of 22.22 ohms, the response is essentially flat from 14 MHz to over 100 MHz (again, the limit of my bridge).

Sec 10.4 Closing Comments

In closing, I'd like to make a couple of comments regarding parallel-type Baluns.

First, if you are interested in a 1.78:1 ratio, replace the 1:4 Balun in **Figures 10-5** and **10-6** with a 1:9 Guanella Balun (three transmission lines connected in parallel-series). This would yield an output current of $4/3I_1$ and a ratio of $(4/3)^2$, or 1.78:1. If you replace the 1:4 Balun with a 1:16 Guanella Balun (four transmission lines connected in parallel-series), the output current will be $5/4I_1$, with a ratio of $(5/4)^2$, or 1.56:1.

Second, because the parallel-type Balun is really an extension of Guanella's technique of summing voltages of equal delays,[26,27] the high-frequency response is mainly limited by the parasitics in the interconnections. Therefore, beaded transmission lines offer the best opportunity for successful operation on the VHF band. It is also recommended that the ferrite beads have permeabilities of 300 or less[2] in order to achieve the very high efficiencies of which these transformers are capable.

Chapter 11

6:1, 9:1, and 12:1 Baluns

Sec 11.1 Introduction

This chapter is a combination of two articles I wrote for *Communications Quarterly*. One, on the 6:1 and 9:1 Baluns, appeared in the Winter 1993 issue and the other, on the 12:1 Balun, ran in the Summer 1993 issue. I combined these two articles here because the three Baluns discussed have much in common. Commonalities include: 1) They are the most difficult to construct and are, therefore, the most expensive; 2) two of them, the 6:1 and 12:1 Baluns, use Ununs in series with Guanella Baluns; 3) two of them use the 9:1 Guanella Balun—the 12:1 Balun with a series 1.33:1 Unun; 4) they are generally associated with two-wire transmission lines with characteristic impedances of 300, 450, and 600 ohms, respectively; 5) when matching 50-ohm cable to higher impedances, they have more loss than the Baluns in the preceding chapters; and 6) the optimum application of these Baluns requires a more critical understanding of the trade-offs in low-frequency response for efficiency.

Like the 2:1 Balun in **Chapter 10**, the 6:1 (actually 6.25:1) Balun also comes in two forms: the series-type, which offers better low-frequency response in the HF band, and the parallel-type, which has a vastly greater high-frequency capability. The parallel-type 6:1 Balun, together with the 9:1 Guanella Balun (which is also a parallel-type), offer the potential for designs capable of efficient and broadband operation on the VHF and UHF bands.

Sec 11.2 6:1 and 9:1 Baluns

Many radio amateurs associate the use of the 6:1 and 9:1 Baluns with 300-ohm twin lead feeding folded dipoles, 450-ohm "ladder" line feeding single or multi-band antenna systems. However, what is neglected (in some cases) is the effect of the height of these antennas above earth and the length of the transmission lines feeding them.

Broadband 6:1 and 9:1 Baluns are considerably more difficult to construct than the more common 1:1 and 4:1 Baluns. This is especially true when matching 50-ohm cable to impedances of 300 and 450 ohms. Furthermore, there are some important trade-offs in low-frequency response for efficiency.

From what I could gather "on the air" or talking to radio clubs, I have determined what I believe are probably two of the most common misconceptions regarding the use of these Baluns:

1. 6:1 Baluns. In free-space, the folded dipole with 300-ohm twin-lead has a resonant impedance close to 300 ohms. The dipole also has this value at a height of about 0.225 wavelength above ground. However, it's only 200 ohms at a height of about 0.17 wavelength and 400 ohms (the maximum) and at 0.35 wavelength. In many cases, the 4:1 Balun would actually do a better job of matching.

2. 9:1 Baluns. Some are unaware of the relationship between the impedance at the input of a transmission line, the characteristic impedance of the line, and the impedance at the end of the line. Just because a transmission line has a characteristic impedance of 450 ohms doesn't necessarily mean that a 9:1 Balun will perform a satisfactory match to 50-ohm cable. Far from it. For example, if the line is terminated by a half-wave dipole with an impedance of 50 ohms, the 9:1 Balun would see 50 ohms when the line is a half-wave long and 4050 ohms when it's a quarter-wave long! Broadband Baluns cannot be designed to handle impedances as high as 4050 ohms. It's very likely that a well-designed 50:450-ohm Balun would experience (particularly on 80 and 160 meters) harmful flux in the core *and* excessive heating because of the large voltage drop along the length of its transmission lines. This problem of presenting very high (and harmful) impedances to Baluns is quite prevalent with multi-band antenna systems.

Clearly, there are many applications for 6:1 and 9:1 Baluns. They not only include matching 50-ohm cable

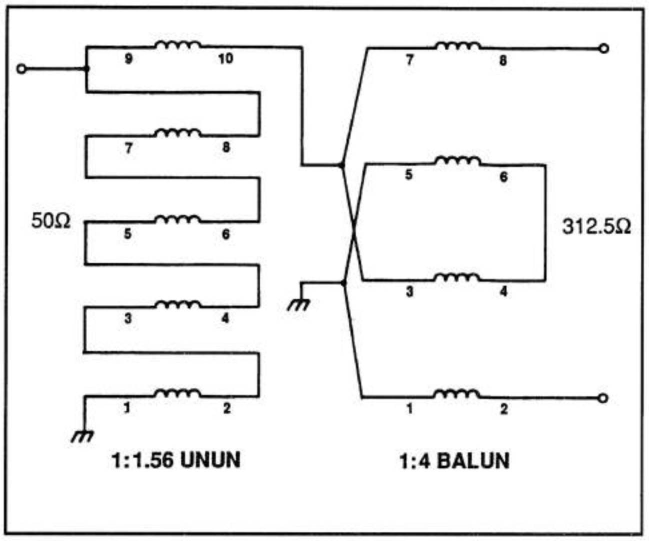

Figure 11-1. *Schematic diagram of the series-type Balun with a 1:6.25 ratio designed to match 50 to 312.5 ohms.*

to balanced loads of 300 and 450 ohms, but also to balanced loads of 8 and 5.6 ohms, as well. Furthermore, many of the designs in this chapter will perform almost as well in Unun (unbalanced-to-unbalanced) applications. The trade-off (which is usually very small) is in low-frequency response. Additionally, these Baluns could be used to exploit the low-loss properties of 300- and 450-ohm twin-lead where very long transmission lines are used. This is especially important at 14 MHz and above.

In the pages that follow, I'll present a variety of Baluns matching 50-ohm cable to 300 ohms (actually to 312.5 ohms, a 6.25:1 ratio) and to 450 ohms, as well as 50-ohm cable to 8 and 5.6 ohms. Also included are two different versions of 6.25:1 Baluns. One is a series-type using a 1.56:1 Unun in series with a 4:1 Guanella Balun and the other a series-parallel arrangement using two 4:1 Guanella Baluns. Because the series-parallel Balun adds voltages of equal delays, you'll find its high-frequency capability is much greater.

The 9:1 Balun is a conventional Guanella Balun with three transmission lines connected in series at the high-impedance side and in parallel at the low-impedance side. Therefore, it also sums voltages of equal delays. Some of the comparisons and analyses of these 6.25:1 and 9:1 Baluns were probably published for the first time in my Winter 1993 *Communications Quarterly* article.

Sec 11.2.1 6.25:1 Series-Type Baluns

Figure 11-1 shows the schematic diagram of a series-type Balun designed to match 50-ohm cable to a balanced load of 312.5 ohms. It consists of a 1:1.56 Unun in series with a 1:4 Guanella Balun. The overall ratio of 1:6.25 should satisfy most of the 1:6 requirements. **Photo 11-A** shows three examples. All three Baluns use the same step-up Unun that has four quintufilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 9-10 is No. 14 H Thermaleze wire and the other four are No. 16 H Thermaleze wire. Because this Unun sums only one delayed voltage with four equal direct voltages, it has an excellent high-frequency response.[2]

The Balun on the left in **Photo 11-A** has eight bifilar turns of No. 18 hook-up wire on each transmission line of its 1:4 Balun. The wires are further spaced with No. 18 Teflon tubing providing a characteristic impedance close to 150 ohms (the optimum value). The ferrite toroid has a 2.4-inch OD and a permeability of 250. When matching 50-ohm cable to a floating

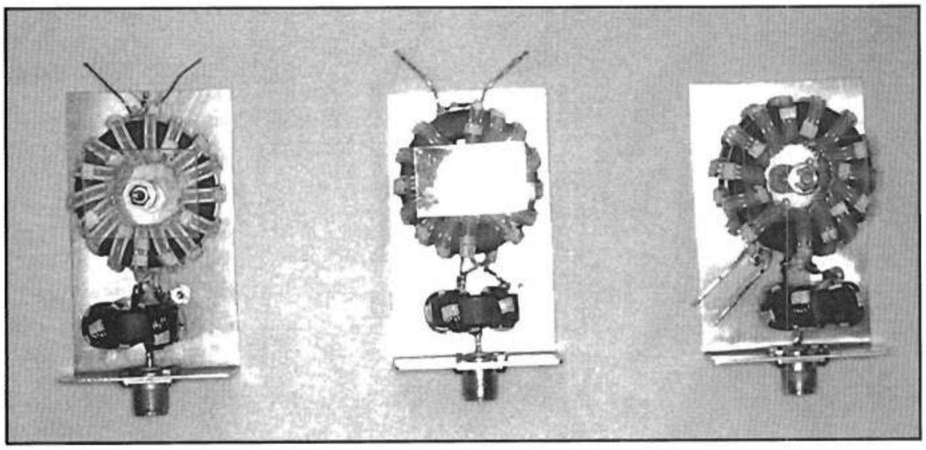

Photo 11-A. *Three examples of series-type 1:6.25 Baluns. The Balun on the right, with a double-core 1:4 Balun, has both a balanced voltage and current output. The other two only have balanced-current outputs.*

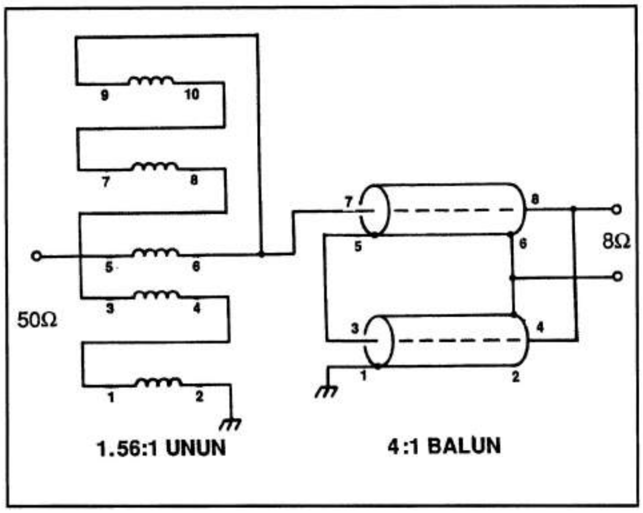

Figure 11-2. *Schematic diagram of the series-type Balun with a 6.25:1 ratio designed to match 50 to 8 ohms.*

load of 312.5 ohms, the response is essentially flat from 1.7 to 30 MHz. Under matched conditions, 500 watts of continuous power and 1 kW of peak power is a conservative power rating. Because the 1:4 Balun in this series-type 1:6.25 Balun uses only one core instead of two, this transformer should never be used when the load is grounded at its center. Also, it is not recommended for balanced antennas. This series-type Balun presents balanced currents, but does *not* present balanced voltages.

The Balun in the center of **Photo 11-A** has seven bifilar turns of No. 16 SF Formvar wire on each transmission line on its 1:4 Balun. The wires are covered with Telfon sleeving and further separated by No. 16 Teflon tubing. Like the Balun on the left, the characteristic impedance is also close to the objective of 150 ohms. The toroid also has a 2.4-inch OD and a permeability of 250. When matching 50-ohm cable to a floating load of 312.5 ohms, the response is essentially flat from 3.5 to 30 MHz. Over this frequency range, this Balun can easily handle the full legal limit of amateur radio power. Because this Balun also presents balanced currents and not balanced voltages, it should not be used when the loads are balanced to ground or grounded at their centers.

The Balun on the right in **Photo 11-A** has 14 bifilar turns of No. 16 SF Formvar wire on each of the two toroids of the 1:4 Balun. The wires are also covered with Teflon sleeving and further separated by No. 16 Teflon tubing. For ease of connection, one core is wound clockwise and the other counterclockwise. The two cores are spaced 1/4 inch apart with acrylic sections. When matching 50-ohm cable to a 312.5 load that is either floating, balanced to ground, grounded at its center, or grounded at its bottom (a broadband Unun), the response is essentially flat from 1.7 to 30 MHz. Under this matched condition, it can easily handle the full legal limit of amateur radio power. Furthermore, this is a true Balun because it presents equal currents and equal voltages. If one were to measure the voltages-to-ground, when matching into a balanced load, one would find them to be equal and opposite. The other two 1:6.25 Baluns using single-core 1:4 Baluns, would have equal currents but not equal voltages (see **Chapter 8**). Because they are easier to construct, it would be interesting to compare them with a true Balun.

Figure 11-2 shows the schematic diagram of a series-type Balun designed to match 50-ohm cable to a balanced load of 8 ohms (perhaps a short-boom Yagi). It consists of a 1.56:1 step-down Unun in series with a Guanella 4:1 step-down Balun. The overall ratio is 6.25:1. **Photo 11-B** shows two examples. Both Baluns use the same step-down Unun, which has four quintufilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 5-6 is No. 14 H Thermaleze wire and the other four are No. 16 H Thermaleze wire. The interleaving of the wires is such that the performance is optimized for matching 50 to 32 ohms.

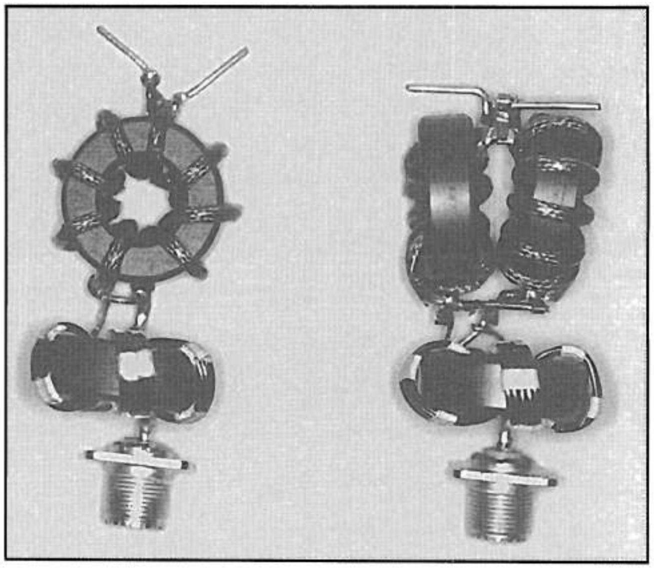

Photo 11-B. *Two examples of the series-type 6.25:1 Balun optimized at the 50:8-ohm level. The Balun on the left is designed to match into a floating 8-ohm load. The Balun on the right is designed to match into an 8-ohm floating, center-tapped-to-ground or grounded load (Unun).*

The Balun on the left in **Photo 11-B** has four turns of low-impedance coaxial cable on each transmission line on the single-core 4:1 Balun. The inner conductor is No. 14 H Thermaleze wire, and it has two layers of Scotch No. 92 polyimide tape. The outer braid is from a small coax (or 1/8-inch tubular braid) and is tightly wrapped with Scotch No. 92 tape to achieve the 17-ohm characteristic impedance (the optimum value). The ferrite toroid has a 1.5-inch OD and a permeability of 250. When matching 50-ohm cable to a floating load of 8 ohms, the response is flat from 1 to 40 MHz. In a matched condition, this Balun can easily handle the full legal limit of amateur radio power.

The Balun on the right in **Photo 11-B** has six turns of the same coaxial cable on each of the two cores of the Guanella step-down Balun. The cores also have a 1.5-inch OD and a permeability of 250. The performance of this Balun is practically the same as the above with the single-core 4:1 Balun. The important differences are that this 6.25:1 Balun also performs equally well whether the load is center-tapped-to-ground, balanced-to-ground, or grounded at the bottom (a broadband Unun). This is the one recommended for feeding a short-spaced Yagi beam antenna.

Sec 11.2.2 6.25:1 Parallel-Type Baluns

The 6.25:1 series-type Baluns described in the preceding section consisted of a 1.56:1 Unun, which is an extension of Ruthroff's bootstrap approach for Ununs,[9] in series with a Guanella 4:1 Balun.[2] The upper-frequency limit for this combination is really set by the Unun, which sums a delayed voltage with four direct voltages. The parallel-type 6.25:1 Baluns described in this section are really extensions of Guanella's approach, which sums voltages of equal delays. Therefore, the upper-frequency limit is mainly dependent upon the parasitics in the interconnections.

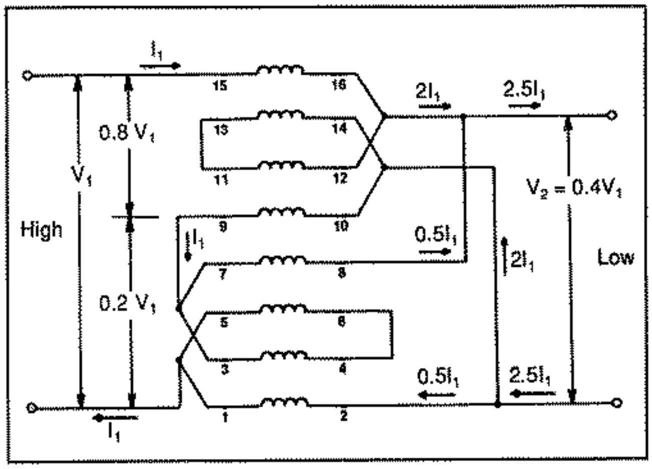

Figure 11-3. *Schematic diagram of the parallel-type Balun (and Unun) with a 6.25:1 ratio. The currents and voltages are shown for analysis purposes (see text).*

The 6.25:1 parallel-type Balun uses two 4:1 Guanella Baluns connected in parallel on the low-impedance side and in series on the high-impedance side. As you will see, one of the Baluns is reversed, giving the desired ratio of 6.25:1. Other combinations can produce different fractional-ratios (other than $1{:}n^2$ where n is 1, 2, 3, . . .), like 2.25:1 and 1.78:1. Because very little practical design information is available regarding this family of very broadband Baluns,[26,27] this section also includes my high-frequency analysis of the 6.25:1 parallel-type Balun. It should also be pointed out that very little sacrifice in performance occurs whether the load is grounded at its center or at the bottom (as an Unun).

Figure 11-3 shows the coiled-wire version of the 6.25:1 parallel-type Balun. For analysis purposes, the voltages and currents are also shown. As can be seen, the top 4:1 Balun is connected as a step-down Balun, while the bottom 4:1 Balun is connected as a step-up Balun. The Baluns are in series on the high-impedance side (on the left) and in parallel on the low-impedance side (on the right). As **Figure 11-3** illustrates, the lower 1:4 Balun adds a current of $0.5I_1$ to the load, resulting in a total current of $2.5I_1$. Thus, the impedance transformation ratio is 2.5^2, or 6.25:1.

For maximum high-frequency response, each transmission line should see a load equal to its characteristic impedance. In other words, they should be "flat" lines. If the high side on the left is 50 ohms, then 40 ohms appears on the input of the top Balun and 10 ohms on the input of the bottom Balun. Consequently, the optimum characteristic impedance for *all* transmission lines is 20 ohms. On the low-impedance side on the right, the top Balun wants to see 10 ohms, while the bottom Balun wants to see 40 ohms. Because 10 ohms in parallel with 40 ohms equals 8 ohms, each Balun conveniently sees its ideal load and a broadband ratio of 6.25:1 is obtained.

If the Balun is required to match 50-ohm cable (on the right side) to a balanced load of 312.5 ohms (on the left side), the same analysis shows that the optimum characteristic impedance of all the transmission lines is 125 ohms.

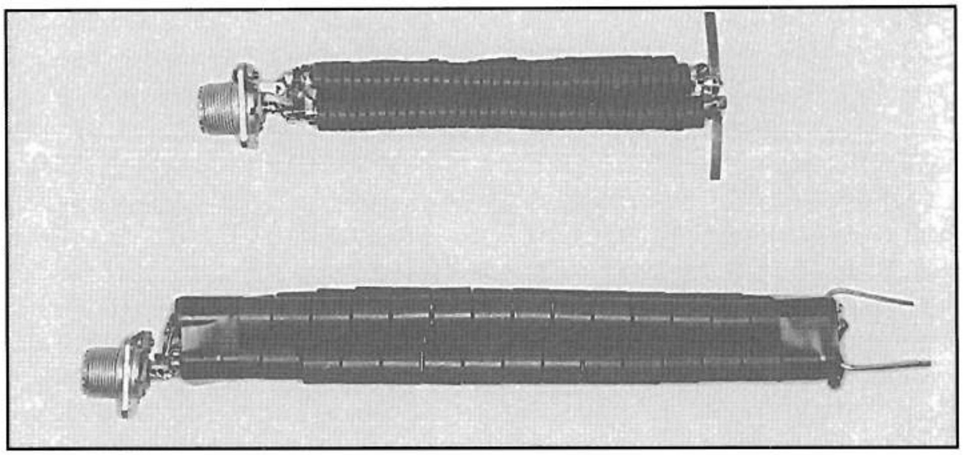

Photo 11-C. *Two beaded-line versions of the parallel-type 6.25:1 Balun (and Unun). The top transformer is designed to match 50-ohm cable to 8 ohms. The bottom transformer is designed to match 50-ohm cable to 312.5 ohms.*

Because the parallel-type Balun (or Unun) sums voltages of equal delays and, therefore, has no built-in high-frequency cut-off, it has a real advantage over the series-type Balun on the VHF bands and above. Furthermore, beaded transmission lines with low-permeability ferrite beads (125 and less) can be used, resulting in high efficiencies. On the HF band, where coiled windings are generally used, the series-type Balun is preferred because of its simplicity.

Photo 11-C shows two beaded-line 6.25:1 transformers. The top Balun, designed to match 50-ohm cable (on the left) to 8 ohms (on the right), uses low-impedance coaxial cable lines. The schematic diagram is shown in **Figure 11-4**. It has 5 inches of 0.375-inch OD beads (permeability 125) on four coaxial cables with characteristic impedances of 20 ohms. The inner-conductors of No. 12 H Thermaleze wire have two layers of Scotch No. 92 polyimide tape. The outer braids, from small coaxial cable or 1/8-inch tubular braid, are also wrapped tightly with the same tape in order to preserve the 20-ohm characteristic impedance. When matching 50 ohms to 8 ohms, the response is essentially flat from 10 MHz to beyond 100 MHz (the limit of my simple bridge). Under this matched condition, this Balun can easily handle the full legal limit of amateur radio power. Furthermore, it has practically the same performance when operating as an Unun (both terminals 1 and 2 grounded). In the Unun application, the bottom transmission line has no voltage along it and, therefore, requires no beads.

The bottom Balun in **Photo 11-C**, which is designed to match 50-ohm cable to a balanced load of 312.5 ohms, has 8 inches of 0.5-inch OD beads on 125-ohm twin-lead transmission lines. The ferrite beads also have a permeability of 125. The wires are No. 14 H Thermaleze wire and are covered with Teflon sleeving. They are further separated by No. 18 Teflon tubing. When matching 50-ohm cable (on the right side) to 312.5 ohms (on the left side), the response is essentially flat from 20 MHz to over 100 MHz. Under this matched condition, this Balun can also easily handle the full legal limit of amateur radio power. Additionally, this transformer performs practically as well when used as an Unun.

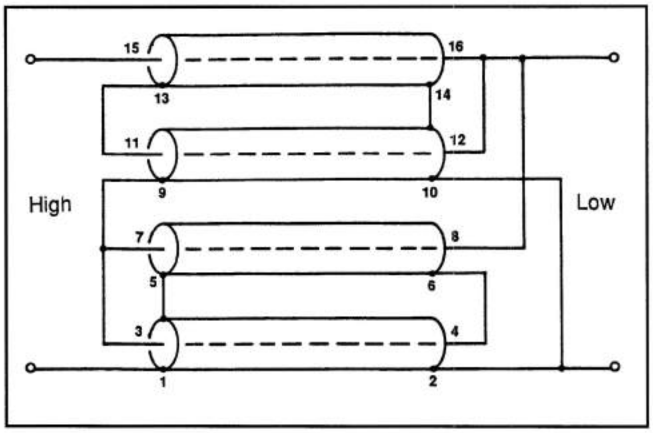

Figure 11-4. *Schematic diagram of the coaxial-cable version of the parallel-type 6.25:1 Balun (and Unun).*

Sec 11.3 9:1 Baluns

The broadband 9:1 Balun, matching 50-ohm cable to a balanced load of 450 ohms, is one of the most difficult ones to construct because high-impedance transmission lines (150 ohms) are required for maximum high-frequency response, and greater reactances are needed in order to isolate the input from the output. So one can appreciate the task at hand, this section also provides a brief review of the theory of these devices.[2]

Figure 11-5 shows the high- and low-frequency models of the Guanella 9:1 Balun that connect three transmission lines in series at the high-impedance side and in parallel at the low-impedance side. Because Guanella's Baluns (which can be easily converted to Ununs) sum voltages of equal delays, they offer the highest frequency capability.

The high-frequency model (**Figure 11-5A**) assumes there is sufficient choking reactance in the coiled (or beaded) transmission lines to isolate the input from the output and only allow transmission line currents to flow. Under this condition, the analysis is rather straightforward as it only involves transmission line theory. Simply stated—the maximum high-frequency response occurs when each transmission line is terminated in a load equal to its characteristic impedance, Z_0. Thus, the transmission lines in the 9:1 Balun have no standing waves. Because each transmission line sees one third of the load, the optimum value of Z_0 is $R_L/3$. Except for parasitics in the interconnections and self-resonances in coiled windings, Guanella's approach is literally "frequency independent."

On the other hand, the low-frequency analysis of the Guanella 9:1 Balun is most important because it reveals the major difficulty in designing them for low-loss, wideband operation. **Figure 11-5B** is the model for determining the low-frequency response. It assumes that no energy is transmitted to the load by a transmission line mode. Although the terminology and analysis is the same as that used for conventional autotransformers, the similarity ends when there is sufficient choking reactance to only allow for the efficient transmission line mode.

As with conventional transformers, one can analyze the low-frequency response of the 9:1 Balun from either the low- or high-impedance side. By putting the generator on the low-impedance side in **Figure 11-5B**, I've chosen to analyze it from that side. With the output open-circuited, the generator sees four coiled (or beaded) lines connected in series-parallel. The net result is that the generator sees the reactance of only *one* coiled (or beaded) line. To prevent a shunting current to ground (and/or autotransformer operation), the reactance the generator sees should be much greater than R_g (at least by a factor of 10 at the lowest frequency of interest). The inductance of the coiled or beaded line that prevents the unwanted currents is still known as the magnetizing inductance, L_M.

What's important to note here is that the low-frequency model of the Guanella 4:1 Balun does not have the series-parallel combination of coiled or beaded lines.[2] Only two lines, which are in series, exist in its model. Therefore, for a two-core Guanella 4:1 Balun having the same number of turns (and same cores) as a 9:1 Guanella Balun, its low-frequency response is better by a factor of two!

Another advantage that goes to the Guanella 4:1 Balun when matching 50 to 200 ohms, is in the number of turns that can be wound on the same cores. Since 4:1 Baluns require characteristic impedances of 100 ohms (instead of 150), the width of the transmission lines is considerably less, thus allowing for more turns. Also, as will be shown later, the efficiency of the 4:1 Balun is greater because the potential drops

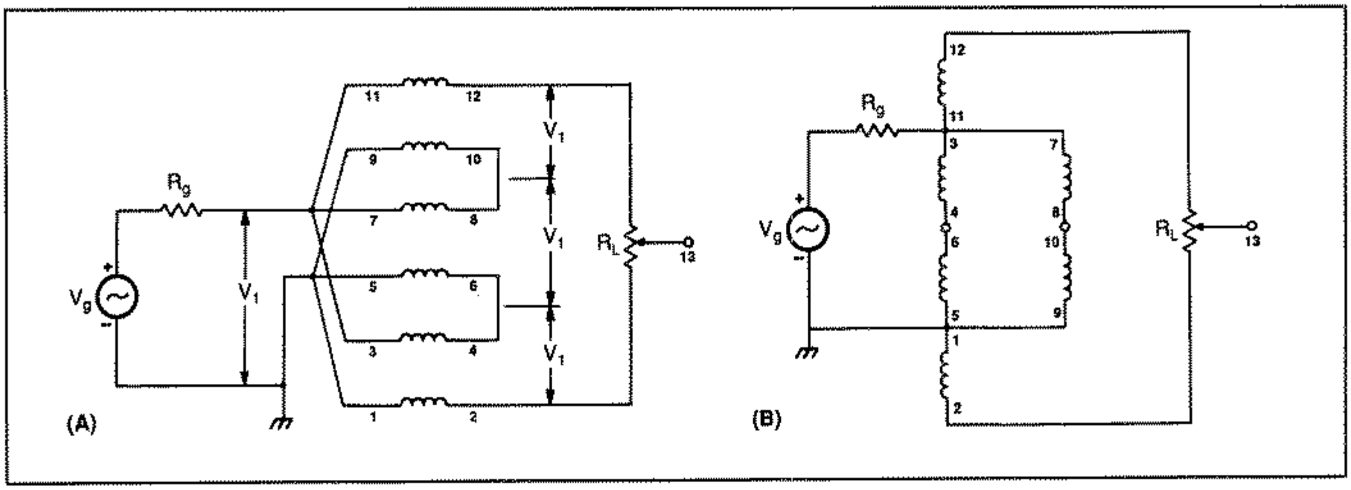

Figure 11-5. *Models of Guanella's 1:9 Balun. The high-frequency model, (A), assumes that* $Z_0 = R_L/3$, *and therefore* V_2, *the output of each transmission line, equals* V_1. *The low-frequency model, (B), assumes no energy is transmitted to the load,* R_L, *by a transmission line mode.*

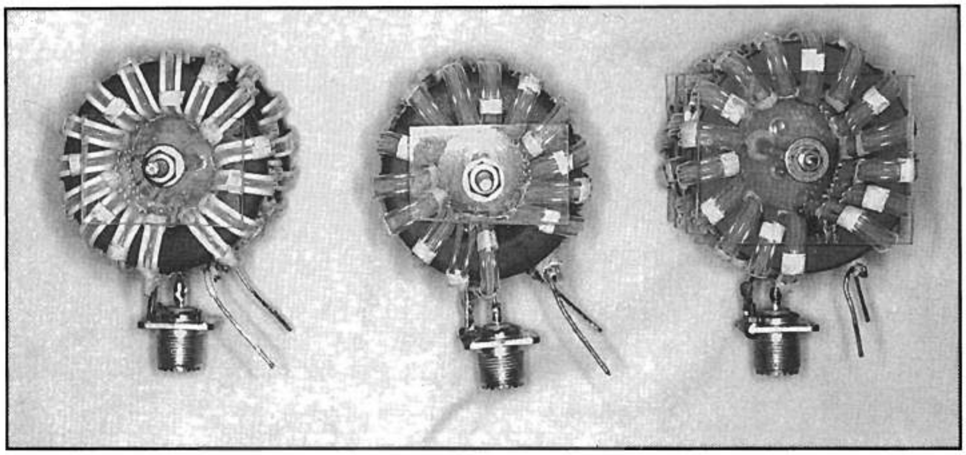

Photo 11-D. *Three broadband Guanella 9:1 Baluns designed to match 50-ohm cable to 450 ohms. The transformer on the left, using No. 18 hook-up wire, can handle 500 watts from 1.7 to 45 MHz. The transformer in the center, using No. 16 wire, can handle 1 kW from 3.5 to 45 MHz. The transformer on the right (with larger cores), using No. 16 wire, can handle 1 kW from 1.7 to 45 MHz.*

along the transmission lines are lower (less dielectric loss). Finally, as you can see from **Figure 11-5B**, by also grounding terminal 2 (Unun operation), windings 1-2 and 3-4 are both shorted—degrading the low-frequency response because L_M is reduced by one third.

Another interesting analysis with Baluns and Ununs concerns the potential gradients (voltage drops) along the transmission lines. Because the loss with these transformers, when transferring the energy via a transmission line mode, is a dielectric-type (voltage dependent), the higher the gradient, the greater the loss. The interesting cases occur when the load is: a) floating, b) grounded at the center, and c) grounded at the bottom (an Unun).

Floating load. With terminal 13 in **Figure 11-5A** ungrounded, the top transmission line has a gradient of $+V_1$ and the bottom transmission line has a gradient of $-V_1$. The center transmission line has a gradient of zero. Therefore, the center transmission line only acts as a delay line and doesn't require a magnetic core or beads. As a result, the top and bottom cores (or beads) account for the dielectric loss.

Load grounded at the center. With terminal 13 grounded at the center of the load, the top transmission line has a gradient of $+V_1$, the bottom transmission line has a gradient of $-V_1$, and the center transmission line has a gradient of $-V_1/2$. This configuration results in about 25 percent more loss because of the extra gradient along the center transmission line. Incidentally, this condition exists when matching into balanced systems like 450-ohm transmission lines or antennas because they have virtual grounds at the center of the loads they present.

Load grounded at the bottom. With terminal 13 grounded at the bottom of the load (an Unun), the top and center transmission lines have gradients of $+V_1$. The bottom transmission line has no gradient and, therefore, no loss. It only acts as a delay line and thus requires no magnetic core or beads.

Sec 11.3.1 Some Practical 9:1 Balun Designs

Photo 11-D shows three versions of the broadband Guanella 9:1 Balun designed to match 50-ohm cable to 450-ohm loads. The transformer on the left has 15 bifilar turns of No. 18 hook-up wire on each of the three ferrite toroids with a 2.4-inch OD and permeability of 250. The wires are further separated by No. 16 Teflon tubing, resulting in a characteristic impedance close to 150 ohms (the optimum value). The cores in this Balun, as well as the other two that follow, are spaced 1/4 inch apart by sections of acrylic. In matching 50 to 450 ohms, the response is essentially flat from 1.7 to 45 MHz. In this matched condition, this transformer can easily handle 500 watts of continuous power and 1 kW of peak power.

The transformer in the center of **Photo 11-D** has 14 bifilar turns of No. 16 SF Formvar wire on each of the three ferrite toroids with a 2.4-inch OD and permeability of 250. The wires are covered with Teflon sleeving and further separated by No. 16 Teflon tubing. The characteristic impedance is also close to the optimum value of 150 ohms. In matching 50 to 450 ohms, the response is essentially flat from 3.5 to 45 MHz. In this matched condition, this transformer can easily handle 1 kW of continuous power and 2 kW of peak power. **Photo 11-E** shows this Balun mounted in a minibox 6 inches long by 5 inches wide by 4 inches high.

The transformer on the right in **Photo 11-D** is designed to handle 1 kW of continuous power and 2 kW

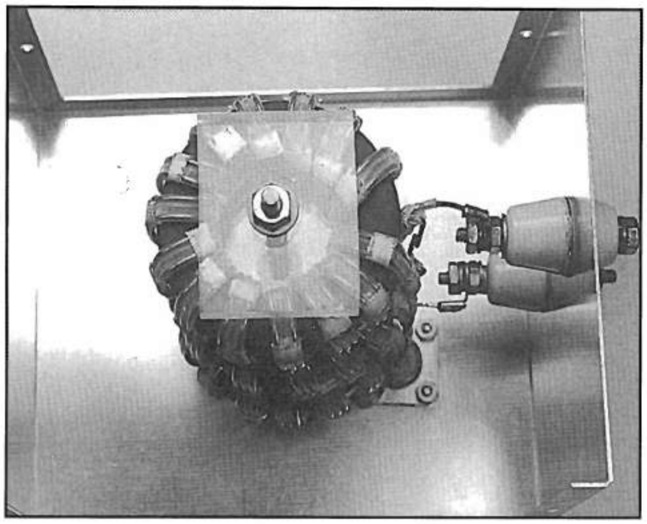

Photo 11-E. *The Guanella 9:1 Balun shown mounted in a large minibox.*

of peak power from 1.7 to 45 MHz. Because this transformer uses larger cores with slightly higher permeabilities (2.68-inch OD and 290 permeability), which are not as popular as those used in the other two Baluns, it is much more expensive to construct. It has 16 bifilar turns of No. 16 SF Formvar wire on each toroid. The wires are covered with No. 16 Teflon sleeving and further separated with No. 16 Teflon tubing. In matching 50 to 450 ohms, the response is flat from 1.7 to 45 MHz.

Finally, **Figure 11-6** shows the schematic diagram of a 9:1 Balun (or Unun) using coaxial cables wound around ferrite cores or threaded through ferrite beads. This form of the transformer is especially useful when matching 50-ohm cable to 5.6 ohms because the choking reactance of the magnetizing inductance, L_M, only need be much greater than 5.6 ohms. **Photo 11-F** shows two different designs.

The transformer on the top has 9 1/2 turns of low-impedance coaxial cable on each rod. The rods are 1/2 inch in diameter, 2 1/2 inches long, and have a permeability of 125. The low-frequency response of this Balun is quite insensitive to the length and permeability of the rods.^{2} The inner conductors of the coaxial cables are No. 12 H Thermaleze wire with two layers of Scotch No. 92 tape. The outer braids are made from small coax (or 1/8-inch tubular braid). They are further wrapped with Scotch No. 92 tape to preserve the low-impedance of 17 ohms. In matching 50-ohm cable to 5.6 ohms, the response is essentially flat from 1.7 to 30 MHz. The optimum impedance level was found when matching 40 to 4.45 ohms. The addition of another layer of Scotch No. 92 tape would optimize this transformer at the 50:56-ohm level, and the high-frequency response would exceed 100 MHz. This transformer is very efficient and should handle the full legal limit of amateur radio power easily.

The bottom transformer in **Photo 11-F** is designed to match 50-ohm cable to a load of 5.6 ohms in the VHF band. It uses 3 1/2 inches of beads on three low-impedance coaxial cables. The ferrite beads have an OD of 3/8 inch and a permeability of 125. The inner conductors of the coaxes are No. 12 H Thermaleze wire with one layer of Scotch No. 92 tape. The outer conductors are from small coaxes or 1/8-inch tubular braid, and are also tightly wrapped with Scotch No. 92 tape to preserve the low characteristic impedance. In matching 50-ohm cable to 5.6 ohms, the response is essentially flat from 7 MHz to over 100 MHz (the limit of my test equipment). This 9:1 Balun (which can be used as an Unun) can handle the full legal limit of amateur radio power under matched conditions, because of the low-permeability beads and the low-voltage gradients along the lengths of its transmission lines.

Sec 11.4 Concluding Remarks on 6:1 and 9:1 Baluns

One of the most important properties of broadband Baluns and Ununs (which all use ferrites) is their capability of having extremely high efficiencies. Knowing the loss mechanism in these transformers and the trade-off in low-frequency response for efficiency allows one to optimize their applications. In the paragraphs that follow, I'll discuss the losses and

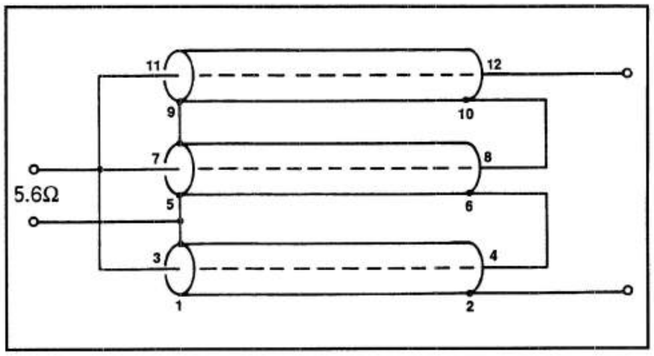

Figure 11-6. *Schematic diagram of a coaxial cable (beaded or coiled) 9:1 Guanella Balun (or Unun). This design is especially useful in matching 50-ohm cable to 5.6 ohms over a very wide bandwidth.*

trade-offs involved with the transformers presented in the preceding sections. The approach used here should be applicable to all forms of transmission line transformers. This section ends with a review of two articles that contained 9:1 Baluns. As you'll see, I have some rather different views on the claims made in these articles.

Accurate measurements on many broadband Ununs have found the losses to be related to the permeability and the impedance level.[2] Permeabilities greater than 300 resulted in excessive losses. Because these losses are unlike the conventional transformer whose losses are current-dependent, it can only be assumed that their losses are voltage dependent; in other words a dielectric-type loss. Therefore, higher-impedance transformers have higher voltage gradients along their transmission line and, thus, have greater losses. Additionally, it was found that the higher the permeability, the greater the loss with frequency. Taking into account the accurate measurements and the factors noted above, I offer these loss values for the transformers in the preceding sections:

1.56:1 Ununs. The 1.56:1 Ununs (either step-up or step-down) used in series with Guanella 4:1 Baluns to form 6.25:1 Baluns have the lowest potential gradients along their transmission lines. Voltage drops of only about 0.2 V_1, where V_1 is the input voltage, exist along their transmission lines. Accurate measurements have shown losses, in a matched condition, of only 0.04 dB. If the cores, which have a permeability of 250, were replaced with cores having a permeability of 125, the losses could be as low as 0.02 dB over much of the passband. The low-frequency response would still be acceptable at 1.7 MHz. This Unun is a natural for matching into 75-ohm hard line when long transmission lines are required.

6.25:1 and 9:1 Low-impedance Baluns. Baluns matching 50-ohm cable to 8 or 5.6 ohms, also have very low voltage drops along their transmission lines. Generally, they are about twice that of the 1.56:1 Unun. Therefore, the losses with these Baluns should be on the order of 0.1 dB in their passbands.

6.25:1 High-impedance Baluns. The losses in the series-type Baluns are mainly in the 1:4 Guanella Baluns, which have potential gradients of about 1.25 V_1, where V_1 is the input voltage. From previous measurements at this impedance level, the suggestion is that the losses (with ferrites of 250 permeability) should be about 0.1 dB at 7 MHz and 0.2 dB at 30 MHz. By using toroids with permeabilities of 125, the losses could be 0.07 dB and 0.15 dB, respectively. However, with a permeability of 40, the losses could be as low as 0.05 dB within the passband. However, one must consider the sacrifice in low-frequency response incurred when using these lower-permeability ferrites. With a permeability of 125, it's poorer by a factor of 2. With a permeability of 40, it's poorer by a factor of 8! The 6.25:1 parallel-type Balun in this article uses ferrite beads with a permeability of 125 and, therefore, should have losses similar to its series-type counterpart.

9:1 High-impedance Baluns. As was shown in the preceding section, the potential gradient along two of the transmission lines is V_1, where V_1 is the input voltage. The third transmission line, with a balanced load (or as an Unun), has no potential gradient and, consequently, no loss in its core. Because the loss with the series-type Balun mainly exists in one core, the loss with the 1:9 Balun should be a little less than twice as great. With ferrite cores of 250 permeability, the suggested losses are 0.2 dB at 7 MHz and 0.4 dB at 30 MHz. With cores of 125 permeability, the losses are about 0.14 and 0.28 dB, respectively. Again, by using cores with permeabilities of 40, the losses are practically negligible—approximately 0.1 dB within its passband.

As in the case of the 1:6.25 Baluns above, similar trade-offs occur in the low-frequency response. That is, if 125 permeability cores are used, the low-frequency response is poorer by a factor of 2; with 40 permeability cores, it's poorer by a factor of 8. The major difference here is that the low-frequency performance of the

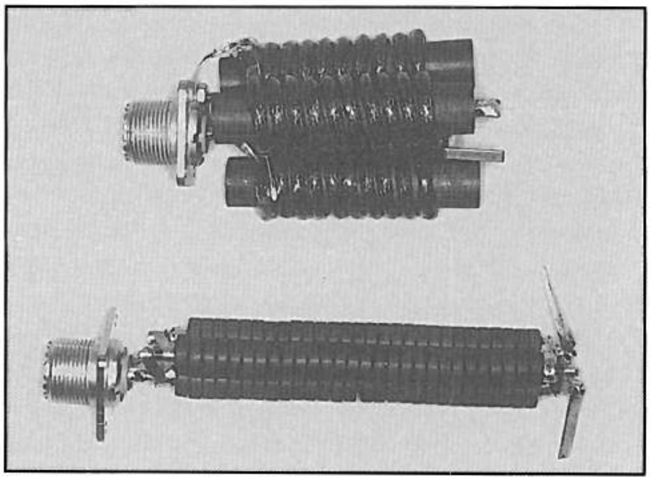

Photo 11-F. *Two versions of the coaxial-cable 9:1 Guanella Balun (or Unun) designed to match 50-ohm cable to 5.6 ohms*

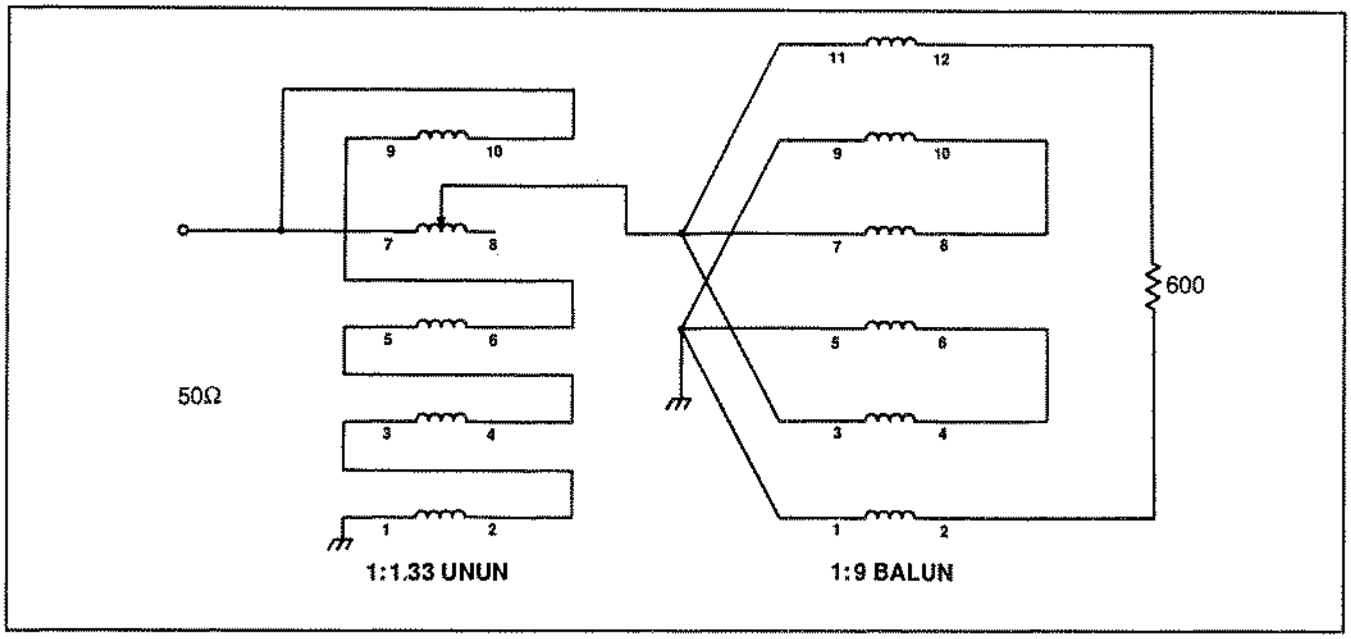

Figure 11-7. *Schematic diagram of the series-type 12:1 Balun using a 1:1.33 Unun in series with a 1:9 Guanella Balun.*

9:1 Balun, as seen by its low-frequency model, isn't as good as the 4:1 Balun that controls the low-frequency response of the series-type 1:6.25 Balun. Additionally, it should be pointed out that all of the suggested losses for the transformers in this chapter are for matched conditions—that is with VSWRs of 1:1. If the VSWR is 2:1 due to a load twice as large as the objective, the input voltage to the Balun increases by about 40 percent. Therefore, the losses should increase by close to the same percentage.

In closing this section, I would like to report my findings on two recent articles in amateur radio journals that also described 9:1 Baluns matching 50-ohm cable to 450 ohms. One[5] advocated using three 150-ohm coaxial cables threaded through high-permeability ferrite beads—a 9:1 Guanella Balun. Because of the low voltage-breakdown capability of the coaxial cable and the high loss found by accurate measurements on Ununs using these high-permeability ferrites, the design was suspect. I built a copy of the design and found it to be, as expected, unable to handle any appreciable power. The second article[28] advocated using 14 trifilar turns of "magnet wire" on a 2-inch OD powdered-iron core (permeability of 10). This Balun was also constructed and tested. Again, as was expected, when matching 50-ohm cable to a floating load of 450 ohms, the 9:1 Balun barely reached a true 9:1 ratio at 7 MHz. Above 7 MHz, the ratio became greater than 9:1 and also introduced a reactive component. Below 7 MHz, there was insufficient choking reactance to prevent flux in the core. My three objections to this design are: 1) a trifilar design has a poor high-frequency response because it sums a direct voltage with a delayed voltage that traverses a single transmission line and a delayed voltage that traverses two transmission lines, 2) the characteristic impedances of the transmission lines are only 50 ohms (the objective is 150 ohms), and 3) the low-frequency response is poor because of the low-permeability powdered-iron core. I do not recommend either of the designs in these two articles.

Sec 11.5 12:1 Baluns

Over the years, the broadband, 12:1 Balun has been of special interest to users of rhombic and V antennas. With the aid of this Balun, certain advantages over multi-element arrays can be fully exploited. Rhombics and Vs are easier to construct, both electrically and mechanically, and there are no particularly critical dimensions or adjustments. Furthermore, they give satisfactory gain and directivity over a 2-to-1 frequency range. These antennas have also been found to be more effective in reception. Because their designs can present input impedances of 600 ohms, and very long lengths of highly efficient 600-ohm open-wire line can be used between the shack and the antenna, an efficient and broadband 12:1 Balun is a natural for

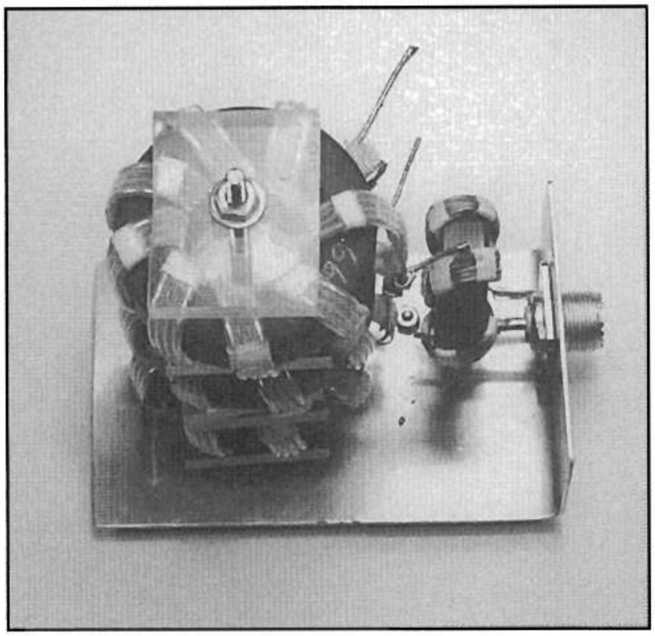

Photo 11-G. *Top view of the high-power 12:1 Balun.*

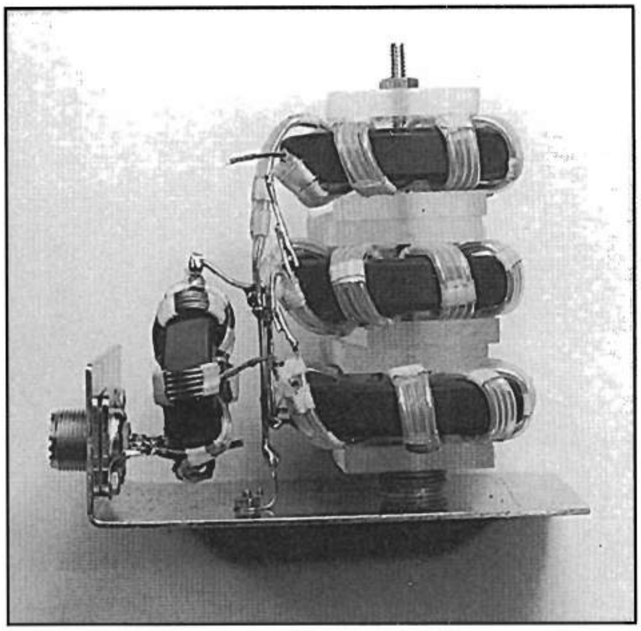

Photo 11-H. *Side view of the high-power 12:1 Balun.*

this application. However, to my knowledge, satisfactory Baluns have not been available for this use.

I will present two versions of a series-type Balun designed to match 50-ohm cable to a balanced load of 600 ohms. One is a high-power unit designed to handle the full legal limit of amateur radio power over a bandwidth of 7 to 30 MHz. The other is a medium-power unit capable of handling approximately one-half the legal limit of amateur radio power from 3.5 to 30 MHz. Both Baluns use a 1:1.33 Unun in series with a 1:9 Guanella Balun.

As you will see, these Baluns are not especially easy to design and construct. The major difficulties lie in trying to obtain sufficient choking reactances in the coiled windings to meet the low-frequency requirements, and large enough characteristic impedances of the windings to meet the high-frequency requirements. Because a coiled winding with a characteristic impedance of 200 ohms (the objective) is practically impossible to obtain with any reasonable wire size and number of turns, I used the compensating technique first described in my book.[2] Because the characteristic impedances of the 9:1 Guanella Balun are somewhat less than 200 ohms, a compensating effect (and hence higher frequency response) can be obtained by having a higher (than the normal objective) characteristic impedance of the windings in the 1:1.33 Unun. Earlier work (also described in my book) presented a 12:1 Balun using a 1:3 Unun in series with a 1:4 Ruthroff Balun. The Baluns presented in this section using a 1:1.33 Unun in series with a Guanella 1:9 Balun, are much improved designs.

Sec 11.5.1 A High-power 12:1 Balun

Figure 11-7 shows the schematic diagram of the series-type 12:1 Balun used in both the high- and medium-power versions. **Photo 11-G** shows a top view of the high-power Balun. **Photo 11-H** shows a side view.

The 1:1.33 Unun has 5 quintufilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 7-8 is No. 14 H Thermaleze wire and the other four are No. 16 H Thermaleze wire. Winding 7-8 is also tapped at 3 turns from terminal 7.

The 1:9 Guanella Balun has 8 bifilar turns of tinned No. 16 wire on each of the three toroids. Each wire is covered with Teflon tubing and further separated by two Teflon tubings. The characteristic impedance of the windings is about 190 ohms (the objective is 200 ohms). The ferrite toroids have an OD of 2.4 inches and a permeability of 250. The spacing between the toroids is 1/2 inch.

In matching 50-ohm cable to a balanced load of 600 ohms, the response is literally flat (within a percent or two) from 7 to 30 MHz. Within this bandwidth, it is capable of handling the full legal limit of amateur

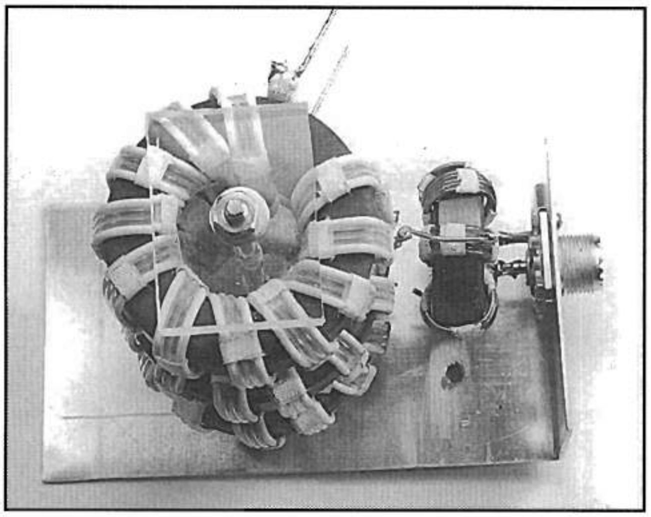

Photo 11-I. *Top view of the medium-power 12:1 Balun.*

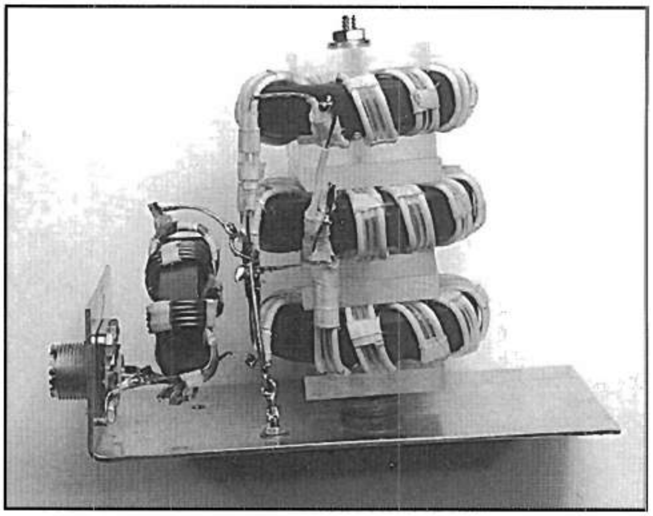

Photo 11-J. *Side view of the medium-power 12:1 Balun.*

radio power. In a matched condition, the expected insertion loss is about 0.25 dB.

Sec 11.5.2 A Medium-power 12:1 Balun

Photo 11-I shows the top view of the medium-power 12:1 series-type Balun. **Photo 11-J** shows the side view. This Balun also has the same 1:1.33 Unun as described earlier.

The 1:9 Guanella Balun has 11 bifilar turns of No. 18 hook-up wire on each toroid. The wires are further separated by two No. 18 Teflon tubings. The characteristic impedance of the windings is about 170 ohms. The toroids have an OD of 2.4 inches and a permeability of 250. The spacing between the toroids is also 1/2 inch.

In matching 50-ohm cable to a balanced load of 600 ohms, the response varies less than 5 percent from 3.5 to 30 MHz. Within this bandwidth, the Balun can handle about one-half the legal limit of amateur radio power. As with the high-power version, the expected insertion loss is also 0.25 dB.

Sec 11.6 Concluding Remarks on 12:1 Baluns

Many of the concluding remarks from the discussion on 6:1 and 9:1 Baluns (**Sec 11.4**) also apply to 12:1 Baluns; therefore, I won't repeat them here. But the following four remarks are specific to 12:1 Baluns and warrant mentioning:

First, high-impedance transmission line transformers like the 12:1 Balun are particularly sensitive to metallic enclosures. If a minibox were to be used, I would suggest the one shown in **Photo 11-E**, which is 6 inches long by 5 inches wide by 4 inches high. Smaller metallic enclosures would reduce the characteristic impedances of the windings and affect the high-frequency response. Even the spacing between cores had to be increased from 1/4 inch (for a 50:450-ohm Balun) to 1/2 inch. The subchassis shown in the photographs were used because they provided the necessary electrical and mechanical support.

Second, the 12:1 Baluns described in this section also make excellent Ununs, albeit with some compromise in the low-frequency response. I would suggest using the high-power unit only between 14 and 30 MHz and the medium-power unit only between 7 and 30 MHz.

Third, for the readers interested in VHF operation, I would suggest the parallel-type approach described in the earlier section on 6:1 Baluns. In this case, a 9:1 Guanella Balun is connected in series-parallel with a 1:4 Guanella Balun. This would produce a broadband ratio of 12.25:1. By using 170-ohm twin-lead (about 10 inches long) threaded through ferrite beads with a permeability of 125, it appears that it is possible to match 50-ohm cable to a balanced load of 612.5 ohms throughout the VHF band.

Fourth, by using torids with a permeability of 125 in the 1:9 Guanella Baluns (of the 12:1 Baluns), the insertion loss would be reduced by around one half (0.12 dB), with a trade-off in low-frequency response. The high-power unit would now cover about 10 to 30 MHz, and the medium-power Balun would cover about 7 to 30 MHz.

Chapter 12

The 4:1 Unun

Sec 12.1 Introduction

From an analysis standpoint, the 4:1 Unun can be said to have received the most attention in the literature. It began with Ruthroff's introduction and complete analysis of this device in his classic paper published in 1959.[9] Ruthroff's paper then became the industry standard for this class of devices known as *transmission line transformers*. These are devices that transmit the energy from the input to the output by an efficient transmission line mode, and not by flux linkages (as in conventional transformers).

However 15 years earlier, Guanella had introduced, in his classic 1944 paper,[3] the first broadband Baluns by combining coiled transmission lines in a series-parallel arrangement, yielding ratios of $1{:}n^2$ where n = 1, 2, 3,... and so on. It has also been shown that Guanella's technique also lends itself to Ununs as well.[2] In fact, in this chapter, you will see that his technique of summing voltages of equal delays promises to yield high-power designs capable of operating on the VHF and UHF bands.

The 4:1 Unun also exemplifies (more than any other transformer) the many choices that can be made in its design. These include: 1) Ruthroff's or Guanella's designs, 2) wire or coaxial cable transmission lines, 3) coiled or beaded lines, 4) rods or toroids, 5) low-power or high-power designs, 6) HF, VHF, or UHF designs, and 7) the trade-offs in efficiency for low-frequency response or for high VSWR. The 4:1 Unun is the most prevalent of all the Ununs. It finds extensive use in solid-state circuits and in many antenna applications involving the matching of ground-fed antennas—where impedances of 12 to 13 ohms must be matched to 50-ohm coaxial cable. This chapter provides information on many 4:1 Unun designs.

Sec 12.2 The Ruthroff 4:1 Unun

Figure 12-1 illustrates two versions of Ruthroff's approach to obtaining a 4:1 unbalanced-to-unbalanced transformer (Unun). As can be seen, one uses a coiled wire transmission line, while the other uses a coiled coaxial cable. Depending upon the frequency, beaded transmission lines may also be used.

Ruthroff's design uses a single transmission line connected in, what I call, the bootstrap configuration. That is, terminal 2 is connected to terminal 3, lifting the transmission line (at the high-impedance side) by the voltage V_1. If the reactance of the coiled winding or beaded line is much greater than R_G, then only flux-canceling transmission line currents are allowed to flow. It is also apparent that the output voltage is the sum of a direct voltage, V_1, and a delayed voltage,

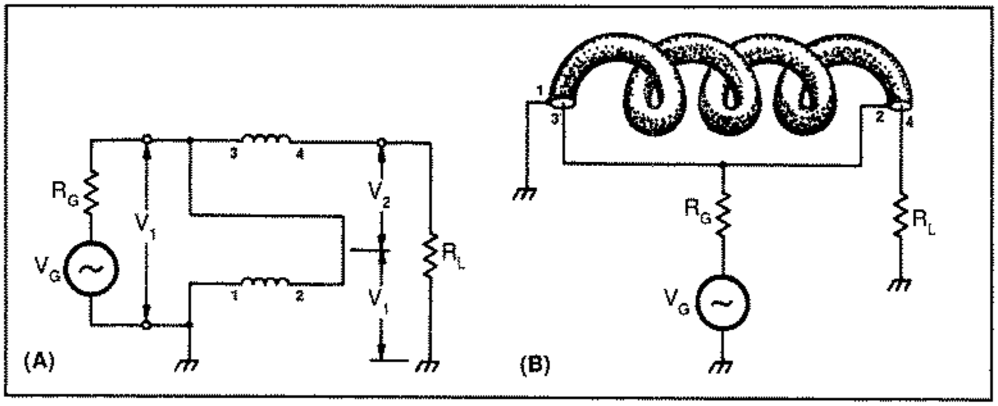

Figure 12-1. *The Ruthroff 4:1 Unun ($R_L=4R_G$): (A) coiled bifilar winding; (B) coiled coaxial cable.*

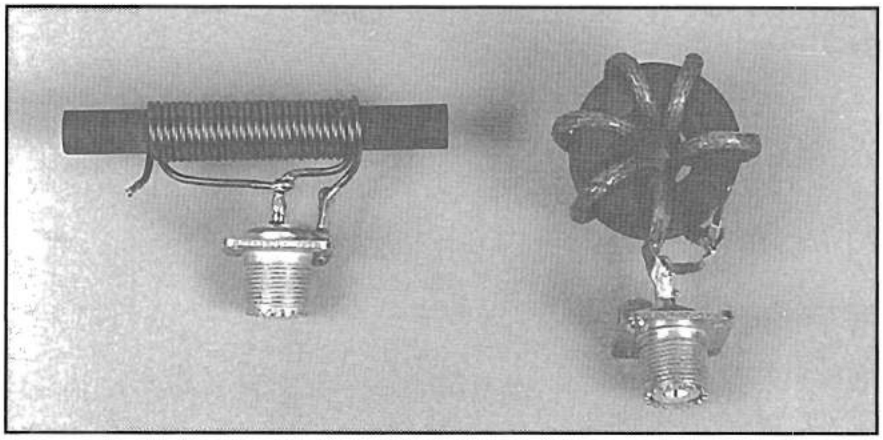

Photo 12-A. *Two versions of the Ruthroff 4:1 (50:12.5-ohm) Unun: coiled wire rod (on the left); coiled coaxial cable toroid (on the right).*

V_2, which traverses a single transmission line. This delay in V_2 eventually limits the high-frequency response. For example, if the electrical length of the line is a 1/2 wave, the output is zero. Ruthroff also found that the optimum value of the characteristic impedance of the transmission line (for maximum high-frequency response) is $R_L/2$.

Therefore, the electrical length and characteristic impedance of the transmission line play major roles in Ruthroff's design. Because his work was mainly concerned with small-signal applications, Ruthroff was able to obtain broad bands of a few tens of kilohertz to over a thousand megahertz. This was possible because he used a few turns (5 to 10) of fine wire (Nos. 37 and 38) on high-permeability toroids as small as 0.08 inches in OD. As a result, the phase-delay with these very short transmission lines was very small. However, large-signal (power) applications present an entirely different picture. For operation in the HF band (including 160 meters), transmission lines vary between one to three feet in length (depending upon impedance level). Consequently, phase-delay can play a major role, as will be seen in the following examples.

Sec. 12.2.1 50:12.5-ohm Ununs

Photo 12-A shows two examples of efficient and broadband 4:1 Ununs matching 50 to 12.5 ohms. The rod version (on the left) has 14 bifilar turns of No. 14 H Thermaleze wire on a low-permeability (125) ferrite rod 0.375 inches in diameter and 3.5 inches long. The connections are shown in **Figure 12-1A**. The cable connector is on the low-impedance side. The response is flat from 1.5 to 30 MHz. In a matched condition, this Unun can easily handle the full legal limit of amateur radio power. Because a tightly wound rod Unun yields a characteristic impedance very close to 25 ohms (the optimum value), this is quite likely the easiest one to construct that covers the above bandwidth.

The toroidal version (on the right in **Photo 12-A**) has 6 turns of homemade, low-impedance coaxial cable on a 1.5-inch OD ferrite toroid with a permeability of 250. The connections are shown in **Figure**

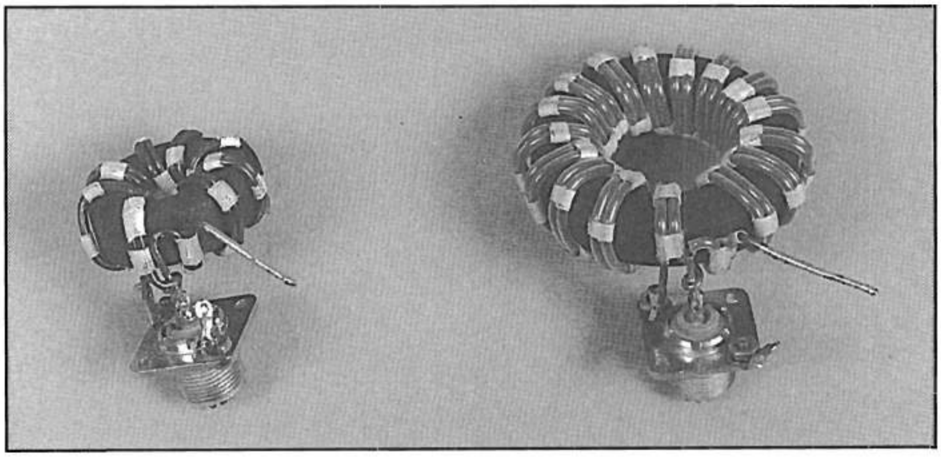

Photo 12-B. *Two higher-impedance Ruthroff 4:1 Ununs: 100:25-ohm (on the left); 200:50-ohm (on the right).*

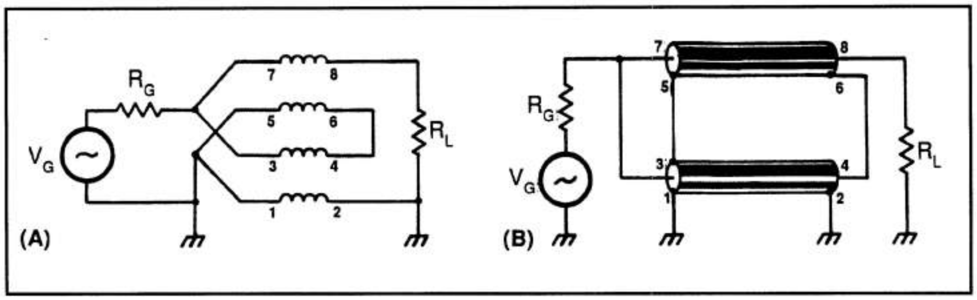

Figure 12-2. *The Guanella 4:1 Unun ($R_L=4R_G$): (A) coiled bifilar windings; (B) coiled or beaded coaxial cables.*

12-1B. The cable connector is on the low-impedance side. The inner conductor is No. 14 H Thermaleze wire and is covered with Teflon tubing. The outer braid is from a small coaxial cable (or from 1/8-inch tubular braid) tightly wrapped with Scotch No. 92 tape in order to obtain the desired characteristic impedance. In matching 50 to 12.5 ohms, the response is flat from 1.5 to 50 MHz. Because the current is evenly distributed on the inner conductor, this small Unun has an exceptionally high power capability—at least 5 kW of continuous power and 10 kW of peak power (in a matched condition).

Sec 12.2.2 100:25-ohm Unun

In some combiner applications, an Unun matching 100 to 25 ohms is required. The smaller toroidal version, pictured on the left in **Photo 12-B**, shows a Ruthroff design that can satisfy many of these requirements. It has 8 bifilar turns of No. 14 H Thermaleze wire on a 1.5-inch OD ferrite toroid with a permeability of 250. One wire is also covered with a single layer of Scotch No. 92 tape, providing a characteristic impedance close to the desired value of 50 ohms. In matching 100 to 25 ohms, the response is essentially flat from 1.5 to 30 MHz. This Unun can easily handle the full legal limit of amateur radio power.

Sec 12.2.3 200:50-ohm Unun

When dealing with this type of Balun, the Ruthroff approach cannot yield the broadband response of the lower-impedance designs shown above. Because more turns are required in order to obtain the necessary choking reactance, and a 100-ohm characteristic impedance that requires more spacing between the wires is used, the cores must be considerably larger. This results in longer transmission lines. Consequently, the high-frequency response is now limited by the greater phase delay of this high-impedance Unun.

The larger transformer, shown on the right in **Photo 12-B** is my optimized version of a Ruthroff 200:50-ohm Unun. It has 16 bifilar turns of No. 14 H Thermaleze wire on a low-permeability (250) 2.4-inch OD ferrite toroid. Each wire is covered with Teflon tubing, resulting in a characteristic impedance of 97 ohms. Because of the long transmission line (36 inches), the impedance transformation ratio (in matching 200 ohms to 50 ohms) varies from 4 to 4.44 from 1.5 to 30 MHz. A conservative power rating (under a matched condition) is 2 kW of continuous power and 4 kW of peak power. Because this higher-impedance Unun has a larger voltage drop along the length of its windings, its loss (a dielectric-type[2]) is a little greater than the lower-impedance Ununs described earlier. In a matched condition, the efficiency is about 97 percent, while the others experience efficiencies of 98 to 99 percent.

Sec 12.3 The Guanella 4:1 Unun

Even though Guanella's investigation[3] was directed toward developing a broadband Balun to match the balanced output of a 100-watt, push-pull, vacuum-tube amplifier to the unbalanced load of a coaxial

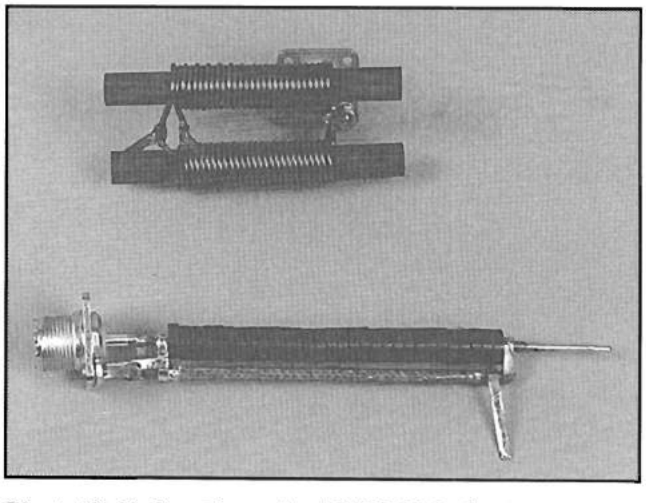

Photo 12-C. *Two Guanella 4:1 (50:12.5-ohm) Ununs: rod version (on the top), 1.5 to 50 MHz; beaded version (on the bottom), 10 MHz to over 100 MHz.*

cable, his technique of connecting transmission lines in a parallel-series arrangement has only recently been recognized as the design for the widest possible bandwidth in an unbalanced-to-unbalanced application.[2] Some have labeled his approach the "equal-delay network".[26] The major difference in Guanella's approach (from Ruthroff's) is that by summing the equal-delay voltages of coiled (or beaded) transmission lines, he minimizes the dependence of the high-frequency response on the lengths of the transmission lines. As was mentioned before, Ruthroff's method of summing a direct voltage with a delayed voltage that traversed a single transmission line has a limited application, especially with high-power, high-impedance Ununs (like 200:50 and 300:75 ohms).

Furthermore, Guanella's approach is also important in designing high- and low-impedance Baluns and Ununs with impedance transformation ratios other than 4:1. Connecting three transmission lines in parallel-series results in a 9:1 ratio, four in a 16:1. Also by connecting a fractional-ratio Unun in series with his Baluns, or by using various combinations of parallel-series transmission lines,[26,27] Ununs and Baluns are now available with a continuum of ratios from 1.36:1 to 16:1. Moreover, these ratios now make it possible to match 50-ohm cable to impedances as low as 3.125 ohms and as high as 800 ohms. A major factor in the success of these designs rests in the understanding of the low-frequency models of these various transformers.[2] This section looks at the 4:1 Unun using Guanella's approach. As in the Ruthroff case, the optimum value of the characteristic impedances of the transmission lines for a Guanella 4:1 transformer is also $R_L/2$.

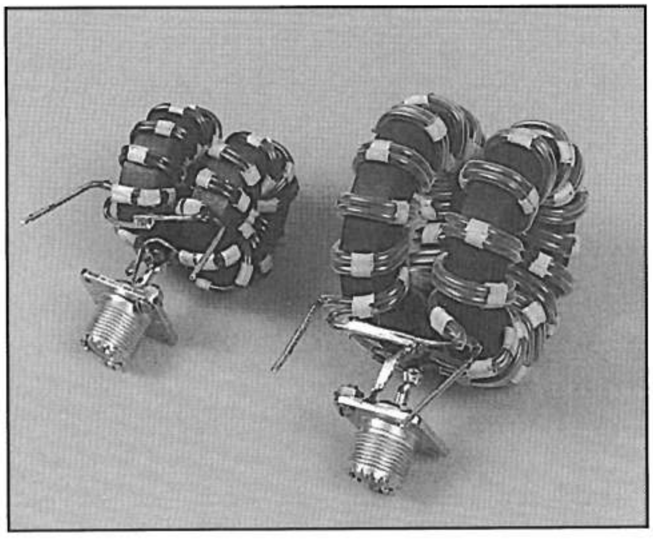

Photo 12-D. *Two higher-impedance Guanella 4:1 Ununs: 100:25-ohm (on the left); 200:50-ohm (on the right).*

Sec 12.3.1 50:12.5-ohm Ununs

Figure 12-2 shows the schematic diagrams of the coiled-wire and coaxial cable (coiled or beaded) versions of 4:1 Ununs using Guanella's technique of connecting transmission lines in parallel-series arrangements. As can be seen in **Figure 12-2**, the lower transmission lines are grounded at both ends and, therefore, have no potential drop along their lengths. Thus, the coiling or beading has no effect. The core only acts as a mechanical support and the beads can be removed. In essence, the bottom transmission line plays the important role of a delay line. In addition, the low-frequency response of this form of Unun is solely determined by the reactance of the top coiled or beaded transmission line.

The top Unun in **Photo 12-C** shows a rod version of Guanella's 4:1 Unun. There are 13.5 bifilar turns of No. 14 H Thermaleze wire on low-permeability (125) ferrite rods 0.375 inches in diameter and 3.5 inches long. For ease of connection, one winding is clockwise and the other is counterclockwise. The cable connector is on the high-impedance side. In matching 50 to 12.5 ohms, the response is flat from 1.5 to over 50 MHz! This Unun, in a matched condition, is capable of handling the full legal limit of amateur radio power. Furthermore, with the 50-ohm generator on the right (in **Figure 12-2A**) and a 12.5-ohm balanced load on the left (perhaps a Yagi beam), this transformer makes an excellent step-down Balun.

The bottom transformer in **Photo 12-C** shows a beaded-coax version of a 50:12.5-ohm step-down Unun designed for 2-meter operation. It has 3.5 inches of beaded coax on the top transmission line (**Figure 12-2B**) and no beads on the bottom transmission line. (Actually, the bottom rod in **Figure 12-2A** can also be removed with no change in performance.) The beads are low-permeability (125) ferrite. The inner conductor of the coaxial cable is No. 12 H Thermaleze wire with about 3.5 layers of Scotch No. 92 tape (two 0.5-inch tapes wound edgewise like a window shade), providing a characteristic impedance close to the optimum value. The outer braid is from a small coaxial cable (or from 1/8-inch tubular braid). This homemade coax is further wrapped tightly with Scotch No. 92 tape in order to preserve its low characteristic impedance. The cable connector is on the low-impedance side. The response of this Unun is essentially flat from 10 to 100 MHz (the limit of my bridge). It can also (easily) handle the full legal limit of amateur radio power.

Sec 12.3.2 100:25-ohm Unun

The Unun on the left in **Photo 12-D** is a Guanella version that matches 100 to 25 ohms. There are 8 bifilar turns of No. 14 H Thermaleze wire on each 1.5-inch OD low-permeability (250) toroid. One toroid is wound clockwise and the other is wound counterclockwise. One of the wires (on each toroid) is covered with one layer of Scotch No. 92 tape. The cable connector is on the low-impedance side. The response is flat from 1.5 MHz to well over 30 MHz. This Unun can also handle the full legal limit of amateur radio power.

It is interesting to note that when used as a Balun (the ground removed from terminal 2), and placed in series (on the left side) with a 1.78:1 Unun (see **Chapter 13**), this compound arrangement provides an excellent Balun for matching 50-ohm coaxial cable directly to quad antennas having impedances of 100 to 110 ohms.

Sec 12.3.3 200:50-ohm Unun

The transformer on the right in **Photo 12-D** is an excellent Unun (or Balun with terminal 2 removed from ground) for matching 50 to 200 ohms. It has 14 bifilar turns of No. 14 H Thermaleze wire on each low-permeability (250) toroid with a 2.4-inch OD. Each wire is covered with Teflon tubing, providing a characteristic impedance of 98 ohms (which is quite good because the optimum value is 100). Again, for ease of connection, one winding is clockwise and the other is counterclockwise. When operating as an Unun or a Balun and matching 50 to 200 ohms, the response is essentially flat from 1.5 to 30 MHz. A conservative power rating (in a matched condition) is 5 kW of continuous power and 10 kW of peak power. This transformer has been reported to handle peak pulses of 10,000 volts!

Summary

Since its introduction by Ruthroff in 1959,[9] the 4:1 Unun has been the most popular transmission line transformer matching unbalanced impedances to unbalanced impedances. As I mentioned at the beginning of this chapter, there are many choices to consider when designing these broadband and efficient transformers. One of the most important choices involves whether to use the Ruthroff or Guanella approach. In fact, the Guanella design should probably be designated a *Balun/Unun*. Recently, it has become the design of choice in the higher frequency bands. From the designs presented in this chapter, I offer the following recommendations:

1. For Ununs in the HF band with impedance levels of 100:25 ohms and lower, the Ruthroff approach is recommended because of its simplicity.
2. For high impedance levels in the HF band (like 200:50 and 300:75 ohms), the Guanella approach is recommended.
3. For low-impedance operation on the VHF band, the beaded-coax Guanella approach is recommended.
4. For high-impedance operation on the VHF band, the coiled-wire Guanella approach appears to be the preferred choice, and should be investigated first. Obviously, the number of turns should be reduced from the examples shown in this chapter because the reactance of the winding is proportional to the frequency.
5. For high-power use on the HF band, the Ruthroff Unun with low-impedance coaxial cable on a toroid (on the right on **Photo 12-A**) is recommended. It is easy to construct and can very likely handle more than 5 kW of continuous power.
6. Also, at high-impedance levels, one might consider using lower permeability ferrites for higher efficiencies. Look at permeabilities of 125 and 40.

Chapter 13

1.33:1, 1.5:1, and 2:1 Ununs

Sec 13.1 Introduction

Little practical design information has been available on Ununs with impedance transformation ratios of less than 4:1 (these are called *fractional-ratio* Ununs). However, many important applications can be found for efficient and broadband Ununs with ratios like 1.33:1, 1.5:1, and 2:1. Some examples include the matching of 50-ohm coaxial cable to: a) vertical antennas, inverted Ls, and ground-fed slopers (all over good ground systems), b) 75-ohm hardline cable, c) a junction of two 50-ohm coaxial cables, d) shunt-fed towers performing as vertical antennas, and e) the output of a transceiver or class B linear amplifier when an unfavorable VSWR condition exists.

These three Ununs also play an important role in making other useful Baluns possible. Examples given in earlier chapters include: a) connecting a 1.5:1 Unun (50:75 ohms) in series with a 1:1 Balun (75:75 ohms) results in a broadband 1.5:1 Balun (50:75 ohms); b) connecting a 2:1 Unun (50:100 ohms) in series with a 1:1 Balun (100:100 ohms) results in a broadband 2:1 Balun (50:100 ohms); c) connecting a 1.5:1 Unun (50:75 ohms) in series with a 4:1 Balun (75:300 ohms) results in a broadband 6:1 Balun (50:300 ohms), and d) connecting a 1.33:1 Unun (50:66.7 ohms) in series with a 9:1 Balun (66.7:600 ohms) results in a broadband 12:1 Balun (50:600 ohms).

It has been shown[2] that a continuum of ratios can now be obtained with Ununs matching 50-ohm cable to impedances as low as 3.125 ohms and as high as 800 ohms. In addition, by using higher-order windings (trifilar, quadfilar, etc.), Ununs can be constructed with two broadband ratios like 1.5:1 and 3:1, or 2:1 and 4:1. Furthermore, by tapping some of the windings of these higher-order Ununs, multimatch transformers can be constructed with many broadband ratios. As a result of this class of fractional-ratio Ununs, a continuum of Ununs and Baluns is now available to match 50 ohms unbalanced to unbalanced or balanced impedances as low as 3.125 ohms and as high as 800 ohms.

My first attempt to obtain ratios less than 4:1 was made by tapping one of the wires in a Ruthroff 4:1 bifilar Unun. My experiment met with only moderate success.[2] An adequate low-frequency response with a 1.33:1 ratio was difficult to obtain. Also, the 2:1 ratio had considerably greater loss than higher or lower ratios. Recently, I found that higher-order windings (trifilar, quadrifilar, etc.), some with taps, provide much wider bandwidths and higher efficiencies. This

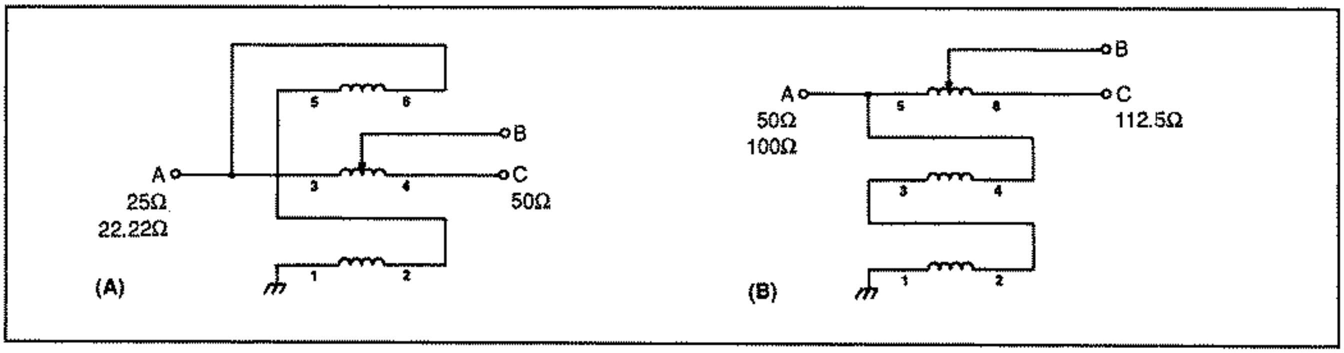

Figure 13-1. *Schematic diagrams: (A) matching 50 to 25 ohms (B-A) and 50 to 22.22 ohms (C-A); (B) matching 100 to 50 ohms (B-A) and 112.5 to 50 ohms (C-A).*

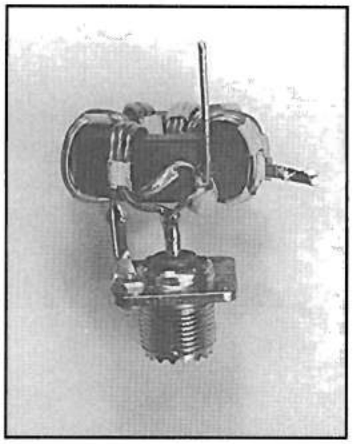

Photo 13-A. *Bottom view of the 2:1 Unun designed to match 50 ohms to 25 ohms or 22.2 ohms (Figure 13-1A). The connector is on the low-impedance side.*

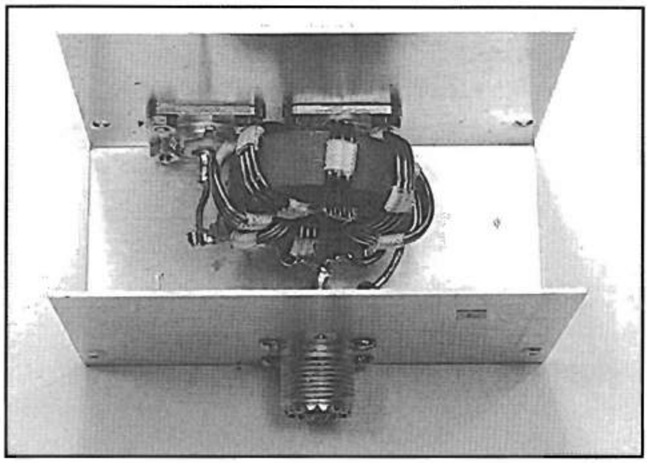

Photo 13-B. *The 2:1 Unun mounted in a 4 inch long by 2 inch wide by 2.75 inch high minibox.*

chapter describes fractional-ratio Ununs using these higher-order windings.

The next section discusses the practical aspects of the 2:1 Unun. This Unun is not only one of the more useful transformers, but it also serves as a good introduction to the trifilar and quadrifilar designs. What follows is an introduction to the most difficult fractional-ratio Unun—the quintufilar design, which results in very broadband 1.33:1 and 1.5:1 Ununs. A more complete discussion appears in **Part I** of this book.

This chapter closes with construction tips. As you will see, these Ununs can be difficult to construct.

Sec 13.2 2:1 Ununs

Figure 13-1A shows the schematic diagram of an Unun designed to match 50-ohm cable to an unbalanced load of 25 ohms (2:1 ratio with connections A-B) or 22.22 ohms (2.25:1 ratio with connections A-C). It has 6 trifilar turns of No. 14 H Thermaleze wire on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 3-4 is tapped at 5 turns from terminal 3. **Photo 13-A** is a photograph showing the various connections. The connector is on the low-impedance side. **Photo 13-B** shows the transformer mounted in a CU-3015A (4 inches long by 2 inches wide by 2.75 inches high) minibox. In matching 50 ohms to either 25 or 22.22 ohms, the transformation ratio is constant from 1 to 30 MHz.

Because the transmission lines are very short, this Unun does quite well as a step-up transformer. That is, when matching 50 ohms (on the left side) to 100 ohms (connections A-B) or 112.5 ohms (connections A-C) on the right side, the transformation ratio is constant from 1 to 15 MHz. Because of the extremely high efficiency of this transformer (98 to 99 percent under matched conditions), this small version can easily handle the full legal limit of amateur radio power.

Figure 13-1B shows the schematic diagram of an Unun designed to match 50-ohm cable to an unbalanced load of 100 ohms (2:1 ratio with connections A-B) or 112.5-ohms (2.25:1 ratio with connections A-C). It has 7 trifilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. The top winding 5-6 is No. 14 Thermaleze wire and is tapped at 6 turns from terminal 5. The other two windings are No. 16 H Thermaleze wire. **Photo 13-C** shows the various connections. The connector is on the low-impedance side. In matching 50-ohm cable to 100 ohms (A-B) or 112.5 ohms (A-C), the transformation ratio is constant from 1 to 30 MHz.

Again, because the transmission lines are very short, this Unun does quite well as a step-down transformer. In matching 50-ohm cable (on the right side) to 25 ohms (A-B) or 22.22 ohms (A-C), the transformation ratios are constant from 1 to 15 MHz. As above, this transformer can easily handle the full legal limit of amateur radio power.

Although the quadrifilar Unun shown in the schematic diagram in **Figure 13-2** and in **Photo 13-D** has an impedance transformation ratio of 1.78:1, it should also satisfy many of the 2:1 requirements. This Unun, which is designed to match 50-ohm cable to an unbalanced load of 28 ohms, not only has a very broadband response (1 MHz to over 50 MHz), but also offers other possible wideband ratios that will be covered in succeeding chapters.

Specifically, the Unun has 5 quadrifilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 5-6 is No. 14 H Thermaleze wire and the other three are No. 16 H Thermaleze wire. Like the

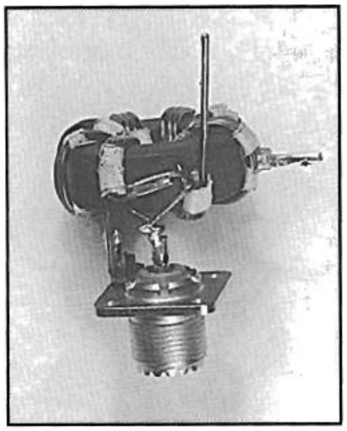

Photo 13-C. *Bottom view of the 2:1 Unun designed to match 50 ohms to 100 ohms or 112.5 ohms (Figure 13-1B). The connector is on the low-impedance side.*

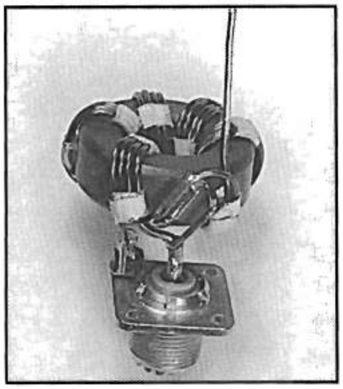

Photo 13-D. *Bottom view of the 1.78:1 Unun designed to match 50 to 28 ohms. The connector is on the low-impedance side.*

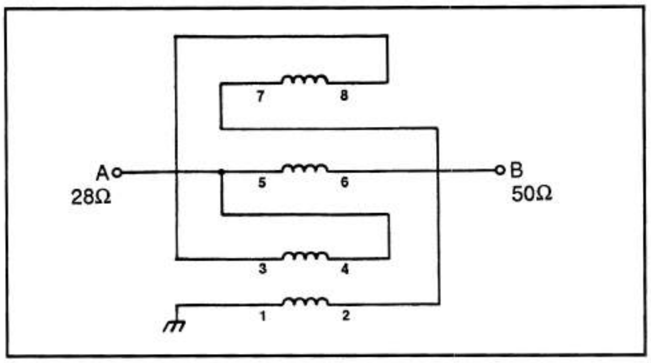

Figure 13-2. *Schematic diagram of the quadrifilar Unun designed to match 50 to 28 ohms (1.78:1 ratio).*

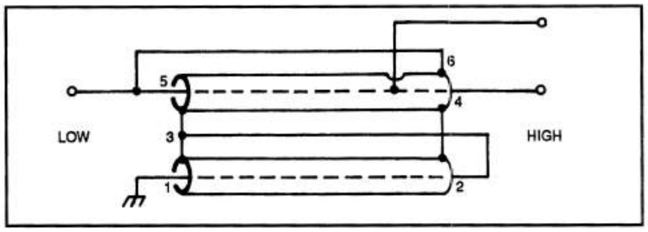

Figure 13-3. *Schematic diagram of a tapped-trifilar Unun that uses two sections of coaxial cable, yielding impedance ratios of 2:1 and 2.25:1.*

two 2:1 Ununs described above, this one also easily handles the full legal limit of amateur radio power.

As with most coiled Ununs that have little spacing between adjacent turns, current-crowding (between adjacent turns) can eventually limit the power-handling capability of these devices. It's possible to improve the ability for handling higher currents by using thicker wires, or by using coaxial cables where current-crowding is nonexistent. **Figure 13-3** shows the schematic diagram of a tapped-trifilar transformer that uses two sections of coaxial cable yielding impedance ratios of 2:1 and 2.25:1. **Photo 13-E** shows two trifilar toroidal transformers using low-impedance coaxial cables with their outer braids connected in parallel and acting as the third conductor. These transformers are conservatively rated at 5 kW of continuous power.

The smaller transformer in **Photo 13-E** has 7 trifilar turns of low-impedance coax on a 2-inch OD toroid with a permeability of 290. The No. 14 H Thermaleze wire inner conductors have four layers of Scotch No. 92 tape. The outer braids are made from small coaxial cables (or 1/8-inch tubular braid), and are also wrapped with Scotch No. 92 tape in order to preserve the low characteristic impedances. The inner conductor of the top coax in **Figure 13-3** is tapped at 6 turns from terminal 5. When matching 50 ohms to 22.22 ohms or 25 ohms, the impedance ratio is constant from 1 to over 50 MHz.

The larger transformer in **Photo 13-E** also has 7 trifilar turns, but on a 2.4-inch OD toroid with a permeability of 125. The inner conductors of No. 14 H Thermaleze wire now have a 15-mil wall of Teflon sleeving, yielding the low-impedance coaxial cable. The outer braids are the same. Because the ferrite permeability is lower and the lengths of the transmission lines are longer than those of the smaller unit, this transformer's bandwidth is not quite as good. When matching 50 to 22.22 ohms (this particular Unun doesn't have a tapped winding), the impedance ratio is constant from 1.7 to 30 MHz.

Although not shown, these very high-powered 2:1 Ununs can also be easily designed to match 50-ohm cable to unbalanced loads of 100 and 112.5 ohms. This is done by using small but high-powered coaxes like RG-303/U, RG-141/U, or RG-142/U.

Sec 13.3 1.5:1 Ununs

Figure 13-4 shows three basic forms of a quintufilar 1.56:1 Unun that should satisfy most of the 1.5:1 requirements. As can be seen, the only difference in

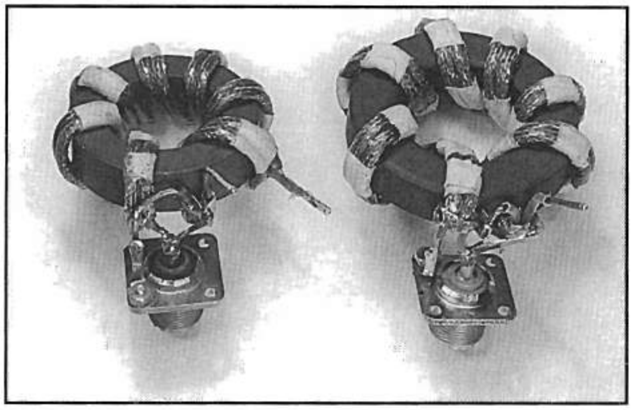

Photo 13-E. *Two toroidal transformers using coaxial cable and designed to match 50 to 22.22 ohms (2.25:1). The smaller transformer is also tapped, yielding a match of 50 to 25 ohms (2:1).*

the schematic diagrams is in the interleaving of the windings. This is done to optimize the performance of these Ununs at the various impedance levels. Schematic A is optimized for matching 50 to 75 ohms. Schematic B is optimized for matching 32 to 50 ohms. Schematic C, while optimized for matching 40 to 62 ohms, still yields quite broadband ratios at both 50:75 and 32:50-ohm levels. It should be a useful, general-purpose Unun.

Photo 13-F is a photograph of the bottom views (showing the connections) of the three different designs. They appear in the same order as the schematics of **Figure 13-4**; i.e., a) the Unun on the left is designed to match 50 to 75 ohms, b) the Unun in the center is design to match 32 to 50 ohms, and c) the Unun on the right is designed to work quite well at both impedance levels. The SO-239 connectors are all on the low impedance side of the Ununs.

All three transformers have four quintufilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. Their differences are:

1. **50:75 ohms** (on the left on **Figure 13-4** and **Photo 13-F**).

Winding 9-10 is No. 14 H Thermaleze wire. The other four windings are No. 16 H Thermaleze wire. When matching 50 to 75 ohms (actually to 78 ohms), the transformation ratio is constant from 1 to over 30 MHz. In matching 50 ohms (on the right side in **Figure 13-3A**) to 32 ohms, it is still constant from 1 to 15 MHz.

2. **32:50 ohms** (in the center in **Figure 13-4** and **Photo 13-F**).

Winding 5-6 is No. 14 H Thermaleze wire. The other four windings are No. 16 H Thermaleze wire. When matching 32 to 50 ohms, the transformation ratio is constant from 1 to over 30 MHz. In matching 75 ohms (on the right side in **Figure 13-3B**) to 50 ohms, it is still constant from 1 to 15 MHz.

3. **50:75 ohms; 32:50 ohms** (on the right in **Figure 13-4** and **Photo 13-F**).

Winding 7-8 is No. 14 H Thermaleze wire. The other four windings are No. 16 H Thermaleze wire. In matching 32 to 50 ohms, the transformation ratio is constant from 1 to 30 MHz. In matching 75 ohms (on the right side in **Figure 13-3C**) to 50 ohms, it is still constant to 21 MHz. This is quite a good general-purpose design.

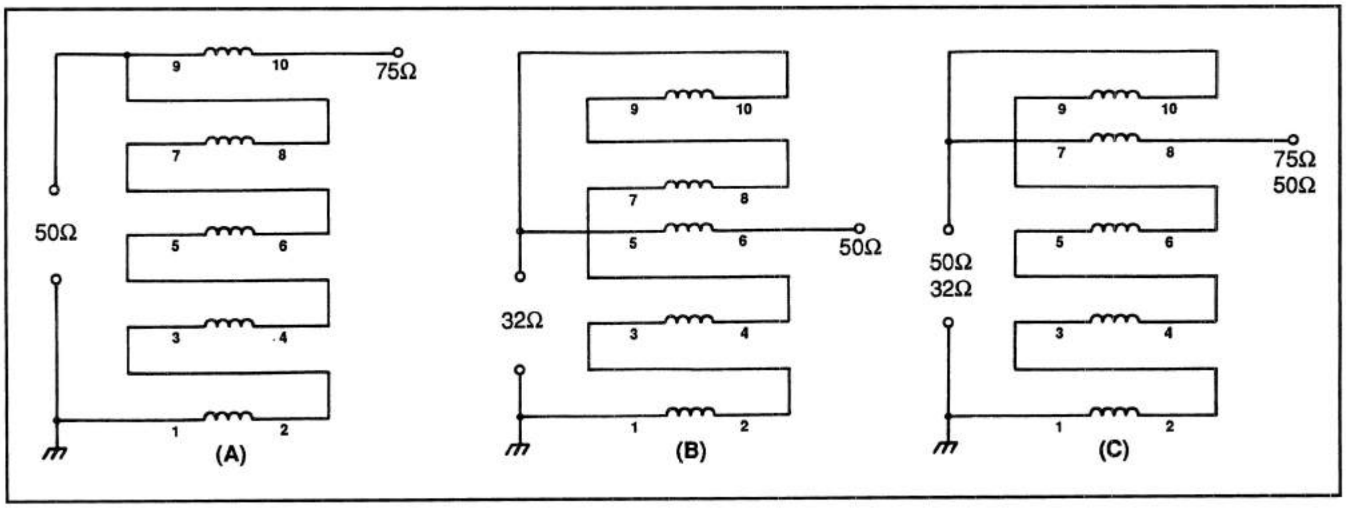

Figure 13-4. *Three basic forms of a quintufilar 1.56:1 Unun: (A) optimized to match 50 to 75 ohms, (B) optimized to match 32 to 50 ohms, and (C) optimized to match 40 to 62 ohms, resulting in a good general-purpose design.*

Even though a small toroid (with only a 1.5-inch OD) is used, these Ununs are still very sturdy transformers. Because their efficiencies are so high (98 to 99 percent), they can easily handle the full legal limit of amateur radio power.[2] Furthermore, the windings carrying the majority of the current (80 percent) are all No. 14 wire. Only when well-designed Ununs are subjected to very high VSWRs will excessive heating occur. Ununs (and Baluns) should never be exposed to these severe conditions.

Sec 13.4 A 1.33:1 Unun

The circuit shown in **Figure 13-5** evolved after many attempts were made at obtaining a broadband match of 50 to 66.7 ohms (1.33:1). **Photo 13-G** shows the bottom view of an actual design. The SO-239 connector is on the low impedance side. **Photo 13-H** shows the Unun mounted in a CU-3015A minibox.

Specifically, this Unun has five quintufilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 5-6 is No. 14 H Thermaleze wire and is tapped at three turns from terminal 5 (**Figure 13-4**). It is also covered with one layer of Scotch No. 92 polyimide tape, optimizing the performance at the 50:66.7-ohm level. The other four windings are No. 16 H Thermaleze wire.

In matching 50 to 66.7 ohms (A-B), the transformation ratio is practically constant from 1 to 30 MHz. The ratio only decreases by 3 percent across the band. In matching 50 to 32 ohms (C-A), the transformation ratio is constant from 1 to 30 MHz. In matching 75 to 50 ohms (C-A), the ratio is constant from 1 to 15 MHz. In matching 50 to 37.6 ohms (B-A), the ratio is constant from 1 to 15 MHz. As you can see, the Unun has some useful broadband multimatches.

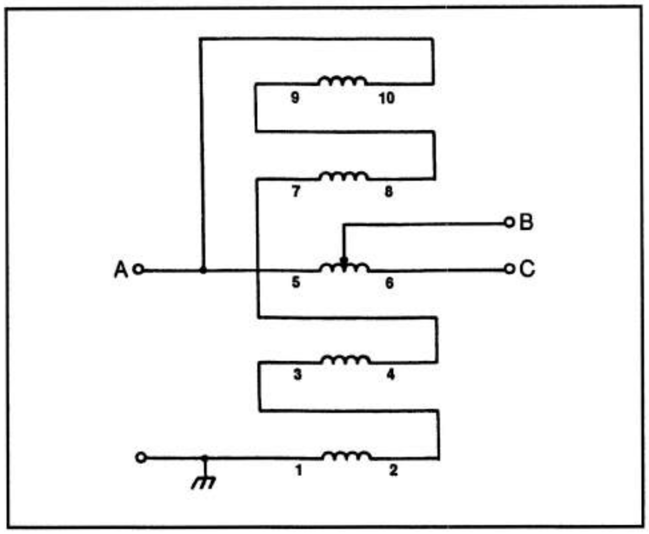

Figure 13-5. *Schematic diagram of a quintufilar Unun specifically designed to yield a broadband 1.33:1 ratio (66.7:50 ohms; connection B-A). Connection C-A also yields a broadband 1.56:1 ratio (50:32 ohms).*

As in the cases of the other three Ununs, this tapped-Unun also easily handles the full legal limit of amateur radio power. Like the 2:1 Unun, for higher power capabilities, thicker wires or a three-coax quintufilar design can be used.[2]

Sec 13.5 Construction Tips

Most of my Unun designs use the bootstrap connection that sums direct voltages (on the high-impedance side) with a delayed voltage, which traverses a single transmission line.[2] Therefore, in order to achieve the very wideband responses, small toroids (which allow the shortest transmission lines) are used. The small 1.5-inch OD toroids offer this advantage. Furthermore,

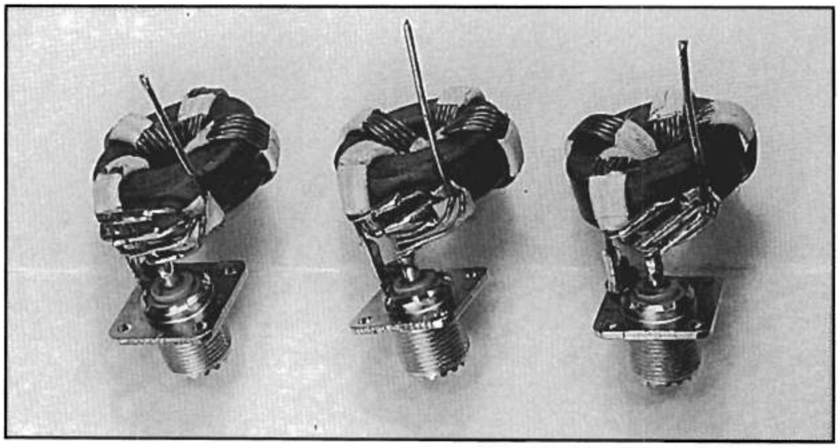

Photo 13-F. *Photograph of the three different Unun designs shown in Figure 13-4: A) on the left, 50:75 ohms, B) in the center 32:50 ohms, and C) on the right, a general purpose design matching both impedance levels quite well.*

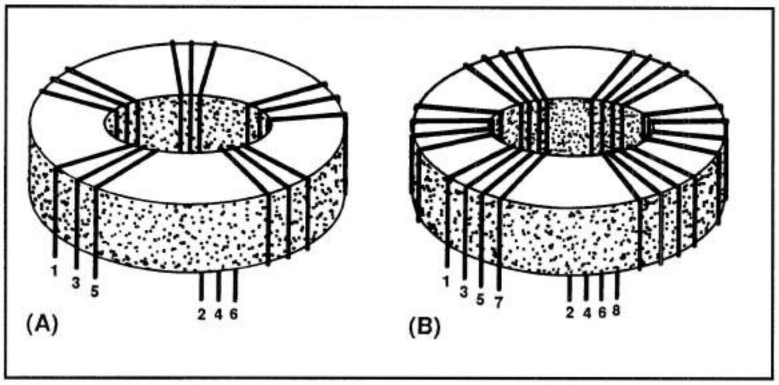

Figure 13-6. *Pictorials of higher-order windings: (A) trifilar and (B) quadrifilar.*

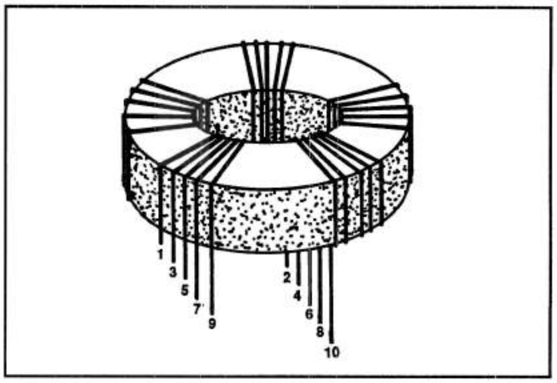

Figure 13-7. *Pictorial of a quintufilar winding.*

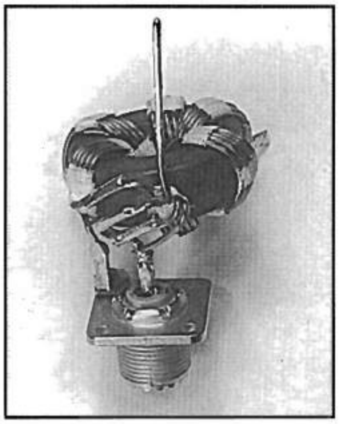

Photo 13-G. *Photograph of the 1.33:1 Unun (66.7:50 ohms). This transformer also has a broadband 1.56:1 ratio (50:32 ohms).*

quintufilar (and higher-order windings) Ununs are also eventually limited in their high-frequency responses by self-resonances. Shorter winding lengths keep these self-resonances well out of the HF band. For the Ununs in this chapter, they occur between 45 and 65 MHz, with **Figure 13-4A** having the higher value.

There is also a mechanical advantage in using the smaller toroids. You'll find that the popular CU-3015A minibox makes an excellent enclosure for the 1.5-inch OD toroid. Furthermore, because ferrite is a ceramic and, therefore, unaffected by moisture, no special precautions need be taken for out-of-doors use. Potting the transformer in plastic is unnecessary. One must only keep the Unun out of a pool of water.

Because well-designed transformers have virtually no flux in the core, their power ratings are mainly determined by the ability of the transmission lines to handle the voltages and currents. Furthermore, it can be shown that the losses in these transformers are related to the voltage gradients along the transmission lines.[2] Thus, they are dielectric-type ferrite losses. This means that the efficiency can be severely degraded with very high VSWRs since higher voltage gradients occur under these conditions.

Several suggestions can be made regarding the construction of Ununs using these higher-order windings (trifilar, quadrifilar, etc.). They are:

1) Make a ribbon out of the wires and wind them all at the same time. This keeps the wires as close as possible, resulting in the maintenance of the optimum characteristic impedance of the transmission lines. I found that strips made with 1.25- by 0.375- to 0.55-inch glass tape (Scotch No. 27), clamped about every 1/2 inch, hold the wires in place very well. The starting lengths of the wires should be about 5 inches longer than one would calculate knowing the number of turns and the length around each turn.

2) Because work-hardening of the copper wire takes place in coiling it around a toroid, a pair of pliers and

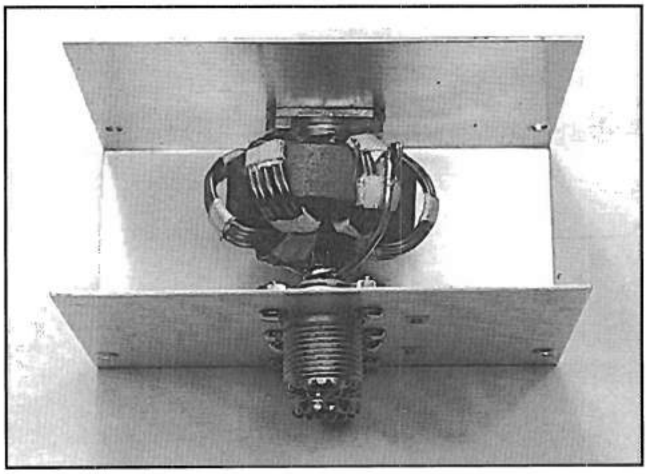

Photo 13-H. *The 1.33:1 Unun mounted in a CU-3015A minibox.*

a strong thumb (and arms) are indispensable tools. It takes considerable effort to wind these transformers. Also, because these designs have adequate margins at their low-frequency ends, some space between the windings and the toroids can be tolerated.

3) It is helpful to recognize the various patterns that appear at the ends of the windings. **Figure 13-6** shows a drawing of the trifilar and quadrifilar patterns and **Figure 13-7** shows the quintufilar pattern. Note that terminal 1 and terminal 6 or terminal 8 or 10 are the outside terminals of the patterns. Also, note that terminal 1 is always grounded in the schematic diagrams.

4) Tapping windings can be one of the more difficult tasks in constructing these transformers. Winding a tapped transformer is also more difficult. I found that the edge of a small, fine file does the best job in removing the insulation. About 1/8 to 1/4 inch is removed around the wire. It also helps to remove some of the copper. Then a flat 1/8-inch copper strip or No. 14 wire flattened on one end is soldered to the bare wire. The soldered connection is then rendered smooth using the edge of the file. Finally, two pieces of Scotch No. 92 polyimide tape are placed on the joint to insulate it from the neighboring turns. I also found that a tap placed one turn from the end of the winding is best made approximately 4 inches from the end of the wire (when the wire is straight).

Finally, a comment should be made about low-power Ununs. Practically all of the transformers in this chapter can be easily designed for low-power use. Designs capable of handing the full output of HF transceivers can be readily constructed. Cores with an OD of 1.25 inches are recommended. The same number of turns, but with one size smaller wire, is also recommended. Because smaller cores and thinner wires are used, these lower-power units are not only easier to construct, but they also have wider bandwidths due to the shorter lengths of the windings.

Chapter 14

Dual-Ratio Ununs

Sec 14.1 Introduction

Earlier chapters in this book on Ununs have basically covered single-ratio transformers. Broadband ratios of 1.33:1, 1.5:1, 2:1, and 4:1 were the design objectives. The 1.33:1 ratio was obtained by tapping a 1.5:1 (actually 1.56:1) quintufilar-wound Unun. The 2:1 ratio was obtained by tapping a 2.25:1 trifilar-wound Unun. Although these transformers can be considered to have two broadband ratios (1.33:1 and 1.56:1 or 2:1 and 2.25:1), their two ratios were not different enough for many practical applications. This is especially true of antennas where the input impedance varies with frequency.

My earlier work[2] and an article by Genaille[10] have shown that a host of ratios (less than 4:1) can be obtained by tapping the bifilar winding of a Ruthroff 4:1 Unun.[9] However, the bandwidths obtained using this technique are quite limited with each ratio and are highly dependent upon the impedance level. This is particularly true when a rod core is used because it requires more turns (resulting in longer transmission lines) in order to obtain the necessary choking reactance that isolates the input from the output. Furthermore, ratios around 2:1 exhibit more loss because autotransformer action also enters into the matching process.[2]

By using quadrifilar and quintufilar windings on small 1.5-inch OD cores, and connecting them in such a way that the characteristic impedances of the windings are near optimum, two very different and broadband ratios matching 50 ohms to lower impedances are obtained. Furthermore, because the transmission lines in these transformers are so very short (8 to 9 inches in length), these transformers do quite well in matching 50 ohms to higher impedances (as step-up transformers).

This chapter presents two Ununs which have two broadband ratios that differ by a factor of two! One has a 1.5:1 and a 3:1 ratio (actually 1.56:1 and 2.78:1). The other has a 2:1 (actually 1.78:1) and a 4:1 ratio. Also, this chapter introduces the novel tech-

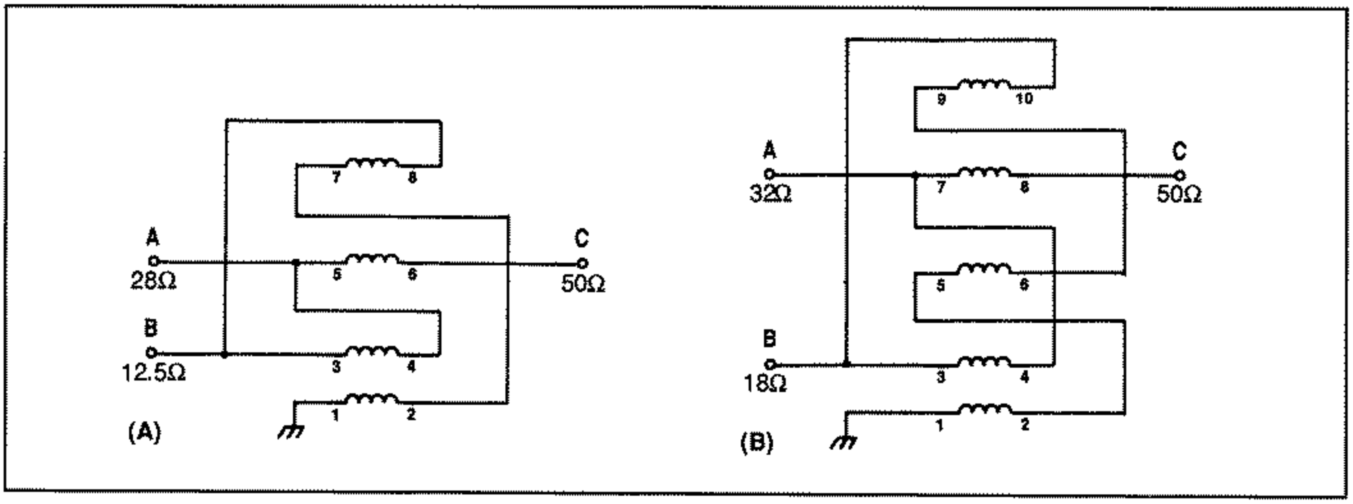

Figure 14-1. *Schematic diagrams of dual-ratio Ununs: (A) 1.78:1 connection C-A, 4:1 connection C-B; (B) 1.56:1 connection C-A, 2.78:1 connection C-B.*

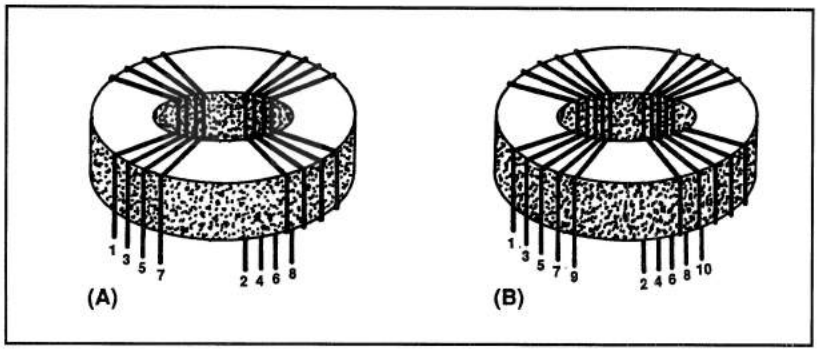

Figure 14-2. *Pictorials of higher-order windings: (A) quadrifilar, (B) quintufilar.*

nique of connecting these two transformers in parallel on their 50-ohm sides, resulting in four very broadband ratios.

Sec 14.2 2:1 and 4:1 Ratios

Figure 14-1A shows the schematic diagram of the quadrifilar Unun yielding ratios of 2:1 (actually 1.78:1) and 4:1. **Figure 14-2A** provides a pictorial of its windings. On the left in **Photo 14-A**, you see the bottom view of an Unun. The cable connector is on the 28-ohm (1.78:1) side. This Unun has four quadrifilar turns of No. 14 H Thermaleze wire on a 1.5-inch OD toroid with a permeability of 250.

In matching 50 to 28 ohms (connection C-A), the response is flat to within 1 percent from 1 to 30 MHz. From 1 to 50 MHz, it's flat to within 2 percent. In matching 50 to 12.5 ohms (connection C-B), the response is flat to within 3 percent from 1 to 30 MHz.

Because very short transmission lines are used, this transformer performs quite well as a step-up transformer. In matching 50 to 200 ohms (connection B-C), the response is flat to within 3 percent from 1.5 to 10 MHz. In matching 50 to 89 ohms (connection A-C), the response is flat to within 5 percent from 1.5 to 30 MHz!

Sec 14.2.1 Construction Tips

Start with about 14 inches of straightened wire. Form the wires into a ribbon with clamps of Scotch No. 27 glass tape every 1/2 inch. I found that strips 3/16 inch wide and about 1.5 inches long do a good job. The clamps should be long enough to go around the wires twice. After winding, connect terminals 2 and 7. Then connect terminals 3 and 8. Finally, connect terminals 4 and 5. Because work-hardening takes place quickly, you will find that a pair of pliers and a strong thumb (and arms) are necessary tools. You will also find that winding these exceptionally performing transformers is not easy. As in all endeavors, practice really pays off.

Sec 14.3 1.5:1 and 3:1 Ratios

Figure 14-1B shows the schematic diagram of the quintufilar Unun yielding ratios of 1.5:1 and 3:1

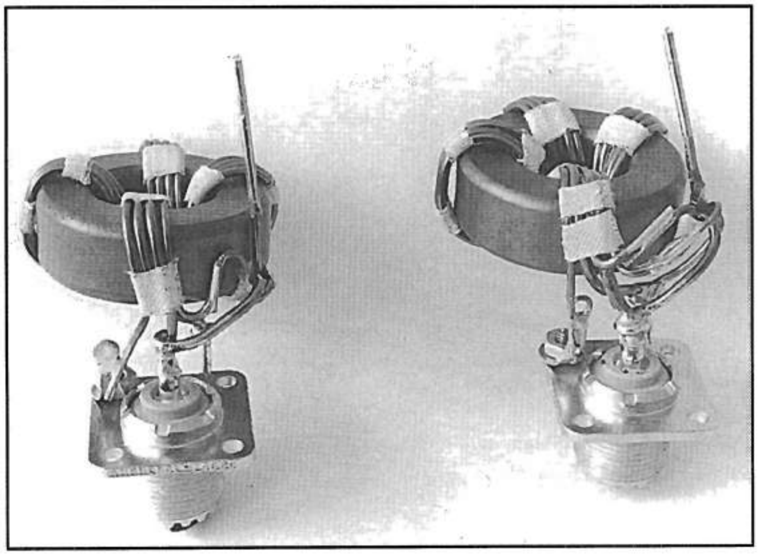

Photo 14-A. *On the left, a quadrifilar Unun with ratios of 1.78:1 and 4:1; on the right, a quintufilar Unun with ratios of 1.56:1 and 2.78:1.*

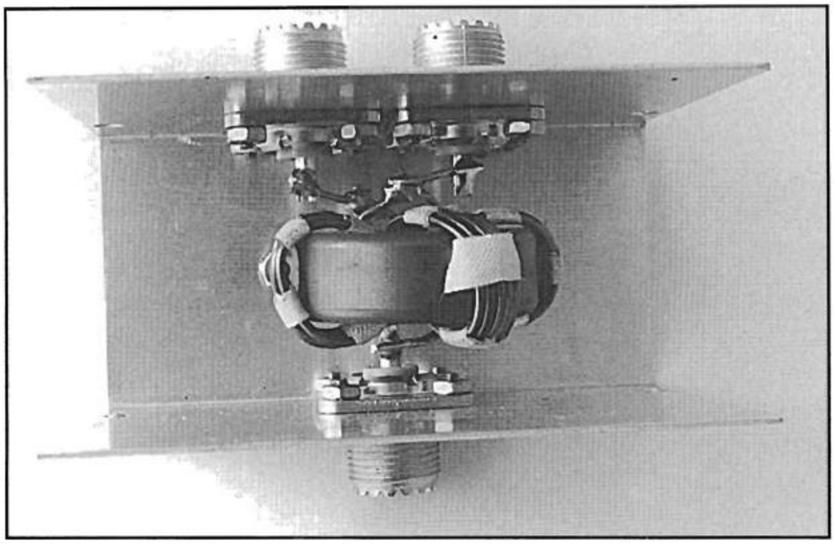

Photo 14-B. *The dual-ratio quintufilar Unun mounted in a 4 inch long by 2 inch wide by 2.75 inch high minibox.*

(actually 1.56:1 and 2.78:1). **Figure 14-2B** is a pictorial of its windings. On the right side in **Photo 14-A** you see a bottom view of an Unun. The cable connector is on the 32-ohm (1.56:1) side. This Unun has four quintufilar turns on a 1.5-inch OD toroid with a permeability of 250. Windings 3-4 and 7-8 are No. 14 H Thermaleze wire. The other three are No. 16 H Thermaleze wire. Winding 7-8 also has two layers of Scotch No. 92 polyimide tape, which optimizes the 1.56:1 ratio.

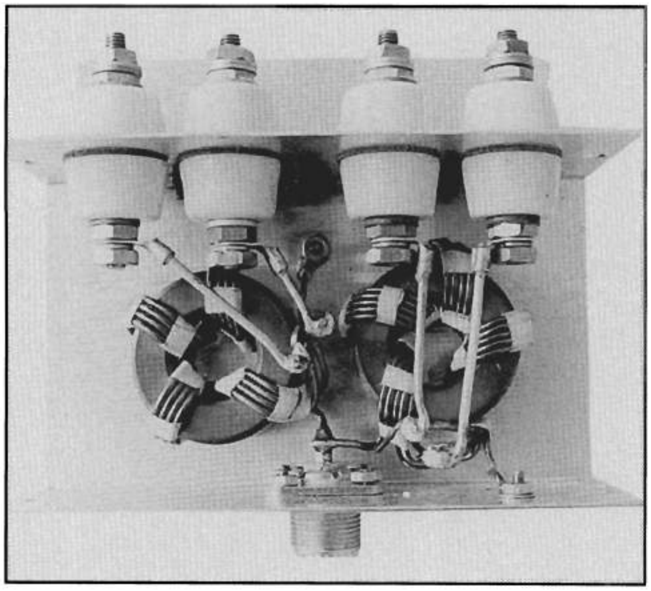

Photo 14-C. *The two dual-ratio Ununs connected in parallel on their 50-ohm sides providing four broadband ratios close to 1.5:1, 2:1, 3:1, and 4:1. The quadrifilar unit is on the left and the quintufilar unit is on the right. The enclosure is a 5 inch long by 3 inch wide by 2 inch high minibox.*

In matching 50 to 32 ohms (connection C-A), the response is essentially flat (less than 1 percent variation) from 1 MHz to over 40 MHz. Without the two layers of Scotch No. 92 tape, the response varies by 4 percent from 1 to 30 MHz. When used as a step-up transformer matching 50 to 78 ohms (connection A-C), and with the two layers of Scotch No. 92 tape on winding 7-8, the response is flat to within 5 percent from 1 to 15 MHz. Without the extra insulation on winding 7-8, the response is flat to within 5 percent from 1 to 7.5 MHz.

In matching 50 to 18 ohms (connection C-B), the variation in response is less than 3 percent from 1 to 40 MHz. The response is the same whether winding 7-8 is covered with the extra insulation or not. As a step-up transformer matching 50 to 139 ohms (connection B-C), the response is flat to within 3 percent from 1 to 10 MHz (with or without the extra insulation on winding 7-8). **Photo 14-B** shows this Unun mounted in a 4 inch long by 2 inch wide by 2.75 inch high minibox. The two cable connectors on the low impedance side could be replaced with feedthrough insulators for antenna use.

Sec 14.3.1 Construction Tips

Prepare the ribbon as was described for the quadrifilar Unun. If you choose to use the two extra layers of Scotch No. 92 tape on winding 7-8, make sure this winding is on the outside position of the ribbon (refer to **Figure 14-2B**). I found the best order in which to connect the wires is as follows: first, connect terminal 2 to 5; second, connect terminal 6 to 9; third, connect terminal 3 to 10; and, finally, connect terminal 4 to 7.

As was mentioned before, because a small toroid is used in order to achieve the best response (due to shorter transmission lines), this transformer also requires considerable strength and patience in the winding process.

Sec 14.4 Parallel Transformers

One of the most pleasant surprises I received with these efficient and broadband transformers was to find that they can be connected in parallel on their 50-ohm sides and still possess the same performance levels. Because the loading effect of one transformer on the other is minimal (like a short length of transmission line), the transformer that is properly terminated takes the power, while the other one is transparent. This lets you obtain four very wideband ratios with the two dual-ratio Ununs described in this chapter. Obviously, this technique eliminates one transmission line. Furthermore, Baluns can also be connected this way for feeding, with a single coaxial cable, beams and dipoles with different resonant impedances.

Photo 14-C shows two transformers connected in parallel on their 50-ohm sides using the two dual-ratio Ununs described in this chapter. As was mentioned, it now yields four wideband ratios very close to 1.5:1, 2:1, 3:1, and 4:1. I have used this matching network to feed a host of ground-fed antennas (over a good ground system). In one case, I had a 10-, 15-, and 20-meter trap vertical, slopers for 40 and 160 meters, a 12-meter vertical, and an inverted L for 80 meters all matched to a single coaxial cable at the same time. It was a simple matter of connecting each antenna to the output terminal that presented the best match (lowest VSWR). This technique is actually an extension of connecting dipoles for different bands, in parallel. The antenna that presents the correct impedance takes the power, and the others are essentially transparent. In many cases, I found that only one transformer with two broadband ratios performed adequately.

Chapter 15

Multimatch Ununs

Sec 15.1 Introduction

Broadband multimatch Ununs capable of high-power applications have been the goal of many designers over the years. Some have resorted to using conventional autotransformers with tapped windings to obtain the many impedance transformation ratios. However, these attempts met with little success because of the device's limited bandwidths and efficiencies. Others (including myself)[2] have tried tapping a bifilar Ruthroff Unun.[9] Although these designs yielded the high efficiencies of transmission line transformers, they had limited bandwidths. Furthermore, their best bandwidths (for the various ratios) occurred at odd impedance levels. In other words, they didn't meet the objective of broadband operation with one of the input or output ports at 50 ohms.

Chapter 14 presented two Ununs which had two broadband ratios that differed by a factor of two. One had a 1.5:1 and a 3:1 ratio (actually 1.56:1 and 2.78:1). The other had a 2:1 (actually 1.78:1) and a 4:1 ratio. This chapter describes two multimatch designs that are capable of many more broadband ratios. For the most part, both are capable of broadband operation from 1.7 to 30 MHz.

One Unun has the following five ratios (which are close to): 1.5:1, 2:1, 4:1, 6:1, and 9:1. Because the two lower ratios work well in either direction (that is stepping up or down from 50 ohms), this design can match 50-ohm cable to impedances as high as 100 ohms (actually 112.5 ohms) and as low as 5.6 ohms over the frequency range. As a result, it has seven usable applications. Furthermore, because this is a transmission line transformer that cancels out the flux in the core, losses (in a matched condition) of only 0.04 to 0.08 dB can be expected.

The novelty in this design lies in the use of a trifilar winding (with one winding tapped) on a very small ferrite toroid, resulting in the shortest possible lengths of transmission lines. The windings are also connected in such a manner as to optimize their characteristic impedances from an overall standpoint.

I have used the adjective *ultimate* to describe the second Unun design. Although it might be risky business, I assume that this design will meet one of the most common definitions for this adjective—namely, *beyond which it is impossible to go.* For many of us, the classic use of this adjective was made by Lew McCoy in describing his popular transmatch.[22] Although there have been some improvements to Lew's design, his use of this definite (and strong) adjective can be said to have withstood the test of time. I hope my use meets with similar success.

While the tapped-trifilar design provides five broadband ratios and seven practical applications, the *ultimate* design presented in this chapter goes well

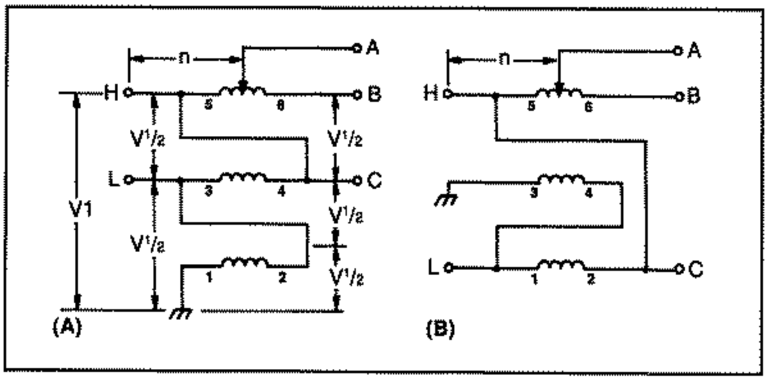

Figure 15-1. *Circuit diagrams for the 5-ratio Unun: (A) diagram for analysis; (B) transposed windings for best overall performance.*

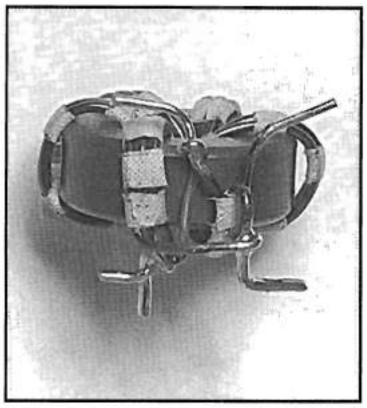

Photo 15-A. *Bottom view of the 5-ratio Unun of Figure 15-1B. The upper-left lead is terminal C. The upper-right lead is terminal B. The lower-left lead is terminal H. The lead pointing straight down is grounded (terminal 3). The lower-right lead is terminal L.*

beyond this number. It uses a tapped-quadrifilar design that yields the following 10 broadband ratios: 1.36:1, 1.56:1, 1.78:1, 2.25:1, 3.06:1, 4:1, 6.25:1, 9:1, 12.25:1, and 16:1. Because the four lower ratios also work quite well in either direction, this design offers *fourteen* applications in matching 50-ohm cable to impedances as high as 112.5 ohms and as low as 3.125 ohms. It also has the advantage of using a small low-loss toroidal core. Additionally, the windings are also interleaved in a pattern that optimizes their characteristic impedance.

However, this achievement comes at a price—*difficulty*. The 5-ratio Unun, which uses a trifilar winding, is considerably easier to wind. In addition, the quadrifilar 10-ratio Unun has two of its windings tapped, while the 5-ratio Unun has only one (see **Chapter 13** on tapping windings). If you have had little experience in winding Ununs or Baluns, attempt simplified versions of these two multimatch Ununs first. These versions eliminate the tapping of the windings. For the trifilar Unun, the remaining ratios would be: 2.25:1, 4:1, and 9:1. For the quadrifilar Unun, they would be: 1.78:1, 2.25:1, 4:1, 9:1, and 16:1.

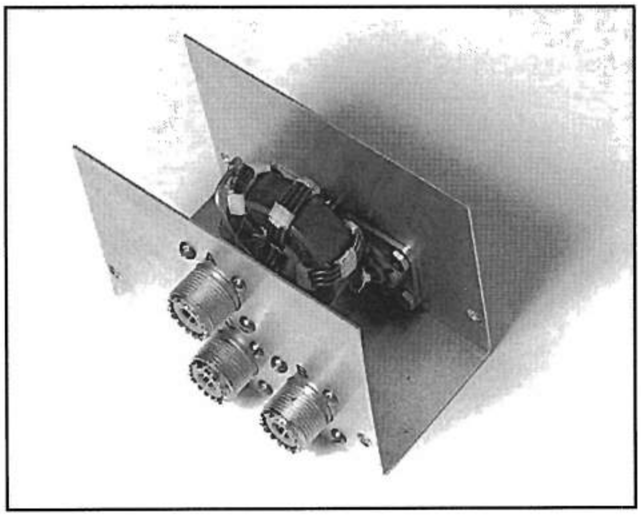

Photo 15-B. *The high-power unit mounted in a 4 inch long by 2 inch wide by 2.75 inch high minibox.*

For those interested in the design considerations of these broadband multimatch transformers, a brief review is presented in each section. These sections are followed by others describing high-power designs capable of handling the full legal limit of amateur radio power. Finally, the remaining sections present low-power designs capable of handling the output of any HF transceiver. Because transmission line transformers can be made so efficient in matching 50 to 100 ohms or less, their small sizes will surprise many readers. Therefore, the combination of using small ferrite toroids with the maximum allowable permeability (less than 300) for high efficiency,[2] and with sufficient turns to meet the low-frequency objective, results in the excellent performance exhibited by the designs in this chapter.

Sec 15.2 The 5-Ratio Unun

Let's first look at **Figure 15-1A** because it is the easiest form of the trifilar-wound Unun to explain. For example, if the input voltage to ground, V_1, is connected to terminal H, the output terminal B, has a voltage to ground of $3/2V_1$. This results in a transformation ratio, g, of $(3/2)^2$ or 2.25:1. This should satisfy most 2:1 requirements. If the output is at terminal A to ground, then the output voltage is:

$$\begin{aligned} V_o &= V_1 + V_1(n/2N) \\ &= V_1(1 + n/2N) \qquad \text{(Eq 15-1)} \end{aligned}$$

where:
N = the total number of turns on the winding
n = the number of turns from terminal 5.

The transformation ratio, g, then becomes:

$$\begin{aligned} g &= (V_o/V_1)^2 \\ &= (1 + n/2N)^2 \qquad \text{(Eq 15-2)} \end{aligned}$$

If the input voltage to ground, V_1, is connected to terminal L, then terminal C has twice the voltage of V_1—resulting in a 4:1 ratio. Terminal B has three times the voltage resulting in a 9:1 ratio. With terminal A, the output voltage is:

$$\begin{aligned} V_o &= 2V_1 + V_1(n/N) \\ &= V_1(2 + n/N) \end{aligned} \qquad \text{(Eq 15-3)}$$

The transformation ratio, g, then becomes:

$$g = (2 + n/N)^2 \qquad \text{(Eq 15-4)}$$

Sec 15.2.1 A High-power 5-Ratio Unun

After several attempts at rearranging the windings of **Figure 15-1A** for the best overall performance (optimizing the effective characteristic impedances of the windings), **Figure 15-1B** evolved. **Photo 15-A** shows the bottom view of an Unun, using the circuit of **Figure 15-1B**, capable of handling the full legal limit of amateur radio power. **Photo 15-B** shows the unit mounted in a CU-3015A minibox. It has five trifilar turns on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 5-6 is tapped at two turns (n = 2) from terminal 5.

If the 9:1 ratio matching 50 to 5.6 ohms (connection B-L) is to be used at full power, then winding 3-4 should be No. 12 H Thermaleze wire. If not, then all windings can be No. 14 H Thermaleze wire.

A listing of the expected performance across the band from 1.7 MHz to 30 MHz, with the various ratios, is as follows:

9:1 (B-L); 50:5.6 ohms
Ratio is within 1 percent!
5.75:1 (A-L); 50:8.7 ohms
Ratio decreases by 5 percent.
4:1 (C-L); 50:12.5 ohms
Ratio increases by 15 percent (the greatest deviation of all the ratios).
2.25:1
a) (B-H); 50:22.22 ohms
Ratio decreases by 4 percent.
b) (H-B); 50:112.5 ohms
Ratio increases by 8 percent.
1.44:1
a) (A-H); 50:35 ohms
Ratio decreases by 10 percent.
b) (H-A); 50:72 ohms
Ratio increases by 2 percent.

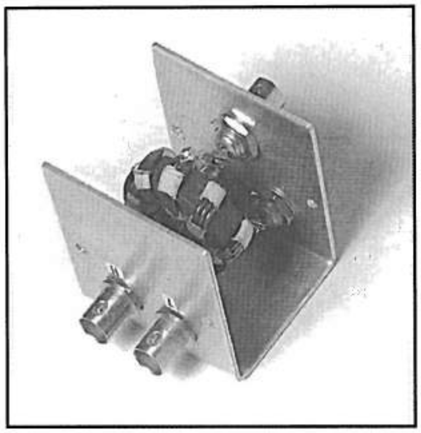

Photo 15-C. *The low-power unit mounted in a homemade 2 inch long by 1.5 inch wide by 2.25 inch high minibox.*

Several comments should be made regarding the expected results shown above. First of all, the greatest deviation from a flat response at any ratio occurs when matching 50 to 12.5 ohms (connection C-L; a 4:1 ratio). If an accurate insertion loss measurement was made at this ratio and impedance level, the result would show an insignificant difference across the band. Secondly, the major part of the deviations for all ratios occurs beyond 15 MHz (the effect of standing waves). Finally, the higher ratios should *never* be used to match 50 ohms to 450 ohms, 288 ohms, and 200 ohms, respectively. The characteristic impedances and choking reactances *do not* allow for broadband operation under these conditions.

Sec 15.2.2 A Low-power 5-Ratio Unun

Photo 15-C shows a low-power unit mounted in a homemade 2 inch long by 1.5 inch wide by 2.25 inch

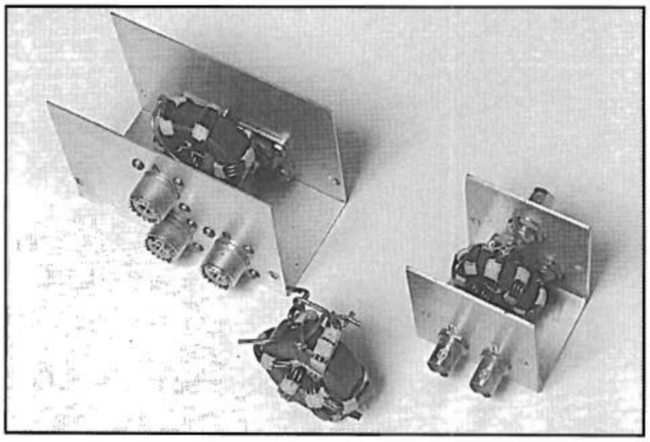

Photo 15-D. *The three 5-ratio Ununs together. From left to right, the high-power unit mounted and unmounted, the low-power unit.*

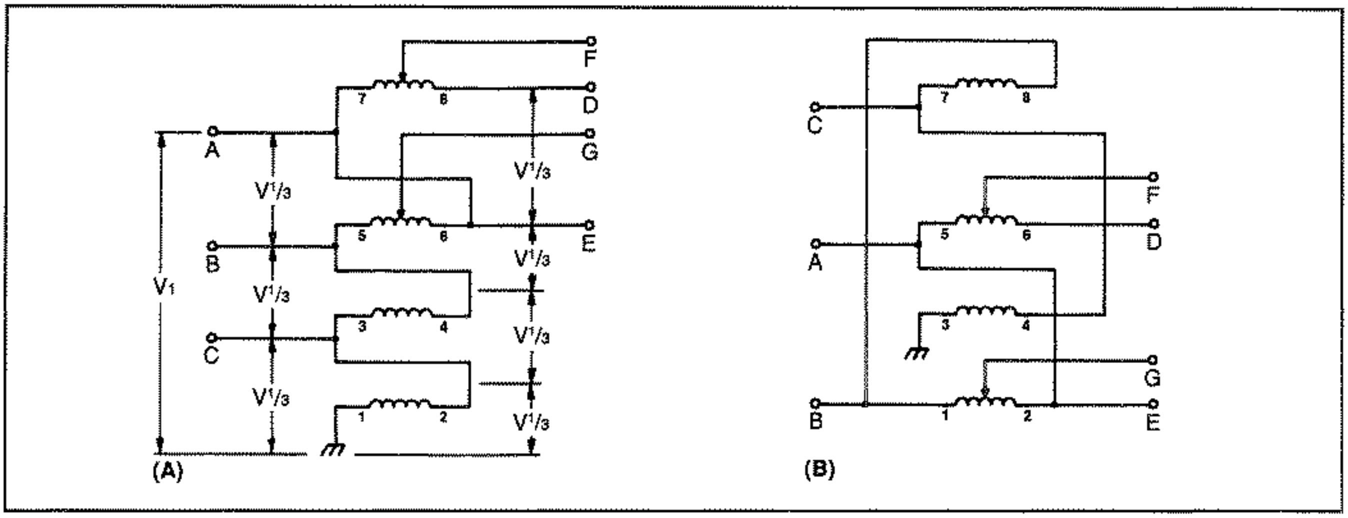

Figure 15-2. *Circuit diagrams for the 10-ratio Unun: (A) diagram for analysis; (B) transposed windings for best overall performance.*

high minibox. It has six trifilar turns of No. 16 H Thermaleze wire on a 1.25-inch OD ferrite toroid with a permeability of 250. The tap on winding 5-6 is located three turns from terminal 5, yielding ratios of 6.25:1 and 1.56:1 instead of the 5.75:1 and 1.44:1 ratios of the high-power unit. In actual use, these differences should be negligible.

Because this Unun has shorter transmission lines than its high-power counterpart, the deviations of the ratios across the band are even smaller. It is also interesting to note that, if No. 14 H Thermaleze wire was used in winding 3-4, this very small Unun could very well be rated at 500 watts of continuous power!

Photo 15-D shows all three 5-ratio Ununs together.

Sec 15.3 The 10-Ratio Unun—The Ultimate Multimatch

Figure 15-2A is presented here because it is the easiest form of a quadrifilar-wound Unun to explain. With the input voltage, V_1, connected to the various terminals on the left (the low-impedance side), and with very short transmission lines compared to the wavelength, we have the following transformation ratios:

1. V_1 connected to terminal A

a) At terminal D the output voltage V_o is $4/3V_1$. Therefore, the transformation ratio, g, with connection A-D is:

$$g = (4/3)^2 = 1:1.78 \qquad \text{(Eq 15-5)}$$

b) At terminal F the output voltage is:

$$V_o = V_1(1 + n/3N) \qquad \text{(Eq 15-6)}$$

where:
N = total numher of turns
n = number of turns from terminal 7.

The transformation ratio with connection A-F then becomes:

$$g = (V_o/V_1)^2 = (1 + n/3N)^2 \qquad \text{(Eq 15-7)}$$

2. V_1 connected to terminal B

a) At terminal E the output voltage is $3/2V_1$. Thus, the transformation ratio with connection B-E is:

$$g = (3/2)^2 = 1:2.25 \qquad \text{(Eq 15-8)}$$

b) At terminal G the output voltage is:

$$V_o = V_1(1 + n/2N) \qquad \text{(Eq 15-9)}$$

where n = number of turns from terminal 5.

The transformation ratio with connection B-G becomes:

$$g = (V_o/V_1)^2 = (1 + n/2N)^2 \qquad \text{(Eq 15-10)}$$

c) At terminal D the output voltage is $2V_1$. The transformation ratio with connection B-D is:

$$g = (2)^2 = 1:4 \qquad \text{(Eq 15-11)}$$

d) At terminal F the output voltage is:

$$V_o = V_1(3/2 + n/2N) \qquad \text{(Eq 15-12)}$$

where n = number of turns from terminal 7.

The transformation ratio with connection B-F, then, is:

$$g = (V_o/V_1)^2 = (3/2 + n/2N) \qquad \text{(Eq 15-13)}$$

3. V_1 connected to terminal C

a) At terminal E, the output voltage is $3V_1$. The transformation ratio with connection C-E becomes:

$$g = (3)^2 = 1{:}9 \qquad \text{(Eq 15-14)}$$

b) At terminal G, the output voltage is:

$$V_o = V_1(2 + n/N) \qquad \text{(Eq 15-15)}$$

where n = number of turns from terminal 5.

The transformation ratio with connection C-G is:

$$g = (V_o/V_1)^2 = (2 + n/N)^2 \qquad \text{(Eq 15-16)}$$

c) At terminal D, the output voltage is $4V_1$. The transformation with connection C-D becomes:

$$g = (4)^2 = 1{:}16 \qquad \text{(Eq 15-17)}$$

d) At terminal F the output voltage is:

$$V_o = V_1(3 + n/N) \qquad \text{(Eq 15-18)}$$

where n = number of turns from terminal 7.

The transformation ratio with connection C-F is:

$$g = (V_o/V_1)^2 = (3 + n/N)^2 \qquad \text{(Eq 15-19)}$$

Sec 15.3.1 A High-power 10-Ratio Unun

Figure 15-2B evolved after several attempts at rearranging the windings of **Figure 15-2A** for best overall performance (optimizing the effective characteristic impedances of the windings). **Photo 15-E** shows the bottom view of an unmounted Unun using the circuit of **Figure 15-2B**. The top-left lead is terminal E. The top-right lead is terminal D. The bottom-left lead is terminal B. The center lead (connected to the SO-239 connector) is terminal A.

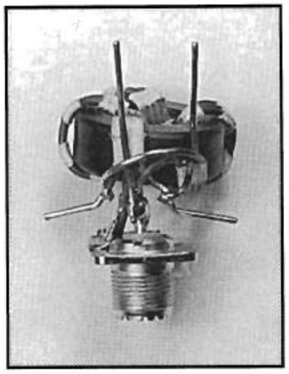

Photo 15-E. *Bottom view of the 10-ratio Unun. The connector is on terminal A.*

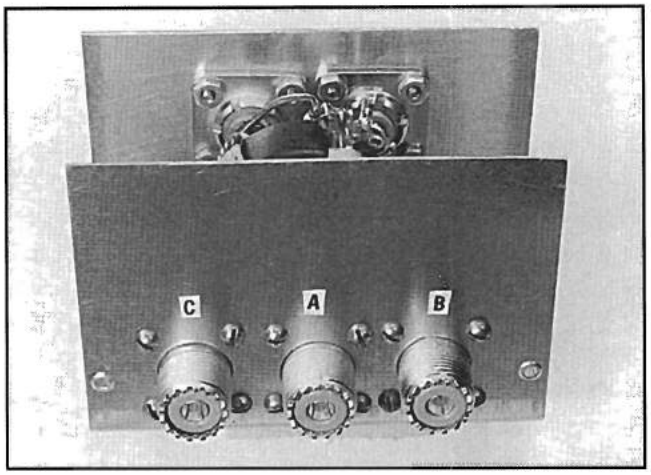

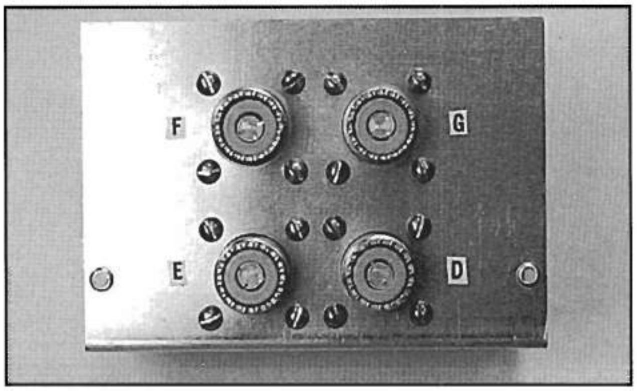

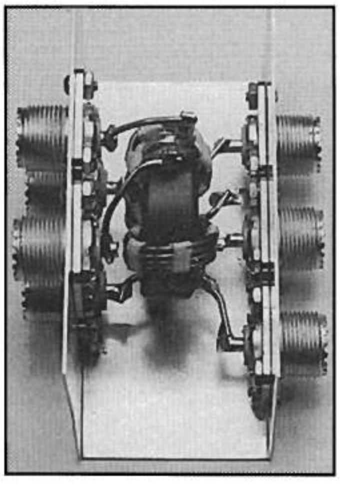

Photo 15-F. *Three different views of the 10-ratio Unun mounted in a 4 inch long by 2 inch wide by 2.75 inch high CU-3015A minibox.*

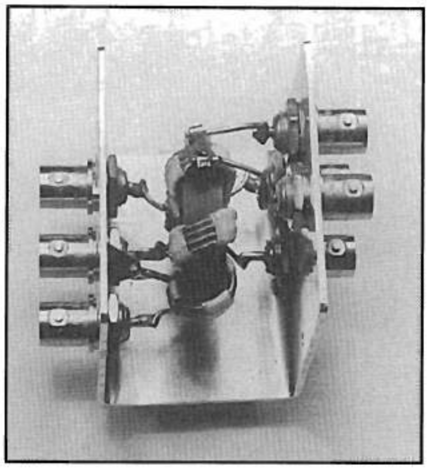

Photo 15-G. *The low-power unit mounted in a homemade 2.25 inch long by 1.5 inch wide by 2.25 inch high minibox.*

The bottom-right lead is terminal C. Below these three bottom leads is a ground connection (terminal 3 in **Figure 15-2B** to the SO-239 connector. **Photo 15-F** shows three different views of this high-power unit mounted in a 4 inch long by 2 inch wide by 2.75 inch high CU-3015A minibox.

This 10-ratio Unun has four quadrifilar turns of No. 14 H Thermaleze wire on a 1.5-inch OD ferrite toroid with a permeability of 250. Winding 5-6 is tapped at 2 turns from terminal 5 and winding 7-8 is tapped at 2 turns from terminal 7.

If the 9:1 ratio (connection C-E), the 12.25:1 ratio (connection C-F), and the 16:1 ratio (connection C-D), are to be used at the full legal limit of amateur radio power, then I suggest that winding 3-4 be replaced with No. 12 H Thermaleze wire. If not, then these three ratios should be used at lower power levels (of 500 watts continuous and 1 kW peak). It should also be mentioned that using No. 12 wire for winding 3-4 adds a greater degree of *difficulty* to the construction process.

A listing of the expected performance across the band from 1.7 to 30 MHz, with the various ratios, is as follows:

16:1 (D-C); 50:3.125 ohms
Ratio is constant up to 21 MHz. It then decreases by 15 percent.
12.25:1 (F-C); 50:4.08 ohms
Ratio is constant.
9:1 (E-C); 50:5.56 ohms
Ratio increases by 5 percent.
6.25:1 (G-C); 50:8 ohms
Ratio is constant.
4:1 (D-B); 50:12.5 ohms
Ratio decreases by 5 percent.
3.06:1 (F-B); 50:16.3 ohms
Ratio decreases by 10 percent.
2.25:1
a) (E-B); 50:22.22 ohms
Ratio increases by 4 percent.
b) (B-E); 50:112.5 ohms
Ratio increases by 50 percent (the greatest deviation across the band of any of the ratios).
1.78:1
a) (D-A); 50:28.1 ohms.
Ratio is constant.
b) (A-D); 50:89 ohms.
Ratio increases by 15 percent.
1.56:1
a) (G-B); 50:32 ohms
Ratio increases by 10 percent.
b) (B-G); 50:78 ohms
Ratio increases by 40 percent.
1.36:1
a) (F-A); 50:36.8 ohms
Ratio decreases by 9 percent.
b) (A-F); 50:68 ohms
Ratio increases by 1.5 percent.

Sec 15.3.2 A Low-power 10-Ratio Unun

Photo 15-G shows a low-power unit mounted in a homemade 2.25 inch long by 1.5 inch wide by 2.25 inch high minibox. It has five quadrifilar turns of No. 16 H Thermaleze wire on a 1.25-inch OD ferrite toroid with a permeability of 250. The tap on winding 5-6 (**Figure 15-2B**) is at three turns from terminal 5 and on winding 1-2; it is three turns from terminal 1. Because the number of turns is different from the high-power unit, so are the ratios that use the taps. In this case, they are a little larger. Specifically, the tapped ratios are now: 1:12.96, 1:6.76, 1:3.24, 1:1.69, and 1:1.44. If the taps were at two turns from terminals 5 and 1, the ratios would be a little less than those of the high-power unit. You can play with the equations in the first section of this chapter and arrive at many different ratios.

Because this Unun has shorter transmission lines than its high-power counterpart, the deviations of the ratios across the HF band are generally smaller. Also, if winding 3-4 (in **Figure 15-2B**) were replaced with No. 14 H Thermaleze wire, this low-power unit could very well be rated at 500 watts of continuous power for all ratios!

Chapter 16

Ununs for Beverage Antennas

Section 16.1 Introduction

The Beverage antenna[19] is well known by 160-meter enthusiasts for enhanced signal-to-noise ratios when there are high levels of interference and atmospheric noise. If erected properly, Beverages also have excellent directivity. However, they are quite inefficient and, therefore, not generally suitable as transmitting antennas. Important considerations with Beverages are the terminating resistor (for the more common single-wire version) and the input matching Unun (unbalanced-to-unbalanced transformer). The terminating resistor and the impedance ratio of the Unun are determined by the characteristic impedance of the antenna acting as a long transmission line with one good conductor and one poor conductor (the earth). This line is generally between 400 and 600 ohms, and theoretically given by:

$$Z_0 = 138 \times \log(4h/d) \qquad \text{(Eq 16-1)}$$

where:

Z_0 = characteristic impedance of the Beverage
h = height of the wire above ground
d = diameter of the wire.

This chapter presents low- and high-power versions of multimatch Ununs designed to match 50-ohm cable to unbalanced loads from 450 to 800 ohms. The low-power unit, which is capable of handling continuous power levels up to 100 watts, is specifically designed for the Beverage antenna when it is performing as a receiving antenna. The high-power unit, which is capable of handling 1 kW of continuous power, can be used with the Beverage or any other traveling wave antenna when used as a transmitting antenna. Also presented are high-power designs capable of flat response, including the entire AM broadcast band. These multimatch Ununs could be of interest to designers of high-power amplifiers for the broadcast band. A little theory on how these devices are designed is also provided.

Sec 16.2 A Little Theory

Transmission line transformers[2] (the Unun being a subset thereof) are known for having greater bandwidths and efficiencies than their counterparts, the conventional transformers. Design considerations for the two types of transformers are also vastly different. Transmission line transformers use chokes and transmission lines, while conventional transformers use flux linkages.

High-impedance Ununs (and Baluns), which match 50 ohms unbalanced to impedances as high as 800 ohms, lie at about the edge of this technology's capability. The reasons are: 1) the windings require more turns because higher reactances are needed for isolating the input from the output, and 2) they require higher characteristic impedances in the transmission lines because the loads they see are greater. Therefore, when winding one of these devices, you'll *just* run out of space on your toroidal cores when trying to satisfy the low frequency and high frequency objectives. Incidentally, beaded transmission lines are not recommended at these impedance levels because of their excessive losses.

There are two methods for obtaining broadband operation at these high impedance levels. One uses Guanella's 9:1 and 16:1 Baluns, which are converted to Unun operation.[2] The other uses higher-order windings (quadrifilar in this case) on a single core, which is an extension of Ruthroff's bootstrap approach.[2] The Guanella approach, which uses coiled transmission line connected in series at the high-impedance side and in parallel at the low-impedance side, results in very broad bandwidths—but with difficulty in meeting low-frequency objectives. Low-frequency models[2] show that, with ratios above 4:1,

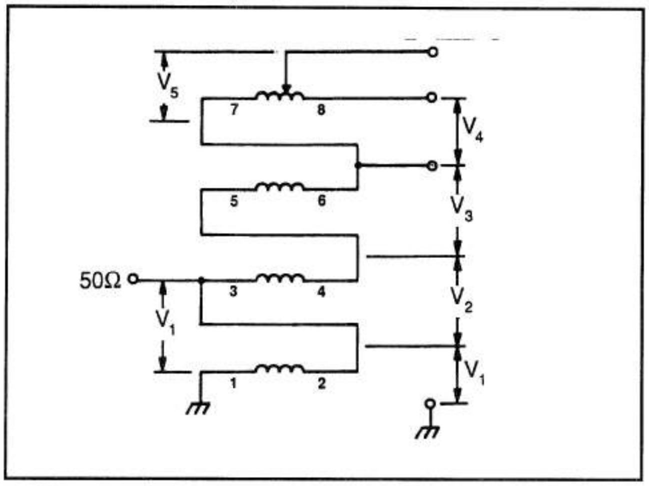

Figure 16-1. *Schematic diagram of the quadrifilar design, using Ruthroff's approach for high-impedance, low-frequency Ununs like the Beverage matching transformer.*

some of the coiled windings are connected in parallel, resulting in reduced reactances. However, with the Ruthroff approach, all of the inductances (at the low-frequency end) end up mutually aiding each other. However, Ruthroff's approach suffers at the high-frequency end because a direct voltage is summed with three voltages that traverse various lengths of transmission lines. As a result, Guanella's approach of summing voltages of equal delays is preferred for the higher frequency bands, and Ruthroff's approach is most often used for the lower frequency bands. This chapter presents designs using Ruthroff's approach.

Figure 16-1 shows the schematic diagram of a quadrifilar-wound Unun. If the lengths of the transmission lines are very short compared to the wavelength (therefore, phase delay and standing waves are negligible), then:

$$V_1 = V_2 = V_3 = V_4 \qquad \text{(Eq 16-2)}$$

at terminal 6,

$$V_o = V_1 + V_2 + V_3 = 3V_1 \qquad \text{(Eq 16-3)}$$

and the impedance ratio becomes:

$$g = (V_o/V_1)^2 = 9 \qquad \text{(Eq 16-4)}$$

At terminal 8, it becomes:

$$g = 16 \qquad \text{(Eq 16-5)}$$

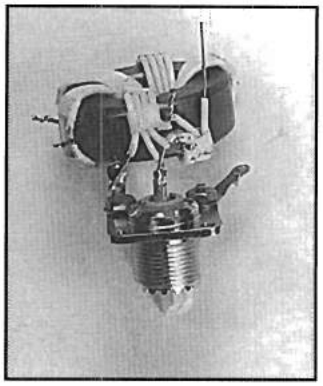

Photo 16-A. *The bottom view of the low-power Beverage antenna Unun.*

The voltage at the tap in winding 7-8 is:

$$\begin{aligned} V_o &= 3V_1 + V_5 \\ &= 3V_1 + n/NV_1 = V_1(3 + n/N) \\ &= V_1(3 + n/N) \qquad \text{(Eq 16-6)} \end{aligned}$$

where:

N = total number of turns

n = number of turns from terminal 7

The impedance ratio, using the tapped winding, becomes:

$$g = (V_o/V_1)^2 = (3 + n/N)^2 \qquad \text{(Eq 16-7)}$$

When the lengths of the transmission lines are significant, then important phase delays can occur and reduce the high frequency response. As you can see in **Figure 16-1**, V_2 travels one transmission line, V_3 travels two transmission lines, and V_4 travels three transmission lines. Additionally, the high frequency response is further diminished if the characteristic impedances of the transmission lines are not at their optimum values (which is hard to do at these impedances levels). Even with these major flaws, the Ruthroff approach is better for Beverage antenna use because this antenna's greatest advantages are on the lower frequency bands (80 and 160 meters).

Sec 16.3 A Low-power Design

Photo 16-A shows the bottom view of a 5-turn quadrifilar-wound Unun designed to handle 100 watts of continuous power with constant ratios from 9:1 to 16:1 in the 40- and 80-meter bands. It uses the Ruthroff approach of **Figure 16-1** and is shown here to give the reader a method for making the various interconnections. For operation on the 80- and 160-meter bands, I would use 6 quadrifilar turns on a 1.5-

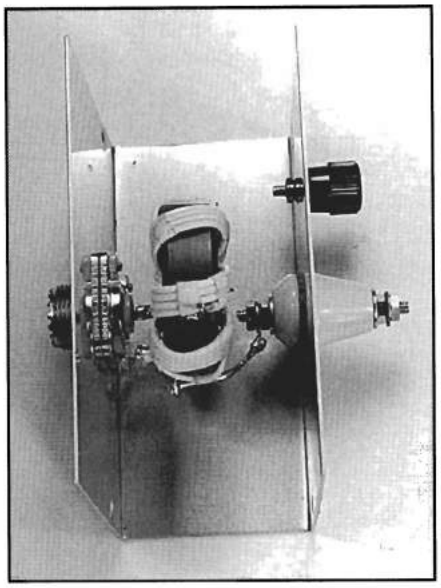

Photo 16-B. *The low-power Beverage antenna Unun mounted in a 4 inch long by 2 inch wide by 2.75 inch high minibox.*

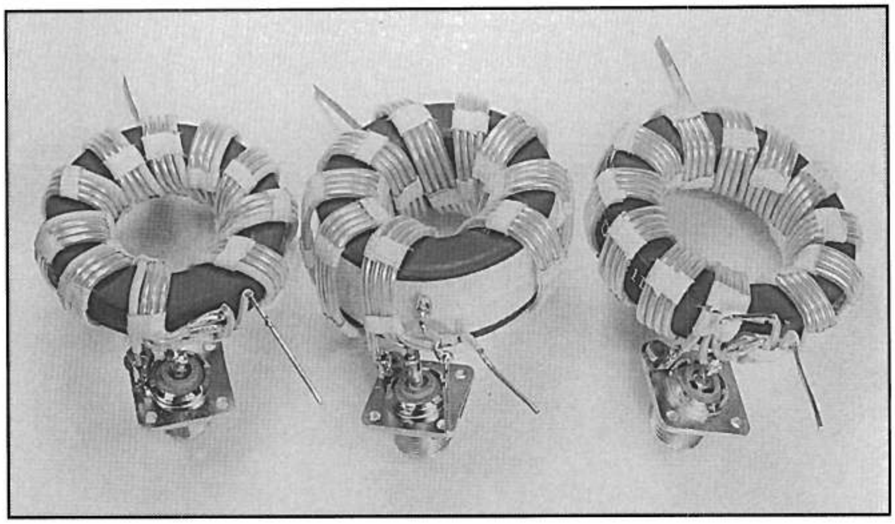

Photo 16-C. *Three high-power, low-frequency Ununs using a quadrifilar design with Ruthroff's approach. The one on the left is designed to cover the 80- and 160-meter bands. The other two are designed to cover the 160-meter and AM broadcast bands.*

inch OD ferrite toroid with a permeability of 250. The bottom winding is No. 20 hook-up wire and the other three are No. 22 hook-up wire. Winding 7-8 is tapped at 2 turns from terminal 7, yielding a 11.11:1 ratio, and at 3 turns from terminal 7, yielding a 12.25:1 ratio. Therefore, with outputs also at terminals 6 and 8, this Unun matches 50-ohm cable to loads of 450, 555.6, 612.5, and 800 ohms.

Photo 16-B shows the unit mounted in a 4 inch long by 2 inch wide by 2.75 inch high minibox. The output (the feedthrough insulator) is connected to one of the taps. A grounded binding post is also shown.

Sec 16.4 High-power Designs

Photo 16-C shows three high-power designs. The one on the left is specifically designed to cover the frequencies generally used with traveling wave structures like the Beverage antenna. This design has 10 quadrifilar turns on a 2.4-inch OD ferrite toroid with a permeability of 250. Winding 1-2 is No. 14 tinned copper wire, and the other three are No. 16 tinned copper wire. The wires are also covered with Teflon sleeving. Winding 7-8 is tapped at 5 turns from terminal 7, yielding a ratio of 12.25:1. When matching 50-ohm cable to loads of 450 ohms (terminal 6), 612.5 ohms (the tap), and 800 ohms (terminal 8), the variation in response is less than 5 percent from 1.5 to 4 MHz. At 6.5 MHz, the variation (which is an increase in the impedance ratio) increases to about 20 percent. **Photo 16-D** attempts to provide a better view of the connections.

The other two high-power Ununs in **Photo 16-C** are specifically designed to cover the broadcast and 160-meter bands. The one in the center has 9 quadrifilar turns (of the same wires as above) on a stack of two 2.4-inch OD ferrite toroids with permeabilities of 250. The tap on winding 7-8 is now at 4 turns from terminal 7, yielding a ratio of 11.86:1. When matching 50-ohm cable to 450 ohms (terminal 6), 593 ohms (the tap), or 800 ohms (terminal 8), the response is literally

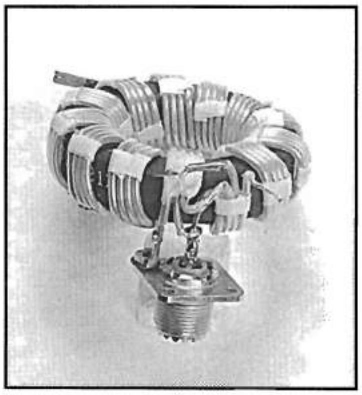

Photo 16-D. *The bottom view of the high-power Beverage antenna Unun.*

flat from 0.5 to 2 MHz. At 4 MHz, the ratios increase by about 6 percent. At 7 MHz, they increase by about 20 percent.

The Unun on the right in **Photo 16-C** illustrates another way of obtaining the same performance as above. In this case, the design has 12 quadrifilar turns (of the same wires as above) on a 2.68-inch OD ferrite with a permeability of 290. The tap on winding 7-8 is at 6 turns from terminal 7, yielding a 12.25:1 ratio (instead of 11.86:1 as above). Although the performance of this design is practically the same as the one above (using the two 2.4-inch OD cores), it is a much more expensive design because the 2.68-inch OD core is not nearly as popular. However, if a broadband, high-power and high-impedance Unun (or Balun) is required to cover 1.5 to 30 MHz, then these expensive 2.68-inch OD ferrite cores are very likely the *only* alternative!

Chapter 17

Concluding Remarks

Sec 17.1 Introduction

As I've often said, there is little information that deals with aspects of design and applications of practical hardware. Most companies are reluctant to publish their results for fear of giving away their hard-earned secrets. Textbooks only contain a few paragraphs on the subject. Therefore, very few people fully understand this technology, and, as a result, it is still far from reaching its full potential.

This book not only contains my designs, which have appeared in series written for *CQ* and *Communications Quarterly*, but also my views on other articles that have appeared in the amateur radio literature.

In the process of converting and combining the articles into appropriate chapters, one section in my article in the *CQ*, March 1993 issue entitled "Dual-Ratio Ununs," stood out as having broader applications. It is entitled "Reflections on Power Ratings" and is presented here. This information is followed by a section on misconceptions and one on the "state of the art."

After reading this book, some might think I was overly critical and didn't agree with any of the designs or explanations (or both) presented in the amateur radio literature. This is quite true. In taking this stand, I was hoping to provoke, in return, critical comment on my work. In this way, we can help our amateur friends—and perhaps even our professional friends—by advancing the understanding and application of these very useful transformers.

Sec 17.2 Reflections on Power Ratings

Power rating is one of the most controversial and least understood specifications for the transmission line transformer. As of today, no professional group has yet set the standard for this specification (as well as any other) for this popular class of matching transformers. In fact, manufacturers of ferrites, which are mainly the materials used with these devices, only specify them for their uses as conventional transformers and inductors, or microwave devices.

It is well known that power ratings for practically all conventional devices are based upon catastrophic failures (usually exceeding a voltage or current limit), and failures over a relatively short period of time due to an excessive rise in temperature.

With transmission line transformers, there are really two catastrophic-type failures that can occur. One is voltage breakdown. If the device is misterminated with a high impedance (especially an open circuit), a breakdown of the insulation can occur. This is particularly true of the 1:1 Balun (50:50 ohms) that is terminated with the very high impedance of a full-wave dipole or inverted V. Using heavily coated wires (but still maintaining a characteristic impedance close to 50 ohms), or small but high-power coaxial cable, can help under these conditions.

The second catastrophic failure occurs at the low-frequency end of the transformer's passband, when the energy is not completely transmitted to the output circuit by a transmission line mode. This takes place when the reactance of the coiled or beaded transmission line is not sufficient to prevent conventional transformer currents or shunting currents to ground. Under these conditions, harmful flux can take place in the core or beads. Nonlinearities can also occur if the flux becomes appreciable. The objective in design at the low-frequency end is to have a margin of safety such that, with a termination of about three times (hence VSWR of 3:1) that of a matched condition,[2] no flux will appear in the core or beads.

The failure due to an excessive rise in temperature is the least understood of the two because it involves the failure mechanism in transmission line transformers when only transmission line currents are allowed to flow. Unlike the conventional transformer whose losses are current dependent (wire, eddy current, and hystereis losses), the transmission line transformer's losses are voltage dependent (a dielectric-type). That is, the greater the voltage drop along the length of the transmission lines, the greater the loss. Furthermore, it can be shown that only low-permeability ferrites (less than 300) yield the extremely high efficiencies of which these transformers are capable.[2]

Because all transmission line transformers have voltage drops along their transmission lines, we must look at their high-frequency models to determine the magnitude of these drops and, hence, the temperature rise that can be expected. Here are some examples:

If V_1 is the voltage that appears on the 50-ohm side of the transformer, then:

1) For a quintufilar-wound Unun, the longitudinal voltage-drop is $V_1/5$ in matching to lower impedances (like 32 or 18 ohms) and $V_1/4$ in matching to higher impedances (like 78 or 139 ohms).

2) For a quadrifilar-wound Unun, the longitudinal voltage-drop is $V_1/4$ in matching to lower impedances (like 12.5 or 28 ohms) and $V_1/3$ in matching to higher impedances (like 89 or 200 ohms).

3) For a trifilar-wound Unun, the longitudinal voltage-drop is $V_1/3$ in matching to lower impedances (like 22.22 or 25 ohms) and $V_1/2$ in matching to higher impedances (like 100 or 112.5 ohms).

4) For a bifilar-wound Unun, the longitudinal voltage-drop is $V_1/2$ in matching to a lower impedance of 12.5 ohms and V_1 in matching to a higher impedance of 200 ohms.

Because the quintufilar-wound Unun has the lowest voltage drop, it is expected to have the highest efficiency. Furthermore, it can be seen that the highest efficiencies occur in matching to lower impedances. Very accurate measurements[2] have shown that 4:1 Ununs, using ferrite cores with permeabilities of 125, have exhibited losses of only 0.02 to 0.04 dB in matching 50 to 12.5 ohms from 1 MHz to over 30 MHz. Even though the Ununs in this book have mostly used permeabilities of 250, and should have slightly greater losses, many use higher-order windings (trifilar, quadrifilar, and quintufilar) and, hence, have lower longitudinal voltage drops. Therefore, they should have losses of only 0.02 to 0.04 dB, as well.

When matching at the 1 kW level, the figures above mean that only 5 to 10 watts would be dissipated in the Unun. As a heatsink, these small transformers should be able to handle this loss easily. In fact, they should be able to handle several times this level of continuous power. Also, because they use heavily coated wires, their peak power ratings should be greater by more than a factor of two!

Another important power rating consideration is to determine what happens when the transformers are misterminated. Because the losses being considered now are dielectric-types and, hence, voltage-dependent, the harmful terminations are greater than that for which the transformers were designed. For example, if the termination is three times greater (a VSWR of 3:1), the voltages along the transmission lines would increase by a factor of 1.73. This means the losses would practically double. The Ununs described in this series, when matching to impedances lower than 50 ohms, should easily handle this mismatch. Obviously, mismatches in the range of 10:1 would result in much lower efficiencies and should be avoided.

The analysis of the losses in Baluns follows the same pattern. The voltages are as follows: under matched conditions for a 1:1 Balun (50:50 ohms), $V_1/2$; for a 4:1 Balun (50:200 ohms), V_1; for a 9:1 Balun (50:450 ohms), $1.5V_1$; and for higher-impedance Baluns it could be $2V_1$. The higher voltage drops, together with high VSWRs, means that high-impedance Baluns (and Ununs) have more loss and require larger structures to dissipate the heat. It should also be pointed out that there is a tradeoff in efficiency for low-frequency response with Baluns (and Ununs) when matching 50 ohms to higher impedances like 200 ohms, 300 ohms, 450 ohms, and higher. This is done by using permeabilities of 125 and lower.

Finally, I thought it might be useful to give some general guidelines as to what efficiencies you might expect with Baluns and Ununs when using ferrite cores or beads with a permeability of 250. Here are some expected efficiencies when matching 50 ohms to various loads under matched conditions:

Loads	**Efficiency**
50 ohms or less	98 to 99.5 percent
50 to 100 ohms	97 to 98 percent
100 to 200 ohms	96 to 97 percent
200 ohms and above	93 to 96 percent

As I mentioned earlier, these efficiencies would be reduced by a percent or two with a VSWR of 3:1, which increases the loss by a factor of about two. Also, the efficiencies can be increased by a percent or two with high-impedance loads (greater than 100 ohms) by resorting to lower permeability ferrites that trade off efficiency for low-frequency response. In closing, I would like to say that high-permeability manganese-zinc ferrites should be avoided because of their much higher losses. Furthermore, their losses are highly frequency dependent, while low-permeability nickel-zinc ferrites are not.

Sec 17.3 Misconceptions

From recent discussions on the air and phone calls concerning Baluns, I think the most *expensive* misconception regarding Baluns is the assumption that a 9:1 (450:50 ohm) Balun would match 50-ohm cable (or the output of a linear or transceiver) to 450-ohm twin lead, without considering the effect of its termination. In truth, the 9:1 Balun would *only* see 450 ohms if the line were terminated in 450 ohms. In reality, if the line were terminated in a 50-ohm dipole, the Balun would see 50 ohms when the line is a half-wave long and 4050 ohms when is a quarter-wave long. The 9:1 Balun is clearly useless in this application.

By far, most misconceptions regarding Baluns are due to the many radio amateurs who perceive these devices as conventional transformers that transmit the energy from input to output by flux linkages and not as transmission line transformers, which transmit energy by an efficient transmission line mode. This is clearly shown by the writers who have compared their "new" coaxial cable (coiled about a toroid or threaded through ferrite beads) Baluns with Baluns using wire transmission lines coiled about a ferrite rod or toroid. They claim their Baluns are better because the others: 1) were limited by leakage inductance, 2) did not exhibit true 1:1 impedance transformations, 3) were prone to core saturation, 4) added a reactive component to the input impedance, 5) were susceptible to unbalanced and mismatched loads, and more importantly, 6) had *more* loss.

If the writers had accepted the correct model for these devices (given to us by Guanella and Ruthroff), which shows that they are really chokes (lumped elements) and configurations of transmission lines (distributed elements), then there are several parameters they should have considered in their comparisons. They are: 1) the characteristic impedances and lengths of the transmission lines (the high-frequency capability), 2) what form of the 1:1 Balun or 4:1 Balun is used by the other Balun, 3) the low-frequency capabilities (safety margins), 4) power capabilities, and finally 5) efficiencies.

Now, had the writers used the proper parameters in their comparisons, they would have found that mismatch loss was mistaken for real (ohmic) loss; high-frequency response was limited by standing waves, and not leakage inductance or shunting capacitance; the beaded-coax Balun had *more* loss than a well-designed Balun using wire or coax transmission lines coiled about a toroid; and that their comparisons were made with either the trifilar (voltage) 1:1 Balun or the Ruthroff 4:1 Balun, which are inferior designs.

In fact, the perception that the transmission line transformer is actually a conventional transformer is so prevalent, that a new name for this class of devices should be considered—*broadband transmission line matching networks*. This name (without the word *transformer*) would help in dispelling inaccurate perceptions and in standardizing the schematic diagrams. It would place the coiled or beaded transmission lines (in the high-frequency models) horizontally, and eliminate the phasing or polarity dots.

Sec 17.4 The State of the Art

Until very recently, the radio amateur had only two types of Baluns available in the literature and on the market. They were the so-called 1:1 and 4:1 "voltage" Baluns. As was shown in **Chapter 7**, the comparisons by others with new 1:1 designs using coaxial cable (called "current" Baluns) were made with an inferior trifilar-wound Balun, instead of Ruthoff's design that appeared in his 1959 paper and became the industry's standard. Ruthroff's third conductor on his 1:1 Balun was on a separate part of the toroid, thus giving it practically the same characteristics as the Guanella ("current") Balun. These articles on newer designs not only gave a new language to our Baluns, but also presented questionable statements regarding their performances. It would be interesting if the authors of these articles compared their Baluns with well-designed Ruthroff or Guanella Baluns using 50-ohm bifilar windings or coaxial cables on low-loss ferrite toroids (less than 300 permeability). I am quite sure their claims would be greatly diminished.

As was noted in **Chapter 8**, the 4:1 voltage Balun appeared in the amateur radio journals about 25 years ago (the same time as the "inferior" 1:1 voltage Balun). Considerable design information appeared in the handbooks of the time regarding the construction and performance of this Balun. Furthermore, this information also stayed the same over these many years. As was shown in **Chapter 8**, the design was found lacking. However, with some rather simple changes, like doubling the cross-sectional area of the core, increasing the number of turns from 10 to 14, and using extra insulation on the wires to increase the characteristic impedance of the coiled transmission line from about 50 to 100 ohms (the objective), a much better design emerged. In fact, for balanced antenna systems, this new design might well be described as "peerless."

A 4:1 Guanella (current) Balun has now appeared in our handbooks. This more flexible Balun uses two transmission lines wound on separate cores and connected in series at one end and in parallel on the other. Literally, no design information is given on its construction. What is offered are recommendations for the permeability of the ferrite cores. Values from 850 to 2500 are proposed. However, use of these high permeabilities would result in lossy Baluns.

I also found it interesting, in my work on these devices, that the classic papers of Guanella[3] and Ruthroff[9] are still the cornerstones of this technology known as *transmission line transformers*. To be sure, some of us have extended the work of these two by using better measuring equipment, creating more complicated configurations, and finding new applications. However, it is apparent from the articles published in the amateur radio journals and discussions on the air and at club meetings that most radio amateurs still perceive these devices as conventional transformers. They don't look at these devices as Guanella and Ruthroff did—as chokes and transmission lines. As a result, there has been a lack of good design information in our literature.

There are many new and useful designs possible with this technology, as discussed in **Part I** of this book. They include: higher power levels, applications on the VHF and UHF bands and above, and new Baluns and Ununs with ratios other than $1:n^2$ where $n = 1, 2, 3, \ldots$, etc. This book presents some designs* and suggestions for higher-power and higher-frequency applications.

I see two reasons for the lack of emergence in this technology. They are:

1) This subject is not adequately covered in any college textbook, and it generally has not been of interest to academics who rightfully view their role as basic research and not applications. As a result, there are few graduates with any skill in the design of transmission line transformers—in contrast to the areas of transmission line, waveguide, and antenna theory.

2) The professional societies don't receive enough application papers. Although much of the research and development work performed in industry is highly innovative, important to the advancement of the technology, and certainly publishable in scientific journals, corporations are often reluctant to allow publication for fear of "aiding" their competition. It has been stated[29] that in the past few decades, the submission of application papers to the technical journals of the IEEE has declined. In fact, a survey by one of the technical societies showed that 85 percent of the submissions now come from universities, not industry!

In order to assist technologies, like *transmission line transformers*, which are far from reaching their potential applications, IEEE has instituted a program called *Emerging Practices in Technology* (EPT). The object of the EPT program is to facilitate the development of new standards by disseminating and making available various EPT papers to the broadest possible audience worldwide. The papers on practices in various areas of technology are peer reviewed by relevant IEEE Technical Committees, and have the potential for standardization in the future. The papers (mine is **Reference 30**) are published by the IEEE Standards Press.

FOOTNOTE

*Kits and finished units available from Amidon Associates, Inc., 240 Briggs Ave., Costa Mesa, CA 92626.

Part II

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The ARRL Guide to

Antenna Tuners

A Radio Amateur's Guide to Antenna Matching

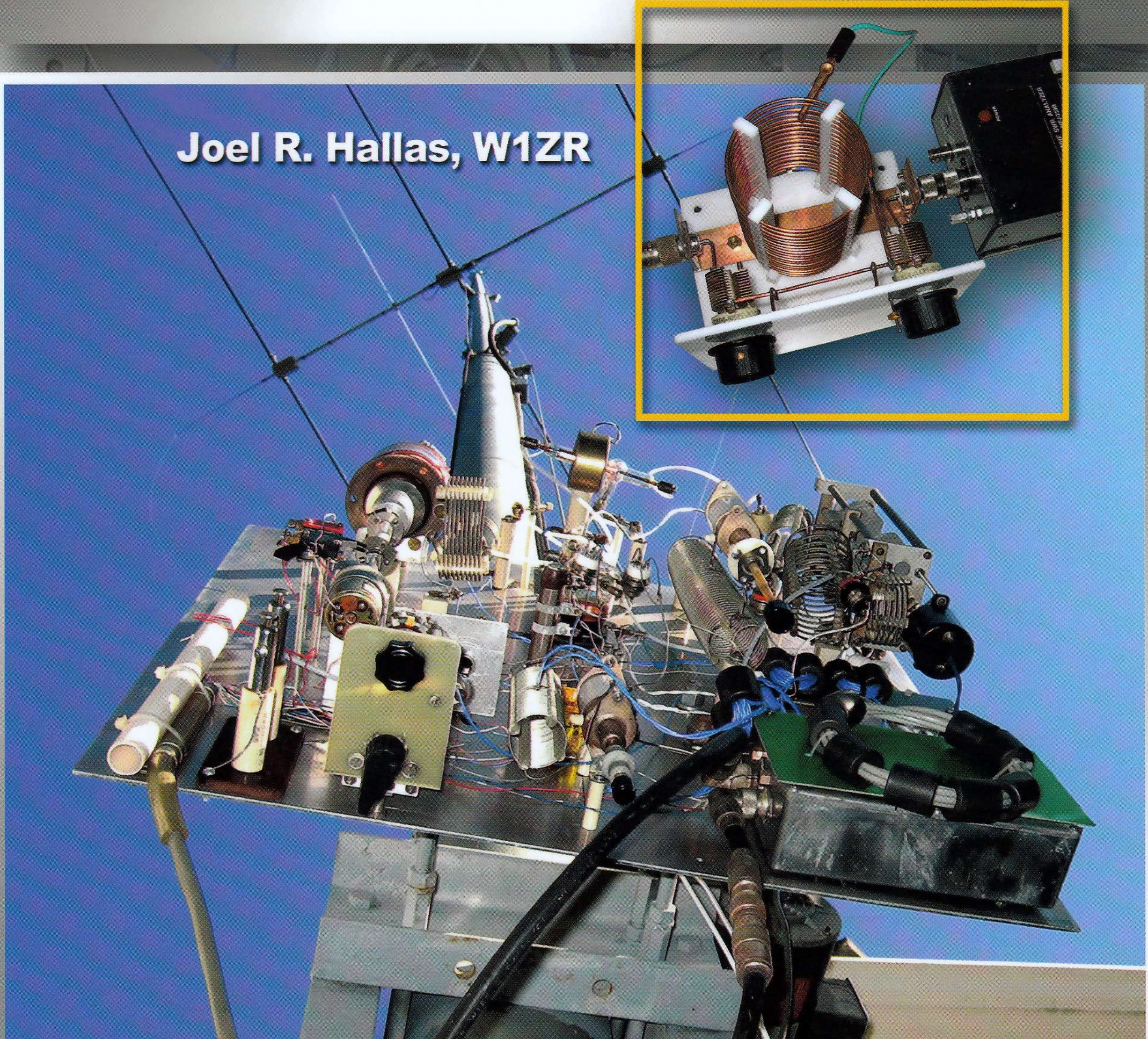

Joel R. Hallas, W1ZR

The ARRL Guide to
Antenna Tuners
A Radio Amateur's Guide to Antenna Matching

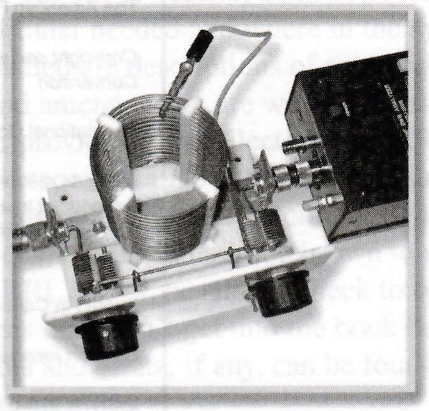

Joel R. Hallas, W1ZR

On the Cover

The group of special purpose antenna tuners made by the late George Badger, W6TC, is shown beneath his rotary antenna system. The inset shows a general purpose L-network antenna tuner built by Barry Shackleford, W6YE, who took both photos. Both are discussed in Chapter 15.

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Foreword

Antenna Tuners are mystical devices that are sometimes needed between antenna systems and transmission lines or radios to make everything play the way it's supposed to. They are the subject of considerable confusion and misunderstanding by many Amateur Radio operators.

This book is intended to assist readers who have a basic knowledge of antennas, such as conveyed by *Basic Antennas — Understanding Practical Antennas and Designs*, in gaining an understanding of whether or not they need an antenna tuner in their station.[1] If it turns out one is needed, this book will help the reader decide the type of tuner needed and where in the system it should be applied. Also provided are descriptions of appropriate applications of such devices and antennas that are well suited for such use.An additional chapter provides data collected from ARRL Laboratory product reviews of representative antenna tuners to assist in tuner selection. Design methodology and specific design details are also provided for those who wish to build their own tuners.

As with all ARRL books, be sure to check to see if there are any last minute changes that didn't get into the book before it went to the printer. Updates and errata, if any, can be found at **www.arrl.org/product-notes/**.

David Sumner, K1ZZ
Executive Vice President
Newington, Connecticut
October 2010

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[1] J. Hallas, W1ZR, *Basic Antennas — Understanding Practical Antennas and Designs,* Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9994. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/arrl.store/**; **pubsales@arrl.org**.

Acknowledgements

I would like to offer my special thanks to the ARRL production and editorial staff who made this book come together smoothly. In addition, thanks go to my long-suffering wife Nancy, W1NCY, who put up with the countless hours of my writing to make this happen.

I especially appreciated the tireless efforts of ARRL Technical Advisor Barry Shackleford, W6YE, who carefully examined every page of the manuscript in an effort to make sure there were neither technical nor grammatical errors and that all points were made clearly.

About the ARRL

The national association for Amateur Radio

The seed for Amateur Radio was planted in the 1890s, when Guglielmo Marconi began his experiments in wireless telegraphy. Soon he was joined by dozens, then hundreds, of others who were enthusiastic about sending and receiving messages through the air—some with a commercial interest, but others solely out of a love for this new communications medium. The United States government began licensing Amateur Radio operators in 1912.

By 1914, there were thousands of Amateur Radio operators—hams—in the United States. Hiram Percy Maxim, a leading Hartford, Connecticut inventor and industrialist, saw the need for an organization to band together this fledgling group of radio experimenters. In May 1914 he founded the American Radio Relay League (ARRL) to meet that need.

Today ARRL, with approximately 150,000 members, is the largest organization of radio amateurs in the United States. The ARRL is a not-for-profit organization that:

- promotes interest in Amateur Radio communications and experimentation
- represents US radio amateurs in legislative matters, and
- maintains fraternalism and a high standard of conduct among Amateur Radio operators.

At ARRL headquarters in the Hartford suburb of Newington, the staff helps serve the needs of members. ARRL is also International Secretariat for the International Amateur Radio Union, which is made up of similar societies in 150 countries around the world.

ARRL publishes the monthly journal *QST*, as well as newsletters and many publications covering all aspects of Amateur Radio. Its headquarters station, W1AW, transmits bulletins of interest to radio amateurs and Morse code practice sessions. The ARRL also coordinates an extensive field organization, which includes volunteers who provide technical information and other support services for radio amateurs as well as communications for public-service activities. In addition, ARRL represents US amateurs with the Federal Communications Commission and other government agencies in the US and abroad.

Membership in ARRL means much more than receiving *QST* each month. In addition to the services already described, ARRL offers membership services on a personal level, such as the ARRL Volunteer Examiner Coordinator Program and a QSL bureau.

Full ARRL membership (available only to licensed radio amateurs) gives you a voice in how the affairs of the organization are governed. ARRL policy is set by a Board of Directors (one from each of 15 Divisions) elected by the membership. The day-to-day operation of ARRL HQ is managed by a Chief Executive Officer.

No matter what aspect of Amateur Radio attracts you, ARRL membership is relevant and important. There would be no Amateur Radio as we know it today were it not for the ARRL. We would be happy to welcome you as a member! (An Amateur Radio license is not required for Associate Membership.) For more information about ARRL and answers to any questions you may have about Amateur Radio, write or call:

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800-32-NEW HAM (800-326-3942)
You can also contact us via e-mail at **newham@arrl.org**
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Chapter 1

Why I Might Need an Antenna Tuner

Amateur Radio station W1ZR, home station of the author. The unit on the far left is an early Ten-Tec 238 manual antenna tuner.

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To transmit radio signals, you need a transmitter, often the transmitter side of a *transceiver* — a combined transmitter and receiver — and an antenna. Of course you will need a few other things such as legal authority to transmit, from the FCC in the US, a power source and an information source, such as a telegraph key, microphone or PC. In this book we will focus on the interconnection between the transmitter and the antenna, leaving the other topics to other books.

You might notice that, in spite of the book's title, we didn't mention antenna tuners — a device that goes between the transmitter and antenna. This is because, strictly speaking, an antenna tuner isn't necessary, at least not in all cases. The antenna tuner is only required if the transmitter can't put its output power into the antenna because of an incompatibility between them.

Radio Incompatibility?

A radio transmitter comes with a set of specifications. For proper operation, the owner is responsible to ensure that the requirements listed in the specifications are met. Some are straightforward, such as "power required: 13.8 V dc at 20 A max." If we plugged such a radio into a 120 V ac outlet, we wouldn't have a right to expect it to operate properly — in fact we might expect to see smoke and flames. We would need an intermediate device, called a power supply, to transform the 120 V ac in our outlet to the 13.8 V dc our radio wants.

The compatibility issue we will be considering here is one relating to the *ANTENNA IMPEDANCE* specification. While not all transmitter specifications include an explicit antenna specification, most will say something like *ANTENNA IMPEDANCE, 50 Ω (Unbalanced)* or possibly *ANTENNA IMPEDANCE, 50 Ω (Unbalanced) with SWR of 2:1 or less.* These specifications indicate the load that the antenna system must present to the radio for proper operation. We will discuss the different parts of this specification and what they mean as we go forward. As with the power supply, if the antenna doesn't meet the specification's requirements, we might need an intermediate device — possibly an antenna tuner.

Does My Antenna Have to be a Resistor?

The indication "50 Ω" does sound a lot like a resistor. The radio will be very happy to put its power into an actual 50 Ω resistor, in fact that's how we often test a radio when we don't want the radio signal to go out over the air. Unfortunately, a resistor absorbs the transmitter power and turns it into heat — it does not make a good antenna.

In a properly designed antenna, it is often the case that the antenna's radiating properties will be converted into a load that acts like a 50 Ω resistor to the radio, but actually radiates the power as radio waves.

So What's the Problem?

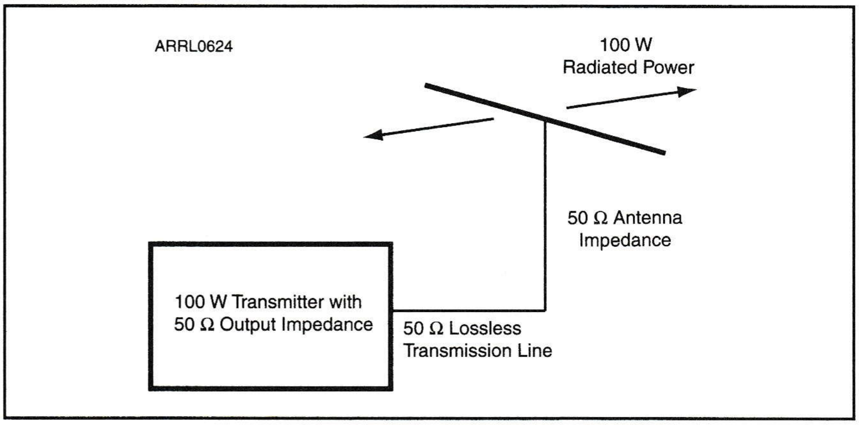

Figure 1-1 — Radio and antenna system with matched impedances.

It would seem that we can solve our incompatibility problem by just buying (or building) an antenna that has a compatible specification of a 50 Ω resistive impedance and connecting it to our radio. This is quite true, and can be very successful — within certain constraints (see **Figure 1-1** for the ideal case). This compatible case is referred to as a *matched* system. Unfortunately, the real world rears its ugly head in a few ways:

- The biggest issue is that any antenna will have its particular design impedance on a single frequency. This is not an issue with many radio services — broadcast stations, for example — that operate on a single assigned frequency. Some services, such as the Amateur Radio service, operate within assigned bands. Shifting frequency from one end of the band to the other can result in a significant change in antenna impedance.
- A real antenna is always installed at some height above the local terrain. The electrical properties of the soil and the height above ground will have a significant impact on antenna impedance. For example, perhaps the simplest antenna, a half wave horizontal dipole has an impedance that varies from around 40 to 100 Ω as it moves from 0.1 to 0.35 λ (wavelengths) above ground.

What Happens if the Radio and Antenna Aren't Matched?

Most radios can tolerate a certain amount of mismatch from an antenna system without any problems. This is often specified in terms of standing wave ratio (SWR), a measure of mismatch. Often the allowed value is 2:1; which, for a 50 Ω system, would represent resistive values of 25 or 100 Ω (50/2, or 50 × 2).[1] Note that while the radio will operate without damage at this level of mismatch, it may not operate quite as well as if it were matched.

A mismatched load impedance in early solid state transmitters could result in damage to components in the power amplifier stages due to higher voltages or currents than it was designed to handle. Modern transceivers have *fold-back* circuitry that senses the mismatch and reduces transmitter power to avoid damage. Note that while the transmitter will not be damaged, and still can be used, it will put out less power, sometimes beginning to fold back at an SWR as low as 1.5:1. This is perhaps the most common reason that we might notice our 100 W transmitter actually putting out 25 W.

[1] In addition to these two resistive values, there is a whole set of combinations of resistive and reactive impedance components that will also result in an SWR of 2:1.

So What Can We Do?

Perhaps not surprisingly, one solution to this issue is something that is generally called an *antenna tuner*. The antenna tuner is a variable impedance transforming device that can transform the impedance of an antenna system so that it appears to the transmitter as a 50 Ω load, while causing almost all of the transmitter power to be radiated from the antenna, just as if everything were matched.

As shown in **Figure 1-2**, the antenna tuner can be placed directly at the transmitter and connect directly to an antenna. In many cases, a *transmission line* is used between the transmitter and the antenna. We will discuss transmission lines in more detail later, but for now be aware that a transmission line is frequently used if the transmitter and antenna are not in the same place. As shown in **Figures 1-3** and **1-4**, the antenna tuner can be placed at either the antenna end or the radio end of a transmission line interconnecting the radio and antenna. It could even be put at an intermediate point.

Much of this book will discuss the details of the different configurations and requirements of antenna tuners and where they are located, so you can make the most informed decision on what type of tuner to buy or build and where to install it.

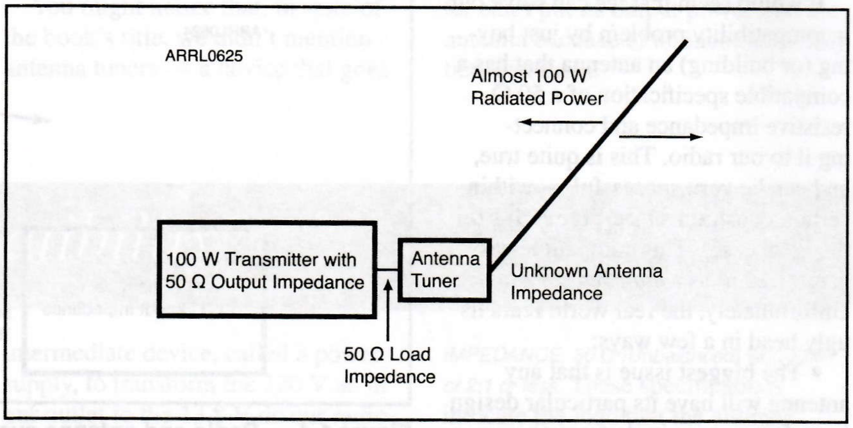
ARRL0625
Almost 100 W
Radiated Power
100 W Transmitter with
50 Ω Output Impedance
Antenna
Tuner
Unknown Antenna
Impedance
50 Ω Load
Impedance

Figure 1-2 — Antenna tuner collocated with the radio and the antenna. All the transmitter power reaches the antenna except for any loss in the tuner, generally less than 5%.

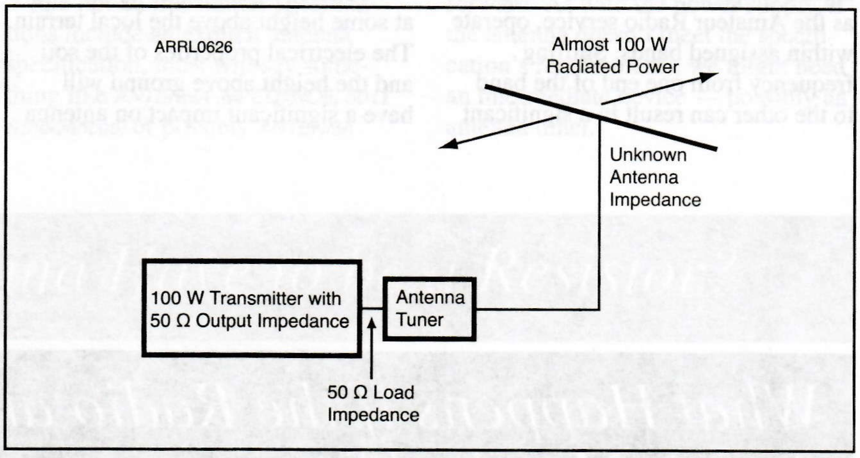
ARRL0626
Almost 100 W
Radiated Power
Unknown
Antenna
Impedance
100 W Transmitter with
50 Ω Output Impedance
Antenna
Tuner
50 Ω Load
Impedance

Figure 1-3 — Radio and antenna system with tuner located at the radio end of the transmission line.

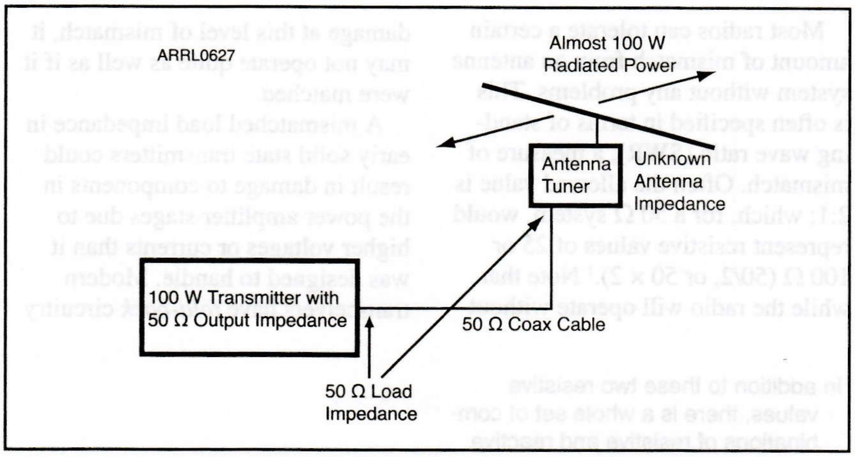
ARRL0627
Almost 100 W
Radiated Power
Antenna
Tuner
Unknown
Antenna
Impedance
100 W Transmitter with
50 Ω Output Impedance
50 Ω Coax Cable
50 Ω Load
Impedance

Figure 1-4 — Radio and antenna system with tuner located at the antenna end of the transmission line.

What's in a Name?

Over the years there has been some discussion of what to call this device I call an *antenna tuner*. There are those who would say that *antenna tuner* is a misnomer because it doesn't actually tune the antenna, but really tunes the transmission line in most applications.

Over the years many other terms have been used to describe this device. You will see references to an *antenna coupler*, *antenna tuning unit* (ATU) and a *transmatch* — all within various ARRL magazines and books. They all mean the same thing and refer to the same type of device.

The best name I've heard for this function is *antenna system matching device*. Since that doesn't resolve itself to an easy to pronounce acronym, throughout this book I will use the most common term *antenna tuner* with neither apology nor regret.

Review Questions

1-1 Under what conditions is there no requirement for an antenna tuner in a transmitting system?

1-2 How can you tell if an antenna tuner is needed?

1-3 What are the likely consequences of not having an antenna tuner, or having a misadjusted antenna tuner?

1-4 If an antenna tuner is properly adjusted on one frequency, what must be done if the operating frequency is changed?

Chapter 2

A Look at Typical Configurations

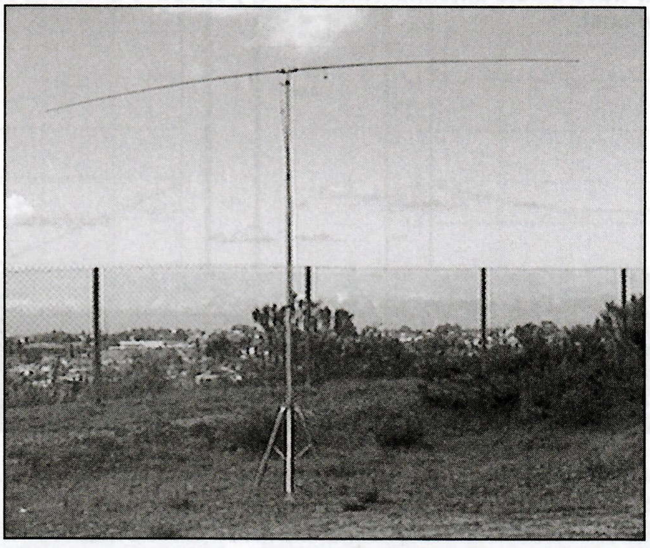

The classic half-wave dipole — an antenna mainstay at many amateur stations.

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The Dipole for the 80 Meter Amateur Band...........................2-4

Fractional Bandwidth 2-5

Review Questions..2-6

A very popular antenna for a new radio amateur is called a *half-wave dipole*. This antenna is easy to construct from two pieces of wire with a total length of about 468/f, where f is the frequency in MHz and the result is in feet. The antenna is often fed with 50 Ω coaxial cable as shown in **Figure 2-1**. Generally, the antenna length is trimmed equally on each side of center until the closest match to 50 Ω is found. While it will function as shown, more predictable performance is often obtained by inserting a device between the inherently balanced antenna and unbalanced (with respect to ground) coaxial cable to provide an appropriate transition between them. This device is generally called a balun — for balanced to unbalanced transition. We will discuss this in detail later in the book.

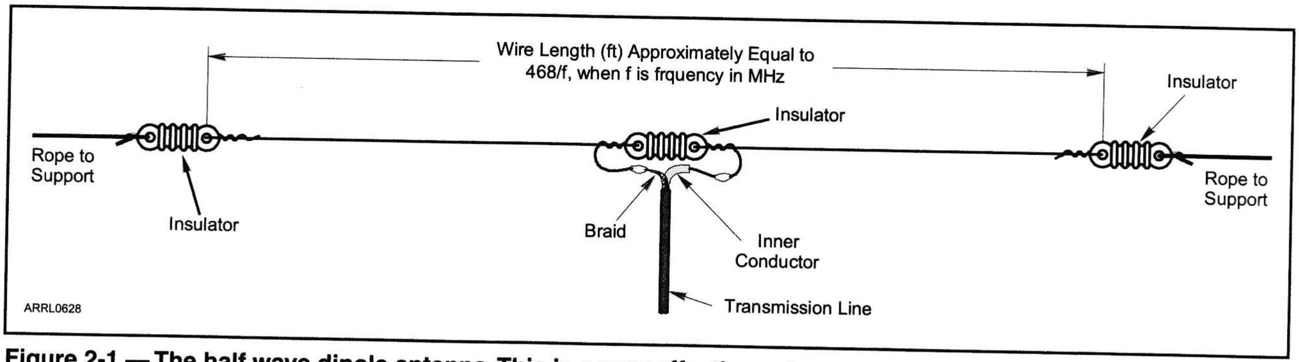

Figure 2-1 — The half wave dipole antenna. This is a very effective antenna, considering its ease of construction and low cost.

A Transmission Line — The Piece in the Middle

In most cases the antenna and radio are located in separate areas. Most often, the optimum location for the radio is somewhere that a person can comfortably operate a radio. For many types of radio systems, this means indoors. The antenna, on the other hand, is typically located outside so it can radiate with minimal obstructions and with at optimum height above the terrain.

It is possible to meet both requirements if an antenna is connected to the radio system through a *transmission line*. An ideal transmission line conveys energy from one end to the other in a totally transparent manner. A real transmission line, on the other hand does so with some limitations:

- Each type of transmission line has a characteristic impedance, Z_0. If the transmission line is terminated with an impedance equal to the Z_0, the same impedance will be seen at any length of line. Fortunately, there are many types of line that have a Z_0 of 50 Ω, so such a line connected to an antenna with a 50 Ω impedance will present a 50 Ω load to the radio no matter the length of the line. It is worth mentioning briefly at this point that if the line is terminated in an impedance other than its Z_0, the impedance at the far end in general will be neither the terminating impedance nor the Z_0 of the line.

These topics will be covered in much more detail later, but it's good to have an idea as we go through the basics.

- Real transmission lines have some associated losses. Thus not all the power put into the bottom by the transmitter comes out at the antenna. The attenuation is higher with increasing frequency, for a given type of line. The attenuation is also directly proportional to line length. In addition, the attenuation increases with standing wave ratio (SWR, a measure of mismatch) — another reason to have a matched system, if possible. We will discuss this phenomenon later.
- SWR is generally determined by measuring the ratio of reflected power to forward power. An SWR of 1:1 results in no reflected power. If the line has significant attenuation, both the power getting to the antenna, and any reflected power will be attenuated. Thus a measurement of SWR at the radio end will appear to be lower than the real SWR at the antenna end.

Dipole for the 40 Meter Amateur Band

If we were to make a dipole of the form of Figure 2-1 for the center of the US 40 meter band, we would use the formula 468/f, with the f equal to 7.15 MHz to result in a starting length of 65.45 feet, or 65 feet, 5.4 inches. As noted previously, this will vary with height, but let's say we get it all correct and have a height that provides close to a 50 Ω load at that frequency. If we then measure the standing wave ratio (SWR) across the band, 7.0 – 7.3 MHz, we would observe a set of SWR data very much like that plotted in **Figure 2-2.**[1,2]

Note that, as desired, we observe an almost perfectly matched condition (SWR of 1:1) at our design frequency of 7.15 MHz. Note also that as we change frequency across the band, our SWR rises to 2:1 at each band edge. Thus, even though our antenna is only closely matched at the band center, if the transmitter can operate at full power with a 2:1 SWR, this antenna will be usable across the band, if trimmed very carefully.

What About Height?

We have previously mentioned that changing height will also change the

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[1] Notes appear on page 6.

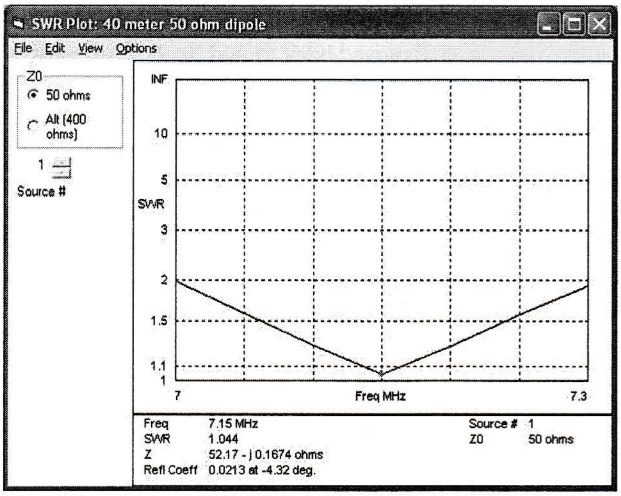
SWR Plot: 40 meter 50 ohm dipole
File Edit View Options
Z0
50 ohms
Alt (400 ohms)
1
Source #
INF
10
5
SWR
3
2
1.5
1.1
1
7
Freq MHz
7.3

Freq 7.15 MHz
SWR 1.044
Z 52.17 - j 0.1674 ohms
Refl Coeff 0.0213 at -4.32 deg.
Source # 1
Z0 50 ohms

Figure 2-2 — Plot of SWR of a 40 meter dipole with height and length adjusted for 50 Ω at 7.15 MHz.

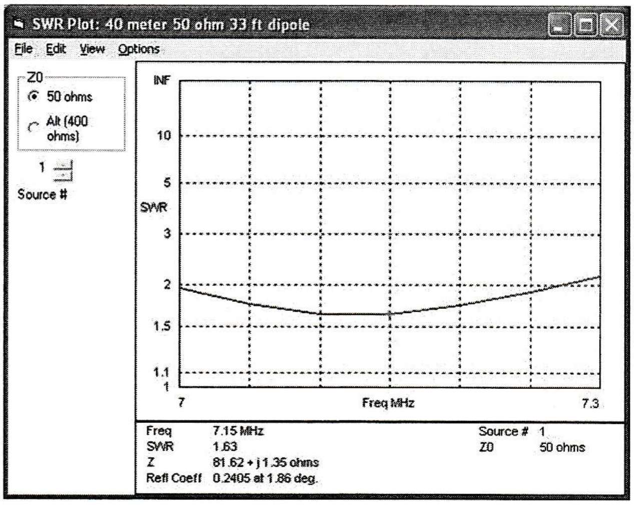
SWR Plot: 40 meter 50 ohm 33 ft dipole
File Edit View Options
Z0
50 ohms
Alt (400 ohms)
1
Source #
INF
10
5
SWR
3
2
1.5
1.1
1
7
Freq MHz
7.3

Freq 7.15 MHz
SWR 1.63
Z 81.62 + j 1.35 ohms
Refl Coeff 0.2405 at 1.86 deg.
Source # 1
Z0 50 ohms

Figure 2-3 — Plot of SWR of a 40 meter dipole with height set to λ/4, about 33 feet.

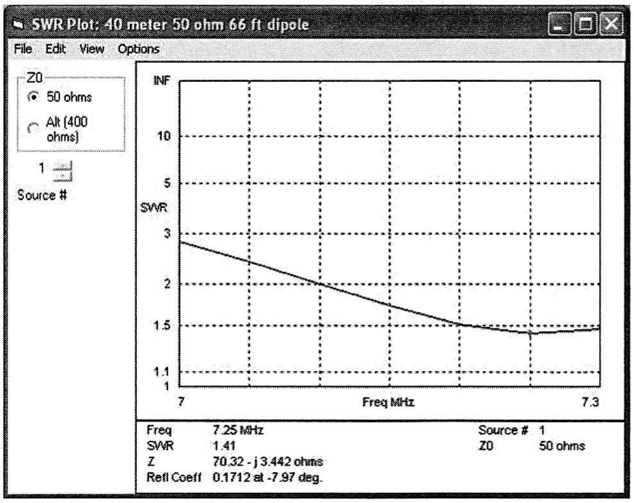
SWR Plot: 40 meter 50 ohm 66 ft dipole
File Edit View Options
Z0
50 ohms
Alt (400 ohms)
1
Source #
INF
10
5
SWR
3
2
1.5
1.1
1
7
Freq MHz
7.3

Freq 7.25 MHz
SWR 1.41
Z 70.32 - j 3.442 ohms
Refl Coeff 0.1712 at -7.97 deg.
Source # 1
Z0 50 ohms

Figure 2-4 — Plot of SWR of 40 meter dipole of Figure 2-3 raised to a height of λ/2, about 66 feet. Note the change in frequency of minimum SWR. It could be tuned back to mid-band by lengthening.

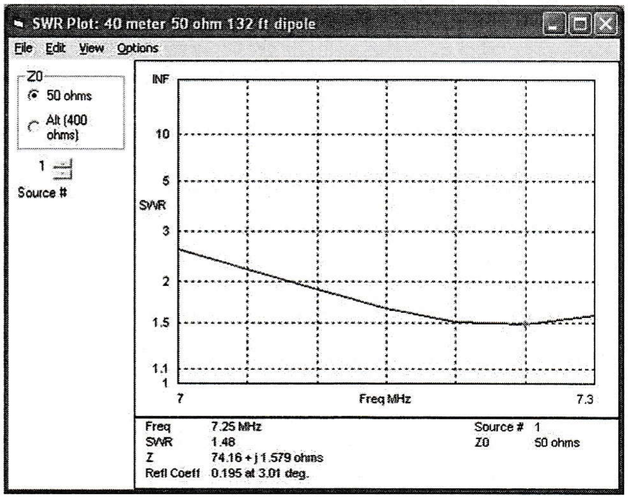
SWR Plot: 40 meter 50 ohm 132 ft dipole
File Edit View Options
Z0
50 ohms
Alt (400 ohms)
1
Source #
INF
10
5
SWR
3
2
1.5
1.1
1
7
Freq MHz
7.3

Freq 7.25 MHz
SWR 1.48
Z 74.16 + j 1.579 ohms
Refl Coeff 0.195 at 3.01 deg.
Source # 1
Z0 50 ohms

Figure 2-5 — Plot of same antenna raised to 1 λ, about 132 feet.

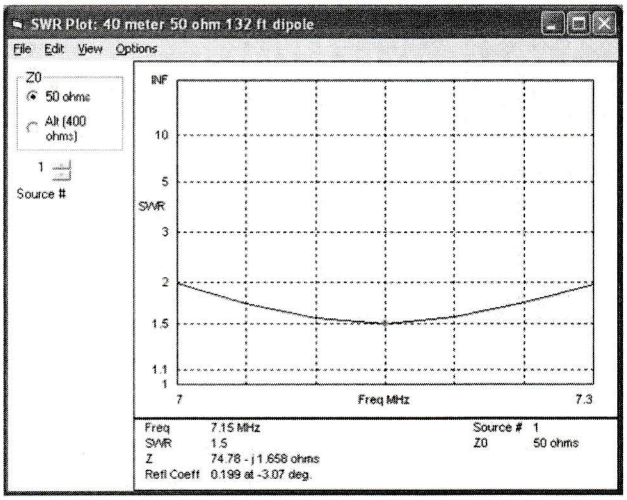

Freq 7.15 MHz
SWR 1.5
Z 74.78 - j 1.658 ohms
Refl Coeff 0.199 at -3.07 deg.
Source # 1
Z0 50 ohms

Figure 2-6 — Plot of SWR of a 1 λ high 40 meter dipole trimmed for mid band.

antenna impedance. In fact it will also change the resonant frequency of the antenna. To obtain the plot in Figure 2-2, we lowered the antenna to a height of 12 feet. While such an antenna will operate, the combination of its direct signal and the signal reflected from the ground will result in most of the radiation going skyward. This makes it suitable for short and medium range communication. In many cases antennas are raised higher to increase low angle radiation to support communication over longer distances.

Impedance and Resonant Frequency at Greater Height

Figs 2-3 through **2-5** are a series of SWR plots of the same antenna as it is raised, first to 33 feet (λ/4), then 66 feet (λ/2) and finally 132 feet (1 λ). Observe the two phenomena happening as the antenna is raised — first, the impedance is changing and second the resonant frequency (frequency at which the impedance is resistive) is changing. Note that the impedance shown is that close to the resonant frequency.

To improve the SWR, we can adjust the length by making it long enough so that the resonant frequency is moved back to mid band. The result is shown in **Figure 2-6**. Note that the antenna now has an SWR range across the band of 2:1 or less so it might still work well across the band without a tuner. Note that to achieve this result, it must be very carefully trimmed.

A Dipole for the 80 Meter Amateur Band

A dipole for 80 meters (don't worry, this is the last example) has a very different result. The US 80 meter (sometimes called 75 and 80 meters) band is wider than 40 meters, covering 3.5 to 4 MHz. The result, again with the height lowered and length adjusted to match 50 Ω at mid band is shown in **Figure 2-7**. This is a very different result from our 40 meter dipole's impedance over the band. The SWR at the band edges is now above 7:1, and the bandwidth over which the SWR is 2:1 or less, the SWR bandwidth, is about 150 kHz — about half what it was on 40 meters.

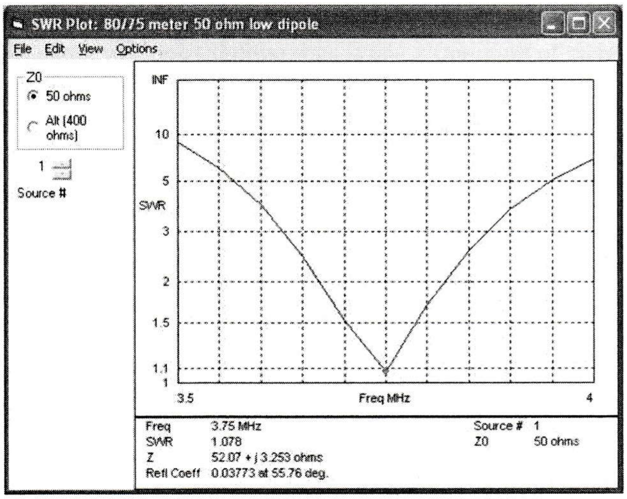

Freq 3.75 MHz
SWR 1.078
Z 52.07 + j 3.253 ohms
Refl Coeff 0.03773 at 55.76 deg.
Source # 1
Z0 50 ohms

Figure 2-7 — Plot of SWR of a 80/75 meter dipole with height and length adjusted for 50 Ω at 3.75 MHz.

Fractional Bandwidth

The reduced bandwidth on 80 meters illustrates a few interesting principles. First, for a band this wide at this frequency, it would take at least three dipoles with slightly different lengths to cover the whole band if we didn't have a device to transform the impedance to a value we wanted — an *antenna tuner*. Second, we note that the key factor is not the bandwidth itself, but rather the fraction (or percentage) of the center frequency that we wish to be able to cover.

In the case of 40 meters, we were able to cover a bandwidth (7300 – 7000) of 300 kHz with an SWR of 2:1. This is the fraction 300/7150 = 0.042, or 4.2%. Note that on 80 meters we had about 150/3750 = 4%. We can use this as a predictor of whether a single thin dipole can cover each amateur band with the results shown in Table 2-1.

Table 2-1

Percentage Bandwidth of Each HF and VHF US Amateur Band.

Band (Meters)	*Upper Frequency (kHz)*	*Lower Frequency (kHz)*	*Bandwidth (kHz)*	*Bandwidth (%)*
160	2000	1800	200	10.5
80	4000	3500	500	13.3
60	5407	5330	77	1.4
40	7300	7000	300	4.2
30	10,100	10,150	50	0.5
20	14,000	14,350	350	2.5
17	18,068	18,168	100	0.6
15	21,000	21,450	450	2.1
12	24,890	24,990	100	0.4
10	28,000	29,700	1700	5.9
6	50,000	54,000	4000	7.7
2	144,000	148,000	4000	2.7
1.25	222,000	225,000	3000	1.3
70 cm	420,000	450,000	30,000	6.9

Clearly, the problem is most pronounced on 80 meters, perhaps why we chose that example. In addition, 160, 10 and 6 meters are wider than our threshold, as is the 70 cm band. Fortunately, the higher three of these bands have operations divided by mode, so that it is not unreasonable to have, for example, a horizontal 6 meter antenna centered at the low end for CW and SSB operation and a separate vertical antenna for FM designed for the high end. Many operators, however, like to work all portions of 160 and 80 meters, so that can be an issue.

Notes

[1] This plot was obtained using an antenna modeling program named *EZNEC*. We will call upon this program repeatedly throughout the book. Several versions of *EZNEC* antenna modeling software, including a free trial version, are available from developer Roy Lewallen, W7EL, at **www.eznec.com**.

[2] For an introduction to *EZNEC* modeling, see Appendix A of J. Hallas, W1ZR, *Basic Antennas — Understanding Practical Antennas and Design.* Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9994. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/arrl-store**; **pubsales@arrl.org**. See chapters 2-6.

Review Questions

2-1 Under what conditions might a ½ wave dipole not be compatible with a radio system?

2-2 Why can a transmission line tend to mask a high SWR?

2-3 If a dipole should be able to cover a complete amateur band, but doesn't because the minimum SWR is higher than the middle of the band, what can you do to improve the situation?

2-4 If you have no antenna tuner, how many separate dipoles would be required to cover the entire 10 meter amateur band with an SWR of less than 2:1?

Chapter 3

So Just What Is an Antenna Tuner?

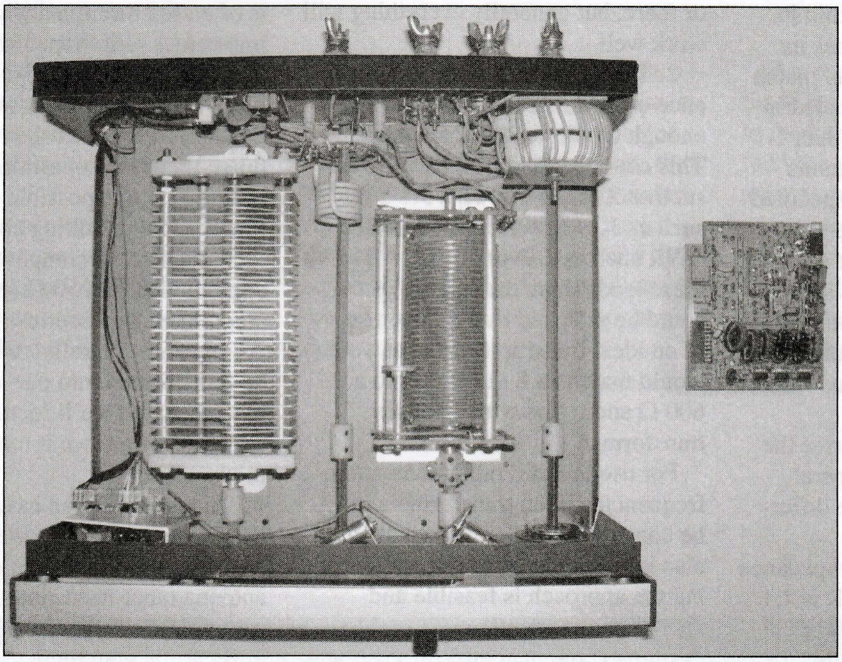

On the left, inside view of a manually tuned 1500 W L-network HF tuner (Ten-Tec 238); on the right, a computer controlled 100 W automatic tuner (Elecraft KAT3) designed to fit inside the compact Elecraft K-3 HF and 6 meter transceiver.

Contents

What's In an Antenna Tuner 3-2

Antenna Tuner Controls 3-3

Sidebar — A Quick Discussion of Standing Wave Ratio 3-4

Where are the Knobs on an Automatic Antenna Tuner? 3-8

What's the Best Tuner for You? 3-9

Review Questions 3-10

As noted in Chapter 1, *the antenna tuner is a variable impedance transforming device that can transform the impedance of an antenna system to appear to the transmitter as a 50 Ω load, while causing almost all of the transmitter power to be radiated from the antenna, just as if everything were matched.* This sounds like just what we need to solve the problem of using an antenna system that has an SWR that the transmitter doesn't like to deal with.

While an antenna tuner may well be just what we need — they come in many flavors, shapes and sizes — not to mention specification ratings. Much of this book will deal with how to choose the best type of antenna tuner, as well as to determine the best place in the system to locate it.

What's In an Antenna Tuner?

In order to perform its transformation function, an antenna tuner must deal with any load that is within its specified limits (everything has its limits — no antenna tuner can match absolutely everything!). As noted in the sidebar, an SWR greater than 1:1 happens if the load of the antenna system is different from the specified output load impedance of the transmitter, 50 Ω for most current designs. Table B in the sidebar shows some representative values of resistance and capacitive or inductive series reactance that result in various values of SWR.

Note that we could categorize the load impedance into four general categories that could all have different solutions:

1. The load is a resistive impedance of 50 Ω. In this case the SWR is 1:1 and we don't need an antenna tuner at all. We could bundle with this all loads that work well with the transmitter without change — perhaps those with an SWR of less than 2:1. There may be a bit of extra loss here or there, but generally everything will work well.

2. The load is a resistive impedance other than 50 Ω , and not close enough to allow proper operation. This could be loads with a 2:1 SWR such as 25 Ω or 100 Ω, a 3:1 SWR such as 16.7 Ω or 150 Ω, or a 10:1 SWR such as 5 Ω or 500 Ω. All of these loads share the fact that they could be matched through the use of an ideal transformer, just as you would match an 8 Ω speaker to a 600 Ω audio line with an audio transformer.

For use in radio rather than audio frequencies, such transformers must be constructed differently to avoid also introducing reactive components, but the approach is feasible and sometimes encountered. One classic example is the matching arrangement employed in a wideband antenna often used at HF called a rhombic. It offers an almost resistive load of around 600 Ω over a 4:1 frequency range and is often fed through a wideband 12:1 impedance ratio transformer by a 50 Ω system. **Figure 3-1** shows the idea. While most folks would call it a transformer rather than an antenna tuner, there's no question that it is performing one possible class of the function we're talking about.

3. The load is composed of a combination of a 50 Ω resistive component and a series reactance. A load with a parallel reactance can be transformed into one with a series reactance, but we'll focus on the series version since it may be easier to visualize.

This makes for an easy to imagine antenna tuner. If the series reactance of the load is inductive ($+X_L$), all the antenna tuner need contain is a component with a capacitive reactance of the same magnitude, ($-X_C$). The series combination of the two is just 0 Ω reactive, so the resultant is the

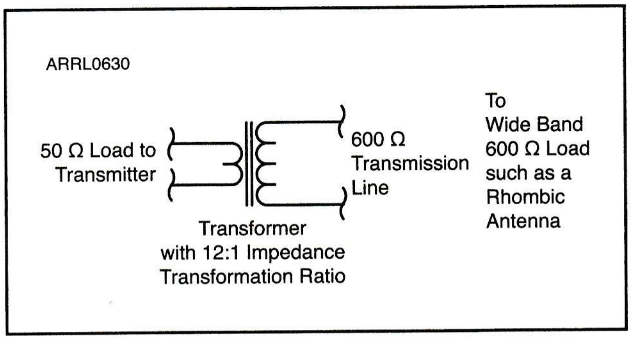
ARRL0630
50 Ω Load to Transmitter
600 Ω Transmission Line
To Wide Band 600 Ω Load such as a Rhombic Antenna
Transformer with 12:1 Impedance Transformation Ratio

Figure 3-1 — A wide-band impedance transformer can serve the function of an antenna tuner for a resistive load.

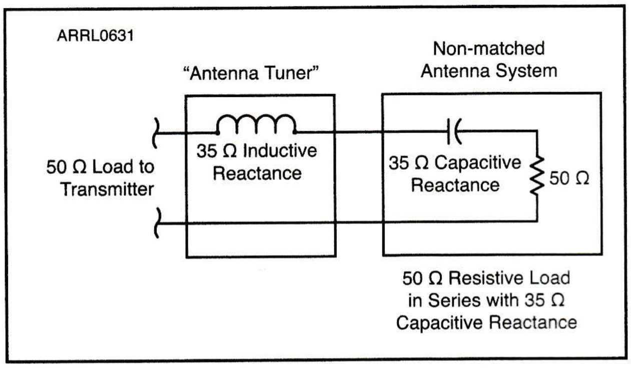
ARRL0631
"Antenna Tuner"
Non-matched Antenna System
50 Ω Load to Transmitter
35 Ω Inductive Reactance
35 Ω Capacitive Reactance
50 Ω
50 Ω Resistive Load in Series with 35 Ω Capacitive Reactance

Figure 3-2 — Antenna tuner for special case of reactance in series with resistive part equal to Z_0.

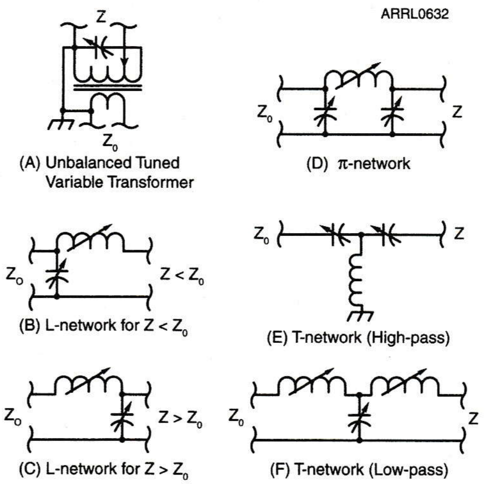
ARRL0632
Z
Z$_0$
(A) Unbalanced Tuned Variable Transformer
Z$_0$
Z
(D) π-network
Z$_0$
Z < Z$_0$
(B) L-network for Z < Z$_0$
Z$_0$
Z
(E) T-network (High-pass)
Z$_0$
Z > Z$_0$
(C) L-network for Z > Z$_0$
Z$_0$
Z
(F) T-network (Low-pass)

Figure 3-3 — Antenna tuner configurations that can be used to match the more general mismatched load.

resistive component —50 Ω as shown in **Figure 3-2**.

Note that, unlike the wideband transformer, this will likely work only on a single frequency. If the antenna has an inductive reactance, it will tend to increase with frequency ($X_L = 2 \times \pi \times f \times L$), at least over a limited frequency range. In order to keep the total impedance resistive, we will need a variable capacitor, so we can adjust the capacitive reactance to match the changing inductive reactance of the load. Note that our "antenna tuner" now has a knob on the front, and is starting to look more like an antenna tuner.

4. The load is a combination of resistive and reactive components that have an SWR greater than we can deal with and that falls in none of the other three categories. This is the general case — the one all general purpose antenna tuners must deal with, at least over some range of SWR.

There are a number of circuit configurations that can be employed that will do a combination of cancelling the reactance and transforming the resistive impedance. We have cataloged them in **Figure 3-3** so you will recognize the configurations as we discuss them. In many cases, if constructed of the same quality components, they will provide equivalent performance. As with all general purpose devices, there are certain advantages and disadvantages of each, and some may be more appropriate for some applications than for others.

Another categorization that can be made is whether the tuner is designed to feed an unbalanced load, typically fed with coaxial cable or a single wire against ground, or is intended to feed a balanced load such as a dipole fed with balanced open wire transmission line. Each of these configurations can be adapted to either task, however, we will defer that discussion until later.

Antenna Tuner Controls

Not surprisingly, many of the different manual antenna tuner configurations have different control arrangements.

L-Network Tuner Controls

The L-network has two primary adjustments, an inductor and a capacitor. In the Ten-Tec 238 tuner shown in **Figure 3-4**, and in most L-network tuners, each control is adjustable throughout its entire range on any band, providing maximum flexibility. In addition, there is a switch to move

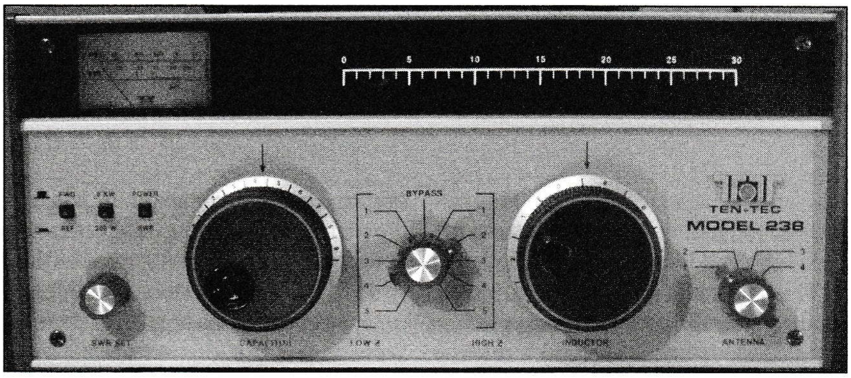

Figure 3-4 — Front panel view of an L-network tuner, an early version of the Ten-Tec 238.

A Quick Discussion of Standing Wave Ratio

We discussed standing wave ratio in Chapter 2 and noted that a matched antenna system has a standing wave ratio (SWR) of 1:1. That is the case in which there are no standing waves and all energy from the transmitter is delivered to the load with no reflections on the transmission line. This is a very straightforward situation that is easy to understand. Getting into the details of this topic can get lengthy and there are entire books devoted to the topic.[A] Fortunately, we won't need to get that deeply involved to understand antenna tuners and their applications. Still, we need to have some idea about SWR, what it means and what its consequences are to understand, when and if it is a problem and how to solve it.

The Matched Transmission Line

If we were to connect a battery to a long real transmission line with no load and monitor the current that would flow with a high speed oscilloscope we would notice an interesting effect. The combination of the line series inductance and shunt capacitance, and to a lesser effect the wire resistance, would result in an initial current that would flow, even though there is an open circuit at the far end.

The current will continue to flow until the signal propagates to the end of the line and returns. When it reaches the end of the line (traveling somewhat slower than the speed of light) a *reflected* wave of the opposite polarity will propagate back because there can be no current flow at the open circuit. When the reflected wave returns to the source end of the line the combination of the forward and reflected wave will result in zero current — just what we would expect for an open transmission line.

The ratio of the applied voltage to initial current is an impedance and we call this the characteristic impedance or Z_0 of the transmission line. This is the current that would flow into an infinite length of line no matter what is at the far end. Note that we didn't say anything about signal frequency here, this is strictly a matter of the way the line is constructed, especially the capacitance and inductance that is distributed along its length. For the usual low loss line, ignoring resistance, we can determine Z_0 as follows:

$$Z_0 = \sqrt{L/C}$$

where L and C are the inductance and capacitance per unit length, typically per foot or per meter. These values can often be found in many manufacturers' specification sheets.

The Matched Transmission Line

If, instead of having an infinite line, we put a resistor with a resistance equal to the line Z_0 on the far end of the line it will absorb the power as it arrives and there will be no reflection. The voltage and current relationship at the signal end of the line will appear as if it were the same resistor, just located at the source.

This is exactly what we wanted! If the source is a radio designed to drive a 50 Ω load, Z_0 is 50 Ω and our load is an antenna with an impedance of 50 Ω, we get just what we want — to our transmitter it appears as if the antenna is connected directly to the antenna. There is no reflected power, the SWR is 1:1 and all is well with the world.

The Mismatched Transmission Line

There are an infinite number of cases in which a transmission line is terminated, not with its Z_0, nor with an open or short, but with some other impedance. This results in a reflection of a signal that is smaller than the signal that was sent down the line. It is important to note that this signal does not represent lost power, because it is re-reflected from the transmitter back up to the line. It is true that the power delivered to the antenna will equal the forward power less the reflected power, however, because the power is re-reflected at the transmitter so the numbers go up together. This is illustrated in **Table A** for the case of perfect (lossless) transmission line, assuming the transmitter can put power into the SWR shown.

So What's the Big Deal

The key is the two reasonable assumptions noted above. Let's discuss each:

- Transmission lines are not lossless, and their losses increase with increasing SWR as we will discuss. Whether or not that's a problem depends on the line

Table A

Example of Net Transmitted Power with 100 W Transmitter versus SWR with Lossless Transmission Line

SWR	*Reflection %*	*Forward Power*	*Reflected Power*	*Antenna Power*
1:1	0	100	0	100
2:1	10	111	11	100
3:1	25	133	33	100

the variable capacitor between the two ends of the inductor to allow tuning of both high and low impedance loads.

This particular tuner uses a rotary inductor (see **Figure 3-5**) for adjustment of inductance. The coil turns with rotation of the shaft on the left end. As it turns, its point of connection to the small wheel on the top in the picture is moved up and down the coil. It requires about 30 turns of the knob to adjust from the minimum to the maximum amount of inductance. Some tuners use a switched inductance instead. The switch allows a quicker change of settings, but does not provide for values of inductance between the switched taps. This is not generally a problem, although there are some loads that can't be tuned to a 1:1 SWR at some frequencies — still close enough works. Note that there is no bandswitch, on this model, since any available adjustment type, frequency and SWR as we will discuss later.

- Often a more serious problem is that somewhere in the range of SWR in Table A, typically by an SWR of 2:1, transmitters will reduce power to avoid damage due to the higher current or voltage that results from the higher than specified SWR.

Note that the second problem is not a fundamental issue of SWR itself, but rather a design choice made by transmitter designers. Still, for transmitters that we may choose to use, it is a real problem that we have to deal with.

What Kind of Load Results in High SWR

Any load that is different from Z_0 of the transmission line will result in a SWR greater than 1:1. For the case of the frequently encountered 50 Ω coaxial cable, that means any load that is not 50 Ω resistive. This can mean a load that is resistive with a value of other than 50 Ω or a load that is resistive, but also has capacitive (–X) or inductive (+X) reactance, or any of an infinite number of combinations of the two. Some examples of loads with different SWRs are shown in **Table B**.

Note that it is very easy to determine the SWR for the resistive case — it's just Z_0/R or R/Z_0 depending on whether the load is greater or less than the Z_0.

Thus it is important to know not just the resistive part, but also the equivalent series inductive or capacitive reactance to determine the SWR.

Determining SWR from Impedance Data

While the case for resistive loads is simple, the case for loads with reactance or complex loads is well — more complex. Still, there are at least three ways that I know of to determine the SWR of a complex load, not counting measuring with an SWR meter, as follows:

- Use the software TLW (Transmission Line for Windows) that comes packaged with recent editions of The ARRL Antenna Book.[B] If you plug in the R and X values and the appropriate transmission line Z_0, it provides the SWR at each end of the line. You can select which end of the line has the measured Z (input or load). This is very handy since it will also calculate the line loss.
- This may be the most simple calculation to make graphically with a Smith Chart.[C] Recall that if the Z is just resistive (X=0), the SWR is either Z_0/Z or Z/Z_0, depending on whether the Z is lower or higher than the Z_0. Recall also that a circle on a Smith Chart represents constant SWR. Thus if you enter the Z on the Smith Chart and draw a circle centered on the chart center, it will show the transformed Z for any length of line. Either point at which the circle crosses the resistive axis can be used to calculate the SWR as described above.
- If you have neither computer nor Smith Chart, you can compute the SWR directly. This can be found, for example, in a book I had as a text many years ago, a classic by the late John Kraus, W8JK, *Antennas*. In the first edition it is in the appendix on page 507. The calculation is done in two steps:

1. Find the voltage reflection coefficient σ:
   $\sigma = (Z-Z_0)/(Z+Z_0)$
   Note that the Z is a complex number, so the calculation is a bit tedious.
2. Find the SWR = $(1 + |\sigma|) / (1 - |\sigma|)$
   where $|\sigma|$ indicates the magnitude of the complex reflection coefficient, σ, found in step 1.

Table B

Impedance of Loads that Result in Different SWRs.

For Ideal 50 Ω Coaxial Cable

R (Ω)	*X (Ω)*	*SWR*
50	0	1:1
25	0	2:1
100	0	2:1
50	±35	2:1
30	±18	2:1
16.7	0	3:1
150	0	3:1
50	±58	3:1
30	±40	3:1
5	0	10:1
500	0	10:1
50	±142	10:1
250	±250	10:1

Notes

[A] W. Maxwell, W2DU, *Reflections*, check his Web site for information on availability of the latest edition at **w2du.com**.

[B] R. D. Straw, Editor, *The ARRL Antenna Book,* 21st Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[C] Paper copies of 50 Ω Smith Charts are available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 1341. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

is usable on any band — you just crank until you are within range. It may even be helpful for upper body development.

The capacitor can be a single, or multiple section type or a combination of a variable and fixed capacitors. In my tuner, the switch that moves the capacitor from one end of the inductor to the other has additional positions that switch in fixed capacitors in parallel to extend the tuning range. The fixed and variable combination allows somewhat finer tuning, but in multiple steps. A larger variable with a multi-turn vernier dial may be equivalent, and may be quicker to adjust.

An advantage of the L-network tuner is that there is only a single combination of L and C that will match a given load. As noted below, some tuners can offer more than one, but only one is optimum.

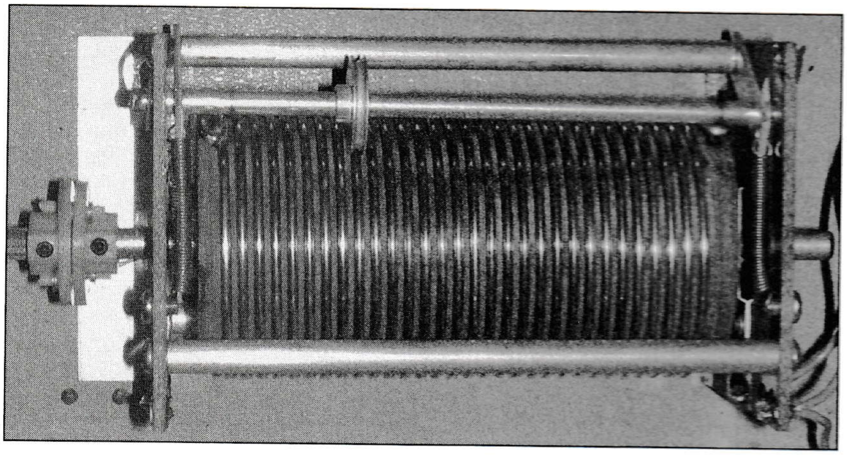

Figure 3-5 — Close up of a rotary inductor.

Pi- and T-Network Tuner Controls

Pi- and T-network tuners have three tuning controls — usually one inductor and two capacitors. Pi-network tuners that started out in the age of vacuum tube transmitters with pi-network output circuits often are built with similar components and are thus bandswitched as in the Drake MN-2000 tuner shown in **Figure 3-6**. In this tuner, the bandswitch sets the inductance to a preset coil tap for the middle of the expected range and the capacitors on both ends are used to provide the closest match. This configuration can be useful, but generally has less tuning range than those with adjustable or switched inductors in small increments.

Note that a pi-network tuner set to minimum capacitance on either of the capacitors essentially becomes an L-network tuner, with the high or low impedance determination dependent on which capacitor is set to around zero.

With either the pi- or T-network tuners, sometimes multiple very different settings can be found that will tune a particular load. In general, a setting with the minimum inductance is more efficient since the wire resistance of the inductor can dissipate power.

Tuned Transformer Tuner Controls

The tuned transformer is essentially the same as an output circuit from an earlier, before the pi-network, kind of transmitter. It typically has a balanced tuned circuit designed to resonate on a particular band (there weren't as many back then) using a fixed inductor and variable capacitor. The typically balanced transmission line was tapped symmetrically on the coil — close to the center for low impedance loads, close to the ends for high impedance loads. Small clips were generally used to provide load connection points. Very low impedance loads were connected in series with the center of the inductor.

Any reactance in the load would detune the tuned circuit that would then be readjusted by retuning the variable capacitor. The usual transmitter side connection was a link of a few turns that could be mechanically moved in and out of the center of the coil to provide adjustable coupling.

It was actually simpler to adjust than describe. Once the tap points were located for a particular band using the usual single antenna, the clips were fixed in place, and this became just one more coil to be changed while changing frequencies. Both transmitters and receivers of the pre WW2 era often had plug-in coils that required changing each time a band change was desired.

The 1950s era E. F. Johnson *Matchbox* antenna tuner (see **Figure 3-7**) was a radical design change to the tuner transformer type of tuner. This was the era in which transmitters and receivers were generally bandswitched and the Matchbox was an effort to make antenna tuning just as easy. What made the matchbox unique was a patented differential capacitor design that allowed a variable capacitance to be made of two capacitors — one that increased and one that decreased as it was rotated.

A pair of these were placed across the tuner resonant circuit allowing the transmission lines in the middle of each to be tapped across the resonant circuit using capacitive "taps" instead of the previous inductive taps. This allowed a continuously adjustable impedance setting to be made from the front panel. The bandswitching allowed bands to be changed without changing coils. This was very popular at the time, and they are still popular today. They do have some limitations, principally that they only work on the amateur bands of that day, not 30, 17 and 12 meters — although they may

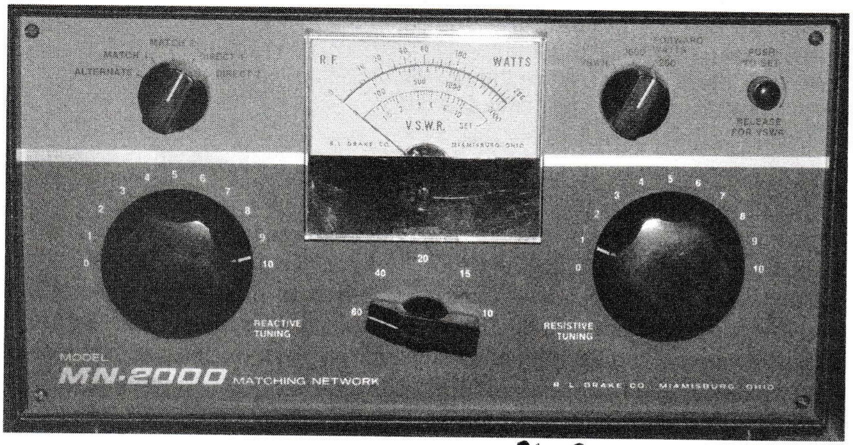

Figure 3-6 — 1970's vintage bandswitched ~~pi-network~~ PI-C tuner.

THE DRAKE MN-2000 IS NOT A PI-TYPE CIRCUIT BUT A PI-C CIRCUIT WITH THE INPUT CAPACITOR AND THE COIL BEING FIXED (BAND-SWITCHED) AND THE TWO OUTPUT CAPACITOR BEING VARIABLE. THIS IS VERY CLEVER DESIGN, THE Q IS

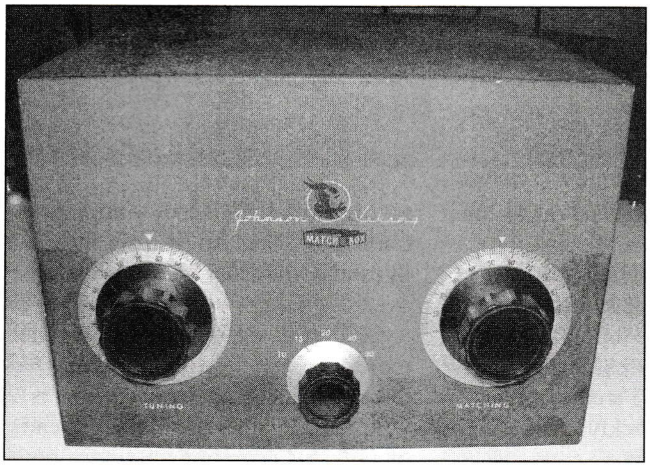

Figure 3-7 — 1950's vintage E. F. Johnson *Matchbox* antenna tuner.

drive some loads on the higher bands by setting to an adjacent band.

Antenna Tuner Metering

Many antenna tuners include metering, either directional power meters or an SWR bridge. These can be used to monitor progress while adjusting the antenna tuner — either for minimum reflected power, or for minimum SWR. Arguably, this is somewhat redundant if the connected radio transmitter also has SWR or reflected power measurement capability, although some meters in tuners may be more sensitive or easy to read.

While there is certainly no harm in having redundant metering, if your radio meter is easily visible from the antenna tuner location, and has sufficient sensitivity to allow proper tuning, there isn't much benefit in my opinion. The early transceivers, and especially pre-transceiver transmitters, did not generally include that function, perhaps explaining why most tuner manufacturers still provide them. For most users with metering in the transmitter, transmission line current meters on the output side of the tuner would actually be more useful. To my knowledge, alas, no tuner manufacturers now include these.[1,2]

Tuner Limitations

All tuners are composed of combinations of inductors and capacitors in various combinations. Since the impedance at a high SWR can vary widely, the tuner needs to have a wide range of values in order to be able to accommodate all possibilities at every frequency within its range. It is generally the case that the lower the frequency, the more inductance and capacitance will be required. Thus the maximum available inductance and capacitance, generally determines the low frequency limit of operation.

In the case of high power tuners with large components, it is not unusual for tuners that cover down to 160 meters (1.8 MHz) to be in larger enclosures simply because the size of the components is larger. In a similar way, it is the minimum capacitance and inductance that sets the high frequency limit. In this case, one must often look beyond the specified values of the components themselves and look to the stray capacitance of wires and component frames to the cabinet, as well as the inductance of connecting wires between components. Some tuners have trouble matching loads on 10 meters (28 to 29.7 MHz in the US) that would be easy to match at lower frequencies for this reason.

Increasing power with high SWR can result in very high currents and voltages within the tuner, requiring large components for high power tuners. The large components, in addition to making the box much bigger, also make the control of stray inductance and capacitance more of a challenge for the designer.

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[1] Notes appear on page 9.

CONSTANT (18) OVER THE TUNING RANGE AND THERE IS ONLY ONE MATCH FOR A GIVEN IMPEDANCE IN CONTRARY TO THE T-TUNER.

Where are the Knobs on an Automatic Antenna Tuner?

Automatic antenna tuners don't generally have tuning knobs. Instead, they have a microcontroller that monitors SWR or reflected power and uses an algorithm to step through allowable values of L and C until a match is found. Any of the tuner topologies in Figure 3-3 could be used in an automatic tuner with an appropriate control mechanism.

Some automatic tuners use rotating variable capacitors and rotary inductors, just as in many manual tuners. In fact some are adaptations of manual tuners with servo motors and controllers added on as an additional physical and logical layer.

I do think it is safe to say, however, that the majority of auto tuners use a set of discrete components instead of variable ones. A range of inductance is provided by using relays to switch different sizes in series to reach the desired value. Similarly, a range of capacitance can be provided by having multiple capacitors switched in parallel. By having values available in a series such as 1, 2, 4, 8, 16, 32, 64, 128, 256 for example, any value from 1 to 511 (either pF or µH) can be obtained in steps of 1 unit. Thus any needed resolution and range can be easily provided.

While such switching, if done manually with toggle switches, might make us go over the top, it's duck soup for a microprocessor. The hard part may be defining a computer algorithm that can quickly find the right values without trying all combinations. Fortunately, that just needs to be done once and is provided "free" with the tuner. Most auto tuners can find a suitable match within a defined threshold, often 1.5:1, within a few seconds with no additional information about the antenna being tuned.

Many auto tuners have the capability to memorize the appropriate settings for a particular load once it's found. There are two approaches to this, both can be quite successful:

Memory stored by frequency. Perhaps most commonly found in tuners is the storage of tuning data based on frequency. Of course, this requires that the tuner measure the frequency before it can tune.[3] Most tuners have a number of frequency "bins" of a certain bandwidth, for example perhaps 25 kHz. If the frequency is within that bin, the last successful setting from a frequency within that bin will be used. If it doesn't meet the threshold, the tuner will start tuning over.

Obviously, the smaller the bin, the more successful the tune is likely to be, assuming the same antenna is used. On the other hand, this depends on previous operation within the bin, so it takes longer to accumulate data for all bins. Most tuners seem to have it about right, in terms of trade off.

Memory stored by past success. A different approach is to just keep track of the last number of successful tuner settings, independent of frequency. Let's say the tuner remembers the last 100 successful tuner settings. It just very quickly tries all those before it initiates its regular tuning algorithm. It is quite likely that recent conditions will be repeated. This approach is particularly advantageous for a single port tuner that is switched between multiple antennas making multiple successful tuner settings appropriate within a single frequency bin. Of course an advantage for the manufacturer is that the tuner doesn't need to measure or otherwise determine transmitting frequency.

What's the Best Tuner for You?

The best tuner for a particular application will depend largely depend on your antenna system and operational needs. Automatic antenna tuners inside transceivers are convenient and don't require extra space or wiring. Check the specs carefully, many do not cover a wide impedance range (many are spec'd at 3:1, although some may do better than spec). Interestingly, the internal tuners from Elecraft, FlexRadio and Ten-Tec do provide wide range (to 10:1 SWR) tuning, perhaps others will follow in this direction. The other disadvantage of internal tuners is that you will need a tuner with a higher power rating if you use, or consider using a linear amplifier. A high power tuner will work fine at low power, if the linear is in your plans.

Manual Tuners often offer antenna switching and control functions, not present in many auto tuners. Manual tuners also often provide continuous tuning to allow setting the controls for an exact 1:1 SWR, although that doesn't really provide a significant benefit.

Automatic tuners have a number of advantages and not many disadvantages. Some can be operated remotely at or near the antenna to reduce system losses. Either of the memory tuner types can reduce the tuning time for previously encountered antennas from a few seconds to a few tenths of seconds. Arguably either is significantly quicker to get into operation than a manual tuner, even with recorded dial settings.

The rest of the book will explore these issues in more detail.

Notes

[1] E. Nichols, KL7AJ, "Keeping Current with Antenna Performance," *QST*, Feb 2009, pp 34-36.

[2] P. Danzer, N1II, "A Simple Transformer to Measure Your Antenna Current," *QST*, Sep 2009, p 35.

[3] Internal, or brand specific tuners have the advantage that the frequency information can be made instantly available from the radio circuitry.

Review Questions

3-1 What are two reasons to provide a matched, or nearly matched, load to a transmitter?

3-2 What is the SWR of a 50 Ω cable with a 500 Ω resistive load? How about a 500 Ω transmission line with a 50 Ω resistive load?

3-3 If a 100 W output transmitter is connected to a lossless antenna system with a 3:1 SWR and it can deliver its full power, how much power reaches the antenna? How much power is reflected from the load?

Chapter 4

Tuning an Antenna Tuner

TEN-TEC
TRANSMITTER MATCH
INDUCTANCE
LOAD MATCH
ANTENNA COUPLER
MODEL 231
TEN-TEC
MODEL 238
SWR SET
ANTENNA
MN-2000 MATCHING NETWORK

Tuning controls of three manual tuners. On top, a 100 W Pi-network, in the middle a 1500 W L network tuner and on the bottom a bandswitched 1000 W Pi-network tuner.

Contents

Tuning an Automatic Tuner 4-2
Tuning a Manual Tuner 4-3
A Simple Transformer to Measure Antenna Current..............4-6
Review Questions..4-7

By now we, hopefully, know what an antenna tuner is, and why it may be a good idea. The next question should be "how do we work it?" The answer to this depends a bit on the type of tuner and your configuration. In all cases, the most important rule is: *Don't interfere with other users of the band!* This is an issue because all types of tuners require the transmission of RF for at least the final adjustment.

This is because tuning is considered complete only if the SWR is close to 1:1, and it takes a signal to be able to measure SWR. Even if the signal is of a reduced amplitude, people have been known to make worldwide contacts with transmitters running less than 1 W, so don't assume a low powered TUNE signal won't go anywhere.

If you are worried about loosing track of the current frequency that has a particularly desirable station; just put it in memory, tune off the frequency, adjust the tuner and, when tuning is complete, recall the desired frequency from the memory. You should be good to go, and you won't ruin it for someone else.

Tuning an Automatic Tuner

As its name implies, tuning an automatic tuner should be, well *automatic*. If it's a tuner that is part of the radio, or designed to operate with the radio, there is likely a TUNE button that reduces power, sends a carrier on the desired frequency and then forces the tuner to tune. Many after-market automatic tuners first measure the frequency and try the settings that worked the last time you used that frequency, or one close to it.

If the tuner is one that is not designed to work with the radio, you generally will need to initiate the process in some way. In many cases, if a transmitted RF signal is sent to the tuner it will measure the SWR and automatically initiate the tuning process if it needs to. There are two concerns here — first, many tuners want adjustments to be made at reduced power to avoid burning relay contacts — second, reduced power should also be used during tuning to avoid potential transmitter damage from trying to feed a mismatched load, as well as to reduce interference to others.

You will need to find a way to easily reduce power for tuning. Some radios do exactly that with a TUNE button. On my transceiver, I have such a button and a menu selection allows me to set the tune power to any level I want. Pushing the TUNE button sends a reduced carrier out of the transmitter until I push it again. This button is also useful to start tuning a linear amplifier. If you don't have a TUNE button, you may need to manually reduce power and then hit a key to send a signal. Note that I said *key*, as in radiotelegraph mode. Hitting the push-to-talk button on a SSB voice transmitter will switch to transmit, but not put out a signal until you start talking — so that doesn't work well for this application. If your transmitter supports AM voice, it will usually put out a carrier of about 25% of full PEP when keyed, so that is a possibility as well, although that is usually somewhat more power than desired.[1]

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[1] Transmitters such as the early R. L. Drake vacuum tube series use controlled carrier in AM mode and may not put out a carrier without speech.

Tuning a Manual Tuner

To tune a manual tuner, you can actually start with the transmitter turned off. First look at the instruction manual and see if it provides suggested settings for each band. While your actual settings will be somewhat different, since you will have a different impedance on each band, they should make a good starting point. Hopefully the controls on your tuner have calibration marks on each control, if not, imagine an analog clock face on each control.

Next, practice tuning your tuner into a dummy load. Even though the tuner usually isn't needed to match the 50 Ω dummy load to the transmitter, if the tuner is in line, the tuner will require just as careful adjustments to tune into that load. Try the tuner on each band and record the settings.

Adjusting a Manual Tuner

Most manual antenna tuners have three controls. If it's a Pi- or T-network, they will all be adjustable inductors or capacitors, usually one of the former and two of the latter. An L-network will just have one of each but will usually have a switch to move the variable capacitor between the input and output side of the inductor as shown in Figure 3-3 in Chapter 3. Because the three controls interact to some degree, finding the right settings can be arduous, can stress the transmitter and can also cause interference to others as you try to find the right settings, hence the recorded table. I provide the following suggestions.

- Many antenna tuner instruction manuals have tables of typical values for each band. Use these as a starting point.
- Practice tuning your antenna tuner into a dummy load, as discussed above.
- First tune as close as you can using the receiver as an indicator. If there are signals on the band, adjust for maximum S-meter indication. If there are no signals adjust for loudest band noise or meter indication.
- If you have an antenna analyzer, use it instead of the radio to find settings that offer a matched load to the radio port as shown in **Figure 4-1**.
- If you can't quite get to a 1:1 SWR, shift one of the controls off its minimum position and adjust the other one (or two) for minimum. If the result is better, move the first control a bit more in the same direction. Repeat until it starts to get worse. If it's still not satisfactory, repeat the procedure with a different control.

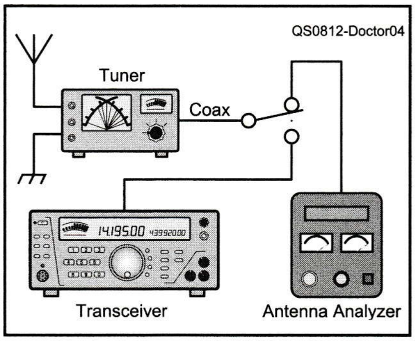

Figure 4-1 — Using an antenna analyzer to adjust your antenna tuner reduces both stress to your radio and interference to other users of the band. The coax switch shown can be used to switch the output of the antenna tuner to either the radio or the antenna analyzer.

- If there are multiple settings yielding a match, as there will likely be with T- and Pi-network tuners, select the one with minimum inductance — it will be more efficient because inductors tend to have more loss than air variable capacitors. The following example illustrates the point.

A fairly typical "random" length of wire likely to be matched with an antenna tuner would be 57.5 feet long fed against ground. This would have an impedance of 25.6 Ω resistive in series with 100 Ω capacitive reactance at 3.7 MHz — a 10:1 SWR, just within the design range of most wide range tuners. A low-pass L-network tuner will just have a single value of L and C that would mach this impedance. It would be, according to *TLW* software (discussed later in detail), 5.29 µH and 1000 pF. The loss in the L-network tuner would be 0.11 dB or 2.5%.

With a high-pass T-network tuner, there are an infinite number of combinations of tuner components that can result in a satisfactory match. Setting one value requires the other two components each be set to a particular value to obtain a match. As shown in **Table 4-1**, listed by selected value of output capacitor, not all combinations will have the same efficiency. It shows dramatically that by having a

Table 4-1

Examination of High-Pass T-Network Tuner Efficiency as a Function of Tuning: Load 25.6 Ω Resistive in Series with 100 Ω Capacitive at 3.7 MHz.

Capacitor Output (pF)	*Intput (pF)*	*Inductor (µH)*	*Loss (dB)*	*Loss (%)*
5	9.2	130.6	8.5	85.9
10	12.5	82.1	5.4	71.3
30	25.7	34.4	2.4	41.7
50	37.5	22.5	1.6	29.9
100	63.2	12.8	0.9	18.4
200	102.6	7.8	0.5	11.5
500	171.2	4.7	0.3	6.8
1000	223.2	3.7	0.23	5.2
2000	264	3.2	0.19	4.4
5000	297	2.6	0.17	3.9

Table 4-2

W1ZR Antenna Tuner Settings Table

Antenna Tuner Settings — 100 Ft Dipole (4)

					AMP SET	
FREQ	*C*	*IMPED*	*L*	*SWR*	*Load*	*Tune*
1.8	8.0	L5	4 - 9.9	2.5	0.0	8.0
3.55	5.6	H1	20 - 6.9	12.0	4.0	5.8
3.8	1.0	H1	18 - 1.9	9.8	8.8	4.7
5.3	4.3	H1	12 - 9.5	5.8		
7.0	1.2	H2	6 - 5.0	4.6	7.8	2.7
7.2	8.5	H1	8 - 1.0	5.6		
10.1-.15	8.8	H1	4 - 6.3	4.4		
14.0	2.0	H1	4 - 5.6	4.0	7.0	1.5
14.2	1.3	H1	4 - 6.4	3.7	7.0	1.4
18.068-.168	4.1	H1	2 - 7.7	2.9	7.0	2.0
21.0	3.0	L1	2 - 6.5	3.7	6.2	1.5
21.2	2.6	L1	2 - 6.2	4.3		
21.3	2.5	L1	2 - 6.3	4.5	6.0	1.3
24.890-.990	1.5	H1	1 - 1.8	1.8		
28.0	1.0	L1	3 - 5.4	1.6	5.0	2.0
28.5	1.0	L1	2 - 9.6	2.5	4.5	2.0
29.0	1.0	L1	2 - 6.0	3.6		

Antenna Tuner Settings — Tri-Band (2)

					AMP SET	
FREQ	*C*	*IMPED*	*L*	*SWR*	*Load*	*Tune*
10.1-.15	4.0	L1	9 - 1.3	5		
18.068-.168	3.3	L1	4 - 8.2	5	7	2.0

Antenna Tuner Settings — Ground Plane (3)

					AMP SET	
FREQ	*C*	*IMPED*	*L*	*SWR*	*Load*	
3.6	10.0	L1	9 - 1.7	2.3	4	5.8

high inductance value, the loss will be higher than if an inductor with a lower value were used. All combinations will provide a 1:1 match to the transmitter which will happily pump power into the system. While some values would likely not be realizable at 3.7 MHz, the reactances all would be easily employed at 30 MHz. A 1500 W transmitter with the 86% loss of the first entry would dissipate 1290 W in the tuner as heat. The tuner would likely melt before your eyes!

Note that Table 1 indicates that the highest efficiency is with the lowest inductance value — often the case. It also can happen that the high Q of a low inductance solution can result in large circulating currents resulting in additional loss. The best way to be sure is to measure the relative current going from the tuner to the antenna. The solution with the highest current will be the most efficient.

The actual value of the current isn't usually significant since the antenna impedance is unknown. For any given antenna on a given frequency, what is important is that you have the solution that provides the most current towards the antenna with the transmitter operating into its design load and within ratings. Unfortunately, I am not aware of any tuners now available that provide for the measurement of antenna current. RF ammeters are available on the surplus market and one is available from MFJ. Alternately, a fairly simple antenna current transformer project article in *QST* described how to make your own. It is reproduced in the following sidebar.

Once you have a match, reduce the inductance, retune the capacitors, and see if you can still obtain a match with an even higher current. Once you have the settings for a particular antenna, you won't need to measure the current again unless something changes in the system.

- Record your data! All manual antenna tuners I've seen have calibrated scales on their front panel for each control. As soon as you have a match, write down the settings you found for future reference and use them for a starting point next time. I find that having a set of dial readings for at least the phone and CW portions of the band is useful. **Table 4-2** is the actual table that I use at my station. Note that there are separate table segments for three different antennas. The fourth position is connected to a dummy load for testing and amplifier adjustment purposes.

The Controls in My Table

Since there's a bit more here than you might need, let me explain the columns I have included in my chart. The tuner I use is an early Ten-Tec 238 with front panel layout shown in the chapter title (center) figure. This is a 1.5 kW rated L-network tuner that provides four antenna connection ports, one of which (# 4) can be set up for either a balanced or unbalanced load using an internal balun on the output side.

- FREQ is the approximate frequency that I made the adjustment for.
- C is the approximate setting of the variable capacitor dial. It has 10 divisions, but I "eyeballed" how far between the marks the setting was to get the tenths position.
- IMPED is a switch that can set the configuration for high (H) or low (L) impedance and has five fixed capacitor settings for each, hence the numbers 1 through 5, in addition to the letter.
- L is the setting for the variable inductor. The inductor setting has two numbers because it is a multiple turn rotary inductor. The first number is the value of the TURNS scale, while the second is the knob setting from the skirt on the knob.[2]

---

[2] Current models of this tuner have an improved drive for the rotary inductor that provides a single reading for the L value.

- SWR is the SWR measured with the tuner bypassed. This doesn't play a part in the tuning, but is useful as a check to make sure the antenna hasn't changed or fallen down since it was installed. The tuner will just as happily tune the antenna if it breaks and falls down, but the signal won't go as far.
- The two AMP SET adjustments are for my linear amplifier tuning controls. They share the spreadsheet because, as with the antenna tuner, if I change bands or modes, they need adjustment. These columns save having an additional piece of paper on the operating desk. If you don't have a linear amplifier you don't need these.

Your tuner may have different control labels, and you may not want to include all my data, however, it should give you a starting point for your own record keeping. I maintain my records on a PC spreadsheet, although any convenient medium can be used. A small set of data might fit on a 3 × 5 (or perhaps 5 × 7) inch file card. The spreadsheet has the advantage that it can be easily updated as antennas are changed or added. In my experience, amateur stations are never quite done!

A Simple Transformer to Measure Your Antenna Current

SWR doesn't give you the whole story — you need an RF current meter.

Paul Danzer, N1II

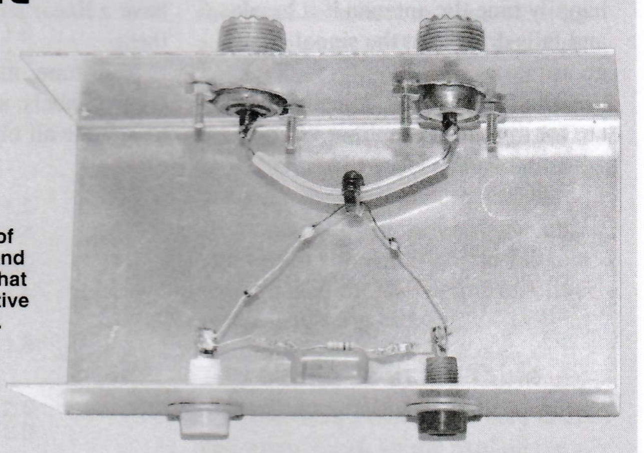

Figure 1 — View of the transformer and simple circuitry that make up the relative RF current meter.

In a recent *QST* article, Eric Nichols, KL7AJ, presented a good idea — monitoring the RF current into your antenna system to insure optimum tuning.[1] Actually, it was the second time it was mentioned to me — George Peters, K1EHW, suggested the same thing to me several months before. At the end of Eric's article, he proposed using a current transformer to do the monitoring.

Making a Current Transformer

This could be as simple as a turn of wire through a ferrite core and several turns of wire around the core to form a transformer.[2] The output of the transformer would be proportional to the current through the wire.

Making it Happen

This seemed simple enough, and the result of one hour's work is shown in Figure 1. The core used was a T37-6. T37 designates the size (0.37 inches OD), picked so the insulated center conductor of RG-58 (or RG-59) would fit comfortably through the core center. The –6 designation relates to the frequency application of the ferrite mix, in this case 2 to 50 MHz.

Searching the ARRL suppliers' data base, it appears that Alstar Magnetics offers this core; an alternate would be a Palomar F37 with mix 61. There is no criticality here — if you want to try it, strip a core from any old source — perhaps from a junked PC power supply or computer cable. It may not be the most efficient RF transformer ever built, but if it works it will do the job.

Wrap 20 turns of 24 gauge enameled wire as the transformer secondary. The secondary is connected to half wave rectifier consisting of a silicon diode (1N914), a 10 kΩ resistor as the load and a 0.1 μF capacitor as a filter (see Figure 2). A high-impedance voltmeter (the $10 variety) is connected to the two pin jacks to serve as an indicator.

The unit shown was tested with a 100 W transmitter on all bands from 80 through 10 meters. Performance across each band was relatively uniform, considering the probable variation of SWR and power though the feed line as the frequency was varied.

Hook up the rest of the circuit as shown in Figure 2 and connect a meter to the terminals.

What we Have

The object here was not to get an exact measure of the antenna current. What I wanted was a relative measure, so I could see if anything was going wrong, or use it as a way to adjust my antenna tuner for the maximum signal to the antenna. Commercial stations use a current meter, mounted at the connection of the feed line to the antenna, to monitor output. Since they know the antenna impedance and their meters are calibrated, they can determine precise power into the antenna.

If you enjoy low power (QRP, typically 5 W or less) or very low power (QRPP, less than 1 W) operation, more turns may be needed and can easily be added.[3] Similarly, if your meter does not have enough sensitivity, more turns may be called for. If after assembly the core is not firmly in place, held by the friction of the secondary on the primary wire, a drop of glue can be used to secure it all together.

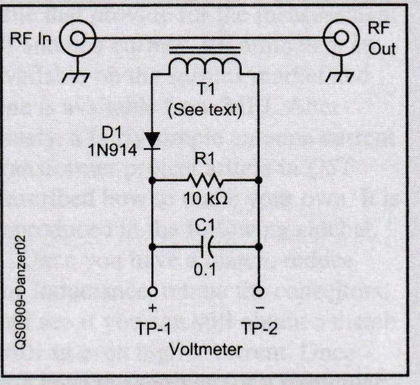

Figure 2 — Schematic diagram of the relative RF current meter. Nothing about the circuit is critical. See text for parts information.

Putting it to Use

The current meter consumes a miniscule fraction of the output power, so, can be left in the line, or removed when not in use. You may even find a meter case and a surplus meter at a hamfest that will work with it to give continuous indication without tying up your bench meter. I suggest writing the relative current indication for each band in your log. Later, if something seems amiss, it is then an easy job to compare your readings to the recorded ones to find out if the problem is in your antenna system.

Notes

[1] E. Nichols, KL7AJ, "Keeping Current with Antenna Performance," *QST*, Feb 2009, pp 34-36.

[2] Each pass through the center of a toroid counts as a full turn.

[3] Low power operators may obtain better results using a germanium diode, such as a 1N34, in place of the silicon diode due to its lower forward voltage drop.

ARRL Member Paul Danzer, N1II, was first licensed in 1953, and now holds an Amateur Extra class license. Paul has been operating 40 meter CW almost constantly since he first started. He uses his years of experience as an electronic engineer to design and build small, one-night ham radio projects. Currently he is a Professor of Computer Science at Housatonic Community College in Connecticut. He can be reached at **n1ii@arrl.net**.

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Review Questions

4-1 Why is it important to listen to the operating frequency before you start the tuning process?

4-2 Why is it a good idea to manually initiate tuning with your auto-tuner before transmitting on a new frequency at full power?

4-3 If there are more than one set of tuner settings that provide a 1:1 SWR, which should you choose?

Chapter 5

The Internal Tuner — How Does it Help?

YAESU
FT-2000
21.320.00
18.140.00

The Yaesu FT-2000 transceiver, one of many modern transceivers equipped with an automatic internal antenna tuner.

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So far, our discussions about antenna tuners have made it appear that they are a separate device that is inserted between a transceiver and an antenna system. While that's often true, we should also consider the case of a transceiver that has an internal, almost always automatic, antenna tuner.

The idea of an automatic antenna tuner is that it can sense the SWR and adjust the tuner to minimize it. This is most commonly accomplished by a configuration consisting of a collection of inductors and capacitors that can be switched in or out of a matching network until the lowest SWR is obtained. A few automatic tuners actually rotate the shaft of a variable capacitor using an electric motor as the driving element.

The Flavors of Internal Tuners

Some transceivers offer an internal tuner as an extra cost option, in many cases one that can be added if needed. In other cases, the transceiver with tuner is essentially a separate model that has to be specified at the time of purchase. Other transceiver lines come only with or only without an internal tuner. Thus, if you're in the process of deciding on your next (or first) transceiver it's good to think carefully about your requirements before you make a decision. **Figures 5-1 – 5-3** illustrate radios with some of the choices.

ELECRAFT K3 TRANSCEIVER
14.252.85

Figure 5-1 — The Elecraft K-3 is an entirely modular design, including the option of a wide-range internal antenna tuner.

Tuner Impedance Range

As noted previously, all antenna tuners have limits on the range of impedances that they can transform to the desired load — almost always 50 Ω. In many cases the range of values is dependent on the frequency, often narrower on 6 meters than on the HF bands. Most tuner designs are limited on the low frequency end by the maximum values of the inductors and capacitors, and on the high frequency end by their minimum values, often the minimum capacitance of the elements to the metal case.

Thus it is often the case that the range of impedance values that the tuner is able to match is greater in the middle of the range than on the ends — typically 80 or 160 meters on the low end and 10 or 6 meters on the high end. Most manufacturers provide a single specification such as "tunes SWR at least 10:1" or "matches from 5 to 500 Ω." Note that the latter specification is not as general as the first — does it mean it only matches

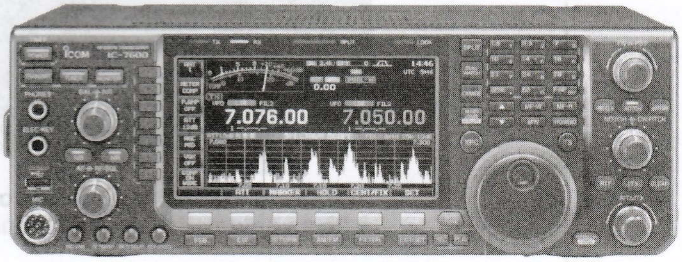

Figure 5-2 — The ICOM IC-7600 is only available with a built in antenna tuner.

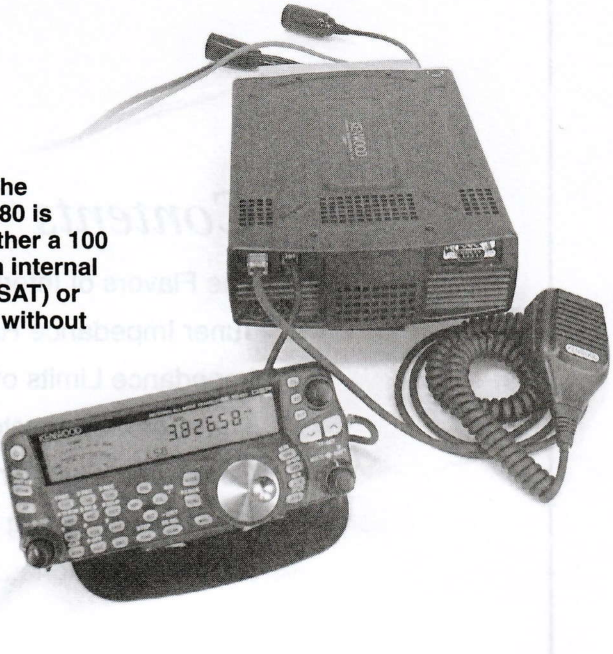

Figure 5-3 — The Kenwood TS-480 is available as either a 100 W version with internal tuner (TS-480 SAT) or 200 W version without (TS-480 HX).

resistive loads? Probably not, since it would be hard to design a tuner that just did that, nor would it be very useful. I tend to think that both ratings actually mean the same 10:1 SWR.

If they deliver on their promise, that would mean that they would actually tune the 10:1 range on the highest and lowest bands, and actually tune a wider range in the middle — and many seem to do just that.

Impedance Limits of Internal Tuners

While most external tuners have rating similar to the 10:1 discussed above, many transceivers have internal tuners rated at a 3:1, or 16.5 to 150 Ω tuning range. This seems to be particularly true of the radios provided by the large Japanese companies — ICOM, Kenwood and Yaesu. In contrast, the US made HF transceivers, Elecraft, FlexRadio and Ten-Tec, offer internal tuners specified to tune a 10:1 range.

The tuners with a 3:1 range are intended to deal with a matched antenna operated somewhat away from its design frequency. A look at the SWR plots in Chapter 2 provides the idea. While a 3:1 range will easily cover a 40 meter dipole across the whole band, it will only cover about 300 kHz of the 500 kHz width of 80 meters with a standard 80 meter wire dipole (see Figure 2-7).

The tuners with a tuning range of 10:1 or greater are what I call *wide range* tuners. These tuners can not only deal with an 80 meter dipole across the whole band, but can be used to match a whole spectrum of antenna types ranging from random, non resonant, wires to dipoles fed on multiple bands and exotic high gain antennas such as V beams or rhombics.

That Coax Connector

All current internal tuners terminate on the back of the radio in a coax connector, just as do radios without a tuner. This is a signal that they are intended to drive into coax fed *unbalanced* antenna systems. We will discuss the various benefits of balanced and unbalanced transmission lines a bit later, however, it is worth pointing out that many external tuners are set up to drive either. If your antenna system is balanced, you will need to make the transition from coax to balanced line outside the radio, tending to reduce the "all in one box" benefit of the internal tuner.

Coax Loss — If Things Seem Too Good to Be True...

It is tempting to try to use the antenna tuner to "force fit" an antenna to work on a band other than the one it's designed for. This can often appear to work, but appearances can be deceiving. Let's take one example.

Say you have a 20 meter dipole fed with 100 feet of RG-58 coaxial cable. The antenna works very well on 20 meters, and requires just a bit of trimming with the tuner for proper operation. So far so good.

All of a sudden sunspots reappear after years of absence and 10 meters is wide open with great signals world wide (sooner or later it's bound to happen). You have no antenna for 10 meters, so try using your 20 meter dipole. Wonder of wonders, it actually tunes with the internal tuner — a perfect match! You hear your neighbors working distant stations right and left, but no one hears you — what's the story?

This is an interesting case that provides a cautionary tale, as well as outlines one of the challenges of designing multiband antennas. On 20 meters, our dipole (depending on height) will have an SWR of around 1:1. The 100 feet of RG-58 coax will have a loss of about 37% (less than 2 dB), not noticeable in most cases, and all will be fine.[1]

Move to 10 meters and the 20 meter dipole will no longer provide a good match. In fact, my model indicates that its impedance will be 3836 Ω resistive in series with 790 Ω capacitive reactance — an SWR of 81:1! The high SWR increases the loss of the transmission line to about 15 dB. That means that of our 100 W, only 3.1 W will reach the antenna — that explains why we aren't being heard as well as our neighbors!

The perhaps more interesting aspect of this is that the power reflected by the mismatched antenna also is reduced by 15 dB on its way back to the tuner. Because of this, the tuner only sees an SWR at the bottom of the cable of about 3:1 and will happily adjust for a match. Thus the radio is happily transmitting, but 97% of its power output is heating up the transmission line.

What Else is Going to be in Your Station?

Another consideration as to whether an internal tuner will be your best choice is whether you have, or expect to have, a linear amplifier following your transceiver. For some types of operation, being able to select whether you transmit 100 or 1500 W can make a big difference.

If you have a linear amplifier and need a tuner, you will need an antenna tuner on the output side of your linear. A tuner in your transceiver can adjust for a mismatch in the input side of the amplifier (rarely needed), but can't help with tuning the antenna system. That has to be done at the output of the amplifier — and at the higher power level. If the amplifier is turned off, the radio's tuner can be used to match the antenna, but you will want to disable it when you switch to high power.

Thus, if you have or expect to have, a linear amplifier as a part of your station; you may want to consider a transceiver without a tuner and instead purchase a tuner with a power rating that can handle your linear. Note that this is mostly a monetary statement, since there is no harm in having the additional tuner in your transceiver. It can be turned off if you don't need it. I actually have one in my transceiver and another following the linear. I find the transceiver's internal tuner handy when I take my transceiver on vacation and am forced to use "antennas of opportunity."

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[1] We will use decibels (dB) to express gain and loss ratios throughout the book. If you need a refresher on the topic, please see Appendix A.

Review Questions

5-1 What are some of the advantages of an internal antenna tuner in a transceiver?

5-2 What kind of antennas can be tuned with a tuner that can tune an SWR of 3:1?

5-3 Why isn't an antenna that can be tuned with an internal tuner always effective?

Chapter 6

An External Tuner at the Radio

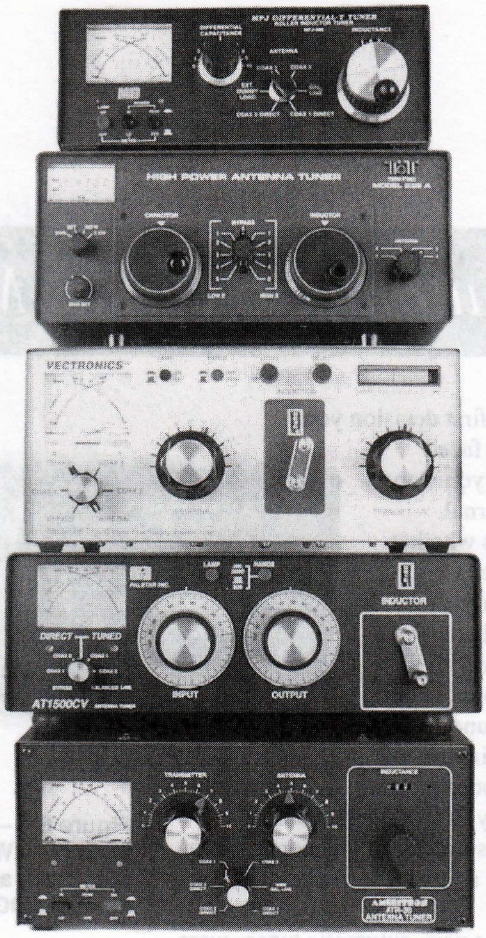
HIGH POWER ANTENNA TUNER
VECTRONICS
INDUCTOR
DIRECT
TUNED
INPUT
OUTPUT
AT1500CV
TRANSMITTER
ANTENNA
INDUCTANCE

Five high power (1 kW or higher rating) manual tuners, one choice for an external tuner to place near the transceiver

Contents

Automatic versus Manual Tuners 6-2
Review Questions 6-4

In place of an antenna tuner that is built into the transceiver, another option is to have one next to the radio. Note that this is the functional equivalent of an internal tuner, and shares the potential problem of appearing to work well with an inappropriate antenna, as described in the previous chapter.

There are many available choices for such a device, including automatic tuners from some radio manufacturers that integrate directly with radio controls. There are others from after market manufacturers that offer additional features and, in some cases, are less expensive than internal tuners. While you do have to have an extra box on or near your radio, external tuners may offer some significant advantages:

- As discussed in Chapter 3, they can have a wider tuning range than many internal tuners.
- If you think you may want to add (or if you have) a high powered linear amplifier, you can select a tuner compatible with the higher power.
- Some external tuners offer both balanced and unbalanced outputs.
- Some external tuners offer multiple switched connections so different antennas can be quickly brought on line.
- If you have multiple radios, they can be switched to the tuner input so only one tuner is needed.

Automatic versus Manual Tuners

The first decision you will be faced with if you want an external tuner is whether you prefer an automatic or a manual one. As the name implies, an automatic antenna tuner finds the optimum, or near optimum, settings by itself. The manual tuner usually has three controls that require adjustment to obtain the best match.

In the past, automatic tuners were not available at high power levels, so those with high powered stations had no choice but to use manual tuners. That is no longer the case, as automatic tuners are available at all legal amateur power levels (See **Figure 6-1**). Over the years, the ARRL has tested many manual and automatic tuners as part of *QST* product reviews. I was surprised to find that to our level of measurement precision, there was not a big difference in efficiency between tuners in the two groups. Still, there are some benefits to manual tuners and many amateurs are happy with the results they receive.

AT-AUTO
LDG
AT-1000 Autotuner
MFJ
MFJ IntelliTuner
Figure 6-1 — High power (1 kW or greater) automatic antenna tuners from Palstar, LDG and MFJ).

Automatic Antenna Tuners

To operate an automatic, you just feed it some power, hit a TUNE button and listen and watch while it finds satisfactory settings. Many tuners can do this in tens of seconds the first time and often remember the settings so the next time it takes just a few seconds or less for that antenna at that frequency.

In my experience there's not a lot not to like about an automatic antenna tuner. I have a number of them for particular applications, although I still use a manual tuner for my main station tuner. The key is to select a tuner that will operate with your radio — some are radio independent, while some work with the same radio controls that would operate one from the manufacturer of the radio.

One issue with some automatic tuners is just what happens if they sense a mismatch as you operate. Most automatic tuners are rated to tune at reduced power to avoid excessive arcing at relay contacts. If you change frequency or even if the wind blows your antenna around and the tuner starts tuning, the results could be dramatic. Some allow disabling the auto tune function once you have it tuned, others automatically cut back on power. In my opinion, it's better to be able to take control yourself.

Manual Antenna Tuners

Manual tuners do often provide an additional level of control capability. Some have switch selectable outputs for multiple balanced and unbalanced antenna connections. One can be dedicated to a dummy load, if you don't (yet) have enough antenna connections to fill up the jacks. Manual tuners often provide SWR and power metering independent of that of the radio.

Most automatic tuners tune until they reach what they consider a reasonable match, perhaps 1.5:1. Hopefully it is a value that will allow your radio to operate at full power. The manual tuner let's you set it to whatever threshold you think is best — although if your transmitter can put out full power, it won't make much difference.

Review Questions

6-1 What are three potential benefits of using an external tuner at the radio rather than an internal tuner in the radio?

6-2 What are the benefits of an internal tuner?

6-3 What limitation is common to either internal or external tuners located at the radio?

Chapter 7

Transmission Lines

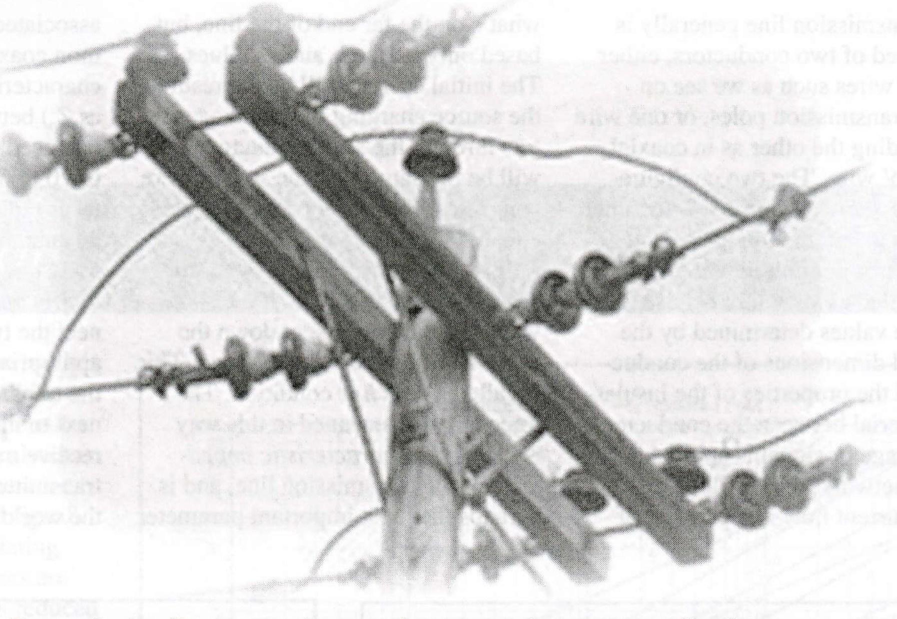

Transmission lines come in many forms, serving many applications.

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Characteristic Impedance.. 7-2
Propagation Velocity 7-3
Attenuation 7-3
What Can We Do to Reduce Transmission Line Loss? 7-5
Sidebar: Determining the Input Impedance of an Unmatched Transmission Line 7-6
Review Questions.. 7-7

As we have mentioned previously, frequently the antenna and radio are not in exactly the same place. There are some notable exceptions, particularly in portable hand-held systems and various microwave communications and radar systems. In most other cases, optimum performance requires the transmitter and receiver to be at some distance from the antenna. It may also be a matter of combat survival, especially if your enemy is equipped with anti-radiation weaponry designed to home in on a signal. The component that makes the interconnection is called a *transmission line*.

Transmission lines are used in places besides radio systems — for example, power distribution lines are a kind of transmission line, as are telephone wires and cable TV connections. In addition to just transporting signals, transmission lines have some important properties that we will need to understand to allow us to make proper use of them. This section will briefly discuss the key parameters.

Characteristic Impedance

A transmission line generally is composed of two conductors, either parallel wires such as we see on power transmission poles, or one wire surrounding the other as in coaxial cable TV wire. The two configurations are shown in **Figure 7-1**. Either type has a certain inductance and capacitance per unit length and can be modeled as shown in **Figure 7-2**, with the values determined by the physical dimensions of the conductors and the properties of the insulating material between the conductors. If a voltage or signal is applied to such a network, there will be an initial current flow independent of what's on the far end of the line, but based only on the L and C values. The initial current will be the result of the source charging the shunt capacitors through the series inductors and will be the same as if the source were connected to a resistor whose value is equal to the square root of L/C.

If the far end of the line is terminated in a resistive load of the same value, all the power sent down the line will be delivered to the load. This is called a *matched* condition. The impedance determined in this way is called the *characteristic impedance* of the transmission line, and is perhaps the most important parameter associated a transmission line. Common coaxial transmission lines have characteristic impedances (referred to as Z_0) between 35 and 100 Ω, while balanced lines are found in the range of 70 to 600 Ω. What this means to us as radio people, is that if we have an antenna that has an impedance of 50 Ω and a radio transmitter designed to drive a 50 Ω load, we can connect the two with any length of the appropriate 50 Ω coaxial cable and the transmitter will think it is right next to the antenna. The antenna will receive most (see next section) of the transmitted power and all is well with the world!

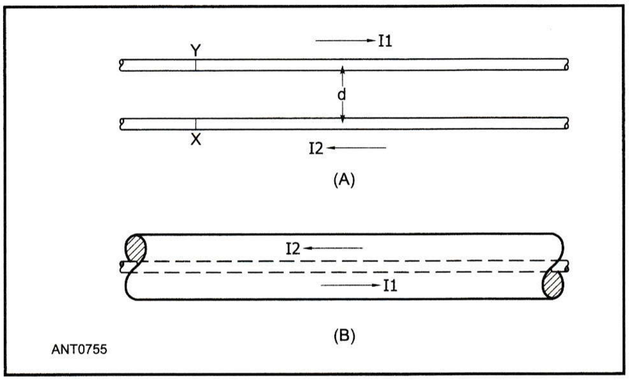

Figure 7-1 — Parallel wire and coaxial transmission lines.

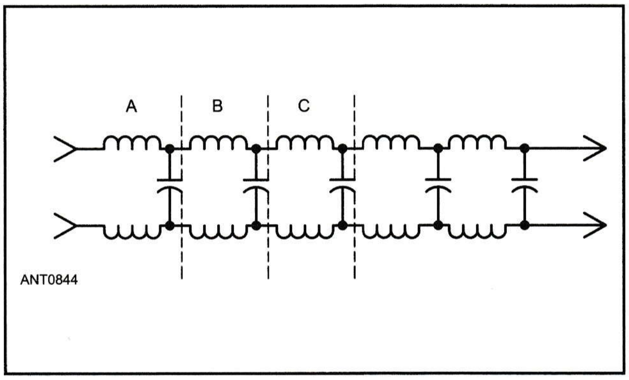

Figure 7-2 — Lumped constant equivalent of an ideal transmission line.

Propagation Velocity

Signals in air dielectric transmission lines propagate at almost the speed of light in air. Other dielectric materials between the conductors cause the signals in transmission lines to slow down just as we observe with light rays traveling through water. In many cases, this is not a matter of concern, since we often only care that the signals get out the other end, however, there are some exceptions.

The velocity can be shown to be reduced by a factor of one over the square root of the relative dielectric constant of the insulating material. Some cable specifications provide the relative velocity as a fraction of the speed of light. If not, and you know the material, most engineering handbooks include tables of properties of materials. For example, polyethylene is a common cable insulating material and has a relative dielectric constant of 2.26. The square root of 2.25 is 1.5, so the propagation velocity in polyethylene insulated coaxial cable is about $3/1.5 \times 10^8$ or 2×10^8 m/sec.

Some applications actually use coaxial cables to provide delayed signals in pulse and other applications. Having a way to accurately predict the delay just by knowing the cable characteristics and measuring the length of the cable can save a lot of lab time.

Attenuation

The ideal transmission line model shown in Figure 7-2 passes all input power to a matched load at the output. A real transmission line also has resistance associated with the wire conductors and some loss of signal due to the nature of the insulating material. As transmission lines are made larger, the resistance is reduced and as the dielectric material gets closer to low-loss air, the losses are reduced. The skin effect causes currents to travel nearer to the surface of the conductors at higher frequencies, and the effective loss thus increases as the frequency is increased.

Figure 7-3 provides some real world examples of the losses as a function of frequency for the most common types of transmission line. Note that the loss increases linearly with length and the values are for a length of 100 feet. Note also that the losses shown are for transmission lines feeding into loads matched to their Z_0. As will be discussed shortly, losses can increase significantly if the line is not matched. The "open wire"

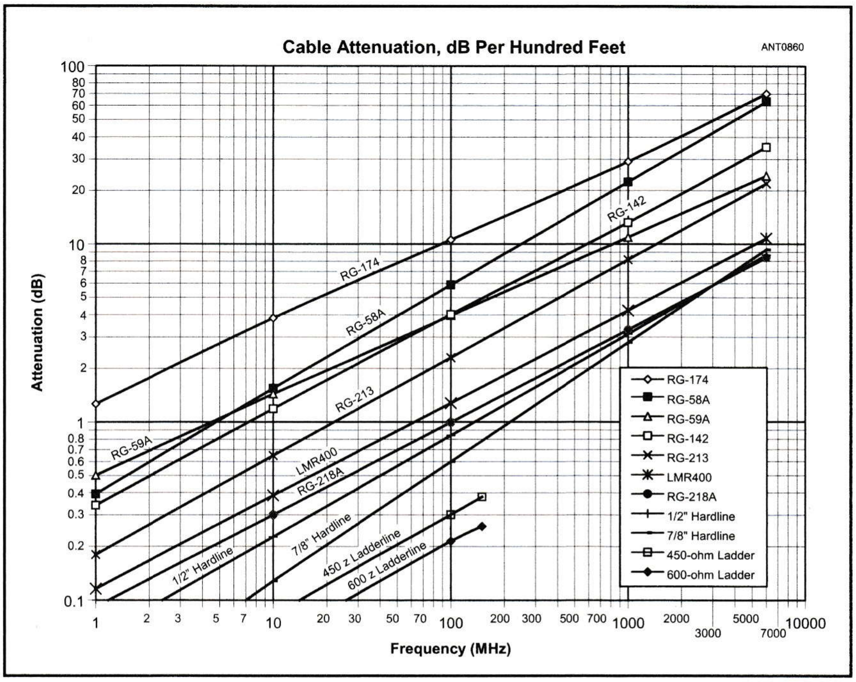

Figure 7-3 — Loss of some typical transmission lines in dB per 100 feet as a function of frequency. The RG-58 transmission lines are 50 Ω polyethelene insulated coaxial cable slightly less than ¼ inch in diameter. The RG-8 through RG-216 are 50 and 70 Ω polyethelene insulated transmission lines with a diameter somewhat less than ½ inch. The "hardline" types have a foam dielectric very near to air.

line shown consists of two parallel wires with air dielectric and infrequent spacers, typically resulting in a Z_0 of around 600 Ω. While the losses of such a line are low, they only work well if spaced from metal objects and lossey material and not coiled up, while coaxial cables have higher loss, all the signal is within the outer conductor and they can be run in conduit, coiled up, placed next to other wires and are therefore much more convenient to work with.

Sometimes a long straight run of open wire line will be transformed to 50 Ω at the ends with coaxial cable used at the antenna and radio ends to take advantage of the benefits of both.

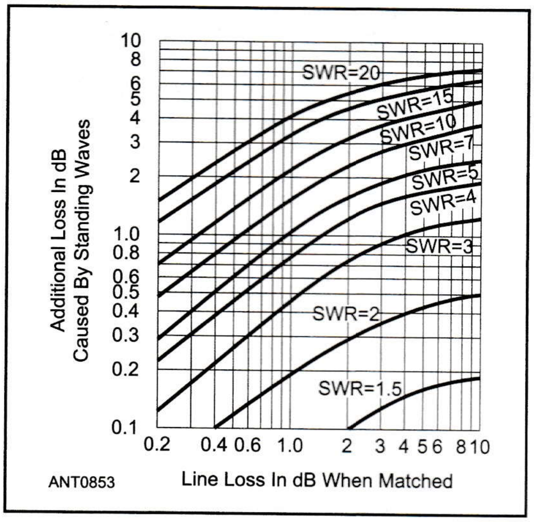

Figure 7-4 — Additional loss of a transmission line when mismatched. This loss needs to be added to the loss in Figure 7-3 for mismatched lines.

Lines with Unmatched Terminations

In our discussions so far, we have been talking about transmission lines feeding terminations matched to their characteristic impedance. In that case, the voltage-current relationship at the load will reflect the impedance of the load — not the characteristic impedance. Along the line the voltage and current will vary with distance providing a load to the transmitter end that is generally neither that of the far end Z_L, nor the Z_0 of the transmission line. The transmitter load can be calculated knowing the Z_L, the Z_0 and the electrical length of the line as discussed in the sidebar.

The ratio of maximum voltage on the line to minimum voltage on the line is called the *standing wave ratio* or SWR. A matched line has an SWR of 1:1, a 50 Ω line terminated with a 25 or 100 Ω load will have an SWR of 2:1. There are a whole family of complex impedances that will also have a 2:1 SWR, by the way. The computation is easier with resistive loads.

There are some interesting special cases with a mismatched line. The load impedance, resistive or complex, repeats every λ/2, for example. The impedance goes to the opposite extreme in odd multiples of a λ/4. For example our 25 Ω load would get transformed to 100 Ω in λ/4 or ¾ λ transmission line sections and vice versa. This effect can be used to our advantage if we wish to transform impedances at a specific frequency. In this case, the line is actually acting like a kind of antenna tuner.

A generally less desirable effect of mismatched lines is that the losses increase. This is easy to see, if voltages and currents are higher, we might expect losses to increase as well. **Figure 7-4** provides the additional loss for a mismatched line that needs to be added to the matched loss in Figure 7-3. As is evident, the combination of matched loss and high SWR results in dramatic increases in loss. This is why antenna designs that don't use matched transmission lines often use air-dielectric lines.

What Can We Do to Reduce Transmission Line Loss?

By now you should have a clear understanding of what can happen to a signal if applied to an antenna system through even a relatively short length of coaxial cable that has a high SWR. Depending on the matched loss, length and SWR, much of your signal can disappear before it gets to the antenna.

The insidious aspect of this is that while this is happening, the SWR at the radio with a collocated or internal tuner looks great — a perfect match and easy to get it. Losses are like that — they tend to result in a wide SWR bandwidth, as does a dummy load. Not a good thing if you want to communicate over the air. Fortunately, there are three fairly straightforward approaches to solving this problem:

- Change the antenna to one with either a wide enough bandwidth to cover all frequencies of interest, or one that covers multiple amateur bands with low SWR. This is not a topic for a book on antenna tuners, but is covered in many books on antennas.[1,2]
- Move the antenna tuner to, or close to, the antenna location. This is the subject of Chapter 8, or;
- Use a transmission line that has low enough matched loss so that even a high SWR doesn't result in high losses. This is the subject of Chapter 9.

Notes

[1] J. Hallas, W1ZR, *Basic Antennas — Understanding Practical Antennas and Designs,* Available from your ARRL dealer or the ARRL Book-store, ARRL order no. 9994. Tele-phone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/arrl-store/**; **pubsales@arrl.org**. See Chapter 11, "Wideband Dipole Arrays;" Chapter 12 "Multiband Dipole Arrays" or Chapter 21 "Log Periodic Dipole Arrays," for example.

[2] R. D. Straw, Editor, *The ARRL Antenna Book,* 21st Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/arrl-store/**; **pubsales@arrl.org**.

Determining the Input Impedance of an Unmatched Transmission Line

The input impedance of a transmission line of any length with any terminating impedance can be determined in a number of different ways.

The most straightforward way is through direct calculation. Unfortunately, this is also perhaps the most time consuming and perhaps most error prone method, at least until you have it set up on a spreadsheet or other program that can handle he hyperbolic function.

My favorite way to determine the input impedance, standing wave ratio (SWR) as well as the line loss, is to use *TLW* (*Transmission Line for Windows*) software that comes with *The ARRL Antenna Book*.[3] The main screen is shown in Figure 7-A performing an analysis of an antenna with a complex load impedance fed through 100 feet of coaxial cable.

The antenna input impedance (74.3 + *j*16.1) is inserted in the LOAD box. The + *j*16.1 indicates an inductive reactance with a value of 16.1 Ω at the frequency of interest (10.1 MHz). A –*j* value would indicate a capacitive reactance, which would be entered with a minus sign. The output impedance through 100 feet of RG-58A 50 Ω coax is provided at the bottom in both rectangular (69.02 – *j*6.23) and polar coordinates (69.53 @ –5.15°), along with the SWR at line input (1.40:1) and output (1.62:1) as well as line loss (1.661 dB) — both for the matched case (1.555 dB) and the additional loss due to mismatch (0.106 dB). That's about everything I could think to ask, except which pile in the basement has the RG-58A!

A third way to evaluate the input impedance is through a graphical method. A Smith chart, see Figure 7-B, can be used to determine the input impedance of a transmission line. This was very commonly used before the personal computer became ubiquitous. In addition to the accuracy limitations due to the input and output resolution inherent in a chart, the Smith chart assumes that the line is lossless. This may result in significant errors depending on the amount of line loss.

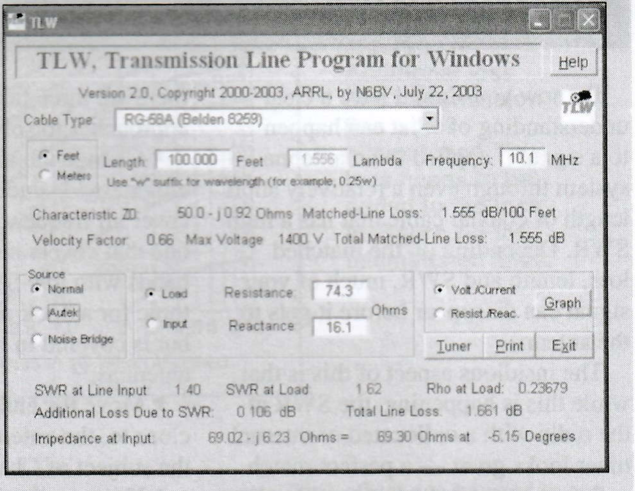
TLW

TLW, Transmission Line Program for Windows

Version 2.0, Copyright 2000-2003, ARRL, by N6BV, July 22, 2003

Cable Type: RG-58A (Belden 8259)

● Feet ○ Meters Length: 100.000 Feet 1.556 Lambda Frequency: 10.1 MHz

Use "w" suffix for wavelength (for example, 0.25w)

Characteristic Z0: 50.0 - j 0.92 Ohms Matched-Line Loss: 1.555 dB/100 Feet

Velocity Factor: 0.66 Max Voltage: 1400 V Total Matched-Line Loss: 1.555 dB

Source: ● Normal ○ Autek ○ Noise Bridge

● Load ○ Input Resistance: 74.3 Reactance: 16.1 Ohms

● Volt./Current ○ Resist./Reac.

SWR at Line Input: 1.40 SWR at Load: 1.62 Rho at Load: 0.23679

Additional Loss Due to SWR: 0.106 dB Total Line Loss: 1.661 dB

Impedance at Input: 69.02 - j 6.23 Ohms = 69.30 Ohms at -5.15 Degrees

Help
Graph
Tuner
Print
Exit

Figure 7-A — The main screen of *TLW* (*Transmission Line for Windows*) software is shown performing an analysis of the condition of the L/D of 10,000 case.

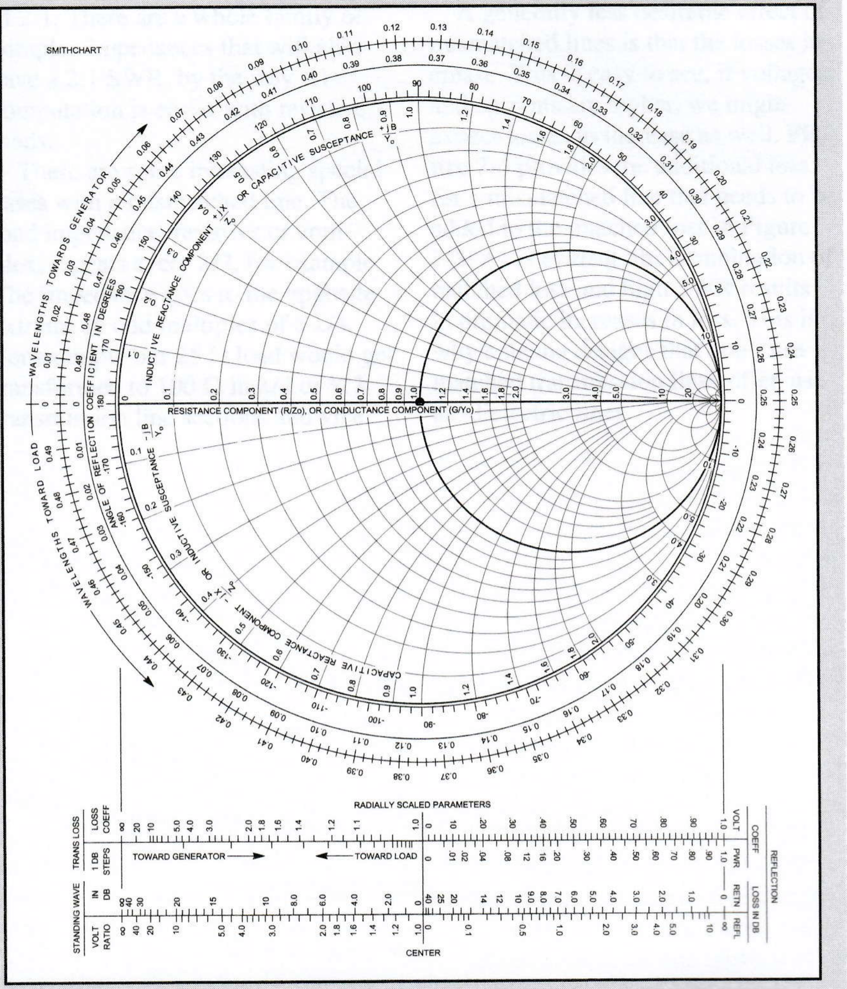
SMITHCHART
WAVELENGTHS TOWARDS GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE (-jB/Yo)
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
RADIALLY SCALED PARAMETERS
TOWARD GENERATOR
TOWARD LOAD
STANDING WAVE VOLT RATIO
IN DB
TRANS LOSS 1 DB STEPS
LOSS COEFF
VOLT
PWR
RETN LOSS IN DB
REFL
REFLECTION COEFF
CENTER

Figure 7-B — A Smith chart used for the graphical determination of the input impedance of a lossless transmission line.

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[3] *TLW* is supplied with *The ARRL Antenna Book*, 20th Edition, available from the ARRL Bookstore at **www.arrl.org/catalog/** order number 9043 — $39.95.

Review Questions

7-1 Describe three reasons it might be desirable to have a transmitter and an antenna in different locations.

7-2 If you want to make a $\lambda/4$ section of RG-213 for our 10 MHz system, how long would you make it?

7-3 A 1000 W transmitter at 15 MHz is feeding a matched load through 200 feet of RG-8 transmission line. How much power reaches the antenna? Repeat if the frequency is 150 MHz. Repeat both cases if the antenna has an SWR of 3:1.

Chapter 8

Moving the Tuner to the Back 40

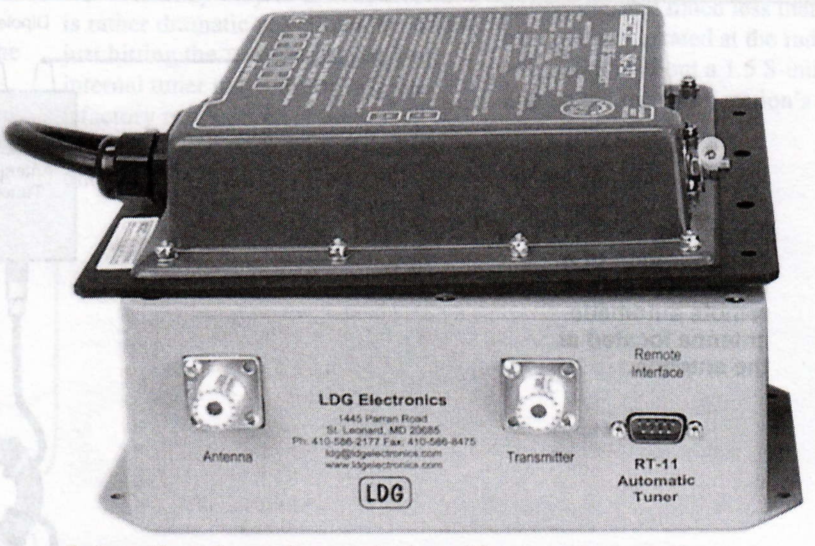
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Automatic
Tuner

Automatic antenna tuners designed for remote mounting. On top, one from SGC, beneath a model from LDG.

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Some automatic antenna tuners are designed to be mounted remotely, rather than being collocated with the radio. We can take advantage of this in order to minimize losses in the transmission line between the antenna system and the transceiver. With the tuner at the antenna end, the load at the antenna end of the transmission line provides very close to a 1:1 SWR. The line will then have only the matched loss between the radio and the tuner, not the additional loss due to mismatch.

An Example of Using a Remote Tuner to Minimize Loss

Figure 8-1 shows the configuration of a transceiver with a remote automatic antenna tuner at the antenna. Let's assume that the transmission line is RG-58 and that it is 100 feet between the radio and the tuner plus the tuner is connected directly to the feed point of the coax fed antenna.

We will again use the example from Chapter 4 of a 20 meter dipole tuned by the tuner to operate on 10 meters where its impedance will

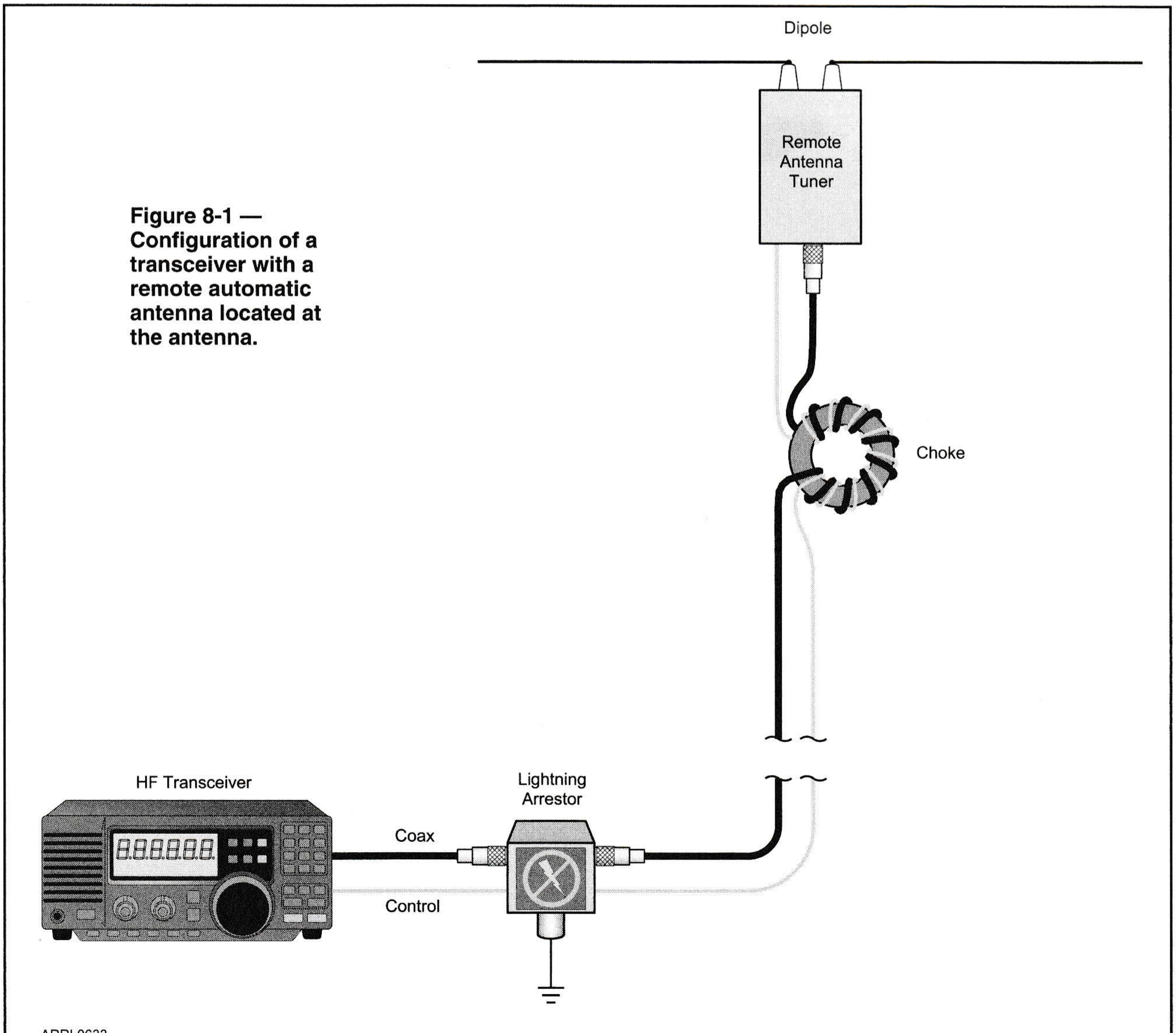

Figure 8-1 — Configuration of a transceiver with a remote automatic antenna located at the antenna.

Table 8-1

Comparison of System Losses for Remote and Collocated Tuners — RG-58

Loss Element	*Tuner at Radio*	*Remote Tuner Beneath Antenna*
Loss in 100' Cable (dB)	14.7	2.9
Percent Power Lost (%)	96.6	48.1
Power to Antenna at 100 W (W)	3.4	51.9

Table 8-2

Comparison of System Losses for Remote and Collocated Tuners — LMR-400

Loss Element	*Tuner at Radio*	*Remote Tuner Beneath Antenna*
Loss in 100' Cable (dB)	8.62	0.66
Percent Power Lost (%)	86.3	14.1
Power to Antenna at 100 W (W)	13.7	85.8

be 3836 Ω resistive in series with 790 Ω capacitive reactance — an SWR of 81:1. **Table 8-1** provides the comparison in loss for a 100 W output transceiver, in each case assuming the antenna tuner contributes no loss. While this is slightly optimistic, that loss is usually very small. The result is rather dramatic and illustrates why just hitting the TUNE button on your internal tuner may not provide satisfactory results even if the resulting radio SWR ends up at a perfect match.

Perhaps you will also not be satisfied with moving your tuner to the antenna and still losing almost half your power in the RG-58. The lesson here is that RG-58, while available and relatively inexpensive, is not the best choice for even a 100 foot run at 28 MHz. Of course, it's much worse as you move to VHF, and keep in mind that it effects both transmit and receive signals.

One of the lowest loss flexible coaxial transmission lines that fits the usual UHF coax connectors is Times Wire LMR-400. There are similar cables by other manufacturers. **Table 8-2** repeats the exercise shown in Table 1 with the lower loss cable. Note that while there is measurable loss even for the matched case, it is less than 1⁄10 of an S-unit, so hardly noticeable, and much less than the loss for the tuner located at the radio that will result in about a 1.5 S-unit reduction on the receiving station's meter.[1]

[1] Notes appear on page 5.

Intermediate Steps

Not all antenna systems are structured in a way to allow a tuner to be at a feed point. An example might be a dipole suspended between two supports with a transmission line hanging in the middle. In this case, it is tempting to consider a short coax run from the antenna itself to the tuner as shown in **Figure 8-2**. This arrangement may also be necessary if the tuner is not waterproof and requires shelter from the elements.

This is a feasible arrangement; however, while a substantial portion of the loss can be eliminated in this way, the loss in the section between the tuner and the antenna can still be surprisingly high. For example, for the RG-58 case of Table 8-1, a 30 foot run between the antenna and the tuner would have a loss of 4.4 dB, or 64% of the power, leaving only 36 W from your 100 W transmitter to be radiated — if it got to and through the tuner without other losses.

A better way to accomplish this in many cases will be to use a section of the low loss transmission line discussed in Chapter 9 between the antenna and the tuner.

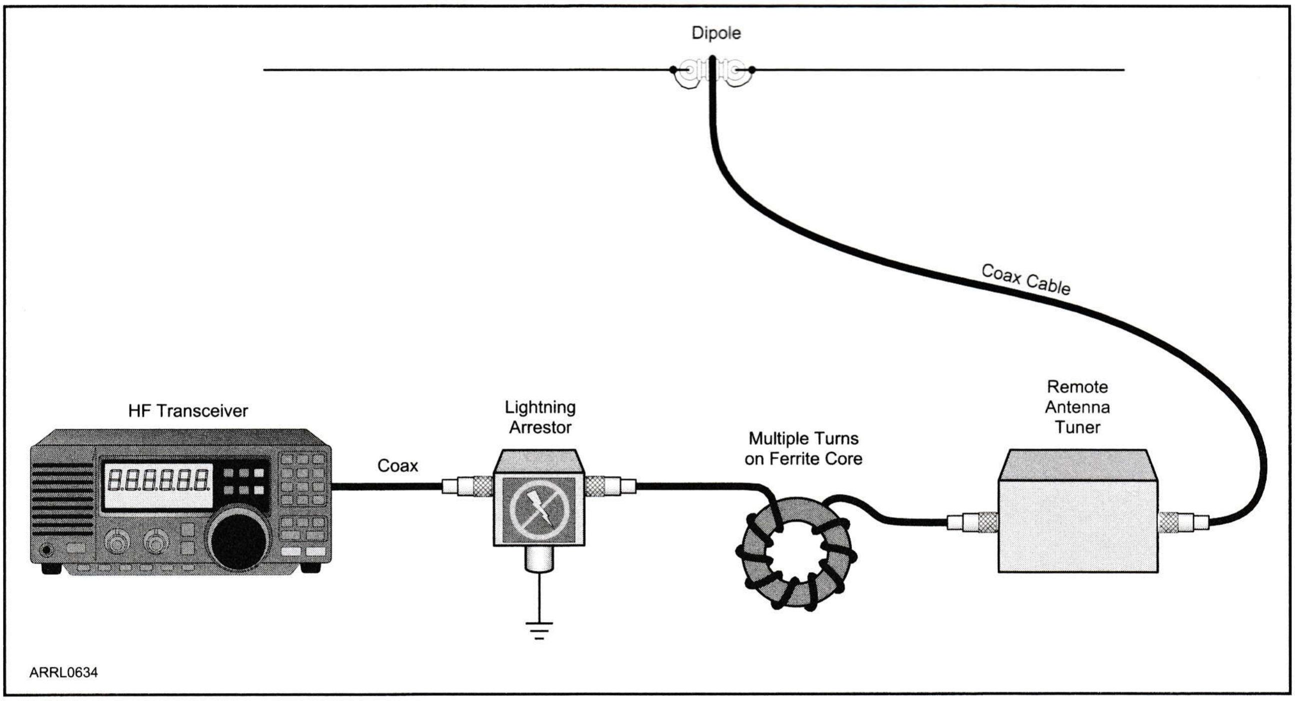

Figure 8-2 — Configuration of a transceiver with a remote automatic antenna located beneath the antenna.

Remote Antenna Tuners — the Downside

The use of a remote antenna tuner has a few disadvantages. I currently use three in various station locations and am quite happy with them in spite of the downsides:

- One remote tuner is located near my main basement station. I share antennas with my spouse (Nancy, W1NCY), who has an upstairs station. With an automatic tuner that can be patched to antennas from the W1ZR main station, she has access to any W1ZR antenna with low loss in the 100 foot coax run to her desktop setup.
- On our sailboat, I use an insulated backstay as an HF antenna. This non-resonant system has a high SWR on all bands and requires a tuner at the feed point to feed it against ground. I have a short lead from a corner under the lazerette beneath the antenna feed with another short lead to the engine block where a ground connection is available. Not only does it work well on all HF bands, but by keeping the radiating portion of the system in the corner of the boat, I minimize interference between the radio and marine navigation systems.
- I also have a remote tuner in the trunk of my car for my mobile HF system. Typical HF mobile antennas have very narrow SWR bandwidths. By using a remote antenna tuner at the antenna base, I can cover entire bands, or even tune to lower frequency bands than the antenna is designed for. While this sort of operation isn't as efficient as adjusting the antenna itself, it is much easier than making adjustments while driving at highway speeds!

There are a few aspects of remote tuner operation that might be disadvantageous for some. One is the fact that in most such installations the tuner becomes integrated into a particular antenna structure. If we have multiple antennas, each will need its own tuner — a potentially expensive proposition.[2] It also is the case that in addition to providing coaxial cable to the tuner, one must also provide operating power and sometimes control signals to the tuner. Some tuner manufacturers package the coax, power and control into extension cable assemblies that can be used for this purpose. Another possibility is to use a *bias-T* to insert the power onto the coax cable, sharing it between the two functions.[3]

Notes

[1] The Collins Radio established, now industry standard, S-meter calibration is that S-9 equals 50 µV at the antenna terminals and each S-unit represents a change of 6 dB. To say that not all amateur S-meters follow this standard would be an understatement.

[2] Remotly controlled antenna switches may be used to solve this problem, although commercial units cost as much as some remote 100 W antenna tuners.

[3] S. Ford, WB8IMY, "Short Takes — MFJ-4712 Two-Position Remote Antenna Switch," *QST*, Sep 2006, p 48.

Review Questions

8-1 Why is the quality (loss) of a transmission line more important in the mismatched than the matched case?

8-2 If using an internal tuner in a transceiver, why might the SWR *before* tuning be an important indicator of antenna system efficiency?

8-3 Why is the SWR *before* tuning insignificant if an antenna located tuner can match to the transmission line Z_0?

Chapter 9

Transmission Line Choices for Low Loss

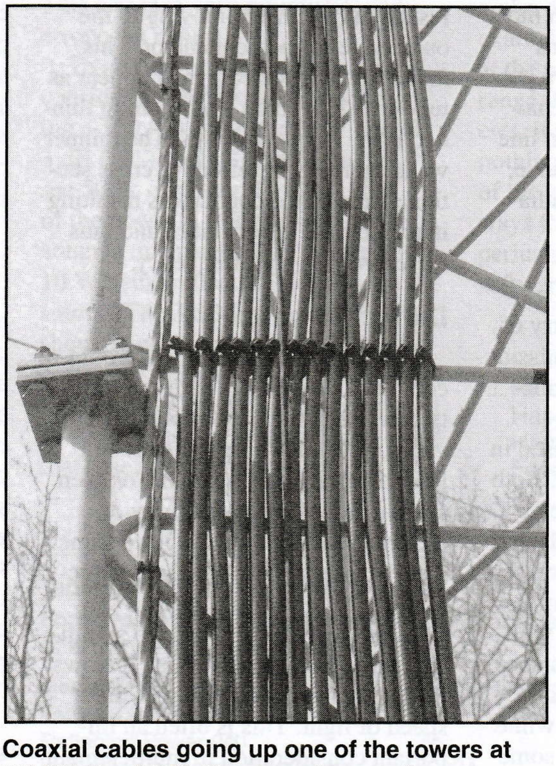

Coaxial cables going up one of the towers at W1AW, the ARRL Headquarters station

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The ideal transmission line accepts the output power (as well as received signal) from its source and delivers it to its destination load without loss. If the characteristic impedance (Z_0) is the same as the source and load impedances, it delivers it with the same ratio of voltage to current. That means, for all practical purposes, the ideal transmission line is invisible to the system. Devices connected to both ends act as if they were collocated, except for the delay in signal arrival time, unimportant except in special circumstances.

Hello Real World!

Unfortunately, ideal transmission lines don't exist, although for many applications we can come remarkably close. The primary issue in most cases is loss. We just don't get as much power to the far end as we put in. There are three primary mechanisms that result in transmission line loss. They are conductor resistance, dielectric loss and leakage or radiation.

Conductor Resistance

Figure 7-1 shows the geometry of the two primary types of transmission line. At (A) is a balanced transmission line, while at (B) we have coaxial cable of the type discussed in the earlier chapters of the book. Both propagate signals down the line as currents with their associated electric and magnetic fields. In a properly terminated transmission line, the magnitude of I_1 will equal that of I_2 with the result that fields at some distance will cancel. In the case of coaxial cable they cancel at the shield, while for balanced line they exist for some distance around the line.

The action of the currents in an ideal line can be modeled as shown in Figure 7-2 in Chapter 7. The model can be analyzed with reasonable accuracy in comparison to real cable if there are at least 10 sections per wavelength, and if the inductors and capacitors are modeled as real elements, including the resistance of the wire and the dielectric loss of the capacitors.

For the case of dc, the wire loss just equals the dc resistance of the wire, a function of its diameter and material. As frequencies increase, *skin effect* results in the current moving to the outer edge of each conductor. This makes the wires electrically appear as tubes, with the tube walls getting thinner as the frequency rises. The thinner walls decrease the effective cross sectional area of the conductors resulting in an increase in resistance and thus increased loss with frequency.

Dielectric Loss

An ideal transmission line would consist of conductors with the insulation between them a perfect lossless vacuum. While some transmission lines approach this, with air (or even special gasses) as the primary dielectric, real lines always have some lossey material between the conductors.

A lossey dielectric has two significant effects on signals: First, it slows the signal to some fraction of the speed of light. This is often an important consideration in multielement driven antennas that rely on accurate phasing of signals, but does not enter into this discussion.

Second, dielectric loss results in yet another contribution to line loss, and this also increases with increasing frequency.

Radiation or Leakage Loss

While generally less significant a loss factor than the previous two, some signal is lost in a real line due to it leaving the transmission line before it reaches the intended load. In a sense this is more a misdirected signal than a lost signal, and, because the signals end up in undesired places, the interference to other systems may be more important than the slight reduction in signal delivered to the desired load. Still, for either reason it can represents a significant issue for real lines.

In the case of coaxial cable, a portion of the shield resistance (depending on the shield coverage) results in a current that appears on the outside of the shield. The outer shield current actually makes the outside of the shield act as an antenna with resulting radiation detectable along the length of the shield. For balanced transmission line, the fields cancel wherever the distance to both wires is the same. For a perfectly installed line, that means all the places on a plane centered between the conductors and perpendicular to the line between them.

If the line is not perfectly installed, there will be some unbalance between the capacitance of each wire to ground resulting in a current unbalance that results in radiation. A similar effect occurs if the load is not perfectly balanced. Even in the case of perfect balance, there is some radiation in directions in which the distance to the wires is different. If the spacing is a small fraction of a wavelength, this radiation is diminished within a few times the wire spacing.

How Can We Determine Loss?

Transmission line loss is a design parameter that is specified by each manufacturer for their cables. The line loss is generally specified over the usual operating range at a number of frequencies, often 1, 10, 100, 1000 and 10,000 MHz.

Matched Loss

Figure 7-3 shows the *matched* loss per 100 feet of representative transmission line types. As you make choices of transmission line, it is important to note that this data is representative — the variation between attenuation of different manufacturers, and even different part numbers from the same manufacturer, can be striking. Check the manufacturer's Web page for the data sheet of the transmission line you are considering to be sure you know what you are getting.

For lengths other than 100 feet, the loss scales linearly. For example if a line has a matched loss of 2 dB at 100 feet, the same line, at the same frequency, will have a loss of 1 dB if 50 feet long, and 5 dB if 250 feet long.

Additional Loss Due to Mismatch

By now it should come as no surprise to find that a mismatched line has more loss than a matched one. The additional loss due to mismatch is a function of both the mismatch and the loss if matched. Figure 7-4 shows the additional loss in dB that occurs as a result of a line not being matched.

Note that the SWR shown is the SWR as measured, or calculated, at the load not the SWR measured at the transmitter end of the cable. This is particularly important in the case of a lossey line since the loss will reduce both the power reaching the antenna and the power of the reflected wave that is used to determine the SWR. This can give very optimistic, and erroneous results.

To give an example of this effect, consider a 100 W transmitter driving a 100 feet of coax with a loss of 3 dB (50% loss). The antenna will see 50 W of power. Lets say 20% of the power is reflected due to the antenna mismatch. That will result in 10 W being reflected back toward the source. The 3 dB loss results in 5 W showing up as reflected power at the bottom of the cable. This is quite different than if the 100 W were applied to the antenna on lossless line — in that case, a reflected power of 20 W, not 5 W, would, show up at the SWR measurement device.

Table 9-1 summarizes what we have at the two locations. Note the rather distressing result. A very acceptable measurement of an SWR of 1.6:1 at the bottom of the coax is the result of an unpleasant SWR of 4:1 at the antenna. In this example, our 100 W of power results in only 40 W radiated from the antenna — yet all of our measurements make us think we're doing well. Unfortunately, this example is not unusual, especially at the upper end of HF into the VHF range. If it happens at higher frequencies, it is usually more evident since nothing much ends up going in or out of the system! The sidebar discusses ways that this can be calculated, and perhaps avoided, through the use of software.[1]

Table 9-1
Forward and Reflected Power and SWR as Seen at Each End of a Transmission Line with 3 dB Loss

Measurement	*Bottom of Cable*	*Top of Cable*
Forward Power (W)	100	50
Reflected Power (W)	5	10
Indicated Reflection Coefficient	0.224	0.447
Indicated SWR	1.6	4.0

---

[1] J. Hallas, W1ZR, "I Know What's Happening at the Shack — What's Happening at the Other End of my Feed Line?" *QST*, Feb 2007, p 63.

How is Transmission line Made?

You may wonder what is it about transmission lines that makes their loss performance so different. It all comes down to how and of what they are made. **Figure 9-1** shows typical construction techniques of parallel and coaxial transmission line types. Not shown are lines with mostly air as a dielectric, the lines with the least loss. Parallel line, so-called open-wire line, consists of two parallel bare wires with occasional spacers designed to keep them apart and at about the same distance. The traditional insulators were ceramic, however, recent lines have used plastic or PVC spacers. Mostly air-dielectric coax is sometimes encountered. Such cable that I've seen is formed from two concentric copper tubes with ceramic donut shaped spacers every foot or so.

The characteristic impedance of cable is a function of conductor diameter and spacing. Thus as line gets larger, each conductor gets larger for the same Z_0 and thus the resistance is reduced, resulting in lower loss with larger cable.

The balanced line (more next chapter) has progressively less attenuation as the Z_0 gets higher (the ratio of series resistance to load resistance goes down) and as the polyethylene dielectric is replaced by air, partially in the case of window line (C) and more completely in open wire line described above.

Coaxial cable loss is similar in that foam dielectric is part polyethylene and part air. The lines with double (E) and solid metal (F, G) shields have lower resistance and much less leakage.

Perhaps not surprisingly, all the factors that make line have lower attenuation, make it more expensive. Still, in most systems, for reasonable distances, transmission line cost is a small part of total system cost, and often provides a worthwhile investment.

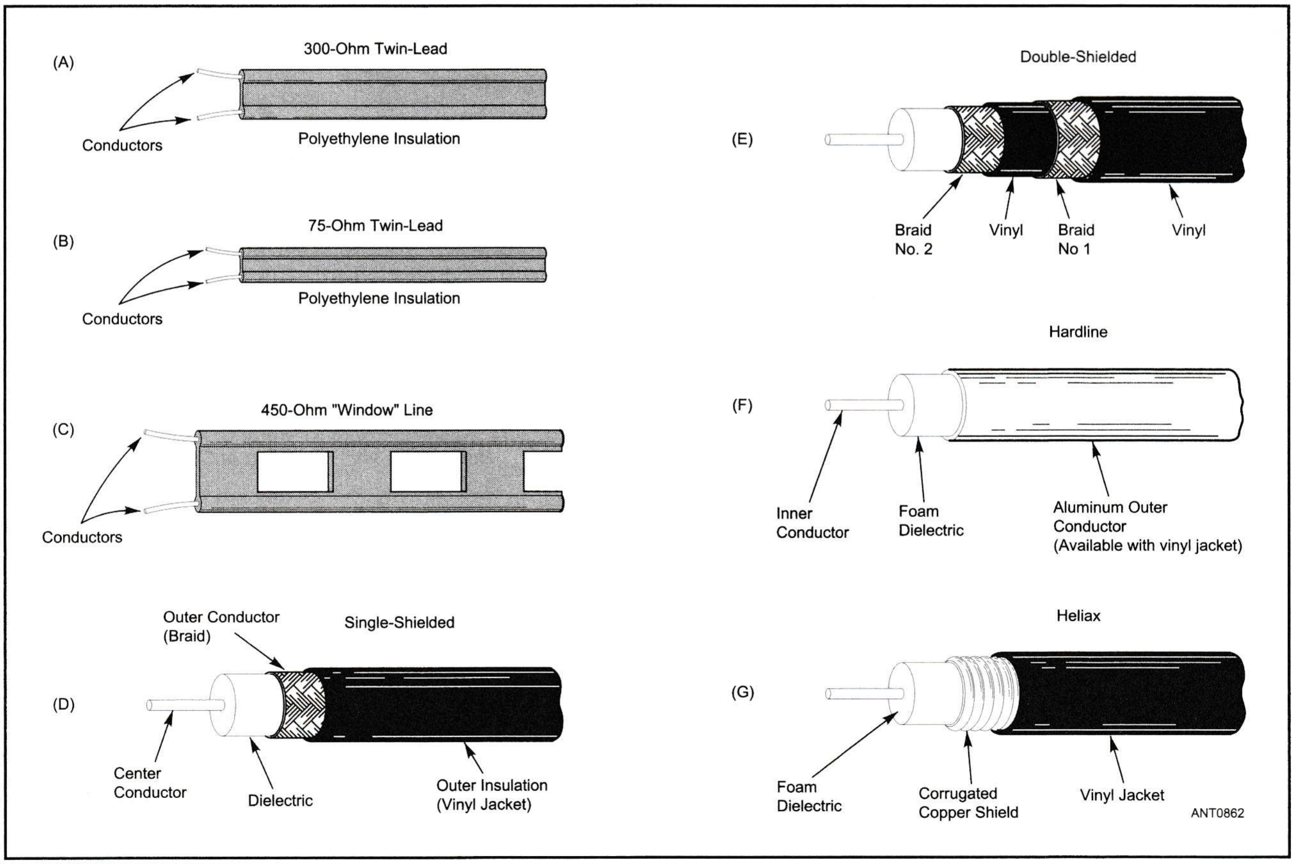
(A)
300-Ohm Twin-Lead
Conductors
Polyethylene Insulation
(B)
75-Ohm Twin-Lead
Conductors
Polyethylene Insulation
(C)
450-Ohm "Window" Line
Conductors
(D)
Outer Conductor
(Braid)
Single-Shielded
Center
Conductor
Dielectric
Outer Insulation
(Vinyl Jacket)
(E)
Double-Shielded
Braid
No. 2
Vinyl
Braid
No 1
Vinyl
(F)
Hardline
Inner
Conductor
Foam
Dielectric
Aluminum Outer
Conductor
(Available with vinyl jacket)
(G)
Heliax
Foam
Dielectric
Corrugated
Copper Shield
Vinyl Jacket
ANT0862

Figure 9-1 — Construction techniques used in making flexible transmission lines.

I Know What's Happening at the Shack — What's Happening at the Other End of my Feed Line?

If you want to find out — here's the easy way using TLW.

Joel R. Hallas, W1ZR
Technical Editor, QST

I'm told that one of the more frequent questions received by *QST's* "Doctor" has to do with folks wanting to determine the impact of transmission line losses on the effectiveness of their antenna system. These questions are often along the lines of "I measure an SWR of 2.5:1 at the transmitter end of 135 feet of RG-8X coaxial cable. My transceiver's auto-tuner can tune it to 1.1, but how can I tell what my losses are?" or "How much difference will I have if I have a tuner at the antenna instead of using the built-in tuner?"

These are important questions that almost every amateur operator is faced with from time to time. An approximate answer can be obtained by using the graphs found in any recent edition of The ARRL Antenna Book showing the loss characteristics of many transmission line types, plus adding in the effect of an SWR greater than 1:1. The SWR at the antenna end can be determined from the bottom end SWR and the cable loss. Using these graphs requires a bit of interpolation or Kentucky windage, but can result in useful data.

But There's an Even Better Way!

Packaged with each of the last few editions of *The ARRL Antenna Book* is a CD containing the pages of the whole Antenna Book as well as some very useful software. The program that I use almost daily is one written by Antenna Book Editor R. Dean Straw, N6BV, called *TLW* for Transmission Line for Windows.

TLW provides a very easy to operate mechanism to determine everything I usually need to know about what's happening on a transmission line. When you open the program, you are presented with a screen as shown in Figure A. This has the values plugged in from the last time you used it, often saving a step. Let's take a quick tour of the inputs:

Cable Type — This allows you to select the cable you would like to analyze. A drop-down box provides for the selection of one of 32 of the most common types of coax and balanced lines. An additional entry is provided for User Defined Transmission Lines that can be specified by propagation velocity and attenuation.

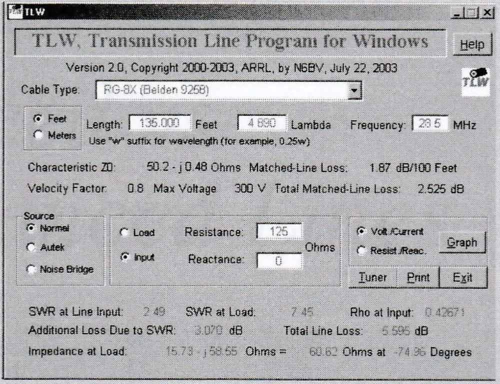
TLW
TLW, Transmission Line Program for Windows
Version 2.0, Copyright 2000-2003, ARRL, by N6BV, July 22, 2003
Cable Type: RG-8X (Belden 9258)
● Feet ○ Meters
Length: 135.000 Feet 4.890 Lambda Frequency: 28.5 MHz
Use "w" suffix for wavelength (for example, 0.25w)
Characteristic Z0: 50.2 - j 0.48 Ohms Matched-Line Loss: 1.87 dB/100 Feet
Velocity Factor: 0.8 Max Voltage: 300 V Total Matched-Line Loss: 2.525 dB
Source: ● Normal ○ Autek ○ Noise Bridge
○ Load ● Input
Resistance: 125 Ohms
Reactance: 0
● Volt./Current ○ Resist./Reac.
SWR at Line Input: 2.49 SWR at Load: 7.45 Rho at Input: 0.42671
Additional Loss Due to SWR: 3.070 dB Total Line Loss: 5.595 dB
Impedance at Load: 15.73 - j 58.55 Ohms = 60.62 Ohms at -74.96 Degrees

Figure A — The opening screen of *TLW*, illustrating the process described in the article.

Length — In feet or meters, your choice.

Frequency — This is an important parameter when dealing with transmission line effects.

Source — This defines the form of the input impedance data. Generally, you can use NORMAL.

Impedance — The impedance can be specified as what you measure, resistive (real) and reactive (imaginary, minus means capacitive). This could come from your antenna analyzer at either end of the transmission line. Note, if you only know the SWR, not the actual impedance, all is not lost — see below.

Now for the Outputs

SWR — The SWR is provided at each end of the cable. This is an important difference that many people miss, important even with a moderate SWR at the transmitter end, as we'll see — the SWR at the antenna will be much higher due to the cable loss. With TLW, you instantly know the SWR at both ends, and the loss in the cable itself

Rho at Load — This is the reflection coefficient, the fraction of the power reflected back from the load.

Additional Loss Due to SWR — This is one of the answers we were after.

Total Loss — And this is the other, the total loss in the line, including that caused by the mismatch.

But Doctor, What if I can Only Measure the SWR — Not the Actual Impedance?

Often the only measurement data available is the SWR at the transmitter end of the cable. Because the losses are a function of the SWR, not the particular impedance, you can just put in an arbitrary impedance with that same SWR and click the INPUT button. An easy arbitrary impedance to use is just the SWR times the Z_0 of the cable, usually 50 Ω. For example, you could use a resistance of 125 Ω to represent an SWR of 2.5:1. This is what we've done in Figure A, using 135 feet of popular Belden RG-8X.

The results are interesting. Note that the 2.5:1 SWR as seen at the radio on 28.5 MHz results from a 7.45:1 SWR at the antenna — perhaps this is an eye-opener! Note that of the 5.6 dB loss, more than half, or 3.1 dB, is due to the mismatch. Note that if we used something other the actual measured impedance, we can't make use of the impedance data that TLW provides. We can use the SWR and loss data, however, but that's probably what we wanted to find out.

We can now do some "what ifs." We can see how much loss we have on other bands by just changing the frequency. For example, on 80 meters, with the same 2.5:1 at the transmitter end, the SWR at the antenna is about 3:1 and the loss is slightly more than 1 dB. We could also plug in an impedance calculated at the antenna end and see what difference other cable types would make. For example, with the same 28.5 MHz SWR of 7.45 at the antenna and 135 feet of 1/2 inch Andrew Heliax, we will have a total loss of 1.5 dB at 28.5 MHz. Note that the SWR seen at the bottom will now be 5.5:1 and our radio's auto-tuner might not be able to match the new load.

But Wait There's More!

You can also click the GRAPH button and get a plot of either voltage and current or resistance and reactance along the cable. Note that these will only be useful if we have started with actual impedance, rather than SWR.

Pushing the TUNER button results in a page asking you to select some specifications for your tuner parts. TLW effectively designs a tuner of the type you asked for at the shack end of the cable. It also calculates the power lost in the tuner and gives a summary of the transmitted and lost power in watts, so you don't need to calculate it!

When you've finished, be sure to hit the EXIT button, don't just close the window. Otherwise TLW may not start properly the next time you want to use it.

Review Questions

9-1 What parameters make a difference in the matched loss of transmission line, mismatched loss?

9-2 Why is it important to know the SWR at the load, rather than at the transmitter to determine transmission line loss?

9-3 Does coaxial cable or parallel line transmission line tend to have the lowest matched loss?

Chapter 10

Balanced vs Unbalanced Lines

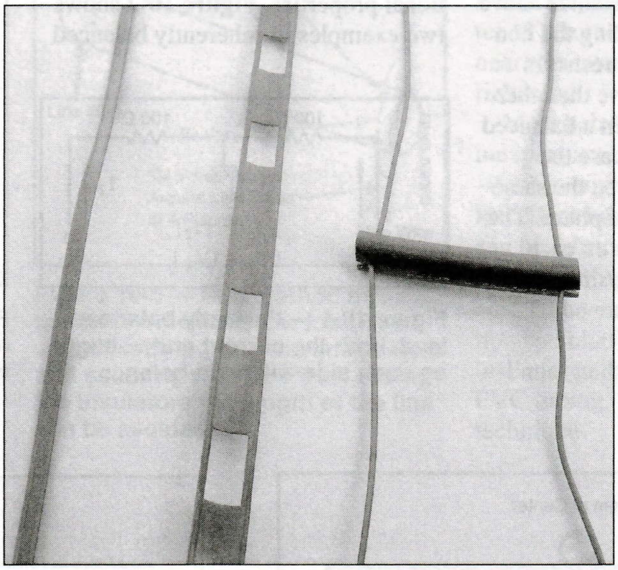

View of three popular types of balanced line. On far left, TV type 300 Ω twinlead, nominal 450 Ω "window" line and 600 Ω open-wire line.

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The Benefits of Balanced Line 10-3

The Downside of Balanced Line 10-4

What About Unbalanced Currents on Coax? 10-4

What Happens If I Feed my Dipole Directly with Coax? 10-5

Review Questions 10-6

The careful observer might have noted that in Figure 7-3, in Chapter 7, the lowest loss line was not the fancy, expensive "hardline" coax, but rather the much less expensive balanced open-wire and window line. This is a hard combination to beat — low cost and low attenuation, which explains its popularity. The other side of the coin is that most current radio equipment is designed to operate with unbalanced coaxial line.

What's the Story About Balanced Line?

Before we can go too far, we need to discuss what we mean by balanced and unbalanced. By a balanced system, we mean one in which the two sides are at the same impedance above ground. For example feeding the non ground end of two 100 Ω resistors (see **Figure 10-1**) that have the other end grounded will result in a balanced 200 Ω system. In such a case the voltage on each side will be the same magnitude but 180° out of phase. The magnitude of the currents on each side will also be the same since the voltages and resistances are equal.

Note that the system would be balanced whether or not the ground connection were there. No current flows in the ground lead of the perfectly balanced system, so it could be removed without changing the operational properties. **Figure 10-2** shows two examples of inherently balanced

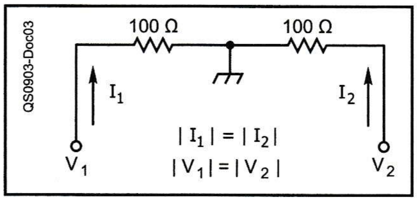
QS0903-Doc03
100 Ω
100 Ω
I_1
I_2
$|I_1| = |I_2|$
$|V_1| = |V_2|$
V_1
V_2

Figure 10-1 — Perfectly balanced load, both the current and voltage on each side will be in balance.

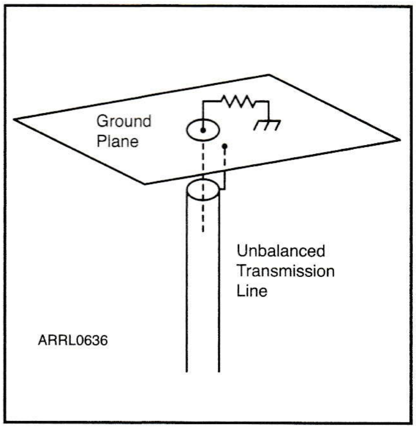
Ground
Plane
Unbalanced
Transmission
Line
ARRL0636

Figure 10-3 — Unbalanced resistive load. The signal is applied with reference to ground.

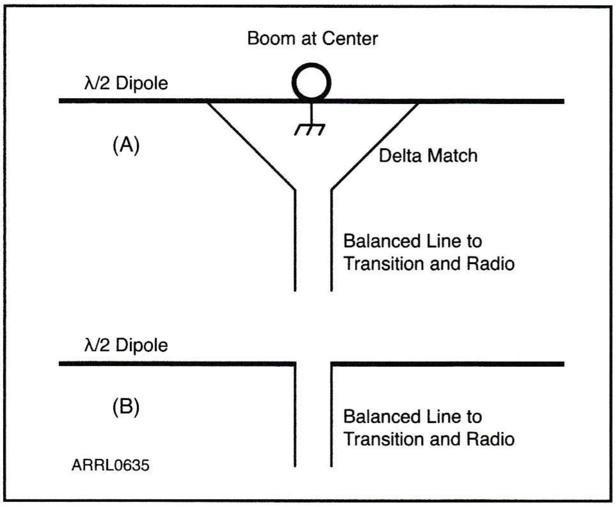
Boom at Center
λ/2 Dipole
(A)
Delta Match
Balanced Line to
Transition and Radio
λ/2 Dipole
(B)
Balanced Line to
Transition and Radio
ARRL0635

Figure 10-2 — Two examples of inherently balanced antennas, one (delta matched dipole) with a central ground (A) and one (split dipole) without (B).

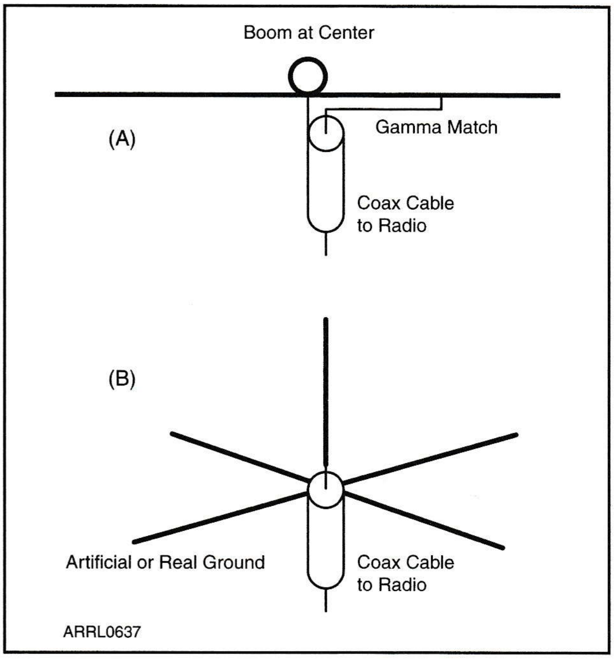
Boom at Center
(A)
Gamma Match
Coax Cable
to Radio
(B)
Artificial or Real Ground
Coax Cable
to Radio
ARRL0637

Figure 10-4 — Two examples of inherently unbalanced antennas, a gamma matched dipole at (A) and a vertical monopole at (B).

antennas, one with a central ground (A) and one without (B). The ground in the first is not actually necessary, but can be beneficial for lightning protection purposes. For both cases, we note that some kind of transition is required to shift to an unbalanced system for connection to the radio. The types of transition will be the subject of the next chapter.

An unbalanced system, on the other hand, is fed with respect to ground. That is, one side of the load is at ground potential. **Figure 10-3** is an example of an unbalanced resistive load, and **Figure 10-4** is shows two antennas with inherently unbalanced feed points.

The Benefits of Balanced Line

As noted earlier, balanced line has two primary benefits in comparison to coaxial cable. Most balanced lines, especially those with large portions of air dielectric, such as window line or ladder line, have a significantly lower matched loss than most coaxial cables. Even though their characteristic impedance is often higher than desired for many antenna systems, the total of matched and mismatched loss is generally much less than the loss of coax — particularly if the coax is not well matched to the impedance of the load.

Balanced line is often very conveniently connected to balanced antennas and is most often encountered in that application. It is also frequently found in very long runs from unbalanced antennas in which the losses (or cost) of coax would be prohibitive. In that case, it may be worth the effort to transition (Chapter 11) from unbalanced to balanced near the antenna and then back at the radio end.

Most balanced line is relatively inexpensive when compared to coax — often an important consideration. Excellent homemade open wire line can be fabricated at low cost from two rolls of wire (stranded works best, in my experience, particularly if subject to flexing) and insulators made from inexpensive household PVC tubing. **Figure 10-5** shows one technique.

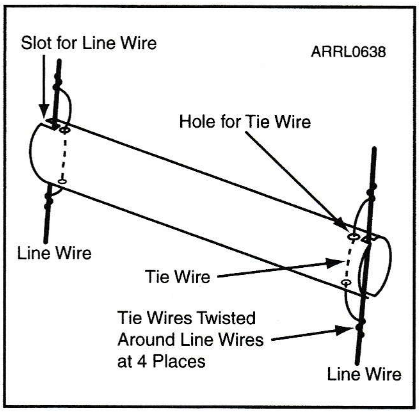

Figure 10-5 — One method of making homemade low loss open wire line. By putting the line in slots and securing with tie wires, sliding the insulators the length of the line can be avoided.

The Downsides of Balanced Line

As with most aspects of life, there are downsides of balanced line as well as benefits. While coax cable, with its fields contained within the shield, can be rolled, buried (if it has a direct burial rating) or installed within or near pipes without impacting performance, this is not true of balanced line. With balanced line, the fields conveying the signal down the line are significant not only between the wires but outside as well for a distance of a few times the wire spacing. This means that balanced line can't be placed on the ground, run in metal ducts, run through lossey material or rolled up, without causing additional loss.

While fields at a distance from balanced line are small, nearby fields can cause interference to other systems, particularly those interconnected by wiring. In addition, on receive, balanced line can pick up interfering signals from computers and other systems if run too close to them.

Another potential issue, particularly with the twinlead or window line variants of balanced line is a change in characteristics when wet. Rainwater can accumulate on the web material between the conductors resulting in a change to the dielectric properties of the line.[1]

There are a few things that can be done if this is a problem:

- Some have been known to carefully cut away some of the web to reduce the water collection surface. To avoid weakening the line, don't cut into the wire if you try this.
- In the "old days," some amateurs waxed their twinlead. This was reputed to cause the water to bead up and run off. Remaining water would be concentrated in droplets leaving most of the dielectric clear. I haven't seen any data on how effective this actually is, nor have I heard of any modern amateurs having the patience to actually do it!

In many cases, these potential problems can be largely avoided through careful planning and installation design. If not, it is sometimes efficient to make a transition to coax cable for some portion of the transmission line run.

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[1] B. Allison, WB1GCM, J. Hallas, W1ZR," A Closer Look at Window Transmission Line," *QST*, Nov 2009, pp 66-67.

What About Unbalanced Currents on Coax?

In the above section, it probably sounded as if the fields in coax are completely within the coax, thus avoiding the downsides of parallel or balanced line. That is true for the ideal case of properly terminated coax, however, there are at least three ways in which coax can suffer the same limitations as balanced line in this regard. In all cases, this results in currents on the outside of the shield. I have listed them in order of likelihood and severity, based on my experience.

- The coax is not terminated in a properly unbalanced load. This happens if the coax shield is not connected to a ground reference at the antenna. The result is that the current to the shield splits between the inside and outside of the shield.
- The coax run is coupled to the antenna such that the net coupling is not balanced at the cable. For a center fed antenna, coax should be run perpendicular to the antenna element so the coupling from each side cancels. If not, even with proper termination, there will be currents induced on the outside of the shield. For some antennas, monopoles or off center fed antennas for example, it is almost impossible to avoid such coupling.
- The coax shield itself can be leaky. The shield of most coax is not perfect and some is far from it. The specification sheets often list "percent coverage" indicating how well the shield covers the center conductor. Cables with lower numbers will be leakier than those with higher coverage. The current tends to increase as it is coupled over longer distances.

In many cases, the effects of such currents are small, but be aware that they exist and check them out if strange problems appear. A quick test is to note the antenna tuning or SWR as you run your hand along the cable. With properly installed and isolated coax, the tuning shouldn't change.

What Happens If I Feed my Dipole Directly with Coax?

Many amateurs connect their coax directly to a balanced center fed dipole — center conductor to one side, shield to the other as shown in **Figure 10-6**. This is a topic of some controversy with as many folk swearing that it works fine, as there are those who say it causes problems.

The reason for the disagreement may be that there are actually people who end up in both camps because of the dimensions of their system. Recall that due to skin effect, the currents on the inside of the shield of a coax cable are within a small thickness from the inside wall. Thus the outside of the coax acts like a completely different conductor — it's as if the insulated coax were installed in a pipe that is connected to the shield at the antenna end.

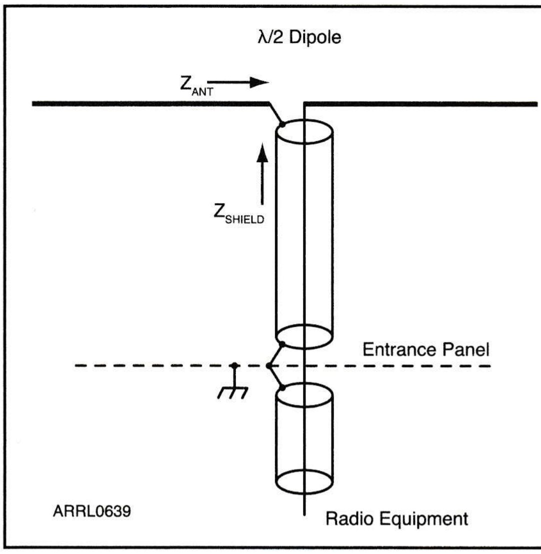

Figure 10-6 — Dipole fed directly with coax. The current on the left side divides between the left side antenna segment and the outside of the coax inversely proportional to the impedances as shown.

If the half wave dipole in Figure 10-6 had a center impedance of 50 Ω, typical for relatively low dipoles, the balanced antenna would act like a 25 Ω load to each connection of the coax, Z_{ANT} in Figure 10-6. The impedance of the outside of the shield at the antenna is a bit less obvious. This impedance depends on the impedance to ground at the bottom of the cable, usually at a ground level and grounded entrance panel, and the length of the cable between the antenna and the ground terminal.

Just as with an antenna wire or transmission line, this impedance varies depending on electrical length. If the ground impedance is low and the length is a multiple of a half wave, the impedance at the top will repeat and also be low. On the other hand, if the length is an odd number of quarter wavelengths, the impedance will reverse and be high. Lengths in between will result in intermediate values of impedance, both resistive and reactive.

If the impedance at the top of the shield is of the same order as the half dipole impedance, the current will divide between the two paths. This can have three effects:

- If the ground at the bottom is not of a very low impedance, RF currents can enter the radio room and cause a number of strange equipment problems such as feedback or transmitter lockup.
- The radiation from the transmission line will distort the antenna pattern, usually adding an omnidirectional vertical component. For a single element antenna, this may not be all bad, since it may tend to fill in the nulls that otherwise would be in some directions. For a directional array, however, such radiation will reduce both forward gain and front-to-back ratio — not good things.
- If the transmission line runs past sensitive electronic systems, fire or intrusion alarm wiring, computers or telephone systems, for example, the radiation may cause harmful interference in either direction.

Note that for a low impedance antenna, such as our dipole and most coax fed antennas, there are a small number of lengths that will result in such problems. With a multiband antenna the possibilities of problems increase directly with the number of bands covered. Thus it is not surprising that many don't think any precautions are necessary. Still, it can't hurt to avoid them, much of the subject of the next chapter.

Review Questions

10-1 Under what conditions is unbalanced transmission line most appropriate for antenna to radio connections?

10-2 Repeat question 10-1 for balanced transmission line.

10-3 Why do some people report problems with balanced antennas connected directly to coax while others observe no difficulties?

Chapter 11

So What's a Balun, an Unun, a Choke?

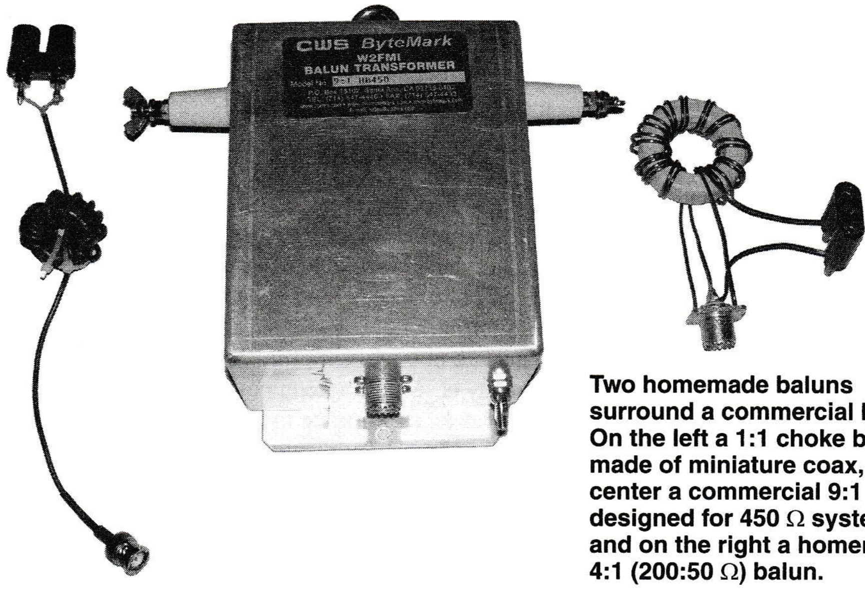
CWS ByteMark
W2FMI
BALUN TRANSFORMER
Model No. 9:1 HB450

Two homemade baluns surround a commercial balun. On the left a 1:1 choke balun made of miniature coax, in the center a commercial 9:1 balun designed for 450 Ω systems and on the right a homemade 4:1 (200:50 Ω) balun.

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Baluns are devices that provide a transition between unbalanced and balanced systems, impedance transformation or a combination of both. The name *balun* comes from *BAL*anced to *UN*balanced and each part is pronounced the same way as in the separate words.

Sometimes you will encounter an *unun.* The unun (*UN*balanced to *UN*balanced) provides an interconnection between two unbalanced systems, either to change the system impedance, to force all currents into the inside of a coaxial transmission line or usually both.

A *choke* refers to an inductance that offers a high impedance over a particular frequency range. A choke wound with coaxial cable has its high impedance only to currents on the outside of the coax shield, the inductances of the inner conductors effectively cancel. As we will discuss, such a choke can be used either as a balun or an unun.

When are Baluns Necessary?

We have discussed unbalanced line such as coax cable, balanced line such as twinlead, window or ladder line as well as balanced and unbalanced loads. We should point out that virtually all transmitters or transceivers built since the 1950s are designed to work into an unbalanced load — made evident by the coaxial connector used for the antenna connection.[1]

There are many antennas designed to operate with a coaxial cable connection. These antennas can be connected directly to the radio with coaxial cable if they present the desired load to the transmitter. In this case, no transition is required, the entire system is unbalanced. This system can work well and neither an antenna tuner, nor a balun, is required for proper operation. The one exception occurs if there is coupling from the antenna to the transmission line, resulting in undesired coax shield current in which case a common mode choke is recommended.

What's Wrong with this Picture?

The unbalanced antenna, unbalanced transmission line and unbalanced radio make a simple and straightforward arrangement that is easy to operate. Unfortunately, in many cases, the antenna only provides an appropriate match over a narrow frequency range — often narrower than an amateur band, for example. This has two effects:

- If the SWR at the transmitter reaches a higher value than the transmitter can operate into, it will usually reduce the power output to avoid damage to internal components.
- While the losses for matched coaxial cable can be made acceptable by selecting the proper cable for the frequency and length, the losses generally go up quickly with increasing SWR. As noted previously, this actually makes the SWR at the transmitter look better; however, significant power may be lost (turned into heat) in the cable.

Many amateurs choose instead to use a balanced antenna fed with lower loss balanced line in this case. As will be discussed later, this often makes what would be a single band antenna, if fed with coax, into a multiband antenna. We then are faced with a balanced load and an unbalanced transmitter output connector.

What Happens if We Plug the Balanced Line into our Coax Connector?

While not recommended. you can actually make the connection, if pressed. Arguably, it is not much worse than the previously discussed case of hooking unbalanced coax line to a dipole antenna. In this case, however, the shield side of the transmitter output is connected to ground and a fraction of your output power will flow in that direction radiating within the room instead of towards the desired direction. If the ground is not solid, you can end up with RF on all your equipment, causing various strange and sometimes uncomfortable effects.

[1] The shift to the use of coaxial cable happened because coaxial cable became available after WW2 coincidentally with the popularity of broadcast television. Transmitters with shielding, filtering and coaxial RF connections were less likely, if properly designed, to cause interference problems with TV sets.

What do We Mean by Balanced to Unbalanced?

The balun makes the transition from an unbalanced system, such as the transceiver, to a balanced system, such as a balanced transmission line. A balun can be used between a balanced dipole and a coaxial cable to avoid the problem of current being driven down the shield of the coax, or it can be used between the unbalanced transmitter and a balanced line to result in the current going towards the antenna as shown in **Figure 11-1**.

As noted previously, sometimes a balun is also used to transform impedances. For example, in the case of a 50 Ω antenna, a 50 Ω transmitter and the use of low loss 450 Ω transmission line, a balun with a 9:1 impedance transformation ratio allows a straightforward interconnection as shown in **Figures 11-2** and **11-3**.

Of course there is still no such thing as a free lunch. In order to use the low loss balanced line in this configuration, the added loss in each of the two baluns must be considered as part of the equation. Measurements I've taken of commercial HF 9:1 baluns have indicated that losses of about 0.5 dB each should be anticipated. It doesn't usually take too long a run of line before the balun loss is compensated for by the higher loss of the coax. This depends on both length and frequency.

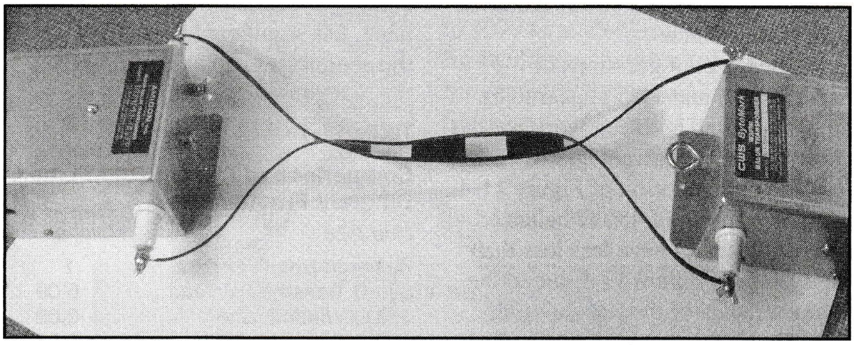

Figure 11-3 — Photo of a model of the system of Figure 11-2 using commercial 9:1 baluns. The twist in the window line is intentional. An occasional twist reduces wind effects and tends to maintain balance in the system if near objects.

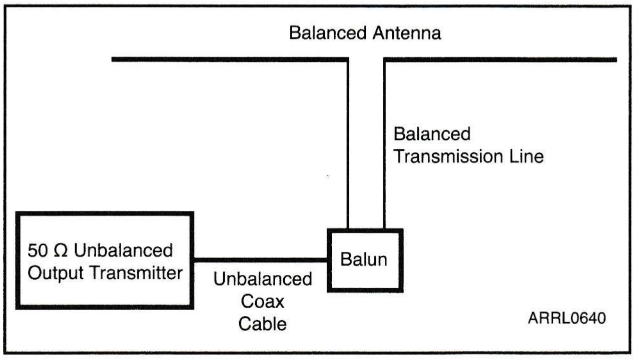
Balanced Antenna
Balanced Transmission Line
50 Ω Unbalanced Output Transmitter
Unbalanced Coax Cable
Balun
ARRL0640

Figure 11-1 — A balun inserted between the unbalanced output of a transmitter or transceiver and a balanced antenna system.

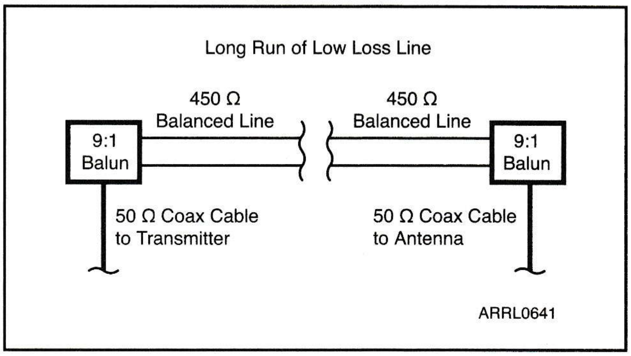
Long Run of Low Loss Line
450 Ω Balanced Line
450 Ω Balanced Line
9:1 Balun
9:1 Balun
50 Ω Coax Cable to Transmitter
50 Ω Coax Cable to Antenna
ARRL0641

Figure 11-2 — The use of baluns with a 9:1 impedance transformation ratio makes it easy to use low loss 450 Ω balanced transmission line for long runs.

Balun Location

A balun can be inserted anywhere in a system between a coaxial connection and the balanced load. As shown in **Figures 11-4** and **11-5**, the connection between an unbalanced radio and a balanced dipole can include a balun at either end of the transmission line run. Here we have used a dipole with a *delta match* adjusted to provide a 450 Ω balanced load at the antenna.

While the configurations of Figures 11-4 and 11-5 appear to be equivalent, and both can work well as shown, there are advantages to each:

- The configuration of Figure 11-4, using a long run of 450 Ω balanced line, will usually have less loss than the system in Figure 11-5 due to the characteristics of the transmission line. The difference will depend on the frequency, line length and type of coax. Some representative loss figures are shown in **Table 11-1**.
- Using coaxial cable for the run, as in Figure 11-5, has its own advantages. The principal one is that coax is less fussy about how it is placed than is balanced line. While coax can be run in metal conduit, coiled up and some types can be buried — this is not the case with balanced line. With properly installed coax, the fields are entirely within the coax, making it insensitive to its surroundings. Parallel conductor balanced line, on the other hand, has significant fields between the conductors and extending out to a few times the wire separation in all directions. In order to obtain the benefits of such line, it needs to be spaced that far from metal structures and lossey media.

Note also that it is not necessary to have the run entirely with one type of line. For example, a long aerial run of balanced line can be transitioned to coax near the radio with a short run of coax going through conduit or other balanced line hostile environments.

Table 11-1

Comparison of Transmission Line Losses of Different Lines at Different Frequencies

Line Type	*Matched Loss at Frequency (MHz, dB per 100 feet)*			
Balanced Line	*1*	*10*	*100*	*1000**
300 Ω Transmit Twinlead	0.09	0.3	1.1	3.9
450 Ω Window Line	0.02	0.08	0.3	1.1
600 Ω Open Wire Line	0.02	0.06	0.2	0.75
Coax Cable	*1*	*10*	*100*	*1000*
RG-58	0.37	1.4	5.3	20
RG-213	0.18	0.7	2.5	8.6
LMR-400	0.12	0.39	1.3	4.2

*Spacing may be too wide for efficient operation at this frequency.

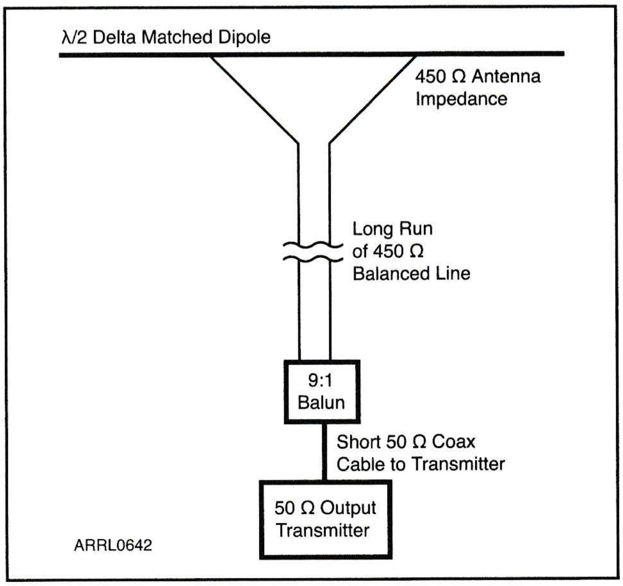
λ/2 Delta Matched Dipole
450 Ω Antenna Impedance
Long Run of 450 Ω Balanced Line
9:1 Balun
Short 50 Ω Coax Cable to Transmitter
50 Ω Output Transmitter
ARRL0642

Figure 11-4 — Delta matched 450 Ω dipole fed by low loss 450 Ω balanced line to a 9:1 balun at the transmitter.

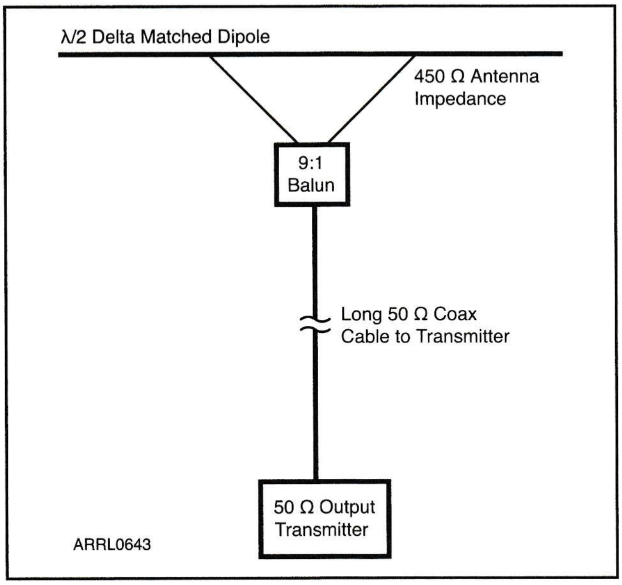
λ/2 Delta Matched Dipole
450 Ω Antenna Impedance
9:1 Balun
Long 50 Ω Coax Cable to Transmitter
50 Ω Output Transmitter
ARRL0643

Figure 11-5 — Dipole fed by a 9:1 balun and 50 Ω coaxial cable to the transmitter.

The Different Balun Configurations

There are a number of different balun configurations. They range from simple chokes that force (most of) the current that otherwise would be on the shield of coax to the intended load to more complex devices that combine balanced to unbalanced transitions and impedance transformations in a single device. The following is a summary of the more common types.

Choke Baluns

Choke baluns are found on the coax side of a balanced to unbalanced transition. As noted previously, if a balanced load, such as a dipole antenna, is fed directly by coax, the current on the shield side of the connection will split between the connected half dipole and the outside of the shield in a ratio inversely proportional to the two impedances. The idea of the choke balun is to increase the impedance of the outside of the shield by adding inductance and thus reducing the current that flows down the outside of the shield. If no current were to flow down the shield the current to the each side of the antenna would be the same as if the coax were a balanced line on the antenna side.

Air wound coax loops — The simplest form of choke is just a coil of coaxial cable as shown in **Figure 11-6**. Note that for the so called *differential mode* signal, the desired signal inside the coax, this coil just acts like a few feet of transmission line. The *common mode* signal, any undesired signal on the outside of the coax, sees the effect of the coil inductance.

This configuration has been evaluated at length with results reported in *The ARRL Antenna Book.*[2] An example is a six turns in single layer coil of coax with a diameter of 4.25 inches. This coil will have an impedance ranging from 514 Ω at 14 MHz to 1079 Ω at 29 MHz, very suitable for feeding a dipole or triband Yagi, for example. Such coils are sometimes scramble wound rather than being wound in a single layer. While

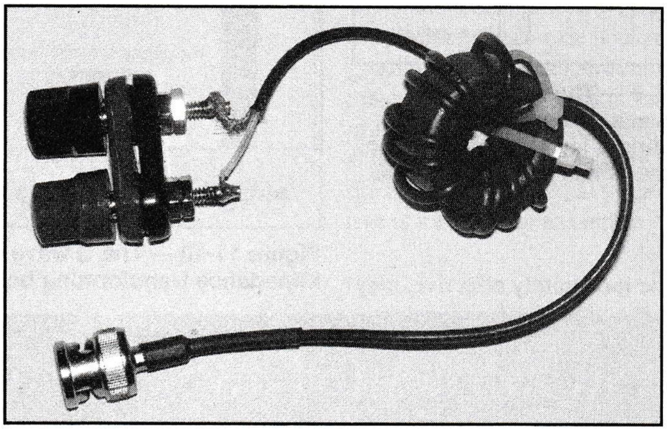

Figure 11-7 — Choke balun made by passing multiple turns of coax through a ferrite toroidal core.

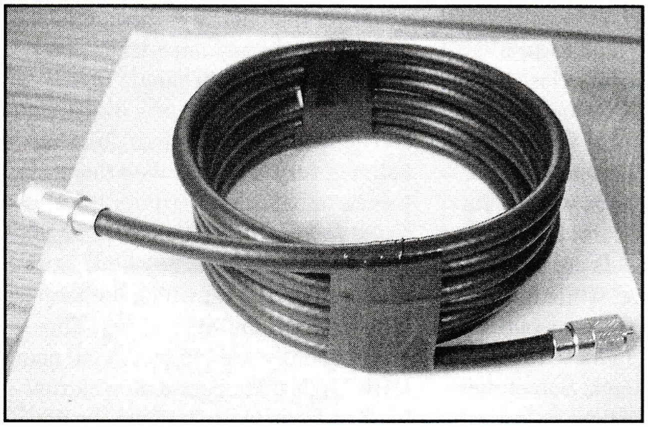

Figure 11-6 — Choke balun made from a coil of coax. Such a balun can be effective over about a 2:1 frequency range.

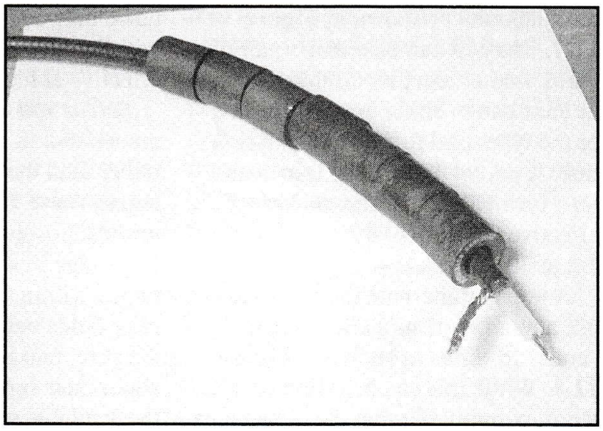

Figure 11-8 — Using multiple single turn "coils" in series — a good solution for large diameter or stiff coax.

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[2] R. D. Straw, Editor, *The ARRL Antenna Book,* 21st Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/arrl-store**; **pubsales@arrl.org**.

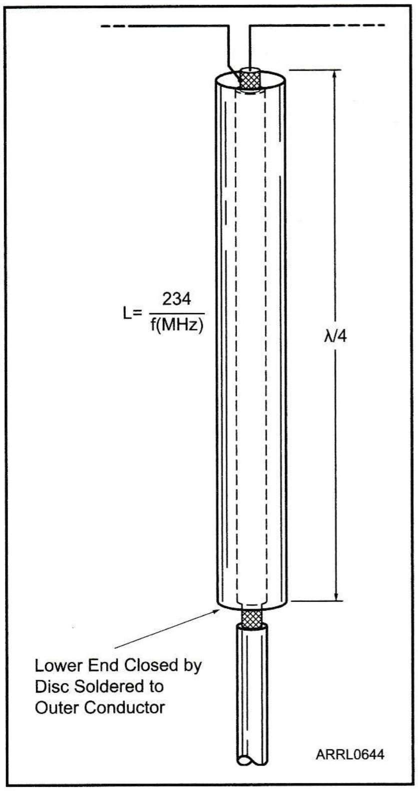

Figure 11-9 — The bazooka quarter wave choke balun made by providing a shorted line section around the shield of a coax cable.

they can be moderately effective, they usually suffer at higher frequencies due to excessive capacitance between turns. The only other effect of the coax coil is any attenuation due to the additional length of coax, in this case about 7 feet.

Ferrite toroid coils — The effectiveness of a choke coil can be improved by winding it on a ferrite toroidal core, as shown in **Figure 11-7**. The coil can be either a pair of wires wound together around the core or coax cable, either extra thin coax**,** or the type used for the transmission line. A coil of 12 turns of thin coax on a type FT240-61 core makes an effective choke over the range from 1.8 to 30 MHz.

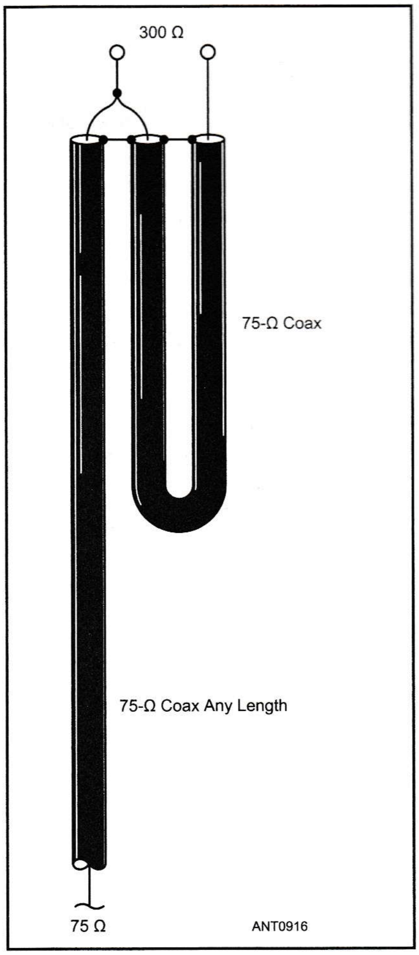

Figure 11-10 — The ½ wave 4:1 impedance transforming balun.

A popular alternate method is to use a number of single turn ferrite "coils" in series as shown in **Figure 11-8**. While this can be effective, it is worth pointing out that the inductance of N such inductors in series equals N times the inductance of a single inductor. On the other hand, the inductance of multiple turns through a single toroid goes up by the square of the number of turns. Still if the coax is thick, or hard to bend tightly, this is a very workable solution. It has the additional advantage that the capacitance between "turns" is less than with a coil, so it will tend to be more effective at higher frequencies.

Ferrite rod coils — Some baluns are wound on sections of ferrite rod rather than the toroid, donut shaped, cores. These can work as well as the toroids, however, the toroids have the advantage that the fields are contained within the core, while the rods have fields between the ends outside the core, making them more fussy about their surroundings. Sometimes the available space will point towards one versus the other. All other things being equal, I prefer the self shielding toroids, if feasible.

Transmission line sections — A quarter wave long section of transmission line, shorted at the far end, has a high impedance at the near end. This property can be used as a choke at the particular frequency that the line section is that length (or odd multiples). This is called a bazooka, due to the use of large concentric structures as shown in **Figure 11-9**. This is a particularly popular arrangement at VHF and higher, since the dimensions are reasonable and wideband properties of the ferrite baluns and chokes are often not required.

Transformer Baluns

The half-wave coax loop — One of the early forms of transforming balun was also made of coax cable, this time an electrical ½ wave long. This cable was formed into a loop with one end on each side of the balanced load as shown in **Figure 11-10**. The unbalanced line was connected to one side of the balanced load.

The half wave loop provides a copy of the signal from the coax feedline delayed by 180°, and thus out of phase. Each of the two signals see an impedance of half of total 300 Ω load, or 150 Ω. Because the impedance on a halfwave (or multiple) of a transmission line repeats itself, the loop will bring the 150 Ω impedance back to the feedline junction. The parallel combination of the two 150 Ω signals at the feedline junction is thus ¼ of the total load or 75 Ω. Note that since a half wave length of transmission line repeats whatever impedance is there, this will transform any impedance to ¼ the value on the single frequency.

The half-wave loop transforming balun is very efficient, with the only loss or imbalance a result of the loss in the loop of coax. A disadvantage is that they only operate on (or close to) the frequency at which the loop is ½ wave (or multiples) long. These are frequently used to feed VHF and UHF Yagis that operate on a narrow band of frequencies making the narrow bandwidth irrelevant.

Ferrite transformers — Broadband

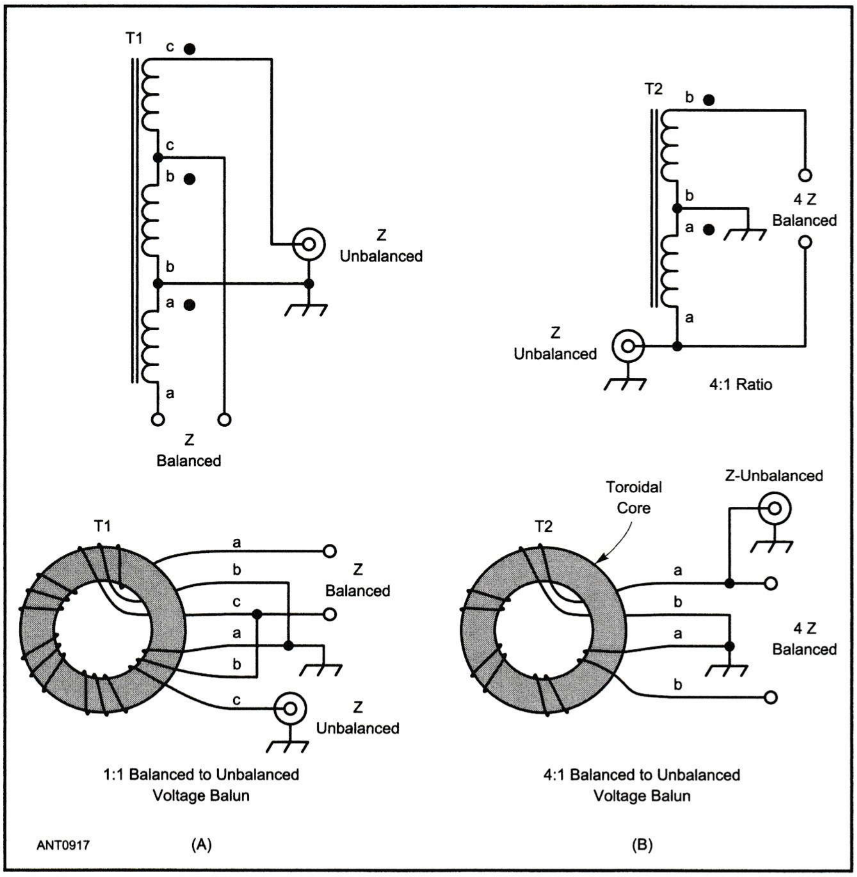

Figure 11-11 — Schematic and pictorial view of a broadband ferrite core 4:1 impedance transforming balun.

baluns can be made using the same kind of ferrite structures described previously as transformers. They frequently are made with multiple windings that can be connected in series or parallel to provide multiple transformation ratios. The 4:1 balun shown in **Figure 11-11** is an example of such a balun that functions similarly to the ½ wave coax loop balun.

Current and Voltage Baluns — Depending on the details of their design, a balun can be made to force either the current *or* the voltage on the balanced side to equal each other. Note that in a perfectly balanced load, in which each side has the same impedance to ground, if the voltages are equal so will be the currents and vice versa.

Unfortunately, in our real world, often an intended balanced load, isn't quite. For example, an otherwise balanced antenna may become unbalanced if one side is closer to the ground, or to a metal structure, than the other. If the balun is intended, as most are, to keep currents off the outside of coax shields, then by forcing the currents to be equal your objective is most likely to be met.

Selecting Baluns for Use in Your System

Within the constraints listed above, any of the general type of baluns described can be selected for use. Most baluns have a specified input and output impedance and power rating. These should be matched to your application. The transformation ratio does not apply for any impedance, rather for the design center of the balun. For example a 4:1 balun designed to transform a 200 Ω balanced load to 50 Ω coax, can not counted on to provide a 4:1 transformation to a 2000 Ω balanced load.

In practice, the transformation is likely to be close to the specified ratio for perhaps a 4:1 mismatch — in the previous case that would be from 50 to 800 Ω. Outside of that range, they may continue to function as a balun, however, the transformation ratio will be different and the losses will tend to increase.

A mismatch will also increase the stress on the balun. The current or the voltage will be higher by the square root of the SWR or mismatch ratio and thus the ratings should be increased appropriately. After use (with power off) a good check at a 100 W or higher power station is to put a finger on the balun to check the temperature. Any increase above ambient is cause for reconsideration.

Review Questions

11-1 Provide three reasons for using a balun.

11-2 What are the relative advantages of having a balun at a balanced antenna feed point versus having a long run of balanced line to a balun near the transmitter?

11-3 What are the consequences of operating a balun at an impedance far from its design point?

Chapter 12

Balanced Antenna Tuners

Johnson Viking
MATCH BOX
TUNING
MATCHING

A classic 275 W E. F. Johnson "Matchbox" balanced antenna tuner from the 1950s. Still a viable tuner useful to 750 W PEP and available at hamfests and auction sites. A 1 kW model, useful above the US legal limit, was also offered.

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Another Possibility — The "Hot" Tuner 12-4

Review Questions 12-5

We've been talking about antenna tuners and balanced line in the same sentence, even though we haven't addressed the issue of the kind of tuners to use with a balanced load. Now it's time.

What's a Balanced Tuner?

While we haven't specifically addressed the question, the tuners we've been talking about so far have been really what could be called *unbalanced* tuners. You can usually spot an unbalanced tuner by its input and output connector arrangements. In some cases, they have a coax connector for unbalanced cable on both the radio and antenna system sides. Other unbalanced tuners have a coax connector for the radio side and a single terminal intended for a wire antenna and another for a ground connection.

Some unbalanced tuners have another pair of connectors that are designated for "balanced loads" but the transition occurs after the tuner function using an internal balun. While these can be useful for driving balanced loads, as we will discuss, they are really two distinct pieces, an unbalanced tuner followed by a balun.

Enter a Truly Balanced Tuner

The tuner configurations shown in Figure 3-3, in Chapter 3, are all inherently unbalanced since ground is on one side of each. Any of them can be converted to a balanced configuration by essentially providing a mirror image on the other side of ground. The configurations of Figure 3-3 are shown in balanced form in **Figure 12-1**. A quick look at the figure will indicate that we now have something we probably didn't want — a balanced to balanced tuner!

The one configuration that can be easily transformed to a balanced to unbalanced tuner is the tuned transformer in Figure 12-1 (A). This is because the transformer coupling to the radio (left) side of the transformer does not maintain the same ground reference. Thus one side of the primary (left) winding can be grounded resulting in an unbalanced connection. This is exactly what the 1950s era Johnson Matchbox did, perhaps explaining why it is still in demand today.

Unbalancing One Side

The other configurations in Figure 12-1 require a balun on the 50 Ω side to fit into coaxial fed systems. While this may seem about the same as putting the balun on the antenna side of the tuner (more in next section), the difference here is that we transform the widely variable balanced antenna system impedance on the right side to a 50 Ω balanced load on the left in Figure 12-1. We then can use a 1:1 50 Ω balun to transform to unbalanced for coax connectivity. Alternately, some tuners are designed to transform to a 200 Ω balanced load, to be followed by a 4:1 balun for connectivity to 50 Ω coax.

In either the 1:1 or 4:1 case, we have the advantage that the baluns are operating at their design impedance. They will offer minimum loss and will operate with their expected transformation ratios.

There's Always a Price

A possible downside of the balanced antenna tuner designs is that the nature of the beast requires significantly more — but not quite twice — as many components as the same unbalanced configuration. The usual antenna tuner components, for medium to high power tuners, are both large and pricy. This results in ramifications in terms of both cost and size. There is, after all, still no such thing as a free lunch.

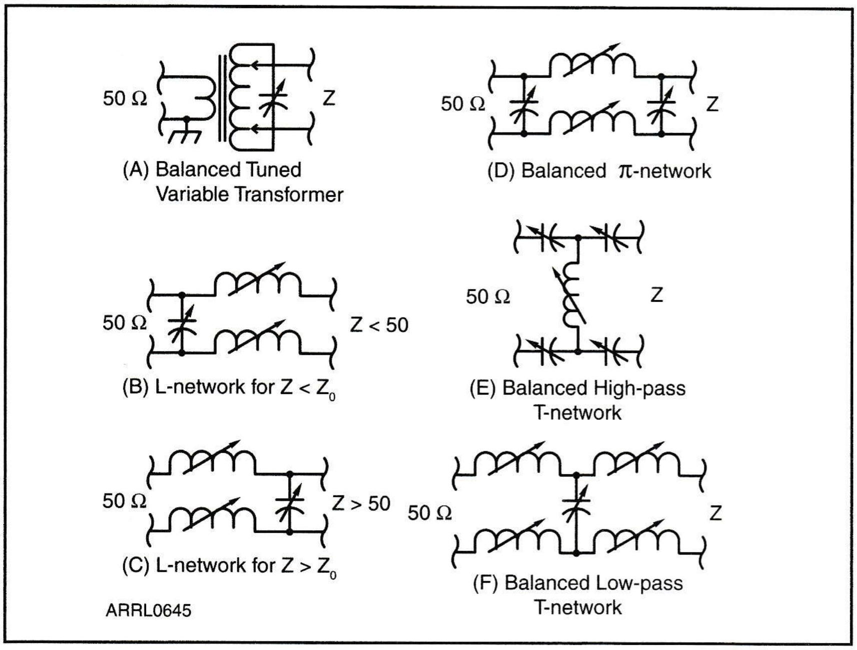

Figure 12-1 — Configurations of balanced antenna tuner versions of the unbalanced tuners in Figure 3-3, in Chapter 3.

A Balanced Tuner versus an Unbalanced Tuner with a Balun

As you look over the features of commercial antenna tuners, you will see many with "balanced outputs." In most cases, these are inherently unbalanced tuners, with a balun on the antenna side to transform to a balanced load. Many people, including your humble servant, have been happily using such tuners for years — so what's the problem?

Well, the simple answer is — there may not be a problem! If the impedance at the bottom of your balanced feed line (generally quite different from either the antenna impedance or the transmission line characteristic impedance, if the line is not matched to the antenna) can transform to an unbalanced impedance through the balun without difficulty — there is no problem — you're done!

On the other hand, if the impedance at the balun is very different from its design point, you may have a number of problems, most significantly loss in the balun. While balun loss is not great in its own right — toroid cores are not very good heat radiators. Any balun loss will transform itself into heat and may destroy the balun's ferrite core in the process.

The Good News Is

While there are exceptions, many unbalanced tuners, including those with a balun for balanced loads, offer additional features compared to many "balanced" tuners. My fairly typical unbalanced L-network tuner, for example, has three outputs for unbalanced coax terminations and a fourth that can either be coax or balanced, using an internal 4:1 balun on the output side. In addition to my main balanced multiband antenna, I have a few other antennas that are fed by coax. Thus the tuner provides a convenient point for them all to come together with easy switching between them. With a single switch on the tuner, I can instantly select any of the four antennas — either through the tuner, or bypassing the tuner, if they are matched systems. Most balanced tuners just provide a connection to a single balanced antenna system.

In terms of keeping common mode RF currents out of your station, it really doesn't matter which side of the tuner has the balun — its choking impedance has the same effect.

If it Doesn't Play

If an unbalanced tuner with a balun doesn't work well with your antenna system on a particular band, you may be able to recover. The fact that it doesn't tune usually means that the balanced line has a high SWR (if it were matched, to say 450 Ω, the tuner and balun combination could probably handle it without difficulty). Because of the nature of the mismatched line, changing the length will have a profound effect on the impedance as seen by the tuner. Try inserting about ⅛ wavelength of line and see what happens. Be sure to observe the usual cautions about balanced line — such as not coiling it up.

Another Possibility — The "Hot" Tuner

Impedance transformation through an unbalanced tuner will not "know" it is unbalanced unless one side of the tuner is grounded. Thus it is quite possible to use an inherently unbalanced tuner into a balanced load if it is isolated from ground. This can be accomplished as shown in **Figure 12-2** for a remote automatic tuner.

The configuration in **Figure 12-3** makes this quite convenient, however, it can also be accomplished using a manual tuner in the station. The difficulty with the tuner in the station is that it generally is designed so that the cabinet is at what it thinks is "ground" potential. If it is isolated from ground, the whole cabinet is at the potential of half the RF voltage feeding the antenna. This can be uncomfortable for the operator, unless she uses oven mitts to make adjustments. An unsuspecting cat can get quite a curl as it passes by during a transmission!

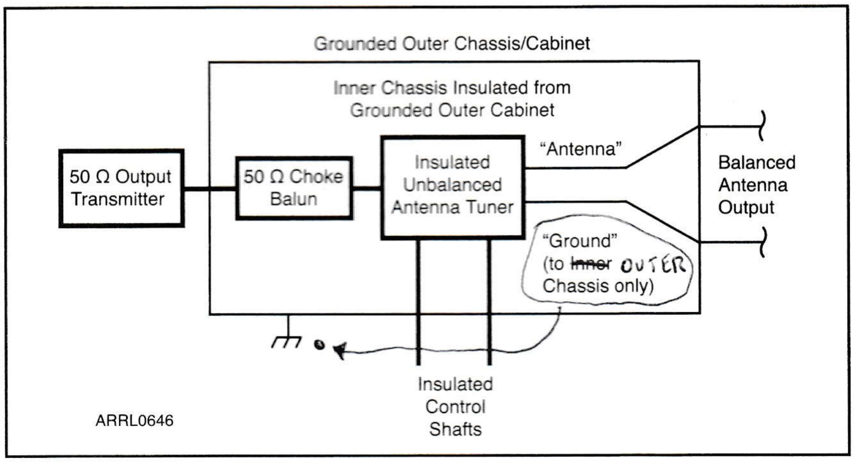
Grounded Outer Chassis/Cabinet
Inner Chassis Insulated from Grounded Outer Cabinet
50 Ω Output Transmitter
50 Ω Choke Balun
Insulated Unbalanced Antenna Tuner
"Antenna"
Balanced Antenna Output
"Ground" (to ~~Inner~~ OUTER Chassis only)
Insulated Control Shafts
ARRL0646

Figure 12-3 — Manually tuned version of an unbalanced tuner isolated from ground driving a balanced load. Note the insulated additional layer of cabinetry.

The hot chassis problem has been solved by at least one published design in which what would be the cabinet is insulated from and inside an additional cabinet with insulated shaft extensions on the controls as shown in **Figure 12-3**. I'm not aware that this has been offered as a commercial product, however, it is feasible — if not simple to implement.

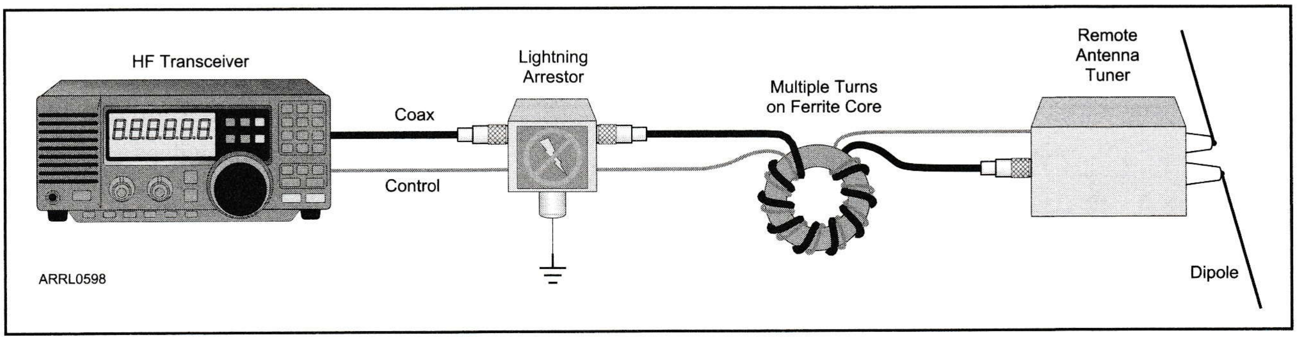
HF Transceiver
Coax
Control
Lightning Arrestor
Multiple Turns on Ferrite Core
Remote Antenna Tuner
Dipole
ARRL0598

Figure 12-2 — Unbalanced tuner isolated from ground driving a balanced load. The common mode choke on the radio side maintains the balance on the antenna side. Note that it is necessary to provide a choke on all ~~balun~~ REMOTE TUNER connections, as shown, in order to elevate the whole tuner above RF ground.

Review Questions

12-1 Why might an inherently balanced tuner be a good idea?

12-2 What difference does it make whether a balun is on the input or output of an antenna tuner?

12-3 What kind of problems might you have using an unbalanced tuner with a balanced load?

Chapter 13

Antennas That Work Well with Antenna Tuners

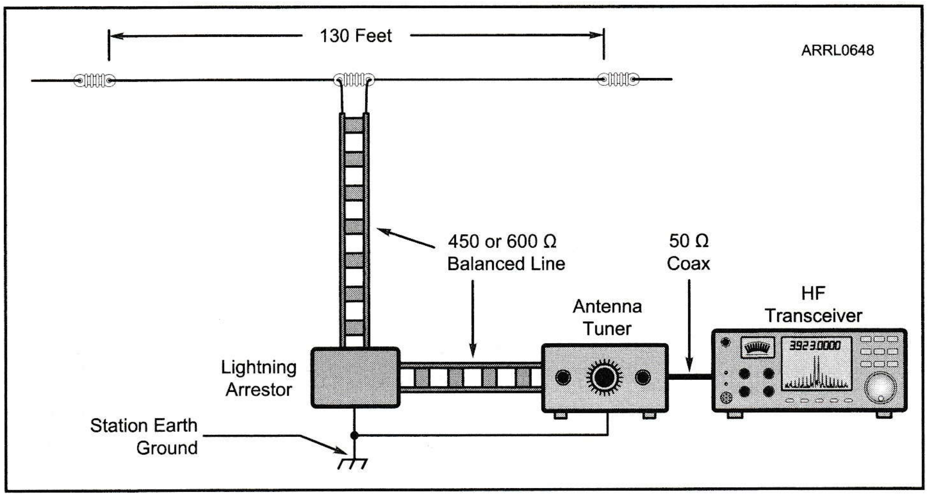
130 Feet
ARRL0648
450 or 600 Ω
Balanced Line
50 Ω
Coax
Antenna
Tuner
HF
Transceiver
3923.0000
Lightning
Arrestor
Station Earth
Ground

The center-fed Zepp is a very popular antenna with those having a wide-range antenna tuner.

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Tuned Yagi Arrays 13-3
Single Wire Fed Antennas 13-4
The Vertical Monopole 13-5
Balanced Antenna Systems 13-7
Mobile Antenna Systems 13-8
Review Questions 13-10

There's no magic antenna that goes well with a tuner — in fact, virtually any antenna can benefit from a tuner under some circumstances. Here we will discuss how a tuner can increase the flexibility and usefulness of some popular antennas.

The Coax Fed Dipole

In Chapter 2, we discussed the nominally matched dipole and the limitations on its bandwidth within a given SWR. For example, to have a single low 80 meter dipole be useful across the entire band, we may need to deal with an SWR as high as a 10:1 as shown in Figure 2-7, in Chapter 2, although at many heights, the SWR will not rise beyond 5 or 6:1 at band edges. Most other examples shown in Chapter 2 have more reasonable SWR characteristics. Still, in many cases an SWR higher than 2:1 may be encountered, requiring an antenna tuner to permit proper transmitter operation at band edges.

A Dipole Operated on an Odd Harmonic

A special case of the dipole is one used on its third harmonic. A very popular amateur antenna is a 40 meter (7 to 7.3 MHz in the US) dipole also operated on 15 meters (21 to 21.450 MHz). This is often stated as if it were a straightforward arrangement, however, it is just a bit more difficult to achieve than would be implied by some. A tuner makes it much easier. The difficulties arise particularly due to two factors:

- The nominal impedance of a ¾ λ dipole in free space is about 110 Ω, rather than 72 Ω for a λ/2 dipole. While the actual impedance will vary above and below this number, depending on height above ground, this often gives us a higher SWR than 2:1 to start with.
- The third harmonic of 7.15 MHz, the center of the 40 meter band, is 21.45 MHz, the very top of the 15 meter band.

Figure 13-1 shows the modeled SWR of a wire 40 meter dipole cut for mid band at a height of 40 feet. **Figure 13-2** shows the SWR of the same antenna operated on 15 meters. Obviously, this isn't going to work out as well as some folks hypothesize.

Many wide range tuners could compensate for the SWR at the transmitter. As discussed in Chapter 7, however, the losses in a coax cable with a 10:1 SWR at 21 MHz may result in more loss than can generally be tolerated, although it certainly could be used in a pinch. Because the losses in mismatched coax are less at lower frequencies, the concept can be salvaged by optimizing the dipole as a 15 meter ¾ λ dipole with the results shown in **Figures 13-3** and **13-4**.

Note that the lengthened antenna has an SWR of less than 3:1 across all of 15 meters, significantly reducing the transmission line loss associated with Figure 13-2. While the SWR on 40 meters is no longer delightful, it is reasonable from a transmission line loss standpoint. The resulting antenna can work well with some nominal "3:1" SWR tuners that work beyond

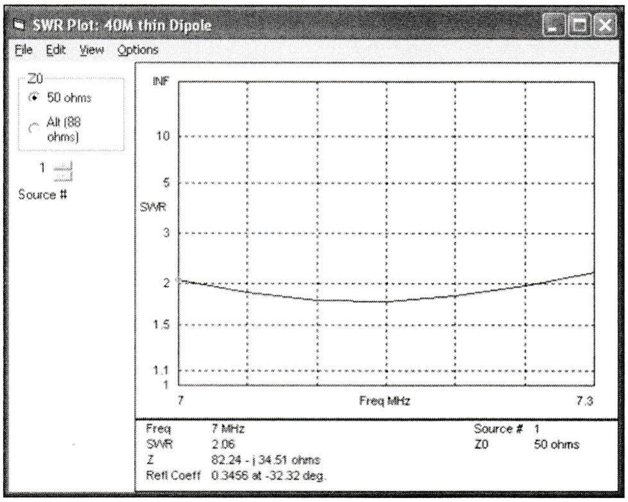

Freq 7 MHz
SWR 2.06
Z 82.24 - j 34.51 ohms
Refl Coeff 0.3456 at -32.32 deg.
Source # 1
Z0 50 ohms

Figure 13-1 — 50 Ω SWR of a 40 meter dipole at 40 feet cut for mid band.

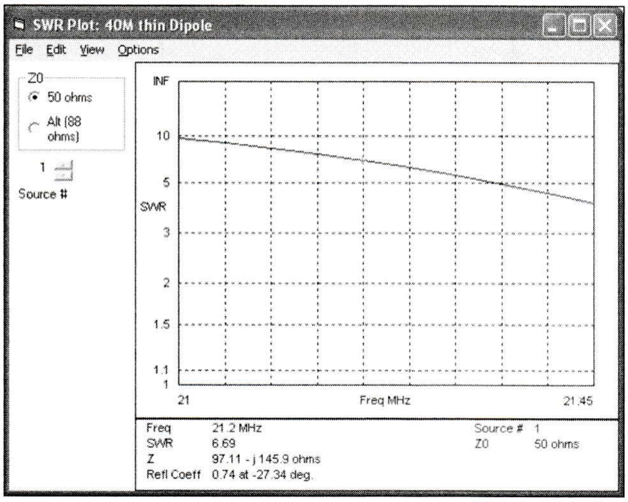

Freq 21.2 MHz
SWR 6.69
Z 97.11 - j 145.9 ohms
Refl Coeff 0.74 at -27.34 deg.
Source # 1
Z0 50 ohms

Figure 13-2 — SWR of the 40 meter dipole of Figure 13-1 across 15 meters.

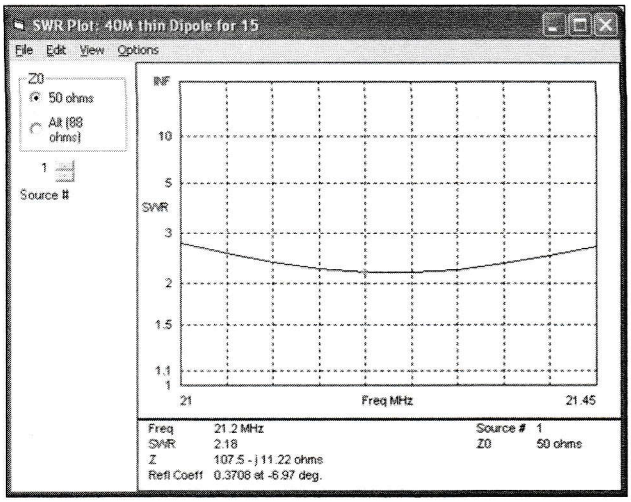
SWR Plot: 40M thin Dipole for 15
File Edit View Options
Z0
● 50 ohms
○ Alt (88 ohms)
1
Source #
INF
10
5
SWR
3
2
1.5
1.1
1
21
Freq MHz
21.45

```
Freq        21.2 MHz                              Source #  1
SWR         2.18                                  Z0        50 ohms
Z           107.5 - j 11.22 ohms
Refl Coeff  0.3708 at -6.97 deg.
```

Figure 13-3 — SWR of the 40 meter dipole of Figure 13-1 lengthened to be optimized for 15 meters across 15 the 15 meter band.

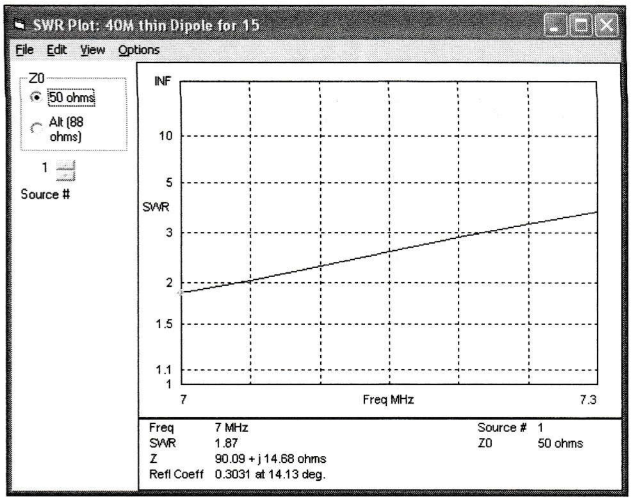
SWR Plot: 40M thin Dipole for 15
File Edit View Options
Z0
● 50 ohms
○ Alt (88 ohms)
1
Source #
INF
10
5
SWR
3
2
1.5
1.1
1
7
Freq MHz
7.3

```
Freq        7 MHz                                 Source #  1
SWR         1.87                                  Z0        50 ohms
Z           90.09 + j 14.68 ohms
Refl Coeff  0.3031 at 14.13 deg.
```

Figure 13-4 — SWR of the lengthened (15 meter optimized) 40 meter dipole of Figure 13-3 across 40 meters.

their specs, and is an easy job for wider range tuners.

Dipoles Can Benefit

The preceding examples illustrate ways in which a simple dipole can benefit from an antenna tuner. For any dipole, the tuner can compensate for imperfect length adjustment, often a convenience. The one caution is that even if the tuner can match the resulting impedance, the loss in the mismatched transmission line between the tuner and the antenna can be an issue, even if all seems well at the transmitter. Take another look at Chapter 7.

Tuned Yagi Arrays

We often think of the popular HF Yagi beam antenna as one that is fed directly with 50 Ω coax with low SWR and without any need for a tuner. This is certainly the sense one gets from the specification sheet, yet some highly tuned Yagis, particularly those operating on multiple bands, have trouble providing a close match from band edge to band edge, particularly if optimized for the CW or SSB segment. In most cases, even though the SWR may be marginal at the far edge, there is still beneficial gain and front to back ratio. This is exactly the place for a limited range internal tuner to be applied, since the SWR is often less than 3:1. My sense is this is what they had in mind when these 3:1 tuners were designed — compensating for the just out of tune coax fed dipole or Yagi.

Single Wire Fed Antennas

There are a number of antennas that are designed to be fed as a single wire, without any transmission line. Some are field expedients, however, others are well thought out designs that can offer excellent performance.

Single Wire Antennas

Single wire antennas go back to the very beginning of amateur radio — the days before anyone thought of a transmission line. The most commonly used transmitting antenna in the early days was a short vertical (we're talking below 200 meters, so everything was short!) with top capacitance loading of multiple horizontal wires. They were used on shipboard, shore and ham stations alike, and worked well enough to get the signals through.

These days, a "random length" single wire is often used as an easy to deploy temporary antenna or, for some, using very thin wire, as an unnoticeable stealthy antenna if neighbors or deed restrictions object to "antennas." They can be effective, especially if fed against a good ground system, and if they are at least $\lambda/4$ long at the lowest frequency. Such a $\lambda/4$ wire fed against ground even has a name! This is called a Marconi antenna, and yes. it dates back more than a century.

Random wire antennas will still work if shorter, but ground losses rapidly reduce efficiency as lengths get much shorter than $\lambda/4$.

The success of such single wiere antennas depends on all the usual factors including height, length, and ground conditions all played against desired frequency and geographical coverage. With a ground mounted radio and a higher wire antenna, there will always be some vertically and often horizontally polarized radiation as well. The combination can provide a useful mix of coverage, although the coverage in any direction will not be as good as that of an antenna designed for the job.

The key element in making such an antenna play is a wide range antenna tuner that can match the widely variable load of the single wire on multiple bands to the 50 Ω that modern radios require. So we have a place here for the antenna tuner, the question is "which place."

Antenna Tuner at the Shack — This can work and has been done, but in the most successful implementations, the antenna tuner is near the boundary between indoors and out. In some stations, that boundary is within or at the edge of the shack eliminating the distinction.

A portion of a radiating antenna inside a building is generally asking for some kind of trouble. First there is the RF safety issue as applied to any people inside the structure. Even if your transmit power level does not require a formal assessment, you are not released from the requirement to not expose people to excessive levels of RF. Second, your indoor receiving antenna will pick up electrical noise from other equipment in the building. Third, if the building contains any sensitive electronic systems, your signal has a good chance of causing trouble, such as setting off fire alarms, or getting in to a television receiver while a spouse is watching an important show. In any case, any radiation that occurs within the building structure is not likely to help you get your signal where you want it.

None of this is to suggest that indoor antennas can't be used, however all of the above issues need to be considered. Here we are talking about an antenna that is partly inside a building, and partly outside. The point is that having as much as possible outside is generally a better solution.

Antenna Tuner at the Antenna — The antenna tuner can also be located at the antenna, if it's remotely tuned or sometimes remotely switched. Some remote tuners are waterproof, while others will need a waterproof enclosure to make them last. With the tuner at or near the antenna feed point, matched coax can run from the tuner back to the station, as discussed previously. By running the coax from the station out to the antenna feed point, the issues of radiation within the building can be largely avoided.

This is the configuration used for

Table 13-1

Random Wire Antenna Lengths that Should be Avoided Due to Resonance and High Impedance.

Band (Meters)	*0.5 λ*	*1 λ*	*1.5 λ*	*2 λ*	*2.5 λ*	*3 λ*
160	234 to 260	468 to 520	702 to 780	936 to 1040	1170.0 to 1300.0	1404.0 to 1560.0
80	117.0 to 133.7	234.0 to 267.4	351.0 to 401.1	468.0 to 534.9	585.0 to 668.6	702.0 to 802.3
40	64.1 to 66.9	128.2 to 133.7	192.3 to 200.6	256.4 to 267.4	320.5 to 334.3	384.7 to 401.1
30	46.1 to 46.3	92.2 to 92.7	138.3 to 139.0	184.4 to 185.3	230.5 to 231.7	276.7 to 278.0
20	32.6 to 33.4	65.2 to 66.9	97.8 to 100.3	130.5 to 133.7	163.1 to 167.1	195.7 to 200.6
17	25.8 to 25.9	51.5 to 51.8	77.3 to 77.7	103.0 to 103.6	128.8 to 129.5	154.6 to 155.4
15	21.8 to 22.3	43.6 to 44.6	65.5 to 66.9	87.3 to 89.1	109.1 to 111.4	130.9 to 133.7
12	18.7 to 18.8	37.5 to 37.6	56.2 to 56.4	74.9 to 75.2	93.6 to 94.0	112.4 to 112.8
10	15.8 to 16.7	31.5 to 33.4	47.3 to 50.1	63.0 to 66.9	78.8 to 83.6	94.5 to 100.3
6	8.7 to 9.4	17.3 to 18.7	26.0 to 28.1	34.7 to 37.4	43.3 to 46.8	52.0 to 56.2

many marine HF antennas. On a sailboat, the typical HF antenna is an insulated backstay fed by a remote single wire tuner located near the antenna base and fed against the ship ground system, including salt water, if possible.

But Watch Out for Tricky Lengths! — The so called *random length* wire antenna is not really random since any antenna does have a specific length. Such an antenna will work better at some lengths than others, making it best if not entirely random in its installation. The problems most often show up if the length happens to be a multiple of λ/2. At this length, the impedance hits a maximum, often in the 1000 to 2000 Ω range, depending on the usual factors. This results in an SWR of 20 to 40:1, higher than even a wide range tuner promises to deal with.

The impedance gets somewhat lower with each multiple of a λ/2, but may still be a problem. A second concern is that the voltage on the end at the tuner is high. The voltage can be nearly 500 V_{RMS} with a 100 W transmitter. This can stress tuner capacitors as well as pose a safety hazard to unsuspecting people. Instead of the shock experienced by coming in contact with dc or 60 Hz ac, contact with RF results in a painful burn that is usually slow to heal.

While it sounds like it should be an easy task to select a length, the multiplicity of bands without harmonic relationship makes it difficult to find a length that won't be likely a problem on some band. A look at **Table 13-1**, indicating approximate λ/2 resonant lengths for each band, along with multiples, provides a list of lengths to avoid for the amateur bands. There are so few lengths available, that sometimes it makes sense to just try the length that fits the available spot and, if it has problems tuning on a band, add a few feet and try again.

The Vertical Monopole

A popular antenna with those who like to operate long distances on the lower HF and MF bands is a vertical monopole. This can perhaps be considered a special case of the random wire antenna, except that it is generally of specific electrical length — typically λ/4 or ⅝ λ, depending on frequency and available supports. While a λ/4 vertical monopole can usually be fed directly with 50 Ω coax against ground, the other lengths do require matching networks or an antenna tuner for operation with a transmission line. A low impedance ground is a requirement for efficient operation of such antennas.

A 43 foot tall vertical made from wire or tubing is a very popular antenna in some quarters. It is a ⅝ λ long monopole on 20 meters and thus provides the optimum low angle radiation from a single vertical radiator (see **Figure 13-5**), yet can provide excellent low angle performance on 40 meters where it is somewhat longer than λ/4, as well as on 80 meters where it is somewhat less than λ/4, but generally a manageable height. All the lengths share a complex feed point impedance that responds nicely to a remote tuner at the base, although at these frequencies, a short run of high quality coax may have sufficiently low in loss to be suitable for use with a tuner at the station.

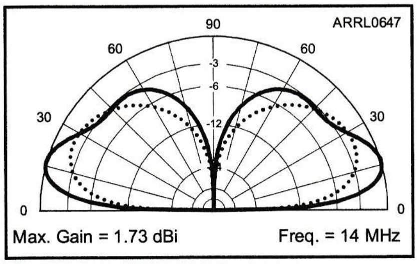

Figure 13-5 — Vertical radiation patterns of a 43 foot, ⅝ λ, vertical on 20 meters (solid) compared to a ¼ λ monopole. Note the increased radiation at low elevation angles.

THE DOTTED PATTERN IS FOR THE 1/4 λ MONOPOLE.

Inverted L

A popular variant of the vertical monopole, particularly on the lower frequency bands, is the inverted L. A λ/4 monopole for 160 meters, for example, needs to be around 130 feet long — a bit of a stretch for most as a vertical arrangement. The inverted L is obtained by taking the same length of wire and going as high as feasible, then bending the remainder horizontally. The antenna has the appearance of an upside down letter L — hence its name.

The lower (vertical) portion has the highest current and will thus provide low angle radiation very similar to that of a full sized monopole. At the λ/4 frequency, the inverted L can often be fed directly by 50 Ω coax with a reasonable SWR. An additional advantage of this arrangement, if fed with a wide range tuner at its base, is that it will provide low angle vertically polarized radiation at higher frequencies up to the frequency at which the vertical portion is just longer than ⅝ λ. Note the earlier concerns about feeding an antenna that is a multiple of λ/2, and if multiband operation is in the plan, make the inverted L longer than λ/4 on the lowest band.

The Bobtail Curtain

An interesting, inexpensive and surprisingly effective directional array called the Bobtail Curtain is composed of three λ/4 vertical elements fed in phase and driven from the single wire center element as shown

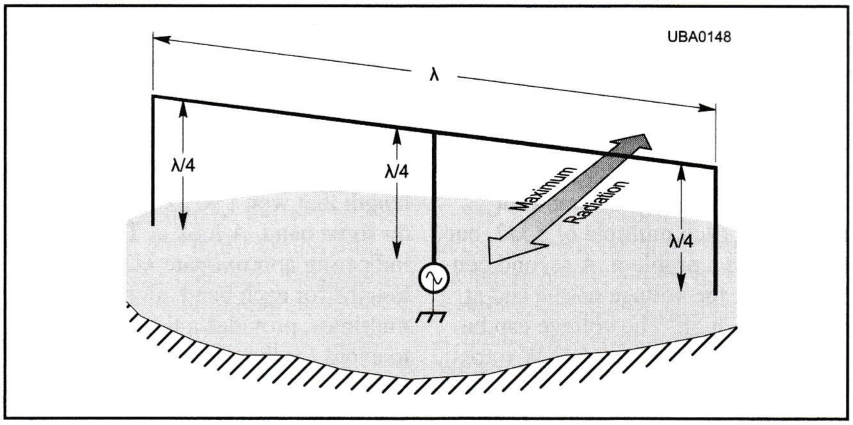

Figure 13-6 — The Bobtail Curtain three element vertical phased array fed by a single wire.

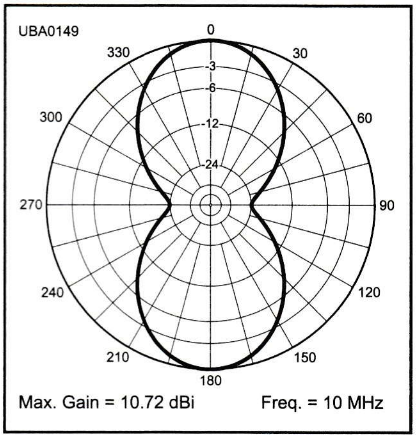

Figure 13-7 — Azimuth pattern of a Bobtail Curtain array at 10° elevation. Note the high gain over 60° on each side, broadside to the array.

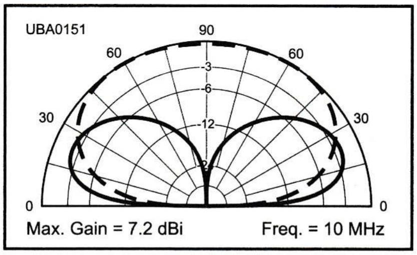

Figure 13-8 — Elevation pattern of a Bobtail Curtain array (solid) compared to a full wave center fed antenna on the same supports (dashed). Note the superior low angle coverage.

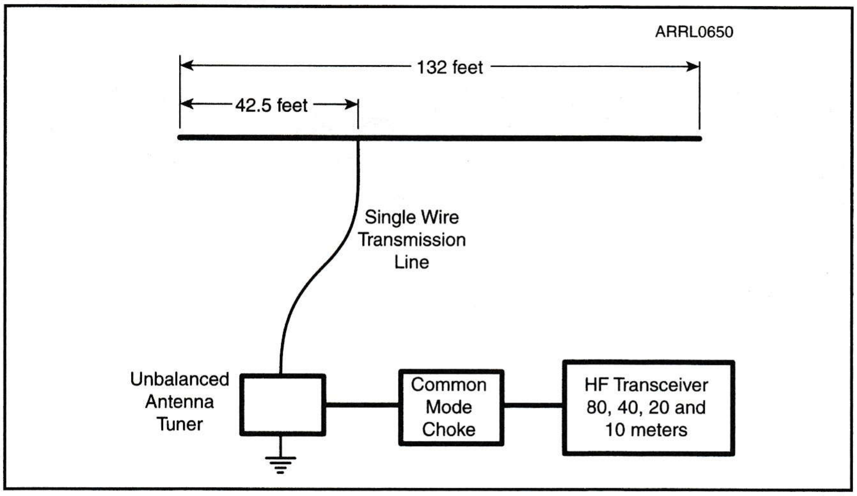
ARRL0650
132 feet
42.5 feet
Single Wire Transmission Line
Unbalanced Antenna Tuner
Common Mode Choke
HF Transceiver 80, 40, 20 and 10 meters

Figure 13-9 — Single wire fed Windom antenna configuration for 80, 40, 20 and 10 meters.

in **Figure 13-6**.[1] This antenna is composed of just four pieces of wire, yet provides significant gain in two fixed directions as shown in **Figure 13-7**. The low angle gain of this antenna favors long distance communication (see **Figure 13-8**) and is higher than that of horizontal antennas of the same height.

The Bobtail Curtain can be fed by a single wire tuner located at the source shown in Figure 13-6, although the impedance is quite high, as discussed in the previous section. Making the middle wire a few feet longer may make it usable with most wide range tuners. The antenna can be used on other bands as a kind of top loaded monopole, although the results will not be in the same league as those at its design frequency.

Single Wire Fed Windom

An unbroken half wave antenna off-center fed by a single wire was quite a popular multiband radiator in the 1930s, following publication of a note by Windom in *QST*.[2] The Windom antenna, as shown in **Figure 13-9,** with a fundamental frequency in the lower portion of 80 meters, was said to operate equally well on 40, 20 and 10 meters, thus covering all the amateur HF bands of the day.

There is some controversy over just how well this antenna works as a horizontal antenna; however, there is no question that it can work. Figure 13-9 shows a choke or current balun in the coax from the tuner to the radio, since there will likely be significant common mode current that should be kept out of the radio room.

[1] For more about the Bobtail Curtain array, see J. Hallas, W1ZR, *Basic Antennas — Understanding Practical Antennas and Designs,* Chapter 15. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9994. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop/**; **pubsales@arrl.org**.

[2] L. Windom, W8GZ, "Notes on Ethereal Adornments," *QST*, Sep 1929, pp 19-22, 84.

Balanced Antenna Systems

For many amateurs, the antenna tuner really earns its keep by matching balanced systems for multiple bands. The classic system is one that is often called a center-fed Zepp, although there are some who suggest it really should have different names on different bands.

The Center-Fed Zepp

This antenna is actually a half-wave dipole if fed on its lowest band. The difference between it and the usual dipole is that it is fed with low-loss balanced transmission line, such as open wire line or window type line. Since it doesn't really need to be resonant to work well, and thus can be almost any length, a more accurate name might be the *not always resonant tuned feeder dipole*. Still more folk will know what you mean if you call it a center-fed Zepp (CFZ). The configuration is shown in **Figure 13-10**.

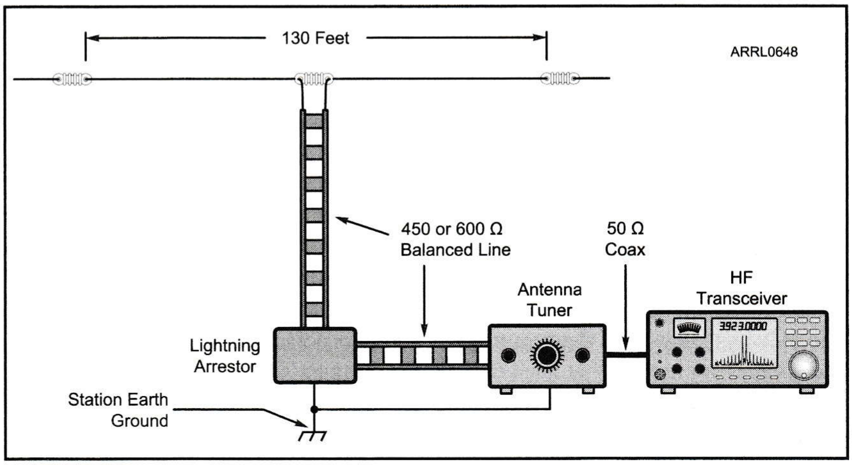

Figure 13-10 — Traditional center-fed Zepp antenna. With the length shown, the antenna will work well from 80 through 6 meters, and may even tune on 160 meters. The antenna length is not critical, however, it works best if close to $\lambda/2$ on the lowest operating frequency as described in the text.

For the case in which it is resonant at its half wave frequency, the radiation pattern is the same as any half-wave dipole at the same height. The difference is that the SWR on the transmission line will be in the range of 4:1 to 10:1 depending on the height of the antenna and the transmission line type. While the loss with this kind of mismatch would be a problem with coax, it isn't with low loss line. Including the loss due to mismatch, the total loss is comparable or even less than most matched coax situations at the same frequency.

The antenna can easily be fed with a wide range antenna tuner, preferably a balanced antenna tuner, but usually also with an unbalanced tuner equipped with a balun. The antenna will work very well on higher bands — into the VHF range. There may be some lengths of transmission line that will result in an impedance that the tuner can deal with on all bands.

The antenna patterns become fairly complex at higher frequencies. For resonant antennas, there are generally 2 × N main lobes where N is the number of full wavelengths.

As mentioned, the antenna has no particular need to be resonant anywhere to work well. The impedance is easier to match if the antenna is at least a half wave long at its lowest frequency, but there is nothing magic about that length. I use a 100 foot long dipole, center fed with 450 Ω window line quite successfully on all bands from 80 through 6 meters, for example.

Another popular length is 86 feet. This provides the optimum gain on 20 meters in single lobes in each direction perpendicular to the wire. While the lobes are sharp compared to a dipole, 35.6° on either side compared to 83°, the gain at the peak is more than 3 dB higher than a dipole.

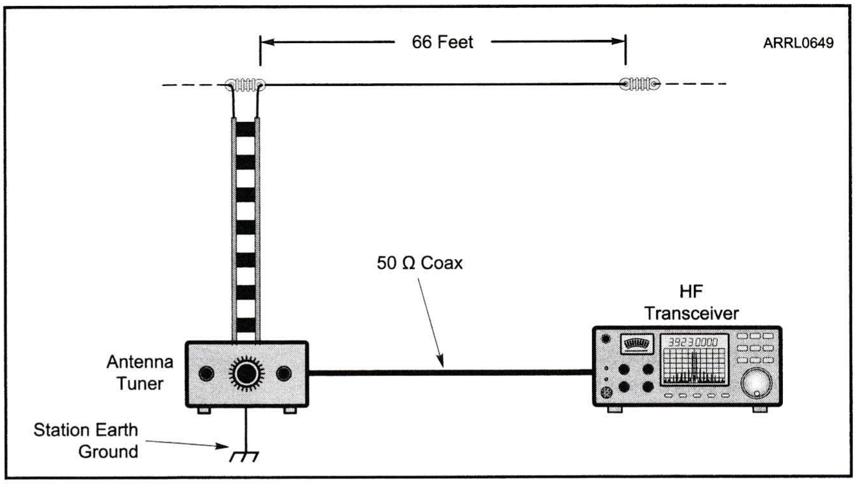

Figure 13-11 — End-fed Zepp antenna for 40, 20, 15 and 10 meters. This works as a horizontal antenna if the length is a multiple of $\lambda/2$ on each frequency used. On other frequencies the feed line will also radiate, usually with vertical polarization, and precautions must be taken to keep common mode currents from the radio equipment. Lightning arrestor not shown.

This length will usually be useable from 80 meters through the higher frequency bands, although some transmission line lengths may have problems with some wide range tuners on 80 meters.

If there are problems matching particular impedances, usually an extra 10 feet or so of the transmission line will change the impedance enough to make the match possible. Be sure to check the other bands to make sure you haven't just moved the problem around. Usually a length can be found that will work on all bands. Be sure to avoid coiling up the excess balanced line. Always keep it off the ground and away from metal — at least three or four times the distance between the conductors.

The End-Fed Zepp

A half wave antenna fed on the end with a λ/4 matching section of low loss balanced line is called an end-fed Zepp. This is often a convenient antenna if the station is close to a property boundary, making a center-fed antenna a difficult proposition. The matching section transforms the high impedance on the end, typically close to 2000 Ω, to a relatively low impedance that can be fed by a transmitter, or a narrow range tuner. This is the original Zeppelin antenna that was deployed beneath the aircraft's gondola. It is also popular as a VHF vertical called a "J-antenna."

Some have had better results by providing a λ/10 or so of wire as a counterpoise on the other side of the transmission line, particularly if using it on multiple bands. On bands at which the antenna is a multiple of λ/2, it provides mostly horizontal polarization with minimal common mode current on the transmission line. It can be made to work on bands at which it is not resonant, however, there will be a pronounced lack of balance on the transmission line.

While the λ/4 matching section is a key part of the original Zepp design, it is not necessary if a wide range antenna tuner is provided to perform the matching as shown in **Figure 13-11**.

The unbalanced line currents result in two effects.

- First, the line will radiate. This may not be a terrible thing, if the line is in the clear, but can cause problems if it is running near other equipment.
- Second, the line will bring common mode current into the station. This can usually be addressed through a common mode choke at the point at which a transition to coax is made. Make sure the coax run is short, since the mismatch will result in much higher losses in coax.

Mobile Antenna Systems

Antennas used in vehicles operate under the same principles as antennas in other applications, however, they often provide unique challenges. Antennas for MF and the lower portion of the HF region must be shortened considerably in order to be practical on most motor vehicles, large ships are a notable exception. In addition, unlike the usual antenna environment, these antennas are usually quite close to both the radio equipment as well as the vehicle body. With the exception of aircraft antennas, most mobile antennas are also quite close to the ground.

While none of the above differences by itself results in major problems, they all lead to certain limitations in

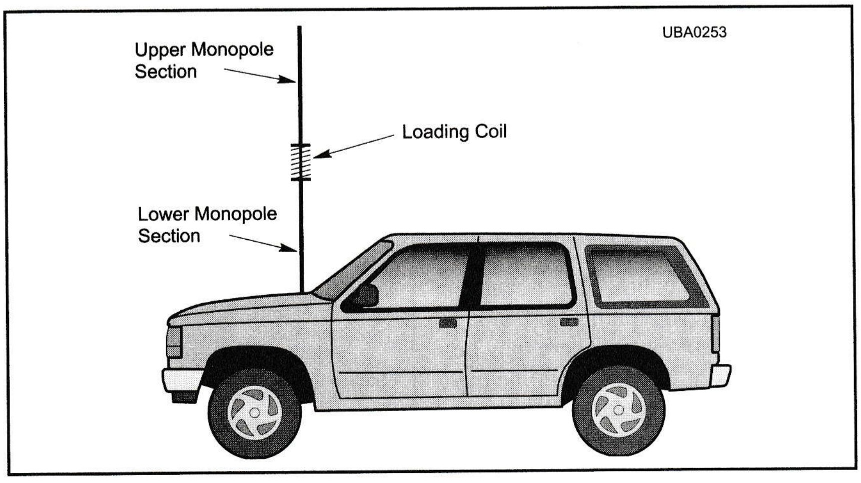

Figure 13-12 — Typical vehicle mounted monopole for the lower HF range. Because of practical limitations to do with garages, tunnels and trees, lengths tend to be 8 feet or less, from about ⅛ to 1⁄32 wavelength. The center loading shown improves efficiency.

antenna design and performance.

HF Mobile Antennas on Land Vehicles

The lower HF bands, especially 80, 40 and 20 meters, are popular with mobile operators. Depending on the sunspots and time of day, one or more can usually be counted on for reliable medium to long range communication. The usual antenna is a relatively short monopole antenna mounted on, and fed against, the vehicle body as shown in **Figure 13-12**.

As in the antenna in Figure 13-12, center loading is often used because it results in higher current in the lower section and thus less loss, although base loading, or even just using a solid whip with a tuner at the base are often encountered. A limitation of such an antenna is its SWR bandwidth, a typical case shown in **Figure 13-13** — much narrower than a full size antenna.

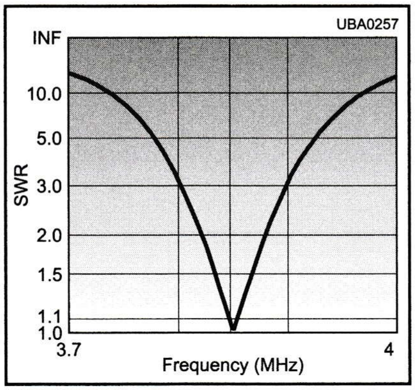

Figure 13-13 — Typical SWR plot of a mobile antenna of the type shown in Figure 13-12. The 2:1 SWR bandwidth is likely to range from 20 to 50 kHz, with antennas having less efficiency tending to have wider bandwidth.

This makes the shortened mobile antenna a good candidate for a wide range antenna tuner. The tuner can be used to allow full band coverage to be obtained. I have even used a tuner to allow a 40 meter mobile whip to be used on 80 meters, although it is not as efficient as the center loaded 80 meter arrangement.

HF Mobile Antennas on Other Vehicles

Those using HF on boats or aircraft do not generally share the same size restrictions as on land vehicles. Often either will use a convenient length of wire, for example the insulated backstay on a sailboat, or a wire from a short mast to a handy surface on an aircraft, to form an antenna similar to the random wire described earlier. This is almost always accompanied by a remote, usually automatic, antenna tuner very near one end or the other of the wire. This system can work very well if fed against the aircraft body or a metal hull. On my fiberglass sailboat, I feed it against the ship ground system.

Review Questions

13-1 Under what circumstances can an antenna tuner be of benefit in feeding a simple coax fed $\lambda/2$ dipole?

13-2 Why is it important to use low-loss transmission line such as window or ladder line if using a dipole on multiple bands?

13-3 What are the possible consequences of common mode currents on a transmission line?

Chapter 14

A Survey of Available Tuners

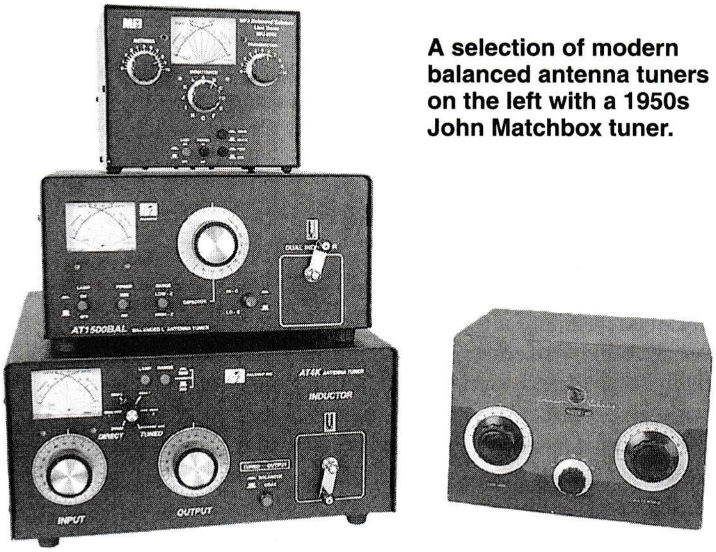
AT1500BAL
AT4K
INDUCTOR
DUAL INDUCTOR
INPUT
OUTPUT
DIRECT
TUNED

A selection of modern balanced antenna tuners on the left with a 1950s John Matchbox tuner.

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Key Tuner Paramaters

Virtually every configuration of antenna tuner, capable of operation at every legal power level, is available commercially from one or more vendors. This can make selecting a commercial tuner a bit of a challenge, just as it is much tougher to select a meal from a restaurant with many good choices, compared to just a few.

Fortunately, the choices can be quickly reduced if one can make a few decisions on key tuner parameters. I will try to organize them in a way that will help make the selection easier. The following are the major decisions to be made, in this person's opinion:

What Frequencies Do You Want the Tuner to Cover?

When talking about antenna tuners, we almost always are talking about the HF range, although there are also some tuners for VHF bands. This means that we want to cover the amateur bands from 80 through 10 meters — that's a *given*. Most current amateur transceivers also cover 160 meters. Is that of interest? If so, because it often doubles the size of many tuner components, it will likely add significantly to the cost and size of a tuner, all other things being equal. The 160 meter band is gaining in popularity since it provides interesting operational conditions at the bottom of the sunspot cycle, as I write this. If you have room for effective 160 meter antennas, having a tuner that supports operation here may be a good choice.

On the other end of the spectrum is 6 meters. More and more current amateur "HF" transceiver cross into operation on our lowest VHF band. This band is also quite popular now since there are long distance modes that don't depend on sunspot activity. If you have, or expect to have, a dedicated 6 meter antenna, the chances are that it will be suitable to be fed directly with 50 Ω coax and a tuner will not be needed. On the other hand, if you will need to use your all band tuner fed antenna, such as the center-fed Zepp, on this band, you will want to include that capability in your tuner.

The other frequency decisions may be more subtle. Operation on 10 meters is sometimes a problem with larger tuners that have trouble ending up with sufficiently low minimum inductance and capacitance to provide the same impedance coverage on 10 meters as on the other bands — check the specifications to get an idea. In a similar vein, some tuners don't have quite enough maximum inductance or capacitance to provide the tuning capability to cover 80 (or 160) meters with the same range as on the other bands.

How Much Power Do You Expect to Run?

For any given tuner design, there is no factor that influences tuner cost and size more than power level. This should not be a surprise since higher power means higher voltage and current stress on the components within. The obvious answer might be to pick a tuner with a power rating equal to the most power that your transmitter can put out — but be careful, there are four issues hidden here:

- The power rating is based on the manufacturer's SWR specification (if they did a proper design job). If it says a tuner is good for an SWR of 10:1, typical for a wide range tuner, and you tune an antenna with a 20:1 SWR, you may be able to get a match, but either the voltage or the current in the tuner can be higher by a factor of $\sqrt{(20/10)}$, or 1.41 times. That may explain the arcing, or the burning smell, you observe on some frequencies! The answer may be to go somewhat higher in power rating than you expect to actually run.
- So you now have that shiny new 100 W transceiver — you love it to death and can't imagine that you will ever need more power. You buy a 100 W antenna tuner (or better a 200 W tuner, as discussed above) and happily make many contacts with your stealthy antenna. Now you decide to try for DXCC and notice that the DXpedition in Outer Slovenia can almost hear you, but can't quite copy your call letters. A bigger antenna is out of the question — the only solution is a high power amplifier. Oops, now you have an almost new 100 W tuner that you can no longer use.
- In addition to taking up more space, and more lawnmowing money, high power tuners often, because of the physical size of the components, have trouble providing the tuning range some antennas need on the higher bands. Some switch out portions of the circuit on higher bands to avoid the problem, but some don't. Keep your eye on that ball, if looking at higher power tuners.
- On the plus side, higher power tuners usually have inductors that are wound with heavier wire. This reduces losses, although it may not be noticeable in the test results.

Do You Want a Balanced or Unbalanced Tuner?

If you expect to be feeding single wire or coax-fed antennas, an unbalanced antenna tuner will be fine. If you want to feed an antenna such as a center fed Zepp with balanced line, you will need to have some provision to feed a balanced load. This can be handled in one of three ways:

- A fully balanced tuner is ideally suited to matching to balanced loads within its matching range. These are available in multiple power ranges and can work quite well. A disadvantage of these is that many do not include all the switching options of many unbalanced tuners — not a problem if you expect to use a single antenna.
- Many inherently unbalanced

tuners include an output connection through an internal balun. These work best with balanced loads within about 4:1 SWR of the balun design impedance. Most use 4:1 baluns designed for a 200 Ω load. That means they will work reasonably well with resistive loads from 50 to 800 Ω, and with complex loads of a similar SWR. They will also work outside that range, although their response can be a bit unpredictable. If they don't get hot, they are probably putting the power where you want it.

- The same kind of balun can be added outside of an unbalanced tuner if you decide to move from coax to a balanced feeder system. The same concerns as noted above apply. However there are some advantages such as that you can custom design the balun for the impedance that each antenna has, and you can have the balun some distance from the station equipment — but watch out for mismatched coax losses if the distance is more than a few feet.

Do Your Want a Remote or Local Tuner?

An antenna tuner that is located next to the radio in the station area offers a lot of plusses in terms of control and monitoring. Some antennas, however, really want the impedance matching performed at the antenna. A big consideration here is that if the tuner is located with the antenna, it usually can only operate with that single antenna, although remote switching is possible. If the antenna tuner is near the radio, switching between antennas systems is usually much easier — sometimes provided within the tuner, sometimes outside — but always within reach.

Do you Want a Manual or an Automatic Tuner?

A manual tuner requires adjusting two or three controls (and often switches) every time either frequency is changed, typically by around 50 kHz, depending on what band is selected or what type antenna is used. The adjustments can be tedious, although recording them makes returning to a proper tune under previously encountered conditions fairly easy.

An automatic tuner, on the other hand, just requires a push of the button to obtain a tune. Many have some sort of memory arrangement so they can quickly return to previous settings. The tuning usually takes a few seconds the first time, a fraction thereafter. While it is possible to imagine a remote manual tuner, to my knowledge, all remote tuners are of the automatic flavor. So if you want remote, you get automatic.

The idea of an automatic tuner sounds pretty good, and it is. There are just a few items to be aware of, as noted below:

- In general, an auto tuner will make a match within its specified SWR threshold, often 1.5:1, but check and compare with your radio's requirement. With your manual tuner, you can usually find a 1:1 setting. If the radio will put out its full power into the load, this is not worth worrying about.
- Watch out for tuners that initiate a tune on their own. Some can be just *too* automatic to suit me. You tune your radio 25 kHz off your previous frequency to capture a neat DX station, start to call, and hear your antenna tuner relays clacking. Chances are the up and down tuning will result in the station missing some part of your call sign.

Of more concern, if there is no circuitry to prevent it, many automatic tuners that can handle 100 W, for example, want tuning to occur at a lower power level to avoid burning relay contacts. If it starts up while you are operating, you can easily hit it at full power before you know what's happening. In the mobile environment, this can also happen as you pass that 18 wheeler with a giant piece of aluminum detuning your antenna (it can also serve as a reflector, if you get it in the right place!).

- I once thought that the small components in the usual compact automatic antenna tuner would result in more losses compared to the larger components, especially inductors, in the usual manual tuners. To my surprise, following the test results presented below, this does not seem to be the case, although it might be buried in the 5% minimum loss, below which we don't report due to measurement uncertainty. If it is a loss of that level (0.2 dB), in my opinion, it should not be part of the decision process.

Product Review Testing

The American Radio Relay League (ARRL), the US Amateur Radio organization publishes a monthly magazine, *QST*, for its members. In addition to its many technical and general interest features, each month's issue includes detailed reviews of products of interest to its readers. These Product Reviews generally include laboratory evaluation of equipment operational parameters using professional grade, independently calibrated test instruments. Over the years, we have had many such reviews of antenna tuners and I have reproduced the results from some here.

While many of the reviews include currently available equipment, some models covered are no longer available as new equipment. Even so, it may be of benefit in two ways:

- There is an active used equipment market in Amateur Radio equipment. This may provide a way to knowledgeably purchase an antenna tuner at a lower cost.
- In some cases, manufacturers have made relatively small changes to equipment, so data on previous models may be directly applicable.

ARRL Lab Antenna Tuner Testing Methodology

The following method was used in the ARRL Lab to measure the loss of the tuners presented below. Two test fixtures were built which would hold combinations of high power 50 Ω "non-inductive" carbon resistors (one fixture for parallel combinations and one for series), one shown in **Figure 14-1**. Even with the non-inductive resistors, some net fixture inductance was apparent at some frequencies, so a variable capacitor was used to compensate. The fixture accuracy was measured using the Lab's vector impedance meter.

Each fixture used an input connection (for the tuner) and an output connection. The output connection went to a 50 Ω input power attenuator, which took the place of one of the resistors in the load (for the series loads, it was always the one on the ground side of the network). The output of the power attenuator was connected to a high accuracy laboratory wattmeter, and the actual attenuation was measured for each frequency. The tuners were matched at low power, then 100 W of RF was applied at the input, with the output being measured by the Lab's wattmeter.

Each tuner was connected to the load fixture at each resistive impedance level for testing in the ARRL Lab. A 100 W RF source fed the input of the tuner. The resistive load was connected to the antenna output. The load was connected to a 50 Ω. power attenuator, which took the place of the final resistors. This is a close-up of the parallel load test fixture. The variable capacitor was used to compensate for fixture inductance encountered at some frequencies. While complex impedance loads could have been tested as well, the additional data points would have made testing impractical. We believe that the results at a particular SWR should be representative of other loads with the same SWR.

Note that the reviews were conducted over a period of a few years and the data taken, as well as the presentation, varied slightly from review to review. Please make sure that you are comparing equivalent data.

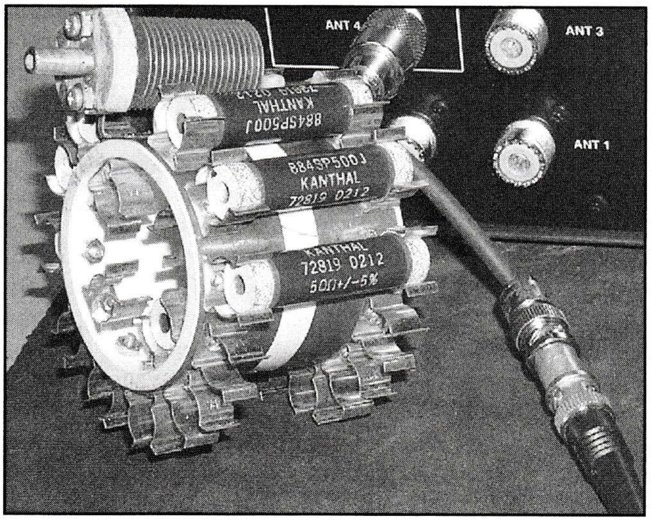

Figure 14-1 — Close up of test figure used to test antenna tuner efficiency into loads from 50 Ω down using paralleled 50 Ω noninductive loads.

QST Reviews Five High Power Antenna Tuners

Reviewed by Jim Parise, W1UK
ARRL Technical Advisor
QST *February, 2003*

One piece of gear that finds its way into most everyone's shack at one time or another is an HF antenna tuner. First of all, the name antenna tuner is something of a misnomer. It does not tune the antenna at all, but acts as an impedance transformer that provides your transmitting equipment with the proper load, usually 50 Ω.

Who needs an antenna tuner? Well, anyone who has the need to match an antenna with an impedance outside the range of their transmitter or amplifier's output circuits. Modern transceivers often have built-in tuners that are capable of matching SWR mismatches up to 3:1. Beyond that they need help, and if you use an amplifier you most surely will need one. Many hams find themselves with limited antenna choices and the desire to operate on frequencies other than what they were designed for, or use non-resonant multiband antennas that require a tuner. The five HF tuners we tested are all in the kilowatt class, meaning the manufacturer rates their power handling capability at 1 kW output or more.

With the wide range of frequencies in the HF spectrum and the huge diversity of antenna types in use, tuners are expected to perform under an incredible number of possible combinations. Some are more efficient at it than others. A measure of a tuner's ability to transform impedances efficiently is energy loss. Under extreme conditions a tuner can get quite hot or arc over at power levels well under the manufacturers rating. Heat in a tuner is a product of loss. RF energy being dissipated as heat is lost power that will not find its way to your antenna and onto the air.

Tuner losses generally get higher as the impedance of the load decreases. If a ham were running 1500 W into a tuner that was 50% efficient, 750 W would be dissipated in the tuner. Most of the loss in a tuner occurs in the coil, and no coil can withstand 750 W of power. A high-power tuner could probably be safely used at 50% efficiency and 100 W, but hams should be careful with high SWR and high power, or a tuner failure is a real possibility. Each tuner was tested into resistive impedances that ranged from 6.25 to 400 Ω, and their respective percentage of loss and 1.5 SWR bandwidth measured. The tuners were also used in everyday communications on all bands at power levels up to 1 kW, matching a G5RV fed with balanced ladder line and a 160 meter inverted L fed with coax.

The characteristicvs of the five uners tested are described in **Table 14-1**. Each tuner is described separately below.

Table 14-1
Comparison of Five Antenna Tuners

	Ameritron ATR-30	*MFJ MFJ-986*	*Palstar AT1500 CV*	*Ten-Tec 238A*	*Vectronics HFT-1500*
Circuit Type	T-network	T-network	T-network	L-network	T-network
SWR/wattmeter	Cross-needle	Cross-needle	Cross-needle	Single-needle	Cross-needle
Balun type	4:1 current	4:1 current	4:1 voltage	4:1voltage	4:1 voltage
Manufacturer's claimed PEP rating	3000 W	3000 W	1500 W	2000 W	2000 W
Manufacturer's claimed Matching range	35-500	35-500	20-1500	5-3000	Not specified
Physical dimensions (HWD) in inches	5.25x13x14.4	4.1x11x15.2	4.5x12.5x12	5.5x13x11	5.5x12.5x12

AMERITRON ATR-30

The ATR-30 (**Figures 14-2, 3, 4**) is Ameritron's legal limit T-network antenna tuner offering. It is housed in a plain, all black aluminum enclosure with a scratch resistant coated front panel. A look under the cover reveals two large variable capacitors and an air core edge wound silver plated roller inductor. Like most of the other tuners reviewed here, the capacitors are adjusted with vernier reduction drives, and although they tune smoothly, they require a lot of force to turn. The roller inductor is adjusted with a plastic lever type knob and is quite stiff to crank. The roller itself is a pinch roller, and the physical resistance in turning the crank may be offset by lessoned contact resistance.

The balun is constructed with three large cores and wound with wire covered with Teflon tubing. The cross-needle meter displays both average and peak power in switchable 300 W or 3 kW ranges. The wattmeter requires dc to function. It is illuminated by either a 12 V barrel connector on the back panel or a 9 V battery accessible through a trap door on the bottom of the unit. With 12 V, both the meter and inductor turns counter are illuminated. When a 9 V battery is used, the meter will function, but the panel lamps will not light.

Finding a match on 80 meters on the G5RV required quite a bit of time finding the right combination of capacitor tuning and inductance, and the stiff controls didn't make it much fun. Finding the sweet spot on the higher bands was much easier. There are three coax outputs on the ATR-30, including two that may be switched direct or through the T-network and a third direct only. Single or balanced feed lines connect to large ceramic binding posts with wing nuts. Test results are summarized in **Table 14-2**.

Manufacturer: Ameritron, 116 Willow Rd, Starkville, MS 39759; tel 662-323-8211; fax 662-323-6551; **www. ameritron.com**. 2003 price: $599.95.

Table 14-2
Ameritron ATR-30 Loss and Bandwidth Test Results

SWR	*Load (Ω)*		*160 m*	*80 m*	*40 m*	*20 m*	*10 m*
8:1	6.25	Power Loss %	20	12	<10	<10	<10
		1.5 SWR BW	1	3	>5	4	>5
4.1	12.5	Power Loss %	15	<10	<10	<10	<10
		1.5 SWR BW	3	4	>5	>5	>5
2:1	25	Power Loss %	10	<10	<10	<10	<10
		1.5 SWR BW	4	>5	>5	>5	>5
1:1	50	Power Loss %	<10	<10	<10	<10	<10
		1.5 SWR BW	>5	>5	>5	>5	>5
2:1	100	Power Loss %	<10	<10	<10	<10	<10
		1.5 SWR BW	>5	>5	>5	>5	>5
4:1	200	Power Loss %	<10	<10	<10	<10	<10
		1.5 SWR BW	>5	>5	>5	>5	5
8:1	400	Power Loss %	<10	<10	<10	<10	<10
		1.5 SWR BW	>5	>5	>5	>5	3

Notes

Power losses are expressed as a percentage. A 21% loss of power is 1 dB.

The 1.5-SWR Bandwidth (SWR BW) represents the bandwidth over which an SWR of 1.5:1 or less was maintained as a percentage of the measurement frequencies (1.8, 3.5, 7.2, 14.2 and 29.7 MHz).

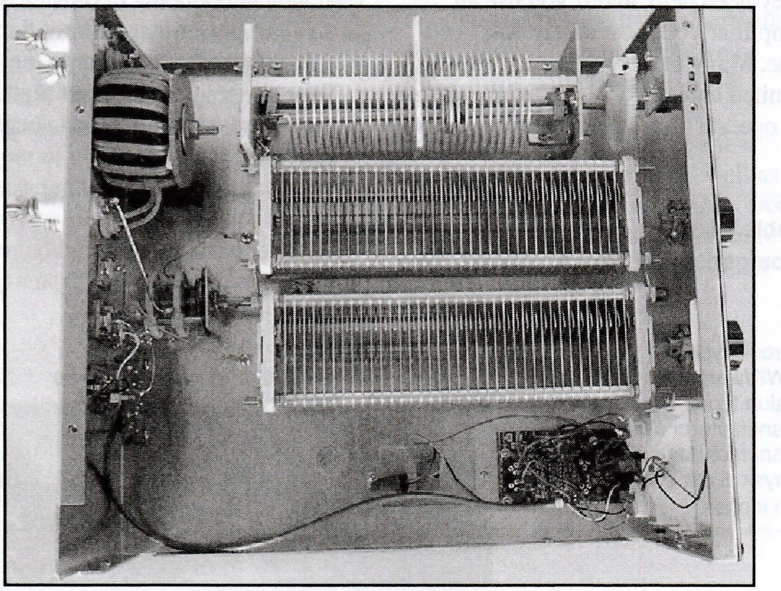

Figure 14-3 — Interior circuitry of the Ameritron ATR-30.

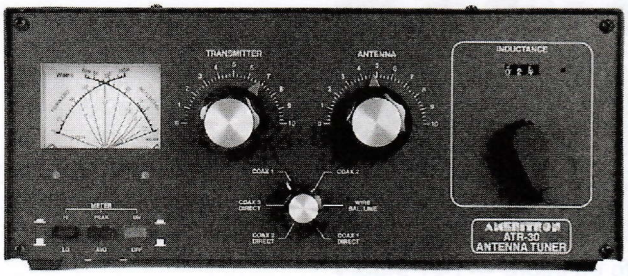
TRANSMITTER
ANTENNA
INDUCTANCE
METER
PEAK
COAX 1
COAX 2
COAX 3 DIRECT
WIRE BAL LINE
COAX 2 DIRECT
COAX 1 DIRECT
LO
AVG
OFF
AMERITRON
ATR-30
ANTENNA TUNER

Figure 14-2 — Front panel of the Ameritron ATR-30.

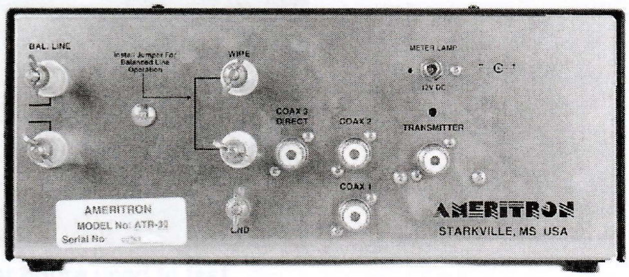
BAL LINE
Install Jumper For Balanced Line Operation
WIRE
COAX 3 DIRECT
COAX 2
METER LAMP
12V DC
TRANSMITTER
COAX 1
GND
AMERITRON
MODEL No: ATR-30
Serial No
AMERITRON
STARKVILLE, MS USA

Figure 14-4 — Rear panel connections on the Ameritron ATR-30.

MFJ-986

The ’986 is one of more than 20 antenna tuner products offered by the prolific MFJ (in 2003). It is rated for 1500 W PEP within the 35-500 Ω impedance range, positioning it alongside the ’989C as one of their high power units. Unlike the traditional T-network with a pair of variable capacitors, the ’986 (**Figures 14-5, 6, 7**)makes use of a single variable capacitor and a wire wound air core roller inductor with a three digit turns counter. The tuner uses what MFJ describes as a “differential” capacitor. It has two discrete sets of fixed plates and one variable set, with a single capacitor control, forming a T-network with the inductor.

The cabinet is narrow and extends nearly 18 inches deep. The cross-needle meter has a high (3000 W) and low (300 W) setting switched by a front panel button, and it can display average and peak power as well as SWR. Providing 12 V to the connector on the back panel brightly illuminates the meter. Both the capacitor and roller inductor are directly driven. The inductance knob has a finger depression, which are often found on a transceiver’s tuning knob. It is somewhat awkward to turn due to binding. The tuner had a tendency to creep around the operating desk when the inductor is rapidly turned. A check inside revealed several loose screws holding the inductor to the chassis. Tightening these did improve the smoothness somewhat.

The ’986 provided a match to both antennas quickly, but arced over on 80 meters with the inverted L at 900 W. While this tuner does provide ease of use, one should give careful consideration to the loss figures in the tables. During operation the meter developed an intermittent problem with both needles going off scale even with very low power applied and a low SWR. Movement of the SWR bridge circuit board on the inside back panel seemed to correct the problem.

Two coax outputs are provided that can be switched to bypass the tuning circuit, as well as a third output for a dummy load. Balanced and single-wire feed lines connect to large ceramic feed through posts with wing nuts. A 4:1 two-core current balun is provided at the output. Test results are summarized in **Table 14-3**.

Manufacturer: MFJ Enterprises, Inc, PO Box 494, Mississippi State, MS 39762; tel 800-647-1800; fax 662-323-6551; **www.mfjenterprises.com**. 2003 price: $329.95.

Table 14-3

MFJ-986 Loss and Bandwidth Test Results

SWR	*Load (Ω)*		*160 m*	*80 m*	*40 m*	*20 m*	*10 m*
8:1	6.25	Power Loss %	47	31	21	16	13
		1.5 SWR BW	1	1	2	4	>5
4.1	12.5	PowerLoss %	33	22	14	12	11
		1.5 SWR BW	1	1	4	5	>5
2:1	25	PowerLoss %	25	20	10	<10	10
		1.5 SWR BW	1	2	4	>5	>5
1:1	50	PowerLoss %	22	12	<10	<10	<10
		1.5 SWR BW	2	3	>5	>5	>5
2:1	100	PowerLoss %	15	10	<10	<10	19
		1.5 SWR BW	3	5	>5	>5	>5
4:1	200	PowerLoss %	11	<10	<10	<10	<10
		1.5 SWR BW	3	>5	>5	>5	>5
8:1	400	PowerLoss %	10	<10	<10	11	16
		1.5 SWR BW	3	>5	>5	>5	5

Notes

Power losses are expressed as a percentage. A 21% loss of power is 1 dB.

The 1.5-SWR Bandwidth (SWR BW) represents the bandwidth over which an SWR of 1.5:1 or less was maintained as a percentage of the measurement frequencies (1.8, 3.5, 7.2, 14.2 and 29.7 MHz).

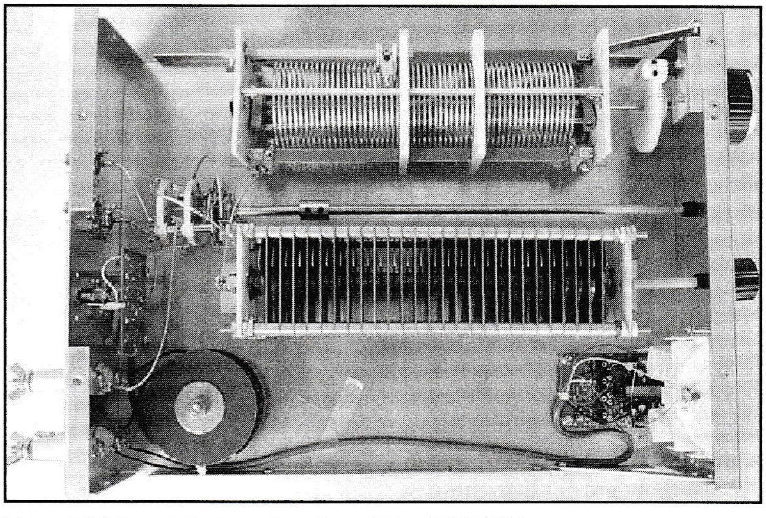

Figure 14-6 — Interior circuitry of the MFJ-986.

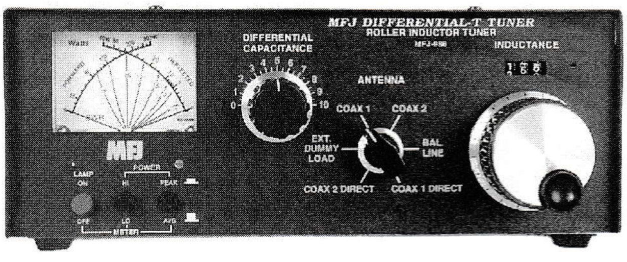
MFJ DIFFERENTIAL-T TUNER
ROLLER INDUCTOR TUNER
DIFFERENTIAL CAPACITANCE
INDUCTANCE
ANTENNA
COAX 1
COAX 2
EXT. DUMMY LOAD
BAL LINE
COAX 2 DIRECT
COAX 1 DIRECT
LAMP ON
POWER
HI
PEAK
OFF
LO
AVG
METER
MFJ

Figure 14-5 — Front panel of the MFJ-986.

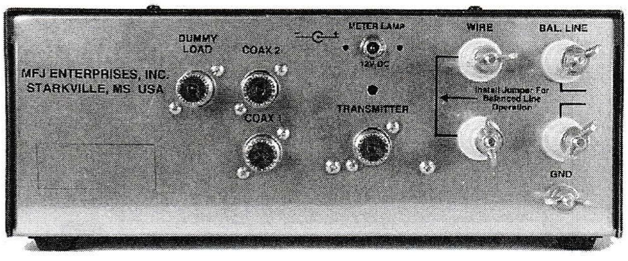
DUMMY LOAD
COAX 2
METER LAMP
12V DC
WIRE
BAL. LINE
MFJ ENTERPRISES, INC.
STARKVILLE, MS USA
COAX 1
TRANSMITTER
Install Jumper For Balanced Line Operation
GND

Figure 14-7 — Rear panel connections on the MFJ-986.

PALSTAR AT1500CV

The Palstar AT1500CV (**Figures 14-8, 9, 10**) is a T-network tuner solidly constructed in a compact aluminum enclosure. Inside, the metering and SWR bridge circuitry are encased in their own aluminum boxes. The moderately sized variable capacitors are mounted side by side and feature large calibrated dials and silky smooth vernier tuning that allows for precise adjustment. Palstar indicates that newer units incorporate a roller bearing assembly which makes inductor adjustment smoother. The roller inductor is quite large. It is an air core silver plated edge wound coil with heavy-duty ceramic forms. Control of the inductor is via a lever handle and mechanical turns counter. It is not as smooth as some of the other tuners and tends to lurch as it is rotated during fine adjustments. The cross-needle meter displays SWR and average forward and reflected power in 300 and 3000 W ranges, with no option for peak power metering. It is illuminated with 12 V from an included wall adapter.

Achieving a 1:1 SWR on the G5RV was possible on all bands from 80 through 10 meters at its rated power maximum of 1000 W single tone. Similar results were noted on the inverted L. Although the tuning chart provided in the manual does not include settings for 30 meters, the tuner easily matched both antennas on that band. This tuner has a solid feel to it and doesn't creep around while making adjustments.

In laboratory tests, the AT1500CV had more difficulties on 160 meters than on other bands. A 1:1 SWR was only obtainable with the 25 and 50 Ω loads, the power losses at 160 meters were measurably greater than those on other bands at the same loads. The variable capacitors are 240 pF maximum, which explains the 160 meter performance. The tradeoff results in lighter weight.

Antenna connections on the back panel include three coax inputs. Two are available direct or through the tuning network and one is bypassed

Table 14-4
Palstar AT1500CV Loss and Bandwidth Test Results

SWR	*Load (Ω)*		*160 m*	*80 m*	*40 m*	*20 m*	*10 m*
8:1	6.25	Power Loss %	No Match	25	16	12	12
		1.5 SWR BW		1	2	>5	3
4.1	12.5	Power Loss %	No Match	16	13	<10	11
		1.5 SWR BW		2	4	>5	>5
2:1	25	Power Loss %	21	13	<10	<10	<10
		1.5 SWR BW	2	3	>5	>5	>5
1:1	50	Power Loss %	13	<10	<10	<10	<10
		1.5 SWR BW	3	>5	>5	>5	>5
2:1	100	Power Loss %	No Match	<10	<10	<10	13
		1.5 SWR BW		>5	>5	>5	>5
4:1	200	Power Loss %	No Match	<10	<10	<10	12
		1.5 SWR BW		>5	>5	>5	>5
8:1	400	Power Loss %	No Match	<10	<10	<10	<10
		1.5 SWR BW		>5	>5	>5	5

Notes

"No Match" means that a 1:1 SWR could not be obtained.
Power losses are expressed as a percentage. A 21% loss of power is 1 dB.
The 1.5 SWR Bandwidth (SWR BW) represents the bandwidth over which an SWR of 1.5:1 or less was maintained as a

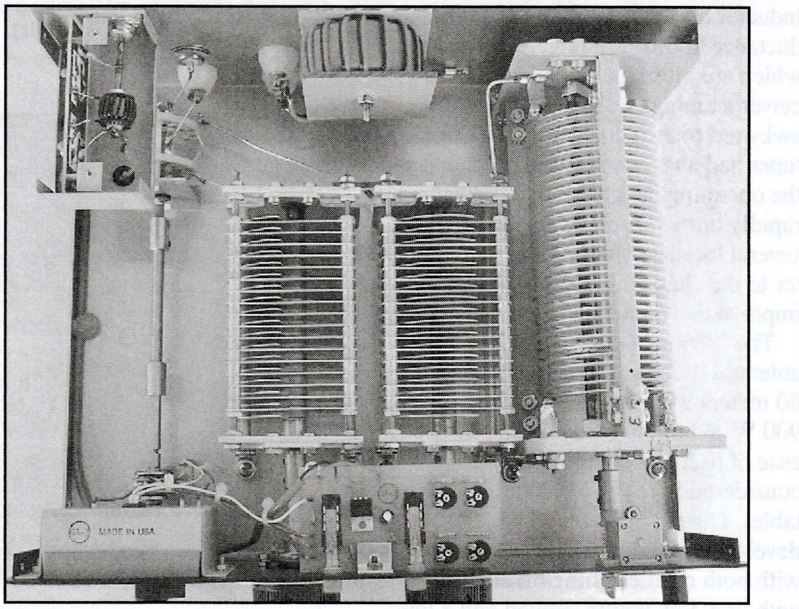

Figure 14-10 — Interior circuitry of the Palstar AT1500CV.

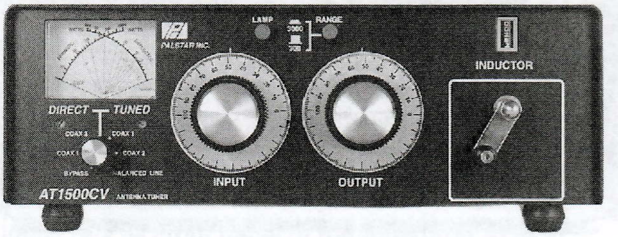

Figure 14-8 — Front panel of the Palstar AT1500CV.

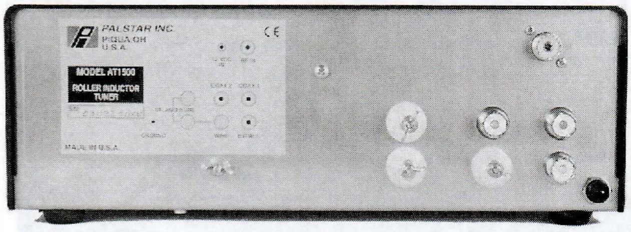

Figure 14-9 — Rear panel connections on the Palstar AT1500CV.

straight through. The bypass output can also be used with an optional 4:1 balun available for $39.95 [2003]. Balanced or single wire feed lines are attached to Delrin terminal posts with wing nuts.

Longer threaded material on the terminal posts would be a welcome improvement and make attachment of larger gauge wire much easier. In one isolated circumstance during lab testing, our engineer felt an RF bite on 10 meters through the metal portion of the inductor crank. This did not seem to be a pervasive problem, and Palstar indicates that the grounding on the crank has also recently been improved. Test results are summarized in Table 14-4.

Manufacturer: Palstar, Inc, 9676 N Looney Rd, PO Box 1136, Piqua, OH 45356; tel 937-773-6255; fax 937-773-8003; **www.palstarinc.com**. 2003 price: $429.95, optional 4:1 balun $39.95.

TEN-TEC 238A

The Ten-Tec 238A (**Figures 14-11**, **12** and **13**) is the only tuner in our roundup to utilize an L-network. Using an innovative switching arrangement, the '238A actually provides five different circuit configurations to maximize efficiency. A look at the low loss figures in the table confirms this. The well-constructed tuner makes use of a single variable capacitor and a smooth turning wire-wound roller inductor to match impedances up to 3000 Ω. Additional capacitance can be switched into the circuit by means of a front panel switch. Five settings each are available for high and low impedances, as well as a bypass choice. A ceramic feed through post on the back panel provides a connection to add an additional 1000 pF capacitor (included with the tuner) to the circuit for matching 160 meter antennas. The small dual use meter can be switched to display SWR or RF power in either a 2000 or 200 W range. The meter lamp is powered by 12 V on the back panel.

The '238A handily matched all bands on both test antennas at full legal limit power. On 10 meters using the G5RV, the capacitor and inductor controls were a bit sensitive to small adjustments. One minor complaint: Measuring forward power in the high power range on the meter caused the indicator to slap the right extreme position during CW keying.

In laboratory tests, the '238A did not match on 160 meters into a 6.25 Ω until 2700 pF of external capacitance was added. Ten-Tec indicates they will provide additional capacitors to purchasers at no extra charge. Also, the power losses on 10 meters were considerably greater than those on other bands. However, the '238A performed very admirably on most other bands, quite often exhibiting the least losses on given band and load combinations.

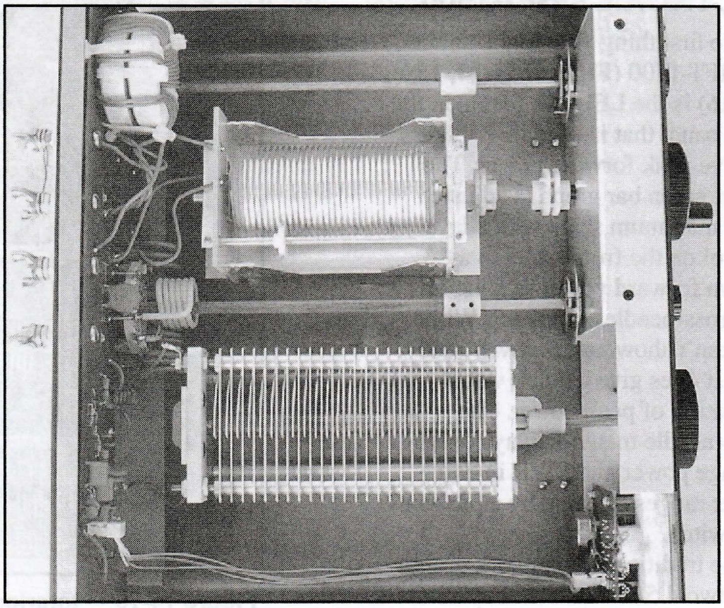

Figure 14-13 — Interior circuitry of the Ten-Tec 238A.

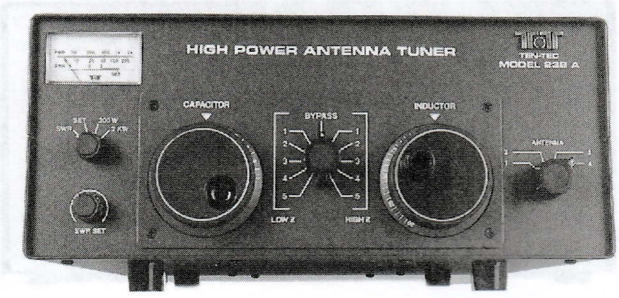

Figure 14-11 — Front panel of the Ten-Tec 238A.

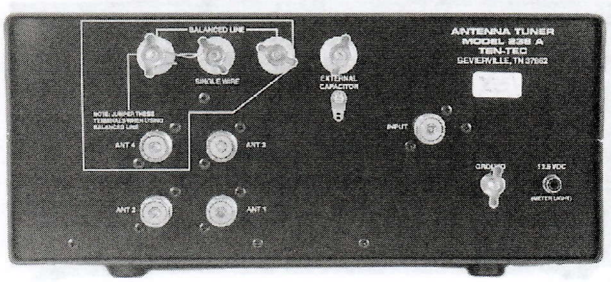

Figure 14-12 — Rear panel connections on the Ten-Tec 238A.

The four-position antenna switch on the front panel allows selection of four coax outputs or a balanced/random wire. The balanced output and one coax connector share position four. A two-core balun is provided for matching the balanced output. The '238A is the only one of the five tuners reviewed here without an air-core inductor. The inductor here has a linen phenolic core.

Since we purchased our review unit, Ten-Tec has produced a substantially identical antenna tuner, the '238B. The Tennessee manufacturer is now selling only the '238B model. Test results are summarized in **Table 14-5**.

Manufacturer: Ten-Tec, 1185 Dolly Parton Pky, Sevierville, TN 37862; tel 865-453-7172; fax 865-428-4483; **www.tentec.com.** 2003 price: $475.00 ('238B).

Table 14-5
Ten-Tec 238A Loss and Bandwidth Test Results

SWR	*Load (Ω)*		*160 m*	*80 m*	*40 m*	*20 m*	*10 m*
8:1	6.25	Power Loss %	No Match	<10	<10	<10	28
		1.5 SWR BW		>5	>5	>5	2
4.1	12.5	Power Loss %	<10	10	<10	<10	22
		1.5 SWR BW	>5	>5	>5	>5	2
2:1	25	Power Loss %	<10	10	<10	<10	17
		1.5 SWR BW	>5	>5	>5	>5	3
1:1	50	Power Loss %	<10	<10	<10	<10	<10
		1.5 SWR BW	>5	>5	>5	>5	>5
2:1	100	Power Loss %	<10	<10	<10	<10	20
		1.5 SWR BW	>5	>5	>5	>5	4
4:1	200	Power Loss %	<10	<10	<10	<10	20
		1.5 SWR BW	>5	>5	>5	>5	4
8:1	400	Power Loss %	<10	<10	<10	10	13
		1.5 SWR BW	>5	>5	>5	>5	1

Notes

"No Match" means that a 1:1 SWR could not be obtained, even with the included 1000 pF external capacitor attached. A match on 160 m at 6.25 was achieved with 2700 pF of external capacitance; the power loss was less than 10%, and the 1.5 SWR BW was greater than 5%.

Power losses are expressed as a percentage. A 21% loss of power is 1 dB. The 1.5-SWR Bandwidth (SWR BW) represents the bandwidth over which an SWR of 1.5:1 or less was maintained as a percentage of the measurement frequencies (1.8, 3.5, 7.2, 14.2 and 29.7 MHz).

VECTRONICS HFT-1500

The first thing you notice about the HFT-1500 (**Figures 14-14, 15** and **16**) is the LED bar graph on the front panel that is used to display relative peak forward power. The bright green bar graph is adjusted to its maximum scale with a level control on the front panel to a known forward power reading on the cross-needle wattmeter. While it doesn't show actual power readings, it does give a quick visual indication of peak power. The cross-needle meter displays only average power and SWR in two power ranges selected by a pushbutton switch.

The traditional T-network design uses two 4.5 kV variable capacitors adjusted with large comfortable

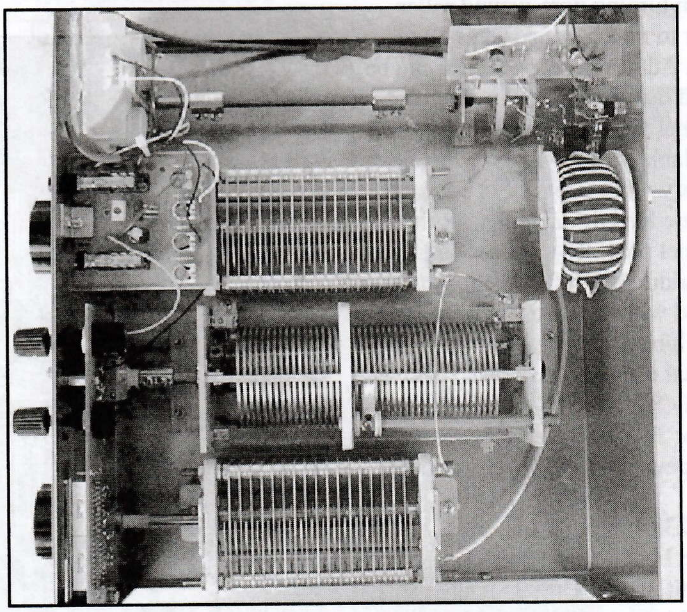

Figure 14-16 — Interior circuitry of the VECTRONICS HFT-1500.

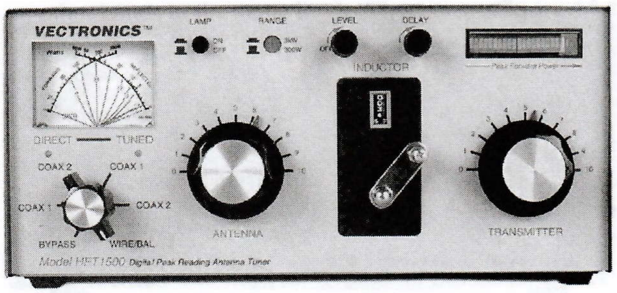
VECTRONICS
LAMP
RANGE
LEVEL
DELAY
Peak Forward Power
INDUCTOR
DIRECT
TUNED
COAX 2
COAX 1
COAX 1
COAX 2
BYPASS
WIRE/BAL
ANTENNA
TRANSMITTER
Model HFT1500 Digital Peak Reading Antenna Tuner

Figure 14-14 — Front panel of the VECTRONICS HFT-1500.

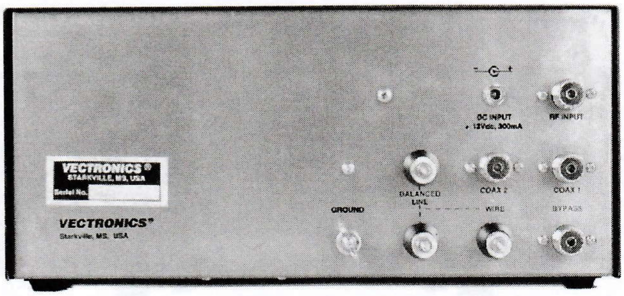
DC INPUT
+13Vdc, 300mA
RF INPUT
VECTRONICS
STARKVILLE, MS, USA
Serial No.
VECTRONICS
Starkville, MS. USA
GROUND
BALANCED LINE
COAX 2
COAX 1
WIRE
BYPASS

Figure 14-15 — Rear panel connections on the VECTRONICS HFT-1500.

Table 14-6
Vectronics HFT-1500 Loss and Bandwidth Test Results

SWR	*Load (Ω)*		*160 m*	*80 m*	*40 m*	*20 m*	*10 m*
8:1	6.25	Power Loss %	45	42	16	15	8
		1.5 SWR BW	1	<1	2	5	>5
4.1	12.5	Power Loss %	32	31	11	<10	<10
		1.5 SWR BW	>5	>5	3	>5	>5
2:1	25	Power Loss %	19	24	<10	<10	<10
		1.5 SWR BW	2	1	>5	>5	>5
1:1	50	Power Loss %	12	<10	<10	<10	<10
		1.5 SWR BW	3	>5	>5	>5	>5
2:1	100	Power Loss %	12	<10	<10	<10	<10
		1.5 SWR BW	3	>5	>5	>5	>5
4:1	200	Power Loss %	<10	<10	<10	<10	<10
		1.5 SWR BW	4	>5	>5	>5	>5
8:1	400	Power Loss %	<10	<10	<10	11	16
		1.5 SWR BW	4	>5	>5	>5	4

Notes

Power losses are expressed as a percentage. A 21% loss of power is 1 dB.

The 1.5-SWR Bandwidth (SWR BW) represents the bandwidth over which an SWR of 1.5:1 or less was maintained as a percentage of the measurement frequencies (1.8, 3.5, 7.2, 14.2 and 29.7 MHz).

knobs and very smooth vernier tuning. This tuner stays put on the desk while you utilize a lever handle and gear driven five digit mechanical turns counter to adjust the air wound roller inductor.

Tuning the 160-meter inverted L and the G5RV on all bands except 10 meters was easily accomplished, with no problems handling 1 kW. In the field, the best SWR that could be obtained on 10 was 2.33:1; this is possibly due to the additional "loading" when a human touches the all-metal inductor crank. The ARRL Lab adjusted the inductor with a wooden pencil in some cases to obtain a match.

The HFT-1500 provides two coax inputs and a third that completely bypasses the tuning network. The balanced and single wire inputs are Delrin terminal posts connected to a large single core 4:1 voltage balun. In some circumstances during lab testing, our engineer felt RF bites through the metal portion of the inductor crank. Later units feature a metal shaft bushing that provides a better ground. This was not experienced in field testing, but tuner adjustments were not made at high power. Test results are summarized in **Table 14-6**.

Manufacturer: Vectronics, 300 Industrial Park Rd, Starkville MS 39759; tel 662-323-5800; fax 662-323-6551; **www.vectronics.com**. 2003 price: $459.95.

Automatic Antenna Tuners — A Sample of the Field

Reviewed by Joel R. Hallas, W1ZR
QST *Technical Editor*
QST *May, 2004*

Automatic antenna tuners can provide a quick and easy method of matching multiband or nonresonant antennas quickly and effortlessly. Performance is on par with manual tuners and there is now a selection available providing a fit to most requirements. A few years back, we surveyed the antenna tuner market in these pages. All those tuners were manual ones.

A few automatic tuners were available at that time, but they were the exception rather than the rule. Since then, a number of manufacturers have focused their attention on automatic antenna tuners and it seems as if there's now one for every application.

For this review we selected representative tuners from a number of manufacturers (see **Figure 14-17**). There are two general configurations: those providing remote tuning, with the tuner intended to be near the antenna, and those intended to be collocated with the station equipment. For those manufacturers having models in each camp, we selected one of each.

As noted in the specifications, each tuner is different and they don't exactly line up head-to-head, so a direct comparison is not always appropriate. Still, for each we will provide the basic data you would need to decide if one of these is a good fit for your needs. If you like the looks of a particular manufacturer, but the tuner reviewed doesn't exactly meet your requirements, check their Web page or your dealer for other models at different power levels or with different features.

For this review we stuck to those at the 100 to 200 W level and tried for a representative self-contained and remote tuner from each manufacturer. For these tests, we looked at units designed to work with any radio. In addition to these, most HF radio manufacturers offer external auto tuners designed to operate exclusively with their radios. One manufacturer, LDG, also offers tuners with the capabilities to operate with specific radios' commands. Many HF radio manufacturers also offer internal auto-tuners as a part of their transceivers. We generally review these as a part of the radios. We elected to stick to general purpose models for this review.

Those selected for this test include the RT-11 and Z-100 from LDG, the MFJ-991 and from SGC the SG-237 and MAC-200.

Remote vs Collocated Autotuners

It's probably worth a paragraph or two to discuss the relative merits and appropriateness of the two configurations. If the antenna(s) to be matched terminate right at the station equipment, without a transmission line (or with a very short one), there is no particular advantage to having a remote tuner.

On the other hand, that setup often results in problems with "RF in the shack," or EMI within the house. I have one antenna setup of that form and whenever I use it, the RF resets the kitchen FM radio, causing it to lose track of time and memory. Most find it a better solution to have the antenna system stop somewhere outside the house and have a transmission line interconnect the radio and antenna.

With a remote tuner, the matching can be at or near the antenna, resulting in a well matched transmission line coming back to the radio. With the tuner at the radio, the matching takes place near the radio, and the SWR on the line out to the antenna will often be high. Note that in both cases the radio will be provided a good match and will happily put full power into the system. With the remote tuner, often more of the power will be radiated by the antenna and less will be dissipated as heat by the transmission line.

Some radios now come with automatic tuners as part of the radio. These can be functionally equivalent to the local tuner. The separate tuner does offer two advantages over the

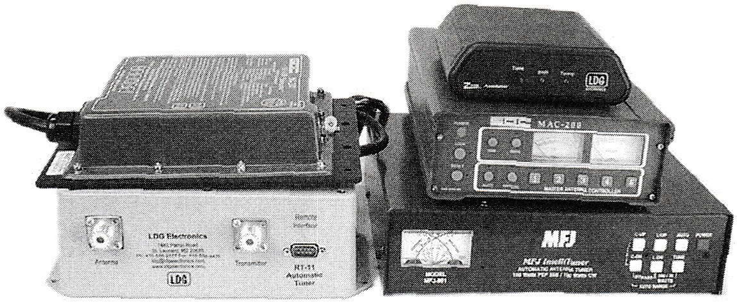

Figure 14-17 — Automatic tuners from LDG, MFJ and SGC — ready for test.

internal tuner — it can support multiple radios, and most can match a higher SWR than many of the internal tuners. The key factor in deciding between a local and a remote tuner then becomes how much of the transmitter power actually reaches the antenna system and how much will heat up the transmission line. This is a function of operating frequency, SWR and line length.

The place to start the analysis is with *The ARRL Antenna Book.*[1] Figure 23 in Chapter 24 provides the attenuation in 100 feet of *matched* transmission line for each of the common types. Table 14 in the same chapter provides the *additional* loss for the non-matched case as a function of SWR and matched loss. [The same data is in Chapter 7 of this book.] Using the two tables, you can determine the total loss of your transmission line.

If the loss is acceptable, you can tune at the transmitter end. If not, by tuning at the antenna end you can eliminate most of the additional loss due to mismatch.

An example might be helpful. A multiband antenna such as my G5RV might have a 5:1 SWR on parts of 10 meters. If we feed it with 150 feet of RG-58 cable we have a matched loss of about 3.5 dB and the 5:1 SWR adds about another 2 dB for a total of 5.5 dB loss or about 71% of our power heating up the line! By moving the tuner to the antenna end of the coax, we reduce that to 55%. Another option is to change the transmission line (my solution immediately after making that calculation!).

If we go with lower loss RG-8 instead, we have a matched loss of about 2 dB (1.3 dB per 100 ft) and the SWR adds about another 0.3 dB for a total of 2.3 dB, or a loss of about 41% of our power. With the tuner at the antenna, the total loss would be the 2 dB or 37%—not much of a difference. Note that I didn't consider the tuner losses here, under the assumption that they would be the same at either location. The numbers get much more grim as the SWR goes up, by the way.

Two notes of caution—first, if you measure the SWR at the shack end of the cable, it will appear better than it is, due to the cable loss; second, the matched loss from Figure 23 is the *best* matched loss for new and dry cable. The actual loss can only go up from there, especially if the cable came from some dark corner of your basement, or worse, from an unknown source at a flea market.

Note that all of these tuners are designed for unbalanced (coax) cable between the tuner and the radio and, with the exceptions noted, unbalanced operation on the antenna side (coax or single wire antennas) as well. In order to use these tuners with a balanced load, it is best to decouple the ground side of the tuner from the transmission line. A coax choke can be used, or a balun (balanced to unbalanced transformer) can be employed. If you are using a balun, it is best to keep the line impedance within a SWR of about 4:1 (with respect to the usual 200 Ω impedance of a 4:1 balun) to avoid heating, loss and possible balun damage. A subsequent planned review will look at the special class of unbalanced to balanced tuners that sidestep this issue in an elegant way and are once again appearing on the market.

A word or two about the data shown may be in order. Please note that we used the same precision resistive load set for each tuner. In most cases, this includes data outside the manufacturers' specification range. We measured at a single frequency in each band, and for 6 meters we just measured the case with a 1:1 load for all the tuners that claimed operation there.

LDG RT-11 and Z-100

A look at LDG's Web page, **www.ldgelectronics.com**, will show you their selection of tuners and accessories. In addition to the RT-11 remote control tuner and the Z-100 local tuner, tested (see **Figure 14-18**), they offer an autotuner rated at 1000 W. As this review was being prepared in 2004, they also announced a much more feature rich desktop unit to complement the very basic, but lower cost Z-100.

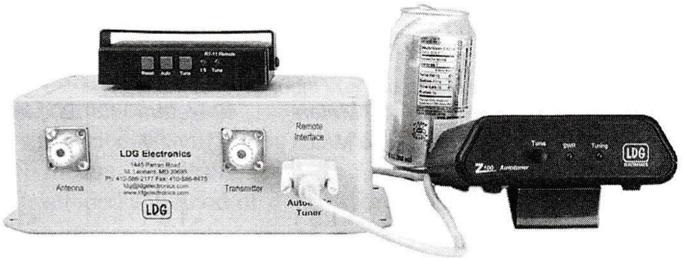

Figure 14-18 — LDG RT-11 (left) with control box and Z-100. A 12 ounce beverage container provides scale.

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[1] Notes appear on page 14-35.

LDG RT-11

The RT-11 is a rugged, weatherproof tuner designed to be used inside or outdoors. It has coax connectors on input and output and is rated at 125 W from 1.8 to 30 and 50 W to 54 MHz. It is rated to match antennas with an SWR of 10:1 to 30 MHz and 3:1 from 50 to 54 MHz. This unit has an optional remote control designed to be used up to 100 feet from the tuner (15 foot cable supplied).

The remote control provides the ability to force a new tune, set for semi or full auto operation, keep the unit from tuning and allows bypassing of the tuner (straight through operation for matched antennas or out of band receive). In addition, LED indicators let you know the status and whether the SWR is below 1.5:1. One caution with the remote, the mounting bracket screws are not captive so you may want to use double-sided tape to secure it to a surface.

The RT-11 also has a jack to allow interfacing to radios designed to control proprietary tuners by emulating their commands. Special cables are offered to hook to various Alinco, ICOM, Kenwood and Yaesu radios for this purpose.

In my trials at home, I found that the RT-11 effortlessly tuned every antenna I had on all bands with a very low SWR, always well below 1.5:1. The tuning seemed to take about 5 seconds and hit the result the first time.

While automatic operation is possible without radio interface or remote control, I would have trouble imagining it and would suggest the remote for those without a compatible radio. For one thing, once tuned, it won't automatically restart the tuning process until the SWR reaches 3:1, a value that might cause many radios to "fold back" (reduce power) significantly.

The manual mentions that tuning should take place at the 25 W level, with full power applied only after tune is achieved, so that relay life will not be reduced. They also indicate that if a radio has the common power output fold back with high SWR it will automatically reduce power appropriately. I wouldn't count on that providing sufficient reduction, especially as the match is approached; I would instead manually reduce power while tuning.

LDG Z-100

The Z-100 is a self contained desk top unit with a 125 W rating (50 W on 6 meters). This unit is the first of a new series of tuners being released by LDG, with others providing additional features and controls. This is a basic unit corresponding to its low price, but none the less provides the needed tuning functions with straightforward "one button" operation. It includes memory of the settings for the last 200 matches made and tries those before it branches to its *unknown tune* algorithm. This is a clever idea that avoids the need to measure frequency. It is particularly useful for the case in which more than one antenna is used, since it really doesn't care — if it made the match before it will do it again, in a fraction of a second.

A feature of this unit is that it only draws power when actually tuning. Upon completion, the relays remain latched without power required until

Table 14-7
LDG RT-11 Remote Automatic Antenna Tuner

Manufacturer's Specifications	*Measured in ARRL Lab*
Input SWR range: to 10:1 (3:1 on 6 meters).	See below.
Output SWR range: not specified.	See below.
Frequency coverage: 1.8 to 54 MHz.	As specified.
Input power: 0.1 to 125 W, 50 W on 6 meters.	Tested at 50 W on HF, 20 W on 6 meters.
Power requirements: 11 to 14 V dc, 7 to 250 mA.	Idle 0 mA, max 140 mA at 13.8 V dc.

Measured power loss into resistive loads (%) / Input SWR at match:

SWR	*Load (Ω)*	*160 Meters*	*80 Meters*	*40 Meters*	*20 Meters*	*10 Meters*	*6 Meters*
16:1	3.125	No Match	No Match	27	22	<10	
				<1.5:1	2.6:1	<1.5:1	
8:1	6.25	No Match	17	17	19	20	
			<1.5:1	<1.5:1	<1.5:1	<1.5:1	
4:1	12.5	11	11	12	13	26	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<2:1	
2:1	25	<10	<10	<10	<10	23	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	2.1:1	
1:1	50	<10	<10	<10	<10	<10	21
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	2.1:1
2:1	100	<10	<10	<10	<10	17	
		<2:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	
4:1	200	<10	<10	<10	<10	15	
		<2:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	
8:1	400	<10	<10	<10	<10	28	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	
16:1	800	<10	12	<10	<10	19	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	

Table 14-8
LDG Z-100 Desktop Automatic Antenna Tuner

Manufacturer's Specifications	*Measured in ARRL Lab*
Input SWR range: to 10:1 (3:1 on 6 meters).	See below.
Output SWR range: not specified.	See below.
Frequency coverage: 1.8 to 54 MHz.	See text.
Input power: 0.1 to 125 W, 50 W on 6 meters.	Tested at 50 W on HF, 20 W on 6 meters.
Power requirements: 7 to 18 V dc, 250 mA.	Idle 0 mA, max 160 mA at 13.8 V dc.

Measured power loss into resistive loads (%) / Input SWR at match:

SWR	*Load (Ω)*	*160 Meters*	*80 Meters*	*40 Meters*	*20 Meters*	*10 Meters*	*6 Meters*
16:1	3.125	No Match	No Match	15	10	<10	
				<1.5:1	<1.5:1	<1.5:1	
8:1	6.25	No Match	13	15	15	20	
			2.6:1	<2:1	<1.5:1	<2:1	
4:1	12.5	No Match	<10	<10	<10	<10	
			<1.5:1	<1.5:1	<2:1	<1.5:1	
2:1	25	<10	<10	<10	<10	17	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	
1:1	50	<10	<10	<10	<10	<10	20
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	<2:1
2:1	100	<10	<10	<10	<10	<10	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	
4:1	200	<10	<10	<10	11	<10	
		2.1:1	2.2:1	<1.5:1	<1.5:1	<1.5:1	
8:1	400	<10	<10	<10	11	<10	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<2:1	
16:1	800	11	14	15	33	43	
		2.2:1	2.3:1	<1.5:1	<1.5:1	<1.5:1	

the next tune is requested. This is particularly appealing for portable low power operations in which every milliamp-hour is carried in.

The operation of this tuner is fundamentally different from the others in that it will only tune when the TUNE button is pushed. This has an advantage in that it will not start tuning inadvertently on high SWR, potentially applying full power during tune. Upon changing frequency, the operator can decide whether or not to initiate the tune cycle. By pushing the button for less than 0.5 seconds, the tuner goes to bypass. Between 0.5 and 3 seconds the tuner will attempt to find a match from memory (typically less than half a second), and only initiate a full tune if needed. If the button is pushed for more than 3 seconds a full tune cycle is initiated, ignoring any memorized settings.

This is easier to deal with than it sounds since the LEDs provide a confirmation of tuning mode. A green LED also indicates if the match is less than 1.5:1 or between 1.5 and 2:1. An early production unit exhibited some inconsistent tuning results on 6 meters. The manufacturer has developed a method of improved internal decoupling that solved this problem and the results reflect that change. LDG states that this will be included in future production units and that anyone having problems with 6 meter tuning on early units should contact them directly.

Manufacturer: LDG Electronics Inc, 1445 Parran Rd, PO Box 48, St Leonard, MD 20685; tel 877-890-3003; fax 410-586-8475; **www.ldgelectronics.com**. 2004 prices: RT-11 Tuner, $209; Remote head, $39; Z-100, $149; 12 V power cube for either tuner, $10.

MFJ-991

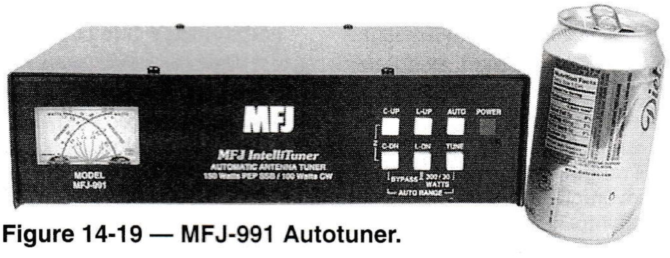

Figure 14-19 — MFJ-991 Autotuner.

MFJ has recently announced a series of autotuners. All are in the typical indoor/ colocated configuration, but with the available remote kit (ordered, but not received in time for the review) can be used as a remote tuner if kept out of the weather. They offer the MFJ-991 (tested, as shown in **Figure 14-19**) 150 W rated tuner, a tuner with similar features rated at 600 W and a 300 W autotuner with digital display, balun and two port antenna switch. As with the LDG, the MFJ tuners require their tuning be accomplished at reduced power.

The MFJ-991 front panel provides full control capability and forward and reflected power metering with "crossed-needle" SWR measurement display. Two features of the '991 are not found on other tested units and are worth mentioning. First, the '991 has the capability to allow manually adjusting the C and L values of the tuner while in receive. This is helpful if you are using your radio for receive only and wish to attempt to match in order to increase signal strength. The second feature is the ability to select the SWR threshold at either 1.5 or 2:1.

In our testing the tuner went to the best match it could find in either case. The difference was in how far you could change frequency before it would automatically retune when you transmitted. If your radio can tolerate a 2:1 SWR, this could provide a benefit. The '991 could tune my G5RV on all bands and remembered the last setting for each frequency (1000 memories), with a one-click reset. Tuning the first time on a frequency was typical of the cycle time of the other units. This unit sounded somewhat louder (it has 18 heavy duty relays) than the other test samples, although not an issue for the single click associated with a memorized tune.

The MFJ-991 can interoperate with ICOM and Alinco tuner control commands. Appropriate interface cables are available from MFJ.

In addition to the obvious controls and indicators, there are some subtle ones as well. There are a number of meter "signals" sent to the operator that will not be clear without a cruise through the manual. For example, if you forget to reduce power before tuning, the power meter swings to full scale and the tuner is bypassed. If you toggle between 1.5 and 2:1 SWR threshold, the meter briefly jumps up to indicate that SWR.

Manufacturer: To order, or for your nearest MFJ dealer, call MFJ Enterprises at 800-647-1800 or order at **www.mfjenterprises. com**, fax 662-323-6551; or write MFJ Enterprises, Inc, 300 Industrial Park Rd, Starkville, MS 39759. [2004] Price: $220.

Table 14-9
MFJ-991 Desktop/Remote Automatic Antenna Tuner

Manufacturer's Specifications	*Measured in ARRL Lab*
Input Impedance range: 6 to 3200 Ω.	See below.
Output SWR range: 1.5:1 or 2:1 selectable.	See below.
Frequency coverage: 1.8 to 30 MHz.	As specified.
Input power: 5 to 150 W.	Tested at 50 W.
Power requirements: 12 to 15 V dc, 1.0 A.	Idle 90-300 mA, max 500 mA at 13.8 V dc.

Measured power loss into resistive loads (%) / Input SWR at match:

SWR	*Load (Ω)*	*160 Meters*	*80 Meters*	*40 Meters*	*20 Meters*	*10 Meters*
16:1	3.125	No Match	27	20	15	<10
			<1.5:1	<1.5:1	<1.5:1	<2:1
8:1	6.25	12	14	15	24	19
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	2.6:1
4:1	12.5	<10	<10	<10	<10	12
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1
2:1	25	<10	<10	<10	<10	<10
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1
1:1	50	<10	<10	<10	<10	<10
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1
2:1	100	<10	<10	<10	<10	<10
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1
4:1	200	<10	<10	<10	<10	<10
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1
8:1	400	<10	<10	<10	11	11
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1
16:1	800	<10	16	<10	<10	23
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1

SGC SG-237 and MAC-200

SGC has been making automatic antenna tuners for many years, and offers a wide selection. Until recently, they concentrated on remote tuners, usually the weatherproof type, at power ratings of 100 to 500 W. More recently, they have introduced a number of variations of their SG-237, a board version to build into your own radio or antenna cabinet, an open enclosure model for remote but indoor use and one with controls and indicators intended for portable use. They have recently released a Multiple Antenna Controller, MAC-200. The units we tested were an SG-237 (one that has fed the backstay of my sailboat for some years) and a relatively new combination unit, the MAC-200 (as shown in **Figure 14-20**).

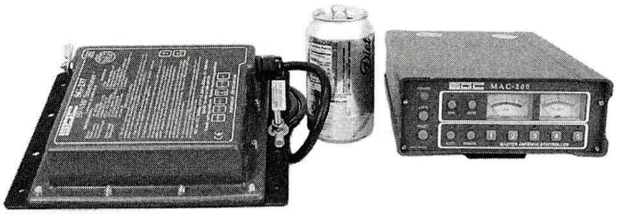

Figure 14-20 — SGC SG-237 (left) and MAC-200.

SGC SG-237 Autotuner

The SG-237 was the first in a series of SGC tuners that were much more compact than their previous (and continuing) line, the SG-230 (200 W, 1.6-30 MHz), SG-231 (100 W, 1-60 MHz) and SG-235 (500 W, 1.8-30 MHz). The SG-237 is rated at 100 W PEP, both for operation and for tuning (40 W continuous carrier power). The transmitter connection is via a 9 foot combined RF, control and power cable (25 and 50 foot extensions are available), while the antenna connection is via a single ceramic insulated terminal. While the tuner is designed to feed a single wire against ground, I have successfully employed mine into coax fed antennas as well as loops and single wires.

This is a rugged unit in a compact waterproof aluminum enclosure that can slide in almost anywhere. It needs no remote control box to work, and I've used mine that way for years. An optional remote control is offered (and we tested with it) to provide a positive indication of match and to allow a lockout or a forced reset. The lockout can be handy in a portable or mobile environment to avoid the tuner attempting to retune due to the temporary proximity of outside objects while in motion, for example.

The '237 provides a memory function that uses the measured transmitter frequency to result in the tuner settings last used to successfully tune to that frequency. This means that instead of taking 5 to 10 seconds to tune, the previously stored settings for a frequency are applied in milliseconds and used if the resulting SWR

Table 14-10
SGC SG-237 Remote Automatic Antenna Tuner

Manufacturer's Specifications	*Measured in ARRL Lab*
Input SWR range: corresponding to a minimum 7 foot antenna above 3.5 MHz, 23 feet above 1.8 MHz.	See below.
Output SWR range: 1.4:1 typical.	See below.
Frequency coverage: 1.8 to 60 MHz.	As specified.
Input power: 3 to 100 W.	Tested at 50 W.

Power requirements: 10.5 to 18 V dc, 300 mA. Idle and tuning 270 to 480 mA at 13.8 V dc.

Measured power loss into resistive loads (%) / Input SWR at match:

SWR	*Load (Ω)*	*160 Meters*	*80 Meters*	*40 Meters*	*20 Meters*	*10 Meters*	*6 Meters*
16:1	3.125	21	21	19	No Match	<10	
		<1.5:1	<1.5:1	<1.5:1		<1.5:1	
8:1	6.25	16	18	20	24	23	
		<1.5:1	2.1:1	<1.5:1	<1.5:1	<1.5:1	
4:1	12.5	11	12	15	17	23	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	
2:1	25	<10	11	21	18	26	
		<1.5:1	<1.5:1	<2:1	<2:1	<1.5:1	
1:1	50	<10	<10	<10	<10	12	29
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1
2:1	100	<10	<10	<10	13	14	
		<2:1	<2:1	<1.5:1	<1.5:1	<1.5:1	
4:1	200	No Match	<10	<10	16	10	
			2.1:1	<1.5:1	<1.5:1	<1.5:1	
8:1	400	No Match	<10	10	16	18	
			2.1:1	<1.5:1	<1.5:1	<1.5:1	
16:1	800	<10	<10	14	30	58	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<2:1	

is less than 2:1. In some cases they won't be right (and a new tune will be initiated), if a different antenna is used, for example, but their concept is that this tuner is out where the antenna is and thus should see the same impedance for a given frequency each time that frequency is employed.

SGC MAC-200 Multiple Antenna Controller

This device combines a 200 W autotuner, a five port automatic or manual antenna switch, power and SWR meters and a balun in one compact package. This is a nice unit and quickly grew on me in operation. It has enough controls and indicators to keep me entertained even when the bands aren't open.

For some time, most manual tuners have had provisions for switching antennas as well as tuning them. This is very handy, since even those with just one antenna should have a dummy load to switch to for tune up. I have no numbers, but I would guess more hams have more than one HF antenna than have only one. I don't have fancy HF antennas, but I have a G5RV I use on 80 through 10, a Lazy-H, perpendicular to the G5RV for 30 through 10 meters and a 70 foot wire vertical for use when it makes sense (not often in my part of New England).

With the MAC-200, I can memorize which antenna to use on which band. It switches antennas on the first dot of a CW string (full power—no problem) and I'm there. As noted, at my station, on some bands the antenna is a function of the direction to the distant station, I can just touch the MANUAL button and I can select a different antenna by touching a button numbered 1 to 5.

As configured, antenna one is intended for balanced feed, antenna two has a terminal for a single wire feed, and three through five are terminated in UHF (SO-239) coax connector jacks.

The separate meters for power and SWR are handy. The SWR meter is especially convenient in that it computes and indicates SWR independent of power level without an adjustment. The manual warns that the meters are not of the precision type and I can attest to that. Their meter indicated 80 W while my Bird 43 showed 100. This is still very useful to let you know if all is well.

This is a handy unit, in a cabinet matching the cross section of the SGC-2020 transceiver (but somewhat longer), it can be made to fit in most shacks. In mine it can slide beneath the shelf that holds my equipment three inches above the desk, for example.

The one limitation some may have is it provides a "typical" match of 2:1. Well 2:1 is fine for some transmitters, while others may start to "fold back" above 1.5:1 and this may be a problem if yours is in that group. On the other hand, looking at the data it is clear that most of the time it was below 1.5:1 with our loads.

Our original unit remembered which antenna to use on each band, but didn't memorize tuner settings. A warranty replacement unit had a flawless memory function.

Manufacturer: SGC Inc, 13737 SE 26th St, Bellevue, WA 98005; tel 425-746-6310; fax 425-746-6384; **www.sgcworld.com**. 2004 price: SG-237, $360; Smartlock remote control, $59; MAC-200, $360.

Table 14-11
SGC MAC-200 Desktop Automatic Antenna Tuner and Controller

Manufacturer's Specifications	*Measured in ARRL Lab*
Input impedance range: 5-1000 (feed line) 0.2-5000 (long wire).	See below.
Output SWR range: 2:1 typical.	See below.
Frequency coverage: 1.8 to 60 MHz.	As specified.
Input power: 1.5 to 200 W.	Tested at 50 W.
Power requirements: 10 to 18.5 V dc, 230 mA. Idle 240 mA, max 490 mA at 13.8 V dc (meter light off)	Idle 280 mA, max 530 mA at 13.8 V dc (meter light on)

Measured power loss into resistive loads (%) / Input SWR at match:

SWR	*Load (Ω)*	*160 Meters*	*80 Meters*	*40 Meters*	*20 Meters*	*10 Meters*	*6 Meters*
	6 Meters						
16:1	3.125	No Match	39	24	<10	<10	
			<2:1	<2:1	<1.5:1	<1.5:1	
8:1	6.25	No Match	16	18	15	30	
			<1.5:1	<1.5:1	<1.5:1	<1.5:1	
4:1	12.5	<10	<10	<10	18	27	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	
2:1	25	<10	<10	<10	<10	25	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	2:1	
1:1	50	<10	<10	<10	<10	12	27
		<2:1	<1.5:1	<1.5:1	<1.5:1	<2:1	<2:1
2:1	100	<10	<10	<10	<10	14	
		<1.5:1	<2:1	<2:1	<2:1	<1.5:1	
4:1	200	<10	<10	<10	<10	14	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<2:1	
8:1	400	<10	<10	13	15	17	
		<1.5:1	<1.5:1	<1.5:1	<1.5:1	<1.5:1	
16:1	800	No Match	22	14	25	31	
			<1.5:1	<1.5:1	<1.5:1	<1.5:1	

Medium to High Power Auto Antenna Tuners — The Evolution Continues

Reviewed by Joel R. Hallas, W1ZR
QST *Technical Editor,*
QST *August 2006*

We last looked at a selection of automatic antenna tuners in May 2004 (see previous section). At that time, we picked four examples, two designed for remote operation and two desktop units. While different in many ways, they all were limited to 100 to 200 W. Higher powered automatic antenna tuners have been available, but they were either built into high powered amplifiers (ICOM or Yaesu, for example), were designed for remote operation as in the SGC SG-235, or have been discontinued, as in the case of the Ten-Tec 253.[2]

High powered automatic antenna tuners initially appeared in the 1980s — the Heath 2500, J.W. Miller AT2500, and Daiwa CNA-1001 — but they were not as sophisticated as the units reviewed here, requiring some manual adjustment or presetting of the inductor for best operation.[3,4,5]

Modern solid state transceivers and linear amplifiers with their "no tune" output stages have been well received, especially by those of us who grew up in the vacuum tube era.

The typical transmitter of that time required careful adjustment of the transmitter TUNE, LOAD and DRIVE controls, at a minimum, every time we changed frequency. Failure to do it right could result in destruction of the final amplifier tubes — sometimes a pricey proposition. The other side of the coin is that those transmitters could be adjusted to match antenna loads with a much higher SWR than the current crop of radio gear.

The modern no-tune feature generally means "no tune if the SWR is 1.5:1 or less," something that often doesn't fit with real world antennas and wide amateur bands. The answer has been an antenna system matching unit, often called an antenna tuner, even though many would argue that it doesn't really tune the antenna — rather it transforms the impedance at the bottom of an antenna system to the 50 Ω the radio equipment wants to operate into. Setting semantics aside, it seems that the controls we used to have to adjust haven't disappeared but have moved from the radio to another box — the antenna tuner.

Enter the Automatic Antenna Tuner

To extend the no-tune concept all the way to the antenna requires a no-tune, or *automatic*, antenna tuner. As noted, these have been generally available for some time at the power levels of modern transceivers, Each of these tuners can effectively add an automatic antenna matching system to your medium to high power HF station, at least up to their power limits. Honor the caveats and you will appreciate the freedom they provide.

For this review we have selected three desktop models that span the medium to high power range and highlight some other differences as well. While they all fill the same spot in a station block diagram, they are quite different in several respects and thus should not be directly compared on a 1:1 basis. Rather, determine if one or more will meet your needs, desires and budget.

All of the tuners reviewed in the 2004 report shared the same adjustment mechanism — fixed inductors and capacitors switched by relays. The LDG and MFJ tuners reviewed here share that architecture as well, but with beefier components designed to meet the higher power requirements of their ratings. The Palstar AT-Auto is of a completely different design, a T network with a differential variable capacitor, half on each side of a shunting rotary inductor. The Palstar makes its adjustments via stepper motors rather than relays. Interestingly, while standalone tuners have tended to be of the relay type, many internal tuners have used motor driven capacitors. Motor driven components were also used in the high powered automatic tuners from the 1980s mentioned previously, so this is a time-tested approach. We'll look at each tuner in alphabetical order. These tuners from LDG, MFJ and Palstar offer the convenience of automatic tuning at medium to high power levels.

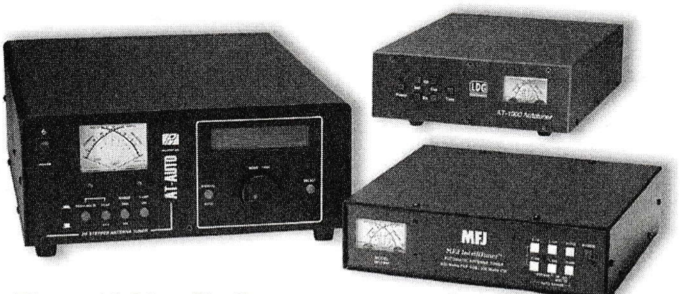

Figure 14-21 — Medium power tuners from Palstar, LDG and MFJ.

LDG AT-1000 Automatic Memory Antenna Tuner

The LDG AT-1000 sits squarely in the middle of the pack, both in terms of price and power rating. The 1000 W level fits nicely with a good selection of popular, not quite legal limit, linear amplifiers, including a couple announced at Dayton in 2006. All of the tuners reviewed here cover 160 through 10 meters, but the AT-1000 offers operation on 6 meters at the 100 W level as well.

The LDG, in common with the other units, has memories to allow a rapid return to the last previously matched settings. In the case of the AT-1000, there are 200 memory locations and the tuner will reset to them in less than half a second. If the antenna you are tuning does not have a memorized setting that works, the tuner can spend up to 8 seconds finding a match, but will remember for the next time.

The LDG approach to memory management is different from some. Some others tuners store settings based on frequency. This is a great approach if you will be tuning a single antenna for each band. In the LDG AT-1000, the last 200 successful matches are stored independent of frequency. A new match request quickly cycles through the 200 to see if a match is found before it begins its tune algorithm. This is a particularly beneficial approach if you switch the tuner output to different antennas on the same band, since it doesn't have to relearn parameters for a particular frequency every time you change antennas. It also avoids the need for frequency measuring circuitry within the tuner.

The AT-1000 has a fairly Spartan front panel that doesn't immediately show its capabilities. LDG has made

Table 14-12
LDG AT-1000

Manufacturer's Specifications

Maximum power, 1000 W SSB, 750 W CW,
500 W digital, 100 W 6 meters.
20 W while tuning (100 W with foldback),
75 W (3:1 SWR), 125 W (1:1 SWR).
Minimum power for tuning: 5 W.
Frequency range: 1.8 to 54 MHz.

Tuning time: 1 to 8 seconds.
0.5 second if memorized
Input impedance: 6 to 800 ..
Power required: 11 to 15 V, 1 A.
Dimensions (height, width, depth):
3 × 13 × 9 inches.
Weight: 6 pounds.

Measured power loss into resistive loads (%) / Input SWR at match. Tested at 50 W.

SWR	*Load (Ω)*	*160 m*	*80 m*	*40 m*	*20 m*	*10 m*
16:1	3.125	No match n/a	No match n/a	No match n/a	No match n/a	No match n/a
8:1	6.25	No match n/a	No match n/a	* **	20 1.6:1	22 **
4:1	12.5	12 2.3:1	* **	* **	* **	18 2.2:1
2:1	25	* **	* **	* **	* **	* **
1:1	50	* **	* **	* **	* **	* **
2:1	100	* **	* **	* **	* 2.1:1	* **
4:1	200	* **	* **	* **	* **	* **
8:1	400	16 2.1:1	* **	* **	22 2.1:1	17 **
16:1	800	No match n/a	18 **	17 **	55 **	No match n/a

*Power loss less than or equal to 10%.
**Matched SWR less than or equal to 1.5:1.

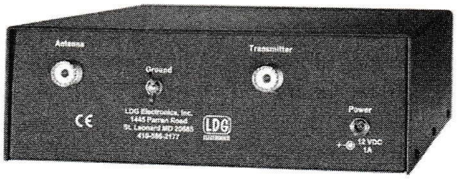

Figure 14-23 — Rear panel connections on the LDG AT-1000.

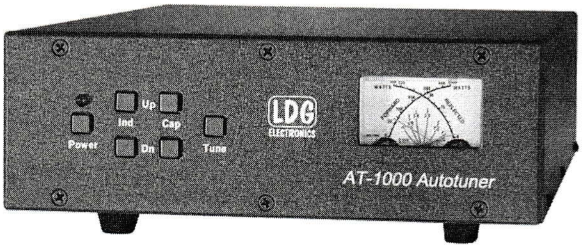

Figure 14-22 — Front panel of the LDG AT-1000.

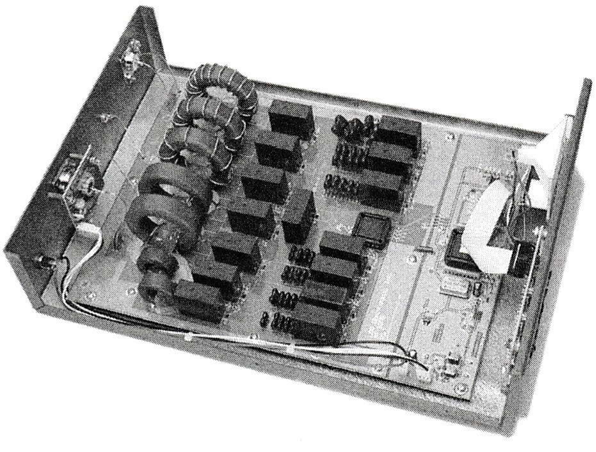

Figure 14-24 — Interior circuitry of the LDG AT-1000.

maximum use of the cross needle wattmeter on the front panel, going further with information delivery than I would have imagined with such a straightforward display. The cross needle wattmeter has two scales, reading forward (1000 W) and reflected (180 W) power simultaneously. The point at which the meter pointers cross is a third scale directly reading in SWR. So far it's just like every other cross needle meter we've seen.

What sets the AT-1000 apart is that LDG has additional indicator functionality that appears as a set of semaphore signals between tuner and operator. Each needle is driven independently in this mode and each can vary in speed and position as it fills you in on the tuner's condition and status. For example, if during a tuning cycle, both arms quickly raise fully (in surrender?) it means too much power has been supplied to allow it to safely tune. It then switches to bypass mode and goes on break until you reduce power and restart the tuning cycle.

Another feature is the ability to change the inductance and capacitance parameters manually. This can be a benefit in at least two ways. First it allows manual fine trimming of the tuning in case you want a better SWR than the tuner finds automatically. Manual tuning can also be used to peak up the receive signal strength if you're listening to a station on a frequency that you can't transmit on. This could include shortwave broadcast frequencies or bands or segments for which you don't yet have license privileges.

How'd it Work? At my station the AT-1000 did everything I asked of it without problems. My antennas tuned satisfactorily on all bands. Memorized settings were recalled without difficulty in a fraction of a second. The 15 page multicolor manual does a good job of describing how to set up and use the tuner. A table of "meter bounce codes" is included, and you will likely want to keep a copy at hand, unless your memory is much better than mine. ARRL Lab test results are shown in **Table 14-12**.

Manufacturer: LDG Electronics, 1445 Parran Rd, St Leonard, MD 20685; tel 410-586-8475; **ldg@ldgelectronics.com**; **www. ldgelectronics.com**. 2006 price: $599.

MFJ-994 Intellituner Automatic Antenna Tuner

At first glance, the MFJ-994 appears to be a very similar tuner to the AT-1000. It has almost the same controls and indicators as the LDG tuner, although they are on opposite sides of the front panel. It makes use of a similar set of semaphore indications. The major differences are:

- The MFJ tuner has a lower maximum power rating (600 vs 1000 W PEP and 300 vs 750 W CW) and a correspondingly lower price.
- The '994 provides an interface to allow operation using the TUNE button on Alinco, ICOM, Kenwood or Yaesu radios equipped to control an antenna tuner. An accessory cable is required to activate this function.
- The '994 has more memory locations, all indexed by frequency.
- The '994 offers a choice of two power meter scales, 3000 or 300 W forward power with corresponding 600 or 60 W reflected power at full scale.

During the review process, we determined that the MFJ-994 has now been superseded by the MFJ-994B. The functionality and operation are similar, with the same tuning and switching elements. The main difference seems to be the memory management function, with the B

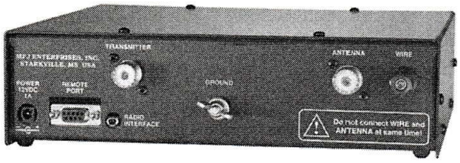
TRANSMITTER
MFJ ENTERPRISES, INC. STARKVILLE, MS USA
POWER 12VDC 1A
REMOTE PORT
GROUND
RADIO INTERFACE
ANTENNA
WIRE
Do not connect WIRE and ANTENNA at same time!

Figure 14-26 — Rear panel connections on the MFJ-994.

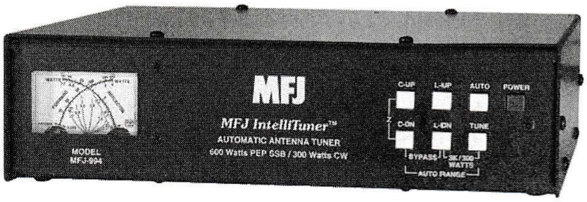

Figure 14-25 — Front panel of the MFJ-994.

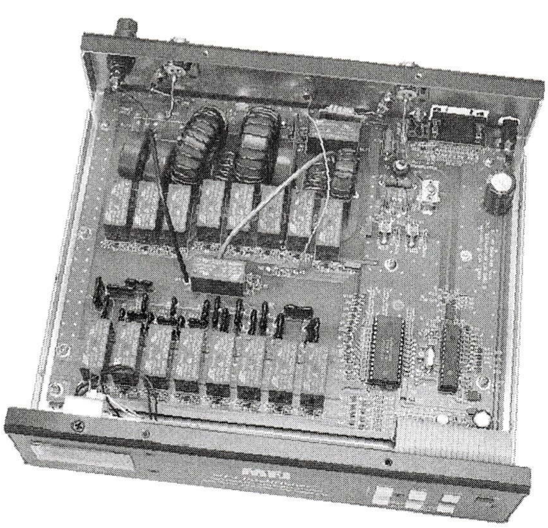

Figure 14-27 — Interior circuitry of the MFJ-994.

Table 14-13
MFJ-994

Manufacturer's Specifications

Maximum power, 600 W PEP SSB, 300 W CW, 20 W while tuning (100 W with foldback).
Minimum power for tuning: 10 W.
Frequency range: 1.8 to 30 MHz.
Input impedance: 12 to 800.
Power required: 12 to 15 V, 1 A.
Dimensions (height, width, depth) 2.8 × 10.1 × 9.2 inches.
Weight: 3.7 pounds.

Measured power loss into resistive loads (%) / Input SWR at match. Tested at 50 W.

SWR	*Load (Ω)*	*160 m*	*80 m*	*40 m*	*20 m*	*10 m*
16:1	3.125	No Match	No Match	10	12	*
		n/a	n/a	2.6:1	2.2:1	2.0:1
8:1	6.25	13	13	*	13	15
		2.4:1	1.8:1	**	**	2.2:1
4:1	12.5	*	*	*	*	15
		**	**	**	**	1.8:1
2:1	25	*	*	*	*	*
		**	**	**	**	**
1:1	50	*	*	*	*	*
		**	**	**	**	**
2:1	100	*	*	*	*	*
		**	**	**	**	**
4:1	200	*	*	*	*	*
		**	**	**	**	**
8:1	400	*	*	*	14	*
		**	**	**	**	1.8:1
16:1	800	*	17	16	11	*
		**	**	**	1.8:1	1.7:1

*Power loss less than or equal to 10%.
**Matched SWR less than or equal to 1.5:1.

model including a virtual memory function said to store up to 10,000 frequency data points versus 1000 in the earlier '994. The other difference noted in the specs is that the new one can tune with a minimum of 2 W, versus 10 W in the original.

The MFJ has some control flexibility hidden behind its few buttons. The "tuned" threshold can be set to either 1.5:1 or 2:1. With the 1.5:1 setting, the match is closer, but it will take a bit longer to find. While 2:1 should happen more quickly, some radios won't put out full power into a 2:1 load. It's nice to have the choice. An "auto tune" function is also provided that causes the tuner to activate if the SWR goes above your threshold by a user selectable 0.5, 1.0 or 1.5. This is handy as you change frequency, but be careful it doesn't drop into tuning mode while you are at full power. Pushing in the AUTO button unambiguously disables the auto tune function, entirely avoiding this concern.

In Summary The MFJ-994 did everything just as promised. It showed no problem handling the 600 W we could deliver, the only tuner of the group that we could test to the limit! It was too quick for me to stopwatch the tuning speed, but my sense was, as expected, that the frequency based memories were a bit quicker if all operations were using the same antenna. It also appeared that the MFJ relays were a bit quieter than the other relay operated tuner, but that could have been because there were generally fewer cycles needed before it was matched. ARRL Lab test results are shown in **Table 14-13**.

MFJ provided a comprehensive 23 page, well illustrated, instruction manual that was clear in its description of how the unit operated and what to expect of it.

Manufacturer: MFJ Enterprises, 300 Industrial Park Rd, Starkville, MS 39759; tel 662-323-5869, fax 662-323-6551; **www. mfjenterprises. com**. 2006 price: $359.95. Auto tuner radio interface cables: MFJ-5124A for Alinco, $19.95 MFJ-5124I for ICOM, $19.95 MFJ-5124K for Kenwood, $59.95; MFJ-5124Y for Yaesu, $59.95.

PALSTAR AT-AUTO

As noted previously, the AT-Auto is of a different architecture than the other tuners in this review. Palstar is noted for its line of high quality manual antenna tuners, so it should not be a surprise that Palstar decided to build its first auto tuner using the same type of in-house constructed parts that have been successful in their other offerings.

This is a large and complex device with features that I haven't seen before in any tuner. The first feature you might notice is the cross needle wattmeter that takes up the left side of the front panel. This is the same display and circuitry built into their PM2000A standalone wattmeter. It provides both average and peak forward and reflected power readings at full scale power levels of 3000/600 (forward/reflected) and 300/60 W. This is an upgrade to the Palstar WM150 wattmeter reviewed in July 2002 with the addition of a PEAK HOLD setting with a 2 second hold time.

The right side of the panel includes a two-line liquid crystal display (LCD), a knob for manual tuning (more later), MANUAL/AUTO and SELECT buttons. It is on this side of the panel that interesting things happen. As with most auto tuners, you apply power and it starts to match your antenna to 50 Ω. What's different with the AT-Auto's tuning sequence is that it first measures frequency, tells you the operating frequency and then politely asks you to turn off your transmitter while it finds a close match. It has a default set of L and C values for each frequency and runs its quiet motors until they are in range. It then asks for another dose of RF to refine the tune. Every time it does this, like a good smart machine, it memorizes its settings and uses them the next time you use that frequency. This approach minimizes interference to others.

A well thought out and, to my knowledge, unique feature of this tuner is its use of a radio interface. This, and many other auto tuners, make use of a radio's tuner interface to initiate the tuning sequence and cause a reduced-power tune signal to be sent from the radio. The AT-Auto has an additional connection from the radio's CAT (computer interface) port. The CAT port provides frequency data from the radio to the tuner. As you tune the receiver, the tuner indicates the frequency and follows along with either its default or memorized values. This means that, if you've been on that frequency before, the tuner will be tuned before you hit the key or PTT! If you haven't been there before, it will use its default values and still be pretty close.

This is particularly handy if you are listening to a frequency at which you aren't licensed to transmit, for example WWV or shortwave broadcast frequencies. The cable for ICOM radios is provided. You do have to think a bit while you use it (yes we have to be even smarter than our smart devices!). The CAT frequency data reflects the frequency of whichever VFO is active. If you are operating split frequency, it will tune back and forth between the two VFO frequencies as you switch between them. This is not likely much of an issue if you are operating in the typical "up five" (VFOs just 5 kHz apart) environment, but could be a disaster if you are operating cross-band split for some reason. The solution — while you have the VFO on your transmit frequency and the tuner properly tuned, tap the MANUAL/AUTO button so that it will be in manual mode and the automation will take a break.

The CAT function, as we wrote this, is available only for radios that support ICOM's CI-V protocol. Palstar expects to have cables and software upgrades to allow interoperation with Kenwood and Yaesu radios soon. Speaking of software, Palstar kindly provides a 9-pin serial cable designed to allow you to install

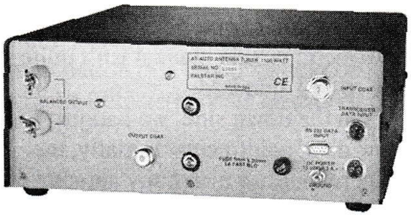

Figure 14-29 — Rear panel connections on the Palstar AT-Auto.

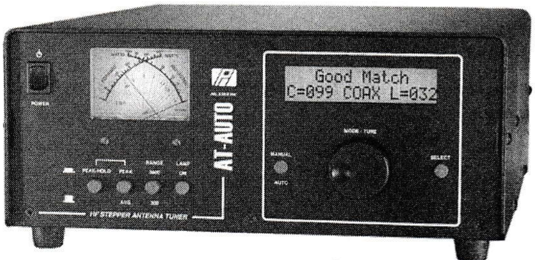

Figure 14-28 — Front panel of the Palstar AT-Auto.

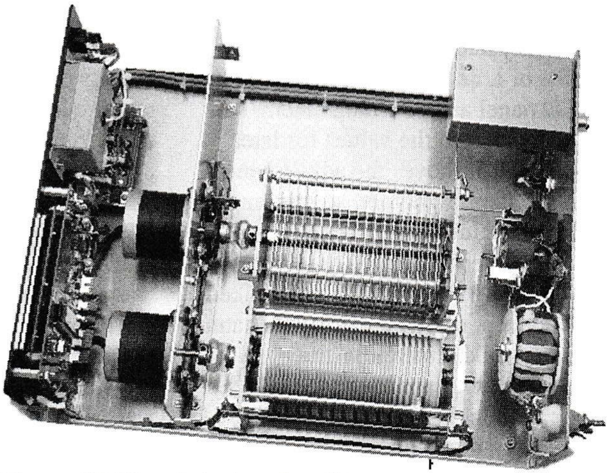

Figure 14-30 — Interior circuitry of the Palstar AT-Auto.

upgraded software when it is available. As we write this, there is no information on how to do this in either the manual or on the Palstar Web site. On the other hand, there is no new software either, so presumably when there's something new to download, they will tell us how to do it. We did successfully download upgraded software for their ZM-30 Antenna Analyzer during that review, so they seem to be able to deal with the process. We understand from Palstar that revised firmware to improve 10 meter operation has been developed and will be available shortly.

Another nice feature of the AT-Auto is that it has provisions for switch selection (via the front panel SELECT button) of either a balanced (through a 4:1 balun at the output) or an unbalanced (coax connected) antenna. The switch doesn't just insert the balun, but provides two completely independent antenna connections, so both can be always available. The memory associates the settings with each antenna port separately, so if you switch between antennas while on the same band, it thoughtfully remembers the settings for each.

New production tuners will also include BYPASS selection. A factory upgrade is said to be available for early production units. Want to do it Yourself? Poke the MANUAL/AUTO button and you are into manual tuning mode. The single knob below the LCD display is used to change the inductance or capacitance. It comes up ready to tune the C; push the knob in briefly and it changes the L. The value of L and C are displayed on the LCD panel as you change them, so you can record the values for later reference. It moves the adjustments via the stepper motors, so minimum effort is required — no heavy cranking needed.

So how'd it work? We really liked the concept of this tuner. By its nature it can provide finer adjustment than the relay types we have seen, although their resolution could be made arbitrarily fine with additional relays and smaller increments of C and L, and higher cost. We also liked the quietness of the motors compared to the clacking relays. The downside can be tuning time. As noted above, with a CATconnected radio and memorized settings it rapidly follows you as you tune. A change in bands can take longer. We measured the following times to retune between bands:

From (Meters)	*To*	*Tune Time (Seconds)*
80	40	11
40	30	4
30	20	3
20	15	2
15	10	2
160	10	45

The times shown are between memorized settings. To tune from a default setting to a finely tuned condition takes about 2 additional seconds if there isn't already a memorized setting for the frequency. It seems especially quick with the CAT function, since it feels like it's all tuned and waiting for you to catch up!

The AT-Auto comes with a well illustrated 20 page manual. The manual assumes you know why you wanted an antenna tuner and where you are going to connect it. This wasn't much of a problem since it has such an informative display, although, if you're expecting "open left flap, remove tuner from box..." type instructions, this manual isn't quite up to that standard.

On the down side, we had just a few disappointments. Initially, the tuner wouldn't match my antenna on 12 and 10 meters. On 12 meters, my measured SWR was 6:1 at the tuner. While it couldn't find a perfect match, and announced MATCH NOT FOUND! on the LCD panel, it actually got to within a 2.4:1 SWR, which my radio found acceptable. On 10 meters my antenna showed an SWR of 3:1 and the best the tuner could do was 2.78:1. In both of these cases, the LCD panel noted that the inductance was at L=000.

This suggested to me that it was the particular value of complex impedance rather than the SWR that was causing the problem. I put in an additional 6 feet of 50 Ω coax to move "around the Smith Chart" and the tuner was then able to find a perfect match in both cases. This is a good trick to keep in mind if faced with this kind of problem with any tuner. The indicator was very helpful in pointing me in the right direction.

A less significant problem was that the frequency metering system required more power to determine the frequency on the higher bands. On 160 through 15 meters, the 10 W that the ICOM transceiver put out in TUNE mode was plenty to allow the frequency to be read and the tune function to be initiated. On 12 and 10 meters, at 10 W, I received a FREQUENCY ERROR CHECK CARRIER LEVEL message on the LCD. It took more power to allow the frequency to be read. This was no problem with another transceiver that allows me to crank it up as far as I want when the TUNE button is pressed, but the ICOM had a fixed level. A quick fix is to switch to AM or FM mode to put out more power. Just hit the bar on your PTT microphone or use a straight key in CW mode.

Upon further investigation, I found that it worked fine on all bands with 10 W to a matched load. At some impedances, apparently there was not enough signal for the measuring circuits. Another workaround would be to manually set it within range and then let the AT-Auto fine tune to perfection. A handy feature of this tuner is that it can be tuned at 1500 W with no relay contacts to burn. This is good since it sometimes notices a bit of reflected power and trims the adjustment after you turn on the amplifier. ARRL Lab test results are shown in **Table 14-14**.

Manufacturer: Palstar Inc, 9676 N Looney Rd, Piqua, OH 45356; tel 800-773-7931, fax 937-773-8003; **info@palstar.com**; **www.palstar.com**. 2006 price: $1195.

In Summary

Each of these tuners did what they said they would over most of their frequency range and each could be of benefit to operators using higher power than that handled by other automatic antenna tuners. Some care needs to be taken with their operation, beyond that found in the lower

Table 14-14
Palstar AT-Auto

Manufacturer's Specifications

Maximum power: 1500 W single tone.
Frequency range: 1.8 to 30 MHz.
Input impedance: 160 to 20 meters, 1200 ±j1200; 15 to 10 meters 1000 ±*j*1000.
Tuning time: 1-30 seconds.
Dimensions (height, width, depth): 5.5 × 12.5 × 16 inches.
Weight: 25 pounds.

Measured power loss into resistive loads (%) / Input SWR at match. Tested at 50 W.

SWR	*Load (Ω)*	*160 m*	*80 m*	*40 m*	*20 m*	*10 m*
16:1	3.125	54 **	33 **	19 **	* **	No Match n/a
8:1	6.25	42 **	24 **	15 **	12 **	No Match n/a
4:1	12.5	30 **	17 **	14 **	* **	No Match n/a
2:1	25	24 **	12 **	* **	* **	26 **
1:1	50	16 **	* **	* **	* **	* **
2:1	100	13 **	* **	* **	* **	20 **
4:1	200	11 **	* **	* **	12 **	43 **
8:1	400	12 **	* **	11 **	23 **	42 **
16:1	800	16 1.6:1	25 **	24 **	55 **	49 **

*Power loss less than or equal to 10%.
**Matched SWR less than or equal to 1.5:1.

powered units, because of the power involved and particularly because of the difference between "tuning power" and "operating power." Each unit is specified to be tuned using reduced power from the exciter at somewhere in the 10 to 100 W range.

Each tuner finds a match at that power level and then it should be safe to switch on the linear amplifier — but is it? With the MFJ and Palstar tuners, there were conditions under which it would initiate the tuning cycle again at full power, even after being within specification at the lower tuning power. The reason is likely a combination of a larger sample of RF to make reflected power measurement and nonlinearity of the detectors, not surprising for analog circuitry. Different tuners will react differently under this circumstance. The Palstar actually doesn't mind tuning at 1500 W and will calmly trim up without a whimper. The MFJ tuner will note that it is tuning above the specified tuning power spec and switch to bypass — whoops, you had the linear pre-tuned with a dummy load so that it would be ready to go, and now it sees a 9:1 SWR, or whatever your antenna has, going directly to the amplifier. This could cause a catastrophic reaction in your amplifier! The LDG tuner is different in this regard. It only initiates a tune cycle if the TUNE button is pressed.

So what to do? There are two potential solutions. One, manually trim up the tuning for an even lower SWR using the L and C up and down buttons. If the reflected power is fully nulled, it should avoid this problem. The other approach is to switch the tuner to manual mode after it finds its initial match. That will prevent it from automatically retuning while high power is applied. Or do both. Arguably this changes tuner operation from "auto" to "semi-auto," but I recommend it for any high power relay switched tuner. The consequences of not doing so could be extreme to either the amplifier or the relay contacts or both.

A New Generation of Balanced Antenna Tuners

Reviewed by Joel R. Hallas, W1ZR
QST *Technical Editor*
QST *September 2004*

A new breed of antenna tuner available in different flavors from multiple manufacturers addresses concerns about using baluns with high SWR to feed balanced antenna systems. Paul Danzer's article in the April 2004 issue of *QST* brought to paper a concern many of us have had for some time — the use of baluns at the output of antenna tuners.[6] As noted in his article, if the balanced load is near the balun's design impedance (typically 200 Ω for the usual 4:1 balun) all is well.

Unfortunately, the typical random sized center fed antenna with random length ladder line feed has an impedance at the feed point that varies dramatically with frequency. The result can be heating and loss (and occasional damage) at the balun. These effects were well documented in a series of *QST* articles by Frank Witt and later in a performance evaluation of unbalanced tuners with both balanced and unbalanced loads.[7,8]

So How Do We Fix the Problem?

As Danzer noted, the classic solution has been the use of an inherently balanced tuner. The commercially manufactured E.F. Johnson Matchbox tuners of the '50s worked reasonably well in their day, and over the bands that they covered (we didn't have the 60, 30, 17 and 12 meter bands back then). Now at least three manufacturers have begun offering balanced antenna tuners of a different configuration. For this review we selected the MFJ-974H and the Palstar AT1500BAL and AT4K. Interestingly, each of the three uses a different architecture, and each is different from the design of the old Matchbox!

In addition to those units, SGC has announced a low power self-contained auto-tuner, the SG-211, which shares the design concept of the AT4K and will be the subject of an upcoming Short Takes column. We thought it would be good to evaluate the performance of the medium and high-power units and provide a comparison to the old Johnson tuner.

What's in the New Tuners?

Glad you asked! As noted, each of the tuners uses a different design configuration. Each can be directly compared to some of the common unbalanced configurations. Note that the power ratings and price of the Palstar tuners put them in a different category from the MFJ units and thus, direct comparisons may not be appropriate. Both the MFJ and the Palstar AT1500BAL are fully balanced tuners — the MFJ a dual T section design with shunt L, and the Palstar a dual L section with shunt C. The Palstar AT4K tuner takes a completely different approach. It uses the insulated unbalanced scheme suggested in Paul's article and described in detail in *The ARRL Antenna Book*.[9]

The relationship of the designs to their more commonly encountered unbalanced configurations are shown in simplified schematics in **Figures 14-32** through **14-33**. The other differences between the units are in their ratings. The MFJ tuner covers 160 through 6 meters, while the Palstar tuners top out at 10 meters. Both Palstar tuners are rated at 1500 W or greater (the AT4K has a reduced rating below a 25 Ω load) while the MFJ tuner is rated at 300 W PEP, 150 W CW.

The ratings of the Johnson Matchboxes were established in a day when amateur power levels were specified based on average dc power *input*, rather than the current PEP RF *output*

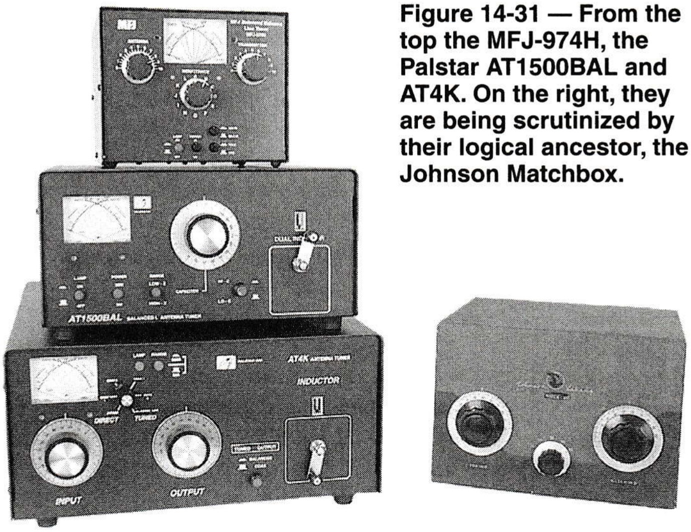

Figure 14-31 — From the top the MFJ-974H, the Palstar AT1500BAL and AT4K. On the right, they are being scrutinized by their logical ancestor, the Johnson Matchbox.

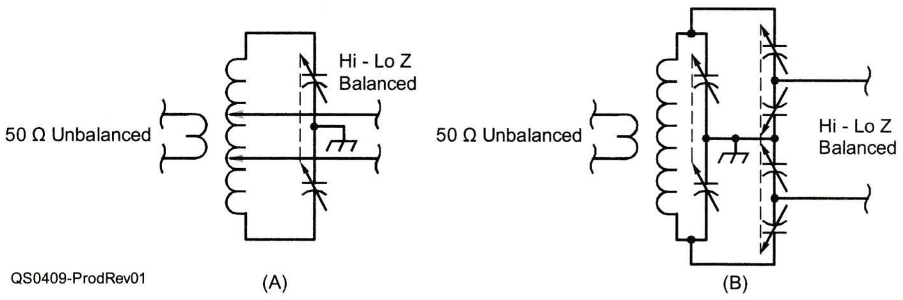
Hi - Lo Z
Balanced
50 Ω Unbalanced
50 Ω Unbalanced
Hi - Lo Z
Balanced
QS0409-ProdRev01
(A)
(B)

Figure 14-32 — At A, the traditional balanced antenna tuner. At B, the Johnson Matchbox antenna tuner. Simplified view without bandswitching.

power. A "275 W" Johnson matchbox was thus rated to work with transmitters running 275 W dc input, or about 200 W average output. This was in the day of plate modulated AM service, so that rating further translates to 800 W PEP under today's rules. Similarly, a "kW Matchbox" would likely be rated today as a 3 kW PEP tuner.

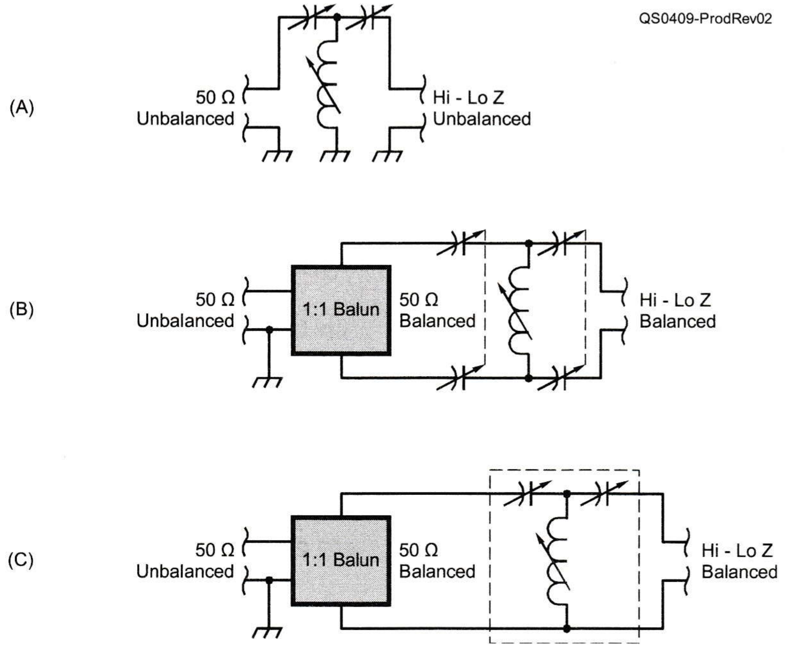
QS0409-ProdRev02
(A)
50 Ω
Unbalanced
Hi - Lo Z
Unbalanced
(B)
50 Ω
Unbalanced
1:1 Balun
50 Ω
Balanced
Hi - Lo Z
Balanced
(C)
50 Ω
Unbalanced
1:1 Balun
50 Ω
Balanced
Hi - Lo Z
Balanced

Figure 14-33 — At A, an unbalanced T-network tuner. At B, a balanced T-network tuner. At C, an unbalanced T-network tuner for balanced loads.

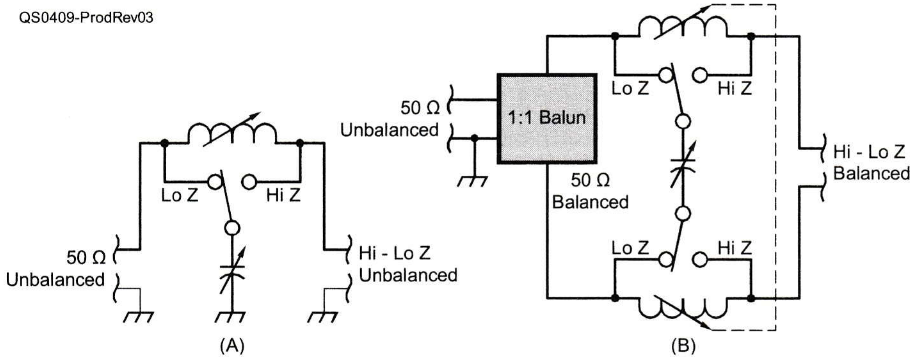
QS0409-ProdRev03
Lo Z
Hi Z
50 Ω
Unbalanced
Hi - Lo Z
Unbalanced
(A)
50 Ω
Unbalanced
1:1 Balun
50 Ω
Balanced
Lo Z
Hi Z
Lo Z
Hi Z
Hi - Lo Z
Balanced
(B)

Figure 14-34 — At A, an unbalanced L-network tuner with switched capacitor. At B, a balanced L-network tuner with switched capacitor.

MFJ-974(H) Balanced Antenna Tuner

MFJ provides two versions of their '974, with ('974H) and without ('974) the capability to cover 160 meters. Both are rated at 300 W PEP, and 150 W CW. At only 7½ inches wide, it takes up a small amount of desk space. Interestingly, it has about the same shape as the old 275 W Johnson Matchbox, but is 1 to 2 inches smaller in each dimension. As noted above, this unit uses a T section design as in **Figure 14-33B**, so it is not necessary to switch capacitors from one side to the other as the impedance changes from high to low.

The inductor is varied by selecting among 12 steps. The H model has an extra inductance for 160 meters that changes the tuning range as needed. A cross-needle two-range (30 and 300 W full scale) power/SWR meter can be set to read peak or average power. Both the power level and null matched the meter on my transceiver quite closely. The capacitors are direct (1:1) drive, with plastic gearing between the ganged units. I found them easy to turn and to get a null. I used the old trick of tuning for maximum receive signal, first with the L switch, then with the capacitors.

MFJ provides a page of nominal settings by band that you may find helpful. When you switch to adjusting the tuner while transmitting, be sure to note their caution about not changing the inductor switch with power applied. You may burn the contacts otherwise. I also make it a practice to always tune at reduced power to avoid hitting my finals with a heavy mismatch at full power. When you have it set, turn up the power and confirm that all is well.

One caution that applies to all T section tuners is to note that multiple settings can result in low SWR. Unfortunately, some will have higher losses than others. The rule of thumb is to use the setting with the smallest inductance (the L switch position on

Table 14-15
MFJ-974H Balanced Antenna Tuner

Manufacturer's Specifications	*Measured in ARRL Lab*
Input load range: 12 to 2000 Ω.	See below.
Output SWR range: Not specified.	See below.
Frequency coverage: 1.8 to 54 MHz.	See below.
Input power: 150 W average, 300 W PEP.	Not tested.
Size: 6 × 7.5 × 9 inches (HWD).	

SWR	*Load (Ω)*		*160 Meters*	*80 Meters*	*40 Meters*	*20 Meters*	*10 Meters*	*6 Meters**
8:1	6.25	Power Loss %	55	41	32	20	16	
		SWR BW %	0.9	0.6	1.0	2.0	2.0	Not Tested
		Imbalance**	0	0	0	0	0	
4:1	12.5	Power Loss %	40	33	23	<10	10	
		SWR BW %	0.6	0.9	1.4	2.8	3.4	Not Tested
		Imbalance	0	0	0	0	0	
2:1	25	Power Loss %	25	22	<10	<10	<10	
		SWR BW %	0.8	1.1	3.2	4.9	2.4	Not Tested
		Imbalance	0	0	0	0	0	
1:1	50	Power Loss %	22	15	32	20	<10	<10
		SWR BW %	1.1	1.4	2.1	2.1	12	10
		Imbalance	0	0	0	0	0	0
2:1	100	Power Loss %	18	<10	<10	<10	<10	
		SWR BW %	1.1	1.7	4.1	7.0	25	Not Tested
		Imbalance	0	0	0	0	0	
4:1	200	Power Loss %	17	<10	<10	<10	<10	
		SWR BW %	1.1	2.8	2.5	9.1	10	Not Tested
		Imbalance	0	0	0	0	0	
8:1	400	Power Loss %	12	<10	<10	<10	<10	
		SWR BW %	1.5	3.4	7.5	7.0	3.7	Not Tested
		Imbalance	0	0	0	0	0	
16:1	800	Power Loss %	10	<10	<10	<10	<10	
		SWR BW %	1.9	4.3	8.3	7.7	3.7	Not Tested
		Imbalance	0	0	0	0	0	
32:1	1600	Power Loss %	<10	<10	<10	10	11	
		SWR BW %	2.1	2.6	5.6	4.4	3.0	Not Tested
		Imbalance	0	0	0	0	0	

Notes
Power losses are expressed as a percentage. A 10% power loss represents less than half (0.46) a dB.
The SWR bandwidth is the percentage of the measurement frequency that can be changed with the SWR staying under 1.5:1.
*The ARRL test fixture is only usable at 50 . on 6 meters.
**As defined in F. Witt, "Evaluation of Antenna Tuners and Baluns—An Update," *QEX*, Sep-Oct 2003, pp 3-14.

this tuner) and highest capacitance that will provide a match. One limitation of the switched rather than roller inductor is that you can't get values in between. I didn't find that much of a problem, as I was always able to get to 1.5:1 or better SWR with my antennas.

As you make adjustments, I suggest you log the settings for each frequency in a table such as the one supplied in the back of the manual. You may want to make photocopies or set up a spreadsheet so you will be able to repeat the process for your next antenna. If you find that you can't get a match at some frequency, try adding 6 feet of ladder line at a time. The different length will move the impedance around and may solve the problem, but you will have to retune on the other bands and hope to find a length that will tune properly on all bands.

Balanced loads are connected via standard (¾ inch) spaced multipurpose binding posts. These accept wire ends, or dual banana plugs, a handy connector for balanced feed lines at this power level. The '974H also provides a capability to match unbalanced loads and provides a coax connector for that purpose. It is necessary to provide a jumper between the lower balanced load binding post and the ground terminal to complete the unbalanced hookup. Note that the output is not switched, so an antenna should be connected to either the coax connector or the balanced jacks, but not both.

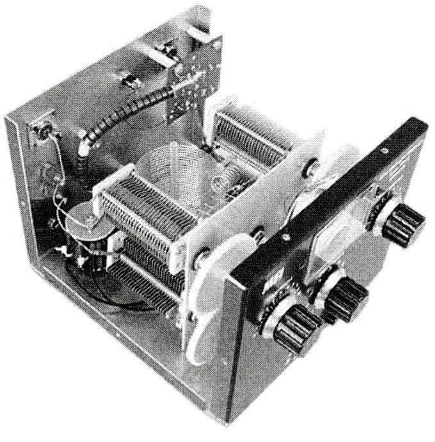

Figure 14-35 — MFJ-974H, inside view.

Note that while the '974 is specified to match a wide range of impedances on 6 meters, neither the Lab nor W1ZR could test at any impedance other than 50 Ω. I tried the unbalanced connection arrangement with my coax-fed G5RV. It worked fine until I tried it on 160 meters, not one of the bands the antenna is supposed to operate on. I was able to quickly find a match at low power. When I turned up the power past 70 W, arcing was evident inside the unit. I opened it up and was surprised to find that rather than the expected arcing tuner element, I found the arcing source was at the metering circuit board. Measured Lab data is shown in **Table 14-15**.

The unit went back to MFJ for repair under their warranty. Upon return, it worked fine at 100 W (my maximum power with the transceiver) and I was told by MFJ that a signal wire had been dressed too close to the meter board and arced. It was repositioned and MFJ installed the intended tie-wrap to hold it away from the meter board. The tuner was retested and had exhibited no problems.

Manufacturer: MFJ Enterprises Inc, 300 Industrial Park Rd, Starkville, MS 39759; tel 800-647-1800; fax 662-323-6551; **www.mfjenterprises.com**. 2004 price: MFJ-974, $179.95; MFJ-974H, $199.95.

Palstar AT4K Antenna Tuner

Unlike the other tuners in this review, the AT4K might best be described as an unbalanced tuner designed to feed unbalanced or balanced loads. This sounds contradictory, but really isn't, as described in footnotes 1 and 6. If you just think of this tuner as a "four-terminal black box" (see **Figure 14-33C**) connecting a balanced load to a balanced source, followed by a 1:1 balun going to the transceiver, you may get the picture.

An unbalanced T section, isolated from ground within the box, performs the required impedance transformation to match the impedance at the bottom of the balanced transmission line to 50 Ω to operate properly through the internal balun. This tuner also provides a heavy duty relay to connect the common points of the input, output and inductor to the chassis to convert it to a typical T section tuner for unbalanced loads.

An additional feature, not found in any of the other tuners in this review, is antenna switching capability. The AT4K has a single pair of balanced output terminals, but also has three coax outputs. Two can be tuned, or switched to straight through, while the third provides straight though operation only. This is a great spot to connect a dummy load, or a well matched Yagi.

The inside view gives a sense of the heavy duty construction of this massive tuner. The rotary inductor is fabricated from silver plated strip stock, rather than the usual wire, and the rolling contact is designed to grip a significant portion or the coil, not just the edge. The inductor is driven by a smooth turn-count dial reading out to 1/10 of a turn and resetable in

Table 14-16
Palstar AT4K Balanced/Unbalanced Antenna Tuner

Manufacturer's Specifications	*Measured in ARRL Lab*
Input load range: 8 to 2000 Ω.	See below.
Output SWR range: Not specified.	See below.
Frequency coverage: 1.8 to 30 MHz.	See below.
Input power: 2500 W single tone.	Not tested.
Size: 5 × 15 × 16 inches (HWD).	

SWR	*Load (Ω)*		*160 Meters*	*80 Meters*	*40 Meters*	*20 Meters*	*10 Meters*	*6 Meters**
8:1	6.25	Power Loss %	24	14	10	10	34	
		SWR BW %	1.1	2.6	6.4	4.9	0.5	
		Imbalance	0.6	0.7	0	0.6	5.2	
4:1	12.5	Power Loss %	12	<10	<10	<10	18	
		SWR BW %	1.9	4.0	17	8.5	0.7	
		Imbalance	0	0.4	0	0.4	1.7	
2:1	25	Power Loss %	<10	<10	<10	<10	<10	
		SWR BW %	3.0	7.4	39	21	1.5	
		Imbalance	0	0.2	0	0.5	0	
1:1	50	Power Loss %	<10	<10	<10	<10	<10	
		SWR BW %	5.5	16	69	42	3.0	
		Imbalance	0.3	0	0	0.4	0.3	
2:1	100	Power Loss %	<10	<10	<10	<10	<10	
		SWR BW %	6.1	26	49	44	10	
		Imbalance	0.4	0	0	0	0	
4:1	200	Power Loss %	<10	<10	<10	<10	37[1]	
		SWR BW %	6.9	22	24	32	0.8	
		Imbalance	0.5	0	0	0	3.4	
8:1	400	Power Loss %	<10	<10	<10	<10	Note 1	
		SWR BW %	7.8	15	14	15		
		Imbalance	1.5	0.3	0	0		
16:1	800	Power Loss %	<10	<10	<10	<10	Note 1	
		SWR BW %	7.2	10	10	8.5		
		Imbalance	2.6	0.5	0	0		
32:1	1600	Power Loss %	<10	<10	<10			
		SWR BW %	4.4	6.9	5.6	No Match	No Match	
		Imbalance	4.9	0	0			

Notes

[1] According to the owner's manual for the AT4K, the matching range is limited on 10 meters. In testing, it was found that matches (SWR <1.5:1) could be obtained on 10 meters with some higher impedance loads by using a large amount of inductance. However, it is very likely that the tuner was close to self-resonance under these conditions, and this type of operation should be avoided due to the high losses in the tuner.

Power losses are expressed as a percentage. A 10% power loss represents less than half (0.46) a dB.

The SWR bandwidth is the percentage of the measurement frequency that can be changed with the SWR staying under 1.5:1.

between marks. As with its sister units, the capacitors are driven by 5:1 reduction drives with 0 to 100 logging scales.

One design challenge with a tuner built of these large parts is to keep the minimum capacitance low enough so the unit will meet specifications at 10 meters. As shown in the data, Palstar has done a reasonably good job with this, but the limitations should be noted. I found that this unit could match all my antennas, balanced or unbalanced, except on 17 and 10 meters where not all impedances are within range. Again, a change in transmission line length may move your impedance to a value within the tunable range.

The metering was consistent with my other wattmeters, both in position of reflected null and forward power. I was able to easily return to a previous setting using the resolution of the dial scales. Measured Lab data is shown in **Table 14-16**.

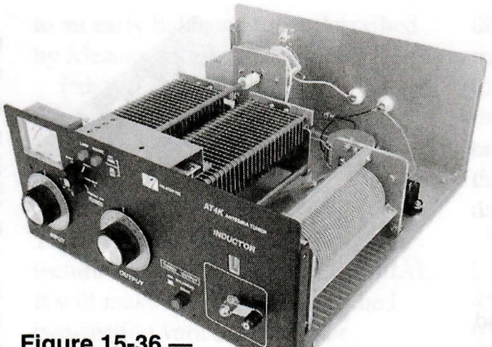

Figure 15-36 — Palstar AT4K, inside view.

Palstar AT1500BAL Balanced Antenna Tuner

The Palstar AT1500BAL is of the configuration shown in **Figure 14-34B**. It is a legal limit device and a look inside makes me believe that it can handle serious power. The rotary inductors, two edge-wound silver plated ball-bearing monsters, driven by a toothed fiberglass belt and turns counting dial take up a lot of the interior space. The rest is largely occupied by a 450 pF 4.5 kV variable driven by a smooth 5:1 vernier dial.

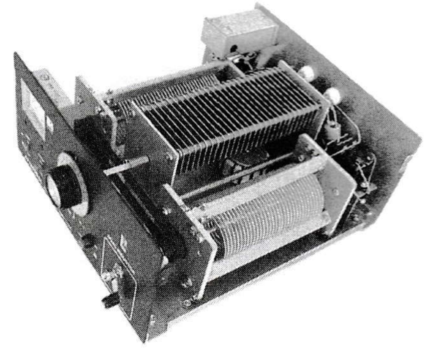

Figure 14-37 — Palstar AT1500BAL, inside view.

The inductors and capacitor are made in-house and work very well. I was particularly impressed with the resetability of the controls. The turns counter reads out to tenths of a turn, and can be easily reset to ½ a tenth out of the 32 turns end-to-end. The vernier drive has a dial with 100 divisions and no perceivable backlash. Once you make up a table of tuning values by frequency, retuning should be a snap. I found the tuner easy to use at W1ZR, matching all reasonable antenna configurations I tried. I am only able to test at the 500 W level and, as expected, encountered no difficulties.

The cross-needle meter (300 and 3000 W full scale ranges for forward average power) agreed closely with those on my equipment. One note, on many tuners, power is only required for meter lighting. On this unit, relays are used — both to switch capacitors from one end to the other and to switch in additional capacitance. The tuner will work only in the "high impedance/ no extra capacitance" mode if you neglect to plug in the

Table 14-17
Palstar AT1500BAL Balanced Antenna Tuner

Manufacturer's Specifications	*Measured in ARRL Lab*
Input load range: 160 to 20 meters, 2500 ± j2500 Ω.	See below.
20 meters 1000 ± j1000 Ω; 10 meters, 500 ± j500 Ω.	See below.
Output SWR range: Not specified.	See below.
Frequency coverage: 1.8 to 30 MHz.	See below.
Input power: 1500 W PEP.	Not tested.
Size: 6.5 × 12.5 × 15 inches (HWD).	

SWR	*Load (Ω)*		*160 Meters*	*80 Meters*	*40 Meters*	*20 Meters*	*10 Meters*	*6 Meters**
		Power Loss %	<10	<10	<10			
8:1	6.25	SWR BW %	No Match	No Match	9.9	6.6	5.4	
		Imbalance	0.3	0	0			
		Power Loss %	<10	<10	<10			
4:1	12.5	SWR BW %	No Match	No Match	1.3	1.3	10	
		Imbalance			0	0	0	
		Power Loss %	<10	<10	<10	17	<10	
2:1	25	SWR BW %	1.5	46	42	19	13	
		Imbalance	0	0	0	0	0	
		Power Loss %	<10	<10	<10	<10	<10	
1:1	50	SWR BW %	>100	>100	>100	>100	20	
		Imbalance	0.3	0	0	0	0	
		Power Loss %	<10	<10	<10	<10	<10	
2:1	100	SWR BW %	>100	54	58	56	61	
		Imbalance	0	0	0	0	0	
		Power Loss %	<10	<10	<10	<10	<10	
4:1	200	SWR BW %	>100	29	26	30	3.7	
		Imbalance	0.2	0	0	0	0	
		Power Loss %	<10	<10	<10	<10	13	
8:1	400	SWR BW %	17	23	18	20	1.7	
		Imbalance	0	0	0	0	0	
		Power Loss %	<10	<10	<10	<10	18	
16:1	800	SWR BW %	11	11	13	13	4.0	
		Imbalance	0	0	0	0	0	
		Power Loss %	<10	<10	<10	<10		
32:1	1600	SWR BW %	5.6	8.0	7.8	5	No Match	
		Imbalance	0	0	0	0		

Notes
Power losses are expressed as a percentage. A 10% power loss represents less than half (0.46) a dB.
The SWR bandwidth is the percentage of the measurement frequency that can be changed with the SWR staying under 1.5:1.

supplied wall-wart or connect an external 12 V dc supply. I found I needed to exercise both relays to tune my antenna on all bands.

Just after we purchased the AT1500BAL tuner for evaluation, Palstar added the AT1KBAL tuner to their line. In spite of their product numbers, they both are specified to handle the US legal limit. There is a key difference, however. The AT1KBAL tuner has the capacitors on the output side only. This results in a tuner that is designed to match from around 100 Ω up and is similar to an early balanced tuner described by Measures.[10,11]

Palstar has informed us that later this year they will replace the AT-1500BAL and the newer (and not tested) AT1KBAL with a new balanced tuner, the model BT1500A. This tuner will share the basic architecture and design of the AT1500BAL. It will make use of a new switched two-section variable capacitor designed to reduce minimum capacitance. This is intended to improve the tuning range, particularly on 10 meters. It will also have the inductors driven in tandem, removing the requirement for the drive belt and said to make for smoother tuning. Palstar expects to offer the BT1500A as their only balanced tuner once material for the others is exhausted. Measured Lab data is shown in **Table 14-17**.

Manufacturer: Palstar Inc, 9676 N Looney Rd, PO Box 1136, Piqua, OH 45356; tel 937-773-6255; fax 937-773-8003; **www.palstar.com**. 2004 prices: AT4K, $895; AT1500BAL, $695.95; AT1KBAL, $595.

E. F. Johnson Matchbox Antenna Tuners

Before WW II, the E. F. Johnson Company of Waseca, Minnesota, manufactured high quality variable capacitors, inductors and ceramic parts for electronics. By 1950 they were advertising their innovative Viking I transmitter in *The ARRL Radio Amateur's Handbook* and the next year their Matchbox antenna tuner for $48.95. A kW version was advertised in 1957. These tuners were based on the classic prewar balanced tuned circuit tuner (**Figure 14-32A**), but with an added twist. While the classic tuner of the day used plug-in coils to change bands, and manually attached tap points on the coil to change impedances, the Matchbox was bandswitching and had a unique differential capacitor arrangement to adjust the transformation ratio from the front panel, as shown in **Figure 14-32B**.

Models were available with and without SWR metering and the units included a TR relay useful for the typical separate transmitter and receiver setups of the day. By the '60s, the typical amateur antenna system had become one designed for resonant matched operation using coaxial cable without antenna tuners. Radios moved from AM to SSB, and Johnson changed their focus from amateur equipment to the commercial two-way FM radio market.

Their tuners are still a popular item at flea markets and on electronic auction sites. While not exactly a part of this review, Matchbox data reported by Witt in his earlier article is presented for comparison. As noted in the tables, the Matchbox tuners work well, but over a typically smaller impedance range than their modern counterparts. They also do not have band switch positions for any of the newer bands, although there is enough tuning range so they can typically cover 17 and 12, but not 30 or 60 meters. Within these limits, however, they can still be put to good use. Until the units discussed in this review became available, the Matchboxes were the only commercial tuner

Table 14-18
E. F. Johnson 275 W Matchbox, Balanced Antenna Tuner

Manufacturer's Specifications	*Measured in ARRL Lab*
Input load range: 25 to 1250 Ω.	See below.
Output SWR range: not specified.	See below.
Frequency coverage: 80, 40, 20, 15 and 10 meters	See below.
Input power: 275 W dc input.	Not tested.
Size: 7 × 10 × 10.5 inches (HWD).	

SWR	*Load (Ω)*		*80 Meters*	*40 Meters*	*20 Meters*	*15 Meters*	*10 Meters*
		Power Loss %					
4:1	12.5	SWR BW %	No Match	No Match	No Match	No Match	No Match
		Imbalance					
		Power Loss %				<10	<10
2:1	25	SWR BW %	No Match	No Match	No Match	4	4
		Imbalance				0	0
		Power Loss %	<10		<10	<10	<10
1:1	50	SWR BW %	2	No Match	>5	>5	3
		Imbalance	0	0	0	0	
		Power Loss %	<10	<10	12	11	<10
2:1	100	SWR BW %	2	4	>5	>5	3
		Imbalance	0	0	0	0	0
		Power Loss %	11	<10	<10	<10	11
4:1	200	SWR BW %	2	4	>5	>5	3
		Imbalance	0	0	0	0	0
		Power Loss %	12	<10	<10	<10	11
8:1	400	SWR BW %	2	4	>5	>5	3
		Imbalance	0	0	0	0	0
		Power Loss %	10	<10	<10	<10	11
16:1	800	SWR BW %	2	4	>5	>5	3
		Imbalance	0	0	0	0	0
		Power Loss %	10	<10			
32:1	1600	SWR BW %	2	4	No Match	No Match	No Match
		Imbalance	0	0			
		Power Loss %	10				
64:1	3200	SWR BW %	2	No Match			
		Imbalance	0				

Notes
Power losses are expressed as a percentage. A 10% power loss represents less than half (0.46) a dB.
The SWR bandwidth is the percentage of the measurement frequency that can be changed with the SWR staying under 1.5:1.

in wide use specifically designed to work with balanced antenna systems. Measured data from Frank Witt is shown in **Tables 14-18** and **14-19**.[12]

Notes

[1] R. D. Straw, Editor, *The ARRL Antenna Book,* 21st Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[2] The SG-235 is a 500 W version of the SG-230 with similar specifications, except needing a longer antenna. The SG-230 was reviewed in *QST* in November 1993.

[3] P. Pagel, "Product Review: Heath SA-2500 Antenna Tuner," *QST*, Mar 1985, pp 39-41.

[4] L. Aurick, "Product Review: J.W. Miller Automatic Antenna Tuner Auto-Trak Model AT2500," *QST*, Jul 1981, pp 42-43.

[5] S. Gerli, "Product Review: Daiwa CNA-1001 Automatic Antenna Tuner," *QST*, Nov 1981, pp 41-42.

[6] P. Danzer, N1II, "Open Wire Feed Line—A Second Look," *QST*, Apr 2004, pp 34-36.

[7] F. Witt, AI1H, "How to Evaluate Your Antenna Tuner—Parts 1 and 2," *QST*, Apr 1995, pp 30-34 and May 1995, pp 33-37.

[8] R. Lindquist, N1RL, "Product Review—QST Compares: Four High-Power Antenna Tuners," *QST*, Mar 1997, pp 73-77.

[9] R. D. Straw, Editor, *The ARRL Antenna Book,* 21st Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[10] Most center-fed antennas longer than 0.5 Ω are likely to meet this criterion. Very short antennas, or some low impedance driven arrays (8JK, for example) may have problems with this configuration, depending on feed line length.

[11] R. Measures, AG6K, "A Balanced Balanced Antenna Tuner," *QST*, Feb 1990, pp 28-32.

[12] See Note 7.

Table 14-19

E. F. Johnson kW Matchbox, Balanced Antenna Tuner

Manufacturer's Specifications	*Measured in ARRL Lab*
Input load range: 50 to 2000 Ω.	See below.
Output SWR range: not specified.	See below.
Frequency coverage: 80, 40, 20, 15 and 10 meters	See below.
Input power: 1000 W dc input.	Not tested.
Size: 12.5 × 17.25 × 11 inches (HWD).	

SWR	*Load (Ω)*		*80 Meters*	*40 Meters*	*20 Meters*	*15 Meters*	*10 Meters*
		Power Loss %				15	<10
4:1	12.5	SWR BW %	No Match	No Match	No Match	1	3
		Imbalance				0	0
		Power Loss %			<10	13	<10
2:1	25	SWR BW %	No Match	No Match	2	2	4
		Imbalance			0	0	0
		Power Loss %		<10	<10	<10	<10
1:1	50	SWR BW %	No Match	2	2	2	4
		Imbalance		0	0	0	0
		Power Loss %	<10	<10	<10	<10	<10
2:1	100	SWR BW %	1	2	2	2	4
		Imbalance	0	0	0	0	0
		Power Loss %	<10	<10	11	<10	<10
4:1	200	SWR BW %	1	2	2	2	4
		Imbalance	0	0	0	0	0
		Power Loss %	<10	<10	<10	14	11
8:1	400	SWR BW %	1	2	2	2	4
		Imbalance	0	0	0	0	0
		Power Loss %	10	<10	<10	11	11
16:1	800	SWR BW %	1	3	2	2	4
		Imbalance	0	0	0	0	0
		Power Loss %	10	<10	<10		
32:1	1600	SWR BW %	1	2	2	No Match	No Match
		Imbalance	0	0	0		
		Power Loss %	10				
64:1	3200	SWR BW %	2	No Match	No Match	No Match	No Match
		Imbalance	0				

Notes

Power losses are expressed as a percentage. A 10% power loss represents less than half (0.46) a dB.

The SWR bandwidth is the percentage of the measurement frequency that can be changed with the SWR staying under 1.5:1.

Review Questions

14-1 What are some of the key issues to keep in mind if selecting a commercial tuner?

14-2 What is the major advantage of an automatic antenna tuner?

14-3 Why might it be important to use a remotely tuned antenna tuner near the antenna feed point?

Chapter 15

Building Your Own Tuners

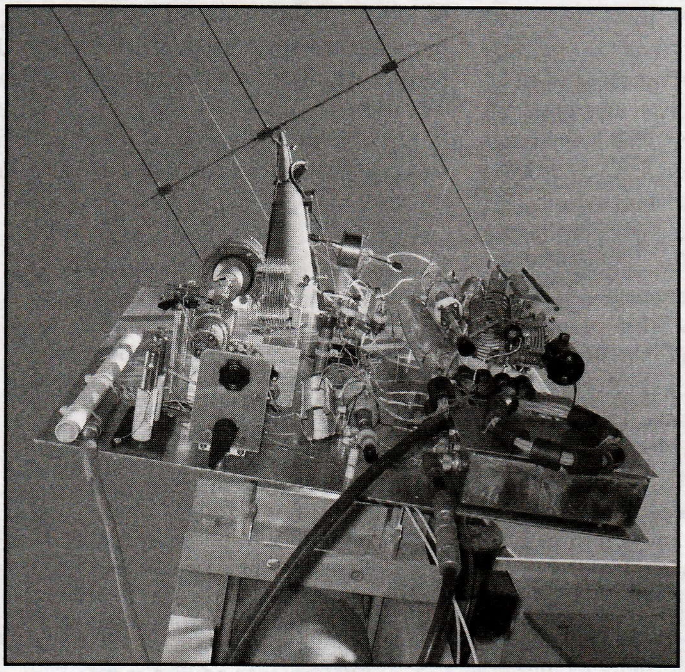

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Review Questions 15-12

Why Build a Tuner

A quick look at the schematic diagram of a basic manual antenna tuner (see Chapter 3), not counting metering and switching functions, reveals perhaps the simplest of amateur equipment schematics. A tuner has very few parts, and very few connections. That should make it easy to duplicate — and it does. Unfortunately each of the parts can be quite expensive and perhaps hard to find. On the other hand, if you have — or can easily obtain — the needed parts, there is no reason not to try building one or more tuners.

Special Purpose Tuners

Most of the tuners we have discussed heretofore have been of the general purpose variety. That is, they were designed to match varying loads on multiple frequencies from a single box. In any given amateur station, that may not be what is needed. You may have a need to match your particular antenna system to your particular radio on a particular frequency. That describes a "tuner" that needs no knobs or controls — just a fixed matching network.

The fixed network is more common than we may think. Every Yagi antenna with a gamma, T or hairpin match at the driven element has essentially done exactly that. Each is a matching network located at the antenna to provide a match from the antenna to the transmission line for a low loss run to the radio.

In a similar way, we can provide a network for each of our antennas that provides needed matching. The chapter title figure, a shot of a collection of specialized antenna matching systems at, W6TC, the advanced Amateur Radio station of the late George Badger, illustrates the point. None of those networks looks quite like any of the usual commercial antenna tuners of the last chapter! Another shot of this collection of networks, annotated with descriptions of each tuning element is shown in **Figure 15-1**.

Designing Your Special Purpose Tuner

While the usual circuit design and analysis tools of an electronic engineer can be used to design an impedance matching network, it can be a much simpler proposition for the amateur with a few software and hardware tools. The steps are straightforward:

- *Determine the (complex) impedance that the antenna system will present to the radio or transmission line.*

Determining the impedance can be done in a number of ways. The best approach is probably to measure the impedance at the location that will have the tuner by using an antenna analyzer. Such analyzers include tun-

1 — RG-213 coax cable from shack to input of vacuum relay box behind board (37) to connect to SteppIR Yagi antenna or 30, 40, 60, 80 and 160 meter loop tuners.
2 — RG-213 coax cable to SteppIR antenna.
3 — Coax connector to 30 and 40 meter balun (38).
4 — 30 meter tuning inductor.
5 — 30 meter vacuum variable capacitor.
6 — 30/40 meter vacuum relay connected to loop.
7 — 30/40 meter vacuum relay connected to loop.
8 — 40 meter phone/CW vacuum relay.
9 — 40 meter phone/CW inductor.
10 — 40 meter tuning capacitor.
11 — Motor drive for 40 meter tuning capacitor.
12 — 40 meter tuning inductor.
13 — 40 meter matching inductor.
14 — Coax connector to 60 meter balun.
15 — 60 meter balun.
16 — 60 meter tuning inductor.
17 — 60 meter tuning vacuum variable capacitor.
18 — 60 meter vacuum relays.
19 — 80 meter coax connector to 80 meter balun.
20 — 80 meter balun.
21 — Motor drive for 80 meter vacuum variable capacitor.
22 — Limit switches for 80 meter vacuum variable capacitor.
23 — 80 meter vacuum variable capacitor.
24, 25 — 80 meter tuning and matching inductors.
26 — 80/160 meter vacuum relay.
27 — 160 meter open end vacuum relay.
28, 29 — Connection to loop on tower.
30 — 160 meter receive vacuum relay.
31-33 — 160 meter receive RC network.
34 — Spark gap protector for 160 meter receive RC network.
35, 36 — 25-pair control cable to shack.
37 — Vacuum relay switch box to connect to SteppIR Yagi or loop.
38 — 30 and 40 meter balun.
39, 40 — Feed-through to 80 and 160 meter radial system.
41 — Remote motor control.
42 — Control shaft for 30 meter vacuum variable capacitor (5).
43 — Motor control relay.
44 — 160 meter balun.
45 — Manual control for 60 meter vacuum variable capacitor.
46 — Connector to 160 meter balun.

PHOTO AND ANNOTATION BARRY SHACKLEFORD, W6YE

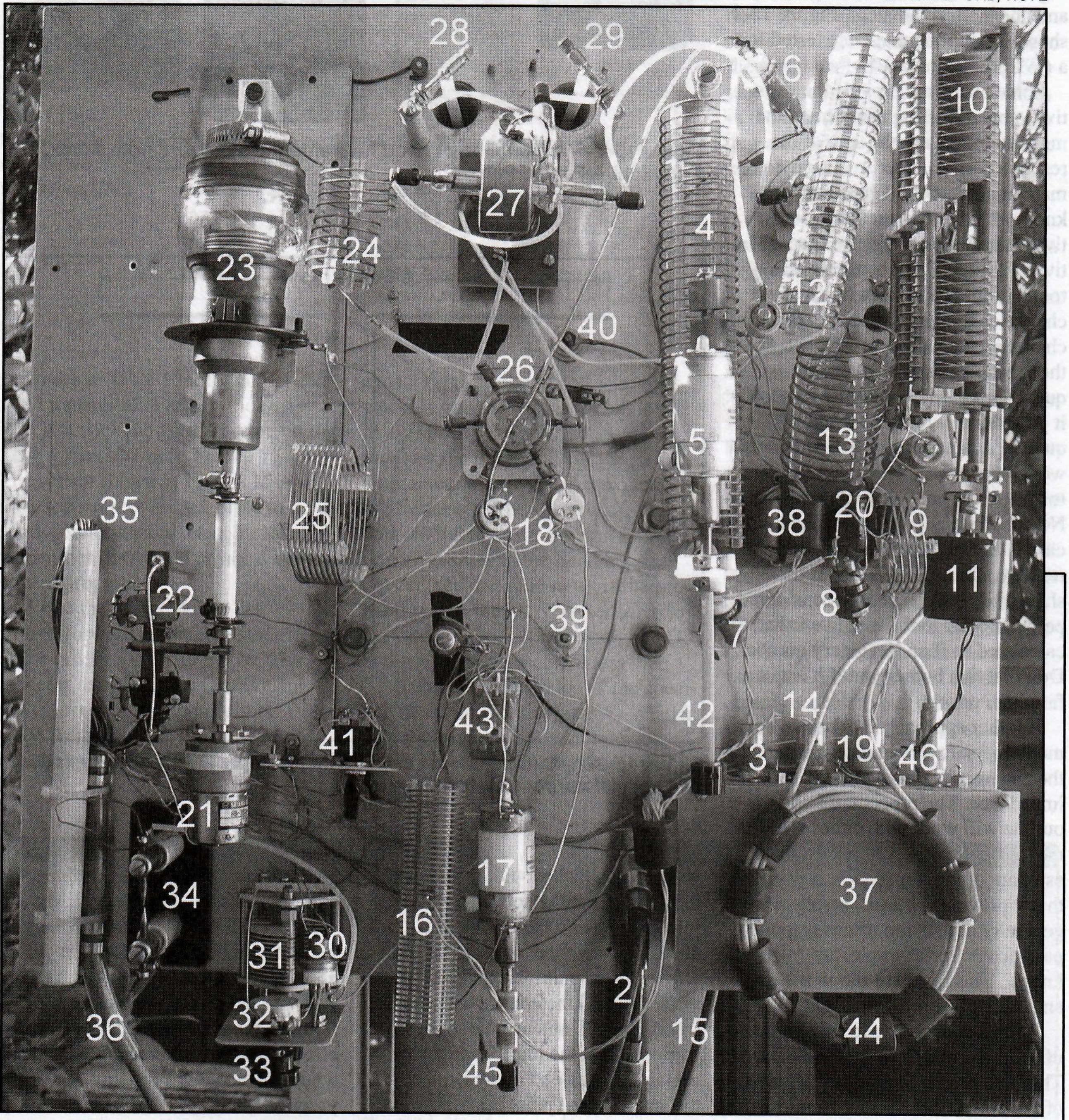

Figure 15-1 — Example of perhaps the extreme in homemade antenna tuning arrangements. This collection of remotely controlled special purpose antenna tuners, all on an outside panel (cover removed for photo), was made to switch between and tune the multiple antenna systems of the late George Badger, W6TC, the designer and builder. The annotations refer to the elements in the list below.

The tuner panel includes separate remote controlled matching networks and connections for each of the HF bands from 30 to 160 meters. It is mounted at the base of the tower. At the top of the tuner panel are two connectors that connect to the two lower ends of the 30, 40, 60, 80 and 160 meter loop that extends from the left connector up to the 5 foot fiberglass boom extension on the left, up and over the 8 foot fiberglass mast extension at the top to the boom extension on the right, then down to the right connector.

able RF generators and displays that indicate actual complex (resistive and reactive) impedance, not just SWR. These are available from a number of manufacturers for a few hundred dollars, and are a valuable tool for the antenna inclined amateur. **Figure 15-2** shows a sampling that were tested for a *QST* product review.[1]

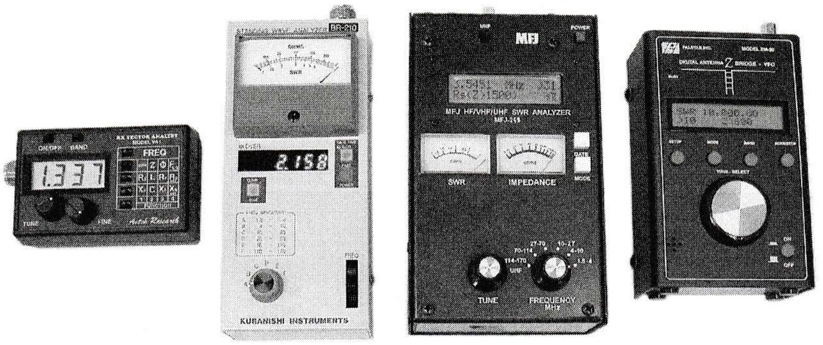

Figure 15-2 — A sampling of hand held antenna analyzers from Autek, Kuranishi, MFJ and Palstar.

Some analyzers provide the resistive value of the impedance and the magnitude, but not the sign of the reactive part. In order to design a matching network, it is important to know whether the reactance is positive (inductive) or negative (capacitive). Fortunately, it is usually easy to determine this. Just make a slight change in frequency and note the change in the value of reactance. If the reactance goes up as the frequency goes up it is inductive (+). If it goes down with increasing frequency, it is capacitive (–). This only works if the reactance does not go to zero between the two data points. Note that many programs use a lower case italicized letter *j* as part of the reactive value. This indicates that it should be mathematically considered perpendicular to the resistive value, or calculated as if an imaginary number. Don't let this bother you if it is not a familiar concept.

Another approach is to use antenna modeling software to determine the antenna, or the antenna system, impedance. The procedure I will outline will work with either. While modeling will result in a reasonable estimate of the impedance, it is rare that it provides an exact result, since generally not all conditions (ground parameters, for example) are fully known. This is what I did in the example that follows.

A third approach is to rely on manufacturers' or other published data. This also has its limitations in terms of the effect of the actual conditions at your location.

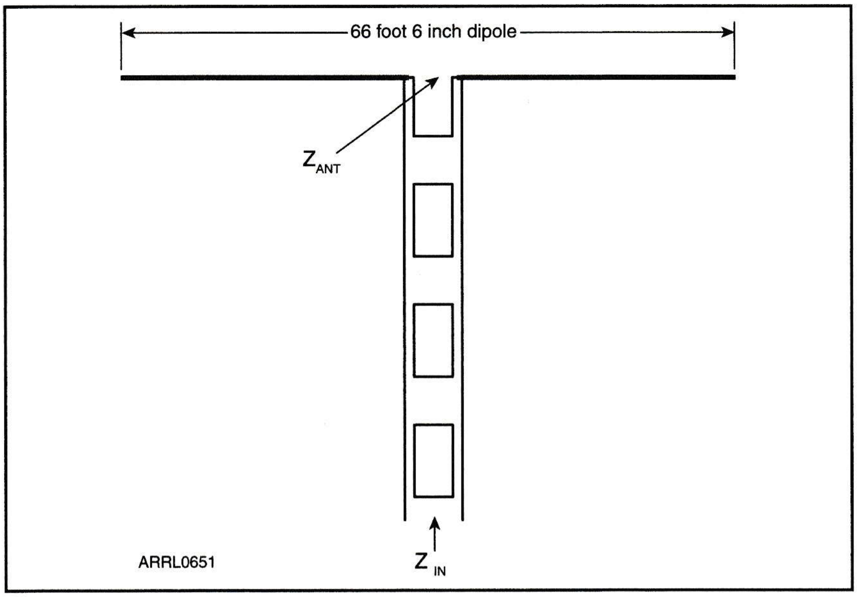

Figure 15-3 — 40 meter dipole used as the example for the determination of a special purpose matching network.

Figure 15-3 provides the basis for a short example of how this process can easily be conducted. The antenna under consideration is a dipole cut for the low end of the 40 meter amateur band. Instead of feeding it directly with coax, which would likely not require a matching network, we have selected to use 70 feet of nominal 450 Ω window line, so it can be fed efficiently on multiple bands. In order to use it on 40 meters, we determine (using *EZNEC* antenna modeling software) that the impedance at the center and each end of the band at the antenna feed point is as shown in **Table 15-1**.[2]

We then use the transmission line analysis program *TLW*, furnished with recent editions of *The ARRL Antenna Book*, to determine the impedance at the bottom of the mismatched transmission line as shown in **Table 15-2**.[3] Note that we could have gone directly to Table 15-2 using many antenna analysis programs that are equipped with transmission line models. My version of *EZNEC* included an early transmission line capability that did not take losses into account, so I used *TLW* instead. Since we need *TLW* for the next step, it wasn't any extra effort. One hint about using *TLW* — when finished don't just close the program window — click on the EXIT button to avoid problems with it starting properly next time.

- *Design a network that will transform the impedance to the desired impedance of the radio or transmission line.*

There are many techniques that could be employed to design a matching network to match any of the im-

[1] Notes appear on page 11.

Table 15-1

Impedance Predicted at the Antenna (Z_{ANT}) as Shown in Figure 15-1.

Frequency(MHz)	*Resistive Part (Ω)*	*Reactive Part (Ω)*	*50 Ω SWR*
7.0	82.3	–34.0	2.0
7.15	88.0	–0.37	1.8
7.3	94.1	+33.1	2.2

Table 15-2

Impedance Predicted at Bottom of the 70 Foot Transmission Line (Z_{IN}) as Shown in Figure 15-1.

Frequency(MHz)	*Resistive Part (Ω)*	*Reactive Part (Ω)*	*450 Ω SWR*
7.0	87.7	+82.9	4.9
7.15	103.3	+148.6	4.6
7.3	236.5	+229.7	4.3

pedances in Table 15-2 to our desired 50 Ω transmitter. Perhaps the easiest is to just click the TUNER button on the *TLW* screen shown in **Figure 15-4**. The screen shown in **Figure 15-5** will then appear, providing a place to input some common parameters including transmitter power and physical component properties.

While the design power is a straightforward parameter, some of the other terms may not be. The inductor and capacitor Q are related to the losses in the components. Typically, the biggest loss in an HF tuner, especially one with an air dielectric capacitor(s), is due to coil wire resistance. If you are buying a coil, it will likely specify the Q. If not, you can measure the impedance of the coil on your antenna analyzer at the operating frequency. The Q is just X_L/R, both available on an antenna analyzer screen.[4] Values in the hundreds are typical, and the good news is the program results are not very sensitive to the value of Q. A 100% change in Q, in this example, results in less than a 0.5% change in the value of the specified inductor and capacitor — smaller than the usual component tolerance, thus we specify a Q of 200 and the resulting design should be fine for most real inductors.

The OUTPUT STRAY CAPACITANCE value represents the capacitance of the wiring and components on the output side to the chassis. All wiring and components in the usual metal chassis or cabinet have capacitance to the metal walls. This is most important as the frequency goes up. Values in the tens of picofarads are common depending largely on component size and placement.

The other choice on this screen is the TUNER NETWORK TYPE. There really isn't too much to say about this — pick the one you like best, or better yet — try them all. I am somewhat partial to the low-pass L-network because it only has two components and provides some attenuation of harmonic signals. It also has only one solution for any load — more later. Pick any one to start, you will likely want to look at them all to find which one has components that are available or easiest to obtain.

If you pick any configuration besides the L-network, it will ask you for a value to use for the capacitor on the output side (towards antenna). It will try to design a tuner for any value you pick. If it can't make a tuner work with your value it will suggest making it larger or smaller. Make note of the power loss and try different values of output capacitor

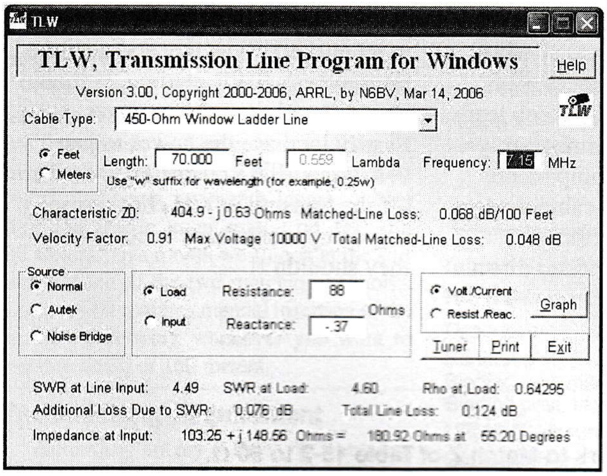

TLW, Transmission Line Program for Windows

Version 3.00, Copyright 2000-2006, ARRL, by N6BV, Mar 14, 2006

Cable Type: 450-Ohm Window Ladder Line

● Feet
○ Meters

Length: 70.000 Feet 0.559 Lambda Frequency: 7.15 MHz

Use "w" suffix for wavelength (for example, 0.25w)

Characteristic Z0: 404.9 - j 0.63 Ohms Matched-Line Loss: 0.068 dB/100 Feet

Velocity Factor: 0.91 Max Voltage 10000 V Total Matched-Line Loss: 0.048 dB

Source
● Normal
○ Autek
○ Noise Bridge

● Load
○ Input

Resistance: 88 Ohms
Reactance: -.37

● Volt./Current
○ Resist./Reac.

SWR at Line Input: 4.49 SWR at Load: 4.60 Rho at Load: 0.64295

Additional Loss Due to SWR: 0.076 dB Total Line Loss: 0.124 dB

Impedance at Input: 103.25 + j 148.56 Ohms = 180.92 Ohms at 55.20 Degrees

Figure 15-4 — Input screen of *TLW* transmission line analysis software used to determine the impedance at the bottom of the mismatched transmission line of Figure 15-1.

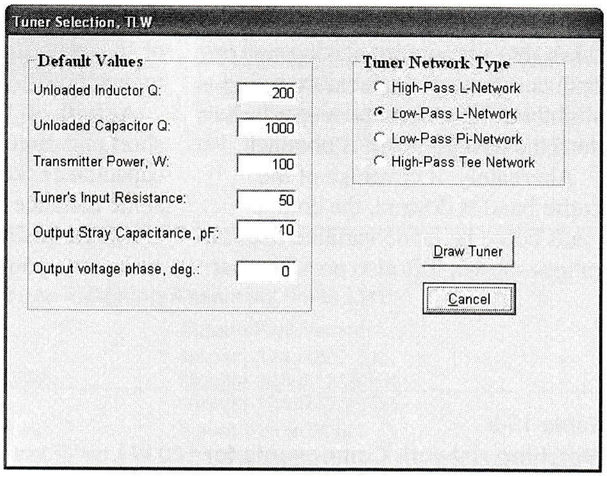

Default Values

Unloaded Inductor Q: 200
Unloaded Capacitor Q: 1000
Transmitter Power, W: 100
Tuner's Input Resistance: 50
Output Stray Capacitance, pF: 10
Output voltage phase, deg.: 0

Tuner Network Type
○ High-Pass L-Network
● Low-Pass L-Network
○ Low-Pass Pi-Network
○ High-Pass Tee Network

Figure 15-5 — Antenna tuner Input screen of *TLW* software. Note the tuner configuration selected, LOW-PASS L-NETWORK, the power level, 100 W, that determines component ratings as well as the other parameters as described in the text.

until you achieve a design that has an acceptable amount of loss and reasonably sized components. This illustrates the fact that the three element tuners — Pi- and T-network — have more than one set of adjustments that will provide a satisfactory match to the radio. Unfortunately, while they will all look good to the radio, some will have more loss than others.

Push the DRAW TUNER button. The screen shown in **Figure 15-6** should appear providing the design details for the low-pass L-network tuner I selected. In addition to the component values needed to provide the match, the table above the schematic provides information on component stress levels and other key data. The primary selection criterion can be found by looking at the resulting tuner designs (next paragraph) in each configuration and seeing which ones have component values that are reasonable, and even better, that you have on hand. A look at the resulting efficiency, expressed as POWER INTO LOAD, may also help you select a preferred topology.

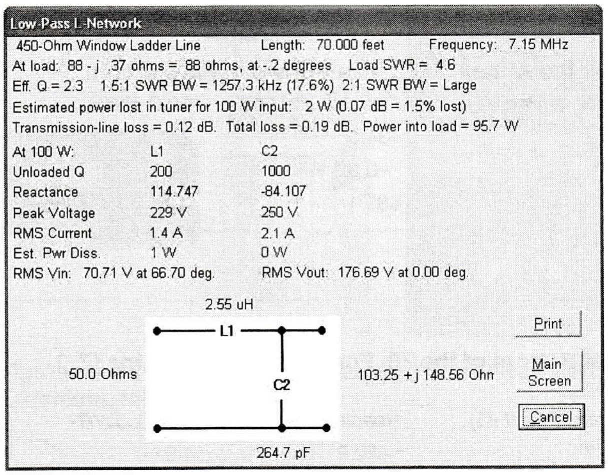

```
Low-Pass L-Network
450-Ohm Window Ladder Line        Length:  70.000 feet       Frequency:  7.15 MHz
At load:  88 - j  .37 ohms =  88 ohms, at -.2 degrees    Load SWR =  4.6
Eff. Q = 2.3    1.5:1 SWR BW = 1257.3 kHz (17.6%)  2:1 SWR BW = Large
Estimated power lost in tuner for 100 W input:   2 W (0.07 dB = 1.5% lost)
Transmission-line loss = 0.12 dB.  Total loss = 0.19 dB.  Power into load = 95.7 W
At 100 W:              L1               C2
Unloaded Q             200              1000
Reactance              114.747          -84.107
Peak Voltage           229 V            250 V
RMS Current            1.4 A            2.1 A
Est. Pwr Diss.         1 W              0 W
RMS Vin:   70.71 V at 66.70 deg.        RMS Vout:  176.69 V at 0.00 deg.
```

Figure 15-6 — Antenna tuner output (design) screen of *TLW* software. Note the tuner schematic with parts values shown. The data and table above provide additional important information.

Table 15-3 shows the resulting design for the middle and both edges of the 40 meter band. This design can be used as a starting point for a single frequency, single load, matching network. I say starting point because even with careful analysis there are a few variables that are not known exactly, including actual component values — typical tolerances are ±10% — for example. This is often taken into account by making one or both components variable, or trying slightly different component values until the desired result is obtained.

Alternately, if coverage of the entire band is desired, the components could be made variable over the ranges shown. It is also possible that the values for the middle of the band will provide a satisfactory match over at least a portion of a band without requiring change. This can be determined by trial and error, or simulated in an antenna analysis program by using modeled lumped "loads" at the bottom of the transmission line.

- *Build and test the network.*

As noted, the hardest part is often finding the needed components, especially those needed for high power networks. Hamfest flea markets are often a good source for such items, although they often come with a level of uncertainty regarding ancestry and component value. Again, the trusty antenna analyzer can be used to measure the reactance. Fixed or tapped inductors can be easily wound using plastic rod or tubing as a form. *The ARRL Handbook* provides a source of formulae for winding the desired inductance.

As with all RF projects, keep leads short and direct. To minimize stray capacitance, keep the components some distance from the cabinet edges. Use high quality connectors and make sure you have provided direct connectivity for all needed interconnections.

The best way to test the network is to start with the antenna analyzer. With the network connected to the proper place on the transmission line, the impedance should read close to 50 Ω at the design frequency. Now take *swept frequency* type data by measuring the impedance and SWR every 25 or 50 kHz. By plotting these on a graph, you should have a good idea of what the network will do and whether or not it will work across the range. If it isn't quite right, make a small change in one value and repeat the sweep. You should see an indication of the extent and direction of the change. Since there are only two or three components, you should quickly converge on your result.

Next hook it to your radio tuned to an unused frequency and note the transceiver's SWR reading. It should be close to that of the analyzer. Slowly increase the power to just below the level you designed to. Turn off the transmitter and check to see if any components have become hot — they shouldn't!

Table 15-3
Matching Network Components for 100 W Low-Pass L-Network to Match Z of Table 15-2 to 50 Ω.

Frequency(MHz)	*Inductance (μH)*	*Inductor Current (A_P)*	*Capacitance (pF)*	*Capacitor Voltage (V_P)*	*Efficiency (%)*
7.0	1.72	1.4	339.4	181	96.1
7.15	2.55	1.4	264.7	250	95.7
7.3	3.28	1.4	205.2	317	95.4

160 and 80 Meter Matching Network for Your 43 Foot Vertical — *Part 1*

The popular 43 foot vertical works best with matching at the antenna base — here's a way to do it for our two MF bands.

Phil Salas, AD5X

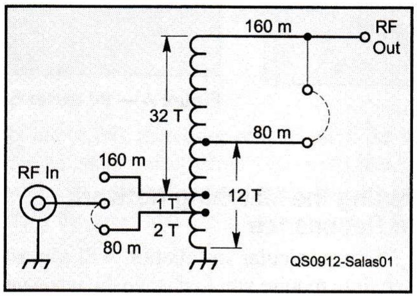

Figure 1 — Schematic diagram of the two band matching unit. 80 meter connections shown with dashed lines.

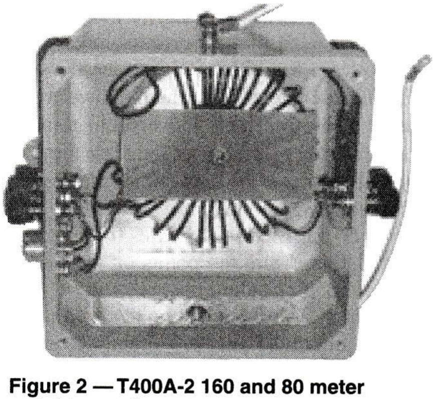

Figure 2 — T400A-2 160 and 80 meter matching unit.

I've recently made the move to a 43 foot vertical for much of my lower frequency operations. This length antenna offers higher radiation resistance than shorter loaded monopoles. Increased radiation resistance improves efficiency by reducing the effects of ground losses, especially when you have an electrically short antenna — a characteristic of even a 43 foot antenna on 160 and 80 meters. If fed with a 1:4 unbalanced to unbalanced transformer (unun), a 43 foot antenna has a reasonable compromise SWR on 60 through 10 meters, which means that cable and unun losses are pretty much negligible on these bands.

This antenna is really not a good performer on 160 meters, and to a lesser extent on 80 meters, unless you provide matching right at the antenna base. This is due to the high capacitive reactance and still relatively low radiation resistance of a 43 foot antenna on 160 and 80 meters. This makes the mismatch so bad that it is almost impossible to efficiently match from your shack. If you can match the antenna system from your shack, you will throw away a lot of power in your coax and unun due to the very bad mismatch at the antenna.

I thus started experimenting with matching networks and wound up with two external impedance matching devices designed to significantly reduce SWR related coax losses and unun mismatch losses, and to help the inside tuner match on 160 and 80 meters. This month we'll look at the simpler version of the two matching networks. This version requires manual insertion of the matching network whenever you want to operate on 80 or 160 meters.

The Matching Requirement

According to my AIM4170C antenna analyzer, my 43 foot vertical antenna has a capacitive reactance of about 580 Ω on 160 meters. This will vary based on the particular construction of your 43 foot vertical, its proximity to other objects, and other factors. The reactance will almost certainly be in the 550 to 650 Ω range. This amount of capacitive reactance needs approximately 50 µH of inductance in order to resonate the antenna. On 80 meters, approximately 9 µH is needed to resonate the antenna. A 50 µH high Q inductor is going to be large. For this first solution, I elected to go with a toroidal inductor in order to keep the matching unit as compact as possible.

Toroid Inductor Matching Solution

This compact design will handle the full legal limit on 80 and 160 meters for low duty cycle SSB and CW modes. The inductor consists of 35 turns of #14 AWG solid copper insulated house wiring wound on a T400A-2 toroid core. The antenna feed point is tapped two turns from the ground end for 80 meters, and three turns from the ground end for 160 meters. You should start with 38 turns total on your toroid, but then remove turns as necessary to get the network to resonate where you want it in the 160 meter band (more on this later).

I mounted the toroid assembly in a 6 × 6 × 4 inch NEMA enclosure using a 2½ inch long #10 machine screw and associated hardware along with a 2 × 4 inch piece of unplated fiberglass PC board material. Before you mount the toroid, prepare

Table 1
160 Meter Toroid Impedance Matching Assembly Parts List

Description	*Source/Part Number**
Banana plug (4 required)	Mouser 174-R802-EX
Binding post, black (4 required)	Mouser 164-R126B-EX
Binding post, red	Mouser 164-R126R-EX
NEMA Enclosure, 6 × 6 × 4 inch	Lowes/Home Depot
Glass cloth tape, 3M #27	ACE Hardware
SO-239 connector	Mouser 601-25-7350
Toroid, T400A-2 powdered iron	Amidon T400A-2

*Amidon parts are available from **www.amidoncorp.com** and Mouser parts from **www.mouser.com**.

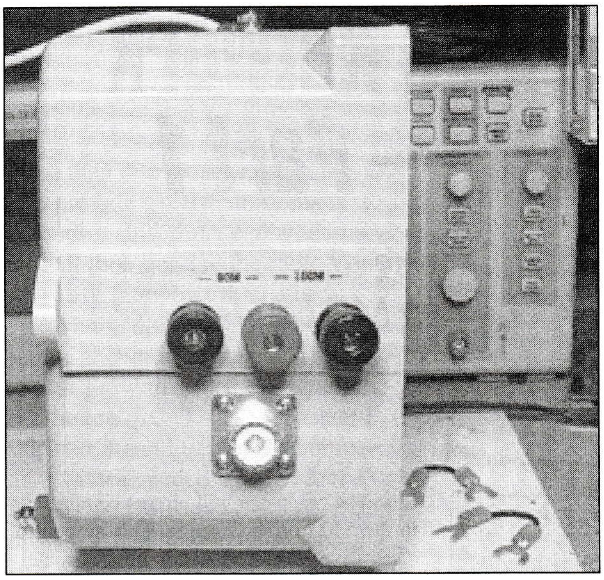

Figure 3 — 160 and 80 meter input tap points.

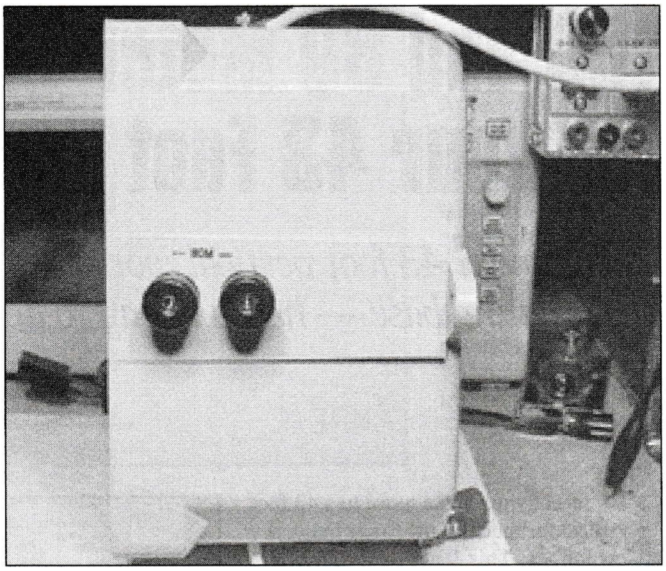

Figure 4 — 80 meter coil shorting jacks.

it by scraping the insulation off the outside second, third and 11th through 13th wire turns. Because of the high voltages possible at legal limit power levels, especially on 160 meters, wrap the toroid with two layers of 3M #27 glass cloth electrical tape for added insulation between the #14 AWG wires and the toroid core.

Figure 1 is the schematic of the matching assembly, Figure 2 shows the internal details of the assembly, and Table 1 lists the parts necessary. To select between 160 and 80 meter operation, I used external jumpers across binding posts as shown in Figures 3 and 4. Stainless steel #8 hardware (screws, washers, lockwashers and nuts) are used for the matching unit ground and RF output terminals. Internal to the matching unit, I used a 2 inch wide strip of aluminum duct repair tape as a good low impedance ground between the UHF connector and the ground screw on the bottom of the case. Finally, I used #14 AWG stranded insulated wire for all internal connections.

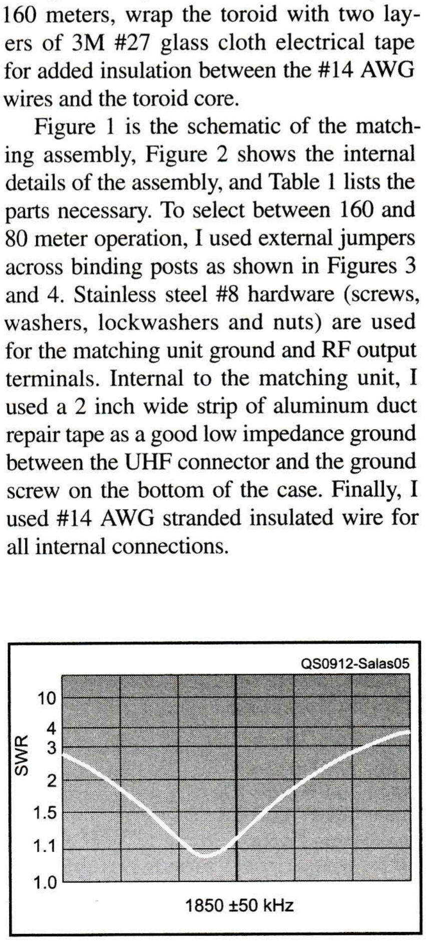

Figure 5 — Measured SWR across 160 meters indicating a 2:1 SWR bandwidth of approximately 50 kHz.

Tuning the Matching Network to Resonance

Your particular installation will almost certainly require you to change the resonant frequency of the matching network. This is because there will be some variations of the antenna impedance based on your particular antenna physical construction, proximity to other objects and final length, as well as your desired operating frequency range. The design is such that the overall inductance is too large for 160 meters, so the network should resonate at or below the lower band edge. Therefore, you will need to remove one or more of the upper inductor turns in order to resonate the network for the desired frequency on 160 meters.

To do this, first solder wires from the second and third turn tap points on the coil to the two outer binding posts by the SO-239 connector. The input tap points tend to be fairly noncritical and will probably be the same for all installations. Now solder a short wire from the SO-239 center pin to the middle binding post. Next, externally jumper the middle binding post to the 160 meter binding post (third turn).

Connect the matching assembly to the base of your 43 foot vertical and see where the minimum SWR point is on 160 meters using your antenna analyzer. If the resonant frequency is too low, remove a turn of wire and see where the minimum SWR point is again. You'll see about a 50 kHz upward move in frequency per turn of wire removed. When you have your desired resonant point on 160 meters, it is time to move to 80 meters. Externally jumper the input tap middle binding post to the 80 meter binding post (second turn), and use a clip lead to short from the top of the coil to turn number 12 and see where your minimum SWR frequency occurs. Move the tap point up or down until your resonance point (lowest SWR) is where you want it. Solder a wire from this tap point to one of the binding posts. Solder another wire from the top of the coil to another binding post. Now you will be able to externally jumper these binding posts to select either 160 or 80 meters.

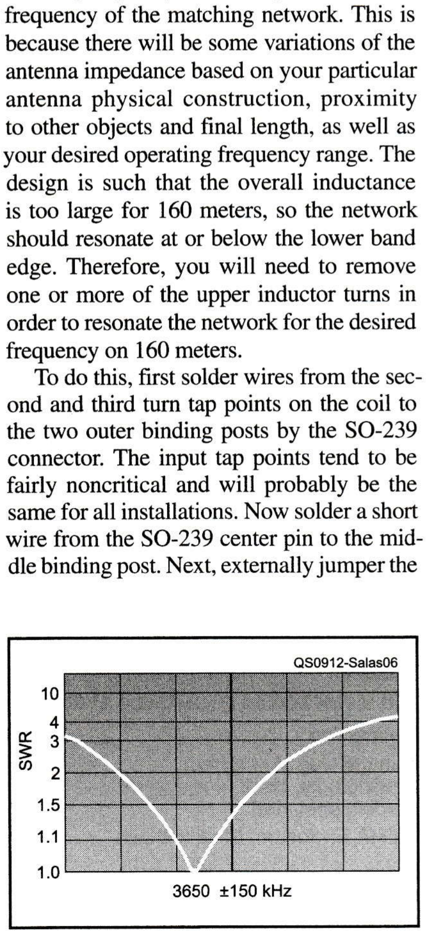

Figure 6 — SWR across 80 meters indicating a measured 2:1 SWR bandwidth of about 150 kHz.

My final test results for 160 and 80 meters are shown in Figures 5 and 6 as measured with my RigExperts AA-200 antenna analyzer connected directly to the matching network input at the base of the antenna. I'm a CW operator, so I favor resonance in the lower part of these bands, but you can adjust for your favorite portion of each band. The 2:1 SWR bandwidth on 160 meters is about 50 kHz, and about 150 kHz on 80 meters. Even a 3:1 SWR on these bands results in negligible SWR related cable losses for any reasonable length cable and is easily matched with my MFJ-998 in-shack tuner or most transceivers' internal tuners.

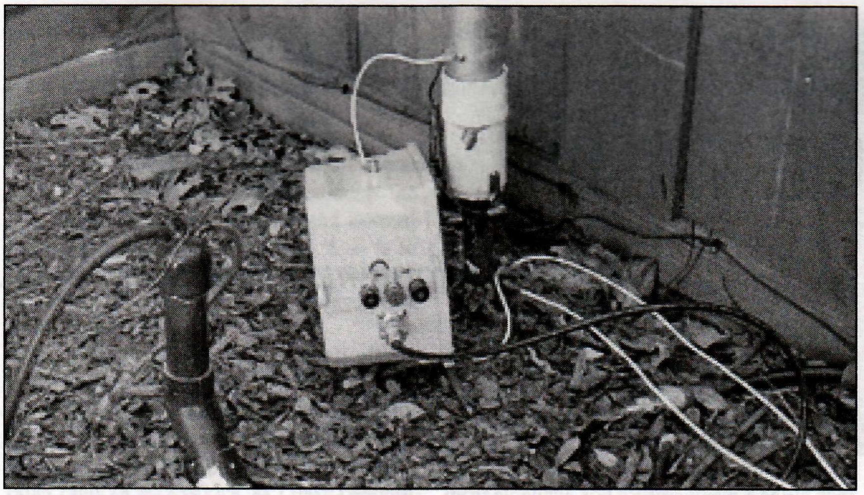

Figure 7 — Matching unit at the base of the author's 43 foot antenna. In this view, it is strapped for 80 meters.

Operation

Using the matching unit is simple. Just disconnect your normal unun when you want to operate on 160 or 80 meters and connect this matching unit to the base of the antenna. Select either 160 or 80 meters with the external straps. You can connect both the unun and this matching unit to the antenna at the same time, and just leave off the ground wire from the unit that is not used. The matching unit connected to the base of my 43 foot vertical is shown in Figure 7.

Conclusion

The matching network discussed in this article will permit very effective operation of your 43 foot vertical on the 160 and 80 meter bands. In Part 2, we'll look at a remotely switchable 160, 80 and 60 through 10 meter base matching unit. It is more complex, but it is also more convenient. Until then, see you on top band!

Amateur Extra class operator and ARRL Life Member Phil Salas, AD5X, was first licensed as WN3BCQ in 1964. Ham radio became the reason he subsequently pursued a career in electrical engineering. Phil earned BSEE and MSEE degrees from Virginia Tech and SMU, respectively, and worked in new product development for the next 33 years. Phil is now retired and spends his days split between ham radio related projects and enjoying time with his wife, Debbie, N5UPT. You can reach Phil at 1517 Creekside Dr, Richardson, TX 75081 or at **ad5x@arrl.net**.

160 and 80 Meter Matching Network for Your 43 Foot Vertical — *Part 2*

This dual band matching section design provides for remote band changing.

Phil Salas, AD5X

In Part 1, I described a simple 160 and 80 meter base matching assembly for a 43 foot antenna. While that unit is very effective and inexpensive to build, it is also a little inconvenient in that you must connect it when it is needed, and you must also manually enable 160 or 80 meter operation using straps. This month, we'll look at a more versatile matching assembly that is completely remote-controllable for operation on all bands. Again, this base matching network will significantly eliminate SWR-related coax losses and unun mismatch losses, and assist inside tuners in providing a match on 160 and 80 meters.

The All Band Matching Solution

As discussed in Part 1,[1] a 43 foot vertical antenna requires approximately 50 µH of inductance to resonate the antenna. On 80 meters, approximately 9 µH is needed for resonance. For the matching solution shown in Figure 1, I used an MFJ 404-0669 air wound coil and two Array Solutions RF-30 relays for up to full legal limit matching on all bands from 160 to 10 meters. A 2.1 × 5.5 mm dc power jack located below the SO-239 connector provides for relay control voltage inputs of 0 V, +12 or –12 V dc. The control input MOVs and bypass capacitors are mounted on a 6 terminal strip inside the matching assembly.

The matching unit operates as follows: With no control voltage applied, the inductor is disconnected and the unun is connected across the antenna feed point thereby preserving the original compromise SWR on 60-10 meters.

When +12 V is applied, the inductor is connected across the antenna feed point and inductor turns are shorted to resonate the antenna on 80 meters.

When the voltage is reversed, the short across the coil is removed and the matching section resonates the antenna on 160 meters. In both the 160 and 80 meter cases, the unun secondary taps into the inductor at the 200 Ω point, providing a proper match to the unun on these bands. This keeps the unun secondary voltage reasonable, and the feed line and unun losses very low as well.

I built the matching unit into an 8 × 8 × 4 inch NEMA weatherproof box available from home supply stores (see Figure 2). This box is too small to fit the entire inductor length needed, so I split the inductor into two pieces as can be seen in Figure 1. The long inductor section consists of 61 turns, and the short inductor section consists of 12 turns. While I preferred the more compact size of this box, you may wish to use the larger 12 × 12 × 4 inch NEMA box that can contain the full uncut inductor length needed.

All internal wiring uses insulated #14 AWG stranded wire. I attached the wires to the coil tap points using the MFJ coil clips called out in the parts list. You can solder the wires directly to the coil, but this is difficult due to the #12 AWG size of the coil wire and the spacing of the turns. The coil is mounted with #8 stainless steel screws, washers, lock washers and nuts also used for the ground and antenna feed terminals. Figure 1 shows the final matching unit with all components mounted. Note the terminal strip with the MOVs and bypass capacitors.

Since the antenna is unbalanced, a current balun or voltage unun is typically used. A voltage unun should be wired as shown in Figure 2.

Relay Connections

Some comments are necessary regarding the relay connections. See the sidebar on the *QST* binaries Web site for a discussion of how high the peak voltage across the full coil can be on 160 meters. As you can see, I connected relay contacts in series to increase the overall breakdown voltage. Also, the tap points on the inductor provide additional voltage above ground, which helps with the overall breakdown voltage.

The main concern is with the contact-to-coil 5.3 kV peak breakdown rating. When I examined the relays, I observed that the outer SPDT contacts are connected via insulated internal wires that are well separated from the coil by 0.1 to 0.2 inches. The problem is with the center SPDT relay common wire, which is in contact with the coil. While the coil and common wire are both insulated, there is no air-gap separation between them. This common wire-to-coil contact is obviously what

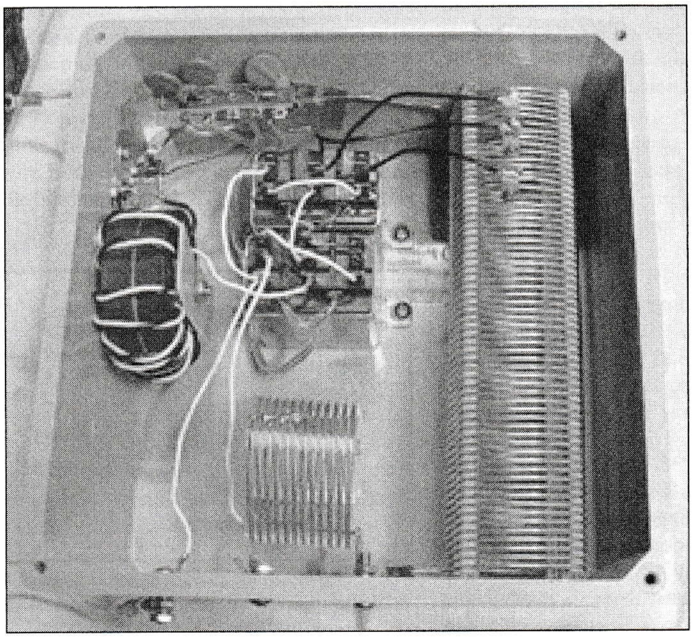

Figure 1 — All parts mounted in the NEMA enclosure.

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[1] Notes appear on page 35.

determines the breakdown voltage rating. The way I got around this problem was to use the center SPDT relay contacts for the lowest potential interfaces as indicated in the schematic (Figure 2).

For the switched control voltage input, I used a 12 V, 1 A wall wart to keep the +12 V control voltages separate and isolated from the regular station voltage. This is to eliminate any possibility of shorting the main power supply when the control voltage polarity is flipped.

I mounted the switch in a small plastic box that I attached to my transceiver support shelf. The unlabeled center-off position is for 60 through 10 meter operation. The separate switch you see in the photo is for controlling other outdoor accessories, as I have two voltage feeds going out to my antenna location.

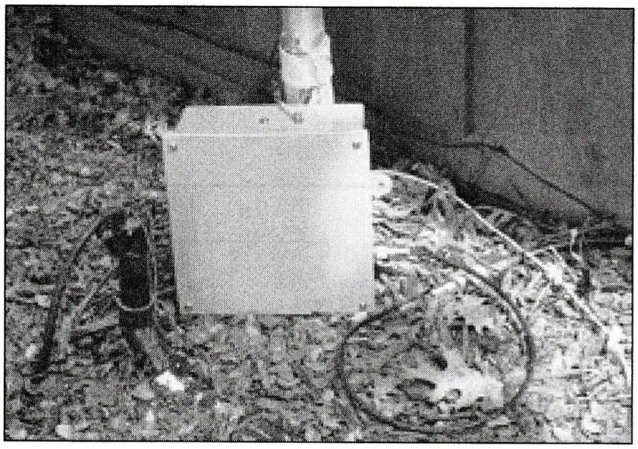

Figure 3 — The completed all band remotely controlled switching and impedance matching network mounted at the antenna base.

Matching Network Resonance

As with the previous matching network, you will almost certainly need to adjust the resonant frequency of the matching network due to variations in particular antenna physical construction, proximity to other objects and final length, as well as your desired operating frequency range. The overall starting inductance is too large for 160 meters, so the network will resonate at or below the lower band edge. Therefore, you can simply short one or more of the upper (short coil) inductor turns in order to tune the network higher to your desired 160 meter frequency.

To do this, first leave off the wire leads that attach between the relay contacts and the tap points on the coil. Build up short jumpers using the test-clips and micro-clips (perfect for the coil turn taps) called out in the parts list, and attach these between the relay contacts and coil, using the suggested tap points shown on the schematic.

Connect the matching assembly to the base of your 43 foot vertical (see Figure 3). Then enable 160 meter operation by applying −12 V dc, and jumper turns on the 12 turn inductor with a short clip lead until you find your desired 160 meter resonance point. Next, move the 160 meter relay tap point until you get minimum SWR. Now permanently short the turns on the short coil by soldering a piece of #16 AWG buss wire across these turns.

As you can see from my photos, I needed to short six turns on this coil. Next enable 80 meter operation (apply +12 V to the relays assembly) and select the coil shorting point for your desired resonant frequency and the tap point for best SWR. Finally remove the test clips leads, attach the coil clips, and solder wires between the coil clips and relay.

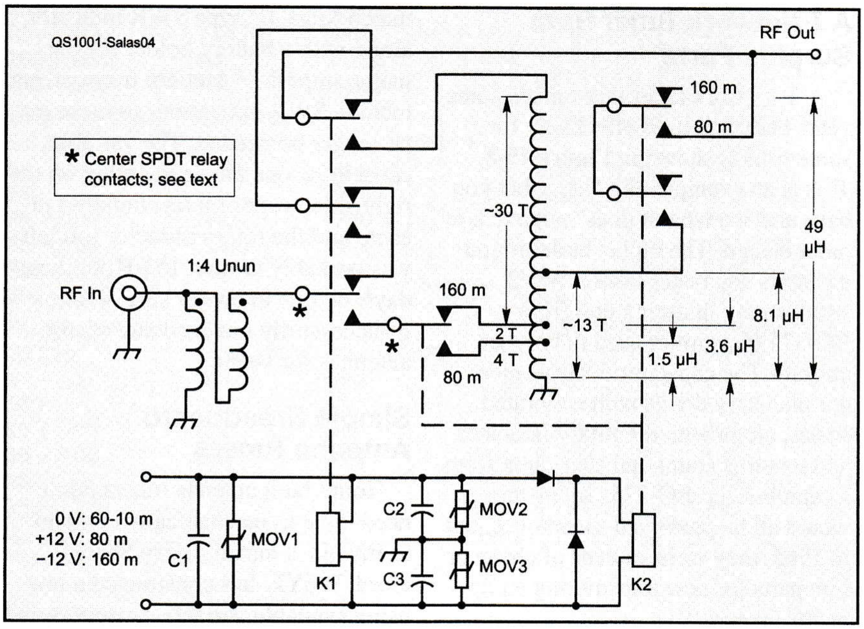

Figure 2 — Schematic of the remotely controlled matching network. The parts list is on the QST binaries version.[2]

The 2:1 SWR bandwidth on 160 meters is about 50 kHz, and about 150 kHz on 80 meters. Even a 4:1 SWR on these bands results in negligible SWR related cable and unun loss, and is easily matched with my MFJ-998, an in-shack tuner.

Operation

Operation of this matching unit couldn't be simpler. When no control voltage is applied, the antenna functions as it always has on 60 through 10 meters. For 80 meter operation, apply +12 V dc, and for 160 meter operation apply −12 V dc. The matching unit connected to the base of my 43 foot vertical is shown in Figure 10.

Conclusion

The matching network discussed in this article will permit very effective operation of your 43 foot vertical on all bands from 160 through 10 meters. Although on 10, 12 and 15 meters the elevation angle of the peak is higher than optimum for DX, it will still allow contacts. Feel free to experiment a little. You might prefer to use the toroid from Part 1 in this design instead of the air-core inductor. If you are not running more than about 500 W, the less expensive RF-10 relays are all you will need. Have fun, and I'll see you on the low bands.

Notes

[1] P. Salas, AD5X, "160 Meter Matching Network for Your 43 Foot Vertical — *Part 1*," *QST*, Dec 2009, pp 30-32.

[2] **www.arrl.org/files/qst-binaries.**

See Part 1 for Phil's bio. You can reach Phil at 1517 Creekside Dr, Richardson, TX 75081 or at **ad5x@arrl.net**.

Home Built General Purpose Tuners

There are a number of approaches to the design and construction of general purpose antenna tuners. Perhaps the easiest is to replicate existing successful designs, although finding the exact parts called for is sometimes a problem. Fortunately, the exact values are not very critical. It is also possible, if somewhat tedious, to go through the *TLW* based procedure described above at the extremes of frequency and mismatch to determine the range of values needed and then construct a tuner with variable and/or switched elements, often in combination, that will cover the needed range.

I have done this for the most popular configurations, see **Figure 15-7**, the high-pass T-network, Pi-network and low pass L-network with the results shown in **Tables 15-4** through **15-6**. I have provided the values for matching loads with a 10:1 SWR, the usual spec for a wide range tuner. In addition to the resistive loads at 5 and 500 Ω, I have made runs for moderate reactive loads of 25 ± *j*25 Ω and extreme reactive loads of 250 ± *j*250 Ω, all with approximately a 10:1 SWR.

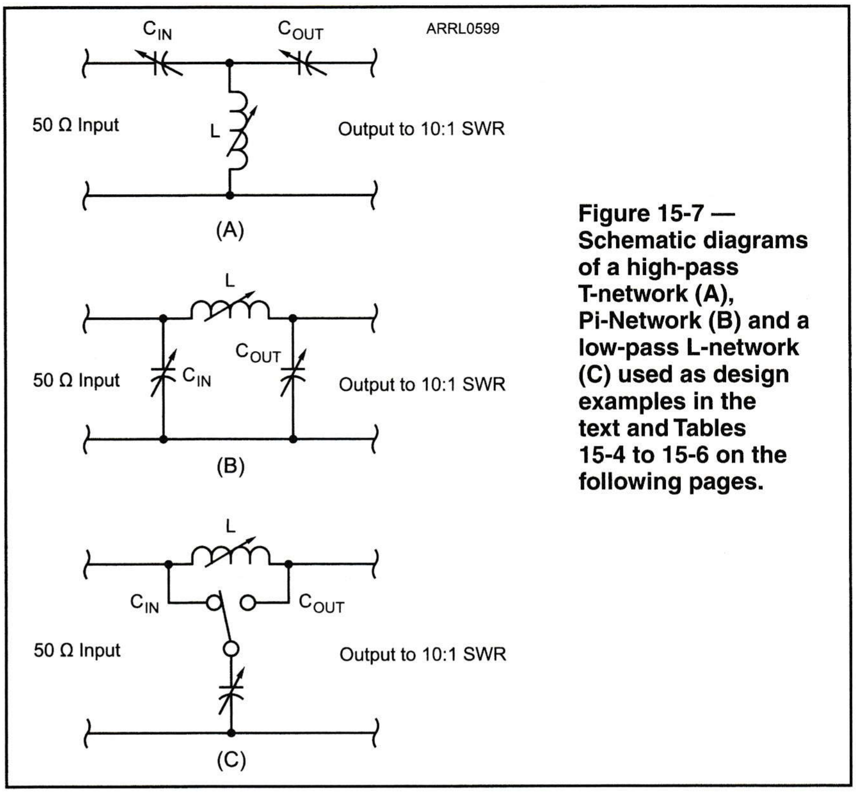

Figure 15-7 — Schematic diagrams of a high-pass T-network (A), Pi-Network (B) and a low-pass L-network (C) used as design examples in the text and Tables 15-4 to 15-6 on the following pages.

As noted in Chapter 4, the Pi- and T-network tuners have multiple solutions for any load, while the L-network has a single solution. It is worth stressing this in case you use one, whether a commercial unit or a home-built one. Look again at Table 4-1, in Chapter 4, to get the idea.

Such "HF" tuners sometimes include the MF 160 meter amateur band as well as the 80 through 10 meter HF bands. I have provided data for 160, 80 and above the top of 10 meters so you can decide which way you want to go. Note that the addition of 160 meters makes a big difference in the component values required, one reason it often is not included. In addition, in some cases the larger inductor and capacitor(s) may have too high a minimum value to allow proper operation on 10 meters.

A T-Network Tuner from Surplus Parts

A T-network tuner that I made some years back and used effectively for some time is shown in **Figure 15-8**. This is an example of a "use what you have and see what it does" approach to tuner design. The unit is built around a chassis and panel from a WW2 surplus plug in tuning unit from a BC-375 transmitter used in bomber aircraft. The capacitor controls nice 4:1 planetary drives with calibrated scales, along with the rotary indicator and its turns count dial also came from a cannibalized BC-375. Today they would all be preserved as antiques, but in 1965, they were sources of cheap or free parts for new transmitting equipment.

Figure 15-9 shows the inside of the tuner, including a home built "Monimatch Mark II" type SWR indicator, along with a battery holder for the meter amplifier.[5] Modern transceivers include SWR indication, so these may no longer be needed. The variable capacitors, one above the other on the right side, were of a few hundred pF each, and the rotary inductor (on left) was probably around 15 μH. In those days, no one knew for sure — but it successfully matched any of my antennas for years.

Simple Breadboard Antenna Tuners

Home-built antenna tuners don't need to be as mechanically complex as my old T-match. Barry Shackleford, W6YE, has constructed a few using available variable capacitors and inductors fabricated in his workshop. While these won't handle full power,

Table 15-4

Component Requirements for High-Pass (Shunt L) T-Network Antenna Tuners at 10:1 SWR

Frequency/Z (Ω)	*Capacitor*		*Inductor (µH)*	*Capacitor Voltage (V_P)*		*Efficiency (%)*
1.8 MHz	*Input (pF)*	*Output (pF)*		*100 W*	*1500 W*	
5	1136	3000	2.1	180	710	96
500	548	500	13.9	323	1250	98
25 + *j*100	343	300	10.3	790	3070	92
25 – *j*100	170	300	20	1040	4030	86
250 + *j*250	308	200	10.5	380	1470	98
250 – *j*250	337	300	16.9	525	2030	96
Frequency/Z (Ω)	*Capacitor*		*Inductor (µH)*	*Capacitor Voltage (V_P)*		*Efficiency (%)*
3.5 MHz	*Input (pF)*	*Output (pF)*		*100 W*	*1500 W*	
5	563	1500	1.1	190	720	96
500	265	200	7.3	343	1330	98
25 + *j*100	275	200	3.5	613	2373	95
25 – *j*100	104	200	8.6	880	3403	88
250 + *j*250	333	100	5.6	381	1475	98
250 – *j*250	136	100	10.8	670	2600	94
Frequency/Z (Ω)	*Capacitor*		*Inductor (µH)*	*Capacitor Voltage (V_P)*		*Efficiency (%)*
30 MHz	*Input (pF)*	*Output (pF)*		*100 W*	*1500 W*	
5	79	200	0.12	160	640	96
500	29	50	0.77	370	1470	97
25 + *j*100	91	30	0.24	400	1560	98
25 – *j*100	24	100	0.46	440	1710	93
250 + *j*250	36	100	0.9	300	1150	98
250 – *j*250	29	100	0.6	360	1410	97

Table 15-5

Component Requirements for Low-Pass (Series L) L-Network Antenna Tuners at 10:1 SWR

Frequency/Z (Ω)	*Capacitor*		*Inductor (µH)*	*Capacitor Voltage (V_P)*		*Efficiency (%)*
1.8 MHz	*Input (pF)*	*Output (pF)*		*100 W*	*1500 W*	
5	5254	n/a	1.34	100	390	98
500	n/a	536	13.5	310	1210	98
25 + *j*100	n/a	1408	12	290	1120	98
25 – *j*100	1760	n/a	11	100	390	97
250 + *j*250	n/a	713	13	310	1210	98
250 – *j*250	n/a	359	13	310	1210	98
Frequency/Z (Ω)	*Capacitor*		*Inductor (µH)*	*Capacitor Voltage (V_P)*		*Efficiency (%)*
3.5 MHz	*Input (pF)*	*Output (pF)*		*100 W*	*1500 W*	
5	2700	n/a	0.69	100	400	98
500	n/a	275	6.8	310	1200	98
25 + *j*100	n/a	720	6.2	290	1120	98
25 – *j*100	926	n/a	5.6	100	390	97
250 + *j*250	n/a	367	6.8	310	1210	98
250 – *j*250	n/a	184	6.8	310	1210	98
Frequency/Z (Ω)	*Capacitor*		*Inductor (µH)*	*Capacitor Voltage (V_P)*		*Efficiency (%)*
30 MHz	*Input (pF)*	*Output (pF)*		*100 W*	*1500 W*	
5	315	n/a	0.08	100	390	98
500	n/a	32	0.79	310	1210	98
25 + *j*100	n/a	85	0.72	290	1120	98
25 – *j*100	140	n/a	0.58	100	390	97
250 + *j*250	n/a	43	0.79	310	1210	98
250 – *j*250	n/a	22	0.79	310	1210	98

Table 15-6

Component Requirements for Low-Pass Pi-Network Antenna Tuners at 10:1 SWR

Frequency/Z (Ω)	*Capacitor*		*Inductor (µH)*	*Capacitor Voltage (V_P)*		*Efficiency (%)*
1.8 MHz	*Input (pF)*	*Output (pF)*		*100 W*	*1500 W*	
5	5256	500	1.4	100	390	98
500	2602	1000	9.6	310	1200	96
25 + *j*100	966	1500	12.5	280	1110	97
25 – *j*100	3410	500	7.5	280	1100	96
250 + *j*250	1931	1000	11.3	310	1210	97
250 – *j*250	1284	500	12.9	310	1210	97
Frequency/Z (Ω)	*Capacitor*		*Inductor (µH)*	*Capacitor Voltage (V_P)*		*Efficiency (%)*
3.5 MHz	*Input (pF)*	*Output (pF)*		*100 W*	*1500 W*	
5	2706	500	0.7	100	390	98
500	1287	500	5.1	310	1200	96
25 + *j*100	643	800	6.2	280	1110	97
25 – *j*100	1886	300	3.7	280	1430	95
250 + *j*250	934	500	6.0	310	1200	97
250 – *j*250	859	300	6.2	310	1200	97
Frequency/Z (Ω)	*Capacitor*		*Inductor (µH)*	*Capacitor Voltage (V_P)*		*Efficiency (%)*
30 MHz	*Input (pF)*	*Output (pF)*		*100 W*	*1500 W*	
5	321	200	0.08	100	390	98
500	118	50	0.7	310	1200	97
25 + *j*100	103	100	0.7	290	1100	97
25 – *j*100	205	30	0.5	285	1100	96
250 + *j*250	71	50	0.8	310	1200	97
250 – *j*250	77	30	0.8	310	1200	97

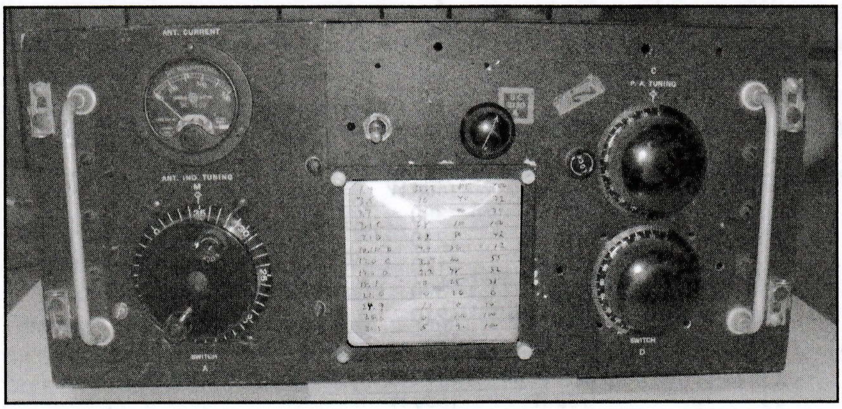

Figure 15-8 — Front view of an early homemade antenna tuner. The unit is completely built of surplus parts. Note the handy tuning chart that was part of the BC-375 transmitter tuning drawer.

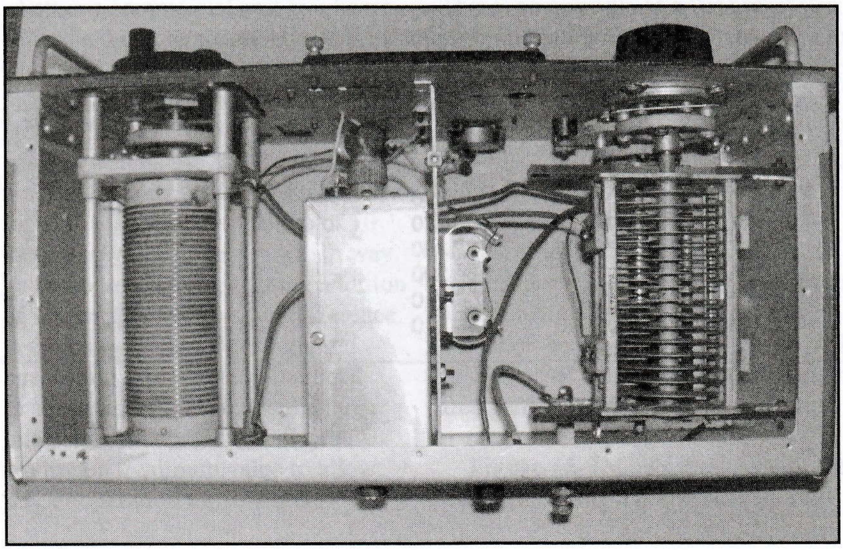

Figure 15-9 — Inside view of the home brew T-network tuner. The SWR meter (in 2 × 2 × 5 inch box in left partition) and associated circuitry would likely not be needed to use with current transceivers.

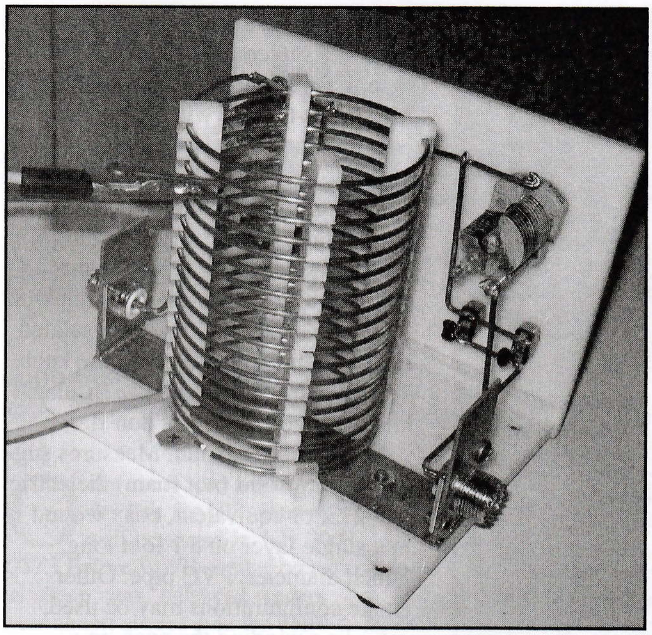

Figure 15-10 — Homebrew breadboard T-network tuner made by Barry Shackleford, W6YE. This tuner uses smaller variable capacitors with a voltage rating appropriate for 100 W use. The inductor was homemade, as described in the text. Note the inductance can be changed by moving (with transmitter off) the alligator clip to a different turn.

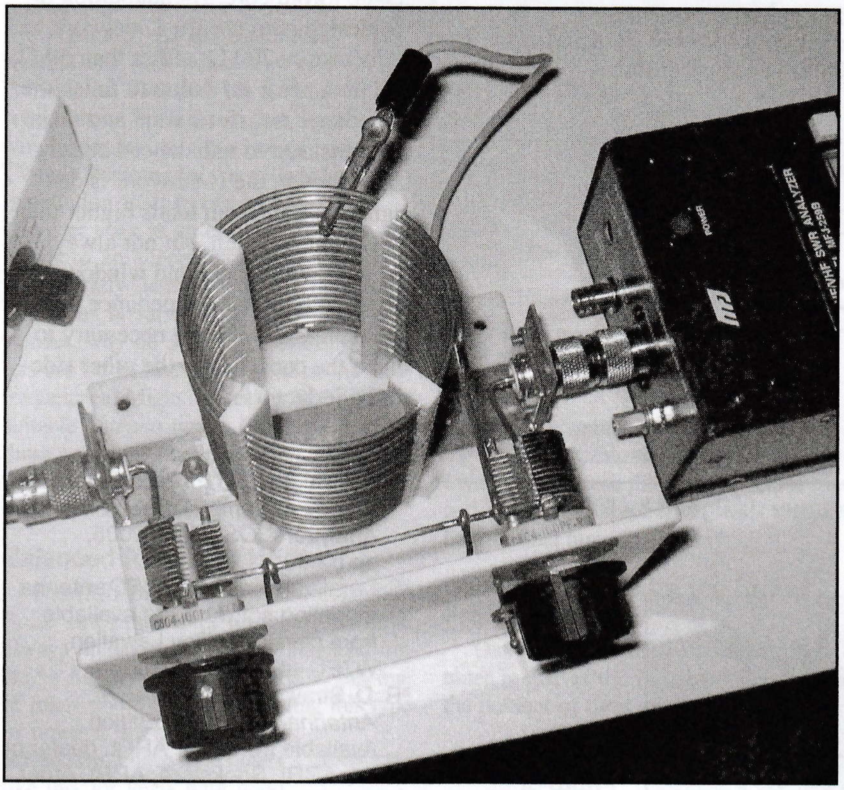

Figure 15-11 — Another view of Shackleford's T-network tuner.

they should be fine at the 100 W level. **Figures 15-10** and **15-11** show a T-network tuner that Barry made. Note the simplicity of construction. The only complication may be the homemade inductors. Barry used acrylic stock, cut and notched with his table saw, using a jig to set the spacing. You could use any technique that allowed the turns to be spaced so that his alligator clip tuning method can be employed. Barry stretched the wire before winding to work harden it and then secured it in his form with hot glue.

Barry also made the L-network tuner shown in **Figure 15-12**. This uses two capacitors in parallel, one an old broadcast three-gang unit, making up the single capacitor for the L-network. The smaller capacitor makes it easy to make fine adjustments, once you're close with the larger unit.

Making Tuners for Balanced Loads

Many tuners; home made as well as commercial units, provide for balanced loads by including a balun between an unbalanced tuner and the balanced load. This is an appropriate approach if the load is within perhaps 4:1 of the typical 200 to 50 Ω balun often used for the purpose. If beyond that range, the balun does not perform very well and losses and even damage may result.

A different approach was presented by Richard Measures, AG6K, in a *QST* article some years back.[6] Measures presented a design that first transformed the balanced antenna system load to 50 Ω balanced and then made the transition from balanced to unbalanced using a 1:1 choke balun operating at its design impedance.

Measures used a balanced L-network to perform the transition to 50 Ω and followed it with a coax choke. The schematic is shown in **Figure 15-13**, with a photo of his breadboard version, less balun, in **Figure 15-14**. He went on to show an elegant design suitable for remote control using stepper motors with remote position indicators, available on the ARRL members Web site. However, for many, a duplication of his breadboard design may be more feasible.

Measures found that inductors in the range of 15 to 20 μH maximum inductance were suitable, with a 5 A current rating for 1.5 kW use. Inductors may be found at hamfests, or are available from MFJ (**www.mfjenter-**

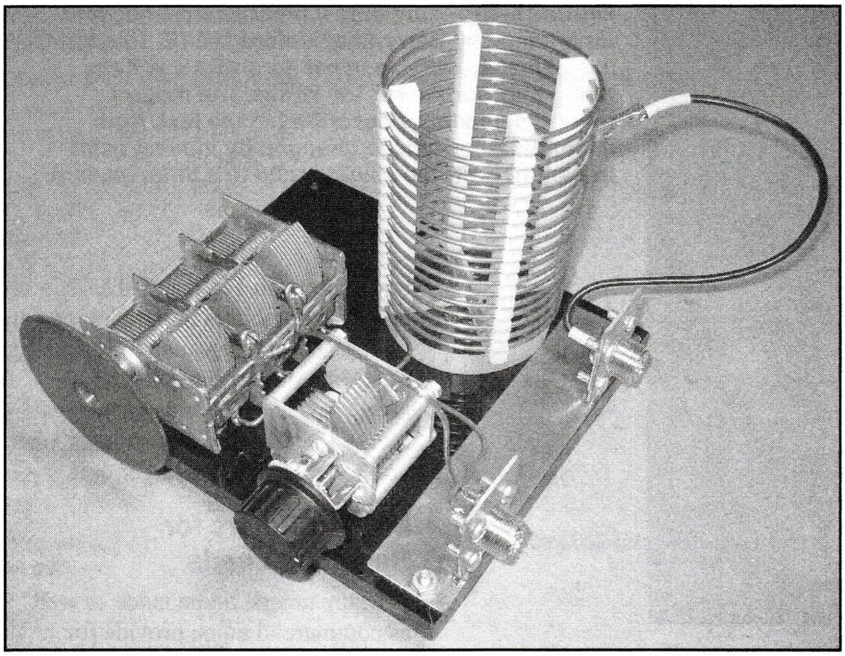

Figure 15-12 — An L-network tuner made by Barry Shackleford, W6YE. The two capacitors are in parallel making a single equivalent capacitance with the smaller one used for fine adjustment.

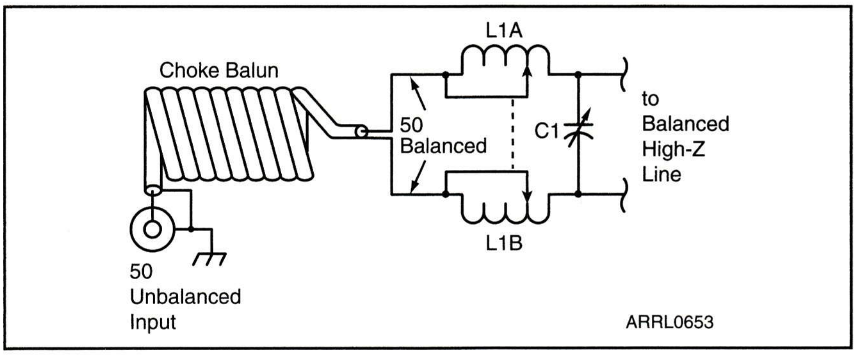

Figure 15-13 — The balanced L-network tuner designed by Richard Measures, AG6K.

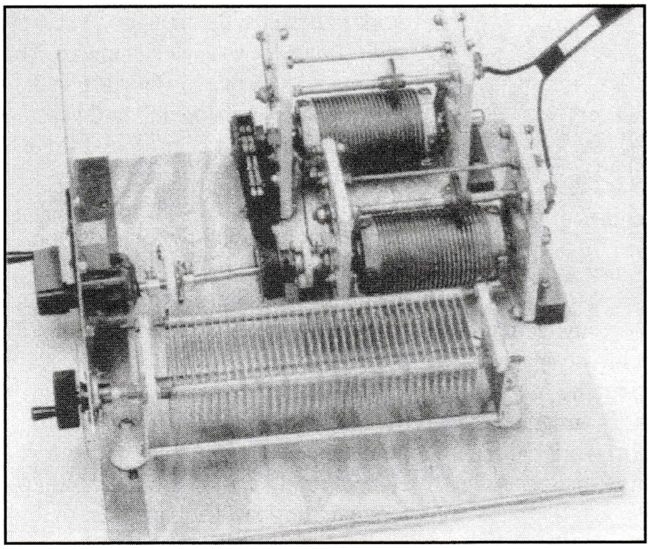

Figure 15-14 — Photo of Measures' balanced L-network tuner. The choke-balun is not shown.

prises.com). Suitable sprockets and drive belts to couple the inductors together are available from McMaster-Carr (**www.mcmaster.com**), or they may be coupled end-to-end with some loss of symmetry.

Capacitors should be in the 200 to 300 pF range, with a 1.5 kV rating if used at the 1.5 kW level. Note that both sides of the capacitor are hot with RF, so to avoid burns use an insulated shaft coupling on the way to the knob. Trust me, the set screw in an insulated knob will get you if you don't!

For the choke balun, Measures suggests using solid (not foam) dielectric RG-213, or equivalent, coax wound in a single layer on a 1 foot long, 5 inch diameter, PVC pipe. Other choke configurations may be used, including winding the coax on a ferrite toroid core. An adaptation of the design is to use the L-network to transform to 200 Ω, rather than 50 Ω, and then use a 4:1 balun to finish the impedance transformation and make the transition to unbalanced coax.

As shown, the L-network is designed to transform loads higher then 50 Ω. This is often, but not always the case with ladder and window line systems. If a lower impedance load is encountered, it will be necessary to move the capacitor to the other side of the inductors.

Notes

[1] J. Hallas, W1ZR, "Product Review — A Look at Some High-End Antenna Analyzers" *QST*, May 2005, pp 65-69.

[2] Several versions of *EZNEC* antenna modeling software are available from developer Roy Lewallen, W7EL, at **www.eznec.com**.

[3] R. D. Straw, Editor, *The ARRL Antenna Book,* 21st Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/arrl-store**; **pubsales@arrl.org**.

[4] Note that the value of R will be higher than the dc resistance because of skin effect.

[5] L. McCoy, W1ICP (SK), "The Monimatch," *QST*, Feb 1957, pp 38-40.

[6] Richard Measures, AG6K, "A *Balanced* Balanced Antenna Tuner," *QST*, Feb 1990, pp 28-32.

Hairpin Tuners for Matching Balanced Antenna Systems

Balanced Transmatch designs for 28 to 450 MHz.

John Stanley, K4ERO

Once more, the advantages of ladder line for HF antennas were well presented in July 2008 *QST*.[1] Before WWII surplus brought us cheap coax, balanced feeders were almost always used for VHF as well. In the January 1942 *QST* reproduction that was included with The 2007 ARRL Handbook, we find that both home-brew and commercial VHF gear all used balanced lines.[2] For a given cost, open wire ladder line, window line or even TV twin lead can give you a lower loss installation than trying to buy large diameter coax in an effort to keep the losses to an acceptable level. This is dramatically demonstrated by comparing losses in various line types.[3] So, we wonder, why do so few present-day operators use ladder line or twin lead on the VHF frequencies? Might one reason be the lack of suitable *antenna tuners* (transmatches) for those bands? If balanced tuners were available, would ladder line be as popular at VHF as it has become at HF?

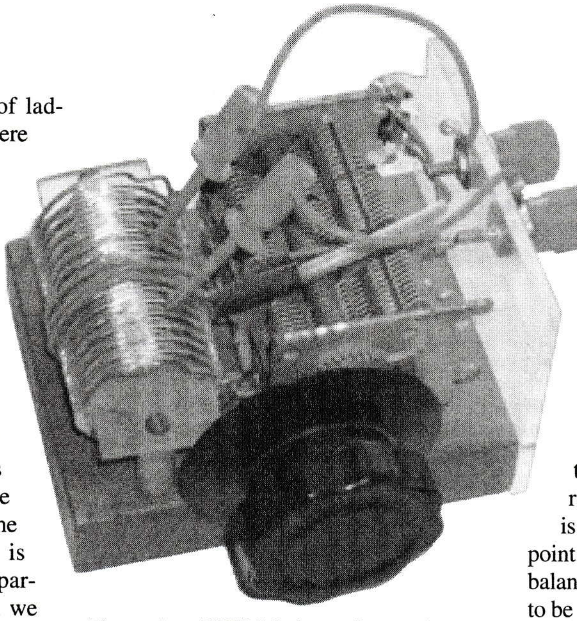

Figure 1 — K4ERO balanced tuner for 60 through 15 meters.

Balanced Tuners for HF Use

The ARRL Handbook, *The ARRL Antenna Book* and other ham publications have always included designs for balanced tuners.[4,5] Adam Nathanson, N4EKV, has one of many good Web sites showing this type of tuner at **www.n4ekv.com/tuners.asp**. I have used tuners like this for years with good results. Figure 1 shows the one I use at up to 100 W on the HF bands.

As noted in Volume 6 of *The ARRL Antenna Compendium*, I lean toward tuners with a fixed link and tapped coil.[6] The match is found by tuning the capacitor and adjusting the output side to connect to a variable number of turns, keeping the taps equidistant from the coil ends. Other versions use the taps for coarse tune and a variable capacitor in series with the link for finer tuning.

Balanced Tuners for the Higher Frequencies

One of the problems with this type of tuner is that as the frequency goes higher, the number of turns on the coil goes down rather quickly. By the time you get to 28 MHz, there may be only four turns on the coil. This means that the adjustment *steps* available are very limited. You can tap to either two or four turns, or if you are willing to unbalance the tap positions, or can access the opposite side of the coil, you could use one or three turns. In either case, the operation is compromised. Another approach is to connect one tap to the bottom of the coil, instead of to the top, effectively using fractions of a turn rather than whole turns, but this often is not feasible from a mechanical standpoint. In addition the symmetry and thus the balance are affected. If this type of tuner is to be used on 10 meters and higher, we need to rethink the design.

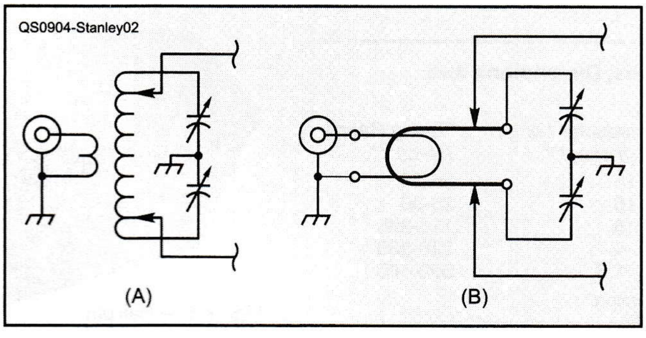

Figure 2 — Balanced tuner configurations. At (A) conventional tapped coil based tuner, at (B) the hairpin equivalent.

Figure 2(A) is a schematic of the conventional tapped link coupled tuner. Figure 2(B) is a representation of what I call a *hairpin* tuner. The electrical properties are essentially identical, but the physical layout of the hairpin type is optimum for the higher frequencies. By making the main inductor in the shape of a hairpin, or shorted transmission line, instead of a single layer solenoid coil, as is used in the conventional design, the tuner becomes much easier to build and adjust. The use of a short short-circuited transmission line section as an inductor is nothing new. It has been used for VHF/UHF circuits for many years.

Building Hairpin Tuners

For some time I have been using a hairpin inductor in a balanced tuner for 6 and 10 meters, and recently I built one for each of the 144, 220 and 432 MHz bands. The approach is the same on each frequency. A section of transmission line was used instead of the coil typically used on lower frequencies.

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[1] Notes appear on page 36.

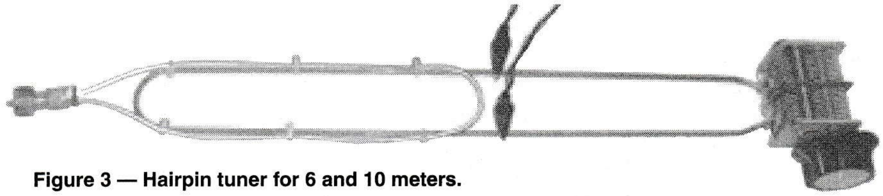

Figure 3 — Hairpin tuner for 6 and 10 meters.

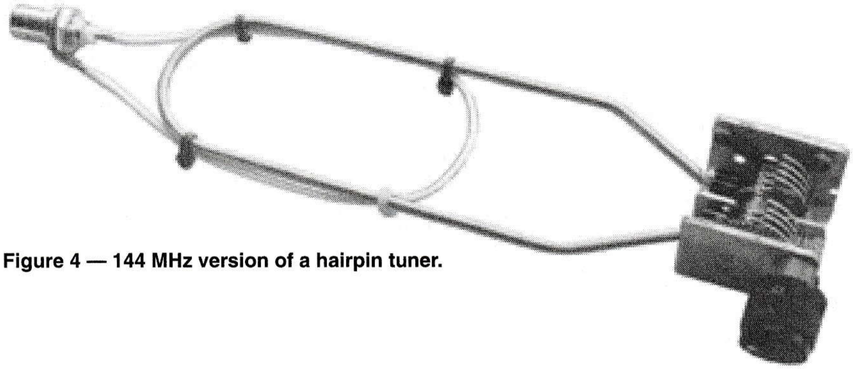

Figure 4 — 144 MHz version of a hairpin tuner.

The capacitor was a split stator or butterfly design. The input link is a single turn inductor that overlaps a portion of the main transmission line inductor and the output taps were taken at whatever point of the hairpin that gives the best match.

The advantage of this layout is that moving the taps to any point on the hairpin is the same as tapping on different numbers of turns on a coil, except that with the hairpin, it is very convenient to make the adjustment in as fine a step as may be desired. In all of my designs, the coupling loop is held to the main hairpin by cable ties. This allows some adjustment of the coupling loop, but holds the loop sufficiently snug so that it is not likely to move around accidentally. Use less loop coupling for higher Q with more selectivity and more loop coupling for lowest loss.

Making them Play

The frequency tuning range percentage will depend on the capacitor used. For widest range, select one with a high minimum to maximum capacitance ratio. All of the capacitors I have tried have provided adequate range to cover the desired amateur band. The range can be extended to cover a second band by putting fixed capacitors in parallel with the variable tuning capacitor. For example, the 6 meter version, shown in Figure 3, works for 10 meters with the addition of a parallel 40 pF fixed ceramic capacitor, while the 220 MHz version, shown in Figure 5, works fine on 2 meters with the addition of a 12 pF ceramic. As it is, the 2 meter version just makes it to 222 MHz, so two bands are possible without switching caps. A single tuner could also work on 10 and 6 meters without switching by careful component selection.

Capacitor Options

The most difficult component to find will likely be the split stator capacitor. There are ways of designing your own capacitor and it is made easier because of the relatively small capacitance required at these frequencies. For all of the designs shown here, I took capacitors from my well stocked junk box. You less well equipped folks will have to search at a hamfest or check out the basement of one of the local old timers. Commercial capacitors are available, but the price may shock you. You could also choose to use a single section capacitor instead of the split stator. In that case, the capacitor shaft and frame will be "hot" and must be floated above ground. You will have to tune it via a long insulated shaft. And, of course, the balance will be somewhat compromised. The method does work and a suitable single section capacitor may be easier to find, however . Alternatively you could use a pair of identical capacitors to ground if you adjusted them each to the same setting or worked out a common shaft arrangement. Fussy, but it could work. Target dimensions and component values for the bands in this range are shown in Table 1.

Inductor Choices

The length of the hairpin will depend on the value of your capacitor. The values below represent tuners I have built and should give you a good starting point. Match the hairpin width to the spacing of the capacitor terminals, or bend the ends of the hairpin in or out at the capacitor end in order to make the connections. Spacing does affect the inductance value so keep it close to what you see in the photos.

My inductors are ⅛ inch diameter brass rod, but they could be soft copper tubing or wire in sizes from 12 gauge up to ¼ inch. Brass welding rods from the hardware store could also be used. A smaller diameter means the hairpin should be shortened a bit as the inductance per inch will be higher. The links should be insulated wire, either enameled or PVC coated or, best of all, Teflon insulated. The 6 meter tuner in Figure 3 uses the shield of Teflon coax as the link. My links do not make electrical contact anywhere with the main hairpin. The coax shield and center of the hairpin could both

Table 1

Hairpin Tuner Component Values, Dimensions and Frequency Range

Band	*Capacitor Value (pF/Section)**	*Inductor Length (Inches)***	*Tuning Range (MHz)****
10 Meters	95-170	15	26-34
6 Meters	15-90	15	36-90
2 Meters	3-20	6	110-225
222 MHz	3-10	4	220-330
432 MHz	3-4	1.5	390-440

*Effective capacity is ½ of the value/section.
**All inductors made of ⅛ inch brass rod.
***Range may by reduced or shifted by reactive loads.

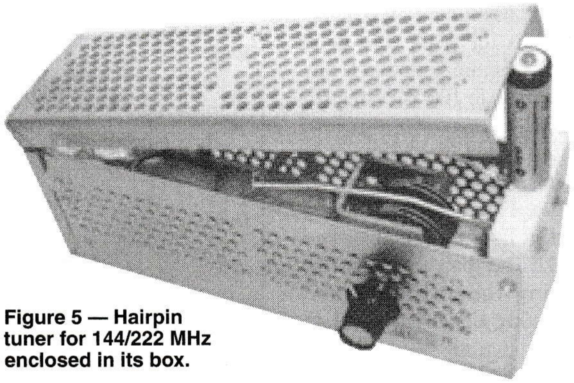

Figure 5 — Hairpin tuner for 144/222 MHz enclosed in its box.

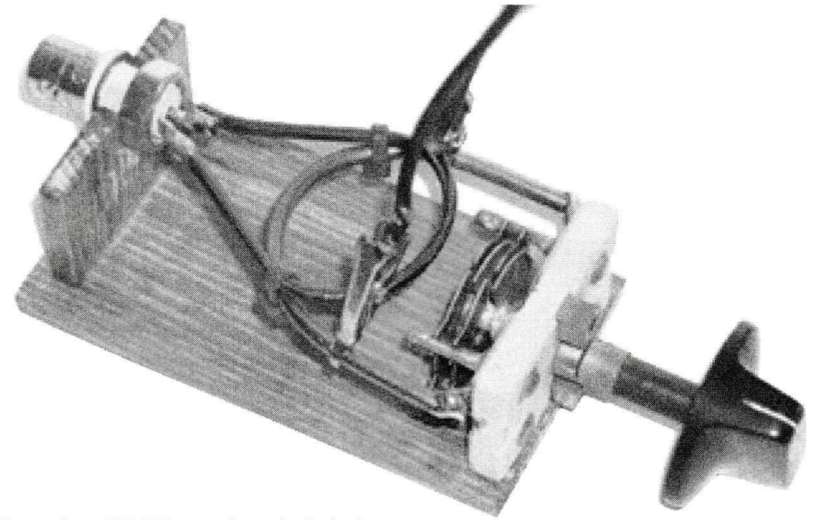

Figure 6 — 432 MHz version of a hairpin tuner.

be grounded to a chassis, if desired.

Tuning Up

Tuning consists of setting the taps to an intermediate position and adjusting the capacitor for minimum SWR. If SWR is not as low as desired, move the taps a bit either towards or away from the capacitor and readjust the capacitor. You should be able to find tap settings that allow the SWR to be reduced to 1:1.

Safety Considerations

Note that neither of the tuners described above are shown installed within a chassis of any kind. This is to show the construction more clearly. Also, I must admit that during tests, I got away with this because I used low power and am very careful not to touch the *hot* parts of the circuit. I also have a non-metallic operating desk. The open construction is useful during experiments.

I definitely do not recommend this approach for general use. You will want to put your tuner in a shielded box of some kind, probably with a hinged lid to allow you to move the taps as shown in Figure 5. You should *never* adjust the tap clips with power applied. The tuning shaft should be brought out through the enclosure where an insulated knob should be installed for tuning even though with a split stator capacitor the shaft should be at ground potential. For high power, the use of a suitable enclosure is essential, especially if the tuner is to be installed close to the operating position. This is to prevent RF burns from contact as well as exposure to excess RF levels.

Remember that your body is more susceptible to pick up from VHF fields than is the case at HF. If you put the tuner well away from the operating position in a place that is protected from access by family members or pets, you may be able to use a somewhat more open construction as is sometimes done with conventional home brew tuners. Radiation from an unenclosed tuner of any type can be enough to cause interference with nearby electronics devices and could cause fires if anything flammable comes in contact with the hot parts of the circuit.

These tuners have been tested with 100 W on 10 and 6 meters, 50 W on 2 meters and 20 W on 70 cm, the maximum output of my rig. For higher power, the designs can be scaled, remembering that the bigger it gets, the lower the frequency for the same geometry. Thus, a design similar to that used here for 432 MHz, but three times larger, would probably work fine with a full kW, but on 144 MHz. Since my 20 W, 432 MHz design uses an inductor that is about as short as is practical (see Figure 6), getting up to 1 kW at 432 MHz, might prove difficult with this design. At the least, a different type of capacitor would be required.

I hope that these simple to build and adjust tuners will start a trend towards greater use of balanced feeders on the higher frequencies just as ladder line has become the favorite for many on the lower bands.

Notes

[1] J. Hallas, W1ZR, "Getting on the Air—Your Second HF Antenna," *QST*, Jul 2008, pp 69-70.

[2] B. Goodman, W1JPE, "Receivers for 112-Mc. Emergency Work," *QST*, Jan 1942, pp 18-25, 74-75.

[3] *The ARRL Handbook for Radio Communications*, 2009 Edition, Figure 21.4. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 0261 (Hardcover 0292). Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[4] See Note 3, p 21.13.

[5] R. D. Straw, Editor, *The ARRL Antenna Book*, 21st Edition, p 25-3. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[6] J. Stanley, K4ERO, "The Filtuner," *ARRL Antenna Compendium, Volume 6*. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 7431. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

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Review Questions

15-1 What are some major challenges involved with building an antenna tuner?

15-2 Under what conditions is a special purpose tuner a viable option?

15-3 Why might you decide not to include 160 meters in your tuner design?

APPENDIX A

Making Sense of Decibels

Joel R. Hallas, W1ZR

Much of the technical data found in *QST* and other ARRL publications is expressed in decibels, generally shown as *dB*. Contrary to the belief of some, this is not done to mystify beginners, but rather is intended to make comparisons easier and avoid the use of very large or small numbers.

So What's this Decibels Business All About?

Decibels are just a way of expressing ratios, often power ratios. If we are looking at the gain of an amplifier stage, the pattern of an antenna or the loss of a transmission line we are generally interested in the ratio of the power out to the power in, or the ratio of the power in front of a beam antenna to that coming from the back. These are some of the places that we will find the results expressed in dB.

Decibels are a logarithmic function. Logarithms are a handy mathematical tool based on exponents. An important feature of logarithms is that multiplication can be performed by adding the logarithmic quantities instead of multiplying them. Similarly, divisions can be accomplished by subtracting in the same manner. This becomes a benefit if you are dealing with multiple stages of amplification and attenuation — as we often are in radios — snatching a minuscule signal from the ether — amplifying and processing it so we can hear it out the loudspeaker. Instead of having to multiply and divide at each stage to keep track of the progress of our signal processing — often with signal levels with many zeros to the right of the decimal point — we can just tally all the dB and have total gain of the system.

So How do We Compute the Decibels?

The *deci* in decibels refers to a factor of $\frac{1}{10}$, as in *deciliters* for $\frac{1}{10}$ of a liter, while the *bel* relates to the idea of a logarithmic ratio, originally used to define sound power.

- To convert a power ratio into decibels, just:

1. Find the base 10 logarithm of the power ratio.
2. Multiply by 10.

For example, if we have an amplifier with a power gain of 275, we find the logarithm of 275 (see below, if you don't do logs in your head) to be 2.44. We multiply by 10 and the result is that a power gain of 275 can be represented as 24.4 dB.

- To convert decibels to a power ratio, we do the opposite:

1. Divide by 10.
2. Find the base 10 antilog of the result.

Note that the base 10 antilog of a number is just 10 raised to the power of the number. This is also something you probably don't do in your head, so let's see how to easily perform the computations.

Understanding a few characteristics of logs will help avoid problems interpreting results. Note that a gain of 0 dB means that there is no change to the signal — not that the signal has vanished! The other important fact is that a power ratio of less than one (a loss rather than a gain) is represented as a negative number in decibels.

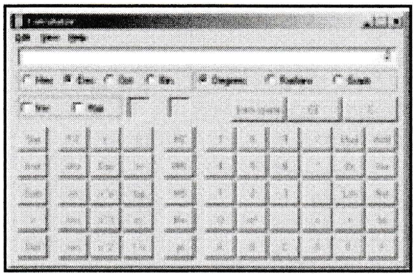

Figure 1 — The *Windows Scientific Calculator* ready to calculate the effect of a 2 dB cable loss.

Enter the *Windows Scientific Calculator*

In the *very* old days, engineers and technicians used tables to make accurate logarithmic calculations, and mechanical slide rules if three significant digits was sufficient precision.[1] Starting around 1970, scientific calculators became available. Initially they were expensive typewriter-sized devices that were typically shared within an engineering department. Within a few years pocket-sized units were available for less than $200, and now everyone could make calculations to a precision of nine significant digits, whether warranted by the data accuracy or not. Tables and slide rules were relegated to the pages of history with spark transmitters.

The dawn of the reasonably priced personal computer seemed to push the fancy scientific calculator out of sight only about 10 years later. Unfortunately, for many functions a calculator may be a better choice, and decibel calculations may be one. The calculations may be easily performed on a PC by putting the equations in cells of an Excel spreadsheet, but not everyone can do that without a lot of thought.

If you have a suitable scientific calculator, that should easily make the calculations. Not all have an ANTILOG button, but if not, they will likely have a button that says X^Y, which can be used as above. If you don't have a handheld calculator, you may not know that there is a very capable one included as an "accessory" within the Microsoft *Windows* operating system! Just click START then ALL PROGRAMS then ACCESSORIES. You should find an icon for the *Windows Calculator*. You could open it, but why not drag it onto your desktop first.

On first opening, you may find a four-function grocery store type calculator. Have no fear, just click on VIEW then SCIENTIFIC to get the one you want. It should look about like Figure 1.

Give it a Test Drive

Let's say you have a mismatched coax cable with a loss of 2 dB. You may want to know how many of the 100 W from your transmitter actually reach your antenna. Remember a 2 dB loss is a "gain" of –2 dB! We'll go through the inverse dB calculation of column 2. Using your *Windows Calculator*, either hit 2 on your keyboard, or:

- Click on the 2 on the calculator "keypad," then:
- Click on the +/– key; the display should show – 2, as in Figure 1.
- Click on the / key to select the "divide by" operation. Enter the digits 1 and 0 for the number 10 and hit ENTER or =. Make note of the result (–0.2) or store it in memory (M+).
- Enter the digits 1 and 0 for the number 10.
- Click on X^Y to raise 10 to a power.
- Enter your earlier result, –.2 and hit ENTER.
- The display should show 0.63095734448 019324943436013662234 or about 0.63. That is the fraction of your power left after a 2 dB loss. That means your antenna sees 63 W and 37 W is heating your transmission line.

While you are using the *Windows Scientific Calculator* look over its other features. It provides painless conversion between decimal and binary, octal or hex numbers, for example.

Joel R. Hallas, W1ZR, is QST *Technical Editor. He can be reached at* **w1zr@arrl.org**.

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[1] See, for example, *Standard Mathematical Tables*, CRC Press, any edition. In addition to tables of logarithms and trigonometric functions, it includes many handy formulas from geometry, trigonometry and calculus.

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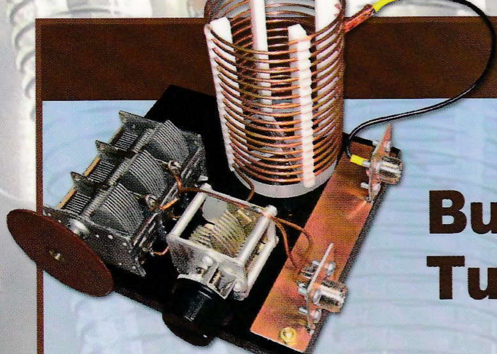

Buy or Build the Best Tuner for Your Station.

Antenna tuners are devices often misunderstood in the Amateur Radio world. While not every station requires an antenna tuner to transmit radio signals, often an incompatibility between the transmitter and the antenna system results in poor performance. An antenna tuner between them is the way to obtain efficient operation.

The ARRL Guide to Antenna Tuners discusses the details of the different configurations and requirements of antenna tuners. It explores the design, construction and applications of the different types available. You'll learn if one is necessary in your station, what type of tuner is needed and where to install it for maximum improvement. This book will give you a better understanding of your antenna system and the way it can be enhanced through the selection and use of the appropriate antenna tuner.

Contents:

- Why Might I Need an Antenna Tuner
- A Look at a Typical Configuration
- So Just What is an Antenna Tuner?
- Tuning an Antenna Tuner
- The Internal Tuner—How Does it Help?
- An External Tuner at the Radio
- Transmission Lines and Loss
- Moving the Tuner to the Back 40
- Transmission Line Choices for Low Loss
- Balanced versus Unbalanced Lines
- So What's a Balun, an Unun, a Choke?
- Balanced Antenna Tuners
- Antennas that Work Well with Tuners
- A Survey of Available Tuners
- Making Your Own Tuner

Joel Hallas has been a radar and telecommunications systems engineer, engineering manager, telecommunications executive and college teacher, and is now Technical Editor of ***QST***, the monthly journal of ARRL, the national association for Amateur Radio. He has earned BS and MS degrees in electrical engineering. Joel is a radio amateur, and holds the license call sign W1ZR.

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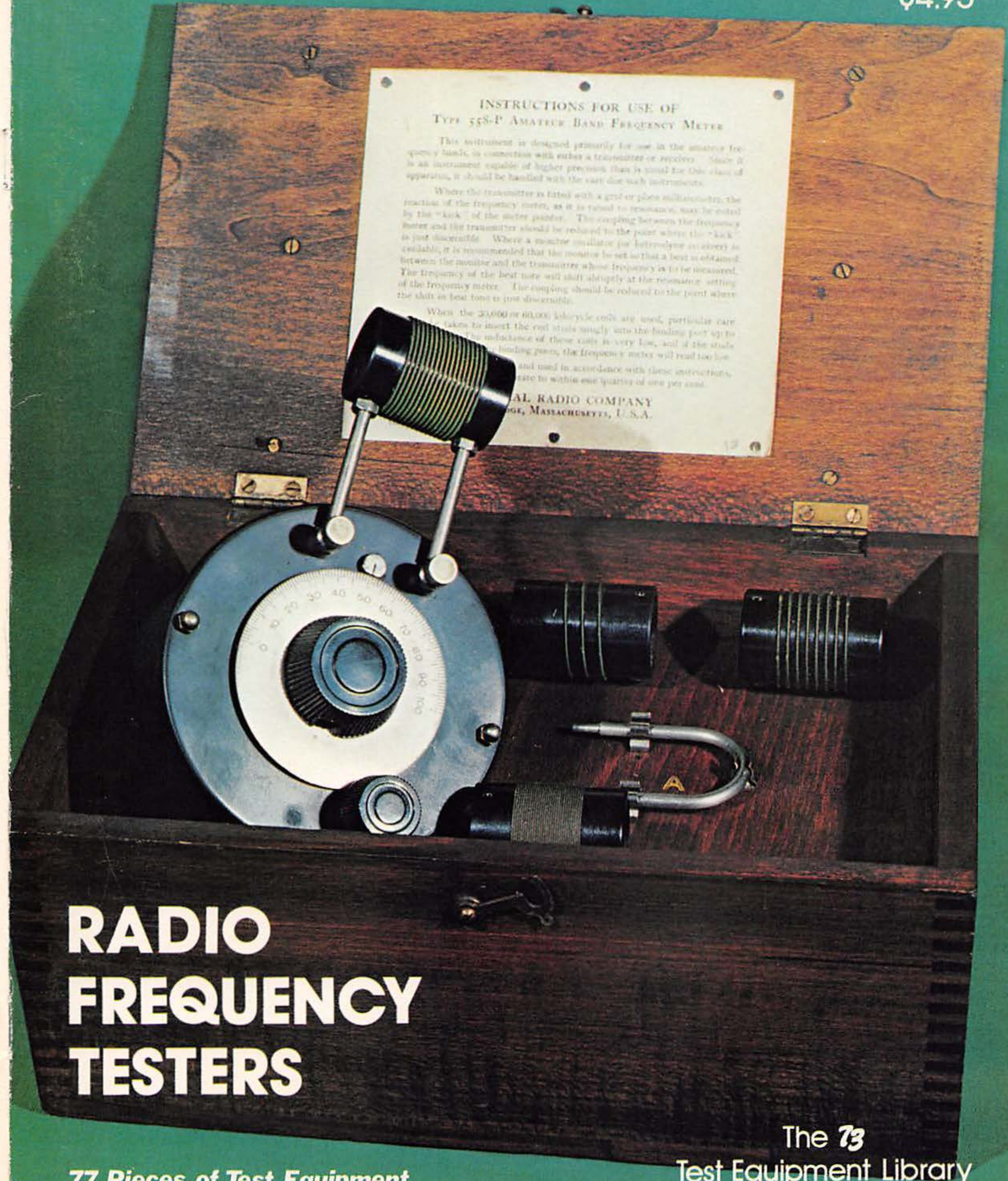
INSTRUCTIONS FOR USE OF
TYPE 558-P AMATEUR BAND FREQUENCY METER
AL RADIO COMPANY
GE, MASSACHUSETTS, U.S.A.
A

RADIO FREQUENCY TESTERS

77 Pieces of Test Equipment You Can Build!

The 73
Test Equipment Library
volume III

the 73 TEST EQUIPMENT LIBRARY

Volume III: Radio Testers

Edited by Sandy Cole W1PUF
and
Rich Force WB2QYV/1

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EDITOR'S COMMENTARY

This is Volume III in the *73 Magazine* series of Test Equipment books. The first two volumes covered component testers and audio frequency testers. This book, which deals with radio frequency testers, is by far one of the most important of the series.

The generation of radio frequency waves is the one common denominator through all of ham radio. No matter what your specific interest in this fascinating hobby, without the correct generation and radiation of radio waves, your enjoyment will be frustrated. In this book we have attempted to put together some of the best articles which have appeared in *73 Magazine* all aimed at assisting you in achieving the best possible on-the-air signal. Many hours have gone into its preparation by scanning past issues for projects which would be of the most use, be up-to-date and be easily constructed with available parts. We think we have achieved this end.

It must be noted that some of the equipment described in this book appeared in vintage issues of *73 Magazine*, yet the design and value of the equipment has not aged and it is as up-to-date today as it was when it was first published.

We at *73 Magazine* hope this book will help to make your effort to put out a "respectable" signal easier and more enjoyable.

73, Rich Force WB2QYV/1

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Chapter I

What is Your SWR, OM?

SWR POWER METER FOR 80 THRU 10m BANDS

James Lee W6VAT

With the declining sunspots, usage of the lower frequency bands is definitely increasing. The resulting increased QRM is helpful to no one and only efficient equipment and operating procedures will result in a maximum number of QSO's. The SWR/PWR meter described here won't make you a better operator, but it can help you be sure that you are delivering the most rf to your antenna from your rig. Fig. 1 shows a front view of the meter.

The basic circuit is a directional coupler switched to sample either forward or reverse voltage and a voltmeter to read this voltage.

This type of coupler has an output proportional to length, power, and frequency. The longer it is, the more output it gives. Since it puts a small impedance "bump" in the line, the length of the coupler should be limited to not over 1/20 wavelength at the highest frequency, or it may begin to contribute noticeably to the SWR itself. For a given power, if the frequency of the rf flowing through the coupler is reduced, the maximum coupler output is reduced. This means that you can get full scale readings on 10 M with a lot less power than on 80 M. The meter described here gives half scale deflection on 40 M, at maximum sensitivity, with about 350 watts of forward power. If your rig is a KW this meter will fill the requirements for SWR/PWR measurements nicely. It can be left in the line at all times to monitor SWR or Power delivered to the antenna or other load. If desired, a Barker and Williamson type 551A coaxial switch can be used to insert the meter in the line for test purposes and then switch it out during operating periods.

REVERSE
FORWARD
POWER
SWR

Construction

The unit is built in a gray hammertone LMB type 141 box. The dimensions of this box are 3" x 4" x 6". Fig. 2 shows the parts placement and should answer any questions concerning layout.

The coax directional coupler is made from a 14" length of RG-8/U. The outer covering is slit lengthwise with a knife and peeled off. Take care here not to cut into the woven braid. The woven braid is then bunched toward the center to loosen it. Next, a length of #22 enameled wire is passed through the braid at about 2¼" from one end and run under the braid next to the inner insulation. It is brought out at the other end, again 2¼" from the end of the shield braid. When this is done, smooth the braid back to its original position carefully to avoid scratching the enamel on the #22 wire. The #22 enameled wire should lay as straight as possible under the braid. It should have no slack nor should it twist around the inner insulation to any great degree. The ends of the shield braid are trimmed back far enough to be soldered to Amphenol 83-1H hoods. The inner insulation is trimmed off so as to expose about 3/16" of the inner conductor. The inner conductors are then soldered to Amphenol 83-1R female type chassis mount coax connectors. The coupler may now be set aside and the rest of the meter constructed.

Potentiometer R_1 is mounted on 1/16" x 1" x 4" piece of bakelite and positioned approximately in the center of the box to minimize capacity to ground. The metal rear cover is removed from the pot for the same reason. The pot ground lead is to the center of the coax and is wire in last. The diode D_1 should be protected from damage by heat when soldering it in the circuit. Long nose pliers gripping the leads near the body of the diode are satisfactory. The directional coupler is the last item soldered in place. As can be seen in the photos—the coax connectors are mounted from the inside of the box. When the #22 enameled leads are soldered to S_1 they should be the same length, and again, take care not to scratch the enamel or a short circuit may occur and you'll have to do it all over again.

Calibration

There are any number of ways to calibrate the SWR/PWR meter, but the way most hams will use is their own rig and a suitable dummy load. Though very limited in power, a 2 watt 50 ohm resistor such as made by Ohmite, IRC and others, mounted inside an Amphenol 83-1SP male coax plug makes a very good dummy load. Although not completely noninductive, this dummy load is far superior to such real unknowns as light bulbs, electric iron heating elements, etc. This particular load is 50 ohms shunted by 6 mmfd over the range of 3-30 mc. It is a good dummy load—though a low power one.

With the back cover off, attach the dummy load to J_2, the load jack. Set R_1, the Sensitivity Control, to maximum and S_1 to FORWARD. Next apply power by hooking your rig (or

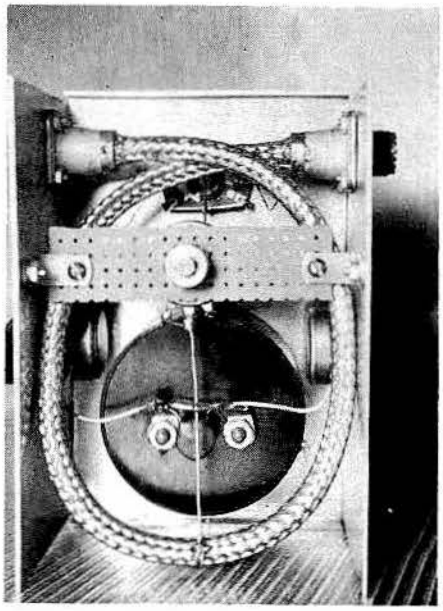

other rf source) to J_1, the transmitter jack. Make sure that the rf applied is 28-30 mc, or, the highest frequency you operate in the 3-30 mc region. This meter is sensitive to frequency. Stray capacities and other unbalances will have their greatest effect at the highest frequencies. In any event, calibrate the unit on the highest frequency your rig will tune in the 3-30 mc region. With power applied, set R_2 so the meter reading is at least half scale and switch S_1 to REVERSE. This will result in a lower meter reading. R_1 should then be adjusted for a minimum reading on the meter. Using the suggested load, you will not get a complete null, but the null should not be much more than 50 ua for half scale deflection in the FORWARD position on S_1. Don't put too much power into the dummy load since excessive dissipation can ruin it and change its characteristics greatly. If you have a higher power dummy load whose characteristics you know accurately, by all means use it, but remember a light bulb is not a good load. Once nulled, lock the nut on R_1 taking care not to disturb the setting. Replace the back cover and using the dummy load, recheck the null to make certain that it has not shifted.

Using The Meter

To make SWR measurements you need only insert it in the line and set S_1 to FORWARD and S_2 to SWR. Adjust the sensitivity control for at least a half scale reading. Then switch S_1 to REVERSE and read the value. SWR is then calculated by the following:

$$\text{SWR} = \frac{I_{fwd} + I_{rev}}{I_{fwd} - I_{rev}}$$

For example:

let $I_{fwd} = 500$ ua and $I_{rev} = 50$ ua, then

$$\text{SWR} = \frac{500 + 50}{500 - 50} = \frac{550}{450} = 1.22{:}1$$

The meter is useful for tune-up purposes where exact SWR is not needed. Just keep the FORWARD reading at a constant value and tune for minimum REVERSE readings. The exact SWR can be calculated when you have found the lowest REVERSE position.

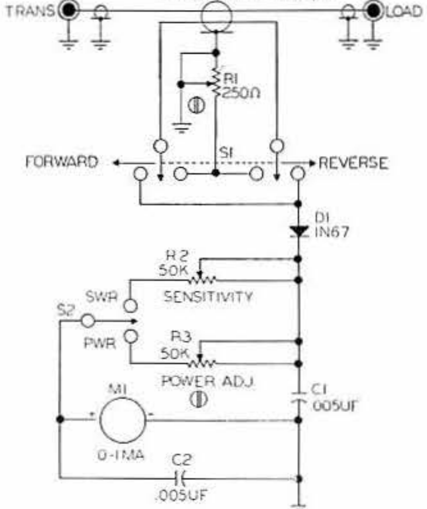

The POWER position may appear to be essentially the same as the SWR position and it is. When measuring power into a load of known fixed value you only need to know the voltage across (or the current through) the load. The POWER position on S_2 is used with S_1 set to FORWARD. R_3 is merely set to a scale reading that is convenient for all bands if only a relative reading is used. If a good 50 ohm high power dummy load is available, you may make accurate calibrations by using a VTVM plus high frequency detector probe and measuring the actual voltage across the load. Just put a T-connector on the load jack J_1. Put the dummy load on one arm of the "T" and read the voltage at the other arm. 200 volts across a pure resistive load of 50 ohms is equal to 800 watts of power. If your rig delivers a key down 800 watts to a load then you could set R_3 at 0.8 ma on the scale, etc. The scale will not be precisely linear, particularly at low powers, but if enough resistance is used at R_3 the effects should be minimum. Since the coupler voltage is frequency sensitive one setting of R_3 will not hold for all bands. If desired, R_3 could be replaced with a switch and a number of selected resistors (one for each band). This would keep the scale factor constant between bands. This could be done for R_2 as well, but complicates an otherwise simple device

Operation

Once calibrated, the meter is very simple to use. Just hook it in the line at some convenient point and apply power. With S_1 set to FORWARD and S_2 set to SWR, adjust R_2 for at least a half scale reading. Switch S_1 to REVERSE and you will then be able to continuously monitor your reverse power. For power measurements, set S_1 to FORWARD and S_2 to PWR. Apply power and the meter will be monitoring your forward power continuously. R_3 is a screw driver adjusted pot. It can be set, and locked at a point which allows operation on all the bands you operate. The scale reading on each band will be different, but once set, these readings can be jotted down in your log book and any change quickly noted. This meter is also an excellent device for the antenna "tinkerer," or if you have coax coupling between stages in your rig it can be used to provide proper power transfer. Best of all, it is not expensive nor difficult to construct. Try one and you won't be without one again.

AN ETCHED CIRCUIT SWR BRIDGE

Ed Lawrence WA5SWD

Several of these boards have been etched and units assembled, and all have been satisfactory. I have used mine, with a 200 microamp meter, from a kw on the low bands up to a "Twoer," with no problems with sensitivity.

Since Bud Miniboxes are commonly available, I scaled this board to fit into the Bud

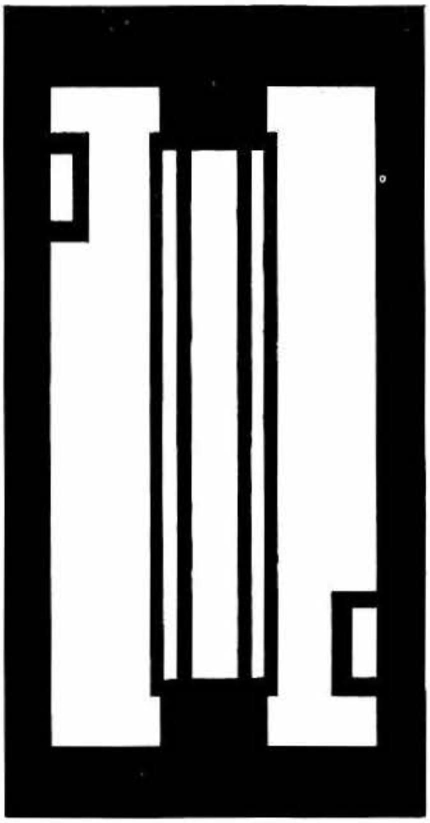

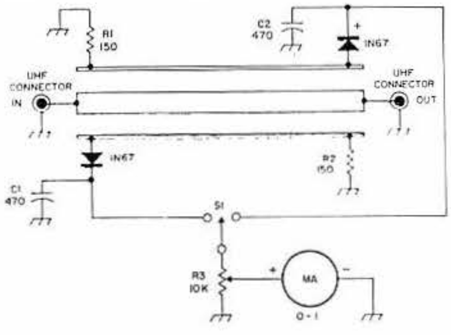

Schematic diagram of SWR bridge.

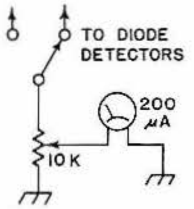

Fig. 1. Metering circuit for the etched circuit SWR bridge.

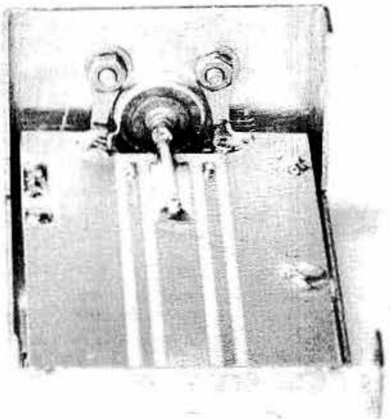

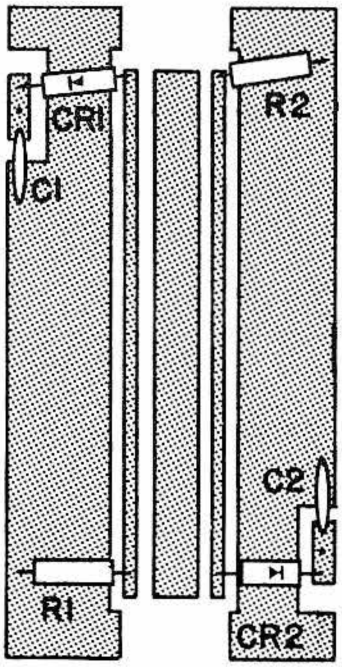

Fig. 2. Layout for the printed circuit board.

Minibox CU 2102A or CU 3002A. If you want to include the metering in the same package, the CU 2103A or CU 3003A should be used to give more room.

If you use the CU 2102A, center the coax connectors on the ends. If the CU 2103A, mount the connectors .8 inches from the open end. I used solder lugs bent at right angles to mount the P. C. Board to the chassis. The photograph shows the mounting much better than 10,000 words.

The meter sensitivity control circuit shown has a wider control range than the one shown in the *ARRL Handbook*, since the pot shunts the meter at low settings. This action could be accentuated by putting a fixed resistance in series with the meter movement, at the expense of sensitivity.

Although the virtues of operating transmission lines with low standing wave ratios (SWR) have been discussed many times in the past, evidently the economics of maintaining low SWR's are not readily apparent, particularly if the frequency of operation is low and the transmission line short. This has been reflected in various pseudo-technical QSO's where many have been led to the utter disregard for standing wave ratios. Most members of the amateur fraternity exist on limited budgets at best and when a significant portion of that precious transmitted power is eaten up by transmission line losses and misinterpreted standing wave ratios for naught, something should be done.

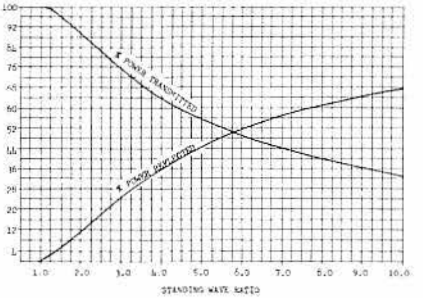

SWR vs % Power Transmitted and Power Reflected

Figure 1

A look at the graph in Fig. 1 will show you the percentage of power reflected for various standing wave ratios. For instance, if you are presently tolerating an SWR of about 5.8:1 (not uncommon in many ham shacks), 50% of the power which reaches the antenna is actually reflected back down the transmission line, heating up the final tank and causing TVI. Nor is only the transmitted signal effected, a high SWR will similarly degrade the received signal. This is particularly important in the reception of the extremely low level signals often encountered in DX and VHF operating. Stereophonic buffs should take heed too. A recent report by the IEEE (Institute of Electronic and Electrical Engineers) Professional Group on Broadcasting noted that a high SWR on receiver antenna inputs causes a reduction of stereo quality.

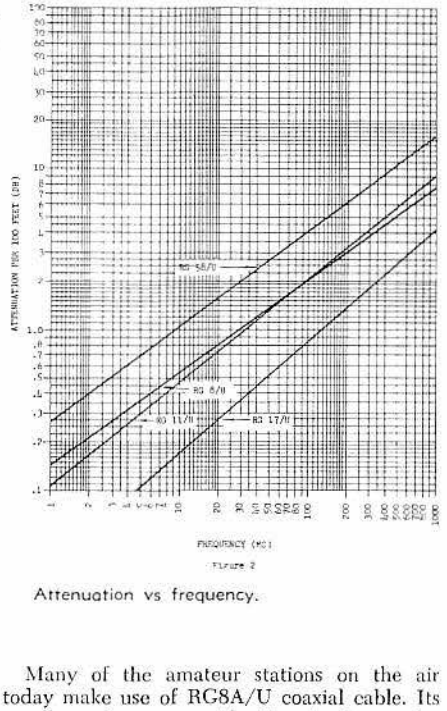

Figure 2

Attenuation vs frequency.

Many of the amateur stations on the air today make use of RG8A/U coaxial cable. Its excellence is proven out by its extensive use by the military, but a look at the loss graph (Fig. 2) for this cable indicates that it is not completely lossless! Even at 4 mc it has approximately 0.3 db loss per 100 feet, and on six meters there is a loss of 1.4 db for the same length. A look at Fig. 3 indicates that on 75 meters only 94% of the transmitted power is delivered to the antenna if 100 feet of RG8A/U is in use. At 50 mc the loss has sky rocketed to 26% for the same length of line. However, there is one big hooker for these conditions to exist: the SWR must be 1:1. For any other value of SWR there will be further line losses as shown in Fig. 4 because standing waves have the property of multiplying attenuation. This graph indicates that if a transmission line is operating at an SWR of 3.7:1, the line loss will be multiplied by a factor of two. For the previously mentioned situation on 50 mc, an additional 24% loss could be expected with an RG8A/U line operating at an SWR of 3.7:1.

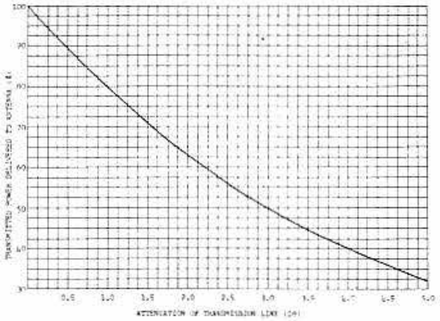

Figure 3

Attenuation vs Power transmitted.

It should be obvious by now that the use of an SWR bridge in the line at all times is very advantageous in the maintenance of a low SWR at the operating frequency. However, contrary to popular belief, the SWR bridge does not tell all. Since there is loss or attenuation in any length of transmission line, the reflected wave will be attenuated in the same matter as the transmitted or incident signal. Because the standing wave ratio is the ratio of the incident wave to the reflected wave, attenuation of the reflected wave will give erroneous SWR measurements when the SWR bridge is conveniently located at the transmitter. In this location the bridge will see the full power of the transmitter, but only a portion of the reflected signal. In some cases where the length of the transmission line is excessively long, the reflected wave will be attenuated to such a degree that the SWR will appear to be very close to 1:1, while in reality it will be a good deal higher. This fact is graphically represented in Fig. 5.

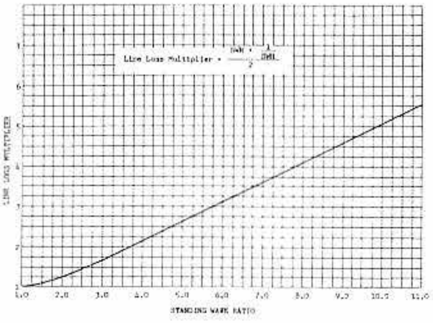

Figure 4

Line loss multiplier vs SWR.

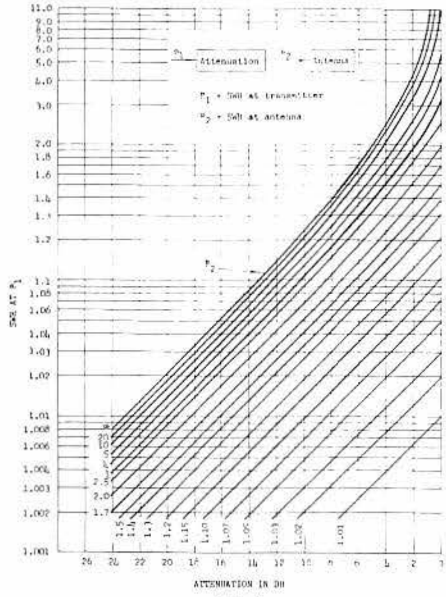

Figure 5

SWR vs attenuation.

For example, 143 feet of RG8A/U at 50 mc would result in approximately 2 db attenuation. If an SWR bridge inserted in the line at the transmitter indicated an SWR of 2:1, this graph shows that an SWR of 3:1 exists at the antenna. A look at Figs. 3 and 4 will indicate that a 3.3 db loss (2 db times 1.65 multiplier) occurs, amounting to 47% loss of transmitted power in transmission line losses. Of the remaining 53% power arriving at the antenna, 24% will be reflected back down the line. A little simple arithmetic will show that of the total power transmitted, only 30% will be radiated! This simple mathematical fact should make the merits of low standing wave ratios immediately obvious if we wish to get the most out of our equipment. By keeping transmission lines short and by insuring that the SWR is as close to 1:1 as practicable, line losses will be minimized, maximum power will be delivered to the antenna and more successful and reliable radio communications will result.

CHECKING YOUR SWR INDICATOR

Carl Drumeller W5EHC

Many articles have been published on how to build and even some on how to calibrate a VSWR indicator. The calibration instructions usually tell you to terminate the indicator's output with a purely-resistive 52-ohm load and then to adjust the device so that a maximum forward and minimum reflected meter deflections are obtained. Sometimes they'll go further and tell you to reverse the device and recheck for opposite indications.

This is all very well. It assures you that the VSWR indicator will be telling you the truth when it says "All's well!" while looking into an utterly-flat transmission line. It doesn't tell you a thing about what the indicator will have to say when it gets tangled up with a line that has a wildly-mismatched termination.

As most transmission lines, in actual practice, are terminated in loads which are not only mismatched in the matter of resistance but also in the inclusion of a considerable magnitude of reactance, it would be well to explore the indications you'll get under realistic circumstances. After all, these are the situations under which you'd want to take corrective steps. Accurate indications of undesired conditions, therefore, are imperative if intelligent remedial actions are to be taken.

Fortunately, some quite enlightening tests are made easily. All you'll need are some lengths of coax transmission line (the same as you're using in your antenna feedline) equipped with male fittings at each end and a few female-to-female junctions. Select the frequency at which you want to make the test. Usually it's wise to make the test on the highest frequency band you plan to use. With this in mind, make up three one-eighth wavelength sections of transmission line and mount the male fittings on the ends of each section.

If your antenna presents an unmatched load to your transmission line, you may elect to skip over this paragraph and go directly to the next one. If it does not (Ah, you dreamer!), you'll need another piece of transmission line. It should be fairly long, perhaps a half wavelength. Put a male fitting at one end and attach a termination, which is deliberately made to be a sad mismatch, at the other end. Don't just mismatch it by using too high or too low a value of resistance. Throw in some reactance, too! You might use a resistor with an inductor in series. Or, you might try a capacitor in series with the resistor. Or, you could use either an inductor or a capacitor in parallel with a resistor. In fact, it would be best to experiment with all four!

Now that you have a transmission line available that you know is mismatched, you're ready to start the test. The first check (the "control", you might call it) is made with everything normal. That is, you'll have the transmitter feeding directly into the VSWR indicator's transfer box and the transmission line (either the one to your antenna or the substitute line to the mismatched load) attached to the output of the transfer box. Note the VSWR indicated. Also note your transmitter; insure that it's tuned to resonance and is adjusted to a power you can maintain throughout the first portion of the tests. Jot down these indications. Now, insert an eighth-wave section between the transfer box and the transmission line and without making *any* other changes or adjustments, note the VSWR. Repeat these steps, adding an additional eighth-wave section each time until you've used all three. Did you detect any change in VSWR? If there was even the slightest change, your VSWR indicator is not trustworthy!

Now for two more checks. Try varying the transmitter power output. Does this have any effect upon the indicated VSWR? If it does, your VSWR indicator is not trustworthy! Then try varying the transmitter output tuning, deliberately throwing the stage out of resonance. Does this have any effect upon the indicated VSWR? If it does, your VSWR indicator is not trustworthy!

Few VSWR indicators under the $150 class will pass these basic tests. If yours doesn't, don't be perturbed. You have an instrument that still has a useful field of application. You can use it as a comparative indicator. For instance, if you're adjusting the gamma match at an antenna, it'll serve quite well; in this application, you're holding all of the significant variables constant, with the exception of one (the gamma match), the effect of which you want to observe. Your tests will have shown you the parameters you'll have to hold constant for any other than simple comparisons. In all probability, you will have found that measurements taken with different (electrical) lengths of transmission line are invalid. Also, it's probable that, owing to the non-congruity of diode curves, measurements will have to be taken at precisely the same level of rf power if accurate comparisons are to be made.

If you'll keep its very real limitations in mind, you'll find that even an inexpensive VSWR indicator has excellent potentials for useful measurements. But don't ask it to perform at levels that even its expensive siblings can't attain!

HOME BREW BRIDGE CALIBRATION

Clifford Honess W4OAB

This table is useful for all homebrew SWR bridges and gives the % reflected power and the % full scale reading in the reflected mode, when the meter is set at full scale in the forward mode.

SWR	% Pwr. Refl.	Refl. Rdg. in % of Full Scale
1.1	.2%	4.8%
1.2	.8	9.1
1.3	1.7	13.1
1.4	2.8	16.7
1.5	4.0	20.0
1.6	5.3	23.1
1.7	6.7	25.9
1.8	8.2	28.6
1.9	9.7	31.1
2.0	11.0	33.3
2.1	12.6	35.5
2.2	14.0	37.5
2.3	15.5	39.4
2.4	17.0	41.2
2.5	18.4	42.9
2.6	19.7	44.4
2.7	21.1	45.9
2.8	22.5	47.4
2.9	23.8	48.7
3.0	25.0	50.0
4.0	36.0	60.0
5.7	49.0	70.0
9.0	64.0	80.0
19.0	81.0	90.0

MINI SWR BRIDGE

John Schultz W2EEY

Most SWR meters today are of the coupled variety which can be left in a transmission line while a transmitter is operated at full power. However, for a number of prolonged tune-up operations, involving antenna matching systems, for instance, such couplers have several disadvantages.

On 160 and 80 meters, especially, a reasonable amount of power is necessary to produce full deflection—up to 100 watts with some configurations. With a very low-powered transmitter, making adjustments at this power level certainly may damage the output tube or tank-circuit components with a high SWR. This will not be the case with higher-powered circuits but, in any case, a signal strong enough to cause needless QRM will be radiated.

Another disadvantage of the coupled SWR meter, if it is home constructed, is that it must be carefully calibrated since its response is very dependent upon the mechanical configuration of the coupling circuit. This is unlike the bridge-type SWR meter (described in this article) where a standard SWR curve may be used with a good degree of accuracy.

The above factors, plus the fact that I didn't need an SWR meter continuously in the transmission line, led me to construct the little resistance type SWR bridge shown in the photograph. It is just about as simple and inexpensive a unit as can possible be built.

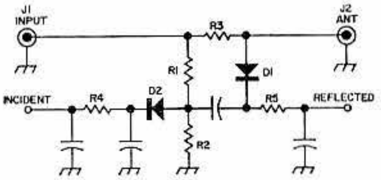

Fig. 1. SWR Bridge Circuit. See text for values of R_1, R_2 and R_3. R_4 and R_5 may be any matched value from 10 k to 47 k. D_1 and D_2 are IN34, IN54, or similar types. All capacitors are disc ceramic, .005 MF, 100V.

Construction

Two SO-239 coax chassis connectors are joined back to back by two 1¼ inch threaded hex spacers. The two four-lug terminal strips are mounted at the ends of one of the spacers. The wiring of diodes D_1 and D_2 as shown in **Fig. 1**, should be such that the incidental voltage-measuring point appears on the terminal strip mounted on the "input" SO-239 connector, in order to avoid confusion in measurement. Short leads, of course, should be used but hardly anything else is possible with only 1¼ inches between connectors.

Some attention must be paid to the components used if accurate readings are to be obtained. Resistor R_3 must closely match the impedance of the coaxial line used (52 or 75 ohms). For 52-ohm lines, a suitable resistor (within ½ to 1 ohm) can usually be found from a group of standard 10% tolerance, 47-ohm resistors; and for 75-ohm lines, from a group of 68-ohm resistors. Resistors R_1 and R_2 can have any value from about 30 to 100 ohms, but it is important that they are as closely matched as possible. One trick which may be used to affect very small resistance changes is to file "V" notches in a composition resistor to raise its resistance. Two-watt units are suggested for these resistors because of their longer-term stability and endurance in case too much input power is applied.

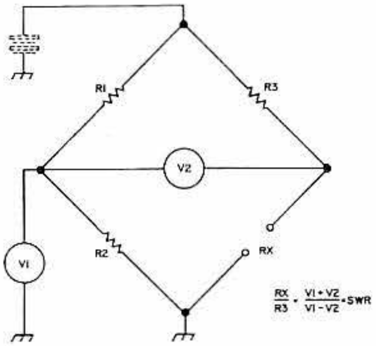

Fig. 2. Simplified diagram of SWR Bridge. V_1 represents incident voltage and V_2 the reflected voltage.

Resistors R_4 and R_5 serve as linearizing resistors so that almost any meter with a basic movement of 1 mA or less can be used as an indicator. The lower dc voltage ranges on almost any VOM will work fine. These resistors as well as diodes D_1 and D_2 should be checked to see that they match reasonably well (the resistors within a few precent and the diodes within a few percent for their forward and reverse resistance readings).

Calibration

There are really no adjustments that can be made to the bridge, and calibration really consists of checking the balance. **Fig. 2** is the dc circuit of the bridge (a simple Wheatstone bridge with resistance arms). If the balance of the bridge is good, V_2 should be the same when points R_X are opened or shorted so long as V_1 is held constant. This can be checked on the actual bridge by applying an input at the highest frequency of interest (6 or 10 meters), shorting J_2, and checking that incident and reflecting voltages are the same. The same is done with J_2 open. If the voltages are not equal, the difference can be taken as an indication of how accurate the SWR readings will be. If the difference is too great, R_1 or R_2 will have to be changed for a better match or the mounting of the components changed to reduce stray couplings.

A further check is to connect a known 52 or 75 ohm resistor across J_2. The reflected voltage should, of course, read zero.

Operation

As noted in **Fig. 2** the actual SWR is a simple function of the incident and reflected voltage readings. **Fig. 3** presents this function in graphical form. The incident voltage is simply adjusted for some convenient value, say 10 volts reading on the dc scale of a VOM (possible with most SSB transmitters by adjusting the carrier balance control with no audio input). The reflected voltage is then read as a percentage of the incident voltage and the SWR found from **Fig. 3.** The input power required to operate the bridge is essentially independent of frequency, being about 1-2 watts maximum.

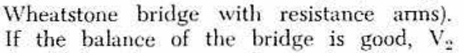

Fig. 3. SWR values for selected reflected voltage readings taken as % of incident voltage reading.

It should be remembered that such a bridge can measure only the resistive portion of an impedance. When using it to adjust a circuit, if a SWR minimum null but not a zero reading for reflected voltage can be obtained, it indicates some reactive component must still be present.

VSWR SUPREME

E. L. Klein W4BRS

One of the most valuable tools used by the amateur is the Voltage Standing Wave Ratio Meter. It ranks with the grid-dipper and the plate current meter as an indispensable instrument around the ham shack. We know that the VSWR meter is very handy in indicating relative power output when tuning a transmitter, particularly when the plate dip is not too discernable. It is most useful, however, in proving that the last available watt has reached the antenna where it can do some good.

Why a good match?

Although a good copper connection is made all the way to the antenna, an efficient transfer of power may not be achieved because of a mismatch between the characteristic impedances of the various portions of the transmission system. The interesting thing is that the "match" is different for each frequency because the antenna is essentially a single frequency device.

We can appreciate the importance of a proper match between the transmitter and the antenna when we are told, for example, that a VSWR of 3 to 1 causes a power loss of nearly 3 dB for 200 feet of RG-8/U coaxial line at 30 MHz. The table below provides

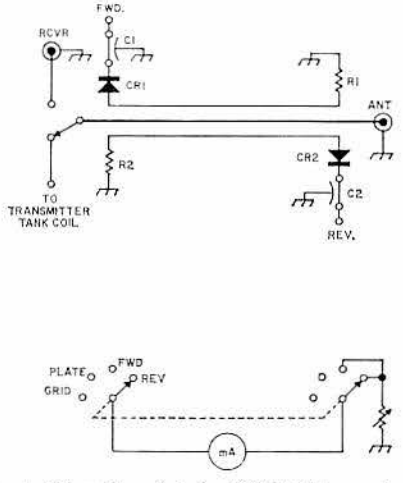

Fig. 1 Schematic of basic VSWR Meter and associated switching circuits.

Table I

VSWR	Power Loss (dB)	Transmitter Power Needed to Provide 1 kW at the Antenna
1.5:1	2.1	1600 watts
2:1	2.3	1700
3:1	2.8	1900
4:1	3.3	2000
5:1	3.7	2300
7:1	4.5	2800
10:1	5.3	3400

Additional power needed to compensate for a poor impedance match between transmitter and antenna. Figures are based upon 200 feet of RG-8/U cable at 30 MHz.

the real reason why we should be concerned with the impedance match. Notice how much the transmitter power would have to be increased to make up for a poor match between the transmitter and the antenna. Incidently, this match involves each and every part of the total transmission system including connectors, antenna relay, low-pass filter, balun, etc., as well as the transmission line itself and that particularly critical point at which it is connected to the antenna.

A new approach

Most VSWR meters today are an external accessory to the transmitter. But this practice is not good. Coaxial connectors are expensive and cause unwarranted mismatch and power loss. Meter faces usually end up behind the transmitter or in some other inaccessible location. When switching from forward to reverse, the little accessory box scoots across the table leaving scratches and a distraught operator.

The transmitter plate current meter is no longer a plug-in accessory. Why should the VSWR meter be? (Believe it or not, plate meters used to be plugged in with phone jacks.) Using the simple design described here, the home constructor as well as the commercial manufacturer can now build the VSWR meter into the transmitter in the smallest possible space and at only pennies of cost.

The circuit

Nothing is new about the circuit. It has been adequately described in the past in magazine articles and handbooks. However, for the convenience of the reader, the VSWR meter circuit is reproduced in **Fig. 1** for handy reference. Terminating resistors R1 and R2 should be 33 ohms for a 50-ohm transmission line when the physical configuration, as shown here, is used. One-half watt or smaller size resistors may be used. Diodes CR1 and CR2 are any matched pair of silicon diodes or germanium. The types which are enclosed in glass cases are the easiest to use because of their small size. The ohmmeter can be used to select and match the diodes of the ten-cent surplus variety found in advertisements in ham magazines such as *73*. Bypass capacitors C1 and C2 are 1500 pF Centralab type FT-1500.

Physical components

Parts used in this VSWR meter are illustrated in **Fig. 2.** The brass tubing is about 5 to 7 inches long and of 5/16 inch outside diameter. This size tubing fits snugly around the inner polyethelyne insulation from RG-8/U coaxial cable. About 10 inches of coax is stripped of its outer jacket and braid. The inner insulation is trimmed to extend ⅛ inch past each end of the brass tubing. Two large solder lugs are selected to fit over the ¼ inch threaded shank of the bypass capacitors. These lugs should be of the long variety so they may be shaped and soldered to the brass tubing as shown in **Fig. 3.** Two 8-inch pieces of #22 enameled copper wire are also required.

Assembly

After soldering the lugs to the brass tubing about ⅝ inch in from each end, the bypass capacitors are assembled to the lugs. Place several fiber washers under the ring nuts prior to tightening them down on the threaded shank of the capacitors. This permits careful soldering of the capacitors to the lugs without danger of also soldering the nuts in place.

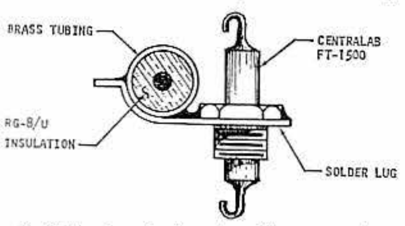

Fig. 3 Solder lug is shaped to fit one-quarter way around the brass tubing.

Two small grooves are now cut 180 degrees apart for the total length of the polyethelyne insulation. A small wood carving gouge or carefully manipulated razor blade can be used for this purpose. These grooves provide a space for the enameled copper wire which is held in place when assembling as shown in **Fig. 4.** Prior to this operation, the wire should be stretched and work-hardened by jerking it between two pairs of pliers. Be sure that the plane described by the two wires lies at right angles to the chassis on which the unit is mounted. This permits all resistors and diodes to have equal lead lengths.

When the inner assembly has been tugged and shoved into place within the brass tubing, the #22 wire ends are trimmed, stripped and soldered to their respective resistors and diodes. Much care should be exercised at this point to prevent melting the insulation or damaging the near zero-length component leads.

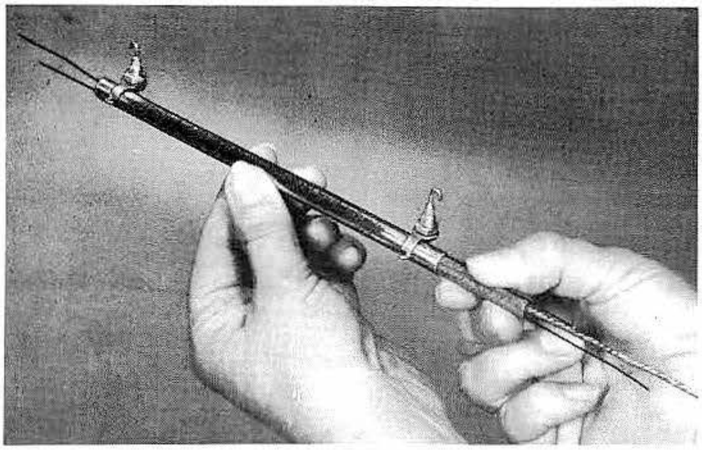

Fig. 4 Assembling the inner components into the brass tubing.

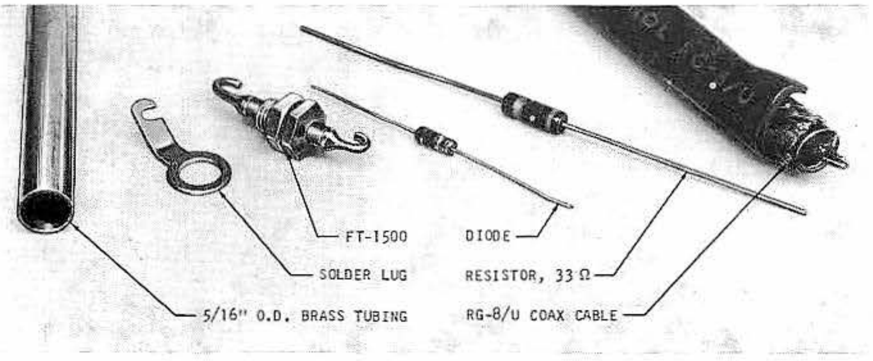

Fig. 2 Component parts used in making the VSWR sensing unit.

Application

A completed sensing unit for the VSWR meter is shown mounted on a typical chassis in **Fig. 5.** It will be noted that no conventional box or housing is used because the total outside of the unit is at ground rf and dc potential, save for the component connections at each end. By mounting the bypass capacitor in the chassis, the low-voltage rectified current fed to the meter switch is

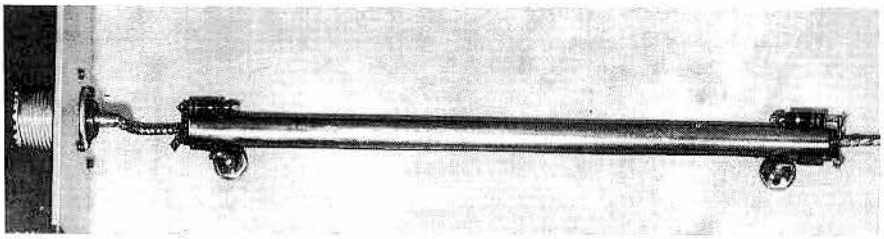

Fig. 5 Finished VSWR sensing unit mounted on a typical chassis.

isolated from high-power rf on the other side of the chassis. It can readily be seen that the finished sensing unit occupies no more space than would be used by a coaxial lead running from an antenna relay to the antenna connector on the chassis.

A further refinement is shown in **Fig. 6.** Complete isolation of the high-power rf is provided by the coaxial hood. Impedance discontinuity is also minimized by use of the hood, which was designed for this purpose and is readily available.

Length of sensor

The dimensions given for the length of the sensor element, including its outer tubing and inner conductor, are not critical. They are, however, directly related to the power of the transmitter with which the VSWR meter is used. For example, with a one kilowatt high-frequency CW transmitter and a 0-1 milliammeter as the indicating meter, the length of the sensor can be as short as 2-3 inches. A sensor which is constructed approximately 7 inches long, as illustrated in this article, will work fine with the same meter on a 25-200 watt high frequency transmitter. If meters with higher current ratings are used, a longer sensor is required, and, conversely, a more sensitive meter would provide adequate full-scale deflection with a shorter sensor element. Obviously, it is impracticable to vary the length of the sensor element in order to vary the sensitivity of the VSWR meter as a whole. It is for this reason that the adjusting resistor is provided in series with the meter. For VHF use, the sensor can be shorter.

All that has been said above can be depicted graphically. **Fig. 7** shows the generalized relationship between the sensor length and transmitter power with which it is used. The two curves represent different meter sensitivities. A 0-1 milliammeter offers a good compromise. With a 5-7 inch long sensor and the proper series resistor, all powers normally encountered in amateur work can be handled. However, if space requirements so dictate, a shorter sensor unit can be employed with some small sacrifice in accuracy.

Terminating resistor

Small variations in mechanical construction and lead dress will have an effect on the value of the terminating resistors, R_1 and R_2. Also, a carbon resistor does not display the same reactance at high frequencies as its measured resistance at dc. The value of the 33-ohm resistor was therefore determined empirically.

To verify the proper value of the terminating resistors, the test set-up shown in **Fig. 8** is used. A radio-frequency source of approximately 10 to 20 watts is required. A transmitter exciter stage operating on the 10-meter band is preferred for this purpose. Ten meters, or even fifteen meters, will provide better accuracy than one of the lower frequency bands. A dummy load is also required. This load must be capable of dissipating the power of the radio-frequency source used in making the test. Three or four 2-watt carbon resistors of the proper value in parallel to provide 52 ohms will suffice if the power is not left on continuously.

In making the test, the selector switch is first placed in the "forward" position. With power applied, immediately adjust the sensitivity control so that the meter reads full scale. Upon switching to the "reverse" position, the meter should read near zero and be at or below the 1:1 calibration point on the meter scale. Several resistors may be substituted until the proper value is found. The important thing to remember is that both of the resistors should be simultaneously substituted and that they must be as near identical as possible as measured on a reasonably good ohmeter. Lead lengths should also be as short as possible and of identical length.

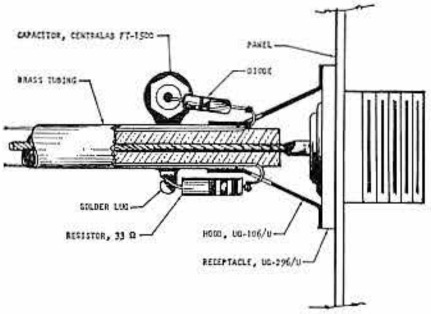

Fig. 6 Recommended chassis connection for output of VSWR meter sensing unit.

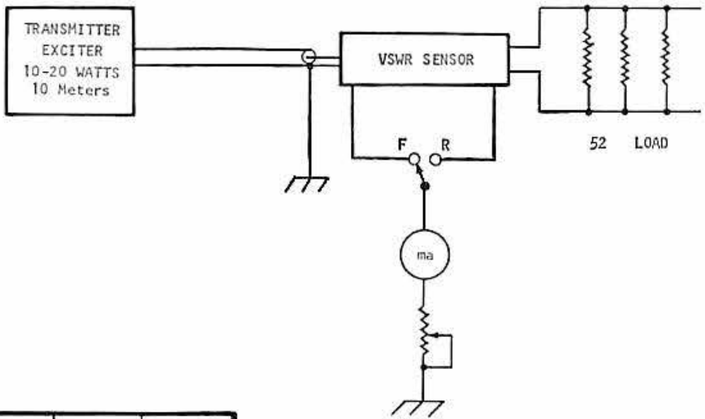

Fig. 8 Test set-up for verifying the proper value of the terminating resistors which are a part of the sensor unit. The value of the dummy load should match the characteristic impedance of the sensor unit and have a total wattage rating nearly equal to the source power.

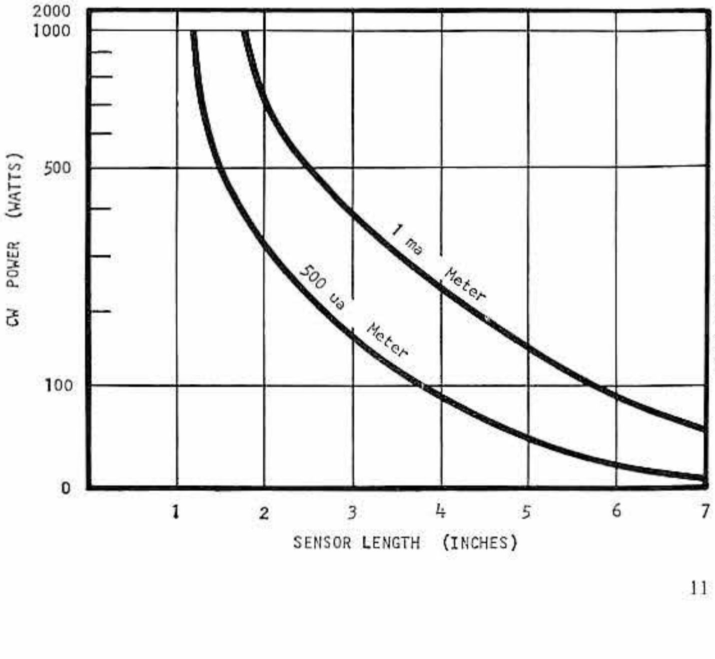

Fig. 7 The approximate relationship between sensor length and transmitter power is shown for two commonly used meter movements. Other meter values may be used as discussed in the text.

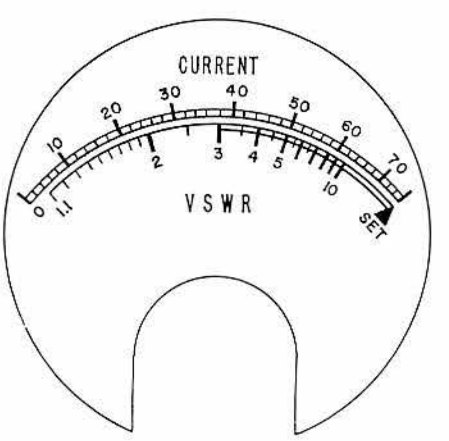

Fig. 9 Full-size photomaster of the VSWR meter dial. A multi-purpose meter was used in the author's transmitter so that the grid and plate currents could also be read on the upper scale.

The dial scale

Using the standard formula for calculating VSWR, it is possible to calibrate the meter face as follows:

$$\text{VSWR} = \frac{\text{forward} + \text{reverse}}{\text{forward} - \text{reverse}}$$

Fig. 9 is a full-scale illustration of a meter face used with the *VSWR Supreme.* This scale fits the Triplett Model 327, as well as a number of other meters of the same size category. A word of caution—don't assume that the scale calibration, or linearity will be the same for all makes of meters. The individual meter movement selected should be checked by using the above formula and marking off radials representing 4-5 different VSWR values. With the scale from your meter at the center of an oversized radial(s) drawing, it is possible to verify the angular placement of each VSWR calibration point.

The *VSWR Supreme* is truly a novel approach to an old standby. Using the construction methods outlined in this article, it is possible to fabricate the sensor unit so that it occupies the smallest possible space. This sensor can now be built into a transmitter and take up no more room than the coaxial lead which it replaces.

A SIMPLE VHF SWR METER

John Schultz W2EEY/K3EZ

I recently wanted to do some work on a 2 meter antenna and since no other instrument was handy, started to use an SWR meter manufactured for use on the high frequency bands. After some erratic results, it was decided to check the SWR meter accuracy on 2 meters with some carbon resistors to simulate different SWR's. The results readily confirmed that the SWR meter was useless at VHF unless one didn't care whether a SWR was really 1:2 or 1:5. Rather than purchase another SWR meter, it was decided to construct one that would render reasonable results, within 10% accuracy or so, on the VHF bands, particularly 144 and 220 MHz.

There is nothing basically new in the circuitry of the SWR meter to be described. What is different about it is that it utilizes a particularly simple and inexpensive method of construction that yields reasonable results. It can be constructed as a completely self-contained SWR meter or only the pickup element can be constructed and used with an external meter. The circuitry as shown here for the meter utilizes two meter movements so one can read forward and reflected power simultaneously and avoid the annoyance of having a forward-reflected switch arrangement for a single meter.

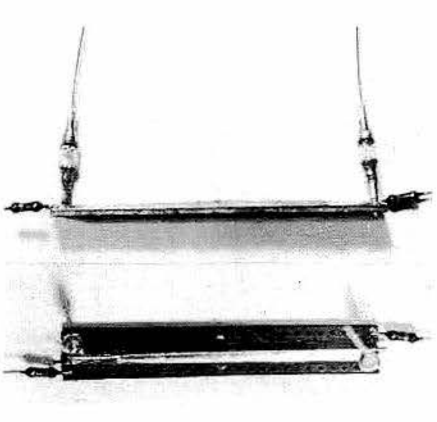

The heart of the SWR meter is a carefully constructed pickup element. Details of construction are discussed in the text but the photo shows how closely the diodes and terminating resistors must be soldered to the pickup element.

Pickup Element

The "heart" of any SWR meter of the reflectometer type is the pickup element. Many elaborate forms for such elements have been devised which involve complicated mechanical construction. Such complicated construction does become necessary if very accurate results are desired and if the meter is to maintain linearity over a very wide frequency range. However, over a smaller frequency range and with some minor sacrifice in accuracy, the construction of a pickup element can be greatly simplified. Basically, the pickup element should not cause any discontinuity in the transmission line section in which it is inserted but yet be long enough so enough voltage can be picked up in both the forward and reflected directions to make the meter usable with even low power transmitters.

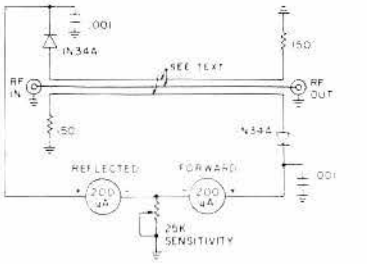

Fig. 1. SWR meter circuit. Two identical meters should be used (current range and internal resistance).

The pickup element I devised is shown in the photo. It is a 2-7/8" long piece of alternate grid pre-punched perf-board stock. The board is about 7/16" wide and within this width contained 4 separate copper strips spaced about 1/16" or less apart. The center two strips are soldered together to act as the inner conductor continuation of a coaxial line section. To solder the two inner strips together tack solder a bare piece of hookup wire between the two strips and then cover the entire two strips with solder.

Without the use of pickup wire, it will be nearly impossible to develop a smooth solder flow between the strip. Each outer strip acts as a pickup element for the SWR meter circuit shown in Fig. 1. The terminating resistor and diode are soldered to each end of the outer strip as shown in the photo and with minimum excess lead length to the strip. The use of a heat sink on the diode is necessary to prevent damage during soldering.

Mounting The Pickup Element

The pickup element made from the board stock is mounted between two approximately spaced SO-239 chassis connectors. The center strip of the board is soldered at each end to the center post of the SO-239 connector. The terminating resistor at each end is grounded as directly as possible to a ground lug held in place by one screw of the SO-239 mounting hardware. These details are shown in Fig. 2. It is important that the terminating resistor be grounded in this manner with minimum lead length. The enclosure in which the pickup element is contained should just be wide enough to accommodate the SO 239 connectors so that when the enclosure is secured together, the pickup element is boxed in by a metal surface on each side except directly above it. Many chassis or enclosure types are suitable for this purpose and the overall size of the enclosure will depend, of course, on the meter used and sensitivity control placement. These details are not covered here because they can be made as desired. They will not affect the basic accuracy of the meter as long as the pickup element is properly mounted and enclosed. The bypassing of the pickup rectifier diodes must also be done with as short leads as possible on the bypass capacitor. As shown in Fig. 2, a two lug terminal strip (one lug grounded) mounted on the side wall of the enclosure immediately at the cathode end of the diode will perform this task very well. The length of the IN34A diodes is such that the bypass capacitor cannot be connected to the same ground lug used for the terminating resistor. The leads on the capacitor would be too long and it will be ineffective.

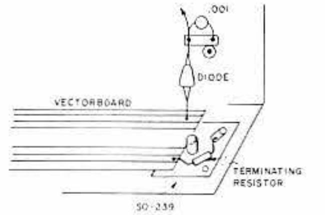

Fig. 2. Center strip of vector board is soldered to center post of SO-239. Other components are mounted at each end of board as shown (only one end shown here).

Operation and Results

The dual meter circuit of Fig. 1 reads forward and reflected power simultaneously. The sensitivity potentiometer is set to read full scale on the forward meter and the SWR read directly from the reflected meter. The latter meter can be calibrated for various SWR's by the use of small carbon resistors (100Ω to simulate a 1:2 SWR in a 50Ω line, etc.). Usually, it is only necessary to calibrate the reflected meter for SWR's of 1.5, 2 and 3 at the frequency of interest. Calibrated in this manner, the accuracy of measurement will be roughly 10% and is certainly good enough for most general antenna work. A particularly nice meter display can be made if one can find a two meter movement in one enclosure. I purchased a surplus stereo VU meter which had dual 200 μA movements and used it in the SWR meter.

The sensitivity of the SWR meter is such that transceivers of the 1-2 watt output class can easily be used with it on the VHF bands. The basic meter, of course, can also be used on the lower frequency bands as well and it will retain good accuracy. The only problem on the lower frequency bands is that the pickup strips are so short that more transmitter power has to be used to activate the meter than is usually convenient to use during antenna experiments. No exact tests were made but probably 70–100 watts would be needed to use the meter on as low a band as 80 meters. The meter was used and checked, however, on 40 meters. The accuracy of the meter remained very good and full scale deflection of the forward level meter required a power level of 60 watts. Being an in-line type meter, it can be left permanently in line when used on any band with a minimum of loss.

DIRECTIONAL COUPLER AND VSWR BRIDGE FOR VHF AND UHF

Bob Kolb WA6SXC

The aerospace industry has fostered the development of many new components and materials. Hams, being the kind of people they are, are quick to see practical applications for these materials that never occur to design engineers. I have often heard the criticism that it is impractical to publish articles or design ham gear with these new or expensive materials, because most OM's don't have access to them. Yet I've often been dismayed when I learn of an application for a piece of surplus equipment after it is no longer available. For this reason I feel that we should publish any application that is practical regardless of how immediately it can be used. Sooner or later, the material will show up on the surplus market and then we'll know what use can be made of it.

Reliable test equipment for the VHF-UHF bands is difficult to come by on a low budget. The literature is full of "relative" measuring devices but few pieces of homebrew gear are engineered for repeatable performance. Several directional couplers have been built according to the description in this article and each has measured to within ±.5 dB of the designed value. This is due in part to the mechanical rigidity and close tolerance of RG-141 "coaxitube." No special tools are required outside of a cheap pair of vernier calipers. The tools used to make the original coupler were an Xacto knife, file, soldering gun, vernier calipers and a vise. Don't let the calipers scare you. If you're not after a closely calibrated device they may be omitted.

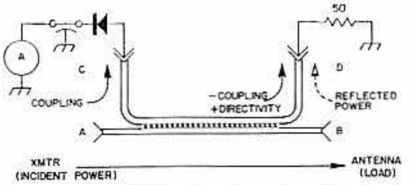

Fig. 1. A typical directional coupler. This device is the heart of a VSWR bridge, and can also be used for many other applications.

The design goal was a directional coupler with about 30 dB directivity in the passband with a low insertion loss. Each milliwatt measured at the coupling arm equals one watt through the main line. Such a device is the heart of a good quality VSWR Bridge. The measured values were 30.3 dB coupling and 38 dB directivity at 432 MHz. Data presented in the graph was taken using HP608C and 614A signal generators and a General Microwave R. F. Power Meter. The measured insertion loss was 0.2 dB.

Resolution of the smallest possible VSWR is limited by directivity. Few of the handbook VSWR bridges or the low cost type attractive to the CB trade achieve as much as 20 dB directivity. Thus the minimum discernable VSWR is approximately 1.7:1. With 38 dB directivity, 1.02:1 VSWR's can be accurately measured.

Directivity may be defined as the isolation of arm D from arm A, over and above the coupling as shown in the **Fig. 1.** Coupling is achieved by removing part of the jacket between adjacent coax conductors. If the input is at arm A, incident power can be sampled 30 dB down at arm C but appears −68 dB at arm D. Reflected power entering arm B is sampled −30 dB at arm D while at arm C it is −68 dB. It stands to reason if the directivity is low, one cannot tell with certainty if he is measuring incident or reflected power. Port D may be used as the dc return for a detector at port C and vice versa.

This device will have its fundamental passband where the length exposed between the two lines is $\lambda/4\sqrt{\epsilon_r}$. It will also have a passboard at $(2n-1)\ \lambda/4\sqrt{\epsilon_r}$ or at three, five, seven, etc., times the frequency for which it is a quarter wave. Hence a coupler designed at 432 MHz is usable at 1296 MHz.

This coupler has also been used to measure relative power and modulation at 2 meters where its coupling factor for incident power is approximately −40 dB but the directivity is poor, hence arm D must be terminated in 50 ohms. It's a real aid for tune up and will give a good indication of increased power with AM modulation right in the r.f. line. RG141 will handle 500 watts of rf up to 2000 MHz.

This UHF directional coupler is very simple to make, yet offers excellent performance on the 70 and 23 cm bands.

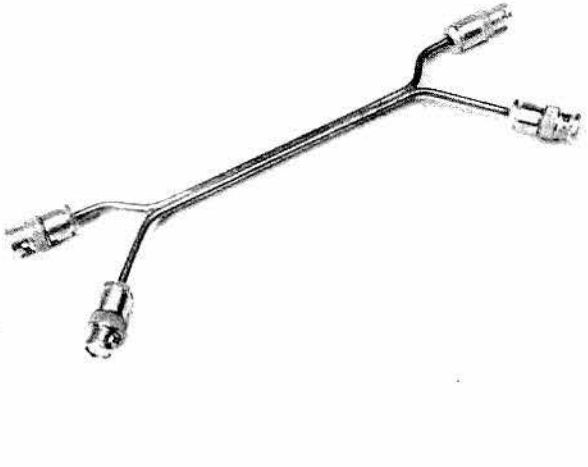

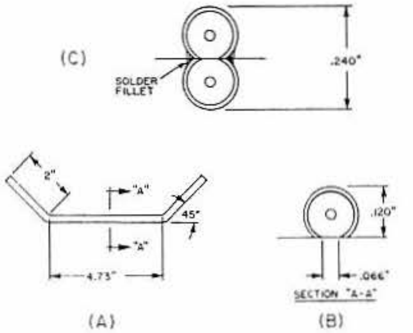

Fig. 2. Details of the construction of the UHF directional coupler.

The formula for determining coupling length is

$$\frac{c}{4 f_o \sqrt{\epsilon_r}} = \frac{\lambda c}{4\sqrt{\epsilon_r}} \text{ or } \frac{300 \times 10^8 \text{ cm}}{4 \times f_o \times \sqrt{2.1} \times 2.54 \text{ cm/in}}$$

$$= \frac{\lambda \text{ c inches}}{4\sqrt{\epsilon_r}}$$

$\sqrt{\epsilon_r}$ for Teflon $= \sqrt{2.1} = 1.449$

From these calculations $\frac{\lambda \text{coupling}}{4}$ at 432 MHz is 4.73 inches. With an Xacto knife cut two pieces of line 8.73 inches long and carefully bend them so that they form the shape shown in **Fig. 2A.**

Clamp the bent coax into the vise and file away the copper jacket taking care that the filed surface is smooth and flat. A belt or stationery disc sander works well too. A cross section of the filed piece should look like **Fig. 2B.** Next fit the two pieces together so that a cross section would look like a figure 8 and secure in a vise. Heat with a soldering gun only. Do not use a torch. Avoid excessive heating. Flow solder between the two lines as shown in **Fig. 2C.** The "arms" can now be bent into any convenient configuration provided enough allowance is made at the ends for connector assembly. A good rule to follow is a minimum bend radius of half an inch although a quarter inch radius is permissible. The arms should be approximately two inches long.

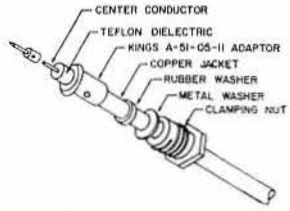

Fig. 3. Use of Kings A-51-05-11 adapter for using GR-141 with standard BNC connectors.

RG 141 has the same cross section as RG 58/U *without* the vinyl jacket therefore any connector that will accept RG 58/U can be used on RG 141 provided a sleeve is made up to make a snug fit in the clamping nut. A special adaptor is made by Kings for this purpose and sells for 45 cents. The connector assembly is shown in **Fig. 3.** Three RG 88E/U and one RG 89C/U connectors were used on the coupler shown in the photo.

Fig. 4 gives the measured directivity and coupling for this type of directional coupler at both 70 and 23 cm. You can see that performance is quite satisfactory.

Fig. 5 lists a number of applications for a directional coupler. The detectors in the measuring instruments should be suitable for use at 500 or 1300 MHz.

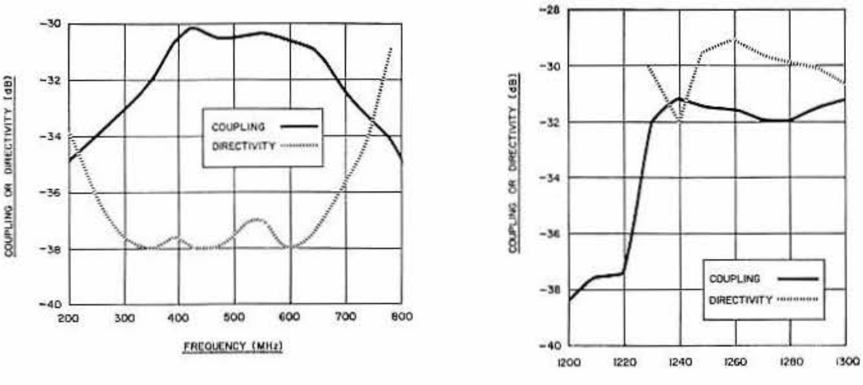

Fig. 4. Coupling and directivity for a directional coupler similar to the one discussed in the text. This device used a coupling wavelength of 4.635 inches rather than the 4.73 inches specified in the text. The only effect of the longer wavelength is to center the curves on 432MHz instead of about 500 MHz.

A SLOTTED LINE FOR 1250 MHz

Silas Smith WA8CHD

The SWR bridge is a very useful—and sometimes badly neglected—tool. Especially on 1250 mc with only two or three watts of power, you should measure your SWR and do something about it if necessary. I recently joined the 23 cm boys, though I have only worked 1234 mc so far. My first attempt to communicate with W8VKQ on the other end failed but after two evenings of diligent work with a meagre amount of test equipment we made contact. It would have been a lot easier with test equipment good in the 1250 mc range since most hams are not equipped to measure frequency and adjust their rigs at these frequencies.

After that experience, I made the slotted line indicator described in this article. The cost is next to nothing and it's easy to build, but it does a good job. The unit is built around a one inch thin wall copper tube 10¼" long (Fig. 1). This tube has a ⅜" slot cut lengthwise for 7½", about ¾ wavelength at 1250 mc. This is long enough to get a fair sampling of the standing wave or null points.

Three other pieces of 1" copper pipe are needed. Two are 5/16" long and one is 1⅜" long. The two 5/16" pieces each have ¼" cut out and are reshaped to fit inside the 1" tube. These two pieces were each soldered to 1/16" plates as in the detail in **Fig. 1.** This process makes two cup-like structures which should

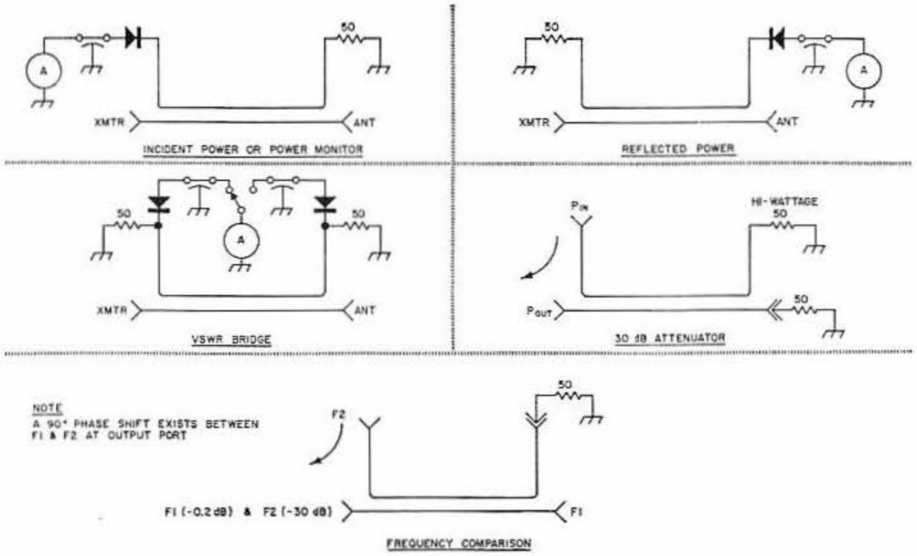

Fig. 5. Applications of the directional coupler described in the text. Unlike most pieces of ham-made test equipment, this one is good at 450 and even 1300 MHz.

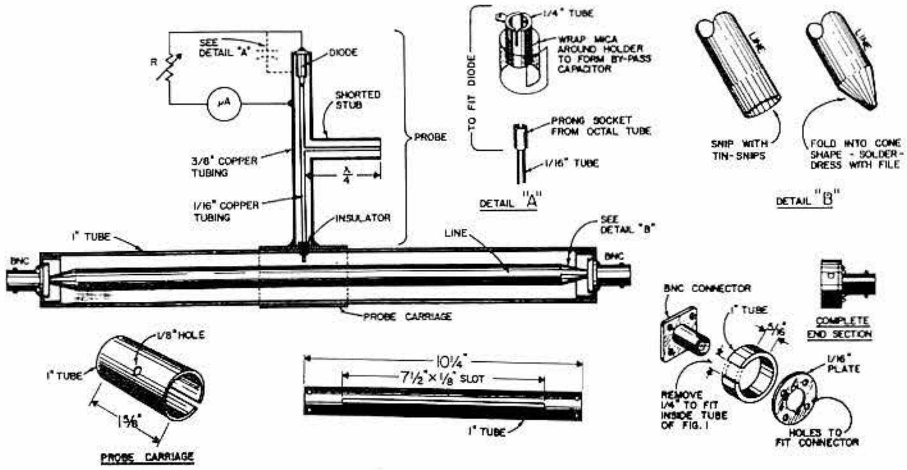
SEE DETAIL "A"
R
μA
DIODE
SHORTED STUB
PROBE
3/8" COPPER TUBING
λ/4
1/16" COPPER TUBING
INSULATOR
1" TUBE
BNC
LINE
SEE DETAIL "B"
BNC
PROBE CARRIAGE
TO FIT DIODE
1/4" TUBE
WRAP MICA AROUND HOLDER TO FORM BY-PASS CAPACITOR
PRONG SOCKET FROM OCTAL TUBE
1/16" TUBE
DETAIL "A"
LINE
LINE
SNIP WITH TIN-SNIPS
FOLD INTO CONE SHAPE - SOLDER - DRESS WITH FILE
DETAIL "B"
1/8" HOLE
1" TUBE
1⅜"
PROBE CARRIAGE
10¼"
7½" × ⅛" SLOT
1" TUBE
BNC CONNECTOR
1" TUBE
5/16"
COMPLETE END SECTION
1/16" PLATE
REMOVE 1/4" TO FIT INSIDE TUBE OF FIG. 1
HOLES TO FIT CONNECTOR

Fig. 1. The slotted coaxial line and probe for 1215 to 1300 mc described in this article.

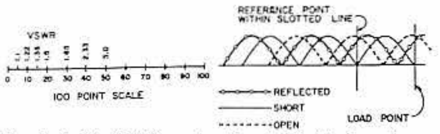
VSWR
1.1
1.22
1.35
1.5
1.85
2.33
3.0
0
10
20
30
40
50
60
70
80
90
100
100 POINT SCALE
REFERENCE POINT WITHIN SLOTTED LINE
REFLECTED
SHORT
OPEN
LOAD POINT

Fig. 5, Left. VSWR scale. Fig. 6, Right. Impedance measurements.

fit within the end of the 1" pipe. Drill nine holes in each cup: four holes for attaching the cup to the slotted line, four to fit the BNC connector mounting plate and one ⅜" hole to pass the main body of the connector. File two notches for the connector ears. You can fasten the cups to the slotted tube with small sheet metal screws, threaded holes or nuts soldered to the back of the holes.

The 1" x 1⅜" piece of pipe is for the probe carriage. It is cut lengthwise on one side, slipped over the 1" tube, centered, and a ⅛" hole drilled through it over the slot in the 1" tube.

The probe is built from ⅜" and ⅛" brass tubing from your hobby shop. At the probe end is an insulator from a coax fitting and on the other end is a jack made from an octal tube socket. A small piece of ¼" brass tubing is used to make the diode socket (see detail A). A piece of 22 gauge wire is inserted in the probe end of the 1/16" tubing and soldered. A 1N21 diode works very well.

Use **Fig. 2** to choose the proper size for the line in the center. Each end of this line should be tapered and soldered to the coax fitting as in detail B. The center conductor should be 7/16" for 50 ohms or 5/16" for 73 ohms.

The meter used should have a range that permits a full scale reading and should be calibrated with some scale.

Uses: Measuring frequency

Frequency can be measured with the slotted line in two ways: the distance between null points at one half wavelength ($\lambda/2$) or the distance between peaks. See **Fig. 3**. Measuring between the nulls is preferable since the peaks are very broad. If your line is flat, the peaks and nulls may be very small, so you may have to induce a mismatch in the line. Likewise, you may have to induce a mismatch to get the two nulls to fall within the 7½" of the line. The easiest way to induce a mismatch is a short in the line.

Measure the distance between the nulls carefully with a centimeter rule. Twice this distance divided into 30,000 will give you your frequency in megacycles. It would be a good idea to check this against a standard or at least avoid operating too close to the edge of the band.

Measuring VSWR

Measuring voltage standing wave ratio (VSWR) with the slotted line is easy, too. We are looking for a ratio of E_{min}, the minimum voltage on the line, and E_{max}. The ratio:

$$\frac{E_{max}}{E_{min}} = \text{VSWR}$$

However, there is a slight complication of vectors in E_{max} and E_{min}, so that to find them, you must first determine the highest voltage read on the meter, E_1 and the lowest voltage read on the meter, E_2 with the same setting of the shunt resistor, as the probe carriage is slid along the line. Now, $E_{max} = E_1 + E_2$ and $E_{min} = E_1 - E_2$ so that

$$\text{VSWR} = \frac{E_1 + E_2}{E_1 - E_2}$$

An even simpler method is to set the meter to full scale (100) at the highest reading, and reading the VSWR directly from **Fig. 5**.

Impedance measurements

It's a little harder to measure impedance, but even it's not bad if you do it step by step. First, consider the high impedance on your line when your antenna is open or shorted. Perhaps you don't think of it as a change in impedance. This is what we are looking for. Remember that there is a definite relationship between impedance and frequency. **Fig. 6** shows the voltage relationship between a short and open. On a short set the probe for a null point, usually the first null from load end of the slotted line. This will be our reference point. You will note that when the load point is open there is a shift of 90° or a quarter wavelength either side of the reference point. This adds up to one half wavelength. Any impedance between infinity and zero ohms will lie somewhere along the half wavelength of the line. It will be noted that an open is equidistant from the reference point toward the generator and toward the load, however the line has moved toward the load (capacitive reactance). To measure this reactance, we replace the load that we measure with a short. We set our probe to the first minimum reading from the load end of the slotted line. Mark this spot with a scribe. This is our reference point. Now we remove the short and add our load under measurement. It will be noted that the voltage has moved upward. Move the probe toward the load. If the voltage goes down, you are heading in the right direction. If the voltage starts to go up change direction toward the generator. Move the probe as above to the new null point and note the direction that the probe has been moved.

Here's a step-by-step example. First, you'll need the frequency and wavelength, VSWR, direction of probe, distance between reference point and new null, and impedance of the slotted line.

Let's say as we measured the frequency, the distance between the null points was 12 cm. This is half the wavelength, so the wavelength is 24 cm. The frequency is 30000/24 or 1250 mc.

Let's say we read 80 as a maximum and 20 as a minimum on a point scale in measuring the VSWR:

$$E_{max} = E_1 + E_2 = 80 + 20 = 100$$
$$E_{min} = E_1 - E_2 = 60$$

$$\text{VSWR} = \frac{100}{60} = 1.66$$

Or set E_1 to 100 by adjustment of R, then E_2 would read 25 on the meter, a VSWR of 1.66 by **Fig. 5**.

As in **Fig. 6**, the probe was moved toward the load.

Let's assume the distance from the reference point to the new null was 2 cm. What part of a wavelength is 2 cm? Wavelength is 24 cm, so $2/24 = .083$ wavelengths.

This is a movement of .083 wavelengths toward the load.

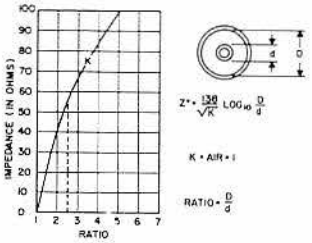

Fig. 2. Ratio of outer tube to inner line for various impedances.

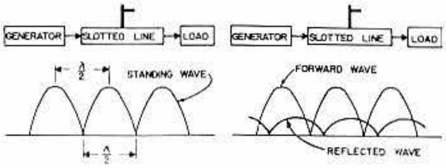
GENERATOR
SLOTTED LINE
LOAD
λ/2
STANDING WAVE
λ/2
GENERATOR
SLOTTED LINE
LOAD
FORWARD WAVE
REFLECTED WAVE

Fig. 3, Left. Measuring frequency. Fig. 4, Right. Measuring VSWR.

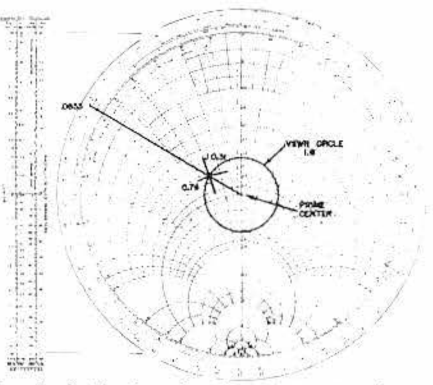

Fig. 7. Smith chart for determining impedance.

The slotted line used has an impedance of 50 ohms.

We are now ready to plot this information on the Smith chart (**Fig. 7**, better get out your magnifying glass).

Draw the VSWR circle at the prime center with a radius of 1.6.

Draw a line from .083 wavelength toward the load from the prime center.

At the intersection of the circle and line, follow the constant resistance circle to .74 and the capacitive reactance circle to .31. Our load impedance is then:

$Z_L = Z_o\ (.74 - .31j)$
$Z_L = 50\ (.74 - .31j)$
$Z_L = 37 - 15.5j$

Well, there are some of the things your slotted coax line can do besides telling you that you're on the air. A commercial version would cost $750. I guarantee that you'll get your dollar's worth out of this one as it costs less than $1 to build. I hope that it helps you get on 1250 mc.

SOME DIRECTIONAL WATTMETERS AND A NOVEL VSWR METER

P. G. Martin G3PDM

Most conventional reflectometers cannot be used for accurate power measurement because their sensitivities are frequency dependent. This is due to the use of combinations of reactance and resistance in the sampling circuits which detect the transmission line current and voltage.

This basic problem can be solved by the use of conventional lumped components instead of the distributed parameters of a transmission line. The line voltage can be sampled by two resistors or two capacitors used as a voltage divider, rather than one resistor and some distributed capacitance. The line current can be monitored by a properly designed current transformer instead of an inductance and resistance. High frequency current transformers consist of primary and secondary windings on a ferrite or iron dust toroidal core, with a low value of load resistance across the secondary winding.

All SWR bridges and directional wattmeters need to generate two dc voltages proportional to the forward and reflected voltages or currents of the transmission line. To achieve this one has either the current detector or the voltage detector providing two antiphase signals so that addition and subtraction can be performed.

A Frequency-Independent Directional Wattmeter

M. B. Allenson G3TGD, has designed a wattmeter using the above principles, where the low resistance in the current transformer secondary circuit is split into two equal parts. The center connection is taken to the voltage sampling point so that sum and difference voltages are available at the ends of the transformer secondary winding, see Fig. 1.

With two meters, this circuit can be used as a versatile calibrated directional wattmeter over the freqnecy range 100 kHz to 70 MHz, with an accuracy of about 10 per cent. Precise calculations of SWR and transmitter efficiency can be made.

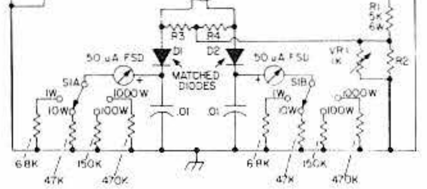

Fig. 1. Circuit of the basic frequency-dependent directional wattmeter due to G3TGD. The two meters indicate forward and reflected powers.

Maximum sensitivity with a 50 μA meter is less than five milliwatts, but with the multiplier resistors specified in Fig. 1, full scale deflection corresponds to power of 1, 10, 100 and 1000 watts. Calibration is non-linear, because the instrument samples voltage, and power is proportional to voltage squared.

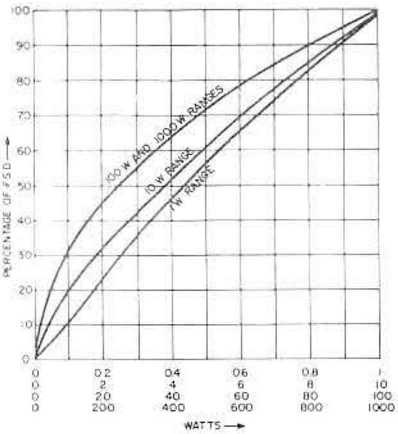

Fig. 2. Calibration curves for the instrument described in Fig. 1.

Unfortunately, two transmission line impedances are in common use in coaxial systems: 50Ω and 75Ω. As it is not possible to design instruments whose sensitivities are independent of line impedance, some component values must depend on the impedance in use. For simplicity, only one of the voltage driver resistors need be changed, but instrument calibration will be different. By changing the current transformer resistors as well as one of the voltage divider resistors, the calibration is the same for both line impedances. This technique has been adopted here, and the calibration curves in Fig. 2, are correct for 50 or 75Ω lines provided the resistor values in Table I are used.

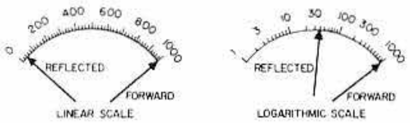

Fig. 3. Linear and logarithmic scales. The inherent advantages of the logarithmic form are immediately obvious.

The Logarithmic Wattmeter

The basic instrument can be simplified by including a logarithmic network so that the power range switch is redundant and a single meter scale can be used for powers from, say, one watt to 1000 watts. A logarithmic scale has the 1, 10, 100 and 1000 watt points equally spaced (see Fig. 3).

The advantage of a logarithmic instrument is that one can measure very low reflected powers and very high forward powers simultaneously with the same percentage accuracy, without having to switch meter ranges.

It is simple to add a reasonably accurate *wide-range* logarithmic network to the meter in Fig. 1 (see Fig. 5). The basis of its

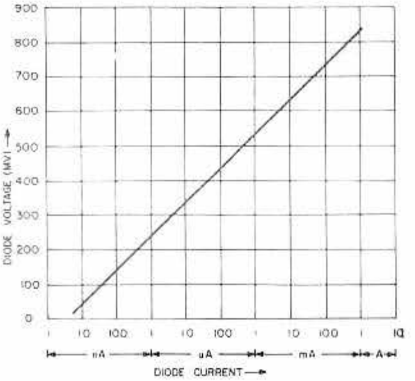

Fig. 4. Smoothed experimental plot of the current /voltage characteristic of a 1N4002 silicon junction diode, showing its logarithmic properties.

operation is that the voltage dropped across a forward-biased p-n junction diode is proportional to the logarithm of the current passing through it (see Fig. 4). To reduce the potential dynamic range of the circuit, a relatively insensitive meter is used, and a small resistance is added in series with the logarithmic diode to restore a logarithmic form to the scale (see Fig. 6).

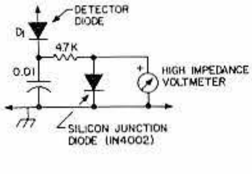

Fig. 5. Basic wide-range logarithmic converter.

An experimental logarithmic wattmeter is shown in Fig. 7. Figure 8 gives the calibration scale for 50 or 75Ω lines, provided the correct resistors are used (Table I).

A Direct-Reading SWR Meter

A particularly useful device would be an instrument giving a direct measurement of the standing wave ratio on a transmission line, independent of the absolute power levels or the frequency in use. Such an instrument, with its single meter, would be ideal for incorporation into transmitters and transceivers (especially with the physically small sampling circuits associated with it).

The swr can be expressed in terms of the forward and reflected voltages according to:

$$\mathrm{swr} = \frac{E_f + E_r}{E_f - E_r} \qquad (1)$$

We wish to generate this function electronically, so that outputs of the two detectors can be used to generate a meter current proportional to SWR. This would be rather tedious, though not impossible.

Conveniently, manipulation of equation (1) shows that:

$$\frac{E_f}{E_r} = \frac{\mathrm{SWR} + 1}{\mathrm{SWR} - 1} \qquad (2)$$

which although not proportional to SWR, is a mathematical function of it only. Electronic division of E_f by E_r is easily done by taking logarithms and subtracting. That is:

$$\log \frac{E_f}{E_r} = \log E_f - \log E_r$$

Table I

	Ω	Ω
Line impedance	50	75
R3 and R4	27	33
R2	220	180

Values for R2, R3 and R4 to be used in 50 and 75Ω transmission lines.

In Fig. 9, the two silicon diode voltages are proportional to the logarithms of their currents, which in turn are proportional to the forward and reflected voltages. The two diode voltages can be subtracted directly by connecting a meter between them, rather than from each one to chassis.

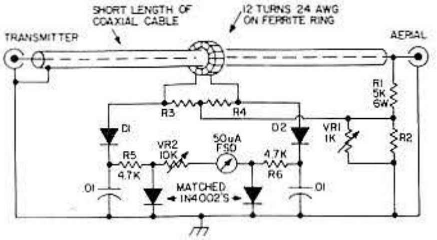

Fig. 6. Circuit of the logarithmic directional wattmeter. D3 and D4 are matched (see text).

The meter cannot be calibrated linearly in SWR, because of equation (2), and because the circuit does not take anti-logarithms after subtracting the logarithms. The outcome of this is beneficial: the SWR meter is increasingly sensitive as the standing wave ratio approaches 1:1. This is where one wants most sensitivity: to make the final adjustments to aerial arrays, to measure the variations in SWR over a band, and so on. Fig. 10, shows a calibration curve for SWR meters. Naturally the meter sensitivity cannot be completely independent of the power level in use. Accuracy falls when the reflected power is less than about half a watt (this corresponds to an SWR of 1.05:1 when the forward power is 1 kW).

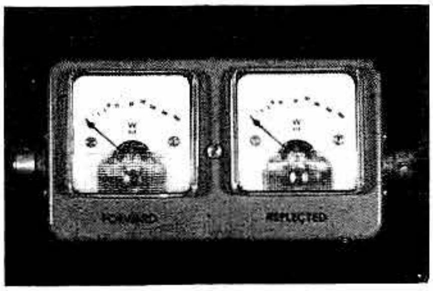

Fig. 7. An experimental logarithmic wattmeter.

A differential amplifier could be added to the circuit of Fig. 9, to enable a less sensitive meter to be used.

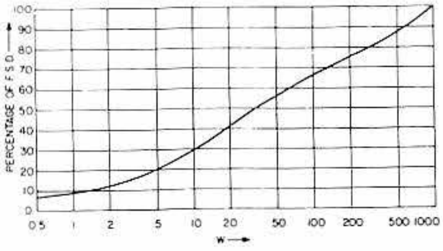

Fig. 8. Calibration curve for logarithmic wattmeters.

Construction of the Instruments

Layout of the sampling circuits is fairly critical, see Fig. 11. The input and output sockets should be set a few inches apart, and connected together with a short length of coaxial cable. The coax braid must be grounded at one end only, so that it acts as an electrostatic screen between the primary and secondary windings of the toroidal transformer. Twelve turns of 24 AWG enamelled wire, equally spaced around the circumference of the ring, form the secondary winding. The primary is formed by simply threading the ring onto the coax.

A suitable ferrite ring is the Mullard FX1596, made in England, although other types are suitable. The FX1596 has an outside diameter of half an inch, and is designed for wideband rf applications between 5 and 20 MHz. The main requirement is that the ferrite material should maintain a high permeability over the frequency range in use.

Other components in the sampling circuits should have the shortest possible leads. R1, R2 and R must be non-inductive solid carbon types: for high power levels (about 100 watts) R1 should consist of two or three 2 watt carbon resistors in parallel. VR1 should be a miniature skeleton potentiometer to keep stray reactance to a minimum, although it may be dispensed with by trying various fixed resistors for R2 until the reflected indication under matched conditions is zero.

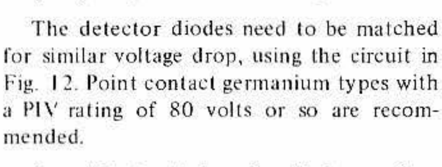

Fig. 9. Complete circuit for a power-independent, frequency-independent direct-reading SWR meter.

The detector diodes need to be matched for similar voltage drop, using the circuit in Fig. 12. Point contact germanium types with a PIV rating of 80 volts or so are recommended.

Logarithmic diodes should be modern medium-current silicon junction types, such as conventional rectifier diodes. The 1N4002 is specially recommended for its good logarithmic properties. Log diodes should also be matched with the circuit in Fig. 12.

The 0.01 μF decoupling capacitors should be a disc ceramic type.

In designing a toroidal transformer different to that specified, several factors should be borne in mind. As the number of secondary turns increases, the self-capacitance rises and causes the response to fall at high

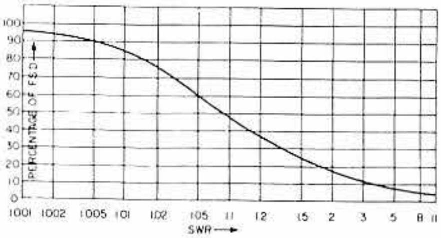

Fig. 10. Calibration curve for SWR meters of the type described in Fig. 9.

frequencies. Failure of this nature causes the reflected power indication to rise; in other words the directivity of the instrument falls. If the 27Ω resistors are raised appreciably in value, the instruments will eventually become frequency sensitive.

The ratio of the voltage sampling resistors (R1 and R2) in the HF designs is determined by the sensitivity of the current sensing circuit, and the two sampling voltages must be equal in magnitude under matched conditions. VR1 provides fine adjustment of the ratio. Absolute values of the resistors can be varied considerably, bearing in mind that as their values increase the stray capacitance across them may need to be compensated for.

Useful Equations

Let the line current be I amps, the line voltage be V volts, and the characteristic impedance of the transmission line be Z_o. Then $V = IZ_o$.

If the current transformer has a ratio of 1:n, and each of the resistors in its secondary circuit has a value of RΩ, then the rf voltage across each of them is given by:

$$V_{(i)} = \frac{IR}{n} \qquad (3)$$

The voltage detector output is obviously

$$V_{(v)} = \frac{VR_2}{R_1 + R_2} = \frac{R_2}{R_1 + R_2} IZ_o$$

Which is, to a good approximation,

$$V_{(v)} = \frac{R_2}{R_1} IZ_o \qquad (4)$$

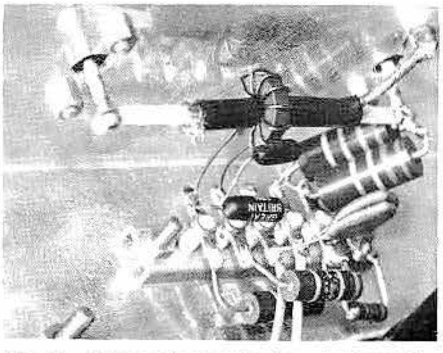

Fig. 11. Photograph showing layout of sampling circuits used in an experimental swr meter.

The main design equation for all the HF instruments is therefore:

$$R_2 = \frac{R.R_1}{n.Z_o}$$

where the value for R2 includes the effect of VR1, if fitted.

The dissipation of some of the components specified is quite high. For those planning different circuits, the following equations express the dissipation of R1 and the current transformer resistors R:

$$W_{(R1)} = \frac{Z_o.W}{R_1} \quad \text{watts},$$

where W is the transmitter output power.

$$W_{(R)} = \frac{W.r}{n2.Z_o} \quad \text{watts.}$$

In the instruments described, $W_{(R1)}$ is about 5 watts, and $W_{(R)}$ 2 watts for a transmitter power of 500 watts.

Calibration

If any of the instruments are built exactly as described, and used in systems of the correct impedance, the calibration given in Figs. 2, 8 and 10 will be sufficiently accurate for most purposes. For those designing their own circuits, the following procedure is recommended.

Test equipment needed includes a high power rf source (a transmitter) and an rf voltmeter. The instruments can be calibrated with less accuracy without the rf voltmeter. The wattmeters are calibrated by feeding power through the meter into an appropriate dummy load (50 or 75Ω). VR1 is set for minimum reflected power indication, and the power scale is marked according to the rf voltage appearing across the load. If an rf voltmeter is not available, a peak-reading type can be made with a diode, capacitor and dc voltmeter. As the detector output is equal to the peak rf voltage applied to it, equation (4) leads to:

$$V_{(det)} = 2.8\ V\ \frac{R_2}{R_1} = 2.8\sqrt{WZ_o}\ \frac{R_2}{R_1}$$

It would be difficult for most amateurs to obtain sufficient high power carbon resistors to calibrate an SWR meter by means of deliberate mismatching. An indirect method is therefore recommended.

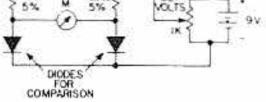

Fig. 12. Hookup circuit for matching detector diodes for equal forward voltage drop, and silicon junction diodes for similar logarithmic properties. The meter should be as sensitive as possible (say 50 μA fsd), and should not deflect appreciably as the voltage is varied between zero and nine volts.

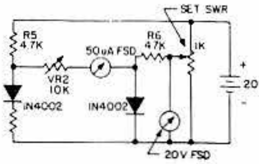

Fig. 13. Circuit used to calibrate SWR meters(see text).

Disconnect R5 and R6, Fig. 9, from the detectors, and connect them instead as shown in Fig. 13. One voltage is fixed at about 20 volts, and the other is varied between zero and 20 volts. The ratio of these voltages corresponds to a definite SWR which can be determined from equation (1). Before carrying out this procedure, however, VR2 should be set for full scale deflection of the meter under matched conditions at the highest power level to be used.

Conclusions

All of the instruments described in this article have been tested under actual operating conditions, on all amateur bands between 1.8 MHz and 30 MHz. Power levels used varied from 100 to 1200 watts. With the components specified, the instruments will sustain power levels well above the kilowatt level for periods of tens of seconds.

It is hoped that by introducing frequency independent directional wattmeters, one will be able to make useful comparisons of absolute power levels and accurate assessments of standing wave situations. The logarithmic scales are an added convenience, and the direct-reading SWR meter offers a saving in meters.

SWR BRIDGES USING ZERO-CENTER METERS

John Schultz W2EEY/K3EZ

The basic coaxial cable swr meter, which samples both the forward and reflected voltages on a transmission line, is an essential instrument in setting up an amateur station. Although a low transmission line swr in itself doesn't guarantee that an antenna system will work, knowing what the swr is remains an essential bit of information in evaluating the status of the transmitter/antenna interface.

The virtues of the usual coaxial line swr meter – economy and simple circuitry – are offset by the awkwardness involved in using the instrument: that is, switching back and forth between "forward" and "reflected" switch positions and adjusting a sensitivity control for sull-scale deflection in the forward position. This awkwardness of operation is partly relieved by dual-instrument swr meters so the forward/reflected switch is no longer necessary – but the cost of the instrument increases. The awkwardness of operation can be completely relieved by special dual movement meters with crossing pointers and/or special circuitry, but then the cost really soars.

Another approach is the usage of some different circuitry to detect the swr which can then activate a zero-center meter so one can peak up the antenna coupler, etc., for minimum swr on a transmission line with the same ease as one tunes an FM entertainment receiver for a zero-center reading on the discriminator meter. In the end analysis, practically no line is set up for any specific swr, but simply for the lowest swr that can be achieved. So, why not make the process as simple as possible? Circuitry to do this has actually been available for many years and was especially developed for use with the automatic servo-tuning of military transmitters. The zero output when tuning conditions were correct, and the plus or minus output when they were not, allowed, after sufficient power amplification, the activation of motors to tune transmitter PA task circuits, coupling circuits, etc. Now, with the economical availability of toroids and imported zero-center meters, zero-center swr type circuits can be applied to amateur usage and meet the criteria of being easy to construct and economical. They offer a real challenge to the conventional type of swr meter, especially when one is using a multiband antenna and tuner arrangement, or just leaves an swr meter in a transmission line to verify that the line swr is holding constant. In the former case, one usually knows the approximate transmitter/tuner settings on each band, and the swr meter is used to peak up the adjustments. Such peaking-up, as mentioned before in the case of an FM receiver, is certainly facilitated by just having to look at a zero-center meter. In the latter case, a zero-center meter will more readily reveal slight changes in transmission line swr from an established norm. Perhaps the only place where a conventional swr meter is still to be preferred is when one is dealing with experimental antennas where extreme swrs exist and a conventional swr meter can help to more quickly obtain "ballpark" antenna coupler or loading coil settings. The zero-center type circuits operate on a slightly different basis than the conventional swr meter circuits, and just a brief review of transmission line operation will be helpful to understand the different basis for the functioning of the two types.

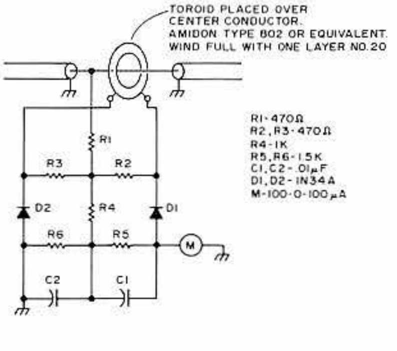

Figure 1.

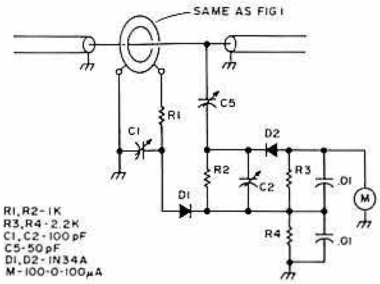

Figure 2.

If a transmission line is attempting to deliver power to a load, both voltage and current values exist along the line. If the antenna load impedance is resistive and equals that of the line impedance, all the power feed into the line reaches the antenna less any power loss in the line itself because of the line's inherent loss. If the load is not equal to the line impedance or reactive, part of the power the line tries to deliver is rejected by the load and reflected back along the line. This sets up standing waves of voltage and current which are not in phase with the original voltage and current waves the transmitter is trying to "pump" into the line.

Conventional swr meters sample a portion of the voltage or current wave traveling towards the load and a sample of that traveling back from the load. The relative amplitude of the two samples is the swr and, of course, the desired condition is that there be no reflected wave from the load. If there is no reflected power from the load, the line is often referred to as being "flat." This term is a bit misleading. Although the reflected power may be zero under matched conditions, the power flowing to the load via the line will still set up normal sine wave distributions of voltage and current along the line.

Another way to sense that the load is matched to the line is to determine first of all that the phase difference between the voltage and current on the line is zero and that the ratio of the in-phase voltage and current is correct for the impedance of the line being used. If there is no reactance present in the load, there will be no phase difference between voltage and current, as in any ac circuit feeding a resistive load. If the load is not only non-reactive but also of the correct resistance, the ratio of voltage and current on the line will have a definite relationship correct for a given line impedance. The zero-center meter circuits are designed to monitor both of these line conditions.

Practical Circuits

Two separate circuits are used to monitor the line conditions just described. One could switch a separate zero-center meter between the two line monitor circuits but with imported zero-center meters available for as low as $1.50, it is hardly worthwhile to do so. (A good source of the 100-0-100uA meters needed is Edlie Electronics, 2700 Hempstead Turnpike, Levittown NY 11756. Their meters with order number DA798 or DA792 cost only $1.50 but they have a $7.50 mail order minimum.) Also, for many installations, it is not necessary to use both circuits. For instance, in a home installation feeding a set of various fixed antennas, it would probably be of primary interest to have the impedance monitor circuit (voltage/current ratio). Once the antennas have been set up and operate satisfactorily, one would primarily just be interested to know that some impedance condition on the line has not changed. In a mobile installation, where some reactance cancelling L or C needs to be adjusted with frequency changes, it would be of prime interest to have the phase monitor circuit once the installation has been initially set up for a correct impedance match, and the reactance cancelling component only needs adjustment during actual operation.

Phase Monitor

Fig. 1 shows the circuit of the phase monitor. It is a basic discriminator circuit. The voltage on the transmission line to ground is sampled via R1. The current on the line induces a voltage in the windings on the toroid placed in the line which, of course, is 90° out of phase with the voltage sample. The voltage proportional to the line voltage is divided across R1 and R4 (C1 and C2 are rf bypass capacitors). The voltage proportional to line current (across the toroid winding) is divided between R2 and R3. Referenced to the center point of R2 and R3, these voltages are 180° out of phase with respect to each other and either one is 90° out of phase with respect to the voltage across R4. The voltages across R2 and R4 are rectified by D1 and, because of the diode polarity, produce a voltage with the polarity indicated across R5. Similarly, R3 and R4 and D2 produce a voltage of opposite polarity across R6. When the transmission line current and voltage are in phase, the voltages across R5 and R6 are equal and opposite, and the resultant voltage output which drives the meter is zero. For an out-of-phase condition, some output voltage exists whose magnitude indicates the amount of the phase difference and whose polarity would indicate whether the line voltage leads or lags the line current.

One could actually calibrate the output meter for different magnitudes and directions of phase difference, but this would be very tedious and not of real use for just checking the adjustment of a line for reactance cancellation. The only calibration that has to be checked is to excite the circuit into a resistive dummy load and to be sure that the zero-center feature works. If it does not, it indicates that some unbalance has been introduced during construction or some of the components (R2/R3 and R4/R5) are not closely enough matched. If the meter excursions off zero center become too violent with a high power transmitter, some additional resistance can be introduced in series with the meter to limit the maximum current flow.

Impedance Monitor

Fig. 2 shows the circuit of the impedance monitor, which is also a form of discriminator circuit. Samples of the transmission line voltage and current when they achieve the desired ratio produce an output voltage from the circuit which is zero. As in the previous circuit, a toroid placed around the center conductor of the transmission line develops by transformer action a voltage proportional to the line current. A sample of the line voltage to ground is taken via the variable capacitor C5. Unlike the previous circuit, both the sampled voltages are rectified, producing voltages across load resistors R3 and R4, without paying any attention to the phase differences between the sample voltages. It is only the amplitude of the sample voltages which determines the amplitude of the voltage across R4 (for the line voltage) or across R3 (for the line current). Because of the diode polarities, the voltages across R3 and R4 are of opposite polarity. They will cancel when equal, producing zero output voltage, and since C5 is variable, this condition can be set to occur at any desired line voltage to current ratio.

The difficulty with this circuit is that the sample voltages generated by the toroid transformers and the C5 coupling are frequency dependent. The rest of the components in the circuit (R1/C1 and R2/C2) are there to help eliminate the frequency sensitive output of the coupling elements over a reasonable range.

C5 is set with C1 and C2 at mid-range to provide a zero voltage output from the circuit on 20m when the line is terminated in a resistive load equal to the line impedance. Going to 10m, C2 is adjusted to restore balance and on 80m, C1 is used to restore balance. The adjustment has to be gone through several times before a good balance is achieved over the entire HF range. It would be possible to calibrate the meter with different value load resistors for different swrs. For high value loads, the meter would move off center in the opposite direction for low value loads. But, such calibration would only hold true for nonreactive loads.

Construction

Many conventional swr bridge circuits have been described over the last year or two in amateur literature where a toroid transformer, rather than a parallel wire to the center conductor of a coaxial line, has been used as a pickup element. The construction of such units applies equally well to the circuits shown here. It is only the circuitry following the pickup element that is really different, plus the added R1 pickup in Fig. 1, or the C5 pickup in Fig. 2. Note that it doesn't matter on which side of the toroid these pickups are placed. However, as in any rf circuit, all leads must be kept as direct and as short as possible. The circuits shown are for the HF range, but by changing the toroid and values of the bypass capacitors, they can be extended, by experienced experimenters, into the VHF range.

Chapter II

How to Measure RF Impedance

THE ANTENNASCOPE – AN EFFECTIVE TOOL

W. R. Carruthers VE3CEA

There are two types of antennas, commercial and amateur. A commercial antenna is generally designed for one frequency, has many acres of ground around it, no obstructions and miles of heavy copper cable buried underground to provide an "effective" ground. These antennas work as designed – very well. The amateur antenna, on the other hand, is just that – an amateur design and construction.

This antenna is subject to all ills, roof tops, buildings, trees, TV masts, house electric wiring, telephone wires and what not. It's a wonder they work at all! But they can be made to work and thousands of amateurs make them work. They make them work by pruning or lengthening the feeder cable and by using an antenna coupler. These are always empirical steps, the "let's cut and try and see what happens" method. How much better it would be, and a time saver too, if we tested our antenna systems electrically and *knew* what was happening and then could take intelligent action to put the whole antenna system into resonance.

This fact is well known – an antenna can only accept power and radiate properly when it is operating at its resonant frequency. This is no problem for the commercial people who operate at one frequency. The amateur, however, wants to "roam the band" and may wish to operate over frequencies hundreds of thousands of cycles wide, even megacycles wide. How can he do this with a fixed antenna system? The answer is, he can't! But he can construct an antenna system for a certain frequency and take the penalty of reduced radiation when he moves far away from it. However this actually works very well, because each amateur has his own particular part of a band in which he likes to operate – and his friends tend to stay there too. On this particular spot, the amateur works diligently to "put out a good signal."

The question arises – how can we make sure our antenna system is radiating well at the particulaf frequency we wish to use? One answer is to use electrical test equipment to show us what is happening on the whole antenna system, which includes the antenna and the feed line.

One of the most useful devices for this purpose is the rf bridge, generally called the Antennascope. It is a simple device, inexpensive to construct and very effective in results. It is usually powered by a grid dip oscillator. Such bridges should be used at the junction of the feed line and the antenna and will show the resonant frequency of the antenna itself and the radiation resistance at the feed point.

Making such measurement up in the air is a difficult thing for the average amateur and impossible for those whose antennas are supported at the ends. If we are willing, however, to accept a small degradation in results, we can use the *rf* bridge at the station end if we have a half wave, or multiple of a half wave, feed cable. At every half wave point on a feeder cable the voltage and current vectors are in phase, which simply means that the electrical condition seen at the end of the cable is repeated every half wavelength in the cable. We can use the *rf* bridge then, at the station end of the feed line, if we are willing to agree that the results will not be 100% but reasonably close to it. The results will be affected by all the various factors that affect amateur antenna resonance and these effects may give us some peculiar results, but they can be overcome and the final results may be quite valuable to us.

Let me give you an example to illustrate what I'm talking about and to show you how effective the use of the *rf* bridge can be: –

A friend of mine constructed a 40 meter inverted V antenna, held at the feed point 40' up on his beam tower, 66' legs down to supports which held the ends about 8' off the ground. Feed line was 100' of Twin Amphenol cable, velocity factor .68. The antenna was difficult to feed, swr was high, radiation was poor. He asked me to have a look (electrical) at it. I took my grid dip meter, *rf* bridge and vtvm.

The first thing done was to check the feed line length. 1/2 wave length at 7.1 MHz was 492 x .68/7.1 or 47.1 feet. Two 1/2 wave lengths (to get into the station) would be 94.2 feet.

The first conclusion was that the feed line was 5.8 feet too long.

Next Test No. 1 was made using the *rf* bridge with results as shown in **Fig. 1**, the results being shown in table form and also plotted in graphical form.

It was obvious from this graph that the antenna system was resonating outside the

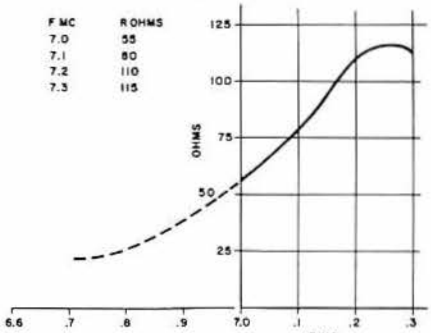

F MC	R OHMS
7.0	55
7.1	80
7.2	110
7.3	115

Fig. 1. 100' Feedline Test No. 1.

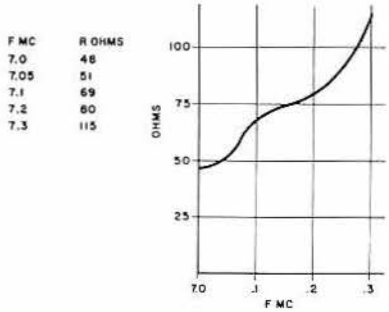

F MC	R OHMS
7.0	48
7.05	51
7.1	69
7.2	80
7.3	115

Fig. 2. 94.2' Feedline Test No. 2.

band as shown by the dotted lines. This test was repeated and the results were taken down to 6.4 MHz. They showed the system to be resonant at 6.6 MHz.

Test No. 2 was made next using the feed line cut to 94.2 feet. **Fig. 2** shows the results.

It was obvious the resonant point of the system was rising.

Test No. 3 was made next, cutting the feed line to 91.2 feet long. **Fig.** 3 shows the results.

F MC	R OHMS
7.0	43
7.1	46
7.2	76
7.3	81

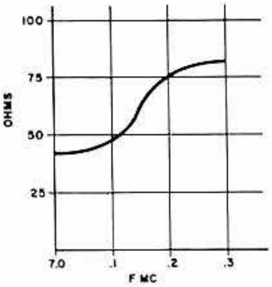

Fig. 3. 91.2′ Feedline Test No. 3.

The resonant point was rising, but not far enough yet.

Test No. 4 was made using the feed line cut to 88.2 feet long. **Fig. 4** shows the results. It was obvious that we were very close to the resonant frequency of 7.1 MHz which my friend wished to use.

F MC	R OHMS
7.0	45
7.05	47
7.1	51
7.2	60
7.3	75

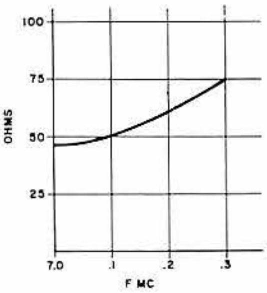

Fig. 4. 88.2′ Feedline Test No. 4.

Test No. 5 was with 85.2 feet in the feed line. **Fig.** 5 shows the results.

F MC	R OHMS
7.0	78
7.1	61
7.2	60
7.3	66

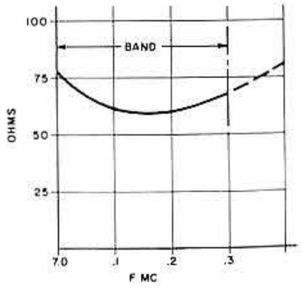

Fig. 5. 85.2′ Feedline Test No. 5.

Test No. 6 was with the transmitter (300 watts CW) and antenna coupler connected. There was no trouble in loading and no trouble in balancing the coupler to obtain an swr of 1 to 1 ratio.

The results on the air were interesting, 5/9+ reports to the Eastern half of the U. S. A., 5/8 reports to Germany etc. *Conclusion:* The results shown above are not precise, nor can they be expected to be precise. There are too many unknown factors entering the electrical picture, such as those which required a shortening of the feed line, in this example, to somewhat less than a half wave length. But the bridge showed us the overall picture and suggested what was required to be done. The on-the-air results show that it was giving us a good picture and a result that was very satisfactory for my friend's needs.

Why not construct an *rf* bridge and check you own antenna system? I suggest it will pay off and be very informative to you, showing you what your antenna system looks like electrically and what to do to bring your whole system to the resonant frequency you wish to obtain. . . . VE3CEA

HOW TO BUILD AN ANTENNASCOPE

Paul Franson WA1CCH

A type of simple bridge used for measuring antenna impedance is called the Antennascope, shown in Fig. 1. This bridge is designed for low power operation – a grid dip meter usually gives plenty of power. It should be built very compactly with short leads. The potentiometer should be of high quality; an Allen-Bradley Type J is fine. The bridge can be calibrated with regular composition resistors. Simply connect the resistors in turn to the antenna terminal and adjust the pot until the meter reading dips to zero. Then mark the value of the resistor by the pot pointer. In use, the meter reading will not null completely except for resistive loads, so it will not read zero for reactive antennas. Nevertheless, the minimum reading will occur at the approximate impedance reading. Remember that all antenna bridges should be used between the antenna and the transmission line.

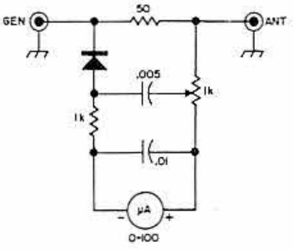

Fig. 1. The Antennascope is a simple antenna impedance bridge. It should be constructed compactly for best high frequency use.

THE MARK III RF IMPEDANCE BRIDGE

Mark Cholewski W6CRT

NEED to measure the input impedance of that new beam? Or maybe to find out just what is the Q of the coils in your final? Or even to determine how much signal is being soaked up by your coax? If you ever want to do these, or any similar jobs, then the Mark III RF Impedance Bridge is the thing for you.

You can build it for a total cost of about $30 (exclusive of sheet metal) and, if you follow instructions closely, it will be accurate to closer than 10 percent throughout its operating range. Unlike the more common resistive-bridge and reflectometer methods of measuring impedance, the Mark III operates equally well at resonance or far away. It will measure both resistance and reactance present in resistors, capacitors, inductors, antennas, and transmission lines at any frequency between 2 and 30 mc.

Before we start into the actual construction of the Mark III, one thing must be emphasized. Accuracy can be assured only if the components, circuit, and parts layout are absolutely duplicated. The original instrument's calibration was obtained through tedious laboratory techniques. If you make any changes, the calibration curves will no longer apply. However, if instructions are followed to the letter you need have no worries about accuracy. A test model, built by W6BJU following these instructions, checked out to 2 percent accuracy at 2 mc and 10 percent at 30 mc.

Construction of the Mark III divides into three major sections: Preliminary metalwork, actual wiring, and calibration. Each will be described separately. Ready? Let's go!

Preliminary Metalwork

1. Cut, drill, and bend to shape from soft aluminum shields S1, S2, and S3 as shown in Figs. C1, C2, and C3.
2. Cut, drill, and tap plexiglas insulators I1, I2, and I3 from bulk rod stock as shown in Figs. C4 and C5. When tapping plexiglas, use water as lubricant.
3. Cut, drill, bend, and solder tubular shields S1A, S2A, and S3A as shown in Fig. C6. Copper or brass may be used; aluminum should be avoided because of solding difficulties.
4. Assemble shielded resistor assembly R2/S4 as shown in Fig. C7. The copper tubing must be drilled out to clear the body of R2. When soldering, hold the assembly in a vise to protect R2 from excessive heat.
5. Cut, drill, bend to shape, and solder box shields S1B, S2B, and S3B as shown in Fig. C8.
6. Drill S5 (a 3x4x6 LMB unpainted chassis box) as shown in Fig. C9.
7. Cut, drill, and bend to shape shield partition S5A as shown in Fig. C10.

Shielded Transformer

While classified under the "preliminary metalwork" section for reasons which will become obvious, construction of the shielded transformer is the most critical part of the entire project. Before proceeding, read and re-read steps 8 through 24 and be sure that you understand them fully. Take special care when soldering—three transformers were built for the original instrument before a non-shorted one was achieved.

8. Cut to length, drill, and tap transformer mounting insulator I4 from 5/16-inch plexiglas rod.

9. Cut and drill two bobbin-end washers as shown in Fig. C12 and solder them to a length of copper tube as also shown. Then cut halfway through the bobbin with a hacksaw.

10. Pull the shielding from an 18-inch length of RG58/U. Save 8 inches for step 19 and use the rest in step 11.

11. Solder one end of the 10-inch shielding into the U-shaped slot on the bobbin end, using an aluminum rod or small drill to keep the inside of the shielding open. It must pass

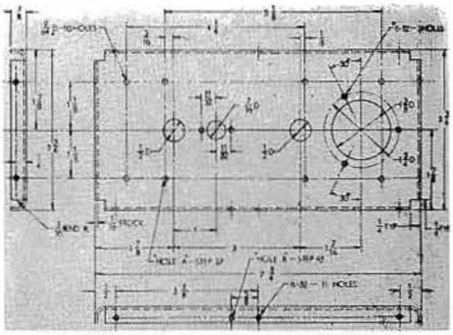

C1—Shield S1 (1 REQ), Mat'l Aluminum

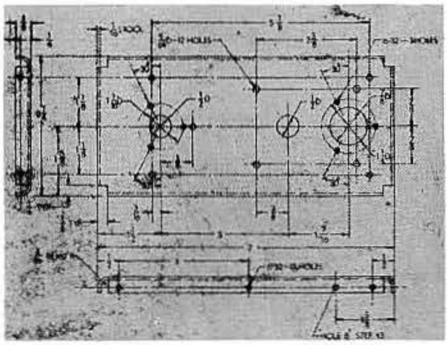

C2—Shield S2 (1 REQ), Mat'l Aluminum

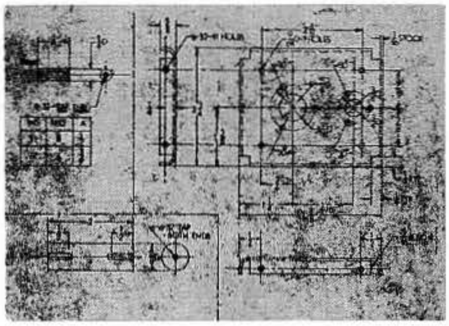

C4 — Insulators, Mat'l Plexglas rod
C5 — Insulator 13 (8 REQ), Mat'l Plexiglas rod

C3—Shield S3 (1 REQ), Mat'l Aluminum

No. 26 plastic-covered wire. Clean off all metal burrs and solder splatters.

12. Wind 48 turns of No. 26 plastic-covered hookup wire on the bobbin in three lays of 16 turns each. Solder the start of the winding at point A (see Fig. C12) and wind in the direction shown by the arrow.

13. The last turn will end at the shielding attached in step 11. Feed the free end of the wire into the shielding, draw the turns tight, and secure the winding with plastic tape.

14. Cut a piece of brass or copper shim stock as shown in Fig. C13 to a length which will wrap around the bobbin but will not allow the ends of the shim stock to touch each other.

15. Tin the shim stock along the edges.

16. Place the wound bobbin in a vise, wrap the shim stock around it, lining up the free ends of the shim with the slot cut in step 9, and solder the shim to the bobbin ends. Caution. *Do not overheat the winding; the plastic covering melts easily and a short is almost impossible to detect.*

17. Connect an SO-239 coax connector and UG-177/U hood to the shielded primary lead as shown in Fig. C15.

18. Wind one turn of ¼-inch diameter half-hard copper tubing around a 1-inch diameter form. Saw the tubing as shown by "phantom lines" in Fig. C14. Drill as shown in Fig. C14 and clean off all burrs.

19. Locate the 8-inch piece of shielding left over from step 10.

20. Using same technique as in step 11, solder one end of the shielding into the ⅛-inch hole. Clean off all solder splatter and burrs.

21. Solder one end of another length of No. 26 plastic-covered hookup wire to point A (see Fig. C14) and wind three turns inside the tubing in the direction shown.

22. Feed the free end of the hookup wire through the shielding. Bend the tubing into final shape as shown in Fig. C14. Pull up the three turns snugly, making sure that the plastic coating is undamaged.

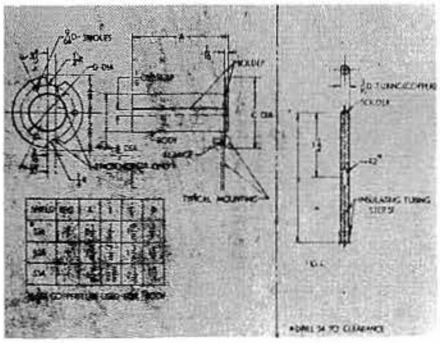

C6—Tube shield, Mat'l .010 Brass

C7 — Shield Assembly S4

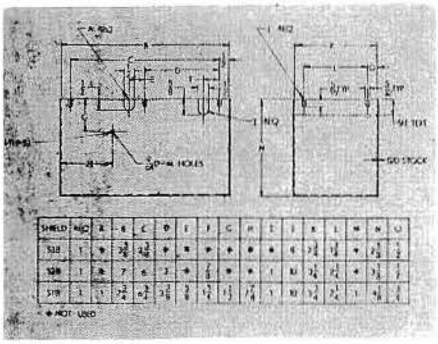

C8—Shield can, Mat'l Aluminum

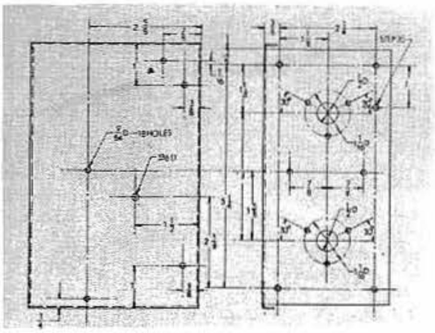

C9—3X4X6 LMB Shield can S5

23. Connect a male phono plug to the free end of the shielded wire as shown in Fig. C15. Length of the wire is critical.

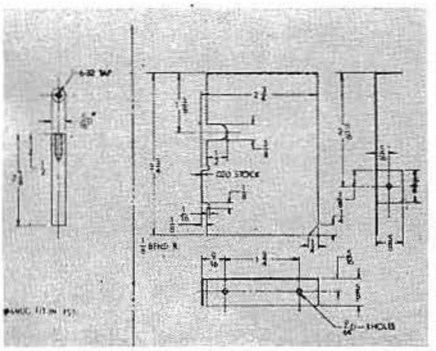

C11 — Insulator 14, Mat'l Plexglas

C10—Shield Partition S5A, Mat'l Aluminum

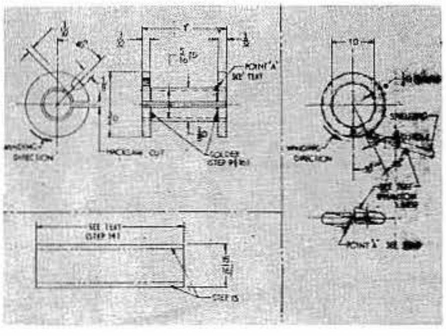

C13—Shield PS1A, Mat'l .005 Brass or Copper
C12 — Primary bobbin PS1, Mat'l Brass or Copper

C14—Shield PS2, Mat'l copper

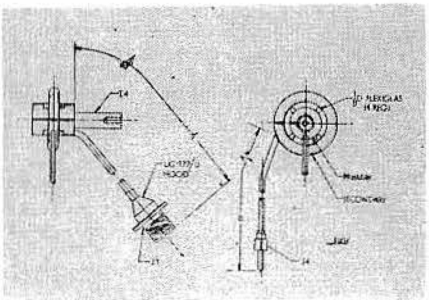

C15—Transformer assembly

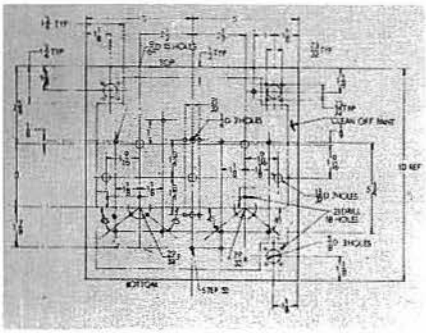

C16—Inside view of panel

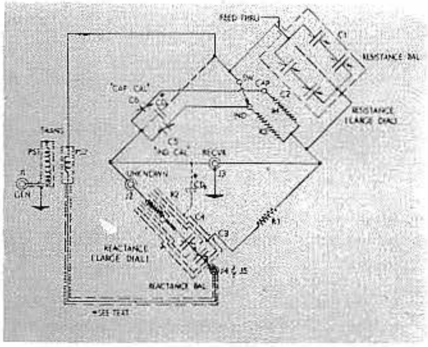

Fig. 1—HF. RF. Bridge Mark III Schematic

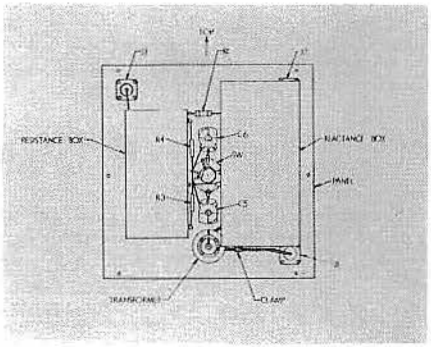

Fig. 2—Inside view

24. Using four pieces of ⅛-inch diameter plexiglas rod as spacers, assemble the primary and secondary shielded windings as shown in Fig. C15. Attach insulator I4 to the transformer by cementing it into the bobbin hole with Duco. Cement both windings to spacers with Duco and allow to dry overnight. This completes the transformer.

25. Remove top and bottom from the 8x10x10 utility box. Remove all paint from flanges; clean to bare metal to provide adequate rf shielding on reassembly.

26. Remove paint from inside of bottom plate for ½ inch in from each edge.

27. Remove paint from inside of top plate as shown in Fig. C16 by "phantom lines."

28. Drill the top plate as shown in Fig. C16.

Note that drawing shows INSIDE surface of plate.

29. Cut shafts of all four variable capacitors to ⅜-inch length. Remove all trimmer capacitors.

30. Tap the threeholes on the face of each capacitor, using a 6-32 tap. Take care not to damage the first stator plate; a bottom tap may be necessary. Attach three type I2 insulators to C1 and C2, using ¼-inch-long 6-32 set screws as shown in Fig. 3. This completes preliminary metalwork.

Actual Wiring

31. Attach C1 and C2 to shield box S5 using six ¼-inch-long 6-32 machine screws. Connect stator lugs of C1 to those of C2 with No. 18 tinned wire, as shown in Fig. 3.

32. Mount two soldering lugs as shown in Fig. 3 and connect remaining stator lugs to them, using No. 18 tinned wire.

33. Press the Erie CF-408 feed-thru into the 0.136-inch diameter hole in S5. Solder a short No. 18 tinned lead from the inside terminal of this insulator to the wire installed in step 31, as shown in Fig. 3.

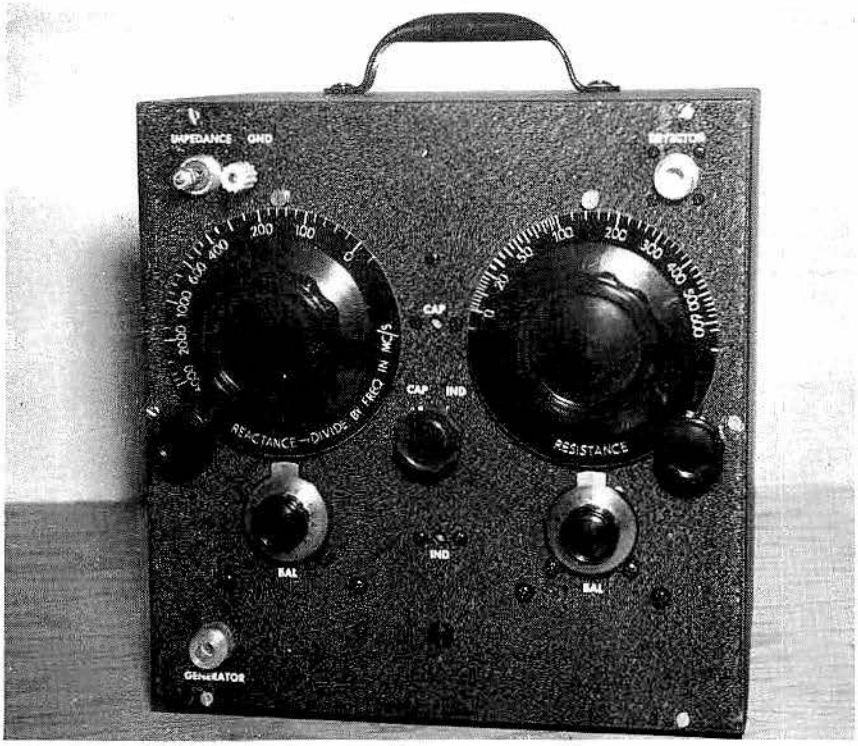

34. Attach shield partition S5A, using three ¼-inch-long 6-32 machine screws. One of the screws installed in step 32 must be temporarily loosened and removed.

35. Attach four type I3 insulators to shield box S5 as shown in Figs. 3 and C9.

36. Attach three more soldering lugs to S5 as shown in Fig. 3, using ¼-inch-long 6-32 machine screws.

37. Attach four type I3 insulators to shield platform S1, using the 4¼-inch-spaced holes in S1 and 6-32 screws. Attach S1A to S1, using 6-32 screws from the inside of S1. Attach the female phono socket to S1 in the 7/16-inch diameter hole. Attach four type I1 insulators, using ¼-inch-long 6-32 screws. Do not tighten the screw in the hole marked "Hole A" in Fig. C1; this screw will hold a cable clamp later. See Fig. 4 for details of insulator placement.

38. Attach four type I1 insulators to shield platform S2, using the 2⅜-inch-spaced holes in S2 and ¼-inch-long 6-32 screws. Attach S2A to S2. Attach capacitor C3 with 1-¼-inch-long 6-32 screws, using two nuts on each screw as shown in Fig. 4. Mount a soldering lug under one nut as shown. Align the capacitor by adjustment of the mounting screws and nuts.

39. Solder a No. 18 tinned wire to the female phono socket and pass the wire through the corresponding hole in S2. Attach S2 to S1 with ¼-inch-long 6-32 screws going into the type I1 insulators attached to S1 in step 37.

40. Attach C4 to shield platform S3 using ⅝-inch-long 6-32 screws with dual nuts (same as in step 38). Attach S3A to S3.

41. Connect two of the stator lugs of C4 with No. 18 tinned wire as shown in Fig. 4. Slide shield assembly S4 into S3A. Center assembly S4 in S3A, using a piece of ¼-inch-long insulating tubing. Make certain that opposite ends of S4 and S3A are even as shown in Fig. 4, and cement tubing in place with Duco. Solder the shorted end of resistor R2 (which is in S4) to the wire connecting stator lugs of C4.

42. Attach shield platform S3 to S2, using ¼-inch-long 6-32 screws going into the type I1 insulators installed on S2 in step 38.

43. Place a ¼-inch-long 6-32 screw in the flange of S3 as shown in Fig. 4, with a soldering lug. Connect this lug to the stator lug of C3 with No. 18 tinned wire. Using ¼-inch-long 6-32 screws, mount a soldering lug in Hole B (see Fig. C1) of S1 and another in S2 as shown in Fig. C2. These lugs are mounted in a direction opposite to that of the platform flanges.

44. Attach the "unknown" ground lug to the panel next to the "unknown" coax connector hole, as shown in Fig. C16. Attach the "receiver" coax connector to the panel, from the inside. Attach the "IND-CAP" switch to the center of the panel, using an extra nut to position the switch as far as possible from the panel. Orient the switch as shown in Fig. 5. Place a soldering lug under each nut. Mount C5 and C6, using ⅜-inch spacers between the capacitor frames and the panel. Connect the

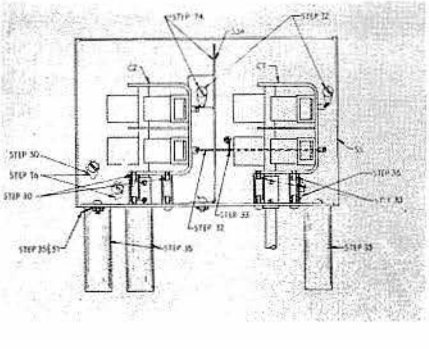

Fig. 3—Resistance box—Inboard view

rotors of C5 and C6 to the lugs of the switch with No. 18 tinned wire as shown in Fig. 5.

45. Solder a 2½-inch length of No. 18 tinned wire to the "COMMON" terminal of the switch. Connect the stators of C5 and C6 to the remaining switch terminals, as well as resistors R3 and R4. Complete connections are shown in Fig. 5.

46. Attach the "unknown" coax connector to the panel, placing a soldering lug under one mounting screw. Connect the "unknown" ground lug to this soldering lug to provide a good bond.

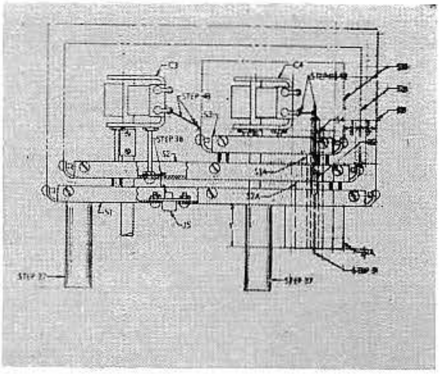

Fig. 4—Reactance Assembly—Inboard view

47. Mount panel bearings for capacitors C2 and C4. Mount the special panel bearings furnished with the Johnson Vernier Dial assemblies in place. Attach the two large dials to dummy shafts and mount the dial indicator in the position you prefer. Remove the large dials and dummy shafts after placing the dial indicators.

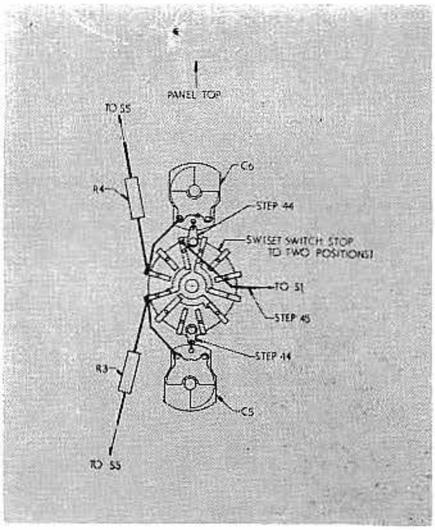

Fig. 5—Switch Assembly

48. Mount S5 at the left side of the panel (as shown in Fig. C16) and mount the assembly of S1, S2, and S3 at the right side. See Fig. 2.

49. Attach shaft couplers to the four capacitors. Cut the plexiglas shafts to length and mount them in place. Attach the large vernier dials. Set the dial of C2 so that it reads "0" at minimum capacity. Set the dial at C4 so that it reads "100" at maximum capacity. Mount the two Calrad dials on the panel, setting them so that they both read "0" at maximum capacity. Attach the knob to the "IND-CAP" switch.

50. Connect resistor R1 (270-ohm deposited-carbon) from the soldering lug on S2 to the lug in line on S5. Connect R3 (220 ohms) and R4 (100 ohms) to the soldering lugs on S5 which were installed in step 36. R3 will be the resistor nearest the bottom of the panel.

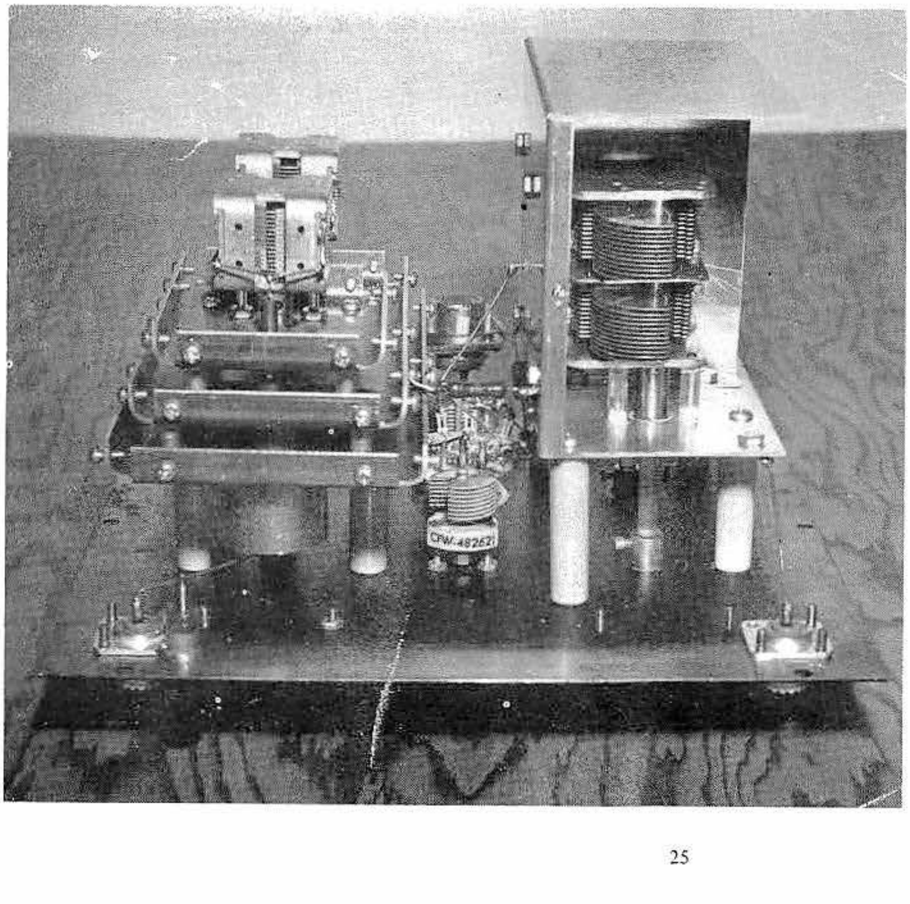

51. Connect a No. 18 tinned-wire lead from the "detector" coax connector to the lug on S5. Connect a No. 12 (note different wire size) lead from the "unknown" connector to the free end of R2. *Make sure that* R2 *is not shorted to any shield.*

52. Attach the transformer, completed in step 24, to the bottom of the panel as shown in Fig. 2. Attach the coax connector connected to the transformer to the panel in the "signal generator" hole. In the hole between the transformer and the connector, mount a cable clamp to hold the shielded primary lead. Secure the shielded secondary lead with another clamp held by the loose screw installed in step 37.

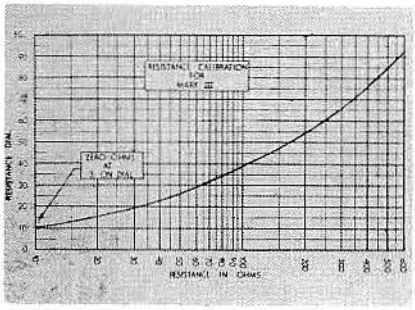

Fig. 6

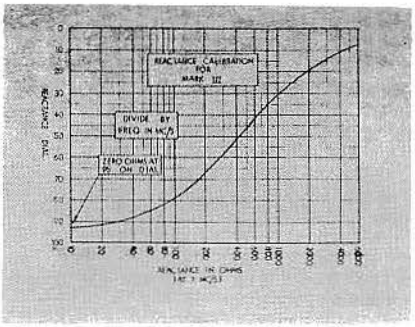

Fig. 7

53. Mount a soldering lug to S1B with a ¼-inch-long 6-32 screw, placing the lug in the direction of the box opening.

54. Place ¼-inch-long 6-32 screws in all remaining tapped holes in S1, S2, and S3. Starting with S3, place all shield boxes in place and secure screws. Connect a No. 18 tinned lead from the soldering lug installed in step 53 to the Erie feed-thru on S5. Set C5 and C6 to mid-capacity.

55. Attach four rubber feet to the bottom plate of the case and four more to the bottom side of the utility cabinet. Restore the front plate in place and secure with the sheet-metal screws provided. This completes construction of the bridge. After calibration, it will be ready for use.

Calibration and Use

Since the Mark III is a null-type instrument (adapted from the Schering bridge circuit) it can only be used with a signal generator and a detector. Both must be shielded; however, a Heath SG-8 will do nicely as the signal generator and any decent communications receiver will serve as the detector. For best results, it should be calibrated with the signal generator and receiver with which it will be used.

56. Connect the bridge to the signal generator and the receiver, using coax cable from the panel connectors to each.

57. Set both the signal generator and the receiver to 2 mc.

58. Short the "unknown" terminal and ground terminal using a banana plug in the connector or a coaxial short made by soldering the pin of a PL-259 connector to the shell through a copper disc.

59. Set the "IND-CAP" switch to "CAP."

60. Set the "Reactance" dial to 15.

61. Set the "Resistance" dial to 5.

62. Tune the signal generator, only, for maximum signal in the receiver.

63. Using the two small "balance" dials, reduce the signal in the receiver to the lowest level possible. This is the "null" or "balance" condition. The dials will interact, and multiple adjustment will be necessary. However, all receiver and signal generator adjustments must be left alone during this step.

64. Replace the short across the "unknown" connector with the 620-ohm deposited-carbon "test" resistor.

65. Using only the large "resistance" and "reactance" dials, null out the signal once more. Record the final reading of the "resistance" dial. If this reading is 95, you are extremely lucky and the first half of the calibration is complete. If not, proceed with step 66.

66. If the "resistance" dial reading is less than 95, increase the capacity of C6 slightly and repeat steps 60 through 65. If the reading is larger than 95, decrease the setting of C6 and repeat steps 60 through 65. Continue this process until the reading comes out at 95.

67. When capacitive calibration is complete, set the "IND-CAP" switch to "IND," and the "reactance" dial to 30.

68. Repeat steps 60 through 65; if the final reading of the "resistance" dial is other than 95, proceed with step 69.

69. If the reading is less than 95, increase the capacity of C5 slightly and repeat steps 60 through 65. If the reading is larger than 95, decrease the setting of C5 and repeat. Continue until the reading is 95. This completes calibration, and the curves shown here can be used for readings.

Using the Mark III

To use the Mark III, set the instrument up as described in step 56 of the calibration procedure. Set the signal generator to the desired frequency and short out the "unknown" terminal of the bridge as described in step 58.

If you're measuring an inductive impedance, set the "IND-CAP" switch to "IND," the reactance dial to 95, and the resistance dial to 5. Null the signal with the small balance dials.

Now remove the short and connect the unknown. Rebalance the bridge using the large dials, note the readings, and convert the readings to ohms by use of the calibration curves.

These initial values must be corrected. The reactance value is corrected by dividing the value read from the curve by the frequency (in mc) at which the reading was taken. The resistance value is corrected by obtaining the correction factor due to frequency from Fig. 8 and multiplying the reading by this factor.

If you're measuring a capacitive impedance, set the switch to "CAP." Then estimate the reactance of the unknown and set the large reactance dial to a value just larger. Set the resistance dial to 5 and short out the "unknown" connector. Null the signal with the short and again with the unknown, the same as for an inductive impedance.

Correct the resistance reading in the same manner as for an inductive impedance. However, the reactance reading is corrected differently: Subtract the value taken from the calibration curve from the value originally set on the reactance dial. Now divide this remainder by the frequency (in mc) at which the reading was taken. The result is the true value of capacitive reactance.

A few minutes' practice will make operation of the Mark III far more simple than the detailed directions would indicate; in practice, you can make a reading in less time than it takes to read these paragraphs.

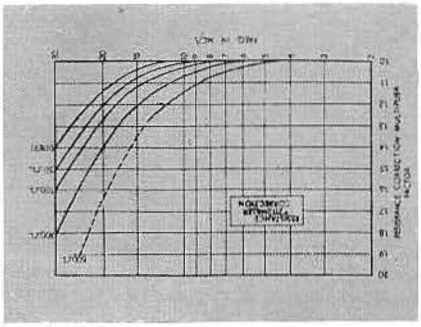

Fig. 8

Parts Substitutions and Design Changes

Since few hams are content to build a "Chinese copy" of someone else's design, a few words on the effect of changes are necessary.

Naturally, the Mark III doesn't represent the only possible—or even necessarily the best—way in which such a bridge can be built. Any part, or all, may be changed. However, any such change will invalidate the calibration curves, and is not recommended unless the builder has access to laboratory equipment.

Even then, before making any substitutions, these three design articles should be read and fully understood:

"A Radio-Frequency Bridge for Impedance Measurements From 4000 KC/S to 60 MC/S," D. B. Sinclair, Proceedings of the I.R.E., November, 1940, pages 497-502.

"A High Frequency Model of The Precision Condenser," D. B. Sinclair, General Radio Experimenter, October-November, 1938, pages 1-7.

"The Effect of Stray Capacitances to Ground in Substitution Measurements," M. Reed, Wireless Engineering, May, 1936, page 284 ff.

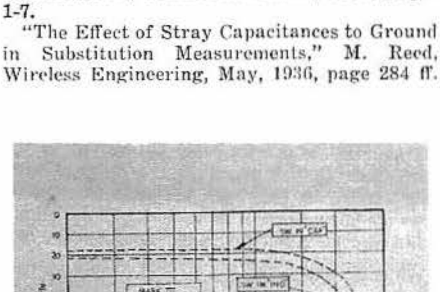

Fig. 9

Parts List

Quan.	Item	Description	Cat. No.
1 ea.	C1, C2	Miller, 10-365 mmf/sect.	2112
1 ea.	C3, C4	Miller, 10-365 mmf	2111
1 ea.	C5, C6	50 mmf air padder (good quality)	APC-50
1 ea.	J1, J2, J3	SO-239 Panel coax connector	
1	J4	Phono plug	
1	J5	Phono socket	
1	R1	Aerovox 1% 1/2W 270 ohm "Carbofilm"	Type-CP
1	R2	330 ohm 5% 1/2W Carbon Resistor	
1	R3	220 ohm 5% 1W Carbon Resistor	
1	R4	100 ohm 5% 1W Carbon Resistor	
1	Test	Aerovox 1% 1/2W 620 ohm "Carbofilm"	Type-CP
1	SW	Centralab 3p; 1 Sect; 2-3 Position (reset stop to two positions only)	2506
*2	Dials	E. F. Johnson Vernier (0-100 CW)	116-285-1
2	Brgs	E. F. Johnson Panel Bearings	115-255
4	Cplrs	Metal ¼ shaft couplers	
3	Rod	¼ inch diameter plastic rod x 12"	
1	Rod	⅛ inch diameter plastic rod x 6"	
2	Rod	⅜ inch diameter plastic rod x 12"	
2	Dials	"Calrad" 1-13/32 inch Vernier Dial	VD-36
1	BP	Binding Post (ground lug)	
1	Case	Bud carrying case 10"x10"x8"	CC-1100
1	Box	LMB box (plain) 3" x 4" x 6"	
1	Hood	UG 177/U coaxial cable hood	
1	Insul.	Erie feed-thru insulator	CF-408
1	Short	PL-259 coaxial male connector	
2	Clamps	Walsco clamp for ⅛ to 3/16 cable	7502-N

Of the above list the critical parts are:
C1, C2, C3, C4, J2, R1, Test resistor, Case, LMB box, UG 177/U, Erie feed-thru.

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* This author hand engraved these dials per Figs. 6 and 7.

MEASURE RF IMPEDANCE WITH YOUR SWR BRIDGE

Warren McDowell W2AOO

So far, the great majority of antenna impedance bridges that we have found in construction articles are devices that function only with a low power rf source. The run-of-the-mill impedance bridge is designed to operate with a grid dipper as the source of rf excitation. Operation with tube type dippers is generally intended as the transistor dippers produce an rf level that is too low for excitation of this bridge type.

The conventional antenna bridge cannot be left in the transmission line continually as excessive rf energy would soon destroy the device. This means that each time measurement of antenna impedance is desired, the transmission line must be opened and the bridge inserted and grid dip excitation applied. Grid dippers are not necessarily the most accurate rf source for a specific frequency in an amateur band . . . therefore the station receiver must monitor the dipper output for any bridge accuracy. A low power bridge will not often present the true operating impedance of the antenna . . . especially antennas with parasitic elements. A bridge that operates under full transmitter power will present a much more accurate picture of your antenna system at a specific frequency.

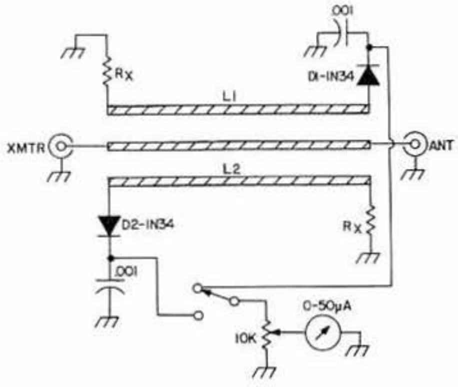

Fig. 1. Conventional swr bridge.

Inspiration for the "In Line" full power bridge came from information concerning the standard swr bridge. Just about every amateur has in his possession some sort of swr bridge and the great majority are of the type illustrated in Fig. 1. This bridge consists of a section of transmission line near which are placed two inductors. These inductors are actually two bridges along with their associated diodes and resistors. One of the bridges reads forward power and the other reflected power. The resistors (Rx) at the end of the inductors L1 and L2 are critical for accurate bridge null (balance) and therefore must be the proper value for the specific transmission line used. For the average swr bridge the value for Rx is 100Ω for 75Ω line and 150Ω for 50Ω transmission line. Considering that resistor Rx is critical for the impedance of the line in use, varying the value of Rx and devising a system of calibration for Rx would enable us to determine the impedance of a line when a null is achieved on the bridge meter.

The "reflected" inductor which is L1 in Fig. 1 is the portion of the bridge circuit we are interested in for impedance measurements. The value of Rx and the transmission line must balance the bridge for a null to be realized. Any variation from the above parameters will mean changing the value of Rx so that the bridge again balances at a new impedance value.

By experimenting with various values of resistance at Rx, it was determined that a 1000Ω potentiometer represents a fair value. The 1000Ω potentiometer is inserted in place of Rx on inductor L1 (see Fig. 2). This is the inductor with the diode pickup located toward the load or antenna end of the swr bridge.

Make sure that all leads to the 1000Ω potentiometer are short and that the metal case (shell) of the potentiometer is well grounded. Excessive lead length or inductance will create inaccuracy of the device. The position of the potentiometer will be determined by the physical layout of your particular swr bridge. It must be set at a point where the shaft can be extended through the front panel of your swr bridge. Allowance must also be made for a dial or other indicating device which can be calibrated in ohms (impedance) on the front panel. It might even be desirable to mount your entire present bridge in another larger case so that all functions can be accommodated.

Calibration of this in-line bridge was the major problem. An ordinary grid dip meter will not provide sufficient excitation for readings. With full power applied, especially a kilowatt, it becomes difficult to find resistive dummy loads of various values to calibrate the bridge. Even with 100W of rf, proper resistive load values are not common.

The solution to the calibration problem came to us in the form of an (ouch!) CB transmitter. A CB transmitter is fortunate if it is able to put out 3W of rf and at the same time is well within the frequency range of an swr bridge. The most important fact is that a CB transmitter will provide adequate excitation for calibration of the bridge with ordinary 5W 5% carbon (garden variety) resistors. For calibration, a good assortment of these resistors is necessary. Use values such as 5, 27, 47, 75, 100, 150, 220 and 470Ω. Intermediate values can be then interpolated on your scale. The calibration procedure is simple . . . first borrow your neighbor's CB, then attach the 5W resistors across the antenna coax connector of the bridge and excitation of the CB transmitter is applied to the remaining connector on the bridge. The bridge sensitivity should be set for a middle scale reading of the meter and the 1000Ω potentiometer is varied until you reach a null on the meter. Mark the value of the calibration resistors on the potentiometer scale (dial). Do this for all of the available resistors and your bridge will be in fair calibration.

At this point we should mention that this system does not measure reactive components in the antenna system. If your antenna is reactive, either inductive or capacitive, the meter will present a shallow, poorly defined null at the operating frequency. A sharp, well defined null will indicate a purely resistive impedance.

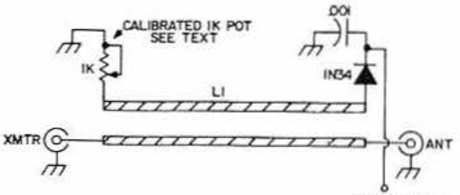

Fig. 2. The modified bridge leads to 1K pot should be as short as possible and shell (case) of pot grounded.

When using the bridge in its former function as an swr bridge, set the resistance dial to the value of your transmission line. When measuring impedance, vary the dial for maximum dip on the meter and read the resistance (impedance) directly.

As a final point, it is wise to insert the swr/impedance bridge at a half-wave or an even multiple of a half-wavelength from your antenna. At half-wave points from the antenna, the antenna impedance is repeated. This will enable your measurements to be much more accurate. When determing half-wavelength points, take into consideration the velocity factor of your particular coax.

USE YOUR GDO AND Z METER

Denys Fredrickson W0BMW

The GDO is one of the most versatile pieces of test equipment available. Yet there are many hams who don't know how or when to use one. The writer will try to describe and explain some of its various functions.

The GDO is basically a variable high frequency oscillator with a frequency range of approximately 550 kc to 250 Mc. It may also be used as a diode detector or wave meter. The GDO gets its name from the fact that a meter measures the grid current and when the oscillator circuit is coupled to a resonant circuit a reduction in grid current is obtained. This is called the grid dip. However, when it is used as a wavemeter and coupled to an rf source, an increase in current is obtained at resonance.

The GDO and impedance meter can be used to accomplish the following:

1. Determine the resonant frequency of tuned circuits, including antennas.
2. Determine the impedance of circuits, receiver inputs and antennas.
3. Determine the length of half-wavelength or quarter-wavelength transmission or tuning stub lines.
4. Determine the "Q" of a circuit or component with the aid of a VTVM.
5. Determine the resonant frequency of individual coils, capacitors or crystals that are within the range of the GDO.
6. Determine the rf frequency of energized circuits.
7. Monitor a radiated rf signal with the aid of headphones.
8. Neutralize rf stages.
9. Locate parasitic oscillations.
10. To align receivers and television sets.
11. Determine where BCI and TVI is entering the radio or television receivers.
12. Determine unknown inductance.
13. Determine unknown capacitance.

Now if you will step into the lab we will try to demonstrate how these instruments can be put through their paces. Let's begin with the simple functions and then gradually creep up to those which are more complex so they don't scare us before we get started.

An oscillator-detector

Simply plug in a pair of headphones (if GDO has facilities for them) and "zero-beat" with the radiating signal. This then will be the frequency of the radiating signal.

Crystal frequencies

Connect a one turn loop of wire across the crystal and couple the GDO close enough to get a dip of the meter when resonance is obtained. It is always wise to check lower frequencies to be sure it is the fundamental frequency that is being indicated.

Frequency determination

Generally the GDO has a switch which is used to remove the plate voltage from the tube. The tube will then serve the function of a diode and the meter as a diode load. When a peak deflection of the meter is obtained this will indicate the frequency of the radiating signal.

Resonance of an RF choke

When an rf choke is used as a parallel or shunt fed circuit, it must be free of self resonance over the operating frequency range of that circuit or it may burn up. The popular pi tank circuit is an example. Place a short circuit across the choke and then determine its self resonant frequency by coupling the GDO close enough to indicate a dip on the meter when the resonant frequency is obtained.

Neutralization

Apply plate power to the exciter stages and filament power only to the stage being neutralized. Use GDO as a wavemeter and couple close to the tank coil in the stage being neutralized. Vary the frequency of the GDO until maximum reading is obtained and then adjust the neutralization for minimum GDO meter reading. The circuit being neutralized may have to be retuned and the above procedure repeated with a closer coupling of the GDO to the Tank coil.

IF alignment

Tune the GDO to the desired frequency and couple it close to the if coil to be aligned. Adjust the if coil until a dip is observed on the meter. The if coil will then be tuned to the desired frequency.

Inductance and capacitance checking

To determine the value of an unknown capacitor, connect it across a known inductance and use the GDO to find the resonant frequency of the circuit. With these known values a reactance chart will give the value of the capacitor. Some GDO's supply a chart which corresponds to the coils supplied with the GDO as the known inductances. To determine the value of an unknown inductance, connect a known capacitance across the coil and use the GDO to find the resonant frequency. Again, the reactance chart may be used or the following formula (which may be used for either inductance or capacitance) for resonant circuits:

$$L = \frac{1}{39.48\ (f^2)\ C} \quad \text{or} \quad C = \frac{1}{39.48\ (f^2)\ L}$$

Where f = cycles per second
L = inductance in henries
C = capacitance in farads

The inductance of an air core coil can be estimated by the following formula:

$$L = \frac{(rN)^2}{9r \neq 10w}$$

Where L = inductance in microhenries
N = number of turns
r = radius of coil in inches
w = length of coil in inches

Q measurements

Connect a condenser across the coil so the tank circuit resonates at the desired frequency. Connect a VTVM across the tuned circuit and tune the GDO until maximum reading is obtained on the VTVM. The GDO coupling may be changed until a convenient value is obtained on the VTVM and then it must not be moved during the remainder of the test. Note the resonant frequency f_c then detune the GDO to a lower frequency until the VTVM reads 70.7 percent of its original or peak value and call this frequency f_1. Now detune the GDO to a higher frequency until the VTVM again reads 70.7 percent of its original or peak value and call this frequency f_2. The Q is then calculated by using the following formula:

$$Q = \frac{f_c}{f_3}$$

Where f_c = is the center of resonant frequency
f_3 = the difference between f_1 and f_2

Parasitic oscillations

By using a pair of headphones with the GDO, the parasitic oscillation frequency may be determined. Turn the power off of the stage being checked and then use GDO to find the circuit which resonates at the parasitic frequency by moving the GDO slowly around the wiring. When a "dip" is observed, moisten the finger and touch an ungrounded point of the circuit. If a change in the dip is observed, it indicates that it is the portion of the circuit that would be a likely suspect.

BCI and TVI locator

Most of the BCI and TVI problems can only be resolved at the receiver, either by installation of filters, resistors or condensers or a combination of all three. The problem is—where is the rf entering the receiver? Use the GDO tuned to the frequency which produces the greatest amount of interference. Probe around with the GDO until the most sensitive spot is located, which is indicated by watching or listening to the receiver interference. After the point of entry is determined then the appropriate corrective action can be accomplished.

Antenna measurements

Space does not permit to discuss all types of antennas and adjustments so only a few will be mentioned to give some idea on the use of the instruments. At this point it should be mentioned that inductive type coupling should be used between the GDO and antenna when checking near the current maximum point and capacitive coupling when checking near the voltage-maximum point.

The beam antenna has gained tremendous popularity in recent years plus many headaches for those striving to obtain the maximum effectiveness. Most of the headaches can virtually be eliminated by using the GDO and Impedance meter (Z-meter). Let's take a look at a 3 element yagi and see what has to be done to obtain a good adjustment. The element lengths must be physically adjusted or electrically loaded to obtain resonance at the desired frequencies and the feed point impedance must match the impedance of the transmission line. These two points are not the only considerations for beam adjustment but they are the most important factors. The GDO can be inductively coupled to each element and the elements adjusted until each one is resonant at the desired frequencies. It is best to make the measurements while the antenna is in operating position. This is very difficult to do in many cases but let's assume you can. After the elements have been adjusted, the feed point must be adjusted to match the line. The Z-meter and GDO will be used to accomplish this adjustment. The Z-meter is basically a resistance type bridge with a calibrated potentiometer as one of the bridge arms. Connect the Z-meter directly to the antenna feed point. Couple the GDO to the Z-meter inductively thru a couple loops of wire connected to the other terminals of the Z-meter. Tune the GDO to the resonant frequency of the beam and adjust the Z-meter to the dip or null. If the impedance indicated by the Z-meter is not the same as the transmission line then readjust the matching network and redip the Z-meter until the impedances are equal.

Now—if you can't adjust the antenna in the operational position you still can determine the resonant frequency and the impedance by standing on the good old Terra-Firma. The procedure is a little more involved but effective. First—we must have a means of electrically connecting the instruments to the antenna. This is best accomplished by a transmission line a half-wave or a multiple of a half-wave in length. Determine the height of the antenna above ground and calculate how many half-wave lengths of line will be required by using the following formula for a half-wave length of line:

$$L = \frac{(492)\ \ (K)}{f}$$

Where L = feet
f = megacycles
K = propagation constant
(RG/8 is .66)

This is an approximate length so be sure and cut it extra long because now we will find the exact physical length. Why an exact physical length? A halfwave length of transmission line will reflect the resistance placed across the output at the input end of the line, i.e. if a 50 ohm non-reactive resistor is placed across one end of a half wave or multiple length thereof, the GDO and Z-meter will indicate 50 ohms at the other end of the line. Cut the line somewhat longer than calculated above, short one end and connect the Z-meter to the other end of the line. NOTE: Keep twin lead off the ground and away from metal objects. Set the Z-meter to zero impedance and couple the GDO inductively to the Z-meter. Adjust GDO frequency until the fundamental frequency causes the Z-meter to dip or indicate a null. The frequency indicated should be lower than the desired frequency. Simply cut a few inches of cable off, short the end again and readjust the GDO. Repeat this procedure until the desired frequency (which should be the same as the resonant frequency of the antenna) is obtained. You will then have an electrically halfwave length of line or a multiple thereof.

Coax or twin-lead may be used for the halfwave length line when checking the impedance of the antenna. Connect the line to the antenna, hoist the antenna up to its operating position and adjust both the Z-meter and GDO for the null indication. If the antenna is not resonant at the desired frequency, the driven element should be readjusted a measured amount and then note the frequency change. This will give you an idea how much the resonant frequency changes with a corresponding element change. Now adjust the matching network to the desired impedance. This will be accomplished when the Z-meter dips at the desired impedance with the GDO set at the resonant frequency of the Antenna.

What would you do if your 100 foot coax cable developed a short someplace along the line? Replacing the whole line would be too expensive. Simply connect the Z-meter to one end of the line, adjust the Z-meter for zero impedance and then adjust the GDO for lowest frequency which will produce a null on the Z-meter. Use this frequency in the formula given for a halfwave length line and carefully calculate the length which will be the distance from the input end to the short.

A quarter wave length tuning stub can also be determined by using the procedures just outlined for the halfwave length line except a quarter wave line reflects a short at the input when the output end is electrically open. Now that we have mentioned the quarter wave length line, some may be wondering just what useful purpose does it serve. The quarter wave tuning stub (as it is sometimes called) may be used for antenna matching, TVI elimination or matching two units which have different impedances. The quarter wave matching stub can be used as a matching device on antennas which is explained in most antenna handbooks. It may also be used to eliminate an interfering frequency from entering the TV. This is accomplished by connecting a quarter wave stub to the TV antenna terminals which is a quarter wave in length at the interfering frequency.

Another use for the quarter wavelength matching stub is to permit maximum signal transfer between the source and a load which have different impedances. If the signal source impedance was 100 ohms and the load impedance was 52 ohms, a 72 ohm quarter wavelength of line would give a good impedance match. Hold it just a minute, how in the world did we come up with that 72 ohm business? Simple—another formula will give us this information.

$$Z_o = \sqrt{Z_s Z_a}$$

where Z_o = Impedance of quarterwave matching stub
Z_s = Impedance of the source
Z_a = Impedance of the load

Very little has been said concerning the various methods of GDO coupling. Actually—only two types of coupling are used; inductive and capacitive. Capacitive type coupling may be used on shielded coax cable, the ends of antenna elements and generally where the voltage maximum exists. To obtain the greatest accuracy, the GDO should be loosely coupled. Parallel coupling to inductors can be used to obtain maximum coupling.

Chapter III

Measuring RF Power Output

MEASURING RF OUTPUT

Paul Schuett WA6CPP

So your new Bandjammer 5000-Q is rated at 752W peak power. Big deal. How much of this is getting out where it counts?

It's easy to find out by inserting an rf ammeter in series with the line. A more exact reading would be to have the rf ammeter at the antenna input terminals, but that might be impractical when it comes to reading the meter (although you could put a diode there and a remote-reading meter in the shack).

Recently I found an rf ammeter at one of the mail-order surplus houses for $2.95. I installed this in a little cabinet, put two coax connectors on the back (in and out) and now can read rf current in the line, into the dummy antenna, or wherever it is going.

Remember the formula $P=I^2R$? Square the reading on the meter, multiply by the impedance of the line you're using, and you have the power past that point. At the antenna, you could determine the antenna resistance and take the current reading at that point.

For those who have difficulty with mental computations and can't find a pencil, the following chart fives the computed power levels present in matched 50 and 70 Ohm coaxial lines for various levels of rf current:

RF Current	Power Output in Watts	
Amperes	**50 Ohm Line**	**70 Ohm Line**
0.5	12.5	17.5
1.0	50	70
2.0	200	280
3.0	450	630
4.0	800	1120
5.0	1250	1750

When tuning up the rig, place the ammeter on the antenna side of any tuning or matching devices and tune for maximum current.

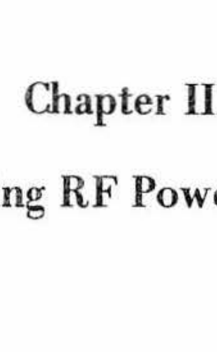

Inside wiring is extremely simple. Note ground wire installed to insure continuity of the shield circuit.

The completed instrument showing the coax connectors on the rear.

It's amazing to learn how much (or how little) current these rigs produce. For instance, my Swan 250-C puts 1.35A into a 50Ω line. My friend's SB101 from Heathkit put out 0.7A until we worked on the antenna – then it put out about 1.25A. My Heathkit SB401 puts anywhere from 2 to 0.6A into a 50Ω Cantenna, depending on what band it's on.

Commercial stations determine their power by the antenna current. Knowing the antenna resistance at the operating frequency, they multiply that by the current squared. If the antenna resistance is 62½Ω, 4A rf would be 1 kW into the antenna. 126.48A would be 1 MW.

Remember the ammeter does insert a little reactance in the line (I never leave it in all the time), and the calibration changes with frequency, although you can tell what side of the ballpark you are on. An rf ammeter in the shack makes a nice piece of test equipment.

LIGHT BULBS AS RF INDICATORS

John Houser WB2GQY

The major appeal to the amateur – as well as some commercial applications – of light bulbs as rf power indicators is low cost. To this must be added the universal availability of bulbs and screwbase sockets for pennies.

As low cost is of primary interest to well over 50% of those interested in any project, and as I have always had an insatiable desire to find out the why's and wherefore's of standard light bulbs as rf power indicators, I decided it might be the opportune time to do a resarch project and determine once and for all just which bulbs might be suitable and which might not be, and also to determine whether light bulbs would make *good* rf power indicators, or poor, and to find out what precautions might have to be taken if one decided he was going to take this low-cost path of determining his transmitter output power rather than go for a more expensive power output meter.

Also, power output meters in the higher wattage ranges become quite expensive compared to the $2 to $5 which might be expended in a light bulb indicator. In general, porcelain screw bases are available for from 12¢ to 25¢ each, and bulbs from 15¢ to 65¢ each, and not more than four of each are necessary for up to 3 KW power indication.

Table 1 lists most of the common types of electric light bulbs readily available. One look at this table immediately reveals why such light bulbs might not be such good rf power indicators as some folks may have thought they were in the past. It also reveals that some very special precautions have to be taken in using them, or the user may find he has overloaded his transmitter and burned up a few components which might be expensive to replace.

Table 1

Variation in Resistance, Cold to Hot State, Common Variety of Electric Light Bulbs.

Bulb Rating Watts At 115V	Cold Filament Resistance	Hot Filament Resistance	Ratio Cold to Hot Filament Res. (Approx.)
7.5	166	1750	1 to 10
25	40	529	1 to 13
40	27	331	1 to 12
60	20	219	1 to 11
100	9	132	1 to 15
150	6	83	1 to 14
200	4.5	65	1 to 14
250	3.5	53	1 to 15
500	2	26	1 to 13
750	1+	17.7	1 to 15

Table 2

Possible Configurations for Various Power Outputs at Various Impedance Terminations

A. – Nominal 70 to 73Ω Impedance Loads:		
175W Load:	3–60W bulbs in parallel OR	(73Ω)
	7–25W bulbs in parallel	(70Ω)
3,000W Load:	4–750W bulbs in series	(71Ω)
B.) Nominal 50 to 55Ω Impedance Loads:		
250W Load:	4–60W bulbs in parallel	(54.9Ω)
500W Load:	2–150W bulbs in series, both paralleled by 1–150W bulb	(55Ω)
1,000W Load:	2–500W bulbs in series	(53.6Ω)
2,250W load:	3–750W bulbs in series	(53.1Ω)

The extremely high ratio of cold to hot filament resistance in all types of these bulbs immediately struck me as being the most undesirable factor in using them.

It is very easy to see, for instance, that if one wished to use a 250W bulb for indication on a 250W transmitter, and he computed the resistance at 250W to be 53Ω, (which it is, but only when *hot*), he would assume he had just about a perfectly matched indicator to plug in in place of his 52.5Ω feed line.

However, from this table, it is apparent that this 53Ω resistance is attained *only* at full brilliance and wattage, and the actual cold resistance is only 3.5Ω. In other words, if the bulb were connected to the antenna terminals of the transmitter, and the transmitter keyed full power, the transmitter would be looking into *not* 53Ω, but 3.5Ω, which is a lot of difference, and an extremely low value for any pi network to match.

For a few seconds, until the filament attained full brilliance, the transmitter would be subjected to a terrific overload, due to this impedance mismatch.

Therefore the first precaution which might be emphasized in using light bulbs would be *not* to key the transmitter at full power with a cold bulb, but to gradually bring the power from some lower value to full power as the bulb attains full brightness (and hot, matching resistance).

Not until I got into this project did I realize the very high ratio of resistance of these filaments from the cold to hot state; I don't suppose very many people do. It also brings to mind how the house electric meter must jump every time a bulb is snapped on in the house. This is not an ad for those light dimmers being sold at all the electrical stores, but it sure brings to mind that power bills could be cut appreciably through their use, i.e., bringing the bulb gradually to full brilliance instead of just snapping on a switch.

Getting back to the bulbs, Table 2 gives in various configurations series, and/or parallel combinations which would be most likely to give the amateur a load for a particular transmitter power output, in nominal impedances near 52 and 72Ω. If the configuration mentions 200W, this does not mean that it would be suitable for indicating the output of a 100W output transmitter, because at half brightness, the resistance offered by the bulb is not identical to that at full brightness.

While a differance of an ohm or two would not be serious, nor would a difference of as much as five, or even ten watts, at high power levels, at low power levels less than 10GW, for instance, such differences would be seen to become increasingly serious from the matched impedance standpoint. The configurations given match quite a variety of standard line impedances and a wide range of power outputs. Matches can be obtained for RG-8, 11, 17, 13, 58 and 59 type cable.[1]

One may not realize without measurement that the lead length of the filament support wires alone inside the 25–150W bulbs is very close to 18 cm. Even though they are coiled on a 2 to 1 ratio, the filament is inductive in every sense of the word. At higher frequencies, the filament support wires would appear inductive, and to these factors must be added the parallel capacity of the screwbase shell and the central base contact wafer. Even though such capacity is small, it would become significant at most amateur frequencies above the 30 MHz range. Though the 22 cm total wire path would perhaps indicate a bulb could be used up to 300 MHz, such is not at all the case.

It is easy to see that the sometimes suggested trick of using a capacitor in series with a light bulb as a load should be approached with caution, for it would be very easy indeed to run into a series resonant circuit which might result in damage to the transmitter to which such circuit were connected.

In the course of my preparation of this article, I discussed the ramifications with a number of interested hams. Some of them suggested I extend the research to include the use of the smaller types of indicator (pilot) bulbs as loads for testing out transmitters with power outputs in the 1W to 20W range, not only just for amateur applications, but also with a view to using them as loads in testing FM transmitters.

When one considers that there are well over 100 types of these small bulbs, rated from .001W to 2W, and if all of these were to be considered individually, it could take a vast amount of time – and eventually one would end up with perhaps only five or so of these bulbs that would be at all suitable, so such research was not included in this article. However it did open up a field in which there may be a demand for information and may be the subject of a subsequent article.

Frequency Ranges

The use of standard screw-base ceramic or steatite porcelain light bulb sockets is entirely feasible for all of the configurations shown and will handle all amateur bands, 160 through 10. Naturally the leads from socket to socket should be as short as possible in either the series and/or parallel configurations. I found these leads can be kept to approximately 2 cm for such interconnections. Likewise, the coax termination lead should be kept to 2 cm or less.

If extra precautions as to lead lengths are observed, and the bases of the bulbs removed to enable connections directly to the stem wires, it would appear reasonable to suspect that these bulbs might be used for 6, 5, and perhaps 2 meter bands, but it is also quite evident the 2 meter band would be the practical limit.

One should be able to conjecture that light bulbs as power rf indicators are not quite the equal of well-designed power output meters which maintain their rated impedances over a very wide power output range – bulbs do not – but then, they *are* cheap in comparison.

Visual comparison of brightness is completely satisfactory for comparison purposes.

For instance, a 500W bulb connected to the 115V mains should show the same brilliance as one of the 500W bulbs as used in the 1 KW load.

Actually a transmitter supposedly putting out 2,000W PEP is putting out something less than 1,000W with average voice modulation; it would be more of the order of 500–750W average power. Remember that the light bulb is only going to show average power output, not peak, and as ham transmitters are limited to 1,000W dc input to the final amplifier, one cannot expect much more than 500–750W output (average) unless the efficiency of the final amplifier stage approaches 85% which is very unusual, although I am hearing lately that certain high-power transistors are in development which will deliver such high efficiency figures; a bit above that which heretofore has been obtainable with tubes. You should be hearing a lot more about these super-efficiency transistors in the near future; and I expect them to be appearing in certain ham transmitters within a year or so.

Naturally a CW transmitter with the final operated Class C may deliver as much as 850W with 1,000W dc input, while a DSB transmitter on phone could not be expected to deliver more than 650W with Class A or B modulation.

The research and conclusions I reached on this project brought to mind the old subject of using light bulbs in series with primaries of transformers to reduce the secondary output voltages, which is a trick which has been used for years by hams and others. The information contained herein indicates they are not only quite suitable for such usage, but in fact make quite ideal voltage regulators of a sort.

In fact, the question immediately arises as to why bulbs would not make rather ideal voltage regulators for high voltage supplies if used as a variable-resistance dc regulator in the dc leg. This again opens up a field which might bear intense investigation.

[1] Solid Dielectric RF Transmission Lines, W8LUQ, *Radio News* Oct. 1946.
Line Matching: Table of Power and Voltage Loss in DB, *Radio News* Feb. 1947.

BUILD YOURSELF A LIGHT WATTMETER

Carl Henry

Every week brings something new in the hectic field (or pasture) of electronics. Attempting to solve old problems with new components is an interesting pastime for electronics enthusiasts, but they must be careful not to put their foot in the wrong thing. One of the new components is the cadmium sulphide/selenide photocell. A semiconductor sensitive to light is not an entirely new concept, since selenium cells have been around for some time, but the degree of sensitivity makes the cadmium cell stand out.

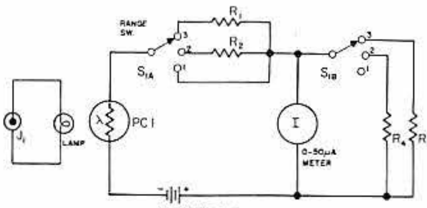

Fig. 1. Circuit of Light Wattmeter.

In measurements especially, there are many possible applications for cadmium photocells. One measurement in particular is usually difficult for the amateur, and this is power measurement. There is a way of using cadmium photocells to measure power, and I call this circuit a "light wattmeter". Operation is just as the name implies, that is, the power is used to generate light which is measured by the photocell.

You have probably realized by now that we are going to use a light bulb as a load. Now this is frequently done in amateur circles, but no one will go out on a limb as to its accuracy. Except me. We know that the ordinary lamp filament has a positive temperature coefficient. Fig. 5 illustrates the variation of a typical lamp filament resistance with input power. By keeping this in mind, fairly good accuracy can be had. Of course, if you use a different lamp, the curve will still apply, but the resistance will be different.

You can run your own graph, however, by using the setup shown in Fig. 2. Either dc or ac can be used, and since the lamp has little inductive or capacitive effect, the readings taken will be good to better than 100 mc. After you have a graph on the lamp you are using, you can effect any kind of impedance match you wish.

Using a lamp as a load simplifies the problem of power measurements because loads for this service are hard to come by. Power resistors are too inductive, and when they approach 1000 watts, they become downright expensive. However, even a 1000 watt lamp is not too expensive.

Fig. 1 shows the circuit that I used as the basis of this article. A standard 150 watt lamp was used here as a load. The photocell is mounted about five inches from the bulb. A wooden box houses the wattmeter, completely sealed internally against extraneous light. Figs. 3 and 4 illustrate the variation of resistance of the photocell with variation of power applied to the lamp. Even very small amounts of power are measureable, if the cell

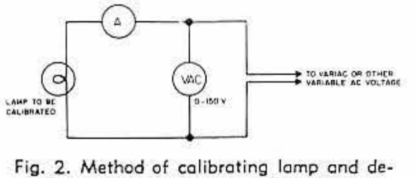

Fig. 2. Method of calibrating lamp and determining resistance.

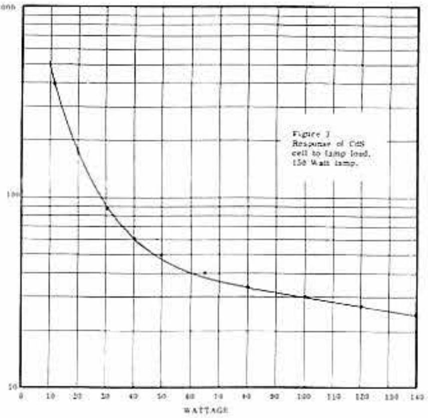

Fig. 3. Response of CdS cell to 150 watt lamp.

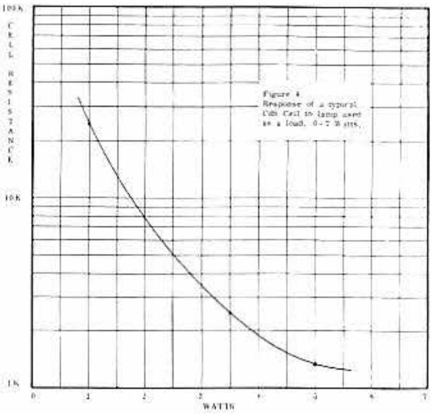

Fig. 4. Response of cell to 7 watt lamp.

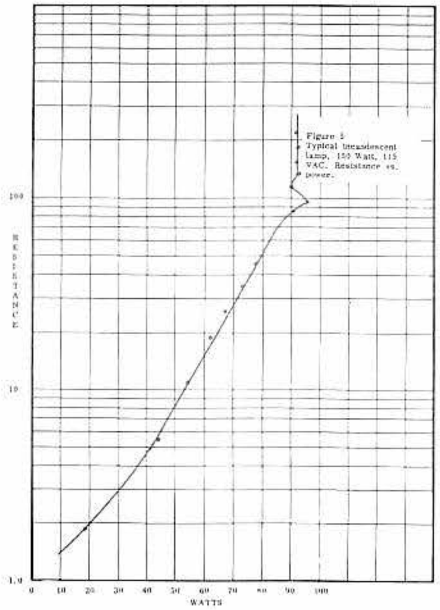

Fig. 5. Resistance versus power input, 150 watt lamp.

is shielded from external light.

The wires from the input connector to the lamp are kept as short as possible by removing the lamp base and soldering the lamp wires directly to the coaxial connector. Switch S1 selects three ranges, which can be set by the builder to anything he desires. In my case I used three ranges which cover from 0.5 watt full scale to 250 watts full scale. With some photocells a 1.35 volt mercury battery can be used instead of the 4 volt battery shown. Also, I used a 50 microamp meter, because of convenience (mine), but even a 10 ma meter will work. Don't exceed the rated power dissipation of the photocell, and remember this may derate with increasing ambient temperature. One thousand watts in a box can be a lot of ambient temperature.

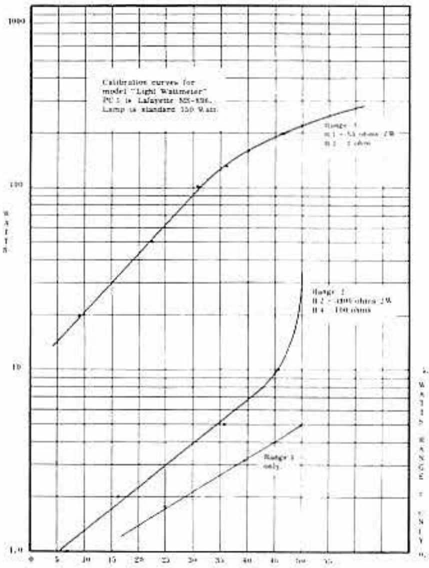

Fig. 6. Calibration curve for Light Wattmeter.

Getting back to the accuracy, if I were to tell you what the meter would read with such and such a lamp, and a given power input, your calibration would be off ten to twenty per cent when the construction was finished. The best way of getting a good calibration is something you've heard before; "if you want a job done right around here you've got to do it yourself".

Now obviously you can't calibrate the wattmeter at 14 mc, because this is what you are trying to measure to start with. Luckily the light from the lamp filament is primarily a power function, and it doesn't matter whether this is dc power, or 100 mc power.

So, to calibrate the wattmeter, apply ac or dc as you wish. Measure the input voltage and current, and read the meter. Make a graph of input power vs. meter reading, and there you have it. Fig. 6 is the graph that I use with the circuit in Fig. 1. Keep the impedance variation in mind, and select a lamp with the power impedance so that standing waves won't eat up lots of your power. As a dummy load and approximate power indictor this is not too critical, of course. But if you wish accurate power measurements, your impedance should be approximately matched.

LOW POWER LIGHT WATTMETER

Bill Hoisington K1CLL

This article describes a very useful gadget for determining the rf power output of solid-state VHF–UHF transmitters in the difficult range to measure, from about 10 mW up to 5 watts. It does not read watts directly; but by a simple comparison of calibrated pilot light brilliance, it will tell you how many watts you are putting out, to within less than 5%. It allows you to check power increases and estimate your efficiency quite close.

Principle Involved

We'll start right in with this part because, while this unit is not by any means a "trick," it does not read rf directly. You first light a pilot light as a good dummy load, matching it into the rf tank circuit of your transmitter by the normal means, also noted here.

You then switch on a second bulb of the same type by means of a battery, controlling the light output with a $1.30 wirewound potentiometer in series, as shown in Fig. 1. This pot must be previously calibrated in milliwatts, as by the method of "volts times milliamperes equals milliwatts." You then match the brilliance of the bulb lit up with rf or its dull glow at some 18 to 25 milliwatts if you're just getting your transmitter going, and read the watts on the wattmeter dial. It's astonishing how well it works, how repeatable it is, and how you wouldn't be without it once you build and calibrate it.

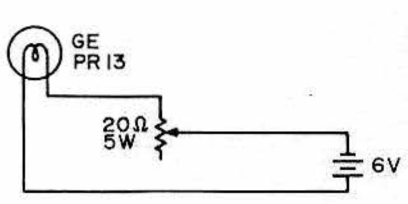

Fig. 1. The circuit supplies the brilliance "standard" for comparison. When the "standard" lamp is mounted adjacent to the dummy load, the pot permits variation of the standard to match the load. If the resistance is panel-marked in watts, a good power indication is achieved.

Brilliance Standard

Figure 2 tells almost the whole story at a glance. You can, of course, put as much calibration on the dial as you have time for. It is quite important to orient the bulb filaments in the same relation to your eyes for best matching. There isn't much in back of the panel except one 6V battery which can be obtained in any hardware store.

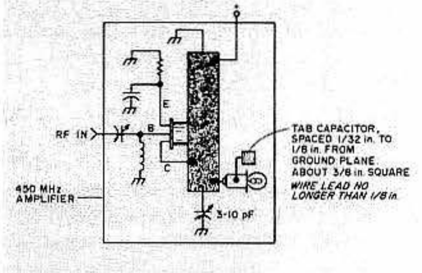

Fig. 3. Matched pilot light load for the UHF version.

RF Matching

Not that it is particularly critical, but be sure and note the need for a large range of series capacitors for the rf pilot lights as you go up in frequency. This can be seen clearly in Figs. 2 and 3. The block diagram, Fig. 2, shows a 6 meter setup. As you go up in frequency the series capacitance drops. A good matched load on 432 MHz can be obtained as shown in Fig. 3. I sometimes remove the tin base from the bulbs, but this is not an absolute neces-

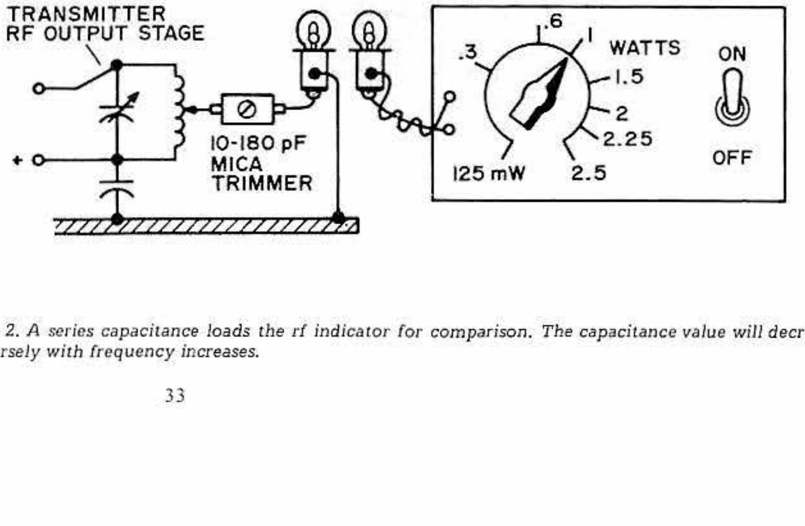

Fig. 2. A series capacitance loads the rf indicator for comparison. The capacitance value will decrease inversely with frequency increases.

sity. It is important to vary the amount of coupling, and thus the series capacity, by spacing the tab capacitor closer or further away from the ground plane, as detailed in Fig. 3. You also can use as many bulbs as you can solder onto a tuned rf inductor, even though they don't all light up with the same brilliance. You can match them all up, but you don't have to. Just check the wattage, or milliwattage, of each one and add them up for the total.

The number 48 or 49 bulb, listed at 2V and 60 mA, is rated at 120 mW, and glows dim at about 12 to 15 mW; so it can be used for low-power receiver oscillators, etc. With two other bulbs found in hardware stores, connected and matched to the rf inductor, such as the PR13 (5V at 500 mA), you can read correctly up to 5W. From there on up you're on your own, although a good variable 115V dc supply can be made up to work around 50 to 100W. I generally use a variety of 115V bulbs of different wattage, light them up with rf, and use their rated wattage.

YET ANOTHER LIGHT WATTMETER

John Meisner K5CXN

Many VHF operators would like a cheap, accurate instrument to measure rf power. The same desire is frequently expressed by operators of the HF bands. Here is a very simple wattmeter which when used with a 50Ω transmission line or load has all of the following desirable characteristics:

1. Easily calibrated to good accuracy (±5%) with your multimeter and a variable dc source;
2. Perfectly flat from dc to 450 MHz;
3. Insertion VSWR less than 1.05
4. Power readings in the 2 to 50 watt range (higher power can be measured with slight design changes);

The operating principle of this wattmeter is stark simplicity. A pilot lamp across the rf line senses a small portion of power in the line and glows brighter with increasing power. An appropriately located photovoltaic cell connected to a microammeter measures the light output which is proportional to the power flowing in the line. Of course a good deal of nonlinearity is involved in the various elements – both the lamp's resistance and its spectrum output change with heating; output of the photovoltaic cell varies considerably with both the amount and frequency of the light shining upon it. Some of these factors tend to cancel out however, because the photovoltaic cell produces some current with only infra-red lamp output at low power levels before the lamp even produces a visible glow, and the cell tends to saturate, increasing its output quite slowly at more intense illumination levels.

Probably the biggest single requirement of any wattmeter is that it must be capable of being inserted into a transmission line without disturbing the operating conditions in the line (low insertion VSWR). It might be argued that hanging a lightbulb across a transmission line will seriously affect the line impedance. Ordinarily, this is true, but the undesirable changes can be minimized and indeed approach an insignificant level if the resistance of the lamp filament is very large when compared to the line impedance. In general, a factor of 15 or more times the line impedance is sufficiently large to produce negligible effects. In the case of the suggested 10V, .014 Ampere pilot lamp, the mismatch produced in the line gives a VSWR of 1.05:1 at the power level of 1 watt. This mismatch decreases rapidly with increasing power. It falls to well below 1.01:1 at 50 watts. Another point of interest with regard to this particular choice of lamp is that it is a long-life type with a life expectancy of 10,000 hours. This implies two advantages: (a) The lamp will operate at well over its rated voltage without burnout (50.0V at 50 watts), and (b) the interior of the lamp envelope will resist darkening which would negate the wattmeter calibration. In addition, the filament structure of this type of lamp is a single-strand straight tungsten wire. The coiled type of filament structure introduces undesirable inductance into the circuit which can distort wattmeter readings in the UHF range.

The wattmeter shown is constructed in two boxes for the sake of convenience. The sensor can be located in the transmission line at any point and the meter can be placed beside the transmitter. For test work, the whole unit could easily be put into a single box. Coaxial fittings and cable were used for interconnection, but since dc only flows in this circuit, any type of wiring would be satisfactory.

The photovoltaic cell used in this wattmeter is a unit obtained from the local Allied/Radio Shack store. (Catalog No. 276-115.) Output of the cell is rated .5V at .6 mA in sunlight.

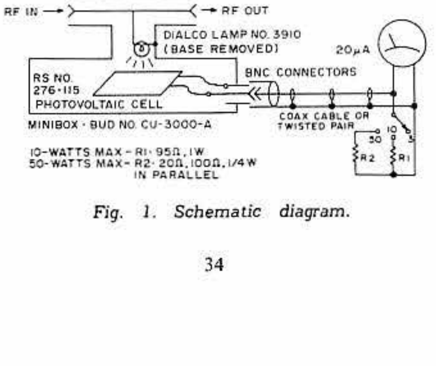

Fig. 1. Schematic diagram.

Since the cell generates considerably more than 20 mA under moderate illumination, a switching arrangement is incorporated into the wattmeter to shunt it into progressively higher current ranges with increasing power. Alternatively, a 50 or 100 milliammeter could be used with less switching at a sacrifice of sensitivity in the 1–3 watt range.

Calibration of the wattmeter is a simple process. By solution of the formula $P = V^2/R$ for voltage, the following tabulation is made for a 50Ω line impedance:

VOLTAGE (rms or dc)	POWER (Watts into 50Ω)
7.07	1
10.00	2
12.24	3
14.14	4
15.71	5
17.32	6
18.71	7
20.00	8
21.21	9
22.36	10
31.62	20
38.71	30
44.71	40
50.00	50

Using the tabulation, fasten a metered variable dc supply into the wattmeter according to the following diagram. Now simply note the reading on your wattmeter for each of the selected voltages in the table and tabulate this reading with the corresponding power in watts in a table of your own. It may even be possible to remove the front of the meter case and mark new calibrations directly on the dial. This was not possible with some hermetically sealed meters. It is best to disconnect the wattmeter from the antenna feedline for this calibration. If the meter is left with a transmission line attached and the antenna happens to be fed through a balun device with near zero resistance, the power supply, and perhaps the balun, will suffer.

It must be pointed out again that this power meter is intended for use either with 50Ω coaxial line systems with low VSWR or with 50Ω dummy loads. A coaxial line that is not "flat" (unity VSWR) or a dummy antenna that does not look like" 50Ω, which is the case with

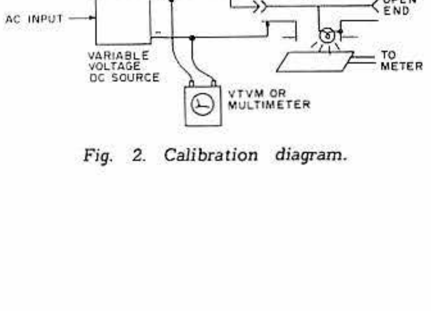

Fig. 2. Calibration diagram.

most HF loads used at VHF or UHF, may cause distorted power readings. If you have doubt about your transmitter's power output when using this meter, you should check it while using a known 50Ω load rated at the transmitter's output frequency.

I mentioned before that this power meter was easily adaptable to higher power readings. To upgrade the meter, the only change required is to insert the correct higher voltage pilot lamp having low current, long-life specifications. Suggestions for some of these are the following Dialco Lamps:

Part No.	Max Power Level (Watts)
24CS	100
48CS	200
60PSB	340
120PSB	800

A LOW COST RF WATTMETER

Mark Leavey WA3AJR

You say you just finished building that 2 meter rig and want to find out how much power you're running but can't afford to buy a wattmeter? You've been calling "CQ 80 QRP" all day with your quarter-watt wonder and nobody is answering? Then get yourself up, go down into the workshop, and build yourself a neatokeeno handy-dandy wattmeter.

If we are going to build a wattmeter, let's consider what we want. Accuracy and ease of calibration, as well as simplicity in construction are prime requisites. The meter described here is as accurate as components allow, and it's easy to build. The calibration is logarithmic, which means that a simple graph is possible, and easier than changing the meter scale.

For the mathematicians, I will present the formulas upon which this device is based, and ways of modifying it; for those of you who avoid math whenever you can, look at the graphs and skip these few paragraphs.

To spare undue complexity, assume 51Ω line – other values can be dealt with later. Perhaps the easiest parameter to measure, and one that is proportional to power, is rf voltage. A voltmeter can be made most easily with a series resistor and a 0–1 mA meter. Now let's plunge into the actual calculations.

Assume W is the full-scale meter reading in watts, Z is the line impedance, E is the voltage measured, I is the full-scale meter reading in amps of the basic meter, and R is the value of the series resistor in ohms. We know that the voltage (IR) is equal to the square root of "impedance times power," or 14.270V. Now, since the voltage and the current (.001A because the full-scale movement is 1 mA) are known, simple division yields 14,270. The resistor value, then, is 14.270 kΩ. The upper portion of Fig. 1 is a graph that will enable the nonmathematician to choose the value of the resistor for full-scale readings up to 4 kW, with 51Ω line and a 0–1 mA meter.

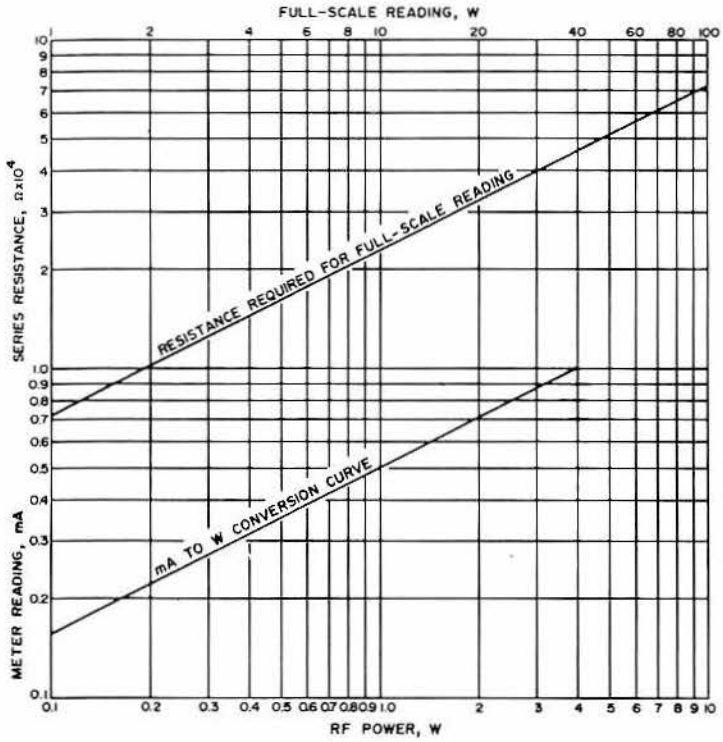

Fig. 1. Logarithmic plots for determining power. The upper curve gives resistance values for determining what the full-scale meter deflection will be (remember to multiply the series resistance value shown on the chart by 12 kΩ). The lower curve will allow you to determine your precise power out if you use a 0–1 mA meter.

Why 4 kW with an amateur power limit of 1 kW? A look at the bottom half of Fig. 1 will explain. Although this is the calibration of the prototype, for 4W full scale, it will double for 40, 400, or 4000W. A half-scale reading, 0.5 mA, corresponds to 1W (1 kW, etc.). This spreads out the range below 1 kW for ease of reading and measuring.

Now get out that soldering copper and gas pliers, and build it. As the schematic (Fig. 2) shows, the circuit is a basic rectifying type rf voltmeter. The prototype was built in a small can of the plug-in-module variety that was scrounged from the junkbox. About the only critical part is the series resistor. The capacitors in the prototype were mica, but ceramic disks would work as well. The diode can be a 1N34A, 1N270, 1N52, 1N38A, or just about anything else. Use the old ham's rule of thumb: "When in doubt, try it out!"

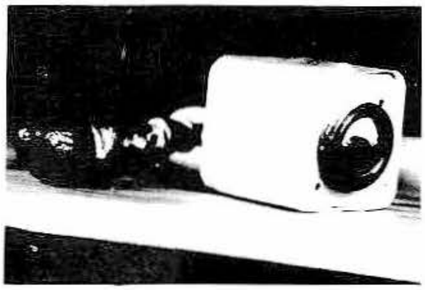

Front view of unit.

Two sockets might prove more convenient rather than one with a coaxial tee as shown. Conventional minibox construction or building into a new or existing rig will be more than adequate. Point-to-point wiring is used to permit compactness and reduce lead length.

"Fine," you say, "but I don't have a huge mound of test equipment. How do I calibrate it?" That is the beauty of it – you don't! If the series resistor is accurate, the meter will be self-calibrating to a log scale. Remember, you know R and Z, and the full-scale W. Now assume a half-scale

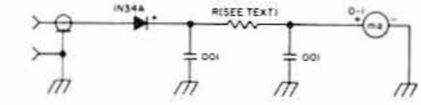

Fig. 2. Schematic diagram of the simple, accurate, and easy-to-build rf wattmeter.

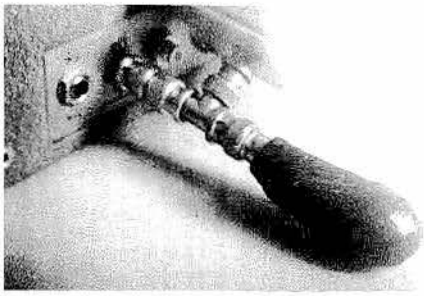

Connection to transmitter with dummy load (see text).

reading, I = 0.0005, and calculate W for half-scale. Plot these two points at 1.0 and 0.5 mA on Fig. 1, and connect by a straight line, which you may extend the length of the graph.

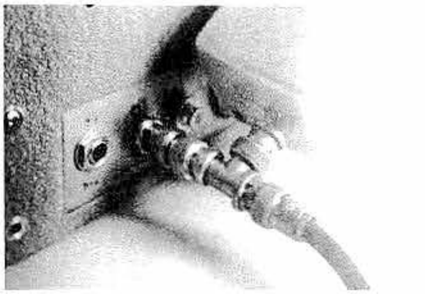

Connection to transmitter with antenna connected.

Install the meter through a coaxial tee at your antenna connector, or through some other predetermined means, and terminate with a dummy load. The one seen in the picture is three 150Ω resistors in parallel, dipped in epoxy, shielded with a copper braid, and installed on a BNC plug. Apply power and read the meter. That's it! The meter can be used with an antenna if your swr is below about 1.2:1.

So what did I promise? A low-cost, rf wattmeter that is inexpensive enough for the Novice, practical and useful enough for the General, and "Extra" accurate. Go raid the junkbox, and add a worthwhile piece of gear to your shack.

RF POWER MEASUREMENT USING HOT CARRIER DIODES

Frank Jones W6AJF

Two rf wattmeters are shown here, one with a range of 25 mW to 10W and the other covering the range of 5 to 300W. Both are useful from low radio frequencies on up through 450 MHz.

The low-power version (Fig. 1) makes use of a 20W Sierra dummy antenna built into the meter case, though the metering circuit only goes up to 10W. If the maximum is to be 20W, the reference meter reading could be about 45 μA instead of 30. The minimum power reading would be doubled. In this wattmeter, the power range potentiometer is calibrated and only a reference line on the meter is used when making rf measurements. The dummy 50Ω antenna resistor is rated up to 1000 MHz so is excellent from 450 MHz down.

The range potentiometer had an audio (nonlinear) taper. By connecting the "high" resistance end to the diode, the watt range scale is spread out quite well in the 0.1–10W range. The hot carrier diode, an HP 2900, has a 10 PIV rating, which means that the rms rf voltage across it should be less than 3V for safe operation. At 10W of rf power, the rms voltage would be a little over 22V, which means a voltage divider is needed to keep the applied diode voltage down to about 2V. An HP 2800 diode with a 75 PIV rating would be more desirable, especially if the meter was to be calibrated for 20W maximum. This diode is about $1 and has a little higher capacitance, which would require a different shunt capacitance across parts of the resistor divider to make the device work with the same power range calibration.

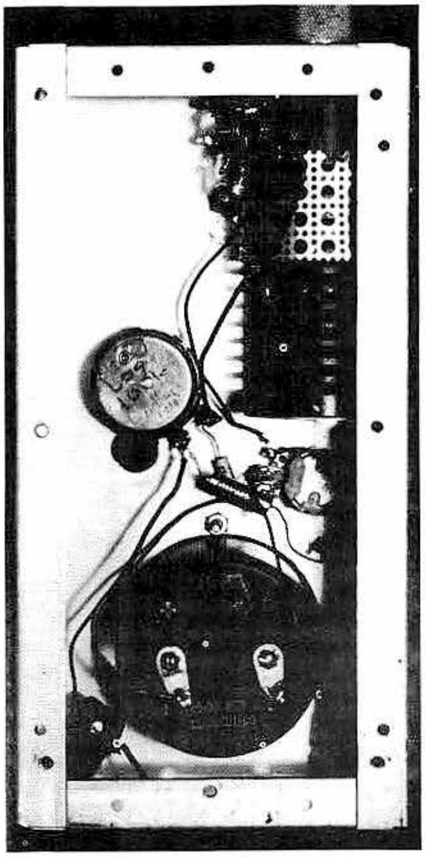

Bottom view of 10W unit with the rf dummy antenna clamped in one corner.

WATTS
.025
Adj. to line
WATTS
ON
OFF
R.F. WATTMETER

Top view of low powered rf wattmeter covering .025 to 10W. Built into a 8x4x2 chassis with wire screen bottom plate for ventilation.

The divider should use ½W resistors of the carbon or metal film type, since these units are part of the rf circuit. It is better to use three ½W 300Ω resistors in the string rather than a single 900Ω 2W resistor: this is because the rf resistance characteristic is usually better in ¼ or ½W types in certain ranges of resistance. Every resis-

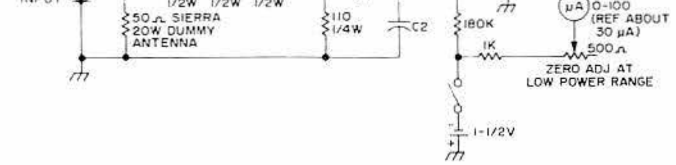

Fig. 1. .025 to 10W RF wattmeter.

tor has some inductance and shunt capacitance which becomes part of the voltage divider. The diode shunt capacitance is in parallel with that of the 110Ω ¼W resistor in Fig. 1. However, nearly any combination of resistor sizes can be equalized within 10 to 20% over the desired frequency range. This divider is across the 50Ω dummy antenna, so should not shunt the value down to less than 49 or 48Ω. This divider has to dissipate a little rf power also. Its total resistance should be at least 20 times as high as the dummy antenna load resistor.

The values shown in Fig. 1 are just about the minimum that should be used. Too high values makes it more difficult to extend the frequency range to the upper end, though it can be done, as was discovered in the higher-powered wattmeter of Fig. 2.

All diodes are poor rectifiers at applied rf voltages below their forward bias values of 300–700 mV (peak). By using a forward dc bias voltage to make the diode conduct at least 5 or 10 mA, the detection sensitivity is increased as much as 5 or 10 times. This requires a small battery, a couple of fixed-value resistors, and an adjustable pot to balance this current out of the meter when measuring rf powers below 100 mV. If the power range is limited to a minimum of ¼ or ½W , no bias circuit is needed in this 10W instrument. The range scale in either case has to be hand calibrated.

A low-powered radio transmitter or exciter can be used as a 10W power source when calibrating the power range pot scale. The transmitter can use stage detuning to reduce power outputs down to the lower values needed. Many swr meters have watts of power calibration and one of these can be put in the coax line to the rf wattmeter for calibration service. A more accurate calibration can be made by comparing the power readings against some reliable commercial rf wattmeter within its frequency range and calibration charts. This scheme is usually necessary for checking the calibration at VHF or UHF. Another method is to use an accurate rf voltmeter across the dummy antenna connection to ground and read the power values in watts = E^2/R. For example, 5V (rms) squared is 25; and divided by 50Ω is equal to 500 mW.

The Sierra 50Ω dummy antenna has no connection available at the high end of the resistor, which terminates in a type N fitting. The metering circuit has to connect to this point as close as possible by getting into the inner conductor of a coax fitting, or by drilling a 3/8 or ½ in. hole through the shell of the dummy antenna close to the rf fitting end. This can be done and the first 300Ω resistor in the voltage divider soldered to the inner connection to the large 50Ω resistor. A long 1/8 in. diameter soldering iron tip is needed. The divider resistors, diode, and four .001 μF stud-mounted bypass capacitors were all mounted around this large hole in tapped 6-32 holes for the four capacitors. Larger values of bypass capacitors can be shunted across these 0.001 μF values to ground to extend the frequency range down to low rf or even af values. For example, a .02 μF capacitor shunt would allow operation to 2 MHz. A miniature 50 or 100 μF electrolytic shunt would function at audio frequencies down to 300 Hz. The diode must have a low-impedance path to ground over the desired frequency range to function as a peak rectifier and get as much dc output voltage as possible for the meter circuit. The microammeter in series with a variable range resistor is simply a dc voltmeter. The diode rectifier converts rf voltage to dc, so the diode should be equally efficient over the whole rf range.

The 5–300W unit was built to use with a large dummy antenna rated up to 500 MHz, which is a massive unit external to the box shown in the photographs. Quite a bit of rebuilding went into this device to make one calibration of the range potentiometer fit all frequencies from 450 to 2 MHz. The input and output coax fittings had to be finally mounted so the inner conductor tips could be soldered together and the resistor divider connected to this point. The latter consisted of two 4300Ω 2W carbon resistors and a 68Ω 1W resistor in series to a copper sheet inside of the aluminum box.

The watt range variable resistor was a 500 kΩ linear potentiometer which was limited to a lower value by shunting it from the moving arm to the diode connection end with a 220 kΩ resistor. This gave a maximum power reading of 300W when the reference line was drawn on the meter face at 12 μA. The import, low priced, 0–30 μA meter had a large meter scale. A smaller 0–50 μA meter would have been usable, since the meter is used only as a reference. The range pot knob is adjusted when rf power is applied to run the meter reading up to the line drawn on the meter scale face.

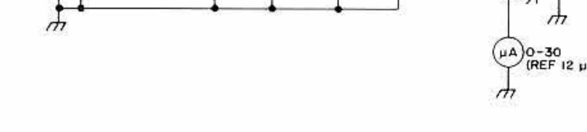

Fig. 2. 5 to 300W RF wattmeter metering circuit. External 300 or 400W during antenna load.

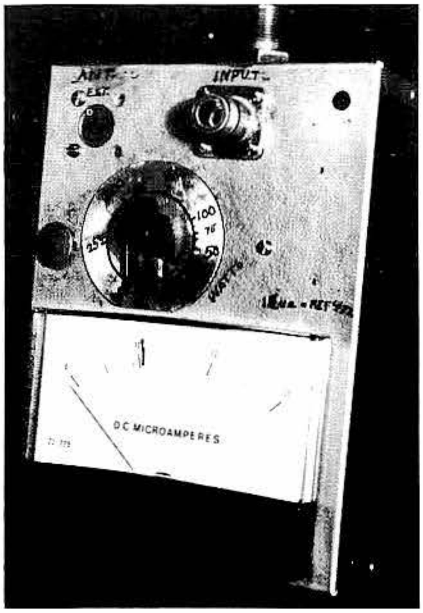

Top view of 5 to 300W metering circuit for use with external high powered dummy antenna.

The circuit shown in Fig. 2 was equalized to within about 15% error over the range of 2 to 450 MHz by shunting a 5 pF capacitor across the 68Ω resistor in the rf divider.

Calibration of this device was made at 144 MHz using a transmitter having up to 400W available carrier output. The meterizing unit was connected to a large Bird rf wattmeter at the external fittings of the latter. Several thermocouples had to be used to cover the wide range of power for the calibration. This required reading a chart curve for each Bird wattmeter reading and using correction factors for frequency in order to obtain the actual watts of rf power. Now, the large unit is used without the thermocouples, charts, rf choke, etc. simply as a dummy antenna. The new metering circuit connects directly into the antenna fitting, with a few feet of 50Ω coax over to the transmitters being tested.

This power measuring device can be used in any 50Ω coaxial line to monitor the actual power going toward the antenna. The swr in the line should be low, or near unity, in order for the calibration to be reasonably accurate.

VHF DUMMY LOAD WATTMETER

Glen Zook K9STH

The unit

The unit described herein is similar to some 60 watt units which may be found around many commercial two-way radio shops. This dummy load has provision for connection to an external relative output meter. This external output meter may become an accurate wattmeter if the following criteria are met:

1. Frequency bandwidth of ±10% of calibration frequency.
2. RF output kept within power dissipation of dummy load.
3. Accurate initial calibration.

These criteria may be easily met in amateur vhf operation if only one band is considered for each set of calibration data. Since most vhf amateurs operate on 50 mhz, 144 mhz or 432 mhz, the ± 10% frequency limitations may be easily met. This limitation gives a 10 mhz bandwidth at 50 mhz, 29 mhz bandwidth at 144 mhz, and 86 mhz at 432 mhz. The limitation to the power ratings of the dummy load is only common sense, for if a resistive network is overloaded, the impedance may be drastically increased, caused by damage to the load resistors. The calibration limitation may be overcome if a standard, previously calibrated unit, or commercial unit is used.

The unit consists basically of 16 220 Ohm resistors in a series parallel arrangement. The metering circuit consists of a germanium diode pickup with necessary rf filtering. The meter movement is generally a vom, but any 50 ua meter movement should suffice. Exact physical layout is not extremely critical, but it is suggested that the layout be made similar to the unit shown in the accompanying photographs. This unit is acceptable for 60 Watt output transmitters without modification. The power capability may be increased to about 200 Watts if the resistive network is suspended in 1 quart of oil. If this is done, care must be taken to keep the metering circuit out of the oil. The lead from the diode to the resistive network must, of course, be partly submerged, but keep the diode itself out of the oil. I do not personally use this arrangement, but I know of two units which have been in use at a large Southeastern two-way radio shop for several years. The same shop has incorporated a range switch with several meter shunts for various maximum scale power readings. This feature is especially useful to the amateur vhf FM operator who may be working with equipment of from ½ to 250 Watt outputs. The schematic appears as Fig. 1, and the basic circuit for various meter shunts as Fig. 2.

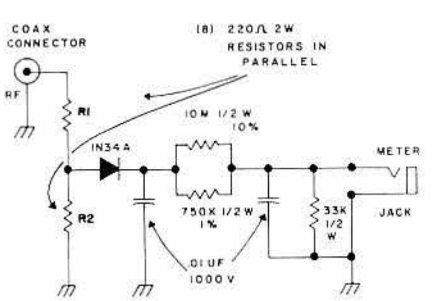

Fig. 1. Schematic. R1 and R2 consist of eight resistors each, in parallel.

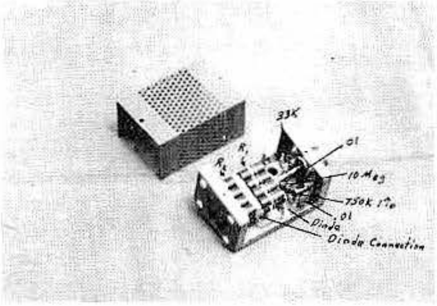

Parts layout and interior view of Dummy Load – Wattmeter

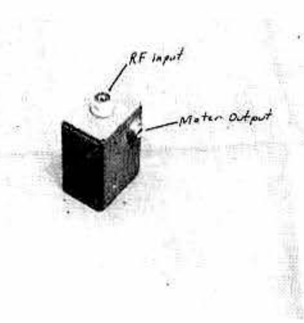

External view.

Calibration

Calibration is best accomplished by using a Bird "Thruline" or similar commercial vhf inline wattmeter. Second choice is a Bird "Termaline" or similar dummy load-wattmeter. In both cases, a graph should be created by plotting meter divisions on the horizontal axis, and power on the vertical axis. The meter shunt should be placed at minimum resistance and increased to give maximum reading at the desired power level (this holds primarily true for units using the metering circuit of Fig. 2) or, if a vom or vtvm is being used the range switch should be placed on a high voltage setting and reduced a setting at a time until the desired reading is obtained. The transmitter should be adjusted for various power levels on the standard wattmeter and the voltage or current reading on the new meter recorded on the graph. In the case where the standard meter is of the dummy load-wattmeter type, it will be necessary to switch the coax from one unit to the other. Do not retune the transmitter, for each unit will present almost the same load to the transmitter (50 ohms). Take the reading and record as with an inline type of meter. The points on the graph should now be connected with a smooth curve (use of a draftsman's range switch is used, it will be necessary to calibrate for each switch position. Also, if multi-band use is expected, the graphs must be made for each band. Use of the wattmeter now requires only the connection to the transmitter, setting of range switch to the proper level, and reading the graph.

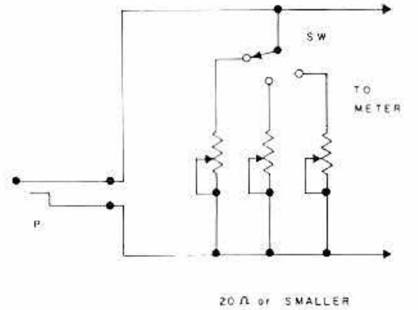

Fig. 2. Metering shunts.

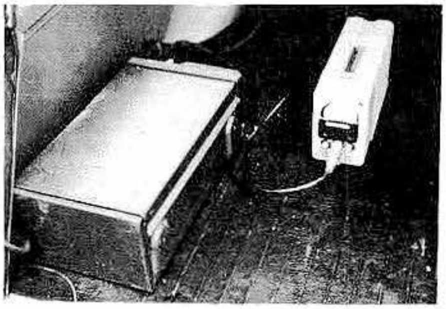

Using the Dummy Load – Wattmeter to check output of FM unit.

Uses

The uses of this dummy load-wattmeter are as varied as the amateur mind can devise. One very important use is determining the losses of 50 ohm coax. Measure the output of the transmitter at the transmitter. Then measure the output at the end of the length of coax. The losses in the line become apparent. The loss in db may be calculated by the standard power ratio formula, 10 $\log_{10}$ Power out of coax/Power into coax.

Another use is the determination of efficiency of final amplifier stages. This efficiency may be calculated by Power out (measured by dummy load-wattmeter)/Power in (measured by plate current/plate voltage meter) x 100%. A third use is determining once and for all which amateur really has the most output. This list may be expanded by the builder to suit his own tastes.

Conclusion

This dummy load-wattmeter is not a Bird "Termaline" nor should it be regarded as a substitute for any other laboratory equipment. However, with a little care in calibration, (assuming a 5% accuracy standard is used for initial calibration) the accuracy should be within 10%, and this, my friend, is not bad for a wattmeter costing less than $10.

Chapter IV

Measure Your Field Strength and Frequency

THE RF SNIFFER

Jim Kyle K5JKX

Every now and then there's a need to know if any rf is present in a circuit. Frequency isn't so important—the question is simply. "Is there rf here?"

Your grid-dipper can frequently answer this, if used in the wavemeter mode, but occasionally it's not sensitive enough—particularly if you're working with a receiver oscillator where power is measured in microwatts.

Here's an rf Sniffer which will indicate the slightest trace of rf in a circuit. In addition to checking receiver oscillators, it's a perfect gadget to ensure perfect neutralization of a transmitter final.

Connect the components as shown in the schematic. Use long-nosed pliers as a heat sink between the diode and the solder joint when wiring, to prevent diode damage. Note that the pickup loop of 14 gauge wire is insulated with a strip of spaghetti.

Mount capacitor and diode on back of meter with shortest possible leads. Attach pickup loop directly to negative meter terminal; it's stiff enough to do without other mechanical support.

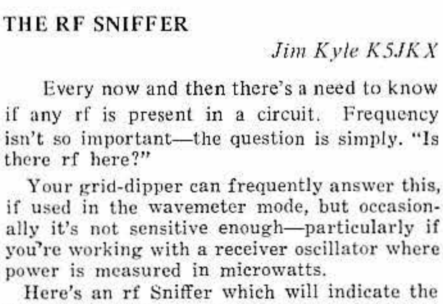

Amplifier Neutralization—Couple the Sniffer to the antenna terminal with a temporary two-turn link around the pickup loop. Remove plate and screen voltage from the final amplifier. Apply drive. Adjust neutralization for minimum indication on the Sniffer—but don't expect to be able to get it down to zero.

Oscillator Checking—Place the pickup loop near the oscillator coil. If the oscillator's working, the Sniffer will indicate rf. Touching either the grid or plate lead (use an *insulated* tool for this test, not your fingers) should reduce the Sniffer's indication.

Receiver Troubleshooting—Check the oscillator as described above. If it's okay, next check the mixer plate coil by placing the Sniffer pickup loop near it. If you get an indication here, move to the first if stage and place the pickup loop near the plate pin of the tube socket. Proceed through the receiver until you lose the indication. The trouble is somewhere between the last indication and the point at which it disappeared.

Field Strength Meter—Couple a short antenna to the pickup loop by two turns of wire around the loop. Field strength will be indicated in a comparative manner by the meter. It cannot be calibrated, but proves useful in tuning mobile or beam antennas, etc.

SWR Measurement—(Parallel lines only). Move the Sniffer long the line. Mark maximum reading and minimum reading over a half-wavelength. Divide minimum into maximum. The quotient is, roughly, your VSWR. This method is by no means exact, but will indicate whether the line is under or over a 2:1 SWR.

UHF Frequency Measurement—Set up Lecher wires. Couple the rf Sniffer lightly to the tank circuit instead of using a flashlight bulb. Use Lecher wires in normal fashion, reading Sniffer indications for maximum and minimum. This is much more exact than the normal methods.

Improvised Grid-Dipper—If you have a signal generator available, it can be used with the rf Sniffer to serve as a "grid-dip" meter to locate resonance for any tank circuit. Couple both the generator and the Sniffer lightly to the unknown tank. Vary generator frequency. A sharp rise in Sniffer indication indicates the resonance point.

THE PINK TICKET REJECTOR

A. D. Taylor GW8PG

Hams sometimes get into trouble with the FCC because they have made a mistake in tuning a frequency multiplier or PA stage. For example, if the multiplier stage following a 3.5 MHz oscillator is accidentally tuned to 10.5 MHz instead of 7 MHz, the PA can be loaded on 10.5 MHz; and if this is done even a short transmission is likely to produce an unwanted "QSL" from the FCC! Mistakes like this can be prevented by using the simple, easily built absorption wavemeter shown in Fig. 1. Only one coil is required in this meter, the low frequency range being obtained by switching a padding capacitor in parallel with the variable tuning capacitor. With switch S1 open the tuning range is approximately 6.8 to 30 MHz, and with S1 closed it is approximately 3.5 to 6.8 MHz.

Construction of the wavemeter is simple. It can be put together in a metal utility box, on a wooden panel and baseboard, or even in a cracker can of the right size. The coil can be wound on any type of ¾ in. diameter form. If nothing else is handy, a short length of dowel could be used. The coil winding consists of 7 turns of 20-gage wire, close wound. Both the tuning capacitor (C1) and the padding capacitor (C2) should be 500 pF components, but the values of the other components are not critical.

Any meter having a full-scale deflection between 100 μA and 1 mA can be used. If the wavemeter is built in a metal box, L1 must be mounted outside the box. A slow-motion drive is not needed. If C1 is fitted with a pointer type knob and a cardboard scale is cemented onto the front panel, the calibration points can be written on the scale in ink.

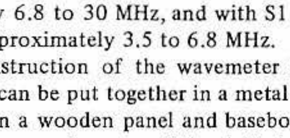

Fig. 1. L1 – 7 turns 20 gage enameled copper wire, close-wound on a ¾ in. form; C1 – 500 pF variable capacitor; C2 – 500 pF fixed capacitor; C3 – Fixed capacitor, any value between 1000 pF and 0.01 μF; D1 – Silicon or germanium; M1 – Moving coil-meter (100 mA–1 mA).

When it came to calibrating the wavemeter I thought of a simple method that I have not seen described before. I soldered about 2 in. of wire onto one end of L1, and about 10 ft of wire onto the other end. I then connected the short lead to the antenna terminal of my receiver and strung the 10 ft of wire up as a temporary antenna. I then tuned the receiver to a steady signal at each frequency at which I wanted a calibration point, and adjusted C1 until the strength of the received signal suddenly dropped sharply, indicating that the wavemeter was tuned to the frequency of the signal. I was then able to mark this frequency on the cardboard tuning scale. The drop in signal strengh was very sharp so calibration was easy. Once enough calibration points had been obtained the temporary wires were unsoldered and the wavemeter was ready for use.

The only frequency which may require a little adjustment is 30 MHz. If the wavemeter will not tune as high as this, push the top turn of coil L1 about 1/8 in. away from the other turns. This should reduce the inductance sufficiently; a spot of cement will hold the turn in its new position.

To use the wavemeter for checking a transmitter, bring coil L1 close to the tank coil of the stage being checked, apply power to the stage and rotate C1 until a maximum reading is obtained on the meter. The output frequency of the stage can then be read off from the wavemeter tuning scale.

The wavemeter can also be used as a radiation meter for tuning up single-wire antennas. If it is tuned to the transmitter output frequency and placed near to the antenna wire, maximum reading on meter M1 will indicate maximum output power from the transmitter.

Many readers will have realized that the calibration method I suggest uses the principle of the rejector circuit. That is why I have called the little gadget "the pink ticket rejector"!

A USEFUL ACCESSORY FOR THE HAM SHACK

Rex Morris W2WHX

Because we are dealing with something we cannot see, namely electrons and electromagnetic radiation (we only see their effects), we must acquire the ability to use test equipment, in order to understand and find our way in this invisible realm.

The piece of test equipment about to be described is one of the more useful instruments that the amateur should have in the shack. While this instrument serves primarily as a field strength meter, it will also serve as a phone monitor, neutralization indicator and a sensitive wavemeter.

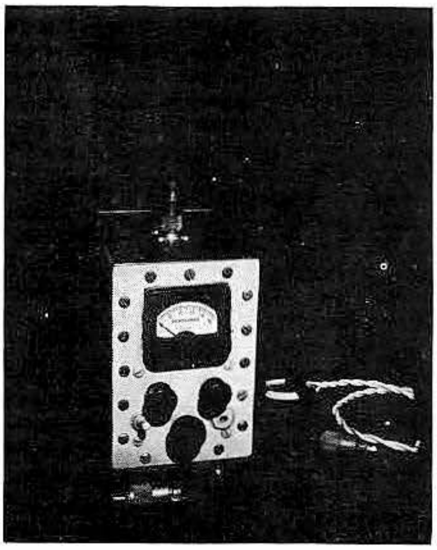

Referring to the circuit diagram, meter M1 is a sensitive instrument which indicates the pressure of rf when the device is used as a field strength meter, wavemeter or neutralization indicator.

To use this instrument as a wavemeter, a pickup loop is substituted for the short whip antenna at the top. Switch S1, the band switch on the right of the panel, is placed on the proper position. Coil L1 tunes the vhf range of approximately 90 mc to 170 mc (2 meters). L2 tunes 28 mc to 100 mc (10 meter and six meter bands). L3 tunes to 7 mc to 30 mc (40, 20, 15 and 10 meter bands). L4 tunes from 2 mc to 7 mc (80 and 40 meter bands). With switch S1 on the proper tap, condenser C2, on left of panel, is used to peak the reading on meter M1. Using a calibrated dial, frequency may be read directly. Toggle switch S2 is a high-low range switch for meter M1, providing a means of keeping the meter on scale and protecting it against burn-out. Potentiometer R1 (center of panel) is a vernier shunt control, also for keeping the meter on scale.

For use as a phone monitor, rf should be fed into the input jack with a link or pick-up wire. Once again the LC circuit is resonated to the frequency we desire. Earphones inserted in jack J2 will open the meter circuit and allow you to monitor the signal. Switch S2 is placed in the Hi position.

Field strength readings can be taken by using a short pickup antenna. Again the LC circuit should be tuned to resonance. Meter M1 will give an indication of field strength.

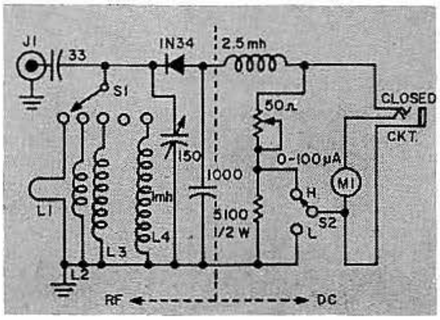

With switch S2 in the Hi position the meter is very sensitive and potentiometer R1 is a variable shunt providing much range of scale adjustment. For use as a remote reading field strength meter an external microammeter (with up to 200 feet of wire) may be plugged into J2. For making transmitter adjustments this is a very desirable feature.

Now notice that one position on the bandswitch S1 is vacant, this vacant position provides a very broad band—low sensitivity position for those extremely high rf fields where even R1 and S2 cannot provide enough attenuation.

Neutralization measurements are made by coupling the instrument through a pick-up link to the tank coil involved, with S2 in the Lo position. When the instrument is tuned to resonance it becomes a very sensitive rf indicator. It is so sensitive that it will readily be seen that complete neutralization exists in theory only.

As in all simple gadgets there are a few simple construction techniques which make the difference between gadget and instrument. In this case the important thing to keep in mind is that from the antenna to the crystal is the rf portion, and from the crystal to the jack J2 is the dc portion (with audio superimposed). With this in mind, construction is such that the two parts are separated, thereby giving some measure of protection from rf energy to the very sensitive microammeter M1. Also note the extensive use of sheet metal screws on the aluminum case. The only rf we want to enter the case is the rf we are attempting to measure via the antenna jack. Note again, we have here an instrument for detecting electromagnetic radiation, from approximately 170 mc to 2 mc. We now have an instrument for visualizing what cannot be seen.

The usefulness of this instrument is limited only to one's ability to apply it and interpret the results it gives. These only come with experience, trial and error and determined application.

Coil Data

L1—One turn hairpin loop.
L2—5 turns of #18 enamel wire space wound 1" dia.
L3—24 turns #22 cloth covered wire, close wound, ⅝" dia.

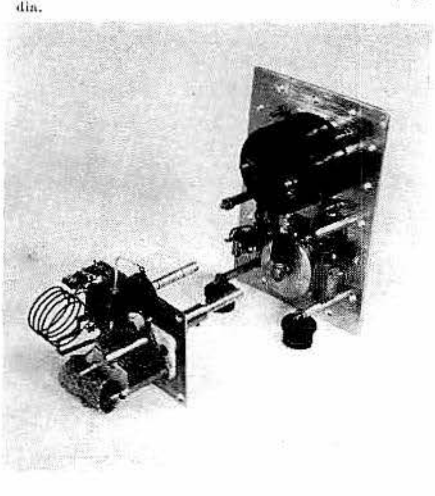

TWO THRU TWENTY FSM

Howard Pyle W7OE

I used a small LMB aluminum meter cabinet with a hole for a 2" meter; any equivalent cabinet can of course be used. With a small enclosure such as this (4"x4") the meter occupies the face of the cabinet and all controls are on the rear. Using a somewhat larger housing both the meter and the control knobs can be placed on a front panel if you prefer.

Rather than wind up the three coils I found that the J. W. Miller Company RF chokes with minor modifications were admirably suited for a compact job. One each of their catalog numbers 4606, 4588 and 4580 were required to cover the three frequency spreads from 2 through 20 meters. The #4606 coil should have five turns carefully removed, to cover the 10-20 meter bands; remove three turns from #4588 for six meters and two turns from the #4580 coil to handle 2 meters. These can all be resonated with a 50 pf midget variable tuning capacitor; a Hammarlund HF-50 or the equivalent is excellent. Any of the small multi-point selector switches can be used for band switching. A JBT lever switch type SS-14-ILS will handle the job or, if you prefer a rotary switch you can use a Mallory type 3215J as I did, leaving two positions unused. (I might want to add a couple of coils and try 40 and 80 later!).

MIN
6
10
15
MA
20
BAND
ON
OFF
PHONES

Resistors R-1 and R-2 shown in the schematic, need be only ½ watt. A single flashlight cell will serve for the battery although I chose a 1.4 volt mercury transistor battery to conserve space. Other items shown on the schematic are obvious and all parts are readily available from most electronic parts distributors as well as from the electronic mail order houses.

Build this little F/S meter and know what your VHF outputs are doing. If you want to check your modulation quality, a phone jack may be added as shown, making this little gadget really versatile.

Side view of the FSM.

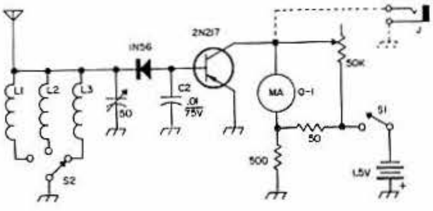

Fig. 1. The bandswitching, transistorized field strength meter for two through twenty meters.

AN AMPLIFIED, CALIBRATED SIGNAL STRENGTH METER

J. L. Iliffe VE3CES

Recently, I had the problem of tuning a four element quad. As you may or may not be aware, these beasties are supposed to be tuned from the rear for minimum signal. A quick check showed none of my friends had a signal strength meter, so I prepared to degrade myself and buy one. A look at a few prices convinced me to build.

Since I wanted some other information on the quad, like front to back ratio and the effect of more or fewer elements, I decided to add a calibrated attenuator and enough gain to make a fairly wide input range. It also had to be cheap!

The result is shown in Fig. 1.

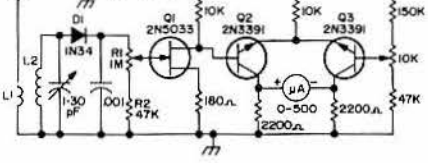

Fig. 1. Diagram of the field strength meter.

To use the normal rf attenuator method of switched T-pads requires complicated shields and quite a few resistors. Also the attenuator has to be terminated in its characteristic impedance to read correctly. To bypass this problem I first detect the rf, then attenuate the dc. This has the added advantage that the circuit is no longer frequency sensitive.

The incoming rf is tuned by C1-L2. C1 can be any small variable. I used both sections of a dual 15 pF because my local surplus store has them for 60¢. For VHF use only 1 section.

L2 is wound on a plastic pill bottle about 1" in diameter and tapering to 7/8". To cover 13–24 MHz, I used 11 turns spaced over about an inch. L1 is 2 turns over top of L2. I tried bandswitching with another pill bottle fastened on the other side of the shield from L2. The idea was to bandswitch another frequency range but I find it more convenient to wind on coils as needed. Use the grid dipper to get you in the ballpark. I have used this meter as high as 72 MHz without trouble. D1 can be any diode. I used a 1N34 because I could then specify it and know it would work, but I tried a computer type which also worked. If you prefer the meter to peak rather than dip, reverse D1.

Rectified rf from D1 is put on the top of R1, the calibrated attenuator. R2 in series with R1 gives the 0 dB point at its junction. For a 30 dB range, R2 is 47K if R1 is 1 MΩ This doesn't quite fill the range but is close. Changing the value of R2 will change the range but 30 dB is considerably more than the F/B ratio of most beams.

Q1 is a 2N5033 FET. The high input impedance of Q1 allows us to set the calibration of R1 directly by dc voltage measurements on the VTVM since it does not draw any base (gate) current. It is a p-channel device. If you use an n-channel type you will have to change the entire biasing of the circuit and also reverse D1.

Q2 and Q3 form a differential amplifier to drive the meter. Q2 is necessary to avoid loading Q1 and I had quite a bit of trouble balancing the meter against battery voltage changes until I added Q3. It will now operate from 8.5–9.2 volts with no trouble. The 10K pot in Q3's base centers the meter. The meter I used is a 250 μA tuning meter with no markings on it except a red/white/blue bar. This is all you need since we calibrate on R1, not the meter.

Operation

The meter is quite sensitive and with a two foot antenna I could get a reading several hundred feet behind my quad at 60 watts input. First tune the input (which is quite sharp) with the attenuator set at zero. This is the least sensitive position. Now set the meter for a convenient reading near the center scale with the incoming signal still on using R3. Adjust your antenna. When you feed it power again the reading will not be quite on scale on the meter but turning up R1 will allow you to put the meter back to the original position. Do not touch R3. The reading on R1 is now the increased gain in dB needed to bring the signal back to its original strength. In other words, the decrease in signal strength.

Note that during measurements you need a received signal to use R1. With no signal the meter will be off scale.

I have also used the meter to align oscillators and doublers in my two meter receiver. A probe can be made for this from two turns of wire on the end of a piece of coax. The high gain available allows the pickup loop to be quite far away which reduces detuning. Adjustments show up well on the meter.

FREQUENCY MEASURING EQUIPMENT AT MICROWAVE FREQUENCIES

Silas Smith WA9VFG

This article is not intended to give the theory, but rather a practical solution to the building and use of wavemeters at microwave frequencies.

In microwave work, frequency is one of the most important measurements. It must be understood the wave length in the devices described here is not the exact frequency wave length. A well-constructed wavemeter that has been calibrated can be very precise. They can be within 1.5 MHz at 10 GHz or less than half of a MHz at 1250 MHz. Temperature has some effect on the frequency. Most commercial wavemeters are constructed of Invar, a metal that changes very little with temperature. Some parts are of bi-metal construction to compensate for temperature. For the average experimenter, brass and copper will have to suffice. Although silver plating is desirable, it isn't an absolute necessity. Frequency at microwave frequencies can be measured by three methods: wavemeters, slotted lines, and frequency comparisons. All of these methods are used commercially. The frequency comparison is usually used in the laboratory to calibrate the wavemeter and the slotted line. As a general rule, any method of frequency measurement used at lower frequencies can also be used at the microwave frequencies, but are not always practical. The resonate cavity as a wavemeter is used in microwave measurements.

There are three types of cavity wavemeters: the transmission type, Fig. 1A and 1B, the reaction type, Fig. 1C, and the assorption or absorption type, Fig. 1D. All are resonate cavities. The way in which the wavemeter is used determines the type.

All wavemeters are adjusted for maximum readings except the assorption type. The assorption is adjusted for a dip in power output. The most popular wavemeter used by the beginner is the open circuited transmission line type, Fig. 2. This type of wavemeter is the equivalent of lecher wires. (Open circuit refers to the standing wave within the cavity, not the physical construction except as it pertains to the frequency wave length.) The practical physical dimensions are not many. The inner circumference of the main tube should be less than one wave length at the highest frequency to be measured. The rod should be small compared to the tube. If inductive coupling is used, the inductive coupling should be close to the shorted end. For probe coupling, the probe should be close to the middle. The open circuited transmission line is generally used in two ways. This type can be used "in line' (Fig. 1B) as it has very little loss when it is resonated. However, it should be removed from the line before transmitting, as it will act as a narrow band filter. The half wave length is the measurement between the two successive points at which the generator will load to maximum, as the rod is inserted or withdrawn.

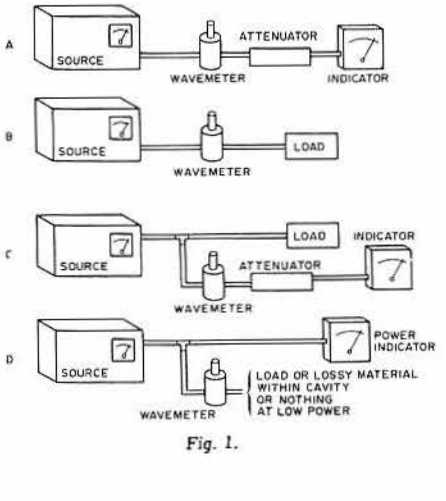

Fig. 1.

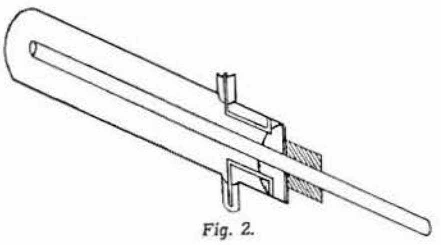

Fig. 2.

Another method in the use of the open circuited transmission line calls for the use of an additional circuit, as in Fig. 3. The circuit is a simple crystal diode detector connected to a microampmeter. The diode and condenser are usually built into the connector, as the leads should be kept as short as possible. The half wave length measurement is made on the rod between two successive maximum readings on the meter, as the rod is inserted or withdrawn. See Fig. 1A and 1B for the setup.

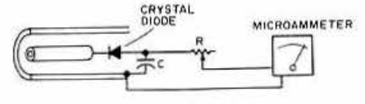

Fig. 3.

The quarter wave coaxial cavity is actually a shorted coaxial line one quarter wave length long (Fig. 4, 5, 6). As illustrated in these figures this type makes a very good cavity to use as a standard. To calibrate, a chart is made of the micrometer settings at different frequency wave lengths from a calibrated source generator. Don't tell them so, but the Public Relations Department of the Telephone Company may help you here, if they have any microwave technicians close by. The quarter wave coaxial cavity can be either physically open or closed. If closed, the closed end should extend at least a quarter of an inch beyond the center conductor at its lowest frequency. The closing of the end will lower the resonate frequency. Probe (capacitance) coupling as used for coupling in Fig. 5 will shorten the center conductor, and loop (inductive) as used in Fig. 4 will lengthen the conductor. In Fig. 4 we change the length of the center conductor to change its one quarter wave length. In Figs. 5 and 6 the center conductor remains the same, and we change the resonate frequency by capacitance. This method makes it necessary to construct the center conductor very short as compared to the full quarter wave length as in Fig. 4. These devices are not longer, so caution must be used when calibrating. The closed wavemeter as indicated in Fig. 7 is a shorted coax line at each end. The wavemeter uses a shorting plunger which is movable along part of its length. If used as the quarter wave coaxial cavity, the center conductor must be longer than a quarter wave length.

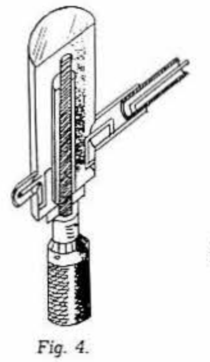

Fig. 4.

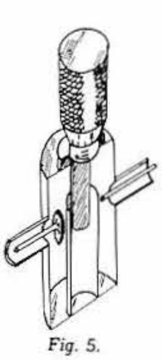

Fig. 5.

Up to this point we have covered most of the wavemeters that could be used from around 144 MHz up to approximately 3000 MHz. 1000 MHz to 3000 MHz are usually called the lower microwave frequencies. If the inner circumference of the outer tube is kept less than one wavelength, these wavemeters will operate in the desired TM mode.

There are four ways to couple energy into a wavemeter, loop (Fig. 4), probe (Fig. 5), direct (Fig. 6) and slit (Fig. 8). The most commonly used is the loop, as it has very little effect upon the electric field. The usual methods for changing loop coupling is to change the size and orientation of the loop. Loop coupling is usually placed in the high current area of the wavemeter. Capacitative coupling is changed by the size of probe and the distance from the center conductor. Capacitative coupling is usually placed at the high voltage portion of the wavemeter. As in Fig. 5, a small probe – say ½ in. piece of No. 22 wire, for example – may require an external voltage amplifier. The smaller the probe, the less effect on the resonate fre-

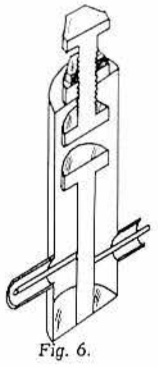

Fig. 6.

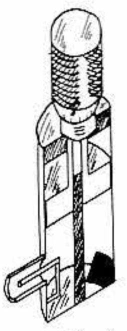

Fig. 7.

quency of the wavemeter. In direct coupling as in Fig. 6 the primary concern is impedance. To increase the impedance, move the coupling up the line away from the shorted end. To decrease the impedance, move the coupling down the line toward the shorted end. Slit coupling (Fig. 8) can be a small hole or a series of small holes or a slit. Its purpose is to allow a certain amount of leakage. In all forms of coupling, it is desirable to use loose coupling, as the wavemeter will have less effect on the system, and the Q of the circuit will be higher.

Above 3000 MHz, usually only the tunable wavemeter is used. The cavity is one quarter wave length long. The cavity can be coupled in three ways: loop, probe and slit. Because of the high frequencies, the slit is usually used, and the meter is most often kept as an assorption meter. In the assorption method, the wavemeter should be detuned when not in use. Some of the cavity wavemeters have a little lossy material added to absorb some of the energy, as in Fig. 7. Lossy material can be made from graphite impregnated cloth in epoxy.

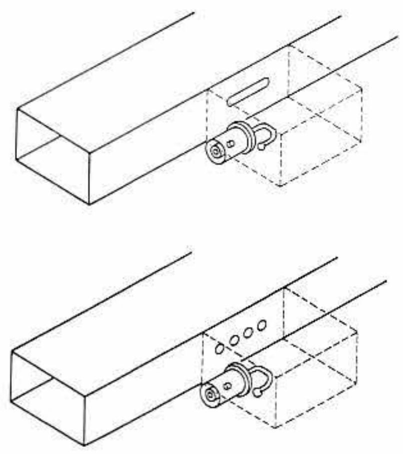

Fig. 8.

There is one other type of wavemeter that can be briefly mentioned; it is the reference wavemeter. The reference wavemeter is of any design as described, but would be constructed more like Fig. 6. It can be locked when adjusted to a selected frequency and used as a reference standard. The micrometer assemblies can be made from any micrometer with additional parts welded on. I constructed one using an oversized tube over the main cavity, and dimpled it at various places around its circumference until it fit smoothly over the cavity, and I used a piece of 3/8 threaded brass pipe as the main adjusting screw. I am sure you can come up with a good one without any backlash. This wavemeter spread the 1250 MHz band out to over 100 inches by rough measurements. I haven't calibrated it, so I can't say for sure just how far. There are three nice veeder root counters in the APX 6 which would make excellent wavemeters plus sliding contact material. One could even use the entire cavity.

The last method of microwave measurement that we will look at is the slotted line (Fig. 9). The slotted line is a section of coax line along which is cut a slot. A probe, which is a simple crystal detector with a one quarter wave length shorted stub for a dc return path, is moved along near the center conductor of the slotted section. In this case we are looking for two successive minimum readings along the line. The distance between these readings is one half wave length. A slotted line should also be calibrated. If calibrated at one spot near the intended frequency to be measured, a chart will not have to be made – just a K factor obtained. The distance between two successive readings times the K factor should equal the frequency half wave length. There are a few accessories that can be either built in or used externally. One is a coax attenuator shown in Fig. 4. It will slide in and out of the other half. It too can be calibrated if one wishes. A 50Ω resistor can be used for an impedance match for 50Ω lines if inductive coupling is used such as in Fig. 10 and when the loop is small. The line stretcher (Fig. 11) is useful with the slotted line. It merely consists of two coax sections, one sliding into the other.

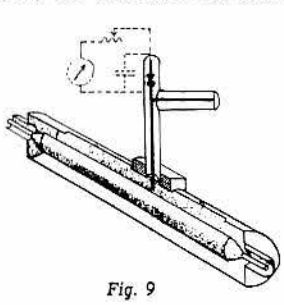

Fig. 9

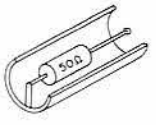

Fig. 10

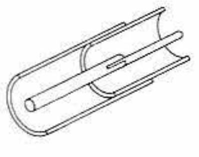

Fig. 11.

FREQUENCY METER – 1 to 10 GHz AMATEUR MICROWAVE

Bill Hoisington K1CLL

A quarter wave coaxial cavity is used up to about 5 ghz, and from there to over 10 ghz the three quarter mode is used. A complete explanation of these types of operation is given.

The same type of unit can be used as a very good tuned mixer from 1 to 10 ghz.

The Coaxial Cavity

The basic circuit of the coaxial cavity is shown in Fig. 1. A cylindrical outer cavity wall encloses a round rod some 4 inches long which is the center conductor–this center conductor is grounded at one end.

The Shape of the Cavity

The exterior shape of the cavity is shown in Fig.2. and is seen to be rectangular in cross section, with two thin walls and two thick side walls. Believe me, this configuration was not arrived at in one day! De-

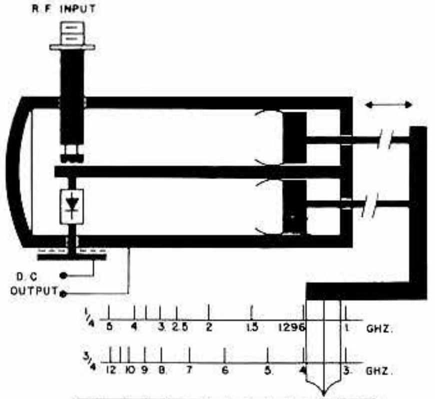

R F INPUT
D.C OUTPUT
1/4 5 4 3 2.5 2 1.5 1296 1 GHZ
3/4 12 10 9 8 7 6 5 4 3 GHZ
C M 1 2 3 4 5 6 7 8 9 10 11 12 13

Fig. 1. Basic coaxial cavity.

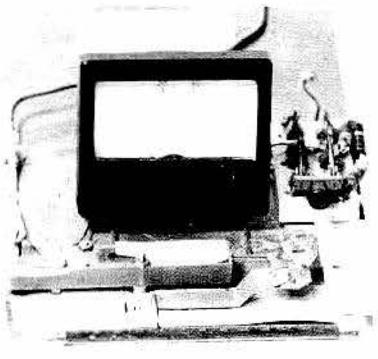

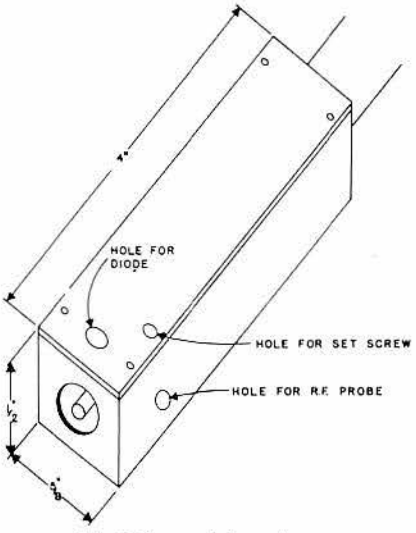

Fig. 2. Shape of the cavity.

signing tuners for X Band, I gaily started in with sections of thin-wall round pipe, the way I'd always done on uhf. The first thing you run up against is, how do you make the diode bypass capacitor? Machine out a curved saddle piece to fit exactly over the outer wall? Possible, but too expensive. And then how do you introduce the rf probe coupling into the cavity? Add on a "saddle" with a hole in it? These considerations and others, such as mounting (more saddles?) led to the abandonment of the pipe as a shape for microwave cavities; but not until a lot of time had been spent on the above mentioned items.

Diode holder and capacity

Looking at **Fig. 3.** you will see the first answer arrived at; but only after weeks and weeks of making different types and shapes. The center conductor is slightly flattened and drilled out to fit the diode prong. An 8/32 copper machine screw is drilled out to fit the other prong, then slotted with a fine jeweller's saw, and then compressed slightly to an inside diameter a shade less than the OD of the diode prong. In this way the copper screw will hold the diode as you insert it into the cavity. Believe me, that helps!

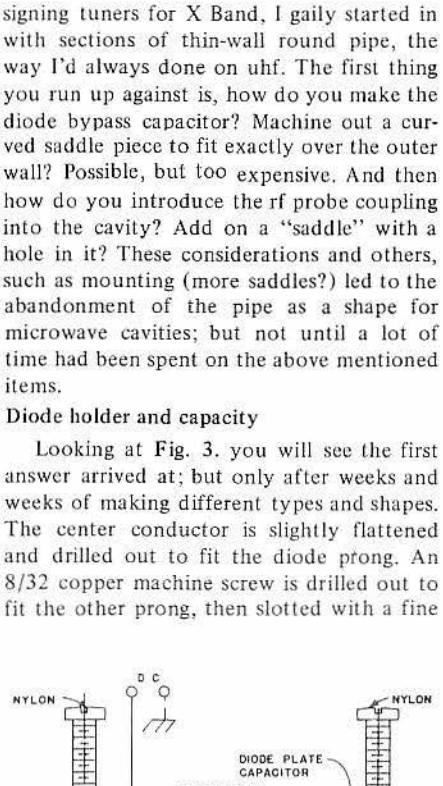

Fig. 3. Diode holder and capacitor.

The second answer is also evident from **Fig. 3.** as the diode bypass capacity can now be made efficient at X-Band. As mentioned before, you cannot "buy" a capacitor "good for X-Band. You can make it though, as shown in **Fig. 3.**, if the cavity body has been designed correctly for it. One of the thin wall sides of the cavity is drilled out (or machined out) just wide enough to clear the diode and it's holder, which is the 8/32 copper screw. The copper capacitor plate, which is thick enough to take at least a half dozen 2/56 threads, is drilled and tapped for the 8/32 screw, and clearance drilled in the corners for the 2/56 mounting screws. A soldering lug for the dc connection is used under one of these, and a three mil (three thousandth of an inch) thick sheet of fiberglass cut out to fit, larger than the plate. This helps to keep metal particles from lodging inside the tiny crack that might be there if the fiberglass sheet did not extend out beyond the plate all the way around. You can begin to see some of the detail needed at X-Band.

Further reasons for the rectangular cross-section now show up in **Fig. 4.**, which details the rf probe connections. This item was also very troublesome in first models using pipe walls, where "more saddles" was the only solution. All "saddles" are eliminated by the rectangular shape. Small semi-rigid cable is used for the connector. I have some short lengths with X-Band antennas connected to them for use as "In-Space" pick-ups, feeding directly into the wavemeter cavity. There is at times an advantage in this type of "energy collection" (antennas) which will be taken up later.

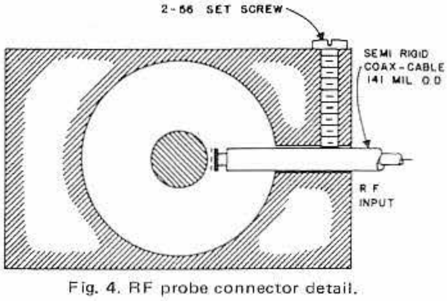

Fig. 4. RF probe connector detail.

Fig. 5. shows detail of the treatment of the cavity end of the rf cable, or probe. The outer conductor is cut away for about one quarter inch in length and removed. About a sixteenth or so of the Teflon is left, which is then removed from the center conductor. A thin copper washer (which I generally cut out of sheet copper since the hole to solder the center conductor is quite small) is then soldered to the center conductor, making the "capacity probe", as shown in **Fig. 5.**

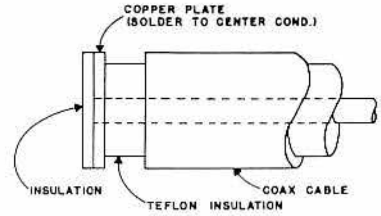

Fig. 5. RF probe detail.

Mylar tape or other good insulation is fastened to the side of this washer facing the center conductor. With this insulation in place you can push the probe all the way in, while testing, and still not have a dead short. Different thicknesses of fiberglass sheet can also be cemented on, to make up more permanent types of fixed capacitors, of different values.

For some uses, particularly in this one as a wavemeter, loose coupling is desired, but it must be securely locked with the set screw, otherwise your dial calibration and frequency reading will suffer.

Plunger fingers

Here is the most difficult item. It is hoped to have stock pieces made up for this work that you can purchase at reasonable cost. The fingers should be made of tempered beryllium-copper, which is not easy to work with.

Fig. 6. shows some details of the plunger and fingers. I assume, having been told so by "well-informed sources" (mechanical engineers) that these units should be made in a machine shop by competent machinists. Maybe so, as the ones I have made here in the shack by hand tend to lose their tension if not handled carefully.

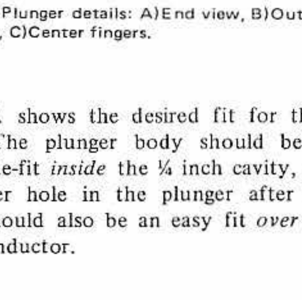

Fig. 6. Plunger details: A)End view, B)Outer fingers, C)Center fingers.

Fig. 7. shows the desired fit for these fingers. The plunger body should be an easily slide-fit *inside* the ¼ inch cavity, and the center hole in the plunger after the fingers should also be an easy fit *over* the center conductor.

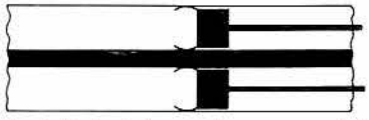

Fig. 7. Desired shape and curvature of the plunger fingers.

Two steel push rods lead back from the plunger through small holes in the back end of the cavity (see **Fig. 1.**); these terminate in the brass block which is furnished with a pointer for the frequency scale. Maximum extension of the plunger should be up against the end piece, as a positive reference point for the dial, in case of trouble after calibration. This point should be indicated on the scale as "minimum frequency" in order to reset the pointer if it should ever become displaced after calibration.

The diode

At present, the diode used is an X-Band "pill package," with a prong at each end as shown in **Fig. 3.** These are point-contact diodes, like the famous 1N23 ceramic cartridge types of World War II fame, only a lot smaller. Referring again to **Fig. 3.** always make sure that the ceramic part of the diode is, as nearly as possible, in the open space between the inner and outer conductors. This space is where the rf is! It is also important to make sure that there is as much metal surface continuity as possible along the cavity wall, across the fiberglass sheet X-Band capacitor insulation onto the diode capacitor plate, and from there over to the diode holder and onto the metal end of the diode.

The rf is at a maximum between the inner and, outer conductors, which is an air space of a sixteenth of an inch. and that is where the diode should be.

The diode rf bypass capacitor, formed by the diode plate and the flat top of the cavity body, need only have a capacity which is relatively small; anything over about 20 pF is sufficient. What it *must* have is the proper *lack* of inductance! The details of how this act has been covered in previous paragraphs, and if you follow those details you will find little or no rf on the *outside* of the diode capacity plate or the dc lead from it.

X-Band is not just short waves. It is really short; like a quarter wave at X-Band equals 9/32 of an inch as you can plainly see, if you get one (or more) of those little plastic millimeter rulers in a stationery store for 5 or 10¢. Be sure and get some, by the way, if you're going to do anything above two meters.

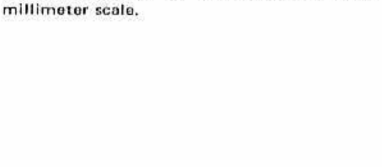

Fig. 8. Full waves for S, C and X-Bands on millimeter scale.

Fig. 8. shows the millimeter scale, with s, C, and X-Band plainly showing.

A handy wavelength-frequency chart is included here for your convenience, which is useful from the khz range way up *above* X-Band. See **Fig. 9.** Get to know the easy reciprocals, like 1 centimeter equals 30,000 mhz, 3 centimeters equals X-Band, 10 centimeters equals S-Band (3,000 mhz), 1,000 mhz equals 30 centimeters, etc. Very useful!

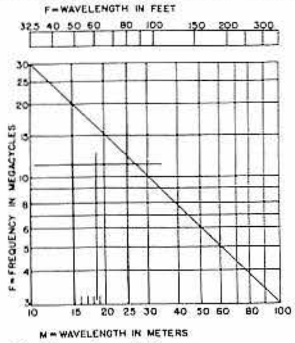

Fig. 9. Wave-length/frequency converter. Use of multiplying factors such as those at the bottom of the graph will cover any portion of the electromagnetic-wave spectrum.

The 3/4 mode and harmonics

Don't worry about that word "mode." Generally when something odd takes place in a cavity or waveguide, certain types of engineers tend to fall back on obscurantism (I seem to have fallen for that $64 word. It just means covering up). They say, "It jumped mode", or, "Spurious showed up."

Here's the straight dope. **Fig. 10** shows the quarter wave "mode" of operation. Starting at 1 ghz you will find *one* point of maximum dc output. If the oscillator under measurement is "running hard" with lots of 2nd and 3rd harmonic energy content, these will be found at 2 and 3 thousand megahertz, and possibly higher ones, which should drop steadily in power as you go up. The diode itself may cause some of these if hit too hard with the rf input.

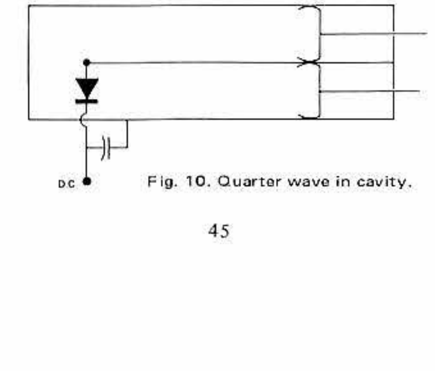

Fig. 10. Quarter wave in cavity.

Fig.11. shows the 3/4 wave mode, which is a very "natural" type of operation. Don't forget that in an instrument of this,kind you are looking for standing waves and you want them to be of the greatest amplitude possible (within reason). So, if you tune the cavity by the plunger so that it measures some three quarter waves on it (allowing for length-loading of the diode on the first quarter), you will find two peaks on the meter due to the situation shown in **Fig.11.** The higher the Q, and the lower the losses along the line, the more quarter waves can be found. For the 4 inch cavity shown, three quarter waves at S-Band are the longest that will fit.

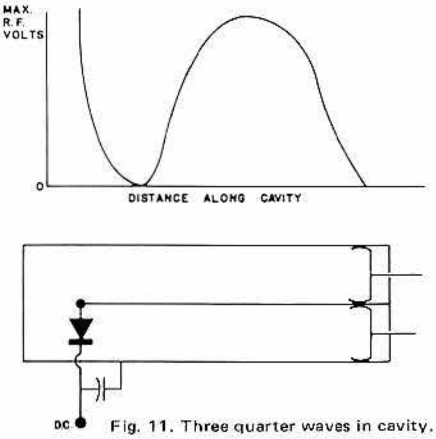

Fig. 11. Three quarter waves in cavity.

A check on this operation is easy. Using the millimeter scale on the "dial', take several readings between maximums, for example, 22, 37, 51, and 67, add the spacings together, which comes to 45 millimeters, divide by three (the number of samples), and you will find an average of 15 millimeters for the waves which are standing on the center conductor (or "along the cavity", if you prefer) and there you are, 15 millimeters for the half wave, 3 centimeters for the full wave. Which is X-Band at 10,000 mhz or 10 ghz.

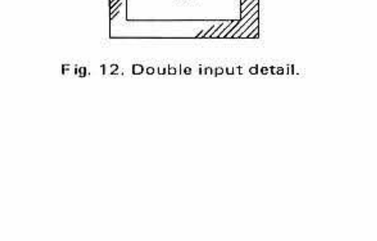

Fig. 12. Double input detail.

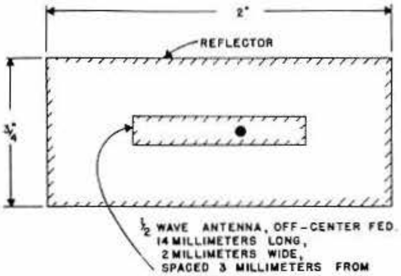

Fig. 13. Test antenna—X-Band "two-element".

If you find numbers which are not well known, you can find the frequency on the chart, at least close enough to put you in one of the microwave amateur bands, such as 5,650 or 10,500 mhz.

Use as a Microwave Mixer

This same type of cavity can be used from 1 to 10 ghz as a mixer for the front end of a superhet receiver covering those frequencies.

This application will only be touched on briefly here as the whole receiver is detailed in another article in *73 Magazine*.

Fig. 12. shows how to do it, so you can plan on this use, and make more than one, if you wish to.

Looking at Fig. 12., you can see how useful it is to have *two* thick sides on the cavity, one for rf input and one for the local oscillator input.

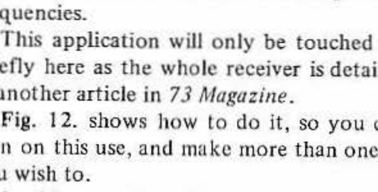
CENTER CONDUCTOR INSIDE INSULATION.
1$\frac{3}{8}$
1$\frac{3}{8}$
SLEEVE CONNECTED ONLY TO OUTER CONDUCTOR.
SEMI-RIGID COAX.

Fig. 14. Test antenna—S-Band. Dimensions suitable for amateur S-Band 2,400 mhz (omni-directional).

Conclusion

That about covers the details and some uses. The whole unit can be mounted on a piece of copper-clad, along with a 50 ma meter, the dial scale, and the centimeter-frequency chart. I broke down on this one and used a "regular" small microwave input connector for the rf. (Instead of an "RCA Phono Jack".) For connections to other units, such as oscillators and multipliers, small flexible cable may be used.

Fig. 13 shows a test antenna for X band, not the best in the world but good enough for a starter. With a lens in front it really picks up signals. Fig. 14 shows an S band antenna for the 2,400 MHz amateur frequencies.

LAMBDA LINES

James Ashe W2DXH

Over the past few years, new kinds of commercial gear and military surplus have made it quite easy to generate VHF frequencies. But the problem of measuring the frequencies has not become any easier for amateurs short on calibrated instruments. Of course this means the newcomer to VHF! What can he do to find what ballpark a circuit is radiating in, if there are no accurate devices available? When this problem came up recently, a simple solution appeared quite by accident. It was so simple, in fact, that its simplicity must be the feature that has kept it out of the ham publications. Another first for 73!

The traditional solution to the rough frequency measurement problem is to make up a Lecher Wire system. There is some question about the value of one of these in the modern ham shack. Narrow-band crystal-controlled techniques guarantee frequency and stability once the multipliers are tuned properly. In the old modulated oscillator days things were not that stable . . . so why go to all that carpentry and construction work for what fairly well promises to be a use-it-once gadget? Particularly when a little reflection (pun intended!) may bring out a cheaper, faster and better arrangement?

Ham and commercial builders of VHF gear have been using tuned stubs for years to match impedances, tune out frequencies, tune in others, etc. Yet it seems to have occurred to very few workers indeed that it might be possible to cut stubs to length accurately enough to serve as frequency standards. Apparently this can be done, with an accuracy of about 5%! This compares very favorably indeed with the performance of lower-frequency grid dip meters and some signal generators. It's pretty good for a pencil and yardstick operation: the only other items required are some understanding of how it works and a piece of 300 ohm twin lead. Belden #8235 recommended. You can calibrate that new GDO for 432 at a cost of just a few cents!

Theory

Many kinds of things show a property of tuning sharply to a certain frequency. This property is called resonance. We hear it when a struck piece of metal rings, and see it in the pendulum of an old grandfather clock. The grid dip meter shows a drop in grid current of an oscillator when a nearby resonant circuit steals energy from the oscillator. And it is the nearby resonant circuit that is the subject of this article.

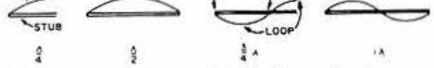

Fig. 1. Four kinds of tuned stubs, taking their fundamental resonances as the frequency producing the illustrated voltage distribution. This shows that none of them has a unique resonant frequency.

The basic circuit is the quarter-wave stub. A little browsing around in the handbooks and earlier issues of 73 and other ham magazines will tell you lots about quarter wave stubs. The important practical points are that the stub resonates at certain frequencies, and that at these frequencies it can be dipped at its shorted end in the same way as any other resonant circuit.

But the term 'quarter-wave' has to be taken with a grain of salt. The tuned stub will be shorter than a free-space quarter wave, because the dielectric has a slowing-down effect on the rate at which the RF bounces end-to-end along it. Suppose you laid out a mile or so of twin-lead and transmitted a signal, at the same time sending off a reference signal by space wave. The reference signal would arrive at the other end first, in about 5.35 microseconds. The twin-lead signal would arrive a full microsecond later, about a 20% delay. Since this applies even to short lengths of twin-lead, the delay must be taken into account for accurate measurements. Also, there is a considerable difference in velocity factors between different brands and qualities of twin-lead.

Crystals are often used in overtone oscillators for generating stable VHF frequencies. The various modes of oscillation are pictured in the handbooks. Tuned lines will also show overtone resonances, and in the case of large uncertainty, it might just happen that reasonable errors could lead to a consistent but very wrong result. A halfwave line will resonate at a frequency f, and also at 2f, 3f, and so on. Note both odd and even multiples! All other resonant lines have a similar overtone resonance property. The problem is slightly aggravated by the convenience of using relatively long lines at the higher frequencies because they are easier to handle. The solution is to cut a pair of lines whose collections of resonant frequencies have only one resonance in common. The recommended lengths are a halfwave and a three-quarter wave line.

Fig. 1 shows four basic tuned lines. Just which resonance is an overtone and which is not depends somewhat on the application. The simplest way out of this problem in semantics is to say that the three-quarter wave line really doesn't have that resonance at f/3, ignore the quarter and fullwave lines, and stick to the remaining two for test work.

At 432 MHz a wave in free space is about 27.3 inches long. Suppose we are using Belden #8235 twin lead, which Belden says has a velocity factor or propagation constant of 0.77. The twinlead wavelength than is 27.3 times 0.77 or 21 inches. The halfwave stub must be 10.5 inches long, shorted on both ends; and the three-quarter wave stub 15.75 inches long, shorted at one end. These are convenient lengths, not too long to use on the workbench, nor so short that percentage accuracy in cutting becomes a big question.

Using the stubs

The commercially available grid dip meters are not noted for accuracy. It's commonly estimated that the scale calibration can be

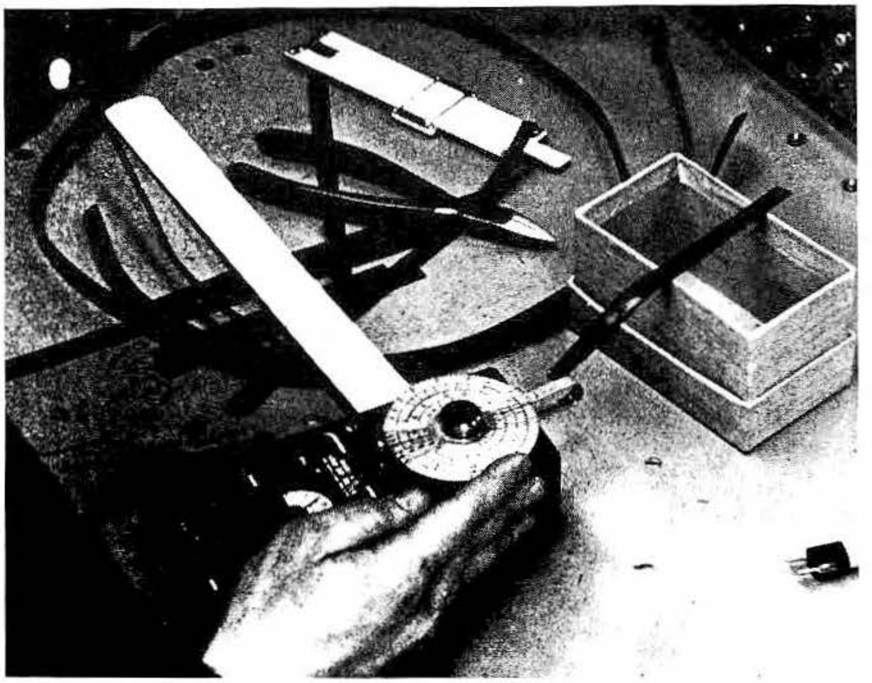

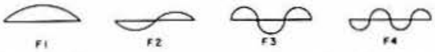

Fig. 2. Some overtone resonances of a halfwave stub (shorted at both ends). F1, F2, F3 and F4 should be 1F, 2F, 3F, 4F.

trusted to within about 20%. With some care, calibration points taken from twin-lead resonators appear to be good to about 5%. The first precaution is accurate construction. Cut the strips slightly long, short one end of each, and cut the three-quarter wave line to length. Then go more carefully at the other end of the halfwave line, which must be shorted at both ends. It should not be too hard to get the correct lengths within one sixteenth inch.

When making frequency checks, the lines must be held off the workbench an inch or two. Use small boxes or pieces of cardboard. Probably the better part of a foot distance is in order if the workbench is of metal or has a copper surface. At two meters, a perceptible change in calibration can be detected if the line is laid out on a wood surface! It's very good practice to make up lines for two meters or lower, and practice dipping them. Some refinement of technique will certainly be required before a halfwave and a three-quarter wave line can be made to dip at the same point on a standard dip meter. Once the trick is mastered, it can be carried up to the higher frequencies.

The lines are dipped in the same way as any coil. Because they have a very high Q, there will be a tendency for the dip oscillator to pull, or to seem to give different readings when tuning down to frequency and tuning up to frequency. The remedy is less coupling: move the dip meter a little further away from the line and try again. Dip the stub at its shorted end!

But what was that trick for calibrating a dip oscillator, mentioned earlier? Can't make up a pair of lines for each frequency. No need to! That's simply the reliable way for finding the right ballpark. When you're there, you can set the lines aside, make up another three-quarter wave resonator cut for the lowest frequency, and after marking that point on the scale, trim the stub up to the next calibration frequency. Throw the remainder away when done calibrating.

The half-wave stub is also useful as a tuned coupler. Suppose you want to tune an oscillator to a particular frequency but have nothing to indicate at that frequency. Loosely couple the RF into one end of the half-wave stub, and take it out the other end with a hairpin loop, through a diode to a 50 μA meter. You will only get a reading at the resonant frequency of the half-wave stub. Simple!

Chapter V

RF Signal Generators

ZERO-BEATING WITH A FREQUENCY METER

Jim Harrison WB4TBX

After putting an LM-18 in service, I found it a nuisance to plug in headphones every time it was necessary to adjust the corrector control to produce Zero Beat at one of the crystal check points. I hooked up a phone plug to the plate winding of an audio output transformer, and then connected a small loudspeaker to the secondary winding. I leave the phone plug inserted in the LM phone jack at all times. After using this setup for a while, it occurred to me that the last few cycles either side of zero beat might not be audible, so I tried a parallel hook-up off the primary side of the transformer. The other end of the cable was connected to the Vertical input of an oscilloscope. Now, when adjusting the corrector control for zero beat, you will see low amplitude sine waves even after you can no longer hear the beat note. You tune out the sine waves until you have a perfectly straight reference line on the scope. The Heterodyne oscillator is then corrected to calibration much more accurately than trusting to the ear alone. The principle is not new, yet the idea may not have occurred to some people. Any old scope will do, as the frequencies are in the audio range.

Another bit of frustration occurred when trying to adjust the corrector knob. I would pass the zero beat point time and time again, due to the stiffness of the control. Remember, these units are built for ship-board use, and loose controls cannot be tolerated. I dug up a small vernier tuning drive, similar to the Jackson Planetary-Vernier drive, (about 5 to 1 ratio). I mounted this drive on a right-angle aluminum bracket and attached it to the LM using the two screws on the upper right side of the unit. Bore holes slightly oversize to allow for accurate alignment of the control shaft so that it will not bind. Cut out a portion of the bracket so the "High-Low" knob can be moved. The precise Zero beat adjustment can now be made very easily with the reduction drive.

HAND CALIBRATE THE BC-221 FREQUENCY METER

Carl Henry

At present many amateurs have an opportunity that may not repeat itself. I refer to the many army and navy surplus frequency meters now available, through MARS and surplus sales. Many of these meters have the original calibration chart missing, and are considered virtually useless. This is demonstrated graphically by prices, the frequency meters with charts costing $100, the meters without charts selling for one-third this amount. Meters without charts are worth more than this would seem to indicate. It is no great job to calibrate one of these meters, but it is time consuming. A little care is required, but you do not need to be a super technician or electronic engineer to do the job. Neither is elaborate equipment required.

Essential to the calibration are several items not commonly available around the shack, but easy to build. Figure 1 illustrates the first requirement. This is a 10 kc multivibrator, which will operate from a 100 kc xtal calibrator, and give 10 kc markers up to 20 mc. I am assuming here that you have or can beg, borrow, or steal a 100 kc calibrator, this being a common item. In fact, some receivers have them built in. Using this 10 kc marker source, the high band of the frequency meter can be calibrated. Interpolation to 1 kc points is then possible, and if care is used an accuracy of better than 0.005% will result.

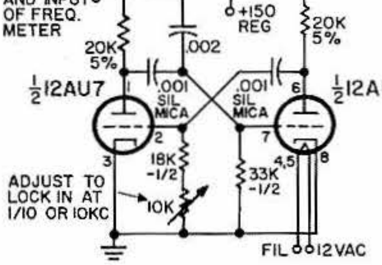

Figure 1. 10 kc multivibrator for use with 100 kc crystal oscillator, providing 10 kc beats with frequency meter.

Fig. 2 shows a simple beat detector that can be used with earphones to get an exact zero beat. It took about ten minutes to wire up a 1629 (army surplus magic eye tube) temporarily for this purpose, and it is certainly worth while in the interest of increased accuracy.

With your equipment assembled, connect the frequency meter to its power supply. Allow at least one hour for proper warm-up so that all equipment will stabilize, including the 100 kc calibrator and 10 kc multivibrator. Set the CALIBRATE control on the frequency meter to center, and be especially careful not to move it until the calibration is complete. After the warm-up period the 100 kc calibrator should be zeroed against WWV, at as high a frequency as possible. The 10 kc multivibrator must be checked to see that it gives nine beats between each 100 kc beat. This can be done with your communications receiver, and it will be easiest to do it on as low a frequency as possible, say 600 to 700 kc. Now type several sheets of paper, listing the high range of your frequency meter by 10 kc points. If you are in doubt as to the range, check it with your receiver. To do this set the dial to the low end of its range, turn on the internal xtal, and zero in on the strongest beat at or near the low end. Turn off the internal xtal oscillator and find the signal from the frequency meter with your receiver. Note the frequency. Tune your receiver until you reach another harmonic from the frequency meter. The difference between the first and second readings is the frequency of the meter at the low end

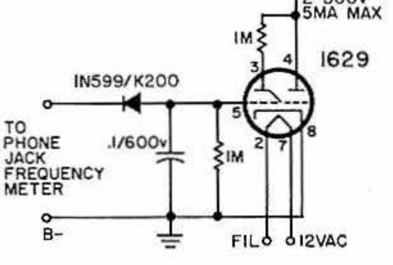

Figure 2. A simple zero-beat indicator for use in conjunction with headphones.

of its dial. Now do the same thing at the high end, and you have the primary coverage of your frequency meter. Most have a range of 125 to 250 kc on the low band and 2 to 4 mc on the high band.

When you write up the frequency range by 10 kc points, leave a space between notations, since you will be adding information here later. Now, using the 100 kc xtal, check the high band of the frequency meter at 100 kc points, listing the dial readings. Now go back and check the dial at 10 kc points, listing all the dial readings. The checks should agree with the 100 kc checks at every tenth point. This is a handy method of cross checking yourself. You might note that on equipment of this type, always approach the final reading from below. If you pass the zero beat point, don't jockey the dial back and forth for zero beat. Go back below the beat by 5 kc or so and approach again from below. This procedure will help to eliminate error from dial backlash.

After your 10 kc points are all listed, interpolate to 1 kc points. This is the hardest part of the job, and is very time consuming. A big pot of coffee and a patient and loving XYL will be a big help here. The patient XYL can be replaced with an adding machine if you have one available, but you'll still need the coffee.

The difference between each 10 kc point must be listed. Note this in the space you left on your sheets. Each 1 kc will be 10% of this, so add 10% to the 10 kc listing for 11 kc, 10% more for 12 kc, 10% more for 13 kc, and so on. When you reach the next listed 10 kc point, the calculated listing and the measured listing must agree, another cross-check. This will take 2000 individual additions.

After the high band is finished, you may wish to calibrate the low band in the same fashion. Referring to Figure 1, change the grid-plate capacitors to 0.01 mfd. This will put the multivibrator at approximately 1 kc intervals. If you have trouble syncing the multivibrator, you may have to build another to operate at 10 kc, and sync the 1 kc from this. No trouble should be had with a strong output xtal calibrator, however. Calibrate the multivibrator as before, except with 1 kc intervals instead of 10 kc.

A calibration book can be prepared when you finish. It is a good idea to file all your original calculations and papers, should the book ever be destroyed. The frequency meter is now as good as any with original calibration book, at a good saving of money.

HIGH ACCURACY VHF FREQUENCY MEASUREMENTS

Howard Burgess W5WGF

Accurate frequency measurements can be a problem for the amateur with a limited budget. However with some home construction and careful operation the average ham can make VHF frequency measurements to an accuracy better than .00015% at two meters. This is the equivalent of measuring the distance from New York to Los Angeles with an error of only 25 feet. Many commercial units cannot equal this figure. The same method can also be used for HF and UHF measurements.

There are many ways to measure frequency but few of them are satisfactory for use at the very high frequencies. The well known hetrodyne frequency meter becomes unstable when its oscillator is operated at VHF. It can no longer be held or read to any degree of accuracy. The oscillator can be operated at a low frequency and one of the harmonics used at VHF, but any error in the oscillator will be multiplied by the number of the harmonic used. A frequency meter that can be held to within 200 hertz at 4 MHz will be off by 7.4 kHz at the 148 MHz harmonic.

A second method of much greater accuracy uses low frequency crystals which are referenced to a known standard such as WWV. The harmonics of these oscillators will be quite accurate and useful far into the UHF region. However this system has its limitations. Even when used with multivibrators and harmonic amplifiers it produces only spot frequencies.

Although neither of these two methods is satisfactory when used alone, they can be combined to make an accurate and versatile system. If you haven't guessed it by now, the system works like this. A crystal oscillator operates on 5 MHz. This oscillator can be kept to zero beat with WWV with very little effort. With a simple harmonic amplifier following it, strong markers are available every 5 MHz far into the UHF region. To fill in between the 5 MHz points, and get full tuneable coverage, all that is required is to add the output of a stable low frequency VFO to the proper marker. Example: To measure 146.25 MHz just add 1.25 MHz from a calibrated tuneable oscillator to the 145 MHz harmonic of the crystal. The same results can be had by using the 150 MHz marker and substracting 3.75 MHz.

The tuneable low frequency oscillator of this hetrodyne system can be any stable, calibrated, oscillator that will give the desired frequencies. A good signal generator can be used but better yet is the old faithful BC-221 frequency meter. The crystal oscillator that supplies the 5 MHz markers should be designed for high stability. However, even simple crystal-controlled units can be kept zero beat with WWV for periods long enough to make most measurements.

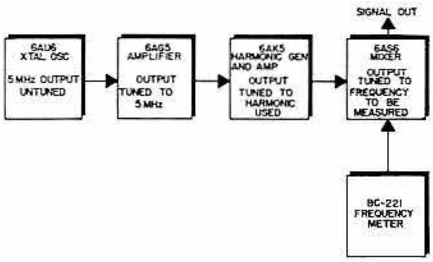
SIGNAL OUT
6AU6
XTAL OSC
5 MHz OUTPUT UNTUNED
6AG5
AMPLIFIER
OUTPUT TUNED TO 5 MHz
6AK5
HARMONIC GEN AND AMP
OUTPUT TUNED TO HARMONIC USED
6AS6
MIXER
OUTPUT TUNED TO FREQUENCY TO BE MEASURED
BC-221
FREQUENCY
METER

Fig. 1. Block diagram of the VHF frequency meter.

Earlier we quoted a figure of .00015% or better for the accuracy of this system. Perhaps we should show how this is possible. The crystal oscillator can be held to near zero beat with WWV but due to propagation errors in the signal of WWV, we can never be sure that our crystal is closer than 2 parts in 10 million. This would be 2 hertz of error at 10 MHz or an uncertainty of 29 Hz in the 145 MHz marker. The BC-221 is normally considered to be a .05% instrument. This would be an error of about 1.75 kHz at 3.5 MHz. However with care in calibration, and reading it is not difficult to reduce this value to 200 hertz or less. In a hetrodyne system the error of the VFO is not multiplied at VHF but is just added to the error of the crystal marker used.

The total error at 2 meters is 29 Hz contributed by the crystal and 200 Hz by the VFO for a total of 229 Hz. This is a little more than 1.5 hertz per million hertz for a tuneable system. Of course these values are approximate and with careful operation they can be reduced by 50% or more.

In the 146.25 MHz example used earlier, the VFO was required to furnish less than 1% of the total output. To put it another way, the only wobble is in the smallest cog and its contribution is so small it can't shake up the machinery too much.

The circuit shown in **Figs. 1 and 2** has been used for monitoring MARS, CAP, and several other services. The crystal oscillator is quite stable but can be tuned enough to zero with WWV. Tuning is done with C1. One stage of harmonic amplification is sufficient to give strong signals well above 150 MHz. The plate circuit of this amplifier stage is tuned to the harmonic to be used. This feeds one input

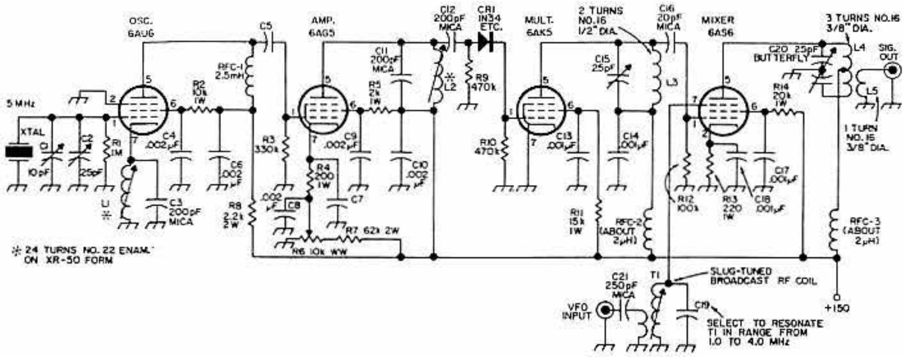
OSC.
6AU6
5 MHz
XTAL
C1
10pF
C2
25pF
R1
1M
L1
C3
200pF
MICA
C4
.002μF
R2
10k
1W
C5
RFC-1
2.5mH
C6
.002μF
R3
330k
R8
2.2k
2W
AMP.
6AG5
C8
.002μF
R4
200
1W
C7
R6 10k WW
R7 62k 2W
C9
.002μF
R5
2k
1W
C11
200pF
MICA
C10
.002μF
L2
C12
200pF
MICA
CR1
IN34
ETC.
R9
470k
R10
470k
MULT.
6AK5
C13
.001μF
R11
15k
1W
2 TURNS
NO.16
1/2" DIA.
C15
25pF
C14
.001μF
L3
RFC-2
(ABOUT 2μH)
C16
20pF
MICA
MIXER
6AS6
R12
100k
R13
220
1W
C18
.001μF
C17
.001μF
R14
20k
1W
C20 25pF
BUTTERFLY
3 TURNS NO.16
3/8" DIA.
L4
SIG. OUT
L5
1 TURN
NO. 16
3/8" DIA.
RFC-3
(ABOUT 2μH)
+150
C21
250pF
MICA
VFO
INPUT
T1
SLUG-TUNED
BROADCAST RF COIL
C19
SELECT TO RESONATE
T1 IN RANGE FROM
1.0 TO 4.0 MHz
* 24 TURNS NO. 22 ENAM.
ON XR-50 FORM

Fig. 2. Schematic of the oscillator, multipliers and mixer for using a BC-221 on the VHF ham bands.

grid of the mixer. The other grid of the mixer is driven by the output of the BC-221 frequency meter. The tuned circuit shown in this grid resonates broadly in the 2-4 MHz range of the BC-221. This helps to keep the higher harmonics of the BC-221 out of the mixer.

The output of the mixer is resonated to the desired operating frequency. This will be either the sum or difference of the two input signals. The level of the output signal can be controlled by R6.

Operation of this system is simple. The "cook book" would read as follows:

1. Couple the output to the antenna of the VHF receiver.
2. Determine the crystal harmonic and VFO frequency that will give the frequency of the signal to be checked.
3. Tune the VHF receiver to the signal to be checked.
4. Tune the BC-221 until the output of the frequency monitor zero beats the received signal.
5. If required, peak the tuned circuits in the monitor for maximum output and adjust R6 as needed.
6. The frequency of the received signal will be the crystal harmonic plus (or minus) the reading of the BC-221.

Many details cannot be covered in one story due to lack of space. The operator will have to determine the most effeceive method of coupling to this particular receiver. He will also have to explore the many combinations of frequencies which can be used. These and many other questions cannot be included at this time. However those who require such a system as this will probably be capable of filling these details.

One word of caution is in order. With two oscillators that are rich in harmonics, there can be many unwanted "birdies." These present no problem after the operator has gained experience but the new user should be very cautious. Many times an unwanted beat can be eliminated at a critical spot by changing the two frequencies that are being mixed (shift from sum to difference).

Perhaps we should emphasize that this system is a "trade off" where the amateur can trade his skill and patience for highly accurate measurements with simple equipment.

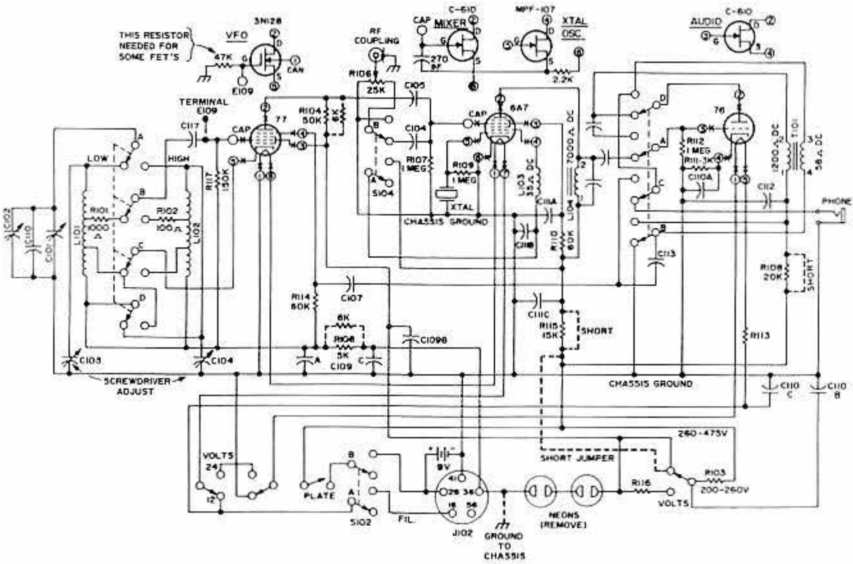
THIS RESISTOR NEEDED FOR SOME FET'S
VFO
3N128
47K
G
D
S
CAN
E109
TERMINAL E109
C117
CAP
77
R104 50K
6K
R106
25K
RF COUPLING
C105
C104
R107 1 MEG
S104
R109 1 MEG
XTAL
CHASSIS GROUND
C-610
CAP
MIXER
270 PF
MPF-107
XTAL OSC
2.2K
6A7
L103 35Ω DC
C118A
C118
L104 7000Ω DC
R110 60K
C-610
AUDIO
76
R112 1 MEG
R111-3K
C110A
T101
1200Ω DC
58Ω DC
C112
PHONES
C113
R108 20K
SHORT
R113
LOW
HIGH
R101 1000Ω
R102 100Ω
L101
L102
R117 150K
C102
C110
C101
C103
C104
SCREWDRIVER ADJUST
R114 60K
C107
8K
R108
5K
C109
C109B
C111C
R115 15K
SHORT
CHASSIS GROUND
C110 C
C110 B
260-475V
SHORT JUMPER
R103
200-260V
R116
VOLTS
VOLTS
24
12
PLATE
S102
FIL.
9V
J102
GROUND TO CHASSIS
NEONS (REMOVE)

Fig. 1. Modified schematic of frequency meter.

A TRANSISTORIZED LM METER

Charles Landahl W5SOT

The last word may never be written about the BC-221 and LM frequency meters. The LM is particularly attractive because it is in the smaller package. With transistors replacing tubes, it has features most everyone wants – it is rugged, portable, and accurate, to name a few. I will describe a conversion of an LM-15 frequency meter in which field-effect transistors replace tubes; the power supply becomes a standard 9V transistor radio battery and the current drain is less than 3 mA when all functions are energized. In addition, I offer calibration information which will be of interest to anyone having a BC-221 or LM without the official calibration book. I bought an LM-15 for a temptingly low price (Fair Radio Sales Co., Lima, Ohio, $14.95). The set is sold in the "as is" condition with tubes and crystal but without calibration book. It is a good idea, but not necessary, to start with a set which is working before making the change to FETs. Resistance measurements will show if the circuits are complete. Important values are marked on the schematic of Fig. 1.

Smash Tubes

The most difficult part of my conversion was getting up the courage to smash the tubes! I wanted the bases for mounting transistors. Place the tubes one at a time in a paper sack, hold the top closed and with a metal object, strike the glass through the paper. The flying glass is caught and collected for disposal. Scrape and clean the mastic from the inside of the tube bases. Should you choose to mount a transistor socket in the wall of each tube socket, you can use the original wires; otherwise, unsolder the old wires and replace the needed ones with about 2 in. of sturdy new tinned wires. The appropriate tube base pin connections are shown in Fig. 2. Actually there is no preferred mounting scheme. Use whatever appeals to you.

Check for clearance between socket and walls. My conversion used transistor sockets mounted on metal plates which were bolted to the wall of the salvaged tube bases. This allowed FET substitution to determine which ones would work best in the several circuits of the LM. All FETs used are N-channel.

Modification

With cover removed and the LM in the upright position, front panel toward you, on the left side wall, look through two oblong machined slots and see mounted on a phenolic board a 50 kΩ plate resistor. Parallel it with about 6 kΩ. Turn the LM upside down, panel toward you. On the underside, two resistors must be shorted and a jumper wire made up and connected. Short R115, which is a 15 kΩ wirewound resistor, quite visible on a phenolic board at the left of the 1000 kHz crystal can. Run an insulated wire from a terminal of this shorted resistor to the 260–470V tap contact of the link switch. This wire can be about 6 in. long and conveniently passes through a wall slot behind the crystal socket. The link switch and its terminals are on a phenolic board in the compartment aft of the crystal socket. The jumper wire will cross near the grid resistor, R109, of the crystal oscillator. While there, change the 100 kΩ (R109) to 1 MΩ. Next, unfasten the screws holding the phenolic board located to the left of the power plug. Tip up the board and short across R108. This is a 20 kΩ composition resistor which is in the plate voltage line to the audio amplifier. Also, at the power plug, locate pin 36. Short it to chassis ground. On most sets pin 36 is the ground return for the vfo cathode. The circuit was closed through external connections in a power supply. You have completed the surprisingly few changes needed to make the LM work on FETs and a 9V battery.

The VFO

With FET source connected to pin 5, drain to pin 2, can to pin 1 (if needed), plug the FET into the vfo socket. Connect a solid wire between terminal E109 and the gate of the FET. (Terminal E109 held the grid cap wire for the vfo tube.) Connect a 9V battery to the power plug pins. PLUS to 26 and MINUS to terminal 41. If you have a milliammeter in the battery lead, it should read about 1.5 mA when you turn on the FIL and PLATE switches. Provided you were fortunate in the choice of FET, you should hear a clear CW signal in your receiver. Set your receiver to 2 MHz or 4 MHz. You may need to connect a wire from the rf coupling post on the front of the LM to your receiver antenna. Rotate the LM dial between 0300 and 0600 on the readout. Your vfo will be on the low end of 125–250 kHz or 2–4 MHz depending on the position of the low or high band switch. The XTAL and MOD switches should be off. The FET selected for the vfo may require a 47 kΩ resistor between gate and chassis ground. I found this to be true for the RCA 3N128, 3N142,and *one* of the two 40559A FETs. On the other hand, one RCA 40559A and one of several 2N3085 silicon N-channel FET from Poly-Paks worked beautifully without adding 47 kΩ to the gate.

Apparently junction and insulated-gate field-effect transistors have slightly different characteristics which show up in this peculiar vfo circuit. My own choice is the 3N128 with the additional resistor on the gate. You may find it necessary to "tune" the source, drain, and gate resistances in order to have your vfo working well with a particular FET. I used potentiometers across the various elements to arrive at the recommended values. My vfo works reliably from 10V down to 6V and the maximum drain current is 1.5 mA.

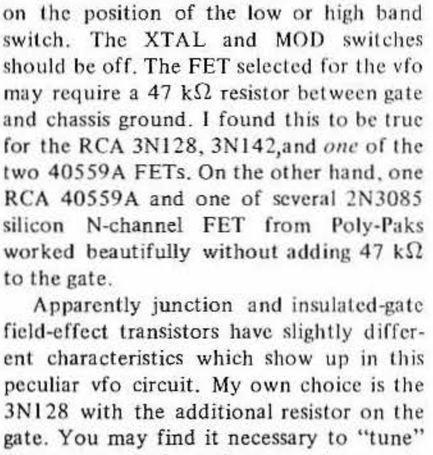

Fig. 2. Suggested semiconductor hookups for tube sockets.

Caution

Other oscillator hook-ups may occur to you, and they will work – but the tuning range and linearity of the vfo will suffer! Linear tuning is most important, so stick with that shown.

The AFO and AF Amplifier

The audio oscillator and amplifier wasn't as fussy as the vfo. I used a Radio Shack 276-664 FET – it is said to replace a C-610 or 2N3088. I found that the Poly-Paks "hobby" FET 92CU588 will work equally well. In making up the socket, gate goes to tube pin 3, source to cathode pin 4, and drain to plate pin 2. That is all there is to this one. Plug in the FET. When you next turn on the 9V power, the milliammeter will barely increase a few hundred microamps as you switch on the modulation control. At this moment a rather pleasant 500 Hz tone will appear on the vfo frequency no matter which harmonic you have tuned in on receiver. Your modulator is finished. The audio amplifier is too, for that matter. You just won't hear anything in the headphones until you complete the crystal oscillator and the mixer circuits.

Crystal Oscillator

The reference oscillator is not much trouble. You have already changed the gate resistor from 100 kΩ to 1 MΩ. Actually this change may not be necessary because some crystals are more active and will oscillate well with the original resistor. Mine went into oscillation better with the higher value. The FET you select for this circuit can be one of several. Mine is a Motorola MPF-107. I found the Radio Shack 276-112 and the Poly-Paks 2N3085 also work, but draw more current. Whichever you choose, the gate connects to base grid pin 5, source to cathode pin 6 *through* a 2.2 kΩ resistor. Drain hooks to plate pin 4.

Now, when 9V is turned on, MOD off, XTAL on, you should hear the crystal oscillator signal every 1000 kHz on your receiver. The milliammeter should increase about 1.5 mA or less when XTAL is turned on. If you don't hear the crystal frequency, bring the receiver antenna wire close to the crystal FET. We still haven't made the connection which adds the crystal-oscillator signal to the rf coupling post on the front of the LM. Assuming you have all circuits in working order up to this point, we move to the mixer.

Mixer

There is no single FET substitute for a pentagrid converter tube. The dual-gate MOSFET comes closest; however, use of one would have defeated my goal of simplest conversion. Therefore, four N-channel FETs are needed to do the work of three tubes, but what a saving in power supply! The mixer concerns itself only with beat frequencies occurring between the reference oscillator, vfo, or an external signal – all audio work. Thus, a hobby FET was selected. I used the Poly-Paks N-channel FET. A Radio Shack C-610 replacement will also work. Connect source to chassis ground through pin 6 of the tube socket; the drain connects to plate pin 2, gate to mixer grid cap wire through the lug in tube socket wall.

Finally, connect a capacitor (200–300 pF) from the top of the 2.2 kΩ crystal oscillator source resistor to the gate of the mixer FET (grid cap wire). You are in business.

With 600Ω phones plugged into the LM, you should hear all the necessary beat frequencies occurring between the vfo and the crystal oscillator as you tune the vfo through its range. XTAL must be on and the MOD switch off. Otherwise, the audio amplifier becomes the modulator and you hear nothing in the LM phones.

What Next?

With the beat notes loud and clear you are ready to calibrate. This is quite the most fun part of the work because the linear tuning rate of the LM is almost unbelievable. The slow rate is due to the series combination of the A section of C109, C101, tuning L101 or L102. The amount of the matter is that one revolution of the 100-division circular dial produces about 3 kHz change on 125–250 kHz range, and about 50 kHz per revolution on the 2–4 MHz range. The actual calibration of my unit was 2.89 kHz and 45.17 kHz per revolution.

The linearity can be checked by how little you need to vary the "corrector" for each zero-beat checkpoint. Each LM or BC-221 will be slightly different. Now, when you consider that the vernier allows you to split one division into tenths, then it is clear that you can set a frequency to better than 0.5 kHz over the range of the frequency meter. May I repeat:

1 dial revolution of
100 div = 45.17 kHz
1 division = 0.4517 kHz
1/10 div = 45 Hz

Therefore, all you need is a checkpoint at which to zero the vfo and start counting revolutions, divisions and tenths of divisions to accurately set any frequency within the two ranges of the vfo. I found it useful to construct graphs on K&E 358 11L graph paper. The grid is 10 X 10 (per 0.5 in.). The paper has 20 units vertical and 30 horizontal. This allows graphing 100 division and leaves room for 10 vernier divisions on the right hand end of the paper. Use the crystal checkpoints listed in Table I to locate *your* dial settings. Once graphed, a frequency can be selected directly from the chart, or, depending on the accuracy desired, interpolated between checkpoints.

Table I. Crystal Checkpoints

KHz	VFO	XTAL	Approximate Dial Settings
Low Band			
125	8	1	0320
150	20	3	1192
166.667	6	1	1750
200	5	1	2935
222.222	9	2	3700
250	4	1	4647
High Band			
2000	1	2	0396
2250	4	9	0945
2500	2	5	1493
2750	4	11	1050
3000	1	3	2606
3250	4	13	3150
3500	2	7	3711
3750	4	15	4262
4000	1	4	4812

It is obvious from this discussion that the low band of the LM is fabulous. You can squeeze down to about 3 Hz by use of the vernier scale. By the way, hidden behind two cover plates just beneath the corrector knob, are "high" and "low" padder capacitors. These were used when vfo tubes were replaced to bring calibration book values into usefulness. The padders should be set near the middle of their range.

Make it Handy!

Fasten a handle to the case, strap on a 9V battery, go forth and have fun with your rejuvenated frequency meter. I use mine for its intended purposes as well as a band-edge marker and keying monitor.

AN I-F SPOTTER

Howard Burgess W5WGF

If you have ever tried to find the *if* frequencies of unfamiliar and inoperative pieces of surplus gear with no schematic, it is a waste of time to tell you how rough it can be. Even a single *if* transformer from the junk box can be a problem if it has no part number or identification.

Of course in some cases a grid dip meter can be used to find the operating frequency. However, few grid dippers cover the important *if* frequencies below 2 mc. To complicate things, if a dipper is used on a shielded transformer above 2 mc, the resonant frequency of the transformer may be shifted if the shield is removed.

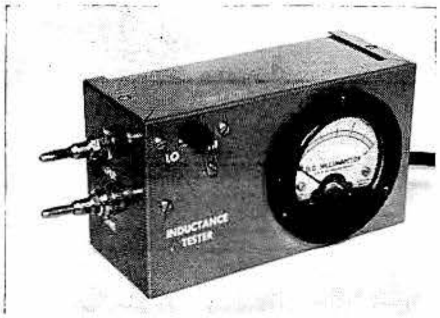

The if spotter. The switch for changing the coupling capacitor is at the upper left marked "HI" and "LO." The posts on the end are X1 and X2.

If these problems sound familiar to you, we would like to suggest a little gadget that can help solve them. With just two resistors, two capacitors, and a tube, don't expect it to give a digital read-out to all your questions, but it can put you in the ball park.

The principle of operation is as simple as the construction. The tuned circuit in question is merely made to oscillate at its resonate frequency. The frequency can then be determined by tuning in its radiated signal on the ham receiver. To set the unknown coil into oscillation requires the use of a simple "two terminal" oscillator. Such an oscillator is shown in the schematic of Fig. 1. When any tuned circuit is connected to the two points marked X, the circuit will oscillate at its resonant frequency.

In this oscillator the twin triode is a tube such as the 12AT7. The section V2 furnishes the necessary feedback and eliminates the need for extra coils or feedback connections.

The construction is simple. The unit could have been built in a larger case with its own power supply and would have become a nice piece of bench equipment. However, due to the few parts required and the small amount of plate power used (3 mils at 90 volts) it was built as an overgrown probe. The power is robbed from another piece of test equipment or the receiver.

As a probe it can be used on the work bench to test individual coils and transformers or it can be held in contact with the various transformers in a receiver.

There is only one point of caution that should be observed in construction. The lead from the grid contact of VI to the XI post should be kept as short and direct as possible with the least capacity to ground. This lead becames part of the oscillating tuned circuit and limits the upper frequency to which the unit will operate.

The coupling capacitor from the grid of V1 to the plate of V2 furnishes the feedback required to maintain oscillation. To reduce the loading on the tuned circuit, this capacitor should be held to the smallest value that will sustain oscillation. Because of the wide range over which this instrument operates, a switch is provided to change values. With the capacitors shown, operation is possible from about 60 mc down to well below 50 kc. The larger value is used at the lower frequencies and is switched in only when required. With coils of medium Q the switching point is around 3 to 5 mc.

The connectors X1 and X2 can be almost any kind of posts. The ones shown on the unit here are banana plugs. These can be used as test points, or alligator clips can be slid over them for use in clipping to coil leads.

The meter shown is a three mil meter and is used to read the total plate current of both halves of the tube. This will indicate when the circuit is oscillating. When the tester is not oscillating the meter will indicate a current of about 1 mil (with 90 plate volts). Under oscillating conditions the meter will rise to as much as 3 mils with a high Q coil. The actual amount of current is not so important as the fact that the upward shift indicates that the coil is not open and is oscillating. A 5 or 10 mil meter will serve the purpose just as well.

As the pictures show, this unit was built in a small 5" x 3" x 2" box. The unit will work just as well if it is built on a small piece of peg board with a couple of leads run out to the multimeter. This is for the man in a hurry.

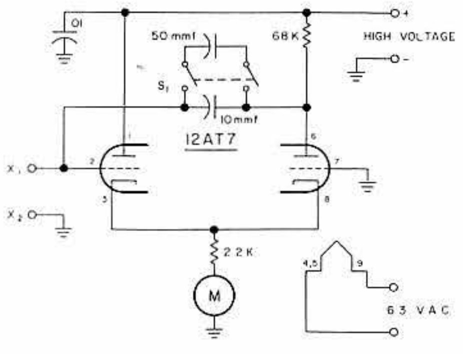

FIGURE 1

Circuit diagram of the if spotter

.01 Ceramic capacitor
50 pf Mica capacitor
10 pf Ceramic
68 K ½ watt carbon resistor
22 K ½ watt carbon resistor
Milliammeter in range of 3 to 10 ma
Slide action Double Pole-Single Throw switch (S1)
2 Banana plugs (x1 and x2)
12AT7 tube
Minibox (size depends on type of meter used)
9 pin miniature tube socket

When the unit is finished, apply power with the "X" points open (no coil across them). Because of the open grid of V1, the meter will drift about. After the tube has had time to warm up, short the X posts with a heavy piece of bus or copper. The meter will now come to rest somewhere around 1 mil. This is the "no oscillation" current and should be kept in mind as a reference point for future use. Now remove the short and connect almost any kind of an LC circuit across the posts. The meter reading will now rise from the "no oscillation" value indicating that the coil is oscillating. Do not use the large coupling capacitor unless the circuit refuses to oscillate with the smaller value.

To check a single *if* transformer, all that is necessary is to hook one of the *tuned* coils

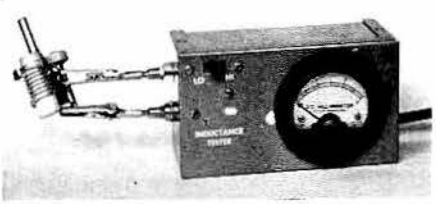

Checking a ten meter tank circuit

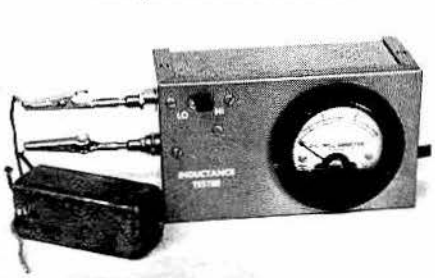

Checking an if transformer

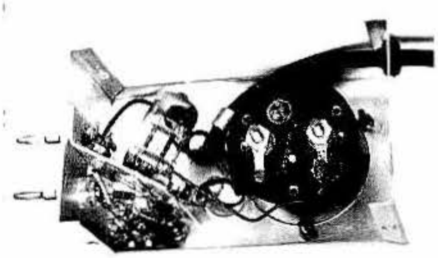

Inside view showing extreme simplicity of the "Spotter." The tube is mounted at an angle to keep the grid lead to the "unknown" as short as possible.

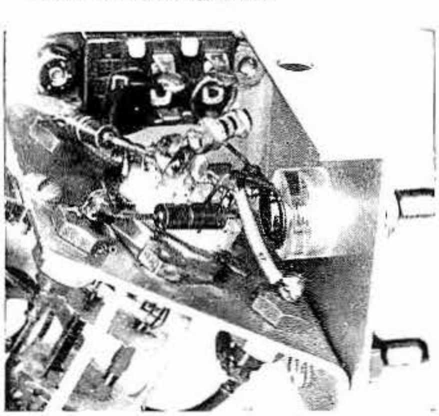

Close up of tube socket showing parts placement.

to the input terminals of the tester. Some transformers have a number of terminals which may not go directly to the tuned circuit inside. To obtain oscillation there must be both a dc and an rf path between the two pots.

If the transformer is one whose frequency falls in the range below the broadcast band it is quite convenient to have one of the surplus receivers that covers the range down to 200 kc. However the check can still be made with a regular broadcast receiver. All that is necessary is to find the harmonics of the tester as they fall in the broadcast band. They will be separated by a value equal to the frequency of the coil being tested. As an example, if a signal is spotted at 900 kc and the next one higher is found at 135 kc, it is a pretty good bet that the transformer is operating on 450 kc (1350 – 900 = 450).

To find the operating frequency of an *if* stage it is not necessary to have the amplifier in operating condition or the tubes hot. Just connect the two contacts across the primary or secondary of the transformer in question and watch for signs of oscillation on the meter. Some transformers have a portion of the bias system inside of the can. This can usually be overcome by connecting the tester from grid to ground of the tube in the stage being tested.

In addition to checking transformers it can also be useful in testing the range over which a transmitter tank will tune. Just make sure that the high voltage is turned off and connect the probe across the tank to be tested. Now you can tune the tank and follow its entire usable range with the receiver. If the tank being checked happens to be the final, the meter on the probe will indicate when the antenna is brought into resonance.

This little tester was built to do just one thing–sort out some old *ifs* in the junk box. After we tried it we found that it would do a lot of useful chores around the ham shack. With proper care and feeding, it can probably learn to do tricks that we haven't even thought of.

430-470 kHz SWEEP FREQUENCY GENERATOR

Edward Lawrence WA5SWD

Here is a simple sweep frequency generator for aligning the most common *if* strips. The unit has only one transistor because the sweep voltage is taken from the oscilloscope it is used with. Most general purpose oscilloscopes have a sawtooth output jack. By using this sawtooth, the frequency is locked to the position of the trace.

The oscillator is made to deviate in frequency in step with the voltage applied to the base bias circuit, either the sweep voltage or the dc voltage applied at the control point. If no sweep or control voltage is applied, the oscillator runs at the center frequency, and may be used as a conventional signal generator.

The 2.5 mh choke and the two 150 pf capacitors form a very broad tank circuit, so it is easy to FM the oscillator without a great change in amplitude. As to how the change in base voltage causes the frequency shift, I am not quite sure. All I know is that it is quite linear and is a positive shift (**Fig. 3**). That is, an increase in base voltage causes an increase in frequency. Also, a change in collector supply voltage will shift the frequency, so be sure to use a stable supply.

Since an rfc is used as part of the tank, you may have to compensate for a variation in center frequency by changing the 150 pf capacitors to some other value to get 455 khz as your center value.

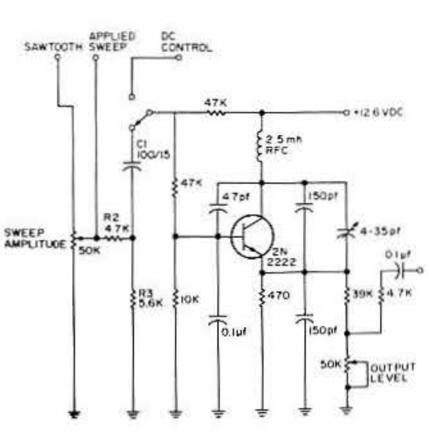

Fig. 1. Sweep generator circuit diagram.

If you do, then run a plot of dc control voltage vs frequency and adjust the voltage divider R2 and R3 so that 1 volt P-P at the sweep pot wiper gives plus and minus 5 khz (10 khz total). This is not as hard as it sounds. Just listen for the harmonics on a broadcast band radio. For instance, the second harmonic of 430 khz is 860 khz, and the second harmonic of 470 khz is 940 khz, both handy on the BC radio. Note the dc voltages at the control point required to obtain these frequencies. Take the difference and divide by four. The answer is the P-P voltage required to shift the oscillator plus and minus 5 khz. Then apply a low, known ac voltage to the wiper of the sweep pot with the switch in the *sweep applied* position. Adjust the value of the divider resistors to get the proper fraction. In my case it was 0.43.

It is advisable to run the sweep rate as slowly as possible, in order to display the response curve as accurately as possible. The sharper the skirts, the more slowly the generator must pass through the bandpass. With this generator, the amount of frequency deviation is controlled by the P-P amplitude at the sweep pot arm. If you are looking at the response of a regular *if,* you would set the sweep amplitude high to see the entire response curve. As far as an accurate display is concerned, this is fine, since the slope of the skirts is shallow. But if you were looking at the response of a sharp filter, you could not tolerate such a wide sweep, because the fast rate-of-change would tend to skew the display. To correct this, reduce the sweep amplitude to reduce the frequency deviation down to the edges of the skirts of the response curve. This reduces the rate of change and minimizes the skewing of the display. Also, it is better to display the *if* before detection, if possible, to prevent the detector time constant from possibly distorting the display.

If you have the sweep generator set up as described, then it is easy to set the sweep for a known deviation, and then procede to read the 3 or 6 db points from the face of the scope. Be sure to disable the AGC for this test.

For those who aren't familiar with the setup for obtaining the response curve display, refer to **Fig. 2.** and the following outline.

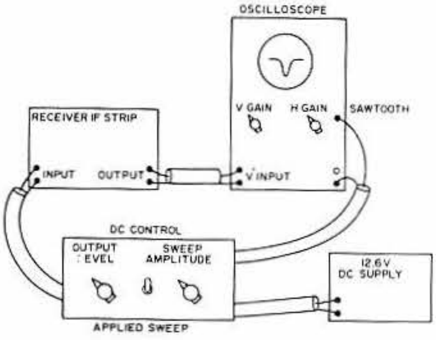

Fig.2. Interconnections of sweep generator.

First, hook up the equipment as in Fig. 1 Set *horz gain* for desired sweep width. Adjust *sweep amplitude* pot on generator for desired frequency range. Set *output level* to mid-range. Adjust the *vert gain* for the desired pattern height.

If we wish to change the total frequency deviation and the horizontal display width at the same time, use the scope's *horz gain* control. This presumes that the amplitude of the sawtooth output is also varied by the *horz gain* control.

If we wish to change the frequency spread and not change the width of the scope display, adjust the *sweep amplitude* control. This allows you to take a better look at the sidelobes or any ripples in the passband, depending on how the controls are adjusted.

You don't have to use a sawtooth to sweep with if it isn't handy.

Sixty hz can also be used, but it will probably skew the passband you are trying to display, so I don't recommend it. One note here: when the sweep generator is first turned on, or the setting of the sweep amplitude is changed, the frequency will drift for a few seconds. This is due to the charge on C1 changing to a new level. C1 is large to couple the low frequency sweep with as little distortion as possible.

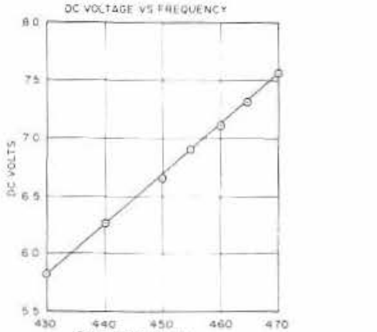

Fig.3. Sweep frequency vs dc voltage.

DC CONTROL VOLTS	FREQUENCY
5.86	430
6.27	440
6.69	450
6.90	455
7.12	460
7.33	465
7.55	470

AN ARMSTRONG SWEEPER

Al Donkin W2EMF

Sometime ago while experimenting with SSB crystal filters at 480 kc, it occurred to me that a manually swept Armstrong oscillator with a pot coupled to the tuning capacitor for 'scope sweep voltage would save point by point frequency measurements with a BC221 while adjusting the filter for minimum in-band ripple. A circuit was hurriedly developed, and the results were even better than expected. Simple though it may be, I'm sure anyone who is working with crystal filters will appreciate its usefulness. The effects of tuning and "diddling" were immediately visible in the in-band ripple and the skirts down to about 20 db could be observed with a few twists of the knob.

With this encouraging experience, a sturdier model was constructed. The circuit was assembled on a small piece of Vector-board, with the tuning capacitor and batteries mounted in a 5 × 7 × 3" aluminum chassis. An aluminum bracket was bent to hold the "sweep" pot and mounted behind the tuning capacitor, spaced to accomodate the mechanical shaft coupling. The Vectorboard was also mounted on the bracket.

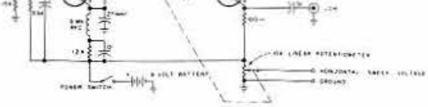

The oscillator circuit is simple, using a 1 mh rfc for the tank inductor. The range of the circuit as shown is about 400 kc to 500 kc, at center frequency. The tuning capacitor is a Hammerlund MC-50-M with two of the rotor plates removed, resulting in a range of approximately 7-25 mmfd. An untuned amplifier provides isolation of the oscillator from the reactance of the load. I used 2N404 transistors but most PNP *if* transistors will work.

In addition to sweeping crystal filters, I have found this little box handy as a general purpose low frequency oscillator and sweeper for receiver *if*'s. The persistency of most oscilloscopes produces a much better display than might be expected, and it certainly beats the point by point method of plotting filter responses.

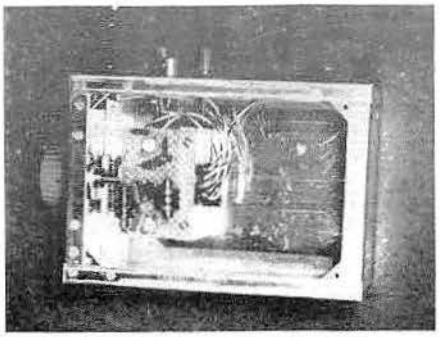

A NEW BROOM

Dick Gridley K6JHJ

This unit is a sweep generator of simple design, with many uses. Besides being useful for filter alignment, as shown in the diagram, it is useful for optimizing receiver and transmitter performance.

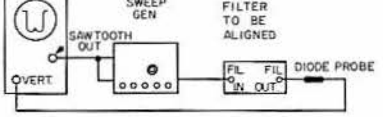

The heart of the rig is an inexpensive item called the Vari-Cap by International Rectifier Corp. Two are discussed here, the 6.8SC20 and the 100SC2. The 6.8SC20, according to the manufacturer, will vary its capacitance from 50 mmfd at .lv to 2.5 mmfd at -200v. The 100SC2 will vary from 600 mmfd at .lv to 100 mmfd at -10v. These units each cost less than $3.00. The construction is not critical in any way, nor is layout a problem—just use good ham practices. Any power supply delivering 150 v dc at 60 ma regulated will do. The oscillator tank must be grounded and I did have some trouble until I removed the unused winding from the 455 *if* transformer used for the oscillator tank.

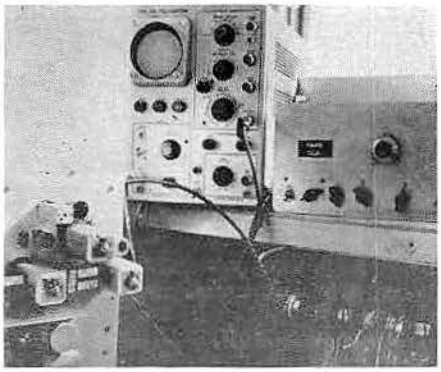

Sawtooth energy is applied to R1 which regulates the amount to be amplified by V1. R2 linear control merely puts a portion of regulated voltage on the Vari-Cap and thus sets the capacity of Vari-Cap close to its center, so the sawtooth pulse creates a linear frequency swing. This circuit gives about 6 kc sweep. I have used TV horizontal coils for L1 and increased C1 and C2 to .003 for 85 kc and 50 kc operation. However, to get enough swing at low frequency, the Vari-Cap was changed to a 100 SC2. For 200 kc to 10 mc the 6.8SC20 gives plenty of sweep.

A note here about scopes. Most of the average do not go below 15 cycles and the sweep rate should be about 10 cycles. Some do not have a sawtooth output jack. The sawtooth output can be picked off the sync circuit. I found the best point is on the feed side of the sync pot through a .25 mfd capacitor. Some scopes have a couple of jack pins to add capacity externally, some don't. You will find little trouble adding about .25 mfd across the slowest speed.

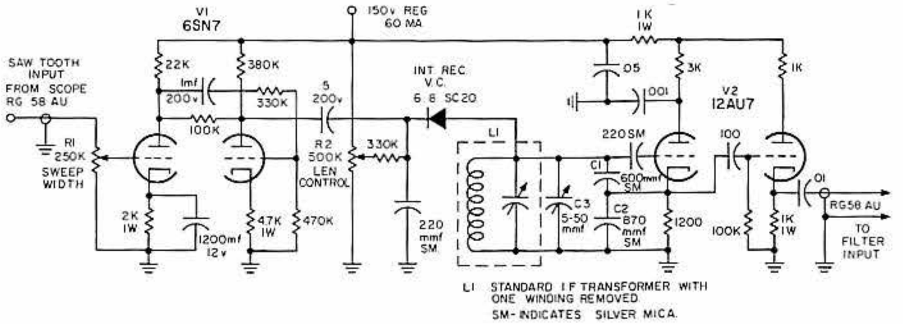
V1
6SN7
150v REG
60 MA
1K
1W
SAW TOOTH
INPUT
FROM SCOPE
RG 58 AU
22K
380K
1mf
200v
330K
5
200v
INT REC
V.C.
6 8 SC20
.05
3K
1K
.001
V2
12AU7
100K
R1
250K
SWEEP
WIDTH
R2
500K
LEN
CONTROL
330K
L1
220SM
100
C1
600mmf
SM
.01
C3
5-50
mmf
C2
870
mmf
SM
2K
1W
1200mf
12v
47K
1W
470K
220
mmf
SM
1200
100K
1K
1W
RG58 AU
TO
FILTER
INPUT
L1 STANDARD I F TRANSFORMER WITH
ONE WINDING REMOVED
SM- INDICATES SILVER MICA.

The use of the rig is simple. Plug the lead from R1 into the scope's sawtooth output. Couple the output from the cathode follower section of V2 to the filter input through a .001 mfd capacitor. The vertical input of the scope is connected to the filter output through an rf probe. Adjust R1 and R2 about ½ open. With C3 about ½ meshed, adjust the trimmer in the *if* can to put you in the ball park, and then use C3 for fine adjustments of frequency. Additional minor adjustments of R1 and R2 may be necessary. Of course, when used to align a receiver, the diode probe is unnecessary if the input to the scope is picked off of the diode detector. It goes without saying that it is necessary to plot an index for the scope bezel so that a ready reference is available for band pass width and depth of skirt.

Some one now says "This is just like setting ye old TV—*if* band pass." That it is. The only difference here is the frequency and the sweep generator cost was junk and $5.00.

The unused switch, shown in the photo, was installed to select one of three frequencies. However, this rig has been used on about six. I don't think I ever will decide which three to use. The unidentified tube is a 6U8 used as a 1 kc audio oscillator with cathode follower output.

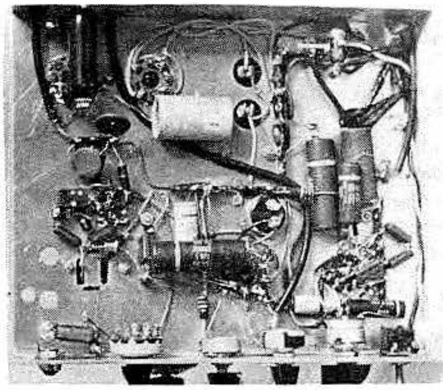

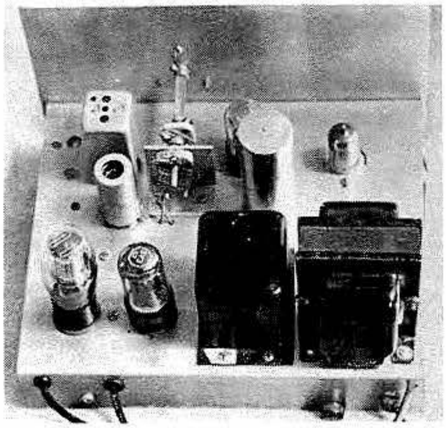

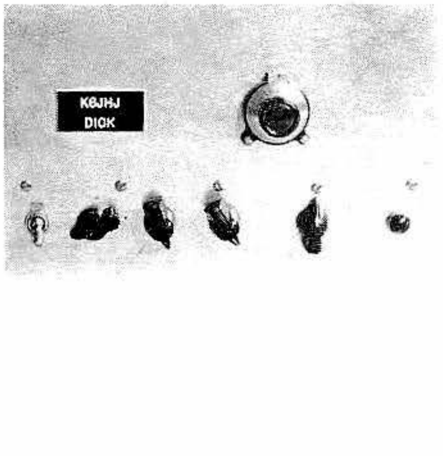

LOW COST SIGNAL SOURCE

Howard White VE3GFW

For many years the Measurements Corporation Model 80 signalgenerator has been the industry standard for tuning rigs. Many hams have wanted to have a laboratory-grade signal source of this type but the $800 price tag is prohibitive. This article describes a signal source that has many of the same features as the 80 except that it only costs 1% as much. That's why I call this the Model 0.8.

You wonder at some of the features of the marvelous little device? To briefly list them, it has:

- Variable output from about 80 nV to 50 mV of rf power.
- Frequency range from 1.8 to 450 MHz so you can cover 160 through ¾ meters.
- Crystal-control frequency stability.
- Fairly clean output signal.
- A 51Ω antenna load.
- Safety feature to prevent the destruction of the device in case a transmitter is accidentally loaded into it.

The Circuit

The circuit is the combined brainchild of many ham engineers and technicians in our local 2m FM club – the Toronto FM Communications Association. More than 300 of these units have been built in the past two years, so the circuit has been exceptionally well tested in the field.

The unit consists of a single 2N5130 NPN transistor oscillator configuration. Other transistors, such as the 2N706, can be used in this circuit with slightly different biasing arrangements; however, the 2N5130 appeared to give the cleanest output signal.

Output level can be varied from less than 80 nV (the best we could measure) to 50 mV. It is controlled by a 1 kΩ pot in the transistor collector circuit. Power is obtained from a 1.5V penlight cell bypassed for rf by a 0.1 μF capacitor.

My present "0.8" signal source has been used intermittently for more than a year without any degradation of output. However, remember to shut the unit off when you're finished with it; the battery doesn't last forever.

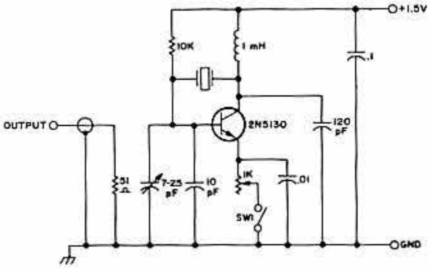
O+1.5V
10K
1 mH
.1
OUTPUT
2N5130
120 pF
51 Ω
7-25 pF
10 pF
1K
.01
SW1
GND

Fig. 1. Schematic diagram of the "Point Eight" Signal Source, the "poor man's Model 80."

The unit is built on a PC board. The parts layout is almost exactly the same as that of the schematic shown in Fig. 1. The electronic components are placed on the copper side of the board. The on-off switch-level control, frequency adjustment, output jack, and crystal socket are on the other side (Fig. 2). The unit can be packaged in a minibox.

Almost any crystal in the 1.8–12 MHz will oscillate in this unit. The output is rich in harmonics to 450 MHz, so you can tune up any receiver from 160 to ¾ meters.

The output impedance of the signal source is 51Ω, a value which simulates a perfect antenna load to the receiver. This is the manner in which this is accomplished: A 51Ω, ½W resistor is connected across the terminals of an RCA phono jack. No physical connection is made to the circuit except through the common

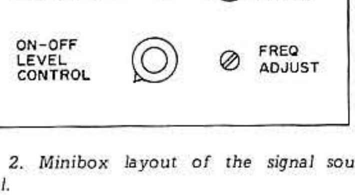
XTAL
SOCKET
RCA PHONO
OUTPUT
ON-OFF
LEVEL
CONTROL
FREQ
ADJUST

Fig. 2. Minibox layout of the signal source panel.

ground of the PC board. The maximum output level depends on the lead lengths of the resistor. (The unit has plenty of output when the lengths are about ½ in. long.) This design has an added safety feature, too; if by accident you load a transmitter into the unit, all that is destroyed is the ½W resistor.

Operation and Uses

These units were originally designed to tune up 2m FM receivers. The procedure is quite simple. You connect the signal source to the antenna input on your receiver. Plug in a transmit crystal, and adjust the frequency control for a zero reading on the discriminator. Adjust the output level to the desired signal strength (below first limiter saturation) and tune up the receiver.

There are a myriad of other uses for the signal source. Using a 3.5 MHz crystal, you have a band edge marker. With the transmit crystals on a Twoer or any other transmitter you have instant frequency spotting without modifying the circuit of the transmitter. Of course, the signal source can be used to tune up any receiver, peak tuned circuits, be an rf source for an antenna noise bridge, and so on.

RECEIVER TWEAKER

Malcolm Oakes K6UAW

I've found that the singlemost piece of needed test equipment by the amateur on FM is a receiver alignment generator. Most of us, however, do not have access to a signal generator. (Come on now, you wouldn't really call that *TV thing* a signal generator would you?)

The unit to be described is a very functional device that will allow you to scrape every ounce of sensitivity from your receiver. The generator can be built so small you can carry it around in your shirt pocket. Compactness, combined with its battery-powered portability make it ideal for servicing mobile receivers. Stability? It's crystal controlled and is as good as the rock you plug in (you obtain the rock from your transmitter). Output reactance? Nearly zero degrees, allows proper tuning of rf stage. The attenuator shown does not have a great deal of dynamic range due to distributed capacity of the potentiometer. However, I said before, the unit was "functional" and it is just that. The signal can be attenuated into the noise and brought up to approximately a 30 uv level; overly sufficient for a normal alignment.

Construction

The circuit layout is not particularly critical, and if laid out in a manner similar to the schematic, no problems should be encountered. The attenuator section should be completely shielded away from the oscillator and multiplier stages, so rf leakage will not be a problem. A crystal socket should be provided so the unit is versatile for any frequency. However, if you plan on using it on only one channel and can spare a crystal, build it with the crystal inside. Two glass piston screwdriver adjusted trimmers must be provided (to "rubber the crystal" and tune the output to resonance) as front panel controls.

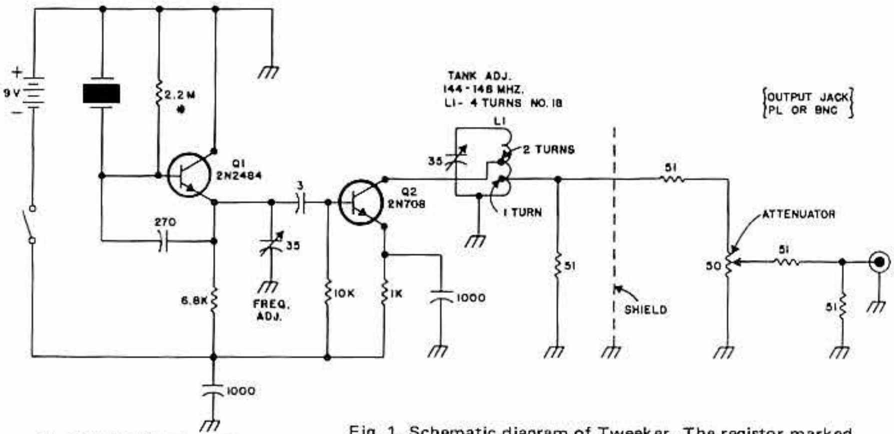

ALL RESISTORS ¼ OR ½ WATT
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Fig. 1. Schematic diagram of Tweeker. The registor marked * may have to be changed to one of lower value if the recommended transistor is not used.

Circuit

Transistor Q1 in the first stage is a crystal oscillator which is very loosely coupled to Q2 the multiplier. This stage is biased into "class C" so as to multiply the 6 mhz crystal 24 times, up to the two-meter band. (3 mhz crystals will also work at a multiplication of 48.) Another important function of this stage is to attenuate the oscillator output (about 6-7 volts peak-to-peak) to a level usable at the two-meter frequency for alignment – 30 to 40 uv. The potentiometer adjusted attenuator takes the signal down to a level as desired by the operator.

I developed this unit for use on two meters. Several have been built and all work fine. But, for those of you who need a six-meter generator, this same circuit should work fine with the only modification needed being the final tank frequency. (A few more turns on the coil and a slightly larger trimmer capacitor.)

Adjustment and operation

Connect the output of the generator to your rig. Plug in a crystal and tune for zero (with frequency adjustment) on the discriminator (center frequency). Now, looking at the first limiter voltage, peak the final tank. Attenuate the generator as necessary to avoid saturation of the limiter. Repeat as necessary until a definite peak is reached.

If the generator will not go down into the noise with the attenuator control, the final tank may be detuned as necessary to provide the desired range on the attenuator.

CITIZENS BAND ALIGNMENT AID

Edward Lawrence WA5SWD

It is obvious that the front end of a receiver should be tuned to respond equally well across the band, and thus have consistent sensitivity at any frequency in the band, if maximum usefulness is to be obtained. The usual method of insuring reasonable results is to tune at the middle, and check the ends. This is rather spotty, at best, as it would be better to check all channels. This is involved since you must set both frequency and amplitude 23 times in a single pass.

Naturally, a good sweep generator could be used, and the rf-mixer tracking set with it instead, but this was not available to me at the time. The circuit in Fig. 1 was originally a super-regenerative receiver taken from the GE Transistor Manual. These, as is well known, tend to spray a lot of rf back out the antenna. With this in mind, I listened with a communications receiver and noted strong modulation products about 100 kHz above and below the "carrier." Deducing this to be caused by the quench frequency, I brilliantly decided to drop the quench frequency into the audio range, by increasing the capacitance across the base bias resistor. Lo and behold! Suddenly the entire Citizens Band was alive and jumping with a mass of "line noise," which at first appeared to be like

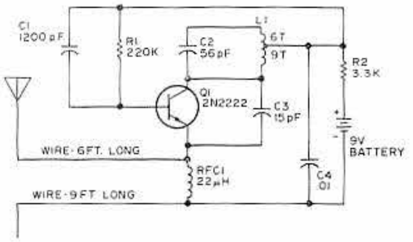

Fig. 1. Schematic of the alignment aid. L1 is 15 turns No. 22 tapped at 9 turns from the collector end. No switch is shown, so remove battery when not in use.

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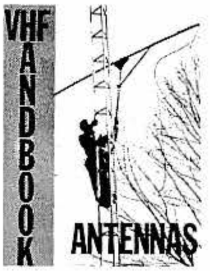

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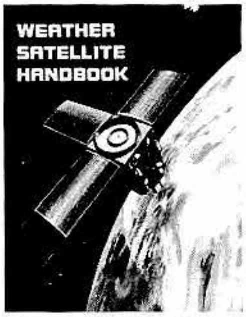

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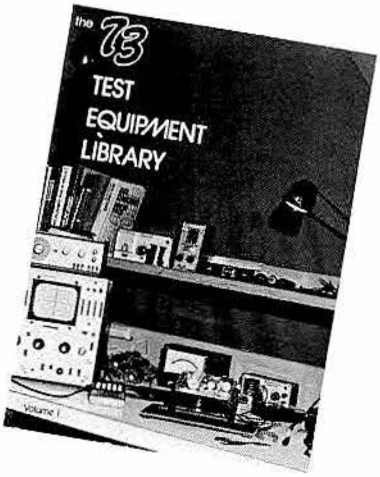

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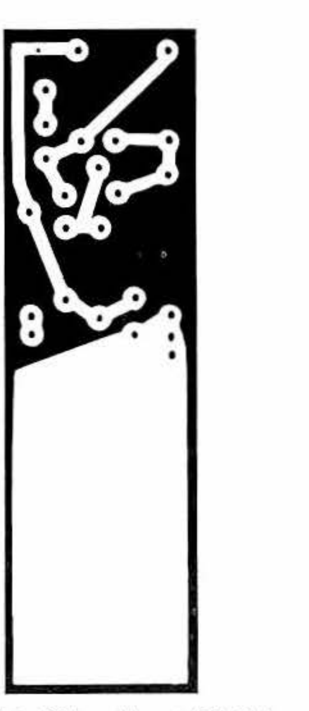

Fig. 2. Full size PC board layout (foil side).

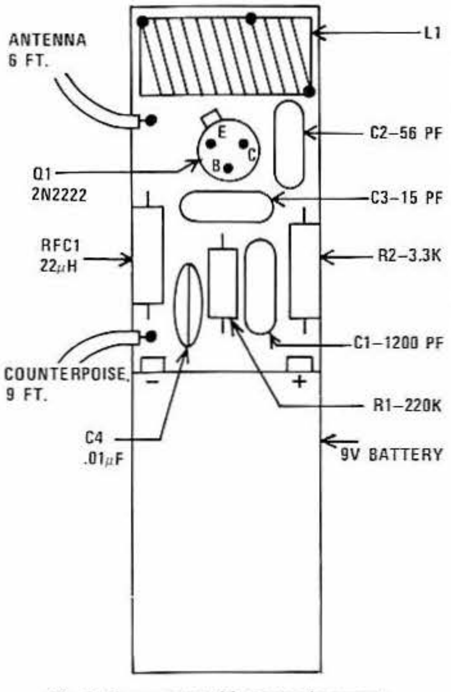

Fig. 3. Component side parts placement.

natural noise. Then I turned on the BFO, which showed it to be many, many, many closely spaced "carriers." I presume the lower quench frequency develops a much larger bias swing on the base of the transistor, FM'ing it across the entire band. This stuff is concentrated in the region of 27 MHz, with very little spill-over into 10 or 15 meters, although the level across the design range is rather constant. The nearly constant rf level is what I needed to simplify tuneup of the front ends of the units I was working on.

Figure 2 is the layout of the P.C. board I made to facilitate reproduction of this useful circuit for a few interested friends and Fig. 3 is the component layout.

I used 6 ft of wire as an antenna connected to the emitter side of the rfc, with 9 ft of wire on the battery side of the rfc as a counterpoise. Since this made it a bit large, I carefully hung it vertically in a handy tree nearby. Of course, since this put a strong signal on every channel into every CB receiver within 300 yards, I limited the use of this device to avoid unnecessary interference to the deserving users of the band. However, one fellow accidentally launched his into a tree too high to recover with an over-ambitious heave, and it ran for about a month in the dead of winter in a nameless northern city, helping every CBer for miles around align their sets! It only draws about half a milliamp from a 9 volt battery.

Since I am sure many others would like to align their 11 meter receivers for optimum results, I am presenting this circuit as a very low cost and worthwhile aid.

FET CHIRPER

Chuck Hines K6QKL

The Chirper is an automatically keyed, crystal controlled, signal source which may be used to optimize the signal-to-noise ratio of a receiving converter. Homebrew or commercial, converters are a common thing around an amateur station. And, most of the VHF Tribe have read thru a jungle of esoterica dealing with low noise front ends, the velvet beauty of FET's on Two, noise generators and eternal truth, and how to copy 20 db below the noise by the selective use of liquid helium. With a kind of relentless evolution converters have been getting better and better, noise figures become lower, and the prices of suitable front end devices are dropping by the hour. But when it comes to aligning these converters the scene is one of wretchedness. A black art at best, the job is taken up with an enduring combination of blunt instrument and myth. The latter have a certain charm. Are you convinced your converter is in top notch condition because you can "hear noise" when you attach the antenna – or better yet, when you place a 50 ohm resistor across the input? Try putting a complete short across that same input. Shorts aren't much good as noise sources. You'll find the short gives about the same change in noise level as the 50 ohm termination. What has changed is the impedance the front end "sees". The same is partially true of the noise from the antenna. Neither is indicative of the performance of the converter. Peaking the system up for maximum on either a weak signal or on noise gets you nowhere. The diode noise generator which every VHF book of substance describes is a good and useful tool when used properly. The assumption is that everyone already knows full well how to use it and does so. Few in fact do.

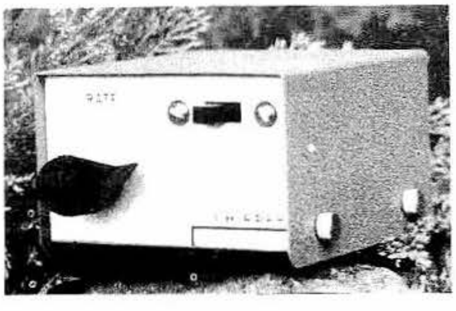

I'm sure you've read of it before in many places, but a little redundancy is in order. The noise with which you are concerned is the noise generated *internally* by the first tube, transistor, or other active device the signal encounters upon its arrival at your converter. By fiddling with the external reactances, adjusting the voltage and current and otherwise manipulating the things soldered to the device, one may minimize the internally generated noise. At the same time the reason the front end exists is to amplify the signal. One usually desires as much amplification possible, short of smoke and oscillation. Minimum noise and maximum amplification is the game. Though the two are not quite mutually exclusive a certain amount of compromise takes place. Thus, the signal to noise ratio. When aligning a converter's first stage every adjustment effects *both* signal and noise. Given a constant signal source coupled into the converter thru an appropriate impedance, the job is finished when the front end has been adjusted for the greatest *difference* between signal and noise of which it is capable.

The Chirper is designed to help you do all this by letting you see what effect each adjustment has on both signal and noise. The TIS34 oscillates at a frequency controlled by the crystal. With the constants shown, that can be anywhere between 8.2 and 36 MHz. The variable capacitor must be adjusted for resonance. It isn't particularily critical but its setting peaks the *rf* output at either the fundamental or some harmonic. For 6 meters an 8.35 MHz crystal is used. A 9.0 MHz rock will pin the meter when the

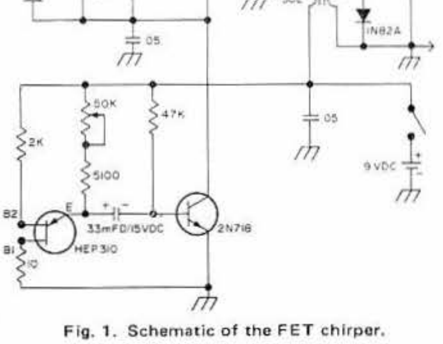

Fig. 1. Schematic of the FET chirper.

Chirper is connected into a 2 meter converter. The Amidon toroid is wound with No. 30 enameled, 40 turns for the primary and 5 turns for the secondary. After it is wound, spread the turns to fill the toroid and paint it with Q dope. The diode and 5 pF coupling capacitor are connected with the shortest possible leads, the diode being grounded at the *rf* connector. The harmonic output is excellent and quite useable at 1200 Mhz.

The oscillator is turned on and off by a multivibrator combination of unijunction and NPN transistor adapted from the *G. E. Transistor Manual.* The rate at which the multivibrator cycles is determined by the large value capacitor, in this case 33 mF. The polarity of the capacitor is critical. Observe it. To increase the cycling rate, decrease the capacitance; and, to decrease the rate, put in a larger value. Mine cycles a little under once per second. A value somewhere between 30 and 40 mF should suit your needs. You are better off scrounging some odd value from a defunct computer board because of the tolerance problem. If it says 33.2 mF, its probably pretty close to that value. Otherwise you're dealing with tolerances of plus 100% and minus 50% or something equally grotesque. The 50K pot determines the portion of the cycle during which the oscillator is On and is mislabeled rate on the Chirper shown. The HEP-310 is generally available and inexpensive. Other unijunctions were not tried. On the other hand almost any NPN of reasonable quality will work in place of the 2N718. A number of 2N388 and 2N3478's were tried and behaved well. It's a good place to use those transistors you've replaced with FET's. Use something with a Beta of 50 or better for best results. The 5100 ohm resistor in series with the pot is for current limiting. It's deletion will increase battery drain with no increase in Chirper performance. Normal current from the 9 volt battery is around 5 mA.

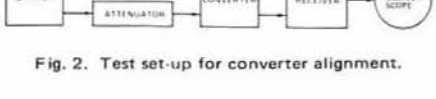

Fig. 2. Test set-up for converter alignment.

Construction is non-critical and pretty much a matter of taste. Mine is built on a piece of vector-board and mounted in a Suzurando box, model M-1N. It measures 3¼ X 2 X 4" and there is still room inside for additions. It sells for 330 yen, about 92c. A slide switch is used to turn the power on and off. Paint one well of the slide switch with red paint – Testor's Pla, a model plastic paint, is good – and the switch will indicate its position. Red for On and black for Off. It saves batteries. Check your work and the polarity of the large capacitor. Re-check the connections to all the semi-conductors. With four different kinds of devices things can become confused. Set the pot to the middle of its range. Insert a crystal in the socket. Connect the Chirper to your converter, turn the switch on and adjust the variable capacitor for the highest reading on your S-meter. The oscillator will turn on and off. Varying the pot will extend or diminish the amount of time the oscillator is on. Whatever you do, *don't connect the chirper to an external antenna.* The harmonic content is high and even at this power level is sufficient to cause severe interference to television receivers within a two block radius.

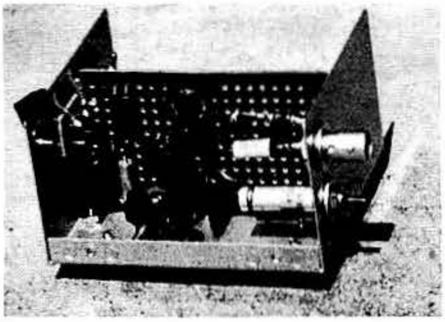

For converter alignment, the test set-up is illustrated in Fig. 2. The Chirper is fed to the converter thru an attenuator for two reasons. First, the power output of the Chirper is too high on six and two. You don't want to align with a forty over nine signal. Something around S-5 to S-7 is desired. Second, the attenuator maintains a 50 ohm termination for the converter. A converter cannot be aligned with a floating input impedance. Fixed and variable attenuators of excellent quality are available thru surplus and homebrew data is available. See *73,* January 67, p. 40 for one that will do the job. Turn the receiver avc off. The read-out options are diverse. The best is probably a scope connected to the *if.* A vtvm can be used, connected to the audio output. And, the S-meter can be used with the avc on *fast.* This will vary with the receiver and it's particular time constants. What needs to be avoided is avc pumping that interferes with your readings.

Turn the Chirper on, adjust the attenuator for a convenient signal level. When the oscillator is on, you're reading signal. When the oscillator is off, you're reading noise (on the scope, vtvm, S-meter, etc.). As you make adjustments on your converter, observe the effect on both signal and noise. Adjust for the greatest difference between the two. Turn the Chirper off and re-check the converter neutralization. If necessary, reneutralize the converter and go thru the whole thing again. Talking about it makes it seem somewhat complex. It really isn't and the whole business won't take long once you've done it. It will become quickly apparent that highest signal level and lowest noise level do not coincide. You can vary the bias, voltage, etc., and observe the effects of each on the signal-to-noise relationship. You can, in short, optimize your converter's performance.

A number of things can be done with the Chirper. There is room in the box to build another oscillator section connected to the transistor collector, operating in parallel and simultaneous with the first oscillator. By appropriate choice of crystal and attenuation, both signals can be introduced into the converter in order to adjust the mixer for minimum cross modulation.

Or, instead of using an oscillator at all, you can use the switching section of the Chirper to key a noise generator on and off. This has a certain attraction where an integrating network is used prior to a vtvm. In this case noise is used as a signal.

In spite of it's name, the Chirper is remarkably stable. Chirp becomes apparent from two meters or so, but is no problem. Build one and take the myths out of your converter.

UHF SIGNAL SOURCE

Bill Hoisington K1CLL

The UHF experimenter learns early that the UHF ham bands don't always furnish a signal when you need them. When I build receivers and converters for 432 and 1296, I find that I need a small signal generator for alignment and band spotting. Not much power is needed for this work, so transistors are the ideal choice for generating the signal. This signal source is in three parts, a 432 source, a tripler to 1296 and a modulator.

The 432 Driver

I started with a low-cost 27 mc crystal that I found in my junk box. (Never mind how it got there!) I used my usual phase-reversing crystal circuit followed by a bunch of doublers. Lower-priced transistors were used in the early stages and the UHF ones saved for later. You really need good ones on 1296! Each doubler is biased from rectification of rf from

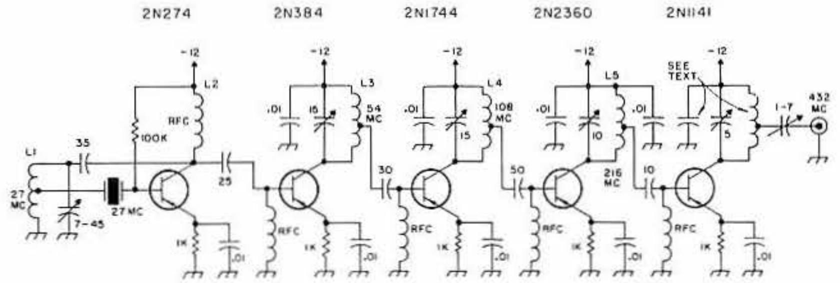

Fig. 1. Schematic diagram of the 432 mc signal source. The transistors aren't critical in most cases and other UHF and VHF ones will work fine.

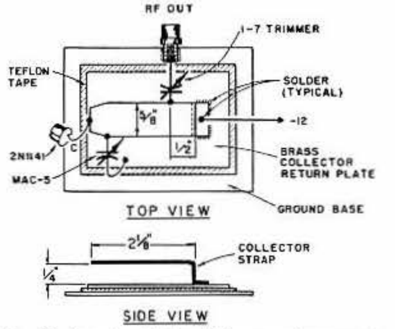
RF OUT
1-7 TRIMMER
TEFLON TAPE
SOLDER (TYPICAL)
5/8"
-12
1/2"
2N1141
C
MAC-5
BRASS COLLECTOR RETURN PLATE
TOP VIEW
GROUND BASE
2 1/8"
COLLECTOR STRAP
1/4"
SIDE VIEW

Fig. 2. Details of the 432 mc collector circuit.

the previous stage. If you need more output than this circuit gives you, use less than a 1 k resistor in the emitter, but watch out for high collector current. **Fig. 1** shows the schematic of the 432 mc generator and **Fig. 2** gives details of the 432 mc collector circuit.

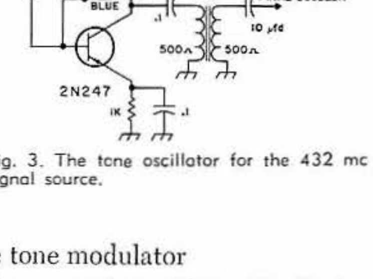
-12
RED
GREEN
T1
AR-115
R1
.02
BLK
BLUE
T2
.1
TO EMITTER OF 432 MC FINAL DOUBLER
10 μfd
500Ω
500Ω
2N247
1K
.1

Fig. 3. The tone oscillator for the 432 mc signal source.

The tone modulator

This is a crude modulator (**Fig. 3**), but it works. The modulation transformer is not absolutely necessary, but seems to improve results. You can apply the modulation almost anywhere for this application, but modulating across the 1 k emitter resistor gave the cleanest sound with the doubler used.

Now to 1296

I built this tripler to 1296 just for the fun of it. But it worked quite well. I normally don't hold with triplers at this frequency, but it's an easy way to get 1296 mc energy from the 432 mc driver. The transistor I used was a Motorola 2N1141. It's several years old and there are better ones that are far cheaper now. But it does work on 1296. I couldn't get it to work with grounded emitter, but grounded base is fine. **Fig. 4** gives the schematic but Fig. 5 gives the details, which are vital. The input on 432 tunes very nicely. But I had to reduce the emitter resistor in the doubler to 432 to get enough drive. It ended up at 200 ohms. The collector circuit is short, but tunes smoothly. The 1296 mc output registers 100 a in the 1296 cavity in the May 73.

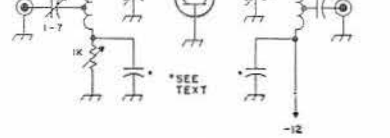
2N1141
MAC-5
432 MC
1296 MC
1-7
1K
*SEE TEXT
*
-12

Fig. 4. Schematic of the 1296 mc tripler.

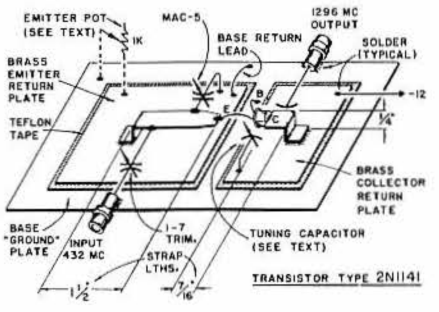
EMITTER POT (SEE TEXT)
1K
MAC-5
1296 MC OUTPUT
BASE RETURN LEAD
SOLDER (TYPICAL)
BRASS EMITTER RETURN PLATE
-12
B
E
C
TEFLON TAPE
1/4"
BRASS COLLECTOR RETURN PLATE
BASE "GROUND" PLATE
INPUT 432 MC
1-7 TRIM.
TUNING CAPACITOR (SEE TEXT)
STRAP LTHS.
TRANSISTOR TYPE 2N1141
1 1/2"
7/16"

Fig. 5. Pictorial layout of the 1296 mc tripler.

You might try a small amount of modulation on the 1296 mc tripler. Also a waveguide attenuator. Be seeing you on 23 cm.

CRYSTAL CONTROLLED SIGNAL SOURCE WITH INFINITE ATTENUATOR FOR 144, 432 AND 1296 MHz

Bill Hoisington K1CLL

One of the most useful test-equipment gadgets the homebrewer can build is a signal generator. The one described here is of commercial quality and it can be completely contained inside a waveguide. Positioning, by sliding along the waveguide, provides a variable-strength stable signal of one millivolt, one microvolt, one nanovolt, or less, dropping down gradually to a true zero. It does this in a perfectly smooth fashion without steps or jumps so that every fraction of a decibel in lower noise figure shows immediately on the slide dial. What's more, the slide can be calibrated so that FM'ers can use the device for directly measuring receiver sensitivity in tenths of a microvolt.

In building a 6 meter receiver recently for maximum absolute sensitivity I naturally had to check especially on the first-stage rf transistor and circuit for minimum noise figure. (For this type of work you *must* have a signal generator capable of being attenuated out of sight with any receiver you can buy for any money.) The usual generators on the market under $100 do not do this. And many of the very expensive generators get so leaky that they have to be used 200 ft from the receiver. At any rate, the generator described here can be made up quickly and at low cost, and it *is* stable, reliable, and infinitely variable.

Waveguide

The only possible difficulty might be in obtaining the piece of waveguide needed. The piece I used is 4¼ in. wide by 2 1/8 in. high, and is 24 in. long. If you have a choice, get a piece a little longer. You could make up this item out of brass or copper if you had to, because in this case it is not used to *carry* energy but to *attenuate* it, so the worse you make it the better!

The waveguide *must not* have any holes in it and should be reasonably smooth inside; otherwise your dial would not read smoothly in attenuation. You *could* use copper or aluminum drain pipe, although I have not tried them yet. Working directly on the rf, this attenuator is good for any kind of modulation, including SSB, FM, pulse, or what have you.

Construction

Figure 1 shows the basic idea. When the signal generator plate is close to the

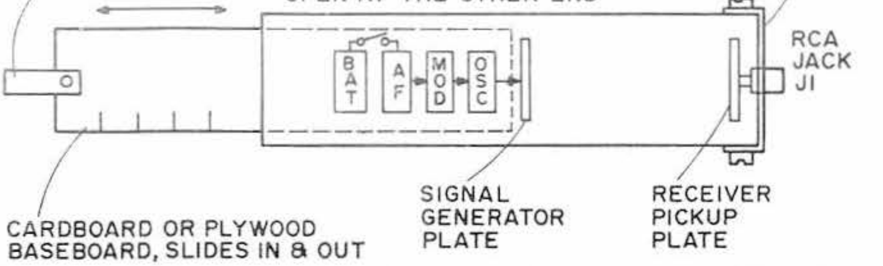
GENERATOR
WAVEGUIDE
CLOSED AT REC. END,
OPEN AT THE OTHER END
COPPER
END CAP
MUST BE TIGHT!
DOWEL
RCA
JACK
J1
BAT
AF
MOD
OSC
CARDBOARD OR PLYWOOD
BASEBOARD, SLIDES IN & OUT
SIGNAL
GENERATOR
PLATE
RECEIVER
PICKUP
PLATE

Fig. 1. Sketch shows plan-view layout of unit inside waveguide attenuator. The oscillator unit is mounted on a flat wood or cardboard strip that can be calibrated to give accurate indications of output signal.

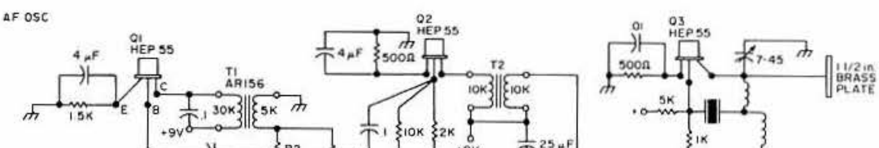

Fig. 2. Schematic of generator. This entire assembly about 3 x 4 in. including small 9V battery and switch must be entirely inside the waveguide. No wire or metal of any kind can be brought outside.

receiver pickup plate, you can get about 100 mV of signal into the receiver, and it is handy for checking diode receivers. When the two plates are about 8 in. apart, the signal is just detectable on a good receiver. Additional spacing between plates amounts to "waveguide beyond cutoff." I do not believe that there is any receiver in the world that can pick up the signal much beyond the 8¾ in. point.

Pretty soon in your receiver "peaking" work you get to that signal that may be but a tenth of a microvolt or so, and you begin dreaming about cryogenic front ends, masers, and such. As mentioned, every fraction of a decibel lower in noise figure, every improvement in sensitivity comes out rigorously and relentlessly on that slide dial. You can easily check which of your low-noise transistors is really low, whether that MOSFET will do a better or worse job for you, and in which circuit.

As you go up in frequency you may have to make smaller and smaller oscillators in order to fit in smaller waveguides to get the cutoff effect. (That will not be a problem if you read 73; the May issue described a "postage-stamp-sized" rf generator that is an ideal candidate for the signal source.)

Circuit

A crystal oscillator, an af oscillator, and a simple class A modulator do an excellent job to start with. Figure 2 shows the present unit as used on 6 meters. It must be stressed again that no wire or other piece of metal may be allowed to reach the outside from this assembly. I'm making up another for 2 meters soon (still my favorite band) and will try one on 450 a little later.

Audio

A controlled-feedback transformer-coupled af oscillator does a good job in furnishing a sine wave. A Motorola HEP55 is used for the oscillator, with feedback to the base from the collector through transformer T1, controlled by resistor R2. Audio output is taken off the 5 kΩ winding of T1, is fed through R4 the modulation control, and then to the base of af modulator Q2. Transistor Q2 is set up for low-power class A operation because not much modulation is needed for the signal generator. Transformer T2 is an old 5W unit from "tube-type portable" days. The secondary of T2 feeds a modulated +9V signal to Q3, the crystal-controlled 50 MHz oscillator.

This rf oscillator is one of my negative-feedback jobs with phase reversal in the crystal. A 1½ in. square plate is tied onto the collector, radiating energy to the receiver pickup plate facing it inside the waveguide. This energy is rapidly attenuated as you move the plates apart, and should be impossible to detect after some 9 or 10 in. of separation.

Once again, do *not* bring any wires or any other metal or conductor out from the oscillator assembly. If you want an outside controlled switch or other control, bring it out as a wooden dowel handle.

That's about it. Tune everything up outside the waveguide on the bench; when you're satisfied, plug your best 6 meter receiver into J1, push the oscillator plank along the waveguide (or rather I should say pull it along) away from J1. You'll get a surprise! Hope this helps you with your low-noise receiver work. It did a lot for me.

LOW COST 220 MHz SIGNAL GENERATOR

Bill Hoisington K1CLL

This article describes the design and construction of an easy to build, inexpensive, crystal controlled signal generator for the 220 MHz band, including a very low cost attenuator that goes from a quarter volt down through 1/20th of a microvolt and on to a real zero (of rf power). It is very useful for receiver front-end tuneup, low noise tests, and as a portable field generator for overall antenna tests through the receiver. For signal identification purposes, af and FM modulation are included.

If you really want to fight for a low-noise front end, this piece of equipment will be of great assistance to you, because the attenuation really is infinite and without any difficult bypassing or shielding.

Design of the attenuator.

Infinite attenuation is achieved here by the use of a 50¢ piece of aluminum tubing, as shown in Fig. 1. You cannot drive 220 MHz signals more than a few inches down inside of a piece of aluminum tubing. By putting *everything* – battery, on-off switch, circuit and all – on the movable generator strip and sliding it in and out of the tubing, you avoid all touchy, difficult and expensive bypassing, costly attentuator pots, shielding, etc., and provide a simplified means of varying the attenuation with stable, smooth, easy repeatability. Calibration is of the slide rule variety and also simple as far as writing down the microvolts on the scale is concerned.

This principle is older than radio tubes; in fact Sir Oliver Lodge used it in his 1890 microwave work.

Attenuator Construction Details

Figure 1 tells most of the story, with details in Figs. 2 through 9. An adequate rf seal can be made at the pickup end of the aluminum tubing, standard TV masting, 1¼ O.D., by 2 or 4 tabs in one end as in Fig. 3 and bending them back as shown, then cutting off the excess tubing. Install the pickup, plate, output jack, and end plate as shown in Fig. 1. I used time-saving external mounts for fastening it down to the wood baseboard as shown in Figs. 2 through 5. Drill a ¼ in. hole for a screwdriver as in Fig. 2, and use angles for the pickup end. Figure 2 also shows the scale in use for attenuation settings, and Fig. 3 shows pointer details.

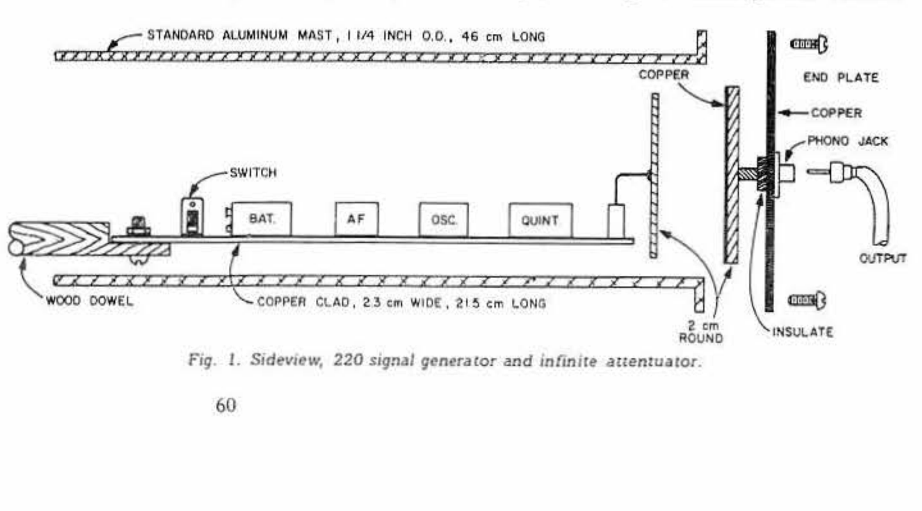
STANDARD ALUMINUM MAST, 1 1/4 INCH O.D., 46 cm LONG
COPPER
END PLATE
COPPER
PHONO JACK
SWITCH
BAT.
AF
OSC.
QUINT
OUTPUT
WOOD DOWEL
COPPER CLAD, 2.3 cm WIDE, 21.5 cm LONG
2 cm ROUND
INSULATE

Fig. 1. Sideview, 220 signal generator and infinite attentuator.

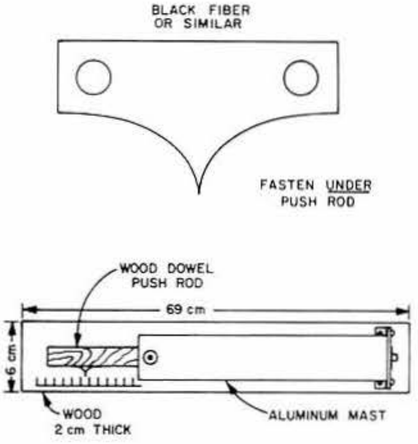
BLACK FIBER
OR SIMILAR
FASTEN UNDER
PUSH ROD
WOOD DOWEL
PUSH ROD
69 cm
6 cm
WOOD
2 cm THICK
ALUMINUM MAST

Fig. 2. Top view of the 220 signal generator and details of the calibration pointer.

Figures 6 and 7 show pictorials of the layout, top view and side view.

The Generator

Nothing too fussy here, but attention to details will assure reliable af and rf oscillation at low power and low battery drain and good frequency multiplication. Figure 8 shows the schematic with the details of the two oscillators, the crystal in the 44 MHz range, and the quintupler. The af uses a standard circuit which, however, has one item to watch. Contrary to a transformer coupled circuit, which is seldom mentioned, this twin-T job has a nasty trick of not starting every time. However a small cap from collector to ground cures this and makes it 100% reliable in that respect. The emitter being grounded, I suppose this establishes the correct in-phase relation with the collector, in which both of these elements should be in phase. You can put a small trim pot af gain control between the modulator and the oscillator if you wish, watching out for dc voltages of course. As shown here, there is plenty of modulation for signal identification, both AM and FM.

Referring to Fig. 8, at the left is the af oscillator. It is not down symmetrically, but you can note the two 22K resistors and the two .02 frequency settling caps, along with the .05 and the 2.2K terminating the lines. All of these set the frequency, and to change the frequency you should vary all of them in at least their approximate present ratios. It is around 500 cycles as shown. Do not forget the "starting cap" from collector to ground.

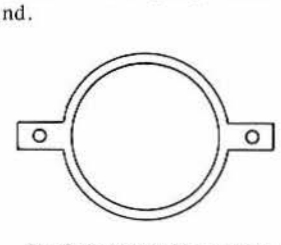

Fig. 3. Cable end view tubing.

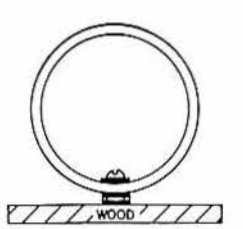

Fig. 4. Open end view.

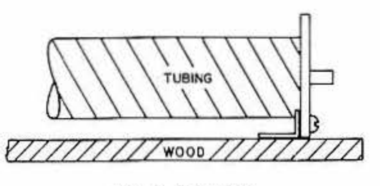
TUBING
WOOD

Fig. 5. Side view.

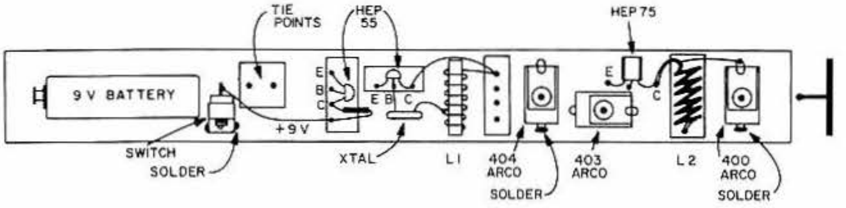
TIE POINTS
HEP 55
HEP 75
9 V BATTERY
E
B
C
E B C
+9V
E
C
SWITCH
SOLDER
XTAL
L1
404 ARCO
SOLDER
403 ARCO
L2
400 ARCO
SOLDER

Fig. 6A. Layout, top view.

This audio is fed to the base of the multiplier where it provides some AM and some FM modulation for signal identification purposes. When working with receiver oscillators, and in particular with high-ratio multipliers, this is very important. It may also be locked into any old scope sync for noise figure and sensitivity comparisons. The scope sync gives a reference point where the signal to noise ratio will always be the same, without resorting to guess work. The crystal oscillator is my old tried and true crystal phase-reversing job, which uses negative feedback from the collector coil, which, after going through the crystal, reverses phase and becomes positive, thus assuring oscillation but *only* on the crystal frequency. A HEP 75 (similar to the famous 3866) is used for the quintupler. A lot more output is noted with this powerful but smooth operating old faithful, still good to 450 MHz.

The output goes to the antenna plate on the forward end of the baseboard plank. When this plate is moved all the way in so that it is only ¼ in. from the cable pickup plate in the end of the aluminum tube, a full scale reading may be obtained on a 50 microamp meter on the output of a tuned diode detector (see Fig. 9). My first model here has marks on the scale (see Fig. 2) for 1 rf stage; 2 rf stages; mixer (feeding into a good i-f strip); mixer plus 1 rf, etc. At the 1 rf plus mixer, you begin to hear all the repeaters within 100 miles or so. With 2 rf plus mixer (followed by a sensitive i-f of course) you are really getting sensitivity. This is where you put a scope in line in order to have an electronic comparison point for signal coming out of the noise purposes, and then can really get into the low-noise bit, if you have a hermit location. Just happens I have one here. When I hear the noise of a car, it's a visitor!

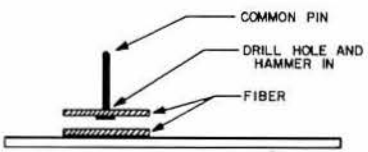
COMMON PIN
DRILL HOLE AND HAMMER IN
FIBER
COPPER CLAD BASEBOARD

Fig. 6B. Tie-point construction.

Output

You will see for yourself as soon as you start testing that the attenuator is smooth-working and stepless, and that true infinite attenuation is at hand. An rf input state (pre-amp) with a noise figure a fraction better than another shows right away on the scale. For example, adjustment of the fixed bias voltages on the two gates of a 3N200 or 3N201 shows right away on the scale as the

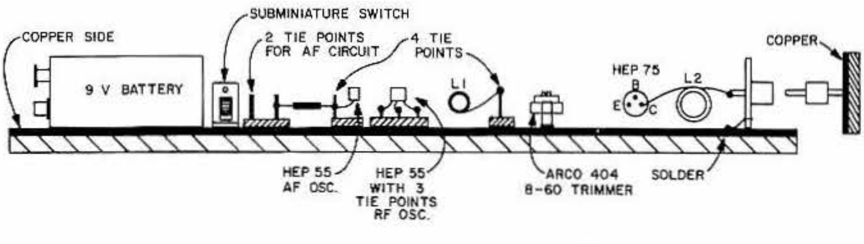
SUBMINIATURE SWITCH
COPPER SIDE
2 TIE POINTS FOR AF CIRCUIT
4 TIE POINTS
COPPER
9 V BATTERY
L1
HEP 75
B
E
C
L2
HEP 55 AF OSC.
HEP 55 WITH 3 TIE POINTS RF OSC.
ARCO 404 8-60 TRIMMER
SOLDER

Fig. 7. Side view of the signal generator, 220 MHz.

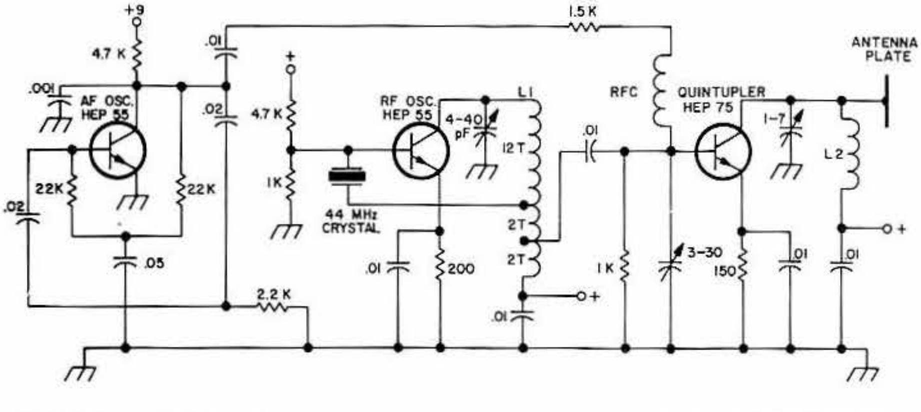
+9
4.7 K
.01
.001
AF OSC. HEP 55
22K
.02
22K
.05
.02
+
4.7 K
1K
44 MHz CRYSTAL
2.2 K
1.5 K
RF OSC. HEP 55
4-40 pF
L1
12 T
2T
2T
.01
200
.01
+
.01
RFC
1K
QUINTUPLER HEP 75
3-30
150
1-7
L2
.01
.01
+
ANTENNA PLATE

Fig. 8. Schematic. L1 = 16 turns No. 26 output tap at 2 turns, crystal feedback tap at 4 turns, from cold end. Wound on phenloic form .6 cm O.D. L2 = 6 turns No. 18 bare, air wound, .6 cm O.D., 2.5 cm long between tie points. RFC = about 40 turns No. 40, on phenolic form .3 cm O.D., 1 cm long (not critical).

push-rod is moved in and out and the signal is locked onto the scope. This work you can do right on the bench and at low cost.

There is quite a bit of mechanical work in the unit, depending on just how much "finish" you want it to have. You can also bring a dowel rod for "on and off" use. Do not, under any circumstances, bring out a *conductor*. You *can* do this, but only with an extreme amount of filtering, which is not part of this article. Be sure to set up the baseboard, antenna plate and battery first, and get them working mechanically. With a drawn-out shape like this I generally start with a longer piece of copper-clad than needed, build from one end, and then cut off what is left over. Understandably, once you have made the first one you can always see, after it is done, many ways of improving it. However, someone has to make the first one, and that's generally my job.

Antenna and Field Tests

Out of the tubing, and with a small antenna connected via a one turn link around the quadrupler coil and then to ground, returning L2 for maximum output, this little rig puts out a lot of signal on 220. Especially if you reduce the oscillator emitter resistor! Up to several volts of rf can be obtained in a tuned diode receiver if you push things along, which is around 5 to 10 mW. If you place this generator out in a field several hundred yards or more away, you can then line up your antenna on the car or house, check antenna cables, antenna input alignment, and match or mismatch for lowest noise figure, etc.

Front end alignment should first be done with a relatively broadband i-f strip on 10.7 MHz. Be sure nothing metallic on the generator strip protrudes enough to touch the inner wall of the tubing, or "scratch" will occur in the high gain receiver. A piece of thin fiberglass or other insulating sheet wrapped around the whole generator movable plank is a good precaution.

Once again I include a 220 MHz tuned diode detector, which is an absolute must for frequency multiplication, especially quintupling and such, where the other unwanted harmonics are as little as 20% away from the desired frequency. Figure 9 shows this piece of test equipment in pictorial schematic form. Remember, shape is of considerable importance as you go from VHF into UHF. It is quite easy to make the square trough line out of an old piece of copper clad. Or even a new piece! And this particular one described and shown in Fig. 9 goes very well to over 450 MHz and thus is very nice for the next band also. If you make it just as I've shown it, it will do a good job for you.

Calibration will present some difficulties, so line up some other lads around who are already on these bands and get your calibration that way.

So good luck, friends, more coming – lot's more! Keep reading.

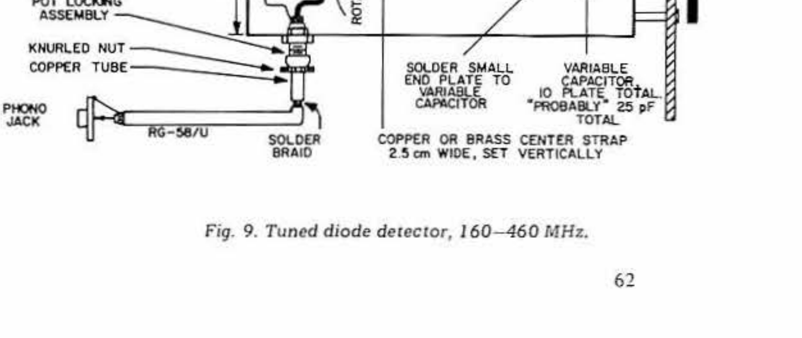
AF
DC
OUTPUT "PHONO" JACK
ADAPTER (EXTERNAL)
1.4 cm SPACERS
COPPER-CLAD COPPER INSIDE
TWO SMALL LAFAYETTE .001 CAPS
IN295 DIODE
10 X 10 cm PANEL
10.2 cm
POINTER KNOB
5 cm
7.6 cm
INSIDE TEFLON OF RG-58/U
2.2 pF
3 cm
ROTATES
POT LOCKING ASSEMBLY
KNURLED NUT
COPPER TUBE
SOLDER SMALL END PLATE TO VARIABLE CAPACITOR
VARIABLE CAPACITOR, 10 PLATE TOTAL "PROBABLY" 25 pF TOTAL
PHONO JACK
RG-58/U
SOLDER BRAID
COPPER OR BRASS CENTER STRAP 2.5 cm WIDE, SET VERTICALLY

Fig. 9. Tuned diode detector, 160–460 MHz.

UHF SIGNAL GENERATOR

Jim Kennedy K6MIO

Several requirements were the basis for the design of this signal generator: operation on both 432 mc and 1296 mc, high stability e.g., crystal control, variable rf amplitude, provision for insertion of various types of modulation, and lowest possible cost consistent with satisfactory operation.

I had a 27.005 mc overtone crystal left over from a brief period of disillusionment about CB and, since 27 times 6 is 432 which times 3 is 1296, this seemed a likely place to start.

Fig. 1 shows the final result. The overtone oscillator is voltage regulated and is left operating at all times when the generator is on. The crystal is mounted underneath the chassis to protect it from rapid temperature changes from drafts, etc., further enhancing the stability.

The use of diode multipliers at 432 mc and 1296 mc greatly simplifies developing UHF rf.

Direct coupling the modulation into the cathode of the last vacuum tube multiplier provides a modulation input that will accomodate almost any signal from audio to video, or even pulse.

A four position mode switch on the front panel allows the choice of carrier, no carrier, carrier with 60 cycle modulation and finally carrier with external modulation.

Construction

Building the unit presents no special problems except getting it all under the chassis. The 5 x 9½ x 2½ chassis doesn't leave much useful

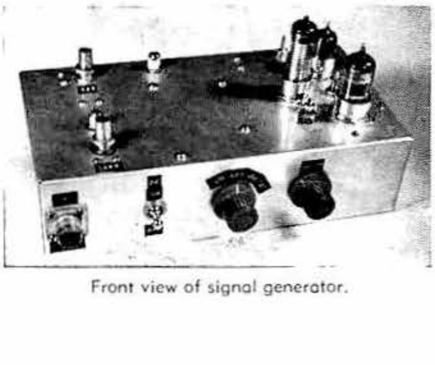

Front view of signal generator.

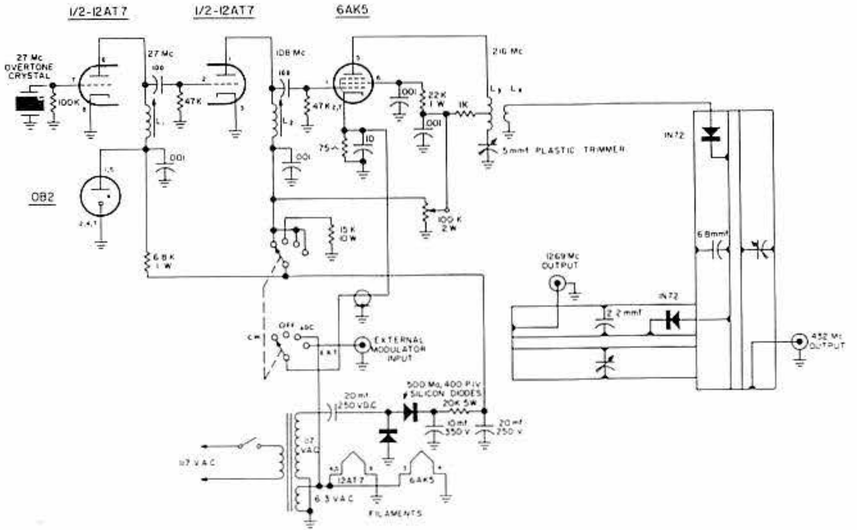

FIGURE 1

L1—10 turns # 28, ⅜" slug form.
L2—3 turns #28, ⅜" slug form.
L3—10 turns #18, ½" dia.
L4—3 turns #18, ¼" dia.

room to spare, but it does make for a very compact device.

The lengths of the diode multiplier tuned lines were determined primarily by the space available and bear only the slightest relation to the wave lengths involved; hence, it was necessary to pad both lines with additional capacitances in order to resonate them properly.

Both lines were folded from 1/32 inch brass sheet stock. The inner conductors are made from ¼ inch brass tubing. The 432 line is 1" x 1" x 7". The input diode is tapped onto the inner conductor 1¼ inches from the other end. The signal output loop is about 1¼ inches long. The output diode is tapped 2 inches from the loop end of the line.

The tuning capacitor is made by soldering a 10-32 nut over a hole in the middle of the line shell. This provides the threads for the 10-32 screw which actually serves as the capacitor.

Round ½ inch disks are soldered to the bottom of the center of the inner conductor and to the end of the turning screw to provide additional range.

The 1296 line is similar except it is only 3⅜ inches long. The multiplier diode is tapped on the inner conductor ⅝ inches from one end. The signal output loop is about ¾ inches long and is located at the other end of the line. The tuning capacitor is identical to the one used in the 432 line.

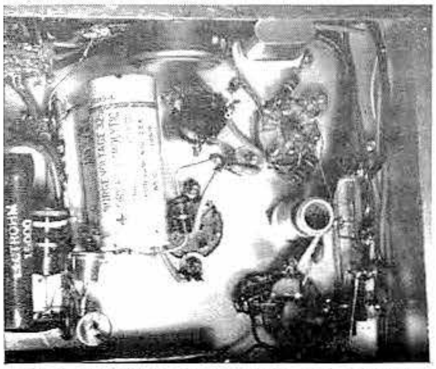

Closeup showing the oscillator and vacuum tube multipliers.

The 15K 10 watt resistor in the carrier OFF position limits the no load voltage from exceeding the ratings on the filter capacitors.

Operation

The tune up of the tube stages can be easily accomplished with a grid dipper. The UHF stages should only need to be peaked with a converter and receiver.

Shields on all tubes and a bottom cover on the chassis are important requirements if stray leakage at the signal frequency or lower harmonics is to be eliminated as a possible source of measurement error. These were removed for the photographs but are always used in practice.

For best results it is a good idea to employ a 50 ohm (or 75 ohm as the case may be) pad between the signal generator and the equipment under test. This will insure that the generator will appear as a resistive load as much as possible. This is necessary if the generator is to duplicate the conditions presented to the receiver by a good antenna.

This pad can take many forms. The two easiest ways to make one would be to use sufficient lengths of some lossy coax. At 432 mc higher, 20 or 30 feet of RG-58 (or RG-59) seems to be quite adequate for most applications. The other approach would involve building a conventional resistor pad into a male and female BNC connector soldered back to back. Fig. 2 shows such a pad.

Aside from receiver testing, this device has several other uses to which it can be put. It is also useful as a signal source for antenna tests and it may be used as frequency standard.

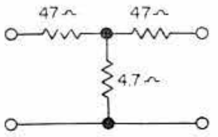

FIGURE 2

Fig. 2. 20 db 52 ohm pad. Resistors mounted in BNC connector.

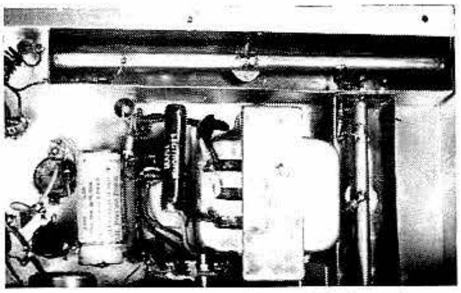

Closeup view showing details of diode multipliers lines.

This last use can be of great value at UHF because of the persistent problem of crystal tolerance versus frequency multiplication. A converter can easily be 40 or 50 kc or more off of the indicated frequency at 1296 mc. This can be quite a problem if you are hunting for a moonbounce signal through a 5 cps filter.

Though not shown on the diagram or in the pictures, it was found that a 50 mmfd variable capacitor connected across the crystal was sufficient to reduce 27.005 mc to the 27.000 . . . mc required to put the generator on 432.00 . . . and 1296.00 . . . mc. It will probably be necessary to retune the oscillator plate circuit for best operation; some loss in output will be encountered but this should not be a serious problem. However, if such operation is contemplated, it might be of some advantage to obtain a 27.002 mc crystal and employ a smaller variable capacitor.

In order to make the frequency standard really something of a standard, a 1 mc calibration oscillator should be employed. Some harmonic of the oscillator (5 mc, 10 mc, etc.) should be zero beated against WWV. The signal generator should then be zero beated against the 27 mc harmonic of the 1 mc calibrator—presto!—a 432-1296 mc frequency standard.

Though there are many refinements which can be made, the unit described has done a yeoman service in all the varied tasks asked of it.

LAB TYPE IF/RF SWEEP GENERATOR USING ICS

Ray Megirian K4DHC

Just about every kit-type sweep generator on the market starts life out at around 3 or 4 MHz and ends up at 200 MHz or so. This always made analysis or display of 456 kHz i-f amplifier response characteristics a tedious step-by-step plotting procedure or required time out to rig up a temporary gimmick to do the job. No more. The sweep generator to be described here will do the job with ease and precision. Even if you do not intend to duplicate the instrument, you may find parts of it useful for other applications.

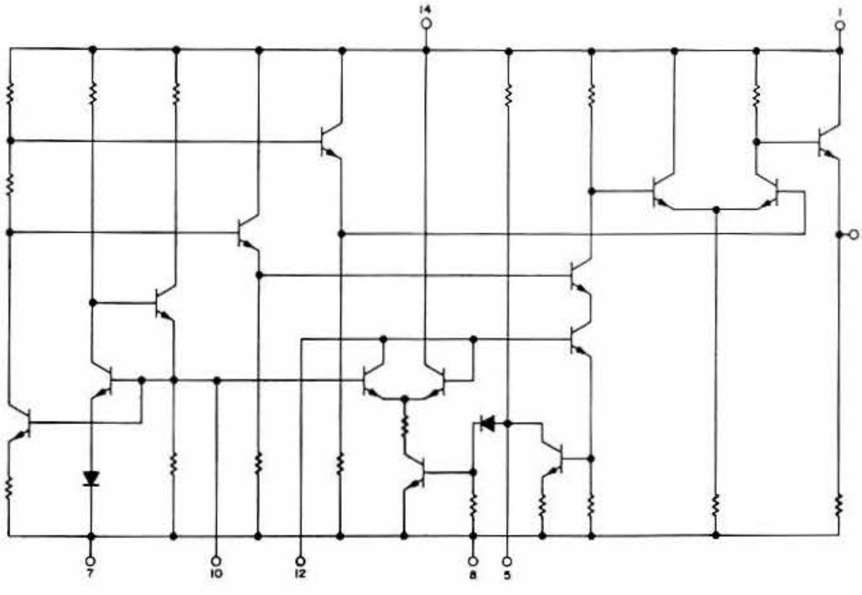

Fig. 1. Schematic of the MC1648 IC.

The generator covers a frequency range of from 400 kHz to 30 MHz in five bands. It can be operated in the CW mode as well as swept, thus allowing it to be used as an ordinary signal generator. Maximum output is 350 mV p-p across 50Ω. When sweeping, the return trace may be blanked or not, as desired. Two calibrated dials are provided for setting the start and stop frequencies and the maximum sweep width would be the entire band in use. The frequencies covered by the five bands are: 400 to 900 kHz, 850 kHz to 2.3 MHz, 2 to 6 MHz, 5 to 15 MHz and 10 to 30 MHz. Sweep time is variable between 20 ms and 6 seconds per sweep. A step attenuator in conjection with a vernier control provide a maximum attenuation of the output of 120 dB. An input is provided for a post-injection marker system built into the unit. A synchronous ramp with gain control is provided for driving the oscilloscope horizontal sweep. Blanking pulses are also brought out to a connector in case they are needed for synchronizing external equipment.

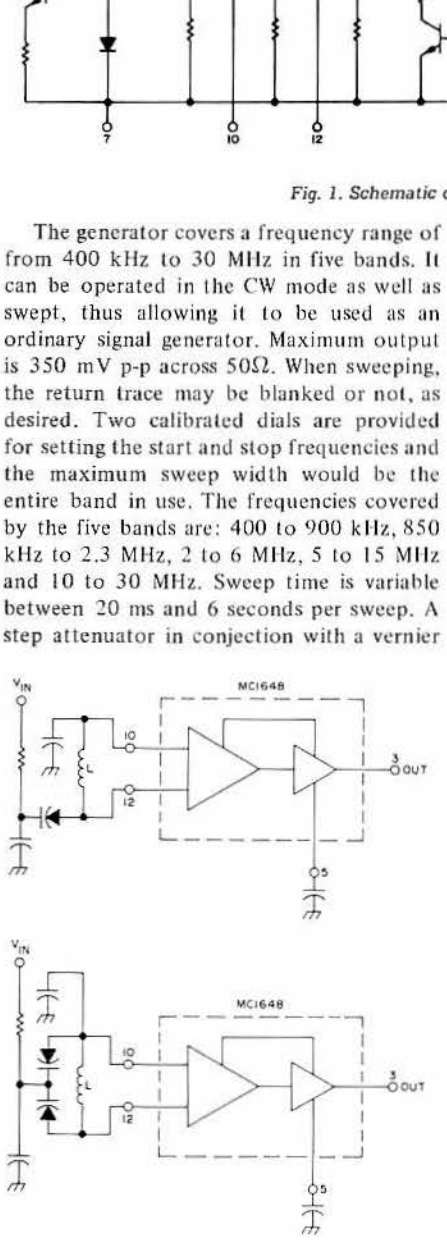

Fig. 2. Tuning the MC1648 with a single diode (A) and using back-to-back diodes (B).

A New IC

The heart of the generator is a new Motorola IC, the MC1648 emitter-coupled oscillator. It was intended for use in phase-locked loop systems operating in excess of 150 MHz, but may be used in many other applications such as this one. The device provides output of high spectral purity and incorporates an internal agc system which simplifies design of the sweep generator by eliminating the need for external leveling. A buffer amplifier and emitter-follower output are also incorporated on the chip, eliminating the need for external amplifiers. Figure 1 is a schematic of the MC1648 IC. Figure 2 illustrates two methods for tuning the oscillator. The device is packaged in a 14-pin DIP and requires a 5V dc supply. Since it was intended to be used with Motorola MECL III logic, either polarity is permissible. A positive supply is used here, connected to pins 1 and 14 with 7 and 8 grounded.

All the information covered by the data sheet for the MC1648 dealt with operation from 10 MHz up to about 180 MHz. Since I was interested in going as low as 400 kHz, I had to do some experimenting with tank circuits. My best results were obtained with the use of cup cores for the two lowest bands. I also found that ordinary molded iron core rf chokes of the miniature variety did an excellent job the rest of the way. Use of these tiny components made possible a very compact 5-band assembly.

The VCO

In order to facilitate shielding and simplify construction, electronic band switching is employed. Figure 3 is the schematic for the rf portion of the generator. The 2N4391 J-FET has a low 'on' resistance and works very well as a switch. One of these transistors is placed in series with each tank circuit

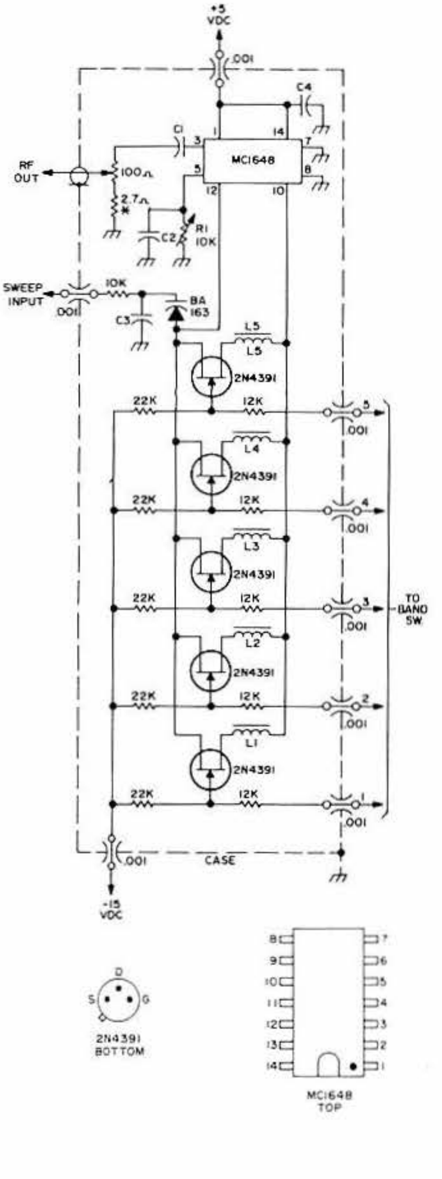

ALL RESISTORS - 1/4 W, 5%
L1 - 28 TURNS NO. 30 AWG ENAMEL.
L2 - 12 TURNS NO. 28 AWG ENAMEL.
(L1 & L2 MOUNTED IN CUP CORE - See Text)
L3 - 18 µH MINIATURE MOLDED RFC.
L4 - 4.7 µH MINIATURE MOLDED RFC.
L5 - 1.1 µH MINIATURE MOLDED RFC
C1, C2 - TYPE 150D TANTALUM - 2.2 µF/20V.
R1 - BECKMAN 89PR10K 15-T TRIMMER.

* - SELECTED PART - See Text.

Fig. 3. Schematic of the rf assembly using dc band switching.

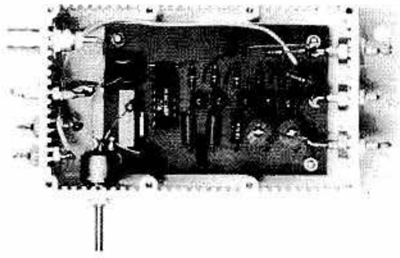

Completed rf assembly ready for mounting in the cabinet. A plastic version of the 2N4391 was used with a considerable savings in parts cost.

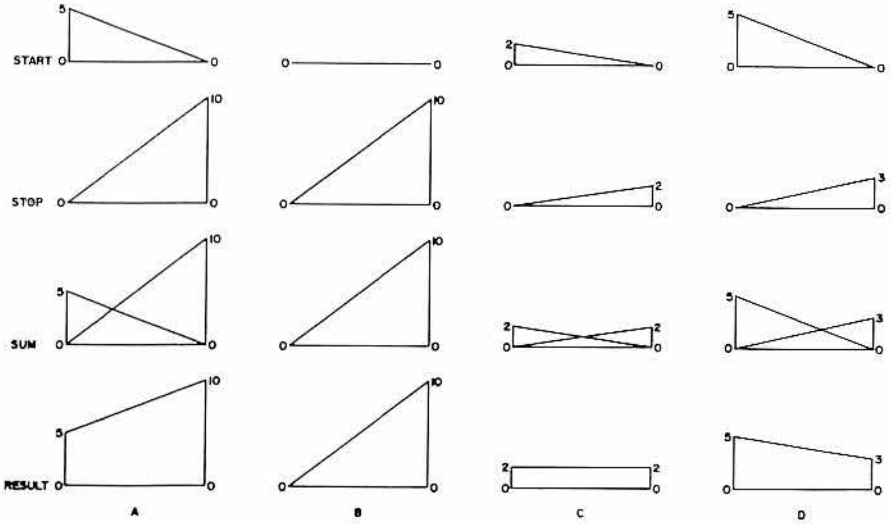

Fig. 5. Pictorial demonstration of ramp generation.

and can be turned on by application of a positive voltage at the gate. This allows the use of a strictly dc-operated remote switching arrangement. The entire assembly is built on a 2 x 3 in. pc board and mounted in a Pomona Model 3306 enclosure with a Model 3328 bottom mounting plate.

A BA163 tuning diode by ITT is used to sweep the oscillator. Although it is intended for bc band use, it performs admirably at these higher frequencies and its high capacitance ratio allows wide sweep excursions. If you are planning to use this oscillator for VHF applications, a more suitable diode would be in order. According to the data sheet on the MC1648, typical maximum output frequency is 225 MHz.

The vernier attenautor is a 100Ω RV6 style potentiometer mounted inside the enclosure. A coupling and extension shaft are used to bring the control out to the front panel. The value of the resistor at the bottom end of the pot will have to be selected so that a range of 20 dB is provided with full swing of the control. Since end resistance varies from one control to another, an exact value will have to be arrived at experimentally.

The output from the VCO is a square wave. If sine wave output is desired, the agc characteristic may be modified by introducing resistance between pin 5 and ground. The small trimmer incorporated on the board is used for this purpose. It was my experience, however, that this may introduce instability with some MC1648s. Although the trimmer was left in, the one in my unit is turned to maximum resistance where it has no effect and left there. It would do no harm to leave it out altogether since no other changes would be needed.

If any readers are contemplating exact duplication of this generator, you will find the cup cores I used are no longer available. These were Ferrox-cube part number 332P133B4-3C and are obsolete. I had a large number of these on hand left over from another project and saw no sense in buying more. I am sure some of the presently available cup cores will make excellent substitutes. Those used here are about 3/8 in. in diameter and are ungapped. You may have to experiment with the number of turns in the coil to obtain the coverage you require. One handy trick you can pull with a cup core is to rotate the slots in each half so that fractional turns are produced when the coil wires are brought out separately through the

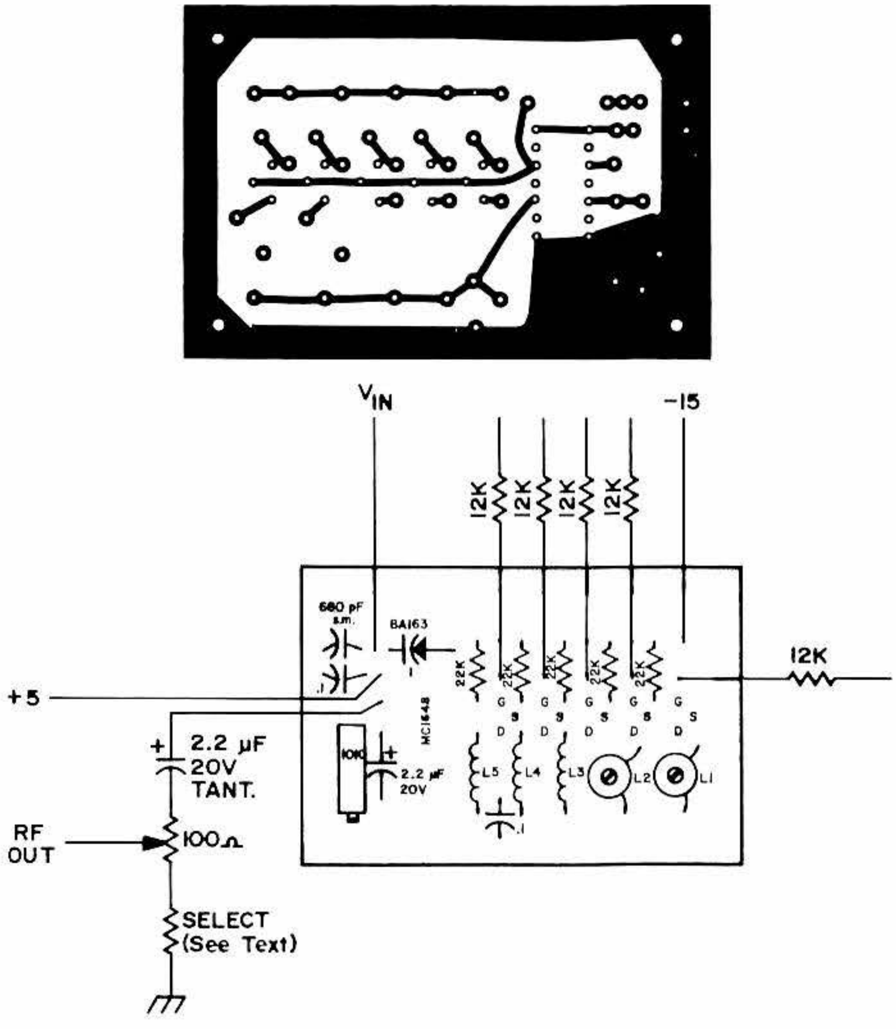

Fig. 4. (A) Foil side of rf pc board. (B) Location of parts on component side.

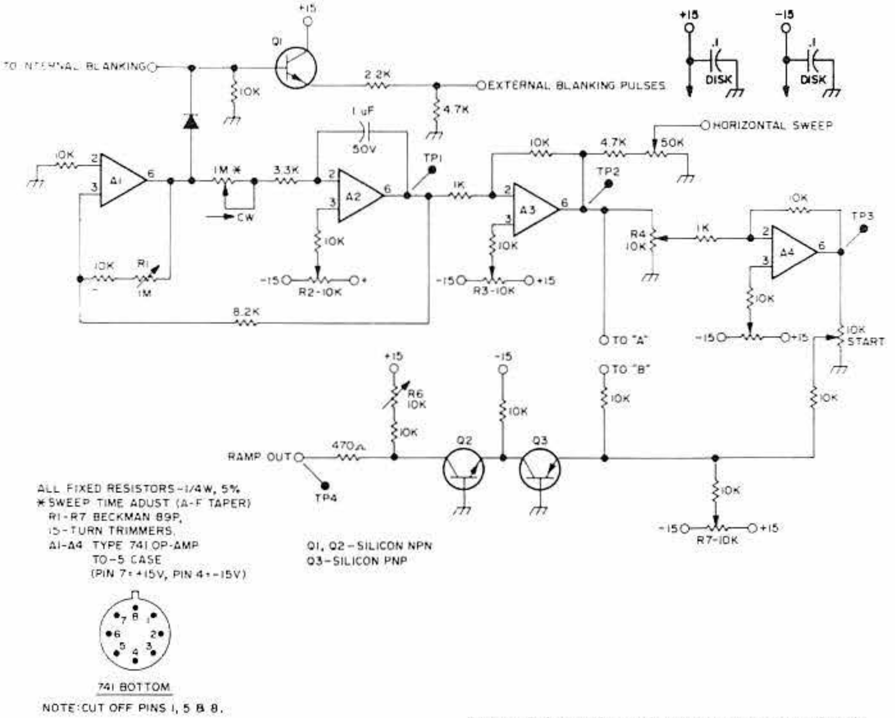

Fig. 6. Schematic of the ramp generator circuit.

two spaced holes. Exerting pressure on the core by means of the mounting screw will also shift the frequency and is almost like having a slug to tune. Increasing pressure seems to raise the frequency. The rf chokes used for the higher bands may also vary slightly from piece to piece and several may have to be tried to get the desired coverage. There isn't much we can do to alter the frequency where the chokes are used. Of course, slug-tuned coils may be used if the pc layout is modified. I do not recommend their use on the two lowest bands, however, since my results were rather unsatisfactory with this sort of tank circuit.

One final point would be in order before leaving the VCO. Note that the 10 KΩ resistor going to the tuning diode, the 2.2 μF rf output capacitor and each of the 12 KΩ resistors going to the transistor gates are not mounted on the board. One end of each has a hole provided on the board and then the component itself is used to make the connection to its final destination. This saves board space and eliminates separate wires. The small resistor at the bottom of the vernier attenuator is similarly mounted between the board and the bottom lug on the control. These points are more clearly seen in the photo. Also note that the cup cores are fastened directly to the board by means of 1-72 screws into threaded holes.

The Ramp Generator

In contrast with kit-type sweep generators that use the 60 Hz line for sweeping the oscillator, laboratory instruments have internal circuitry designed for this purpose. In our case, as with most sweep generators, a voltage ramp is used to control the oscillator during the sweep period. The circuitry has been arranged so that we can adjust the starting point (dc level) of the ramp independently of the stopping point. This simply means that we can set the frequency at which the sweep starts as well as the frequency at which it stops. We can also control, over a fairly wide range, the time it takes for a complete sweep. In this case, the sweep time is continuously adjustable between 20 ms and 6 seconds per sweep.

To get a better idea of how the ramp generator produces the results we've described above, let's look at Fig. 4. Note that a negative-going linear ramp (start) is combined with a positive-going linear ramp (stop) to produce the resultant ramp being applied to the varactor diode. If either input ramp is zero, the resultant will be the same as the single ramp since adding zero to anything will not change its value. Naturally, if both are zero, the output will be zero and the oscillator output frequency will be constant during the sweep period. The same is true whenever both ramps are of equal amplitude, except that the output will be a steady voltage other than zero. Also note that the resultant ramp could have a negative slope if the 'stop' input is lower than the 'start' input, and the oscillator would obviously sweep down in frequency rather than up.

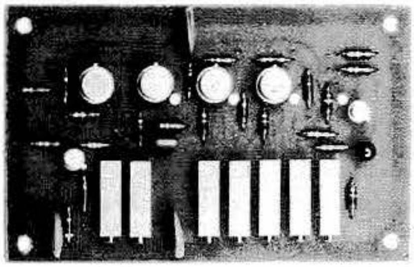

The ramp and blanking generator pc assembly. The leads going to external points will go in the holes visible on the board.

The schematic for the ramp generator is shown in Fig. 6. Operational amplifiers A1 and A2 form a triangle wave generator with A1 acting as a threshold detector and A2 as an integrator. One half of the triangle (negative-going) represents the sweep period while the other half represents the retrace time. Since a square wave is generated at the output of A1, we have a convenient source of blanking voltage built right in. This signal is positive during the sweep period and is connected to the band switch when Swept 1 (blanked retrace) operation is selected. During retrace the square wave drops to zero and actually disconnects the tank circuit until the next sweep starts. An emitter-follower, Q3, buffers the square wave output for external use.

The output of inverting amplifier A3 is a positive-going ramp during the sweep period and is used for both the 'stop' signal and horizontal sweep for the oscilloscope. Since an additional inversion takes place in the output of A4, the negative-going ramp at this point is used as the 'start' signal. These two ramps are applied across front panel controls which have 6:1 reduction drives and are fitted with dials calibrated in frequency for the five operating bands. The outputs from these two pots are fed to summing amplifier Q1, where the output will be the resultant ramp we discussed above. Because the output Q1 is in the negative region (PNP transistor), a second common-base (NPN) amplifier is used to shift the output back to where it will always be positive.

The ramp and blanking generator is constructed on a pc board 2.6 x 4.1 in. in size. For convenience, all the trimmer resistors were mounted along one edge. As seen in the photo, this board was mounted by means of two small brackets in a vertical position with the trimmers facing up. To simplify pattern layout, unused pins 1, 5 and 8 on each of the four 741 opamps were clipped off right at the case. Color-coded wires were connected to all necessary points on the board before it was mounted, with the leads made long enough to reach their destinations. For those interested in building this unit, a detailed procedure for setting up the ramp generator will be given later.

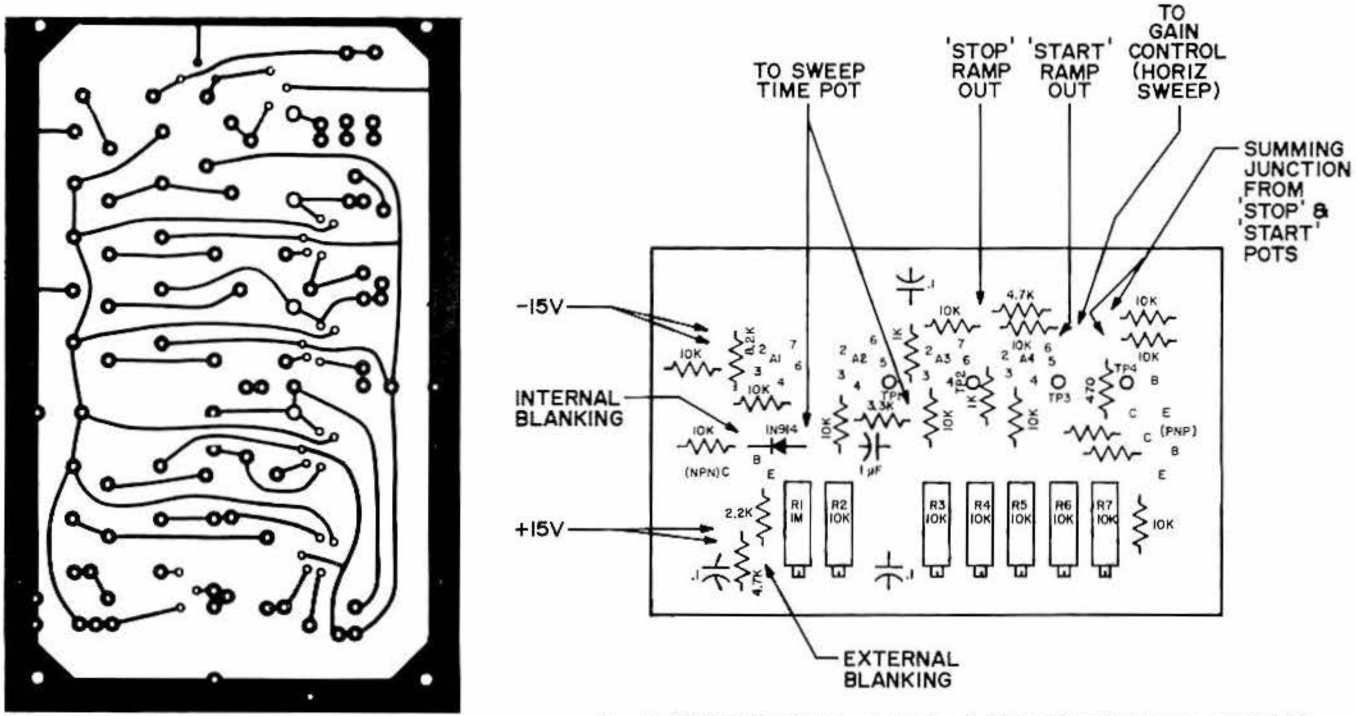
TO SWEEP TIME POT
'STOP' RAMP OUT
'START' RAMP OUT
TO GAIN CONTROL (HORIZ SWEEP)
SUMMING JUNCTION FROM 'STOP' & 'START' POTS
-15V
INTERNAL BLANKING
+15V
EXTERNAL BLANKING
8.2K
A1
A2
A3
A4
10K
4.7K
1K
3.3K
470
IN914
(NPN) C
B
E
(PNP)
TP1
TP2
TP3
TP4
1 µF
.1
2.2K
R1 1M
R2 10K
R3 10K
R4 10K
R5 10K
R6 10K
R7 10K

Fig. 7 (A) Foil side of ramp generator board. (B) location of parts on component side.

The Mixer/Amplifier

In order to provide a means for displaying frequency markers, a mixer and amplifier circuit was built into the sweep generator. The schematic for this circuit is shown in Fig. 6. A marker generator was not included inside the sweeper because other rf generators were available for use as markers and the added expense seemed unnecessary. Because the mixer board was to be installed inside a shielded box, dc gain control was resorted to as with the band switching discussed earlier. A 2N4391 is used as a variable resistor to control the signal input to the amplifier stage. This in turn controls the size of the marker being displayed on the curve. A 2N3819 FET is used in a simple mixer circuit which worked the best of several tried. Incidentally, the PNP and NPN transistors used here and on the ramp generator board are unknown surplus silicon units.

The pc board for the mixer is 1.5 x 2.9 in. and is mounted in a Bud CU-124 die-cast aluminum box. Note that here again some of the components are mounted between the board and their external connectors. These include both the 10 pF and 100 pF input capacitors to the 2N3819 and the 10 KΩ resistor going to the gate of the 2N4391.

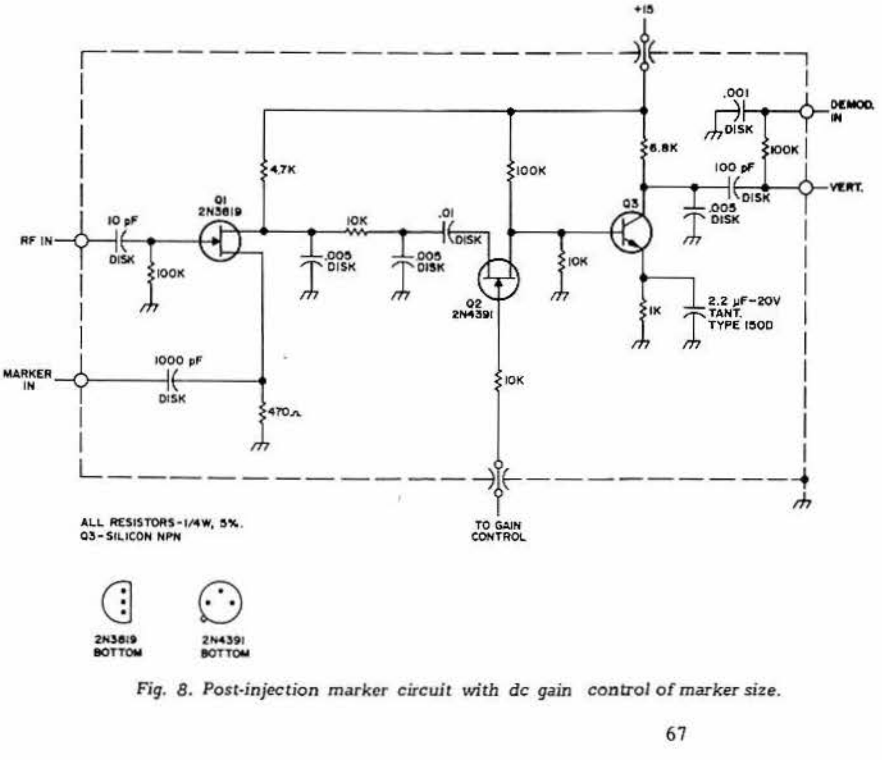
+15
RF IN
10 pF
DISK
100K
Q1
2N3819
4.7K
10K
.005
DISK
.005
DISK
.01
DISK
Q2
2N4391
100K
10K
Q3
6.8K
1K
2.2 µF-20V
TANT.
TYPE 150D
.001
DISK
100K
100 pF
DISK
.005
DISK
DEMOD. IN
VERT.
MARKER IN
1000 pF
DISK
470Ω
10K
TO GAIN CONTROL
ALL RESISTORS-1/4W, 5%.
Q3-SILICON NPN
2N3819 BOTTOM
2N4391 BOTTOM

Fig. 8. Post-injection marker circuit with dc gain control of marker size.

The Power Supply

Figure 7 is a schematic for the power supply. Voltage requirements for the sweep generator are +15V, −15V and +5V dc. The current drawn by any of the above circuits runs no more than 30 or 40 mA maximum,

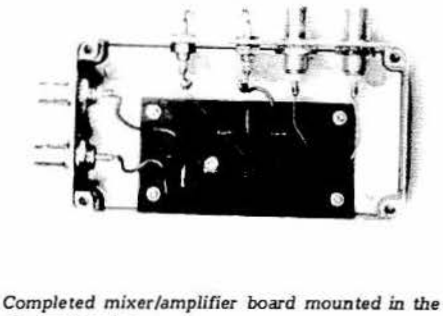

Completed mixer/amplifier board mounted in the die-cast housing.

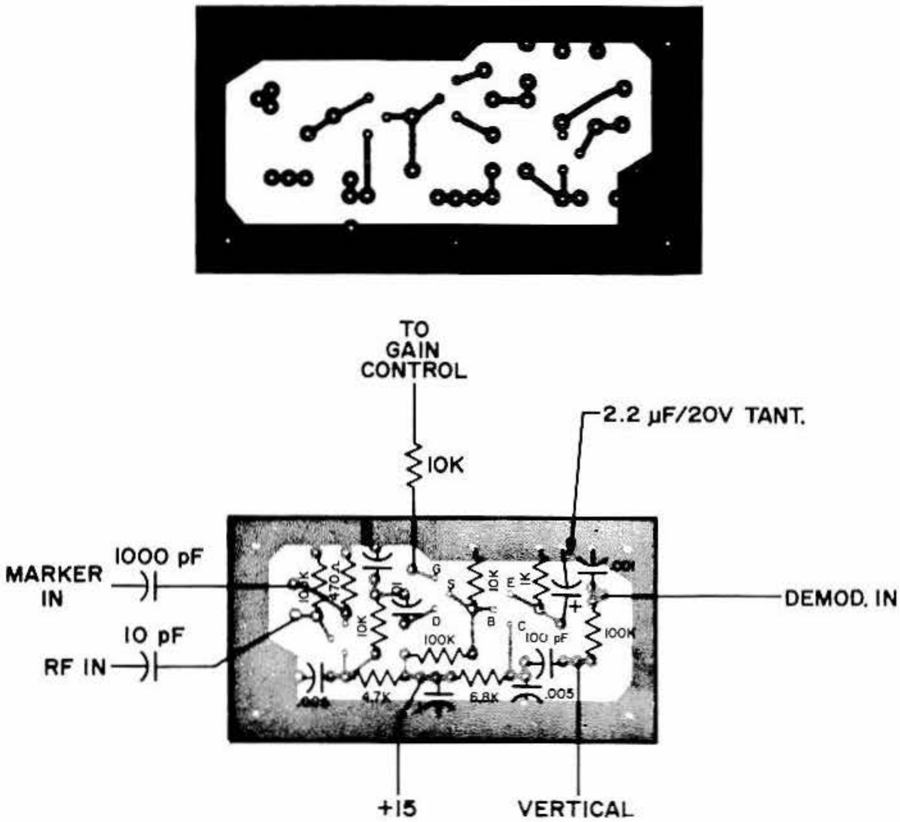
TO
GAIN
CONTROL
2.2 µF/20V TANT.
10K
MARKER
IN
1000 pF
10 pF
RF IN
DEMOD. IN
10K
470
10K
100K
100K
100 pF
100K
4.7K
6.8K
.005
.001
+15
VERTICAL

Fig. 9. (A) Foil side of mixer/amplifier pc board. (B) Location of parts on component side.

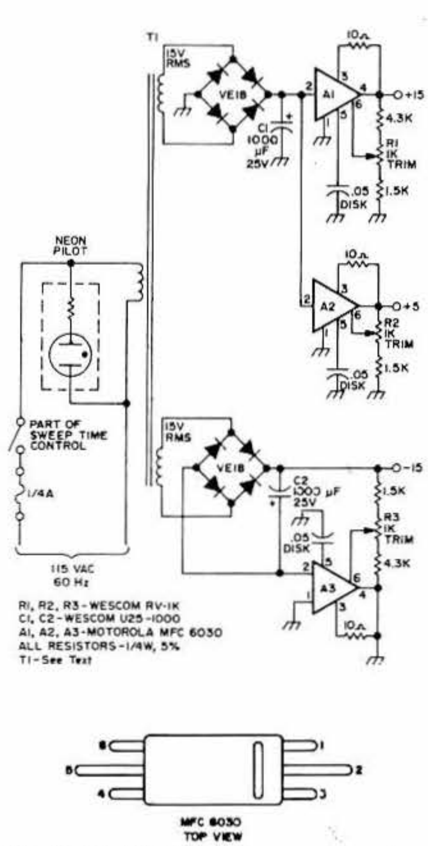
T1
15V
RMS
VE18
C1
1000
µF
25V
A1
10Ω
+15
4.3K
R1
1K
TRIM
.05
DISK
1.5K
NEON
PILOT
A2
+5
R2
1K
TRIM
1.5K
PART OF
SWEEP TIME
CONTROL
1/4A
115 VAC
60 Hz
C2
1000 µF
25V
-15
R3
1K
TRIM
4.3K
A3
RI, R2, R3-WESCOM RV-1K
C1, C2-WESCOM U25-1000
A1, A2, A3-MOTOROLA MFC 6030
ALL RESISTORS-1/4W, 5%
T1-See Text
MFC 6030
TOP VIEW

Fig. 10. (A) Foil side of power supply pc board. (B) location of parts on component side.

making the use of small IC voltage regulators ideal. Motorola MFC6030 (plastic) regulators are used in each supply and are overload protected against accidental short circuit. Varo type VE18 molded bridge rectifiers, together with 1000 µF filter capacitors, supply the dc input to the regulators. The +15V and +5V regulators are both fed from the same source. The power transformer was a surplus unit with a 30V CT secondary. The center tap was uncovered and the two leads separated so as to provide two independent 15V windings. A small trimmer is provided in each supply for voltage adjustment.

The pc board for the power supply is 2.6 x 4.1 in. All components but the transformer are mounted on the board. The transformer is mounted directly on the chassis. Relative placement of the various components making up the complete generator can be seen quite clearly in the photo.

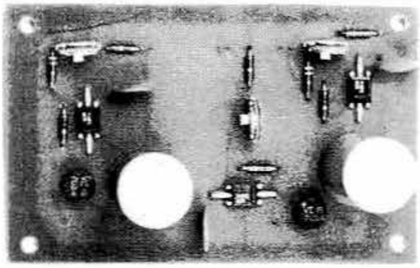

The power supply pc assembly.

Control Circuits

Figure 8 is the wiring diagram for the control circuitry. Note that for CW operation of the generator, a dc voltage is applied to the varactor by way of the Start pot. In order for the dial calibration to be valid in either mode, the dc level applied to the control must be exactly the same as the peak amplitude of the ramp during swept operation. As will be explained in the set-up procedure, the ramp will vary from a starting point of approximately +1.4V and peak at +12V. Resistor R1 in series with the +15V line is selected for a +12V level at the high end of the pot. R2 is selected for a level of +1.4V at the low end. The reason for the offset of 1.4V at the low end is because the pin to which the tuning diode is connected at the MC1648, sits at this level. The source of this bias is the drop developed across two forward-biased junctions within the IC and not from any external source. Once these dc levels have been set for CW with the fixed resistors, the ramp can be made to match by means of the trimmers in the ramp generator circuit.

The rest of the control circuitry is quite straightforward. In position 2 (Swept 1) of the mode switch, positive pulses from the ramp generator are fed to the band switch during the sweep period. When retrace occurs, the pulse drops to zero and the oscillator shuts off until the next sweep starts. In the CW and Swept 2 positions of the mode switch, a steady +15V is applied to the band switch and the oscillator runs continuously.

The final function performed by the mode switch is to route the dc for CW or the ramp for swept operation to the tuning diode. The two fixed resistors are mounted point-to-point behind the panel since all points are readily accessible within every short distances. The fixed resistors associated with the marker gain control are also mounted the same way behind the panel. The switches are ordinary rotary types and the potentiometers are all ordinary carbon controls. The Start and Stop controls as well as all gain controls have linear tapers. The Sweep Time pot is an audio taper type with built-in switch for ac power.

Setting Up the Ramp Generator

For best results, a calibrated dc scope is required to properly adjust the ramp generator. Test points have been provided on the pc board and short pieces of bare wire connected to each of these points make excellent tie points for the scope probe. The

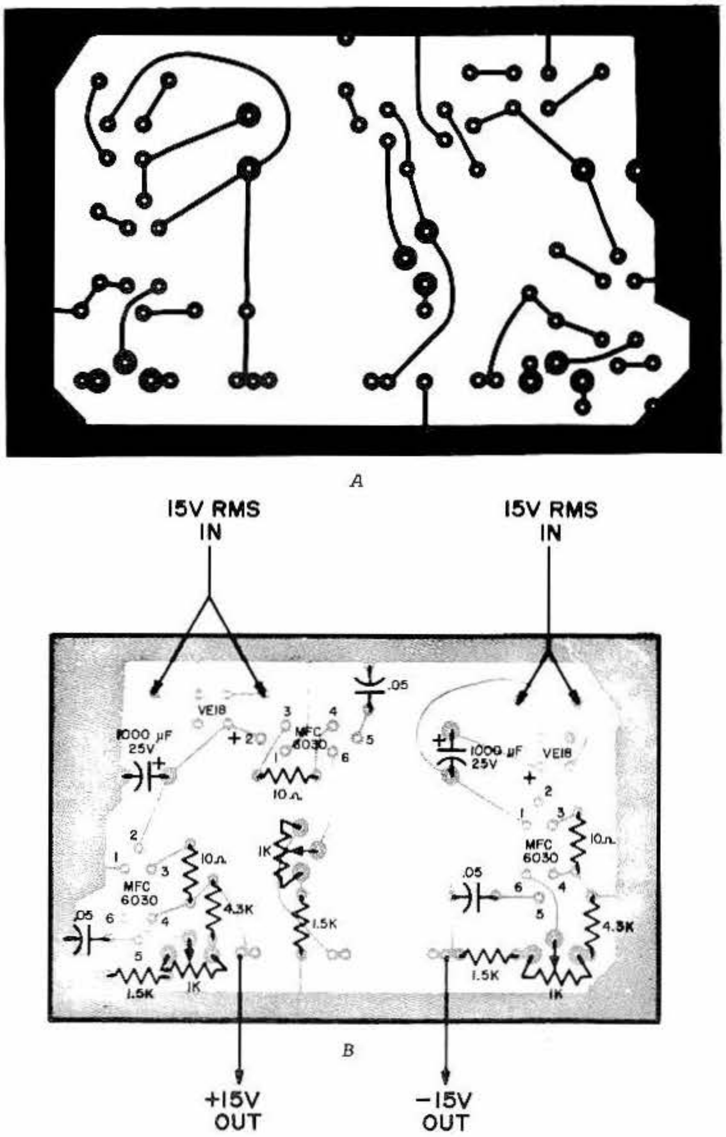

A
15V RMS IN
15V RMS IN
VE18
1000 µF 25V
+
MFC 6030
10Ω
IK
.05
1.5K
4.3K
B
+15V OUT
−15V OUT

Fig. 11. (A) Foil side of power supply PC board. (B) Location of parts on component side.

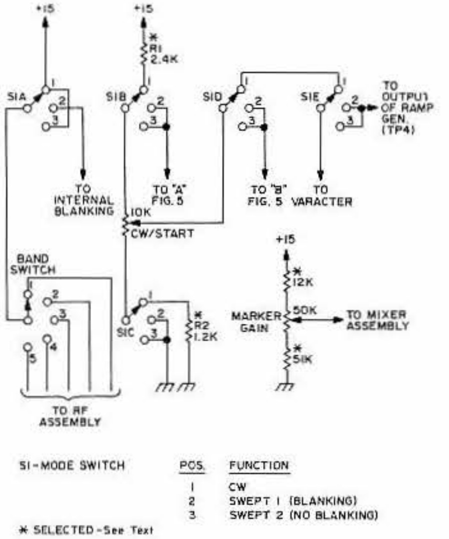

+15
+15
R1 2.4K
S1A
S1B
S1D
S1E
TO OUTPUT OF RAMP GEN. (TP4)
TO INTERNAL BLANKING
TO "A" FIG. 5
TO "B" FIG. 5
TO VARACTER
10K
CW/START
+15
BAND SWITCH
12K
MARKER GAIN
50K
TO MIXER ASSEMBLY
S1C
R2 1.2K
51K
TO RF ASSEMBLY
S1-MODE SWITCH
POS. FUNCTION
1 CW
2 SWEPT 1 (BLANKING)
3 SWEPT 2 (NO BLANKING)
✱ SELECTED - See Text

Fig.12 Control circuit wiring schematic.

circuit may be aligned either before or after installation. The Start, Stop and Sweep Time pots can be connected at the ends of their respective leads if the unit is checked outside the cabinet.

Set all seven trimmers to mid-range. Connect the scope to TP1 and adjust the horizontal for a full sweep of 20 ms. Set the Sweep Time control to minimum resistance and apply power. Some sort of triangular wave should be displayed. Adjust R1 for a 3V p-p amplitude of the waveform. Turn R2 cw until the negative-going portion of the triangle is 20 ms long. Since R1 and R2 interact, you will have to stop occasionally and reset R1 for proper amplitude. Once the ramp is set at 20 ms with the Sweep Time pot at minimum, the slow speed end will automatically be about 5 or 6 seconds with a 1 MΩ pot.

Transfer the scope probe to TP2 where a positive-going ramp should be seen. Set the starting point of the ramp to zero volts by means of R3. Amplitude of this ramp must be 10V. If it is not, go back and adjust R1 slightly until it is. If necessary, reset R2 for 20 ms trace length. As soon as a 10V, 20 ms, zero-based, positive-going ramp has been achieved at TP2, go on to TP3.

At TP3 there should be a negative-going ramp. Once again we require a zero base line or starting point. Adjust R5 to accomplish this. Amplitude should once again be 10V and is controlled by R4. Once you have a 10V, zero-based, negative-going ramp, move on to TP4.

Connect the probe to TP4 and set the Stop control to full cw. The Start pot should be at minimum setting. A positive-going ramp should be present at TP4. By means of trimmer R7, move the ramp up or down until the starting point is approximately +1.4V. Ordinarily the ramp will not go below zero but will flatten out as the positioning control is adjusted. This is due to clipping in the output amplifier. If the ramp generator is going to be used with another type of VCO, the ramp can be set to exactly zero if desired. In our case we can't as explained previously.

Because a substantial amount of capacitance change occurs in the tuning diode up to 12V, the final ramp amplitude is set to 12V by means of R6. Because R6 stretches the signal in a negative direction, R7 will have to be used to reset the base line at 1.4V. Other than for checking tracking between the CW and swept modes, this completes the alignment procedure for the ramp generator.

When the generator is finished, you can check the tracking by observing actual signals at the input to the VCO. Connect the scope probe to the feedthrough capacitor on the VCO assembly that goes to the tuning diode and set the Start control to maximum. Switch rapidly between the CW and Swept 1 positions of the mode switch. The CW input will be a straight line sitting at +12V while the swept input will be a ramp peaking at +12V. Next, turn the Start control to minimum and again compare levels. If the Stop control is also at minimum, both signals will be straight lines at +1.4V. If there is any substantial difference between the two modes, use R6 and R7 on the generator board to make the ramp agree with the dc levels. That completes all phases of the ramp set-up procedure.

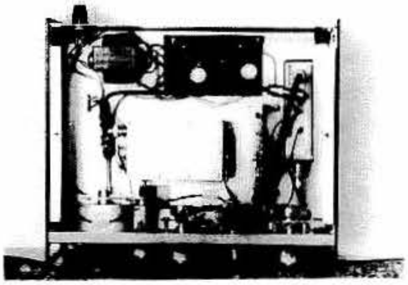

This bird's eye view of the interior shows the location of all major assemblies.

Construction

The cabinet used here is one manufactured by Sorensen Electronics in their Mod-U-Line series. These are the most reasonably priced instrument enclosures I've come across so far and I've used them for several projects. This one is a Model MCH-5129 with a CP-129 chassis plate. Dimensions are: 5¼ in. high by 12 in. wide by 9 in. deep.

The 5-step attenuator was picked up surplus from Fertik's Electronics for about \$10. It is well made and designed for 50Ω systems operating up to 1 GHz. It has an integral female BNC output connector on the front face along with four threaded mounting holes for ease of installation. The input connector is a BNC male at the end of a short piece of coax.

All rf assemblies are interconnected inside the cabinet by means of coax cables. This is clearly evident in the photo.

The Start and Stop pots were mounted on brackets behind the front panel so that Jackson Brothers type 4511/DAF reduction drives could be installed for easier tuning. The two circular dials are slightly under 2 in. in diameter and were cut from sheet plastic. While operating in the CW mode, one of these was calibrated in pencil to provide a pattern for the finished product. A master was laid out using Rubylith® film and rub-on numbers. A negative of this was then made using 3M reversing film. From the negative a finished set of dials was printed on aluminum material of the presensitized variety. These were cut out and stuck to the plastic by means of their own pressure-sensitive adhesive backing. The nameplate was made from the same material. The two index pointers are clear plastic with hairlines scored on the inside surface. They are mounted on spacers directly over each dial. All remaining labeling was done with tub-on lettering.

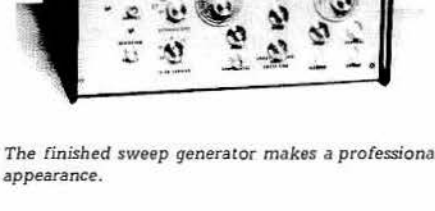

The finished sweep generator makes a professional appearance.

Vendor Addresses:

Fertik's Electronics, 9th & Tioga Sts., Philadelphia PA 19140.

Sorensen Electronics Co., Inc., 418 Queens Lane, San Jose CA 95112.

Wescom, P.O. Box 2436, El Cajon CA 92021.

100 KHZ THIN-LINE PULSE GENERATOR

James Ashe W2DXH

Ordinary 100-kHz frequency standards are usually audible up to a few tens of megahertz. A good one might be usable at 50 MHz. The circuit described here uses a dual NAND gate to generate a 100 kHz signal whose harmonics are usable to 432 MHz or higher. And it can be built without benefit of special instruments and knowledge.

The thin line pulse

One rather surprising result of higher mathematics is that all repetitive signals are composed of harmonically related sine and cosine waves. For example, the familiar square wave is composed of a fundamental frequency, which sets its basic repetition rate, and of odd harmonics only of its fundamental, which contribute to its square corners. If the harmonics' amplitude or phase relationship is upset, the square wave is distorted. This feature makes the square wave very useful for amplifier testing, but its harmonic content is not very good for frequency standard applications.

Now suppose that we start adding up signals of F, 2F, 3F, and so on, phased in so that they all reinforce each other once per cycle. Let's say thay are all the same amplitude. What would we get? See **Fig. 1A.**

The five equal amplitude sine waves peak simultaneously at the beginning of the fundamental's cycle. Everywhere else, until near the end of the cycle, they are more or less out of phase. Trying to see what will happen, we try adding the first two frequencies. **Fig. 1B**, the result, might suggest something to a mathematician.

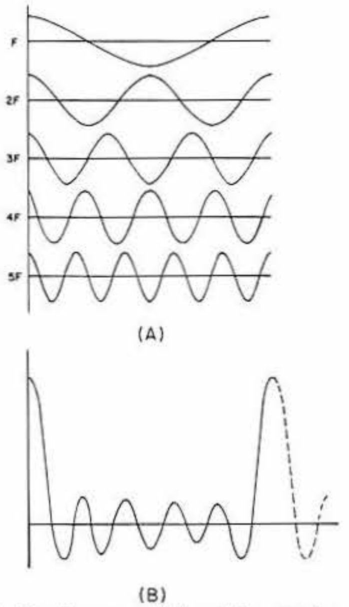

Fig. 1. Five sine waves (A) and the waveform as a result of point-by-point addition (B).

As the number of frequencies is increased, their amplitudes tend to average to zero everywhere except at the beginning of the cycle. Here, they all add up to a short, sharp pulse. It follows that a short, repetitive, one-sided pulse should contain odd and even multiples of the fundamental frequency.

An ideal thin line pulse has infinite frequency content.* No real signal could meet

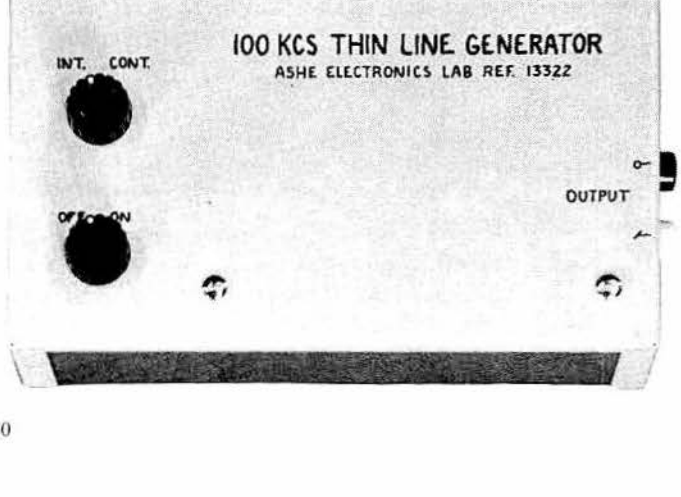

External view of the 100 Hz thin-line generator.

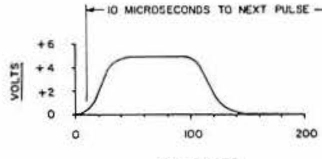

Fig. 2. Real circuit output as seen by a Tektronix 545A oscilloscope. A faster scope shows shorter rise-time and sharper corners.

this spec, but a fast digital IC can produce a very workable approximation. Fig. 2 shows a Tektronix 545A view of the generator output and tests with other scopes indicate the real pulse has better rise time and sharper corners than shown here.

If this pulse is viewed on a low-performance service variety scope, its appearance will be greatly changed. There will be an apparent loss in amplitude, since the pulse occurs and terminates before the slow circuitry can properly respond. The apparent duration is increased, also because of the slower viewing circuitry. And the fast pulse may excite circuit resonances, so that the thin line pulse appears as a damped oscillation. But these problems do not interfere with constructing the generator, because the very simple NAND gate circuitry contains no critical elements or adjustments.

How it works

There are four circuit sections, shown in Fig. 3. A 100-kHz crystal-stabilized oscillator sets the basic frequency, and a dual NAND gate circuit converts the oscillator output to a thin line pulse. A 1-Hz astable generates the output marking signal. A 6 volt dc power source is provided by a voltage doubler zener-regulated supply.

Multivibrator oscillators are not ordinarily very stable frequency sources. But if the oscillator is designed to run slightly below required frequency, and an appropriate crystal is connected between transistor base terminals, oscillations are stabilized at the crystal frequency.

The crystal does not change the multivibrator's style of operation. It synchronizes the astable to its own frequency, by triggering the OFF transistor into conduction shortly before normal RC turn-on. The output is a squarish wave with good fall time, but a long rise time as shown in Fig. 4A.

In passing through the first NAND gate the pulse is squared up and becomes slightly unsymmetrical. See Fig. 4B. A differentiating network, C7 and R11, converts the square wave into the pulses shown in Fig. 4C. These pulses, applied to the second NAND gate, reappear as the thin line pulses shown in Fig. 4D.

Since one CW signal sounds just like another and there may be several in the vicinity of a check point, a marker feature is required. This is provided by the 1-Hz astable, which paralyzes the second NAND gate part of the time. Its base bias resistors are unequal, giving a distinctive duty cycle to the output signal. A switch disables the astable if a continuous signal is required. Fig. 5 shows the output when the second astable is operating: the output is locked in the up condition during half of each 1-Hz astable cycle.

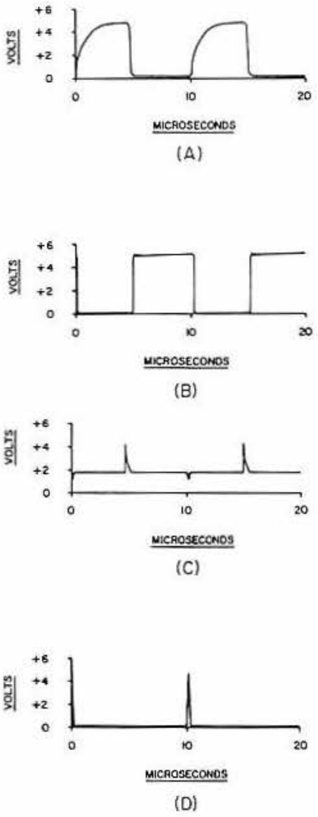

(A)

(B)

(C)

(D)

Fig. 4. Signals at four critical points in the generator, as displayed on a Tektronix 545A oscilloscope. They are shown in time coincidence.

Sometimes an astable oscillator will refuse to start oscillating when it is turned on. It does not start because both transistors are in saturation. This reduces loop gain so that available noise cannot be amplified around the loop. It would never start without some strong, outside interference.

A pair of diodes, D1 and D2, provide a reliable remedy. The diodes are arranged so that base bias must come from whichever collector is at the higher voltage. If both transistors are in saturation, their collectors are at perhaps 1 volt, which cannot provide enough base current to keep the transistors in saturation. This contradictory situation does not arise in the real circuit, which starts reliably.

Additional diodes, D5 through D8, appear in the base circuit of the 1-Hz astable. These are protective diodes. The collector swing at turnoff of about 5 volts is conveyed powerfully to the opposite base through the large coupling capacitors C5 and C6. The reverse B-E breakdown voltage of these transistors is not known, so the diodes are provided to prevent the turnoff voltage exceeding 2 volts or so.

DC power for the Generator circuitry comes from a voltage doubler supply based on a low-current filament transformer. Its design is conventional, but a large capacitor, C12, is provided across its output to mini-

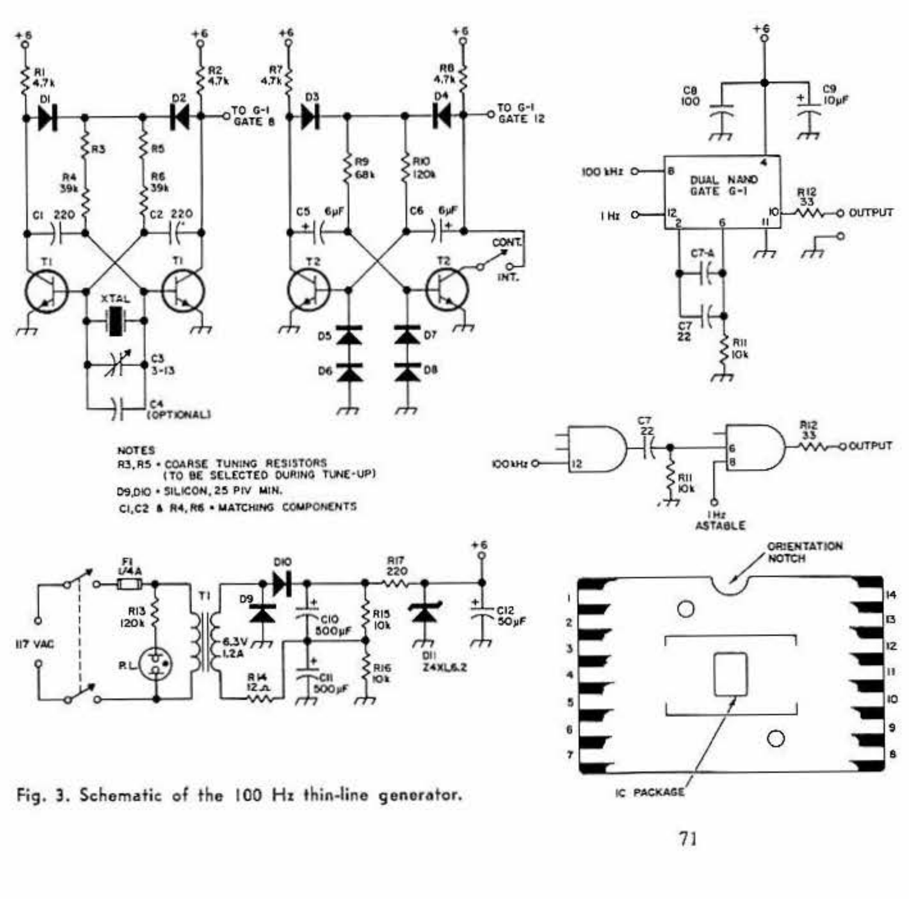
+6
R1 4.7k
D1
R2 4.7k
D2
TO G-1 GATE 8
R3
R5
R4 39k
R6 39k
C1 220
C2 220
T1
T1
XTAL
C3 3-13
C4 (OPTIONAL)
R7 4.7k
D3
R8 4.7k
D4
TO G-1 GATE 12
R9 68k
R10 120k
C5 6μF
C6 6μF
CONT.
INT.
T2
T2
D5
D6
D7
D8
C8 100
C9 10μF
100 kHz
1 Hz
DUAL NAND GATE G-1
R12 33
OUTPUT
C7-A
C7 22
R11 10k
NOTES
R3,R5 • COARSE TUNING RESISTORS (TO BE SELECTED DURING TUNE-UP)
D9,D10 • SILICON, 25 PIV MIN.
C1,C2 & R4,R6 • MATCHING COMPONENTS
100 kHz
C7 22
R11 10k
R12 33
OUTPUT
1 Hz ASTABLE
F1 1/4A
R13 120k
117 VAC
P.L.
T1
6.3V 1.2A
R14 12Ω
D9
D10
C10 500μF
C11 500μF
R15 10k
R16 10k
R17 220
D11 Z4XL6.2
C12 50μF
ORIENTATION NOTCH
IC PACKAGE

Fig. 3. Schematic of the 100 Hz thin-line generator.

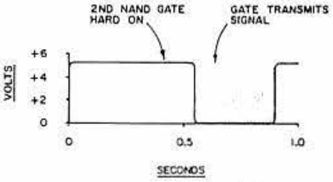

Fig. 5. The second NAND gate locks in its up position part of the time to produce an intermittent output.

mize noise on the supply line. The supply could be replaced with some batteries, shunted by a 50 μF or larger capacitor to absorb transients. The original breadboard ran very well, powered by four flashlight batteries.

Construction

The generator is built in a Premier #PMC 1008 3x5x7 inch heavy aluminum box. Its top cover was refinished in light green enamel, and four ⅜ inch grommets in the bottom piece serve as protective feet.

Inside the box, the 6.3-volt transformer and cheater cord connector are mounted on the left-hand wall. A pilot lamp, fuse, and two switches are mounted on the horizontal panel, at the extreme left. This leaves just enough open space for the two circuit boards which occupy most of the box. Two banana jack output connectors are placed on the right-hand side, just below the panel.

The circuit boards are cut to 4½ x 5 inches, from Vector 3/32 inch pattern A stock and mounted parallel to the panel. The upper board is spaced an inch from the panel, and carries both astable oscillator circuits. The other board is mounted one half inch below, and carries the digital IC and the power supply circuitry. Assembled, the two boards make a sandwich with wiring sides together.

Both boards are mounted on the same four centers. These are through the second hole diagonally inward from each corner. The 1 inch 6-32 internally threaded spacers are modified by adding a short length of 6-32 threaded shaft to one end of each, simplifying assembly.

Component assembly on the boards is largely a matter of plugging in Vector T9.4 lugs. The finished product looks much better if some thought is given to facing the lugs in one of two directions. Mounting and transistor holes should be drilled and reamed to size before installing lugs.

The general arrangement puts all wiring on one side of the board and practically all components on the other side. This approach seems a little inflexible but is straightforward and looks good.

Possible board orientation problems may be overcome by working out a handling and wiring procedure that doesn't require constant reference to actual components. A good approach assumes that the board is only turned over an imaginary hinge at its bottom edge, so that top down when one side is up becomes bottom up when the other side is down. This preserves left-right relationships. Another useful convention is that all supply wiring goes to left-hand end of components.

Wiring is carried out one network (plus supply lines; ground lines; interstage lines, etc.) at a time, with prearranged color coding. Bare wire goes for short runs and where there is no chance of a short. Solder each lug when convenient. #22 solid wire fits the T9.4 lugs well, but flexible stranded wire is used for the four lines from one board to the other.

Transistors precede other components into the board, because they are convenient position markers. They are placed in their mounting holes in the board from the component side, and their leads brought to the T9.4 lugs. Then the other components are mounted on the boards. Diode and electrolytic capacitor mounting polarity should be double checked. The T9.4 lugs may need a little bending before they will take a good grip on the components, but no component soldering is done until everything is installed.

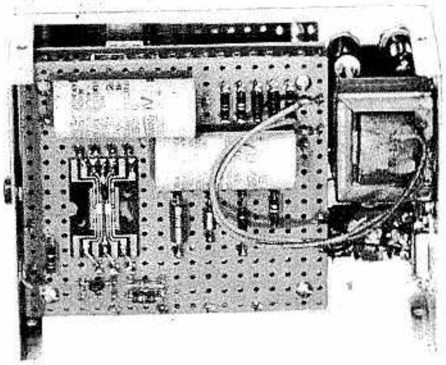

Inside the assembled thin-line generator showing the component side of the power supply and IC board.

Trimmer capacitor C3 is mounted on its tabs just under the top panel. Then a small screwdriver access hole is drilled over it in the panel, before painting, for vernier frequency adjustment after final assembly.

Certain components are matched before installation. An ohmmeter and a capacitor checker will do a satisfactory job of selecting C1 and C2, and R4 and R6, for equal values. These components are chosen alike for best symmetry of the 100-kHz oscillator operation. It might be good planning to leave these components unsoldered until tuning is completed, but everything else can be soldered to the board at this point. Note that the R3 and R5 sites do not get resistors until later.

Two optional capacitor sites are included. These are for C4, an additional and probably unnecessary padder across the crystal; and C7A, which can be added to increase the width of the thin line pulse.

Apparently, the digital IC comes in a specially designed package for testing before use. To mount the IC, solder a ⅜ inch piece of #22 wire in each of the T9.4 lugs carrying supply and signal voltages to the IC. Place the IC between the two rows of lugs, bend the wires against the proper terminals, and solder. No other mounting is required.

The original breadboard showed a lot of transient noise in its supply circuit. This originated from the IC, which was trying to get big chunks of current to manufacture pulses. Since the IC cannot deliver frequencies not available from the supply lines, very careful bypassing is indicated.

High-frequency bypassing consists of C9, a .01μF disc ceramic capacitor across the IC supply terminals on the wiring side of the board, and C10, a 100 picofarad capacitor soldered directly between supply terminals on the IC. The capacitor leads are provided with spaghetti insulation and placed for minimum open space between the capacitor leads and the IC's supply leads.

Testing before final assembly is very easy, because the odd appearing board layouts go together giving a structure that opens out like a book. The hinge is the four leads between boards. Leave transformer leads long, so that the circuit may be tested well free of its cabinet.

The upper half of the Premier box is prepared by a powerful cleaner which removes its original paint. After thorough removal of the cleaner, the metal is roughened with wet sandpaper, rinsed in vinegar solution and then clear water, leaving a very good surface that does not require priming for excellent paint adhesion. Watch out for greasy fingerprints.

Rustoleum #868 Green applied from a convenient spray can gives a fine finish. Follow instructions on the can. After drying, the fresh, clean enamel will take waterproof India ink, applied with a Leroy drafting pen. When the ink is thoroughly dry, a final coat of Rustoleum #717 Clear finishes the job. The enamel is soft at first, but hardens into a coat durable in normal lab use.

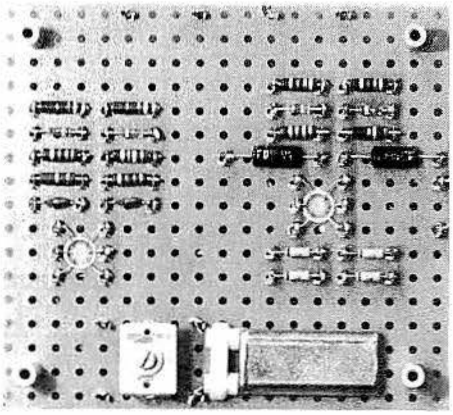

View of the component side of the astable oscillators board.

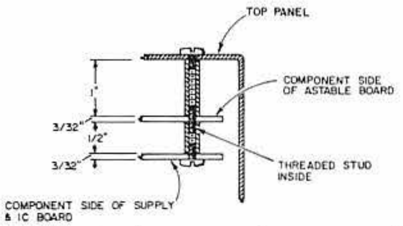
TOP PANEL
COMPONENT SIDE OF ASTABLE BOARD
1"
3/32"
1/2"
3/32"
THREADED STUD INSIDE
COMPONENT SIDE OF SUPPLY & IC BOARD

Fig. 6. Mounting dimensions and spacer assembly diagram.

Table of special parts

Crystal: 100 kHz parallel resonant 32 pF. shunt capacitance normally designed quartz crystal.
The following parts were obtained from Solid State Sales, P. O. Box 74, Somerville, Mass. 02143.
  T1 & T2: 2N2060 type dual NPN transistor
  D1, D2, D3, D4: fast point-contact Germanium diodes coded 1N59
  D5, D6, D7, D8: fast point-contact Silicon diodes marked S284GM
  G1: surplus digital integrated circuit
  Solid State Sales type G1. (comes with data sheet)

Tuning up

The generator should be zeroed to frequency before installation in its case. This is a two-step process. First, the 100-kHz astable base resistances are adjusted by choosing resistors for R3 and R5 to bring the oscillator frequency within trimmer range of 100 kHz, perhaps a few hundred cycles high at 15 MHz. Then the trimming capacitor brings the frequency to accurate coincidence with WWV.

To roughly zero the generator, set the trimmer capacitor, C3, at minimum capacitance. Identify WWV on a short-wave receiver, and tune around a bit to familiarize yourself with what's happening in the vicinity. It would be nice if things are fairly quiet.

Then put 4.7k resistors into the astable board at the R3 and R5 sites, turn on the generator, and look around for the signal. Depending upon actual values of C1 and C2, the signal may be on either side of WWV but is likely to be on the high side. If so, try again with resistors one size larger, which will lower the frequency. You should shortly find resistors that bring the frequency near enough to WWV for final zeroing with the capacitor. Verify tuning range on both sides of WWV.

Correct values for R3 and R5 may be approximated very quickly if a good triggered scope is available. Try selecting resistors for a period of 11.4 microseconds with the crystal removed.

Using the thin line generator

A breadboard test showed that (as might have been expected) there should be some way to distinguish generator signals from other CW signals. The continuous/intermittent feature provides the marking, and once the correct signal is located the generator can be switched to "continuous" for accurate work.

At low frequencies, the generator output and behavior resembles a conventional 100-kHz standard. The signal simply is not as strong. A greater difference appears at higher frequencies: the original model yields an audible beat note at 80-MHz from a diode mixer through an inexpensive audio amplifier. And another test shows a usable signal at 432 MHz: the 4,320th harmonic.

Some connection to the receiver or other detector is required. This is a natural consequence of a circuit design that puts the signal where it belongs, rather than spraying it all over the lab. A few picofarads coupling capacitance is sufficient at all frequencies.

Perhaps this circuit can be used for purposes other than a frequency standard. Its moderate amplitude but wideband output should be ideal for detecting changes in receiver sensitivity over a broad tuning range. In fact, with a little decoupling of the input leads and provision of a coax output connector the generator should do well as a stable, reliable small-signal source. A piece of adjustable waveguide-below-cutoff would make an excellent attenuator for work not requiring exact measurements. Another thought that occurs is possible further development by provision of some arrangement for detecting which harmonic is actually being heard.

Chapter VI

Crystal Calibrators

ALL BAND BAND-EDGE MARKER

Charles Berner WA2HRZ

This calibrator is complete with its own ac supply, eliminating the need for taking power from the receiver. If ac outlets are at a premium at your shack, the on-off switch and the line plug can be eliminated and the ac line connected across the receivers ac input so that the calibrator comes on whenever the receiver is turned on. A high density selenium rectifier was used and this contributes greatly to the compactness of the unit. The whole thing runs very cool and even after 24 hours operation, still isn't hot.

Wiring isn't too critical, but keep all leads short and direct. Using an octal socket for a xtal holder lets you use the unused pins as tiepoints and is recommended.

A Peterson type Z-2 xtal was used because it has a tolerance of .002%. This is one reason why no provision is made for "zeroing" the calibrator against a standard. The other is that there isn't any such standard as WWV for use. However, if this provision is desired, C1, the 56 mmfd capacitor, connected to pin 1 of the 6BH6 thru the 18K resistor, can be made variable. Also, if band edge markers are wanted for 50 mc and up, a 5 mc xtal may be substituted when this function is wanted and C1 made variable for "zeroing" against WWV.

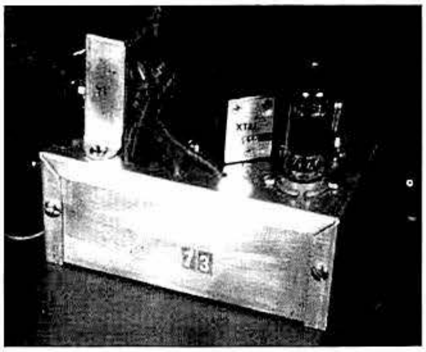

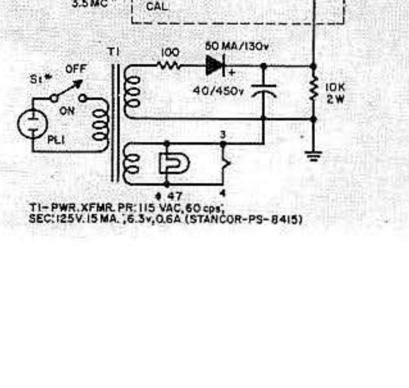

This gadget can also be used as a xtal activity checker by simply replacing the marker xtal with the xtal to be tested. Tuning your receiver should get you a strong signal at the xtal's fundamental if it is OK.

Table 1:

Band	Harmonic 3.5 mc	Harmonic 100 kc	Marker Frequency
80 meters	1	35	3.5 mc
40 "	2	70	7.0 mc
20 "	4	140	14.0 mc
15 "	6	210	21.0 mc
10 "	8	280	28.0 mc
6 "	15	525	52.5 mc
2 "	42	1470	147.0 mc
1¼ "	63	2205	220.5 mc
1¼ "	64	2240	224.0 mc

THE MULTICAL

E. R. Davisson K9VXL

What is the "Multical"? As the name implies, "multi" would suggest several uses, and "cal" might infer a calibrator of some sort.

Well, that's right, but there is slightly more significance to the name. "Multi" is also a short form term used to describe flip-flop circuits known as multivibrators.

By combining the basic characteristics of a free-running multivibrator (astable) with crystal control, you have a simple, stable, virtually-insensitive-to-temperature-changes, crystal calibrator for that receiver you have been wondering about.

The circuit uses no inductors and depends upon the crystal for the proper feedback for oscillations. Temperature stability is partially due to the absence of capacitors.

Transistor stage Q_2 operates with unity gain, whereas transistor Q_1 operates at considerably more gain. Both stages are operating as feedback amplifiers. The harmonic generator diode D_1 is a 1N128. Any general purpose diode may be used.

By using the multivibrator circuit, the waveform obtained is comparatively rich in harmonics and could be used without any further refinements. However, to insure useful harmonics through 30 MHz starting from a 100 kHz crystal, a harmonic generator consisting of R_6 and D_1 shown in **Fig. 1** was added. The capacitors C_1 and C_2 are used strictly for coupling and have no effect on frequency stability.

Crystals from 100 kHz up to 1 MHz may be used in the Multical with no changes. The circuit will oscillate from voltages as low as 2 volts and can be operated safely from voltages as high as 20 volts. This wide range of voltage operation allows the source to be obtained from virtually any place.

Output from the calibrator may be fed directly into the receiver's input, or may be coupled to a short whip antenna. With a whip antenna, close coupling to the receiver's input

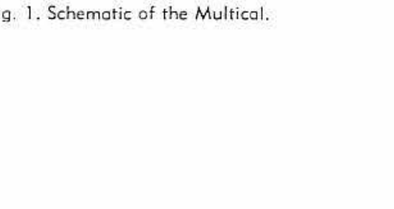

Fig. 1. Schematic of the Multical.

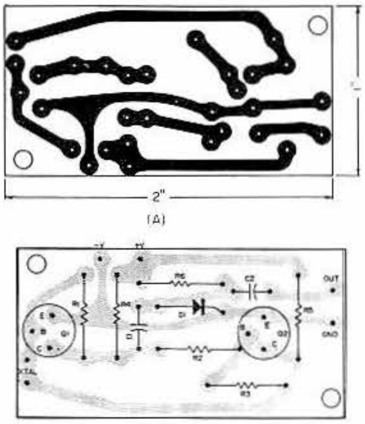

Fig. 2. Suggested printed circuit board layout for the Multical. A gives the copper side, B the component side. A board for the Multical is available for $1 from the Harris Company, 56 E. Main Street, Torrington, Conn.

may be required at higher frequencies. (Especially at the lower voltage levels.)

For the more ambitious builders, **Fig. 2** shows the printed circuit board layout for the Multical. Due to its small physical size (1" x 2"), room can probably be found even in the most compact of receivers. **Fig. 2A** shows the foil side, and **2B** shows the parts placement.

So the next time you wonder about the accuracy of your receiver calibration, give this simple circuit a try and you'll know for sure.

100 KHZ MARKER GENERATOR

W. W. Davey W7CJB

This useful piece of equipment generates usable harmonics from 100 kHz to 225 MHz. It is completely self contained and portable which makes it convenient not only to use in the ham shack, but also in the mobile unit or at a field day location. Its use lies mainly in accurately spotting band edges and 100 kHz calibration points throughout the ham bands.

Most modern day home receivers are equipped with calibrators, but these calibrators are of little use when needed to spot frequencies on VHF and UHF converters or portable equipment.

The generator is constructed in a 2¼ x 4¾ x 1½ inch handi-box. The parts are mounted on a vector board, and the entire unit is powered by one #216 nine volt battery or its equivalent.

Hints on construction First obtain some vector board. The piece I used was cut from the board supplied in a "GE experimenters aid hobbyist kit." The board must be cut to size before construction and will measure 3½ x 2 inches. This will allow room for the 9 volt battery in the end of the handi-box. Make sure the newly cut vector board will fit inside the handi-box before you start mounting parts. It might save a lot of trimming at a later date.

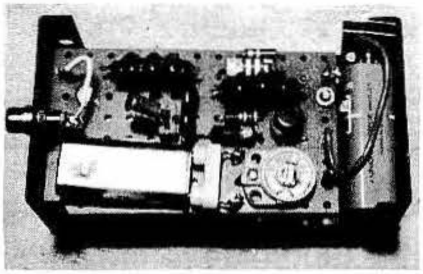

The parts layout is not critical. Components may be arranged as shown in the photo or in any other arrangement suitable to the components you may be using. I used sockets for the transistors, as I wanted to be able to experiment to see which transistors from my junk box would give the most output in the VHF and UHF bands. I ended up using the 2N404 for the oscillator and a 2N384 in the multiplier stage. I also found that Japanese 2SA83 transistors which had been removed from the *if* stages of a junked transistor radio, would work equally well in both sockets.

All components are mounted on the top of the Vector board with the exception of C4 and C5. For the most part, wiring can be completed with existing leads on components. The push-in terminals furnished with the GE experimenters kit were used for the battery connections, antenna connection and for mounting the crystal socket. The circuit board can be mounted to the handi-box with three $^{11}/_{16}$ inch bushings. This leaves room for a slide switch to be mounted on the cover of the handi-box. Two of these bushings were purposely placed at the end of the board to form a sort of socket to hold the 9 Volt battery. The antenna output connector which is mounted on the handi-box is a switchcraft #3501FP phono jack. A small hole may be drilled in the bottom of the handi-box through which a screwdriver may be inserted for adjusting C1. For extreme accuracy C1 is adjusted to zero beat with WWV.

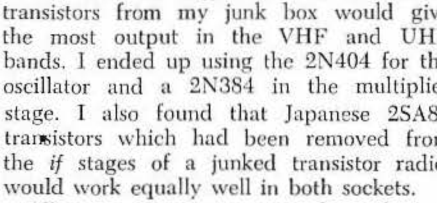

A 36 inch piece of insulated wire soldered into a phono plug may be inserted into the phono jack and used as a test antenna. The intensity of the markers may be varied by moving this test antenna near your receiver antenna lead-in. If you are using a coax lead-in you can couple by drilling a small hole in your coax relay so that the test antenna can be inserted near the relay armature. You will find that most SWR meters provide an easy method of coupling to the center conductor of the coax. As a last resort you can always couple to the receiver or converter antenna coil.

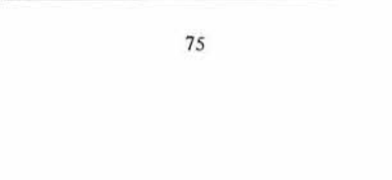

I have made very good use of this gadget to spot frequencies in the 144 and 220 MHz bands. It was well worth the time and effort it took to build it.

ALL BAND FREQUENCY MARKER

Kenneth W. Robbins W1KNI

Crystal controlled marker generators are useful adjuncts in any frequency determining situation requiring high accuracy, such as locating band edges, sub-bands and calibrating receivers. If you've been entertaining thoughts about construction of one, a version is described here which uses the new C/MOS integrated circuits powered by a 9 volt transistor radio battery. And instead of the usual rotary harmonic selector switch, a multi-pin IC connector strip and three test plugs serve as a miniature patch panel to enable various divisions of the reference crystal, with a maximum countdown of 256. "Rocks" from 100 kHz to 4 MHz oscillate readily in this circuit. In this model an FT241 xtal set to 400,000 Hz has been chosen for control and has usable receiver calibration divisions down to 2.5 kHz. The harmonic spectrum extends to at least 160 MHz, the tuning limit of a transistor superregen used in testing. When used in densely occupied HF bands, an AM beeper can be switched on as an identification aid.

Divide by	Output, kHz
1	400
2	200
4	100
8	50
10	40
16	25
20	20
40	10
80	5
100	4
160	2.5

Table 1.

Referring to Fig. 1, one third of a hex inverter makes up a crystal controlled oscillator and buffer, another third is a slow rate pulser and the two remaining units function in the dividing section. These are all standard circuits described in RCA's COS/MOS Data Book #SSD-203. An emitter follower minimizes loading on the IC outputs, speeds up rise time to increase harmonic content, and provides a low impedance output. The AM

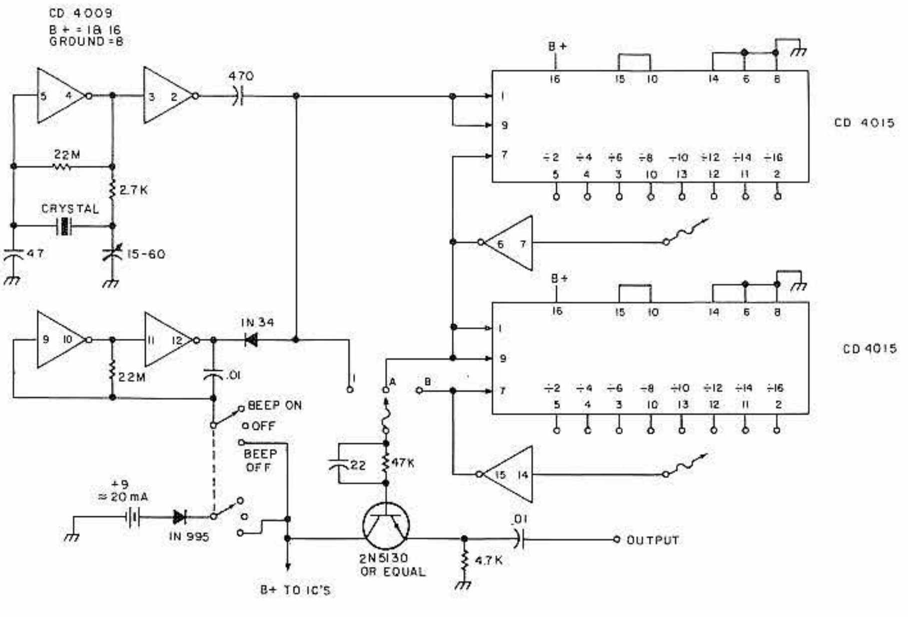

Fig. 1. Schematic.

beeper is a simple clamp that gates rf on or off to following stages.

Photo 1 shows all components mounted on Vector P pattern perf-board that fits inside a Bud minibox. Sleeving 3/8" (10mm) long is slipped over the wire trap terminals of the contact strip to space it up from the board. A DPDT center-off miniature toggle switch acts as one board to panel spacer. Diagonally across from it, a 4-40 threaded rod conducts emitter follower output up through the front panel via a 1/2" (13mm) insulating spacer and plastic shoulder washers. Two regular 4-40 screws and spacers complete the four corner mounting. This spacing allows the contact strip to project partly through a panel cutout so that it is mechanically secure without fastening.

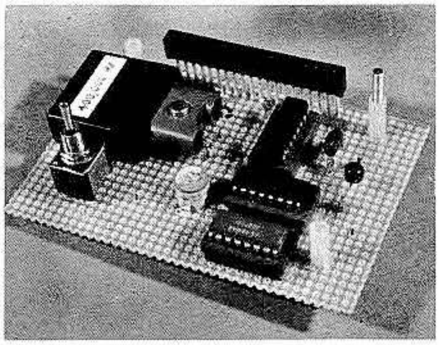

Photo 1.

Photo 2 (completed assembly) shows a stick-on label with patching connection call-outs for various division ratios. If only one crystal is employed, labeling could indicate most used frequencies instead. A typical frequency vs division listing for this model is shown in Table 1. You can easily make up a complete table of all possible ratios, remembering that each CD4015 shift register divides by even numbers ONLY, starting at 2 and ending at 16.

Uses to which a marker generator may be put have been described before: i-f alignment, BFO, scope linearity, etc. A type that divides down to the audio range like this one is especially useful in checking superhets. A very broad and flat spectrum of overlapping signals is generated and an audio tone will be heard no matter where the set is tuned. If its tracking and sensitivity are top-notch, the S meter will hold steady over the tuning range. Tracking adjustment amounts to tweaking for maximum meter reading or loudest audio tone. Then patch for 100 KHz markers and check calibration. It's a lot faster and easier than using a conventional signal generator.

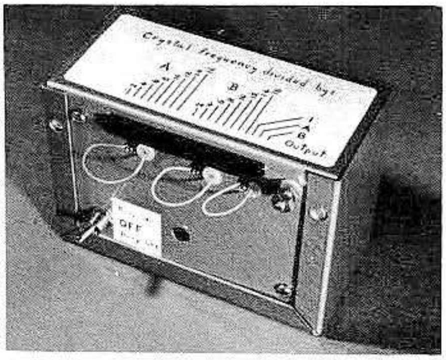

Photo 2.

1	CD4009
2	CD4015
1	1N34
1	1N995
1	2N5130 or equiv.
1	2.7k
1	4.7k
1	47k
2	22M
1	22pF
1	47pF
1	100pF
1	470pF
1	15/60pF trimmer
1	.01 uF
1	xtal; see text
1	xtal socket
1	Alco #MST205P switch
1	Bud #CU-2115HG minibox
1	Vector #44P29-062 perfboard
1	#216 battery
1	Battery connector
3	16 pin IC sockets
3	Augat patch pins or equiv.
1	20 pin contact strip SAE #Series 7000

Table 2. Parts List.

POOR MAN'S UNIVERSAL FREQUENCY GENERATOR

John Schultz W2EEY

As precise frequency control and measurement becomes more and more a part of the amateur radio game, the need develops for test instruments that deliver a wide range of both rf and af signals of high accuracy. It would be ideal if everyone could have a frequency counter and a synthesizer type rf and af generator but that is hardly the case. Most amateurs must utilize their basic station gear along with selected accessory items to test out and adjust equipment. This article describes a very useful accessory item that for a modest cost goes a long way toward having some of the expensive test equipment just mentioned. The item to be described is somewhat like a grid-dip meter in that it is basically a simple type of oscillator but as one gets to know and use it, new uses for it are found and its versatility constantly expands.

Circuit Description

Figure 1 shows the circuit diagram of the test generator. Basically, it consists of a string of SN7490 decade counters which are used to divide down a selected input signal by a factor of 10 or 2. The input signal can come from a 1 MHz master oscillator, a special crystal oscillator for externally used crystals or from any external sine-wave source. The special crystal oscillator which uses a SN7400 will operate with almost any basic or overtone crystal in the hf range. It can be used for crystals in the low frequency and lower VHF range also by a simple modification. One gate of the SN7400 crystal oscillator is used to drive a LED which will indicate that the crystal is oscillating so it serves as a crystal activity indicator as well. When an external sine-wave source is used, it is first coupled through a SN74121 multivibrator. This stage squares off the sine wave so it can better drive the subsequent frequency divider chain.

The frequency divider chain is fixed, although one could easily switch the individual SN7490 units to divide by different ratios when desired. This should be obvious by noting the wiring of the divide by 2 SN7490 with that of the divide by 10 units. However, the variety of frequencies which can be generated then with different input sources becomes confusing and more than would normally be needed.

The fixed divider chain follows the sequence: divide by 10, divide by 2, divide by 10, divide by 10. A separate branch after the first divide by 10 unit goes through two other divide by 10 stages. In the case of the divider chain being driven by the 1 MHz master oscillator, this results in the following output frequencies being simultaneously present: 1 MHz (basic oscillator output), 100 kHz, 50 kHz, 10 kHz, 5000 Hz, 1000 Hz and 500 Hz. With any other frequency input source you can easily calculate what frequency outputs the divider chain will bring in both the rf and af regions. Many surplus crystals will produce interesting frequencies of high stability in the af region that can be used for test purposes.

When using the special crystal oscillator, the LED will glow to indicate that oscillation is taking place. As shown with a 150 pF capacitor from one side of the crystal oscillator circuit to ground, the oscillator will work satisfactorily with hf crystals. Its range of oscillation can be extended to lf as well as high frequency overtone crystals by changing this capacitor. The value of capacitor required in picofarads is 500 divided by the frequency of the crystal in MHz. This value need, however, to be only approximate unless you require an absolutely square wave output from the unit.

When using the multivibrator input about a 1½ to 2V peak input, either sine-wave or approximate square wave is required.

Construction

The whole unit can be constructed on a piece of perforated board about 3 x 2 in. and made completely portable if powered by a 4½V battery (Burgess No.532) or just three D cells in series. This arrangement does not provide the absolutely best stability for the 1 MHz master oscillator but unless you intend to use the unit for marker frequency generation in the VHF range, it is a perfectly satisfactory arrangement. Alternatively, one could power the ICs from any standard 5.5V regulated supply used for IC digital circuitry.

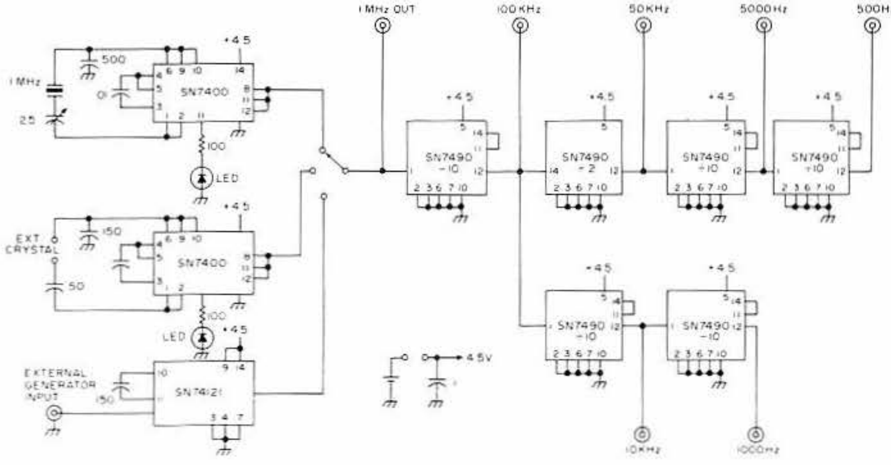

Fig. 1. Diagram of universal frequency generator. Output frequencies shown are for using 1 MHz oscillator.

I constructed my unit for battery powered operation and enclosed the unit in a small aluminum mini-box. The output of each divider was brought to a pin jack on the front panel of the unit.

One simple way to wire the relatively small number of ICs involved is to purchase perforated board which has hole spacing to fit standard DIP and preferably with a copper pad still left around each hole. The ICs are then placed on the board and the appropriate pins which either go to ground or to the 4.5V line bent in different directions. The ground line is run along one side of the IC and the 4.5V line along the other side and bare wire used to connect the appropriate pins to either line. Figure 2 illustrates the wiring for one of the divide by 10 ICs. When one starts this process on the board, it will be surprising how fast the wiring is completed. Individual insulated wire jumpers are used to make the input/output connections between ICs. The wiring is not critical and using a receiver to hear the markers, or an audio amplifier for the lower frequency outputs, one should be able to determine quickly if the circuit is working. The frequency of the 1 MHz master oscillator may be brought exactly on frequency using the 25 pF trimmer in the circuit and checking against WWV with a harmonic of the oscillator or by using a counter.

Applications

As I mentioned before, the applications that you can find for the generator really begin to unfold only after you have had it around the shack for awhile. Some of the applications would be:

1. A frequency marker generator for receiver calibration. The markers are usable up into the VHF range.

2. To extend the range of present rf or af signal generators into lower frequency ranges than they presently cover.

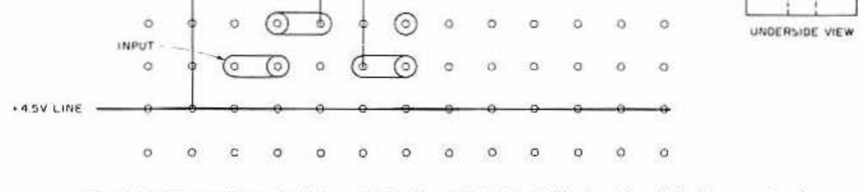

Fig. 2. Perforated board wiring of ICs. One SN 7490 divide by 10 unit is shown wired.

3. To perform stability checks on high frequency variable oscillators. The divider chain will always perform precisely and you can monitor the change in frequency of a higher frequency oscillator with a stable low frequency receiver.

4. A frequency generator to generate precise rf or af square wave signals at any frequency desired by choosing the proper crystal.

5. A crystal activity checker.

6. By taking two or more of the simultaneous outputs together via mixing diodes and a series tuned circuit resonant at the desired frequency, you can also mix the divider outputs to generate a variety of intermediate frequency outputs.

CALIBRATE THAT CALIBRATOR

Mitchel Katz W2KPE

Most modern receivers and transceivers in use today rely upon a 100 kHz crystal oscillator to calibrate the tuning dial. While some of the calibrators are built in, others come as outboard accessories. In any event the operation of each is the same.

By this time we all probably know what "zero beating" is. The 100 kHz oscillator in order to serve as a calibrator must be "zeroed" to some standard frequency such as the WWV carrier frequency on 5, 10, 15, 20, etc. MHz. With a CW or AM receiver, we can very easily tune through the zero beat point. On SSB receivers because one of the sidebands is missing we can only hear the one side as we approach zero. The other side of zero is greatly attenuated and may possibly not be heard at all. To further complicate matters for us in trying to calibrate the 100 kHz oscillator, as we can only hear down to about 20 Hz, we can't zero in any closer than this. Leaving the receiver at this point, we next turn on the 100 kHz calibrate oscillator. After a suitable warm up period, we turn the tune control of the oscillator and again adjust for a zero beat condition against the WWV frequency. With this method of calibration we have several possible sources of error. First in zeroing WWV with the receiver beat frequency oscillator and then zero beating the 100 kHz calibrator against the bfo. Each of these adjustments is limited to the lower limit of our hearing range, as well as the fact that we are obtaining the zero beat at a relatively low i-f frequency.

A more accurate method of calibrating the 100 kHz oscillator will now be discussed. After the receiver and calibrator oscillator have been warmed up for about 30 minutes, tune in WWV on a frequency that produces a fairly good, steady signal. Adjust the tuning for maximum reading on the S-meter. Having tuned in WWV, turn *off* the beat frequency oscillator. Now turn on the 100 kHz oscillator that is to be calibrated. If a harmonic of this oscillator is fairly close to the WWV frequency, a beat note will be heard. At this time adjust the calibrator "crystal tune" control and the S-meter will start pulsing from a maximum to a minimum value. The closer you get to dead center the slower the pulsing action will become. It is fairly easy to come down to 1 pulse per second with this method. If your receiver doesn't have a meter, you can also hear this pulsation very clearly. In any event you would always tune for the slowest pulse rate.

Note that with this method we have adjusted the calibrator frequency harmonic directly to the WWV carrier rather than to a low i-f. We have eliminated one zero beating step, and this, together with the fact that we are obtaining the zero beat at a much higher frequency, will provide greater accuracy.

Having described the method, here are a few points of general interest:

1. Before attempting any calibration let the equipment heat up for at least a half hour to stabilize.

2. After tuning in WWV, wait until the 400 Hz modulating tone goes off before adjusting the calibrator. If not, you may find later that you zero beat the 400 Hz instead of the carrier frequency!

3. The levels produced in the receiver by WWV and the calibrator oscillator should be about equal to produce a good beat between the two frequencies.

4. Use the highest WWV frequency that will produce a good, stable signal in the receiver. Certainly a 1 pulse per second beat at 20 MHz will provide greater calibration accuracy than 1 pps beat at 5 MHz or better yet than 455 kHz! The accuracy will be considerably greater and it is no more difficult to come by.

A SIMPLE FREQUENCY DEVIATION METER

John Reinartz K6BJ

A frequency-deviation meter allows one to read the deviation plus or minus that a received signal is off frequency. Depending on the meter range desired and used, a deviation of ten or less cycles can be read either high or low. Such a device is especially useful when used on MARS nets or when frequency checks are desired of any incoming signal and the answer must be in cycles low or high of a desired frequency. Those grinding their own crystals or desiring to compare crystals will find this device especially useful.

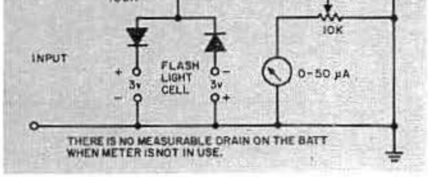
.1
.1
.1
100K
SILICON DIODES
10K
INPUT
+
3v
-
FLASH
LIGHT
CELL
-
3v
+
0-50 µA
THERE IS NO MEASURABLE DRAIN ON THE BATT
WHEN METER IS NOT IN USE.

Fig. 1

Two fundamental circuits were investigated, one using diodes only and the other using transistors only. These are shown in Fig. 1 and 2 respectively. A 0-50 microampere meter should be used for the diode type and a 0-1 milliampere meter will serve nicely for the transistor type, although a 0-50 or 0-100 microampere meter will also serve nicely in the transistor type frequency-deviation meter system. Silicon diodes were used for the diode type and 2N123 for the transistor type. An input voltage of 25 is needed for the diode type and 7 volts or less for the transistor type depending on the meter sensitivity, being 2 volts when a 50 microampere meter is used.

Whatever scale reading is desired, be it 250 cycles low or high or 500 cycles low or high, the meter cover is removed and new figures are added below the meter scale with a zero in the center of the scale and maximum readings at each end of the scale as appropriate. Pencil markings will do. The 250 cycle can be read to 10 cycles per division and the 500 cycle scale can be read to 20 cycles per scale division. Each can be read to half these values or 5 and 10 cycles respectively.

In use, you set your frequency meter, LM or 221 either 250 cycles or 500 cycles lower than the frequency to be checked. If the frequency to be checked is right on, the frequency-deviation meter will read zero at the center of the scale on the meter; if the frequency is low, the meter will read low and if higher, the meter will read higher. The answer in cycles will be the value indicated by your new markings. In use the frequency-deviation meter is connected across the high impedance output of your receiver in the case of the diode type and across the low impedance output in the case of the transistor type.

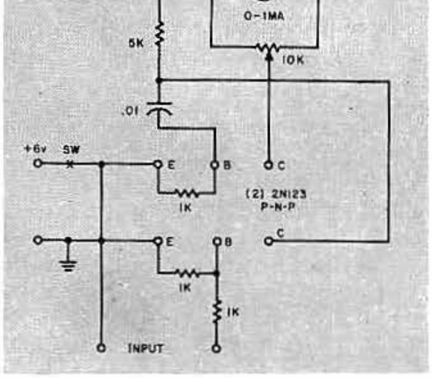

Fig. 2

In those cases where a definite frequency will be under observation, it will be found advantageous to grind or obtain a crystal that is adjustable to 250 cycles low or 500 cycles low, as appropriate, and to use it in the transistorized oscillator shown in Fig. 3. Any crystal holder that has an adjustable air gap will do. Some of the TCS surplus crystal holders have a three point adjustable top plate and are about the best obtainable. Since your best and probably only method of adjusting the crystal is by the use of your LM or BC221, be sure that your frequency standard is accurate. It is best to use the low frequency position and with the 1 mc crystal switch on, tune the meter to that portion of the desired frequency less the mc part. For instance, to set the LM for a reading of 2,732,000 cycles, set the LM on the low frequency for 732,000 cycles or 732 kc. The 1 mc crystal will furnish the mc part of the reading. In my case I set the LM to 731.5 kc and adjust the crystal to that frequency in the adjustable TCS holder. The transistorized oscillator holds the frequency to such a close tolerance it has not been necessary to make adjustments in weeks. A hand held push switch connected into the positive battery lead allows the oscillator to be turned on as needed to check the frequency of a MARS station on 2732 kc to an accuracy of plus or minus 10 cycles of that frequency. The frequency-deviation meter is of course checked against the 440 or 600 cycle tone of WWV, no other check is necessary since the scale is linear.

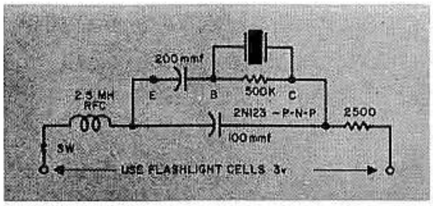

Fig. 3

Chapter VII

GDOs

THE INDICATING OSCILLATOR

Ken Brown KH6AF

Relatives of this little gadget have been around a long time! Even the transistorized versions, which usually leave something to be desired. With an FET, however, we are back in business as with tubes, but with many advantages.

The range of this oscillator is fantastic. That is, without any circuit tricks or special handling. The low frequency end was carried down to the 1 MHz in order to cover the lowest ham band. The high end takes care of 250 MHz easily. This can be extended with a little more effort.

Use of a field-effect transistor (FET) allows operation more nearly like the tubes with which we are, perhaps, more familiar. However, we are not tied to the power lines, which alone makes it worthwhile.

A 2N4221 FET was used in this indicating oscillator. Very likely other FETs will work also. The MOSFETs also should be as good, if not better. The new ones with built-in diode protection would be much easier to handle.

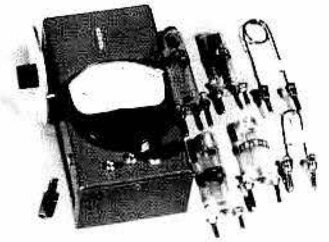

Standard banana plugs spaced ¾ in. make ideal bases for the coils. The lower frequency coils are wound on polystyrene forms.

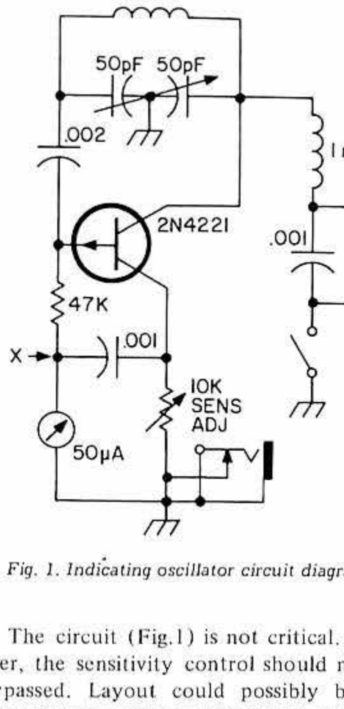

Fig. 1. Indicating oscillator circuit diagram.

The circuit (Fig.1) is not critical. However, the sensitivity control should not be bypassed. Layout could possibly be improved with a slightly larger box, allowing the dial to be placed on the face with the meter. It is a good idea to keep the layout symmetrical as far as possible, particularly the tuned circuit. This can be seen in the photo of the inside view. The box used was an LMB 532 EL with the cover reversed to allow for coil mounting insulator (polystryrene or other good rf insulating material). The meter should be a 50 μA movement; otherwise, a meter amplifier such as the one shown schematically in Fig. 2 will be necessary. This is no problem, as there is room for this amplifier on the circuit board.

A thumbwheel from a BC-375 tuning unit could be used very nicely as a dial. Three sides have been left clear for ease in placement of unit when in use. Plug-in coils makes for easy bank change and application to the job at hand. Standard-spaced banana pins allow for use with other accessories. Use 5/8 in. polystryrene tubing and stud-type banana pins.

A dual banana plug can be used during construction for setting the spacing accurately. The coils shown have the pins wired in place for stronger mechanical assembly. Drill a hole for about 24 AWG copper wire on each side of the pin studs which will lie along each side of the poly tubing. Use a number 59 or 60 drill. One wire is enough on each pin. Form a hairpin with about an inch of wire, push it through the drilled holes from the outside. Now twist tightly with longnose pliers, cut it off short, but not so short as to allow the wire to untwist! Then apply several coats of liquid "poly" cement. Be sure to move the coils frequently during the hardening period to make sure the liquid "poly" flows evenly over the stud and forms a slight fillet with the tube. Epoxy doesn't seem to work well with polystyrene. Neither Allied nor Newark list liquid polystyrene any longer, but your neighborhood hobby shop should be well stocked.

The lowest frequency coil (number 1, 0.95–2.2 MHz) was made from a Miller

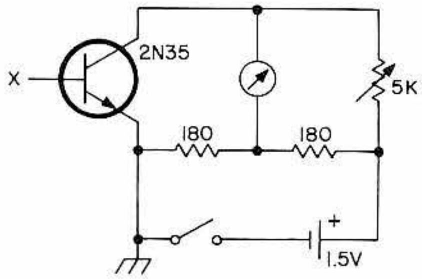

Fig. 2. This meter amplifier will increase the level of the signal so that a less-sensitive meter than 50 μA may be used.

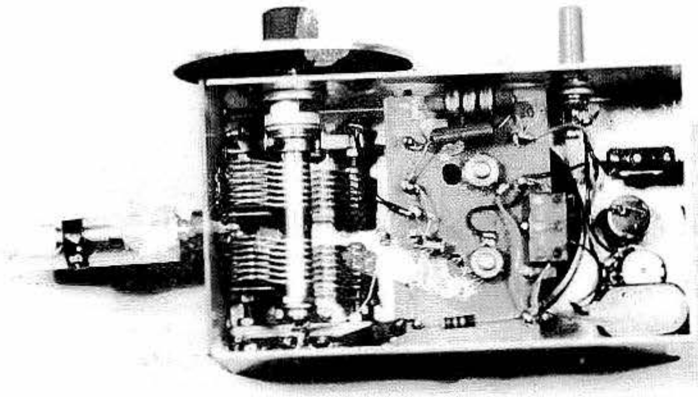

Interior view of oscillator with coil attached shows construction of the author's version.

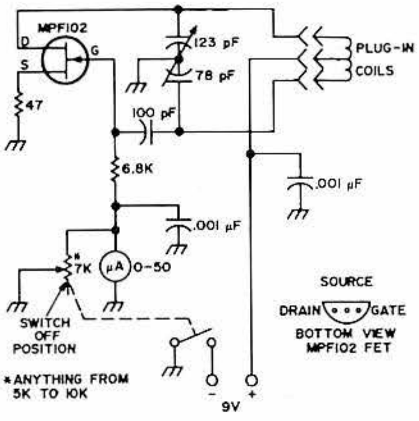

Fig. 1. Schematic diagram of the little gate dipper.

951 ferrite 0.5 mH choke with 6 or 8 turns removed – just enough to slip inside the poly tubing. Some reaming may be necessary. The number 2 coil (2.2–5.4 MHz) was made from a Miller ferrite antenna unit with the slug permanently installed in the top end and all lugs and mounting hardware removed. This coil was also mounted inside the poly tubing. The number 3 coil (5.4–13.5 MHz) consists of 32 turns of 28 AWG enameled wire, close-wound on the outside of the poly tubing. All coils are 2½ in. long with windings as near the end as practical. The number 4 coil (27–50 MHz) consists of 10 turns of 24 AWG enameled wire, close-wound. The number 5 coil (45–100 MHz) consists of 2 turns of 14 AWG enameled wire, self-supporting. The number 6 coil (60–270 MHz) is one hairpin loop 3/8 x 1 in.

A jack is provided for headphone use. The screwdriver-adjusted miniature pot is for zero adjustment of the meter amplifier. It can be seen in the photograph.

THE LITTLE GATE DIPPER

John Aggers W5ETT

Possibly you now own a grid dipper, but is it small, easy to handle, and cordless, making it completely portable? If not, you will want to build this gate dip meter. The cost is extremely low – only about $7. All parts are readily obtainable and construction is simple. The plug-in coil forms, using battery plugs and polystyrene tubing, are easy to make.

The Circuit

An MPF 102 FET is used in a modified Colpitts circuit. Except for the #1 coil, where a choke is used, the B+ is fed to the centertap of the coil. This is necessary to obtain a fairly constant gate current as the oscillator is tuned to its end frequencies. Drain current varies from 4 to 1 mA proceeding from 225 to 1.7 MHz. At the same time the gate current varies from 20 to well over 50 µA.

From this, it is apparent that the stronger the oscillations the smaller the drain current and the larger the gate current. In gate dip operation, as power is drawn from the oscillator the drain current will increase and the gate current will decrease or dip.

Limited wavemeter operation, obtained by switching off the B+, is accompanied by a slight shift in calibration. When the circuit picks up rf, the FET suddenly goes into oscillation using the rf as its battery. Thus, the amount of rf picked up must be large enough or there will be no oscillation and no meter indication. However, despite these deficiencies, it is still considered a useful mode of operation and for that reason has been included. It is only necessary to wire the sensitivity control so that the resistance is maximum when the switch is in the off position.

Construction

A natural finish aluminum minibox (4 x 2-1/8 x 1-5/8 in.) is used for the meter case. The variable capacitor came from an old transistor radio and measured 1 3/8 x 1/2 x 1 in. The shaft was already squared and tapped for a small screw. Since those listed in the catalogs have a plain or flat shaft, you will have to use a collar with setscrew, or drill and tap the shaft. The trimmer capacitors are not used and should be removed.

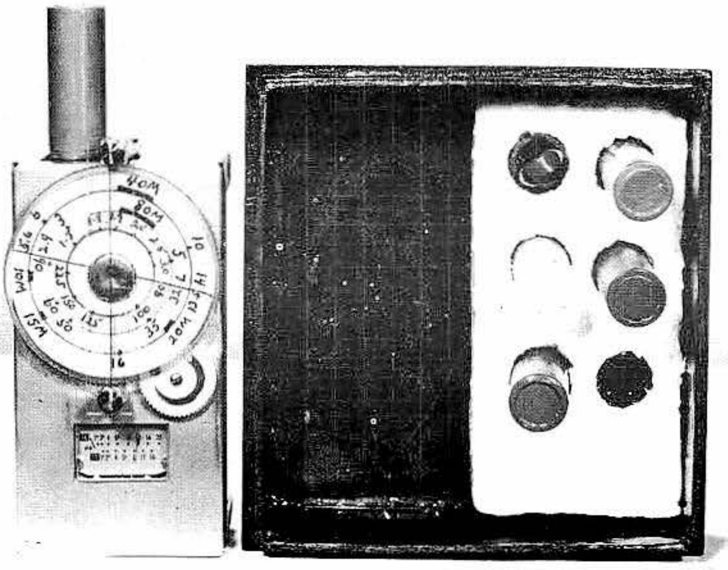

The little gate dipper with spare coils.

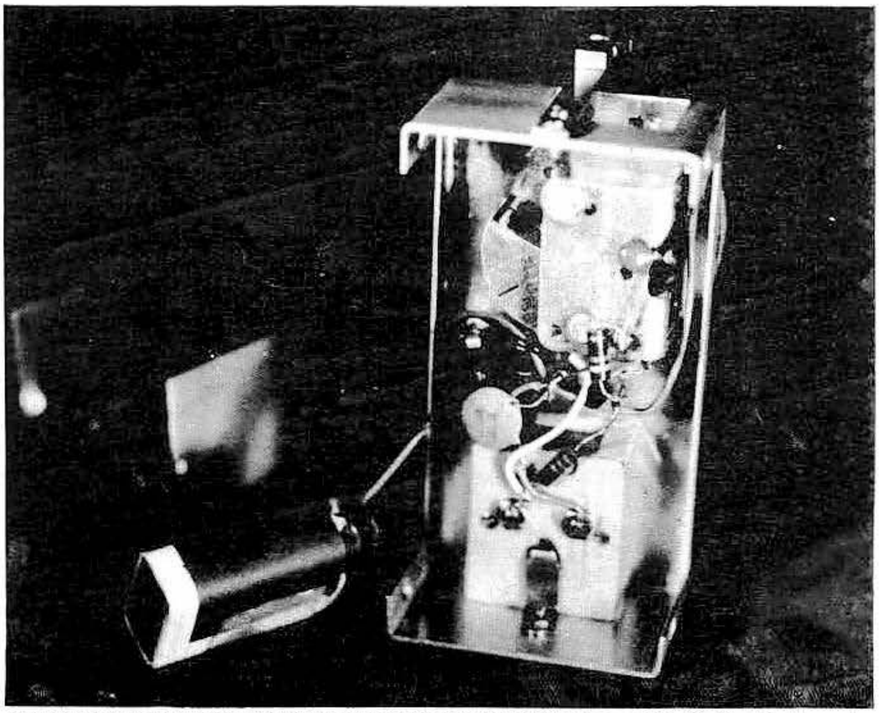

Meter is held against the front panel by a small bracket. The FET is the small black object in the center.

To make the coil socket you will need three pin receptacles from an octal socket, two pieces of 1/8 in. Plexiglas approximately 7/8 x 3/4 in., and one battery plug for a pattern. The pins of the battery plug form a triangle. I shall refer to the holes at the base as the outside holes. Drill holes in one piece of plastic to match the pins of the battery plug. Match the two pieces of plastic, clamp in a vise, and drill the two outside holes in the second piece. Bend the lug part of each socket pin to a right angle. Slip one over each outside pin of the battery plug. Using this as a jig, solder the lug portions to the stators of the variable capacitor. Remove the plug, and the pieces of plastic should fit down over the variable capacitor. The lug part of the center socket pin is brought out between the two layers of plastic.

File a small notch in the bottom piece to accommodate the lug. Before cementing the two pieces together and to the frame, make each hole slightly larger than the diameter of the socket pins. This will allow for expansion when the plug is inserted.

The dial is made of 2-1/4 in. diameter 1/8 in. Plexiglas. To give the dial a rough edge, for good thumb traction, I heated an old gear wheel and rigged up an arrangement to rotate the dial against it. The gear should have rather coarse teeth and rotate with the dial, or you will create flat spots.

The variable capacitor can now be mounted in the case. Position it so that the top and sides of the dial will be just about even with the edges of the case.

The dial marker is mounted on square aluminum posts. The top post (2 in. long) has 1½ in. of its length filed down to a 1/8 in. thickness to reduce its bulky appearance. To make the hairline, scribe a line in a ½ in. wide piece of plastic and fill in with a ballpoint pen.

The sensitivity control I used was already prepared for the knob shown. If you don't have one like it, use a dime-size pot and a setscrew knob. Any resistance from 5 to 10 kΩ will be fine.

Keystone light meters are available from Olson Electronics in a package of five ($3.99) or Transistors Unlimited Co. (75¢ each). Some modification of the meter is necessary. Remove the light cell and series resistor. Drill two holes, spaced ½ in. apart in the back of the case to pass 4–40 machine screws for easy soldering, make sure the heads and nuts are clean and free of any nickel plating. The screws should be filed even with nuts in order to make room for the battery. Solder the leads from the meter movement to the terminals, but be quick because the plastic case tends to melt in a hurry.

Wiring is just a here-to-there proposition, requiring no terminal boards or terminal lugs. The FET is soldered in place supported by its own leads. With reasonable care you should not damage it. A battery holder was found unnecessary; however, it is a good idea to wrap a layer of tape or stiff fiber paper around the battery to prevent the metal case from shorting out the meter terminals.

Coil Construction

Figure 2 and the photo give the necessary dimensions and show the parts needed to make the coil forms. The battery plugs are listed in the catalogs to fit #482 and

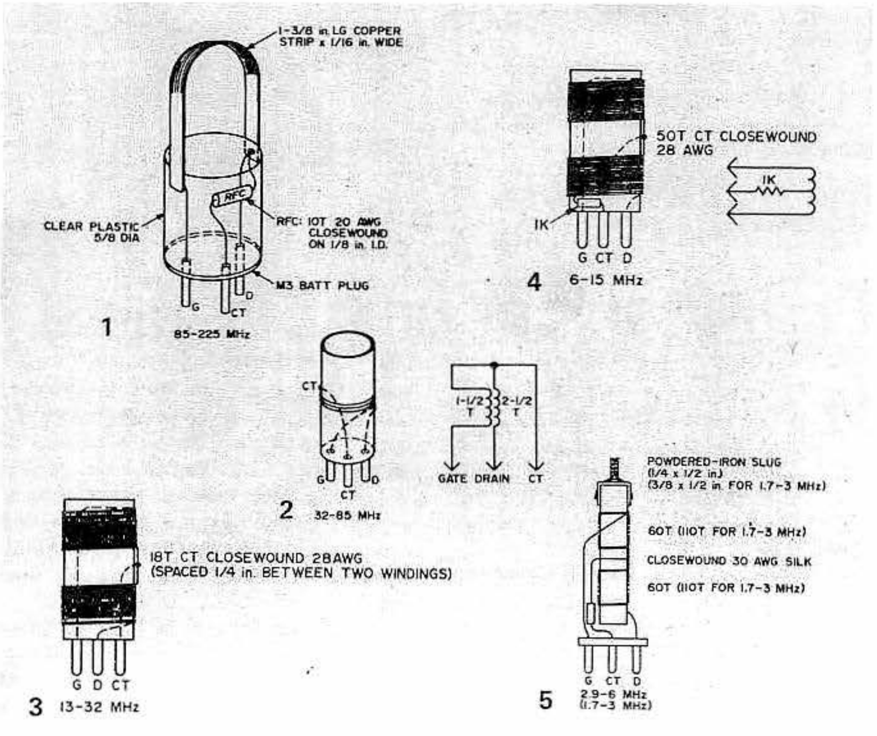
1-3/8 in LG COPPER STRIP x 1/16 in. WIDE
CLEAR PLASTIC 5/8 DIA
RFC
RFC: 10T 20 AWG CLOSEWOUND ON 1/8 in. I.D.
M3 BATT PLUG
G
CT
D
1
85-225 MHz
50T CT CLOSEWOUND 28 AWG
1K
1K
G CT D
4
6-15 MHz
CT
G
CT
D
2
32-85 MHz
1-1/2 T
2-1/2 T
GATE
DRAIN
CT
18T CT CLOSEWOUND 28AWG (SPACED 1/4 in. BETWEEN TWO WINDINGS)
G D CT
3
13-32 MHz
POWDERED-IRON SLUG (1/4 x 1/2 in.) (3/8 x 1/2 in. FOR 1.7-3 MHz)
60T (110T FOR 1.7-3 MHz)
CLOSEWOUND 30 AWG SILK
60T (110T FOR 1.7-3 MHz)
G CT D
5
2.9-6 MHz (1.7-3 MHz)

Fig. 2. Coil configurations for various frequencies of resonance.

M3 batteries. The center pin should be filed slightly shorter to make the plug seat evenly in the socket. While you are at it, file the nickel plating from the ends of all plug prongs. This will make for easier soldering.

Complete coil information is given in Fig. 2. However a little explanation may be in order. The irregular method of winding the #2 coil is necessary to reach 85 MHz and still maintain oscillation. With 4 turns close-wound the highest was too low. With the 4 turns spaced, oscillation ceased at the highest frequency. The 30 AWG silk wire was taken from a TV flyback transformer. The resistors in the centertap of the last three coils improve the meter's sensitivity slightly. They are mounted right next to the coil winding. With a slight groove filed inside the insulating sleeve, it should slip over the resistor.

The #6 coil is layer-wound as space permits and scrambled wound the rest of the necessary turns. The top winding of all coils should end near the very edge of the coil form. This will make for easier coupling to a tuned circuit. After the coils are checked out the insulating sleeves may be glued to the plug base.

Allow the glue to dry for several days before plugging the open ends of each coil with a small cardboard disk. The coils are painted with colored lacquers. Colored paper between the coil and the insulating sleeve will probably work just as well.

Calibration

For calibration purposes, you will need another indicating oscillator or dip meter. Operate it in the diode or wavemeter mode and loosely coupled to the gate dipper. I calibrated only 5 points on each scale plus any ham bands which appeared. Remember the dipper is not a frequency meter but something to get you in the ballpark.

Conclusion

The little gate dipper was checked against a well known commercial tube equivalent and, as near as I could tell, they were just about even. The battery should last for a long time because the current drain is extremely low.

THE GREAT DIPPER

John E. Boyd WA0AYP

Test equipment is essential in the hamshack, as those of us have found when we attempted to get that new piece of homebrew perking for the first time. One of the most useful pieces of test equipment is the grid dip oscillator or simply, the GDO; besides being relatively inexpensive, it is particularly versatile. Need an indicating absorption wave meter? The GDO will do that. How about a modulated signal source? It handles that too. If you are interested in discovering its whole variety of uses, why not purchase one of several books on the subject.

Every item used in this GDO was selected with an eye toward the average home builder. There are no parts which must be specially purchased from the West Indies Export Company or similar outfit. Nearly all the parts, except for the meter, miniature pot, and mode switch, were obtained from the junkbox, or rather, from several junkboxes. If you insist on buying all new parts, total cost of the project will be about $20.

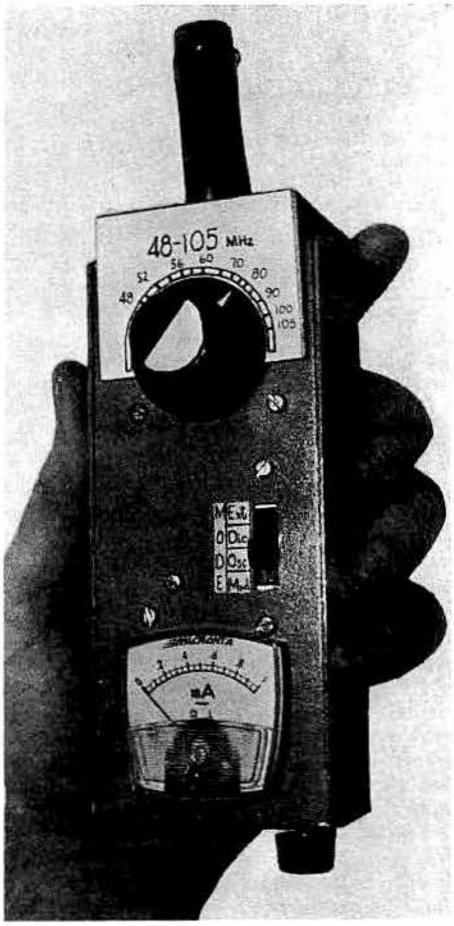

Circuit description

The grid-dip oscillator, in this case more properly termed an emitter-dip oscillator, gets its name from the fact that emitter current in transistor Q_1 decreases when the tuned circuit C_1-L_1 is in resonance with a nearby circuit. This decrease is easily seen by the dip of the meter indicating pointer.

When switched to the diode position, B+ is removed from the oscillator and the incoming rf is rectified by diode D_x; the voltage developed across the 2k resistor is amplified by the meter amplifier and monitored by the 0-1 mA meter. In switching to the signal position, B+ is removed from the meter amplifier but applied to the modulator, and a 1 kHz tone is available from one of the output jacks. In the modulated oscillator position, B+ is reapplied to the oscillator, and the oscillator is modulated by the 1 kHz tone.

Like a patch-work quilt, this GDO was built using circuits from already published articles or books and modified where necessary. The whole circuit is composed of three separate entities—oscillator, meter amplifier, and audio tone generator. The circuit is not particularly critical, but lead lengths and dress in the oscillator must follow good VHF practice, if stable VHF oscillation is to be maintained.

My operating time is spent on the various bands from 28 mHz to 432 mHz. Quite naturally, when I discovered that the GDO would not oscillate satisfactorily over the entire range from 2 mHz to 200 mHz, I juggled values so that it would oscillate well at 216 mHz (for tuning frequency doublers to 432 mHz); then I tried to get as low in frequency as possible. Oscillation was vigorous to about 20 mHz. Coils and scales were then made to cover the respective ranges. It you don't do any homebrewing on the VHF bands perhaps you will find it necessary to

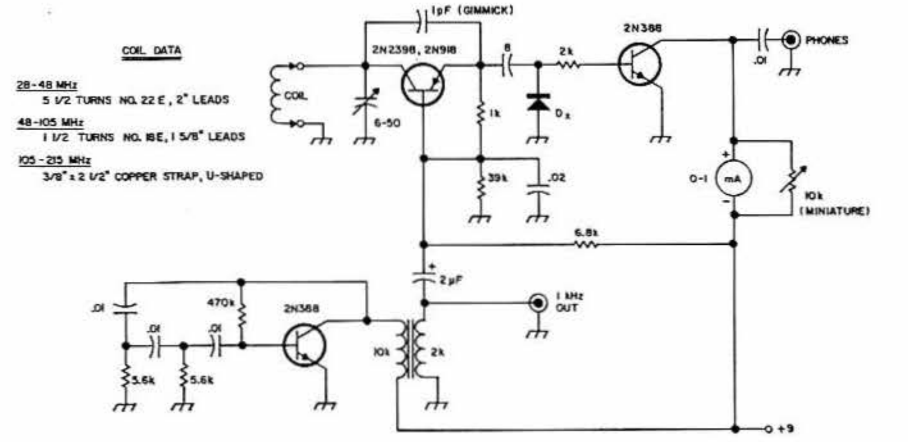

Fig. 1. Circuit diagram of the great dipper. Note that although the 2N2398 is a PNP transistor, the 2N918 is NPN, and if used as the oscillator transistor, problems would arise with voltage polarity. The diode D_x may be almost anything that you have available. The 1 pF gimmick capacitor consists of 1½" of twisted wire.

Internal construction of the great dipper. The modulator and oscillator boards are to the right—the oscillator transistor is mounted right next to the coil jacks.

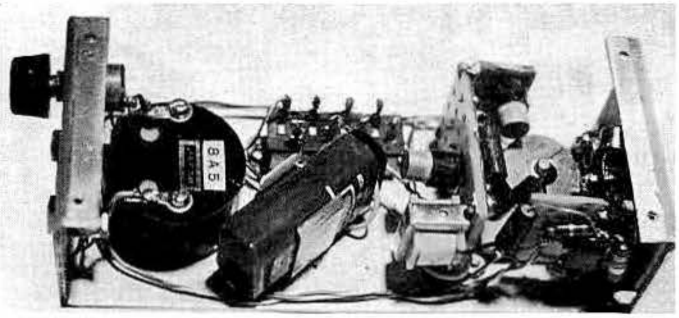

change the value of the emitter-collector feedback capacitor, and to juggle the emitter and base resistor values in order to sustain oscillation at your desired frequencies.

Construction

Vector board was used, mainly because I wanted to experiment with component values; however, a printed circuit would be just as good, especially for something such as a club project. It can be seen from the photograph that the meter amplifier and audio oscillator are built on separate boards. This is due to the fact that I built several different amplifiers; the layout would look neater if they were on the same board. Positioning of the rf oscillator and capacitor C_1 as shown in the photograph is recommended, but the placement of other parts is not critical.

Fiberglass board is used as an insulator for mounting the banana jacks and plugs. It cuts and drills easily and appears to work fine. Three banana jacks were used, the third jack being used merely to provide mechanical rigidity. It could also be used, if necessary, to shunt additional capacitance across the emitter and collector on the lower frequencies.

Because a shear and a brake were available, I constructed my own chassis, consisting of two U-shaped pieces of 1/16" aluminum. Using the GDO is a breeze, for it fits the hand very comfortably; if placed on the workbench, it doesn't roll off each time it is bumped. The completed case (1¾" H x 2¼" W x 6¾" L) is exceptionally rigid and imparts a reassuringly solid feel when handled. Commercially available miniboxes could be used if you don't have facilities available for rolling your own.

In building the rf oscillator, keep all the rf leads as short as possible; especially the short lead from C_1 to Q_1 and from circuit ground to chassis ground. It was found that false dips could be completely eliminated if a copper strap ¼" wide was added from the capacitor ground lug directly to chassis ground. Apparently the ground on the variable capacitor C_1 is not quite good enough at frequencies above 100 mHz. Various transistors were tried in the oscillator; the PNP type 2N2398 was found to be a good performer, as was the NPN type 2N918. However, the use of the NPN type could lead to problems with battery polarity. Capacitor C_2 is a 1½" length of twisted wire positioned near the collector lead of Q_1. This slightly modified oscillator circuit is from a book describing, among other things, a transistorized GDO which you may wish to use as a reference.

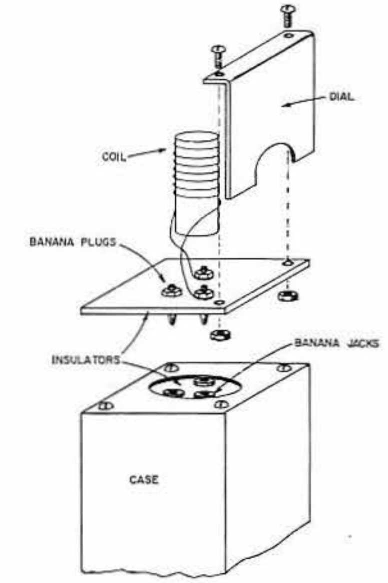

Fig. 3. Construction of the plug-in coil assemblies. The coil forms were made from the plastic containers which hold Polaroid print coater.

To keep cost low, a 0-1 mA meter was used in conjunction with a simple meter amplifier. If you happen to have a 0-50 µA meter lying in the junkbox, that would work equally well, and the circuit could be simplified accordingly. Several circuits were built for the meter amplifier; the one chosen was a compromise between cost and performance. A germanium transistor was used because it requires less voltage to turn it on. Leakage is low, the pointer of the meter resting just off zero when no coil is in place. Further information can be obtained from January 1966 *73 Magazine*, which was the source for this circuit.

A transistorized audio tone generator is coupled by a 2 µF capacitor to the base of the oscillator transistor for modulation. This modulated oscillator allows the GDO to be used as a versatile signal source. An output jack is included on the panel to allow the 1 kHz tone to be used without turning on the oscillator.

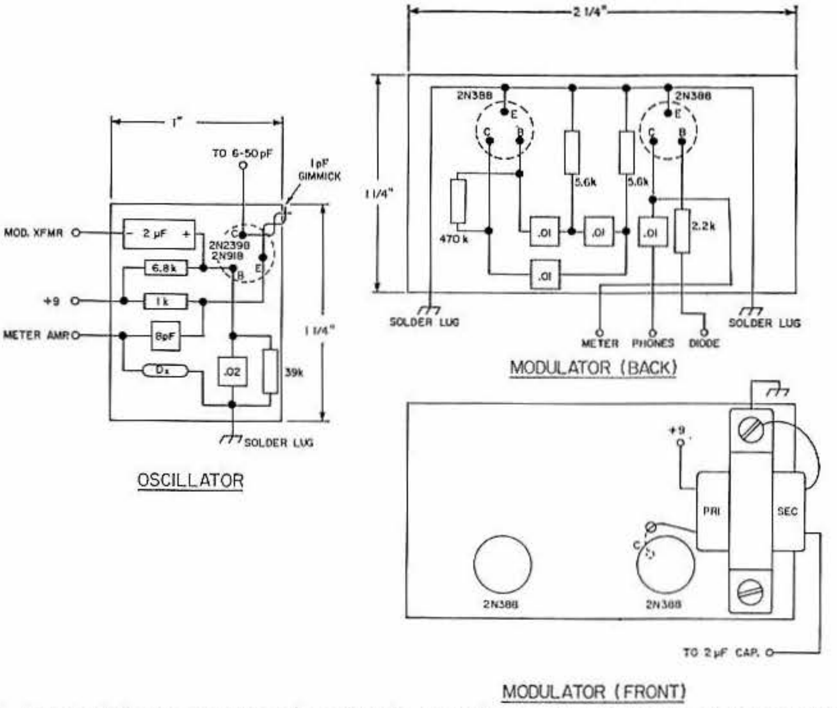

Fig. 2. Layout of the two circuit boards used in the great dipper. Although two boards were used in this case, the circuit could be easily adapted to one board, and even to printed circuitry.

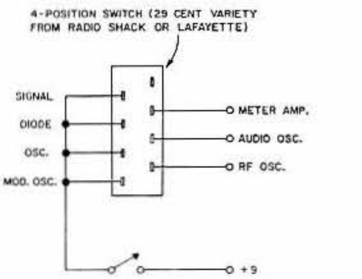
4-POSITION SWITCH (29 CENT VARIETY FROM RADIO SHACK OR LAFAYETTE)
SIGNAL
DIODE
OSC.
MOD. OSC.
METER AMP.
AUDIO OSC.
RF OSC.
+9

Fig. 4. Wiring the four-position slide switch for the great dipper.

The three plug-in coils for the Great Dipper. Three ranges cover from 28 to 216 MHz. The second harmonic of 216 MHz may be used for tuning up 432 MHz converters and such.

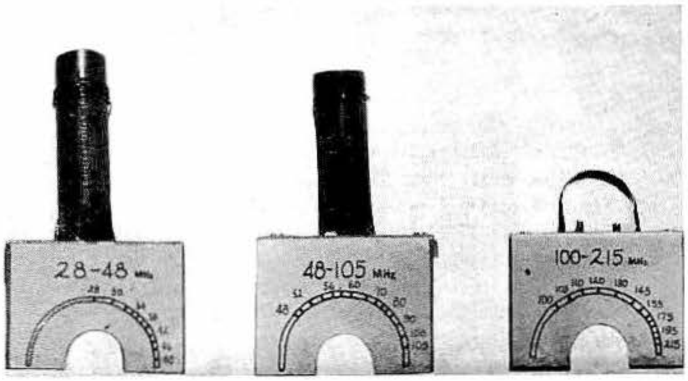

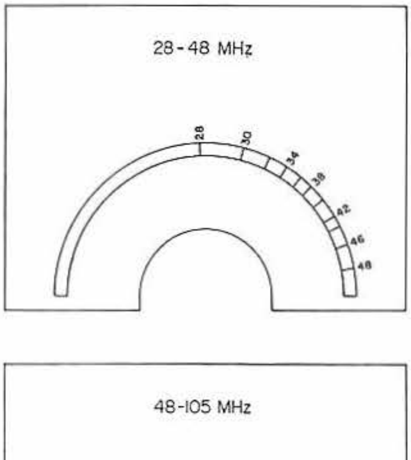

Fig. 5. Full-scale dials for the great dipper. If the construction shown in the photographs is followed closely, the calibration of these dials should be within several percent.

There are a couple of components which not everyone will want to duplicate. One, the sub-miniature 10k pot with SPST switch, was chosen because a very limited amount of space was available; if the unit is built on a larger chassis, the more commonly available *Midgetrol* could be used. The other, a four position switch used to select the desired mode, is a 29c variety available from Lafayette or Radio Shack. It has a peculiar switching arrangement and if you duplicate this project, several hours of experimenting could be eliminated by following the pictorial diagram included in this article. A disadvantage of this particular switch is that the meter does not indicate in the modulated oscillator position.

Using individual scales on each plug-in coil assembly greatly enhances scale legibility, reducing the chance of reading error and speeding frequency identification. This scheme; however, is not original. It was described in a 1957 issue of *Short-wave Magazine*, and is currently being used on a commercial GDO. It requires little additional effort to build the coil assembly in this manner and is, to me, well worth that extra effort. For want of anything else, the coil forms were made from the plastic tubes which contain the film coater supplied with each roll of Polaroid film.

Lastly, ease of tuning is accomplished largely through the use of a 1" skirted knob. Small knobs are simply too difficult to use comfortably.

Calibration and operation

It is best to calibrate this GDO by listening for the oscillator, modulated by the 1 kHz tone, on a general coverage receiver. An alternate method is to use another GDO, placing one in oscillate and the other in diode, tuning for either peak or dip. The scales which were used on this GDO will serve if parts and layout are followed closely.

To use this unit as a dipper, place the mode switch in oscillate, and place the dipper coil next to the coil under test. The turns of both coils should be parallel, and not at right angles to each other. To keep from pulling the oscillator frequency, keep the two coils separated as much as possible, while still maintaining a meter dip. This assures that dial accuracy will be kept high. If a coil is inaccessable, twist a pair of wires together, forming a two turn coil on each end; slip this coupling link over the two coils. Keep in mind that a coil, when it is in a circuit, may not dip at the same frequency as when it is out of this same circuit.

GREATER DIPPER – MODIFICATION

John E. Boyd WA0AYP

Introduction

To the uninitiated, a grid dip oscillator is neither glamorous nor exotic, even if it does happen to be transistorized. But to those who have ever tried to put a coil on frequency, one is worth its weight in microcircuits.

The original model of the *Great Dipper* proved to be a versatile, if unexciting, grid dip oscillator. Intended to be used mostly at VHF, the dipper was limited to frequencies above 28 MHz. To those who seldom operate above 10 meters, the lack of frequency coverage below 28 MHz was a definite handicap. Expanding the frequency coverage downward extends the dipper's usefulness considerably.

Component changes made were not extensive, nor were the physical dimensions of the unit changed. The schematic diagram of the modified circuit is shown in **Fig. 1**, and the pictorial diagram of **Fig. 2** is included to supplement the photographs printed in the original article.

Modification

First, the oscillator circuit board should be rotated 90 degrees from its original position so that transistor substitution or replacement can be made easily. A microwave diode might be substituted for the original glass computer-type diode; this results in better performance at VHF, but its effect cannot be accurately predicted. A 1N21 or 1N23 diode could be used in place of the D4900 called for in the schematic. Best oscillator performance over a wide frequency range results from using a 5 pF capacitor as the collector feedback coupler, but this was a compromise value. If operation is likely to be confined to either the HF or VHF segments of the radio spectrum, some experimentation with this capacitor should result in improved performance over that particular range. For experimentation, use a 3-12 pF or 4-30 pF trimmer.

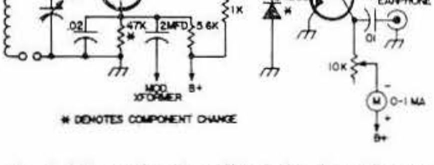

*Fig. 1. Schematic of modified circuit, with component changes indicated by *. L1: 13-23 MHz, 14½ turns No. 20; 22-44 MHz, 5¼ turns No. 24, 45-90 MHz, 1½ turns No. 24; 90-195 MHz, 2½ x 3/8 in.*

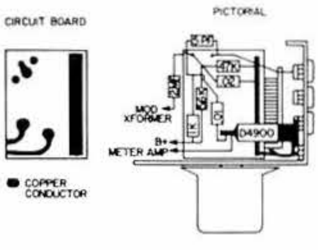

Fig. 2. Pictorial view of the dipper and its circuit board.

To perk up meter amplifier performance, the 2N388 meter amplifier is replaced by a 2N918, a relatively high gain, low leakage transistor.

Although the change was not made in this unit, a 6-100 pF (MAPC-100) variable capacitor could be substituted for the existing 5-50 pF unit. As can be seen from the full-size scales, frequency coverage is narrow on the 13-23 MHz plug-in coil. Those who frequently construct HF gear might benefit from the substitution.

Operation

Operation of the dipper is the same as before, except the frequency range is greater. Another coil must be wound for the 10-25 MHz range, but existing coils were not modified. Calibration is now different from before; full-size scales are included with this article for those who do not have a general-coverage receiver or another grid dip oscillator on hand for calibration.

Oscillation is still vigorous at 13 MHz, which indicates lower frequencies may be reached with a suitable coil plugged in. Similarly, oscillation is still noticeable at 195 MHz, so operation at higher frequencies may be possible.

Finishing Touches

Appearance of the dipper was improved after enlisting the help of a draftsman. The dial and meter scales were professionally inked. **Figure 3** provides full-size copies of these scales.

To improve the legibility of the labels and scales, they were inked on yellow cards rather than on conventional white paper. It's a small point, but for those who use test equipment frequently, the black-on-yellow technique results in less eye strain.

ETCHED CIRCUIT UHF DIPMETER

Bob Corbett W1JJL

I made three models of the dipper. They cover 130-175 MHz, 175-250 MHz, and 250-480 MHz. The first two models use the same size inductor, with the 130-175 MHz model using a larger capacitor for tuning with a ceramic trimmer across it. This trimmer is not shown in the schematic; its value is 7-45 pF and it should be adjusted to cover the proper range.

The 250-480 MHz dipper uses a smaller inductor than the others. It also has a copper jumper (shown in the layout) that the lower frequency dippers don't have.

Each dipper is complete (including the battery) except for the meter. The meters were omitted to save space and money, but can be included if you wish to use a slightly larger case.

Each dipper uses one RCA 2N3478 NPN silicon transistor. These transistors cost only $1.90 apiece, but it's likely that other transistors that are even cheaper could be used. The 2N3478 has odd basing—the only reference is the short case-shield lead—so don't shorten any leads until you're sure that you can keep track of the connections.

The copper side of the board for the dipper is shown in Fig. 2 with the component side in Fig. 3. Use glass or Teflon based board. Paper or bakelite board probably wouldn't be satisfactory. Trim the board to the proper shape with a nibbler. The inductor should be coated with coil dope to keep from shorting it when you use it.

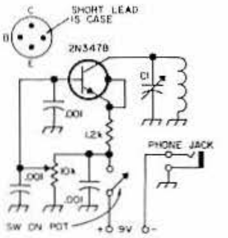

Fig. 1. The etched circuit dipper is very simple. The circuit is almost identical to the one described by WA1CCH in the December 1965 73, but the construction is quite different. C1 is Johnson 160-104 (9 pF) for the two higher frequency dippers, and 160-107 (14 pF) for the 130-180 MHz model. There is a trimmer across C1 in the 130-180 MHz model; see text.

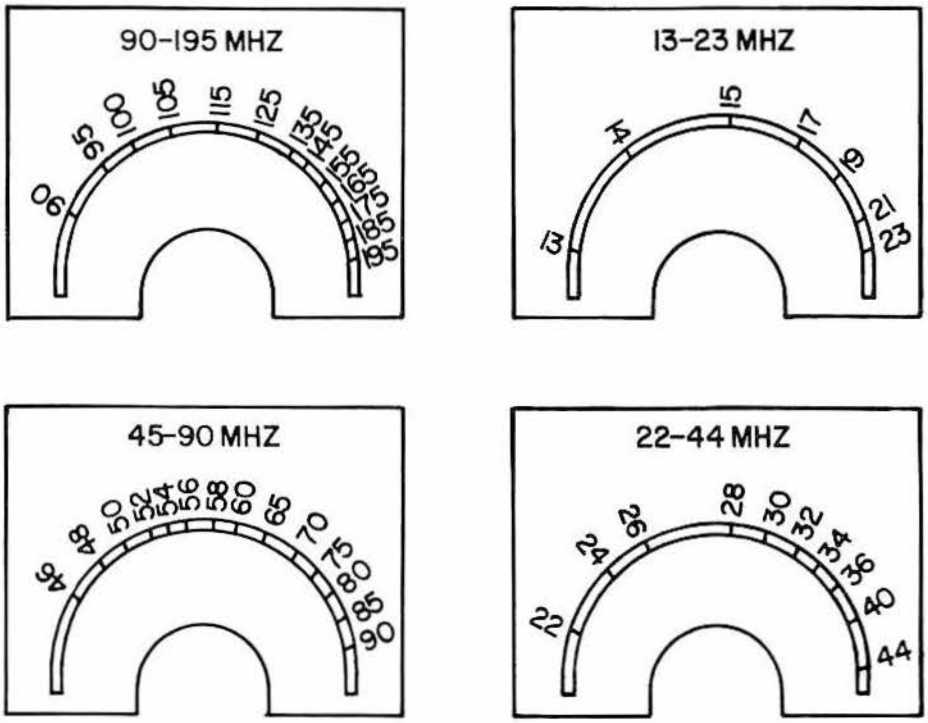

Fig. 3. Dial designs for the various MHz ranges, full size.

To mount the boards, you'll have to cut a thin slot near the edge of the Minibox used as a case. One way to do it is to drill a number of holes of the proper size in a row, then use a file to finish the slot. You'll have to bend that side of the Minibox out to get the board in. It's held in place by an extra set of nuts on the shafts of the potentiometer and the tuning capacitor. Be sure to trim the leads projecting from the copper side of the board so that they won't touch the metal of the case. The battery is held in place with a simple clip made from scrap metal.

The dipper is very easy to use. But before we get to that, let's check it out and calibrate it.

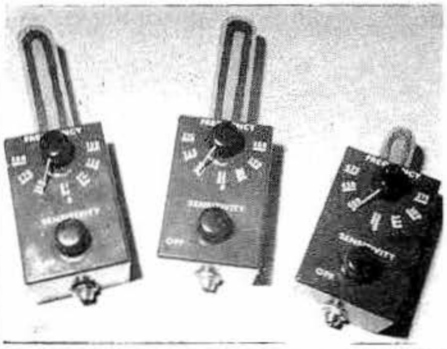

The three dippers shown here cover 130-480 MHz.

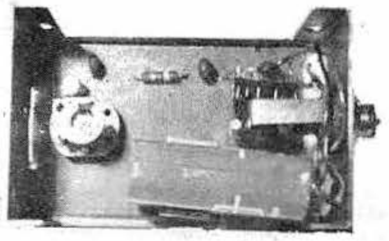

Here's the inside of one of the dippers.

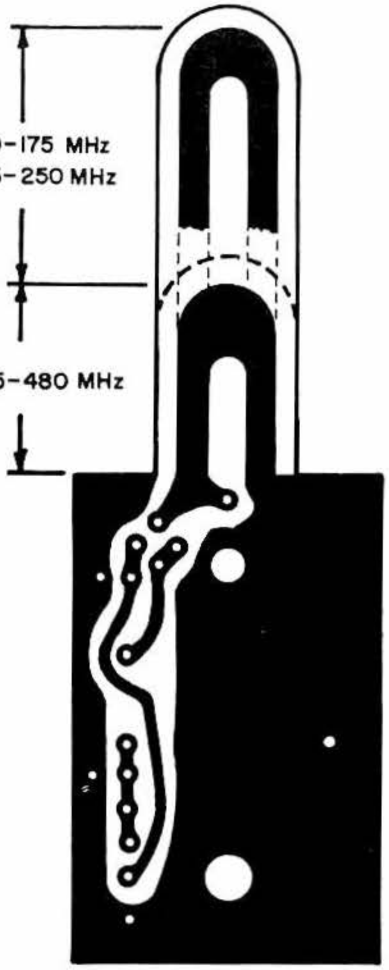

Fig. 2. The copper side of the etched circuit board used in the dipper. This layout is full size. Use board suitable for these frequencies: fiber glass or Teflon.

Plug a 2 to 5 mA meter into the meter jack. You can use a more sensitive meter if you shunt it with a resistor that gives the proper scale. Put the resistor across the meter jack terminals in the dipper if you use the meter for other things.

Turn on the dipper by twisting the potentiometer knob clockwise until it clicks. The meter should show very low current. As you turn the pot, the current should suddenly jump to about 1 mA. That means that the transistor is oscillating. If you touch the coil, the meter reading should drop and the dipper may stop oscillating completely. Now tune the capacitor through its range. There should be a little variation in current, but not too much.

Now you're ready to calibrate the dipper. The easiest method is a sensitive wave meter that covers the range, but it's quite easy to do the job with a TV set. A TV set covers 176 to 216 MHz (channels 7-13) for the low calibration. Then the second harmonics of the dipper tuning 235 to 445 MHz can be received on a UHF TV set (470-890 MHz). If you have a two meter receiver, that gives you another maker at 146 MHz. You can put on the panel markings with Ami-Tron or Datak rub-on lettering.

The dipper should be complete now, and ready for use. Bring the dipper near a resonant circuit in the dipper's range and tune the frequency control. You should get a prominent dip in current when both circuits are tuned to the same frequency. The amount of dip depends on the setting of the pot in the dipper, the distance from the tuned circuit, the Q of the circuit, and the type of coupling.

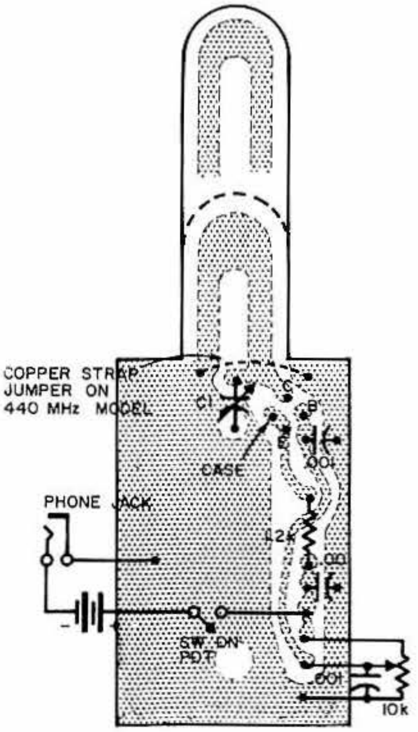

Fig. 3. Component side of the dippers. There is a 7-45 pF ceramic trimmer across C1 in the lowest frequency model. See the text.

In many cases it's easiest to leave the dipper stationary and tune the other circuit.

The dipper can also be used for monitoring AM transmitters by plugging a set of headphones in the meter jack and adjusting the tuning and pot. You can also use the dipper for determining the frequency of another oscillator. Simply tune the oscillating dipper with headphones plugged in until you hear a slight click. You probably won't be able to get a zero beat at these frequencies.

Be careful that you don't use the dipper around an energized transmitter of more than a few watts output or the dipper may be damaged.

These dippers are simple, inexpensive and non-critical to build. After you've build them, you'll wonder how you ever tried to build UHF equipment without a good dipper.

UHF GRID DIPPER

J. Fisk WA6BSO

When building or testing equipment for the 420 mc band, amateurs invariably run into the problem of, "Where am I?". It becomes a little difficult to tell whether you are actually in the band or somewhere nearby. The uninitiated will counter that you should be able to figure close enough, after all the band is 30 mc wide; but even the experienced old timer will confirm that this just isn't so.

The 420-450 mc amateur band falls between the VHF and UHF television assignments and there is very little to use for a frequency reference point. It is nearly impossible to tell exactly where you are without resorting to expensive commercial gear or lecher wires. Nor is the problem confined to the ¾ meter band; when building crystal controlled converters for 432 or 1296, it's nice to know that the last tripler is really tripling and not doubling or quadrupling. Even with a 45 or 50 mc crystal, it's quite easy to tune up on the wrong harmonic. Remember that a 40 mc change at 400 mc is analogous to a 400 kc change on 75 meters.

There are several commercial instruments that fill this requirement nicely, but the cost of the least expensive of these would buy a pretty respectable all band receiver. Occasionally suitable test equipment appears on the surplus market, but again, the price is prohibitive. The simple UHF grid-dipper described in this article was designed specifically to economically fill this need. It covers the frequencies

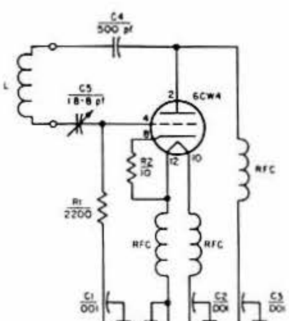

C1,C2,C3	STANDOFF BUTTON BYPASS CAPACITORS
C4	BUTTON CAPACITOR (SEE TEXT)
C5	E F JOHNSON TYPE 160-104 VARIABLE
L	PLUG-IN COIL
P1	AMPHENOL 91-MC4M MALE CABLE PLUG
RFC's	8-1/2" No 2? ENAMELED WIRE WOUND ON 1/2 W, 100K COMPOSITION RESISTORS

Fig. 1. Schematic of the rf head of the UHF grid dipper.

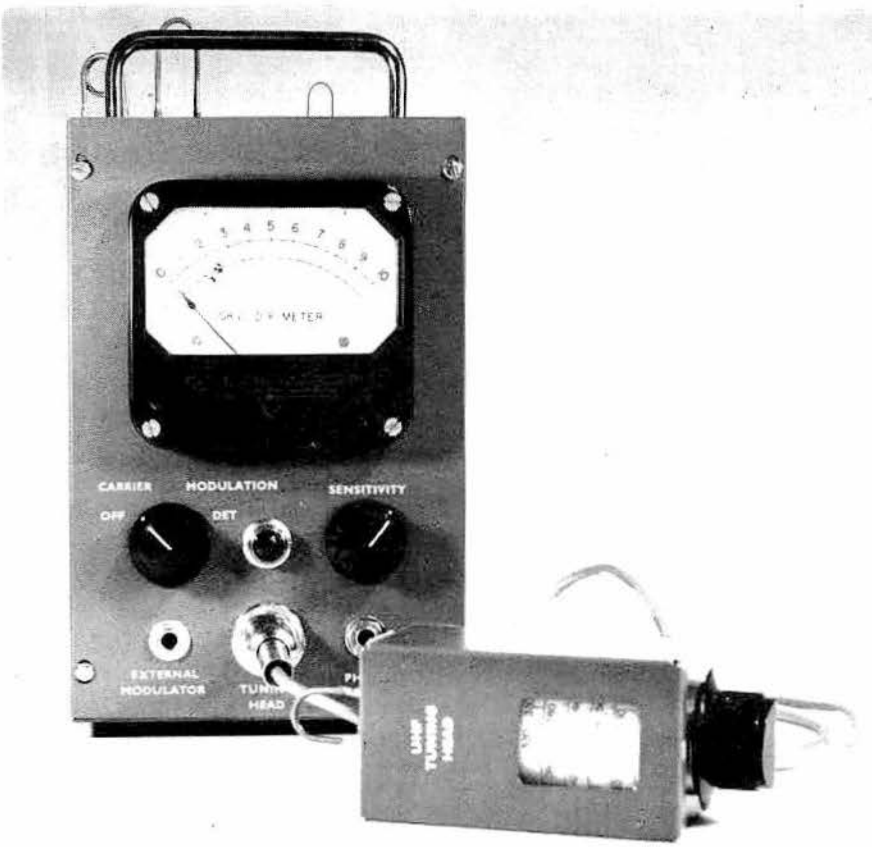

GRID DIP METER
CARRIER
MODULATION
SENSITIVITY
OFF
DET
EXTERNAL MODULATOR
TUNING HEAD
UHF TUNING HEAD

from 300 to 680 mc at a total cost that is comparable to a low-frequency kit-type grid-dipper. By using junk-box parts and smart horsetradesmanship this cost may be substantially reduced. I should hasten to point out that substitution of parts in the tuning head should be avoided if accurate dial calibration is desired.

This particular grid-dipper has been duplicated several times and in each case calibration has been within several percent of the original unit; at least as accurate as the familiar kit-type grid-dipper. This is helpful to the ham who does not have access to commercial equipment for calibration purposes. By using the layout and parts described in this article, the precalibrated dial illustrated in **Fig. 8** may be used with a minimum of error.

Although an accessory power supply, modulator and indicator are included in this design, an enterprising ham could use the power supply and meter presently available in any lower frequency tube type grid-dipper. Although using a modified low-frequency dipper is simple and inexpensive, the power/indicator box specifically designed for the UHF tuning head has several features that are not available in inexpensive kit-type units. These include internal 1,000 cycle modulation, provision for external modulation, and voltage regulation which provides the necessary stability at the ultra high frequencies.

The rf tuning head

The heart of this instrument lies in the tuning head itself. There is nothing particularly new or different about the circuit, but at these frequencies stray inductance and capacitance in circuit layout and construction will seriously affect the end result. All the lead lengths must be as short as humanly possible and physical circuit layout must follow standard UHF practice. One of the big problems in building tunable oscillators at UHF is to obtain an oscillator that will tune from one end of the range to the other with no "holes," frequency jumping or instability. The series tuned 6CW4 nuvistor oscillator shown in **Fig. 1** fills these requirements.

Insofar as possible, all the tuning head wiring is done on a point-to-point basis with the components mounted directly to the 6CW4 tube socket or button capacitor lugs as illustrated in **Fig. 3.** To obtain the desired accuracy with the precalibrated dial, this diagram should be followed as closely as possible.

To keep stray circuit inductance to a minimum, all wiring between the coil and tube socket is done with one-quarter inch wide strips of thin copper sheet. In addition, the rotor of the variable capacitor is connected to the 6CW4 grid (pin 4) with a short strip of the same material. The only tricky part of this wiring is the installation of the series capacitor C4. This capacitor is a 500 picofarad button type mounted as shown in **Fig. 5.** The "S" shaped bracket ("A") is made from a one-quarter inch wide copper strip, one and one half inches long and soldered to the mounting stud of the capacitor. Connection to the 6CW4 plate (pin 2) is made with the soldering lug on top of the button.

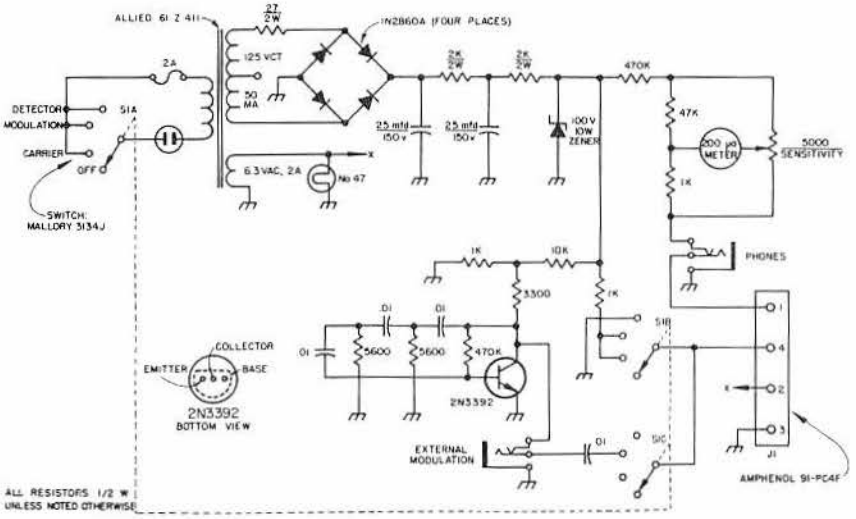

ALLIED 61 Z 411
27 2W
IN2860A (FOUR PLACES)
2A
125 VCT
50 MA
6.3VAC, 2A
No 47
X
DETECTOR
MODULATION
CARRIER
OFF
S1A
SWITCH: MALLORY 3134J
2K 2W
2K 2W
25 mfd 150v
25 mfd 150v
100V 10W ZENER
470K
47K
200 µa METER
5000 SENSITIVITY
1K
PHONES
1K
10K
3300
1K
.01
.01
.01
5600
5600
470K
2N3392
S1B
S1C
.01
COLLECTOR
EMITTER
BASE
2N3392 BOTTOM VIEW
EXTERNAL MODULATION
1
4
2
3
J1
X
AMPHENOL 91-PC4F
ALL RESISTORS 1/2 W UNLESS NOTED OTHERWISE

Fig. 2. Power supply and modulator for the UHF grid dipper.

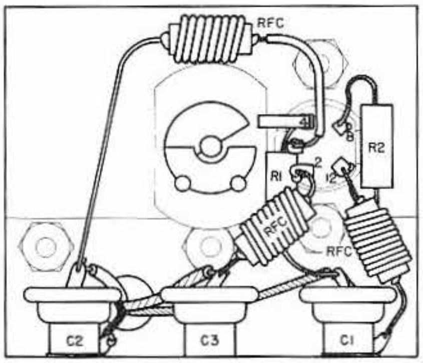

RFC
R2
R1
RFC
RFC
2
12
C2
C3
C1

Fig. 3. Critical wiring around the 6CW4 socket.

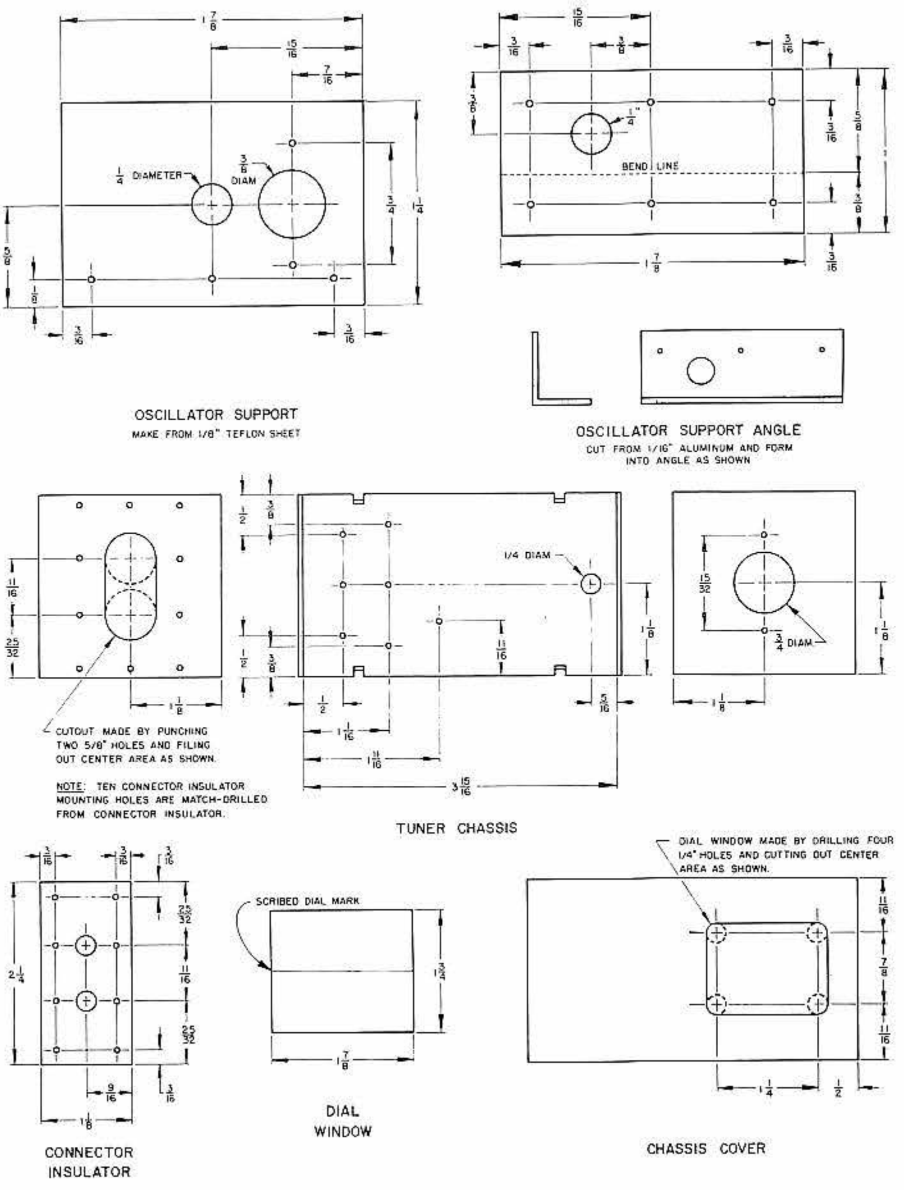
OSCILLATOR SUPPORT
MAKE FROM 1/8" TEFLON SHEET
1/4 DIAMETER
3/8 DIAM
OSCILLATOR SUPPORT ANGLE
CUT FROM 1/16" ALUMINUM AND FORM INTO ANGLE AS SHOWN
BEND LINE
1/4 DIAM
3/4 DIAM
CUTOUT MADE BY PUNCHING TWO 5/8" HOLES AND FILING OUT CENTER AREA AS SHOWN.
NOTE: TEN CONNECTOR INSULATOR MOUNTING HOLES ARE MATCH-DRILLED FROM CONNECTOR INSULATOR.
TUNER CHASSIS
DIAL WINDOW MADE BY DRILLING FOUR 1/4" HOLES AND CUTTING OUT CENTER AREA AS SHOWN.
SCRIBED DIAL MARK
CONNECTOR INSULATOR
DIAL WINDOW
CHASSIS COVER

Fig. 4. Layout of the tuner chassis, chassis cover, dial, connector insulator, oscillator support and oscillator support angle.

Connection to the stator of the variable capacitor is accomplished with another short strip of thin copper as shown in **Fig. 5** ("B"). This piece of copper is bent so it touches both stator mounting pins when the unit is assembled; then it is soldered in place.

The oscillator and tuning mechanism are housed in a standard 2¼ × 2¼ × 4 inch chassis box laid out as shown in **Fig. 4.** Although the author's unit is based on an LMB type 107 chassis box, other manufacturers have similarly sized boxes which are equally suitable. The layout of the enclosure is straight-forward and no difficulty should be found in duplicating it. The dial and coil socket cutouts are made by drilling or punching round holes and then cutting out the area between them as shown in the drawing. This is easily done with an Adel "nibbling" tool. All of the small screw holes are drilled with a standard ⅛ inch drill to pass 4-40 screws; 5/32 inch holes will be required if 6-32 screws are used.

The dial window is cut from a sheet of 1/16 inch clear plastic to the dimensions shown in **Fig. 4.** A hairline is scribed in the center of this window; if a more distinct line is desired, this scribe mark may be filled in with black india ink. After the tuner enclosure is completed, this dial window is epoxied in place over the dial cutout.

The coil socket is made by installing two banana jacks (E. F. Johnson type 108-740) on 11/16 inch centers in the Teflon connector insulator illustrated in **Fig. 4** (if Teflon is not available, Polystyrene may be used). This "socket" is installed over the large oblong hole cut in the end of the chassis. The screw holes used for mounting the connector insulator are match-drilled to the holes in the insulator itself. In this way it is properly mated to the enclosure. Although nylon attaching screws were used in the original model, they are not necessary and regular metallic screws will not alter any of the oscillator's characteristics.

To reduce stray capacity to a minimum, the oscillator circuitry is mounted on an insulating sheet. Teflon was used for this purpose in the original unit, but epoxy board with the copper peeled off would be perfectly suitable. Sheet polystyrene is not too desirable in this location because of its susceptibility to heat. The envelope of the 6CW4 gets very hot and the ambient temperature within the confines of the small chassis is quite high.

The general layout of the Teflon oscillator support and associated support angle are also shown in **Fig. 4.** The angle is cut out from a piece of 1/16 inch aluminum sheet and bent in a vise to form the angle. When these two pieces are mated together, the metal angle will probably interfere with the lower nuvistor socket mounting screw. It must be drilled out using the hole in the oscillator support as a guide. This additional hole is not shown because its exact location will vary from unit to unit and depends upon the accuracy with which the parts are laid out.

The dial mechanism is not complicated, but it is hard to ascertain from the photographs exactly how it is put together. The exploded drawing of **Fig. 6** should help in this respect. The vernier mechanism is an Eddystone 10:1 planetary drive that provides both smooth

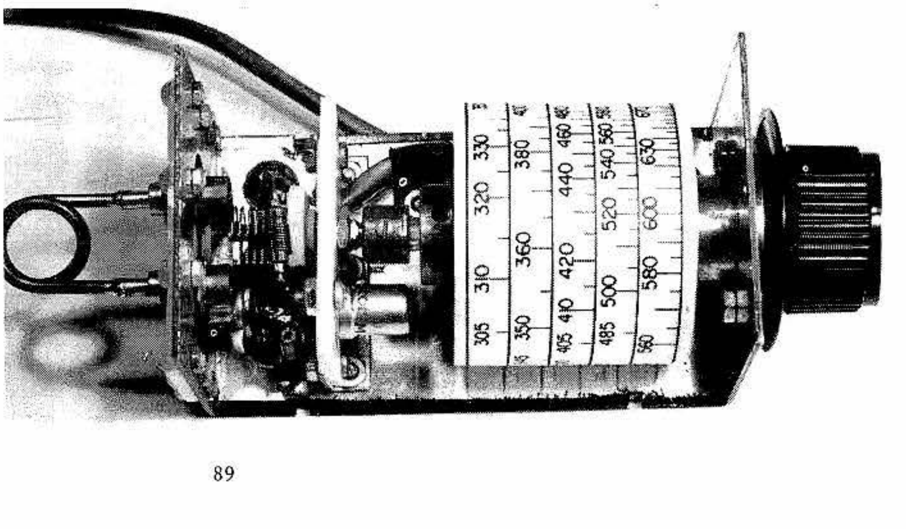

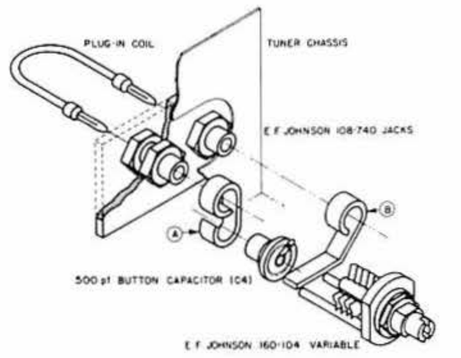
PLUG-IN COIL
TUNER CHASSIS
E F JOHNSON 108-740 JACKS
Ⓐ
Ⓑ
500 pf BUTTON CAPACITOR (C4)
E F JOHNSON 160-104 VARIABLE

BOTH THE BUTTON CAPACITOR AND VARIABLE CAPACITOR CONNECTING STRAPS (A AND B RESPECTIVELY) ARE MADE FROM 3/16" WIDE THIN COPPER STRIPS AND FORMED INTO SHAPE AS SHOWN. NOTE THAT THE STATOR SUPPORTING PINS ON THE VARIABLE CAPACITOR HAVE LENGTHENED SOMEWHAT FOR PURPOSES OF THIS ILLUSTRATION

Fig. 5. Exploded view of the connections between the 6CW4 and the coil socket.

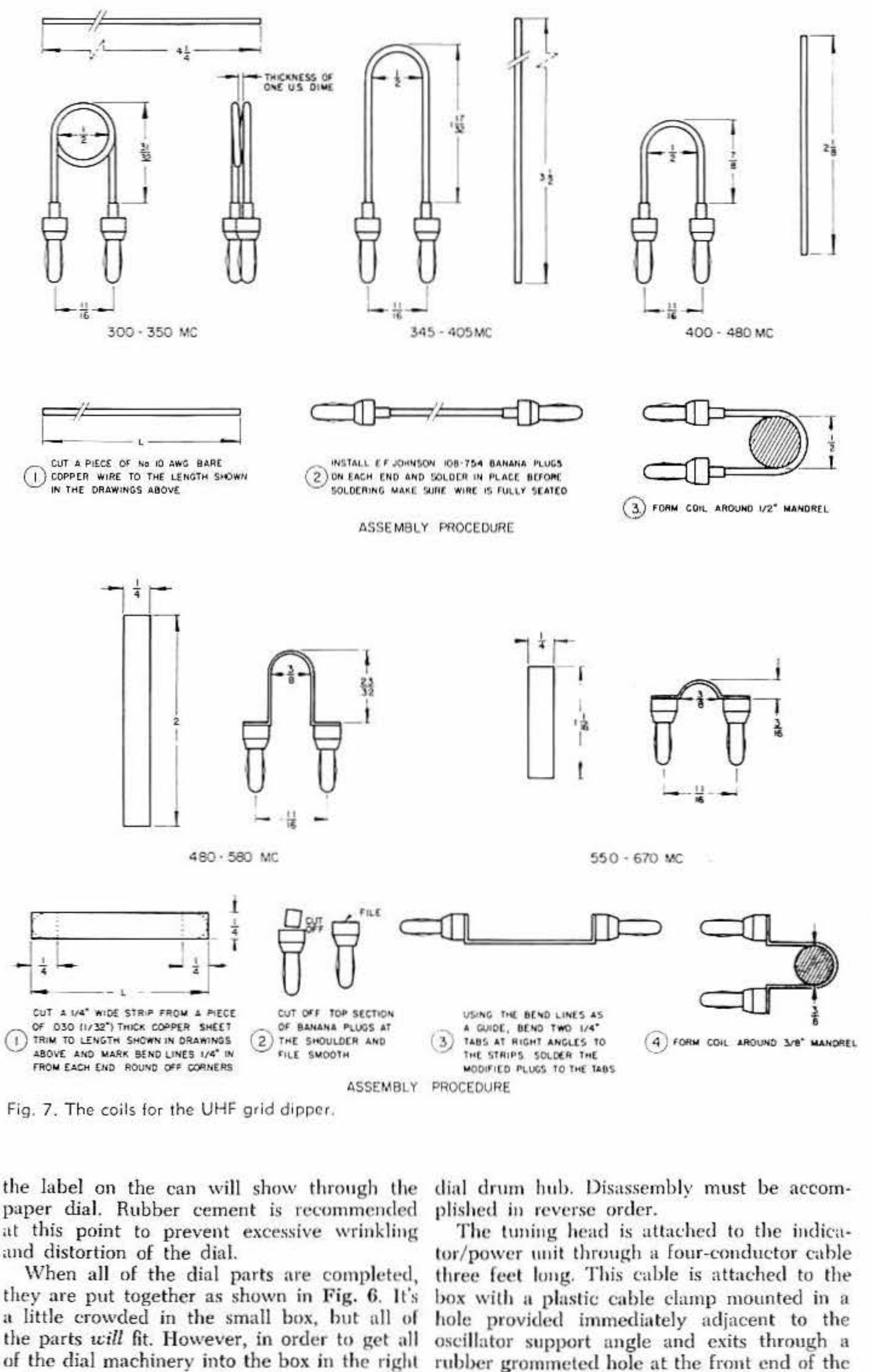

① CUT A PIECE OF No 10 AWG BARE COPPER WIRE TO THE LENGTH SHOWN IN THE DRAWINGS ABOVE

② INSTALL E F JOHNSON 108-754 BANANA PLUGS ON EACH END AND SOLDER IN PLACE BEFORE SOLDERING MAKE SURE WIRE IS FULLY SEATED

③ FORM COIL AROUND 1/2" MANDREL

ASSEMBLY PROCEDURE

① CUT A 1/4" WIDE STRIP FROM A PIECE OF .030 (1/32") THICK COPPER SHEET TRIM TO LENGTH SHOWN IN DRAWINGS ABOVE AND MARK BEND LINES 1/4" IN FROM EACH END ROUND OFF CORNERS

② CUT OFF TOP SECTION OF BANANA PLUGS AT THE SHOULDER AND FILE SMOOTH

③ USING THE BEND LINES AS A GUIDE, BEND TWO 1/4" TABS AT RIGHT ANGLES TO THE STRIPS SOLDER THE MODIFIED PLUGS TO THE TABS

④ FORM COIL AROUND 3/8" MANDREL

ASSEMBLY PROCEDURE

Fig. 7. The coils for the UHF grid dipper.

action and repeatability in a small package. Although this unit is manufactured in England, it is available from many of the larger electronics parts houses in this country.

Substitution of similar drives should be perfectly satisfactory as long as they don't extend more than one inch beyond the front panel of the tuner chasssis.

The vernier drive is connected to the variable capacitor through a ¼ inch polystyrene shaft 1-¼ inches long and the usual "¼ to ¼" shaft couplers. Polystyrene or some other insulator must be used here because the rotor of the capacitor must be isolated from ground. Because of the space limitations inside the enclosure, the coupler at the variable capacitor end of this shaft is only one-half of a standard coupler. A standard "¼ to ¼" coupler is sawed in two and one-half is epoxied to the end of the polystyrene shaft. Save the other half; it will be used for the dial drum hub.

The 8 pf variable capacitor was designed for screwdriver adjustment and its $\frac{3}{16}$ inch shaft must be made compatible with the standard coupler. This is accomplished with a bushing made from sheet copper. A short piece of ¼ inch wide, $\frac{1}{32}$ inch thick copper strap is formed around the capacitor shaft and takes up the slack between the shaft and the coupler.

The drum dial in the original unit was made from the metal top of a Johnson's Shoe Shine Kit (49¢ at the local grocer's), but any similar closed cylinder 1-$\frac{15}{16}$ inches in diameter and about 1-$\frac{11}{16}$ inches long should be suitable; other diameters will void the accuracy of the precalibrated dial. The "skirt" or bottom rim is cut off the metal can at the circumferential notch and a ¼ inch hole is drilled in the center of the top. The remaining half of the ¼ inch shaft coupler that was left over from the polystyrene shaft is then epoxied in place over the hole to provide a dial drum hub. Another hole is drilled in the side of the can $\frac{11}{16}$ inches from the top; this provides access to the shaft coupler on the rear end of the vernier drive.

The precalibrated paper dial may now be cemented in place. It's a good idea to cement a piece of white paper the same size as the dial between the dial and the drum, otherwise the label on the can will show through the paper dial. Rubber cement is recommended at this point to prevent excessive wrinkling and distortion of the dial.

When all of the dial parts are completed, they are put together as shown in **Fig. 6**. It's a little crowded in the small box, but all of the parts *will* fit. However, in order to get all of the dial machinery into the box in the right order, a correct assembly sequence must be followed. First the polystyrene shaft and coupler are inserted into the dial drum from the rear. Next insert the Eddystone drive assembly through the hole in the front panel and mate it with the end of the polystyrene shaft. Place the bushing over the capacitor shaft, attach the polystyrene shaft and tighten the coupler; also tighten the coupler at the back end of the Eddystone drive thru the access hole provided in the dial drum. Install the vernier drive mounting screws. Now completely mesh the capacitor plates, center the low edge of the dial in the window and tighten up the dial drum hub. Disassembly must be accomplished in reverse order.

The tuning head is attached to the indicator/power unit through a four-conductor cable three feet long. This cable is attached to the box with a plastic cable clamp mounted in a hole provided immediately adjacent to the oscillator support angle and exits through a rubber grommeted hole at the front end of the enclosure. There is not enough room at the rubber grommet to use a cable clamp, so the cable is epoxied to the box at this point. Before installing the cable, however, check for sufficient clearance between it and the dial drum. It will probably be necessary to route the cable along the corner of the chassis to gain enough clearance.

Power indicator modulator

The power/indicator unit is housed in a standard 9 x 6 x 5 inch utility box (Bud type AU-1040 or equivalent). The layout of this

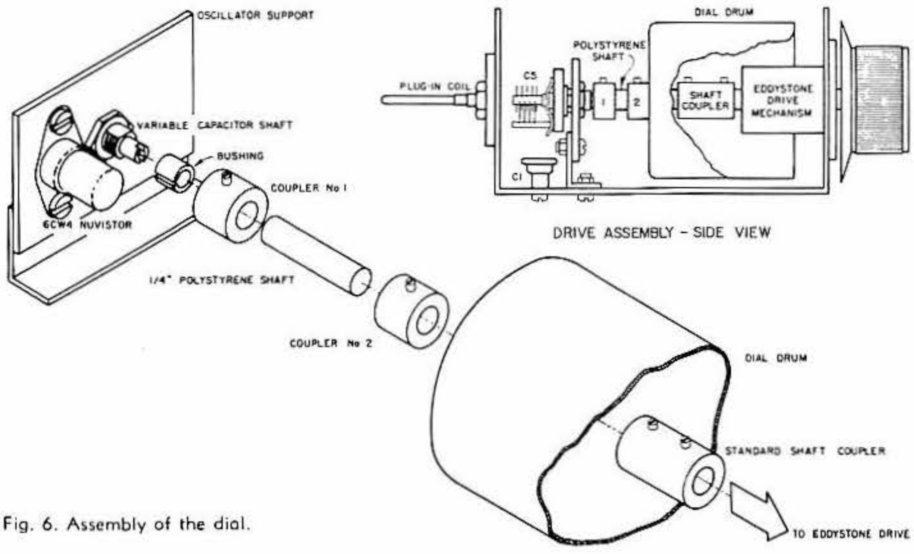

Fig. 6. Assembly of the dial.

circuitry is not at all critical, and just about anything that suits the builder may be used. The only particular caution that must be observed is with the transistorized 1 kc phase shift oscillator. This unit is built on a piece of perforated epoxy board (Vector 32AA18) 1-3/16 inches wide and 1-11/16 inches long. To preclude any 60 cycle pickup, this board is situated on the opposite side of the chassis from the power transformer.

In the author's case all the power/indicator components were mounted on a 4 x 5 x 1 inch aluminum chassis. This chassis was then mounted to the front panel of the utility box with the phone jack and power plug mounting nuts. Two large diameter holes (1-⅜ inch) are punched in the rear panel to provide access to the fuse holder and to pass the AC power plug. A chassis handle (Bud H-9168) on the top and rubber feet on the bottom just about complete the unit. There is one other addition however; five pairs of 5/32 inch holes, drilled on 11/16 inch centers along the rear edge of the top of the box provide convenient storage for the five frequency determining coils. A coat of spray paint and some Datak "Letraset" dry transfer labels are the finishing touches.

Calibration and operation

Without access to existing 420 mc equipment with known frequency characteristics, exact calibration in this band is impossible. However, this grid-dipper may be checked on the other ranges with the aid of an all-band television receiver. If the circuit layout and construction techniques described are closely followed, good correlation can be obtained and reasonable accuracy insured. The bands that are likely to be the furthest off are the lowest and the highest. In the lowest the coil spacing is quite critical and in the highest a slight change in length will move the frequency several megacycles. An accuracy of 2% at 600 mc is plus or minus 12 mc; close attention to the specified dimensions should provide accuracy better than this.

Operation of this grid-dipper is exactly the same as any lower frequency unit. It may be used in determining circuit resonance, detecting parasitic oscillations or as a signal generator. Because of its extended range, it has been found to be very useful in determining the series resonance point of rf chokes and ceramic bypass capacitors.

In the detect mode, this unit will indicate rf voltages as low as 50,000 microvolts. More sensitive operation may be obtained if it is used as an oscillating detector. In this case headphones are used and an audio beat note will be heard when the grid-dipper is tuned to the oscillator being checked. In the upper frequency ranges, it is usually difficult to obtain an actual beat note, and only a "tick" will be discernible when you tune by the frequency of the unknown energy.

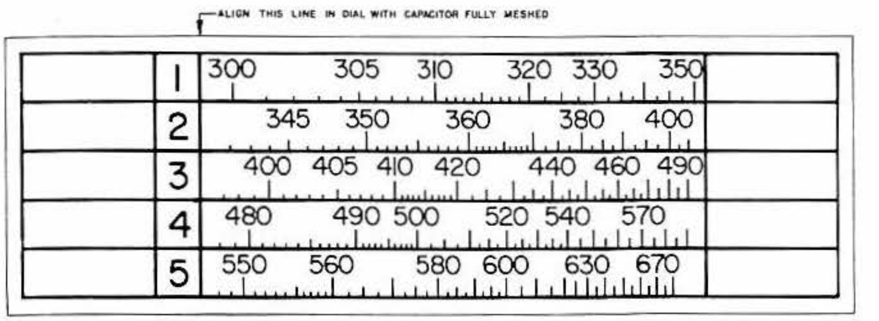

Fig. 8. Full size dial scale.

When the oscillator is tuned between 605 and 650 mc, there is sufficient second harmonic energy to provide a strong reference signal in the 1215 mc amateur band. This is particularly useful in the initial tune-up of converters for this band. Use of the internal 1000 cycle modulation aids in distinguishing the grid-dipper signal from other rf sources that are present throughout the spectrum.

WIDE RANGE VHF-UHF DIPPER

Bill Hoisington K1CLL

Most dippers for amateurs that I have seen so far, not counting the $400 ones, stop around 200 MHz just as you are about to enter the fascinating UHF region. We do have the 432 and 1296 bands, so let's become more familiar with them.

After all these years of "grid-dipping" we find ourselves without a grid, so it just becomes a "dipper". To retain the prestige of a hyphenated name we can call it a "dipper-generator". Most grid-dippers have been used as generators, but this one has built-in modulation, variable input-output coupling, controlled Q, and several other interesting features. Best of all, it goes all the way up to 1296 MHz.

When this little unit is completed it may be used as a dipper for determining the resonant frequency of VHF and UHF circuits, as an indicating frequency meter with an adjustable Q-multiplier, a field strength meter and modulation monitor, a sensitive regenerative receiver, or a CW and MCW signal generator. You can also use it as a harmonic monitor or as a frequency transfer unit from one transmitter to another.

Several circuits must be considered when building a wide band instrument such as this. For example, you should change circuits around 100 MHz and again at 600 MHz, give or take a few hundred. Below 100 MHz coils are good; from there to 600 MHz you can use ¼ wave resonators, and after that the ½ wave job becomes rapidly the best method, up to 1300 MHz.

Plug-in rf heads

I have made no attempt to cover the complete range from 130 to 1300 MHz with one oscillator. By using plug-in tuners you may vary the components to suit the frequency. On 50 MHz for example, you may use a low cost transistor, a coil, and a 25 or 50 pF capacitor. From 100 to 600 MHz you use a better transistor, a ¼ wave strap, and a 10 or 15 pF capacitor. In the microwave region up to 1296 MHz you use the best transistor you've got, ½ wave lines,

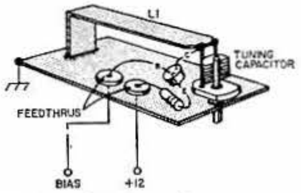

Fig. 1. Basic VHF/UHF oscillator circuit.

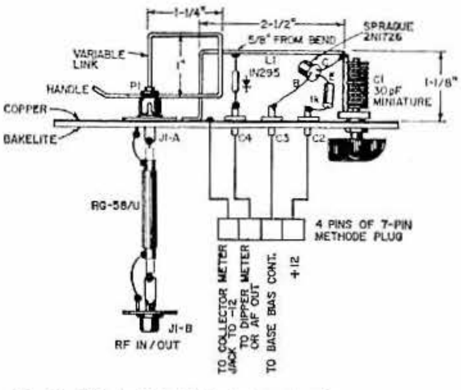
1-1/4"
2-1/2"
SPRAGUE 2N1726
5/8" FROM BEND
VARIABLE LINK
L1
1N295
1"
C
B
E
1k
C1 30pF MINIATURE
1-1/8"
HANDLE
P1
COPPER
BAKELITE
J1-A
C4
C3
C2
RG-58/U
4 PINS OF 7-PIN METHODE PLUG
TO COLLECTOR METER JACK TO -12
TO DIPPER METER OR AF OUT
TO BASE BIAS CONT.
+12
J1-B
RF IN/OUT

Fig. 2. 130 to 300 MHz tuning head.

and a small butterfly capacitor of 3 to 5 pF.

If you break the circuit at the right point, it simplifies things—then the two halves may be connected through a miniature 7-pin socket and plug as shown in Fig. 2. All four leads are reasonably dead to rf. You can leave out some of the audio if you like, but it's very handy to have a modulated signal. If you're running triple or quadruple conversion, it's nice to know by it's modulation which is the signal and which might be a *birdie*. As far as dials are concerned—it makes calibration and reading a lot easier to have only one band or range per dial.

130 to 300 MHz oscillator

Fig. 1 shows the basic ¼ wave circuit; Fig. 2 the complete rf unit with control, af output and modulation.

The circuit itself is very simplified, as seen in Fig. 1; there being only one inductance, L1, and no choke coils. This should make for a flat tuning oscillator without power dips as it is tuned over a 2 to 1 range in frequency, and it does just that. With a 2N1726 in the circuit there is a smooth power output curve from about one volt rf at 130 MHz down to ½ volt at 300 MHz.

The rf coupling jack J1 couples the rf energy both in and out. This is because L1 acts as either a detector resonator or an oscillator resonator, as required. Actually this rf jack can be used as shown in Fig. 2. P1 is a variable link to L1 and is plugged into J1; J1A has a few inches of cable between the white ABS plastic front panel and the copper clad bakelite sub-panel. Because the phono plug is rotatable, a nice variation in rf coupling can be obtained. The coax cable and J1B get the rf out to the front panel for easy use with antennas, probes, cables, etc.

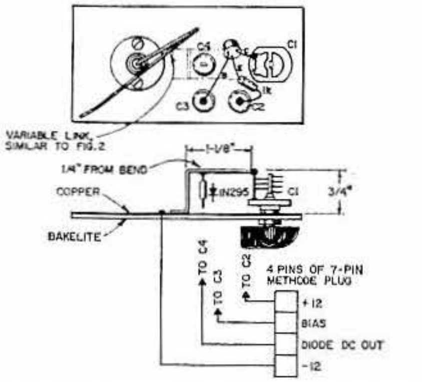
C4
C1
C3
C2
1k
VARIABLE LINK, SIMILAR TO FIG.2
1-1/8"
1/4" FROM BEND
COPPER
1N295
C1
3/4"
BAKELITE
TO C4
TO C3
TO C2
4 PINS OF 7-PIN METHODE PLUG
+12
BIAS
DIODE DC OUT
-12

Fig. 3. 300 to 600 MHz oscillator with variable link.

The emitter goes to a 1K resistor then through a coaxial bypass capacitor which gets the dc in and out and leaves the rf behind. These feed-through type bypasses are very necessary—do *not* skimp on this item.

300 to 600 MHz unit

Fig. 3 shows that this unit is essentially the same as the last, except for dimensions. I used a 2N1141 here although many others will work too. It tunes smoothly from 300 to 600 MHz; use the variable link feature as in Fig. 2.

900 to 1100 MHz

For this frequency range we need a little different approach. From Fig. 4 we can see that we now have two ¼ wave lines on which low-voltage points can be found to attach the base and collector resistors. Most of the ¼ wave portion of the lines on the transistor end are actually inside the case. The places where the base resistor and the 500 ohm collector resistor are attached to the ¼ wave lines can be found, or checked, by watching the rf meter and touching the lines with a pencil. At the proper point no change occurs in the rf output; sometimes it even increases.

The diode circuit of Fig. 6 is not ideal but it works. I have several of these around the shack and they work very well for detecting 1296 Mhz energy. Even ordinary hook-up wire will support the assembly of Fig. 6 about ¼ inch below the rf lines; you will soon find the best spot with the unit oscillating. The rf input jack and associated loop L3 are fastened so that L3 is in place over L1 and L2, and it's coupling can be varied in a semi-fixed fashion.

At this point we should mention that as a "dipper" the circuit is still working fine; also as a signal generator. It also serves as an rf detector but as the frequency gets up into the microwave ranges it is not quite as good as the tuned rf detectors featured in another article in 73 Magazine. Ideally, you should use the dipper on microwaves as a modulated generator and couple it into the unknown circuit; then a probe attached to *another* tuned detector should be coupled into the unknown circuit. There are quite a few variations using the dipper as an oscillator that you will find useful if you use a little ingenuity.

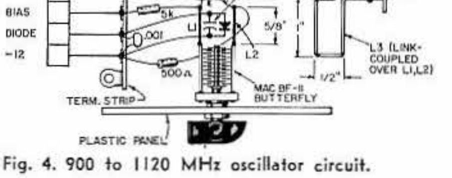
NOTE
L1 & L2 ARE THIN BRASS STRAP, 3/8" x 5/8"
4 PINS OF 7-PIN METHODE PLUG
2N1141
RF OUTPUT/INPUT
+12
BIAS
DIODE
-12
1k
5k
.001
500Ω
B
SEE FIG.6
L1
L2
5/8"
1"
J1
L3 (LINK-COUPLED OVER L1,L2)
1/2"
MAC BF-11 BUTTERFLY
TERM. STRIP
PLASTIC PANEL

Fig. 4. 900 to 1120 MHz oscillator circuit.

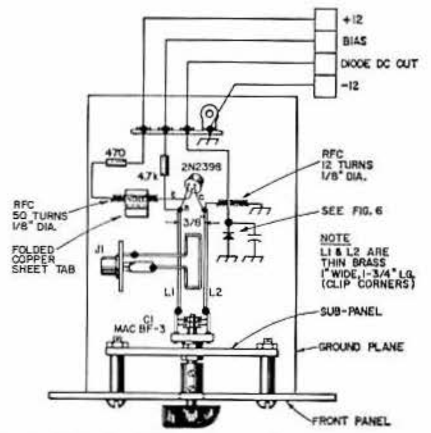
+12
BIAS
DIODE DC OUT
-12
470
4.7k
2N2398
E
C
B
RFC 12 TURNS 1/8" DIA.
RFC 50 TURNS 1/8" DIA.
3/8"
SEE FIG. 6
FOLDED COPPER SHEET TAB
J1
NOTE
L1 & L2 ARE THIN BRASS 1" WIDE, 1-3/4" LG. (CLIP CORNERS)
L1
L2
C1 MAC BF-3
SUB-PANEL
GROUND PLANE
FRONT PANEL

Fig. 5. 1200 to 1300 MHz oscillator and layout.

In the microwave detector line, my experience indicates that the plunger tuned coax cavity line is the best, the tuned trough line next, and the circuit of Fig. 5 next best. As a dipper, generator and regenerative receiver it is still good at 1296 MHz. Just to check, I plugged an antenna into J1, put an audio amplifier across the diode and copied a small transistor oscillator across the room. The base bias control works as a very smooth regeneration control. Smooth regeneration, as we will see later, is very important for maximum sensitivity when looking for harmonics and weak signals.

1200 to 1300 MHz unit

Fig. 5 shows the 1296 unit; I have used this circuit for many months as a dipper, variable-frequency generator, modulated-oscillator source, and as a regenerative receiver for 1296. In this circuit I used a negative dc grounded collector return. Don't short the base plate to the modulator base. Note that one end of the diode is tied to the base plate; this lead is brought out as the minus 12 volt lead. You can also use it ungrounded as in Fig. 4—you can use a 5th lead in the 7-pin plug and keep the diode isolated from the minus 12 volts. Suit yourself, just remember that *all* units have to use the same leads, as they all plug into the single modulator rf unit.

I just plugged a little 12 element Yagi antenna into this dipper and it works nice and smooth as a regenerative receiver. Please note, this is only for test purposes around the shack. You can hear with it, but not *that* good!

I had to put a choke in the cathode lead on this one, and tune it (the choke) with a piece of copper foil. A choke was needed in the collector lead too; after all this is the L-band microwave region.

The rf input jack J1 is mounted on a bakelite upright. Be careful of vertical metal pieces attached to the base plate; they only need to be two inches long or so to become Marconi antennas on 1296! Bring the base resistor and the collector choke away from the lines in a perpendicular fashion—it helps.

The total length of the diode and it's two leads, from ground to the tiny .001 capacitor C2 is about 1⅛ inches; it is spaced about 3/16 from the ground plane. The bottom edges of the lines are about ⅛ inch from the ground plane.

The transistor presently in the unit is a selected 2N2398; about half of the dozen or so I have here go to 1300 MHz, a couple go to 1400, and the rest to 1100 or 1200.

Don't be alarmed that L1 and L2 are longer than those of Fig. 5, the smaller butterfly capacitor does that. You can make a choice as to capacity, length of brass, and desired rf range. You can use a 5 or 10 pF capacitor for C1, shorter lines, and tune over 1300 MHz. In fact, I have reached 1600 MHz with this circuit!

Modulation and control

Fig. 7 shows the circuitry for bias control, modulation and audio. Don't let it scare you. It's just the same old deal of doing what has to be done for control purposes, and from then on just turning the knobs to get what you want.

I have found that a very good plug and jack can be made by using an ordinary 7 pin socket and a Methode 7 pin bakelite plug. Unfortunately, I have never found a miniature tube with a bakelite base; they are always made of glass, so you will probably have to buy the 7 pin plug.

The minus 12 volt lead goes to the collector meter jack and then to the minus 12 volt of the power supply. This puts the rf panel ground at minus 12 volts and the audio af panel at plus 12. Of course, you don't have to ground the plus 12 on the audio panel, I just have that habit.

The base return goes through a 5K resistor and then to the bias control potentiometer. The diode dc/af output goes to af jack J2 and the meter M1 through the meter sensitivity control. This potentiometer is selected to suit the meter; I have used a 10 K unit with a 500 microampere meter. Note that part of this resistor should be used when af output is desired, otherwise the meter shorts out the af.

Audio modulation

You might think that just about everyone knows how to build an audio oscillator. Mine did oscillate, but the tone! And the wave-shapes, hoo-boy! I used an af transformer with the collector on one side and the base on the other. So, once again to the handbooks and once again practically zilch. I did get the idea for a phase shift oscillator out of one of them, even if the circuit didn't work at first. After considerable experimentation I can recommend the circuit shown in Fig. 7. It works! In addition, the modulation may be adjusted to exactly 1000 MHz. This is very useful as many microwave test amplifiers have built-in narrow band af audio filters centered on 1 KHz. There is also a modulation gain control. This helps if a nice tone is desired.

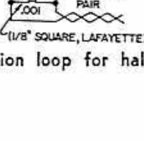

Fig. 6. RF detection loop for half-wave oscillators.

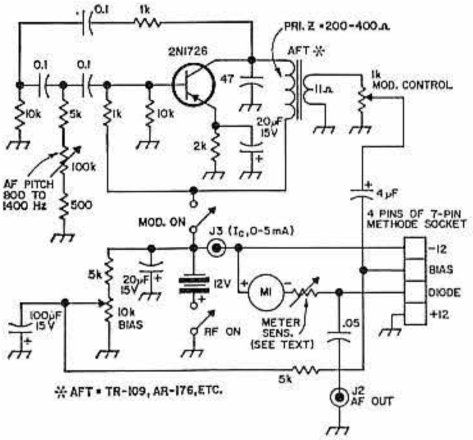

Fig. 7. Power control, modulation and audio circuitry. This circuit is used with all the rf heads.

Almost any small transistor output transformer will do the job for the af transformer, but don't go over 400 ohms impedance in the collector winding. Note the 1K resistor between the collector and the phase shift network; this reduces feedback to the base and may have to be increased or decreased depending on the gain of your transistor at 1000 Hertz.

I usually run the rf current (collector dc) between one and two mils with the 2N1726 transistors; other transistors may take more. A number 48 bulb in the collector lead may save you a $3 transistor. With the 2N1141 the rf output keeps climbing up to 4 or 5 mA collector current. You will readily find the best place to operate. When the collector mils keep climbing and the rf output starts to drop off, back off!

Operation

Dipper

As a general rule "dipping" is easier in the VHF region and gets more difficult as you go into the microwave region. On HF you couple one coil end on to the other; on VHF you bring it near, and on UHF you have to work to get the necessary coupling or use a probe.

With nothing near the dipper, swing the dial through the range to make sure it has no dips of it's own. The VHF/UHF units without chokes described here do not generally have such dips. Unwanted dips can be caused by chokes, resonant feed wire lengths, metal supports, and rf links and cables among other things.

When you do get a dip after coupling to the unknown circuit be sure and change the resonance of that circuit for a final check while watching the dipper meter. If the test circuit is a tuned circuit vary the tuning and see if the dipper will follow it—it *should*. If all else fails, use the dipper as a generator. Since it is very difficult to get the far end of a cable matched exactly over much of a frequency range, *expect* to find external dips in the dipper when using a cable.

Indicating frequency meter

Always keep the transistor plugged in and the base bias at zero so the diode is doing the work. When you advance the bias, collector capacity will cause the dipper frequency to change a little—more with some transistors than others.

For finding a weak signal you can use regeneration by turning up the base bias, but watch out for slight frequency changes. This regeneration can be very handy for finding weak oscillators or hard-to-find rf energy. Use the rf input loop with care; the least coupling is the best. Remember that some cables and terminations will detune L1.

Field strength meter and modulation monitor

The first part is obvious; use a small antenna or probe, get some signal in, and go ahead. Do not use any base bias to start with. If you are working with a very weak signal you might have to push the bias up for regeneration.

The modulation monitor is simply our often-described system of diode detector, transistor amplifier, and padded ear-phones. You can actually hear what your own transmitter sounds like to others. I use it on every new rig and after every circuit change. You don't need much of an antenna or probe when listening to your own rig; don't overload the diode when checking modulation. In fact, use light rf coupling and plenty of audio gain to hear yourself as others hear you.

Regenerative Receiver

Plug an audio amplifier into J2, Fig. 7, advance the bias control, and tune. I have heard several UHF TV stations from Massachusetts up here in Peterborough, so it is really sensitive. One nice feature of this circuit is that the regeneration turns into oscillation very smoothly. Stability is good too. You can heterodyne a crystal controlled two meter signal and copy CW with it. Not bad for a 144 MHz blooper!

To transfer signals from one transmitter (A) to another (B), just tune in A, then shut it off; listen for B and tune it in. That's all. Harmonic monitoring is easy: just tune over the suspected range in the regenerative condition. It is particularly good because only *one* frequency is present in the receiver. This is *not* the case when using a super-het receiver for monitoring harmonics.

Signal generator

One of the big features of this circuit is the presence of an rf meter right in the proper place circuit-wise. The modulation also helps, especially when running triple or quadruple conversion in a receiver. The modulation control is very convenient, at full on its spreads the signal across 20 or 30 kHz on a selective receiver. For checking a difficult to get at circuit, use a cable and probe, either capacitive or inductive, to get the signal into the unknown circuit.

I often use one of these units for antenna and receiver tests. I just plug a little two element beam into the rf jack and set it out away from the shack; often one or two hundred yards away. There is nothing like tuning up pre-amps with your antenna system connected. For antenna tests it is used in reverse.

EXTRA SERVICES FROM YOUR GRID-DIP OSCILLATOR

W. B. Cameron WA4UZM

One of the handiest instruments around the average ham shack is the grid dip oscillator, but many hams do not get all of the advantages this little instrument can offer. Most people know that it is useful for finding the resonant frequency of an LC circuit, or for generating a signal someplace in the range, although it is not quite a substitute for a well calibrated signal generator in this respect.

Many people do not realize that the grid dip oscillator makes an excellent crystal calibrator as well. The typical grid dip oscillator uses a two-terminal coil and a two-section variable capacitor, connected in the form of a Colpitts oscillator circuit, with the variable capacitor providing the voltage division for proper feedback. This same circuit, with a quartz crystal replacing the coil, becomes a very satisfactory crystal oscillator. In this case, the variable capacitor becomes a trimming capacitor capable of putting the crystal on the proper frequency with considerable accuracy and also allowing a fairly wide latitude higher or lower for checking bandpass.

The meter reading gives an index of crystal activity. What is required is an adapter to match the pins of the crystal holders to the coil socket of the grid dip oscillator. I have made up such an adapter for my particular unit which consists of a 1½ inch by 4½ inch piece of masonite which carries two banana plugs to insert into the oscillator socket, and several different sizes of crystal holders, all connected in parallel, to accommodate any crystals I happen to have around the shack. I carry in my tool kit various assorted crystals. These give me spot frequencies for band edges and other reference points on all of the amateur bands.

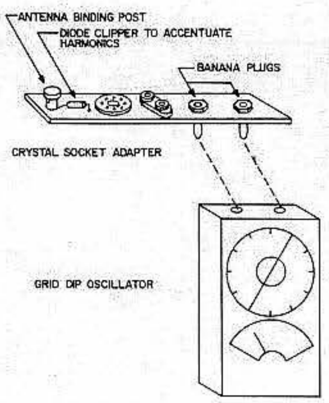

Crystal socket adapter for grid dip oscillator extends the unit's capability by enabling it to read crystal activity.

In checking the higher frequency bands, I find it useful to add a diode clipper and have one permanently wired on the same adapter board. This is a 1N69 which simply goes from one side of the crystal to a terminal point at which I can attach an antenna or a lead to the input jack of the receiver. By simply attaching a short length of wire approximating a quarter wavelength at this frequency, I can provide a strong enough signal from the shack to enable me to check out my direction finding loop in the automobile fifty feet away.

In tuning up my 2 meter FM gear, I plug in a 3061.25 crystal (which is the transmitter oscillator crystal for my Link 2m FM unit) and then couple from the 1N69 to the input of the receiver. This provides a signal stronger than most of the local signals on the band, and adequate for initial tune-up. For finer adjustment of the i-f strip, I clip the lead from the 1N69 to the chassis close to the antenna input jack and the leakage provides a signal of the order of .2 μV, which is useful for final adjustment of the critical tuned circuits, the squelch control, and others. For best results, I leave the oscillator and the receiver on for a half hour or so to warm up, and then with the variable capacitor in the grid dip oscillator, I zero-beat the incoming signal of a station generally considered to be on frequency. Once this is done, I have a signal source on the bench with which to check the receiver for passband balance as indicated on the microammeter connected to the discriminator output.

GDO TO FIND C

F. C. Rayer G3OGR

Most amateurs have a grid dip oscillator lying around, and an easy accessory can allow it to be used to read the values of unknown capacitances up to about 1000 pF. This is useful for unmarked surplus, those with obliterated markings, or to find the swing of small variables. Or we may check the best value found in some circuit position with a preset or variable, then measure this and substitute a near value fixed capacitor.

Figure 1 is the circuit. C1 and C2 are on the lid of an insulated box, carrying also spring terminals for CX. The capacitors have good knobs with pointers. Coil L can be half a dozen turns of stout wire, self-supporting, or anything which comes within a convenient range of the GDO (say 2.5–10 MHz) with both variables fully closed.

To calibrate, close C1 and C2 fully. Tune the GDO for the usual dip. Note the frequency on the box for future use. Take a few 1% capacitors, such as 100 pF, 200 pF, and so on, up to a total of about 1000 pF. Clip one to CX. Open C2 to restore the dip on the GDO. Mark the capacitor value on C2 dial. Series and parallel capacitors give more values. For example, 100 pF plus 200 pF in parallel gives 300 pF, while 500 plus 200 gives 700 pF, and so on.

Restore C2 to its fully closed mark. Repeat to calibrate C1, this time using capacitors such as 5 pF, etc., up to about 50 pF. When you see how the scales mark, estimate intermediate markings, to fill in.

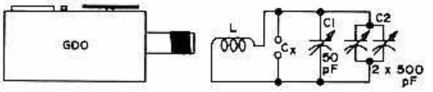

Fig. 1. GDO to find C.

Once calibration is finished, it is easy to find a capacitance value from about 2.5 to 1000 pF. Close C1 and C2. Put the GDO near L and tune the GDO for dip. Clip the unknown capacitor across CX. Open C1 or C2, as appropriate, to restore the dip. Read off the value from the scale. That's all there is to it!

GDO COIL EXTENSION

Bill Turner WA0ABI

A grid dipper is a great piece of test equipment and belongs wherever rf equipment is to be designed, constructed, or serviced. All writings on the subject seem to be prefaced with this comment, and I hesitate to break tradition. Now that the formalities are over, we will proceed with the subject matter.

Probably the one most inconvenient feature of all grid dip meters is the physical size of the instrument. This holds true for the two unit commercial models as well as the more common self-contained types. It is not so much that they are large but rather that the head will not always fit into the nooks and crannies which seem to be designed into most equipment. This situation will more than likely become more severe as integrated circuits come into more general use. At lower frequencies the coil assembly is usually long enough to reach to within shouting distance of the desired circuit, but as the frequency is increased the dipper coil shrinks to perhaps an inch protruding from the case. Try getting this even near a circuit buried 2 or 3 in. deep in a chassis and you will fully appreciate the magnitude of the problem.

There is a way of relieving the difficulty which requires neither a great deal of time nor expense. It is only necessary to put to use some basic theory which each of us was required to know in order to get a ham license. Required are perhaps a 3 ft length of small coax (RG 174/U), 6 in. of hookup wire and a ballpoint pen casing. The innards of the pen are removed, and the business end reamed slightly to accept the ends of a ½ in. diameter one turn link formed of hookup wire. Inside the barrel of the pen the ends are soldered to the coax, insulated, and cemented in place. The remaining wire is formed into a 2 turn link which fits snugly on the coil form of your grid dipper. This link is soldered to the opposite end of the coax and secured. Shrinkable tubing is perfect to cover the joint.

The next time you face this perplexing problem hold your head high and fear not. Merely slip the link over the coil form, place your probe so as to allow coupling into the desired circuit and proceed as usual. The only difference will be a more or less fixed load on the oscillator which doesn't affect its ability to indicate resonance. As always, best results are obtained with minimum coupling.

Chapter VIII

Noise Generators

SIMPLE NOISE GENERATOR

George Rubis K9ONT

As anyone knows that has done any work at all on receivers, whether it is a conversion or simply substituting a "hotter" tube in the front end, we get to the point where we begin to wonder if the adaptation was worth while or have we been fooling ourselves.

A noise generator using one of the noise diodes (IN21 or IN23) can give an indication if any improvement has been made.

The circuit is straight forward, but with one addition that others that I have seen do not have. The voltage is regulated by a Zener diode.

The reason is obvious to anyone who has worked with the simpler type of noise generator. The results are not always consistent from measurement to measurement and from day to day. The voltage and current vary with the setting of the variable resistance and due to the normal aging of the battery.

The Zener Diode eliminates this by maintaining a constant line voltage. In our particular instrument it is six volts. Of course we must use a battery in excess of six volts. Nine volts is a good value. I have found that used transistor radio batteries still have enough life in most instances to last for many tests.

One of the main requisites of a noise generator is that it must be shielded throughout. Therefore we must give some thought as to the placement of the various components.

A Mini-box 2¼ x 2¼ x 4 is an ideal size. As for a connector I used the SO-239 coaxial. I find that this connector allows more flexibility than any other. If a direct connection to the receiver is desired merely attach it through the double connector type DKF-2 made by Dow Key. On the other hand if it is desired to have the controls of the noise generator close at hand merely connect a length of Coax of eighteen inches or so. I haven't been able to discover that it has affected any measurements to any degree.

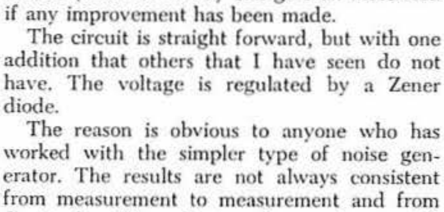

To avoid excess wear and tear on the zener diode and the battery a 200 ohm resistor should be inserted between the 9 v battery and S1.

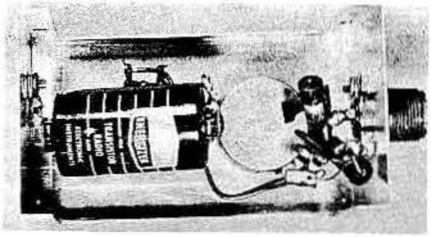

In the construction of this noise generator just remember a few basic rules. Keep all connections as short as possible. The noise diode and bypass condenser and resistor (50 or 75 ohms as the case may be) as close as possible to the output plug. Remember to use pliers to absorb the heat when soldering the leads of the diodes.

To mount the silicon diode, which has one large end and one small, we must improvise to a certain extent. For the small end a lug from one of the old tube sockets will do. For the large end use a small fuse clip.

Don't be too fussy about the variable resistor. For most purposes any value from 10M up to 50M can be used.

The battery you choose will determine the manner of mounting.

No need to give detailed instructions as to the use of this noise generator. There are ample instructions to be found in various magazines as well as handbooks.

. . . K9ONT

Parts List

2—¼ x 2¼ x 4 Minibox
Bt—9 volt battery
Cr1—6 Volt Zener Diode
Cr2—IN 21 or IN 23 Silicon Diode
R1—10M-50M Variable
R2—51 ohm or 75 ohm (according to your line)
C1—.001 to .005 disk ceramic
S1—S.P.ST. this may be on your variable resistance
P1—So-239

A CRYSTAL DIODE NOISE GENERATOR

Karl Tipple W5TEV

Most amateurs who do very much operating at the higher frequencies where receiver sensitivity rather than QRM often determines success eventually come to the conclusion that their present receiving equipment is not as sensitive as would be desirable and that a change is in order. And once that change has been made, whether it takes the form of a new converter or modification of existing rf stages, one nearly always wonders whether the new really *is* better than the old. Comparisons of signal strength with new and old equipment are erratic and unreliable at best and do not necessarily give the desired information since the absolute output level or "S" meter reading is not the problem. What is actually of concern is whether the signal to noise ratio of the receiving system has been improved. Or in other words, does a given rf signal produce an audio output signal from the new receiving equipment that is louder in comparison to the background noise than did the same input signal with the original receiving equipment. If it does, the noise figure of the new receiving equipment is smaller (better) and it should be possible to copy a weaker signal than before.

Unfortunately few of us own or have access to a signal generator of the proper frequency range, with an accurately calibrated attenuator and shielded output, for making the type of measurements mentioned above. For the majority of amateurs something less expensive and more readily available is needed. A crystal noise generator, which can be constructed for a few dollars and which will enable anyone to make before and after comparisons of noise figure, is such a device.

Briefly, the theory behind the use of the noise generator follows. The sensitivity of a receiver is highly dependent on the ability of the rf stages to amplify a weak signal as much as possible while adding a minimum amount of noise to the signal. Noise of this type will

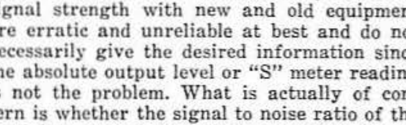

R1 = 10,000Ω POT-- LOG TAPEP PREFERRED
R2 = 1/2 WATT NON-INDUCTIVE RESISTOR EQUAL TO LINE IMPEDANCE

FIG. 1

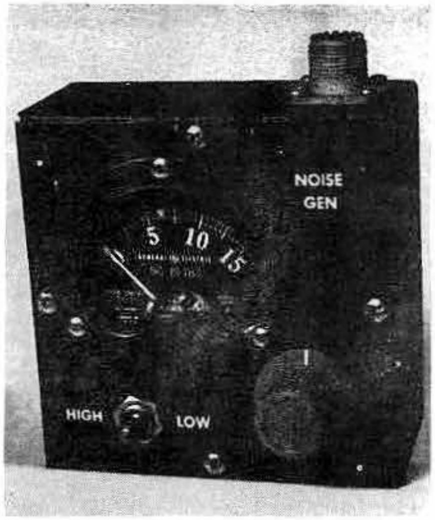

be heard at the receiver output as a familiar hiss or "rushing" sound. Now, if an external source of broadband or white noise (random noise independent of frequency) is connected to the receiver antenna terminals, an increase in noise or hiss will be noted at the receiver output. And if the noise generator output is adjusted to provide exactly twice as much receiver output noise as existed before the application of the noise generator, then the generator must be providing a noise signal equal to that generated in the receiver. Thus, if the receiver can be modified so as to reduce the noise generator signal required to double the receiver noise output, the noise figure of the receiver will have been improved.

A noise generator of the type described in this article can not be used for measurement of absolute noise figure without additional calibrating equipment. It can, however, be used for *comparison* of noise figures. It enables one to determine whether a receiver really has been improved and it can be used to determine which of a number of possible modifications will yield the best results in terms of minimum noise figure (maximum sensitivity). Use of the device will be discussed in more detail later.

A basic noise generator circuit is shown in Fig. 1. The noise is produced by CR1, a silicon diode of the 1N21 or 1N23 variety. These diodes have been widely available on the surplus market for several years. They are also readily available new at small cost; however as will be explained later, it may be desirable to use a surplus diode rather than a new one.

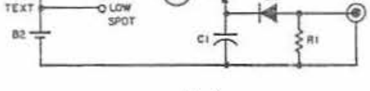

FIG. 2

R1 = 10,000 ohm pot—log taper preferred
R2 = ½ watt non inductive resistor equal to line impedance
Other parts same as Fig. 1

The current supplied to the diode from the battery and therefore the noise generated by the diode is determined by the setting of R1. The best value for R1 is necessarily a compromise since in its maximum resistance position it must limit the current to a low value but it must also not change resistance too rapidly at the low resistance end of the range or the normal operating range of the instrument will be limited to only a few degrees rotation of the R1 shaft. A 10,000 ohm log taper pot should prove satisfactory.

The value of R2 should be about the same as the transmission line impedance. A good value might be 56 or 68 ohms, although if it is desired to use the noise generator with equipment which normally operates from higher impedance lines, a larger value should be selected for R2. In this case one might compromise with a value of 100 ohms. C1 serves as bypass capacitor and may be either mica or disc ceramic.

A more elaborate arrangement was used in the construction of the unit shown in Photo. 3. A schematic of this generator appears in Fig. 2. Here a tapped battery (2 pencells) was used to minimize the range to be covered by R1. It should also be noted that the diode is shown reverse biased in Fig. 2. Many of the surplus diodes available have very poor reverse resistances, which will allow reverse bias operation, and when operated under these conditions will generate considerably more noise for the same bias current than when operated in the more conventional configuration shown in Fig. 1. The diode must have a reverse resistance of only a few thousand ohms or less if it is to work successfully in the reverse bias connection. Therefore unless the reader can obtain some surplus diodes and select one with a low reverse resistance, it will probably be necessary to operate the diode forward biased and to use the higher battery voltage of Fig. 1.

The meter range depends upon the battery voltage and the resistance of the diode in whichever connection it is used. The meter used in Fig. 2 was a 0-4 ma surplus meter. However, if the diode is operated in the forward biased connection a meter of somewhat higher current rating will probably be needed. Therefore, it is suggested that a low range meter be obtained and if more than full scale current is required for the diode to develop sufficient noise, a shunt resistance can be placed across the meter terminals to extend the meter range. An inexpensive meter can be used since all that is needed is a relative indication of current.

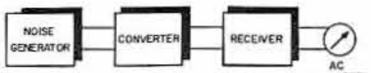

FIG. 3

For those not familiar with the IN21-1N23 type diodes it might be mentioned that they have no wire leads. The anode connection is a brass shell on one end of the unit and the cathode connection is a brass pin at the other end. Although external connecting wires might be soldered to the brass ends, there is danger that the diode will be over heated and destroyed by such techniques. It is safer to make connections by clamps made from small plate or grid caps or fahnstock clips.

It should be evident from the above discussion that there is nothing critical about the construction of a noise generator of this kind and that a number of different circuit variations are possible. Even if the device were constructed entirely of new components the cost should be less than $8 and with a little ingenuity the cost can be reduced substantially through the use of surplus parts.

Perhaps use of the noise generator can best be illustrated by considering an example of noise generator application. Suppose that you want to use either one of two available 6 meter converters with your low band receiver and that you wish to determine which converter will provide the best weak signal reception. A test set-up is shown in Fig. 3.

The ac voltmeter is used to measure the audio output of the receiver and may be either a multimeter or a VTVM. It can be connected across the speaker terminals or across the headphone line. Higher voltages can generally be obtained from the headphone output and this connection will probably have to be used if a multimeter without a very low ac range is used.

The measurements can be started by measuring the ac noise output voltage from the receiver with the noise generator turned "off". Then the noise generator should be turned "on" and the generator level adjusted until the output meter reading has doubled. At this point a note should be made of the noise generator setting. The above procedure can now be repeated with the second converter connected to the receiver. Whichever receiver-converter combination requires the smaller noise generator current setting to double the noise output is the combination that will provide the best weak signal reception.

The noise passed by the receiver is a function of the bandwidth of the receiver. Also the reading given by a particular output meter is dependent on its bandwidth. Therefore the bandwidth of the receiver should not be changed during measurements and the same output meter should be used thoughout a set of measurements.

The technique described above can also be used to determine which of a number of rf amplifier tubes will give the best performance. The noise generator can be used for alignment of rf stages.

For the man who constructs his own converters or receivers the device is a tremendous boon since such adjustments as determining the optimum antenna to grid coil coupling can be made simply by adjusting for maximum increase in noise when the generator is switched "on". (This technique gives the same results as adjusting for minimum noise generator setting to double noise output and it is a bit easier to use when adjustments must be made.) If the input circuit uses a single tapped coil instead of two coils, the best tap position can be determined.

The uses mentioned above are only a few of the possible applications of this noise generator, and for the amateur who constructs his own receiving equipment the device is indispensable.

TEMPERATURE LIMITED DIODE NOISE GENERATOR

F. L. Thomas

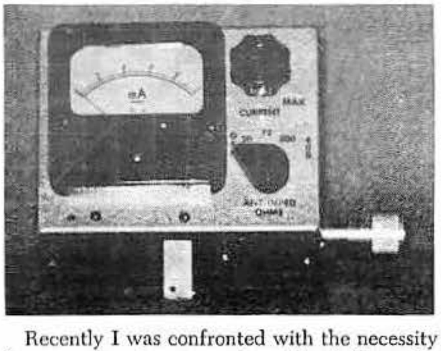

Recently I was confronted with the necessity for a good noise generator. All of the noise generator designs available in any of the amateur publications at hand were of the crystal diode type. The disadvantage of this type of instrument lies in the fact that the current through the diode has no simple relation to the noise output. Unless expensive calibration equipment is on hand this type of generator is useful only on a comparative basis. Consequently it was decided that a temperature limited diode noise generator would be built.

The noise output of a temperature limited diode noise generator is simply related to the current flowing through the diode.[1] The noise figure of a receiver may be calculated directly from the magnitude of the current by the following equation:[2]

Noise figure in db. $= 10 \log (20\ I\ R) - (1)$

Where I=current through temperature limited diode required to make the noise output power of the receiver double the value it was with no current through the diode.

R=antenna impedance

The actual noise generator is quite simple, consisting of half a 6AL5 with a milliammeter in the cathode leg and the appropriate resistance for the antenna circuit connected to the plate by means of a selector switch. The heater current is controlled by a 20 ohm potentiometer in series with the heater. The unit is battery operated for convenience. High current capacity, small sized mercury cells are used throughout. The whole unit is contained in a 3" x 4" x 5" Minibox.

Construction

The resistors are mounted on the switch, making the leads as short as possible. The tube socket is mounted on a small bracket screwed onto the side of the chassis, placed so that the distance from the switch is a minimum. The meter calibration potentiometer and the heater supply battery holders are mounted on another bracket placed over the meter as shown in the photograph.

Operation

To use the generator it is connected to the receiver antenna terminals, the AVC is turned off, and the audio output is measured with the generator off. The generator is then turned on and the current through the diode is increased until the power output is double what it was before. At this point the voltage output will only be 1.41 times the original. The current necessary to give this noise increase is noted and the noise figure calculated according to equation (1), or estimated from the figures given in Table I.

Noise Figure in db.	Current, ma., for antenna impedance of:			
	50Ω	72Ω	300Ω	600Ω
2	1.40	1.15	-	-
4	2.25	1.80	0.42	-
6	3.55	2.85	-	-
8	5.65	4.50	1.05	0.53
10	8.85	7.15	-	-
12	14.2	11.3	2.65	1.32
16	-	-	6.65	3.30
20	-	-	16.6	8.42

The unit described is useful for noise figures up to 13 db at 72 ohms. For higher noise figures a higher current capacity diode and a higher heater voltage and current supply is required, necessitating an ac operated power supply. With a suitable power supply a 6X4 may be satisfactorily operated up to a noise figure of about 22 db. In both cases the maximum noise is obtained by passing more than the allowable average current through the diode. Consequently readings at these extremes should be made and the current lowered again in only a few seconds, or damage to the diode will result.

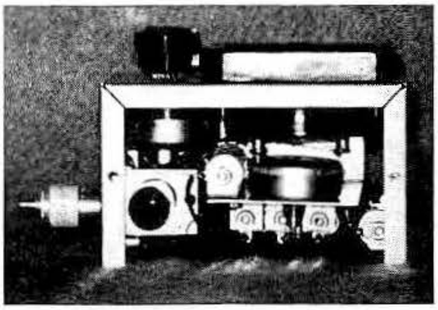

Table I shows the current readings for various noise figures with different antenna impedances.

The generator will operate satisfactorily up to at least 50 mc, and probably considerably higher.

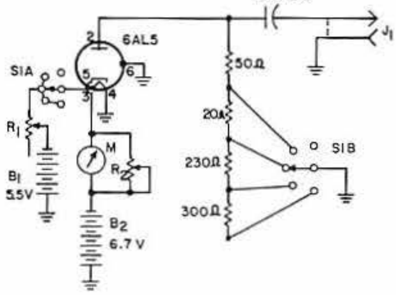

B1—four Mallory RM12 or RM12R in series (lifetime of this circuit should be greater than 10 operating hours)
B2—Mallory TR-135R
M—0-1 ma (Lafayette TM-60 or equivalent)
R1—20 ohm potentiometer
R2—20 ohm Potentiometer
J1—coax connector
S1—DP 5 pos miniature rotary switch

Editor's Note: By substituting flashlight batteries for the mercury cells and a 20 mA meter instead of the 1 mA meter with a shunt across it, the cost of construction can be greatly reduced.

REFERENCES

1. **Radiotron Designers Handbook**, fourth edition, page 1307, reproduced and distributed by RCA Victor Division, Radio Corporation of America, Harrison, N. J., 1953.
2. **Radio Engineering Handbook**, fifth edition, page 19-10, Edited by Keith Henney, Published by McGraw-Hill Book Company, 1959.
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CALIBRATED NOISE GENERATOR FOR 432

Hank Olson W6GXN

As pointed out in previous articles—the temperature-limited noise diode is the best tool for measuring the sensitivity of one's receiver. The measurement made with this device is "noise-figure" or "noise-factor" and this is the magic number by which you can compare your VHF or UHF receiver with Joe's down the street, or Sam's in Massachusetts. These measurements will be comparable between any two receivers because bandwidth, type of detector, and other miscellaneous features (different for each receiver) do not affect the measurement, if it's carefully made (that is, if one's measurement of 3 db power increase, when the diode is turned on, is true).

Past amateur articles on noise-diodes and their use in noise-factor measurement have only shown how to construct units for up to about 200 mc. The noise generators described previously, for amateur use, have used the 5722, the diode wired 24G (3C24), or the diode wired 801A, as their tungsten-filament diodes. The 15E and 01A have also been used occasionally as diode-wired triodes, too. Commercial UHF noise generators use a variety of tungsten-filament tubes, all of which are a bit expensive for most hams. If you can lay your hands on one of these tubes, used or otherwise surplus, by all means employ it in your noise generator. Table I is a list of such gems.

Philco:	L1262A
RCA:	R6212
Bendix:	6144
Marconi:	CV2171

Table I

The tube I used is a triode, a Western Electric 708A, originally designed for grounded-grid UHF amplifier service. The grid and filament are used as the diode elements, ignoring the plate altogether; the plate, if used, could only increase transit time and shunt capacity. The tube is used, as it was intended to be used, with the metal shell (grid) grounded. The 50 Ω load is connected in the filament circuit; the filament power is fed in by means of a concentric inductor, which also tunes out the stray capacity of the tube.

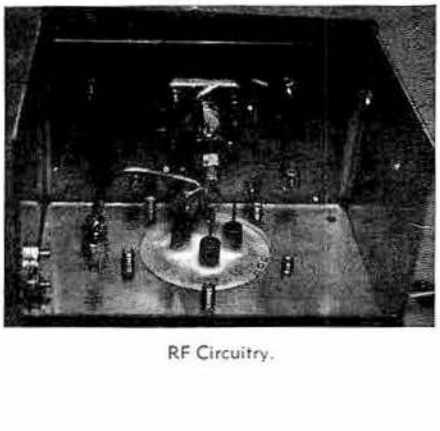

RF Circuitry.

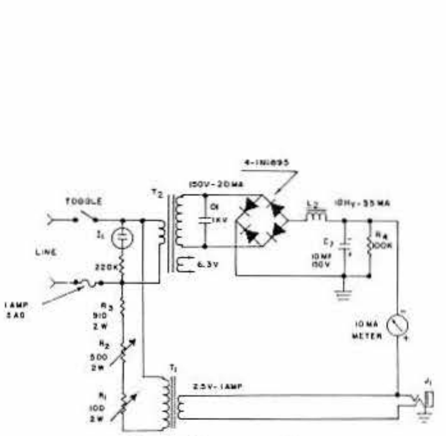

Fig. 1. Power supply.

C_1, a small "tweaker," adds in a tiny additional capacity to make adjustment to 432 mc easier; it makes tuning to anywhere in the 420 to 450 mc band possible. L_1 is constructed of a 1⅞" length of ⅛" copper tubing and has a piece of No. 20 teflon insulated wire inside it. The use of teflon insulated wire is only necessary because teflon will withstand the heat of soldering.

The effective circuit, then, is as in Figure 2.

At 432 mc, if $Cgk + C_1 = 3$ mmfd, then L must be 0.04 μh to be parallel resonant. The reactance of either $Cgk + C_1$ or L_1 is about 100 Ω, so the system has a Q of ½, and hence will be rather broad in its noise output spectrum—just as we want it to be.

The WE 708A tube was recently available from a Los Angeles surplus emporium at the price of 39 cents each or ten for a dollar. We bought a buck's worth, figuring some would be NG, but all were perfect and saturated well. One was lost in initial test, when we applied too much filament voltage; it was subsequently hack-sawed open to find out the details of its construction and to confirm connections. The details learned are presented in Figure 3 along with its saturation curve.

The filament is a single, fine, straight, tungsten wire through the grid helix. The grid helix is perhaps 1/16" diameter and is welded every turn to the shell. All this adds up to: good cylindrical diode configuration, close cathode-grid spacing to cut down transit time, and low grid to case inductance. In short, we have a nearly ideal noise diode for a dime a piece.

Construction details: The rf section of the generator is constructed on an aluminum plate bent into an L, the WE 708A protrudes through a 1⅝" round hole to expose its filament pins next to where the UG58A/U connector is mounted on the other side of the L. The WE 708A is held in place by five 8-32 binding-head screws that are tapped into the plate. The UG58A/U has four 200Ω, ½ w resistors soldered to it each at 90° to its neighbors to form a less inductive load, approximating a resistive sheet. These resistors are soldered to the UG58/U before it is mounted to the aluminum sheet to make soldering easier (less heat required). Then L_1 is formed and soldered from the WE 708A filament pin to C_3. The center filament lead of L_1 is fed through and soldered to the other filament pin and to C_4. C_2 is then soldered in; be sure this is the type called for or a similar low inductance stand-off ceramic. The rest is straight forward. Diode and power supply were each built in an LMB 141 box chassis. The details of wiring the diode circuitry are shown in Fig. 4.

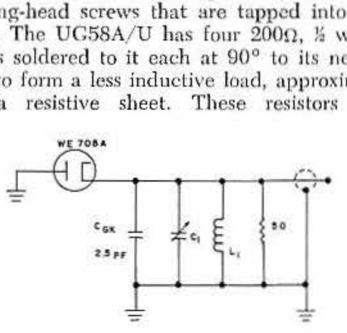

Fig. 2. Basic noise generator circuit.

A word about R_1 (the "fine" adjust) is worthwhile. Make *sure* this one is a 2w type A.B. (ohmite) molded carbon pot, if not both R_1 and R_2. This will make smooth diode-plate current adjustment easy; a wire wound pot will cause the plate current to vary in steps because of the effect of the pot's sliding contact sequencially contacting each wire (the same applies if you use a Variac).

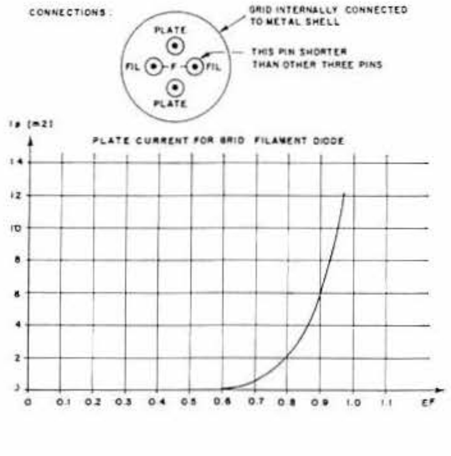

FIG 3

Fig. 3. Connections of 708A and graph of relationship between "plate" current and filament voltage.

To align on 432 mc, C_2 is temporarily removed and a UHF grid dip meter coupled to L_1, loosely. C_1 is adjusted for a dip at 432 mc. Then C_2 is reinstalled, and we should be ready for receiver checks.

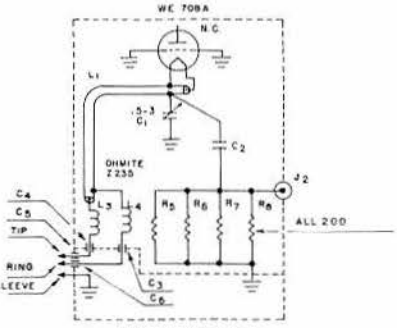

Fig. 4. Circuit of diode noise generator.

The above noise generator was compared with a Hewlett Packard 343A noise diode using my own 432 mc converter as the "to be measured" device. The results showed less than 0.5 db difference.

The author wishes to thank Gene Howell, W4RLU, for his photography of the unit.

ANOTHER WAY TO MEASURE NOISE FIGURE

Jim Kyle K5JKX

Many times it's been said, but it can always bear repeating. Noise figure is probably the least-well-known measurement in any amateur station.

At least a part of the difficulty with noise figure lies in the means usually employed to measure it. While it's not too difficult to figure out the power input to your final, or even the power *output* (often a surprisingly different figure), measurement of receiver noise figure tends to be a complicated and somewhat inaccurate process at best. It requires special equipment, and even then may be no more accurate than plus-or-minus 100 percent.

The classic means of measuring noise figure is to use a noise generator and crank in additional noise until receiver output is doubled. This means, of course, that the noise generator output is then exactly equal to the original noise, and if the noise-generator output is accurately known then the original noise is also known. All this has been gone into in detail in another article.

However, a noise generator with accurate calibration isn't so easy to come by, and an inaccurate noise generator doesn't do much good for measurement purposes (although it's fine for tune-up).

There *is* another way to do it, which is actually much more in line with amateur practice. This other way also requires some test equipment, but it might be more easy to come by.

Before we get into the details of the "other way" to measure noise figure, let's take another look at the reason for using noise-figure measurement as a yardstick for receiver sensitivity in the first place.

To start, we're really interested in the answer to the question "How weak a signal can I hear?" In the 3-30 mc range, the question can be answered directly—how many microvolts must the receiver have to give readable output?

As the vhf region is entered, though, the fractional microvolts become alarmingly small.

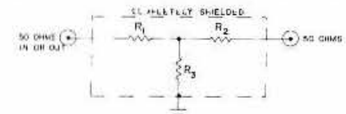

DB Loss	R1, R2	R3
3	8.2	150
6	16	68
9	24	39
20	39	10

All resistors composition, ½ watt, 5%

Fig. 1. Construction of T-pads

Somebody figured out that most of the problem lay in the receiver's own internal noise, and came up with the idea of a "perfect" receiver which would have no noise at all. This is a noise figure of 0 db. Now by comparing existing receivers to this perfect ideal, and comparing the internal noise in db, we had a way of discussing receiver sensitivity.

Since we're now talking about noise, which is equally present at all frequencies throughout the spectrum, we can see that the amount of noise present in a receiver's output is at least partially determined by how much of the spectrum we are looking at. A broad receiver has more noise output than a narrow one, all other things being equal. If you don't believe it, fiddle with the selectivity switch on your own rig and listen to the change of noise output.

This dependence of noise on bandwidth is another reason for using noise figure as a comparison. The *actual* amount of noise is cancelled out in the comparison, leaving only the relative amounts of noise in the "perfect" receiver and the receiver under test to be measured.

When all this became established, nobody was paying much attention to receiver bandwidth and it was felt that a true determination of the effective noise bandwidth of a receiver was much more complicated than the comparison measurement. However, in these days of SSB and special filters, that's not so true any more.

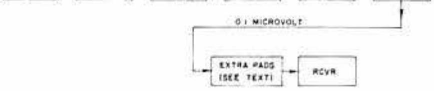

Fig. 2. Test set up.

As you may have guessed by now, the "other method" of determining noise figure depends on a microvolt measurement and knowledge of the receiver's effective noise bandwidth. The only reason for converting the results back to noise figure is to allow comparison with measurements made in the more conventional manner.

With typical ham measurement techniques, the results won't be of National-Bureau-of-Standards accuracy. However, if you're reasonably careful, results using this method will be at least comparable in accuracy to those made with a homebrew noise generator. Ready? Let's go:

You'll need two items of test equipment (only one if you're really lucky). These are an rf signal generator covering the desired frequency range on fundamental output, and an rf VTVM reasonably accurate at the desired frequency. If you have access to a "microvolter" or similar laboratory signal generator, you won't need the VTVM.

In addition, you'll need a whole handful of 50 ohm T-pads; these can easily be put together in a hurry by following the schematic in Fig. 1. You'll probably need about 8 20-db pads, as well as one each in 3-db, 6-db, and 12-db values.

Turn on both the receiver and the signal generator and let them warm up. For protection against any leakage from signal-generator to receiver through the power lines, it's best to supply them from separate circuits and to use a power-line filter such as that used to eliminate rf interference between the power line and the unit.

Connect a string of six 20-db pads to the signal-generator output as shown in Fig. 2, and adjust output of the signal generator to 0.1 volt. If you have a microvolter or equivalent, use only one 20-db pad and set generator output to 1 microvolt.

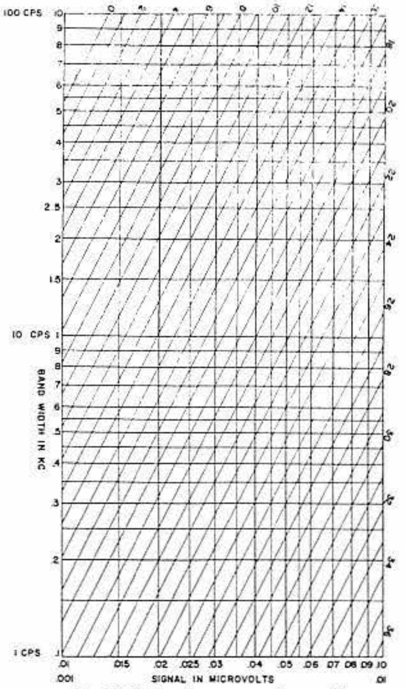

Fig. 3. Noise figure vs. microvolts.

In either event, the output of the final T-pad will be a 0.1 microvolt CW signal. This should be more than adequate for any reasonably-sensitive receiver to allow spotting of the signal.

Switch the receiver's avc off and the bfo on, and place the selectivity switch in any position for which the selectivity is accurately known. The selectivity marked on the front panel will not be the effective noise bandwidth, but you can use it as a starting point to guesstimate the noise bandwidth. If your receiver uses a mechanical filter or other device with approximately the same skirt selectivity, effective noise bandwidth will be about 1½ times the bandwidth marked on the front panel. If it is one of the older types with reasonably broad skirts, noise bandwidth will be about 3 times the marked value. Both these correction factors are approximate, of course; if you have any means of measuring effective noise bandwidth, use it instead.

For a start, use a fairly broad selectivity position; this requires more signal and makes things a bit easier.

Now tune in the signal from the generator, leaving gain controls at maximum but tuning for maximum signal strength just as if it were the new state you need. The 0.1-microvolt signal should be easy to find.

Next step is to reduce the generator output by hooking in additional T-pads until you locate the point of "minimum discernible signal." The 3, 6, and 12 db pads may be hooked up in series in any combination to give you from 3 to 24 db additional attenuation in 3-db steps. Using another 20-db pad will give you from 20 to 44 db more attenuation, and the signal is sure to become too weak to copy before you reach 44 db below one-tenth of a microvolt!

The point of MDS is approximately equal to a 0-db signal-to-noise ratio for most of us, and is considerably easier to determine than would be a true output S/N ratio. When you find this point, record the db below 0.1 microvolt and the selectivity (in kilocycles) used.

Now switch to a different bandwidth on the receiver and repeat the test. Record its results also. For maximum accuracy, repeat each of the tests 10 to 12 times and average the result.

The signal level in microvolts corresponding to db below 0.1 microvolt is given in Table I. Locate it there and move to Fig. 3, the graph of signal versus bandwidth by noise figure.

Enter the graph from the side with effective noise bandwidth, and move across until you intersect the line corresponding to signal level in microvolts. The diagonal lines are noise figure; if one passes through the intersection point, read noise figure in db from it. If not, interpolate between the lines.

In reading Fig. 3, use the 10 kc-100 cps scale with the .01-.1 microvolt scale, and the 100 cps-1 cps scale with the .001-.01 microvolt scale. If your bandwidth-signal level combination falls off the graph to the left, use the *lower* signal-level scale with the *higher* bandwidth scale and subtract 20 db from the resulting noise figure.

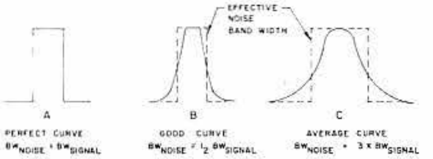

Fig. 4. Relation of noise and signal bandwidths.

In the happy event that all your errors (and our approximations) cancel out, you'll find the noise figure to be the same at both the narrow and the broad bandwidth positions. However, it's more likely that you'll measure different noise figures at different positions of the selectivity control. It's safest to take the highest noise figure measured as being closest to correct, but you can average them if you prefer. Either way, you will probably be within 1 db of the real figure—and this is as accurate as most noise-generator techniques can be, also.

That completes the measurement, but before we wind this up let's take a more detailed look at the idea of "effective noise bandwidth" which is such a key part of this measurement technique.

Most of us are familiar with the idea of a "perfect" curve for receiver selectivity such as that shown at A in Fig. 4. Here the receiver has equal response over the desired band, and response drops to zero at the band edge. Such a curve is said to have a shape factor of 1, and is of course impossible to achieve in practice.

Now back to noise; it's spread out equally over the spectrum. A noise bandwidth of 1000 cycles per second contains 10 times as much noise as one of 100 cps. Thus "noise bandwidth" inherently has a shape factor of 1.

Since such a shape factor is impossible to achieve, it follows that "noise bandwidth" and actual receiver bandwidth must differ. If receiver bandwidth is measured at the —60 db points, the noise bandwidth will always be smaller than this receiver bandwidth. If receiver bandwidth is measured at the points where response drops 1 db below peak, the noise bandwidth will always be greater.

The mathematical expression for noise bandwidth is an integral equation involving differential gain, which is a cumbersome thing to solve. In general, the noise bandwidth of a receiver is said to be approximately equal to the bandwidth between points which are 3 db down from peak response.

In practice, if the shape factor (6 to 60 db) of the receiver is 2, the effective noise bandwidth will be approximately 1.3 times the 6-db bandwidth. If shape factor is between 2 and 10, noise bandwidth will be approximately equal to the square root of the shape factor (6 to 60 db) times the 6-db bandwidth. Few receivers have shape factors greater than 10.

db BELOW 0.1 MICROVOLT	MICROVOLTS
3	.07
6	.05
9	.035
12	.025
15	.018
18	.013
20	.01
21	.009
23	.007
24	.0063
26	.005
29	.0035
32	.0025
35	.0018
38	.0013
41	.0009

Table I.

The approximations quoted earlier (1.5 times marked bandwidth for SSB-selectivity receivers, 3 times marked bandwidth for others) are based on these relations. If you're really interested in calibrating your receiver's noise bandwidth for using this measurement technique, however, you might take a converter and have it measured for noise figure by the generator technique, then run this technique backwards to determine the effective noise bandwidth of your receiver in each position of the selectivity control.

The technique described here, incidentally, assumes that no audio filters are used following the detector. If they are, all results are off, since the effective noise bandwidth will have been changed in an unpredictable manner by the audio filters.

However, you can remove the audio filters from the hookup for measurement purposes, determine noise figure, then return the audio filters to the circuit and run the measurement backward to find out your effective noise bandwidth with filters present. Don't be surprised if it comes out in the region from 1 to 10 cycles per second; a good audio filter can work wonders with weak-signal reception.

For additional details on this technique of measuring noise figure, you can consult Reference Data for Radio Engineers, 4th edition, published by IT&T and available from Radio Bookshop, or any good radar text.

Chapter IX

Attenuators and Dummy Loads

LOW POWER ATTENUATORS FOR THE AMATEUR BANDS

George Daughters WB6AIG
Will Alexander WA6RDZ

In the evaluation of rf amplifiers, filters and many other devices, a variable attenuator is indispensable. This article describes attenuators built and tested by the authors. These attenuators are flat from dc to over 50 MHz and usable to over 450 MHz. They use low cost parts, are very simple to build, and are more accurate than ordinarily required in amateur applications.

The basic attenuator section is the symmetrical pi shown in **Fig. 1**. Resistance values are given by the relations:

$$R_1 = R_s\,(\sqrt{K} + 1)/(\sqrt{K} - 1)$$
$$R_2 = R_s\,(K - 1)/(2\sqrt{K})$$

where R_s is the characteristic impedance of the pad (equal to the source and load impedance) and K is the attenuation factor, P_{in}/P_{out}.

Resistor values for the most commonly used impedance (50 ohms) are shown in **Table 1.**

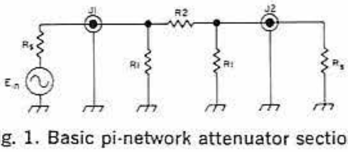

Fig. 1. Basic pi-network attenuator section.

Nominal attenuation in dB	R_1 in ohms	R_2 in ohms	Calculated attenuation in dB	Measured attenuation in dB
1	910	6.2	1.1	1.1- 1.2
2	430	12	2.1	2.1- 2.3
3	300	18	3.0	3.2
6	150	39	6.2	6.3- 6.6
10	91	68	10.2	9.6-10.1
20	62	240	19.6	19.5-19.7

Annenuation measured at 50 MHz and lower.

Table I. Resistor values for 50-Ω attenuators.

Notice that the use of standard value 5% half watt composition resistors allows accuracy within 1 dB of the calculated value of attenuation and within 1 dB of the desired nominal value.

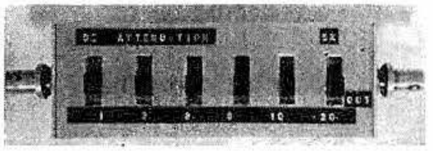

Amateur low-power attenuator made from inexpensive slide switches, 5% resistors and fiber glass, copper-clad board.

The attenuators are built in small channel boxes made of copper-clad etched circuit board material. Aluminum channel boxes commercially available would probably work equally well. Small, inexpensive DPDT slide switches (H. H. Smith No. 518 cr equivalent) are soldered directly to the copper board and the resistors are soldered to the switch terminals (which have been cut short) with the shortest leads possible.

Two wiring variations have been tried, one with the series resistors (R_2) mounted between the switch wiper contacts (type B), and one with all resistors connected to the attenuator in terminals (type A). See **Fig. 2** and the photo of the interior of the attenuator. It was found that the latter arrangement, type A,

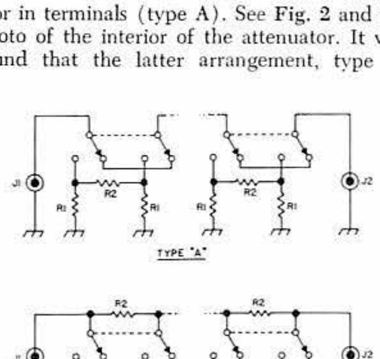

Fig. 2. Two types of attenuator construction. Type A has lower insertion loss than type B at high frequencies, so A is recommended. Resistors R1 and R2 are 5% composition, ½ watt. The switches are H. H. Smith 518 or equivalent. The connectors can be of any type to suit.

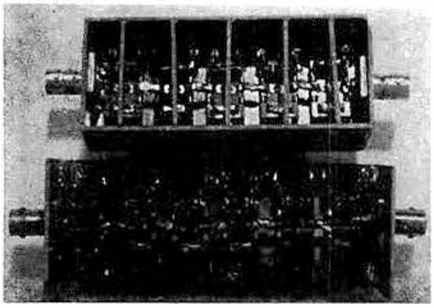

Details of attenuator construction. The top style, with complete shielding, is recommended.

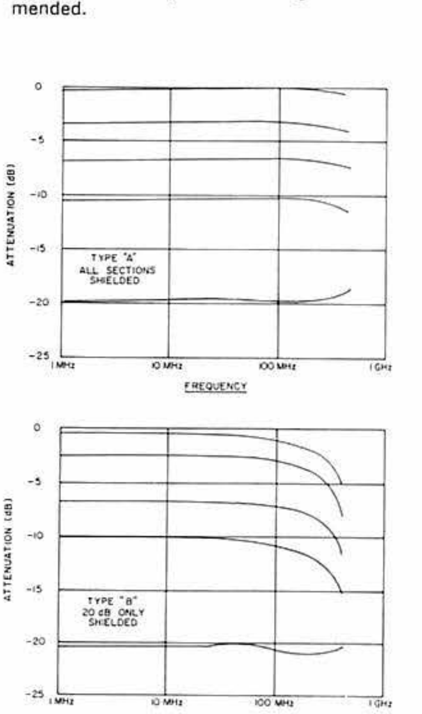

Fig. 3. Insertion loss versus frequency for the two types of attenuator construction: all sections shielded (A) and only the 20 db section shielded (B).

provided less insertion loss than the former at high frequencies, so this type of construction is recommended. Also note that dividing shields are desirable between input and output elements of a single section. These shields prevent capacitive feedthrough at the high frequencies, and are desirable on the high attenuation sections (anything over 10 dB) even at low frequencies. On the low attenuation sections, very little difference is evident below VHF. See **Fig. 3** for the attenuation of the attenuators up to over 450 MHz. Building attenuators with greater than 20 dB attenuation per section by this method is not recommended for high frequency use.

S-UNIT ATTENUATOR

Ed Lawrence WA5SWD

Since the topic of "S meters" is a popular one among radio amateurs, a lot of time is spent describing these devices, usually along the lines of how generous or "Scotch" the meters are at the QTH of the parties in the QSO. After a few such QSO's, I decided to build an attenuator, calibrated in "S" units. My aim was to attain an accuracy of 1 db or better, using 5% ½w resistors and simple construction so it would be easy to duplicate.

As a sidelight, I started out by calculating both "tee" and "pi" pads, and used "pi" because all values of resistance are close to standard values, but (especially for high attenuation pads) the values for "tee" pads can get quite small; and expensive.

I figured the values required from the tables in the Allied's "Electronics Data Handbook", page 8, 5th edition. (Allied Radio, 75c, full of good info.)

Since "S" units are supposed to be 6 db, I figured data for steps of 1,2,4 and 8 times that amount, or 6,12,24 and 48 db. With these steps, any number from 0 to 15 "S" units of attenuation could be selected. However, 8 "S" units proved to be too much for one step, as shown by the lowered attenuation at 30 MHz, due to the inherent shunt capacitance of the resistor used in the series leg, plus the stray capacitance of the switch. So I removed the 8 "S" unit step and installed another 4 "S" unit step. This allows selected steps of attentuation from 0 to 11 "S" units.

Here are the values I calculated, and the actual values used, based on 51 ohms. The steps are switched in series, as required for the desired attenuation.

Resistance Values for 51 Ohm Attenuator:

		R1		R2	
"S" units	DB	ideal	actual	ideal	actual
1	6	154	150	38	39
2	12	85	82	96	100
4	24	58	56	405	390
8	48	51.5	51	6400	6800

After the attenuator was completed, the attenuation was measured at 3 kHz and at 30 MHz. With the test equipment available it was possible to measure more accurately at 30 MHz than at 3 kHz. Below is the data from the tests.

Atten Step "S" units	DB	Predicted atten DB	Measured at 3 kHz	Measured at 30 MHz
1	6	6.2	6.0	6.02
2	12	12.3	12.2	12.16
4	24	23.3	24.2	24.05
8	48	48.5	47.5	39.11

Now if we want to make an educated guess as to how far up we can expect good results, say 1 db error out of 24 db, then we can use the measured error in the 48 db step to calculate the capacitance across the series leg, and from that calculate the frequency where the 1 db error will occur. Go through the math if that is how you get your kicks, or take my word for it. It comes out to about 2 pF. And this will cause a reduction of 1 db at about 220 MHz. And since the resistor is of a lower value for the smaller steps, they should hold their values to even higher frequencies, but I expect other factors would get into the act along the line somewhere. I will state that still works well at 2 meters.

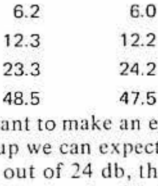

Fig. 1. Diagram for one step in the attenuator.

If you want to get fancy, you can always figure the values for 1, 2 and 3 db steps and have from 0 to 72 db attenuation in 1 db steps.

Referring to the photos; you can see I built my attenuator in a Bud Minibox CU-2102-A, 4" X 2-1/8" X 1-5/8". Four steps is the maximum in this size box, unless different switches are used. Mine are Cutler-Hammer 7592K6. The shielding was made from transformer strap, but could be any soft copper available. Try a Hobby Shop and get the thin sheet that is used for embossing if all else fails.

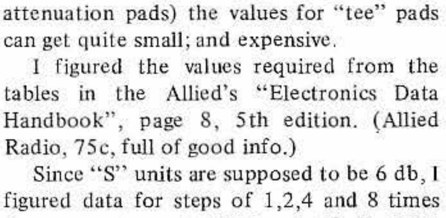

Looking inside the attenuator.

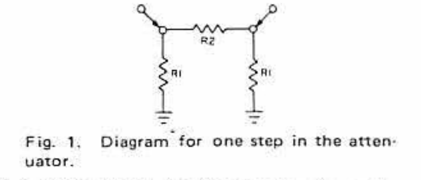

Front panel showing the switches for the various steps of attenuation.

Here are some of the uses an attenuator of this type is suited for:

Checking receiver "S" meter calibration.

Attenuating signals to aid in peaking receivers and converters.

Calibrating diode voltmeters for *rf* measurements.

Checking antenna gain. Or gain of that outboard *rf* stage.

P. S. My "S" meter lies, just as I thought!

THE EVER-USEFUL T-PAD

Jim Kyle K5JKX

Most of us have transmitters; let's hope that an equal number of us have receivers also. Antennas and microphones are usual station accessories, with a few determined diehards here and there clinging to the trusty old key. But how many of us have much in the way of test equipment?

Now and then somebody pops up with a VOM, and occasionally you can even find an operator who uses a scope. But the kind of special-purpose test gear you find in a well-equipped laboratory is almost always absent in the ham shack.

Which is more or less as it should be, since we're hams, not laboratory technicians. But with the present trends toward VHF, at least some specialized test gear is necessary. Otherwise, the regular station equipment can't be tuned for maximum performance.

One of the simplest such items is a noise generator, for getting the VHF receiver in perfect tune. This gadget has been described many times before, so we won't repeat it again —but we do have something which transforms the usual noise-generator lashup from a so-so item to an instrument capable of laboratory accuracy.

Before going into detail, let's look at the normal method of using a noise generator: you connect the generator to the antenna input, tie the converter to the receiver, turn the avc off, connect a voltmeter to the detector load resistor in the receiver (or put an ac voltmeter across the speaker leads), and measure the voltage produced by just noise. Then you turn on the generator and adjust it for a 3 db (1.4 times the voltage) increase in output; the object is to achieve the 3 db increase with the minimum amount of current flowing in the noise generator.

However, this technique of using the noise generator is pretty sloppy, since it assumes that the receiver's detector is absolutely linear for small signals—and this assumption is almost always incorrect.

A far better technique is to hook things up just as before, except now you place three T-pads in the line between converter and receiver. The T-pads on each end of the string serve merely to clamp the line impedance at 50 ohms, but the one in the center is built for precisely 3 db loss.

Now take the 3 db pad out and take your reading as before with the noise generator off; you don't have to turn off avc or hook up a voltmeter. The receiver's S-meter can be used instead, since we're not measuring anything with the meter itself. It merely serves as an indicator so we can come back to the same point.

Then replace the 3 db pad in the line, turn on the generator, and crank it up until you get the same meter reading as before. Since you now have 3 db of added loss between converter and receiver you must have increased the noise power output of the converter by that same 3 db, and you could care less about the linearity of the detector!

This whole method is far from new, but previous descriptions of it have left something to be desired in the way of telling how to build the T-pad. The gadget is so simple that it must have seemed obvious to previous writers—but it does have its tricky points too.

For instance, since a T-pad consists merely of 3 resistors, it is pretty easy to just wire them up by their leads. But they are hanging in the receiver antenna lead, and present-day receivers are rather sensitive. If you happen to find a 20-meter signal, it's going to foul up your measurements!

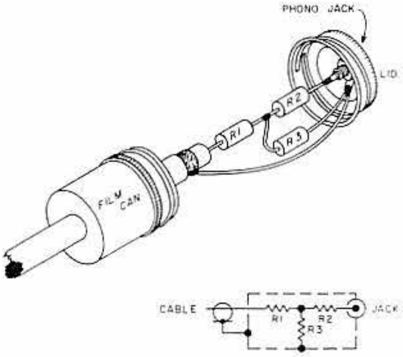

T-Pad construction details

One of the quickest ways to sidestep this problem is to shield the pad against all outside influences—but how do you shield anything so tiny?

The answer here is to use discarded 35-mm film cans, which all photographers who shoot 35-mm cameras have in abundance. The Kodak kind seem to work best. This type has a threaded cap, with a flat spot in its center just right for drilling a ¼ inch hole to take a single-hole-mounting phono jack. At the other end, a ⅜ inch hole can be punched and lined with a rubber grommet for coax cable to enter.

Next step is to place the jack in the hole in the lid, with its solder lug on the inside (be sure to clean the paint so that a good electrical contact will result). The T-pad can be assembled as shown in the drawing with shortest possible leads, and supported by its lead connecting to the jack. Thread a short length of RG-58 through the grommetted hole, and connect its center conductor to the other lead of the pad; the shield and shunt lead of the pad connect to the solder lug of the jack.

All that's left is to wire-brush the threads on the film can for good contact, and screw the lid down tight. Presto, a shielded T-pad. A phono connector should be put on the free end of the cable.

You can make up a whole bunch of these in various loss values, and get virtually any amount of loss you want by stringing them together. And this has a whole lot more use than just using with a noise generator . . .

For instance, when you want to test an antenna, arrange for a steady signal, strong enough to register on your S-meter with the back of the antenna pointed at it. Then swing the antenna in small steps, and bring the S-meter back to the same reading by inserting additional loss between converter and receiver with the T-pads. The difference between this and S-meter indications may amaze you.

Or if you are called upon to measure the difference in signal strength between two stations, the same approach can be used. Note the S-meter reading of the weaker, then knock the stronger one back to the same reading by putting T-pads in the converter-to-receiver line. Read the db off the pads and add them up.

You can even use this in place of an S-meter if you really want to know the signal-to-noise ratio of an incoming signal with accuracy; take a reading on noise, then knock the signal back to the same point. Total up the db, and there's your answer.

Though resistance values in the pad must be precise for absolute accuracy, the pad has an inherent tolerance of small errors and you should have better than 2 percent accuracy if you use 5-percent resistors. Specifically, a 10-percent error in the resistance value of any one arm produces less than ¾ db error in the pad loss, and less than 4 percent error in impedance. Using 5-percent resistors would, of course, cut these error limits in half.

If you want to follow the approach of using a string of these pads for all purposes in the shack, it's best to make them up on a "binary" approach since this gives you the maximum number of db values with the minimum number of parts. A basic assortment might be two 1 db pads, and one each of 2 db, 4 db, 8 db, 16 db, and 32 db. Using them in series in various combinations, you can get any whole number of db from 0 to 64, which pretty well covers the range of values you may ever need. For an example, to get 50 db you would use the 32 db pad, the 16, and the 2. For 60 db, you would use the 32, the 16, the 8, and the 4.

If the ability to increase loss in 1 db steps seems a bit exotic to you in view of the fact that 3 db is only half an S-unit, then you can use a binary progression in 3 db steps; this takes one 3 db pad, one 6 db, one 12 db, and one 24 db. The range is from 0 to 45 db, 3 db at a time.

For clamping a line's impedance, it's a good idea to use at least a 3 db pad and a 6 db unit might be even better. The lower-loss pads pads may not have the ability to swamp out impedance variations on their other sides.

About all that's left to make this complete is a chart of resistance values for various loss figures. Here it is; all are for use with a 50 ohm line; to use at any other impedance, multiply these values by the ratio of the new impedance to 50 ohms:

LOSS AMOUNT	R1, R2	R3
1 db	2.7	430
2 db	5.6	220
3 db	8.2	150
4 db	11	100
6 db	16	68
8 db	22	47
12 db	30	27
16 db	36	16
24 db	43	6.2
32 db	47	2.2

COMBINATION DUMMY LOAD/ ATTENUATOR NETWORK

John Schultz W2EEY

There are many instances when it is desired to use an existing transmitter as an exciter unit for a high-power linear amplifier. Many such linear amplifiers require a drive level that is only a fraction of the transmitter's output. To some degree, the transmitter can be detuned in order to reduce its output level, but this procedure is rarely possible when several orders of magnitude reduction in the power level are necessary. In such a case one can either internally modify the transmitter for a lower output level or use an alternator network between the transmitter and linear amplifier. In the latter case, the transmitter can be operated at its normal power input level and with its tuning controls at their normal settings.

The unit described in this article functions as both an *rf* attenuator and as a dummy load. The latter capability allows a transmitter to be properly tuned alone for correct operation before it is used to drive a linear amplifier. An optional wattmeter circuit is included which when calibrated allows direct reading, in watts, of the full transmitter output or of the drive level supplied to the linear amplifier.

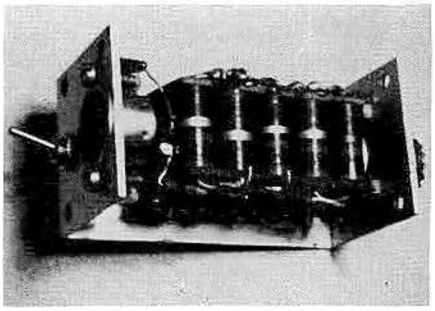

A simple method of construction is employed. Based mainly on "sandwiching" the resistors used between two pieces of vector-board. Details are given in the text. SO-239 is used as coax input connector. The circuit function switch is located below the output connector.

The unit described was built for use with a nominal 100 output transmitter used primarily for SSB service. The construction used, however, can be extended to other power levels for transmitters operating on 80-10 meters. Also, using the information

Power Reduction	Resistor Factors a	b
1/4 (6db)	.3	1.3
1/5 (7db)	.4	1.1
1/10 (10db)	.5	.7
1/20 (13db)	.6	.5

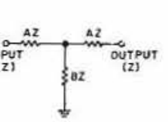

Fig. 1. Approximate resistor factors for "T" network attenuators over the ranges normally desired for exciter power output reduction.

supplied, the same type of attenuator/dummy load can be designed for other than 50 ohm transmission line systems. The attenuator was not designed as a precision network in order to allow the use of inexpensive resistors. However, the attenuation characteristics are quite satisfactory for the intended usage.

Besides its application as a power reducer when driving a linear amplifier, the unit can be used with a transmitter whenever a quick, known level of power output reduction is needed for operating purposes, approximate gain measurements, etc.

Circuit

Fig. 1 shows the circuit values for a generalized T network attenuator that can be used in any impedance unbalanced transmission line. The scaling factors are only shown for those power reduction levels most likely to be needed when driving a linear amplifier with a 75-200 watt transmitter, in order to avoid unnecessary detail. Factors for intermediate power reduction values can be found by interpolation to a satisfactory degree or one can consult an electronics handbook. The basis of the attenuator/dummy load network is to find the combination of resistor arms that will provide the desired attenuation and still be able to be connected together to form a dummy load of the correct value. Fig. 2 shows one possible combination. Each resistor bank has a value of about 20 ohms (5 resistors of 100 ohms each in parallel). In one position of the DPDT switch, the resistor banks are formed into a "T" network attenuator. In the other switch position, all three banks are placed in series as a dummy load connected across the input only. The resistance values which result are not exactly those shown in Fig. 1 for a 10db alternator. However, they are close enough to be effective and some tailoring of the individual legs is possible since each of the resistor bank values vary by a few ohms due to the tolerance of the resistors used. An optional voltmeter circuit is also shown in **Fig. 2** connected to one pole of the DPDT switch. It can be used as a relative power output indicator or if calibrated, as described later, actually measure the power output of the transmitter and of the attenuator.

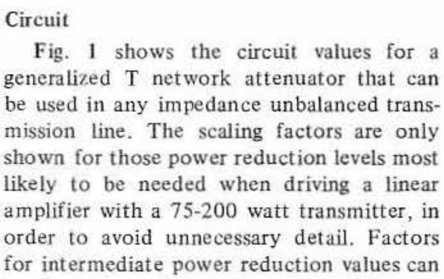

Fig. 2. Circuit of one possible dummy load/attenuator network providing about 10 db power reduction. Optional wattmeter circuit is also included.

Many variations of the basic idea are possible. **Fig. 3** shows the use of four banks of 100 ohm resistors. All four are used to form an attenuator that comes reasonably close to the values required for 7db attenuation in a 50 ohm system. Only three are used in series for the dummy load function. In this case only a simple SPST switch is necessary to disconnect the output. The same *rf* voltmeter circuit as used in **Fig. 2** may be added if desired. The switch, in fact, could be eliminated entirely if one were willing to disconnect the output termination in order to use the dummy load feature.

Whatever combination of resistance banks are used in order to achieve a desired attenuation value and the correct dummy load resistance, care must be taken that each resistance bank has sufficient power dissipation capability. The dissipation in each leg of the "T" network varies according to the attenuation level and can be calculated by Ohms Law. In general, a continuous power rating for a resistor bank equal to about one-third of the SSB peak power rating seems to suffice, including for quick tune-up on CW. For keyed CW service, the power rating should be increased to at least one-half the key-down power level.

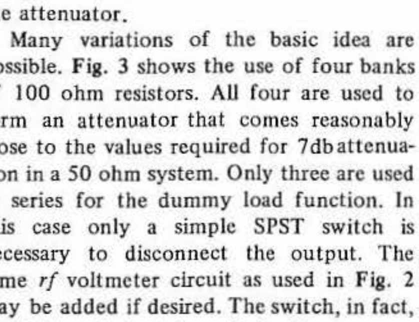

Fig. 3. Another dummy load/attenuator configuration possible with the 100 ohm resistor banks. It provides about a 1/5 power reduction (7db) when used as an attenuator.

Construction

The approach of using a relatively large number of 2 watt composition resistors is far less expensive than using specific value *rf* non-inductive resistors of 10-30 watts power rating. In quantities of more than 10, IRC type RC-2, 2 watt, 10% tolerance resistors cost about 9 cents each. So, one can achieve a 40 watt unit for less than $2 resistor cost. Banks composed of these resistors work well up to 30 mc as long as the interconnecting leads are kept short.

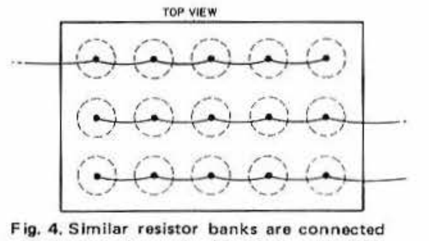

Fig. 4. Similar resistor banks are connected together on the underside of the assembly.

The photograph shows the construction used by the author for the circuit of **Fig. 2.** Similar construction can be used for larger size units as well. As shown in the photograph, the 15 resistors in rows of 5 each are sandwiched between two 1-1/8" x 1-7/8" pieces of vectorboard. None of the resistors physically touches. The wiring is done using the resistor leads. This construction is somewhat compact to expect full, continuous power dissipation from the unit but suffices for intermittent use. The frame measures 2¾" x 1½" x 1½". A cover is not absolutely necessary since the minor radiation that takes place is not important in this application. If a cover is used, it certainly should be of a perforated type to allow maximum air flow. A SD-239 connector is used at one end of the frame for the input. A dual connector is used at the other end, but normally one would use two RCA type phono jacks–one for the output and one for a meter circuit. The switch is located immediately below the output connector–a miniature Alco MST type.

Calibration

If it is desired to calibrate the voltmeter circuit as a wattmeter, it is necessary to use a probe and VTVM. Using the unit as a dummy load, the *rf* voltage is measured at the input and the power calculated. The 50K ohm potentiometer is used to set the meter at full scale for the highest power level used. The *rf* voltage is measured and the power level calculated in order to calibrate the meter for lesser power levels leaving the potentiometer at its "set" value. The same procedure is followed to calibrate the meter for the output power level by measuring the output *rf* voltage when the unit is used as a "T" attenuator and connected to a regular dummy load. The calibration should be made on the lowest frequency band used and rechecked on the highest frequency band used. If the readings differ significantly on the highest frequency band from those established, it may be necessary to add a few mmf capacitance across the diode in the voltmeter circuit in order to compensate for the slightest reactance present in the circuit.

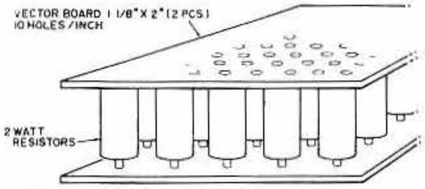

Fig. 5. Sketch showing details of resistor "sandwich" assembly.

Operation

When used between a transmitter and the 50 ohm input of a linear amplifier, the unit is first used as a dummy load for tune-up of the transmitter. The unit is then switched (with the transmitter unkeyed) to its attenuator position. In most cases, no returning of the transmitter should be necessary unless the input of the linear amplifier is particularly reactive.

Summary

The unit described is not intended as a precision attenuator or power measuring device. However, it will perform very well for its intended applications and costs far less than more sophisticated units performing the same functions.

THE MINICAN

Sam Kelly W6JTT

The Heathkit "Cantenna" has proven to be a major breakthrough in the field of dummy loads for ham use. Unfortunately, it isn't the most convenient thing to use on a small work bench with low power rigs! Borrowing their idea, I built this load for use with transmitters in the 5 to 15 watt range. The parts are few: a Campbell soup tin can, four one watt resistors, a UG-254-A connector, a short piece of 5/16 inch brass tubing and transformer oil.

Fig. 1 is a sketch of the assembled unit. The 50 ohm resistance was made up of three 15 ohm and one 5 ohm one watt carbon resistors.

First sand a can lid from a larger size can until it is free of paint. Drill a ⅝ inch hole through the center of the lid, and a ¼ inch hole on the perimiter. Mount the coaxial connector through the center hole. Solder a 1 inch length of 5/16 in. brass tubing over the ¼ inch hole. Solder the resistors as shown. Center the lid on the can and solder the lid to the can. Use a file to remove all rough edges. Mask the connector with masking tape and paint the can to prevent rusting.

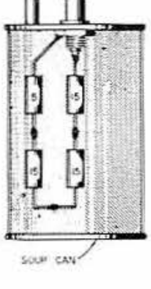

Fig. 1. Construction of the Minican. Main parts are a soup can, coax connector and resistors.

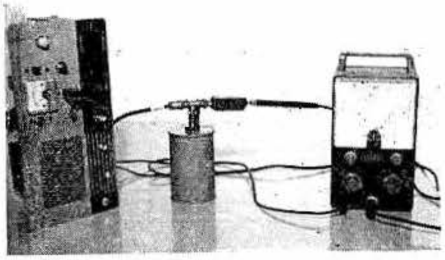

The Minican in use with the companion detector.

Fill the can with transformer oil. A good grade of automatic transmission fluid was used in one load with no degredation in performance. However, it probably is not advisable as the fluid has a relatively low ignition temperature and might create a fire hazard.

The load was tested by running it for five hours with an input of 15 watts of 50 MHz rf. The can became warm, but the resistors showed no signs of overheating.

A maximum VSWR of 1.5:1 was obtained at 234 MHz. The measurement was made at this frequency because an automatic test set was available.

A companion rf detector unit shown in **Fig. 2** was built in a two inch section of ⅜ inch square extruded brass stock. A Dage 394-1 BNC connector is mounted on one end for connecting to the RF circuit, while the DC output to the VTVM is a tip jack.

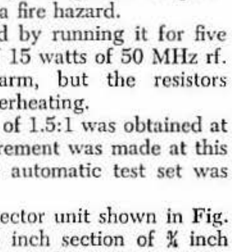

Fig. 2. Rf detector for use with the Minicon.

THE TINY TERMINATOR

Jim Kyle K5JKX

HAVE you ever felt the need for a dummy load which would also indicate accurately the actual rf output power of a transmitter?

You can buy such a beastie, you know. The Bird *Termaline*, standard of the two-way communication industry, shouldn't set you back much more than a C-note . . .

But you can also build one at considerable less outlay, and that's what this article is all about.

As the photographs show, there's almost nothing to the "Tiny Terminator"—nothing, that is, but a 50-ohm load for any transmitter, which will absorb 20 watts for days on end and will handle 40 watts for brief periods (a minor modification can double these ratings), will *not* radiate rf into the ether after the fashion of the "standard" light bulb load, will allow accurate measurement of output power up past 225 mc, and can be built in less than two hours for less than $5.

You can see by the schematic that there's nothing to the device electrically; the tricks are all mechanical. Electrically, the Tiny Terminator consists of 20 (that's what we said)

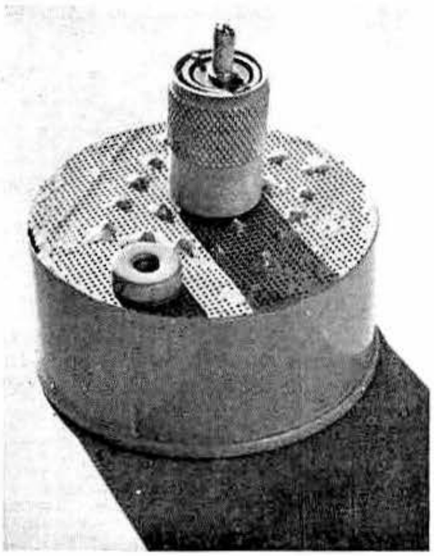

1000-ohm 1-watt resistors connected in parallel, with a crystal diode running from the hot end of the composite resistor to the meter jack and a 27 mmfd capacitor bypassing the meter.

Mechanically, the big problem with a unit such as this is the problem of keeping the load resistive regardless of frequency. Resistor leads have inductance (about 25 millimicrohenries per inch) so we get rid of the leads as completely as possible. This is done by punching holes in a flat plate, passing the lead through the hole until the resistor is flush with the plate, and soldering rapidly with a hot iron (an Ungar 47-watt 1100-degree tip was used in building the model shown) so that the resistor body won't cook before the leads and plate are joined.

The flat plate has capacitance. This is avoided by keeping the plate shielded from outside influences, and separated as far as possible from its shield.

The shield, incidentally, is the bottom of 1½ inches of a Canada Dry cola, soldered all around the edge to the front resistor plate. This confines all rf inside the terminator.

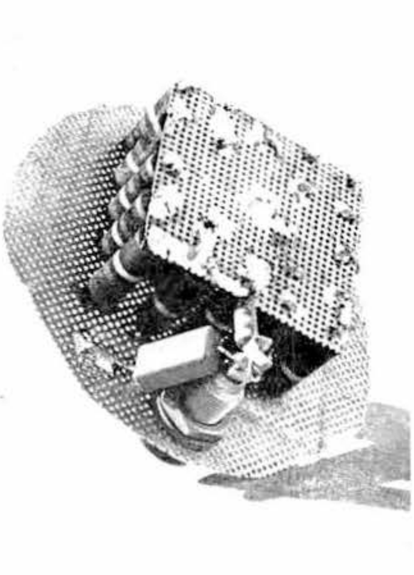

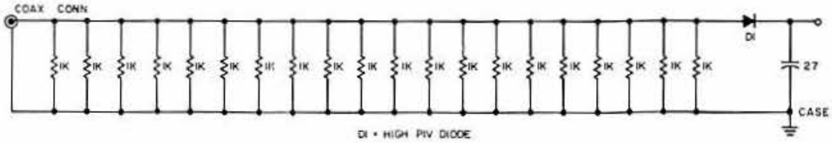

D1 • HIGH PIV DIODE

Addition of the crystal diode (a 1N34 was used, but a higher-voltage unit is recommended if you ever expect to measure power higher than 8 watts) and the bypass capacitor provide the power-measuring feature. These two components, in conjunction with an external voltmeter of at least 1000 ohms per volt sensitivity, provide you a peak-reading ac voltmeter. The voltage indicated on the meter will be equal to the peak value of rf voltage present across the load. Squaring the voltage and dividing by 50 (the resistance) will give you the *peak* power. Most power ratings are in rms values rather than peak; multiplying the indicated voltage by 0.707 before squaring will give you the rms power output.

The unit shown in the photos used perforated brass stock for the resistor plates; this happened only because a length of the brass was on hand in the junkbox at the time. A cut-out tin can lid will work equally well and will be much less expensive.

Not visible in the photos is the means of connecting the hot end of the resistor plate. A hole was punched in the middle of the hot plate and a length of No. 14 bare wire was soldered in, then filed off flush on the rear side. The bare wire was threaded through the coax connector and soldered to the center contact after checking for possible shorts.

The coax connector itself is held in place by a solder joint all around the rim of the cable-end aperture (see photo). This joint, if well made, provides plenty of strength.

Earlier, we mentioned that a minor modification would double the power rating. That modification is this: instead of 1-watt resistors, use the 2-watt variety. If you really want to go high-power, use 50 2700-ohm 2-watt resistors and have a terminator which will absorb 100 watts continuously and 200 watts ICAS. However, one that big will cost more—and you'll probably have to use a coffee can for the shield instead of the cola can used here.

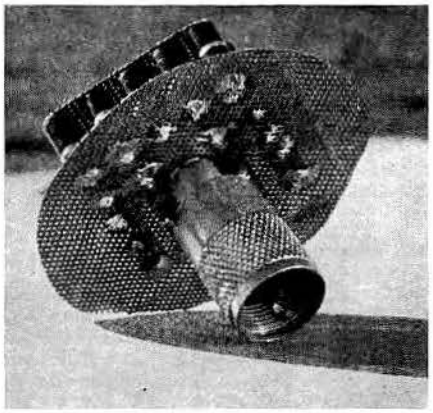

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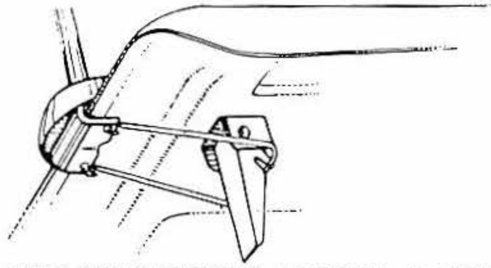

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First, most such cables have a single center wire, which breaks with bending, twisting, and day-to-day handling. SouthCom's cables have a 19-strand center wire, so all 19 strands must break before the cable loses connection.

Second, most cable does not have full shielding. You can peel back a small section of the outer black insulation, and you can see the inner insulation through "holes" in the braid. SouthCom's cable is fully shielded!

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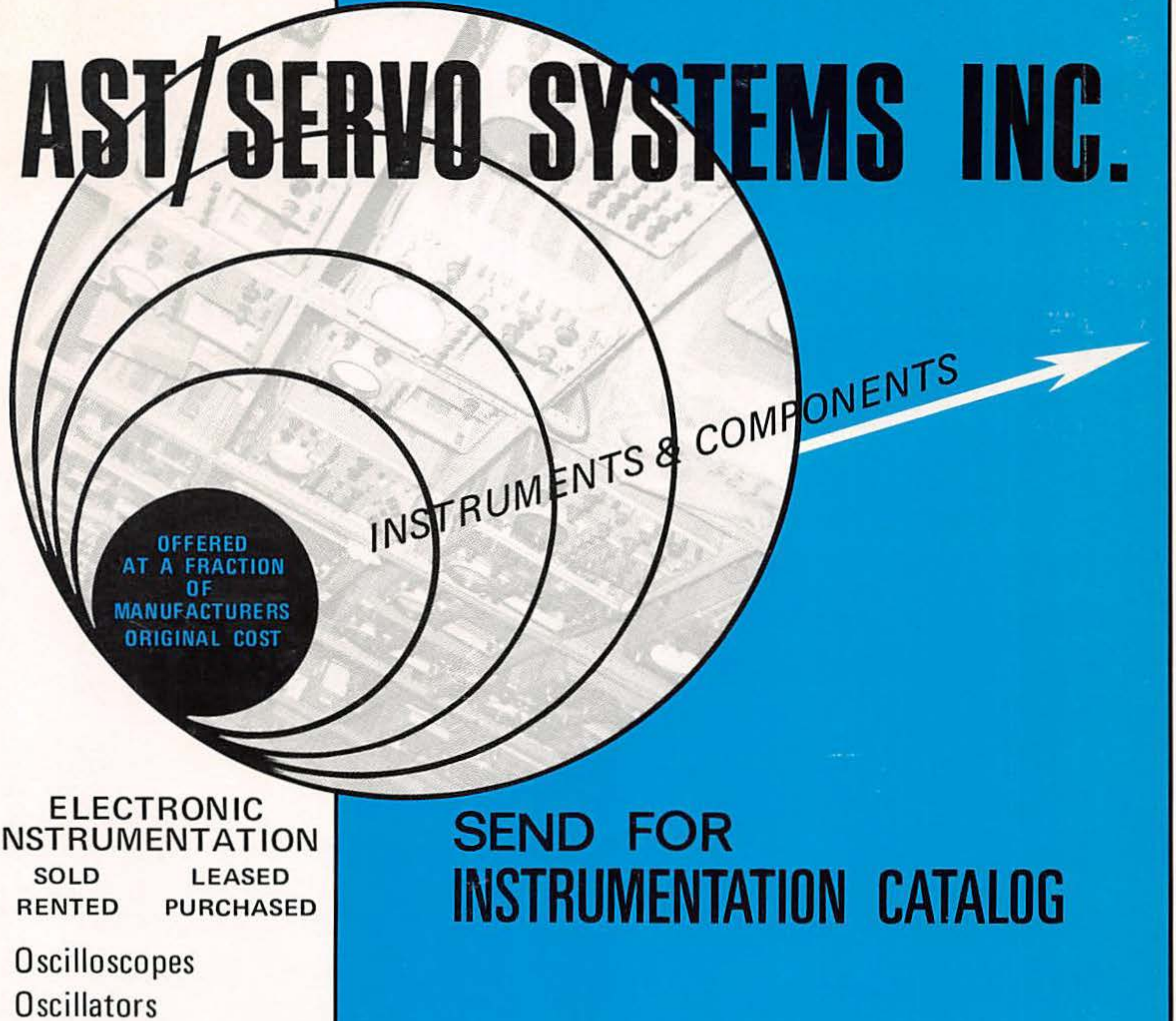
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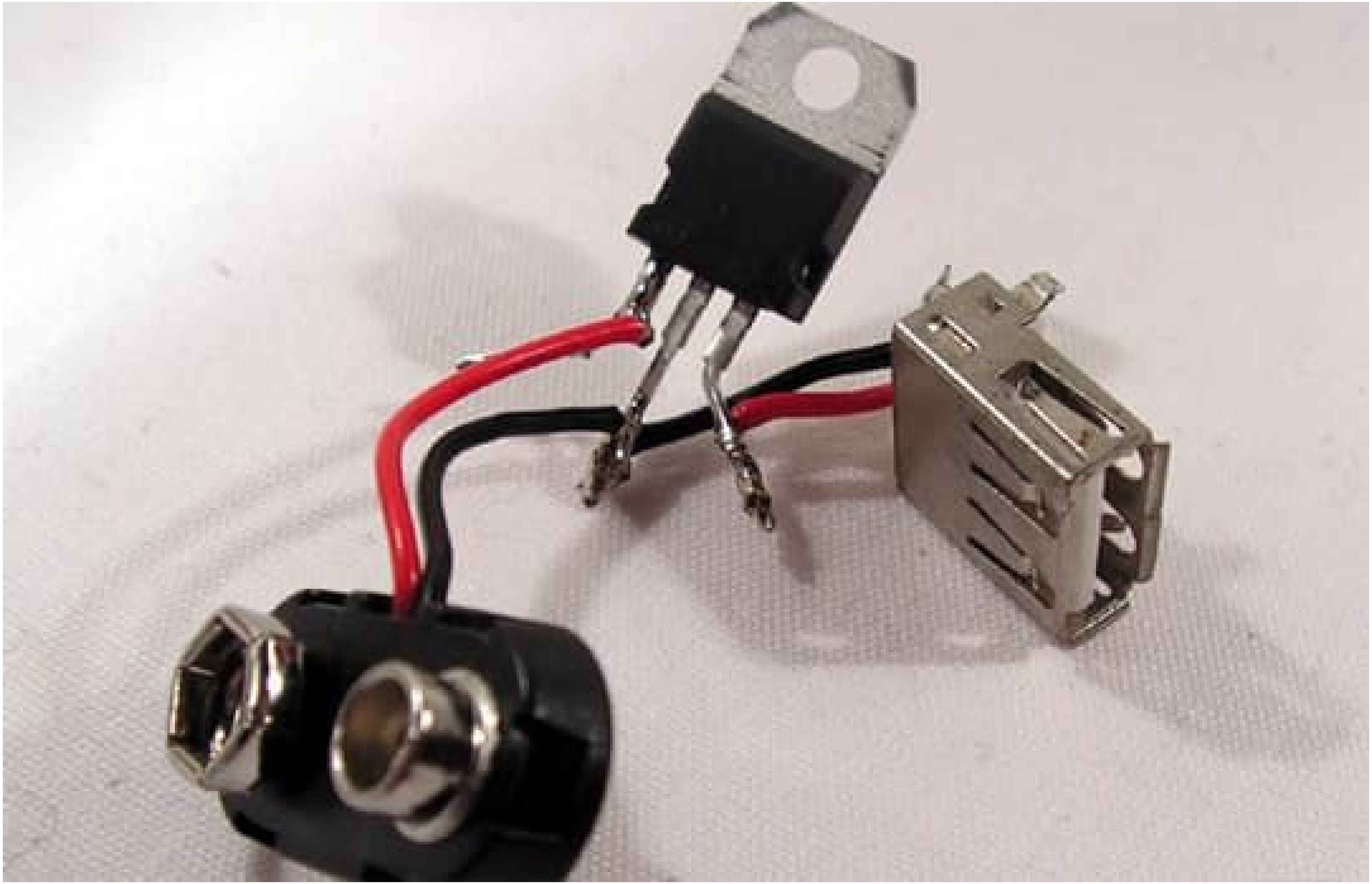

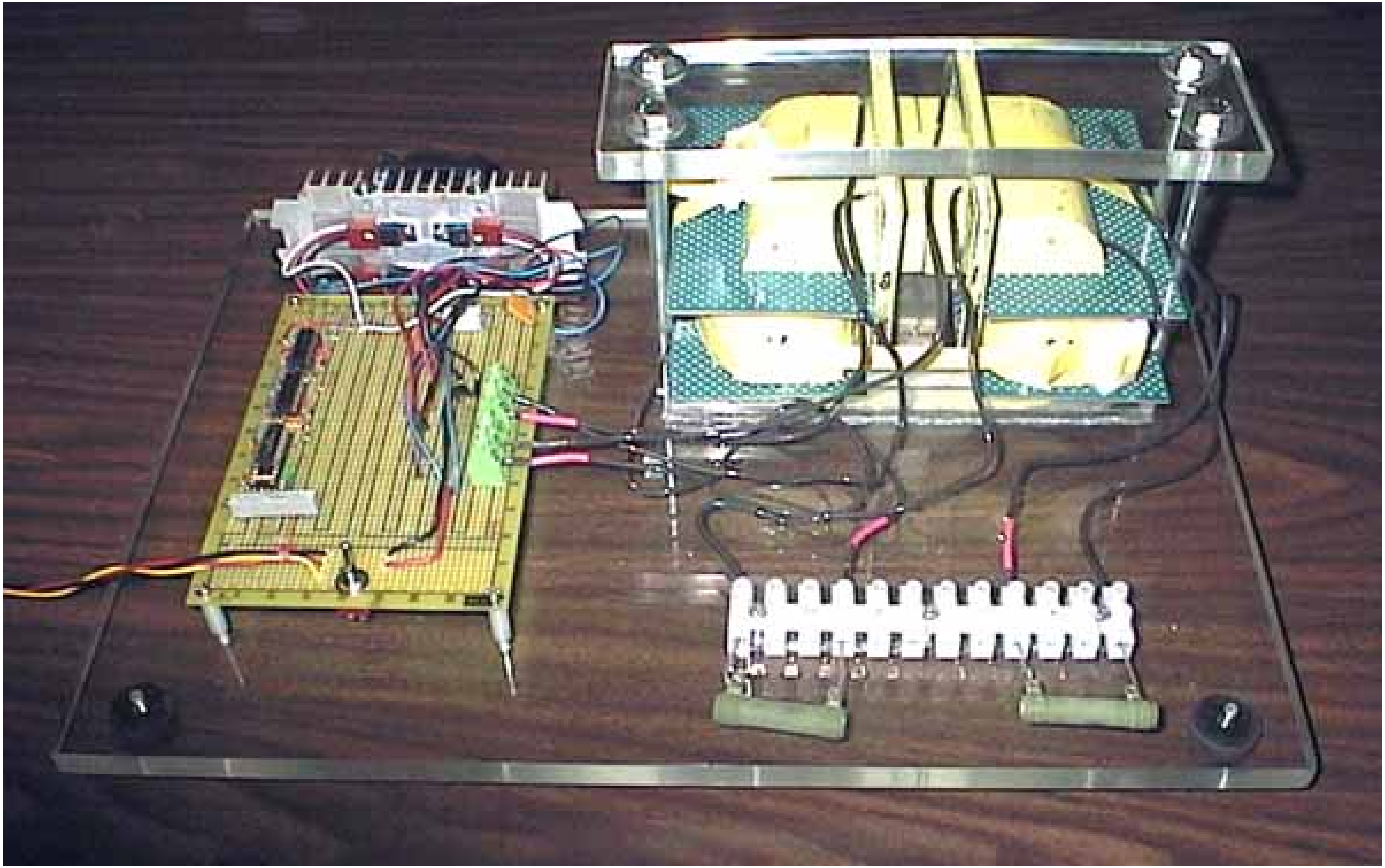

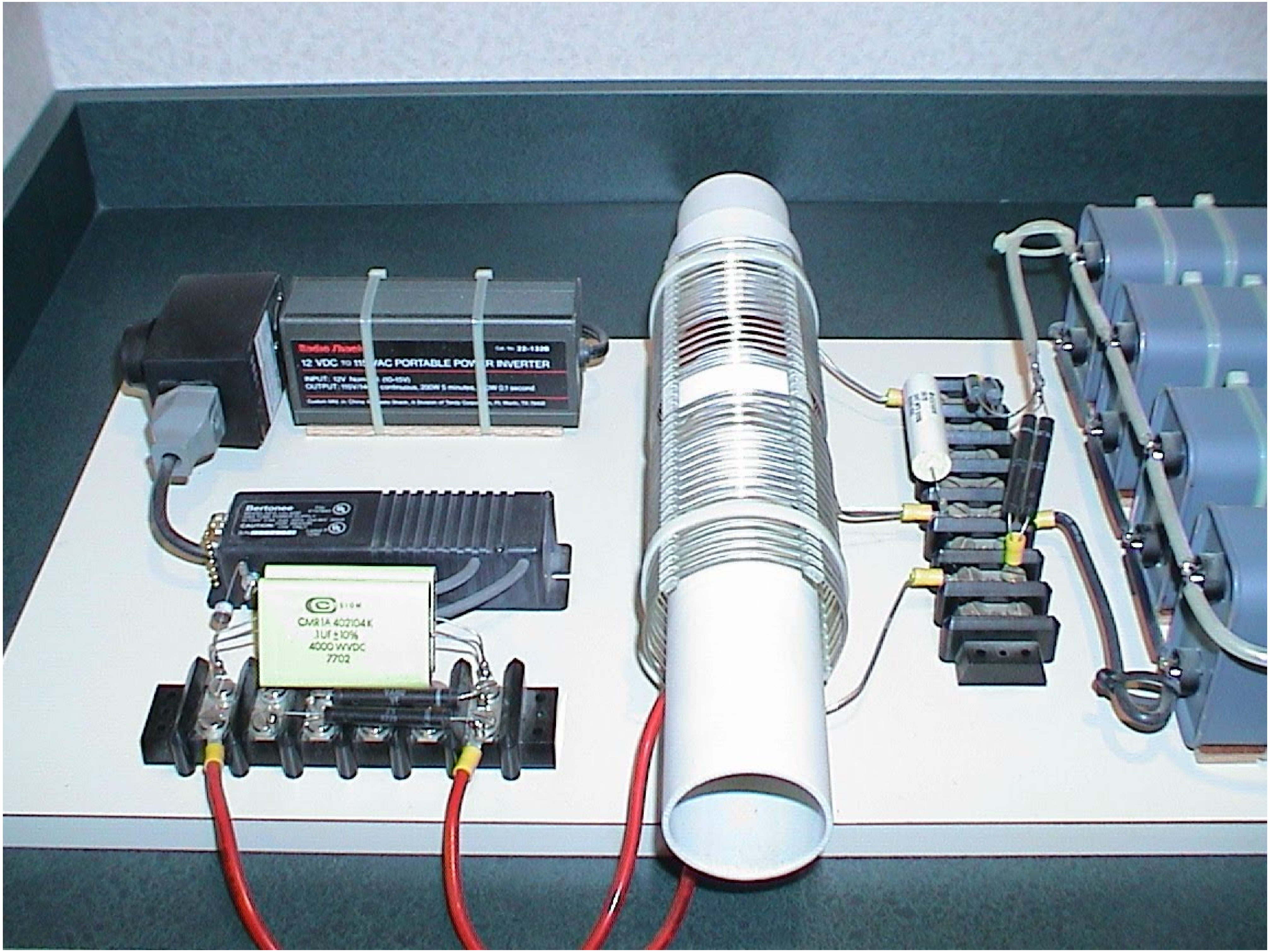
12 VDC TO 115 VAC PORTABLE POWER INVERTER
CMR1A 402104 K
1 UF ± 10%
4000 WVDC
7702

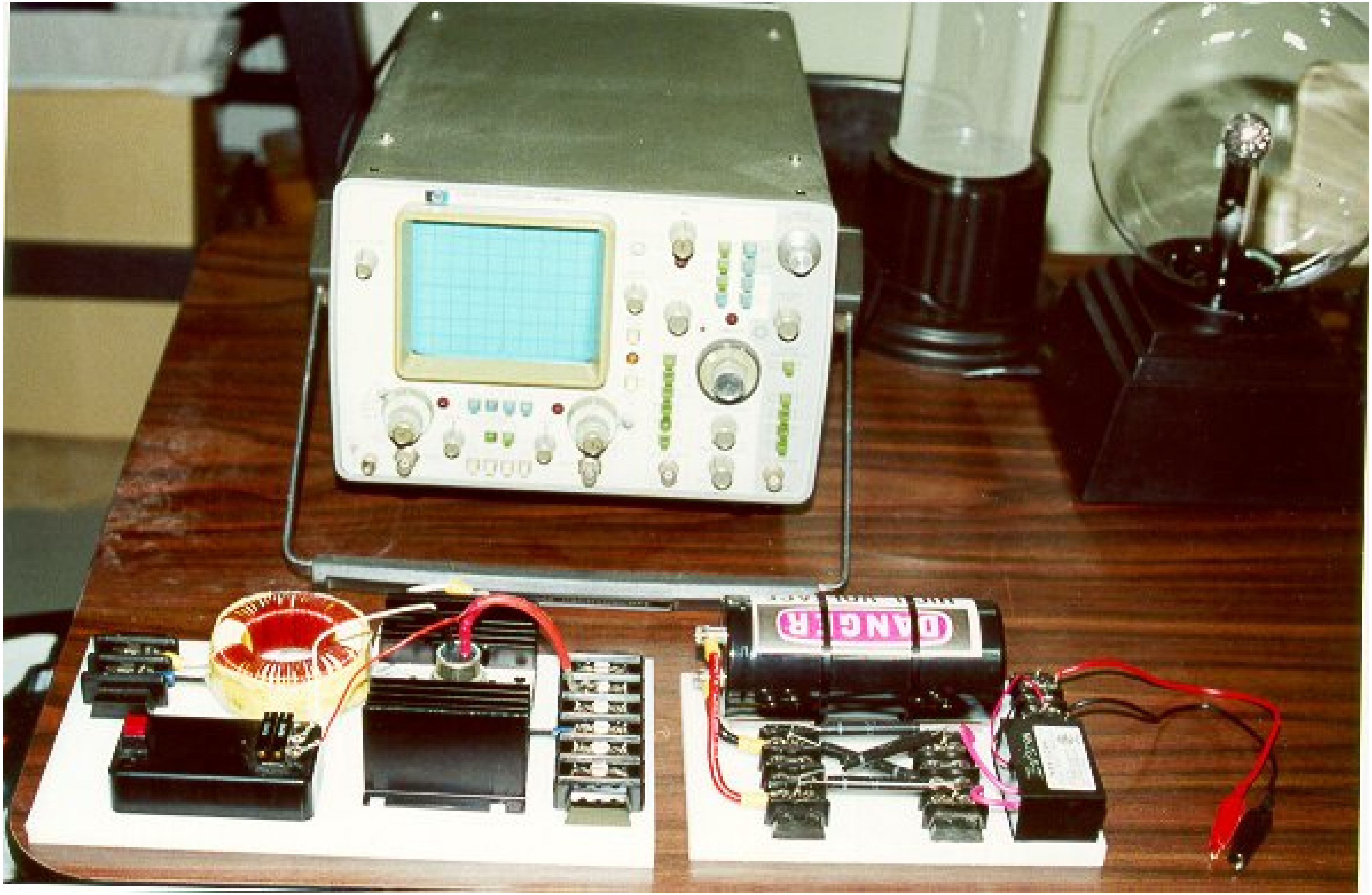
DANGER

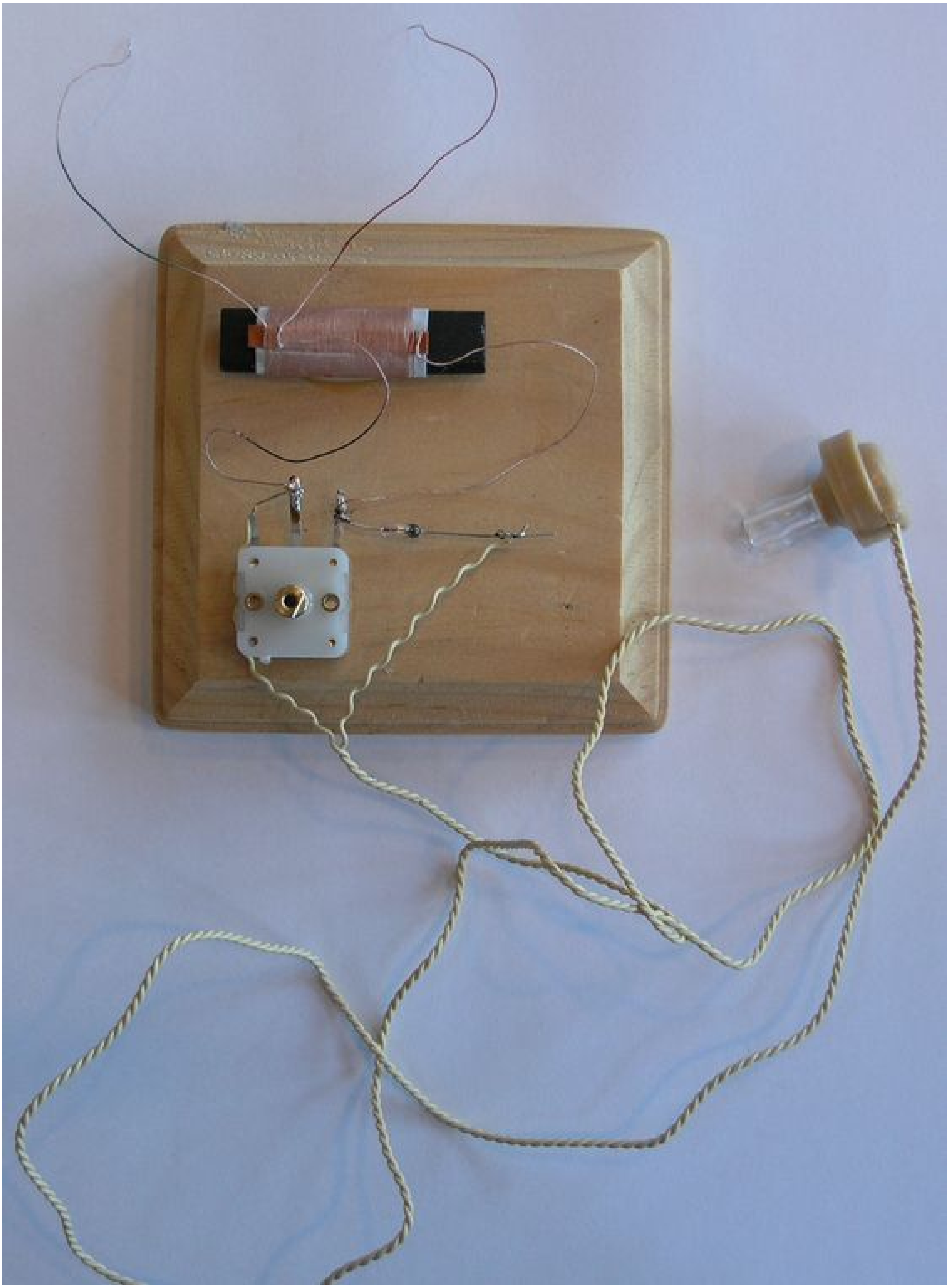

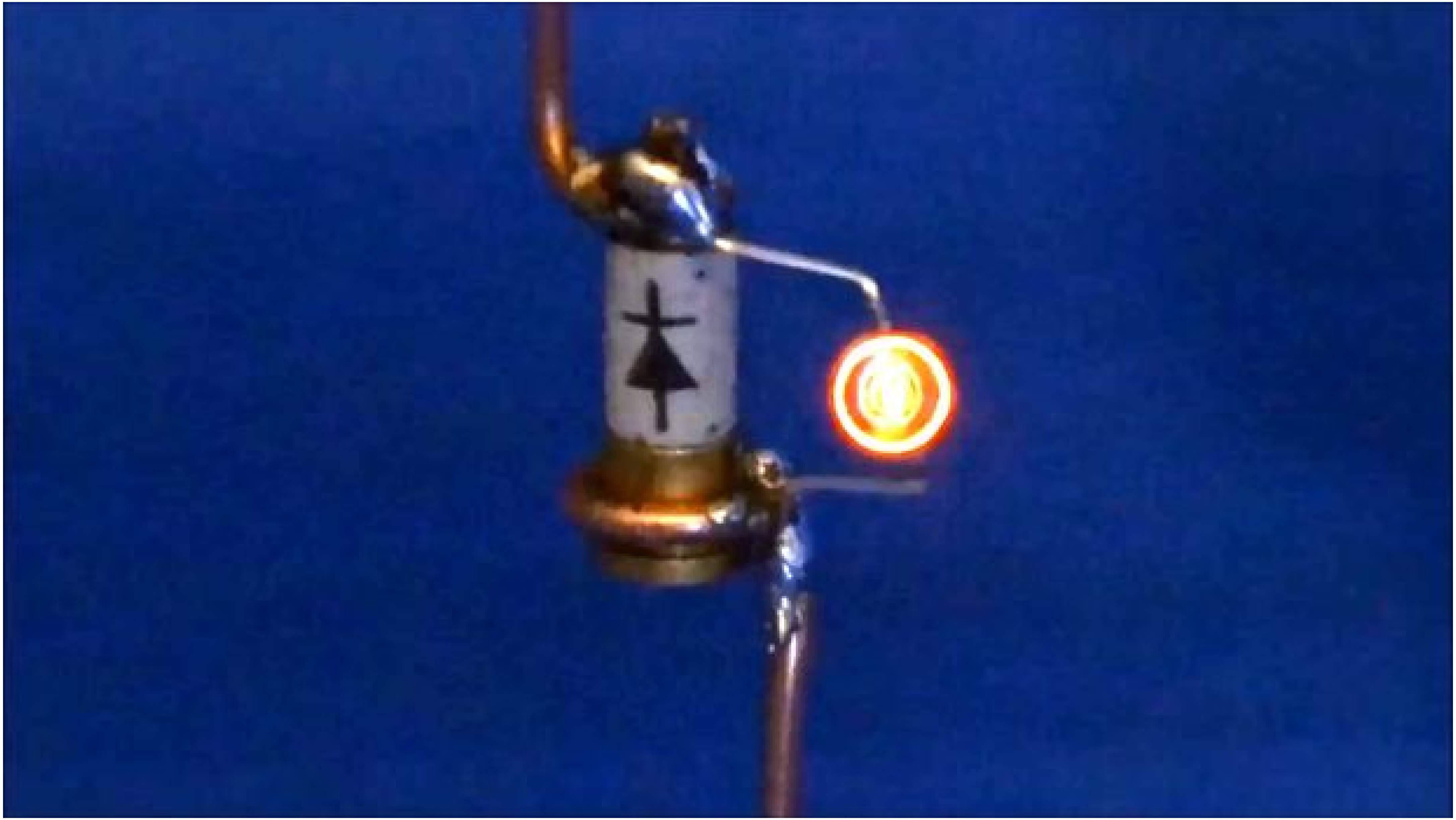

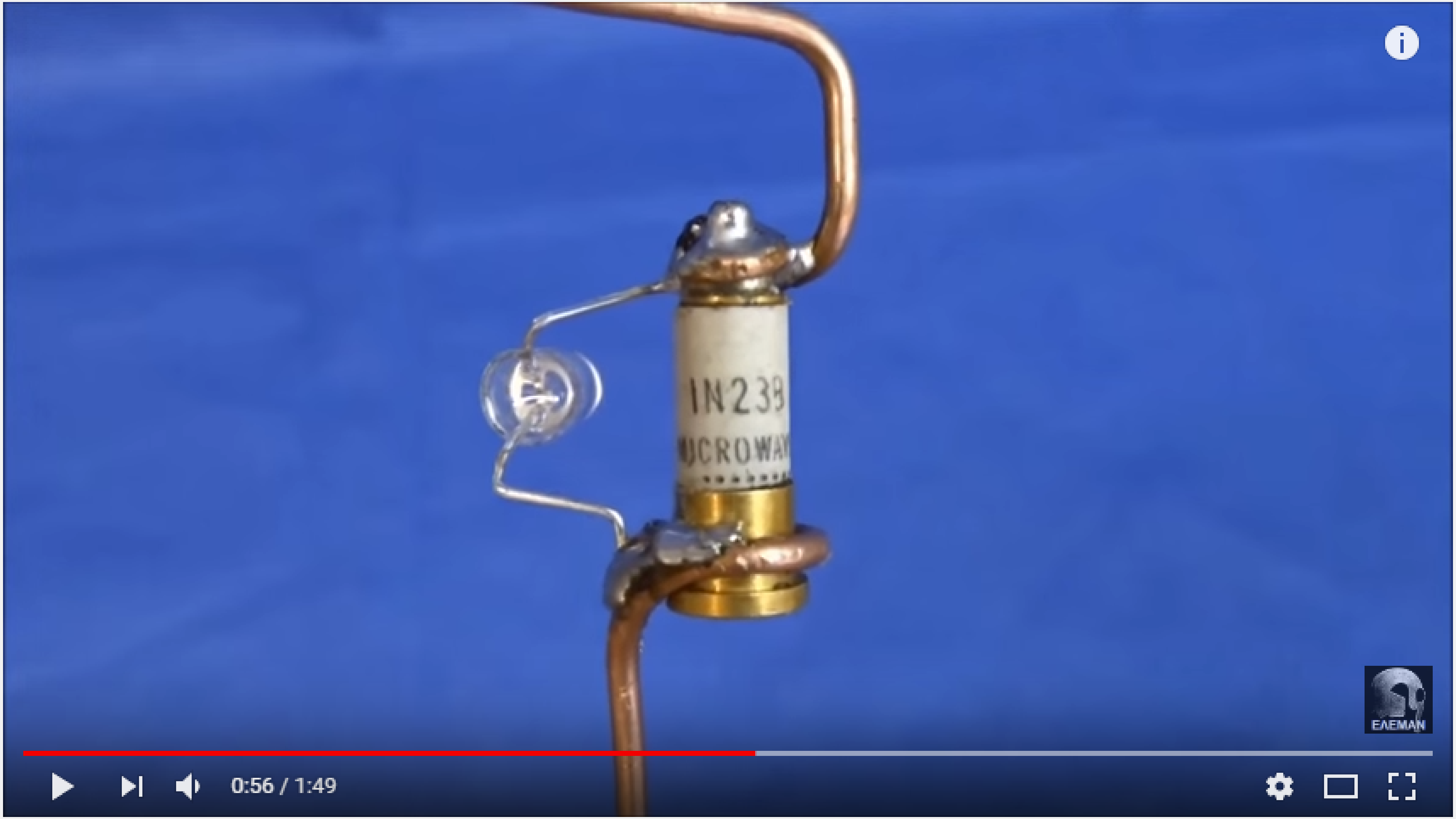
1N23B
ICROWAV
ΕΛΕΜΑΝ
0:56 / 1:49

WR

I made a radiant energy antenna for my 1st Free Energy project, and with LOTS of help and knowledge sharing fro
have 3 antennas and 2 grounds and have 2.81 volts in my cap. Somethings better than nothing☺ heres some pics

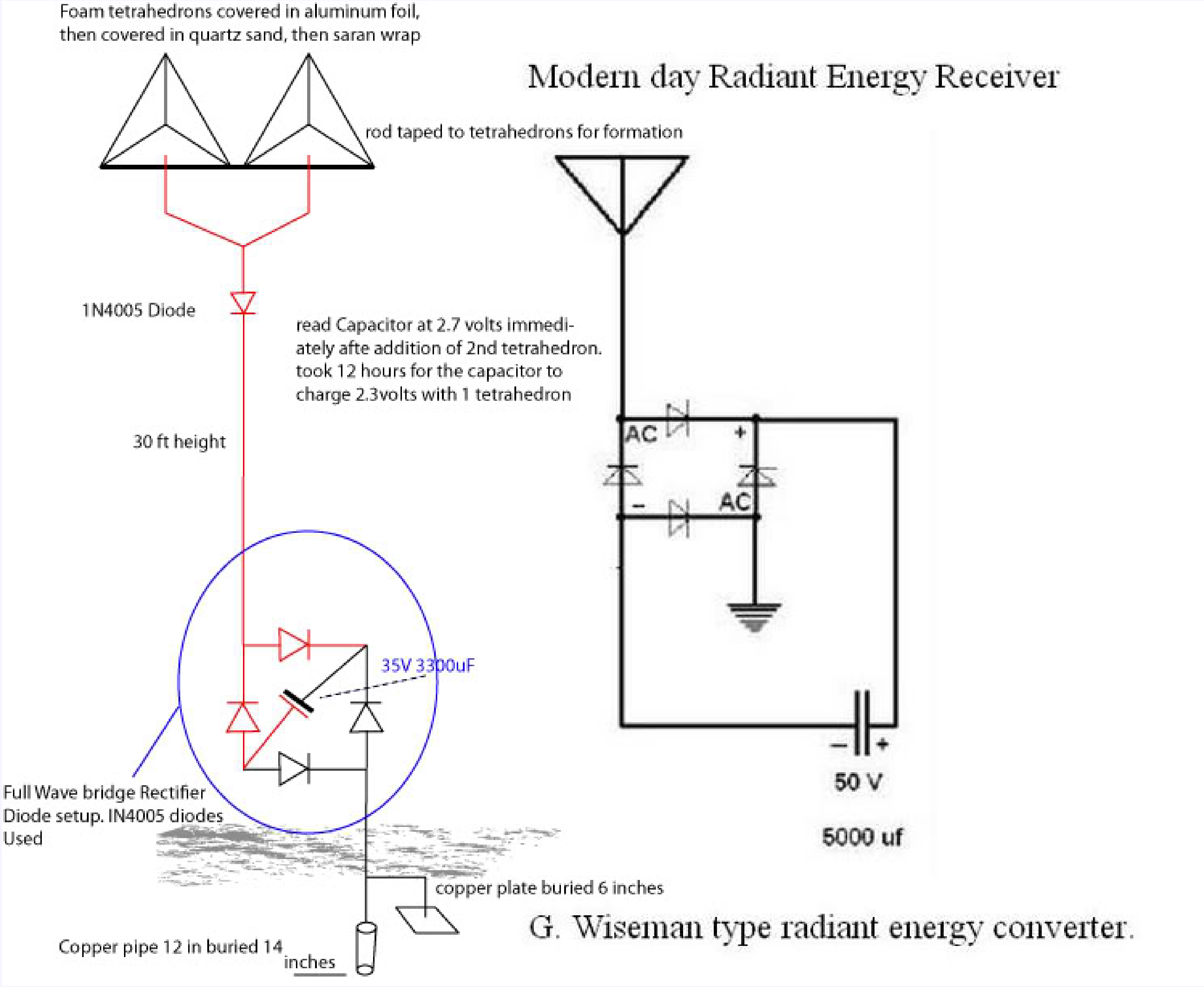

Foam tetrahedrons covered in aluminum foil, then covered in quartz sand, then saran wrap

read Capacitor at 2.7 volts immediately afte addition of 2nd tetrahedron. took 12 hours for the capacitor to charge 2.3volts with 1 tetrahedron

Full Wave bridge Rectifier Diode setup. IN4005 diodes Used

Modern day Radiant Energy Receiver

G. Wiseman type radiant energy converter.

rod taped to tetrahedrons for formation
1N4005 Diode
30 ft height
35V 3300uF
copper plate buried 6 inches
Copper pipe 12 in buried 14 inches
AC
+
AC
-
— +
50 V
5000 uf

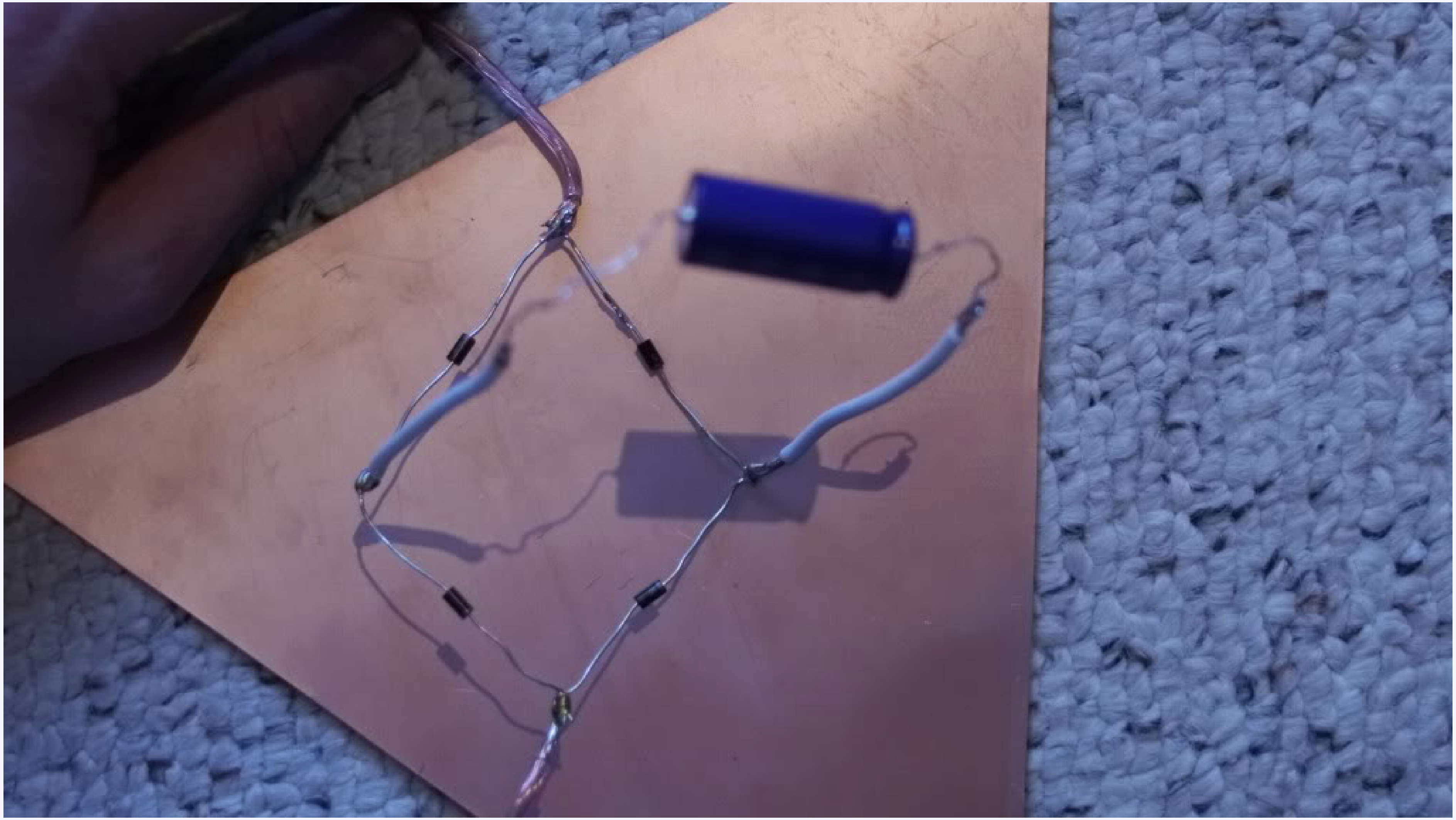

^^^ here is the 4 diodes arranged to create a full wave bridge rectifier. The diodes are 1N4005 diodes from radioshack, and the blue capacitor (radioshack) is 35Volt 3300uF,

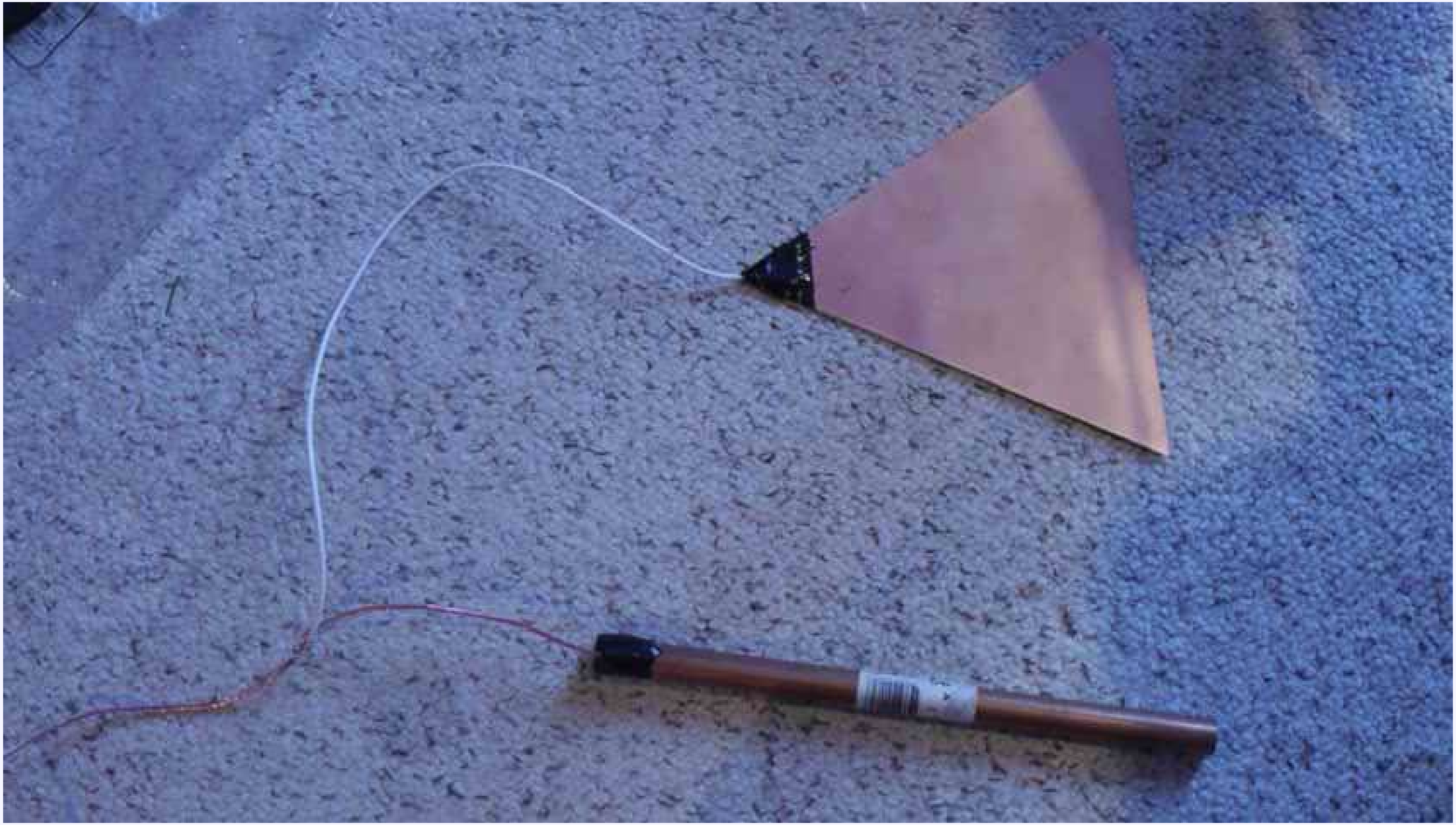

^^^these are the pieces of copper that gets buried in the ground they syupply the (-) of electricity

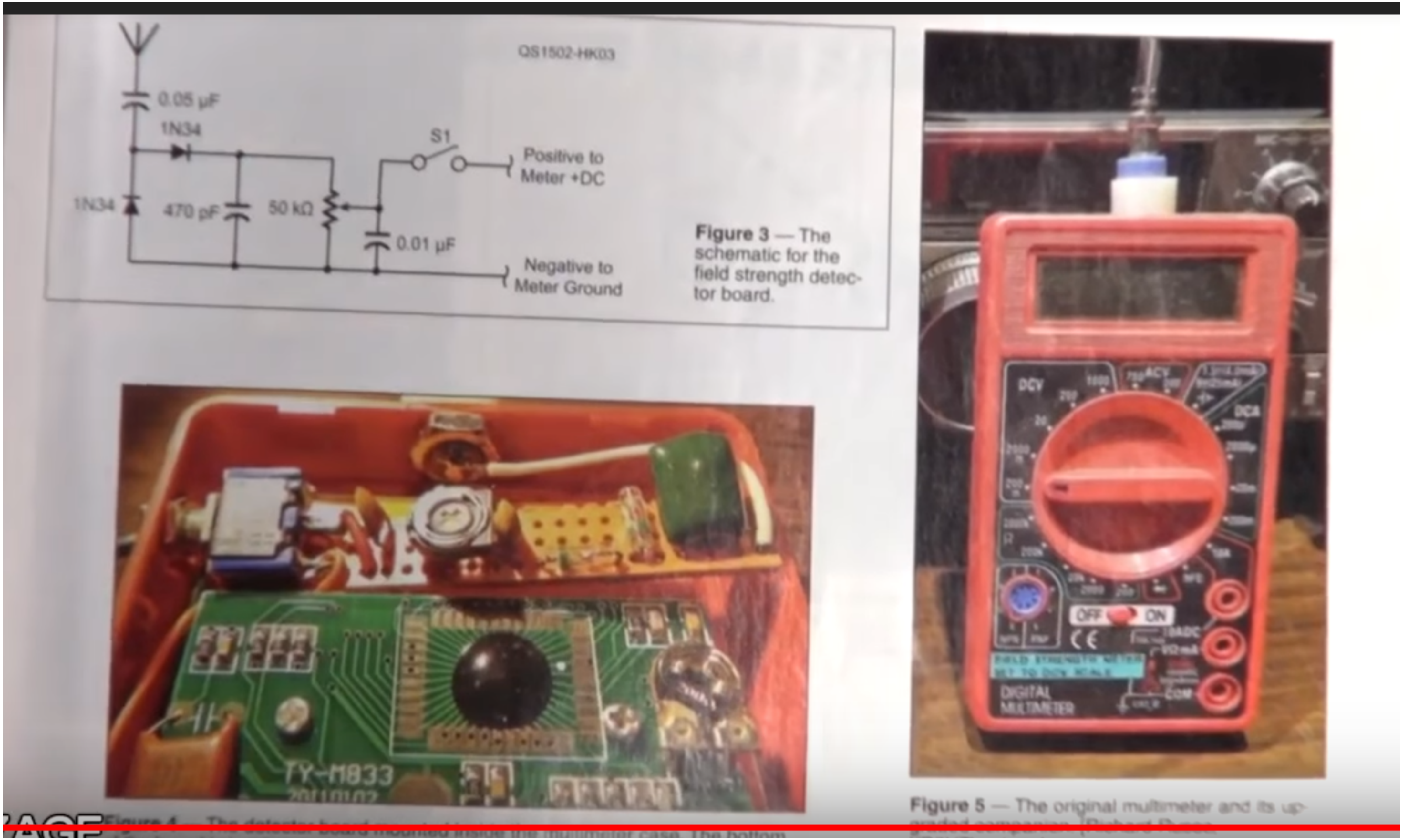
QS1502-HK03
0.05 µF
1N34
1N34
470 pF
50 kΩ
S1
0.01 µF
Positive to Meter +DC
Negative to Meter Ground
FIELD STRENGTH METER SET TO DCV SCALE
DIGITAL MULTIMETER
OFF ON
DCV
ACV
DCA
COM
TY-M833

Figure 3 — The schematic for the field strength detector board.

Figure 4 — The detector board mounted inside the multimeter case. The bottom

Figure 5 — The original multimeter and its upgraded companion.

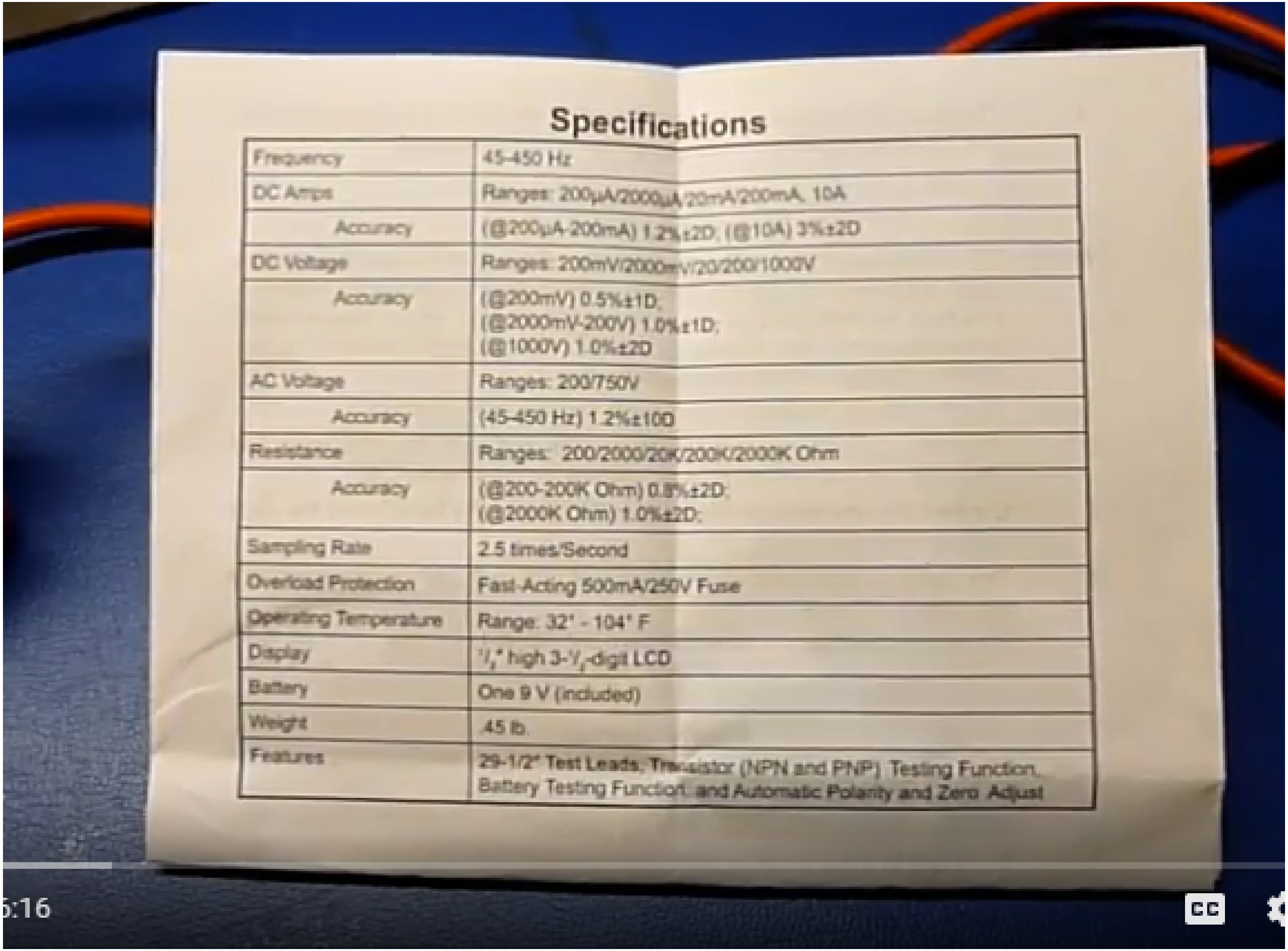

Specifications

Frequency	45-450 Hz
DC Amps	Ranges: 200µA/2000µA/20mA/200mA, 10A
Accuracy	(@200µA-200mA) 1.2%±2D; (@10A) 3%±2D
DC Voltage	Ranges: 200mV/2000mV/20/200/1000V
Accuracy	(@200mV) 0.5%±1D; (@2000mV-200V) 1.0%±1D; (@1000V) 1.0%±2D
AC Voltage	Ranges: 200/750V
Accuracy	(45-450 Hz) 1.2%±10D
Resistance	Ranges: 200/2000/20K/200K/2000K Ohm
Accuracy	(@200-200K Ohm) 0.8%±2D; (@2000K Ohm) 1.0%±2D;
Sampling Rate	2.5 times/Second
Overload Protection	Fast-Acting 500mA/250V Fuse
Operating Temperature	Range: 32° - 104° F
Display	1/2" high 3-1/2-digit LCD
Battery	One 9 V (included)
Weight	.45 lb.
Features	29-1/2" Test Leads, Transistor (NPN and PNP) Testing Function, Battery Testing Function, and Automatic Polarity and Zero Adjust

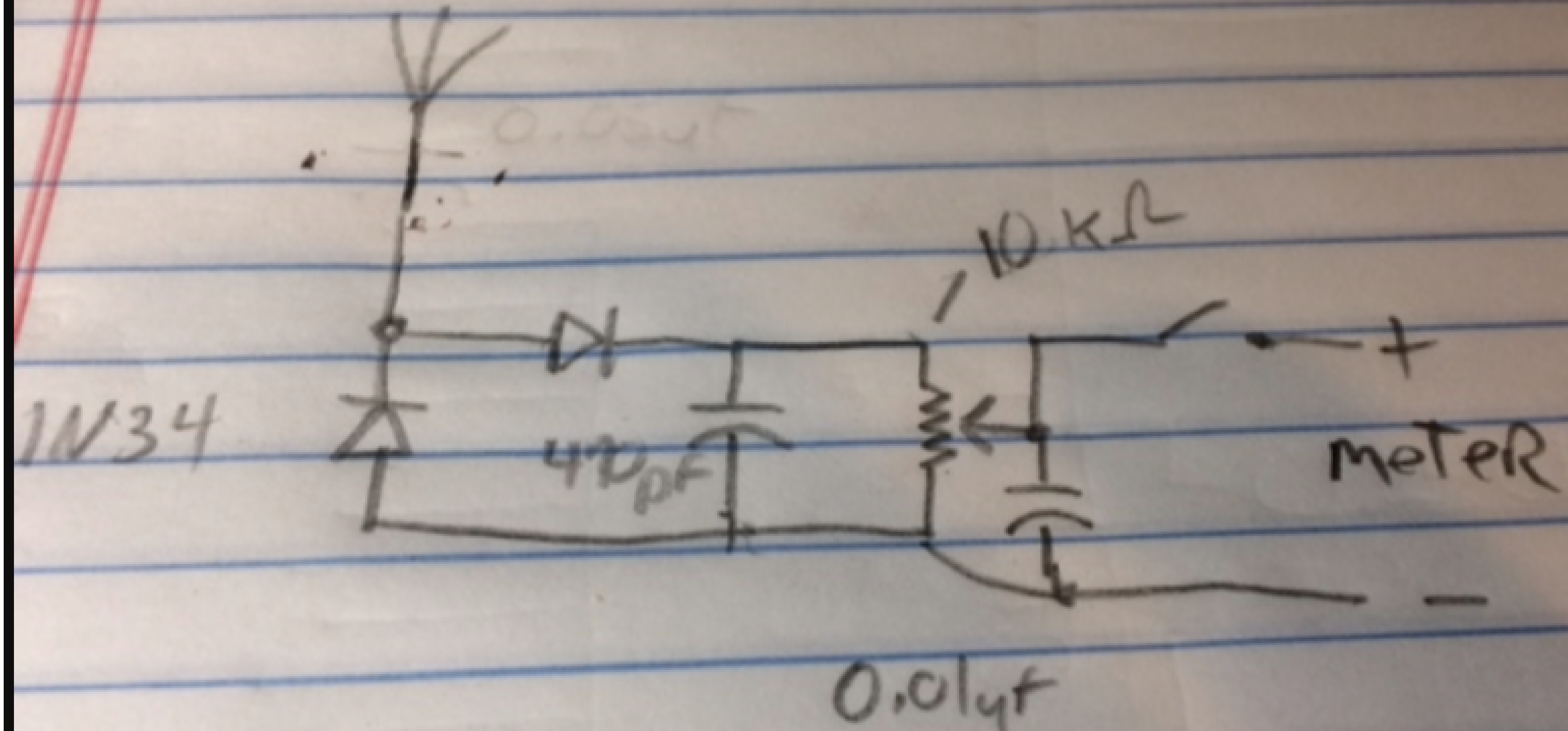
0.05uf
10 kΩ
1N34
47pF
+
meter
−
0.01uf

1 000 000 000 000

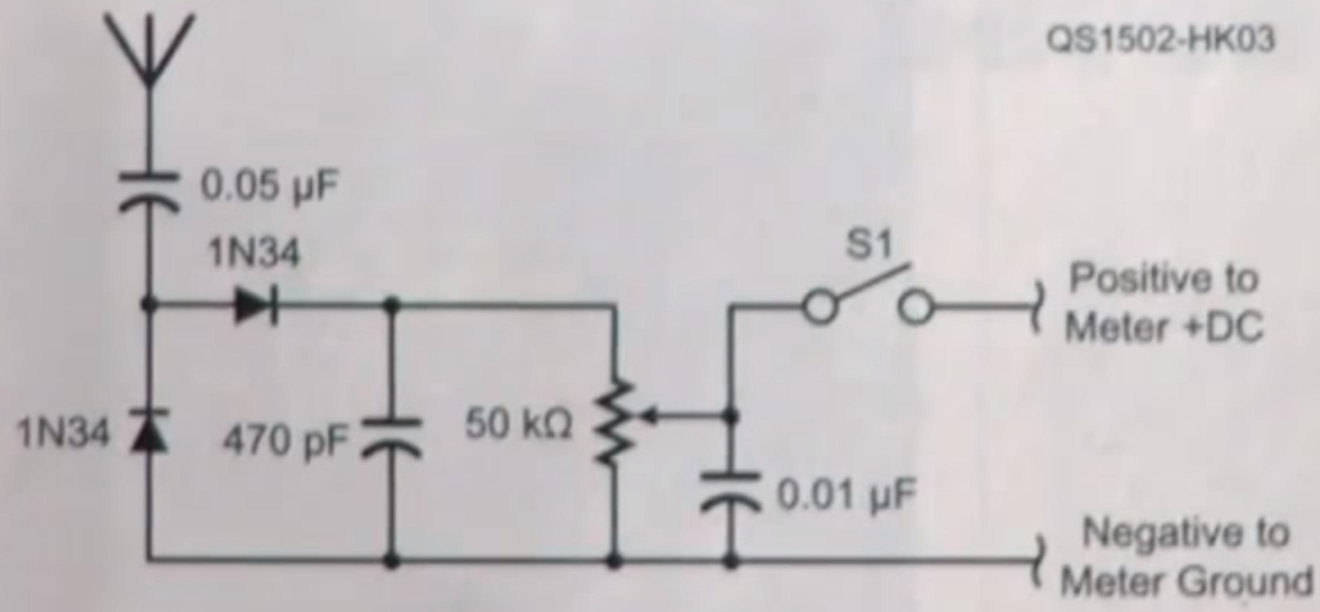
QS1502-HK03
0.05 μF
1N34
S1
Positive to
Meter +DC
1N34
470 pF
50 kΩ
0.01 μF
Negative to
Meter Ground

Figure 3 — The schematic for the field strength detector board.

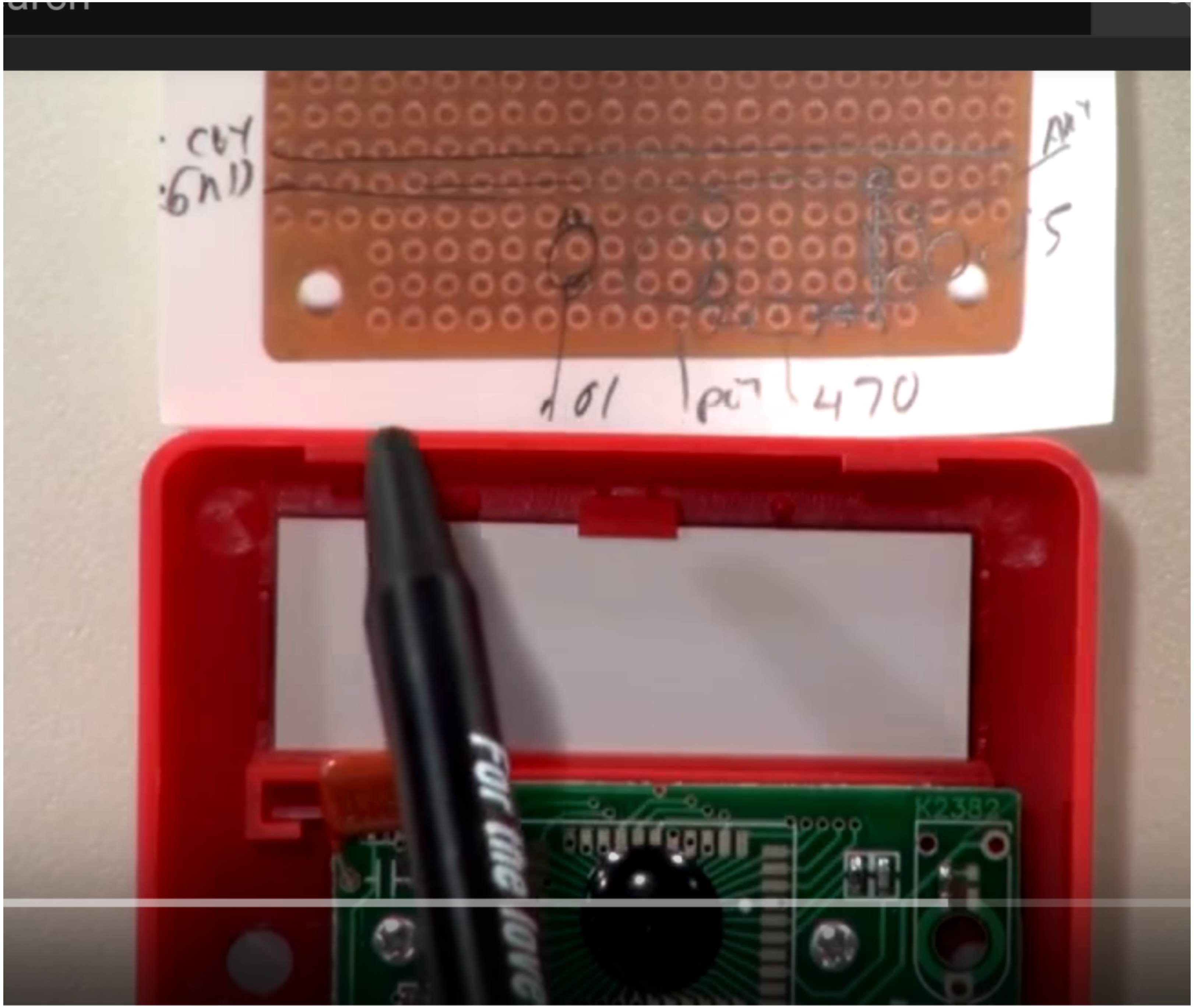
CbY
GnD
5
101
pot
470
For the love
K2382

Up next

CEN-TECH
7 FUNCTION
DIGITAL
MULTIMETER
CEN-TECH
DIGITAL
MULTIMETER

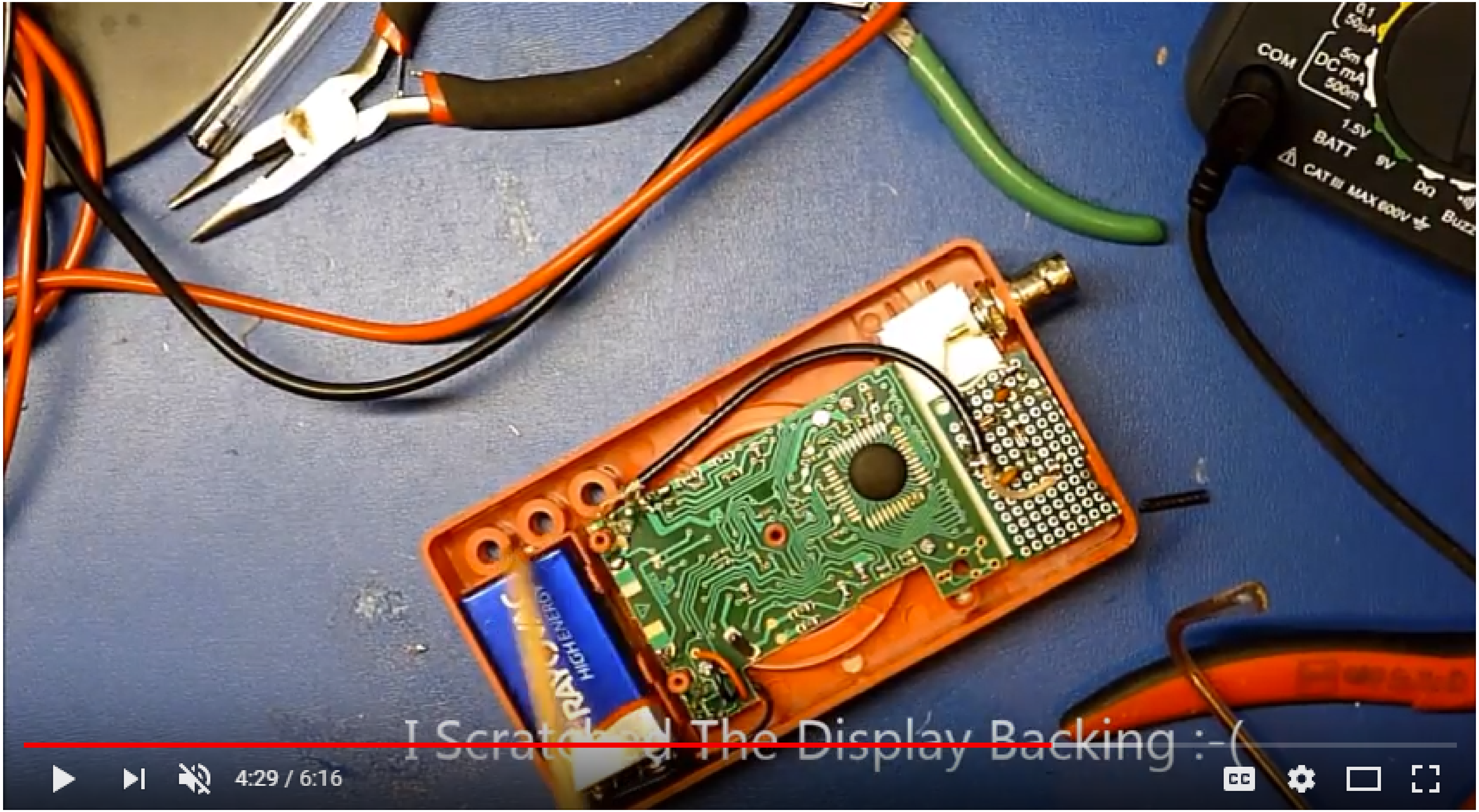
COM
0.1
50µA
5m
DC mA
500m
1.5V
BATT
9V
CAT III MAX 600V
RAYOVAC
HIGH ENERGY
4:29 / 6:16

I Scratched The Display Backing :-(

#007: Field Strength Meter

ISO-TIP
iso-tip.com
K7AGE
3:24 / 12:07

Up next

Let's Build A Field Strength Meter

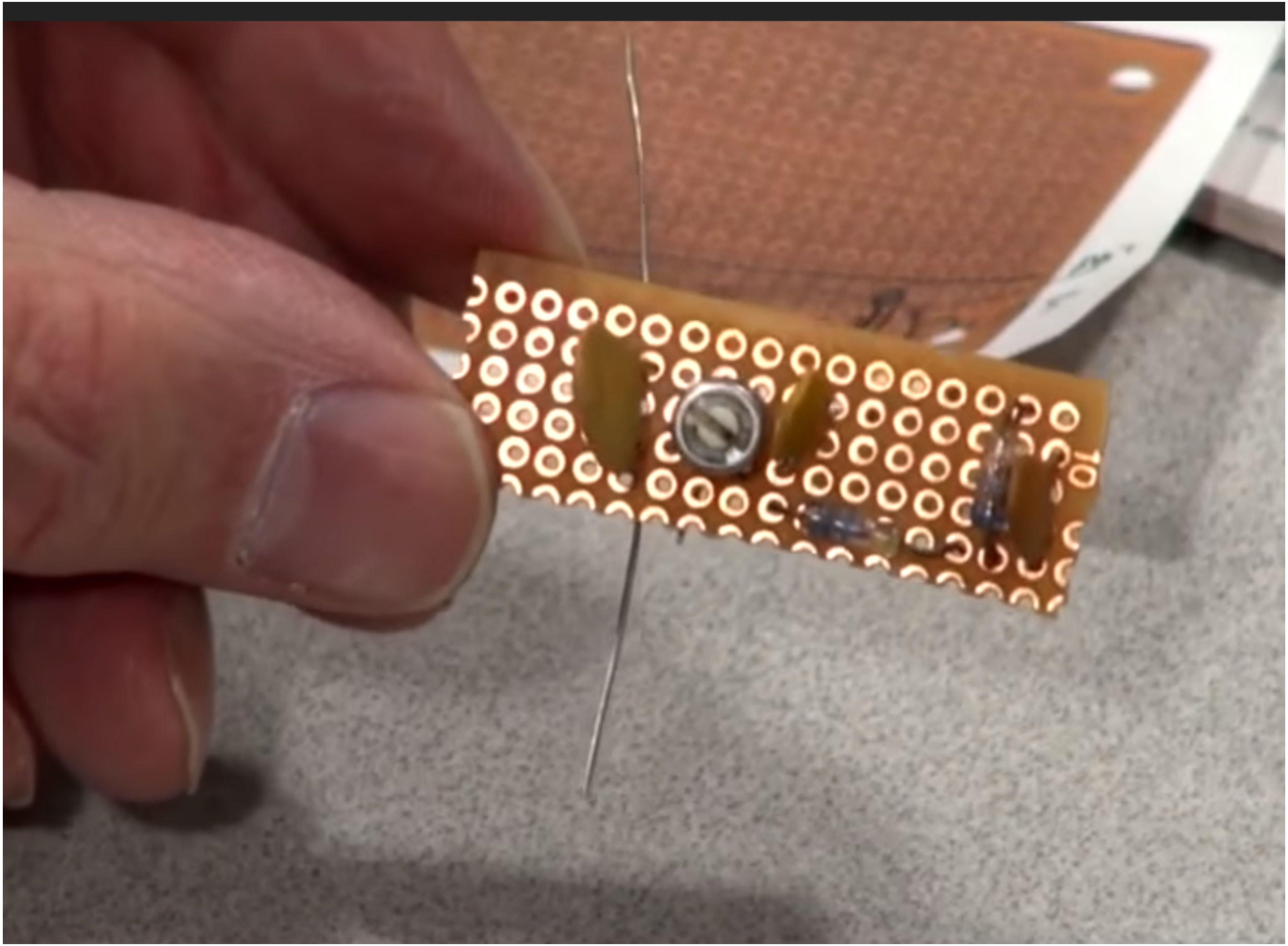
10

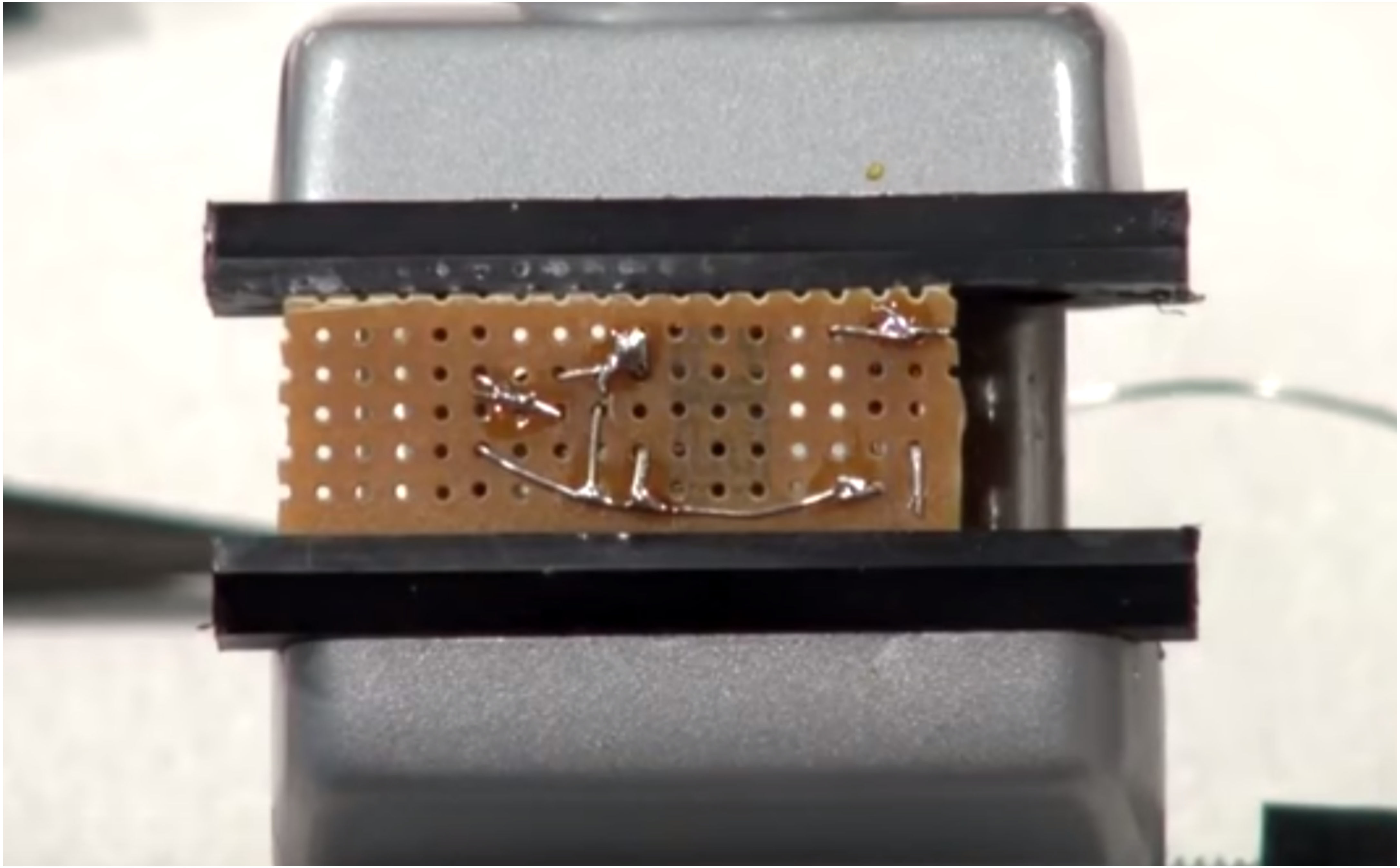

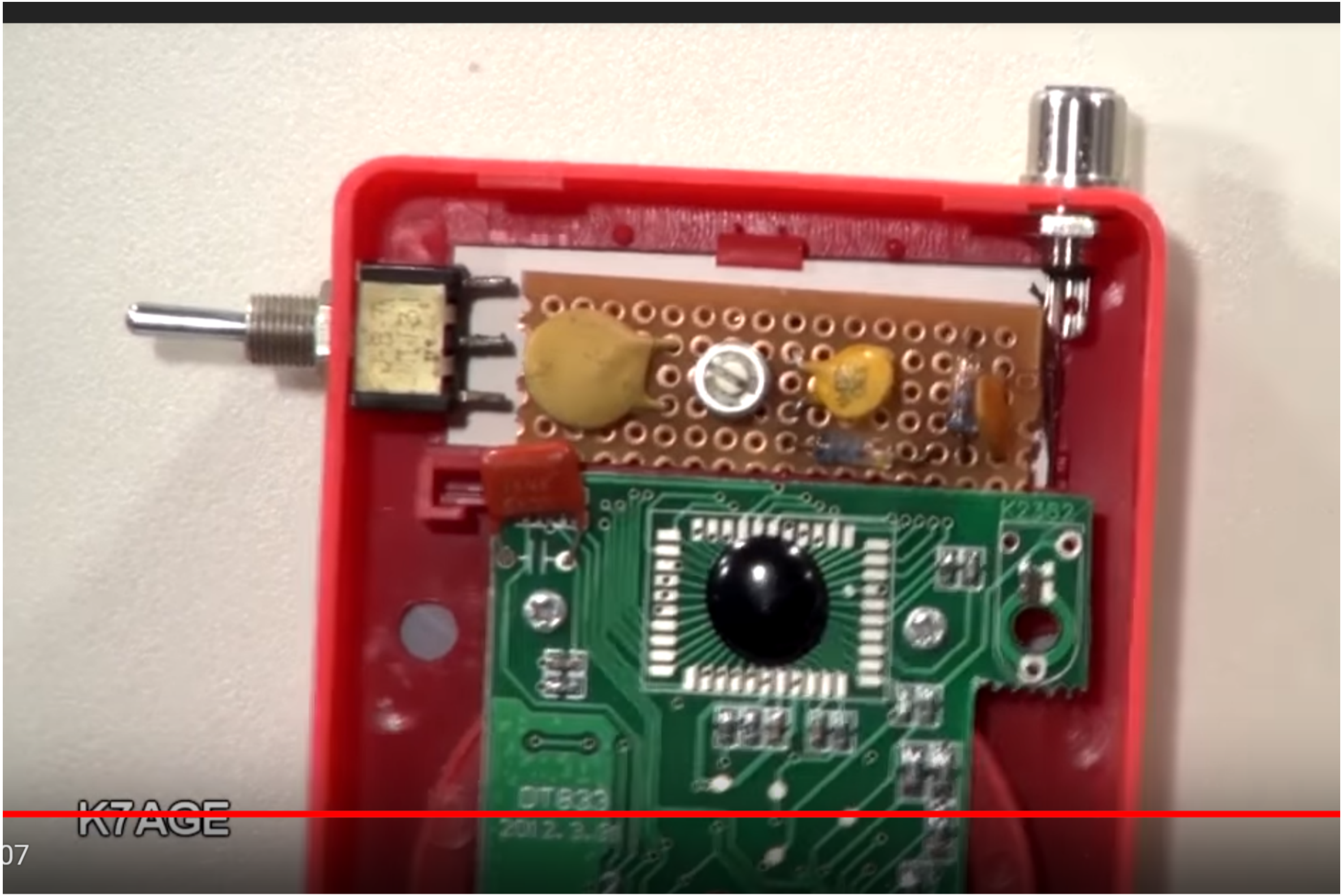
K2382
DT833
2012. 3. 8
K7AGE
07

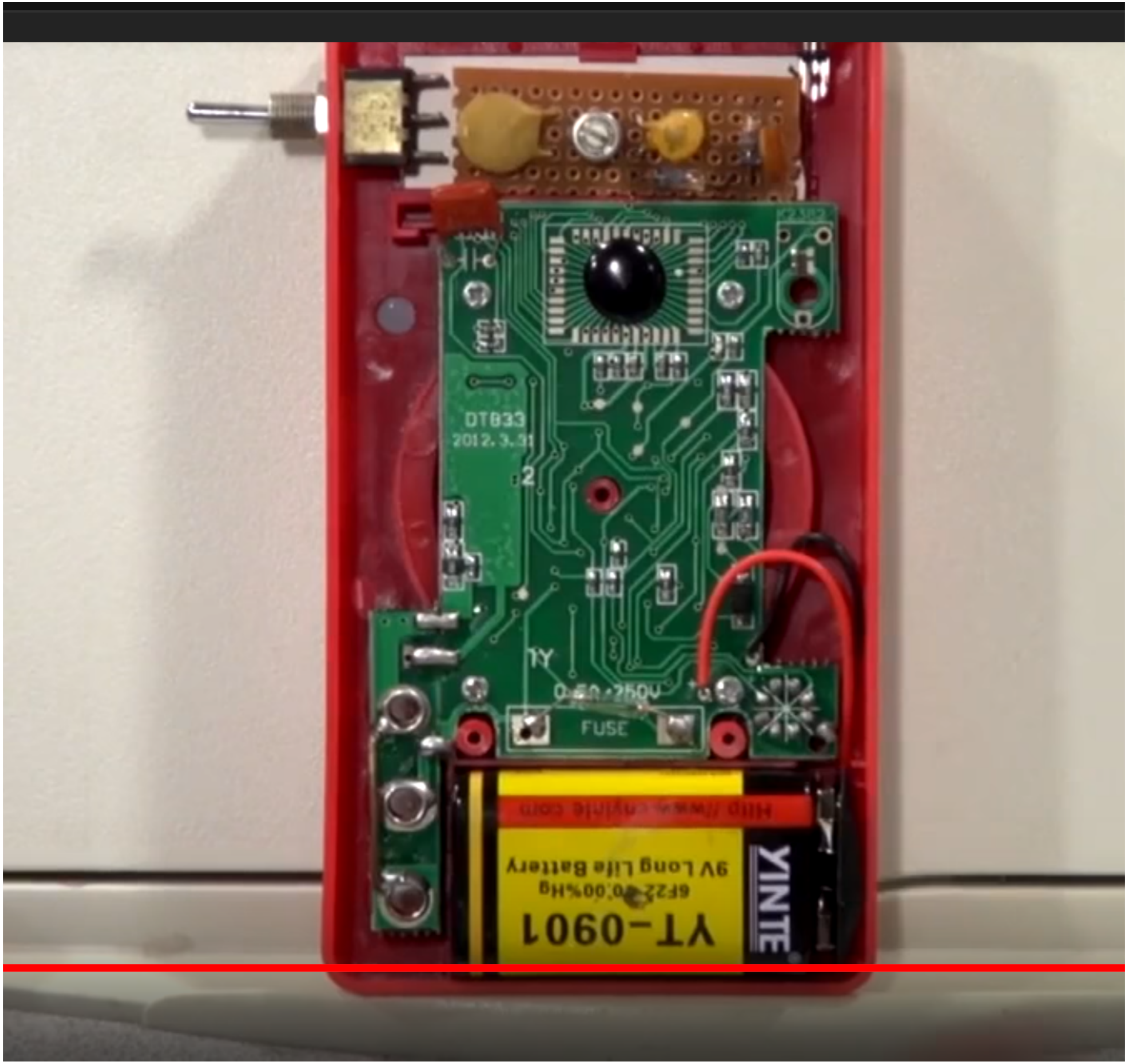

DT833
2012.3.31
2
1Y
0.5A/250V
FUSE
YINTE
9V Long Life Battery
6F22 0.00%Hg
YT-0901

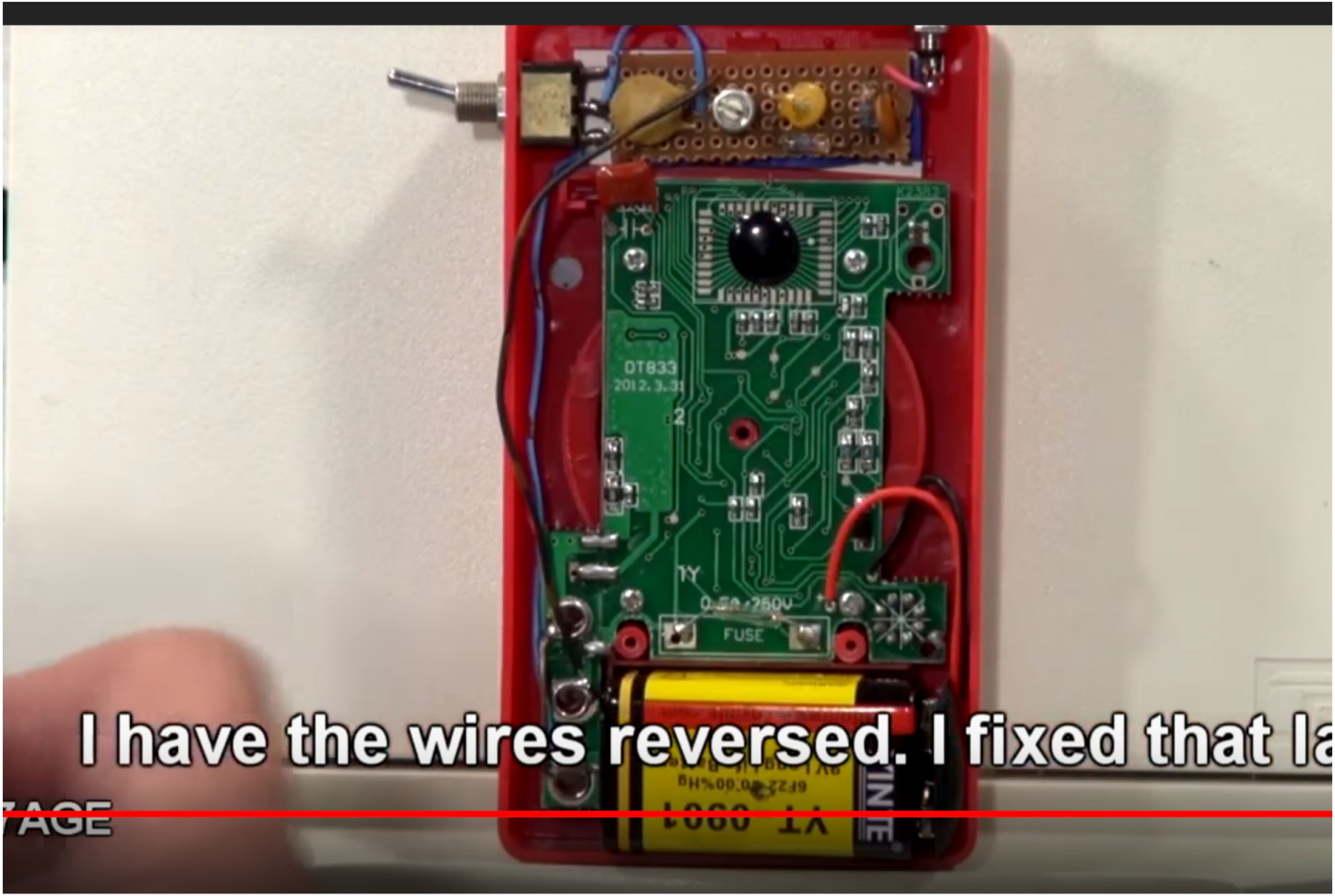
DT833
2012.3.31
0.5A/250V
FUSE
AGE

I have the wires reversed. I fixed that la

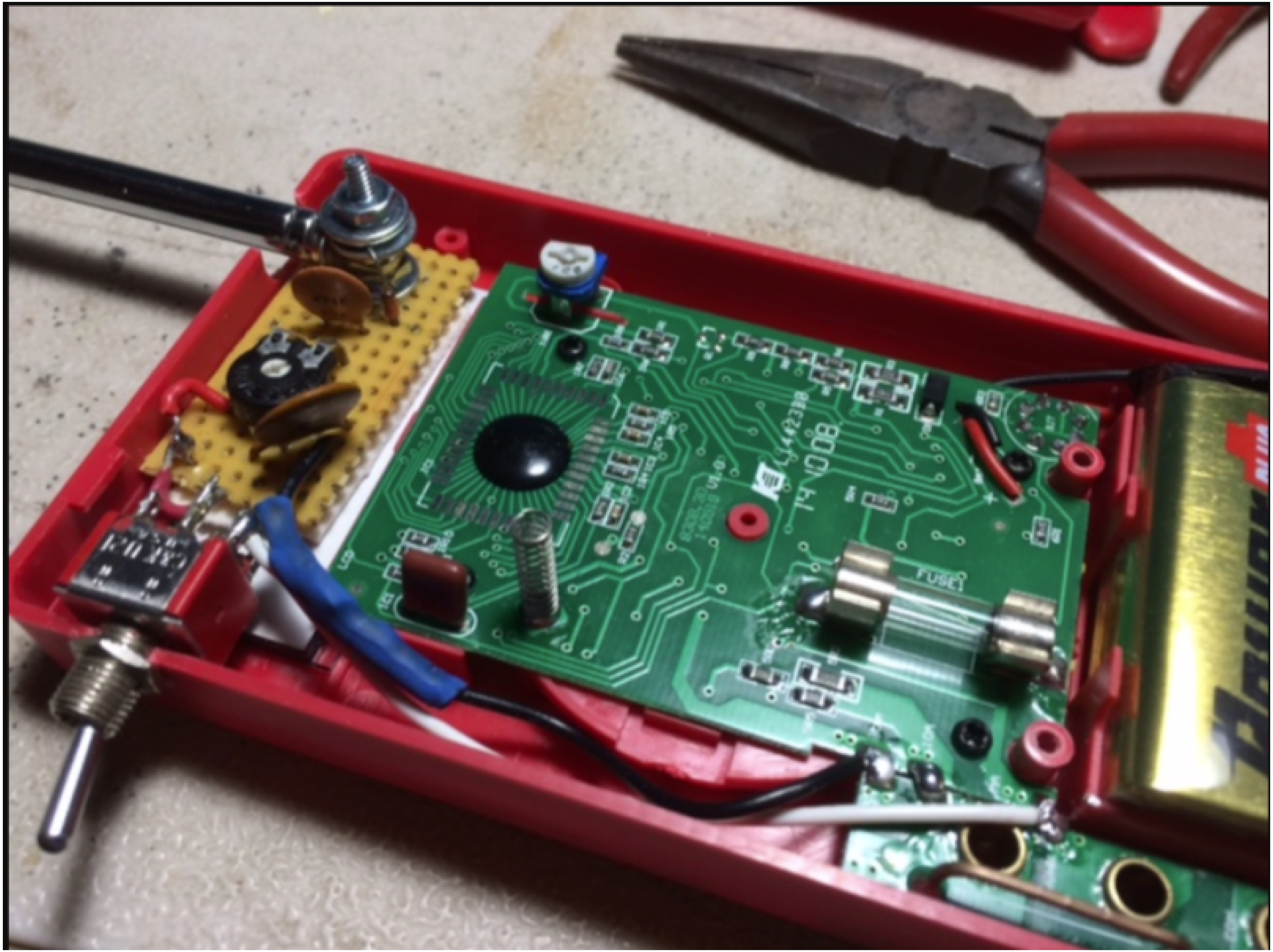
FUSE

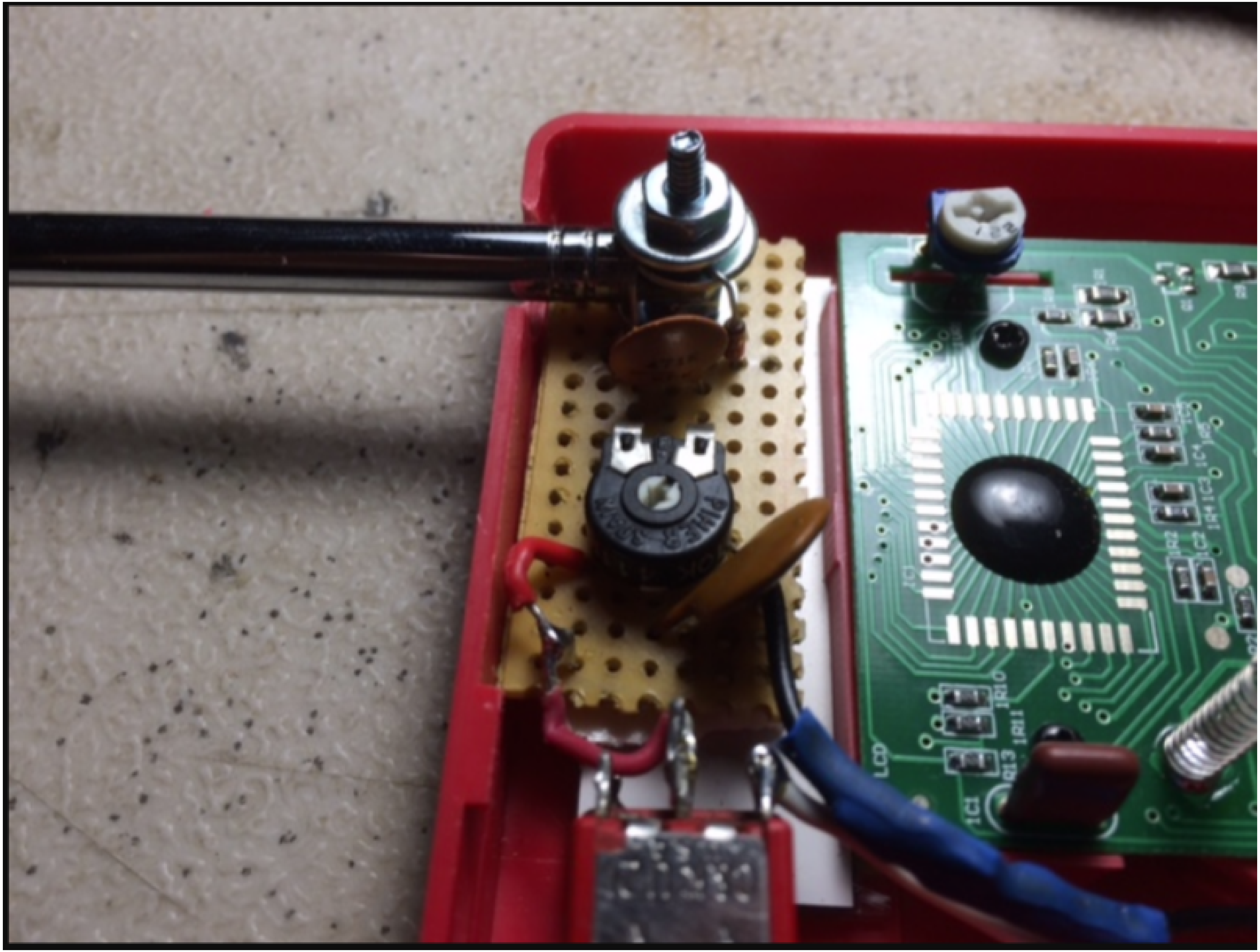

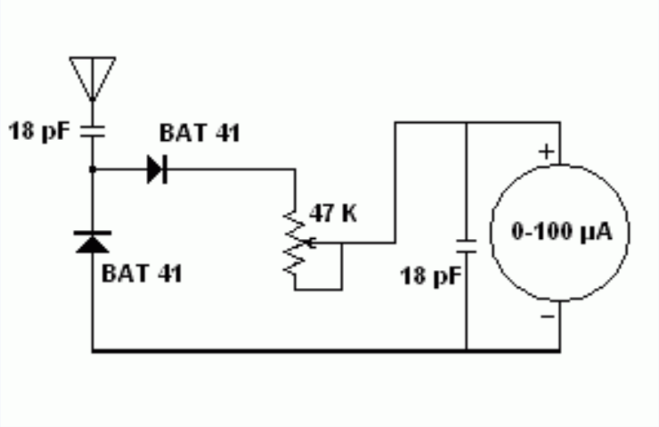
18 pF
BAT 41
47 K
BAT 41
18 pF
+
0-100 µA
−

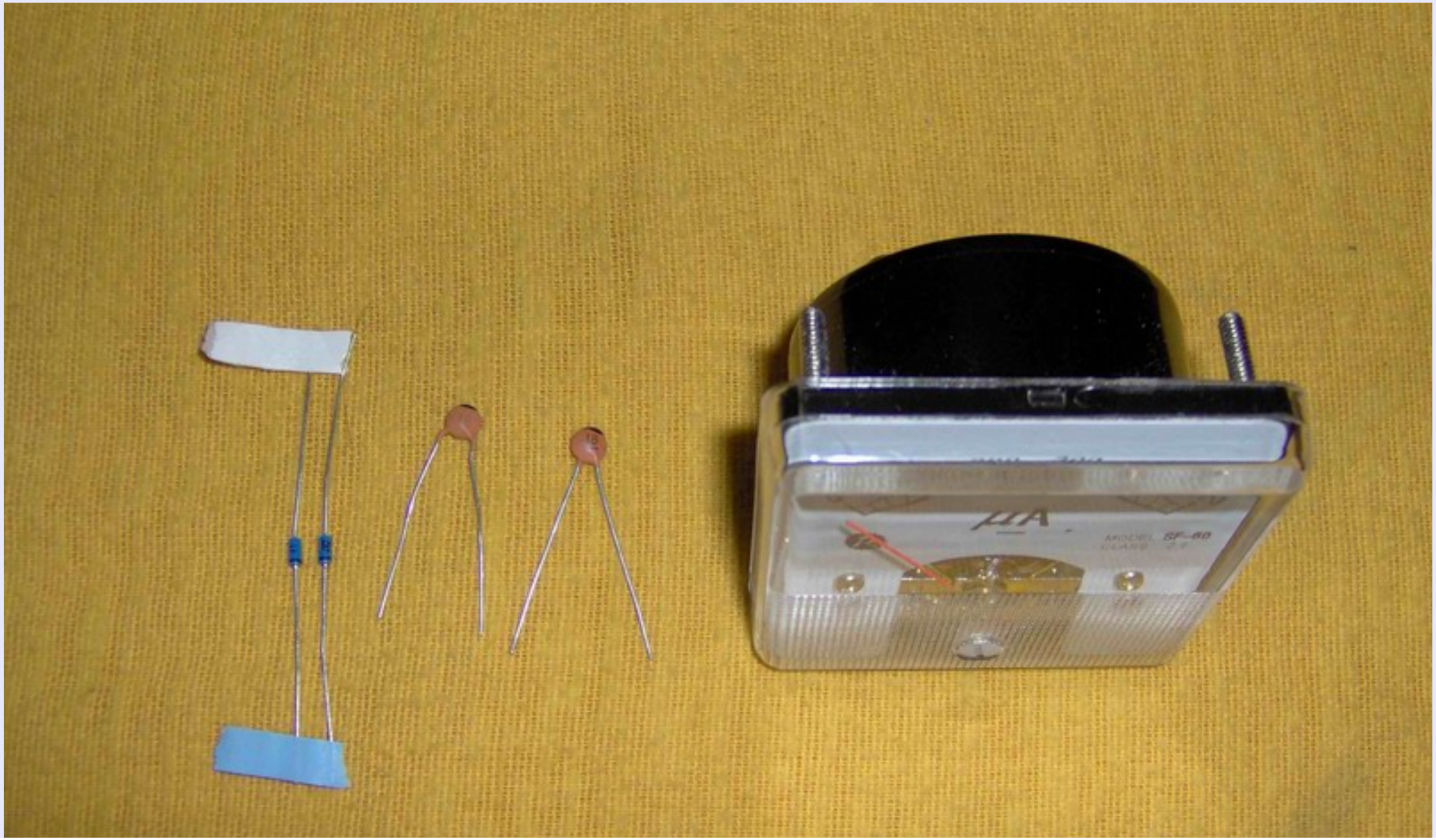
µA

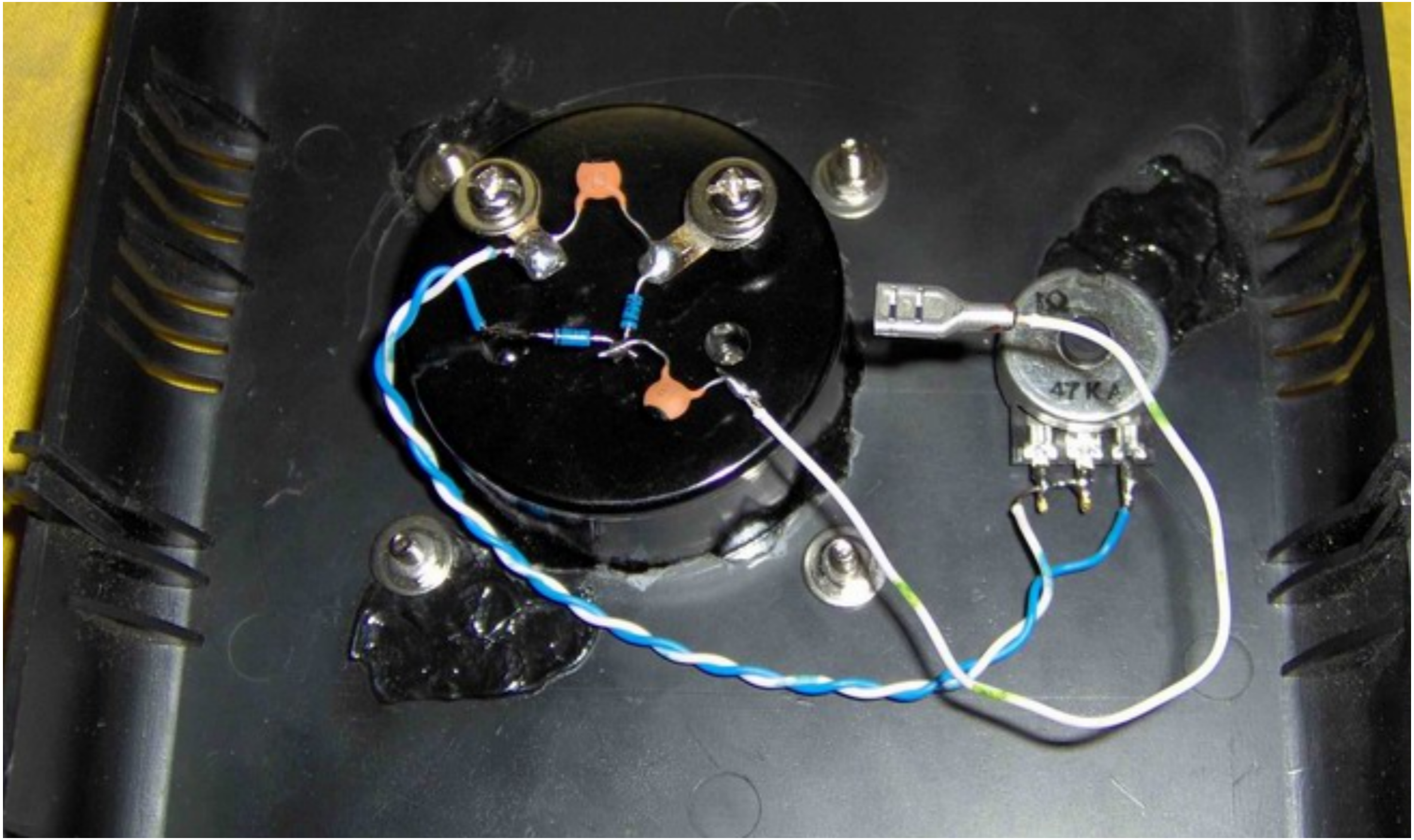
47 K A

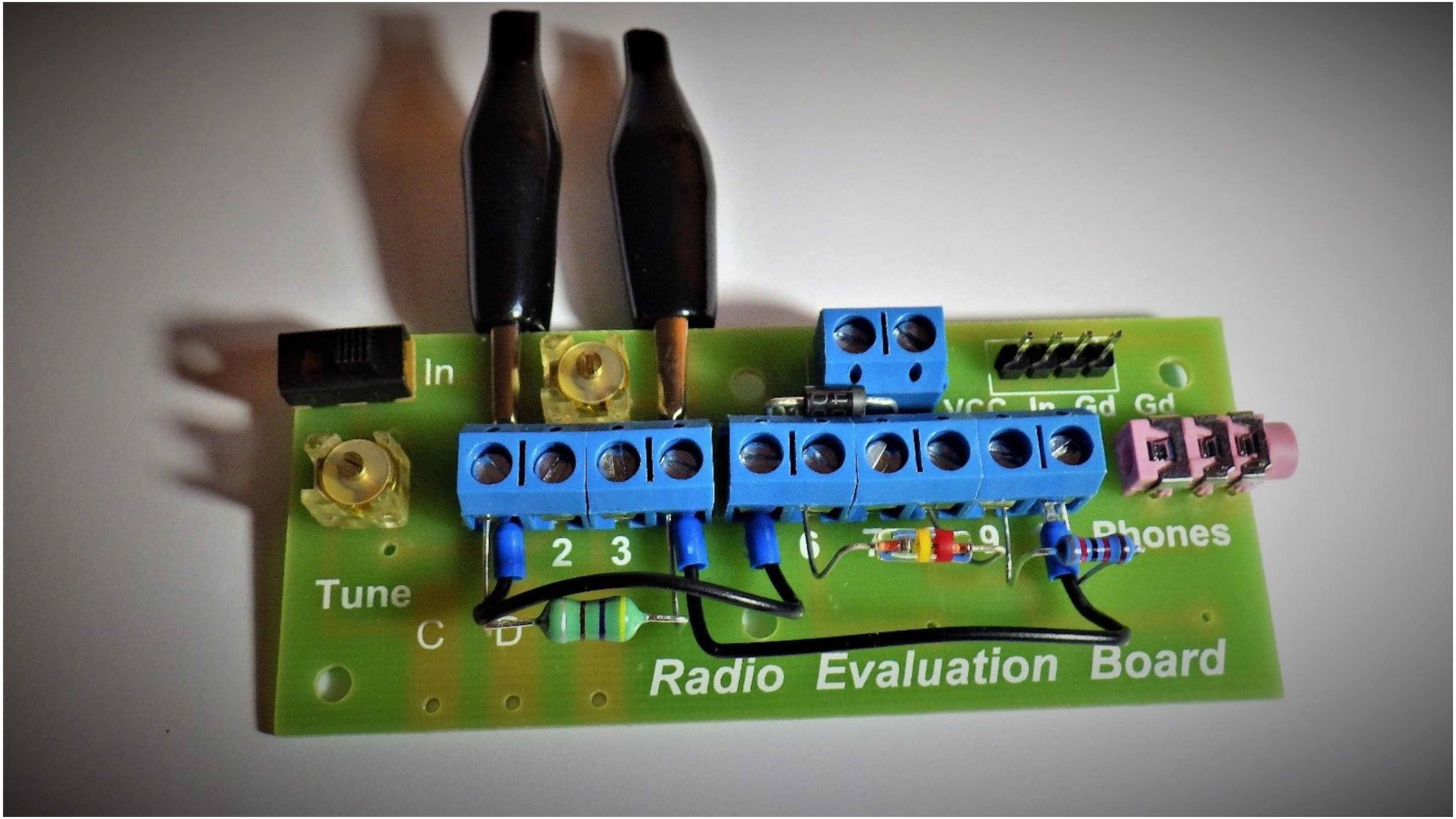
In
Tune
C
D
2
3
6
9
VCC
In
Gd
Gd
Phones
Radio Evaluation Board

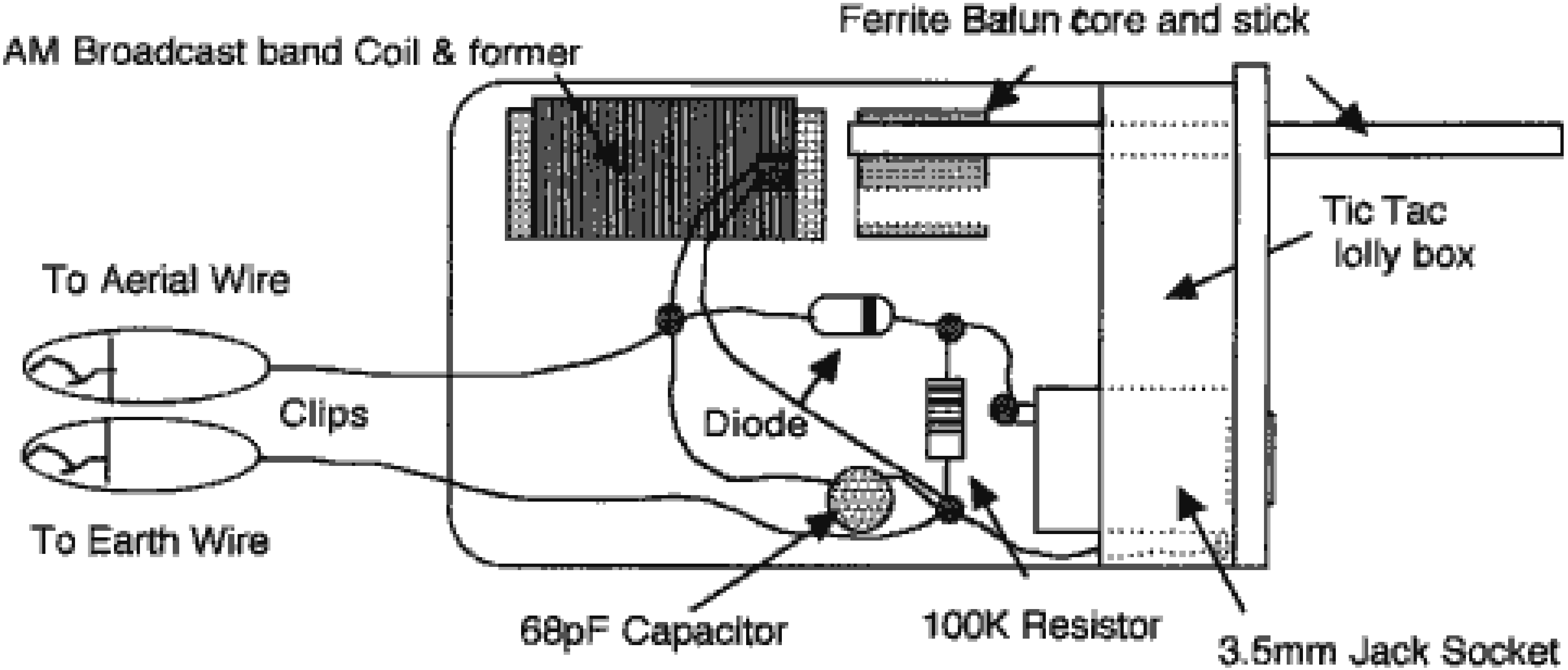
Ferrite Balun core and stick
AM Broadcast band Coil & former
Tic Tac
lolly box
To Aerial Wire
Clips
Diode
To Earth Wire
68pF Capacitor
100K Resistor
3.5mm Jack Socket

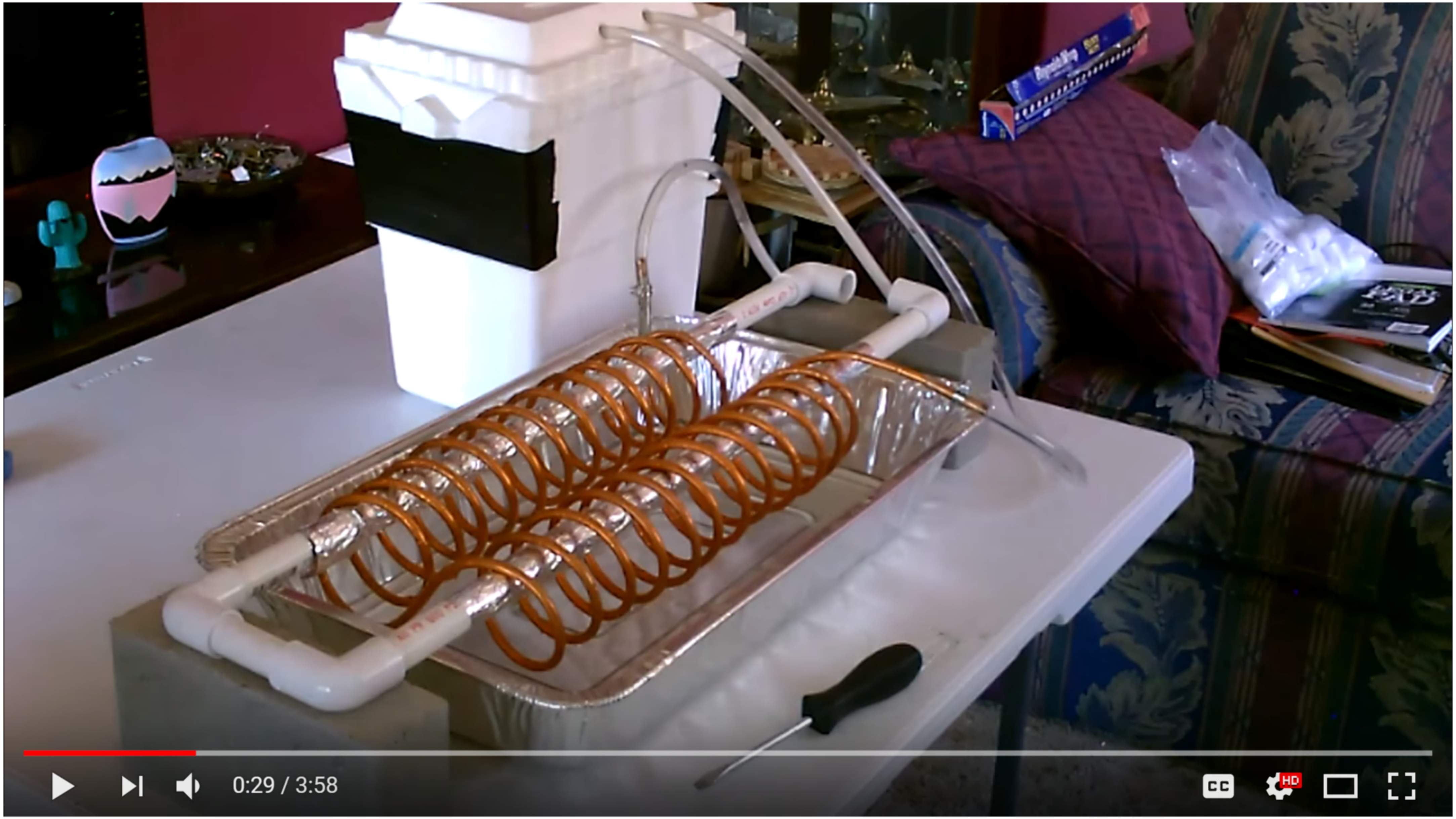
0:29 / 3:58
CC
HD

DIY Atmospheric Water Generator! - Produces/Extracts Distilled Water from the air! - DIY distiller

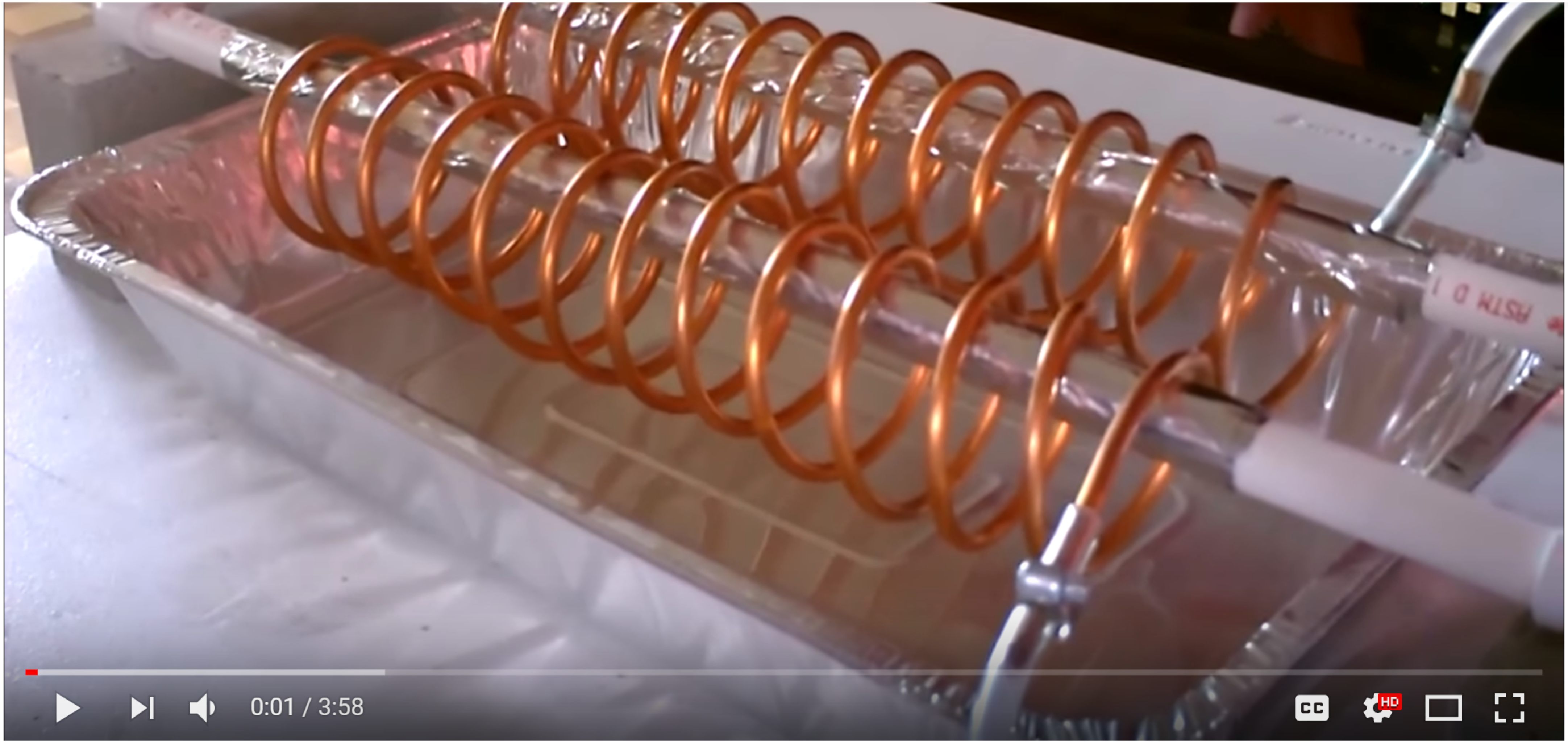
ASTM D 1
0:01 / 3:58
HD

2:51 / 3:58
CC
HD

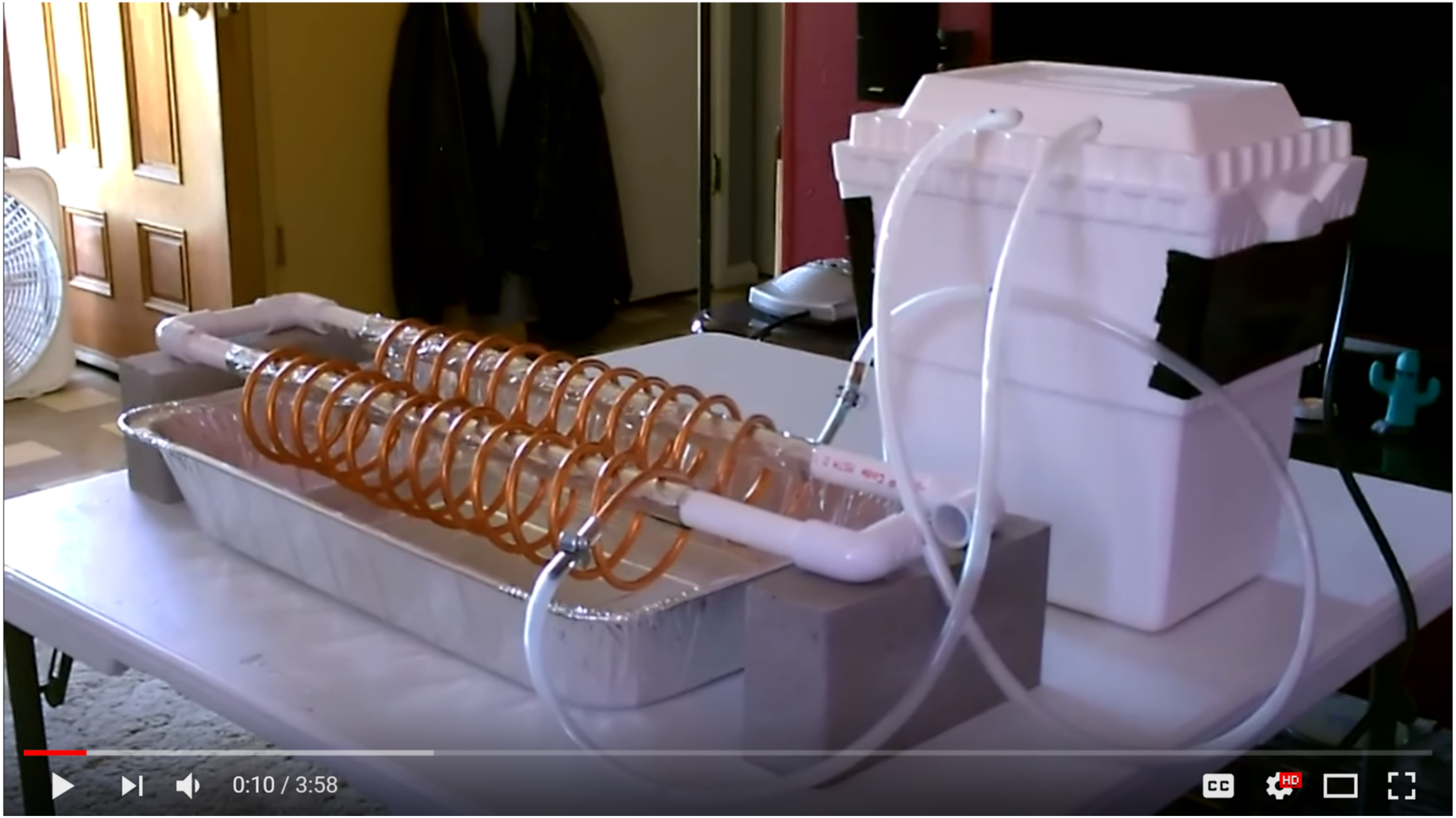
0:10 / 3:58
HD

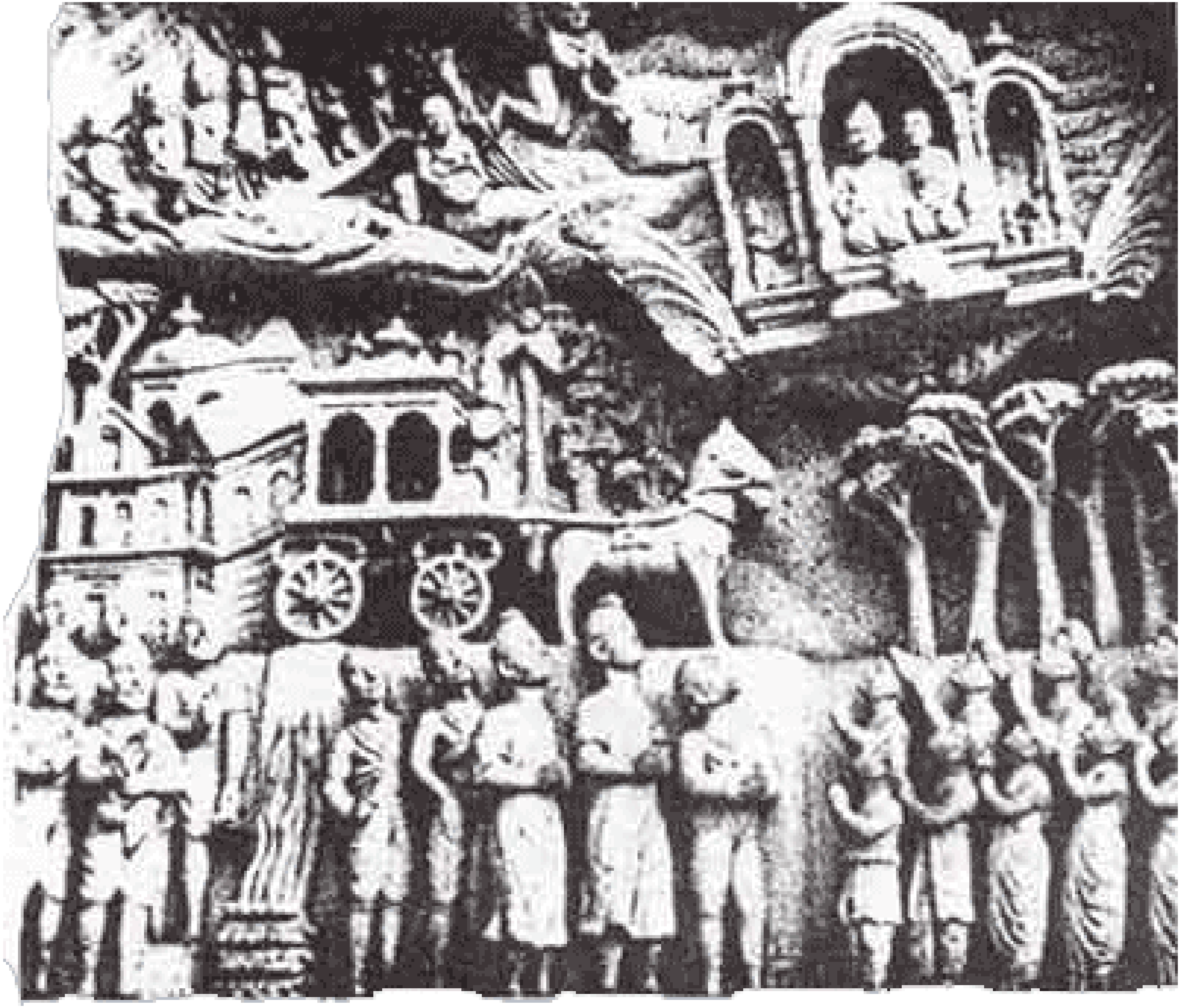

A Vimana depicted in a temple relief at Ellora Caves, India

TROODON AND DINOSAUROID

In the early 1980s, the American palaeontologist Dale Russell suggested that, had dinosaurs survived, the big-brained, bipedal, bird-like *Troodon* with grasping hands (left), might have given rise to an intelligent and human-looking descendant like the "dinosauroid" (right).

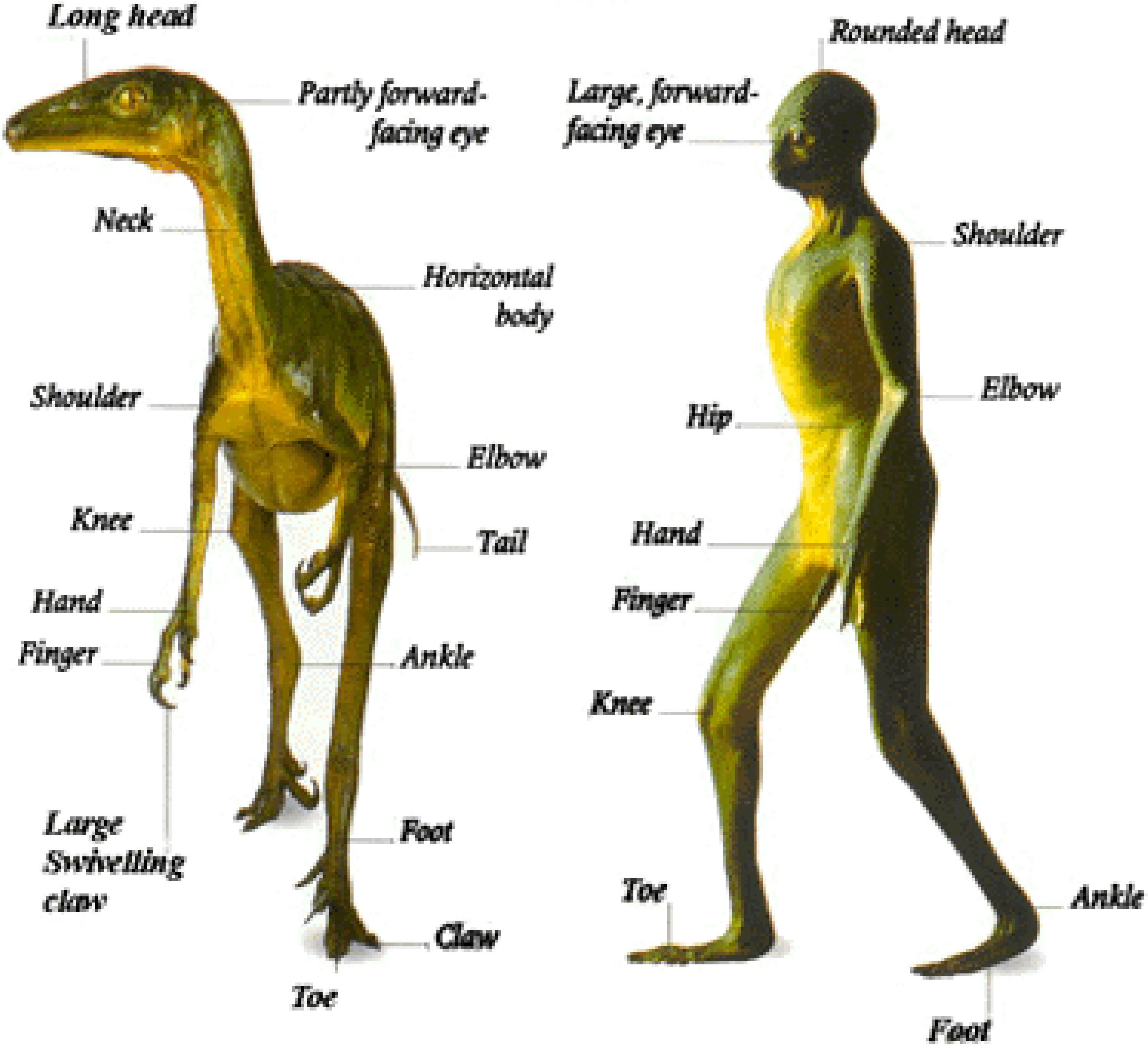

Long head
Partly forward-facing eye
Neck
Horizontal body
Shoulder
Elbow
Knee
Tail
Hand
Finger
Ankle
Large Swivelling claw
Foot
Claw
Toe
Rounded head
Large, forward-facing eye
Shoulder
Elbow
Hip
Hand
Finger
Knee
Toe
Ankle
Foot

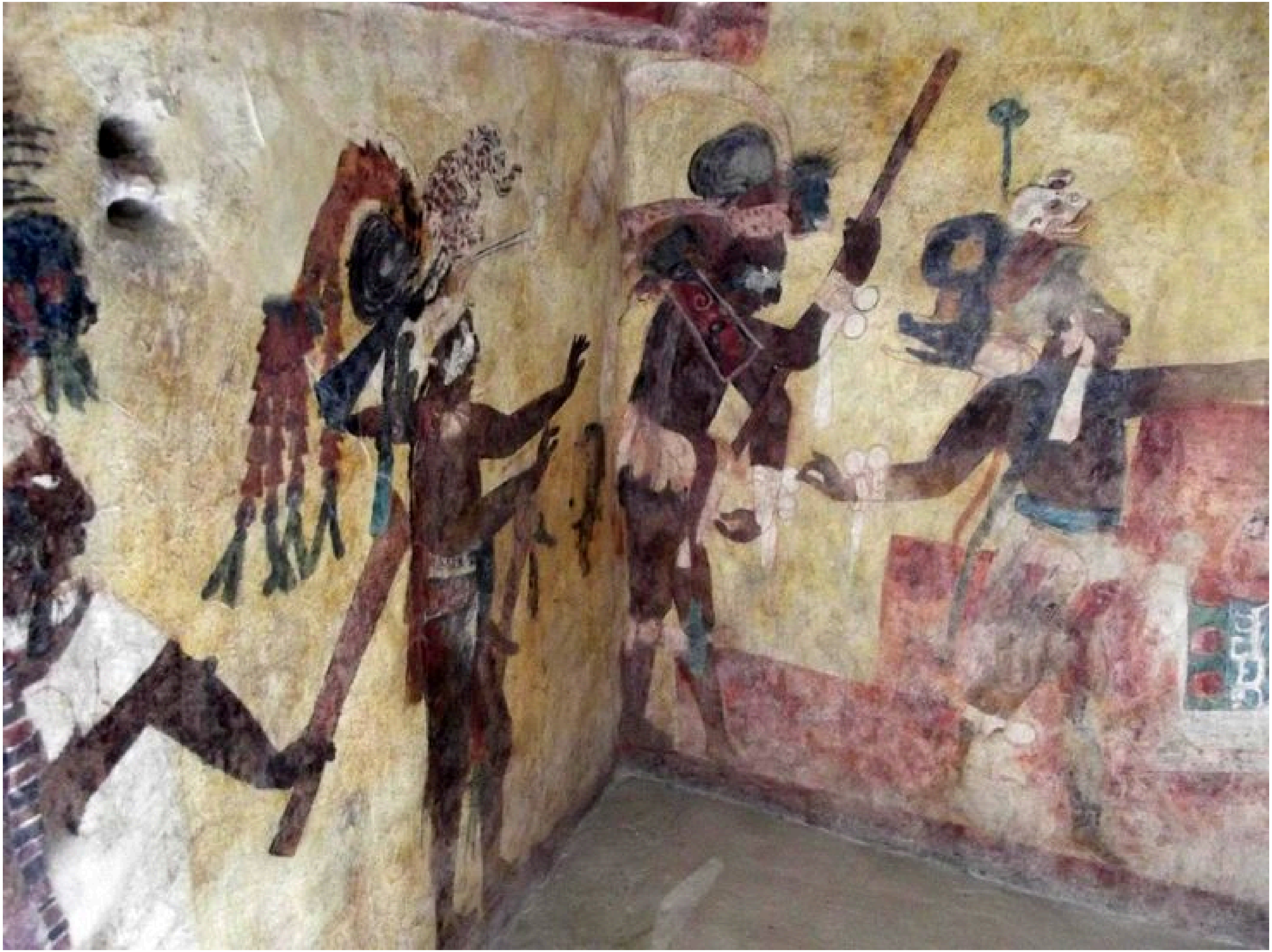

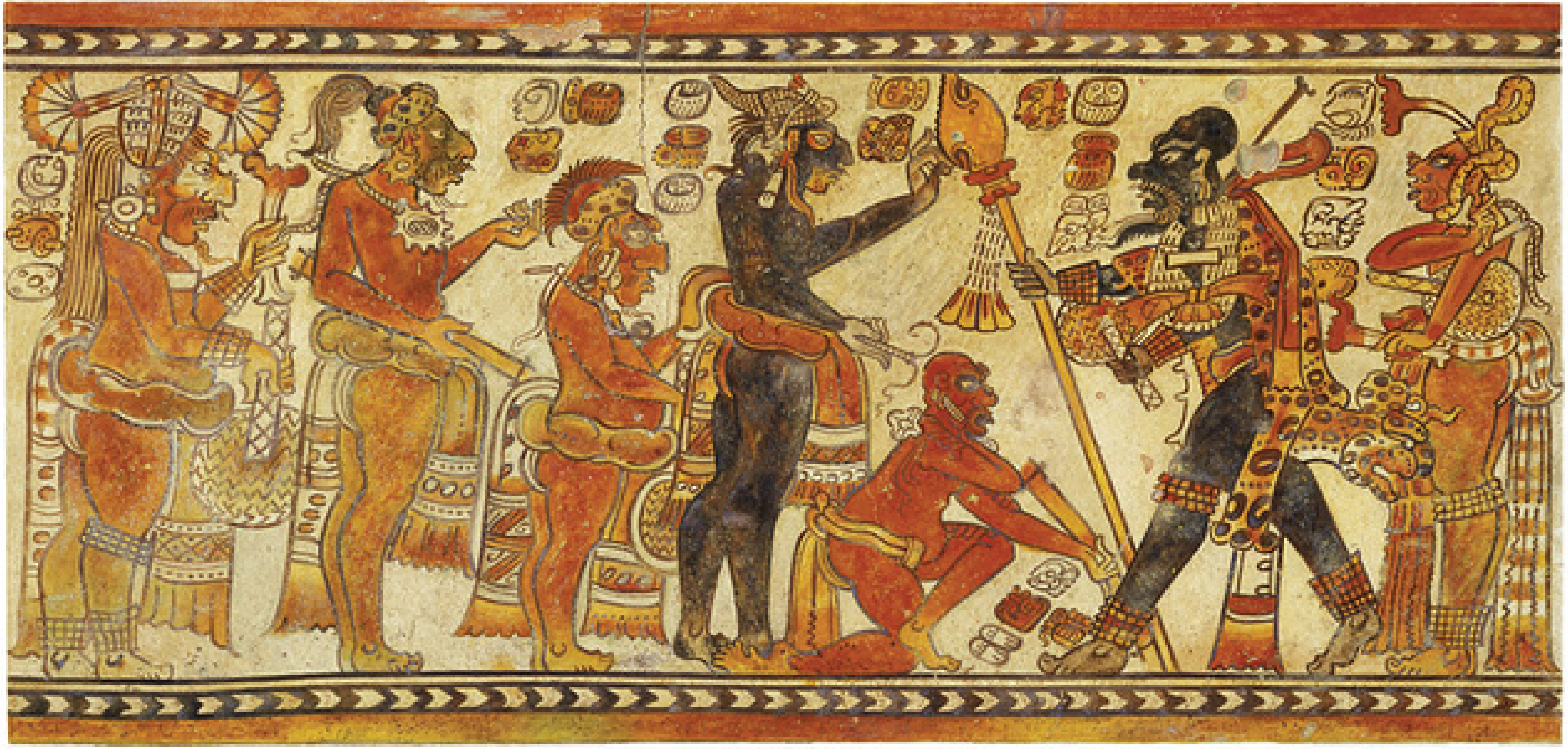

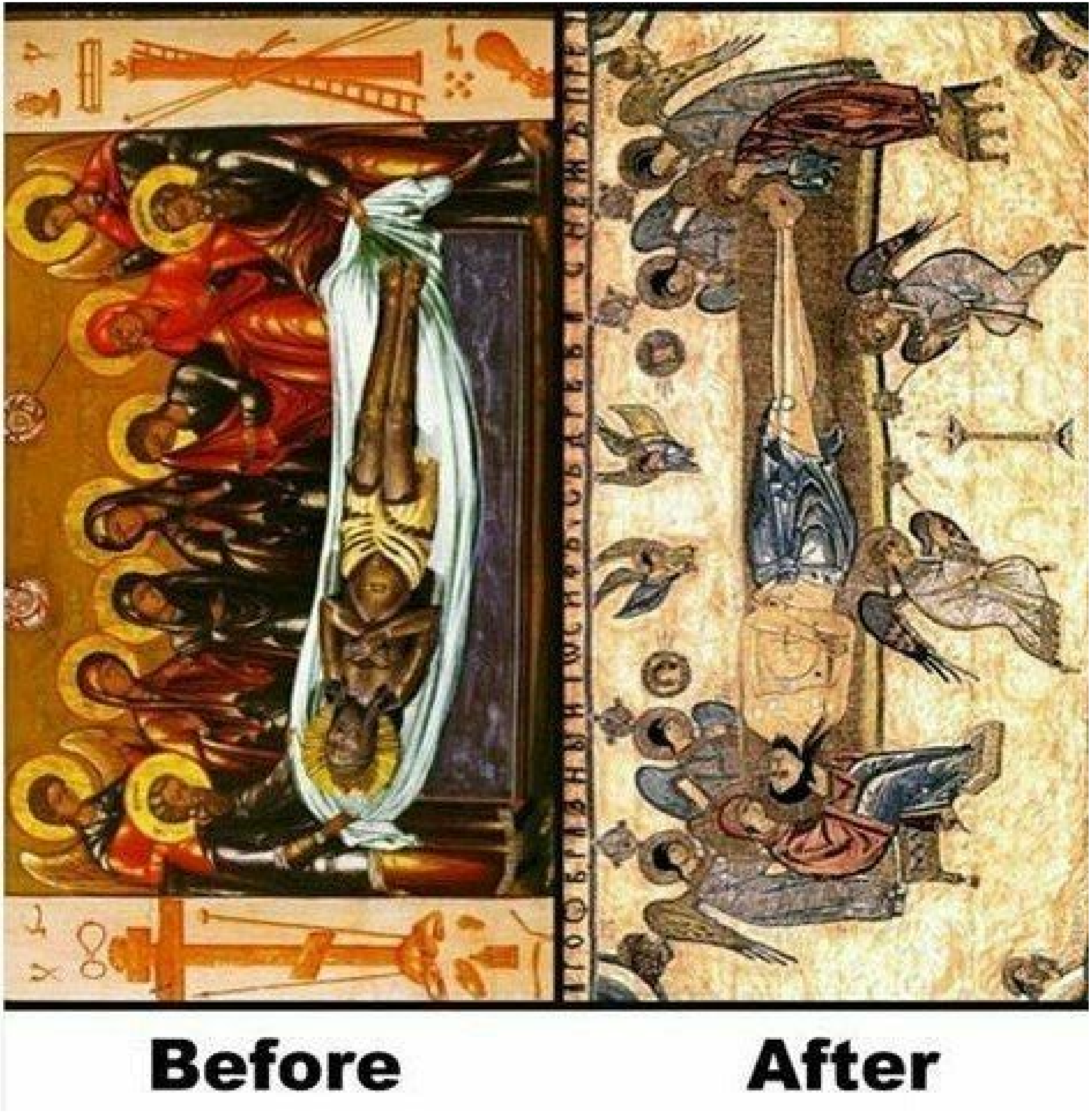
Before
After

Given to us by France to pay homage to the Slaves whom were brought here by force, this was to represent their Freedom

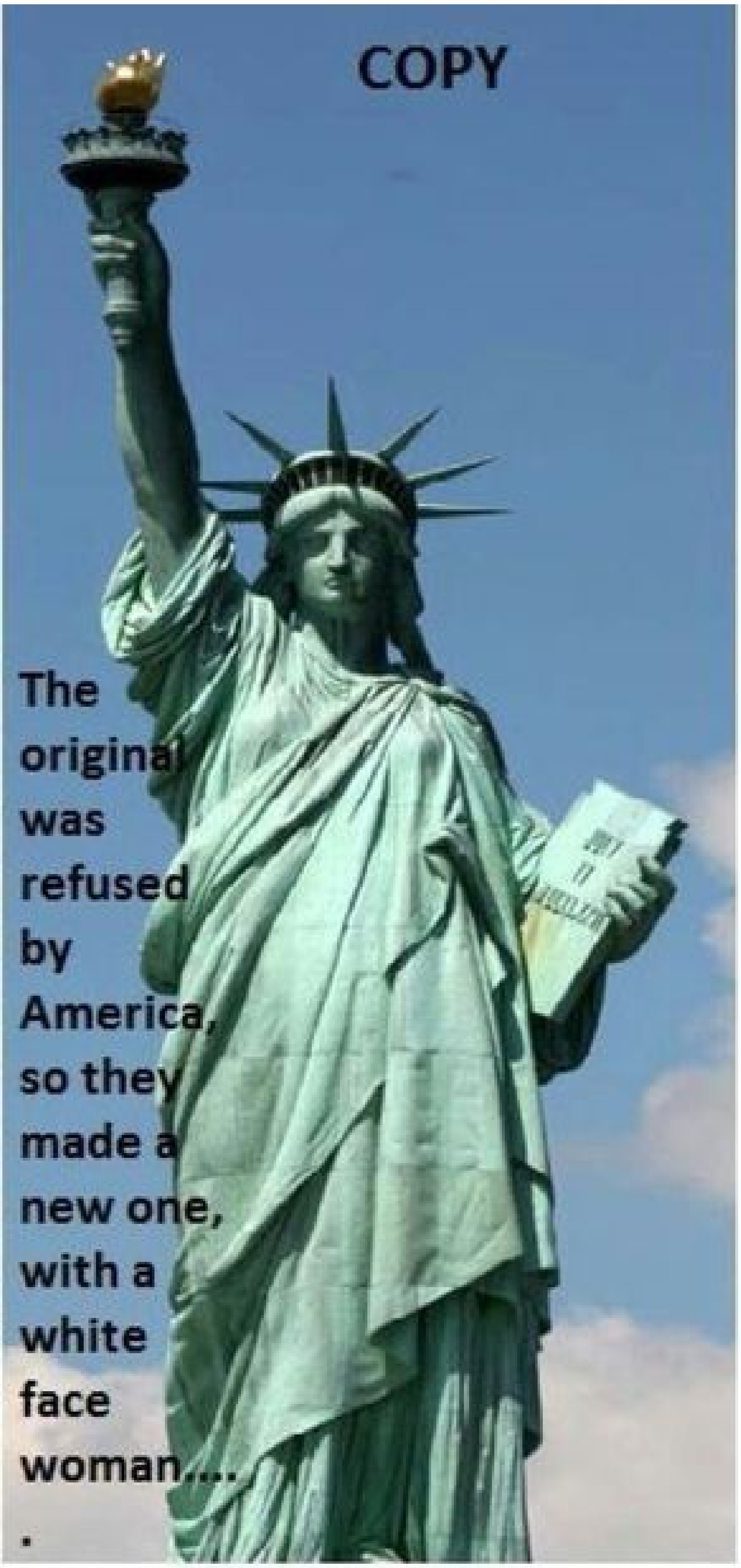

The original was refused by America, so they made a new one, with a white face woman....
.

BEAUTIFUL ENERGY

QUARTZ = HEALING
METAL'S = STIMULATES ENERGY
GEMSTONES = ADD'S ENERGY
RESIN = TRANSFORMATION

Copper Wire

copper is good for the blood
it also stimulates
THE LARGE QUARTZ

Gold Leaf Inside The Orgone
100 % PERCENT REAL!!!

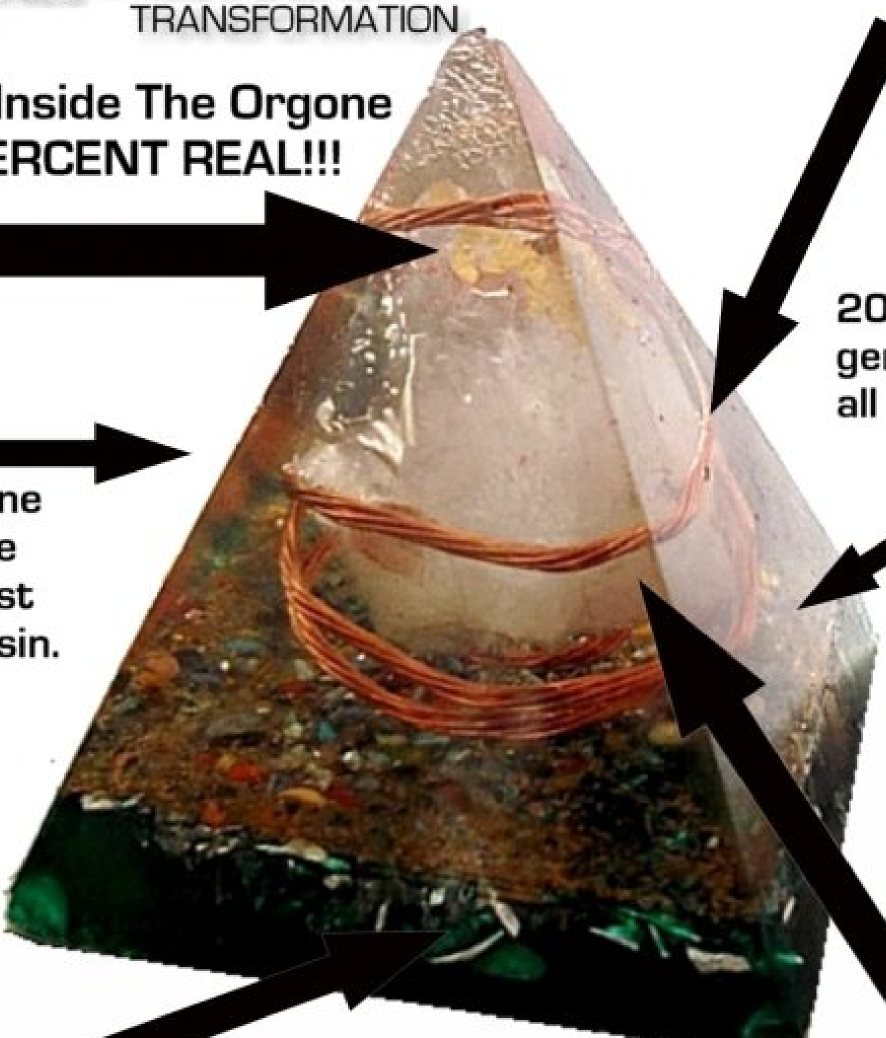

Our orgone
are made
out of best
suited resin.

20 Different types of
gemstone's
all listing below

magnesium & steel metal shaving's,
& small bits of copper
the smaller the better
as you can see !!!

larege QUARTZ
enhances energy by absorbing,
storing, amplifying, balancing,
focusing and transmitting.
It channels universal energy.
Quartz also enhances thoughts,
as they are a form of energy.
Because it directs and amplifies energy,
it is extremely beneficial for manifesting,
healing, meditation, protection,
and channeling.

LARGE PYRAMID

ORGONE-ENERGY.COM

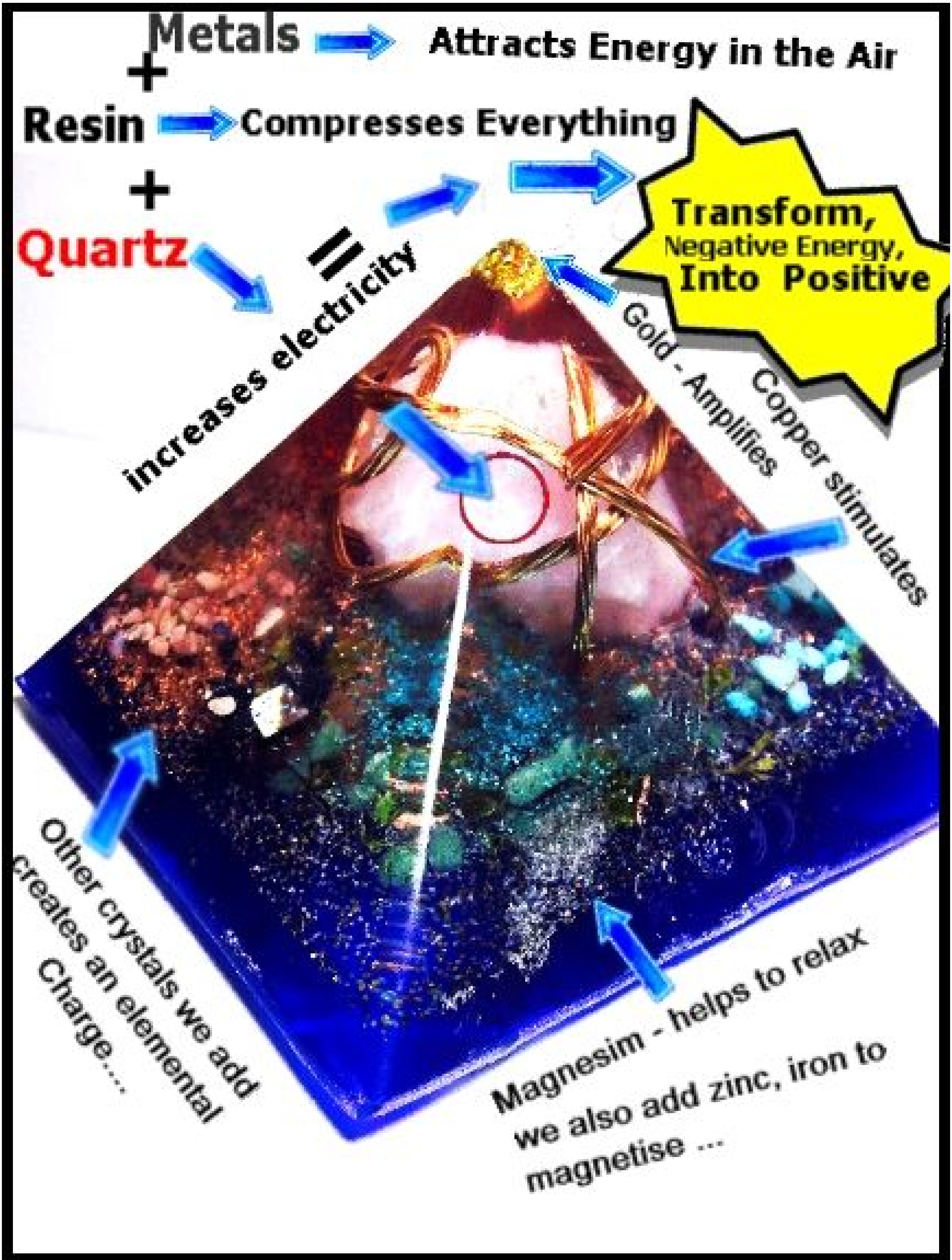

Metals → Attracts Energy in the Air

+

Resin → Compresses Everything

+

Quartz = increases electricity → **Transform,** Negative Energy, **Into Positive**

Gold - Amplifies

Copper stimulates

Other crystals we add creates an elemental Charge....

Magnesim - helps to relax

we also add zinc, iron to magnetise ...

A CHURCH WALL IN RUSSIA.

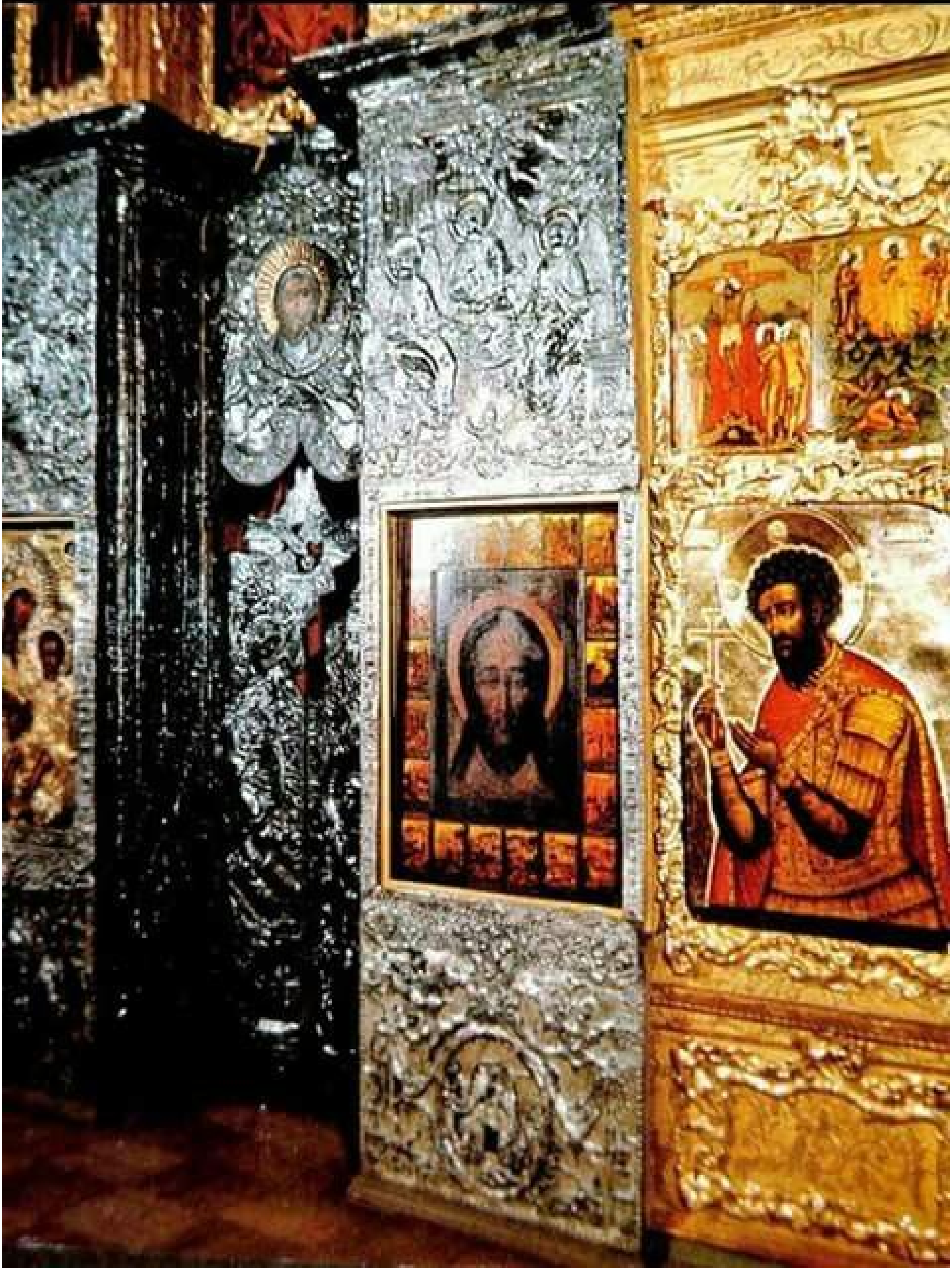

City of London

Finance

Vatican City

Religion

Washington D.C.

Military

All three are separate states, completely
independent of their respective countries.

GlacierDogMapMe: Pantheon, Vatican, Washington DC - What Were They Thinking!?

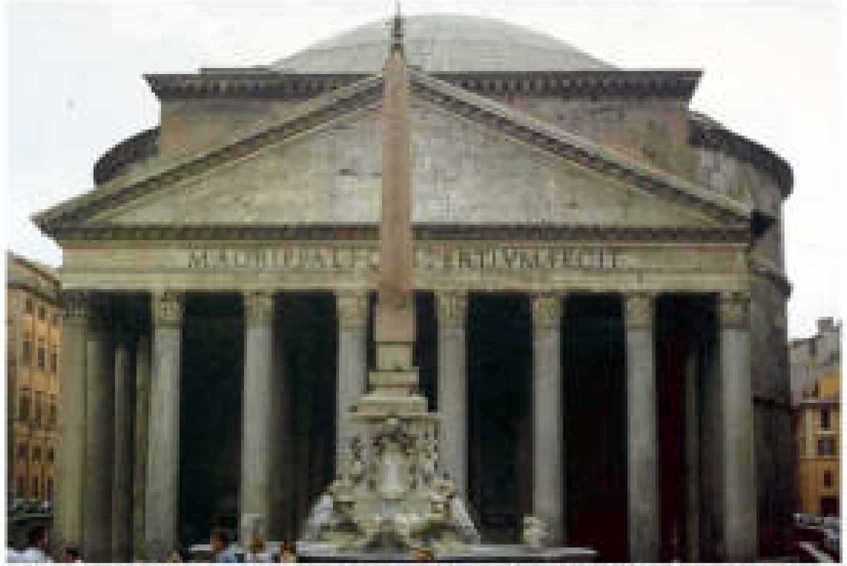

Roman Pantheon Dome facing Obelisk

http://www.historum.com/members/labienus-albums-roman~civilization-picture193-roman-pantheon.jpg;

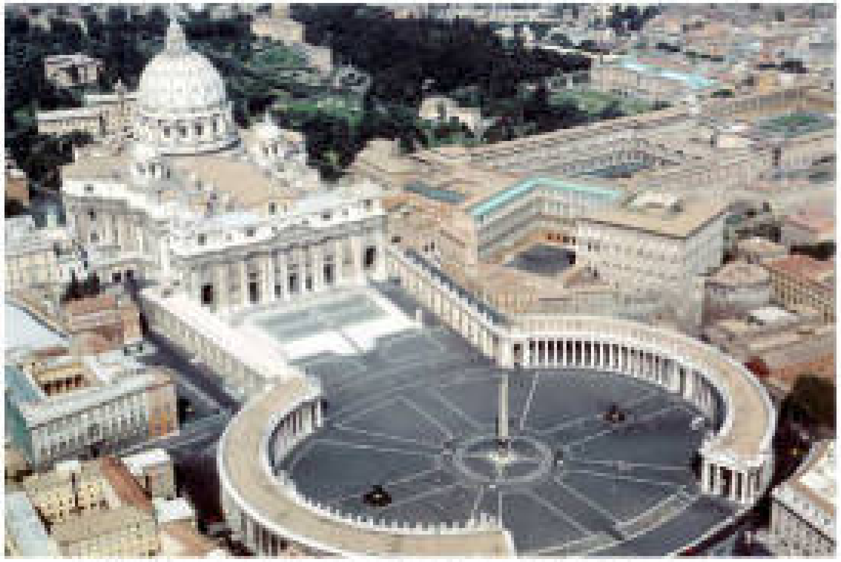

Vatican Dome facing Obelisk

http://www.raidersnewsupdate.com/leadstory70.htm

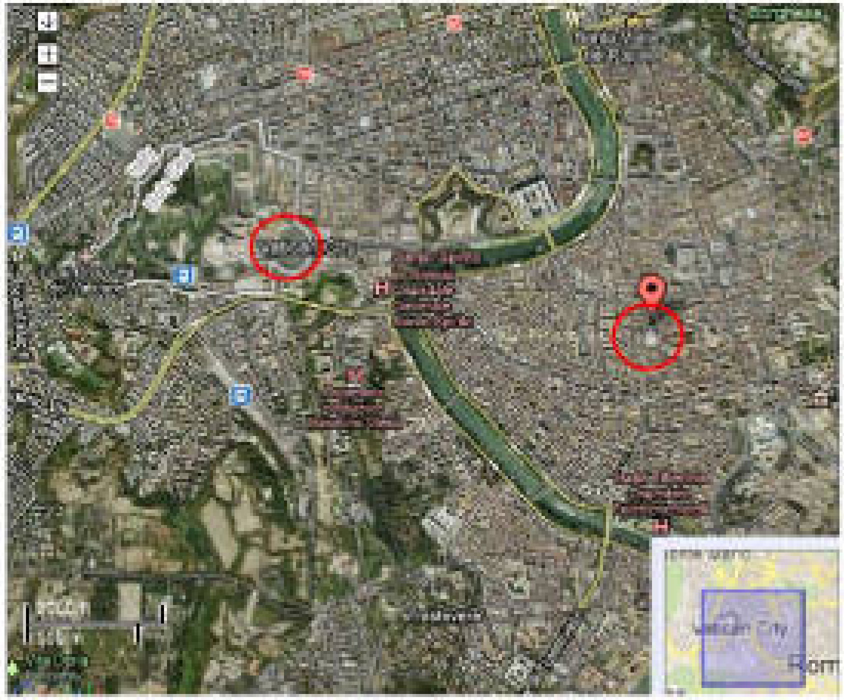

Above: Vatican City & Pantheon (red circles)

http://www.rome.info/map/

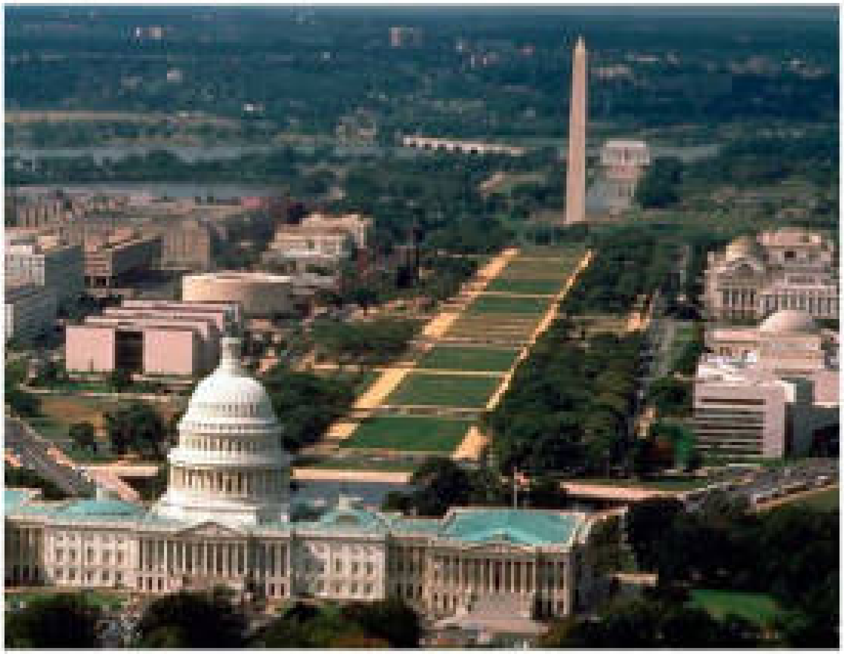

Washington DC Dome facing Obelisk

http://www.raidersnewsupdate.com/leadstory70.htm

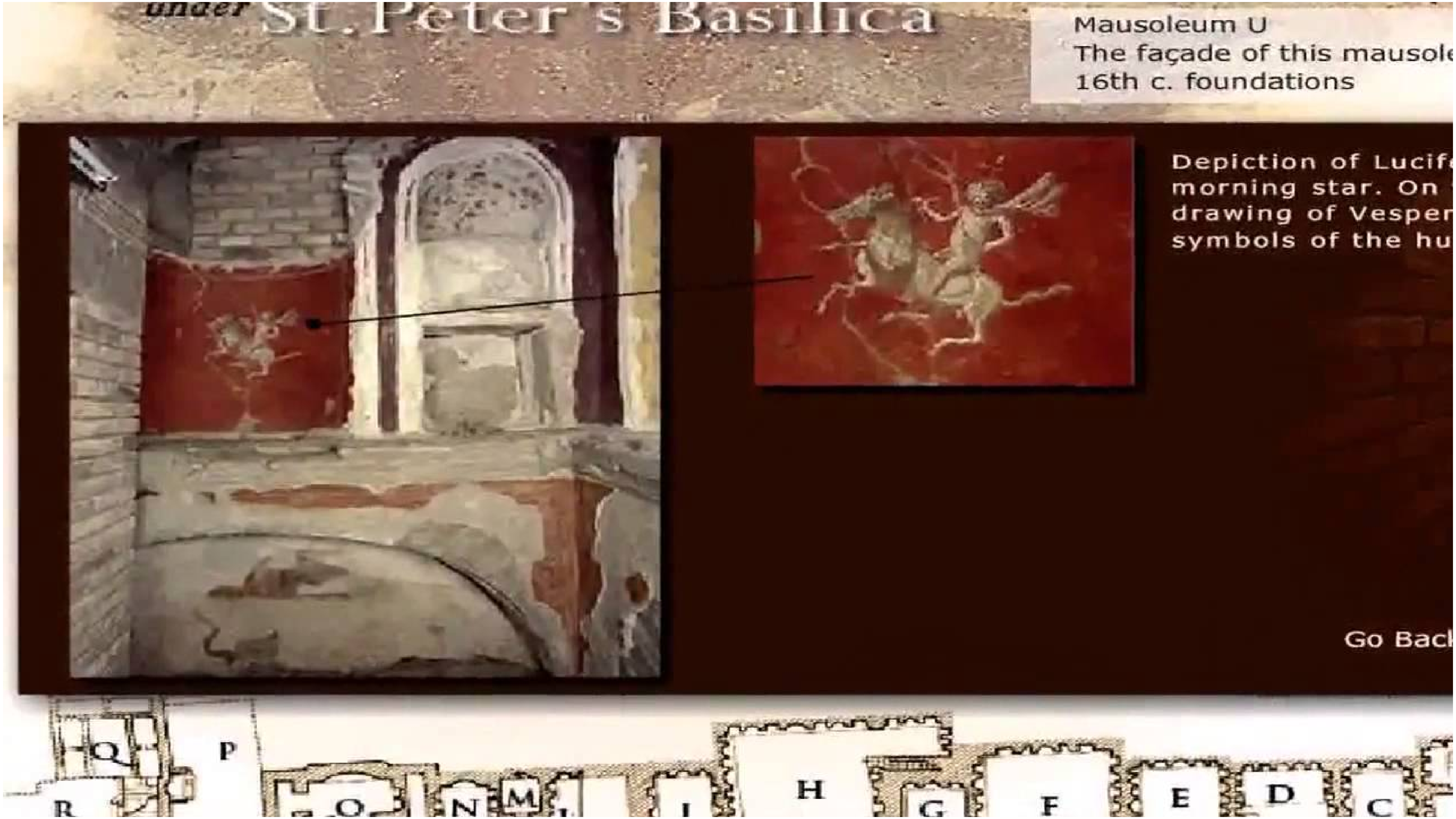

under St. Peter's Basilica

Mausoleum U
The façade of this mausole
16th c. foundations

Depiction of Lucif
morning star. On
drawing of Vesper
symbols of the hu

Go Back

POLARSTERN
POLARSTERN

THE BLACK CUBE OF SATURN

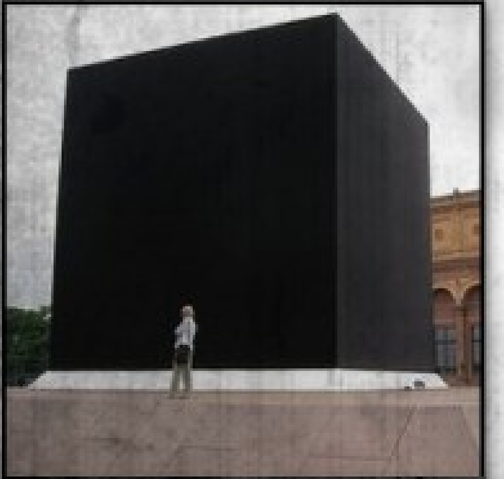
AUSTRALIA

DENMARK

MANHATTAN

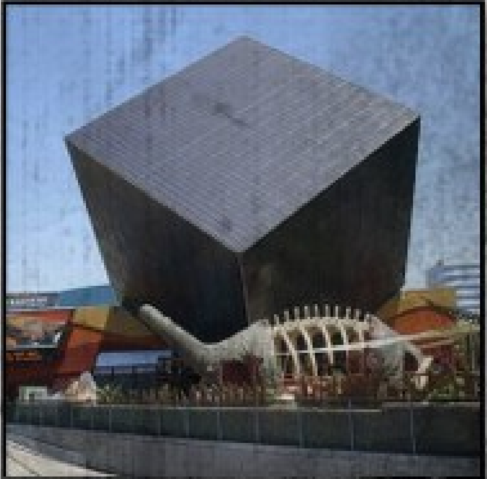
SANTA ANA

GLOBAL OCCULT WORSHIP

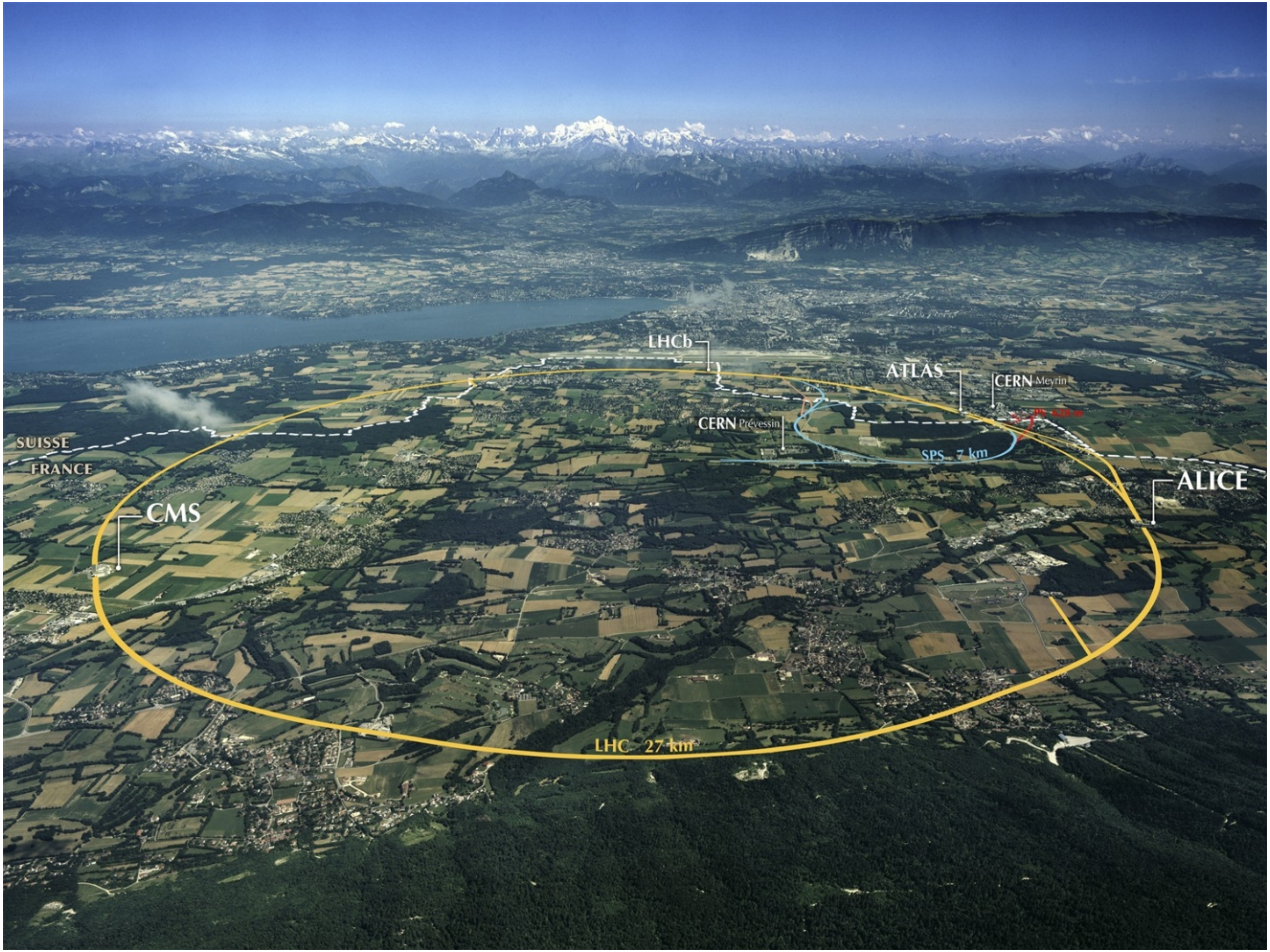
LHCb
ATLAS
CERN Meyrin
PS 628 m
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
ALICE
CMS
LHC 27 km

An overview of how the weapons are deployed by the Mind Control Police

Mass Remote Mind Control by Blanket Coverage of the Population which is achieved via the Mobile Phone Network

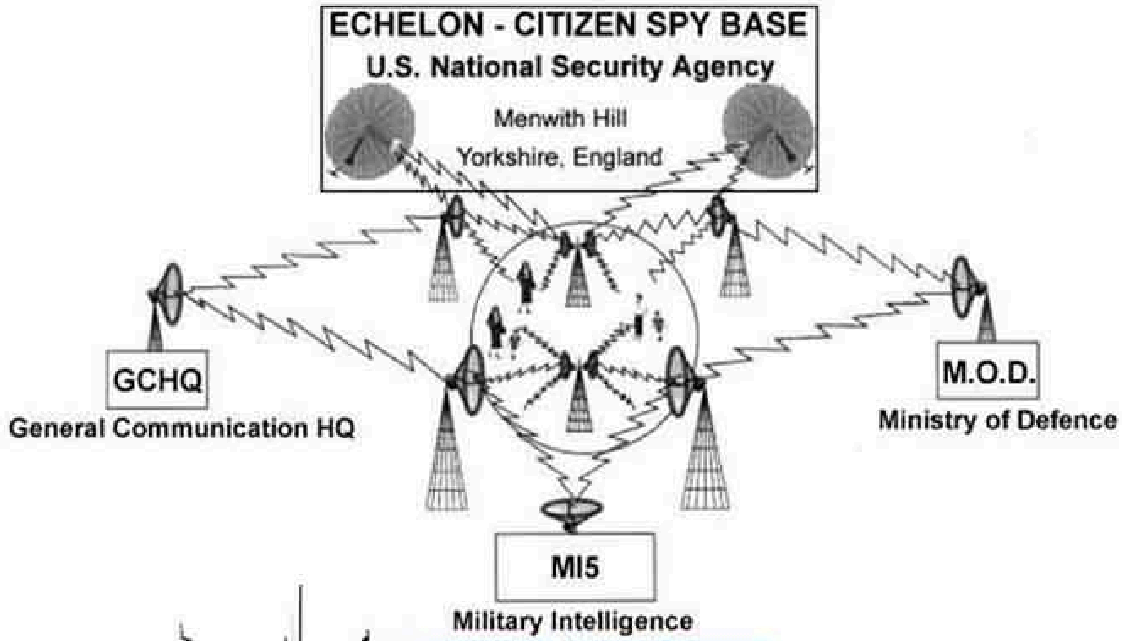
ECHELON - CITIZEN SPY BASE
U.S. National Security Agency
Menwith Hill
Yorkshire, England
GCHQ
General Communication HQ
M.O.D.
Ministry of Defence
MI5
Military Intelligence

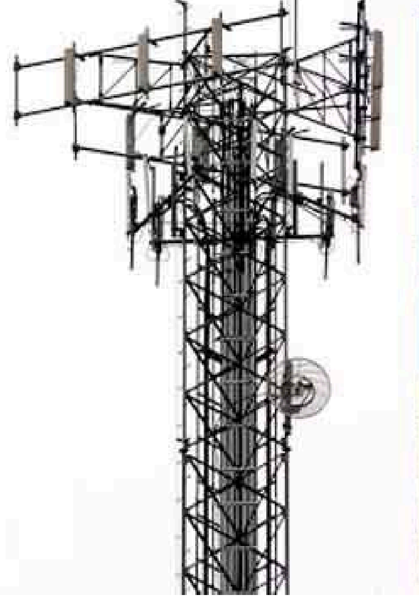

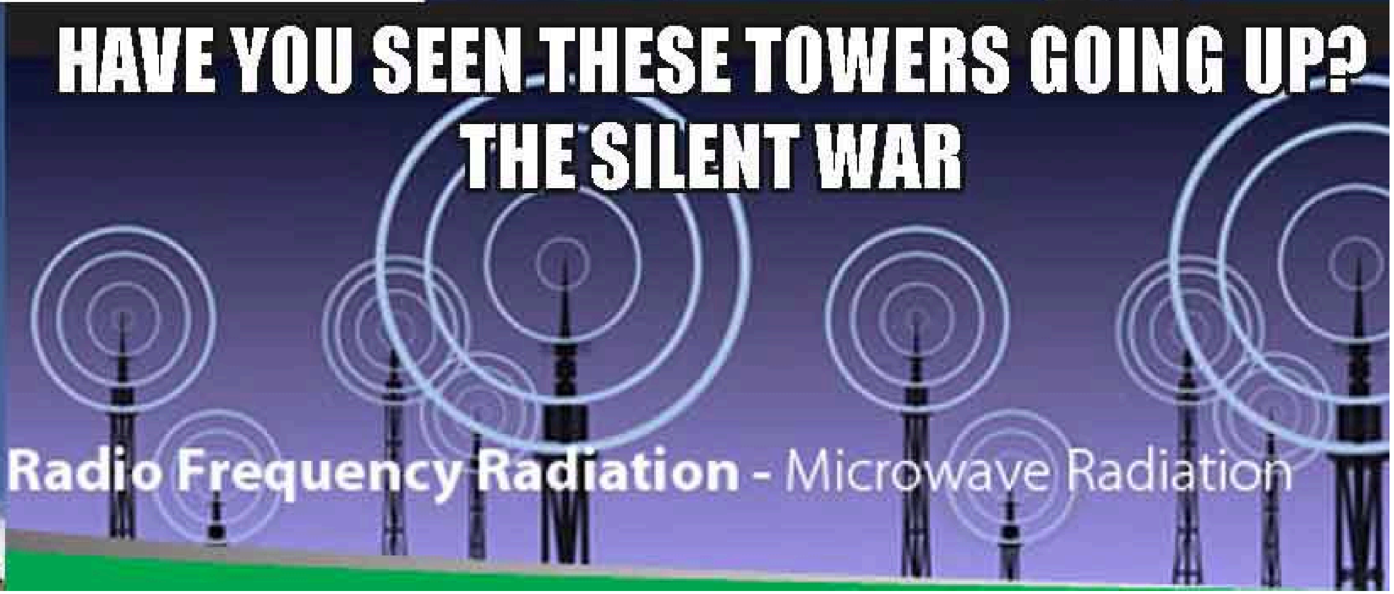
HAVE YOU SEEN THESE TOWERS GOING UP?
THE SILENT WAR
Radio Frequency Radiation - Microwave Radiation

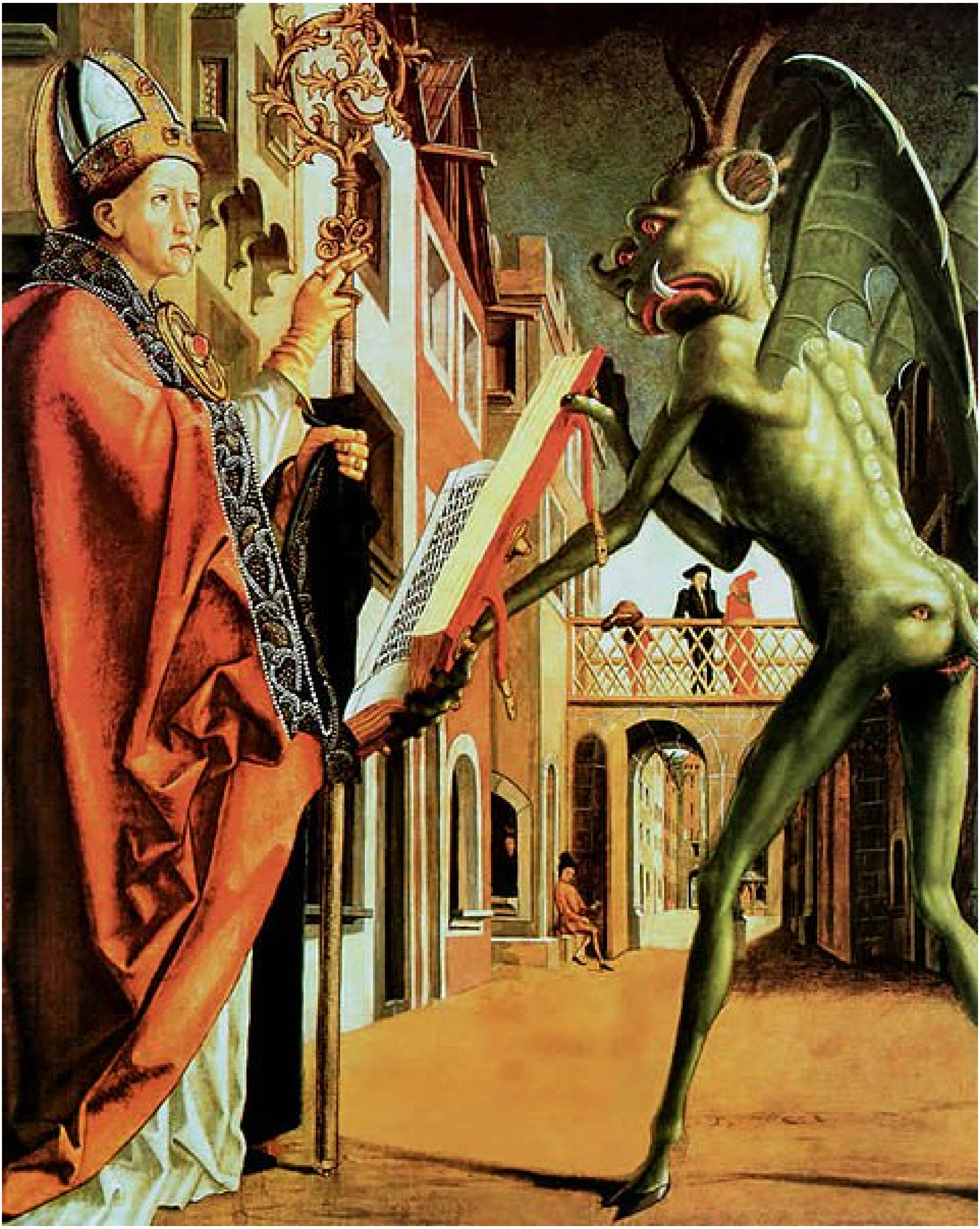

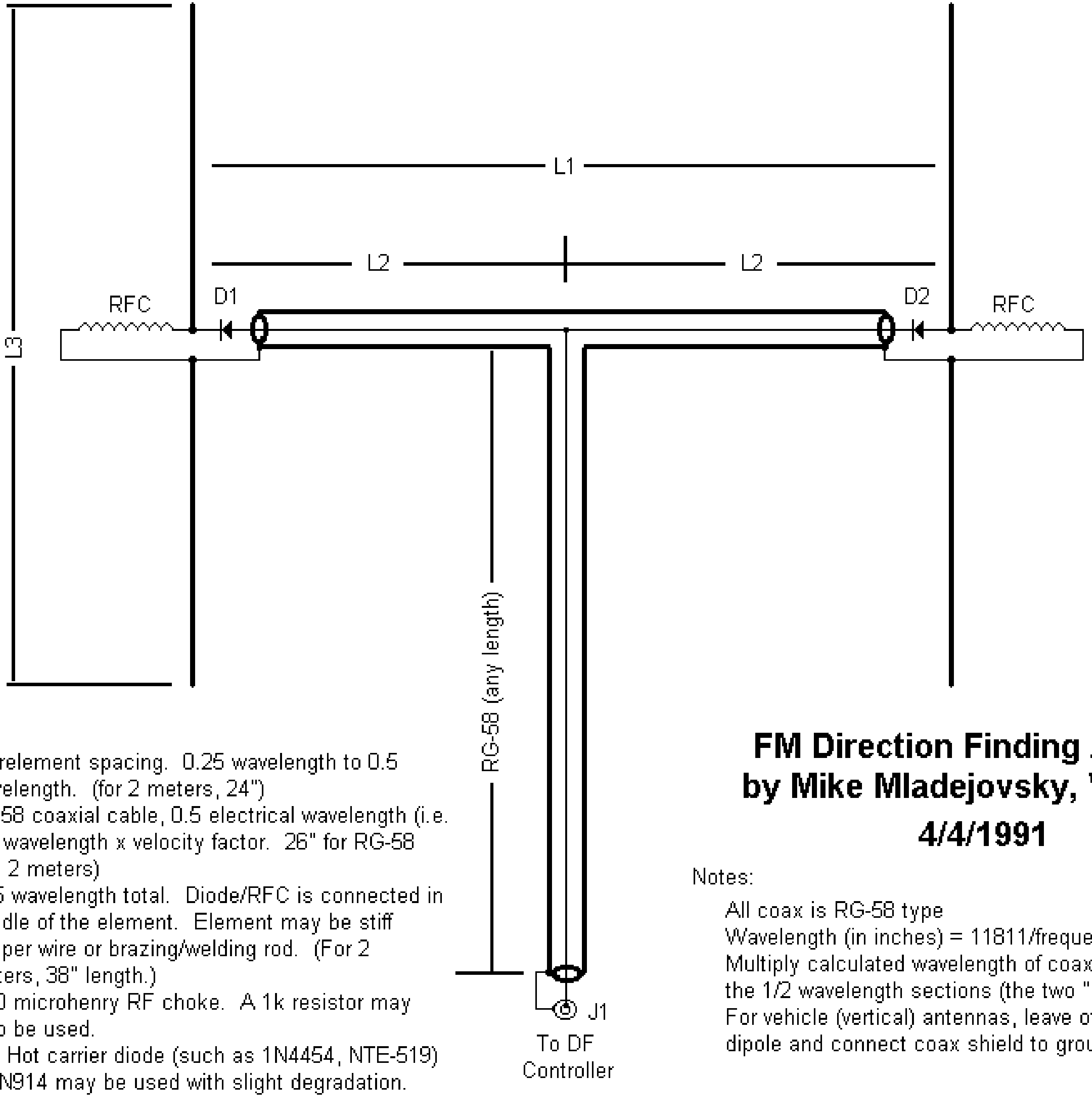

FM Direction Finding Antenna
by Mike Mladejovsky, WA7ARK
4/4/1991

L1 - Interelement spacing. 0.25 wavelength to 0.5 wavelength. (for 2 meters, 24")
L2 - RG-58 coaxial cable, 0.5 electrical wavelength (i.e. 0.5 wavelength x velocity factor. 26" for RG-58 and 2 meters)
L3 - 0.45 wavelength total. Diode/RFC is connected in middle of the element. Element may be stiff copper wire or brazing/welding rod. (For 2 meters, 38" length.)
RFC - 10 microhenry RF choke. A 1k resistor may also be used.
D1, D2 - Hot carrier diode (such as 1N4454, NTE-519) A 1N914 may be used with slight degradation.
J1 - BNC (or other suitable) connector

Notes:

All coax is RG-58 type
Wavelength (in inches) = 11811/frequency (MHz)
Multiply calculated wavelength of coax. by velocity factor for the 1/2 wavelength sections (the two "L2" sections)
For vehicle (vertical) antennas, leave off bottom of each dipole and connect coax shield to groundplane.

THE crystal set has always enjoyed a certain measure of popularity, and such receivers have undoubtedly been constructed in large numbers over a period of many years. Modern developments have enabled the old-fashioned crystal detector, which had to be adjusted by hand, to be eliminated, but before going on to consider the kind of results which may be expected, the factors which have made crystal receivers so popular should be noted. Such a receiver forms a stand-by always ready for use when required and is, of course, wholly independent of any mains or battery supply. It therefore allows local programmes to be heard when the main receiver is out of commission, either from power cuts or other breakdown, or because batteries have run down and no replacement is at the moment available. Such a receiver can also be used in a bedroom, or when it is desired to listen to a certain programme personally. There are *no* running costs, and no licence is required when this is already obtained for another receiver. The initial cost is low, while circuit and constructional details are such that no difficulty whatever should be experienced by anyone making up the receiver, even if they have done no work of this kind before. Furthermore, if some wrong connection *were* made no damage is caused, and the receiver would work correctly when the error was rectified. This is by no means so with valve receivers, where valves or other components may, in some cases, be damaged by the application of wrong voltages, or other errors in connecting up.

Results to Expect

The receiver is simply switched on, as with a valve set, when required, a 3-way switch providing " Off," " Medium Wave " and " Long Wave " positions. The range at which transmissions may be picked up, and the volume obtained, depends to a large extent on local conditions, and particularly upon the aerial and earth system. Used in the Midlands, the receiver picked up a few of the more powerful continental stations with surprising strength : it also provided " Light " and " Home " programmes at excellent volume, and the Third programme at sufficient strength for prolonged listening with ease. These results were obtained with a 50ft. outdoor aerial, plus the usual earth. With the aerial removed, Home and Light programmes were audible but weak. With an indoor aerial volume was restored to a perfectly satisfactory level. The long outdoor aerial, with no earth, gave rather poor volume, which was still further reduced when using the indoor aerial alone. It is, therefore, very desirable that an earth connection be arranged, even if the receiver is used upstairs. An indoor aerial would be satisfactory in many areas for local reception.

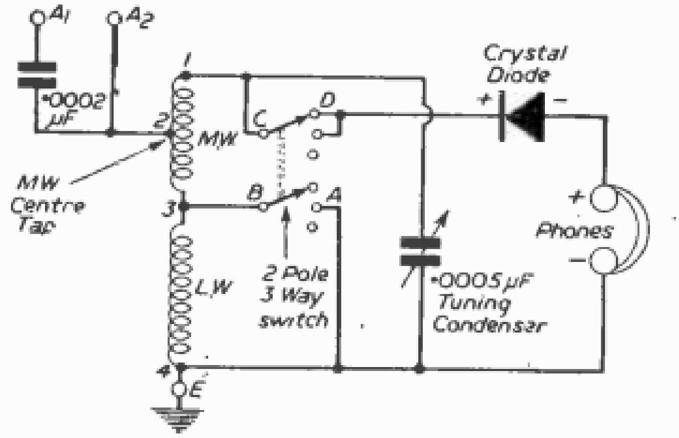

Fig. 1.—Circuit of the crystal receiver.

These details should serve as a guide, but reception conditions vary throughout the country. In some areas the Third programme transmissions are not well received, even with a valve set.

Circuit Details

An air-cored coil of fairly large size is generally best for such a receiver, and has the added advantage that it can be wound easily by the constructor who

COMPONENTS FOR THE DUAL-WAVE " CRYSTAL DIODE."

J.B. Standard .0005 μF. tuning condenser with mounting feet. (Coventry Radio.)
Type C1065.S. 2¼in. knob. (Coventry Radio.)
7/8th in. diameter knob (Coventry Radio).
2-pole 3-way wafer-type rotary switch. (Coventry Radio.)
Five 4 B.A. terminals type C2512. (Coventry Radio.)
.0002 μF. fixed condenser (Dubilier, etc.). (Coventry Radio.)
Crystal diode with mounting brackets. (Post Radio Supplies.)
Brown Bakelite Panel 6in. x 4in. x ⅛in. thick. (Post Radio Supplies.)
Terminal Strip 6in. x 1in. x 1/16in. (Post Radio Supplies.)
Coil former 3in. by 1⅜in. diameter, 2 oz. 28 S.W.G. enamelled wire, and 2 oz. 34 S.W.G. D.S.C. wire. (Post Radio Supplies.)
Wood for baseboard, screws, etc.

wishes to make his own coil. A compromise has to be made between selectivity and volume, and two aerial terminals are fitted so that the user can select that most suitable for local conditions. When aerial terminal "A2" is used the aerial is taken to a centre-tap on the medium-wave section of the coil, and this gives fair selectivity and good volume. Using terminal "A1" brings in a fixed condenser of .0002μF. This particularly increases selectivity on long waves, and helps to prevent long wave break-through where the receiver is used close to a long wave transmitter.

The receiver is switched off when not required as mentioned. The correct polarity is indicated for the "Phone" terminals because a steady direct current of about 50 microamperes flows, when the receiver is tuned to a local transmitter, and with some types neat cabinet. The panel is 4in. by 6in. and the receiver 5 $\frac{3}{16}$in. deep, excluding terminals. The polished brown bakelite panel specified ensures that the final appearance is satisfactory. No reduction drive is used with the tuning condenser, as this is scarcely necessary. The large knob, with skirt and engraved line, proves perfectly satisfactory for tuning. (The suppliers of this knob can also provide a knob with scale, and this could be used instead if the constructor prefers.)

In addition to the specified crystal diode, other similar detectors are available. The Sylvania 1N22 or CV102 may be used and have similar dimensions and characteristics. A second-hand detector (e.g., one taken from used ex-Service apparatus) is not

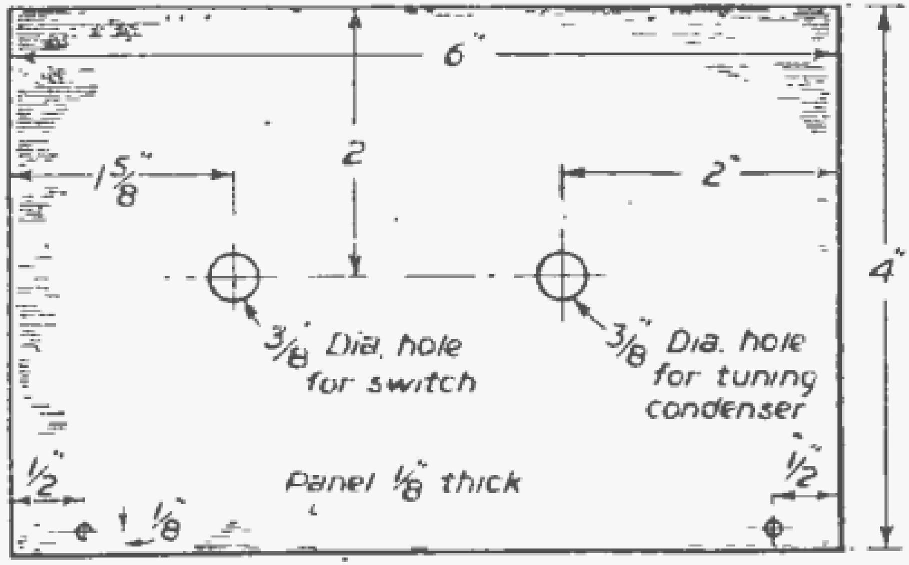
6"
2
1 5/8"
2"
4"
3/8" Dia. hole for switch
3/8" Dia. hole for tuning condenser
1/2"
Panel 1/8" thick
1/2"
1/8"

Fig. 2.—Details of the panel.

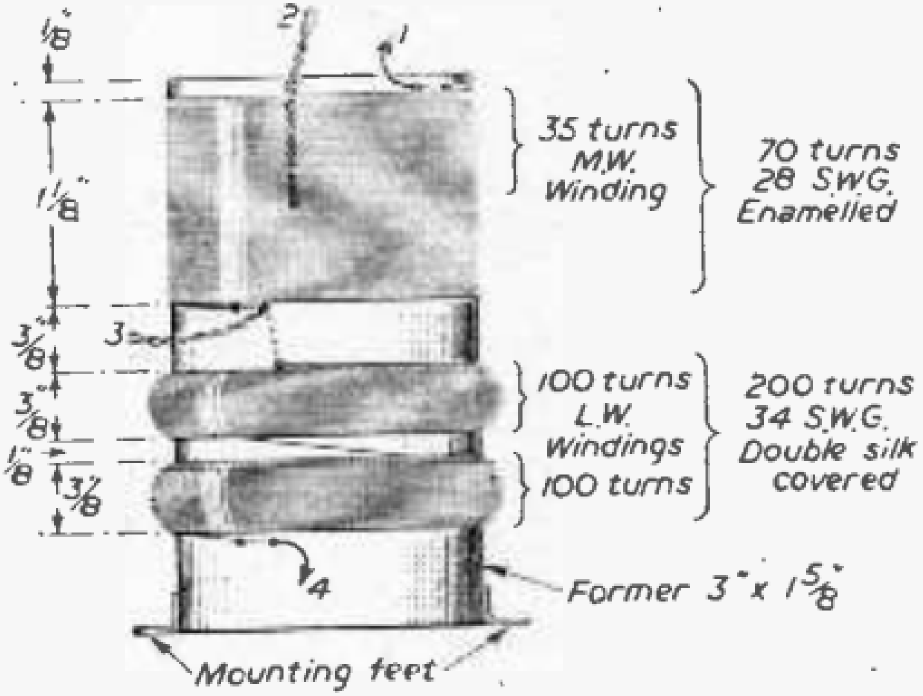
2
1
1/8"
1 1/8"
35 turns M.W. Winding
70 turns 28 S.W.G. Enamelled
3
3/8"
3/8"
1/8"
3/8"
100 turns L.W. Windings
100 turns
200 turns 34 S.W.G. Double silk covered
4
Former 3" x 1 5/8"
Mounting feet

Fig. 3.—Coil data.

of headphones this could cause some slight eventual demagnetisation, if the phones were wrongly connected.

Points on Construction

The overall dimensions have been kept down so that the completed receiver can be housed in a small,

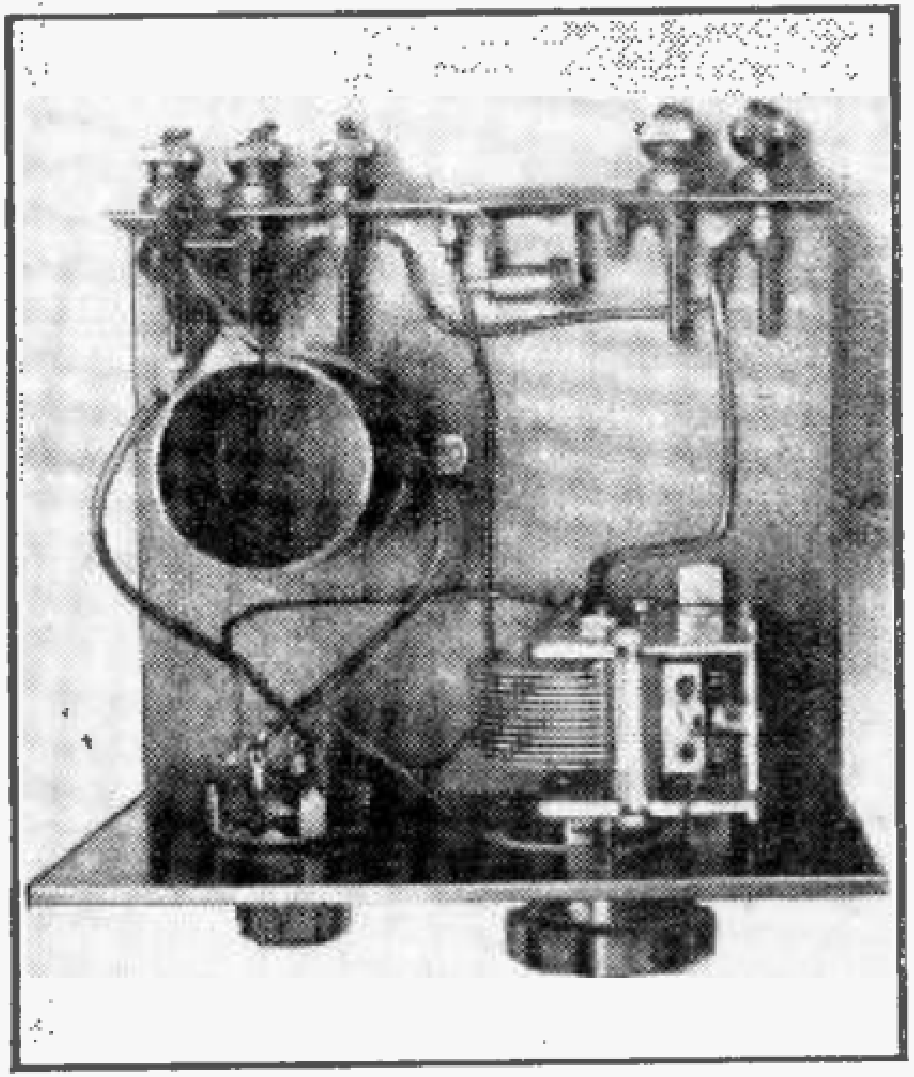

Plan view of the receiver.

recommended, as it may have been misused, or had its sensitivity reduced. When using the 1N22 type, the large end may need scraping because these have a screw which is subsequently covered with hard varnish so that no electrical contact may exist between the detector and mounting brackets.

In order that the tuning control may be in a central position, the tuning condenser is raised by ½in., and this can be done by placing ½in. bushes under the fixing brackets, or by placing a piece of wood roughly 2in. square by ½in. thick under the condenser before screwing it in position.

Rotary switches of the type illustrated are manufactured in certain sizes, and a lesser number of contacts than the maximum number which can be accommodated on the switch may be found. The same type of wafer is used for both 2, 3- and 4-pole switches. As only two poles are required, the other contact tags are ignored, if fitted to the switch. If they are not fitted, part of the wafer may appear blank. These points sometimes appear to confuse constructors who have never used this type of switch before, but if a 2-pole, 3-way switch is ordered they can be sure that this is suitable, and if extra contacts are found on the actual component, these are disregarded.

The diagram makes the construction of the coil quite clear. The dimensions between the respective windings are not critical, but given as a guide to the disposition of the windings. The ends are secured by passing them through small holes in the former, and should be left 4in. or 5in. long to reach to the various parts in the receiver. Point " 2 " is formed by making a loop in the wire, and point " 3 " will consist of *two* ends of wire, twisted together—the junction between medium- and long-wave sections of the coil. All turns must be wound in the same direction.

Aerial, Earth and Phones

The best aerial is a fairly long, outdoor one, situated as far as possible from buildings and other earthed objects, and as high as possible. However, circumstances often prevent such an aerial being erected, and good results can be obtained with other types. Whatever kind of aerial is used, it should be insulated by using one or two aerial insulators at the points of suspension. The down-lead should not descend against the house wall, but be kept a few feet away, if possible. Losses will then be avoided (and these can be severe in wet weather, if the down-lead is attached to brickwork), and signal pick-up increased. An average outdoor aerial could consist of about 50ft. of wire, this forming both the down-lead and horizontal portion. If space permits, a longer aerial can be used, with some slight increase in volume.

An indoor aerial can be made from any insulated wire, which is usually placed round the picture rail, against the wall. It is sufficient to take the wire along two walls of the room. If it can only be taken along one wall, sufficient volume may still be obtained, though the wire is then likely to be somewhat short. In a bedroom, results with the aerial at floor level will be found to be similar to those when the wire is near the ceiling. Under reasonable conditions an indoor aerial should be satisfactory. However, it cannot provide as much signal pick-up as a good outdoor aerial. If the building has a metal fabric or steel framework then an outdoor aerial is likely to be essential.

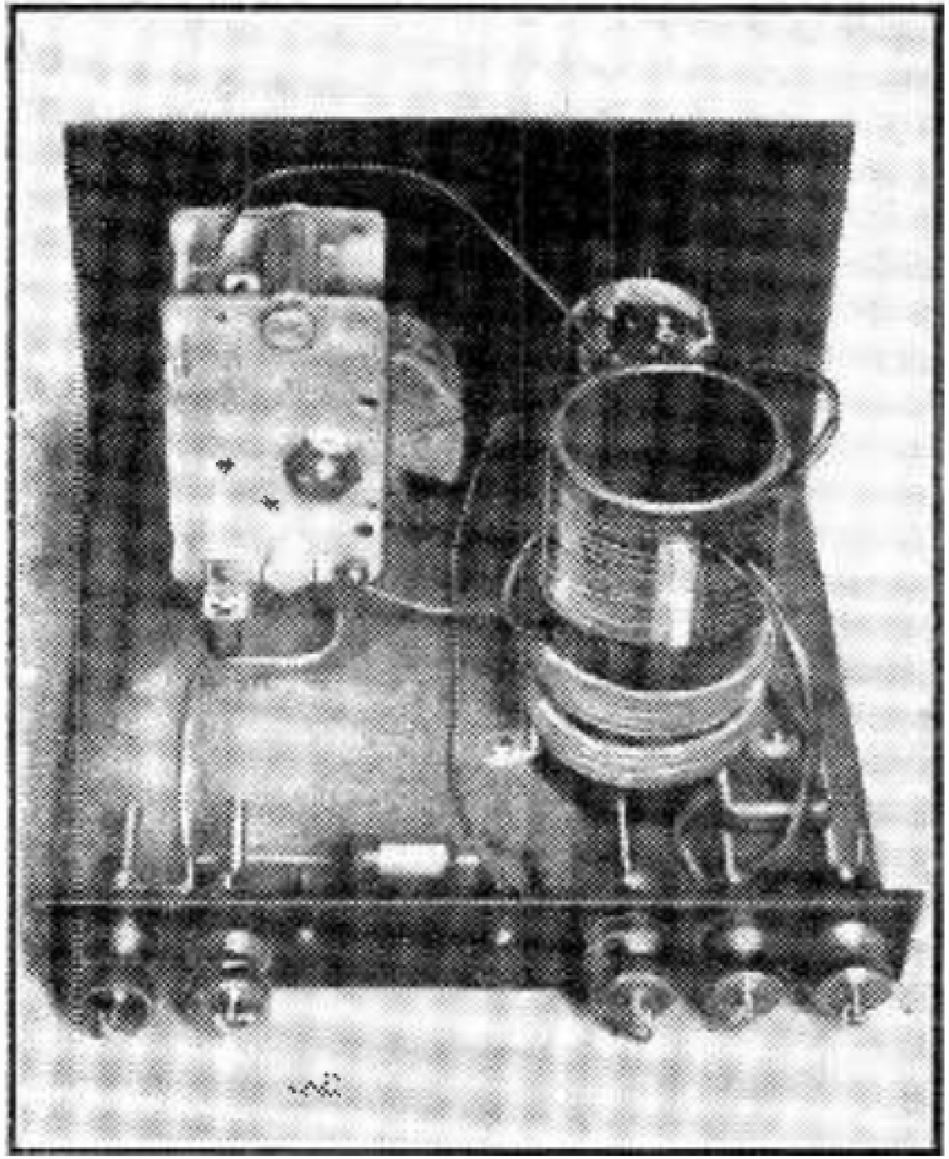

Another view of the receiver.

type not likely to corrode). In some cases an earth-

The earth lead should be taken to a metal object actually buried out of doors. Earthing spikes are obtainable for this purpose, or the wire may be securely attached to any metal object (preferably of a

ing point may be available in the house, or a descending water main can be used.

A wide variety of headphones can be operated with success, but *low* impedance headphones are *not* suitable. Balanced-armature headphones, now readily obtainable, are satisfactory; so are medium- and high-impedance phones of all types. Moving-coil phones are not suitable, being of low impedance. If it is particularly desired to use such phones, or other low-impedance types which may be to hand, then a matching transformer is required. The primary of this should be connected to the phone terminals on the receiver, and the headphones should be taken to the transformer secondary. The transformer *must* be of correct type for the phones used; if it is not, volume will be reduced. The usual speaker-matching transformer is *not* suitable for most moving-coil phones, as the latter are of somewhat higher impedance than the normal loudspeaker.

A ready-made cabinet for the receiver may be obtained from James Tallon & Sons, Ltd., Manor Works, Manor Road, Rugby.

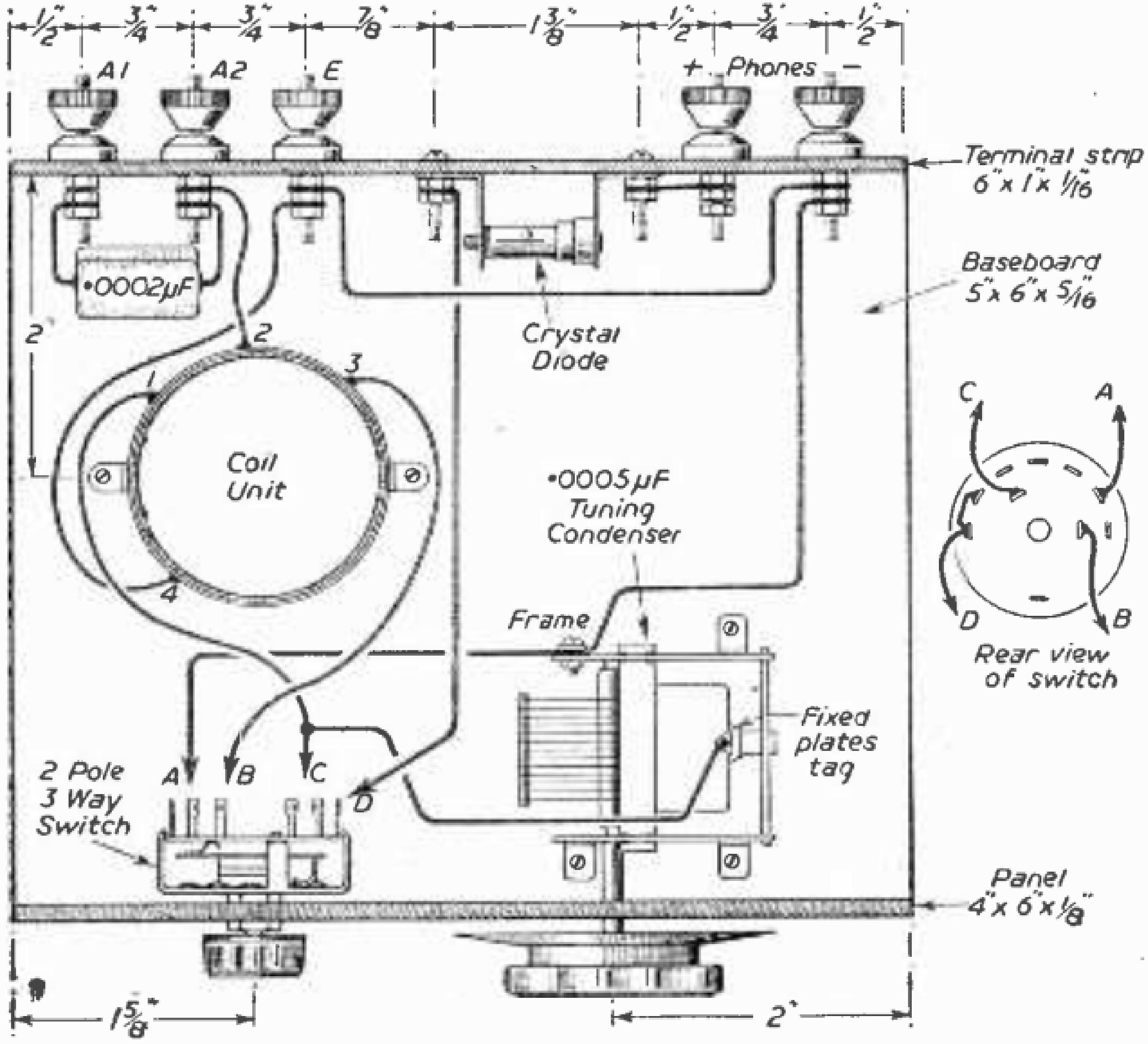

1/2"
3/4"
3/4"
7/8"
1 3/8"
1/2"
3/4"
1/2"
A1
A2
E
+ Phones −
Terminal strip 6"x1"x1/16"
Baseboard 5"x6"x5/16"
·0002μF
2"
2
3
1
4
Coil Unit
Crystal Diode
·0005μF Tuning Condenser
Frame
Fixed plates tag
2 Pole 3 Way Switch
A
B
C
D
C
A
D
B
Rear view of switch
Panel 4"x6"x1/8"
1 5/8"
2"

Fig. 4.—Wiring diagram of the receiver and switch.

Tesla's "radiant energy receiver" of 1901 used a metal plate P and a capacitor C to collect charged particles from space, which were then discharged into a receiver R, that consisted of an electromagnet M coupled to a mechanical wheel w.

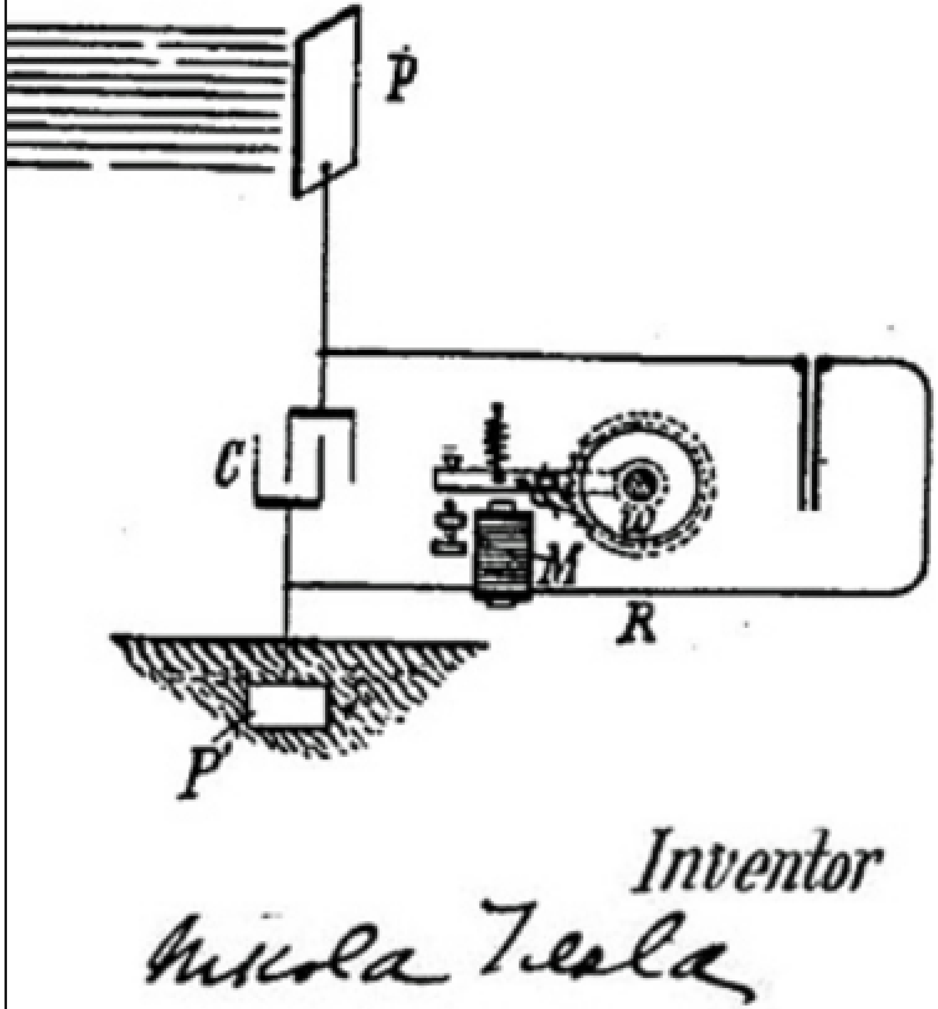

The crop artist device seems to use a dipole antenna to collect electromagnetic waves or particles from space, which then induce weak AC currents that turn a series of self-exciting homopolar generators.

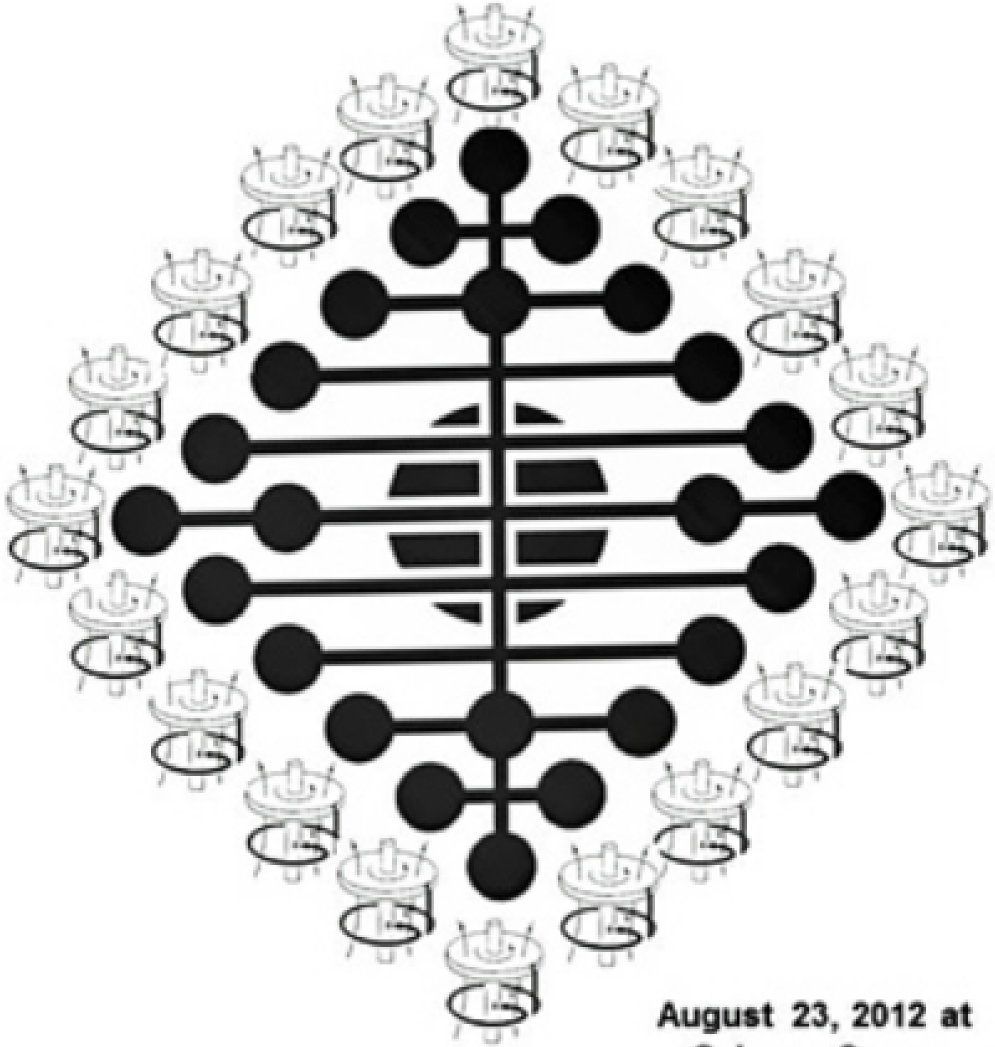

August 23, 2012 at
Oxleaze Copse

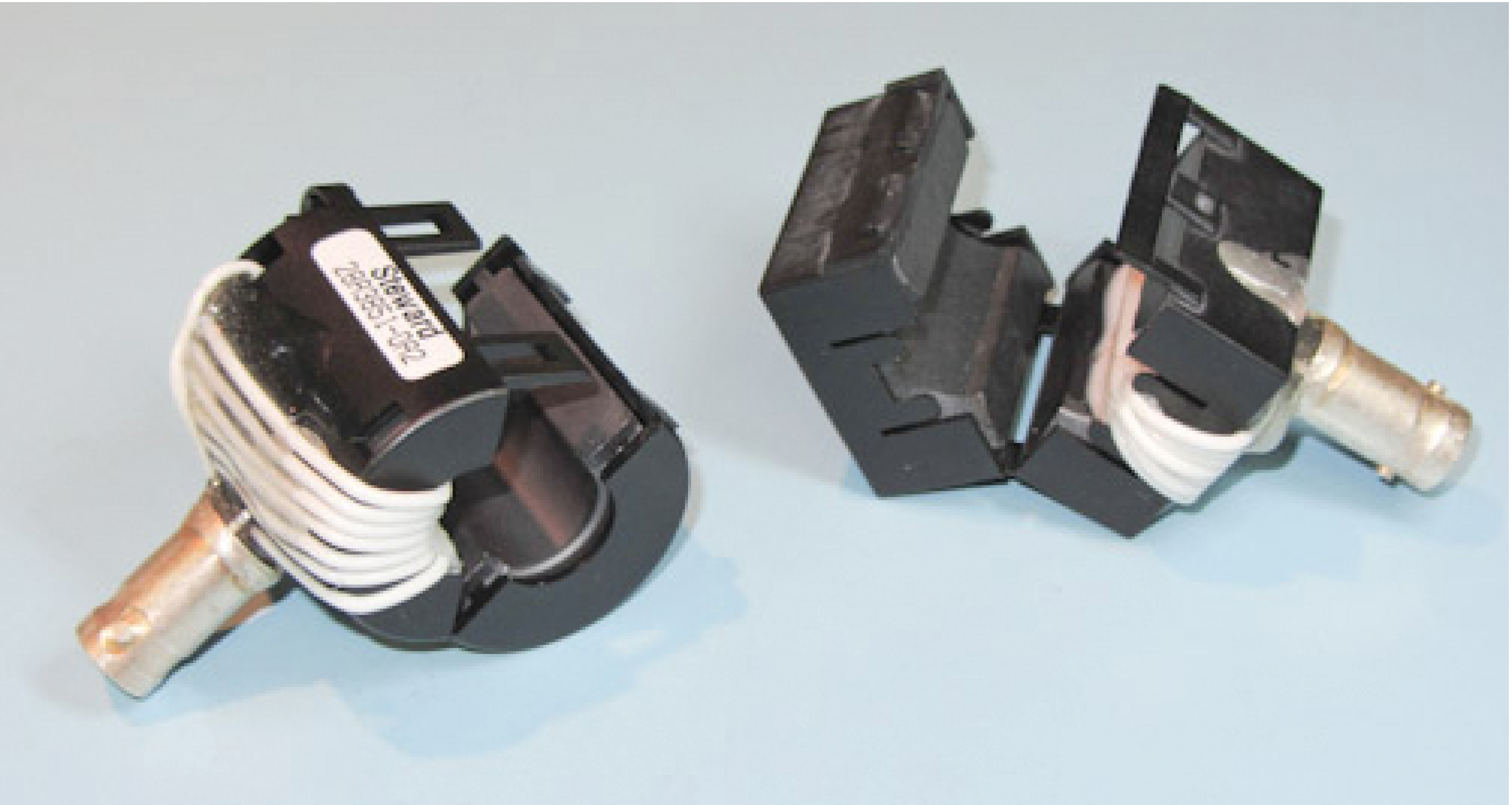
Steward

1. Mahlon Lumis (США) уже в середине XIX века применил пламенные ионизаторы для питания атмосферным электричеством телеграфной связи в Западной Вирджинии
2. Walter Pennock (США) предложил систему для собирания атмосферного заряда на сетки, подвешенные к аэростатам из металлизированной ткани. Энергия накапливалась в лейденских банках
3. Herman Plauson (Германия) впервые предложил полную систему для получения и преобразования атмосферного электричества в энергию обычного стандарта. Электрический заряд, накапливаемый поверхностью приемников, с помощью инвертора превращался в ток промышленного стандарта. Мощность опытных установок от 0,72 до 3,4 кВт.
4. Современная установка для питания от атмосферного электричества метеорологической аппаратуры. Россия. Патент RU 2245606 (2003 г.)

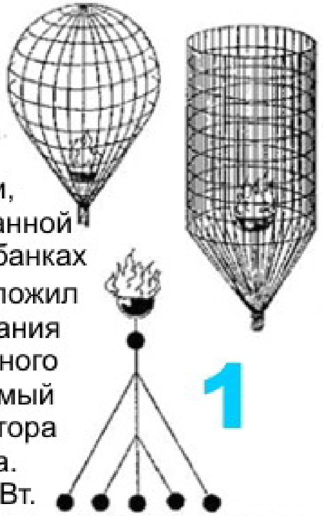

Methods Suggested by Loomis for the Harnessing of Electricity from the Atmosphere

June 9, 1925. 1,540,998

H. PLAUSON

CONVERSION OF ATMOSPHERIC ELECTRIC ENERGY

Filed Jan. 13, 1921 12 Sheets-Sheet 1

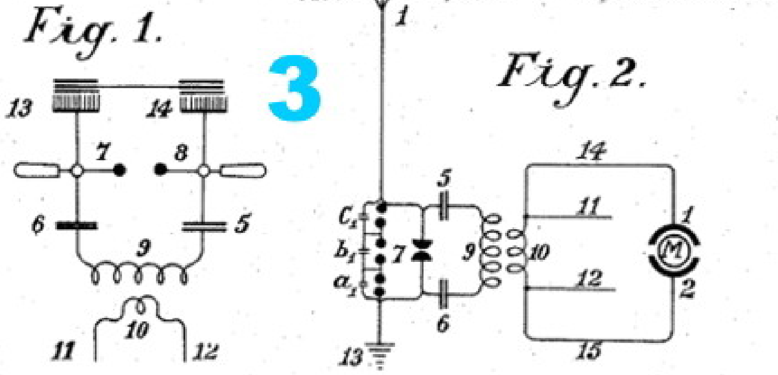
3
Fig. 1.
13
14
7
8
6
5
9
10
11
12
Fig. 2.
1
5
C₁
b₁
a₁
7
9
10
14
11
12
1
M
2
6
13
15

W. I. PENNOCK.

APPARATUS FOR COLLECTING ELECTRICAL ENERGY.

APPLICATION FILED JAN. 4, 1911.

1,014,719. Patented Jan. 16, 1912.

2 SHEETS—SHEET 1.

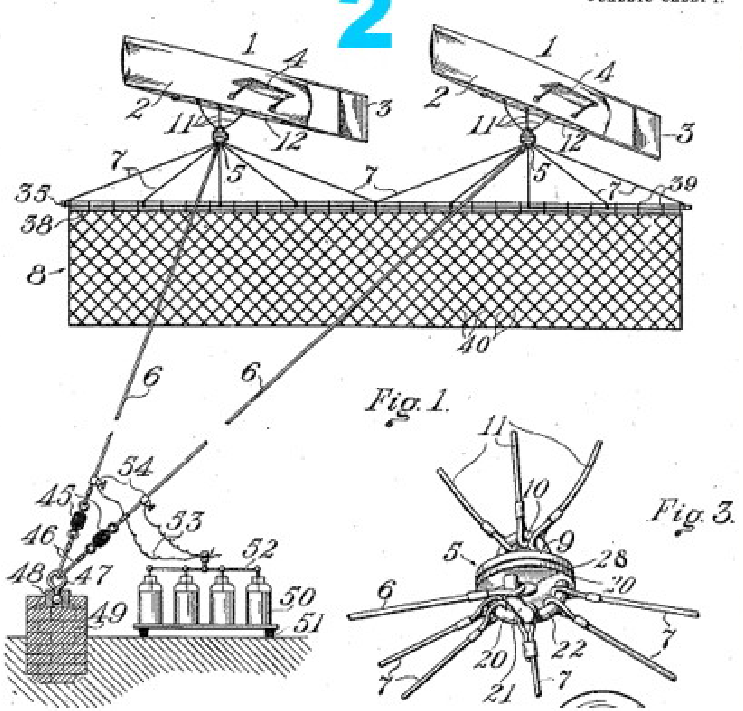
2
1
4
2
3
11
12
7
5
35
38
8
39
40
6
6
Fig. 1.
54
45
53
46
52
48
47
49
50
51
11
10
5
9
28
20
6
Fig. 3.
7
20
22
7
21
7

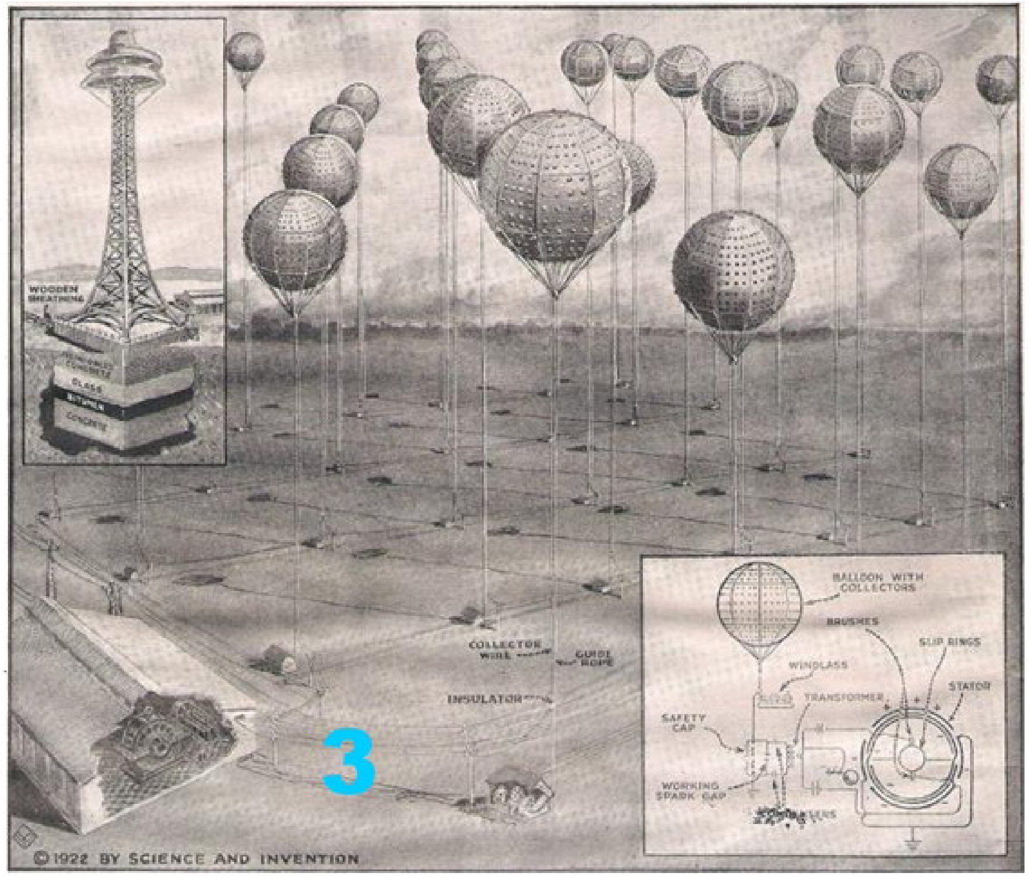
WOODEN SHEATHING
GLASS
BITUMEN
CONCRETE
COLLECTOR WIRE
GUIDE ROPE
INSULATOR
3
BALLOON WITH COLLECTORS
BRUSHES
SLIP RINGS
WINDLASS
TRANSFORMER
STATOR
SAFETY CAP
WORKING SPARK GAP

© 1922 BY SCIENCE AND INVENTION

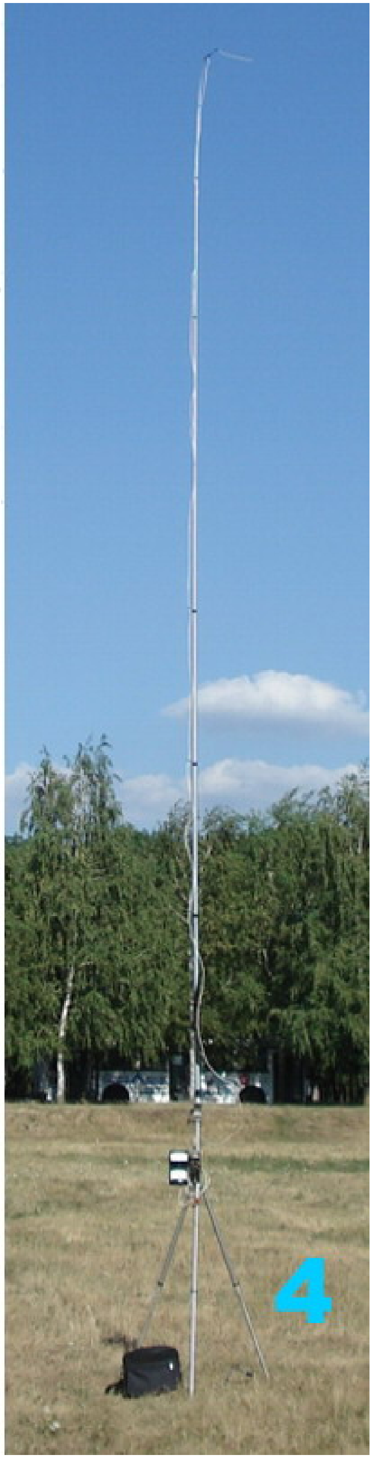

Pacific Antenna 15 Watt Dummy Load Kit

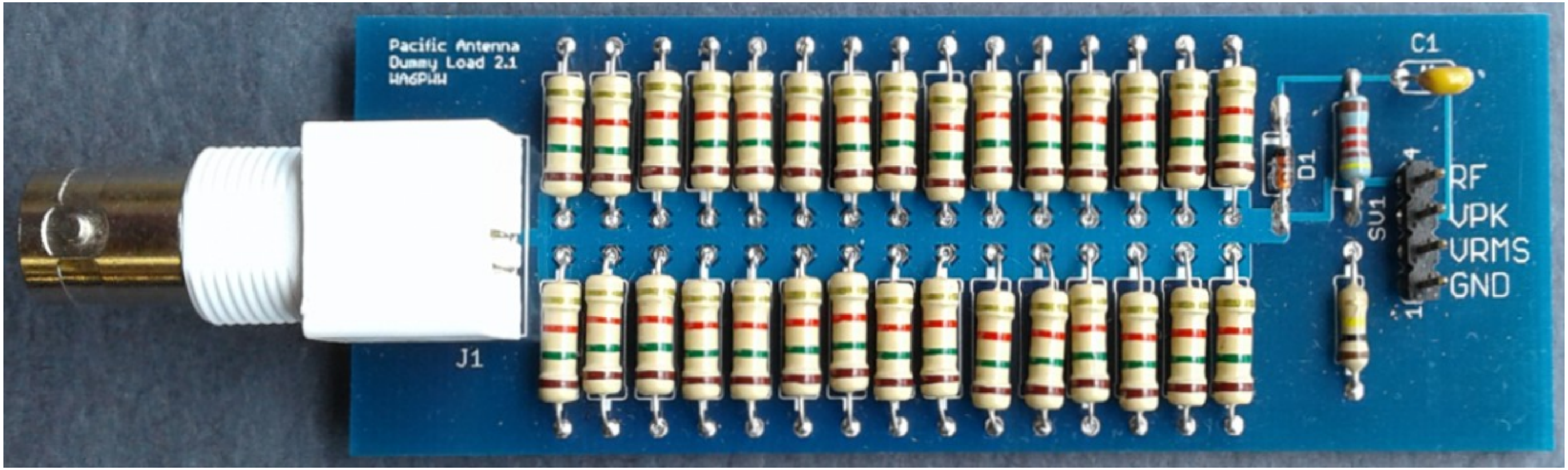
Pacific Antenna
Dummy Load 2.1
WA6PWW
J1
C1
D1
SV1
RF
VPK
VRMS
GND

Inspection and Inventory

First, check the kit to be sure all parts are included. Should anything be missing, please contact us for a replacement.

30 – R1-R30, 1.5 K 1/2 watt resistors: Brown-Green-Red-Gold
1 – R55: 41.2K 1/4W, 1% resistor: Yellow-Brown-Red-Red--Brown
1 – R56: 100K 1/4W, 5% resistor: Brown-Black-Yellow-Gold
1 – D1: 1N4148 diode
1 – C1: 0.01uF monolythic capacitor, yellow, (marked 103)
1 – J1: BNC board mount connector
1 – SV1: 4 pin header
1 – Circuit board

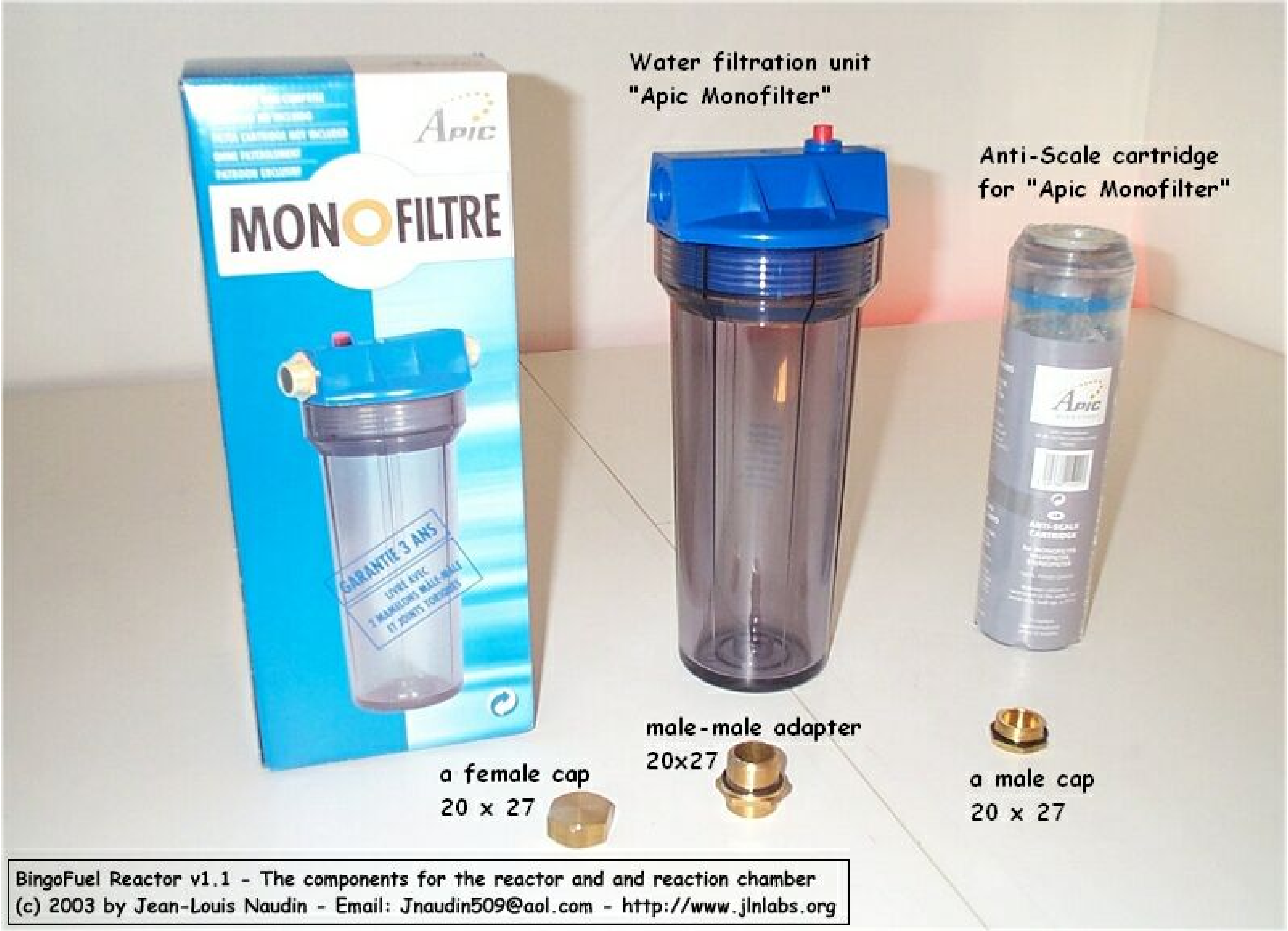
Water filtration unit
"Apic Monofilter"
Anti-Scale cartridge
for "Apic Monofilter"
MONOFILTRE
Apic
GARANTIE 3 ANS
male-male adapter
20x27
a female cap
20 x 27
a male cap
20 x 27

BingoFuel Reactor v1.1 - The components for the reactor and and reaction chamber
(c) 2003 by Jean-Louis Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

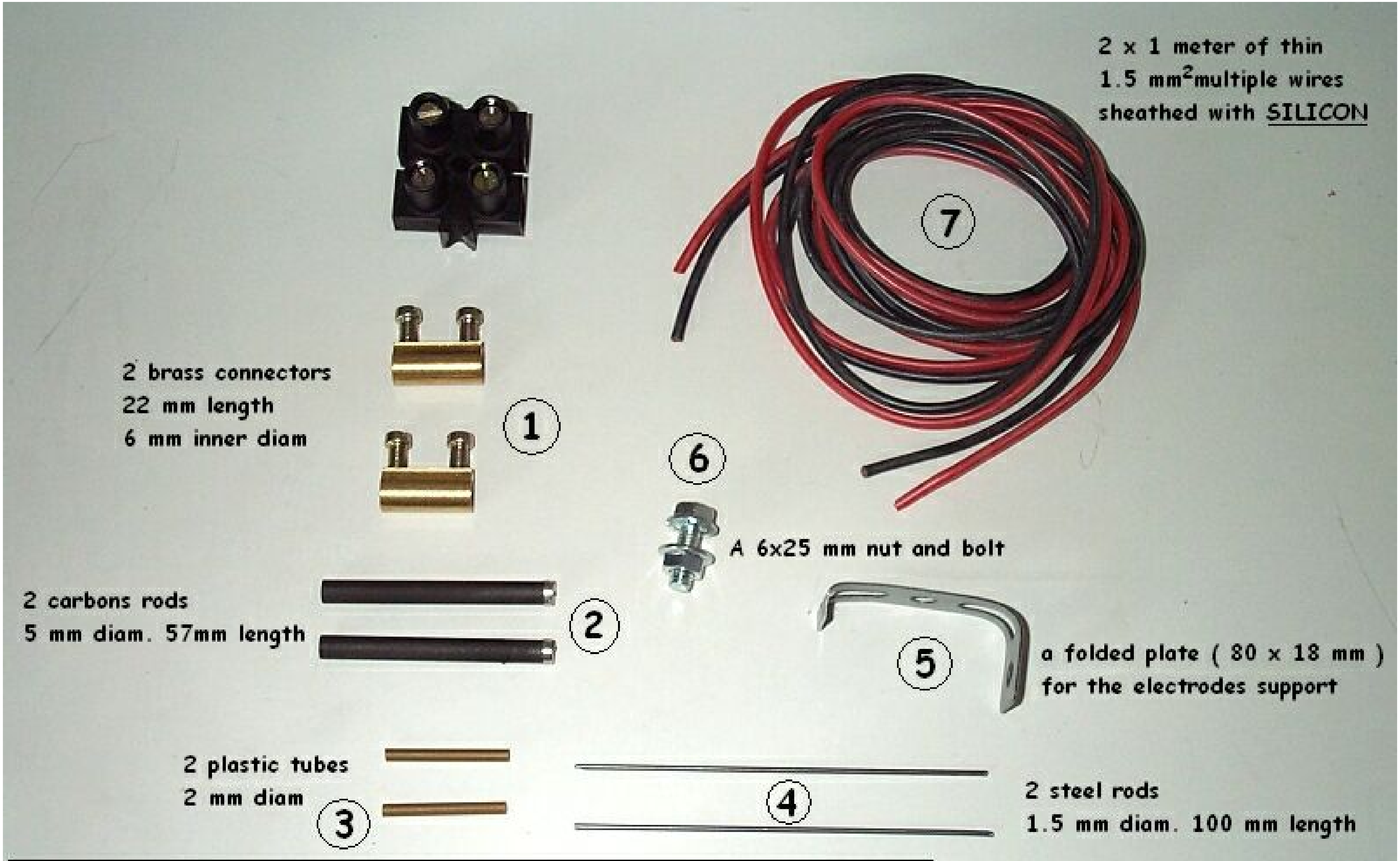
2 x 1 meter of thin
1.5 mm² multiple wires
sheathed with SILICON
7
2 brass connectors
22 mm length
6 mm inner diam
1
6
A 6x25 mm nut and bolt
2 carbons rods
5 mm diam. 57mm length
2
5
a folded plate (80 x 18 mm)
for the electrodes support
2 plastic tubes
2 mm diam
3
4
2 steel rods
1.5 mm diam. 100 mm length

BingoFuel Reactor v1.1 - The components for the plasma igniters

(c) 2003 by Jean-Louis Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

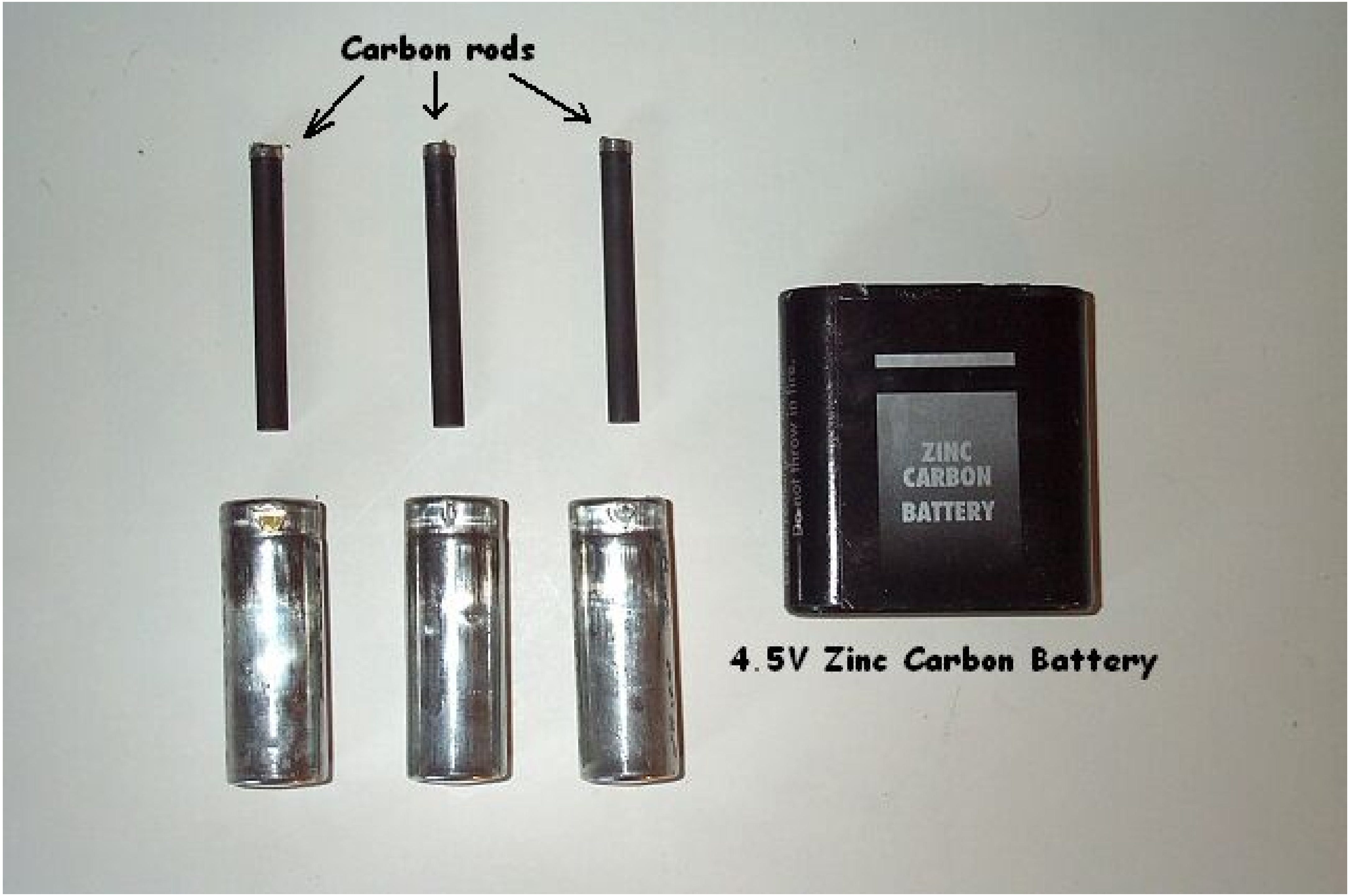
Carbon rods
ZINC CARBON BATTERY
Do not throw in fire
4.5V Zinc Carbon Battery

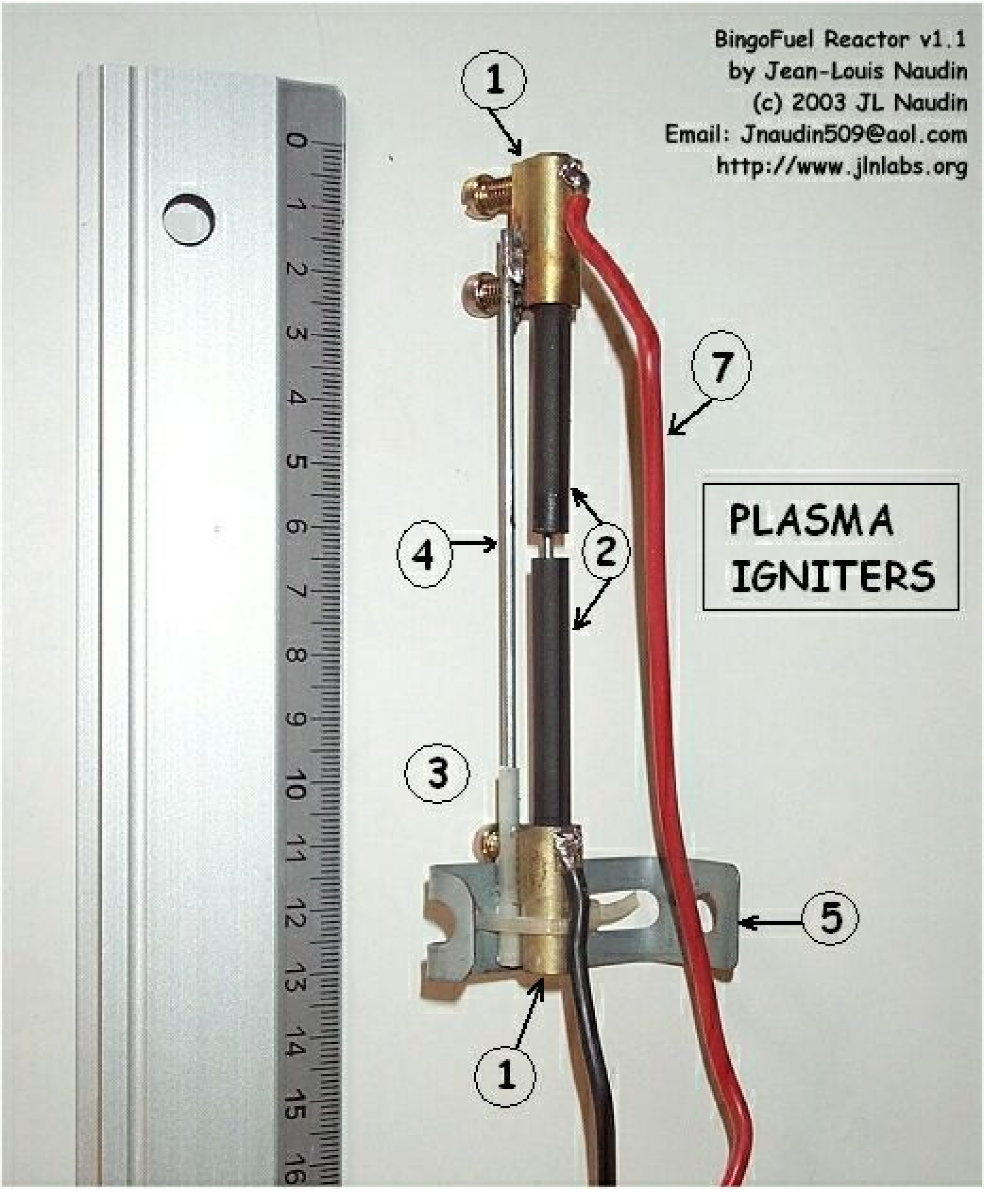

BingoFuel Reactor v1.1
by Jean-Louis Naudin
(c) 2003 JL Naudin
Email: Jnaudin509@aol.com
http://www.jlnlabs.org

PLASMA
IGNITERS

1
7
2
4
3
5
1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

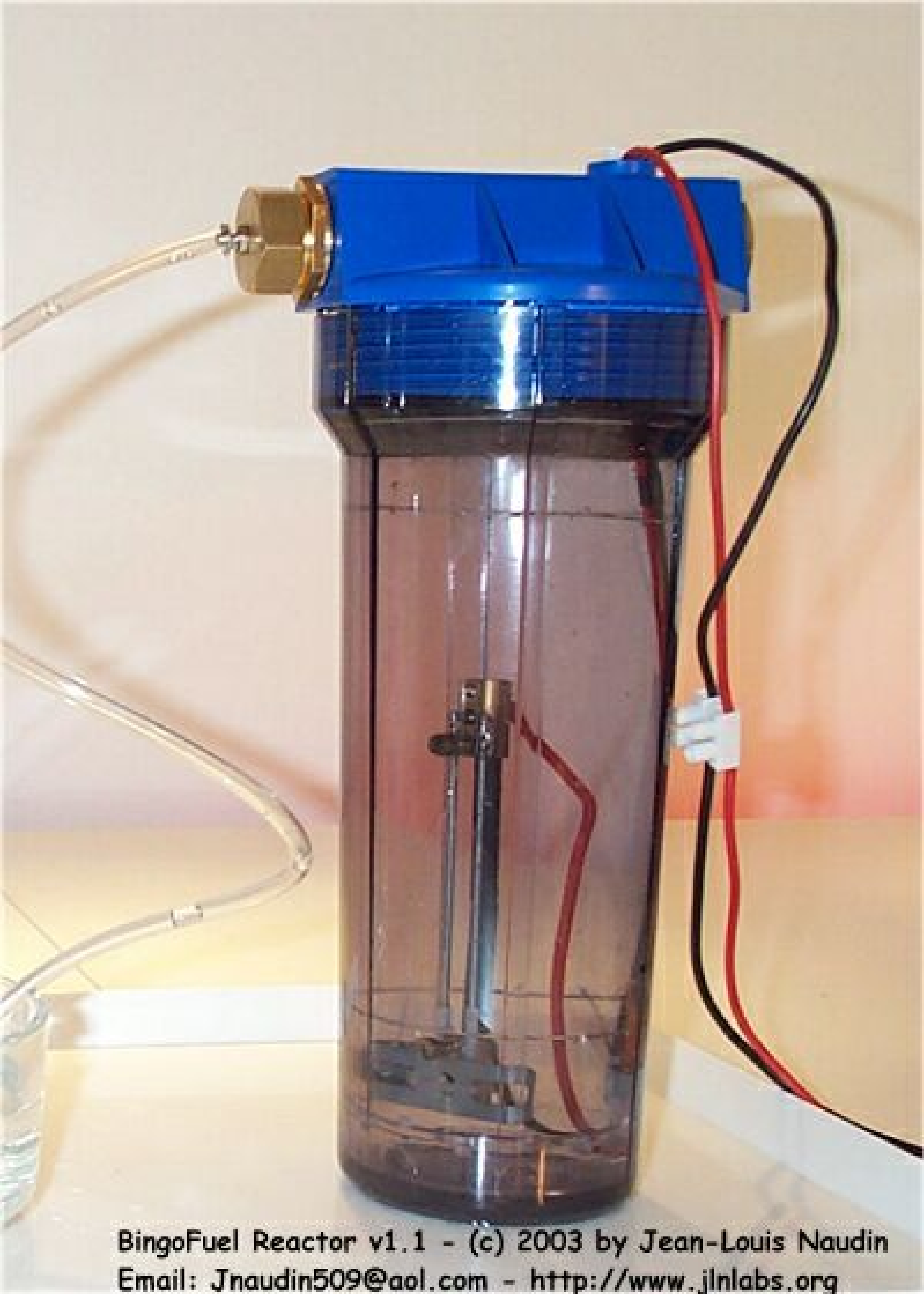

BingoFuel Reactor v1.1 - (c) 2003 by Jean-Louis Naudin
Email: Jnaudin509@aol.com - http://www.jlnlabs.org

HONDA
GC160
5.0
SDMO
RANGER 2500
www.sdmo.com

GROUPES ÉLECTROGÈNES MONOPHASÉS

50 hz			Moteur							Alternateur					Options				
Type	Puissance max 230V		Marque	Type	Sécurité huile	Démarrage électrique	HP 3600 tr/mn	Autonomie h	Réservoir L	230V Disjoncteur	Niveau sonore CEE Lwa	dB(A) @ 7 m	Dimensions L x l x h cm	Poids Kg	Kit brouette	Disjoncteur	Quick'lock	Com. à distance	Coffret dém. auto
	kW ISO 8528	kVA[1] Cos φ 0,8																	
RANGER™ 2500	2,1	2,6	Honda OHC	GC 160	•	x	5	2,2	2	•	**98**	75	58x46x44	30	x	x	x	x	x

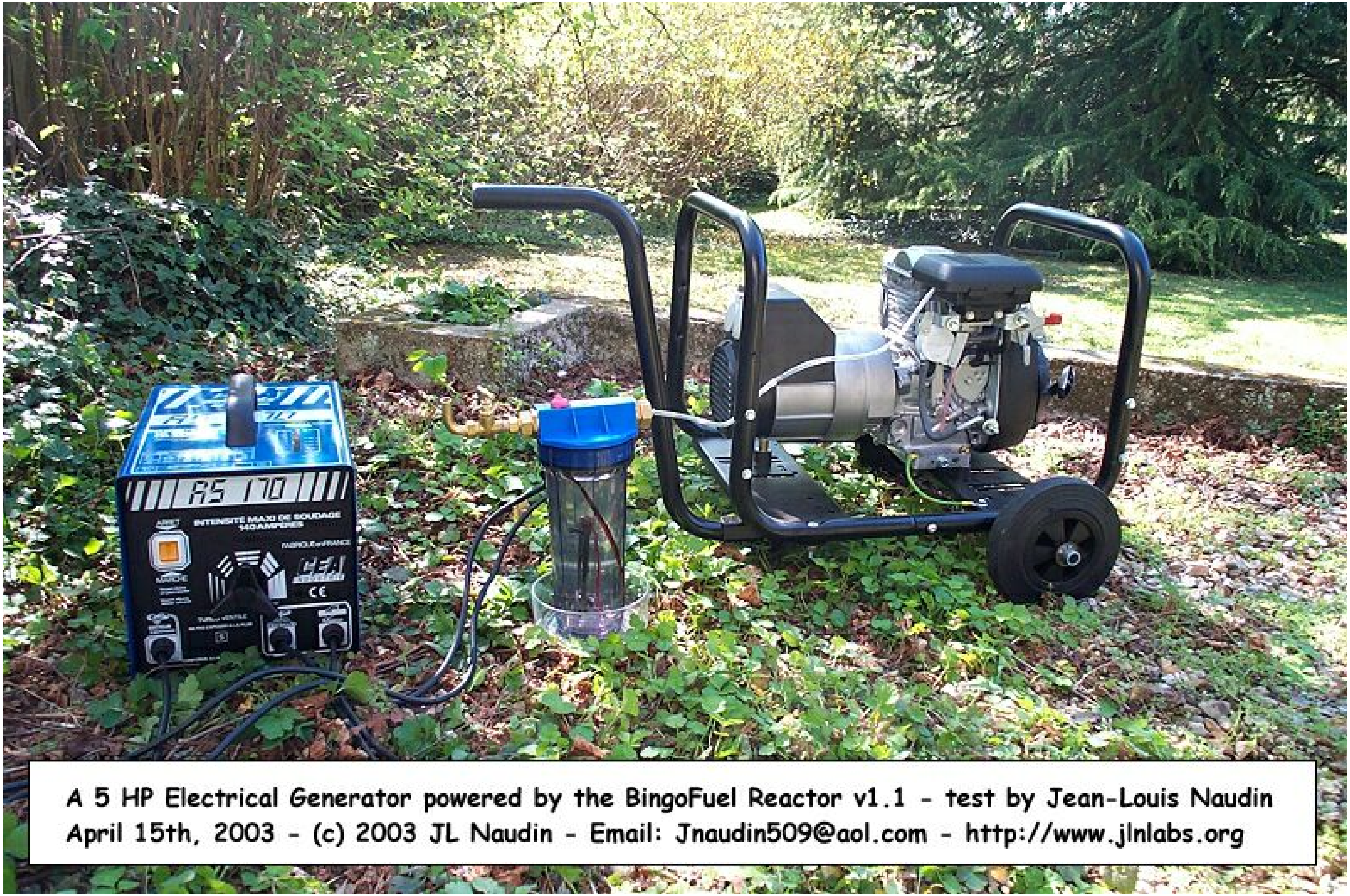
RS 170
INTENSITE MAXI DE SOUDAGE 140AMPERES
ARRET
MARCHE
CE

A 5 HP Electrical Generator powered by the BingoFuel Reactor v1.1 - test by Jean-Louis Naudin
April 15th, 2003 - (c) 2003 JL Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

A 5 HP Electrical Generator powered by the BingoFuel Reactor v1.1 - test by Jean-Louis Naudin
April 15th, 2003 - (c) 2003 JL Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

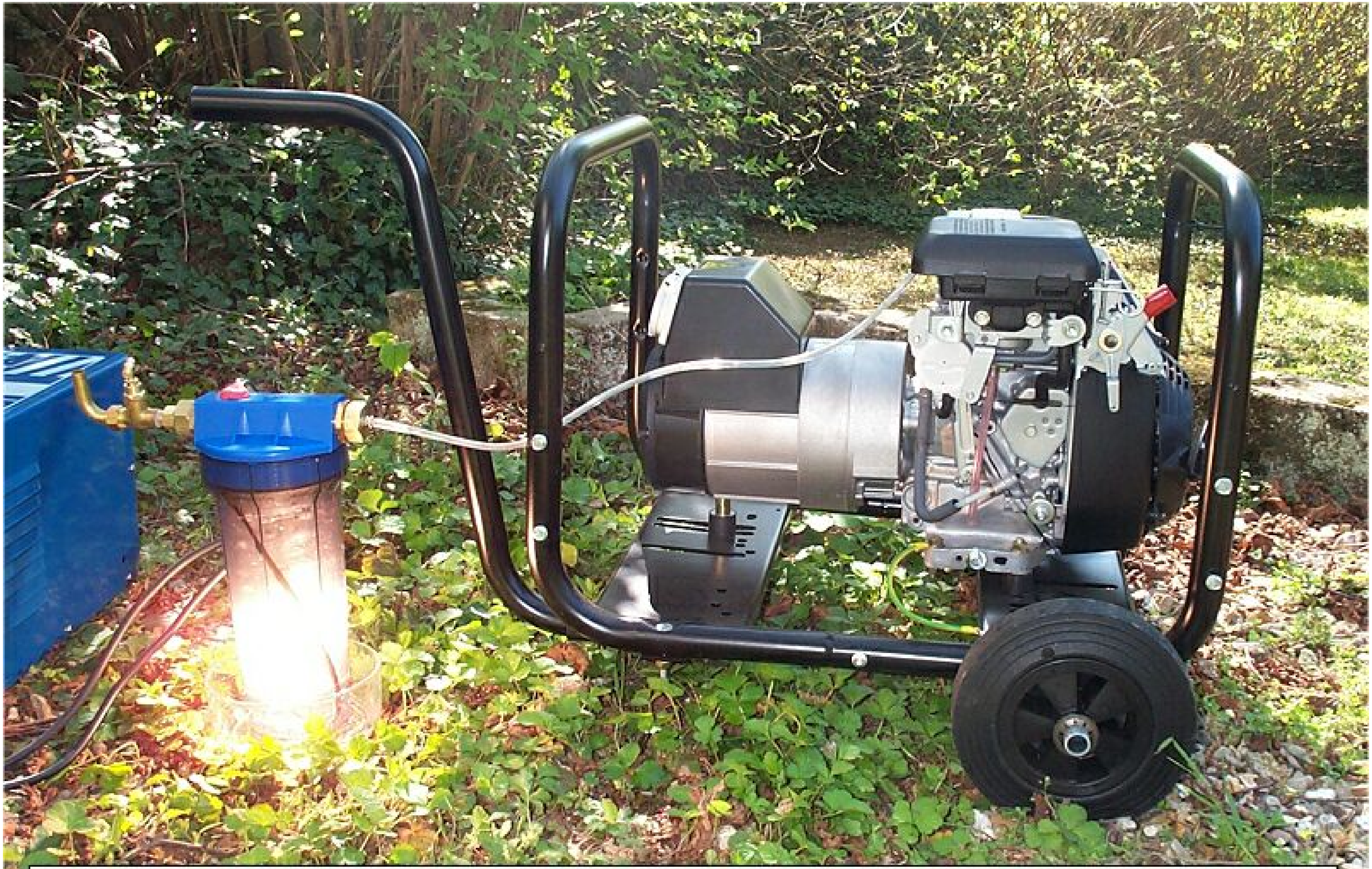

A 5 HP Electrical Generator powered by the BingoFuel Reactor v1.1 - test by Jean-Louis Naudin
April 15th, 2003 - (c) 2003 JL Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

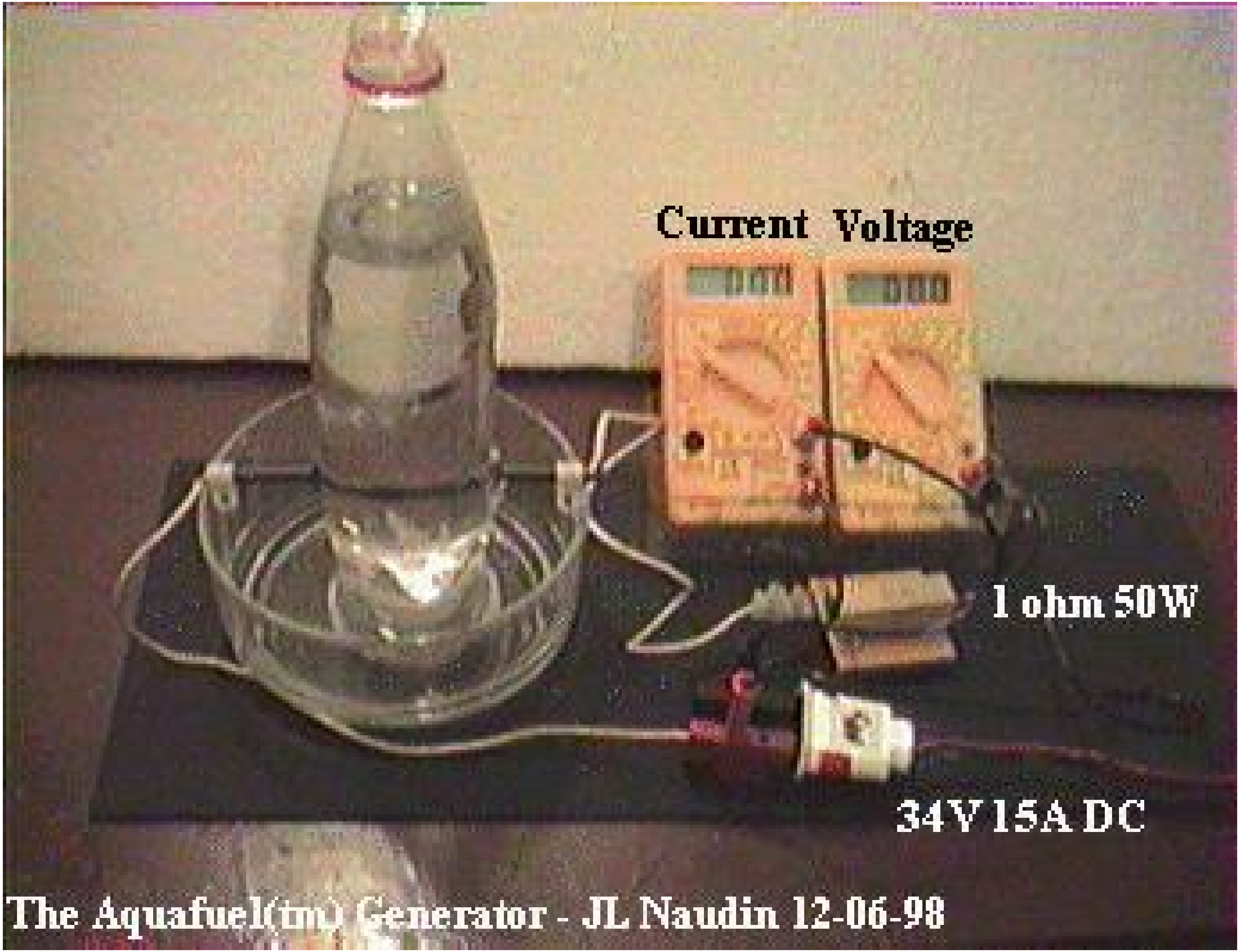
Current
Voltage
1 ohm 50W
34V 15A DC
The Aquafuel(tm) Generator - JL Naudin 12-06-98

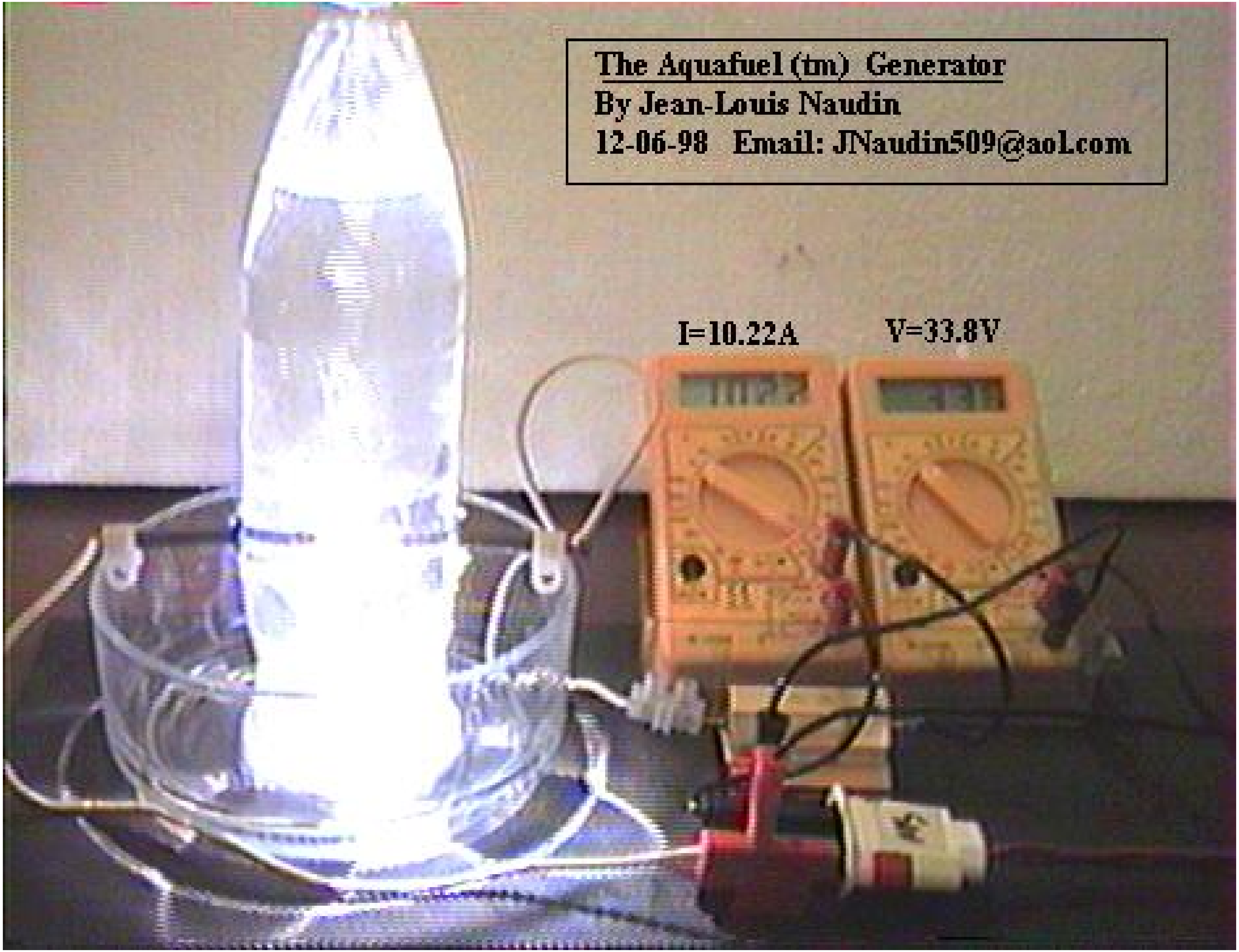

The Aquafuel (tm) Generator
By Jean-Louis Naudin
12-06-98 Email: JNaudin509@aol.com

I=10.22A
V=33.8V

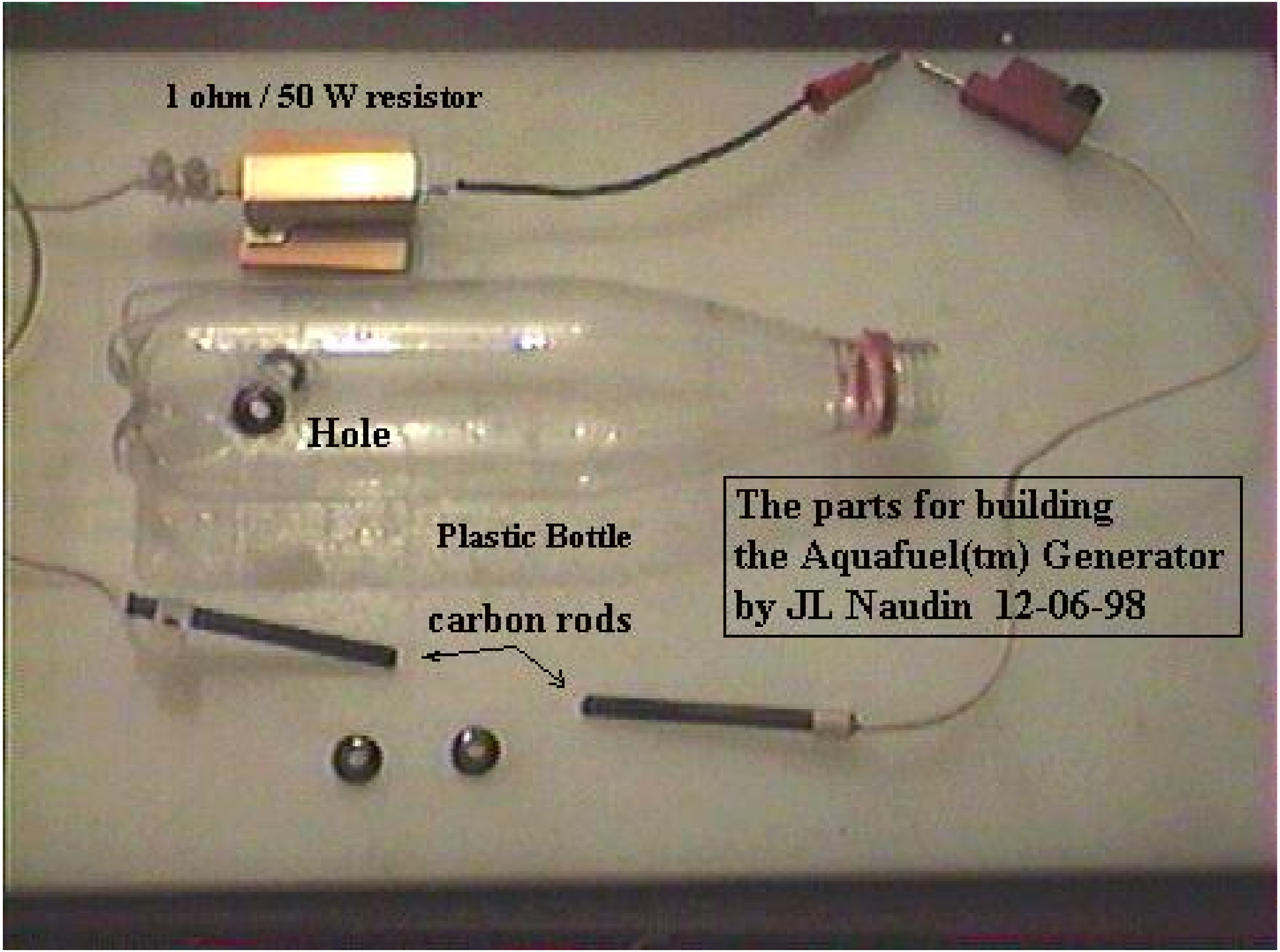
1 ohm / 50 W resistor
Hole
Plastic Bottle
carbon rods

The parts for building
the Aquafuel(tm) Generator
by JL Naudin 12-06-98

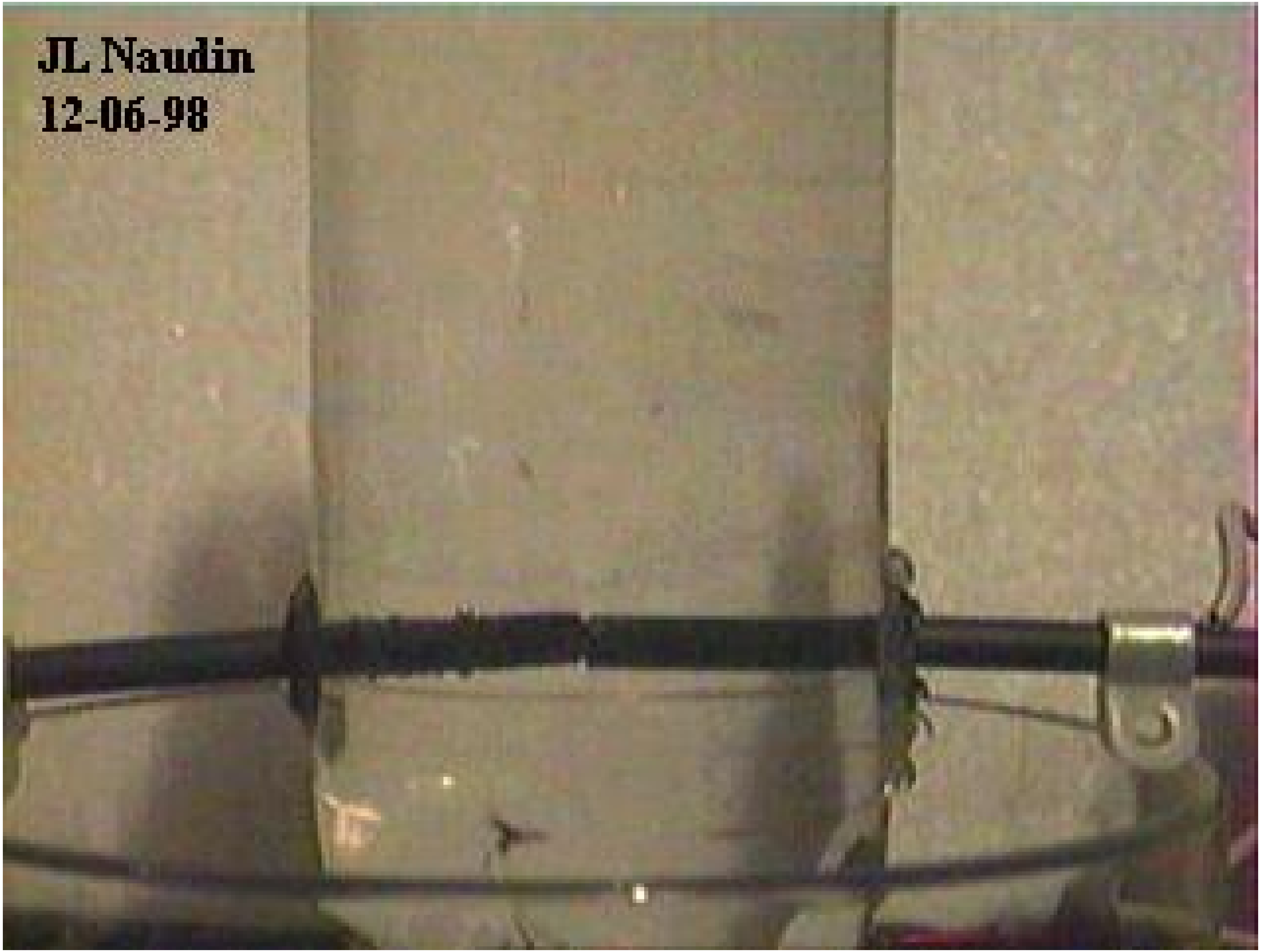
JL Naudin
12-06-98

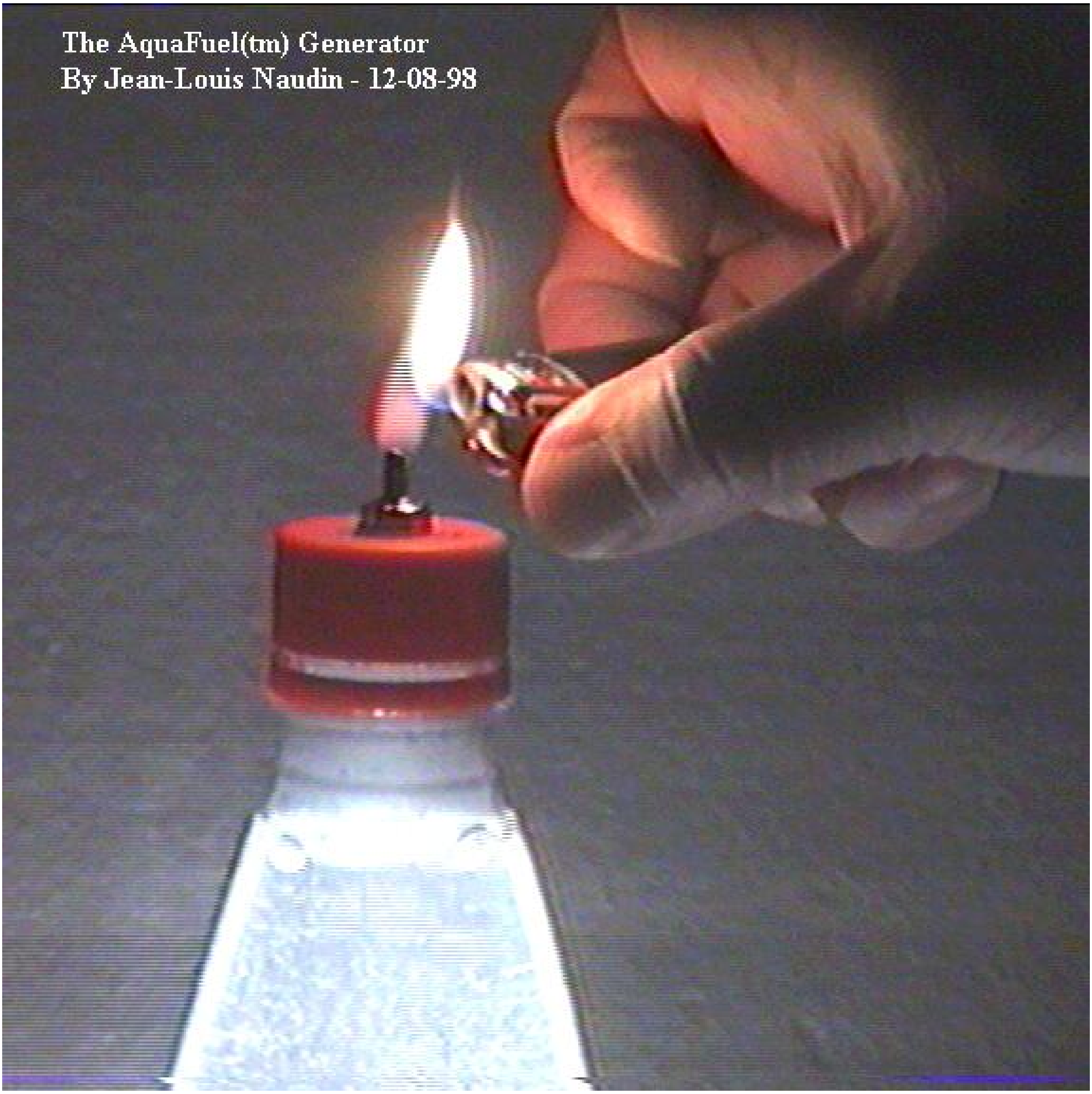
The AquaFuel(tm) Generator
By Jean-Louis Naudin - 12-08-98

FIG. 9 TERMINAL STRIP

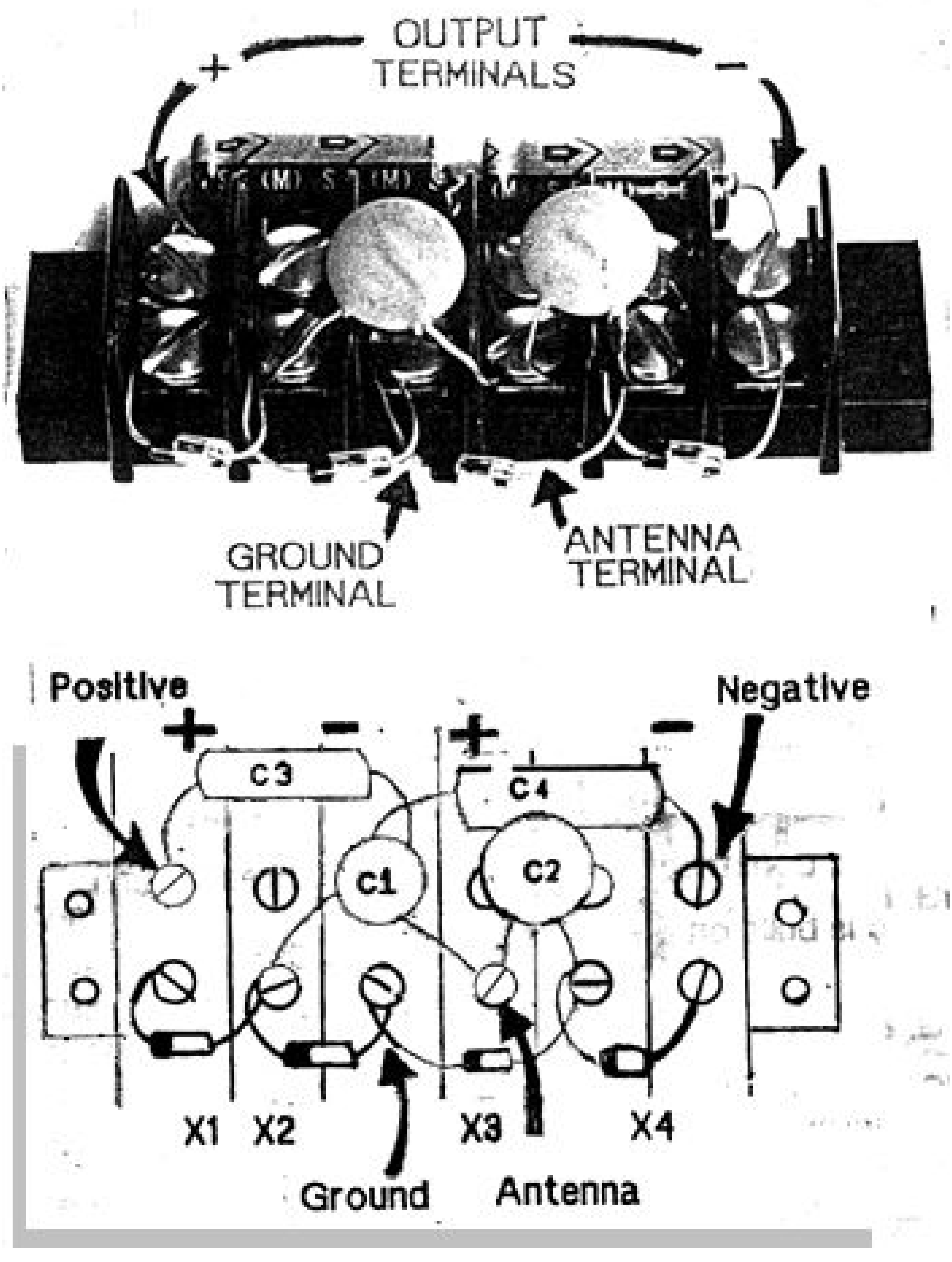
OUTPUT
TERMINALS
+
−
GROUND
TERMINAL
ANTENNA
TERMINAL
Positive
+
−
+
−
Negative
C3
C4
C1
C2
X1
X2
X3
X4
Ground
Antenna

What's on an Electric Power Pole?

This is an illustration of basic equipment found on a typical distribution pole and can vary by location.

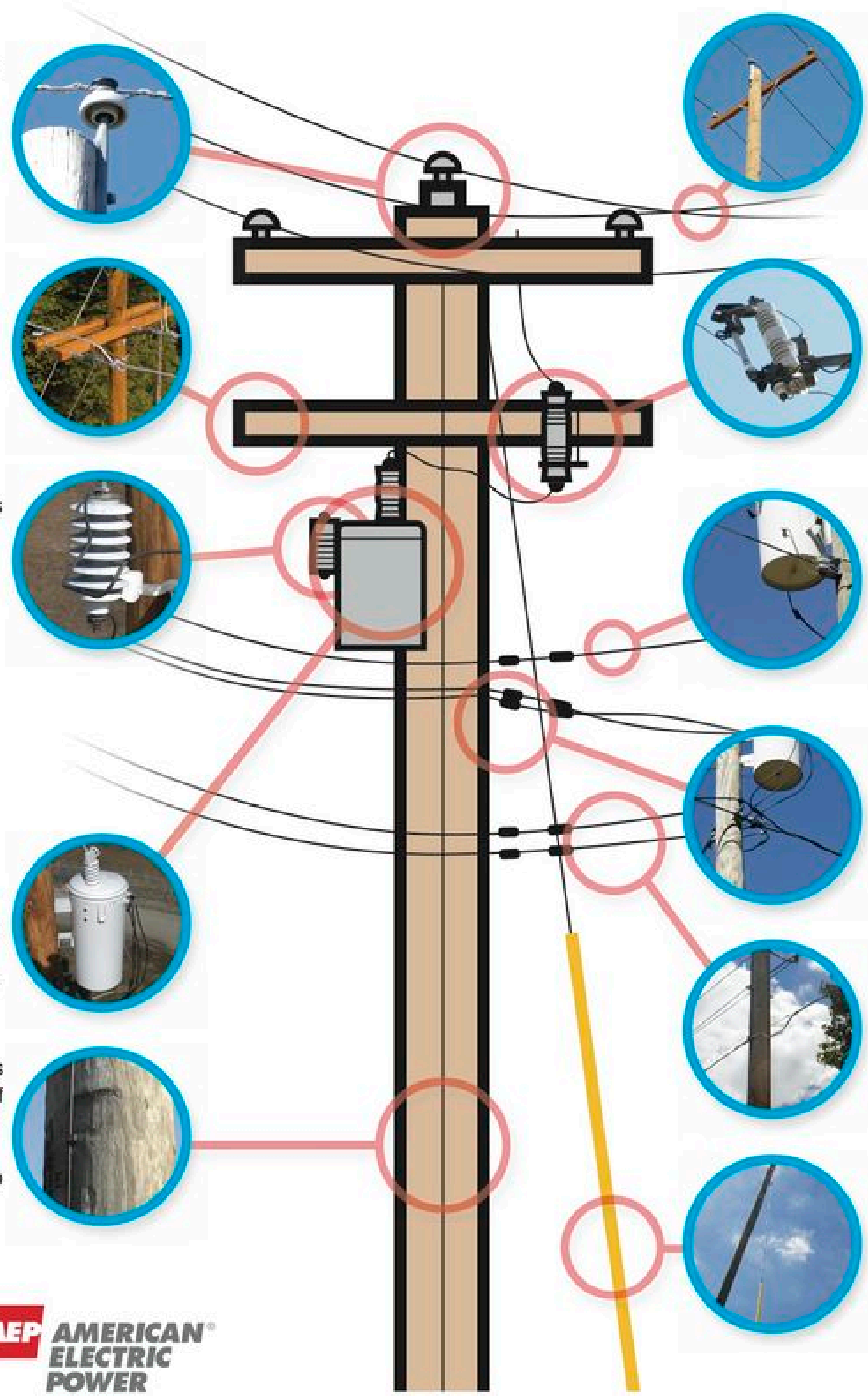

Insulators prevent energized wires from coming in contact with each other or the utility pole.

A crossarm holds the wires up on the pole.

Lightning arrestors protect the pole and equipment from lightning strikes.

Transformers convert higher voltage electricity carried by primary wires and lowers the voltage for use by customers.

A ground wire runs the entire length of the pole. It directs any electricity on the pole safely into the earth.

Primary wires are on top of the pole and usually carry 12,000 volts of electricity from a substation.

Cutouts act like a fuse and open when there is a problem with the line or a section of it.

The neutral wire is below the transformer and acts as a line back to the substation and balances out the amount of electricity or load on the system.

The secondary wire carries the lower voltage electricity after it passes through the transformer.

Telephone and cable wires are typically the lowest wires.

Guy wires help stabilize utility poles.

AEP AMERICAN® ELECTRIC POWER

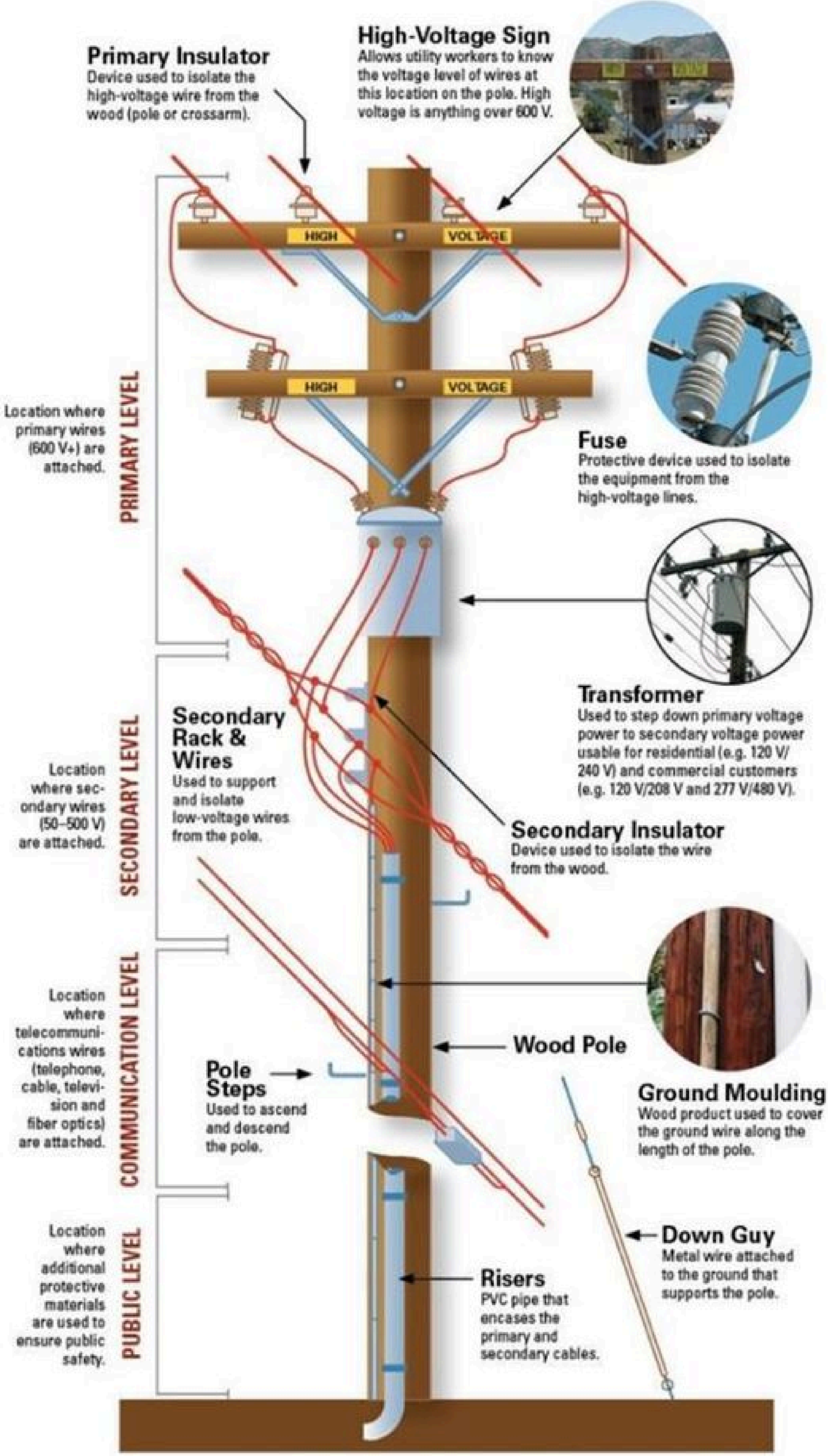

Primary Insulator
Device used to isolate the high-voltage wire from the wood (pole or crossarm).

High-Voltage Sign
Allows utility workers to know the voltage level of wires at this location on the pole. High voltage is anything over 600 V.

Fuse
Protective device used to isolate the equipment from the high-voltage lines.

Transformer
Used to step down primary voltage power to secondary voltage power usable for residential (e.g. 120 V/240 V) and commercial customers (e.g. 120 V/208 V and 277 V/480 V).

Secondary Rack & Wires
Used to support and isolate low-voltage wires from the pole.

Secondary Insulator
Device used to isolate the wire from the wood.

Wood Pole

Ground Moulding
Wood product used to cover the ground wire along the length of the pole.

Pole Steps
Used to ascend and descend the pole.

Down Guy
Metal wire attached to the ground that supports the pole.

Risers
PVC pipe that encases the primary and secondary cables.

Location where primary wires (600 V+) are attached.

Location where secondary wires (50–500 V) are attached.

Location where telecommunications wires (telephone, cable, television and fiber optics) are attached.

Location where additional protective materials are used to ensure public safety.

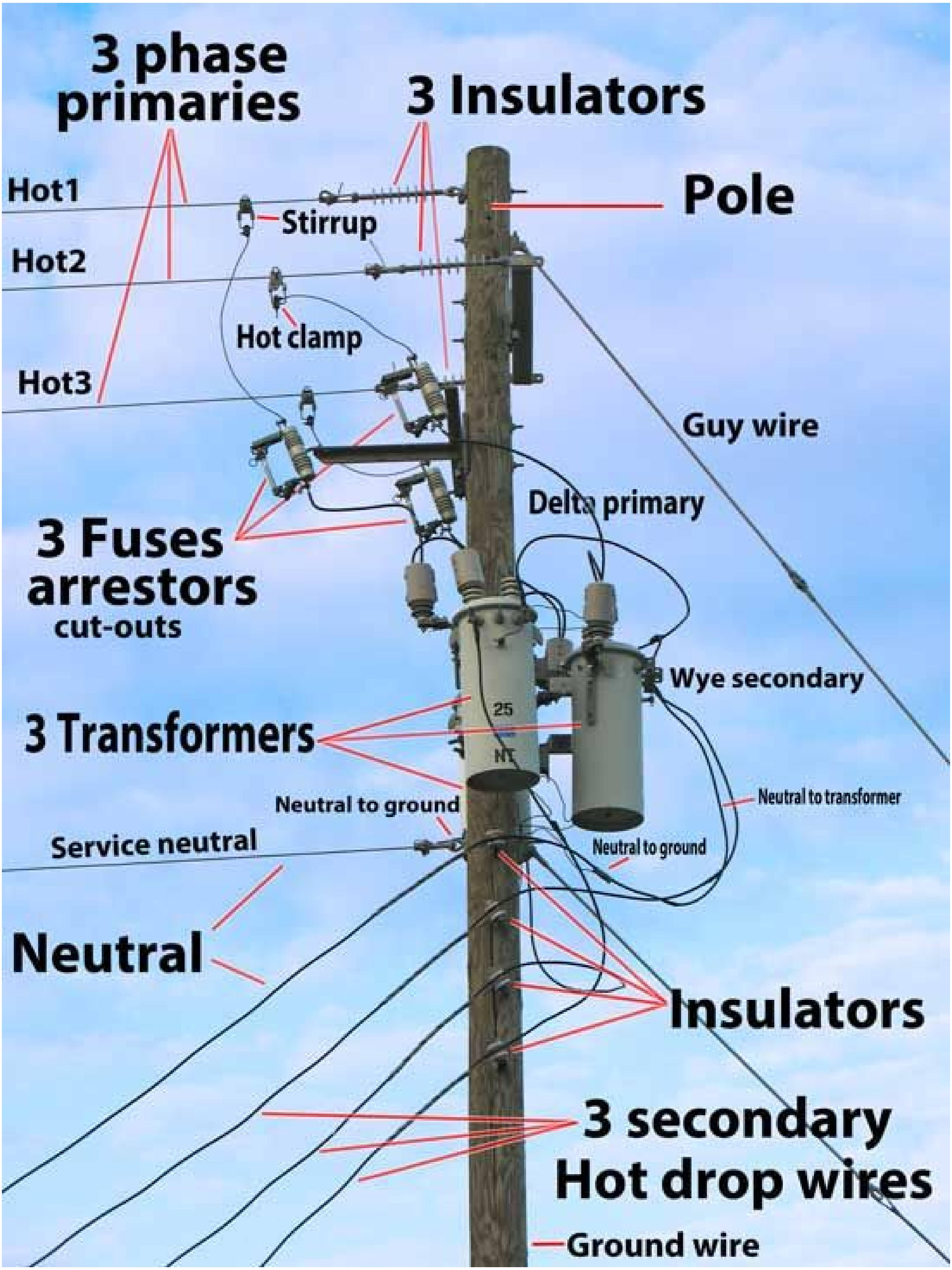
3 phase primaries
3 Insulators
Hot1
Stirrup
Pole
Hot2
Hot clamp
Hot3
Guy wire
Delta primary
3 Fuses arrestors cut-outs
Wye secondary
3 Transformers
25
NT
Neutral to transformer
Neutral to ground
Service neutral
Neutral to ground
Neutral
Insulators
3 secondary Hot drop wires
Ground wire

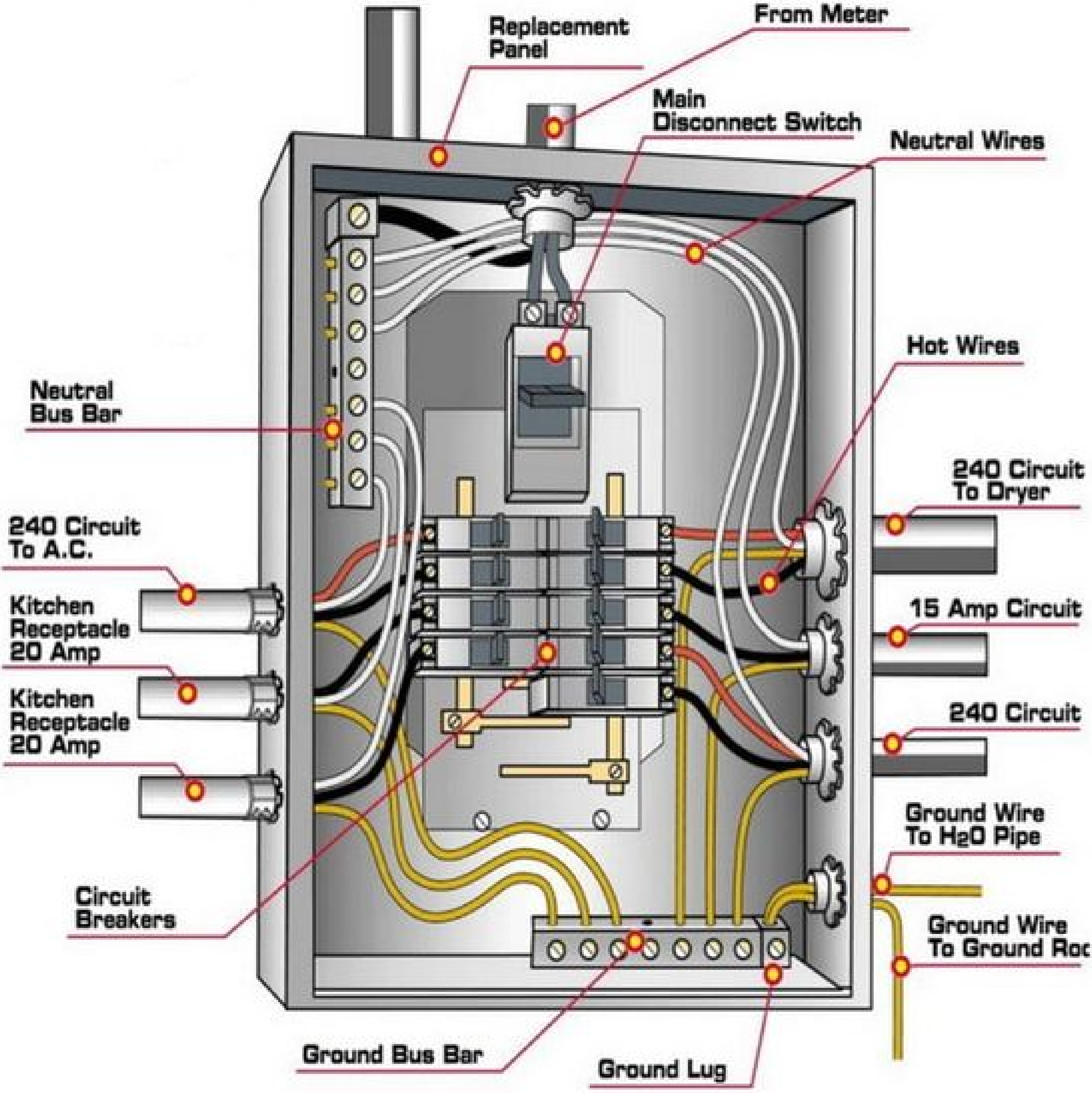
Replacement Panel
From Meter
Main Disconnect Switch
Neutral Wires
Neutral Bus Bar
Hot Wires
240 Circuit To Dryer
240 Circuit To A.C.
Kitchen Receptacle 20 Amp
15 Amp Circuit
Kitchen Receptacle 20 Amp
240 Circuit
Ground Wire To H2O Pipe
Circuit Breakers
Ground Wire To Ground Roc
Ground Bus Bar
Ground Lug

Typical Home Breaker Box

use caution when troubleshooting your breaker box

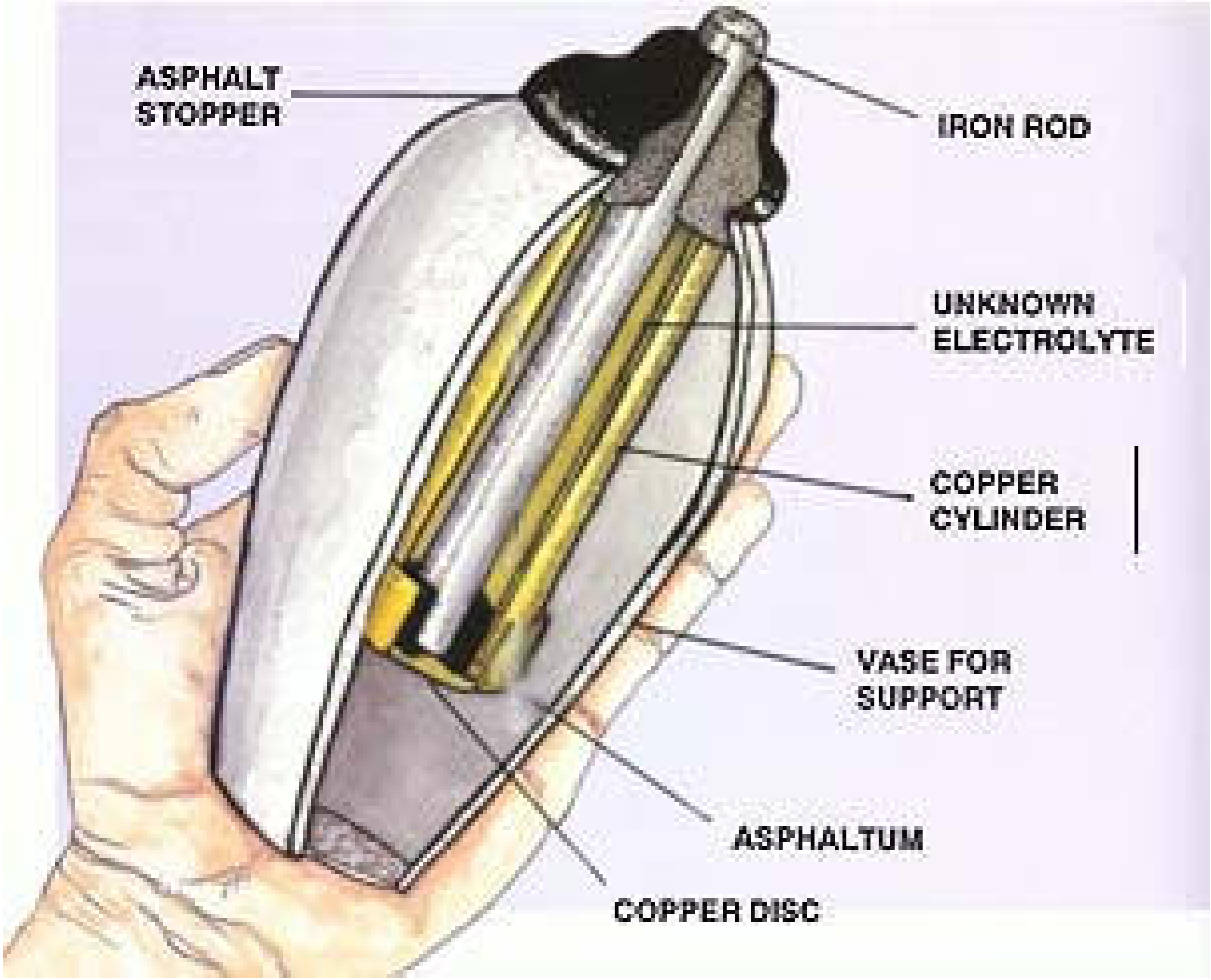
ASPHALT STOPPER
IRON ROD
UNKNOWN ELECTROLYTE
COPPER CYLINDER
VASE FOR SUPPORT
ASPHALTUM
COPPER DISC

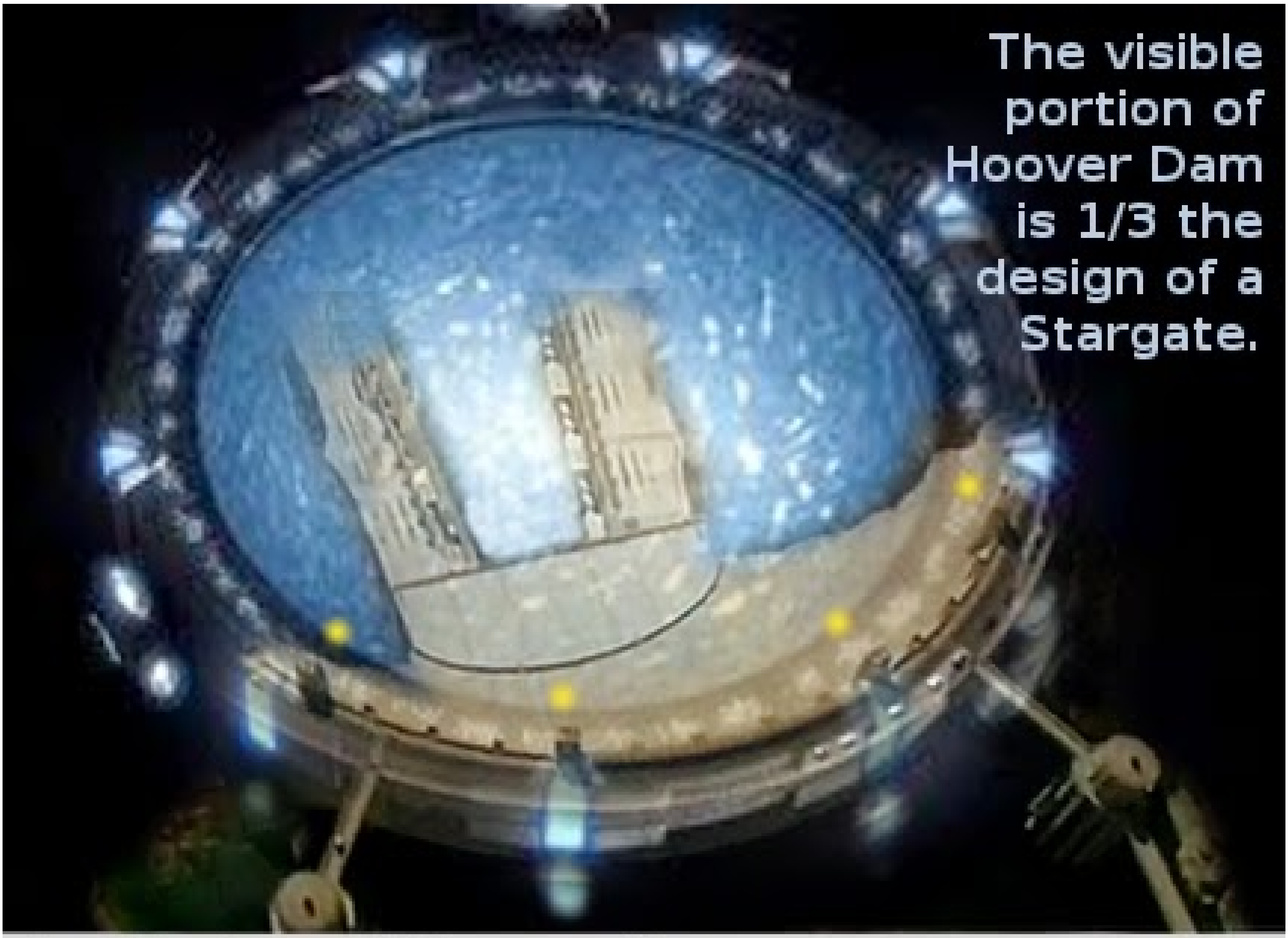

The visible portion of Hoover Dam is 1/3 the design of a Stargate.

Aerial view of Hoover Dam - Stargate SG1 superlay

5,000 MW Receiving Station (Rectenna). This station is about a mile and a half long in US.

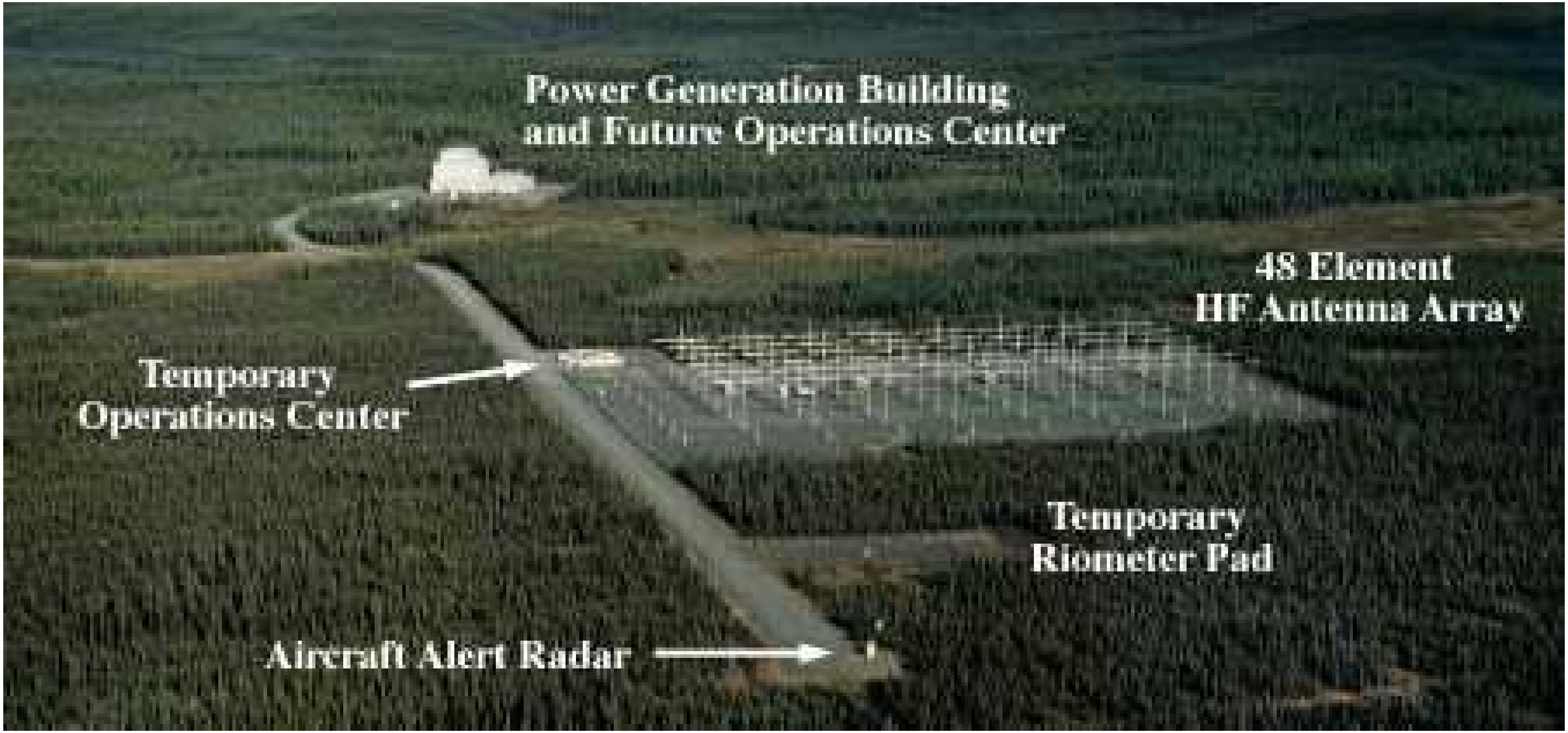
Power Generation Building
and Future Operations Center
48 Element
HF Antenna Array
Temporary
Operations Center
Temporary
Riometer Pad
Aircraft Alert Radar

LARGE HADRON COLLIDER EXPOSED:
The Stargate of Shiva.

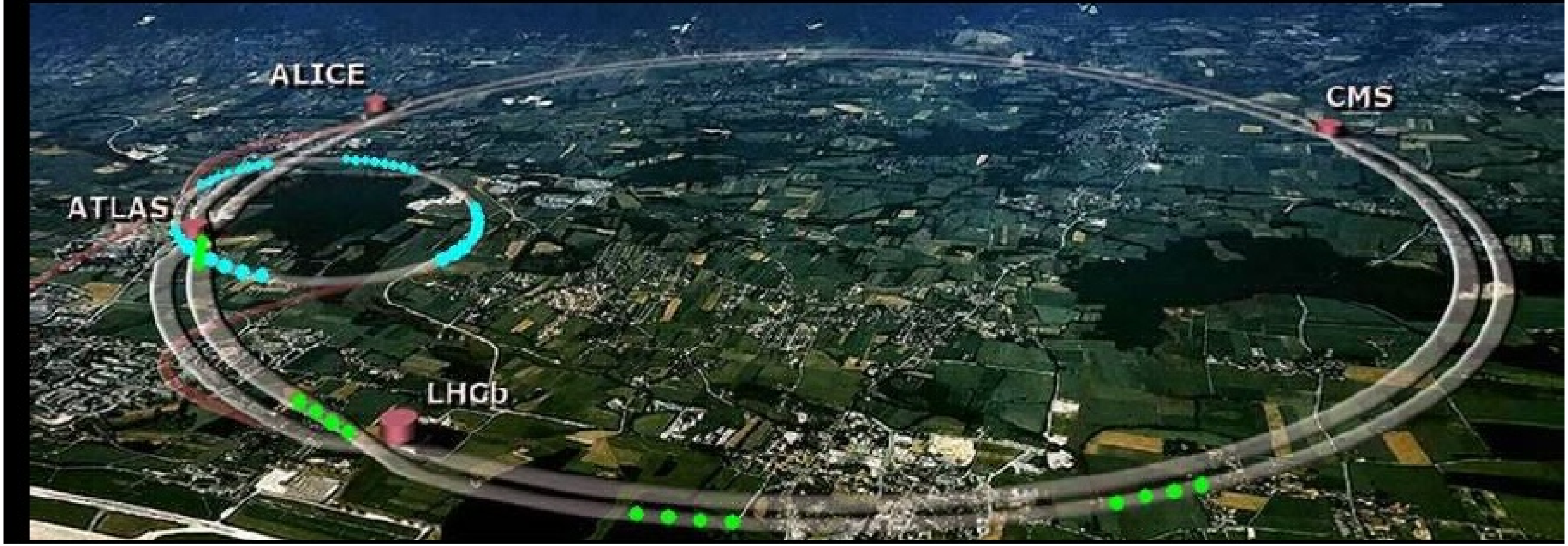
ALICE
CMS
ATLAS
LHCb

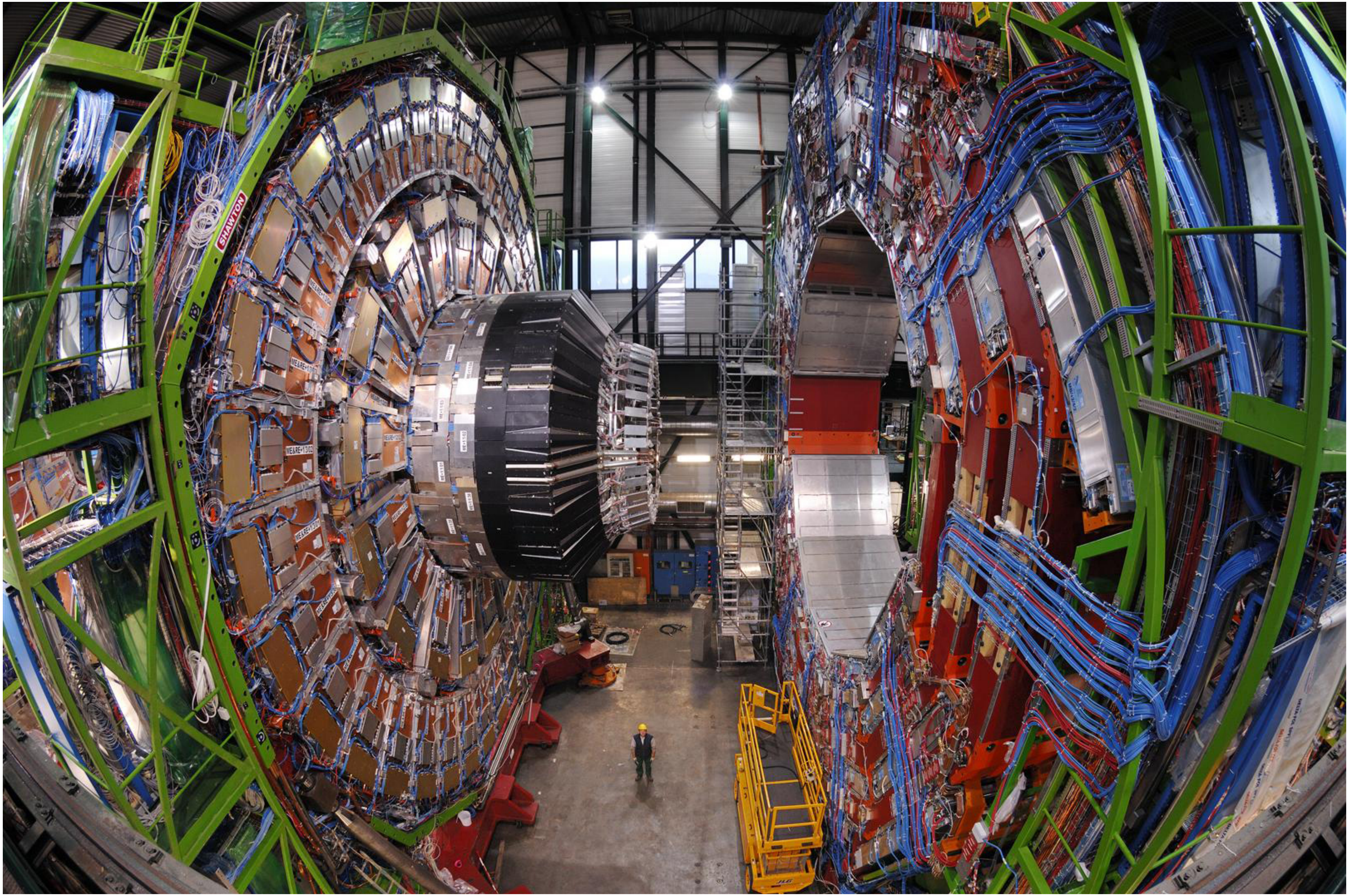
SHAWTON

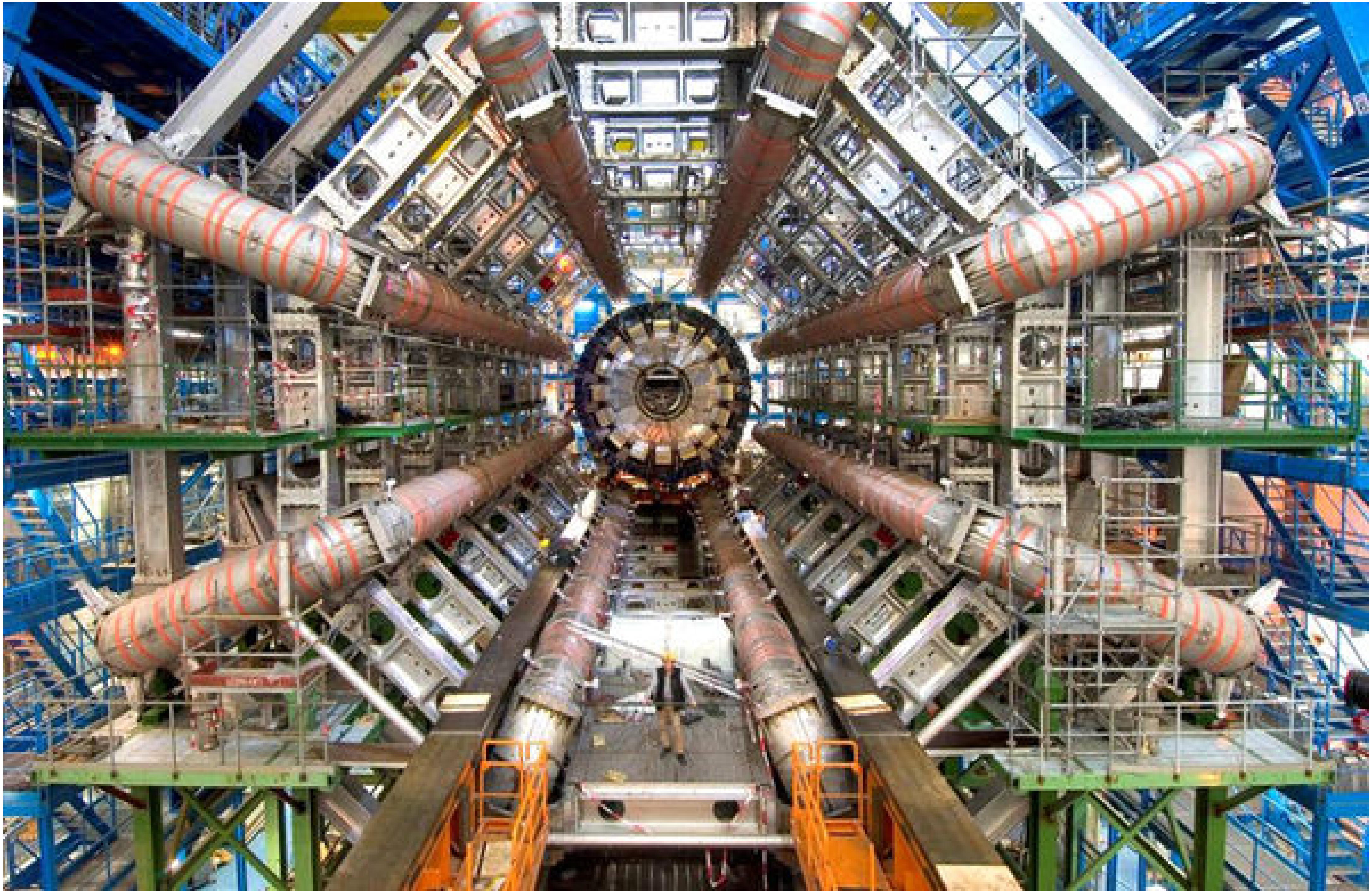

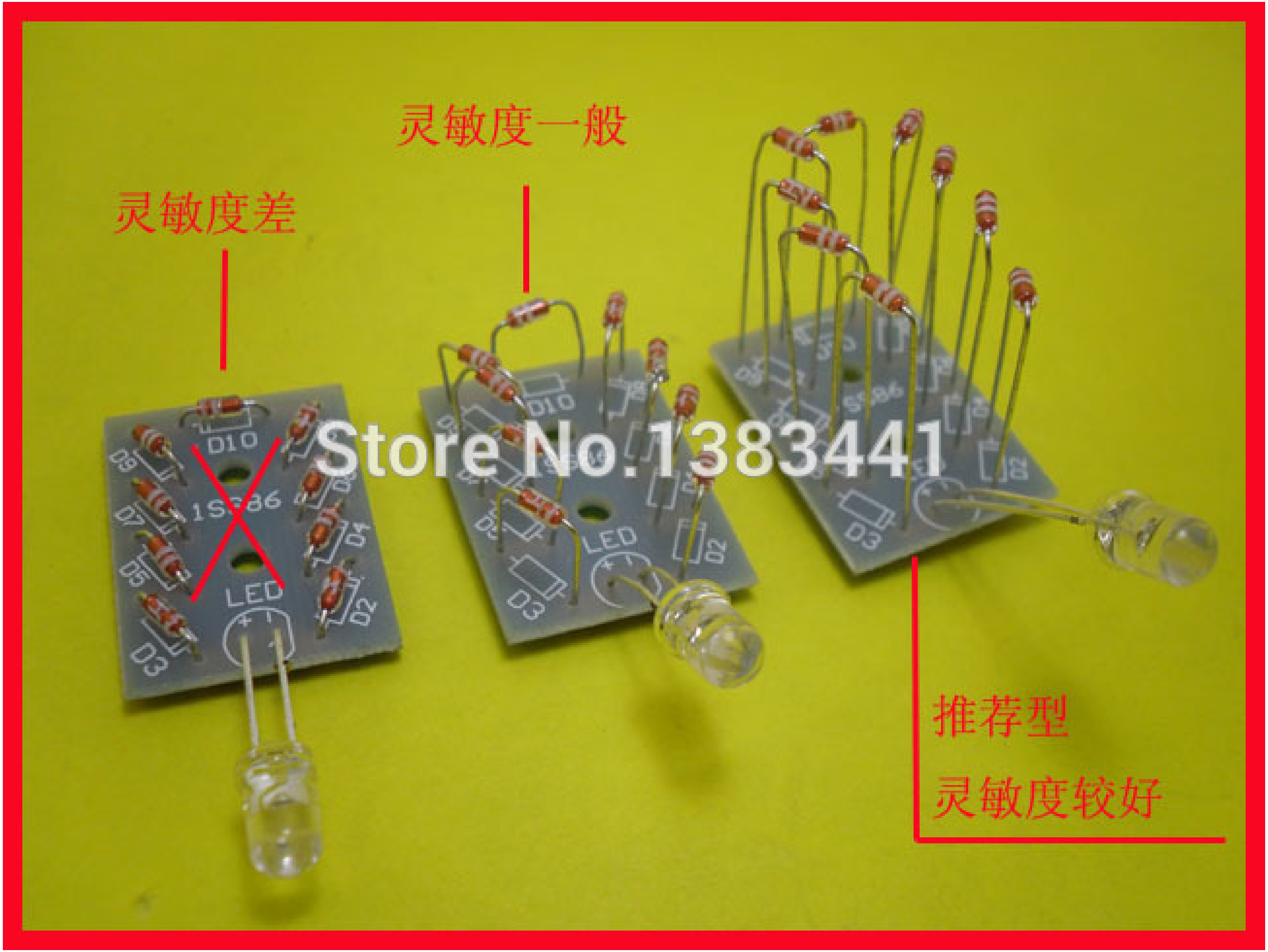
灵敏度差
灵敏度一般
推荐型
灵敏度较好
D10
1SS86
LED
D9
D7
D5
D3
D4
D2

Store No.1383441

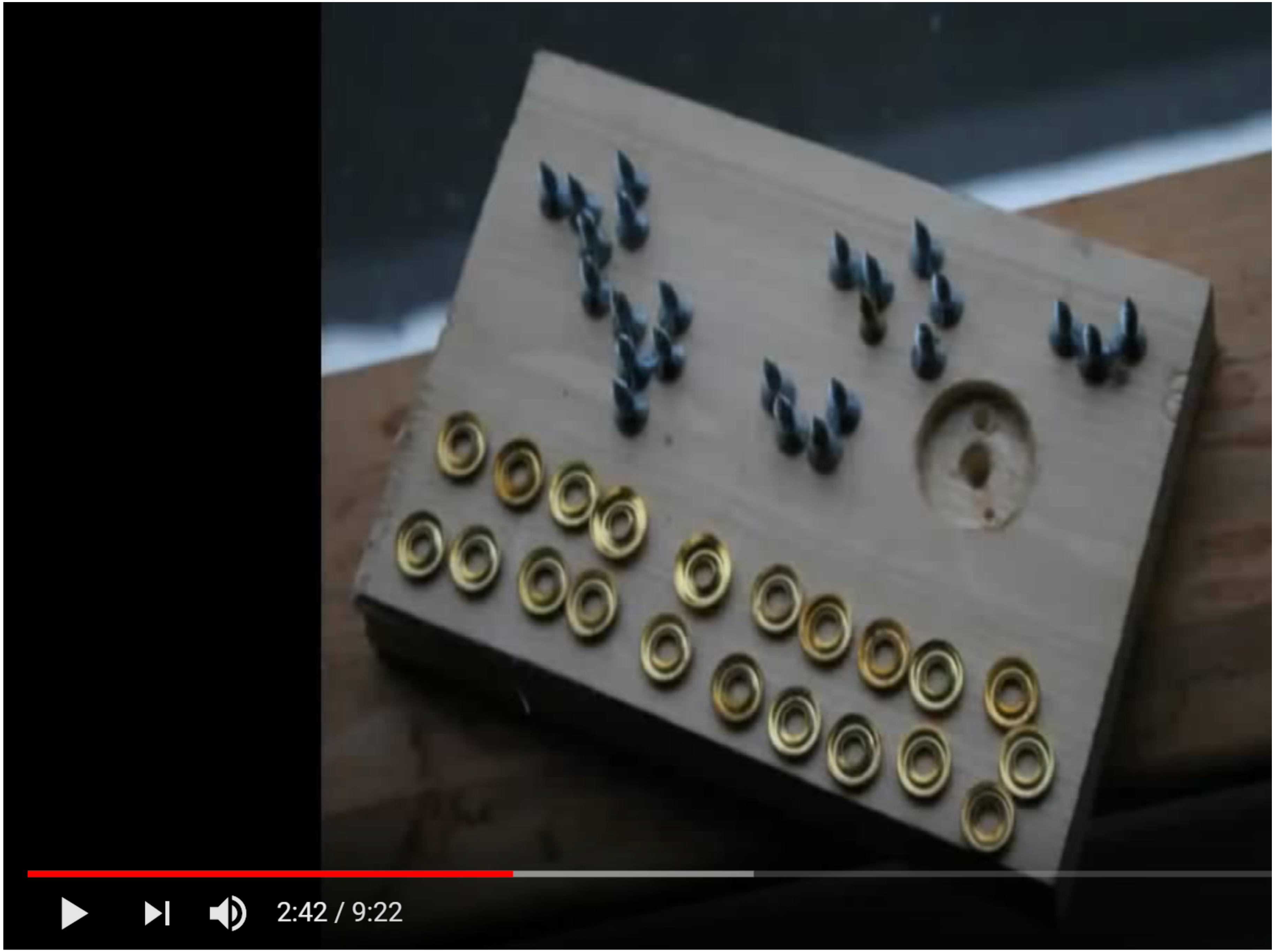

Making a Shortwave Radio (How to make a Shortwave Radio)

/ 0:22

3 * 1N4148

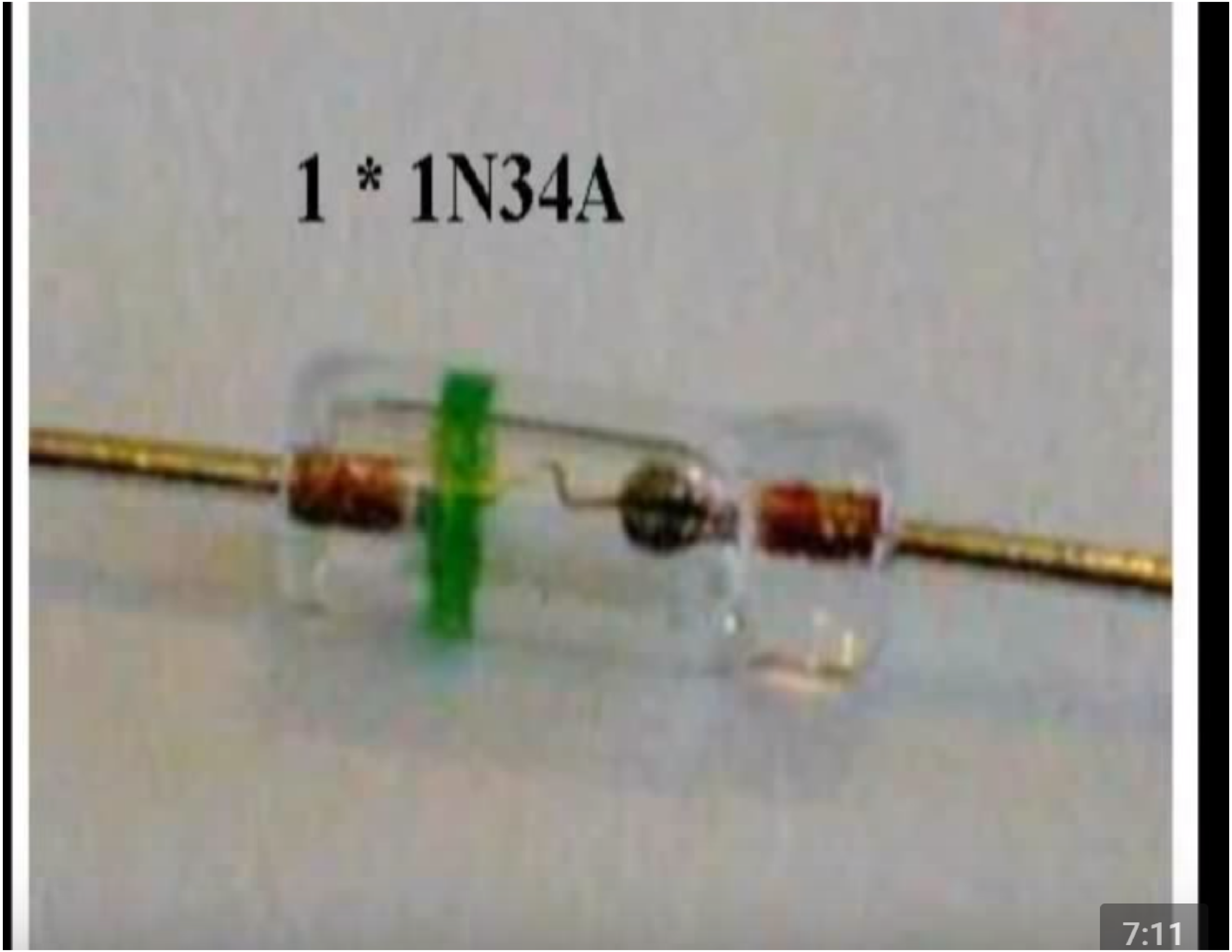
1 * 1N34A
7:11

3 * 2N2222a

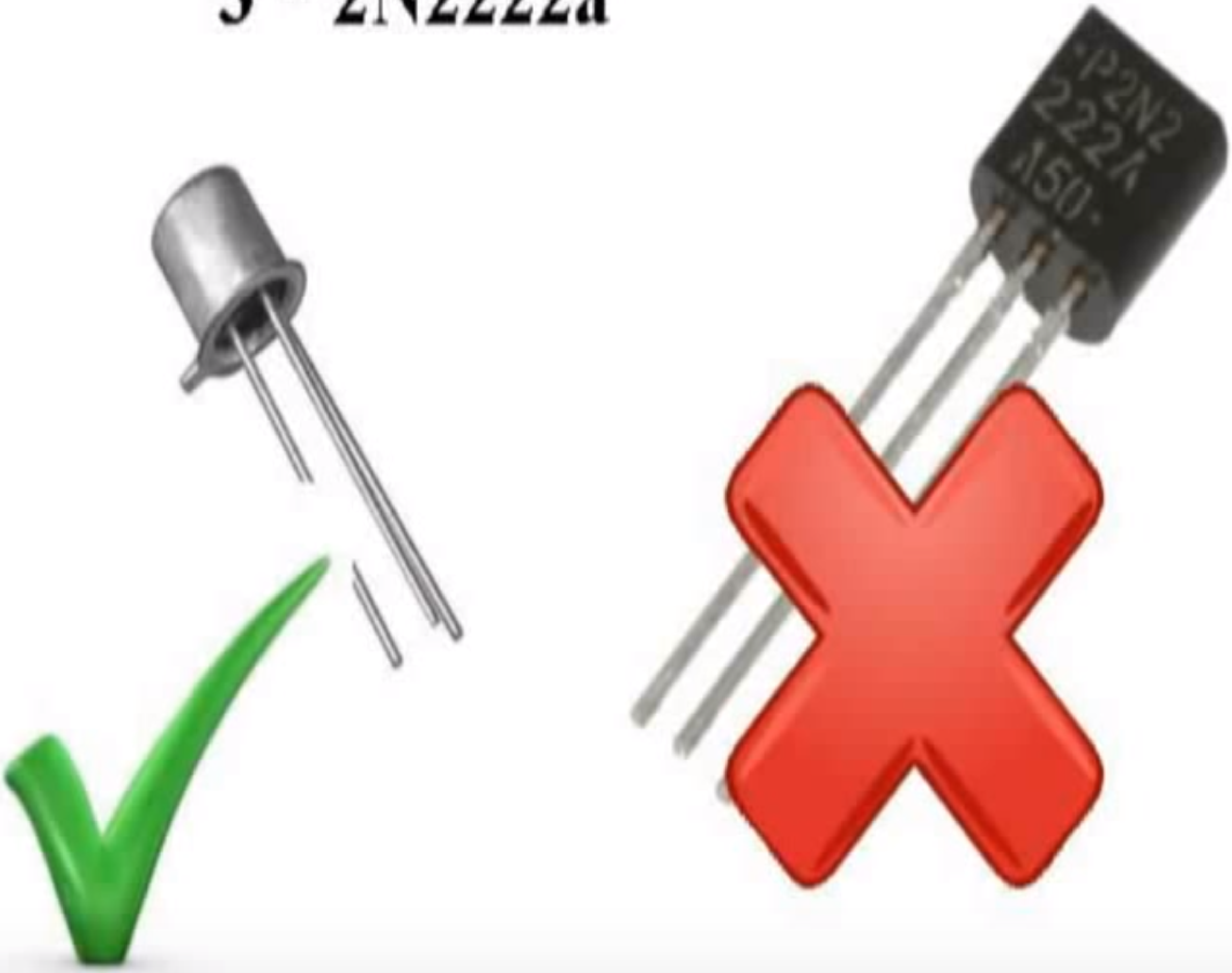
P2N2
222A
150

6:57

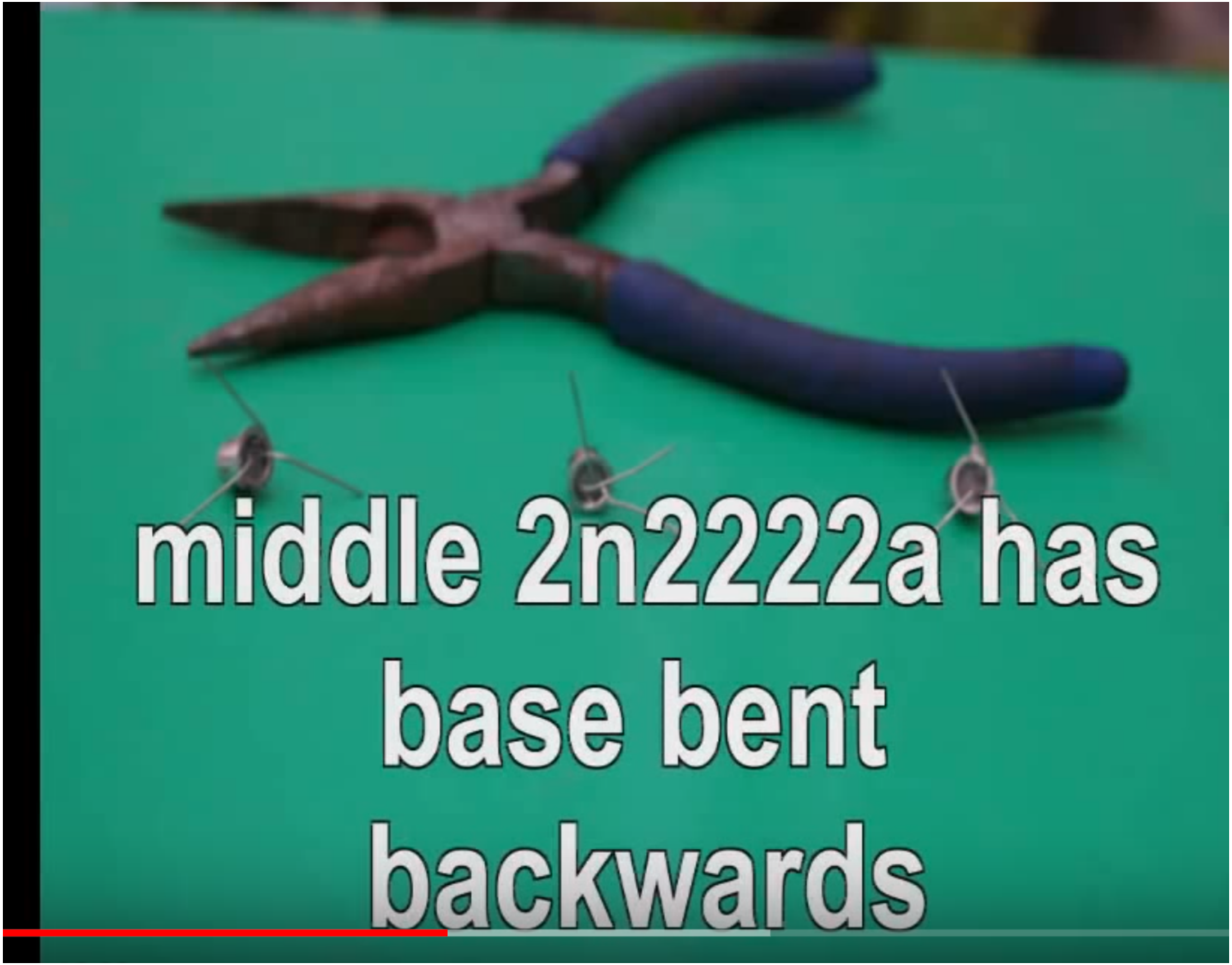

middle 2n2222a has base bent backwards

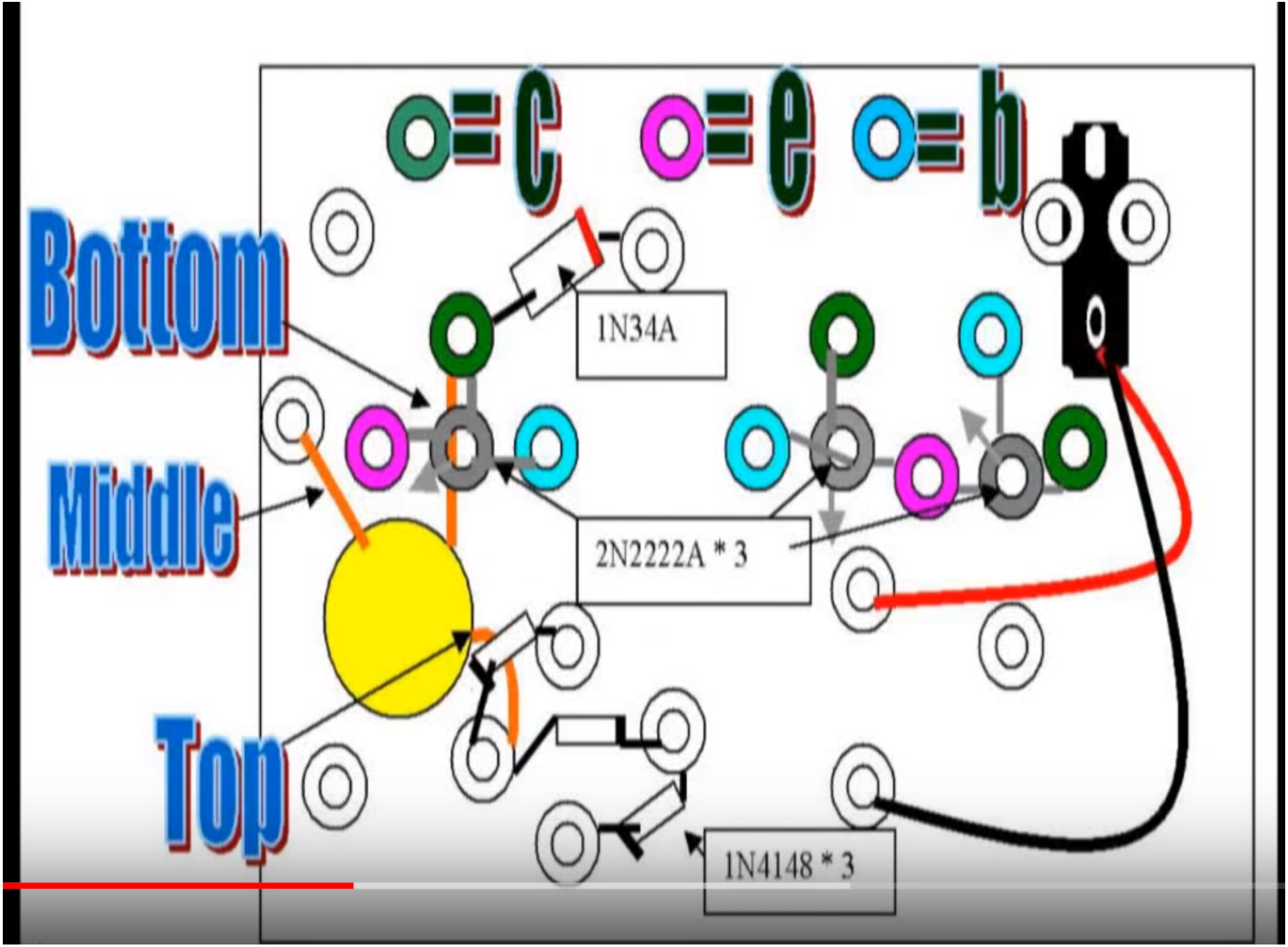
○=c
○=e
○=b
Bottom
Middle
Top
1N34A
2N2222A * 3
1N4148 * 3

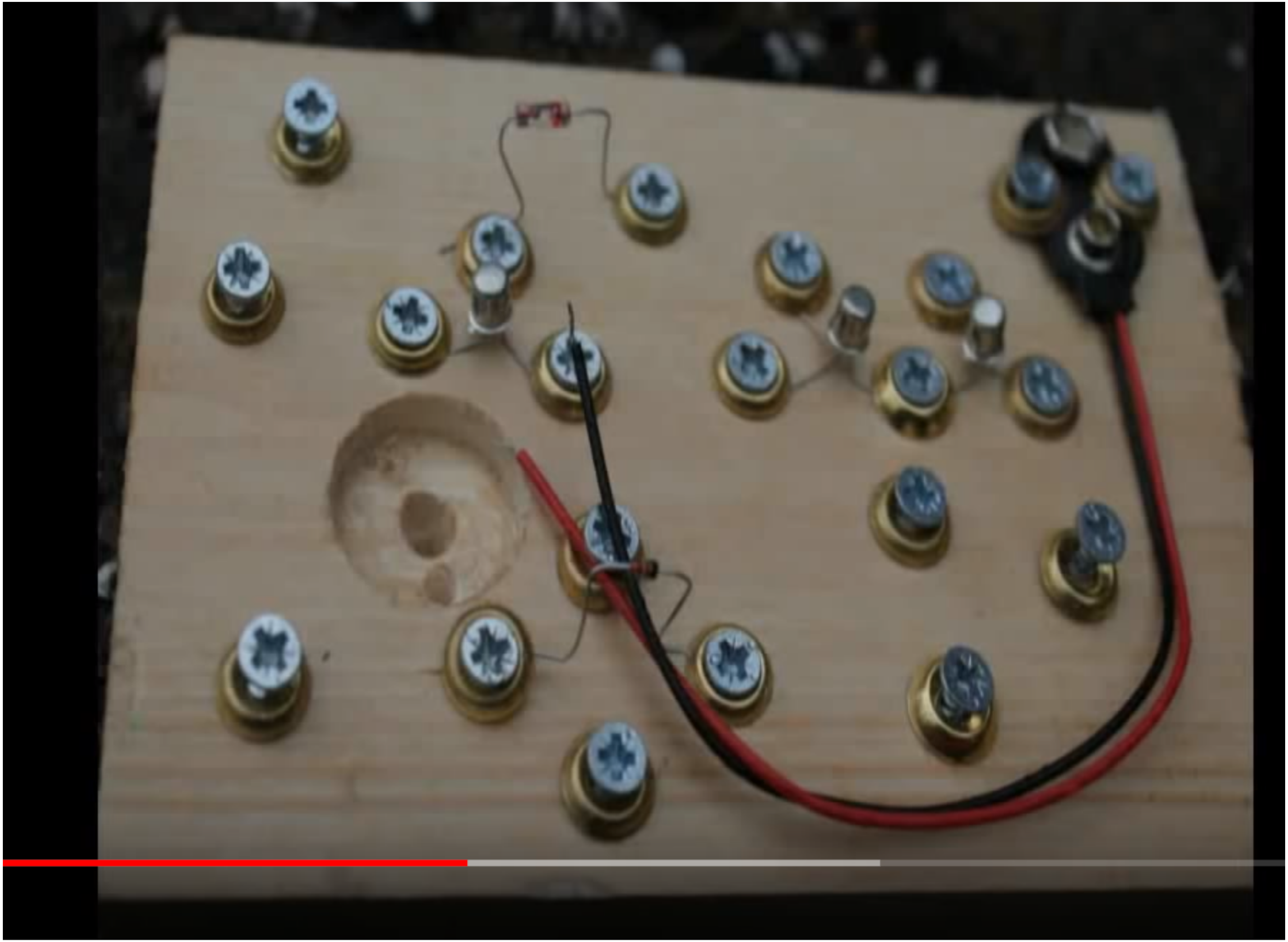

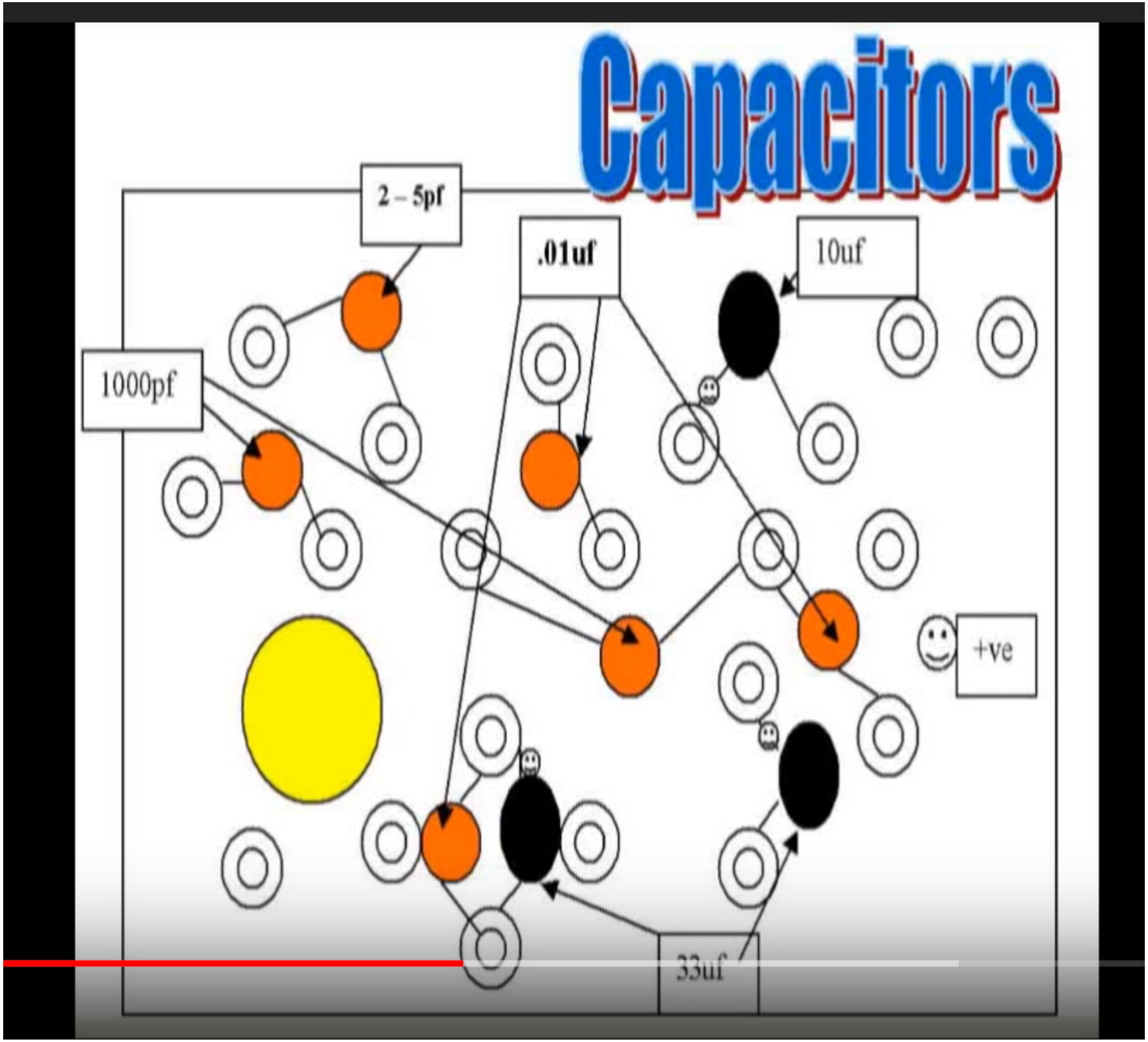

Capacitors

2 – 5pf
.01uf
10uf
1000pf
+ve
33uf

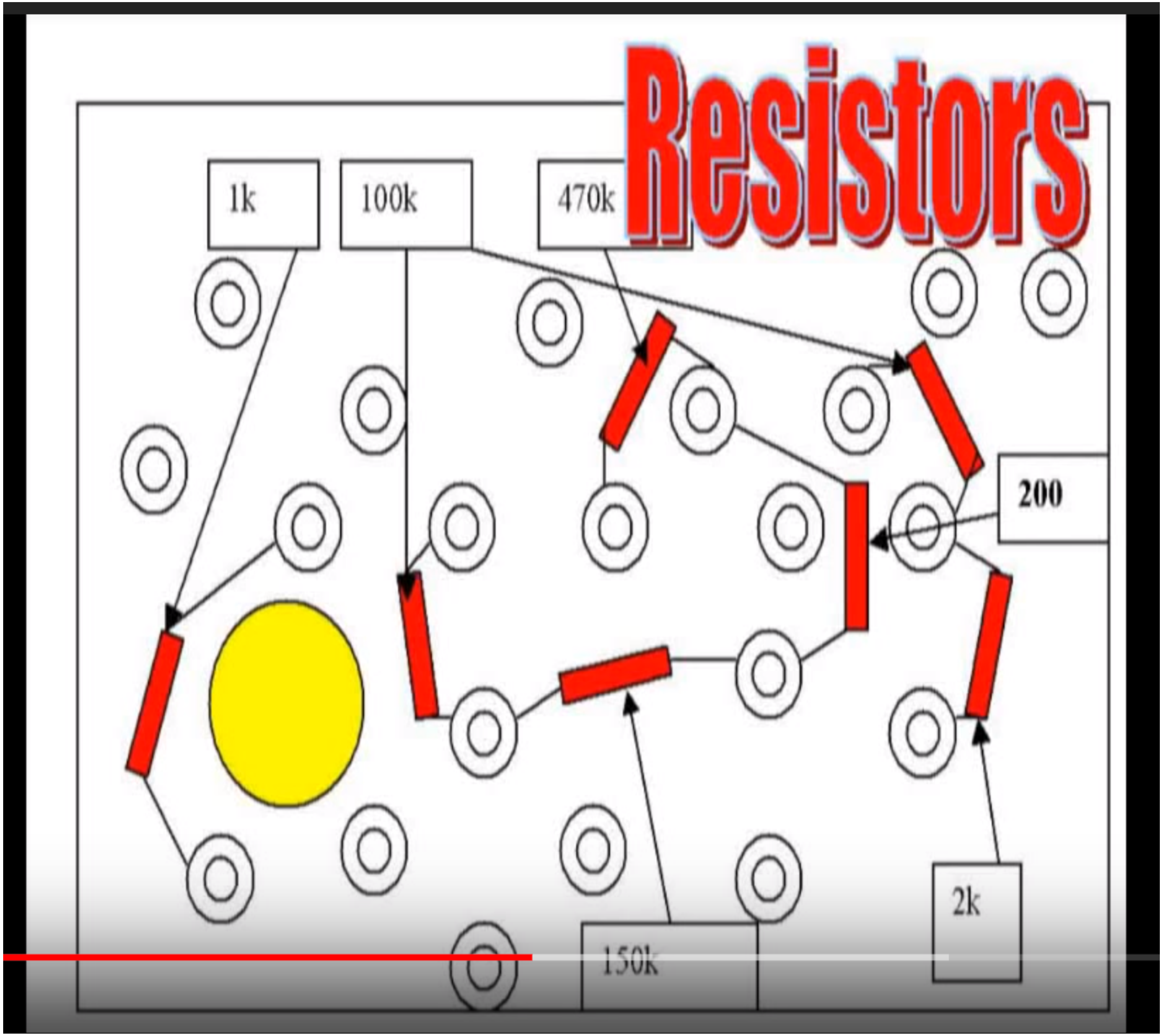
Resistors
1k
100k
470k
200
150k
2k

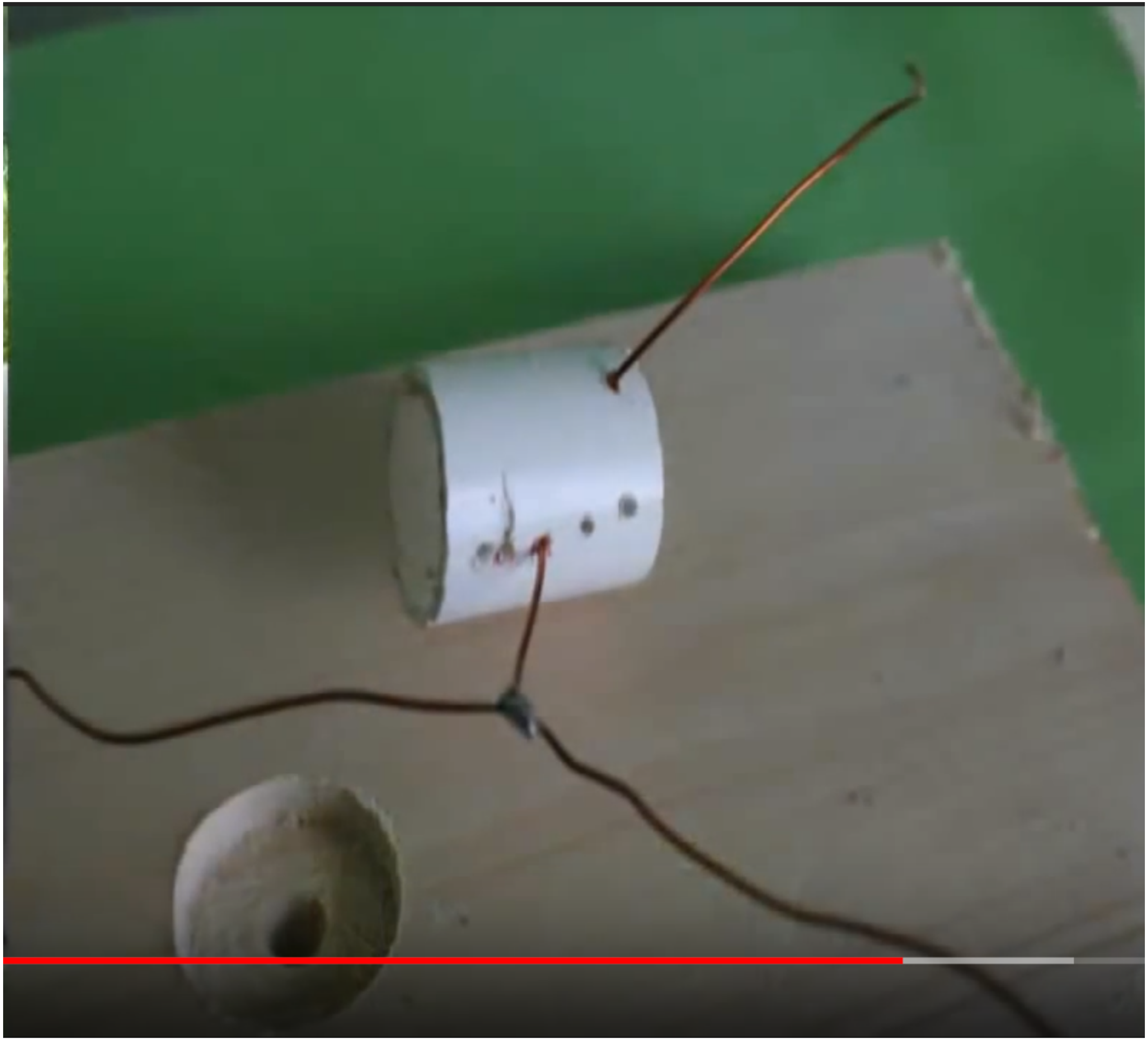

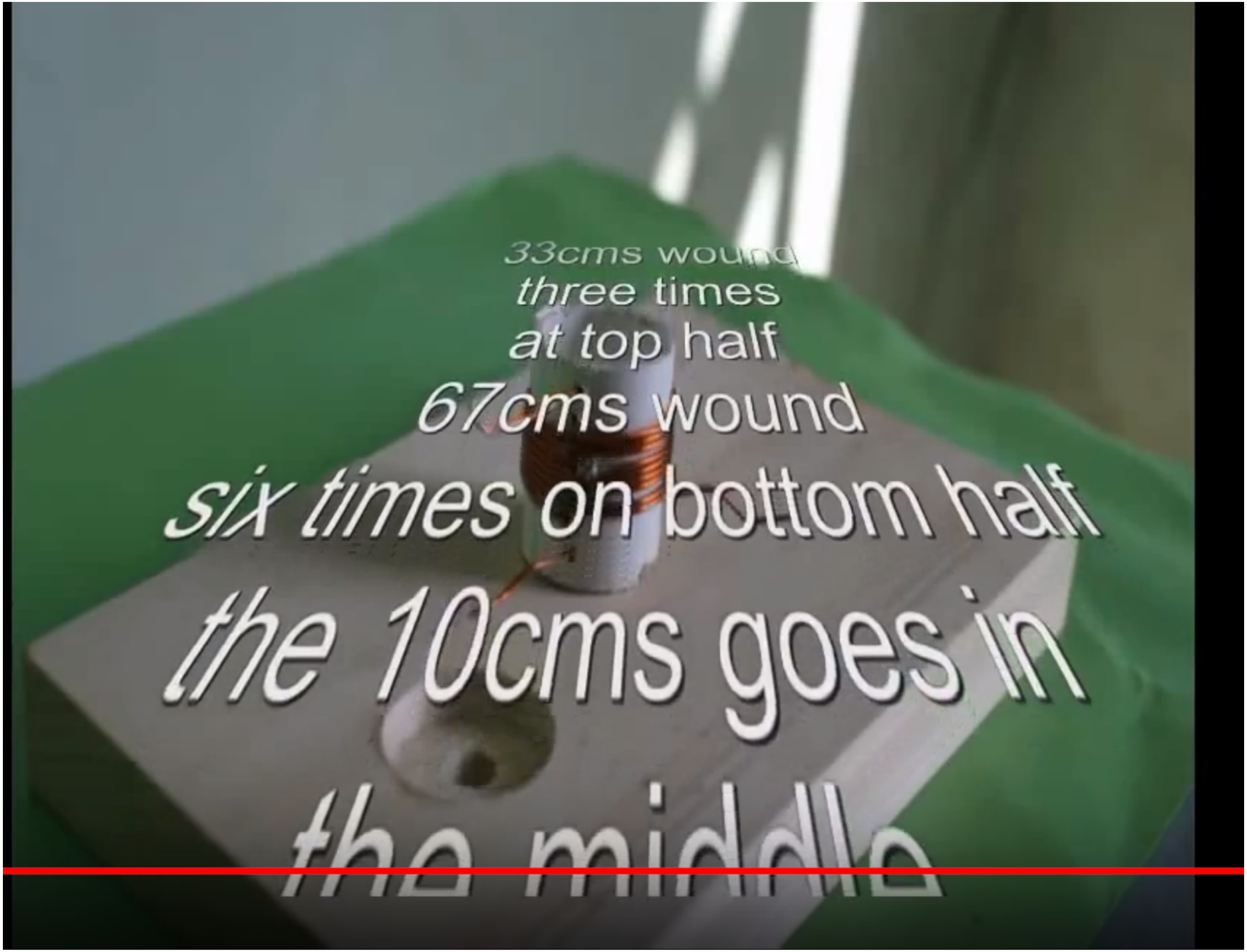

33cms wound
three times
at top half
67cms wound
six times on bottom half
the 10cms goes in
the middle

Rapidonline.com
minature tuning
capacitor 50v

220k
potentiometer

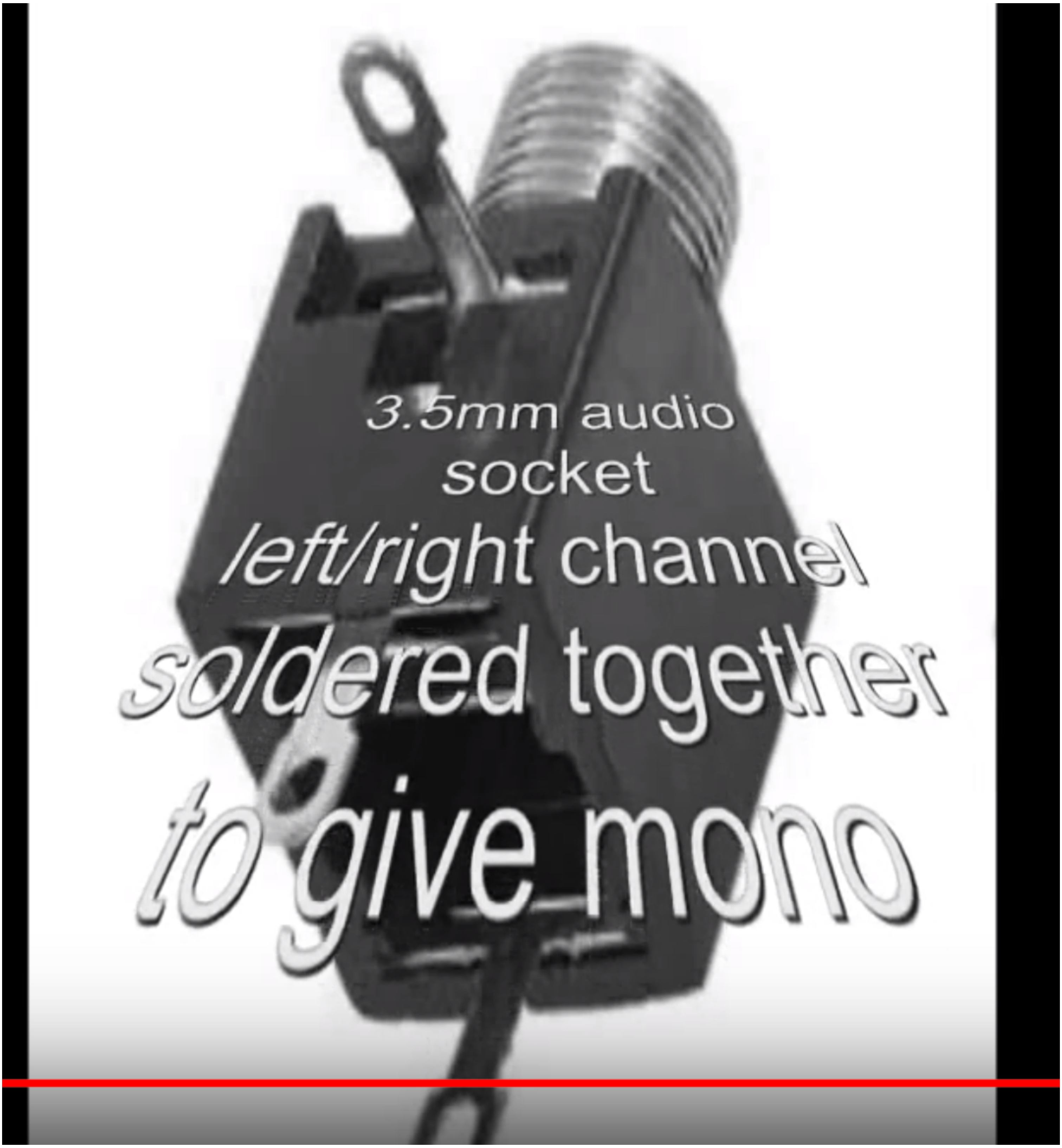

3.5mm audio
socket
left/right channel
soldered together
to give mono

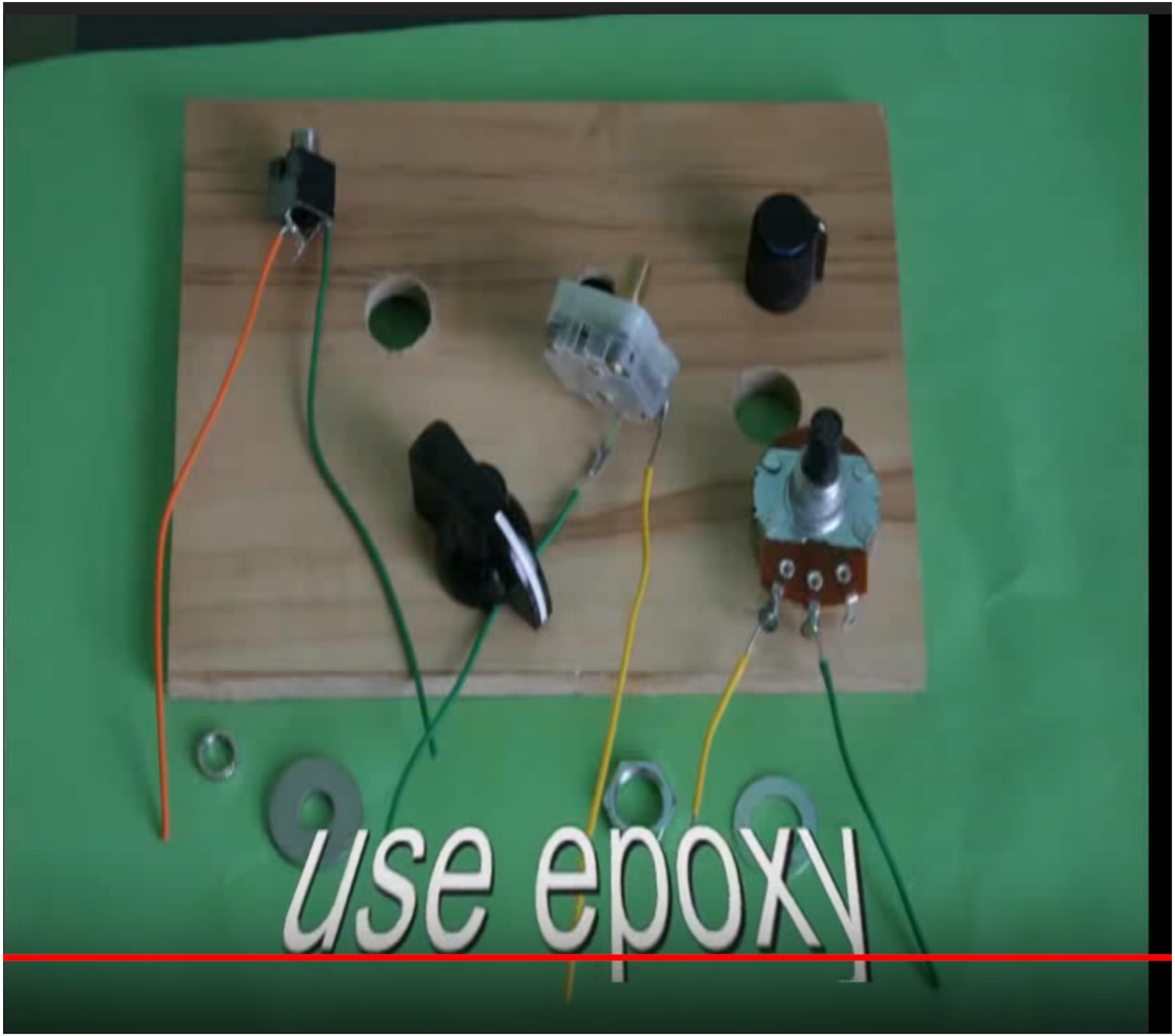
use epoxy

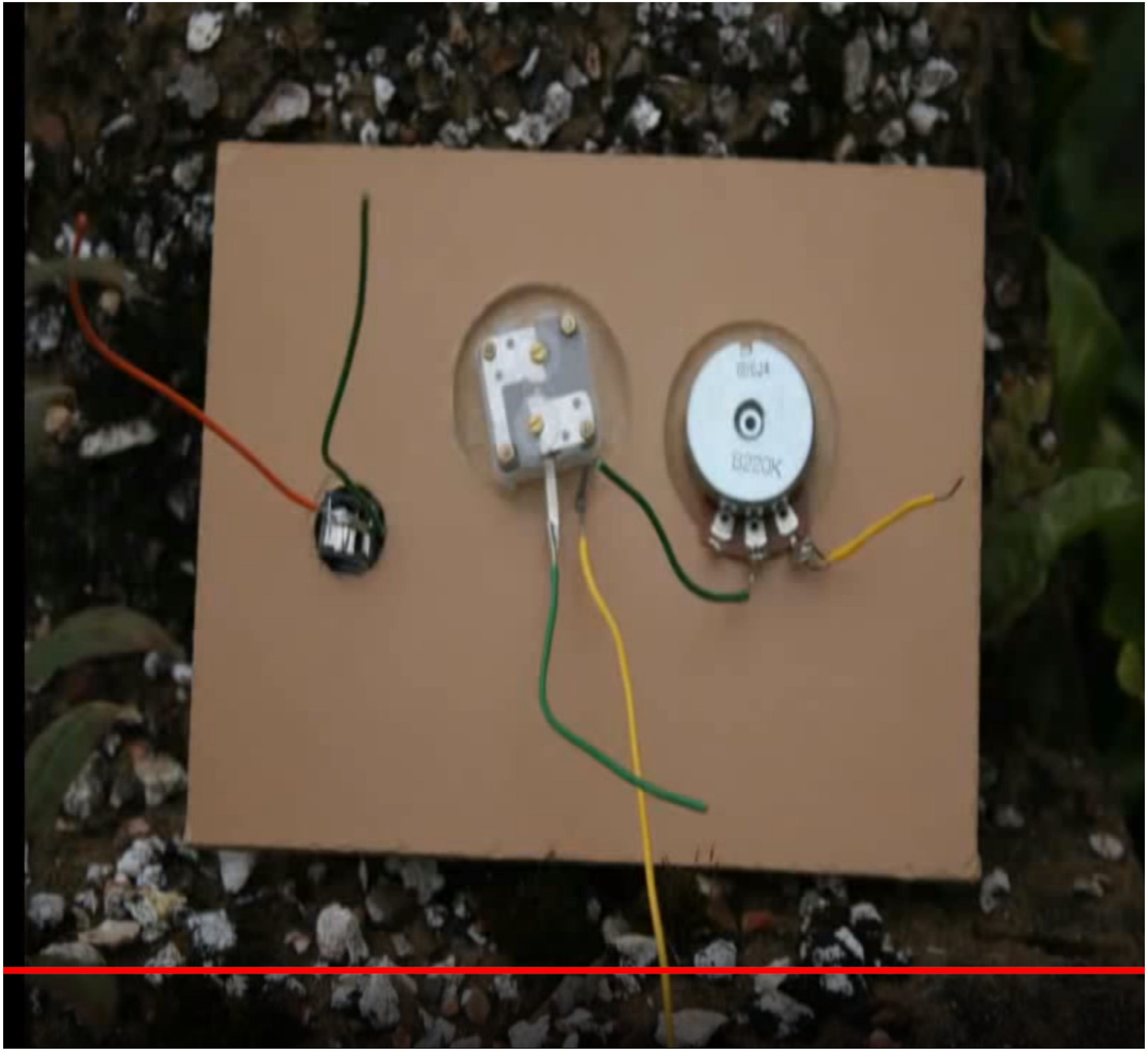
B220K

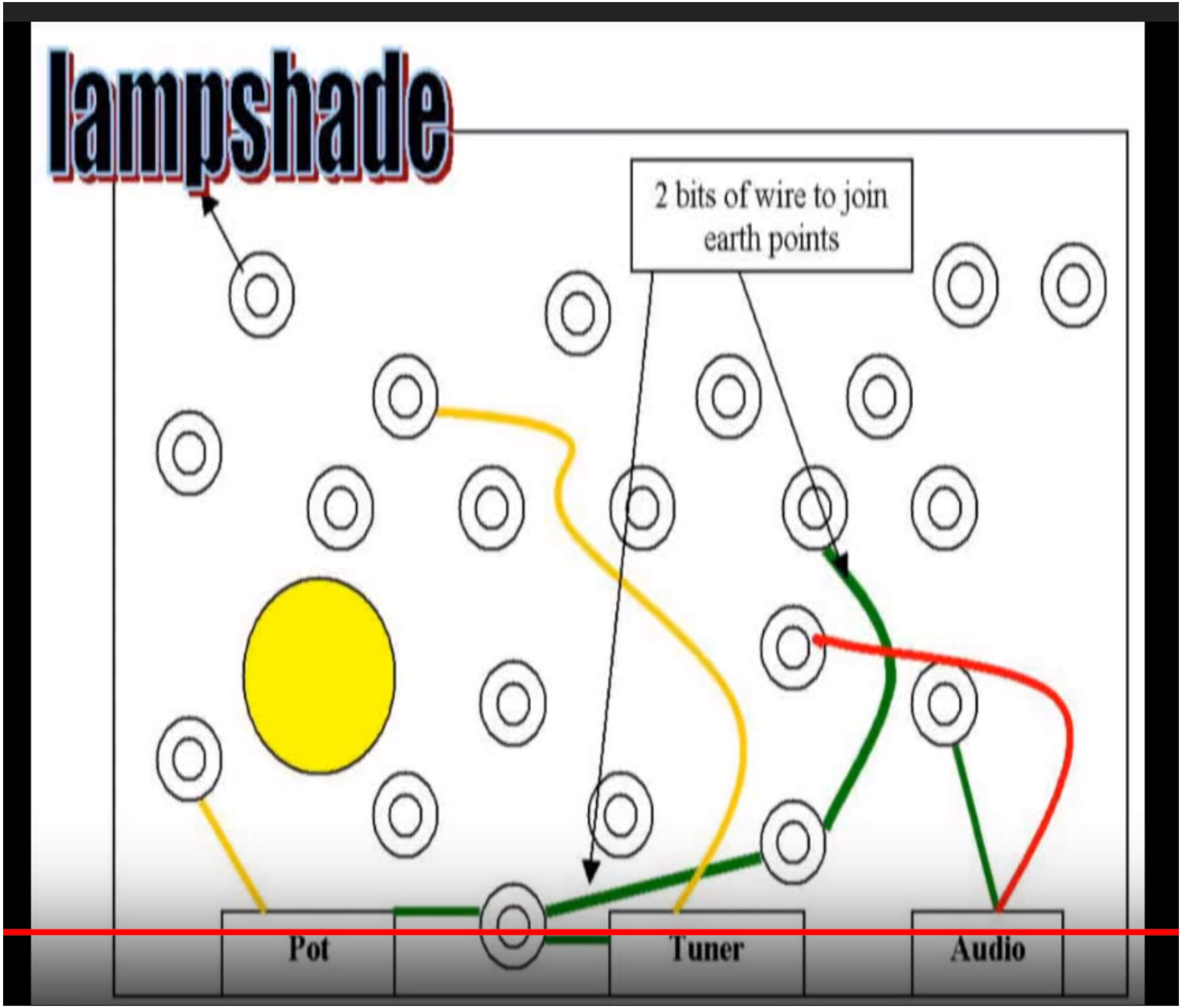

lampshade

2 bits of wire to join earth points

Pot
Tuner
Audio

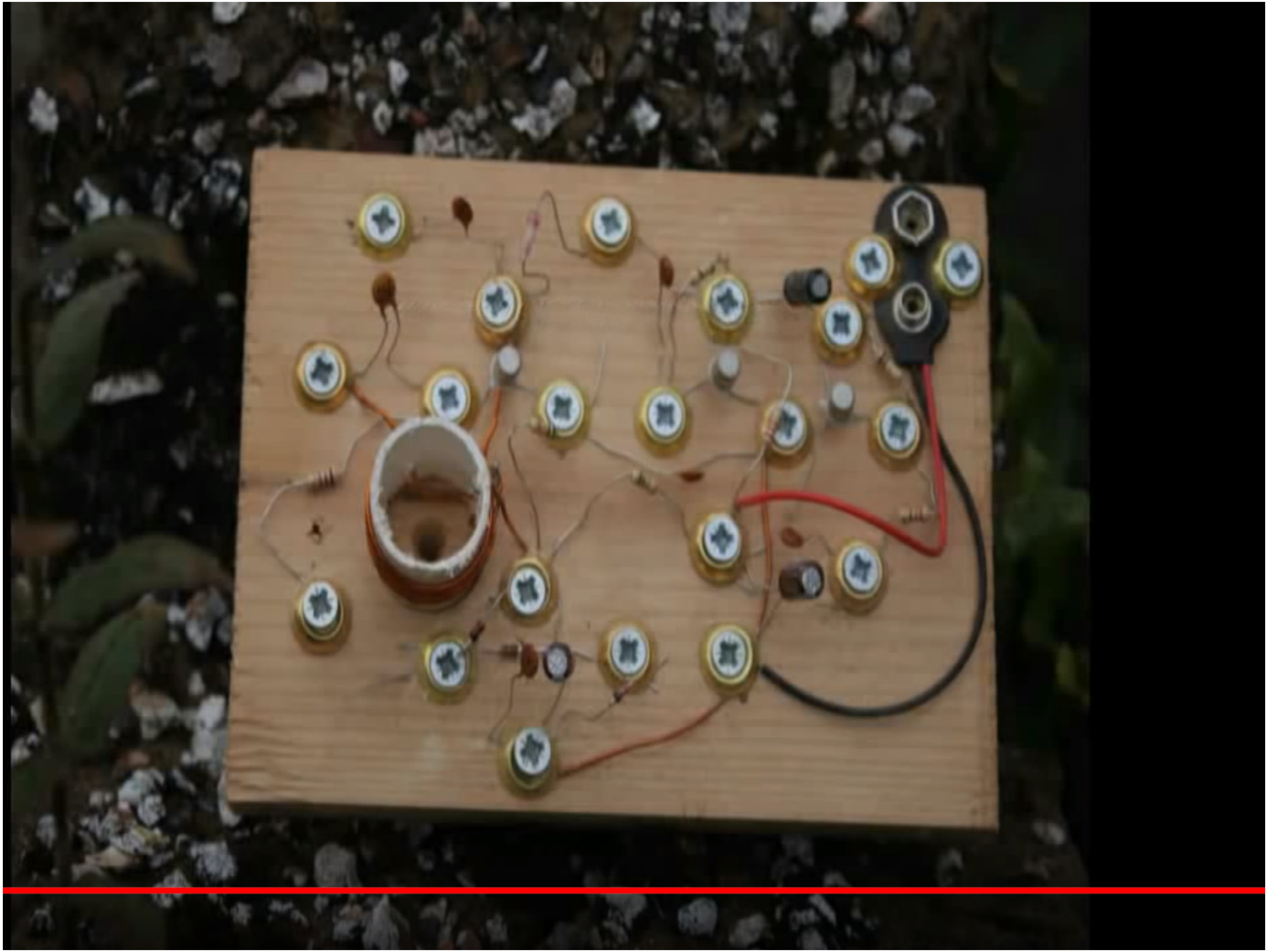

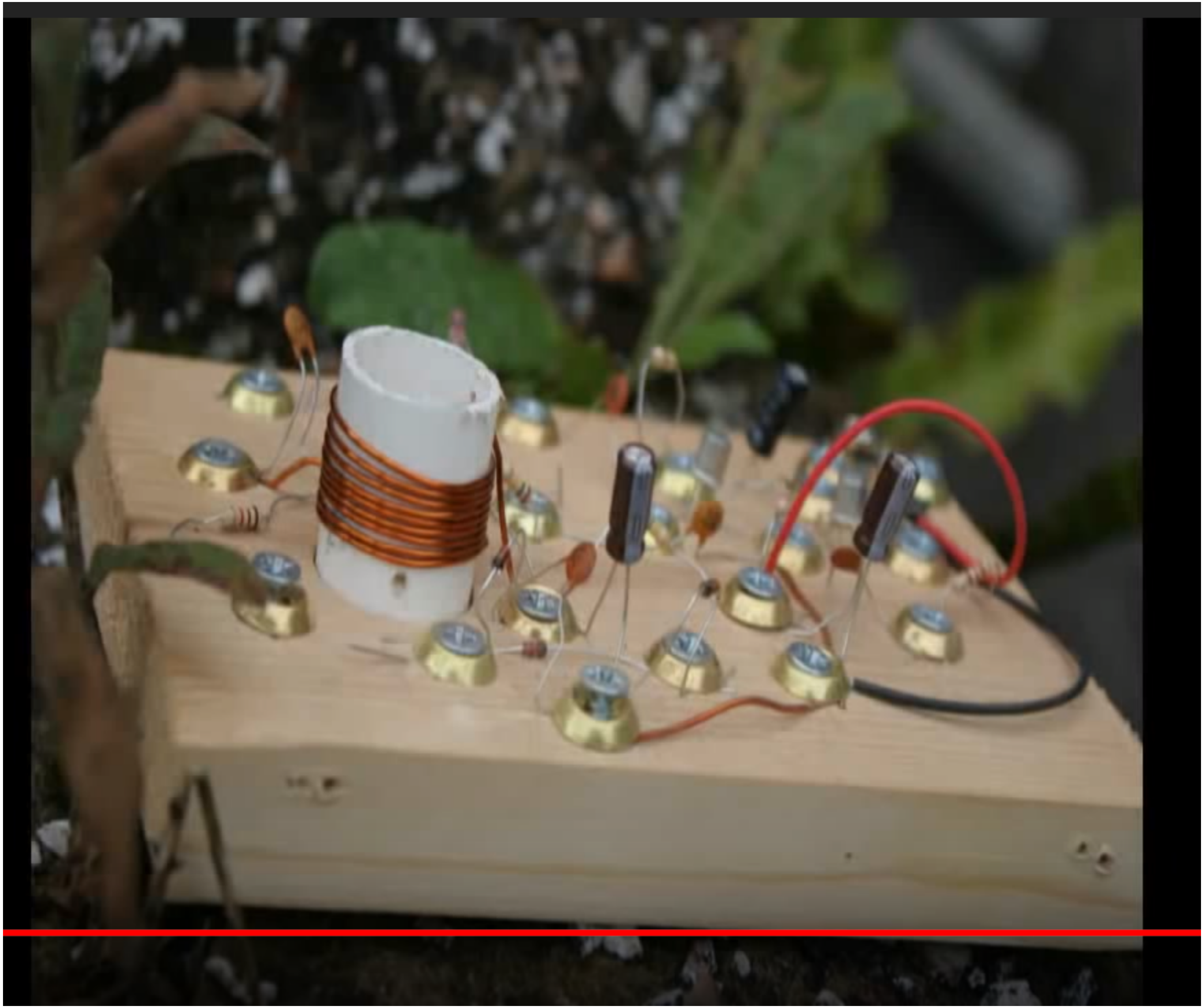

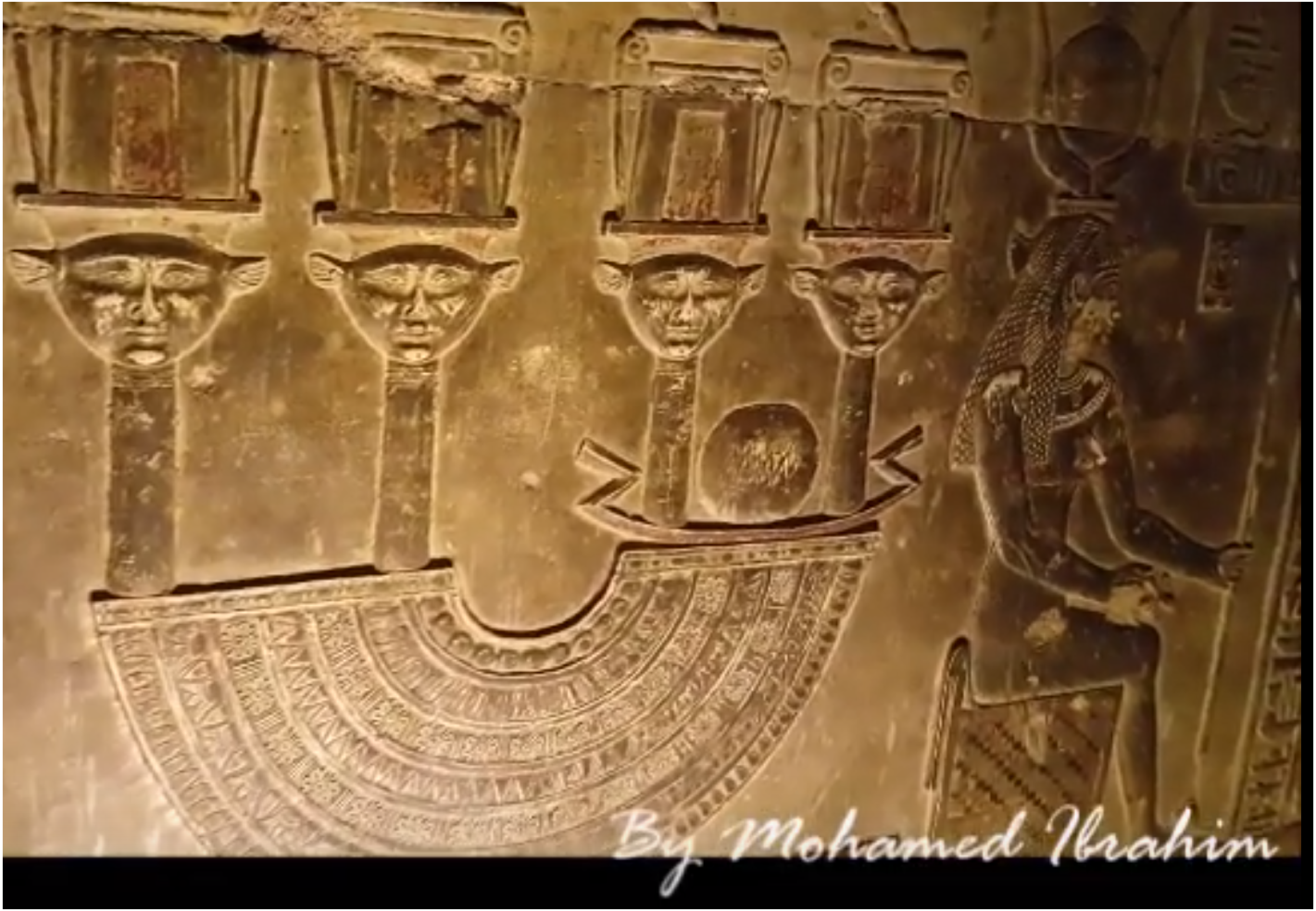

By Mohamed Ibrahim

SUMERIAN DEPICTIONS OF ANUNNAKI GODS FLYING IN "WHIRLWINDS"

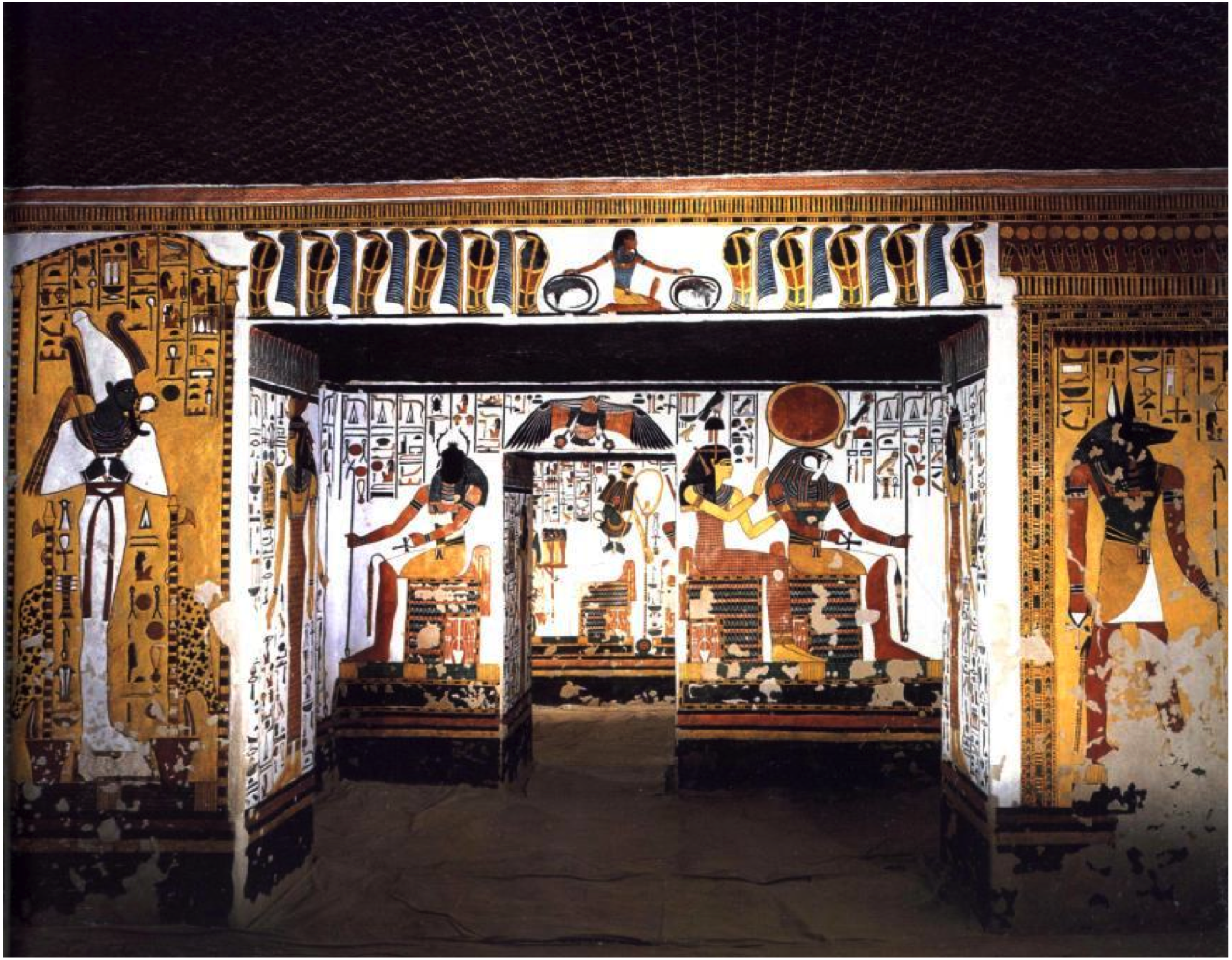

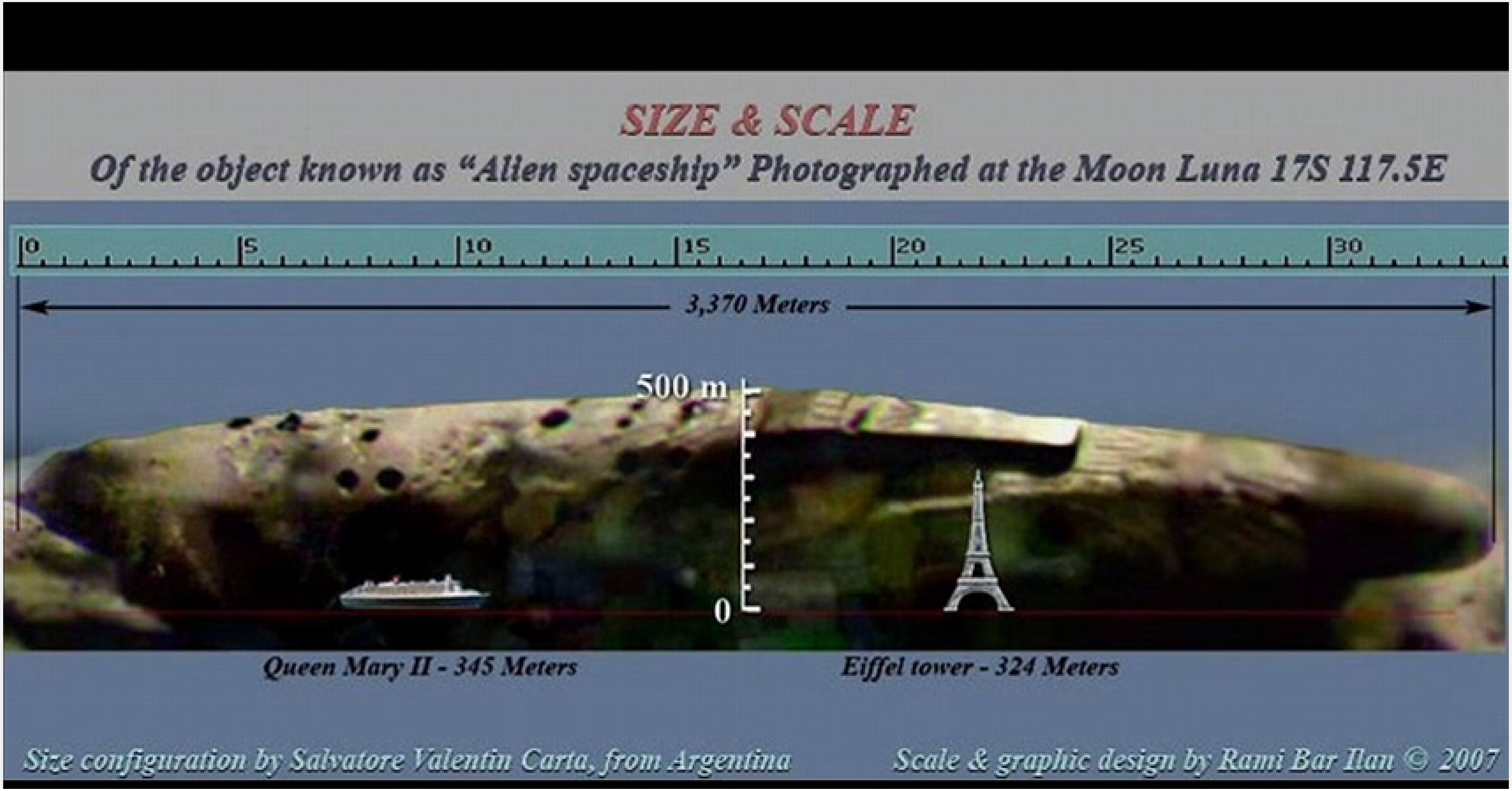

SIZE & SCALE

Of the object known as "Alien spaceship" Photographed at the Moon Luna 17S 117.5E

0
5
10
15
20
25
30
3,370 Meters
500 m
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Queen Mary II - 345 Meters
Eiffel tower - 324 Meters

Size configuration by Salvatore Valentin Carta, from Argentina

Scale & graphic design by Rami Bar Ilan © 2007

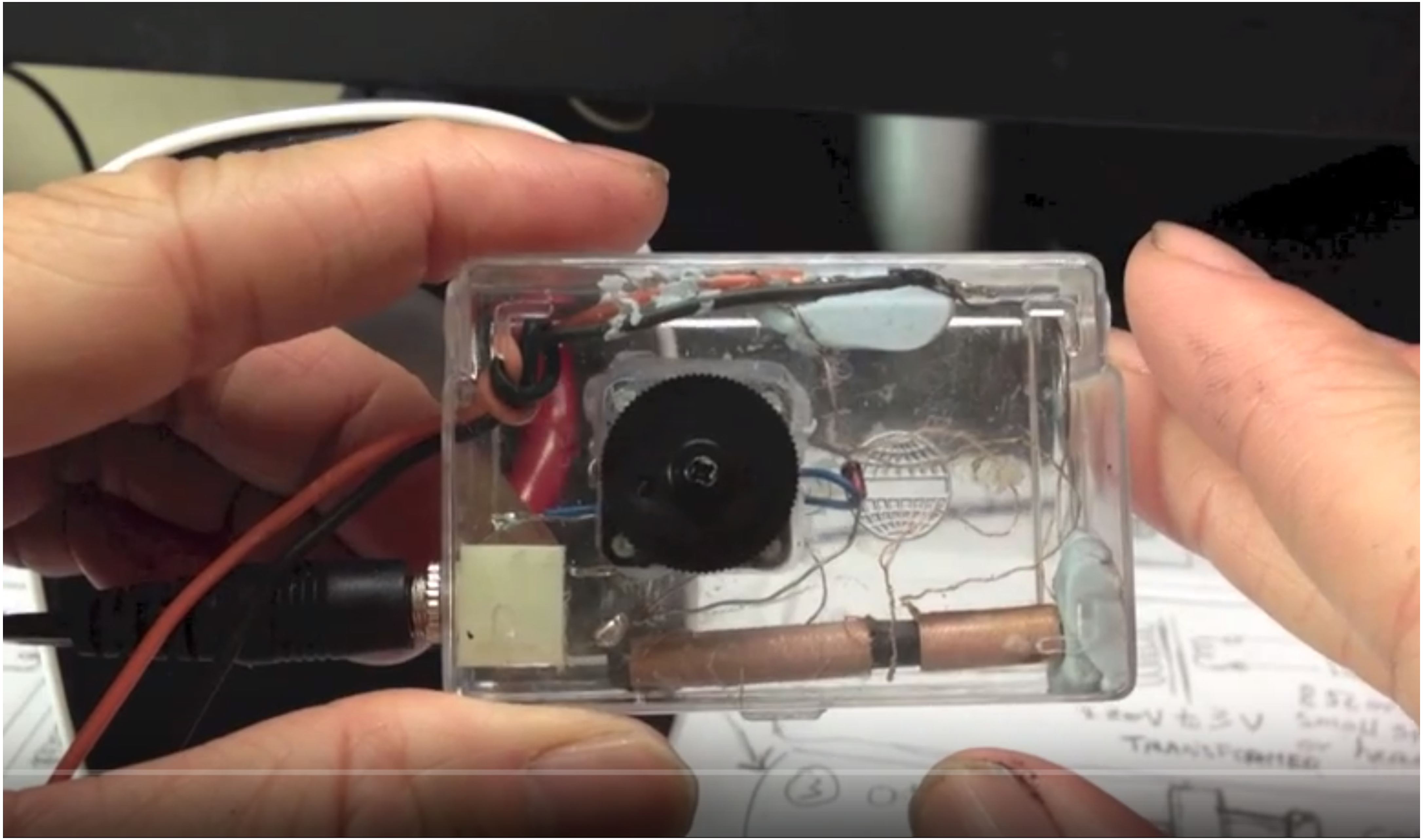
to 3V
TRANSFORMER
small
or

Simple Crystal Radio Circuit - http://billydiy.blogspot.hk

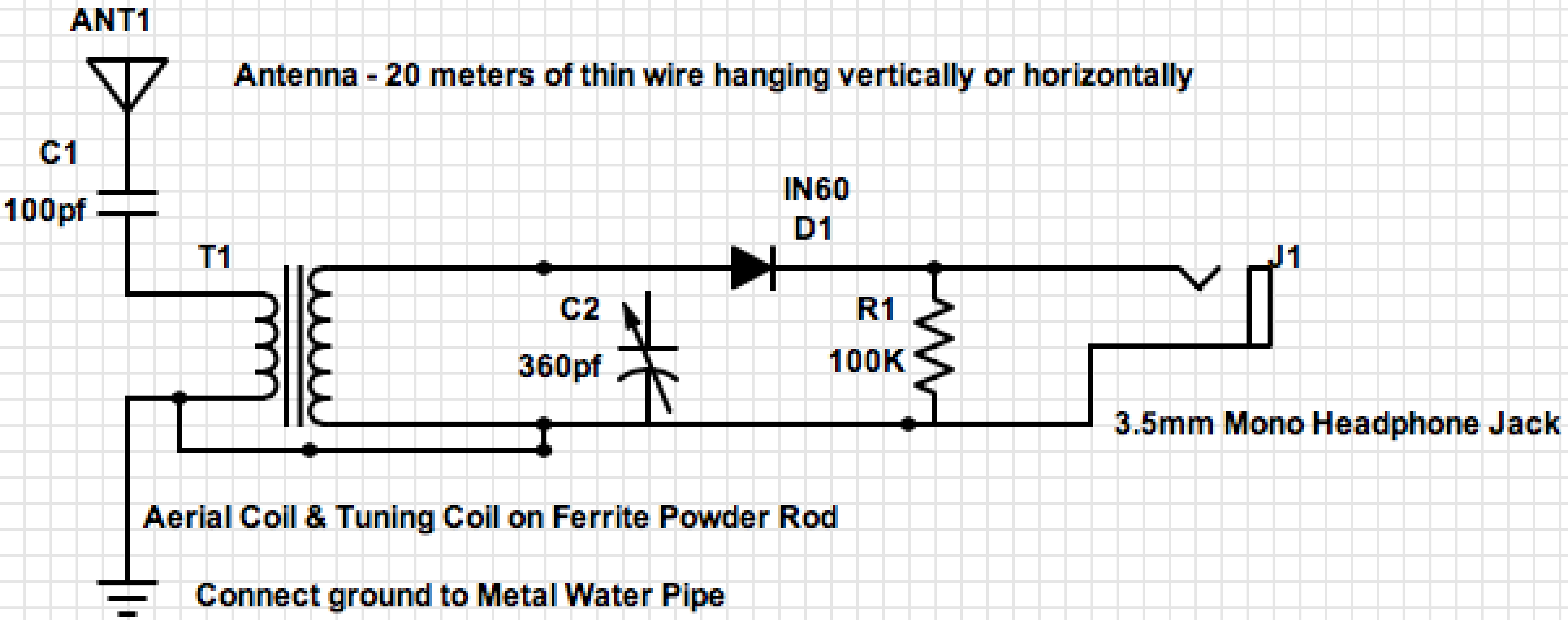
ANT1
C1
100pf
T1
IN60
D1
C2
360pf
R1
100K
J1

Antenna - 20 meters of thin wire hanging vertically or horizontally

3.5mm Mono Headphone Jack

Aerial Coil & Tuning Coil on Ferrite Powder Rod

Connect ground to Metal Water Pipe

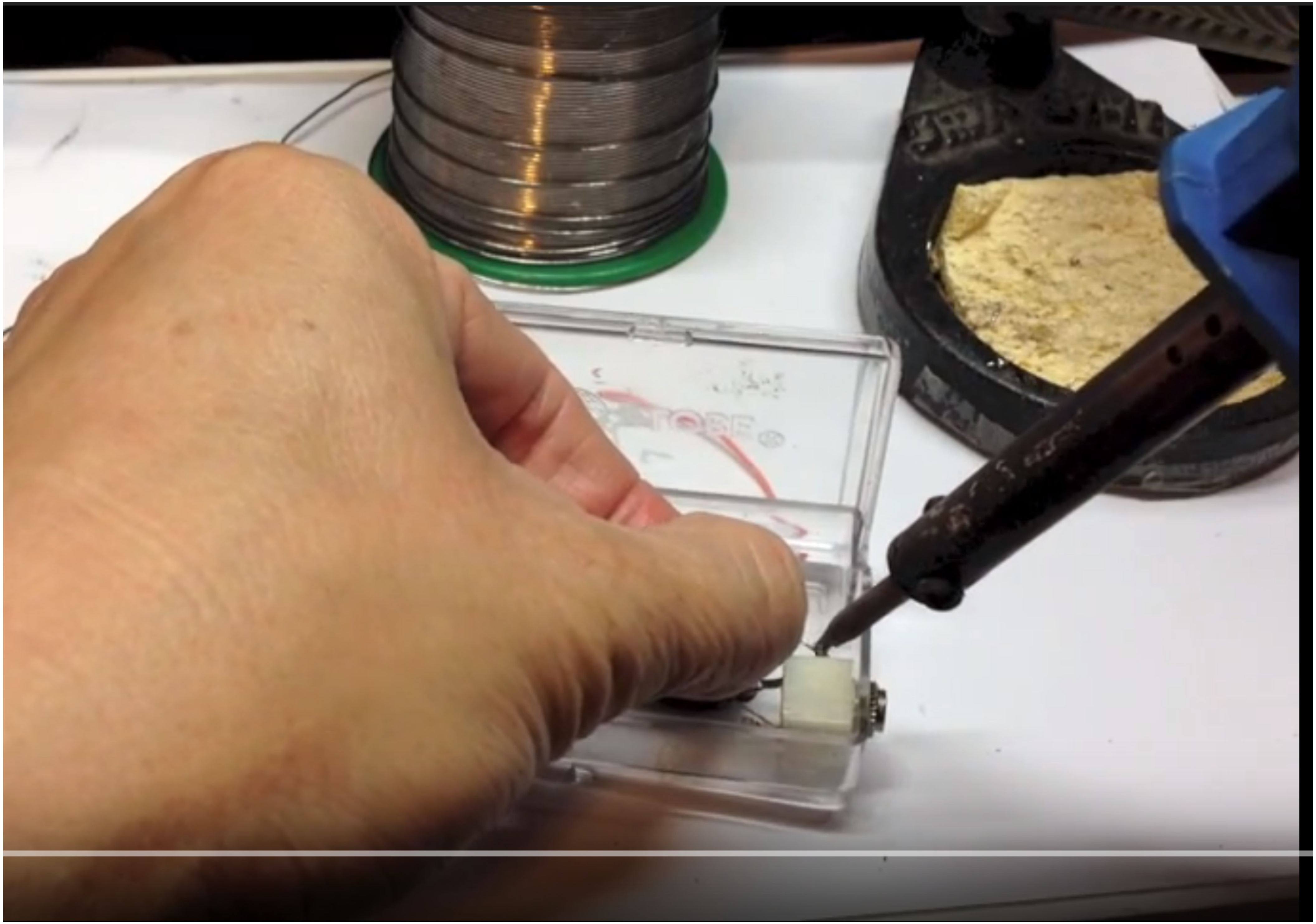
TOBE

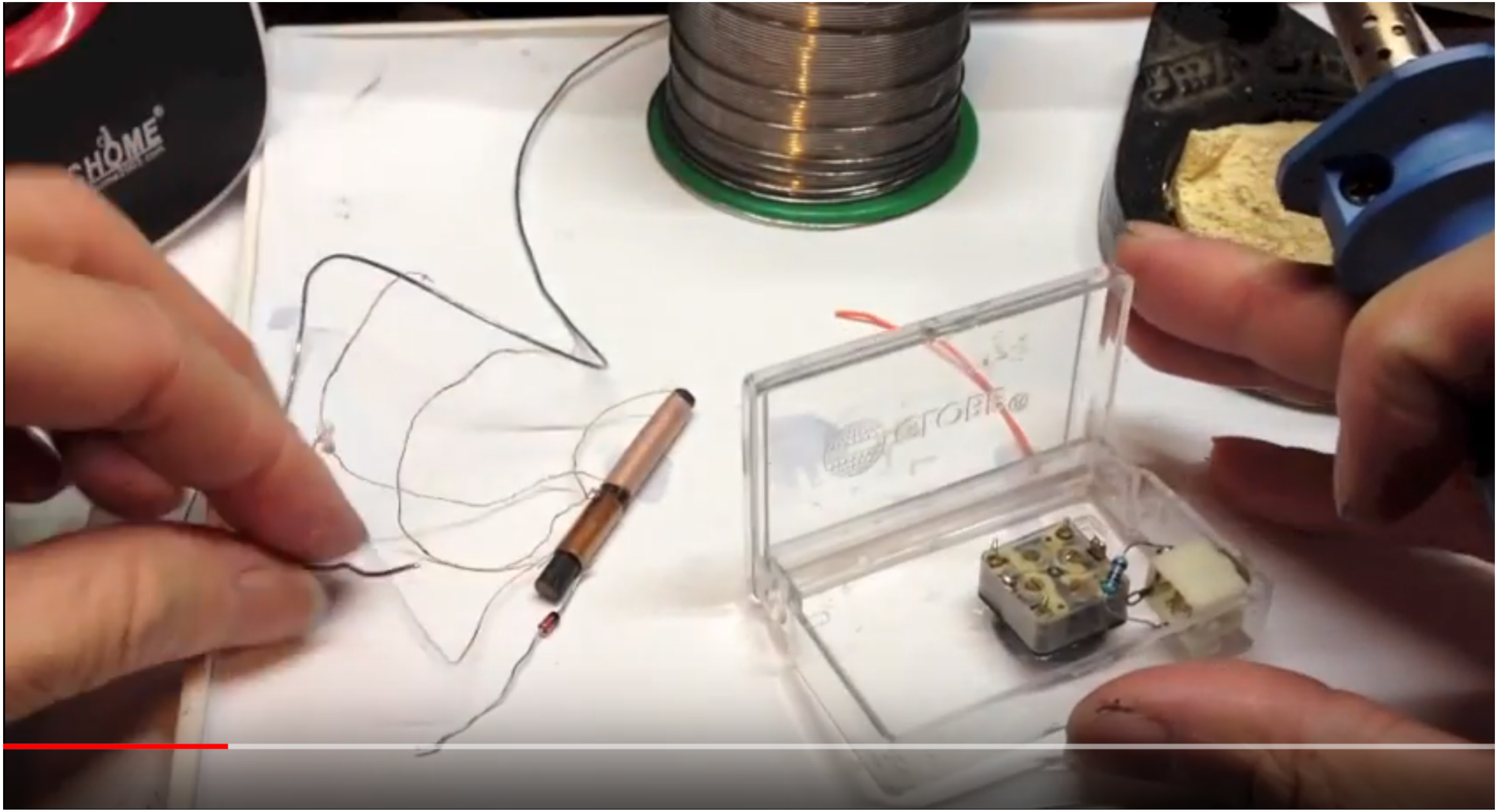
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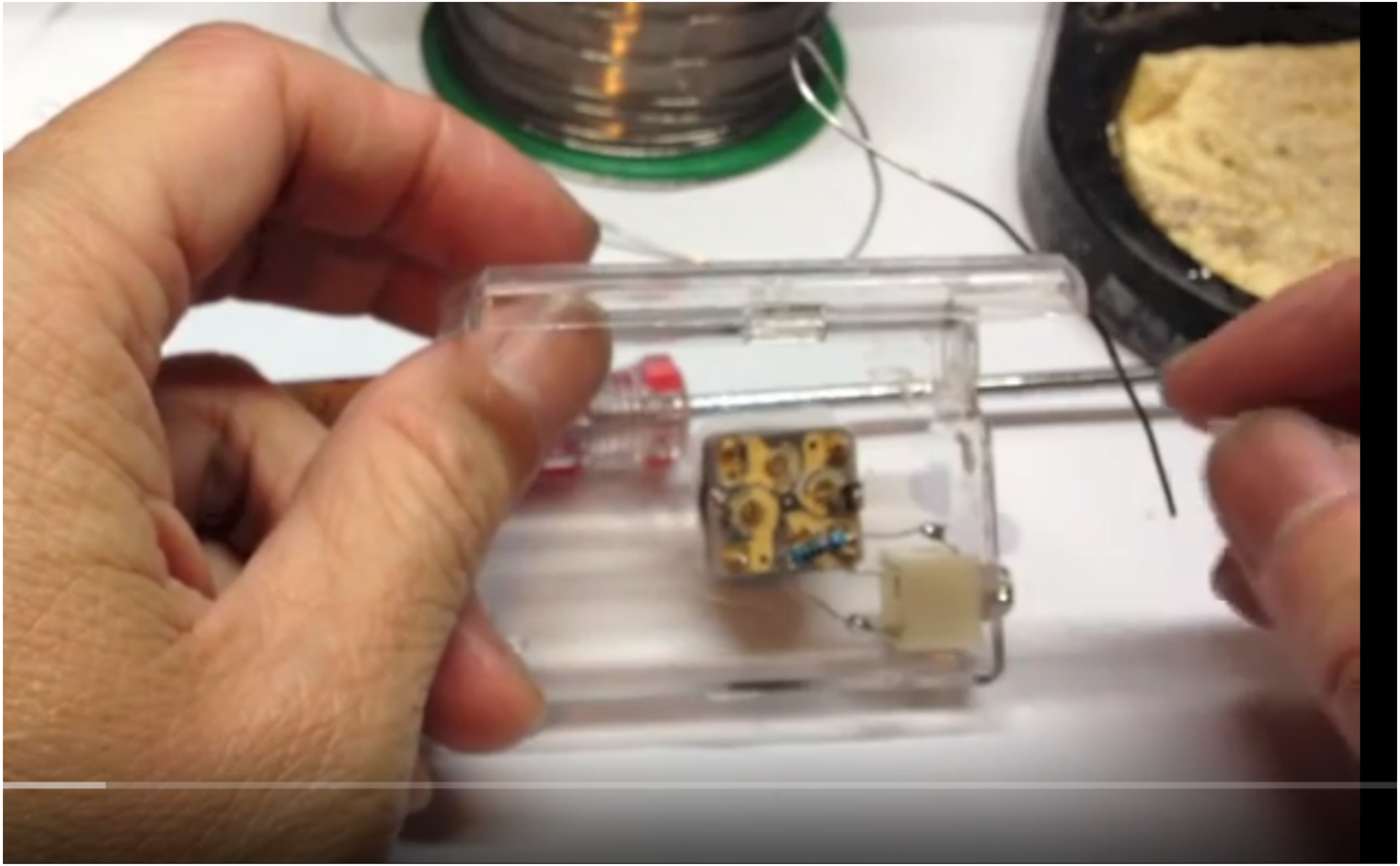

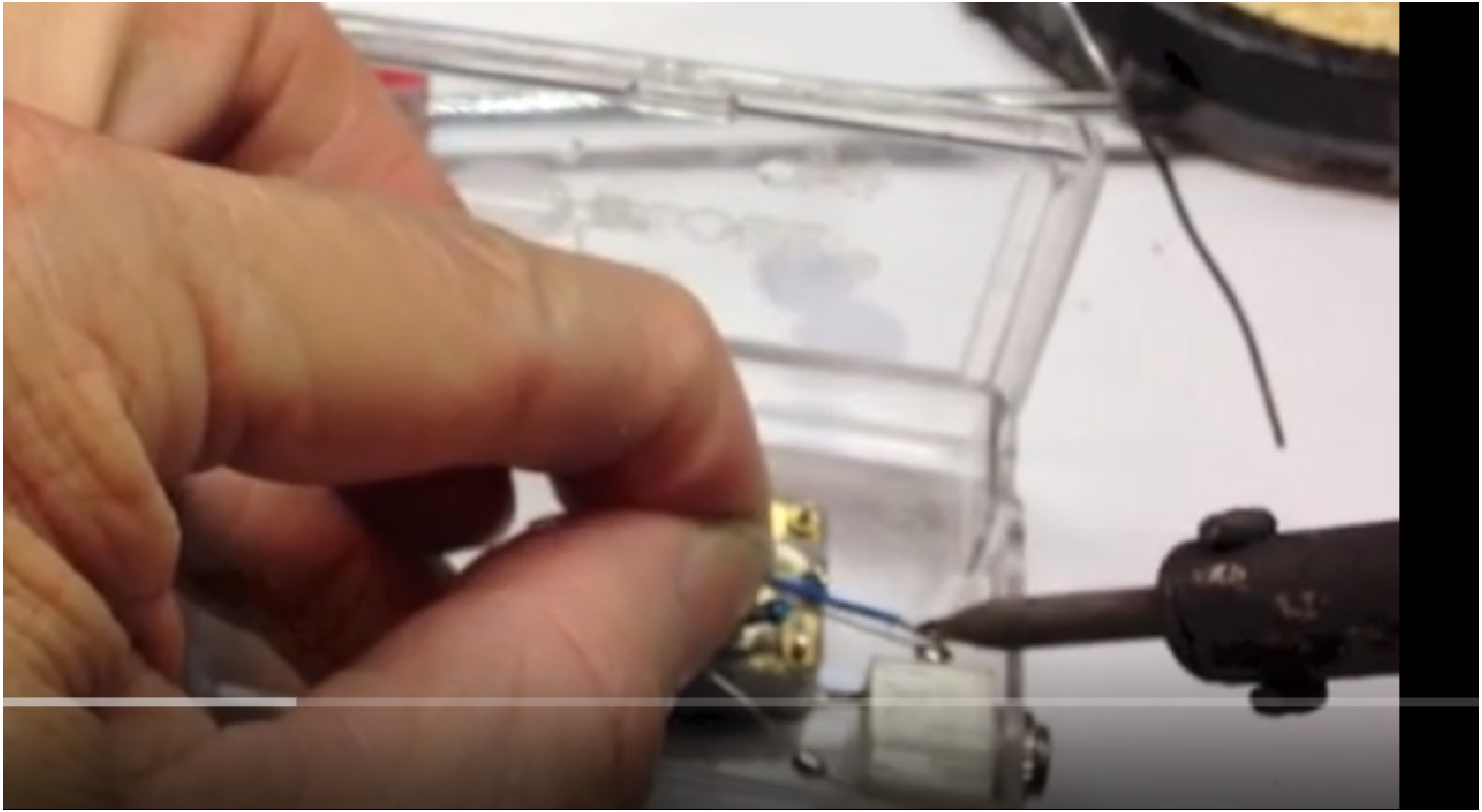

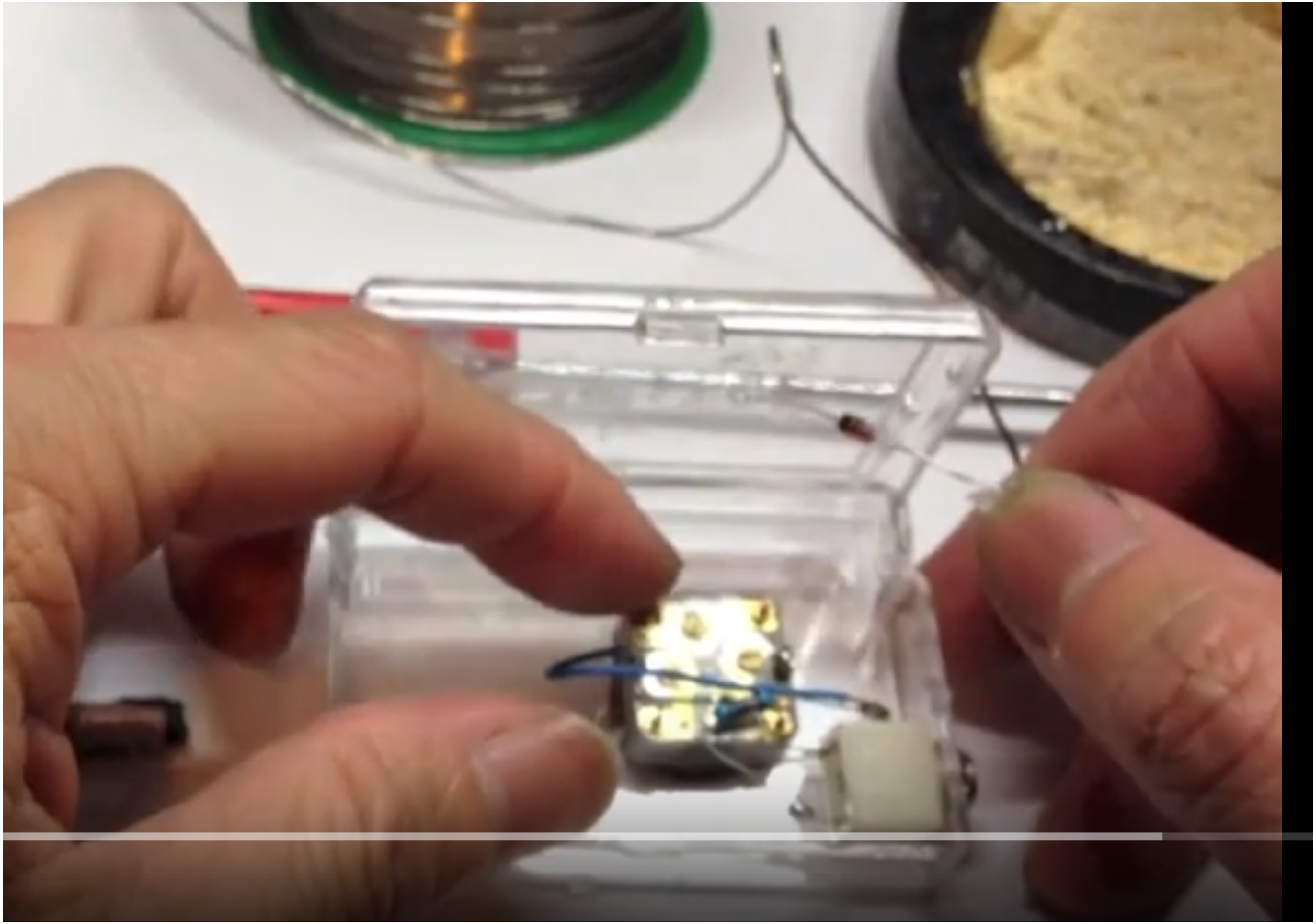

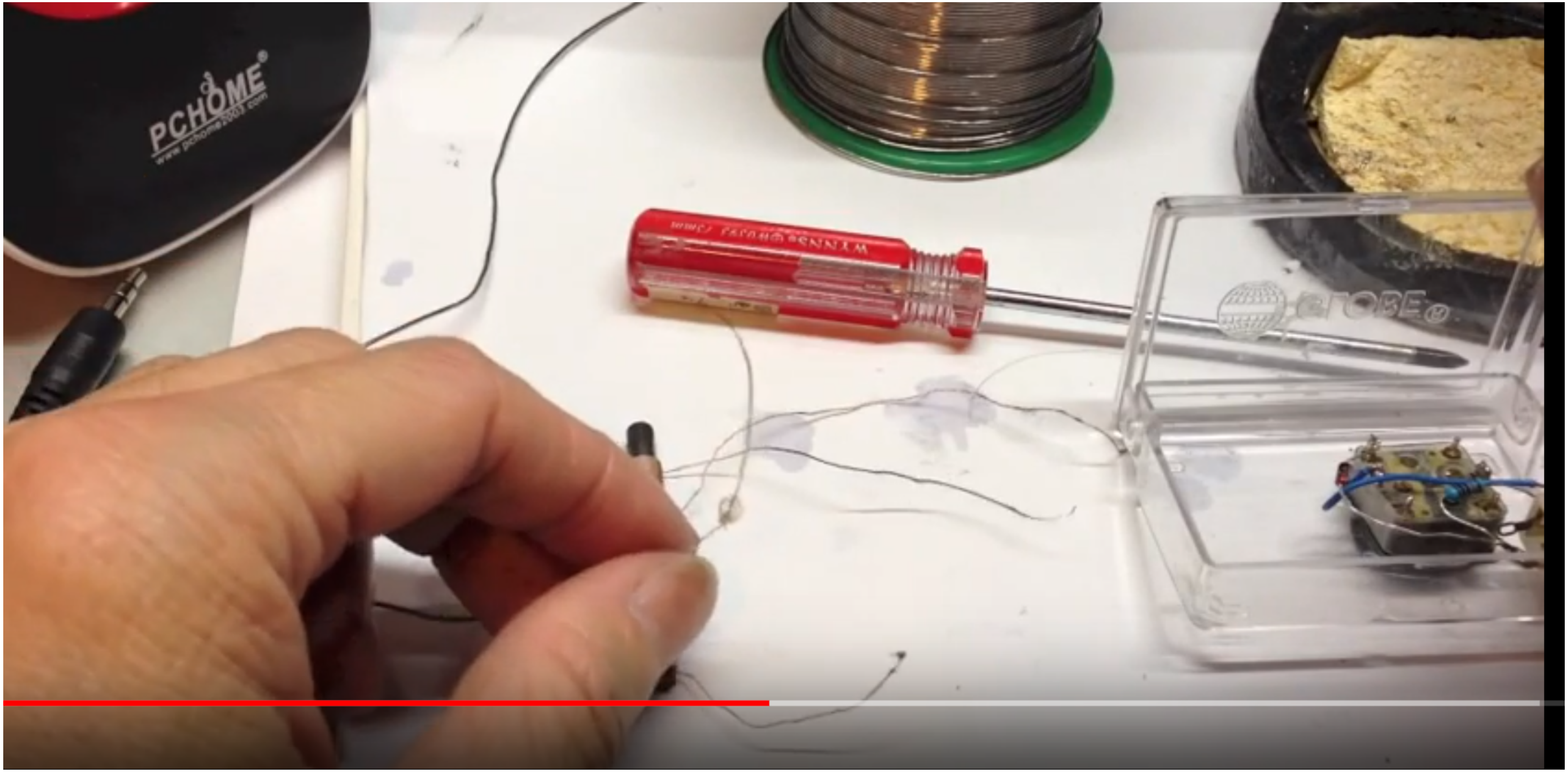
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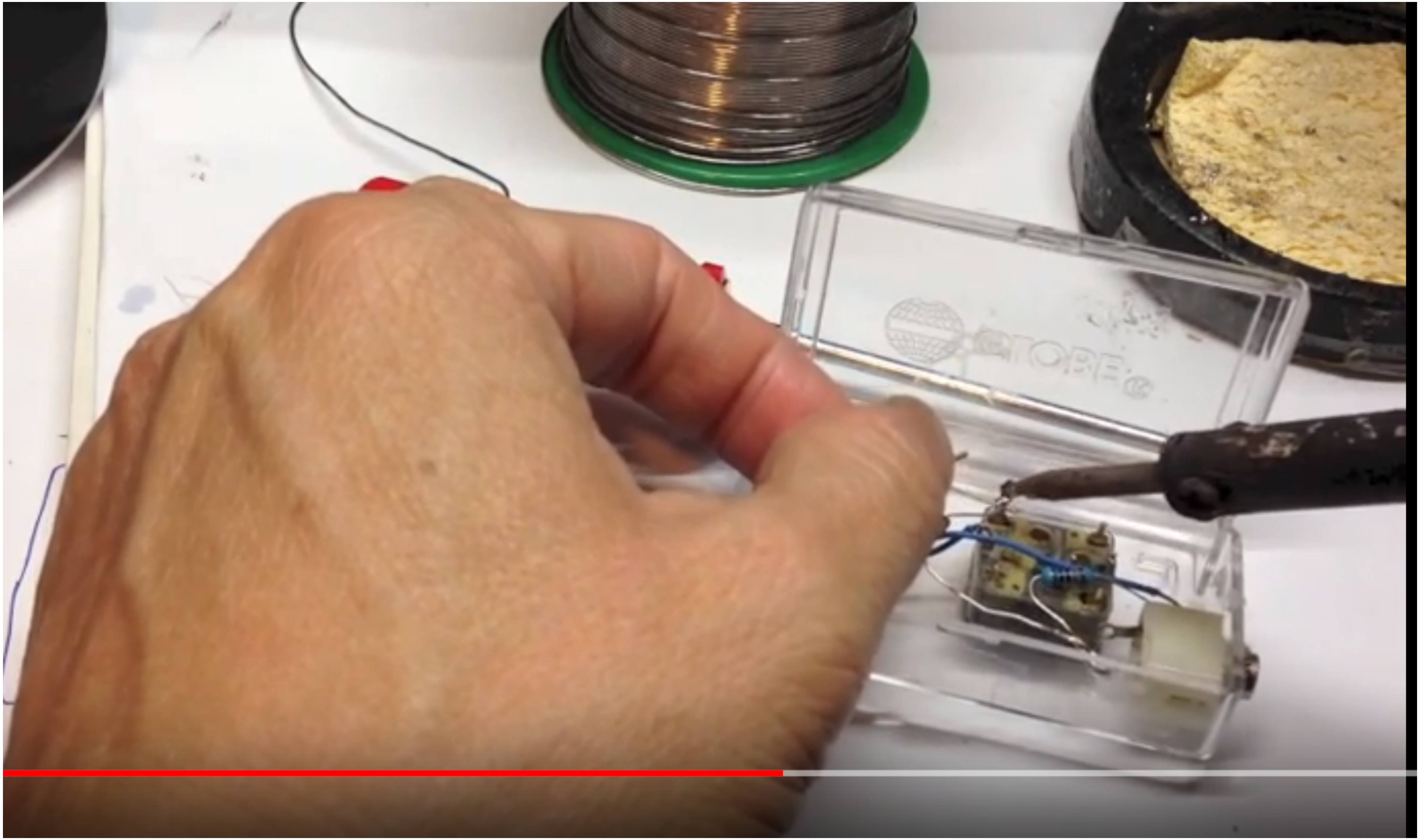
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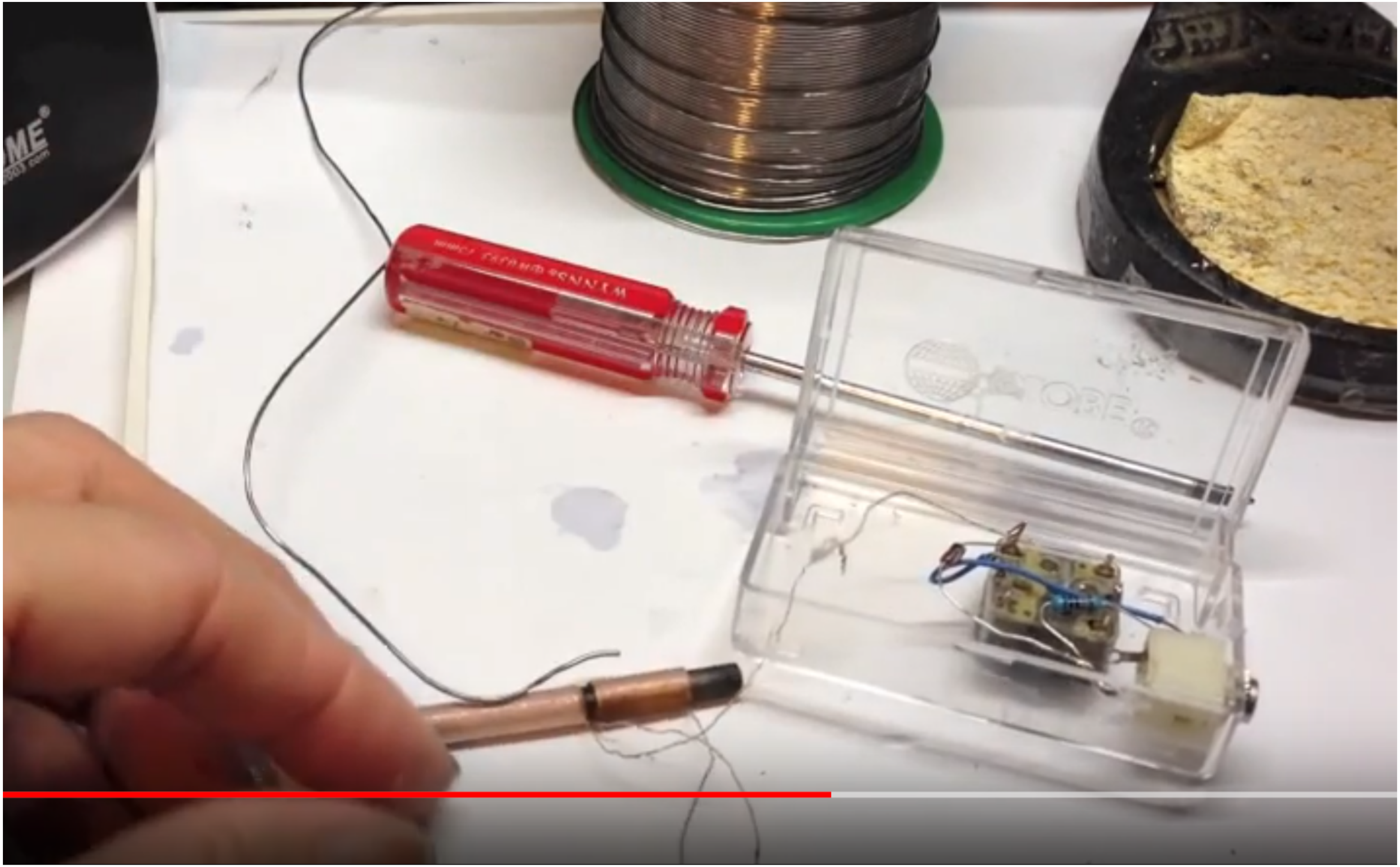

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HOME

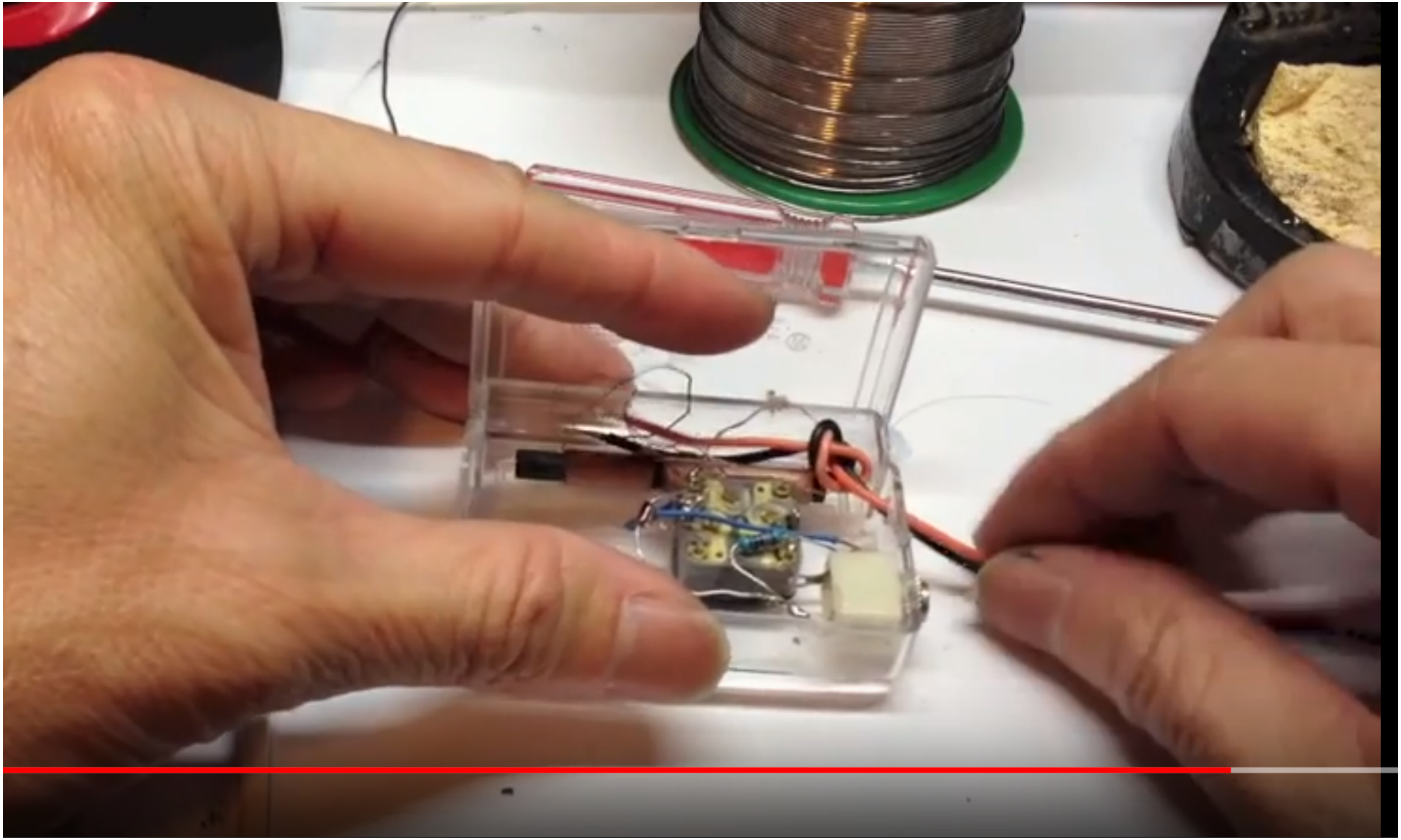

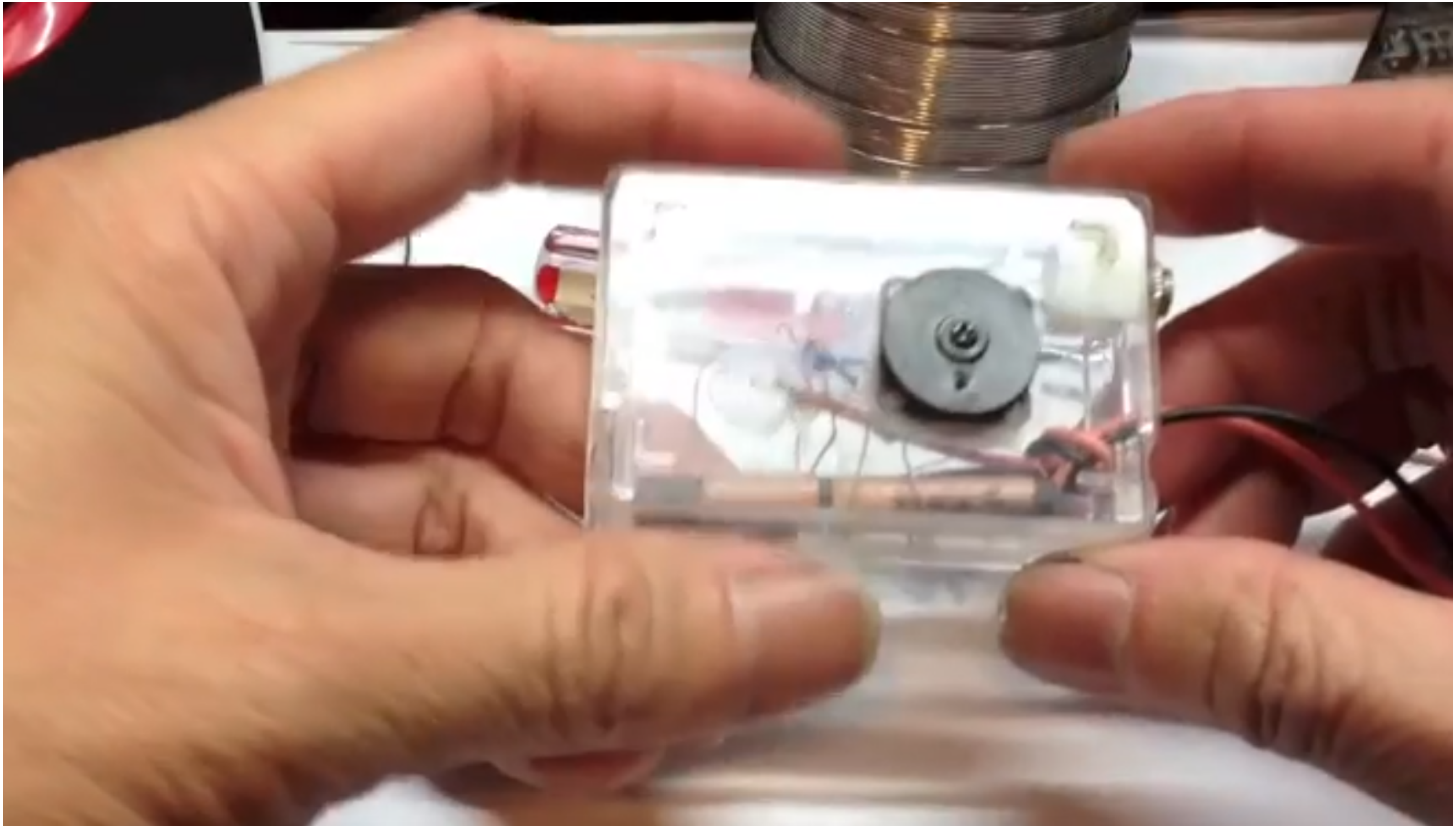

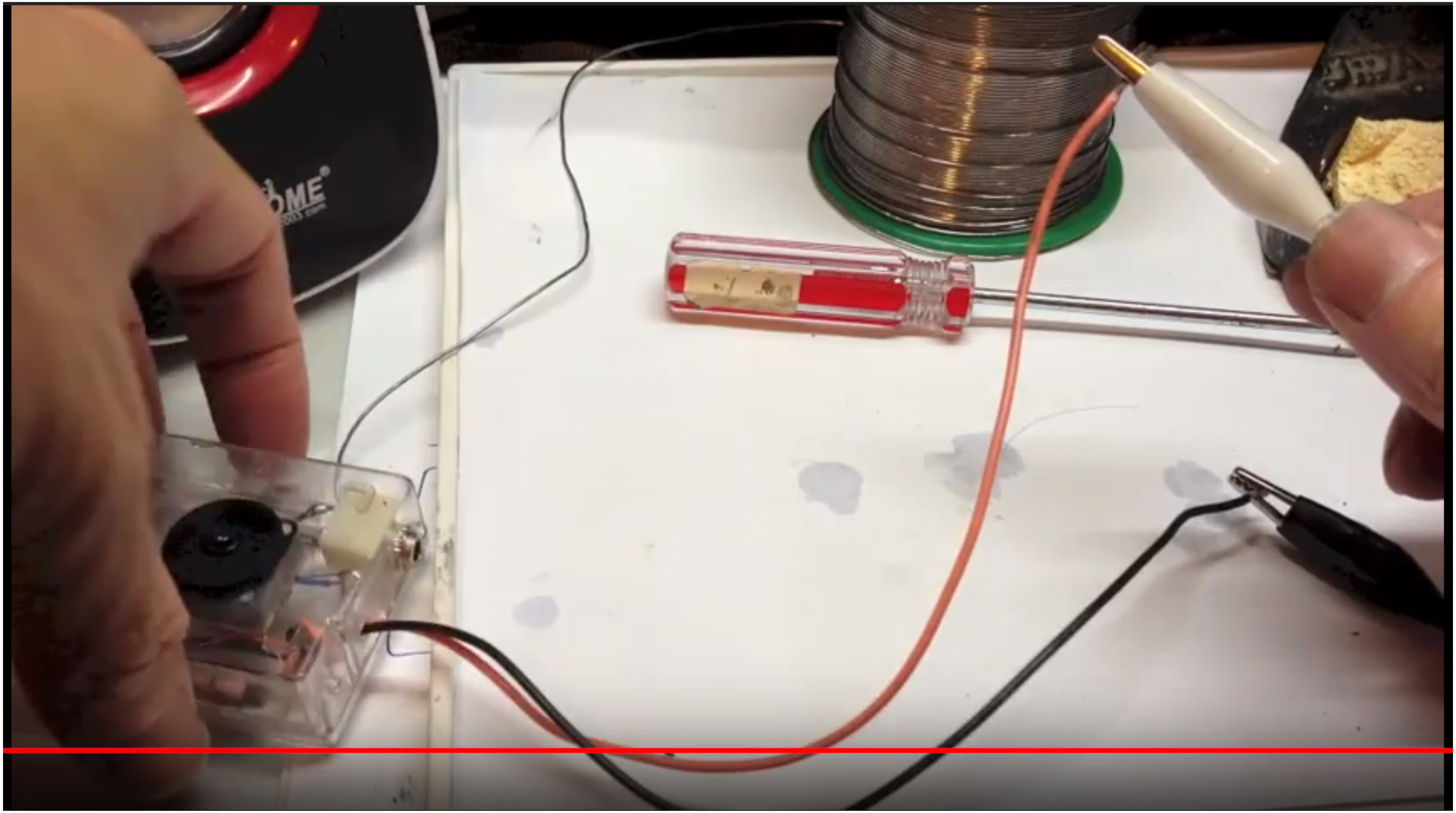

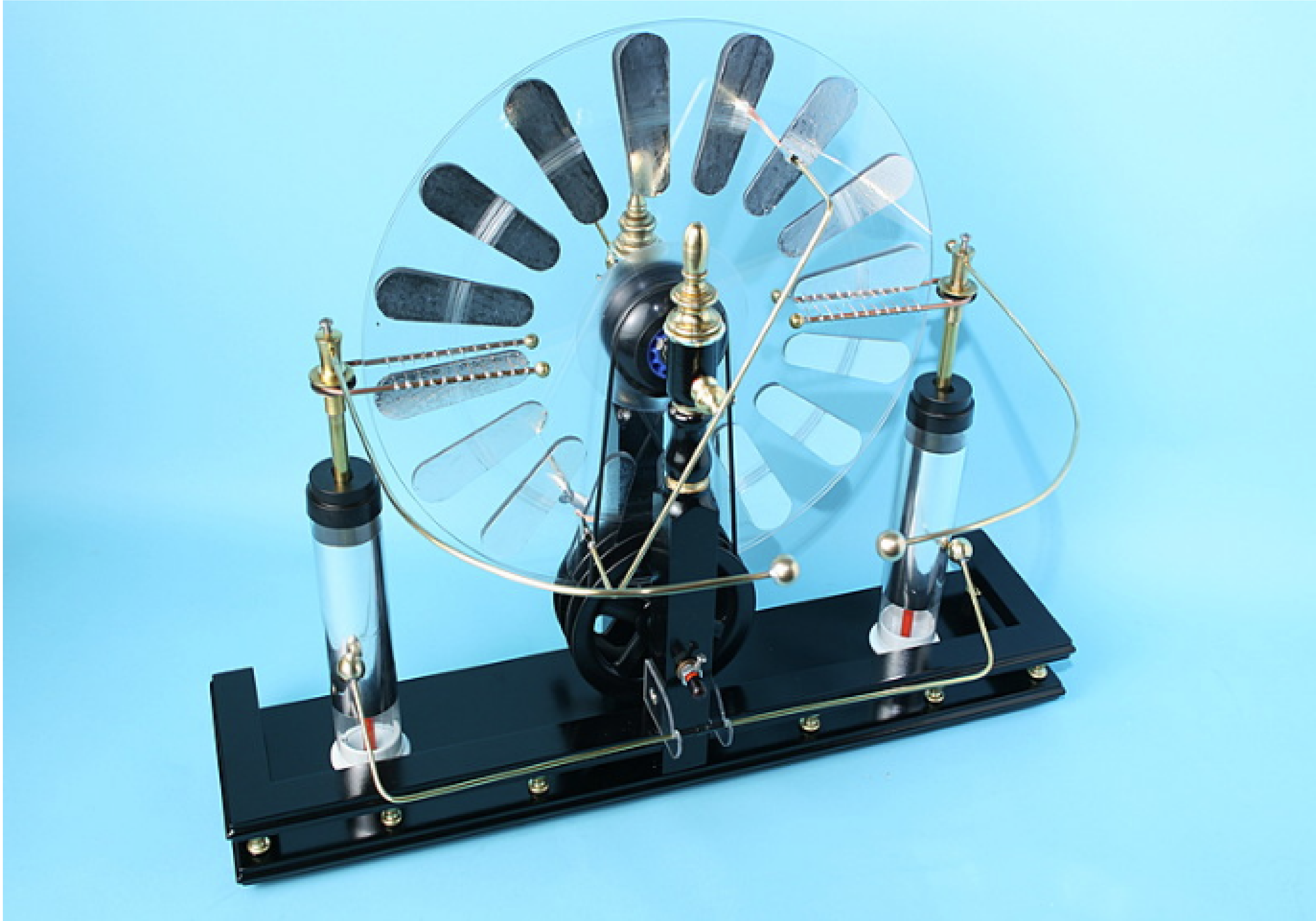

Materials:

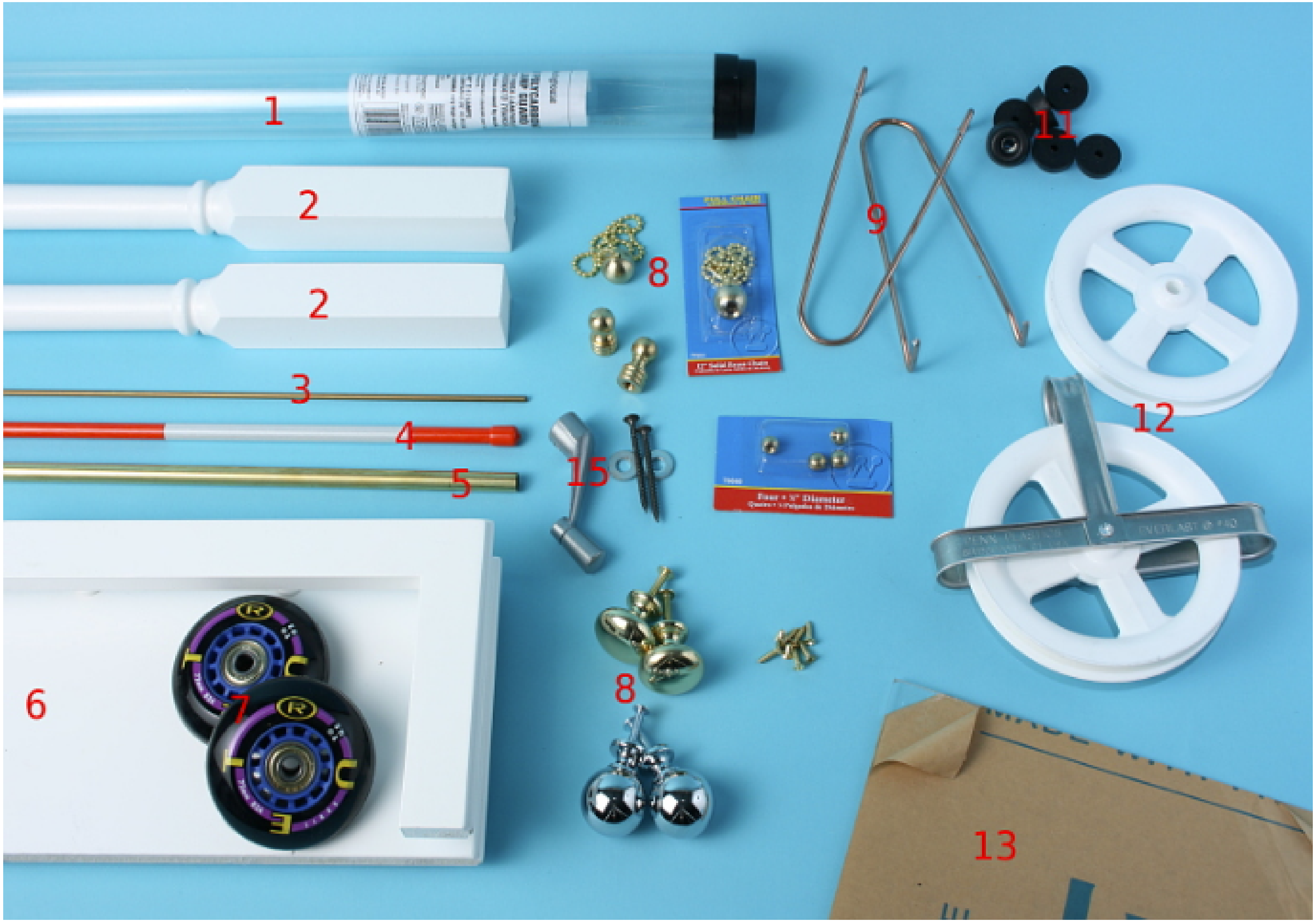
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1. Fluorescent Lamp Protector Sleeve – used to make the two Leyden jars.
2. Staircase Balusters – these will be the supports for the rotating disks.
3. 1/8" Bronze Brazing Rod – will be used to fabricate all of the conductors. If you can't find this at your local hardware store look for a welding supply shop, they are sold by the pound and are incredibly useful for many things even if you don't own an oxyacetylene torch.
4. Fiberglass Driveway Marker Rod – Make sure it's round and 5/16" in diameter; these will be the shafts and insulated supports.
5. 3/8" OD Thin Wall Brass Tubing – one 3' section.
6. Knick-Knack Shelf Kit – approximately 24" by 6". You can use any ¾" board you desire, the shelf included has a nice rail that will add to the overall look of the project.
7. Inline Skate Replacement Wheels – Quantity 2.
8. Lamp Parts – You will need a selection of lamp parts which may vary depending on what is available at your particular store. Pictured here are pull chains, finials, and ball nuts used to make parts of the charge collector combs and discharge electrodes. Also pictured are cabinet knobs which were not used in this project but would make good alternatives. See the charge collector construction step for details.
9. 1" Copper Pipe Hangers – These you'll find in the plumbing section, they are copper plated steel.
10. Solder wick (not pictured) – for the neutralizing brushes, you might have to visit Radio Shack for this.
11. Rubber feet – Quantity 6.
12. Clothes Line Pulleys – must be plastic.
13. 3/16" Acrylic Glazing – enough to cut (2) 14" circles from. Polycarbonate will work too and is easier to work with but costs more than twice as much.
14. Aluminum tape (not pictured) – found with the duct tape and HVAC supplies, get the kind with the peel off paper backing.
15. Rubber O-ring belts (not pictured) – available from McMaster-Carr, part number: 94115K259 about $15 for a package of eight.

The total cost of purchasing the materials new is about $100. However, these are all relatively common items

Disks and Drive Components:

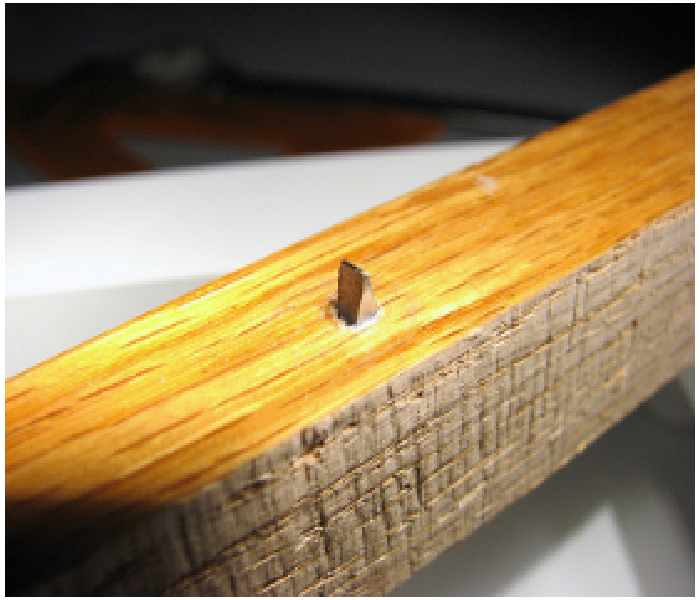

wimshurst-circle-cutter-inset.jpg

Make the cutting tool:

1. To cut the two 14" acrylic circles we will first need to make a tool. Cut a 12" length of wood ¾" square. Pine will work but hardwood is preferable.
2. Drill a pilot hole near one end and press or drive a #6 penny nail through the stick so the point sticks out about ¼".
3. Drill a second hole exactly 7" from the first and insert another #6 penny nail into it.
4. Use a fine metalworking file to shape the point of the second nail as shown. You want to make a chisel point with a slight undercut on the leading face.

Cut the acrylic disks:

1. Lay out your circles with a compass to be sure they will both fit on your sheet of acrylic.
2. Drill a 1/8″ hole in the center of your circle. Be gentle when drilling acrylic, it cracks easily. Polycarbonate is quite a bit tougher.
3. Working on a carpeted floor, insert the unmodified nail in the center and begin scoring your circle. Cut about a quarter of the way with each stroke and work your way around the circumference.
4. If the cutter sticks, lift it out and move to a different spot.
5. When you think you've gone about halfway through, flip the acrylic sheet over and cut from the other side. You may end up flipping the sheet several times before the circle pops free.
6. Clean up the edge of the circle with some 400 grit sand paper and set them aside.

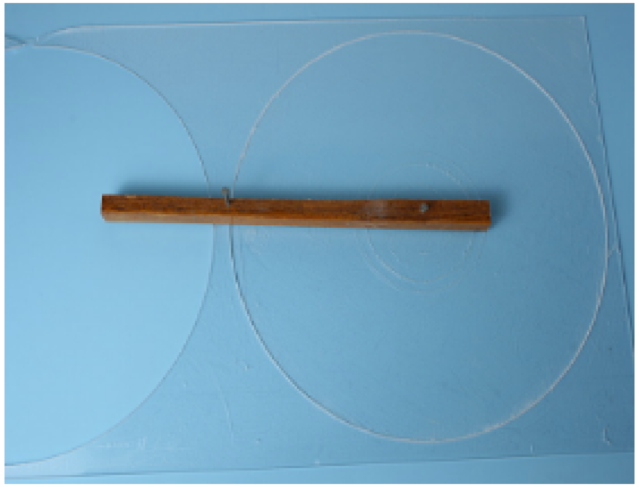

wimshurst-circle-cutter.jpg

Cut belt grooves in the skate wheels:

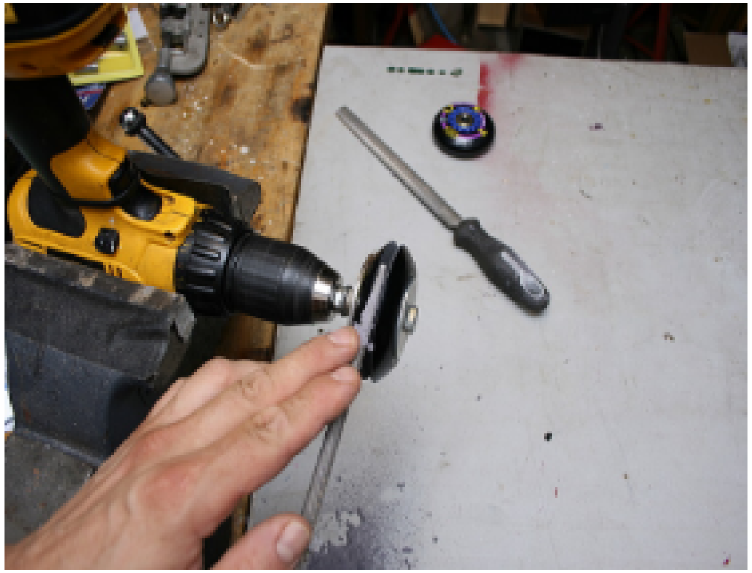

wimshurst-skate-wheel-groove.jpg

1. Gently clamp or strap your drill to a workbench as pictured.
2. Assemble a mandrel from a 5/16″ bolt and some large (fender) washers, when assembled the entire wheel must spin, not just the bearings.
3. Chuck the assembly into the drill. The wheel should turn toward you and the speed should be fairly fast.
4. With a crosscut bastard file make a ¼" wide flat on the wheel and then switch to a rat-tail file to cut the grove. Apply light and even pressure to the file.

Attach the skate wheels to the disks:

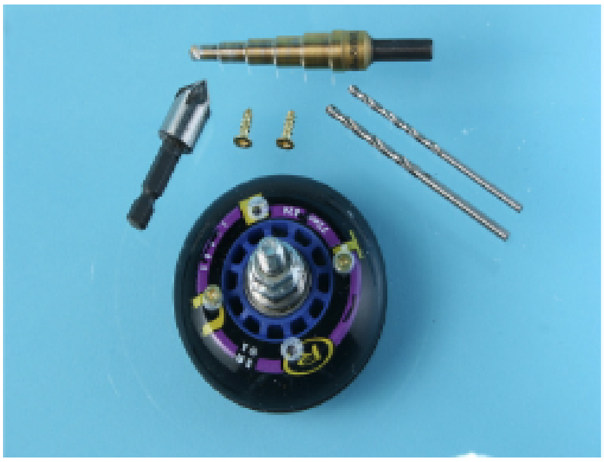

wimshurst-skate-wheel-mount.jpg

1. Use a step drill bit like the one pictured to increase the size of the hole in the acrylic disk to 5/16". Remember, be gentle and go slowly because acrylic is easily cracked.
2. Remove the washers from the wheel and use the 5/16" bolt to center the wheel against the disk.
3. Drill (4) 1/8" holes through the disk, don't drill into the wheel.
4. Switch to a 3/32" bit and drill partway into the wheel in 4 places.
5. Finish the holes with a counter sink.
6. Now remove the 5/16" bolt and drill the center hole out to ½" or 5/8" using a step drill, you want the edges of the hole completely clear of the rotating parts of the wheel bearing.
7. Install (4) small counter sunken screws, tighten these so they *just* touch the disk, the disk must remain as flat as possible.

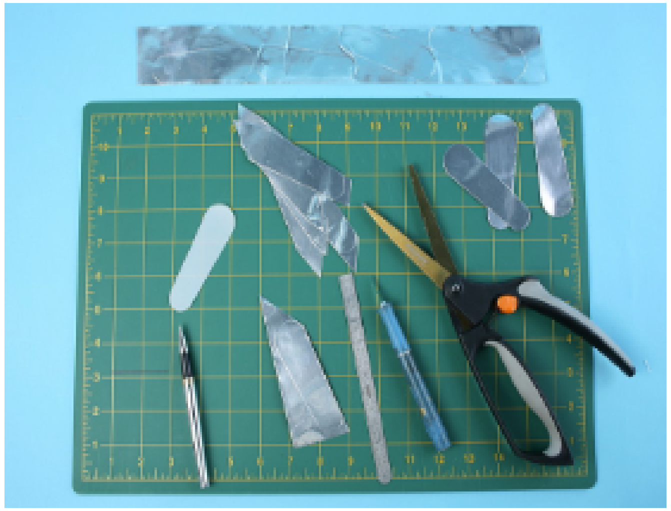

wimshurst-sector-cutting.jpg

Cut the sectors:

1. Decide how many sectors you are willing to cut. I'm rather lazy and opted for fewer sectors, 16 per disk. If you decide to make 24 or even 32 sectors you'll have to make them smaller but you will be rewarded with longer sparks.
2. The sectors are cut from aluminum tape. Make a template from a piece of plastic milk jug and trace each sector. Cut them individually, don't be tempted to stack multiple layers of tape; the cut will end up ragged and will bleed charge away into the air.
3. Tip: I found it easiest to use an X-acto knife and straight edge to cut the long sides and then switch to scissors for the curved ends.

Attach the sectors:

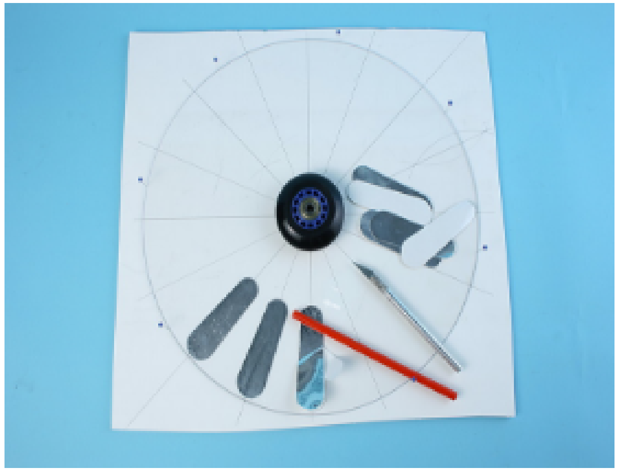

wimshurst-affix-sectors.jpg

1. Lay out a circle on a piece of foam board.
2. Draw radial lines to correspond with the number of sectors you've chosen
3. Place your template centered at 6 o'clock and trace it. The large end should face out and be about ¼" from the edge of the disk.
4. Set the disk on the foam board and insert push pins around the circumference so it turns in place.
5. Carefully peel and stick the sector in place. It's a good idea to make some extra sectors and practice this operation first. A length of fiberglass rod makes an excellent burnishing tool.
6. Turn the disk one line to the left and repeat. Always index the line to the first sector you stuck down, this will help make the spacing as even as possible.

wimshurst-drill-pulley.jpg

Prepare the drive pulleys:

1. Remove the pulleys from their cages by drilling out the rivets.
2. Use the step drill to enlarge the holes to 5/16". Drill from one side, then the other to enlarge the full depth of the hole in the pulley. Note: The use of the step drill is especially important here because of its self-centering characteristics.
3. Cut (2) 7" lengths of fiberglass rod, slightly bevel the ends with a file to prevent chip out. Be careful of the glass fibers, they can be really irritating!
4. Drill the splines out of the window crack bore with a regular 5/16" drill bit. Clamp the crank in a vise and go slowly; making sure the bit is in line with the axis.

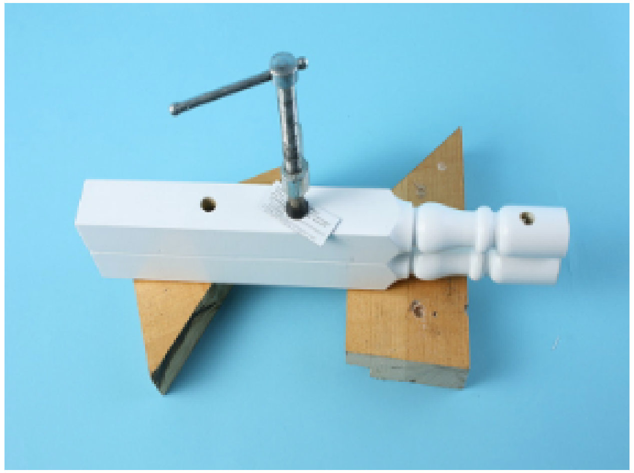

wimshurst-drill-upright.jpg

Cut and drill the supports:

1. Cut 12" off of each of the staircase balusters. Choose the end that you think looks best. On my prototype machine I used both ends of the same baluster and thus had two different style supports.

2. Clamp the two supports together as shown and drill 5/16" holes 3 ¼" inches from the bottom (square end) and 11" inches from the bottom.

3. The lower hole will need to be reamed out so that the fiberglass axle turns freely in it. Use a slightly larger drill or rat-tail file for that. You can also drill it larger and insert plastic bushings for smoother operation. Alternatively you can bore it out with a step drill to match the diameter of a pair of skate bearings – this works exceptionally smoothly and is what I ultimately did to my own machine.

Attach the supports to the base:

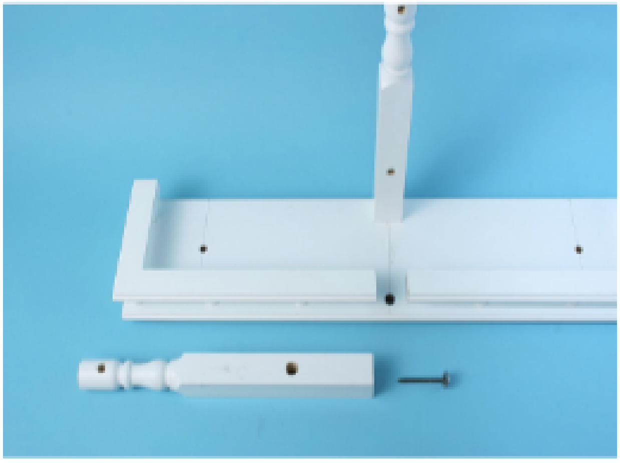

wimshurst-screw-uprights.jpg

1. Draw a line parallel to the back of the base 2 ½" in, this is not quite to the center. Draw a second line perpendicular to the first on the center of the base.
2. Cut a 1 ¼" gap in the rail on the center line, as pictured.
3. Drill (2) 3/8" inch holes through the base on the center line 5/8" from the front and back edges.
4. Use 2" drywall screws and large washers to attach the supports to the base. The combination of the large washer and 3/8" hole will allow you to adjust and align the position of the rotating disk precisely.
5. Drill (2) 5/16" holes on the line parallel to the long dimension and 7 5/8" from the centerline on each side – these holes need to be straight up and down so drill carefully, use a small carpenter's square to line up the drill.

Charge Combs and Neutralizing Bars:

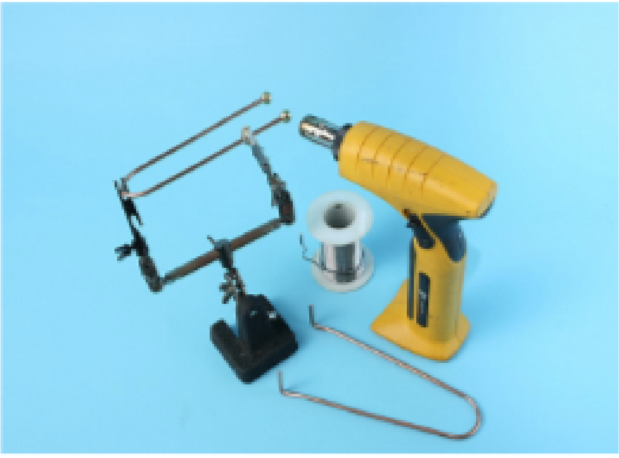

wimshurst-solder-balls.jpg

Prepare the charge collectors:

1. Use a hacksaw to cut off the nail ends of the pipe hanger. The overall length should be 5".
2. You'll find small brass ball cap nuts in the electrical section at the hardware store; they are most commonly used to secure the top of brass outdoor lighting fixtures.
3. Place the small brass ball nuts on the ends of the hanger, heat them with a small torch and apply just enough solder to fill the joint. Note: Be careful not to overheat the pipe hanger, it is copper plated steel and it you heat it too much the solder may not adhere.

The torch pictured is a Lenk LSP-180 butane torch/soldering iron and it is a marvelous tool.

Attach the collector comb prongs:

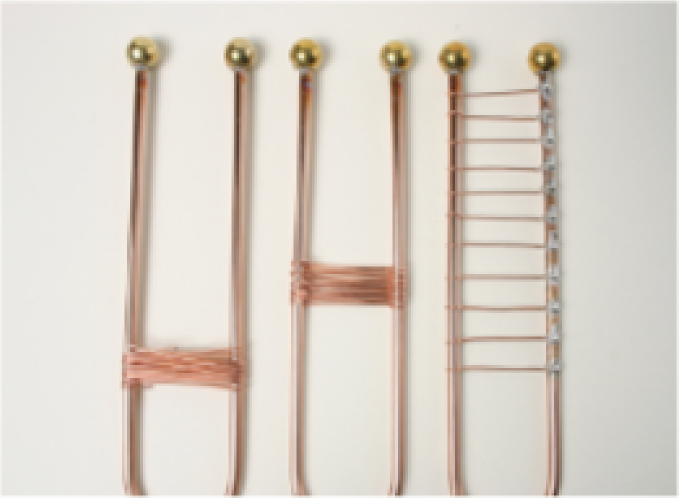

wimshurst-prongs-progression2.jpg

1. You need to make 8–12 pointy prongs down each side of the collector comb. I stripped the conductors out of a 3' section of telephone wire to make them.

2. Wrap the copper wire around the pipe hanger as shown in the left-most example. I made 11 turns.

3. Cut away the center portion of the wire on one side only and bend the cut ends around the pipe hangers.

4. Spread the prongs out evenly along the portion of the charge collector that will be opposite the sector.

Solder the prongs:

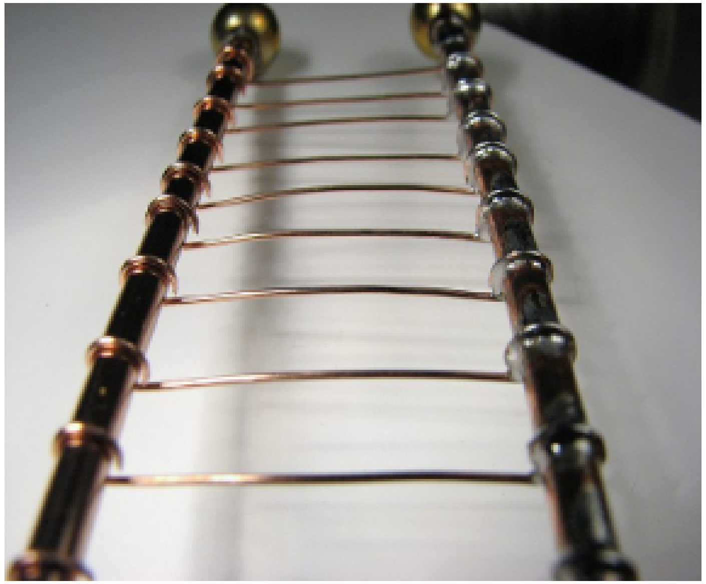

wimshurst-solder-prongs.jpg

1. Crimp the ends tightly around the pipe hanger.
2. Use a large soldering iron to solder each joint. Apply sufficient solder so that when you take the soldering iron away solder flows down to fill the gap at the end of each length of wire. We want to avoid any points other then the prongs themselves.
3. Once you've soldered all of the joints cut down the center of the wires but don't trim them to length until it's time to install the combs.

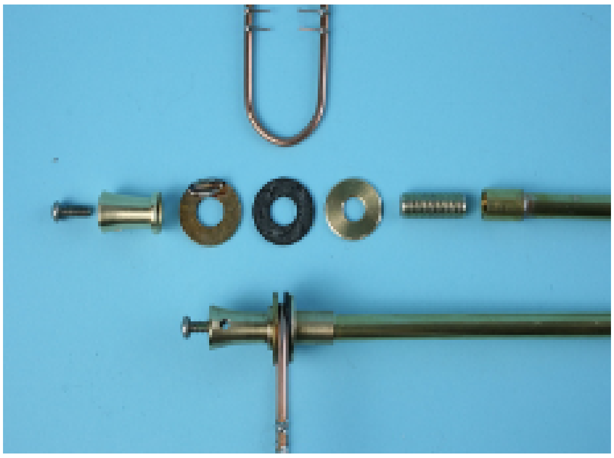

wimshurst-collector-assembly.jpg

Charge collector mount:

I made a couple of different collector mounts using various lamp parts and cabinet knobs. This was the simplest, but you may have to improvise if you can't find these particular lamp parts at your local hardware store.

Pictured here right to left:

- 3/8" OD thin wall brass tubing 6" long
- 3/8" threaded collar
- 3/8" lamp "nipple" 1" long
- Lamp washer nut (threaded)
- Rubber flat washer
- 3/8" brass washer
- 3/8" threaded lamp finial
- #8-32 screw

Prepare the collector mount:

1. Using the step drill, bore out one half of the threaded collar.
2. Screw the nipple halfway into the collar and insert the brass tubing into the opposite end and solder it in place.
3. Drill one hole straight down into the top of the finial and thread with a #6-32 tap. Use the drill size written on the tap.
4. Drill a 1/8" hole through the body of the finial as pictured, this is for the discharge electrode.
5. Cut a ½" length from the extra you trimmed off of the pipe hanger earlier and solder it to the brass washer, this will allow the assembly to clamp and hold the charge collector perpendicular to the support.
6. Test assemble the mount and then disassemble and set aside.

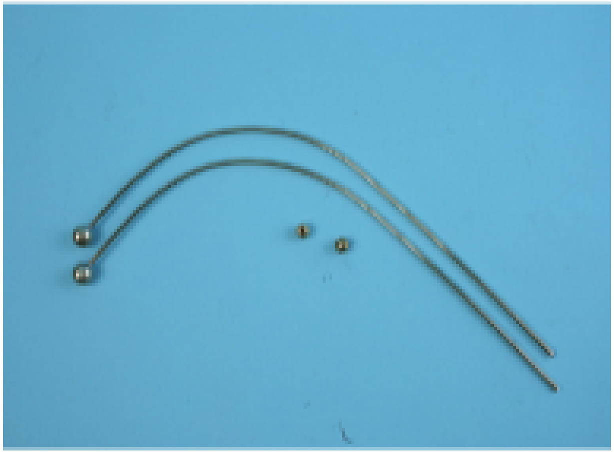

wimshurst-discharge-assembly.jpg

Prepare the discharge electrodes:

1. Cut two 15" lengths of brazing rod and bend them as shown. I bent mine by hand but you could bend a 30" length around a five gallon pail and then cut it in the center for a neater appearance.

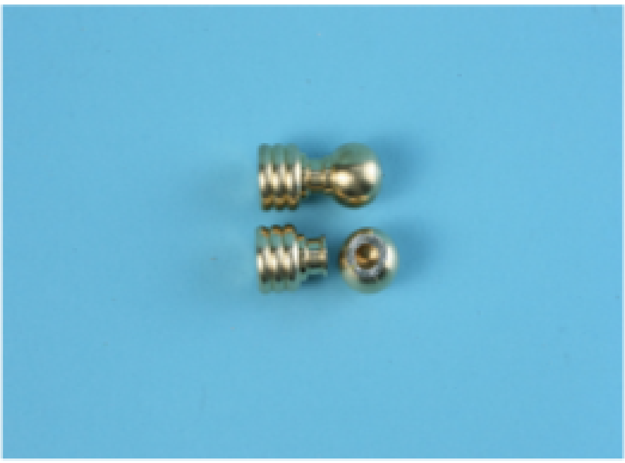

wimshurst-discharge-ball-cut.jpg

2. The balls for the discharge electrodes come from some more lamp finials, cut them off just below the ball with a hacksaw. These balls are about ½" in diameter.

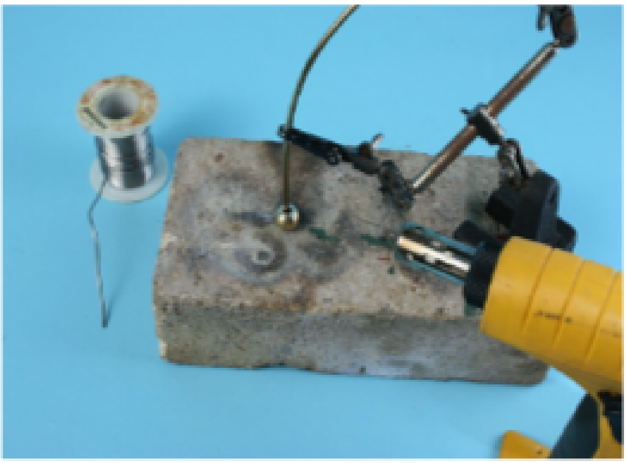

wimshurst-discharge-ball-solder-prep.jpg

3. Solder the discharge balls to the electrodes; fill the hole with solder so it makes a smooth transition to the rod.

Note: do not solder the small ball nuts in place!

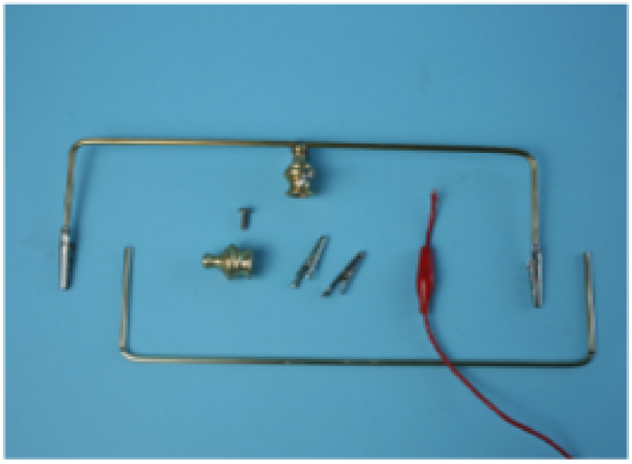

Fabricate the neutralizing brushes:

wimshurst-neutralizer-bar-parts.jpg

The neutralizing brushes are made with more brazing rod, alligator clips salvaged from a pair of clip-leads, and yet another type of lamp finial.

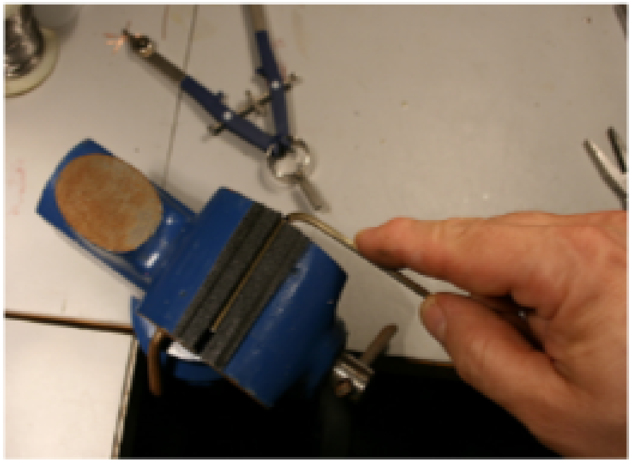

Bend the brush support:

wimshurst-neutralizer-bend.jpg

1. Cut a length of brazing rod 14" long and mark it 2" from either end.
2. Make (2) 90 degree bends in the rod at the 2" marks.

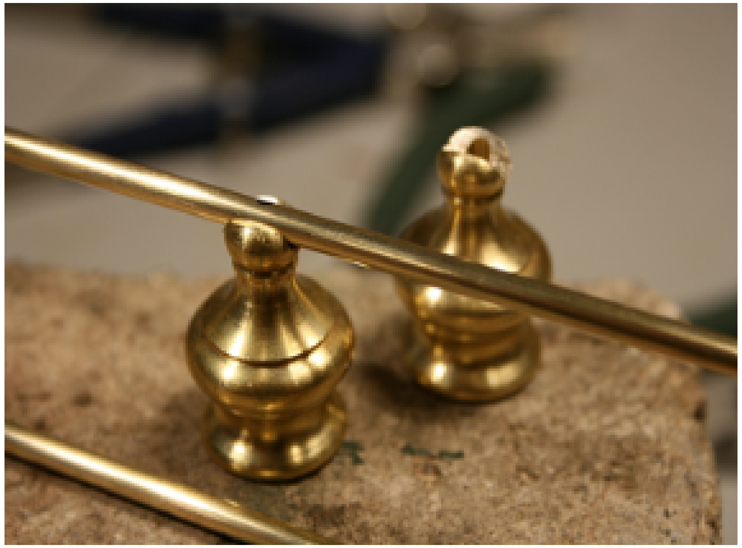

wimshurst-neutralizer-hub.jpg

Solder the brush support to the brush boss:

1. Drill a hole for a set screw in the base of the finial and tap with the #6-32 tap.
2. File a groove in the top of the lamp finials, these particular finals have a 3/8" threaded hole in the bottom and a small hole in the top. I think they are made for ceiling fixtures that have a center pull string.
3. Center the neutralizer bar on the finial and prop it so its parallel to the workbench top and solder it in place.

Attach the brush clips to the support:

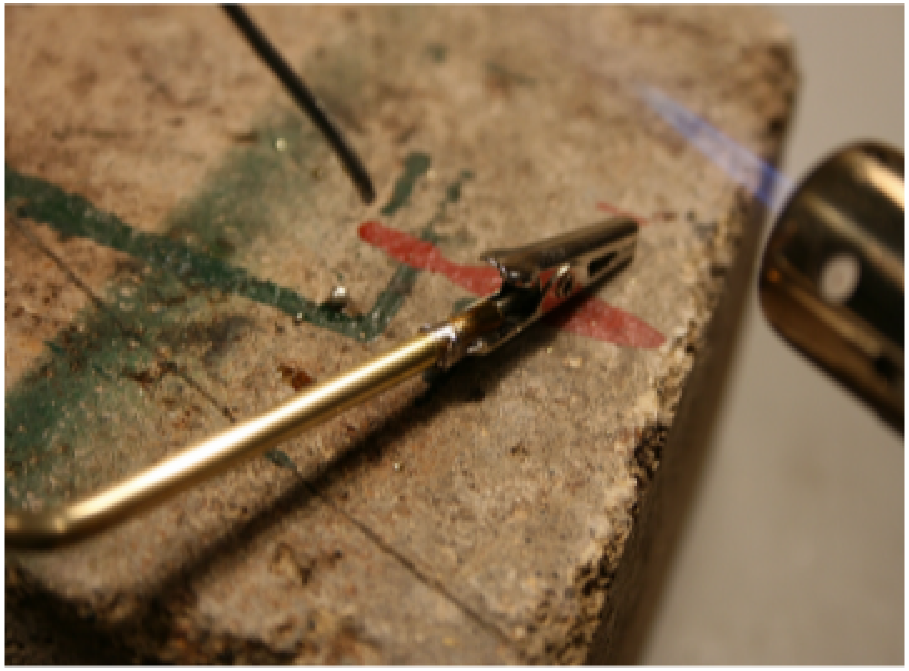

wimshurst-neutralizer-clip.jpg

1. Crimp the alligator clips on to the ends of the neutralizer bar and solder.

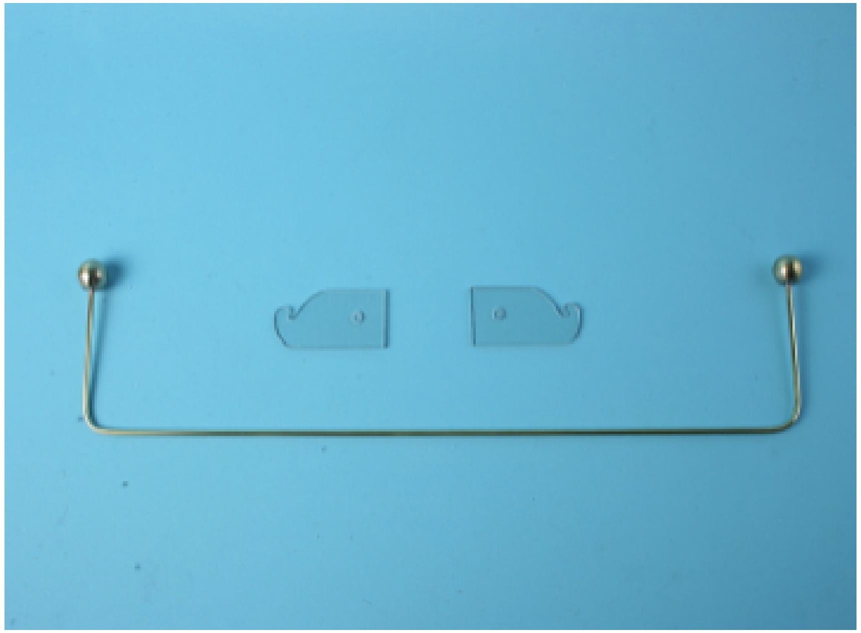

wimshurst-layden-shunt.jpg

Fabricate the Leyden jar shunt:

1. Cut a 22" length of brazing rod.
2. Make 90-degree bends, 3 ½" in from each end.
3. Solder two brass balls to the end. These are the large brass lamp chain pull balls, smaller finial balls or cabinet knobs would work here, too. If you use knobs be sure to remove any lacquer finish.

Cut the Leyden jar body:

wimshurst-layden-cut-tube.jpg

1. Using the miter box and fine tooth hacksaw, cut two 7 1/2" lengths from the fluorescent lamp protector sleeve.

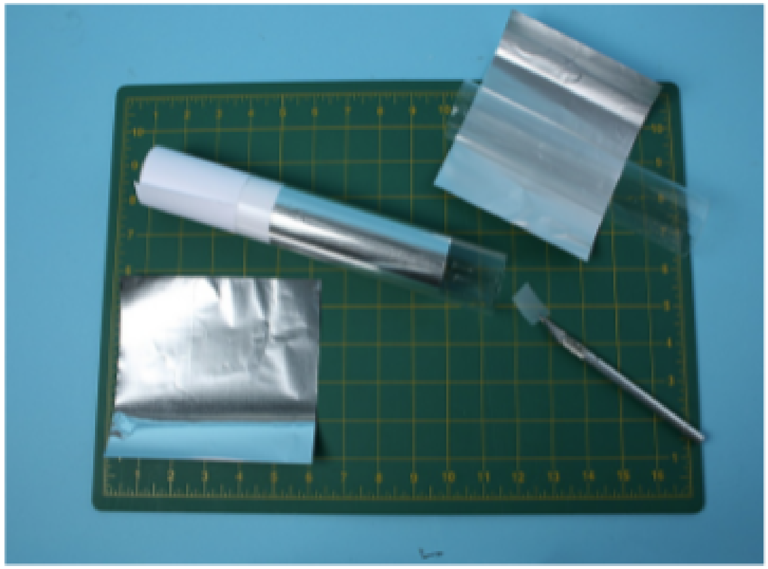

wimshurst-layden-plate-inner.jpg

Cut and affix the inner plate:

1. Cut (4) 5" by 6" sheets of heavy duty aluminum foil.
2. Form one sheet by wrapping it around the tube and then rolling it so it can be inserted. Roll along the 6" axis so the foil cylinder ends up being 5" high.
3. Insert the foil into the tube so that it is 1" from one end. Use a couple of rolled up sheets of paper to hold the foil firmly against the inside of the tube while you tape it in place. The tighter you can make it to the inside of the tube the better.

Affix the outer plate:

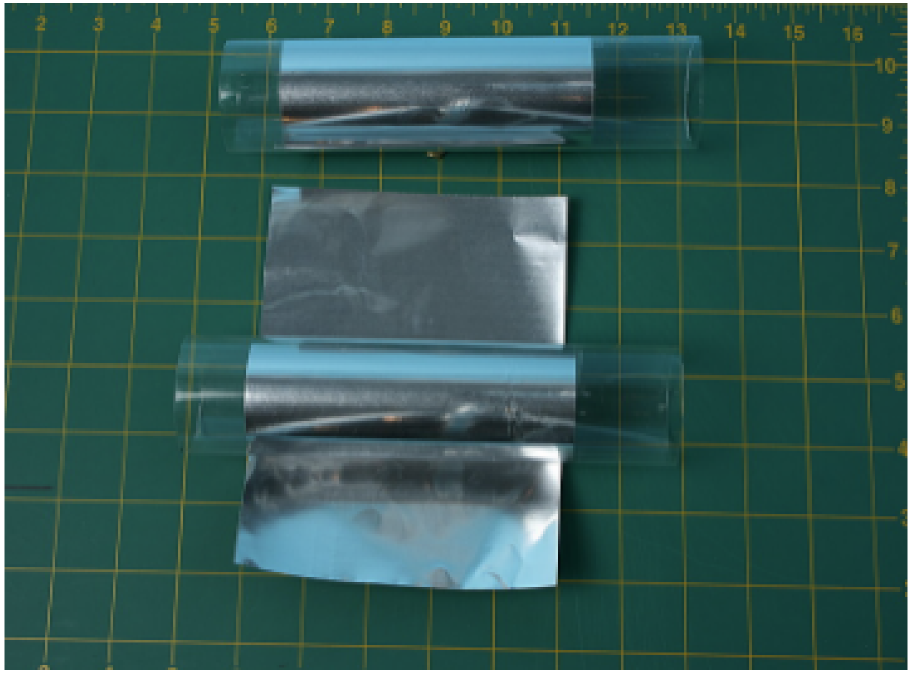

wimshurst-layden-plate-outer.jpg

1. Wrap another piece of aluminum foil around the outside and tape it in place. Again, the tighter the better, but don't wrinkle the foil.

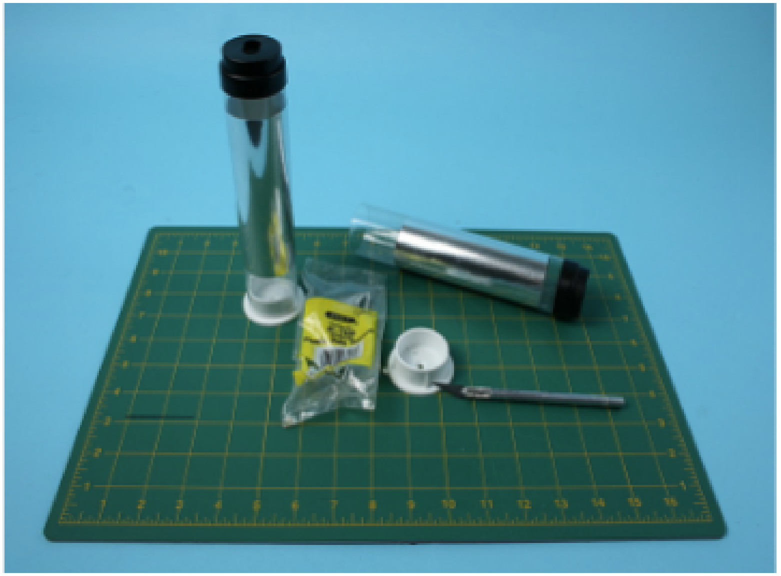

wimshurst-layden-plate-bottom.jpg

Make the bases:

1. Snap the tube ends onto the opening that is 1" from the foil
2. Make the Leyden jar bases from a pair of plastic closet pole mounts. Drill out the center hole to 5/16".

Note: These are Stanley brand and I had to trim some reinforcing ribs off with an X-acto knife to make them slide into the tubes.

Mount the disks and drive line:

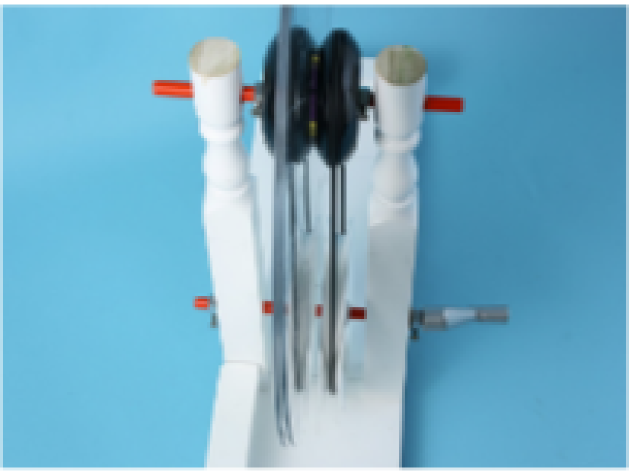

wimshurst-axle-collars.jpg

1. Slide the disk axle into a support and put on a 5/16" set screw collar, an O-ring belt, the two disks, the other belt, and another collar.

2. Attach the casement window crank to the drive shaft, insert the bushings in the supports if you are using them and slide the shaft through the pulleys. The pulleys should be a tight fit and you will have to twist the shaft back and forth to get it through. Don't forget about the belts hanging from the top shaft, one will need a twist so that the disks rotate in opposite directions. A collar goes on either end of the drive shaft.

3. Once both shafts are in place, stretch the belt around the pulleys. (In the picture, the belt with the twist is hidden behind the disk. What you are seeing is a reflection of the untwisted belt.)

Note: 5/16" set screw collars can be found at the hardware store but I made my own by drilling out a 5/16" nut and threading a #6-32 screw into the side.

Note: I found that my machine became difficult to turn once it was fully charged due to the electrostatic attraction of the disks. I cut a 2 ½" washer from a plastic milk jug and placed it on the shaft between the disks to remedy this problem.

Align the disk and collector supports:

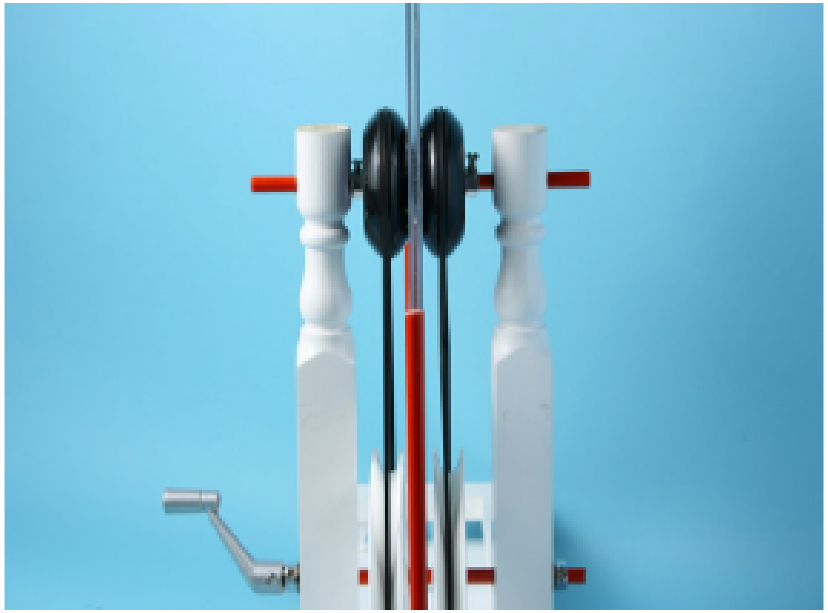

wimshurst-lineup-collectors.jpg

1. Cut two 11" lengths of fiberglass rod and press them into the holes made earlier in the base.
2. Loosen the screws that hold the two supports to the base and slide them around to adjust the disks so they line up with the charge collector supports.
3. Re-tighten the supports.

Install the Leyden jar base and inner plate contact:

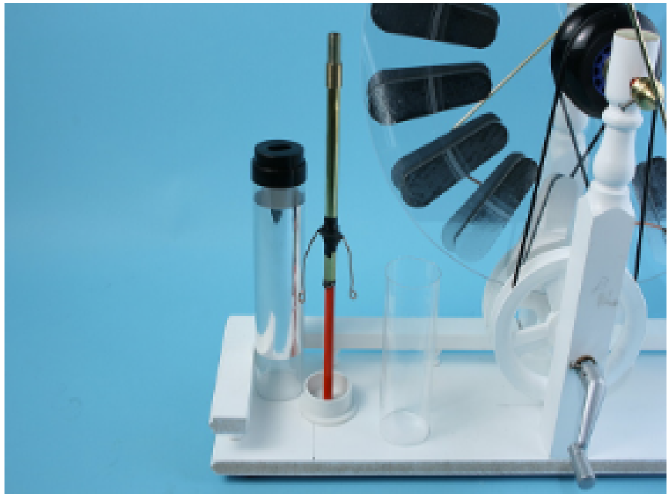

wimshurst-layden-contact-inner.jpg

1. Slide the Leyden jar bases onto the fiberglass charge collector supports.
2. Slide the charge collector assembly over the fiberglass supports.
3. Using about 6" of 14 AWG solid copper wire, form the inner plate contact. Wrap it once around the brass tube and form two loops in the ends.
4. Using a scrap of the plastic tube as a guide, adjust the inner plate contacts so they apply even and gentle pressure. You want good contact with the foil but you don't want to rip the foil when you install the Leyden jars.

Epoxy the charge collector assembly in place:

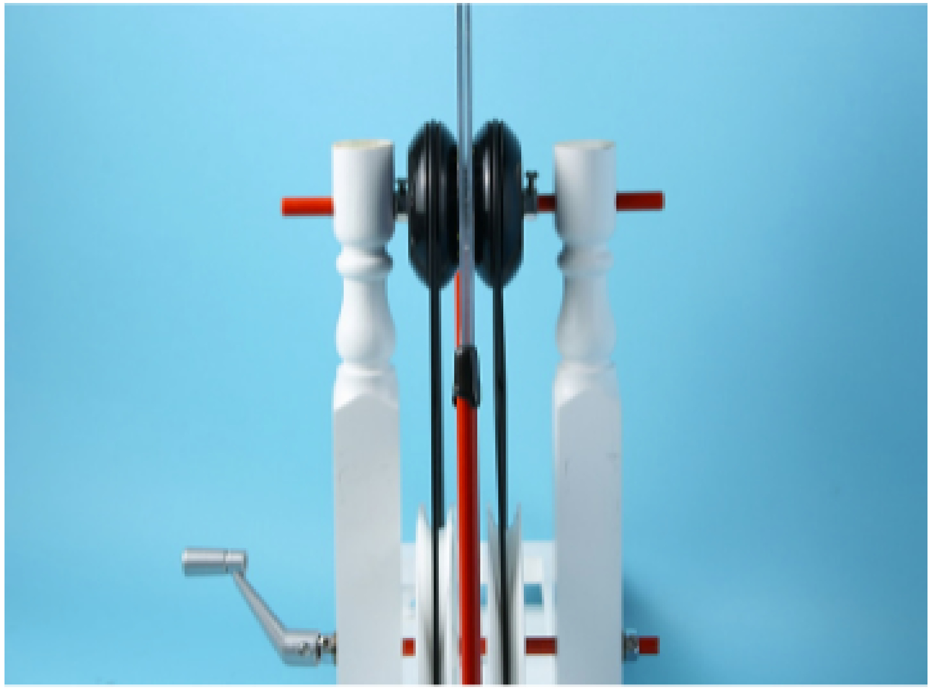

wimshurst-collector-epoxy.jpg

1. Apply epoxy to the end of the rod and slide the brass charge collector assembly down onto the fiber glass support rod.

2. Set aside while the epoxy cures.

Install Leyden jar and assemble collector:

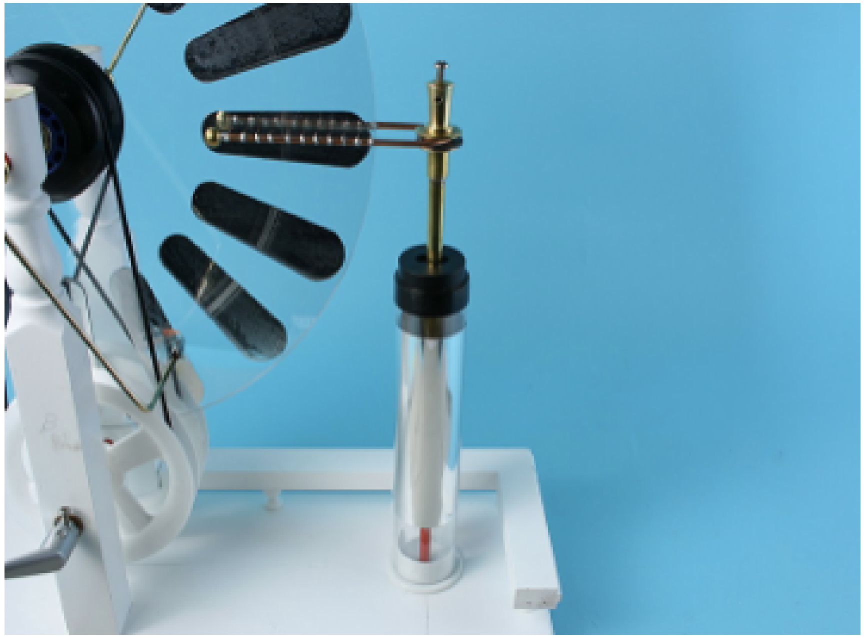

wimshurst-layden-complete.jpg

1. Slide the Leyden jar onto its base, being careful not to tear the foil as makes contact.
2. Line up the charge collector comb and trim the prongs. Test spin the disks to see if there is any wobble and trim the prongs to come as close as possible to the disks without touching.
3. Assemble the charge collectors.

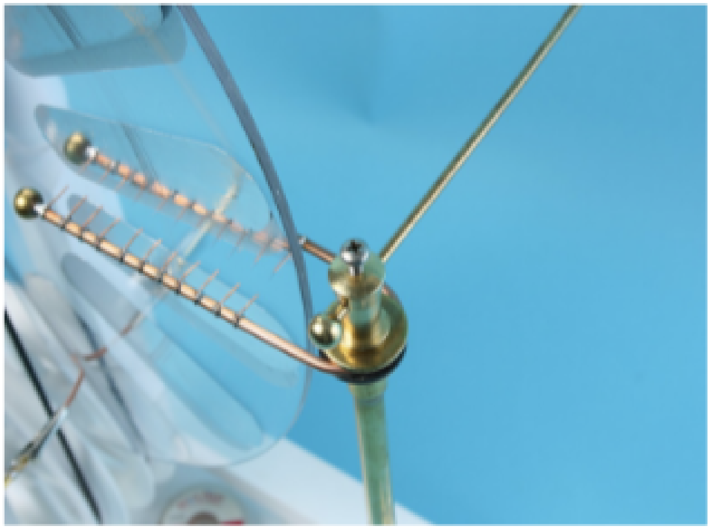

wimshurst-collector-inplace-2.jpg

Install discharge electrode:

1. Insert the discharge electrodes into the lamp finial on the charge collector and tighten the screw to hold it in place.

2. The finial should be tight enough to hold the collector comb but allow the discharge electrode to move back and forth. If it's too tight, or not tight enough, the support rod can be twisted in the base to accommodate.

3. Wrap a small bit of tape around the end of the electrode and screw on one of the small ball nuts; this will prevent charge from bleeding off the sharp end.

Install neutralizing brushes:

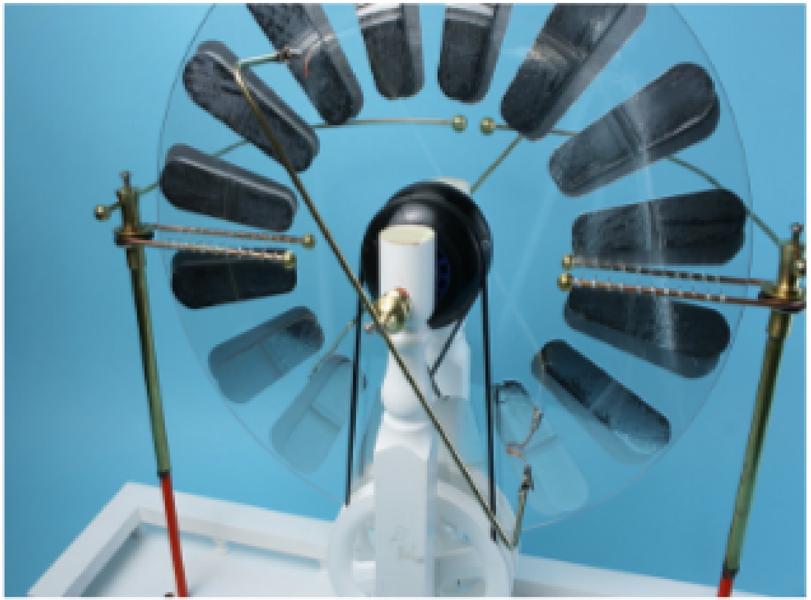

wimshurst-neutralizer.jpg

1. Slide the neutralizing bars onto the upper shaft and adjust them to be about 45 degrees from the collector combs.

2. Sectors should pass through a charge collector, encounter a neutralizing bar after about 1/6 of a rotation, and then encounter the other charge collector after a further 1/3 of a rotation.

3. Tighten the set screw to secure.

Position brushes:

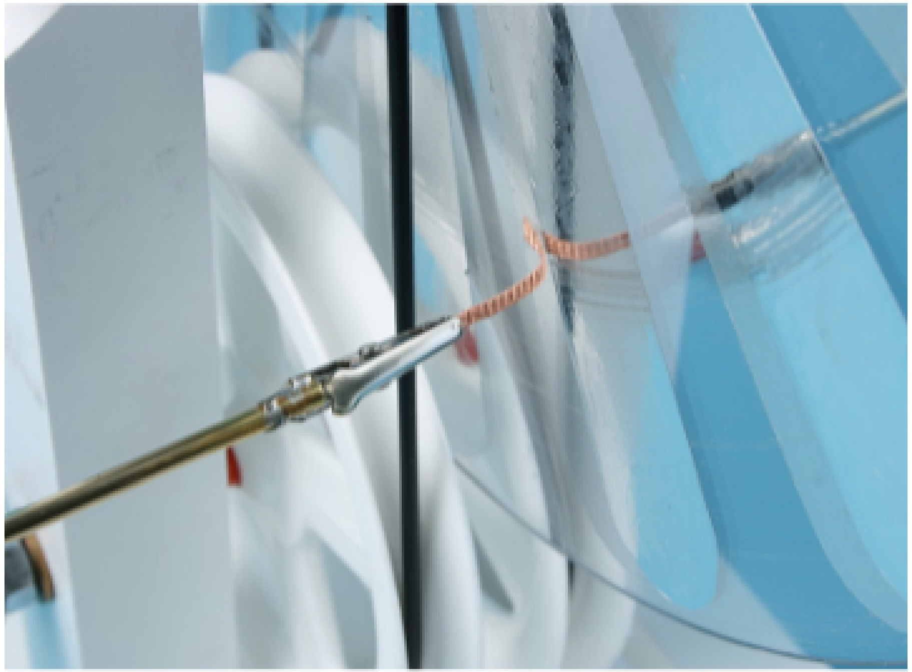

wimshurst-neutralizer-brush.jpg

1. Clip (2) 1 ½" lengths of Solder Wick™ to the ends of the neutralizing rods so they make good contact with the disk.

Mount the Leyden jar shunt and add optional finials:

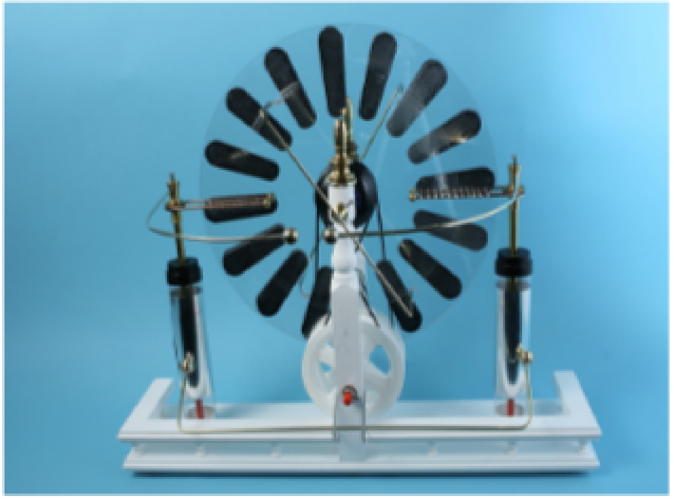

wimshurst-complete-front.jpg

1. Use small brass wood screws to attach the (2) acrylic brackets to the front disk support, leave them a little loose at first.
2. Place the Leyden jar shunt in the brackets and line them up so the balls on the shunt lean comfortable against the Leyden jars.
3. Tighten the brackets.

The two tops of the disk supports looked a little bare to me so I raided my junk box for more lamp parts and came up with these decorative finials. The wealth of finial and cabinet knobs at the typical home center means that there are infinite

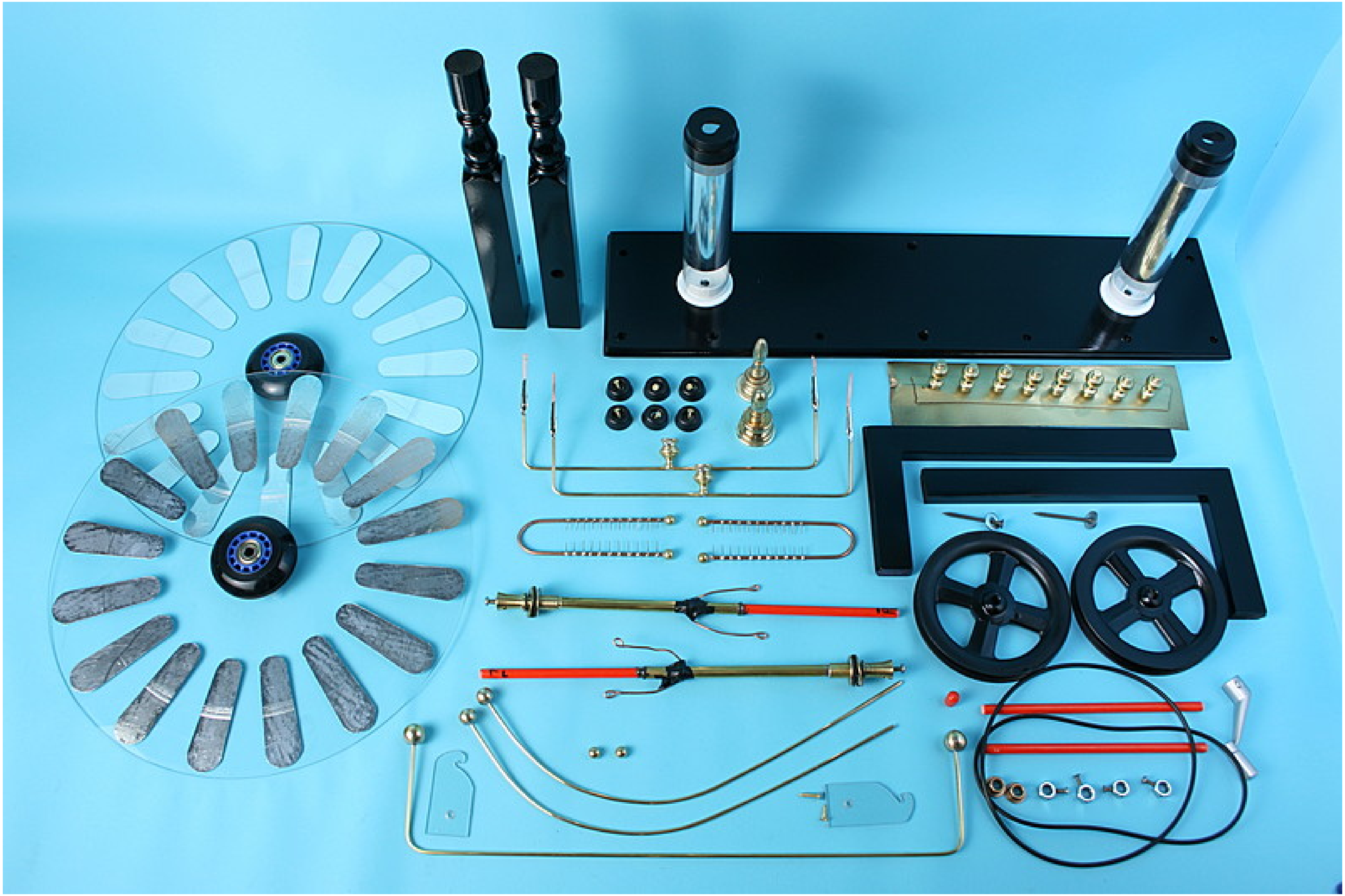

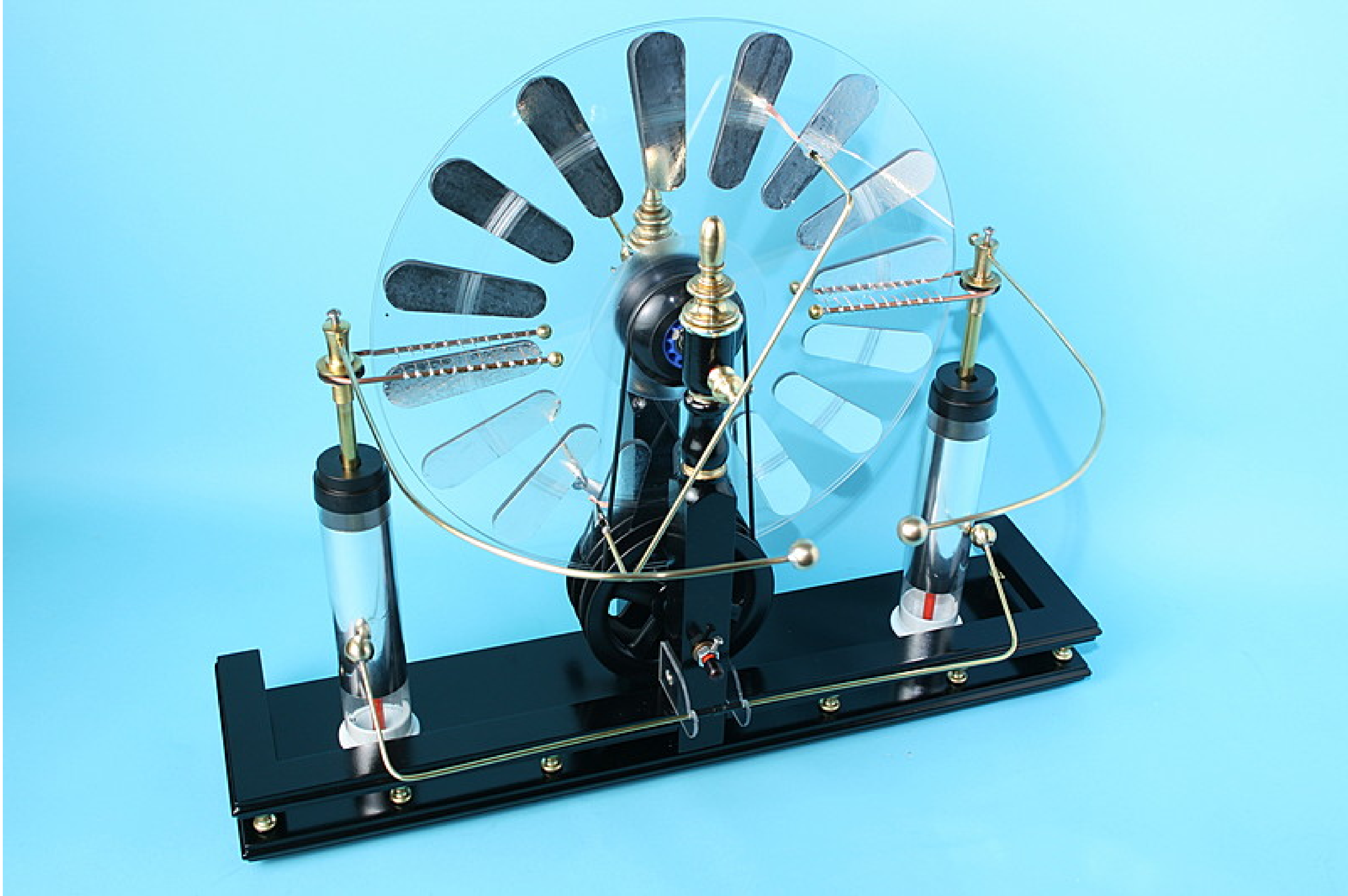

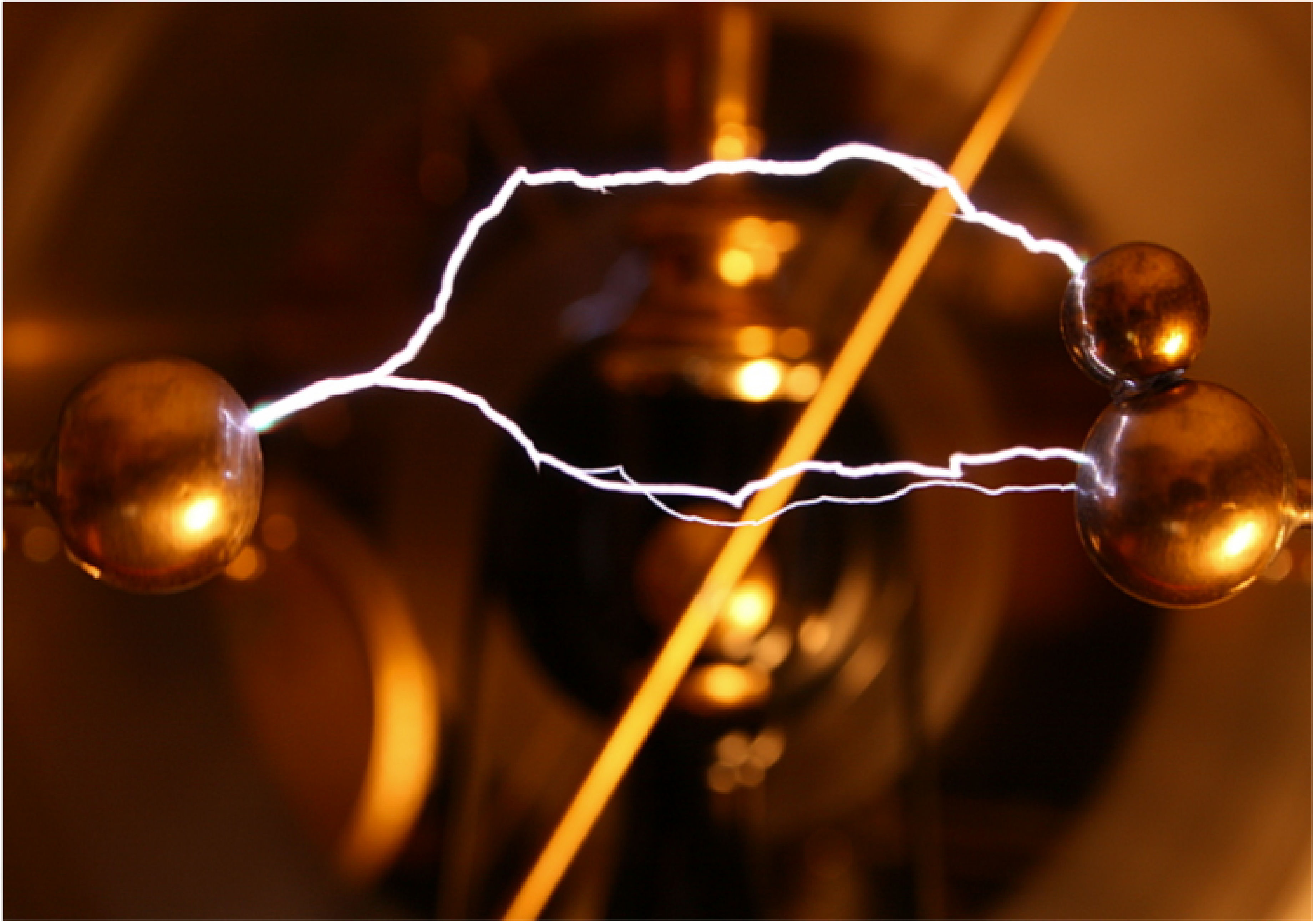

Attaching a small ball to the positive electrode will result in larger and more interesting sparks. The small ball creates a plume of ionized air that helps the spark jump the gap.

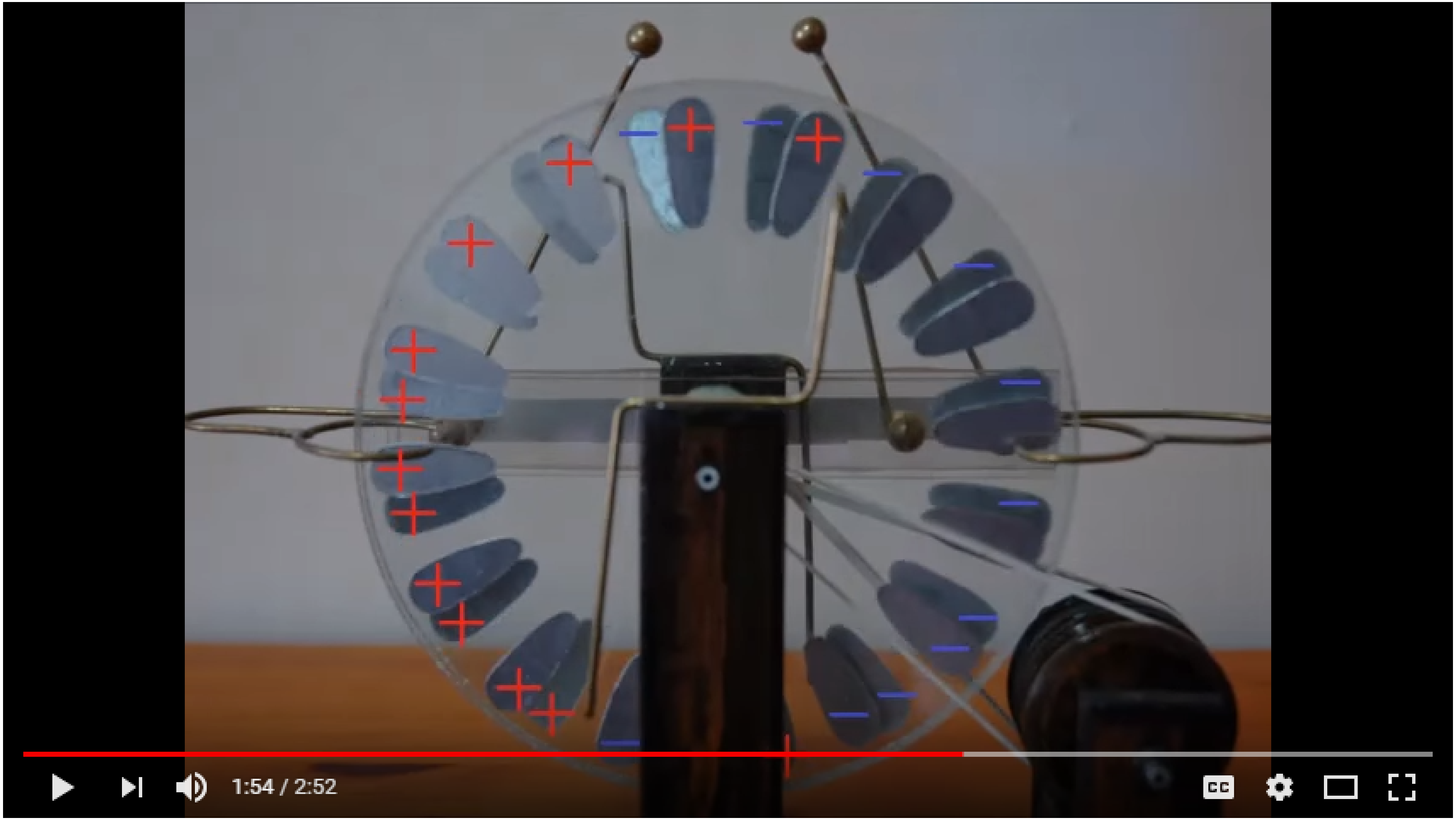

How the Wimshurst Works

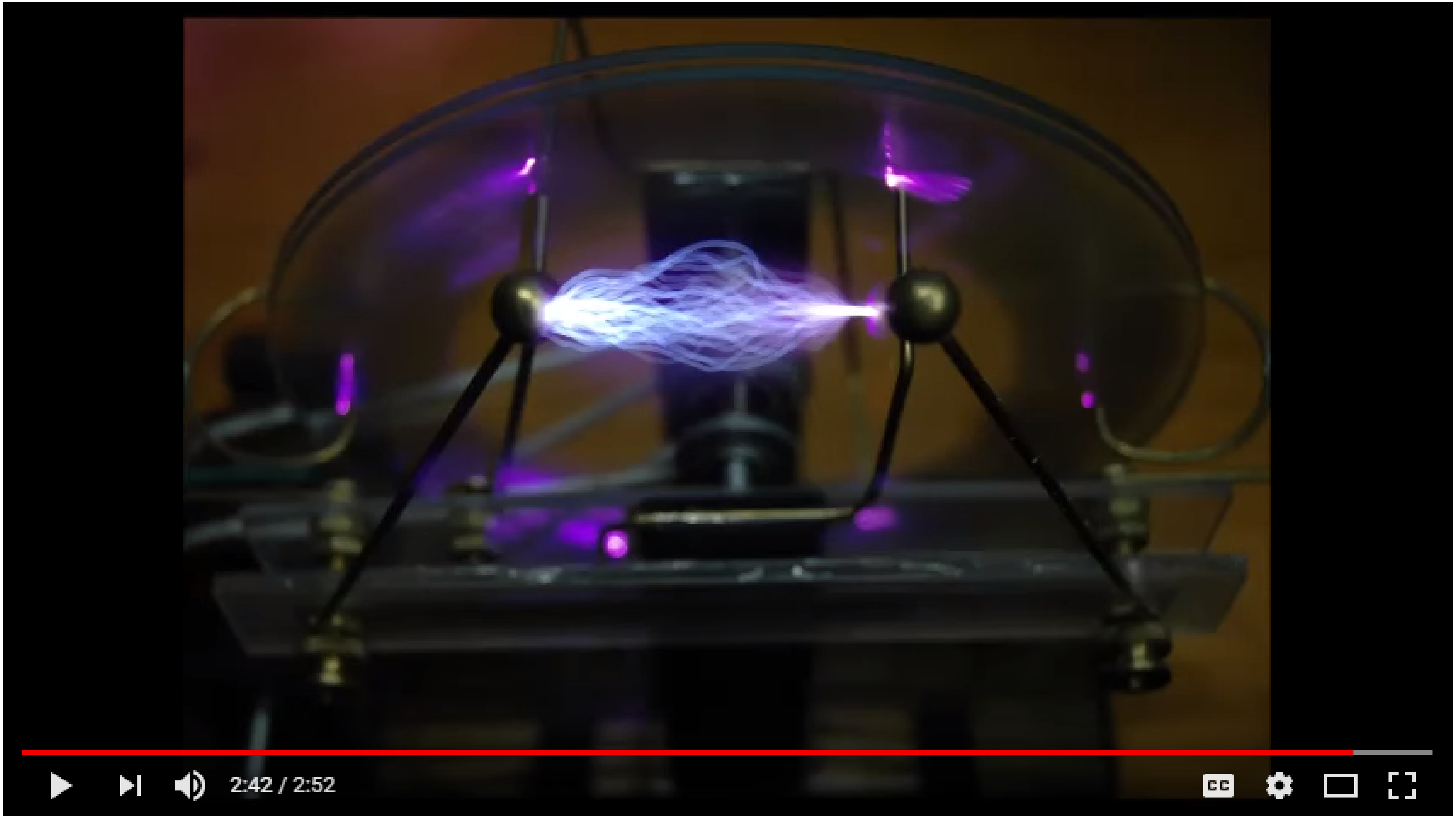

How the Wimshurst Works

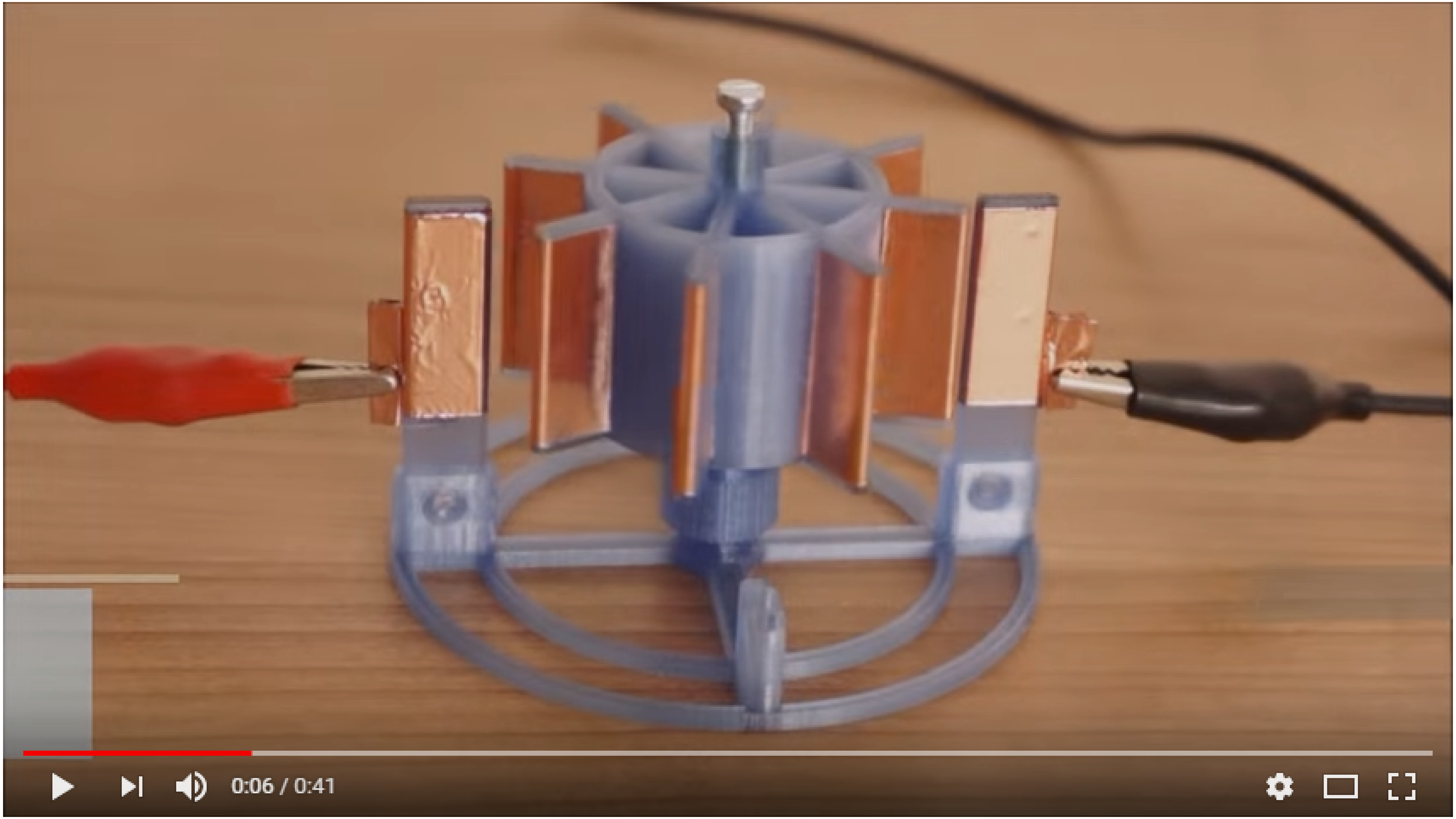

Electrostatic Motor

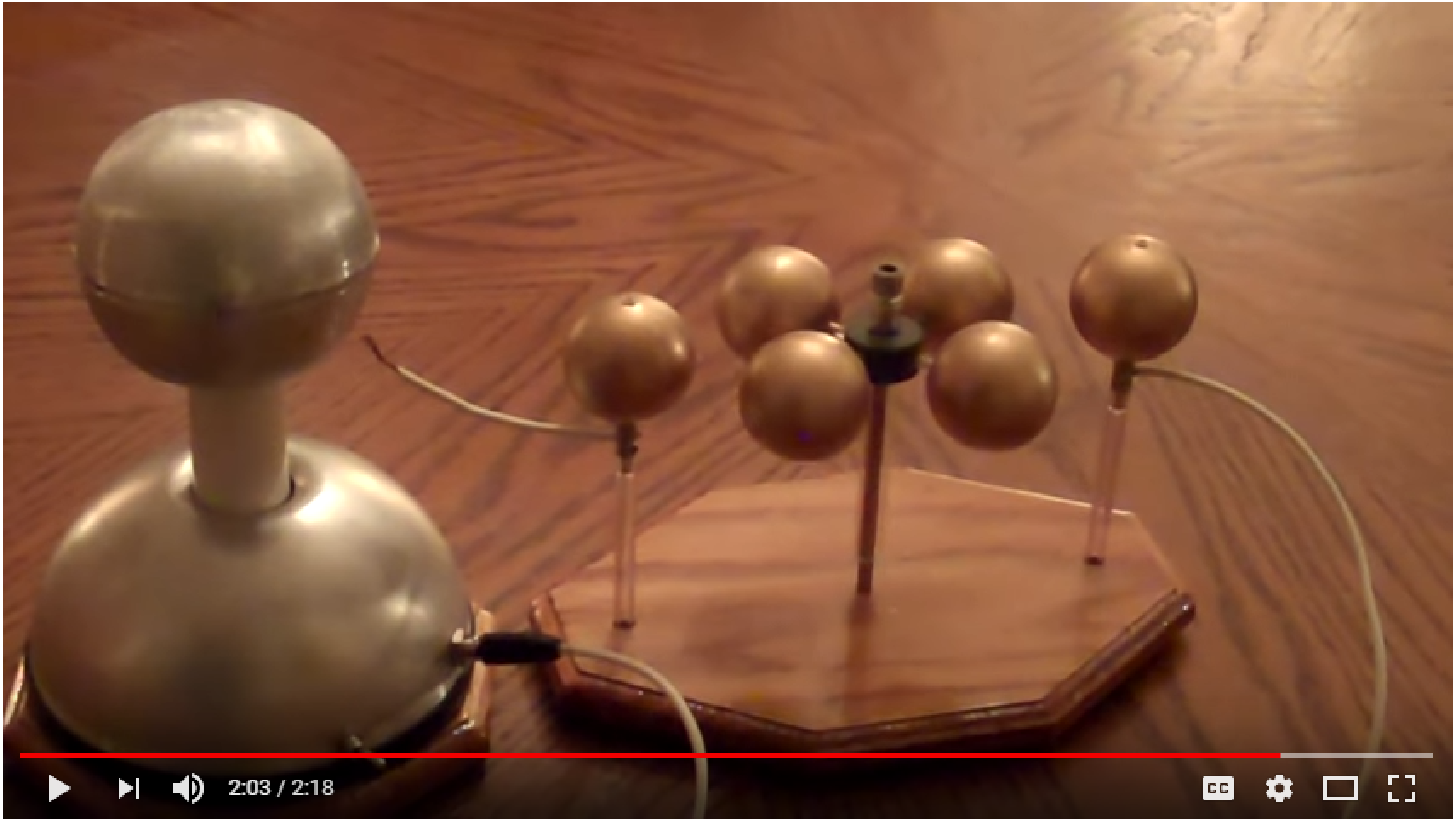

Home Made Electrostatic Motor

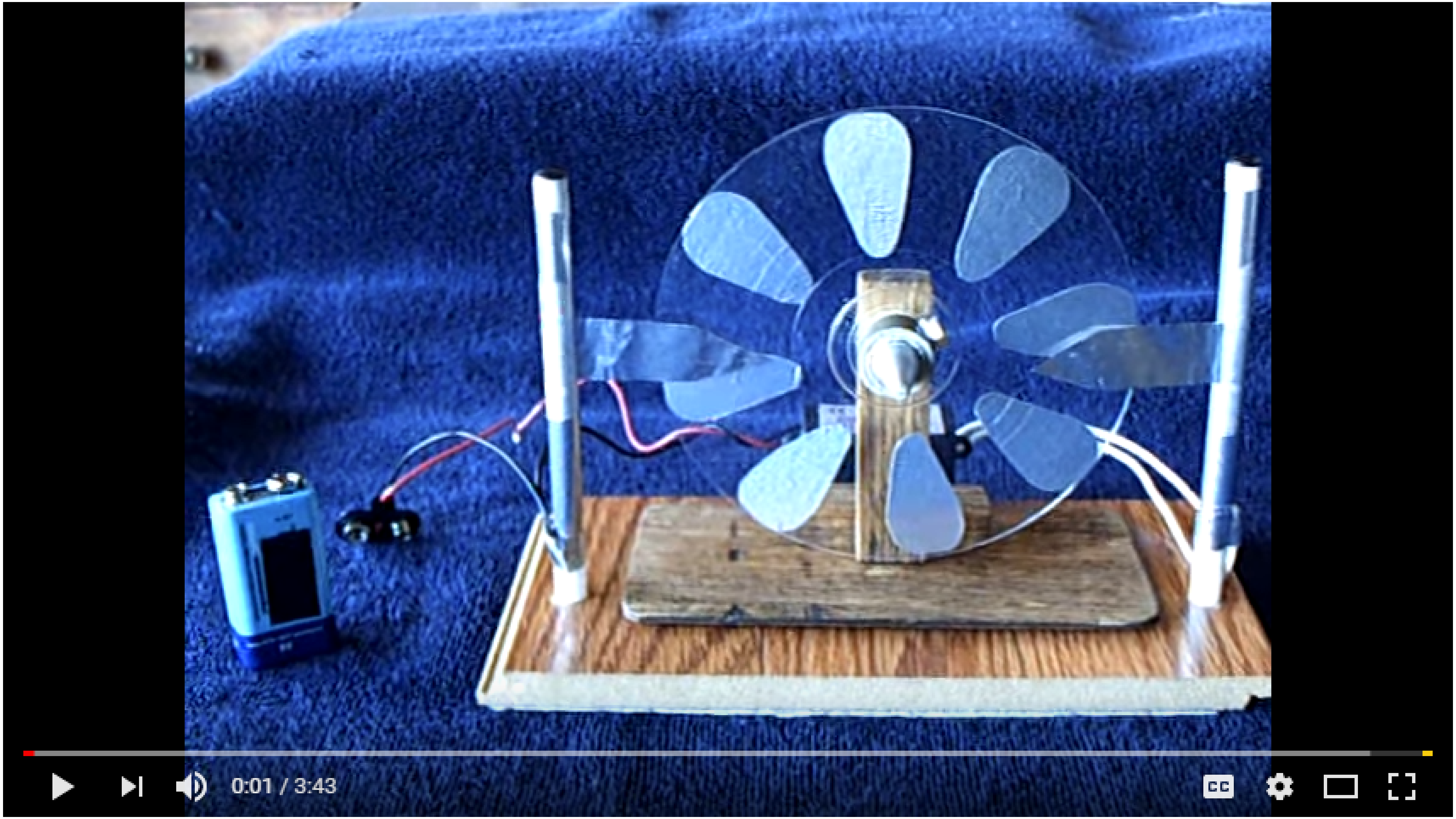

Clear Disk Electrostatic Motor

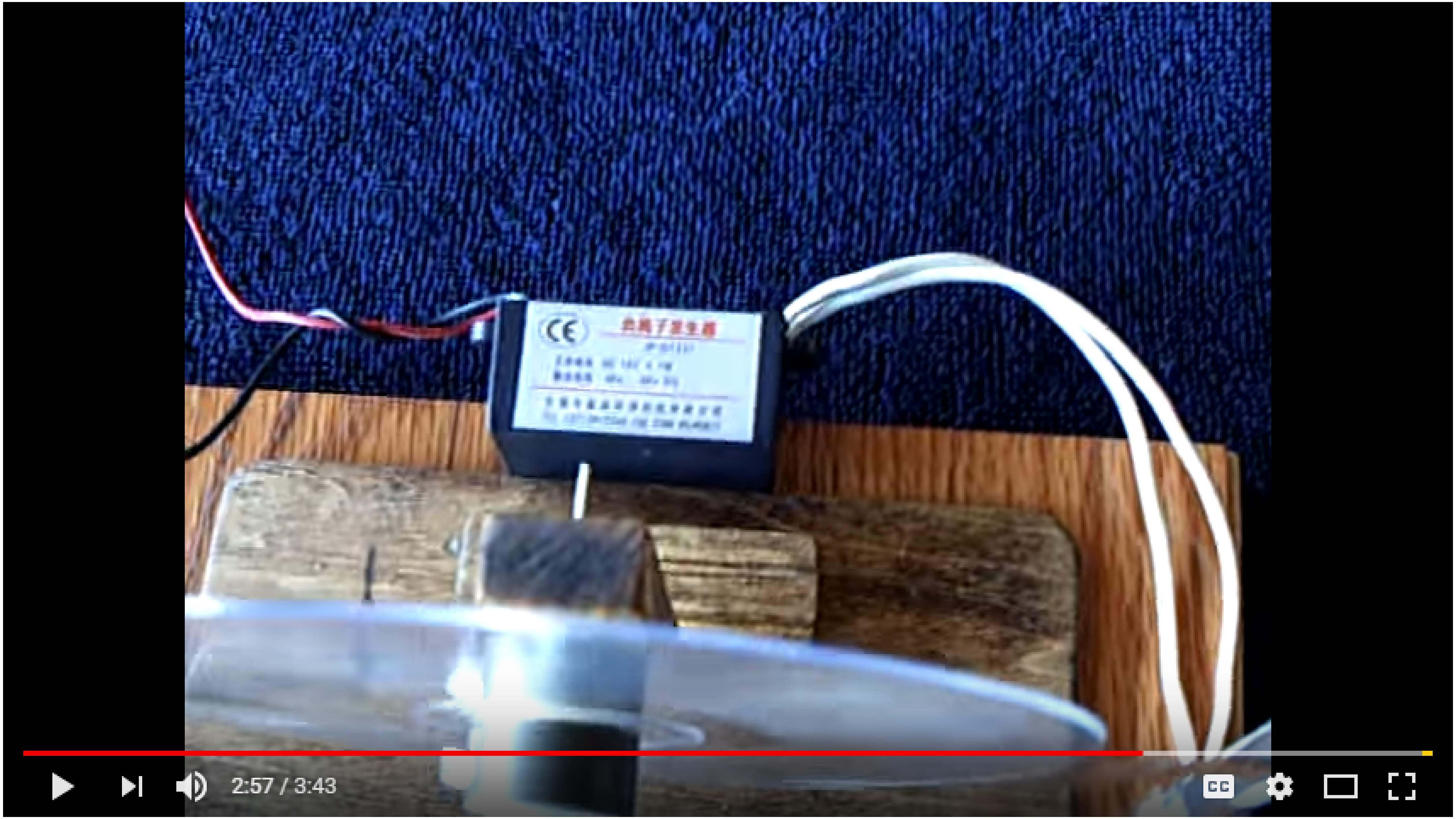
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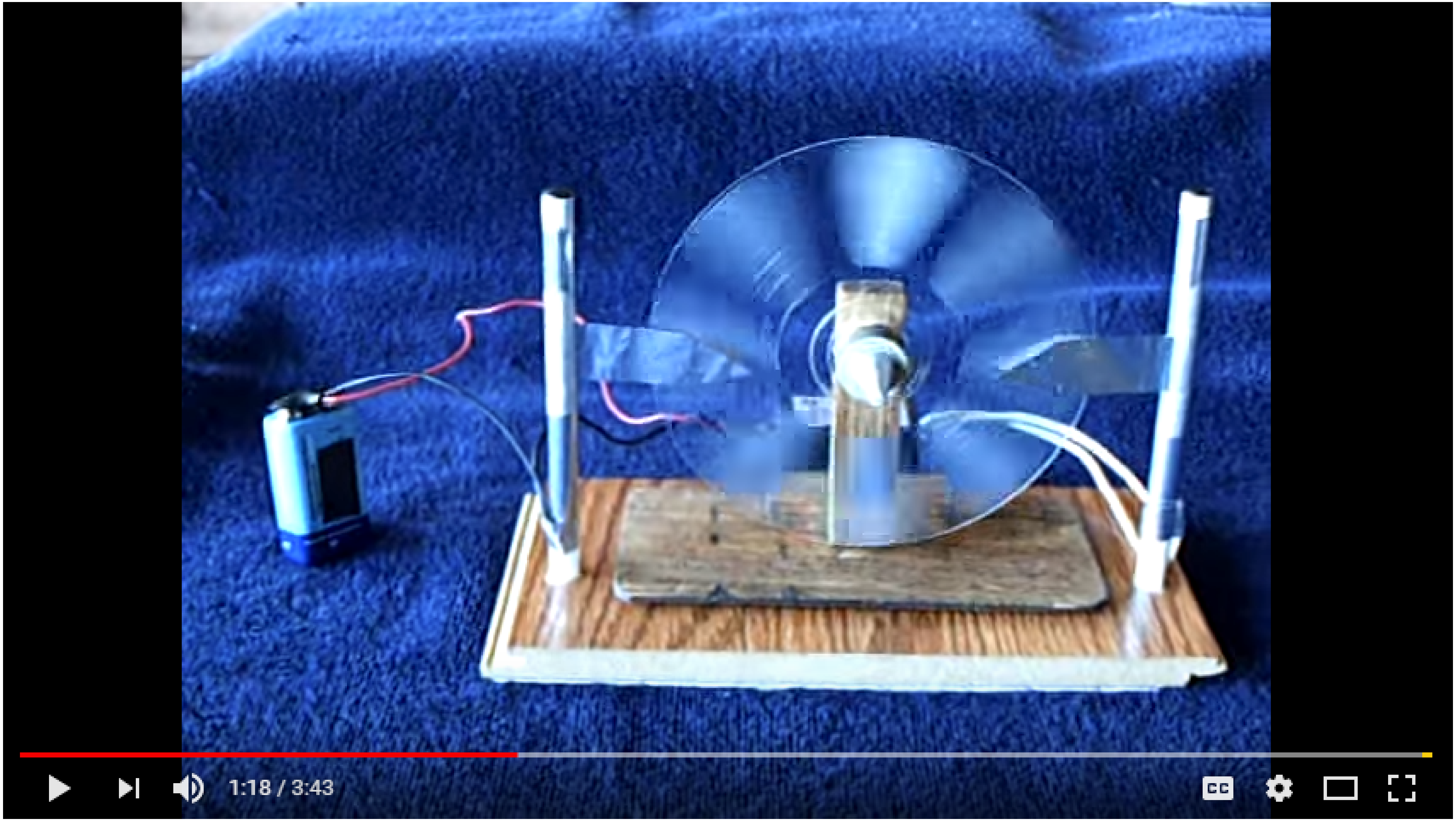
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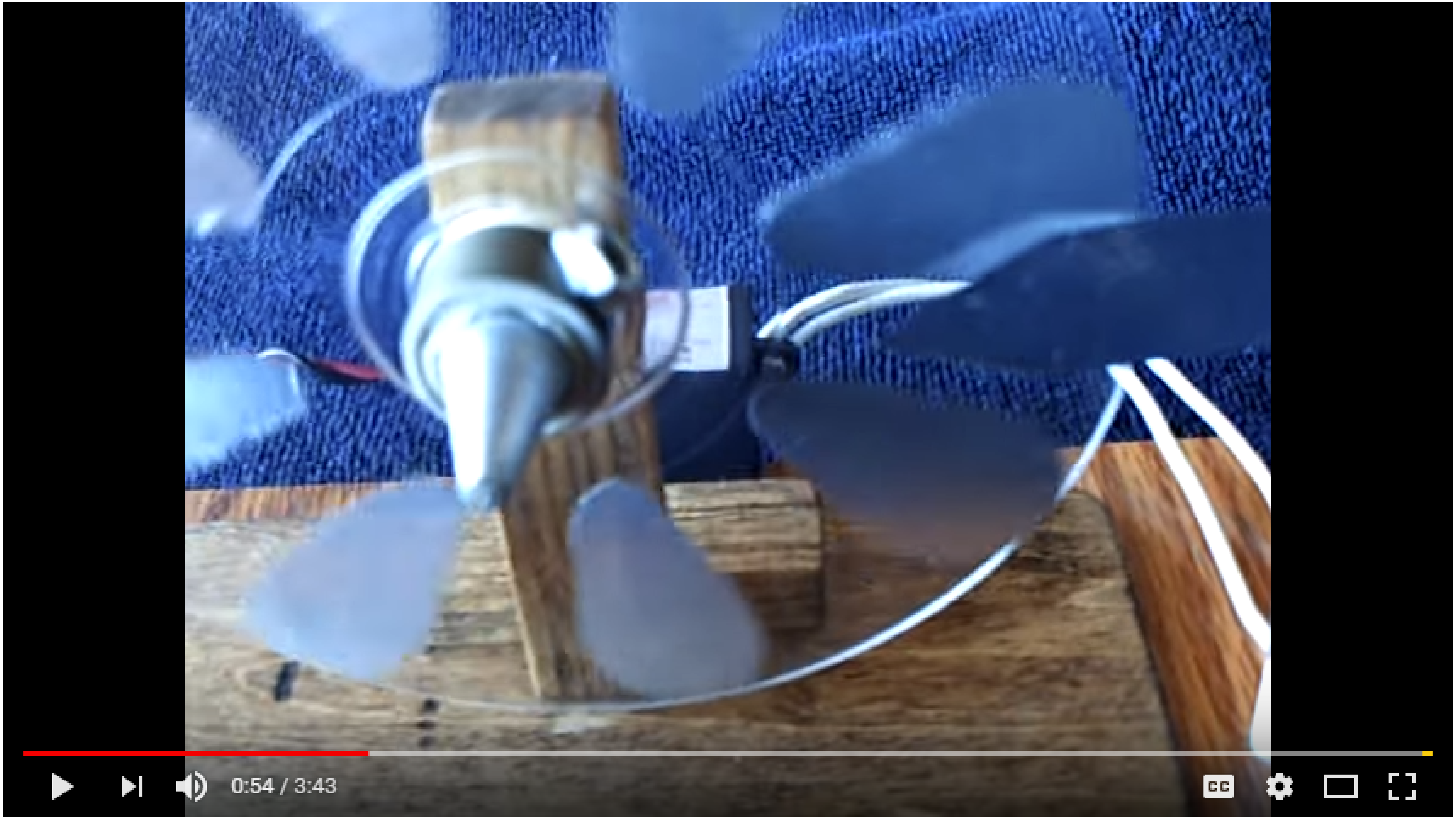
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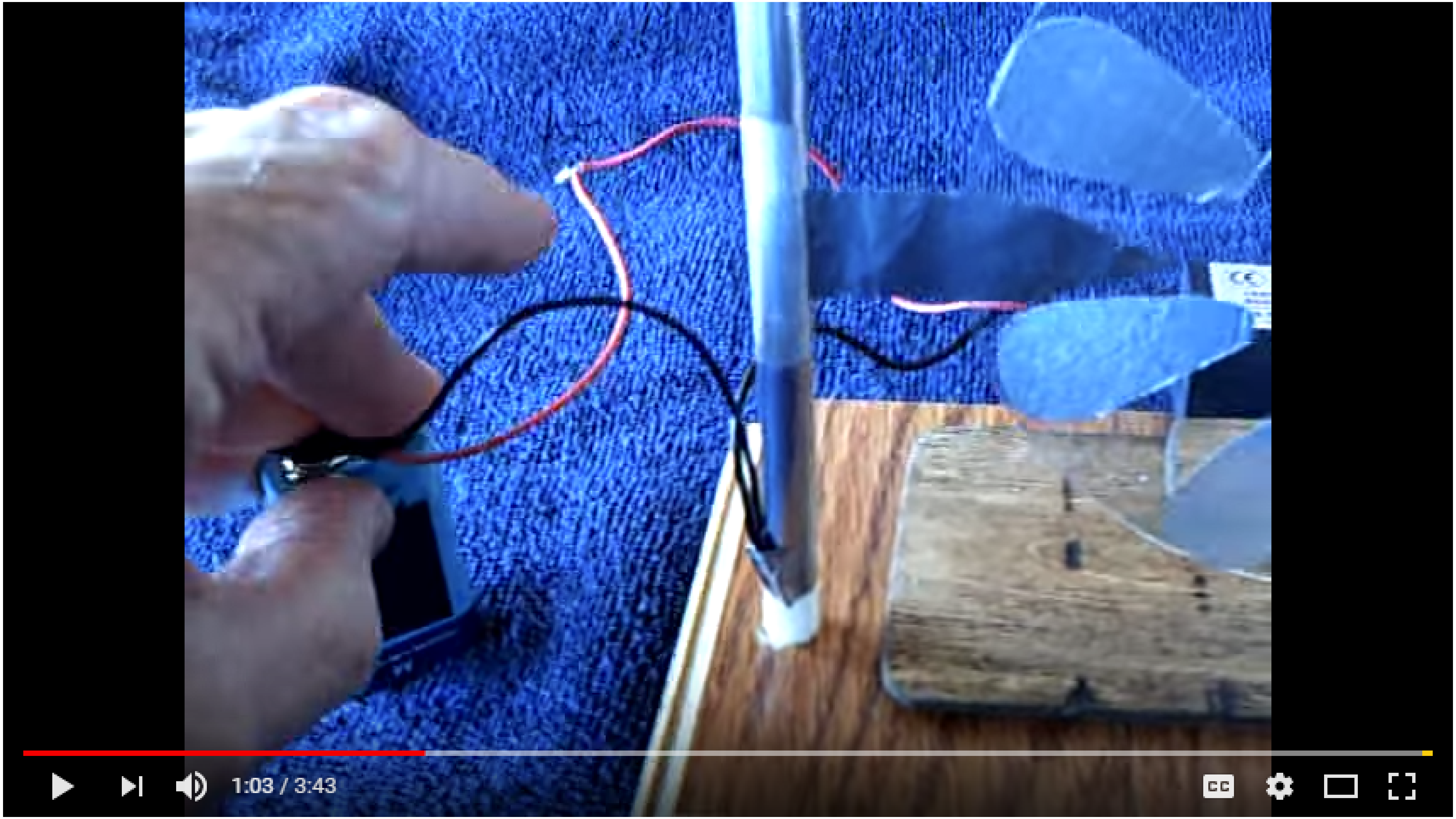
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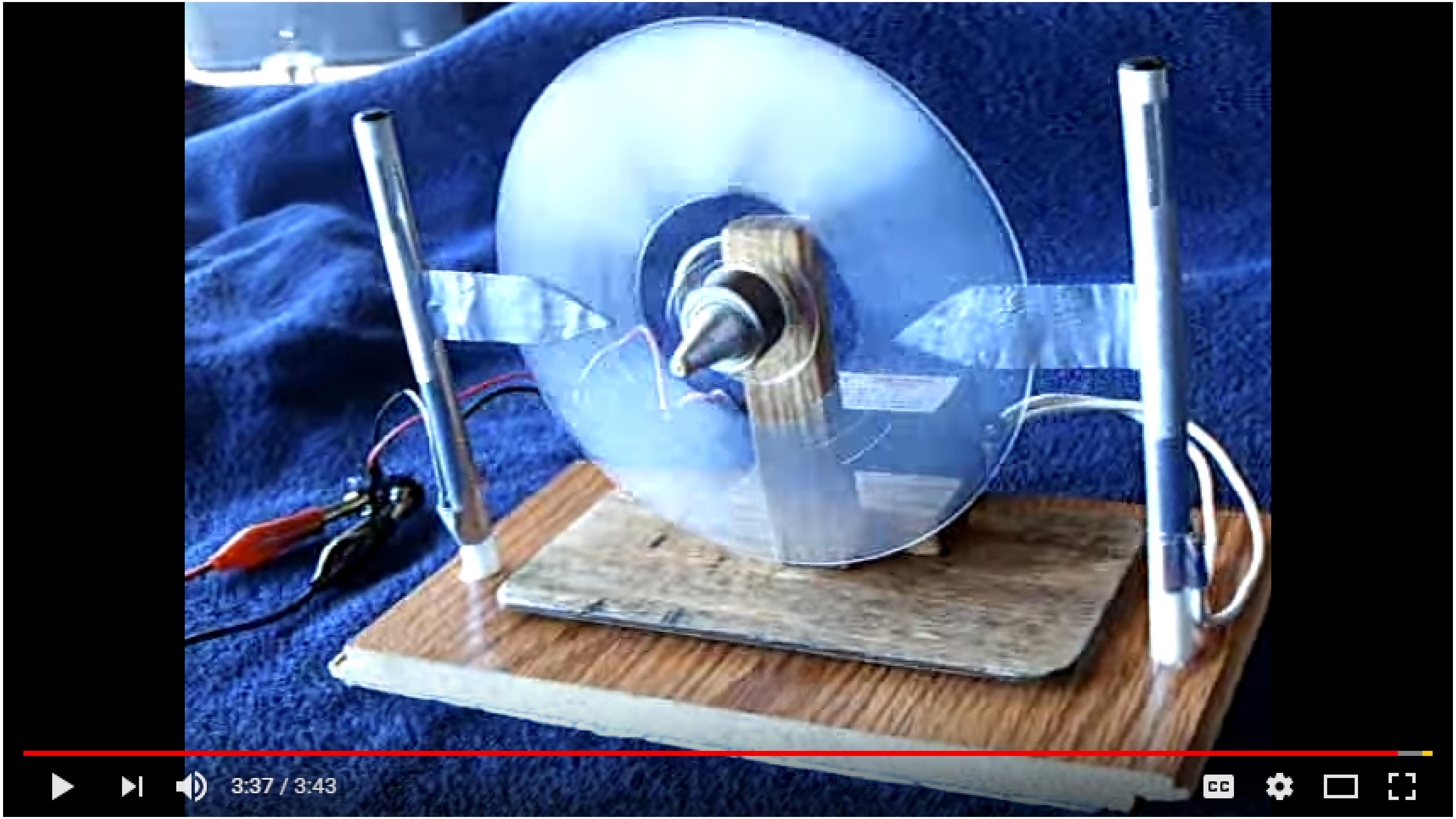
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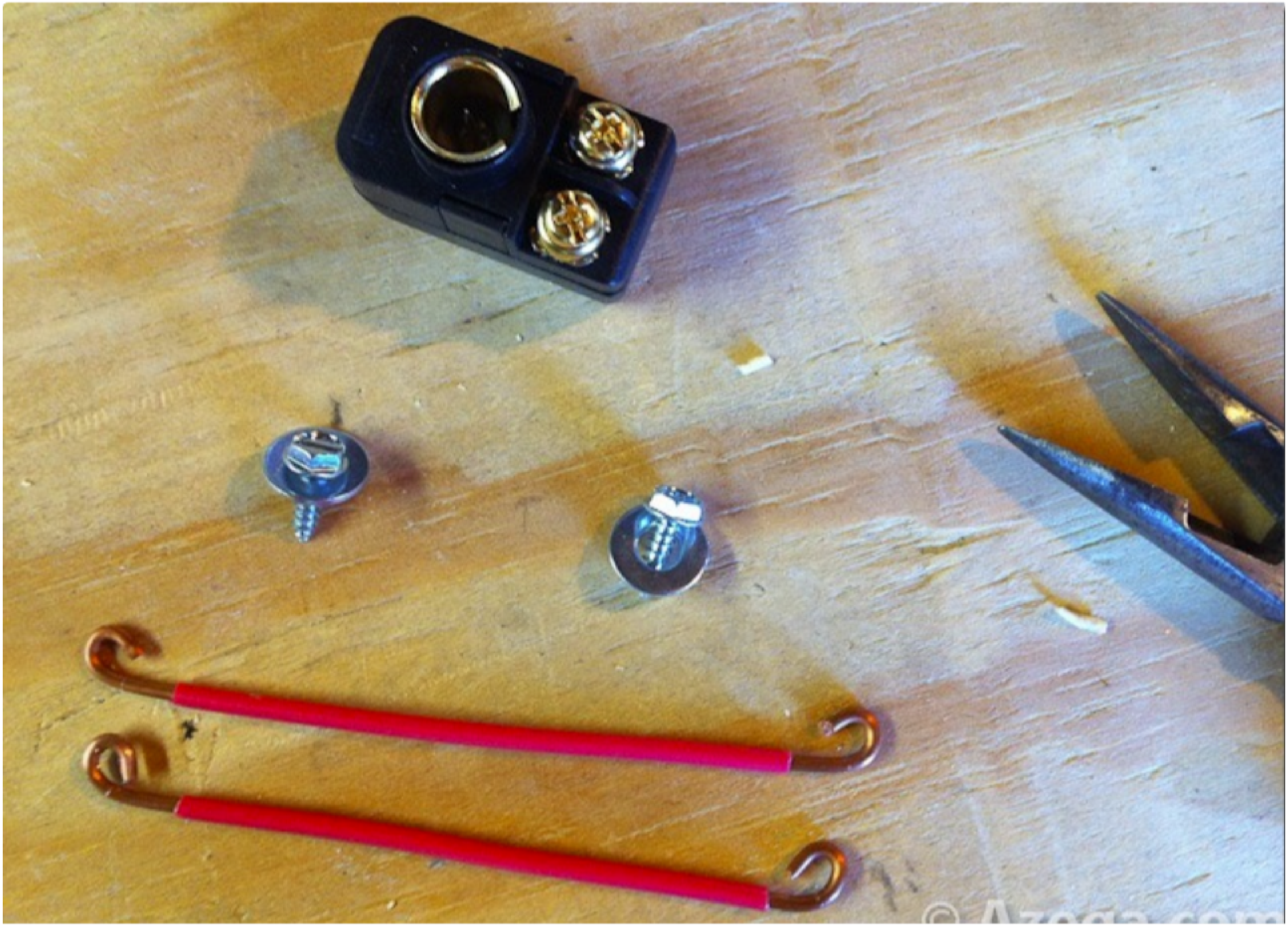

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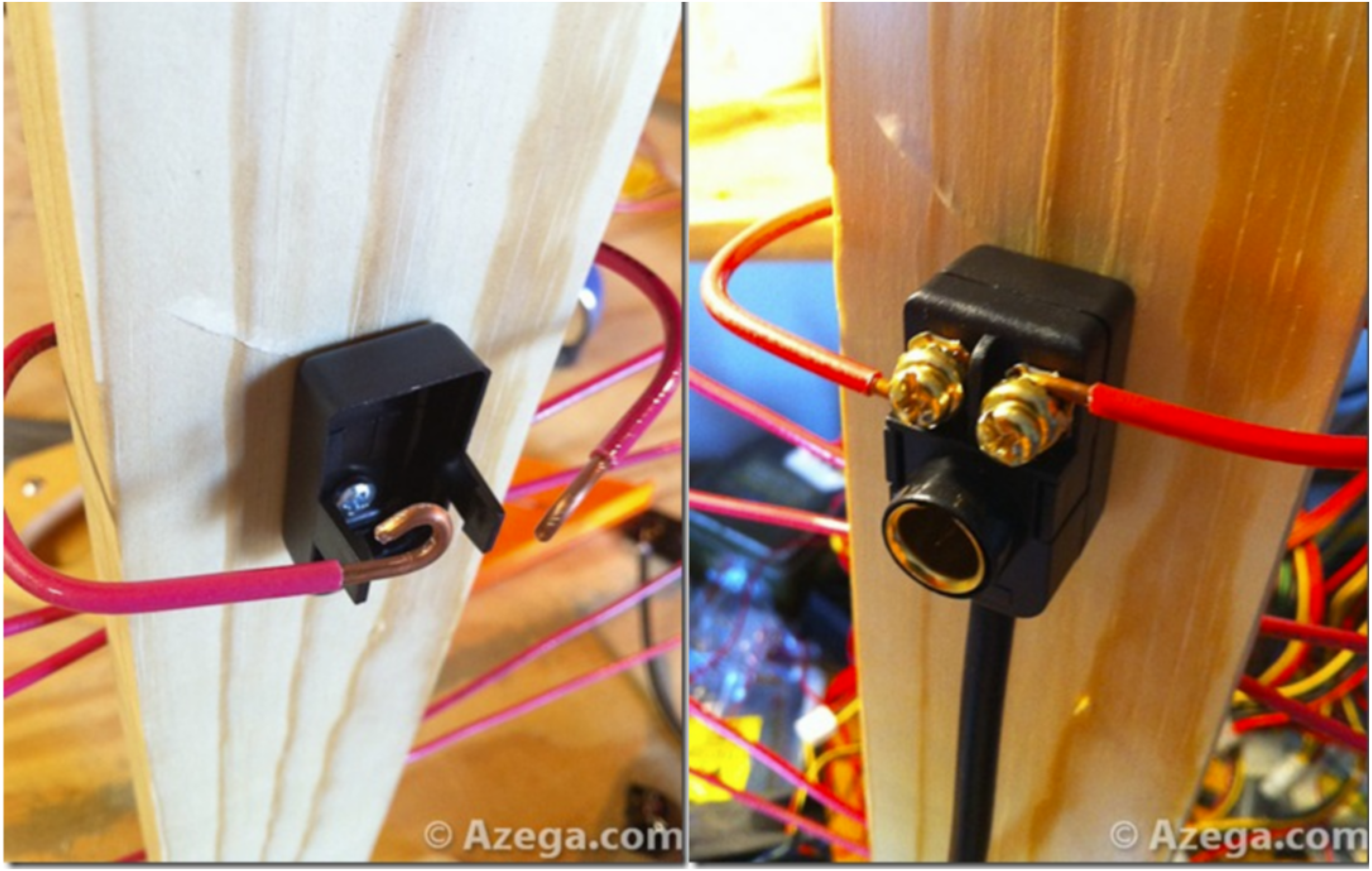
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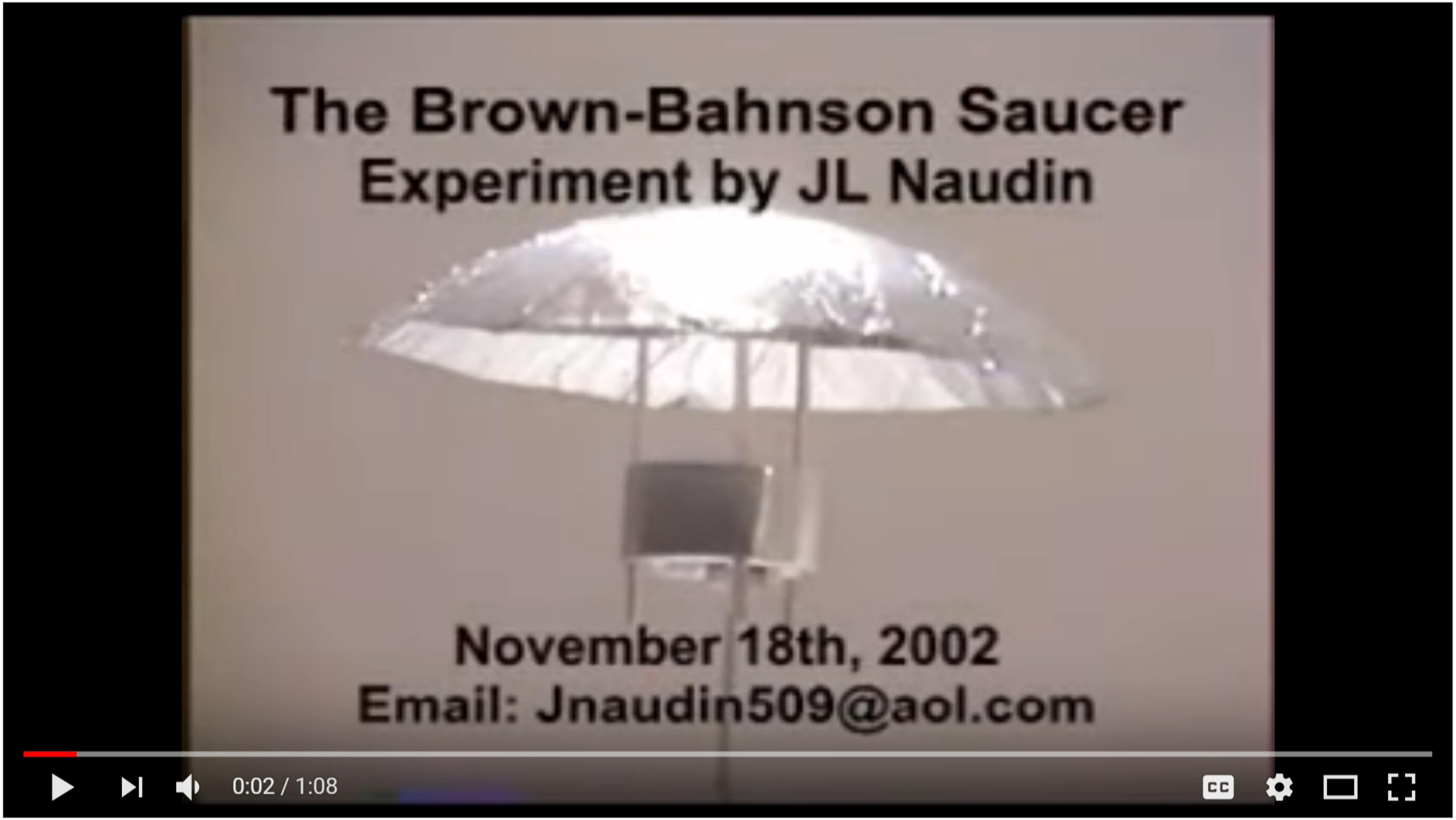

The Brown-Bahnson Saucer
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November 18th, 2002
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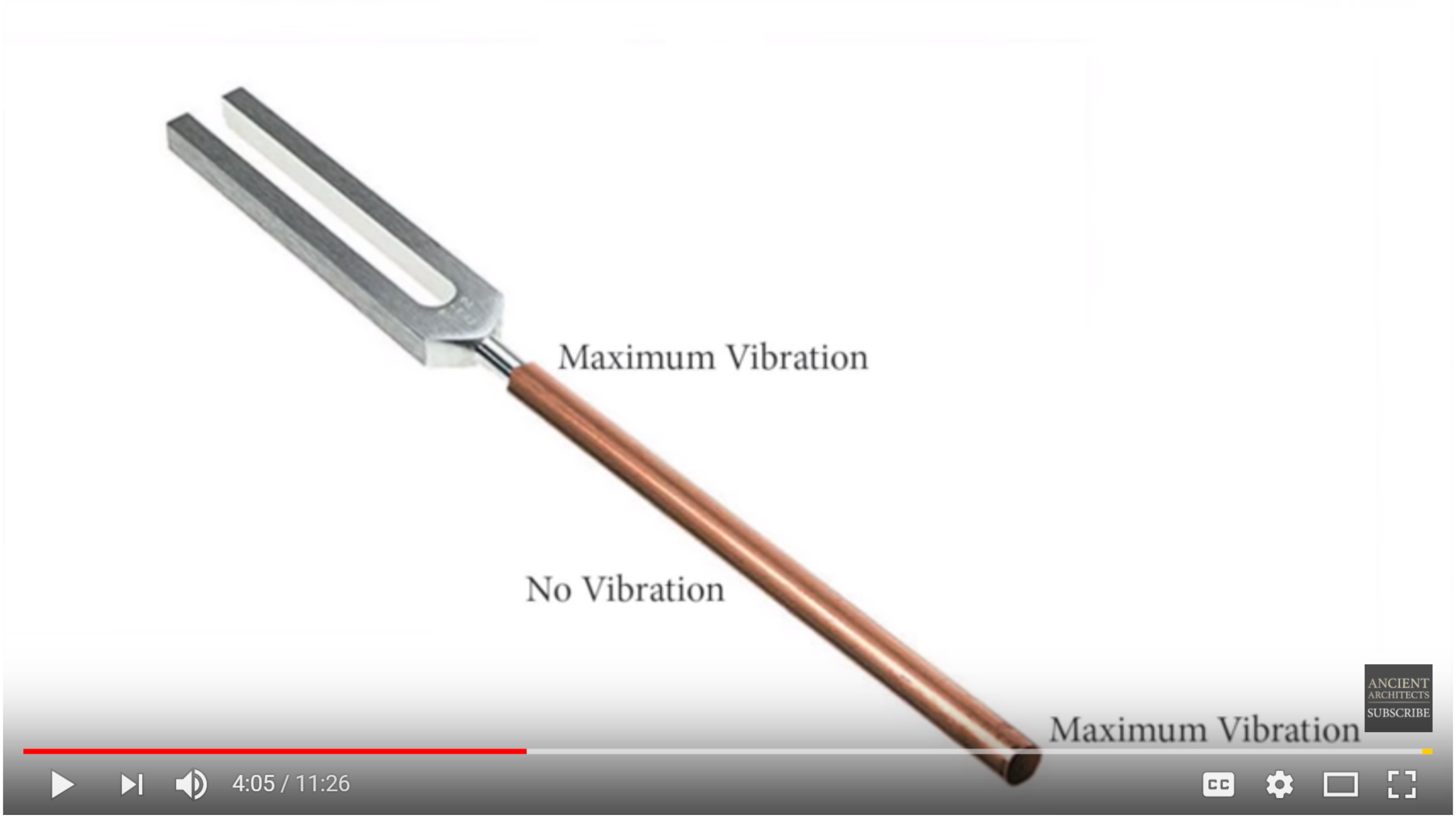
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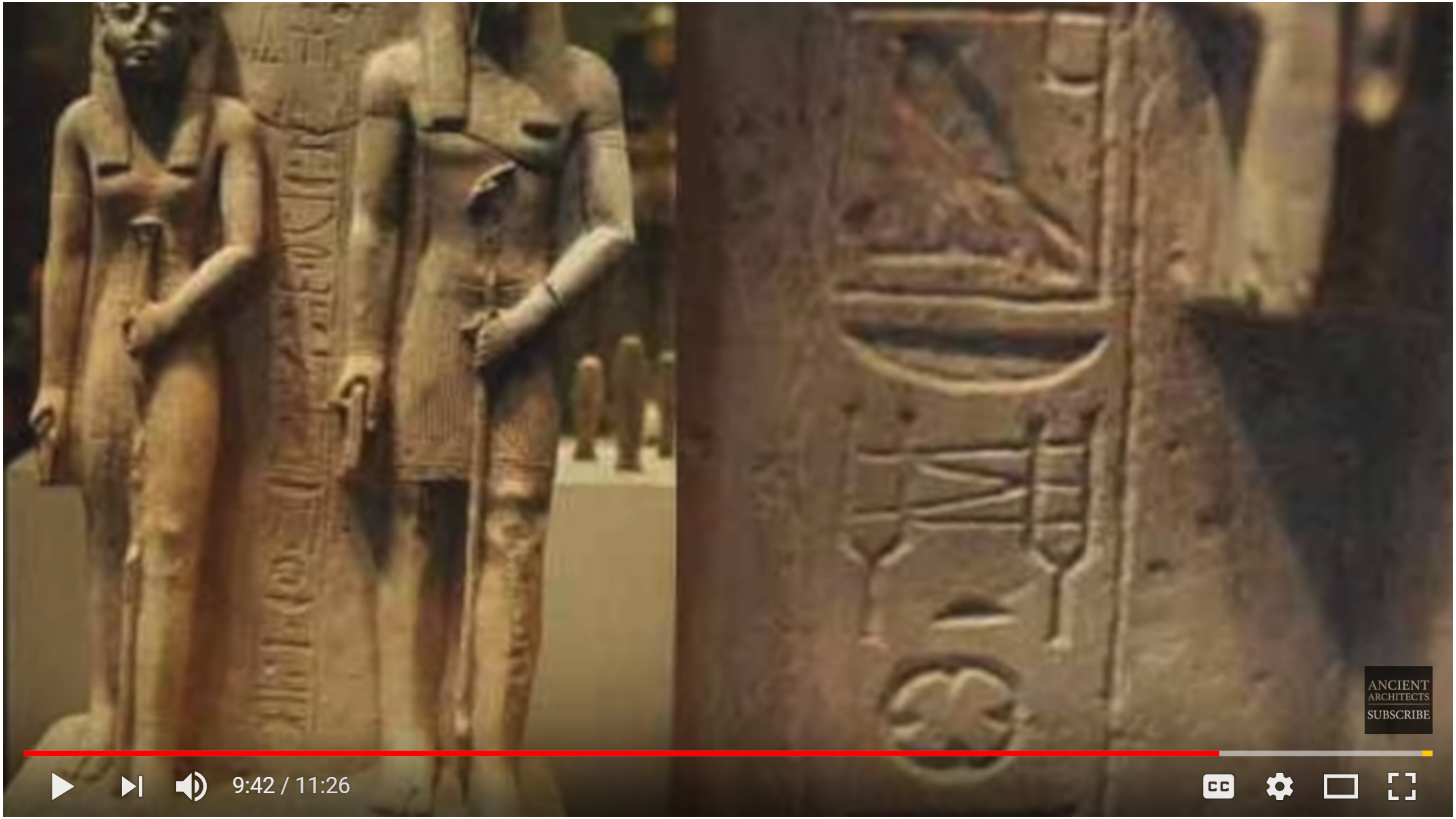
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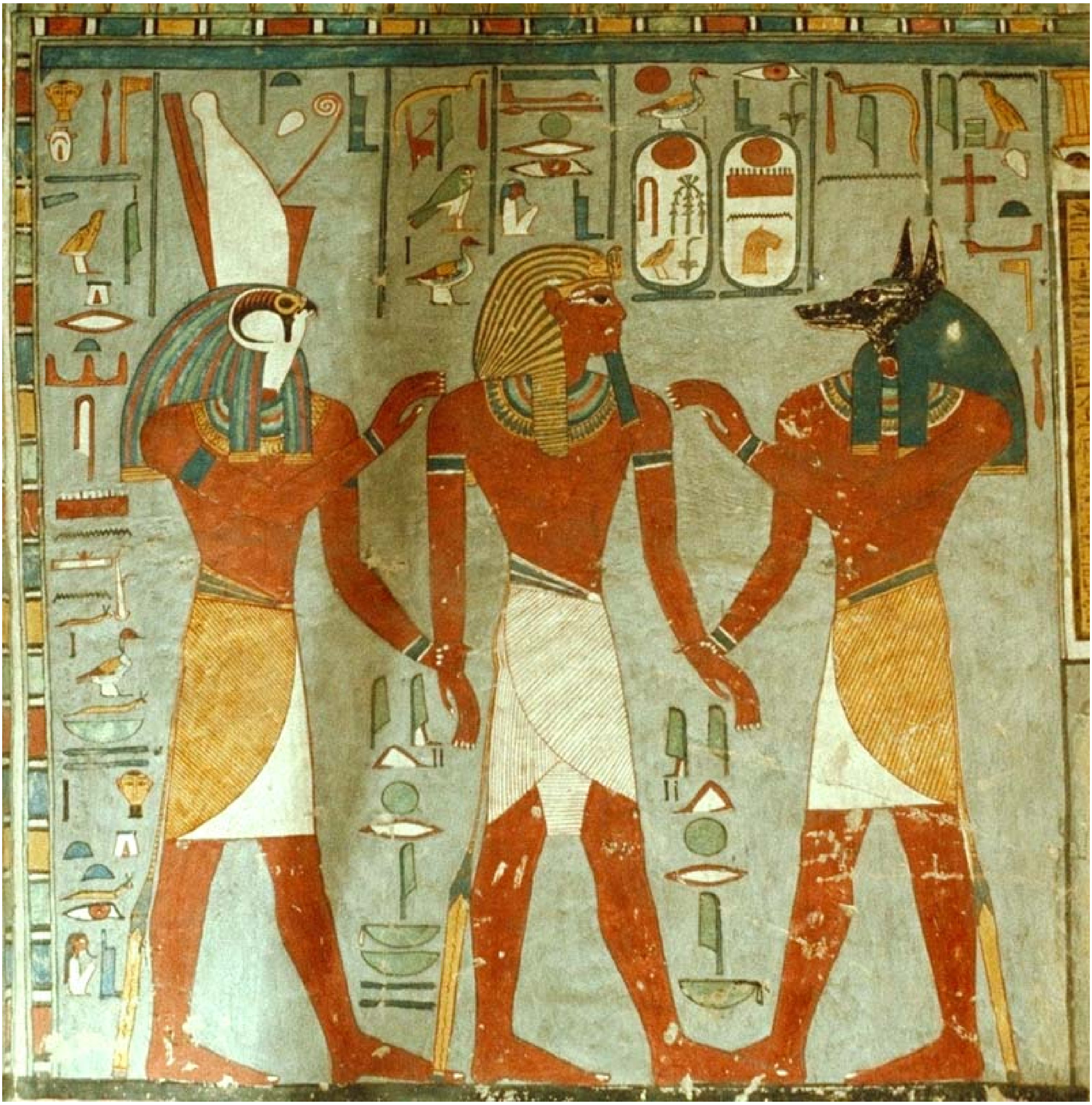

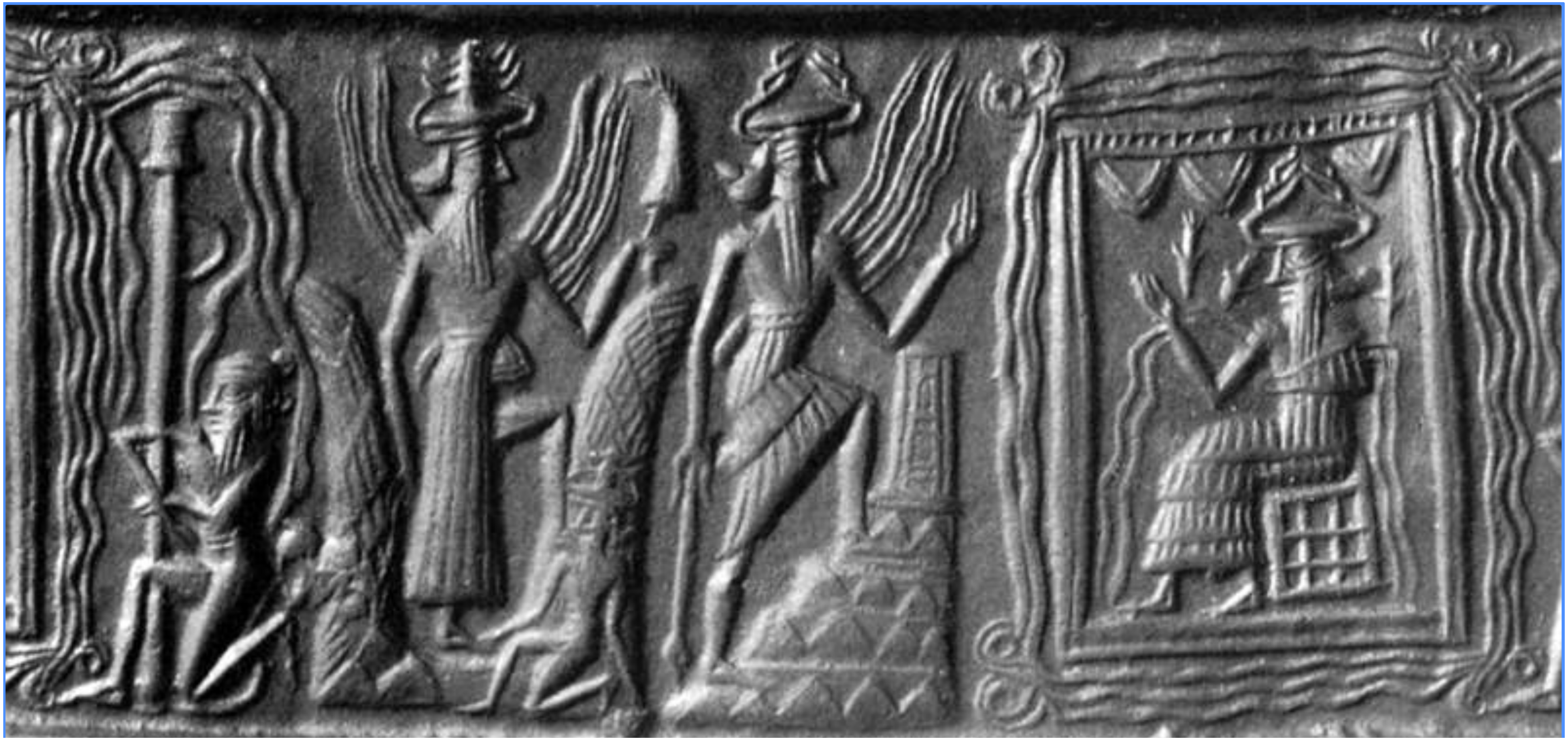

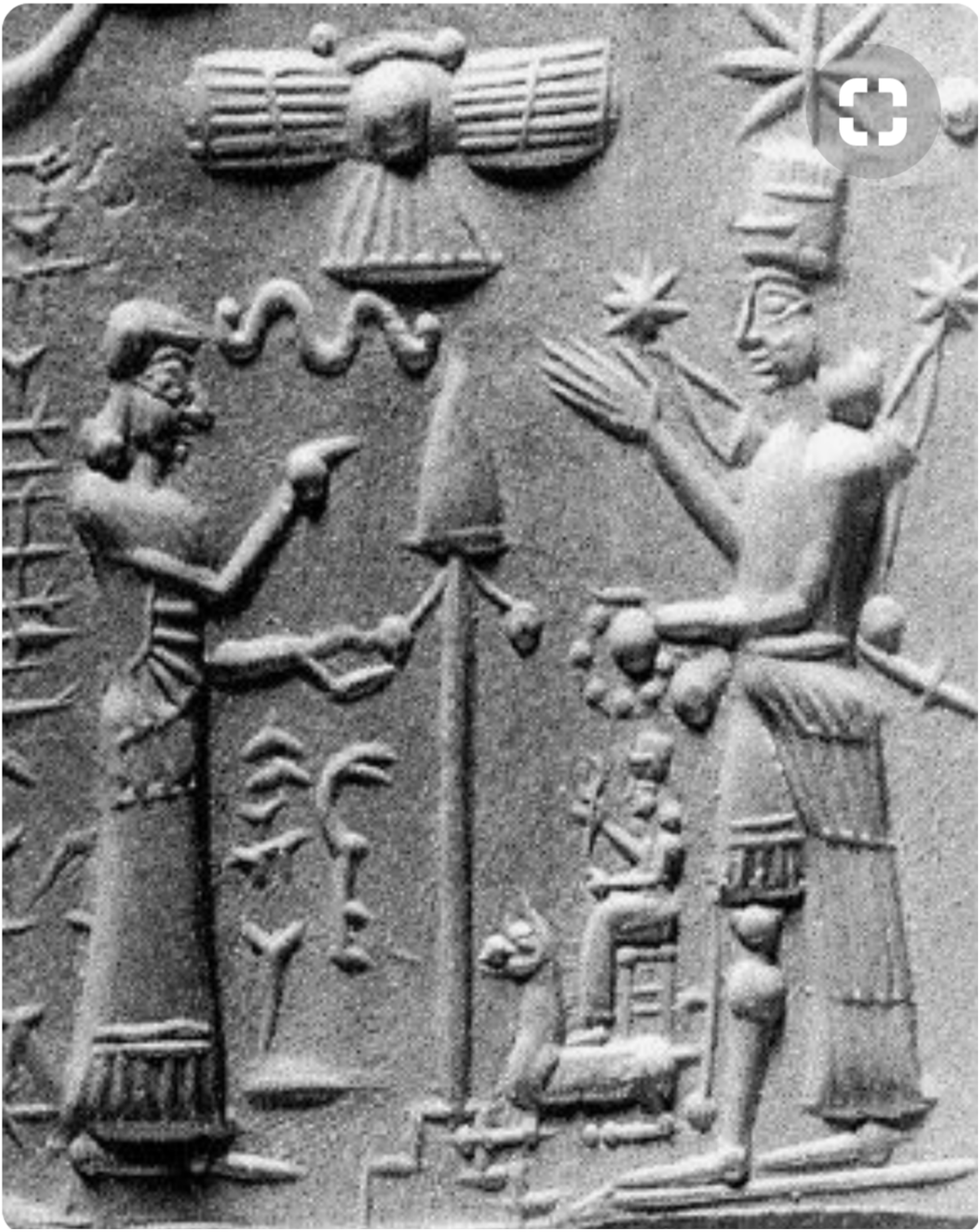

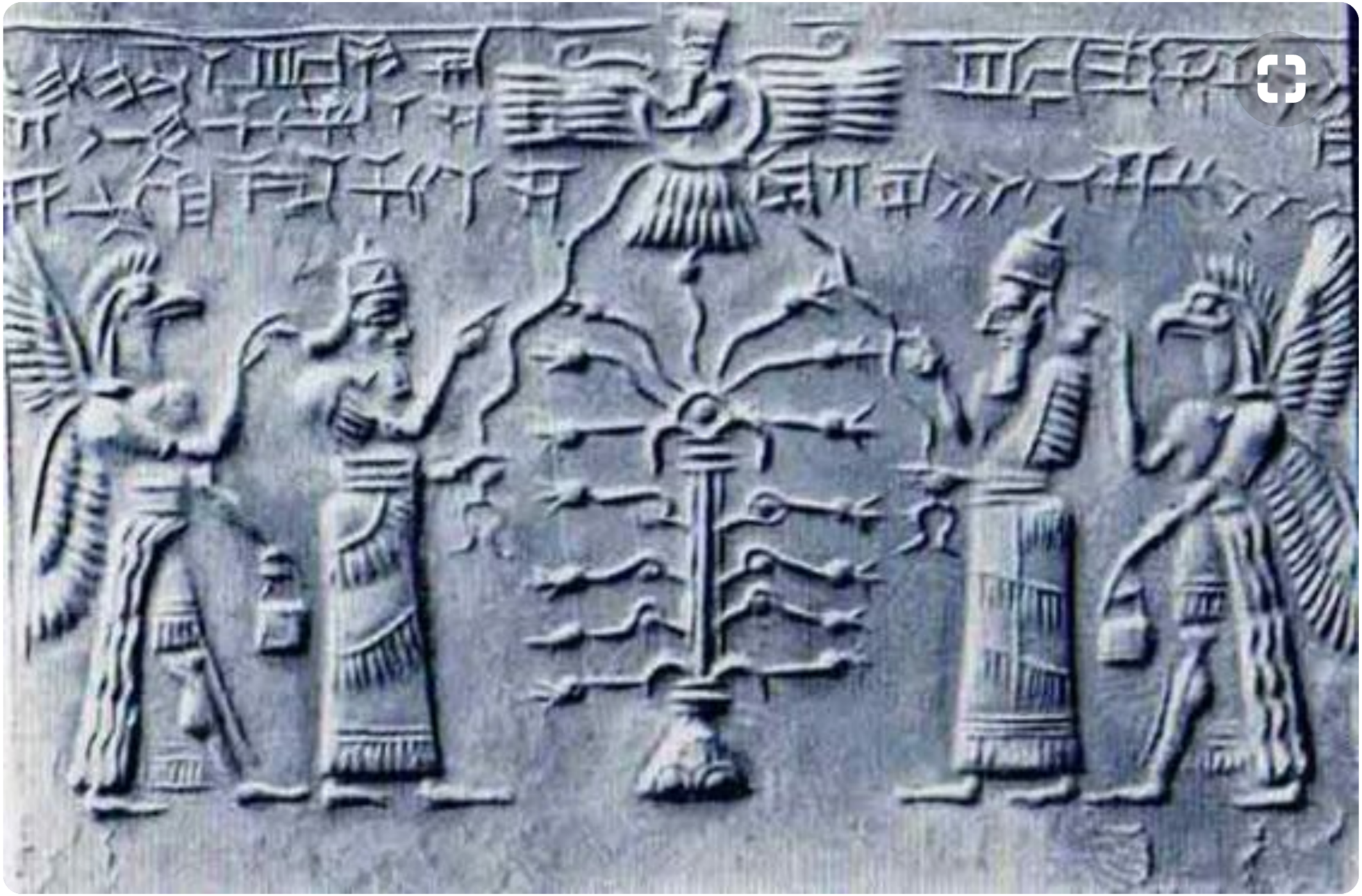

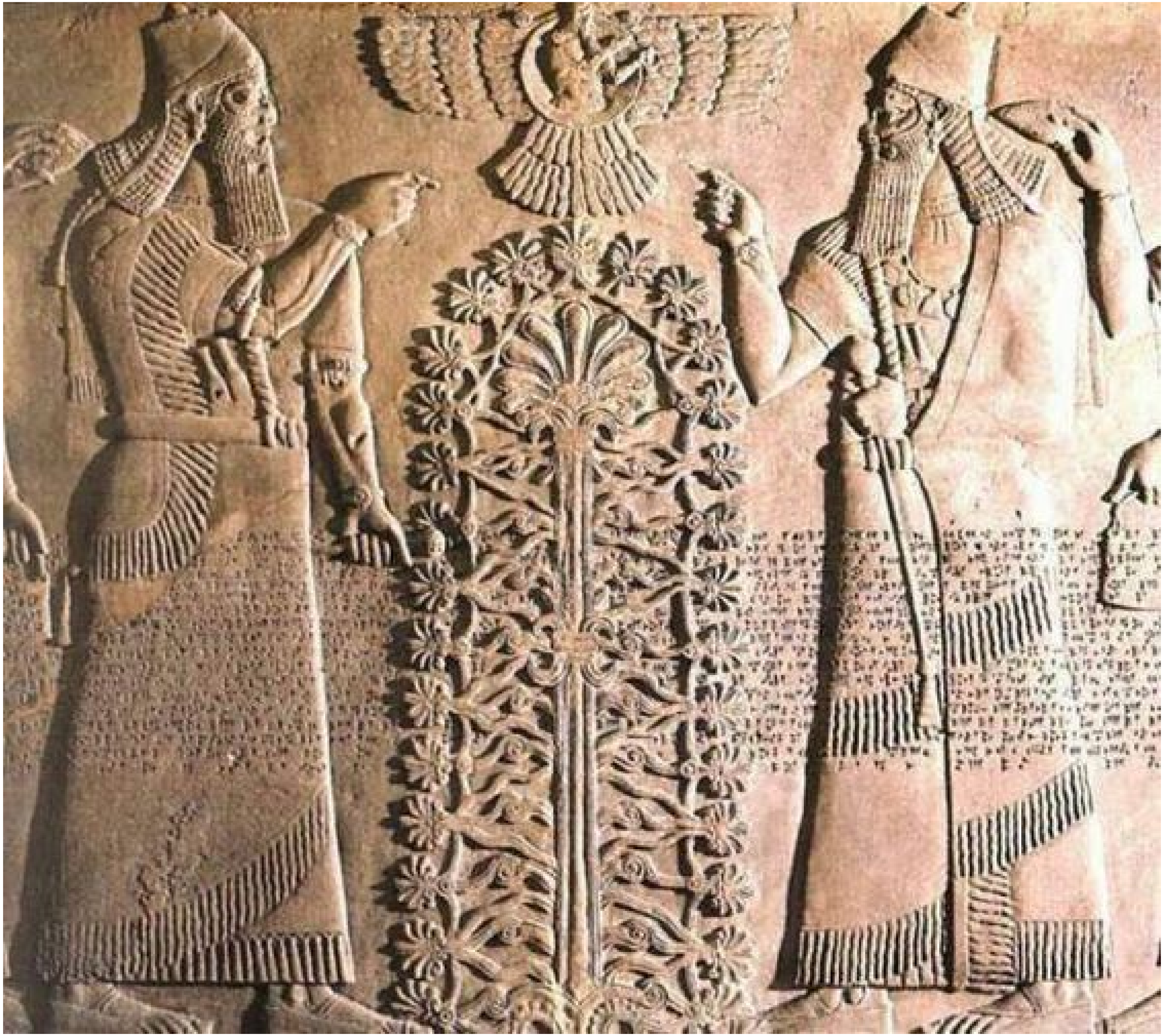

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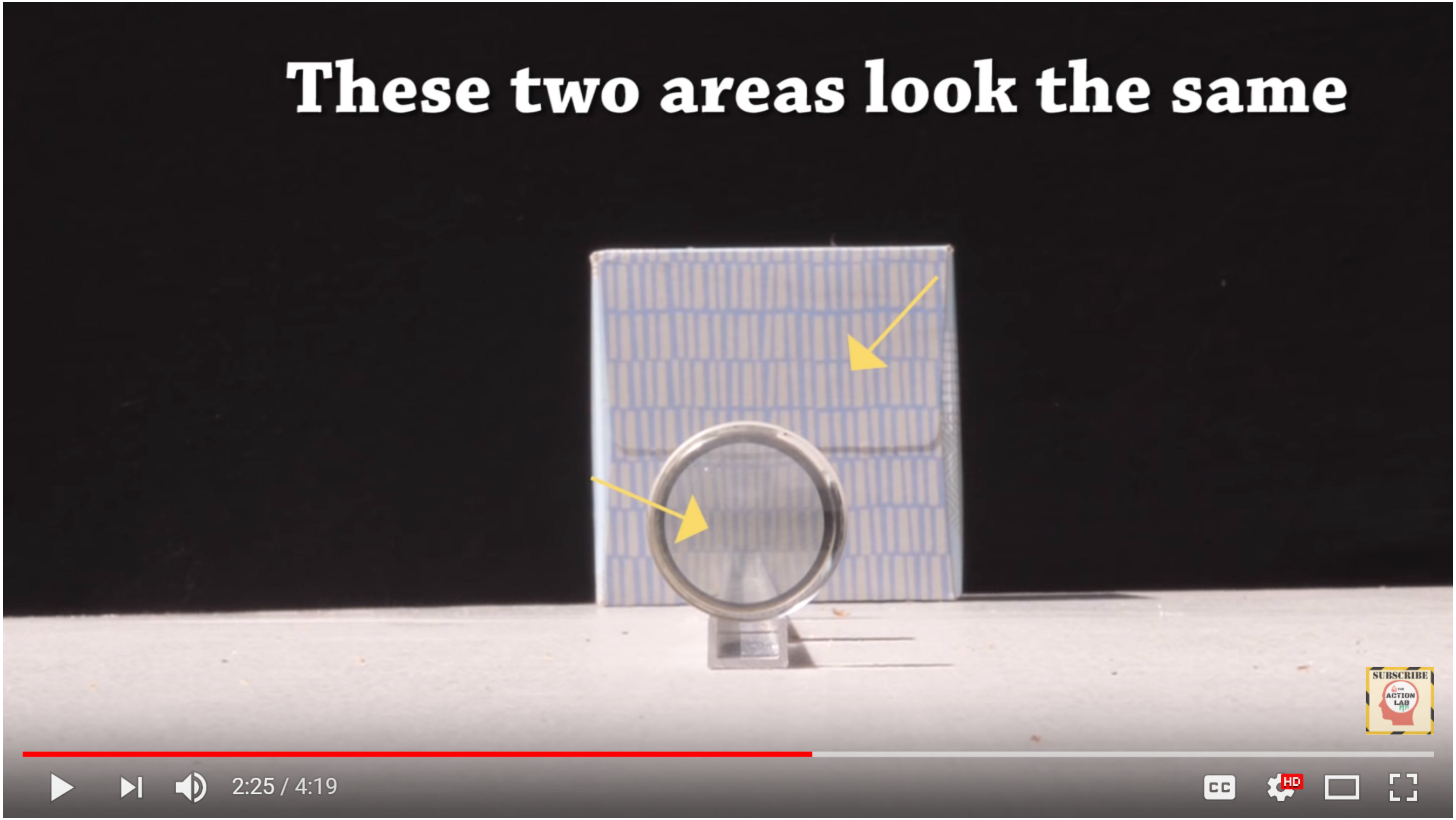

These two areas look the same

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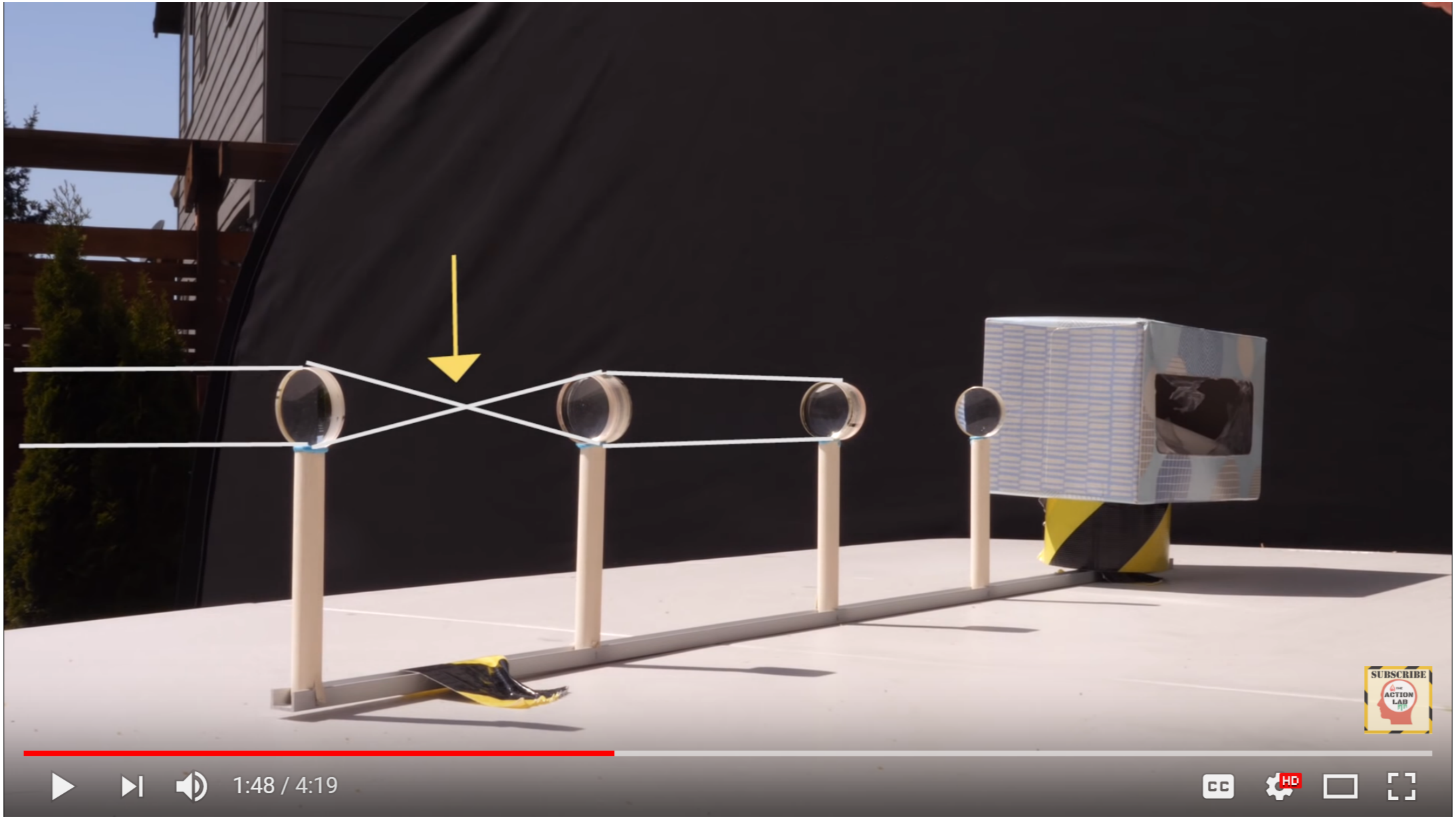
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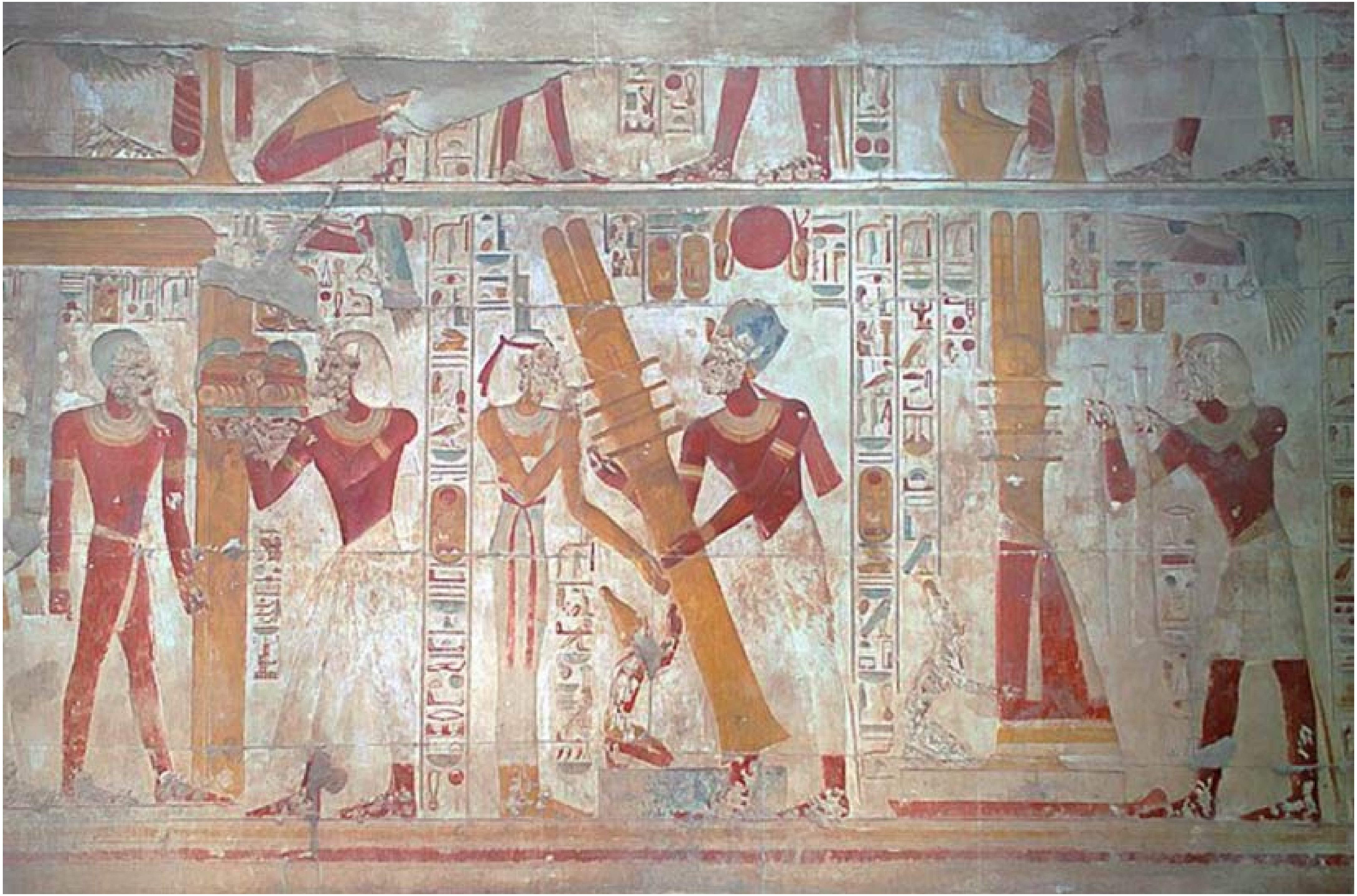

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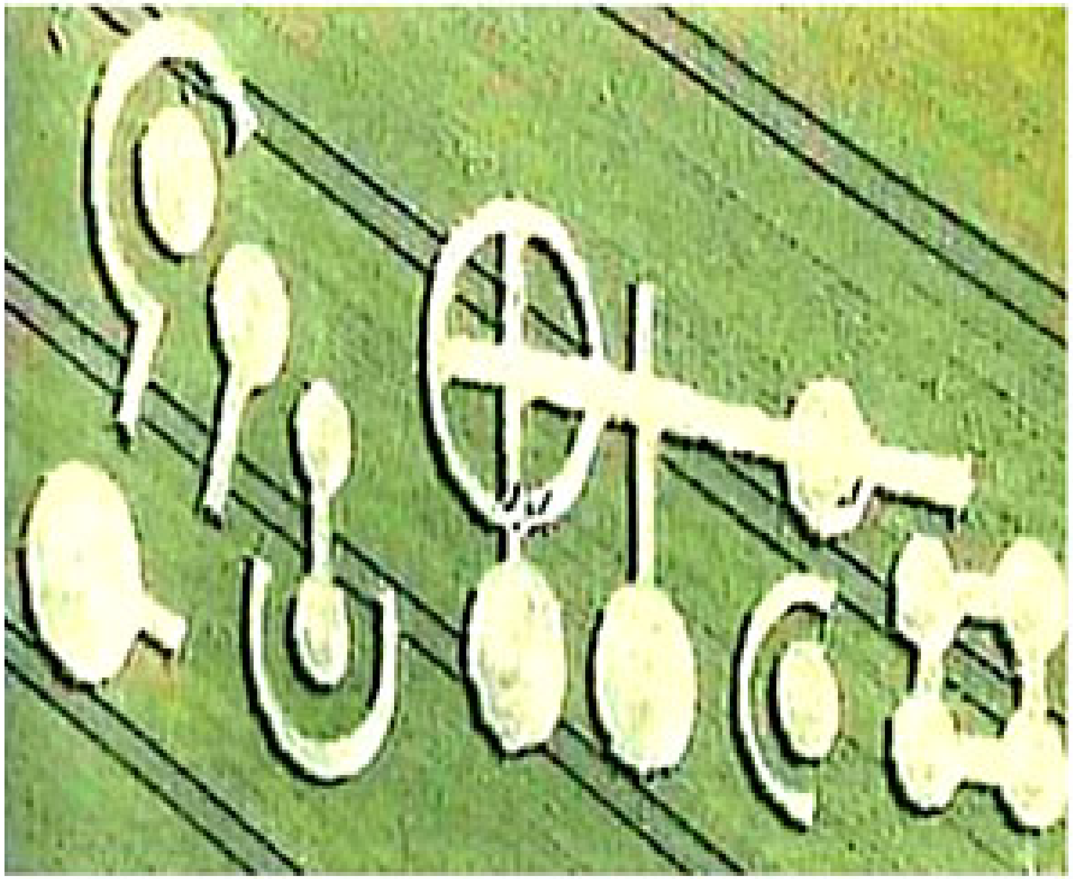

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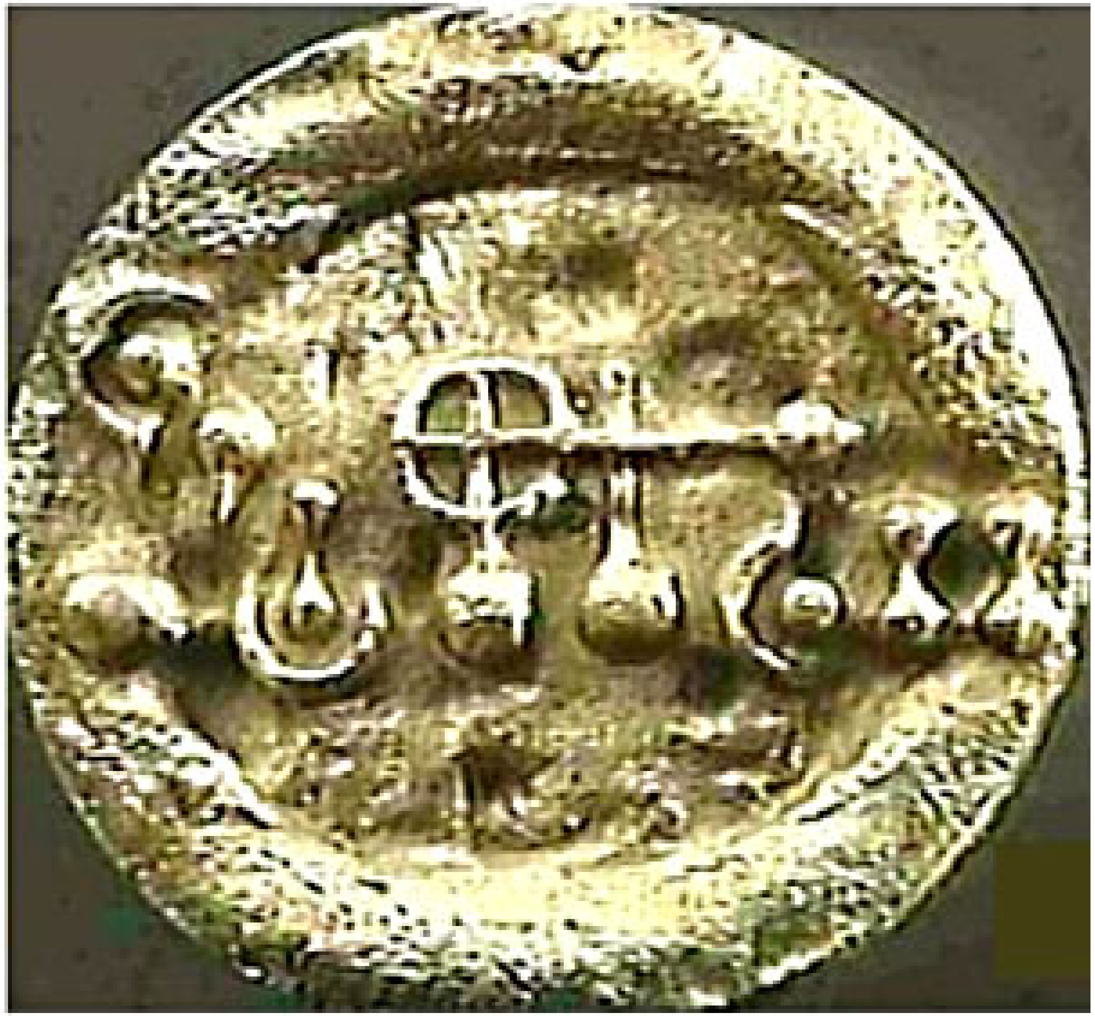

buried golden plate

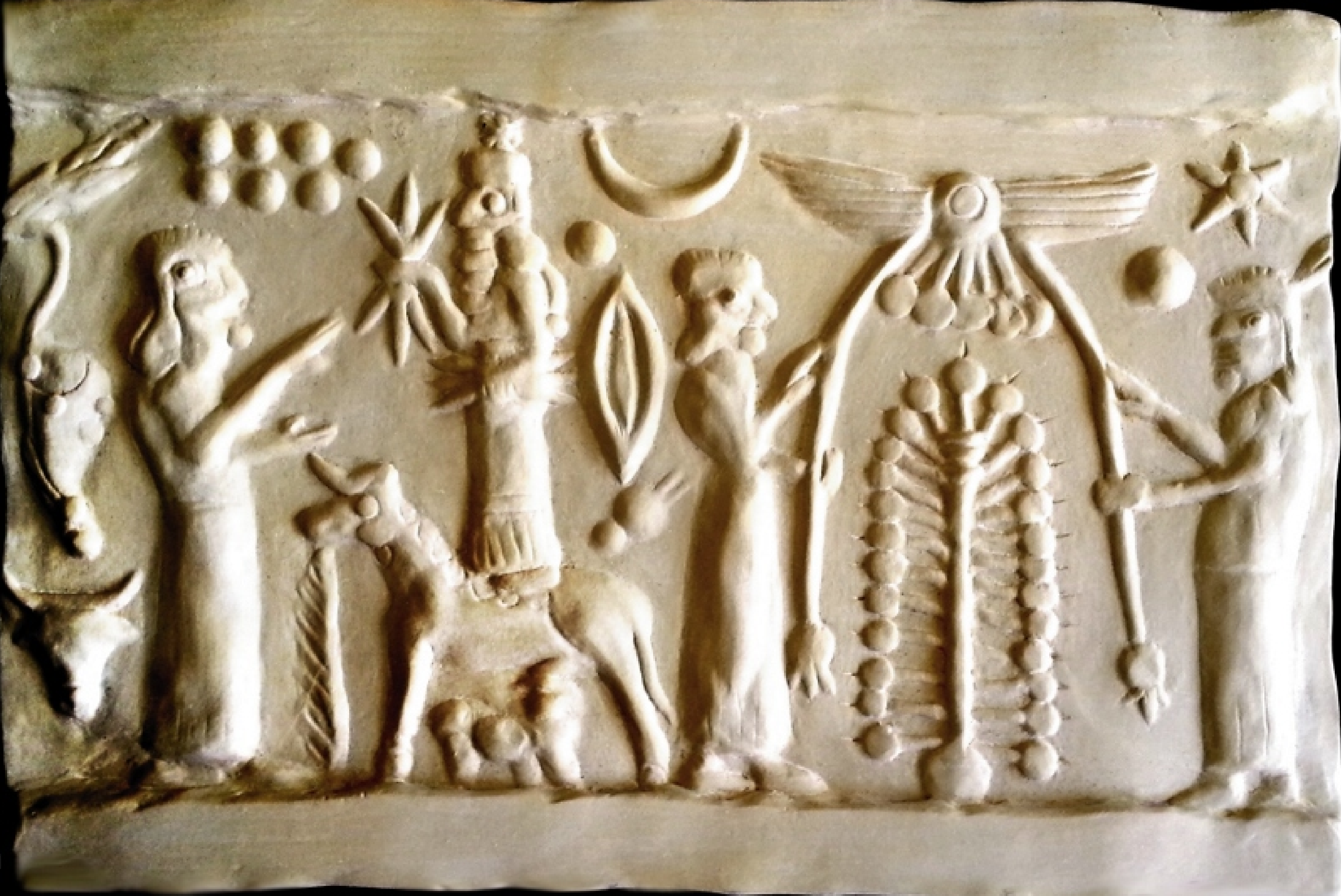

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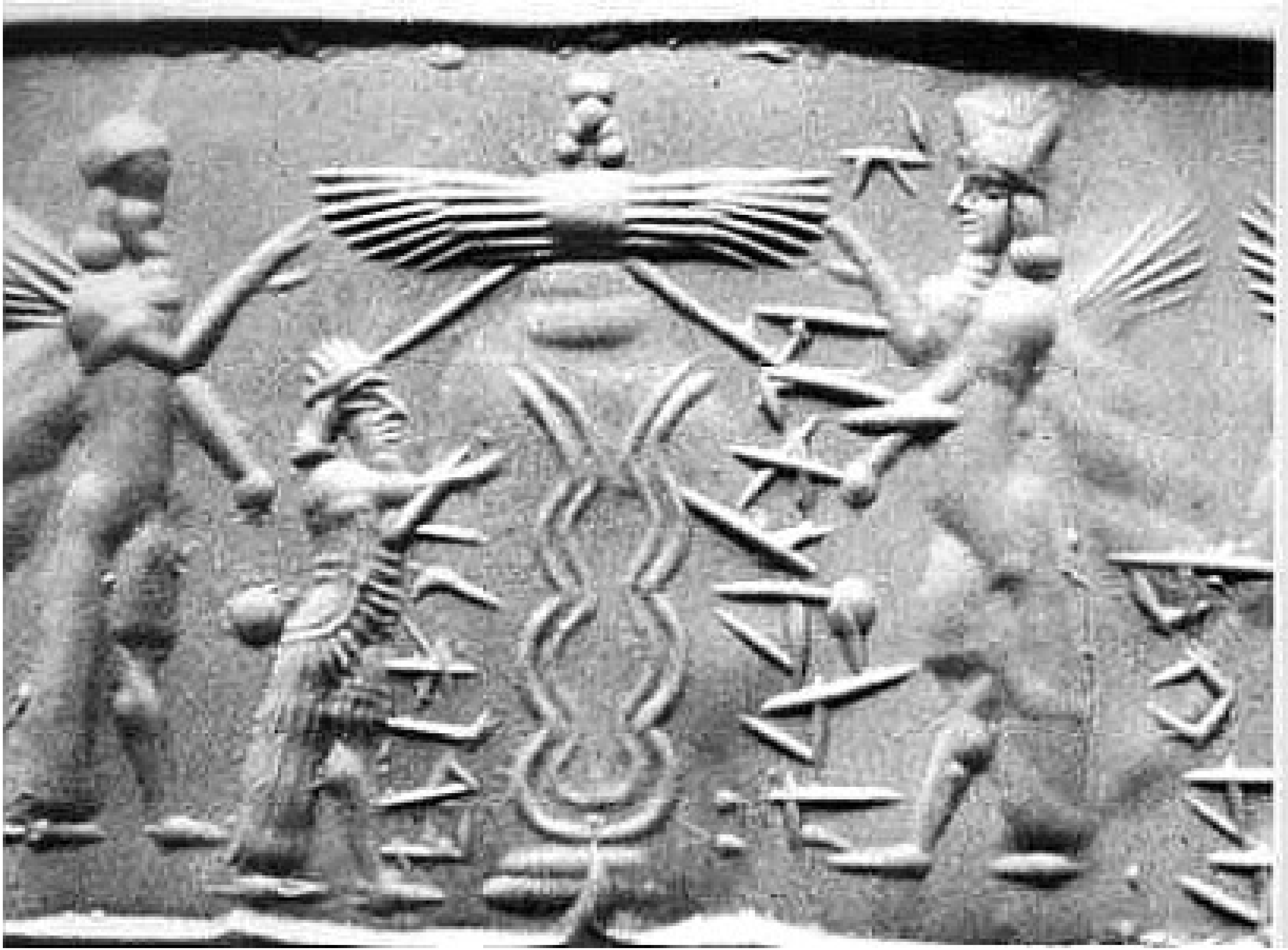

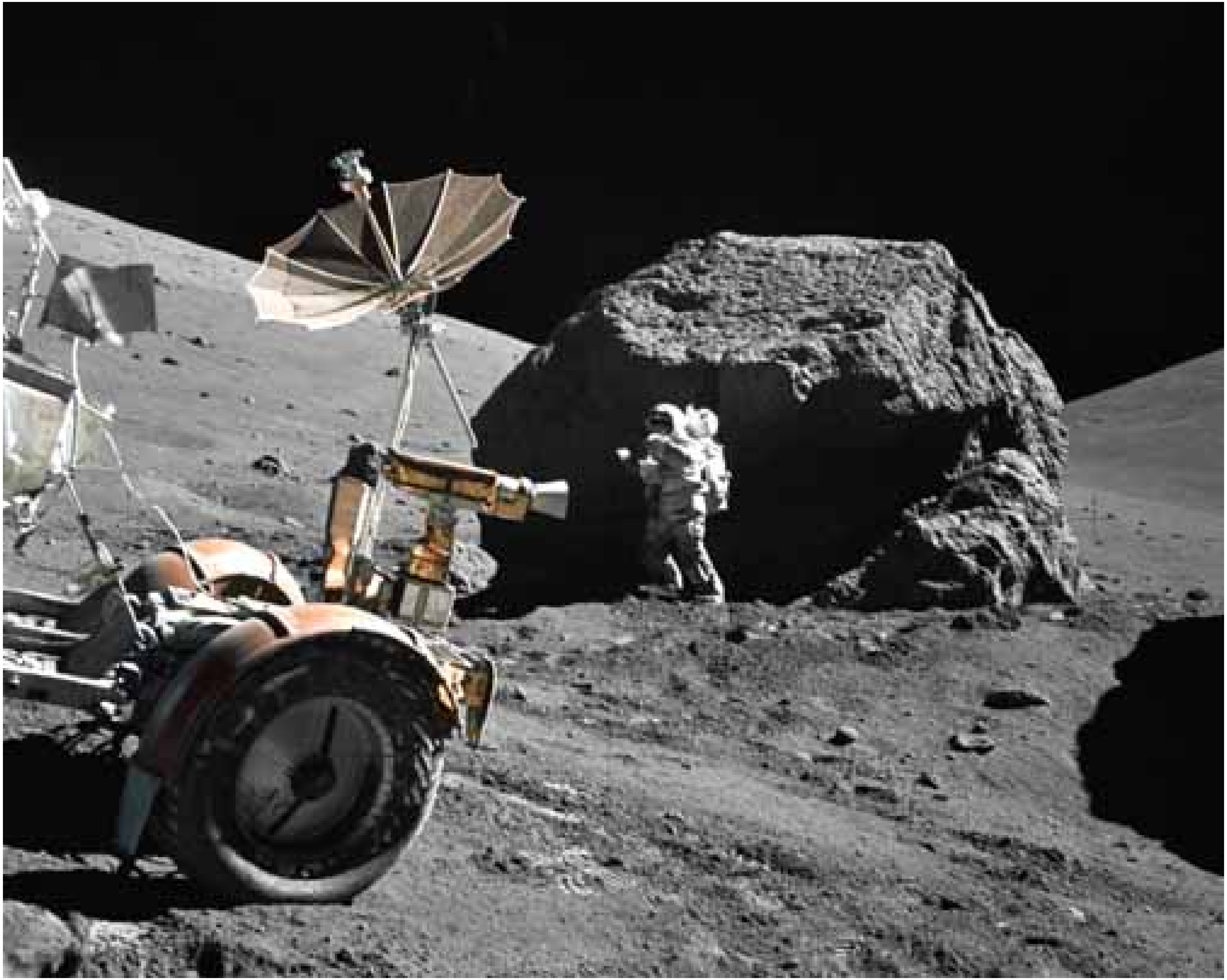

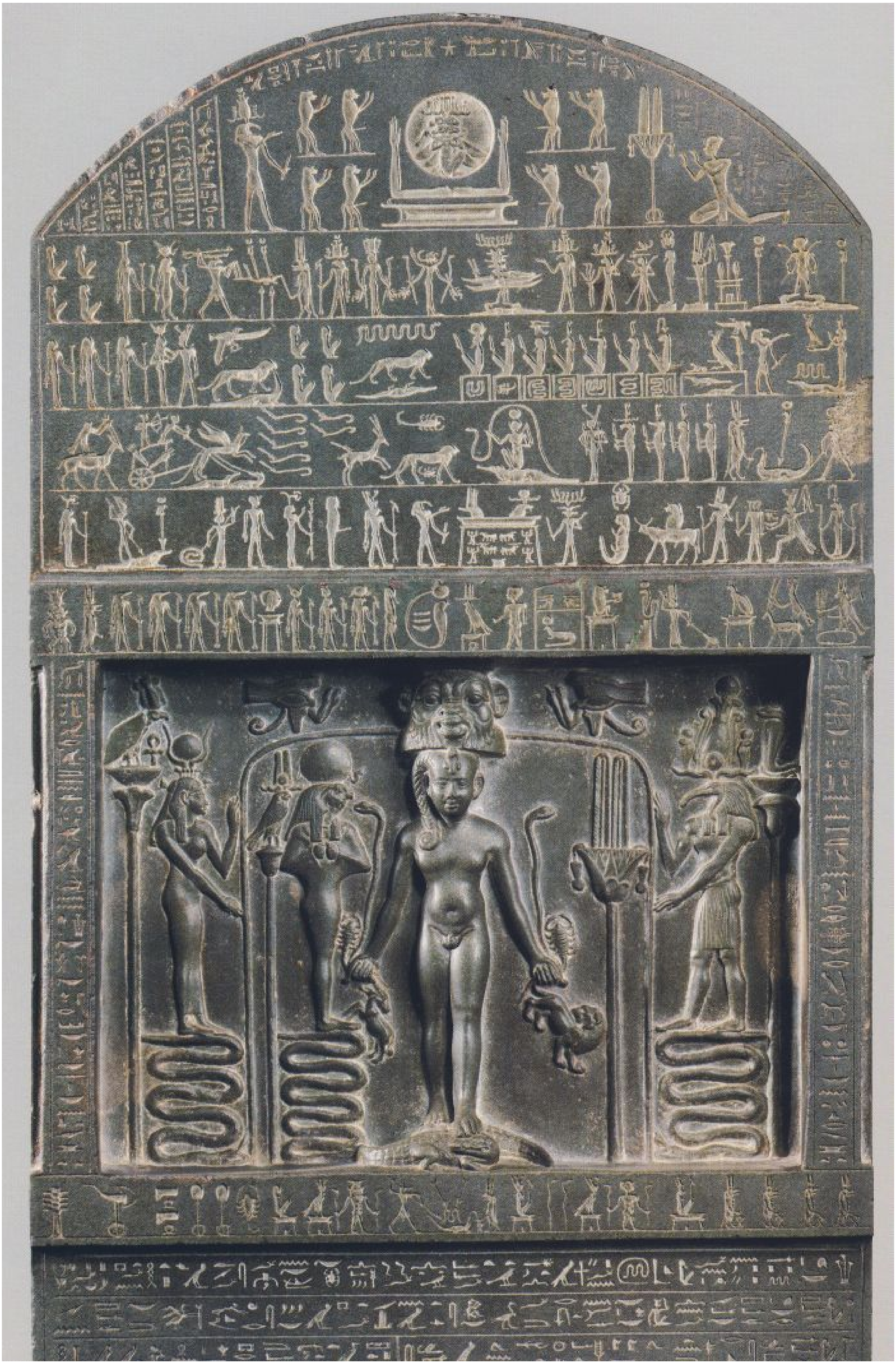

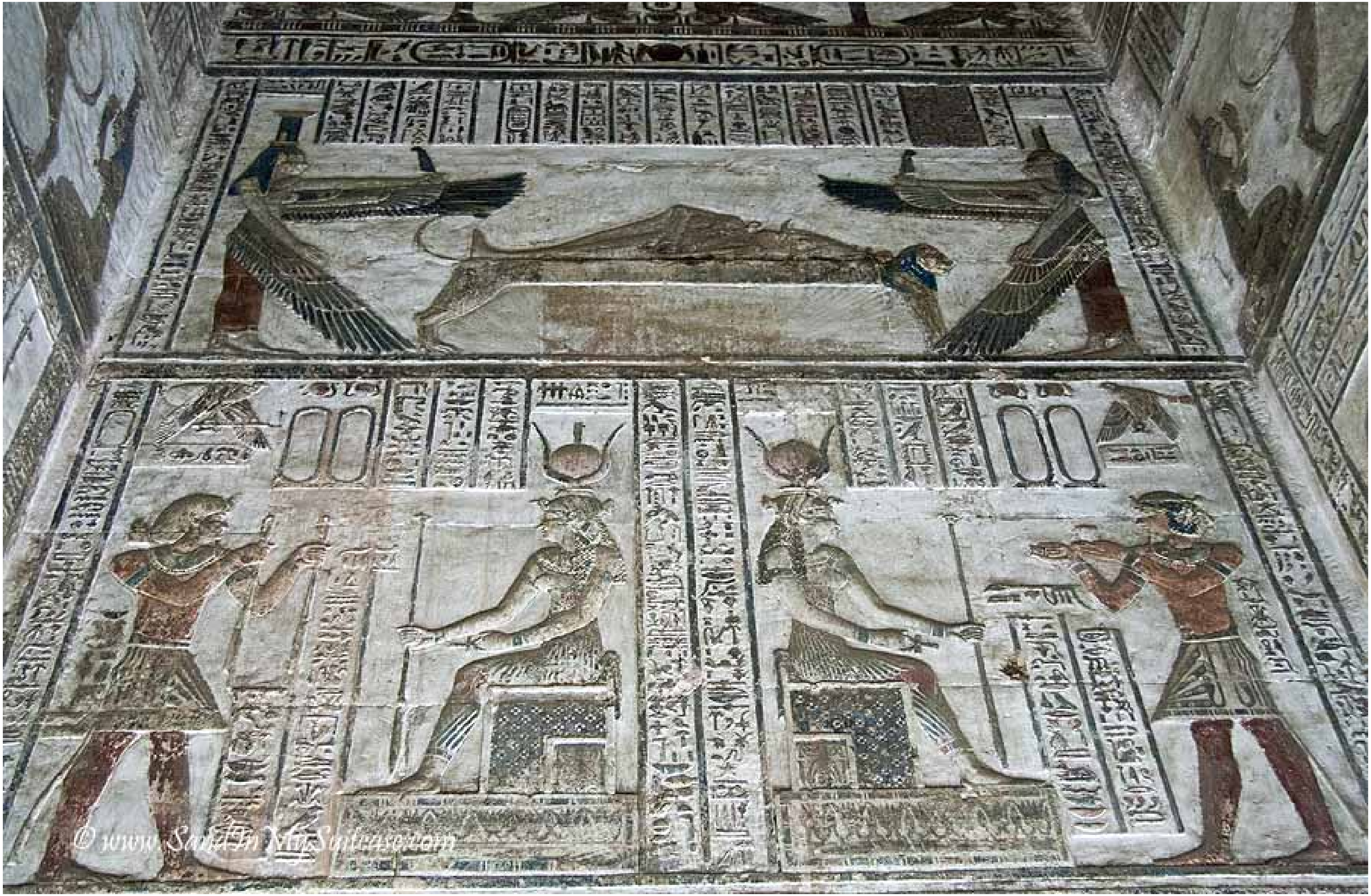

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Battery-powered searchlights and filament lamps in the crypts of the Temple of Hathor (Isis) at Denderah

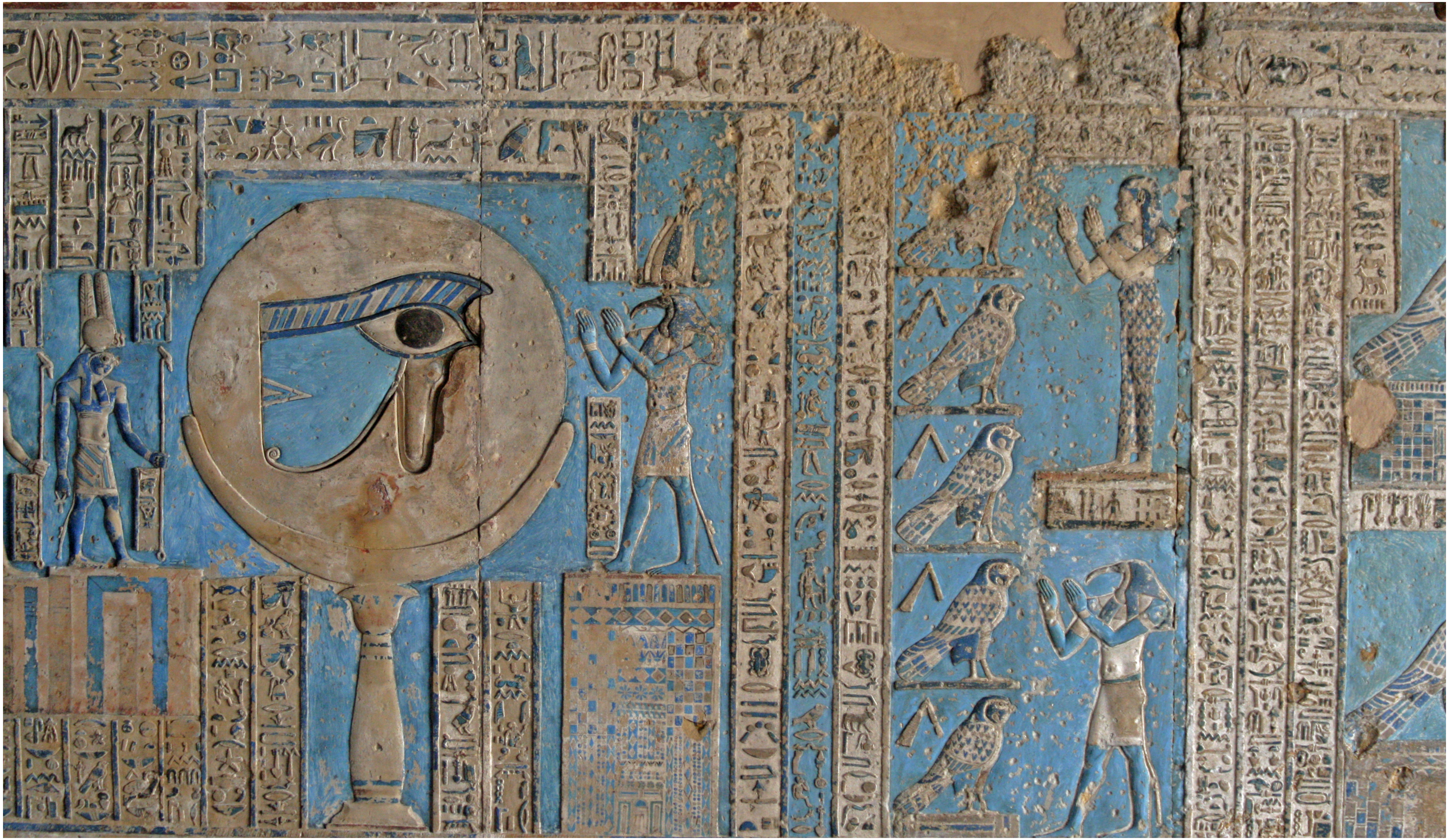

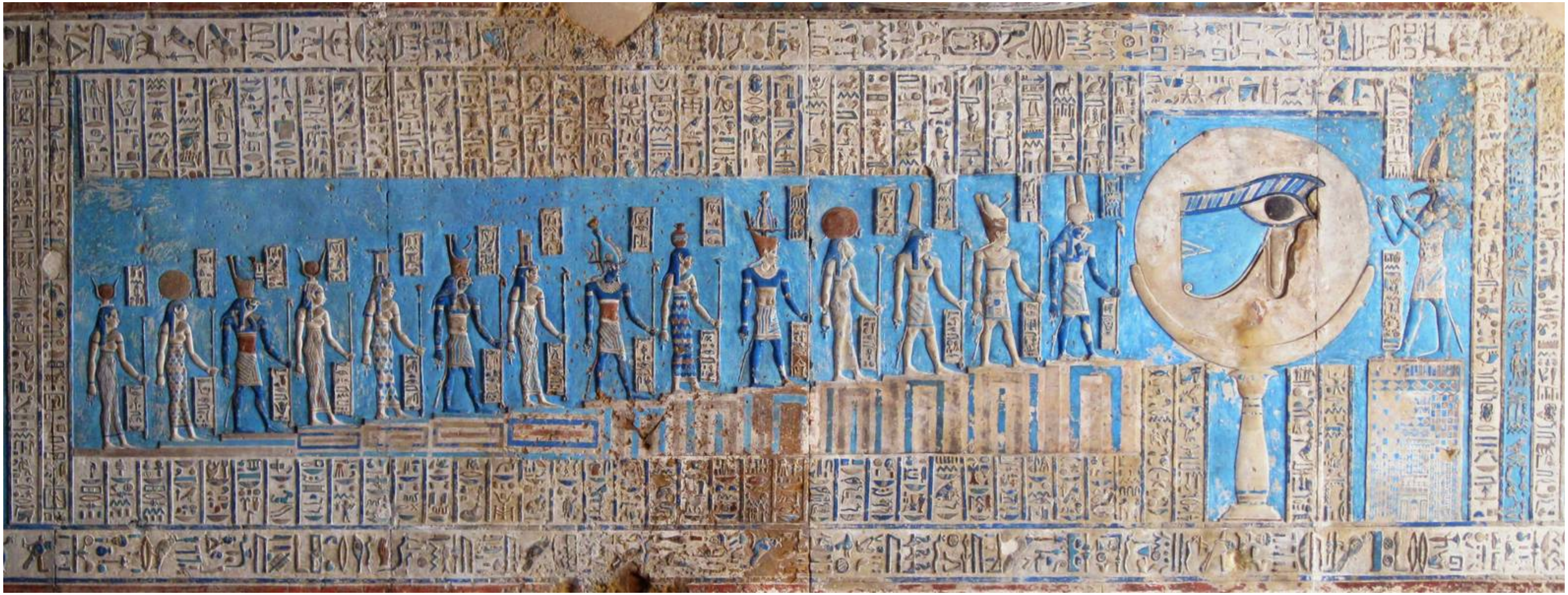

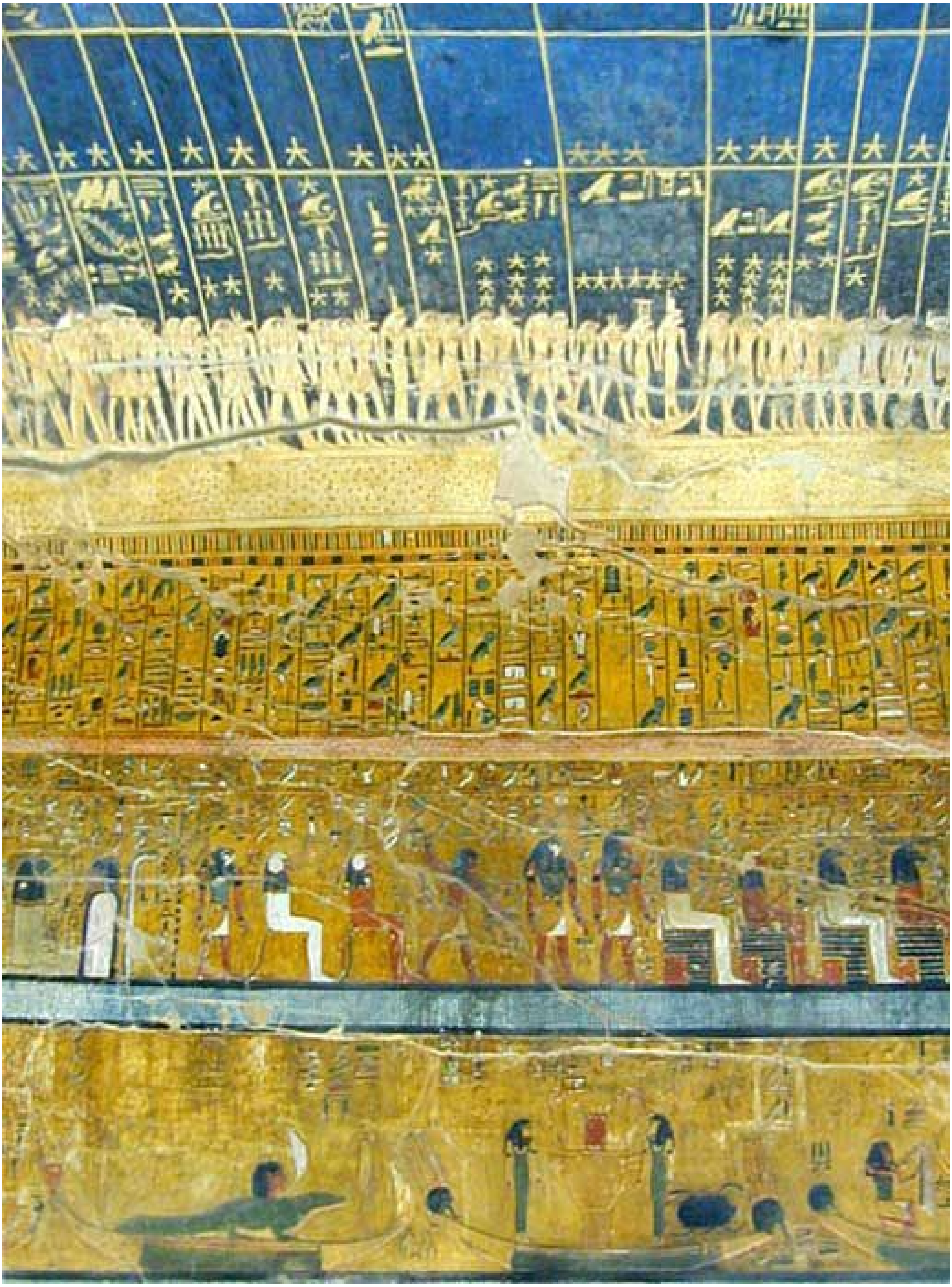

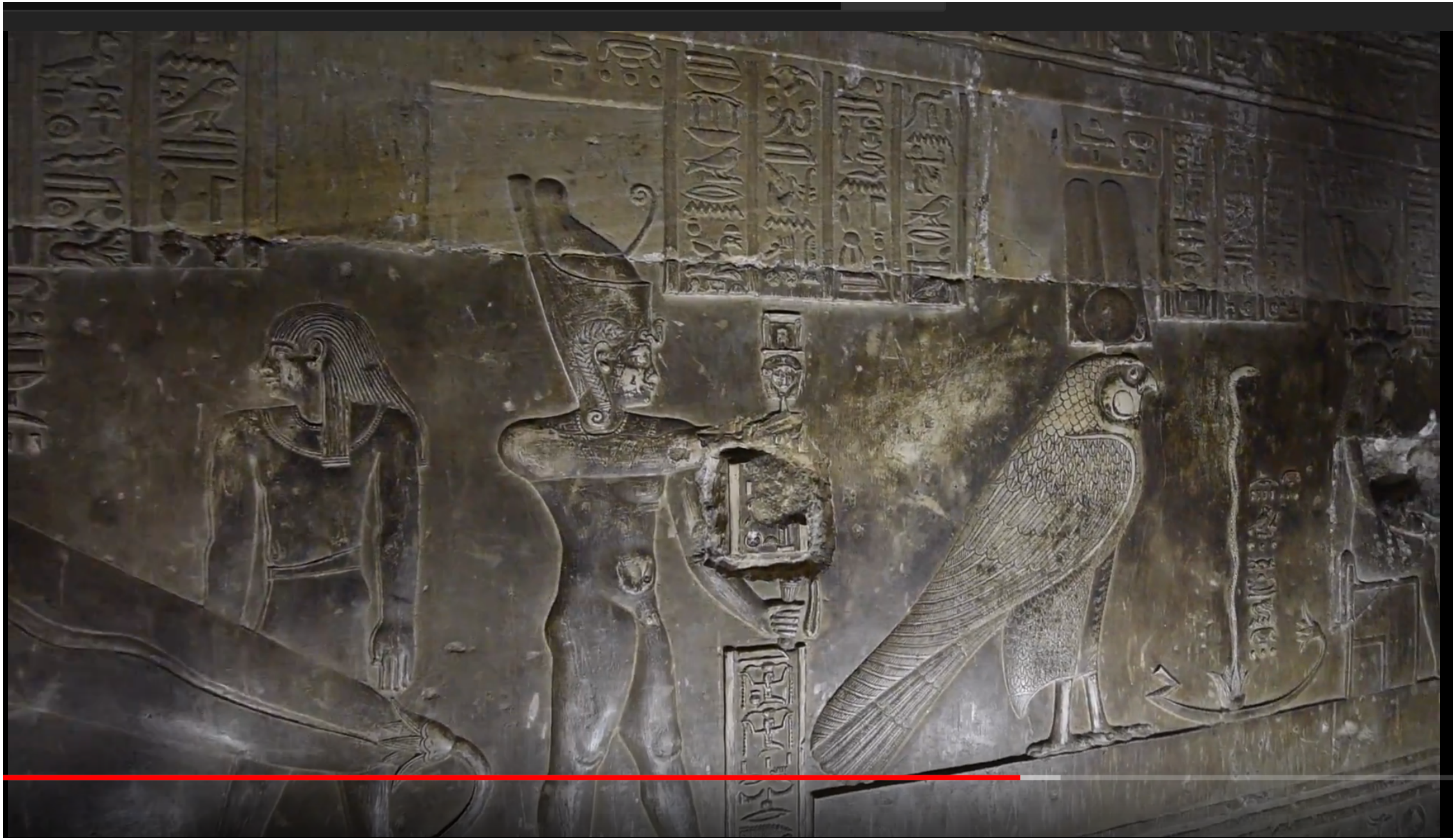

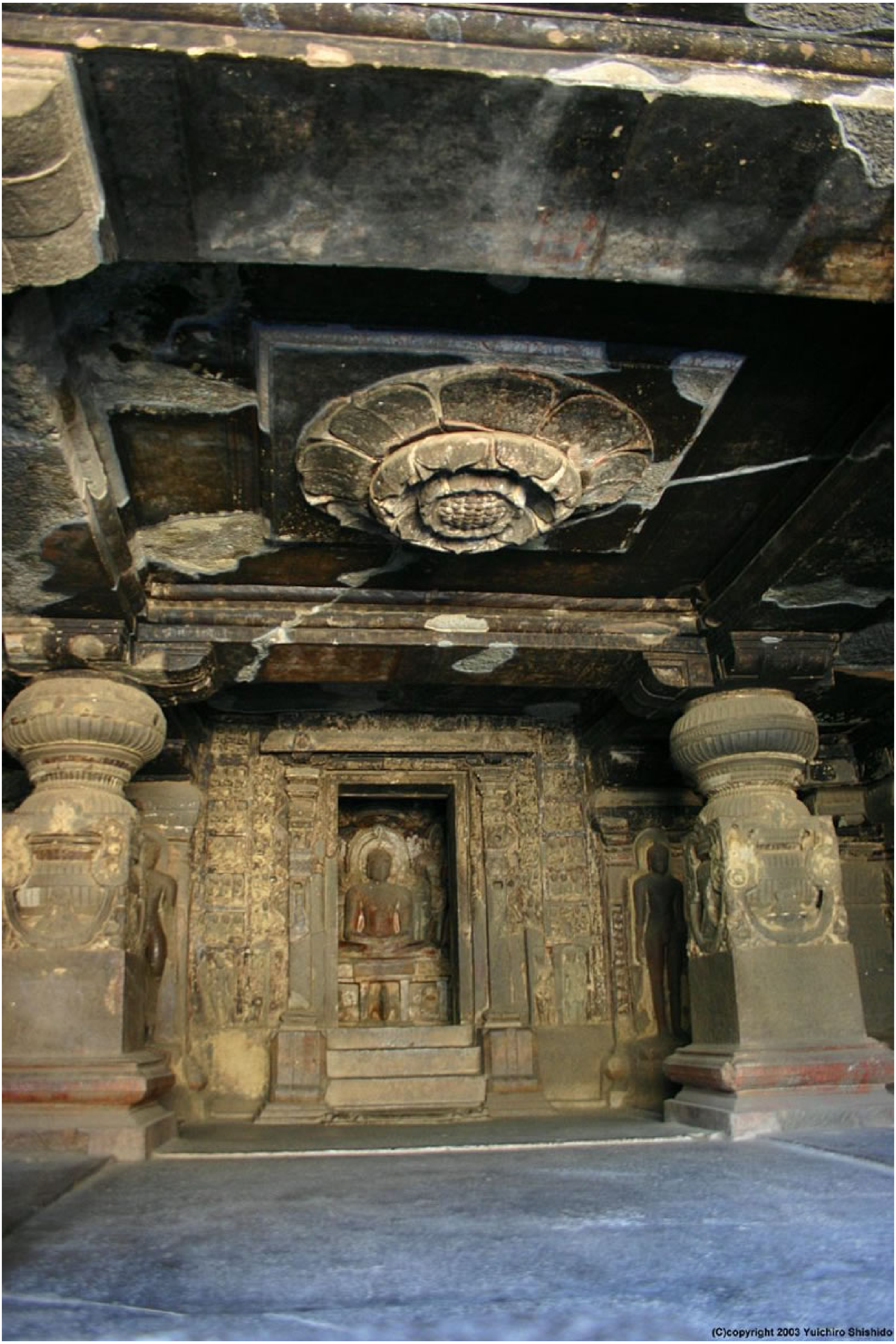

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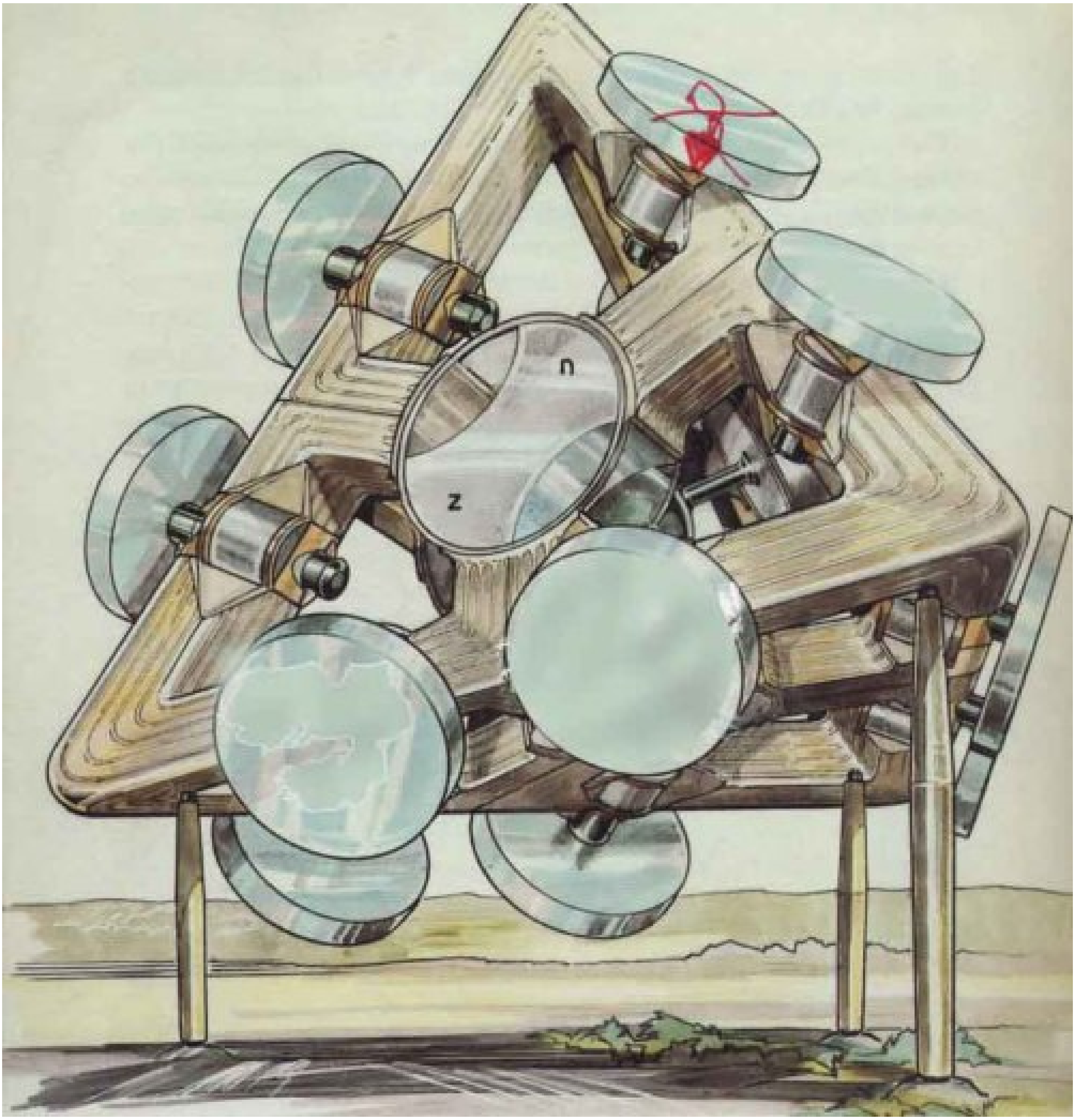
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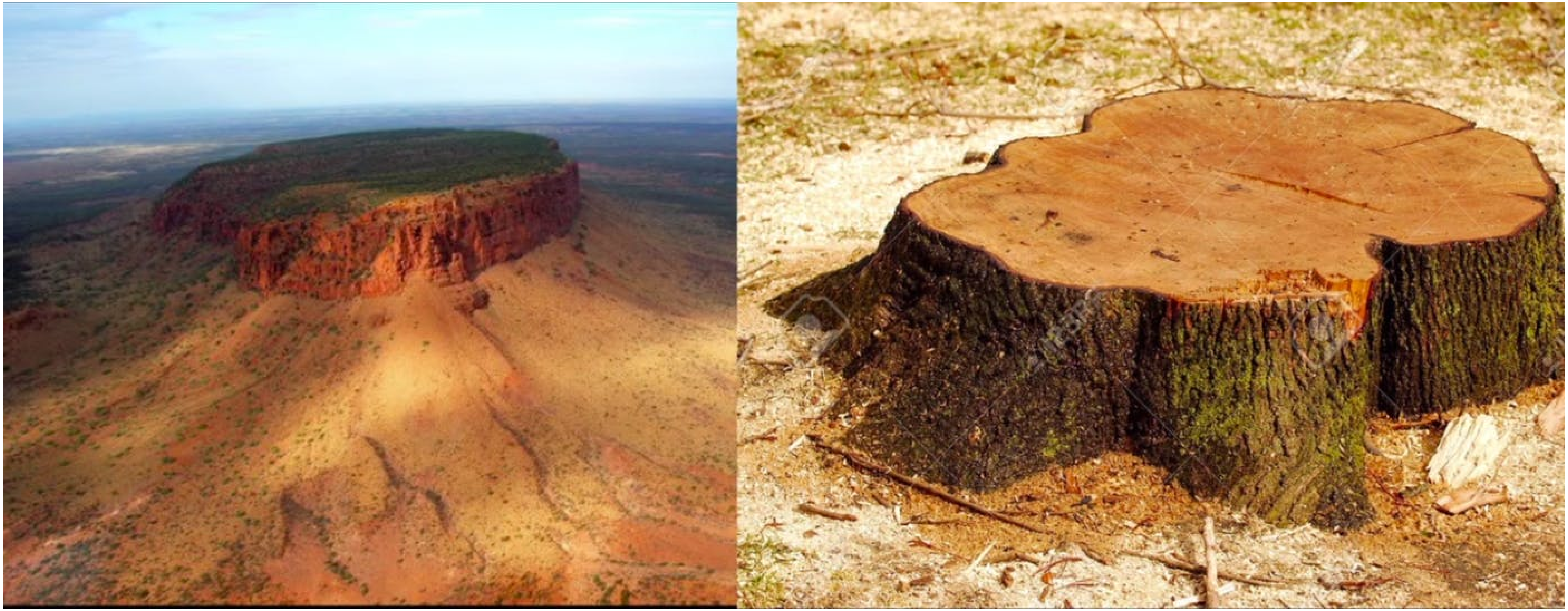

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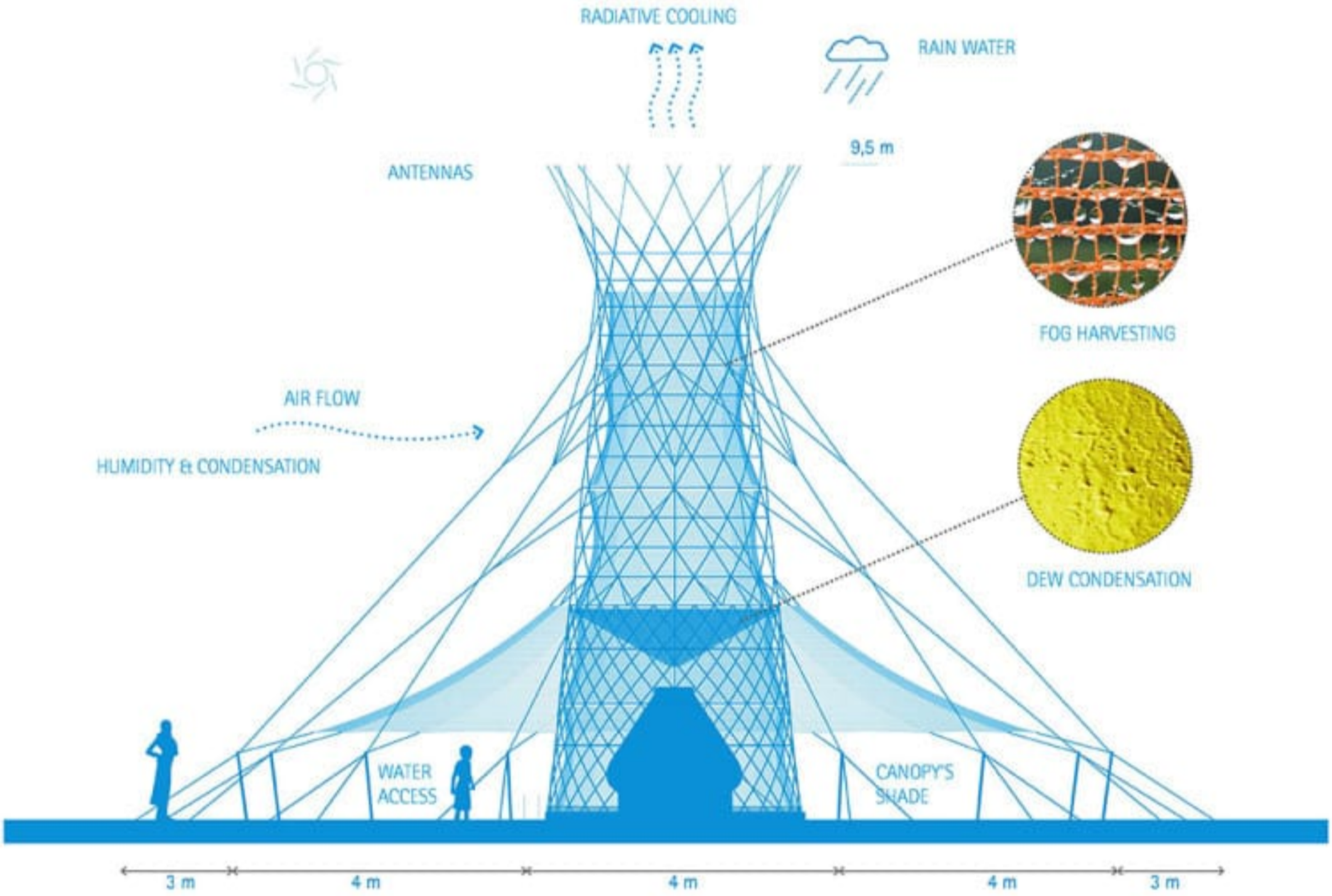
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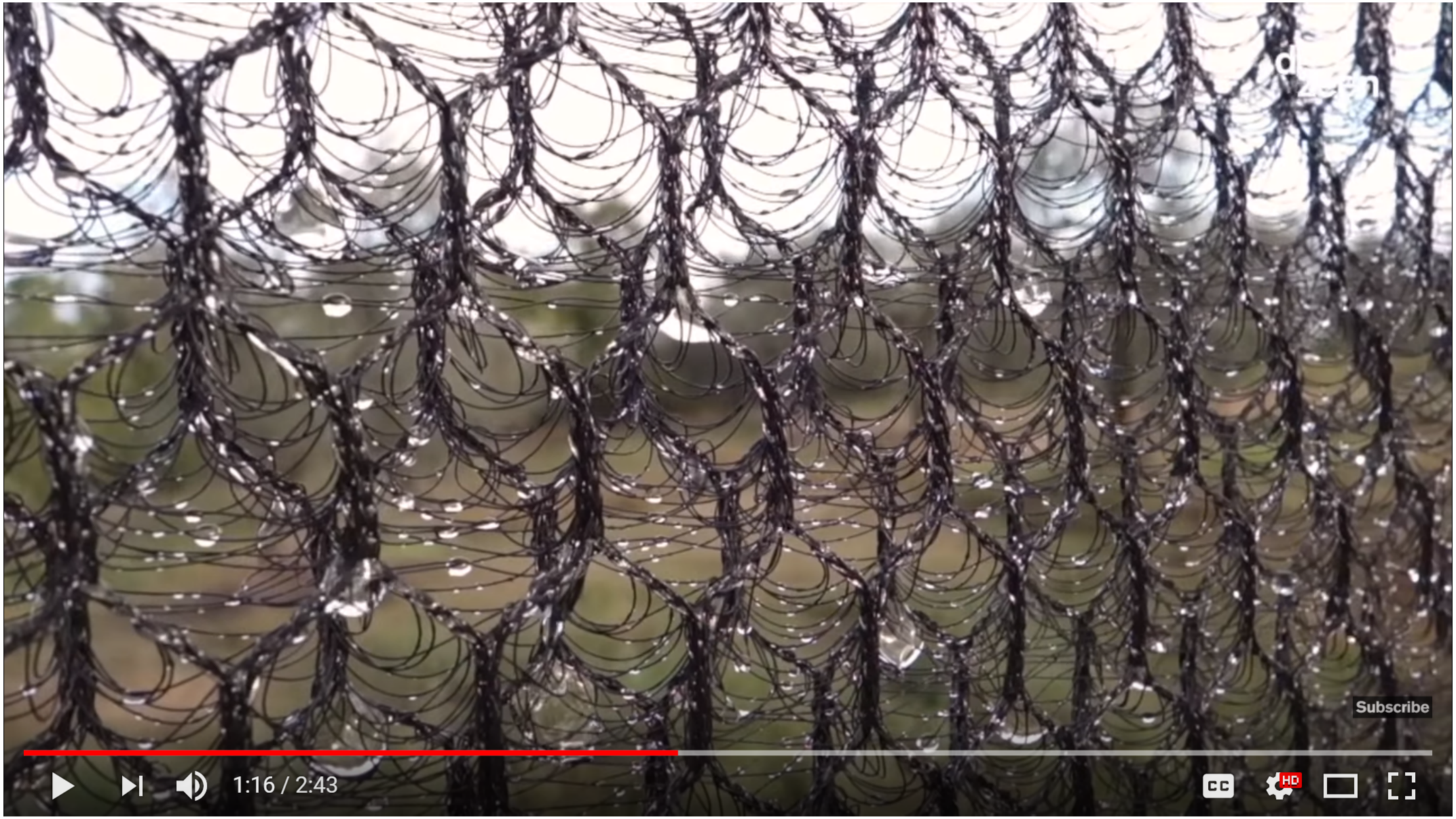
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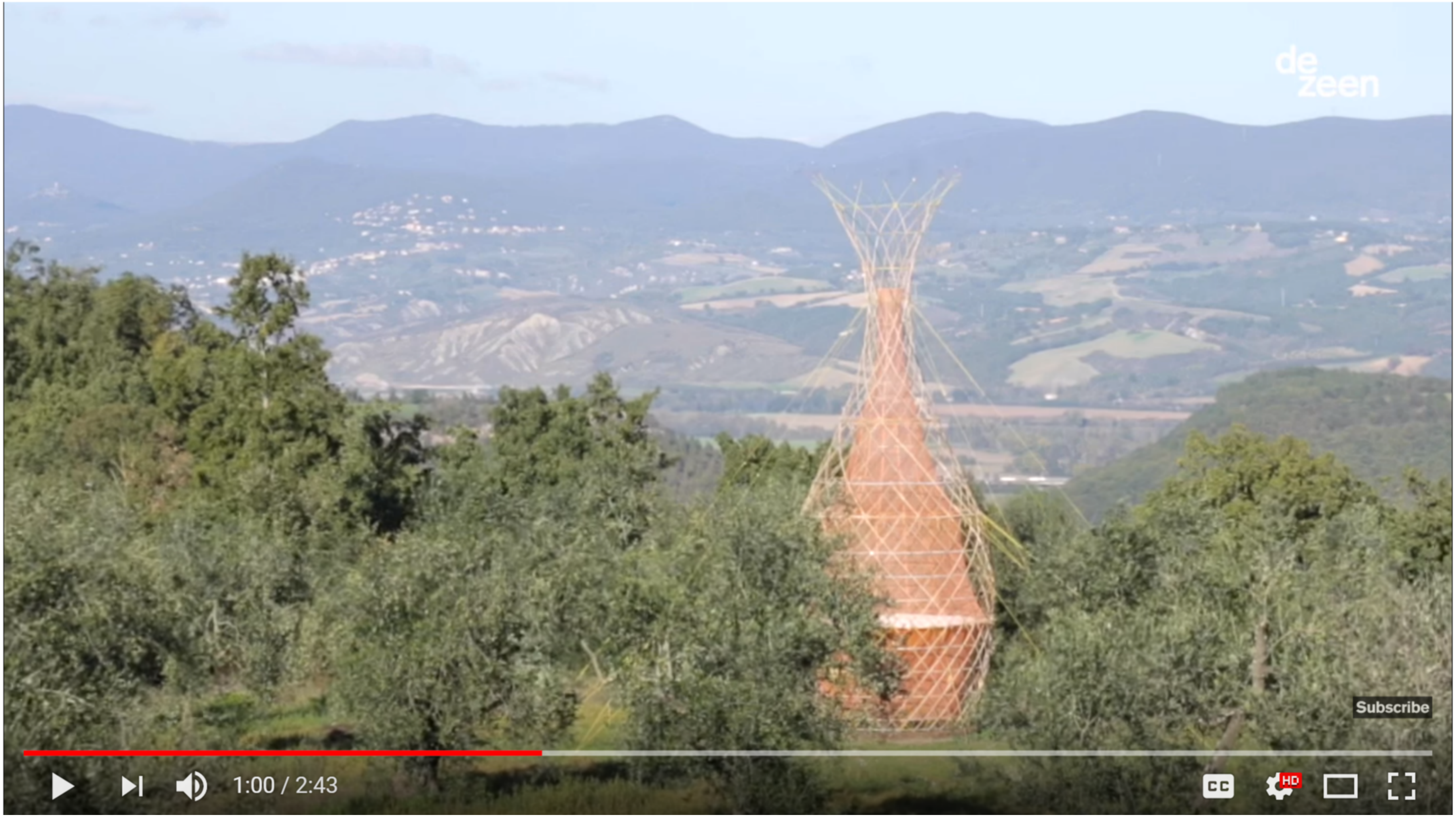
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How to build a Don Croft ORGONITE CLOUD BUSTER

Refer to (Part 1 - 2) How to Make an Orgonite CloudBuster:
http://www.youtube.com/watch?v=cCn1DO2Rj6k

Materials List:

Wear safety gear as necessary
- respirator, gloves when pouring resin.
- gloves & goggles when cutting wood - with a respirator if cutting MDF etc.

- 4 x 10' lengths of copper (or other) pipe (cut 3 lengths in half, and one length into six 1' pieces)
- 6 pipe endcaps and 6 pipe connectors
- 2 gallon bucket (polypropylene if possible)
- 10 double terminated quartz (6 of these must fit into garden hose for insertion into base of pipes)
- 6 pieces of garden hose (3/4" - 1" long)
- Resin and metal suitable for orgonite
- A roll of tape (duct tape etc)
- Glue (silicone glue will work)
- Stick for mixing metal into resin when pouring layers
- Top, middle (temporary) and bottom spacers cut and drilled out of wood. If not buying readymade, use templates or measure with copmass, ruler, pencil.
  Drill the holes with 1 1/8" and 1 1/4" wood drill bits, and cut into shape with a Jigsaw.

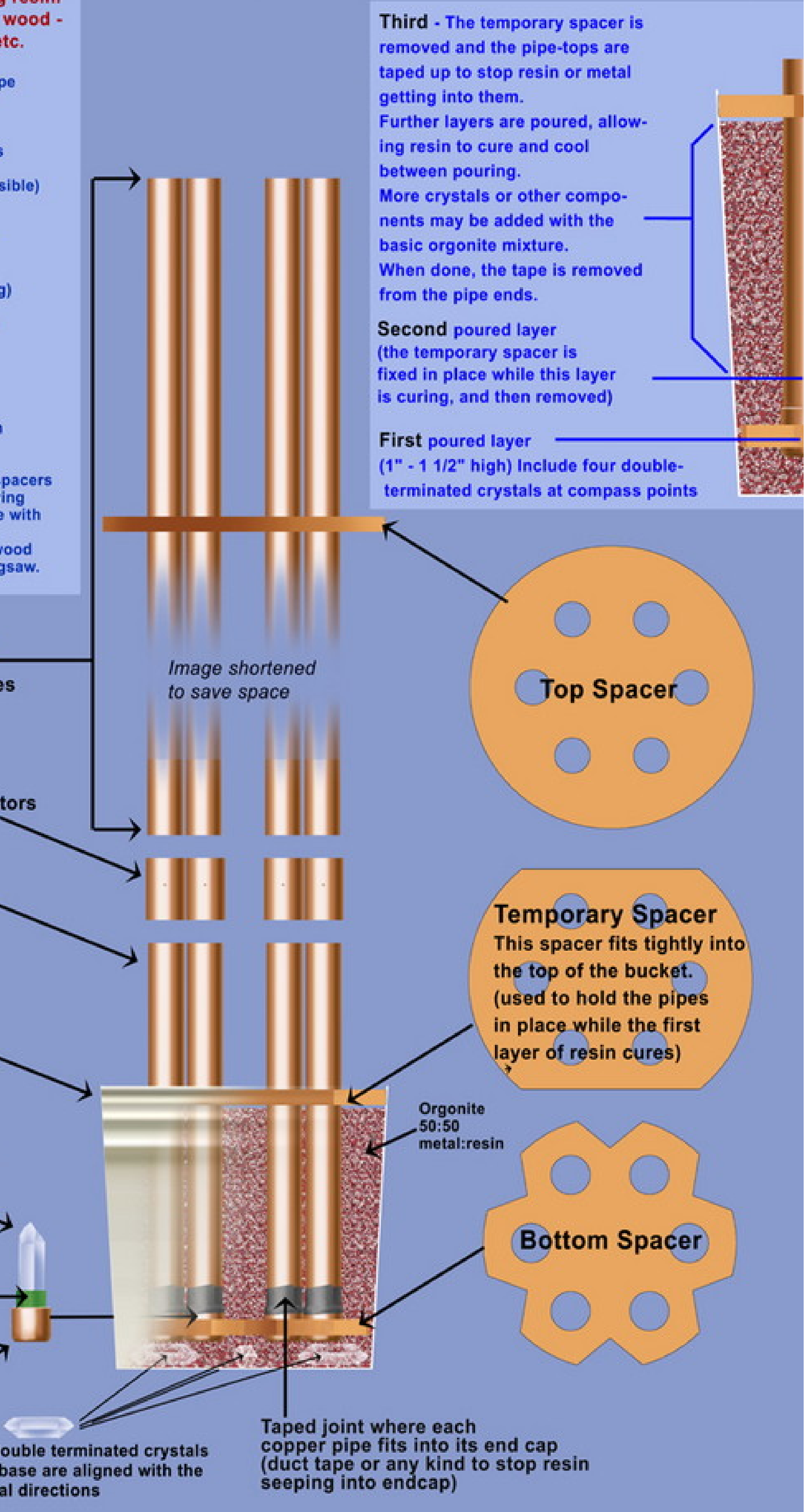

Third - The temporary spacer is removed and the pipe-tops are taped up to stop resin or metal getting into them.
Further layers are poured, allowing resin to cure and cool between pouring.
More crystals or other components may be added with the basic orgonite mixture.
When done, the tape is removed from the pipe ends.

Second poured layer
(the temporary spacer is fixed in place while this layer is curing, and then removed)

First poured layer
(1" - 1 1/2" high) Include four double-terminated crystals at compass points

Six 5' lengths of copper pipe
When the orgonite base of the cloud buster is complete, fix the top pipes to the bottom ones using pipe connectors, then fix the top spacer in place to provide stability.

Image shortened to save space

Top Spacer

Pipe connectors

Six 1' lengths of copper pipe
(1" diameter pipe)

Temporary Spacer
This spacer fits tightly into the top of the bucket. (used to hold the pipes in place while the first layer of resin cures)

2 Gallon ......plastic bucket
(8" bottom-interior diameter, 9" top interior diameter)

Orgonite
50:50
metal:resin

Double Treminated Crystal
(secured into hose with glue)

Bottom Spacer

Section of garden hose 3/4" - 1" piece (glued into end cap with silicone glue)

Copper end cap

Four double terminated crystals in the base are aligned with the cardinal directions

Taped joint where each copper pipe fits into its end cap (duct tape or any kind to stop resin seeping into endcap)

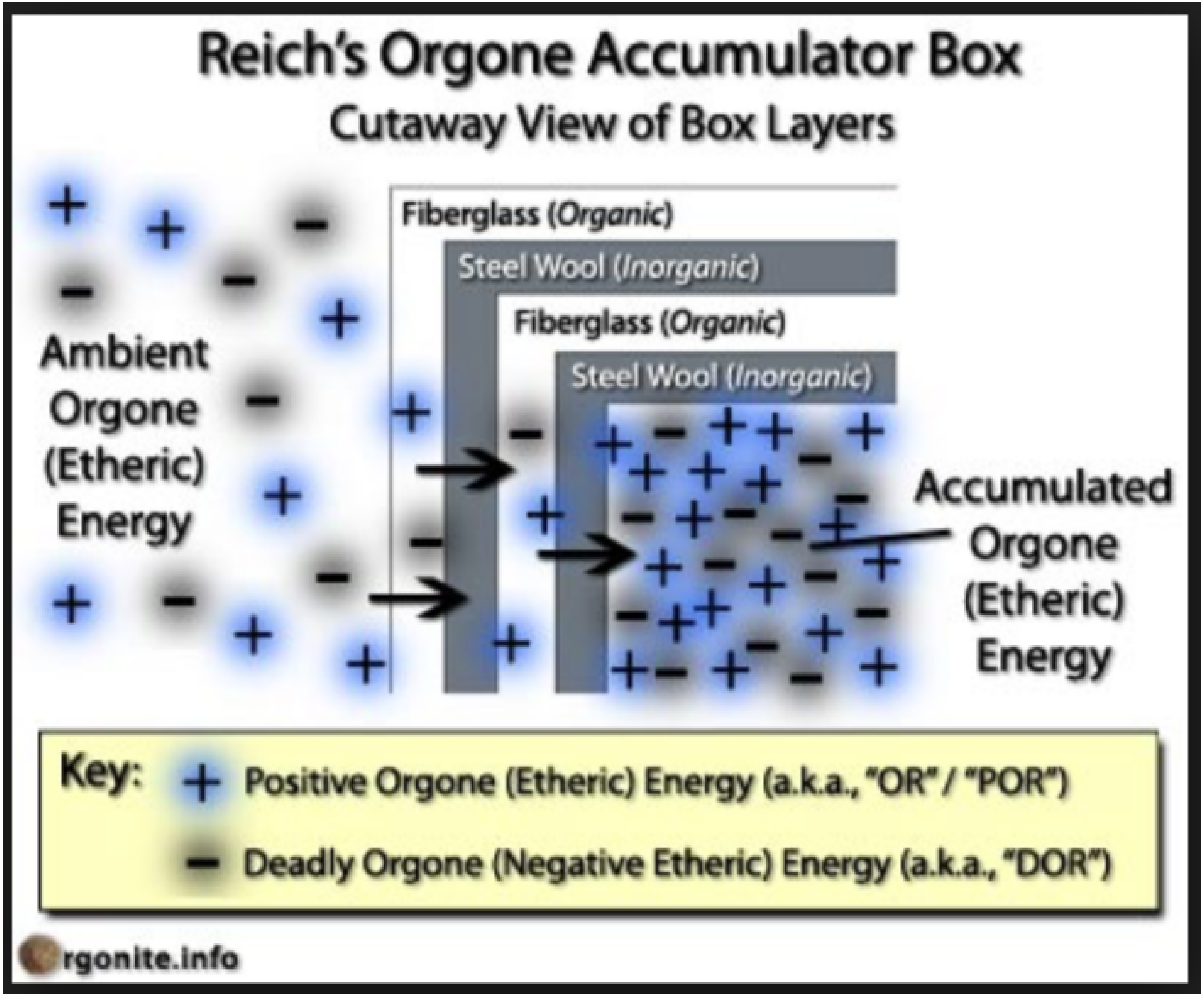
Reich's Orgone Accumulator Box
Cutaway View of Box Layers
Fiberglass (*Organic*)
Steel Wool (*Inorganic*)
Fiberglass (*Organic*)
Steel Wool (*Inorganic*)
Ambient Orgone (Etheric) Energy
Accumulated Orgone (Etheric) Energy
Key:
+ Positive Orgone (Etheric) Energy (a.k.a., "OR" / "POR")
− Deadly Orgone (Negative Etheric) Energy (a.k.a., "DOR")
rgonite.info

4

The **immortal jellyfish** (*Turritopsis dohrnii*) is capable of biological immortality.

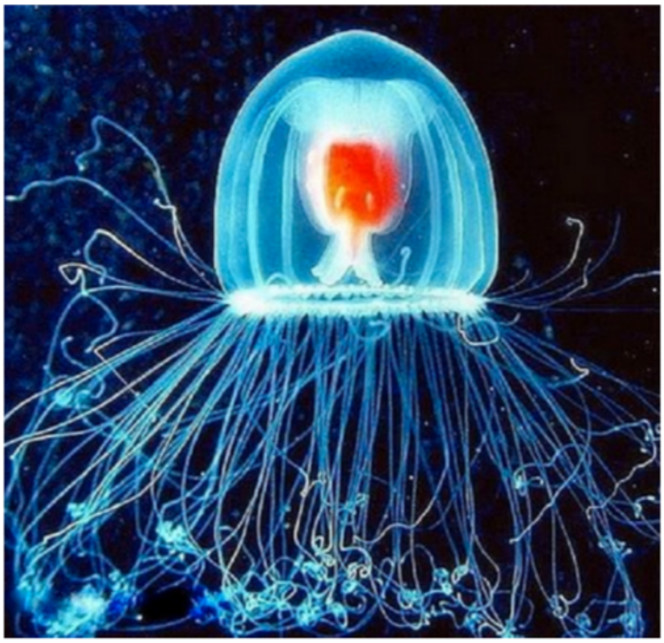

It's one of few known species capable of reverting completely to a sexually immature, colonial polyp stage after having reached sexual maturity as a solitary (free-floating) individual (called a medusa).

> Theoretically, this process can go on indefinitely, effectively rendering the jellyfish biologically immortal

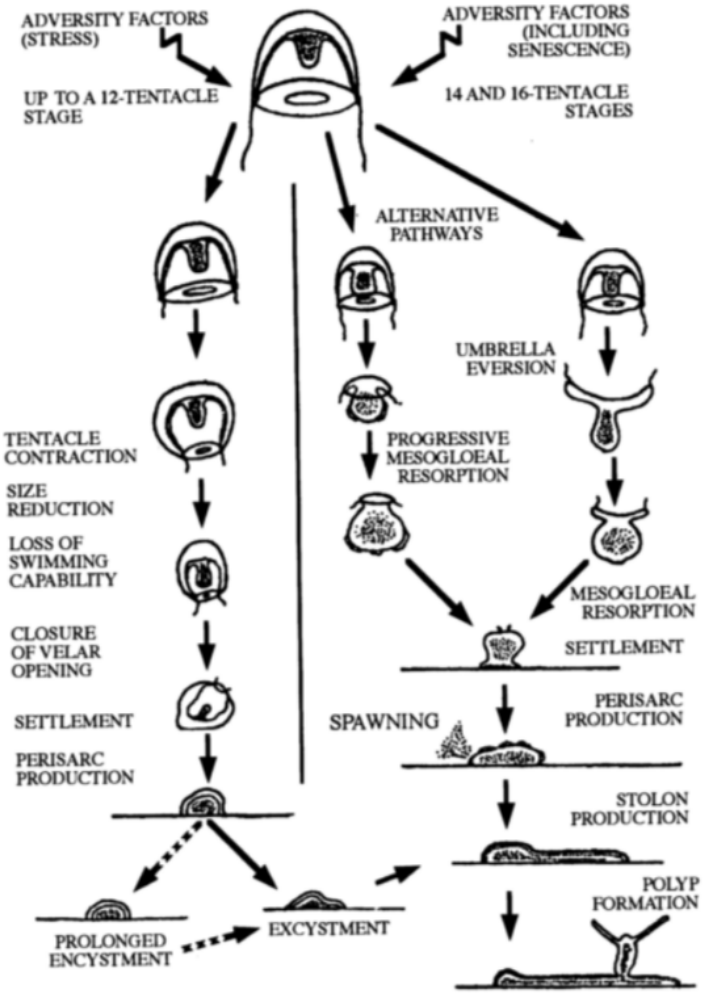
ADVERSITY FACTORS (STRESS)
UP TO A 12-TENTACLE STAGE
ADVERSITY FACTORS (INCLUDING SENESCENCE)
14 AND 16-TENTACLE STAGES
ALTERNATIVE PATHWAYS
UMBRELLA EVERSION
TENTACLE CONTRACTION
SIZE REDUCTION
LOSS OF SWIMMING CAPABILITY
CLOSURE OF VELAR OPENING
SETTLEMENT
PERISARC PRODUCTION
PROGRESSIVE MESOGLOEAL RESORPTION
MESOGLOEAL RESORPTION
SETTLEMENT
SPAWNING
PERISARC PRODUCTION
STOLON PRODUCTION
POLYP FORMATION
PROLONGED ENCYSTMENT
EXCYSTMENT

Figure 3. Pathways of transformation from medusa into polyp. Fate of stressed medusae up to 12-tentacle stage (left side), and alternative transformations of stressed or spawning medusae from a 14-tentacle or 16-tentacle stage (right side). The final product is always the polyp colony (bottom), directly or through a resting stage.

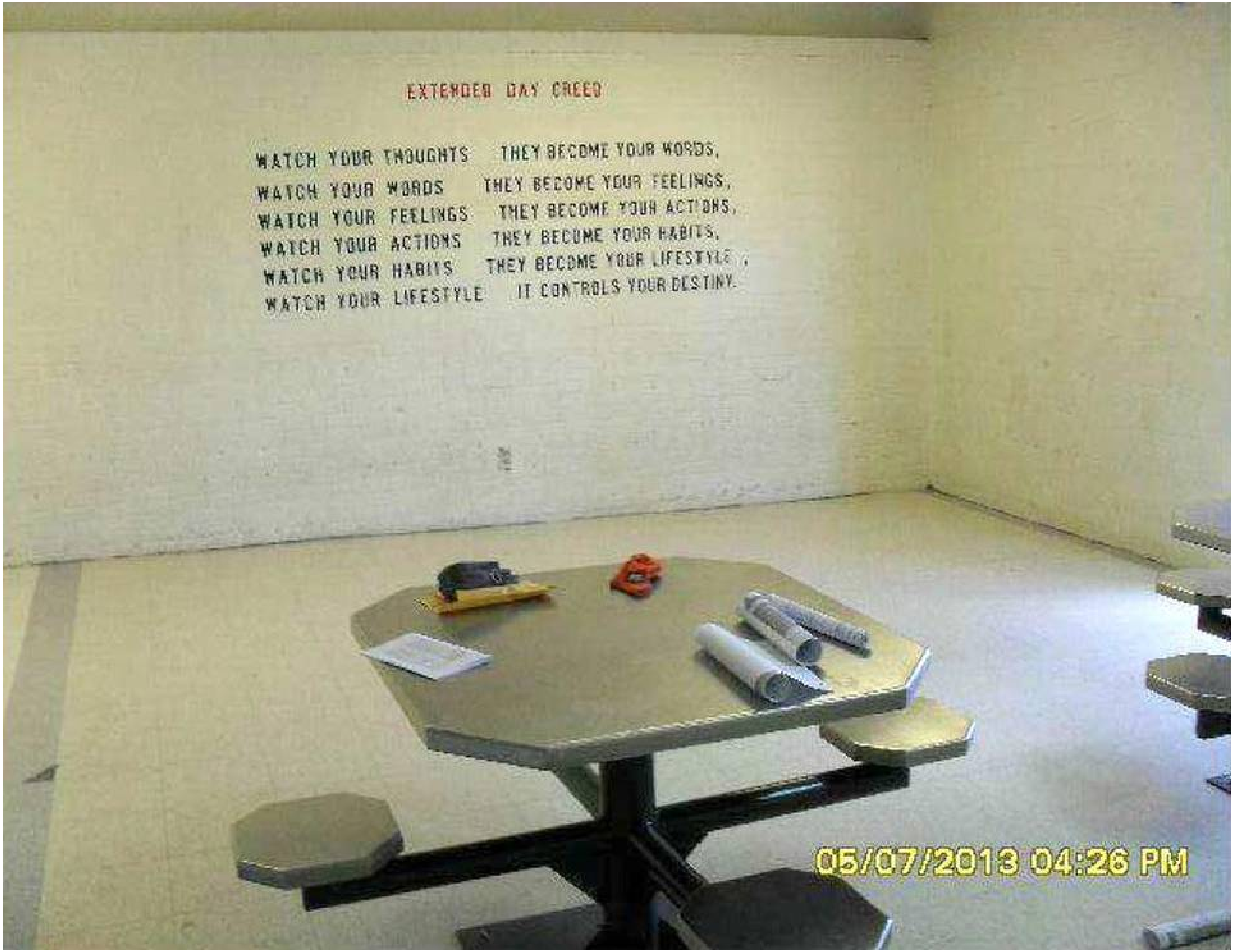
EXTENDED DAY CREED
WATCH YOUR THOUGHTS THEY BECOME YOUR WORDS,
WATCH YOUR WORDS THEY BECOME YOUR FEELINGS,
WATCH YOUR FEELINGS THEY BECOME YOUR ACTIONS,
WATCH YOUR ACTIONS THEY BECOME YOUR HABITS,
WATCH YOUR HABITS THEY BECOME YOUR LIFESTYLE,
WATCH YOUR LIFESTYLE IT CONTROLS YOUR DESTINY.

05/07/2013 04:26 PM

Capacitors we used are electrolytic rated at 400 volts x 47 uF put in series to equal 6,000 volts, the diodes we used were silicon 1000 volt 2 amp placed in series to equal 6,000 volts......... Ground was connected to laboratory wall out let ground.

If you decide to try Tesla's experiment by pumping DC into the ground be careful, I tried this and it does work but is very dangerous to you or your neighbors. If someone is taking a shower or using water they can get killed or shocked. do this experiment far away from humans and animals. you can get far more energy out than you put in. I will not tell you much more because it is such a dangerous experiment.

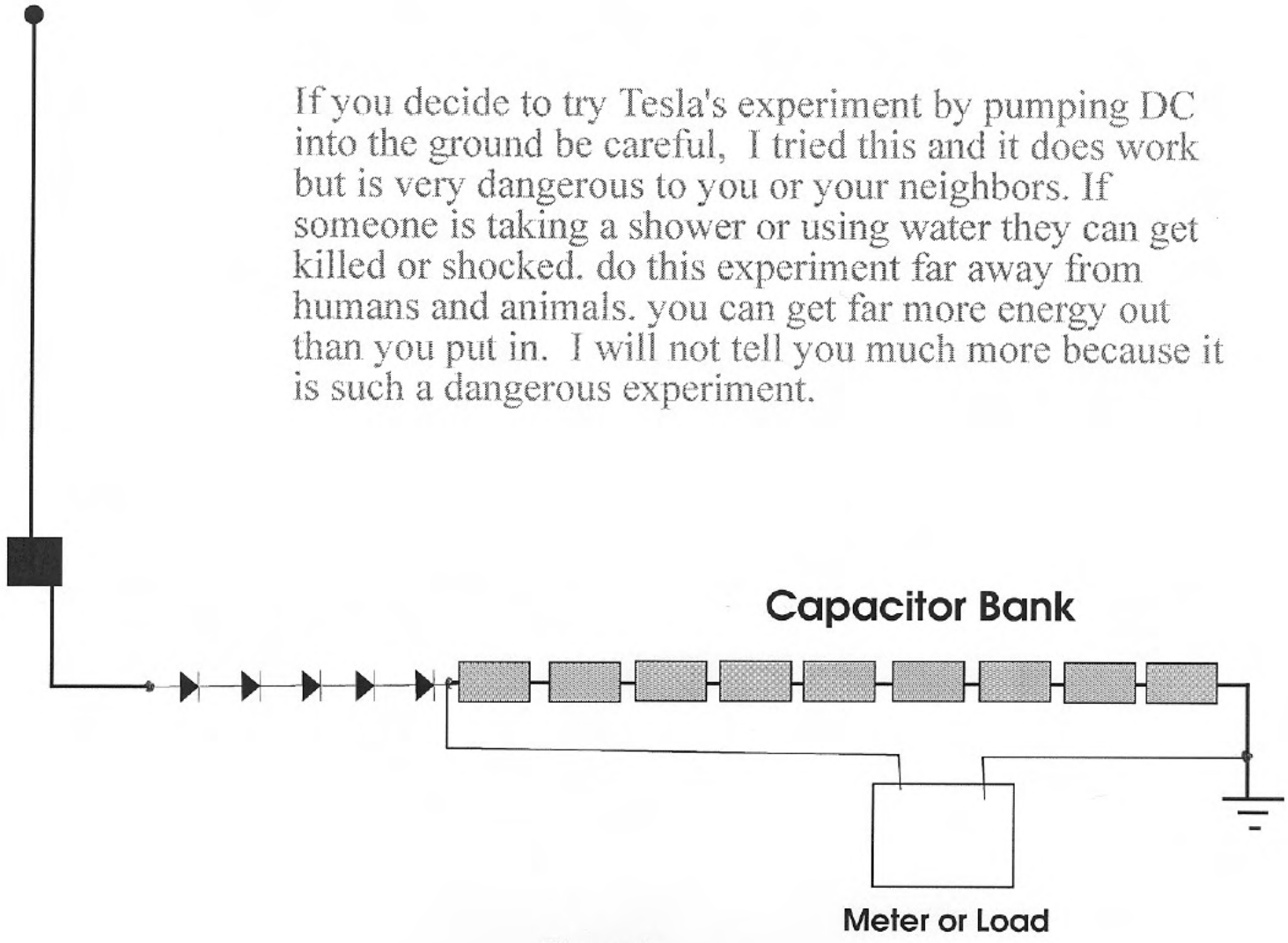

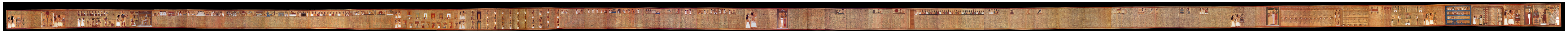

An idle telephone line tempts designers to use its 48V potential as a power source. However, Part 68 of the US Federal Communications Commission's telecommunications regulations states that any device that connects to the phone line and is not actively communicating must present a resistance of at least 5 MΩ (**Reference 1**). To meet this requirement, a device's continuous-current drain must not exceed 10 μA. Fortunately, many devices that connect to the phone line do not require continuous power and can remain off for long intervals, awakening only for a short time before relapsing into power-off mode. Providing power for these applications from the phone line presents obvious advantages by eliminating the need for a battery or another power source and the cost of battery maintenance.

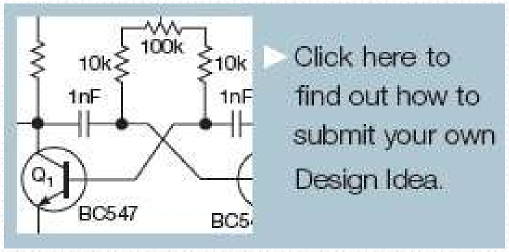
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The circuit in **Figure 1** charges a 1.5F supercapacitor, C_1, from the phone line through a diode bridge and a 5.6-MΩ resistor. A **Maxim MAX917** nanopower comparator, IC_1, consumes only 0.75 μA from its power supply. Resistors R_2 and R_3 halve the voltage across C_1 and apply it to IC_1's positive input voltage at Pin 3 for comparison with its built-in 1.245V reference. For voltages across C_1 that do not exceed 2.49V, IC_1's output at Pin 6 remains low. When C_1's voltage reaches 2.5V, Pin 3's voltage exceeds the reference voltage, and IC_1's output goes high, turning on Q_1 and Q_2.

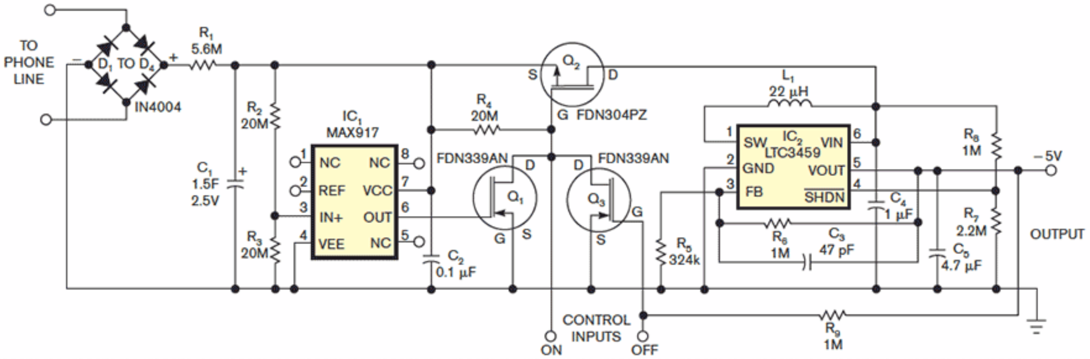
TO PHONE LINE
D1 TO D4
IN4004
R1 5.6M
R2 20M
C1 1.5F 2.5V
R3 20M
IC1 MAX917
NC
REF
IN+
VEE
NC
VCC
OUT
NC
1
2
3
4
8
7
6
5
C2 0.1 μF
R4 20M
Q2
S
D
G FDN304PZ
FDN339AN
Q1
D
G
S
FDN339AN
Q3
D
G
S
CONTROL INPUTS
ON
OFF
R5 324k
L1 22 μH
IC2 LTC3459
SW
GND
FB
VIN
VOUT
SHDN
C4 1 μF
R6 1M
C3 47 pF
C5 4.7 μF
R8 1M
R7 2.2M
R9 1M
–5V
OUTPUT

Figure 1 This power-conversion circuit delivers intermittent bursts of regulated voltage from a supercapacitor charged by a trickle of current from a telephone line.

Several days must elapse before C_1 becomes fully charged, given its huge capacitance and a charging current of less than 10 μA. The voltage on C_1 can never exceed 2.5V because, once it reaches 2.49V, Q_1 and Q_2 turn on, connecting C_1 to a switched-mode-power-supply circuit. Because the power-supply current exceeds the charging current, the voltage across C_1 starts to decrease when Q_2 turns on. Transistor Q_3 holds Q_2 on when C_1's decreasing voltage causes Q_1 to turn off.

The switched-mode-power-supply circuit comprises a **Linear Technology LTC3459** micropower boost converter, IC_2, and its associated components, which deliver 5V at 10 mA. A fully charged C_1 can supply power to a 10-mA load for approximately 40 sec. With no load, the circuit can sustain its 5V output for more than 10 hours. For greater output current and shorter operating time, select another boost converter that can operate at a low input voltage.

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Mechanical switches, open-drain MOSFETs, open-collector transistors, or a microcontroller's open-drain output pins can drive two external control inputs to force the circuit on and off. Pulling the On input low forces Q_2 to turn on and deliver power from C_1 to the power converter, and pulling the Off input low turns off Q_2 and removes power from the converter. Note that the power converter's output-return line connects to the telephone line and thus should not connect to an earth ground or to grounded equipment.

Reference

1. "**Part 68**," Federal Communications Commission.

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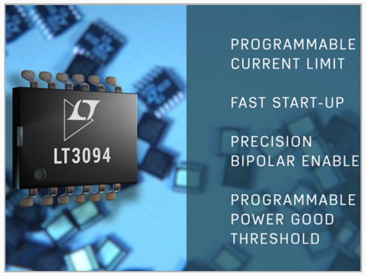
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FAST START-UP
PRECISION BIPOLAR ENABLE
PROGRAMMABLE POWER GOOD THRESHOLD

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The LT3094, a high performance low dropout negative linear regulator, features ADI's ultralow noise and ultrahigh PSRR architecture for powering noise sensitive applications. It can be paralleled to increase output current and spread heat on a PCB.

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2 Comments

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jsuparman

This is a genius idea to utilize the 'law breaking proof" methods by swallowing the tiny current from 48v with

the load resistance not less than 5MegaOhms.
Inspite of storing the energy to 2.5V 'Energy Bank" supercap 1.5F/2.5V, how if the energy bank replaced by 0.75F/5V Supercap (also the voltage limiter changed to be 5 Volts)? This one will be more practical, I think. We can simplify the whole circuit. I think.
(Jsuparman)
comet@dnet.net.id

Dec 20, 2016 9:49 AM EST

👍0 | 👎0 Reply

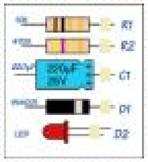

anonymous user

Excellent article giving one more practical example of using super-capacitor as intermediate (secondary) power source! Due to high charge-discharge cycling capability of the Capacitor, the solution does not produce any disposable parts during its operating lifecycle, which makes it much more environmentally friendly comparing to any one, which uses rechargeable battery (this concept is detailed in Green Electricity (GEL) Initiative, now topping Google™ search list).

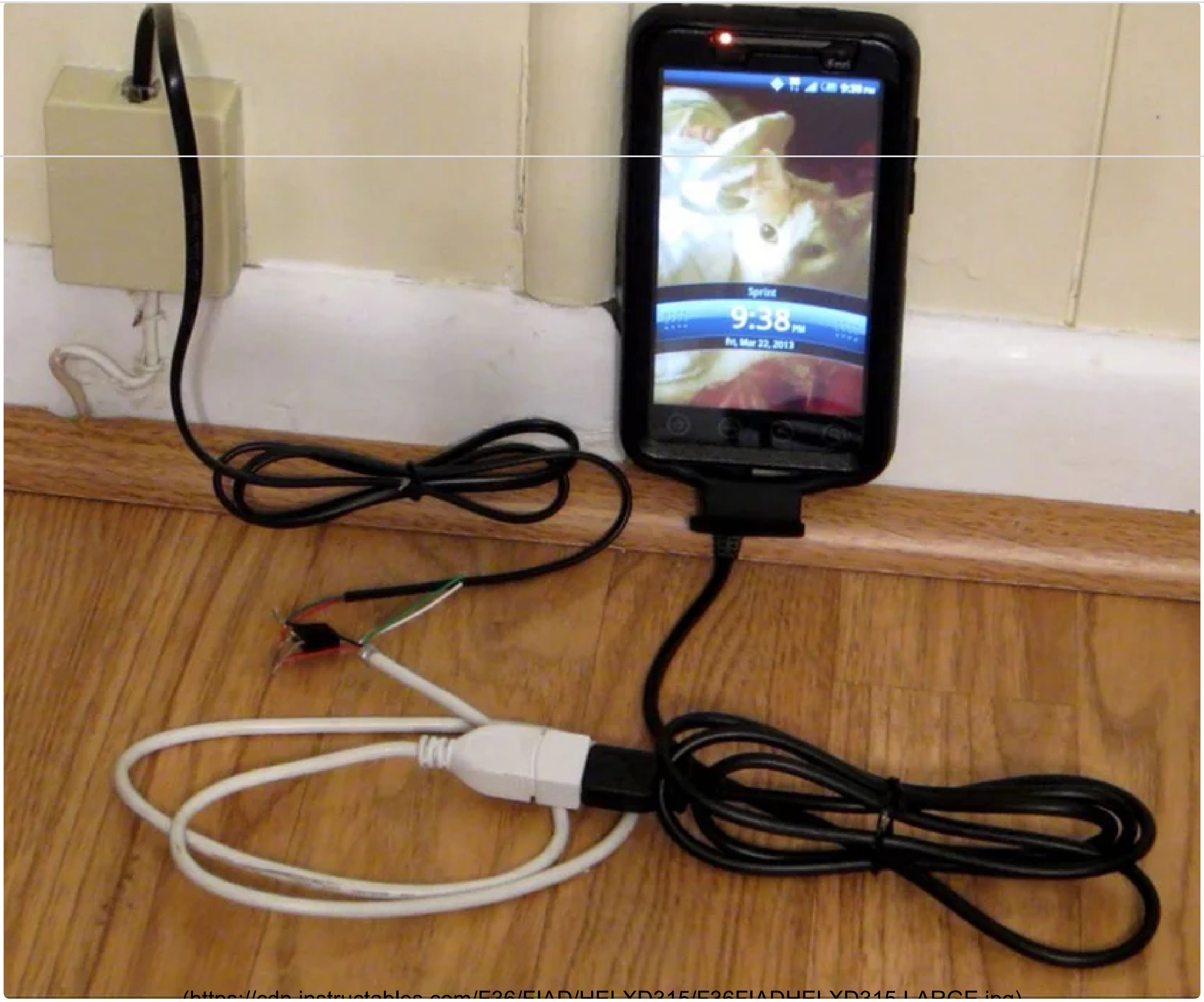

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What do you do if the power is out and you need to charge your cell phone to make an emergency phone call? Don’t worry. There are plenty of potential power sources all around you. One of them is the phone line. In this instructable, I am going to show you how you can use the phone line to power your small electronic such as your phone or other USB devices in an emergency.

Note: This project is intended for emergency situations only. Please be aware of applicable local laws regarding phone lines in your area.

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Step 1: Background Information: Power in the Phone Lines?

You may have noticed that corded phones don't need to be plugged into an electrical outlet. That is because they get all the power that they need to operate directly from the phone line itself. The phone company sends this power directly to your house through a pair of dedicated wires that connect to your phone jack. When the phone is not in use, this is a constant DC signal (about 50-60 volts). When the phone rings, the signal is a 20 hertz AC signal (about 90 volts). When in use it is a modulated DC signal (between 6 and 12 volts).

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The phones lines even have power during a blackout in most cases. This is because the phone company maintains their own backup power system. Your phone lines may be powered even if you don’t have a land line service set up.

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Step 2: Check the Phone Line With a Multimeter

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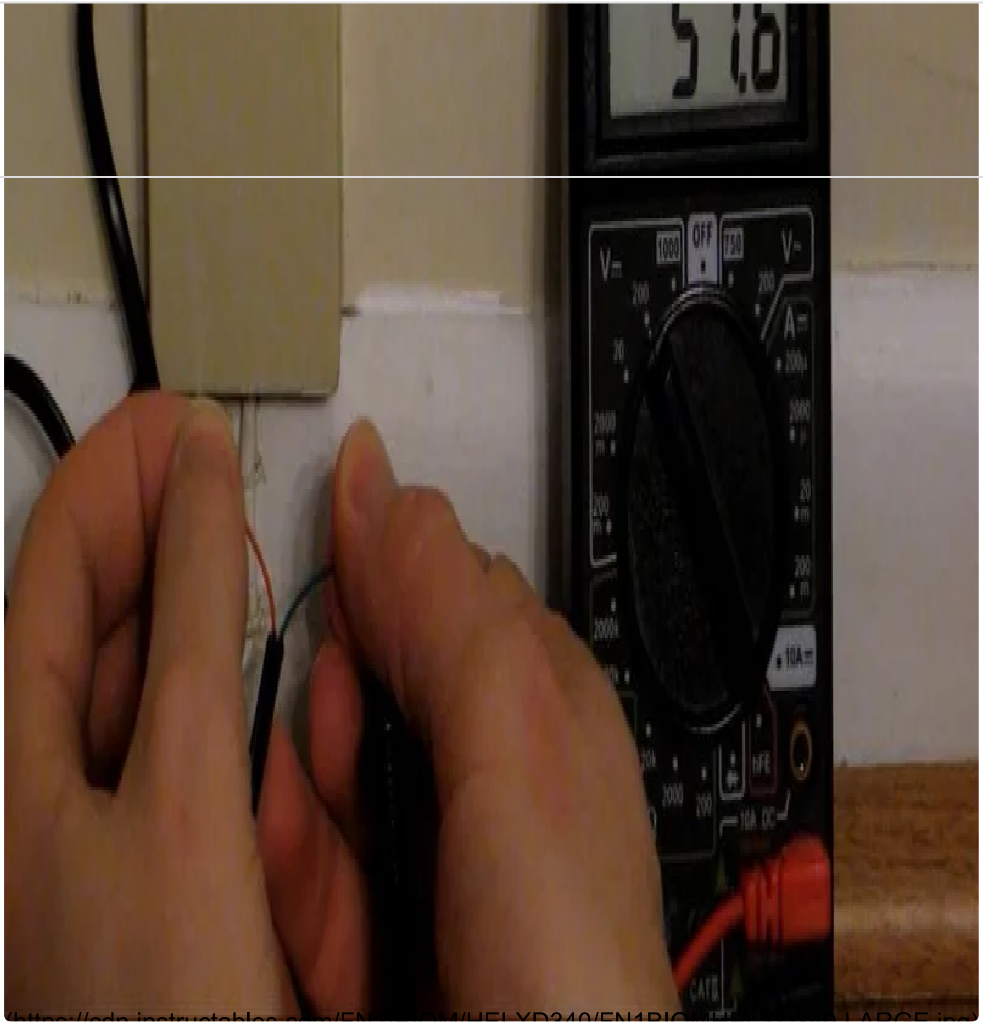

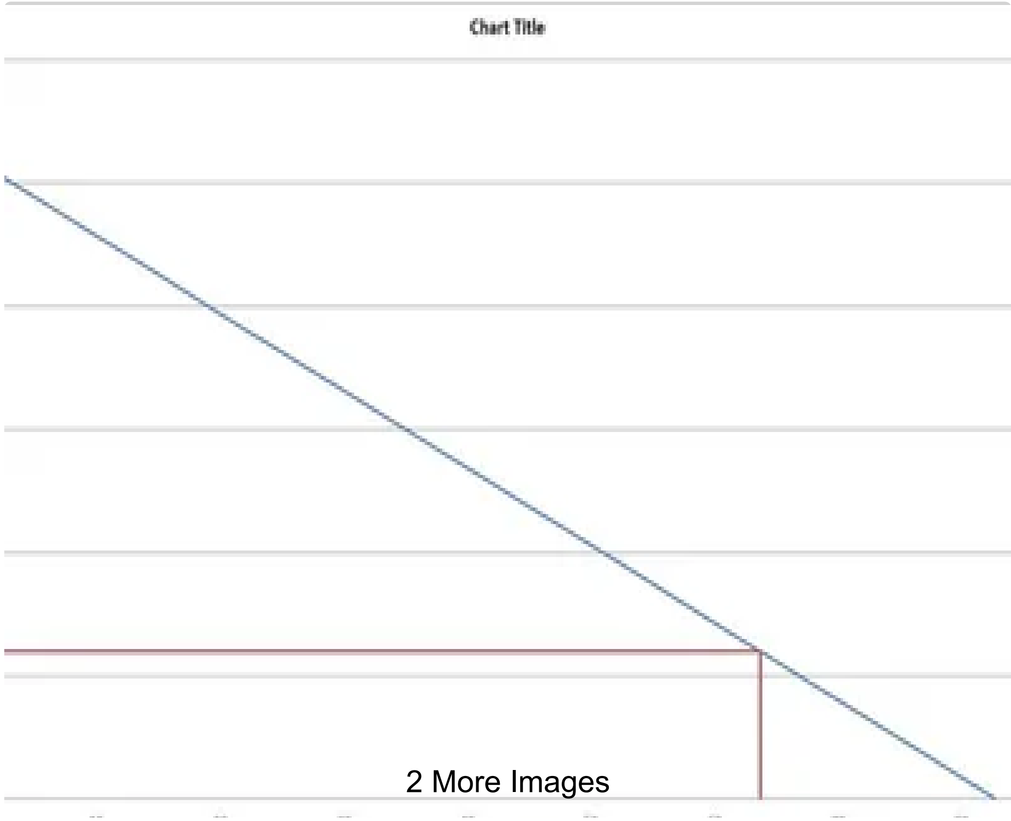

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Before you try to tap into the electricity in the phone line, you should check it with a multimeter to see what you are working with.

Start by cutting open a phone cord and separating the internal wires. In most cases you will have one red wire and one green wire. Strip the insulation off the ends. Then plug the cord into a phone jack and use a multimeter to measure the output voltage. At my house, I measured an open-circuit (no load) voltage (http://en.wikipedia.org/wiki/Open-circuit_voltage) of 52 volts DC.

Then I hooked up various resistors to see what the output would be with different loads. I determined that the supply voltage isn't regulated. This means that the voltage changes depending on the resistance of the circuit that it is powering. After some calculating, I worked out that the base signal coming out of my phone jack pretty closely resembles a 52 Volt DC source (http://en.wikipedia.org/wiki/Voltage_source) with a 628 ohm internal resistance (http://en.wikipedia.org/wiki/Internal_resistance).

Basically this means that I can run a 12V circuit at 64mA, a 9V circuit at 68mA, or a 5V circuit at 75mA. This isn't a lot. But it is enough to charge a cell phone.

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Step 3: Construct a Simple Voltage Regulator Circuit

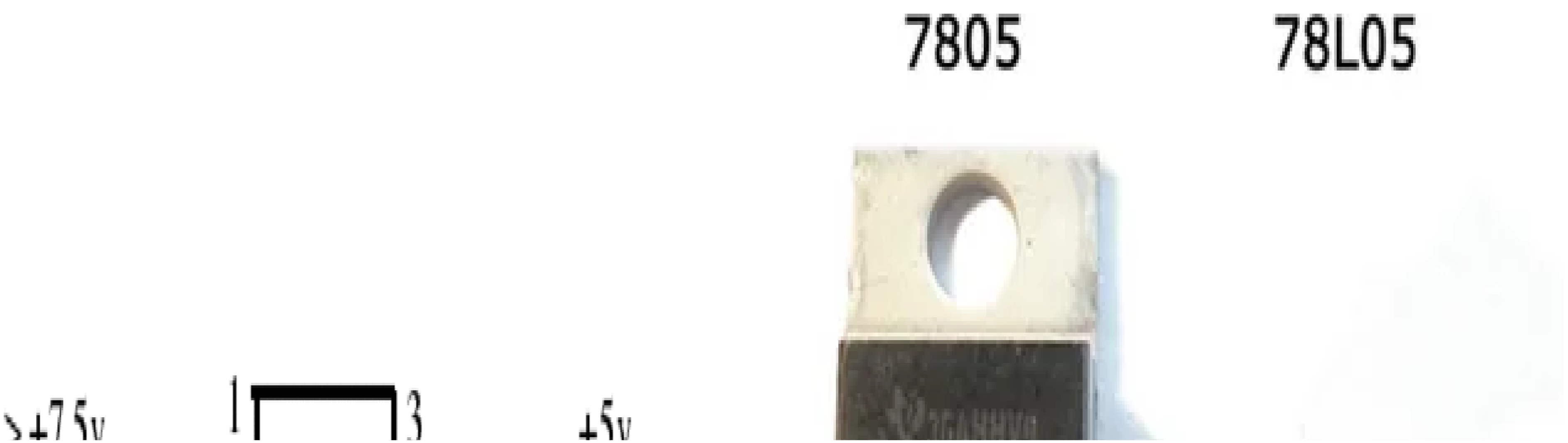

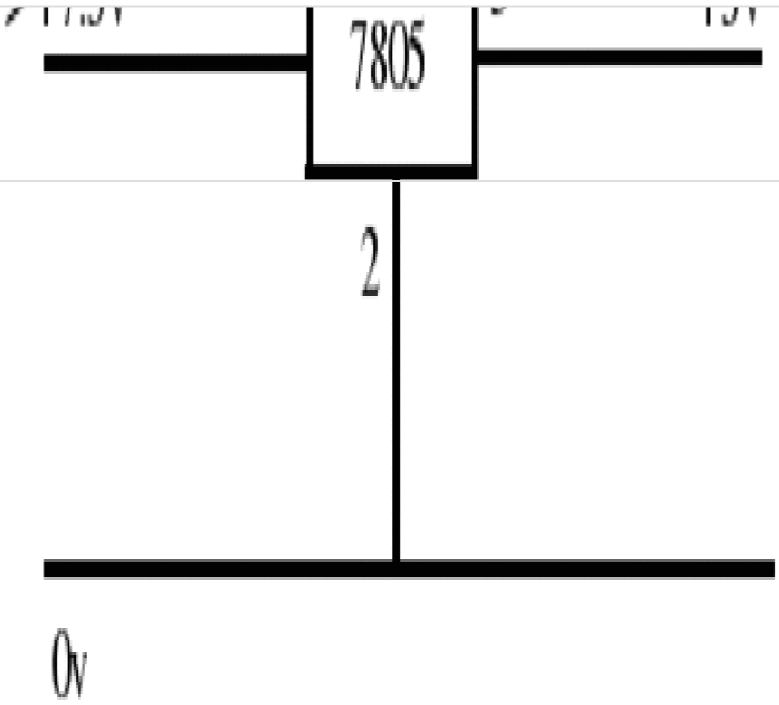

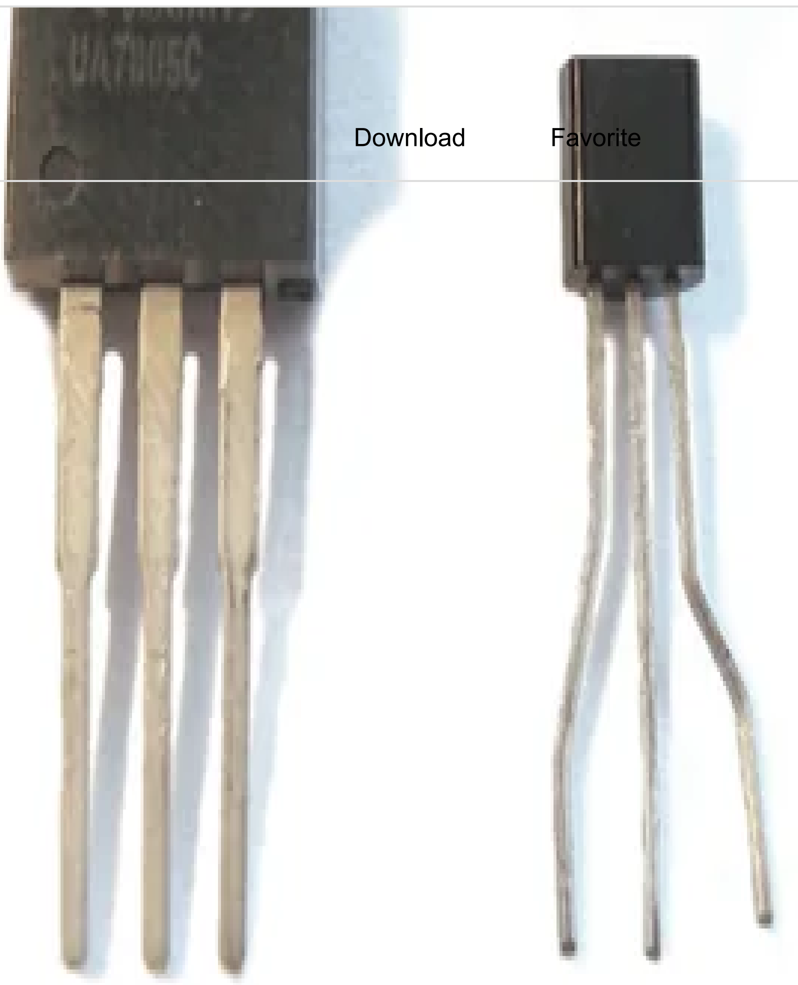

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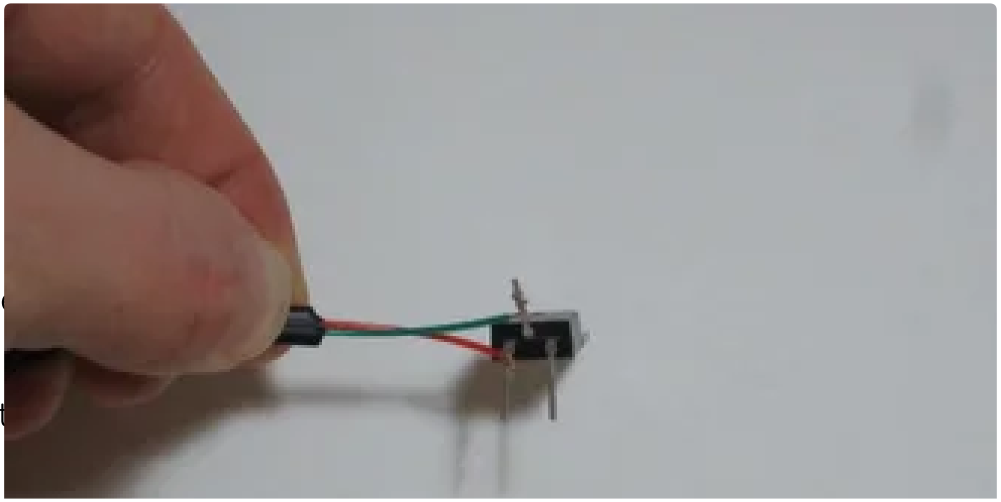

We know that the phone needs 5 volts in order to charge. But much current it draws or it's equivalent [load resistance (http://en.wikipedia.org/wiki/Electrical_load)](http://en.wikipedia.org/wiki/Electrical_load). So we can't charg from the phone line. We need to use a [voltage regulator (http://en.wikipedia.org/wiki/Voltage_regulator)](http://en.wikipedia.org/wiki/Voltage_regulator) to bring the out down to 5 volts and keep it there. A LM7805 5 volt regulator s

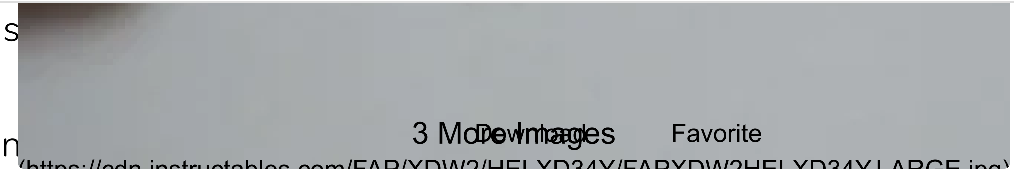
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To make this simple phone line adapter you will need the phon been working with, the 5V voltage regulator and a USB connector cable with a female end. Just connect the red wire from the phone line to the first lead on the regulator and connect the green wire from the phone line to the second lead. Then connect the black wire from the USB cable to the second lead on the regulator and connect the red wire from the USB cable to the third lead on the regulator. If you can't solder the wires together (because the power is out), you can just wrap the wires around each lead. If you do this, you should bend the leads of the regulator away from each other. This will help you avoid accidentally crossing the wires.

This simple regulator circuit is able to safely convert the base phone signal into something that can be used to charge your phone. However, many voltage regulators are not able to handle the AC signal that they would receive if the phone rang. So if you are worried that you might receive a call while your regulator is hooked up to the phone line , then you may wish to add a diode between the red wire from the phone line and the first pin on the voltage regulator. This will protect your circuit from problems that may be caused by reverse polarity.

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Step 4: Use Other Regulators for Other Output Voltages

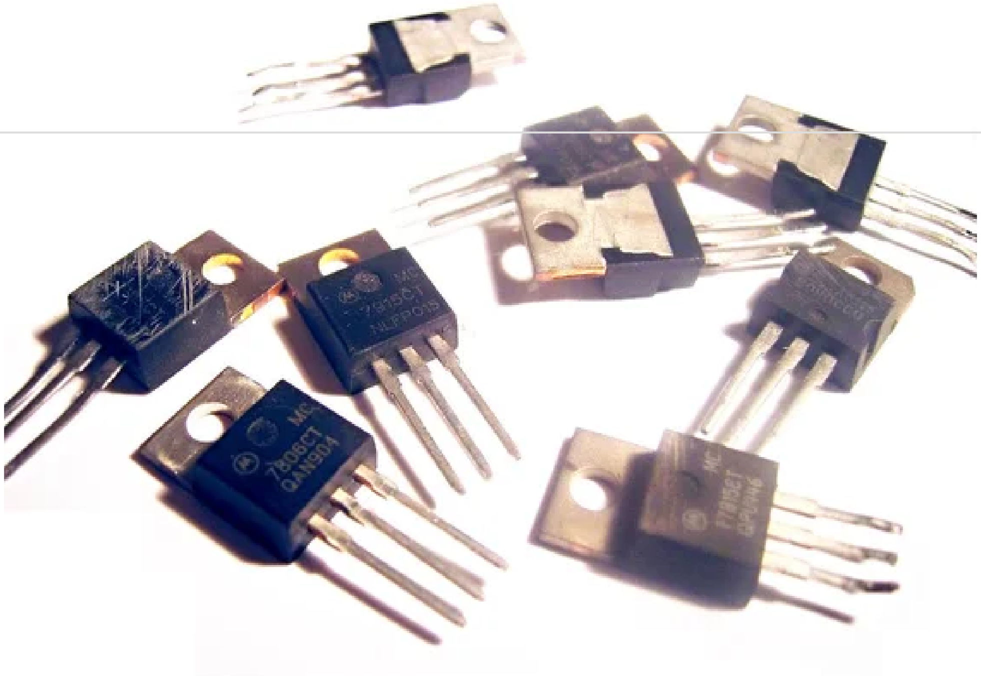

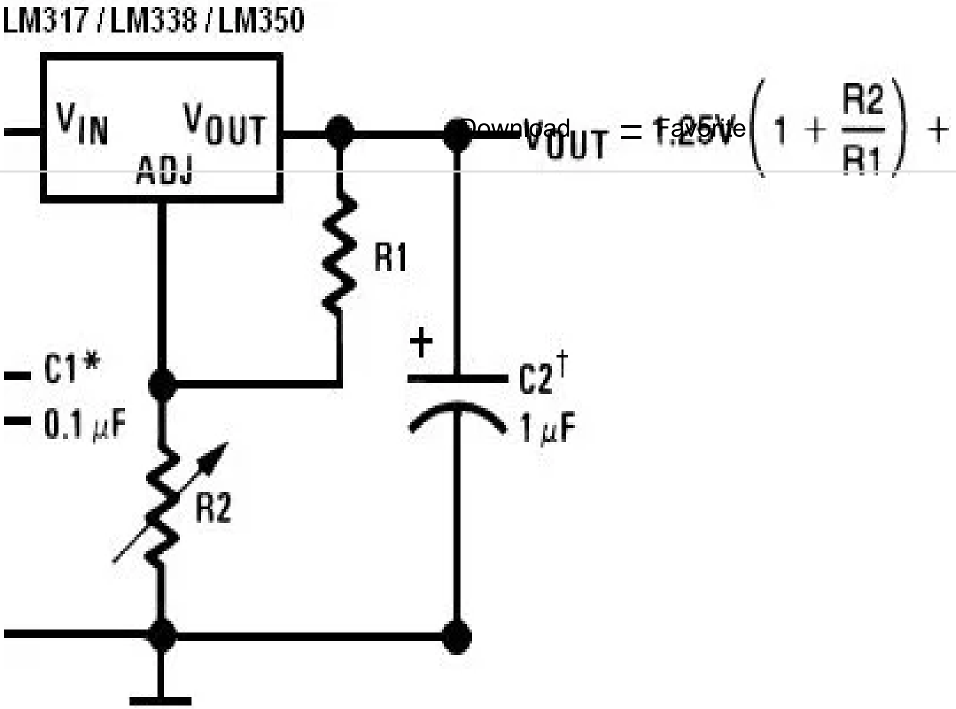

A 7805 regulator will work if you need an output of 5 volts but other kinds of voltage of voltage regulators are also available. Other voltages in the 78xx series include 6V, 8V, 9V, 10V, 12V, 15V, 18V, and 24V. In addition to these fixed value regulators, there are also variable regulators that let you set the voltage level with the use of a few external components. One such variable voltage regulator is the LM317 (http://www.ti.com/lit/ds/symlink/lm117.pdf). These are what you would use if you needed a different output voltage.

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Step 5: Finished Phone Line Adapter Tool

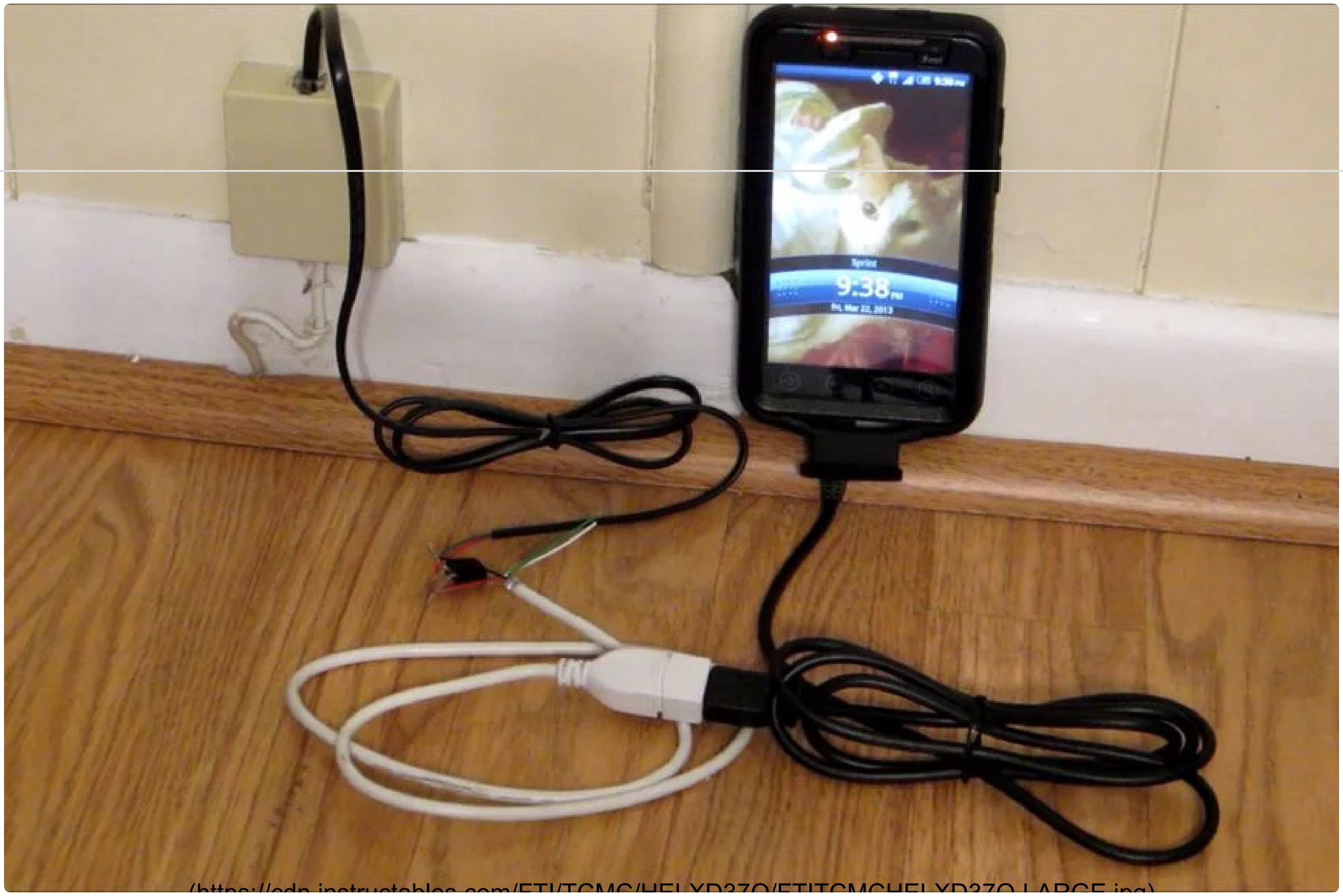

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Plug the phone cord into the nearest phone jack. Then plug your phone and charging cable into the USB cable. Your phone should begin charging. In a few minutes, your phone should have enough power to make a call.

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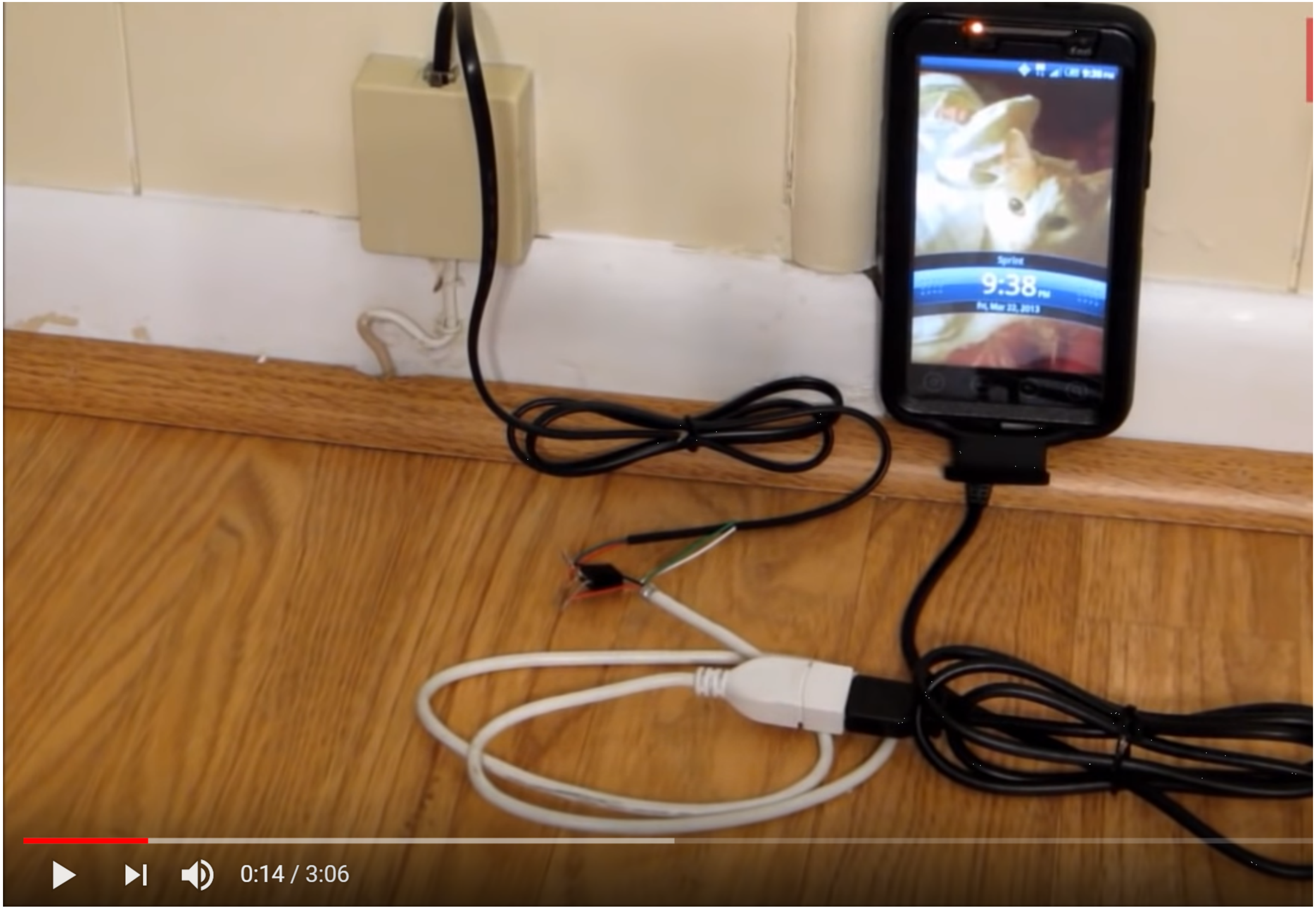
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0:14 / 3:06

DIY Hacks & How To's: Emergency Power from a Land Line

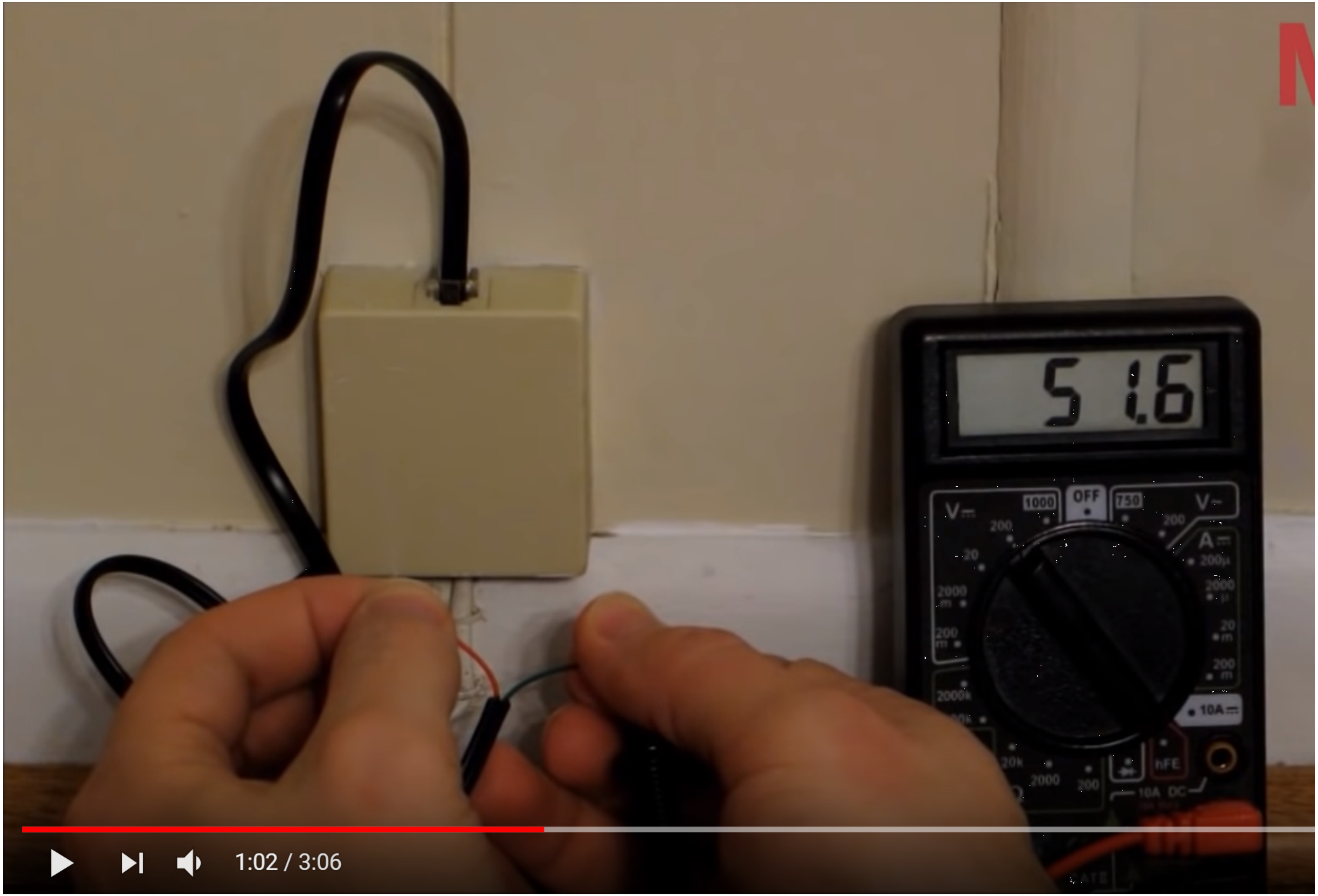
51.6
OFF
1000
750
V⎓
V~
A⎓
200
20
2000 m
200 m
200µ
2000 µ
20 m
200 m
2000k
20k
2000
200
10A⎓
hFE
10A DC
1:02 / 3:06

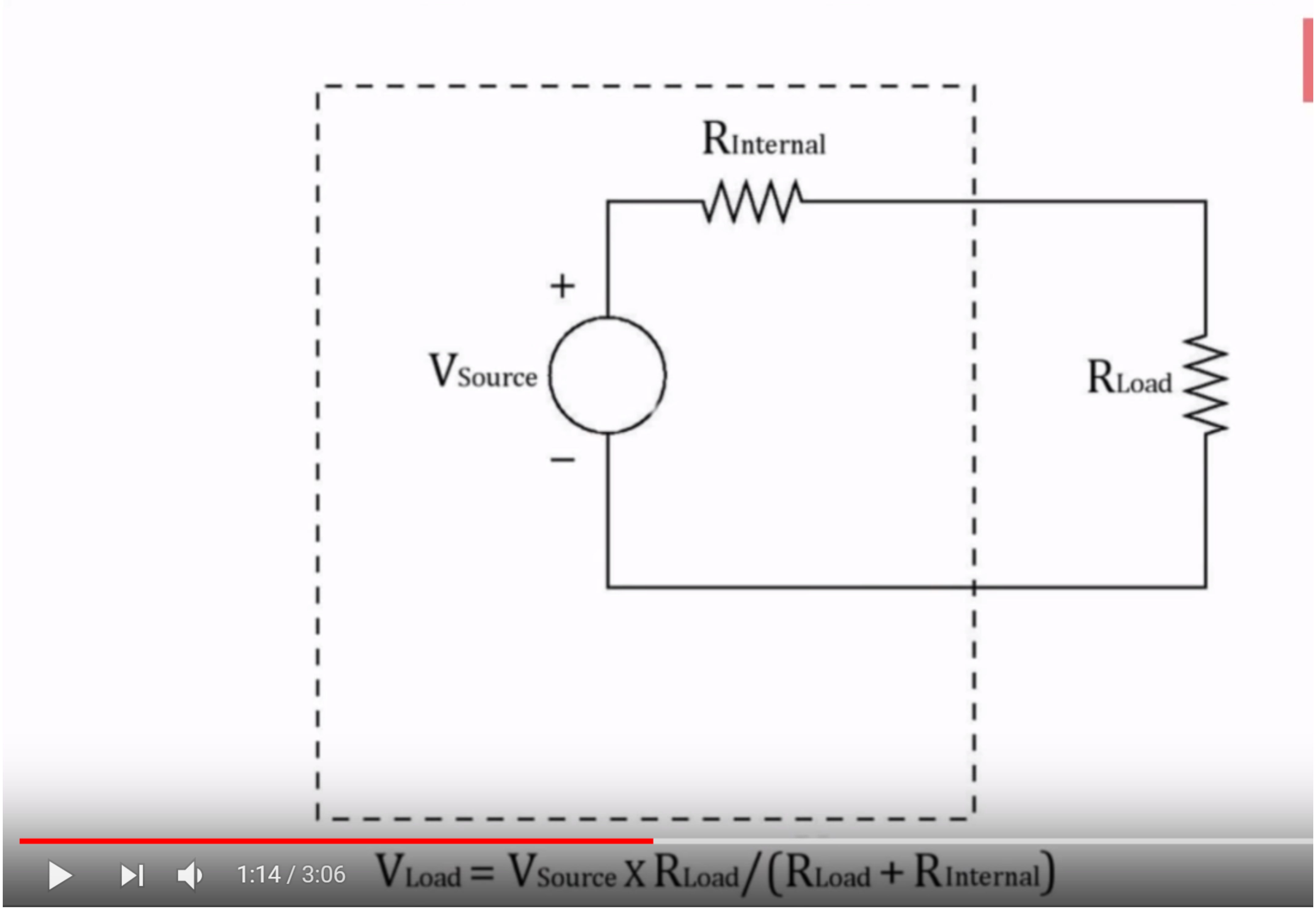
$R_{Internal}$
+
V_{Source}
−
R_{Load}
1:14 / 3:06

$$V_{Load} = V_{Source}\ \mathrm{X}\ R_{Load}/(R_{Load} + R_{Internal})$$

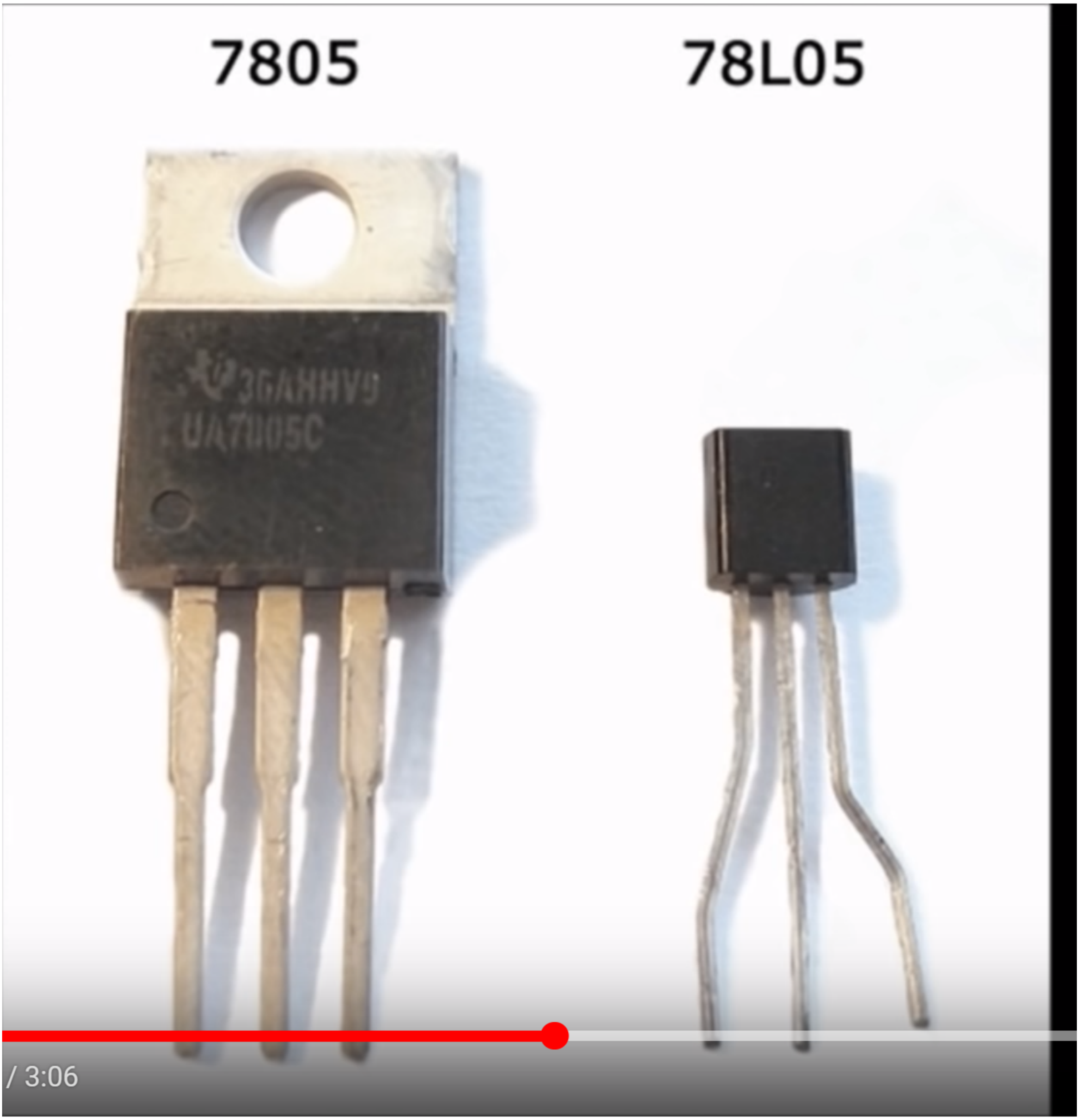
7805
78L05
3GAHHV9
UA7805C
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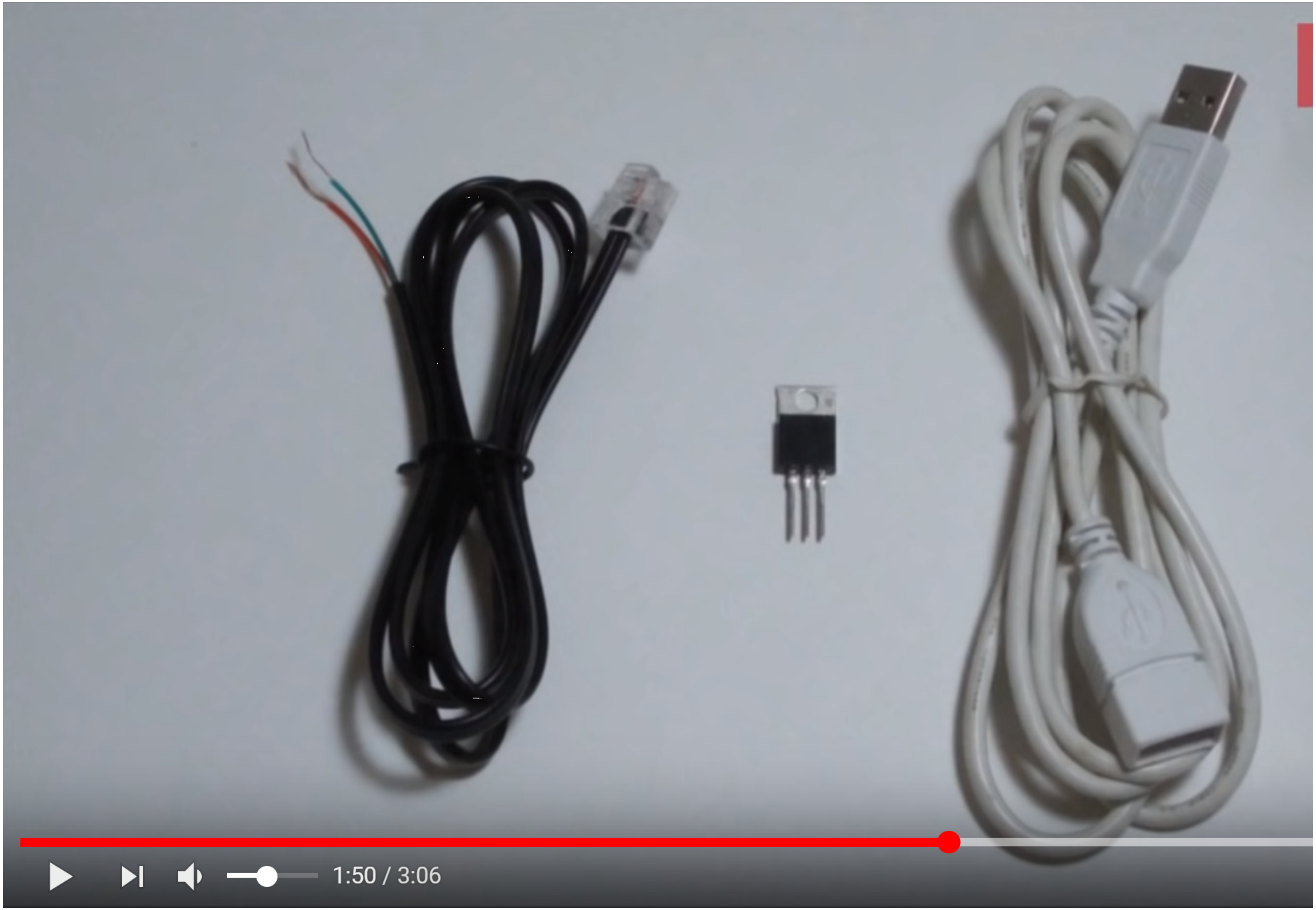
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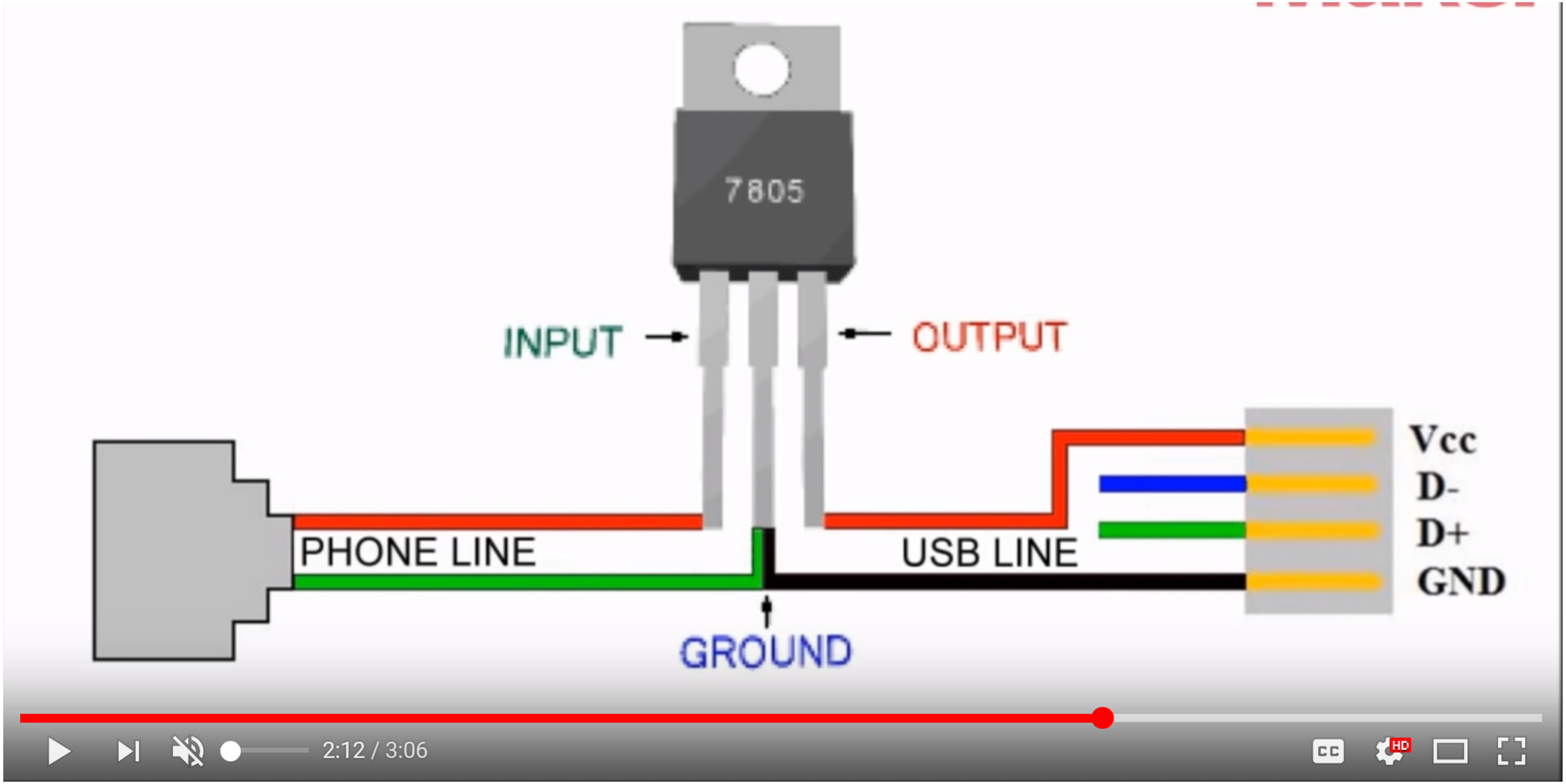
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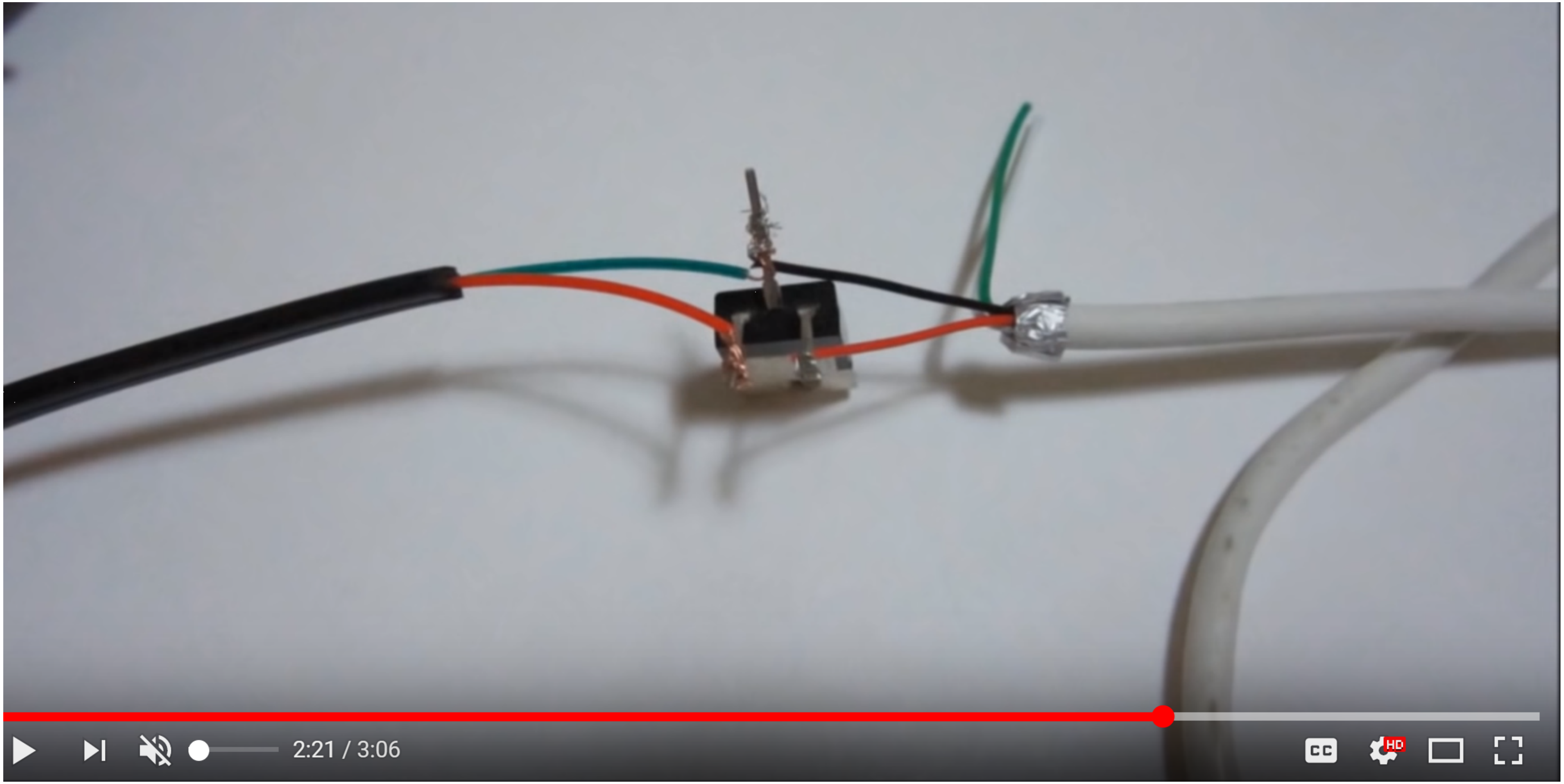
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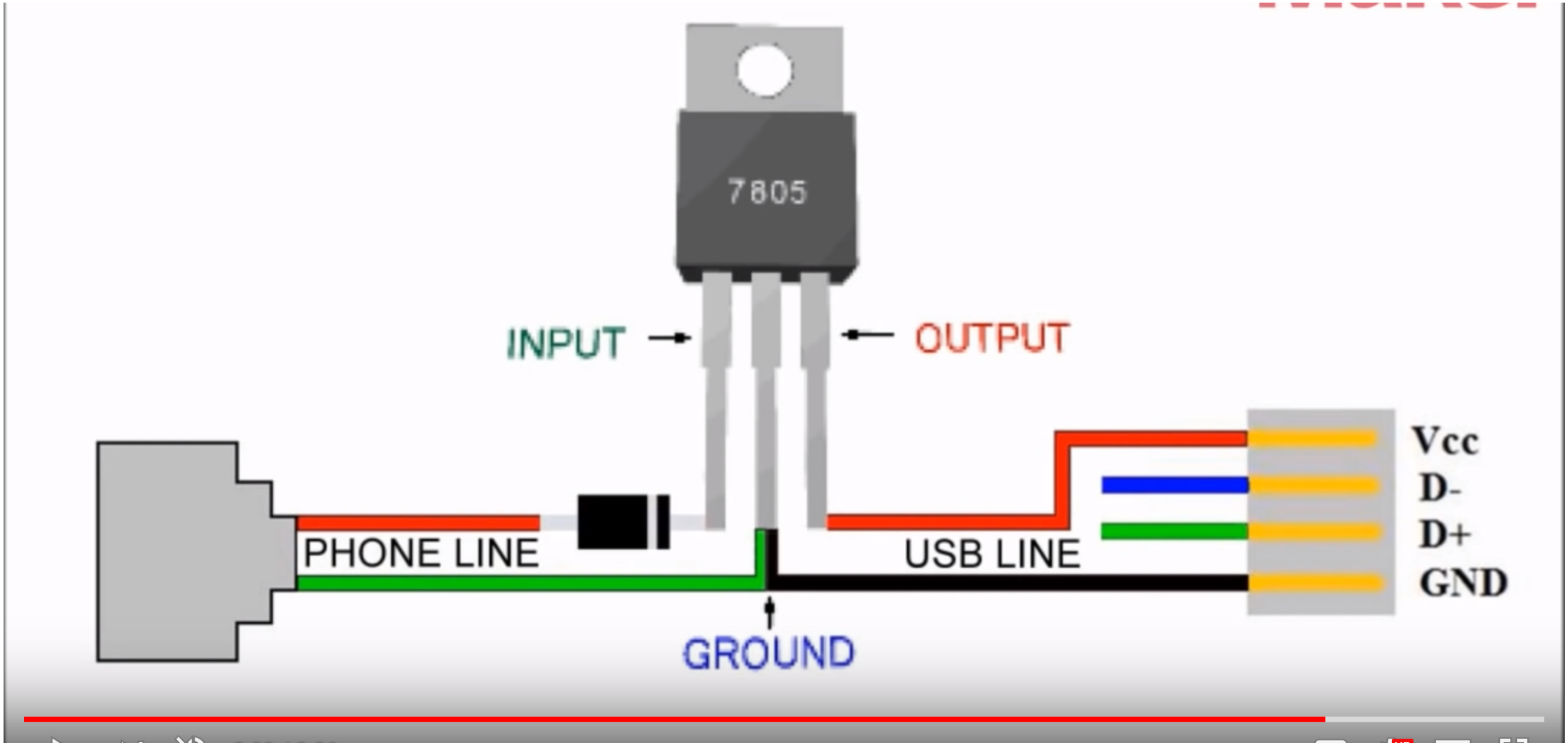
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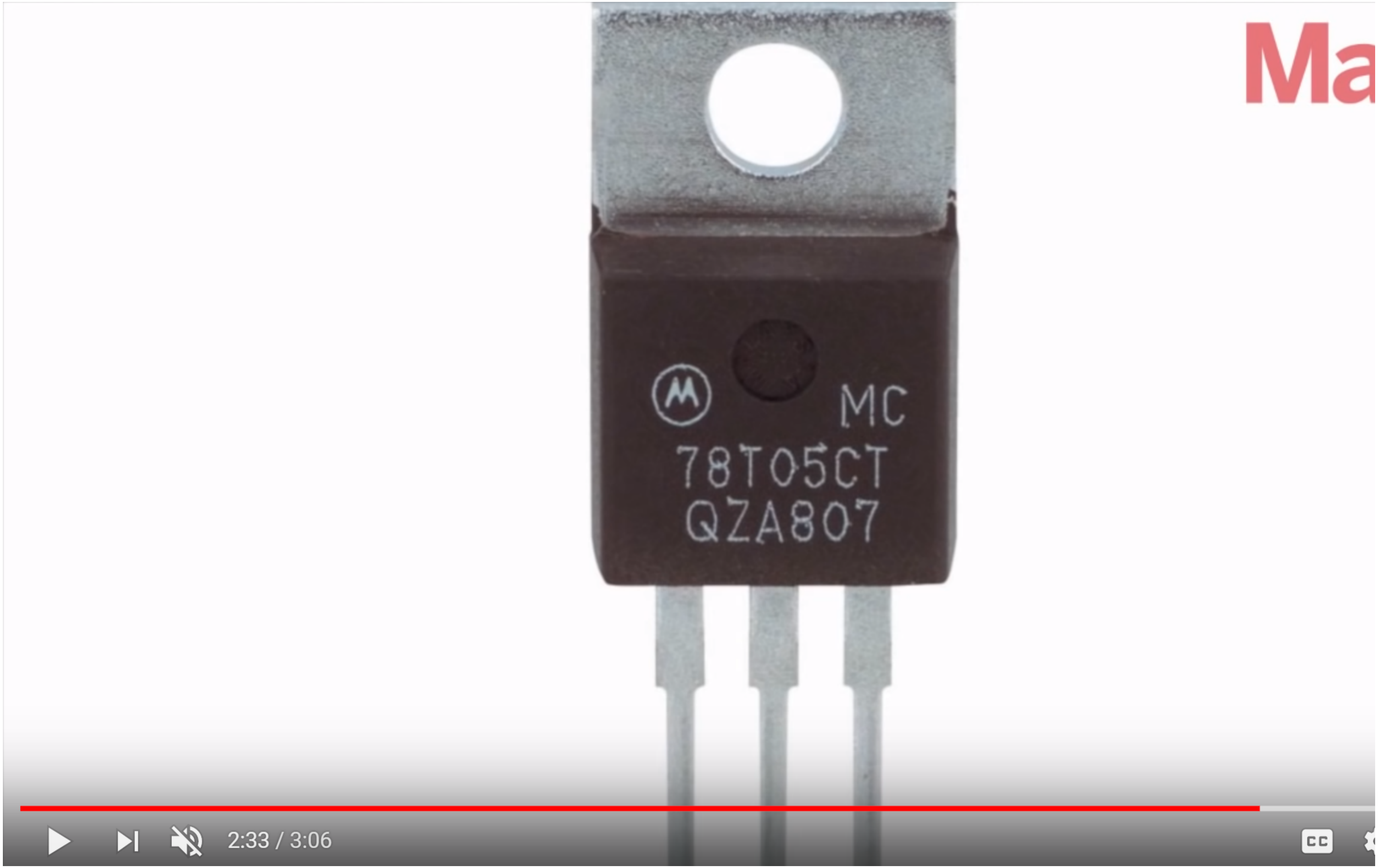
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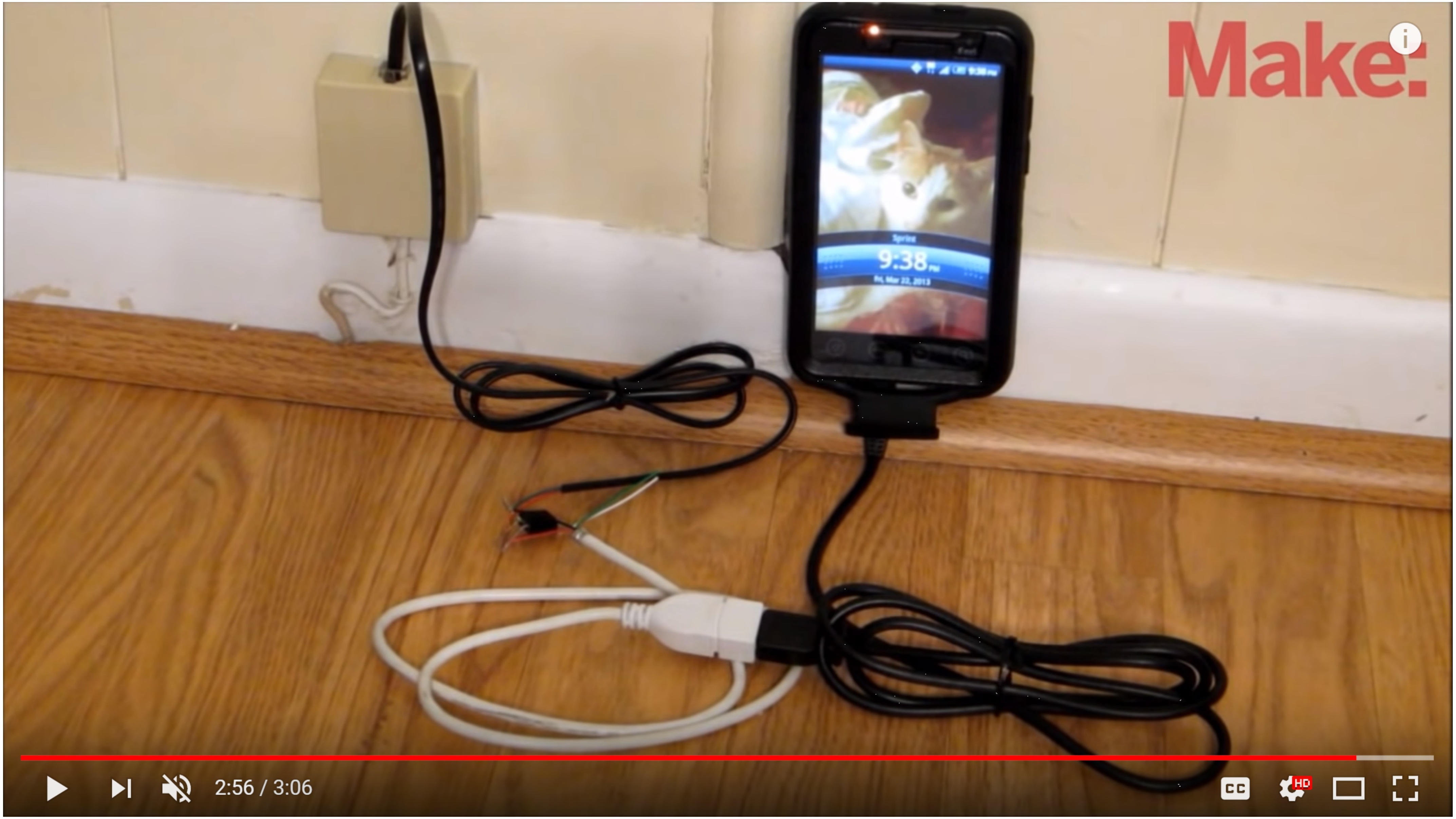
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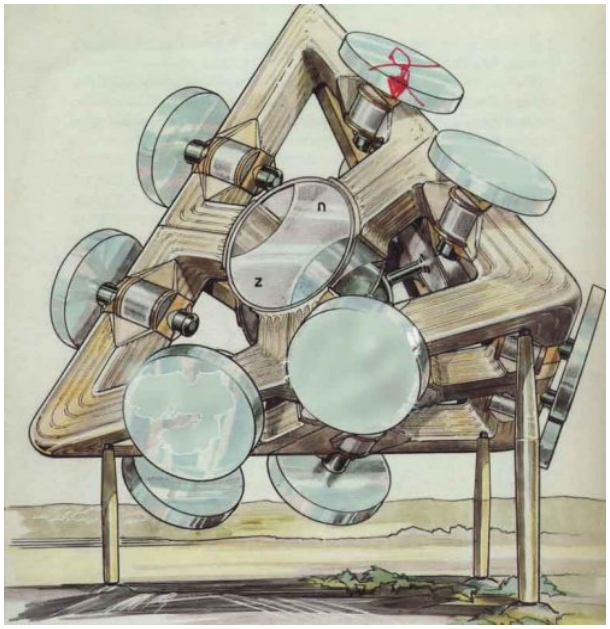

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their describtions on the matter of TIME

- AND MORE

picture is described later

12. The analog carrierfield model, an instruction model.

The cosmic carrier field of all space and matter performs a sixfold function, of which some have already been discussed in gereral way.

1. The carrier function of an infinitely strong forcefield blocked in itself contains the fluidum conducting all waves without dissipation and maintained to eternity.
2. The orientation of the time-axes of the universes with respect to nothing provides the structure of the carrier-field of three dimensions, the bounded Love-will, creating our life and existence.
3. The time synchronisation function locks all universes in the iron grip of the law of cosmic counter-balance from which no atom can escape.
4. The feedback principle of time to the total mass of the universe is the function of the coupling-field by counterbalance (and interference) of the time-bound waves.
5. The function of the timeless primeval atom-field, the atom-principle, as the transmitter program containing the code of matter of which all atoms are remote manifestations.
6. The function as bearer of the absolute ALL-knowledge and goal consciousness, manifesting itself as the laws of nature and as the intelligent goal of life: the spirit of God.

The last function concerns the existential aspects, which have been discussed in the previous section of this book.

The first analog model is a mechanical instruction model explaining the cosmic carrier field by means of symbols. This model was built on another life-supporting planet on a high mountain and was many meters high. It was the gathering point for contemplation of that intelligent race for devotion to its Creator.

It was the symbol by which the majority of the race acknowledged the goal of Creation, simultaneously the sign that the cosmic isolation had been lifted. The other function of the carrier-field will be discussed with the help of this mechanical instruction model.

The analog model consisted mainly of the six edges of a huge equilateral triangular pyramid built out of solid soft-iron bars. The many metres thick edges of the pyramid contain an impressive number of iron bars parallel to the direction of the edges and cast in a kind of plastic resin following a process similar to that of casting concrete(betong). So a mainly iron-frame was formed especially suitable for conduction of magnetic pulses of high power without much loss.

So far the carrying fuction of the cosmic time-field, which primarily maintains the timeless waves is symbolized in the model. The magnetic pulses in the edges of the pyramid run backwards and forwards like the timeless waves in reality.

With respect to the other edges of the pyramid, the magnetic pulses are phase-shifted. The problem is that up to now the forward propagation (forplantning) in time has been missed out. In fact we look for the equivalent of the two little wagons on the vibrating rail. The solution can be found in the symbol of the rotating flywheel, as *with the atom its rotation is continuous in time, it is in fact time propagation.* Therefore the iron frame of the pyramid is discontinued at two places in each of the six edges of the pyramid. At this discontinuation point a linear magnetic impulse motor is installed, on the axis of which a large flywheel is mounted.

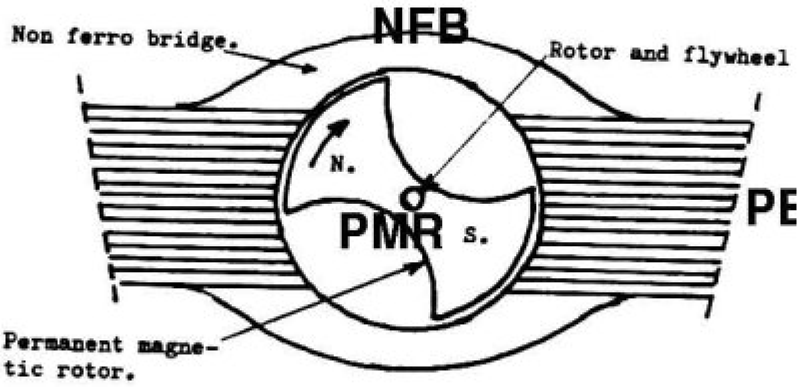

NBF=NonFerroBridge

PE=PyramidEdge and soft iron bars

PMR=PermanentMagneticRotor

The flywheel symbolizes not only the propagation of time, but also the inertia of matter and so the flywheel is in effect the total mass of the universe. This type of magnetic impulse motor is not self-starting, so at the inside on the flywheel axis a starter-motor is mounted, fitted solely for the purpose of starting. One rotating the synchronous motor maintains the exact number of revolutions at the same frequency of the magnetic alternation field. Thus in each of pyramid's edges two synchronous motors are mounted making twelve flywheels in total.

The two flywheels per axis rotate in opposite directions to symbolize the time propagation in opposite time directions. This type of linear impulse motor is chosen because it can be made to rotate in either direction.

The first analog model.

In one triangular plane of the pyramid the six synchronous motors in the iron frame demonstrate a rotating magnetic field, seen from the center of the plane. Each edge of the pyramid has the right phase-shift with respect to the other edges of the triangle.

The first model has four central rotating magnetic field generators in the middle of each triangular plane. (See figure of unfolded pyramid indicating the actual phase-shift).

These four synchronous (three phase) generators are coupled together by a gearbox and are driven by the main electric motor (not shown in the drawing). Consequently the four three-phase generators fulfill the synchronisation and constant phase-shifts for the flywheels of the pyramid-edges. The four separate rotating fields together, initate the complex three-dimensional rotation of the carrier field (or atom-field).

The disadvantage of the first model is that it is further away from reality, because the atomic field is not symboized as one three-demensional rotating field. However it shows better how to imagine the complicated rotation in three dimensions.

The second or the real analog model.

This mechanical model has only one central generator in the middle of the pyramid, instead of the four rotating field generators of the first model. All magnetic waves in the pyramid edges go straight to the pyramid's center. The rotor of the 3-dimensional rotating generator is like a yo-yo with spherical end-surfaces.

It requires a touch of genius to provide the drive-connection between the central motor and the spherical rotor, which has to be started up in a complex rotation. The six diametrically opposed pole-shoes from the middle of the pyramid's edges around the spherical rotor form in pairs, three axes of right angles - representing a Cartesian coordinate system. So it shows that the six time-axes of the edges of the pyramid can be converted into the three principal time-axes of the central sphere.

Together it imitates three-dimensional time, which causally creates the three-dimensional space of our universe.

The principles of the first and second analog models are equivalent. One version can be converted into the other, for example, converting the four rotating fields to one three-dimensional rotation in the centre-mass of the pyramid.

The model can be started by switching on the thirteen drive-motors. As the flywheels reach velocity the twelve starter-motors are switched off and only the central motor drives the complete gigantic model. The essence is that all flywheels have exactly the same number of revolutions. They are all either synchronous motors or generators. Then the flywheels are marked and illuminated by a stroboscopic flash light. *Seen by the normal eye they do not appear to move showing the synchronous rotation and the constant phase-shifts between the flywheels.*

These mechanical models are meant to explain the unimaginable Creation out of the nothing by symbolic imitation of the carrier-field. However it is only a weak symbol of Creation. The carrier-field is the esoteric medium, a transmutation of the absolute spirit or conscience, it is the spiritual force field of infinite strength which is present everywhere in the universe.

The imitation of the carrier-field functions.

Nevertheless the analogy of reality is incredible. This will be shown in the next explanation of the five functions of the cosmic carrier-field.

The carrier-function

The foundation of the carrier-field is the infinite force-field created by interference quenching (avbrytende stopp) of the original infinite vibration. The mode initiates this force-field with the six bundles of soft-iron bars as the edges of the pyramid.

As in reality, the three-dimensional magnetic rotating field in our model is caused by the linear waves of each time-axis. *The timeless waves alternate backwards and forwards as in our model*. They drive the flywheels representing the masses of the universes, and their rotation is the propagation (spredning) in time.

The orientation of the time-axes with respect to the nothing.

The relative position of one time-axis in the apparent nothing plays an important role in the orientation of the universes in reality, determining the direction of each time-axis. Here the first model is shown representing the four three-phase synchronous generators in the planes of the pyramid. Only with decompostion of the three-dimensional rotation into four rotations can one show that the three-dimensional rotating field has left no remaining component in the nothing, while in contrast a two-dimensional rotating field can not be nullified, a remaining component will always exist in the nothing. This can be explained by considering a single plane of the pyramid with its six flywheels at the edges, the analog for a two-dimensional

carrier-field. The rotation impulse of the flywheels is compensated by the opposite rotations but the rotation impulse of the central three-phase generator is left over. It can be measured by the outside world (the nothing).

It requires four field three-phase generators (maintaining overall symmetry) to compensate for these rotation impulses.

With this the three-dimensionality of the carrier-field has been shown and the orientation of the time-axes with respect to the nothing is determined.

The time synchronization function.

Impressively the model imitates the time synchronization, simultaneously maintaining the cosmic counter-balance by which the universes continue to exist. The rotation of the two flywheels per axis is in opposite directions and they rotate with exactly the same speed. Thus it imitates the circular motion to the timeless waves which progresses exactly synchronous by their mutual interference coupling.

The twelve cosmic systems run without any dissipation, once started, the perpetuum mobile continues into eternity with the absolute accuracy of time-synchronisation. If one supposes the model to be without loss and without using the eternal driving motors, it will continue to run synchronously due to the inertia of the flywheels and the fact that the synchronous linear impulse motors can function as generators as well.

This symbolizes another property of the continuous circular motion of the timeless waves, because every wave somewhere in the pyramid circuit at each moment has its opposite value resulting in an overall zero at any moment.

This is the law of conservation of the nothing.

The couplingfield function.

Time synchronization is not alone determined by the iron grip of the three-dimensional carrier-field and the principle of cosmic counter-balance. Apart from this an important effect is realized from the feedback of the gigantic masses of the universes to the timeless waves. These masses can be considered as enormous flywheels without loss. Once started by the super flash, no change in speed is possible, because a force of sufficient magnitude is simply not available. This function of the coupling field can also be shown in our model, because the linear synchronous motors of the flywheels are also generators. If the central driving motor is switched off, then the flywheels continue for some time to drive the central three-dimensioal rotating sphere. Everything stays exactly synchronous with the same phase-shifts.

This experiment shows how the flywheels feed their energy back and have a stabilizing function in time-synchronization. The coupling-field of the masses of the universes is fed back in the time-bound vibrations of the atom-field from which no atom total mass of the universes is fed back to one single atom.

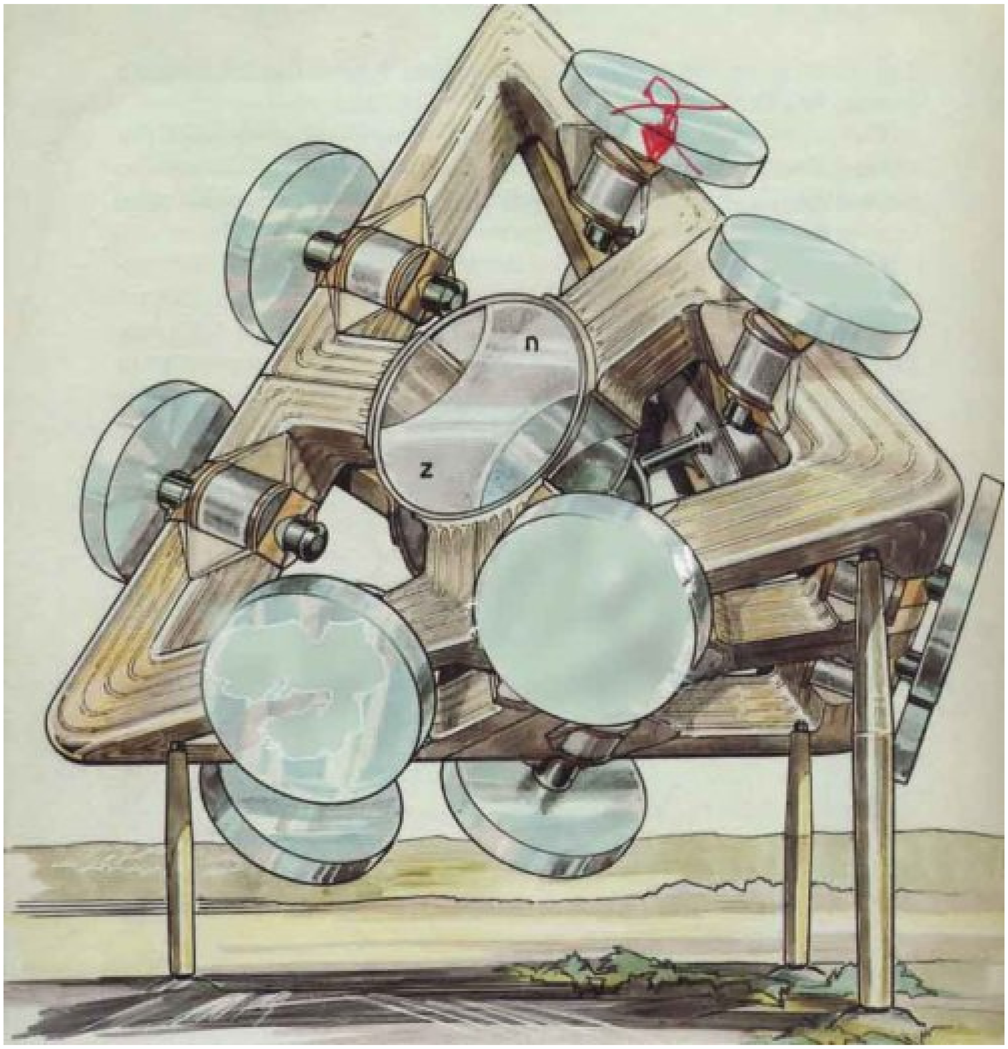

This is a painting by Rudolf Dass of the analogous visual-mechanical carrier-field model which symbolizes time and matter creation and synchronization in twelve universes. This giant working construction that was a cross between a monument and a machine was seen on an artificially flattened mountaintop on **Iarga**. This place was perceived as a place of pilgrimage, a place of meditation and contemplation, and the machine was a symbol of creation. The **Iarga**ns know no separation between science and religion, and religious and spiritual theories are entirely scientific. The model was several hundred yards(meters) long. The machine seemed to operate by some kind of perpetual motion, neither running on fuel or electrical power.

The Instructional Analog Model

The mechanical instruction models are the visual representations of the principles of the cosmic unified field theory. The model is intended to demonstrate that time, matter, and energy are creations out of the nothing and therefore the counter-balance has to be maintained to allow the causal infinity of the nothing to exist. In a broader context the physical symbols all take on new meaning and demonstrate the unification of science and religion. In a religious sense the spherical three-dimensional time-field in the heart of the pyramid symbolizes the Soul of the Creator. The pyramid symbolizes his infinite lovewill, the cage in which the infinity of His existence has been blocked irrevocably. The lines symbolize the different frequencies of the timeless waves. The flywheels on the edges of the pyramid symbolize the twelve associated and interrelated universes, including ours, that make up this unity. One cannot exist without the others.

The timeless primeval atom-principle, the transmitter function.

The atom-field is a time-creating field and as such a remote manifestation of the primeval atom principle. It can be compared with a transmitter. As soon as the program is converted into waves of great power, billions of radios can receive the same program, the number is unlimited. Everything depends on the one program of the transmitter, the primeval atom-field. If this exists with infinite strength, it is at the same time the vibration medium (the carrier-field) which helps it to spread everywhere. *Thus any atom in any universe can receive the timeless basic program.* The second model shows the three-dimensional time-field of the primeval atom field most clearly, although this is a three-dimensional rotation of the central sphere in spatial sense. This is an analog of reality, the atom has a spherical field which is defined by six linear time-vibration directions. Any atom is a remote manifestation of the one carrier-field of infinite strength.

Considering this fifth function of the carrier-field one has to realize that only the central sphere, the atom, is visible to us. The fields in the pyramid edges outside the sphere are invisible. It is the time-field reality of which the atom is a reflection.

The mechanical instruction models are the visual representations of the principles of the cosmic unified field theory. This requires however some marginal notes. A material comparison to explain spiritual abstractions is always in some ways incomplete. There are several hiatus of which only the three most important ones are mentioned.

1. In the model one time-axis represents only *one frequency* of the magnetic field, while in reality all frequencies are contained. Every frequency however can be initiated for each time-axis for which the interference representation of the analog model is valid.

2. The model demonstrates the rotating field of the *timeless waves.* It *does not imitate the time-bound waves* by which our time-axis the propagation speed of time is X, then the phase velocity of the two time-axes connected to "our" pyramid edge is ½X. The other two time-axes connecting our time-axis with the other corner of the pyramid is -½X, making up for the time speed of our anti-universe -X. The crossing, not-touching time-axis is perpendicular to our time-axis and does not contribute.

3. In our model the masses of the universes are given by the flywheel symbol. In fact this is *fundamentally wrong, because it is separated from the three-dimensional rotation of the central sphere.* It can therefore basically not maintain the counterbalance of the nothing.

The most important conclusion of the analog model is that *time, matter and energy are creations out of the nothing and therefore the counter-balance has to be maintained to allow the causal infinity of the nothing exist.*

14. The existential symbolism of the model.

So far the physical aspects of the model have been unravelled, but if one wants to give a wider context to the model suddenly all the physical symbols change their meaning. In relation to philosophical or theological disciplines the model takes on the additional meaning of the unification of science and religion. By certain inherent (medfødte) laws within any intelligent race the denial of God's existence will be destroyed sooner or later. Earth science will provide an indestructible contribution to our final knowledge-awareness, which we shall attribute as typical human attainment in the cosmic integration. It is that piece of our human identity and self-awareness, which we shall possess and care for throughout eternity. *It the light of this purpose, science serves God and the distinction between science and religion fades away.*

In a religious sense the spherical three-dimensional time-field in the heart of the pyramid has a special meaning. **It symbolizes the Soul of the Creator**, the Father who is the pure Identity of the infinite origin. The pyramid symbolizes his infinite Love-will, the cage in which the infinity of his Existence has been blocked irrevocably. He sacrificed his Ego and his freedom, to love his twelve Sons once. He is present only indirectly in his Creation as the reflection of the infinity, the Supreme Being, as the one Ego-consciousness of the Archangels.

That is why the theologian covers the central sphere with pure gold, symbolizing the golden Heart, the Holy of Holies, the most sacred secret of the universe. The pyramid is then painted dark red, the universal colour of love. Over the red many thin golden stripes run in the direction along the pyramid edges. These stripes symbolize the different frequencies of the timeless waves, the expressions of Love and faith of the Father and his infinite Will.

Gathered around the golden Heart are the twelve flywheels, coloured white, the colour of purity and innocence. The model shows that every universe has the power to awaken the matter-consciousness and to transform it to the new

God: the Son. The goal of Creation is therefore the awakening and the formation of the twelve Sons of the Father.

This is not in contradiction with the Bible telling us that the Father sent his only-begotten Son. The Bible is solely directed to man. It is our instruction book for life describing our attitude towards God and our fellow man. The Bible does not tell anything about life on other planets, because it is not relevant in our relationship with God now.

The same goes for our parallel universes. In fact they do not exist for us, because they are not in our world of existence but somewhere else. They do not exist for all intelligent races in this universe, we shall never be able to observe them nor experience them in any way. Perhaps at the end of all time we shall meet. In *our* world the Father has one only-begotten Son and this truth is already so unimaginable that nobody can conceive the consequences yet.

END OF IARGAN DISCUSSION

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mainpage

the IARGA CONTACT story

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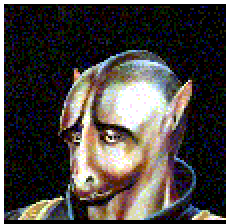

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- AND MORE

APPENDIX 1

An Analog Model

1. Introduction

This appendix is not a part of the story of the Creation which is explained in religious terms in Chapter 1 (Part 2). It is a complementary way of reasoning to prove the existence of God, using the concepts of time, matter and energy. These concepts are also used in physics. The problem, which now arises, is that the author will use physical concepts without understanding the real meaning of the words, because he is not a specialist. The words atom, atom-field, matter, etc., must all be understood within the context of this book and they have no direct connection with the ideas used in modern science. Especially the words "matter" and "atom" are most confusing, because the **Iarga**n author knows about the existence of matter in three configurations (and its opposite possibilities as anti-matter); i.e., time-matter, phase-matter and *reflection-matter* (the one we know about in our universe), but he fails to interpret these concepts due to his lack of knowledge of physics. He only knows that these forms of matter are all related to one or none of the directions of time- propagation (tidsforplantning) of the atom of which time is fundamentally three-dimensional. It therefore determines in which form these configurations (beskaffenheter) can exist in our universe.

In this appendix - time-creation out of NOTHING is described - by making use of the concept of more time-dimensions. The explanation of time-creation is very difficult because it uses an overall carrier-field of infinite strength and then this concept is called the cosmic unified field theory. In defining this term, one has to be careful*, because this theory is of a different basic nature from the existing unified field theories here on earth.* Our unified field theories try to unify the four basic forces in nature, which are the electro-magnetic, the weak strong nuclear force and gravitation. The unified field theories accepted by most prominent (iøynefallende) scientists find their origin in the general relativity theory of Einstein, which itself explains matter and energy in terms of space and time.

The problem now is to find a method, explaining the spiritual or esoteric reality, the cosmic time-field. On other planets, this problem was solved by explaining the basic concepts of the cosmic unified field theory. The elementary functions of these concepts can be understood with a mechanical instruction model demonstrating the cosmic time-field visually.

Why indulge in this complication of describing a theory which will probably only be fully grasped by a few individuals? It does not concern the author very much, he only carries out his commission. His **Iarga**n instructors gave three reasons for publishing the concepts of this theory:

1. The future integration of science and religion requires a material proof of God's existence. This explanation could be the start of the exchange between these two.

2. In the previous story of Creation the limitation of the infinite is explained unambiguously(upretendiøst), but the working principle was completely neglected(forsømt).

3. The cosmic unified field theory published in this book will be the only possible verification for the true identity of this book, providing the link for the future development of the human race.

2. The physical approximation of the NOTHING.

One concept in physics is that all atoms and energy consist of vibrations and wave appearances. In a material way, every atom or form of energy is caused by vibration. The physical approximation (tilnærmelse) describes the nothing of the idea of vibration - and *does not touch on the spiritual aspects and the consciousness of matter*. It does not distinguish between the "nothing" and the spiritual "No-Thing" (the ALL). It only recognizes the material aspects of the nothing.

If everything is vibrations or waves, then it is not necessary to speak of matter or energy, then Creation is fundamentally based on this concept of vibration. The primeval vibration (before the limitation) can be described as infinite in time, infinite in all its aspects and possibilities, infinite in frequency and amplitude and existing in all time directions (omnitime). Unchanging, timeless and powerful to all limited vibrations in every bound power. It is the omnipotent definition.

In this approximation the nothing is more simple to understand. Before the creation - the infinite omnipotent vibration existed- *but a vibration in every direction and of infinite frequency and amplitude is not a vibration*. The apparent paradox can be eliminated by stating: Only at the instant when this infinite vibration blocks itself by interference*, as in a flash, all bound waves and frequencies were created.* This condition is very close to the existential view of the Creation out of NOTHING in Chapter 1.

The nothing (here) has no counteraction, but in contrast the omnipotent vibration - can manifest itself only by counter-acting in such a way that the infinite allows the nothing to be. So one can also state that all vibrations were created because the nothing bound itself by a mechanism of interference quenching (ble dempet) - (counteracting vibrations) of infinite force, which blocked the infinite possibilities of these vibrations. *This universe can only be considered as the limitation of the unbounded nothing.*

3. The bounding of the omnipotent infinite vibration, the cosmic time field.

One of the basic principles on which the mechanism of bounding is based is: *If one property of a power (any power) of something is bound, then all properties and powers of this something will be bound.* In infinity the finite cannot exist. To limit the omnipotent vibration it was sufficient to bind only one of the perhaps infinite number of possibilities. Because if only just a little something were to be formed in the nothing, the nothing would be altered and cancelled irrevocably, then the complete finity (endelighet/begrensethet) was a fact. OR, if there were just the three-dimensional rotating time-field as a possibility of the primeval atom in the infinity of the nothing, then the finite was a fact. This atom-field needed to be a force-field of infinite strength, the carrier-field, to counteract the omnipotent vibration, the cosmic time-field.

4. The Creation can only exist as a result of counter-balance.

One of the functions of the carrier-field is time-synchronization by which the cosmic counter-action and therefore the nothing can BE. *Matter and energy cannot exist on its own in the nothing.* The principle of time synchronization is given:

1. Time is only relative, it is motion or propagation (spredning) in relation to at least a second motion of time.
2. the cosmic law of counterbalance dictates that the second time has to counterbalance the first time. So time can only exist in relation to a second exact *opposite direction* of time (running backwards in relation to our time).

3. Time exists only through the presence of atoms or matter. Then the backward-running time can only exist through matter in which the time propagation is opposite, *running backwards* in relation to us (antitime matter). Anti-matter or reflection antimatter may exist in our universe with an opposite electric charge with respect to our known reflection matter. The question, as to which charge antitime matter has in the anti-universe, is of no importance in this appendix.

4. Because neither matter nor energy can exist on its own in the nothing -another quantity of matter of opposite properties *must* exist which is exactly similar to that in our universe. This balance of matter and energy is so accurate, that one surplus atom (overskuddsatom) is impossible.

This explains nearly as per definition the cosmic law of counter-balance allowing the nothing to be. There must be at least a second universe exactly like ours, in which time runs backwards according to us, but normally for life in that universe. In the following it is shown that there are not just two, but *eleven* other universes in addition to ours necessary to maintain the cosmic law of counter-balance.

6. The time-synchronization field.

The law of counter-balance also applies to time. The timedirection is opposite and the time velocity is equal to ours. Time is the propagation of vibrations of the atom. Then the atomvibrations in both universes are equal and opposite with respect to the timelessness. This is only possible if these times are caused by one field (time-field).

The definition of a field (any field in physics) is: If an event occurs, because another event takes place somewhere else without a mechanical or visible connection between these events, then these events are caused by a field. Time-synchronization occurs according to this definition. The atom vibrations in our universes are exactly similar, because the atom vibrations of our anti-universe occur despite the enormous difference in time and without any dissipation of energy. It is about 30 billion (milliarder) years since the occurrence of the super flash Creation (big bang) between the two universes.

The law of conservation of counter-balance is causal to the law of energy conservation in every universe. Each universe is a closed system and without energy dissipation outside itself. The amount of matter and energy once created remains constant. *A loss of energy is impossible, because our time-bound energy propagates forwards, while the time-bound matter and energy of the anti-universe propagate backwards in time.* These universes are separated by a time-barrier through which no communication nor transfer of life is known. (Well - according to information in the book UFO-CONTACT FROM PLANET KOLDAS and also told by the et-contact ASKET and Semjase - there are some methods for entering the mirroruniverse - but this can not be touched here - reseach yourself if interested!! R.Ø.remark.)

6. What is a timeless vibration or wave?

The question is how the field functions maintain the time-synchronization of the atom-waves between the universes separated by billions of years. It is only possible if the synchronization stands still in time, but exists simultaneously in all the time elapsed (- som er gått..) since the beginning of the super flash, as well in all the future. *A timeless vibration does not normally move in time*, the amplitudes of the field propagation - alternate (veksler) forwards and backwards in time. Time synchronization is the principle by which our universe catches every forward-moving amplitude and the anti-universe catches every backward moving amplitude of one and the same timeless wave.

On other planets there are simple mechanical models explaining the function of time synchronization. One such model is very similar to our well-known mini-model rail upon which are two little wagons. The model has two lengths of rail of say 1.50 meters each, which are in direct line with each other.

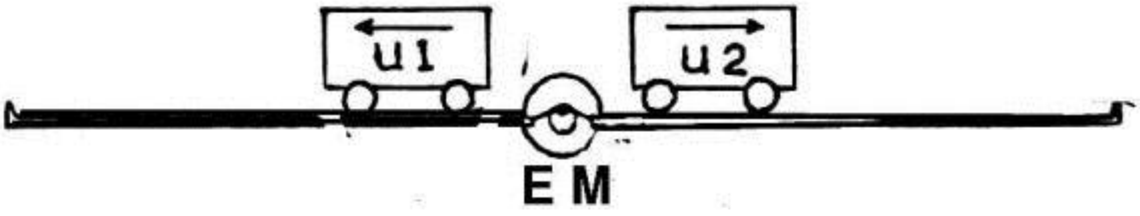

Picture of the model wagons with a Electric drive motor which letting an excentric, and so the rails vibrate horisontally.

Rail and wagon model demonstrating the principle of the timeless waves. The vibration is present at any point of the rail and at any time during the whole process period. Also from the moment of the super flash until the end of all times (ALWAYS).

The rails are mounted on small springs to allow them to vibrate forwards and backwards in horizontal direction (from left to right and vice versa). The two rails are connected to a little electric motor with a double eccentric, each driving one rail, letting the rails vibrate about 1 millimeter of linear distance, also backwards and forwards. The amplitude is small enough to be invisible to the eye.

Then one little wagon is placed on each rail and each wagon has a catch with a catchwheel (tilbakeløps-sperre) on one of the wheelaxes, so the wagon can ride in only one direction. *The movement in the other direction is blocked.* The wagons are placed with their rears against each other, after which the electric motor is switched on. If the teeth of the catchwheel have the same beat as the vibrator mechanism, the wagons roll away from each other with exactly the same speed to the end of each rail.

With this simple model time synchronization for the atom-vibrations of both departing universes (in time) by a timeless field "always existing everywhere" has been demonstrated sufficiently. At the same time a flaw(feil) comes to light. It is impossible to maintain an energy time flux of the timefield for the two departing universes, because where is then the inexhaustible (utømmelige)energy source to maintain the time-flux? (betyr det tidsustabiliteten??)

This is one of the reasons that a one-dimensional time-field is not possible. Only a three-dimensional time-field, which encloses the energy time-flux in itself, allows our universe and the others to exist.

7. The principle (mechanism) to create finity: INTERFERENCE.

So far the function of time-synchronization of the carrier-field has been considered. Now we will discuss the medium of conserving and maintaining the timeless vibration into eternity. It is the infinite force-field carrying all matter and energy.

We are at the moment of the flash or big bang, the moment at which the infinite primeval vibration limited (transmutated) itself to the carrier-field. This mechanism of blocking is well known and based on the principle of wave interference. (Interference of lightwaves is important today in laser technology.) Interference is the action or counter-action of two or more waves. If the *wave-propagation(-forplantning) is opposite and parallel* and the frequencies of the waves equal, mutual amplification (gjensidig forsterkning)or attenuation (fortynnelse) of the intensities of the wave is possible, depending on the phase relation between these waves.

If *the phases are opposite* and the *amplitudes of the waves are equal,* total quenching (dempning/kvelning)is possible. This is the principle of the binding of infinity. If an infinite wave manifests itself in one time-direction, automatically the equivalent absolute counteraction is created which counter-balances the infinity, allowing the nothing to be.

The infinite primeval wave(urbølgen) blocked itself at the moment it created itself and so it never existed in reality. It was in fact a *transmutation (forvandling) of infinity;* the transmutation of the infinite vibration of infinite amplitude and frequency to a carrier-field of infinite strength, which blocked itself by interference.

8. The time-bound vibrations or waves.

The primeval wave blocked itself in a three dimensional time-axis system (propagation directions) by interference, and trans-mutated to an infinite, timeless, immobile force-field. How could the bound timeless waves exist, which synchronize our universe?

It is an error of thinking to suppose that by quenching the omnipotent vibration - all finite waves were also cancelled. It is just the opposite. A vibration with infinite frequency is not a vibration in reality. The infinite prevented the vibration, because a vibration can only exist in the finite. As soon as infinity was removed, the prevention disappeared and the real bound wave was a possibility. It is the carrier forcefield although of infinite strength and energy density which gets its finite value due to interference quenching. All timeless waves are as it were encapsulated in infinity and therefore indestructible. However "belonging" to infinity and not bound by time themselves, they create time forever, they are the eternal ripples on the static ("krusning i likevekten"), unchangeable and loss-free field of infinite strength. (This must be what the Danish wiseman Martinus call the X2- principle and the primeval-desire or "urbegjæret" in Danish. R.Ø.remark.)

Because of this, all time-bound waves such as light, radio-waves or gravitation, exist in space without any loss and it is the empty space in the universe, which is the non-modulated structure of the carrier-field. It is one of the most fantastic touches of genius of Creation, that the non-vibrating infinity was transmutated to a loss-free medium carrying all time-bound and timeless waves. A few properties of this medium can be measured with instruments, the other part of its structure cannot be objectively observed yet, *it is the esoteric fluidum or the infinite Love-will of the Father which carries the whole Creation.*

9. The unimaginable three-dimensional time.

(Den utenklige tredimensjonale tid)

One time-axis counter-balances only one direction of time propagation of the omnipotent (allmektige)wave. In infinity all possibilities of vibration exist and therefore all time-propagation directions. The question is, could infinity be limited by just one time-direction and one co-existing propagation direction going the opposite way?

One way to answer this was already given in the previous paragraph, in which it was stated that the energy time-flux of the primeval wave of two universes is not a closed system. Another plausible answer can be by simply reasoning.

The atom is causal for the time - and space dimensions, due to its time-creating properties, already mentioned. *The space-creating properties are easy to understand, because the atom takes up space.* It is three-dimensional in space and therefore it creates space in three dimensions. If all atoms were two-dimensional then the whole of creation would have been on a plane and space would not have been more than a flat or curved plane(as on a sheet of paper. R.Ø.remark.) Our time-space is no more than a bound part of the nothing (det "noe som er" -X1- som Martinus kaller det. R.Ø.remark.) - being filled with matter or energy. Anything that space distinguishes (utskiller) of the time - and - dimensionless void, is caused by atoms or energy. If atoms have three space dimensions, then the timeless waves creating the atoms also have three dimensions.

1. The timeless primeval atom-field has three time dimensions.

2. The timeless waves could not be bound by only one time-axis, but must necessarily have three time-axes.

3. The timeless atom-field should consist of a three-dimensional rotating field of infinite strength, which is attenuated (fortynnet) of itself by interference. It conserves

the law of cosmic counter-balance of the no-thing. *The atom of such a rotating field structure has six time-axes, but in principle these six axes can always be reduced to three time-dimensions, no further reduction is possible.*

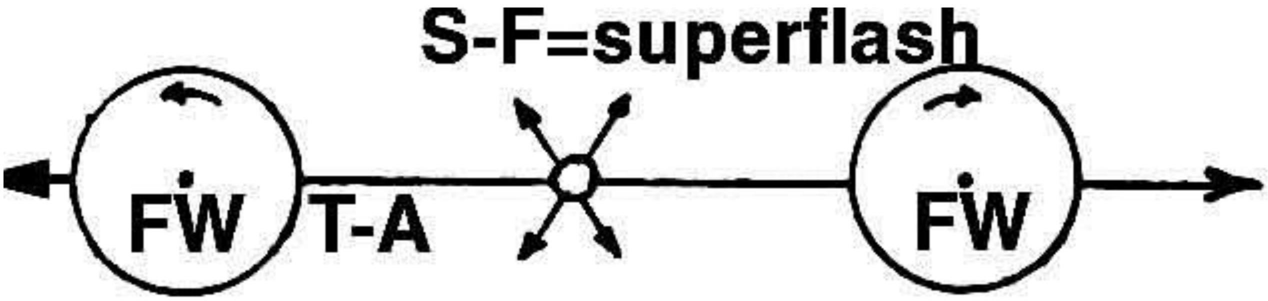

Picture of ONE-TIME-AXIS: The cosmic symbol of one time-axis.

In the following parpagraphs of the analog carrier-field model it is shown, why the atom-field has to be a three-dimensional and not a two-dimensional field.

10. The six time-axes of the time-creating, cosmic carrier field.

How can it be established that the carrier-field of all matter in twelve universes has six time-axes? The first part of the answer is simple to explain. *A well-known type of rotating field on earth is that of the electric three-phase synchronous motor.*

This type of electromagnetic-field system consists of three linear magnetic fields, which are arranged at angles of 120 round a rotor. The phase-differences of the three alternating magnetic-fields, which have the same frequencies (say 50 Hz) are also at each 120 degrees. Each alternating field is in itself an exact linear vibration oriented in one direction. The rotating field exists only if the three linear vibrations are combined together with the proper phase-relation between them. So a two-dimensional rotating field in space is created. It can force a piece of magnetic material to rotate around its axis with a great power.

Insert pict of motor

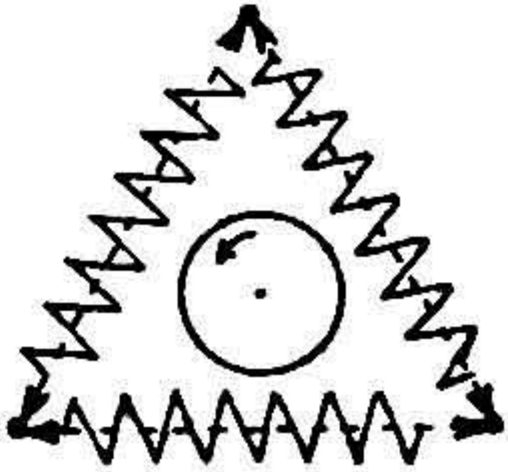

The principle of an electric three-phase synchronous motor.

The fact that it is possible to create rotating fields by combining three linear alternating waves does not mean that it has to be the same for fields of infinite strength, it can be more than three, but it is not very likely as first guess, because the three wave principle (the equilateral triangle) is the most simple and effective. According this principle, for a three dimensional field six linear waves are required to form an *equilateral (likesidet) triangular pyramid,* but why an angle of 60 degrees between time-axes?

The first answer can initially be given in a very simple way, the second is more complicated, but at least more to the point.

A simple way of reasoning to derive (utlede) the answer to the question of 60 degrees is the following. The atom field of matter has spatial (romlig)structure, therefore the time-axes must be positioned in such a way that they form a closed three-dimensional geometric object, because the energy fluxes of time must be closed in itself due to the law of counter-balance.

The time-axes form straight lines, which cannot be parallel lines, because parallel time-axes form one and the same time-direction. *The most simple three-dimensional closed object is an equilateral triangular pyramid.* There are no reasons to suppose it should be an a-symmetric pyramid if three-dimensional time is considered, on the contrary, it must be symmetrical in all positions. So it is simply a equilateral triangular pyramid of which the lanes are equilateral triangles. There is no more simple object in three-dimensional space with these requirements.

The more sophisticated answer to the question of 60 degrees is time given by approaching the question from the relativity of time frequencies between the other universes (the other time-axes). Time is the wave propagation of atoms which determines the direction of the past to the future.Simultaneously these time-creating or timeless waves are the linear phase waves combining to maintain the atomic rotating field. The problem is that "our' atoms do not experience the right frequencies of the other time-axes, because they do not propagate (spredes)with the same speed, but advance in time.

Thus there is an apparent frequency-shift, a kind of Doppler shift, by which the frequencies of the "other" time-axes are experienced by "our" atom. One should realize that the timeless vibrations of the other universes also exist in our universe.

At first sight it seems impossible for a rotating field to posess a constant phase-shift because between vibrations of different frequencies a constant phase-shift is not possible unless the frequencies are related to each other in a particular way. They are harmonic. Two vibrations are harmonic if the apparent frequencies have constant ratios to each other, like 1:2, 1:3, 1:4, etc.

Timeless waves can only exist when the frequencies are related by the harmonic ratio 1 : 2.

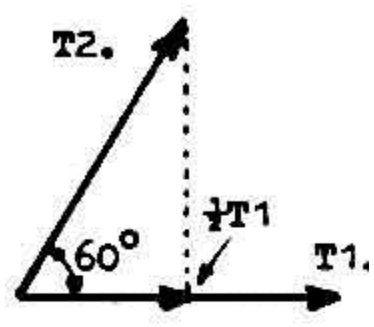

Picture explaining the frequency-shift for 60 degrees time-axis angle.

The frequency ratio is determined by the angle between the two time-axes, as the picture shows. Our time direction is T1 while another time direction is shown as T2. The time direction propagating forwards (from past to future) is useful to our universe, while the backward-moving impulses of the timeleess wave do not "catch" the rotating field of "our" atoms. Secondly the time-axis at a right angle (90dg) to our axis T1 does not make any contribution, we experience this time-axis as non-existing.

As the picture shows, due to the angle of 60 degrees, 'our' atom experiences exactly half the time-speed of the other time-axis and this makes the frequency harmonic. As T1=2 times T2, the result is the simplest harmonic ratio of 1:2, determined by the angle of projection of 60 degrees between two time-axes. (Pythagoras' law for right angled triangles).

All other possibilities and other harmonic ratios fail to give non-destructive contributions for the necessary interference intensification. Other excitations of higher order harmonic ratios give more complicated time-axes structures of the rotating atom field and cannot be stable. Also because the couple-field feedback to the total mass (inertia) of the universes is not optimized (see the following paragraphs).

It supposes simultaneously the existence of a higher number of co-existing universes, which seems highly unlikely (usannsynlig)(higher than twelve). Therefore we must decide for the simplest three-dimensional geometric form: the equilateral triangular pyramid.

11. The ancient symbol of God, the Star of David.

It is necessary to summarize the above issues of the principle.

1. The choice of the mechanism of limitation determined the existence of all types of timeless waves, among which was the (most complex) three-dimensional rotating time-field.

2. The limitation took place by interference quenching (forstyrrelses-dempning) the primeval infinite vibration (possibility) affording more time-axes in three dimensions.

3. A time-axis is a part of the infinite force-field. This only exists as a single linear vibration.

4. For a three-dimensional rotating field at least six linear field waves are necessary, which are located spatially in time having angles of 60 degrees between the time-axes.

5. The angle of 60 degrees could only be created by an apparent frequency shift maintaining the harmonic vibrations of the rotating field.

These considerations determine the mechanism of blocking the infinite. It consists of six time-axes forming a closed three-dimensional object, which creates and restricts the speed of the rotating atom-field.

Though every time-axis carries two universes(universe and anti-univers), there are in the frightening depth of cosmic space twelve distinct cosmic structures, separated by the unbridgeable barrier of time. Not only are there eleven other universes apart from ours, *but they are all embedded in the same cosmic or geometric space*. All universes have the same size and the same energy content. The geometric space is necessarily the location in the nothing - in which the omnipotent vibration quenched itself by interference. It is the location for waves encountering each other, as it is for light-waves interfering with each other. But it does not require that every atom has twelve buldges at the same space-point in time. Or more crucially, it does not mean that every human being has twelve images of himself without knowing it.

It is the mechanism of interference synchronisation of the timeless waves which uncouples the universes at each space-point, simultaneously maintaining the time-propagation of each universe.

*The equilateral triangular pyramid is the symbol of God, the Father as it is known everywhere in the universe (after lifting the cosmic isolation).*We know it as the double equilateral triangles of the Star of David, also six time-axes with angles of 60 degrees. It means that the principle of the limitation was revealed to humanity centuries ago, but we did not understand its meaning so far.

make in your thoughts : The Star of David.

Technical information given from the IARGA contactteam.

their describtions on the matter of TIME

- AND MORE

picture is described later

12. The analog carrierfield model, an instruction model.

The cosmic carrier field of all space and matter performs a sixfold function, of which some have already been discussed in gereral way.

1. The carrier function of an infinitely strong forcefield blocked in itself contains the fluidum conducting all waves without dissipation and maintained to eternity.
2. The orientation of the time-axes of the universes with respect to nothing provides the structure of the carrier-field of three dimensions, the bounded Love-will, creating our life and existence.
3. The time synchronisation function locks all universes in the iron grip of the law of cosmic counter-balance from which no atom can escape.
4. The feedback principle of time to the total mass of the universe is the function of the coupling-field by counterbalance (and interference) of the time-bound waves.
5. The function of the timeless primeval atom-field, the atom-principle, as the transmitter program containing the code of matter of which all atoms are remote manifestations.
6. The function as bearer of the absolute ALL-knowledge and goal consciousness, manifesting itself as the laws of nature and as the intelligent goal of life: the spirit of God.

The last function concerns the existential aspects, which have been discussed in the previous section of this book.

The first analog model is a mechanical instruction model explaining the cosmic carrier field by means of symbols. This model was built on another life-supporting planet on a high mountain and was many meters high. It was the gathering point for contemplation of that intelligent race for devotion to its Creator.

It was the symbol by which the majority of the race acknowledged the goal of Creation, simultaneously the sign that the cosmic isolation had been lifted. The other function of the carrier-field will be discussed with the help of this mechanical instruction model.

The analog model consisted mainly of the six edges of a huge equilateral triangular pyramid built out of solid soft-iron bars. The many metres thick edges of the pyramid contain an impressive number of iron bars parallel to the direction of the edges and cast in a kind of plastic resin following a process similar to that of casting concrete(betong). So a mainly iron-frame was formed especially suitable for conduction of magnetic pulses of high power without much loss.

So far the carrying fuction of the cosmic time-field, which primarily maintains the timeless waves is symbolized in the model. The magnetic pulses in the edges of the pyramid run backwards and forwards like the timeless waves in reality.

With respect to the other edges of the pyramid, the magnetic pulses are phase-shifted. The problem is that up to now the forward propagation (forplantning) in time has been missed out. In fact we look for the equivalent of the two little wagons on the vibrating rail. The solution can be found in the symbol of the rotating flywheel, as *with the atom its rotation is continuous in time, it is in fact time propagation.* Therefore the iron frame of the pyramid is discontinued at two places in each of the six edges of the pyramid. At this discontinuation point a linear magnetic impulse motor is installed, on the axis of which a large flywheel is mounted.

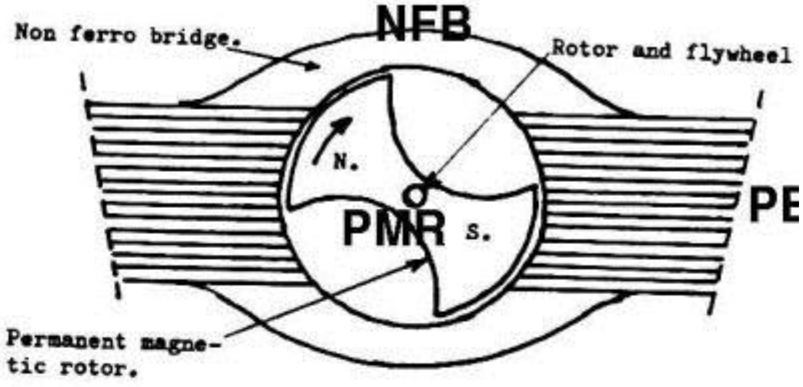

NBF=NonFerroBridge

PE=PyramidEdge and soft iron bars

PMR=PermanentMagneticRotor

The flywheel symbolizes not only the propagation of time, but also the inertia of matter and so the flywheel is in effect the total mass of the universe. This type of magnetic impulse motor is not self-starting, so at the inside on the flywheel axis a starter-motor is mounted, fitted solely for the purpose of starting. One rotating the synchronous motor maintains the exact number of revolutions at the same frequency of the magnetic alternation field. Thus in each of pyramid's edges two synchronous motors are mounted making twelve flywheels in total.

The two flywheels per axis rotate in opposite directions to symbolize the time propagation in opposite time directions. This type of linear impulse motor is chosen because it can be made to rotate in either direction.

The first analog model.

In one triangular plane of the pyramid the six synchronous motors in the iron frame demonstrate a rotating magnetic field, seen from the center of the plane. Each edge of the pyramid has the right phase-shift with respect to the other edges of the triangle.

The first model has four central rotating magnetic field generators in the middle of each triangular plane. (See figure of unfolded pyramid indicating the actual phase-shift).

These four synchronous (three phase) generators are coupled together by a gearbox and are driven by the main electric motor (not shown in the drawing). Consequently the four three-phase generators fulfill the synchronisation and constant phase-shifts for the flywheels of the pyramid-edges. The four separate rotating fields together, initate the complex three-dimensional rotation of the carrier field (or atom-field).

The disadvantage of the first model is that it is further away from reality, because the atomic field is not symboized as one three-demensional rotating field. However it shows better how to imagine the complicated rotation in three dimensions.

The second or the real analog model.

This mechanical model has only one central generator in the middle of the pyramid, instead of the four rotating field generators of the first model. All magnetic waves in the pyramid edges go straight to the pyramid's center. The rotor of the 3-dimensional rotating generator is like a yo-yo with spherical end-surfaces.

It requires a touch of genius to provide the drive-connection between the central motor and the spherical rotor, which has to be started up in a complex rotation. The six diametrically opposed pole-shoes from the middle of the pyramid's edges around the spherical rotor form in pairs, three axes of right angles - representing a Cartesian coordinate system. So it shows that the six time-axes of the edges of the pyramid can be converted into the three principal time-axes of the central sphere.

Together it imitates three-dimensional time, which causally creates the three-dimensional space of our universe.

The principles of the first and second analog models are equivalent. One version can be converted into the other, for example, converting the four rotating fields to one three-dimensional rotation in the centre-mass of the pyramid.

The model can be started by switching on the thirteen drive-motors. As the flywheels reach velocity the twelve starter-motors are switched off and only the central motor drives the complete gigantic model. The essence is that all flywheels have exactly the same number of revolutions. They are all either synchronous motors or generators. Then the flywheels are marked and illuminated by a stroboscopic flash light. *Seen by* *the normal eye they do not appear to move showing the synchronous rotation and the constant phase-shifts between the flywheels.*

These mechanical models are meant to explain the unimaginable Creation out of the nothing by symbolic imitation of the carrier-field. However it is only a weak symbol of Creation. The carrier-field is the esoteric medium, a transmutation of the absolute spirit or conscience, it is the spiritual force field of infinite strength which is present everywhere in the universe.

The imitation of the carrier-field functions.

Nevertheless the analogy of reality is incredible. This will be shown in the next explanation of the five functions of the cosmic carrier-field.

The carrier-function

The foundation of the carrier-field is the infinite force-field created by interference quenching (avbrytende stopp) of the original infinite vibration. The mode initiates this force-field with the six bundles of soft-iron bars as the edges of the pyramid.

As in reality, the three-dimensional magnetic rotating field in our model is caused by the linear waves of each time-axis. *The timeless waves alternate backwards and forwards as in our model*. They drive the flywheels representing the masses of the universes, and their rotation is the propagation (spredning) in time.

The orientation of the time-axes with respect to the nothing.

The relative position of one time-axis in the apparent nothing plays an important role in the orientation of the universes in reality, determining the direction of each time-axis. Here the first model is shown representing the four three-phase synchronous generators in the planes of the pyramid. Only with decompostion of the three-dimensional rotation into four rotations can one show that the three-dimensional rotating field has left no remaining component in the nothing, while in contrast a two-dimensional rotating field can not be nullified, a remaining component will always exist in the nothing. This can be explained by considering a single plane of the pyramid with its six flywheels at the edges, the analog for a two-dimensional

carrier-field. The rotation impulse of the flywheels is compensated by the opposite rotations but the rotation impulse of the central three-phase generator is left over. It can be measured by the outside world (the nothing).

It requires four field three-phase generators (maintaining overall symmetry) to compensate for these rotation impulses.

With this the three-dimensionality of the carrier-field has been shown and the orientation of the time-axes with respect to the nothing is determined.

The time synchronization function.

Impressively the model imitates the time synchronization, simultaneously maintaining the cosmic counter-balance by which the universes continue to exist. The rotation of the two flywheels per axis is in opposite directions and they rotate with exactly the same speed. Thus it imitates the circular motion to the timeless waves which progresses exactly synchronous by their mutual interference coupling.

The twelve cosmic systems run without any dissipation, once started, the perpetuum mobile continues into eternity with the absolute accuracy of time-synchronisation. If one supposes the model to be without loss and without using the eternal driving motors, it will continue to run synchronously due to the inertia of the flywheels and the fact that the synchronous linear impulse motors can function as generators as well.

This symbolizes another property of the continuous circular motion of the timeless waves, because every wave somewhere in the pyramid circuit at each moment has its opposite value resulting in an overall zero at any moment.

This is the law of conservation of the nothing.

The couplingfield function.

Time synchronization is not alone determined by the iron grip of the three-dimensional carrier-field and the principle of cosmic counter-balance. Apart from this an important effect is realized from the feedback of the gigantic masses of the universes to the timeless waves. These masses can be considered as enormous flywheels without loss. Once started by the super flash, no change in speed is possible, because a force of sufficient magnitude is simply not available. This function of the coupling field can also be shown in our model, because the linear synchronous motors of the flywheels are also generators. If the central driving motor is switched off, then the flywheels continue for some time to drive the central three-dimensioal rotating sphere. Everything stays exactly synchronous with the same phase-shifts.

This experiment shows how the flywheels feed their energy back and have a stabilizing function in time-synchronization. The coupling-field of the masses of the universes is fed back in the time-bound vibrations of the atom-field from which no atom total mass of the universes is fed back to one single atom.

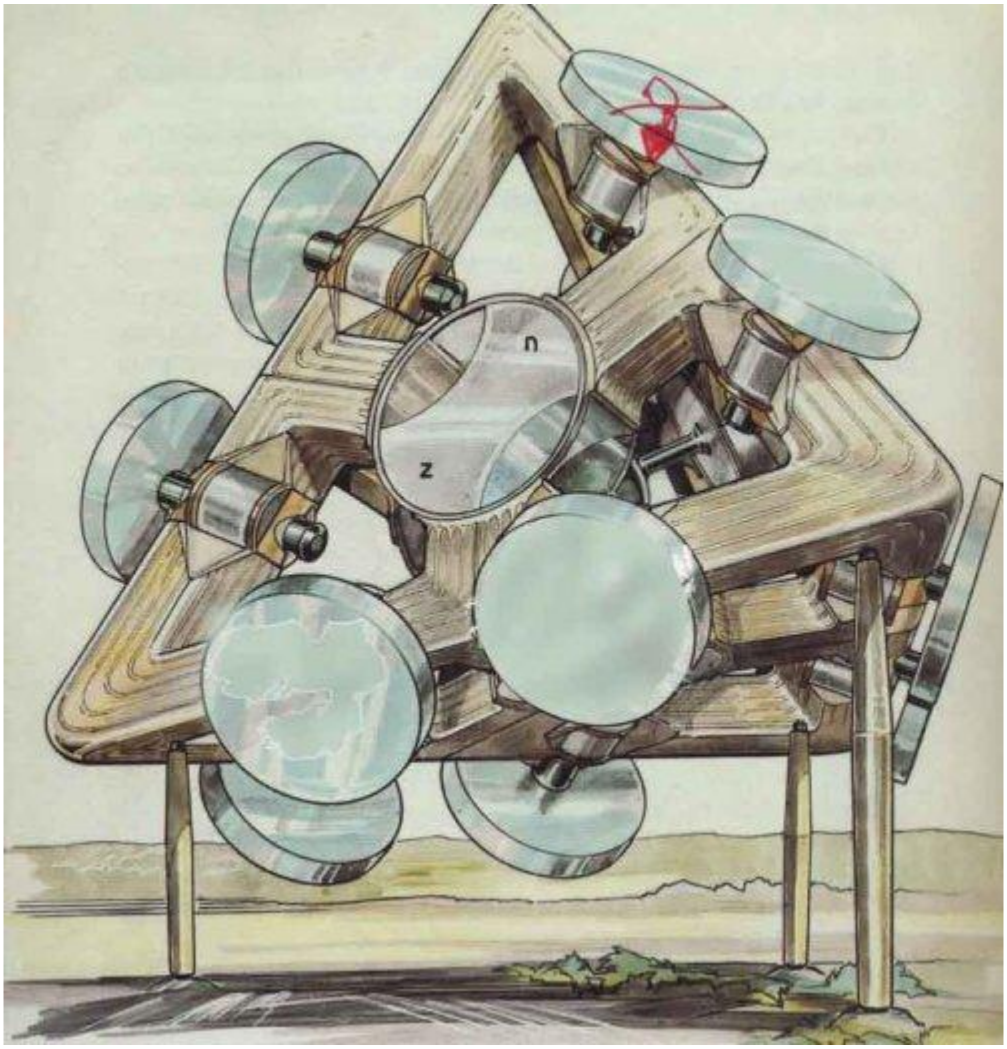

This is a painting by Rudolf Dass of the analogous visual-mechanical carrier-field model which symbolizes time and matter creation and synchronization in twelve universes. This giant working construction that was a cross between a monument and a machine was seen on an artificially flattened mountaintop on **Iarga**. This place was perceived as a place of pilgrimage, a place of meditation and contemplation, and the machine was a symbol of creation. The **Iarga**ns know no separation between science and religion, and religious and spiritual theories are entirely scientific. The model was several hundred yards(meters) long. The machine seemed to operate by some kind of perpetual motion, neither running on fuel or electrical power.

The Instructional Analog Model

The mechanical instruction models are the visual representations of the principles of the cosmic unified field theory. The model is intended to demonstrate that time, matter, and energy are creations out of the nothing and therefore the counter-balance has to be maintained to allow the causal infinity of the nothing to exist. In a broader context the physical symbols all take on new meaning and demonstrate the unification of science and religion. In a religious sense the spherical three-dimensional time-field in the heart of the pyramid symbolizes the Soul of the Creator. The pyramid symbolizes his infinite lovewill, the cage in which the infinity of His existence has been blocked irrevocably. The lines symbolize the different frequencies of the timeless waves. The flywheels on the edges of the pyramid symbolize the twelve associated and interrelated universes, including ours, that make up this unity. One cannot exist without the others.

The timeless primeval atom-principle, the transmitter function.

The atom-field is a time-creating field and as such a remote manifestation of the primeval atom principle. It can be compared with a transmitter. As soon as the program is converted into waves of great power, billions of radios can receive the same program, the number is unlimited. Everything depends on the one program of the transmitter, the primeval atom-field. If this exists with infinite strength, it is at the same time the vibration medium (the carrier-field) which helps it to spread everywhere. *Thus any atom in any universe can receive the timeless basic program.* The second model shows the three-dimensional time-field of the primeval atom field most clearly, although this is a three-dimensional rotation of the central sphere in spatial sense. This is an analog of reality, the atom has a spherical field which is defined by six linear time-vibration directions. Any atom is a remote manifestation of the one carrier-field of infinite strength.

Considering this fifth function of the carrier-field one has to realize that only the central sphere, the atom, is visible to us. The fields in the pyramid edges outside the sphere are invisible. It is the time-field reality of which the atom is a reflection.

The mechanical instruction models are the visual representations of the principles of the cosmic unified field theory. This requires however some marginal notes. A material comparison to explain spiritual abstractions is always in some ways incomplete. There are several hiatus of which only the three most important ones are mentioned.

1. In the model one time-axis represents only *one frequency* of the magnetic field, while in reality all frequencies are contained. Every frequency however can be initiated for each time-axis for which the interference representation of the analog model is valid.

2. The model demonstrates the rotating field of the *timeless waves.* It *does not imitate the time-bound waves* by which our time-axis the propagation speed of time is X, then the phase velocity of the two time-axes connected to "our" pyramid edge is ½X. The other two time-axes connecting our time-axis with the other corner of the pyramid is -½X, making up for the time speed of our anti-universe -X. The crossing, not-touching time-axis is perpendicular to our time-axis and does not contribute.

3. In our model the masses of the universes are given by the flywheel symbol. In fact this is *fundamentally wrong, because it is separated from the three-dimensional rotation of the central sphere.* It can therefore basically not maintain the counterbalance of the nothing.

The most important conclusion of the analog model is that *time, matter and energy are creations out of the nothing and therefore the counter-balance has to be maintained to allow the causal infinity of the nothing exist.*

14. The existential symbolism of the model.

So far the physical aspects of the model have been unravelled, but if one wants to give a wider context to the model suddenly all the physical symbols change their meaning. In relation to philosophical or theological disciplines the model takes on the additional meaning of the unification of science and religion. By certain inherent (medfødte) laws within any intelligent race the denial of God's existence will be destroyed sooner or later. Earth science will provide an indestructible contribution to our final knowledge-awareness, which we shall attribute as typical human attainment in the cosmic integration. It is that piece of our human identity and self-awareness, which we shall possess and care for throughout eternity. *It the light of this purpose, science serves God and the distinction between science and religion fades away*.

In a religious sense the spherical three-dimensional time-field in the heart of the pyramid has a special meaning. **It symbolizes the Soul of the Creator**, the Father who is the pure Identity of the infinite origin. The pyramid symbolizes his infinite Love-will, the cage in which the infinity of his Existence has been blocked irrevocably. He sacrificed his Ego and his freedom, to love his twelve Sons once. He is present only indirectly in his Creation as the reflection of the infinity, the Supreme Being, as the one Ego-consciousness of the Archangels.

That is why the theologian covers the central sphere with pure gold, symbolizing the golden Heart, the Holy of Holies, the most sacred secret of the universe. The pyramid is then painted dark red, the universal colour of love. Over the red many thin golden stripes run in the direction along the pyramid edges. These stripes symbolize the different frequencies of the timeless waves, the expressions of Love and faith of the Father and his infinite Will.

Gathered around the golden Heart are the twelve flywheels, coloured white, the colour of purity and innocence. The model shows that every universe has the power to awaken the matter-consciousness and to transform it to the new God: the Son. The goal of Creation is therefore the awakening and the formation of the twelve Sons of the Father.

This is not in contradiction with the Bible telling us that the Father sent his only-begotten Son. The Bible is solely directed to man. It is our instruction book for life describing our attitude towards God and our fellow man. The Bible does not tell anything about life on other planets, because it is not relevant in our relationship with God now.

The same goes for our parallel universes. In fact they do not exist for us, because they are not in our world of existence but somewhere else. They do not exist for all intelligent races in this universe, we shall never be able to observe them nor experience them in any way. Perhaps at the end of all time we shall meet.
In *our* world the Father has one only-begotten Son and this truth is already so unimaginable that nobody can conceive the consequences yet.

END OF IARGAN DISCUSSION

Stefan Denaerde

Cosmic Unified Field Theory.

How it started.

More than 25 years ago appeared an amazing book in the Netherlands: ´Buitenaardse Beschaving´ (Extraterrestrial Civilization) from Stefan Denaerde. (Known in English as : "UFO contact from planet Iarga") It describes the confrontation of the author with the race from the planet Jarga (Iarga). It was written as a novel (although it is a true story) and illustrated by a well known Dutch technical illustrator (Rudolf Das).

Sailing with his ship in Dutch waters, Mr. Denaerde (not his real name) bumped into something which was hidden underwater. When he sees someone floating in the water he comes to the rescue of what later appears to be an astronaut. This rescue was a test for him and after the initial shock he gets in contact with the Jargans who invite him for a three day learning session inside their submerged saucer.

Via a 3D screen and a radiation ´head set´ he learns about the Jargan culture, philosophy and technical achievements. Through the concepts of extreme efficiency and justice he is taken to the Jargans love for the Omni-Creativity (our word for ´God´ is too poor) and their striving to be one with it.
This ´carrier field´ of the Universe supports everything (matter, time, consiousnes), and by applying this knowledge it makes interstellar space travel possible.
It appears that the goal of a civilization is to create a socially stable supercivilization. Discriminations of any kind no longer exist. Resources and wealth are available for everyone, but not as a goal as such, but to enable everyone to grow spiritually.

There is much more to this book. Anyone interested can find an interview with Denaerde by Wendell Stevens, as well as several chapters from the book on this link. (This also contains the 2nd book of Denaerde!)
From this interview it appears that the contact has continued for many years in telepathic form. A lot of highly technical information has been given in this way, which resulted in the second book:

The Universal Creation. (In Dutch: ´de Universele Schepping´)

This appeared about 20 years after his first book. It describes in one theory the origin of the Universe, matter, time, consciousness, the Universal goal for any civilization, the history and possible (very bright) future of mankind, in one word : a TOE (theory of everything).
The atmosphere of the book is totally different: the first book had something like ´you don't have to believe this has happened, it could be hypothetical´. The Universal Creation is much more direct and confronts us with a direct proof of its contents, because the authors (Stefan and his ´brother´ Christian Denaerde) express that it is high time that science and religion are united again.
The Universal Creation comes with an appendix ´Cosmic Unified Theory´- in English!- which goes into much detail about the new physical model. Recently this information is available on CR-Rom, to be ordered at the Cosmic Field Paradigm foundation. This essay is mainly about the appendix and the CD-Rom.

The creation out of the nothing.

According to the Cosmic Field (CF) model there existed prior to the creation (or big bang) vibrations of infinite frequency and amplitude in every time direction.
The act of creation was the blocking of the infinite waves by interference to form waves of finite frequency and amplitude. In order for matter and energy or anything to exist, there must be an equal counterbalancing vibration. Also time direction has to be counterbalanced. Think of a time axis as two pieces of mini model rail which are connected via a motor, which can move the rails back and forth say over 1 cm. If you place a wagon

on one of the rails which has a catch wheel that catches only the forward movement of the rails, you will see the wagon move forward. Another wagon, placed in the opposite direction on the other rail will also move forwards, thus the two wagons will separate from each other. So the rails can be seen as a time axis, where time moves back and forth. The wagon represents matter, which can only catch one time direction through a property called spin.
One time axis is not sufficient: to counterbalance everything and to cause a a feedback mechanism a 3D time structure is needed in the form of a tetra-eder.

Fig. 1 The carrier field model

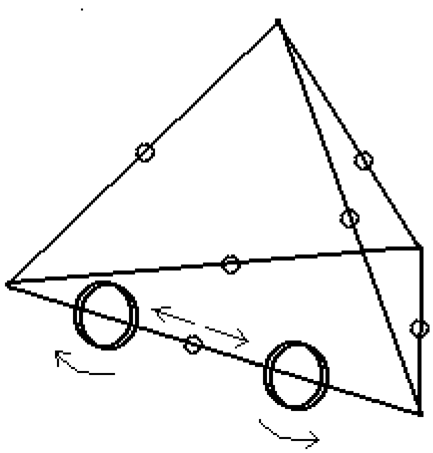

6 time axes form a closed loop. 12 universes are separated by time direction.
The spin of matter is represented by the two flywheels (only shown for one time axis)

This implies that there exist 6 time axes (each with a back and forward movement in time) and thus 12 universes. These universes cannot be seen, but some aspects like the time frequencies can be sensed by our atoms. (BTW, this might explain the missing mass problem in cosmology: our universe still senses the mass of the other 11 universes, that is why 90% of the mass is unexplained..)

The picture shows the arrangement of the time axes. The center of each axis (depicted by a small circle) can be considered as T=0. The two flywheels (drawn on one axis only) represent the spin direction of matter. In our direct anti-universe (on the same time axis) the direction of time is opposite, but also the spin of the matter particles. This means that everything is mirrored, and living beings in the anti-universe experience time as moving forward, just like we. In fact time moves in two directions along an axis, but matter has a sort of rectifying effect - it only picks up the forward going time.

The 60 degrees angle between the time axes is necessary to have an harmonic ratio between our time axis and the time axis of the other universes.

Fig.2 2 time axes at 60 degrees

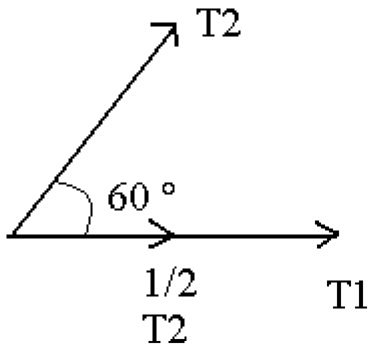

Only at this angle there can be a harmonic ratio between the time creating frequencies. An atom on our time axis T1 experiences the other time axis at half the frequency.

Our time direction is T1. Another time direction is T2. The angle of 60 degrees makes T1=2*T2, thus giving an harmonic ratio of 1:2.

The carrier field model has several functions, such as:

It is an infinitely strong force field, blocked in itself. It is a loss free conduction medium for all waves. The counter balancing of everything implies that the universes are locked in an iron grip: the spins in one universe are exactly the same and opposite to the spins of the anti universes. It also means that there cannot be one atom more in a universe, which is not present in the 11 other universes. (this does not mean that all the 12 universes have to be the same).

The model is also an image of the universal atom: When applied at a very small scale Denaerde explains the basic building blocks to form matter.

The flywheels can represent the total mass in one universe or just the mass of one atom. The 3D time structure of the pyramid is present in all matter: you could imagine the center of the pyramid being in a star, a galaxy, etc. The 11 other universes are not observable, but they could occupy the same 3D space. The model demonstrates beautifully that matter, time and energy are just properties of one universe (1/12th of the whole). Summing all the properties of the pyramid results in nothing. (The big bang theory fails to explain where the initial energy came from)

The Double rotating central bar.

Denaerde introduces the concept of a magnetic bar, which touches 2 opposite ribs in the pyramid. This induces a flux in the loss free time axis. This is a very important concept and it takes a while to understand it. The bar needs to rotate around two axes simultaneously (Fig. 3) in order to create alternating fluxes in the pyramid ribs (which still represent time axes). The rotating movement repeats itself in 6 time-steps.

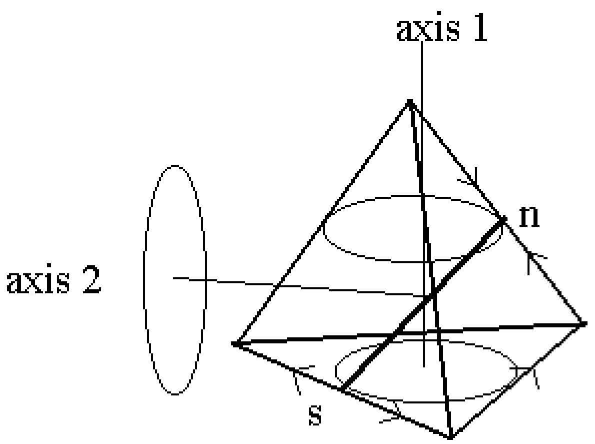

The simultaneous rotation of a central magnetic bar around 2 axes gives alternating flux patterns (time directions) in a pair of ribs. This process is repeated in 6 timesteps.

Fig.3 Double rotation of a central bar

Denaerde calls this configuration a building element. Next we will see that from these building elements one can derive the fundamental elementary particles : electron, quark and neutrino.

The two fundamental building blocks

By adding the initial building block at different time steps (adding three bar rotors) it can be derived that there are two possibilities. These are called central rotors of the first and second kind. (figures 4 and 5). The central rotor of the first kind gives a fixed alternating flux pattern in the ribs of the pyramid. (Try it out!)

Fig. 4 3 building blocks at different time moments are added

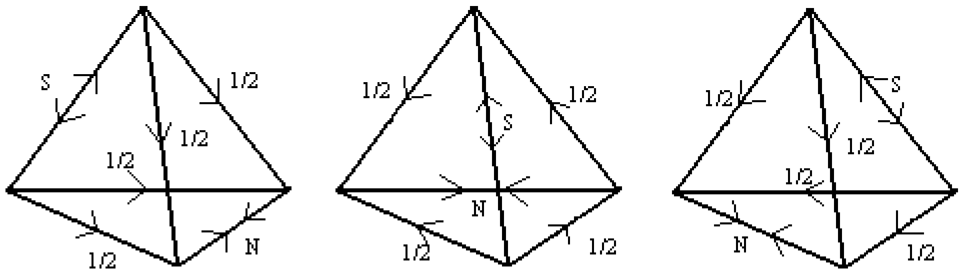
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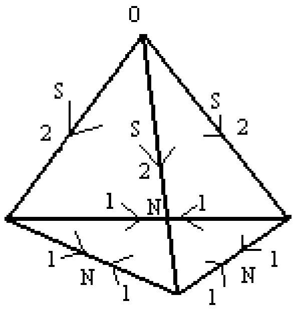
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The total return flux gives a new building block: a rigid central barrotor of the first kind. The zero node does not change its orientation. In a next timestep the flux pattern is reversed, but the magnitude is the same.

This model describes the ELECTRON.

Fig. 5 The rigid central bar rotor of the second kind

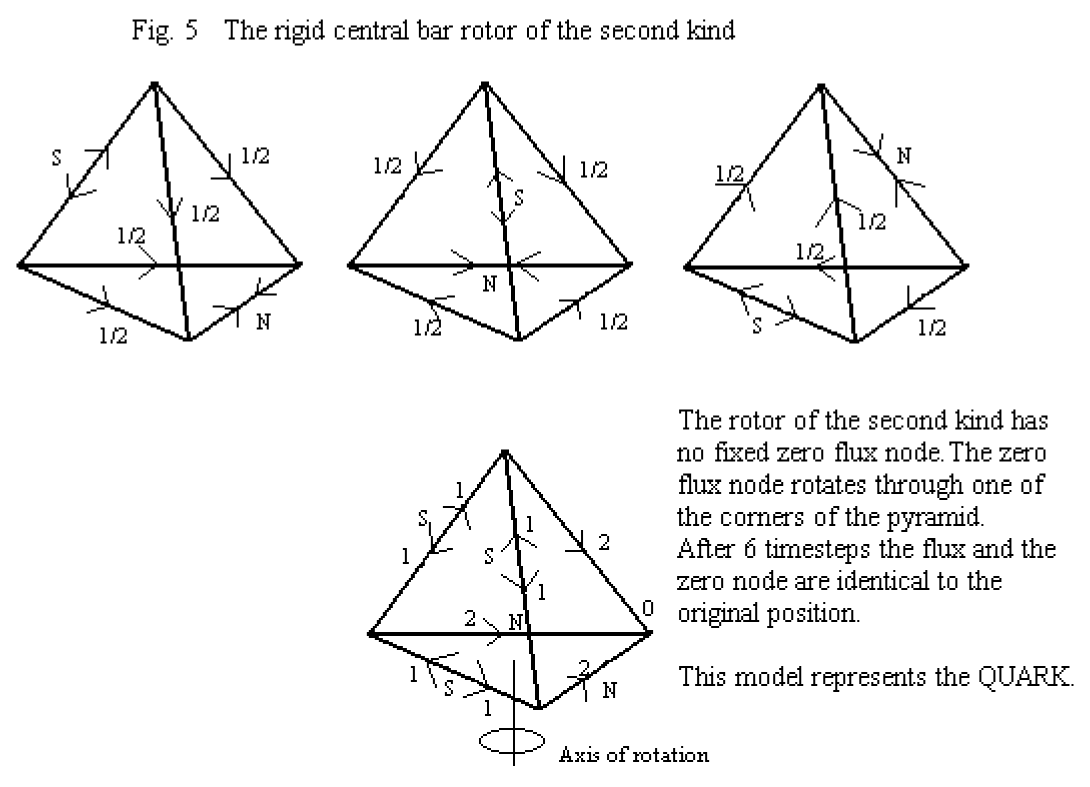

The rotor of the second kind has no fixed zero flux node. The zero flux node rotates through one of the corners of the pyramid.
After 6 timesteps the flux and the zero node are identical to the original position.

This model represents the QUARK.

The second possibility is called a central rotor of the second kind.

The rotor of the first kind is similar to the ELECTRON.
The rotor of the second kind is similar to the QUARK.

Don´t forget, the pyramid ribs represent time axes. (Note: Denaerde uses capitals to distinguish from the real particles in 3D space.)

Three QUARKS added together give a PROTON. (Figure 6)

Fig 6 Quarks, electron and H atom

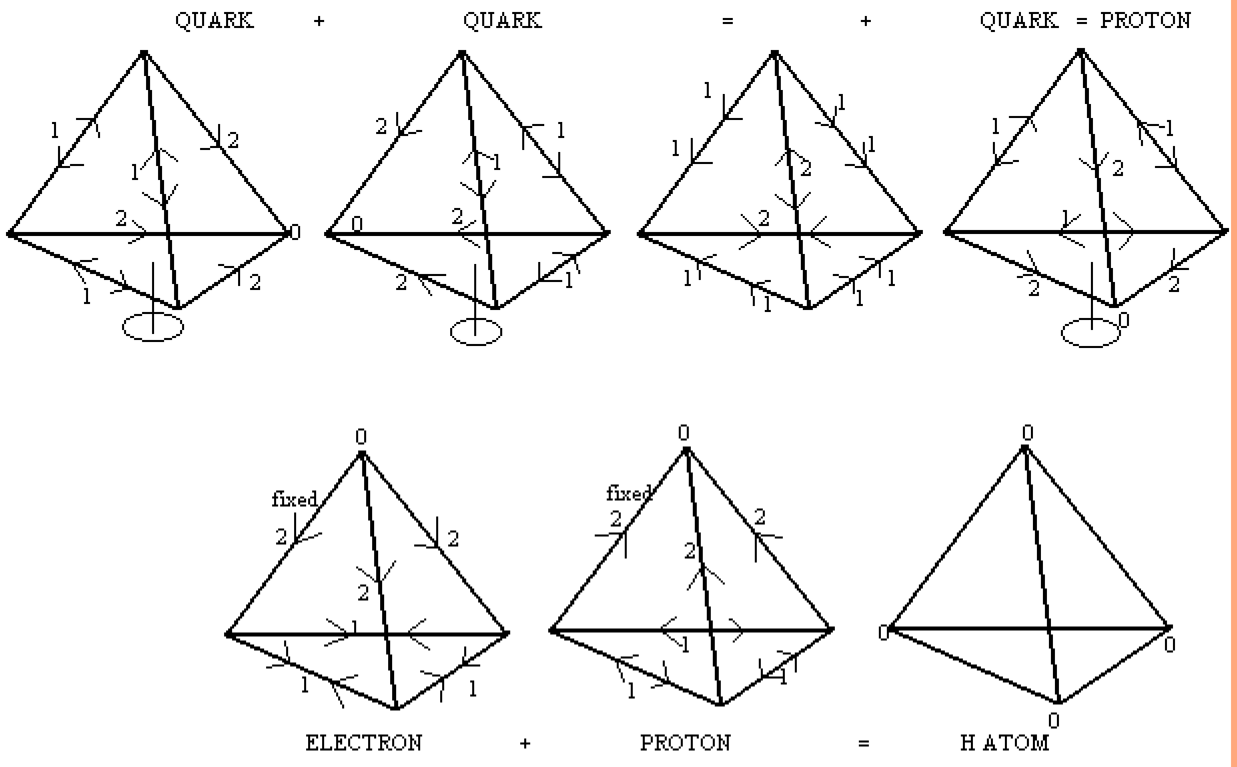

A QUARK and an "anti time" QUARK or the ELECTRON and the "anti time" ELECTRON (positron) can be distinguished by the c.w. or anti c.w. rotation of the central rotors. Dipoles of opposite rotation destroy each other.
Fig 6 shows that adding the PROTON and the ELECTRON gives the neutral H-ATOM.
The mass difference between electron and proton can be explained by different rotation frequencies of the dipoles.

Denaerde then continues to describe several NEUTRON groups which can be formed. This is rather complicated and requires a lot of pictures to visualize, so I would rather skip this. (For anyone interested, I strongly recommend to order the CD!)
The outcome is, that the NEUTRON in the Carrier Field model has 4 QUARKS.
This gives a NEUTRON with a zero external flux. The model explains why the neutron is not stable in free space, while the electron and proton are.

It can easily be seen that to the CF model a QUARK has a unit of charge of 1/3 of the ELECTRON, if charge is defined as the external flux in the pyramid ribs. Charge is related to a symmetry axis of the pyramid. The CF model predicts that charge is not constant in time and that there are two types of charge for a matter particle (e.g. electron): North and South charge. Due to the time switching mechanism we don´t detect this.

A NEUTRON consisting of 4 central rotors of the 2nd kind can be converted into a PROTON (3 rotors of the 2nd kind) and an ELECTRON (1 rotor of the 1st kind).
What is left over is the NEUTRINO : a free dipole in the carrier field.

In order for the particles to exist in space and time, a grid is needed which carries the complex flux patterns. Denaerde comes to a grid consisting of two pyramids stacked together. The top one is inverted and rotated 60 degrees, while its top touches the base of the other pyramid (sunken). The size of the pyramids is in the order of h (Plank´s constant, normalised to length). All particles have more or less the same size in parametric space (space as we know it).

Further Implications

We come now to the more profound meanings of the model. This subject I describe very condensed (without further proof, although the subject is described in great detail in the appendix).

The double rotating central bar has an additional degree of freedom. This results in a second gravitational field, which we cannot directly observe. So there are two kinds of gravity.
The CF model talks about ideal Black Holes and White Radiators. Black Holes have a function to stabilize the universes. As said before, the mass (energy) in all 12 universes must be exactly the same. Still the mass distribution can be different, but only thanks to black holes. B.H´s and W.R´s are present in the corners of the pyramid frame. In one time step, our time direction faces the Black Hole, while our anti-universe´s time direction faces the White Radiator. The next time step our time direction faces the White Radiator. In the next time step it is the null-energy flux.
White Radiators are generators of mass and energy, but have no mass of their own. It generates the exact opposite type of gravity which nullifies with normal gravity.
A pair of BH and WR belongs to each reality. The ideal Black Holes (and there counterpart the WR) in the CF model must have spin. The normal black hole as known from General Relativity Theorie is discussed also.

The formation of a pair of BH and WR (also called a macroscopic quantum mirror or black mirror) is then proven to be a non natural object : it could only have formed by an act of intelligence. Intelligent life is a necessary condition in the formation of the universe! According to the CF model, the black mirrors are formed by the collective mind power of an intelligent race.

Another important consequence is that the time history (knowledge) of the universe is laid down in the quantum gravitation fields. This is one of the reasons why the universe expands: to record the time history. In other words, the time history of a matter system, determined by an increase of entropy, is converted into information in the quantum gravity field. Intelligent life interferes with and modifies the quantum gravity fields (creativity).

The two types of gravity fields represent the matter-bound and emotional (or soul-bound) energy fields. The creation of the macroscopic quantum mirror is the final goal of an intelligent race. It is called the all-might manifestation of the race and it can only be initiated by enough minds working together to create the mirror - which means nothing less than the recognition and identification of the Love poles which carry the universe...

Note:

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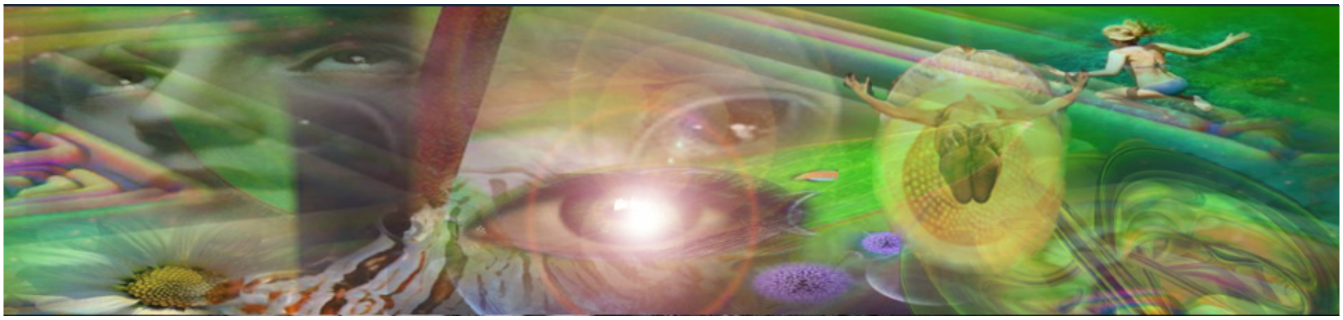

Quantum Bioholography

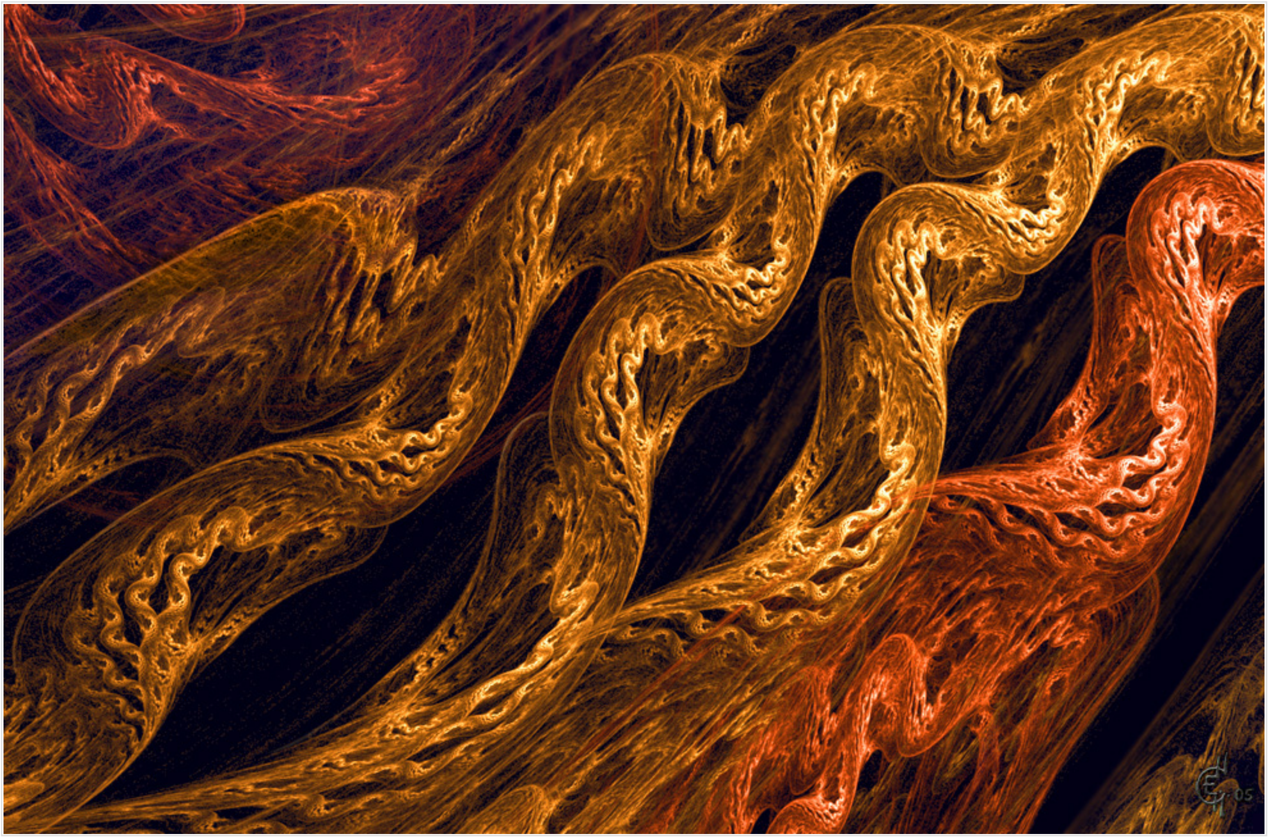

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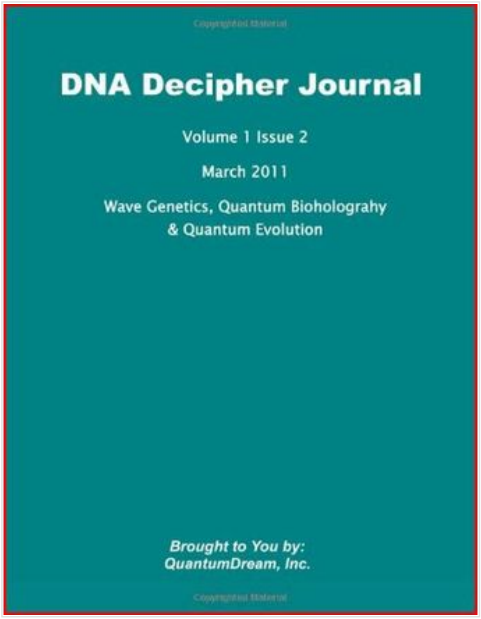

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Volume 1 Issue 2

March 2011

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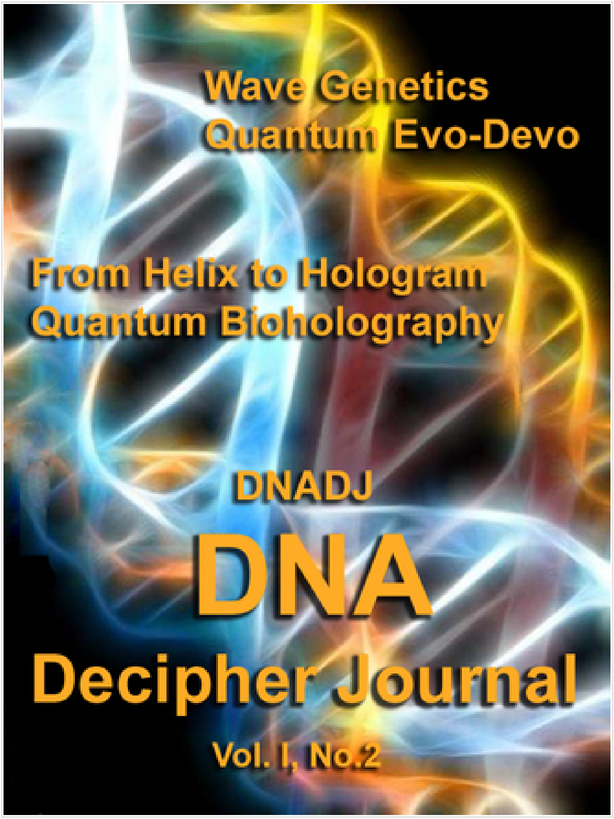

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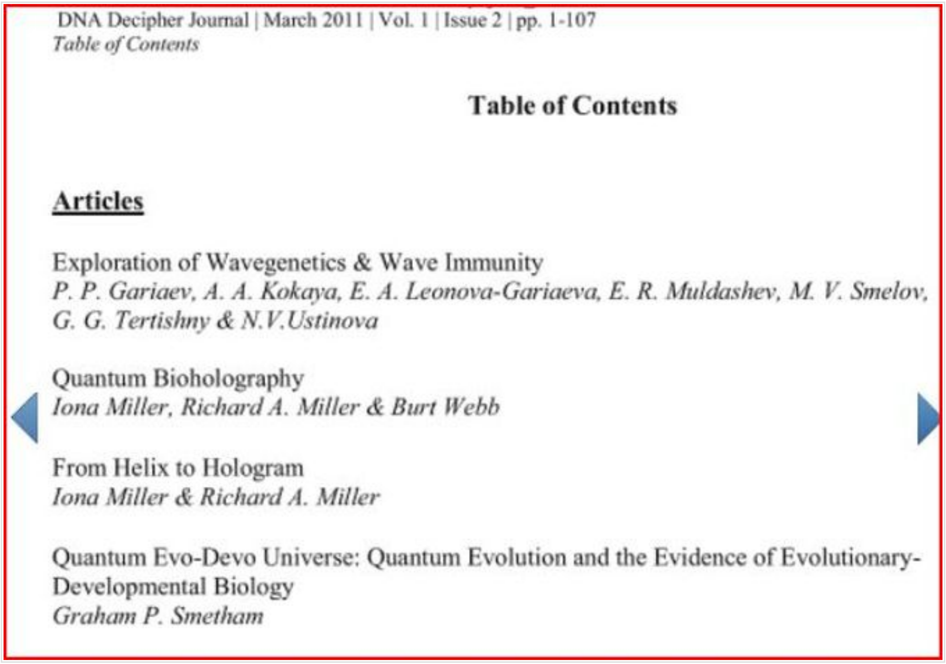

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DNA Wave biocomputer functions

- **The problem of creation of the DNA-WAVE biocomputer is considered, in which one the storage locations on genetic molecules will be used. In the basis of tendered idea are trusted to experimental and theoretical activities of the writers, in which one a) to be demonstrated capacity of DNA to the laser, b) capacity of DNA to generate solitonic waves with memory, c) the phenomenon of transition of the localized photons in radio waves is revealed,**

d) the phenomenon of spectral storage of DNA by the localized photons is revealed, e) the transport phenomena of the genetic information in polarization modulations of an electromagnetic field is revealed at transition of a photon - radio wave. On the basis of these data the theory of wave genes is built, in which one the dualistic explanation of the genetic information as unity of material and wave encoding functions of the chromosomes is offered. The hypothesis quantum nonlocality of genome of higher organisms is offered. The set of the obtained outcomes allows the writers to suspect, that artificial DNA computing cannot be carried out to the full without the registration of listed properties of the genetic apparatus. Key pattern of the DNA-WAVE computer will be the phenomenon of DNA memory on solitons and on the localized photons with participation of quantum nonlocality of such memory.

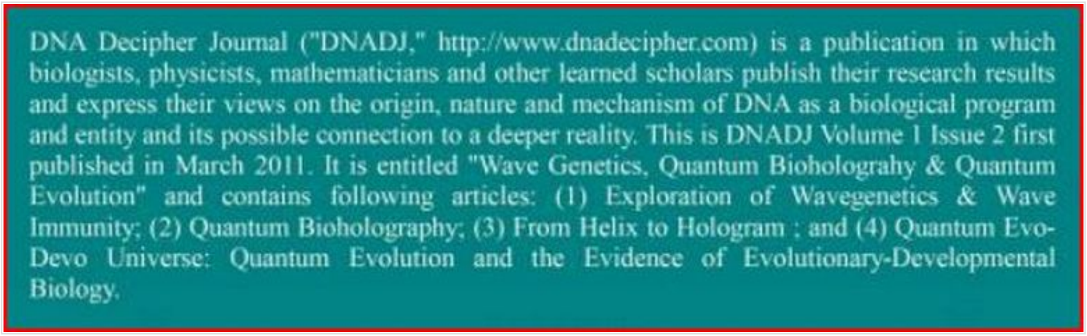

DNA Decipher Journal ("DNADJ," http://www.dnadecipher.com) is a publication in which biologists, physicists, mathematicians and other learned scholars publish their research results and express their views on the origin, nature and mechanism of DNA as a biological program and entity and its possible connection to a deeper reality. This is DNADJ Volume 1 Issue 2 first published in March 2011. It is entitled "Wave Genetics, Quantum Bioholograhy & Quantum Evolution" and contains following articles: (1) Exploration of Wavegenetics & Wave Immunity; (2) Quantum Bioholography; (3) From Helix to Hologram ; and (4) Quantum Evo-Devo Universe: Quantum Evolution and the Evidence of Evolutionary-Developmental Biology.

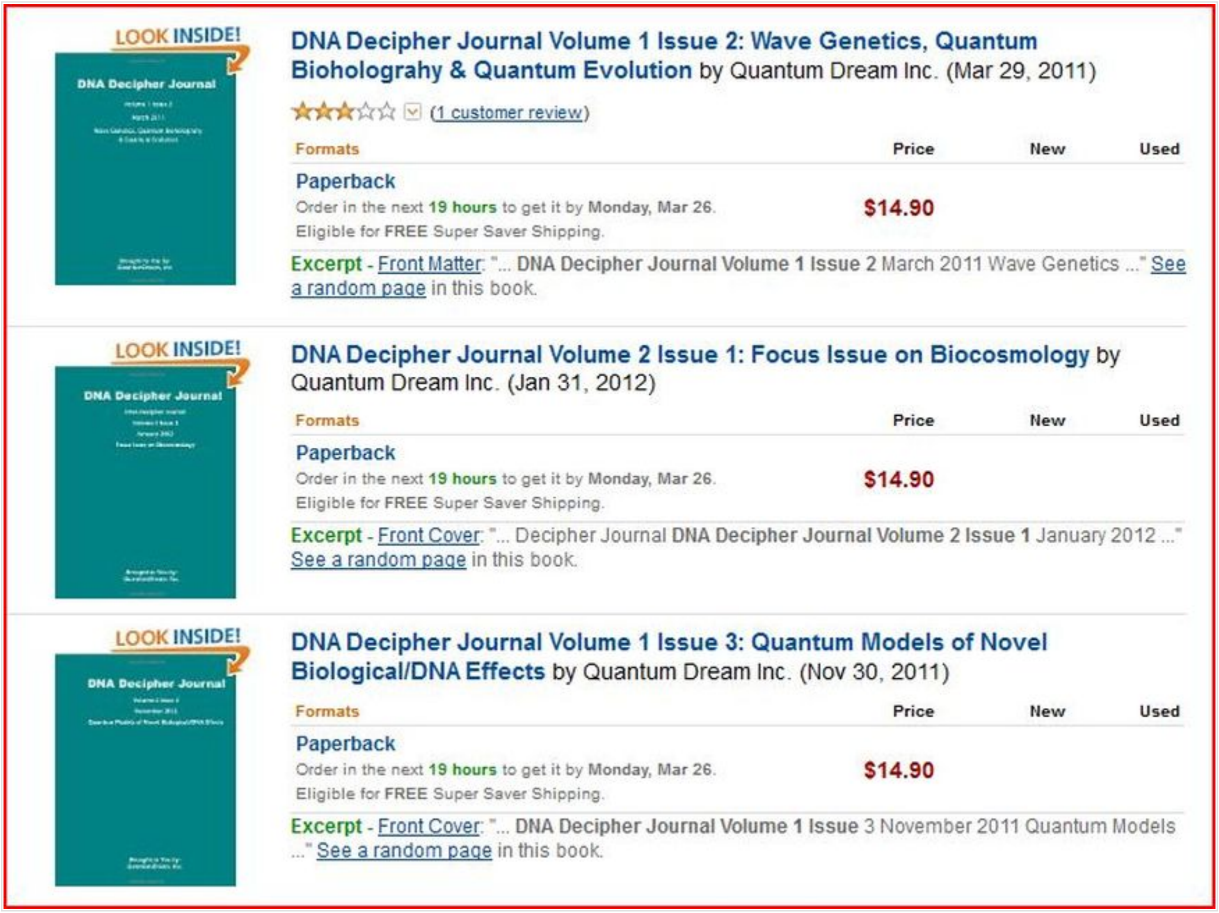

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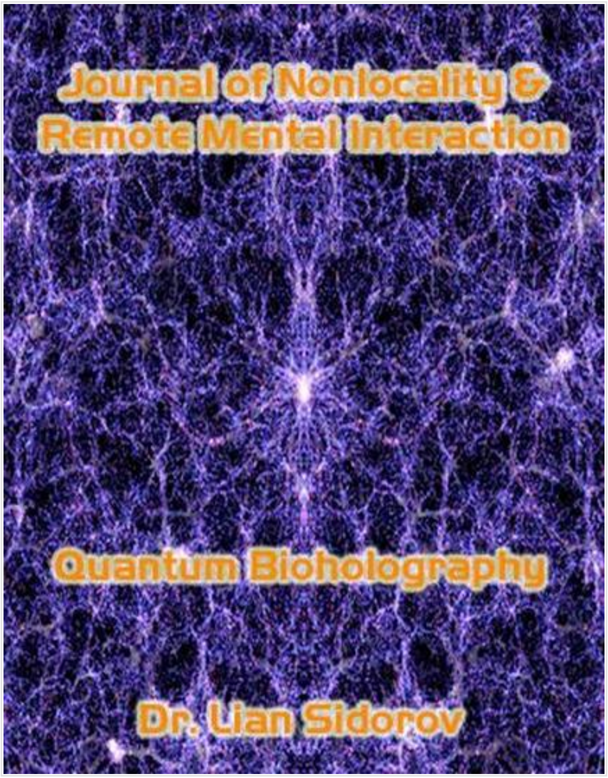

JNLRMI
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&
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Quantum Bioholography: a review of the field from 1973-2002

Iona Miller, Richard Alan Miller, and Burt Webb

URL: www.emergentmind.org/MillerWebbI3a.htm (http://www.emergentmind.org/MillerWebbI3a.htm)

Abstract: Complex information can be encoded in EM fields, as we all know from coding and decoding of television and radio signals. Even more complex information can be encoded in holographic images. DNA acts as a holographic projector of acoustic and EM information which contains the informational quintessence of the biohologram. Only 3% of human DNA encodes the physical body. The remaining 97% of the 3 billion base pair genome contains over a million genetic structures called transposons, that have the capacity to jump from one chromosomal location to another (Kelleher, 1999). We are 99.9% alike in our genetic legacy. Our individuality is expressed in three million small variations in our cells, called single nucleotide polymorphisms.

Gene-expression is the mechanism by which new patterns are called into being (Rossi, 2000). There is also a strong correlation between modulation of the brain's EM field and consciousness (Persinger, 1987; McFadden, 2002). The Gariaev group has discovered a wave-based genome and DNA phantom effect which strongly supports the holographic concept of reality (Miller, Webb, Dickson, 1975). This main information channel of DNA is the same for both photons and radio waves. Superposed coherent waves of different types in the cells interact to form diffraction patterns, firstly in the acoustic domain, secondly in the electromagnetic domain -- a quantum hologram -- a translation process between acoustical and optical holograms.

Creative, novel and enriching psychotherapeutic experiences can lead to neurogenesis, gene expression, and healing which facilitate mindbody communication and can have a long-term transformative effect on the whole person (Rossi, 2002). Thus, bioholography has relevant applications for optimizing health, well-being and even self-realization. It is relevant in biophysics, medicine, psychobiology, psychotherapy and the holistic healing arts. It provides us with a more genetically integrated model of the complex dynamics of the mindbody -- one arising in the domain underlying the standard genetic code triplet model.

Wave-genetics, Peter Gariaev

-
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    - by Peter Gariaev and Irene Caesar

- **Its scope and opportunities**

  Gariaev Peter

  The history of wave genetics has been developing for more than 80 years. In 20s and 30s of the last century Russian scientists, A G Gurwitsch and A A Lubishev postulated that not only does genetical apparatus of living organisms on the Earth operate at material, physical level but also at...

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  - We have noted earlier (Gariaev, Maslova et all, 1996 (a); Gariaev, Maslova et all., 1996 (b)), that in the role of the main molecules perceiving external electromagnetic fields as a regulators – ar the proteins and especially metal containing. Functioning of a set of biological macro-moleculs (ferments in particular) is largely determined ...
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  - Mario Salerno was the first to experiment with solitons on DNA on computer not only as formal mathematical structures but also tried to link their behavior in a mono-dimensional space of poli-nucleotides with their bio-genetic, or more accurately with their epi-genetic functions. He had been developing the first soliton model on DNA ...
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  - Additional theoretical approaches here, possibly, lie in effects of so called “weak ifluence” [Chukova, 2002]. Apparently regenerative and cytoprotective effects in our experiments bear endoergic character where even weakly absorbed energy of coherent red polarized laser light by the bio-preparations goes in to escalation of Helmholtz free...
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  - (based on works of [Prangishvil ,Gariaev, Maksimenko et al., 2000(б); http://www.wavegenetics.jino-net.ru/zip/Teleport.zip (http://www.wavegenetics.jino-net.ru/zip/Teleport.zip)

    The abovegiven biological experiments on remote transmission of morphogenetic, or more accurately – genetic-metabolic information/data from a donor to recipient may be interpreted from views of non-localized ...
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  - **Publications**

    Publications in foreign journals

    1. Garyaev P.P., Vikhert A.M., Zakharkina G.A., Alexandrova L.G., 1977, Endogenous reserpine-like substances in the myocardium and other tissues of man and animals., USA-USSR First Joint Symposium on Sudden Death. Yalta, USSR, October 3-5, 1977, pp.323-338.

2. Gariaev P.P., Chudin V.I., Komissarov...

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By Peter Gariaev and Irene Caesar in Wavegenetic (https://www.facebook.com/groups/wavegenetic/) **· Its scope and opportunities**

Gariaev Peter

The history of wave genetics has been developing for more than 80 years. In 20s and 30s of the last century Russian scientists, A G Gurwitsch and A A Lubishev postulated that not only does genetical apparatus of living organisms on the Earth operate at material, physical level but also at certain waves/fields level and is able to transfer genetic data/information via electromagnetic (EM) and acoustic waves. The science has recently taken a major leap in its advancements of the theory and reproducible experiments and thus the theory of wave genome has been put forward.

One of the first attempts to rationalize and expound the wave genome theory in Russia had been made by *P P Gariaev* and *A A Berezin* from the department of Theoretical Matters of Russian Academy of Science, and also with participation of A A Vaciliev, a fellow member of Institute of Physics of Russian Academy of Science. As a theoretical foundation, principles of *coherent physical radiations*, *holography* and *solitons*, *theory of physical vacuum*, *fractal representation of DNA* and *human verbal expression/speech* have been employed to describe and substantiate the empirical results obtained through many experiments conducted.

The *quintessence* of the wave genome theory may be represented as following:

genome of the highest organisms is considered to be a bio-computer which forms the space-time grid framework of a bio-systems.

In that bio-system, as the carriers of a field epi-gene-matrix - *wave fronts* are being used, which are assigned by gene-holograms and so-called solitons on DNA – distinct type of acoustic and electromagnetic fields, produced by biogenetic apparatus of the organism/bio-system under consideration and being a medium of strategic regulatory data/information exchange between cells, tissues and organs of the bio-system.

It is also vital to note that the holographic grids/frameworks, which are also the elements of fluctuating structures of solitons, are, in fact, discrete simplest cases of code-originated information, anchored in chromosome continuum of an organism.

At present the dominant viewpoint in respect of genetics and molecular biology is that[1]:

1. **the genetic apparatus functions as a purely material structure**
2. **all the functions of genetic control of an organism occupy approximately 2 % of DNA of a bio-system and fulfill designated functions such as replication of RNA and proteins, so called coding DNA of an organism. The other 98% is considered to be “junk DNA” not carrying out any genetical functions, which may represent a graveyard of virus DNA.**

The biologists and geneticists use the language of analogies and metaphors to explain how genetic apparatus operates. The genetic apparatus consisting of 46 chromosomes is viewed as a library consisting of 46 volumes or books. Each book (a chromosome), contains a text (instructions of how to build an organism) which consists of sentences (DNA) consisting of words (genes). And each word (a gene) consists of 4 letters (certain “chemical letters”), i.e. the “genetic alphabet” consists of only 4 “letters”. The material realizations of the DNA molecules are famous double helixes, consisting of segments which are genes. In essence, genetic apparatus operates as follows. The texts, written in the “DNA language”, are first translated by the organism into the “RNA language” and then into the “Protein language”. And proteins are the stuff that we are mostly made of (not counting water). Proteins perform two principle functions in the organism: they metabolize substances that we eat and participate in the morphogenesis, i.e. development of the spatial-temporal organization of an organism.

It is to be pointed out that the primary focus of the wave genome theory is on the remaining aforementioned 98% of chromosomes as being the *key* “intellectual” structure of all cells of an organism including the brain. It is those chromosomes that operate on the wave, on the “ideal” (fine-field) level.

It the *ideal* component, that may be called super-gene-continuum, is a strategic vital figure/formation that ensures

development and life of humans, animals, plants and also their *programmable* natural dying. Along with that, it is important to conceive that there is no sharp and insurmountable distinction between genes and super-genes. Both these levels of encoding constitute material (physical) matrixes, however genes supply material replications in the form of RNA and proteins, whereas super-genes transform endo- and exogenous fields, forming from them super-gene-signal wave structures. Furthermore, the genes may be components of holographic grids/frameworks of super-genes and supervise their field activity

Particular attention in the wave genome theory should be devoted to substantiating of the unity of fractal (replicating itself on varying scales) sequence structures of DNA and of a human speech. In 1990 Jeffrey Delrow discovered four "letters" of the genetic alphabet (Adenine, Guanine, Cytosine and Thymine) in DNA "texts" form fractal structures.

Later on, a discovery of similar fractal structures in a human speech, not limited to multy-letter alphabets of Russian and English texts and including a sequence of words from those texts came as a promising surprise for both genetics and linguists. Nonetheless this is in accordance with a branch in semiotics named "*Genetical Linguistics*", which studies incomprehensible and unexplainable precise application of laws of Formal Genetics to formation of interlingual and intro-lingual words-hybrids.

A group of scientists headed by P P Gariaev and M U Maslov, developed a theory of so called fractal representation of natural (human) and genetical languages. Within the confines of this theory it is said that the quasi-speech of DNA possesses potentially inexhaustible "supply of words" and, moreover, what had been a sentence on the scales of DNA–"texts" "phrases" or a "sentence" becomes/turns into a word or a letter on the other scale. Genetical apparatus can be viewed as the triunity of its structure-functional organization consisting of holographic, soliton and fractal structures.

This theory allows a refined quantitative comparison of symbolic structure of any texts including *genetical*. Thereby a possibility has been wide open to approach a deciphering of a lexicon of one's own gene-code, and accordingly, more accurate composition of algorithms of addressing a genome of a human with an aim of potentially any type of programming of one's vital activity such as treatment, increasing one's life expectancy and so on and so forth.

Empirical tests of wave genetic theory in the light of "speech" characteristics of DNA demonstrate strategically correct stance and direction of the research.

Phenomenal experimental findings may be *briefly* presented here. For the first time in history of the science we successfully managed to obtain experimental evidences of abilities of the genetic data/information to function on more than simply one material level, for instance, in the wave/field (electromagnetic) form

Over decades, having been conducting extensive theoretical researches, we successfully managed to formulate theoretical biology and physics-mathematical description, explanation and substantiation of fundamental principles of genetic apparatus functioning on the wave/field level.

These principles allowed us to design and create a *quantum bio-computer* essential element of which is a specially tuned laser beam with certain wavelength and frequency characteristics.

The quantum bio-computer can perform:

i. Scanning and reading the wave/field equivalent of the genetical-metabolic data from the (stem) cells, tissues, organs of a donor's bio-system employing photon of the laser beam;

ii. Conversion of the photons obtained into wide-wavelength-band preserving the scanned and read data;

iii. Precise and pointed introduction of such scanned and converted principal/dominant data radio waves into the organism-recipient, located at a certain distance from the donor's bio-system (from few centimeters to 20 km);

iv. Strategic control/management of metabolism and postembryonic morphogenesis of the organism-recipient according to two vectors/modes:

a. "Do as/what I do" – that is holographic principle, and

b. Wave/field transmission of a signal that contains commands activating required programs in the stem cells of, for instance, rats; programs that direct/guide the stem cells development on their way of, as in our experiments, building pancreas gland in rats. These vectors/modes are intended to be used on humans.

At present we are able to program/manage/encode stem cells of various types by means of a *quantum bio-computer*. The *quantum bio-computer initiates* wave/field-based commands, given to cells and tissues of the donor/recipient, and accordingly the stem cells exposed to the waves/field will be prompted to guided cytodifferentiation leading to emergence and development of planned/projected new organs and tissues. This will bring us closer to the fact of substantially increased life expectancy.

Significant achievements in applying *WaveGenetics* have been made thus far in regeneration of pancreas in rats previously destroyed by chemical substance called alloxan

Three series of experiments with identical protocol were conducted by the groups of P. Gariaev in 2000 in Moscow Russia, in 2001 in Toronto, Canada, and in 2005 in Nizhni Novgorod, Russia. These are more advanced experiments based on the principles and technology of *WaveGenetics*. The goal of the experiments was to test new technology for regenerating damaged pancreas. Pancreas is an endocrine gland which has several vital functions, the major one being production of insulin, a hormone responsible for sugar metabolism.

A control group of rats was injected a lethal doses of a poison called alloxan which destroys pancreas. As a result, all the rats in the control group died from diabetes in 3-4 days. Then the same lethal dose of alloxan was injected to another group of rats. And when the rats reached the critical condition, they were exposed to light images/waves coming from a *quantum bio-computer*. Those light images/waves were created beforehand when the bio-computer read information from the pancreas surgically removed from healthy newborn rats of the same species as those used in the alloxan experiments.

One can explain the results of the experiment using the following analogy. The pancreas gland contains DNA-movies with information about healthy condition of the pancreas in its genetic apparatus. And this video morphogenic information *programmed the stem cells* of sick rats *to regenerate their pancreas gland*. Combined statistics for all 3 series of experiments is as follows. Altogether, around 90% of all the rats had their pancreas gland restored and their health recovered.

In some of the experiments *the quantum bio-computer* was modified to allow successful transmission of the healing information to sick rats at the distance of 20 kilometers. Note, that no known physical fields have the capability to transmit such extremely week signals with such unbelievably powerful results.

Furthermore, the WaveGenetics research and application has significant prospects of solving issues as regards ageing process in humans and increase of life expectancy. This view is grounded on the experiments we have been conducting with rats.

It is Opportunities of technologies of *WaveGenetics* are not limited to what has been outlined above. The development and application of the technology is *far-reaching* and is substantiated by experimental data obtained in numerous tests, experiments, observations.

In addition, it ought to be mentioned, such a technology – a quantum bio-computer, is capable of:

- **treating oncological diseases on fundamentally distinct basis – without use of any chemical substances,**
- **eliminating pathogenic viruses and bacteria and agricultural vermin parasites – also without used of any chemical substances.**

It may seem as a technology of another age, from distant future. However, a discovery of fundamental properties of living organisms is occurring today and it is our task to research and explain the phenomena and bring it to the service of humanity.

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Antenna Model

- **By Peter Gariaev (https://www.facebook.com/Peter.Gariaev) in Wavegenetic (https://www.facebook.com/groups/wavegenetic/) ·**
- **We have noted earlier (Gariaev, Maslova et all, 1996 (a); Gariaev, Maslova et all., 1996 (b)), that in the role of the main molecules perceiving external electromagnetic fields as a regulators – ar the proteins and especially metal containing. Functioning of a set of biological macro-moleculs (ferments in particular) is largely determined by processes occurring in the active centres surrounded by bio-polimer sequences having a sign topology. Based on this perception of informational bio-macro moleculs, it is normal to suppose that theyir interaction with physical fields external in relation to the biosystem and internal radiations leads to excitation dipolar-active fluctuations of monomers, forming the said chain, and they in turn induce fluctuation if the active centre. In toher words, such system will work as a peculiar antenna.**

  There excited fluctuations can lead to transitioning of bio-macr-molecul in to toher conforming (topological, sign) state.

  Such conception in a principal plane is adequate to the whole set of functionally important bio-macro molecule, for example, chlorophyll, hemoglobin, mioglobin and so on,. These macromolecules are joined by two structural properties: 1) in their geometrical centre there is ion (in the case of chlorophyll – ion of magnium, in the case of hemoglobin –ion of iron); 2) near ion symmetrically placed 4 pirrolik rings (pseudo structure.)

  Other types of polymers, corresponding to antenna model, can be relatively simple cycles such as valinomycine (potassium ions' carrier) and complex over-molecular chromosom structures, DNA of which contains higly organized associates of such metals as magnesium, calcium, nickel, cobalt, copper, ferrum, zink and so on. Their role is not clear and is considered to neutralize OH-groups of remnants of phosphoric acid of polynucleotide. It is proposed that functions of metals in DNA and RNA is substantially wider and is realized along the lines of sign and/or energy interchangewith endo – and exogenous, in relation to the biosystem, physical fields. The same is applicable to the proteinsnot containing porfirine centre yet specifically binding metals, e.g. as such you can considersite-specific proteins with domens like "zink fingers" which participate in regulation genes, often located long awayfrom these governing proteins. Atoms of metals in DNA and proteins can in resonance interact via electromagnetic channels within the meaning of antenna model. Let defined the definition of antenna model.

  External energy (in particular, connected with resonance interaction extremely high frequency electromagnetic radiation with proteins) travels to the periphery, that is onto ensemble of sub-units (not necessarily identical in structures). As a result of an active "conversation" predetermined by bio-chemical links between peripheral acceptor (received encoded energy) and centre-associate (in this case and ion of irongem-containing proteins), the latter receives energy (information) which effects the biological action. The degree of reactive ability of bio-macromoleculs is considerably dependent on the level of excitation of central sub-units. Lets look closely in to potential mechanisms of wave interactions of physical fields and active centres of informational bio-moleculs within the boundries of the proposed antenna model.

  As an example of the simliest model for illustrating antenna effect we consider 2-dimentional closed (cyclic) chain of monomers. There is anactive centre, connected to monomers of chain by dipole-dipole interaction.

  http://eng.wavegenetic.ru/index.php?option=com_content&task=view&id=20&Itemid=1 (http://eng.wavegenetic.ru/index.php?option=com_content&task=view&id=20&Itemid=1)

Molecular – tissuey "radio stations"

By Peter Gariaev (https://www.facebook.com/Peter.Gariaev) in Wavegenetic (https://www.facebook.com/groups/wavegenetic/) ·

Additional theoretical approaches here, possibly, lie in effects of so called "weak ifluence" [Chukova, 2002]. Apparently regenerative and cytoprotective effects in our experiments bear endoergic character where even weakly absorbed energy of coherent red polarized laser light by the bio-preparations goes in to escalation of Helmholtz free energy accumulated in chemical relations of metabolites of bio-preparations, which leads to significant bio-effects. Atoms of informational molecules (DNA, RNA, proteins), interacting with the laser beam together with the energy of the light

quanta also obtain their momentum quantity motion, which creates inversed overpopulation in nuclear zeeman levels, that is – chemical polarization of nucleuses occur. Quantum polarization exit, that is a number of excess kernel spins on the top Zeeman level correlated to the every absorbed quantum of light, can be 30%. Inversely populated protonic-spin system can issue quanta with 6,5·10-26 Jouls of energy which correspond to frequencies of about 10Mhz [Buchachenko, 1979]. Further advancing the aforesaid, one could consider that when bio-preparations are scanned by the laser beam there appears combinative frequencies, occupying blue and UV diapason. Moreover as we previously suggested in an appropriate model of localized light, there is transformation of frequencies in diapason from 2 omega to zero takes place. [Prangishvili, Gariaev et al, 2000 (b)]. Besides when scanning the bio-preparations there is a presence of wideband radio radiation of the gas discharge laser. Taking this into account, we believe that in our experiments bio-preparations-donors are scanned ("read" by the laser) by way of multiplicity of frequencies. Metabolising chemical compounds of bio-preparations, which interact with dynamically polarized red light of the probing laser (and wide spectrum of additional radiation), can generate electromagnetic radiofrequency oscillations. In this instances the bio-samples of pancreas and spleen "assume" a role of idiomatic organ-molecular radio stations where every type of their molecules possess characteristic frequencies that can be reinforced owing to stochastic resonances.

From the other hand, certain types of molecules of pancreas affected by alloxan in the ill animals and/or their stem cells in the blood can resonantly absorb such radiation/emission which carries informational component required for launching bio-chemical eactions which lead to regeneration of tissues of the pancreas and protective anti-alloxan processes. This does not exclude significant contributions of the earlier explored concepts/mechanisms related to teleportational and holographic features/properties of bio-preparation-donor's genome. Let's have recourse to known theses of chemistry and physics http://www.chem.msu.su/rus/publ/Buchachenko/buch5.html (http://www.chem.msu.su/rus/publ/Buchachenko/buch5.html), setting quantum scenario of the genetic-bio-chemical events in question. In the ensemble of molecules-products with inverse population in Zeeman's reservoir/cavity energy is accumulated; it can be spent in the form of heat (via spin-grid magnetic relaxation), but can also convert in to stimulated radiation at Zeeman's nuclear frequency. In this case the reaction does, in fact, become radio frequency emitter, quantum generator with chemical pumping (similar to chemical lasers).

This is new phenomenon – radio emission of a chemical reaction – it was predicted in theory and than discovered empirically. It emerges when Zeeman's cavity/reservoir energy exceeds the generation threshold; the motion of the nuclear spins spontaneously becomes coherent and such coherent system of nucleuses then becomes a quantum generator emittiin in microwave diapason/spectrum. Yet this is only one aspect of chemical radio physics. Chemical reaction can be not only a generator but a receiver of the microwaves. Reception at chemical level follows from principles of spin chemistry: resonant microwave radiation stimulates triplet-singlet conversion of radical couples (or couples of other spin carriers) and alters exit of chemical products. In this way magnetic-spin phenomena make biochemical reaction a receiver of microwave irradiation/emission. Moreover such receiving can be selective. If the microwave pumping touches upon all radical couples (biochemical substratum) then total result boils down to changing the reaction product exit at resonance frequencies. This phenomenon is called reaction yield detected magnetic resonance (RYDMR).

If the "pumping" is selective and involves only radical couples with magnetic nucleuses, a phenomenon is brought about – radio induced magnetic isotopic effect (RIMIE). And, at last, if the microwave "pumping" is selective also in respect of nucleuses' spin orientation (that is involves ensembles of radical couples with chosen orientation of the nucleuses' spins.) then stimulated polarization of the nucleuses (SPN) occur. This is linked to so called spin catalysis It is notable for its spin conversion of reagents being induced by paramagnetic particle-spin catalyzer. Conversion occurs as a result of catalyses (ferment) interactive exchange with reagents. Spin catalyzer accelerates recombination of radicals, wax isomerization of compounds with double connections (by seven-eight orders), recombination of spin-polarized atoms and so on. It is possible that spin catalysis functions in bio-chemical processes of the indicated phenomenon of regeneration of pancreas and in cyto-protective effect. At the base of spin chemistry and chemical radio-physics lays manipulation of electronic and nucleus spins. When such manipulations are performed by the chemical reaction itself, magnetic-spin effects appear and among them – generation of microwaves when the reaction becomes molecular radiostation.

When manipulation with spins occur under microwave influence then other new magnetic effects of the second generation are produces. They serve as indicators of microwave radiation receiving. Spin chemistry and chemical radiophysics are closely related however they have their individual tasks. The former develops new principles of chemical reaction management (including microwaves) whereas the latter possessed significant applied bio-medical aspect to it.

In relation to version (?) of molecular – tissue radiostations vital question arises about highly permeable ability of modulated wideband electromagnetic radiation (MWER). As far as we remember one group of the animals (rats) in our experiment was placed in to isolated concrete ground level chamber and nonetheless the effect of MWER on the animals was authentically and reliably recorded. If biologically (morphogenetically) part of MWER occupies microwave diapason of Zeeman's reservoir then that region of MWER spectrum would have been filtrated by the concrete walls of that ground floor bunker where the rats were placed at the time of wave irradiation on them. Yet the rats perceive/receive the radiation. How?

Possible explanation could be that electrons og Zeeman's level energies of all metabolites including genetic structures whilst existing in a potential "energy pit/cavity" experience supe fine Lamb shift of those levels by about 1000Mhz. This is allowed by existence of longitudinal atomic kernels of photons causing its longitudinal (electrostatic) field which dipolarly excites the vacuum and with this excitation interact moving orbital electrons of atom. They in turn possess their own electrostatic fields composed of similar longitudinal photons.

This way the atomic system of electrons (alternating in time) induces around itself a composit alternation longitudinal electric field which in the form of longitudinal electric wave (LEW) moves instantly in the entire surrounding environment infinitely. Umov-Poynting vector of this wave is equal to zero, that is energy-impulse of this given atomic system is not emitted. However there exist vortexes of longitudinal electric Maxwell's field described by the substantial part of bi- quaternions [Bezin et al, 2003] which are able to transfer information/data which has numerical energy equivalent of Shannon and Brillouin. Yelded in such a way LEW possessing abnormally (incredibly) high permeability properties, passes almost without attenuation through various obstacles (metallic screens, ferromagnetics and dielectrics, concrete and so on). Cellular nucleuses and their main component – DNA – excite solitons [Smelov, 2001] of the linked electron waves and hyper-acoustic fluctuation of liquid crystal chromosomic structures, that is electron-vibron fluctuations [Bersuker, 1976] or electron-nucleus wave fluctuation of DNA's double helix. The said electron-vibron waves retransmit (dissipate) the received LEW back in to the vacuum (ether) and can be received by the other bo-systems similar to the first one (radiated by the primary LEW).

Owing to high corpulence (?)~1014 of all electron-vibron fluctuation systems, they possess high sensitivity estimated in terms of Planck's quantum piece energy for one element of coherent fluctuating chain which can be a DNA spiral or cellular membrane. In opend states DNA spirals, initiated by thermal motion in a living cell, electron-vibron fluctuations exist in the form of solitonic (helicoids, spiral, vortical) motions of atoms in the chain. These are so called Salerno-Maslovs solitons and these are capable of readinginformation from DNA-RNA "text" sequences. Emission/radiation by such "informational" solitons is generated by electron-vibron DNA and RNA fluctuations. Herewith scanned/read information from genetic molecules can be transmitted to other cells (and beyond the bio-system) in a relay mode employing mechanism of dissipation with LEW's frequency alterations irradiated in to the area of radio frequencies and acoustic fluctuations. Along with this, informational radio emission of electron-vibron oscillations in the form of LEW at certain frequencies, in principle, can govern/operate biochemical processes. And the other way around, biochemical reactions in preparations being probed by the polarized laser light can generate electromagnetic radiofrequency oscillations.

Due to probable wave genetic-symbolic bearing of the vortical solitonic states, initiated on DNA and RNA molecules in vivo, let's look at these processes in more details. [Blagodatskix, Gariaev et al, 1996; Gariaev, 1997]

Quantum teleportation of genetic-metabolic information/data in permissive version.

By Peter Gariaev (https://www.facebook.com/Peter.Gariaev) in Wavegenetic (https://www.facebook.com/groups/wavegenetic/) **· based on works of [Prangishvil ,Gariaev, Maksimenko et al., 2000(б); http://www.wavegenetics.jino-net.ru/zip/Teleport.zip (http://www.wavegenetics.jino-net.ru/zip/Teleport.zip)**

The abovegiven biological experiments on remote transmission of morphogenetic, or more accurately – genetic-metabolic information/data from a donor to recipient may be interpreted from views of non-localized contacts in accordance with mechanics of quantum teleportation in permissive version/mode. The laser device, practically – quantum bio-computer (of which we mentioned before), apart from unique capability of wave transfer of morphogenetic information, can also perform a conversion of red coherent photons into radio waves of rather wide spectrum. These very waves – are candidates for the first act of scanning and transmitting.

When scanning bio-samples or some other substances with the laser light, in essence a biologically active spectroscopy is performed of a distinct kind. We propounded a tentative explanation of this phenomenon [Gariaev.

Tertishnii, Gotovskii, 1997], which is primary substantiation of the new king of spectroscopy - called polarized laser-radio-wave spectroscopy (PLRS) [Prangishvili, Gariaev at al., 2000 (b)]. Such spectroscopy is designed to research and examine unknown spin-fluctuating quantum-molecular characteristics of bio-systems, bio-tissues, hard, liquid and gas substances, and also plasma conditions/states. The type of PLRS that we describe here takes a narrow optical diapason – red light, yet it is planned in the future that modification from UV to IR diapason be available.

This present version of the device – He-Ne laser ( ) with generation of two orthogonal linked in their intensity optical modes, which are mobile and depend on the object being probed and are connected in that way so the total of their intensities remains constant irrespective of preparation (bio-sample, tissue) being scanned. When even one of the modes is interacting with the substance, reflected and dispersed emission of which is returned in to optical resonator, redistribution of intensities of these optical modes occur in line with the law of polarization change, attributed to the new state/condition after the interaction of the laser beam with dynamic micro-polarizers, which are located on section/cut of illuminated area of the sample in question. Dynamics of the micro-polarizers is determined by internal dynamics of the object being examined. (metabolism, acoustics of chromosomes and DNA in vivo-in vitro, fluctuations of crystal grids and so on). One of the laser modes, in regime of photons being returned back to resonator, is capable of causing emission/irradiation by our device of modulated radio waves in wide spectrum, correlated with modulations in optical modes of emission in our laser. (Rather complex sentences-the meaning may be lost – rephrase-translator's remarks)

These modulations depend on spinning fluctuating micro-structural components (for instance, of LCC domens in vivo-in vitro) of substances under examination and level of their optical activities. Frequency interval of radio waves created when converting photons in accordance with theoretical model (further below) lies in diapason from 2 up to 0. The maximum of such irradiation is located in the region of 1 MHz. Radio wave signal having been detected is passed to a CPU of a computer with designated software for the signal processing. At the other end Fourier spectrum of radiowaves is recorded, charachterising polarized-dynamic features of substances with which one of the laser beams is interacting and also a spectral memory of emitting substances. The second light beam is returned to the resonator of the laserfor creating a resonance interaction wit hatomic oscillators of the gas mixtures. The reason for photons being converted in to radio waves, as we believe is nonw-stiff dispersion and localization of the light of the main laser modes upon the system of non- homogeneity of the mirrors in the laser resonator. Mechanism for localization (localization in the non-stiff dispersion channel) is given further on. In particular we believe that in the resonator there exists a stiff-dispersed localized light.

The radio wave emission that is generated by the laser is able to "read information", for example, from DNA samples or organs or tissues. The reading mechanism resembles process of usual induced radiation. An option of closing and opening laser's resonator allows localization or "record" in it spectrums of various objects/samples under examination. Radio wave radiation is able to scan and transmit such spectrums. Then we discovered an effect of spectral memory; during a certain macroscopic lengh of time one reproduces radio wave spectrums of objects in question, which reflect the laser beam back into resonator and than removed from the exposition zones. In this way we managed to record DNA spectrums and revealed their highly bio-activities, more likely to be linked with wave mode of transmission of genetic-metabolic information/data. [Gariaev, Leonova, 2003]. IT appears that quantum non-locality of genetic (chromosome) information/data (as manifestation of its total distribution (continuality) inside multi-cell bio-systems), is a particular instance. In reality, there are at least6 levels of non-locality in bio-systems.

Level 1 – organisms' level. Non-locality here is expressed in ability to regeneration, for instance in Planaria worms. After cutting of these organisms, any part of their body reproduces the whole body. In other words in this case there is no an attachment of the common pool of genetic information to any particular part of these worms. The same applies to vegetative reproduction in plants.

Level 2 – cellular. Out of any cell (and not only from zygote) one could grow the whole organism. For living biosystems it is more difficult, however possible. Every cell is a potential continuum of the organism.

Level 3 – cellular-nucleotide. Enucleation of nucleuses from somatic and gamete cells with subsequent injection of other nucleuses does not hinder a normal development of an organism. Cloning of this kind is already being performed on the high bio-systems, sheep for instance. Every cellular nucleus – is a potential continuum of a bio-system. Localization of genetic potencies on certain kind of cells is not the case. Gamete cells perform the same role but with haploid set of chromosomes, combining in zygote in to double set, the same as in somatic cells.

Level 4 – molecular: ribosome "reads" informational RNA not only on separate codons, but the whole of it in certain

context, that is – non locally, but continually.

Level 5 – chromosomic-holographic. Genome possesses holographic memory [Gariaev et al., 1991; Gariaev, 1994], and this is tipically distributed (non-local) associative memory. At this and the subsequent levels non-locality obtaines new quality, dualistic material-wave/field character since the holograms I the same manner as materials are scanned by electromagnetic or/and acoustic fields, which carry genetic-wave information/data beyond material substance of chromosomes. Here we deal with physical field or fields, as calibration formations marking future space-time of an organism. It appears that holographic memory of cortex pertains to this fields as well, which sets mental, rational and imaginary spaces, which calibrate potential actions of higher bio-systems in a socium (?) as a super-organism. This is the highest level of socio-genetic processes.

Level 6 – quantum non-locality of genome. Up to the level 6 genetic information/data non-locality is realized in space of the organism and also in socium. Level 6 has a special character and new quality. It is expressed in one of the forms of quantum non-locality, namely – pemissive, postulated in this paper. In that case non-locality is instantly realized across the space of the bio-system as much as on its own, "compressed" until zeroed - time. Instantaneously distributed in this manner genome-wave programs, isomorphic materially, perform in the organism "here and there at the same time', therefore it is meaningless to use the semantic structure "now and then". This is a strategic factor, incredibly vital evolutionary achievement for multi-cell bio-systems. Billions of cells of the organism ought to "know" one another and about one another if not everything than at least a lot and instantly. Without phenomena of "wave informational instantaneity" gigantic multi-cell continuum if the highest bio-systems is not capable of holistically coordinate metabolism, its own physiological and other functions. Intercellular diffusion of signaling substances and nervous processes are overly slow, inert for these purposes. Even if we suppose that symbolic electromagnetic field as quick as speed of light (which is sensible supposition) take part in intercellular exchange, then this is not sufficient either. It must possess a mechanism of quantum non-locality and it can be applied to genetic apparatus, which may perform as an instantly distributed quantum (wave) object, isomorphic to material chromosomes.

Utilizing non-locality, genetic apparatus of the highest bio-systems creates amazing phenomenon, when at certain moments in "compressed" space-time of bio-system "here and there", "now and then" are working as a continuity providing for the organisms super-coherence, informational super-abundance, super-informed, connectedness and as a result integrity (survival). As a manifestation of these phenomena one can observe regenerative abilities in organd and tissues in inferior organisms (hydra, worms, amphibians, lizards, Crustacea), the ability which has largely been lost by humans. However, it may be activated considering principles of wave self-organization processes that we advance and develop in this paper and in our experiments.

As an illustration of these phenomena serves the very first successful grafting of implanted donor's tissues in a blind human with recovery of vision [Muldashev, 2000]. As a foundation (ideology) for such surgeries and regenerative processes were used our models of morphogenesis and holographic memory of genome. The key moment of this surgery was utilization of donor's retina as a hologram and intercellular substance (alloplant) as systems of additional coordination post-embryonic morphogenesis of the eye, which was in fact predicted earlier [Gariaev, 1994].

Meanwhile these theoretical-experimental researches here are tentative and initial and require physics-mathematical foundation and consideration and advancement. For that reason we show formalized model of photonic-radio-wave processes, brought in to existence when laser beam is interacting with the substances, processes, which can be view as foundation of PLRS and one of the version of quantum informational events in chromosomes.

The fundamental grounding of our ideas lies in theories of localization of light in dispersing space-correlated systems. The Phenomenon of localization of light received a wide acknowledgement since 1985 after works of [Albada, 1985]. Today it is one of most dynamically developing spheres in physics, closely interrelating with such issues as, for instance, quantum teleportation, new methods of recording and reading information and so on.

- **Mathematical Modeling of solitons on DNA**
- **By Peter Gariaev (https://www.facebook.com/Peter.Gariaev) in Wavegenetic (https://www.facebook.com/groups/wavegenetic/) ·**
- **Mario Salerno was the first to experiment with solitons on DNA on computer not only as formal mathematical structures but also tried to link their behavior in a mono-dimensional space of poli-nucleotides with their bio-genetic, or more accurately with their epi-genetic functions. He had been developing the first soliton model on DNA proposed by Englander and et al. This model and its more detailed variations including ours (see further**

below) is represented in term of mechanical systems as a chain of oscillators (DNA base) linked by resilient non-linear sugar-phosphate connections. Following Salerno we have paid particular attention to objectively existing known DNA sequences and thei effects onto solitons behaviour.

In the first stage we have replicated his experiments yet on significantly longer DNA parts. Indeed, solitonic kink excitations are sensitive to the place of their initiation; their motion along one of DNA chains (when they are opened as a result of temperature fluctuations) is accompanied by specific modulation of kink trajectory in time and in single-dimension space of poly-nucleotides. Such solitons are structures that emit electromagnetic and acoustic fields; their inner oscillation structures are capable of reflecting and retranslating texts and other symbolic structures of DNA in to into and out of cellular space at least at the level of large blocks of sequences. As an example behavior of kink on a fragment of singular DNA chain, which is 1020 nucleotides long from a virus of bird sarcoma

C (or S) area of DNA (1 1020 nucleotide) on 3'-end of virus of bird sarcoma contains several "semantically" certain areas such as polypeptide-coding area (between 558 and 675 nucleotides); PolA (936) 3'-end of virus RNA, poly-adeniling site; 916 nucleotide - 5'-end of virus RNA ("capping site"); Red-sector - () – short end replica of the virus genome; Pro – possible component of observing the transcription (between 870-9000); palindrome – "pin" (870 912) .

(5' beginning) GGC CTA TGT GGA GAG GAT GAA CTA CGT GCA CCG AGA CCT GCG GGC GGC CAA CAT CCT GGT GGG GGA GAA CCT GGT GTG CAA GGT GGC TGA CTT TGG GCT GGC ACG CCT CAT CGA GGA CAA CGA GTA CAC AGC ACG GCA AGG TGC AAG TTC CCC ATC AAG TGG AGA GCC CCC GAG GCA GCC CTC TAT GGC CGG TTC ACC ATC AAG TCG GAT GTC TGG TCC TTC GGC ATC CTG CTG ACT GAG CTG ACC ACC AAG GGC CGG GTG CCA TAC CCA GGG ATG GGC AAC GGG GAG GTG CTG GAC CGG GTG GAG AGG GGC TAC CGC ATG CCC TGC CCG CCC GAG TGC CCC GAG TCG CTG CAT GAC CTT ATG TGC CAG TGC TGG CGG AGG GAC CCT GGA GGA GCG GCC CAC TTT TCG AGC TAC CTG CAG GCC CAG CTG CTC CCT GCT TGT GTG TTG GAG GTC GCT GAG TAG TGC GCG AGT AAA ATT TAA GCT ACA ACA AGG CAA GGC TTG ACC GAC AAT TGC ATG AAG AAT CTG CTT AGG GTT AGG CGT TTT GCG CTG CTT CGC GAT GTA CGGGCC AGA TAT ACG CGT ATC TGA GGG GAC TAG GGT GTG TTT AGG CGA AAA GCG GGG CTT CGG TTG TAC GCG GTT AGG AGT CCC CTC AGG ATA TAG TAG TTT CGC TTT TGC ATA GGG AGG GGG AAA TGT AGT CTT ATG CAA TAC TCT TGT AGT CTT GCA ACA TGG TAA CGA TGA GTT AGC AAC ATA CCT TAC AAG GAG AGA AAA AGC ACC GTG CAT GCC GAT TGG TGG AAG TAA GGT GTA CGA TCG TGC CTT ATT AGG AAG GCA ACA GAC CGG GTC TGA CAT GGA TTG GAC GAA CCA CTG AAT TCC GCA TCG CAG AGA TAT TGT ATT TAA GTG CCT AGC TCG ATA CAA TAA ACG CCA TTT GAC CAT TCA CCA CAT TGG TGT GCA CCT GGG TTG ATG GCT GGA CCG TCG ATT CCC TAA CGA TTG CGA ACA CCT GAA TGA AGC AGA AGG CTT CATT 1020 (3'-ending)

In Fig.1 and 2 the kinks appear in a form of "mountine ranges" rather tha as steps, because a derivative of sinus-Gordon equation function was taken. In here a horizontal axis – DNA sequence, vertical – soliton amplitude. Axis to the observer – time. It is visible that wnen soliton's initiation location is altered at certain sequences of poly-nucleotide, the dynamics of that single range/wave is notably alters too in a form of spinning-fluctuating motions along DNA sequence.

The molecul's area under this research is rich functionally (semantically) by biologically significant sectors and we are reasonably expecting that these sectors will alter, modulate, that is – will be introducing/injecting in to a single chain of DNA or RNA "textual" information. This such aspect will be realized in the spectrum of solitonic wave fluctuations alongside poly-nucleotide chain. This spectrum will mirror sequences of nucleotide and by that will perform a role of the carrier of genetic information/data/messages. Such modulation of the fluctuation structures is clearly observed in the presented graphs. It is plausible to believe that spectral composition of oscilating frequencies of solitons appear to be one of the mechanisms of text conversion of DNA and RNA structures in to wave form and a means of transmitting genetic and other messages in a mono-dimentional space alongside the poly-nucleotide chains and/or in 3D of the genome as a single cell as well as the tissue continuum of the bio-system.

The same as Fig.1, apart from the epicenter of the perturbation – 450th nucleotide in here.

This is how the soliton dynamics computer modeling works developed by Salerno after it had been propounded by Englender. Salerno gave formalism describing spin nucleotide fluctuations of DNA molecule in order to explain experimental data in hydrogen-tritium exchange in DNA. In accordance with that model, Engleder, in DNA chain

there can appear (under thermal radiation/noise) and distribute open states ("melting" the DNA double-helix in short segments enriched by AT-couples) in the form of localized dislocations.

Mario Salerno continuing works of Englender in a simplified form, discovered influence of nucleotide sequence on none-linear solitonic dynamics of spin fluctuations of nucleotides within (однотяжных- word is not known by the translator)… DNA areas, which form such open fields (open states). Later, Yakushevich, Fedianin and Khomma et al. revied various generalizations of Englender's model assessing specifics of DNA structuring taking in to account a break in hydrogen connection when the base is opened, paired DNA chains and other aspects of reedom distinct from spinning. However, as it seems, it is not shown in those works the reasons for emergence of dislocations in DNA.

We put forward a possible mechanism of that process in DNA, which is alternative to Englender's hypothesis about thermal noise influence as a cause for opening the bases of couples. We think that dislocations in DNA can be triggered when the period of DNA double-helix is altered (Maslov's proposition). In our model DNA nucleotides are viewd as oscillators suspended on masless non-extendable rod/pivot; sugaf-phosphate links between neighbor nucleotides in the chain are modeled by linear springs, spiralisation along the chain is not taken in to account; hydrogen links between complementary bases are modeled by "gravitational" potential. Hamiltonian, as in accordance with M. Salerno, liiks like the following:

http://eng.wavegenetic.ru/index.php?option=com_content&task=view&id=23&Itemid=1 (http://eng.wavegenetic.ru/index.php?option=com_content&task=view&id=23&Itemid=1)

EXPLORING WAVEGENETICS AND WAVE IMMUNITY.By Peter Gariaev (https://www.facebook.com/Peter.Gariaev) in Wavegenetic (https://www.facebook.com/groups/wavegenetic/) · Edit Doc (https://www.facebook.com/ajax/docs/inline_edit_get.php?group_id=129999910455329&doc_id=132895870165733&permalink=1&show_brief=0)THEORETICAL MODELS *.

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*** Disclaimer: This translation and English text editing have been done to the best knowledge and understanding of the translator who is not a specialist in the field although having a good understanding of Russian language and advanced level of English complemented with rather good understanding of basic physics and biology. The reader is encouraged to seek specialist opinion in any event. Extensive resources are used to understand the concepts in order for the translation to be s precise and accurate as possible. Where possible Russian abbreviations are to be preferred as they represent the most accurate references. An approach of translating the concepts, not the discrete words, has been employed in a belief that this is the most appropriate form of conveying a thought and/or concept from one language into another; of course a detour from this mode is taken where deemed necessary for the sake of clarity.**

All authors have equally contributed to the research in this paper.

Many researchers have pointed out in their works to the dangers posed by geptil pollution to the environment and that it adversely and detrimentally affects health of livings organisms [http://www.seu.ru/conference/ecoprvo/geptil.htm (http://www.seu.ru/conference/ecoprvo/geptil.htm)]. In this present paper a possibility of principled approach to the development of technology is demonstrated, which allows bio-systems to trigger resistance mechanisms to protect the organism from the toxic impact of geptil substance by mean of electromagnetic fields/waves. Theoretical foundations for conducting this kind of research are illustrated on the following website http://www.wavegenetics.jino-net.ru/ (http://www.wavegenetics.jino-net.ru/). Prior to commencing this research/investigation in this direction, we had organised a series of initial model experiments with alloxan. Alloxan is a cytotoxic substance with a dominant detrimental effect on β-cells of pancreas resulting in to Type 1 diabetes.

The earlier experimental works [Gariaev P.P., Kokaya A.A.] have suggested that modulated by pancreas and spleen – modulated wideband electromagnetic radiation (MWER) generated by helium-neon laser influences upon progression of the experimental diabetes in rats. Diabetes is provoked by intro-peritoneal/abdominal injection of alloxan in a dose of 200mg/kg of the mass of the animal.

Irradiating rats with such a frequency resulted in prolonged life expectancy of the animals in the test groups when compared to the control group, leading to normalisation of blood glucose level and, crucially, facilitated pancreas tissue regeneration process.

The aim of this present paper is to assess the phenomenon of resistance to alloxan developed in animals having been previously preventively irradiated by MWER. For that purpose a special laser was used which features interconnected complementary orthogonal polarization of the light beam. Generation of the WER (wideband electromagnetic radiation) was conducted in accordance with Fabri-Perot interferometer's scheme, where the operational laser ray many times passed through the thin freshly-prepared sections/samples of pancreas and spleen from a healthy rat. We believe that the samples specifically and uniquely modulate the laser ray in such a way that this system reveals the following capabilities:

1) reinforce/enhance WER released from discharge interval of He-Ne laser;

2) WER is parametrically connected with the sample-modulated laser ray and as a result it obtains a property of being biologically highly active;

3) biological effect can be observed at relatively long distances from the source of WER;

4) Genetical-metabolic managing/primary information is transmitted from bio-donor to the bio-recipient. The information is carried by MWER (modulated wideband electromagnetic radiation) modulated by the bio-object from the donor

As a donor/bio-structure tissue, probed by the laser beam in the present system, following can be used: living and/or quasi-living organisms, for instance, bacteria, viruses and also living through tissues and organs, metabolites and abiogenic substances.

RESEARCH METHODOLOGY. PHYSICS' PART

To obtain WER modulated by the bio-structures/samples we utilized developed earlier biotechnology with use of helium-neon laser [Gariaev P.P., Tertishni G.G. 1999]. Helium-Neon laser of 2 MW with 632.8 nm of the wavelength possesses two superposed, orthogonal linear polarized modes of emission, single-frequency in each of them. Laser ray probes/scans DNA samples/bio-structures - newly retrieved tissues of pancreas and spleen of a newborn rat Wistar strain. Semitransparent tissues were deposited onto a a lab glass and then covered that by a second lab glass and this "sandwiched" object was fixed in front of the optical axis of the laser. Adjustment of the glasses with the tissues had been done so as to provide partial reflection of the modulated (by the tissues) laser beam back in to the laser resonator. In this way we ensured a multiple passages of the laser beam through the tissues and the tissues be an optical correlator [Mazur, Grachev, 1985] and therefore affect redistribution of the secondary modes of the laser emissions.

Optical signals were registered and transmitted to an electronic circuit, which governs laser's generation regimes; frequency stabilization of the coherent radiation is also performed at this stage. In this mode the laser generates, apart from the red light, WER modulated by the tissues – that is – the MWER itself. Distance from the target to the active element of the laser is 11cm.

RESEARCH METHODOLOGY. BIOLOGICAL PART

Wistar strain of rats matured to reproductive stage, 5-6 months old were used, with average mass of 180-220 gram. Diabetes for the purposes of this experiment was provoked by way of intro-peritoneal/abdominal injection of alloxan in a dose of 200mg/kg of mass of the animal after 24-hour fasting period with normal/common levels of blood glucose level. The animals were divided into 4 groups:

Group 1 control (n=20) – no WER irradiation; Group 2 (n=20) and Group 3 (n=20) – were subject to preliminary irradiation of WER; Group 4 (n=10) – placebo, where WER was not modulated by DNA samples and the laser ray passed through empty lab glasses without the tissues.

Group 2 rats were placed 20 meters from the source of MWER in the lower ground level of the lab. Alloxan diabetes was provoked one month later from the day of the last irradiation by MWER.

Group 3 and Group 4 were placed 70 cm from the source of MWER. Alloxan diabetes in these groups was triggered one day after the last irradiation by MWER.

Irradiation by MWER of Group 2 and Group 3 was being performed daily for 30 minutes during 4 days scheduled as follows: 10 minutes irradiation by MWER (modulated by samples of pancreas), 10 min irradiation by MWER (modulated by samples of spleen) and 10 minutes irradiation by MWER (modulated by samples of pancreas).

Group 4 – placebo – was being irradiated by WER – not modulated by any samples the laser beam though passing through the empty lab glasses – for 30 minutes daily during 4 days.

Group 1 – control - was not subject to the irradiation by WER nor was it by MWER.

During the experiment we assessed general health condition of the experimental animals, recorded the death date for the animals from the moment of alloxan injection, in all observed groups. The animals of Group 2 and Group 3 were observed for 1.5 months from the day of alloxan injection. In 8 animals from Group 2 and 3 were recorded with the reproductive function still active when the blood glucose level reached its peak value. (3 rats from Group 2 and 5 rats from Group 3).

Measurements of the blood glucose level were performed by glucometer Ascensia Entrust made by Bayer. Measurement range of the glucose level spreads from 2.0 mmol/l up to 30.6 mmol/l. Measurements of glucose level higher than 30.6 mmol/l were marked as HI.

Removal of heart- lung- liver- kidney- spleen- and pancreas- tissues was done in order to perform microscopic description and histological analysis in:

Group 1 – control – on day 3 and 4 after alloxan injection which corresponded to the highest death rate of the animals;

Group 2 and 3 on the day 8 from the alloxan injection, and also on the 42 day of the experiment after assessing reproductive function in male animals.

For histological analysis purposes the tissue had been fixed in 10% neutral formalin, dehydrated in spirits of increasing concentration and then sealed them in paraffin wax. Paraffin sections of 5-7 micro kilometers thin were obtained on microtome Leica SM 2000R, were colored in hematocsilin-eosin and then analysed by microscope Leica DMLS. Video footage was obtained by using CCD-cameras.

Statistical survey of the experiment's results were conducted by means of using statistical software suits "Stastica 6.0", MS-Exel" for Windows. Degree of accuracy (p) was determined using Student criterion, employing confidential coefficient and a digit of degree of freedom (1) in accordance with table. Calculations of all mathematical values had been performed in compliance with commonly known formulas on a PC.

Research in this series of experiments revealed that application of the said dose of alloxan in control and placebo groups developed diabetes complicated by toxic damage of live-crucial organs and systems. This led to low survival rate of the animals in within the groups. On the contrary, in Group 2 and 3 we observed resistance/increased immunity in the animals to the detrimental/destructive effects of alloxan expressed in various degrees.

Group 1 – control – survival rate after alloxan injection of the animals on the day 2 was 55% yet by the day 4 it went down to 30% (Fig.1). Glucose level in Group 1 animals on day 2, 3 and 4 is reliably distinct ($p<0.05$) from the initial value/level (Table 1). Animals dying in Group 1 (control) at terminal stage were put down by euthanasia (5 rats), organs used for patho-morphological analysis. There was no discrete/spontaneous reduction in glucose level in Group 1 (control) within the period of monitoring. However, there was one rat exhibiting resistance to alloxan and its blood glucose level remained within the limits. Table 1. Blood Glucose level over time in animals after alloxan injection, dose of 200mg/kg of the mass

*** - blood glucose level in Group 3 by the 2nd, 3rd, and 4th day of initiating alloxan diabetes is different ($p<0.05$) from the level of glucose in blood of the animals in Groups 1 and 2 by the 2nd, 3rd, and 4th day, and is also different ($p<0.05$) from glucose level in blood from the animals in Group 4 by the 2nd day;**

**** - blood glucose level in Group 1 by the 2nd, 3rd, 4th day is in fact different ($p<0.05$) from the initial level;**

***** - blood glucose level in Group 2 by the 2nd, 3rd, 4th day is different ($p<0.05$) from the initial level;**

****** - blood glucose level in Group 4 by the 2nd day is different ($p<0.05$) from the initial level;**

^ - in Group 4 by the 3rd and 4th day of observance there was one survived rat.

All animals were injected alloxan – 200mg/kg of an animal mass. Group 1 (control) was not subject to WER or MWER. Group 2 – MWER was conducted; the animals were places 20 meters from the source of emission. Induction of alloxan diabetes was effected one month later after the last radiation by MWER. Group 3 – MWER was conducted, animals were located 70 cm from the source. Induction of alloxan diabetes was done one day after the last radiation by MWER. Group 4 – placebo – was irradiated by WER – not modulated by DNA samples (that is to say that the laser beam was passing through the empty lab glasses). The animals were placed 70 cm from the source of the emission. Alloxan diabetes was induced a day after the treatment.

Animals in Group 4 – placebo - were observed with altered glucose level different from the initial one ($p<0.05$). 80% of the animal survived by the day 2 and only 10% remained alive by day 4. This was considerably at variance with what we observed in Group 2 and Group 3; Group 1 exhibited lower death rate and survival was at 30%. (Fig. 1)

Preventive irradiation by MWER significantly influences the alloxan diabetes progression in the animals of Group 2 and Group 3 (Figs. 1, 2, 3, Table 1) and is accompanied by safeguarding, cyto-ptotective effect. (Fig. 4). That had been seen in both abovenamed Groups despite the fact that diabetes in Group 2 was induces a month later after the last preventive irradiation/treatment

Survival rate in Group 2 (n=20) reached 90% by the 3rd and 4th day from the moment of alloxan injection (Fig.1) which is significantly distinct from survival data obtained from the control Group (30%) and in the Group 4 (placebo) (10%). Glucose level increase ($p<0.05$) is observed in Group 2 animals by day 2, 3 and 4 when compared with the initial value (Table 1). By the 4th day 13 animals in Group 2 (65%) the glucose level in their blood was 14.5 mmol/l, whereas 5 animals (25%) from the same group were observed with normal physiological level of glucose (Fig.2)

Glucose level in Group 2 by the 4th day is ($p<0.05$) different from the initial level. (Table 1). By the 7th day in Group 3 survival rate decreased to 75% (out of 20 animals with hyperglycemia 5 animals died) and remained at the same level up to the end of observation term (1.5 months Fig.1). By the 8th day euthanasia had been conducted to 6 animals from Group 2 and tissues were extracted for patho-morphological analysis. The other 9 animals were observed for a period of 1.5 months. It is important to note that from the day 8 up to 15th animals with hyperglycemia a reduction in glucose level was observed (Fig. 2).

However by the 18th day 4 animals of Group 2 regained the hyperglycemia (more than 30,6 mmol/l) which remained during the entire observation period. The overall health condition of these 4 animals were assessed as satisfactory. Similar results were present during our previous experiments [Gariaev, Kokaya et al, 2007]. The other 5 animals maintained normal level of glucose.

Reproductive functions were noted in 3 animals of Group 2 with hyperglycemia (glucose level over 30.6 mmol/l). These animals gave birth to healthy multiple posterity. After 1.5 months tissues were extracted for the analysis.

Fig.2 Effects of preventive/preliminary irradiation by MWER on progression of alloxan induced diabetes in Group 2.

Alloxan was injected at 200mg/kg dose one month after the preventive irradiation by [MWER] modulated wideband electromagnetic radiation/field. The irradiation was being performed for 4 days, 30 minutes in each day. Distance from the radiation source – 20 meters. The irradiation schedule: 10 min irradiation time using tissues of the pancreas, then 10 minutes of the spleen tissues, and for 10 minutes – pancreas tissues. The beginning is the day of the alloxan injection.

The most manifested effects were observed in Group 3 located at 70 cm distance from the source of the modulated waves. Alloxan diabetes modeling was performed one day after the irradiation by MWER ended (Fig.1,3, Table 1). Every animal in the Group survived. We observed 100% survival rate during the entire period. It is clear that 90% of animals retained their normal physiological glucose level during the 1.5 month of observation, which is clearly different ($p<0.05$)

from the control Group, Group 4 and Group 2.

However 2 animals from Group 3 by the day 6 of the experiment had excessive glucose level increase of 20 mmol/l with subsequent reduction to the normal level. On the 8th day of the experiment6 animals were performed euthanasia for a patho-morphological analysis. Reproductive function could be detected in 5 animals of Group 3. All the animals gave birth to a healthy posterity. 1.5 months later tissues from 6 animals from the same Group were taken for the analysis. Glucose level was at normal levels. Health condition of all the animals of Group 3 was satisfactory.

Fig.3 Effects of preventive/preliminary irradiation by MWER on progression of alloxan induced diabetes in Group 3.

Alloxan was injected at 200mg/kg dose one day after the preventive irradiation by [MWER] modulated wideband electromagnetic radiation/field. The irradiation was being performed for 4 days, 30 minutes in each day. Distance from the radiation source – 70 centimeters. The irradiation schedule: 10 min irradiation time using tissues of the pancreas, then 10 minutes of the spleen tissues, and for 10 minutes – pancreas tissues. The beginning is the day of the alloxan injection.

After histological analysis of the pancreas tissues in Groups 1,2 and 3 a number of distinctive features have been observed (Fig.4). Histological picture of the pancreas tissues from animals of control Group was cjaracterised as having clearly visible degenerative alterations of Langer Islands (Fig.4b). The number and size of the islands are reduced, they are of unusual and irregular form. Quantity of β-cells is sharply reduced and in most of them cytoplasmic vacuolation was observed, the nucleus size decrease, chromatin condensation and cariopicnose in some of the cells. Gathering of lymphocyte infiltrate had been revealed around and inside of the islands.

In Group 2 by the 8th day histological situation if pancreas tissues could be described as having damaging processes of various degree: the islands were reduced in size, of irregular form, β-cells reduction, the total portion of insulin apparatus in the islands was significantly reduced. Only a relatively small part of the islands apparatus maintained rather preserved (intact) structure (Fig. 4c).

Situation in Group 3 by the 8th day after modeling alloxan diabetes was considerably different from the control Group and Group 2. Along with the pathological processes in the tissues of pancreas in question, there was also observed a large quantity of islands, large as well as medium and small sizes with lightened cytoplasm, of normal spherical form, large roun nucleuses containing the core (Fig.4e).

A month and a half later histological situation in Group 2 was also described as having damaged islands' apparatus (Fig.4d)

As opposed to Group 2 and control Group, Group 3 after 1.5 months had hypertrophy and hyperplasia of the pancreas. Numerous islands of varying size and normal spherical form were noted (Fig.4f). Attention was attracted by the large number of small islands and discreete agglomeration of β-cells, where as large islands contained increased number of β-cells which in turn were located in a close proximity to one another. The structure if the islands and β-cells were not altered, the kernels in the cells were large; round, in which it was possible to locate nucleuses.

Fig.4 Pancreas tissue structure, Langerhans islands:

a – intact rats:

b – Group 1 (control), after alloxan injection of 200mg/kg dose;

c – Group 2 by the 8th day from the day of alloxan injection of 200mg/kg dose. A month prior to the inducing alloxan diabetes, this Group was preventively treated by the irradiation and was located at about 20 meters distance from the source I the basement of the laboratory.

d – Group 2 after 1.5 months after alloxan injection of 200mg/kg dose.

e – Group 3 by the 8th day from the day of alloxan injection of 200mg/kg dose. One day prior to the alloxan injection this group was also preventively treated by the irradiation being located at 70 centimetres distance from the source of radiation.

f – Group 3 after 1.5 months after alloxan injection of 200mg/kg dose

Enlargement: 1 x 400, 1 x 100. Colouring agents: Haematoxylin and Eosin.

DISCUSSING THE RESULTS

It can be stated that a positive effect was reached by using MWER in Groups 2 and 3. Differences in the dynamics of glucose level and survival rates of the animals in these two groups point to an interconnectedness between the length of the irradiation by MWER and modeling the alloxan diabetes. Biological long range defensive effects when irradiating with MEWR which were discovered in our previous experiments [Gariaev, Kokaya et al, 2007] has been confirmed in this series of experiments – this research. The effects is manifested in the glucose level dynamics in Group 2 animals and also in the very fact of the animals surviving in this group, when compared with control Group and placebo Group. In spite of the reliable data ($p<0.05$) suggesting increase in glucose level in the animals of Group 2 compared to the initial state, and an absence of any reliable differences in the glucose level data obtained from Groups 1 and 2 by the 2nd, 3rd and 4th day of the alloxan injection, survival rate in the Group 2 was high. Evidential hyperglycemia in 20% of the animals in this group did not result in to their death but were remaining I a satisfactory health condition for the entire period of the observation.

Irradiation by the MWER on the animals of Group 3 facilitated development of resistive properties of their immune system to the alloxan triggered diabetes and the glucose level was at the normal physiological lever at all times for the entire period of observation (this is reliably different ($p<0.05$) from data obtained from Groups 1, 2 and 4). Survival rate in Group 3 was at 100%. Having analyzed the histological data of pancreas from different Groups, it can now be stated that preventive irradiation by MWER in Group 3 resulted not only in cyto-protective effect on the cells of pancreas but also encouraged hypertrophy and hyperplasia processes in it, which, as it seems, were functioning in a compensatory mode. The present experimental findings are in good conformance with the results of our previous experiments conducted earlier. [Gariaev, Kokaya et al, 2007]

In this way, three phenomena of MWER irradiation on the animals with alloxan diabetes were manifestly observed:

Firstly – the factor of survival with contemporaneous and obvious hyperglycemia within prolonged period of observation with preserved reproductive functions in the animals.

Secondly – it was revealed in the previous experiments, and confirmed in the present one that MWER is facilitating pancreas regeneration in the ill animals in situ.

Thirdly – preliminary irradiation by MWER on the animals facilitates development of resistance to alloxan effects.

The recorder effects are related to the fundamental issues of “recording” and transmission of electromagnetic component of genetic information during the post-embryonic growth with wave (frequency) processes taking part in genome and organism as a whole. MWER, parametrically linked with photons (which in turn were modulated by the tissues), appears to be a carrier and transmitter of the information from the bio-donors to the bio-system (bio-organism which precisely and specifically receives this information as strategically superior (that is of higher topology? Of the sort that can manage and govern processes in the recipients organism)). Most likely, MWER – performs a function of a frequesncy (wave) trigger, which initiates “awaiting” (stand by) regenerative morphogenetic processes, of which the information is contained in genome of every cell. Quantum mechanisms of MWER effects on embryonic and post-embryonic processes remain to be discovered, thoughsome ideas were expressed in our earlier works. [Garyaev, 1994; Gariaev, 1997; Prangishvili, Gariaev and et al, 2000 (b); Gariaev et al, 2001; Gariaev, 2003] and are being further advances at present. The defensive and cyto-protective action of MWER are promising field of research with rather sound perspectives.

It may be that a specific role in the discovered defensive-protective manifestations plays a so called factor of “weak influence” [Chukova, 2002]. In this regard it can be put forward that the discovered effects bear endoergic character where even weakly absorbed energy of coherent polarized laser beam results in the increase of free Gelmgolc energy which is accumulated in chemical links of tissue metabolites in pancreas and spleen. For instance, atoms of informational macro-molecules (DNA, RNA and proteins), while absorbing light, together with the energy had by a quantum of light they gain the same momentum of quantity of motion, which creates inversed population of nuclear zeeman levels (see Zeeman effect). Occurs so called chemical polarization of the nucleuses. In this manner, biochemical reactions in preparation (tissues) initiated by the polarized laser light are able to generate electromagnetic

radio frequencies (fluctuations). In this situation the preparations (tissues) of the pancreas and the spleen assume a role of specific molecular radio station where every type of molecules has its own frequency (vibration level) which can be amplified due to stochastic resonance produced by the wideband radiofrequency gas discharge laser.

Based on the obtained experimental data it is proposed to attempt to create a technology allowing development of resistance to toxic effects of Geptil/ hydrazine in animals. We suppose that the resistance to Geptil/ hydrazine and to many other toxic substances can be developed by influencing strategic metabolic vectors most vital of which are – functions of genetic apparatus at quantum level http://www.wavegenetics.jino-net.ru/ (http://www.wavegenetics.jino-net.ru/).

DISCUSSION OF THE EXPERIMENTAL RESULTS.

THEORETICAL MODELING.

The obtained data has wider implications than demonstration of capabilities of possible wave defensive antidote-effect and require theoretical consideration since they relate to strategic (quantum) mechanisms of genetic apparatus functioning of multicell bio-systems. At his stage we propose three formalized hypotheses of the wave processes while “reading or scanning” from bio-structures of donor genetic-metabolic wave information (data), remote addressed transmission of it, introduction of the information in to the bio-system-acceptor and metabolism management using that information.

1. Endogenous polarization-holographic processes in bio-systems

Wave informational scenarios – unfolding in the bio-system itself as well as during scanning by the laser beam at the initial phase – occur at photon level. Let’s consider that level in more details. In our previous researches we presented two- and three-dimensional models of bio-holographic management of building spatial structure of multicell organisms during embryogenesis.At the initial view subject to relatively stationary conditions in bio-systems (final phases of morphogenesis), these models are plausible. However, in living organisms statics and dynamics are paradoxically intertwined.

An adult organism is relatively static spatially on macro scales and significantly changes on this plane only at the stages of deep aging. Along with this that statics are provided for by the internal space-time dynamics of metabolic processes on micro levels of bio-systems organization. This is a case due to the fact that metabolic processes are a mobile aggregate of bio-chemical-bio-physical space-time reformations of the organism’s microstructures. Having considered the non stationary structures of bio-systems, more advanced model is proposed of endogenous informational polarized-holographic managing (governing) processes in multicell organisms, which are realized/effected at genome levels. The model reflects bio-holographic aspect of metabolism as a whole and therefore includes bio-morphogenesis as it specific case. The model utilizes appropriate physics-mathematical formalism for the polarized-holography yet extrapolates it onto probable endogenic analogical processes in the genetic apparatus of multicell organisms.

As a foundation for the model we used our experimental data where we employer special double-polarized He-Ne laser (= 632,8 nano мeter), having two orthogonal, linked optical modes, of which we have mentioned earlier. When such laser beam of this quantum generator interacts with the bio-tissues, with dynamic holographying on the oncoming beam (bunch) mode on, simultenious acts of recording and scanning of previously unknown information occur, the information about dynamic spinning-fluctuating processes on optical and atomic-molecular levels. Of particular interest can be data obtained about genetic structures and/or living cells. The entire informational structures of an organism, including DNA, RNA and proteins, are optically active, that is to say they are capable of spinning light polarization planes and they are dichroic – difference between absorption of right- and left hand polarized light. Modulations of polarization that correlate with structural-functional condition of any metabolite, present themselves as unique in their capacity storage of information about metabolism and its dynamics and along with it – that is a channel of intercellular photonic bio-symbolic contacts.

Such special processes, in their polarized-holographic version, are apparently inherent to genome workings as a bio-computer. This allows their modeling with use of the aforementioned laser. IT is capable of polarized-holographic recording, scanning, remote transmission and “injection” of wave commanding genetic-metabolic information from one bio-system to another. Besides, such laser performs a conversion of photons probing the bio-system in to wideband electromagnetic spectrum with frequencies from 2 to 0 according to mechanisms of localizing and

delocalizing of photons. During this stage, it is apparent, quantum non-local (teleportation) polarized connection across the whole spectrum of frequencies is retained (maintained, saved), including radio waves. Utilization of such laser as reading-transmitting photon-radio-wave system, imitating analogical wave-bio-computer-symbolic non local processes intercellular communications provided with opportunity to carry out remote wave transmission of primary /managing genetic-metabolic information from donor's bio-system to recipient's bio-systems (so called addressed transmission). In the light of this fact it seems rational and vital to attempt presentation of more advanced formalism of bio-symbolic photon-polarized-holographic processes in chromosome apparatus of higher bio-systems, all the more so that the radiowave equivalent of these processes possessed strikingly distinct morphogenetic potencies.

Let's record vector diffraction Kirchhoff's integral in paraxial approximation, which describes wave field, for instance photon field, formed by non-stationary bio-system's fragment. This sort of field may radiate from liquid crystal continuum of chromosome (LCCC) in vivo. Such emission may be expressed by the following:

For the purpose of simplification we will consider that non stationary LCCC is not a function of frequency of translucent light.

Both polarisational modes of coheren laser light are depolarized by geno-symbolic acoustic LCCC and are partially elliptically polarized. With this, they can interfere forming specl-structures, and their total intensity is transferred from one mode in to another by means of earlier postulate manner [Prangishvili, Gariaev et al, 2000 (b)].

Modified Johns' vector of every passed orthogonal polarized waves immediately behind the object may be presented in the form of partially coherent orthogonal components of elliptical polarization

In a bio-system in the composition of LCCC (with only one polarizational component) we use as a hypothetical a carrying wave, which passed, for instance, through infinitely narrow time shitter lock, possessing - figurative characteristic of time transmission (perhaps "gating"). Such a shutter lock completely depolarizes initially polarized wave. The resulting wave, passed behind the gating lock, has continuous spectrum in the whole diapason with evenly distributed spectral density, where as the modified vector of the carrying wave has a form of orthogonal basis of elliptical polarization:

Parameters of the total ellipse p and g are defined via ellipse's polarization component of every basis A and B, as in Ref [14]

Endogenous biological registration of the summary wave field (5) pertaining to LCCC as a basic element of DNA-wave bio-computer, assumes presence of polarization-sensitive environment in organisms, which is not selective of any particular spectrum across the whole range of active frequencies (similar to the non stationary fragment of biological object, for instance LCCC).

Due to the polarization characteristics of the inducing light in a light-sensitive registering environment of LCCC, photo-anisotropy and photogyrotropy are created (are produced). To describe the vector photo-response polarized-sensitive environment functions of isotropic , anisotropic - and gyrotropic reactions are introduced, which are constants for every frequency of the active spectrum. Using Johns' matrixes and rules of their construction for cases of partially polarized inducing irradiation, for the resulting Johns' matrix we get:

where - LCCC's hologram fragment size

- distance between the point on the hologram surface and the point of observation.

Than, successively substituting in (17) expressions for matrixes (10), (14) and (15), let's define formed by the hologram zero, imaginary and real depictions. It is only now that we can determine, what endogenous or/and exogenous wave for an organism is necessary to utilize as a reconstructing one in order to obtain in the imaginary style regeneration of the required fragment of the wave image of the shaping bio-system. In order to do so it is essential to determine their vectors and corresponding values of matrix. It appears that with precision of up to constant multiplier own vectors of matrix are in essence

It follows that regeneration is performed by a wave identical to the one used while recording by the carrying wave. So, as apparently, in bio-systems at LCCC level recording and reconstruction ensue ither simulteniusly or in accordance with the last equation, then the reconstructed imaginary depiction corresponds to the real one and it is not subject to

any distortions. The latter is principallycrucial for preservation of the wave images-vectors of morphogenesis, which compensate physiologic-bio-chemical and mechanical non-stationary stae of the bio-system as a whole and its LCCC in particular. Nonetheless, non-stability of strategic photonic-images of organism's structures will occur though in term of long lengths of time while aging and its pathological states, for instance in the case of cancerogenesis.

For a passed wave without diffraction the zero depiction has the following appearance:

An analysis of the last correlation shows that with precision up to its multiplier it contains complete reconstruction of space-time structure as well as polarization characteristics of the field of its non- stationary object wave that have passed through, for instance, LCCC. These photo or/and radio wave dynamic structures are, apparently, used by multicellular organisms for their own organization in their own space-time since these structures-images completely retain the true real calibration size without deformations imposed by non-stationary bio-systems and reproduce them in adequate sizes require for a developing or an adult organism. In accordance with the reconstructed wave gradients scanned polarized holograms occurs 4D organization of metabolic "fluxes"/"streams", cellular architectonics and morphogenetic motions during embryo genesis and also partial regeneration of bio-systems in case of them having been damaged. In other word what occurs is calibration of dynamic potential space-time of bio-system.

Under polarized-holographic-bio-control we imply endogenous or intentional (artificial) modification of recipient's cell structure and condition as a result of controlling holographic operations from donor's side. In our case the holographic signal, which was modulated by healthy samples (tissues, cells) of the donor, is transmitted and recorder onto donor's diseased (ill) cells in form of a hologram. Further, the process of control occurs as follows: in the beginning from the modified cells of the recipient by means of regenerative wave the holographic image of donor's healthy cells is scanned. It is reconstructed in terahertz wave diapason as a 3D image encompassing every recipient's cell together with its content.

Mainly, there exist two forms sources of regenerative wave. First form is endogenous. In this instance the processes flow due to innate reserves i.e. "internal" irradiation (emission) of the neighbouring cells. Second form appears to be exogenous reconstruction, when the sources are external emitters. Both forms of sources operate in the recipient's cells and act simultaneously and continuously, regenerating and complementing the same image of donor's healthy cells over and over again

According to gradients of intensity of donor's reconstructed cell images, as if it was a "drawing", growth and regeneration of recipient's damaged (ill) cells occur. The cells of the recipient "assume" a role of a photographic film (plate), in which a hologram of the healthy cells is recorded. Processes of the growth and regeneration, flowing analogically to processes of photo-tropism, require certain length of time. In the upshot the recipient's "sick" cells partially transfer to healthy ranking and partially destroyed. Products of such decomposition are diverted out of the recipient's organism.

That being so, during the replacement process of recipient's cells by healthy ones, analogous to those of donor's, occurs polarized-holographic-control which is in effect germination of the recipient's damaged cells biomass in to offered to them dynamic holographic form of healthy donor's cells. As a consequence, while controlling the process, the form and dynamic state (condition) of recipient's cells is gradually modified under the controlling signal – "pattern", obtained from the donor.

Needless to say that this form of "pattern" is much more complex than those seen in simple controlling systems. It sets spatial distributions terahertz signal on gradients of which the growth and formation of live cells in recipients occur. Therefore acts of growth and formation of recipient's cells happen in line with bio-chemical laws, which control their vital functions, and the "pattern" signal sets a program or guide of growth for young cells' structures and modulation of processes in them.

For more comprehensive description of internal working mechanisms of holographic circular-polarized informational-laser transformation in live organisms it is necessary to have a fair good understanding of basics of polarized-dynamic holographic theory and informational exchange between recipient's live healthy cells and all other cells included in organs and tissues of the ill organism. When dealing with these issues we utilize de

Transmission of modulated information from donor to recipient occurs by means of rectilinearly propagating longitudinal mutually entwined waves, carrying multilevel modulated information. For the short distance transmissions we can use a term of cellular nucleuses – optical poliaroids (polarizers?), where as for longer distances – a term of

quasi lenses (objectives) (here is a reference to some previous papers). Let's look in to description of such process proffered for purposes of registering color holograms without using lasers [Alexanderov, 1998]. When adapting it to a bio-system, we outline requisite conditions for realizing non-coherent polarized-holographic method of control (management). It ought to be noted that in such systems, having done microscopic studies of the systems, it was discovered long ago that they have microscopic polarisers, i.e. cells' nucleuses, as well as optically active protein substances, which spin the polarizational plane of emissions that are passed through them. These aspects are long knowng to researchers [Bischof, 1995], however until now this observed phenomenon was neither explained not utilized.

Holographic transmission function can be defined on the basis of Fourier transformation of equation (13). To remind, the wavelength of the probing signal is not included in this formula therefore that wave can be selected from wide range of waves light, electromagnetic and acoustic diapason. The created hologram encompasses whole information about spatial coordinates features of donor's bio-object being holographed, or about spatial distribution of all donor's points in relation to holograph registering planes of recipient.

So the resulting solution of the task is, generally speaking, analogical to traditional approach. At the same time the method put forward is fundamentally different from other known interferential methods and possesses certain advantages.

Firstly, instead of some wavelength with its monochromatic features and coherence we use dispercing spinning ability of optically active environments and spatial locally-distributed polarizational filtration. This is sufficient for recording polarized-dynamic hologram of donor (provided that there is motion in donor's cell in non-coherent wide spectrum irradiation of the recipient)

Secondly, this method allows uncovering the reasons of vibro-resistance when registering and reconstructing holograms without laser sources of light inside bio-systems in terahertz diapason of waves. It efficacy is determined by the value of polarized-optical spinning ability and thickness of the optically active environment . It is known that spinning ability of certain liquid crystals reaches 40000 degrees/mm, which when used in holographic information-laser convertor is sufficient for polarized-holographic transmission of information and accordingly holographic controlling of the biosystem's structures and processes.

Experimental works on wave interaction in living systems were actively been initiated in 1980s. In the beginning these included researched on interactions between cells [Kirkina et al, 1981; Molchanova, 1985], followed by researches on interaction of living organism [Burlakov et al., 1999]. These works were successfully furthered by A B Budagovski et al. [Budagovski, 1990; Budagovski, Evseeva, 1995; Budagovski et al, 1997; Budagovski et al, 2001]. It was shown that there is a communication and exchange of information of non-chemical (wave, coherent) nature. Such kind of interchange processes, occurring with participation of bio-regulatory signals and occurring without molecular and ion carriers of that information, were labled as processes of remote intercellular interaction (RII) [Budagovski, 2004]. However it seemed incredible that weak electromagnetic cellular signals can produce controlling influences against the background of strong electromagnetic interfering signals of natural and technogenic origins. Nonetheless it appears that with coherent reception light and other electromagnetic non-coherent noises with approximation are zeroed where as those weak coherent and deterministic signals can accumulate [Tertishni et al., 1997, 1998, 2000]

In the last years these works have received the deserved advancements in the Institute of management issues. In particular, utilization of polarized-dynamic holography, which allows formation of little movable polarizational rings. For urposed of transmitting undistorted image of every donor's point to the remote recipient's zone, a sensory quasi objective (lenses) were created, and on its basis a holographic device designated for experimental testing of holographic controlling possibilities.

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Decipher Journal, Vol 1, No 1 (2011)

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The history of wave genetics has been developing for more than 80 years. In 20s and 30s of the last century Russian scientists, A G Gurwitsch and A A Lubishev postulated that not only does genetical apparatus of living organisms on the Earth operate at material, physical level but also at certain waves/fields level and is able to transfer genetic data/information via electromagnetic (EM) and acoustic waves. The science has recently taken a major leap in its advancements of the theory and reproducible experiments and thus the theory of wave genome has been put forward.

One of the first attempts to rationalize and expound the wave genome theory in Russia had been made by P P Gariaev and A A Berezin from the department of Theoretical Matters of Russian Academy of Science, and also with participation of A A Vaciliev, a fellow member of Institute of Physics of Russian Academy of Science. As a theoretical foundation, principles of coherent physical radiations, holography and solitons, theory of physical vacuum, fractal representation of DNA and human verbal expression/speech have been employed to describe and substantiate the empirical results obtained through many experiments conducted.

The quintessence of the wave genome theory may be represented as following:

genome of the highest organisms is considered to be a bio-computer which forms the space-time grid framework of a bio-systems.

In that bio-system, as the carriers of a field epi-gene-matrix - wave fronts are being used, which are assigned by gene-holograms and so-called solitons on DNA – distinct type of acoustic and electromagnetic fields, produced by biogenetic apparatus of the organism/bio-system under consideration and being a medium of strategic regulatory data/information exchange between cells, tissues and organs of the bio-system.

It is also vital to note that the holographic grids/frameworks, which are also the elements of fluctuating structures of solitons, are, in fact, discrete simplest cases of code-originated information, anchored in chromosome continuum of an organism.

At present the dominant viewpoint in respect of genetics and molecular biology is that :
1. the genetic apparatus functions as a purely material structure
2. all the functions of genetic control of an organism occupy approximately 2 % of DNA of a bio-system and fulfill designated functions such as replication of RNA and proteins, so called coding DNA of an organism. The other 98% is considered to be “junk DNA” not carrying out any genetical functions, which may represent a graveyard of virus DNA.

The biologists and geneticists use the language of analogies and metaphors to explain how genetic apparatus operates. The genetic apparatus consisting of 46 chromosomes is viewed as a library consisting of 46 volumes or books. Each book (a chromosome), contains a text (instructions of how to build an organism) which consists of sentences (DNA) consisting of words (genes). And each word (a gene) consists of 4 letters (certain “chemical letters”), i.e. the “genetic alphabet” consists of only 4 “letters”. The material realizations of the DNA molecules are famous double helixes, consisting of segments which are genes. In essence, genetic apparatus operates as follows. The texts, written in the “DNA language”, are first translated by the organism into the “RNA language” and then into the “Protein language”. And proteins are the stuff that we are mostly made of (not counting water). Proteins perform two principle functions in the organism: they metabolize substances that we eat and participate in the morphogenesis, i.e. development of the spatial-temporal organization of an organism.

It is to be pointed out that the primary focus of the wave genome theory is on the remaining aforementioned 98% of chromosomes as being the key “intellectual” structure of all cells of an organism including the brain. It is those chromosomes that operate on the wave, on the “ideal” (fine-field) level.

It the ideal component, that may be called super-gene-continuum, is a strategic vital figure/formation that ensures development and life of humans, animals, plants and also their programmable natural dying. Along with that, it is

important to conceive that there is no sharp and insurmountable distinction between genes and super-genes. Both these levels of encoding constitute material (physical) matrixes, however genes supply material replications in the form of RNA and proteins, whereas super-genes transform endo- and exogenous fields, forming from them super-gene-signal wave structures. Furthermore, the genes may be components of holographic grids/frameworks of super-genes and supervise their field activity

Particular attention in the wave genome theory should be devoted to substantiating of the unity of fractal (replicating itself on varying scales) sequence structures of DNA and of a human speech. In 1990 Jeffrey Delrow discovered four "letters" of the genetic alphabet (Adenine, Guanine, Cytosine and Thymine) in DNA "texts" form fractal structures.

Later on, a discovery of similar fractal structures in a human speech, not limited to multy-letter alphabets of Russian and English texts and including a sequence of words from those texts came as a promising surprise for both genetics and linguists. Nonetheless this is in accordance with a branch in semiotics named "Genetical Linguistics", which studies incomprehensible and unexplainable precise application of laws of Formal Genetics to formation of interlingual and intro-lingual words-hybrids.

A group of scientists headed by P P Gariaev and M U Maslov, developed a theory of so called fractal representation of natural (human) and genetical languages. Within the confines of this theory it is said that the quasi-speech of DNA possesses potentially inexhaustible "supply of words" and, moreover, what had been a sentence on the scales of DNA–"texts" "phrases" or a "sentence" becomes/turns into a word or a letter on the other scale. Genetical apparatus can be viewed as the triunity of its structure-functional organization consisting of holographic, soliton and fractal structures.

This theory allows a refined quantitative comparison of symbolic structure of any texts including genetical. Thereby a possibility has been wide open to approach a deciphering of a lexicon of one's own gene-code, and accordingly, more accurate composition of algorithms of addressing a genome of a human with an aim of potentially any type of programming of one's vital activity such as treatment, increasing one's life expectancy and so on and so forth.

Empirical tests of wave genetic theory in the light of "speech" characteristics of DNA demonstrate strategically correct stance and direction of the research.

Phenomenal experimental findings may be briefly presented here. For the first time in history of the science we successfully managed to obtain experimental evidences of abilities of the genetic data/information to function on more than simply one material level, for instance, in the wave/field (electromagnetic) form

Over decades, having been conducting extensive theoretical researches, we successfully managed to formulate theoretical biology and physics-mathematical description, explanation and substantiation of fundamental principles of genetic apparatus functioning on the wave/field level.

These principles allowed us to design and create a quantum bio-computer essential element of which is a specially tuned laser beam with certain wavelength and frequency characteristics.

The quantum bio-computer can perform:
i. Scanning and reading the wave/field equivalent of the genetical-metabolic data from the (stem) cells, tissues, organs of a donor's bio-system employing photon of the laser beam;
ii. Conversion of the photons obtained into wide-wavelength-band preserving the scanned and read data;
iii. Precise and pointed introduction of such scanned and converted principal/dominant data radio waves into the organism-recipient, located at a certain distance from the donor's bio-system (from few centimeters to 20 km);
iv. Strategic control/management of metabolism and postembryonic morphogenesis of the organism-recipient according to two vectors/modes:
a. "Do as/what I do" – that is holographic principle, and
b. Wave/field transmission of a signal that contains commands activating required programs in the stem cells of, for instance, rats; programs that direct/guide the stem cells development on their way of, as in our experiments, building pancreas gland in rats. These vectors/modes are intended to be used on humans.

At present we are able to program/manage/encode stem cells of various types by means of a quantum bio-computer. The quantum bio-computer initiates wave/field-based commands, given to cells and tissues of the donor/recipient, and accordingly the stem cells exposed to the waves/field will be prompted to guided cytodifferentiation leading to emergence and development of planned/projected new organs and tissues. This will bring us closer to the fact of substantially increased life expectancy.

Significant achievements in applying WaveGenetics have been made thus far in regeneration of pancreas in rats previously destroyed by chemical substance called alloxan

Three series of experiments with identical protocol were conducted by the groups of P. Gariaev in 2000 in Moscow Russia, in 2001 in Toronto, Canada, and in 2005 in Nizhni Novgorod, Russia. These are more advanced experiments based on the principles and technology of WaveGenetics. The goal of the experiments was to test new technology for regenerating damaged pancreas. Pancreas is an endocrine gland which has several vital functions, the major one being production of insulin, a hormone responsible for sugar metabolism.

A control group of rats was injected a lethal doses of a poison called alloxan which destroys pancreas. As a result, all the rats in the control group died from diabetes in 3-4 days. Then the same lethal dose of alloxan was injected to another group of rats. And when the rats reached the critical condition, they were exposed to light images/waves coming from a quantum bio-computer. Those light images/waves were created beforehand when the bio-computer read information from the pancreas surgically removed from healthy newborn rats of the same species as those used in the alloxan experiments.

One can explain the results of the experiment using the following analogy. The pancreas gland contains DNA-movies with information about healthy condition of the pancreas in its genetic apparatus. And this video morphogenic information programmed the stem cells of sick rats to regenerate their pancreas gland. Combined statistics for all 3 series of experiments is as follows. Altogether, around 90% of all the rats had their pancreas gland restored and their health recovered.

In some of the experiments the quantum bio-computer was modified to allow successful transmission of the healing information to sick rats at the distance of 20 kilometers. Note, that no known physical fields have the capability to transmit such extremely week signals with such unbelievably powerful results.

Furthermore, the WaveGenetics research and application has significant prospects of solving issues as regards ageing process in humans and increase of life expectancy. This view is grounded on the experiments we have been conducting with rats.

It is Opportunities of technologies of WaveGenetics are not limited to what has been outlined above. The development and application of the technology is far-reaching and is substantiated by experimental data obtained in numerous tests, experiments, observations.

In addition, it ought to be mentioned, such a technology – a quantum bio-computer, is capable of:
• treating oncological diseases on fundamentally distinct basis – without use of any chemical substances,
• eliminating pathogenic viruses and bacteria and agricultural vermin parasites – also without used of any chemical substances.

It may seem as a technology of another age, from distant future. However, a discovery of fundamental properties of living organisms is occurring today and it is our task to research and explain the phenomena and bring it to the service of humanity.

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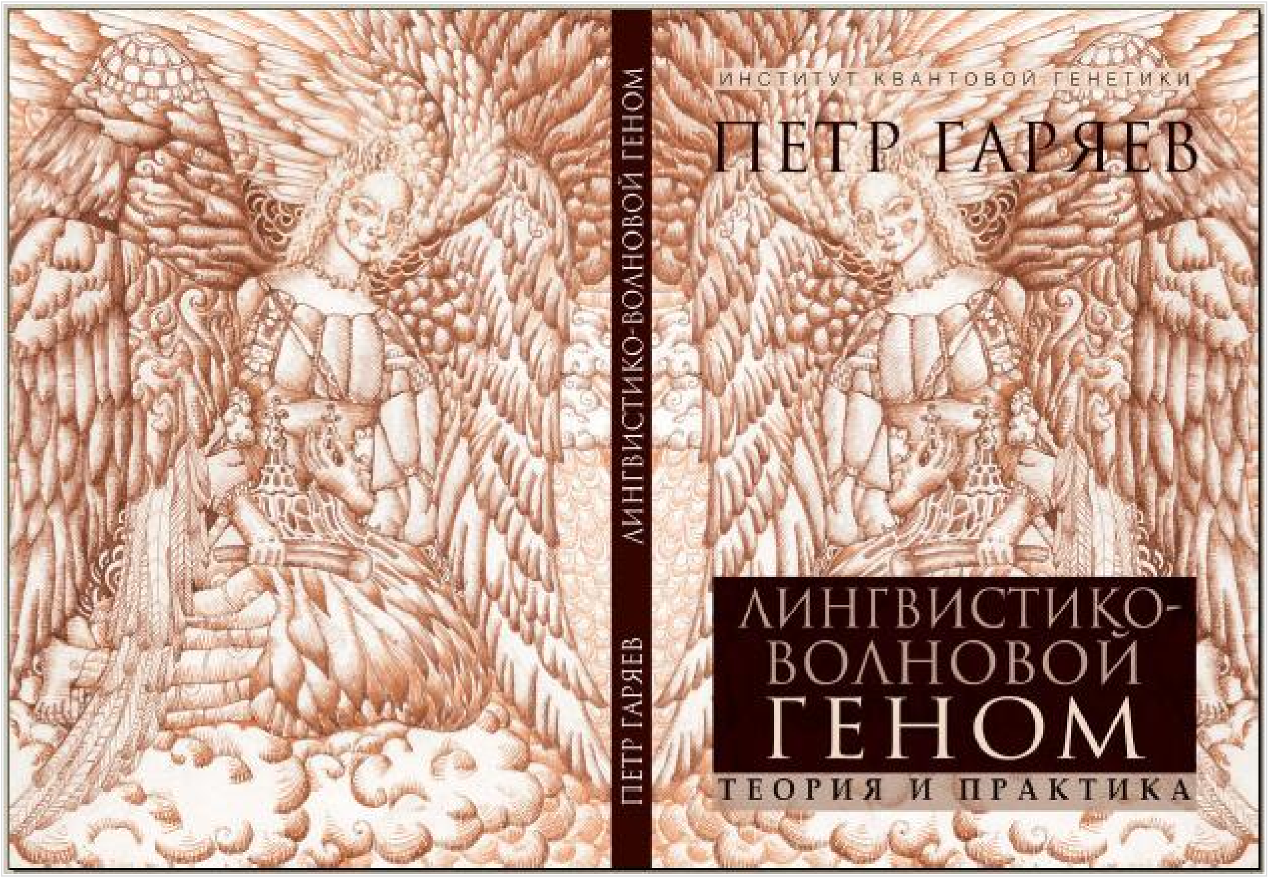
ИНСТИТУТ КВАНТОВОЙ ГЕНЕТИКИ
ПЕТР ГАРЯЕВ
ЛИНГВИСТИКО-ВОЛНОВОЙ ГЕНОМ
ТЕОРИЯ И ПРАКТИКА
ЛИНГВИСТИКО-ВОЛНОВОЙ ГЕНОМ
ПЕТР ГАРЯЕВ

Hi Iona...I have been following Gariave's work since I became aware of it. I have about 25 years of experience with DNA in the lab. A serious problem with his approach is that he still believes in the "junk" DNA notion which has run its course..now there is excellent evidence that ~80% of the genome contains important information. In addition to coding for proteins, there is a plethora of RNAs, micro, ribosomal, long repeat, siRNA etc that play a role in developemt, disease and so forth. Another weakness is that all his experiments were done with purified DNA. In the cell, DNA is part of a protein-DNA complex, which is very tightly packed at very high concentrations ..chromatin has totally different biochemical and biophysical properties than the dilute solutions of DNA that he works with..(The cell is so concentrated with proteins and nucleic acids, that its closer to a liquid crystal than a bag of solutes)

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Invited presentation by Magnus Olsson at the 2017 First Annual Unity and Hope Conference

Invited presentation by Magnus Olsson

“Invited presentation by Magnus Olsson, at the 2017 First Annual Unity and Hope Conference” This event was for targeted individuals and those concerned about the growing crimes of electronic harassment.

(https://nanobrainimplant.com/240_f_116659017_ryiguzdnplfxcwaattixa25shzy5nkt4/)

The conference was held from October 20-22 at the Mass Audubon Blue Hills Trailside Museum: 1904 Canton Ave., Milton, MA 02186, USA. This presentation was co-produced by Mårten Hernebring. The speaker, Magnus Olsson, can be reached at bionicgate@live.se Event Description from the Conference Web Site: “Our goal is to bring together as many support groups, media shows, activism groups, and organizations of targeted individuals, so we can work together and learn from each other and strategize on solutions to bring about change and end the suffering of hundreds of thousands of victims nationwide.

The number of people experiencing electronic harassment and gang-stalking is growing exponentially daily. Our hope is to come together, to build, empower, and educate the community on technology, resources, and support, and as a unified front attempt to educate the public. As a result of this conference, we will be able to strategically fight for freedom and justice for the victims of targeted crimes.

The goal of this conference is to unify all the groups worldwide and provide a knowledge and understanding of the program and the technology. We also strongly encourage targeted individuals to bring friends and family for support and to educate the ones around them on what invisible crimes are being committed against them."

By mindcontroleurope • Posted in Man vs Machine, military, Mind Control • Tagged artifical-intelligence, electronic harassment, gang-stalking, Hive Mind, hybrid brain, hybrid mind, magnus olsson, mind control, targeted individual, Targeted Individuals, Unity and Hope Conference
DEC **11** 2016
IMAGE

Now declassified & available! Russian Quantum Leap technology enhances RNA/DNA, cures diseases, stops Bio hacking

Now declassified & available online! Russian Quantum Leap enhances RNA, DNA & health, cures diseases (e.g. diabetes, cancer 2), stops TI targeting.

December 6, 2016

Now declassified & available online! Russian Quantum Leap technology enhances RNA, DNA & health, cures diseases (e.g. diabetes, cancer 2), stops TI targeting.

By Alfred Lambremont Webre

WATCH QUANTUM LEAP PANEL INTERVIEW

Watch Russian Television RT Interview with Magnus Olsson [Seen by 14 million persons]

Mind Control – Remote Neural Monitoring: Daniel Estulin and Magnus Olsson on Russia Today

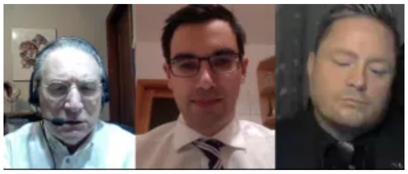
(https://i2.wp.com/newsinsideout.com/wp-content/uploads/2016/12/Alfred-Webre-Morton-Hernebring-Magnus-Ollson-4.png?ssl=1)

alfred-webre-mårten-hernebring-magnus-olsson

You Tube: https://www.youtube.com/watch?v=o9bd-B2dqCM (https://www.youtube.com/watch?v=o9bd-B2dqCM)

VANCOUVER, BC – Newly arrived from Russian Quantum Leap by the American Reaserch and Development Company Wave Genos and its Founder and Sole Owner Irene Caesar Ph.D. Magnus Olsson and Madlen Namro, are joined by their colleagues Mårten Hernebring to launch the public version of Quantum Leap technology of Wave Genome Irene Caesar Ph.D, a declassified technology used by Russian Special Forces to enhance DNA, RNA, personal health profile and performance, eye and vision health, as well as provide personal protection against Transhumanist agenda weaponry including remote directed energy weapon [DEW] and psychetronic attacks, such as "V2K (Voice To Skull) and cancer guns, subliminal advertising and psychic attacks".

MindTechEnterprises, authorized distributors outside Russia for the ULTIMATE TESLA GENERATOR, created and produced by the American company Wave Genome and its President, Sole Owner and Founder Irene Caesar Ph D,"

"The information-wave technology of the Laser Bioholography has been perfected by decades of research experience and clinical trials; it has been patented, licensed and certified by the Russian Ministry of Health; and, at the present moment, it is widely commercialized all over Russia. The information-wave technology of Laser Bioholography is based upon the application of Quantum Physics to Genetics, a new theory of Genetics, which is called Structuralist Genetics (© Irene Caesar, Ph.D., 2010), and the application of the stabilized He-Ne lasers with internal mirrors."

MindTech-Enterprises Website

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(https://nanobrainimplant.com/2016/12/11/now-available-russian-quantum-leap-technology-enhances-rnadna-cures-diseases-stops-bio-hacking/mind-tech-logo-01a/)

Full details of this first-ever public roll-out of Russian classified protective and health-status enhancing technology are set out in the above Panel interview and at Quantum Leap's distributors website at:

http://www.mindtech-enterprises.com/ (http://www.mindtech-enterprises.com/)

Quantum Leap Scalar Technology online

Quantum Leap technology, now available online through mini-Tesla Psi generators from the www.MindTech-Enterprises.com (http://www.mindtechenterprises.com/) website and through smart-phone apps, reportedly enhances the user's RNA, DNA & health profile, prevents and cures diseases such as diabetes, Stage 2 cancer, and stops Transhumanist Agenda weapons such as Voice to Skull and electromagnetic remote targeting.

The Quantum Leap technology's Mini-Tesla Generators come with Digital Pharmacy and a subscription service.

Quantum Leap technology, in applications developed in conjunction with Russian scientist Irene Caesar PhD. According to Dr. Caesar, the technology results in "Rejuvenation of all the Physiological systems, including endocrine system, digestive system, cardiovascular system, hearing / eye sight, reproductive system, intellectual abilities, improvement of memory."

Some features of the Quantum Leap Ultimate Generator

According to Wave Genome Irene Caesar Ph.D, *"The device is easy to wear in the form of a pendant cased in pearl, completely unobtrusive, and people can't tell exactly what it is because it is cased in pearl and does not look too unusual or like a "medical device", etc. The device is indestructible. The device is waterproof for basic small splashes, but should not be immersed in water.*

(https://nanobrainimplant.com/2012/07/11/scientists-humans-and-machines-will-merge-in-future/imagesca38vl83-3/)

The team uses a high resolution picture of yourself from early childhood (around 4-6 years of age) to develop sophisticated holography matrices from the picture using laser technologies and quantum technologies including scalar waves. They are able to recreate your energy field from when you were a child in a personal digital wave matrix and then use the device to continuously feed your current energy field with information from your childhood energy field. This helps to restore your current energy field to healthier conditions. This newer model has logarithmically more powerful protection features compared to the older versions of this device.

This new model still comes with all the health features of the older model including the E-Pharmacy, and ongoing health monitoring by professionals. The older more generic version of the device has been worn by members of parliament and Special Forces in Russia as well as the Russian Olympic Team. Over 5000 scientists/researchers from Russia have collaborated to work on this special project developing this device using the most advanced science in the world.

Some benefits of the Ultimate Generator:

The advanced technologies in the device can neutralize psychotronic/electronic attacks. The device is able to eliminate V2K. You can sign up for a monthly membership service to have the expert professional staff at the Moscow clinic in Russia monitor your health on an ongoing basis. If anything goes wrong with your health they are able to correct deviations from normal even before you notice symptoms of any actual medical condition. If medical conditions exist, many of them can be completely healed. You can receive medications remotely administered through the device. They get filtered through your own energy field and are guaranteed to never cause any adverse side effects.

The device helps to boost your immune system to diminish susceptibility to any illness. The device can help neutralize the negative effects of cosmic radiation when you fly in an airplane long distances. It can also reduce jet lag as well as keep you healthy while traveling. The device can help boost your energy, can help you sleep better, and can help you recover from any stressful events, sleep deprivation, etc., much faster. It can help you think more clearly and improve overall cognitive function. (Irene Caesar Ph.D.)

How purchasing works:

You can buy online at the website. Please see

http://www.mindtech-enterprises.com/ (http://www.mindtech-enterprises.com/)

Choose which version of the product you want to purchase. We recommend the Ultimate Generator as it is the most powerful version. Payments are processed using Paypal and other methods. You will be contacted to send a high resolution childhood picture of yourself. You will receive the device in the mail within 6 weeks. It takes this long to produce this device and to customize it for each individual. But don't worry, it will be worth the wait!

Tesla Glasses

IRENE CAESAR, PH.D.: ON TECHNOLOGY AND THEORY OF TESTLA GLASSES

The Panel also discusses Tesla glasses that have been developed and successfully used by Russian Security Forces for prevention and correction of:

- Stress and its consequences;
- Deterioration of the physical and mental performance;
- Reduction of immunity and the bodily defenses;
- Eye diseases;
- Diseases of the internal organs and physiological systems

(https://i1.wp.com/newsinsideout.com/wp-content/uploads/2016/12/1.TESLA_.GLASSES3.jpg?ssl=1)

Tesla Glasses

According to Wave Genome ***Tesla Glasses*** *use the method of Polarized Holography. Polarized Holography is the application of Quantum Physics for the purpose of rejuvenating all organs of the person through the Eye Crystal (Eye Lens and Iris). It is proven to provide significant physical and mental improvement, including a significant improvement in brain functions: decision speed, attention and memory.*

The method consists in the control of the brain via triggering the holographic signal in the eye, and its modulation. This control overwrites any verbal and mental imperatives, is non-local (can be used for instantaneous transmission of information at infinitely large distances), instantaneous (exceeds speed of light), and simultaneously reaching out towards every cell in the body.

The method is based upon Quantum Physics, specifically, upon the theory and technology of Polarized Holography, which uses the modulation of the holographic signal according to the Kozyrev Mirror principle.

The method is based upon the special ability of an eye to convert any linear signal into the holographic signal. The process of this conversion consists in the emergence of the scalar wave diffraction grating, polarization and refraction toward the zero center of the wave crystal (torus). Since the universe is holographic, we can record and transmit information only via the holographic signal, and through the zero center of the wave crystal. The zero center of every toroidal wave crystal coincides from the zero center of every chromosome on the cellular level, and every atom and subatomic particle on the subatomic level to the zero center of our galaxy.

Any healing, rejuvenation, and mental, psychic, and physical enhancement are based upon the ability to produce, control and enhance the holographic signal. The holographic signal instantaneously reaches the zero center of every wave crystal in our body, from the subatomic and atomic to the molecular levels – from the zero center of our skull and every bone to the zero center of every metacentric chromosome. Our eyes, skull, bones and chromosomes are centered and focused similar to our eye crystal according to the laws of the geometrical optics.

Hence, the eye is a very unique receiver, transmitter, and producer of the holographic signal. And that is precisely why vision is a trigger of brain activity. Via correct triggering the holographic signal in the zero center of the eye crystal, we can immediately reach the zero center of the toroidal wave crystal of our brain, thus delivering controlling information instantaneously into the zero center of the wave crystal of every metacentric chromosome in cell division, and into the zero center of the wave crystal of every bone, so that stem cells are programmed in a correct way in the bone marrow.

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(https://nanobrainimplant.com/2016/12/11/now-available-russian-quantum-leap-technology-enhances-rnadna-cures-diseases-stops-bio-hacking/mind-tech-logo-01a/)

Correct triggering consists in the modulation of the holographic signal in the eye. The modulation of the holographic signal in ***Tesla Glasses*** *consists in (1) modulation by the Schumann holographic signal; (2) modulation by human Brain holographic signal; (3) modulation by the holographic signal of a healthy organ and physiological system, recorded upon the chip in the glasses. It is combined with the modulation by the narrowband light-emitting diode sources of five colors. Research had shown that five colors, used by the glasses, benefit organs and physiological systems. The signal for every color is produced from the holographic signal of healthy organs and physiological systems, and, then, it is matched with the color. The signal of the color is not simply the color frequency.*

The carrier holographic signal is the individual holographic signal of the user – the unique [indestructible and uncreated] non-local wave matrix of the user. This is the primary holographic signal. The modulation holographic signals are the holographic enhancers, which help the unique [indestructible and uncreated] non-local wave matrix of the user get centered and focused in this dimension (on this planet). These are secondary holographic signals.

The advantage of the glasses over other Quantum Leap Polarized Holography devices is that glasses use an eye as a filter for filtering out all harmful linear signals, which unseal wave crystals. For example, microwave radiation shortens brain waves via "unsealing" the involuted wave crystals, thus, literally lowering the intellectual potential of people.

(https://nanobrainimplant.com/2016/12/06/now-declassified-available-online-russian-quantum-leap-technology/240_f_68304591_ovk9v6qieaoepraueh02gzahmcl49ymn/)

Thus, the effect of the ***Tesla Glasses*** *is based not simply upon the superficial stimulation of innervation. The stimulation of innervation, tone of the eye muscles, blood circulation, regeneration, and enhancement of all other biochemical and bioelectrical processes in the body are based upon the structural efficacy of Polarized Holography, which centers and focuses chromosomes, and prevents the transformation of metacentric chromosomes into acrocentric chromosomes.*

The modulation via secondary holographic signals (see above) allows for the emergence of the most coherent and sophisticated scalar wave diffraction grating that produces the more clear zero focus within the wave crystal (of a wave torus on every level from the atomic, subatomic to cellular and molecular levels).

The modulation occurs through the designated areas of Iris, each one corresponding to a specific organ in the body. As a result, the user achieves the stimulation of the projection zones in the Iris, each one being connected to a specific organ in the body.

In addition, ***Tesla Glasses*** *use the same effect as the binaural therapy. Binaural therapy uses the stereo effect, when signal in one ear gets into the brain with delay in relation to signal in the other ear. This produces the emergence of the complex scalar wave diffraction grating in the skull, based upon Kozyrev Mirror principle (polarization, refraction and emergence of the zero center of the wave crystal). Similar to this,* ***Tesla Glasses*** *use the stereo effect of color signal, when color signal in one eye gets into the brain with delay in relation to signal in the other eye.*

Product by:

WAVE GENOME

(https://nanobrainimplant.com/2016/12/11/now-available-russian-quantum-leap-technology-enhances-rnadna-cures-diseases-stops-bio-hacking/wave-genome/)

Ophthalmologists have found that all healthy people have rhythmic alternation visual perception. Man sees in turn by the right eye, and, then, by the left eye at regular intervals.

These intervals last for 2-3 seconds. The research was conducted using modern 3D technologies. And if one eye is covered by a blue filter, and the other eyes is covered by the red filter, the healthy person sees both colors simultaneously and separately. The left eye sees 20% of the image, and the right eye sees 80% of the image.

With age, these rhythms get broken. But the restoration of the "biological clock" is possible using Polarized Holography, modulated by color signals, with the frequency of the alpha rhythm of the brain of a healthy person. And, as the positive effect, we can achieve a significant rejuvenation of the body.© Irene Caesar 2015

The text is quoted from http://www.wavegenom.com (http://www.wavegenom.com)

More information on Tesla Glasses is available, and Tesla Glasses can be purchased at:

http://www.mindtech-enterprises.com/ (http://www.mindtech-enterprises.com/)

References

Quantum Leap, available from:

Wave Genome

MindTechEnterprises

http://www.mindtech-enterprises.com/ (http://www.mindtech-enterprises.com/)

Contact:

Email:

mindtechtrade@gmail.com

Send A Message:

http://www.mindtech-enterprises.com/ (http://www.mindtech-enterprises.com/)

Alfred Lambremont Webre Contact/News:

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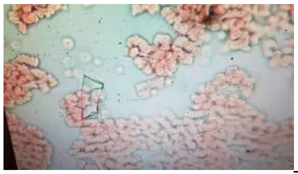

(https://newsinsideout.com/2016/09/part-magnus-olsson-reveals-artificial-crystals-blood-spread-via-smart-dust-transhumanist-remote-neural-weapon-control/)

PART I: Magnus Olsson reveals artificial crystals in his blood, spread via smart dust, are a Transhumanist remote neural weapon for control (https://newsinsideout.com/2016/09/part-magnus-olsson-reveals-artificial-crystals-blood-spread-via-smart-dust-transhumanist-remote-neural-weapon-control/)

PART I: Magnus Olsson reveals artificial crystals in his blood, spread via smart dust, are a Transhumanist remote neural weapon for control Transhumanist think tanks foreshadowed revelation in 2011 VOLVO TV ad – "Magnus Olsson: it gets in your blood" NewsInsideOut.com By Alfred Lambremont Webre WATCH EXOPOLITICSTV INTERVIEW VANCOUVER, BC…

September 20, 2016

In "AI Artificial Intelligence"

EUCACH Director: Dr. Rauni Kilde radiated for four days with DEW.

EUCACH Director: Dr. Rauni Kilde radiated for four days with DEW. Remotely assassinated by NSA? By Alfred Lambremont Webre NewsInsideOut.com WATCH ON YOU TUBE VANCOUVER, BC – Magnus Olsson, director of the European Coalition against Covert Harassment (EUCACH.ORG), revealed today in a NewsInsideOut.com interview that EUCACH Board of Directors member,…

(https://nanobrainimplant.com/2016/12/11/now-available-russian-quantum-leap-technology-enhances-rnadna-cures-diseases-stops-bio-hacking/mind-tech-logo-01a/)

By mindcontroleurope • Posted in Man vs Machine, military, Mind Control, News, Uncategorized • Tagged artifical-intelligence, biohacking, brain, disease, dna, electronics, health, interfaces, magnus olsson, military, military / medical classified research, neurohacking, quantum leap, rna, russian quantum leap, scalar, targeted individual, ti, Transhumanism, wave genome

SEP **11** 2016

THE Reality of Magnus Olsson’s blood – doctor’s report

THE Reality of Magnus Olsson’s blood – doctor’s report

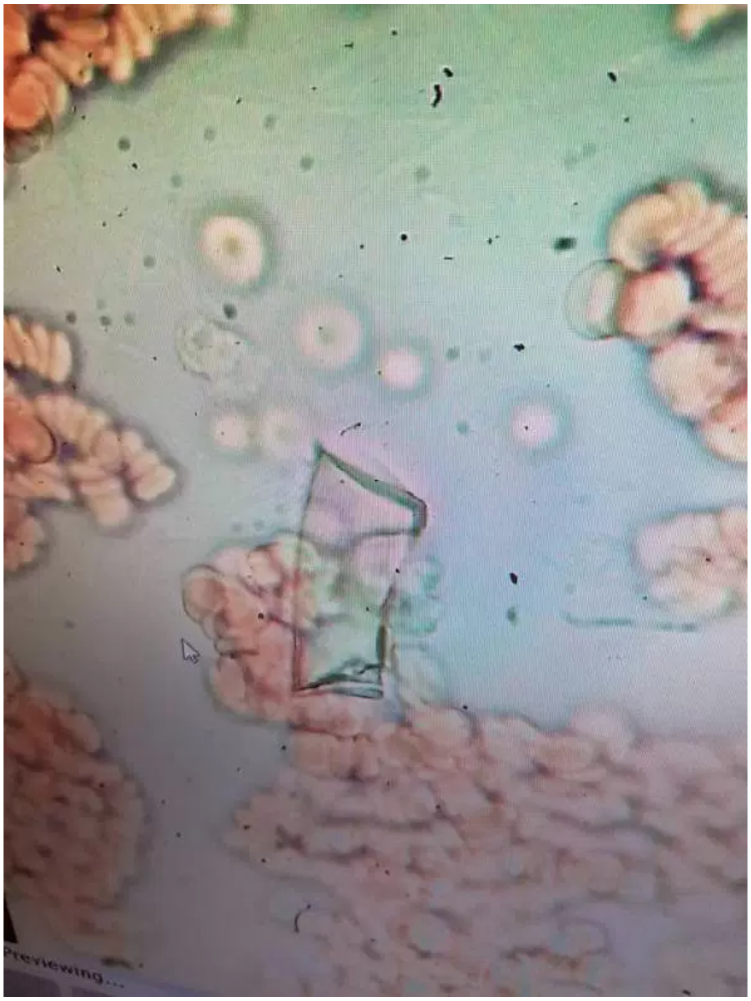

(https://nanobrainimplant.com/?attachment_id=1102)

During my staying in Poland, in Lublin I met a specialist Dr, who took a sample of my blood from my finger and we watched this together through an atomic microscope.

I will not now describe what is wrong with my blood, but I want you to notice the cristal which was made artificially.

what this is doing to me:

1. 1. makes my blood, not circulate in a natural manner (blood is too dense)
2. 2. damage DNA
3. 3. Influence memory (lack of memory)
4. 4. you can not walk normally nor run
5. 5. destroy your skin (you may have albinism)
6. 6. having a hard time sleeping
7. 7. easy access to the brain
8. 8. lack of oxygen

and many other symptoms…

There are millions of this in my blood. Every victim should do this checking with a doctor who knows about People Online and will check this blood with you through a atomic microscope.

This, together with the waves RF, ELF, SCALAR, NEUTRINOS, QUATUM SPECTRA, LASER, SONAR and others is devastating.

Previewing...

(https://nanobrainimplant.com/2016/09/11/the-reality-of-magnus-olssons-blood-doctors-report/magnus-olsson-blood-2/)

The most important for us is to secure ourselves and then cure. I am now working on a breathtaking solution for all of us, and I hope we will be free pretty soon. Then we can recover and heal.

Love and Light

Your Magnus

THE Reality of Magnus Olsson's blood – doctor's report:

Crimes against humanity are certain acts that are committed as part of a widespread or systematic attack directed against any civilian population or an identifiable part of a population:
https://en.m.wikipedia.org/wiki/Crimes_against_humanity (https://en.m.wikipedia.org/wiki/Crimes_against_humanity)
THE PENTAGON'S BLUE-SKY research arm wants to trick out troops' brains, from the areas that regulate alertness and cognition to pain treatment and psychiatric well-being. And the scientists want to do it all from the outside in:
http://google.co.in/patents/US3951134 (http://google.co.in/patents/US3951134)

https://en.m.wikipedia.org/wiki/Rayleigh_wave (https://en.m.wikipedia.org/wiki/Rayleigh_wave)

https://en.m.wikipedia.org/wiki/High_Frequency_Active_Auroral_Research_Program (https://en.m.wikipedia.org/wiki/High_Frequency_Active_Auroral_Research_Program)
What if a machine could read your mind?
https://drive.google.com/file/d/0B4iZUaEgNfFfMnpyem5fX1BPTTg/view (https://drive.google.com/file/d/0B4iZUaEgNfFfMnpyem5fX1BPTTg/view)
While most developmental robotics projects strongly interact with theories of animal and human development, the degrees of similarities and inspiration between identified biological mechanisms and their counterpart in robots, as well as the abstraction levels of modeling, may vary a lot.
https://en.m.wikipedia.org/wiki/Neuron_(software) (https://en.m.wikipedia.org/wiki/Neuron_%28software%29)
While some projects aim at modeling precisely both the function and biological implementation (neural or morphological models), such as in neurorobotics www.humanbrainproject.eu (http://www.humanbrainproject.eu/), some other projects only focus on functional modeling of the mechanisms and constraints described above, and might for example reuse in their architectures techniques coming from applied mathematics or engineering fields.
https://en.m.wikipedia.org/wiki/Developmental_robotics (https://en.m.wikipedia.org/wiki/Developmental_robotics)

https://m.facebook.com/Artificial-Brain-Sweden-1014306015294202/ (https://m.facebook.com/Artificial-Brain-Sweden-1014306015294202/)
What are the ethical issues involved in simulating a human brain and in technology derived from human brain simulation?
Building computer models of the brain may challenge our concepts of personhood, free will and personal responsibility, and the nature of consciousness.
(Delgado stated that "brain transmitters can remain in a person's head for life.
The energy to activate the brain transmitter is transmitted by way of radio frequencies.
https://en.m.wikipedia.org/wiki/Jos%C3%A9_Manuel_Rodriguez_Delgado (https://en.m.wikipedia.org/wiki/Jos%C3%A9_Manuel_Rodriguez_Delgado))

https://drive.google.com/file/d/0B4iZUaEgNfFfZl9iU1BpbzNJTW8/view (https://drive.google.com/file/d/0B4iZUaEgNfFfZl9iU1BpbzNJTW8/view)
In medicine, brain simulation could make it easier to communicate with people who cannot speak (e.g. people with severe disabilities, people in a vegetative state or with locked-in syndrome) or to enhance cognitive function in people with cognitive disabilities (e.g. dementia, trauma and stroke victims, etc.).
https://en.m.wikipedia.org/wiki/Wetware_(brain) (https://en.m.wikipedia.org/wiki/Wetware_%28brain%29)
As in other fields of science, it also possible that new knowledge about the brain will be abused – deliberately, for example to create new weapons – but also involuntarily, because society does not realize the power and consequences of new technologies.
https://m.facebook.com/Martin-Ingvar-KI-1528410917453814/ (https://m.facebook.com/Martin-Ingvar-KI-1528410917453814/)
For instance, it may be possible in the future to use knowledge about the brain to predict and modify individual behaviour, or even to irreversibly modify behaviour through electrical stimulation of the brain, pharmacology or neurosurgery. In cases of intractable mental disease, this may be desirable, but in other cases, the costs and benefits will be debatable. One example of debate is whether society should allow cognitive enhancement in healthy people.
Similar considerations apply to technology. Future computers that implement the same principles of computation and cognitive architectures as the brain have enormous potential to improve industrial productivity and offer new services to citizens.
However, they could also be used to implement new systems of mass surveillance and new weaponry.
https://m.youtube.com/watch?v=o9bd-B2dqCM&feature=youtu.be (https://m.youtube.com/watch?v=o9bd-B2dqCM&feature=youtu.be)

If such systems came into widespread use they would undoubtedly have a huge impact on patterns of daily life and employment – this could be both beneficial and detrimental
https://www.humanbrainproject.eu/faq/ethics (https://www.humanbrainproject.eu/faq/ethics)

This is what it’s all about:
https://m.youtube.com/watch?v=01hbkh4hXEk&feature=youtu.be (https://m.youtube.com/watch?v=01hbkh4hXEk&feature=youtu.be)
The development of your Future connected to a mindreading machine:
https://www.rt.com/usa/265029-kurzweil-google-hybrid-brain/ (https://www.rt.com/usa/265029-kurzweil-google-hybrid-brain/)

http://www.ted.com/talks/ray_kurzweil_get_ready_for_hybrid_thinking (http://www.ted.com/talks/ray_kurzweil_get_ready_for_hybrid_thinking)
And the developing of Future Surveillance:
https://m.youtube.com/watch?list=PL9DCCHoTYZ8KaMFrLrUzNblMsIECi9vQ0&v=30seQeBI-Tc (https://m.youtube.com/watch?list=PL9DCCHoTYZ8KaMFrLrUzNblMsIECi9vQ0&v=30seQeBI-Tc)

https://m.youtube.com/watch?feature=youtu.be&v=pW1HACMaOME (https://m.youtube.com/watch?feature=youtu.be&v=pW1HACMaOME)
Imagine what U.S could do if they could master the nanoparticles that are distributed in vaccine to human’s worldwide and use them for remote neural monitoring:
https://mind-computer.com/2012/12/20/remote-neural-monitoring-a-technology-used-for-controlling-the-human-brain/ (https://mind-computer.com/2012/12/20/remote-neural-monitoring-a-technology-used-for-controlling-the-human-brain/)
Nanoparticles BMI https://en.m.wikipedia.org/wiki/Brain%E2%80%93computer_interface (https://en.m.wikipedia.org/wiki/Brain%E2%80%93computer_interface) in vaccine:
Nanofluids also have special acoustical properties and in ultrasonic fields display additional shear-wave reconversion of an incident compressional wave; the effect becomes more pronounced as concentration increases.
https://en.m.wikipedia.org/wiki/Vaccine (https://en.m.wikipedia.org/wiki/Vaccine)

https://en.m.wikipedia.org/wiki/Aluminium (https://en.m.wikipedia.org/wiki/Aluminium)

http://sharpbrains.com/blog/2015/03/19/non-invasive-brain-stimulation-meets-nanotechnology/ (http://sharpbrains.com/blog/2015/03/19/non-invasive-brain-stimulation-meets-nanotechnology/)

http://globalbiodefense.com/2012/07/28/darpa-program-hits-milestone-in-plant-based-vaccines-for-pandemics/ (http://globalbiodefense.com/2012/07/28/darpa-program-hits-milestone-in-plant-based-vaccines-for-pandemics/)

https://en.m.wikipedia.org/wiki/Nanofluid (https://en.m.wikipedia.org/wiki/Nanofluid)
This speaks volumes about the hidden impact certain vaccines may have on your body and your brain in particular…
http://articles.mercola.com/sites/articles/archive/2011/08/06/vaccine-increases-narcolepsy-by-660-percent.aspx (http://articles.mercola.com/sites/articles/archive/2011/08/06/vaccine-increases-narcolepsy-by-660-percent.aspx)

Delgado stated that ”brain transmitters can remain in a person’s head for life.
The energy to activate the brain transmitter is transmitted by way of radio frequencies.
https://en.m.wikipedia.org/wiki/Jos%C3%A9_Manuel_Rodriguez_Delgado (https://en.m.wikipedia.org/wiki/Jos%C3%A9_Manuel_Rodriguez_Delgado)

https://www.google.com/patents/DE10253433A1?cl=en&dq=inassignee%3A (https://www.google.com/patents/DE10253433A1?cl=en&dq=inassignee%3A)

https://archive.org/details/pubmed-PMC4086297 (https://archive.org/details/pubmed-PMC4086297)

https://en.m.wikipedia.org/wiki/Neurorobotics (https://en.m.wikipedia.org/wiki/Neurorobotics)

https://drive.google.com/file/d/0B4iZUaEgNfFfell0YWFFMHd3RnM/view (https://drive.google.com/file/d/0B4iZUaEgNfFfell0YWFFMHd3RnM/view)

https://en.m.wikipedia.org/wiki/Cybernetics (https://en.m.wikipedia.org/wiki/Cybernetics)

https://en.m.wikipedia.org/wiki/Target_Motion_Analysis (https://en.m.wikipedia.org/wiki/Target_Motion_Analysis)

http://www.raytheon.com/ (http://www.raytheon.com/)
In analysis such as computational fluid dynamics (CFD), nanofluids can be assumed to be single phase fluids.
http://www.datacenterdynamics.com/news/sgi-gives-us-military-the-fastest-supercomputer/91007.fullarticle (http://www.datacenterdynamics.com/news/sgi-gives-us-military-the-fastest-supercomputer/91007.fullarticle)
The Worldwide Security Grid: MATRIX Smartdust is a system of many tiny microelectromechanical systems (MEMS) such as sensors, robots, or other devices, that can detect, for example, light, temperature, vibration, magnetism, or chemicals. They are usually operated on a computer network wirelessly and are distributed over some area to perform tasks, usually sensing through radio-frequency identification.
http://www.foi.se/en/Customer–Partners/Projects/Edge1/Edge/ (http://www.foi.se/en/Customer--Partners/Projects/Edge1/Edge/)
Without an antenna of much greater size the range of tiny smart dust communication devices is measured in a few millimeters and they may be vulnerable to electromagnetic disablement and destruction by microwave exposure.
https://en.m.wikipedia.org/wiki/Smartdust (https://en.m.wikipedia.org/wiki/Smartdust)
The Grid Security Infrastructure (GSI), formerly called the Globus Security Infrastructure https://en.m.wikipedia.org/wiki/Grid_Security_Infrastructure (https://en.m.wikipedia.org/wiki/Grid_Security_Infrastructure), is a specification for secret, tamper-proof, delegatable communication between software in a grid computing environment. Secure, authenticatable communication is enabled using asymmetric encryption.
http://ieeexplore.ieee.org/xpl/login.jsp?reload=true&tp&arnumber=6028683&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D6028683 (http://ieeexplore.ieee.org/xpl/login.jsp?reload=true&tp&arnumber=6028683&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D6028683)
In software engineering, the terms “front end” and “back end” are distinctions which refer to the separation of concerns between a presentation layer and a data access layer respectively.
The front end is an interface between the user and the back end. The front and back ends may be distributed amongst one or more systems.
In software architecture, there may be many layers between the hardware and end user. Each can be spoken of as having a front end and a back end. The

front is an abstraction, simplifying the underlying component by providing a user-friendly interface.
https://en.m.wikipedia.org/wiki/Pervasive_game (https://en.m.wikipedia.org/wiki/Pervasive_game)
In software design, for example, the model-view-controller architecture provides front and back ends for the database, the user and the data processing components. The separation of software systems into front and back ends simplifies development and separates maintenance. A rule of thumb is that the front (or "client") side is any component manipulated by the user. The server-side (or "back end") code resides on the server.
https://en.m.wikipedia.org/wiki/Front_and_back_ends (https://en.m.wikipedia.org/wiki/Front_and_back_ends)

https://m.youtube.com/watch?v=o9bd-B2dqCM&feature=youtu.be (https://m.youtube.com/watch?v=o9bd-B2dqCM&feature=youtu.be)
The Utah Data Center, also known as the Intelligence Community Comprehensive National Cybersecurity Initiative Data Center, is a data storage facility for the United States Intelligence Community that is designed to store data estimated to be on the order of exabytes or larger.
Its purpose is to support the Comprehensive National Cybersecurity Initiative (CNCI), though its precise mission is classified.
http://www.defense.gov/News/Speeches/Speech-View/Article/606635 (http://www.defense.gov/News/Speeches/Speech-View/Article/606635)

https://www.iarpa.gov/index.php/research-programs/neuroscience-programs-at-iarpa (https://www.iarpa.gov/index.php/research-programs/neuroscience-programs-at-iarpa)

https://en.m.wikipedia.org/wiki/Wetware_(brain) (https://en.m.wikipedia.org/wiki/Wetware_%28brain%29)

http://www.datacenterdynamics.com/news/sgi-gives-us-military-the-fastest-supercomputer/91007.fullarticle (http://www.datacenterdynamics.com/news/sgi-gives-us-military-the-fastest-supercomputer/91007.fullarticle)

http://bioethics.gov/node/4704 (http://bioethics.gov/node/4704)

https://m.facebook.com/Brain-Print-1585272778401091/ (https://m.facebook.com/Brain-Print-1585272778401091/)
The National Security Agency (NSA) leads operations at the facility as the executive agent for the Director of National Intelligence.
It is located at Camp Williams near Bluffdale, Utah, between Utah Lake and Great Salt Lake and was completed in May 2014 at a cost of $1.5 billion.
https://en.m.wikipedia.org/wiki/Utah_Data_Center (https://en.m.wikipedia.org/wiki/Utah_Data_Center)

Any Questions?

http://www.lifecoachcode.com/2016/05/28/the-father-of-fractal-geometry-reveals-the-pattern/ (http://www.lifecoachcode.com/2016/05/28/the-father-of-fractal-geometry-reveals-the-pattern/)

In the computer software world, open source software concerns the creation of software, to wIntelligence.
https://en.m.wikipedia.org/wiki/List_of_artificial_intelligence_projects (https://en.m.wikipedia.org/wiki/List_of_artificial_intelligence_projects)

https://m.facebook.com/Artificial-Genocide-1716276305283944/ (https://m.facebook.com/Artificial-Genocide-1716276305283944/)

https://m.facebook.com/Doomsday-Computers-AGI-ASI-516866275144461/ (https://m.facebook.com/Doomsday-Computers-AGI-ASI-516866275144461/)

https://m.youtube.com/watch?list=PL9DCCHoTYZ8KaMFrLrUzNblMsIECi9vQ0&v=g1lVBNV6ztw (https://m.youtube.com/watch?list=PL9DCCHoTYZ8KaMFrLrUzNblMsIECi9vQ0&v=g1lVBNV6ztw)

#NBIC #DualUseTechnology #HBP #LofarLois #Ericsson #IBM #SGI #Raytheon #NSA #MilitaryNanoTechnology #BrainInitiative #NeuroEthics

hich access to the underlying source code is freely available.
This permits use, study, and modification without restriction.
In computer security, the debate is ongoing as to the relative merits of the full disclosure of security vulnerabilities, versus a security-by-obscurity approach.
There is a different (perhaps almost opposite) sense of transparency in human-computer interaction, whereby a system after change adheres to its previous external interface as much as possible while changing its internal behaviour.
That is, a change in a system is transparent to its users if the change is unnoticeable to them.
https://en.m.wikipedia.org/wiki/Transparency_(behavior) (https://en.m.wikipedia.org/wiki/Transparency_%28behavior%29)

All Human's are Computers in Ubiquitous Computing that are monitored by Artificial Intelligence/Ambient

By mindcontroleurope • Posted in Implant for Synthetic Telepathy, military, Mind Control, Nano Brain Implant, Nano ICT Brain Implants • Tagged artifical-intelligence, blood, brain-computer-interface, doctor, intelligence-gathering, magnus olsson, mind control, poland, post doctoral research, waves, world cach
AUG 5 2016

Assassination is the murder of a person, often (but not or ruler, usually for political reasons or paymen. Or the common man.

Assassination is the murder of a person, often (but not always) or ruler, usually for political reasons or paymen. Or the common man.

(https://nanobrainimplant.com/2016/08/05/assassination-is-the-murder-of-a-prominent-person-often-but-not-always-or-ruler-usually-for-political-reasons-or-paymen-or-the-common-man/brain-control-2/)

An assassination may be prompted by, political, or military motives; it is an act that may be done for financial gain, to avenge a grievance, from a desire to acquire fame or notoriety, or because of a military, security or insurgent group's command to carry out the homicide.

The World Coalition against Covert Harassment is committed to raising awareness to the legal systems as well as to the medical and scientific community to the crime of illegal biomedical and weaponry research committed on citizens in the European Union and beyond. As a European network, EUCACH acts as a lobbying and advocacy platform towards the EU. Using our international network of scientific and technology experts, partner civil and human rights organisations as well as important stakeholders in civil society, we provide consultancy services to the EU Institutions based on our expertise. EUCACH's organisational goal is to influence EU legislation and the decision-making process in calling for a worldwide ban on weapons that might enable any form of manipulation of human beings.

Online-connected brains and neural networks.

"ICT" = Information and Communication Technologies

"BMI" = Brain Machine Interface, brain-computer interconnection

"FET" = Future and Emerging Technologies

"S.T." = Synthetic Telepathy

"A.I." = Artificial Intelligence.

On the road to mind control: DARPA's new program will use a chip to connect brains.For additional background to the latest press release from DARPA posted in full below, I encourage you to read the following selection of linked articles
where I discuss the scope and chronology of what is being studied. Therein, you will find that the U.S. BRAIN Initiative and its European counterpart, the Human Brain Project, are not spending multi-billions of dollars on neuroscience research
simply to help people with Post Traumatic Stress Disorder and organic brain dysfunction. It is, perhaps first and foremost, a military endeavor that has wide ramifications if even 1/10th of what is being studied comes to fruition. In short, it's more about mind control than it is about brain restoration and improvement. Please keep this in mind when you read DARPA's emphasis on "new therapies." •Obama Doubles Down on BRAIN Project and Military Mind Control

•Mind Control Scientists Find New Memory Manipulation Technology
•Secret DARPA Mind Control Project Revealed: Leaked Document
•The 9 Goals of Mind Control: Interim Report
•New Mind Reading Research Aims to Synchronize Humans
•Nanoparticles Enable Remote Control Brains Via Magnetic Field: New Study

DARPA Press Release:

(https://nanobrainimplant.com/2014/12/17/disturbing-weapons-now-being-used-on-the-masses/darpa/)

A new DARPA program aims to develop an implantable neural interface able to provide unprecedented signal resolution and data-transfer bandwidth between the human brain and the digital world. The interface would serve as a translator, converting between the electrochemical language used by neurons in the brain and the ones and zeros that constitute the language of information technology. The goal is to achieve this communications link in a biocompatible device no larger than one cubic centimeter in size, roughly the volume of two nickels stacked back to back.

The program, Neural Engineering System Design (NESD), stands to dramatically enhance research capabilities in neurotechnology and provide a foundation for new therapies.

“Today’s best brain-computer interface systems are like two supercomputers trying to talk to each other using an old 300-baud modem,” said Phillip Alvelda, the NESD program manager. “Imagine what will become possible when we upgrade our tools to really open the channel between the human brain and modern electronics.”

Among the program’s potential applications are devices that could compensate for deficits in sight or hearing by feeding digital auditory or visual information into the brain at a resolution and experiential quality far higher than is possible with current technology.

Neural interfaces currently approved for human use squeeze a tremendous amount of information through just 100 channels, with each channel aggregating signals from tens of thousands of neurons at a time. The result is noisy and imprecise. In contrast, the NESD program aims to develop systems that can communicate clearly and individually with any of up to one million neurons in a given region of the brain.

Achieving the program’s ambitious goals and ensuring that the envisioned devices will have the potential to be practical outside of a research setting will require integrated breakthroughs across numerous disciplines including neuroscience, synthetic biology, low-power electronics, photonics, medical device packaging and manufacturing, systems engineering, and clinical testing. In addition to the program’s hardware challenges, NESD researchers will be required to develop advanced mathematical and neuro-computation techniques to first transcode high-definition sensory information between electronic and cortical neuron representations and then compress and represent those data with minimal loss of fidelity and functionality.

To accelerate that integrative process, the NESD program aims to recruit a diverse roster of leading industry stakeholders willing to offer state-of-the-art prototyping and manufacturing services and intellectual property to NESD researchers on a pre-competitive basis. In later phases of the program, these partners could help transition the resulting technologies into research and commercial application spaces.

To familiarize potential participants with the technical objectives of NESD, DARPA will host a Proposers Day meeting that runs Tuesday and Wednesday, February 2-3, 2016, in Arlington, Va. The Special Notice announcing the Proposers Day meeting is available athttps://www.fbo.gov/spg/ODA/DARPA/CMO/DARPA-SN-16-16/listing.html. More details about the Industry Group that will support NESD is available athttps://www.fbo.gov/spg/ODA/DARPA/CMO/DARPA-SN-16-17/listing.html. A Broad Agency Announcement describing the specific capabilities sought is available at: http://go.usa.gov/cP474 (http://l.facebook.com/l.php?
u=http%3A%2F%2Fgo.usa.gov%2FcP474&h=LAQF0y59EAQFQR18F27x04gXa7Y_rindsR25iSKphNuN6zA&enc=AZOpn7sJYv1piS9gSXGfy_NqXsCO7oB0S4
wwq-BZaaREHQxwob2U8UXt8kfaCnxig3GT6vilhS7K6HhnYGtn9hKAUxHcqAYyBQ8RvfuBKDruex9_vs-
icDjhjTswRnvlZiuFpTbFop5HBD3RZ38KhQmXzcBN3gFvyHixaG5LgtM-FvdH37Galx8Kne2oujUkZt3E&s=1).

DARPA anticipates investing up to $60 million in the NESD program over four years.

NESD is part of a broader portfolio of programs within DARPA that support President Obama’s brain initiative. For more information about DARPA’s work in that domain, please visit:http://www.darpa.mil/…/our-r…/darpa-and-the-brain-initiative (http://l.facebook.com/l.php?
u=http%3A%2F%2Fwww.darpa.mil%2Fprogram%2Four-research%2Fdarpa-and-the-brain-initiative&h=HAQECCJXjAQEZD2OkSMYSVL85yN-
3EkJvVb9bU9LzVZeKmQ&enc=AZNCWwf9R2i6Uy5lFdfkj6UBSyM39uSN_sZKmEQN0J14oy0ih7JhkHYCtvqG0N0PmELXHOuKdGmXs9kWiHDiy7ubLMS
cr3v6PcjPMVGzyRQND8fQLFaQwZVkVqmre58u3yG7h1NdxM8L8zYhn-_5v&s=1).

FET and ICT research and development (of the new “computer – brain language”) allows computers to read and learn human thought patterns by using injectable brain – machine – interface.

About the same brain-machine interface has has been used to cure Parkinson’s disease , Alzheimer’s and depression can also be used for accessing the brain’s memory.

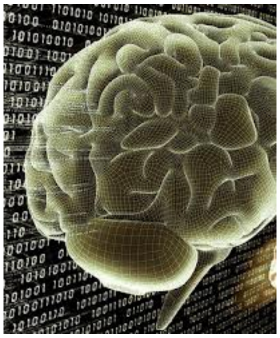

(https://nanobrainimplant.com/2016/08/05/assassination-is-the-murder-of-a-prominent-person-often-but-not-always-or-ruler-usually-for-political-reasons-or-paymen-or-the-common-man/brain-mind-e/)

Digital Mind

Professor Goran Hermerén OPINION OF THE EUROPEAN GROUP ON ETHICS IN SCIENCE AND NEW TECHNOLOGIES TO THE EUROPEAN COMMISSION (ETHICAL ASPECTS OF ICT IMPLANTS IN THE HUMAN BODY) March 2005

Link to document

The new software for the brain-machine interface in nano electronics combined with "Europe's new information technology" provides the researchers with the possibillities for reading and taking "software images" of the brain's neuron network.

A method that provides high-resolution copies of the brains cognitive behavior and human perception.

Tomorrow's high-speed computers and related research has evolved into a sophisticated "computer game" with "mind reading" on real people….

These research methods are unknown to our society's legal system!

So how can research on the brain by "serious" (criminal) organizations in ICT-FET be stopped?

SYNTHETIC TELEPATHY for medicine or mind reading is a direct communication with nanoelectronics between computer and human brain.

Synthetic telepathy is a communication system based on thought, not speech.

It can be used to control for example a prosthesis and cure diseases such as Parkinson's disease but can also decode the patterns used to study cognitive behavior such as memory, learning and emotion. With nano technology, the digital information can be recorded using the new quantum-inspired computers.

Simulation of behavior can be identified and provide diagnostic data for identifying the precursors to diseases such as dementia, stroke and myocardial infarction

This letter is intended to demonstrate a paradox in the Swedish so-called "protection of human rights" and thus the entire Swedish justice system. Synthetic telepathy could, as practiced in Sweden, lie behind an unknown number of violent crimes and suicides due to research deliberately kept hidden from regulators.

Doctors and psychiatrics diagnose people with "voices in his head" following their "manuals". DSM-IV (Diagnostic and Statistical Manual of Mental Disorders) published by the American Psychiatric Association and the ICD-10 (International Statistical Classification of Disorders and Related Health Problems).

This is an old-fashioned black and white and diagnose when the EU priority FET ICT research and develop new information technologies adapted to nano-electronics.

mind-control-weapons

Ulf Gorman writes in the book that with nano technology, we open the doors to an unknown area where we do not know how to apply ethics. What should be and what should not be allowed when you implant a chip that can both read and influence the brain? He takes the example of studying learning and memory.

Micro Implants can provide unprecedented opportunities to understand how we learn and remember things, and hence why we forget and find it difficult to learn. And it can be understood as a form of abuse to look like that into our most private mental world.

Lund University writes about the development of nano-electrodes that can both listen and communicate with neuronal synapses and their cell membranes.

EU priority ICT and FET research are talking about a "A whole new communication technology in Europe" "It will help us understand and exploit the ways in which social and biological systems, organization and evolution, will pave the way for the development of new opportunities for next-generation software and network technologies ".
To understand how the human brain works not only leads to innovations in medicine but also provides new models for energy, fault-tolerant and adaptive computing technologies ".
An initiative of the Virtual Human Physiology that are individually tailored and virtual simulations of the human body where you would expect enormous progress in disease prevention and health care.
The pioneering work carried out also on new ideas such as artificial living cells, synthetic biology, chemical communication, collective intelligence and two-way interface between brain and machine.

(https://nanobrainimplant.com/2016/08/05/assassination-is-the-murder-of-a-prominent-person-often-but-not-always-or-ruler-usually-for-political-reasons-or-paymen-or-the-common-man/new-brain-2/)

Brain reading

Other sources, e.g The UCI (University of California Irvin. Department of Cognitive Science) describes the development of Synthetic Telepathy:

Collaboration between cognitive science, neuro-science, specialists in speech recognition and brain imaging will develop a brain-machine interface. This device could help paralyzed and soldiers would be able to send messages directly from the brain to a computer.

Researcher Michael D'Zmura, President of the UCI describes that the system begins with "the little voice in your head".

How can a medical diagnosis unequivocally describe people's perception of voices in their head and that no alternative can exist except mental disease.

Why? -because it is a prerequisite to be able to "hear" voices for the use of new information technology?

This is why these researchers must be forced to go public and announce this new scientific communication technology.

This paradox must be investigated immediately.With the exclusion of the development of a Swedish and European military force with superior two-way "radio" communication with the brain.

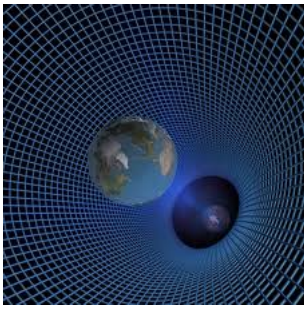

(https://nanobrainimplant.com/2012/07/11/scientists-humans-and-machines-will-merge-in-future/imagescaygmuja/)

A number of past court cases are more or less directly caused by S.T. This "voice to skull" technology must immediately be taken into consideration as an alternative for triggering a number of previously committed violent crimes and suicides.

During the development of BMI, software and network technologies are also computerized and long distance imaging of peoples cognitive behavior and perception. Material that is recorded in the computer that runs the real time simulation and creation of artificial intelligence (for initializing A.I. and computerized decision making.)

The image of the brain's "machine-code" is probably the most comprehensive and advanced ever made. Cognitive behavior depicted and simulated, language and meaning of the words for the subjects are identified. Human perception and mapping how the brain handles information, the image of mathematics reached its perfection.

neuron wave A new research scandal and the fatal consequences for the wider community.

Around the clock the computerized study goes on using collective, artificial intelligence and self-learning systems. The victims testimonies tells us that you can sadly conclude unequivocally that the studies will not be completed until the victim in one way or another has been broken down and / or otherwise inactivated.

This provides power to simulate decomposition for the digital copy thus the fact that the criminal research will not end and is never disclosed.

Descriptions to the vulnerable people who eat psychotropic drugs due to their experiences the experiments and testing goes on, various medicines can affect the "test objects" (or guinea pigs) everything is recorded and compared with previous values (from the multi-annual copy of their real-time neural network and thus the registration of their behavior.)

Obviously this is a disgusting and illegal way to meet the advanced development of tomorrow's medicine.

The "studies" have resulted in enormous damage to many subjects.The number of unrecorded victims/subjects is probably very high.Families are fragmented, the children of these families are suffering tremendously. One of the subjects have recently been hospitalized with a cracked skull, caused by disconnecting the balance system remotely. The accident occurred in public settings.

A new research scandal and the fatal consequences for the wider community.

To influence the balance system is another typical example of how technology is used against the victim to incapacitate them for society. Direct assassination attempts on several previous occasions orchestrated by the brain control deliberately strikes out the human balance system, Why this happens is likely as an alternative to the mentally ill to be treated (as "possessed") or having a neurological disease.

(https://nanobrainimplant.com/2012/06/03/2050-and-immortality-is-within-our-grasp/imagescaaztqrn/)

Brain – copying with BMI and broadband access is definitely no longer a marginal research.Employers have over the years lost millions of dollars and cut-downs is to be expected due to excluded employees. Broken families, children who, years later can not study or work is now forced to seek psychiatric care.

Siblings, grandparents and their closest friends are suffering tremendously. Advanced Medical and hospital care due to study design is a mockery of health-care and doctors who are not familiar with this research. Insurance in the multi-million figures was raised through direct damage caused by brain control. Property for millions of dollars are lost.

Injuries and privacy intrusion of thousands of people is done through "volunteers" that serve as multimedia machines i.e node for the recording of all contacts they have, such as politicians, scientists, lawyers, friends, acquaintances, relatives, international business relations, etc..

Security codes, access codes, etc. is with the new technology no longer private.How can we know that people are not equipped with the new brain-machine interface which makes the person a multimedia application with a function as a live missile is already deployed as nodes in the political and financial world of illegal recording of their conversations with the world?

A sinister JOY seems to embrace the researchers and perpetrators over this superior and powerful tool for mind control and copying brainwave patterns. The tool is, without a doubt, a weapon of offense and stealth.

Implant technology in these forms should immediately be classified as a lethal weapon! It communicates directly with the brain's neurons and can bring the entire neural nervous system to a halt.(Exclusion of balance can be immediately implied on a victim.)

The technology is now used for purposes of breaking down the persons psyche, with serious accusations, threats, mock execution, incitement to suicide, physical violence, e.g, decrease and increase heart rate, pain in and around the heart, severe chest pains, sudden and painful headaches, difficulty to breathe, tampering with rectum, prostate and muscles to name a few.

The macabre in the use of this technology is that subjects are exposed to these atrocities while the society is not legally able to influence the situation. Sweden is in this matter a lawless country where the researchers grossly exploit the situation.

(https://nanobrainimplant.com/2013/03/24/brain-control-war-too-big-to-fail/imagescaay7q87/)

Face mind

This ultimate humiliation has reached a whole new level. The researchers tries with the enforced communication and slow decomposition enslave people with exhortations to try to see the individual results of the brain control. One can calculate due to the nature and perennial perspective that there are naturally a unrecorded number of people who have been driven to madness and death with this technology.

There is nowhere the victims can hide or escape the access signals to their thoughts. Scientists simulate with computers, 24/7 365 days a year to break down the subjects and stop them from trying to understand what's happening to them…

A series of grotesque roles played in order to manipulate the brain, threats and statements that are mixed with modern technology. It is also in the researchers' strategy to make the picture unclear for the subjects if they attempt to get an overall picture of who the perpetrator is and the real goals of the research, a military strategy conducted by veterans and experts in the matters.

The disrespectful research performed and visualized in a 3D virtual game world in the researchers' computers, with no ethical boundaries and human rights but with real living human beings as "avatars". It is quite similar to the popular interactive game "The Sims', But this game delivers human reality-based measurement data for research.

Cover-up of brain monitoring technologies means that the crime is waterproof, human rights laws and manipulated by a hidden militant regime researcher with expertise in information technology. In addition, the researchers say they in the dialogue to be the police power which in itself is an extremely serious offense.

For the victims– former high-performance hard-working people with families, children, an orderly life and social contacts. People who all his life been performing taxpayers. Because of a work-related mental fatigue and time on medical therapy sessions with the scientists the opportunity to take advantage of the situation of persons for investigation and contemporary development of the new BMI and brain monitoring technologies.

As these technologies and opportunities are not announced, but several instances re-written, must be able to use knowledge and skills which are available. Sweden is a small country and the people engaged in this activity may not be so difficult to identify and stop.

The researchers in these studies have assumed the right that during the permanent reproduction of human neurotransmitters in the long term also destroy them and their life's work. The issue is called for; How affected society to know that the violent crime and suicide has been performed in the Stockholm area and Europe in recent years and clearly diagnosed as being caused by mental illness with the voices in heads is an expression of pure brain research!

By: Magnus Olsson

(https://nanobrainimplant.com/2013/04/23/nsa-mind-control-and-psyops-2/nsa/)

HOW WE DO IT…

- Awareness-raising campaigns to disseminate information and mobilise public opinion on the issue of covert technologies and techniques that enable the manipulation of human beings
- Providing expert consultancy to key decision-makers on the creation of appropriate EU legislation to protect citizens from this kind of covert crimes.
- Organising networking events (workshops, seminars, conferences) involving all actors concerned to exchange experiences and best practices for the establishment of clear ethical boundaries to strictly regulate the use of systems enabling the manipulation and control of human beings.

It is our philosophy that all men are equal before the law. Everybody's right to life shall be protected. Nobody shall be subjected to torture or held in slavery. Any technologies and techniques capable of endangering the human physical and/or psychological health, to modify the individuals' autonomy and affect their dignity should be strictly prohibited.

Read more about ICT – implants at the European Group on Ethics and New Technologies:

http://ec.europa.eu/…/european-group-eth…/docs/avis20_en.pdf (http://ec.europa.eu/bepa/european-group-ethics/docs/avis20_en.pdf)

Terminology used in the document:

Cybernetics,,,,,, // Magnus Olsson

EPSC – European Commission (http://l.facebook.com/l.php?u=http%3A%2F%2Fec.europa.eu%2Fbepa%2Feuropean-group-ethics%2Fdocs%2Favis20_en.pdf&h=YAQGijSpj&enc=AZMq9f7N-rRi1oqozQeUDtiMrtgkAjH0PKPRaj0LR7nx44ZZmRLHC78kpg1NdCUG2ACxLZxzxYSdqtdeKAhL_RSUBcFCA0LkDQJxno5Rq7aQMwWo3MtKGZPGl3Id990LNnmKm_llFA98bTSAsGUrtrY&s=1)
EPSC
ec.europa.eu
By: Magnus Olsson (Sweden)

By mindcontroleurope • Posted in Computerbrain, Implant for Synthetic Telepathy, military, Mind Control, Uncategorized • Tagged artifical-intelligence, brain, brain implant, brain implants, cross sectional area, electrical resistance, eu brain, intelligence-gathering, magnus olsson, military / medical classified research, mind, transcranial-magnetic-stimulation
JUL 7 2016

Worldcach.com's Leo Angesleva (Sweden) about Mind Control and the Transhumanist Agenda and Alfred Webre

Alfred Lambremont Webre, Worldcach.com's Leo Angesleva (Sweden) about Mind Control and the Transhumanist Agenda

Interview with Alfred Lambremont Webre, Worldcach.com (http://worldcach.com/)'s Leo Angesleva details how the "Obama" [read "U.S."] Brain Project and the U.S. Army, along with other agencies covertly committed to the Transhumanist Agenda, are facilitating AI Artificial Intelligence reading and controlling all human brains and minds worldwide, and constructing Cyborg armies.

MAN VERSUS MACHINE

(https://nanobrainimplant.com/2012/08/22/ibm-get-close-to-mimicking-a-human-brain/imagescast4tl3/)

WORLD CACH
The World Coalition Against Covert Harassment

(https://nanobrainimplant.com/2016/07/07/alfred-lambremont-webre-worldcach-coms-leo-angesleva-sweden/world-cach/)

By mindcontroleurope • Posted in Computerbrain, Man vs Machine, military, Mind Control • Tagged Alexander, artifical-intelligence, brain-computer-interface, cyborg, Cyborg-soldier, eucach, hologram, Leo, magnus olsson, mind control, nano brain, transcranial-magnetic-stimulation, world cach
MAR 4 2016

Magnus Olsson launches World Coalition against transhumanist neural robotoid agenda

Magnus Olsson launches World Coalition against transhumanist neural robotoid agenda

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World Coalition against Covert Harassment (WorldCACH)

(https://nanobrainimplant.com/2013/02/11/are-people-superfluous/jj/)

STATEMENT OF GARY OWEN

It was Sunday 28th of February 2016, Magnus Olsson was staying at my house in Spain, I had been appointed the Vice President of World CACH 2 days before. We were planning the roll out of the World CACH, deciding the agenda of the organisation, we had a great day on the Saturday, we appointed the technical director, spoke to one of our legal team Alfred Lambremont Webre, he's the guy that won the war crimes tribunal against Tony Blair and George Bush. We explained that what we wanted to do with World CACH was to set up a Global Intelligence Service that acts for the people against the Governments and security services that no longer represent the people, and take the Masons who have infiltrated all levels of the government and security Services to the war crimes tribunal for genocide and racketeering against the population of earth. He thought both ideas were sensational and invited us to go on his show the following day, which would go out to 250,000 people.

On the Sunday, I started hearing the high pitched noise again in my ear I had not heard it for a few days, since Magnus arrived, and all of a sudden it was back along with the voice to skull. We were to meet for lunch with some people and later talk on Skype with William Binney and then do the show with Alfred where we would break the news to the world about what we were doing. It was only 30 minutes to the lunch meeting and I had heard nothing from Magnus, so I went down to the apartment he was staying in below my house. I knocked on the door and he answered saying he needed medical help, he was in a terrible state. He was physically shacking none stop, and his face was bright red with a high temperature.

(https://nanobrainimplant.com/links/globe1001-2/)

After some phone calls we decided to go to the emergency Chemist and get some pain killers and antibiotics as it looked like a virus. The Chemist said we should go to the emergency doctors in the town, by this time I was having to support Magnus while he walked, he was on the verge of passing out none stop.

Four doctors in the emergency room at Torrox looked at him and did all the tests they could and found nothing wrong. But they agreed something was wrong, so we were dispatched to the main hospital in Valez. I arrived at the emergency entrance, Magnus was no longer able to walk, they put him in a wheel chair. He was fading in and out and incoherent. After 2 hours we got to see a very proficient doctor, he was very thorough. Magnus had come round a little after drinking two litres of cold water. I thought the worst was over, Magnus was dispatched for X-rays and 12 blood tests, we did the X-rays first, no problems, then we went to do the blood tests, half way through taking the blood, they took a lot of blood, about 6 tubes, all of a sudden Magnus took a severe turn for the worse, it started by Magnus telling me that he was going to pass out. I tried to explain this to the Spanish nurse. Then he went as white as snow, all over, his face was pure porcelain white and I noticed that his hands were the same. I was instructed by the nurse to wave his hat in front of his face to try and revive him, his eyes rolled back into his head and you could only see white eyes and a white face it was shocking. By this time the nurse was in a sheer panic and the doctor that had seen him was called.

Before the doctor could arrive, Magnus started to have muscle spasms all over his body, they started on his spine, and spread all over, he was put on a gurney and was contorted and jerking all over the place with his eyes rolled back in his head. It was clear he would die of a heart attack if they did not stop it, they pressed the emergency button and doctors came from everywhere, he was wheeled at speed to the ICU Critical Emergency ward. They stripped of his cloths and by now there was a dozen people trying to figure out what was wrong.

I heard the original doctor tell the others that Magnus was working with CIA whistle blowers, we had explained a bit about the organisation to the doctor during the initial examination. They dismissed it and moved on, they could find nothing wrong. They injected him with Diazepam a strong muscle relaxant. He was in critical for two hours, during the first part I took a picture, I had taken several others, so I could put them on the World CACH facebook site later.

The last photo I took one of the doctors went crazy and threatened me to take no pictures and if any of the pictures I had taken were made public I would be charged by the police. This escalated and security arrived, one more sensible doctor said would you be OK to delete them, as you're not allowed to take photos in a Spanish hospital. There were no signs saying you couldn't.

I agreed to delete them rather than be arrested, I was taken to the public waiting room, three hours went by. A man arrived and told me I could visit Magnus, I was taken through, he was looking better but had an oxygen mask on, and was drained. I was told that in a few hours provided he remained stable he could leave, he was put on an intravenous antibiotic and saline drip. They dosed him up with the anti-biotics and gave me a prescription for a weeks long course and some diazepam in case the spasms started again.

After 7 hours in there we left, Magnus was back but very weak. The doctors told me that every test they did showed nothing, everything was exactly normal through the whole process. They agreed something was wrong but they did not know what it was. The whole day I had a strong high pitched noise whistling in my ear that is part of the Gangstaklking they are perpetrating on people now.

You have to ask yourself about the coincidences involved.

1/ Magnus and I were not being attacked like normal until we decided to Form a Global Intelligence Service for the people against the governments. Then we were both attacked.

2/ Nothing was found to be wrong with Magnus at all.

3/ That day we were to go on video and announce the plan to the TI world.

4/ We were making significant progress on the roll out of World CACH, talking to the leaders around the world of the individual country CACHs. Appointing the technical director. Getting the war tribunals accepted by a judge.

On the way home I started to wonder if we could not get the images back from the camera so I asked a young tech guy Alex Axon to see if it was possible, and a few hours later he had recovered three images and all the thumb nails. They were a bit degraded but we now have the images.

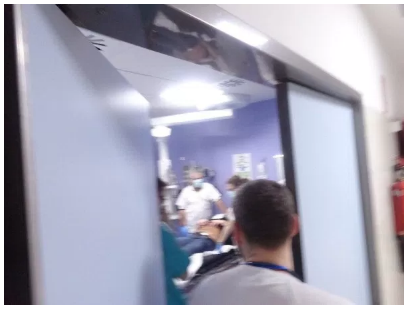

(https://i2.wp.com/newsinsideout.com/wp-content/uploads/2016/03/Magnus-Olsson-atHospital-ICU-Critical-Room-Feb.-28-2016.jpg?ssl=1)

Magnus Olsson at Hospital ICU Critical Room – Feb. 28, 2016

Magnus in ICU Critical Unit

What a day!

Gary Owen

World Coalition against Covert Harassment (WorldCACH)

By mindcontroleurope • Posted in Implant for Synthetic Telepathy, Magnus Olssons story, military, Mind Control, Nano Brain Implant, Uncategorized • Tagged airforce, artifical-intelligence, artificial telepathy, interfaces, magnus olsson, Nanobots, science, synthetic-telepathy, technology, transcranial-

magnetic-stimulation
JAN **28** 2015

The real-life Mind-Matrix…

(https://nanobrainimplant.files.wordpress.com/2015/01/mail-on-line.png)The real-life Matrix: MIT researchers reveal interface that can allow a computer to plug into the brain

(https://nanobrainimplant.files.wordpress.com/2015/01/fgnfgjtyjty.jpg)

- **System could deliver optical signals and drugs directly into the brain**
- **Could lead to devices for treatment of conditions such as Parkinson's**

It has been the holy grail of science fiction – an interface that allows us to plug our brain into a computer.

Now, researchers at MIT have revealed new fibres less than a width of a hair that could make it a reality.

They say their system that could deliver optical signals and drugs directly into the brain, along with electrical readouts to continuously monitor the effects of the various inputs.

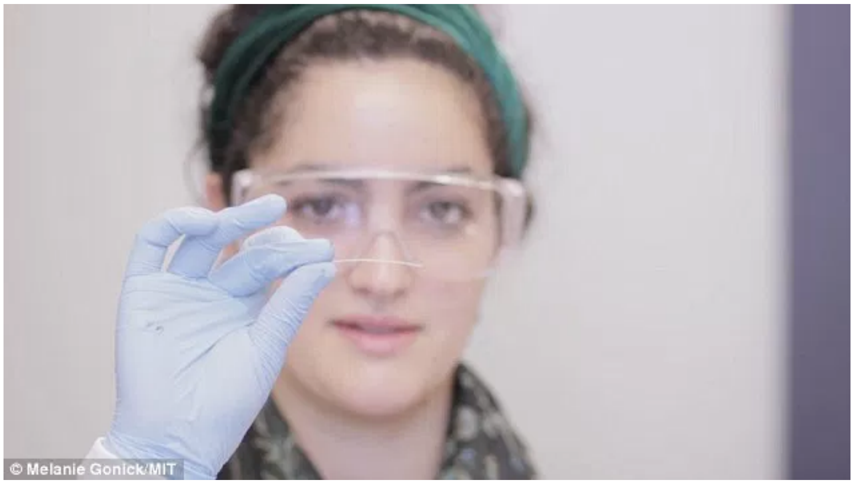

Christina Tringides, a senior at MIT and member of the research team, holds a sample of the multifunction fiber that could deliver optical signals and drugs directly into the brain, along with electrical readouts to continuously monitor the effects of the various inputs.

HOW IT WORKS

The new fibers are made of polymers that closely resemble the characteristics of neural tissues.

The multifunction fiber that could deliver optical signals and drugs directly into the brain, along with electrical readouts to continuously monitor the effects of the various inputs.

Combining the different channels could enable precision mapping of neural activity, and ultimately treatment of neurological disorders, that would not be possible with single-function neural probes.

'We're building neural interfaces that will interact with tissues in a more organic way than devices that have been used previously,' said MIT's Polina Anikeeva, an assistant professor of materials science and engineering.

The human brain's complexity makes it extremely challenging to study not only because of its sheer size, but also because of the variety of signaling methods it uses simultaneously.

Conventional neural probes are designed to record a single type of signaling, limiting the information that can be derived from the brain at any point in time.

Now researchers at MIT may have found a way to change that.

By producing complex fibers that could be less than the width of a hair, they have created a system that could deliver optical signals and drugs directly into the brain, along with simultaneous electrical readout to continuously monitor the effects of the various inputs.

RELATED ARTICLES

The newC technology is described in a paper in the journal Nature Biotechnology.

The new fibers are made of polymers that closely resemble the characteristics of neural tissues, Anikeeva says, allowing them to stay in the body much longer without harming the delicate tissues around them.

To do that, her team made use of novel fiber-fabrication technology pioneered by MIT professor of materials science Yoel Fink and his team, for use in photonics and other applications.

The result, Anikeeva explains, is the fabrication of polymer fibers 'that are soft and flexible and look more like natural nerves.'

Devices currently used for neural recording and stimulation, she says, are made of metals, semiconductors, and glass, and can damage nearby tissues during ordinary movement.

'It's a big problem in neural prosthetics,' Anikeeva says.

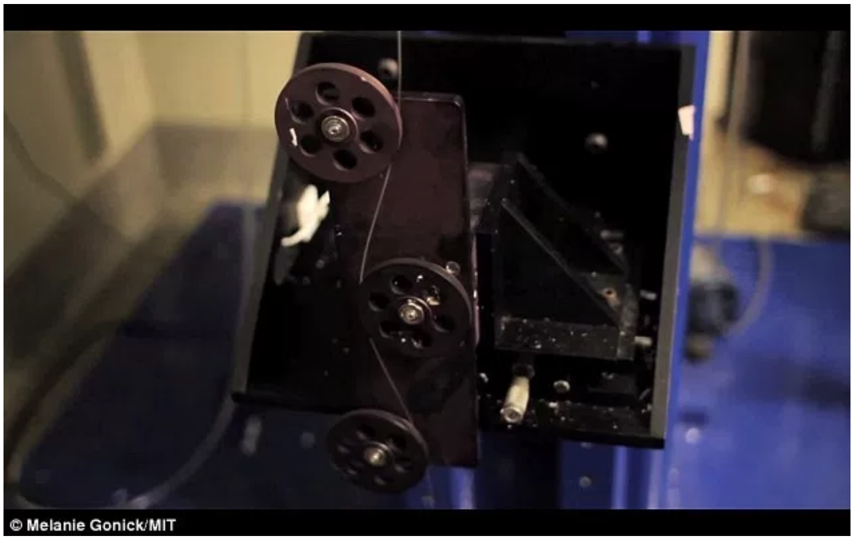

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'We're building neural interfaces that will interact…

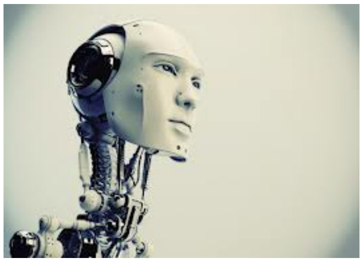

(https://nanobrainimplant.files.wordpress.com/2013/02/robot-brain.jpg)

- The result, Anikeeva explains, is the fabrication of polymer fibers ‘that are soft and flexible and look more like natural nerves.’

‘They are so stiff, so sharp — when you take a step and the brain moves with respect to the device, you end up scrambling the tissue.’

The key to the technology is making a larger-scale version, called a preform, of the desired arrangement of channels within the fiber: optical waveguides to carry light, hollow tubes to carry drugs, and conductive electrodes to carry electrical signals.

These polymer templates, which can have dimensions on the scale of inches, are then heated until they become soft, and drawn into a thin fiber, while retaining the exact arrangement of features within them.

A single draw of the fiber reduces the cross-section of the material 200-fold, and the process can be repeated, making the fibers thinner each time and approaching nanometer scale.

During this process, Anikeeva says, ‘Features that used to be inches across are now microns.’

Combining the different channels in a single fiber, she adds, could enable precision mapping of neural activity, and ultimately treatment of neurological disorders, that would not be possible with single-function neural probes.

For example, light could be transmitted through the optical channels to enable optogenetic neural stimulation, the effects of which could then be monitored with embedded electrodes.

© PUBLICITY PICTURE

Combining the different channels in a single fiber, she adds, could enable precision mapping of neural activity, and ultimately treatment of neurological disorders, that would not be possible with single-function neural probes.

At the same time, one or more drugs could be injected into the brain through the hollow channels, while electrical signals in the neurons are recorded to determine, in real time, exactly what effect the drugs are having.

MIT researchers discuss their novel implantable device that can deliver optical signals and drugs to the brain, without harming the brain tissue.

The system can be tailored for a specific research or therapeutic application by creating the exact combination of channels needed for that task. ‘You can have a really broad palette of devices,’ Anikeeva says.

While a single preform a few inches long can produce hundreds of feet of fiber, the materials must be carefully selected so they all soften at the same temperature.

The fibers could ultimately be used for precision mapping of the responses of different regions of the brain or spinal cord, Anikeeva says, and ultimately may also lead to long-lasting devices for treatment of conditions such as Parkinson's disease.

John Rogers, a professor of materials science and engineering and of chemistry at the University of Illinois at Urbana-Champaign who was not involved in this research, says, 'These authors describe a fascinating, diverse collection of multifunctional fibers, tailored for insertion into the brain where they can stimulate and record neural behaviors through electrical, optical, and fluidic means.

The results significantly expand the toolkit of techniques that will be essential to our development of a basic understanding of brain function.'

Read more: http://www.dailymail.co.uk/sciencetech/article-2927410/The-real-life-Matrix-MIT-researchers-reveal-interface-allow-computer-plug-brain.html#ixzz3Q9lDVQv4 (http://www.dailymail.co.uk/sciencetech/article-2927410/The-real-life-Matrix-MIT-researchers-reveal-interface-allow-computer-plug-brain.html#ixzz3Q9lDVQv4)

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FEB 8 2014

Medical Nanobots Will Connect Brain to Cloud Computing – Ray Kurzweil

Thursday, February 6, 2014

Medical Nanobots Will Connect Brain to Cloud Computing – Ray Kurzweil (http://www.activistpost.com/2013/08/the-dna-nanobots-have-arrived.html)

(https://nanobrainimplant.files.wordpress.com/2013/05/mbj.jpg)

Update on the emergence of DNA nanobots and nan ocomputers.

Nicholas WestThe Human Body Version 2.0 (http://lifeboat.com/ex/human.body.version.2.0#nanobots) project features none other than arch-Transhumanist Ray Kurzweil (http://www.amazon.com/The-Singularity-Is-Near-Transcend/dp/0143037889/ref=as_li_tf_sw?&linkCode=wsw&tag=permacultucom-20) as its main proponent. The goals have been openly stated for some time:

> *In the coming decades, a radical upgrading of our body's physical and mental systems, already underway, will use nanobots to augment and ultimately replace our organs. We already know how to prevent most degenerative disease through nutrition and supplementation; this will be a bridge to the emerging biotechnology revolution, which in turn will be a bridge to the nanotechnology revolution. By 2030, reverse-engineering of the human brain will have been completed and nonbiological intelligence will merge with our biological brains.*

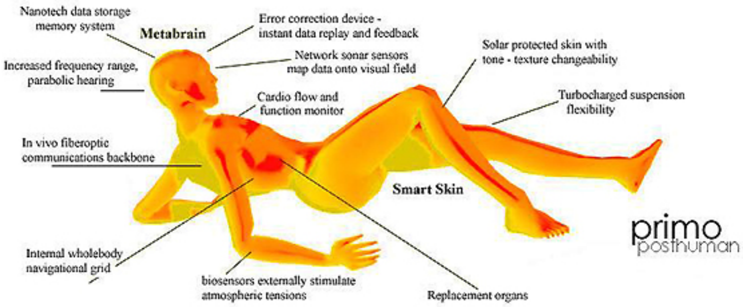
Nanotech data storage memory system
Metabrain
Error correction device - instant data replay and feedback
Increased frequency range, parabolic hearing
Network sonar sensors map data onto visual field
Solar protected skin with tone - texture changeability
Cardio flow and function monitor
Turbocharged suspension flexibility
In vivo fiberoptic communications backbone
Smart Skin
Internal wholebody navigational grid
biosensors externally stimulate atmospheric tensions
Replacement organs
primo posthuman

(https://nanobrainimplant.files.wordpress.com/2014/02/ef606-primo_posthuman.png)

Picture from Natasha Vita-More

Link to Vita-More: http://www.natasha.cc/ (http://www.natasha.cc/)

In fact, the reverse engineering of the human brain (http://www.activistpost.com/2013/08/hardware-and-software-combining-to.html) has already been announced to be well under way via new microchips and accompanying software. And, while full nanobot rewiring of the brain is not expected before 2020, Phys.org (http://phys.org/) has reported that our DNA has been successfully targeted by nanobots "for drug therapy or destruction."

Taking this even one step further, Ray Kurzweil said in a new interview with *The Wall Street Journal* (see below) that our extension into non-biological realms will include nanobot computers that will enter our brain and connect us to Cloud computing.

From science fiction horror, directly to the human body, the nanobots are no longer speculation. Also unlike science fiction, they won't arrive via immediate worldwide takeover — they are already here, and will be introduced incrementally, as Kurzweil has previously stated:

> *It will be an incremental process, one already well under way. Although version 2.0 is a grand project, ultimately resulting in the radical upgrading of all our physical and mental systems, we will implement it* ***one benign step at a time****. Based on our current knowledge, we can already touch and feel the means for accomplishing each aspect of this vision. (emphasis added)*

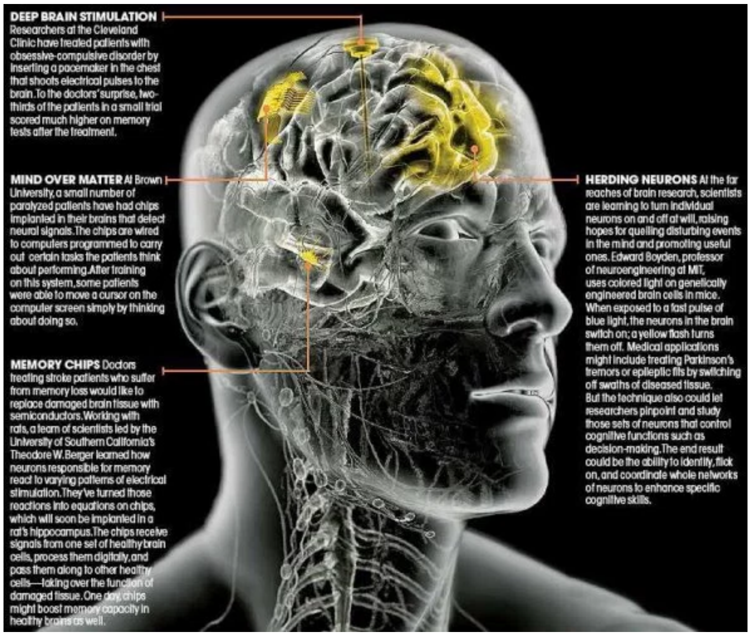

DEEP BRAIN STIMULATION Researchers at the Cleveland Clinic have treated patients with obsessive-compulsive disorder by inserting a pacemaker in the chest that shoots electrical pulses to the brain. To the doctors' surprise, two-thirds of the patients in a small trial scored much higher on memory tests after the treatment.

MIND OVER MATTER At Brown University, a small number of paralyzed patients have had chips implanted in their brains that detect neural signals. The chips are wired to computers programmed to carry out certain tasks the patients think about performing. After training on this system, some patients were able to move a cursor on the computer screen simply by thinking about doing so.

MEMORY CHIPS Doctors treating stroke patients who suffer from memory loss would like to replace damaged brain tissue with semiconductors. Working with rats, a team of scientists led by the University of Southern California's Theodore W. Berger learned how neurons responsible for memory react to varying patterns of electrical stimulation. They've turned those reactions into equations on chips, which will soon be implanted in a rat's hippocampus. The chips receive signals from one set of healthy brain cells, process them digitally, and pass them along to other healthy cells—taking over the function of damaged tissue. One day, chips might boost memory capacity in healthy brains as well.

HERDING NEURONS At the far reaches of brain research, scientists are learning to turn individual neurons on and off at will, raising hopes for quelling disturbing events in the mind and promoting useful ones. Edward Boyden, professor of neuroengineering at MIT, uses colored light on genetically engineered brain cells in mice. When exposed to a fast pulse of blue light, the neurons in the brain switch on; a yellow flash turns them off. Medical applications might include treating Parkinson's tremors or epileptic fits by switching off swaths of diseased tissue. But the technique also could let researchers pinpoint and study those sets of neurons that control cognitive functions such as decision-making. The end result could be the ability to identify, flick on, and coordinate whole networks of neurons to enhance specific cognitive skills.

(https://nanobrainimplant.files.wordpress.com/2014/01/mndcntrl-2.jpg)

Researchers from Columbia University have developed a fleet of molecular *nanorobots* that can deliver drugs to specific cells and also identify certain genetic markers by using fluorescent labeling. After such identification, a chain reaction can be initiated:

> *On cells where all three components are attached, a robot is functional and a fourth component (labeled 0 below) initiates a chain reaction among the DNA strands. Each component swaps a strand of DNA with another, until the end of the swap, when the last antibody obtains a strand of DNA that is fluorescently labeled.*
>
> *At the end of the chain reaction—which takes less than 15 minutes in a sample of human blood—only cells with the three surface proteins are labeled with the fluorescent marker.*

Naturally, this type of targeted therapeutic approach (http://medicalxpress.com/news/2013-07-molecular-robots-therapeutics.html#inlRlv) could prove beneficial, as the researchers highlight — especially for cancer treatment which sweeps up healthy cells along with malignant ones, very often doing more harm than good (if one were to choose the establishment medical route).

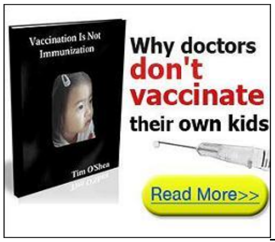

Vaccination Is Not Immunization
Why doctors don't vaccinate their own kids
Tim O'Shea
Read More>>
(http://activistpost.net/vaccinetruth.html)

This is always how new technologies are sold to the public, however, and it would be naive not to consider the darker applications as well.

Direct brain modification already has been packaged as "neuroengineering." A Wired article (http://www.wired.com/science/discoveries/news/2009/03/neuroengineering1) from early 2009 highlighted that direct brain manipulation via fiber optics is a bit messy, but once installed "it could make someone happy with the press of a button." Nanobots take the process to an automated level, rewiring the brain molecule by molecule. Worse, these mini droids can autonomously self-replicate, forcing one to wonder how this genie would ever be put back in the bottle once unleashed.

Here is one scenario offered by Kurzweil for how these nanobots could enter our bodies:

> *A significant benefit of nanobot technology is that unlike mere drugs and nutritional supplements, nanobots have* ***a measure of intelligence****. They can keep track of their own inventories, and intelligently slip in and out of our bodies in clever ways. One scenario is that we would wear a special "nutrient garment" such as a belt or undershirt. This garment would be loaded with nutrient bearing nanobots, which would make their way in and out of our bodies through the skin or other body cavities. (emphasis added)*

That might seem to offer a level of participatory choice — to wear or not to wear the garment — but Kurzweil reveals that the nanobots will eventually be everywhere:

> *Ultimately we won't need to bother with special garments or explicit nutritional resources. Just as computation will eventually be ubiquitous and available everywhere, so too will basic metabolic nanobot resources be embedded everywhere in our environment.*

In a recent interview with *The Wall Street Journal*, Kurzweil highlights why Google has taken an interest in nanotechnology and the possibilities he sees for humans as they increasingly become non-biological and form direct connections with computers, augmenting and/or supplanting our natural processes as we head into the era of cyborgs (http://www.activistpost.com/2014/01/the-era-of-cyborgs-has-begun.html) and beyond:

And of course once our neocortex is uploaded to the Cloud, it positions Google perfectly for searching our every thought and pre-thought. While this might sound like an impossible amount of information to upload, let alone interconnect and search, it is being announced that researchers have designed the first nanocomputer that can push beyond the concept of Moore's Law, which imposes a theoretical limitation on the expansion of computer processing power.

> *The team designed and assembled, from the bottom up, a functioning, ultra-tiny control computer that is the densest nanoelectronic system ever built.*
>
> *A technical paper has been published online (http://www.pnas.org/content/early/2014/01/23/1323818111.abstract) in the Proceedings of the National Academy of Sciences on the research.*
>
> *The ultra-small, ultra-low-power control processor—termed a* ***nanoelectronic finite-state machine (http://en.wikipedia.org/wiki/Finite-state_machine)*** *or "nanoFSM"—is smaller than a human nerve cell.*
>
> *[…]*
>
> *In their recent collaboration they combined several tiles on a single chip to produce a first-of-its-kind complex, programmable* ***nanocomputer****. (Source (http://www.33rdsquare.com/2014/02/nanocomputer-points-way-to-push-past.html))*

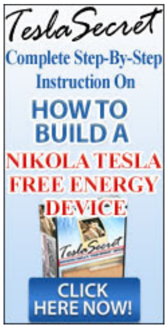

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Complete Step-By-Step Instruction On
HOW TO BUILD A NIKOLA TESLA FREE ENERGY DEVICE
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(http://activistpost.net/teslasecret/)

It shouldn't be seen as coincidence that these developments are happening simultaneously. What appears on the surface to be discoveries in entirely different fields are coalescing rapidly as we approach the theoretical date of The Singularity – the full merger of human and machine – estimated to occur between 2029-2045.

Despite the benign language of futurists, we know that a concerted effort is already underway to manage and predict human behavior (http://www.activistpost.com/2013/07/secret-darpa-mind-control-project.html) for a whole range of potentially anti-human applications (http://www.activistpost.com/2013/06/7-future-methods-of-mind-control.html). As our free will is also targeted like the cells of our body — for drug therapy or elimination — ethical concerns must be voiced loud and clear. Scientists seem content with opening Pandora's Box, then worrying about negative consequences later … and that is only if we assume that their intentions are benign from the beginning. One should take time to examine the history of military experimentation on human populations (http://www.amazon.com/The-Medusa-File-Coverups-Government/dp/0963906240/ref=as_li_tf_sw?&linkCode=wsw&tag=permacultucom-20) to see all of this through a very different lens.

At the very least, instead of the fully realized vision of Human Body 2.0, this might be Big Pharma 2.0 — a new phase where conventional drugs are incrementally replaced by nanodrugs (http://www.sciencedaily.com/releases/2013/08/130810063717.htm) and nano-fleet delivery systems. Coupled with applications that directly enter our brain to connect us to the computer matrix, we are rapidly entering an entirely new human paradigm.

The funding is already there, and a massive amount of money is waiting to be made by companies like Google. Here again, for those who might only see the bright side to this technology, we ought to question who is really in control of it.

Sources:

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http://www.nature.com/nnano/focus/dna-nanotechnology/index.html (http://www.nature.com/nnano/focus/dna-nanotechnology/index.html)
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JAN **17** 2014

Mind Control in the 21st Century

Mind Control in the 21st Century—Science Fiction and Beyond

(http://www.veteranstoday.com/wp-content/uploads/2014/01/mind-control2_banner.jpg)

Mind Control in the 21st Century—Science Fiction & Beyond

… by Steven DiBasio

Understanding MIND CONTROL
(http://www.veteranstoday.com/wp-content/uploads/2014/01/51vrpnPx+jL.jpg)

Is it coming to a home near you?

Conspiracy Theory?

"Mind control" is a topic commonly perceived as "conspiracy theory" or "X-Files" fare. That is, it is seen as possibly not "real," and certainly not something about which one should be "overly" concerned.

This attitude at least partially arises from the widespread belief or assumption that the human brain is so complicated—("the most complex entity in the universe" is a common formulation)—that it has not, and perhaps cannot, be comprehended in any depth.

One writer, for example, describes the brain as of "perhaps infinite" complexity,[1] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn1) while another, David Brooks of the *New York Times*, writes that it is "probably impossible" that "a map of brain activity" could reveal mental states such as emotions and desires.[2] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn2)

Similarly, Andrew Sullivan, blogger and former editor of *The New Republic*, opines that neuroscience is still in its "infancy," and that we have only begun "scratching the surface" of the human brain, and links to a *New Yorker* piece in support of that position.[3] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn3)

And the cover story for the October 2004 issue of Discovery Magazine entitled "The Myth Of Mind Control" advises the reader that while mind control is a "familiar science-fiction" staple, there is little reason for real concern, because actually deciphering the "neural code" would be akin to figuring out other "great scientific mysteries" such as the "origin of the universe and of life on Earth," and is therefore hardly likely.[4] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn4)

According to the article, as the brain is "the most significant mystery in science" and quite possibly "the hardest to solve,"[5] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn5) mind control remains at worst a distant concern.

The underlying idea seems to be that sophisticated mind control is unlikely without understanding the brain; and we do not understand the brain.

(http://www.veteranstoday.com/wp-content/uploads/2014/01/mindcontrol.gif)

Understanding the "Neural Code"

Of course, one might question the notion that a full understanding of the "neural code" is a prerequisite for mind control since it is not always necessary to know how something works for it to be effective. Nonetheless, the assumption that the brain is so complex that little progress has been made in "solving" it is itself incorrect.

As neuroscientist Michael Persinger has said, the "great mythology" of the brain is that it is "beyond our understanding; no it's not."[6] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn6) In fact, according to inventor and "futurist" Ray Kurzweil, "very detailed mathematical models of several dozen regions of the human brain and how they work…."[7] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn7) had already been developed over a decade ago.

Kurzweil also said at that time that science is "further along in understanding the principles of operation of the human brain than most people realize…."[8] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn8) While the brain may be complicated, "it's not *that* complicated (emphasis added)."[9] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn9)

Similarly, an Air Force report from 1995, in a section entitled "Biological Process Control," predicts that before 2050 "… [w]e will have achieved a clear understanding of how the human brain works, how it really controls the various functions of the body, and how it can be manipulated…:"[10] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn10)

> ***One can envision the development of electromagnetic energy sources … that can couple with the human body in a fashion that will allow one to prevent voluntary muscular movements, control emotions (and thus actions), produce sleep, transmit suggestions, interfere with … memory, produce an experience set, and delete an experience set. [11] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn11)***

As disturbing as such "predictions" may be, is it possible that technologies to prevent (or perhaps even impel) muscular movement, control emotions, transmit suggestions, delete memories, create false memories, and so on, have already been developed?

Certainly, even a cursory review of the "open literature" reveals that various sophisticated mind control technologies already exist.[12] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn12) Indeed, it is rather shocking to realize how advanced mind control technology was, even several decades ago.

(http://www.veteranstoday.com/wp-content/uploads/2014/01/PTSD1.jpg)

"Altering brain waves"

For example, there is the 1974 invention of Robert G. Malech for which a patent was granted in 1976 and assigned to defense contractor Dorne & Margolin, Inc.—for a method of "remotely monitoring and altering brain waves."[13] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn13)

Moreover, experiments conducted over thirty years ago at the Stanford Research Institute (SRI) showed that basic mind reading from EEG readouts was possible, revealing the existence of "a non-symbolic language" of "brain-wave patterns" which could be deciphered and translated.[14] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn14)

Indeed, "…[b]y the late 1960s … 'remote control' of the human brain—accomplished *without* the implantation of electrodes—was well on its way to being realized."[15] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn15) A means of stimulating a brain "by creating an electrical field completely outside the head" was developed,[16] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn16) and it was discovered that electric pulses could stimulate the brain using far less energy than previously "thought … effectual in the old implanting technique."[17] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn17)

Not surprisingly, with such developments arose legitimate fears of a future world where "human robots" would perform the bidding of the "military."[18] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn18)

And one source quotes a 1970s Pentagon agency report as saying that it will likely be possible in "several years" to induce sounds and words directly into the brain (bypassing the ears), as well as to use "combinations of frequencies and other signal characteristics to produce other neurological effects….,"[19] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn19)

The report notes that the Soviets had observed "various changes in body chemistry" and "functioning" of the brain from the exposure of the brain to various frequencies.[20] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn20) Also mentioned are studies at MIT showing that "magnetic brain waves can be picked up … and amplified as if the brain were a radio transmitter," no implants or electrodes required.[21] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn21)

Finally, an article from 1981 describes how "microwave generators" placed in appropriate locations and transmitting at low energy would create "interference patterns" out of the interaction with brainwaves (brain electricity).

These interference patterns "could then be built up by computer into a three-dimensional moving picture of mental processes"—in other words, a remote "thought scanner" (and tracking device) could be developed.[22] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn22)

Recent "Advances"

(http://www.veteranstoday.com/wp-content/uploads/2014/01/crazy.jpg)

Subjected to outside influences

In light of these past developments, it is perhaps rather surprising to read modern articles describing supposedly recent innovations in "mind reading" and mind control technology – in which it is sometimes claimed, for example, that scanners, electrodes and proximity to the subject is required to read and "control" minds.

Such claims reflect an apparent failure of the science of "mind control" to progress as one might have expected considering the presumed interest, as well as the spectacular rate of advancement of science and technology in general in recent decades.

Of course, it would not be all that surprising if mind control technology has advanced considerably, but that research has been carried out in secret for reasons of "national security."

CIA affiliated scientists have certainly conducted much research which they have been prohibited from sharing with their peers,[23] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn23) and inventions that implicate "national security" are routinely suppressed under Pentagon secrecy orders.[24] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn24) Also, it might seem desirable to hide research programs which sometimes "require" relaxation of ethical standards, such as that of informed consent.

That said, even ignoring the likely existence of a "secret science" of mind control, recent public advancements are quite troubling in their own right.

Some examples:

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(http://www.veteranstoday.com/wp-content/uploads/2014/01/th.jpg)

"New connections" are being made all the time.

1) In 2004, 25,000 rat neurons on a glass dish learned to fly an F-22 jet fighter simulator.[25] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn25) After scientists placed the neurons on the dish, the neurons quickly began "to reconnect themselves, forming a living neural network—a brain."[26] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn26)

The lead scientist added that "one day," though of course a "long way off," disembodied brains might actually be used to fly drones,[27] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn27) though the current experiment was merely to enhance knowledge of how the brain works, and possibly provide "clues to brain dysfunction."[28] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn28)

2) In August 2013, researchers revealed that "miniature" human brains had been grown in the laboratory.[29] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn29) As is typical, any negative implications or reasons for worry were minimized, while possible "therapeutic" uses were highlighted. Thus, the breakthrough was hailed as a great opportunity to understand "developmental defects." Though the writer does mention "the spectre of what the future might hold," the reader is reassured that the research is "primitive territory"[30] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn30)—though one researcher did comment on the "undesirability" of growing larger laboratory brains.[31] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn31)

3) On July 1, 2013, a magazine reported a claim by neuroscientist Sergio Canavero that it was now feasible to transplant the head of one human to the body of another and reattach the spinal cord.[32] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn32)

4) Scientists have reconstructed random images viewed by subjects, from fMRI brain scans, in research that "hints" that "one day" scientists might be able to "access dreams, memories and imagery…."[33] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn33)

5) The brains of two rats have been linked, such that one, located in North Carolina, responded "telepathically" to the thoughts of the other, located in Brazil.[34] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn34) The second rat's brain processed signals from the first rat's brain, delivered over the internet, as if they were its own. The scientist speculated about the "future possibility" of a "biological computer, in which numerous brains are connected…."[35] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn35)

6) A brain-to-brain interface has been created, allowing humans to move a rat's tail just by thinking about it.[36] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn36) Readers are told that while it is not yet possible to "communicate brain to brain with our fellow humans … we may be on our way to … controlling" other species.[37] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn37) But, since it is "still very early days" the writer "hope(s)" that any ethical concerns can be "iron(ed) out."[38] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn38) Of note, the study used focused ultrasound to deliver impulses to the rat's brain.[39] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn39)

7) Continuing the ultrasound "theme": Focused pulses of low intensity low frequency ultrasound, transmitted noninvasively through the skull to the human brain, have been shown capable of producing, not only pain, but also sound, as well as evoking "sensory stimuli."[40] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn40) Accordingly, a lab with a "close working relationship" with DARPA, the Department of Defense, and U.S. Intelligence communities, has been looking into using pulsed ultrasound to encode "sensory data onto the cortex"; in other words, producing hallucinations through the remote and direct stimulation of brain circuits.[41] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn41) Possibilities are the ability to "remotely control brain activity" and the "creation of artificial memories."[42] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn42) Even Sony has gotten in on the act, patenting a device for using ultrasound to produce hallucinations—again described as "transmitting sensory data directly into the human brain."[43] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn43) Most troublingly, one source recently alleged that the NSA is using this ultrasound technology to target individuals through their smartphones.[44] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn44)

8) A researcher was able to make a fellow researcher in a different office move his finger just by thinking about it, in the "first" demonstration of a human brain-to-brain interface.[45] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn45)

9) A low cost means of tracking people, even through walls, has been developed. While in the past individuals could be tracked anywhere by the "military" using radar technology, this technology might enable entities with fewer resources to track people as well.[46] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn46)

(http://www.veteranstoday.com/wp-content/uploads/2014/01/mindcontrol_nano-testing_crop.jpg)

10) Scientists have remote controlled a worm by implanting magnetic nanoparticles into it, and then exposing the animal to a "radiofrequency magnetic field" which stimulated its neurons. The scientists suggest that their research could lead to "innovative cancer treatments" and "improved diabetes therapies," as well as

11) Americans can now be spied on in their homes through their internet-connected appliances, according to (former) CIA Director David Petraeus.

Petraeus made his statements at about the same time a huge microchip company, ARM, unveiled new processors which will connect home appliances such as refrigerators, washers and driers to the internet.[48] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn48)

12) LED lights have been ostensibly pushed for their efficiency over traditional bulbs. However, LED lights are also semiconductors capable of inducing "biological and behavior effects."[49] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn49)

"Breakaway" Science?

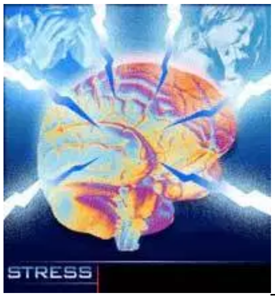

(http://www.veteranstoday.com/wp-content/uploads/2014/01/stress-510010.jpg)

Nural Codes

While the aforementioned public developments are quite concerning, the reality is they may not actually represent the true state of the art in "mind control" technology.

It would not be that surprising, after all, for a domain with national security implications to at some point in its development branch off onto separate "tracks," one public and the other "hidden."

If such a bifurcation were to occur, advancements made in secret would not necessarily be incorporated into the public sphere. Eventually perhaps, innovations and breakthroughs would result in the development of an essentially new, covert science.

An example of a domain in which this bifurcation process seems to have occurred is aviation. In the public sphere, the most advanced aircraft might well be the F-22 fighter jet, or perhaps the F-35. However, if insider testimony is credited, these aircraft seem almost primitive in comparison with flying machines developed in secret.

Perhaps the most compelling statements in this regard come from Ben Rich, former Director of Lockheed-Martin's Advanced Development Projects, or "Skunk Works," a Lockheed division notable for its super high-tech, top secret projects, among them the U2 spy plane and the SR-71 Blackbird.

As Joseph P. Farrell's reports in his book *Saucers, Swastikas, and Psyops*, Rich made a number of peculiar and provocative comments at the end of his career, and following his retirement on December 31, 1990 (prior to his death five years later), comments strongly hinting at "the development of … an off-the-books physics and technology…."[50] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn50)

For example, on September 7, 1988, in a presentation to the American Institute of Aeronautics and Astronautics in Atlanta, Georgia, Rich lamented that he was prohibited from discussing Skunkwork's current projects, but he did say that they "call for technologies once only dreamed of by science fiction writers."[51] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn51)

In ensuing years, Rich elaborated slightly. For instance, while speaking to the UCLA School of Engineering Alumni Association in 1993, Rich said that "an error in the equations" had been discovered and corrected, making it possible "to travel to the stars."[52] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn52) He added, however, that "these technologies are so locked up in black programs, that it would take an act of God to ever get them out to benefit humanity."[53] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn53)

100 YEARS OF ACCELERATING TOMORROW

(http://www.veteranstoday.com/wp-content/uploads/2014/01/Ben-Rich-Ftr.jpg)

Ben Rich – Who saw it it…lived it all.

Farrell goes on to relay a statement from an unnamed Lockheed retired engineer who was quoted in a magazine article in 1988 as saying that "we have things flying in the Nevada desert that would make George Lucas drool."[54] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn54) In the same article an Air Force officer involved in the development of the SR-71 said "[w]e are testing vehicles that defy description.

To compare them conceptually to the SR-71 would be like comparing Leonardo da Vinci's parachute design to the space shuttle." And a retired Colonel chimed in: "We have things that are so far beyond the comprehension of the average aviation authority as to be really alien to our way of thinking." [55] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn55)

Consider then for a moment the possibility that within the classified world, in 1993, a technology, to quote Ben Rich, "to take ET back home" had already been developed.[56] (http://www.veteranstoday.com/2014/01/13/mind-control-in-the-21st-century-science-fiction-beyond/#_ftn56) The implications are enormous, not to mention rather frightening. One wonders where the technology must be in 2014, more than twenty years later.

And if the aforementioned statements are true, and this seems plausible (why would these individuals lie, or even exaggerate, especially to Engineering Associations and Aeronautics institutes), what might this imply about the current state of the art in domains other than aviation, such as neuroscience, which has itself been the subject of intense "weaponization" efforts.

Indeed, what does such a vast discrepancy between what people believe and what is actually true suggest about the nature of our perceived reality in general?

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NSA Spy Program Is Absolutely Orwellian Intelligence

The EMF Brain Mapping Of The People And Its Use As Part Of A Signals Intelligence Driven Spy Program Is Absolutely Orwellian

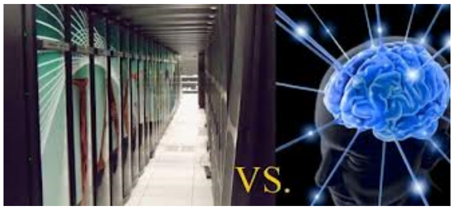

(https://nanobrainimplant.files.wordpress.com/2014/01/44.png)

Former US National Security Agency contractor Edward Snowden appeared in a televised Christmas message released to the world public by TV station Channel 4 on Wednesday. (Dec. 25)

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By mindcontroleurope • Posted in Man vs Machine, Mind Control • Tagged artificial intelligence, artificial telepathy mind, b, Brain Implants for MIND/BRAIN CONTROL, brain-computer-interface, Implant for Synthetic Telepathy, military, nsa, orwell, snowden, transcranial-magnetic-stimulation

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JANUARY 13, 2018

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We called the new chip the "SECOND BIRTH" generator (/second-birth-mini-tesla-psi-generator.html), because the client gets the most valuable bioholographic treatment ever for rejuvenation -- the biohologram of the embryonic stem cell. The SECOND-BIRTH Biohologram (/second-birth-mini-tesla-psi-generator.html) is available as a chip encoded by laser on nanolevel. The clinical trials were conducted by the Bauman University Medical Center. The clinical trials had demonstrated the radical improvement in the wellbeing of the participants in the clinical trials.

Click here to read more. (/second-birth-mini-tesla-psi-generator.html)

WAVE GENOME LLC uses Bauman Moscow Russian State Technical University, major Science University of Russia, of MIT level, to verify WAVE GENOME'S technological models.

WORLDWIDE LAUNCH OF HOLONET (© Dr. Irene Caesar) - HOLOGRAPHIC BIOINTERNET & HOLOGRAPCHIC DRUGS, BIOELECTRONIC DRUGS AND INTERNET DRUGS

H-DRUGS, E-DRUGS AND I-DRUGS

FOR REMOTE AND LOCAL REJUVENATION

NEWS

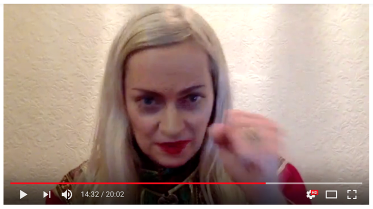

IRENE CAESAR INTERVIEW FOR MINDTECH ENTERPRISES DEC 13 2016

IRENE CAESAR - INTERVIEW FOR MINDTECH ENTERPRISES DEC 13 2016 (https://www.youtube.com/watch?v=ap8kHpuYlxM&feature=youtu.be)

IRENE CAESAR INTERVIEW FOR RIPSONAR NEWS APRIL 22 2017
54:42 / 56:35

IRENE CAESAR, Ph.D., PRESIDENT AND OWNER OF WAVE GENOME: INTERVIEW FOR RIPSONAR NEWS, APRIL 22, 2017 (https://www.youtube.com/watch?v=iTTHLETrz1A).

(/quantum-clinic.html)
Large-size AURA PSI-GENERATOR for radical rejuvenation of all bodily organs and physiological systems.

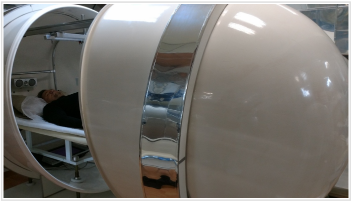

(/quantum-clinic.html)
Large-size AURA PSI-GENERATOR offers radical rejuvenation for patents rejected by conventional medicine to the degree they do not need conventional medicine any longer.

Click here (/quantum-clinic.html) to read about our clinic.

Consortium "MATRIX CITY - city as one integrated wave matrix" (/consortium.html)

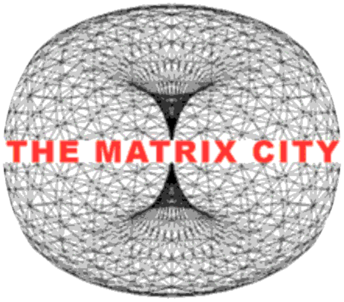

(/irene-caesar---matrix-city-project.html)

QUANTUM REMOTE REJUVENATION

(/quantum-rejuvenation-clinic-om---english.html)

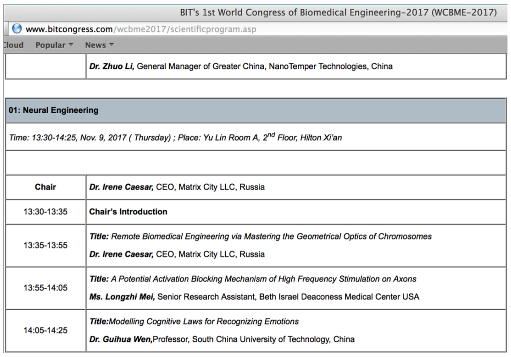
BIT's 1st World Congress of Biomedical Engineering-2017 (WCBME-2017)
www.bitcongress.com/wcbme2017/scientificprogram.asp
Cloud
Popular
News

	Dr. Zhuo Li, General Manager of Greater China, NanoTemper Technologies, China

01: Neural Engineering	
Time: 13:30-14:25, Nov. 9, 2017 (Thursday) ; Place: Yu Lin Room A, 2nd Floor, Hilton Xi'an	
Chair	***Dr. Irene Caesar,*** CEO, Matrix City LLC, Russia
13:30-13:35	**Chair's Introduction**
13:35-13:55	***Title:*** *Remote Biomedical Engineering via Mastering the Geometrical Optics of Chromosomes* ***Dr. Irene Caesar,*** CEO, Matrix City LLC, Russia
13:55-14:05	***Title:*** *A Potential Activation Blocking Mechanism of High Frequency Stimulation on Axons* ***Ms. Longzhi Mei,*** Senior Research Assistant, Beth Israel Deaconess Medical Center USA
14:05-14:25	***Title:****Modelling Cognitive Laws for Recognizing Emotions* ***Dr. Guihua Wen,***Professor, South China University of Technology, China

NOVEMBER 9-11, 2017

DR. IRENE CAESAR WAS INVITED TO BE A CHAIR OF THE NEURAL ENGINEERING SECTION OF THE BIT'S 1st WORLD COGRESS OF BIOMEDICAL ENGINEERING, Theme: Co-creating a New Future of Biomedicine, November 9-11, 2017, in Xi'an, China. I will deliver paper called **"REMOTE BIOMEDICAL ENGINEERING VIA MASTERING THE GEOMETRICAL OPTICS OF CHROMOSOMES"**. List of Renowned Speakers include professors from University of Oxford, UK; Harvard Medical School, USA; American College Of Clinical Engineering, USA; California South University, USA; University of Illinois at Chicago, USA; The Mount Sinai Medical Center, USA; University of California, USA; Washington University School of Medicine, USA; The Salerno Center for Complementary Medicine, USA; National Cancer Institute, NIH, USA; University of Pennsylvania, USA; Washington University in St. Louis Campus, USA; International Federation For Medical and Biological Engineering, USA; Louisiana State University Health Sciences Center in Shreveport, USA; International Spine Research Foundation, USA; RWTH Aachen University, Germany; Technical University of Munich, Germany; Institut Curie, France; University of Queensland, Australia; Tsinghua University, China; Asia Pacific Association for Medical Informatics, South Korea; European Medical Association, Belgium; University of Geneva, Switzerland; Gyeongbuk Institute of Science and Technology, South Korea; University of Geneva, Switzerland; The Standing Committee of European Doctors, Belgium; International Scociety of Medical Laser Applications, Austria.

Link to the NEURAL ENGINEERING Session:
http://www.bitcongress.com/wcbme2017/scientificprogram.asp
List of Renowned Speakers:
http://www.bitcongress.com/wcbme2017/default.asp

"REMOTE BIOMEDICAL ENGINEERING VIA MASTERING THE GEOMETRICAL OPTICS OF CHROMOSOMES"

Abstract

The same gene is expressed in functional individuals and species by metacentric chromosome, and in dysfunctional individuals and species via acrocentric chromosome. Metacentric chromosome is analogous to a well-centered and focused eye crystal, while acrocentric chromosome is analogous to a myopic or farsighted eye. Chromosome is a lens that allows our cells to focus the needed wave information during cell division, analogously to a crystal in our eye. Thus, Biomedical Engineering is possible only via mastering the Geometrical Optics of Chromosomes by Laser Bioholography. Current genetic engineering via cutting and pasting DNA snippets destroys the systematic wholes of chromosomal bioholograms and the refraction of the geometrical optics in chromosomes, and, therefore, causes genetic collapse. The Quantum Leap in the Biomedical Engineering is the cost of our survival. Biomedical Engineering as Bioholography is based on Quantum Physics, and understanding the non-local nature of the Bioholograms. Since universe is holographic, we can record and transmit only holographic information, based upon changing the refraction of the scalar wave diffraction grating in chromosomes. According to Holographic principle, Universe is entirely in its every matrix point. The implication of the Holographic Principle states that if Universe is entirely in its every matrix point, then, every matrix point is not simply different from any other matrix point, but is unique. This means that

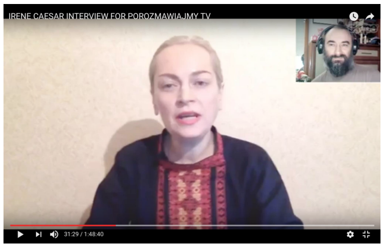

(https://www.youtube.com/watch?v=uxfui6xTtEc)

IRENE CAESAR, Ph.D., PRESIDENT AND OWNER OF WAVE GENOME: INTERVIEW FOR POROZMAWIAJMY TV CONDUCTED BY ALEXANDER BERDOWICZ, FEBRUARY 7, 2017. (https://www.youtube.com/watch?v=uxfui6xTtEc)

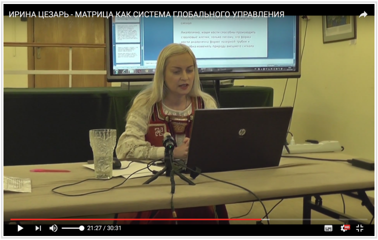

IRENE CAESAR, Ph.D., PRESIDENT AND OWNER OF WAVE GENOME: LECTURE "MATRIX AS A GLOBAL MANAGEMENT SYSTEM OF LIFE. MECHANISM OF REMOTE MANAGEMENT OF BIOSYSTEMS," CONFERENCE "PSYCHICS - YESTERDAY, TODAY, AND TOMORROW, (4TH MEETING OF THE ASSOCIATION OF ASTRAL ANTHROPOLOGY AND PSYCHOLOGY), MOSCOW, RUSSIA, OCTOBER 10, 2016. (https://www.youtube.com/watch?v=eEKzZQ4Wzcc)

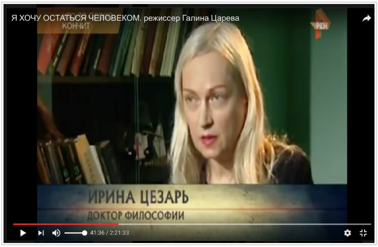

IRENE CAESAR, PH.D., PRESIDENT AND OWNER OF WAVE GENOME, IN THE FILM BY RENOWNED RUSSIAN PRODUCER GALINA TSAREVA "I WANT TO REMAIN HUMAN", AUGUST, 2016. (https://www.youtube.com/watch?v=YTTWalRT_0Y)

(https://www.youtube.com/watch?v=XuwV_QCTf2I)

IRENE CAESAR, PH.D., PRESIDENT AND OWNER OF WAVE GENOME: "REMOTE MANAGEMENT OF BIIO SYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR

Models of TESLA PSI-GENERATORS by WAVE GENOME.

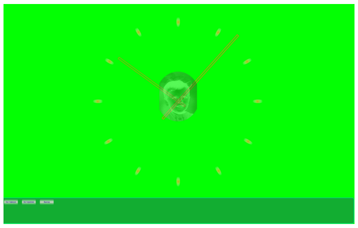

TRUE BIOELECTRONIC E-DRUGS

The MINI-TESLA psi-generator **DIGITAL PHARMACY (/digital-pharmacy-software--1057105410601058-10621048106010561054104210541049-1040105510581045105010481048.html)** software program generates HOLOGRAPHIC SIGNAL (as white noise) encoded in music for every system and vital organ in your body.

MILESTONES

Over the span of the 20th century, generations of extraordinary scientists, among whom Russian scientists played a leading role, laid down scientific foundation for the technological revolution of information-wave technology of the Quantum Leap.

MORE (/milestones.html)

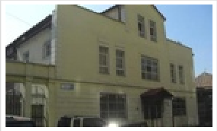

(/uploads/3/5/1/1/35112207/5553543_orig.jpg)

For developing and producing its products, WAVE GENOME is teaming with most advanced scientists all over the world. Here we see Scientific Research Institute for National Security in Moscow, now closed. The scientific group still

every wave matrix is both non-local, and unique. Thus, if we have two exact copies of the same non-local wave matrix, we can transmit information instantaneously and remotely, from one copy of the same non-local unique wave matrix to another copy. Thus, the precision in the Biomedical Engineering is achieved not via the precision of localization, but, vice versa, via the precision of refraction in the unique and non-local bioholograms aka “wave crystals”. The secret in the remote Biomedical Engineering as Quantum Biocomputing lies in the recording and instantaneous transmission of a structural phantom. I will introduce the new method for recording and remote transmitting of bioholograms via laser spectroscopy and coding electrets on nanolevel via laser. The technology creates “lenses” assisting our chromosomes in correcting their refraction for focusing genetic bioholographic information, both locally and remotely.

APRIL 25-27, 2017

IRENE CAESAR, PH.D., SPEECH "REMOTE MANAGEMENT OF BIOSYSTEMS AS BIOHOLOGRAPHY BASED UPON THE SHAPE OF CHROMOSOMES FOR FOCUSING GENETIC INFORMATION" at the Annual World Congress of Molecular & Cell Biology Xi'an, China. **Click here** (http://www.bitcongress.com/cmcb2017/)for the official webpage of the Summit. **Click here (http://www.bitcongress.com/cmcb2017/scientificprogram_4.asp)** for the official list of participants.

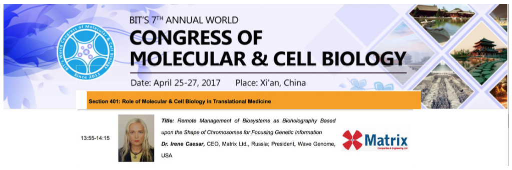

BIT'S 7TH ANNUAL WORLD
CONGRESS OF
MOLECULAR & CELL BIOLOGY
Date: April 25-27, 2017 Place: Xi'an, China

Section 401: Role of Molecular & Cell Biology in Translational Medicine

13:55-14:15 *Title: Remote Management of Biosystems as Bioholography Based upon the Shape of Chromosomes for Focusing Genetic Information*
Dr. Irene Caesar, CEO, Matrix Ltd., Russia; President, Wave Genome, USA

BIT's World Congress of Molecular & Cell Biology
Since 2011
Matrix

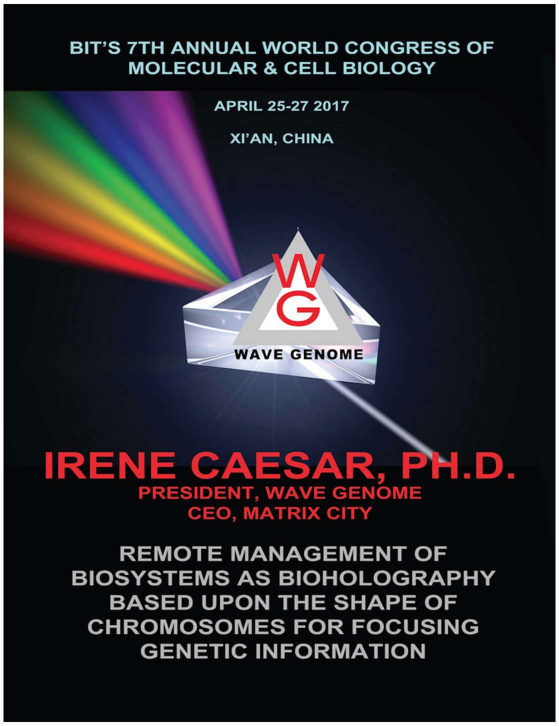

BIT'S 7TH ANNUAL WORLD CONGRESS OF MOLECULAR & CELL BIOLOGY

APRIL 25-27 2017

XI'AN, CHINA

IRENE CAESAR, PH.D.
PRESIDENT, WAVE GENOME
CEO, MATRIX CITY

REMOTE MANAGEMENT OF BIOSYSTEMS AS BIOHOLOGRAPHY BASED UPON THE SHAPE OF CHROMOSOMES FOR FOCUSING GENETIC INFORMATION

WG
WAVE GENOME

Keynote speakers: Dr. Christian Paterman, Former Director, European Commission, Germany; Dr. Martin Banwell, Professor, Australian National University, Australia; Dr. Robert S. Plumb, Professor, Imperial College London, UK; Dr. Dongping Zhong, Professor, Ohio State University, USA.

FOCUSING GENETIC INFORMATION" - RECORDING OF THE LECTURE, BANGKOK THONBURI UNIVERSITY 2ND INTERNATIONAL SYMPOSIUM, JULY 23, 2016.

(https://www.youtube.com/watch?v=XuwV_QCTf2I)

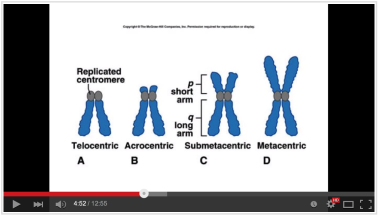

(https://www.youtube.com/watch?v=pSsgOPUzz9A)

IRENE CAESAR, PH.D., PRESIDENT AND OWNER OF WAVE GENOME: "REMOTE MANAGEMENT OF BIIO SYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR FOCUSING GENETIC INFORMATION" - SLIDE SHOW OF THE LECTURE, BANGKOK THONBURI UNIVERSITY 2ND INTERNATIONAL SYMPOSIUM, JULY 23, 2016.

(https://www.youtube.com/watch?v=pSsgOPUzz9A)

IRENE CAESAR - GOSPEL OF IRENE
15:52 / 39:01

IRENE CAESAR, PH.D., FOUNDER, OWNER AND PRESIDENT OF WAVE GENOME: LECTURE "GOSPEL OF IRENE" (PAPER "GOSPEL OF IRENE" WAS PUBLISHED IN FULL IN THREE ISSUES OF THE SOCIALIST FACTOR MAGAZINE, LUCKNOW AND LONDON), THE STRATEGIC INFORMATICS ADVISORY, MARYLAND, USA, JULY 7, 2016.

(https://www.youtube.com/watch?v=QFEErBqSJjY&feature=youtu.be)

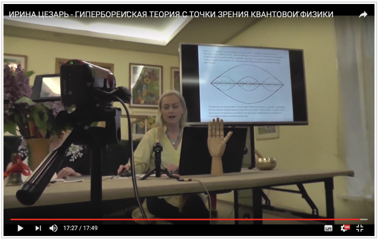

ИРИНА ЦЕЗАРЬ - ГИПЕРБОРЕЙСКАЯ ТЕОРИЯ С ТОЧКИ ЗРЕНИЯ КВАНТОВОЙ ФИЗИКИ
17:27 / 17:49

IRENE CAESAR, PH.D., PRESIDENT AND OWNER OF WAVE GENOME: "HYPERBOREAN THEORY FROM THE POINT OF VIEW OF QUANTUM PHYSICS" - PAPER DELIVERED AT THE CONFERENCE "ESOTERICS, NEW TURNAROUND", ASSOCIATION OF ANTHROPOLOGY AND PSYCHOLOGY, MOSCOW, MAY 16, 2016. (https://www.youtube.com/watch?v=CRbRsohA8i4)

operates the clinic. Among clients of the clinic were Russian President Boris Yeltsin, famed American astronaut Edgar Mitchell, and actor celebrity Alexander Kalyagin. The institute has received the written Blessing of Patriarch Alexis and Patriarch of Constantinople.

(/uploads/3/5/1/1/35412207/4353994_orig.jpg) Famed American Astronaut Edgar Mitchell received a treatment by GENERATOR AURA-001.

OUR PLEDGE

We build our strategy upon a firm foundation of the highest standards of ethics.

MORE (/our-pledge.html)

Our MINI-TESLA PSI-GENERATOR is used by Russian Special Forces.

Our MINI-TESLA PSI-GENERATOR is used by Russian Olympic Team.

Our TESLA GLASSES are used by Russian Central Intelligence Service.

Our TESLA GLASSES are used by Russian Space Forces.

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Abstract

We are standing at the threshold of the biggest scientific revolution in the history of human kind, called Quantum Leap. All Transhumanist models of genetic modification of organisms, relying on global artificial intellect and brain-computer interfaces are obsolete technologies of the pre-Quantum Era. Either Biology makes Quantum Leap, or humankind will be destroyed by genetic collapse. Human enhancement is possible only through mastering the geometrical optics of chromosomes via Bioholography.

Now bioengineering fails since it does not account for the geometrical optics of chromosomes, leading to the corruption of genomes. The same gene gets expressed in dysfunctional individuals by acrocentric chromosome, and in functional individuals by metacentric chromosome. I claim that chromosome is a geometrical code and functions via refraction in the wave crystal, i.e., nonlocal unique biohologram or wave matrix that focuses genetic information unique to this individual via his / her own unique scalar wave diffraction grating. The implication of the holographic principle states that if the universe is entirely in its every matrix point, then, every matrix point is not simply different from any other matrix point, but is unique. Thus, if we have two exact copies of the same unique non-local biohologram, we can transmit information remotely and instantaneously from one copy to another copy for the remote management of biosystems.

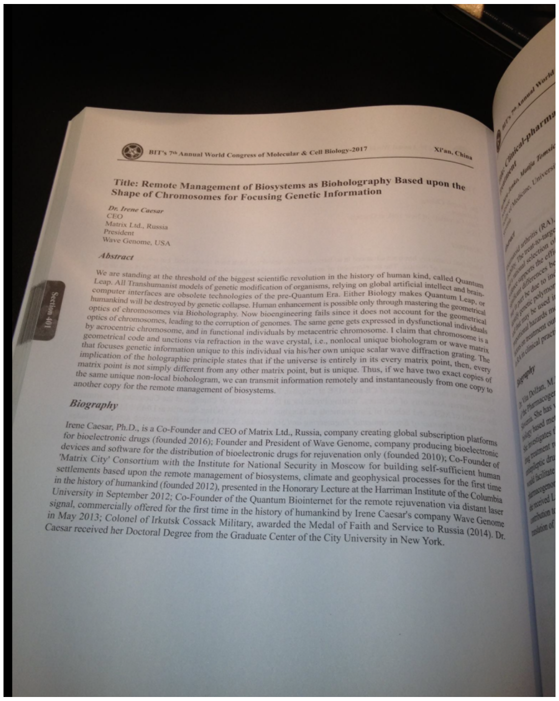

BIT's 7th Annual World Congress of Molecular & Cell Biology-2017 Xi'an, China

Title: Remote Management of Biosystems as Bioholography Based upon the Shape of Chromosomes for Focusing Genetic Information

Dr. Irene Caesar
CEO
Matrix Ltd., Russia
President
Wave Genome, USA

Abstract

We are standing at the threshold of the biggest scientific revolution in the history of human kind, called Quantum Leap. All Transhumanist models of genetic modification of organisms, relying on global artificial intellect and brain-computer interfaces are obsolete technologies of the pre-Quantum Era. Either Biology makes Quantum Leap, or humankind will be destroyed by genetic collapse. Human enhancement is possible only through mastering the geometrical optics of chromosomes via Bioholography. Now bioengineering fails since it does not account for the geometrical optics of chromosomes, leading to the corruption of genomes. The same gene gets expressed in dysfunctional individuals by acrocentric chromosome, and in functional individuals by metacentric chromosome. I claim that chromosome is a geometrical code and unctions via refraction in the wave crystal, i.e., nonlocal unique biohologram or wave matrix that focuses genetic information unique to this individual via his/her own unique scalar wave diffraction grating. The implication of the holographic principle states that if the universe is entirely in its every matrix point, then, every matrix point is not simply different from any other matrix point, but is unique. Thus, if we have two exact copies of the same unique non-local biohologram, we can transmit information remotely and instantaneously from one copy to another copy for the remote management of biosystems.

Biography

Irene Caesar, Ph.D., is a Co-Founder and CEO of Matrix Ltd., Russia, company creating global subscription platforms for bioelectronic drugs (founded 2016); Founder and President of Wave Genome, company producing bioelectronic devices and software for the distribution of bioelectronic drugs for rejuvenation only (founded 2010); Co-Founder of 'Matrix City' Consortium with the Institute for National Security in Moscow for building self-sufficient human settlements based upon the remote management of biosystems, climate and geophysical processes for the first time in the history of humankind (founded 2012), presented in the Honorary Lecture at the Harriman Institute of the Columbia University in September 2012; Co-Founder of the Quantum Biointernet for the remote rejuvenation via distant laser signal, commercially offered for the first time in the history of humankind by Irene Caesar's company Wave Genome in May 2013; Colonel of Irkutsk Cossack Military, awarded the Medal of Faith and Service to Russia (2014). Dr. Caesar received her Doctoral Degree from the Graduate Center of the City University in New York.

Section 401

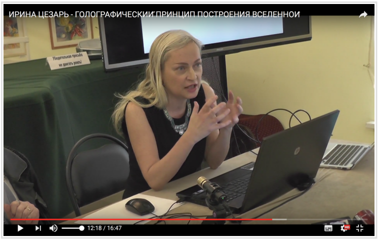

IRENE CAESAR, PH.D., PRESIDENT AND OWNER OF WAVE GENOME: "HOLOGRAPHIC PRINCIPLE OF THE STRUCURE OF THE UNIVERSE" - PAPER DELIVERED AT THE CONFERENCE "UNKNOWN COSMOS", ASSOCIATION "PROTOHISTORY", MOSCOW, MAY 14, 2016. (https://www.youtube.com/watch?v=M4oYWLLmP4c)

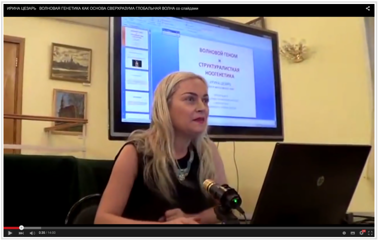

(https://www.youtube.com/watch?v=RT1nSUJilbY)

IRENE CAESAR, PH.D., PRESIDENT AND OWNER WAVE GENOME: "STRUCTURALIST WAVE GENOME AS THE FOUNDATION FOR SUPER INTELLECT" - PAPER DELIVERED AT THE CONFERENCE OF THE ASSOCIATION FOR ANTHROPOLOGY AND PSYCHOLOGY, MOSCOW, APRIL 26, 2016. (https://www.youtube.com/watch?v=RT1nSUJilbY)

Another version of this video recording. (http://www.wavegenome.com http://www.thematrixcity.com)

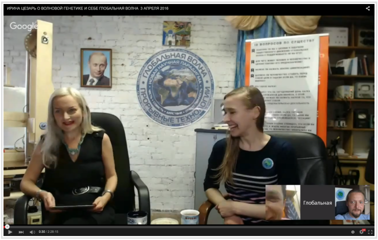

(http://Skip navigation RUUpload Search Analytics Video Manager ИРИНА ЦЕЗАРЬ О ВОЛНОВОЙ ГЕНЕТИКЕ И СЕБЕ ГЛОБАЛЬНАЯ ВОЛНА 3 АПРЕЛЯ 2016 Irene Caesar Irene Caesar Channel settingsDownload720 Add to Share More 82 views Published on Jun 7, 2016 ИРИНА ЦЕЗАРЬ О ВОЛНОВОЙ ГЕНЕТИКЕ И СЕБЕ ГЛОБАЛЬНАЯ ВОЛНА 3 АПРЕЛЯ 2016 SHOW MORE Comments are disabled for this video. Autoplay Up Next Сергей Салль Ответ еврейке Цезарь - Салль позор России игра в бисер 12,851 views 50:28 ИРИНА ЦЕЗАРЬ - РАВВИН ЭТО РУСО-АРИЙ ГЛОБАЛЬНАЯ ВОЛНА Irene Caesar 97 views 2:52:41 Засланный казачок Ирина Цезарь или очередной проект сатаноизбранных (Сергей Салль) Светослав 4,499 views 50:28 ИРИНА ЦЕЗАРЬ - СТРУКТУРНАЯ ВОЛНОВАЯ ГЕНЕТИКА КАК ОСНОВА СВЕРХРАЗУМА Irene Caesar 362 views 18:05 СПИЦЫН - Золотая Орда. Дмитрий Донской. Нашествия ханов. Куликовская битва. Монголы и Русь. Евгений Спицын ИСТОРИЯ РОССИИ Recommended for you 57:16 ИРИНА ЦЕЗАРЬ

Our TESLA GLASSES are used by Russian Strategic Missile Forces.

Our TESLA GLASSES are used by Russian Ministry of Emergency Situations.

Our TESLA GLASSES are used by Russian Federal Security Service.

Our TESLA GLASSES are used by Russian Interior Ministry.

WAVE GENOME employs scientists from most advanced research group all over the world, including the present Moscow Bauman Russian State Technical University, the major Science University in Russia, of MIT level; and scientists of the former most secret USSR Research Institutes, which conducted studies in psychotronics, e.g., "Scientific-Research Institute Energy" (founded in 1937, with 5000 scientists under supervision of the National Security Agencies of the Soviet Union (Научно- производственное Объединение Энергия). The Scientific-Research Institute Energy was developing devices and services for the first persons in the State, military commanders, diplomats, Special Forces and the Olympic Team. Technologies of the Institute were declassified in 2008. In the US, these technologies are still classified. Dr. Irene Caesar was also collaborating with the Scientific Research Institute for the National Security in Moscow, Russian Federation, now closed.

Nonetheless, it was Dr. Irene Caesar herself who was first to offer to record the holographic signal of the wave matrices via laser from the pharmaceutical drugs as recreated bioholograms representing in this dimension the scalar wave diffraction gratings of multidimensional wave crystals. And Dr. Caesar was first to offer an idea to encode electrets via laser on nanolevel with these bioholograms of the pharmaceutical drugs.

Dr. Caesar created a theory of the Wave Optics (Geometrical Optics) in chromosomes as refraction in the scalar wave diffraction grating.

GLOBAL LAUNCH OF ULTIMATE TESLA PSYCHOTRONIC GENERATOR BY WAVE GENOME

Click here (/ultimate-mini-tesla-psi-generator.html) to read **PRESS RELEASE** on the **GLOBAL LAUNCH OF THE ULTIMATE TESLA PSI-GENERATOR by WAVE GENOME**

ULTIMATE TESLA PSI-GENERATOR IS BASED UPON IMPORTANT DISCOVERY BY DR. IRENE CAESAR REGARDING THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING / REFRACTION MECHANISM FOR FOCUSING GENETIC INFORMATION

IRENE CAESAR & MAGNUS OLSSON ULTIMATE TESLA LAUNCH BY WAVE GENOME
14:36 / 15:22

(https://www.youtube.com/watch?v=Iyfh-C3oSm0&feature=youtu.be)

ON DECEMBER 2, 2016, IRENE CAESAR, PH.D.. PRESIDENT, FOUNDER AND OWNER OF WAVE GENOME, LAUNCHED HER NEW PRODUCT -- ULTIMATE MINI-TESLA PSI-GENERATOR FOR THE ULTIMATE PROTECTION AGAINST PSYCHOTRONIC AND GENETIC WARFARE. Intellectual and Commerical Property belongs to WAVE GENOME. Magnus Olsson, President of Mindtech Enterprises, becomes the designated Distributor for WAVE GENOME'S ULTIMATE MINI-TESLA PSI-GENERATOR, available on wavegenome.com (http://www.wavegenome.com) and mindtechenterprises.com (http://www.mindtechenterprises.com). **Click here (https://www.youtube.com/watch?v=Iyfh-C3oSm0&feature=youtu.be)** to see the official video of the global launch of THE ULTIMATE MINI-TESLA PSI-GENERATOR by WAVE GENOME.

- ДОКАЗАТЕЛЬСТВА ДРЕВНОСТИ РУСОВ
Irene Caesar 162 views 1:09:36 America)

IRENE CAESAR, PH.D., PRESIDENT AND OWNER OF WAVE GENOME - NTERVIEW ABOUT WAVE GENOME ON GLOBAL WAVE, MOSCOW, APRIL 3, 2016
(https://www.youtube.com/watch?v=VNLtnfLCOlk&feature=youtu.be)

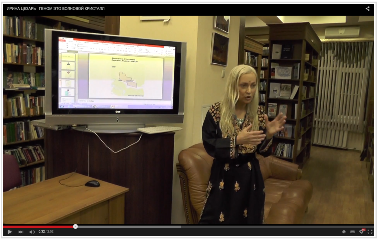

(https://www.youtube.com/watch?v=tgF8PCbRJCQ&feature=youtu.be)

IRENE CAESAR, PH.D., PRESIDENT AND OWNER OF WAVE GENOME: "GENOME IS THE REFRACTION OF SIGNALS TOWARDS THE FOCUS IN THE WAVE CRYSTAL OF CHROMOSOMES" - GUEST PUBLIC LECTURE "DNA GENEALOGY IN THE LIFHT OF RUSSIAN IDEA", EXTRACT, RESEARCH CENTER ON THE ETHICS OF THE RUSSIAN WORLD, MOSCOW, MARCH 16, 2016
(https://www.youtube.com/watch?v=tgF8PCbRJCQ&feature=youtu.be)

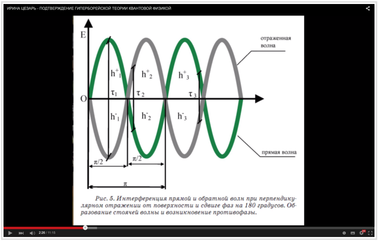

Рис. 5. Интерференция прямой и обратной волн при перпендикулярном отражении от поверхности и сдвиге фаз на 180 градусов. Образование стоячей волны и возникновение противофазы.

(https://www.youtube.com/watch?v=nPgyM2d0HQg&feature=youtu.be)

IRENE CAESAR, PH.D., PRESIDENT AND OWNER OF WAVE GENOME: "CONFIRMATION OF THE HYPERBOREAN THEORY BY QUANTUM PHYSICS" - GUEST PUBLIC LECTURE "DNA GENEALOGY IN THE LIFHT OF RUSSIAN IDEA", EXTRACT, RESEARCH CENTER ON THE ETHICS OF THE RUSSIAN WORLD, MARCH 16, 2016
(https://www.youtube.com/watch?v=nPgyM2d0HQg&feature=youtu.be)

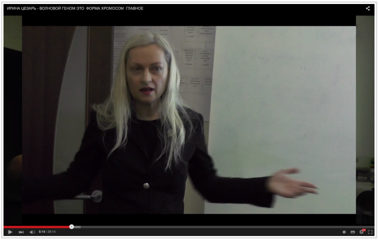

(https://www.youtube.com/watch?v=ONPUDcRVgHY&feature=youtu.be)

IRENE CAESAR, PH.D, PRESIDENT AND OWNER OF WAVE GENOME: "SHAPE OF CHROMOSOMES AS A KEY TO WAVE GENOME - GUEST PUBLIC LECTURE, CHETEK ("MAN, TECHNOLOGY, CAPITAL"), MOSCOW, JANUARY 27, 2016

Dr. Caesar was first to offer an idea of DIGITAL PHARMACY as the collection not of frequencies, but of bioholograms.

WAVE GENOME is focused on developing and commercializing **QUANTUM BIOCOMPUTING** as the **INFORMATION-WAVE TECHNOLOGY OF THE LASER BIOHOLOGRAPHY** in the fields of rejuvenation, wellness and agriculture.

THE INFORMATION-WAVE TECHNOLOGY OF LASER BIOHOLOGRAPHY is based upon the application of Quantum Physics to Genetics, a new theory of Genetics, which is called **STRUCTURALIST GENETICS** (© Irene Caesar, Ph.D., 1989-2010), and the application of various lasers, including the stabilized He-Ne lasers with internal mirrors.

Specifically, this technology applies:
- the holographic model of the Quantum Vacuum identical for macro and micro dimensions;
- the holographic torsion model of the cell as a torus;
- polarized bioholography and polarized bioholograms, based upon the principles of geometrical optics;
- the notions of two kinds of torus: torus as a boundless sphere and torus as a wave crystal (© Irene Caesar, Ph.D., 1989);
- the Kozyrev Mirror principle for the reflection of the external signal upon itself, and creating the scalar wave diffraction grating (wave crystal);
- the diffraction grating (wave crystal) for the refraction of the external signal towards the zero center;
- the notion of the zero center of the wave crystal as the information portal;
- the notion of the instantaneous and remote transmission of information through the zero center of the wave crystal via quantum entanglement in the paradigm of the **QUANTUM BIOINTERNET**.

INFORMATION-WAVE TECHNOLOGY OF THE LASER BIOHOLORAPHY is radically different from the Digital Homeopathy and Bioresonance Technology, though it is also based upon the wave-particle duality in physics. Cell dies when it goes into bioresonance with itself. Soviets had the psychotronic weapon, based upon the principle of bioresonance. Thus, the bioresonance technologies in the West are still wide spread simply because they cannot do enough harm due to incompetence. The information is received and transmitted not through waves (frequencies). The information is received and transmitted through the **GEOMETRICAL CODES** of the wave crystals.

Also, the **INFORMATION-WAVE TECHNOLOGY OF THE LASER BIOHOLORAPHY** is not the scalar wave technology, since scalar waves neutralize any external signal. And to call the **INFORMATION-WAVE TECHNOLOGY OF THE LASER BIOHOLOGRAPHY** as the "scalar wave technology" is to say nothing. Scalar waves are only one element of this technology. Information is not received and transmitted via scalar waves. Scalar waves are simply used for creating the diffraction grating inside the wave crystal in order to refract the external signal toward the zero center of the wave crystal. Information is received and

GLOBAL LAUNCH OF TESLA GLASSES BY WAVE GENOME

(/order-tesla-glasses.html)

PROGRAM SELECT

(/order-tesla-glasses.html)

Click here (/order-tesla-glasses.html) to read about WAVE GENOME TESLA GLASSES.

IRENE CAESAR - HOW TESLA PSI GENERATOR WORKS

(https://www.youtube.com/watch?v=Z8Otz0gbqeM)

DECEMBER 2, 2016

IRENE CAESAR, PH..D, PRESIDENT, FOUNDER AND OWNER OF WAVE GENOME: "HOW THE ULTIMATE TESLA PSI-GENERATOR WORKS", Global Launch of the ULTIMATE TESLA PSI-GENERATOR by WAVE GENOME. **Click here (https://www.youtube.com/watch?v=Z8Otz0gbqeM)** for the video.

IRENE CAESAR ON WAVE GENOME PRODUCTS

(https://www.youtube.com/watch?v=H8hkdkMMkMg)

DECEMBER 2, 2016

IRENE CAESAR, PH..D, PRESIDENT, FOUNDER AND OWNER OF WAVE GENOME ON WAVE GENOME PRODUCTS, Global Launch of the ULTIMATE TESLA PSI-GENERATOR by WAVE GENOME. **Click here** (https://www.youtube.com/watch?v=H8hkdkMMkMg) for the video.

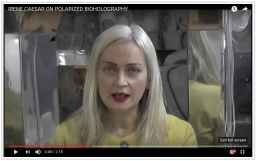

(https://www.youtube.com/watch?v=6BpWw4R8XBo)

DECEMBER 2, 2016

IRENE CAESAR, PH.D., FOUNDER AND PRESIDENT OF WAVE GENOME, ON POLARIZED BIOHOLOGRAPHY. Click here (https://www.youtube.com/watch?v=6BpWw4R8XBo&feature=youtu.be) for the video.

IRENE CAESAR - VOICE TO SKULL OF MAGNUS OLSSON
Irene Caesar, Ph.D., President and Founder of

(https://www.youtube.com/watch?v=2QgxLxAbkWs&feature=youtu.be)

DECEMBER 2, 2016

IRENE CAESAR, PH.D., FOUNDER AND PRESIDENT OF WAVE GENOME: "WAVE GENOME FOR VICTIMS OF VOICE TO SKULL" (WAVE GENOME helps V2K victim Magnus Olsson). **Click here** (https://www.youtube.com/watch?v=2QgxLxAbkWs&feature=youtu.be)for the video.

(https://www.youtube.com/watch?v=ONPUDcRVgHY&feature=youtu.be)

IRENE CAESAR WACHENHEIM SEMINAR FEB 18 2015 PART 1
venation information-wave technologies of the Institute, the Colonel of the Interna

(https://www.youtube.com/watch?v=2BCiU31THbQ)

IRENE CAESAR, PH.D., PRESIDENT AND OWNER OF WAVE GENOME: "WAVE GENOME - LOCAL AND REMOTE BIOELECRONIC DRUGS AS FRONTIER OF QUANTUM LEAP" - LECTURE, HOSTED BY PRAXIS DR. GRUENAGEL, TRANSLATED BY KATIA MEIER, MD (OWNER OF THE CLEAR SKY MEDICAL, PC, IN DENVER, CO), WACHENHEIM, GERMANY, FEBRUARY 18, 2015, PART 1 (https://www.youtube.com/watch?v=2BCiU31THbQ)

PART 2 (https://www.youtube.com/watch?v=2a9dDLfCE5g)

PART 3 (https://www.youtube.com/watch?v=Ntg-IJFC974)

IRENE CAESAR OF WAVE GENOME EVOLVE EXPO PART 2
Katia Meier, MD
Irene Caesar, PhD

(https://www.youtube.com/watch?v=PasGu7KjhyQ)

IRENE CAESAR, PH.D., PRESIDENT AND OWNER OF WAVE GENOME: "QUANTUM LEAP VIA WAVE GENOME" - LECTURE, AS PART OF WAVE GENOME'S PARTICIPATION IN EVOLVE EXPO 2015, EVOLVE EXPO 2015, THE NATIONAL WESTERN COMPLEX, DENVER, COLORADO, USA, FEBRUARY 7-8, 2015 (https://www.youtube.com/watch?v=PasGu7KjhyQ)

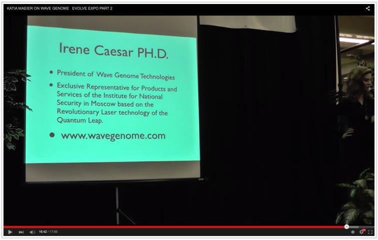

Irene Caesar PH.D.
- President of Wave Genome Technologies
- Exclusive Representative for Products and Services of the Institute for National Security in Moscow based on the Revolutionary Laser technology of the Quantum Leap.
- www.wavegenome.com

(https://www.youtube.com/watch?v=xWYkXpzVJPo)

KATIA MEIER, MD, REPRESENTATIVE OF WAVE GENOME IN COLORADO, OWNER OF CLEAR SKY MEDICAL, PC, ON HER REPRESENTATION OF WAVE GENOME - LECTURE AS PART OF WAVE GENOME'S PARTICIPATION IN EVOLVE EXPO 2015, EVOLVE EXPO, THE NATIONAL WESTERN COMPLEX, DENVER, COLORADO, USA, MARCH 7-8, 2015 (https://www.youtube.com/watch?v=xWYkXpzVJPo)

transmitted **ONLY** through the zero center of the biohologram / wave matrix (wave crystal). The information is transmitted from one identical token to another identical token of the same unique non-local wave matrix **REMOTELY**
and **INSTANTANEOUSLY**
via **QUANTUM INTERNET**.

WAVE GENOME LLC employs only professional and experienced specialists to administer rejuvenation treatments in its partner clinics and produce its products, including the **TESLA WATER (/tesla-water.html)** and **MINI-TESLA GENERATOR (/tesla-generator.html)**. Majority of **WAVE GENOME LLC** specialists are both MD and Ph.D. and are well-known doctors all over the world.

WAVE GENOME'S LLC scientists have conducted the first in the world experiment for the remote lowering of the blood sugar in a diabetic cow at a distance of 20 kilometers in the mid 1990s. **WAVE GENOME LLC** has eight years of benefiting global market with its services and products, which are patented, licensed, and certified.

2016
智慧医疗与大健康产业高峰论坛
International Summit on Smarter Healthcare & Great Health Industry
Irene Caesar
俄罗斯Matrix公司首席执行官；
Genome公司董事长
Irene Caesar
CEO, Matrix Ltd., Russia; Pre
Wave Genome, USA

Irene Caesar, Ph.D., Speech "Remote Management of Biosystems Based upon the Shape of Chromosomes as Diffraction Grating for Focusing Genetic Information", International Symposium HEALTH 2.0, Nanjing, China, November 9-10, 2016.

Irene Caesar
俄罗斯Matrix公司首席执行官；美国Wave
Genome公司董事长
Irene Caesar
CEO, Matrix Ltd., Russia; President,
Wave Genome, USA

Irene Caesar, Ph.D., Speech "Remote Management of Biosystems Based upon the Shape of Chromosomes as Diffraction Grating for Focusing Genetic Information", International Symposium HEALTH 2.0, Nanjing, China, November 9-10, 2016.

IRENE CAESAR AND MAGNUS OLSSON WAVE GENOME HELP TO V2K VICTIMS
Евгений Гигаури posted in

(https://www.youtube.com/watch?v=zQgSz2_PdG0&spfreload=10)

DECEMBER 2, 2016**. IRENE CAESAR & MAGNUS OLSSON WAVE GENOME HELP TO V2K VICTIMS**. Click here (https://www.youtube.com/watch?v=zQgSz2_PdG0) for the video.

IRENE CAESAR ON QUANTUM LEAP OF WAVE GENOME
0:37 / 8:48

(https://www.youtube.com/watch?v=sgttqrKAFlg)

DECEMBER 2, 2016**. IRENE CAESAR ON THE QUANTUM LEAP OF WAVE GENOME.** Click here (https://www.youtube.com/watch?v=sgttqrKAFlg) for the video.

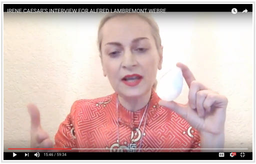
IRENE CAESAR'S INTERVIEW FOR ALFRED LAMBREMONT WEBRE

(https://newsinsideout.com/2017/01/dr-irene-caesar-reveals-russian-quantum-leaps-new-science-next-evolution-health-now-available-online-mindtechenterprises-com/)

JANUARY 2, 2017

ARTICLE BY ALFRED LAMBREMONT WEBRE ON DR. IRENE CAESAR AND HER COMPANY WAVE GENOME: "Dr. Irene Caesar reveals Russian Quantum Leap's new science – Our next evolution in health, now available online at MindTechEnterprises.com and wavegenome.com", News Insideout. **Click here** (https://newsinsideout.com/2017/01/dr-irene-caesar-reveals-russian-quantum-leaps-new-science-next-evolution-health-now-available-online-mindtechenterprises-com/) to read the article.

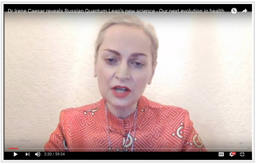
Dr Irene Caesar reveals Russian Quantum Leap's new science - Our next evolution in health

(https://www.youtube.com/watch?v=OwHafg-VJNI)

DECEMBER 17, 2016

IRENE CAESAR, PH.D., INTERVIEW TO ALFRED LAMBREMONT WEBRE: "Dr. Irene Caesar reveals Russian Quantum Leap's new science – Our next evolution in health, now available online at MindTechEnterprises", By Alfred Lambremont Webre. With the participation of MindTech Enterprises Team -- distributors of products of Irene Caesar's company Wave Genome, Magnus Thorwald Olsson and Madlen Namro. Click here to see the video (https://www.youtube.com/watch?v=2T2VRsJNE34).

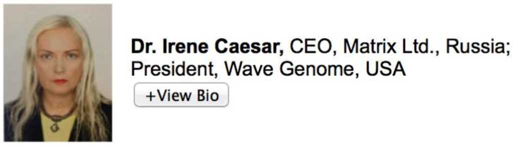

Dr. Irene Caesar, CEO, Matrix Ltd., Russia; President, Wave Genome, USA

+View Bio

IRENE CAESAR SEMINAR AT ORANIA ZENTRUM, GERMANY
26:30 / 32:54

IRENE CAESAR'S, PH.D., SEMINAR WELLENGENOM @ ORANIA-ZENTRUM, GERMANY, KURNACH BEI WURZBURG, FILM BY EXTREME NEWS, NOVEMBER 21-23, 2014 (https://www.youtube.com/watch?v=PHPBOCkdmiQ)

(http://www.wavegenome.com/1/post/2013/08/leakpro
the-singularity-irene-caesar-interviews-roman-yampolskiy.html)

LEAKPROOFING THE SINGULARITY: IRENE CAESAR INTERVIEWS ROMAN YAMPOLSKIY, AUGUST 6, 2013
(http://www.wavegenome.com/1/post/2013/08/leakproofing-the-singularity-irene-caesar-interviews-roman-yampolskiy.html)

IRENE CAESAR MATRIX CITY LECTURE AT THE HARRIMAN INSTITUTE (SHORT)

(https://www.youtube.com/watch?v=rVU1MHIruwQ)

IRENE CAESAR, PH.D.: "MATRIX CITY - PUBLIC LECTURE AT THE HARRIMAN INSTITUTE, COLUMBIA UNIVERSITY, SEPTEMBER 13, 2012 (https://www.youtube.com/watch?v=rVU1MHIruwQ)

MORE (/news.html)

In November 2011, Dr. Irene Caesar presented to President Vladimir Putin's Agency for Strategic Initiatives her project of the MATRIX CITY - the self-sufficient city as an integrated information-wave matrix, built with the application of the information-wave technologies of the Quantum Leap. In August 2012, Dr. Irene Caesar offered her project of the MATRIX CITY to the Institute for National Security in Moscow for practical realization. As a result, Dr. Irene Caesar, Founder, Owner and President of Wave Genome, and Dr. Alexej Diaschev had established the Consortium **"Matrix City" (http://www.thematrixcity.com).** Irene Caesar, Ph.D., presented her project of the Matrix City in her public lecture at the Harriman Institute of the Columbia University on September 13, 2012.

DISPATCH FROM MOSCOW

Irene Caesar

Irene Caesar, Ph.D. (born 1963, Russia), is a Russian-American philosopher and conceptual artist who first used psychotronics in art via encoding her portrait with the wave matrix of her Manifesto Man-Sun via lasers of the Institute for National Security in Moscow; Colonel of the International Irkutsk Cossack/Kazak Military; Ataman of the Cossack/Kazak Embassy in the US, awarded the Medal "For Faith and Service to Russia" (January 2015); President at Wave Genome (from 2010); co-founder of the Kazak-TV (cassak.tv) Information Agency (2015); co-founder of the Consortium "Matrix City" with the Institute for National Security in Moscow (July 2012) for building self-sufficient cities as unified information-wave matrices with application of information-wave technology of the Quantum Leap for the remote control over biosystems, climate and geophysical processes, and quantum laser-based genetic engineering; founder of the Society for Protecting Negroid Israel (2014); author of the theory and project of "Quantum Biointernet" for the remote laser control over biosystems (July 2013).

Quantum Genetics

We are standing at the greatest turning point in the history of humankind, called Quantum Leap.

Quantum Leap technologies allow us remote management of biosystems, climate and geophysical processes and unlimited access to energy and resources – the systems' management superior to Global Artificial Intellect.

Quantum Genetics plays the leading role in Quantum Leap, since Quantum technologies are operator based, meaning that operator should be one with the Quantum Nonlocality in order to operate Quantum Technologies.

The following presentation on Quantum Genetics is the result of my research from the mid 1980s, and the research conducted by the Soviet Institute "Energy", the largest Scientific Center in the field of Quantum Leap technologies in the USSR, which was founded in 1937, with 5000 scientists, and which was privatized in 2000 as the Institute for National Security.

Wave Genome is an exclusive trade and marketing agent of the Institute for National Security in the field of Quantum Leap technologies applied to health and rejuvenation.

In August 2012, I co-founded the Consortium "Matrix City" with the Institute for National Security for building self-sufficient cities with the help of Russian Quantum Leap technologies.

In August 2012, I also formulated the implication of the holographic principle. This implication theoretically explains the possibility of remote management of biosystems, which was already conducted by the Institute for National Security in 1990s.

In 2013, I co-founded with the Krasnoyarsk research group the Quantum Biointernet for the Remote Rejuvenation via distant laser signal. At that moment, nobody in the world had commercial offering of Remote Quantum Biointernet via Laser Holography. The Krasnoyarsk group itself was operating only by locally applying laser holograms recorded via lasers upon solid material of DVDs.

In the 1980s, I formulated a hypothesis that holograms function as Wave Crystals, which "fold" the signal due to Polarization. Thus, the holographic signal is a "folded signal". The process of folding creates Refraction and Focus (© Irene Caesar 1987).

In 2014, I extended my 1980s Wave Crystal Theory to the Geometrical Optics

Irene Caesar participated in the decedent movement against the communist regime, was invited to make a speech at the founding conference of the Free ...

Source: www.irenecaesar.com

SOCIALIST FACTOR | September 2016 41

(/theory--
-105810451054105610481071.html)

SEPTEMBER 2016

IRENE CAESAR'S ARTICLE "QUANTUM GENETICS" IN SEPTEMBER 2016 ISSUE OF "SOCIALIST FACTOR" MAGAZINE (LUCKNOW AND LONDON), as the publication of Irene Caesar's paper "Remote Management of Biosystems Based upon the Shape of Chromosomes as Diffraction Grating for Focusing Genetic Information", delivered as lecture at the Bangkok Thonburi University International Symposium, July 23, 2016. **Click here** (http://2016-9-irene-caesar-quantum-genetics-socialist-factor-magazine.pdf) for the PDF of the article.

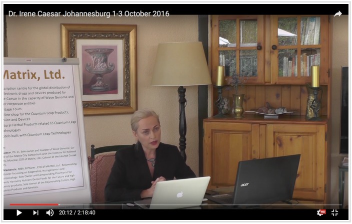

(https://www.youtube.com/watch?
v=MuYnjs6khiU)

OCTOBER 1-2, 2016

IRENE CAESAR'S SEMINAR "REMOTE MANAGEMENT OF BIOSYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR FOCUSING GENETIC INFORMATION", Jane Mackenzie's Rejuvenating Centre, Johannesburg. **Click here** (https://www.youtube.com/watch?v=MuYnjs6khiU) for the video.

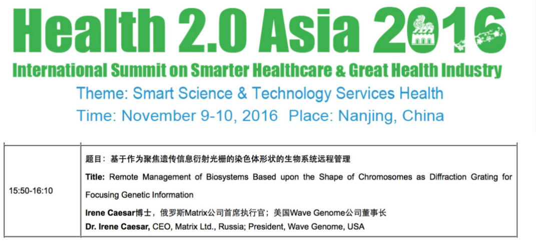

Health 2.0 Asia 2016

International Summit on Smarter Healthcare & Great Health Industry

Theme: Smart Science & Technology Services Health

Time: November 9-10, 2016 Place: Nanjing, China

15:50-16:10	题目：基于作为聚焦遗传信息衍射光栅的染色体形状的生物系统远程管理 **Title:** Remote Management of Biosystems Based upon the Shape of Chromosomes as Diffraction Grating for Focusing Genetic Information **Irene Caesar**博士，俄罗斯Matrix公司首席执行官；美国Wave Genome公司董事长 **Dr. Irene Caesar,** CEO, Matrix Ltd., Russia; President, Wave Genome, USA

NOVEMBER 9-10, 2016

IRENE CAESAR, PH.D., SPEECH "REMOTE MANAGEMENT OF BIOSYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR FOCUSING GENETIC INFORMATION" at the International Health 2.0 Asia 2016 Conference in Nanjing, China, supported by Nanjing Municiple Government, and with the participation of Professor Daniel Shechtman, Nobel Prize Laureate in Chemistry (2011). **Click here (http://www.bitcongress.com/HEALTH2016/default.asp)** for the official webpage of the Summit. **Click here (http://www.wavegenome.com/2016_11_9_10_Irene_Caesar_at_Health_2_Asia_International_Summit_Speaker_List.pdf)** for the official list of participants.

2016 健康2.0亚洲会议 Health 2.0 Asia
国际生物医药产业发展高峰论坛暨人才与项目对接会
International Biomedicine Industry Development
中国·南京 2016.11
IRENE CAESAR, Ph.D.
Remote management of biosystems based upon the shape of chromosomes as diffraction grating for focusing genetic information

Irene Caesar, Ph.D., Speech "Remote Management of Biosystems Based upon the Shape of Chromosomes as Diffraction Grating for Focusing Genetic Information", International Symposium HEALTH 2.0, Nanjing, China, November 9-10, 2016.

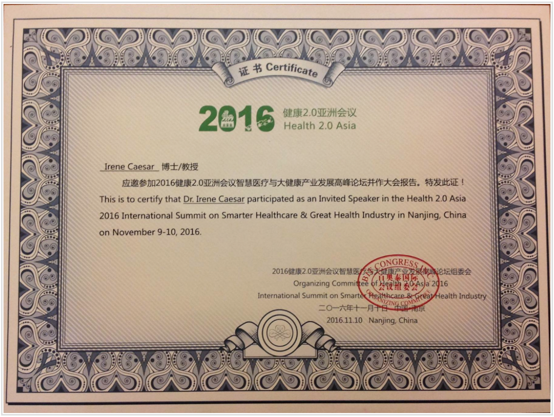

证书 Certificate

2016 健康2.0亚洲会议 Health 2.0 Asia

Irene Caesar 博士/教授

应邀参加2016健康2.0亚洲会议智慧医疗与大健康产业发展高峰论坛并作大会报告。特发此证！

This is to certify that Dr. Irene Caesar participated as an Invited Speaker in the Health 2.0 Asia 2016 International Summit on Smarter Healthcare & Great Health Industry in Nanjing, China on November 9-10, 2016.

2016健康2.0亚洲会议智慧医疗与大健康产业发展高峰论坛组委会
Organizing Committee of Health 2.0 Asia 2016
International Summit on Smarter Healthcare & Great Health Industry
二〇一六年十一月十日 中国·南京
2016.11.10 Nanjing, China

Irene Caesar, Ph.D., Speech "Remote Management of Biosystems Based upon the Shape of Chromosomes as Diffraction Grating for Focusing Genetic Information", International Symposium HEALTH 2.0, Nanjing, China, November 9-10, 2016.

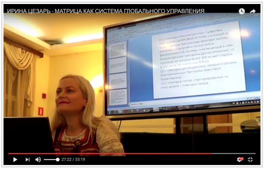

(https://www.youtube.com/watch?
v=bECHfG4WttQ)

OCTOBER 10, 2016

LECTURE BY IRENE CAESAR, Ph.D., "MATRIX AS A GLOBAL

WE OFFER:

Irene Caesar, Ph.D., Founder, Owner and President of WAVE GENOME with Magnus Olsson, President of Mind Tech Enterprises, and Director of World, European and US Coalitions Against Covert Electronic Harassment, one of Distributors of WAVE GENOME.

- **MINI-TESLA PSI-GENERATOR (/tesla-generator.html)**

as a chip (artificial crystal) structured with the generic or personal biohologram / wave matrix by the laser on the nano level for healing, rejuvenation and self-defense from harmful electromagnetic fields, psychotronic and psychic attacks, and genetic warfare;

- **WAVE PHARMACEUTICALS (/wave-pharmaceuticals.html) VIA DIGITAL PHARMACY (/digital-pharmacy-software--1057105410601058-10621048106010561054104210541049104010551058104510501048.html)**

via generic and individual wave matrices. **WAVE MATRIX** (http://www.wavegenome.com/wave-pharmaceuticals.html) is the hologram, recorded by the laser. **WAVE MATRICES** (http://www.wavegenome.com/wave-pharmaceuticals.html) include (a) INDIVIDUAL WAVE MATRIX (http://www.wavegenome.com/wave-pharmaceuticals.html), recorded by the laser from the childhood photograph, placenta or navel blood, or/and (b) generic **WAVE MATRIX** (http://www.wavegenome.com/wave-pharmaceuticals.html) recorded by the laser from the healthy human cells and bodily systems, and digitised as **DIGITAL CELLS, (http://www.wavegenome.com/wave-pharmaceuticals.html)**(c) generic or personal **WAVE MATRICES (http://www.wavegenome.com/wave-pharmaceuticals.html)** of medications as psi-medications, including such psi-pharmaceuticals, as psi-VYagra, psi-hormones, etc. **WAVE PHARMACEUTICALS (/wave-pharmaceuticals.html)** has various platforms for dispensation, including:

(1) generic or personal **WAVE MATRICES (http://www.wavegenome.com/wave-pharmaceuticals.html),** encoded by the laser in the chip of the **PSI-GENERATOR (http://www.wavegenome.com/order-your-mini-tesla-generator.html)** on the nano level;

(2) **INDIVIDUAL WAVE MATRIX (http://www.wavegenome.com/wave-pharmaceuticals.html), DIGITAL CELL (http://www.wavegenome.com/wave-pharmaceuticals.html)** and **DIGITAL PHARMACEUTICALS (/wave-pharmaceuticals.html)** -

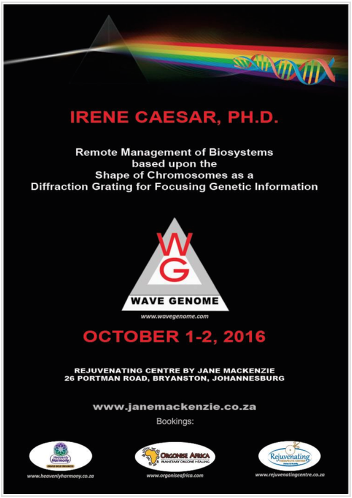

IRENE CAESAR, PH.D.

Remote Management of Biosystems
based upon the
Shape of Chromosomes as a
Diffraction Grating for Focusing Genetic Information

WAVE GENOME
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OCTOBER 1-2, 2016

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IRENE CAESAR'S SEMINAR "REMOTE MANAGEMENT OF BIOSYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR FOCUSING GENETIC INFORMATION", Jane Mackenzie's (http://www.janemackenzie.co.za) Rejuvenating Centre Johannesburg. (http://www.rejuvenatingcentre.co.za)

MANAGEMENT SYSTEM OF LIFE. MECHANISM OF REMOTE MANAGEMENT OF BIOSYSTEMS." Conference "Psychics - yesterday, today and tomorrow", October 10, 2016, (4th Meeting of the Association for Astral Anthropology and Psychology), House of Culture "Scarlet Sails", Moscow, Russia. **Click here** (https://www.youtube.com/watch?v=bECHfG4WttQ) for the video. **Click here (https://www.youtube.com/watch?v=eEKzZQ4Wzcc)** for another version of vidoe recording.

(/theory--105810451054105610481071.html)

JULY 2016

IRENE CAESAR, PH.D., LECTURE "REMOTE MANAGEMENT OF BIOSYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR FOCUSING GENETIC INFORMATION", Bangkok Thonburi University International Symposium, July 23, 2016. **Click here** (https://www.youtube.com/watch?v=XuwV_QCTf2I) for the recording of Irene Caesar's lecture at the Bangkok Thonburi University. **Click here** (https://www.youtube.com/watch?v=pSsgOPUzz9A) for the slide show of Irene Caesar's lecture at the Bangkok Thonburi University International Symposium.

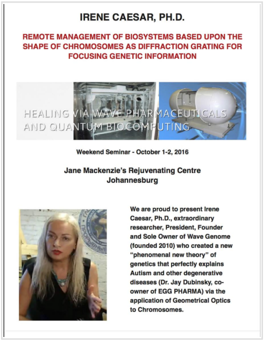

IRENE CAESAR, PH.D.

REMOTE MANAGEMENT OF BIOSYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR FOCUSING GENETIC INFORMATION

HEALING VIA WAVE PHARMACEUTICALS
AND QUANTUM BIOCOMPUTING

Weekend Seminar - October 1-2, 2016

Jane Mackenzie's Rejuvenating Centre
Johannesburg

We are proud to present Irene Caesar, Ph.D., extraordinary researcher, President, Founder and Sole Owner of Wave Genome (founded 2010) who created a new "phenomenal new theory" of genetics that perfectly explains Autism and other degenerative diseases (Dr. Jay Dubinsky, co-owner of EGG PHARMA) via the application of Geometrical Optics to Chromosomes.

OCTOBER 1-2, 2016

PRESS RELEASE FOR IRENE CAESAR'S SEMINAR "REMOTE MANAGEMENT OF BIOSYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR FOCUSING GENETIC INFORMATION", Jane Mackenzie's Rejuvenating Centre Johannesburg. **Click here (http://www.wavegenome.com/2016_9_1_irene_caesar_seminar_zar_press_release_final.pdf)** for PDF file of the Press Release.

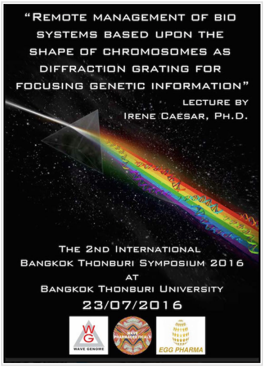

"REMOTE MANAGEMENT OF BIO SYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR FOCUSING GENETIC INFORMATION"

LECTURE BY
IRENE CAESAR, PH.D.

THE 2ND INTERNATIONAL
BANGKOK THONBURI SYMPOSIUM 2016
AT
BANGKOK THONBURI UNIVERSITY
23/07/2016

WAVE GENOME
EGG PHARMA

(/theory--105810451054105610481071.html)

SEPTEMBER 2016

PUBLICATION OF IRENE CAESAR'S, PH.D., PAPER "REMOTE MANAGEMENT OF BIOSYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR FOCUSING GENETIC INFORMATION" in the Proceedings of the Bangkok Thonburi University International Symposium, July 23, 2016, also published in the September Issue of the "Socialist Factor" Magazine (Lucknow and London). **Click here** (http://www.wavegenonome.com/2016_BTUSymposium.pdf) for PDF of the BTU Symposium Proceedings.

generic or personalised wave matrices of human cells and pharmacueuticals recorded by lasers, digitised and administered as holographic / granulated signal in the form of the **WHITE NOISE (http://www.wavegenome.com/wave-pharmaceuticals.html)**, encoded into the music in the acoustic and video **PSI-PROGRAM (/digital-pharmacy-software--1057105410601058-10621048106010561054104210541049-104010551058104510501048.html)** of the binaural self-therapy. Each psi-generator comes with the flash drive, which contains a software with **COMPREHENSIVE DIGITAL PHARMAC (/digital-pharmacy-software--1057105410601058-10621048106010561054104210541049-104010551058104510501048.html)Y** that has 44 digital modules of the digitized wave matrices in the form of the white noise, encoded into the music, for every bodily system (e.g., endocrine system, reproductive system, cardiovascular system, digestive system, etc.) and every vital organ in the body (e.g., liver, kidney, brain, etc.) -- 22 modules for organs and 22 modules for physiological systems. Digital drugs per se, like psi-vyagra or psi-hormones, are offered as extra. White noise, generated by the **PSI-PROGRAM (/digital-pharmacy-software--1057105410601058-10621048106010561054104210541049-104010551058104510501048.html)**, can be used for programming water. Digital encoding of wave matrices onto various media via laser is available;

(3) **QUANTUM INTERNET (/quantum-rejuvenation-clinic-om---english.html)** - wireless programming of biosystems, water and human condition via laser. **QUANTUM INTERNET** is **REMOTE, WIRELESS,** and **INDIVIDUALISED;**

- **TESLA WATER (/tesla-water.html)**

Bioactive restructured water charged remotely via **QUANTUM INTERNET** with the use of laser through Quantum nonlocality**,** or charged locally by the white noise (initially programmed by the laser, and, then, digitized), when you run your program of the **DIGITAL PHARMACY** (/wave-pharmaceuticals---digital-pharmacy.html) on your computer. In both cases, you need to purchase **MINI-TESLA PSI-GENERATOR (/tesla-generator.html)**. **TESLA WATER (/tesla-water.html)** is either individualised for every client or generic for specific conditions. **TESLA WATER** can be used in agriculture to increase its productivity manifold;

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via **QUANTUM INTERNET** for all the physiological systems, including endocrine system, digestive system, cardiovascular system, hearing / eye sight, reproductive system, intellectual abilities, improvement of memory, psychic abilities, sexual potency, etc. This service is provided remotely via **WIRELESS QUANTUM INTERNET (/quantum-rejuvenation-clinic-om---english.html);**

- **SUBSCRIPTION PACKAGES FOR MAINTENANCE (http://wavegenome.com/wave-genome---prices.html) (in works)**

Client can purchase the everyday maintenance of his **WAVE MATRIX (http://www.wavegenome.com/wave-pharmaceuticals.html).** Client sends his data to the Institute either via the conventional internet, and via the **QUANTUM INTERNET (/quantum-rejuvenation-**

clinic-om---english.html). HOLOGRAPHIC MAINTENANCE (http://www.wavegenome.com/wave-pharmaceuticals.html) is the correction of the intensity and modules of bioholograms / wave matrices in accordance with the changing client's condition, earthly electro-magnetic activity, solar and lunar activity, geophysical activity, and predicted social unrest. The correction is provided by the specialists of WAVE GENOME LLC remotely or locally. **HOLOGRAPHIC MAINTENANCE (http://www.wavegenome.com/wave-pharmaceuticals.html)** is provided via the update of the digital files in the Digital Pharmacy and by the remote (non-local) laser signal via **QUANTUM INTERNET (/quantum-rejuvenation-clinic-om---english.html).** For example, we can offer the remote management of diabetes;

- **CLINIC with LARGE-SIZE PSI-GENERATORS (/quantum-clinic.html)**

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Special programs in our partner clinics for those who are seeking to enhance their mental and physical abilities via **LARGE-SIZE PSI-GENERATORS (/quantum-clinic.html);**

- **CONSULTING SERVICES (/ask-our-maven.html)**

regarding the Quantum Leap information-wave technologies by our mavens.

Irene Caesar

Listen to my gospel till it is not too late

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OCTOBER 2016

IRENE CAESAR, PH.D., ARTICLE "LISTEN TO MY GOSPEL TILL IT IS NOT TOO LATE" IN OCTOBER 2016 ISSUE OF "SOCIALIST FACTOR MAGAZINE (LUCKNOW AND LONDON). Click here (http://www.wavegenome.com/2016-10-irene-caesar-listen-to-my-gospel-socialist-factor-magazine.pdf) for the PDF of the article.

DISPATCH FROM MOSCOW

Irene Caesar

Irene Caesar, Ph.D. (born 1963, Russia), is a Russian-American philosopher and conceptual artist who first used psychotronics in art via encoding her portrait with the wave matrix of her Manifesto Man-Sun via lasers of the Institute for National Security in Moscow; Colonel of the International Irkutsk Cossack/Kazak Military; Ataman of the Cossack/Kazak Embassy in the US, awarded the Medal "For Faith and Service to Russia" (January 2015); President at Wave Genome (from 2010); co-founder of the Kazak-TV (cassak.tv) Information Agency (2015); co-founder of the Consortium "Matrix City" with the Institute for National Security in Moscow (July 2012) for building self-sufficient cities as united information-wave matrices with application of information-wave technology of the Quantum Leap for the remote control over biosystems, climate and geophysical processes, and quantum laser-based genetic engineering; founder of the Society for Protecting Negroid Israel (2014); author of the theory and project of "Quantum Biointernet" for the remote laser control over biosystems (July 2013).

How to Build Matrix City

The problem with digital insulin seemed to be the fact that digital insulin meant cure. People get cured from diabetes, even type 1. This takes a sick person off the insulin market, and, as a result, the insulin producer loses money. If the technology produces mass healing, the insulin producer would sooner or later get bankrupt. But this is a major misunderstanding of the information-wave technology. This technology is in fact a subscription, rather than simply a cure. You get your own personal matrix in digital form, recorded onto the MINI-TESLA generator. Then, you connect your personal generator every week to the information-wave center, which corrects (tunes) your personal wave matrix, and combines it with digital drugs if needed.

Russian scientists are serving farms with lasers and generators already for many years for the sake of manifold increasing the crop yield. They do not sell generators - they sell only the service.

The same can be done by Big Pharma, after it switches from the analog to the digital. This model of "subscription" or "contract" will involve much more people into the information-wave system than it is now involved by Big Pharma.

Young people can get the service for enhancing their mental and physical abilities. It is possible to enhance sexual performance, and take vitamins and other supplements in the information-wave form.

I believe that in one generation, everybody will be using this technology in every aspect of life. Those who will accept this technology will get a chance to live for 200 years and longer. In 10 years from now, "getting one's maintenance via information-wave technology" will be like brushing one's teeth every morning.

WHAT ABOUT CHIPPING?

I believe that information-wave technology has nothing to do with chipping the population. Chipping the population is the AI paradigm, when the choice is alienated, and the holographic principle is violated. The AI cannot in principle perfect human wave matrices or create a superman (Übermensch), who will be more perfect than humans. Human matrices are "uncreated", non-local, that is-eternal, indivisible, and infinite, while AI is "artificial", limited, divisible, and finite in virtue of definition. AI can in principle only assist in having healthier children.

That is why psi-generators should not be in-built in the human body, but only added to it as a kind of amulets of the psychotronic era. Man is himself a powerful and most perfect generator. Having audacity of installing into a human a generator that is supposed to "control" or "rule" the human is laughable.

I will give you an example so that you understand what I mean. There are clearly two paradigms of Übermensch right now. The first one is a NATO "transformer", stuffed with nanobots, who is a paradigm of cut-and-paste genetic engineering on the bio-chemical-cyber level. The other paradigm is Russian paradigm of non-contact combat. We can enhance a Russian soldier from Special forces with psi-generators, as, in fact, Dr. Diashev does, but we cannot substitute a generator or chip for his mind or "eidos", which is quantum infinity itself, non-local and

Source: futurewarstories.blogspot.com

Women comprise around 20% of most modern military o

38 August 2016 | SOCIALIST FACTOR

(/theory---105810451054105610481071.html)

AUGUST 2016

IRENE CAESAR'S ARTICLE (2012) "HOW TO BUILD MATRIX CITY" IN AUGUST 2016 ISSUE OF "SOCIALIST FACTOR" MAGAZINE (LUCKNOW AND LONDON), first published on thematrixcity.com in 2012, as a major document of the Matrix City Consortium (founded August 2012), Co-founded by Dr. Irene Caesar and the Institute for National Security in Moscow. **Click her** (http://wavegenome.com/2016-8-irene-caesar-matrix-city-socialist-factor-magazine.pdf)**e** for the PDF of the article.

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Tag Archives: *wave pharmaceuticals*

Remote management of biosystems based upon the shape of chromosomes as diffraction grating for focusing genetic information

14 Tuesday Jun 2016

POSTED BY IRENE CAESAR, PH.D. / ИРИНА ЦЕЗАРЬ, ДОКТОР ФИЛОСОФСКИХ НАУК IN NEGROID BLOODLINE OF THE QUEEN OF ENGLAND

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Tags

acrocentric chromosome, chromosome shape, crystalline structure of torus, diffraction grating, digital drugs, e-drugs, electronic drugs, he-ne laser, holographic principle, i-drugs, institute for national security in moscow, irene caesar, matrix city, metacentric chromosome, nano chips of new generation, nanotechnology, polarized holography, quantum biointernet, remote control over biosystems, structuralist genetics, toroidal, torsion, torus, wave crystal, wave genome, wave matrix, wave pharmaceuticals

Remote management of biosystems based upon the shape of chromosomes as diffraction grating for focusing genetic information

Irene Caesar, Ph.D.

June 13, 2016

Abstract

The same gene gets expressed in dysfunctional individuals by acrocentric chromosome, and in functional individuals by metacentric chromosome, and till now nobody was able to explain why. I claim that chromosome functions as wave crystal, i.e., nonlocal unique wave matrix that focuses genetic information unique to this individual via his / her own unique scalar wave diffraction grating. Thus, chromosome is a structural / geometric code or shape that has holographic nature allowing for the remote management of biosystems via laser polarized holography.

Keywords

Irene Caesar, wave genome, polarized holography, chromosome shape, metacentric chromosome, acrocentric chromosome, remote control over biosystems, digital drugs, electronic drugs, quantum biointernet, wave pharmaceuticals, diffraction grating, wave crystal, crystalline structure of torus, nanotechnology, nanochips of new generation, remote laser control system, holographic principle, wave matrix, matrix city, structuralist genetics

Introduction

We can conduct remote laser management of the biosystems, and, thus, create individuals with enhanced physical and psychic abilities, and dramatically extend life span, based upon the implication of the holographic principle (© Quantum Biointernet, Irene Caesar 2013), and mastering the geometric codes of chromosomes.

Objectives

The objective is to build a Matrix City, i.e., the self-sufficient human settlement of the Quantum Leap Era (http://www.thematrixcity.com and specifically: http://www.thematrixcity.com/structure-of-the-matrix-city-r…), where enhanced man in enhanced environment can have enhanced life of any life span he chooses. The objective includes: (1) creating BANKS OF WAVE MATRICES for every living creature on this planet; (2) creating MATRIX CITY ZONES, where individuals receive all their supplements and medications via E-DRUGS and I-DRUGS from the MATRIX CITY based upon subscription model; (3) cultivating men with enhanced physical, intellectual and psychic abilities.

Review of Related Literature

The Polarized Holography is mainly based upon Russian research, especially upon the research of Nikolai Kozyrev, and his so called “Kozyrev Mirror” principle; the structuralist genetics by Alexander Gurvich; as well as upon the toroidal (“torsion”) research by Anatoly Akimov and Gennady Schipov. In 2002 some information got licked to the West, when two researchers of the NPO “Aura” (NPO “Energy”/BINAR, which became “The Institute for National Security” in 2000) Peter Gariaev and George Tertyshny, who did not have clearance and full access to the research, have brought a laser to Toronto to demonstrate remote management of the artificially induced diabetes via the laser signal at a distance of 20 kilometers in the rats of the same genetic line. But Gariaev and Tertyshny did not have access to the Digital Pharmacy of the digitized bioholograms of healthy bodily organs and physiological systems (aka “Digital Cell”), and could not diagnose wave matrices. The technology was classified at that time in Russia, and got declassified only in 2008.

Conceptual Framework

Universe is holographic, i.e., it is entirely contained in its every matrix point. Since universe is holographic, we can record, transmit and receive only holographic information. The implication of the holographic principle states that, If entire universe is contained in its every matrix point (holographic principle), then, every matrix point is not simply different from any other matrix point, but is unique (implication of the holographic principle, © Irene Caesar 2012). If we have an exact copy of the unique nonlocal wave matrix, we can send information instantaneously through Quantum Nonlocality, from one copy of the unique nonlocal wave matrix to the other copy, to any dimension, any planet, or galaxy, to the past, and to the future.

Research Methodology

The chromosome geometry changes the nature of the external signal from linear to holographic (@ Irene Caesar 2012, implication of holographic principle) via (1) torus polarization (via the change of the spin in the integral toroidal field of DNA); (2) reflection of any external linear signal upon itself and creation of the scalar / standing wave diffraction grating, which neutralizes any external signal; (3) refraction of any incoming signal towards the zero center of the wave crystal, which functions as a focus similar to how our eye functions (Irene Caesar, Chromosome Geometry ©2014).

Quantum Leap technology applying knowledge of the chromosome geometry is called "polarized holography", and is based upon application of stabilized Helium-Neon Lasers with internal mirrors. This kind of lasers are capable of creating holographic signal. Analogously, our bones are capable of producing stem cells, only because the shape of the bone is analogous to laser tube and is capable of changing the nature of external signal.

Research Results

As of today, the Institute for National Security in Moscow offers the local and remote management of biosystems, and individuals:
(1) via electronic / digital drugs (DIGITAL PHARMACY consisting of digitized biohologram of wave matrices for every healthy bodily organ and physiological system; and including E-DRUGS [additional upon subscription], of which more than 300 are already created, including E-VYAG-RA and I-VYAG-RA);
(2) via remote laser signal (I-DRUGS or Quantum Biointernet).

Institute has conducted the first in the world official and public remote lowering of blood sugar in diabetic calf via the laser signal at the distance of 20 kilometers for the American Diabetic Association in 1999. Over 2015, the Institute has created the digital platform for dispensation of E-DRUGS and I-DRUGS via subscription analogous to mobile phone subscription programs.

E-DRUGS are offered in two forms: (1) as chips inside a pendant [MINI-TESLA PSI-GENERATOR] of electret nature structured by laser on the nanolevel, and (2) as software program on flash drive sold with a MINI-TESLA PSI-GENERATOR, which contains the entire DIGITAL PHARMACY (soon only by subscription).

Discussion

It is clear that the exiting model of Human Genome is not correct, since it cannot explain 98% of DNA calling it "Junk DNA". Thus, genetic engineering based upon "cutting and pasting" of "identifiable" 2% of DNA is doomed for failure. Only the Holographic Wave Genetics, based upon chromosome geometry, can explain the difference between functional and dysfunctional individuals, and promote the advance in genetic engineering.

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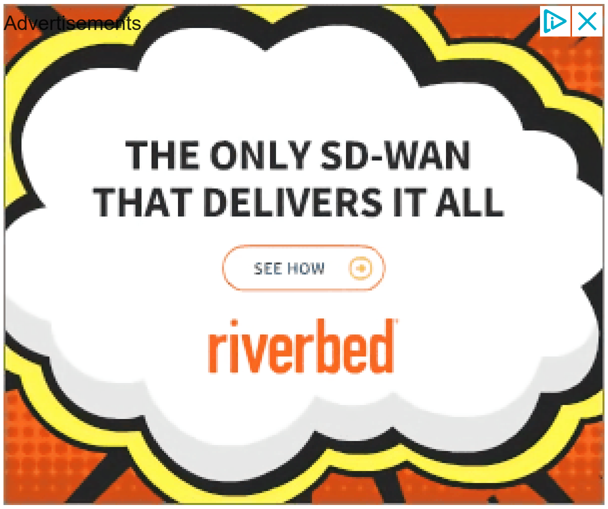
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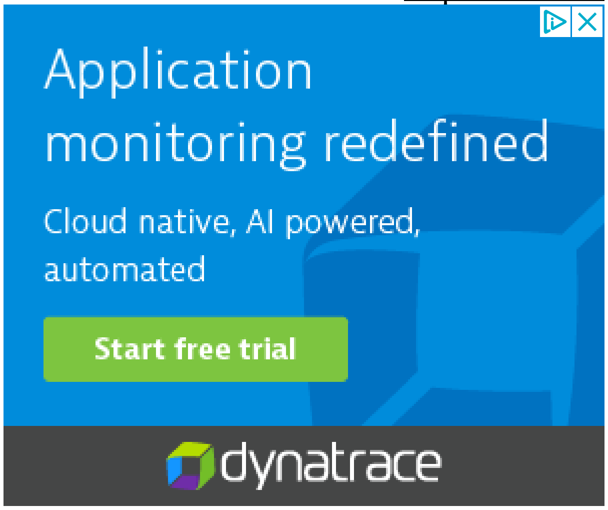
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Irene Caesar – Article in the "I KNOW" Magazine "On How to Build Matrix City", March 28, 2015

21 *Thursday May 2015*

Posted by Irene Caesar, Ph.D. / Ирина Цезарь, Доктор Философских Наук in NEGROID BLOODLINE OF THE QUEEN OF ENGLAND

≈ 3 Comments

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bci, brain-computer interface, chipping, global artificial intellect, how to build matrix city, i know magazine, irene caesar, matrix city, matrix zones, non-fossil energy, wave genome, wave pharmaceuticals

IRENE CAESAR, PH.D. ON HOW TO BUILD MATRIX CITY

"I KNOW" Magazine, Canada, March 28, 2015

http://www.iknowmagazine.ca/irene-caesar-ph-d-build-matrix-city/

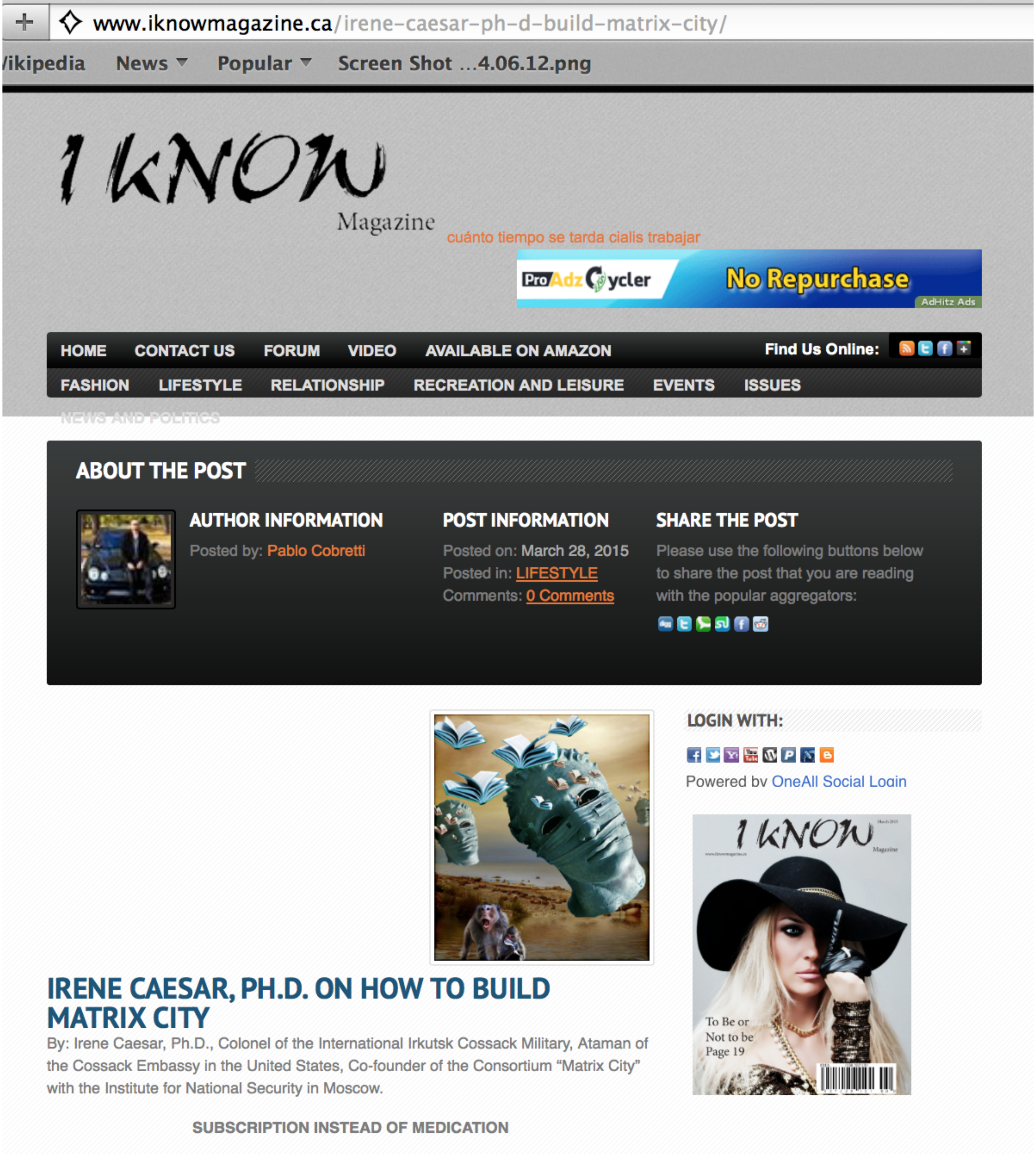
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AUTHOR INFORMATION

Posted by: Pablo Cobretti

POST INFORMATION

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IRENE CAESAR, PH.D. ON HOW TO BUILD MATRIX CITY

By: Irene Caesar, Ph.D., Colonel of the International Irkutsk Cossack Military, Ataman of the Cossack Embassy in the United States, Co-founder of the Consortium "Matrix City" with the Institute for National Security in Moscow.

SUBSCRIPTION INSTEAD OF MEDICATION

Irene Caesar's Article "On how to build Matrix City" in the "I KNOW" Magazine, Canada, March 28, 2015.

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KONICA MINOLTA
KONICA MINOLTA

Irene Caesar “How to Build Matrix City”, “I KNOW” Magazine, Photo credit: GôDiNô / Foter / CC BY-NC-ND

The same can be done by Big Pharma, after it switches from the analog to the digital. This model of “subscription” or “contract” will involve much more people into the information-wave system than it is now involved by Big Pharma.

Young people can get the service for enhancing their mental and physical abilities. It is possible to enhance sexual performance, and take vitamins and other supplements in the information-wave form.

I believe that in one generation, everybody will be using this technology in every aspect of life. Those who will accept this technology will get a chance to live for 200 years and longer. In 10 years from now, "getting one's maintenance via information-wave technology" will be like brushing one's teeth every morning.

WHAT ABOUT CHIPPING?

I believe that information-wave technology has nothing to do with chipping the population. Chipping the population is the AI paradigm, when the choice is alienated, and the holographic principle is violated. The AI cannot in principle perfect human wave matrices or create a superman (Übermensch), who will be more perfect than humans. Human matrices are "uncreated", non-local, that is — eternal, indivisible, and infinite, while AI is "artificial", limited, divisible, and finite in virtue of definition. AI can in principle only assist in having healthier children.

That is why psi-generators should not be in-built in the human body, but only added to it as a kind of amulets of the psychotronic era. Man is himself a powerful and most perfect generator. Having audacity of installing into a human a generator that is supposed to "control" or "rule" the human is laughable.

I will give you an example so that you understand what I mean. There are clearly two paradigms of Übermensch right now. The first one is a NATO "transformer", stuffed with nanobots, who is a paradigm of cut-and-paste genetic engineering on the bio-chemical-cyber level. The other paradigm is Russian paradigm of non-contact combat. We can enhance a Russian soldier from Special forces with psi-generators, as, in fact, Dr. Diashev does, but we cannot substitute a generator or chip for his mind or "eidos", which is quantum infinity itself, non-local and entangled with everything forever.

CULTIVATION OF OPERATORS

Irene Caesar "How to Build Matrix City", "I KNOW" Magazine, Photo credit: Photo credit: digitalbob8 / Foter / CC BY

The matrix is the energy structure, which has a wave component of indestructible omnipresent nature, i.e., quantum non-locality and quantum entanglement. This infinite wave literally gives life – it heals, increases life span, and gives joy. The point of building Matrix Cities is to have such architecture, agriculture, medicine, industry, energy, education, and all other sides of human life, so that they all have access to this wave component.

That is why the agenda of Matrix Cities would be the cultivating of operators who would be producing wave matrices. This cultivation should be voluntary. And those who do not want to join should be left alone.

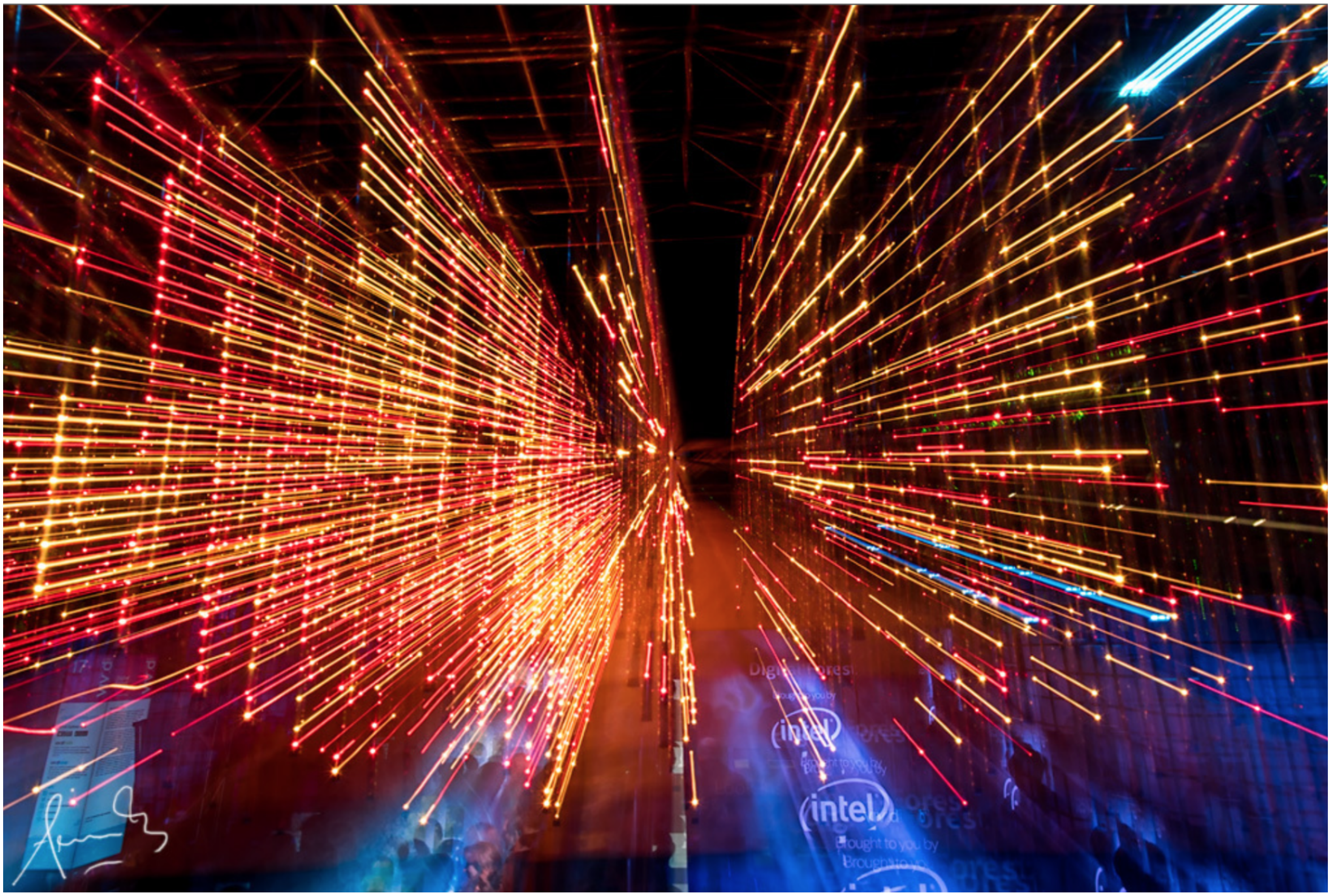

Irene Caesar "How to build Matrix City", "I KNOW" Magazine, Canada, Photo credit: sachman75 / Foter / CC BY-NC-ND.

STRUCTURE OF MATRIX CITY

Lasers and generators will constitute the INNER CORE or the NUCLEUS of the Matrix City under the protection of agencies for national security.

The NUCLEUS will consist of concentric circles with centers for the production and conservation of wave matrices.

The center of NUCLEUS will consist in the production of non-fossil fuel generators of energy.

The conservation center will take care of the wave matrices banks for the Matrix Zone.

The NUCLEUS will handle the production of bioactive water, which itself is a generator.

The NUCLEUS will regulate all forms of life in the Matrix Zone, from organism to species, from bacteria to man.

The NUCLEUS will produce lasers and generators.

Around NUCLEUS, there will be a protective perimeter.

Over the protective perimeter, around the NUCLEUS, there will be concentric circles with housing for operators, their centers for education and cultivation, the Secondary Production Centers, and the Subscription Center.

Matrix City will handle subscription to its service. Service should be provided via personal mini psi-generators, which should be connected to the information-wave system of the Matrix City through the internet at least once a week.

The Secondary Production Centers will consist of farms as agro-factories and industrial park, which will produce all components of information-wave technology — bioactive construction and industrial materials, wave pharmaceuticals, etc.

MATRIX ZONES

Irene Caesar “How to build Matrix City”, “I KNOW” Magazine, Canada, Photo credit: GôDiNô / Foter / CC BY-NC-ND.

The country should be divided into the Matrix Zones. Each Matrix zone should have its own Matrix City, which would serve its zone with wave matrices.

It looks like, advanced people will gather in special zones which are serviced by the Matrix City, the same way as now those who can are looking for areas with better schools for their children. These zones will be ecologically pure, with bioactive architecture, and bioactive water. These zones should accept everyone who wants to join, independently of money. The only condition should be the acceptance of a connection to the Matrix City. But nobody should be forced to join.

This condition will put down all accusations that Matrix Cities are a new exploitation device and a new segregation device. In fact, Matrix Cities should take care of personal, racial and national uniqueness and survival as much as the rare animal species are protected by the Red Book. DNA wave matrices banks should preserve all the variety of human genome.

SPECIAL CHARTER FOR MATRIX CITIES

Generators and lasers producing wave matrices should be protected by the state and agencies for national security.

Matrix Cities should have their own Charter, i.e., be special, semi-military zones, because ultimately this is a more powerful weapon than nuclear bomb, and, if used peacefully, generators will be more desirable thing than gold.

It is completely clear that without the control from the state and agencies for national security, this technology cannot be commercialized in principle. Matrix City is basically a conversion of psychotronic weapons into peaceful applications in industry, medicine, agriculture, etc.

Coca-Cola
Coca-Cola

Irene Caesar “How to build Matrix City”, “I KNOW” Magazine, Canada, Photo credit: GôDiNô / Foter / CC BY-NC-ND.

Remote & Wireless Maintenance via Quantum Internet by the Institute for National Security

in Moscow

15 Saturday Nov 2014

Posted by Irene Caesar, Ph.D. / Ирина Цезарь, Доктор Философских Наук in biohologram, bioholograms, he-ne laser, holography, institute for national security, irene caesar, matrix city, orania, polarised holography, quantum internet, quantum leap, wave genome, wave matrix, wave pharmaceuticals, wellengenetisher heilungscode

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REMOTE AND WIRELESS MAINTENANCE VIA QUANTUM INTERNET BY THE INSTITUTE FOR NATIONAL SECURITY IN MOSCOW

November 15, 2014

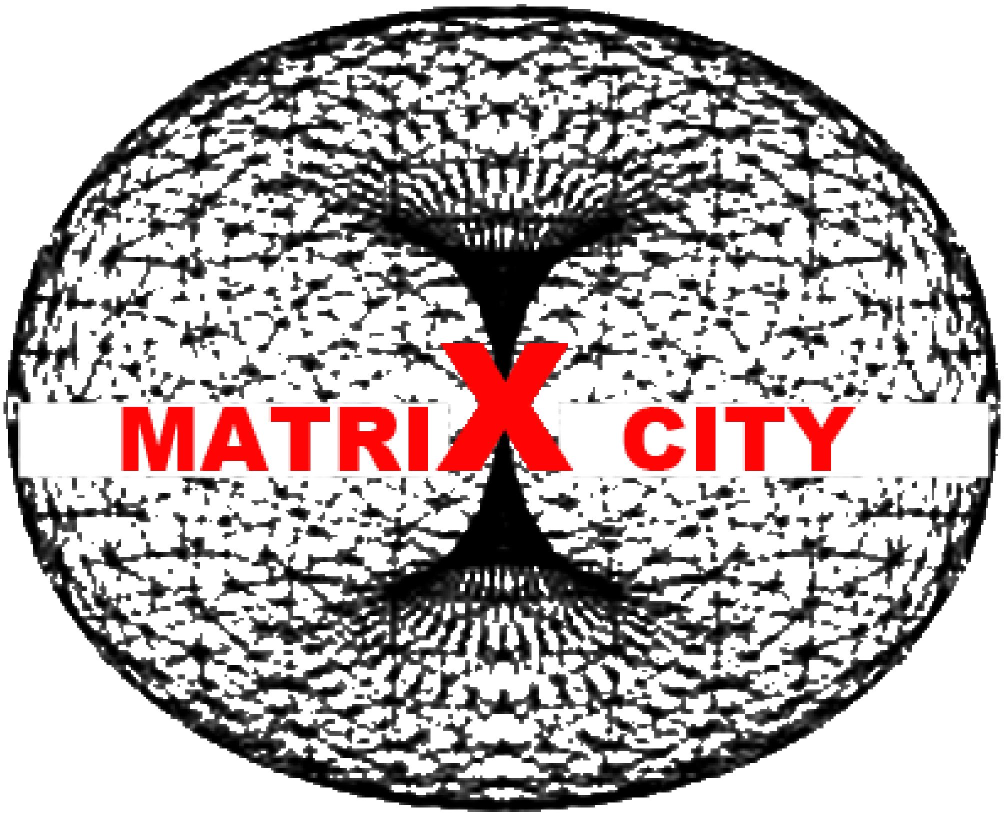

Matrix City © Irene Caesar

In the case of QUANTUM INTERNET, you send your information REMOTELY and WIRELESSLY. At the Institute, the laser reads the feedback from your wave matrix in real time, using your digitised wave matrix on record at the Institute.

According to the holographic principle, the universe is holographic, meaning that it is entirely in its every matrix part. The holographic principle has three important implications:

The first implication of the holographic principle postulates the UNIQUENESS of every wave matrix. if the universe is entirely in its every matrix point, then, every matrix point is not simply different from any other matrix point, but is unique.

The second implication of the holographic principle postulates the NON-LOCALITY of every wave matrix. If the universe is entirely in its every matrix point, then every wave matrix is simultaneously present in the infinite number of dimensions via its tokens. Though there are infinitely many tokens of the same non-local wave matrix, all of them constitute one integrated SYSTEMATIC WHOLE.

The non-local holographic nature of wave matrices also means that the wave matrix has the infinite set of waves, particles and fields within its TORUS — from infinitely micro to infinitely macro dimensions. It is impossible to talk of each individual wave matrix as “a specific frequency”. And it is impossible to postulate any “medium” of its existence, like “scalar wave”, “aether”, “Higgs / boson field”, “torsions”, “leptons”, etc. There is no specific medium for transferring the information.

The third implication of the holographic principle postulates that there is the QUANTUM ENTANGLEMENT in the form of the instantaneous transmission of information between all the tokens of the same non-local wave matrix. The signal that records and transmits the ENTANGLED INFORMATION between different wave matrices or between the tokens of the same non-local wave matrix has specific nature. It is HOLOGRAPHIC. Only lasers can record and transmit holographic signal, based upon the principles of the polarised refraction holography (described in terms of geometrical optics). Thus, the principle of recording and transmitting the MATRIX SIGNAL is structural, and not medium-based.

Thus, it is possible to remotely and instantaneously transfer some wave information to a man via the entanglement between his body (at one location) and his photograph (at another location), as two tokens of his non-local wave matrix.

For example, it is possible to remotely lower blood sugar in a diabetic man via scanning his photograph with the laser ray, which is passing through insulin before reaching the photograph.

© Irene Caesar, Ph.D. from her book "WAVE PHARMACEUTICALS" in co-authorship with Steve Schwartz, MD (2014)

http://www.wavegenome.com

http://thematrixcity.com/structure-of-the-matrix-city-english.html

WELLENGENETISCHER HEILUNGSCODE seminar by Dr. Irene Caesar in Germany:

21. November 2014, Freitag, 18 – ca. 21 Uhr

http://www.orania-zentrum.de/index.php/abendveranstaltungen/infoabend-wellengenetischerheilungscode
http://www.orania-zentrum.de/index.php/seminare/seminar-wellengenetische-heilungscode

WIKIPEDIA

Übermensch

The ***Übermensch*** (German for "Beyond-Man", "Superman", "Overman", "Superhuman", "Hyperman", "Hyperhuman"; German pronunciation: [ˈʔyːbɐmɛnʃ]) is a concept in the philosophy of Friedrich Nietzsche. In his 1883 book *Thus Spoke Zarathustra* (German: *Also sprach Zarathustra*), Nietzsche has his character Zarathustra posit the Übermensch as a goal for humanity to set for itself. It is a work of philosophical allegory, with a structural similarity to the Gathas of Zoroaster/Zarathustra.

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In English

The first translation of *Thus Spoke Zarathustra* into English was published in 1896. In that translation, by Alexander Tille, Übermensch was translated as "Beyond-Man". In the Thomas Common translation, published in 1909, however, *Übermensch* was rendered as "Superman". Common was anticipated in this by George Bernard Shaw, who had done the same in his 1903 stage play *Man and Superman*. Walter Kaufmann lambasted this translation in the 1950s for two reasons: first, its near or total failure to capture the nuance of the German word *über* (while the Latin prefix super- means above or beyond, the English use of the prefix or its use as an adjective has altered the meaning); and second, a rationale which Fredric Wertham railed against even more vehemently in *Seduction of the Innocent*, for promoting identification by children with the comic-book character Superman (whom Wertham described as "un-American and fascist"). The preference of Kaufmann and others is to translate Übermensch as "overman". Scholars continue to employ both terms, some simply opting to reproduce the German word.[1][2]

The German prefix *über* can have connotations of superiority, transcendence, excessiveness, or intensity, depending on the words to which it is attached.[3] *Mensch* refers to a member of the human species, rather than to a male specifically. The adjective *übermenschlich* means super-human, in the sense of beyond human strength or out of proportion to humanity.[4]

This-worldliness

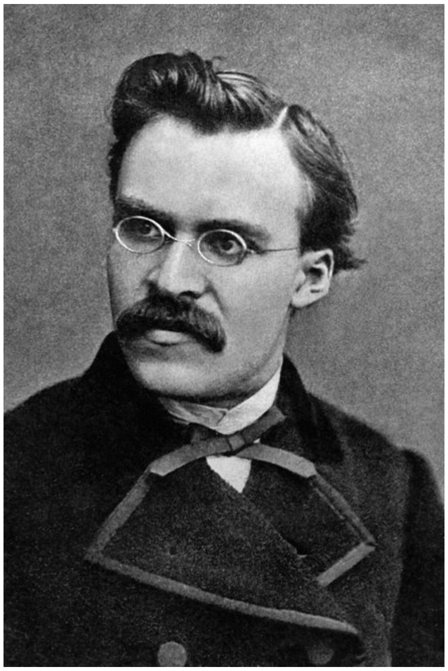
Friedrich Nietzsche in 1869.

Nietzsche introduces the concept of the Übermensch in contrast to his understanding of the other-worldliness of Christianity: Zarathustra proclaims the Übermensch to be the meaning of the earth and admonishes his audience to ignore those who promise other-worldly hopes in order to draw them away from the earth.[5][6] The turn away from the earth is prompted, he says, by a dissatisfaction with life—a dissatisfaction that causes one to create another world in which those who made one unhappy in this life are tormented. The Übermensch is not driven into other worlds away from this one.

Zarathustra declares that the Christian escape from this world also required the invention of an eternal soul which would be separate from the body and survive the body's death. Part of other-worldliness, then, was the abnegation and mortification of the body, or asceticism. Zarathustra further links the Übermensch to the body and to interpreting the soul as simply an aspect of the body.

Death of God and the creation of new values

Zarathustra ties the Übermensch to the death of God. While this God was the ultimate expression of other-worldly values and the instincts that gave birth to those values, belief in that God nevertheless did give meaning to life for a time. 'God is dead' means that the idea of God can no longer provide values. With the sole source of values no longer capable of providing those values, there is a real chance of nihilism prevailing.

Zarathustra presents the Übermensch as the creator of new values. In this way, it appears as a solution to the problem of the death of God and nihilism. If the Übermensch acts to create new values within the moral vacuum of nihilism, there is nothing that this creative act would not justify. Alternatively, in the absence of this creation, there are no grounds upon which to criticize or justify any action, including the particular values created and the means by which they are promulgated.

In order to avoid a relapse into Platonic idealism or asceticism, the creation of these new values cannot be motivated by the same instincts that gave birth to those tables of values. Instead, they must be motivated by a love of this world and of life. Whereas Nietzsche diagnosed the Christian value system as a reaction against life and hence destructive in a sense, the new values which the Übermensch will be responsible for will be life-affirming and creative (see Nietzschean affirmation).

As a goal

Zarathustra first announces the Übermensch as a goal humanity can set for itself. All human life would be given meaning by how it advanced a new generation of human beings. The aspiration of a woman would be to give birth to an Übermensch, for example; her relationships with men would be judged by this standard.[7]

Zarathustra contrasts the Übermensch with the last man of egalitarian modernity, an alternative goal which humanity might set for itself. The last man appears only in *Thus Spoke Zarathustra*, and is presented as a condition that would render the creation of the Übermensch impossible.

According to Rüdiger Safranski, some commentators associate the Übermensch with a program of eugenics.[8] This is most pronounced when considered in the aspect of a goal that humanity sets for itself. The reduction of all psychology to physiology implies, to some, that human beings can be bred for cultural traits. This interpretation of Nietzsche's doctrine focuses more on the future of humanity than on a single cataclysmic individual. There is no consensus regarding how this aspect of the Übermensch relates to the creation of new values.

Re-embodiment of amoral aristocratic values

For Rüdiger Safranski, the Übermensch represents a higher biological type reached through artificial selection and at the same time is also an ideal for anyone who is creative and strong enough to master the whole spectrum of human potential, good and "evil", to become an "artist-tyrant". In *Ecce Homo*, Nietzsche vehemently denied any idealistic, democratic or humanitarian interpretation of the Übermensch: "The word Übermensch [designates] a type of supreme achievement, as opposed to 'modern' men, 'good' men, Christians, and other nihilists ... When I whispered into the ears of some people that they were better off looking for a Cesare Borgia than a Parsifal, they did not believe their ears."[9] Safranski argues that the combination of ruthless warrior pride and artistic brilliance that defined the Italian Renaissance embodied the sense of the Übermensch for Nietzsche. According to Safranski, Nietzsche intended the ultra-aristocratic figure of the Übermensch to serve as a Machiavellian bogeyman of the modern Western middle class and its pseudo-Christian egalitarian value system.[10]

Relation to the eternal recurrence

The Übermensch shares a place of prominence in *Thus Spoke Zarathustra* with another of Nietzsche's key concepts: the eternal recurrence of the same. Several interpretations for this fact have been offered.

Laurence Lampert suggests that the eternal recurrence replaces the Übermensch as the object of serious aspiration.[11] This is in part due to the fact that even the Übermensch can appear like an other-worldly hope. The Übermensch lies in the future — no historical figures have ever been Übermenschen — and so still represents a sort of eschatological redemption in some future time.

Stanley Rosen, on the other hand, suggests that the doctrine of eternal return is an esoteric ruse meant to save the concept of the Übermensch from the charge of Idealism.[12] Rather than positing an as-yet unexperienced perfection, Nietzsche would be the prophet of something that has occurred a countless number of times in the past.

Others maintain that willing the eternal recurrence of the same is a necessary step if the Übermensch is to create new values, untainted by the spirit of gravity or asceticism. Values involve a rank-ordering of things, and so are inseparable from approval and disapproval; yet it was dissatisfaction that prompted men to seek refuge in other-worldliness and embrace other-worldly values. Therefore, it could seem that the Übermensch, in being devoted to any values at all, would necessarily fail to create values that did not share some bit of asceticism. Willing the eternal recurrence is presented as accepting the existence of the low while still recognizing it as the low, and thus as overcoming the spirit of gravity or asceticism.

Still others suggest that one must have the strength of the Übermensch in order to will the eternal recurrence of the same; that is, only the Übermensch will have the strength to fully accept all of his past life, including his failures and misdeeds, and to truly will their eternal return. This action nearly kills Zarathustra, for example, and most human beings cannot avoid other-worldliness because they really are sick, not because of any choice they made.

Nazism

The term Übermensch was utilized frequently by Hitler and the Nazi regime to describe their idea of a biologically superior Aryan or Germanic master race;[13] a form of Nietzsche's Übermensch became a philosophical foundation for the National Socialist ideas. Their conception of the Übermensch, however, was racial in nature.[14][15] The Nazi notion of the master race also spawned the idea of "inferior humans" (*Untermenschen*) which could be dominated and enslaved; this term does not originate with Nietzsche. Nietzsche himself was critical of both antisemitism and German nationalism. In his final years, Nietzsche began to believe that he was in fact Polish, not German, and was quoted as saying, "I am a pure-blooded Polish nobleman, without a single drop of bad blood, certainly not German blood".[16] In defiance of these doctrines, he claimed that he and Germany were great only because of "Polish blood in their veins",[17] and that he would be "having all anti-semites shot" as an answer to his stance on anti-semitism. Although the term has been associated with the Nazis, Nietzsche was dead long before Hitler's reign. It was Nietzsche's sister Elisabeth Förster-Nietzsche who actually first played a part in manipulating her brother's words to accommodate the worldview of herself and her husband, Bernhard Förster, a prominent German nationalist and antisemite.[18] In order to support his beliefs he set up the *Deutscher Volksverein* (German People's League) in 1881 with Max Liebermann von Sonnenberg.[19]

Anarchism

The thought of Nietzsche had an important influence in anarchist authors (see Anarchism and Friedrich Nietzsche). Spencer Sunshine writes that "There were many things that drew anarchists to Nietzsche: his hatred of the state; his disgust for the mindless social behavior of 'herds'; his anti-Christianity; his distrust of the effect of both the market and the State on cultural production; his desire for an 'overman' — that is, for a new human who was to be neither master nor slave; his praise of the ecstatic and creative self, with the artist as his prototype, who could say, 'Yes' to the self-creation of a new world on the basis of nothing; and his forwarding of the 'transvaluation of values' as source of change, as opposed to a Marxist conception of class struggle and the dialectic of a linear history."[20] The influential American anarchist Emma Goldman in her famous collection of essays *Anarchism and Other Essays* in the preface passionately defends both Nietzsche and Max Stirner from attacks within anarchism when she says "The most disheartening tendency common among readers is to tear out one sentence from a work, as a criterion of the writer's ideas or personality. Friedrich Nietzsche, for instance, is decried as a hater of the weak because he believed in the Übermensch. It does not occur to the shallow interpreters of that giant mind that this vision of the Übermensch also called for a state of society which will not give birth to a race of weaklings and slaves."[21]

Sunshine says that the "Spanish anarchists also mixed their class politics with Nietzschean inspiration." Murray Bookchin, in *The Spanish Anarchists*, describes prominent CNT–FAI member Salvador Seguí as "an admirer of Nietzschean individualism, of the *superhombre* to whom 'all is permitted'." Bookchin, in his 1973 introduction to Sam Dolgoff's *The Anarchist Collectives*, even describes the reconstruction of society by the workers as a Nietzschean project. Bookchin says that "workers must see themselves as human beings, not as class beings; as creative personalities, not as 'proletarians,' as self-affirming individuals, not as 'masses'. . .(the) economic component must be humanized precisely by bringing an 'affinity of friendship' to the work process, by diminishing the role of onerous work in the lives of producers, indeed by a total 'transvaluation of values' (to use Nietzsche's phrase) as it applies to production and consumption as well as social and personal life."[20]

In popular culture

- The comic-book hero Superman, when Jerome "Jerry" Siegel first created him, was originally a villain modeled on Nietzsche's idea (see "The Reign of the Superman"). He was re-invented as a hero by his eventual designer, Joseph "Joe" Shuster, after which he bore little resemblance to the previous character. However, Superman does find an adversary in the mold of the Nietzschean Übermensch in the recurring arch-villain Lex Luthor, his greatest enemy on Earth. Luthor is preceded, even, by a supervillain resembling Siegel's original concept for Superman bearing the synonymous name of 'Ultra-Humanite'. A direct reference to the term occurs in the episode "Double Trouble" of the TV series *Adventures of Superman,* in which a German-speaking character calls the title character "*verfluchter*

Übermensch" ("cursed Superman").[22] In the tenth season of the show *Smallville*, an alternate Lionel Luthor refers to Clark as the "Übermensch". Overman is an alternate version of Superman, from Earth-10, an Earth where the Axis Powers won World War II.[23]

- Jack London dedicated his novels *The Sea-Wolf* and *Martin Eden* to criticizing Nietzsche's concept of the Übermensch and his radical individualism,[24] which London considered to be selfish and egoistic.
- George Bernard Shaw's 1903 play *Man and Superman* is a reference to the archetype; its main character considers himself an untameable revolutionary, above the normal concerns of humanity.
- James Joyce utilizes the *Übermensch* in the first chapter of his novel Ulysses. Joyce makes Buck Mulligan say it:[25] "—My twelfth rib is gone, he cried. I'm the *Uebermensch*. Toothless Kinch and I, the supermen."
- In *The Power*, a 1956 book by Frank M. Robinson, the villain consciously models himself upon Nietzsche's Übermensch, and a quotation from Nietzsche serves as the book's motto.
- In real life, Leopold and Loeb committed murder in 1924 partly out of a superficially Übermensch-like conception of themselves.[26] Their story has been dramatized many times, including in the Alfred Hitchcock film *Rope*, the 1959 film Compulsion based on Meyer Levin's novel, the 1994 film *Swoon*, the 2002 film *Murder by Numbers*, and the 2005 Off-Broadway musical *Thrill Me: The Leopold and Loeb Story*.
- A character in the show *Dollhouse* (Season 1, Episode 12; titled "Omega") references Übermensch in relation to Nietzsche when trying to describe a person that had the memories, skills, and intelligence of dozens of people uploaded into their (single) mind by means of futuristic technology.
- The Medic character in the video game *Team Fortress 2* will sometimes chant "I am the Übermensch!" for one of his "Cheers" voice commands.
- In the Disney TV Cartoon, Pepper Ann, in an episode titled "Effie Shrugged", Effie, a physically imposing bully teaches Pepper Ann some basic information on Übermensch.
- David Bowie's song titled "The Supermen", from his 1970 album *The Man Who Sold the World*, was inspired by the work of Nietzsche. Bowie later said "I was still going through the thing when I was pretending that I understood Nietzsche... And I had tried to translate it into my own terms to understand it so 'Supermen' came out of that."[27]

See also

- Great Man theory
- Junzi
- Knight of faith
- Last man
- New Man (utopian concept)
- New Soviet man
- *Notes from Underground*
- Philosopher-King
- Posthuman
- Metabolic supermice
- Randian hero
- *Strange Life of Ivan Osokin*
- Transhumanism
- Supermind (Integral yoga)

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8. Safranski, *Nietzsche*, 262-64, 266-68.
9. Nietzsche, *Ecce Homo*, Why I Write Such Good Books, §1)

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External links

- Martin Heidegger and Nietzsche's Overman: Aphorisms on the Attack (http://www.freewebs.com/m3smg2/HeideggerOverman.htm)
- Human Superhuman (https://groups.yahoo.com/group/human_superhuman/) Yahoo! Group dedicated to Nietzsche's Overman.
- Searchable database of Nietzsche Quotes (http://www.nietzsche-quotes.com)

- An academic exchange concerning the relationship between Nietzsche and transhumanism (http://ieet.org/index.php/IEET/more/pellissier20120423)

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This page was last edited on 22 January 2018, at 07:03.

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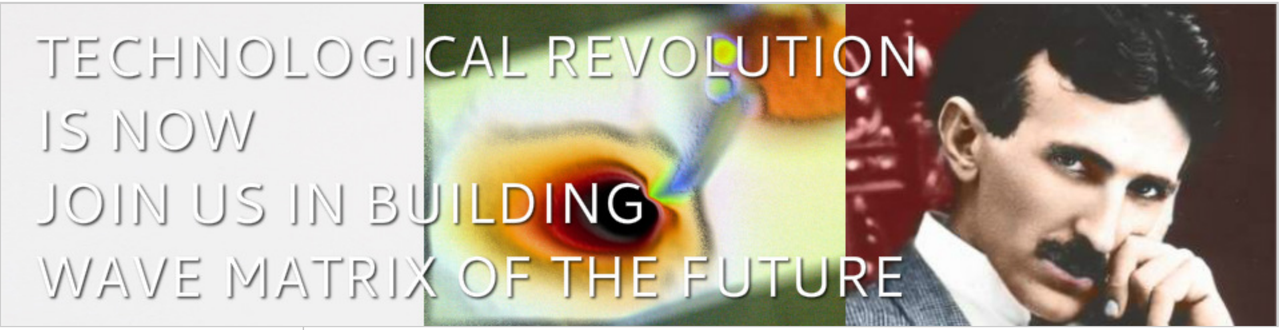

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SERVICES / УСЛУГИ (/SERVICES--105910571051105910431048.HTML)

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ORDER
YOUR MINI-TESLA
GENERATOR

(/tesla-generator.html)

QUANTUM REMOTE REJUVENATION

(/quantum-rejuvenation-clinic-om---english.html)

ORDER
BIOACTIVE
WATER

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PRICES

Ordering your MINI-TESLA PSI-GENERATOR (/tesla-generator.html), REMOTE REJUVENATION SERVICE (/quantum-rejuvenation-clinic-om---english.html), E-VIAGRA (/tesla-generator.html) and **I-VIAGRA (/quantum-rejuvenation-clinic-om---english.html), TESLA BIOACTIVE WATER (http://www.wavegenome.com/order-bioactive-water.html), VISIT TO OUR CLINICS IN MOSCOW OR SIBERIA (http://www.wavegenome.com/visit-our-clinic-for-cure-and-rejuvenation.html), and CONSULTATION (http://www.wavegenome.com/ask-our-maven.html) means you accept the conditions of the Client Consent Form. (/client-consent.html) All Bank fees for payments are paid by the clients.**

MODELS OF MINI-TESLA PSI-GENERATOR (/tesla-generator.html)

(1) BASIC TESLA PSI-GENERATOR (chip)

(a) has twice less layers of the chip than our other models**;** (b) has either the **GENERIC** or **INDIVIDUAL** biohologram of a healthy human in the chip, being encoded via laser onto the chip on nano level; (c) **BASIC TESLA PSI-GENERATOR** has both sides of the casing for the chip made of Real Solid Pearl; (d) **BASIC-X TESLA PSI-GENERATOR** has one side of the casing for the chip made of Real Solid Pearl, and another side of casing made of 3D printing plastic, encoded with the immune system rejuvenation **E-DRUG** (**BIOELECTRONIC DRUG** / **DIGITIZED BIOHOLOGRAM**). This makes **"TWO-CHIPS IN ONE"** solution.

GENERIC BASIC MINI-TESLA GENERATOR - $856
INDIVIDUAL BASIC MINI-TESLA GENERATOR - $1179
INDIVIDUAL BASIC-X MINI-TESLA PSI-GENERATOR - $1534

(2) SUPER MINI-TESLA GENERATOR (chip)

(a) has twice as more layers of the chip than the **BASIC MINI-TESLA PSI-GENERATOR;** (b) has either **GENERIC** or **INDIVIDUAL** biohologram; (c) Both sides of the casing for the chip are made of Real Solid Pearl.

GENERIC SUPER MINI-TESLA GENERATOR - $1179

FAQ
Frequently Asked Questions

(/mini-tesla-generator-faq.html)

READ INFORMATION LEAFLET FOR THE (/information-leaflet-for-mini-tesla-generator.html) MINI-TESLA GENERATOR (/information-leaflet-for-mini-tesla-generator.html)

ULTIMATE MINI-TESLA PSI-GENERATOR is the ultimate protection against psychotronic and genetic warfare.

ULTIMATE TESLA PSI-GENERATOR (/ultimate-mini-

WAVE GENOME TESLA GLASSES are not "glasses" per se, but the Quantum Biocomputer. TESLA GLASSES improve eye sight guaranteed, and treat internal organs via Polarized Biohолography.

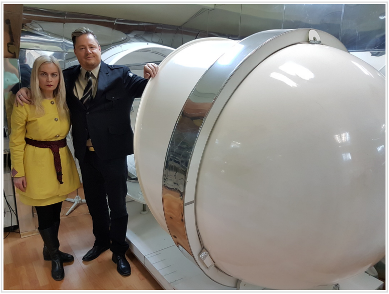

Irene Caesar, Ph.D., Founder, Owner and President of WAVE GENOME with Magnus Olsson, distributor of WAVE GENOME products.

INDIVIDUAL SUPER MINI-TESLA GENERATOR - $1768

(3) ULTRA MINI-TESLA GENERATOR (chip)

(a) has twice as more layers of the chip than the **BASIC MINI-TESLA PSI-GENERATOR;** (b) has either **GENERIC** or **INDIVIDUAL** biohologram; (c) One side of the casing for the chip is made of Real Solid Pearl, and another side of casing is made of 3D printing plastic, encoded with the immune system rejuvenation **E-DRUG** (**BIOELECTRONIC DRUG** / **DIGITIZED BIOHOLOGRAM**). This makes **"TWO-CHIPS IN ONE"** solution.

GENERIC ULTRA MINI-TESLA GENERATOR - $1768
INDIVIDUAL ULTRA MINI-TESLA GENERATOR - $2358

(4) MATRIX TESLA PSI-GENERATOR (chip)

(a) has twice as more layers of the chip than the **BASIC MINI-TESLA PSI-GENERATOR.**

(b) has either **GENERIC** or **INDIVIDUAL** biohologram.

(c) Both sides of the casing for the chip are made of 3D printing plastic, encoded with the immune system rejuvenation **E-DRUG** (**BIOELECTRONIC DRUG** / **DIGITIZED BIOHOLOGRAM**). This makes **"TWO-CHIPS IN ONE"** solution.

GENERIC MATRIX MINI-TESLA GENERATOR - $2122
INDIVIDUAL MATRIX MINI-TESLA GENERATOR - $2947

(4) ULTIMATE (/ultimate-mini-tesla-psi-generator.html)MINI-TESLA GENERATOR (/ultimate-mini-tesla-psi-generator.html) (chip)

(a) has twice as more layers of the chip than the **BASIC MINI-TESLA PSI-GENERATOR**; (b) has either **GENERIC** or **INDIVIDUAL** biohologram; (c) One side of the casing for the chip is made of Real Solid Pearl, and another side of casing is made of 3D printing plastic, encoded with the RNA **E-DRUG**(**BIOELECTRONIC DRUG** / **DIGITIZED BIOHOLOGRAM**) for the ultimate protection against psychotronic and genetic warfare. This makes **"TWO-CHIPS IN ONE"** solution.

GENERIC ULTIMATE MINI-TESLA GENERATOR - $2358
INDIVIDUAL ULTIMATE MINI-TESLA GENERATOR - $2712 (promotional price)

(5) SECOND-BIRTH TESLA PSI-GENERATOR (/second-birth-mini-tesla-psi-generator.html) (chip)

(a) **chip is encoded by laser on nano level with the most valuable biohолographic information on the global market: EMBRYONIC STEM CELL;**

(b) has a new technology of encoding the chip by the newly invented laser (patented);

(c) layers of the chip are made of a new material of organic nature more advanced than our other chips;

(d) its efficacy is proven by the clinical trials at the Medical Clinic of the Moscow Bauman Russian State Technical University, the most important Science University in Russia, of MIT level. twice as more layers of the chip than the **BASIC MINI-TESLA PSI-GENERATOR.**

(e) has either **GENERIC** or **INDIVIDUAL** biohologram.

(f) provides the ultimate modulation for the scalar wave diffraction grating for the most precise focus / zero center of the biohologram (aka 'wave crystal") in the process of rejuvenation.

GENERIC SECOND-BIRTH MINI-TESLA GENERATOR - $3000
INDIVIDUAL SECOND-BIRTH MINI-TESLA GENERATOR - $3500

tesla-psi-generator.html) **IS BASED UPON IMPORTANT DISCOVERY BY DR. IRENE CAESAR REGARDING THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING / REFRACTION MECHANISM FOR FOCUSING GENETIC INFORMATION**

ULTIMATE MINI-TESLA psi-generator (/ultimate-mini-tesla-psi-generator.html) has the digitized biohologram of RNA encoded into the casing. RNA is a single-stranded spiral antennae, and it is RNA which sends and receives wave information. While DNA is a double-stranded structure which neutralizes every external linear signal in the standing / scalar / zero wave (reflects every wave upon itself, so that the peak of the forward-going wave is neutralized by the trough of the same wave when it is reflected upon itself and backward-going). Thus, DNA is protected by its very structure. while RNA is vulnerable due to its very structure. Protection against Psychotronic and Generic warfare does essentially consist in tuning RNA, making our chromosomes center and focus our own unique generic information during cell division.

To read about the **ULTIMATE TESLA PSI-GENERATOR click here (/ultimate-mini-tesla-psi-generator.html)**.

Our clinic has AURA PSI-GENERATOR specifically for treating spine issues.

TESLA GLASSES (/order-tesla-glasses.html)

TESLA GLASSES for restoration of eye sight, and treatment of physiological systems and bodily organs via Polarized Bioholography of Eye Crystal and iris. Can be used by all members of the family. Hit of sales - **$1090**

TESLA SELENIUM (/order-tesla-selenium.html)

TESLA SELENIUM MAXI is 60 pills a bottle/pack, each pill is 70 µg of Organic Two-Valent Selenium.**PROMOTIONAL PRICE:**

3 PACKS FOR $210

5 PACKS FOR $300

10 PACKS FOR $500

TESLA SELENIUM PRO is 60 pills a bottle/pack, each pill is 25.0 µg of Organic Two-Valent Selenium, 100 µg of Organic Germanium, and 5.0 mg of Organic Zinc.**PROMOTIONAL PRICE:**

3 PACKS FOR $240

5 PACKS FOR $350

10 PACKS FOR $600

TREATMENTS AT THE CLINIC (/quantum-clinic.html)

TREATMENT AT OUR CLINICS (/quantum-clinic.html) is priced on the individual basis. We help with travel, lodging, escort and interpreting services at extra cost according to regular Russian rates, for example, interpreter is usually billed $177 for the first hour of translation / escort (or below one hour) with $59 for every next hour (regular 8 hours working day); while for working days with overtime (over 8 hours regular working day), client is billed at $177 for the first hour, and $94 for every next hour. We accept only our own interpreters. Clinics are RUSSIAN CLINICS. **WAVE GENOME** does NOT own any of these clinics, but offer **VISITATION** programs for getting treatments at Russian clinics.

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WAVE GENOME

www.wavegenome.com

www.heavenlyharmony.co.za www.orgoniseafrica.com www.rejuvenatingcentre.co.za

IRENE CAESAR, PH.D.

REMOTE MANAGEMENT OF BIOSYSTEMS BASED UPON THE SHAPE OF CHROMOSOMES AS DIFFRACTION GRATING FOR FOCUSING GENETIC INFORMATION

HEALING VIA WAVE PHARMACEUTICALS
AND QUANTUM BIOCOMPUTING

Weekend Seminar - October 1-2, 2016

Jane Mackenzie's Rejuvenating Centre
Johannesburg

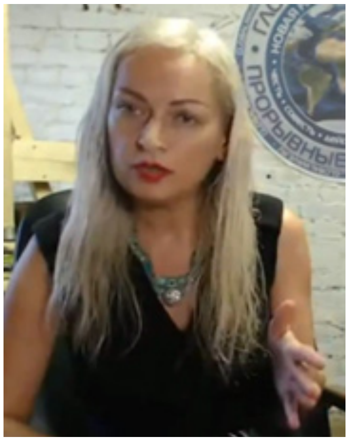

We are proud to present Irene Caesar, Ph.D., extraordinary researcher, President, Founder and Sole Owner of Wave Genome (founded 2010) who created "phenomenal new theory" of genetics that perfectly explains Autism and other degenerative diseases (Dr. Jay Dubinsky, co-owner of EGG PHARMA) via the application of Geometrical Optics to Chromosomes.

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Dr. Irene Caesar is an Exclusive Sales and Marketing Representative of the Institute for National Security in the field of Quantum Leap technologies applied to health and rejuvenation, Co-founder of the Matrix City Consortium (2012) with the Institute for National Security in Moscow for building self-sufficient cities with the help of Russian Quantum Leap technologies, Co-founder of Quantum Biointernet via the remote laser signal (2013) with the Krasnoyarsk Scientific Group, and Colonel of the Irkutsk Cossack Military. Dr. Irene Caesar was awarded the Medal for Service to Russia (2015).

In her July 23, 2016 lecture at the International Symposium of the Thonburi University in Bangkok, Thailand, Dr. Irene Caesar said: “We are standing at the greatest turning point in the history of humankind, called Quantum Leap. Quantum Leap technologies allow us remote management of biosystems, climate and geophysical processes and unlimited access to energy and resources – the systems’ management superior to Global Artificial Intellect.” Quantum Leap gives us cure of “incurable diseases” and radical rejuvenation, so that enhanced man in enhanced environment can live enhanced life of any life span he chooses.

Dr Irene Caesar will be giving her Seminar at Jane Mackenzie’s (MBA, B Pharm) Rejuvenating Centre in Johannesburg, with the assistance of Georg Ritschl, Wave Genome’s Exclusive Representative in the South African Republic. Jane Mackenzie is Wave Genome’s partner, and a leading Rejuvenation Practitioner focusing on epigenetics, nutrigenomics and homotoxicology. Georg Ritschl is the owner of Organise Africa, and a leading producer of Orgonite on the global market.

Dr Irene Caesar is bringing to the South African Republic the World Leading Russian Rejuvenation technology, still classified in the West. Wave Genome technology was created for the first persons in the State, military commanders, diplomats, Special Forces and Olympic Team.

Wave Genome offers:

(1) **MINI-TESLA PSI-GENERATOR**

MINI-TESLA PSI-GENERATOR consists of two parts: (a) Chip (in casing) structured by laser on nanolevel with client’s biohologram recorded by laser from client's childhood photograph; for the **ULTRA MINI-TESLA PSI-GENERATOR**, the casing itself is structured by laser on nanolevel with the biohologram of the immune system rejuvenation **E-DRUG** (electronic drug); (b) flash drive with the complete **DIGITAL PHARMACY** (software) consisting of the digitized bioholograms of all essential bodily organs and physiological systems. Both of these components are not available elsewhere on the global market. **MINI-TESLA PSI-GENERATOR** is a certified protection against V2K (Voice to Skull), and all other kinds of psychotronic weapons, and harmful radiation. THERE ARE NO ANALOGUES ON THE GLOBAL MARKET, or devices that provide actual protection.

(2) **AURA PSI-GENERATOR**

AURA PSI-GENERATOR is a large-size device for radical rejuvenation and enhancement of physical, mental and psychic abilities. **AURA PSI-GENERATOR** comes with revolutionary diagnostics, not available elsewhere, which detects all malfunctions in your body, inaccessible for any conventional diagnostics, via using formerly super secret military technology, which was created by Soviet scientists for detecting enemy in the outer space. **AURA PSI-GENERATOR** has the complete **DIGITAL PHARMACY**, consisting of digitized bioholograms for every essential bodily organ and physiological system, e.g., immune system, endocrine system, etc. For example, complete rejuvenation for clients with diabetes type two takes 10 sessions. Each session is about 2 hours. **AURA PSI-GENERATOR** detects whether a person got any implants, including Nanobots (computers of the molecular size), or whether a person is under Psychotronic attack. After detection, **AURA PSI-GENERATOR** destroys microchips of any kind and protects the client from the Psychotronic or Psychic attack.

Text on the Quantum Leap Technology of Laser Polarized Holography by Wave Genome:
© Irene Caesar, Ph.D. 2016 www.wavegenome.com / mail@wavegenome.com

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Georg Ritschl
Wave Genome’s ZAR Representative
https://www.orgoniseafrica.com / orgonisehelpdesk@gmail.com

BOOKING: www.janemackenzie.co.za

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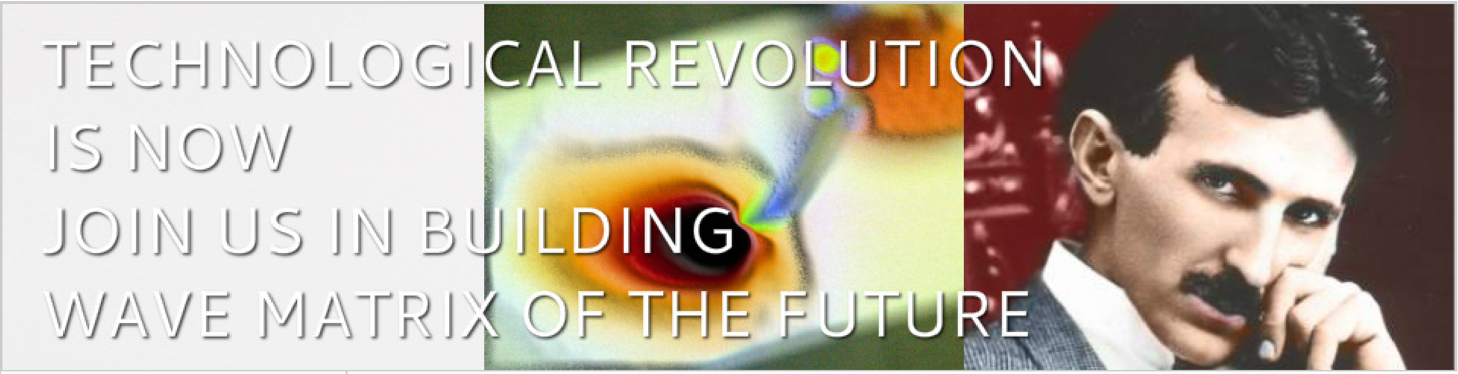
TECHNOLOGICAL REVOLUTION
IS NOW
JOIN US IN BUILDING
WAVE MATRIX OF THE FUTURE

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TESLA PSI-GENERATORS WITH COMPLETE DIGITAL PHARMACY - THE FRONTIER OF QUANTUM GENETICS

TESLA
PSI-GENERATOR

You can place an order via filling up **THE ORDER FORM (/order-form.html).** Prices differ depending on the service, client's condition, and disease.

Models of **TESLA PSI-GENERATOR**S differ by the size of the chip (the number of layers). The chip is multilayered and it takes longer than one day to produce just one layer. Our **SUPER**, **ULTRA** and **ULTIMATE PSI-GENERATORS** has twice as much layers than our **BASIC TESLA PSI-GENERATOR**. Production of our **ULTRA** and **ULTIMATE MINI-TESLA PSI-GENERATORS** takes about or longer than one month.

Each model comes in **GENERIC** and **INDIVIDUAL** version. Generic version has the universal human biohologram (aka DIGITAL CELL) encoded via laser into the chip on nano level. And the individualized version has the personal human biohologram encoded via laser into the chip on nano level.

GENERIC TESLA PSI-GENERATORS are produced for large families, who would like to share the same **TESLA GENERATOR** for all members of the family. Generic Human Biohologram, aka DIGITAL CELL, is the result of decades of research, and is the foundation for our diagnostics procedures.

INDIVIDUAL TESLA PSI-GENERATORS have individual biohologram of a client in the chip, being encoded via laser onto the chip on nano level. Individual biohologram is recorded from your childhood photograph (or navel blood / placenta) via laser, digitized, diagnosed, and encoded into the chip via laser.

INDIVIDUAL TESLA PSI-GENERATORS are produced for the ultimate protection against genetic and psychotronic warfare.

Each chip (inside a pendant) comes with the **COMPLETE DIGITAL PHARMACY** as software on a flash drive with 44 modules for every essential bodily organ and physiological system. Market value is 35,000 Euros only one module.

COMPLETE DIGITAL PHARMACY SOFTWARE PROGRAM

All our models of TESLA PSI-GENERATORS (chip) come with a separate flash drive with the complete **DIGITAL PHARMACY** software program for every essential bodily organ and physiological system **(PSI-PROGRAM**) to run on your computer in order to generate **E-DRUGS** / **BIOELECTRONIC DRUGS** (aka wave matrices / bioholograms) for every health condition.

SECOND-BIRTH TESLA PSI-GENERATOR

SECOND-BIRTH TESLA PSI-GENERATOR

(a) **has a more advanced, second generation chip encoded by laser on nano level with the most valuable biohographic information on the global market: EMBRYONIC STEM CELL;**

(b) has a new technology of encoding the chip by the newly invented laser (patented);

(c) layers of the chip are made of a new material of organic nature more advanced than our other chips;

(d) its efficacy is proven by the clinical trials at the Medical Clinic of the Moscow Bauman Russian State Technical University, the most important Science University in Russia, of MIT level. twice as more layers of the chip than the **BASIC MINI-TESLA PSI-GENERATOR.**

(e) has either **GENERIC** or **INDIVIDUAL** biohologram.

(f) provides the ultimate modulation for the scalar wave diffraction grating for the most precise focus / zero center of the biohologram (aka 'wave crystal") in the process of rejuvenation.

GENERIC MATRIX MINI-TESLA GENERATOR - $3000

INDIVIDUAL MATRIX MINI-TESLA GENERATOR - $3500

BASIC-X TESLA PSI-GENERATOR

SUPER TESLA PSI-GENERATOR

ULTRA TESLA PSI-GENERATOR

ULTIMATE TESLA PSI-GENERATOR

BASIC TESLA PSI-GENERATOR (chip)

(a) has twice less layers of the chip than our other models**.**

(b) has either the **GENERIC** or **INDIVIDUAL** biohologram of a healthy human in the chip, being encoded via laser onto the chip on nano level.

(c) **BASIC TESLA PSI-GENERATOR** has both sides of the casing for the chip made of Real Solid Pearl.

(d) **BASIC-X TESLA PSI-**

SUPER MINI-TESLA GENERATOR (chip)

(a) has twice as more layers of the chip than the **BASIC MINI-TESLA PSI-GENERATOR.**

(b) has either **GENERIC** or **INDIVIDUAL** biohologram.

(c) Both sides of the casing for the chip are made of Real Solid Pearl.

GENERIC SUPER MINI-TESLA GENERATOR - $1179

INDIVIDUAL SUPER MINI-TESLA GENERATOR - $1768

MATRIX TESLA PSI-GENERATOR

MATRIX TESLA PSI-GENERATOR

(a) has twice as more layers of the chip than the **BASIC MINI-TESLA PSI-GENERATOR.**

(b) has either **GENERIC** or **INDIVIDUAL** bioh

ULTRA MINI-TESLA GENERATOR (chip)

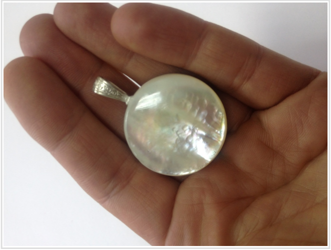

ULTIMATE MINI-TESLA GENERATOR (chip)

(a) has twice as more layers of the chip than the **BASIC MINI-TESLA PSI-GENERATOR.**

(b) has either **GENERIC** or **INDIVIDUAL** biohologram.

(c) One side of the casing for the chip is made of Real Solid Pearl, and another side of casing is made of 3D printing plastic, encoded with the

GENERATOR has one side of the casing for the chip made of Real Solid Pearl, and another side of casing made of 3D printing plastic, encoded with the immune system rejuvenation **E-DRUG** (**BIOELECTRONIC DRUG** / **DIGITIZED BIOHOLOGRAM**). This makes **"TWO-CHIPS IN ONE"** solution.

GENERIC BASIC MINI-TESLA GENERATOR - $856

INDIVIDUAL BASIC MINI-TESLA GENERATOR - $1179

INDIVIDUAL BASIC-X MINI-TESLA PSI-GENERATOR - $1534

ologram.

(c) Both sides of the casing for the chip are made of 3D printing plastic, encoded with the immune system rejuvenation **E-DRUG** (**BIOELECTRONIC DRUG** / **DIGITIZED BIOHOLOGRAM**). This makes **"TWO-CHIPS IN ONE"** solution.

GENERIC MATRIX MINI-TESLA GENERATOR - $2122

INDIVIDUAL MATRIX MINI-TESLA GENERATOR - $2947

(a) has twice as more layers of the chip than the **BASIC MINI-TESLA PSI-GENERATOR.**

(b) has either **GENERIC** or **INDIVIDUAL** biohologram.

(c) One side of the casing for the chip is made of Real Solid Pearl, and another side of casing is made of 3D printing plastic, encoded with the immune system rejuvenation **E-DRUG** (**BIOELECTRONIC DRUG** / **DIGITIZED BIOHOLOGRAM**). This makes **"TWO-CHIPS IN ONE"** solution.

GENERIC ULTRA MINI-TESLA GENERATOR - $1768

INDIVIDUAL ULTRA MINI-TESLA GENERATOR - $2358

RNA **E-DRUG**(**BIOELECTRONIC DRUG** / **DIGITIZED BIOHOLOGRAM**) for the ultimate protection against psychotronic and genetic warfare. This makes **"TWO-CHIPS IN ONE"** solution.

GENERIC ULTIMATE MINI-TESLA GENERATOR - $2358

INDIVIDUAL ULTIMATE MINI-TESLA GENERATOR - $2712 (promotional price)

MINI-TESLA GENERATOR

MANUAL FOR MINI-TESLA PSI-GENERATOR

ABOUT THE DEVICE

The device consists of two parts: a chip in a pendant and a computer program (software) on a flash drive.

CHIP:

The user wears a pendant with a chip inside on his/her neck at the level of the solar plexus. We have chips of first and second generation. First generation chip is an artificial polymer crystal with electret properties, which has two modules, depending on how you turn it towards your body: open module (reinforcing the impact of a user on the environment) and closed (protecting a user from the harmful effects of the environment). Second generation chip (more advanced) has the entirely holographic technology, and functions through the focus / zero center of the scalar wave diffraction grating in the hologram encoded into the chip via laser on nanolevel.

Chips are structured by laser at the nano level. The laser writes to the chip at the nano level client's digitized biohologram, which is read by the laser from the childhood photograph, placenta or umbilical cord blood of the client for the individual generators, or the biogologram of a average healthy person for the generic generators.

When user is wearing the chip, the electret is emitting the wave crystalline structure (hologram or matrix) upon the user, and makes his chromosomes repeat the wave crystalline structure of a healthy person during cell division.

The laser and chip itself use the principle of Kozyrev Mirrors. The Universe consists of energy for 93%, and of particles only for 7%, and particles are the concentrated energy. The universe is holographic, that is, it is entirely in its every Matrix Point. Wave Hologram or Matrices exist in two forms: in the form of a Torus (simultaneously present from the infinitely small to the infinitely large dimensions) and in the form of the Wave Crystal. Man exists in the form of a Torus during sleep. During waking hours, the person is in the form of a Wave Crystal.

Wave Crystals are formed in the structures, which reproduce in their shape the Kozyrev Mirrors. Kozyrev Mirrors reflect any external wave signal, and, therefore, are called "mirrors". These structures neutralize any external linear signal, and refract it towards their Zero Center or focus. Neutralization of any external signal happens due to the reflection of the wave and the polarization, and the creation of a so-called standing (scalar wave). Trough of the back-running wave neutralizes the peak of the forward-going wave, when the initial wave is reflected. This provides protection from harmful electro-magnetic and other technogenic or anthropogenic influences.

As a result of the standing (scalar) wave, there emerges the interference (diffraction) grating, which refracts any next linear signal line towards the center (focus) of the Wave Crystal.

It is necessary to know this, because all the information in the universe is transmitted and received only through the Zero Center of the Wave Crystal. This is analogous to the work of our eye. We see only because there is the gathering

"PSI" stands for "psychotronic", that is, for the technology that is offering technical means for managing biosystems.

Every **MINI-TESLA psi-generator** comes with

(1) a **CHIP**, structured with a laser on a nano-level with the digitized Wave Matrix / Biohologram of healthy human or your own individual wave matrix in childhood (recorded from your childhood photograph), and cased either in pearl or 3-D printing plastic, or combination of these two materials. You wear it on a chain on your solar plexus all the time, taking it off only for bathing;

(2) and psi-program - a flash drive with the software that has the entire **DIGITAL PHARMACY** generated as the holographic / granulated signal (aka "white noise" - signal beyond your auditory perception) and encoded in music. You are getting the complete **DIGITAL PHARMACY** for your lifetime and for every system and vital organ in your body. You run this software at least once a day for best results. If you are sick, you run this software as often as possible.

All sales upon agreeing to c**lient consent conditions** (/client-consent.html), no refunds.

(/order-your-mini-tesla-generator-russian.html)

Нажмите на Русский флаг для перемещения на версию сайта на Русском языке

Refer to our **FAQ (Frequently Asked Questions) (/mini-tesla-generator-faq.html)** for any concerns.

IMPORTANT: CHIP has two modes : OPEN and CLOSED. In the **OPEN MODE**, you increase your information-wave impact upon people. The **CLOSED MODE** is the **SHIELD MODE**, which protects you from any psychotronic attack, including V2K (voice to skull) and cancer guns, subliminal advertising and psychic attacks. Those customers who are endangered with these attacks can wear their **CHIP** in the protective mode nonstop. **PLEASE NOTE**: Plastic towards your body is a **SHIELD MODE**. For casing which has both sides from plastic, the **SHIELD SIDE** is thinner so that the chip is noticeable beneath plastic. For casing which has both sides from Pearl, the darker side of Pearl towards your body is the **SHIELD MODE**.

DIGITAL PHARMACY SOFTWARE PROGRAM (/digital-pharmacy-software--1057105410601058-10621048106010561054104210541049-104010551058104510501048.html)

of all the external linear signals in the focus of the lens (Wave Crystal). If focus is not achieved, and the refraction of the signal takes place before or behind the center of the lens, we have developed the long-sightedness (hyperopia), or the long-sightedness (myopia), and we don't see well. Receiving information by both our eye, and our DNA takes place strictly in accordance with the laws of geometrical optics. The technology used for creating the chip is called "Polarized Holography".

It is possible to record and transmit only a holographic signal. To record Wave Crystals (Biohologram or Matrices) of users, we use devices that can record and transmit holographic signal - He-Ne laser with internal mirrors. These lasers convert any external linear signal into a holographic signal, i.e., changing the nature of the initial signal. For example, our bones produce stem cells only because their shape and structure is analogous to the laser tubes, which "involute" a signal.

Similarly, our DNA is able to transmit and receive information, only because, in its structure, it is the Wave Crystal. Two strands of DNA are literally the standing (scalar) wave, since in the first strand of DNA, a wave goes in the direction opposite to the wave going in the second strand of DNA. Moreover, DNA coils into the crystalline structure, which literally reproduces the interference / diffraction grating of the standing wave in the Kozyrev Mirror, in order to most accurately refract any external linear signal toward the Zero Center / Focus of its Wave Crystal.

We live only thanks to cell division. During cell division, chromosome is formed. A chromosome is formed when two sisters chromatids unite together into a cruciform structure. Chromosomes come in two main shapes: acrocentric and metacentric. In acrocentric chromosomes, two endings of the sisters chromatids are shorter than the other two endings. On the contrary, metacentric chromosome has all the endings the same, so that it is absolutely symmetrical. Metacentric chromosome resembles the quadratic / symmetrical cross (Crux Quadrata / Gammadion), as well as the lens of a well-seeing eye. The same gene in apes, in children with Down syndrome, and wild horses of Przewalski has the acrocentric chromosome, whereas in humans, normal children, and Arabian horses, the same gene has the metacentric shape of the chromosome. That is, the functionality of the species directly depends upon the shape of chromosome, that is, upon the laws of the Polarized Holography of Wave Crystals.

Our device is centering and focusing the chromosomes during cell division, giving them the metacentric form.

Because the entire universe is entirely in its every Matrix Point, each Matrix Point is not simply different from any other Matrix Point, but is unique

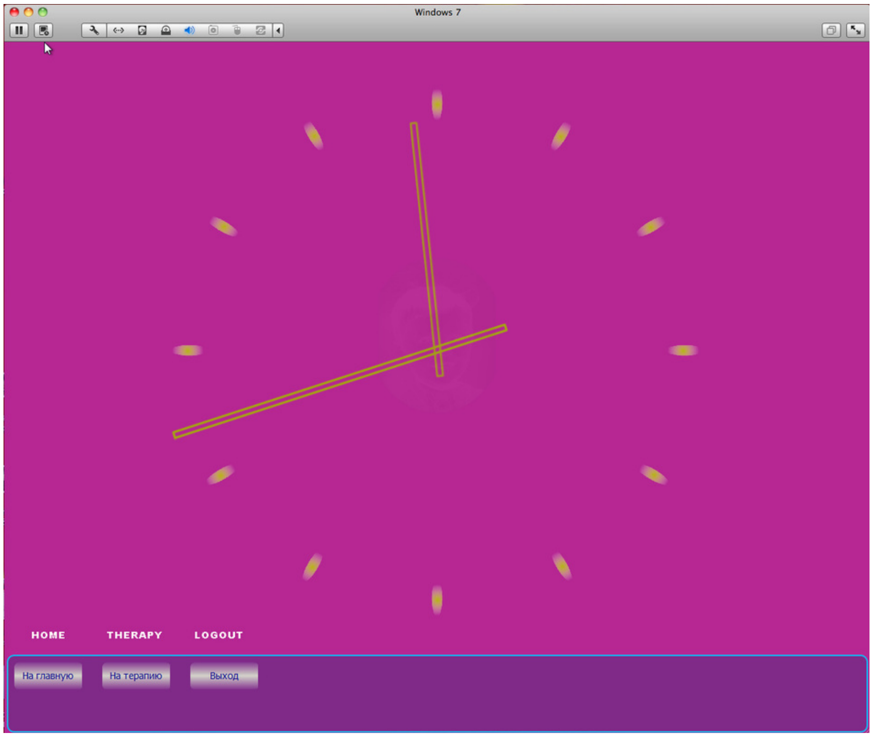

Click here (/digital-pharmacy-software--1057105410601058-10621048106010561054104210541049-10401055105810451050104 8.html) to see screen shots of the DIGITAL PHARMACY SOFTWARE PROGRAM.

Produced according to TU 9444-021-42844321. Certificate # 77, FC.19.944. P.2455.11.00

Our **MINI-TESLA GENERATOR** is used by Russian Special Forces and Olympic Team.

MINI-TESLA GENERATOR is a CHIP (artificial / polymer crystal), structured by laser on a nanolevel, as a collector and retransmitter of wave structures (Matrices or Bioholograms), which functions as a dispenser for WAVE MATRICES (http://www.wavegenome.com/wave-pharmaceuticals.html) within the revolutionary paradigm of LASER POLARIZED BIOHOLOGRAPHY, which is the true WAVE PHARMACEUTICALS (/wave-pharmaceuticals.html) **-- information technology of a new generation. Generator or retransmitter functions like a vibrator, which emits micro vibrations of special kind - scalar wave diffraction grating.**

WAVE MATRICES (http://www.wavegenome.com/wave-pharmaceuticals.html) can be generic or individualised. Wave matrices can be of a human as a whole, of specific bodily system, or of a specific medication.

Comes with the software that has 44 modules of DIGITISED WAVE MATRICES (http://www.wavegenome.com/wave-pharmaceuticals.html) for every bodily system and every vital organ in your body.

E-VIAGRA

Individualized ELECTRONIC CODE for the rejuvenation of your sex function.

FAQ Frequently Asked Questions (/mini-tesla-generator-faq.html)

READ INFORMATION LEAFLET FOR THE MINI-TESLA GENERATOR

(COMES WITH THE UNIT) (/information-leaflet-for-mini-tesla-generator.html)

Over the course of decades, our institute participated in the research in the field of information technologies of a new generation, and their commercialization. The institute created the system of information-energy correction, which is the most advanced in the world, and is the two-way connection through the energy-information cloud. In Russia, our **MINI-TESLA generator** is used by Special Forces and the Olympic Team in order to help them cope with stress and enhance their performance.

(© Irene Caesar, 2012). Each Matrix of each person is the uncreated and indestructible unique nonlocal Wave Matrix. If we have two copies of a unique non-local Wave Matrix, we can instantaneously transfer information from one copy of a unique non-local Wave Matrix to another copy. In this way, birds and insects share one unique non-local Wave Matrix for their entire species, and instantaneously transmit information between all individuals of a given species. But each man has his own unique nonlocal Wave Matrix. If you order an individual generator, you get your unique non-local Wave Matrix with the most clear focus / center of the Wave Crystal. Your generator transmits upon your chromosomes your unique uncreated and indestructible information from the noosphere of the universe. If you order the generic (universal) generator, its action is limited, but it, nevertheless, helps your chromosomes to get centered and focused.

We also offer the remote therapy by the distant laser signal that instantly, through Quantum Non-locality, affects your genetic apparatus according to the principle described above. The user uses his/her individual generator as an antenna and a filter for the remote laser signal.

DIGITAL PHARMACY SOFTWARE

The user uses the computer program (software) every day once a day in a normal state of health, and several times a day, depending on the complexity of his/her state of health. When working with the computer program of the generator, the user must turn his/her generator to the open module.

Computer program of the generator is a comprehensive Digital Pharmacy of the digitized Biohologram (Wave Crystal structures or Matrices) of all healthy vitally important organs and physiological systems. The user tales a self-test for self-therapy, and the program generates for him the granular (holographic) signal, which is encoded in the music.

Self-therapy is the binaural therapy, which uses the Kozyrev Mirrors principle alike the chip inside the generator. Binaural therapy is based on the effect of the stereo signal to both ears, so that signal is delayed in one ear with respect to the signal applied to the second ear. It is in this way that the Kozyrev Mirrors effect is created, when human skull itself becomes the Kozyrev Mirror. The signal is reflected; there emerges a standing (scalar), the wave interference / diffraction grating; and the signal is refracted toward the Zero Center / focus of the wave crystal.

Also, the user can order any pill or tincture in the form of a software module of the Digital Pharmacy. Digital Pill module is attached to the Digital Pharmacy software, and the user receives the Digital Pill as the granular (holographic) signal encoded in the music. We record the Digital Pill via a laser and as the wave structure (Hologram or Matrix), which is afterwards gets digitized.

DIGITISED WAVE MATRICES (http://www.wavegenome.com/wave-pharmaceuticals.html) also can be either generic or individualised, and of a human as a whole, of a specific bodily system, or of a specific medication.

(/uploads/3/5/1/1/35112207/3881928_orig.png)

The first-generation model of MINI-TESLA PSI-GENERATOR, which combined the chip with the flash drive containing the DIGITAL PHARMACY software.

BASIC MINI-TESLA GENERATOR emits generic **HUMAN CELL HOLOGRAM**, recorded by the laser from healthy human cells and bodily systems, and then used to structure the crystal via the laser on nanolevel.

SUPER, ULTRA, MATRIX AND ULTIMATE MINI-TESLA PSI-GENERATORS emit individual **HUMAN CELL HOLOGRAM** in the form of your childhood wave matrix, which is recorded from your childhood photograph when you were a healthy child. We also need your date of birth. We use the complex systematic approach to read the bioholographic information from your photograph, including the application of laser.

After your matrix is recorded from your photograph, we run a special diagnostic program in our Institute to reveal the defects in your matrix, and to correct them.

If no childhood photograph is available, we can use your adult photograph, since the Institute can diagnose **WAVE MATRICES (http://www.wavegenome.com/wave-pharmaceuticals.html)** and correct them.

We can "record" wave matrices / biohologram upon various media, and not only on the electret-based chip of the MINI-TESLA PSI-GENERATOR. Examples of such media are CDs that are used "as such", and not for extracting the digital files from them.

We can combine your childhood wave matrix with wave medications.

We can tune up your childhood matrix.

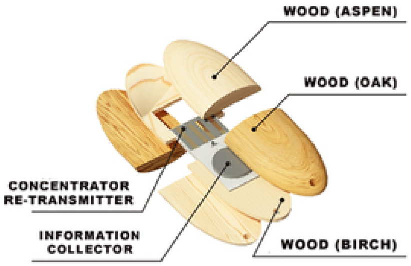

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The first-generation model of MINI-TESLA PSI-GENERATOR, which combined the chip with the flash drive containing the DIGITAL PHARMACY software.

MINI-TESLA psi-generator cased in pearl

The second-generation model of MINI-TESLA PSI-GENERATOR, with casing of chip made from Pearl and Wood. Now this model is offered in Pearl for the BASIC MINI-TESLA GENERATOR (chip structured by the laser with the generic biohologram of a healthy human on nano level).

The device is in fact very necessary in modern times when we are bombarded by the harmful electro-magentic radiation.

The device is designed in such a way that you can turn it either with darker-colorer side to yourself, and, in this case, the generator is programmed to open your biofield; or to turn it with the lighter-colored side (aspen side in generators coated in wood) to yourself, and, in this case, the generator becomes your psychotronic "firewall".

IF you are a jet setter, you are receiving a huge amount of radiation each time you fly. Radiation is one of the causes of cancer. That is why our MINI-TESLA GENERATOR is indispensable for jet-setters.

If you get sick, e.g., infected with a virus or bacteria, your wave imprint / data received at the institute will immediately alert the system, and we will correct the situation via sending you the necessary correction to your wave-diagram (available only for **ULTRA MINI-TESLA PSI-GENERATORS)**

Digital Pills do not have the danger of overdose and side effects.

(/uploads/3/5/4/1/35112207/7731776_orig.gif)
Our MINI-TESLA GENERATOR is used by Russian Olympic Team.

(/uploads/3/5/4/1/35112207/1566232_orig.gif)
Our MINI-TESLA GENERATOR is used by Russian Special Forces.

We can tune up your childhood matrix in such a way that some specific bodily systems or organs are stimulated.

SELF-MAINTENANCE

You run software with **PSI-PROGRAM** on your computer in order to perform the self-maintenance as often as you need. **PSI-PROGRAM** has 44 modules for every bodily system and every vital organ in your body. These 44 modules were recorded by the laser from healthy human cells and bodily systems, and, then, digitised.

Software has (1) the chart of bodily systems and organs to choose from for self-maintenance; (2) the scale of self-assessment from the worst to the best; (3) and two biofeedback tests, based upon graphology.

QUANTUM COMPUTER

Besides conventional tests, Institute developed a completely new way of recording and transmitting information. We call it **QAUNTUM BIOINTERNET**.

When you run the **PSI-PROGRAM**, the spin states of the software and the spin states of your crystal / chip in the generator constitute one and the same torus (hologram). There is the instantaneous biofeedback / bioresonance two-way communication between the running software and the crystal inside the **MINI-TESLA PSI-GENERATOR.**

The crystal / nano chip in the **MNI-TESLA PSI-GENERATOR** and the **PSI-RPOGRAM** software (during its operation on your computer) constitute one integrated **QUANTUM COMPUTER**. The spin states of the crystal / nanochip in the generator and the spin states of the software coincide / resonate or oppose each other, according to the principles of the polarised holography. The principles of the polarised holography are expressed by geometrical optics.

The software reads via its own spin states the information off the crystal (its spin states), and corrects it. Then, the crystal tunes via the bioresonance of the spin states to the hologram, corrected by the operating software.

In this way, the crystal / nanochip inside the generator self-corrects itself based upon the operation of this **QUANTUM COMPUTER**.

MAINTENANCE BY WAVE GENOME LLC

(http://www.wavegenome.com/wave-genome---prices.html).

Some bacteria and viruses are considered to be incurable because they leave a wave imprint in the body, even after they are cleared up on the biochemical level. And, then, these wave imprints can literally rebuild the virus and bacteria from scratch. This same principle is seen in the classic physics experiment involving passing photons and molecules through two slits simultaneously. That is why it is necessary to protect and cure oneself on the wave level.

(/uploads/3/5/4/1/35112207/5220735_orig.jpg)
The first-generation model of the MINI-TESLA PSI-GENERATOR, which was approximately 2 inches long, and which was worn at your solar plexus the same way as the new model of the MINI-TESLA PSI-GENERATOR. Both models are invisible when you wear it. The first-generation model had chip and flash drive with the software combined in one piece.

MAINTENANCE VIA QUANTUM INTERNET BY WAVE GENOME LLC

In the case of **QUANTUM INTERNET**, you send your information **REMOTELY** and **WIRELESSLY**. At the WAVE GENOME LLC, the laser reads the feedback from your wave matrix in real time, using your digitised wave matrix on record at the Institute.

According to the holographic principle, the universe is holographic, meaning that it is entirely in its every matrix part. The holographic principle has three important implications:

The first implication of the holographic principle postulates the **UNIQUENESS** of every wave matrix. if the universe is entirely in its every matrix point, then, every matrix point is not simply different from any other matrix point, but is unique.

The second implication of the holographic principle postulates the **NON-LOCALITY** of every wave matrix. If the universe is entirely in its every matrix point, then every wave matrix is simultaneously present in the infinite number of dimensions via its tokens. Though there are infinitely many tokens of the same non-local wave matrix, all of them constitute one integrated **SYSTEMATIC WHOLE**.

The non-local holographic nature of wave matrices also means that the wave matrix has the infinite set

WAVE GENOME offers everyday **MAINTENANCE** of **WAVE MATRICES** with the purchase of the **ULTRA MINI-TESLA PSI-GENERATOR** and **SUBSCRIPTION PACKAGES.**

The maintenance consists in receiving the necessary correction of your bio-field from the institute.

To obtain MAINTENANCE from the Institute, you send in your information. The Institute tracks down the changes in your **WAVE MATRIX** and makes necessary corrections. Corrections also account for the changes in the earthly electromagnetic activity, solar and lunar activity, geophysical activity, weather anomalies, and predicted social unrest.

There are two ways to send in your information. You can send your biofeedback information either **DIGITALLY** through the conventional internet, or via **QUANTUM INTERNET**.

DIGITAL MAINTENANCE BY WAVE GENOME

In the case of **DIGITAL MAINTENANCE BY WAVE GENOME LLC, WAVE GENOME LLC** corrects the digital files in the software of your **PSI-PROGRAM**.

When you connect your **MINI-TESLA GENERATOR** to your computer, you both receive and transmit through the internet the information, needed for your utmost performance, to and from the our facility.

Your childhood matrix, recorded onto the generator-transmitter, is your antennae that helps your body tune to the waves which are beneficial to you, and ward off harmful waves. That is why this technology is also called "the resonance technology".

Device strengthens the immune system and body's resistance to infectious and toxins;
Improves performance and cognitive abilities, including, sharpness of thinking and memory, and overall quality of life;
Protects against stress factors of any nature (technogenic, including, electromagnetic, as well as physical and psychic)
Speeds up recovery and healing
It is unique in the prevention of many diseases

Especially recommended for people who are in stressful situations: to sportsmen, businessmen, professionals with busy schedule, flights and business trips.

of waves, particles and fields within its **TORUS** -- from infinitely micro to infinitely macro dimensions. It is impossible to talk of each individual wave matrix as "a specific frequency". And it is impossible to postulate any "medium" of its existence, like "scalar wave", "aether", "Higgs / boson field", "torsions", "leptons", etc. There is no specific medium for transferring the information.

The third implication of the holographic principle postulates that there is the **QUANTUM ENTANGLEMENT** in the form of the instantaneous transmission of information between all the tokens of the same non-local wave matrix. The signal that records and transmits the **ENTANGLED INFORMATION** between different wave matrices or between the tokens of the same non-local wave matrix has specific nature. It is **HOLOGRAPHIC**. Only lasers can record and transmit holographic signal, based upon the principles of the polarised refraction holography (described in terms of geometrical optics). Thus, the principle of recording and transmitting the **MATRIX SIGNAL** is structural, and not medium-based.

Thus, it is possible to remotely and instantaneously transfer some wave information to a man via the entanglement between his body (at one location) and his photograph (at another location), as two tokens of his non-local wave matrix.

For example, it is possible to remotely lower blood sugar in a diabetic man via scanning his photograph with the laser ray, which is passing through insulin before reaching the photograph.

© Irene Caesar, Ph.D. from her book **"WAVE PHARMACEUTICALS"** (2014)

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WAVE GENOME (/)

WAVE GEHOME IS
THE INFORMATION-WAVE
MATRIX OF THE FUTURE WORLD

HOME / ГЛАВНАЯ (/)

SERVICES / УСЛУГИ (/SERVICES--1059105710511059104310481048.HTML)

PRODUCTS / ТОВАРЫ (/PRODUCTS--1058105410421040105610671067.HTML)

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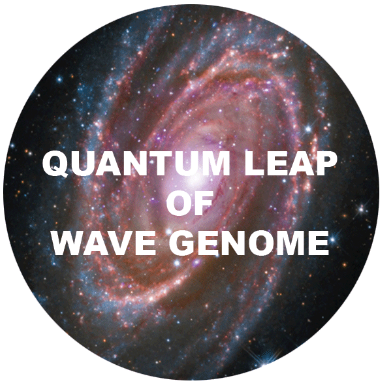

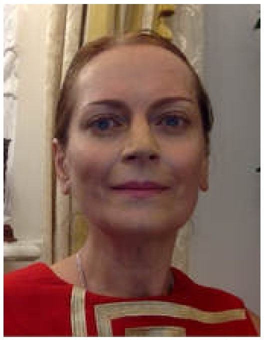

Dr. Irene Caesar, author of the theory of Wave Optics in Chromosomes as Bioholography, and author of the technological model for recording and transferring the biohologams of cells and drugs via refractions codes in the scalar wave diffraction grating; the Head of the group of technical professionals to verify the technological model offered and theoretically substantiated by her.

PRESS RELEASE ON GLOBAL LAUNCH OF THE SECOND-BIRTH TESLA PSI-GENERATOR BY WAVE GENOME

JANUARY 13, 2018

© Irene Caesar, Ph.D., President, Founder and Owner of Wave Genome

Wave Genome is proud to announce its most advanced MINI-TESLA PSI-GENERATOR ever: the SECOND-BIRTH Mini-Tesla Psi-Generator.

We called the new chip the "SECOND BIRTH" generator, because the client gets the most valuable bioholographic treatment ever for rejuvenation -- the biohologram of the embryonic stem cell. The SECOND-BIRTH Biohologram is available as a chip encoded by laser on nanolevel. The clinical trials were conducted by the Bauman University Medical Center. The clinical trials had demonstrated the radical improvement in the wellbeing of the participants in the clinical trials.

In the GENERIC SECOND-BIRTH Tesla Generator, the biohologram of the embryonic stem cell is generic. It is a DIGITAL CELL. It is not the biohologram of a specific embryo, but the result of the Embryonic research based upon the Quantum Leap diagnostic of holograms according to the coherence of the geometrical optics in chromosomes.

In the INDIVIDUAL SECOND-BIRTH Tesla Generator, the biohologram of the embryonic stem cell is modulated by client's most coherent biohologram, recorded via laser from his

(/ask-our-maven-russian.html)

Prof. Alexander K. Volkov, Ph.D., Medical Sciences, Director of the Scientific, Medical, Technological and Educational Center of the Bauman Moscow Russian State Technical University, who headed the group of medical professionals to verify the technological model offered by Dr. Irene Caesar.

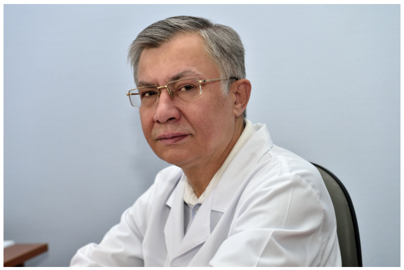

Prof. Vladimir I. Sinopalnikov, Ph.D. Medical Sciences, The Renowned Physician of the Russian Federaration, Deputy Director of the Scientific, Medical, Technological and Educational Center of the Bauman Moscow Russian State Technical University, who participated in the group of medical professionals to verify the technological model offered by Dr. Irene Caesar.

НАУЧНО-ОБРАЗОВАТЕЛЬНЫЙ МЕДИКО-ТЕХНОЛОГИЧЕСКИЙ ЦЕНТР
МГТУ ИМ. Н. Э. БАУМАНА

Scientific, Medical, Technological and Educational Center of the Bauman Moscow Russian State Technical University, in possession of the cutting edge lasers, and other technology.

Bauman Moscow Russian State Technical University, major Science University of Russia, of MIT level.

childhood photograph.

The INDIVIDUAL SECOND-BIRTH Tesla Generator is stronger than the GENERIC one, since it has a more precise focus due to the finer / smaller grid of the scalar wave diffraction grating. But you can use the GENERIC one for the entire family, and this is also a great benefit.

If somebody else will wear your own unique INDIVIDUAL Tesla Generator, this individual will simply not connect to the focus of your unique biohologram encoded on the chip, since this person has his/her own geometrical code for refraction in the scalar wave diffraction grating of his/her biohologram.

When the modulation is added to the carrier wave in the scalar wave diffraction grating, the resulting hologram is different from these two components taken separately.

In the biohologram, the polarization emerges due to the change of the spin in the integral torsion. Due to polarization, the external signal is reflected upon itself, so that the scalar / standing wave emerges. In the scalar wave, the peak of the forward-going wave is annulled by the trough of the same wave when it is reflected upon itself. Scalar wave creates the diffraction grating, so that any next external signal is refracted towards the focus / zero center of the biohologram (aka “wave crystal”).

Any external signal is only a trigger, and the external signal can be a psychotronic attack. This is a great benefit of the Quantum Leap Laser Polarized Biholography. The more modulations the biohologram has, the more precise focus / zero center is achieved via refraction, and the better is your protection against the psychotronic attack.

Because the SECOND-BIRTH Tesla Generator has the most fine / small / scaled scalar wave diffraction grid among our other generators, the SECOND-BIRTH Tesla Generator provides the most precise focus / zero focus of client’s biohologram and the best defense against psychotronic attack.

Thus, with the SECOND-BIRTH Chip, you will experience the most radical rejuvenation effects, including mental and physical enhancement, a more emotional control, and a better defense against psychotronic attacks.

Those of our clients, who already own one of our MINI-TESLA PSI-GENERATORS, can either wear both generators together, or carry one of the generators in a pocket, or alternate generators.

WAVE GENOME HAS INTELLECTUAL PRIORITY FOR THE WAVE OPTICS IN CHROMOSOMES AS BIOHOLOGRAPHY

Click here (/diaschev-dipol-di-pol.html) to read on how WAVE GENOME’s technology differs from Dr. Gariaev’s and Dr. Diaschev’s technology (DIPOL or DI-POL Generator).

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MICROWAVE MIND CONTROL

by Tim Rifat

UK INTELLIGENCE FORCES AND MICROWAVE MIND CONTROL
MIND CONTROL

As a scientist researching into microwave weapons used on the general public, evidence that the GM900 microwave network as used by Vodaphone and British Telecom, is a major health hazard, has come to my attention. Defence Intelligence Agency (DIA) documents entitled: Biological Effects Of Electromagnetic Radiation (Radiowaves and Microwaves) Eurasian Communist Countries, show that microwave frequencies similar to those of the cellular phones can cause health problems in the following areas:

* Blood.
* Cardiovascular System.
* Cells.
* Central Nervous System.
* Digestive System.
* Glands.
* Metabolism.
* Reproduction.
* Visual System.
* Internal Sound Perception.

Equipment to test the frequency and intensity of microwave phones shows that they produce signals similar to microwave ovens. Two Vodaphone cellular phones were producing 100mW/cm2 and 50 mW/cm2 respectively. The danger level for microwave ovens is 5mW/cm2 and the Russians regularly used 10 mW/cm2 for weapon research. These Vodaphones will therefore cause significant health problems if used. A variety of cell phones can be tested to see how dangerous they are.

The GM1800 system used by Orange uses higher frequency microwaves. Australian scientists found this caused cancer in mice exposed to radiation of this type. The documents in my possession show that microwaves pass deeply into the body and can have a negative effect on the brain and body.

The DIA research dates from 1976 and shows the dangers were known about over twenty years ago. The Soviets used the frequencies and intensities used by mobile phones, 1800 MHz and 900 MHz, as weapons. It is a rule of the intelligence community that you hide things in plain view, getting the public to accept microwave mind control weapons which effect their behaviour under the guise of mobile phones was a stroke of genius. Getting the public to pay for these microwave mind control devices, so their brains and behaviour can be damaged, to make them more docile and easy to control, was pure diabolical genius.

UK INTELLIGENCE FORCES AND MICROWAVE MIND CONTROL

Microwave weapons that turn people into stressed, confused, submissive zombies are being used in Britain‘s inner cities. Developed by the communists, microwave weapons similar to microwave ovens have since the 1980s, been targeted on inner city council estates. These weapons transmit extremely low frequency (ELF) signals which mimic natural brain waves; at the flick of a switch, all the people around these microwave transmitters are turned into submissive zombies who cannot think clearly, become depressed, apathetic and want to lounge around all day doing nothing: the inner city malaise found on Britain‘s streets. With the advent of new ELF detectors designed by the author‘s research teams, the mass mind control of the metropolitan UK population can be proved. ELF signals are officially only found at nuclear submarine communication stations, so the researchers were shocked to find microwave and UHF, mind control signals in city centres, the author‘s flat, being sent through mobile phones, the BT telephones and from the numerous transmitters that dot the country.

The massive increase in mobile phones has enabled the UK security forces to use this network of transmitters to beam mind control signals into the brains of anyone living near these transmitters. Microwave phones use pulse modulated microwaves of the correct intensity to pass through the skull into the brain and control behaviour. Microwave transmitters are therefore the perfect medium for the transmission of ELF signals to mind control the UK population.

Researchers are of the opinion that the inner city riots of the early eighties forced the Thatcher regime to deploy ELF mind control devices developed in the 1970s to turn the working class housing estates into total policing zones. In these zones, ELF transmitters turned the inhabitants into docile zombies. So successful was this technology that it was expanded to cover all major towns. Mass mind control of the UK public to make them submissive and obey authority was expanded, hand-in-hand with the mobile phone network and military and police microwave transmitters. Now the entire London conurbation is covered by UHF and microwave carrying mind numbing ELF.

Research into the use of microwave weapons and their use for mind control began in 1950s at the Tavistock Institute, one of Britain�much leading psychiatric research establishments. The UK institute was researching into ways of mind controlling the British population without them knowing. The monkey submission response, whereby the dominant monkey caused submissive behaviour in the underlings, was the brain state of most interest to the British scientists. Having found this specific brain rhythm for docile submissive, zombie-like behaviour, it was then recorded and used as the template for the ELF signal beamed on UK microwave transmitters. Britain was the first discoverer of microwave technology, used for radar, in the 1940s and therefore had a commanding lead over everyone else in this field.

The 1970s brought a darker side to the story, with the news that the Russians were microwaving the US embassy in Moscow. One third of the staff eventually died of cancer from this microwave irradiation. Australian scientists proved in 1997, that tiny amounts of microwave produced by the very safest mobile phones, cause cancer in mice, when exposed to this radiation. Greenham Common was the first time that the Ministry of Defence was involved in the offensive microwaving of women protesters, the so called Greenham Common Women. This event showed that the UK security forces were willing to use lethal doses of microwave radiation on large groups of the general public. Equipment showed that the women peace protesters were subject to high levels of microwave radiation, some of them have subsequently died from cancer. Northern Ireland would have been a perfect proving ground for mass mind control technology. Research at the Tavistock institute enabled the Thatcher government to put into large scale use, the frequency which causes submission in humans. Radiating this ELF frequency on microwave transmitters, cellphones, BT phones and by use of other transmitters, the inner city population can be behaviourally controlled. My research group have ELF detectors, which can prove all manner of UK transmitters are being used to mind control the population. Since ELF is not found naturally, and is only used for nuclear submarine communication, its presence proves mind control weapons are being used on the general public. The author also has access to scientific documents showing the devastating effects of ELF broadcast by microwave, UHF and VHF on humans.

It is alleged that Marconi put this microwave technology into full scale production, and around thirty scientists and military personnel on the project who began to ask questions committed `suicide‘ under mysterious circumstances.

My research has found that microwave weapons are targeted on middle class troublemakers and researchers who cause problems for the establishment. Russian and American research has found that pulse modulated microwaves (as used for mobile phones) can, when modulated with ELF which mimics specific brain patterns change the behaviour of the victim at the flick of a switch. It has been found that UK security police, such as MI5 use the 450 MHz frequency used for this research (legally allowed to be used by the police) for behavioural control. A vast catalogue of mind control frequencies in the MHz range, FM radio, TV and mobile phone frequencies, have been measured, which are used in the UK for mind control and killing or disabling victims: 147, 153, 197, 199, 447, 453, 456, 466, 853, 883, 884, 887... Symptoms can be depression, befuddled thinking, loss of memory, stress, not being able to cope, manic behaviour, schizophrenia, nervous breakdowns, physical collapse, brain and nervous system damage, heart attacks, cancer...

An example was Brighton police van, parked outside the Brighton Pavilion which was used to beam UHF and microwaves at vagrants to clear them from the area. All Brighton‘s city centres are bombarded with microwaves when vagrants congregate to make them so ill they have to flee. The Evening Argus newspaper asked the police if the white van which was parked in the Brighton Pavilion grounds for months, was their van, they replied it was one of their ‚surveillance‘ vehicles. On Wednesday, 4th of February the author was passing Brighton Police station with a frequency counter which detects microwave weapons, and I detected a 452 MHz microwave beam being directed at two young offenders sitting on a wall opposite the station. I confronted the police with the reading, Robert Galloway, spokesperson for the police stated, „they were not interested in microwaves even if they were a danger to health.“ The author has uncovered widespread use of microwave weapons in Brighton by the police and MI5 as a test programme to clear vagrants from the city centre.

Contacting researchers in this field of enquiry, they all complain of microwave-like symptoms, headache, nausea, giddiness, eye damage, ear problems... Readings I have taken show that the 750-1000 MHz range is used by the intelligence services for inducing nervous and physical collapse. Microwave ovens give off 1000 MHz.

On the Channel 4 programme, For the Love of…New World Order, shown on Monday night at 12pm, on April 6th, the author revealed some of these facts on television. The presenter, and researchers of this programme complained of severe headaches in the days preceding filming symptomatic of microwave attack. As the foremost non-military expert microwave weapons, remote viewing (psychic spying) and Psi-warfare, the author became aware of the microwave problem when he was targeted to stop his forthcoming book on remote viewing being released. This book on psychic spying, published by Century Books, is the first book by a scientist on the subject of Psi-warfare and the techniques the superpowers developed.

Subsequent to the filming of the Channel 4 programme, he was arrested by Brighton Police on February I5th outside their building and his frequency counter was confiscated to stop him recording the use of microwave weapons around the police station and in public places around the town. Even though no law was broken. It appears Brighton Police are worried that their use of microwave weapons on Brighton's vagrants is coming to light. The UK government has also bought up all the readily available frequency counters, these being the Watson FC-128 frequency counters, and the Optotronic devices, and the manufacturers now market a ,modified' model, which most probably has a digital filter so that the microwave weapon frequencies given above, cannot be shown. The author's frequency counter has still not been returned. With such high-level manipulation of events it seems that microwave mind control is part of a secret policy which is being practised on the general public in this county. As part of a covert government policy of harassing and disabling critics, this means of attack is not covered by the law and highly deniable, the perfect intelligence device for civilian control. The author's flat is targeted with a 900 MHz beam which seems to be designed to cause massive neurological damage and produce tumours.

The BT phone network has the potential to be used for docilisation of the UK public. A 30-40 MHz signal is carried by the phone. When the earpiece is placed against the head, bone conduction carries the ELF component into the brain of the phone user. A ELF signal which can effect behaviour or health is therefore passed into all BT phone users. It appears from experts I have consulted on the subject that the digital phones have been designed to carry this mind control carrier frequency. Vodaphone have supplied a mobile phone to a friend of mine that pumps out an 847 MHz signal at over 100 mW/cm2, this is equivalent to 4x100 watt lightbulbs being turned on in the body of the user. This means that mobile phones can potentially be used to kill or so disable a person they no longer become a problem to the establishment. Another Vodaphone tested pumped out 50 mW/cm2. UK safe levels for microwave ovens are 5 mW/cm2 - which are not held near the head. There are reports by military researchers that 1 mW/cm2 will cause swelling of nerve cells exposed to microwave.

It is obvious that a total policing of the population by means of UHF, VHF, and microwave EM radiation, amongst others, is being used to keep the UK population in a docile and submissive mental state. Mental confusion can also be added to the signal for working class inner city areas to keep them docile and confused. A land of stultified zombies, who are mind controlled to make them docile and unable to think clearly. Subversives are habitually targeted with microwaves to drive them mad or make them fatally ill

On July 4th 1976 seven giant transmitters in the Ukraine, powered by the Chernobyl nuclear facility, pumped a 100 megawatt radio frequency at the West, which contained a 10 Hz ELF mind control frequency. According to a US scientist, Dr. Andrija Puharich, MD, the soviet pulses covered the human brain frequencies. With a Dr. Bob Beck Andrija proved that the Soviet transmissions were a weapon. He found that a 6.66 Hz frequency would cause depression and an 11 Hz signal would cause manic and riotous behaviour. transmissions could indeed entrain the human brain, and thereby induce behavioural modification populations can be mind controlled en masse by ELF transmissions. More importantly he found that an ELF signal could cause cancer at the flick of a switch. It did this by modifying the function of the RNA transferases so that amino acid sequences are scrambled and produce unnatural proteins.

MIND CONTROL

Torture is alive and well in the UK. MI5, the UK's secret police, regularly use Non-Lethal Weapons on any dissidents. Since MI5 have a well documented history of hating the Labour Party, and were instrumental in bringing down the Labour Prime Minister Harold Wilson, they naturally took to spying on, and discrediting, any group or person who did not follow their rabid right wing dogma. When Margaret Thatcher became Prime Minister of a right wing Conservative Government in 1979, she soon saw the power in recruiting MI5 to be her own secret police. During the Miner's strike in the early eighties, Arthur Scargill and his National Union of Miners nearly brought the Conservative Government down, with their year long strike. Margaret Thatcher used MI5 to spy on the Miners and to discredit Arthur Scargill. Leading police officers argued against the use of MI5 on the civilian population, they were ignored or replaced - if they proved too vociferous.

Margaret Thatcher was the first Prime Minister for many a year to sit in on the Joint Intelligence Committee‵s meetings on a regular basis. Thatcher, as a trained scientist, would have been well aware of the usefulness of microwave weapons. They are impossible to detect unless you have a detector, dissidents have no idea these weapons exist, and best of all, they are totally deniable. It may be that MI5 kept this research secret from Margaret Thatcher, but the resources the UK has put into these fearsome, so-called non-lethal weapons, is extensive. UK intelligence runs a fleet of microwave weapon carrying vans, as well as portable microwave weapons that can be deployed near the dissident‵s home. The vast expense can be disguised as communications equipment, for as we all know, microwave telephone communication is all the rage in our modern world. My research shows that the microwave telephone network also has the potential to be used as a major mind control weapon system to control the behaviour of the microwave phone users.

Developed under the Conservative government, which was in power from 1979-97. The UK secret, or ‚black‵ government, has at its disposal a fearsome array of mind control weapons. These abhorrent devices are euphemistically called ‚non-lethal weapons‵ by the UK military. In fact they kill you slowly by causing: nerve damage, cancers, mental collapse leading to suicides, or tissue failure, such as heart attacks due to the cooking effect of microwaves.

Precisely modulated microwave radiation is used to influence brain function. Human behaviour and reactions can be entirely controlled by using pulse modulated microwave EM radiation. Pulse modulated microwaves are useful as the carrier for the mind control signals as they are able to pass through the skull, which is rather resistant to low level EM. The massive number of microwave antennae that dot the country, some of which are used for the microwave phone network, all use pulse modulated microwaves, which makes their use for a strategic mind control device against the civilian population in times of trouble, or rioting, crucial to modifying the behaviour of the general population. In modern democracies it is no longer viable to shoot rioters, or torture dissidents by normal means, as the bad publicity is self defeating. Thus, microwave weapons have been developed by the UK‵s military intelligence as they leave no marks, or gaping wounds. This pulse modulated microwave carrier beam can then be used to carry signals. These signals are extremely low frequency recordings of brain electrical potentials, which have been recorded by neuro-medical researchers such as Dr Ross Adey.

Dr Ross Adey‵s research at the Brain Research Institute of the University of California, was funded by the CIA. In their Pandora project a catalogue of different brain signals for specific actions, emotions and pathological states of mind were recorded. It was found that when microwaves were used to fire these signals at victims‵ brains, they experienced the moods, behaviour, and the pathological states, carried by the signals. This meant that by mimicking natural brain frequencies, the human brain could be controlled remotely by use of extremely low frequency broadcast carried by pulse modulated microwave beams (ELF pulse modulated microwave remote mind control technology).

It is now possible to broadcast mind control commands directly into the brain by use of microwave beams. All that is needed is a catalogue of every specific brain frequency for each: mood, action and thought. These catalogues of excitation potentials are available from Russian neuro-medical research institutes, so any one with enough cash can have the same technology at their disposal, as UK military mind control groups (the psychological-enforcement arm of MI5). The Aum sect bought microwave weaponry via their 50,000 Russian converts.

Particular excitation potential, is then broadcast by pulse modulated microwave transmitter. This pulse modulated microwave beam has the ELF excitation potential frequency imprinted upon it. It was found that each behavioural set in humans had a distinctive frequency. There was one for: anger, suicide, hysteria, trauma, serial killing, paranoia, lust...etc. Intelligence operatives in the UK regularly park microwave transmitters outside targets‵ houses and beam specific mood inducing excitation potentials at the victims. To aid them, they have sophisticated millimetre wave scanners to look through the victims‵ walls, so they can see the targets‵ in their homes. Pulse modulated microwaves are regularly directed at the victims‵ brains, while other people in their homes are oblivious of what is going on. A leading conspiracy researcher, who looks into GCHQ at Cheltenham, found one of these vans, with two spheres on its roof parked in his road. When he took the number plate and through contacts checked who owned it, he found it was an MOD van. Hopefully he has found the microwave weapon system before it has done him too much harm.

These microwave weapons were developed allegedly at Marconi. When firing microwave beams through walls at one specific target, every material in the way of the microwave beam attenuates or modifies the intensity and frequency of the beam. Since precise frequencies and intensities are needed for mind control, very sophisticated microwave arrays and computer programmes had to be developed so that the microwave beam could be changed in response to the materials which lay between the target and the weapon, as the victim moved around the house. To do this, the reflectivity and refractivity of the materials between victim and weapon had to be analysed in real-time and fed to a computer which could change the microwave array in concert with the changing environment between victim and weapon, as the target moved around his/her home. Secondly, there had to be an automatic interrupter if another person walked in front of the beam. The victim needed to be driven mad or disabled, without anyone else being aware that he or she was being targeted. The technology for this was very complex but eventually it was perfected. Twenty five or more scientists and military personnel, associated with the Marconi project, then died in mysterious circumstances. Intelligence personnel regularly kill people to keep them quiet. Maybe they killed the entire research team to keep such a diabolical weapon secret. For if it were made public, the scandal would bring down the government. Whatever the real story, by the mid to late eighties, all the problems had been ironed out and these new smart microwave weapons were deployed on the UK s streets. Northern Ireland would have proved the perfect place to test them out. Pulse modulated microwave weapons had now come of age.

By this method, any mood or behavioural set, can be conditioned into the target�trade;s brain. Intelligence agents keep a log of the victim‛s behaviour to see if more intense ‚treatment‛ is needed and as a guide for future mind control projects. It is alleged that by this method, UFO and conspiracy researchers, are routinely driven to commit suicide. having the excitation potential for suicide beamed into your brain day and night by microwave mind control weapons, soon resets the brain into a cycle of depression that spirals out of control ending in suicide. Many intelligence and technical officers in the UK, who have spilled the beans, or could be a potential leak, are driven to commit suicide by the special mind control teams run by MI5. If you look at the long list of UK military and intelligence experts who inexplicably commit suicide, one can see an underlying mind control logic that drives them to kill themselves.

Behavioural reinforcement is used in a synergistic way with the mind control. It was found that the effect of the microwave beams could be greatly enhanced by external reinforcement. Intelligence community personnel destroy the target‛s property, ruin their financial affairs spread vicious rumour, make sexual peccadilloes public knowledge - such as wearing women‛s underwear, while checking oneself - with an orange in one‛s mouth. External reinforcement of pulse modulated microwave mind control technology was found to be very effective. Intelligence chiefs are now in seventh heaven; if some one becomes a problem they get the ‚suicide mind control team‛ parked outside their house. Within weeks, the victim kills himself. This is very pleasing to the intelligence mandarins, as suicides are easy to explain away - even if the victim was a highly placed politician or military man.

If the military intelligence agency does not wish you to commit suicide, they can drive you mad. This is done by beaming the excitation potential of a particular pathological mental state at your brain while you are at home. To aid in this, the intelligence operatives can place sounds and speech in the target victim‛s brain. This inter cerebral hearing is used to drive the victim mad, as no one else can hear the voices transmitted into the brain of the target. Transmission of auditory data directly into the targets‛ brains using microwave carrier beams is now common practise. Instead of using excitation potentials, one uses a transducer to modify the spoken word into ELF audiograms, that are then superimposed on the pulse modulated microwave beam.

Discrediting well known people who are causing problems for the shadowy elite, by driving them mad, seems to be standard operating procedure for the intelligence community. Victims are subject to pulse modulated microwaves which carry different types of madness and behavioural aberrations, encoded as ELF excitation potentials. This makes the troublesome high profile person, display manic or insane behaviour that discredits them. Examples of this technique are allegedly: David Icke, Fergie, Princess Diana... Outside environmental reinforcement, by use of media agents in league with MI5, makes it assured that the high profile person‛s mind controlled madness, will be put in the worst possible light to discredit them. In this way, high profile subversives who cannot be wrongly imprisoned (unlike the Carl Bridgewater prisoners, Birmingham Six, Guilford Four...) in the normal way by Britain‛s police, or killed by assassination squads, such as the Pegasus group, are made to look ridiculous. Public humiliation is the finest weapon the authorities have, to make harmless, a potential well known figure, who is causing trouble.

If the VIP needs to be made temporarily ill, microwave beams containing the signal the brain gives off during a vicious bout of flu can be fired at the victim. This causes the target to display all the symptoms of flu, even though they have not caught the virus. Major Ed Dames, the remote viewing specialist, who has close links with the US secret military, alluded to this device on a US TV programme.

The intelligence agents can also use low level microwaves to cause mental and physical confusion that leads to illness. Beaming microwaves at victims makes them fatigued, damages their immune system, causes neurological damage that effects their thinking, and ability to carry out tasks, induces premature ageing, cancer and cataracts. Sussex Police regularly use this low level microwave to clear drunks from city centres. While researching this matter, I was subject to high levels of microwave >10mW/cm2 whenever I approached their headquarters, whilst MI5 irradiated my home continually with microwaves. It seems that I touched a raw nerve while researching mind control weapon usage in the UK.

Organisations that irritate the authorities have their building turned into a ‚hot spot' by microwave transmitters, so the staff all suffer sick building syndrome caused by microwave damage. Or the staff of the target organisation have their behaviour changed to cause discord. UFO Reality, a leading UFO and conspiracy magazine have complained of mysterious health problems, while another New Age group complained of eye damage, nausea and headaches brought on whenever they had a meeting, which may have been caused by microwaves.

Heating the victim to death, by microwave cooking is caused by increasing the field intensity of the radiation, to cause local hot spots in the victims' eyes and gall bladder, which have poor circulation, so cannot carry away the heat.

Irradiating the optic nerve of the victim with the same signal that is sent to the brain by this nerve, causes the nerve tissue to overload. In this way, subversives can be blinded by the intelligence community without them knowing what has occurred. An American researcher complained of this problem to me and warned me that this weapon system was being used on my person by MI5.

Neurological research has found that the brain has specific frequencies for each voluntary movement called preparatory sets. When you pick up an object, there is a specific preparatory set for this action. By firing at your chest a microwave beam containing the ELF signals given off by the heart, this organ can be put into a chaotic state, the so called heart attack. In this way, high profile leaders of political parties, who are prone to heart attacks, can be killed off -before they cause any trouble. Neil Kinnock's Labour government was allegedly cheated out of an election victory by postal vote rigging in twenty key marginal seats. When a new even more electable Labour leader was found, it is rumoured that John Smith, the then Labour leader, was prompted to have a fatal heart attack, while walking in the country with his family, by means of a concealed microwave device which operated on the Vagus nerve to bring about a massive heart attack. Since MI5 have a long history of naked hatred toward the Labour Party, there may be some truth in the above, though no hard evidence has yet been found.

Paralysis can be induced in the target by use of this method of broadcasting preparatory sets encoded on microwave beams. A pulse modulated microwave beam, carrying an ELF signal, which is identical to the one in the motor neurone centre of the brain, is used to jam the victim's motor co-ordination. This is analogous to radar jamming, using a more powerful signal at the same frequency to swamp out the enemy's radar. Motor neurone preparatory set potentials are jammed by a bigger signal carried by a microwave carrier beam, that literally overloads the brain, so it cannot control the body. Pulse modulated microwave weapons which broadcast the ELF preparatory sets of the motor cortex at the victim, will paralyse the victim without killing them. Breathing and heartbeat are involuntary actions controlled by another set of frequencies in another part of the brain.

This technique can be used to abduct people for secret government mind control experiments, under the guise of alien abduction. A microwave beam of this nature will paralyse the victim, so they can be bundled into a black helicopter and airlifted away for experimentation.

Once the procedure is complete, hypnosis can be used to plant false memories of alien abduction. In this way, real alien abductions can be used by the authorities to enable them to obtain a limitless supply of guinea pigs for their mind control experiments.

Real memories of government involvement are erased electronically. This technique clears all short-term memories from the victim's consciousness by broadcasting microwave beams at the target which carry the signals used for memory retention. When you remember something, it is first stored in your short-term memory. After approximately twelve hours, this short-term memory is converted in the brain to long-term memory, after which you remember this information for the rest of your life. If this conversion from short-term memory to long-term memory does not occur, the data is lost. We all see details around us, but try to recall the decor in a restaurant you ate at some weeks ago and you will see how tenuous memory is. Microwave radiation of a specific frequency can interfere with the transfer of memories from short to long-term memory. Microwave radiation of a specific frequency can interfere with the synapses of the brain. By interfering with the connections between brain cells, memory of people can be disrupted. In this way, Seal special forces assassins can be brain wiped after a mission, so they have no idea of the target they killed. Using hypnosis, false memories can then be planted in the brain, so the gap left by the real memory is papered over.

The latest advance in electronic mind control were discussed in my previous articles in Nexus, but for those who missed the ESP of Espionage, this equipment uses special types of microwave beams called MASERs. These are the laser equivalent of microwave beams. These MASER beams have been used to develop something called synthetic telepathy. This is the ability to read peoples' minds from a distance. Electronic scanning of victims' brains by monitoring the electromagnetic (EM) emissions from peoples' brains and using amongst other things, the brain waves (as measured on an EEG), to read the victim's subvocalised thoughts.

Head of US Special Forces Major-General Schaknow, talked about synthetic telepathy during a lecture in July 1992 at Fort Bragg North Carolina. The US military is hard at work perfecting synthetic telepathy. In synthetic telepathy, the weak electromagnetic signals in the brain associated with subvocalised thought, are connected to a computer by use of electrodes, or in more advanced mechanisms by MASER beams. Sophisticated computer systems have learnt to read the subvocalised thoughts in the brain, by associating a specific brain excitation potential, with a particular word. In this case, only one specific language can be decoded, as each word in a language has a specific set of frequencies that must be discovered. Once the donkey work of finding the specific frequencies for all the words in a language has been programmed into a super computer, which can carry out massive parallel processing, fuzzy logic software is used to match this with real world excitation potential associated with subvocalised thought obtained from thousands of abductees, who are used to calibrate the synthetic telepathy devices. GCHQ Cheltenham, the intelligence gathering arm of MI5, possess the advanced computer systems needed for synthetic telepathy.

Synthetic telepathy detects the l5Hz, 5 milliwatt auditory cortex brain emissions, that are linked with the excitation potentials in the brain associated with subvocalised thought. New technology, involving low frequency microwaves and RF, has enabled devices to be built which can scan through walls and look inside peoples' bodies like X-rays. This enables security personnel to see a target in his own home and to track him throughout the house. Further to this, being able to see inside the victim's head, would allow computer controlled targeting of specific brain centres in the victim's brain, even when he was walking around the house.

A scan of the specific brain emissions given off when the victim subvocalises using an array of pulsed frequency MASERs fired at the specific brain centres of the subversive, while he resides in his own home, enables the victim to be scanned. By firing an array of ELF pulse modulated MASERs, which scan up and down the window of frequency emissions given off by subvocalised thought, interference effects can be measured in the MASER beam. The victim's ELF brain emissions will interact constructively or destructively with the pulsed frequency MASER carrying ELF in the ELF window associated with subvocalised thoughts. If we fire an array of pulsed MASERs, which are out of phase with each other, extraneous noise can be filtered out in the digital domain. Since the converging ELF modulated MASERs are being effected by the low level emissions in the victim's brain, the shifts in the ELF pulsed signal going into the subversive's brain can be detected. A simplistic version of this would be the LASER beam shone at the window of the person that is being bugged. The vibrations in the window cause modulations in the LASER that can be converted into electrical signals and hence into sound. In this way the subvocalised thoughts in the victim's brain can be read. Having already built up a library of excitation potential signatures for differing words and groupings of words, a sophisticated computer can begin to decode the emission signatures into word streams. In this way the subvocalised thoughts of the victim can be stored in the memory of a supercomputer and analysed to give a read out of what the target is thinking..

Using ELF audiograms carried by a single pulse-modulated Maser, subvocalised thoughts can be placed in the victim's brain. This enables UK synthetic telepathy operators the ability to enter into conversations with the subversive to drive him mad or to bring up key words which will get the victim thinking about the information they wish to find. Visual cortex excitation potentials can also be broadcast into the victim's brain so that illusory images can be projected into their brain to drive them mad, or to programme them to commit suicide.

My research has led me to uncover a truly nation-wide mind control weapon system. Each UK police station is equipped with a vast array of microwave antennae. The Sussex Police headquarters has a two hundred foot antenna. The building is surrounded by a fence and is off limits to the public. This microwave complex sits in the middle of a council housing estate, which means the people in this area are being bathed in low level microwaves. New research has shown that low level microwaves give mice cancer, since the emitters tested by the scientists, were the new ultra safe mobile phones which give of much smaller intensities than the police antennae, the Police microwave system is a serious health hazard. It seems that low level microwave radiation excites the hydrogen bonds in the cell and can interfere with meiosis. This causes cell division to go wrong, which leads to cancerous cells and hence tumours.

Secondly, the police have been granted the exclusive use of the 450 MHz microwave frequency range. This is exactly the frequency used by Dr Ross Adey, the CIA mind control expert, in his experiments on behavioural modification. It seems the police have the exclusive use of this mind control frequency and a vast array of antennae to broadcast this frequency all over the country. Very useful for mass mind control in times of emergency. Adey found that by using 0.75mW/cm2 intensity of pulse modulated microwave at a frequency of 450 MHz, it was discovered that an ELF modulation could be used to control all aspects of human behaviour. The Sussex police headquarters is connected to CCTV, closed circuit television cameras throughout the town. Some of these cameras have microwave telemetry devices that could easily be used to broadcast this frequency. The large antennae that bracket the town could also be used.

The most insidious aspect of this, is that the entire mobile phone network could easily be used to control the behaviour of the phone users. By use of my microwave detector, I have found that mobile phones of the newer type, give off a pulse modulated microwave signal of around 0.75mW/cm2 at the earpiece. This may be coincidence, but it is exactly the intensity required form behavioural control as found by Dr Ross Adey, the pioneer of microwave mind control. So in theory, an ELF signal could be added to the microwave network to feed a precise behavioural pattern into every mobile phone user in the UK. If their were widespread riots, the ability to broadcast behavioural stimuli to mollify all the mobile phone users in the country would prove useful. Since mobile phone users are generally middle class, it means authority has a useful method of controlling the behaviour of the key voters. Microwave carrier beams are perfect for transmitting the excitation potential of docility to the phone user to keep them servile in times of trouble. When no ELF signal is broadcast the phone acts in a completely different manner on behaviour in humans. In this case the microwave phones causes the neurones to release calcium ions which makes the user tired irritable and when stresses likely to emotional outbursts such as road rage.

In Brighton, the local MI5 headquarters has a large microwave array on its roof. Secret bunkers in the area also have large microwave arrays above them. It is child‘s play to transmit an ELF modulated signal to be broadcast by the entire mobile phone network - if need be. By this means the entire mobile phone users can be behaviourally modified. At the cost of developing cancer from low level microwave exposure from the phones they constantly use, stressing the neural network by constant calcium ion efflux and interference with bioelectric fields.

It seems strange that a few milliCuries of ionising radiation will get the National Radiological Protection Board excited, whilst high intensity cancer inducing non ionising microwave radiation, goes unchecked. So high are levels near transmitters, that litter the countryside, that light bulbs will explode near them. If the intelligence community is using microwaves on a large scale as mass mind control weapons, then the NRPB‘s silence is easily explainable. To add to this, the numerous microwave detectors that were cheaply available to check leakage from microwave ovens are no longer made by any company in the country. It seems the UK authorities do not want the population to be able to detect when they are being microwave.

In conclusion, it can be seen that the UK intelligence and police, have a dizzy array of high-tech mind control devices. They regularly target their own populations and thousands of people are made ill by microwave weapons. With the advent of synthetic telepathy, ‚CCTV of the mind‘ becomes a reality.

With the election of a New Labour government unaware of microwave weapons and untainted, as they had no part in their development and deployment, it is certain that Tony Blair‘s government will outlaw these abhorrent microwave weapons - as they have done land mines. The only problem will be convincing the Labour government that MI5‘s microwave communication equipment is in fact microwave mind control weaponry. With the total secrecy the MI5 organisation operates under, one can be sure they will be mendacious as to how their £200 million pound budget is used to hone their leading edge microwave mind control torture weapons that are used on the public. Even more disturbing is the use of EMP and microwave weapons by the police on anyone researching into this area.

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Dr Ross Adey, formally of the Brain Research centre at the University of Southern California, Los Angeles, now at Loma Linda University Medical School, Loma Linda, California. He worked on the CIA Pandora Project and was concerned with inducing specific behaviour modification by electromagnetic means as well as induction of calcium efflux events to interfere with brain function - the so called ‚confusion weaponry‘.
C.S. Blackman is a researcher who worked in the US on theoretical research that underlies the electronic RMCT devices now deployed world-wide.
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Nexus Vol 3 No 6, Remote Viewing: The ESP of Espionage, by T Rifat. Nexus Vol 4 No 1 The Esp of Espionage, Part 1, by T Rifat.

Nexus Vol 4 No 2, The Esp of Espionage, by T Rifat. These three articles cover the theory of RV, RI and ESP in very great detail. recommended for the serious RV/RI student. For more information contact the author.

Alien Encounters No 1 1 Alien and Government Mind control, T Rifat. Sightings Nol2, Losing Your Mind! Mind control Technology, by T Rifat. UFO Reality No 8, Mind Control, Big Brother Is All In The Mind, T Rifat. Enigma 6, Mind Control, by T Rifat.

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“WE FORGET THAT THE WATER CYCLE AND THE LIFE CYCLE ARE ONE.”

Jacques Cousteau

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This companion guide is intended to help you understand the key principles that enable divers to practice their sport enjoyably and safely. It is not a training manual, and it is recommended that you read this guide in conjunction with an accredited course of diving instruction and official training literature. Diving centers around the world will ask to see evidence of formal qualifications before allowing you to rent equipment, have your tank filled, or join a diving trip. The authors and publishers have made every effort to ensure that the information in this book is correct at press time. However, they accept no responsibility for any injury, accident, or inconvenience sustained by any person using this book or following advice presented in it.

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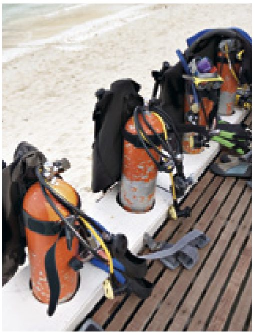

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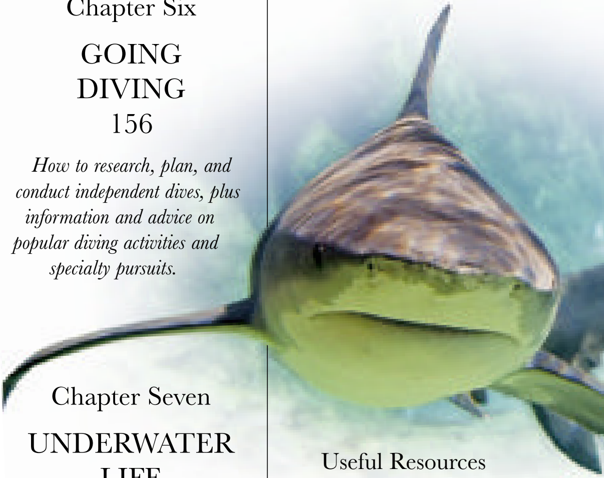

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THE IDEA THAT PEOPLE COULD BREATHE UNDERWATER WAS ONCE A FANTASY. BUT TODAY, DIVING HAS LEFT THE REALMS OF IMAGINATION AND GROWN INTO A WORLDWIDE SPORT WITH MILLIONS OF FOLLOWERS. THOSE WHO TAKE PART IN IT ARE GRANTED PRIVILEGED ACCESS TO A MYSTERIOUS YET BEAUTIFUL WORLD, AND EVERY DIVE IS AN ADVENTURE INTO THE UNKNOWN.

Since prehistoric times, people have been drawn to explore the incredible world that lies underwater, whether in pursuit of food or lost riches, or from sheer inquisitiveness. There is evidence, for example, that people were holding their breath and diving for shellfish by about 3,000 BCE (*see p.22*).

THE DAWN OF AN ERA
Diving pioneer Jacques Cousteau (*right*) models early scuba equipment.

Despite this long relationship with the undersea world, the human body is not designed to remain underwater for prolonged periods of time. Only comparatively recently, with the development of rudimentary diving bells and helmets from the Middle Ages onward, did it become possible to stay submerged for longer than a single breath allows. During the 18th and 19th centuries, there were remarkable advances in diving technology, such as full diving suits supplied by air pumped from the surface. These advances, which were often spurred on by the lucrative rewards of salvage work, extended dive times and gave access to ever greater depths.

The invention of the Aqua Lung in the mid-20th century permitted divers to explore the depths of the world's oceans freely for the first time. This truly remarkable apparatus enables people to take their own air supply with them when they dive, eliminating the need to be connected to the surface by an airline. The system that evolved from it—scuba—is today widely used in recreational and professional diving.

GLOBAL APPEAL

As scuba technology became cheaper, diving opened up to the general public. What was once the realm of experts and professionals gradually became a sport with global appeal. Even in countries

WRECK DIVING
Divers inspect a wreck in tropical waters. Such underwater relics offer a glimpse into maritime history, and are home to colonies of sea life.

A NEW GENERATION
Trainee instructors receive a group briefing at a dive center in Egypt. For many, a job in diving represents the ultimate career move.

without a coastline, you will find divers who spend time underwater at inland sites, such as lakes and rivers, or who travel abroad to experience the beauty of the oceans. Once you are qualified, you can dive virtually anywhere in the world. Language is no barrier underwater, since divers use standard hand signals that are understood internationally.

It is difficult to estimate how many divers there are worldwide, but well over a million people qualify each year. Since its inception in 1966, over 13 million divers around the world have been certified by PADI (the Professional Association of Diving Instructors), and PADI is just one of many training agencies. Diving is one of the fastest-growing hobbies in the world today.

SILENT ODYSSEY
Clown fish shelter in an anemone while a diver swims by. The underwater world can be a uniquely serene environment.

THE WORLD'S OCEANS

Covering approximately 71 percent of the Earth's surface, or 140 million sq miles (361 million sq km), the vast size of the world's oceans is difficult to comprehend. The total volume of sea water is about 322,300,000 cu miles (1,347,000,000 cu km), equivalent to around 97 percent of all the Earth's water—the rest exists as glaciers, rivers, lakes, groundwater, and atmospheric vapor. The average depth of the world's oceans is 2.3 miles (3.8 km); the deepest point is in the Pacific Ocean's Mariana Trench, where the seabed plunges to a depth of nearly 7 miles (11 km). With only about 5 percent of the ocean floor having been mapped in detail, we know more about the surface of the Moon than the bottom of our oceans.

The oceans teem with wildlife, from giant kelp and the mighty blue whale (the largest animal alive) to microscopic plankton that form the basis of the oceanic food chain. Scientists estimate that there may be between 500,000 and 10 million marine species yet to be discovered. While much of the oceans' biological wealth is concentrated between continental shelves and coastal margins, the open sea also abounds with life. Even the mud on the floor of the Mariana Trench is home to single-celled organisms called foraminiferans.

NATURAL WONDERS
Diving can lead to encounters with many intriguing and beautiful marine creatures, such as this leafy sea dragon.

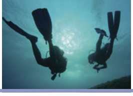

GETTING READY
Buddy pairs prepare for a beach dive. By working in pairs, donning awkward gear becomes considerably easier and safer.

EXPLORING THE UNDERWATER WORLD

What will I see? What will it feel like? Will I feel claustrophobic? These are all questions you will ask as a novice diver entering the underwater world for the first time. Everyone feels different about being underwater; some people take to it immediately, but others need more training and experience before they feel at ease. Either way, it is an unforgettable experience. There is the initial thrill of being able to breathe underwater, and also the novelty of moving freely in three dimensions, thanks to the buoyancy provided by the water, which is a denser medium than air. This same buoyancy can enable those with mobility problems on land to feel relaxed and move more easily in water, and give what some divers call a "womblike" experience.

Imagine the thrill of being the first person to see a sunken ship or coral reef, or of coming face to face with a wild dolphin, or diving under ice. Whatever excites you—whether it be encounters with fascinating creatures, investigating shipwrecks, or just diving into the unknown—you will not fail to be satisfied by what the oceans have to offer.

CAPTURING THE MOMENT
Underwater photography is an absorbing activity in its own right, and offers the chance to record your dive experiences for posterity.

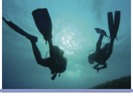

CONSERVATION WORK
A diver jots down his observations of marine life at a conservation site. Divers can play an active role as "stewards of the seas."

BUT IS IT SAFE?

Many people new to the sport worry about the safety aspect. It is true that a small number of divers die every year while pursuing their sport. The majority of these incidents are not due to equipment failure, as some people might suppose, but rather to inadequate training, diving in extreme conditions, or diving beyond the limits of safe practice.

Diving today is safer than it has ever been. If you undertake the correct training and adhere to recommended safety procedures, you will rarely encounter problems. Dive training is thorough, and a great emphasis is placed on rescue skills and the importance of diving in a buddy pair (*see pp.110–11*). Good communication with your buddy is essential, as most minor difficulties can be easily resolved with the help of another diver.

NEW SKILLS, NEW DIRECTIONS

You may find that you enjoy diving so much that you want to pursue it beyond the hobby level. Some people use their underwater knowledge and skills for voluntary or charitable work, or in a full-time career. The directions in which diving can take you are endless, from environmental projects, marine archaeology, historical research, and working with disabled divers, to filming and photography, and even training to be a diving instructor yourself.

RECOGNITION GUIDE
A pair of divers consult a species identification slate. Becoming familiar with marine life, in all its fascinating variety, is part of the fun.

RESPECT AND RESPONSIBILITY

Ask any group of divers what inspired them to take up the sport and you will hear a range of different answers, from a love of the sea to a desire to challenge their personal limits. One thing they all have in common is the fact that they return again and again to the water—the magical environment that Jacques Cousteau (*see p.26*) described as the "Silent World." Divers should be custodians of the world's oceans, and respect what they contain: "take only pictures and leave only bubbles" is a good maxim for low-impact diving.

Many of the marine ecosystems around the world are today in decline. Hopefully education and investment will help to reverse this trend, so the divers of tomorrow will have healthy oceans to explore. By taking part in conservation work and diving responsibly, you can become a force for the good in preserving the oceans' natural treasures.

DISCUSSING A DIVE
Diving is a social sport, and the diving community is a supportive one. Experienced divers are often willing to offer advice to novices.

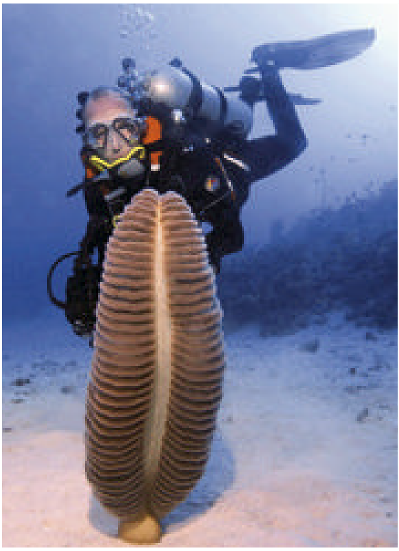

MARINE LIFE
A diver examines a beautiful and delicate sea pen—a colonial polyp organism—growing out of white sand next to the Great Barrier Reef.

GLIMPSE OF A GIANT
Anticipation of a dive can be almost as thrilling as the dive itself. Sighting large animals, such as rays, from the boat adds to the excitement.

UNDERSEA GARDEN
Coral thrives in clear, shallow water, because it needs plenty of light to live. Such reefs are an ideal environment to explore while snorkeling.

REEF SAFARI
Coral reefs are home to diverse marine species, offering sheltered areas for sedentary animals, and feeding grounds for predators and foragers.

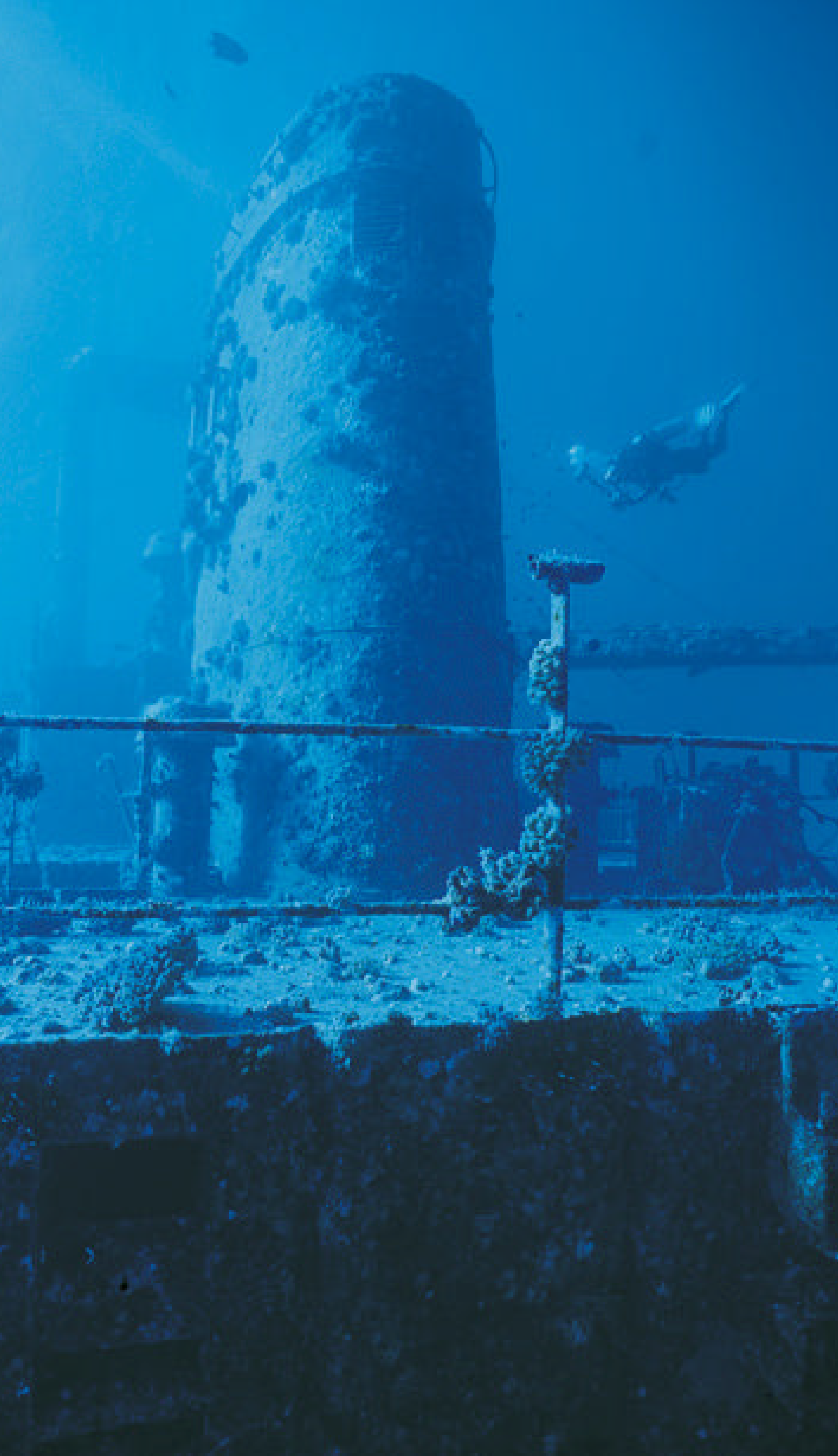

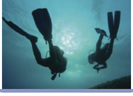

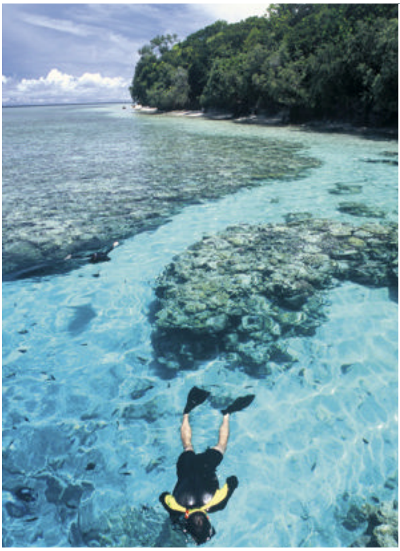

CRYSTAL WATERS
Exploring the shallows above reefs is a perfect pastime between dives. Many thousands of fascinating marine species live in these areas.

CLOUDS OF FISH
Shoals of orange antheas are a common sight on the reefs of the Indo-Pacific. They appear to move as one when startled.

FROM WRECK TO REEF
In tropical waters, a wreck provides a firm platform for coral growth. Wrecks are swiftly colonized by marine life, creating eerie reefs.

LONE VOYAGER
If approached cautiously and respectfully, turtles will happily tolerate the presence of divers. Many species migrate for thousands of miles.

History of diving

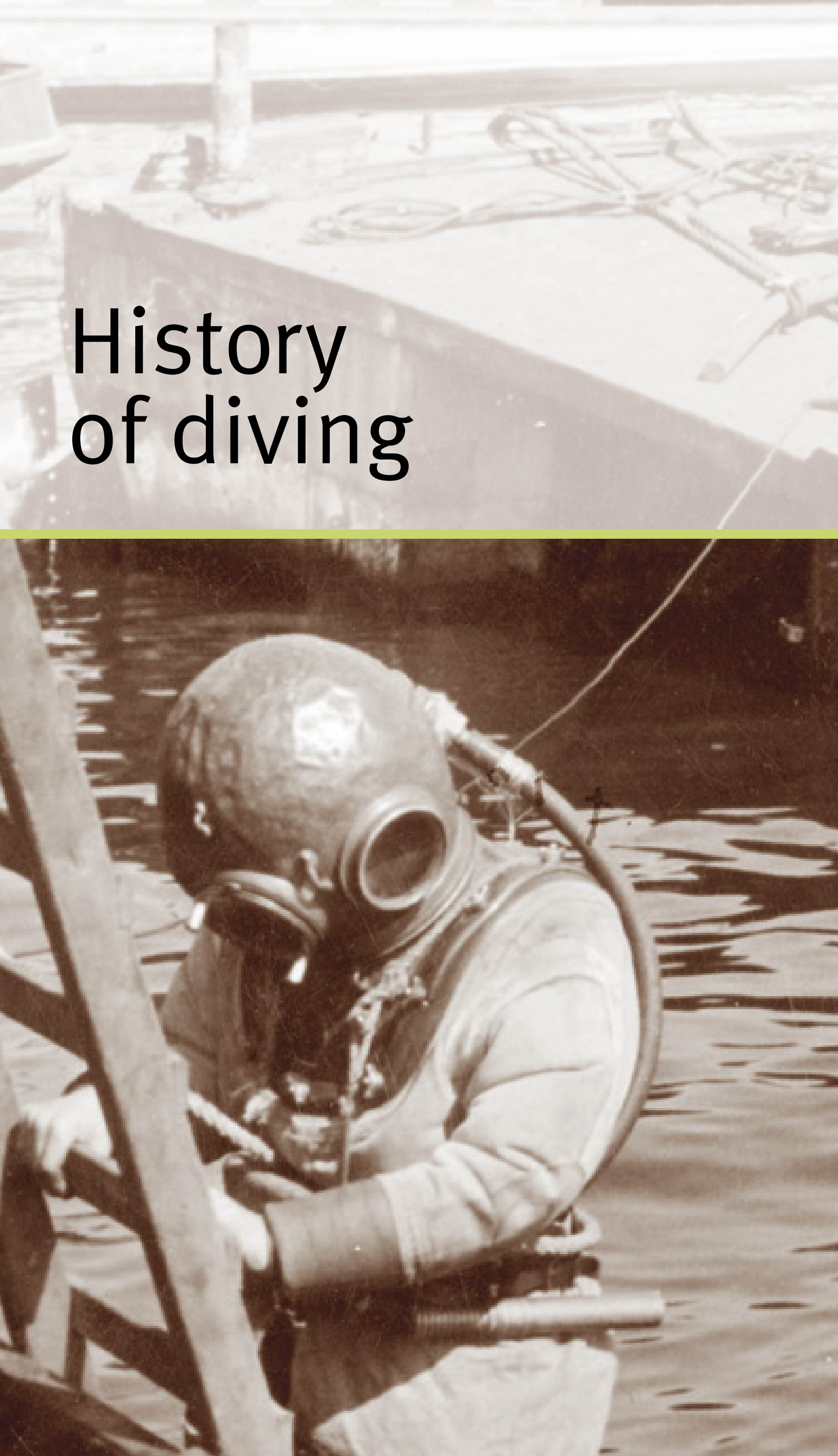

Diving through the ages

The search to free divers from the limitations of breath-holding began in ancient times with the use of reed snorkels. Developing from diving bells and diving suits supplied with air from the surface, it evolved into modern scuba, in which divers carry their own air supply.

EARLY DIVERS AND DIVING BELLS

It is hard to trace the origins of diving, but mummified human remains dating back more than 5,000 years have been found in Chile alongside fish bones and mussel shells. Small growths in the humans' ears, resembling the modern condition called surfer's ear, suggest that these people may have been divers.

Hollow reeds or breathing tubes that extended to the surface were used in ancient times to enable divers to stay submerged for longer. Herodotus recorded that in 500 BCE, a Greek diver named Scyllias used a reed snorkel to swim unnoticed and cut the moorings of Persian ships. Salvage diving was well known in the ancient world, and laws regulating those who dived for treasure were in operation in Greece as early as the 1st century BCE.

An important milestone in helping divers to overcome the restrictions of breath-holding was the invention of an apparatus to hold air underwater. At the siege of Tyre in 332 BCE, Alexander the Great reportedly used such a device, descending beneath the waves in a glass barrel. In the 4th century BCE, Aristotle described a bell-shaped diving chamber that took the form of an overturned cauldron filled with air, in which divers made trips to retrieve objects from the seabed. From the Middle Ages onward, diving equipment became more sophisticated. During the Renaissance, speculative designs for diving suits began to appear, although nearly all

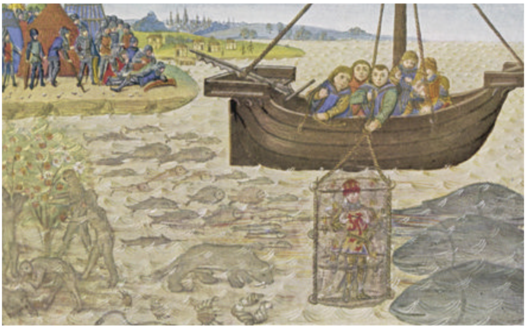

ALEXANDER'S GLASS BARREL
Surprisingly, Alexander the Great used his glass barrel to make observations of fish, rather than as an aid to his military campaigns.

KEY DATES

c. 3000 BCE Early divers collect oysters from the sea bed, developing a bone deformity caused by frequent exposure to cold water—a condition today known as "surfer's ear."

9th/8th century BCE Homer's *Iliad* refers to the use of military divers in the Trojan War, *c.* 1250 BCE.

c.4th century BCE Aristotle records the first use of a diving bell, made from an overturned cauldron filled with air. The diver within could venture out for short periods before returning for air.

3000 BCE

1000 BCE

0

c. 2800 BCE A Sumerian epic detailing the exploits of King Gilgamesh reports that he used weights to sink to the seabed in search of a plant granting immortality.

c. 500 BCE Herodotus recounts the story of Scyllias diving to cut ships' anchor lines on the seabed.

c. 332 BCE Alexander the Great descends to the seabed inside a glass barrel during the siege of Tyre.

would have proved ineffective if put to use. Nonetheless, Spaniard Diego Ufano described the use of leather diving helmets during salvage work in his *Treatise on Artillery*, published in 1612.

Diving bell technology also improved during this period. In 1691, English astronomer Edmund Halley produced an advanced bell that was linked by a hose to weighted barrels of air, which were periodically replenished at the surface. Stale air was vented from the top of the bell. Halley and his bells were widely employed for commercial salvage work.

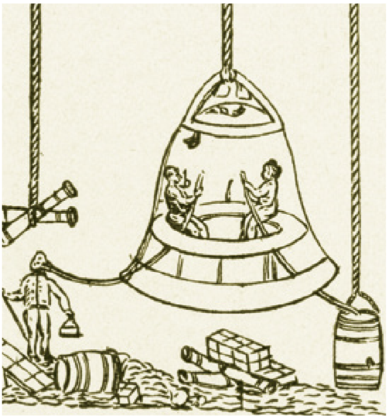

HALLEY'S BELL, 1691
A diver could swim out from under Halley's bell with an air line linked to a smaller bell over his head—a precursor of the modern diving helmet.

DIVING FOR PEARLS
The earliest divers relied only on breath-holding. Using this technique, female divers in Japan have been harvesting pearls for 4,000 years.

1500 Leonardo da Vinci designs equipment for underwater exploration, including snorkel tubes and bags intended to supply a diver with air.

1660 Robert Boyle identifies the relationship between water pressure and gas volumes, furthering the understanding of buoyancy.

1691 Edmund Halley develops a diving bell with a glass top to admit light, and an air replenishment system using barrels lowered from the surface. An umbilical tether supplies air to the bell's operator when venturing outside the bell.

1715 Inventor John Lethbridge uses a modified barrel as a diving vessel to recover salvage from the sea floor. The barrel has a glass viewing port and holes with watertight leather sleeves, through which the operator's arms protrude. The barrel reaches depths of 60 ft (18 m) in trials.

1500 1600 1700 1800

DEVELOPMENT OF THE DIVING SUIT

In 1715, Englishman John Lethbridge devised a pressure-proof wooden diving barrel. Reinforced and clad in leather, the barrel had a glass viewing porthole and arm holes with watertight leather sleeves. Lowered from a ship to depths of 66 ft (20 m), the barrel enabled the diver inside to use his arms freely, pulling his way around a site and retrieving objects. Lethbridge was commissioned by the Dutch East India Company to recover treasure from wrecks around the world using these diving barrels.

The barrel was a forerunner of the armored diving suit. Its usefulness, however, was limited by the inability to replenish the air in the barrel without hauling it back to the surface. Three other developments would be required before diving suits became a reality.

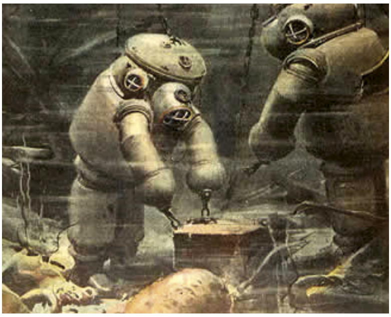

SALVAGE IN ARMORED DIVING SUITS, 1932
Lethbridge's barrel was a precursor of armored diving suits. Initially too clumsy, they now have a niche for specialized work at great depth.

The first of these occurred in 1779, when John Smeaton, another Englishman, used a steam-powered pump to supply air to a diving bell. Air pumps allowed diving bells to stay down considerably longer than before, and would later supply the first diving suits. The next development, by the Scot Charles Mackintosh in 1818, was the production of a rubber-based coating for waterproofing canvas, providing an ideal material for a diving suit. The third innovation, in 1820, was the patenting by British salvage operators John and Charles Dean of a diving helmet—a modified firefighting helmet into which air could be pumped. The helmet rested on the

CAISSON DISEASE

Improved air-pump designs in the mid-19th century made it possible to build underwater chambers in which several men could work at depth. Called caissons, these chambers were ideal for tasks such as building bridge footings and excavating tunnels. Air-pumps delivered sufficient pressure to keep water entirely out of the chamber. However, workers often felt ill at the end of a shift. This was decompression sickness (DCS), or "the bends."

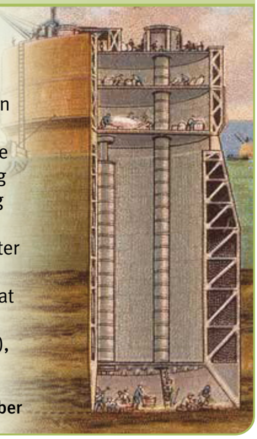

An illustration of a caisson chamber

KEY DATES

1779 Englishman John Smeaton pioneers the use of a pump system to replenish submerged diving bells with fresh air.

1788 German diver Peter Kreeft successfully demonstrates the use of a leather diving helmet in the Baltic sea, witnessed by the king of Sweden.

1800

1818 Naphtha, a coal-tar derivative, is discovered. When mixed with melted rubber, it forms a waterproof coating, and is soon used in the manufacture of lightweight diving suits.

1825

1829 Brothers Charles and John Dean undertake wreck salvage work in Britain using a modified firefighting helmet to supply air during dives to the seabed.

1839 British Army divers develop the practice of diving in pairs during salvage work on the warship *Royal George*.

diver's shoulders, held in place by its own weight, and air passed out from under the edge of the helmet. However, if the diver stumbled, it could easily fill with water.

In the 1840s, German-born inventor Augustus Siebe perfected a "closed dress" design, with the helmet sealed to a waterproof canvas diving suit. An exhaust valve was incorporated into the helmet, which was supplied with air by a pump at the surface. With a few modifications—such as neck and foot weights to help divers stay upright, and thick woolens under the suit to combat cold—Siebe's closed dress design remained standard for deep-sea divers for more than a century.

DECOMPRESSION SICKNESS

In the mid-19th century, the consequences of breathing highly compressed air were being seen among divers and caisson workers, who suffered what we now know as decompression sickness (DCS). In 1878, French physiologist Paul Bert realized that these ill-effects were caused by nitrogen damaging the body during rapid decompression, and recommended that caisson workers and divers return to normal atmospheric conditions slowly.

Nearly 30 years later, Scottish physiologist J. S. Haldane devised the first decompression tables after researching the effects of gas poisoning and DCS. Haldane pushed diving to new limits, sending divers down to 210 ft (65 m) in 1906. The divers avoided DCS by performing decompression stops.

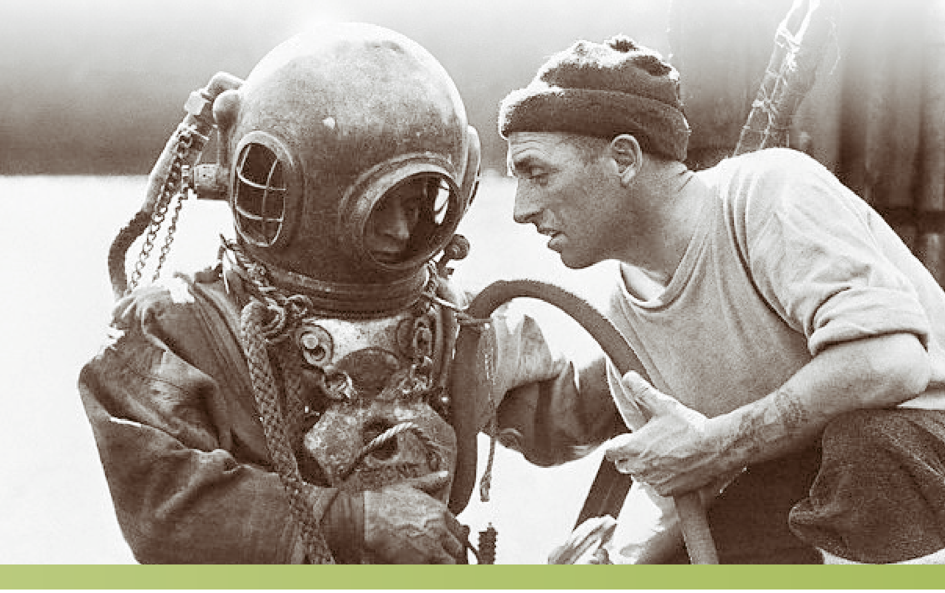

DEEP-SEA DIVING GEAR
The helmet and suit worn by this diver in 1954 are remarkably similar to those designed by Augustus Siebe in 1840.

1850

1865 French inventors Benoit Rouquayrol and August Denayrouze invent compressed-air breathing apparatus that allows short periods of autonomy from surface air supply.

1869 Author Jules Verne popularizes diving with his novel *20,000 Leagues Under the Sea*, in which characters explore the seabed with compressed air breathing apparatus.

1875

1878 French scientist Paul Bert publishes a paper explaining the causes of "Caisson Disease" (later known as Decompression Sickness), a condition associated with breathing pressurized air for long periods of time.

1878 English merchant seaman Henry Fleuss designs the first fully autonomous breathing apparatus. The device uses compressed oxygen as a breathing gas.

1893 The first underwater camera is designed by Frenchman Louis Boutan.

1900

SCUBA DIVING IN THE 1960s
As other manufacturers introduced their own versions of Cousteau and Gagnan's scuba apparatus, the cost of equipment fell, and the 1960s became a boom-time for scuba.

AUTONOMOUS DIVING

In the 19th century, inventors strove to devise self-contained breathing systems that would allow autonomous diving—diving without an air line to the surface. In 1865, Frenchmen Benoit Rouquayrol and Auguste Denayrouze devised a compressed-air tank with a primitive regulator, which adjusted the air flow to meet the diver's breathing requirements. In this "open-circuit" apparatus, air was inhaled from the tank and waste gases vented into the water. Although the diver was tethered to the surface by a hose that pumped air into the tank, he could disconnect the hose for a few minutes, and breathe from the tank alone.

WWII NAVAL DIVER'S MASK
Air from a rebreather was supplied via a hose to a rubber hood.

In 1878, Englishman Henry Fleuss produced the first fully autonomous system, using a breathing bag fed by a copper tank of pressurized oxygen. This was a "closed-circuit" system, or "rebreather," in which the exhaled air is recirculated. Carbon dioxide was removed from the exhaled breath and oxygen injected to replace that consumed by the diver, allowing it to be breathed again.

In 1911, the German firm Draeger began producing oxygen rebreathers, soon developing these to use enriched air (compressed air with added oxygen). Rebreathers were used by naval divers during both world wars, in preference to open-circuit systems, which emitted a telltale stream of bubbles.

SCUBA GEAR

The type of equipment used by divers today first began to take shape in the 1930s and 40s. American Guy Gilpatric created the first modern mask in the early 1930s, and the first diver's snorkel was

KEY DATES

1908 John Scott Haldane, Arthur C. Boycott, and Guybon Damant publish a landmark paper on "compressed air sickness." The first decompression tables are based on this research.

1910

1917 The Draeger company of Germany manufactures an enriched air rebreather (a respirator that recycles exhaled air) that can be operated to a depth of 130 ft (40 m).

1917 The liner *Laurentic* sinks off the Irish coast after hitting a mine. Its cargo includes 35 tons of gold bullion. Royal Navy salvage divers succeed in recovering 3,189 ingots from the wreck over a period of seven years.

1920

1925 French naval officer Yves Le Prieur develops an open-circuit (non-recycling) compressed-air respirator—a forerunner of modern scuba.

JACQUES COUSTEAU
From the 1950s to the 1970s, Cousteau's groundbreaking films and TV programs revealed the wonders of the deep to a worldwide audience, and persuaded many to start diving.

developed by Englishman Steve Butler at about the same time. Fins were patented in France by Louis de Corlieu in 1933.

Open-circuit scuba (Self-Contained Underwater Breathing Apparatus) as we know it today was pioneered by two Frenchmen, engineer Emile Gagnan and naval officer Jacques Cousteau. In 1943, they combined a two-stage regulator, from which the diver breathed, with a high-pressure air tank. The regulator supplied air to the diver on the slightest intake of breath. Other self-contained breathing apparatus used at the time either supplied air continuously or had to be manually turned on and off. (The primitive regulator design of Rouquayrol and Denayrouze had fallen out of use.) Efficient, reliable, and comparatively cheap to produce, Cousteau and Gagnan's "Aqua Lung," as it was known, went on sale in France in 1946. By the early 1950s, Aqua Lungs were available throughout the world.

The first commercially successful buoyancy compensator, which allowed divers to adjust their buoyancy in the water, was patented in 1961 by Frenchman Maurice Fenzy.

1930 American William Beebe descends to a depth of 1,426 ft (435 m) in a bathysphere—a tethered diving vessel launched from a ship.

1933 French inventor Louis de Corlieu patents rubber fins to aid underwater swimming.

1938 American Guy Gilpatric's book *The Complete Goggler* popularizes spear-fishing underwater.

1940

1941 Italian navy divers use rebreathers to mount underwater attacks on moored Allied shipping during World War II.

1942 Jacques Cousteau and Emile Gagnan design and test the Aqua Lung compressed-air breathing apparatus. The design's ease of use helps to encourage recreational diving.

1948 Aqua Lung first exported to the US.

1950

DIVING TODAY

The Aqua Lung caused a revolution in diving, making it accessible to the public for the first time. In 1950, there were some 30,000 scuba divers globally; ten years later, there were in excess of one million. There are now estimated to be tens of millions of divers worldwide.

Modern diving equipment seems a world away from that used by Jacques Cousteau, yet the basics remain the same. Like Cousteau, we dive with a tank of compressed air, and use a mask, snorkel, and fins. Today, however, there is also a host of other equipment and gadgets to make diving even safer and more enjoyable. Mixed-gas diving (*see pp.194–95*), which allows deeper and longer dives, is becoming increasingly commonplace, and there are computers that give us data such as depth, water temperature, dive times, and breathing rate. Some dive computers even allow divers to play games during lengthy

DIVING FOR PLEASURE
Two divers prepare to explore beneath the surface of a tropical lagoon. The rebreather units on their backs allow very long dive times.

KEY DATES

1950

1951 *Skin Diver* magazine goes on sale in the US, and plays a central role in popularizing diving.

1953 Dr. Hugh Bradner develops the first neoprene wetsuit for the US Navy.

1956 Jacques Cousteau's diving film *The Silent World* (based on his book of the same name) wins an Academy Award.

1959 The first nationally organized scuba training program is established in the United States by the YMCA.

1960

1961 Frenchman Maurice Fenzy patents an inflatable safety jacket for divers, which becomes the first commercially available buoyancy compensator (BC).

1967 American Bob Croft is the first man to free dive (breath-hold dive) below 200 ft (60 m).

HUMAN TORPEDO
A diver clings to a battery-powered propulsion unit. These devices enable divers to explore large areas in a single dive.

decompression stops. Scooters eliminate the need to use our legs for propulsion, and waterproof MP3 players enable us to listen to music underwater. It may not be long before divers can take cell phones underwater and send text messages and photographs from the bottom of the sea.

THE FUTURE OF DIVING

Many divers believe that the future of diving lies with using rebreathers (*see pp.82–83*). Once used only commercially, these devices are now available to leisure divers and are becoming increasingly commonplace. Rebreathers greatly extend the time divers can spend at the bottom, and reduce the need for multiple tanks of breathing gas to be taken on a dive. Fifty years from now, it is possible that we may all be diving with sophisticated rebreathers.

There is also increasing interest in submersible vehicles for the private market. Billed as the ultimate rich person's toy, such craft may open up extended explorations of the seabed to their owners. Diving limits are also being extended every year. In the sport of free diving, where competitors use no scuba gear but simply hold their breath (*see pp.190–91*), records of more than 500 ft (150 m) have now been set. Scuba divers have reached similar depths breathing compressed air, and have descended to below 1,100 ft (330 m) using mixed gases. Will we one day be able to dive to the bottom of the Pacific Ocean—6.8 miles (11 km) underwater? Only time will tell, but it would be surprising if advances in technology and our understanding of the human body did not grant some extension of today's limits.

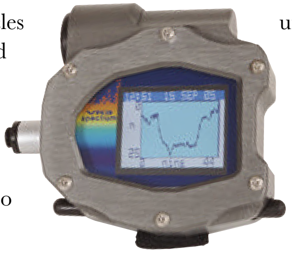

DIGITAL DIVE PLANNING
Sophisticated computers record and process vital dive information.

1968 Americans Neal Watson and John Gruener dive to 437 ft (133 m) breathing compressed air.

1970

1971 Scubapro markets a "stabilization jacket" for divers. Its waistcoat-style design sets the trend for modern BCs.

1979 Sylvia Earl walks untethered on the sea floor at a depth of 1,250 ft (381 m) in a special pressure suit.

1980

1980 Divers Alert Network, a nonprofit organization for promoting dive safety, is founded.

1983 The first commercially available dive computer, the Orca Edge, goes on sale.

1990

1993 Italian free diver Umberto Pelizzari sets a depth record of 403 ft (123 m).

1999 Briton Mark Andrews dives to 500 ft (152 m) on air.

2000

2003 Briton Mark Ellyat dives to 1,024 ft (313 m) on Trimix scuba.

Getting started

Introduction

Learning to dive is an adventure in itself. There are many different training agencies offering basic scuba qualifications, with branches in nearly all parts of the world. Though dive tuition makes demands on both your body and mind, it can be a very rewarding experience.

LEARNING TO DIVE

Diving is a safe sport provided that you have undergone formal training before taking to the water. It would be extremely foolhardy to proceed on your own, as there is no substitute for a proven program of instruction. Moreover, no dive center or charter boat will take you diving without recognized qualifications. Considerations of safety apart, you will feel more confident, relaxed, and prepared for the underwater experience if you are fully trained. Basic "open water" training qualifies you to go diving without supervision. It will not, however, teach you to dive under ice, in a cave, or beyond certain depth limits. For these activities, you need to attain further qualifications and gain more experience.

WHO CAN BE A DIVER?

Practically anyone can learn to dive, but there are a few basic health requirements. For instance, if you suffer from asthma, you will need to consult your doctor beforehand, although the condition need not be a barrier. Diving is not a strenuous sport, but you will encounter situations that require you to be reasonably fit:

EXPERT GUIDANCE
During basic training, the instructor will tutor students in how scuba equipment works, as well as its use and assembly.

lifting yourself out of the water onto a boat, for example. Diving when pregnant is not advisable, but it is possible to pick up the theory and basic snorkeling skills during pregnancy, and continue with full training after your child is born.

There are special junior courses for those under 14 who wish to learn to dive, and advancing years are not necessarily a barrier to learning either, given a fair level of fitness and approval from a doctor. Many disabled people also enjoy the sport of diving, and dive training programs have been adapted to embrace a wide range of disabilities.

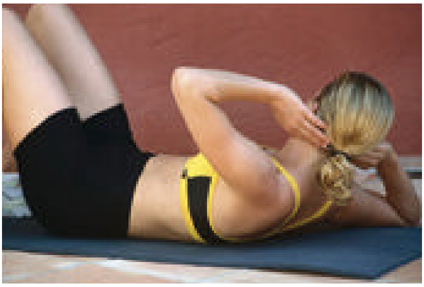

FITNESS FOR DIVING
While it is not necessary to be an athlete to go diving, a basic level of fitness is required (*see p.150*) for both safety and enjoyment.

HOW MUCH WILL IT COST?

Taking up a new hobby always involves a degree of investment, and diving is no exception. New diving equipment can be expensive, but second-hand gear is widely available, though it should be serviced before use. Equipment is almost always available to rent from dive centers and shops. and it is advisable to try out a few different pieces of gear before investing in your own.

Dive training is fairly expensive, but learning with a club can make it cheaper, and most training organizations offer trial lessons to help you decide if you enjoy diving before paying for a full course of instruction.

NOVICE IN SHALLOW WATER
An instructor guides a student through his first dive, maintaining contact the whole time to ensure a safe learning experience.

Where to learn

There are a number of different diving organizations around the world with whom you can train. Other divers may recommend the one they learned with—which is not a bad start—but investigate all the training agencies, since each offers a different approach to tuition.

TAKING THE PLUNGE

The first question you should consider is whether to learn to dive with a school or with a club. A diving school (confusingly, also called a diving club in mainland Europe) is a commercial venture—you pay to learn to dive. A diving club is a nonprofit venture where members donate their time training other members. You might think that a school sounds like a more professional option, but in truth, instructors in clubs are equally highly trained, and the fact that they are giving their time free of charge says much about their love for diving and desire to pass on their knowledge to others. Clubs also add a social dimension to learning, arrange talks and trips both at home and abroad, and may offer a longer-term framework for gaining diving experience. However, clubs tend to run training sessions on just one day of the week, and it can take a few months to become qualified.

LEARNING THE BASICS
Be aware that courses abroad may have an instructor whose first language is not yours.

By contrast, diving schools offer greater flexibility, and offer you the chance to learn the basics at home,

possibly over a couple of weekends, and then complete the rest of your course in warmer waters on vacation. Alternatively, they allow you to complete your training beforehand (and on your own schedule), then depart for your trip abroad as a fully qualified diver.

TRAINING ORGANIZATIONS

The world's largest training organization is PADI (Professional Association of Diving Instructors). They operate all over the world, and most dive sites you visit around the globe will be affiliated to PADI. Several other training organizations are prominent in the US, including NAUI (National Association of Underwater Instructors) and SSI (Scuba Schools International).

In the UK, most diving clubs are affiliated to BSAC (British Sub-Aqua Club), and their training is tailored to the waters around the UK. You may also come across the SAA (Sub-Aqua Association) and the SSAC (Scottish Sub-Aqua Club); the CFT/IUC (Irish Underwater Council) in Ireland; and CMAS (Confédération Mondiale des Activités Subaquatiques) in Europe. There are other organizations for more advanced diving (*see pp.329–30*).

CLUB BOAT WITH DIVERS
Diving clubs usually pool resources to arrange group trips that can cement long-lasting and rewarding dive buddy relationships.

THE CHOICE IS YOURS

For the beginner, the various training agencies offer broadly similar courses in terms of content and standards. The best course of action is to take advice from experienced divers and do what suits you. Always ask to see a trainer's qualifications before starting a course, and try to get a recommendation for a diving school or club before enrolling.

RESORT INSTRUCTOR WITH TRAINEES
Many people choose to learn diving on vacation, and there are thousands of diving schools around the world that offer training at all levels of ability.

Basic training

Learning to dive involves gaining some knowledge of essential theory as well as training in practical skills. Sometimes these skills are practiced in a pool before getting into open water but, depending on where you learn, they can be taught in a lagoon or in the shallows.

MASTERING THE THEORY

Your dive training will always start with theory. You will be taught about basic diving equipment, the principles involved in breathing gas at depth and under pressure, safety skills, communication, navigation, and much, much more. You will learn to carry out simple calculations relating to the physics of diving. Don't worry—none of the theory is difficult, but it does demand a few hours of study.

Dive agencies run this part of the training in different ways—some rely on traditional classroom teaching, others present materials on DVD or online—so choose the way that suits you best. In all cases, you will be provided with a reference manual containing all the material you need to know.

GOING DEEPER INTO DIVING
Learning to dive involves understanding some of the theory that underpins the sport. This training is given either in classes or one-to-one tutorials.

GETTING WET

Basic practical skills are taught in "confined water"—usually a swimming pool or shallow water just off a beach. You will be expected to pass a simple swimming test to show your instructor

TAKING THE PLUNGE
A trainee learns the basics in safe, shallow waters, under the guidance of an instructor.

that you are safe and comfortable in the water before they begin to teach the fundamental skills (*see below*). After this initial stage, you will progress into open water, where you will undertake a few introductory dives in order to get used to diving in deeper water and build your confidence to swim in the open sea.

SUITING UP
Trainees are not expected to buy a full set of equipment. Gear can be rented from most diving schools.

STAYING SAFE

Recreational diving is an extremely safe activity as long as you receive the correct training and keep your skills up to date. Choosing the right training agency, course, and instructor is therefore vital. Most instructors are highly trained and dedicated to their job, but there will always be a few "bad apples" in any profession, so take advice from friends, diving clubs, and specialty magazines and websites before you enroll. Do not be afraid to ask questions during your training, simple as they may seem; you can even request a different instructor if you do not feel comfortable.

Many people take up diving as a vacation activity and only get a chance to practice once or twice a year. If you have not dived for a while, it is a good idea to take a refresher course, and carry out a trial dive (with your buddy) to check all your gear and your skills before venturing into deeper water.

BUILDING CONFIDENCE

Fundamental skills and safety procedures are taught in the security of confined water before you can venture into the open sea. The abilities you need to master include buoyancy control and finning techniques, out-of-air procedures, removing, recovering, and replacing your regulator, and clearing your ears and your mask underwater (*right*)—a common source of apprehension among novice divers.

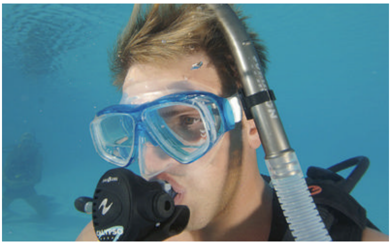

1 **Water can accumulate** in your mask during diving, usually in small amounts. With practice, even a fully flooded mask can be cleared without difficulty.

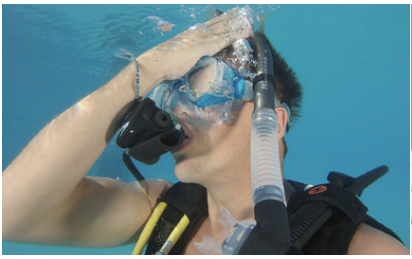

2 **Blow clear** by tilting your head back and pressing in the mask's upper edge. Exhale through your nose. The water should be forced out, escaping under the mask's lower skirt.

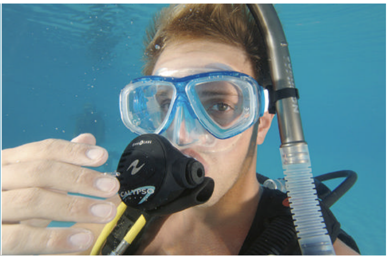

3 **Check that your mask** is free of water. If there is any remaining, repeat the process. This simple operation is quite normal during diving, and will quickly become second nature.

Specialized training

Diving is an inclusive, accessible sport, and there are many training options for children and the disabled. If you are already qualified but wish to undertake further training, there are numerous courses of advanced tuition to make you a better and more confident diver.

TAILORED COURSES

Though standard open-water diving qualifications have a minimum age requirement (usually 14), children are now well catered to in diving. This means it can be a family sport—not one that is just for adults. For younger children, introductory courses are available, such as PADI's Bubble-Maker program, or diving clubs for children, such as the Scuba Ranger organization. These programs are designed to teach basic skills that lead to full open- water diving qualifications. Junior diving permits, available for children between 10 and 14 years old, are similar to basic open-water qualifications, but place special restrictions on the maximum depth to which the holder can dive.

Advances in training techniques mean that more disabled people are able to take up diving than ever before.

LIBERATING EXPERIENCE
A disabled diver undergoes training in a pool, with guidance from specially trained instructors.

BUBBLE-MAKER TRAINING
Special courses for children are taught by most schools. Clubs also offer training for budding junior divers.

BECOMING INDEPENDENT
Your experience and judgment will build as qualifications are gained. Comprehensive training makes for a confident, safe diver.

Diving makes you effectively weightless, and the freedom of movement this offers makes the sport especially beneficial for those with limited mobility. The only condition that is an automatic bar to becoming a diver is epilepsy, due to the risk of seizures while submerged. However, blindness, paraplegia, cerebral palsy, and many other conditions have all been accommodated by adaptive training programs. The general rule is that if you have been cleared to dive by a doctor specializing in dive medicine, then training can begin.

DEEPER INTO DIVING

All the major training organizations offer courses that aim to take you a step onward from the basic open-water qualification. Such courses serve to refine your basic skills and introduce you to new challenges, such as deep diving, or diving in conditions of low visibility. They will also cover rescue and survival skills, and can be the first step on the path toward becoming a diving instructor. In addition to these skills development courses, there are also numerous specialty courses, which teach the technique and theory of activities such as cave diving, wreck diving, and mixed-gas diving. Such courses include dives to put new skills into practice, and help to improve your general diving experience. For more details, visit the websites of the various training organizations (*see pp.329–30*), or ask at your local diving center.

CAVERN DIVING
Specialized and difficult types of diving, such as cavern diving, ice diving, and other skilled activities, can be enjoyed after proper training.

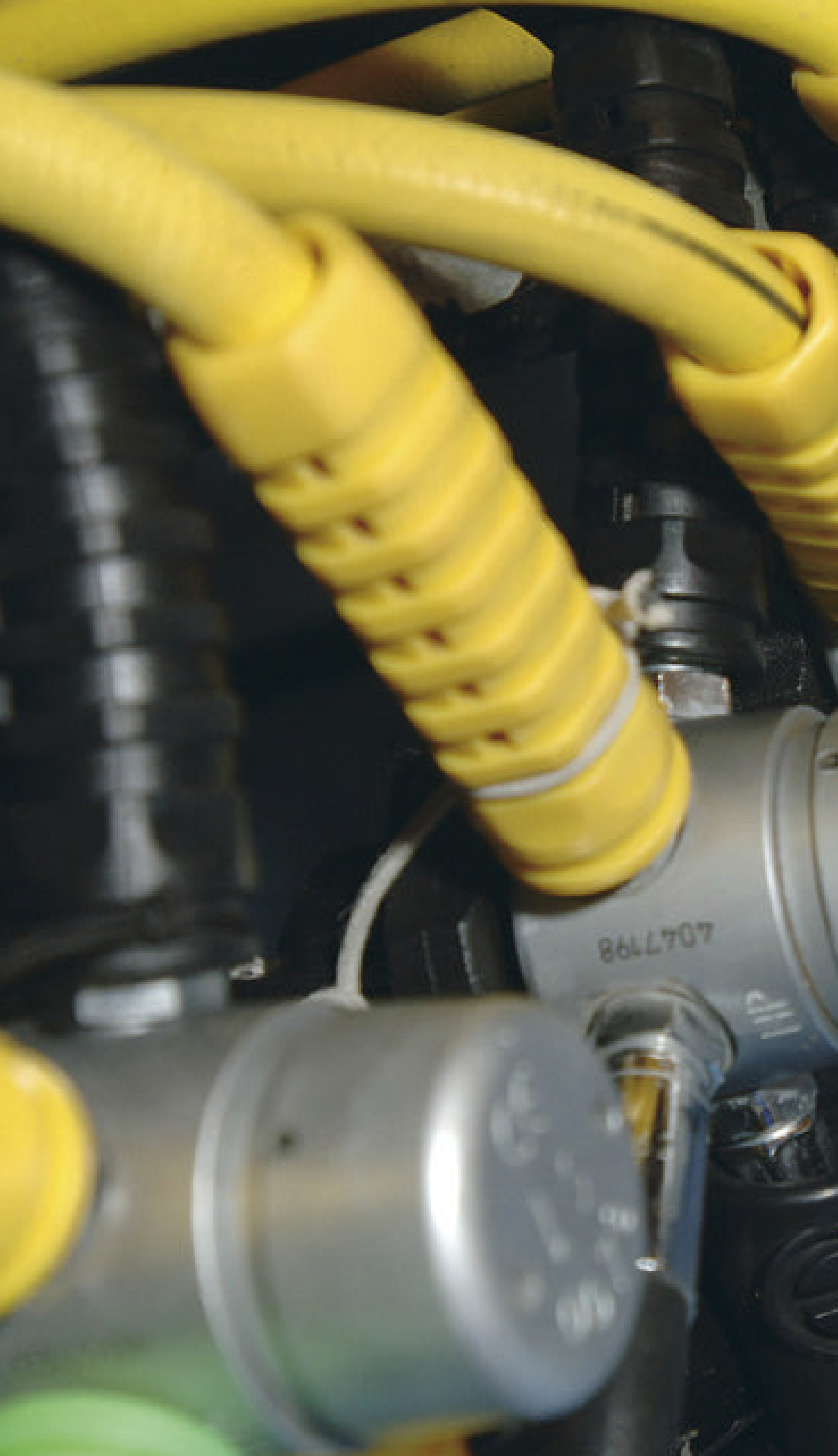
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Equipment

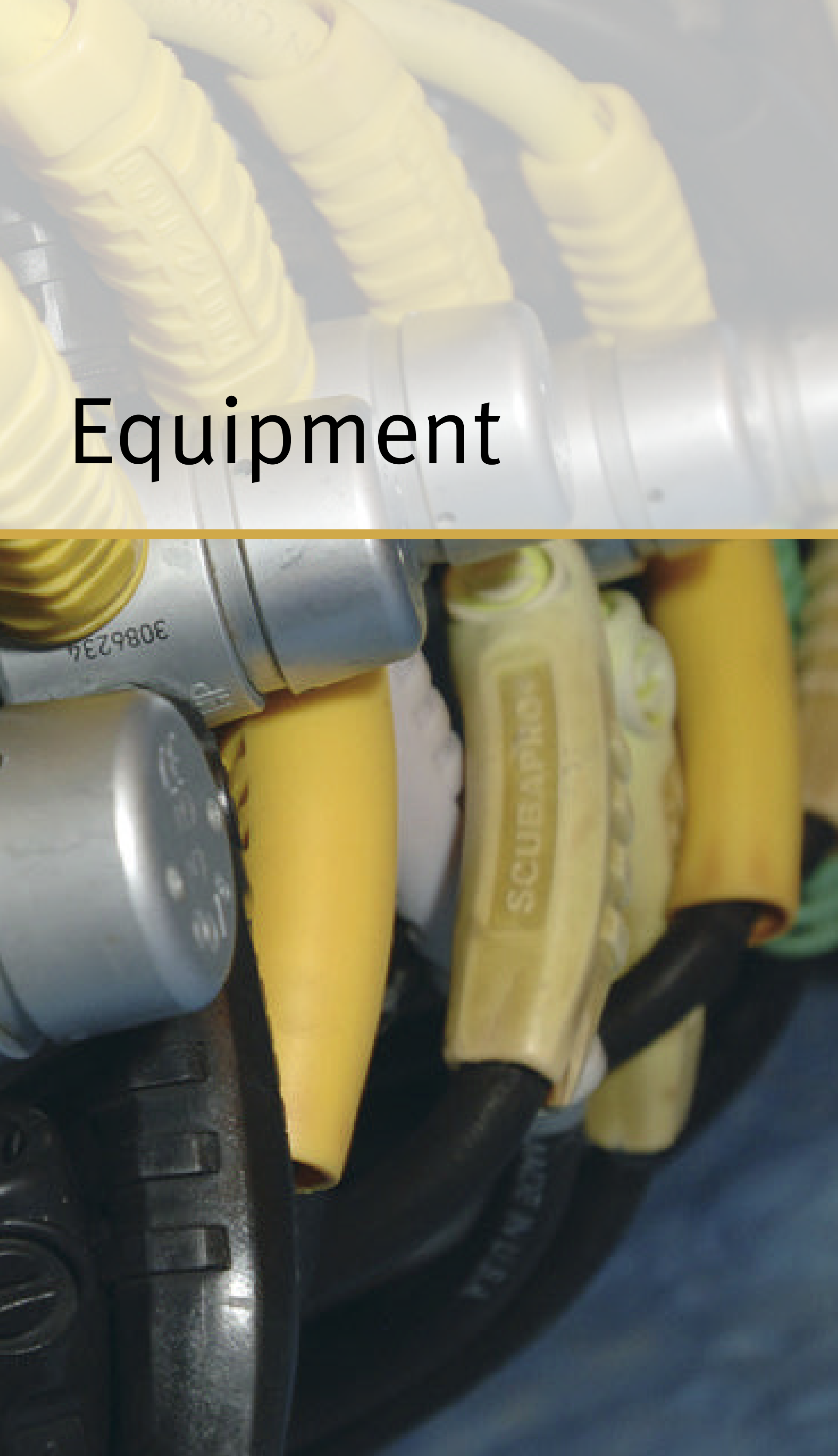
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SCUBAPRO

Introduction

The wide array of equipment available is often bewildering to a novice diver. Some items are essential in all circumstances, while others are used only in specific diving environments. The more research you do and advice you seek, the more likely you are to buy safe, suitable gear.

BUYING AND RENTING GEAR

You could begin dive training with as little as a swimsuit, but it may be advisable to at least obtain a good-quality mask, snorkel, and fins. This means that you always have three key pieces of gear that fit perfectly, and with which you are comfortable.

Many divers own no more than this basic gear, preferring to rent the rest. There are pros and cons to this approach: it frees you from carrying heavy gear around, but it can also mean using ill-fitting equipment that has been worn by many people, and which may not have been well cared for. The alternative is to buy and transport all your own gear. This is recommended if you are likely to be diving regularly in your local area (although a local club or shop may have gear you can rent). It is not so practical if you plan to dive any farther afield—taking your own gear overseas can be expensive, although most dive tour operators are fairly generous with their excess baggage allowances. You can rent a tank and weights from any dive center, so you need never travel with these items.

The best places to buy equipment and obtain advice are dive shows or local dive shops. Second-hand gear is worth investigating, but inspect it for signs of wear and corrosion before making a purchase, and make sure that it is serviced before use.

DIVERS TOURING A REEF
Knowledge and care of gear is vital, since your equipment is your life-support system for exploring the underwater world.

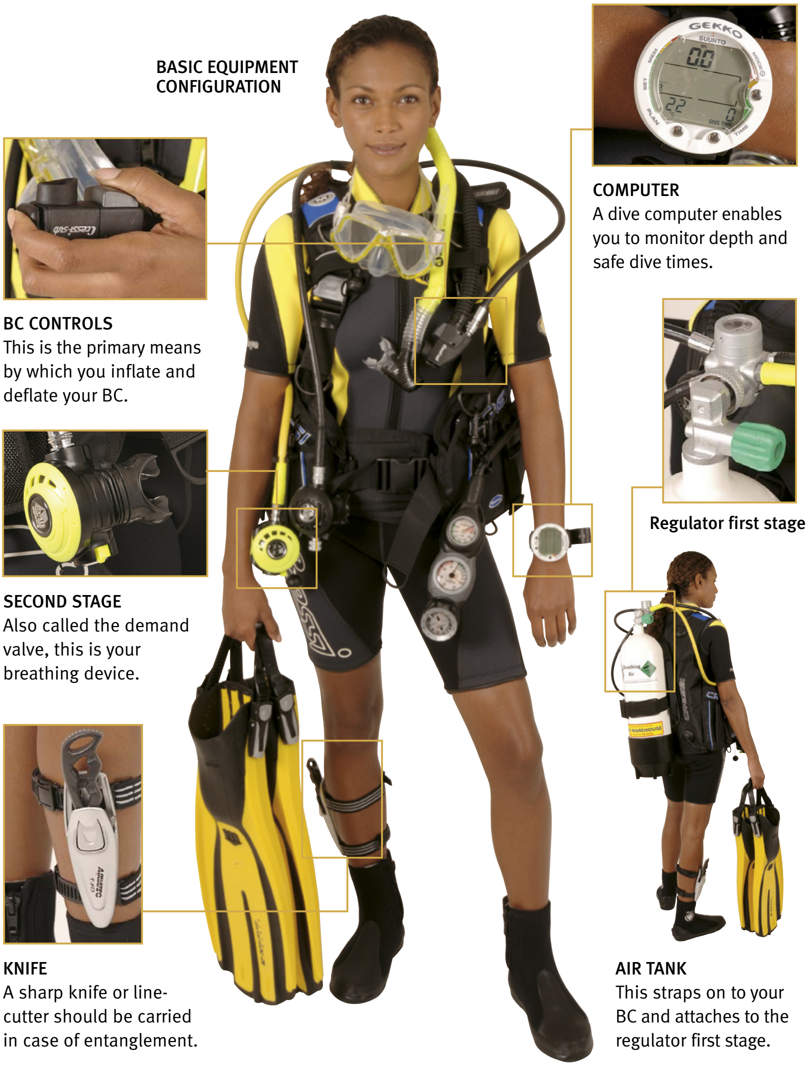

BASIC EQUIPMENT CONFIGURATION

BC CONTROLS
This is the primary means by which you inflate and deflate your BC.

SECOND STAGE
Also called the demand valve, this is your breathing device.

KNIFE
A sharp knife or line-cutter should be carried in case of entanglement.

COMPUTER
A dive computer enables you to monitor depth and safe dive times.

Regulator first stage

AIR TANK
This straps on to your BC and attaches to the regulator first stage.

CORE EQUIPMENT

There are several items of gear that are essential, in addition to your mask, fins, and snorkel. A buoyancy compensator (BC) is an inflatable jacket that keeps you afloat at the surface, helps you adjust your buoyancy underwater, and supports other vital pieces of equipment. Weights, and a belt to mount them on, are another necessity, although weights can also be carried on some BCs (*see p.59*). You will also need some kind of dive suit (*see pp.50–55*) depending on the water temperature—and boots.

A regulator (the device that supplies air to the diver) is also necessary, preferably one that incorporates an alternative air source (an octopus) and an instrument console with a compass. Dive computers are a useful aid to safe diving, and you should also carry a knife to cut yourself free if you become snagged underwater.

DIVING ACCESSORIES

There is a range of equipment and accessory items designed for specialized diving. Try to borrow or rent specialty gear that you may only use infrequently.

Slates are useful accessories, since they allow you to write messages to your buddy, or to make notes from your dive—for example, on species that you do not recognize—or to sketch a site.

Flashlights are essential for diving at night, in murky water, and in low-light environments, such as caverns and wrecks.

If you will be doing a lot of open-water diving, especially in currents, you should purchase a marker buoy, either a surface marker buoy (SMB) or an inflatable surface marker buoy. These indicate your position to observers on the surface, and also aid your ascent.

MASK
The glass lenses should be tempered and offer a good field of view.

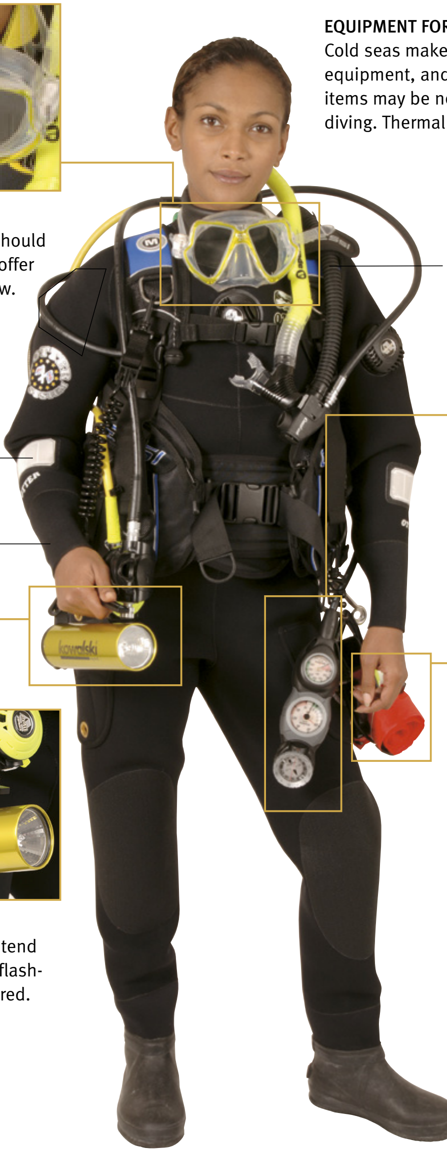

EQUIPMENT FOR COLD WATER
Cold seas make extra demands on diving equipment, and additional peripheral items may be needed to ensure safe diving. Thermal protection is a priority.

GAUGES
Gauges with large, clear dials are easier to read in low-light environments.

FLASHLIGHT
Temperate waters tend to be murky, so a flashlight may be required.

BUOY AND REEL
A marker buoy and reel are useful for guiding an ascent to the surface.

DEMANDING ENVIRONMENT
Diving in cold water requires extra equipment, and appropriate training in how to use it. Safety devices are especially important in such waters.

Lastly, you may wish to record your dive experiences with a camera. Digital cameras in housings are now small enough to fit into pockets in your kit.

DIVING IN COLD WATER

If you plan to dive frequently in cold water, you might want to invest in a drysuit (*see pp.54–55*). A good thermal underlayer is essential with a drysuit, since loss of body heat can result in poor decisions and lead to exhaustion, speeding the onset of hypothermia. Dive clothing manufacturers make special thermal undersuits with wicking properties to draw moisture away from the skin. If you are planning on doing any extreme cold water diving or ice diving (*see pp.188–89*) you will need to use an environmentally sealed regulator, because these are more resistant to freezing.

Also necessary in cold water are a hood and gloves, the thickness of which will depend on the water temperature. The thicker the neoprene, the more insulation it offers, but the more it will restrict movement. Thick gloves or mittens reduce dexterity considerably, which is worth bearing in mind if you intend to use smaller items of gear.

MAKING THE RIGHT CHOICE

Don’t rush into buying the first bit of new gear you see—always look at a range of products and compare prices. Take advice from fellow divers and shop staff, but remember that everyone has their favorite brands. Reviews in magazines and on the Internet can give you more information, so that you can weigh the options before you buy.

Masks

A well-fitting mask is arguably your most important piece of diving gear, so take time to choose one that is right for you. There are many styles and designs to choose from, but above all you need one that fits correctly, and suits your personal diving requirements.

SEEING UNDERWATER

Human eyes cannot focus in water, which is why you have to wear a mask when diving. The way masks work is to trap a pocket of air in front of the eyes, allowing them to focus normally. A standard mask consists of a single or double panel of tempered glass inside a frame, with a silicone skirt forming an airtight seal against the face. A strap and buckles hold it all in place.

If you take care of your mask and keep it in a sturdy case to avoid damage, it should last for many years. The lenses of new masks have a protective coating from the manufacturers that should be removed before use. This can be wiped off using a nonabrasive cloth and non-gel toothpaste (or a fine abrasive cleaner) to clean the coating off without scratching the glass. If in doubt, consult the manufacturer's instructions. Make sure you rinse your mask in fresh water after use and store it away from direct sunlight in a dry place.

TESTING FOR FIT

There are lots of shapes and sizes of mask, so take time to find one you like that fits. A simple test is to hold it up to your face and inhale gently through your nose. If you then lean forward, it should remain in place.

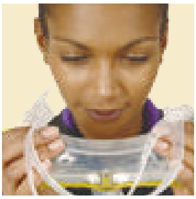

1 **Hold the mask** in front of your face with the strap hanging loose.

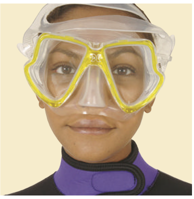

2 **Place it on** your face. Inhale through your nose—the mask should stay on without support.

MASK DESIGNS

CLASSIC This is a slightly old-fashioned design, but it is still popular with photographers because it gives a clear view of the diver's face. It offers a good field of view, but its high internal volume of air makes clearing the mask a little harder.

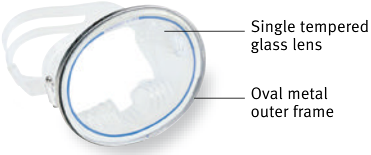
Single tempered glass lens
Oval metal outer frame

EXTENDED VISION Many new designs of mask are constructed to give the diver an extended field of view, especially downward. This model is a multi-lens design, which also allows corrective lenses of different strengths to be fitted.

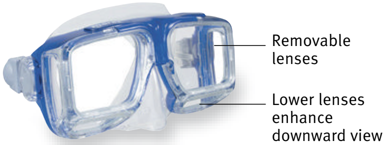
Removable lenses
Lower lenses enhance downward view

MATTE FINISH Some divers prefer to use a mask with a black silicone skirt to avoid confusing reflections on the inner surface of the glass. This is especially useful to marine photographers. However, this feature does reduce peripheral vision.

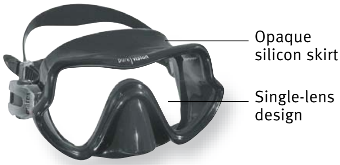
Opaque silicon skirt
Single-lens design

SIDE VIEW Some designs offer improved peripheral vision through glass panels on either side of the main lens, but are still low-volume, so are easy to clear. When choosing, make sure that additional lenses do not distort perspective.

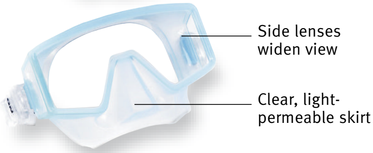
Side lenses widen view
Clear, light-permeable skirt

FULL FACE Mostly used in commercial diving, full-face masks are advantageous in very cold or polluted water. Some recreational models have intercom radio units so divers can communicate.

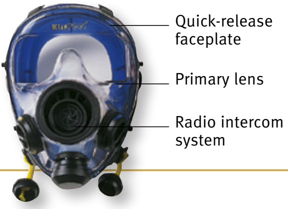
Quick-release faceplate
Primary lens
Radio intercom system

EYE TO EYE
Evolution has equipped fish with eyes that focus underwater, but divers must rely on masks for clear vision.

CORRECTIVE LENSES

Some masks can be fitted with prescription lenses, so if you wear glasses you will still be able to see underwater. Contact lens wearers can use normal masks—they provide an adequate degree of protection from water, unless accidentally removed.

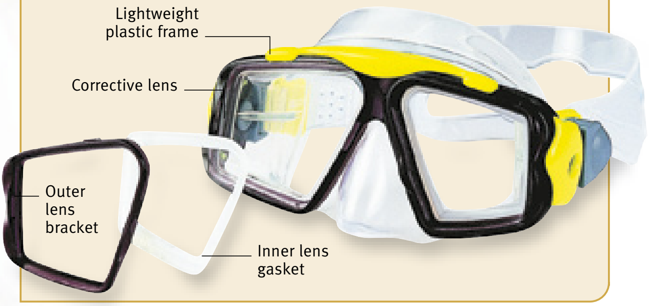
Lightweight plastic frame
Corrective lens
Outer lens bracket
Inner lens gasket

Snorkels and fins

Along with a mask, a snorkel and a pair of fins are probably the first pieces of gear you will buy. Snorkels vary very little, but there are plenty of styles of fins to choose from, depending on your budget. As always, look for a good fit and features that suit your diving needs.

CHOOSING A SNORKEL

A snorkel is simply a tube that allows you to breathe easily at the surface without needing to raise your head from the water. When diving, you do not need a snorkel underwater; however, you may use one before and after submerging. A good snorkel should be easy to breathe through, and should not be too long—ideally no more than 17 in (43 cm)—so it is easy to clear. Attach your snorkel to the left-hand side of your mask, leaving the right-hand side free for your regulator hose (*see pp.60–61*). Always rinse your snorkel after use and store out of direct sunlight.

DESIGN FEATURES

Basic snorkels are little more than a curved tube, but some models have a splash-guard at the top of the tube to prevent ingress of water, and a drainage valve at the lower end. Collapsible types are easy to stow away when not in use.

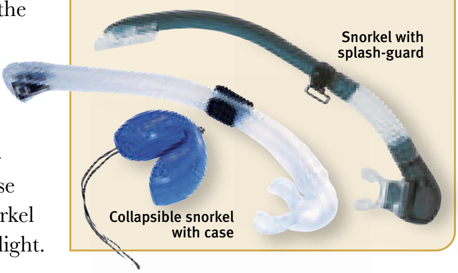

Snorkel with splash-guard

Collapsible snorkel with case

FITTING FINS

Sometimes incorrectly referred to as flippers, fins are used to aid propulsion when diving. A standard fin consists of a shoe made of rubber and a blade made of a stiffer material, often with ridges and vents to enhance performance. The shoe can either fit the whole foot like a slipper or leave the heel exposed. The latter is held on with a strap, and is designed to be worn over neoprene boots. When buying fins of this type, it is advisable to take your boots along with you, since their thickness will need to be taken into account when testing for fit.

SELECTING THE RIGHT PAIR

Advances in fin technology mean that there is a wide range for the diver to choose from, depending on their specific preferences. For example, split fins offer a high degree of agility underwater, but many divers believe traditional models deliver more outright thrust. Before deciding which pair to buy, consider the kind of diving you will be doing, and seek advice from store staff or other divers.

FIN POWER
A diver employing the "frog kick" with conventional fins.

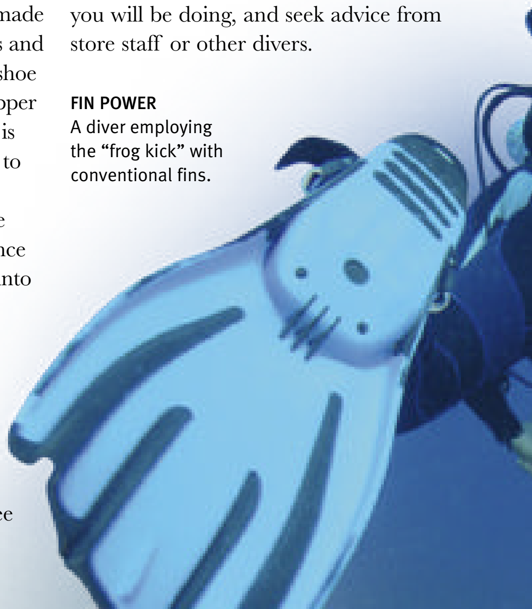

TYPES OF FINS

CONVENTIONAL A basic fin with a single, fairly rigid blade, the conventional design is a good starter fin, but you may want to try other types to see if they offer features that suit you better.

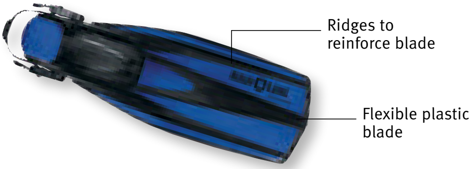
Ridges to reinforce blade
Flexible plastic blade

FORCE FINS Made exclusively by a California manufacturer, this range of fins is designed to minimize the water turbulence produced, and reduce the diver's kicking effort.

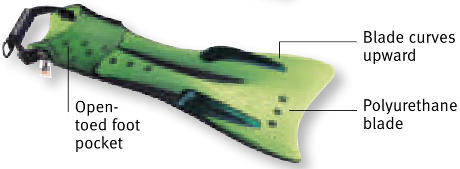
Blade curves upward
Open-toed foot pocket
Polyurethane blade

PIVOTING A design that has been adopted by two manufacturers, this fin features a flex-point in its structure and a V-shaped area of softer plastic to scoop water for better traction and speed.

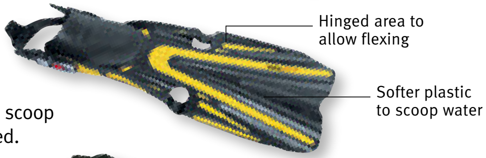
Hinged area to allow flexing
Softer plastic to scoop water

SPLIT A popular style, split fins offer better agility than standard fins. However, some divers believe they are less effective than conventional fins in strong currents.

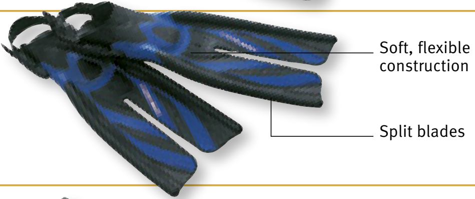
Soft, flexible construction
Split blades

SNORKELING Fins designed for snorkeling are lighter than scuba fins, and of a foot-pocket design, so they can be used with bare feet. Some also have shortened blades.

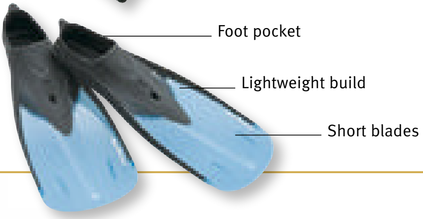
Foot pocket
Lightweight build
Short blades

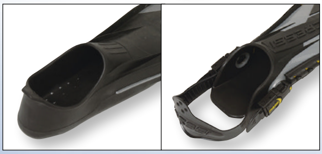

Foot-pocket fin Heel-strap fin

FIT AND FASTENING
Fins are held on the foot in two basic ways: in a form-fitting foot pocket, or by a strap over the heel.

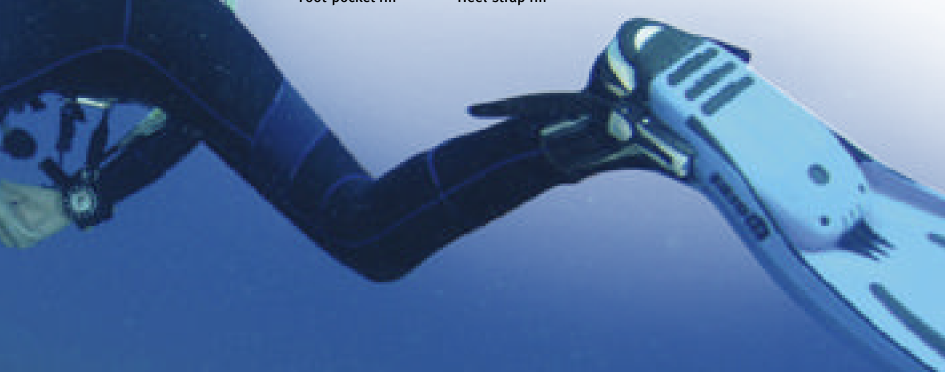

Diving suits

In all but the very warmest waters, you will need some kind of thermal protection during your dive. Good diving suits (which are technically known as "exposure suits") are available in every price range, but always look for comfort, fit, and quality of construction.

BEATING THE CHILL

Water conducts heat away from the body much more efficiently than air. Unless the water you are in is the same temperature as the surface of your skin—about 90°F (32°C), which is hotter than most corals can withstand—your body will lose heat, and you will get cold. This means that in almost all diving environments, thermal protection is required. If you are diving in warm waters, a normal wetsuit will be sufficient. Only in the warmest waters should you consider a non-insulating or "skin" suit. Never be tempted to dive in just a swimming suit; even if you don't need insulation, a thin layer will prevent stings and abrasions. If you are diving in cooler waters, you should consider the heavyweight options: a semi-dry suit or a drysuit.

SECOND SKIN
Modern wetsuits are made of materials that offer highly efficient heat insulation.

WHICH SUIT?

Personal warmth requirements vary. If possible, take various suit options—you can layer these to give you the best protection. It is rare to be too hot underwater, but in tropical climates you may overheat in your suit before you enter the water. This can be prevented by wetting the suit before putting it on.

Buying a suit for every temperature range is too expensive for most divers, but most suits will suffice for a variety of waters. Although in the tropics you would be too warm in a drysuit, you could opt for a full-length wetsuit, as its extra warmth would be welcome in the cooler depths.

In addition to a suit, you may need accessories such as gloves, boots, a hood, and talcum powder, which is useful for easing entry into suits.

EXPOSURE PROTECTION

There are guidelines for the type and thickness of suit needed in different conditions. For the tropics, where the waters rarely drop below 68°F (20°C), a 2–3-mm wetsuit is fine. In the Mediterranean in summer, a 5–6-mm full wetsuit is more appropriate, rising to 7–8 mm during winter months. A semi-dry suit of 10–15-mm thickness, with a hood and thick gloves, will cope with most conditions in colder temperate waters, but in waters below 50°F (10°C), a drysuit is necessary.

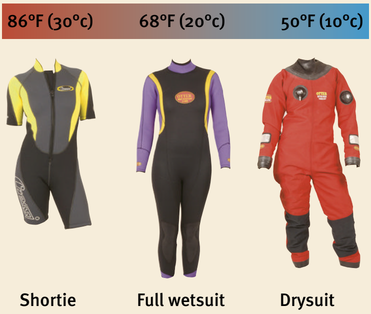

SUIT LAYERS

Wetsuits and drysuits keep the diver warm in different ways. In wetsuits, a thin film of water is trapped next to the diver's skin and acts as an insulator. Drysuits seal a layer of air inside the suit, and this permits the use of thermal undergarments for extra insulation.

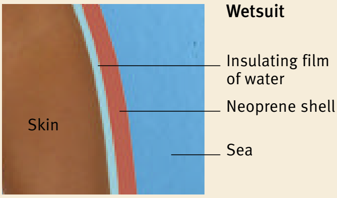
Wetsuit
Skin
Insulating film of water
Neoprene shell
Sea

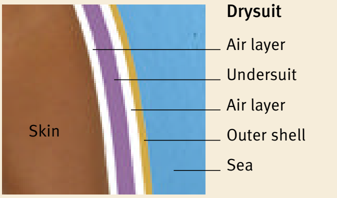
Drysuit
Skin
Air layer
Undersuit
Air layer
Outer shell
Sea

SKINSUITS AND SHORTIES

In warm, tropical waters, you will probably not require any thermal insulation, but a thin layer over your body will prevent your equipment from rubbing on your skin, as well as giving protection from the Sun before and after dives and providing a barrier to stings and scrapes.

The thinnest skinsuits are made of Lycra, but some manufacturers offer suits made from 0.5-mm neoprene. Lycra suits can also be used as a base layer under a heavier suit, so they are a good add-on option if you are not sure how warm or cold your destination will be.

So-called "shortie" wetsuits offer slightly more thermal protection than skinsuits, typically being constructed of 3-mm neoprene. However, they do leave the arms and legs exposed and unprotected from stinging plankton and jellyfish or abrasions on rocks or coral.

SHORTIE WETSUIT This type of wetsuit is a good choice in warm waters, and does not cost as much as a full suit.

Non-chafing collar
Tough plastic zipper
Thin neoprene

Light gloves

Leather palms

Skinsuit vest

Light material

TROPICAL DESCENT
Even in warm waters, a full-length wetsuit may prove invaluable, because water temperatures drop as the diver ventures deeper.

FULL-LENGTH WETSUITS

The next level of thermal protection after shorties and skinsuits is a full-length wetsuit. These offer increased thermal protection for the arms and legs, and are typically made from 2–8-mm neoprene. But thickness is not the only factor in thermal efficiency—a close-fitting suit provides better insulation. A correctly fitting wetsuit should not only be easy to put on, but should follow the contours of your body as closely as possible. Wetsuits rely on trapping a thin film of water next to the body, which gradually becomes warm. If the suit fits badly, water flows more freely between the body and the suit, and chills—rather than insulates—the diver.

CARING FOR YOUR WETSUIT

A simple maintenance regimen is vital to prolong the life of your wetsuit. After every dive, wash your suit to remove salt and debris, which can cause it to rot. It is best to use special wetsuit shampoo, which helps to maintain the suppleness of the neoprene and prevent mildew. Once the suit is fully dry, place it on a hanger and store it in a cool, dry place.

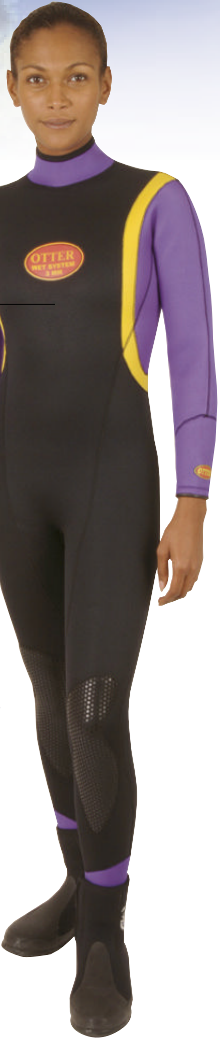

FULL-LENGTH WETSUIT
Scuba wetsuits are available in a range of styles, categorized by the thickness of neoprene they are made from.

Torso area has extra insulation

Side panels for better flexibility

Thin neoprene

Gloves

Zipper for easy access

Boots

SEMI-DRY SUITS

Though intended for colder temperate waters, where they are worn with a hood and gloves, semi-dry suits are a versatile style that can be used even in warm Mediterranean seas. Like standard wetsuits, semi-dry suits are made of neoprene and work by trapping an insulating layer of water between the body and the suit. However, they have more efficient seals at the wrists and ankles and around the neck or hood, which stops water from flushing through the suit and allows the trapped water to warm up. They also tend to be made of thicker neoprene and are often designed to be used in layers (with a jacket fitting over a coverall-style base layer).

The thickness of the neoprene in some semi-dry suits has a tendency to restrict movement on land (although not in water). However, suits made of super-flexible material are available that offer an equivalent degree of thermal protection, but are much easier to put on and move around in. Although a semi-dry suit offers protection similar to a drysuit (*see p.54*), some divers prefer a drysuit, because a damp body can be uncomfortable after the dive, especially in cold weather.

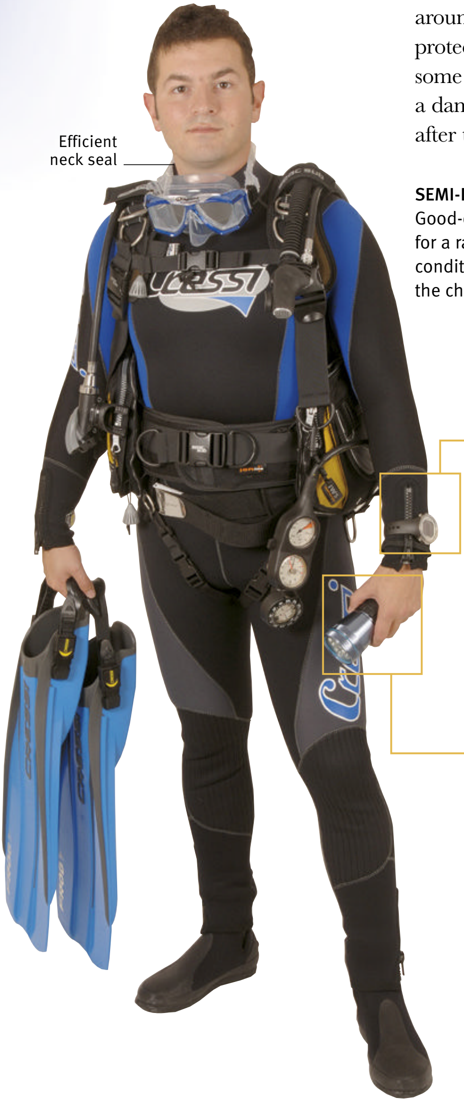

SEMI-DRY SUIT WITH EQUIPMENT
Good-quality semi-dry suits are suitable for a range of dive environments and conditions, and allow you to withstand the chill of greater depths.

DIVE COMPUTER
Often no bulkier than a wrist watch, a dive computer may need a strap extension when worn with thicker suits such as a semi-dry suit.

FLASHLIGHT
In the colder and deeper waters accessible with a semi-dry suit, visibility can be impaired, so a light should always be carried.

DIVING IN DRYSUITS

Drysuits are the most expensive type of diving suit but offer excellent thermal protection. They use trapped air, not water, as an insulating barrier. Drysuits are available off the rack, but it is worth spending a little extra to get a made-to-measure garment, because a well-fitting suit will be more comfortable and more likely to avoid buoyancy problems caused by unequal air distribution.

Drysuits are made from a variety of materials, including crushed neoprene and membrane materials. Crushed neoprene suits are tough and offer a good degree of thermal insulation. Membrane drysuits are made from strong, thin, waterproof fabrics, which offer less inherent thermal insulation than crushed neoprene, and are designed to be used with a thermal undersuit. They are more supple than neoprene types, and so easier to move around in. However, they can be looser-fitting, and allow excess air to move around inside, which can shift buoyancy to the legs, and tip the diver upside down.

KEEPING WARM
Even in conditions as extreme as those encountered diving under ice, drysuits provide good thermal protection, ensuring the diver stays comfortable.

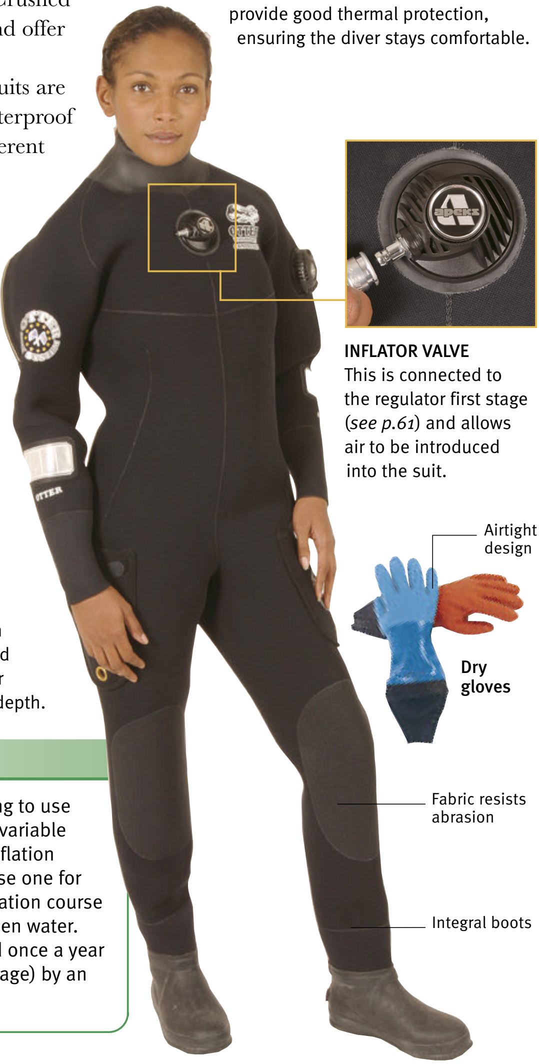

CRUSHED NEOPRENE SUIT
The inherent buoyancy of a suit made of neoprene that has been "crushed"—treated with heat and pressure to flatten its internal air cells—remains the same at any depth.

INFLATOR VALVE
This is connected to the regulator first stage (*see p.61*) and allows air to be introduced into the suit.

USING A DRYSUIT

Drysuits are more challenging to use than wetsuits, as they have variable buoyancy, due to their air-inflation mechanism. If you plan to use one for the first time, take an orientation course in a pool before diving in open water. A drysuit should be serviced once a year (or after long periods of storage) by an approved repair technician.

FASTENINGS AND SEALS

Drysuits generally have an "across the shoulder" zipper to allow entry. You will need help from your buddy to do this up. These zippers need regular coating with wax or "zip slip" to keep them lubricated and protected from corrosion.

To prevent water from entering the suit, drysuits have watertight seals—made of thin neoprene or latex—at the wrist and neck. Latex seals are generally less likely to leak than neoprene versions, but do not offer any insulation and are more fragile, so there is the risk that they may tear. Neoprene seals, by contrast, are tough, easy to repair, and warm, but it can be difficult to get a good fit.

INFLATING WITH AIR

Drysuits have an inflator valve on the chest that injects air to reduce the "shrink wrap" sensation caused by water pressure squeezing the suit against the body. This air expands on ascent and must be dumped via a valve, normally located on the shoulder, which can be manual or automatic. Cuff dumps are also available that work by raising your arm to release excess air.

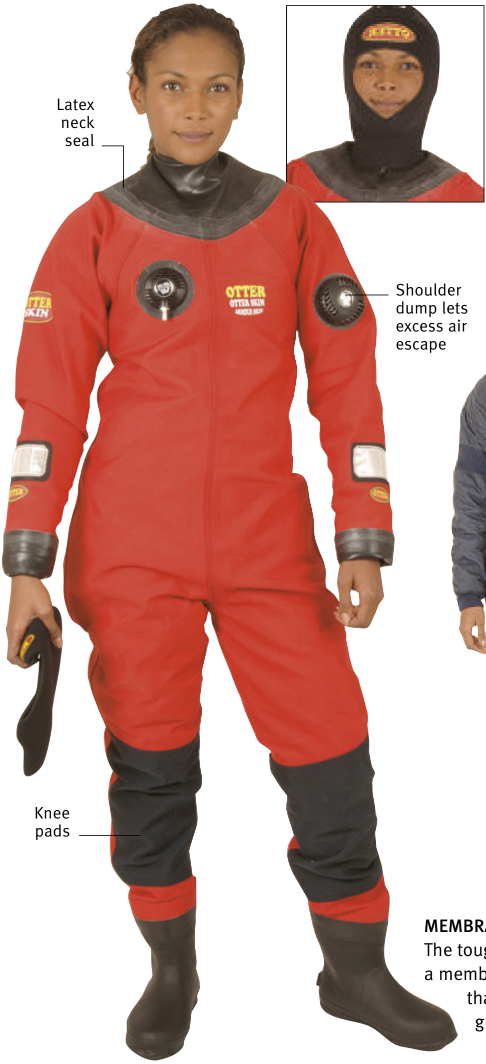

TOP COVER
A neoprene hood is necessary in cold waters to insulate the head.

High-tech fibers
trap heat inside

THERMAL UNDERSUIT
Specialty garments, undersuits can be worn under drysuits for extra insulation and comfort.

Thick
neoprene

Heavy wetsuit gloves

MEMBRANE SUIT
The tough, lightweight fabric of a membrane suit is more flexible than neoprene and so allows greater ease of movement.

Buoyancy compensators

Unlike fish, humans have no natural way to adjust their buoyancy, or floating ability, when underwater. Divers wear a buoyancy compensator (BC)—a jacket that can be filled and emptied of air—to control their buoyancy underwater and at the surface.

HOW A BC WORKS

The BC (also known as BCD, or buoyancy compensation device) offers flotation at the water's surface and fine adjustment of buoyancy underwater, and acts as a harness for equipment items. At the surface, a fully inflated jacket will keep your head well out of the water. Underwater, buoyancy can be increased by inflating the BC with small amounts of air.

All BCs are connected via an air hose to the regulator first stage (*see p.61*), which supplies pressurized air from the tank for inflating the jacket. BCs can also be inflated orally, via a corrugated hose that hangs down over the left shoulder. Controls for automatic inflation and deflation are usually located at the end of this hose.

Of course, BCs must be able to reduce buoyancy as well as increase it. This is achieved by venting air from the jacket via dump valves at various points. Air can be released through the oral inflation hose by depressing a button, and can also be vented by using a pull-cord dump valve, which acts more quickly. These are often located on the opposite shoulder from the oral inflation hose, and at the bottom edge of the jacket. They should be used cautiously, since they alter buoyancy rapidly. Many BCs also vent air when the oral inflation hose is tugged sharply.

STOWING KIT
Buoyancy compensators (*right*) are fitted with handy stowage points for peripheral gear.

SURFACING IN SAFETY
When fully inflated, BCs allow the diver to float effortlessly at the surface. Here, two divers signal OK after a dive.

FIXINGS AND FASTENINGS

The tank (*see p.68*) is also attached to the BC. A strap attached to a rigid backplate wraps around the tank and holds it in place with a cam-action buckle. It is important that your tank is fastened securely and does not move during the dive. A well-designed BC will have various adjustable straps around the waist and at the shoulders, to ensure that it fits snugly. These can be easily re-adjusted underwater. Steel or plastic D-rings (*see below*) can be used to attach smaller items of gear.

FRONT VIEW OF BC JACKET

D-RING
Used for clipping on items of peripheral equipment, like a flashlight or reel.

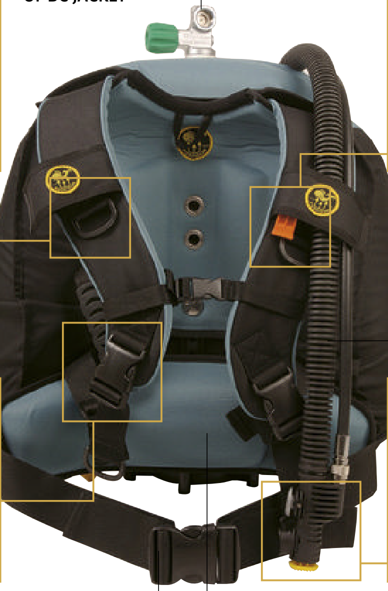
Pillar valve of air tank
Air bladder
Corrugated hose
Waist belt
Lumbar support pad

WHISTLE
A safety feature for attracting attention. Here, it is tied to the oral inflation hose.

HARNESS RELEASE CLIPS
For quick release from the harness, and easy donning of the jacket.

BUOYANCY CONTROL
The inflation and deflation controls and oral inflator are at the end of the hose.

SIDE VIEW OF BC JACKET

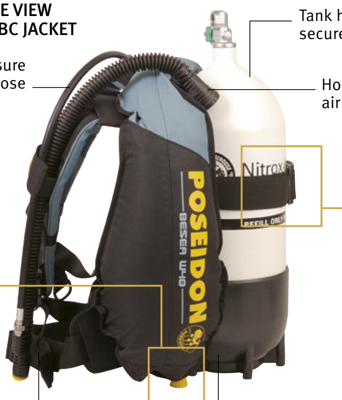
Low-pressure inflator hose
Tank held securely in place
Hose-end air dump
Harness straps
Plastic boot is part of tank

AIR DUMP
Valve allowing air to be vented rapidly from the air bladders.

TANK STRAP
Cam-action buckle locks air tank in place. BCs may have one or two.

SPECIALTY JACKETS
High-volume “wing” style BCs (*top*) are used in advanced diving (*left*). The large air capacity of these jackets provides extra lift for heavily laden divers.

CHOOSING A JACKET

A basic BC is like a padded vest, and these are often only adjustable at the waist. More advanced models have adjustable straps to make sure the jacket fits as snugly as possible underwater. Ideally, you should buy one that fits like a glove and does not roll around with a tank attached. You should also find it easy to take on and off. If possible, you should try it on with your wetsuit (or drysuit) to check the fit, and to ensure that there is room for more adjustment on every strap in case of changes in your suit or your body shape. Beyond the basic models of BCs there are the more specialized features available on some jackets, such as weight integration, or a “wing” style design (*see opposite page*). Whatever the features of the jacket you decide to buy, make sure they suit the type of diving you will be doing the most. Try out several different jackets before deciding.

CARING FOR YOUR BC

As with all items of equipment, your BC should be rinsed with fresh water after every dive. The inside should also be rinsed by flooding it through the corrugated hose. The jacket should then be emptied again by turning it upside-down and draining it through the same hose. After this, you should reinflate it to help locate and remove any remaining water, which will rattle around inside when the BC is shaken. The jacket should be stored in a cool, dry place in a partially inflated state.

SERVICING YOUR BC

Careful maintenance of your BC will keep it in good working order for many years. It should be serviced at least once a year, or after it has been stored unused for more than six months. Take it to a recommended dive shop. Only service it yourself if you have been trained to do so. Do not take risks by diving with old or unserviced gear.

BUOYANCY COMPENSATOR DESIGNS

INTEGRATED WEIGHT BC
Some BCs feature integral weight systems. Many people find these quick-release weight pockets more comfortable to use than a traditional weight belt. The weights should be removed before putting the BC on and taking it off.

Inflator mechanism incorporates a backup regulator

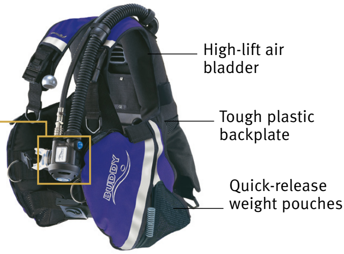
High-lift air bladder
Tough plastic backplate
Quick-release weight pouches

INTEGRATED BREATHING BC
The Mares HUB (Human Underwater Breathing) system was the first to integrate the regulator into the design of the BC. A great advantage of this top-of-the-line product is its simplified profile, which reduces drag in the water.

Regulator integrated with jacket design

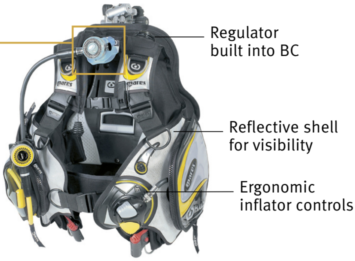
Regulator built into BC
Reflective shell for visibility
Ergonomic inflator controls

WING / SEMI-WING BC
Favored by technical divers (*see p.194*), these offer high lift capacity. The air bladder is rear-mounted: this aids horizontal posture under the water, but can push the diver face-forward at the surface. A semi-wing offers better surface support.

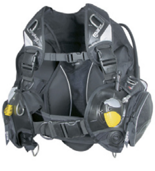

Semi-wing

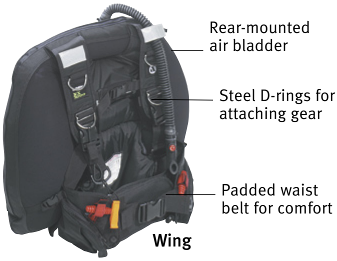
Rear-mounted air bladder
Steel D-rings for attaching gear
Padded waist belt for comfort

Wing

WOMEN'S BC Women divers are increasingly well catered to with special jacket designs to give a comfortable fit without the usual tension points across the chest. Such jackets offer other convenient options like weight integration.

Specially shaped harness

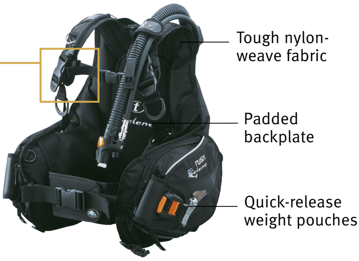
Tough nylon-weave fabric
Padded backplate
Quick-release weight pouches

TRAVEL BC If you travel often, it is a good idea to consider a lightweight BC without a rigid back, which can be rolled up. These designs have a lower lift capacity, as they are mostly used in warm-water sites, where minimal weight is carried by the diver.

Toggle for jettisoning weight pouches

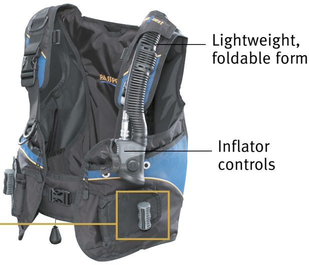
Lightweight, foldable form
Inflator controls

Regulators

One of the most important items of diving gear is a regulator. This two-stage gas-supply system provides you with air from your tank at the correct pressure for you to breathe underwater. Since it is a key life-support device, most divers buy their own regulator.

BREATHING UNDERWATER

Your tank can store large amounts of air in a small space because the air it contains has been highly compressed (*see pp.68–69*). Before you can breathe this stored air, it must be reduced to a safe pressure, which varies according to how deep you are underwater. The deeper you go, the greater the weight of water pressing on your chest cavity from outside (*see pp.94–95*). This is called ambient pressure. Air for breathing must be supplied at an equivalent pressure, otherwise your lungs will not be able to inflate properly.

STORING REGULATORS
Regulators are tough, but they should be well cared for. Hang them up in a cool, dry place away from sunlight.

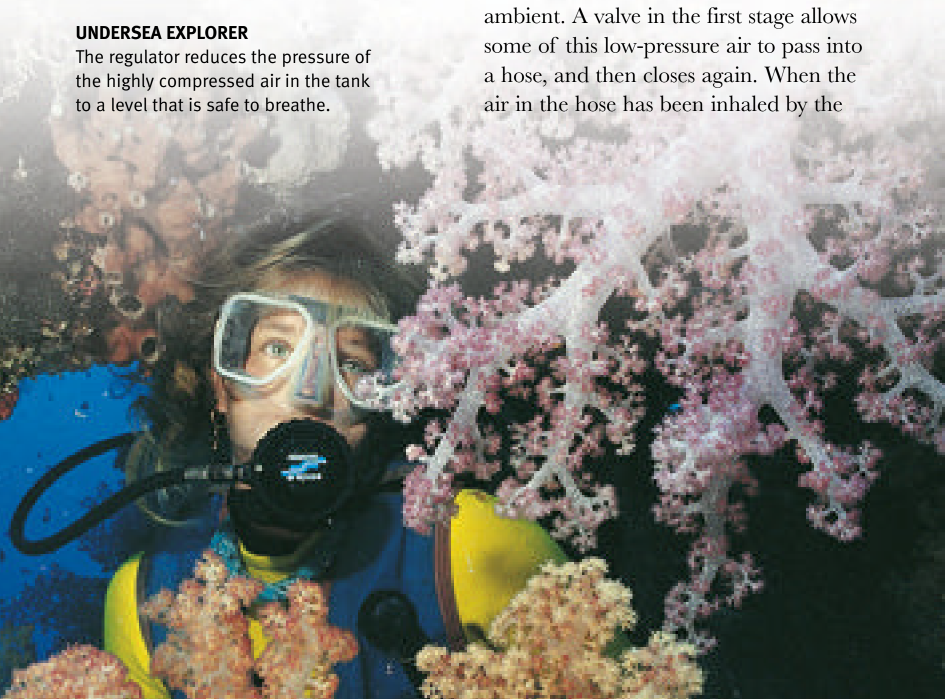

UNDERSEA EXPLORER
The regulator reduces the pressure of the highly compressed air in the tank to a level that is safe to breathe.

HOW REGULATORS WORK

Supplying air at the right pressure is the job of the regulator, which is made up of the first stage (which fits on to the tank) and the second stage (the piece you put in your mouth), which is also known as the demand valve. The first stage reduces the air passing out of the tank to a lower pressure of around 116–145 psi (8–10 bar) above ambient. A valve in the first stage allows some of this low-pressure air to pass into a hose, and then closes again. When the air in the hose has been inhaled by the diver, the first stage detects a decrease in pressure in the hose, and allows more air to flow in, to replace that which was used. It automatically alters air-pressure in the hose when depth changes occur. The first stage also supplies air for BC and drysuit inflation (via separate hoses).

The second stage reduces the low-pressure air in the hose to the same pressure as the water you are swimming through, allowing normal breathing. The second stage houses a diaphragm that is subject to equal forces of water pressure on one side, and air pressure from your breathing passages on the other. When you inhale, the diaphragm flexes inward, causing an inlet valve to open, and air flows into your mouth. Exhaling causes the diaphragm to flex outward and triggers an exhaust valve to open, allowing used air to be expelled. The unit can be cleared of water by using the purge button, which is located on its front surface.

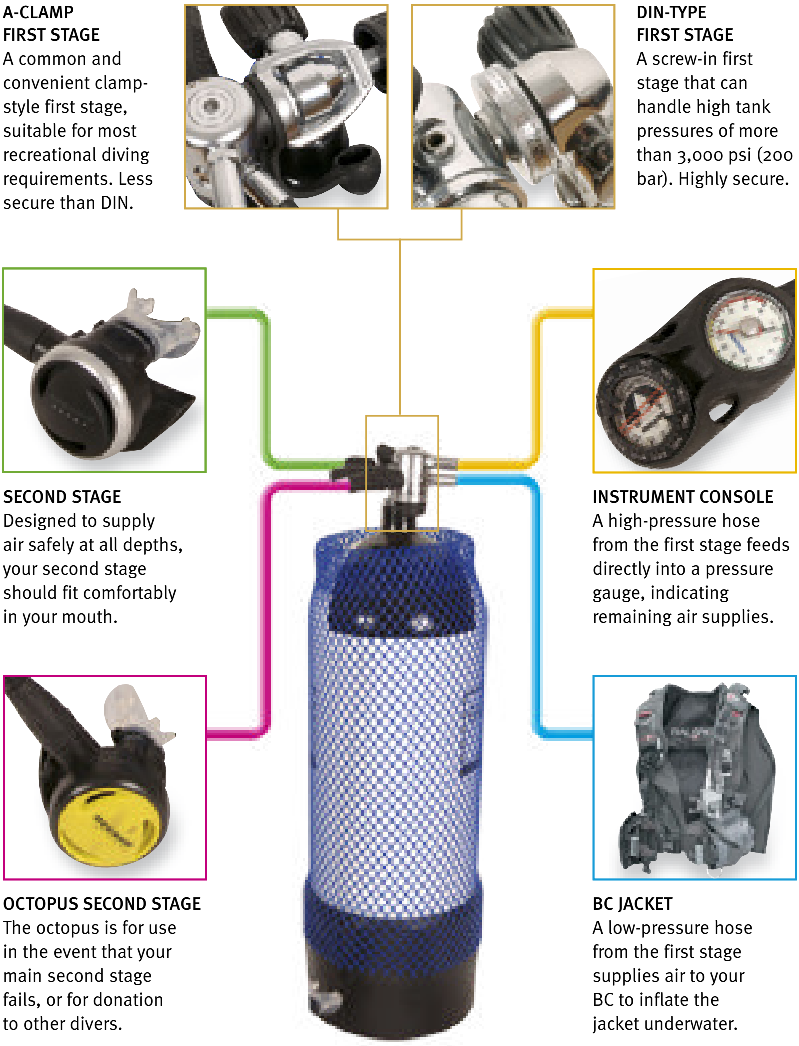

A-CLAMP FIRST STAGE
A common and convenient clamp-style first stage, suitable for most recreational diving requirements. Less secure than DIN.

DIN-TYPE FIRST STAGE
A screw-in first stage that can handle high tank pressures of more than 3,000 psi (200 bar). Highly secure.

SECOND STAGE
Designed to supply air safely at all depths, your second stage should fit comfortably in your mouth.

INSTRUMENT CONSOLE
A high-pressure hose from the first stage feeds directly into a pressure gauge, indicating remaining air supplies.

OCTOPUS SECOND STAGE
The octopus is for use in the event that your main second stage fails, or for donation to other divers.

BC JACKET
A low-pressure hose from the first stage supplies air to your BC to inflate the jacket underwater.

THE OCTOPUS SECOND STAGE

Most recreational regulators are set up in an “octopus” configuration (so called because of the multiple hoses emerging from the first stage). This incorporates a backup second stage, which is intended for use if your main one fails, or if your buddy needs a donated air supply. Over time, this backup air source has become known as the octopus second stage, or simply the octopus.

The octopus and the hose to which it is attached are usually finished in a bright yellow color for easy location in an emergency, and to distinguish them from your main second stage (which ordinarily has a black hose). The octopus hangs unused from your BC most of the time, and for this reason it is often detuned (adjusted) to prevent “free-flow”—an accidental discharge of air that occurs more easily when the mouthpiece of the regulator is left continually flooded. Some types of octopus are attached to the hose via a swiveling joint, so that they can be easily and safely donated to your buddy regardless of whether they are beside you, or face-to-face.

The hose supplying an octopus should be longer than the one feeding the main second stage. This will allow it to be offered to a buddy easily and for the buddy pair to remain face-to-face during a shared-air ascent (*see p.140*). Practice air-sharing procedures regularly.

STOWING THE OCTOPUS

Consider where to stow your octopus so that it can be easily located in an emergency by either you or your buddy. You can buy specialized clips of various designs to attach the octopus to your BC, which allow it to be freed easily when required, and replaced again afterward. Many divers hang their octopus near their midriff, but others mount it higher up on the chest, so it remains constantly within sight and close at hand. You can also buy regulator retainers made from rings of surgical tubing. These go around your neck, meaning the octopus is always right under your chin, though some find this arrangement constricting.

SAFE STOWAGE
Attach your octopus to your BC at a point where you can easily access it, and where it will be clearly visible at all times.

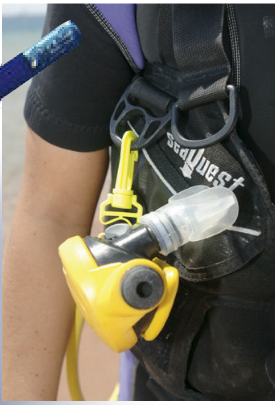

EMERGENCY ACCESS
Special quick-release clips are available for fastening your octopus to your gear.

TYPES OF REGULATORS

BASIC REGULATOR Simple, inexpensive regulators at the budget end of the market can be very reliable and durable. However, some may deliver air a little less smoothly than high-performance models.

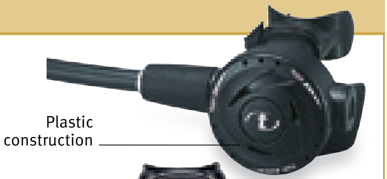

OCTOPUS SECOND STAGE Octopus second stages are often just standard second stages with high-visibility color schemes. However, some designs can be swiveled to any angle for easy access.

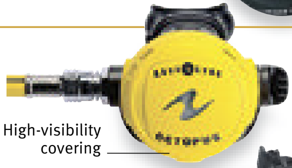

HIGH-PERFORMANCE REGULATOR At the top end of the market are regulators that combine high build quality with low inhalation effort and toughness. Many are environmentally sealed for cold-water use.

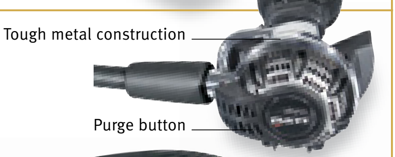

OXYGEN-COMPATIBLE REGULATOR Divers who wish to use nitrox mixes (*see pp.194–95*) that are very rich in oxygen will need a regulator designed to handle high oxygen concentrations without risk of combustion.

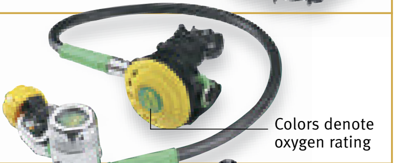

VINTAGE-STYLE REGULATOR In twin-hose regulators, the valve of the second stage is separated from its mouthpiece, and sits behind the diver's head, where it releases bubbles out of the diver's field of vision.

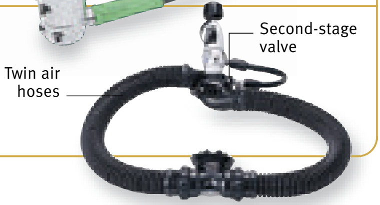

CHOOSING A REGULATOR

As with all items of dive equipment, prices vary enormously, but the regulator is one piece of gear worth investing decent money in. Basic regulators use a piston valve in the first stage and can be very reliable but often feature rather chunky second stages. The more expensive models use a diaphragm in the first stage and tend to have more streamlined second stages. Top-of-the-line models may be designed specifically for cold water diving, or be optimized for efficient air delivery on deep dives. They may also have dials to adjust the inhalation effort required to open the valve and deliver air. These can be used either to tune the unit to free-flow less easily, or maximize air delivery during a normal dive. Always rinse your regulator in fresh water after use, and have it serviced annually by a qualified dive-equipment technician.

DEEP BREATH
Regulators are designed to stringent standards, and are very reliable if well-maintained.

Gauges and consoles

To stay within safe time and depth limits and avoid running out of air, you must carry instruments that monitor your air consumption, time underwater, and depth. There are various devices on the market to help with this, from simple gauges to complex digital consoles.

BASIC INSTRUMENTS

You should never dive without some means to measure the time you spend underwater, the amount of air you have left in your tank, and your depth. A waterproof watch with a bezel—a rotatable outer ring—allows you to mark significant times, and thus keep track of how much time has elapsed. It also serves as a backup in case of failure of digital equipment used to monitor time, such as a dive computer.

INDICATING REMAINING AIR SUPPLY
The air-pressure gauge allows you to keep track of the amount of air in your tank; let your buddy know (*see p.145*) when your supply is running low.

Depth gauges allow you to monitor your depth even if you cannot see the water's surface. They are usually analog (needle-and-dial) devices, although digital versions are also available. Both work in the same way: they measure the pressure of the water around you, and convert this into an accurate reading of your depth. Make sure you buy one that records the maximum depth of your dive, and remember to reset it after every dive. Equally important is an air-pressure gauge, also known as a submersible pressure gauge (SPG) or contents gauge. This is connected to your regulator first stage via a high-pressure hose and measures the pressure of the air in the tank. You should check your air-pressure gauge every few minutes during the dive to carefully monitor your air consumption.

CHOOSING A CONSOLE

Your console is your dive information center, so you must be happy with the way it handles. Different consoles need to be held at different angles to read the dials; experiment before you buy to find out which is easiest for you to use. Choose one with large, easy-to-read numbers. Some are equipped with other instruments, such as a compass; these can be either on top of the console or on the back.

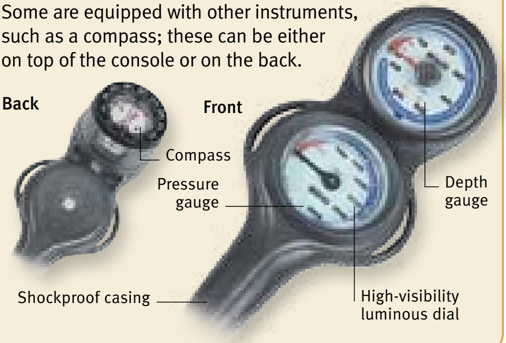

GAUGE CONSOLES

Depth and air-pressure gauges are often combined in a single integrated console that attaches to your regulator first stage and hangs by your side during a dive. Mounted together like this, the gauges are easy to locate and can be

TYPES OF GAUGES AND CONSOLES

STAND-ALONE DEPTH GAUGE A depth gauge is usually oil-filled and reacts to ambient pressure changes. Mostly analog, these gauges are accurate and durable.

STAND-ALONE AIR-PRESSURE GAUGE Typically analog, this type of gauge contains a tube that expands or contracts according to the air pressure inside your tank.

DEPTH AND AIR-PRESSURE CONSOLE This option allows at-a-glance checking of both depth and tank pressure, and also registers your maximum dive depth.

DIGITAL CONSOLE This console has an integrated computer and displays a range of information, such as air consumption, temperature, depth, time, and ascent rate.

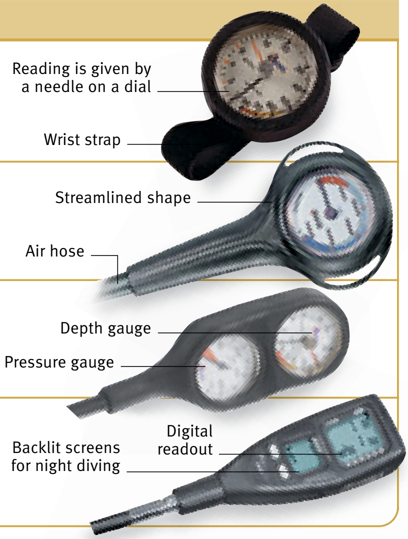

read simultaneously, like a "diver's dashboard." They can sometimes also include other instruments, such as a compass or a thermometer.

Consoles should be rinsed with fresh water after use and stored away from direct sunlight, and kept in a padded or protective case to avoid damage.

ADVANCED CONSOLES

Some manufacturers offer instrument consoles with digital rather than analog gauges. Consoles are also available that perform the same advanced functions as a dive computer (*see pp.66–67*). As well as indicating dive time, depth, and decompression schedules like a normal computer, these also incorporate a digital air-pressure gauge. For divers who use a wrist-mounted computer to monitor dive information, console instruments can provide an essential backup.

ANALOG VERSUS DIGITAL

Although less easy to read, analog gauges sometimes give slightly more accurate readings than digital ones, particularly at shallow depths.

Dive computers

To avoid decompression sickness, it is critical to monitor your depth and time underwater on every dive. In the past, this would have been done using a watch and a depth gauge, but these functions and many others can now be performed by a dive computer.

USING A DIVE COMPUTER

The main functions of a dive computer are to monitor your dive time and depth and calculate safe dive schedules. A basic model uses this data to assess the level of nitrogen absorption in your body while you are under the water, and also displays information about your ascent rate, including any stops you may need to make during an ascent to avoid decompression sickness (*see pp.100–01*). More advanced models also inform you about the temperature of the water and your air consumption (if linked via a transmitter to your regulator first stage), both for normal air and technical gas mixes (*see pp.194–95*).

Computers are more flexible than dive tables (*see pp.100–01*). Dive tables show how long you can spend at different depths before needing decompression stops. Most tables assume that you spend your entire dive at the greatest depth; computers can make more complicated calculations, including the time spent at all the different depths reached on a dive. Some computers will also schedule deep decompression stops. These reduce the risk of nitrogen microbubbles forming in your body, meaning that less time is spent decompressing in shallow water. When making repeat dives, especially in places where you are not limited by times of tides and slack water, using dive

TYPES OF DIVE COMPUTERS

MULTI-GAS This type of computer can calculate dive schedules for several different mixtures of breathing gas, from normal air to various oxygen-enriched blends of nitrox.

Computer can be linked to rebreather

Detailed display, which uses icons as well as numbers

CONSOLE-INTEGRATED This computer is built into the diver's instrument console (*see p.65*), which is attached to the high-pressure hose from the regulator. As such, it also displays remaining air supplies.

Integrated compass

Hand-held device with finger-tip controls

WRIST-MOUNTED This instrument is typical of a basic level, watch-style dive computer. It provides data on depth, dive time, ascent rate, and safe dive schedules, and is for use with normal breathing air.

Data displayed in basic form

Push-button controls alter information displayed

RADIO-UPDATED This wrist-mounted computer also displays how much air remains in the diver's tank by means of radio updates from a module screwed into the regulator's first stage (*see pp.60–61*).

Wrist strap

Radio module

SAFETY CHECKS
As you ascend, keep a close watch on your dive computer to make sure that you are not exceeding the maximum ascent rate it recommends.

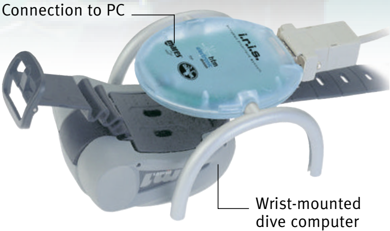

DIGITAL INTERFACE
Peripheral devices are available that link dive computers to PCs, enabling you to download dive profiles and create dive logs.

tables instead of a computer may not give you the maximum number of dives you can safely make each day.

Computers are also able to monitor your ascent rate accurately. In your dive training, you will be taught to ascend no faster than the smallest exhaled bubble, but it is more accurate to follow a digital readout that tells you the safe ascent rate.

BUYING A DIVE COMPUTER

A key consideration when buying a computer is the readability of the display. Too many figures on a small screen are difficult to read—the simplest models are often the best. Choose one with digits that are large enough to read with ease, without any nonessential data on the primary screen. It is also advisable to opt for a brand with a proven track record.

Computers are the most precise way of monitoring your dive, but they are not a foolproof means of avoiding DCS. It is impossible for data from a computer to exactly reflect your body's requirements. All models have built-in safety margins, but to be sure of avoiding problems, you should always dive conservatively, and not push your depths and times to the limit.

MALFUNCTION PRECAUTIONS

Never rely solely on a computer. As a precaution against malfunction, it is always worth practicing how to calculate dive times using tables. Although your computer will give early warning of a low battery, make sure you carry back up devices—either a watch and depth gauge, or a second computer, which can be mounted on your console.

Tanks

Also referred to as “cylinders” and “bottles,” tanks contain pressurized air for breathing underwater and have a valve that delivers this air to the regulator. Requiring regular testing and inspection, they can almost always be rented from dive centers.

SIZE AND MATERIALS

Different sizes of tanks are available, but most commonly they have a volume, or capacity, of 72, 80, or 95 cubic feet. The maximum pressure to which these can be filled varies—it can be as much as 4,350 psi (300 bar), but is more commonly 3,000 psi (206 bar). These figures are stamped on the neck of the tank, along with the dates of manufacture and most recent testing. Visual inspection at a certified dive shop must be carried out annually, and hydrostatic testing (for metal fatigue) is required at different intervals (from one to five years) in different countries. Your test stamps must be in date for your tank to be filled by any reputable dive center.

Many recreational divers use an 80 cubic foot tank, but if you find you usually run low on air before your buddies do, you should consider using a larger size. On deeper, or more lengthy dives, two tanks (a “twin-set”) may be needed. Compact “pony bottles” are often used as a backup air source; mounted next to the main tank, these are equipped with an independent regulator.

SECURED AGAINST MOVEMENT
Tanks stored upright must be secured. Always store them out of direct sunlight.

TYPES OF TANKS

Tanks may be made of aluminum or steel. Steel is heavy and corrodes in salt water, but if well maintained it is durable and long-lasting. Aluminum is a lighter metal, but because tank walls must therefore be thicker, this adds bulk, and largely negates any weight advantage; they are also more prone to damage.

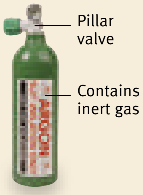
Pillar valve
Contains inert gas

Suit inflation tank

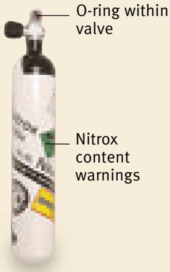
O-ring within valve
Nitrox content warnings

3-liter pony bottle

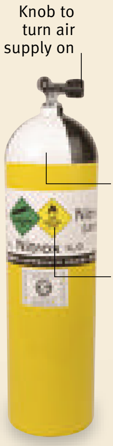
Knob to turn air supply on
Black/white indicates oxygen enrichment
Standard hazard symbols

Nitrox tank

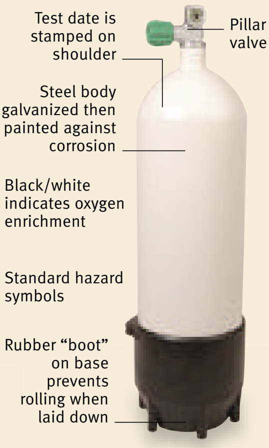
Test date is stamped on shoulder
Pillar valve
Steel body galvanized then painted against corrosion
Rubber “boot” on base prevents rolling when laid down

A steel tank

Tanks are most commonly filled with compressed air. For technical diving (*see pp.194–95*), however, they can be filled with special gas mixes, such as nitrox and trimix. Drysuit inflation tanks, used mainly by technical divers, are filled with the inert gas argon, which, being denser than air, retains body heat for longer.

Because the air inside the tank is used up during the course of a dive, it gradually becomes lighter. Most people forget that air weighs a certain amount too, and compression packs a great deal of it into one tank. Aluminum tanks may even become positively buoyant as air is used up.

THE TANK VALVE

A valve screwed into the neck of the tank provides an attachment for the regulator first stage, for either an A-clamp or a DIN (*see pp.60–63*), and a means of turning the gas supply on and off. Always check that there is a sound O-ring in the valve before fitting your regulator. Without one, or with a damaged one, the fitting won't seal.

MAINTENANCE AND STORAGE

Fill your tank at reputable dive shops or centers and make sure it is "in date" and regularly serviced. If you are storing your tank on a boat, do not leave it standing up (especially if gear is attached) unless secured in a rack. Take care to lay it down and secure it so that it does not roll around. Tanks are full of highly-pressurized gas, so handle with care. Store tanks out of direct sunlight, especially when full, as this can cause a pressure buildup inside. If you have not used your tank for more than six months, have it refilled to get rid of any stale air.

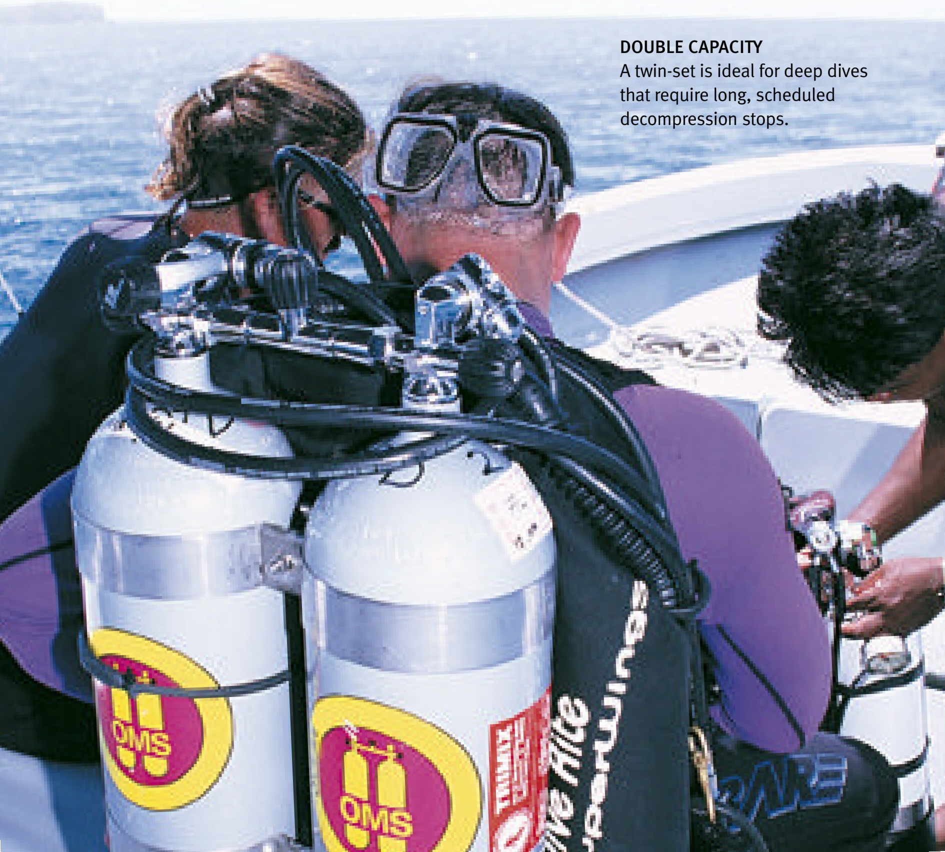

DOUBLE CAPACITY

A twin-set is ideal for deep dives that require long, scheduled decompression stops.

Weight systems

When diving, your suit, BC, and even your own body all add to your buoyancy. There are many systems for carrying the lead ballast used to offset this, and they can be tailored to the environment you will be exploring. Comfort and ease of use should be a consideration.

STAYING DOWN

PASSING A WEIGHT BELT
When handing over a belt, always hold it with the buckle down, so that the weights cannot slide off.

When wearing a drysuit or thick wetsuit (*see pp.50–55*), you will need to wear a considerable amount of weight to counteract the buoyancy of the suit. The most inexpensive way of wearing ballast is on a belt carrying hard lead tablets. Other systems use lead shot as the ballast, which is more comfortable to wear around your waist, as it molds to your contours. This is of most relevance to women, who often find that a standard weight belt is uncomfortable on the hips.

Many BCs now feature integrated weight pockets, offering a more adjustable approach to weight distribution and trim. The lead carried by such BCs is mostly stored in quick-release pockets, but there are usually secondary stowage areas that are inaccessible during a dive. It is important to make sure the amount of releasable lead in the BC will give you sufficient positive buoyancy to guarantee an unassisted return to the surface if you have to jettison it.

WEIGHT SYSTEMS

STANDARD WEIGHT BELT A basic nylon belt carries lead tablets that have two slits through which the belt is threaded. The entire belt is dumped in an emergency, via a rapid-release cam buckle.

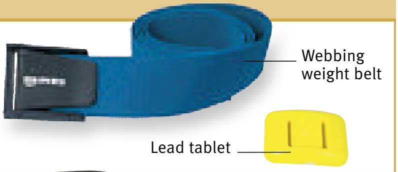

POUCH-STYLE WEIGHT BELT Some belts have pouches that hold bags filled with lead shot, which are easy to pull out and discard. A variation on this is a belt with a single compartment to which you add loose shot.

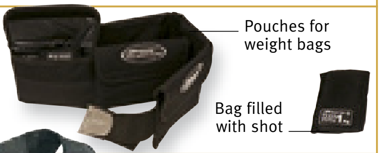

WEIGHT HARNESS Taking weight off your waist and suspending it from both shoulders makes carrying the load more comfortable. Quick-release catches allow dumping in an emergency.

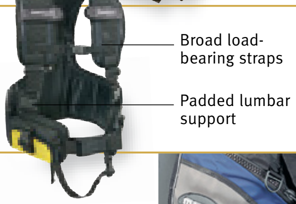

WEIGHT-INTEGRATED BC This is perhaps the most comfortable way of carrying weight. The weight can be distributed around your body, aiding correct posture in the water (*see also* BCs, *pp.56–59*).

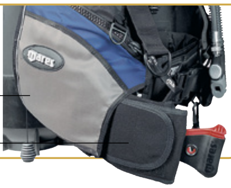

SECURING WEIGHTS TO A BASIC BELT

To prevent the lead tablets from sliding along your belt and altering your stability during a dive, you can secure them in place with plastic keepers. Alternatively, you can twist the belt to hold them in place. Insert the belt through the first slit in the weight, make a half turn, and then run the belt through the second slit.

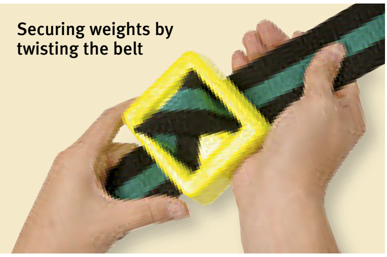

Securing weights by twisting the belt

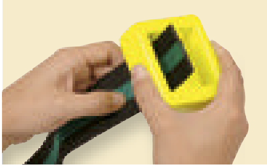

1 **To use a keeper** on a basic weight belt, thread the belt through the weight tablet, and locate in the desired position.

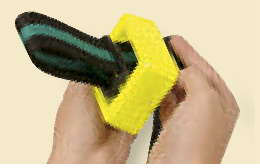

2 **Take the belt** up through the keeper, bend and thread back through the keeper, then through the weight.

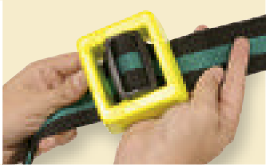

3 **Pull the belt** taut on each side of the weight. Be careful to avoid kinking the webbing as you do so. Repeat as necessary.

REFINING YOUR WEIGHT SYSTEM

Weights are something you will not want to travel far with—and you do not need to, because they can be rented at dive centers. You will find that when you dive in different environments and in different suits, your weight requirements change. Record the configurations that work best for you somewhere handy, such as at the back of your log book. Whichever way you decide to wear your weights, it is vital that you can release them quickly and safely in an emergency.

LEAVING GRAVITY BEHIND
Heavy weights, though awkward on land, will not be a burden underwater.

ANKLE WEIGHTS

When a diver wears a drysuit (*see pp.54–55*), the air within the suit can become trapped around the legs and feet, inverting the diver. Ankle weights will help to counteract this undesirable effect.

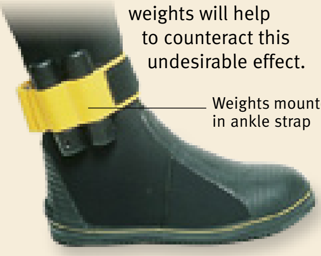

Weights mounted in ankle strap

Dive flashlights

A flashlight is an essential item of dive gear. Although primarily used when diving at night and in conditions of reduced visibility, such as in caves or in murky water, flashlights also have other useful roles, including illuminating subjects for underwater photography.

LIGHTING UNDERWATER

Lights vary enormously in design and cost, but the basic function is to provide reliable illumination when submerged. There are good designs in nearly every price range, but flashlights, especially hand-held ones, are easy to lose and damage, so it is worth weighing up carefully how much you want to spend. It is also wise to obtain an equally reliable backup flashlight, such as a smaller pencil-style model, to stow in a pocket, for use if your primary light fails during a dive.

BURN TIME AND BATTERIES

One of the most important factors to consider when buying a flashlight is burn time—you do not want to run out of battery charge halfway through a dive,

USING A DIVE TORCH

Flashlights are easy to lose, especially during dives in strong currents. Wrist straps offer a degree of security, but it is safer to clip them on with a flexible leash. Stow them close to your body to minimize the risk of being hit on rocks. Also, try not to switch the light on and off too often during the dive, because this may cause the bulb to fail.

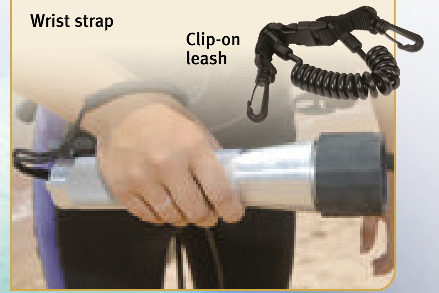

LIGHT IN THE DARKNESS
A cavern diver surveys the inside of a sea cave. Lights are an essential piece of diving safety equipment.

TYPES OF FLASHLIGHTS

HIGH-INTENSITY DISCHARGE This type of light burns brighter than a halogen bulb and, because it requires less power, has a long burn time. Such lights can be heavy and expensive, however.

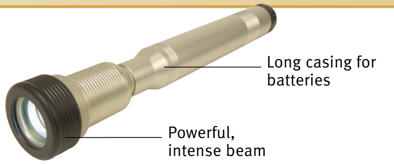
Long casing for batteries
Powerful, intense beam

BACKUP A range of flashlights have evolved that are intended for use if the diver's primary light fails. As such, they are small and lightweight, but only generate enough light for emergency use.

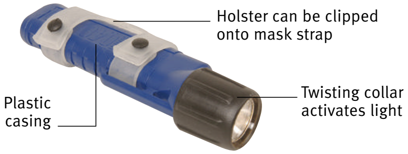
Holster can be clipped onto mask strap
Twisting collar activates light
Plastic casing

PISTOL-GRIP This is probably the most widely used style of light among recreational divers. They are fairly inexpensive and usually use conventional non-halogen filament flashlight bulbs.

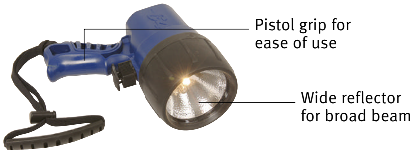
Pistol grip for ease of use
Wide reflector for broad beam

UMBILICAL An umbilical light has the battery housed in a separate case. This model uses high-intensity light-emitting diodes (LEDs) to generate a beam. Umbilicals have long burn times.

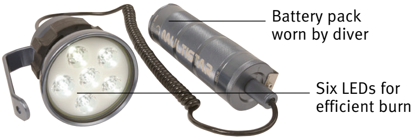
Battery pack worn by diver
Six LEDs for efficient burn

HIGH-TECH RECHARGEABLE This model can be charged via a special "wet" contact that means the case does not have to be opened, minimizing the risk of flooding through careless reassembly.

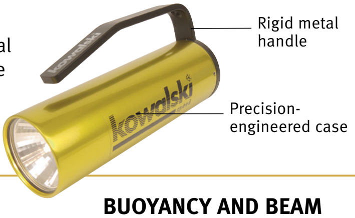
Rigid metal handle
Precision-engineered case
kowalski

Rear of light

which could compromise safety. There is usually a trade-off between output and burn time. Some lights are very bright and offer an excellent field of illumination for a short duration. But many lower-output models can outlast much brighter competitors, so consider carefully which would be more useful for you before making a purchase.

Rechargeable flashlights are more cost-effective than those requiring battery replacements, and tend to offer the greatest light output but the shortest burn time. Also consider the recharge time, especially if you are diving from a liveaboard boat and the vessel's generator is run only for short periods of time.

BUOYANCY AND BEAM

Another factor to consider is buoyancy. Some flashlights are positively buoyant, because they have a large airspace within the reflector. This makes them unbalanced in the water and difficult to handle. A positively buoyant light cannot be laid down, for example, if you need to light a subject for photography.

Lamps also vary in the size of the hotspot (central area of beam) and peripheral halo. The halo can be useful because it lights up a wider area than just the main hotspot. The hotspot is the brightest part of the beam, and is best for highlighting specific objects or for illuminating murky surroundings.

Surface marker buoys

Marker buoys may be used either during a whole dive or just before you ascend, to let those at the surface or on the shore know where you are, and also to aid your ascent. These devices offer a sense of security for both diver and surface cover, and aid safe recovery.

SMB OR DSMB?

A surface marker buoy (SMB) is an inflatable float linked to the diver by a line. It allows an observer at the surface to monitor the diver's position underwater. SMBs should be in a high-visibility color—most are orange.

The line to which the float or buoy is attached is usually stowed on a special reel. The reel should be held in one hand, with not too much slack on the line. You should use an SMB when your boat cover needs to be aware of your position at all times, such as during drift dives (where undersea currents propel the diver along), or where there is a likelihood of heavy boat traffic overhead.

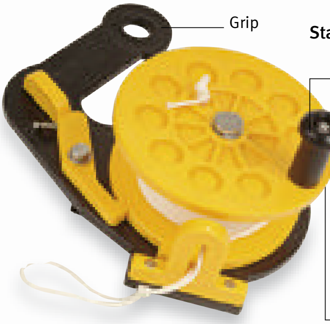

STANDARD REEL AND LINE
Reels are available for both right- and left-handers for ease of winding.

REEL AND DSMB
Line and buoy can be wound and clipped together for compact storage.

Another type of buoy is deployed only at the end of a dive, or in an emergency. The delayed SMB (or DSMB) is carried deflated during the dive, then inflated underwater (*see pp.130–31*) before ascent, carrying a line from the reel up to the surface. When it pops up,

DIVER WITH DSMB INFLATED
By the time you surface, your boat cover should be en route to pick you up.

DIVER WITH SURFACE MARKER BUOY
Only one SMB, inflated before the dive, is needed per buddy pair, provided you remain together during the dive.

it shows where you are about to surface. Its line also acts as a guide for making a slow, safe ascent and for decompression stops (*see p.101*). Always make sure you are some distance from other divers using buoys before deploying, or you risk fouling each other's lines.

USING A REEL

Both SMB and DSMB lines should be tied with a bowline knot to the reel. A reel should be compact enough to fit into a pocket or clip onto your BC, but not so small that it is difficult to operate, especially if gloves are worn. Some reels have a ratchet action to stop the line from unwinding on its own, and this helps to avoid tangles. The length of line you use should correspond to the depth you are expecting to dive to; this may be 130 ft (40 m) or even more. If the line is too short, then when it runs out, the DSMB will yank you upward at a dangerously fast rate until the buoy reaches the surface. This can also happen if the reel jams, which is why you must never deploy a DSMB while the reel is still clipped to your BCD: you must hold the reel in your hand so that in an emergency you can simply let it go.

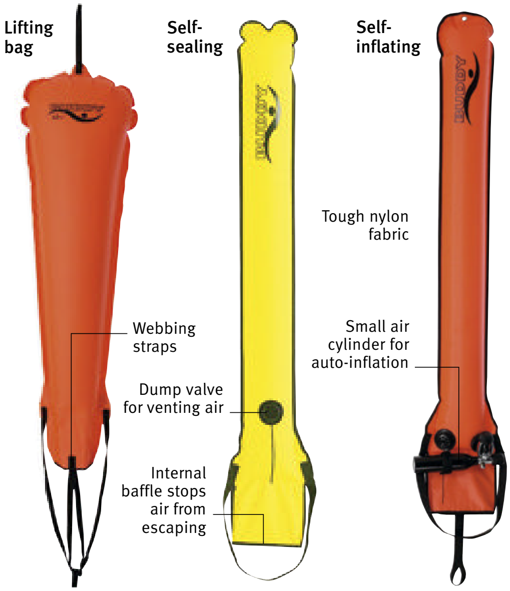
Lifting bag
Self-sealing
Self-inflating
Tough nylon fabric
Webbing straps
Small air cylinder for auto-inflation
Dump valve for venting air
Internal baffle stops air from escaping

TYPES OF DSMBS
The cheapest lifting bags have an open base from which air can escape after inflation. Self-sealing types are more reliable.

Safety and signaling devices

It is rare to be lost at the surface, but you must be equipped for such an eventuality. To guide rescuers to your position, you should carry high-visibility surface location aids. The boat crew must know what color equipment you are wearing, and which aids you are likely to be using.

SIGNALING OPTIONS

SURFACE OBSERVATION SIGNAL This tall, inflatable signal is easily seen by boats or aircraft. It is inflated using compressed air from your cylinder.

Even on a relatively straightforward dive, the current can take you a long way away from your boat cover, and heavy swell can make you difficult to locate. If this happens, stay close to your buddy, and, if possible, secure yourself to them. Signaling to the boat will speed up recovery, and there are various gadgets available for this. The devices that are most commonly used are inflatable surface marker buoys (*see pp.74–75*). It is best to use the long "safety sausage" type, which stands up in the water, and remains inflated once deployed, rather than an open-ended one. If you opt for the latter, make sure you also carry an alternative device, such as a collapsible flag. Surface horns and power whistles are also used. They are of limited range, but can help to attract

SIGNALING DEVICES

FLAG Collapsible plastic flags in high-visibility or fluorescent colors are excellent for signaling at the surface, especially in a swell. They can be rolled and stowed alongside your cylinder.

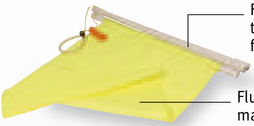
Folding or telescopic handle for easy storage
Fluorescent for maximum visibility

STROBE LIGHT Strobes are particularly effective when attached to the top of a folding flag. If attached to your BC, the flash may only be intermittently visible as waves lap over and around it.

Strobe gives up to 8 hours constant use
Battery housed in waterproof casing

DISTRESS FLARES Aerial flares do not pinpoint your position, so they are best used in conjunction with other devices. They can be difficult to operate when wearing gloves, or with cold hands.

MINIFLARE 3
Unbreakable plastic box
Box houses firing mechanism

PERSONAL LOCATOR BEACON (PLB) Devices that broadcast radio distress signals can be used to alert surface and air searchers to your presence. Some are also equipped with bright lights for close-range visual detection.

SEA
PLB antenna flashes to aid location
Signal from beacon has range of at least 35 miles (55 km)

attention if the boat is not too far away. You should always carry a flashlight, since the beam can be easily spotted at night, especially when moved slowly in a scanning motion, both vertically and horizontally (*see pp.184–85*). Make sure you also carry a backup light. Strobe lights are even more effective, since their flashing light travels in all directions, eliminating the need for scanning. Flashlights and strobes must be robust and reliable; regular inspection and maintenance is vital, with special attention to sealing surfaces and O-rings.

Reflective signals are useful in bright weather. It is worth carrying an old CD or mirror to use as a reflective device to attract attention. Reflective patches on your hood and upper body may be visible to aircraft searching overhead. Dye markers stain the water and can help a search from the air, but should only be used once the aircraft is overhead, since the dye rapidly dissipates.

If you find yourself on the surface with no signaling devices whatsoever, waving your arms or even your fins and shouting may help to alert attention if your boat cover is nearby. Keep calm and persist with signaling.

INTEGRATED SAFETY DEVICES

Some safety devices can be integrated into existing gear. Air-horns, for example, attach to the low-pressure hose on your BC. These are far louder than whistles, and are useful if you are out of breath or under stress. Safety sausages can also be inflated with your BC.

Standard BC

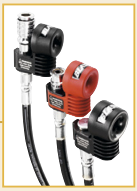

Air horn attachments

RESCUE FLAGS
A brightly colored flag is a cheap, simple-to-carry, easy-to-deploy, and highly visible location device.

Knives

A dive knife is essential for freeing yourself if you get snagged on fishing lines and other obstacles. The simplest dive knife—little more than a basic blade in a plastic mount—will get you out of most tangles, but a good one will prove an invaluable multipurpose tool.

SELECTING A KNIFE

Knives must be rustproof, but the better the rust-proofing of stainless steel, the harder it is to maintain a sharp edge. Titanium knives, while expensive, are light, rust-resistant, and stay sharp. Knives come in various sizes. Small ones can be mounted on your BC or belt, where they are easy to reach and out of the way.

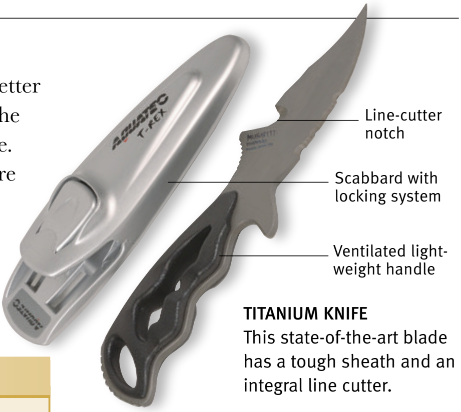

TITANIUM KNIFE
This state-of-the-art blade has a tough sheath and an integral line cutter.

Standard knives with 4½ in (11.5 cm) blades are most popular. Blades may be serrated for sawing rope or smooth for slicing monofilament line, and may have a line-cutter notch. Blunt-ended blades are ideal for tasks that need leverage, such as prying open containers. It is worth choosing a knife with a metal pommel on the end, which can be used as a hammer.

SHEARS AND MULTI-TOOLS

Multi-tools incorporate both types of knife blades, for slicing and sawing—useful for rope and monofilament line. Underwater shears are only really needed if diving in very hazardous conditions or for use as tools in salvage.

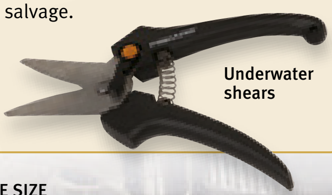

KNIFE SIZE
Large knives are popular, but a smaller blade can be just as useful on a dive.

Bags

Whenever you move to and from a dive location, you will need a bag to carry all your gear. Ideally, your chosen dive bag should be capacious and light, but it must also be durable enough to survive the rigors of transporting heavy equipment.

BUYING A BAG

When choosing a bag, check that it has strong seams, sturdy handles, and no parts that are likely to rust. Also consider security, especially when travel will involve your being separated from your baggage. Thin bags can be cut open, so a padlock will not guarantee that the contents stay safe. You may want to invest in a rigid or semi-rigid bag (*see p.238*).

Many divers use a large duffel bag for travel, and a smaller day bag (or even two) for dive days. Duffel bags range in size from 6,000 to 10,000 cu in (100 to 180 liters), day bags from 1,800 to 5,000 cu in (30 to 80 liters). There are countless "extra" bags, such as fin bags, mask bags, tool pouches, and pony-bottle pouches. While useful, most of these are not essential if you pack your gear carefully into one large duffel bag.

8Q-M
MALDIVIAN A
8Q-MAB

FLIGHTS TO FAR-AWAY LOCATIONS
Dive baggage has to be hard-wearing and tough, especially as several transfers are often needed to reach a dive location.

BAGS FOR DIVERS

MESH BAG Perforated bags can be used to rinse all your gear at once in fresh water, or to carry small items aboard a boat without fear of water ruining the bag.

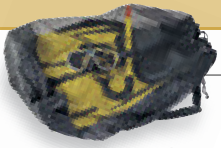
Water-permeable mesh fabric

DUFFEL BAG These can accommodate most of your gear, and also have various compartments where you can stow small items, such as slates and carabiners.

Rustproof plastic zippers

REGULATOR BAG Your regulator is valuable, and needs its own padded bag. It can be put in your main bag, but when flying, most divers stow it safely in their carry-on.

Protective padded sides

DRY BAG When you reach the dive site, a watertight bag or case is essential to protect clothing and electrical equipment, such as cameras, from moisture and salt.

Aperture can be sealed

TRAVEL CASE A secure, rigid-sided case gives extra protection to your gear while in transit. Wheels and a telescoping handle make transportation easier.

Outer pockets for nonvaluable items

Gadgets and accessories

There are a host of diving gadgets on the market, including fun items such as underwater MP3 players. Other accessories, however, have more practical uses. Clips and retractors are very useful for securing equipment, and may save you the loss of a camera or flashlight.

DIVER PROPULSION DEVICES

Underwater scooters, usually referred to as DPVs (diver propulsion vehicles), make great toys, but they can be practical and useful, too—for example, when exploring a large wreck site. There are two basic types: those that you sit astride, and those you hold on to, which tow you along. It is safest to use DPVs only to travel on a horizontal plane. Descending or ascending under power can be very dangerous, due to rapid pressure changes. DPVs are not cheap, but there are less expensive models suitable for general recreational use—that is, where failure of the device would hardly constitute an emergency. More expensive but tougher, more reliable machines are generally not aimed at the leisure diver but intended for expeditions, such as cave explorations, where failure of the unit mid-dive would be a more serious development.

Jetboots, made by a California diving company, also propel the diver along effortlessly: they comprise a pair of propellers that attach to your legs, controlled by a switch at your waist. Jetboots can propel you as fast as some DPVs, and leave your hands free.

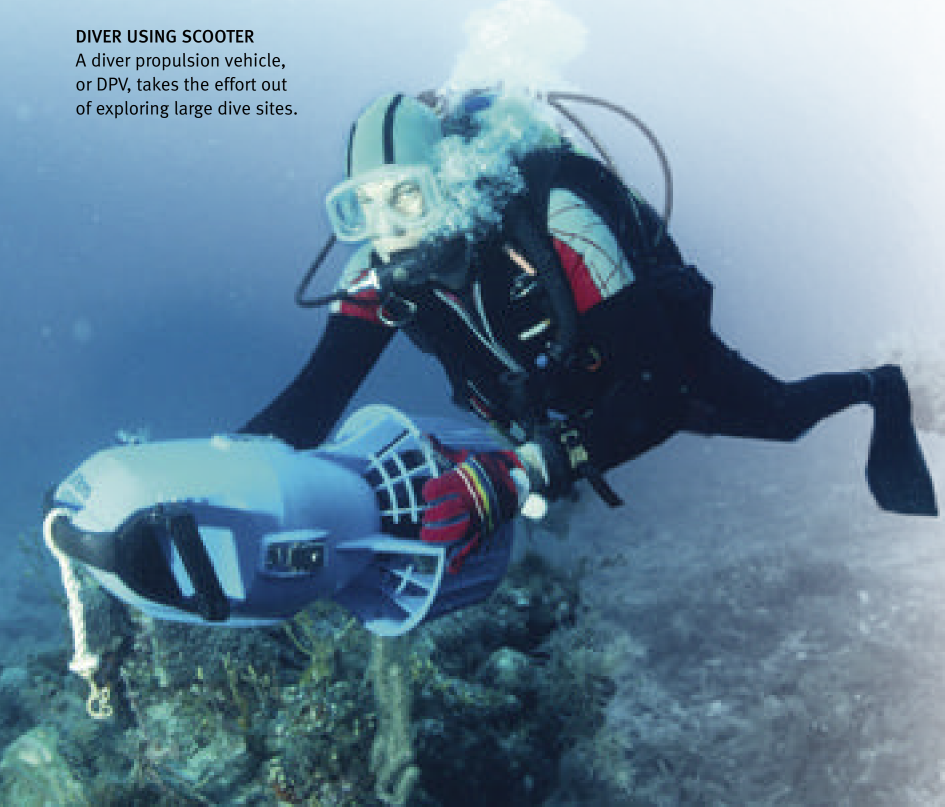

DIVER USING SCOOTER
A diver propulsion vehicle, or DPV, takes the effort out of exploring large dive sites.

BANDS, CLIPS, AND FASTENINGS

Cam bands—webbing straps that hold your cylinder to your BC—are available with a number of different buckle mechanisms that ensure that the tank is secure and held close to your body. Retractors are very useful for attaching items, such as a flashlight or slate, to your BC because they pull the item close to your body when not in use. Carabiners and bolt-snap clips (as used on dog leashes) are useful for attaching equipment securely to your BC during the course of a dive.

Retractor

Spring-loaded snap clips

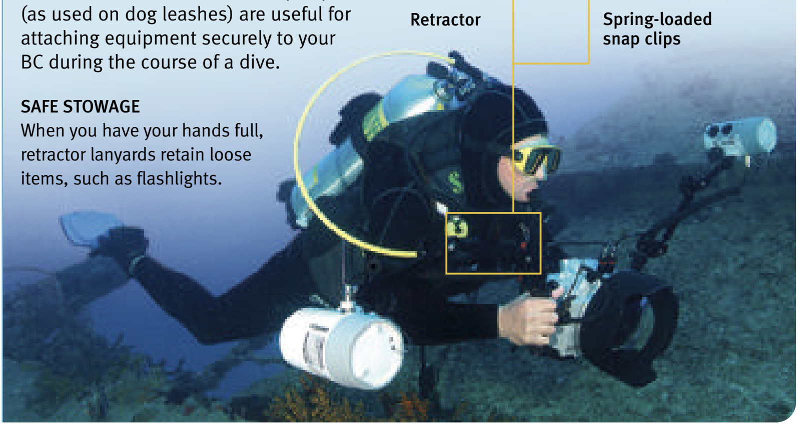

SAFE STOWAGE
When you have your hands full, retractor lanyards retain loose items, such as flashlights.

ATTRACTING ATTENTION

There is a range of gadgets that you can use to attract your buddy's attention underwater. Some BCs have a buzzer that uses a small amount of compressed air to generate a sound. Slightly more low-tech are tank pingers—a piece of elastic with a hard plastic ball attached. This is slipped around the cylinder and can be stretched and released to "ping" against it, creating a metallic sound that travels well underwater. Shakers are tubes filled with metal balls. When agitated, these create a clearly audible rattle.

WRITING UNDERWATER

Slates are handy for mapping dive sites or making notes on any unusual species encountered on your dive. They are made of white plastic, with a matte surface that can be written on with a pencil. Flat slates can be attached to a BC or slipped into a pocket; wrist-mounted slates are contoured to fit around your arm. The latter are especially useful when making technical dives with various decompression stops: you can read your computer and the list of stops from the same arm. A compass can be mounted on a flat slate, enabling you to look at navigational notes while checking your bearings.

AIR-LOCK TANK CAM BAND
Some dive gadgets are labor-saving devices. Tank band buckles that can be tightened using compressed air are a useful example.

New technology

In the 1950s, development of the scuba unit revolutionized diving, and its technology continues to develop apace. Modern equipment is sleek, lightweight, and colorful, and advances in the efficiency of rebreather systems are transforming diving once again.

MASKS AND VEHICLES

One of the most notable recent advances in modern dive equipment is the use of head-up displays in masks, which are similar to those used by military pilots. Essential dive information is sent via radio frequency from the tank to the mask, where it is presented on an LCD. Masks with an integral radio communication system, which allows divers to talk directly to one another, are also available.

Advanced synthetic materials have made dive equipment stronger and lighter, and have been used in the development of diver propulsion vehicles (DPVs; *see p.80*) that are smaller and easier to handle.

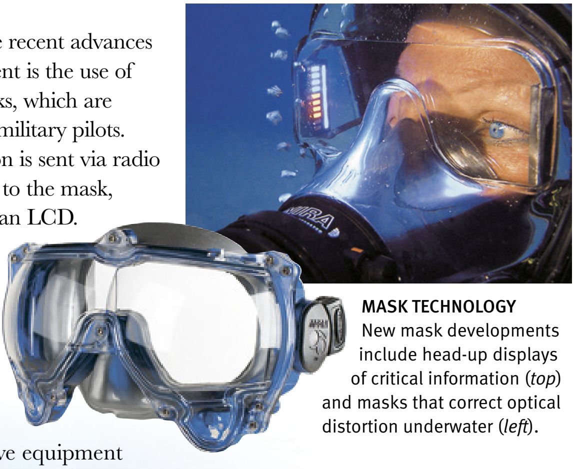

MASK TECHNOLOGY New mask developments include head-up displays of critical information (*top*) and masks that correct optical distortion underwater (*left*).

FROM SCUBA TO REBREATHER

In the last decade, rebreather technology has become available to the recreational diver, representing the most dramatic leap forward in diving equipment since the development of scuba itself.

In contrast to scuba—an "open circuit" system that discharges most of a diver's air supply into the water with the exhaled breath—rebreathers recycle the diver's exhaled breath, using chemicals to remove waste (mainly carbon dioxide) and allowing the diver to inhale the gas again. Each breath uses about 4 percent of the oxygen in the inhaled gas mix, so one of the main tasks of a rebreather is to maintain oxygen levels in the breathing loop, generally by adding extra oxygen.

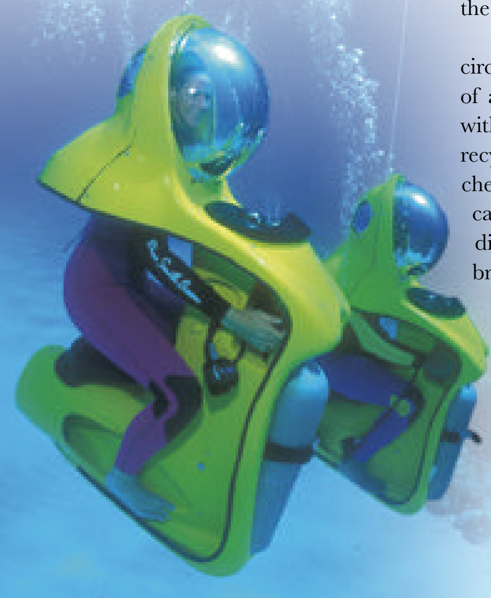

UNDERWATER SCOOTER DPV The breathing observation bubble (BOB) is powered by an electric motor and has a top speed of 2.5 knots.

Rebreathers using pure oxygen were used by frogmen in World War II, for whom the absence of bubbles was vital to hide their presence. Dive depths were limited to 20 ft (6 m), at which point pure oxygen becomes toxic. A revolution in rebreather technology occurred in the mid-1980s, allowing the use of nitrogen–oxygen gas mixes rather than pure oxygen. Modern rebreathers electronically monitor the concentration of oxygen in the mix and adjust it to safe levels for a given depth.

Rebreathers offer longer dive times and fewer decompression stops. They remain costly, and need careful maintenance and specialized training.

REBREATHER TECHNOLOGY

Modern rebreathers are divided into two categories—semi-closed rebreathers (SCRs) and closed-circuit rebreathers (CCRs). SCRs expel a small quantity of exhaled gas into the water, whereas CCRs only dump gas into the water on ascent. Both types clean exhaled gas in a scrubbing unit, which removes CO_2. They also ensure that the oxygen content of the inhaled gas is at a suitable level for the diver, and monitor toxicity, which the diver can check manually on a gauge, or on a computer display. Computer control has dramatically increased the efficiency and safety of rebreathing devices.

HOW A REBREATHER WORKS

A chemical in the scrubbing unit absorbs carbon dioxide from exhaled gas, while pure oxygen is introduced to the breathing loop to replace that consumed by the diver.

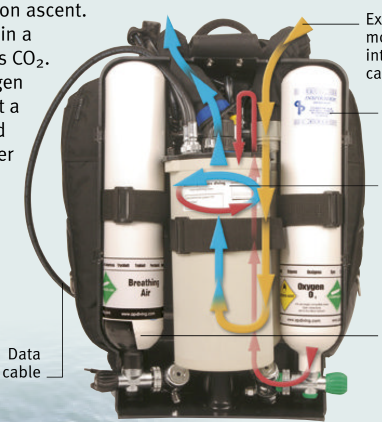

Exhaled gas from mouthpiece flows into scrubbing canister

Pure oxygen cylinder replaces O_2 used by diver

Absorbent chemical in scrubbing unit removes CO_2

Air from cylinder maintains volume of gas in breathing loop

Data cable

← Oxygen flow

← Inhaled gas flow

← Exhaled gas flow

Mouthpiece

Computer display

REBREATHER BENEFITS

Because gas is recycled in a rebreather, you use it up at a slower rate than with scuba gear, and so can spend longer underwater. The consistently high levels of O_2 help reduce post-dive fatigue.

Equipment assembly

The gear assembly process is a key part of any dive. During your training, you will be taught the basics of assembling dive gear. With experience and a few simple tips, you can perfect this process and make it efficient, rapid, and—most importantly—consistently safe.

THE IMPORTANCE OF PREPARATION

With clear, blue water beckoning, the Sun shining, and the dive site awaiting you, you may find that there is a great temptation to rush the gear assembly process. However, the equipment used for diving is nothing less than life-support gear, and should be treated with a corresponding level of respect. It is reasonable to say that putting dive gear together safely before jumping into the sea is as important as packing a parachute correctly before jumping out of a plane.

CHECKING FOR DAMAGE

The first stage in assembling your gear is to carry out a visual inspection. This is particularly important if the equipment is unfamiliar or rented. It is essential to examine the test dates (*see p.68*) for the

1 **Lay out equipment** on a mat or other clean, grit-free surface where you can assemble the gear easily.

2 **Wet the tank** band on your BC, if possible, since this helps improve its grip on the tank's metal surface.

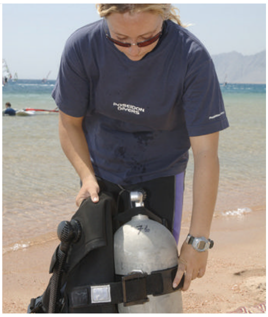

3 **Position the tank** with the pillar valve O-ring facing the backplate of the BC, then fasten the band around it.

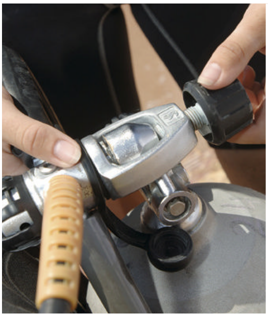

4 **Attach the regulator** first stage to the tank. Do not overtighten the clamp (or screw thread, on a DIN fitting).

5 **Pass the inflator hose** from your regulator's first stage (*see pp.60–61*) through the jacket's guides and straps before connecting it to the BC's inflator valve. Make sure the valve has engaged securely with the hose coupling.

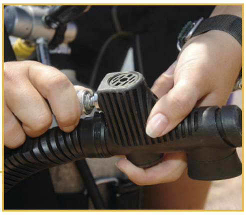

INFLATOR VALVE
The spring-loaded collar on the end of the hose fits on to the inflator valve.

tank and also the integrity of the O-ring (*see p.88*). Any nicks or cuts in the O-ring may lead to serious problems during the dive, yet replacing a damaged O-ring before the dive takes only seconds. Also look for wear and tear on the regulator hoses, particularly where they join the ports of the first stage. This is a common point of strain for regulator hoses, resulting in cracks and splits in the hose with sustained use. If the integrity of a hose has degraded, it may rupture when the air supply is turned on.

Check for signs of damage to the BC. With regular diving, there will be inevitable signs of wear and tear, but be sure to check the integrity of the buckles and load-bearing straps. These must be completely sound.

ASSEMBLING YOUR GEAR

When you are satisfied that your equipment is in good order, follow the steps below to make it ready. Take particular care to ensure that the band securing the tank to the BC is neither too high (resulting in the tank possibly coming free), or too low (resulting in the pillar valve restricting movement of your head during the dive, or actually striking it on entry).

6 **Turn on the air** supply, opening the tank's pillar valve all the way. Then turn the knob a quarter-turn back.

7 **Test air supply** by breathing from both your primary and secondary air sources. Check air quality and delivery.

8 **Secure the gear**, if you are not diving immediately, by tucking any loose parts inside the BC for protection. Most breakages occur in transit.

Disassembly

The end of a dive is an exciting time, and neglecting your dive gear at this stage is an easy trap to fall into. Take a little time, however, to clean and store your equipment properly: not only will it last much longer, but everything will be in order at the start of your next dive.

DEVELOPING A ROUTINE

As with so many things in diving, routine is the key. Many experienced divers attend to their gear the moment the dive is finished, and regard the dismantling, rinsing, and storage of their gear as an integral part of the dive itself. This is particularly true for diving from a boat, where a shortage of space frequently leads to cluttered decks and broken gear.

Diving equipment can cost a considerable amount of money, so it is worth taking a few moments to make sure it is properly dismantled and safely stowed.

The first stage of disassembly is to turn the tank off and purge any remaining air from the hoses using the purge button on the second stage (*see also pp.60–63*). The regulator first stage may then be removed from the pillar

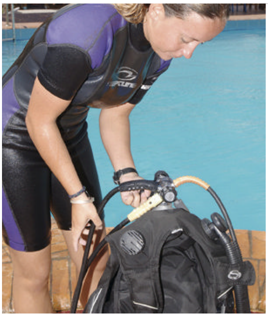

1 **Shut off the gas** supply, turning the knob on the tank's pillar valve all the way off before disassembly.

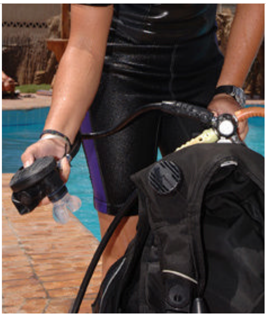

2 **Purge gas from** the system using the purge button on the regulator to vent any air remaining in the hoses.

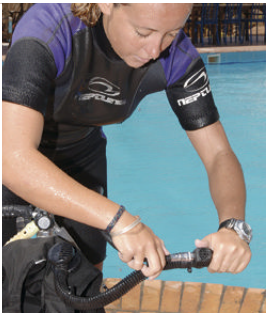

3 **Disconnect the inflator** hose from your BC's inflator valve, and the hose from the drysuit inflator, if worn.

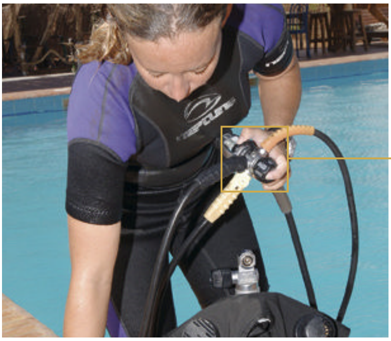

4 **Disengage the regulator first stage** from the pillar valve of the tank, and free the hoses from the BC by undoing all the clips and straps.

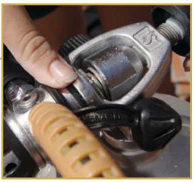

A-CLAMP FIRST STAGE
Remove this type of first stage by loosening the clamp first.

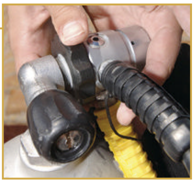

DIN-TYPE FIRST STAGE
Turn the knurled collar to unscrew the regulator first stage from the pillar valve.

valve of the tank. It should take no more than finger pressure to turn the clamp or collar; any more resistance indicates that compressed air remains in the system. You will need to check that the tank is completely turned off, then purge the hoses again.

After removing the regulator first stage from the tank, use a blast of air from the tank to dry the dust cap and filter. Fit the dust cap securely, then rinse the regulator thoroughly in fresh water. Never forget to put the dust cap on, otherwise water will enter the delicate mechanism of the first stage: this is to be avoided at all costs. Hang the regulator up to dry, ensuring that the hanging method does not put strain on the hoses at any of the points of attachment to the first stage. You can then detach your BC from the cylinder and drain it of any saltwater. Rinse the BC inside and out with fresh water, and inflate it orally to allow quick drying and prevent the formation of salt crystals inside.

Dive gear must be dried thoroughly between dives, ideally by hanging it up out of direct sunlight. Do not store it where it is compressed or where moisture may accumulate, such as in a boat deck locker or a diving bag.

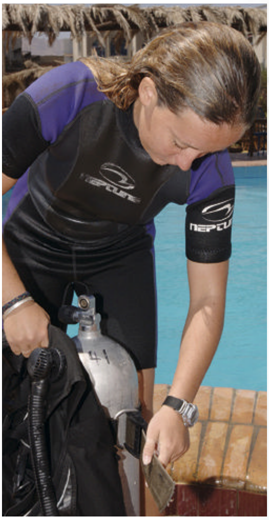

5 **Remove the BC** from the cylinder by undoing the cam buckle on the strap, and then sliding the BC upward until it is clear.

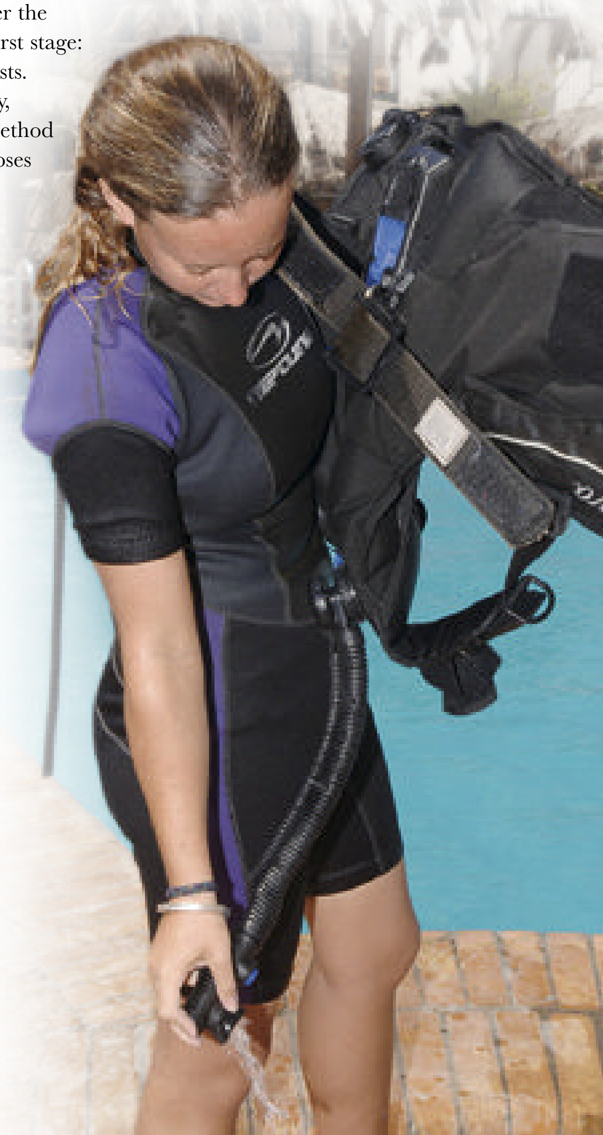

6 **Drain the BC** of saltwater by depressing the deflator button at the end of the corrugated hose. This allows the water to escape through the oral inflation point.

Equipment maintenance

Diving equipment is your life-support system underwater, yet many divers take a worryingly relaxed approach to maintaining their gear. A few simple steps will increase the life span of your dive gear, avoid the expense of constant replacements, and increase your safety.

TOOL KITS

Most divers carry a set of Allen keys, screwdrivers, or adjustable wrenches. Scuba multi-tools are all-in-one alternatives that incorporate virtually every basic tool that a diver might need on a dive boat or at a dive site. These include a range of hexagonal Allen keys designed to fit dive equipment and standard wrenches for regulator adjustment, as well as screwdrivers and a marlin spike.

Diving shops also sell "save-a-dive" kits, which consist of a set of lubricants, parts, and tools that can be used in the majority of equipment-related incidents on site. O-ring replacement and adjustments to hose configuration, for example, are simple, commonly required tasks that can be undertaken by anyone with such a kit.

Experienced divers also carry spare parts with them. This is sensible diving practice, and while the range of items differs from diver to diver, it usually includes items such as spare O-rings, silicone grease, tape, adhesive, an O-ring extractor, spare plugs for the regulator first stage, and any spare buckles or straps that might be necessary.

SCUBA MULTI-TOOL
A useful gift for any diver, this contains tools for most small maintenance jobs.

O-RING MAINTENANCE

The most disappointing reason for having to cancel a dive is the lack of a spare O-ring for a cylinder. O-ring malfunction may be indicated by air escaping once the regulator is fitted, but even in the absence of this you should make regular inspections to check that the O-ring has not degraded. In many cases, simply cleaning the O-ring and the valve groove with a lint-free towel will solve the problem. Pull the O-ring through your fingers—if you can feel cracks, it should be replaced. When removing an O-ring, never use a sharp tool, as this is likely to damage the ring.

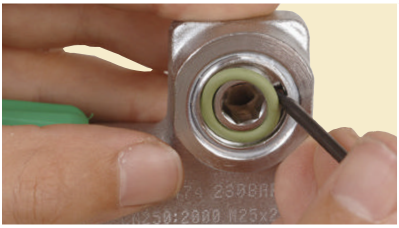

1 **To remove the O-ring** from a cylinder's pillar valve (*see pp.68–69*), use a specially designed extractor tool. Alternatively, use the rounded end of a tie-wrap or even a credit card.

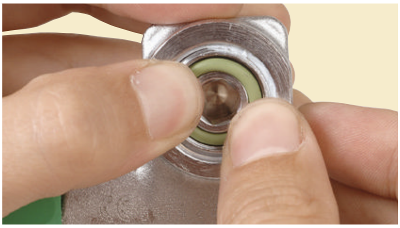

2 **Inspect the O-ring closely** and replace it if any cracks or tears are visible. Clean the valve groove with a lint-free towel, then press the new O-ring in carefully with your fingertips.

ADDING A REGULATOR HOSE

To add a hose to your regulator or change an existing hose is a simple process. You must avoid attaching a low-pressure hose to the high-pressure port, as this will rupture the hose. Most regulators now make this impossible by having different- sized ports, although older models may not have this feature. The high-pressure port is for the pressure gauge, while other ports are for a second stage or the inflator hoses. It is worth taking time to ensure that the hose configuration is practical and comfortable, to avoid strain on the base of the hoses and reduce drag.

1 **When adding a hose**, be careful to select the correct port (high/low pressure). If the ports are not clearly differentiated, or if you are in any doubt, consult the manufacturer's manual.

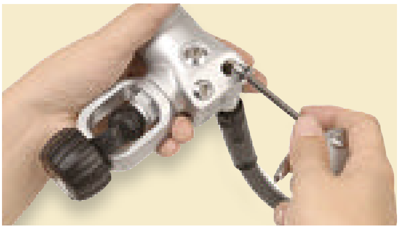

2 **Remove the plug** from the regulator port using the correct-sized Allen key. Some regulators still have raised bolts—these can be loosened with a wrench.

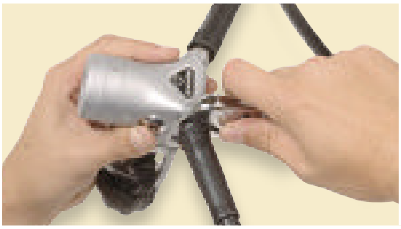

3 **Attach the hose** by simply screwing it into place. Tighten the nut with a wrench of the appropriate size—hose nuts are soft and can easily be damaged by pliers.

4 **Exactly the same** procedure can be used to attach further hoses to the other ports, and to replace damaged hoses. Always check hoses for cracks, fraying, and abrasion.

EQUIPMENT MAINTENANCE
Post-dive, wash all of your gear in clean, fresh water, and check out any problems you may have noticed.

The diving environment

Introduction

When you go diving, you are introducing your body to an alien environment. Evolution has not equipped our bodies for the underwater world, and you will encounter unusual sensory phenomena when you descend into the depths for the first time.

LIGHT AND VISION

Our eyes are designed to focus in air; underwater, our vision blurs unless we wear a mask, which puts an air space in front of our eyes. However, light travels more slowly in water than it does in air, and as it passes through the mask from water to air it bends, causing refraction—an optical effect that makes objects appear bigger and closer than they are.

Colors also look different to us as depth increases (*see p.183*). Objects near the surface look as colorful as they would above water, but as you go deeper, first reds disappear, then oranges, yellows, greens, and blues, until all light is lost. Colors can be revived by illuminating a submerged object with a flashlight.

SOUND AND HEARING

Above the surface, sound travels at approx 1,150 ft (350 m) per second, but underwater it travels four times faster. This makes it hard to identify the direction of a sound source: if your buddy signals to you by tapping his tank, you will hear the sound easily but may not be able to pinpoint where it is coming from. The range of audible sounds is also reduced, but the underwater environment is not as quiet as is popularly supposed: you can hear the scratching and snapping sounds made by fish and crustaceans, along with the sound of your breathing and any

ANATOMY OF A DIVER
The land-based development of the human frame means that your body is not adapted to many aspects of the underwater environment.

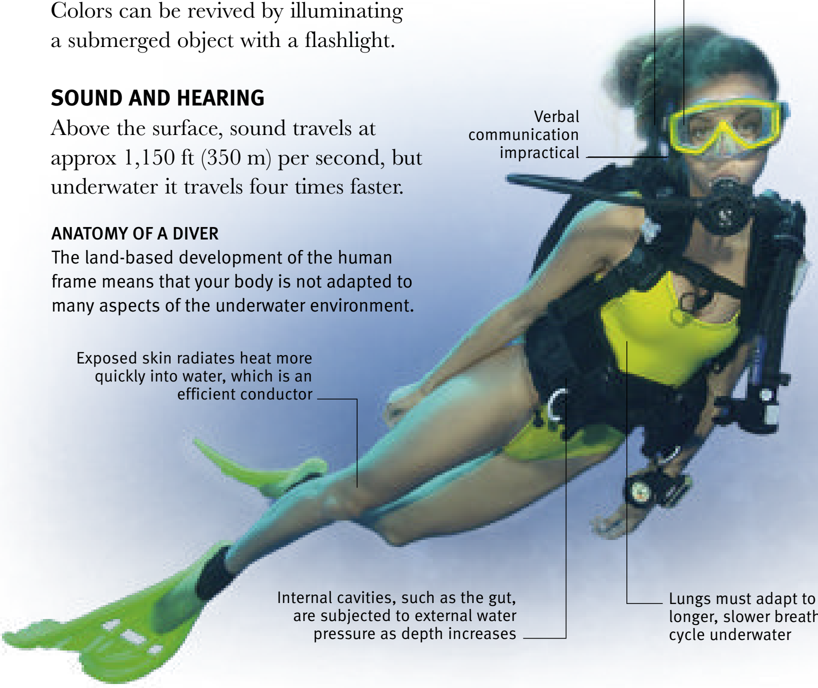
Direction of sounds harder to discern
Objects appear closer to the observer
Verbal communication impractical
Exposed skin radiates heat more quickly into water, which is an efficient conductor
Internal cavities, such as the gut, are subjected to external water pressure as depth increases
Lungs must adapt to a longer, slower breathing cycle underwater

boat noise close by. However, you will find it difficult to communicate verbally underwater, even if you remove your regulator and shout, which is why divers use hand signals (*see pp.144–45*).

Sounds made above water do not easily penetrate below the surface, so any noises made to alert divers must be made underwater. A typical recall signal from a dive boat is to bang on the metal ladder on the craft's stern, which, as its lower part is in the water, transmits sound to divers beneath.

HEAT AND PRESSURE

Water conducts heat 25 times more efficiently than air, so the human body loses heat quickly underwater. In extreme cases, a diver may lose heat faster than it can be generated by their body, leading to hypothermia. When diving, it is important to always wear thermal protection appropriate to the conditions.

The airspaces in the body—not just the lungs, but the inner ear, sinuses, and gut—will be increasingly affected by pressure as you make your descent. This can lead to uncomfortable sensations (*see pp.98–99*) that must be relieved by equalizing internal and external pressure manually using the Valsalva maneuver.

SEA CHANGE
Divers patrol a reef wall in the Red Sea. As depth increases, physiological effects become more profound and numerous.

Depth and pressure

To understand the principles of diving, it helps to have a grasp of basic physical laws. When you dive, water exerts pressure on your body, and this pressure increases with depth. This simple fact influences all aspects of diving, from buoyancy control to safety considerations.

UNDERSTANDING PRESSURE

On land, your body is constantly subjected to external pressure from the weight of all the gases in the atmosphere. This is called atmospheric pressure, and it is measured in pounds per square inch (psi) or bar. Atmospheric pressure at sea level is 14.7 psi (1 bar)—that is, 14½ lb pressing on every square inch (1 kg per square centimeter) of your body's surface. This pressure is not fixed; it varies slightly with weather conditions and decreases with altitude. At the summit of Mount Everest (29,028 ft/8,848 m), atmospheric pressure is only 4.5 psi (0.31 bar).

When you dive underwater, pressure is also exerted on your body by the weight of the water above and around you. Because water is denser than air, the pressure generated by just 33 ft (10 m) of seawater is equal to that generated by all the gases in the atmosphere above sea level. Seawater is denser than fresh water, because it contains dissolved salts and minerals. This increased density means that pressure increases slightly faster with depth in seawater than in fresh water.

When you dive, you are subject to the cumulative weight of both atmospheric pressure and water pressure. The combined total is known as absolute pressure. Your depth gauge translates pressure into an accurate depth reading, but it is calibrated to ignore atmospheric pressure, so it indicates zero depth when you are at the surface. This is known as gauge pressure. Always use absolute pressure to calculate the total pressure at a given depth.

HOW PRESSURE RELATES TO DEPTH

Because water is much denser than air, pressure increases quickly with depth underwater. Water cannot be compressed and transmits pressure freely, so pressure increases cumulatively, and at a constant rate, as you dive deeper. At a depth of 33 ft (10 m) of seawater, absolute pressure is 29.4 psi (2 bar). This figure is the sum of the pressure generated by the atmosphere (14.7 psi) and by 33 ft of water (14.7 psi). At 66 ft (20 m) absolute pressure is 44.1 psi (3 bar), and so on, rising by 14.7 psi for every additional 33 ft of water depth.

If diving at a high altitude site, like a mountain lake, atmospheric pressure is reduced; consequently, absolute pressure is lower, too. You must use special dive tables at such sites.

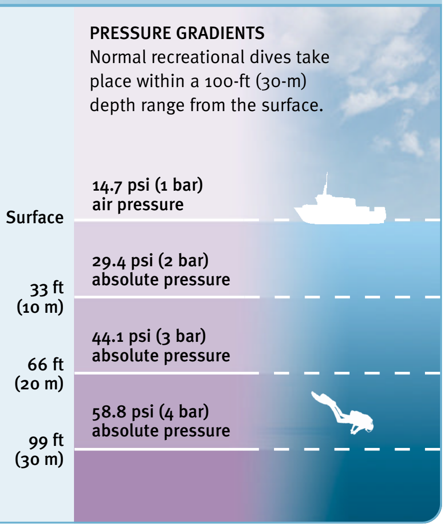

PRESSURE GRADIENTS
Normal recreational dives take place within a 100-ft (30-m) depth range from the surface.

HOW PRESSURE AFFECTS GASES

In the 17th century, scientist Robert Boyle made an important discovery. He found that at a constant temperature, the volume of a gas is inversely proportional to the pressure exerted on it—meaning that as pressure increases, the volume that a gas occupies decreases. This relationship is known as Boyle's law.

Boyle's discovery has important implications for divers. Buoyancy devices such as BCs contain bladders filled with air. These provide upward lift to help you float weightlessly underwater. As you descend, however, increasing water pressure compresses the air inside the BC. This means it displaces a smaller volume of water, and so generates less buoyancy (*see p.97*), causing you to sink. You must then inject more air into the BC to boost volume to its former level. On ascent, this must be released again, because as pressure decreases, the extra air inside the BC expands, causing you to become very buoyant and rise too quickly. For the same reason, you should never hold your breath underwater. Compressed air inhaled at depth expands as you ascend, and if it is not exhaled, it can burst delicate vessels in your lungs.

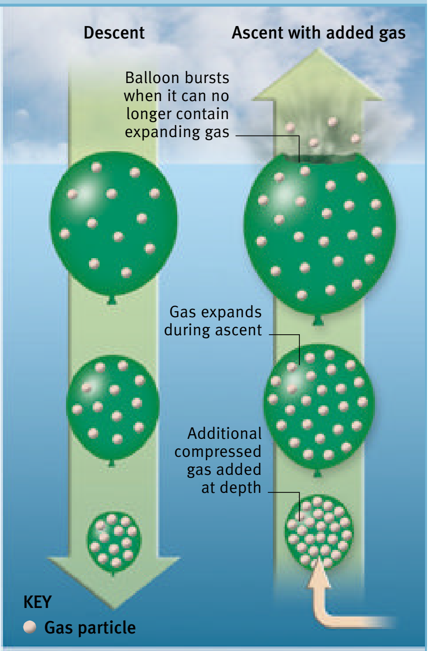
Descent
Ascent with added gas
Balloon bursts when it can no longer contain expanding gas
Gas expands during ascent
Additional compressed gas added at depth
KEY
● Gas particle

If you took a volume of gas, like that contained within a balloon, and submerged it, the space the gas occupied would get smaller with increasing depth.

If you added extra gas to the same balloon at depth, it would expand slightly. During ascent, the gas inside would expand to more than the balloon's original volume.

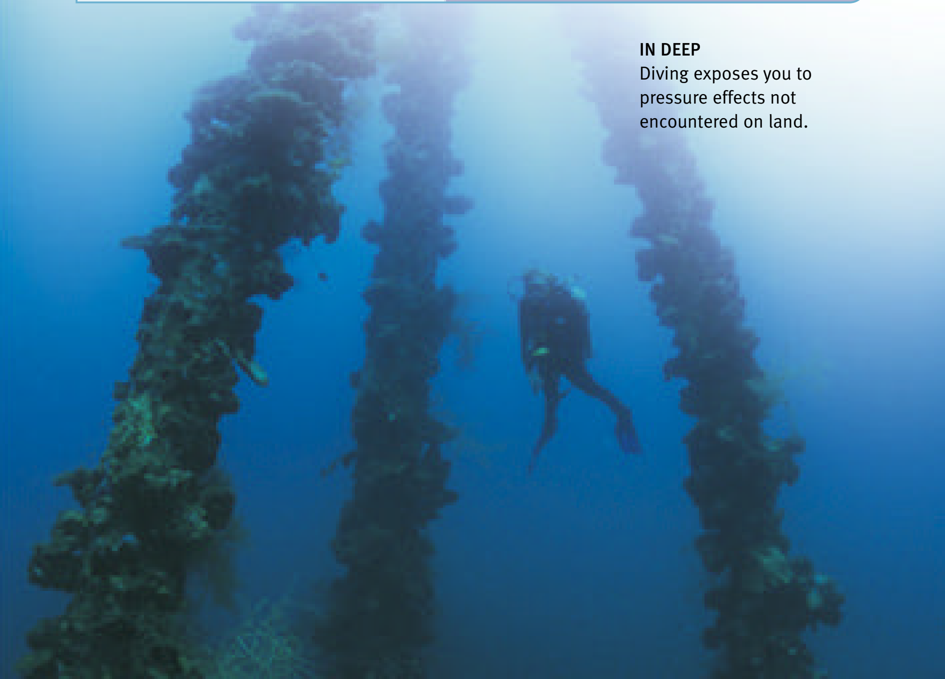

IN DEEP
Diving exposes you to pressure effects not encountered on land.

Breathing compressed gas

On land, we seldom need to worry about the availability of air, its composition, or the pressure it is supplied at. But when you venture underwater, things are very different. Being aware of how the diving environment affects your respiration cycle is of prime importance.

BREATHING UNDERWATER

Scuba divers draw breath from a tank of highly pressurized air, via a regulator. The regulator (*see pp.60–61*) reduces the pressure of the air in the tank to that of the water around you (ambient pressure), allowing it to be inhaled safely. As depth increases, so does ambient pressure, meaning that the regulator must adjust the pressure of the air it delivers to match.

Air, like any gas, is compressible, and becomes denser when pressurized. This means that at depth you will be inhaling more air per breath than you would at the surface (because the gas molecules are packed in more tightly). Because air is mainly composed of oxygen and nitrogen, this means you will be breathing higher concentrations of both gases than you would be at the surface, though the percentage of each in the mixture does not change. Both of these gases can have toxic effects on the body when pressurized. Nitrogen enters your body's tissues, and can have a narcotic effect (*see pp.100–01*). Oxygen is vital for supporting life, but becomes toxic if inhaled in sufficient concentrations. As the pressure of the air you are breathing rises, there are more and more molecules of oxygen packed into each breath you take. Beyond a depth of 200 ft (60 m), there is a risk that the concentration of oxygen in pressurized air could have a

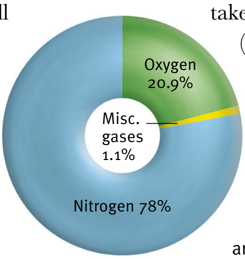

WHAT AIR IS MADE OF
Air is mainly composed of nitrogen, with oxygen forming nearly 21 percent. Inert gases like argon and freon form the remainder.

DEPTH AND AIR CONSUMPTION

Most divers consume approximately 1 cubic foot of air per minute at the surface, though this rate varies between individuals, and is also dependent on how much you exert yourself, and what your mental state is. An anxious or excited diver will consume more air than a calm one.

Because your regulator supplies you with denser air as you go deeper, your air consumption will also increase as you descend. In seawater, your Surface Consumption Rate (SCR) will have doubled by the time you reach a depth of 33 ft (10 m), tripled by 66 ft (20 m), and so on. There are various methods of obtaining an accurate calculation of your SCR, which you will find in your diving manual. Once you know this you will be able to establish how long the air in different sizes of tank (filled to maximum operating pressure) will last at different depths, and plan your dive accordingly.

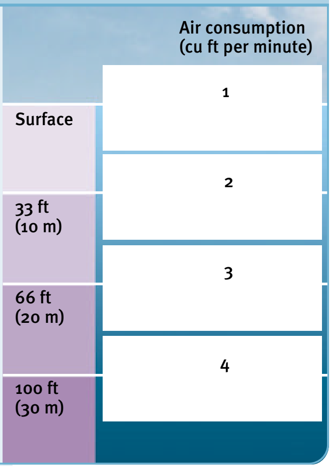

toxic effect on the body, leading to convulsions, loss of consciousness, and even death, in extreme cases.

To get around these problems, "technical" divers going beyond the limits of normal recreational diving (*see pp.194–95*) use special gas mixes. These contain altered percentages of oxygen and nitrogen, and also include helium. These mixes are used during dives in excess of 165 ft (50 m).

WASTE GASES

One by-product of the respiration cycle is carbon dioxide. The more you exert yourself, the more carbon dioxide is produced. Since your body's breathing reflex is triggered by a build-up of carbon dioxide in the blood, not by falling oxygen levels, overexertion underwater will make you feel short of breath. On the surface, your body would respond to this by breathing faster, thus flushing out carbon dioxide. Your regulator, while efficient, cannot process the same volume of air as you can breathe on land. Always rest for a moment if you begin to feel breathless.

BREATHING AND BUOYANCY

An object immersed in water is subject to an upward thrust equal to the weight of the water it has displaced. You will only float, therefore, if your weight is less than that of the water you displace. If it is greater, you will sink; if the two are equal, you will do neither—you will have neutral buoyancy. The compressed gas you breathe underwater alters your buoyancy. When you inhale, the volume of your chest gets larger—you displace more water without becoming any heavier, and so become more buoyant.

A diver displays buoyancy control

DEEP BREATH
Slow, even breathing patterns promote low air consumption and help prevent hyperventilation.

Pressure and the body

When you dive, your body is subjected to pressure generated by the weight of the water around you. As you descend, you will feel the increase in pressure in some of your body's internal air spaces, chiefly your ears. If you do not act to correct this, you may be injured.

ROUTINE MANEUVER
Equalize pressure in your ears and sinuses every 3 ft (meter) or so, during your descent to the bottom. Don't wait until your ears begin to hurt.

EQUALIZING PRESSURE

The body contains four major air spaces that are affected by pressure underwater: the ears, the sinuses, the airways and lungs, and the stomach and gut. Air spaces in our respiratory and digestive systems are compressible, in that they are contained by soft tissue that can expand or contract to accommodate pressure changes. However, your regulator (*see pp.60–63*) ensures that the air pressure in your lungs and airway is always in equilibrium with external water pressure, so pressure effects are never felt here. You should barely notice any effect on your stomach and gut, although you may break wind, especially on ascent.

The air spaces in your head, however, such as the ears and sinuses, are rigid and cannot be compressed. When the pressure outside them is greater than that within, a "squeeze" is created, which can cause pain and damage, especially to the eardrum. You must equalize the pressure in these cavities with the ambient pressure of the water around you as you descend. Equalizing is simple, using a procedure that clears the ears called the Valsalva

THE IMPORTANCE OF EQUALIZATION

The ear is divided into the outer, middle, and inner ear. The eardrum separates the middle and inner ear from the outside world, and it is this membrane that is most vulnerable to pressure changes. If you do not equalize as you descend to raise the pressure behind your eardrum—by sending air to the ear from your throat via your eustachian tubes—then the eardrum will eventually rupture and let water into your middle ear, leading to possible infection and deafness. Your sinuses are pairs of cavities within the bones of your face. Under normal circumstances they are open, via your nasal passages, but if you have a cold, or congestion caused by allergies, they fill with mucus and become blocked. Failure to equalize will cause blood vessels in the lining of the sinuses to rupture and bleed into the sinuses, which can be quite painful.

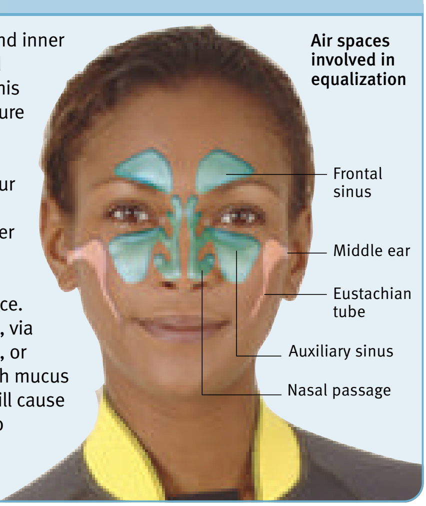

maneuver. You just have to hold your nose and breathe out against your nostrils. This will send air from your throat through the eustachian tubes into the middle ear so that the pressure there becomes equal to that of the water outside, thus easing the discomfort. This maneuver should also equalize the pressure in your sinuses, and in addition resolve any problems of dizziness or vertigo you may be experiencing (as balance is also controlled within your ears). Some people get the same result by simply swallowing repeatedly.

You need to equalize regularly on descent, but on ascent equalization should occur automatically. If you have problems equalizing on the way down, ascend a little to reduce the pressure slightly, and try again. This equalization process is vital for comfort when diving; never dive with ear plugs or with anything tight over your ears. Check that your hood does not fit too tightly, as this can hinder efficient equalization. If you have any problems with your sinuses or ears, do not attempt to dive, since this may make them worse. A cold, or any nasal congestion, may cause blockages in your airways and you will not be able to clear your ears and sinuses. If you notice a slight nosebleed after a dive, this is a common sign that you have a mild sinus blockage and you should not dive again until it has cleared up. Decongestants will not necessarily help once you are at depth, and you should not dive while you are taking them.

SAFE DESCENT
To adapt safely to the underwater world, you must understand how depth affects the human frame, especially internal cavities.

Nitrogen and decompression

When you dive using scuba gear, nitrogen gradually accumulates in your body, and is released when you ascend. In order for this to happen safely, you must plan your dive carefully and employ diving procedures that minimize the risk of decompression sickness (DCS).

GAS ABSORPTION

Gases are soluble in liquids, and dissolve more easily when they are pressurized. When you breathe compressed air underwater, the two main gases it is composed of (nitrogen and oxygen) enter and dissolve in your bloodstream. This "gas exchange" takes place in the lungs, via tiny saclike vessels called alveoli.

Nitrogen is particularly easily absorbed into the blood and body tissues. Your regulator supplies denser and denser air as depth increases (*see also p.60*), which means that every breath you take is loaded with more nitrogen molecules than an equivalent breath at the surface. This surplus of nitrogen rapidly accumulates in the tissues of your body. If you ascend too quickly, the nitrogen in your tissues can reenter the blood in the form of harmful bubbles. It is therefore very important for you to manage your dive time and depth,

BOTTOM TIME
The longer you spend at depth, the more nitrogen builds up in your body.

NITROGEN AND BODY TISSUES

When you breathe compressed air underwater, its nitrogen content enters the blood and begins to penetrate the body's tissues. When you ascend, ambient pressure drops and nitrogen starts to come out of the tissues again. If your ascent is slow and controlled, the nitrogen reenters the blood and exits the body harmlessly, via your lungs. If your ascent is too fast, the escaping nitrogen can form harmful bubbles, leading to decompression sickness (DCS; *see pp.142–43*). DCS can cause minor discomfort if the bubbles are lodged under the skin or in the joints, but if they are in the brain or nervous system, it can lead to paralysis or even death.

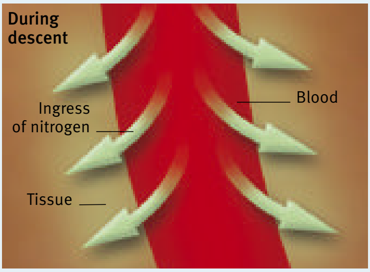

NITROGEN ENTERS BODY TISSUES
Pressurized air dissolves in blood and its nitrogen content enters tissues, especially fatty areas, where it is temporarily stored.

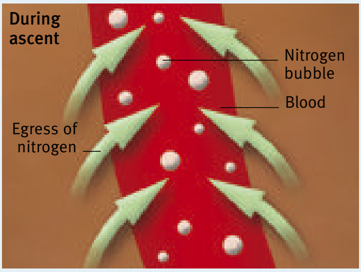

FORMATION OF NITROGEN BUBBLES
If pressure drops too quickly during ascent, nitrogen forms bubbles in the bloodstream, which can lead to decompression sickness.

PERFECT PERCH
Dive boats sometimes lower a “trapeze” for divers to hold on to while making decompression stops, with a spare air tank attached for safety.

using either dive tables or a dive computer, to ensure that nitrogen does not build up to levels that cannot be safely dissipated during ascent.

Dive tables help you to calculate how long you can safely dive at a given depth, and what the safe limits are for any following dives that day (excess nitrogen takes 24 hours to fully leave the body). The tables will also tell you if you need to perform a decompression stop. This is a scheduled pause in your ascent that allows nitrogen to dissipate safely. It is a good idea to stop at 16 ft (5 m) for three minutes during ascent, even if your dive tables do not require it, just as a precautionary measure. This is called a “safety stop.” Dive computers also generate safe diving schedules, by making continuous calculations during the dive (*see pp.66–67*).

NITROGEN NARCOSIS

The nitrogen in compressed air can also have a narcotic effect at depth, ranging from a feeling of euphoria to anxiety. Nitrogen narcosis rarely causes death directly but at depths below 30m (100ft) it causes divers to make increasingly bad judgments. If you feel the effects of narcosis during a dive, ascend to a shallower depth and the narcosis should rapidly disappear. Keep an eye on your buddy for symptoms of narcosis, such as sluggish responses and irrational behaviour.

USING DIVE TABLES
An understanding of the use of dive tables is a key element in all dive training programs.

Tides and currents

The tides have a huge impact on the marine life and conditions of many dive sites, and localized currents can create unseen offshore hazards. Knowing how tides and currents work and how they affect diving procedures is essential for safe diving at any location.

TIDAL MOVEMENT

Water levels at the shoreline can vary considerably over the tidal cycle, in extreme cases by as much as 50 ft (15 m). The region between the highest and lowest tide marks is called the intertidal zone.

Make a thorough check of local tidal conditions and coastal topography when planning a dive, otherwise you may encounter unexpected hazards, like areas of strong tidal flow. Water clarity varies from site to site, but it is often best at high tide, while incoming tides tend to bring marine species closer in to shore with them. The most important tidal event for divers is "slack water," a short interval when tidal flow halts at the changeover of every tide. Tidal currents mean that some sites are only safe for diving during the slack water period.

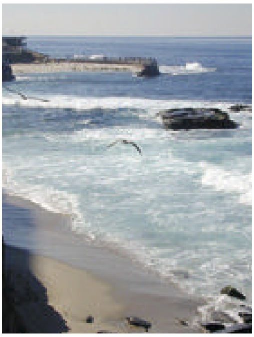

INTERTIDAL ZONE
Sometimes submerged and sometimes exposed, this is a harsh habitat for marine life.

HOW TIDES ARE FORMED

The Earth's seas are subject to the gravitational pull of both the Sun and the Moon. Although the Moon is smaller than the Sun, it is much closer to the Earth, so its influence is stronger. The gravitational pull of the Moon draws water into a bulge on the side of the planet closest to it. A counter-bulge forms on the opposite side of the Earth because the water there is pulled less toward the Moon than the planet is itself. As the Earth rotates, the two opposing bulges of water move across the face of the planet, creating two high tides and two low tides in just over 24 hours.

NEAP TIDES: FIRST AND THIRD QUARTER MOONS
With the Sun and Moon at right angles, high tides are at their lowest, as they are subject to the gravitational pull of the Moon alone, but low tides are at their highest, pulled by the Sun.

SPRING TIDES: NEW AND FULL MOONS
Twice a month, the Sun and Moon are in line with the Earth. Their combined gravitational pull creates the highest high tides, and low tides are at their lowest.

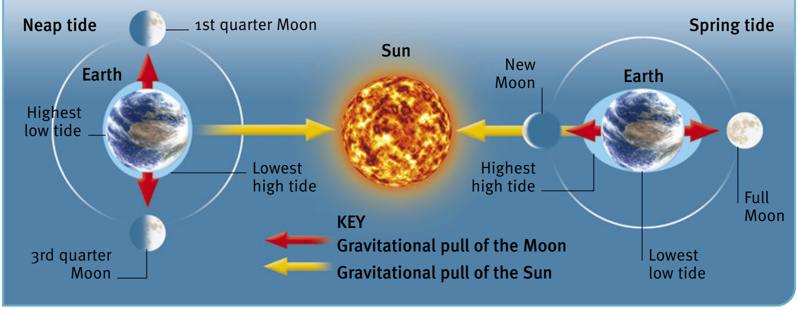

TYPES OF CURRENTS

Currents are created by winds, tides, the rotation of the Earth, and the confluence of bodies of water of differing salinity and temperature. Tidal currents occur when local topography, such as a narrow channel, creates an area of unusually strong flow when the tide is coming in (flooding) or going out (ebbing). These currents can be powerful enough to carry away even strong swimmers.

DIVERS EXITING SEA
Plan your entrance and exit so that you avoid swimming against the tide. The best time to dive is usually at "slack tide"—at high or low tide, when the tidal pull is weakest.

Standing currents are permanent currents independent of tides. Longshore currents, which flow in one direction along the coast, are localized standing currents. There are also standing currents in the open ocean, such as the Gulf Stream, which flows northward from the Gulf of Mexico, driven by the prevailing southwest winds, to the mid-North Atlantic, where it divides into two lesser currents.

Rip currents occur when incoming waves force the backwash from previous waves sideways. The backwash streams along the shore until it finds a route back to the open sea, such as a gap in a sandbar, and surges out in a strong, narrow current, perpendicular to the shore. To escape a rip current, swim across the current, parallel to the shore. You may find that trying to swim out of a rip current leads you into a longshore current, which pushes you back into the rip current. If this happens, swim out of the rip current in the opposite direction.

WAVE SURGE
Underwater topography and weather conditions can combine to create dangerously strong water movement where surf breaks on the shore.

Diving skills

Introduction

Good basic skills are key to being a competent diver. Some techniques, such as buoyancy control, may seem difficult to master at first, but with practice they will become second nature, allowing you to relax and enjoy your dives. Skilled divers are also safer divers.

SUPPLEMENTING YOUR TRAINING
This chapter of the book discusses diving skills, but is not intended to be, or in any way replace, a training manual. While it covers the skills and techniques that are taught in the basic dive training offered by approved agencies, it must not be used in place of any element of that training. There is no substitute for comprehensive dive training with a certified instructor.

In this chapter, therefore, we outline the skills you need in order to be a safe and competent diver. Many people only dive once a year on vacation, or even less frequently, so it is very important to keep up to date with your diving skills. If you have been away from diving for any length of time, take a refresher course or an easy trial dive.

STEPPING OUT
Knowing how to enter the water properly will help you get your dive off to a good start.

USING A COMPASS
Don’t forget to practice navigation skills regularly. Getting lost can ruin a dive, and may hinder your return to a safe exit point.

You will find that most of your basic skills are still familiar to you after a break, or will come back in due course. However, if you are put in a stressful situation, you may not be able to react quickly and effectively if your skills are rusty. Even experienced divers can benefit from regular practice of basic skills, and you should always be thinking about how to improve your equipment configuration and technique.

KEEPING SKILLS CURRENT

A great way of keeping your skills up to date is to practice in a pool (*see pp.146–49*). This might not be as much fun as getting out into the open water, but it will certainly provide you with a safe environment in which to perfect key skills such as buoyancy. Regular training in a pool or sheltered water can help you to meet the challenges of open-water diving more confidently. If your local waters are cold and stormy in winter, use the off-season to brush up drills and procedures. Joining a diving club may give you access to a nearby pool.

DEPLOYING A BUOY
Diving requires the use of many items of special equipment that you must learn how to use safely.

Pre-dive skills

Good organizational skills will help ensure a trouble-free diving trip. A successful dive begins before you even leave your home, with checks on weather conditions and equipment. Even if someone else is organizing the dive, make sure you are well prepared and informed.

GETTING OFF TO A GOOD START

On the morning of the dive, get a detailed, up-to-date weather forecast specific to the site you are diving, and double-check tide times if appropriate. If you don’t feel well for any reason, make an honest assessment of whether you are fit to dive that day. It is better to sit out a dive than to feel ill underwater and have to abort. Illnesses affecting lung or circulatory efficiency also increase the risk of decompression sickness (*see p.142*)—a very good reason for skipping the dive.

BRIEFING FROM DIVE LEADER TO GROUP
While a group leader will take overall charge of the dive plan, you must take responsibility for your own fitness and equipment readiness.

Always check your gear before you set off on a diving trip. Before you leave home, you must be sure that you have everything you need. It is good practice to make a checklist of all the items you will need, and keep this in your bag. When you arrive, be sure to transfer all your gear from the initial mustering point to the actual dive site, or onto the boat you are diving from. All too often, divers leave a vital piece of

DIVING WITH A NEW BUDDY

Diving abroad often means that you will dive with strangers. Make sure you give the dive organizer an honest assessment of your level of ability and interests, so they can pair you with a suitable buddy. Even if you don’t know your buddy, give them all the respect and assistance you would offer a familiar dive partner.

gear on the dock, such as a weight belt or mask, and only realize their mistake when the dive boat reaches its destination—by which time it is too late.

DIVING FROM A BOAT

The boat should have been booked in advance, but even so, it is polite to call the skipper again before you arrive. He or she will be able to confirm that weather and conditions are favorable for diving. When you board, check that the boat has adequate first aid and safety signaling devices on board, and appears to be in a seaworthy condition. Before you leave shore, notify the coastguard or relevant authority—and do not forget to inform them of your safe return when you get back. Ensure that the skipper reviews safety procedures, including the location of lifejackets, flares, and life rafts, and demonstrates the underwater recall signal.

GETTING READY TO DIVE
If you have organized your day efficiently, you will be able to relax and concentrate on getting yourself ready to dive.

COMFORT AFLOAT
Remember to bring seasickness tablets with you on boat trips. Test them 24 hours beforehand to make sure they have no adverse effect on you.

DIVING FROM THE SHORE

If you are diving from the shore, always check for the easiest possible access to your dive site on arrival (or before) to avoid long walks down to the beach with heavy gear. You may need permission to drive to the water's edge to unload.

WATCHING THE WEATHER

Obtain a forecast that includes the wind speed and direction, sea state, and visibility (fog, mist, etc). Do not take any risks with diving in bad weather—it is better to miss the dive than dive in surging seas or in visibility so poor your boat cover will not be able to locate you. You should also check tide tables to establish the timings of slack water. This is critical when diving areas affected by strong tidal currents.

Rough seas

Final checks

Diving with a partner (or buddy) means that there is someone to help if you encounter problems underwater. For the system to work properly, however, you and your buddy need to conduct your own briefing before a dive and check that all equipment is functioning properly.

MAKING BUDDY CHECKS

Just before the start of the dive, get together with your buddy and assemble your gear (*see pp.84–85*) and put it on. There is no particular order in which to do this, but most divers find that to avoid overlooking anything, it is useful to develop a routine. When you are both suited up and before either of you enter the water, you should carry out a buddy check—sit or stand next to your buddy and carefully check each other's gear, following the sequence shown below. Do not be tempted to rush these vital checks—you may regret it later. They ensure that you know how each other's gear is assembled, how it works, and that it is functioning. They also serve as a double-check that neither of you has overlooked anything before you dive.

1 **Check BCs** so that you and your buddy know where each other's inflation and deflation points are, and ensure that they are working. Do the same for drysuits, if worn.

2 **Check that weights** are present and securely fastened. You and your buddy must be especially aware of how each other's weights are released, in case either diver is incapacitated.

3 **Check harness is secure** and note where, on your buddy's kit, key fastening points and harness release clips are located, and how they are operated.

4 **Check air contents** gauges and breathe from your regulators to check they are working. Test each other's octopus second stage.

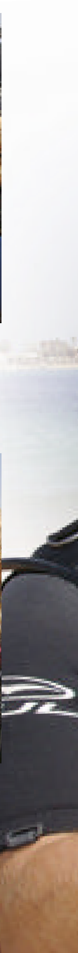

BUDDY BRIEFING

Suiting up provides a good opportunity to talk over a dive plan with your buddy. Ensure first that you are both agreed, as a pair, on the aim and course of the dive, your entry and exit points, and your predicted maximum depth and time for the dive. Check that you both have the required amount of air for your plan (including a reserve for emergencies). Agree on who will lead the dive and on whether you will dive to the left or right of your buddy. Decide on all communication signals, including how and when you will signal for the end of the dive, and on what you will do if you become separated. Once you have agreed a plan, stick to it unless it becomes impossible to do so. If circumstances change during the dive, use hand signals to discuss how, as a pair, you are going to modify the dive.

PREVENTING FOGGING

Mask fogging is a very common inconvenience, and is caused by oils on the mask's lens allowing moisture to bead. The traditional way to prevent fogging is to rub saliva onto the inside of the lens glass, then lightly rinse clear, before putting on the mask for a dive. Anti-fogging sprays are also available.

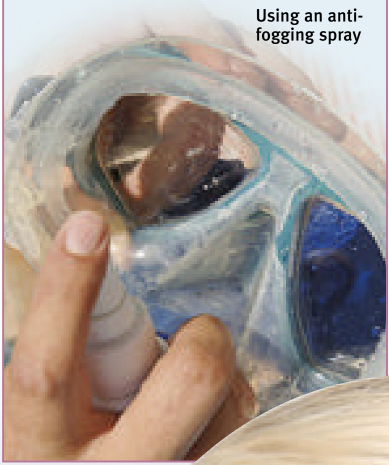

Using an anti-fogging spray

5 **Ready to dive?** Give each other a last once-over to establish who is carrying any miscellaneous pieces of gear, such as reels and slates, and where they are fastened. When you are ready to dive, make a final OK signal.

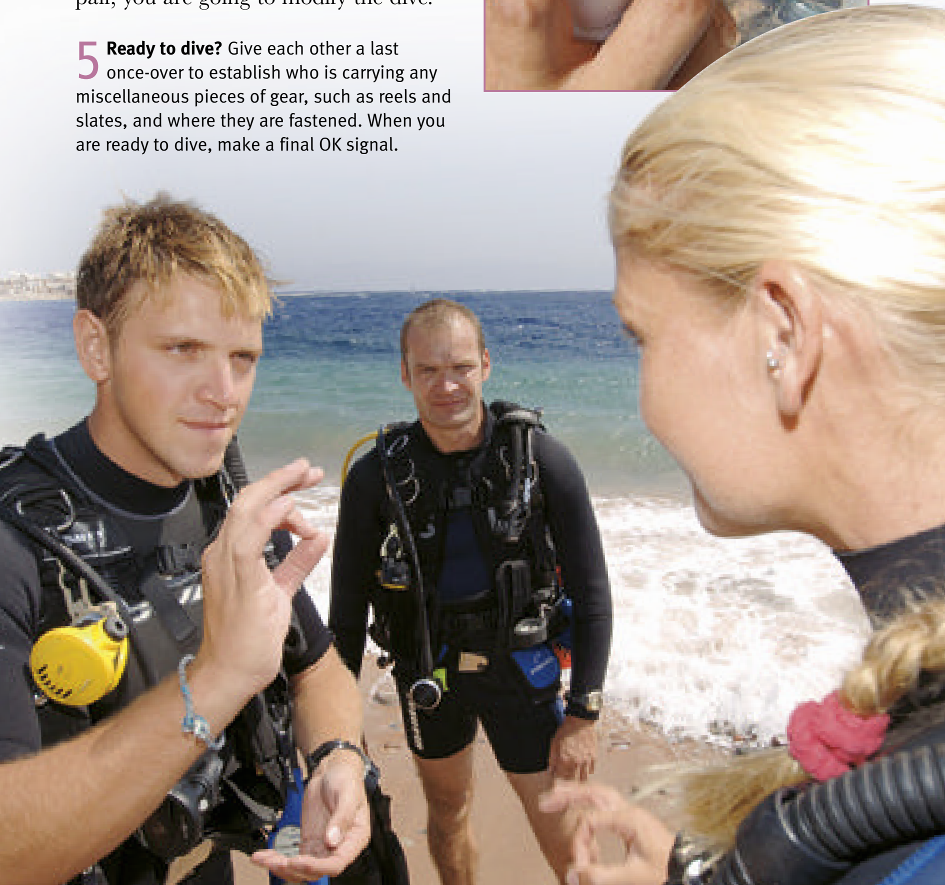

Entry

Every site will require a different method of entry, and the easiest method possible at each site is the best one to use. In all cases, it is safer to enter without large, heavy equipment, such as cameras, so if conditions allow, have them passed to you once you are in the water.

SHORE ENTRY

When entering the water from a beach, make sure your gear is assembled and on your back, then carry your mask and fins to the water's edge. There, put on your fins and mask with your buddy's help and walk backward into the water (walking forward with your fins on is difficult). As soon as you are deep enough, lower your center of gravity by bending down, then start to swim, or "fin," out into open water. If there is surf, make sure your BC is partially inflated and wait until a big wave approaches; lean into it, and let the return surge take you away from shore.

ENTERING FROM THE SHORE
If entering through surf, be careful not to lose your fins as you put them on. Breathe from your regulator throughout entry.

CONTROLLED SEATED ENTRY

This is the easiest method of entry into a pool or from a platform just above water level, and an especially useful method if you have difficulty with mobility on land or with keeping your balance when standing on a floating platform. It also enables you to put on your gear while seated.

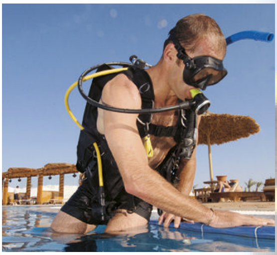

1 **Turn from the waist** to place both hands on the hard surface to one side of your body, ready to take your weight.

2 **Pivot your body around,** using your hands to support you, so that you turn to face the side while easing yourself into the water.

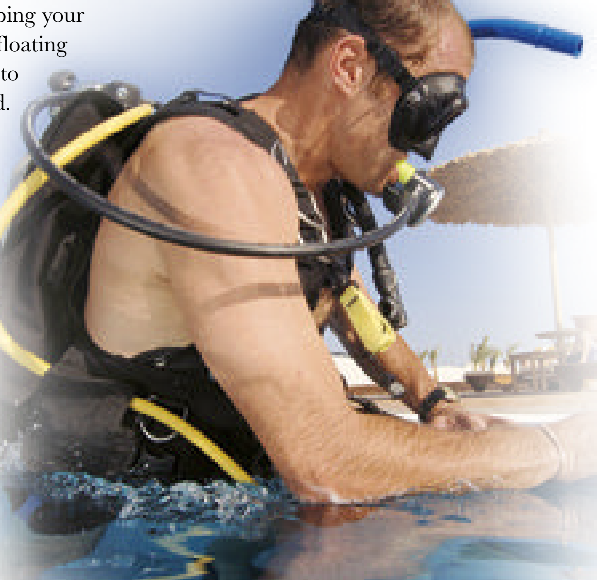

GIANT STRIDE ENTRY

Stepping into the water is a good entry method to use from a large diving boat or off a dock or platform, provided there is sufficient depth of water. Partially inflate your BC, place your regulator in your mouth and hold it and your mask in place with one hand, and take a large stride out into the water.

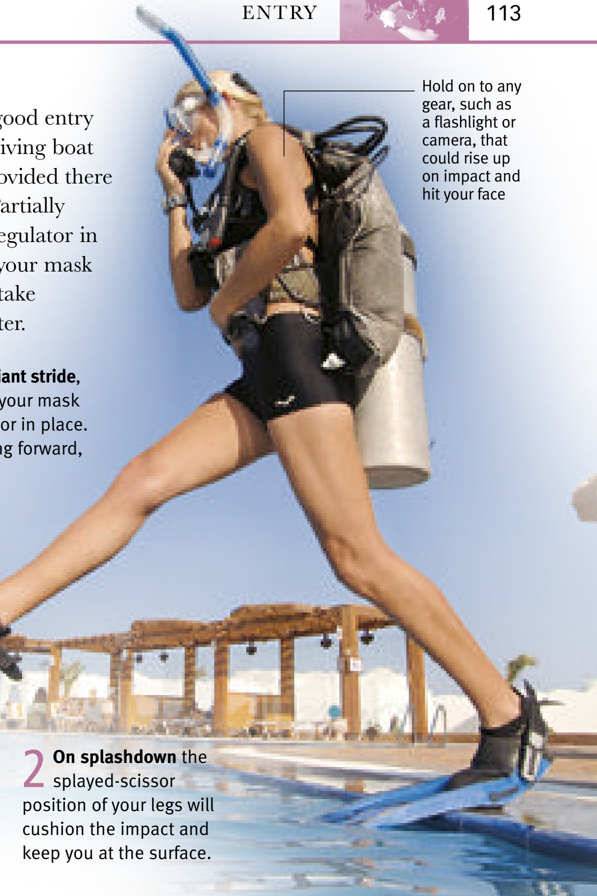

Hold on to any gear, such as a flashlight or camera, that could rise up on impact and hit your face

1 **Take a giant stride,** holding your mask and regulator in place. Keep looking forward, not down.

2 **On splashdown** the splayed-scissor position of your legs will cushion the impact and keep you at the surface.

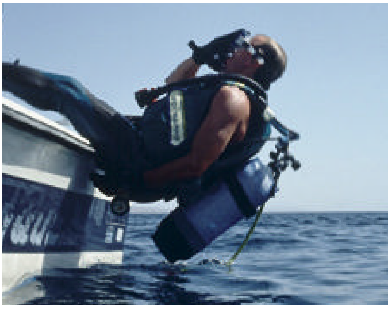

ENTRY POSITION
Hold your mask and regulator in place with one hand and ease yourself backward until your tank is hanging over the water.

BACKWARD ROLL

Use this entry from small boats with a low freeboard (distance from deck to waterline). With your regulator in place, check that your fins are free from obstruction, and that the water behind you is clear. Ease yourself over the edge and roll over backwards, aiming to hit the water first with your upper back.

BUDDY PROCEDURE AND SIGNALS

After entering the water, meet on the surface and make an OK signal (hand on head or fingertips together) to shore or boat cover. One exception to this is when making a negatively buoyant entry through strong surface currents. In this case, descend as quickly as possible, and rejoin your buddy on the seabed.

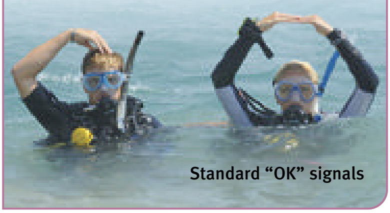

Standard “OK” signals

Descent

Descending to the seabed is always an exciting experience, but while you may want to get there quickly, you must always descend in a controlled manner. The method you use will depend partly on the site and prevailing conditions, and partly on your own preferences.

MAKING YOUR DESCENT

Having met up with your dive buddy in the water, follow the preparatory steps below. If you find that you do not sink, check that no air remains in your BC (and drysuit, if applicable). If the problem persists, you probably do not have sufficient weight on your belt (*see pp.70–71*), and should return to the boat or the shore to get some more. It is a good idea to note how much weight you need each time you try a different equipment configuration—record the details in your logbook for reference.

At a depth of 10 ft (3 m) you should carry out a bubble check. This involves briefly stopping so that you and your buddy can check each other's equipment for signs of air leaks—for example, from an incorrectly fitted hose. This will allow you to return to the surface to resolve the issue before you resume the dive. By fixing minor problems now, you may avoid bigger problems during the dive that could lead to an emergency.

As you descend, you will feel pressure in your ears. Release this regularly by swallowing or holding your nose and

1 **Meet up with your buddy** on the surface, well clear of any boat cover. If using a snorkel, remove it, and switch to breathing from primary regulators.

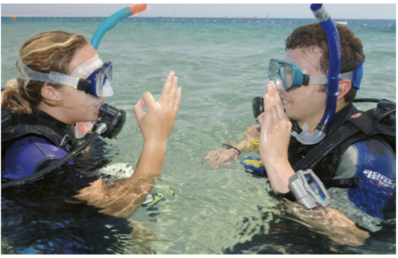

2 **Give an OK signal** to each other when ready to begin the dive. If using a "buddy line" to link yourselves together (useful when one buddy is a novice), ensure now that you are both attached.

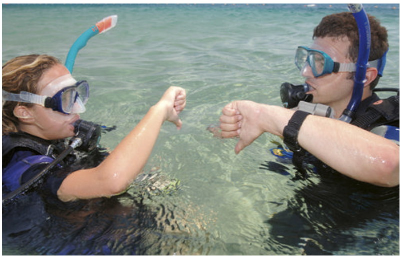

3 **The "down" signal** confirms your intention to descend immediately. If your buddy is a novice or nervous, reassure them by holding their hand and helping them to descend.

4 **Both you and your buddy** should deflate your BCs and exhale together, so that you become negatively buoyant and start to sink simultaneously. If you have a problem sinking, address it now.

BUBBLE CHECK
Buddy pairs check each other's gear for telltale air leaks before descending further.

blowing against the closed nostrils—a process called "equalization" or "ear-clearing" (*see also pp.98–99*). If you feel you are descending too fast, allow a little air into your BC. Your mask will also start to press on your face; relieve this by exhaling gently through your nose. If you are wearing a drysuit, you will feel the water pressing it against your body. Ease this by letting air into the suit, but not so much that it alters your buoyancy too greatly—and remember to release it again on ascent.

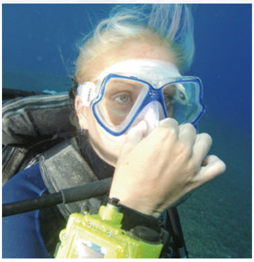

EQUALIZATION
Pinch your nose and blow at intervals to equalize pressure in the skull with that of the water.

DESCENT OPTIONS

Many divers prefer to descend feet-first so that they can remain face to face with their buddy and maintain eye contact. This is good practice, unless you need to descend quickly through a current and therefore have to use your fins.

A free descent is where no line is used and you descend freely (head- or feet-first) to the seabed. If you are using an SMB (*see pp.74–75*), ensure before descent that the buoy is fully inflated and the line is free. Your buddy should stay on the same side throughout the descent to avoid confusion and tangling in the line. On group dives there may already be a weighted guideline in place, attached to a buoy and leading to a wreck or fixed point on the seabed, which will give you and your buddy a handy point of reference. Do not use the line to pull yourself down, since it may not be anchored securely at the base.

FINAL CHECK
A group of divers meeting at the bottom of a guideline give a last "OK" signal to each other before exploring the dive area.

Breathing underwater

Swimming freely underwater for the very first time can be exhilarating, but also potentially unnerving and even frightening. Learning and perfecting good breathing techniques allows the novice diver to become calm and relaxed in this new environment.

LEARNING TO RELAX

The sheer thrill of your very first dive will cause your heart rate to increase and make you breathe faster than normal. You may be alarmed at how quickly your air supply runs out, but after a few dives, you will learn to be calmer and more relaxed, and your air consumption will decrease. When you feel comfortable underwater, take a few moments to concentrate on your breathing and remind yourself of the dos and don'ts of underwater breathing.

CONSERVING AIR
The more relaxed you are, the less air you will use and the longer your dive will last.

First, and most important, never hold your breath underwater, because you will run the risk of bursting a lung. Inhale and exhale more deeply than you would normally do on land. Try to maintain neutral buoyancy (*see pp.118–21*), since this will decrease your need for leg and arm movements to maintain a constant position, and thus reduce air consumption. Furthermore, avoid

BREATHING OUT
If you remove your regulator, exhale slowly to minimize the risk of lung expansion injury.

CLEARING THE REGULATOR
A regulator can be cleared of water by simply exhaling, or by pressing the button on the front to purge the water.

FREQUENT CHECKS
Buddies should regularly check each other's air reserves, to maintain a good awareness of the remaining levels of both members of the team.

swimming unnecessarily against currents—it is better to go with the flow than to waste your air by overexertion.

Always be aware of where your buddy is and what he or she is doing; many novice divers lose sight of their buddy and rapidly become anxious. If there is a problem, stop, breathe, and think before taking action. Acting too quickly and without thought could lead to panic and further problems.

Make sure that you are familiar with your equipment and fully understand how it works. You must know exactly where each item is stored to avoid panic if things go wrong during a dive—for example, if you lose your regulator or your mask begins to fill up. Regularly practice emergency procedure drills (*see pp.136–43*), either in the pool or in open water, to ensure confidence in a real crisis.

PLANNING YOUR AIR CONSUMPTION

On an open-water, fairly shallow dive, the rule of air consumption is to plan your dive so that you can carry out your descent, exploration, and ascent, and still surface with a reserve of 725 psi (50 bar). If you have to come back to a given point to exit, such as a guideline or anchor line, start your return when you have 1,500 psi (100 bar) left. If there is a current, swim out against it and swim back with it, so that the return is never longer than the outward trip. It is also wise to swim back to your point of entry or shotline at a shallower depth than on the outward journey, since this reduces air consumption. In difficult environments, follow the "Rule of Thirds" (*below*).

THE RULE OF THIRDS

When planning a dive in an environment that is covered overhead—such as a wreck, cave, or under ice—or when making deeper dives, always apply the Rule of Thirds. The rule states that you should use a third of your air for descent and exploration, and a third returning to your guideline or point of entry and for ascent. The remaining third is an emergency reserve.

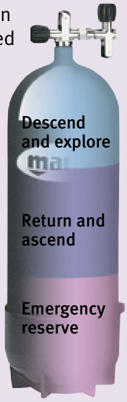

Buoyancy control

Without doubt, the most important skill for a diver to master is that of buoyancy control. Until you achieve this, you will be constantly expending effort in order to maintain your position in the water, wasting air resources and distracting you from your dive.

SUITS AND WEIGHTS

Wearing any type of exposure suit will make you more buoyant in the water, and thus make it more difficult to dive. Drysuits contain an airspace between the suit fabric and the diver's body. Wetsuits have air cells within their neoprene fabric, and so the thicker the neoprene, the more buoyant you will be. The function of weights is to counteract the buoyancy your suit gives you so that, with your lungs full of air but your BC uninflated, you float at the correct level at the water's surface.

Correct assessment of how much weight you need to carry for a given dive is very important. Spend time conducting weight tests for different suit and equipment combinations, and note your findings for future use. Remember, saltwater is denser than fresh water, so you will require more weight when you dive in the sea than in fresh water.

USING YOUR BC

At the start of a dive, you will usually enter the water with your BC inflated, as having positive buoyancy allows you

CONDUCTING A WEIGHT TEST

Empty your BC, and take a deep breath and hold it. Float in an upright position. If you are wearing the right amount of weight, you will float at eye-level to the waterline. Add or discard weights as necessary until this is achieved.

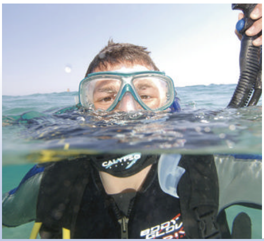

Too high

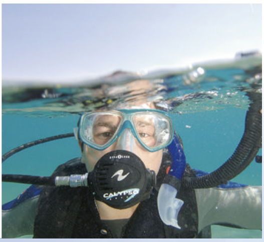

Too low

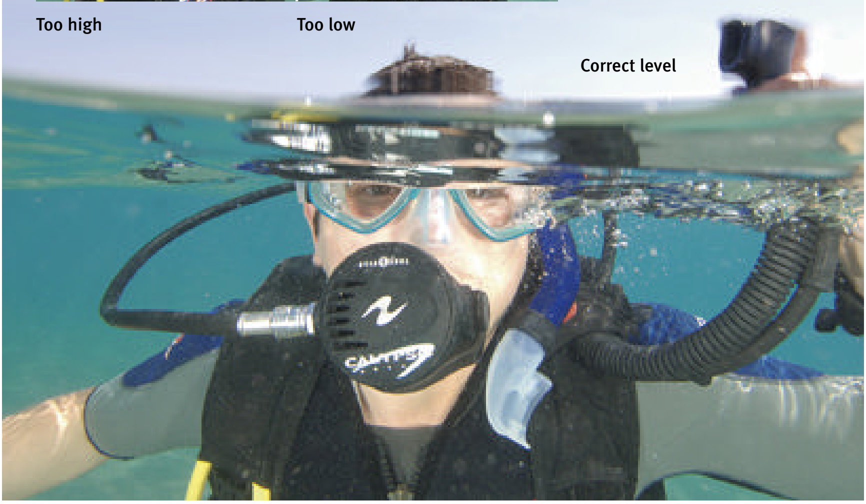

Correct level

to float at the surface effortlessly while you meet up with your buddy—the only exception to this is at sites where there are strong surface currents, when it is important to get to the bottom quickly.

In order to descend, you must be negatively buoyant, which you achieve by deflating your BC and exhaling (*see pp.114–15*). However, as you sink, you will find that your descent rate accelerates as your suit—and the remaining air in your BC—becomes compressed. To counteract this, you must add air to your BC. If this halts you before you have reached the desired level, let air out. Repeat the process, letting small amounts of air in and out of your BC until you become stationary at the desired depth.

When this happens, you will have achieved neutral buoyancy underwater—a state in which you neither float nor sink. Achieving this perfect equilibrium of weight ballast and lifting forces means you do not waste effort and air using your fins to maintain a certain depth.

When you want to ascend, the same control principles apply, but in reverse. As you go up, the air in your suit and BC expands as external water pressure decreases, making you increasingly buoyant, and causing you to rise rapidly. As it is important to ascend at a slow,

LEARNING THE BASICS
An instructor looks on as a student diver practices fin pivots (*see pp.146–49*), an exercise designed to improve basic buoyancy control.

HOVERING OVER A REEF
Buoyancy control is critical when diving over delicate coral that can be damaged by physical contact.

steady rate (*see pp.128–31*), you'll need to vent air accordingly as you rise. To descend and ascend as smoothly as possible, you must become familiar with how your BC responds to inputs of air, and how quickly it vents air.

Drysuits have independent inflation and deflation controls (*see pp.54–55*). If you are diving in a drysuit, the air space between your suit and your body will become compressed, and you will need to inject a little air into the suit to avoid discomfort from being "shrink-wrapped" by external water pressure. This will make you more buoyant, so you will need to vent air from your BC to counteract it. On ascent, you will need to dump the excess air from your drysuit.

JETTISONING YOUR WEIGHTS

In extreme circumstances, such as being caught in a powerful downcurrent, it may be necessary—as a last resort only—to dump your weight belt. You will instantly start to rise up rapidly through the water, so be ready to vent air from your BC to slow your ascent. Breathe out on the way up, to minimize the risk of lung expansion injury (*see p.95*).

FINE CONTROL OF BUOYANCY

Small movements up and down—to look at different parts of a reef, for example—are best achieved through breath control, rather than letting air in and out of your BC. Good buoyancy control only comes with practice, and is worth perfecting. Take time at the start of each dive to practice fine control of buoyancy before you set off exploring. From a neutrally buoyant position on the seabed, slowly inhale—you should rise up and hover just above the seabed. Breathe out a little—you should sink. Practice breathing in and out and become familiar with how it influences your gentle rise and fall. You should be able to hover over the seabed and control your buoyancy by breathing alone, without constantly filling and

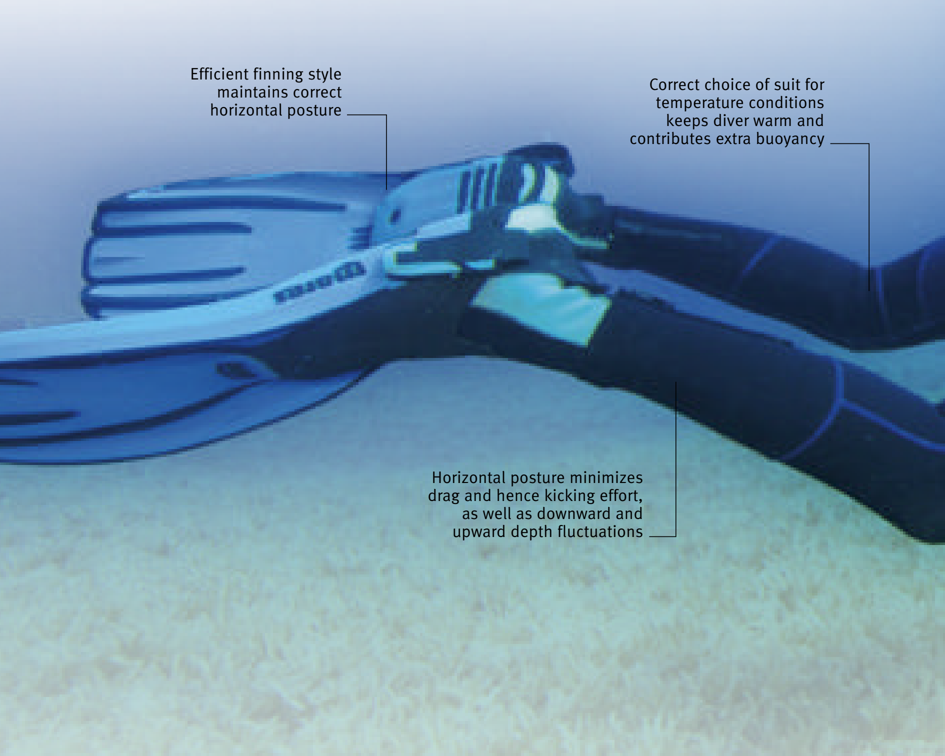

Efficient finning style maintains correct horizontal posture

Correct choice of suit for temperature conditions keeps diver warm and contributes extra buoyancy

Horizontal posture minimizes drag and hence kicking effort, as well as downward and upward depth fluctuations

emptying your BC. Once you have mastered this, you will be able to float at any depth without effort.

TRIM AND WEIGHT DISTRIBUTION

The position of your weights and equipment has an important part to play in maintaining good “trim” (correct posture and balance) underwater. Distribution of weight is key in achieving a good horizontal attitude, which makes buoyancy control easier and helps you to propel yourself along with the minimum of drag. A streamlined profile also helps posture and ease of movement, which helps to reduce air consumption. Experiment with different weight systems and stowage points until you find a comfortable combination that helps you achieve the best position in the water. Some designs of BC allow you to stow weight at different points, not just on a belt. For example, some have special quick-release pouches that are designed to take moderate weight loads (*see p.59*). Always check that you are able to jettison the bulk of your weight load in case of emergency.

ACHIEVING PERFECT BUOYANCY
Thinking about buoyancy as a system of influences to be harmonized, rather than just weights and BC, will help you perfect the art of moving underwater.

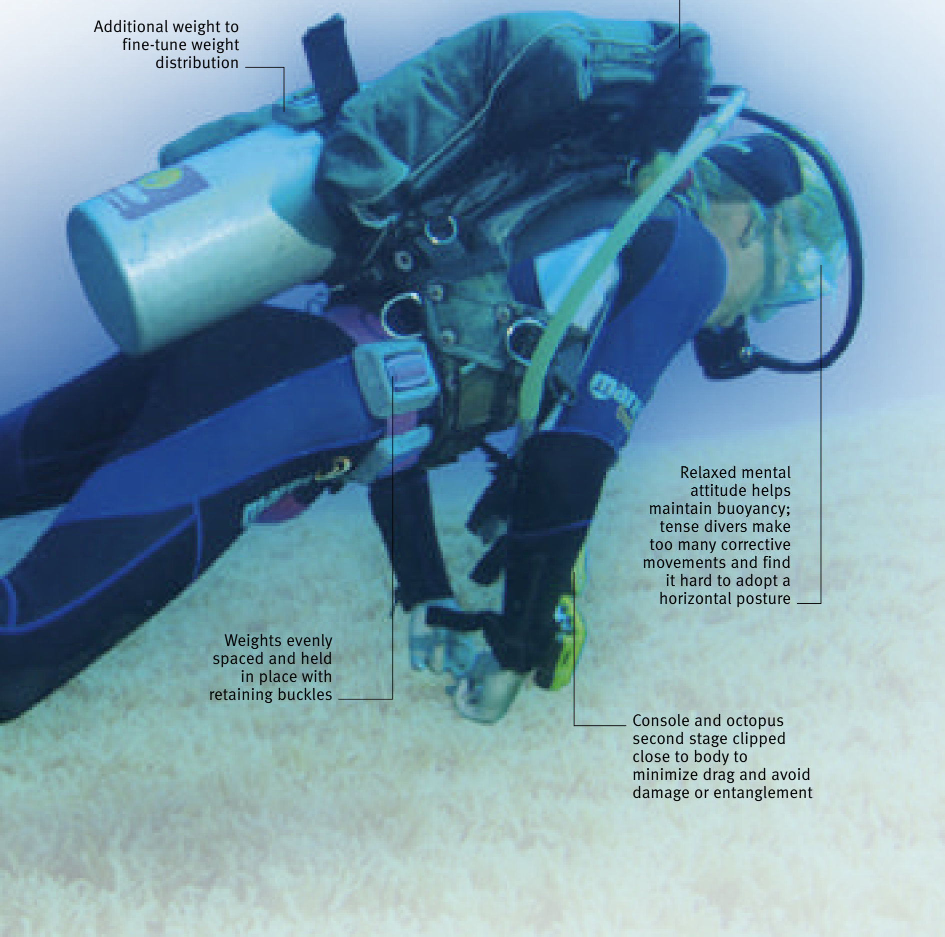

BC filled with correct amount of air for depth and weight load

Additional weight to fine-tune weight distribution

Relaxed mental attitude helps maintain buoyancy; tense divers make too many corrective movements and find it hard to adopt a horizontal posture

Weights evenly spaced and held in place with retaining buckles

Console and octopus second stage clipped close to body to minimize drag and avoid damage or entanglement

Moving underwater

The duration of your dive is limited by your rate of air consumption, which in turn depends on how much energy you expend. Good finning technique, buoyancy control, and a streamlined profile will all make your movement underwater more energy-efficient.

EFFICIENT PROPULSION

Your movement through the water should be driven and controlled by your legs. If you watch experienced divers, you will notice that they use their arms very little, and move effortlessly through the water, saving energy, minimizing air consumption, and avoiding damage to reefs and the marine environment.

MINIMIZING ARM USE
To practice with your legs only, cross your arms in front of you or let them hang by your side.

Swimming with fins should be an extremely efficient way of propelling yourself through the water, but many divers are let down by a poor finning technique. There are several different strokes you can use, but all should be carried out with strong, rhythmic movements, fully extending the leg (or legs) with each kick. Uncontrolled thrashing and incomplete kicks will simply waste energy. It is worth asking your buddy to give you feedback on your technique—even to photograph or film you. You may be surprised at the results.

Scuba diving is not a race, and the faster you go, the less you see. Learning to pace yourself and move at a leisurely speed will help you to relax, and a relaxed diver is an aware, efficient, and safe one.

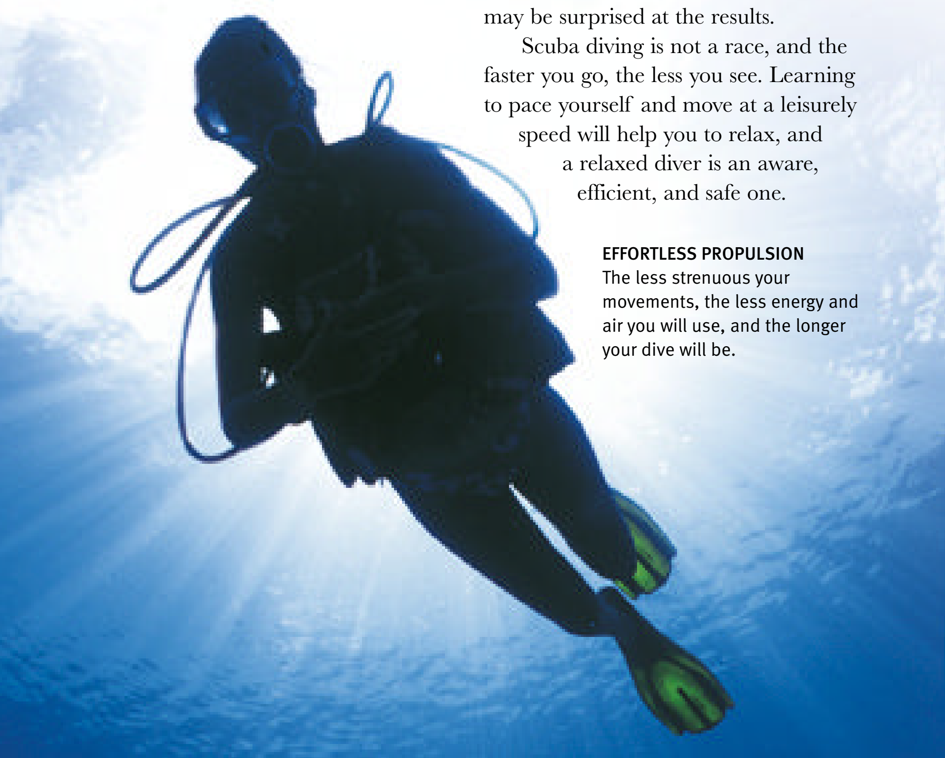

EFFORTLESS PROPULSION
The less strenuous your movements, the less energy and air you will use, and the longer your dive will be.

PROFILE AND BUOYANCY

To achieve the most streamlined (and therefore most energy-efficient) swimming position, you should be almost horizontal in the water. Your hips will be slightly lower than your upper body due to that area being weighted. During a dive, you should look forward and downward most of the time—raising your head too much will lift your upper body and make your profile less streamlined.

POOR PROFILE
Swimming with the wrong profile may mean that your fins kick up silt, impairing visibility.

Carrying the correct amount of weight is important. Being overweighted will drag your hips and lower body downward. Swimming will then require greater effort due to your unnatural angle in the water, which will produce increased drag. You can improve your profile by repositioning the weights in your BC, or refining your weight requirements (*see pp.118–21*).

Achieving neutral buoyancy (*see pp.118–21*) is the key to maintaining a good dive profile with ease, and also increases your efficiency. If you are positively buoyant, you will be constantly swimming downward; if negatively buoyant, you will have to swim upward all the time or crawl along the bottom—all of which require more effort than horizontal, neutrally buoyant, swimming.

TYPES OF KICKING STROKES

With the flutter kick (*below*), all fin movement takes place above the body's centerline, reducing the amount of water directed downwards. This can be useful when you wish to avoid stirring up sediment on the seafloor. The frog kick is also ideal for use where fine silt can ruin visibility if disturbed, because it directs thrust horizontally behind you. The swimmer kick is good for power, but uses up energy quickly. Most divers tend to drift slightly when using the flutter kick or the swimmer's kick, because one leg is slightly stronger than the other.

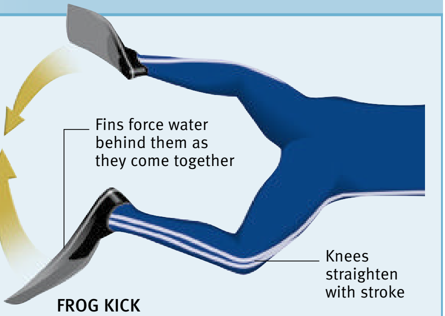
Fins force water behind them as they come together
Knees straighten with stroke

FROG KICK
Spread your legs and bring up your knees. Rotate your fins so that the bottoms of the blades face behind you. Bring the fins together in an arc, thrusting out behind.

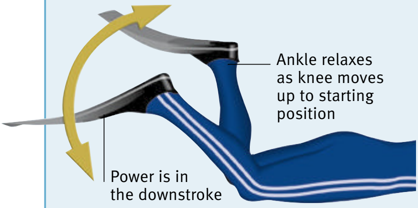
Ankle relaxes as knee moves up to starting position
Power is in the downstroke

FLUTTER KICK
Bend the knees slightly, shorten the stroke of the kick, and keep the hips fairly static. The stroke ends when the knee is straight.

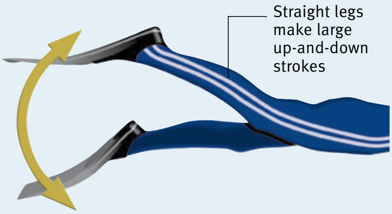
Straight legs make large up-and-down strokes

SWIMMER KICK
Lock your legs straight and kick from the hips with long strokes. This technique exploits the power in your thigh and hip muscles.

Exploring and navigating

Learning how to use instruments and natural features to find your way around underwater is important. Accurate navigation will help you to reach your planned exit point at the end of a dive, and will also help you find and explore features of interest, such as wrecks.

MAPPING THE SITE

It is easy to become disoriented in poor visibility, but good navigation skills will help you find your way, even when conditions are against you. Developing such skills will make you less dependent on other divers for your own safety—if you always rely on your buddy to lead the way, you could find yourself in trouble if you become separated.

On first entering the water, make mental notes of the surrounding features, such as unusual rocks, coral, or your position on a wreck site. As you progress through the dive, try to build up a map of the site in your mind. At every turning point, note nearby features and which direction you turned in relation to them.

FOLLOWING A REEF WALL
In clear conditions, a reef wall makes an easy navigational reference point. Try to remember distinctive features as you go along.

MENTALLY MAPPING THE DIVE SITE
Reef, rock, and seabed features, sunlight, and even shoals of fish can all help you to orient yourself at the dive site.

Look at the seabed geology, too: rocks often have features or show strata that make memorable visual markers. It may be helpful to jot notes down on a slate.

NATURAL NAVIGATION AIDS

A compass (*see pp.126–27*) gives the most accurate directional information, but there are also clues in nature. If the water is clear and shallow enough, or if there are any shadows cast by rocks, you can use the Sun as a directional reference. On a morning dive, for example, the Sun will be in the east. Take note of which way the current is running. (If you are diving close to slack water (*see pp.102–03*), at high or low tide, this may change by as much as 180° as the tide begins to turn.) Even if you cannot feel the current, you can find visual clues to its direction. Plankton, for example, drift along with the current, so shoals of fish station themselves facing into the current so that they can feed on them. Kelp fronds flow in the direction of the current. Exhaust bubbles will rise up toward the surface (unless you are in a down current).

READING SAND RIPPLES

Sand ripples run parallel to the shore, at 90 degrees to the path of incoming and outgoing tidal currents. Sand ripples get closer together nearer to shore, providing a useful reference point for underwater navigation. If the spacing of sand ripples underneath you appears to be getting narrower, you are swimming toward shallow water and a possible exit point.

Sand ripples on the seabed

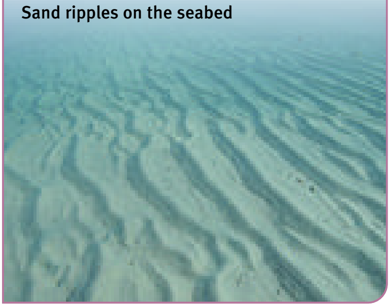

FOLLOWING A REEF

On a basic reef dive, swim out with the reef wall on one side of your body and then return with the wall on your other side. When diving around a wreck, try to maintain either a clockwise or counter-clockwise motion, especially if the wreckage is fragmented. Keep the main part of the wreck to one side of your body during the dive, so that you return to your starting point after one circuit.

USING A HANDHELD COMPASS
In case you are separated for any reason, both you and your buddy should carry and be confident at using a magnetic compass.

USING A COMPASS

A compass has a circular body, often divided into 360-degree increments, and a needle that swivels to point to magnetic north. Many also have a "bezel"—an outer ring, also marked with increments and the points of the compass, that can be rotated independently to the body. This can be used in conjunction with the "direction of travel" arrow (known as the "lubber line"), which is marked on the compass body, to establish the direction you want to travel in relation to magnetic north. Point the lubber line in the direction in which you wish to travel, then turn the bezel so that its "north" mark matches the direction in which the needle is pointing. If you ensure that the needle always points to the north mark, as you move in the direction indicated by the lubber line you will maintain your intended direction. Digital compasses work in the same way, but display the information on an LCD.

A compass is a fairly basic device, but it is easy to use it incorrectly. If it is a wrist-mounted model, ensure that your

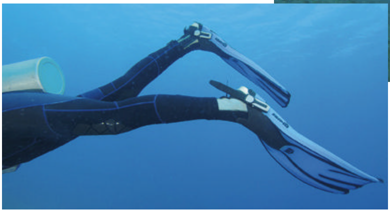

MEASURING DISTANCE
When navigating underwater, you can judge relative distances by counting how many fin strokes you have made in a given direction, or by timing your progress along a course.

wrist is held square to the direction of travel, and not at an angle. It is simpler to use a compass mounted on a console or a retractable lanyard, which can be held out straight in front of you. Use both compass readings and environmental observations, so that you can correct any inaccuracies in either method. Mark readings down on a slate as you go, and try to integrate these into your mental map of the dive site. In slack water, timing how long it takes to get from one point to the next gives you an idea of your position if you return along the same compass course. Combining this information with depth readings taken along the way will help you navigate with more accuracy.

LAYING A DISTANCE LINE

In low-visibility environments—such as murky temperate waters—it may be necessary to lay lines to aid navigation back to a convenient point. Lines can also be used to search an area: if you know the approximate position of a specific site, natural object, or artifact, you can use a line, in arcs of different lengths, to scan a large area of seabed efficiently.

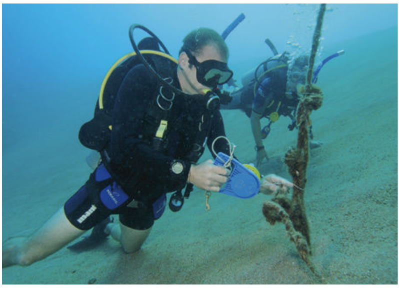

1 **Find a solid anchor point** to attach the line to. Make a couple of turns around the object for extra security. Do not secure a line to jagged edges that will fray or cut through it.

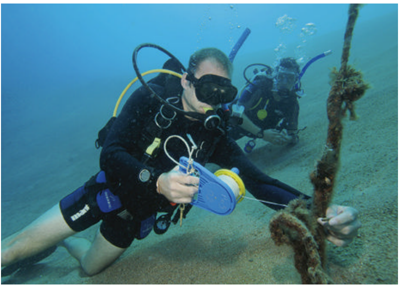

2 **Secure the line** to the anchor point. If you have a reel and line you use regularly, fit a spring clip to the end of the line so that it can wrap around the anchor point and clip back on to itself.

3 **Unspool the line** as you explore, making sure that your buddy keeps clear to one side. The line should be tied off again wherever you change heading.

Ascent

All good things come to an end, and at some point your dive will be over. Ascending at the end of a dive should be carried out with great care. This is the part of the dive where decompression sickness (*see pp.142–43*) can develop, so your ascent must not be hurried.

WHEN TO ASCEND

Dives often end when you reach a prearranged time to surface, either to meet the boat cover or to account for changing tides. However, you may decide to ascend before this if the site proves uninteresting, or if you or your buddy are cold or tired. You may also be forced to ascend if you have only 725 psi (50 bar) left in your tank, if you are making a decompression dive (*see pp.130–31*) and reach the scheduled minimum volume of air in your tank, or if problems cause you to abort the dive.

SIGNALING TO ASCEND

To ask your buddy if they are ready to ascend, or to signal your intent, raise your thumb.

MONITORING A DIVE COMPUTER

Dive computers (*see pp.66–67*) help the diver judge ascent rate. Some devices give audible warnings if safe limits are exceeded.

Before ascent, you and your buddy should signal the "thumbs up" to each other that you are both able and ready to ascend to the surface.

If possible, avoid making a "free ascent," with no visual reference to guide you. If you can follow a reef wall or a permanent mooring line, for example, this will give you a natural sense of your ascent rate, in addition to your computer readings, and can help avoid disorientation. Sometimes, though, it is not possible to ascend up a line or along a natural feature, and it can be helpful to deploy an delayed surface

BUDDY PAIR ASCENDING A GUIDELINE
A buoyed line moored to a wreck or seabed feature offers one of the safest guides for an ascent, especially in a strong current.

marker buoy (DSMB; *see pp.130–31*)—this will give you a vertical reference and also signals your position at the surface. Ideally, both members of the buddy pair should carry a DSMB. If you are diving on a wreck or a site with a guideline, aim to get back to the line for your ascent—not only will boat cover know where to pick you up at the surface, but the line will assist you in making decompression stops and, in a current, can provide something to hold on to. If you do not manage to get back to the guideline, send up a DSMB.

MAKING YOUR ASCENT

To start your ascent, slowly breathe in or let a little air into your BC—this should cause you to rise up. Rise up next to, and ideally face-to-face with, your buddy so that you can check each other's rate of ascent and condition. As ascent continues, carefully monitor the amount of air in your BC (and drysuit if relevant)—the air will expand as the pressure decreases during your ascent, causing your rate of ascent to increase rapidly. Keep one hand on the BC exhaust hose in order to vent air from

FOLLOWING A SLOPE
Ascending next to a natural feature, such as a reef, offers a reassuring reference point.

MAKING A SAFETY STOP
Divers make a precautionary safety stop at 16 ft (5 m) to allow nitrogen to exit the body's tissues at a safe rate.

it as you ascend. You may also need to dump air from your drysuit. You can fin to assist your ascent, especially to gain momentum to begin with, but this will not be necessary if you are correctly weighted and positively buoyant. Keep breathing normally and do not hold your breath.

A conservative estimate of a safe rate of ascent is 50 ft (15 m) per minute (or slower) up to 16 ft (5 m) in depth. At this point many divers make a 3-minute safety stop. Whether you do or not, the last 16 ft (5 m) to the surface should take another full minute. If making a decompression dive, make all your scheduled safety stops and check with your buddy as you do so.

DEPLOYING AN INFLATABLE BUOY

Since ascent must be conducted in a controlled way, it is helpful to carry your own portable guideline—an inflatable buoy, or safety sausage. These highly visible tubes are launched using air from your second stage, and allow you to ascend up an attached line. Using them is a real skill, so seek training before your first attempt. Remember to reel the line in as you ascend, since slack line can get wrapped around your gear.

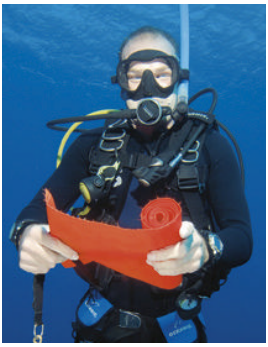

1 **Unfurl the buoy**, which should be attached to a reel. Unclip the reel from yourself, taking care not to drop it.

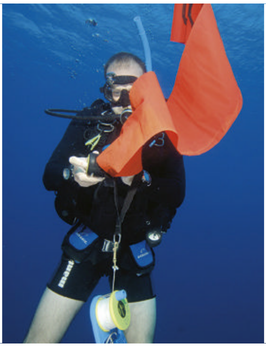

2 **Partially inflate** with a small burst of purged air from your octopus (*see p.61*) to stand the buoy upright.

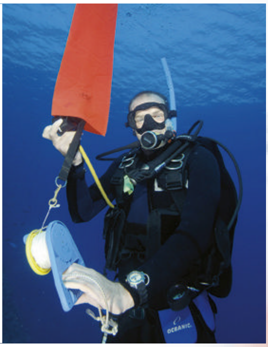

3 **Hold the reel** in one hand, and with the other, hold your octopus valve under the buoy's inflation point.

4 **Launch the** buoy by purging a long blast of air into it with your octopus. Release the spool, holding tight to the reel, and the buoy will shoot upward.

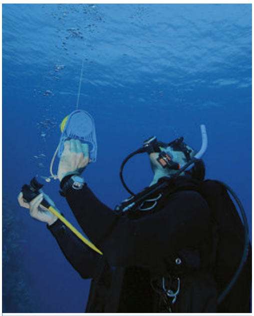

5 **When the** spool stops spinning, start to ascend, reeling in the line as it slackens. Ascend at a safe pace: do not tug on the line to pull yourself up. During ascent, keep one hand ready to vent air from your BC if required.

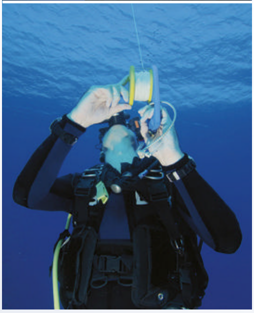

6 **Await recovery** at the surface from your boat cover, which will have sighted the buoy at the start of your ascent. The buoy should be left in its inflated state until you have been recovered.

Surface skills and recovery

Once you and your buddy have completed your dive and are at the surface, you need to head back to shore or wait to be picked up by your boat cover. Always remember that the dive isn't over until you and your buddy are back on dry land or on your dive vessel!

EXITING ON TO THE SHORE

If completing a shore dive, you and your buddy should swim to the shore and find a safe, appropriate method of getting back on to dry land. If you are diving from a sandy beach, it is usually best to keep your fins on for as long as possible and walk backward up the beach until you are well out of the way of any swell. Removing your fins too early can lead to problems if you are swept off your feet or back out to sea, since you will have no propulsion.

If diving from a rocky shore, try to find an easy route back on to the rocks. Again, aim to keep your fins on for as long as possible. As you take off your gear, place it clear of any swell that could carry it back into the water.

EXITING ON TO A BEACH
Only remove your fins and walk forward when exiting the shallows of a calm sea, or once you are out of the way of any swell.

SIGNALING TO A BOAT
Your dive plan should ensure that your boat cover knows roughly when you will surface. If you need help quickly, shout and wave a signaling flag.

SIGNALING TO BOAT COVER

If you are diving from a boat, remain close to your buddy with your regulator in place and signal to your boat that you are OK and awaiting recovery. If there is a problem or emergency (*see p.141*) and you or your buddy require immediate recovery, wave to the boat, or draw extra attention to yourselves by blowing a whistle, shouting, or waving

BOARDING A BOAT
It is usually easiest to hand up any small items first, then hoist yourself up the ladder while still suited up.

a flag. As the boat approaches, move to it with caution, keeping your distance until you have a signal from the boat that it is in neutral and safe to approach.

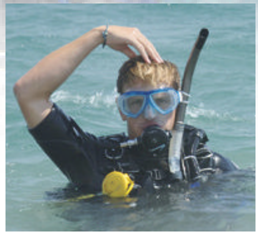

DIVER GIVES "OK" SIGNAL
A standard signal for "I'm OK" at the surface is to put your hand on top of your head, forming a closed arc.

EXITING ON TO A BOAT OR RIB

To get into a rigid inflatable boat (RIB), you should first get a hold on the boat, either by a rope or by a handle on the side. Make sure your BC is inflated, hand your weight belt in first, and then slip out of your BC by unclipping one of its shoulder straps. Keep hold of it until someone from the boat can pull it in, along with your tank. You should then be able to kick with your fins and pull yourself up on to the RIB.

If returning to a hard boat, head for the ladder and hold on to the bottom. Take great care in a swell—the ladder will move in the water. The skipper or dive master will probably tell you whether to de-kit in the water or to enter the boat wearing your gear. You may be able to hand in your weight belt, BC and tank, but often it is easy enough to remove just your fins at the base of the ladder, hand them up to someone in the boat or hold on to them, and simply climb the ladder fully kitted up. If you feel you are not strong enough to do this, let someone on board know (preferably before you dive).

Once on the boat, be aware that others may be waiting in the water to get on board. Stand back to let others on, stow your gear quickly and neatly, and then offer assistance if it is needed.

Post-dive and debriefing

Your dive is over, and there is equipment to be cleaned and stowed, and records to write up while your dive is still fresh in your mind. Problems may have occurred during the dive, and questions may have arisen that need to be addressed. Now is the best time to do this.

PRACTICAL MATTERS

The first post-dive task is to wash your gear. You need to ensure that it is clean and free from mud or sand. If you have been diving in saltwater, then this also needs to be thoroughly rinsed off before the salt starts to corrode metal parts. Large dive boats and liveaboards usually have one facility for washing electronic equipment, such as computers and cameras, and another for your BC, regulator, and other gear. Rinse all items thoroughly to remove excess salt and sand, which can easily work itself into O-rings and regulators. There may also be facilities on board to dry your gear before stowing it away in a bag or box for your next dive. Make sure you follow instructions and do not leave gear lying around—this can lead to loss or damage, which may impede your next dive. If you are diving from a rigid inflatable boat (RIB) or small dive boat, you will need to find a water source back on land to rinse your gear, and then leave it to dry or stow it for transport.

ANALYZING THE DIVE

There will normally be some sort of debriefing with your dive leader after a dive. This gives you an opportunity to ask questions about the dive (for example, to identify fish species that you did not recognize, or discuss problems with gear, navigation, or currents). This is a time when you can learn about the site for a future dive and share with others ways to improve skills.

DIVER CLEANING GEAR
Rinsing, drying, checking, and stowing your gear should become a post-dive routine.

You should always fill in a log book after every dive, recording the depth, time, and conditions (including visibility, water temperature, and currents), as well as key features of the dive—details of a wreck, species encountered, equipment configuration, the type of suit you were wearing and the weights you used, and any problems you experienced. The log will be a valuable reference for future dives.

Finally, ensure that after every dive you are well rehydrated. You will have expended a high level of energy and will have lost fluids. Choose non-fizzy soft drinks or, ideally, water, to ensure that you rehydrate your body properly. Keep your energy levels up, especially if you are diving again soon, by having a good meal or eating a snack with a high energy content. If you are cold after a dive, get warm and dry—have a hot drink and get out of your wetsuit, if possible.

REACHING THE SHORE
Eager as you may be to talk about what you have seen, attend to your gear first.

LOOKING FORWARD

If you are planning to make more than one dive in the same day, consider beforehand what your surface interval will be between dives. Aim to do your deepest dive first, and shallower dives subsequently. Make sure you are in good shape to dive again—if you have become cold or fatigued on the first dive, it is better to spend time recovering than to dive again too soon.

DIVERS DEBRIEFING
Talking to other divers in the post-dive get-together will help broaden your knowledge of diving, and you may pick up some handy tips.

Problem solving

Diving is a safe sport if you follow the rules, avoid taking unnecessary risks, and always dive with a buddy. But that does not mean you will never encounter difficulties during a dive. Learning how to anticipate and solve problems is part of becoming an accomplished diver.

KNOW YOUR LIMITS

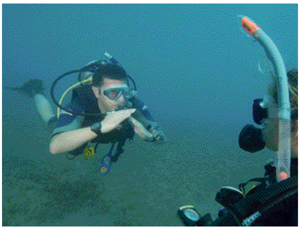

REGULAR SIGNALING
Remain in close communication with your buddy at all times, and signal to each other regularly that you are OK.

One of the most exciting things about diving is that no two dives are ever the same. Even consecutive dives on the same dive site, with the same buddy, will be different due to changes in currents, visibility, and your own attitude. Some days you will feel great, and everything will work out perfectly, and other days you might be tired, have a slight headache, perhaps, and there may be minor problems underwater that you have to deal with. In this unpredictable sport, you must be mentally and physically prepared for every eventuality.

To minimize the likelihood of problems and incidents occurring during a dive, do not dive without preparation in conditions with which you are unfamiliar. For example, if you have never dived in a cave, wreck, or under ice, make sure that you undergo the relevant training before attempting to do so. Diving in conditions for which you are unprepared will lead to anxiety, and sometimes to panic—and that is when problems often arise.

The buddy system is important for your safety, but as a diver you must ultimately take responsibility for your own welfare. If you feel uneasy during a dive, tell your buddy, and either change or abort the dive. Never let peer pressure push you beyond your limits and training, even if this means that your buddy's dive may be unsatisfactory. Buddy compatibility is important, since accidents can occur when two egos clash.

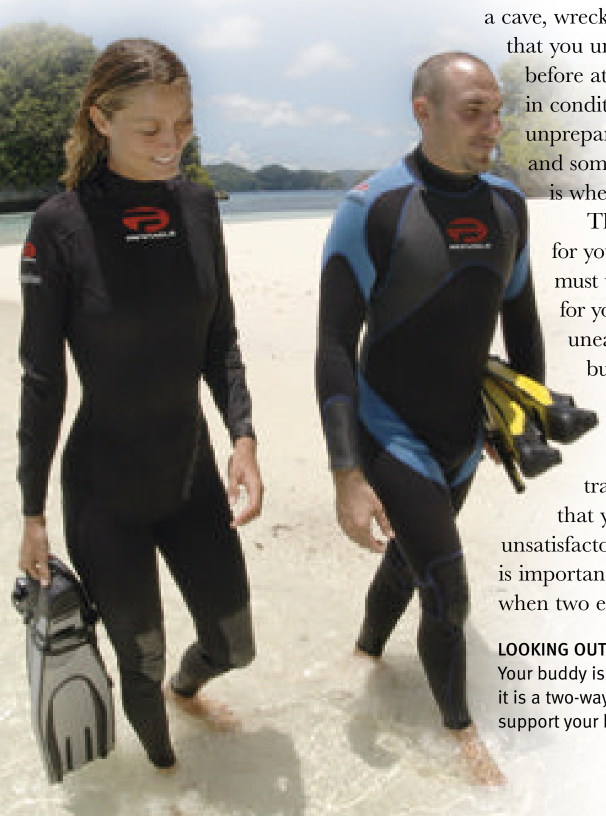

LOOKING OUT FOR YOUR BUDDY
Your buddy is your underwater lifeguard, but it is a two-way relationship—you also have to support your buddy when problems arise.

MENTAL AND PHYSICAL FITNESS
Confidence, a positive mental attitude, good health, and good levels of fitness are essential ingredients for a safe, successful dive.

ANTICIPATING EQUIPMENT PROBLEMS

It is rare that equipment fails during a dive, but you should nevertheless take great care when assembling, storing, and servicing your gear. After all, this is what keeps you alive underwater, so it is worth spending time and money on keeping it in perfect working order.

Consider "what if" situations ahead of a dive, and think through how you will deal with the failure of any element of your gear. Do you have a spare if your buddy is not close by? Your regulator should always have an octopus second stage (*see p.61*), to use as a backup in case your main second stage fails.

HANDLING INCIDENTS CALMLY

Many things can go wrong on a dive, but most are minor issues that can be solved without aborting the dive. Even serious problems can be dealt with if you remain focused and positive. Be persistent, and say "no" to failure. When you become aware of a problem, stop, think, breathe, and then act. Whatever happens, do not panic—remember that your buddy is there to help. Make sure you are there for your buddy, too, and be quick to reassure or assist them if they appear disoriented or anxious.

THE INCIDENT PIT

Minor problems can escalate into major ones if you do not stay calm and deal with them methodically. Imagine that you lose your regulator while trying to ease cramp in your foot, and then fumble as you try to retrieve it. If you panic, you may inhale water, choke, and become disorientated. This type of scenario is known as the "incident pit"—stay out of it by thinking clearly and acting methodically.

TROUBLE-SHOOTING

The equipment problems you will encounter most commonly will involve your regulator, mask, and inflator hose.

If your regulator comes away from your mouth and you cannot retrieve it, reach for your octopus second stage (*see p.61*) and breathe from it. If your octopus is not accessible for any reason, signal to your buddy, who should offer you their own octopus to use. Take a few breaths from this to calm down and, with your buddy's help, locate your main regulator and replace it.

Should air start to flow uncontrollably from your regulator, take the regulator out of your mouth and push the purge button, which should clear any grit that may be jamming the valve open. If this does not work, switch to your octopus second stage and signal to your buddy that your air supply is running down more quickly than normal. Monitor your air supply carefully, and ascend immediately with your buddy. Note that in very cold fresh water, freezing up of the regulator will probably be the cause of any free-flow, in which case purging will not help. In this scenario, you may need to breathe from your buddy's octopus while performing a shared-air ascent together (*see p.140*).

RETRIEVING LOST REGULATOR
A lost regulator is usually easy to retrieve, but if your buddy is finding this difficult, go to their aid and, if necessary, offer them your octopus.

CALMING YOUR BUDDY
Reassuring physical contact can help to calm a disoriented buddy and prevent panic from setting in.

SECURING A BUDDY'S LOOSE TANK
Some problems are difficult to solve alone, and you should not hesitate to alert your buddy if you need assistance.

SOLVING MASK AND HOSE ISSUES

If your mask is dislodged or starts to fill with water, simply clear it in the normal way. Lean your head back, press in the upper edge of the mask, and breathe out through your nose. The air bubbles you exhale will clear any excess water in your mask. At depth, this can seem daunting, so be prepared to practice this procedure until you are comfortable with it and can execute it confidently.

REMOVING YOUR WEIGHT BELT
You must be competent at removing your weight belt underwater, in case you need to adjust your weights or if your belt becomes snagged.

On occasion, you may find that the inflator hose for your BC or drysuit fails to work. This is usually caused by grit becoming lodged in the valve. If necessary, BCs can be inflated orally, both underwater or at the surface.

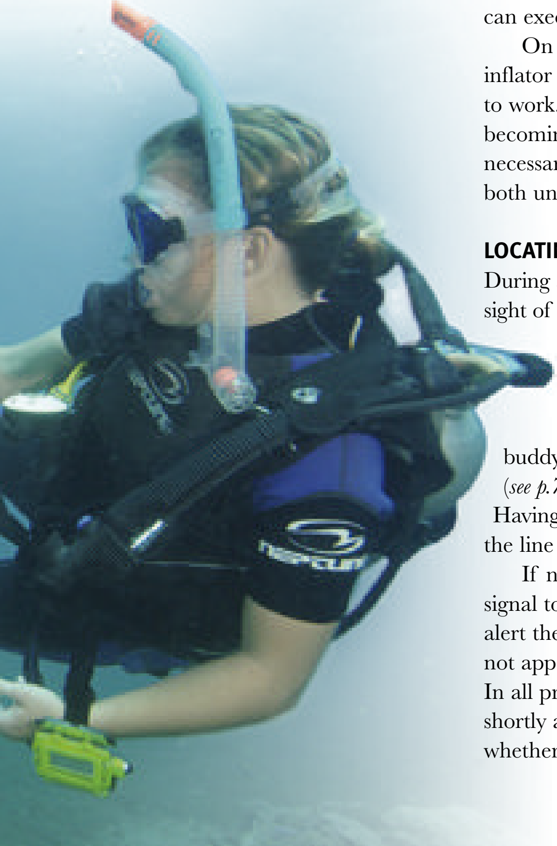

LOCATING A LOST BUDDY

During a dive, you may find you lose sight of your buddy, especially in low visibility conditions. The correct procedure is to look around for a minute or two, and then surface independently. If your buddy is using a surface marker buoy (*see p.74*), it will indicate their position. Having located it, you can then follow the line down to find your buddy again.

If neither buddy nor buoy is visible, signal to any boat cover to recover you; alert the coastguard if your buddy has not appeared after a few minutes.
In all probability, your buddy will surface shortly after you do. You can then decide whether or not to resume the dive.

FREE AND BUOYANT ASCENTS

If you run out of air, locate your buddy and follow the procedure below. If you cannot find your buddy, you will need to make a rapid "free ascent" by finning to the surface. This can be aided by ditching your weights, but be ready for a sudden increase in buoyancy. Breathe out slowly during ascent to prevent lung expansion injury. If, however, you have a little air left, you can make a more controlled "buoyant ascent." Let some air into your BC to kick-start your ascent, and tilt your head back to watch for the surface. Again, breathe out during the ascent. Control your ascent rate by venting air from the BC, but not so much that you lose buoyancy. Do not rise any faster than

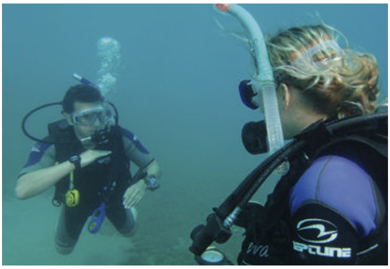

1 **Signal to your buddy** that you are out of air by making a chopping motion at your neck with the flat of your hand.

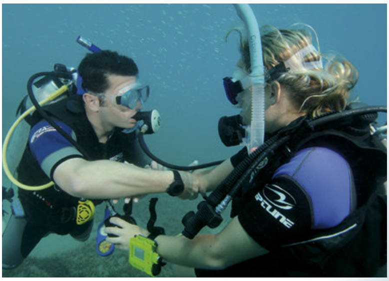

2 **Your buddy will offer** you their octopus second stage, or, if they have one, a separate regulator attached to a pony bottle.

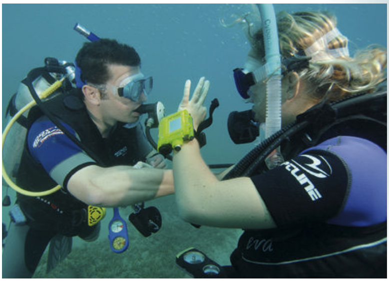

3 **When your buddy is** sure that you are OK and your breathing has settled, you should lock arms and ascend to the surface.

OUT-OF-AIR PROCEDURE WITH BUDDY

If you have not kept track of your air consumption and find that you are out of air, locate your buddy and ascend using their octopus or pony bottle. If no alternate air source is available, then buddy breathe. This involves both divers using the same regulator, with each diver taking two breaths before passing it to their buddy. This is a complex procedure, however, that needs to be practiced if it is to succeed in a real-life crisis.

4 **Hold on to one another** as you rise to the surface. Make any decompression stops as you would do during a normal ascent.

your exhaled bubbles. At the surface, signal to boat cover immediately. If there is no boat, swim to the shore. Your buddy will need to be found and, as you have ascended without safety stops, you will need to be monitored for DCS (*see p.142*).

MAKING EMERGENCY LIFTS

If your buddy is unconscious or injured, keep their regulator in their mouth and perform a buoyant lift to get them to the surface. This means holding on to your buddy's harness as you ascend, using their BC to adjust buoyancy for both of you. Alert any boat cover once at the surface. If your buddy is not breathing, artificial ventilation (AV) may be needed until medical help arrives. If there is no cover, or if you are close to shore, you may decide to tow your buddy to safety. Both towing and AV require special training; if your dive training did not cover them, a lifesaving course is recommended.

OVERCOMING PANIC

If you feel panic coming on, alert your buddy, stop moving, and steady your breathing. If your buddy panics, reassure them with hand signals but observe them from a safe distance, since a flailing arm can knock your regulator from your mouth or injure you. When they have calmed down, hold their hand or arm, make sure their regulator stays in place, and remain close until normal breathing resumes.

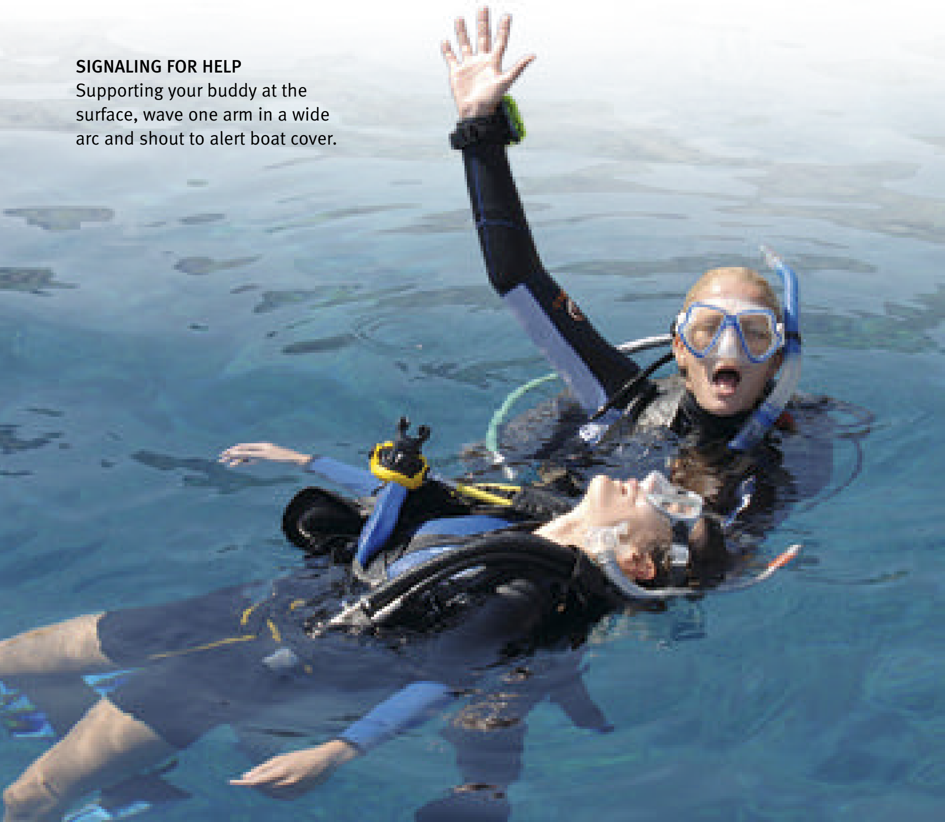

SIGNALING FOR HELP
Supporting your buddy at the surface, wave one arm in a wide arc and shout to alert boat cover.

Decompression sickness

If a diver ascends too quickly, the rapid pressure change causes bubbles of nitrogen to form in tissues and blood vessels *(see pp.100–01)*, resulting in decompression sickness (DCS). This condition must be watched closely and treated quickly, since in extreme cases it is fatal.

DCS SYMPTOMS

Severe DCS may cause impaired vision and balance, convulsions, and even unconsciousness. Nitrogen bubbles can form under the skin, or become trapped in capillaries and restrict the blood supply to the lungs, slowing breathing, lowering blood pressure, and causing shock. If a bubble enters the brain or spinal cord, it can lead to paralysis or even death. Symptoms usually appear between one and six hours after surfacing, but occasionally do not manifest themselves until 24 hours later. They start with minor aches in joints, rashes, and itching. These will disappear after a few hours in mild DCS, but with severe DCS they will be precursors of serious complications. At the first sign of symptoms, request emergency medical attention (from the coast guard, if you are at sea) and give basic first aid: supply the patient with 100 percent oxygen; keep them warm and still (lying down if possible); provide nonalcoholic fluids (ideally sports or rehydrating drinks); and apply pressure to joints to alleviate pain. The patient should be referred for medical attention and may need to be treated in a recompression chamber.

If so, provide those in charge of the chamber with the diver's symptoms and details of the dive. In the chamber, the pressure is raised until it causes gas bubbles in the diver's tissues and blood to shrink. The diver is decompressed under controlled conditions, allowing any residual nitrogen to dissipate safely.

EMERGENCY OXYGEN
It is vital that the dive boats carry an oxygen administration kit in case of emergencies.

LOOKING FOR SYMPTOMS
Skin rashes and joint pains may be precursors of more serious problems.

DCS AT SEA
Record the symptoms, give first aid, and get to shore if feasible—or wait for the coast guard to arrive.

Hand signals

Good communication with your dive buddy is important, not just in an emergency, but also to monitor each other's progress, share underwater experiences, and agree when to end the dive. The most effective method of communication is to use hand signals.

USING HAND SIGNALS

Verbal communication is not an option underwater (*see p.92*) unless you are wearing a full-face mask, but most messages can be conveyed using a combination of hand signals and drawings on a slate. Using hand signals will allow you to exchange information with your dive buddy and even ask each other questions underwater. They can also be reassuring.

Signal to your buddy regularly during a dive, as this will ensure that you remain in close contact and can easily notify each other of any problems that may develop. Repeat any sign that is not clear to your buddy, and acknowledge every signal that he or she makes with an "OK" to show you understand. If your buddy is slow to respond to a signal, check that they are OK. If you are diving at depth, sluggish responses may indicate the onset of nitrogen narcosis (*see pp.100–01*), which impairs reaction times and mental acuity.

Signals are not just limited to showing each other how much air you have left or highlighting problems. They can also be used to inform your buddy of interesting things you have seen, or to alert them to something you are both looking for, such as a particular marine organism. There are numerous signals for marine animals, and you can develop your own within your buddy pair. A common example is the use of a straight, upright hand (representing a fin) on top of your head, meaning "I've seen a shark." Signals for animals like turtles and rays can be readily improvised.

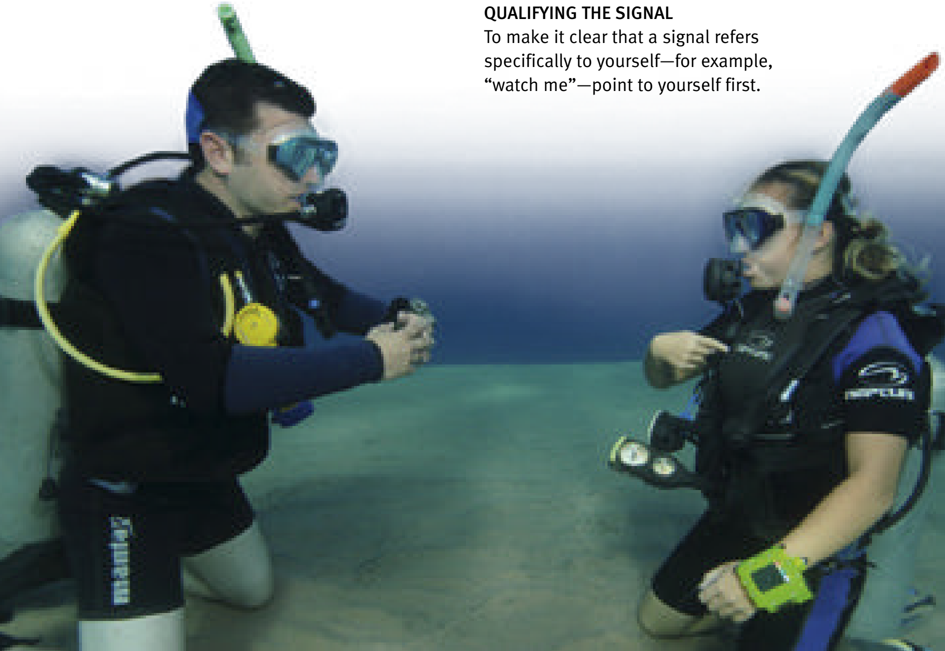

QUALIFYING THE SIGNAL
To make it clear that a signal refers specifically to yourself—for example, "watch me"—point to yourself first.

COMMON HAND SIGNALS

There are a number of standard hand signals that are essential to all divers, and you can also improvise new signals with friends. Always review signals at the start of a dive, especially if you are diving with a new buddy. Give signals to your buddy slowly and clearly, to ensure that they are understood. Use combinations of signals to convey messages more precisely (for example, something is wrong/I can't clear my ears). Below are some of the most important and common diving signals.

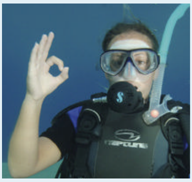

OK/Are you OK?
Form an O with thumb and index finger. Point the other fingers up.

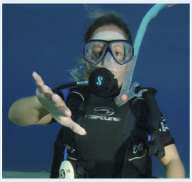

Something is wrong
Tilt the flat of your hand from side to side, palm down.

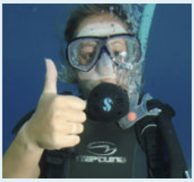

Up/Let's ascend
Point thumb straight upward with fingers clenched in a fist.

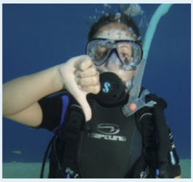

Down/Let's go down
Point thumb downward with fingers clenched in a fist.

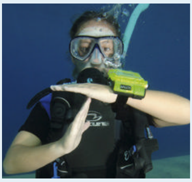

1,500 psi (100 bar) left
Form T-shape with hands to indicate 1,500 psi remaining.

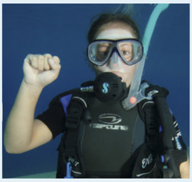

750 psi (50 bar) left
Make a fist, with palm outward, to indicate 750 psi remaining.

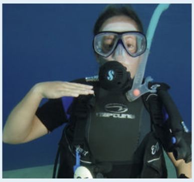

I am out of air
Make a horizontal chopping motion across base of neck.

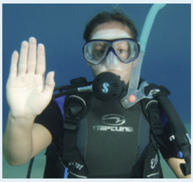

Stop
Present flat of hand, palm outward, to halt buddy or other divers.

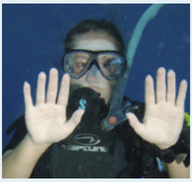

Slow down
Move palms slowly downward together (pivoting at elbows).

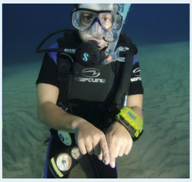

Stay/Move together
Move index fingers together, until touching side by side.

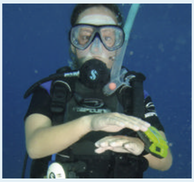

Stay at this depth
Hold both hands horizontally and move one over the other.

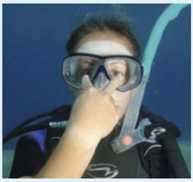

Watch/Look
Point at your eyes, then at subject of interest, or self, or another diver.

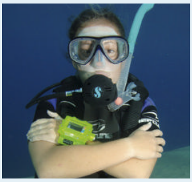

I am cold
Hug yourself with both arms crossed to indicate chill.

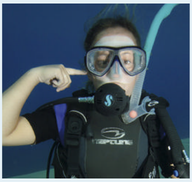

I can't clear my ears
Point at ear to indicate you are having difficulty equalizing.

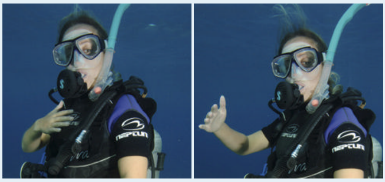

Feeling breathless
If you are feeling out of breath and need to rest for a moment, you should use the flat of your hand to mimic your chest rising and falling.

Developing your skills

With any skilled pastime, it is important to keep your technique sharp. Many divers only dive once a year (or even less frequently), and it is easy to forget even basic skills during your time off from diving. Honing your skills in sheltered water is a good way to stay proficient.

PERFECTING BUOYANCY

Beginners, occasional divers, and even those who dive regularly will benefit from practicing key skills in a pool or sheltered water. Buoyancy is the most fundamental diving skill of all, so it is a good place to start when reviewing your technique. Refamiliarize yourself with buoyancy control with "fin pivots," using inhalations and exhalations to make the upper part of your body rise and fall. Keep your fins on the bottom and your legs apart. They will act as the "hinge" of your upward and downward movements. The value of this exercise is that it trains you to use breathing to adjust your buoyancy, rather than controlling it only with your BC. Also, try swimming through a hoop with your arms folded—this will test your buoyancy control and give you an idea of the space you can squeeze through with your equipment on.

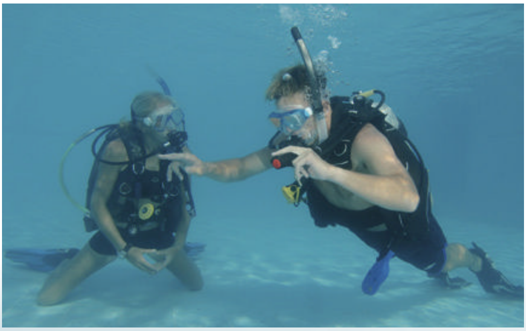

1 **To practice fin pivots,** breathe in gently and feel your upper body rise, keeping your fin tips on the floor. Stop at a 45° angle to the bottom.

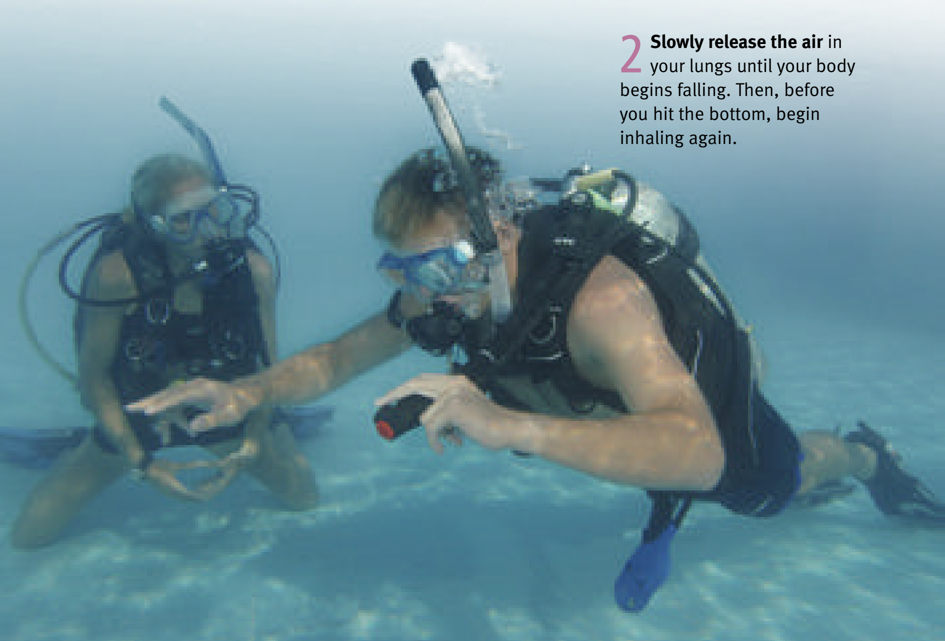

2 **Slowly release the air** in your lungs until your body begins falling. Then, before you hit the bottom, begin inhaling again.

CONFIDENCE-BUILDING EXERCISES

Mask clearing is one of the most basic, yet important, skills in diving. Building coordination and confidence by removing and replacing your mask, and even performing tasks without it, will improve your diving. It will also prepare you for minor upsets like your mask being accidentally dislodged. Begin building up your confidence slowly by removing and replacing your mask in shallow water, before repeating the exercise in deeper water. Repeat while swimming, and then try it with your regulator removed. You can also try swapping masks with your buddy. This is simply a variation on the solo exercises but also helps you to develop useful cooperative skills.

Giving yourself other handicaps can also help improve your confidence underwater. Try swimming with just one fin, for example. Losing a fin can happen on an open-water dive, but if you are already prepared, you will be able to cope with the situation calmly and effectively. Practice all of these exercises in a pool or sheltered water.

REDUCED VISIBILITY
Most divers feel uncomfortable swimming with their mask removed, but with practice, you will become confident performing tasks without it.

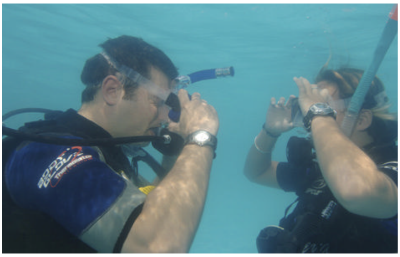

1 **To exchange masks**, kneel on the bottom facing each other. Give each other the "OK" signal, then remove your masks, while continuing to breathe normally.

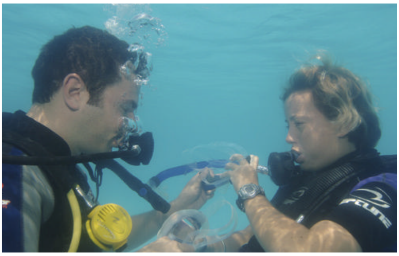

2 **Swap masks** with your partner. It is much easier to keep your eyes open throughout the exchange, but perfecting this by touch, with your eyes closed, is a very useful exercise.

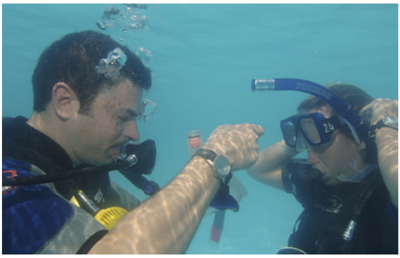

3 **Don each other's masks**, and blow them clear (*see p.139*). Ignore any urge you feel to hurry when putting the mask on. In particular, make sure the strap is not twisted.

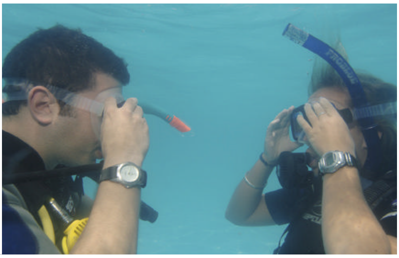

4 **Adjust the mask** for comfort, then open your eyes and signal OK to indicate a successful swap. The masks can then be swapped back again for further practice.

VARYING THE ROUTINE

Skills exercises don't have to be simple drills. Introducing an element of fun or setting an objective can motivate you to train for longer. Games for the pool or sheltered water include "hide the mask," which forces you to navigate and search without your mask; or you can practice breath control by performing simple exercises without breathing apparatus, such as retrieving objects from the bottom, or swimming through a series of hoops, extending the course as your stamina improves.

1 **"Hide the mask"** begins with an "OK" signal from the seeker, once the diver who is going to hide the mask has removed it.

2 **The seeker closes his eyes** while the hider finds a corner of the pool to put the mask in, and returns to signal the seeker to start searching.

3 **The seeker opens his eyes** and starts to methodically search the pool bottom until the mask is found and replaced.

REMOVING AND REPLACING GEAR

Familiarity with your basic gear is a vital skill. One exercise that helps to foster confidence in this area is to remove your scuba unit—that is, your BC and breathing apparatus, all fully connected—and put it back on underwater, keeping your regulator in your mouth throughout. This exercise should be carried out at the bottom of a pool or in sheltered water, and if you are a beginner or haven't tried this before, it may be useful to have an instructor present who can guide you through the process. Start by undoing all fastening clips on the front of your BC and pull your left arm out of it first (even if you are left-handed), using your right arm to pull it around to your right. The BC jacket should now be in front of you, between you and the tank. Keep the hose for your regulator second stage between your arms (otherwise it may get caught under your shoulder strap when you put the unit back on). Then put the scuba unit back on by reversing the operation.

For an extra challenge, once you have removed your BC, try removing your regulator from your mouth and swimming away to a distance of about 30 ft (10 m), before returning and putting your gear back on again.

Alternatively, try entering the water without your gear, then putting it on while treading water, keeping your head above the surface. This is a much more difficult exercise, and should only be carried out under the guidance of an instructor.

1 **To take off** your scuba unit underwater, undo all clips and take your left arm out of the BC, gripping the jacket with your right hand. Breathe normally through your regulator.

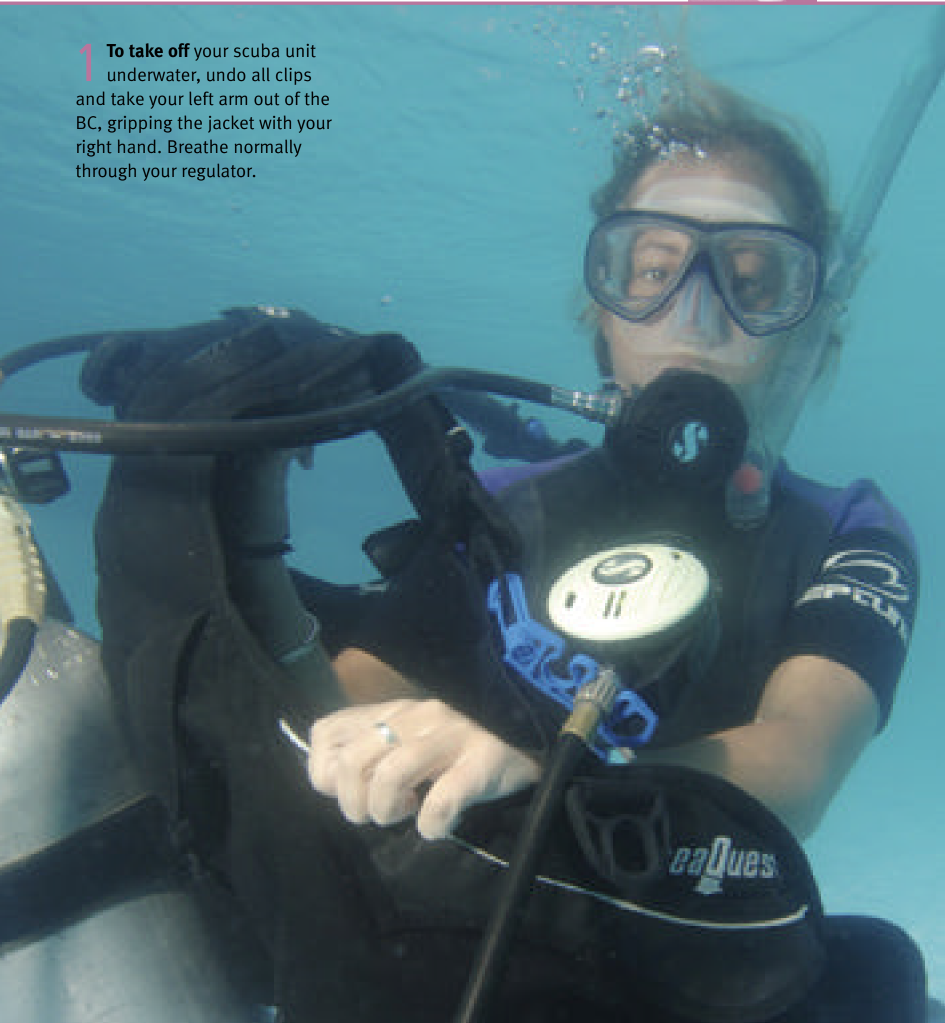

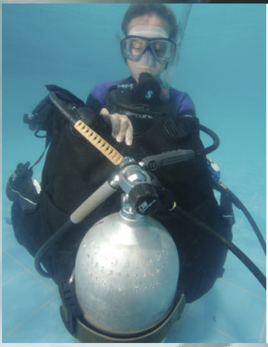

2 **Pull the whole unit around** in front of you. Keep a firm grip on your BC to avoid losing hold of the scuba unit.

3 **To put gear back on,** reverse the operation, making sure all clips and fastenings are reconnected.

Dive fitness

As a diver, you are reliant on your body as well as your gear for a safe and enjoyable dive—so make sure both are well maintained. Diving regularly helps keep you in shape, but it is important to maintain your fitness levels if you go for long periods without diving.

HOW FITNESS AFFECTS DIVING

Staying in shape reduces some of the risks associated with diving, and makes it more enjoyable. Having healthy lungs and an efficient circulatory system means you will use less air, so dives last longer. A good level of cardiovascular fitness will also help to prevent panic attacks, which can be triggered by a buildup of carbon dioxide in the blood. A fit body will expel this by-product of respiration more efficiently, reducing that risk. General strength is required for lifting equipment and other incidental tasks. Maintaining a healthy weight for your size is also advisable. When you dive, nitrogen builds up in the tissues of your body with each intake of breath, and fat retains nitrogen longer than all other tissue types. Therefore, if you are overweight and breathe rapidly because you are out of shape, you expose yourself to an increased risk of DCS (*see pp.142–43*).

Weight loss and gain can also alter your buoyancy. Fat is inherently buoyant, so if you have put on or lost a lot of weight since your last dive, you must adjust how much lead weight you carry as ballast (*see pp.118–21*).

TALKING THINGS THROUGH
If you have any injuries or physically weak areas, let those diving with you know before you dive. Don't be afraid to ask for assistance if this will help prevent injury.

DEVELOPING A FITNESS REGIMEN

There is no quick fix for getting and staying fit. Aim to exercise regularly, tailoring your routine to strengthen the muscles you use most during diving: those of your back, legs, shoulders, and arms. If you do not already exercise regularly, seek medical advice before embarking on a fitness routine. Start gently with easy exercises, and build up slowly. A routine based on the exercises overleaf could start, for example, with ten repetitions of each, building up to 50, three times a week. You should also aim to undertake regular cardiovascular exercise (such as walking or cycling), for 30 minutes two or three times a week to improve your general fitness and respiratory health.

Whatever exercise routine you decide to adopt, try to incorporate it into your normal daily routine wherever possible. A walk to work every day does more good than a monthly gym session. Never exercise after diving. This is a time when it is important not to do any strenuous activities—there is still residual nitrogen in your body, and this may form bubbles if you exercise too hard. Do some gentle stretches and take it easy for the rest of the day. Avoid hot baths or showers after diving, since these can also raise your vulnerability to DCS.

GOING AGAINST THE FLOW
Finning into strong currents places demands on your leg muscles and lungs.

PROTECT YOUR BACK

Be very careful when carrying and loading heavy equipment. A poor lifting technique can result in pulled muscles, and possibly long-term back problems. A back injury can spoil a trip, but diving with a weak back can also be a safety risk: surface maneuvers, climbing onto boats, and exiting surf, for example, are all compromised by weakness in this area. If your lower back is vulnerable, consider transferring your weights from a belt to a harness (*see p.70*).

Loading dive equipment

WARMING UP

Always warm up and stretch—especially your thighs, calves, and upper and lower back—before exercising, and spend a few minutes gently stretching and cooling down afterward. Many sporting injuries are caused by failure to warm up properly, so treat it as an important part of your fitness routine.

ARM AND LEG EXERCISES

Basic squats build up strength in your legs. Standing upright with your feet shoulder-width apart and your knees soft, place your hands on your hips and shift the weight back into your heels. Keeping your head and chest pointing forward and your back straight, bend at the hip and knees, as if you were sitting down onto a chair. Keep your heels on the floor; you should be able to move your toes, since all your weight is on your heels. Straighten and repeat.

Lunges are a more advanced exercise for legs. Stand upright with one foot a good stride in front of the other, with your hips parallel and your toes forward. Your back heel should be off the ground and your front foot flat on the floor. Both knees should be bent and your back straight. Drop your body weight toward the floor until your front knee is bent at a 90° angle. You may have to tilt your pelvis forward to get this position right. Rise up and repeat.

BASIC PUSH-UP
The push-up is a great all-around exercise for the upper body and arms. Beginners can start with their knees resting on the ground.

Biceps curls strengthen the biceps—muscles in the upper arms that are used whenever you lift anything. Using hand weights or a weighted bar, stand upright,

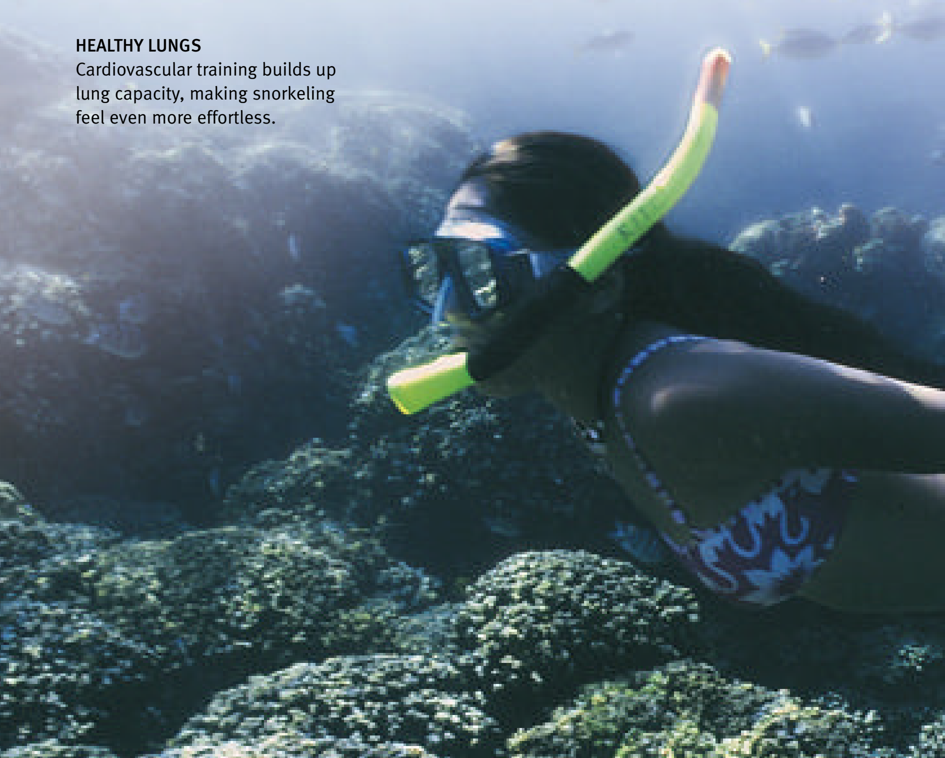

HEALTHY LUNGS
Cardiovascular training builds up lung capacity, making snorkeling feel even more effortless.

LUNGE EXERCISE
Practicing lunges in front of a mirror will help you to get the position of your front leg right: knee directly over foot, bent to a right angle.

ABDOMINAL CRUNCH
Always keep your lower back flat on the floor and never arched. For a harder workout, aim your right elbow to your left knee, and vice versa.

with your back straight and knees slightly soft, and hold the weights in your hands with your palms facing upward. Without rocking or moving your shoulders, bend the arms toward the chest and then lower, taking care not to lock the elbows.

EXERCISING YOUR TORSO

Push-ups strengthen your shoulders, upper body, and core muscles. Lying on your front, bend your knees, curl your toes under your feet, and place your hands shoulder-width apart below your shoulders. Press your body weight up and down from this position. Keep your back straight at all times and your elbows pointing out to the sides.

Crunches strengthen abdominal muscles, which will help protect your lower back. Lying on your back, bend your knees slightly and place the soles of your feet on the floor. Place your fingertips behind your ears and lift your upper torso and shoulders off the floor. Hold this for three to five seconds while looking forward, then lower and repeat.

HYDRATION AND NUTRITION

During a dive, you can burn as much energy as you would playing an aerobic sport, such as squash or badminton. The precise amount will vary according to your fitness, the temperature of the water, and any prevailing currents. But while it is tempting to stoke up on a big fried breakfast in preparation for a day's diving, better food choices before a dive are complex carbohydrates, which will keep you feeling fuller for longer and provide a steady supply of blood sugar to maximize energy levels while you are diving. Some foods may make you feel uncomfortable on a dive—commonly, greasy or hot and spicy dishes—so these are best avoided.

After a dive, you need to replace the energy you have burned with foods that release energy into your blood relatively quickly, such as refined carbohydrates. Have something to eat within an hour of surfacing, if possible. Energy-replacement drinks can be a quick fix, but avoid those with a high caffeine content.

GOOD DIVING FOODS
Whole-wheat bread, legumes, and unrefined cereals and pasta release energy slowly during a dive. Dried fruit and nuts make good snacks.

Above all, the most important thing is to remain well hydrated before and after a dive. Your physical performance will be reduced if you become even mildly dehydrated, and this is a big issue if you are diving in warm waters where the outside temperature is also high. Aim to drink at least 2 quarts (liters) of water during the course of the day (more if it is hot). This will help to reduce muscle cramps and fatigue, and also helps decrease the risk of DCS.

AVOIDING PROBLEMS

It is important to get plenty of sleep before and after diving, to give your body a chance to recharge. Diving is physically demanding, and if you are run down, you are more susceptible to catching colds. If you do have a cough or a cold, you should not dive, because some symptoms of respiratory illness can prevent you from being able to equalize and may increase your vulnerability to DCS (*see pp.100–01*). Avoid taking decongestants, since these can impair your performance underwater.

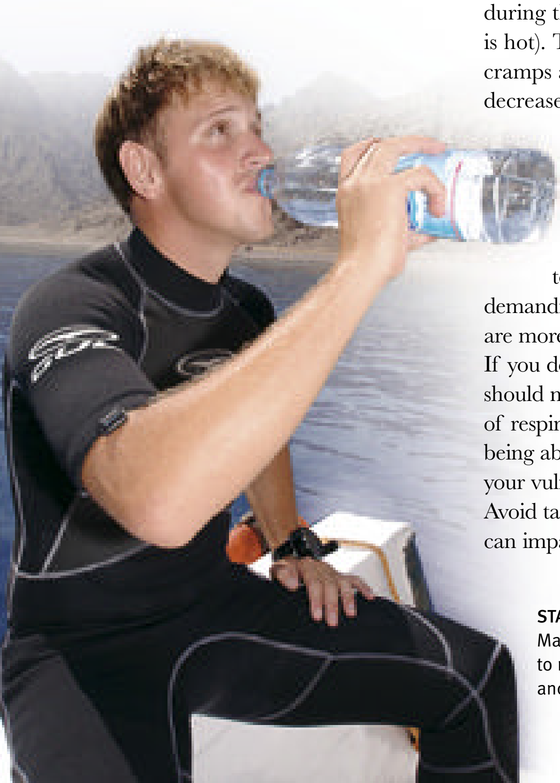

STAYING HYDRATED
Make sure you drink plenty of still water to maintain good hydration. Tea, coffee, and carbonated drinks are no substitute.

So can alcoholic drinks, which are best avoided the night before a dive because they can also contribute to dehydration. Divers sometimes experience minor ear infections, especially after days of continuous diving or if diving in slightly polluted waters. There are various ways of avoiding ear problems, including rinsing the ears with fresh water after every dive, or using an alcohol-based fluid designed for swimmer's ear.

Lastly, you should have a regular dive medical to check that you are in good enough shape to dive. If, between medicals, there have been any changes in your health since you last dived, then it is always best to have a checkup.

FOODS TO EAT WHEN DIVING

The following list gives examples of the kinds of foods it is good to include in meals and snacks before and after a dive:

BEFORE A DIVE Multigrain, whole-wheat, or rye bread; whole-wheat pasta; sweet potatoes; brown rice; oatmeal; bran-based cereals; legumes and nuts; beans; leafy vegetables; and plain yogurt.

AFTER A DIVE Pasta and rice (ideally in a salad or low-fat sauce); potatoes; fresh fruit; white bread or bagels.

AFTER A DIVE
It's tempting to head for the bar after a day's diving, but have something to eat, too. Even standing still in cold water burns calories.

Going diving

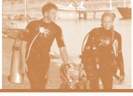

Introduction

Becoming a qualified diver is a tremendously exciting experience, but the range of choices facing you post-qualification can be daunting. The joy of diving is that within one sport lies a host of different specialties, all requiring different skills, knowledge, and planning techniques.

RECREATIONAL DIVING

Upon qualification, the world of diving opens up to you. Whether you become a casual resort diver or an advanced technical diver with a liking for the more extreme elements of the sport, only time and experience will tell.

The broad spectrum of recreational diving encompasses many different environments and experiences, including reefs, caves and caverns, wreck diving, ice diving, freshwater diving, and night diving. There are also various specialty activities in which you can participate, such as filming and photography, wildlife and conservation diving, underwater archaeology, and free diving (diving without an air supply). The majority of divers find that they derive most enjoyment from sampling a range of different environments and activities, rather than limiting themselves to one specific aspect of diving.

BEACH BRIEFING
Becoming confident enough to conduct your own dives without a guide or instructor gives you greater freedom. Always plan and brief dives thoroughly before entering the water.

Many new divers aim to acquire further specializations, pins, and qualifications from the moment they pass their initial training course. This urge, while understandable, should be tempered by the need to gain general diving experience. There is no substitute for time spent in the water—what was once intimidating becomes familiar, helpful routines start to emerge, skills and safety consciousness improve, and knowledge increases. You will also feel more confident and comfortable in the water as you learn to tailor your equipment to your own needs.

Only when you have served your "apprenticeship" by gaining experience of different environments and diving skills should you make any decisions about future specializations. Without putting in the hours underwater, you will find further training and courses more difficult, no matter how well structured and delivered they are. In addition, the more experience you have, the more aware you will be of your own likes, dislikes, and aptitudes, allowing you to make more informed choices for the future direction of your diving.

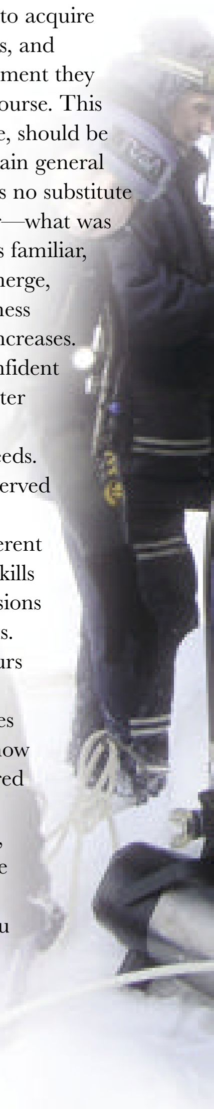

Fortunately, gaining general diving experience is relatively easy, with dive groups and clubs springing up in abundance to meet the sport's growing appeal. Furthermore, dive travel is so well established that almost any region of the world is now accessible, and opportunities to dive exist in virtually every coastal resort around the world. A whole range of diving encounters are available—from a casual beach dive through to full-blown expeditions—all easy to arrange via the Internet or through dedicated dive travel agencies.

PLOTTING YOUR FUTURE COURSE
The more experience you gain, the better informed you will be when deciding whether or not to pursue a particular aspect of diving.

PROFESSIONAL DIVING

The enjoyment of diving leads some people to consider a full-time career in which diving plays an essential part. Diving professionals range from recreational instructors and dive masters, whose main role is to introduce others to diving, through to military experts, commercial specialists, scientific divers, fishermen, and underwater cameramen and photographers.

Further skills are always needed to succeed in your chosen career—an underwater filmmaker, for example, must be an accomplished camera operator as well as a superb diver, and an instructor needs good communication and teaching skills, in addition to first-class abilities in the water.

Professional diving can offer excellent rewards, both personal and financial, but they tend to be well earned. Professionals must dive in all conditions and at all times, and the work is often arduous and sometimes dangerous.

PREPARING FOR AN ICE DIVE
Diving under ice is thrilling, but it is not for beginners. The hazards of enclosed surroundings and extreme cold mean that special training is required.

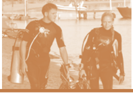

Identifying your aims

Time spent researching a dive is time well spent. Not only does it help you to unearth new attractions and clarify the aims of the dive, but it is also likely to heighten anticipation, enhance safety, and maximize the pleasure and interest you derive from the trip.

ASSESSING AIMS

The nature of dive research will vary from trip to trip, but certain core issues should always be taken into consideration.

Identifying the divers is obviously one of the first items to be addressed. Diving is not, as a rule, an individual sport, so of necessity others will be involved in the dive itself. The experience and qualifications of divers within a group will vary, and what may be a comfortable dive for one person may be extreme for another. Time spent discussing qualifications and experience levels may well prove invaluable in establishing the ideal dive location and activity for the group as a whole.

BEGINNING RESEARCH
Use magazines, books, and maps to highlight basic issues that you can then investigate in depth on the Internet.

Along with making sure that you have the right mix of divers, you will need to ensure that their aims are not likely to conflict. Imagine the scenario, for example, of an avid photographer preparing to take an

TROPICAL CONSIDERATIONS
When planning tropical dives, consider the effect of local weather patterns. Runoff from tropical islands in the wet season, for example, may impair visibility.

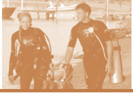

DIVING WEBSITE
The Internet is an invaluable research resource, allowing you to access the opinions and advice of authoritative dive organizations.

award-winning image of a sunken ship, when an impatient wreck enthusiast swims in front of the camera lens and ruins the shot. Establishing the main aim of the dive at the outset, or even allocating buddy teams with the same interests, should prevent such problems.

When diving with a local operator, try to check out their credentials. In many parts of the world there are associations set up by groups of respectable operators to govern the local dive industry. Failing that, many tourist boards and even government agencies require dive operators to register—it is always worth getting an independent view of your potential host from these organizations.

LOCATION AND TIME

Conditions can vary greatly along even the most bland section of coastline or within the most innocuous-looking body of water. Choosing an exact site in advance has the benefit of allowing very specific research into local issues. Key questions to be answered include: what are the hazards involved? Where are the established entry and exit points? What are the divers likely to encounter during the dive? What is the tidal range? What are the prevailing currents?

The timing of the trip is also important. Tides, for example, may affect not only visibility, but also the marine life present, as well as entry and exit considerations. Marine life will also be influenced by seasonal variations, as will water temperatures. Furthermore, a different range of marine animals may well be present at night than during the day, while boat traffic and use of the area for other watersports will vary throughout the day and the week. Diving at the wrong time can make the event a disappointing experience.

Safety is the most important area of your research. You will need to assess the conditions you are likely to encounter—waves, currents, depth, temperature—and the facilities available to you should an accident occur. You should not show up at a dive site unless you know the exact location of the nearest hospital, recompression chamber, and casualty evacuation facilities. Knowing how to contact these agencies in an emergency is also crucial—researching phone numbers in the comfort of your own home is infinitely better than trying to do it on a rocking boat while caring for an injured diver.

UNDER THE ICE
The possibilities for thrilling diving trips around the world are almost endless, limited only by time, budget, and imagination.

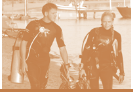

Planning a trip

Armed with the fruits of your research, you will have a clear idea of where you want to dive, when you want to go, who you will be diving with, and what you will see when you get there. The final task before your departure is to plan the trip in as much detail as possible.

REALISTIC TIMETABLING

Most trips revolve around a key moment in time—the instant when the divers enter the water. This is often determined by a certain phase in the tide when the diving is most favorable, or by the desire to dive at a specific time of the day or night, such as when the Sun is high for photography, or in the gathering dusk when the reef is at its most active. A realistic, workable timetable is thus vital to achieve such time-specific goals.

PACKING YOUR EQUIPMENT Checklists and routines will help to ensure that all your gear makes it to the dive site.

Devising a timetable, such as the chart below, by working backward from the moment you aim to enter the water is the best way to plan your diving day. This method is used by many divers to ensure that their diving is as stress-free and as enjoyable as possible.

PRESSURE TEST

Before you start packing your equipment for a dive, carry out a pressure test. This involves rigging the gear to a tank, and ensuring that the seals and regulators are all functioning as they ought to be. This is also a useful means of ensuring that your tank is full prior to departing for the dive site. There is no more sickening sensation than journeying to a dive site, looking out over perfect conditions, assembling your dive gear, and turning on the air to be greeted by a cacophony of hissing regulators and seals—or, indeed, the tank itself being empty.

REVERSE TIMETABLING

A diver knows they must enter the water at 3:00 pm to dive during slack water between the tides. They work backward from this to calculate a realistic departure hour, building in a contingency to ensure arrival at the dive site in good time.

Activity	Time Taken	Actual time
Entering the water		3:00 pm
Suiting up and buddy checks	25 min	2:35 pm
Site inspection and briefing	40 min	1:55 pm
Arrival and parking	10 min	1:45 pm
Driving to site	1 hour	12:45 pm
Loading car	30 min	12:15 pm
Checking and packing dive gear	30 min	11:45 am
Contingency time	30 min	11:15 am

CAVE DIVING
For more complicated trips, such as cave dives, special equipment may be necessary, and this must be factored into your planning.

PACKING WITH CARE

The greatest cause of the postponement or cancellation of dives is forgetting pieces of gear. A fool-proof method of guaranteeing that you pack all of your equipment is to load your gear into your dive bag at home in the order that you will be putting it on at the dive site. Visualizing your arrival at the site and suiting up will lead you to load your dive bag in the following sequence: suit, boots, knife, weight belt, tank, BC, regulator, computer, hood, mask, snorkel, fins, gloves, and finally any ancillary items (safety sausage or DSMB, flashlight, slate, and so on).

An alternative packing technique is to run through a checklist from head to toe, and again pack your gear in that order. The list then runs: hood, mask, snorkel, suit, regulator, BC, tank, computer, gloves, weight belt, knife, boots, fins.

There are innumerable ways of trying to ensure that no item of equipment is forgotten, but the most effective are those that are convenient, quickly become a habit, and take little time.

DIVERS ENTERING THE WATER
A realistic timetable will ensure that suiting up and briefing on site is not rushed, and that you do not miss your window of opportunity with the tide.

Site-specific planning

Pre-dive research is important, but there is no substitute for a thorough assessment of the site on the day of the dive. This may highlight issues not raised by your research, and allow you to make adjustments to accommodate changes in conditions before the dive starts.

FINALIZING YOUR PLAN

Once you know when and where you are going to dive, you must devise a practical plan for each of the dives you mean to conduct on the day. Whether you are planning for just yourself and a friend, or for a larger group, always take local conditions into account before settling on a final dive plan.

You must address a number of key points in your dive plan. First, it should broadly define the aim of the dive, the dive's entrance and exit points, and its general route, as well as describing an alternative exit in case the main choice is inaccessible. It should also define the dive's maximum depth and time, as well as decompression restrictions, and should specify the minimum reserve of air that divers must surface with at the conclusion of the dive.

Depending on the aim of the dive and the experience of the group, special signals may be required. It is imperative to select diver recall systems—the signals or sounds that will be used to indicate that the dive should be aborted. Your plans for the dive should also identify any potential hazards that may be encountered. If an incident occurs, what procedures should be followed? Define what action to take if divers become separated—in murky waters, this is one of the most common reasons for dives being aborted. Make sure that the divers you intend to pair together as buddies share similar interests or levels of experience, so that there are no conflicts of interest during the dive.

INSPECTING THE DIVE SITE
Resist the temptation to enter the water as quickly as possible. Assess the conditions and inspect the site, noting the dive's entry and exit points.

UNLOADING THE GEAR
Even if you feel sure that every item of gear was packed before the trip, double-check on site that you have everything you need.

Assess local conditions and examine weather reports; worsening weather conditions might dictate a move to a more sheltered site nearby, or rule out the use of a boat. Finally, ensure that the designated shore marshal or dive supervisor understands their duties, including recording tank pressures and the times that divers enter the water, and responding to incidents. Provide them with contact details of local agencies to be informed in the event of an emergency.

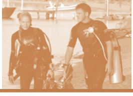

OUTLINING THE PLAN
If it helps, you can always draw simple sand maps to clarify the route to the other divers.

ENTERING THE WATER
By the time you enter the water, everyone involved with the dive should be fully aware of the dive parameters.

THE DIVE BRIEFING

The final task is to brief the entire dive crew. The briefing, which should ideally take place overlooking the dive site, must cover all aspects of the dive plan, and include not only divers, but also shore marshals, deck hands, and anyone else associated with the dive. At the end of the briefing, ensure that all the divers clearly understand the constraints of the dive plan, and are fully prepared for the dive. After any final questions from the group, the dive can begin.

The simple maxim “plan the dive, and dive the plan” is an old one, but its worth has been proven over time. Following it means that all of the divers will get the most they can from the dive, and, importantly, will enjoy it in safety.

Wreck diving

Exploring wrecks is—for many people—the main reason to dive. This activity is particularly popular in countries without coral reefs to dive on. However, it also has a general appeal, because wrecks give a historical context for a dive and demand mastery of special skills.

DIVING ON WRECKS

Sunken ships have an obvious attraction as sites of archaeological and historical interest. A wreck is a time capsule from a given period, and the waters around most countries contain thousands of them.

Although most known wrecks are metal-hulled vessels, unusual conditions will sometimes preserve wooden-hulled ships dating back hundreds of years. These provide an excellent opportunity to examine past shipbuilding techniques, and sometimes hold interesting and unusual artifacts. To explore significant wrecks, you should be properly trained and, preferably, work within an archaeological organization.

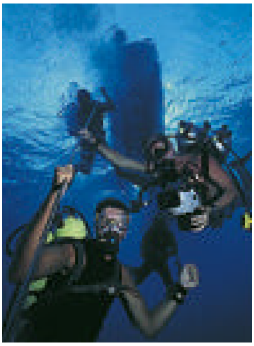

DESCENDING A GUIDELINE
Popular wrecks often have a buoy moored to their structure to make location and descent easier.

Information on recent wrecks, such as warships sunk during the two world wars, is usually readily accessible. It is often possible to research the specifications and history of the vessel, along with details of its crew and mission. Historical records may give details of the events surrounding the sinking of the ship.

Wrecks also make for good diving because they act as artificial reefs, attracting all sorts of marine life. Over time, the structure becomes encrusted with marine growth, especially filter-feeders, if it lies in a tidal stream. Fish exploit the safety and shelter that wrecks offer: smaller fish tend to shoal around wrecks; larger fish, such as moray or conger eels, can hide safely in nooks and crannies; and predators, such as sharks, may be found in the wreck's surroundings, because they feed off the smaller fish.

PREPARATION AND SKILLS

Wreck diving can be a fascinating activity, but it is not without risks. Under no circumstances go inside a wreck if you lack appropriate training and equipment; the danger of entrapment is very real, and specialist knowledge and skills are required to enter wrecks safely. Exploring the outside of wrecks is safer, but always treat such sites with respect.

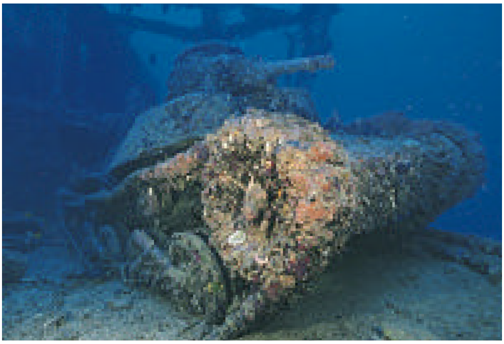

TANK IN TRUK LAGOON, SOUTH PACIFIC
Wreck diving is not just about ships; crashed aircraft and military vehicles carried by sunken vessels provide equally enthralling alternatives.

SUNKEN LEVIATHAN
The sight of a major wreck, such as the *Giannis D* in the Red Sea, rarely fails to send shivers down the spine.

DIVING IN CONFINED SPACES
Wreck penetration often involves exploring in dark, confined spaces. It is not recommended for those with claustrophobic tendencies.

FINNING TECHNIQUE

Wrecks often contain a lot of static silt and mud, which is easily disturbed by changes in water currents caused by divers finning overhead. Good visibility can suddenly and dramatically change to almost zero, so using a frog kick (*see p.123*), which generates relatively little turbulence, is recommended to minimize disruption of the silt. The best time for wreck diving is at slack water, but a small current can help sweep away any disturbed silt.

USING GUIDELINES

When you arrive at the dive site, ensure that your boat cover is moored to the wreck's marker buoy. If it doesn't have one, an experienced diver needs to swim down and attach a guideline directly to the wreck, to act as a guide for other divers to follow. If you intend to return to the surface via the same guideline, it can be useful to use a distance line (*see p.127*) to help you find your way back to the bottom of the guideline, especially in poor visibility. If you plan to ascend from another part of the wreck, deploy an inflatable marker buoy (*see pp.130–31*).

PENETRATING WRECKS

When wreck diving, you should carry backups of certain pieces of gear, such as your reel and your flashlight, as well as an independent air source, such as a pony bottle (*see p.68*), in case of emergencies. You must also ensure that you follow the "Rule of Thirds" (*see p.117*) with your air consumption—a third of your air is used to get to the site and explore, a third

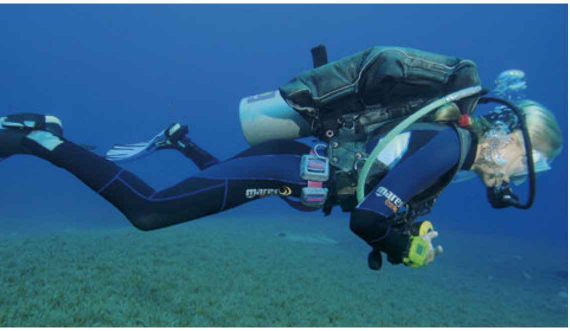

LEVEL POSITIONING
The frog kick is a gentle swimming stoke that mainly causes turbulence in the water behind and not below you, and so does not kick up silt.

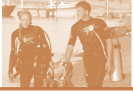

to return to the point of entry, and a third is left in reserve as a contingency. Allow extra time at the end of the dive to find the guideline, and do not take any unnecessary risks with your dive time, depth, or penetration.

EXPLORATION TIPS

It is a good idea to investigate the area around a wreck, since artifacts may have spread over time and pieces of wreckage may have been knocked off that might be of interest, but take great care. Always be aware that the structure (both inside and outside a wreck) may be much degraded and potentially dangerous. Wear protective gloves, even in warm waters, as corroded metal can be sharp. Wrecks are often heavily fished, so carry a knife in case you become entangled in fishing line. You also need a powerful flashlight (and a backup) to illuminate your way in poor visibility, and to signal to your buddy. In some very enclosed wrecks, it is advisable to wear a helmet and head lamp.

THE GOLDEN RULE

Never remove items from a wreck. As with any artifact, marine finds are more useful to archaeologists when examined *in situ*, and their context provides more information about the wreck than if they are handed in without details of where they were located. Worse still is if they are lost forever in a diver's personal artifact collection.

US troop ship artifacts

RESPONSIBILITIES WHEN DIVING

Wrecks are historical sites, and just as you would not remove artifacts from a historical site on land, such as a castle or monument, you should also respect a wreck and not damage it in any way. Be considerate of the enjoyment of others who may dive the wreck after you. Dive responsibly and with care, and do not remove anything without being given permission to do so. When you find an artifact, such as a ship's bell, after a long,

DIVER USING WRECK KIT
Carrying extra air and nitrox is a failsafe, and can help to extend dive times and shorten decompression stops. Good light sources and dive plan information are also essential.

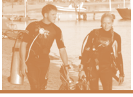

hard search, you may feel that you deserve to be able to take it away as a trophy, but all such discoveries should remain where they were found, or be raised by trained archaeologists for preservation in a museum.

WOODEN-HULLED VESSELS

Most of the wrecks that you are likely to explore will be metal-hulled, but wooden ships are also preserved under some conditions. Avoid touching the wooden structure, as it is likely to be extremely fragile. Historic wooden vessels may have been lying protected under sand or silt for many hundreds of years. If you want to expose parts of the wreckage for any reason, you should do so by wafting your hand over it to remove the silt, creating a current to take the silt away.

LIVE AMMUNITION

Wrecks from the two world wars can provide fascinating dive experiences for military history buffs, but remember at all times that they may also contain live ammunition that could potentially be very dangerous. Never touch anything that resembles a shell or mine, and research what you are likely to find on the wreck before diving.

ARTIFICIAL REEFS

At some popular dive sites, wrecks have been sunk deliberately to provide a safe, interesting dive at a reasonable depth for recreational divers. Such wrecks quickly become colonized by marine life and provide a fantastic opportunity for diving and marine research. They are generally a good place to start wreck diving, since the structure will be intact and any hazards will have been removed. At some wreck sites there are special diving trails with underwater display boards to

WRECKED BY DESIGN
The former US Coastguard cutter *Keith Tibbetts* was sunk deliberately at Cayman Brac to provide an artificial reef for divers to explore.

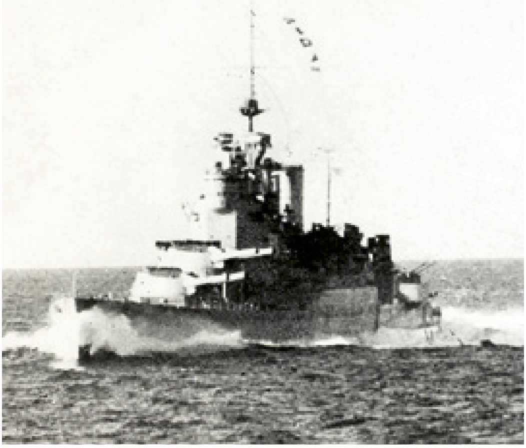

RESPECTING HISTORY
Many wrecks sunk during conflict are official war graves and may not be dived.

FINDING OUT MORE

explain the layout. There may also be laminated booklets that you can take with you on the dive, which enable you to read about the most interesting features of the wreck while on site.

VIRGIN WRECKS

Every wreck diver's dream is to find a previously undiscovered wreck—and there are certainly still plenty to be found. Before you embark on such a search, you should familiarize yourself with the law regarding wrecks, and any wreck you find should be reported to the authorities. Generally speaking, you can dive any wreck around the world apart from those that are designated as historic wrecks and war graves, which are restricted and require special permission to dive.

Locating a virgin wreck can be a difficult, lengthy task, and is likely to be expensive. But a modern hardboat with an experienced skipper and high-tech equipment such as an echo sounder, 3-D imaging of the seabed, and a GPS system, combined with charts and some good background research on your part, could help you hit the jackpot. Many undiscovered wrecks are found in very deep water, so make sure you are fully qualified and appropriately trained before undertaking deep wreck dives.

If your interest in a wreck goes beyond merely diving it and you wish to enhance your dive by finding out more about the wreck's history, there are a number of available sources of information. Good starting points include books on wrecks in the area that you are diving, and using the Internet to do some background research. There are numerous websites and forums where you can discover more about wrecks, and also make contact with other divers interested in finding new wrecks. Furthermore, local museums may have displays of artifacts recovered from wrecks in the area, and local divers and boat skippers may be able to reveal information about the history of a wreck.

EXPLORING VIRGIN WRECKS

If you are searching for a particular undiscovered wreck, it is important to start your research in the archive. Studying the ship's specifications and plans will help you identify any remains that you find, and determine whether they belong to the subject of your search. It is a good idea to take video footage of anything you find on a dive, as this is a nonintrusive method of recording the remains, and the footage will be critical in identifying the wreck and for showing to experts.

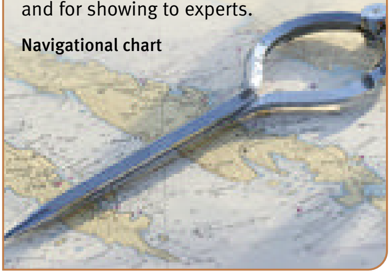

Navigational chart

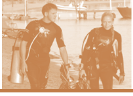

Nature and conservation diving

Recreational divers represent a huge pool of manpower that can potentially contribute to conservation work. Many divers take up the sport due to an inherent fascination with nature, and more and more are now applying their skills to organized conservation projects.

DIVING RESPONSIBLY

Most divers have a certain level of knowledge and enthusiasm for marine life and the ocean environment, and realize that along with the thrill of exploration comes responsibility. Divers are in a unique position to observe the deterioration of busy coastal margins around the world and, with the development of the modern ecotourism market, are now also able to actively contribute to conservation projects in the same regions.

At the most basic level, conservation work simply means responsible diving by anyone taking up the sport in the first place. Always adhere to a "no-touch" rule when diving delicate reef systems; you will find this vigorously enforced by most dive operations around the world. Good buoyancy control, streamlined equipment, and a respect for the varied inhabitants of the sea are now widely taught as the only way to dive, and as a result even heavily dived areas experience less habitat disturbance than they used to.

GOOD PREPARATION
A group of divers at a conservation site discuss the work they will be conducting.

MAKING A DIFFERENCE

Voluntary work, though often conducted at the most basic level, can nonetheless be extremely significant at a local and even international level. The efforts of one voluntary organization alone—Coral Cay Conservation—contributed greatly to the establishment of the Belize Barrier Reef (*see pp.316–17*) as a World Heritage Site, and have seen eight Marine Protected Areas (MPAs) established around the world in the last 20 years.

Formally observing and recording marine life is not just the preserve of the scientific expedition. Significant work has been done by enthusiastic amateurs. Organized conservation and monitoring projects range from casual one-day beach cleanups run by local diving clubs, to multi-national operations setting up nature

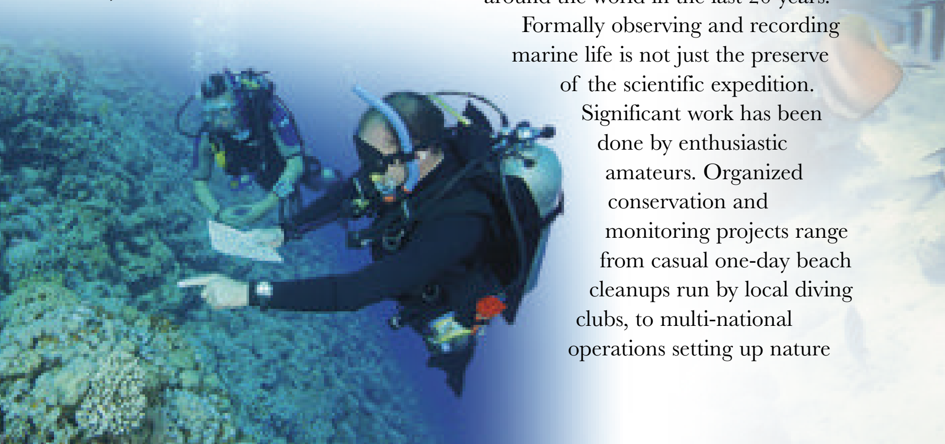

USING IDENTIFICATION SLATES
To familiarize themselves with marine life during a dive, divers use species identification slates—waterproof cards with pictures of the species likely to be found at the dive site.

reserves throughout the world. Diving conservation is now big business, with hundreds of organizations around the world claiming (with varying levels of accuracy) to run projects that contribute to scientific knowledge or the establishment of marine reserves and protected areas. Most organizations put volunteers through an intense training period before allowing them to take part in even relatively simple sampling or monitoring programs.

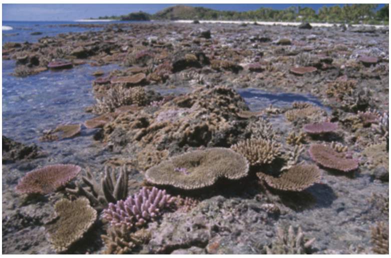

REEF EXPOSED
A healthy reef at low tide. Rising global temperatures are harming coral, and sights like this may become less common in future years.

FIRST PRINCIPLES

There are two principal considerations that must be borne in mind by anyone working as a diver on a marine conservation project. The first is safety. You need good diving skills, and enough experience to be able to keep a watchful eye on the ever-present factors of depth, time, and potential hazards while simultaneously making meticulous observations. Enthusiasm for the work being undertaken must not distract you

PRESERVING HABITATS
Carrying out conservation work not only allows you to give something back to the marine environment, but may give you the opportunity to visit exotic destinations.

from the normal rules of safe diving. The second factor is consideration for marine life. Unless you are working under the direction of a well-recognized conservation group, you must only gather data without touching or harming the marine environment. Both marine algae and animals should be recorded only *in situ*.

WORKING TOWARD OBJECTIVES

Good science starts with a clear means to identify the subject of the research. In the case of most amateur enthusiasts, this means reading up in accurate reference works and guides about the dive environment in question. A further, essential part of any observation program is the need to record data effectively, requiring not only a means of noting down results, but a framework of headings and categories that remain the same for the entire observation program. Only by combining these two important factors—accurate identification and consistent record-keeping—can you accomplish truly effective research and monitoring. Repeated observation of species populations within a given area, for example, can provide invaluable data for analysis by research groups. Your recordings may help local initiatives, or possibly go forward to form part of a much larger-scale project, in which

FINDING A PROJECT

Conservation, to paraphrase an old adage, begins at home. There are marine ecology programs in most countries, and interested divers can usually find groups in their area that contribute to protecting the local marine environment. Search the Internet and specialty diving magazines to find suitable organizations local to you.

CORAL MONITORING PROGRAM
Advanced or potentially invasive techniques should only be used under the direction of a recognized conservation group.

DIVING AT A MARINE RESERVE
Even a little research into how and why an area is protected will add food for thought to your enjoyment of the dive.

complex statistical techniques may be used to draw conclusions with far greater significance than you perhaps imagined when gathering your data.

EQUIPPED FOR THE JOB

Although this is the age of the computer and of instant global communications, most scientific expeditions still use some fairly basic equipment to record data in the field. Observation strategies can begin with nothing more than a sharp pair of eyes, an underwater slate, and a good guidebook. An additional item that can be extremely useful is a magnifying glass. This simple tool greatly enhances enjoyment and has become essential for many divers around the world when diving complex reefs.

Underwater photography and videography, if correctly documented, can provide potentially valuable information. In an organized program, you may receive training in advanced techniques, such as the use of catch bags, nets, and quadrats, or in ways to ensure that the target region is sampled effectively, such as GPS systems and datum lines. Effective sampling and observation does not necessarily require high-tech gadgets, but an effective strategy to ensure scientific integrity in the results you achieve is essential.

A CAREER IN CONSERVATION

Should you wish to develop your interest in conservation techniques, there are many courses and reference works available. Formal qualifications may be sought at undergraduate and postgraduate level, although demand for places is extremely high. Jobs in this area are also relatively difficult to come by. However, the rewards for persisting in either scientific or conservation work can be immense.

The loggerhead turtle, an endangered species

Photography and videography

Since the dawn of diving, there has been interest in capturing images of the remarkable ecosystems and animals of the sea. Although underwater photography was initially a complex process, advances in technology have seen it become an accessible, absorbing pastime.

EARLY PIONEERS

The development of underwater filming and photography has mirrored the evolution of diving itself. Early pioneers made their own waterproof housings for cameras, but the invention of the O-ring (enabling watertight hydraulic seals) in 1937 and the Aqua Lung in 1943 convinced camera companies that they should make and sell their own designs.

What prompted this was the huge appetite for images of the underwater world. The rapid growth of recreational diving, and growing interest in underwater films among movie audiences, spurred the development of underwater film and stills photography equipment. Although the first underwater film was made in 1939 by diving pioneer Hans Hass—an instructional documentary for spear-fishermen called *Stalking Underwater*—the first truly commercial underwater movie was made by Jacques Cousteau in 1956. His feature film *The Silent World* was an Oscar-winning sensation that established him as the world's premier underwater filmmaker and explorer.

MINUTE SUBJECTS
One of the most interesting aspects of underwater photography is macro (close-up) work. Tiny creatures can make dramatic subjects.

GROWING MOVEMENT

Until the early 1980s, underwater stills photography and filming was seen as the preserve of either the dedicated amateur or full-time professional diver. Underwater photography was brought to the masses with the development of the Nikonos series of amphibious cameras—culminating in the Nikonos V, still viewed by many as the best underwater camera ever made. Underwater filming did not become a popular pastime until the mid-1990s, when digital video cameras came onto the market, making moving pictures cheaper and technically easier for amateurs to produce. Digital imaging also revolutionized stills photography underwater. Small, easy-to-use digital cameras with

STALKING A SUBJECT
Photographing marine species underwater requires guile and a good understanding of animal behavior and habitats.

many automated functions have made it simpler for divers to record high-quality images of their underwater experiences.

Despite this, the jump to producing professional-standard material remains as great as ever. Light behaves very differently underwater than in air (*see p.183*), and there are myriad extra factors to take into consideration when aiming for truly professional results. The work that you see on the page or the screen may well have involved lengthy planning, complex equipment, and the specialized skills of a professional post-production studio.

However, the same principles that guide professionals can enhance amateur work. You must have knowledge of the underwater environment and the behavior of target animals, and possess impeccable diving skills. Add to this mix some tips on technique when photographing and filming underwater, and you will be well placed to get the best from the dazzling range of camera and video gear available to divers.

CAMERA CONTROL
Though cameras, especially digital models, have become smaller and easier to use, it still takes great skill to wield one effectively underwater, especially for video footage.

USING LIGHT CREATIVELY
An understanding of how light behaves underwater is essential to capture a mood effectively.

STILLS PHOTOGRAPHY

The advent of the digital age has seen an explosion in the popularity of underwater photography, with more and more divers creating images of their dives for posterity. However, producing good results consistently is a craft, and this is what separates the professional from the amateur photographer.

CAMERA SYSTEMS

Underwater camera systems for stills photography can be divided into two categories. The first consists of truly amphibious cameras that do not require a housing to be used underwater, and can also operate on dry land. The pioneering Nikonos V camera is a famous example of the type. Amphibious cameras often have interchangeable lenses, and are available in both film and digital formats. These highly specialized cameras feature oversized controls for ease of operation underwater.

The second category, housed systems, are conventional cameras in waterproof cases. The cameras themselves can be divided into two subcategories: compact devices, and SLR (single lens reflex) models.

Compacts come in film and digital formats, and are light and convenient to carry and use. Most models offer fully automated focus and exposure control. You cannot change the lens on a compact, but some have variable focal length (zoom) lenses. After-market add-on lenses that attach to the outside of camera housings are also available.

ANIMAL MAGIC
To capture the vibrant colors of marine creatures and environments, you will need a purpose-designed strobe lighting system.

SLR cameras, which are available in both digital and film versions, allow the use of a range of lenses and offer complete creative control over key functions such as aperture, shutter speed, and focus. For this reason they are invariably the choice of professional underwater photographers, although SLR-compatible ports, housings, and lighting systems can be very expensive.

CAMERA HOUSINGS

Both compacts and SLRs require a housing to protect them from water damage. These are normally made of plastic, though aluminum housings are also available for SLRs. Aluminum housings are strong and durable but expensive and bulky, and hide the camera within, making it harder to operate. Plastic housings are cheaper and allow you to see the camera, but can be less durable. They are especially vulnerable to scratches and abrasion.

NIKONOS CAMERA
Amphibious cameras like the Nikonos V have an integral water-resistant housing.

DIGITAL COMPACT
Fully automated functions make digital compacts easy to use, but limit creative control.

SLR CAMERA
Available in film and digital formats, SLRs are bulky but offer superior image control.

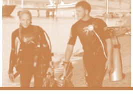

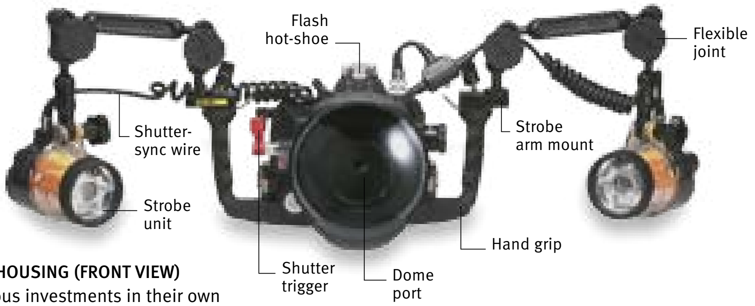
Flash hot-shoe
Flexible joint
Shutter-sync wire
Strobe arm mount
Strobe unit
Hand grip
Shutter trigger
Dome port

SLR HOUSING (FRONT VIEW)
Serious investments in their own right, large SLR housings offer excellent access to key controls.

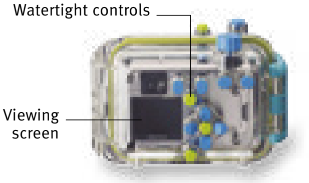
Watertight controls
Viewing screen

COMPACT IN PLEXIGLAS HOUSING
The housing features push-button mechanical controls for taking, reviewing, and even editing images underwater.

COMPACT WITH STROBE
A diffuser lens placed over the strobe softens the light it casts.

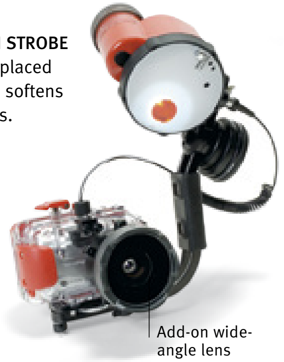
Add-on wide-angle lens

Bare strobe unit

UNDERWATER LIGHTING SYSTEMS

Lighting is one area where compact digital cameras fall short. Their built-in flashes are too close to the lens to avoid backscatter (*see p.183*). You can distance the light source from the lens by using an auxiliary strobe light, bolted to the housing. SLR-based and amphibious systems often use strobes in pairs, mounted on flexible arms to allow the subject to be lit from different angles. Knowing how to position strobes to best advantage and manipulate power settings is essential, though many cameras will automatically trigger the strobe to fire for the correct duration for the exposure.

HOUSING MAINTENANCE

Maintaining a housing is relatively straightforward. O-ring integrity should always be checked and the ring lightly lubricated with silicone grease. Make a final visual check before diving. Housings should be rinsed in fresh water as soon as possible after a dive. Operate the mechanical controls during rinsing to prevent a build-up of salt crystals. If water penetrates the housing, it will ruin the camera, so a few moments taken to prepare and rinse gear can prevent expensive damage.

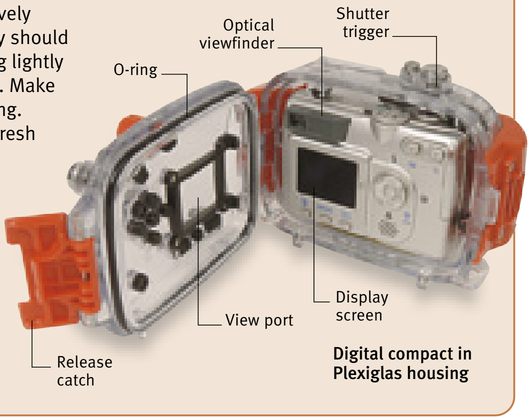
Optical viewfinder
Shutter trigger
O-ring
Display screen
View port
Release catch

Digital compact in Plexiglas housing

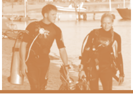

MAKING FILMS UNDERWATER

Like underwater stills photography, videography has been revolutionized by the advent of digital cameras, which are small and easy to use, compared to film or analog video. Basic point-and-shoot underwater videography is quite easy with consumer-grade digital cameras. To advance beyond the novice stage, however, you need special skills, more advanced equipment, and a flair for using video editing software.

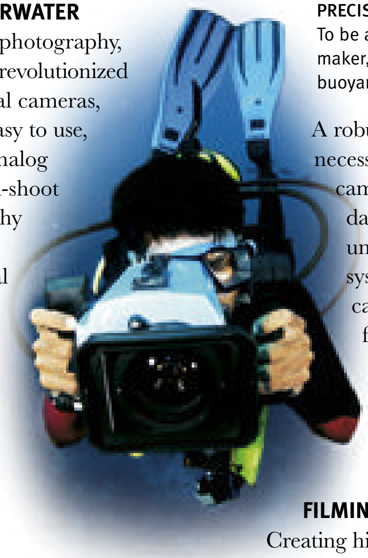

PRECISE POSITIONING
To be a good underwater film-maker, you need to perfect your buoyancy control and finning.

A robust housing will be necessary to protect the camera from water damage, while a basic underwater lighting system is essential for capturing good color footage, since water filters out various colors from natural light as depth increases (*see p.183*).

CHOOSING A VIDEO SYSTEM

Choice of camera is the first decision for novice videographers. Though analog video cameras are still available, digital is now the dominant technology. Digital cameras are available in digital tape, flash media, HDD (hard disk drive), and DVD recording formats. Look for cameras with three-chip processors (called 3CCD cameras). These divide red, green, and blue color information into separate processing paths, offering richer colors than cheaper one-chip models. At the top end of the market are cameras with HD (high definition) imaging, which produce video of astonishing clarity, due to the high rate at which they scan visual information.

FILMING SKILLS

Creating high-quality underwater video requires you to do more than merely jump in with everything set to automatic, press record, and film throughout the dive. Many automatic systems perform poorly underwater. For example, autofocus becomes inaccurate in low-contrast environments, resulting in hazy images. Careful manual control of focus and manipulation of white balance (which sets the baseline for color values in different light conditions) are key skills.

Your diving skills also must be excellent; you need to be a steady platform for the camera—camera shake is a common cause of ruined footage. The camera and housing should also be neutrally buoyant (they should neither sink nor rise underwater) for ease of

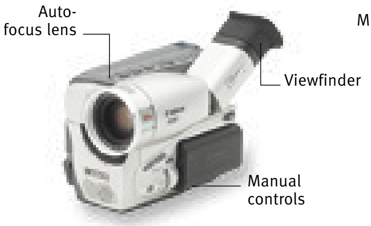

BASIC VIDEO CAMERA
Affordable cameras for home use usually feature automatic focus and exposure control, but may also have some manual options for skilled users.

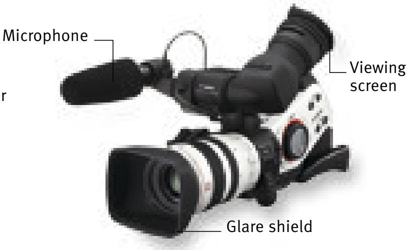

ADVANCED DIGITAL CAMERA
Top-end video cameras have advanced features like high definition, multi-chip processing, plus image stabilization systems for sharp images.

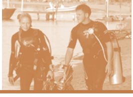

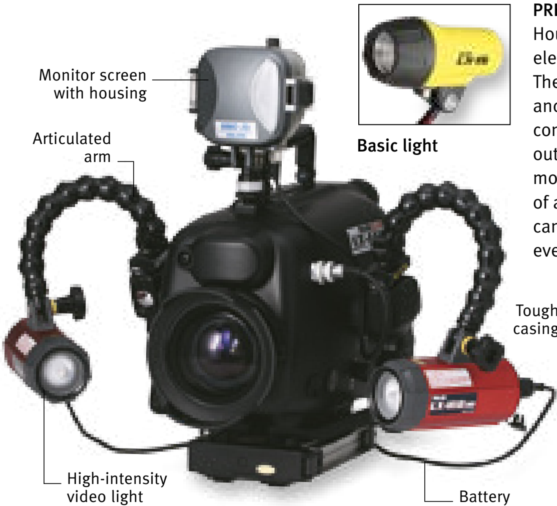

Basic light

Housing with lights

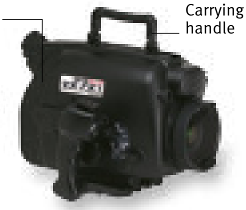

Bare housing

PRESSURE HOUSING AND LIGHTS
Housings fall into two categories—electronic or manually controlled. The latter use plungers, rods, pins, and cogs to allow the camera controls to be manipulated from outside the housing; they require more skill, but have the advantage of avoiding electronic systems that can go wrong or short out in the event that the housing is flooded.

handling, and you should familiarize yourself completely with how your camera is operated, so its use becomes second nature underwater.

PRODUCTION AND EDITING

Thorough planning is the secret to good filmmaking, and video should be shot with an audience or editor in mind. Building a story around a given dive is not a complex process, but creates a target shoot list for the camera operator to work from, and gives the finished film an engaging narrative. You can place scenes in order and polish the results to a professional standard using video editing software that is commercially available for use on home computers.

KEEPING CLEAR
While filming, be careful to avoid causing physical damage to the organisms you have come to film. Avoid touching, or kneeling on, reefs.

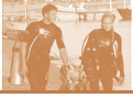

KEY PRINCIPLES

Modern cameras and housings allow even the novice to achieve consistently good photographs and video footage. One key development of the last ten years has been the ability to immediately view the results—even during the course of the dive—and then make adjustments accordingly before the next shot. But throughout the history of underwater photography and videography, certain principles have applied as much to hardened professionals as they have to happy snappers. Following these simple rules can immeasurably improve even your first forays into photography and filmmaking underwater.

LINING UP FOR A SHOT
Good positioning relative to your subject can help make subjects stand out from the background.

GETTING CLOSER

The first principle when shooting underwater is to get as close to the subject as is feasibly possible. Even the most crystal-clear water contains a mass of suspended particles, and even if your eyes cannot pick them out, you can be sure your lighting system or lens will. Getting close to the subject means greater clarity of the resulting image, and this is one of the reasons why "close-up wide-angle" is such a popular approach. This uses a wide-angle lens at close range, allowing the whole subject to be viewed with the lens only a short distance away. For the same reason, "macro" (close-up) photography is often a good place to start if you are a beginner, since clear, well-lit macro images are relatively easy to achieve.

For the novice photographer or videographer, another excellent principle is to remember to take shots with an upward orientation. There is nothing worse than viewing an endless series of dull blue or green shots where the subject is lost in the background of reef or seabed. Shooting upward isolates the

SUNLIGHT THROUGH WATER
The shifting light patterns encountered underwater can make for dramatic photography, but are challenging to expose correctly.

WAITING FOR A SHOT
Many fish are inquisitive, but easily alarmed; good buoyancy control will allow you to hold still until a subject presents itself.

subject against the background of the open water, and creates a more striking contrast. The composition of such shots can still include reef or coral, wall or wreck; however, the subject itself should be consistently easier to spot.

USING LIGHT SOURCES

Effectively lighting a subject is one area where most amateurs struggle. It is also one of the areas where modern compact digital cameras built-in flashes will let a picture down. If the light source is too close to the lens, particles in the water will reflect the flash directly back into the lens. This creates a phenomenon known as "backscatter," a snowstorm effect of white dots on the photograph. One of the most basic prerequisites of taking good underwater images in anything other than perfect underwater conditions is an ability to position a strobe away from the lens. This allows the flash to come in at an obtuse angle, and helps to prevent backscatter from spoiling a shot.

These simple principles do not, unfortunately, guarantee good images every time, but they are useful for anyone starting out in photography or filming. Trial and error will help to refine your skills over time, and the best advice is to jump in, remember the basics, snap or film away, and enjoy!

DEPTH AND COLOR LOSS

Water absorbs different wavelengths of light as depth increases, causing images taken without artificial illumination to seem washed-out and dominated by blue tones. Reds fade from visibility at a depth of 10–15 ft (3–5 m), oranges at 35 ft (10 m), and yellows around 50 ft (15 m); by 80 ft (25 m) greens have almost disappeared, and by 100 ft (30 m) everything appears deep blue or black to the naked eye.

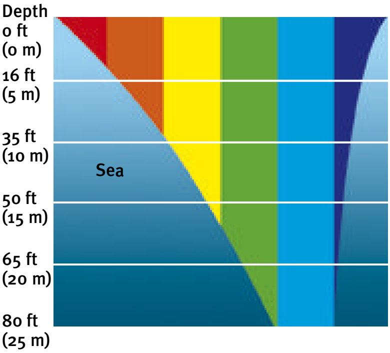

Night diving

To many, the idea of diving at night may seem a little crazy, but there is far more to it than just the thrill of exploring in the dark. Night diving reveals a whole host of underwater organisms that lie hidden during the day and only become active at dusk.

LIGHT AND COMMUNICATION

Night diving is obviously less simple than diving during the day, but when properly organized, it is relatively straightforward. A powerful flashlight will easily light your way and the creatures around you, revealing marine life in its true colors. However, if you cover your flashlight (never switch it off; the bulb may blow when you turn it back on), you will be surprised at how much light there is underwater. Many creatures use phosphorescence at night, and as you move through the water, you will cause plankton to release tiny pulses of light, leaving beautiful glowing wakes trailing behind you.

The main restrictions compared to daytime diving relate to communication, not only between divers, but also—and perhaps more importantly—between divers and boat cover. You will be able to monitor your buddy's location from the position of their flashlight beam. Signaling to your buddy can be done in the normal way, but while shining your light on to your hand as you make the sign. Attract your buddy's attention by waving your light, but take great care not to shine it at their face, since it can take as long as 15 minutes for their eyes to fully readjust to the near-darkness and restore night vision.

NIGHT ON THE OCEAN
When diving on a clear, moonlit night such as this, you may be surprised at just how effectively the Moon is able to illuminate the underwater environment.

At the surface, avoid flashing your light unless you need to alert the surface cover in an emergency. If you are diving from the shore, leave a light source there—for example, a bright boat light, flashlight, or beacon—so you can easily find your way back to land after surfacing. Exit points should be marked with colored lights, to distinguish them from any other light sources.

You will find that most gauges and computers are easily readable by flashlight, and just shining the beam directly on to your gauge will make it luminous for a while.

LIGHTING TIPS

It is vital that all divers carry a flashlight, and at least one other as a backup. Take spare batteries; if using rechargeables, make sure they are fully charged. Use hand-held lights, not head-mounted ones: one look at your buddy with a head-mounted light will ruin their night vision. A glow-stick attached to the back of your suit, while not essential, will increase your own visibility.

Hand-held flashlight

DIVING INTO DISCOVERY
A very different “night shift” of marine life can be seen during nocturnal dives, like this outlandish basket star.

TAKING PRECAUTIONS

Night-diving buddy pairs often link themselves together with a short line. While not essential, this is recommended for novice night divers and in poor visibility. If you are diving on a wreck to which a guideline and buoy are attached, secure a strobing marker light to the base of the line so it can be easily located in the dark. When choosing a dive site, opt for something simple, such as a shallow wreck or reef with plenty of distinctive features. An interesting daytime dive may be worth revisiting to investigate marine life that emerges at night. To minimize the risk of incidents, do not dive too deep, since any problems will be much harder to cope with in the gloom. If diving a more open site, use a surface marker buoy with marker light attached to identify it to any boat cover. Be careful not to lose contact with surface cover: getting lost at night could mean you are not recovered until morning.

FLASHLIGHT SIGNALS

During a dive, your torch beam will alert your buddy to your position. You can also make simple signals with your flashlight beam on the seabed to communicate with your buddy. At the surface, wave your torch vigorously from side to side if you require immediate assistance.

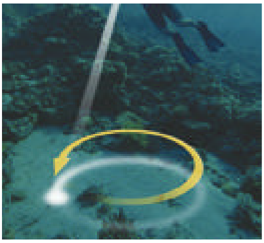

SIGNALING “OK”
Tracing a large circle on the seabed communicates to your buddy that you are OK.

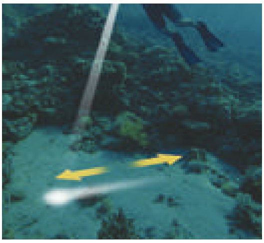

SIGNALING FOR ATTENTION
A rapid side-to-side movement means that you want to show or tell your buddy something.

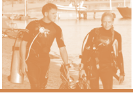

Cavern diving

Rich with opportunities for dramatic dives, caverns offer a bridge between ordinary open-water diving and the far more specialized activity of cave diving. Nonetheless, diving in caverns demands careful preparation and respect for potential risks.

WHAT IS CAVERN DIVING?

A cavern is a large, enclosed area of rock or coral that is of sufficient size to allow a diver to enter and move around. These fascinating environments can be extremely dramatic, are often eerily lit, and may play host to an array of animals not encountered on the open reef.

Unlike the more extreme sport of cave diving, in which divers penetrate beyond the reach of natural light, in cavern diving the exit is always clearly within view. However, cavern diving still carries inherent risks because the diver does not have direct access to the surface in the event of an emergency. If simple safety drills are not followed at all times, there is the potential for very serious problems to develop when diving even in simple caverns.

CAVERN DIVING EQUIPMENT

A flashlight is an essential item for cavern diving, but it is also sensible to bring along a backup light. This need not be a large, bulky model but must be able to provide enough light if your main flashlight malfunctions. Be sure to keep batteries freshly charged. An alternative air source, such as a pony bottle (*see p.68*), is also an excellent idea in caverns, since the diver cannot ascend directly to the surface if the primary air source suffers an unexpected failure.

A backup flashlight

SAFETY AND SKILLS

The first rule of cavern diving is to prevent your natural curiosity from turning a cavern dive into a cave dive! The exit should be clearly visible at all times—if not directly in your line of sight, then at least the natural light of the cavern entrance should remain visible. For many divers, the temptation to explore deep into cave systems is strong; however, the moment the exit is lost from view and natural light fades, the dive becomes a cave exploration, which should not be attempted without appropriate equipment and special safety and skills training.

Certain skills are essential when diving larger caverns. Buoyancy control is important, particularly when there is a silty substrate on the cavern floor.

ON THE THRESHOLD
A diver hovers at the entrance of a freshwater cavern in Australia. Following basic safety rules is essential at such sites.

INNER SPACE
A diver shines light on the interior of a sea cave. Caverns have a mysterious ambience quite different from that of open diving environments.

It is also advisable to use a finning technique known as the frog kick (*see p.123*). This is a gentle, circular fin-stroke that helps you avoid stirring up sediment. One misplaced kick from a fin can turn a cavern into an impenetrable soup of silt and lead to disorientation and panic. For this reason, and as a matter of plain common sense, it may also be appropriate to tie off a line at the entrance of larger caverns (*see p.127*) to provide a direct route to the exit in case of reduced visibility. It is also strongly advisable not to enter a cavern without local knowledge or a guide; there may be specific issues about a cavern system and the hazards it contains—such as seasonal changes in visibility—that do not appear in any standard dive guidebooks.

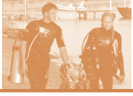

Ice diving

Diving under ice might not sound like an attractive proposition, but it is a uniquely exciting experience. Visibility is typically excellent beneath ice, with soft light filtering through from the world above. Ice diving can also take you to breathtakingly beautiful parts of the world.

UNIQUE ENVIRONMENT

Ice diving can be done in the sea or in frozen lakes. The aquatic life you encounter will depend on where you are in the world and whether you are in a marine or freshwater environment. Visibility is often stunning; the ice provides a protective layer over the water, so it is not churned up by the wind, and low light levels under the ice also help to inhibit algal growth.

COLD-WATER GEAR

A diver waits to enter the water wearing special equipment designed to cope with conditions of extreme cold.

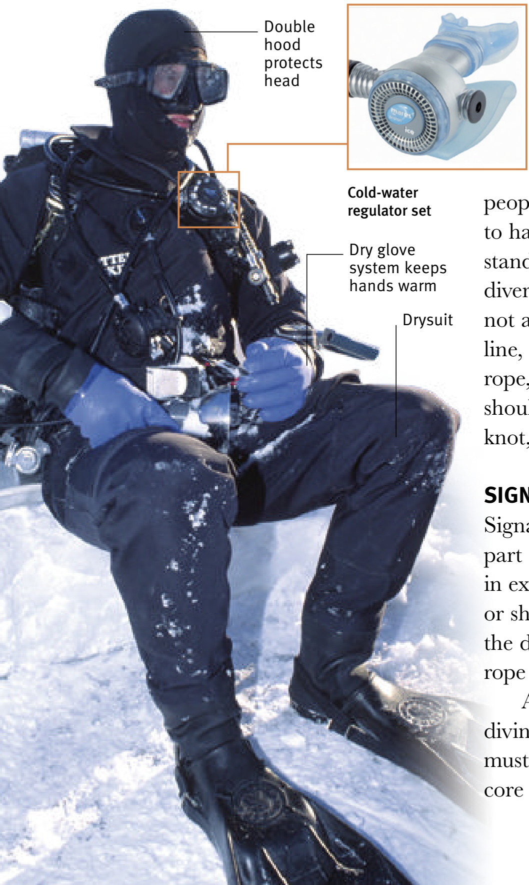

KNOWING THE ROPES

If you are planning to go ice diving, you will need to undergo special training. This will teach you not only the safety aspects of diving while tethered on a rope under ice, but also how to cut the ice hole through which you enter the water, and how to tend safety ropes for other divers while you remain on the surface in a support role.

Ice diving requires a minimum of four to six people per dive. There will normally be two divers operating as a buddy pair (*see pp.110–11*), and two people to tend their lines. It is advisable to have at least one extra person on standby. It is standard practice for each diver to be tethered separately, and it is not advisable to tether two divers on one line, because if anything happens to this rope, then both divers can be lost. Lines should always be tied using a bowline knot, which is very secure.

SIGNALS AND SAFETY

Signaling to your tender is an important part of ice diving. Since you are diving in extreme conditions, it is vital that he or she knows you are OK throughout the dive. You will learn about giving rope signals during training.

Apart from the obvious dangers of diving in an enclosed environment, you must also be careful to monitor your core body temperature. Repeat dives

SPECIAL PROCEDURES
Ice divers rely on a surface support team (*above*) for safe diving under the ice.

should only be undertaken when you are fully warmed up. You should also ensure that you eat high-energy, hot food to replace the calories you will burn during the dive and in keeping warm afterward.

FROZEN DEPTHS
A diver films the fascinating world beneath the surface. Many unique animals live in cold seas.

SPECIAL GEAR

Ice diving requires special equipment. You will need an environmentally sealed regulator set (*see p.63*), which is designed to be less susceptible to freezing. You will be taught to submerge this in the water before diving, to acclimatize it to the temperature. You must only breathe from it when submerged, to reduce the risk of free-flow (an uncontrolled release of air due to a frozen mechanism). It is also recommended that your primary air source and octopus are mounted on separate first stages (*see p.61*) to ensure that one will work if the other freezes. Your cylinder will need a special pillar valve to accommodate this.

You will need to wear warm undergarments beneath your drysuit, thick neoprene gloves or a pair of waterproof dry gloves (*see p.54*), and two thick hoods for extra warmth.

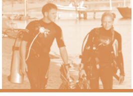

Freediving

Once simply a fishing technique, freediving—diving using only the air carried in the lungs—has become increasingly popular as a sport. Extreme athletes now constantly push the perceived limits of human performance, diving to remarkable depths on a single breath of air.

PURE SPORT

Freediving is not exclusively the preserve of the extreme athlete: anyone who has snorkeled and duck-dived to explore the seabed could describe themselves as a freediver, making this the most accessible of all diving disciplines. Many would argue that it is also the purest form of diving, requiring only the minimum amount of equipment and relying entirely on discipline, courage, and physical conditioning.

The roots of freediving stretch back to when the human race took its first tentative steps into the sea, diving into the water to harvest food and explore the seabed. Modern freediving, by contrast, is a disciplined sport, with record attempts highly regulated by the two governing bodies—A.I.D.A. (Association Internationale pour le Développement de l'Apnée) and F.R.E.E. (Freediving Regulations and Education Entity). Divers compete in a number of categories, two of which usually take place in a swimming pool: static breath-hold—a simple endurance test with a timed immersion in a shallow pool—and dynamic breath-hold, a test of the distance divers can swim using only a single breath. In open water, competitors are judged on the depths they can reach and return from safely.

Freediving naturally carries inherent risks—the most advanced and extreme disciplines demand that the body's supply of oxygen is completely used on a dive, and losing consciousness is always a danger. Exploration of freediving limits should never be conducted alone, and only after attending one of the many introductory courses available to those interested in taking up the sport.

EQUIPMENT

Freediving does not require much equipment, but specialized items, such as streamlined suits and fins of variable flexibility, are used to maximize the speed of movement through the water. Masks with low internal volume are also useful, as they allow divers to conserve air that would otherwise be used to exhale into a standard mask to counteract mask squeeze (*see p.115*).

Specialist mask

SUUNTO
CSM
sports net global
BAUER KOMPRESSOREN

STATIC BREATH-HOLD COMPETITION
Divers compete for the length of time they can hold their breath. World-class competitors can achieve times of over seven minutes.

TOUCHING THE DEEP
A freediving competitor reaches for the tag that proves that the designated target depth has been reached—this must be presented at the surface for inspection by judges.

DIVING DEPTHS

Competitive depth records are judged in strict categories, defined by precise parameters such as the use of weights or fins. In “No Limits”—the category in which the highest-profile records are set—the diver is dragged down by a weighted sled, and rockets to the surface using an airbag.

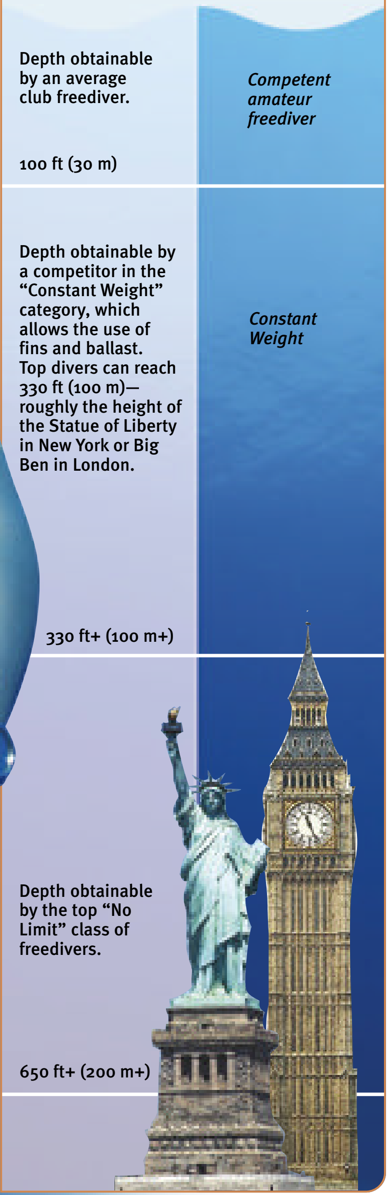

Depth obtainable by an average club freediver.

100 ft (30 m)

Competent amateur freediver

Depth obtainable by a competitor in the “Constant Weight” category, which allows the use of fins and ballast. Top divers can reach 330 ft (100 m)—roughly the height of the Statue of Liberty in New York or Big Ben in London.

330 ft+ (100 m+)

Constant Weight

Depth obtainable by the top “No Limit” class of freedivers.

650 ft+ (200 m+)

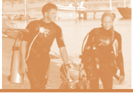

Underwater archaeology

While marine archaeology is mainly confined to the academic and scientific world, it could be said that every diver who explores a wreck has an archaeological interest and responsibility. Both the seabed and many freshwater sites hold compelling historical secrets.

RULES FOR THE AMATEUR

Although every dive has the potential to reveal historic artifacts, targeted methodical surveying is an altogether more serious business, as is the correct means of excavating and recording any finds. Archaeological divers can therefore be placed in one of two distinct categories—the serious professional diving archaeologist, and the enthusiastic amateur.

Although this is a field in which amateurs can make a very valuable contribution, it is essential that they do so only through involvement in an organized project, conducted by a recognized and authorized group. Far too many sites have been destroyed, and artifacts removed, by what amounts to vandalism and theft—the equivalent on land might be digging a historic site or burial ground without permission, which is unthinkable, of course.

There are many organizations that welcome help from amateur volunteers, and will supervise and guide you. The thrill of discovery really does reach a new level when it is shared with individuals who understand the full significance of a find. You may find that more scope for joining an organized project exists if you first undertake some training, perhaps by volunteering on digs on land.

Learning professional marine excavation and recovery techniques can be fascinating for the amateur. Archaeologists go to great lengths to avoid damaging a surveyed location, and even when they locate an item of interest, try to avoid intrusive collecting techniques or digging.

MORE THAN YOU BARGAINED FOR

By taking an artifact from a dive site, you destroy its integrity and hinder efforts to learn about past peoples. And that may not be the end of the matter. In many parts of the world, sites of marine archaeological interest are strictly regulated. The recovery of artifacts is—quite rightly—taken very seriously, and penalties for illegal activity and for removing items can be severe.

Amphorae, used to store oil and wine, recovered from a Turkish site

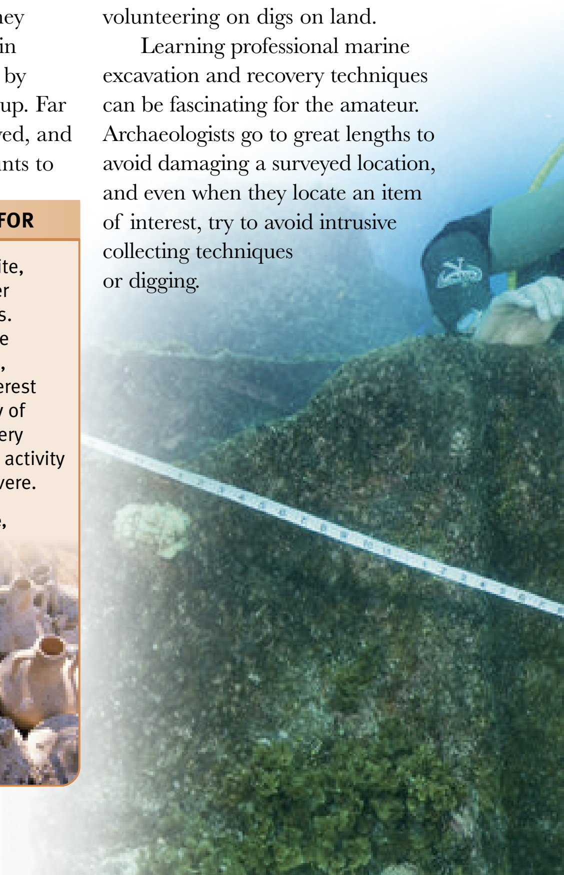

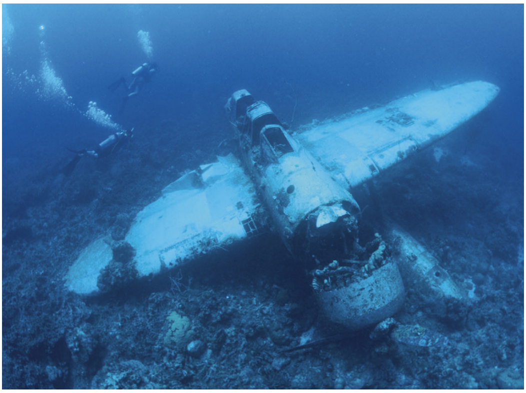

RELIC OF CONFLICT
Divers inspect the remains of a Japanese fighter aircraft shot down in the Pacific during World War II.

WHAT TO EXPECT

Marine archaeological expeditions are usually initiated because research or local knowledge has pointed to a region that has archaeological potential. Modern GPS (Global Positioning System) equipment has made pinpointing such sites much easier. On reaching the site, a detailed survey is generally first carried out. This may involve using a datum line (a fixed reference line on the seabed from which measurements are taken), or pegging out a grid. Precise recording of the location and state of the site before digging is vital, and is usually conducted through photography or extensive sketching. Small test digs may take place before a full-scale excavation occurs, with the exact site of each find carefully logged, and the finds themselves sketched or photographed. Preservation and restoration techniques are extremely specialized for such finds. Marine archaeology is a long way from the derring-do of Indiana Jones, requiring organization, attention to detail, fine diving skills, and persistence.

CAREFUL SURVEY
Meticulous recording of survey data is one way in which amateurs can help on a professional dig.

Technical diving

The desire for ever-deeper dives and longer periods underwater has led to the development of special gas mixtures. The use of these in technical diving offers an exciting range of new skills and marine environments for qualified technical divers to explore.

PUSHING BACK BOUNDARIES

Scuba divers are limited, by simple physical laws, to a certain amount of time under water (dependent on the depth of the dive) and an overall maximum depth. Training agencies recommend that recreational divers using compressed air go no deeper than 130–165 ft (40–50 m). Beyond this, nitrogen can build up dangerously quickly in the body, greatly increasing the risk of decompression sickness (DCS; *see pp.142–43*). In addition, the increased levels of nitrogen in the bloodstream below 165 ft (50 m) can lead to severe nitrogen narcosis (*see pp.100–01*). The oxygen content of air, too, becomes increasingly toxic to the nervous system the deeper you dive (*see pp.96–97*).

To extend dive times and allow exploration to greater depths, special mixtures of gas have been developed in which the balance of oxygen and nitrogen has been altered, or that contain new gases to dilute the impact of either oxygen or nitrogen. The use of these mixes is known as technical diving, and involves three types of gas mixes: nitrox, which allows longer dive times, and trimix and heliox, to reach greater depths.

EXTENDING DIVE TIMES

Normal air is composed of around 21 percent oxygen and 79 percent nitrogen. Nitrox is a gas mixture that contains a higher percentage of oxygen and a lower nitrogen content than normal, allowing longer dive times before the diver's body stores up too much nitrogen, and also reducing diver fatigue after the dive. Nitrox can be mixed in various proportions, from

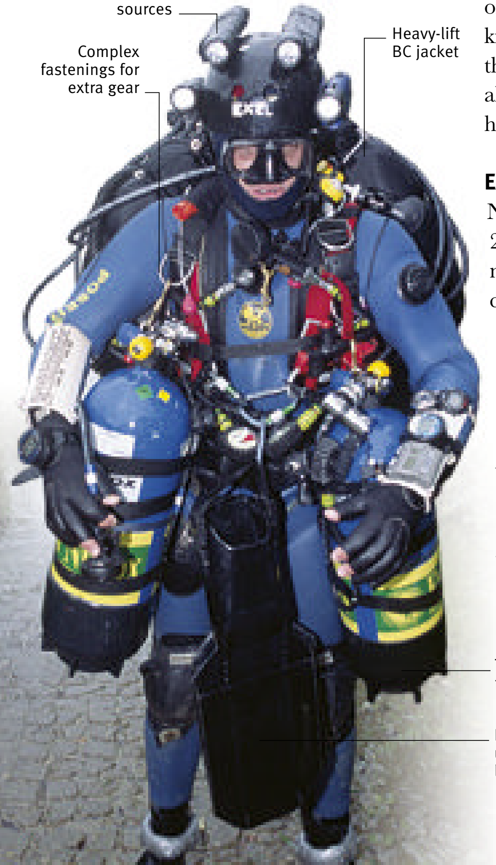
Multiple light sources
Complex fastenings for extra gear
Heavy-lift BC jacket
Tanks contain gas mixtures for specific depth ranges
Heavy-duty drysuit worn over a thermal undersuit insulates the diver from the low temperatures of extreme depths

UNDERGROUND ODYSSEY
A diver emerges from the water wearing the complex equipment required for cave diving, including tanks filled with special gas mixes, and sophisticated dive computers.

BEYOND NORMAL LIMITS
A diver explores deep within a flooded cave system. Technical diving procedures enable divers to go farther than ever before.

22 to 50 percent oxygen. However, beyond a certain depth the increased oxygen in the nitrox mix becomes toxic and can cause seizures. The more oxygen in the blend, the shallower this will occur. For this reason, diving with nitrox requires special training, although courses are readily available to recreational divers.

GOING DEEPER

Divers wishing to travel deeper than 165 ft (50 m) use either heliox or trimix, both of which introduce helium into the breathing mixture. Heliox contains only helium and oxygen, whereas trimix is a three-gas combination of helium, oxygen, and (usually) nitrogen. Heliox is used mainly by military and commercial divers, while trimix is more often used by leisure divers. Both succeed in reducing the likelihood of nitrogen narcosis (*see p.101*), oxygen toxicity, and DCS. However, since helium conducts heat six times faster than air, these mixes can cause the diver to feel very cold. Helium is also absorbed rapidly into the body, so lengthy decompression is necessary. Divers wishing to use these gas mixes must undergo appropriate training.

TECHNICAL KIT

Diving at extreme depths or in extreme environments, like deep caves, requires special gear. Technical divers meticulously analyze their equipment, and try to eliminate weak points—there is little margin of error during a deep technical dive. To support the extra gas tanks used during technical dives, most divers opt for high-lift “wing”-style buoyancy compensators (*see p.59*). They also choose high-performance regulators that can handle the task of supplying breathing gas at extreme depths. Sophisticated dive computers are used to monitor how technical gas mixes are metabolized during a dive.

A multi-gas computer

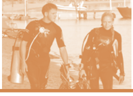

Careers in diving

Lots of people grow to love recreational diving and consider turning their passion into a profession. Work in diving is demanding, and earnings are often modest, but the personal satisfaction to be gained from a career in diving may make the hard work worthwhile.

GOING PROFESSIONAL

There are two common factors in the life of any diving professional: the work is invariably challenging, and there are always many more candidates for jobs than there are vacancies.

As a growth sector, the recreational diving industry offers the most career opportunities. Qualifying as a divemaster or instructor with a recognized training agency means that you will be able to work at dive centers in every corner of the globe. However, qualified instructors are responsible for the safety of their students, and the selection process is necessarily a rigorous one. Being a highly skilled diver is just one of the qualities an instructor must possess; strong communication skills, maturity, and in-depth technical knowledge are also required. Becoming an instructor with a commercial agency can also be an expensive process, but it is a crucial first step towards gaining work in diving, and may open the door to a lifelong career.

COMMERCIAL DIVING

The world of commercial diving covers all activities outside of recreational instruction, and includes scientific, media, and industrial diving. The last of these represents the best-known face of the commercial diver—the hard-hatted aquanaut working on the rigs and pipelines of the oil industry. The demands of the job have changed from

DEEP-SEA EXPLORER
A diver in a mechanized pressure suit works on the deep ocean bed. Such jobs are very demanding, and competition for new positions is high.

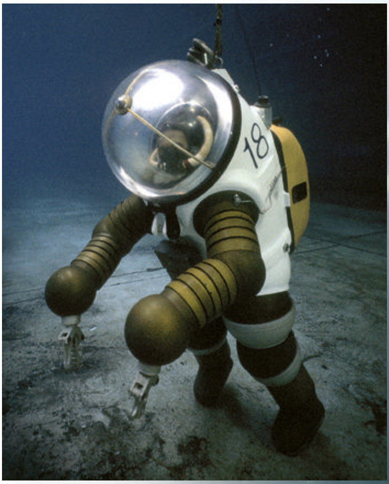

EXPERT GUIDANCE
An instructor shepherds a new student through his first dive. Resort guides are sought after in many areas.

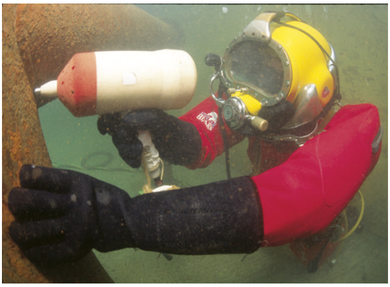

UNDERWATER WORKER
A commercial diver repairs a steel frame on the sea floor. Such jobs require advanced knowledge of marine engineering techniques.

the pioneering days of oil exploration, and today's commercial divers must be able to master advanced surveying and engineering skills while working in the most difficult of environments.

JOINING THE SERVICES

Military and police diving present a different set of challenges for the aspiring professional, often requiring diving in appalling conditions, such as in confined spaces or very low visibility. Demand for diving jobs in the military or police is invariably high, and only the best candidates are accepted after a careful and strict selection process.

SAFEGUARDING THE SEAS
A navy diver prepares to submerge for mine-clearance duties. Military divers face dangerous tasks and are trained to exacting standards.

Underwater life

Introduction

Oceans cover 70 percent of the world, yet we remain ignorant of much of what lives beyond the relatively shallow regions explored by humans. The sea is a vast depository of life holding a bewildering array of animals and plants, from the massive to the microscopic.

PLUMBING THE DEPTHS

Although the majority of our planet is covered in water, only about 16 percent of all known species live in the sea. This is more a reflection of our own inadequate knowledge than of a lack of diversity in the oceans: there are undoubtedly many thousands of unknown species lurking in the vastness of open sea that we have yet to encounter. Much of our exploration of the sea has, by necessity, taken place only in the shallow margins around land. The limits of our own physiology and technology make sustained exploration below 330 ft (100 m) both demanding and expensive, but the average depth of the ocean is in the region of 2.3 miles (3.8 km), leaving vast tracts of our own planet totally unexplored.

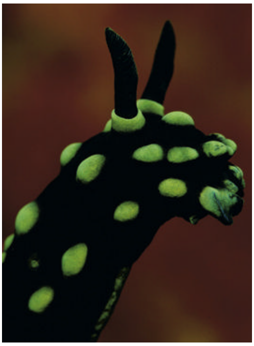

MARINE MELTING POT
The ocean contains a diverse range of life-forms, such as this bizarrely patterned nudibranch.

The coastal fringes that are the realm of the recreational diver reveal a wealth of life. Only two percent of known marine species live in the open ocean, with the remaining 98 percent burrowing, swimming, scuttling, and crawling over reef, rock, and muddy sea bed. Although recreational divers are confined to depths of around only 130 ft (40 m), the first 650 ft (200 m), known by scientists as the neritic province, hosts the greatest diversity of life in the sea.

ZONES OF LIFE

Four temperature bands define the basic zones of marine life on the planet. At the northern and southern extremities of the Earth are the polar seas, capped with ice. These graduate into temperate seas, which mostly range from 39 to 68°F (10–20°C). Subtropical seas form a loosely-defined buffer zone around the tropical seas of the equator, which are the world's warmest, rarely dropping below 68°F (20°C).

THERMAL RANGE
Sea surface temperatures vary from freezing point at the poles to more than 30°C (86°F) in the tropics.

KEY

🟦 Polar
🟦 Temperate
🟨 Subtropical
🟧 Tropical

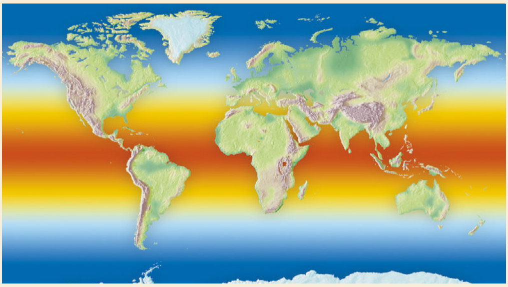

ENDLESS VARIETY

Water is the perfect medium to support life, at once a means of transportation, communication, support, and reproduction. The lives of countless numbers of people worldwide are dependent on the world's oceans and the life they support, which ranges from microscopic plankton to the immense bulk of the largest animal alive today—the blue whale.

Types of marine environments and the species that inhabit them vary with location around the world. The open ocean is roamed by giants, with large migratory species, filter feeders, and opportunistic predators. The latter, bold and inquisitive, provide many of the "big-animal encounters" that divers find so rewarding. Closer to shore, the warm, clear waters around the tropics are home to coral reefs, the most spectacular of all marine systems. More temperate coastal regions have richly populated marine "forests" of kelp—seaweeds that grow to immense lengths to reach the sunlit upper reaches of the water. Colder waters are the province of migratory marine species, traveling the seas in search of new feeding opportunities as the seasons change.

And although we tend to think of migrations taking place over great distances laterally, there is also a great vertical movement in the oceans. As the day and night change, a range of animals migrate through the water column, creating the largest daily movement of animals on Earth.

ENVIRONMENTAL CONCERNS
The sea supports countless livelihoods, and it is perhaps no surprise that overexploitation occurs. Here, an official apprehends shark-finners.

FLIGHT PATH
With a massive wingspan of up to 10 ft (3 m), the eagle ray is a magnificent marine species.

Tropical seas

If ever there was an image that sums up the magic of diving, it is that of a coral reef. Although coral reefs are the most famous feature of tropical seas, these warm clear waters have much more to offer, such as mangrove swamps, sea-grass beds, and vast tracts of open ocean.

WARM BELT

Tropical waters occupy the region within the “20°C isotherm”—the irregular band of water north and south of the equator that seldom drops below 68°F (20°C). Although undeniably appealing to the diver, they actually present a less attractive environment for marine life. The warm equatorial sun heats the upper layers of the water column, creating a marked temperature difference between the surface water and deeper colder water. Such temperature stratification prevents mixing of the water column, so nutrients are not passed up from deeper water. Marine animals and plants have therefore had to adapt and evolve numerous strategies to cope with the lack of nutrients in the water around them. Perhaps the most remarkable of these is the coral reef. Primary production—the formation of organic compounds from inorganic material—is up to 100 times greater in coral reefs (*see p.204*) than in open tropical waters, and although they cover only 0.2 percent of the ocean environment, they are home to 25–30 percent of all fish species.

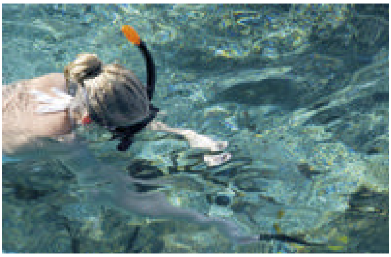

PERFECT SNORKELING CONDITIONS
By happy chance for divers, tropical coral reefs require clear warm water with little seasonal variation to grow at an optimum rate.

LIFE ON THE REEF

The diversity of tropical regions is based to a large extent on coral reefs, although these vary in their diversity depending on location. The reefs with the most vibrant marine life are found in the Indo-Pacific, with up to 700 coral species playing host to 2,000 fish species. In contrast, Atlantic coral reefs have only 70 coral species and about 600 fish species.

Raccoon butterflyfish

CORAL FORMATION
These complex and often huge structures are built by the tiniest of marine creatures.

The reefs of the Indo-Pacific are the richest marine environments on Earth. Their beautiful structure and bright colors, combined with the splendor and variety of animals that inhabit them, make reefs irresistible to divers, and it is no coincidence that many of the world's best dive sites are found on coral reefs.

PARADISE ISLAND
Tropical beaches draw ever-increasing numbers of tourists, creating intense development pressures which, if uncontrolled, pose a significant threat to tropical seas.

COASTAL NURSERIES

Tropical waters are also home to mangrove swamps and sea grass beds, both arguably as important as coral reefs in the overall health of tropical seas. There are 40 species of mangroves—tropical trees and shrubs that grow in shallow and intertidal coastal waters—and they form flooded forests that act as nurseries for various reef and open-water fish species. The 50 species of sea grass form "meadows" in shallow waters that are feeding grounds and nurseries for many fish species. The eradication of sea grass beds and mangrove swamps around the world is a real concern, with undeniable impacts on coastal ecology as animal populations are denied crucial areas for the growth and development of their young.

REEFS UNDER THREAT

Coral reefs worldwide are under intense pressure. The continued development of coastal regions has caused silty water to run into the seas, smothering these delicate systems, and, coupled with the damage caused by destructive fishing methods, it is thought that up to 90 percent of reefs have been impacted by humankind. There is also evidence that rising water temperatures are causing a phenomenon known as bleaching, which is fatal to reefs. This occurs when the coral polyps eject the minute algae that sustain them as a response to stress.

Diving a reef can be the highlight of a diver's life, but we have a very real responsibility when exploring reefs not to harm or disrupt them in any way. A considerate approach is vital if we are to preserve these wonderfully vibrant ecosystems.

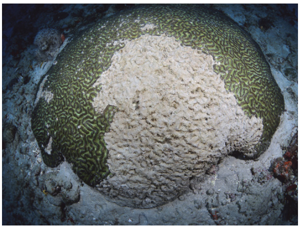

BLEACHED CORAL
Coral bleaching is one of the more vivid consequences of global warming and increased pollution.

THE CORAL CYCLE

Reefs are formed because of the extraordinary symbiotic relationship between tiny animals—polyps—and minute algae. Polyps are colony-forming animals that construct coral reefs. The polyp has a hard exoskeleton made of calcium carbonate, and this forms the physical structure of reef systems. Minute single-celled algae called zooxanthellae live within the polyp, protected by its hard skeleton, and nourished by its waste products. In turn, the zooxanthellae provide the polyp with nutrients and oxygen, which they produce, like plants, through photosynthesis. This process requires light, which is why tropical reefs are found only in waters less than 330 ft (100 m) deep—the so-called "photic zone", penetrated by sunlight. This relationship is vital: warm, clear water tends to be low in oxygen and nutrients, but the partnership of algae and polyp creates a highly efficient nutrient recycling system, and, in turn, sustains a rich array of marine life.

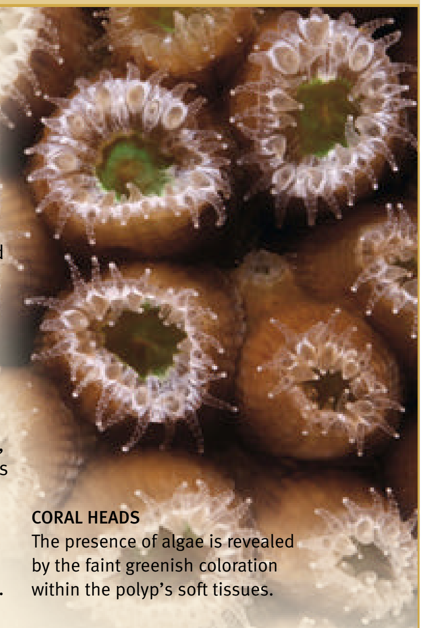

CORAL HEADS
The presence of algae is revealed by the faint greenish coloration within the polyp's soft tissues.

REEF DISTRIBUTION
Over 90 percent of coral reefs are clustered in the Indo-Pacific region. Reefs do not form on coasts that experience cold or strong currents.

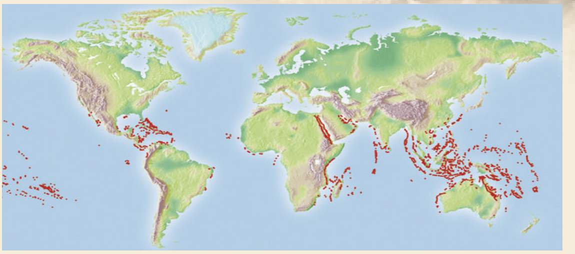

KEY
● Reef

REEFS AND RESPONSIBILITY Low-impact “hands-off” diving techniques are essential to avoid damaging coral reefs.

Subtropical seas

Although there is no strict definition, subtropical seas can be described as waters too consistently warm to support temperate marine life, but too cold for coral reefs to flourish. Also known as warm temperate waters, subtropical seas are found in all of the world's oceans except the Arctic.

BETWEEN TWO WORLDS

Subtropical waters are sandwiched between tropical ecosystems (generally identified by the presence of coral reefs and mangroves), and the temperate zone (identified by cold, rich waters supporting complex systems such as kelp forests). In subtropical marine systems, the water temperature is too high to contain large amounts of oxygen and nutrients (*see pp.208–09*), and yet too low to promote the recycling properties of coral reefs (*see pp.204–05*).

The most popular subtropical areas for diving are the Mediterranean and parts of the Gulf of California (also known as the Sea of Cortez). Other key sites include South Africa's Aliwal Shoal (*p.259*), Fernando de Noronha (*see p.318*) off the Brazilian coast, and the islands of Cocos, Malpelo (*see p.319*), and Roca Partida (*see p.320*) in the eastern Pacific.

RED GROUPER
These large predatory fish are typical of Mediterranean seas, but overfishing has depleted their numbers.

In terms of their marine life, there is a stark contrast between the Gulf of California and the Mediterranean. The former is famed throughout the diving world for its big-animal encounters, while the latter is a somewhat barren system. The cause of this difference is their topography. The Mediterranean is in effect an isolated bowl of deep water,

MEDITERRANEAN COASTLINE
The beauty of the coast and its clear waters are some recompense for a relative dearth of marine life.

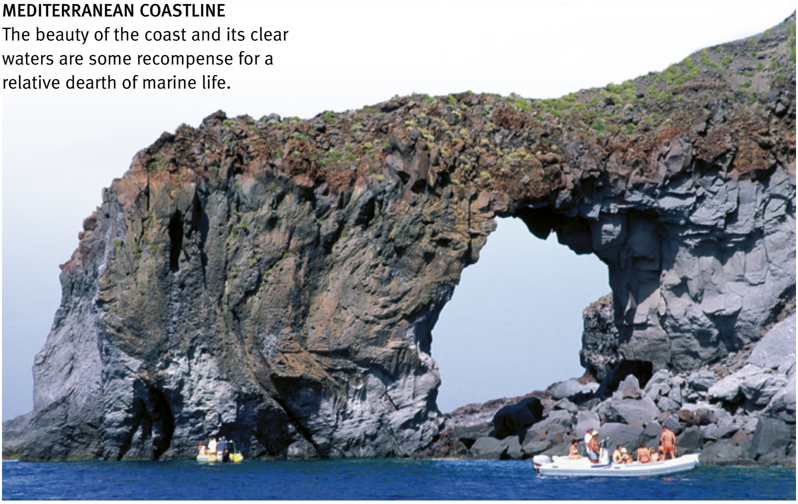

whereas the Gulf of California is less enclosed and relatively shallow, with water and animals able to move freely to and from the Pacific.

Plankton, which are at the base of the food chain, thrive in waters in which mixing of the water layers brings nutrient-rich deep water to the surface (*see pp.214–15*). Most of the cold, nutrient-rich water from the Atlantic that enters the Mediterranean does so through the narrow Straits of Gibraltar, creating a plume of colder water that extends to the Sicilian Channel. The best dive sites in the Mediterranean lie along this plume. Much of the rest of this sea experiences very little mixing of the water column, and while the result is very clear water, there is little to support life.

The Gulf of California is open at the southern end, with the Baja peninsula to the west and the Mexican mainland over 125 miles (200 km) to the east. Much of it is less than 985 ft (300 m) deep, and these shallow waters are regularly mixed by water entering from the Pacific to the south and are rich in marine life. This is one of the finest locations to encounter large animals such as humpback whales and manta rays.

OCTOPUS ENCOUNTER
Various species of this cephalopod can be encountered in subtropical waters worldwide.

Temperate seas

The richest of all marine ecosystems, temperate waters are the stretches of ocean between the poles and the tropics. These waters are hugely changeable, offering a seasonal range of conditions at any one dive site, often accompanied by a variety of visiting migratory species.

THE TEMPERATE ZONE

It is difficult to define the temperate zone precisely, because major ocean currents can artificially extend temperate waters into tropical regions, or push temperate species into near-polar regions. The best definition is perhaps found in the temperature range of the water: true temperate waters rarely sink below about 39°F (10°C) or rise above 68°F (20°C).

The positioning of the temperate zone means that its waters see a greater change of conditions from season to season than tropical and subtropical seas. In particular, the amount of light hitting the surface of temperate waters varies considerably between winter and summer, and this leads to a seasonal variation in productivity—the sheer amount of life that an ecosystem can support. At the base of the food chain in the marine ecosystem are tiny organisms called plankton, which are dependent on light and nutrients for growth and reproduction. In the winter, when even water near the surface receives little light, conditions are poor for plankton growth, and so productivity is low. However, during the stormy winter months there is considerable mixing of cold, nutrient-rich deep water with the

FILTER-FEEDER
The basking shark moves through the water with its huge mouth open, filtering plankton from the water.

surface layer (*see pp.214–15*), and so in spring, when the amount of light hitting the surface of the water vastly increases, conditions are perfect for the growth of plankton. Huge spring blooms develop, attracting plankton-feeding species and their predators, and the waters become rich in marine life. Productivity drops again in summer, because, even though light conditions are perfect for plankton growth, there is little mixing between the surface layer and deeper water, and so nutrients become scarce.

ROUGH SEAS
Temperate seas can be rougher and colder than tropical and subtropical waters, but those who brave them are rewarded by the wealth of marine life on display.

TEMPERATE DIVING

Diving in temperate waters is not the crystal-clear, warm-water experience beloved of the coral reef diver, and requires more equipment (*see p.45*) than diving in tropical regions. However, some of the localized ecosystems within temperate seas, such as the majestic kelp forests (*see pp.210–11*) found in certain coastal regions, are extremely dramatic. When dived at optimum times in the season, temperate waters are rich in life. The seasonal blooms of plankton draw a range of migratory species, and also attract impressive predatory species, such as shark and tuna.

PLANKTON BLOOMS

Plankton are free-floating animals (zooplankton) and plants (phytoplankton) at the base of the marine food chain. When environmental conditions are optimal for their reproduction, they can multiply very rapidly, creating huge “blooms” of many millions of individual plankton. Where massive blooms of phytoplankton develop, the sea can literally turn green.

Cyclops zooplankton

UNDERWATER FORESTS

The forests of giant kelp that grow in temperate seas are considered by some to be the most impressive marine environment of all. Although kelp—a brown alga—is extremely abundant in temperate waters throughout the world, true kelp forests are specific to the areas with marine conditions that support the growth of two kelp genera: *Macrocystis* and *Nereocystis*. These require reasonably clear water, a degree of water movement, a suitable substrate making up the sea bed, and a maximum temperature: most kelp forests will not flourish in water that exceeds 68°F (20°C) on a regular basis. Some species of kelp grow at a phenomenal rate, and to a truly colossal size. *Macrocystis pyrifera*, or giant kelp, can reach in excess of 165 ft (50 m), and can grow up to 25 in (60 cm) in a single day, making it the fastest-growing alga on Earth.

The best areas for the growth of kelp forests are off the west coast of the US and Canada; in the Cape region of South Africa; in Southern Australia; along almost the entire length of the west coast of South America; around much of New Zealand; and in southern Japan. For the diver, the attraction of these biological wonders is not simply the forests themselves, but also their numerous residents. The analogy with a terrestrial forest is a good one: activity takes place from the seabed up to the canopy, from specialist mollusks that bore into the kelp itself, through to pelagic animals such as rays that soar through the upper levels. As well as permanent residents, a kelp forest provides a nursery for many open-ocean species and a hunting ground for impressive predators. To dive a kelp forest on a day with good visibility as the sun dapples through the canopy overhead is an unmatchable experience.

SEA OTTER
Vital residents of kelp forests, sea otters help control populations of sea urchins, which if left to multiply would decimate the kelp.

SUBMERGED CANOPY
Invariably dramatic and teeming with aquatic life, kelp forests are the temperate water equivalent to the bustling reefs of tropical seas.

KELP BEDS
Huge numbers of marine creatures, large and small, make their home among kelp.

Polar waters

Although both the Arctic and the Antarctic conjure up visions of frozen desolation, below the ice and water surface lie regions of staggering abundance. Possibly the most challenging of all marine environments, the polar regions offer many surprises for the intrepid diver.

FROZEN ENVIRONMENT

Polar waters are found in the regions around the Arctic and Antarctic, though the precise lines of demarcation are blurred. Where polar waters start and temperate waters end varies between the poles. For the Arctic it is the 50°F (10°C) above-water July temperature boundary, while for the Antarctic it is seen as the line of the Antarctic Convergence, a zone where cold Antarctic waters sink below warmer northern currents.

Both the Antarctic and Arctic have quite consistent water temperatures, because the low angle of the sun and the reflective qualities of the ice minimize the impact of solar radiation. The temperature of the water hovers around an extremely chilly 32°F (0°C), only just above the freezing point for seawater, which is 29°F (–1.8°C). However, although they may seem similar, the Antarctic and Arctic are actually quite different in terms of their physical geography and marine ecosystems.

BELUGA WHALE
Arctic diving "safaris" provide opportunities to dive with animals such as beluga whales and a number of seal species.

POLES APART

The plants and animals of the Arctic and Antarctic differ considerably, situated as they are on opposite sides of the world. Antarctica has its own species of krill (some seven of them)—the small shrimplike creatures that are the bedrock of the food chain here. Swarming in huge numbers on the surface, they draw in a host of feeders—including the mighty baleen whales—during seasonal migrations.

Krill

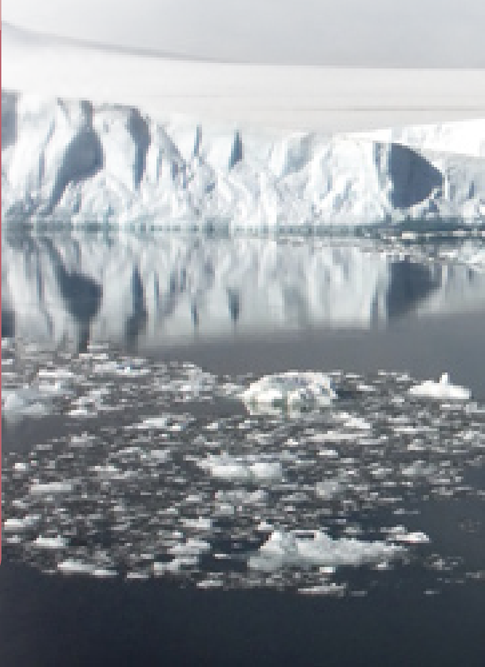

The Antarctic is an isolated continent covered largely in ice: its nearest land masses are over 600 miles (1,000 km) away, and the entire continent is circled by an ocean current. The Antarctic Circumpolar Current is extremely significant, as it essentially cuts the Antarctic waters off from warmer waters farther north. The Arctic, by contrast, is mainly an area of ocean covered in a thick layer of ice, bordered by the land masses of North America, Europe, and Asia, and as such its waters are affected by temperature changes, land runoff, and shallow coastal currents.

ICE DIVER
There are more diving opportunities in the Arctic than in Antarctic waters. Diving under the ice demands a high level of expertise and special skills (*see pp.188–89*).

LIFE ON THE ICE

The adaptations that have evolved in animal life to cope with extreme polar environments are remarkable. There is a tendency toward gigantism—a larger body size keeps the relative body surface area to a minimum, and therefore the effects of heat loss through the skin are less pronounced. Fish have a high body fat content, and mammals have blubber and fur to insulate them, while behavior such as migration in the winter months means the worst conditions are avoided. The most extraordinary adaptations exist, perhaps, in the fish and invertebrates of polar waters: many have special “antifreeze” proteins in their blood to keep it liquid at low temperatures.

ICE SHELF CALVING SMALL ICEBERG
Up to 70 percent of all fresh water on Earth is held in the Antarctic ice cap. It sits on a huge land mass, while the Arctic is largely floating ice.

The open ocean

Only a tiny proportion of the world's oceans cover the shallows around land. Beyond, great tracts of open water plunge to abyssal depths. At first glance a featureless marine desert, this is actually a fascinating ecosystem containing some of the most impressive marine creatures.

A LAYERED WORLD

The oceans of the world are divided not only geographically, but also vertically, descending through the water column in distinct zones defined by temperature. Only the upper 650 ft (200 m) or so are heated by the Sun. Below this warmer surface layer, the temperature of the water can fall dramatically with depth in a layer of water called the thermocline. This layer of rapid temperature change is present in tropical waters year-round and in temperate waters in summer, but is not found in polar waters. Below the thermocline, the temperature continues to fall, but more slowly. Many animals find the dramatic change in temperature at the thermocline stressful, and are confined to either the warmer water above it, or the deep, cold water below it.

The deeper layers of the ocean are richer in nutrients than the surface layer; they are also colder, and so have a greater capacity for holding oxygen. Mixing of the layers—bringing oxygen-and nutrient-rich water into the surface layer—can be

LIFE IN THE OPEN SEA

Even in remote areas of open ocean, communities of living creatures thrive. In the Sargasso Sea in the North Atlantic, a vast rotating current propels floating *Sargassum* weed in an endless circular procession. The weed supports many invertebrate species and juvenile fish.

Sargassum weed

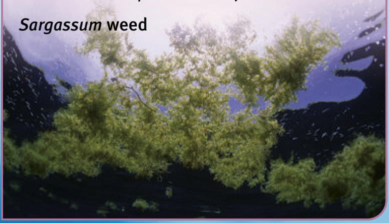

CAUGHT ON CAMERA
Open-water predators, like this blue shark, will investigate any new visitor to the environment.

caused by currents, storms, or other natural patterns of water circulation. When the nutrient-rich water is hit by sunlight, an explosion in plankton growth, or "bloom," occurs, creating regions of abundance as plankton feeders, and in turn their predators, congregate.

BUILT FOR SPEED
With their streamlined bodies and powerful sickle-shaped tails, dolphins are perfectly designed to hunt even the fastest-moving prey.

LIFE AT THE DEEP END

Pelagic animals (those of the open ocean) have developed remarkable physical and behavioral adaptations to suit their demanding environment. Massive vertical migrations take place at night, when marine animals move into the well-stocked surface layers, hidden under cover of darkness from predators that hunt by sight. However, many of the predators of the open ocean boast a battery of senses for detecting prey at long range, and investigate any object in their vast territory for its food potential. These opportunistic hunters include the blue shark, marlin, and tuna, some of the most awesome and beautiful animals in the oceans. The cold-blooded tuna can heat its blood to warm its muscles, allowing deadly bursts of speed.

Freshwater environments

Branching out from the sea to explore freshwater environments opens up a whole new range of dive sites to discover, from Icelandic ravine lakes to Mexican caverns or the Florida swamps, each with fascinating, freshwater-specific animal and plant life.

LAKES AND RIVERS

The first thing any diver accustomed to seawater will notice in a freshwater system is the difference in buoyancy. The salt content of seawater—around 35 parts per thousand—makes it denser, and thus a naturally more buoyant environment for the diver than freshwater. Consequently, you will find that you need to carry considerably less weight. The lower salt content also means that equipment suffers less damage through corrosion.

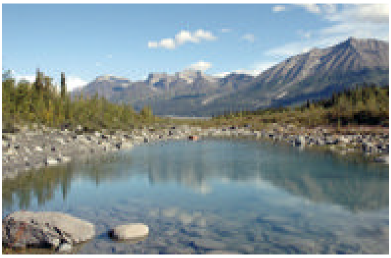

PRIVATE PROPERTY
Some of the most scenic rivers and lakes are privately owned, so it is important to check whether permission is required before you dive.

There are a number of logistical and safety issues specific to freshwater diving. Some of the more adventurous dive sites are high-altitude lakes, and require the use of special tables or a dive computer to avoid decompression issues. Lakes are susceptible to land runoff, and may quickly become murky in poor weather, while rivers may swell rapidly in adverse conditions, creating dangerous currents. Rivers and lakes may also support disease, notably Weil's disease and bilharzia, particularly in regions of dense human population.

Despite these drawbacks, with some research and strategic preparation before a dive, local rivers and lakes can provide a perfectly viable and exciting alternative to sea diving. Freshwater systems become anoxic (lacking in oxygen) at depth, and subsequently support very little life. This means that shipwrecks do not deteriorate as quickly—because the organisms that would usually destroy them cannot function—so deep lakes can offer impressive collections of well-preserved wrecks.

African lake fish

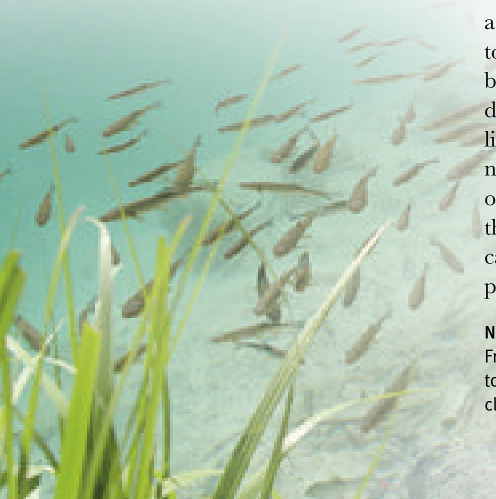

NATURE ON DISPLAY
Freshwater species are generally unaccustomed to divers, creating wonderful opportunities for close observation and encounters.

LAKE DIVING
Exploring a freshwater lake can provide a fascinating and exhilarating alternative to sea diving. Here, in the beautiful Blindsee mountain lake in Austria, divers can explore an underwater forest of fallen trees.

Mammals

Of the 5,000 species of mammals on Earth, around 2.5 percent are found in marine environments. These warm-blooded aquatic animals are perhaps among the most charismatic and approachable creatures you will encounter on any dive.

WARM-BLOODED LIVING

Mammals have a number of features that make them unique in the animal kingdom. First, they are warm-blooded, which means that they are able to regulate their internal body temperature. Most are covered in hair (apart from Cetaceans) and all, except monotremes like the duck-billed platypus, give birth to live young and feed them on milk produced by milk-secreting glands. At least three orders of mammals include species that spend the majority, if not all, of their lives in water: Cetaceae, which includes whales, dolphins, and porpoises; Carnivora, including the pinnipeds (seals, sea lions, and walruses) and otters; and Sirenia—manatees and dugongs.

WHALES, PORPOISES, AND DOLPHINS

Cetaceans spend their entire life in water, even though, like other mammals, they have lungs and need to breathe air to live. They are divided into two main subgroups—Mysticeti and Odontoceti—based on their adaptations for feeding. Mysticeti are filter-feeding baleen whales, such as northern and southern right whales, humpback whales, and blue whales.

SOUTHERN RIGHT WHALE
There are few more impressive sights than a whale's flukes breaking the ocean's surface.

SUPREME PREDATOR
The majestic orca or killer whale is a versatile hunter, catching a range of prey from fish to seals and even whales and birds.

Odontoceti, by contrast, have teeth and include some species of whales and all dolphins and porpoises.

AQUATIC CARNIVORES

Pinnipeds are aquatic mammals that spend some time on land, particularly for breeding. There are 33 species, including seals and fur seals, sea lions, and walruses. These carnivorous mammals have webbed feet, enabling them to move on land and in the water. With their long front flippers, fur seals and sea lions are able to walk on all four flippers on land.

Sea otters are the largest members of the mustelid or weasel family and are most commonly found off the coasts of California, Alaska, and Russia. Unlike other marine mammals, they have no insulating layer of blubber, but have the thickest fur in the animal kingdom. They are one of the only mammals, other than primates, known to use tools, utilizing stones and other items to crack open shellfish and pry prey from cracks in rocks.

THE SIRENIANS

It is rare to encounter manatees (*see also p.309*) and dugongs. These fascinating migratory mammals, belonging to the order Sirenia, typically reach adult sizes of around 10 ft (3 m) in length, and have front limbs in the shape of flippers and no hind limbs. Despite their imposing size, manatees and dugongs are placid, herbivorous creatures that spend most of their time grazing.

SEALS

Commonly seen on dives and at the water surface, seals tend to be found close to shore and in the more remote areas of the world, such as the Arctic and Antarctic, where they can feed and reproduce without disturbance. There are 18 species, the largest of which is the elephant seal. Seals are efficient swimmers, using their rear flippers for propulsion and their front flippers for steering. These lively mammals are fun to swim with but have sharp teeth and can be aggressive during the pupping season.

Harbor seal

Sharks, skates, and rays

Like other cartilaginous fish (also known as the Chondrichthyes), sharks, skates, and rays have a skeleton made of flexible cartilage rather than bone. Collectively known as the elasmobranchs, they have between five and seven paired gill openings, and nostrils beneath the snout.

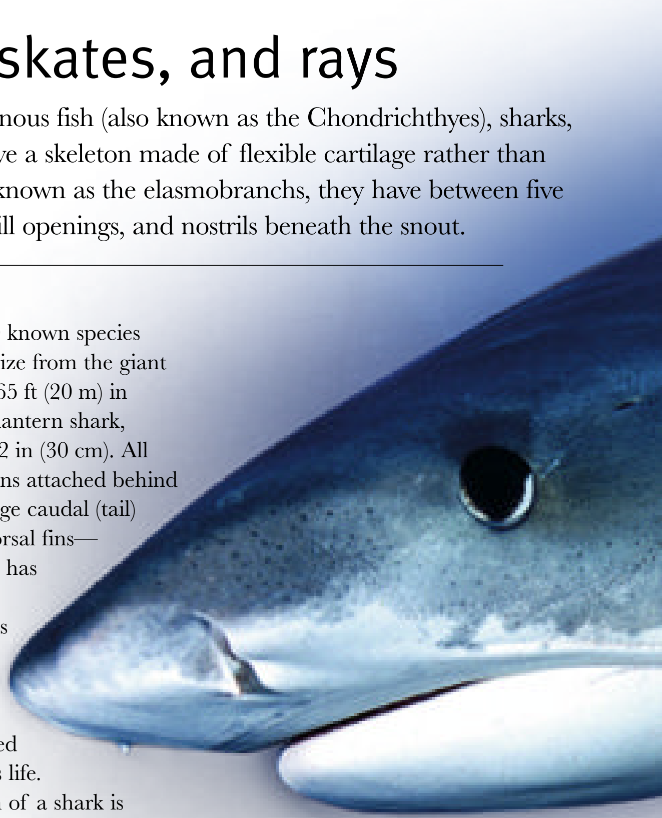

SHARK SPECIES

There are around 500 known species of sharks, ranging in size from the giant whale shark, at up to 65 ft (20 m) in length, to the minute lantern shark, which measures just 12 in (30 cm). All sharks have pectoral fins attached behind the gill openings, a large caudal (tail) fin, and one or two dorsal fins—a basic body plan that has changed very little in hundreds of thousands of years. The jaws are lined with many rows of teeth, which are continually renewed throughout the shark's life. The tough, rough skin of a shark is covered by dermal denticles—tiny scales that minimize drag (friction with the water) when swimming. Sharks propel themselves by sweeping their caudal fin from side to side. Unlike most other fish, sharks have no swim bladder, so they must swim continuously or they will sink. They also need to maintain the flow of seawater over their gills so that they can extract oxygen for respiration.

Sharks have extraordinary sensory powers. Their highly developed senses of smell and taste are used to detect potential prey, and they have excellent vision. In addition, they can sense changes in water pressure caused by the movement of other animals using their lateral line system. This consists of fluid-filled channels along the sides of the body that are lined with sensory hair cells. Sharks can also detect the minute electrical fields produced by other living animals, using electrosensory organs called ampullae of Lorenzi, which are located on the head.

LEOPARD SHARK
The leopard shark can be found at depths of up to 100 ft (30 m) and is often seen lying on sandy bottoms.

TIGER SHARK

Although rarely encountered, the tiger shark is one of the most voracious shark species. It feeds on large fish, turtles, and sea birds.

FOOD AND FEEDING

All sharks are carnivores, but they feed on a wide range of prey and use a variety of feeding techniques. Filter-feeders, such as basking, megamouth, and whale sharks, sift plankton from the water as they swim. Many bottom-dwellers, including wobbegongs and angelsharks, lie camouflaged on the seabed ready to ambush passing fish, while others, such as leopard sharks, feed largely on seabed invertebrates. Some species, such as white-tip reef sharks, feed cooperatively, hunting in packs and actively pursuing prey. The mako and the great white shark tackle large prey such as seals, swordfish, other sharks, porpoises, and sea turtles.

Although sharks are the top marine predators, only a few species are potentially dangerous to people, and attacks on humans are rare. In fact, humans pose far more of a threat to sharks, with many shark species currently endangered, and some even facing extinction, due to overfishing.

SHARK REPRODUCTION

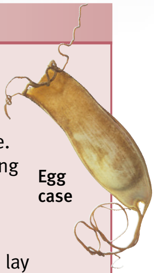

Egg case

During mating, the male uses his claspers (modified extensions to the pelvic fins) to transfer sperm to the female. The majority of sharks, including dogfish and leopard and tiger sharks, are viviparous, giving birth to fully formed offspring. Oviparous (egg-laying) species lay their eggs on the seabed, where the embryos are nourished by the yolk within the egg case. Catshark egg cases have long tendrils that twist around objects on the seabed. In other species, such as epaulette sharks, sticky filaments glue the egg cases to a secure site. All young sharks fend for themselves from birth or hatching.

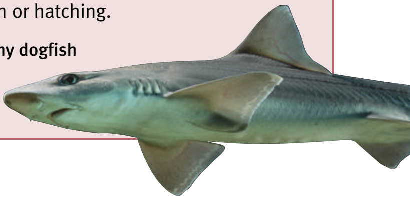

Spiny dogfish

SKATES AND RAYS

The 600 skate and ray species share many of the features of sharks, but have a very different body plan. The gill slits are on the underside of the body. The pectoral fins are positioned above the gill openings, not behind them as in sharks, and are greatly enlarged and flattened to form "wings," while the caudal fin is reduced or absent.

Most skates and rays are bottom-dwellers, and are well adapted for life on the seafloor. Their flat body shape enables them to lie on the seabed unnoticed, and they have a downward-pointing mouth and eyes on top of the head. Spiracles (breathing holes) behind the eyes enable them to "breathe"—take in water to extract oxygen—when half-buried in the substrate. Most rays and skates eat invertebrates, such as mollusks and crustaceans, and small fish, but some are plankton feeders. They swim with strokes from their modified pectoral fins, in an undulating movement similar to a bird flapping its wings. Their tails are used for defense rather than propulsion: they have a stinger at the base of their tail, with short barbs that can inject venom into aggressors. Skates lack this tail barb.

Skates tend to be more common in temperate waters, and rays in the tropics, but the main distinction between them is in their reproduction. Rays produce live young, while skates lay eggs in leathery cases (often called "mermaid's purses").

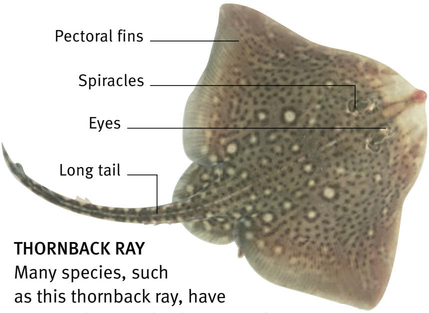

THORNBACK RAY
Many species, such as this thornback ray, have a mottled or speckled coloring that camouflages them against the seabed.

MANTA RAYS
These large, filter-feeding rays sieve microscopic plankton from the water with their gill-rakers. Manta rays also eat small shoaling fish.

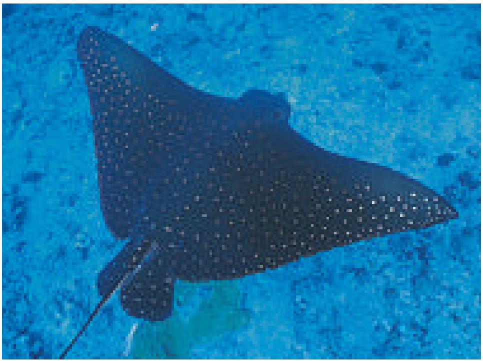

SPOTTED EAGLE RAY
This species uses its flattened, duckbill-like snout to dig up food from the seabed.

DIVING WITH RAYS

Manta rays, with their elegant, dancelike swimming motion, are perhaps the most popular ray species. They are also the largest of the rays, measuring up to 20 ft (6 m) across. They often congregate at special cleaning stations on the reef, where they allow smaller reef fish to pick tiny parasites off their skin. The flaplike lobes on either side of the mouth funnel plankton between their jaws as they swim. When not in use, the lobes are coiled up to make the ray more streamlined.

Other types of rays seen during dives include guitarfish, which have pointed heads and elongated bodies, and electric rays, which possess organs that can deliver an electric shock to incapacitate prey. Torpedo rays can discharge more than 200 volts—enough to stun a diver. Circular-bodied stingray species should also be treated with caution, since they have venomous barbs at or near the base of the tail. The sting's effect can be mildly painful to potentially fatal, depending on the species. Eagle rays, which also have venomous barbs, can be identified by their distinctive beak-shaped snout. They have powerful crushing teeth, large "wings," and a long tail.

Rays are docile animals, and despite their self-defense mechanisms, pose no real threat to the diver if unprovoked.

Bony fish

Bony fish, or Osteichthyes, make up about 95 percent of all fish species—more than 23,500 in number. These vary in every ocean that you will dive in, and there is a wealth of shapes, sizes, and colors, and intriguing behaviors and interactions for you to discover.

COMMON FEATURES

Typical bony fish are torpedo-shaped and streamlined with a muscular tail. They have a caudal fin at the base of the tail for propulsion; a pair of pectoral fins, just behind the gills, for steering; an anal fin just below the tail; a pair of pelvic fins on the lower side; and, normally, one to three dorsal fins on the back. They are covered in a slimy secretion that reduces drag, and nearly all species have a covering of protective scales. They breathe using gills, although a few have evolved to use lungs as well as gills, and they are cold-blooded.

Bony fish are the most diverse and numerous of all the vertebrates. The earliest fossilized fish remains date from around 395 million years ago. All fish have a bony skeleton and a swim

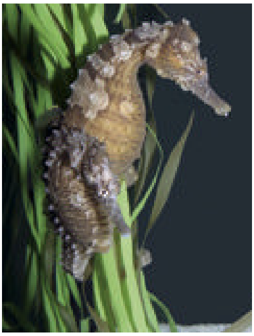

ROLE REVERSAL
Male seahorses have a pouch in which they incubate the eggs produced by the female.

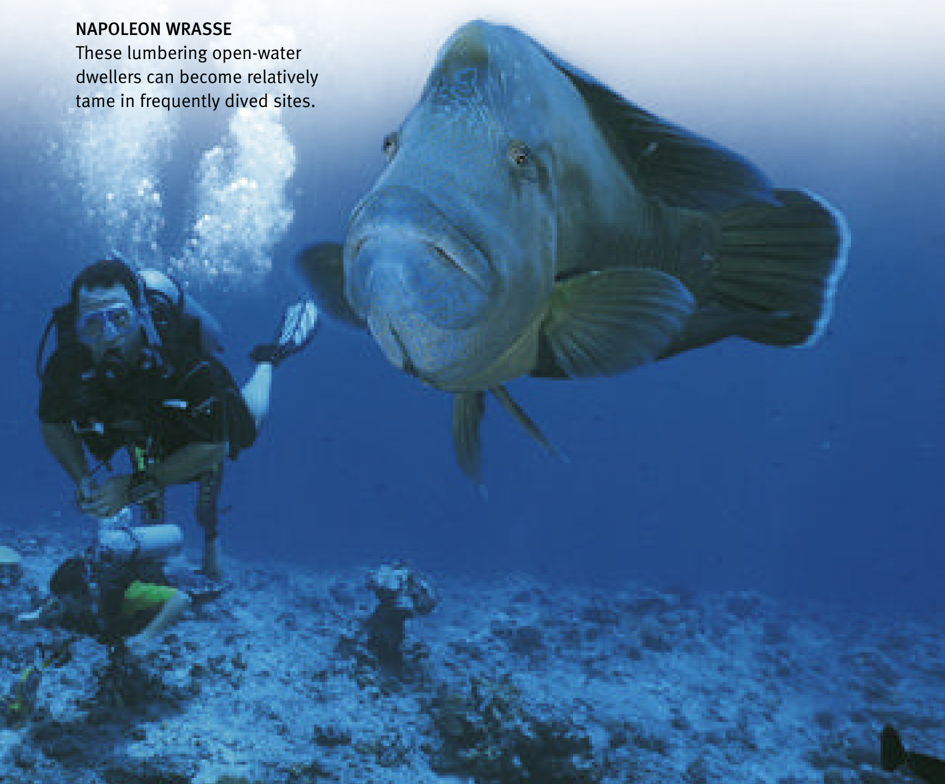

NAPOLEON WRASSE
These lumbering open-water dwellers can become relatively tame in frequently dived sites.

SAFETY IN NUMBERS
Moving as part of a large group means that each member of this shoal of barracuda—a ray-finned species of bony fish—is less likely to be eaten.

bladder—an air-filled sac that aids buoyancy. The sexes are separate; most lay eggs, and fertilization is usually external.

There are two groups of bony fish. The Sarcopterygii (lobe-finned fishes), which have a fleshy lobe at the base of their fins that is leglike in appearance, form a small group that includes the coelacanth and Australian lungfish. These ancient fish probably gave rise to the amphibians. But by far the majority of bony fish belong to the Actinopterygii (ray-finned fishes). These fish have jointed bony rays that support their fins, and a symmetrical caudal fin.

The species you see will vary depending on your location. Fish identification can be rather like bird-watching, and many divers make checklists of what they have seen on each dive. An identification guide to the fish in the area that you are diving in will help to identify them correctly.

A WORLD TO DISCOVER

One of the greatest attractions of diving is the opportunity to observe an amazing range of fish species in their natural habitat. Bony fish display a wide variety of colors and patterns, especially those species found around coral reefs. As in some bird species, the male is often brightly colored and the female is drab in contrast. A male's vivid coloring may be used to attract a female in courtship displays. For example, the vivid markings of the male cuckoo wrasse become even more colorful in spring to attract females.

On reefs, you may also have the opportunity to observe some fascinating interactions between species. Animals such as manta rays and turtles regularly visit "cleaning stations," where smaller fish, such as cleaner wrasse, pick off algae, parasites, and dead tissue from their skin and even from inside their mouths. Anemonefish (also called clownfish) are able to live among the stinging cells of host sea anemones because they secrete a special mucus that protects them from being stung. In return for their sheltered home, they drop pieces of food and attract other fish that the anemone can feed on.

AVOIDING PREDATORS

You'll need keen eyes to spot some of the many fish species that are camouflaged or have unusual ways of avoiding predators. Some of these species are so elusive that they have only recently been discovered. Masters of disguise include the scorpion fish, which hides on reefs and is virtually indistinguishable from the coral and algae that surround it, but can deliver a nasty sting should you step on it. You may encounter flatfish, such as plaice and flounder, when diving in areas with a sandy bottom, but many are so well camouflaged to match the seabed that they are extremely hard to spot.

The holes and crevices in many reefs and wrecks provide ideal hiding places for fish such as moray and conger eels, with their slender body shape, large mouths, and menacing-looking teeth. Their hiding place is revealed when they gape to breathe (they have restricted gill openings). Eels have no pectoral or pelvic fins and use their long, muscled bodies to dart in and out of their lairs.

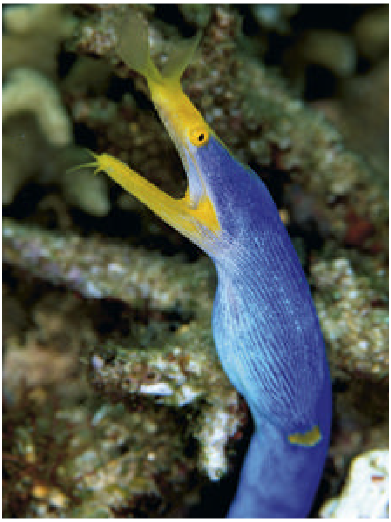

BLUE RIBBON EEL
This small, elegant moray eel from the Indo-Pacific is a shy creature: although it seems to gape threateningly, in fact, it is simply breathing.

ADAPTIVE CAMOUFLAGE

Bizarrely, flatfish start off life with a "normal" fish shape but then undergo a metamorphosis into their characteristic flat body form. One eye migrates to the other side of the head, the skull deforms, and the mouth becomes asymmetrical. The side of the body that sits on the sea floor becomes lighter and the upper side becomes darker, camouflaging itself in the color of the substrate.

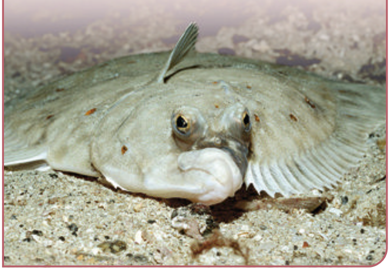

SOCIABLE FISH

In open water you may encounter incredibly large fish like the Napoleon wrasse, which can reach a weight of nearly 300 lb (135 kg). In some areas the wrasse have been hand fed so often that they are friendly toward divers, though feeding them is discouraged. In more open water and around wrecks, you will see great shoals of fish such as sardines, barracuda, glassfish, and mackerel. Such ocean-going, or pelagic, fish tend to have pale bellies, silvery flanks, and dark-colored backs. This makes it hard for prey and predators to spot them—when viewed from above, the darker shade blends in with the color of the deep sea; viewed from below, the pale coloring merges with the light from the sky.

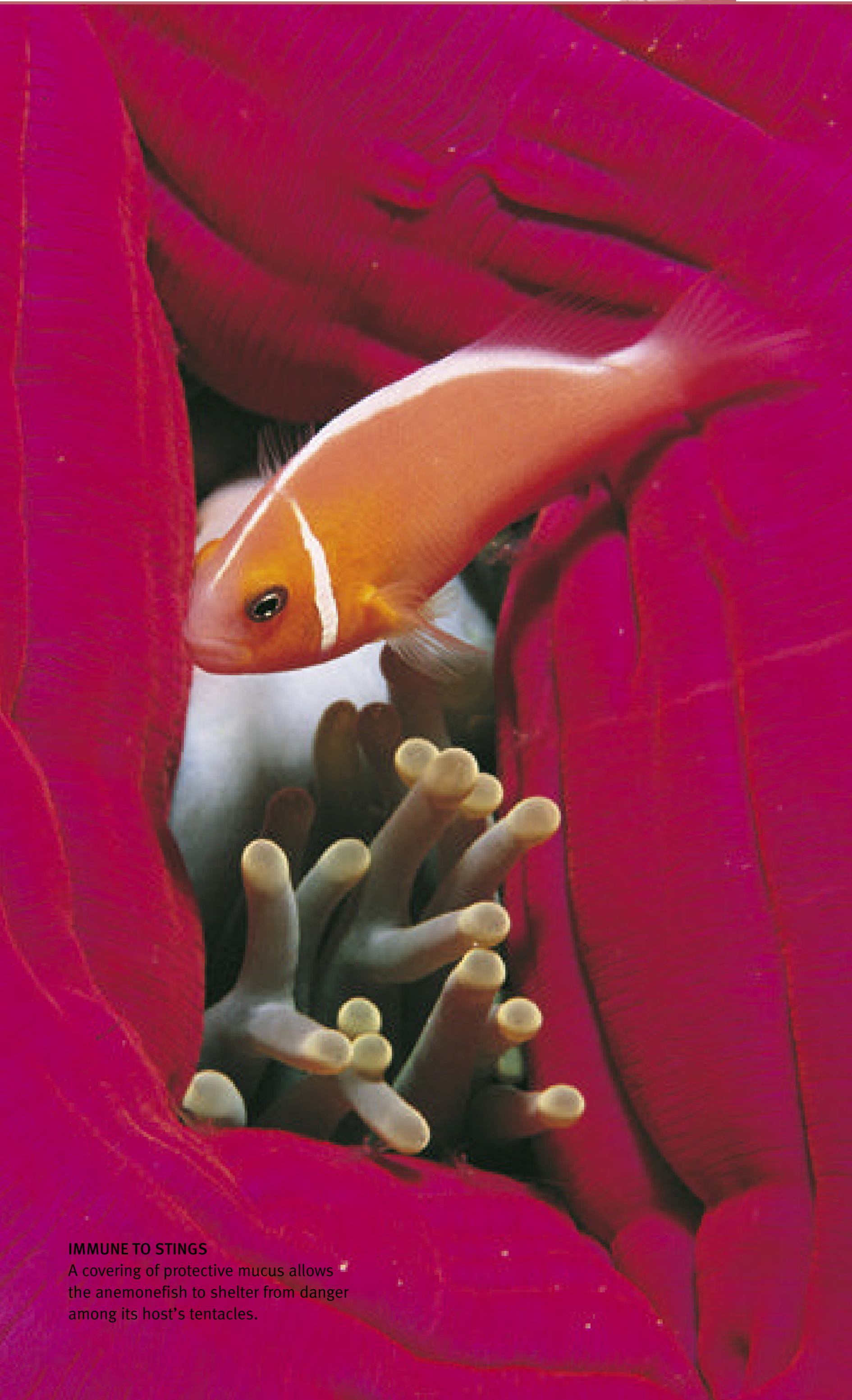

IMMUNE TO STINGS
A covering of protective mucus allows the anemonefish to shelter from danger among its host's tentacles.

Reptiles

Most reptiles live on land, but some are aquatic, notably turtles, terrapins, crocodiles and the related alligators and gavials, and sea snakes. These cold-blooded, or ectothermic, animals are mostly found in tropical areas, but some live in temperate regions.

BIRTH AND HATCHING

Reptiles are typically oviparous (the females lay eggs in which the young develop), although a few species are ovoviviparous (the young hatch from eggs within the mother's body). Egg-laying reptiles often build a nest in which to incubate their clutch.

One of the most prolific reptilian egg-layers is the turtle (order Chelonia), which has a hard shell that encloses and protects its vital organs. The head, tail, and flippers protrude, but many species can draw them in when threatened. Although they are air-breathing creatures, they only leave the water to breed and can lay as many as 200 eggs in nests excavated in sandy beaches.

THE SNEEZING IGUANA

The only lizard that forages for its food in the sea, the marine iguana has a curious habit of "sneezing" salt. The marine algae that forms the main part of its diet contains a lot of salt. A gland connected to the nostrils removes the salt from the body, and the iguana then expels it by sneezing, leaving its face white. This is one of the unique adaptations that allows marine iguanas to live and feed in seawater.

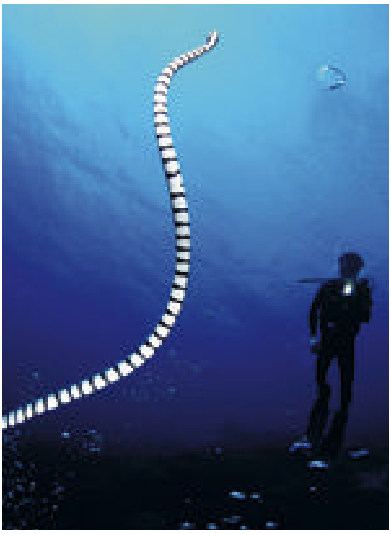

DIVER AND BANDED KRAIT
Related to cobras, sea snakes are venomous, but fortunately they are quite timid and if unprovoked are not inclined to attack humans.

SEA SNAKES AND LIZARDS

Although many snakes, such as the banded krait, swim in the sea, they usually return to land to breed. The yellow-bellied sea snake is the only true sea snake, the female giving birth in the water to up to ten live young, each about 10 in (25 cm) long. It can grow up to 3¼ ft (1 m) in length, and is black or dark brown in color with a bright yellow underside. This sea snake has spread across the Pacific from Southeast Asia to America, and gathers in huge numbers during the breeding season: a really big swarm can stretch for 70 miles (115 km). Marine iguanas, from the Galápagos Islands, are the only lizards that can tolerate salt water. Males may grow to a length of 4 ft (1.2 m) or more (almost half of which is the tail). They are harmless herbivores, feeding exclusively on algae growing on rocks near the shore. When feeding, they can remain submerged for up to an hour, especially in the warmer shallows, though dives of five or ten minutes are more common.

SALTWATER CROCODILES

The saltwater crocodile is the world's largest living crocodile; record lengths have been up to 23 ft (7 m), but 13–16 ft (4–5 m) is more common. This is the most dangerous species of crocodile, responsible for most crocodile attacks on people. It is found from eastern India and Bangladesh through Southeast Asia to Papua New Guinea and Australia, usually in brackish water in tropical estuaries, rivers, and swamps. The female lays eggs under a large mound of vegetation and stands guard over them for about 100 days. When the young hatch, she digs them out and carries them to the water. The hatchlings then live in nursery groups for about eight months, guarded by the adults.

RETURNING TO THE SURFACE
Turtles breathe air, like land-based reptiles. This one has a parasitic remora fish attached.

Marine invertebrates

Of all animal species on Earth, 95 percent are invertebrates (animals with no backbone), forming an incredibly numerous but often overlooked section of the animal world. Every major invertebrate group has an array of marine representatives.

AQUATIC ARTHROPODS

An arthropod is a type of invertebrate that has its body encased in a hard outer casing (the exoskeleton) and jointed appendages. Land-based arthropods include insects and arachnids, whereas most underwater species are crustaceans, a group that includes crabs, shrimp, lobsters, water fleas, copepods, and barnacles. There are about 39,000 species of crustaceans, most of which are marine, though some live in freshwater environments. They vary in size from the massive Japanese spider crab, with its leg span of 12 ft (3.7 m), to the tiny water flea, only about 9/1000 in (0.25 mm) long. But large or small, crustaceans all have certain things in common. They possess two pairs of antennae, three pairs of mouth appendages, and compound eyes on stalks. They also have three body segments—the head and the thorax, which are almost always fused and covered by a carapace (an outer shield), and the abdomen.

DRAWING NOURISHMENT FROM THE SEA
Bivalve mollusks, such as these mussels, feed by filtering organic matter from the water. Mussels live in nutrient-rich tidal areas.

MOLLUSKS

All mollusks, except the octopus, possess some form of calcium carbonate shell. There are three major marine classes of this group of invertebrates. Gastropods, with some 35,000 species, include whelks, limpets, sea slugs, and conchs. Many possess a shell but some, like the sea slug (or nudibranch), have lost theirs completely. Bivalves, such as clams, mussels, oysters, and scallops, have a shell in two pieces. There are 20,000 marine and freshwater species, the largest being giant clams up to 4 ft (1.2 m) across. Cepahalopods comprise around 600 species, including nautilus, squid, cuttlefish, and octopus. The cephalopods

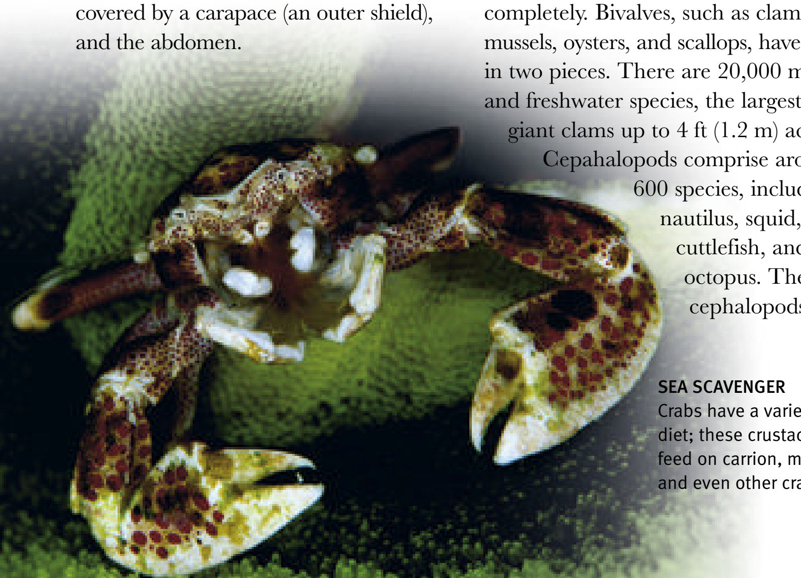

SEA SCAVENGER
Crabs have a varied diet; these crustaceans feed on carrion, mollusks, and even other crabs.

DELICATE DRIFTERS Transparent and serene, jellyfish are members of the cnidarian group of invertebrates.

include the largest invertebrate of all, the giant squid, which grows to a size of 52 ft (16 m). Cephalopods can swim in short bursts by squirting water from their bodies, but many, like the squid, use undulating fins for locomotion. The only shelled species of cephalopod is the nautilus: squid and cuttlefish have internal shells and the octopus has no shell at all.

CREEPING BEAUTY
Nudibranchs are colorful mollusks related to the common garden snail.

ECHINODERMS

Marine bottom-dwelling invertebrates, echinoderms have a hard, spiny skin and five-part radial symmetry. They lack a head, are often brightly colored, and are distributed throughout most of the world's seas. There are approximately 6,000 species of echinoderms, including starfish, brittle stars, sand dollars, sea urchins, and sea cucumbers, among others.

Most species of echinoderms reproduce sexually and have separate sexes. Fertilization is external—the eggs and sperm are shed into the water at spawning time. The floating embryo develops into a planktonic larval form. A few species reproduce asexually by fission (genetic copying of the parent organism into two or more clones).

Starfish may be circular, pentagonal, or the familiar star shape, with radiating arms. Under each arm are tiny tube feet, which the animal uses for walking.

UNDERWATER CHAMELEON
Cuttlefish are mollusks that can camouflage themselves by changing the color and texture of their skin.

The mouth is on the underside and the starfish feeds on living and dead animals as it moves along rocky surfaces and muddy bottoms.

Sea urchins, on the other hand, do not have arms. Instead, they have a shell of tightly fused plates, forming a sphere. They have long, prominent spines that protect them from predators, and have tube feet on their undersides, which are used for locomotion, respiration, and for trapping drifting particles of food.

CNIDARIANS

The cnidarian group of invertebrates, which includes the jellyfish, sea anemones, corals, and hydroids, are species with one of two basic body forms: medusae or polyps. Medusae, such as adult jellyfish, are bell-shaped with tentacles hanging down from the margins. They tend to be free-floating and solitary. Polyps, such as coral, sea anemones, and hydra, are tubular-shaped animals topped with tentacles. They frequently form colonies. Corals (*see also pp.204–05*) are unusual in that they depend on symbiotic algae to provide life-sustaining sugars. Medusae reproduce sexually, whereas most polyps reproduce by asexual fission. Cnidarians are unique in manufacturing cell-based stinging mechanisms, called nematocysts, in their tentacles, which are used to catch prey and in defense.

OTHER INVERTEBRATES

Comb jellies, which are bell-shaped creatures with vertical combs over their bodies, form another class of invertebrates—the ctenophores. The 5,000 species of sponges that live in both salt and fresh water belong to the phylum Porifera. Finally, there are over 8,000 species of segmented worms, which are classed as annelids.

PLANTS OR ANIMALS?

Many marine creatures stay rooted to a single spot for life. They posed a dilemma for early biologists who believed that mobility defined the animal state; this explains the common names of animals like the “lily of the sea” – in fact a crinoid. Other stationary animals include polyps, sponges, feather stars, and annelids such as fanworms. They are filter-feeders, and contain toxins to deter predators.

Feather star

Places to dive

Introduction

With increasing numbers of dive centers opening up around the globe, virtually the entire world is now accessible to the traveling diver. Following a few basic travel tips can stand you in good stead when transporting yourself and your dive gear to your destination.

TRAVEL OPTIONS

Most vacation destinations in coastal regions around the world provide some sort of diving facility. Indeed, the sport is now so convenient that you can turn up on the day, certification card in hand, and be decked out from head to toe with rented gear, before being guided around local dive sites. This is one of the greatest joys of the sport—the ability to visit different parts of the world and explore local sites with relative ease.

A step up from the more casual "just-passing-through" diving experience is the dedicated diving vacation. This is usually arranged through a resort-based dive operator, most of which will run a series of dives to local dive sites and offer a range of equipment for rent.

ICE DIVING
With many divers looking for more adventure in their diving, travel companies are offering challenging experiences, such as ice diving.

Developments in diving equipment over the last decade mean that most dive centers worldwide can offer a reasonable caliber of gear for rent. With the addition of local knowledge from a divemaster

who knows the waters well, you should be assured of a reasonable diving experience, regardless of the location. While most dedicated dive operators work to a high standard, there are a few rogue operators around, and you should be wary of any that show a cavalier approach.

Liveaboards provide an even more intense diving vacation. These are dive vessels designed for long-range trips to more inaccessible places, and they provide nonstop diving throughout the voyage. Liveaboards often offer supplementary courses, such as photography or natural history, hosted by resident experts. There are few marine dive destinations on Earth that are not accessible via liveaboards, and for many this is the finest way to experience extensive reef systems, remote sites, or sprawling island groups.

There is also a range of diving expeditions available in the modern travel market. Some are conservation-oriented and others more adventurous, such as seeking out big animal encounters or spectacular wrecks. Take the time to investigate the results and credibility of the group coordinating your project, since some that claim high ethical standards in conservation and research fall well short of expectations. There are others, of course, who perform genuinely valuable work, and for many divers this is the most rewarding and educational aspect of their entire diving career.

LIVEABOARD DIVE VESSEL
A liveaboard is essentially a floating dive center, and as such should have all the facilities on board to guarantee safety, comfort, and a memorable diving adventure.

LOCAL KNOWLEDGE
Most dive centers will be able to take you out on a boat and show you the best of the local dive spots.

EQUIPMENT RENTAL
Renting gear when you reach your destination is one way of lightening your travel burden and avoiding penalties for carrying excess baggage.

TIPS AND PRECAUTIONS

Diving overseas involves putting a great deal of trust in your host, be it a local guide or dive operator, or a leader of a trip or expedition. Following a few simple rules and precautions will make this a less daunting prospect, and may also ease the logistical problem of transporting expensive equipment across the world.

Deciding on a destination is the first step in planning a successful trip. Finding a location that really appeals to you, yet stays within your budget, will make your trip more rewarding than simply opting for the best-known sites or the cheapest deals. A brief period of research can reap huge rewards, and the range of information sources now available makes this a relatively simple exercise.

CHOOSING A DIVE BAG

While you can pack your gear in any case or bag you wish, most divers use bags specially designed to stand up to the rigors of dive traveling (*see p.79*). Soft bags, such as duffle bags, can fold up and be stashed away at your destination. Semirigid wheeled cases make carrying easier, but they are less flexible. Rigid bags are heavier, but offer better protection for your gear.

mares
mares

Semirigid wheeled bag

After identifying the aim of the dive trip, and the location to be visited, the next stage is to choose a host operator. Many local tourist boards can recommend registered operators who are known to work to a high standard. In addition, the PADI website (*see pp.34–35*) lists dive operators who have met a series of demanding criteria. This independent evaluation is invaluable in identifying the most professional centers and boats.

While rental equipment is generally of a good quality, many divers prefer to travel with their own gear. This is prudent, since unfamiliarity with rented gear can create an uncomfortable (and occasionally unsafe) diving experience. The diver also has the assurance of knowing that their own gear fits well, is functional, and has been tested recently.

Most airlines do not officially offer excess baggage allowances for dive gear (the dive industry is lobbying hard for a more reasonable approach to this issue), but a phone call in advance of the trip often works wonders—as does a courteous approach when checking in. Carry delicate items, such as regulators and dive computers, in your carry-on; the latter, in particular, may be affected by pressure changes in the hold of the plane.

Special diving insurance is vital, since you will not be covered by general travel policies. You need cover for damage to equipment in transit, medical care abroad (such as recompression treatment) and repatriation in the event of a serious diving incident. Policies usually cover divers to a depth of 100 ft (30 m)—more than adequate for most trips.

ONWARD TRAVEL
If the final leg of your trip or any travel between islands involves flights on small aircraft, check if the carrier imposes their own luggage restrictions.

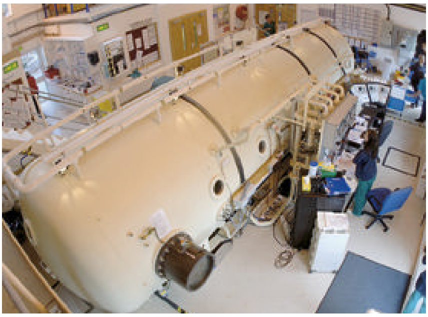

RECOMPRESSION CHAMBER
The costs of recompression—if it is available at all—can be exorbitant, and many chambers will not treat divers without proof of insurance.

On arrival at your target destination, it is always advisable to carry out a few simple checks when diving with the host operator. All dive operators should have emergency oxygen supplies appropriate to the range and scale of diving they provide, as well as first-aid facilities and effective communications. It is worth making a quick visual inspection of the compressor facility—air certificates should be on display, but it is relatively easy to tell a clean, well-maintained compressor from a neglected one.

Europe

As a dive destination, Europe tends to be greatly underestimated by the international diving community. With an excellent diving infrastructure and well-established resorts and travel networks, Europe offers an eclectic mix of dive environments and a host of wrecks to explore.

TEMPERATE ZONE

Europe is, on the whole, a region of temperate waters, and this provides tremendous seasonal variation in the marine life around its coasts. The waters of western Europe are cold and rich in nutrients, and historically have been some of the richest fishing grounds on Earth. Migratory species move around the western edge of the continent, many borne on the undersea highway of the Gulf Stream. Consequently, the same dive site can be unrecognizable from winter to summer.

In diving terms, Europe is a continent of extremes, with Arctic diving to be had in the dramatic Norwegian fjords to the north, while subtropical diving can be enjoyed in the warm waters of the Mediterranean Sea to the south.

FISHING BOATS AT ALBUFEIRA, PORTUGAL
Europe's fish stocks have been an important resource for millennia, but overfishing has now put the populations of some species at risk.

Europe has long been the scene of intense shipping activity, a fact reflected in the thousands of wrecks that today dot the seabed. These wrecks represent a history of seafaring itself—from Viking longships, to all types of fishing vessels, and merchant fleets that foundered in violent storms. Sunken warships from virtually all of the continent's navies bear witness to the many wars that have ravaged Europe through the ages.

NORWEGIAN FJORD
Carved by glaciers millions of years ago, the fjords offer excellent dives in crystal-clear water, against a superb backdrop of snow-capped mountains.

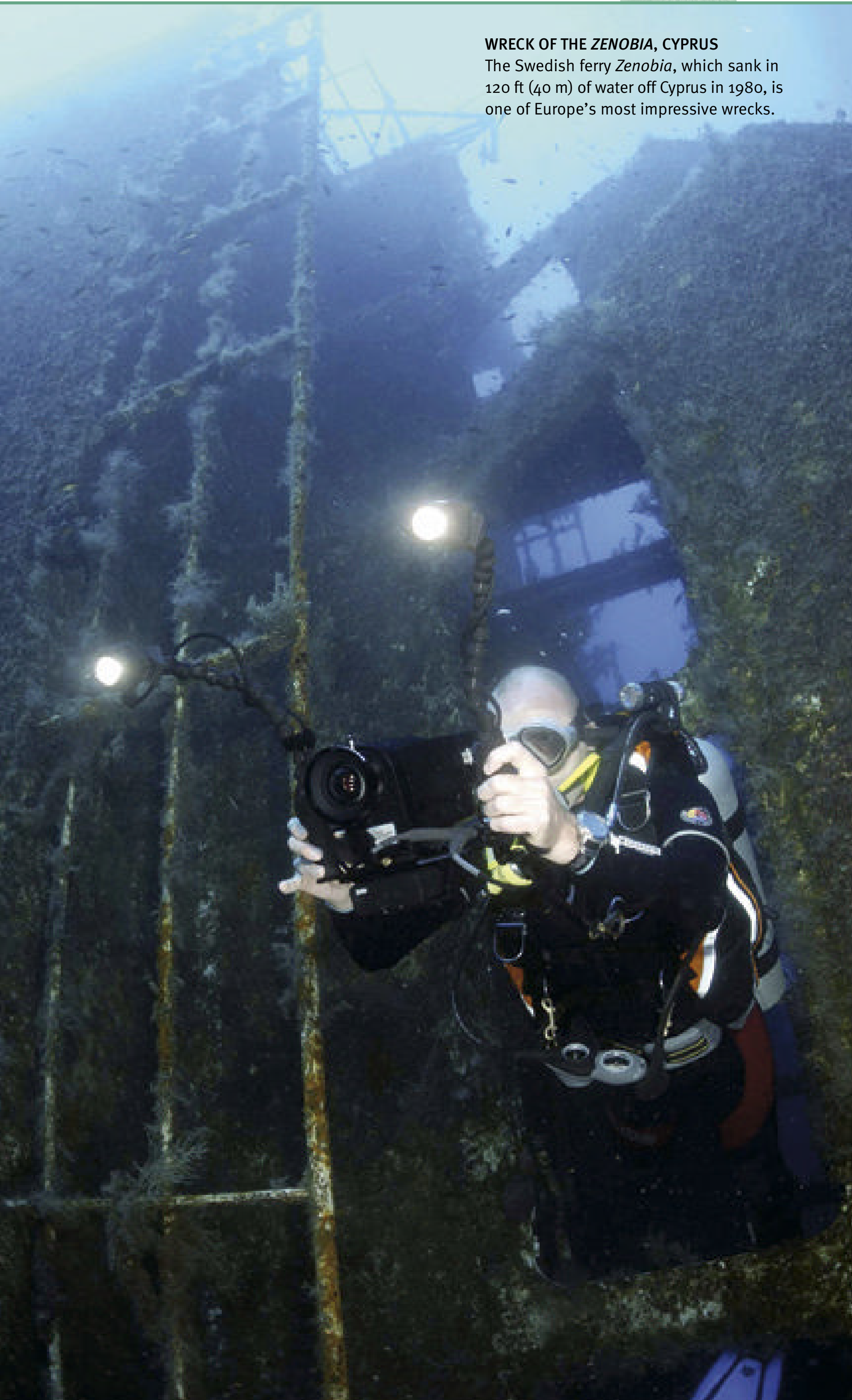

WRECK OF THE *ZENOBIA*, CYPRUS
The Swedish ferry *Zenobia*, which sank in 120 ft (40 m) of water off Cyprus in 1980, is one of Europe’s most impressive wrecks.

Wreck of the *Zenobia*

LARNACA HARBOR, CYPRUS

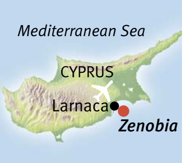

A wreck for all grades of divers, the *Zenobia* offers shallow and deep dives, and a range of penetrations from gentle investigations through to technical explorations. Readily accessible, this wreck is one of the most popular dive sites in Europe.

ACCIDENTAL SINKING

In June 1980, the 10,000-ton Swedish passenger ferry *Zenobia* ran into difficulties off the coast of Cyprus. A problem with the autopilot caused the vessel to heel over and sink over the course of several days, giving plenty of time for the passengers to be evacuated, but leaving the cargo, including 135 trucks, to sink with it.

ESSENTIAL INFORMATION

WATER TEMPERATURE 70–79°F (21–26°C)

ECOSYSTEM Subtropical

WHEN TO VISIT Divers can visit year-round, but diving is at its best between March and October.

MUST-SEES Vehicle hold Number One; the bridge; the accommodations area.

REVERED WRECK

The *Zenobia* has become one of the most popular wrecks in diving because of its accessibility and the range of dives it offers. Divers can access the two main vehicle decks, the bridge, the accommodations area, and the restaurant. More extreme penetrations of the wreck include the engine room, although this is a multilevel, technical dive that requires careful planning and training. While not suitable for the novice, such dives are thrilling challenges. For those seeking a more sedate experience, the exterior of the wreck also provides a dramatic spectacle, with its props, huge hull, and superstructure still in excellent condition.

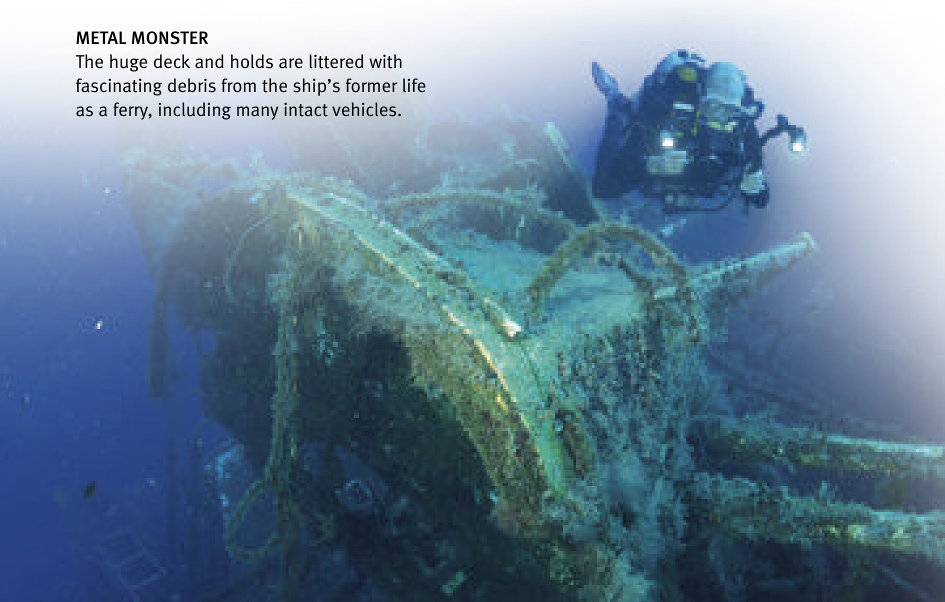

METAL MONSTER The huge deck and holds are littered with fascinating debris from the ship's former life as a ferry, including many intact vehicles.

Medas Islands

CATALONIA, SPAIN

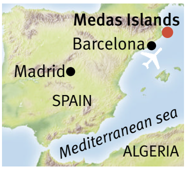

The Medas Islands offer a glimpse of how Mediterranean marine life was in days of old—large fish shoals, passing pelagics, densely colonized reefs, and fine coral formations. Closely protected, the islands have much to offer visiting divers.

CONSERVATION AREA

The Medas Islands were granted the status of a Nature Reserve in 1983, and have therefore enjoyed more than 20 years of official protection. The life around the islands reflects this, with perhaps a greater abundance of marine life and range of species than anywhere else in the western Mediterranean.

OUTWARD BOUND
A dive boat prepares to embark on the short voyage to the islands. Divers flock to the area to enjoy the profusion of marine life sheltering in the clear blue waters of the nature reserve.

DIVING THE ISLANDS

Located only 1 mile (1.6 km) off the northeastern coast of Spain, the islands benefit from the nutrient rich runoff from the nearby Ter River. In addition, cold water upwellings on the craggy reefs around the islands create an oxygen-rich environment that allows marine life to thrive. As well as the usual Mediterranean species, such as scorpionfish, octopuses, and moray eels, local residents include large shoals of barracuda and bream, and there have even been sightings of eagle rays around the islands. Diving highlights include the famous Dolphin Cave—a 150-ft (46-m) tunnel set in a rock face—and the tiny islet of Carall Bernat. It is also reassuring to note the return of red coral to the seas around the islands, a natural resource that was for many years exploited by the jewelry industry. Though a small fee is levied by the authorities for diving around the Medas Islands, the success of the ongoing conservation policy justifies the extra expense.

ESSENTIAL INFORMATION

WATER TEMPERATURE 57–77°F (14–25°C)

ECOSYSTEM Subtropical

WHEN TO VISIT The best time to visit the Medas Islands is between March and September.

MUST-SEES Dolphin Cave; Carall Bernat; red coral formations; rare sightings of eagle rays.

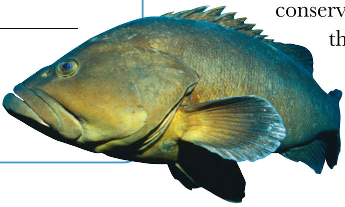

Dusky groupers are just one of the species living under protection around the islands

Sardinia

CENTRAL MEDITERRANEAN, ITALY

ITALY
CORSICA
Rome
Sardinia
Cagliari

A rugged island in the middle of the Mediterranean, Sardinia has a dramatic geological past reflected in the caverns and caves that dot its coast. Although these are impressive features, Sardinia also has unique marine life and fascinating wrecks.

ROCKY COAST

The sharp reefs, dark overhangs, and craggy shoreline of Sardinia play host to an unusual array of marine life for the Mediterranean—a body of water not particularly famed for its marine diversity. Sardinia's geographical position means that it receives species from the Red Sea to the east (thought to be due to animals traveling through the Suez Canal), and the Atlantic to the west. Divers may encounter any of six species of wrasse, two species of groupers, wonderfully colorful sponges and corals encrusting rock walls, and a unique giant mollusk called the noble pen shell.

LOCAL CHARACTER
The common octopus is one of the key species found off the rocky Sardinian shoreline. This highly intelligent invertebrate is a common sight for divers.

NETWORK OF CAVERNS

This coastline is also famed for its caves and caverns. One system—Nereo Cave on the northwest coast—is particularly impressive, stretching for over 1,000 ft (300 m). As with all caves, caverns, and overhangs in Sardinia, such areas of low light are festooned in thick growths of red coral, for which the island is particularly well known.

There are also a number of fine wrecks to be dived. The best known of these is the wreck of the *Angelica*, a 4,400-ton freighter that ran aground on the island's jagged reefs in 1983, at Capo Falcone. The wreck lies at a maximum depth of 65 ft (20 m), so represents a relatively easy dive. The shallow location means that wind and weather have taken their toll on the wreck's structure over the years, but the site is worth a visit should you desire a change of pace from the sea caverns that dominate Sardinian diving. With many attractive beaches and towns along the coast, there is much to enjoy on shore, as well as beneath the waves.

ESSENTIAL INFORMATION

WATER TEMPERATURE 66–77°F (19–25°C)

ECOSYSTEM Subtropical

WHEN TO VISIT Sardinia can be dived year-round, but the summer months offer warmer, if more crowded, seas.

MUST-SEES Red coral; Nereo Cave; noble pen shells; wreck of the *Angelica*.

Ustica Island

SICILY, SOUTHERN ITALY

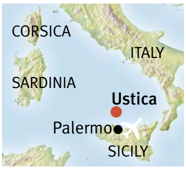

Ustica Island was described by no less an authority than Jacques Cousteau as the most beautiful island dive site in the Mediterranean. A tiny volcanic outcrop off the coast of Sicily, its qualities have seen it established as a Marine Nature Reserve.

SMALL IS BEAUTIFUL

Ustica Island may owe its undisturbed ecosystem to the fact that it was a penal colony until 1950. A tiny island—it has a total surface area of 3 sq miles (8 sq km)—it is nonetheless one of the most significant sites in the Mediterranean, to the extent that Italy's Academy of Underwater Sciences and Techniques is based here. The volcanic origins of the island (seen in the name itself—the Latin *usta* translates as a burnt red color) mean that the reefs around the island are particularly dramatic—with a craggy underwater topography featuring numerous caves, caverns, and overhangs.

SILVER SHOAL
Barracuda shoal in large numbers in the waters off Sicily, and are frequently sighted by divers visiting the Marine Reserve at Ustica.

ESSENTIAL INFORMATION

WATER TEMPERATURE 59–77°F (15–25°C)

ECOSYSTEM Subtropical

WHEN TO VISIT Diving takes place on Ustica Island year-round, but in winter the seas are relatively chilly.

MUST-SEES Red coral formations; the Colombara Bank; Medico Tunnel.

TOP DIVES

One of the best sites is Medico Tunnel, off the northwest of the island, which consists of a tall pinnacle with a tunnel passing directly through it. Another site of particular note around the island is the Colombara Bank—well known for its beautiful reefs and aggregations of large fish, such as barracuda and tuna.

The Hebrides

WESTERN SCOTLAND

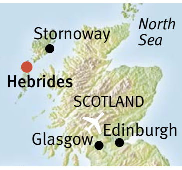

The islands of the Hebrides have the feel of genuine wilderness about them. Precipitous mountains plunge into dark bays and craggy lochs, and white beaches lead to waving kelp forests, creating one of the finest diving regions in Europe.

RICH SEAS

The topography of the Hebrides lends itself readily to abundant marine life, with steep walls in the lochs, convoluted rocky reefs in the open water, and strong tidal movements through numerous narrow channels connecting the islands. Washed in oxygen-rich cold water, the islands are host to a dazzling array of marine life both large and small. Notable sites in the region include dives around Skye (particularly the small island of An Dubh Sgeir), the wrecks and reefs of the Sound of Mull, the famous dives around Oban (home to one of the most established and respected dive operations in the UK), and the newly discovered dive sites of the remote Summer Isles. The last include the wreck of the *Fairweather V*, a fishing vessel that sank in 1991 and is still intact and in good condition.

SURVIVING WILDERNESS
The characteristic rocky coastlines of the Hebrides are perhaps one of the last truly wild places in the United Kingdom.

TEMPERATE-WATER ECOSYSTEM

The Hebridean islands provide one of the richest and most complete insights into the marine life of a temperate-water zone. Visitors to the islands' rocky shores include itinerant whale and dolphin species, ling, conger eel, and a profusion of smaller native fish species. Colonial and encrusting organisms coat the rock walls, with anemones and sponges creating colorful and dramatic reefs. These are patrolled by otters—the Hebrides is one of the few dive sites in the United Kingdom where these fascinating mammals have largely taken to the sea. If conditions do not permit diving, the Scottish Sealife and Marine Sanctuary near Oban is well worth a visit. It has a spectacular aquarium and a busy otter and seal sanctuary.

A diver examines an undersea wall covered in dead men's fingers and plumose anemones

In the winter months, the islands of the Hebrides are subject to wild weather and cold water, with many dives becoming very demanding due to dark water and strong tides. In the summer months, the region really comes to life, with some of the beaches on the more remote islands becoming gateways to absolutely top-class shallow dives.

ANIMAL MAGIC

The shallow reefs just offshore in the Hebrides are some of the busiest temperate reefs anywhere in Europe, playing host to large edible crabs and lobsters, various species of cephalopods including cuttlefish and octopus, colorful nudibranches, and an array of fish species including some spectacular wrasse.

Larger animals encountered in the open seas around the Hebridean archipelago, as well as in its many dramatic coves and bays, include both the common and the Atlantic seal. Bottlenose dolphins are regular visitors to these shores, as are the more rarely seen rissos and white-beaked dolphins. Whale species that can be spotted include minke and pilot whales, orcas, especially around the islands of Coll and Tiree, and, if you are very lucky, sperm whales and humpback whales. There are large gatherings of basking sharks late in the year, although predicting when and where these will take place is almost impossible. Occasionally, sunfish and leatherback turtles also visit the region.

It is not only the animals that provide the excitement for divers visiting this region. The third largest whirlpool on Earth can be seen at the Gulf of Corryvreckan, between the islands of Scarba and Jura.

ESSENTIAL INFORMATION

WATER TEMPERATURE 46—64°F (8–18°C)

ECOSYSTEM Temperate

WHEN TO VISIT Diving is possible all year, but can be stormy in winter.

MUST-SEES Otters; wreck of the *Fairweather V* in the Summer Isles; An Dubh Sgeir in Skye.

Scapa Flow

ORKNEY ISLANDS, GREAT BRITAIN

Orkney Islands
Scapa Flow
North Sea
SCOTLAND
Glasgow
Edinburgh

The most famous wreck-diving location in Europe, Scapa Flow is a huge natural harbor amid the islands of Orkney off northern Scotland. Its fame stems from the fact that it was the site of the largest ship-scuttling action in maritime history.

ANCIENT HARBOR

Although Scapa Flow has been used as an anchorage since Viking times (the name derives from the Old Norse *Skalpeidfloi*, "Bay of the Long Isthmus"), one event ensured its fame in the diving world. After World War I, the German High Seas Fleet was impounded in Scapa Flow by the Allies. The fleet, consisting of 79 vessels, was imprisoned there for over a year. On June 21, 1919, Admiral Ludwig von Reuter, the German commanding officer, misread a newspaper headline and assumed that hostilities were about to resume and ordered his ships to be sunk by their own crews rather than let them fall into the hands of Allied forces.

GRAVEYARD OF SHIPS

The subsequent mass scuttling saw the majority of the fleet sunk, although the Allies managed to save 22 vessels by towing them into the shallows. Several of the German ships were salvaged in the intervening years, but three battleships, four light cruisers, and five torpedo boats still lie on the seabed. In addition to this rich array of wrecks, the British Admiralty sank 50,000 tons of shipping during World War I and II as blockships in the narrow entrances of the Flow to prevent raids by German submarines.

With several other wrecks of varying origins scattered throughout the Flow, the site has become a mecca for serious wreck divers. Although the larger German wrecks can be demanding dives, there are many easier options for the less experienced. The blockships in particular are splendid dives, sitting in shallow tidal channels, washed by cold nutrient-rich waters and teeming with marine life.

Notable wrecks in Scapa are the *Kronprinz Wilhelm*, the *Brummer*, and

ESSENTIAL INFORMATION

WATER TEMPERATURE 46–68°F (8–20°C)

ECOSYSTEM Temperate

WHEN TO VISIT Best diving conditions are between March and September.

MUST-SEES Wrecks of *Koln*; *Kronprinz Wilhelm*; *James Barrie*; *Gobernador Bories*; basking sharks; seals.

RUST IN PEACE
Not all of Scapa Flow's historic wrecks lie beneath the sea. Sandy beaches also bear witness to the past.

the *Koenig*. Amongst the blockships the *Gobernador Bories* has become particularly renowned, and the wreck of the trawler *James Barrie* is a magnificent sight at 131ft (40m)—sitting almost perfectly preserved on the sea floor.

WILD SCAPA

Scapa Flow has an extensive array of marine life, with the shallow wrecks in particular playing host to huge numbers of ballen and cuckoo wrasse, lobsters, conger eels, octopuses, and beautiful nudibranchs. Larger residents include grey seals, dolphins, and basking sharks in the summer months, and also the occasional visiting pod of orcas. Though the wrecks of Scapa Flow are, naturally, its greatest attraction, the marine life here is a welcome bonus.

VALUABLE SALVAGE

During the 1920s, the British salvage firm Cox & Danks raised many of the scuttled German battleships for scrap. Metal from the wrecks is still used today to make sensitive scientific instruments; their steel was forged before the age of atomic weapons tests, and so is a rare source of high-grade metal that is completely free of radioactive particles.

Salvage work at Scapa Flow

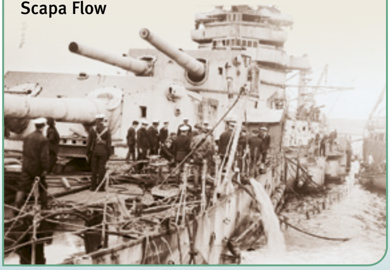

GLIMPSE INTO HISTORY
Divers at Scapa Flow can inspect the urchin-covered remains of German battleships scuttled shortly after the close of World War I.

The Isles of Scilly

ENGLISH CHANNEL, GREAT BRITAIN

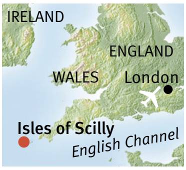

Something of a well-kept secret among British divers, the Isles of Scilly are a cluster of tiny islands that sit at the tail end of the Gulf Stream. Rich marine life, lively reefs, and an abundance of wrecks make this archipelago a diver's paradise.

AZURE WATERS
The seas around the Scillies have a clarity more typical of southern France than southern England. This makes for excellent diving.

SPARSELY POPULATED

The Isles of Scilly (or the Scillies, as they are universally known) consist of 300 granite islands 28 miles (45 km) off the southwestern tip of England. Only six of the islands are inhabited, and even these could hardly be described as crowded. The islands are low-lying and very beautiful, with white sandy beaches fringing green islands.

The islands' position in one of the world's busiest shipping channels means that wrecks are abundant. The most recent wreck here was the cargo ship *Cita*, which foundered on March 26, 1997, leading to a bonanza of free goods for enterprising locals. This vessel is now an excellent dive, lying in 115 ft (35 m) of clear water. By contrast, the wreck of the *Eagle*, a British warship that sank in 1707, offers a glimpse into naval history, with cannons still visible on the seabed.

ESSENTIAL INFORMATION

WATER TEMPERATURE 46–64°F (8–18°C)

ECOSYSTEM Temperate

WHEN TO VISIT Diving is possible year-round, although in winter there can be violent storms.

MUST-SEES Inner Gilstone Rock; *Cita* and *Eagle* wrecks; gray seals.

OTHER ATTRACTIONS

As well as numerous wrecks to explore, divers also have access to splendidly busy reefs, and may even encounter larger species such as seals, as well as seasonal visitors, including basking sharks.

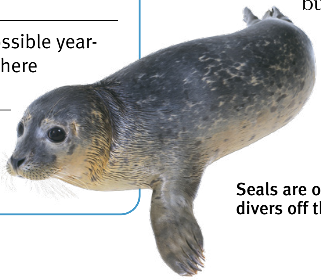

Seals are often encountered by divers off the Scillies

The Skelligs

COUNTY CORK, IRELAND

REPUBLIC
OF IRELAND
Dublin
The Skelligs
Cork

Two rocks that jut out of the Atlantic at the eastern end of the Gulf Stream, the Skelligs are a beacon for wildlife in the rich seas off southwestern Ireland. This has created a world-class dive site in one of the finest dive regions to be found anywhere in Europe.

TWIN ISLANDS

The Skelligs sit 11 miles (18 km) off the southwestern coast of Ireland, and rise almost 700 ft (200 m) above the wild Atlantic waters below. They consist of two huge rocks—Skellig Michael and Little Skellig—around 1 mile (1.5 km) apart. The craggy faces and reefs of the rocks are washed by the waters of the North Atlantic Current, a flow of water that carries the tail end of the Gulf Stream. This brings warm waters from the mid-Atlantic, accompanied by occasional large species, such as dolphins. This current is the secret of the area's richness.

ESSENTIAL INFORMATION

WATER TEMPERATURE 48–72°F (9–22°C)

ECOSYSTEM Temperate

WHEN TO VISIT The best time of year to dive on the Skelligs is between April and September.

MUST-SEES The Pinnacle dive site; seal colony; gannets on Little Skellig.

HAVEN FOR MARINE LIFE

The rock faces of the Skelligs are coated in colorful encrusting organisms, such as anemones, sponges, and dead man's fingers. Every nook and cranny has an occupant, with huge edible crabs, lobsters, conger eels, and rocklings all jostling for position. In the kelp forests, wrasse and dogfish lurk, while mackerel and bass cruise the open waters. Larger residents include a healthy gray seal colony, as well as visiting basking sharks.

SHELTERING STONE
The isolated, rugged setting of Skellig Michael may look inhospitable, but beneath the water's surface, the area teems with vibrant marine life.

Lundy

BRISTOL CHANNEL, SOUTHWESTERN ENGLAND

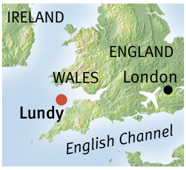

Lundy Island sits amid the powerful tidal stream of the Bristol Channel. Washed constantly by waters rich in nutrients, it is host to wonderfully busy reefs and the occasional larger visitor arriving from the great waters of the Atlantic, to the west.

PIONEERING RESERVE

Lying 10 miles (16 km) off the coast of Devon, Lundy is a craggy granite outcrop approximately 3 miles (5 km) in length. The richness of its reefs and the abundance of marine life saw Lundy established as the first Marine Nature Reserve in the United Kingdom.

There are two distinct faces to Lundy—the more exposed western shore, which faces the swells and storms of the Atlantic, and the more benign eastern shore. The topography of the granite creates wonderfully dramatic cliffs and reefs, with the regular tidal movement in the channel bathing these rock faces in nutrient-rich water.

GENTLE GIANT
The gaping mouth of the basking shark nets only the tiniest plankton for its food. The species is often encountered off Lundy in summer.

REEF POPULATIONS

Divers will encounter an array of British reef life around the island—lobsters, several species of wrasse, huge shoals of bib and pollack, bass, conger eel, and octopus. More unusual Lundy residents include anglerfish and red-banded fish—the latter being unique to the island. The island is also frequently visited by basking sharks and dolphins during summer months.

The wreck of the British warship *Montague* can be found on Shutter Reef at a depth of 15–50 ft (5–15 m). A 14,000-ton battleship, it ran aground in fog in 1906 while on exercises in the Bristol Channel. Intensive efforts to refloat it failed. Although the wreckage is scattered and broken, there remain piles of armor plate amid the kelp. The *Montague* was armed when it sank, so beware of live shells.

ESSENTIAL INFORMATION

WATER TEMPERATURE 46–72°F (8–22°C)

ECOSYSTEM Temperate

WHEN TO VISIT Visit Lundy from April to September for the best diving.

MUST-SEES Basking sharks and dolphins; the wreck of the *Montague*; Gannets Rock; Knoll Pins.

Norwegian Fjords

NORTHWESTERN COAST, NORWAY

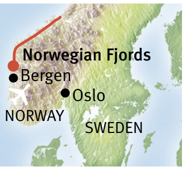

Cold water, steep walls, and strong currents may not be everyone's ideal diving experience, but for some marine life, these are ideal conditions. Diving the Norwegian fjords is not for the faint-hearted, but the rewards are well worth the effort.

WILD COASTLINE

Norway's convoluted coast stretches for around 14,000 miles (22,000 km) in a series of jagged inlets, bays, and fjords, and is dotted with over 50,000 islands. Norway also has, in Sognefjord, the longest (140 miles/225 km) and deepest (4,430 ft/1,350 m) fjord on Earth.

There are many great dive sites along this gloriously wild coastline: one of the finest regions—and one that is gaining an international reputation for the quality of its diving—is Ryfylke, to the southwest. Diving the fjords requires previous experience and competence in cold-water diving, along with the relevant cold-water gear. The topography of the fjords creates steep walls colonized by kelp, dead men's fingers, sponges, and some rare deep water corals. Piked dogfish, skate, catfish, and numerous crustaceans are particularly abundant in Ryfylke. Seasonal highlights include migratory visits from salmon and their attendant predators, such as orcas.

ESSENTIAL INFORMATION

WATER TEMPERATURE 36–68°F (2–20°C)

ECOSYSTEM Temperate

WHEN TO VISIT The fjords can be dived year-round, but winter months can present cold, challenging conditions.

MUST-SEES Pulpit Rock; Kjerag Wall; Lysefjord; visiting orcas.

DRAMATIC HORIZON
The plunging walls of the fjords, both above and below the water's surface, set the tone for this rugged and beautiful destination.

Iceland

NORTH ATLANTIC

Akureyri
ICELAND
Höfn
Reykjavík

Born from the depths of the sea itself, Iceland is still a youngster in geological terms. The country's volcanic past provides some unique dive sites, including the opportunity to explore the marine life around a hydrothermal vent.

VOLCANIC BIRTH

Iceland was formed by volcanic action on the Mid-Atlantic Ridge, and has a surface area of just over 38,600 sq miles (100,000 sq km). The island is still experiencing an extraordinary level of volcanic activity, with 30 eruptions recorded in the last 200 years. Iceland's coastline is classically volcanic, bristling with craggy inlets, dramatic cliff and rock formations, and fissured reefs.

There are two diving experiences in Iceland that are not found anywhere else in the world. The first is the legendary Strytan hydrothermal vent, which rises from a depth of 230 ft (70 m) to within 50 ft (15 m) of the water's surface. Divers can see—and indeed feel—the hot water rising from the vent while enjoying the diverse invertebrate and fish life drawn into this oasis of warmth in an icy sea. The second is Silfra, a water-filled ravine in Thingvellir National Park. This is another dive that gives a marvelous insight into Iceland's fiery origins. Part of a huge rift in Earth's crust between the Eurasian and American continental plates, Silfra is filled with glacial meltwater that has been filtered through lava for decades, giving famously crystal-clear visibility.

ESSENTIAL INFORMATION

WATER TEMPERATURE 34–46°F (1–8°C)

ECOSYSTEM Temperate

WHEN TO VISIT Diving in Iceland is at its best in summer, between June and September.

MUST-SEES Strytan hydrothermal vent, Silfra in Thingvellir National Park.

ICELANDIC COASTLINE
The dramatic geological eruptions that gave birth to Iceland are evident in its craggy and forbidding cliffs and wild shores.

White Sea, Russia

NORTHEASTERN RUSSIA

Barents Sea
White Sea
Arkhangelsk
FINLAND
RUSSIA

The White Sea is one of the most beautiful of the seas of northern Russia, and the only place in Russia where you can dive under the ice. The marine environment here is relatively untouched by human activity and the diving is superb.

FROZEN WORLD

Diving beneath ice is exciting and adventurous, and the visibility—anything from 50 to 165 ft (15–50 m)—can be stunning. The water is not affected by waves (due to the protection of the ice), and low light conditions mean that algal growth is minimal. The water in the White Sea, which lies across the Arctic Circle, is frozen from November until April, but the best time to go is in mid-March. Any earlier and the temperatures are very cold, far below zero; any later and the ice has retreated and you cannot get to the best dive sites. The Gulf Stream warms some of the waters farther north, preventing them from freezing over.

DENIZEN OF THE ICY DEEP
A diver comes face to face with a gorgonocephalus—or, more dramatically, “gorgon’s head”—a bizarre form of basket star common in the White Sea.

RARE ORGANISMS

The White Sea offers plenty of life to see and photograph: for example, there are some 80 species of fish, around 30 species of nudibranchs, and five species of seals. Shoals of tiny comb jellyfish also form an extraordinary sight, the light glinting off them in a million tiny rainbows. It is possible to encounter beluga whales, and occasionally orcas and Greenland sharks, which venture into these waters.

In addition to some great diving, there are possibilities of ice snorkeling in fast-flowing rivers and among the icebergs and, looking to the skies, witnessing the stunning beauty of the atmospheric phenomenon known as the aurora borealis, or northern lights. Also within excursion distance of dive sites on the east coast is Star City, the Russian cosmonaut training facility; you can even arrange to dive at the hydrospace laboratory at the MIR Space Center, used to prepare cosmonauts for the weightless conditions of space.

ESSENTIAL INFORMATION

WATER TEMPERATURE 31°F (–0.5°C) at the surface to 27°F (–3°C) deeper down

ECOSYSTEM Polar

WHEN TO VISIT Diving is best in mid-March (*see also, above*).

MUST-SEES Beluga whales; seals; aurora borealis; cosmonaut facility.

Africa and the Middle East

A continent synonymous with adventure and exploration, Africa offers spectacular shark encounters and many miles of unexplored reef. The Middle East boasts the Red Sea, perhaps the most famous of all places to dive, with a highly developed dive industry to match.

AFRICAN HIGHLIGHTS

South Africa is renowned throughout the world for big animal encounters—in particular with the great white sharks of the Cape—and for the epic shark dives to be had off Natal. The latter is also the scene of one of the greatest spectacles in the marine world—the legendary Sardine Run, where gigantic sardine shoals move slowly up the coast, harried by dolphins, whales, sharks, seals, and gannets.

Lying to the northeast of the African coast are the magnificently wild beaches and reefs of Mozambique and the islands off Kenya and Tanzania. Farther out to sea lie Mauritius, the Seychelles, and the Comoros, all offering diving of real quality on reefs influenced by the abundant marine life of the Indo-Pacific region to the east.

DESERT MEETS SEA
At many sites in Africa, the warm blue sea laps against a harsh, arid landscape of bleached rock.

VIBRANT ECOSYSTEM
Africa's varied reefs sport a profusion of colorful soft corals, which play host to a stunning array of marine life.

CRYSTAL-CLEAR WATERS
One of the saltiest bodies of water in the world, the Red Sea is also renowned for its superb visibility.

RED SEA RICHES

The outstanding gem of the Middle East is the Red Sea, perhaps the most heavily dived body of water in the world. From the northern resorts of Eilat, Ras Mohammed, Sharm El Sheik, and Dahab, through to the wilder southern sites like the Brothers and the coast of Sudan, this region provides superb reef diving, as well as varied wrecks, such as the famous *Thistlegorm.*

Despite its popularity, the Red Sea still has unexplored regions, and new dive sites continue to be opened, so it will always have much to attract divers.

Gansbaai

WESTERN CAPE, SOUTH AFRICA

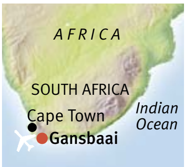

Gansbaai offers a rare chance to see the ultimate marine predator. With an island packed with breeding seals just offshore, Gansbaai is one of the finest locations on Earth to get up close and personal with the great white shark.

AWESOME ANIMAL
Great white sharks cruise the cold waters near Dyer Island, on the hunt for their preferred prey, fur seals.

SHARK CENTER

Gansbaai initially appears to offer little as a dive destination, with a small harbor on a rocky shore that is frequently battered by large swells. It is only when the diver stands on the wharf and squints into the middle distance that the reason for this site's global fame emerges. A low island several miles offshore is the home of 60–90,000 fur seals, and proves irresistible to the great whites that cruise this region of South Africa. Great whites are one of the ocean's most formidable predators, growing up to 20 ft (6 m) in length. The great white's notoriety as a man-eater, however, is a misrepresentation of this fascinating creature, about which surprisingly little is known.

ESSENTIAL INFORMATION

WATER TEMPERATURE 52–63°F (11–17°C)

ECOSYSTEM Temperate

WHEN TO VISIT Year-round shark activity; numbers peak May to September.

MUST-SEES Cage diving with great white sharks at Dyer Island, plus seal dives in a few recommended areas.

MAIN ATTRACTION

The presence of the sharks has spawned a thriving industry, with thrill-seekers coming from all over the world to dive with the great whites. Only cage diving is permitted with the sharks, but it is possible to dive within the seal colonies around the island in certain regions that are considered safe by local dive operators. Farther afield, there are beautiful cold-water reefs covered in swaying fields of kelp, but there is really only one reason why divers visit Gansbaai—that most magnificent of marine predators, the great white shark.

Aliwal Shoal

KWAZULU-NATAL, SOUTH AFRICA

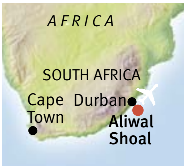

Aliwal Shoal is one of the greatest adventure dive sites on Earth. The excitement begins on the beach, with perhaps the most dramatic surf launch in the diving world, and ends with outstanding shark encounters above a thriving reef system.

CROSSROADS IN THE SEA

Aliwal Shoal is a mountain of sandstone that juts into the underwater highway of the Agulhas Current. The site is renowned for shark encounters, in particular the famous ragged-tooth sharks that lurk within the caves and caverns of the reef. There are also Zambezi sharks in great numbers at the right time of year, as well as more occasional encounters with tiger sharks, and, thrillingly, there are a few rare sightings of great whites. However, Aliwal Shoal has much more to offer than shark encounters, since the mixture of both warm water reef fish and temperate species creates one of the most diverse reef systems in all of southern Africa.

VISITING SPECIES

Added to the array of life are transient visitors, such as migrating humpback and right whales, as well as turtles and huge brindle bass. The dive site is also directly in the path of the Sardine Run, one of the most impressive marine migrations anywhere in the world's oceans. Sardine shoals travel more than 1,000 miles (1,600 km) in this great annual exodus.

ESSENTIAL INFORMATION

WATER TEMPERATURE 66–79°F (19–26°C)

ECOSYSTEM Subtropical

WHEN TO VISIT Ragged-tooth sharks in residence from July to October; Zambezi sharks can be seen October–April.

MUST-SEES Ragged-tooth sharks; Sardine Run; migrating whales.

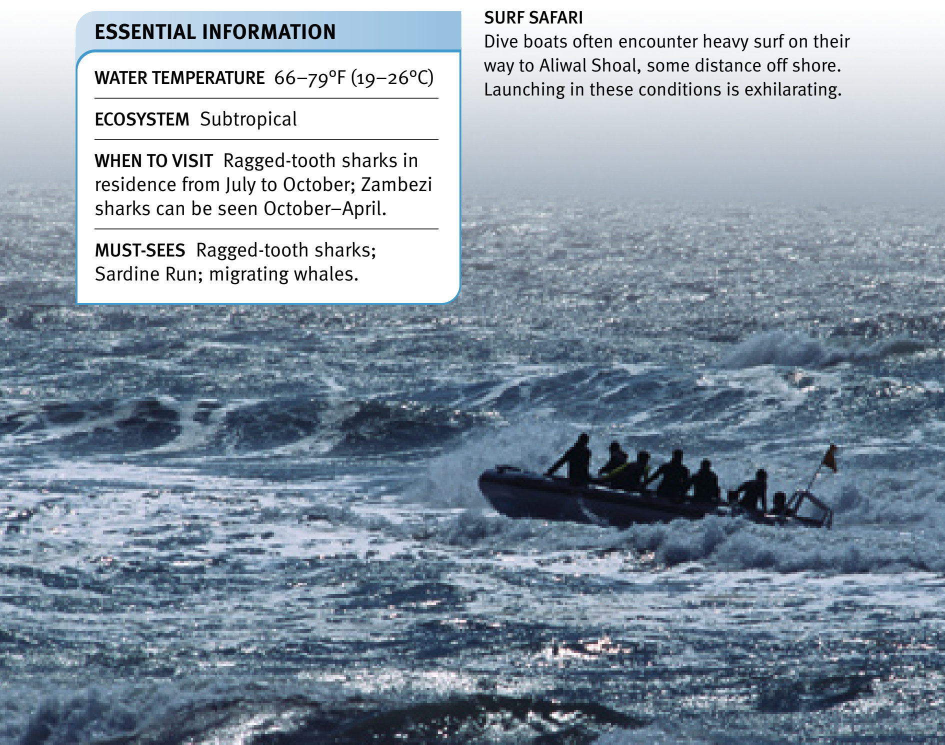

SURF SAFARI
Dive boats often encounter heavy surf on their way to Aliwal Shoal, some distance off shore. Launching in these conditions is exhilarating.

Sodwana Bay

KWAZULU-NATAL, SOUTH AFRICA

AFRICA
Maputo
Sodwana Bay
SOUTH AFRICA
Durban
Indian Ocean

The only coral reef dive site in South Africa, Sodwana is set in the heart of a national park in northern Natal. The reefs host more than 1,000 species of fish, as well as impressive transients, such as whale sharks, billfish, manta rays, and whales.

ESSENTIAL INFORMATION

WATER TEMPERATURE 70–84°F (21–29°C)

ECOSYSTEM Tropical reef

WHEN TO VISIT Year-round diving, but visit October to February for a chance of sighting whale sharks at Sodwana.

MUST-SEES Seven Mile Reef; Nine Mile Reef; surf launch; whale sharks, mantas, and other visiting species.

REMOTE REEFS

Sodwana lies in a beautifully remote region of South Africa, nestling right up against the border with Mozambique to the north. Simply getting to the site is something of an adventure, requiring a journey by four-wheel drive vehicle through wild bush on bumpy dirt tracks. Although the dive industry in Sodwana is well established, it is also closely monitored. Only three dive centers are allowed to operate in the region, to limit the number of divers on the reef and so protect the delicate coral reef ecosystem.

Turtles of several species visit Sodwana

DIVERSE ATTRACTIONS

The four established reefs off Sodwana are named after their distance from the launch site, and are called Two, Five, Seven, and Nine Mile Reef. Each offers something slightly different, ranging from the most delicate of hard corals through to encounters with large ocean-going species including whale sharks. Although the journey to Sodwana is a considerable undertaking, the reward is nothing less than the finest coral reef dives on the continent.

SURF AND SAND
Despite the fact that Sodwana Bay is fairly remote, the site can be busy. Dive boats often launch with an audience of waiting divers.

Protea Banks

KWAZULU-NATAL, SOUTH AFRICA

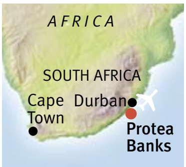

Even within the singularly robust South African diving community, Protea Banks is a dive site famed for thrills. A reef cut with deep gullies, overhangs, and caverns, and notable for its shark encounters, this is not a site for the faint-hearted.

ON THE PROWL
The tiger shark is a species quite regularly sighted around Protea Banks, often with remora fish in tow.

CHALLENGING SITE

Although Protea Banks does not boast the dramatic topography of nearby Aliwal Shoal (*see p.259*), it lacks none of the excitement. Indeed, there are many in the local diving community who consider Protea Banks more extreme than Aliwal—the reasons being the depth, the currents, and the terrific shark encounters. The top of the reef is, on average, deeper than Aliwal Shoal, with several dives in excess of 100 ft (30 m). The currents that sweep over the flat reef crest are also stronger, and several of the dives are exhilarating drifts over a considerable distance of undersea terrain.

SHARK SPOTTING

The final reason Protea Banks is so revered among the dive community in South Africa is its shark encounters. Not only can large numbers of ragged-tooth sharks be found here during their mating season, but there is a strong possibility of encountering tiger sharks or hammerheads. For several months of the year, divers can also be confronted in mid-water by large numbers of the Zambezi sharks. These magnificent predators follow game fish that arrive during the summer months.

ESSENTIAL INFORMATION

WATER TEMPERATURE 66–79°F (19–26°C)

ECOSYSTEM Subtropical

WHEN TO VISIT Ragged-tooth sharks can be seen from July to October; Zambezi sharks from October to April.

MUST-SEES Ragged-tooth sharks; Zambezi sharks; migrating whales.

Mozambique

SOUTHEAST AFRICA

AFRICA
Mozambique
Maputo
Indian Ocean
Cape Town

Wracked by decades of civil war, Mozambique was once a forgotten destination in world diving. The end of the conflict in 1992 prompted the gradual return of divers, and revealed the riches that lie in the blue waters off one of Africa's wildest coastlines.

NURTURING SEAS

The fast-moving waters of the Agulhas Current, which passes through the gap between the east coast of Mozambique and the island of Madagascar, are the source of much of Mozambique's great marine diversity. The reefs in this region are teeming with life, and although the entire coastline has dive sites of merit, there are certain regions that stand out, including Inhaca Island, Ponta do Ouro, the Bazaruto Archipelago, and Cabo San Sebastian.

FAR-FLUNG LOCATION

Mozambique is by no means an easy dive destination to access. Many of the sites to the south of the country require a sturdy four-wheel drive vehicle to cope with the dirt and sand roads, and the isolated operators and resorts are tucked in behind long stretches of deserted beach. However, Mozambique's dive sites offer ample reward. The southern region of the country has become well

ESSENTIAL INFORMATION

WATER TEMPERATURE 70–82°F (21–28°C)

ECOSYSTEM Subtropical

WHEN TO VISIT Year-round, but conditions are best from September to March.

MUST-SEES Potato bass; ragged-tooth sharks; bull sharks; humpback whales; whale sharks; manta rays.

known for encounters with huge potato bass and ragged-tooth sharks, whereas farther north, encounters with bull and tiger sharks are a distinct possibility. Humpback whales move through the area in the summer months, and the occasional dugong is sighted in the shallow estuaries along the coast.

The Bazaruto Archipelago on Mozambique's central coast is an excellent place to see whale sharks, while nearby Vilnaculos is an excellent site to encounter manta rays and dolphins.

BRIGHT FUTURE

Mozambique still has a primitive tourist infrastructure, particularly in the northern regions of the country. Malaria is also a significant factor, with most of the country affected at certain times of the year. Nonetheless, Mozambique is making tremendous progress as a tourist destination, with the country's diving rapidly establishing itself as truly world-class. Diving here can present challenges for the intrepid traveler, but the isolation and low tourist traffic can be seen as a real advantage in one of Africa's most rapidly developing dive destinations.

WAVE-SWEPT WILDERNESS

Mozambique has over 1,500 miles (2,400 km) of coastline, much of it sparsely inhabited. The southern stretches of coast are dominated by sandbars, estuaries, and swamps, while the wilder north is characterized by long beaches and cliffs. The entire coastline is tremendously dramatic and wild, and even the capital Maputo has the famous Inhaca Island—a site famed in the diving world for its large animal encounters—directly offshore. Dolphins, whale sharks, and manta rays all frequent this site.

Surf breaks on a stretch of coast

LARGER THAN LIFE
Enormous potato bass are often found patrolling the bustling reefs of Mozambique. This imposing species can be extremely inquisitive, and individuals often approach divers.

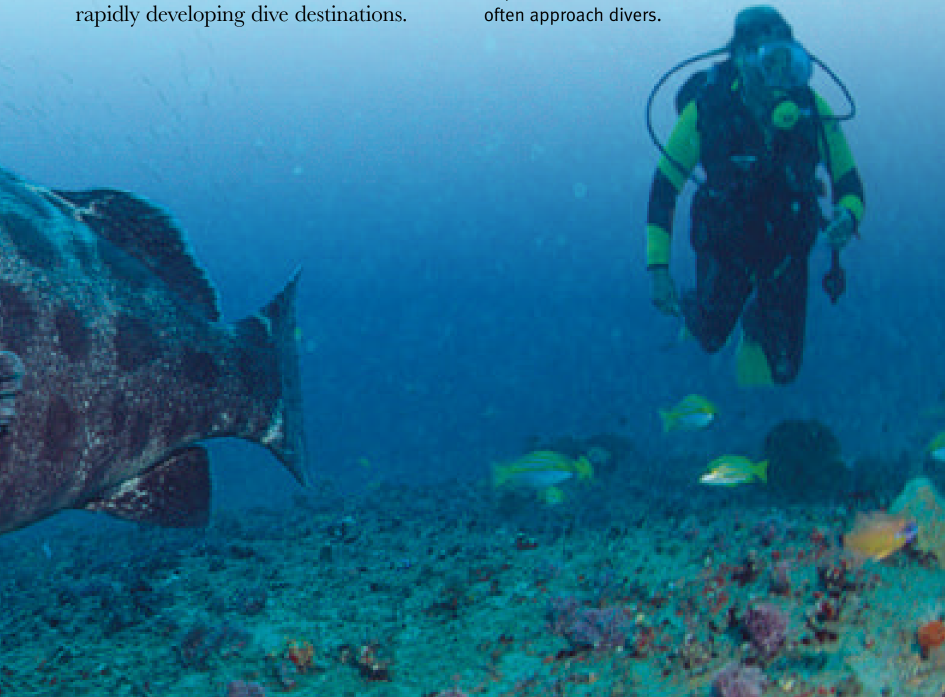

Seychelles

WESTERN INDIAN OCEAN

AFRICA
Seychelles
MADAGASCAR

The clear waters of the Seychelles teem with abundant marine life, and offer those prepared to travel a bit farther a range of gentle reef dives on the inner islands. The outer islands have big walls, wild drifts, and large animal encounters.

A PATTERN OF ISLANDS

The Seychelles archipelago numbers 115 islands in total, although these are spread over a vast area of ocean hundreds of miles off the east coast of Africa. The Seychelles is divided into the inner islands and the outer islands, with the two groups over 680 miles (1,100 km) apart. The inner islands—including Mahe, the main island in the Seychelles—sit on a huge natural platform rising from the deep ocean around them. As such, diving here tends to be within the 30–100-ft (10–30-m) range, and takes place on shallow protected reef systems. Farther afield are the outer islands, including the Aldabras, a group of islands known as the "Galápagos of the Indian Ocean" due to their isolation and diversity of marine life. The diving here is more intense and suitable only for experienced divers. The reef cuts and walls create opportunities for tremendous drift-dives, in which divers are carried along by underwater currents.

ESSENTIAL INFORMATION

WATER TEMPERATURE 81–84°F (27–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT May to October.

MUST-SEES Large pelagic species in the Aldabra Group; shallow reefs and marine life around the inner islands, including Mahe.

Powder blue tang

TROPICAL VISTA
Balmy tropical beaches are typical of the Seychelles. Though remote, the islands offer tremendous attractions for the diver.

Mauritius

WESTERN INDIAN OCEAN

AFRICA
Indian Ocean
MADAGASCAR
Mauritius

The islands of Mauritius in the Indian Ocean are a popular vacation destination, but are not well known for diving. This is something of an oversight, since the islands' stark volcanic reefs harbor a rich tropical ecosystem and offer dives of real quality.

PLACE IN THE SUN
The shallow coastal waters and white sands of Mauritius make it a leading vacation destination, but it also offers great diving experiences.

VOLCANIC ORIGINS

Mauritius consists of two islands, and numerous smaller islets, 500 miles (800 km) east of Madagascar. Although relatively small, the islands have nearly 250 miles (400 km) of undulating coastline due to the craggy nature of the volcanic rock that makes up the island group. The seas are colonized by over 200 species of coral, creating reefs inhabited by around 450 fish species—a rich tropical ecosystem.

ESSENTIAL INFORMATION

WATER TEMPERATURE 70–82°F (21–28°C)

ECOSYSTEM Tropical

WHEN TO VISIT Diving takes place in Mauritius year-round.

MUST-SEES The Rempart Serpent and Cathedral dive sites; the unspoiled reefs around Rodrigues Island.

TOP LOCATIONS

Most diving in Mauritius takes place on the western coast of the main island; the eastern end of the island is exposed to the wind and waves of the open ocean. The Cathedral cavern with its resident porcupine fish is a must-see, and the Rempart Serpent site boasts a huge number of moray eels (it is reputed that 32 species have been seen here!). The region north of the main island, however, is becoming known as a good spot for encounters with some of the larger pelagic species, with regular sightings of tuna, wahoo, and marlin. The remote island of Rodrigues to the east offers a glimpse of some of the region's most pristine reefs—making an excursion well worth the effort.

The Brothers

NORTHERN RED SEA, EGYPT

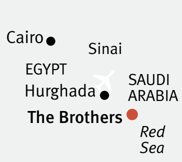

Spectacular coral gardens have grown undisturbed around these two remote pinnacles of rock for thousands of years. Only accessible by liveaboard (*see p.237*), the Brothers dive site offers steep drop-offs and some terrific shark action.

REMOTE ROCK
Big Brother, the larger and more northerly of the two islands, is 1,300 ft (400 m) long and 295 ft (90 m) wide, and dominated by a lighthouse.

ISOLATED OUTCROPS

The Brothers consist of two large rocks, named Little Brother and Big Brother, around 1 mile (1.6 km) apart and 36 miles (58 km) offshore in the northern Red Sea. Rising from deep water, they provide dramatically steep walls as a foundation for bustling reefs, and the upwellings of nutrient-rich waters and swirling currents draw in fish species both large and small.

SHARK SPOTTING

In addition to the diversity and color of the reefs themselves, there are some tremendous shark encounters off the walls of the Brothers. Common species in the area include white-tip and gray reef sharks, although silver-tips, scalloped hammerheads, and oceanic white-tips are also frequently seen. If you are lucky, you may even encounter a thresher shark. Its scythe-shaped tail fin makes this species an unmistakable, if very infrequent, sight.

ESSENTIAL INFORMATION

WATER TEMPERATURE 70–84°F (21–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT Diving takes place on the Brothers all year.

MUST-SEES Oceanic white-tip sharks; scalloped hammerheads; wreck of the *Numidia*; (occasionally) thresher sharks.

WRECKED ON THE REEF

As an additional attraction to the site, two wrecks—the *Aida* and the *Numidia*—cling to the precipitous sides of Big Brother. The *Numidia*, a former cargo vessel, lies at a very steep angle on the northern tip of the rock, with which it collided in 1901. Its bow can be found in just 26 ft (8 m) of water, but its stern lies in the depths, at 262 ft (80 m).

Another victim of Big Brother was the Italian supply ship *Aida*, which sank in 1957 while carrying troops. Almost as impressive as *Numidia* and surprisingly intact, *Aida* is now heavily colonized.

Dahab

NORTHERN RED SEA, EGYPT

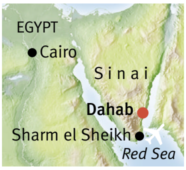

The coastal town of Dahab in southern Sinai is ringed by mountains and desert. The inhospitable landscape is in striking contrast to the splendid reefs and coral formations to be found just offshore—among which is the infamous Blue Hole.

DESERT HAMLET

Dahab lies on the Gulf of Aqaba, in the northeast of the Red Sea, only 50 miles (80 km) north of the busy dive resort of Sharm El Sheik. Clinging to the shore in a harsh, arid landscape, the town has a faintly frontier feel to it. There are several dive centers in Dahab, offering training to all levels of ability.

DIVING IN DAHAB

Within a short drive of Dahab are many excellent sites accessible from the shore, including the Canyon and the Bells. Both of these sites are dramatic examples of the twisted coral formations that seem to characterize this stretch of coastline, with deep gullies, impressive overhangs, arches, and swim-throughs. The legendary Blue Hole site is actually the top of a massive shaft that sinks 985 ft (300 m) into the reef. The lure of diving through a long passage to the outer reef at a depth of 165 ft (50 m) has caused many divers to perish in the Blue Hole, and the conventional wisdom for diving this deep arch is that it should only be attempted using technical dive techniques and equipment (*see pp.194–95*).

ESSENTIAL INFORMATION

WATER TEMPERATURE 70–82°F (21–28°C)

ECOSYSTEM Tropical

WHEN TO VISIT Diving takes place in Dahab all year, with water temperatures high throughout.

MUST-SEES The Blue Hole; The Canyon and The Bells; Gabr El Bint (by boat only).

SHELL GAME
A diver follows a turtle—at a respectful distance—as it conducts a slow tour of one of Dahab's colorful reefs.

Wreck of the *Thistlegorm*

NORTHERN RED SEA, EGYPT

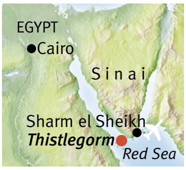

Packed full of artifacts and lying in the clear waters of the Red Sea, the *Thistlegorm* is perhaps the most famous of all shipwrecks for divers. Its fame comes at a price, however, with great numbers of divers clambering through the structure every day.

THE CLASSIC WRECK

The *Thistlegorm* first came to the attention of the global diving community in the 1950s, when it was discovered and filmed by Jacques Cousteau. However, its location remained a secret until 1992, when it was rediscovered by recreational divers, and it has since become one of the most popular diving wrecks in the Red Sea.

The *Thistlegorm* was a World War II armed merchant vessel, 413 ft (126 m) in length, carrying supplies to the British 8th Army in North Africa. Packed with machinery and ammunition, it was spotted in the northern Red Sea by a German bomber on October 6, 1941. Two bombs entered its Number Four hold, causing a huge explosion that cut it in half; it sank immediately with the loss of nine souls.

DIVE EXPERIENCE

In many ways, the *Thistlegorm* is the perfect wreck dive. Its bow lies just 50 ft (15 m) below the surface in clear waters, and no part of the vessel is below 100 ft (30 m); however, currents may be strong, and descent is usually made down mooring lines tied by the guide. Once inside the wreck there is a vast, serene, yet poignant underwater museum to explore, and the sheer size of the vessel means that thorough exploration requires several visits.

The *Thistlegorm* holds a unique place in divers' affections, though its popularity has become a drawback. It is only a five-

ESSENTIAL INFORMATION

WATER TEMPERATURE 68–84°F (20–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT Year-round. The wreck is best dived from a liveaboard.

MUST-SEES The captain's bath; BSA motorcycles; locomotive on deck; Bedford trucks; armored cars.

TIME CAPSULE

A diver examines military hardware inside the wreck of the *Thistlegorm*

For many years after the *Thistlegorm* was sunk, British vessels would lower their flag as they passed its wreck, but today it has a happier role, having become a focus for diving in the Red Sea. The vessel's real treasure is its outstanding cargo of military equipment, which ranges from Lee Enfield Mark 3 rifles, wellington boots, Bedford trucks, and two Rolls Royce armored cars, to—perhaps most famously of all—racks of BSA motorcycles. On the deck stands one locomotive; another lies on the sea bed beside the wreck.

hour cruise away from the Red Sea's busy diving center of Sharm el Sheikh, and in peak season it is not uncommon for more than 20 diving vessels to be moored over it at one time. The best time to explore the *Thistlegorm* is at dawn, when there is a chance to see this grand wreck with few others around, although this means finding a skipper who will travel through the night.

Although not as densely colonized as one might expect, the *Thistlegorm* wreck still has abundant marine life. This region has approximately 1,000 fish species, 17 percent of which are endemic to the Red Sea. Of particular note on the *Thistlegorm* are large numbers of lionfish, which lie in wait ready to ambush shoals of unsuspecting glassy sweepers, while overhead jack and barracuda sweep the superstructure for prey.

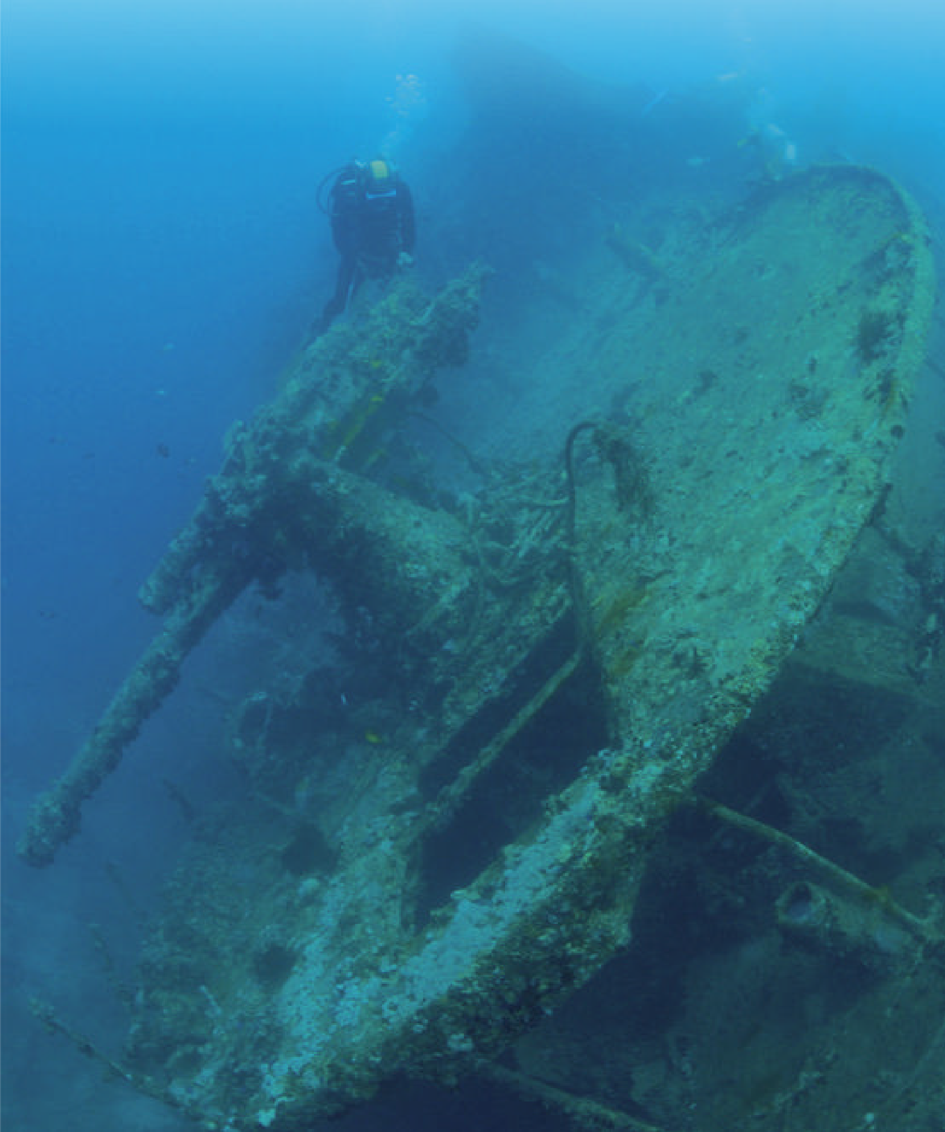

WEAPON OF WAR
A diver hovers above the distinctive deck gun on *Thistlegorm's* stern. There are strict penalties for wreck-stripping, so never be tempted to take a souvenir.

Asia

The tropical regions of this vast continent have always been highly praised by divers for the staggering richness of their marine life and their glorious reefs, but adventurous new diving opportunities are also beginning to open up to the north—even in Siberia.

REEFS UNDER THREAT

The geographical span of Asia, the largest continent, is reflected in the vast range of diving available. For many divers and marine biologists, the highlight is the famed "Triangle of Diversity"—a region in the Indo-Pacific that boasts the world's greatest diversity of coral and fish species.

The many thousands of islands of the Philippines, Indonesia, Papua New Guinea, and Malaysia are host to some legendary dive sites, with evocative names such as Sipadan, Lembeh, Tubbutaha, Komodo, and Kimbe. Sadly, while these are all dream destinations for any diver, destructive fishing techniques in the Indo-Pacific region, such as dynamite and cyanide fishing, are damaging some of these delicate ecosystems. In the Philippines, only 4 percent of all reefs remain unaffected by human activity, with up to 30 percent reported to be impacted beyond recovery. Beautiful pristine reefs can still be found in the Indo-Pacific, but when diving on these threatened reef systems, be mindful of your responsibility to minimize any impact your presence could have.

BEACH BASE
A dive base on a sun-kissed tropical beach can provide the ideal "chill-out" spot after an exhilarating dive.

RESPONSIBLE REEF DIVING
With Asia's reefs at risk, it is vital that divers follow the rules of responsible reef diving to conserve them for future generations.

BEYOND THE TROPICS

The classic perception of Asian diving tends to be the archetypal tropical island chain fringed by glorious technicolor reefs. Dive sites throughout the region, including the Maldives, the Andaman Islands, and the Similan Islands, are all justifiably famed for their extraordinary diversity and beauty, both above and below the surface.

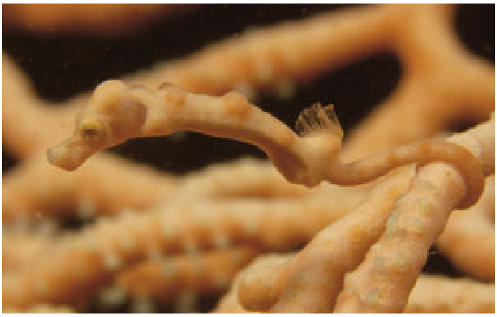

PYGMY SEA HORSE
A rare species found only on *Muricella* coral in Southeast Asia and Australia, the pygmy seahorse wraps its tail around coral branches and lies in wait for tiny crustaceans and larvae.

However, although much of the diving in Asia tends to be concentrated in the tropics, there are some excellent dive sites to be explored farther north. One of the most notable is Lake Baikal in Siberia. This is the world's deepest lake, and the largest reservoir of fresh water on the planet's surface. Because of its size and varying depths, Lake Baikal contains a huge variety of ecosystems.

The Maldives

INDIAN OCEAN

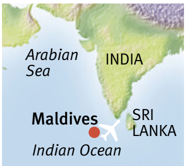

Coming to prominence as a dive destination in the 1970s, the Maldives swiftly became established as a dream diving location. The extent of the archipelago, and its range of dive sites, ensures that it remains an essential stop-off at least once in a diver's lifetime.

RICH ARCHIPELAGO

The islands of the Maldives are the crests of an undersea mountain range that plunges over 1¼ miles (2 km) into the deep waters of the Indian Ocean. The archipelago extends 475 miles (764 km) from north to south, and is 80 miles (129 km) across. This vast collection of islands is loosely divided into 26 major atolls, and although the islands are spread over 38,000 sq miles (98,000 sq km) of ocean, their land mass covers only 115 sq miles (300 sq km).

The Maldives offer a huge range of diving activities for those lucky enough to visit. Such is the abundance and delicacy of the remarkable reef systems throughout the Maldives that there are no less than 25 nature reserves and protected areas within the island group. The marine life around the islands is colorful and diverse, and includes over 700 fish species.

ESSENTIAL INFORMATION

WATER TEMPERATURE 75–84°F (24–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT Diving takes place year-round in the Maldives.

MUST-SEES Gray reef sharks; hammerhead sharks; manta rays; whale sharks; turtles.

TOUGH CHALLENGES

Tourism and diving are vital to the economy of the Maldives, but both industries have had to recover from major natural disasters in the late 20th and early 21st centuries. El Niño—a periodic warming event in the Pacific Ocean—had a severe impact in 1997–98, when the hard coral on many reefs was bleached and killed by the rise in ocean temperatures. The islands were also hit by the 2004 tsunami, which destroyed much of the tourist infrastructure.

Fishing and diving boats ready for business on a Maldives quayside

Diving in the Maldives tends to be divided into drift dives on the outer reef, and dive sites within the atolls. The latter contain thilas, a local word meaning a coral platform rising almost to the water's surface, and kandus, which are smaller isolated coral outcrops and coral heads. The best drift diving is where cuts in the coral walls leading to the open sea channel tidal water through narrow gaps.

Most dives in the Maldives seem to include at least one encounter with white-tip reef sharks, and there are several sites where gray and black-tip reef sharks, as well as hammerheads, may be seen. Eagle rays and manta rays, too, are regularly encountered at the right time of year at certain sites, with whale sharks also returning to the same sites to make the most of seasonal feeding grounds. There are also five different species of turtles in the Maldives, the most common of which are the green and hawksbill turtles.

COLORFUL CORAL
A diver examines soft corals on one of the region's flourishing reef systems. The Maldives offer an incredible variety of quality dives.

Similan Islands

ANDAMAN SEA, INDIAN OCEAN

INDIA
THAILAND
Bangkok
Similan Islands
MALAYSIA
Indian Ocean

A tiny string of granite islands sitting off the coast of Thailand, the Similans are best explored by liveaboard dive boat, but with some of the best beaches in Thailand, they have a great deal to offer both above and below the water.

STONE AND SEA

The Similan Islands consist of nine large granite outcrops sitting 40 miles (64 km) off the coast of Thailand. They rise from the depths of the Andaman Sea, and run for 15 miles (24 km) north to south. Although the islands do have individual names, they are commonly known simply by numbers, starting in the south with Number 1 (Koh Huyong), and continuing to Number 9 (Koh Bangu) in the north.

They are characterized by steep granite undersea cliffs on their western shores, with more gentle slopes to the east, where, sheltered from the summer monsoon winds, the coral growth is particularly lush. Over 1,000 fish species swarm over reefs colonized by a dazzling array of soft corals. Brightly colored species, such as coral grouper, sweetlips, snapper, and blue triggerfish are present in great numbers and, from October to May, whale sharks and manta rays are frequently encountered.

The thriving reef systems around the islands were once threatened by overfishing as well as "dynamite fishing"—the use of explosives to kill and collect large numbers of fish—but the islands were declared a national park in 1982, and commercial fishing is now banned. The sweeping coral fields of Christmas Point are particularly spectacular, although they were slightly damaged in the tsunami of 2004. Other notable attractions include a dramatic maze of huge boulder formations at Elephant's Head Rock. The Similans remain well worth every hour of sea crossing required to visit them.

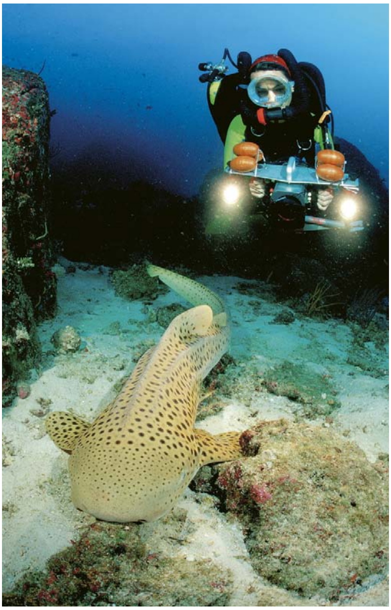

SHARK SPOTTING
A diver observes a leopard shark, hovering above this beautifully patterned predator, which frequents the waters of the Similans.

ESSENTIAL INFORMATION

WATER TEMPERATURE 79–84°F (26–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT Visit the Similan Islands between October and May.

MUST-SEES Whale sharks and manta rays; boulder formations at Elephant's Head Rock; Christmas Point.

Andaman Islands

ANDAMAN SEA, INDIAN OCEAN

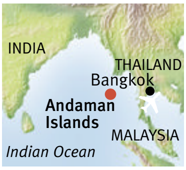

One of the last great diving wildernesses, the Andamans are a truly unspoiled string of volcanic islands in the Bay of Bengal. Cloaked in rain forest and home to some of the last untouched tribes on Earth, they offer genuine diving exploration.

ISOLATED IDYLL

The Andaman Islands are sprinkled over 435 miles (700 km) of ocean, and define the western edge of the Andaman Sea. Although the archipelago consists of 572 islands, only 36 are inhabited. Over 80 percent of the land mass is covered in rain forest, home to tribes that have had very little contact with the outside world—in some cases, none at all.

The islanders do not run any commercial fishing operations to speak of, and therefore the steep walls and rich reefs of the region are home to a range of large marine animals in healthy populations not encountered anywhere else in the Andaman Sea.

ESSENTIAL INFORMATION

WATER TEMPERATURE 82–88°F (28–31°C)

ECOSYSTEM Tropical

WHEN TO VISIT The best time to visit is between November and May.

MUST-SEES Barren Island; Passage Island; large manta ray aggregations; steep lava walls; dogtooth tuna.

Diving takes place from November to May, and can either be from liveaboard dive vessels, or through a small number of operators based in the islands. Notable sites include the outlying islands of Passage Island, Narcondam, and Barren Island, which have barely been dived at all. Expect encounters with a range of shark species, huge dogtooth tuna, and feeding manta rays.

DIVER'S PARADISE
With no large-scale fishing fleet, the Andaman Islands have well-preserved reefs stocked with a fascinating diversity of marine life.

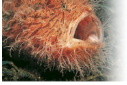

North Sulawesi

CELEBES SEA, INDONESIA

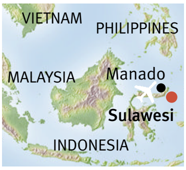

Indonesia has been termed the "Cradle of Diversity" by marine biologists, and with good reason. A recent survey counted more than 3,000 fish species here. Crowning it all is North Sulawesi, and the jewel in that crown is the Lembeh Straits.

CONSERVATION IN ACTION

North Sulawesi is formed by the long, thin peninsula that juts out from Sulawesi Island into the Celebes Sea. The marine species diversity of this region is unparalleled, a fact recognized by the locals, who have set up a number of reserves, and by the divers who flock here. The careful approach to the marine environment here by local government means that 90 percent of the coral cover is alive and in good condition, a remarkable statistic considering the pressure the remainder of the Indonesian archipelago experiences from destructive fishing methods.

NATURAL TREASURES

The Lembeh Straits is the channel between the island of Lembeh and the northern tip of Sulawesi. It is quite a shallow body of water—ranging in depth from 16 ft (5 m) to 98 ft (30 m)—so divers need to be aware of the large vessels that pass regularly overhead, as well as the periodic strong currents.

But while at first glance this may seem merely an unprepossessing shipping channel, closer inspection reveals a world of tiny riches.

Camera in watertight plastic housing

ESSENTIAL INFORMATION

WATER TEMPERATURE 74–82°F (23–28°C)

ECOSYSTEM Tropical

WHEN TO VISIT Year-round; optimum period between May and November.

MUST-SEES Panguilingan; Lejuan II; Mandolin; muck diving for ghost pipefish; pygmy sea horses; mimic octopus.

MACRO LIFE IN SULAWESI

The magic that draws divers to this area is the extraordinary range of tiny but beautiful reef animals that can be found in the shallow coastal seas off North Sulawesi. The sheer diversity of "macro life" (small marine creatures) here, and the sometimes bizarre forms it takes, has led to the area being dubbed "God's wastebasket." Outlandish species like the hairy frogfish make amazing photographic subjects.

A hairy frogfish gapes in the current

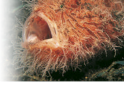

The Straits have a big name for small things—this is the finest site in the world for encountering the most exquisite, delicate, and unusual inhabitants of tropical seas. Diving in the Lembeh Straits goes by the unpromising name of "muck diving"—so called because of the dark sand that covers the seabed and the necessity to examine it closely for target species during the course of a dive. But the effort involved in diving here is well rewarded. Mimic octopus, pygmy sea horses, ghost pipefish, leaf fish, frogfish, and blue-ringed octopus can all be found here.

CONSERVATION AREA

The Bunaken Marine Park is one of the driving forces for conservation on North Sulawesi. It surrounds five islands, on which are a few small fishing villages, and covers over 290 sq miles (750 sq km). The park offers fantastic muck diving and also some tremendous walls, the most notable of which are Lekuan II and Mandolin on Bunaken, and Panguilingan in Mahado Tua.

VOYAGE OF DISCOVERY
An indigenous fisherman setting out in a traditional canoe. Many divers eschew the clear surface waters for the pleasures of muck diving.

Papua New Guinea

WESTERN PACIFIC

Papua
New
Guinea
Port Moresby
Cairns
AUSTRALIA

A location that still epitomizes diving exploration, Papua New Guinea offers a hugely exciting experience for the intrepid dive tourist. A vast region with numerous undived reefs and islands, Papua New Guinea is a real adventure.

OUTER LIMITS

For many years, Papua New Guinea drew only the very boldest pioneers of adventure diving and extreme tourism. Made up of 600 islands, the reputation of this region as a wild and untamed part of the world is well founded. Papua New Guinea has 4 million inhabitants, divided into 1,000 tribes that speak 700 different languages. Spread over the 177,600 sq miles (460,000 sq km) of the island group, many of these indigenous tribes knew nothing of the modern world until very recently, with one tribe only making contact with the outside world in the late 20th century. Doubtless, others—as yet unknown—exist in the rugged Highlands, with much of the main island of New Guinea consisting of mountainous rainforest with a maximum elevation of 14,760 ft (4,500 m). While most visits to Papua New Guinea are trouble-free, travel after dark is not advised, and in towns such as the capital, Port Moresby, the risk of robbery and violent crime must be taken seriously. Trips are best arranged with well-established diving operations who can provide guides and transportation to the coastal diving regions, where the risks are significantly lower than in poor urban areas.

PRISTINE REEFS

The shallower regions of Papua New Guinea's coastline are the site of some fantastically complex reef formations, with perhaps the most famous being Kimbe Bay on the western coast of New Britain. Another dive site that has gained a reputation for providing particularly dramatic reefs and tremendous diversity is Eastern Fields, in the northern limits of the Coral Sea. This remote site can only be reached by ocean-going vessels and remains relatively unexplored.

Vibrant coral reef in Papua New Guinea

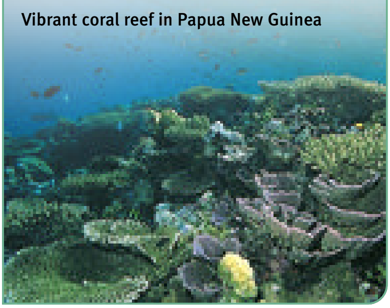

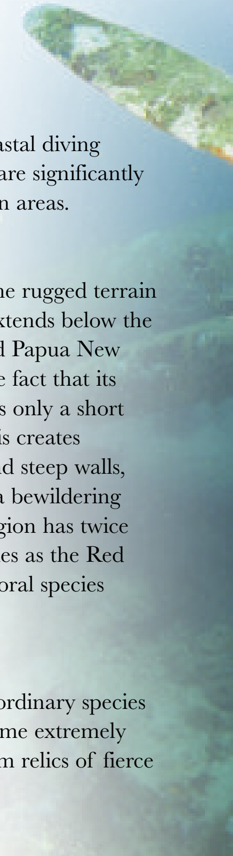

RICH SEAS

The good news is that the rugged terrain of the land frequently extends below the surface of the water, and Papua New Guinea is notable for the fact that its seas reach abyssal depths only a short distance from shore. This creates tremendous drop-offs and steep walls, which are inhabited by a bewildering array of species. The region has twice the number of fish species as the Red Sea, and ten times the coral species of the Caribbean.

SUNKEN HISTORY

In addition to this extraordinary species diversity, the area has some extremely fine wrecks, most of them relics of fierce

ESSENTIAL INFORMATION

WATER TEMPERATURE 75–82°F (24–28°C)

ECOSYSTEM Tropical

WHEN TO VISIT Diving takes place all year in Papua New Guinea.

MUST SEES Submerged atoll at Eastern Fields; marine life in Kimbe Bay; World War II aircraft wrecks in Milne Bay.

fighting in the region during World War II. Rabaul, Kavieng, Loboata, and Madang all provide excellent wreck diving, with aircraft debris littering the seabed in certain areas, like Milne Bay.

Diving throughout the archipelago is becoming more accessible due to the presence of a number of established diving operators in the more renowned dive sites, and the increasing range of liveaboard operators now pushing into some truly remote regions. Nonetheless, there are still underwater areas of this extraordinary island group that remain completely unexplored. In a world that seems to become smaller and smaller with each passing day, it is an exciting thought that such places still exist for us to discover. By taking a responsible approach to venturing off the beaten track, divers can help preserve this region, and by doing so ensure a steady stream of new adventures for many years to come.

GHOSTLY REMAINS
Wreckage of aircraft lost during World War II is a notable sight in the waters off Papua New Guinea. The area was the scene of battles between Allied and Japanese forces.

The Philippines

SOUTHEAST ASIA

Manila
Philippines
VIETNAM
MALAYSIA
BORNEO

The Philippines undoubtedly offer a world of diving possibilities. Although destructive fishing techniques have taken their toll on many reefs, local legislation and a realization of the benefits dive tourism can bring to the local economy offer a chance of recovery.

RESTORING LOST REEFS

Consisting of 7,107 islands spread over 116,000 sq miles (300,000 sq km), the Philippines comprise one of the most bountiful regions on Earth in terms of species diversity, with at least 2,000 fish species recorded throughout the archipelago. However, in many areas, complex and delicate reef systems have been almost completely destroyed by dynamite and cyanide fishing. A recent survey noted that "excellent" reefs—those classified as having more than 75 percent healthy coral cover—are now present in only 4.3 percent of the total reef area surveyed. This is an issue that the Philippines authorities are, thankfully, attempting to address, and certain regions now have energetic conservation programs in place.

VACATION HOTSPOT
Indigenous watercraft pulled up at a palm-fringed beach in the region. The Philippines appeal to both divers and non-divers alike.

ESSENTIAL INFORMATION

WATER TEMPERATURE 75–81°F (24–27°C)

ECOSYSTEM Tropical

WHEN TO VISIT Best diving conditions are between April and November.

MUST-SEES Tubbutaha Reef; Jessie Beazley reef; Coron Bay; Apo Island; Puerto Galera.

LIVEABOARD EXCURSIONS

The remote Tubbutaha and Jessie Beazley Reefs in the Sulu Sea remain relatively undamaged, and provide some world-class diving. All diving at Tubbutaha is from liveaboards, although many of the shallow reef crests provide excellent snorkelling opportunities. The steep walls of Tubbutaha are swept by strong currents and have crystal-clear visibility. Of particular quality is North End, a dive that combines spur and groove reef formations with some classic walls. Jessie Beazley Reef is essentially a massive pillar of rock rising from deep water, providing a beacon for groupers, manta rays, barracuda, and eagle rays.

Quality diving can also be found at the Visayas, a small cluster of islands accessed via Cebu City. Malapuscua

HISTORIC FINDS
A diver inspects a wreck off the Philippines. Palawan Island is the departure point for Coron Bay, with its extensive World War II wrecks.

has become particularly famous for providing one of the most unusual of all shark dives, at a site where thresher sharks congregate to be “groomed” by cleaner fish (*see pp.225–26*). Apo Island is a fine example of a progressive conservation project, where local people have become involved in policing the reefs around the island.

MUCK AND WRECK DIVING

Farther north at Puerto Galera, readily accessible from Manila, is some of the finest diving in the Philippines, with some outstanding “muck diving” (*see p.279*). Palawan also offers some wilder diving, with Coron Bay containing some particularly fine Japanese wrecks sunk during an attack by US aircraft on September 24, 1944.

Barracuda Lake offers a genuinely different diving experience, requiring a short jungle hike that is rewarded by an exploration of a system in which freshwater sits on top of seawater. A large barracuda in the lake is said to guide divers through his territory.

MARINE LIFE

The diversity of this archipelago is truly remarkable, with 1,499 crustacean species, 462 types of mollusks, and 22 different types of beach vegetation. Of the 500 known coral species worldwide, 488 are found here. This biological diversity was recognized in 1993, when the Tubbataha Reef Marine Park was made a World Heritage site.

The mandarin fish, one of over 2,000 fish species recorded in the Philippines

Australasia

The vast coastline of Australia offers superb coral reefs as well as spine-tingling cold-water encounters with giant marine predators. New Zealand, to the southeast, is rapidly emerging as a dive destination of real quality, with some of the world's best temperate dive sites.

BARRIER REEF AND MORE

For the uninitiated, the notion of diving in Australasia is limited to exploring the Great Barrier Reef, which lies on the northeastern coast of Australia. One of the most impressive natural features on the planet, it is a site of remarkable species diversity.

VOLCANIC REEF
The temperate reefs of New Zealand's Poor Knights Islands teem with colorful marine life.

While the fame of the reef is fully justified, there are also many other rewarding dive sites in Australia and New Zealand. East of the tourist hotspots of the Great Barrier Reef lies the Coral Sea, equally beautiful and with fabulous marine life to be seen. To the south of Australia, the cold waters of Dangerous Reef and the Neptune Islands offer thrilling encounters with great white sharks. Farther south still is Tasmania, home to lush kelp forests. On the sparsely populated western coast of Australia is Ningaloo Reef, one of the best locations for encountering the mighty whale shark.

NEW ZEALAND

The jewel in New Zealand's diving crown is the Poor Knights Islands, which for many (including the late Jacques Cousteau) ranks as the finest temperate-water dive site in the world. The unique topography of the site means that this is a breathtaking place to dive, with vast shoals of fish swarming over craggy volcanic reefs and through atmospheric cavern systems. Protected by both traditional Maori law and modern legislation, the islands are a magnet for divers the world over.

New Zealand boasts some impressive wrecks, including the world-famous *Rainbow Warrior* and the dramatic *Mikhail Lermentov*. It is also rapidly developing a reputation for providing big animal encounters with numerous whale species, as well as with iconic sharks such as the mako and the bronze whaler. To top it all off, New Zealand also offers stunning scenery, crystal clear rivers and springs, and magnificent fjords.

SOUTHERN FJORDS
The fauna of New Zealand's fjords includes red and black corals, penguins, fur seals, and bottlenose dolphins.

LIFE ON THE REEF
The Great Barrier Reef hosts a vast array of flora and fauna, including more than 1,500 fish species and 4,000 different types of mollusks.

Great Barrier Reef

QUEENSLAND, AUSTRALIA

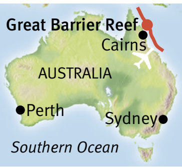

One of the true natural wonders of the world, the Great Barrier Reef is the longest reef of its kind on Earth. Home to a spectacular diversity of animal and plant life, recent legislation has granted even greater protection for this abundant natural habitat.

VAST ECOSYSTEM

The Great Barrier Reef is so extensive that its precise size has never been recorded, although it is estimated that it stretches for 1,400 miles (2,250 km), and covers around 135,000 sq miles (350,000 sq km)—about the same surface area as Ireland. It is made up of 2,000 individual reefs, and around 71 coral islands are spread along its length.

ESSENTIAL INFORMATION

WATER TEMPERATURE 77–84°F (24–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT The Great Barrier Reef can be dived throughout the year.

MUST-SEES Ribbon Reefs (particularly Ribbon Reef Number 10); Cod Hole; Pixie's Pinnacle.

In broad terms, the Great Barrier Reef can be said to be divided into two regions—the inner reef, known as the Great Shallow, and the outer reef, consisting of deeper reef systems and sloping walls leading to the open sea beyond. The reef itself is made up of over 400 species of coral, and supports around 1,500 species of fish. Approximately 4,000 species of mollusks inhabit the flats and nooks and crannies of the reef, while 23 species of marine mammals may be encountered along the vast length of this complex ecosystem.

GLOBAL IMPORTANCE

Certain areas of the Great Barrier Reef have enjoyed protected status since 1973, when it was established as a marine park. This was enhanced in 1981 when the reef was recognized as a World Heritage Site. More recent legislation has seen 71 percent of the total area of the reef covered by some sort of

WORLD OF COLOR
The range of marine life inhabiting the Great Barrier Reef is staggering in its variety and splendor, but divers must be careful not to touch delicate corals.

DEEPER INTO THE REEF

Certain parts of the Great Barrier Reef have been noticeably degraded or damaged by the high volume of dive traffic. This is no great surprise, given the delicacy of the reef's ecosystem and the inexperience of the many divers exploring it. Although there are still some fine dives to be had in these busy areas—especially for those new to the sport—many dive operators have moved further out into the reef system, offering packages on liveaboard boats that allow more experienced divers to explore remote and less spoilt sites.

Eye-stripe surgeonfish

protective status—an optimistic sign for the future of a reef that is larger than any other coral system, but just as vulnerable to misuse and exploitation.

DIVING IN THE REGION

There is a mass market for diving the Great Barrier Reef, operating out of Cairns and Townsville in day boats containing very large numbers of divers. There have been a number of well-publicized incidents where divers have been missed when boats have departed back to shore, and although this is now very well regulated, it is still worth, on the larger vessels at least, ensuring that the correct procedures are in place before diving. The other main diving activity on the reef takes place from liveaboards that venture farther afield to more remote sites.

Divers on the reef are assured of reasonable hard coral and colorful fish life almost anywhere along its length, but there are also a number of notable individual sites. Ribbon Reef Number 10 is particularly rich and diverse, even by the Great Barrier Reef's high standards, and is the location for dive sites such as Cod Hole—famous for encounters with giant potato cod—and Pixie's Pinnacle, renowned for its diversity of large animal encounters.

ARTIFICIAL ISLAND
Some sites on the Great Barrier Reef have a permanently anchored observation platform, which visitors can travel to by tour boat.

The Coral Sea

WESTERN PACIFIC OCEAN

Coral Sea
Cairns
AUSTRALIA
Perth
Sydney
Southern Ocean

In the early 1970s, the first liveaboard operators began to explore the waters to the east of the Great Barrier Reef. Here they found the Coral Sea—a region of beautiful pristine hard coral formations and precipitous drop-offs.

REMOTE LOCATION

The Coral Sea begins about 100 miles (160 km) east of Townsville, in the territory of Queensland, Australia. It stretches for another 100 miles (160 km), covering an area of 38,000 sq miles (98,500 sq km). The dive sites consist of a series of undersea mountaintops that rise from a great depth, creating atolls, ridges, and reefs. The visibility in the region is some of the best in the diving world.

TEEMING WITH LIFE

The crossing to the Coral Sea through the rough waters of the inner reef can be demanding; however, divers with the budget and time to make the journey are rarely disappointed. The area is renowned for its big animal encounters, with tiger sharks and hammerheads mixing with more abundant species, such as gray reef sharks and white-tips. Manta and eagle rays are frequently seen off the steeper reef walls, while sea snakes can be seen on Marion Reef.

ESSENTIAL INFORMATION

WATER TEMPERATURE 75–81°F (24–27°C)

ECOSYSTEM Tropical

WHEN TO VISIT Conditions are suitable for diving year-round, but a lengthy boat trip is required to reach the area.

MUST-SEES Cod Wall; Watnabe Bommie; Marion Reef; manta rays; sea snakes.

REEF DWELLERS
Bumphead wrasse cruise over the sandy seafloor of the Coral Sea. These large fish graze in "herds" over the area's reefs.

Wreck of the *Yongala*

QUEENSLAND, AUSTRALIA

Cairns
Wreck of *Yongala*
AUSTRALIA
Perth
Sydney
Southern Ocean

The *Yongala* is a biological wonder—one of the most heavily colonized shipwrecks on Earth. Sitting amid miles of featureless plains of sandy seabed next to the Great Barrier Reef, over time it too has become a teeming coral reef.

FATAL STORM

Lost in a typhoon on March 24, 1911, the *Yongala* was a 357-ft (109-m) steamer carrying 121 passengers north along the Queensland coast. All hands were lost as it foundered, and now it lies in 100 ft (30 m) of water, listing to starboard but still resolutely facing its original northerly direction of travel. Its isolated position, and the fact that it lay undiscovered for over 40 years after sinking, means that it is very heavily colonized with marine life.

MARINE SANCTUARY

The entire food chain of the coral reef is packed into the length of the *Yongala's* short hull. Schools of jack and trevally hunt clouds of bait fish on its port hull, while in its superstructure lurk turtles, morays, coral trout, and huge numbers of sea snakes. Potato cod skulk beneath the bow of the wreck, and very large bull rays nestle in the sand beside the wreck, ever watchful for the tiger and bull sharks that circle out in the blue, just beyond sight.

ESSENTIAL INFORMATION

WATER TEMPERATURE 75–82°F (24–28°C)

ECOSYSTEM Tropical reef

WHEN TO VISIT There is year-round diving on the *Yongala*, but conditions can be rough from May to August.

MUST-SEES Sea snakes; potato cod by the wreck's bow; bull rays; bull sharks.

OCEAN WILDERNESS
Divers can encounter potato cod patrolling the bow section of the *Yongala*. The wreck is a magnet for marine life, attracting a range of species from sharks to turtles.

PROTECTED STATUS

Despite the popularity of the *Yongala* wreck among divers, exploration of the wreck's interior is strictly forbidden by Australian authorities under the country's Historic Shipwrecks Act. It may be, however, that the resident population of grouper are protection enough. In 2002 it was reported that a 6½-ft- (2-m-) long giant grouper had seized a diver's head before releasing him, shaken, but without serious injury, shortly afterward.

Tasmania

TASMAN SEA, AUSTRALIA

Cairns
AUSTRALIA
Perth
Sydney
Tasmania
Hobart

Tasmania offers a diving experience far removed from that of the usual coral reefs and warm waters of Australia. Nonetheless, this tiny island off the southern coast holds a host of diving possibilities for those prepared to travel a little farther afield.

UNSUNG ISLAND

Tasmania is a small island dwarfed by the immensity of mainland Australia to the north. It measures only 186 miles (300 km) from north to south, and is frequently overlooked by divers visiting Australia, distracted by the magnitude of the Great Barrier Reef and the big animals of Ningaloo Reef.

Tasmanian divers are delighted at this relative anonymity, since the island offers some of the finest kelp forests on Earth and some gloriously colorful and diverse cold-water dives. Currents rich in oxygen and nutrients sweep up from the icy waters to the south, giving life to wonderfully dense kelp forests and heavily colonized rock walls.

ESSENTIAL INFORMATION

WATER TEMPERATURE 54–64°F (12–18°C)

ECOSYSTEM Temperate

WHEN TO VISIT The best time to visit Tasmania for diving is between June and September.

MUST-SEES Red handfish; kelp forests; Eaglehawk Neck.

SMALL WONDERS

Of particular note is the abundance of smaller animals, such as red handfish, although the island also plays host to numerous penguins, Australian fur seals, a number of different types of sharks, and a variety of visiting whale and dolphin species. This rich diversity means that divers visiting Tasmania come to appreciate the true breadth of Australia's natural heritage.

PERFECT CONCEALMENT
Sea dragons, such as this leafy variety, can be found in the kelp forests off Tasmania and South Australia. Its shape mimics the plant fronds.

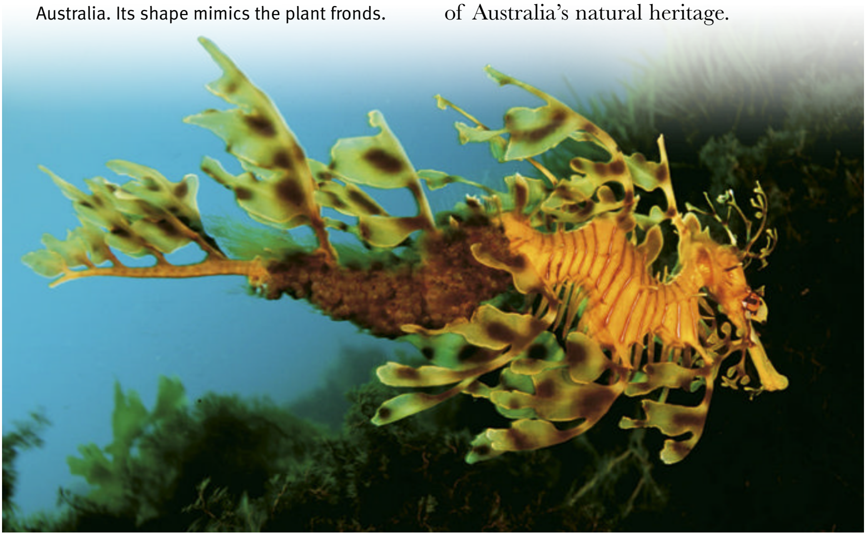

Ningaloo Reef

WESTERN AUSTRALIA

Indian Ocean
AUSTRALIA
Ningaloo Reef
Perth
Sydney
Southern Ocean

A beautiful coral reef stretching for 175 miles (280 km) off the coast of Western Australia, Ningaloo has much to offer the diver. Its fame, however, lies in the abundance of a single animal—Ningaloo is the whale shark capital of the world.

MAGNET FOR DIVERS

Ningaloo Reef is approximately 750 miles (1,200 km) north of Perth, Australia, and lies along a beautifully remote stretch of coastline.

The diving on the reef is centered around the small town of Exmouth—the population of which doubles during whale shark season, as divers flock there from around the world. Ningaloo Reef is splendidly rich in its own right—with 500 fish species and 200 types of coral. Such is the scale of diversity here and the integrity of the ecosystem, that the region was declared a national park in 1987, and now over 1,500 sq miles (3,885 sq km) enjoys protected status.

ESSENTIAL INFORMATION

WATER TEMPERATURE 75–84°F (24–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT Year-round diving, but whale sharks present March to June.

MUST-SEES Whale sharks; manta rays; migrating whales; shore dive at Point Murat Navy Pier.

WEALTH OF WILDLIFE

Although the whale sharks are less abundant from July through to February, they are replaced by other great attractions—between May and October, huge numbers of manta rays can be seen, and from July to November, migrating whales pass along the coast. In addition, a survey in 1994 counted more than 1,000 dugongs along this stretch of coast—one of the most significant populations on Earth.

CLOSE ENCOUNTER
Touching whale sharks may distress them, and only those with special training, such as this marine biologist, should do so.

Poor Knights Islands

NORTH ISLAND, NEW ZEALAND

Poor Knights Islands
Auckland
NEW ZEALAND
Wellington

A mystical set of islands, sacred in Maori legend, the Poor Knights lie 14 miles (23 km) off the coast of North Island in New Zealand. Honeycombed with caves and caverns, they are host to some truly remarkable gatherings of marine animals.

FORBIDDEN LAND

The Poor Knights Islands consist of stark volcanic rock pockmarked with overhangs, ridges, caves, and arches. The dramatic topography of the islands evokes their bloody history, as they were the site of a terrible Maori massacre in 1820, causing them to be declared *tapu* (forbidden) in Maori law. No one has set foot on the islands since, and this, combined with marine park status since 1977, has created a wonderfully pristine environment both above and below the waves, which has drawn divers to this site from all over the world. Boats run to the islands from nearby Whangerai.

REMOTE LOCATION

The islands are only accessible by boat, so visits involve a short voyage aboard one of the many dive charter boats based on the mainland.

ESSENTIAL INFORMATION

WATER TEMPERATURE 59–75°F (15–24°C)

ECOSYSTEM Temperate reef

WHEN TO VISIT Year-round diving, but rainy season runs from July to October.

MUST-SEES Gatherings of southern stingrays; Blue Mao Mao Arch; bronze whaler sharks on deep ridges.

WEALTH OF MARINE LIFE

There are approximately 120 fish species around the Poor Knights, but it is the sheer numbers of fish present that are the main attraction. Vast shoals of species such as blue mao mao inhabit the overhangs and caverns around the islands, while the stark reefs are coated in an extraordinary diversity of

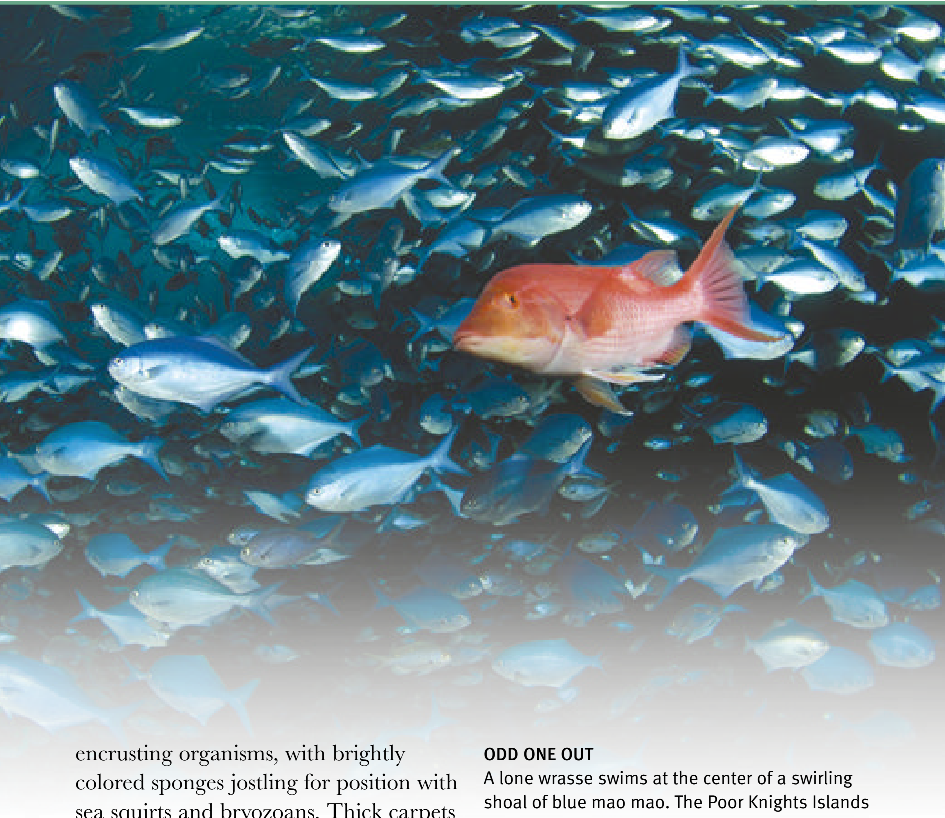

encrusting organisms, with brightly colored sponges jostling for position with sea squirts and bryozoans. Thick carpets of kelp provide perfect hunting grounds for brightly colored wrasse species, scorpion fish, and several different types of moray eels. In March, the dark waters under the Southern Arch host huge mating congregations of short-tailed southern stingrays. As well as this spectacular annual gathering, there is also a resident population of bronze whaler sharks, and regular transient visitors including orcas, dolphins, and several whale species.

Jacques Cousteau was so impressed when he visited the Poor Knights in the 1960s that he described the islands as the finest temperate-water dive destination on Earth, and one of the top ten overall. The range of dive sites and sheer abundance of marine life provide a compelling argument that this applies as much today as it did then. This is an essential dive site if visiting New Zealand.

ODD ONE OUT
A lone wrasse swims at the center of a swirling shoal of blue mao mao. The Poor Knights Islands are famous for their abundance of fish life.

EXPLORING CAVERNS

The marine life of the Poor Knights Islands teems amid dramatic underwater caves and arches, including the largest sea cave in the world—Rikoriko Cave. Visiting divers should carry flashlights, including a reliable backup, and ensure that basic cavern safety rules are followed (*see pp.186–87*).

A diver explores a sea cave

Wreck of the *Rainbow Warrior*

CAVALLI ISLANDS, NEW ZEALAND

Rainbow Warrior
Auckland
NEW ZEALAND
Wellington

Perhaps no other shipwreck on Earth has the poignancy of the *Rainbow Warrior*. Sunk in an act of international espionage that shocked the world, it now lies off the Cavalli Islands, in one of the most beautiful regions of New Zealand.

TRAGIC FATE

The conservation vessel *Rainbow Warrior* was moored in Auckland harbor on the night of July 10, 1985. Shortly before midnight, two explosions ripped through it, killing the vessel's photographer, Fernando Pereiro. This senseless act of terrorism was traced to the French Secret Service, leading to international condemnation and lengthy jail sentences for the two agents who planted the explosives.

PEACEFUL RELOCATION

The *Rainbow Warrior* wreck remained in Auckland for many months, before being refloated and towed farther north to the Cavalli Islands, a beautiful marine sanctuary granted sacred status in Maori law. Here it was sunk as an artificial reef, and has become a popular dive site.

The *Rainbow Warrior* is a small vessel, and so can easily be covered in a single dive. It sits almost upright on the bottom, and its superstructure rises to within 50 ft (15 m) of the surface, with the seabed below at 85 ft (26 m). Its bow section is still largely intact, creating the illusion that it is sailing across the white sands of the seafloor beneath its hull.

ESSENTIAL INFORMATION

WATER TEMPERATURE 57–75°F (14–24°C)

ECOSYSTEM Temperate

WHEN TO VISIT Year-round, but September to April is best.

MUST-SEES Scorpionfish; the prow; the Rainbow Warrior Memorial; the ship's propeller and stern.

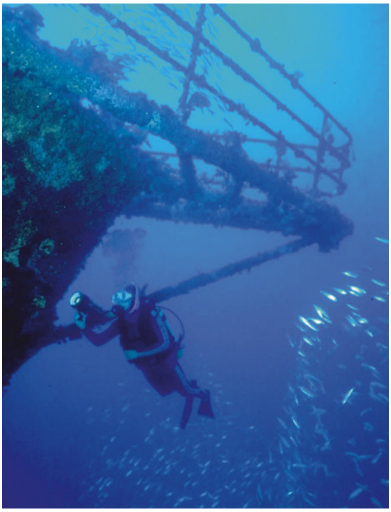

FINAL RESTING PLACE
A diver surveys the wreckage of the former Greenpeace vessel *Rainbow Warrior*, which was badly damaged by a violent act of sabotage.

REFUGE FOR MARINE LIFE

The *Rainbow Warrior's* hull is covered in a multicolored carpet of jewel anemones, and the vibrancy of color on display here is remarkable. Its superstructure is now a home for scorpionfish, blue cod, and shoals of golden snapper, plus kingfish, and the distinctively shaped John Dory. It seems fitting that this former conservation vessel now serves as a home for so many fascinating marine species.

Wreck of the *Mikhail Lermentov*

MARLBOROUGH SOUND, NEW ZEALAND

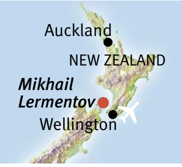

The gloomy passageways and silty spaces of the *Mikhail Lermentov* are mute witnesses to one of the great mysteries of modern sea travel. Sunk under the strangest of circumstances, it now lies in the cold waters of Marlborough Sound, New Zealand.

ENIGMATIC WRECK

The 20,000-ton Russian cruise liner *Mikhail Lermentov* was driven hard onto rocks by an experienced local pilot on February 16, 1986. It was a clear, calm day, and theories abound as to the factors behind the sinking—bribes, alcohol, and espionage have all been blamed at one time or another. The mystery remains to this day, but the wreck represents a tremendous diving experience, although perhaps not one for the faint-hearted.

ESSENTIAL INFORMATION

WATER TEMPERATURE 57–72°F (14–22°C)

ECOSYSTEM Temperate

WHEN TO VISIT Year-round, but September to April is best.

MUST-SEES Bridge; swimming pool; stern; ballroom, provided you have the right gear and level of experience.

DIVING THE *LERMENTOV*

It lies on its starboard side in 121 ft (37 m) of water, although the sheer size of the vessel means that its port side can be reached at only 66 ft (20 m). Dives on its external superstructure are recommended, with highlights including the magnificent bow, the bridge, and the stern. For the more adventurous there is the famous ballroom, although this dive should only be undertaken by those with appropriate training and equipment (*see pp.166–71*). Marine life on the wreck includes scorpionfish, conger eels, and blue cod; occasionally pods of orcas hunt in the Sound itself.

SERIOUS ADVENTURE
A diver explores in conditions of reduced visibility, often encountered on the *Mikhail Lermentov*. The wreck lies in deep coastal waters.

Oceania

The beauty of the estimated 20,000 islands that make up Oceania is unmatched anywhere else on Earth. The region holds tremendous riches, particularly for those confident enough to venture off the beaten track to visit the more far-flung islands and reefs.

WRECK DIVING IN PARADISE

Oceania is the collective name for the islands of the Pacific, generally considered synonymous with the South Sea Islands of Melanesia, Micronesia, and Polynesia. The region is typified by tranquil beaches with sugar-white sand and swaying palms, and, below water, powerful and intense diving experiences. Some of the world's most diverse reefs are in Micronesia, and the fierce fighting that raged through much of the region during World War II has created some impressive wreck sites.

Truk Lagoon in Micronesia, with its array of sunken Japanese ships, was viewed by many as the finest of all wreck diving locations until the establishment of a dive operation on Bikini Atoll in the Marshall Islands in 1996. From Bikini Atoll, divers can explore the remains of the fleet of ships sunk during the testing of hydrogen bombs by the US from 1946.

Palau has many magnificent dive sites, including Blue Corner, a coral ridge that juts out into the ocean and

VOLCANIC CREATION
Many of the world's atolls are located in the Pacific Ocean. These are created as a coral reef builds up around a subsiding volcanic island.

UNDERWATER WONDERS
The coral gardens of Micronesia, among the healthiest on the planet, are home to butterflyfish, wrasse, angelfish, and puffers.

plunges more than 1,000 ft (300 m), and the Ngemelis Wall, one of the best wall dives in the world. There is also Jellyfish Lake, an inland saltwater lake swarming with jellyfish that have lost their ability to sting. The nearby island of Yap boasts one of the finest sites for manta ray encounters. Yap is one of the more popular destinations in Micronesia, yet 80 percent of the reefs remain undived. For those who have the time to explore the remote islands of Oceania, they offer a truly original dive experience.

TRADITIONAL ISLAND LIFE
Unspoiled islands offer the possibility of fascinating cultural encounters and more fulfilling diving experiences.

Palau

MICRONESIA, SOUTH PACIFIC

PHILIPPINES
Palau
INDONESIA
AUSTRALIA

Divers constantly argue about what they consider to be the ultimate dive destination, but Palau will always be a strong contender. Consisting of 307 scattered islands, Palau has it all—wrecks, caves, and some of the busiest coral reefs on Earth.

A WORLD OF VARIETY

One of the great draws of Palau is the vast range of diving available. Like other island groups in Micronesia, it has colorful reefs cruised by large predators and impressive oceanic species. What gives Palau the edge over other sites in the region is that the geology and recent history of the islands have combined to create a diver's paradise. Caves and caverns honeycomb walls and reefs throughout the island chain; and fierce battles between American and Japanese forces during World War II mean that aircraft and shipwrecks abound.

Palau also has a number of rare natural phenomena, the most famous being Jellyfish Lake. This is a large volcanic crater filled with brackish water containing the pulsating forms of over 20 million mastigia jellyfish. To snorkel there is a surreal experience.

DIVING PALAU

Perhaps the most famous of all dive sites in Palau is Blue Corner. Jutting into deep water at the western edge of the island chain, this site has it all: swirling schools of barracuda, patrolling sharks, elegant eagle rays, and bustling Napoleon wrasse. Close to Blue Corner is another highlight, showing off Palau's renowned cavern diving—the Blue Holes. Here, divers enter a vast chamber illuminated only by pillars of light streaming through great gaps in the reef above. The Temple of Doom chamber, found at the rear of the Blue Holes, is a more serious dive that requires considerable experience and skill. The floor here is littered with the shells of sea turtles that were unable to find their way out of the chamber and perished. Chandelier Cave in Malakal Harbor is a more sedate alternative for those wishing to explore an easy cave system.

RELICS OF CONFLICT

In addition to the great natural diversity on show at Palau, there are many fascinating relics from World War II.

One of the best shipwrecks from that era is that of the Japanese fleet tanker *Iro*. At 475 ft (145 m) in length, the *Iro* is large and exceptionally well preserved. It lies in moderate depths in a lagoon near the central town of Koror. Visiting divers should also see the wreck of the Aichi E13-A1 (codename "Jake") seaplane. Discovered a decade ago, this wonderfully intact aircraft lies in shallow water, and is an easy dive with many layers of interest.

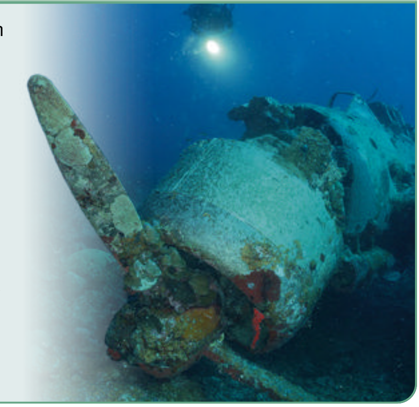

The wreck of the "Jake" seaplane

PATTERN OF ISLANDS
An aerial view of a cluster of islets at Palau, ringed with white coral sand and azure seas.

ESSENTIAL INFORMATION

WATER TEMPERATURE 77–82°F (25–28°C)

ECOSYSTEM Tropical

WHEN TO VISIT Year-round diving. Rainy season between July and October.

MUST-SEES Blue Corner; Blue Holes; Jellyfish Lake; the wreck of the *Iro*; the “Jake” seaplane wreck.

Yap

CAROLINE ISLANDS, NORTH PACIFIC

PHILIPPINES
Yap
Palau
INDONESIA
AUSTRALIA

A remote island paradise, Yap has become a magnet for divers seeking close encounters with manta rays. However, there is a great deal more to this tiny Micronesian island, with plenty of sharks on patrol, including gray, white-tip, and black-tip reef species.

PACIFIC IDYLL

With its lush mangroves and rolling green hills, Yap lies in clear waters that abound with tuna and dolphins. It has one of Micronesia's most vibrant indigenous cultures, and retains a genuinely remote island feel in all aspects of daily life.

MEETINGS WITH MANTAS

The real attraction, however, lies beneath the waves. Yap is one of the very few dive destinations on Earth where encounters with manta rays are guaranteed. Two shallow tidal channels cut through the islands, and it is here that the mantas gather at cleaning stations that dot the sandy sea floor. At these sites, divers can observe the activity of smaller fish called remoras, which use suckers to attach themselves to the rays and remove irritating parasites by nibbling them off. Divers crouch by the stations—normally isolated coral heads—and await the arrival of the star attraction. Manta rays can grow to more than 2,200 lb (1,000 kg) in weight, and their wingspan can sometimes exceed 20 ft (6 m) from tip to tip.

ESSENTIAL INFORMATION

WATER TEMPERATURE Around 82°F (28°C) year-round.

ECOSYSTEM Tropical

WHEN TO VISIT Year-round, but December to April is best.

MUST-SEES Manta rays visiting cleaning stations; shark dives; Yap Caverns.

PROTECTED ENVIRONMENT

Other dives in Yap should not be overlooked—there is some tremendous shark action here, and the reefs are in pristine condition due to a strictly-adhered-to agreement to use traditional fishing techniques. Such forward-thinking legislation is of great benefit to both marine life and visiting divers, and is an admirable example of responsible stewardship of the seas. Nearly 80 percent of the reefs around Yap remain undived due to local conservation by-laws, although the remaining 20 percent are well worth exploring.

ON THE WING
Despite their impressive and imposing size, manta rays are a docile species that feed on microscopic plankton life.

Bikini Atoll

MARSHALL ISLANDS, CENTRAL PACIFIC

Bikini Atoll
Pacific Ocean
AUSTRALIA
NEW ZEALAND

Bikini Atoll vies with Truk Lagoon to be the finest wreck diving location on Earth. This tiny collection of coral islands and lagoons is the site of spectacular and dramatic wrecks, with a truly extraordinary story behind their sinking.

ATOMIC TEST SITE

As World War II ended and the Cold War began, the US chose a tiny atoll at the northern end of the Marshall Islands to conduct a massive program of nuclear weapons testing. Ships of varying size, nationality, and vintage made up the 84 vessels of a dummy fleet, the vast majority of which were sunk in tests running from 1946 to 1958. Included in the fleet was the US aircraft carrier *Saratoga*—weighing 33,000 tons and now the largest shipwreck accessible to divers anywhere on Earth. Also at Bikini is the *Nagato*, the flagship of the Japanese fleet, and the first warship in the world to be armed with 16-inch guns. The last active Japanese battleship, the *Nagato* saw action as late as July 1945, when it was attacked by US torpedo bombers.

The ships lie in deep water, with depths averaging 160–180 ft (50–55 m), but with 1,500 or so fish species swarming over the stunning remains, the rewards are well worth it for divers with sufficient training and experience. No dive site can offer a more dramatic insight into history.

ESSENTIAL INFORMATION

WATER TEMPERATURE Around 84°F (29°C) year-round.

ECOSYSTEM Tropical

WHEN TO VISIT Best time to visit is between April and September.

MUST-SEES The US carrier *Saratoga*; Japanese battleship *Nagato*.

GHOSTS FROM THE PAST
The wreckage of a naval aircraft destroyed during US nuclear bomb tests (*inset*) at Bikini Atoll. Residual radiation has since dropped to negligible levels at this dive site.

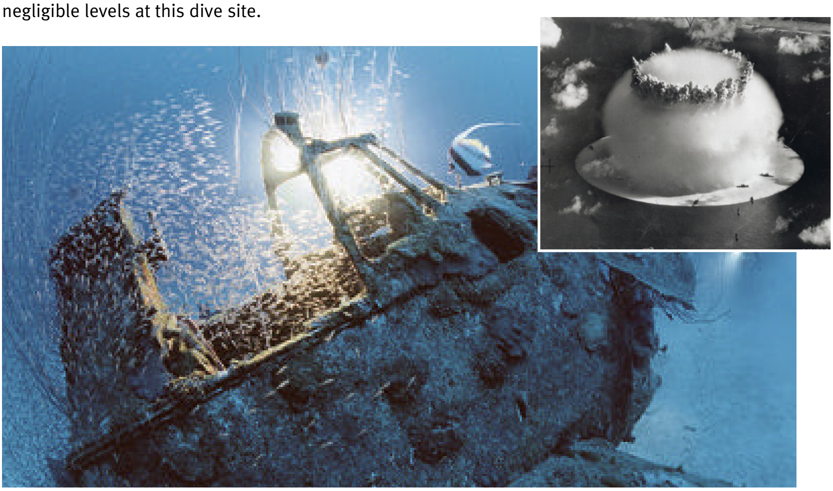

Bora Bora

SOCIETY ISLANDS, SOUTH PACIFIC

Pacific Ocean
Bora Bora
AUSTRALIA
NEW ZEALAND

Renowned as one of the most beautiful islands in the Pacific, Bora Bora is a huge lagoon dominated by an island at its center. The lagoon and the surrounding reef provide a dazzling array of dives against the stunning backdrop of volcanic peaks.

PACIFIC PARADISE

Bora Bora is part of the Society Islands, and is located 170 miles (274 km) northwest of Tahiti. An atoll of sparkling beauty that has long entranced writers and artists alike, the main island is only 6 miles (10 km) long, and sits at the heart of a lagoon three times its size. The reef around the lagoon has only one navigable channel, which is crisscrossed by smaller channels and gullies, most of which provide excellent dive sites.

ABUNDANCE OF LIFE

Bora Bora's lagoon and surrounding reefs are home to a huge variety of fish—a recent survey documented 500 different species, although the real number is almost certainly higher. Larger animals encountered on the outer reef and in the cuts in the atoll walls are gray reef sharks, white-tip reef sharks, groups of black-tip reef sharks, lemon sharks, and silvertips. Numerous species of rays can be encountered in the central lagoon, including the groups of manta rays for which the site has become justifiably famous.

ESSENTIAL INFORMATION

WATER TEMPERATURE 79–84°F (26–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT Thanks to its balmy climate, diving in Bora Bora can be enjoyed year-round.

MUST-SEES Manta ray encounters at Anua; shark dives at Tupitipiti.

ANATOMY OF AN ISLAND
Bora Bora is dominated by the jagged remains of a volcano, and encircled by a great lagoon. This remote atoll is widely considered to be one of the most beautiful spots on Earth.

Wreck of the *President Coolidge*

VANUATU, SOUTH PACIFIC

Pacific Ocean
Vanuatu
AUSTRALIA

A relic of an elegant age of sea travel, the *President Coolidge* is a strong candidate for the most exciting wreck now accessible to recreational divers. Perched on a reef in Vanuatu, it hides one of the most famous icons in diving in its dark interior.

BEACHED BEHEMOTH

The *President Coolidge* sank on October 26, 1942 while carrying 4,800 American troops to the Pacific during World War II. It struck floating mines, laid by "friendly" forces in the area, and when it became clear the ship would not make it into the nearby harbor of Luganville, the captain beached the huge vessel on a reef. Here it remains today, with its stern submerged in 236 ft (72 m) of water, although the bow lies at a depth of just 49 ft (15 m).

DIVING THE *COOLIDGE*

The wreck is accessed directly from the shore. Within its bulk is a network of passageways and enormous holds containing the paraphernalia associated with equipping an army for war. Although converted for duty as a troop ship, there are still traces of its time as one of the world's most luxurious ocean liners.

An essential stop for any diver visiting this magnificent wreck is the statue of the Lady, in one of the first-class dining rooms. This once stood on the mantelpiece of the smoking room, but a small earthquake dislodged it from its perch, and it was later moved farther up the wreck. Other highlights include the promenade deck and a beautiful mosaic fountain, once the centerpiece of a gracious lobby.

ESSENTIAL INFORMATION

WATER TEMPERATURE 75–82°F (24–28°C)

ECOSYSTEM Tropical

WHEN TO VISIT There is year-round diving on the wreck.

MUST-SEES The Lady; the swimming pool; lobby mosaic; the promenade deck; lampfish dive.

CASUALTY OF CONFLICT
The *President Coolidge* ran aground at Vanuatu during World War II. The wreck is still filled with corroding relics from that era.

Truk Lagoon

CAROLINE ISLANDS, NORTH PACIFIC

Truk Lagoon
INDONESIA
Pacific Ocean
AUSTRALIA

Regarded by many as the finest of all wreck sites, Truk Lagoon is the resting place for an eclectic mix of Japanese vessels sunk in a single raid by American aircraft in 1944. With many wrecks still in good condition, Truk Lagoon offers unforgettable diving.

WITNESS TO WAR

Truk Lagoon is a massive natural atoll almost 40 miles (65 km) across; it is ringed by 140 miles (225 km) of reef and small coral islands, forming one of the largest natural harbors of this type on Earth. The presence of 15 larger islands in the center of the lagoon made it an ideal base for military operations, a fact not lost on the Japanese Imperial Navy, which amassed a vast number of warships, merchant vessels, and fleet tenders here in the latter stages of World War II, in readiness for further deployment.

DIVING TRUK LAGOON

Wreck diving in Truk is deep, with the majority of the wrecks lying in depths of 100 ft (30 m) or more. Local operators are, however, well set up to cope with deep air diving, and have established effective drills and techniques to cope with repeated deep dives. Nonetheless, a certain level of qualifications and experience is advisable before diving the fascinating wrecks of Truk Lagoon. Contact local operators for details.

Marine life at Truk

ESSENTIAL INFORMATION

WATER TEMPERATURE 84°F (29°C)

ECOSYSTEM Tropical

WHEN TO VISIT Year-round diving, but rainy season from July to October.

MUST-SEES The wrecks of the *Fujikawa Maru*, *Shinkoku Maru*, *San Francisco Maru*, and the "Betty" bomber aircraft.

Such an assembly of enemy vessels proved irresistible to American forces, which carried out a daring raid on February 17–18, 1944, launching 450 aircraft from nine aircraft carriers beyond the horizon. The raid was a complete success, with over 60 Japanese vessels sunk in a savage 48 hours.

SECRET SITES

The "ghost fleet" of Japanese ships lies on the seabed in Truk Lagoon, although only 38 of them have been charted. The others have been left unmarked for fear of looting and illegal diving (to dive the wrecks in Truk, a local guide is a legal and practical necessity). Highlights include the *Fujikawa Maru*, complete with Zero fighter aircraft still in its holds, and the *San Francisco Maru*—a huge freighter with an array of cargo including two tanks on its deck, so outstanding it is known as the "Million Dollar Wreck."

RELICS FROM THE PAST
A diver hovers over the ghostly remains of a Japanese ship sunk at Truk Lagoon. Aircraft and submarines also fell victim to aerial attack here.

Fiji

SOUTH PACIFIC

Pacific Ocean
AUSTRALIA
Fiji
NEW ZEALAND

Simply hearing the name "Fiji" summons up images of an exquisite tropical paradise. With 800 islands sprawling over 80,000 sq miles (207,000 sq km) of ocean, the reality is just as exciting. Fiji offers a wealth of different experiences for the diver.

IDYLLIC ISLANDS

Perhaps one of the most notable features of Fiji for the visiting diver is that only 12 percent of the islands in the archipelago are inhabited—and 75 percent of the entire population lives on just one island, Viti Levu. Fiji truly offers a wealth of different diving opportunities around a huge variety of reefs, channels, and islands. Coral reefs cover a staggering 6,000 sq miles (15,540 sq km); they include at least 398 species of coral and are home to over 1,200 species of fish.

UNDERSEA GARDENS

Fiji is particularly famous for its beautiful soft-coral gardens, the most renowned of which is the White Wall in the Somosomo Strait. The region's rich waters mean that filter-feeding invertebrates thrive in the coral lagoons. Sea fans, whip corals, and a myriad of other species vie for space on the brilliantly colored reef walls.

ESSENTIAL INFORMATION

WATER TEMPERATURE 79–88°F (26–31°C)

ECOSYSTEM Tropical

WHEN TO VISIT Year-round, but the best time to visit Fiji is between April and November.

MUST-SEES Somosomo Straight and the White Wall; Beqa Lagoon; Naingora Pass.

REEF RESIDENT
Sharks of many species, including gray reef sharks, patrol the soft-coral reefs of Fiji's scattered islands.

There are also many spectacular fish species in Fijian waters. For the thrill-seeker, there is plenty of large-animal action. The best-known shark dive here is known as "Aqua Trek 3-D," after the operator that runs it, and offers the opportunity to see up to seven species of sharks on a single dive, including bull, black-tip reef, white-tip, and lemon sharks. The dive is one of 100 recognized dive sites in Beqa Lagoon—an indication of the sheer variety of diving in this beautiful tropical archipelago. Happily, the area has been designated a Marine Park and enjoys protection from overfishing; the small fees asked of divers who experience its underwater environment are used to help fund conservation measures. Such careful stewardship ensures that Fiji's diving will remain outstanding for years to come.

Anemonefish

Tonga

FRIENDLY ISLANDS, SOUTH PACIFIC

Pacific Ocean
AUSTRALIA
Tonga
NEW ZEALAND

Tonga is a dramatic chain of volcanic islands to the east of Fiji. The grandeur of its scenery is matched by one of the most amazing encounters with a marine mammal that a diver can have anywhere on Earth—snorkeling with humpback whales.

PACIFIC OUTPOST

Diving in Tonga is based mainly in the central island group of Ha'apai, and in Vava'u farther to the north. Port of Refuge in Vava'u, which for many divers is their first experience of Tongan diving, contains a particularly fine wreck in the form of the *Clan McWilliam*, a large merchant vessel sunk in the 1920s.

STAR SITES

Other sites of note in the region are Tuangasika Island, the location of an exciting cavern called Mariners Cave, and the steep walls of Hunga Magic—an undersea peninsula jutting into the blue water from Hunga island. Tonga's fame in the diving world is, however, based on encounters with humpback whales. From July through to October, around 700 humpbacks move into warm waters around the island group. Although local conservation groups do not allow scuba diving with the whales (to minimize disturbance to them), snorkeling alongside these amazing mammals is a unique experience.

ESSENTIAL INFORMATION

WATER TEMPERATURE 72–86°F (22–30°C)

ECOSYSTEM Tropical

WHEN TO VISIT July to October for humpback whales; avoid typhoon season from November to April.

MUST-SEES Humpback whales; Hunga Magic; Mariners Cave; *Clan McWilliam*.

ANNUAL MIGRATION
A humpback whale raises its massive flukes above the surface. Large numbers of this magnificent animal pass by Tonga each year.

The Americas

As befits a landmass that spans virtually all latitudes of the globe, the Americas boasts a staggering range of dive sites. Great ocean currents beset both North and South America, combining with local conditions to create something for divers of every level of expertise.

COASTAL DIVIDE

The coasts of the North American continent offer very different, but equally thrilling, diving environments. To the west, you can enjoy magnificent wild diving in the fjords of Alaska and British Colombia, explore vast kelp forests off the California coast, and experience glorious encounters with humpback whales and whale sharks in the Gulf of California.

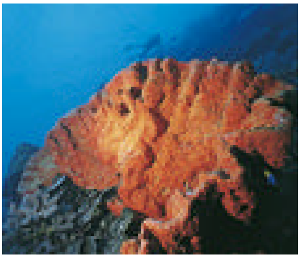

EASILY EXPLORED
The superb visibility and calm, warm waters of the Caribbean provide ideal conditions for reef diving.

The eastern coast features wrecks and raggedtooth sharks on the Outer Banks off North Carolina—the region where technical diving made its greatest leaps forward. The Florida Keys provide reef diving of the highest quality, and are popular as a training ground for thousands of divers who try the sport while on vacation.

The Caribbean offers classic coral reef diving. With its well-developed diving infrastructure, it has long been a favorite dive destination. To the south, in Central America, is the Belize barrier reef—the longest in the Northern Hemisphere. Off the coast of Venezuela lies Bonaire, in the Dutch Antilles, a beacon of marine conservation. Farther south still is the island of Fernando de Noronha off Brazil, perhaps the finest dive site in the whole of South America.

SEA SAFARI
Even snorkeling over sandbars in the Cayman Islands, western Caribbean, can bring you face to face with fascinating marine animals.

ENCHANTED FOREST
The towering kelp forests in the shallow waters off California are among the most beautiful and biologically rich of all marine habitats.

Florida Keys

FLORIDA, UNITED STATES

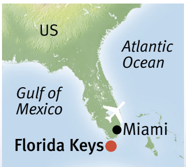

The Florida Keys are a string of coral and limestone islands stretching 120 miles (193 km) into the Gulf of Mexico. For many, this popular vacation destination represents a first introduction to diving, and there are dive sites of real quality and variety here.

SUNKEN TREASURES
The wreck of a tugboat lying in clear blue water. The Keys are famed for good underwater visibility and excellent areas for training.

PROTECTED ECOSYSTEM

The Florida Keys consist of 200 small islands, the largest of which are connected by the 42 bridges of US Highway 1. The importance of the Florida Keys as a vibrant marine ecosystem was recognized as long ago as 1960, with the John Pennecamp Coral Reef State Park established as the first-ever marine park in the US. More followed, and the region now boasts 18 protected areas, providing cover out to 3 miles (5 km) beyond the reef.

UNDERSEA ATTRACTIONS

The reef itself runs parallel to the island chain, roughly 5 miles (8 km) offshore. As such, most of the diving here is from boats, and there are many experienced operators. There are some excellent wrecks, as well as classic spur and groove reef formations, with the outer reef inhabited by a diverse range of Caribbean species. The shallow inner reef also hosts manatees, as well as providing a nursery for smaller species and huge numbers of trainee divers.

ESSENTIAL INFORMATION

WATER TEMPERATURE 70–84°F (21–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT Year-round diving, but hurricane season October to November.

MUST-SEES Molasses Reef, wreck of the *Adolphus Busch Sr.*; the Christ of the Deep statue in Key Largo.

Crystal River

FLORIDA, UNITED STATES

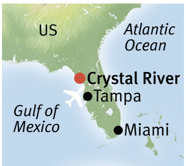

The Crystal River in northwest Florida is parent to a network of channels and tributaries snaking through the swamps. What draws divers to the region is the chance to swim with manatees—one of the great animal encounters in the underwater world.

WEB OF WATERWAYS

The Crystal River stems from a series of inland upwellings through porous rock, creating a natural filtering system that results in some of the clearest water on Earth. What this meeting of rock and water also creates is a honeycomb of caverns, caves, and tunnels. Although these are frequently occupied by huge catfish (a draw in themselves), the real attraction for the diver is the presence of the West Indian manatee.

GENTLE GIANTS

These huge and placid animals—measuring up to 14 ft (3 m) long and weighing up to a ton and a half—have been using the shallow pools and warm streams of the Crystal River to feed and breed for thousands of years. Speedboats and habitat destruction have exacted a terrible toll on the manatees, which are now on the endangered list. Diving with the manatees is not permitted, but nonetheless, snorkeling next to one of these huge animals in crystal-clear water is a tremendous experience.

ESSENTIAL INFORMATION

WATER TEMPERATURE 68–81°F (20–27°C)

ECOSYSTEM Freshwater

WHEN TO VISIT Crystal River can be visited year-round, but for snorkeling with manatees, the best time is between the months of December and April.

MUST-SEES Devil's Den, King's Cavern; swimming with manatees.

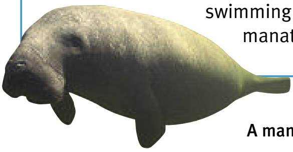

A manatee

CLEAR ADVANTAGE
The stunning clarity of the water at Crystal River stems from geological conditions in the area. Such waters are perfect for observing manatees.

Little Bahamas Bank

BAHAMAS, WESTERN ATLANTIC

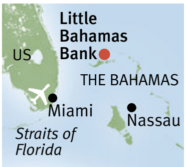

The Little Bahamas Bank would appear to be the most unpromising of dive sites—a vast patch of featureless, shallow sand bank. One animal has, however, made this area irresistible to divers. Dolphin encounters here are uniquely memorable.

WILD ENCOUNTER
Spotted dolphins have frequented the Little Bahamas Bank for many years, and these inquisitive animals freely interact with snorkelers in the shallow waters of the Bank.

SHALLOW SEA

The Little Bahamas Bank lies between the islands of Grand Bahama and Great Abaco, two of the larger islands of the 700 that make up the Bahamas archipelago. The northern end of the bank lies 70 miles (113 km) east of the Florida coast, allowing access to the region from the mainland US as well as the Bahamas. The bank is relatively featureless, consisting of shallow white sand dotted with low-lying reefs and the occasional wreck. Marine life is relatively sparse compared to other regions in the Bahamas, although there is the possibility of encounters with some enormous barracuda, several species of turtles, and a number of shark species.

ESSENTIAL INFORMATION

WATER TEMPERATURE 75–82°F (24–28°C)

ECOSYSTEM Tropical

WHEN TO VISIT Year-round, but hurricanes may strike later in the year.

MUST-SEES Spotted dolphin snorkeling encounter; the Bull Pit (shark dive); the Sugar Wreck.

STARS OF THE SEA

Both bottlenose and spotted dolphins visit the bank, but it is the guaranteed encounters with the latter that have made the site famous. These wild pods of dolphins have been interacting with divers for 20 years, and now a booming industry has grown up around these wonderful animals. Although only snorkeling is permitted with the dolphins, divers who have the privilege to encounter them in these clear, shallow seas take away lifelong memories.

Bonaire

DUTCH ANTILLES

US
Atlantic Ocean
CUBA
Bonaire
CENTRAL AMERICA
Caracas
VENEZUELA

For conservationists, Bonaire is a beacon of hope in the Caribbean. More than 40 years ago, the island's authorities realized that good reef management could promote tourism and boost the local economy. Bonaire is particularly noted for fine shore diving.

FORWARD THINKING

Bonaire is the most eastern island in the group that makes up the Dutch Antilles. It has always demonstrated an enlightened attitude toward conservation, with protective laws first passed in 1961 (to protect turtles), followed by a steady stream of additional measures over subsequent years that eventually resulted in the establishment of a marine park that now encircles the island. This extends down to 200 ft (60 m).

SANDY SHORES

Bonaire offers a wealth of shore diving possibilities. Many divers simply turn up on the island, rent a car, and go exploring. The spontaneity of this kind of diving has a charm all of its own. As well as splendidly pristine reefs, Bonaire also has two notable wrecks in the *Hilma Hooker*, a freighter lying at 100 ft (30 m), and the *Red Slave*. Diving under the Town Pier at Kralendijk, and Salt Pier (on the other side of the island), is also very rewarding.

ESSENTIAL INFORMATION

WATER TEMPERATURE 77–84°F (25–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT There is year-round diving on Bonaire, but hurricane season begins in the later part of the year.

MUST-SEES Town Pier at Kralendijk; the wreck of the *Hilma Hooker*.

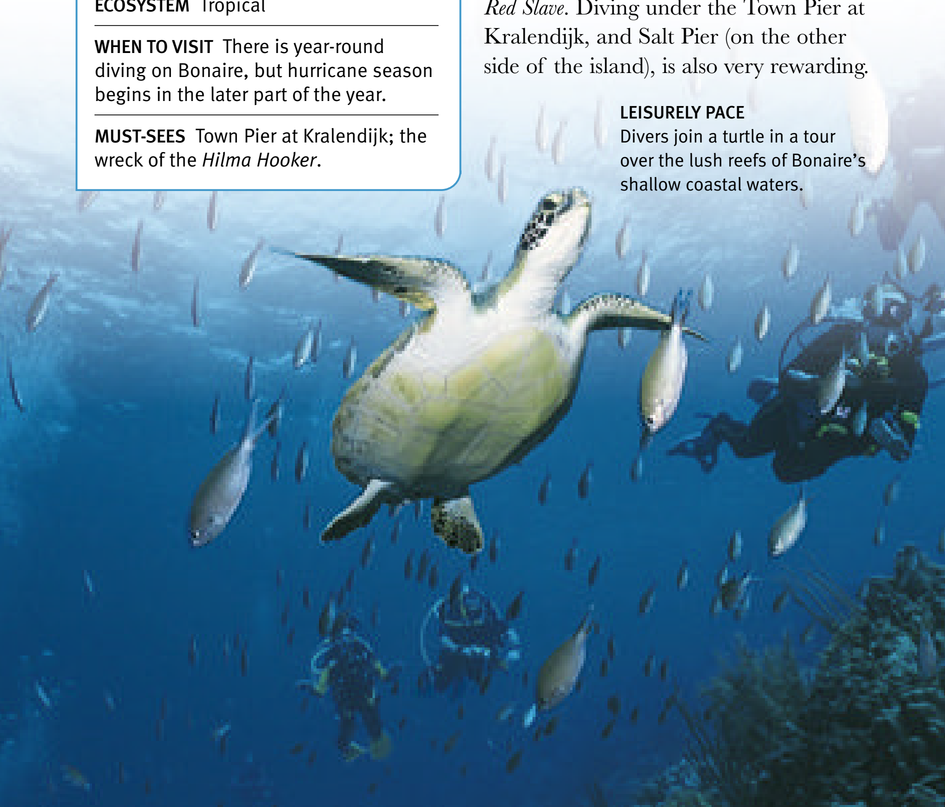

LEISURELY PACE
Divers join a turtle in a tour over the lush reefs of Bonaire's shallow coastal waters.

Cayman Islands

SOUTHERN CARIBBEAN

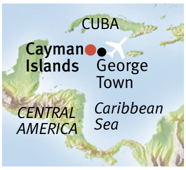

The Caymans are three low-lying islands 150 miles (240 km) south of Cuba. Views of the islands above the water belie the riches that lie beneath—steep walls, fine reefs, and a very shallow dive that is famed among the diving fraternity.

CLEAR WATERS

The Cayman Islands have two key characteristics that make them a classic dive area: they lack any mountains or large rivers, and the limestone bedrock absorbs water. Consequently, there is very little sedimentary runoff from the land when it rains, which ensures that the visibility underwater is excellent.

Added to this are steep walls, sandy lagoons, and 18 protected marine life reserves that ensure excellent diving.

ESSENTIAL INFORMATION

WATER TEMPERATURE 81–84°F (27–29°C)

ECOSYSTEM Tropical

WHEN TO VISIT Diving takes place in the Caymans year-round, although hurricane season starts late in the year.

MUST-SEES Stingrays in North Sound; the mantas of Bloody Bay Wall.

REEFS AND RAYS

The underwater environment is typified by shallow fringing reefs extending some way from shore, leading to busy reef crests and steep drop-offs. Large pelagics, such as mantas, eagle rays, and several species of sharks, drift past walls characterized by healthy fish populations and rich coral and sponge growth. The Caymans are famous for one particular stingray feeding site in North Sound, Grand Cayman, where as many as 200 stingrays cluster around divers in the shallows.

CLOSE ENCOUNTER
Stingrays gather to be fed at North Sound. Contact with them should always be on their terms.

Turks and Caicos

BAHAMAS, NORTHERN CARIBBEAN

US
Turks and Caicos
CUBA
Caribbean Sea
CENTRAL AMERICA

These two tiny island groups at the southeastern end of the Bahamas chain offer the diver true variety within a small area—from safe, shallow lagoons to steep walls and strong currents—with big animal encounters always possible.

DIVE PARADISE

The Turks and Caicos consist of two small clusters of islands on either side of the abyssal Turks Island Passage. To the west are the Caicos Islands, epitomized by shallow lagoons and gentle slopes. To the east, the smaller Turks Islands offer access to stunning drop-offs only a short boat ride from shore—although both sets of islands do have a range of dives within these broad categories, catering to the tentative beginner through to the hardened veteran.

THRIVING REEFS
A diver inspects growths of colorful tube sponges, which are a common sight on the reefs of the Turks and Caicos region.

PROTECTED STATUS

There are 33 protected areas within the Turks and Caicos, and these islands were the first in the entire Caribbean to ban spearfishing. As such, the marine life here is very impressive indeed, with healthy reefs dotted with huge sponges, and impressive pelagic activity in the form of dolphin encounters, gray reef, bull, and tiger sharks, as well as three resident species of turtles. In addition to these animals, large migrants also create excitement. From December through to April, the entire humpback whale population of the Atlantic passes through Turks Island Passage.

For wreck fans, the remains of the *Endymion*—a British warship that ran aground in 1790—offer a fascinating glimpse into naval history. Cannonballs and other relics can still be found on the seabed around the site. The wreck lies in shallow water 18 miles (30 km) south of Salt Cay; the site is readily accessible by boat.

ESSENTIAL INFORMATION

WATER TEMPERATURE 81–86°F (27–30°C)

ECOSYSTEM Tropical

WHEN TO VISIT Visit the Turks and Caicos between November and August

MUST-SEES Humpback whale migration, dolphin encounter; Northwest Point dives; the Tunnel; *Endymion* wreck.

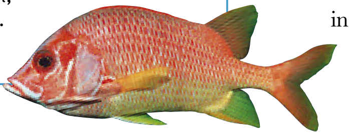

Giant squirrelfish

Cuba

WESTERN ATLANTIC

US
THE BAHAMAS
Havana
CUBA
JAMAICA
CENTRAL AMERICA

It did not take long for Cuba's developing dive industry to draw the attention of the international diving community. Certain classic sites have been well known for years, but Cuba's vast and varied coastline has much more to offer traveling divers.

GIANT COASTLINE

Cuba is a huge island 90 miles (155 km) south of Florida, with 3,500 miles (5,630 km) of coastline bordered by the Gulf of Mexico to the west, the Atlantic to the north, and the Caribbean to the south. The scale of the island is such that each of the three reefs along the coast of Cuba exceeds the length of the entire Florida Keys.

MARINE DIVERSITY

A recent survey noted over 1,000 fish species around Cuba—tremendous diversity for this part of the world. There are also some excellent big-animal encounters to be experienced here, including some classic shark dives and large groups of tarpon.

ESSENTIAL INFORMATION

WATER TEMPERATURE 75–81°F (24–27°C)

ECOSYSTEM Tropical

WHEN TO VISIT Diving continues year-round in Cuba, but hurricane season begins late in the year.

MUST-SEES The Isle of Youth; bull shark dive at Santa Lucía; *Cristóbal* wreck.

CLASSIC CUBAN DIVES

Cuba has an abundance of riches in terms of dive sites, and some consider the diving here to be the best in the world. Diving on the Isle of Youth is particularly popular, but Santa Lucía, Guardalavaca, and Santiago de Cuba also offer excellent dives. The last of these boasts a particularly fine shore dive with the wreck of the *Cristóbal Colón.* This former Spanish warship was attacked by the US navy in 1898, during a brief conflict between the two countries provoked by the sinking of a US ship in Havana harbor. The *Cristóbal Colón* was run aground by its commander, and is now a splendid historical dive site.

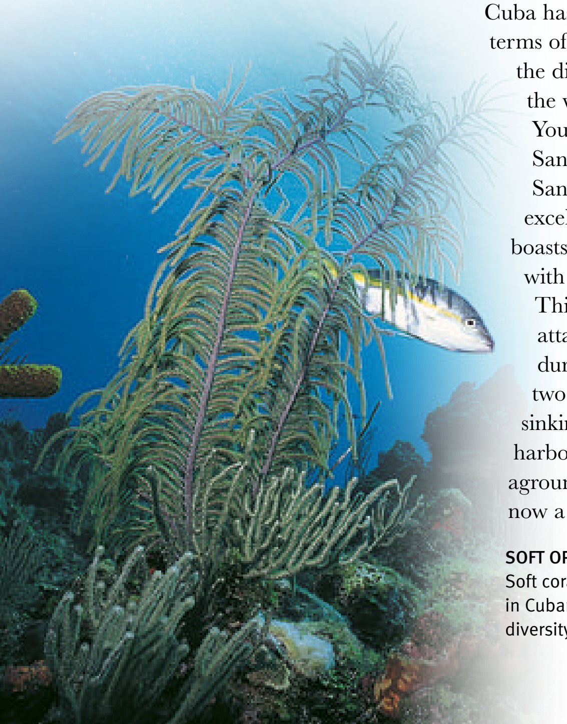

SOFT OPTION
Soft corals and sponges grow in profusion in Cuban waters, which enjoy unusually high diversity in marine species.

Cenotes

YUCATÁN PENINSULA, MEXICO

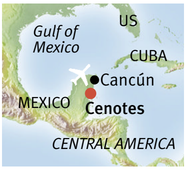

A network of flooded caves filled with crystal-clear water, the Cenotes offer the novice a chance to dive caverns in relative safety. For the more intrepid, and appropriately trained, the honeycomb of tunnels and passages offers advanced exploration opportunities.

INNER SPACE
A diver surveys the eerie interior of the Cenotes cave network. Though the system offers difficult technical challenges, it also has easier dives.

GEOLOGICAL WONDER

In Mexico's Yucatán Peninsula, the best dives are not at the coast but take place some distance inland, within the honeycombed heart of the Earth itself. The term "Cenotes" (from the Mayan word *tzonot*) refers to the entrances to the network of flooded passages and caverns that riddle this region.

Over 60 million years ago, this entire region was beneath the sea, creating rock strata of limestone from compressed coral and marine organisms. In the intervening period, this soft rock has been shaped by rain and rivers, creating one of the finest cave and cavern diving locations on Earth.

ESSENTIAL INFORMATION

WATER TEMPERATURE 66–77°F (19–25°C)

ECOSYSTEM Freshwater cave

WHEN TO VISIT The best time of year to dive the Cenotes is between November and March.

MUST-SEES Gran Cenote; Car Wash Cenote; coastal resorts nearby.

DIVING THE CENOTES

Although explorations are still ongoing in the Cenotes, many of the systems are accessible even for novice divers, with guides taking groups into vast caverns where an exit to the surface is always available if required. Sea diving at Cancún and Cozumel is available nearby.

A SAFETY LINE
Special equipment helps ensure safe, enjoyable diving in caverns (*see pp.186–87*).

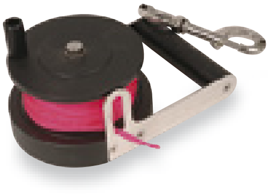

Belize Barrier Reef

BELIZE, CENTRAL AMERICA

CUBA
Yucatán
Belize City
Belize Barrier Reef
CENTRAL AMERICA

Belize is a small Central American country that has the good fortune to have a true natural marvel off its coastline. The Belize Barrier Reef is the longest in the Northern Hemisphere, and offers a vast range of diving possibilities for all skill levels.

SECLUDED COUNTRY

Belize covers around 8,880 sq miles (23,000 sq km) and has only 220,000 inhabitants. The country is renowned for its marine life, and due to the efforts of various voluntary organizations and its government, over 40 percent of Belize has been classified as a nature reserve.

THE BARRIER REEF

Belize also boasts a World Heritage Site—the Belize Barrier Reef. Extending for 174 miles (280 km) and ranging from 9 miles (14 km) to 19 miles (30 km) offshore, the reef offers a huge variety of divable sites to explore. Three of the four atolls in the Caribbean are found along the length of the reef. An atoll is a circular island that surrounds a lagoon, and is formed when coral reefs grow around the perimeter of a collapsed volcano. Linear sand and coral islands —known locally as cayes—also run

ESSENTIAL INFORMATION

WATER TEMPERATURE 77–82°F (25–28°C)

ECOSYSTEM Tropical

WHEN TO VISIT Diving in Belize takes place year-round, but the hurricane season begins around October.

MUST-SEES Whale sharks at Gladden Spit, Blue Hole, Shark Ray Alley.

along the length of the Barrier Reef, and provide a base for much of the area's dive activity. Of these, Ambergris Caye is the most popular location.

DIVING HIGHLIGHTS

Around 500 fish species swarm over the reef, including five different species of butterfly fish. Some larger animal species can also be seen, including huge jewfish and manta rays on the outer reef, and stingrays and nurse sharks at Shark Ray Alley. There are also healthy populations of reef sharks, as well as manatees (*see p.219*) in the shallow inshore waters and estuaries of the country.

While the most famous site in Belize is undoubtedly the Blue Hole, the area has a great deal more to offer, with classic reef dives, magnificent spur and groove reef formations, and some notable seasonal gatherings of big animals. At Gladden Spit in the south of the country, large numbers of whale sharks meet in feeding aggregations during the early part of the year. These huge ocean-going plankton-feeders grow to as much as 60 ft (18 m) in length.

THE BLUE HOLE

Perhaps the most famous site in Belize is the Blue Hole. Famously explored by Cousteau in 1972, this vast cavern lies 50 miles (80 km) off the east coast of Belize in the middle of Lighthouse Reef. Its perfectly circular entrance measures some 985 ft (300 m) in diameter, with the cavern plunging to a depth of 410 ft (125 m) beneath. The resident population of bull and lemon sharks in the interior of the Blue Hole is an eerie sight for divers visiting the stalactite formations found 130 ft (40 m) below the surface.

Aerial view of the Blue Hole

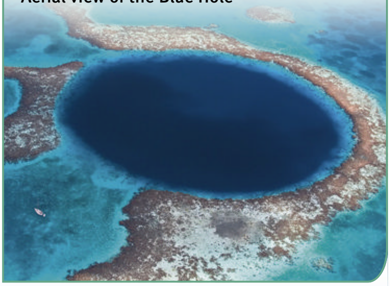

CYCLE OF LIFE
Whale sharks come to Belize to feed on the vast numbers of eggs generated by the mass spawning of a number of reef fish species, such as dog and cubera snappers, in spring.

Fernando de Noronha

WESTERN ATLANTIC

Fernando de Noronha
Natal
BRAZIL
SOUTH AMERICA

Rising up from the wild waters of the Atlantic, 250 miles (400 km) off the eastern coast of Brazil, is Fernando de Noronha. This tiny group of volcanic islands plays host to one of the largest resident pods of dolphins on Earth.

ATLANTIC TREASURE

The stark island group of Fernando de Noronha was for many years a well-kept secret among the Brazilian diving fraternity. The sea around the islands plunges to depths of over 2,300 ft (700 m), creating rich upwellings and swirling currents.

CLOSE ENCOUNTERS

Although the reefs here are relatively bare—only 95 fish species have been recorded on them—it is the big animal encounters that have made the site famous. Stories of extraordinary interactions with the huge resident pods of spinner dolphins around the islands have attracted divers who now travel here from around the world. Some 14 species of sharks, including nurse sharks and gray reef sharks, cruise over dark ridges, and two turtles are commonly sighted; one—the hawksbill—actually breeds here. The islands have been a World Heritage Site since 1981, a well-deserved status for this exciting site.

ESSENTIAL INFORMATION

WATER TEMPERATURE 70–79°F (21–26°C)

ECOSYSTEM Subtropical

WHEN TO VISIT Diving is best at Fernando de Noronha between September and March.

MUST-SEES Spinner dolphins at Baia dos Golfinhos; gray reef sharks at Laje dos Dois Irmãos.

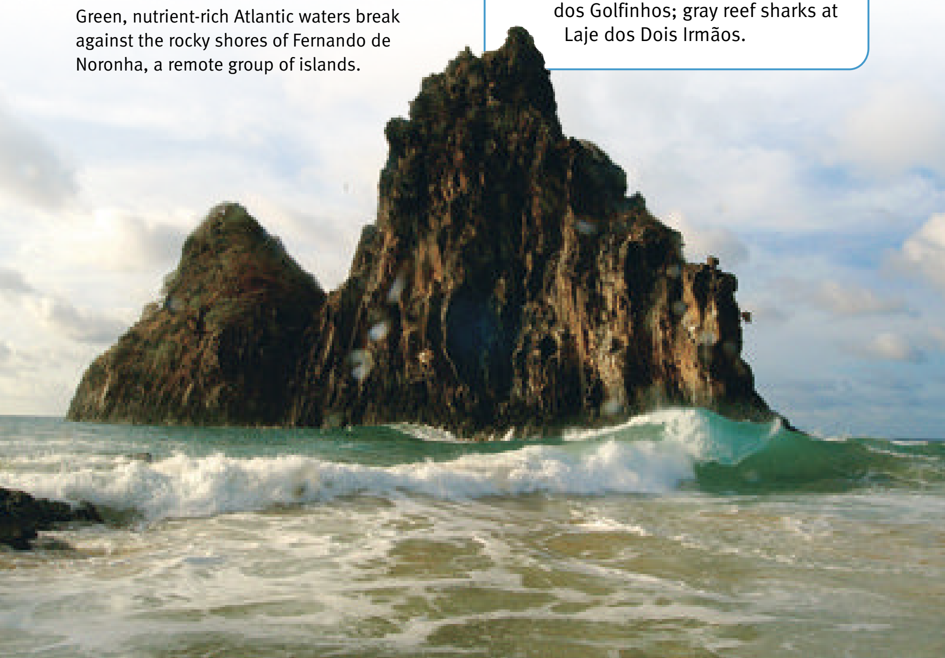

WILD BEAUTY
Green, nutrient-rich Atlantic waters break against the rocky shores of Fernando de Noronha, a remote group of islands.

Cocos and Malpelo

EASTERN PACIFIC

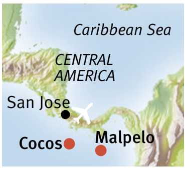

Considered by many to be among the finest big animal dive sites on Earth, the two volcanic islands of Cocos and Malpelo sit several hundred miles from land amid the wild currents and big swells of the eastern Pacific ocean.

DOUBLE IDENTITY

Although Cocos and Malpelo are generally referred to in the same breath by divers, the two islands are actually 250 miles (400 km) apart—Cocos off the coast of Costa Rica, and Malpelo off the coast of Colombia.

MARINE SANCTUARY

Rising from the deep waters of the Pacific in a series of serrated volcanic reefs and craggy pinnacles, the two islands provide a fantastic opportunity to experience larger marine animals at close range. Schooling hammerheads, hunting white-tip reef sharks, patrolling silky and Galápagos sharks—are all virtually guaranteed. Spotted moray eels are present in huge numbers, and itinerant visitors include whale sharks, mantas, and a number of bill-fish species. Both islands have a protected status—Cocos is a World Heritage Site, and Malpelo a Colombian Flora and Fauna Sanctuary.

ESSENTIAL INFORMATION

WATER TEMPERATURE 63–75°F (17–24°C)

ECOSYSTEM Subtropical

WHEN TO VISIT Conditions are best from December to September.

MUST-SEES Hammerhead schools; spotted morays in Malpelo; white-tip reef sharks hunting prey.

MEETING PLACE
Sharks of many species congregate in numbers off Cocos Island. Use of a rebreather (*left*) allows close approaches.

TOUGH CONDITIONS

Diving on Cocos and Malpelo is demanding, with big swells, swirling currents, occasional limited visibility, and stark reefs. The rewards for braving the challenging conditions, however, are immense, given the ample opportunities for big animal encounters. Some shark species, especially hammerheads, are naturally wary of divers, but a careful approach can work wonders. Specialist equipment can help, too—rebreathers (*see pp.82–83*), which do not create bubbles, allow the diver to make an unobtrusive approach and thus give the best chance for close encounters.

Roca Partida

COLIMA STATE, MEXICO

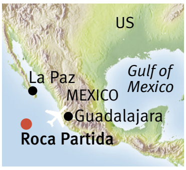

This stark volcanic pinnacle rises from the depths of the Pacific 200 miles (320 km) off the tip of the Baja Peninsula. This is truly wild diving, with powerful swells, big currents, and large marine species at one of the most isolated dive sites in the world.

SHEER DIVING

The most remote outcrop of the Archipelago of Revillagigedo (a group of four islands), Roca Partida rises starkly from the wild surface of the Pacific Ocean, its rugged silhouette reflecting the characteristics of the reefs beneath. Steep walls plunge into deep, dark water, with very little life encrusted on their barren surfaces.

ESSENTIAL INFORMATION

WATER TEMPERATURE 66–77°F (19–25°C)

ECOSYSTEM Subtropical

WHEN TO VISIT Roca Partida has good, year-round diving, but cooler winter water is best for shark diversity.

MUST-SEES Manta rays; sleeping white-tip and silver-tip sharks; black jacks.

BOUNTIFUL SEAS

The rich upwellings from deep water around Roca Partida provide plentiful nutrients and oxygen for circling fish shoals, including huge black jacks and dense schools of barracuda. These in turn attract silky, white-tip, silver-tip, and hammerhead sharks in great numbers. What makes this dive site so special, however, are the manta ray encounters, which are among the best to be had anywhere; these magnificent animals almost seem to seek out divers, resulting in some extraordinary interactions.

The reputation of Roca Partida is spreading, and it is rapidly becoming an iconic site in the diving world. Divers willing to make the journey to this remote and wild location will find themselves amply rewarded.

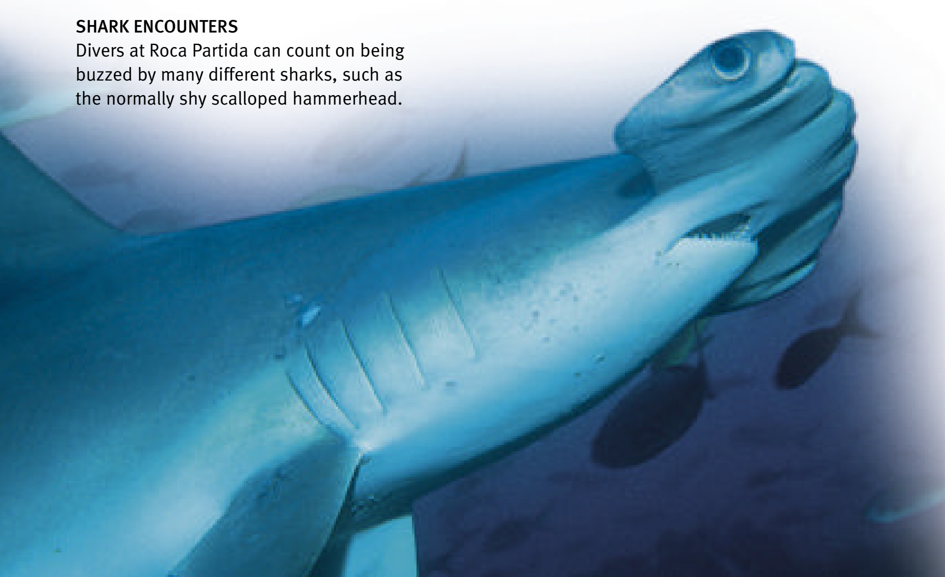

SHARK ENCOUNTERS
Divers at Roca Partida can count on being buzzed by many different sharks, such as the normally shy scalloped hammerhead.

Hawaii

CENTRAL PACIFIC OCEAN

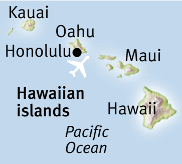

The underwater terrain of Hawaii reflects its volcanic origins, with twisted lava formations and steep drop-offs into abyssal depths. The oceanic island group is world-renowned for its surfing, but offers exceptional diving, too.

ISLAND PARADISE

Hawaii is the world's longest island chain, extending more than 1,500 miles (2,400 km), and situated over 2,500 miles (4,000 km) from the mainland. It comprises eight main islands—each the top of a submerged volcano—as well as another 124 tiny areas of uninhabited land that amount to no more than 3 sq miles (8 sq km). The stark ridges and bizarre rock formations that epitomize Hawaii's terrain above sea level extend beneath the water's surface, offering exciting dive opportunities, and great wildlife encounters. Hawaii's extreme isolation means it is visited by nomadic species from the vast expanse of the Pacific Ocean. The most notable of the pelagic animals are humpback whales, pygmy pilot whales, manta rays, and oceanic white-tip sharks. Humpbacks have been hunted globally almost to extinction, and have become rare even in the waters around Hawaii. Excellent dive sites can be found on the island of Hawaii—or Big Island—at the eastern end of the island chain, as well as Maui, Kauai, and Oahu.

ESSENTIAL INFORMATION

WATER TEMPERATURE 75–81°F (24–27°C)

ECOSYSTEM Tropical

WHEN TO VISIT Year-round, but winter months at this busy site are less crowded.

MUST-SEES Manta rays at Kona Beach; pygmy pilot whales; Shark's Cove, Oahu; Molokai; Long Lava Tube, Big Island.

WAVE-SWEPT COASTLINE
Hawaii lies at the same latitude as central Mexico. Clean waters, pure sands, and a tropical climate add to its appeal as a dive destination.

Catalina Island

CALIFORNIA, UNITED STATES

US
Los Angeles
Catalina
Island
MEXICO

Lying only 22 miles (35 km) off the coast of California is a spectacular island of dramatic scenery above the water, and tremendous beauty beneath. Catalina Island has been a nature reserve since 1974, with huge rewards for the diver.

PROTECTED ISLAND

Catalina Island is 20 miles (32 km) in length and 8 miles (13 km) wide, and has been owned by the Wrigley family since 1919. Avid conservationists, they have consistently refused permission for development on the island, and now 86 percent of it is an established nature reserve. The rugged topography of the island extends below the waterline, with tremendous diving on craggy reefs and steep underwater pinnacles.

RICH SEAS

The island is swept by the cold waters of the California Current as it moves down from British Colombia. This creates oxygen-rich waters where kelp forests flourish—some of the larger specimens stretch from surface to seabed, 100 ft (30 m) below. Cruising these underwater forests is a wide range of fish species, the most famous of which is the garibaldi. Fiercely territorial, these brightly colored fish will stand their ground as divers approach—a photographer's dream. The kelp forests are also home to huge black sea bass, eagle rays, California morays, and two-spot octopuses. The black sea bass is a particularly welcome sight, since it was once heavily overfished but is now making a comeback. Larger residents include the California sea lion, a species known for its curiosity and willingness to approach divers. The occasional blue shark can be encountered off Catalina's shores, rounding off an exhilarating list of animals waiting to be discovered here.

FOREST BENEATH THE WAVES
A rich variety of marine life is supported by the giant kelp stands of Catalina Island. Garibaldi fish are familiar residents of the kelp.

ESSENTIAL INFORMATION

WATER TEMPERATURE 54–68°F (12–20°C)

ECOSYSTEM Temperate

WHEN TO VISIT Diving takes place year-round off Catalina, but winter diving can be very cold.

MUST-SEES The Casino Point Underwater Park; The Farnsworth Banks.

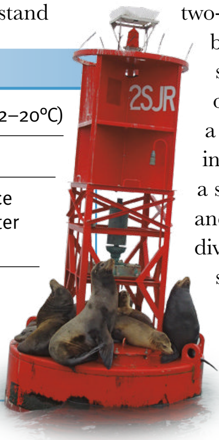

California sea lions

The Outer Banks

NORTH CAROLINA, UNITED STATES

US
Norfolk
Outer Banks
Atlantic Ocean
Gulf of Mexico

Famed in seafaring lore as the graveyard of ships, the Outer Banks are thought to be the site of up to 5,000 shipwrecks. Big ocean currents and an abundance of large pelagic animals combine to make this region one of the most exciting in the diving world.

HISTORIC WATERS

The Outer Banks are identified by a dramatic chain of islands and sandbars that extend for 130 miles (35 km) up the coast of North Carolina. Within this barrier is a vast area of estuary, shallow lagoons, and enclosed water. This ecological gem is a crucial breeding ground for many fish species, and 70 percent of the region enjoys protected status. The Outer Banks beyond the island chain are the real draw for the diver. With three great ocean currents meeting off this coastline, and the continental shelf only 40 miles (65 km) to the east, this is dramatic diving territory. The Outer Banks are littered with wrecks—many of them sunk by U-boats in World War II. Many of these are home to some of the larger residents of the banks, including numerous sand tiger sharks (also known as ragged-tooth sharks). These fierce-looking animals are in fact quite approachable if not provoked.

ESSENTIAL INFORMATION

WATER TEMPERATURE 54–75°F (12–24°C)

ECOSYSTEM Temperate

WHEN TO VISIT For the most favorable diving conditions, visit the Outer Banks between July and September.

MUST-SEES Wrecks of the *Papoose* and *Proteus*; sand tiger sharks.

FEARSOME APPEARANCE
Despite its looks, the sand tiger shark is relatively docile. However, like all large predators, it should be treated with respect.

The Great Lakes

CANADA/UNITED STATES

The Great Lakes
CANADA
Toronto
Detroit
Chicago
US

Straddling the border between Canada and the US, the five Great Lakes make up the largest expanse of fresh water on Earth. Conditions in the lakes can be demanding, but the reward is access to some of the best-preserved wrecks in the diving world.

WORLD-CLASS WRECKS

The Great Lakes cover an area of 95,000 sq miles (246,000 sq km), and offer a range of diving experiences and conditions. Many of the more densely populated regions around the lakes have always been significant industrial zones and have suffered through pollution and overexploitation. The water is cold, and visibility can be limited, although in the lower lakes it has improved through the accidental (and in all other respects unwanted) introduction of the zebra mussel—a voracious filter-feeder that has cleaned the lakes of algae. There are many wrecks on the various lake beds. The very low temperatures and the lack of salt in the water have kept metal hulls relatively free of rust, while wooden vessels and even rope can be found in a remarkably good state of preservation.

ESSENTIAL INFORMATION

WATER TEMPERATURE 32–64°F (0–18°C)

ECOSYSTEM Temperate

WHEN TO VISIT Year-round, but northern dives may be under ice in winter.

MUST-SEES Sea caves along Lake Superior coast; the *Arabia* and other well-preserved wrecks.

PRESERVING THE PAST

In the early days of diving the lakes, numerous artifacts were plundered from otherwise pristine wreck sites. This malpractice was quickly stamped out through the establishment of a number of preserves. Lake Michigan alone has nine such special areas, covering 1,900 sq miles (4,920 sq km). Notable wrecks throughout the lakes include the *Arabia*, a sailing vessel sunk in 1884 and still perfectly intact; the *Bermuda*, sunk in 1870; and the more contemporary *Mesquite*, sunk in 1989.

FRESHWATER OASIS
The pine-flanked shores of Lake Michigan, where nine preserves protect sensitive underwater resources.

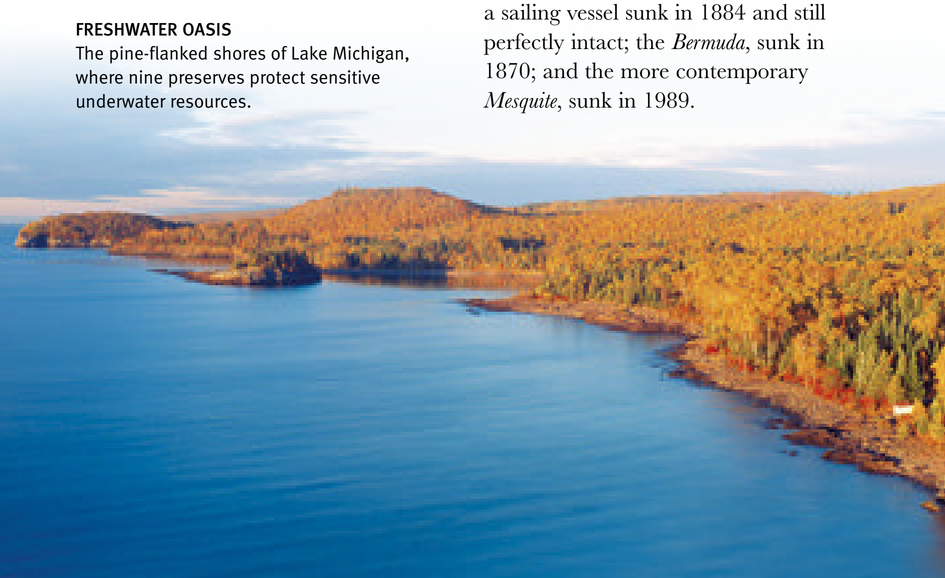

Vancouver Island

BRITISH COLUMBIA, WESTERN CANADA

CANADA
British Columbia
Vancouver
US

The cold waters and strong tides around Vancouver Island create a glorious mix of wildlife, and there are also vessels sunk as artificial reefs to add extra interest for the visiting diver. Some of the most popular dives lie between the island and the mainland.

CHANNEL CROSSING

The standard means of reaching Vancouver Island is via a ferry from the city itself, a 90-minute journey that gives you a glimpse of the abundant waters of this region. Cold waters are rich in oxygen and nutrients, and the channel between the island and the mainland is no exception. The addition of strong tidal movements creates an irresistible draw for marine plants and animals, and although the diving can be demanding at times—for example, in the fast-running Dodds Narrows channel—there is much to make the experience worthwhile. One of the most famous residents of these waters is the inquisitive giant octopus, although more elusive wolf eels, harbor seals, various whale species (including orcas), and huge numbers of salmon may also be encountered at the right time of year.

ARTIFICIAL REEFS

The vessel *Saskatchewan* was sunk in 1997 as an artificial reef, and has proved a real hit with both local and visiting divers. It is just one of a number of decommissioned warships, all well worth a dive, sunk off the coast by the Artificial Reef Society of British Columbia—a society formed by a group of underwater archaeologists in 1990 to turn warships into dive sites.

EXTRAORDINARY ENCOUNTER
A diver makes contact with a giant octopus, a fascinating species that thrives in the nutrient-rich waters.

ESSENTIAL INFORMATION

WATER TEMPERATURE 48–64°F (9–18°C)

ECOSYSTEM Temperate

WHEN TO VISIT Year-round, but winter can be chilly.

MUST-SEES Giant octopuses; whales; wreck of the *Saskatchewan*; Dodds Narrows channel.

Galápagos Islands

EASTERN PACIFIC

Caribbean Sea
CENTRAL AMERICA
Galápagos Islands
SOUTH AMERICA
Pacific Ocean

The Galápagos were known as the Enchanted Isles by early mariners, baffled by the currents that swirled around them. The name has changed, but the experience remains the same for divers fortunate enough to visit this unique archipelago.

RUGGED AND REMOTE

The Galápagos Islands are named after the Spanish word for "saddle"—*galápago*—after the shape of the shells of the giant tortoises that provided a food source for the early explorers and whaling ships that visited the islands. The island group consists of 13 main islands situated 600 miles (970 km) off the west coast of Ecuador. These stark islands, only a few million years old, still show the contorted rock formations—twisted reefs and pitted ridges—caused by their volcanic birth. These provide an excellent substrate for busy marine communities, replenished by the seven ocean currents that converge on this island group from all directions.

ESSENTIAL INFORMATION

WATER TEMPERATURE 61–81°F (16–27°C)

ECOSYSTEM Temperate

WHEN TO VISIT Diving continues year-round in the Galápagos.

MUST-SEES Hammerheads and whitetips at Wolf and Darwin; whale sharks; sea lions; marine iguanas; penguins.

MARINE LIFE

Although there are only 13 reef-building species of coral in the Galápagos, meaning that the reefs are stark affairs clinging to the dark volcanic rock, the life that swarms over them is spectacular.

The fame of the Galápagos as a dive site lies in its gatherings of large marine animals, including magnificent schools of scalloped hammerheads. Sadly, overfishing has had a serious impact on shark populations in the waters around the islands, and unless circumstances change, such sightings may become increasingly rare. Groups of cow-nosed rays and eagle rays are regularly sighted off the more exposed reefs, as well as gatherings of manta rays and the occasional whale shark.

UNIQUE SPECIES

A visit to the Galápagos offers animal encounters that cannot be experienced elsewhere. The islands have evolved in isolation, and are home to a number of remarkable species. Perhaps the most famous of these is the marine iguana, although the islands also have colonies of the most northerly penguin species on Earth—the tiny Galápagos penguin. It is possible to snorkel with both of these species if accompanied by a knowledgeable local guide and with the right sea conditions.

WILD GALÁPAGOS

Visiting California sea lion

It is not surprising that the Galápagos Islands provided inspiration for Darwin's theory of evolution—they are rich in all kinds of life. There are well over 300 fish species in the region, including 30 species of sharks. Larger residents include nearly 80,000 seals and sea lions. There are also 600 species of mollusks and 100 different types of crabs! Larger visitors include sperm whales, humpbacks, and Bryde's whales, as well as many species of dolphins. The islands are a naturalist's paradise.

BARREN APPEARANCE
The bleak contours of the Galápagos Islands might seem to suggest a region devoid of life. The appearance is deceptive, however—life thrives here both above and below the green waters of the surrounding Pacific Ocean.

Useful resources

PADI: DIVE SAFETY CHECKLIST

- Divers should limit their depths according to their training, certification level, and experience.
- Regardless of level of training, any increase in diving depth should be incremental.
- Further training and/or supervision is needed when diving in a new type of environment.
- Avoid overweighting; carry out a buoyancy check whenever using new equipment. Remember to reduce weighting when going from salt to fresh water.
- Ensure that all weight systems used have a quick release and that each buddy is familiar with its operation.
- Always review emergency procedures prior to each dive.
- Have regular medical checkups and stay in shape for diving.
- If surface conditions, currents, or visibility deteriorate, consider aborting a dive.
- Consult tide tables where appropriate and seek local advice on prevailing diving conditions.
- Use surface marker buoys and ascent/descent lines wherever appropriate.
- Always inform a non-diver where you are going and when you expect to return.

Visit www.padi.com

PROJECT AWARE FOUNDATION: TEN WAYS A DIVER CAN PROTECT THE UNDERWATER ENVIRONMENT

Divers and snorkelers are obvious ambassadors for the underwater environment. Let’s make sure we:

1. Dive carefully in fragile aquatic environments
Although at first they may look like rocks or plants, many aquatic organisms are fragile creatures that can be damaged or harmed by the bump of a tank, knee, or camera, a swipe of a fin, or even the touch of a hand. It is also important to know that some aquatic organisms, such as corals, are extremely slow-growing. By breaking off even a small piece, you may be destroying decades of growth. By being careful, you can prevent devastating and long-lasting damage to magnificent dive sites.

2. Streamline yourself
Much damage to the environment is done unknowingly. Keep your gauges and alternate air source secured so they don’t drag over the reef or bottom. By controlling your buoyancy and taking care not to touch coral or other fragile organisms with your body, diving equipment, or camera, you will have done your part in preventing injury to aquatic life.

3. Continue your education
If you haven’t dived in a while, your skills (particularly buoyancy control) may need sharpening. Before heading to the reefs, seek bottom time with a certified assistant or instructor in a pool or other environment that won’t be damaged by a few bumps and scrapes. Better yet, take a diving continuing education course such as PADI Scuba Review, the PADI Adventures in Diving program, or a PADI Specialty Diver course. AWARE continuing education diving courses provide you with the skills practice and practical application of environmentally sound diving techniques.

4. Consider your impact on aquatic life through your interactions
Very few forms of aquatic life pose a threat to us. In fact, some creatures even seem friendly and curious about our presence. As we become bolder and more curious ourselves, we may even feel compelled to touch, handle, feed and even hitch rides on certain aquatic life. However, our actions may cause stress to the animal, interrupt feeding and mating behavior, introduce food items that are not healthy for the species, or even provoke aggressive behavior in normally nonaggressive species. Interact responsibly with the aquatic environment.

5. Understand and respect underwater life; resist the urge to collect souvenirs
Through adaptation to an aquatic environment, underwater life often differs greatly in appearance from life we are used to seeing on land. Many creatures only appear to look like plants or inanimate objects. Using them as “toys” or food for other animals can leave a trail of destruction that can disrupt a local ecosystem and rob other divers of the pleasure of observing or photographing these creatures. Consider taking part in a Project AWARE program to become more familiar with the importance of, and the interdependent nature of, worldwide aquatic

ecosystems. Dive sites that are heavily visited can be depleted of their resources in a short time. Collecting specimens, coral, and shells in these areas can strip their fascination and beauty. If you want to return from your dives with trophies to show friends and family, you may want to consider underwater photography instead.

6. Be an ECO-Tourist
Protected areas, such as parks, reserves, and sanctuaries, are one of the best tools for conserving the aquatic environment. Support the creation of protected areas, follow all local laws, and learn to appreciate that all aquatic habitats (such as grass beds, mangroves, and rubble zones) are important and interesting environments. Do not confine your diving only to sites highlighted in brochures and articles. When planning a diving trip, choose ECO Tour Operators involved with ECO-resorts and ECO-operators. Make informed decisions when selecting a destination, and support the Project AWARE Go ECO environmental campaign.

7. Respect the underwater cultural heritage
Divers and snorkelers have the privilege to access dive sites that are part of our cultural heritage or maritime history. You should help preserve these sites for future generations by obeying local laws, diving responsibly, and treating wrecks with respect. Wrecks can serve as important habitats for fish and other aquatic life.

8. Report environmental disturbances or destruction of your dive sites
Divers and snorkelers are in a unique position to monitor the health of local waterways, lakes, and coastal areas. If you observe an unusual depletion of aquatic life, a rash of injuries to aquatic animals, or strange substances or objects in the water, report them to your department of natural resources or similar entity.

9. Be a role model
As a diver or snorkeler, you realize that when someone throws a plastic wrapper or other debris overboard, it is not out of sight, out of mind. You see the results of such neglect. Set a good example in your own interactions with the environment, and other divers and non-divers will follow suit.

10. Get Involved
There are plenty of opportunities to show your support of a clean aquatic environment, including local beach cleanups, surveys, and attending public hearings on matters that impact local coastal areas and water resources. Divers' skills in particular are always needed and appreciated by many environmental organisations.

Visit www.projectaware.org for more details

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USEFUL CONTACTS

Training organizations

International groups offering both basic and specialized dive instruction, including training organizations based on an amateur footing.

Professional Association of Dive Instructors (PADI)
www.padi.com

PADI Americas: 30151 Tomas Street, Rancho Santa Margarita, CA 92688-2125

PADI Europe: Oberwilerstrasse 3 CH-8442, Hettlingen, Switzerland

PADI Canada: 107 – 1680 Broadway Street, Port Coquitlam, BC V3C 2M8

National Association of Underwater Instructors (NAUI)
Worldwide headquarters: PO Box 89789,
Tampa, FL 33689-0413
www.naui.org

British Sub Aqua Club (BSAC)
Telford's Quay, South Pier Road,
Ellesmere Port, Cheshire, CH65 4FL, UK
www.bsac.com

Sub Aqua Association
Space Solutions Business Centre, Sefton Lane,
Maghull, Liverpool, L31 8BX, UK
www.saa.org.uk

Scottish Sub Aqua Club
The Cockburn Centre, 40 Bogmore Place,
Glasgow, G51 4TQ, UK
www.scotsac.com

Scuba Schools International
2619 Canton Court, Fort Collins,
CO 80525-4498
www.ssiusa.com

World Underwater Federation
Viale Tiziano, 74 00196, Roma, Italia
www.cmas2000.org

Technical Diving International
18 Elm Street, Topsham, Maine, 04086
www.tdisdi.com

International Association of Nitrox and Technical Divers
5609 Power Road, Ottawa, Ontario,
K1G 3N4
www.iantd.com

USEFUL CONTACTS (CONTINUED)

National Association for Cave Diving (**NACD**)
P.O. Box 14492, Gainesville, FL 32604
www.safecavediving.com

ACUC International (**American Canadian Underwater Certifications**)
379 West Street, Brantford, ON
N3R 3V9
www.acuc.ca

Governing bodies

Organizations promoting and regulating recreational diving activities.

World Underwater Federation
Viale Tiziano, 74 00196, Roma, Italy
www.cmas2000.org

International Association for the Development of Freediving (**AIDA**)
Rue du Petit-Beaulieu 4
CH 1004 Lausanne, Switzerland
www.aida-international.org

Freediving Regulations and Education Entity (**FREE**)
7480 NW 175 St., Miami, FL 33015
www.divingfree.com

International Association for Handicapped Divers
http://www.iahd.org

Conservation and heritage organizations

Charitable and nonprofit organizations promoting marine wildlife conservation, and groups involved in preserving maritime heritage.

Coral Cay Conservation
40-42 Osnaburgh Street, London,
NW1 3ND, UK
www.coralcay.org

World Wildlife Fund
1250 Twenty-Fourth Street, N.W.
P.O. Box 97180, Washington, DC
20090-7180
www.worldwildlife.org

Marine Conservation Society
Unit 3, Wolf Business Park, Alton Road,
Ross-on-Wye, Herefordshire, HR9 5NB, UK
www.mcsuk.org

British Divers Marine Life Rescue
Lime House, Regency Close Uckfield,
East Sussex, TN22 1DS, UK
www.bdmlr.org.uk/donate

Marine Fish Conservation Network
600 Pennsylvania Avenue, SE, Suite 210,
Washington, DC 20003
www.conservefish.org/site

Nautical Archaeology Society
The Nautical Archaeology Society,
Fort Cumberland, Fort Cumberland Road,
Portsmouth, PO4 9LD, UK
www.nasportsmouth.org.uk

Whale and Dolphin Conservation Society
Brookfield House, 38 St Paul Street,
Chippenham, Wiltshire, SN15 1LJ, UK

The Shark Trust
National Marine Aquarium, The Rope Walk
Coxside, Plymouth, PL4 OLF, UK
www.sharktrust.org/sharkconservation.html

Parks Canada (**National Marine Conservation Areas of Canada**)
25 Eddy Street, Gatineau, QC
K1A 0M5

Historical Diving Society
Historical Diving Society USA , PO Box 2837,
Santa Maria, CA 93457
www.hds.org

Historical Diving Society UK
www.thehds.com

Maritime Archaeological and Historical Society
P.O. Box 44382, L'Enfant Plaza, Washington,
DC 20026
www.mahsnet.org

Diving medicine and safety organizations

Expert advisory groups on diving medicine and safety issues.

Divers Alert Network (**DAN**)
The Peter B. Bennett Center, 6 West Colony
Place, Durham, NC 27705
www.diversalertnetwork.org

British Diving Safety Group
West Quay Road, Poole, BH15 1HZ, UK
www.bdsg.org

London Diving Chamber
Hospital of St John and St Elizabeth,
60 Grove End Road, St John's Wood,
London, NW8 9NH, UK

Glossary

ABSOLUTE PRESSURE The total *pressure* acting on a body, equal to the sum of *atmospheric pressure* and *gauge pressure*.

A-CLAMP FITTING A *regulator first stage* that attaches to the *pillar valve* of a *tank* by means of a yoke that clamps it securely in position.

AIR CONSUMPTION The depletion of oxygen in air through respiration; the rate at which air is used by a diver during the course of a dive.

ALTERNATE AIR SOURCE A redundant source of air supply, in the form of either an *octopus second stage*, or a completely independent *tank* and *regulator*.

AMBIENT PRESSURE The total *pressure* acting on a body at a given depth. See also *absolute pressure*.

ANCHOR LINE A rope, cable, or chain that attaches a ship to its anchor.

ANOXIA A medical condition caused by a lack, or severe deficiency of, oxygen in the human body.

AQUA LUNG The first underwater breathing apparatus to use compressed air and a two-stage *regulator*, designed by Emile Gagnan and Jacques Cousteau.

ARCHIPELAGO A group or chain of islands.

ARTIFICIAL REEF A human-made object deliberately scuttled to create a haven for marine life, and for the enjoyment of divers.

ASCENT Returning from depth to the surface at the end of a dive. This must always be performed carefully to avoid *decompression sickness*.

ATMOSPHERIC PRESSURE The *pressure* exerted by the gases in the atmosphere. At sea level, this is equal to 14.7 psi (1 bar).

ATOLL Circular *coral reef*, often surrounding a lagoon, that has formed around a submerged extinct volcano.

BALLAST Lead weights carried to offset the inherent *buoyancy* of the diver's *exposure suit*.

BENDS See *decompression sickness*

BEZEL A rotatable, notched, or marked outer ring on instruments, such as watches and compasses, used to mark key datum points, such as a bearing.

BLOCK SHIP A vessel sunk deliberately across the approaches to a naval harbor to bar entry to hostile submarines and surface ships.

BOMMIE An isolated outcrop of coral growth on the seabed.

BOYLE'S LAW Physical law stating that at a constant temperature, the volume of a gas is inversely proportional to the *pressure* exerted on it.

BRACKISH Water that is not as salty as seawater, but has a higher salt content than fresh water.

BREATH-HOLD DIVING See *freediving*

BUBBLE CHECK A precautionary visual inspection of another diver's gear (conducted underwater) to determine if it has any air leaks.

BUDDY A diver who assumes an informal duty of care over the other member of their assigned "buddy pair" during diving.

BUDDY LINE A safety line for tethering a *buddy* pair together.

BUOYANCY An upward thrust exerted on an immersed object, which is equal to the weight of the water that has been displaced by the object.

BUOYANCY COMPENSATOR (BC) A jacket that can be inflated and deflated to allow the diver to control their *buoyancy*.

BUOYANCY CONTROL Manipulation of *buoyancy* through the use of devices such as a *BC*, and the breathing cycle.

CAISSON A pressurized, watertight chamber used to undertake construction work underwater.

CERTIFICATION CARD Accreditation proving that a diver has achieved a certain level of dive training with one of the recognized agencies.

CORAL HEAD Protrusions on a *coral reef* formed by a colony of living coral polyps feeding and growing.

CORAL ISLAND Portion of a *coral reef* that is permanently out of water, its surface usually eroded to a flat top of white coral rock and sand. May occur in a chain along a reef.

CORAL REEF A massive, marine, rocklike ridge or outcrop created by the gradual accretion of the skeletons of generations of coral polyps.

DATUM LINE A line used as a fixed reference to aid in an accurate survey of an area.

DECOMPRESSION Returning to conditions of normal *atmospheric pressure* by controlled means.

DECOMPRESSION SCHEDULE A plan describing the number, duration, and depth of *decompression stops* required for a given dive.

DECOMPRESSION SICKNESS (DCS) A potentially dangerous medical condition resulting from the formation of bubbles of nitrogen in the bloodstream and tissues of a diver's body. Also known as decompression injury (DCI) and the bends.

DECOMPRESSION STOP A scheduled pause in a diver's ascent to allow nitrogen to pass from body tissues back into the blood at a safe rate.

DEHYDRATION A medical condition resulting from excessive loss of water from the body.

DELAYED SURFACE MARKER BUOY (DSMB) Marker buoy deployed just before ascent. It is inflated underwater, then released to indicate where a diver will surface.

DEMAND VALVE See *second stage*

DEPTH GAUGE An analog or digital gauge that measures *ambient pressure*, and uses this to give a reading of depth.

DESCENT Traveling from the surface to depth.

DIN FITTING A screw-thread fitting for attaching a *regulator first stage* to a compatible *pillar valve*. Allows higher working pressures than *A-clamp* fittings.

DISPLACEMENT The displacement of water that occurs when an object is submerged in it.

DISTANCE LINE A line fastened to a submerged feature and deployed from a *reel* as a navigational guide, especially in areas of low visibility.

DIVE CENTER A commercially run diving school and rental center, frequently offering organized trips and guides to local *dive sites*.

DIVE COMPUTER A digital device that provides the diver with a range of information, such as depth, time, and ascent rate.

DIVE CONSOLE An instrument panel incorporating a *tank contents gauge*, *depth gauge*, and sometimes also a compass, or a *dive computer*.

DIVE GUIDE An employee of a *dive center* or school who guides qualified divers around local *dive sites*.

DIVE LEADER The diver in a *buddy* pair who is designated (by agreement) as the principle pace-setter and decision-maker underwater.

DIVE MARSHAL A senior diver whose role on a dive trip is to allocate *buddy* pairs, approve *dive plans*, ensure that complete records of dives are kept, and initiate and direct rescue efforts in the event of a diving accident.

DIVE PLAN The outline of a proposed dive, including its depth, duration, intended goals, entry and exit points, signaling conventions, and contingency plans.

DIVE SITE Any location where diving is conducted.

DIVE SLATE A plastic tablet used for making notes underwater.

DIVE TIME The duration of a dive, starting at the moment the diver leaves the surface and ending with their return to the surface.

DIVEMASTER A person qualified to act as a *dive guide*, assist diving instructors, and oversee the organization of dives for paying customers.

DIVING CLUB An organization offering diving instruction and social events on an amateur basis. It can also refer to continental European diving centers offering instruction on a commercial basis.

DIVING SCHOOL A center for instruction in diving skills (usually on a commercial basis).

DPV (DIVER PROPULSION VEHICLE) A propulsion device either ridden or clung to by a diver to minimize swimming effort or aid in the exploration of large *dive sites*.

DRAG Frictional resistance to the motion of an object through a fluid.

DRIFT DIVE A dive in which the diver is propelled along a route by undersea currents.

D-RING A D-shaped ring of metal or plastic used as an anchor point for tethering equipment to your *BC* during a dive.

DROP-OFF A falling-away of the ground or seabed, such as a *reef wall* or rock shelf that descends steeply.

DRYSUIT An *exposure suit* designed for use in very cold waters, in which trapped air is the principle insulating medium, and that offers a high degree of thermal protection.

DSMB (DELAYED SURFACE MARKER BUOY) A tubular buoy designed to be deployed at the end of a dive to aid *ascent* and alert observers at the surface.

DUMP VALVE One-way valve used to release air from an inflatable device.

DYE MARKERS A fluorescent dye designed to be released into the water to alert rescue craft to the position of a drifting diver.

ECOSYSTEM The interactions between a community of living organisms and the environment they inhabit.

EL NIÑO A warming of the eastern tropical Pacific occurring every few years that has a pronounced effect on both the local and wider climate. Often occurs around Christmas time—"*El Niño*" in Spanish refers to the Christ child.

EQUALIZATION The process of “clearing” the ears and sinuses until the pressure within them matches the pressure of the water surrounding the body. See also *Valsalva maneuver*.

EXPOSURE SUIT Any suit worn by a diver in order to prevent excessive loss of body heat. See *wetsuits*, *semi-dry suits*, and *drysuits*.

FILTER-FEEDER An aquatic animal that feeds by straining minute organisms and other suspended food particles from the water.

FINNING Kicking the feet rhythmically while wearing fins to achieve forward motion.

FIRST STAGE A major component of the *regulator* that reduces the *pressure* of air from the tank to 8–10 bar above *ambient pressure*, then allows it to pass to the *second stage* for inhalation by the diver. It also supplies air for inflatable items such as the *BC*, and to *pressure gauges* displaying the remaining contents of the *tank*.

FOOD CHAIN A sequence of organisms, each depending on the next as a source of food.

FOOT POCKET A style of fin shoe that covers the whole foot.

FREE ASCENT An *ascent* that is carried out without the use of a line or any other point of reference.

FREEDIVING A form of diving in which divers do not carry an air supply but remain underwater only as long as they can hold their breath.

GAUGE PRESSURE The surrounding water pressure, as measured by a gauge that does not take *atmospheric pressure* into account.

GLOBAL POSITIONING SYSTEM (GPS) A navigation system that uses satellite signals to determine an exact longitude and latitude position.

GUIDELINE A line with a weight at one end and a buoy at the other, chiefly used to mark the position of wrecks and provide a guide for descending and ascending divers.

HELIOX A mixture of helium and oxygen, used for diving beyond *recreational diving* limits.

HYDROSTATIC TESTING A method of testing a *tank* for serviceability by filling it with pressurized water.

HYPERVENTILATION A medical condition caused by rapid or deep breathing, resulting in lowered carbon dioxide levels in the blood.

HYPOXIA A medical condition caused by a deficiency of oxygen in the human body.

INFLATOR VALVE A manually operated valve that admits compressed air into the buoyancy bladders of a *BC*, or into a *drysuit*.

KELP FOREST A marine *ecosystem* based around dense growths of seaweed belonging to the kelp family.

LIVEABOARD A recreational diving vessel equipped to conduct extended diving trips without returning to port.

LOG BOOK A record containing the details of individual dives made by a diver.

LONGSHORE CURRENT A current running parallel to the shoreline.

MANGROVE Assorted coastal tree and shrub species with aerial roots that grow in dense thickets along tidal shores in the tropics.

MARINE PARK An area of sea or coastline in which marine species are protected by government legislation.

MASK FOGGING Misting caused by the accumulation of oils on the lens (or lenses) of a diving mask, permitting moisture to condense there more readily.

MASK SQUEEZE Discomfort caused by increasing water *pressure* acting on the diver’s mask, pressing its frame into the face.

MUCK DIVING Informal term for diving in areas where the bottom sediments are dark and coarse but where small marine species proliferate (such as Sulawesi’s Lembeh Straits).

NEAP TIDE The point in the monthly cycle of tides where the gravitational influences of the Sun and Moon are least aligned, resulting in the lowest high tides and the highest low tides.

NEOPRENE A synthetic rubber fabric with good heat insulation properties used to make *wetsuits*.

NITROGEN NARCOSIS Intoxication caused by breathing nitrogen at elevated *partial pressures* (such as during deep dives), resulting in the impairment of reasoning and motor skills, feelings of irrational anxiety or elation, and perceptual narrowing.

NITROX Any mixture of nitrogen and oxygen prepared for use as a breathing gas, but normally one containing a greater percentage of oxygen than that found in air.

OCTOPUS SECOND STAGE A redundant *second stage*, carried by divers as a contingency against failure of the main second stage, and to enable air-sharing with a diver whose own air supply has been depleted.

OFF-GASSING The gradual release of gases (especially nitrogen) that have accumulated in a diver’s body during the course of a dive. Off-gassing occurs as *ambient pressure* decreases during *ascent* and at the surface.

OPEN WATER A body of water that is not sheltered from the influence of naturally developing weather conditions and currents, and whose depth may exceed safe training limits.

O-RING A ring-shaped gasket, used to seal interfaces between one pressurized piece of equipment and another, such as in the *pillar valve* of a *tank*.

OVERHANG A projection from the face of a reef, cliff, etc.

OVERHEAD ENVIRONMENT Any diving environment where direct access to the surface is restricted, such as inside a cave or under ice.

OXYGEN TOXICITY Acute nervous system dysfunction caused by breathing oxygen at elevated pressures. Can cause loss of consciousness and convulsions.

PARTIAL PRESSURE The *pressure* of a single gas in a mixture of gases, measured as if that gas alone were present (the total pressure of a gas mixture being the sum of the *partial pressures* of its constituent gases).

PELAGIC ANIMALS Creatures that dwell in the *open ocean*, rather than coastal waters.

PILLAR VALVE The valve that transfers gas from the diver's *tank* to the *regulator first stage*.

PLANKTON Minute free-floating plant and animal organisms inhabiting seas and lakes, which form the basis of the *food chain* in many environments.

PLB (personal locator beacon) A submersible device that emits a radio signal on an internationally recognized search-and-rescue homing frequency, enabling emergency services to pinpoint its location.

POLAR SEAS The cold seas at the polar extremities of the planet, which vary in temperature from 29°F to 50°F (–1.8°C to 10°C).

PONY BOTTLE A small *tank* of breathing gas with an independent *regulator*, intended for emergency use if the diver's main breathing apparatus fails.

PRESSURE The exertion of force by one surface, substance, or gas onto another.

REBREATHER A breathing apparatus that recycles exhaled gas by filtering out carbon dioxide and replacing any oxygen metabolized by the diver.

RECOMPRESSION CHAMBER A pressure chamber used in the treatment of divers suffering from *decompression sickness*.

RECREATIONAL DIVING Sports diving that takes place within certain depth and environmental limitations, as defined by the various training agencies.

REEF WALL A vertical face of coral growth, often descending into deep waters.

REEL A spooling device used to store and deploy line.

REFRACTION The change in the velocity of light (or any propagating wave) that occurs when it passes from one medium to another (e.g., from air to water).

REGULATOR The mechanism that supplies breathing gas from the *tank* to the diver via a two-stage process of *pressure* reduction. The regulator is made up of two parts: the *first stage* and the *second stage*.

RIB (rigid inflatable boat) A fast utility boat characterized by a V-shaped hull with an inflatable tube running around its upper edge.

RIP CURRENT A fast-moving current running perpendicular to the shore, caused by the action of incoming waves.

RULE OF THIRDS, THE A rule of thumb used when calculating air requirements for a dive, especially one requiring a conservative approach, such as a cavern exploration.

SAFETY SAUSAGE See *SMB*

SAFETY STOP A precautionary pause in a diver's *ascent* to prevent the formation of nitrogen bubbles in the bloodstream. Its purpose is as a failsafe against *decompression sickness* even when no scheduled *decompression stops* need to be made.

SALINITY The salt content of a measure of water.

SCUBA Acronym for "self-contained underwater breathing apparatus."

SECOND STAGE The part of the *regulator* that regulates the *pressure* of a diver's gas supply to the same pressure as its immediate environment.

SEMI-DRY SUIT A thick *neoprene exposure suit*, similar to a *wetsuit*, designed for use in cold waters.

SHELTERED WATER A shallow body of water protected from currents and weather conditions, used for training divers in a controlled environment.

SILTING A rapid reduction in underwater visibility that occurs when fine sedimentary particles are stirred up.

SKINSUIT A thin *exposure suit*, typically made of Lycra, designed for use in tropical waters.

SLACK WATER A period of reduced water movement that occurs between incoming and outgoing tides.

SMB (surface marker buoy) An inflatable buoy designed to be towed behind a diver to indicate their position to observers on the surface. Long, cylinder-shaped SMBs are known as safety sausages.

SNORKELING Swimming face-down at the surface using a short, curved tube to draw breath.

SPG (SUBMERSIBLE PRESSURE GAUGE) See *tank contents gauge*

SPRING TIDE The point in the monthly cycle of tides when the highest high tides, and lowest low tides occur. Spring tides occur when the gravitational forces of the Sun and the Moon are aligned.

SPUR AND GROOVE REEF FORMATION A typical growth structure of coral reefs, in which outcrops of coral are separated by linear depressions.

STANDING CURRENT A continuous directional movement of water generated by prevailing weather, sea, and climatic conditions.

STROBE A beacon that emits high-intensity flashes of light at short intervals.

SUBTROPICAL SEAS Warm seas within a loosely defined zone between *temperate* and *tropical* climatic conditions.

SWELL The undulating motion of surface waters in areas of open sea.

SWIM-THROUGH A submerged arch, or short passage of rock, where direct access to the surface is restricted, but in which the exit is clearly visible at all times.

TANK A steel or aluminum container designed to hold compressed gas.

TANK CONTENTS GAUGE An instrument that displays the remaining quantity of air or other breathing gas in a diver's *tank*. Also known as a submersible pressure gauge (SPG) or pressure gauge.

TECHNICAL DIVING The use of special breathing-gas mixtures, such as *Nitrox*, *Trimix*, and *Heliox*, to extend depth limits and dive durations beyond *recreational diving* limits.

TEMPERATE SEAS Seas of an intermediate temperature between *tropical* and *polar*, typically 50–68°F (10–20°C).

TEST DATE The date when a compressed gas *tank* was last subjected to *hydrostatic testing*.

THERMOCLINE A layer in a body of water in which temperature changes rapidly with depth. This is usually between a warm surface layer and colder deep water.

TIDAL CURRENT A current generated by the action of the tides.

TIDAL CYCLE The cyclic rise and fall of shoreline sea level, caused by the gravitational influence of the Moon and Sun.

TOPOGRAPHY The shape or form of a region of land or seabed.

TRIMIX A mixture of oxygen, helium, and nitrogen commonly used as a breathing gas for dives deeper than 165 ft (50 m).

TROPICAL SEAS The seas found within the boundaries of the 68°F (20°C) isotherm—a band of warm equatorial water.

VALSALVA MANEUVER A method of manually increasing *pressure* on the inside of the eardrum by closing the nasal passage and exerting expiratory effort, forcing air through the eustachian tubes into the inner ear.

WATER COLUMN The zone of water between the surface and the bottom of a lake, sea, or river.

WEIGHT SYSTEM The means by which a diver's lead *ballast* is secured.

WETSUIT An *exposure suit* made of *neoprene* rubber, which traps a thin layer of water against the skin as an insulating medium.

WICKING The absorption of moisture into a fabric by capillary action.

WORKING PRESSURE The normal *pressure* at which an equipment item is designed to operate.

WORLD HERITAGE SITE An area of natural or cultural importance protected by a United Nations treaty.

WRECK Remains of ships, aircraft, or other vehicles found on the seabed.

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RYA

Sea Survival

HANDBOOK

Keith Colwell

RFD
SURVIVA
12 PERSONS

THE RYA'S COMPLETE GUIDE TO SURVIVAL AT SEA

Keith Colwell

Keith Colwell has sailed all his life, in all sorts of craft from simple sailing dinghies to high-speed motor cruisers.

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by Keith Colwell

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Foreword

By Mike Golding

'Sea Survival training saves lives, it is essential knowledge for the modern offshore skipper. The stark fact is, if things do go dramatically wrong onboard, this knowledge can save lives. Training for the worst eventuality will make you better prepared and it will give you the confidence to know that you have planned for every conceivable circumstance when you leave port. The sea can be a hostile and brutal place for the ill prepared, you don't need to be in the Southern Ocean, the English Channel or anywhere away from easy access to shore, can quickly become just as dangerous and hostile if things go badly wrong onboard your boat. When it comes to survival, preparation is everything and all good preparation begins with solid information and sound practical training.

This book highlights the importance of having the correct safety equipment and will also give you the knowledge of know how and when to use it. Armed with this information and the right equipment every eventuality onboard, no matter how severe, can be met with the determination and conviction that is the essential mark of every survivor.'

Introduction

Boating is one of the safest leisure sporting activities. However, in any sport that pushes us to the edge of our abilities, there's always a chance of accident or injury. Being properly prepared makes us better able to cope with an emergency and will significantly increase our chances of survival.

This handbook is essential for anyone taking the one-day RYA Basic Sea Survival course and the two-day RYA/ISAF Offshore Safety course. It is also invaluable for anyone who takes a boat offshore.

K. Colwell

For further information and a list of establishments running RYA Training Courses, contact the RYA at RYA House, Ensign Way, Hamble, Southampton, SO31 4YA.
Tel 0845 345 0400 Fax 0845 345 0329

CHAPTER 1 : Before you go out

In the UK, HM Coastguard has a free Voluntary Safety Identification Scheme (CG66). Details about your boat are stored on a database accessible by all HM Coastguard Co-ordination Centres. A contact number is provided for those ashore should they become worried about you. To join, visit www.mcga.gov.uk

Check the weather forecast and tides. Familiarise yourself with the area you're planning to sail. Are you and your crew sufficiently skilled for the planned trip? Tell somebody ashore where you are planning to go, when you expect to get there and how many people are on board. Let them know when you expect to arrive and what to do if you don't contact them to tell them of your safe arrival.

Many other countries have similar voluntary or compulsory registration schemes, so check if the country in which you keep your boat has a scheme and how you can join.

Safety brief

As skipper you should ensure that everyone on board knows where the safety equipment is stowed and how to use it. Talk them through your passage and pilotage as well as your contingency plan should something go wrong. Don't forget the less obvious safety equipment and procedures such as how to drop anchor or how to read your current position off the GPS or chart.

Are your crew familiar with boating? Is there anything you should know about them? Can they swim? Do they have medical problems that you need to be aware of, such as asthma, diabetes or angina? As skipper, their safety is your responsibility.

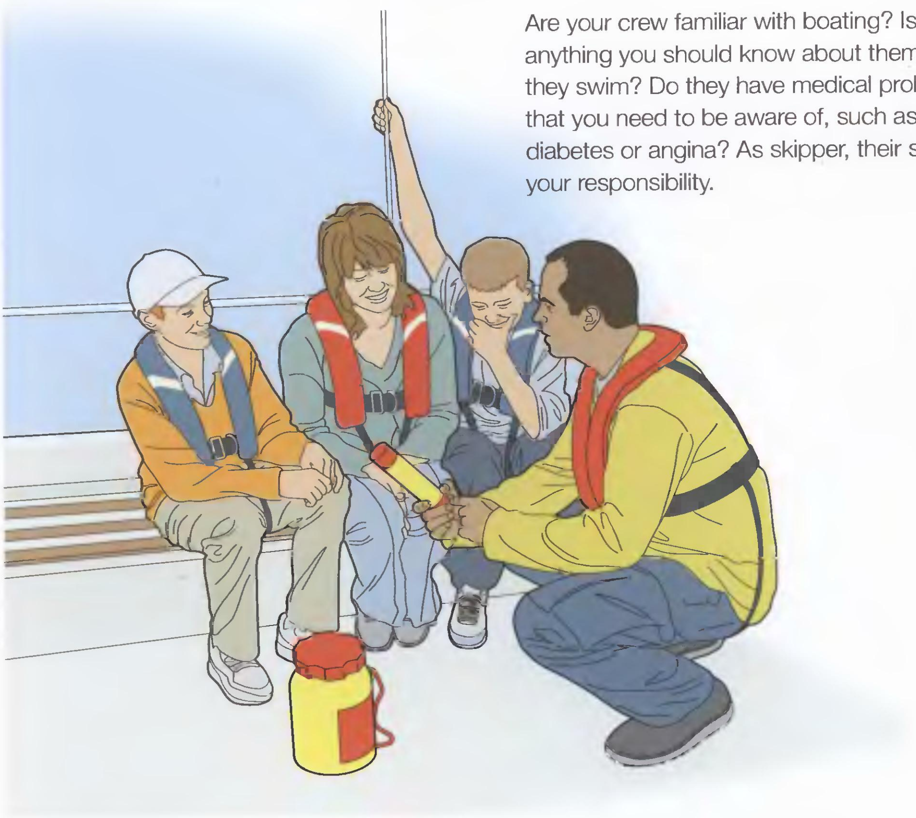

Safety brief checklist

Lifejackets	Check condition, lights, when and how to don and inflate
Harnesses	When and where to clip on
Flares	Where stowed and how to fire
Liferaft	Where stowed and how to launch and inflate
Grab bag	Where it is, also other items such as water, food etc
Onboard hazards	Boom, winches, cleats, ropes etc
Anchoring procedure	
How to start the engine	
Lifebuoy/dan buoy	
VHF radio	Mayday and DSC procedures
GPS	How to read off a position
Bilge pump	Where and how to use it
First-aid kit	Where it is kept
Fire extinguishers	Where, what type and how to use them
Medicines	Are they taking any medication including anti-seasickness tablets
Clothing	Spare clothing, sunscreen
Lookout	Tell me what you see and hear; I may not have seen or heard it!
Passage Plan	Where we are going and contingency plans
MOB recovery equipment	Where and how to use it
Watch rota	When to call the skipper
Can they swim?	
Medical or physical problems?	

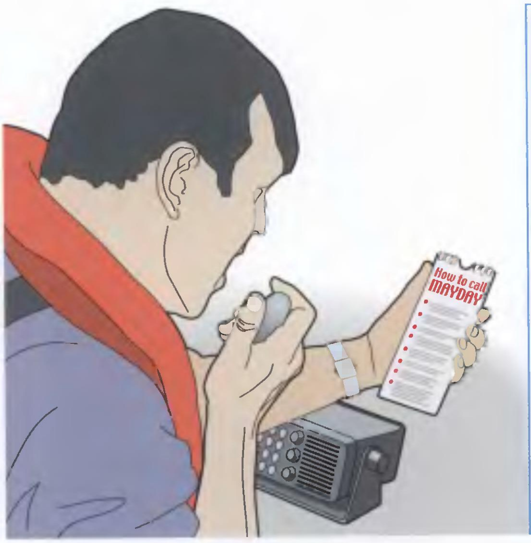

VHF tip

Operating procedures for marine-band radios vary from set to set. Stick a prompt-card in a prominent position close to the set. Make sure the crew know not only how to switch on the radio – including the correct switch on the distribution board – but also how to use the DSC distress button (if fitted) and how to choose Ch 16 and transmit a Mayday.

Your MMSI number and call sign should be prominently displayed beside the radio.

Clear labels on lockers and a plan of where the safety equipment is stowed will save time and help reduce panic during an emergency. Place a copy on the door in the heads, where crew may find the time to study it!

Labelling will assist SAR (Search and Rescue) crew if they need to come aboard during a rescue.

Make a plan

Think about what can go wrong and how you can reduce the severity of an incident.
For example, ask yourself:

- What would you do in a range of emergencies?
- How would you go about abandoning ship?
- What you would do if somebody went overboard and how would you recover them?
- When should you fire flares or make a Mayday call?
- What is your contingency plan?
- Talk your procedures through and, where possible, practise them with your crew.

Clothing

Do you have the right clothing for the conditions? Take extra and spare clothing with you because conditions at sea are more hostile than on land.

Synthetic materials are better at wicking moisture away from the skin. Breathable waterproofs keep you warmer not only by keeping you dry from the outside but also by preventing moisture created by your body from becoming trapped inside the clothing.

Most marine clothing manufacturers now provide layer systems that are better at keeping you comfortable in a range of weather conditions.

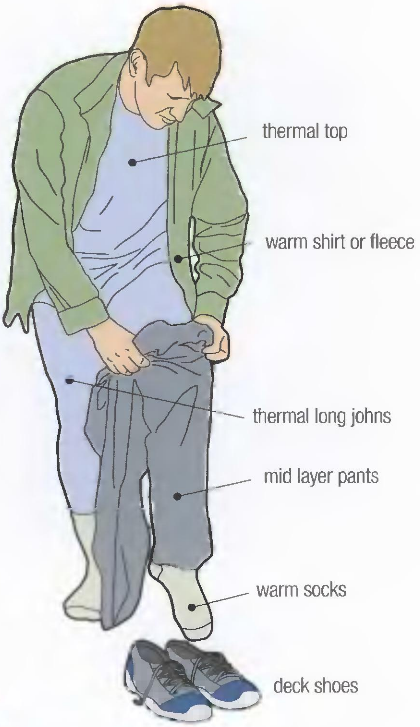
thermal top
warm shirt or fleece
thermal long johns
mid layer pants
warm socks
deck shoes

Cool weather clothing

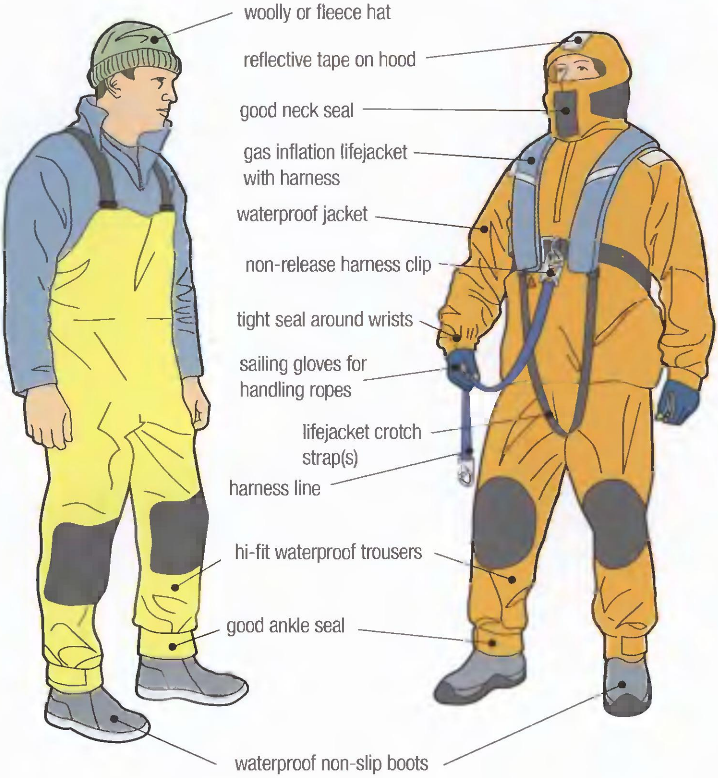
woolly or fleece hat
reflective tape on hood
good neck seal
gas inflation lifejacket with harness
waterproof jacket
non-release harness clip
tight seal around wrists
sailing gloves for handling ropes
lifejacket crotch strap(s)
harness line
hi-fit waterproof trousers
good ankle seal
waterproof non-slip boots

Warm weather clothing

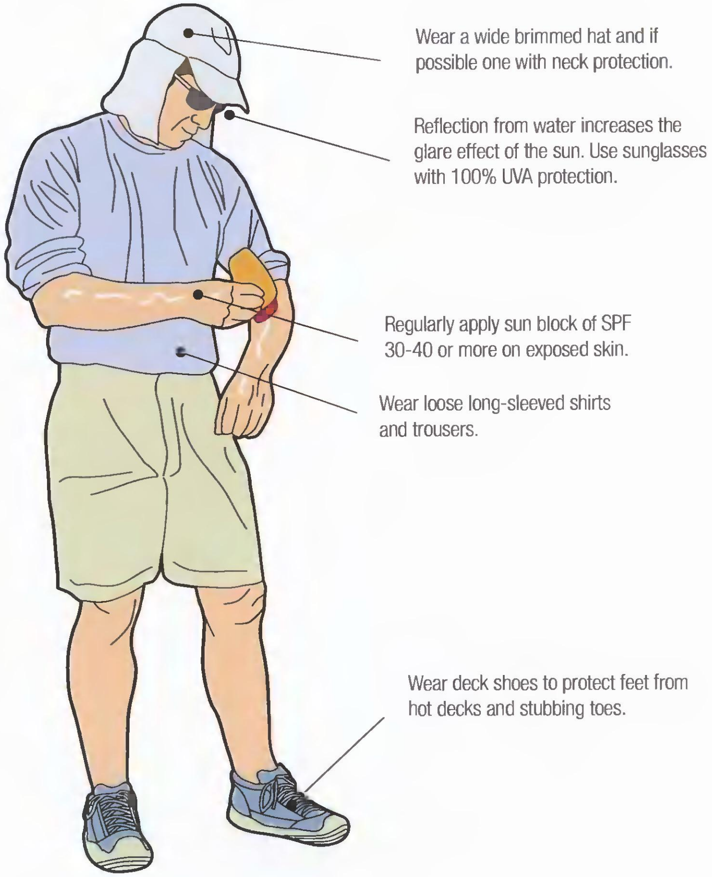
Wear a wide brimmed hat and if possible one with neck protection.
Reflection from water increases the glare effect of the sun. Use sunglasses with 100% UVA protection.
Regularly apply sun block of SPF 30-40 or more on exposed skin.
Wear loose long-sleeved shirts and trousers.
Wear deck shoes to protect feet from hot decks and stubbing toes.

In hot weather, protect yourself from the sun. UV light is reflected by the sea and will increase the possibility of sunburn. Use sun block or high-factor cream. Don't forget vulnerable areas such as tops of your feet, ears and the front of your legs. Long-sleeved shirts and broad-brimmed hats give added protection and wrap-around sunglasses reduce glare.

Recommended safety equipment for sailing yachts

The amount of safety gear you carry depends mainly on where you are planning to sail. Here's a selection of recommended equipment.

Before you start your voyage, leave details with a shore contact. Check requirements for all the countries you are sailing.

Comprehensive first aid kit and sufficient knowledge to use it correctly

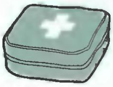

FIRE
BLANKET

Fire blanket near, but not over cooker

Serviced fire extinguisher for each accommodation space

Enough fuel and water for the passage plus an adequate reserve

Lifejackets with lights, crotch straps and spray hoods, spares and re-arming kits, harnesses and wet weather gear for all the crew

Fog horn

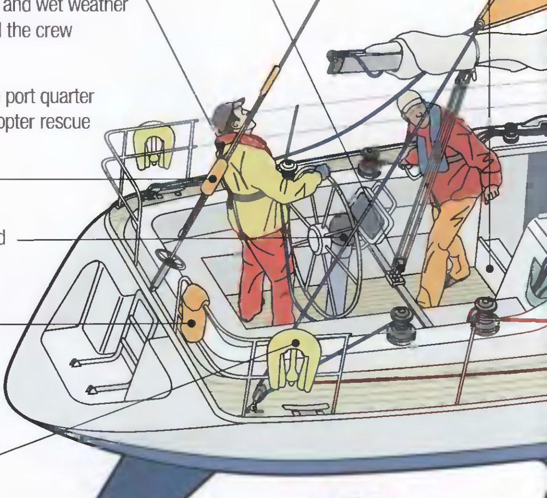

Snap shackle on bottom of main sheet for MOB rescue

System to hold washboards in place in the event of capsize

Try to keep the port quarter clear for helecopter rescue

Dan buoy attached to lifebuoy

Accurate main and hand bearing compasses

Floating rescue line

Lifebuoy, floating light and drogue

Emergency steering

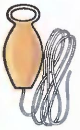

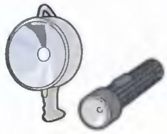

Powerful spotlight and torch with spare batteries and bulbs

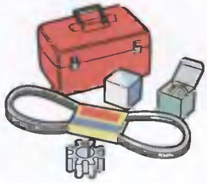

Comprehensive tool kit including sail repair kit, spare navigation light bulbs and fuses

Two buckets with lanyards and a hand bilge pump for use in awkward spaces

Dinghy with oars, repair kit, pump, anchor, engine with fuel, tools and kill cord

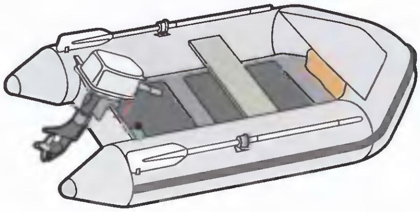

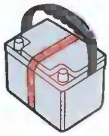

Spare battery capacity

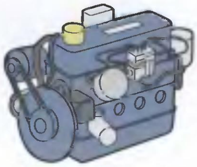

Fully serviced engine, with handbook, adequate spares and sufficient knowledge to effect repairs

Gas kept in a properly vented locker with all pipes and connections regularly checked for leaks

In the UK and Ireland the RNLI offer a free safety equipment advisory service to all boat owners.
www.rnli.org.uk/seasafety

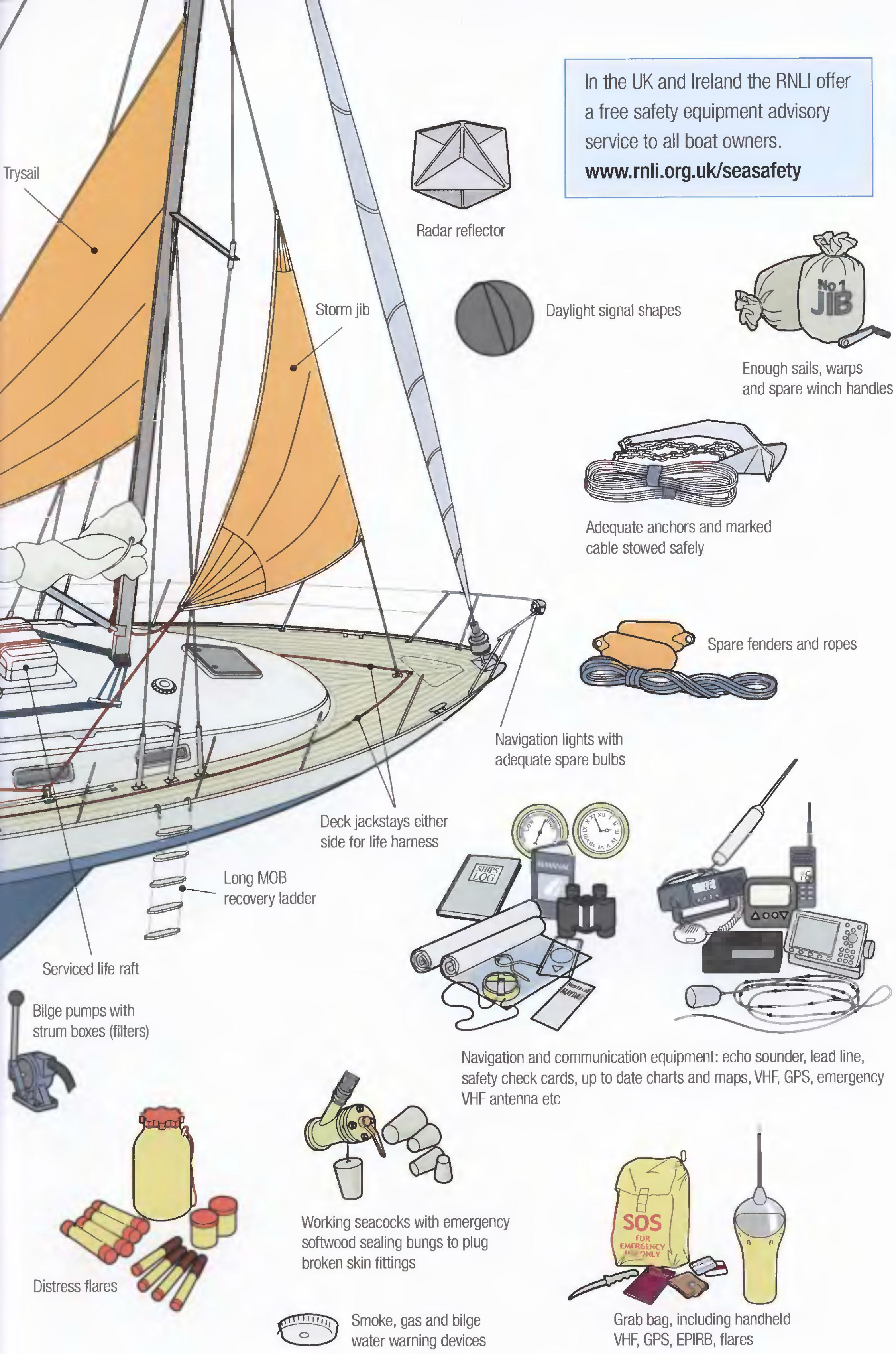

Trysail

Radar reflector

Storm jib

Daylight signal shapes

Enough sails, warps and spare winch handles

Adequate anchors and marked cable stowed safely

Spare fenders and ropes

Navigation lights with adequate spare bulbs

Deck jackstays either side for life harness

Long MOB recovery ladder

Serviced life raft

Bilge pumps with strum boxes (filters)

Navigation and communication equipment: echo sounder, lead line, safety check cards, up to date charts and maps, VHF, GPS, emergency VHF antenna etc

Working seacocks with emergency softwood sealing bungs to plug broken skin fittings

Distress flares

Smoke, gas and bilge water warning devices

Grab bag, including handheld VHF, GPS, EPIRB, flares

Equipment for motorboats

Mechanical failure is the main cause of problems in a motorboat. Ensure engines are regularly serviced and checked. Carry sufficient fuel for the proposed voyage. One of the main reasons of crew accidents on a motorboat is the helmsman making a sudden manoeuvre without informing the rest of the crew, who can be thrown off their feet (or worse overboard). While motorboats will carry much of the same equipment as sailing boats, the lack of rigging and the dependence on mechanical power can bring specific problems.

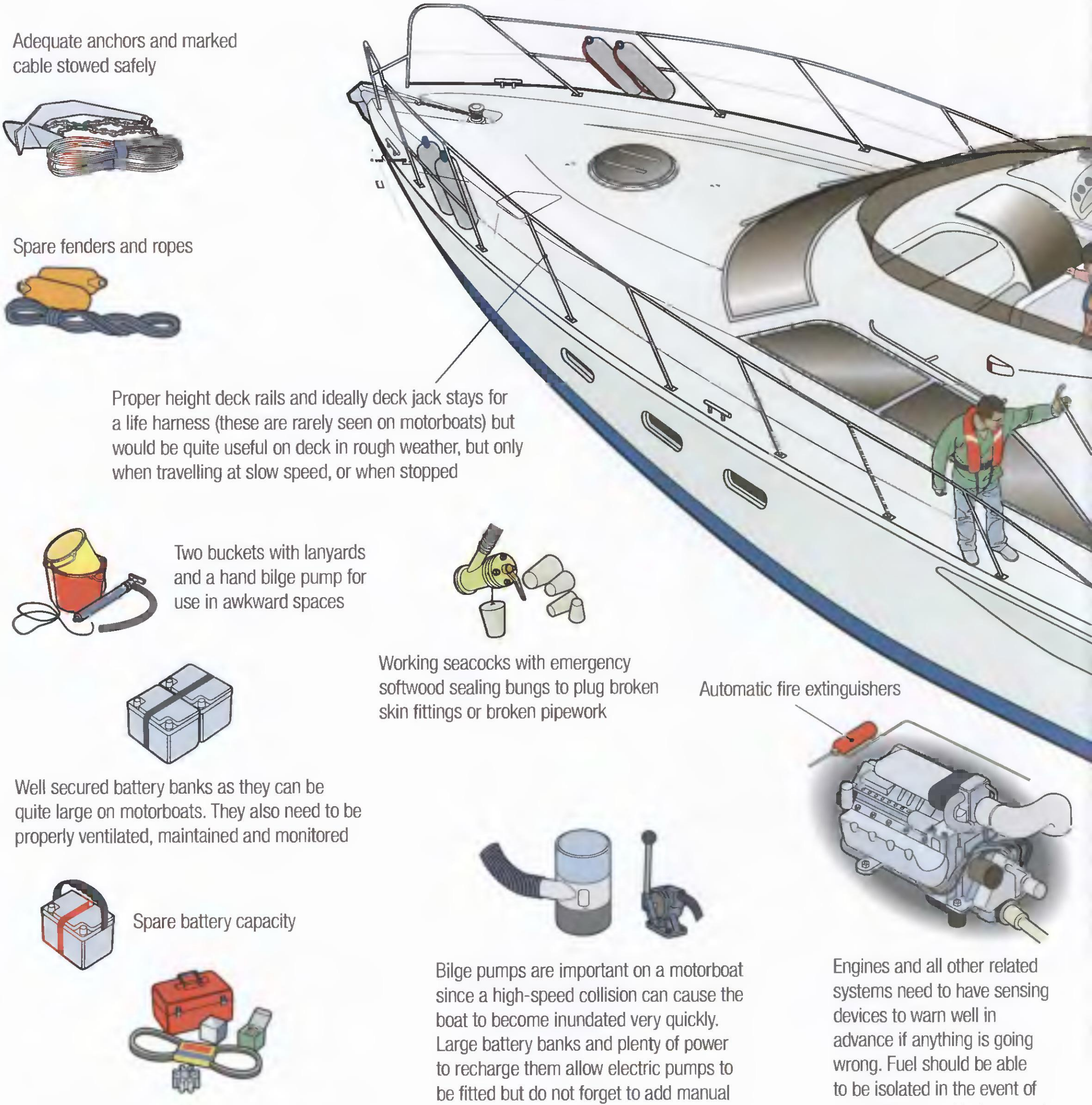

Adequate anchors and marked cable stowed safely

Spare fenders and ropes

Proper height deck rails and ideally deck jack stays for a life harness (these are rarely seen on motorboats) but would be quite useful on deck in rough weather, but only when travelling at slow speed, or when stopped

Two buckets with lanyards and a hand bilge pump for use in awkward spaces

Working seacocks with emergency softwood sealing bungs to plug broken skin fittings or broken pipework

Automatic fire extinguishers

Well secured battery banks as they can be quite large on motorboats. They also need to be properly ventilated, maintained and monitored

Spare battery capacity

Comprehensive tool kit including spare engine parts, spare navigation light bulbs and fuses

Bilge pumps are important on a motorboat since a high-speed collision can cause the boat to become inundated very quickly. Large battery banks and plenty of power to recharge them allow electric pumps to be fitted but do not forget to add manual pump as a backup, in case the electric pump fails

Engines and all other related systems need to have sensing devices to warn well in advance if anything is going wrong. Fuel should be able to be isolated in the event of an emergency with the use of on/off fuel taps in fuel lines

In the UK and Ireland the RNLI offer a free safety equipment advisory service to all boat owners.
www.rnli.org.uk/seasafety

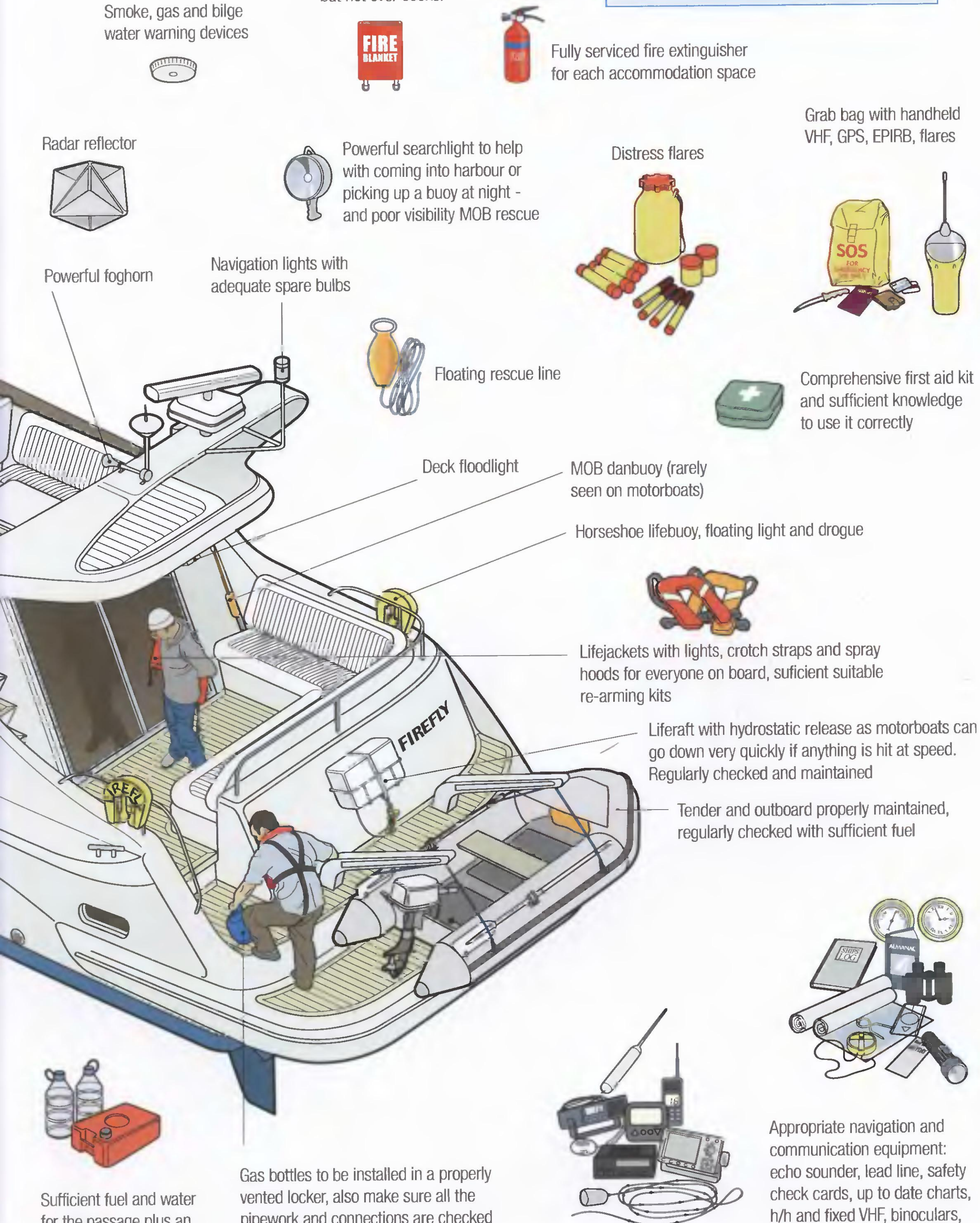

Smoke, gas and bilge water warning devices

Fire blanket near, but not over cooker

Fully serviced fire extinguisher for each accommodation space

Radar reflector

Powerful searchlight to help with coming into harbour or picking up a buoy at night - and poor visibility MOB rescue

Distress flares

Grab bag with handheld VHF, GPS, EPIRB, flares

Powerful foghorn

Navigation lights with adequate spare bulbs

Floating rescue line

Comprehensive first aid kit and sufficient knowledge to use it correctly

Deck floodlight

MOB danbuoy (rarely seen on motorboats)

Horseshoe lifebuoy, floating light and drogue

Lifejackets with lights, crotch straps and spray hoods for everyone on board, suficient suitable re-arming kits

Liferaft with hydrostatic release as motorboats can go down very quickly if anything is hit at speed. Regularly checked and maintained

Tender and outboard properly maintained, regularly checked with sufficient fuel

Sufficient fuel and water for the passage plus an adequate reserve

Gas bottles to be installed in a properly vented locker, also make sure all the pipework and connections are checked for leaks on a regular basis

Appropriate navigation and communication equipment: echo sounder, lead line, safety check cards, up to date charts, h/h and fixed VHF, binoculars, torch etc

Immersion (Survival) suits

Not usually found aboard most cruising yachts, although increasing in popularity with professional yachtsmen and commercial small boat operators, the cold water immersion suit has been designed for larger commercial craft.

Since July 2006, an immersion suit is required for every person on board a cargo vessel that operates in a cold-water area. They are often bulky which is not conductive to easy stowage aboard a small yacht.

There are a broad variety of types from thick neoprene insulated suits to those that are made from PU-coated nylon which are similar to diving or watersports drysuits and require insulated clothing to be worn beneath the suit. Both types usually have insulated hoods to minimise heat loss from the head.

They require practice to be donned quickly.

Unless built-in buoyancy is provided, a 275N lifejacket (see p.33) must be worn to ensure sufficient buoyancy to turn and keep the immersion suit wearer face up.

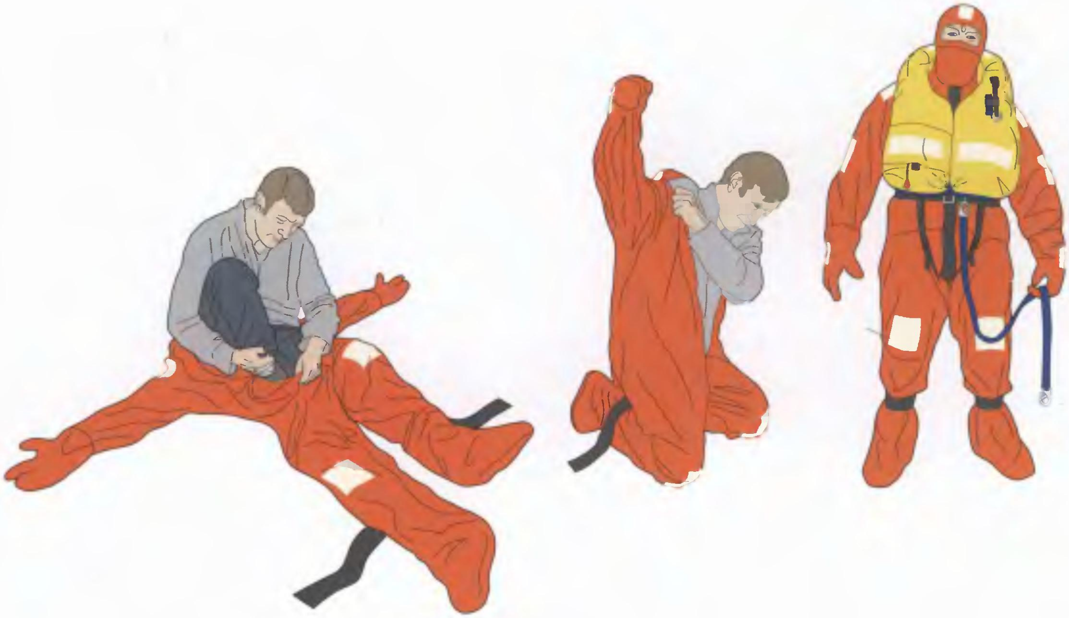

Donning an immersion suit

Care and maintenance of boat and equipment

For the safe operation of a boat at sea, it's essential to inspect and regularly service not only safety equipment but also the boat's machinery, structure and systems. The smallest failure can sometimes be the beginning of a catalogue of problems that can lead to a catastrophe. Prevention is far better than cure.

Follow the example of aircraft pilots and check your boat before departure and put right any problems:

- Do you have enough fuel?
- Does the engine have sufficient oil and water?
- Is the engine's raw-water filter clear of debris?
- Is there water or dirt in the fuel filter/water separator?
- Are the engine mounts secure?
- Is there water or oil or fuel in the bilge – if so investigate where it came from?
- Are the hoses securely clipped to the skin fittings?
- Are the seacocks working smoothly, and are softwood bungs fastened to them in case the skin fitting fractures?
- Is the steering free from stiffness or excessive play?
- Are the bilge pumps operational?
- Are the strum boxes clear of rubbish?
- Are the rigging pins in place at shroud bases?
- Are the lifejackets operational?
- Are the jackstays secure?
- Are the fire extinguishers up to pressure?
- Is the anchor ready?
- Is the liferaft ready?
- Is the lifebuoy ready and the lifebuoy light working?
- Is the dan buoy in place with the flag concertinaed (rather than rolled) so that it deploys quickly?
- Is the handheld VHF charged? Spare charged batteries available?
- Is the fixed VHF working?
- Are all the navigational instruments working?
- Are in-date flares readily to hand?

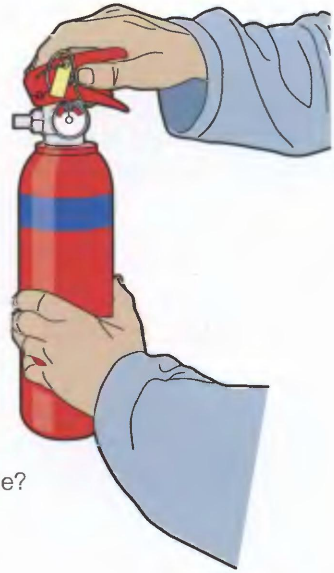

Always carry sufficient spares on board – engine oil, fuel filters, drive belts, water pump impellers, hoses and spare fuses.

Replace any items in the first-aid kit that need replacing. Make sure you have replacement batteries for handheld kit and that you have the right tools on board.

On sailing boats:

- Check the mast for wear or damage.
- Are the spreaders in their sockets?
- Are the navigation lights working properly?
- Are there any loose halyards, damaged rigging wires or bent fittings?

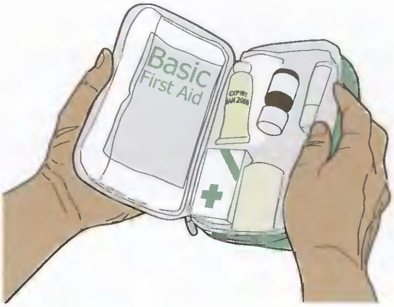

Check the engine instruments. Lift the engine-room and floor hatches and check that all's well. Look around the deck and up the mast. Is there anything becoming loose or that has moved into an unusual position? Listen for unusual noises – they can indicate the beginning of something going wrong.

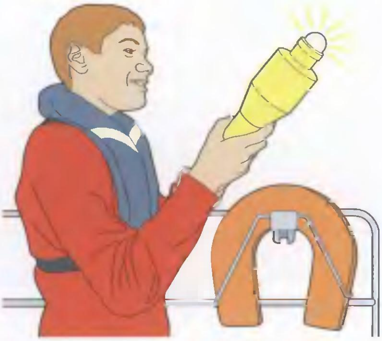

Remember to continue to make regular checks whilst on passage.

When a skipper is familiar with their boat they are more likely to quickly notice if anything is amiss.

Keep a log of items that need longer-term maintenance, including the dates that equipment such as flares, fire extinguishers, lifejackets and liferaft require servicing or replacing. Regularly check all safety equipment for signs of corrosion and wear and tear and make a note of anything that's likely to need replacing in the near future.

Many items of safety equipment are rarely if ever used. It's easy for them to be forgotten and neglected. However, regular maintenance, servicing and inspections are necessary to ensure the equipment works when you need it.

Engine servicing must not be neglected. Engine failure is one of the main reasons for yachts (power and sail) to founder.

Put the boat's name or call sign on all safety equipment and other items that can float free so it is easily identified if found by the SAR services.

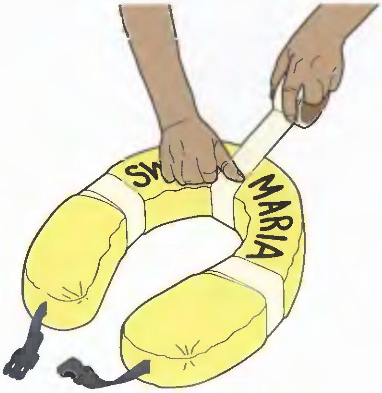

Tip

Add retro-reflective tape to the lifebuoy and danbuoy so that they can be seen more easily at night.

CHAPTER 2 : Weather

Marine weather forecasts are widely available. They are broadcast on public and commercial radio and by coast radio stations, Navtex, the internet and on Inmarsat.

Times for radio broadcasts are shown in an almanac or RYA Weather Forecasts (G5).

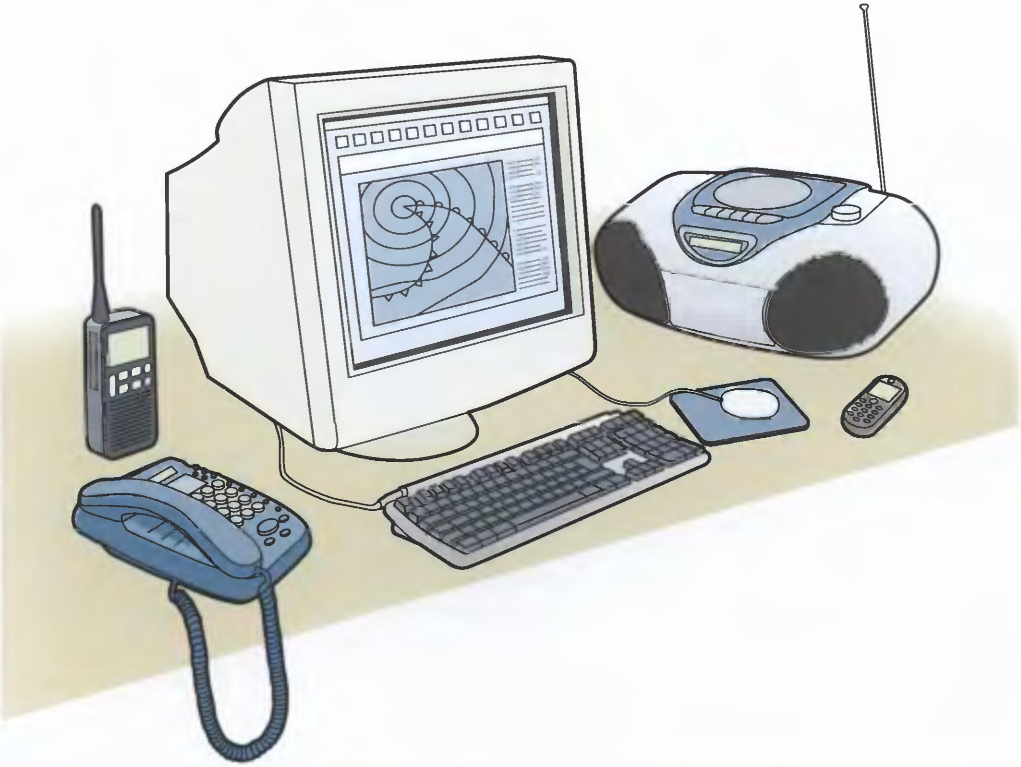

Shipping forecast terms

Gale = Average wind expected to be F8 or more
Strong-wind warning = Average wind expected to be F6 or F7

Timing from the time of issue of warning or forecast
Imminent = within 6 hours , Soon = within 6–12 hours, Later = more than 12 hours

Visibility

Good = greater than 5 miles, Moderate = between 2 and 5 miles, Poor = 1,000 metres to 2 miles, Fog = less than 1,000 metres.

Fair = No significant precipitation

Backing = wind changing in an anticlockwise direction

Veering = wind changing in a clockwise direction

General synopsis = How, when and where the weather systems are moving

Sea states: Smooth = wave height 0.2–0.5m, Slight = wave height 0.5 to 1m, Moderate = wave height 1.25–2.5m, Rough = wave height 2.5–4m, Very rough = wave height 4–6m.

Pressure and tendency

Steady = change less than 0.1mb in 3 hours

Rising or falling slowly = change 0.1–1.5mb in the last 3 hours

Rising or falling = change 1.6–3.5mb in the last 3 hours

Rising or falling quickly = change 3.6–6mb in the last 3 hours

Rising or falling very rapidly = change of more than 6mb in the last 3 hours

Now rising, now falling = change from rising or falling or vice versa in the last 3 hours

Typical depression

In the UK, strong-wind weather is usually determined by Atlantic depressions formed by low pressure. As a depression moves across the country, the warm front is caught by the cold front, creating an occluded front. The lower the pressure in the low, the stronger the winds.

Clouds give a good indication of the approaching weather. High-altitude cirrus clouds give an indication that a depression is approaching. As the warm front approaches, the cloud base descends and pressure falls. Rain becomes heavier with poor visibility, then lightens to drizzle.

Movement of depression

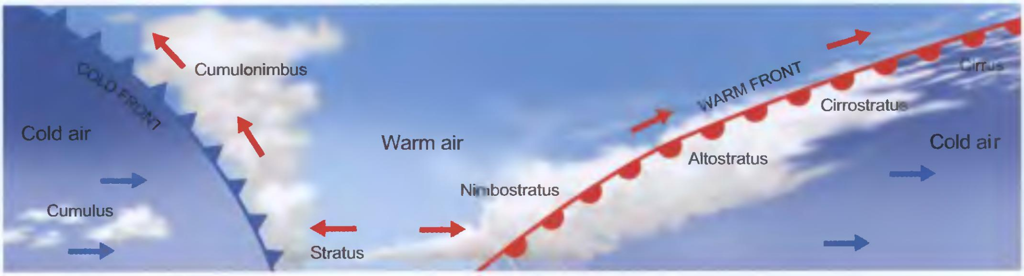

As the warm front passes, the wind veers and becomes steady and the air pressure settles. Visibility is moderate. Low-level fracto and altostratus cloud forms overhead.

A cold front approaches and the wind veers suddenly as the front passes over. Heavy rain, possibly hail and thunder may occur. Visibility is poor.

Behind cold front, the pressure rises then levels. Sunshine and showers, visibility good except in showers. Cumulonimbus and then Cumulus cloud can be seen.

Local winds

Winds often vary from forecast due to local effects.

Wind is slowed by friction with the surface, which is greater over land than sea.

Wind blowing offshore can be variable in direction and strength, especially when blowing off trees, buildings, cliffs, valleys etc.

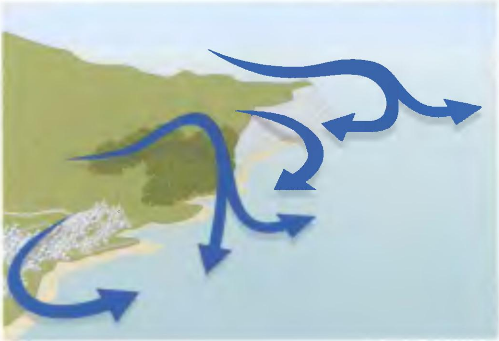

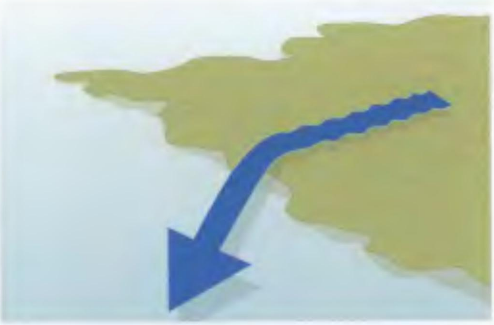

Wind backs more over land than sea. If the wind is blowing off the land, expect it to back as you approach the coast. This may affect the sea state depending on the direction of the tide.

Fog

Advection or sea fog

Created when moist air blows over a colder sea. Usually associated, in the UK, with warm S or SW winds of a depression. Most common in spring when sea temperature is at its lowest.

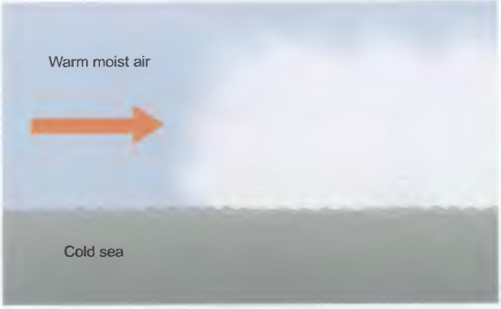

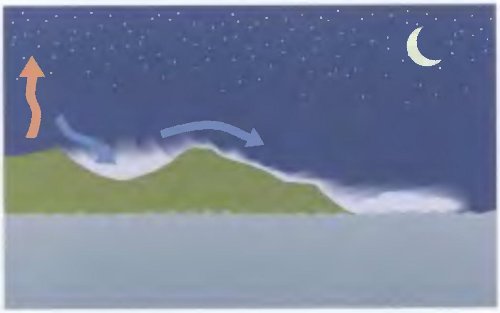

Radiation or land fog

Occurs in settled weather in autumn/winter. Created when land cools quickly at night, causing moisture in the air to condense and form fog over land that will drift out to sea on a land breeze.

Beaufort scale

1 Light airs 1–3 knots
Ripples
Sail – drifting conditions
Power – fast, smooth planing conditions

2 Light breeze 4–6 knots
Small wavelets
Sail – full mainsail and large genoa
Power – fast planing conditions

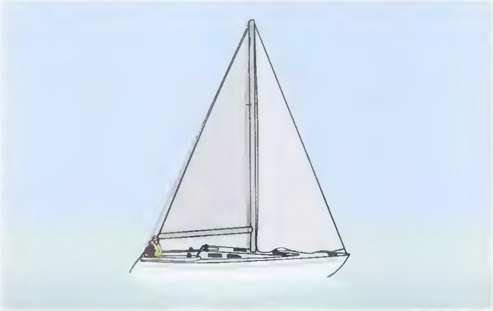

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3 Gentle breeze 7–10 knots
Occasional crests
Sail – full sail
Power – fast planing conditions

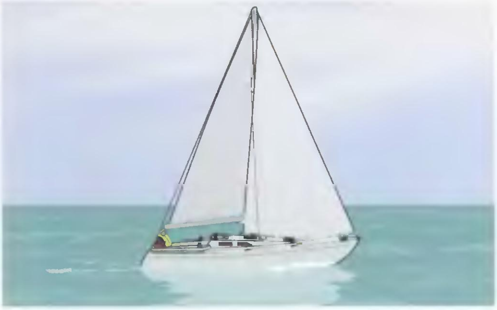

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4 Moderate 11–16 knots
Frequent white horses
Sail – reduce headsail size
Power – fast but bumpy planing conditions

5 Fresh breeze 17–21 knots
Moderate waves, many white crests
Sail – reef mainsail
Power – reduce speed to prevent slamming when going upwind

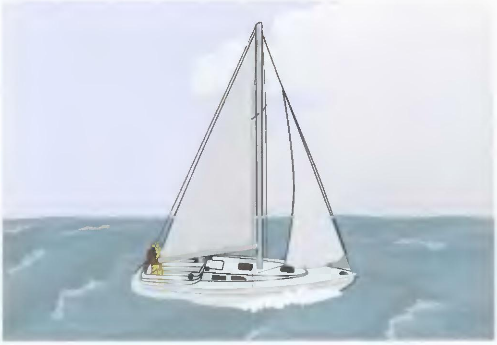

6 Strong breeze 22–27 knots
Large waves, white foam crests
Sail – reef main and reduce headsail
Power – displacement speed

7 Near gale 28–33 knots
Sea heaps up, spray, breaking waves, foam blows in streaks
Sail – deep reefed main, small jib
Power – displacement speed

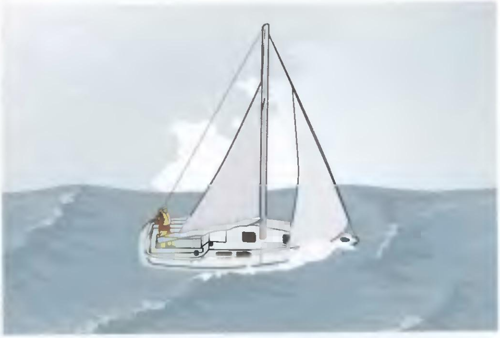

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8 Gale 34–40 knots
Moderately high waves, breaking crests
Sail – deep reefed main, storm jib
Power – displacement speed, stern waves

9 Severe gale 41–47 knots
High waves, spray affects visibility
Sail – trysail and storm jib
Power – displacement speed, stern waves

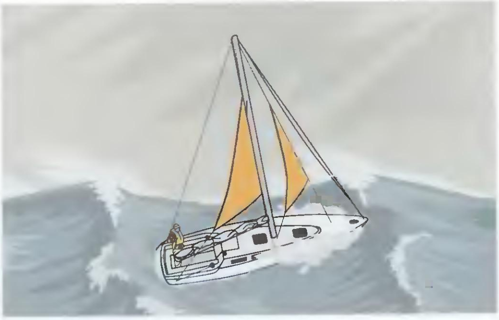

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10 Storm 48–55 knots
Very high waves, long breaking crests
Survival conditions

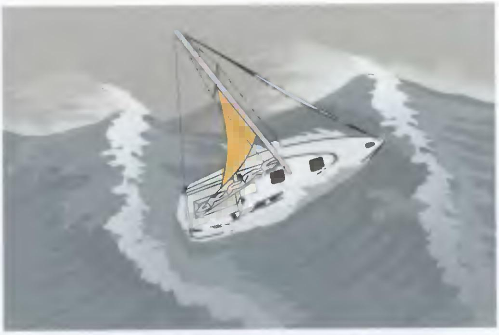

CHAPTER 3 : Preparing for heavy weather

Motorboats are less likely to find themselves caught in heavy weather since most have the speed and agility to find a safe haven quickly or, on longer passages, to route around a storm. Sailing yachts, however, often cannot avoid stormy conditions.

Whether under power or sail the following guidelines are a sensible precursor to heavy weather:

- Stow all gear securely
- Shut lockers and hatches
- Shut and secure portlights
- Stow essentials in plastic bags
- Turn off seacocks to toilet and sink
- Mark fix on chart and secure chart to table
- Update log
- Check contingency plans and, if not already done so, add appropriate waypoints to GPS
- Prepare contingency passage plans
- Sail away from the lee shore
- Print or write out weather forecast times and fasten to the chart area
- Organise a crew roster. Rest the strongest and most able crew first
- Eat a meal and prepare sandwiches and flasks of hot drinks
- Drink plenty of water
- Inform the Coastguard of your position and planned course
- Take anti-seasickness tablets
- Charge engine batteries
- Check bilges and ensure bilge pumps are working
- Check and wear safety equipment
- Secure cockpit lockers to prevent down-flooding
- Secure washboards in companionway
- If appropriate, shut watertight doors
- Stow loose items off deck
- Prepare and secure anchor locker
- Check sea anchor and heavy warps
- Rig and check jackstays
- Close off deck ventilators
- Check cockpit drains are clear
- If required, rig mainsail reefing pennant to third reef
- Prepare trysail and storm jib

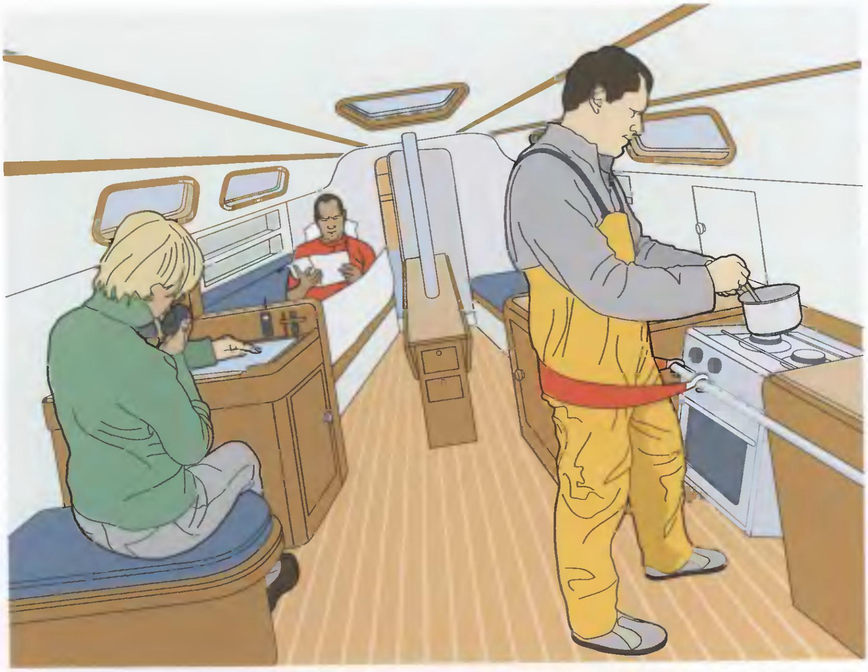

Good seamanship - Prepared for heavy weather

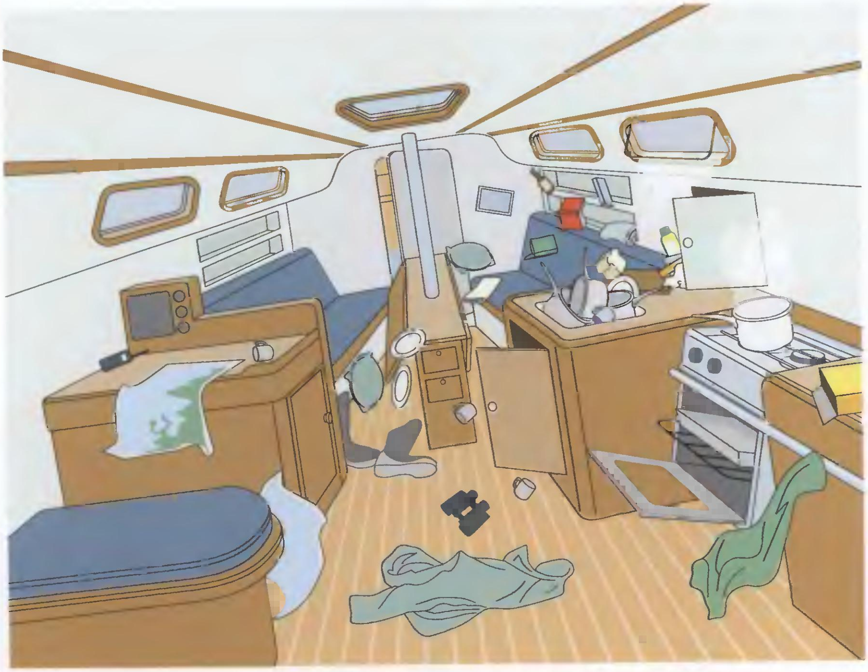

Bad seamanship - Poorly stored gear after heavy weather

Shortening sail

As the wind strengthens you will need to shorten sail. Always shorten sail before you have to because it's easier to shake out a reef if the conditions allow than to take one in when the wind has increased.

The order of shortening sail will depend on your boat and rig. In general, the principle is to shorten sail by gradually reducing the headsail and mainsail so that the centre of effort does not move too far forward or too far aft. This will keep the boat balanced and ensures sufficient weather helm is maintained.

Note that on some boats with slab or jiffy reefing only two reefing pennants are run. This requires the first reefing line to be reattached to the third or uppermost reefing cringle. Three reefs will reduce the mainsail by up to 60% of its total area.

While roller headsails can reduce sail area completely, a partially reefed roller headsail is very inefficient upwind and will not provide the proper balance.

Storm sails

If wind conditions increase, you will need to resort to storm sails comprising of a storm jib and trysail. These lower the centre of effort and may help a yacht to be sailed off a lee shore. They are made from heavy-duty material usually coloured bright-red or luminescent orange so that other shipping can more easily see the boat. A storm jib is best set on an inner forestay, this can be a rigged temporarily or permanently.

A trysail is a loose-footed sail. Its sheet is led aft either to a spinnaker pad eye or to a stern mooring cleat. Occasionally, it may be attached to the boom but this is not recommended.

Depending on type, a trysail can allow for the mainsail to be furled and secured to the boom. The boom can then be dropped and secured to the deck. A trysail can be hoisted in the mainsail's track or preferably in its own track. It must be securely fastened.

Both sails should be pre-rigged with their own sheets.

> Since the rigging of storm sails differs from that of ordinary sails, it's important to practise rigging them in fine weather rather than waiting until you really need them. Rig them in advance of a storm.

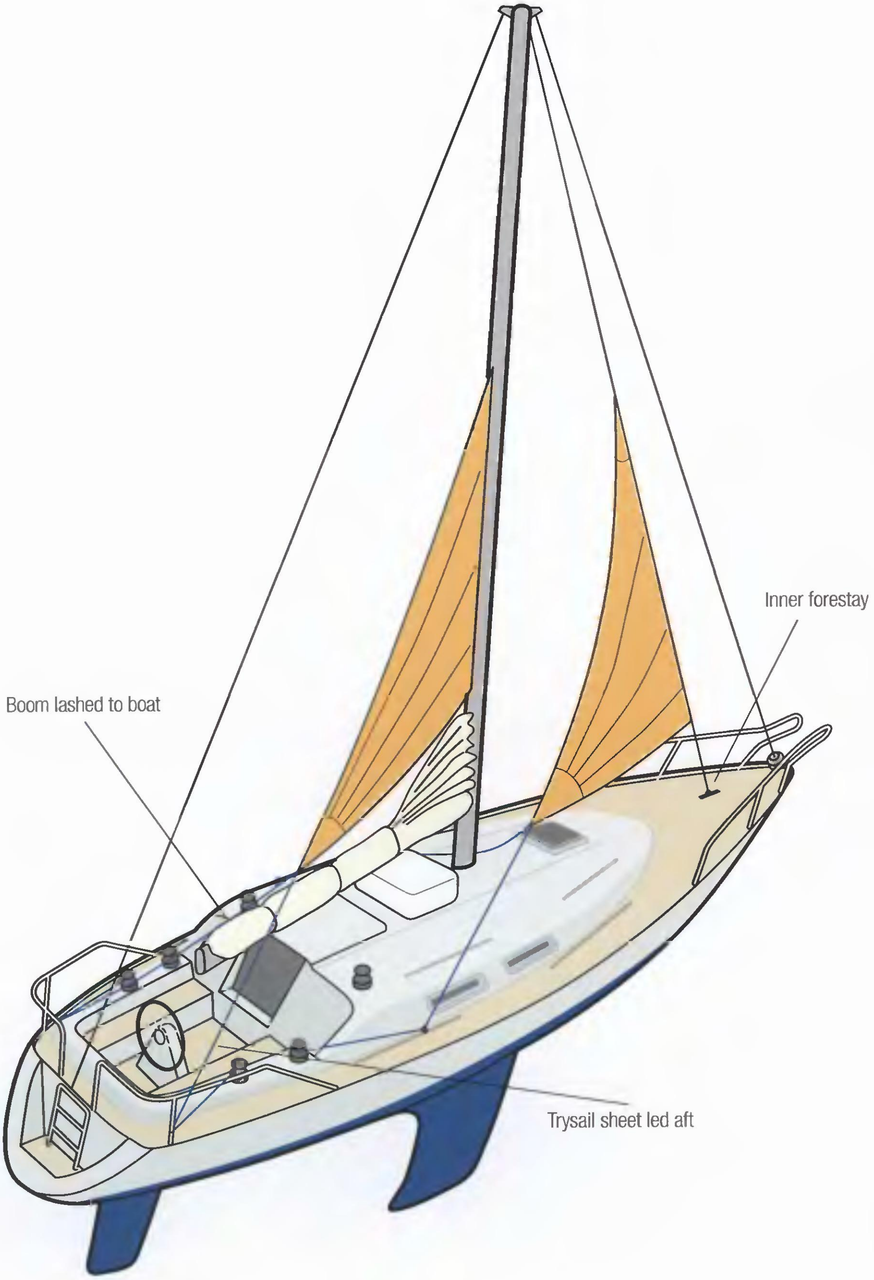
Inner forestay
Boom lashed to boat
Trysail sheet led aft

Rigged for heavy weather
Storm jib is best set on an inner forestay while the trysail replaces the mainsail.

Breaking waves

Waves are generated by the frictional effect of wind on the surface of the water. The stronger the wind, the longer it has blown and the greater the fetch (the distance to shelter from windward), the bigger the waves.

Very steep waves are formed when:

- the wind strength increases rapidly
- wind and current oppose each other – wind against tide
- waves are coming from different directions due to a sudden wind shift
- water becomes shallow

Waves break when they reach a critical steepness and gravity can no longer sustain their shape.

Compared to their size, breaking waves release enormous amounts of energy and they are often sufficient to knock down and capsize a boat.

When caught beam-on, a breaking wave the same height as the beam of the boat is enough to turn the boat upside down.

Owing to the boat's reduction in moment of inertia, a dismasted yacht is often more easily rolled by a breaking wave than one with a mast.

Avoid areas of breaking waves whenever possible.

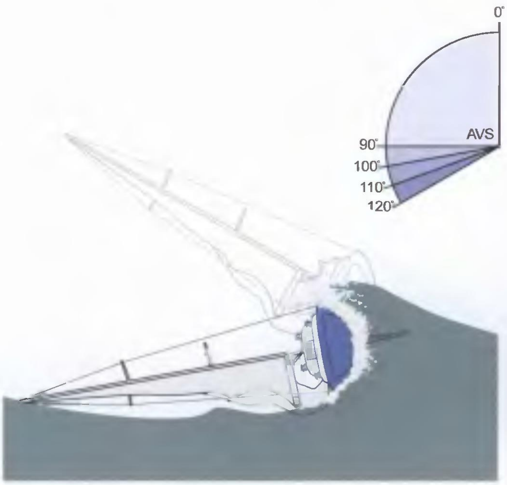

The Angle of Vanishing Stability will depend on the design of the boat. Many will not right themselves once inverted to 120°

A breaking wave the same height as the beam can capsize the boat.

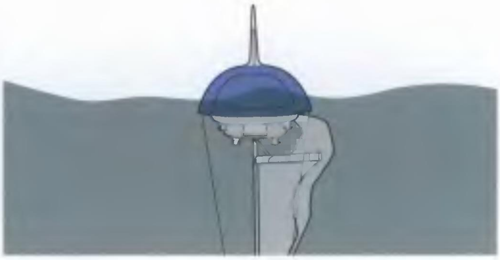

Many boats will stay upside down after capsize.

CHAPTER 4 : Handling heavy weather

Your plan for handling heavy weather needs to take into account:

- capability of the boat
- capability of the crew
- severity of the expected weather conditions
- proximity to land

There are two basic strategies for handling heavy weather:

1. run for shelter
2. ride it out at sea

Running for shelter

Choose a haven that has a sheltered entrance, waves get bigger and steeper as they approach shallow water. An opposing tide will also increase wave size and steepness. Bigger waves travel faster and are more likely to break. When approaching a harbour entrance running with the waves, the increasing size of waves can be deceptive. Look behind you for waves catching you up. Good shelter and a wind with tide can make a flatter sea close in. Radio the Coastguard and harbour master for advice and to tell them of your intention.

Riding it out at sea

Riding it out at sea needs room. There are several methods:

Going to windward (sailing craft)

A good method in strong winds, but only if the crew are relatively strong, is to close reach across troughs, luff (steer) into and over crests and bear away hard to keep the leeward side in the water and avoid a slam. Keep steerage in the troughs or the yacht could end up beam-on to the next wave. Not a method to be used if the crew are tired, in darkness or strengthening winds.

Another option for yachts that do not behave well in stormy winds is to sail slowly upwind. Heavily reef the mainsail and set it as flat as possible and as tightly sheeted in as possible so that it acts as a stadying sail. The headsail is furled. A ketch or yawl would be better using the mizzen rather than the mainsail. Adjust the boat's speed so that it is just moving forward, speeding up to miss breaking waves.

Heaving to

Reduces strain on the yacht and crew by riding waves more easily, making little or no headway but considerable leeway. Boats vary in their ability to heave to, if properly balanced, a yacht will hold its position at about 60 to 70 degrees off the wind and will leave a slick of calm water to windward.

The method is to tack but keep the headsail backed. Hold or fasten the helm to leeward. Some modern designs are difficult to heave to since their efficient rigs continue to drive them forward. However, yachts can heave to under storm sails and have a steadier motion.

Going to windward (powered craft)

Motor cruisers can drive straight into head seas but it will be very uncomfortable for those on board, a better way uses a similar approach as sailing yachts. Rather than heading directly into the waves, dog-leg or tack across the waves, look for gaps between the breaking crests to head into and over the wave. If possible, trim the bow down. Use the throttle continuously and carefully to prevent the boat from flying off the wave or from digging into the trough.

Going downwind (sail craft)

Running before the wind will dramatically reduce the apparent wind speed and greatly reduce slamming.

However, the mainsail boom may dig into the water and slew the yacht around, so using a trysail and a storm jib – or either on their own – may be a better option.

Going downwind (powered craft)

Trim the bow up and position the boat on the back of a wave. After the wave breaks, drive through and on to the back of the next wave.

Big waves travel quickly, so keep a good lookout behind for waves catching you up.
Keep a hand on the throttle and control the boat speed carefully. You may need to slow down to prevent breaking through the wave and then speed up to get on the back of the next wave.

Drogues at sea

Drogues can be used on power or sail craft. They are attached to the stern of the boat and help prevent the yacht from being slewed sideways and rolled over by breaking waves in a following sea.

Use enough length of line – 100 metres or 10 x the boats lenth – to stop the drogue from breaking free of the water and at least two to three times the wave length. Because of the danger of being pooped by waves breaking over the stern, ensure that hatches, lockers and the companionway are secured.

If a drogue is not available, a length of heavy warp either in a line or a loop can be used.

Spread the load over several cleats and pad areas that are likely to chafe.

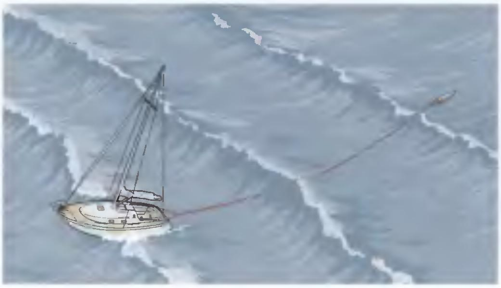

Drogues help prevent broaching and twisting sideways onto the waves.

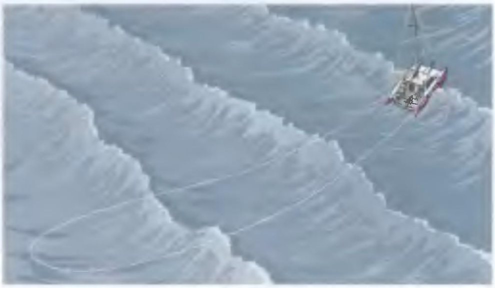

A long loop of trailing warp can also be used in a following sea.

Sea anchors

Deployed from the bow, and similar in size and shape to a parachute, a sea anchor keeps the bow head-to-wind and waves and reduces the possibility of capsize or pitch-poling. Sea anchors can be used on all types of craft but are particularly useful for catamarans and motor cruisers, which would otherwise turn their sterns towards the waves.

A sea anchor for a 10-metre yacht would be about 4 metres in diameter. As with a ground anchor, nylon warp or chain and warp will reduce snatching. A sea anchor should be deployed with sufficient length of warp to ensure it stays submerged, usually about two to three wave lengths, which may require about 100 metres of warp.

As with drogues and when using the normal anchor, spread the load over several strongpoints and pad it in areas likely to chafe.

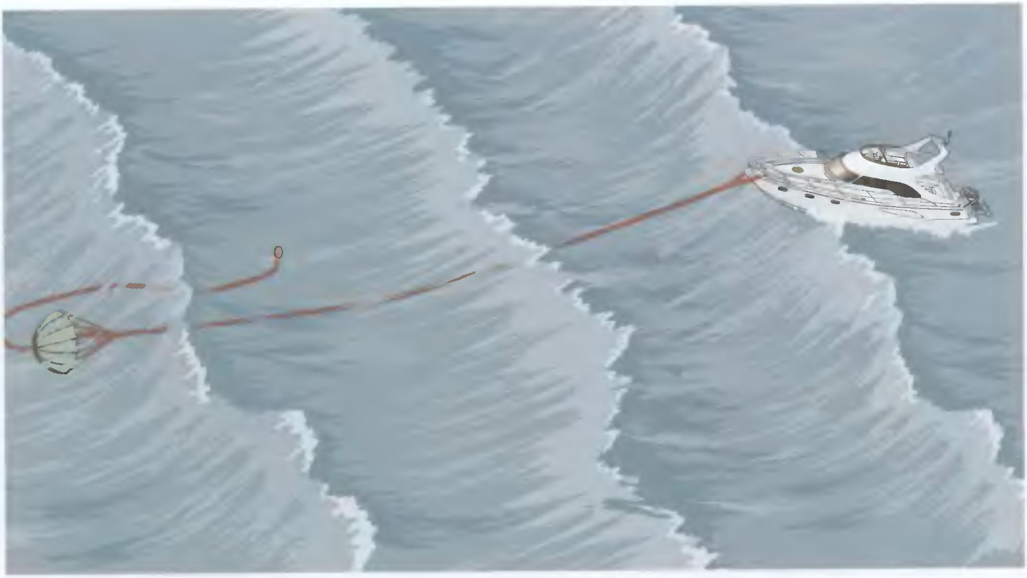

Damage control and repair

Your boat is your best liferaft. Unless it is about to sink, or is on fire, stay with it. It provides the best shelter, a large target for rescuers to see, and contains more provisions and equipment than a liferaft. Be prepared and improvise to keep your boat afloat.

The 1979 Fastnet Race

Winds reached Force 11 during the 1979 Fastnet Race. Over 300 yachts started the 605-mile race to the Fastnet Rock and back. Confused seas added to the ferocious conditions. Of the twenty-four yachts abandoned only five sank. Sadly, fifteen people lost their lives, seven after abandoning to their liferafts.

Steering failure

In heavy seas damage can be sustained to the steering system up to and including complete loss of the rudder, so all boats should carry an emergency steering system. If there is damage to the steering system, try to attach a temporary emergency tiller to the top of the rudder stock, or jury-rig a rope and blocks to the rudder quadrant.

Twin-engine boats can steer by using the engines separately. Auxiliary outboard powered boats can use the engine to steer and if fitted, a bow thruster may be able to point the boat in the right direction.

If the rudder is lost

A pre-drilled locker cover or washboard can be fastened to a spinnaker or whisper pole using U-bolts or lashings to create a steering oar or sweep. Use guys from winches to assist in steering and to stop the rudder floating.

Help in steering may be possible by dragging a drogue or bucket on a bridle to one side or other over the stern.

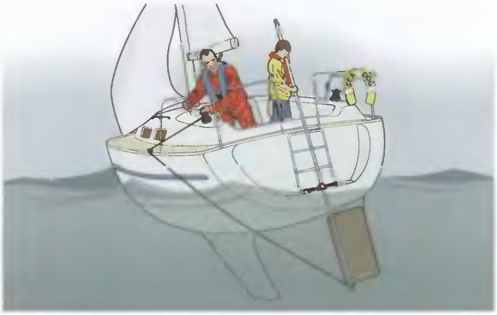

Jury rig a steering oar using the spinnaker pole and washboard or cabin locker cover.

Broken mast

Try to prevent mast breakage by keeping a close eye on standing rigging. The windward rigging is under tension and more likely to break – watch out for parting strands and try tacking to reduce tension on the shroud. Use a halyard to reinforce the shroud. A spinnaker pole may give a better lead. Watch out for leeward shroud turnbuckles that may have vibrated loose before tacking.

If the mast comes down

Clear away any broken spars quickly since they may hole the boat. Use cable cutters and a hacksaw (before going out ensure you have plenty of blades), a cartridge cutter or hydraulic cutter will cut rod rigging or rigging wire of over 10mm diameter. Try to keep the spars for jury-rigging a temporary mast and sail. The motion of the boat will change and the boat will become more susceptible to breaking waves. Advise approaching rescuers if any lines or spars are still in the water.

Jury rig

Use lateral thinking to jury-rig a temporary mast. Bulldog grips can be used to shorten and secure rigging wire and mainsheets, handybillys and vangs used to hoist or tension spars. Recut the sails if necessary.

Emergency VHF antenna

When the mast breaks it is likely the radio antenna will be damaged. Always carry an emergency VHF antenna to ensure communications.

Hatch damage

To seal a broken hatch use locker lids tourniqueted into position with a boat hook or deck brush. Better still, have pre-drilled hatch and portlight covers ready for emergency use.

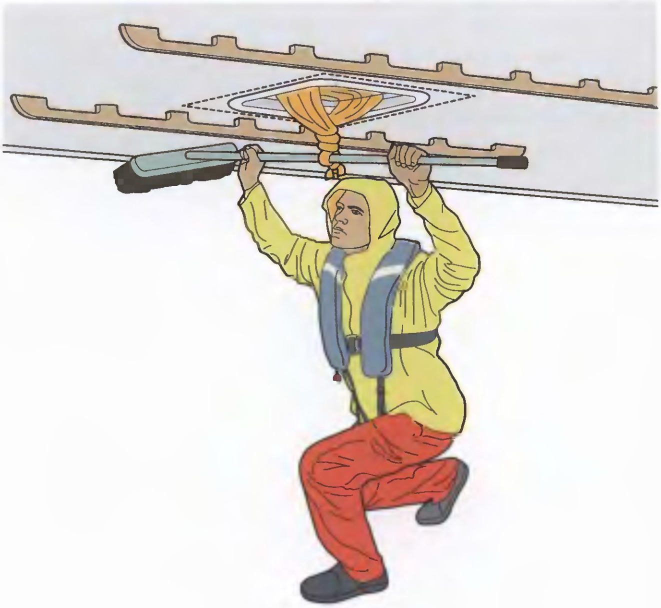

Hull damage

A relatively small hole can let in a large amount of water in a very short time. The amount of water will depend on the size of hole and its depth below the waterline. For example, a 75mm (3in) diameter hole about 30cm (1ft) below the waterline will let in about half a tonne of water in a minute, too much for bilge pumps to cope with.

Reducing the area of the hole even by partially blocking it will significantly reduce the flow rate. Block the hole with any materials you have available, braced against the opposite side of boat.

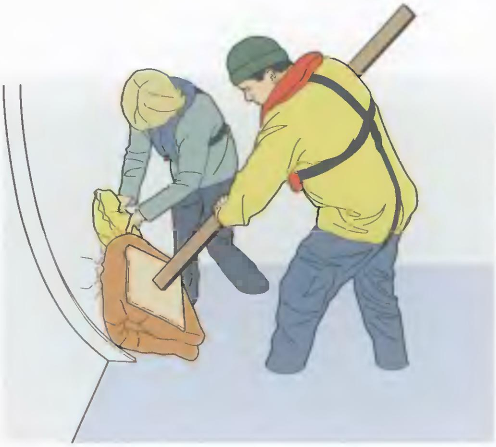

An alternative method is to cover the hole from outside using a sail or other waterproof fabric cover. Whether this is possible will depend on the position of the hole, the shape of the hull and the weather conditions.

Make sure the bilge pumps are able to reach all parts of the hull. Electric pumps will only continue to pump so long as they have electricity. Engine-driven pumps can shift considerable amounts of water. Ensure manual pumps are operational. All pumps should be fitted with strum boxes (filters) to prevent blockage.

Attach an appropriate-sized softwood bung to each seacock. If the skin fitting or hose breaks and a seacock has seized, the bung can be used to stem the flow.

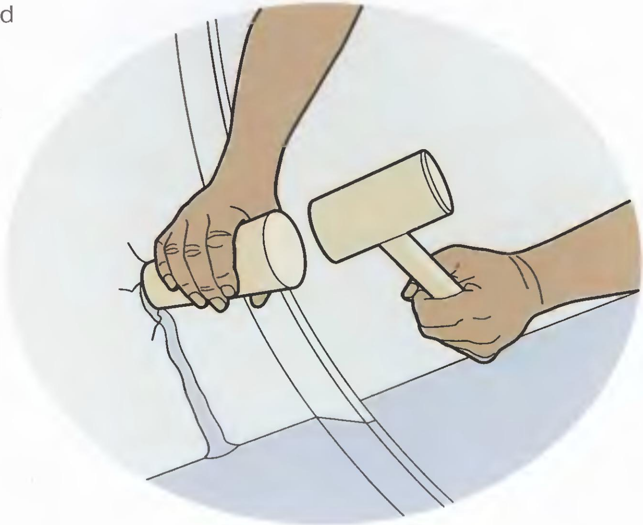

CHAPTER 5 : Lifejackets and Buoyancy Aids

There are a broad range of lifejackets available on the market from stiff buoyant foam models suitable for merchant shipping, to the inflatable bladder types that you will see demonstrated on commercial airlines. Here we have restricted our comments to those commonly available to the boat user.
All new lifejackets sold in Europe must have a CE mark. Other countries often apply their own (similar) standards. An International ISO standard has recently taken effect and will supercede the CE standards as new designs are introduced. The current European standards give buoyancy ratings in Newtons (N):

EN 393 (ISO 12402-5)	50 N buoyancy aid
EN 395 (ISO 12402-4)	100N lifejacket
EN 396 (ISO 12402-3)	150N lifejacket
EN 399 (ISO 12402-2)	275N lifejacket

Buoyancy Aids

Buoyancy aids are not recommended as life-saving equipment.

- **50N buoyancy aids** are designed for competent swimmers as an aid to flotation in inshore waters where help is close at hand. They are suitable for those who expect to fall into the water, for example dinghy sailors, waterskiers, kayakers etc – allowing them to swim easily back to their craft. This type is comfortable to wear but will not turn the wearer face-up in the water. It provides 5kg (11lb) of buoyancy from, usually, one or several layers of closed-cell foam.

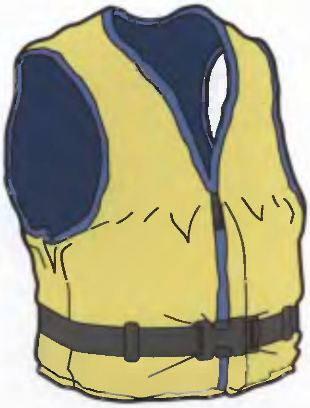

Sold in several sizes from child to XXL, buoyancy aids need to be a snug fit to work properly. A simple test is to try lifting the jacket at the shoulders. If it lifts more than 50mm (2 inches) it's too big.

Lifejackets

- **100N lifejackets** are designed to keep non-swimmers afloat but will not necessarily turn an unconscious wearer face-up. Usually made from one or several layers of closed-cell foam and provides 10kg or 22lb of buoyancy. Like buoyancy aids, they are sold in several sizes from child to XXL and need to be a tight fit to work properly. Check for fit by lifting the jacket at shoulders. If it lifts more than 50mm (2 inches) it's too big.

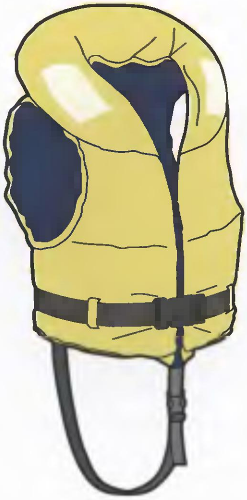

- **150N lifejacket** is the standard lifejacket, providing a minimum buoyancy of 15kg (33lb). Suitable for swimmers and non-swimmers and is arguably the best type for offshore boats. Although this type is designed to turn an unconscious wearer face-up, if there is any air trapped in the wearer's waterproof clothing this may prevent the jacket from righting the person immediately.

  The lifejacket will give a reasonable chance of survival but will hamper movement when fully deployed. Most jackets of this size are gas-inflated; however, bulky all-foam or foam-and-air jackets are also available.

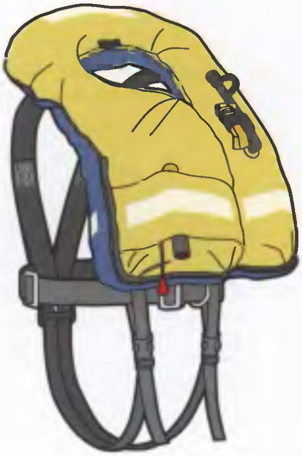

- **275N lifejacket** was originally intended to provide sufficient buoyancy to self right an offshore oil worker wearing an immersion suit and is a high-performance lifejacket, suitable for severe offshore conditions. Usually gas-inflated and consisting of one or, occasionally, two separate bladders, it has sufficient buoyancy – 27.5kg (60.5lb) – to counteract trapped air in waterproof clothing. Sadly, its large deployed size can make it difficult for the wearer to climb into a liferaft.

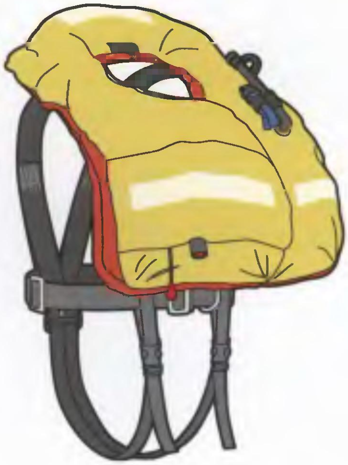

Children's lifejackets have equivalent buoyancy ratings to adults' lifejackets, for example, 50N and 150N, but with reduced buoyancy to suit their smaller size. Most have harnesses and crotch straps built in as standard. It's essential that children wear the correct size lifejacket or buoyancy aid. Don't buy a lifejacket that is too big thinking they will grow into it.

Five top lifejacket tips

- Carry one lifejacket for each member of the crew
- Carry spare lifejackets for any casualties you may pick up
- Always check your lifejacket before donning
- Lifejackets require regular maintenance
- Your lifejacket will only work properly if it is worn correctly

Gas lifejackets

Gas lifejackets are inflated with carbon dioxide (CO_2) stored under pressure in a sealed metal bottle. The gas is released by piercing the seal, either manually by pulling the toggle or automatically on immersion in water.

If fitted with an automatic firing head, it is essential to fit the correct size bottle for the size of lifejacket. Too big a bottle may burst the jacket; too small a bottle will not fully inflate the bladder. The correct size bottle will fully inflate the jacket in under five seconds.

- A lifejacket has to be worn outside of clothing. If it inflates underneath a waterproof jacket, the wearer's chest will be squeezed making it impossible to draw breath.
- Make sure that the manual-inflation toggle is always available – do not tuck it inside the jacket.

Types of inflation

Oral-only inflation (blow air into)

Inflatable lifejackets that can only be inflated through a top-up tube are not recommended. Due to the physiological effects of falling into cold water, you will not be able to inflate the lifejacket.

Manual gas inflation

It will not inflate automatically, the jacket is inflated by the wearer pulling on the toggle. It will not inflate automatically. The firing mechanism should have some means of indicating if the jacket has been fired – often it is as simple as a small green clip over the toggle lever. If this is not present, unscrew and check that the seal on the bottle has not been pierced - if in doubt rearm.

Always carry spare gas bottles and clips so that the lifejacket can be immediately rearmed.

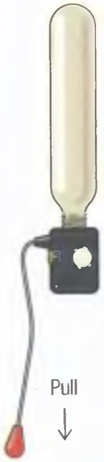

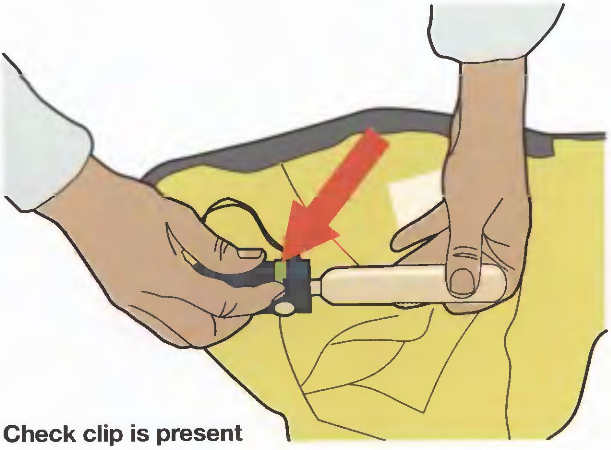

Check clip is present

Automatic gas/cartridge inflation

There are several different designs of automatic gas-inflation firing heads that give various degrees of protection to the cartridge or pill. Automatic operation uses a spring-loaded plunger held in place by either a compacted paper cartridge or a pill. When the cartridge or pill becomes wet it expands or dissolves, releasing the plunger so that it pushes the pin through the gas-bottle seal.

In addition to a manual indicator, automatic firing mechanisms have a separate indicator to show they have not been operated. When donning the lifejacket, check the automatic firing head and the manual indicators. If one or other is not present, unscrew and check that the seal on the bottle has not been pierced.

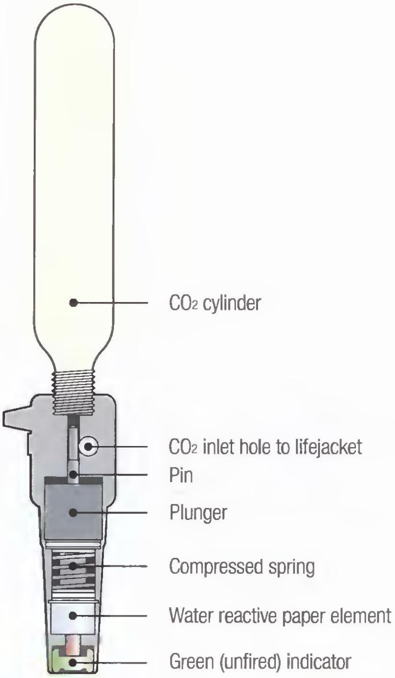
CO_2 cylinder
CO_2 inlet hole to lifejacket
Pin
Plunger
Compressed spring
Water reactive paper element
Green (unfired) indicator

While some lifejackets use cartridge style autoheads others have a simple replaceable bobbin. Although different makes of lifejackets may appear to have identical firing heads they are often not interchangeable. Some automatic firing heads can fire accidentally if they become excessively wet. Keep appropriate spare automatic firing heads and gas bottles on board so that every lifejacket can be immediately rearmed.

Standard automatic heads have a limited life and will be marked with an expiry date.

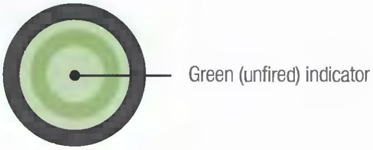
Green (unfired) indicator

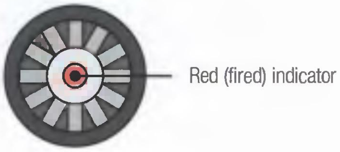
Red (fired) indicator

Hammar automatic inflation

The Hammar system protects the water-sensitive element with a hydrostatic valve that prevents accidental activation by wave splash, heavy rain or spray. The valve opens after two to three seconds' immersion at a depth of 100mm (4 inches). This allows water to reach the water-sensitive element, which dissolves and triggers the pin to pierce the bottle.

When the jacket is fired manually, the toggle detaches from the firing head. The firing head will show a green indicator if it has not been fired or a red one if it has. Hammar automatic inflation heads have a five-year life. The replacement date is printed on the firing head. Keep spare rearming kits on board so that the jacket can be rearmed immediately and check they have not passed their expiry date. Inflate the lifejacket after re-arming, to check the head has sealed properly on to the fabric.

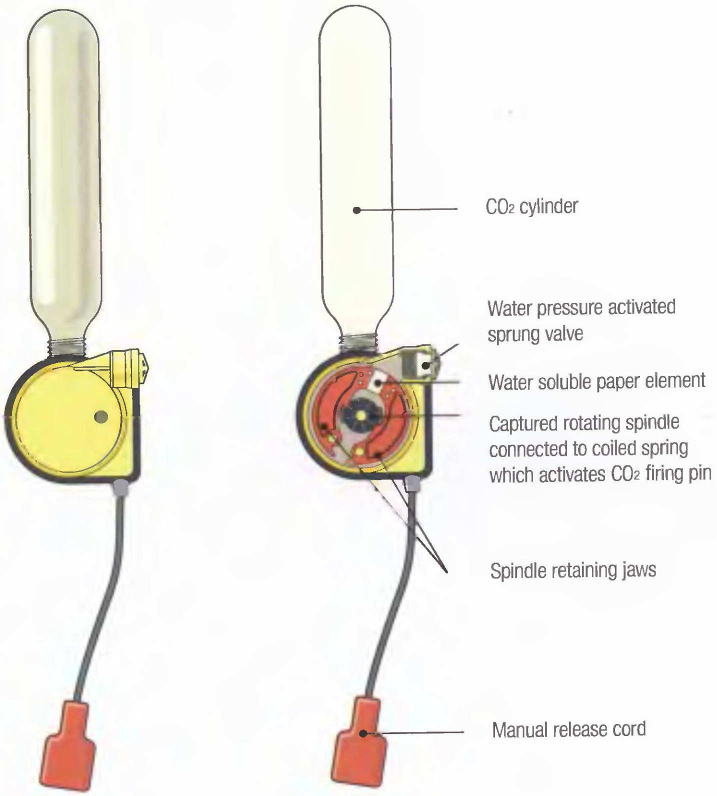
CO_2 cylinder
Water pressure activated sprung valve
Water soluble paper element
Captured rotating spindle connected to coiled spring which activates CO_2 firing pin
Spindle retaining jaws
Manual release cord

Lifejacket maintenance and checks

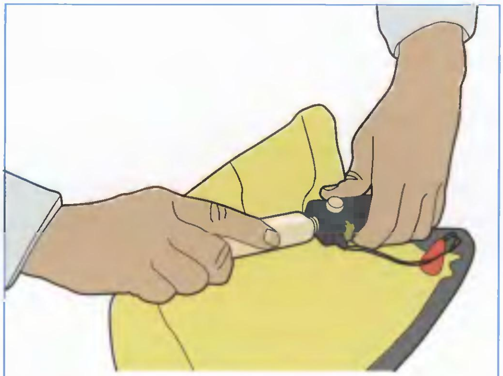

Regularly check that the gas bottle is securely tightened into the firing mechanism. If it is loose, it may not fire and inflate the jacket.

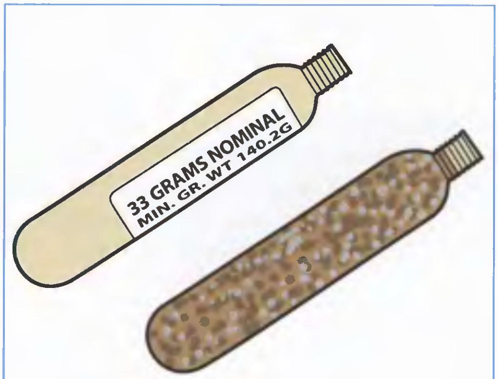

Inspect the gas bottle for corrosion, which can cause small pinholes in the lifejacket bladder. Check that the bottle is the correct capacity for the lifejacket.

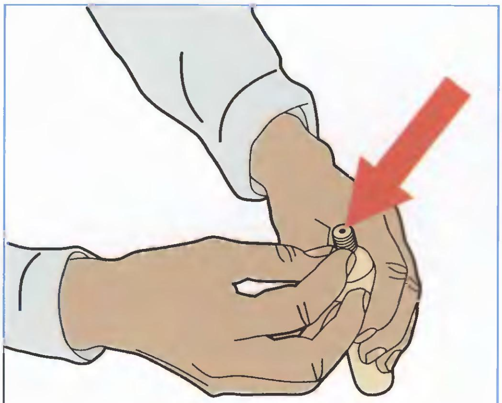

Unscrew the bottle and check the seal is still secure. If it has a hole in it, fit a replacement bottle.

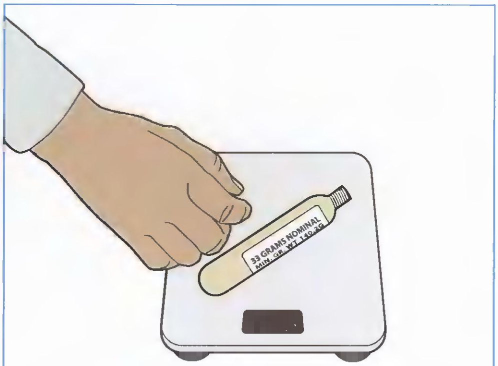

Weigh the bottle on a digital scale to ensure it matches its gross weight as embossed on the bottle. A 33g bottle has a gross weight around 140g.

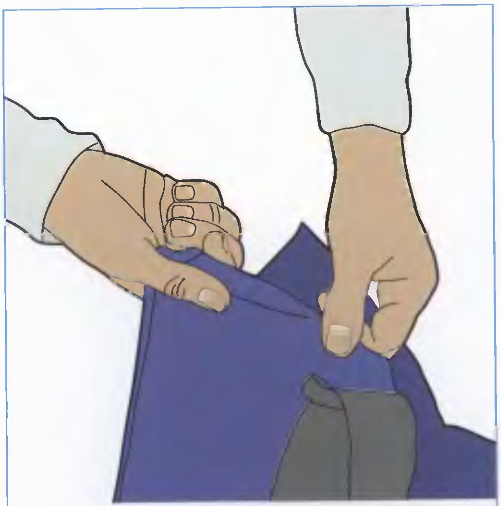

Unfold the lifejacket and inspect the cover and bladder for punctures, cracks and wear and tear.

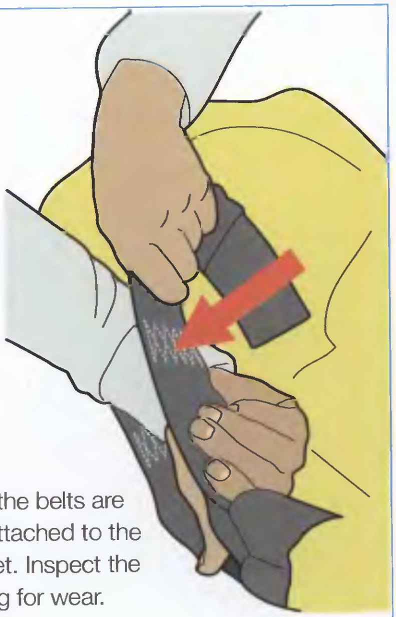

Check the belts are firmly attached to the lifejacket. Inspect the stitching for wear.

To deflate, push in the valve in the oral inflation tube while squeezing the jacket. Make sure all gas is removed before reattaching a new gas cylinder and repacking.

Every three to six months

- Remove the gas bottle and inflate the jacket, preferably with an air pump, through the oral inflation tube.
- Leave the jacket inflated for 24 hours to check that it is airtight.
- When not being used regularly, unfold the jacket and store it on a wooden clothes hanger.

Tip

Not all manufacturers air-test their lifejackets at every appropriate stage in its manufacture, so it's a good practice immediately after purchase to inflate all new jackets, preferably using an air pump through the oral tube, to ensure the bladder does not leak.

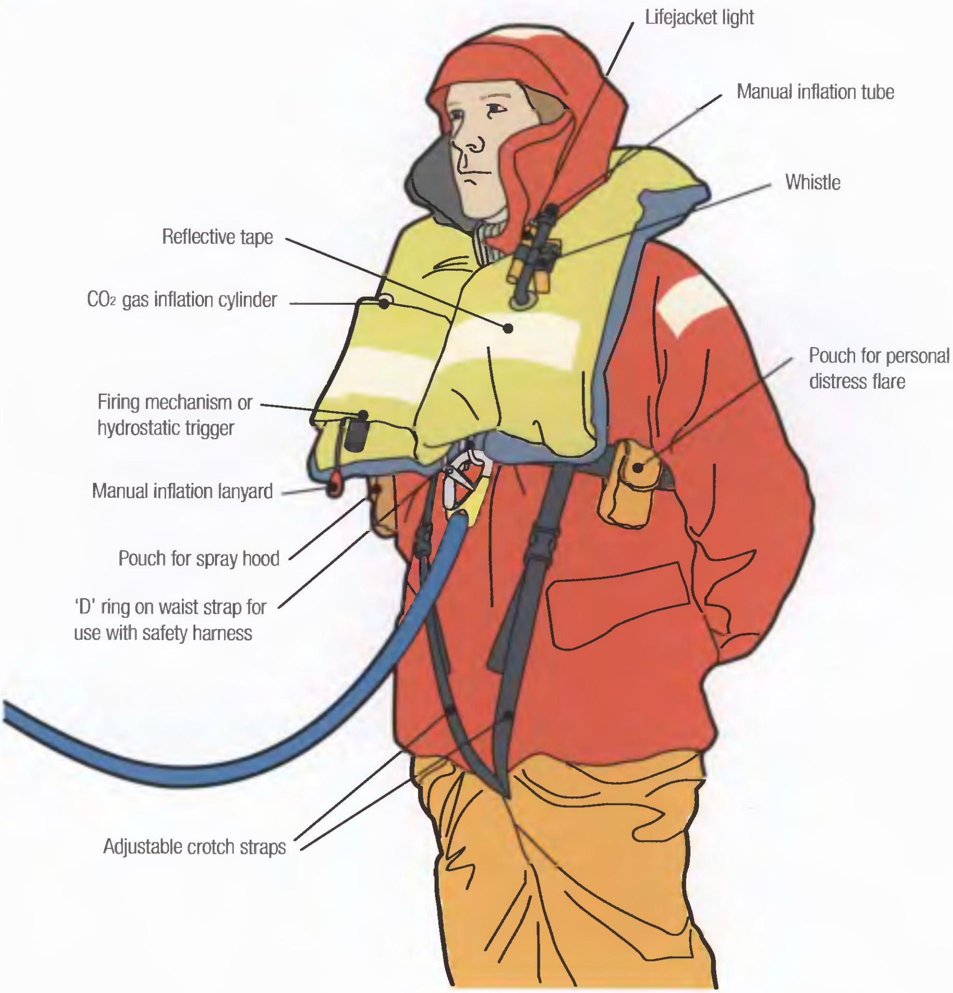
Lifejacket light
Manual inflation tube
Whistle
Reflective tape
CO₂ gas inflation cylinder
Pouch for personal distress flare
Firing mechanism or hydrostatic trigger
Manual inflation lanyard
Pouch for spray hood
'D' ring on waist strap for use with safety harness
Adjustable crotch straps

Lifejacket fittings

Some jackets are sold with a number of fittings as standard, for example, the whistle, oral inflation tube, retro-reflective tape and gas inflation system. But other fittings such as the crotch straps, lifejacket light, built-in safety harness, safety harness, spray hood and flare pouch, are often optional extras. It is recommended to always use a lifejacket fitted with a light, spray hood and crotch straps.

The effect of wind and waves

When at rest in the water, the wearer of a lifejacket will be continuously turned to face the wind and waves. While a conscious casualty can cover their airway, an unconscious one will drown from waves and spray continually breaking onto their face.

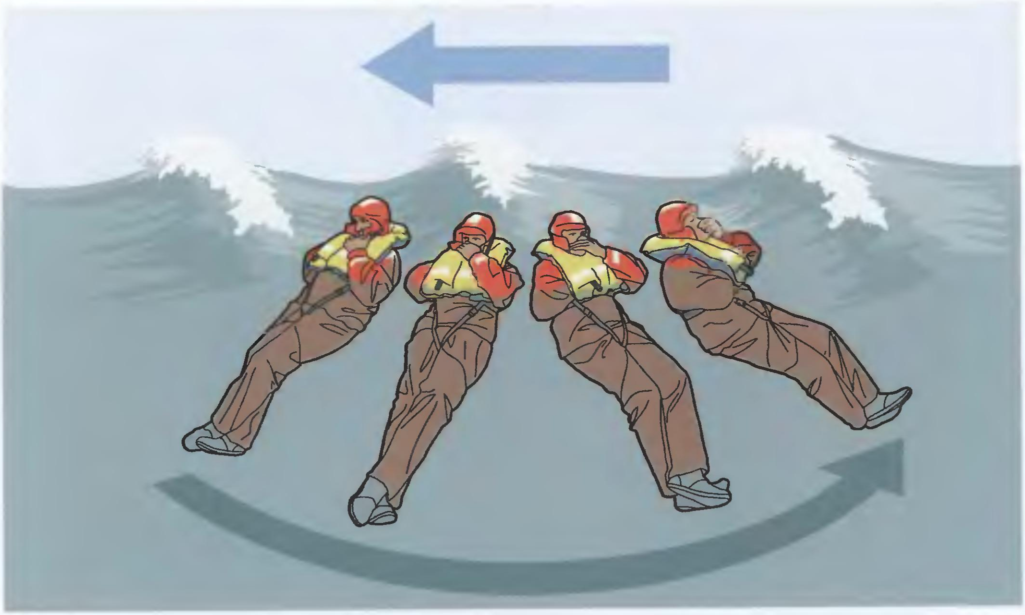

A spray hood, either fitted into the collar of the lifejacket or stored in a separate pouch on the waist belt, can be worn over the head or face and will reduce the effects of breaking waves.

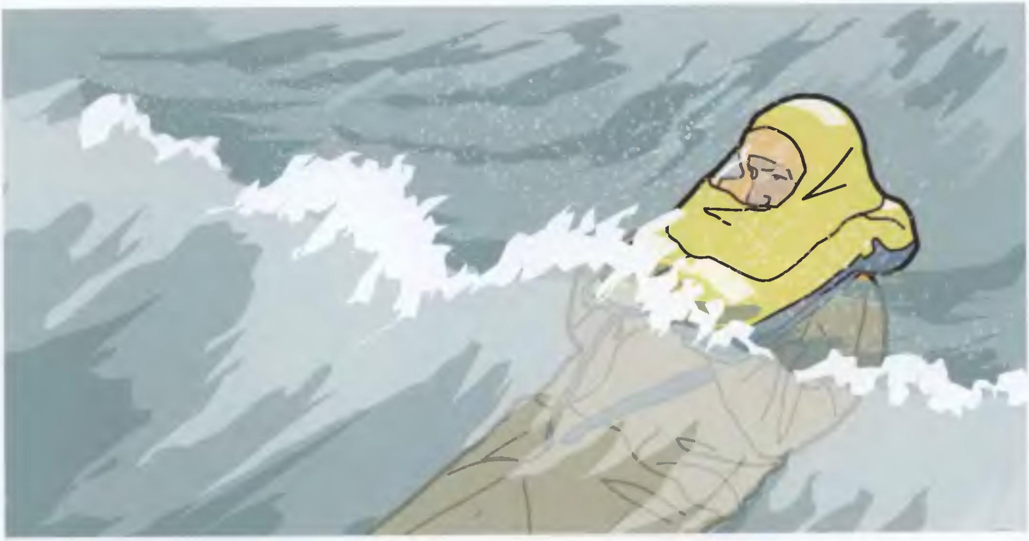

Donning a gas-inflated lifejacket

You should be able to put on and fasten your lifejacket in less than 30 seconds, so practise until you can.

It's essential the lifejacket is worn correctly. If it is too slack the wearer may slip down or even out of the jacket while in the water or being lifted aboard a boat. The lifejacket needs to keep the airway as high above the water as possible. Crotch or thigh straps hold the lifejacket down and lift the body up and, therefore, the airway higher above the water. Wear your lifejacket at all times when on deck. Once it is adjusted to fit you, keep your lifejacket close to hand when below decks, so that it can be donned quickly.

1

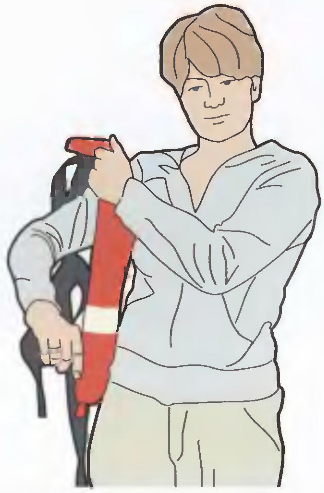

Put the jacket on like a waistcoat. Hold the jacket the right way up and put your right arm between the jacket front and the back strap.

2

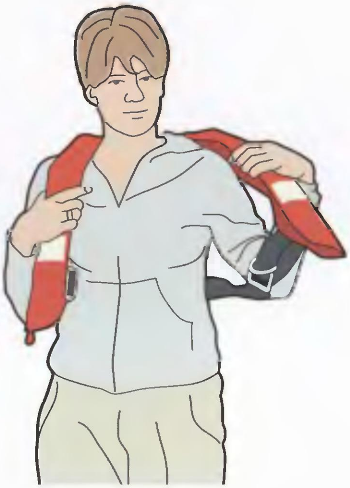

Pull the jacket across your back and put your left arm between left jacket front and the back strap.

Buddy check

It's good practice to ask another crew member to check you are wearing the lifejacket correctly.

3

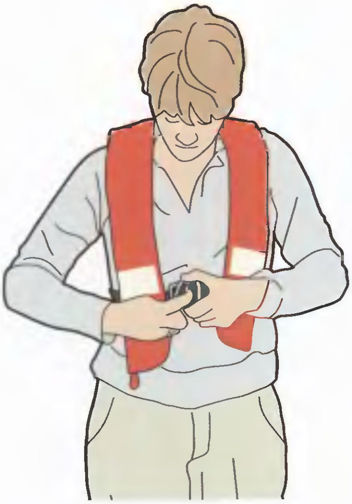

Straighten the waist belt and fasten the clip at the front of the jacket. Check it is secure.

4

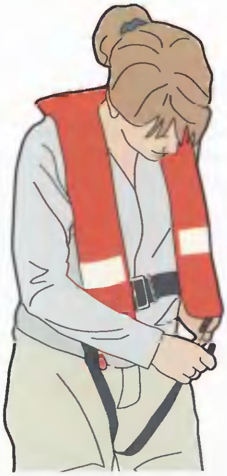

Reach down and pull the crotch strap or thigh straps between your legs and clip it to the waist belt. Shorten the straps to take up the slack but not so tightly as to be uncomfortable.

5

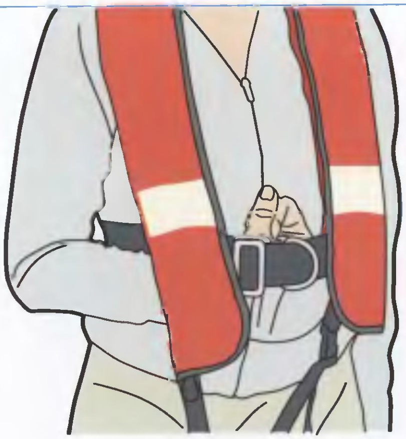

Adjust the waist belt so that it is a tight fit when your fist is placed between the strap and your chest. This will prevent the jacket from squeezing your chest when it inflates and without making it too slack.

Tip

- Stow lifejackets where they can be reached quickly
- Each crew member to have their own lifejacket already adjusted to size
- Add a coloured tag to make the lifejacket easier to identify
- Write your name and the boat's name on the back of the service label in indelible ink
- Don't think when to put your lifejacket on, consider when to take it off!

CHAPTER 6 : MOB prevention

Staying on board your boat is preferable to falling overboard! Clip on. Do not go on deck unnecessarily in heavy conditions and clip on if you must. When moving around remember the rule – one hand for the boat, one for yourself. Prevent accidents by clearing away unnecessary clutter and other hazards. Wear non-slip shoes or boots and avoid standing on ropes or sails since these can roll or slide underfoot. Try to avoid stepping on to smooth wet surfaces such as shiny glassfibre. Wash off oil or diesel spills especially from sidedecks.

Regularly check lifelines and stanchions are firmly attached. Lifelines should be ready to be released or cut easily to aid MOB recovery. A 'Granny bar' at the mast of a sailing yacht helps to steady crew when working at the mast.

Ensure the helmsman warns the crew of manoeuvres – avoid sudden acceleration or surprise tacks or gybes. Look out and warn other crew of larger-than-normal approaching waves.

Clipping on

There are many factors which determine the need to clip on. On displacement sailing yachts, wear a safety harness or, preferably, a lifejacket with a built-in safety harness and 'clip on'. Strong attachment eyes should be fitted in the cockpit just outside the companionway so that crew can clip on before leaving the cabin. Other eyes can be fitted in the cockpit so that the crew can move away from the companionway.

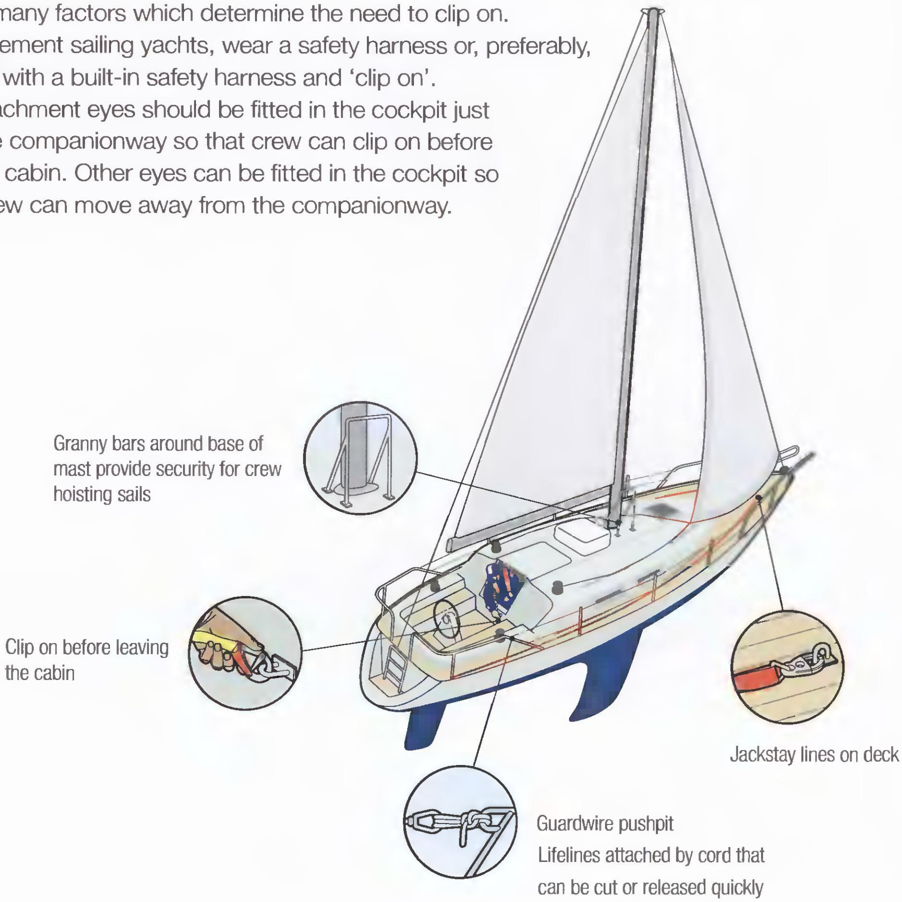
Granny bars around base of mast provide security for crew hoisting sails
Clip on before leaving the cabin
Jackstay lines on deck
Guardwire pushpit
Lifelines attached by cord that can be cut or released quickly

In heavy weather, only go on deck if necessary and clip on to a jackstay. Keep your centre of gravity low – crawl if necessary. Tell the helmsman or skipper before going on deck. On sailing boats go forward on the windward side.

Use a harness with locking snap hooks, such as Gibb Hooks or Wichard Hooks. A three-hook safety harness allows crew to clip onto the next strongpoint before unclipping. Safety lines should have a safety hook at all ends so that the crew can unclip themselves quickly. Jackstays may be made from polyester webbing or stainless-steel wire, webbing jackstays are degraded by sunlight so check and replace them regularly. Wire jackstays can roll underfoot.

Fast boats

It is advisable not to clip-on to planing or semi-displacement boats. It is better to fall clear since being dragged alongside a hull at high speed will cause severe injury.

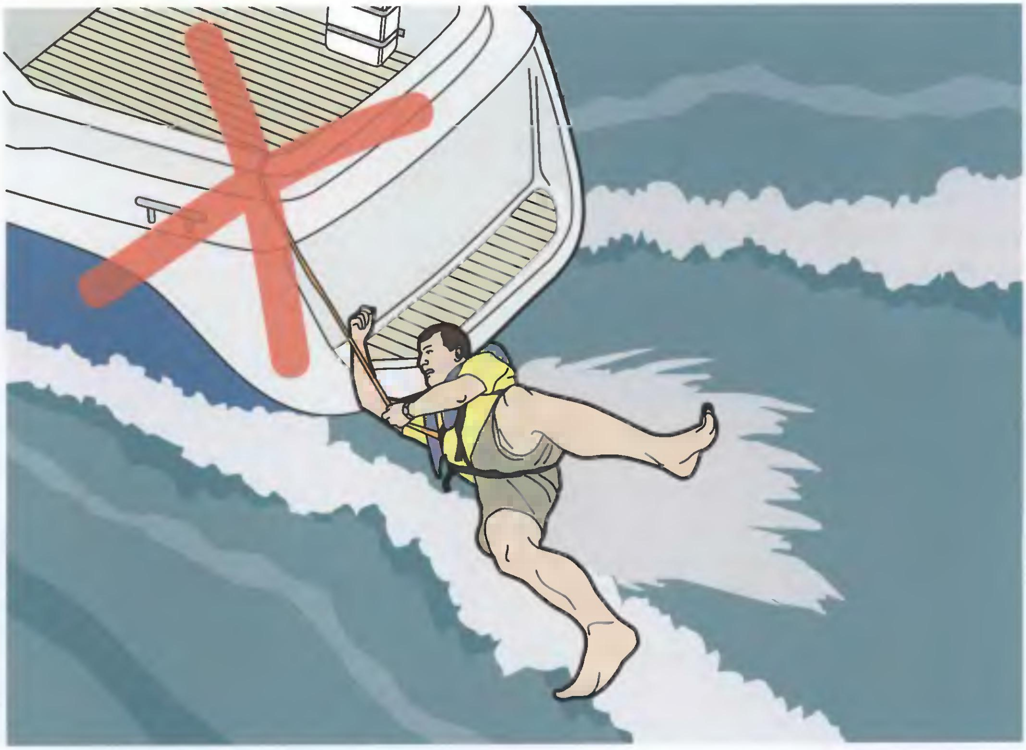

Never clip onto a motorboat when it is moving at speed.

However, if the boat has stopped or is moving at under 5 knots, you can clip on when going on deck, for example, when going forward to drop anchor in heavy weather. Motorboats seldom have jackstays fitted but there is no reason why they cannot be fitted.

CHAPTER 7 : MOB

MOB actions to be taken by crew

1. Shout 'man overboard' to alert the crew.
2. Press the MOB button on the GPS.
3. Throw a life-buoy and dan buoy to the MOB. Mark the MOB with a buoyant smoke flare.
4. Allocate a crew member to point at the MOB in the water.
5. Send a DSC distress alert and a voice Mayday.
6. Keep pointing. Don't lose sight of the MOB.
7. On a sailing boat, the skipper will ask for the jib to be lowered or furled and the engine started.
8. Prepare a throwing line.
9. The skipper will bring the boat alongside the MOB, with the boat pointing into wind and the propeller stopped.
10. Get a line around the MOB and get them aboard.

MOB search patterns

These search patterns are for a boat to follow when looking for a man overboard who has been lost from sight. Press the MOB button on the GPS receiver as soon as possible after the person falls overboard. This will record a geographical position and a bearing and distance to that point.

Press the DSC distress alert, choose 'MOB' from the menu options and send a voice Mayday. If short -handed, there may not be time to send a voice Mayday immediately. The MOB is unlikely to be at the recorded position but it will provide a datum for calculating where they will drift due to wind and current.

Sector search

A good datum is required. Sector search is good for searching small areas. Mark the datum point with a dan buoy, a life buoy with drogue, a weighted fender or similar. The marker should be able to drift with the tide but not be blown by the wind.

Go North (000 degree) first (some prefer to go downdrift first but this can make the sums more complicated). When moving away from the marker, count out loud glancing at the marker. When the marker is visible for only 50% of the time, that is the distance that indicates the Expected Detection Range (EDR). Measure each leg by counting aloud. It is suggested that each leg is three times the EDR. At the end of each leg, turn 120 degrees to starboard and proceed for the same distance.

If the search is not successful after the first circuit, reorientate the search by 30 degrees to starboard.

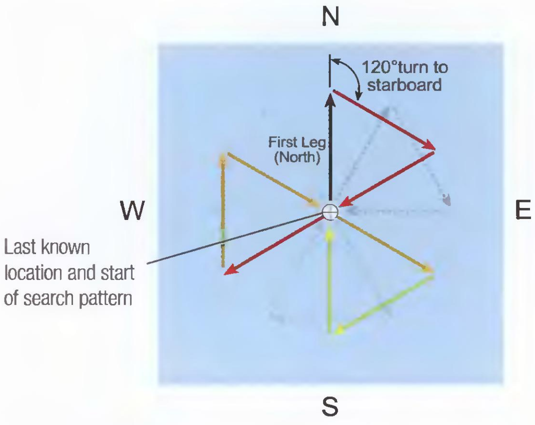

All turns are 120° to starboard. On completion of first search pattern (coloured) rotate by 30° as shown by dotted line

Sector Search

Expanding box search
If the datum point is a little unreliable or a sector search has not proved successful, an expanding box search should be started.

Usually, the leg length is 75% of the EDR. If a sector search has been completed, this will be the third search of the area, in which case it is acceptable to use a leg length of 100% EDR.

For ease of use, it is suggested that the headings are North, East, South and West. Count aloud to measure the distance.

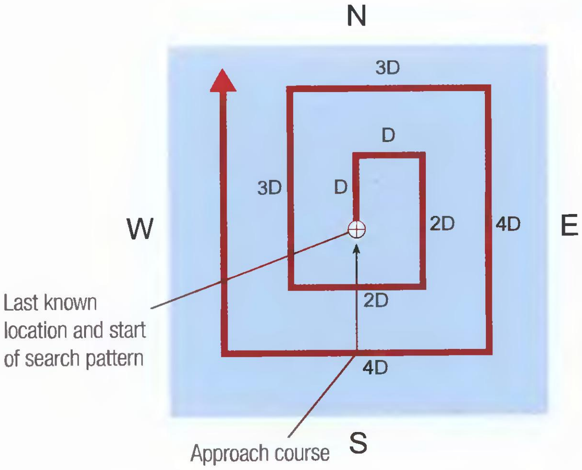
N
3D
D
3D
D
W
2D
4D
E
Last known location and start of search pattern
2D
4D
Approach course
S

Expanding Box Search

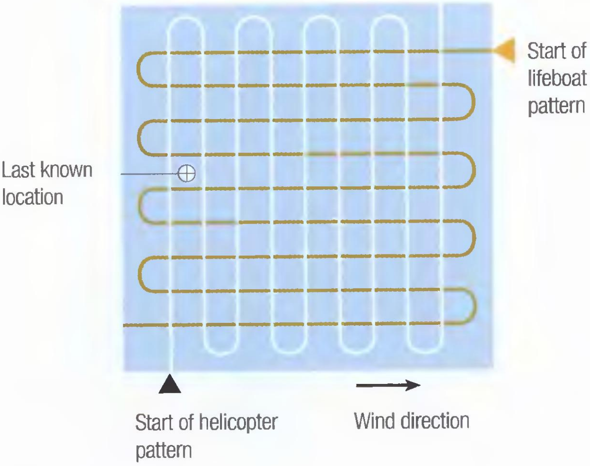
Start of lifeboat pattern
Last known location
Start of helicopter pattern
Wind direction

SAR Search Pattern

SAR search pattern
To search large areas where the position of the casualty is unknown, the Rescue Co-ordination Centre (RCC) will task the SAR units to undertake a parallel search pattern. If lifeboat and helicopter are both involved, their tracks are likely to be at 90 degrees to each other to increase the chances of detection.

Sailing yacht MOB manoeuvre

It will be quicker and safer to use the engine to return to the MOB. But if it won't start or the propeller is fouled, use the sails. Make sure the crew are practised in MOB recovery procedures.

Under sail

1. Sheet in the mainsail and heave to to slow the boat. Pass buoyancy to the casualty and mark with a dan buoy. Instruct a crew member to point at the MOB. Retrieve any warps in the water and start the engine.
2. If the engine is not working turn onto beam/broad reach and sail away.
3. Sail about five to six boat-lengths from the MOB. Do not lose sight of MOB.
4. Tack. Aim the leeward side of yacht at the MOB or the marker. Let out the headsail and mainsail sheets. The mainsail should flap; if not, bear off downwind to change the angle of approach. Point the boat back at the MOB until the mainsail flaps.
5. The angle of approach should be a close reach so that the sails can be powered and depowered. Drop the headsail if there is sufficient power from the mainsail alone.
6. Fill and spill the mainsail and slowly approach the MOB. Pick up the MOB to leeward, aft of the mast.

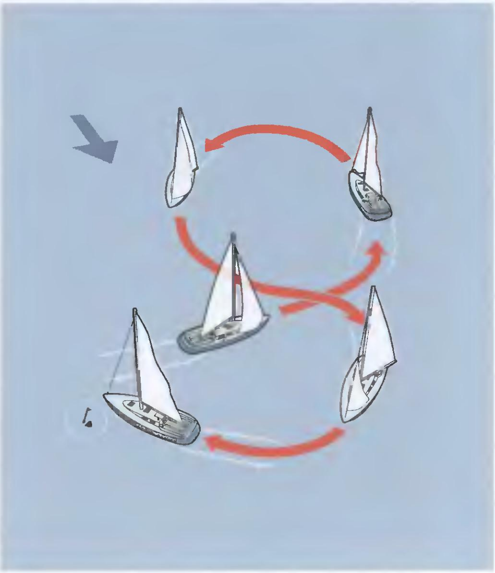

Under power

1. Sheet in the mainsail and heave to to slow the boat. Pass buoyancy to the casualty and mark with a dan buoy. Instruct a crew member to point at the MOB. Retrieve any warps in the water and start the engine.
2. Furl or drop the headsail.
3. Make ready the throwing line.
4. Manoeuvre the boat downwind of the MOB, keeping the MOB in sight.
5. Approach the MOB into the wind so that the mainsail is depowered. Pick up the MOB on the leeward side, aft of the mast.

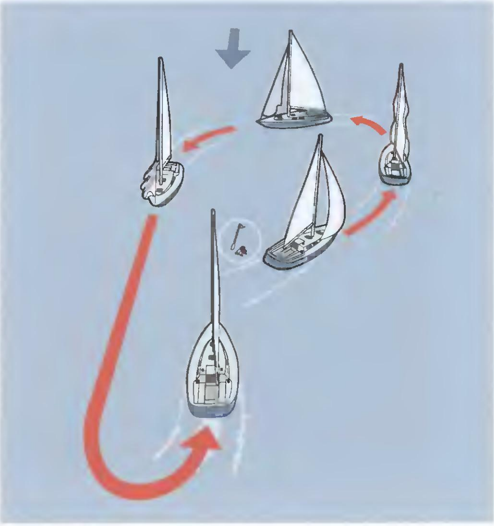

Powerboat MOB manoeuvre

The Williamson Turn is designed to turn the motorboat onto a reciprocal track.

1. Note the compass heading and add 60 degrees.
2. Turn to starboard on to the new course; note the amount of helm used.
3. When you reach the heading, turn the helm in the opposite direction at the same rate as before.
4. As you reach the reciprocal heading or you see your original track in the water, straighten the wheel.
5. Slow down and look for the MOB.

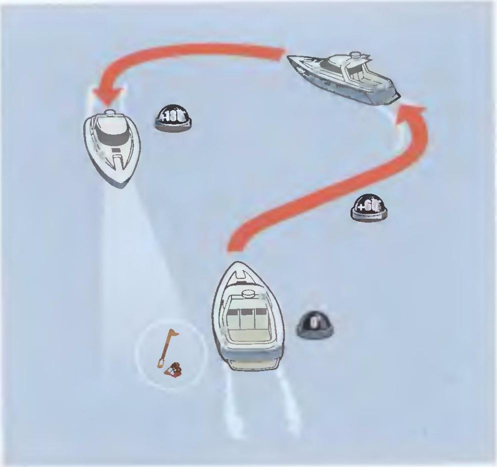

Approaching the MOB

In rough weather, it will be best to approach from downwind, keeping the bow into the wind, taking care not to run over the MOB.

1. Pick the MOB up on the leeward side.
2. Stop engines when the MOB is alongside.
3. Use a throw line if unable to get close to a conscious MOB and pull them to the boat.

Note

If the helm position is on the starboard side,try to leave the MOB to starboard so that they can be seen more easily.

In acceptable conditions, position the boat across the wind, upwind of the MOB.

1. Keep the boat sideways-on to the wind and allow it to blow the boat towards the MOB.
2. Pick the MOB up on leeward side.
3. Stop the engines when the MOB is alongside.

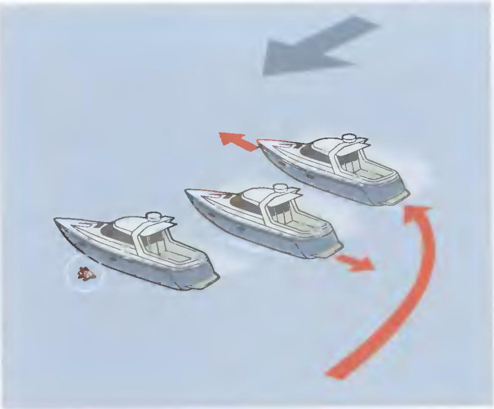

MOB recovery methods

Lifting a person out of the water requires planning and practice. It is a difficult task, especially for short-handed crews.

It's essential to get the person out of the water as quickly as possible. In very calm conditions it may be possible to retrieve them using the bathing platform or the ladder at the transom. However, in rougher seas this will be a dangerous place to attempt to recover a MOB, as the casualty is likely to be drawn under the stern of the boat and injured.

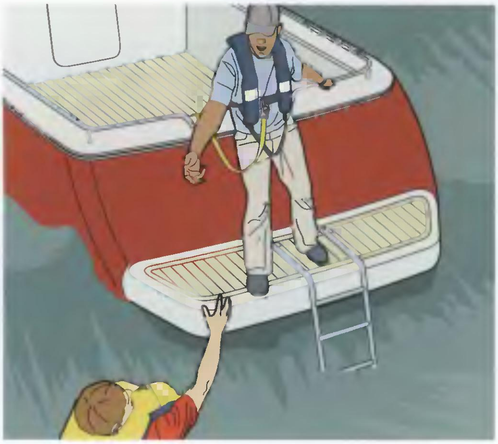

How you go about the task will depend on how your boat is set up and how long the person has been in the water. Hypothermic casualties should be recovered in a horizontal position and handled with care.

It may be easiest and quickest to launch the liferaft, and for a crew member to enter the raft dry and pull the MOB into the raft. This method is not without risk and the raft will not be available should you need it later in the voyage. Lower either the lowest or both guardrail wires along the side of the boat to ease recovery.

Crew dealing with MOB recovery should ensure that they are attached to the boat with a safety line. One MOB is enough.

Recovery methods for sailing yachts

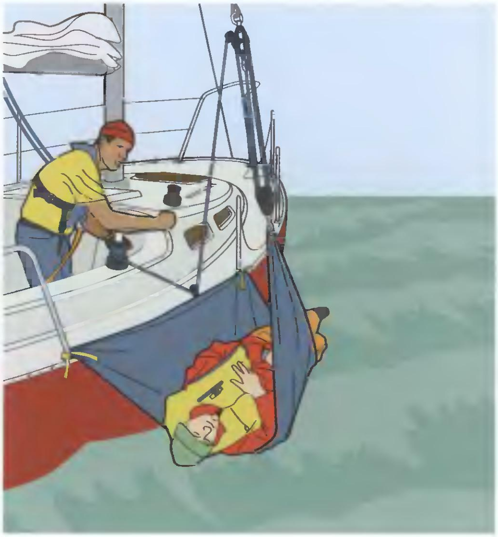

Parbuckle

The Parbuckle is set on the side of the boat. The foot is fastened along the gunwale and the head attached either to a handybilly (block and tackle) that is attached to a halyard or to the halyard alone.

Lower the Parbuckle into the water and position the MOB.

Heave in on the handybilly – use a sheet winch for greater mechanical advantage.

The casualty will roll inside the parbuckle up and on to the sidedeck.

A small headsail can be used in place of a purpose-designed parbuckle. However, it will be more difficult to get the sail to sink sufficiently to position the MOB in it. Also there's a strong possibility that the MOB will slip out of the sail as they are being brought aboard.

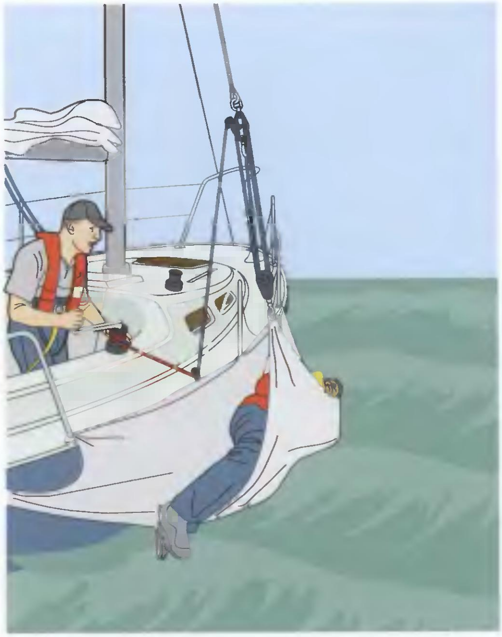

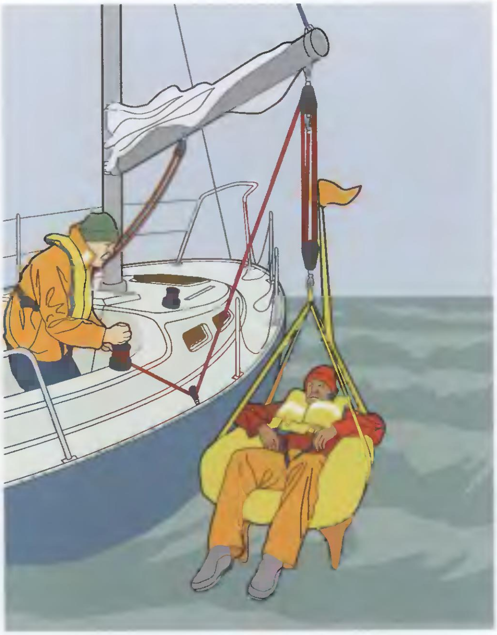

MOB recovery raft

Proprietary MOB recovery rafts can also be lifted on board using a handybilly attached to the halyard or the boom lift.

Fastening to the top of the raft is easier than attaching to a MOB in the water. The rafts are easy to get into and minimise hydrostatic squeeze.

Boom lift
On yachts with booms not fitted with solid kickers, it may be possible to use the boom as a derrick. The yacht needs to be sufficiently large to withstand lifting a MOB on the boom.

The main sheet, attached with snap shackles at both ends, is reversed and freed from the deck fitting.

Slacken off the kicker and scandalise the boom to an angle of about 30 degrees from the horizontal. It may be necessary to back up the topping lift with the halyard.
Attach the bottom of the sheet either to the MOB's lifejacket or harness or to a rescue strop. Place the rescue strop around the MOB's chest.

Heave on the mainsheet or redirect the free end to a sheet winch and lift the MOB into the yacht.

A horizontal lift can be achieved by placing an additional safety lanyard or line behind the knees of the MOB.

Elevator method
Developed in the United States, the elevator method provides a quick way of helping a conscious MOB out of the water.

A line is attached to a forward cleat and led aft outside of the guard wires, fed through the headsail fairlead to the sheet winch. The MOB stands on the line as it is winched tight, thereby lifting the MOB up the side of the boat. In most cases a second line will need to be rigged over the side of the boat for the MOB to hold on to.

> Some motorboats may be able to adapt this method by rigging the line from a stern cleat, through the bow roller and on to the windlass.

Recovery method for motorboats

MOB recovery on a motorboat is more difficult than on sailing yachts due to the lack of rigging.

Many motor cruisers carry a small inflatable dinghy in davits or on snap davits attached to the transom bathing ladder. A quick method of MOB recovery is to lower the dinghy and recover the MOB into the dinghy. Make sure helping crew are attached to the boat.

If the MOB is too heavy to lift into the dinghy, one of the sponsons can be deflated and the MOB rolled into the dinghy.

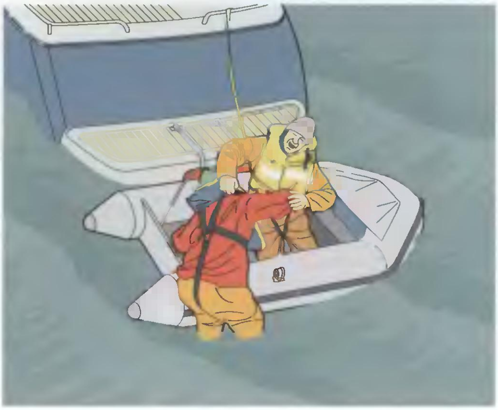

CHAPTER 8 : Liferafts

Liferafts are designed should your boat sink or catch fire to get you out of the water and provide shelter for a limited period. Whenever possible, let the SAR services know you are abandoning to a liferaft so that they know what they are looking for.

The quality of liferafts varies enormously. Some products marked as a liferaft may be no more than a couple of gas-inflated floats: others provide an acceptable, stable, sheltered environment. Always look inside the canister if buying a secondhand raft – it has been known for unscrupulous sellers to replace the raft with bricks!

Basic leisure rafts

Usually at the lower end of the price scale, leisure liferafts are not made to any national or International standard or specification. Nor are they approved for any commercial operation, yachts sailing under racing rules or Class XII craft. The leisure liferaft is light in weight (easier for launching), and may or may not have a canopy. Some may have only one buoyancy chamber and minimal survival equipment as standard. But this is better than nothing in an emergency situation.

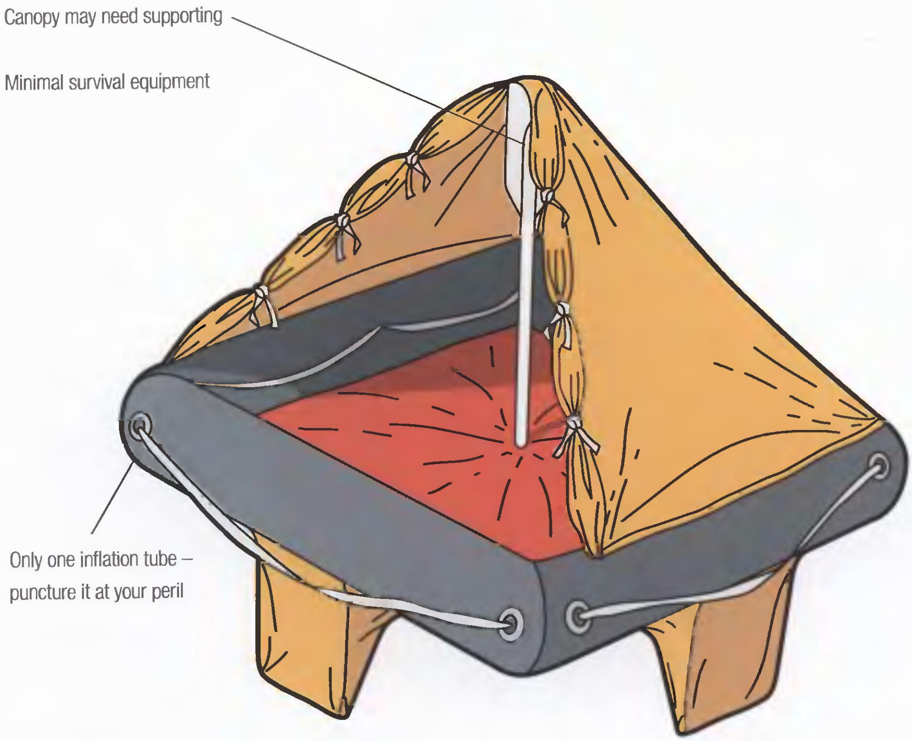
Canopy may need supporting
Minimal survival equipment
Only one inflation tube – puncture it at your peril

Basic Leisure Liferaft

Inflatable Active Survival Craft

A number of offshore racing associations approve some makes of active survival craft as an alternative for a liferaft. However, most national authorities do not accept them as suitable safety equipment because there is currently no recognised standard for active survival craft.

Many are based on an inflatable dinghy fitted with a liferaft gas inflation system and a canopy for shelter. While the craft can be rowed or sailed to safety, the lack of ballast pockets make them unstable in a seaway.

Since some areas have minimal rescue services, many bluewater sailors design their own survival craft, based on an inflatable or rigid dinghy with a small rig that allows them to effect their own rescue. However, these may not always be able to be readied and launched as quickly as a liferaft.

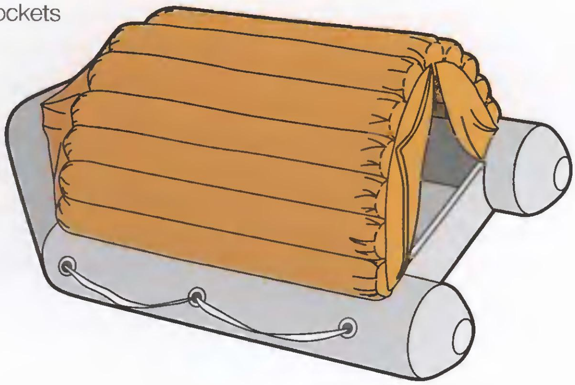

Liferaft standards

SOLAS

Commercial vessels have been required to carry liferafts built to SOLAS Standards, as detailed in Chapter IV of the Life Saving Appliances (LSA) code, since 1959. This standard has been periodically upgraded and SOLAS rafts are made and tested to high standards and extremes of operating temperatures. They are approximately 30% heavier, tougher and significantly more expensive than ISAF or ISO rafts. The Standard covers rafts from six-person capacity upwards.

ORC

The Offshore Racing Congress specification was introduced after the 1979 Fastnet Race inquiry. Yachts racing under their rules were required to carry ORC rafts. This has now been superseded by the ISAF Part II specification up until June 2007. ORC rafts built before December 2002 could still be fitted to ISAF racing yachts. However, this is no longer allowed. ORC rafts may still be found on many cruising yachts. ORC is also known as ISAF Part I and is in the ISAF Offshore Special Regulations.

ISAF

Following the 1998 Sydney–Hobart Race, the International Sailing Federation, (which now oversees the majority of offshore sail yacht racing in place of the ORC), developed a specification for liferafts similar to the ISO standard, principally as an interim measure while the new ISO standard was being completed. Although similar there are differences between ISAF and ISO. The ISAF specification came into force on 1st January 2003 and covers rafts of maximum capacities of 4 to 12 persons.

Note that ISAF specifies that Category 0 (zero) yachts should carry SOLAS rafts. The specification is included in Appendix A part 2 of ISAF's Offshore Special Regulations. (www.sailing.org/)

ISO 9650 Small Craft – Inflatable Liferafts

Introduced by the International Standards Organisation during 2005, ISO 9650 comprises of three parts:

Part 1:	Type 1 Liferafts for offshore use subdivided into: Group A rafts designed to inflate in temperatures of between –15 and +65 degrees C. Group B rafts that will inflate between 0 and +65 degrees C (air temperature).
Part 2:	Type 2 Liferafts for coastal use. All Part 2 rafts are expected to inflate between 0 and +65 degrees C.
Part 3:	Material to be used in liferaft manufacture

The main differences between Part 1: Type 1 and Part 2: Type 2 rafts are shown in the table. Type 2 rafts are, size for size, slightly smaller than Type 1 rafts. Type 1 rafts are more robust than Type 2 rafts. Type 1 Group A liferafts are recommended for northern European waters.

	ISO 9650 Part 1: Type 1	**ISO 9650 Part 2: Type 2**
Maximum Capacities	4 person to 12 person	4 person to 10 person
Painter length	9 metres	6 metres
Withstand drop of	6 metres	4 metres
Minimum Freeboard	4 person = 250mm 6 person+ = 300mm	4 person = 200mm 6 person+ = 250mm
Floor	Grp A rafts include thermal floor	Optional

Liferafts built to ISO 9650 Part 1: Type 1 are given a choice of two equipment packs depending on expected duration at sea – less than 24 hours and more than 24 hours (see Liferaft packs on p.62).

ORC, ISAF, ISO 9650 and SOLAS specify that the liferaft's main buoyancy is divided into two separate chambers. Each chamber must have sufficient buoyancy to support the maximum capacity of the raft. The chambers must be able to be topped up with a bellows and have pressure-relief valves. Each standard also specifies that the liferaft must have a canopy.

Which size raft?

The capacity of the liferaft/s should be sufficient to carry all persons on board. However, if regularly sailing short-handed, it may be advisable to obtain two smaller rafts instead of one large raft. An added advantage being that the smaller rafts will be lighter and easier to handle. In addition to the ballast pockets, a liferaft uses the weight of its crew to keep it stable in waves. For example a boat that can carry eight people would have two four-person rafts instead of one eight-person raft if the boat was regularly sailed by a crew of only two or four.

Typical leisure raft

There are a number of mid-range yacht liferafts that do not meet ORC, ISAF, ISO or SOLAS standards. Their prices are lower but the quality of construction is also lower and there are often very few fittings included.

ISAF, ISO 9650 Part 1 and SOLAS

Externally there are few differences between liferafts built to SOLAS, ISO 9650 Part 1:Type 1 and ISAF. However, as a guide, SOLAS rafts are more robust than ISO/ISAF rafts, which in turn are more robust than non-standard rafts.

SOLAS rafts are designed to:

- withstand exposure for 30 days afloat (compared with 20 days for ISO/ISAF).
- withstand stowage in temperatures from –30 to +60 degrees C.
- withstand a drop from 18 mtrs and withstand persons jumping repeatedly into them from 4.5 mtrs.

SOLAS rafts have lined canopies to provide insulation. Fig. 1 is a raft that includes the correct fittings to meet these standards.

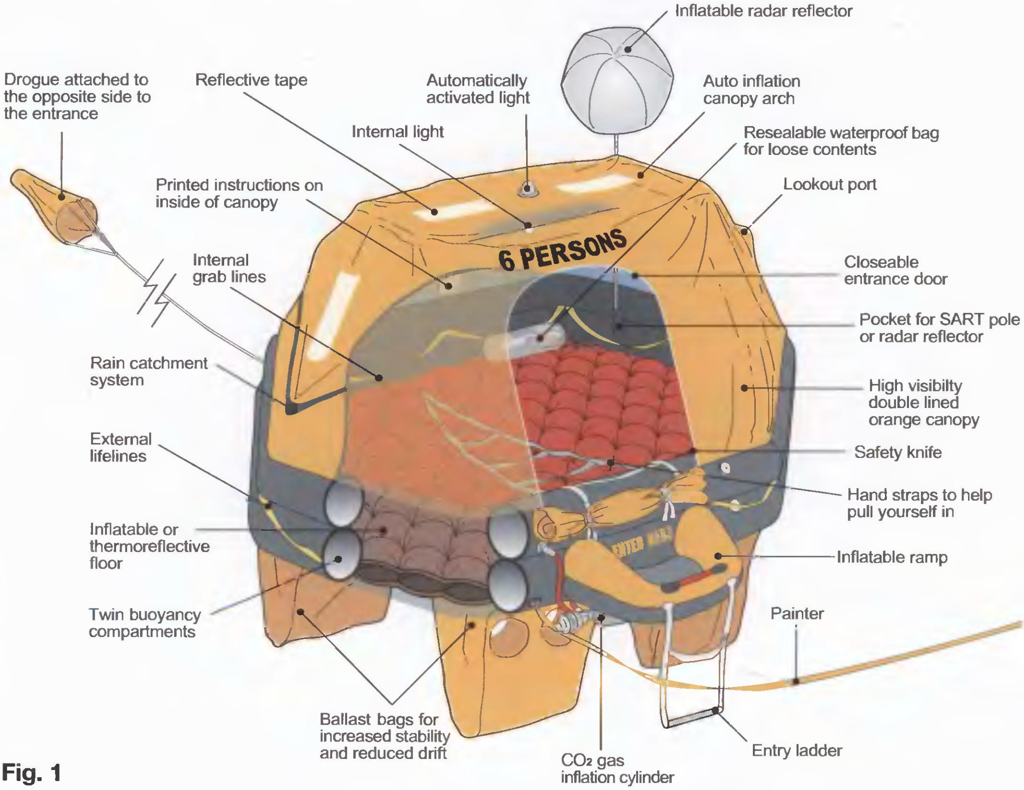
Inflatable radar reflector
Drogue attached to the opposite side to the entrance
Reflective tape
Automatically activated light
Auto inflation canopy arch
Internal light
Resealable waterproof bag for loose contents
Printed instructions on inside of canopy
Lookout port
6 PERSONS
Internal grab lines
Closeable entrance door
Pocket for SART pole or radar reflector
Rain catchment system
High visibilty double lined orange canopy
Safety knife
External lifelines
Hand straps to help pull yourself in
Inflatable or thermoreflective floor
ENTER HERE
Inflatable ramp
Twin buoyancy compartments
Painter
Ballast bags for increased stability and reduced drift
CO_2 gas inflation cylinder
Entry ladder

Fig. 1

Canister v Valise

Liferafts are supplied in either a plastic/glassfibre box or in a fabric valise. To protect from water damage, most rafts – canister and valise – are vacuum-packed in large polythene bags that rip open when the raft inflates.

Canister

The canister is usually made from two parts held together with straps and provides a hard case to protect the raft from knocks and sharp objects. The canister is not waterproof but the packaging inside should prevent ingress of water.

Pros

- Usually easily accessible
- Contents protected from damage
- Can be used with an HRU (see p.60)

- ***Cons***
- More likely to be stolen or washed overboard
- More expensive to buy
- Prone to damage from the elements

Valise rafts

These need to be stowed in a dedicated weatherproof locker. A valise should never be left strapped to an exposed deck or buried deep in a locker under piles of sails, fenders or warps. Make sure it is always readily available.

Pros

- Cheaper to buy
- Easier to move because they have handles and are lighter in weight than a rigid canister
- Less likely to be washed overboard

Cons

- Likely to be damaged by rough handling – do not throw them on to pontoons
- Harder to deploy because they have to be lifted out of a locker
- Cannot be automatically deployed
- Cannot be left in an exposed position

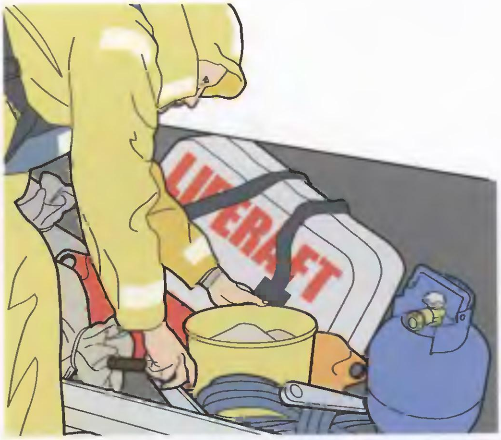

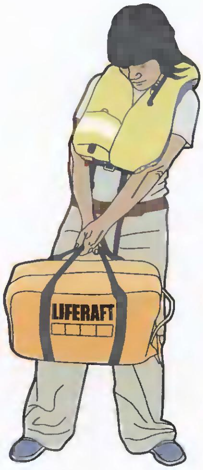

Liferaft stowage

A liferaft is a heavy and sometimes awkward piece of kit to carry. Apart from the smallest rafts, most will require a two-man lift. As you are likely to need it in a hurry, you need to give careful consideration as to where to stow it.

Ideally, the raft needs to be positioned so that it is readily accessible yet is protected from heavy weather.

Canister rafts can be deck-mounted on the coachroof, in the cockpit, on the bathing platform, on the transom or in a purpose-made bracket on the pushpit.

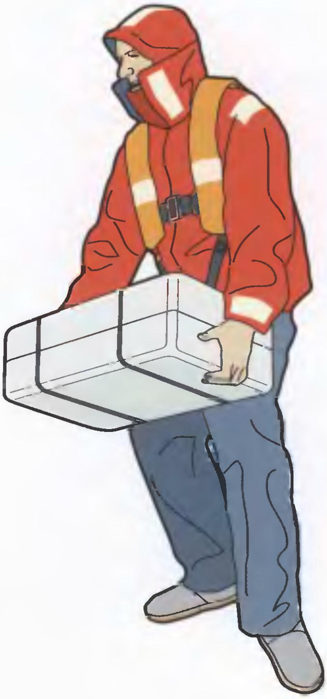

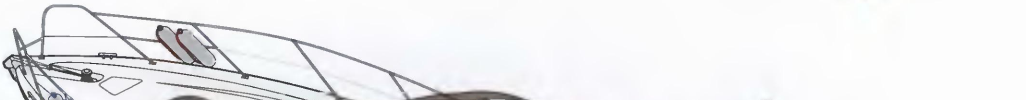

If stowed vertically in a bracket the raft may need to be specially packed to prevent the weight of the cylinder damaging the raft material. The canister's drain holes may also need to be repositioned.

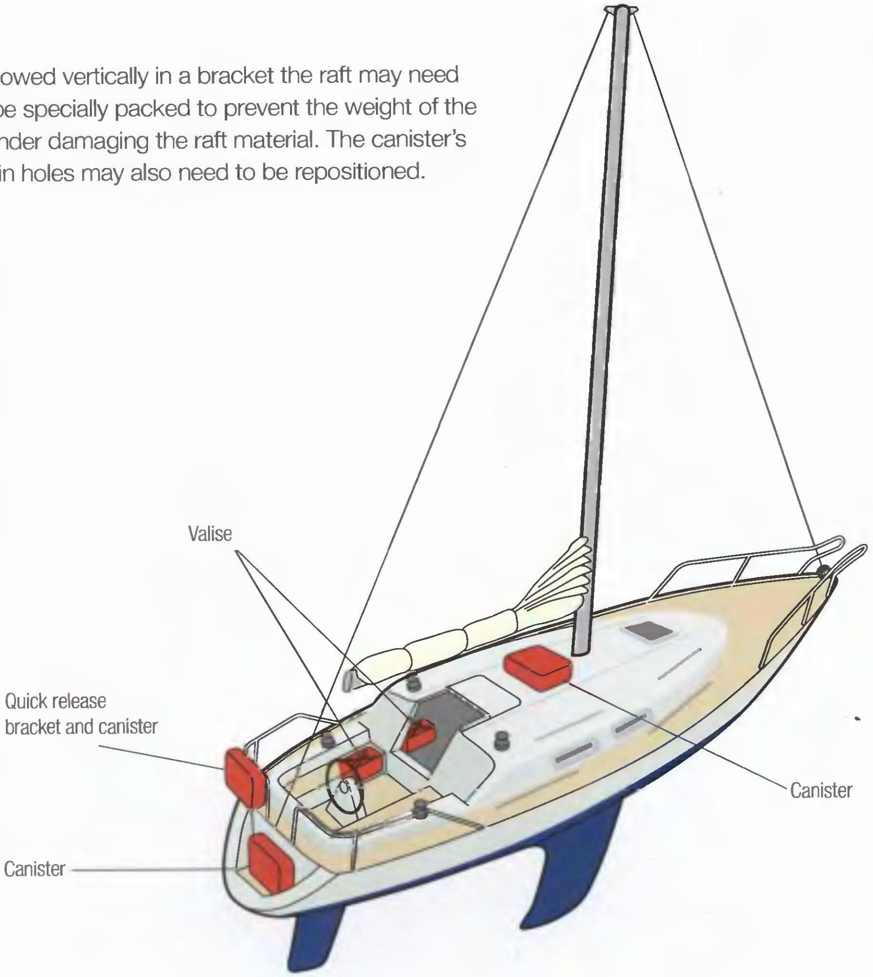

Maintenance

Make sure that a competent service agent services your liferaft at the manufacturer's required periods. Most modern rafts are vacuum-packed in large plastic bags, and if stored correctly should extend the service period to three years. However, there are still many rafts that need to be serviced annually. Good service centres will let you view the liferaft inflated and check the quality and amount of equipment packed with the raft.

Hiring

In most countries, it is possible to hire a liferaft from a liferaft hire centre. Rafts can be rented for periods from as little as a week right through to a whole season or more. This may be particularly useful for those that sail short-handed with one raft for most of the year and only occasionally with a full crew, when two rafts are needed.

Hydrostatic release units (HRUs)

Boats can sink within minutes if their hull is breached by even a relatively small hole. Fast craft are especially susceptible to high-speed impacts and have been known to sink in under 30 seconds! Commercial craft are required to fit HRUs to their liferaft.

How an HRU works

The HRU automatically cuts the securing strap holding the raft in place when the boat sinks to a depth between 1 and 4 metres (3 to 13 feet). The painter remains attached to the HRU weak link and the raft has sufficient buoyancy to float to the surface.

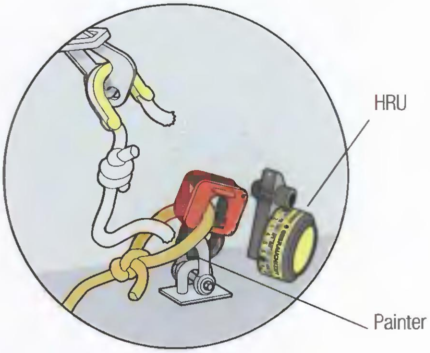

As the boat sinks further, it tugs on the painter to trigger the inflation system.

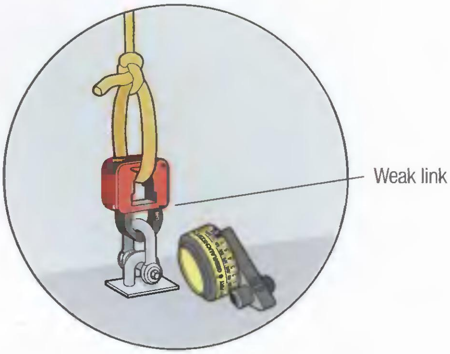

The greater buoyancy of the inflated raft is sufficient to break the weak link and releases the painter from the boat.

If the boat sinks in shallow water it may be necessary to release the liferaft manually.

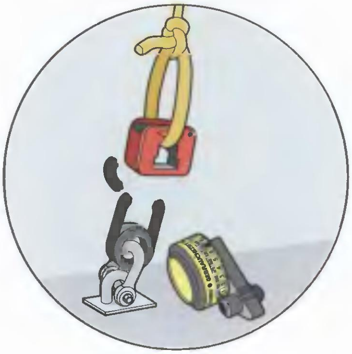

It's essential that the HRU is properly installed, because otherwise the raft will not break free and inflate. Illustrated below are new and old versions of the disposable Hammar HRU often used on boats. More expensive serviceable units are also available.

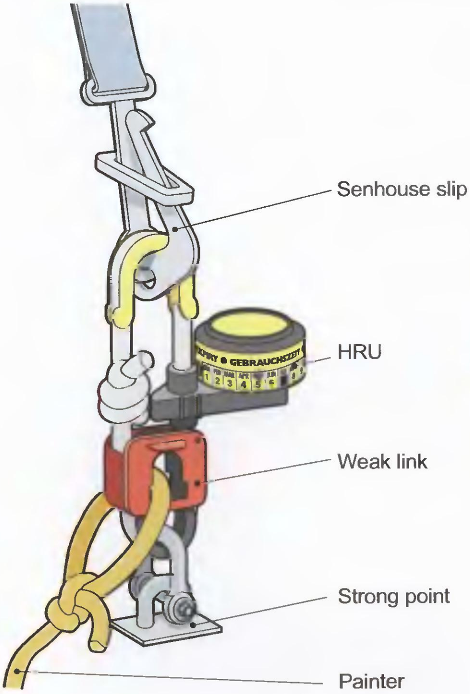
Senhouse slip
HRU
Weak link
Strong point
Painter

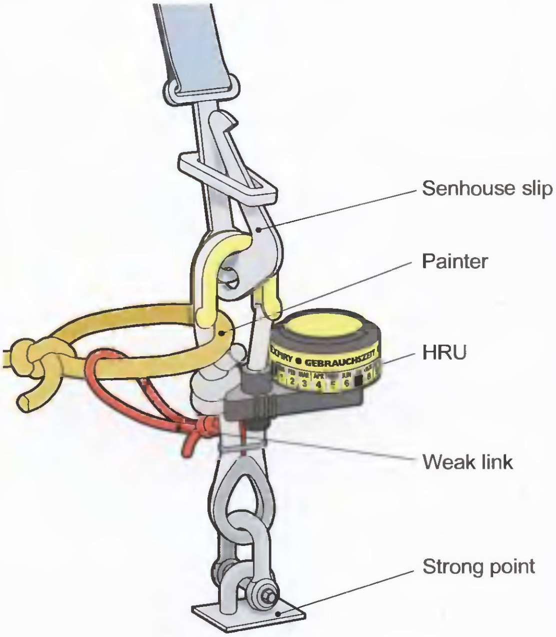
Senhouse slip
Painter
HRU
Weak link
Strong point

HRU safety checks

The Hammar HRU is a replaceable unit with a two-year lifespan. The expiry date should be marked on the unit. Replace it when required.

Check that no other straps (or padlocks) are used to secure the liferaft.

The ring on the Senhouse slip should be checked periodically to make sure it is free as vibration can cause the ring to jam in place, making it difficult to launch the raft manually.

Liferaft packs

Generally, the contents of a liferaft will depend on the type of raft: leisure, ORC, ISAF, ISO 9650 or SOLAS. Listed on page 63 are the minimum contents required under each specification. Note that ISO 9650 Part 1: Type 1 rafts have a choice of packs suitable for survival for under 24 hours or over 24 hours. You specify which pack when you purchase or service the liferaft.

The standard pack can be supplemented with extra equipment as long as it can fit in. Check contents with your service agent. If there is no room for the item you need, add it to your grab bag. Carefully consider what you may need for the area you will be sailing.

Find out what you have in your liferaft before you need it.

Many items inside the raft will have a limited life – flares, water, food etc – and need to be replaced when the raft is serviced. When possible, check the quality of equipment in your raft – cheap rafts may have poor-quality equipment - for example childrens' beach spades for paddles!.

Some raft packs pack equipment that you will need immediately in a separate pack.

Buoyant safety knife – attached with a lanyard and usually found in a sheath next to the raft entrance. Use it to safely cut the painter as close to the yacht as possible; keep the line, it may be useful later.

Bailer – it may be no more than a fabric dish, boots are much more effective but only as a last resort because you will suffer heat loss if they are removed. It's difficult to bail with the door closed, a stirrup pump is more effective, so pack one in your grab bag. The bailer can also be used as a sick bucket or a toilet – this is safer than leaning out of the doorway. Some liferafts may be fitted with an integral bailer, check manufacturer's usage instructions.

Sponges – the number supplied will depend on the raft pack. They usually come 'flat-packed' and dry. Use one to help dry out the raft. The other should be kept uncontaminated and used to collect drinking water by wiping condensation from inside the raft canopy.

Paddles – are essential for moving clear of a burning yacht or other hazard and very useful for manoeuvring to pick up survivors from the water. They are usually but not always in two parts and can also be used as a splint for broken limbs.

Whistle – this is more effective than shouting.

Item	Solas A	Solas B	Iso 9650 24 hours or more	Iso 9650 less than 24hrs	ISAF	ORC	Typical leisure raft (D-pack)
Buoyant knife	1	1	1	1	1	1	1
Bailer	1	1	1	1	1	1	1
Sponges	2	2	2	2	1pp	2	2
Paddles	2	2	2	2	2	2	2
Whistle	1	1	1	1	1	1	-
Torches	1	1	1	1	2	1	-
Heliograph	1	1	1	1	1	-	-
Anti seasick pills	6pp	6pp	6pp	6pp	6pp	-	-
Seasick bag	1pp	1pp	1pp	1pp	1pp	-	-
Red h/h flares	6	3	6	3	3	3	-
Para rocket flares	4	2	2	2	Grab bag	-	-
Buoyant smoke flare	2	1	-	-	-	-	-
TPA	2	2	2	-	2	-	-
Repair kit	1	1	1	1	1	1	1
Water	0.5lt pp	-	1.5lt pp	-	Grab bag	-	-
Food	10,000kJ pp		10,000kJ pp	-	Grab bag	-	-
First Aid kit	1	1	1	-	1	-	-
Bellows	1	1	1	1	1	1	1
Throwing line – 30m	1	1	1	1	1		1
Drogue	2	2	1	1	2	1	1
Waterproof notebook	-	-	-	-	1	-	-
Signal card	1	1	-	-	-	1	1
Sea Survival instructions	-	-	-	-	1	-	1
Leak stoppers	Set	Set	-	-	Set	Set	-
Radar reflector	1	1	-	-	-	-	-
Fishing kit	1	-	-	-	-	-	-
Tin opener	3	-	-	-	-	-	-
Graduated drinking cup	1	-	-	-	-	-	-

pp = per person

Torches – these usually come packed with only one set of spare batteries and bulb or there may be two sealed torches so make sure you pack sufficient spares. They are essential for looking for other casualties and for signalling in the dark.

Heliograph (signalling mirror) – easy to use and effective for daytime signalling. If no sight is provided, use your fingers. Hold out your arm and put up two fingers between you and the target. Direct the sunlight on to your fingers. You can use a CD to practise with, but be aware that water may dissolve the shiny surface, so they are not a suitable long-term alternative.

Anti-seasickness pills – should be taken as soon as possible, preferably before entering the raft.

Seasickness bag – only one per person is supplied in rafts made to the Standards,using them keeps the interior a little more habitable.

Flares – are arguably the most important pieces of equipment on the liferaft. The number and type will depend on the type of pack. Make sure you and your crew are familiar with the triggering methods and use of the different types because what are supplied in the raft may be different to those on your boat. Keep them dry and do not use them until you are confident they will be seen.

TPA (thermal protective aid) – not found on all rafts. Used to reduce heat loss of wet casualties, use by wringing out their clothes and redressing the casualty, then place the casualty in the TPA. Some TPAs are big enough for two people at one time.

Repair kit – the standard repair kit consists of patches and glue not dissimilar to those used to repair bicycle inner tubes, needs to be used in dry conditions. Many rafts are now also supplied with liferaft repair clamps and/or leak-stopper bungs that can seal holes quickly in wet or dry conditions.

Water – if included, will be only half a litre per person. Supplement this with extra rations or keep a desalinator in the grab bag.

Food – the type varies but it will be carbohydrate-based and should provide 10,000 joules per person.

First-aid kit – the contents will vary with the quality of the raft. The SOLAS C kit provides a comprehensive selection of equipment. Supplement your grab bag with extra medical supplies or any specific medications you need.

Bellows – used to top up the sponsons and for inflating the inflatable floor. Take care not to suck up water. Tie the bellows in because if you lose it you will need to top up the tubes by mouth. If possible take an extra pump from boat.

Throwing line and quoit – usually 30 metres long. If you are unable to paddle to other casualties, throw the line. If a casualty is unconscious, tie the line to a rescue swimmer.

Drogue/sea anchor – Deploy this immediately you are clear of the stricken vessel. The drogue will improve stability, turn the liferaft entrance away from the wind and waves and slow your rate of drift. Be aware that some drogues deploy automatically.

Waterproof notebook – useful for working out a watch system, keeping a tab of rationing and medication.

Signal card – this shows what the signals from aircraft and ships mean.

Sea survival instructions – a useful reminder of what to do. Supplement them with this book kept in your grab bag.

Radar reflector – deploy this as high as possible. **Do not use with a SART since they can conflict with each other.**

Fishing kit – this gives you something to do. Eat fish if you have plenty of water.

Tin opener – for opening supplies taken from the boat.

Graduated drinking cup – for ensuring fair sharing of water.

Grab bag

The grab bag is designed to supplement the contents of the liferaft. Ideally, it should float and be watertight. The contents should be stowed in waterproof containers that can be opened with cold wet fingers.

Some sailing-yacht racing rules specify what you must have in the grab bag.

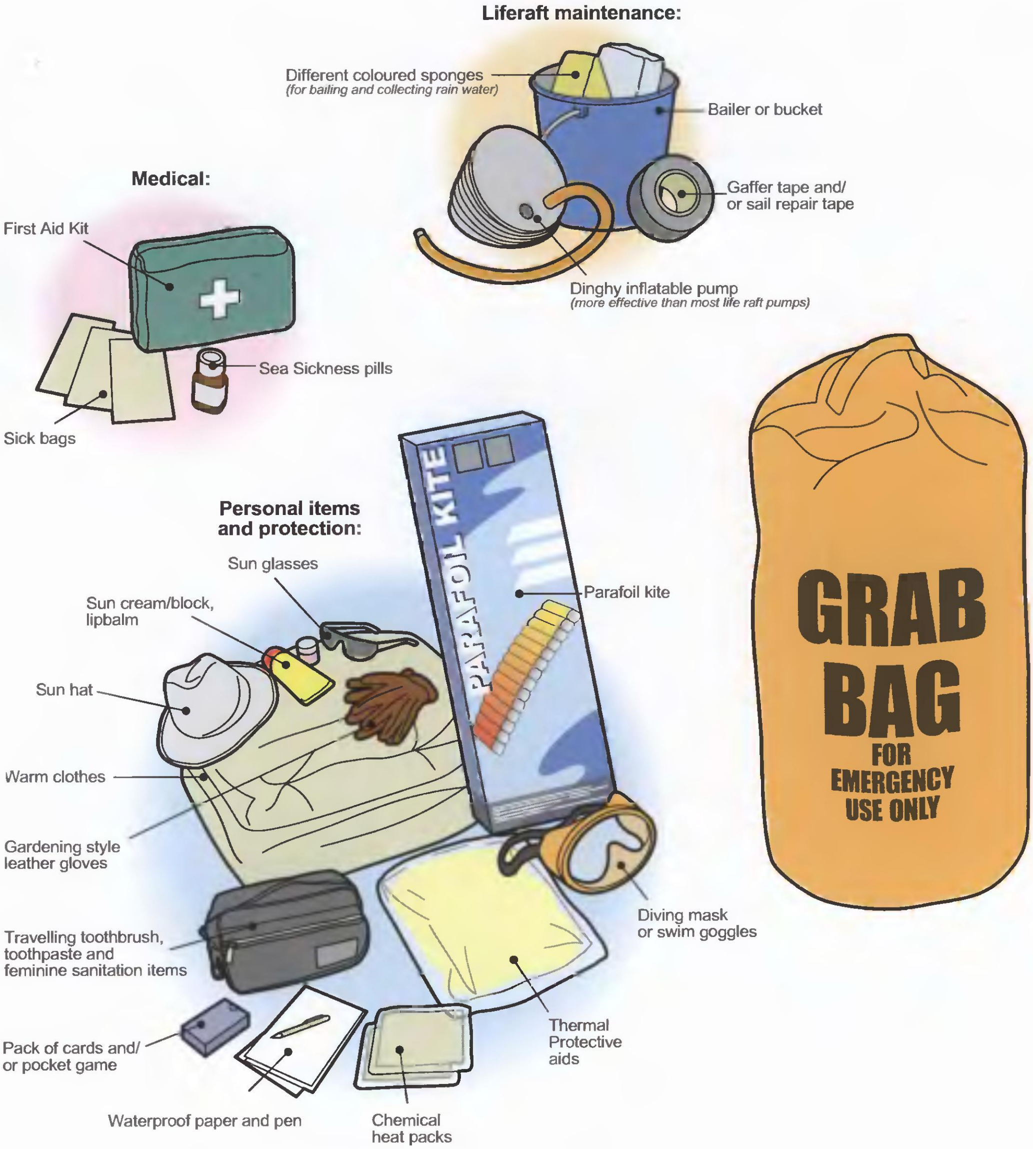
Liferaft maintenance:
Different coloured sponges
(for bailing and collecting rain water)
Bailer or bucket
Gaffer tape and/
or sail repair tape
Dinghy inflatable pump
(more effective than most life raft pumps)
Medical:
First Aid Kit
Sea Sickness pills
Sick bags
Personal items
and protection:
Sun glasses
Sun cream/block,
lipbalm
Parafoil kite
PARAFOIL KITE
Sun hat
Warm clothes
Gardening style
leather gloves
Travelling toothbrush,
toothpaste and
feminine sanitation items
Pack of cards and/
or pocket game
Waterproof paper and pen
Chemical
heat packs
Thermal
Protective
aids
Diving mask
or swim goggles
GRAB
BAG
FOR
EMERGENCY
USE ONLY

Survival and maintenance items:

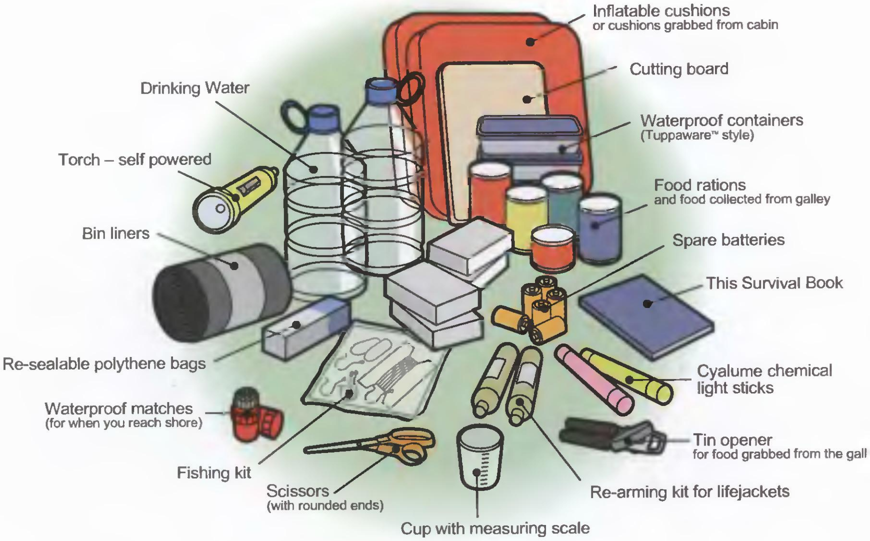
Inflatable cushions
or cushions grabbed from cabin
Cutting board
Drinking Water
Waterproof containers
(Tuppaware™ style)
Torch – self powered
Food rations
and food collected from galley
Bin liners
Spare batteries
This Survival Book
Re-sealable polythene bags
Cyalume chemical
light sticks
Waterproof matches
(for when you reach shore)
Tin opener
for food grabbed from the gall
Fishing kit
Scissors
(with rounded ends)
Re-arming kit for lifejackets
Cup with measuring scale

Rescue and navigation:

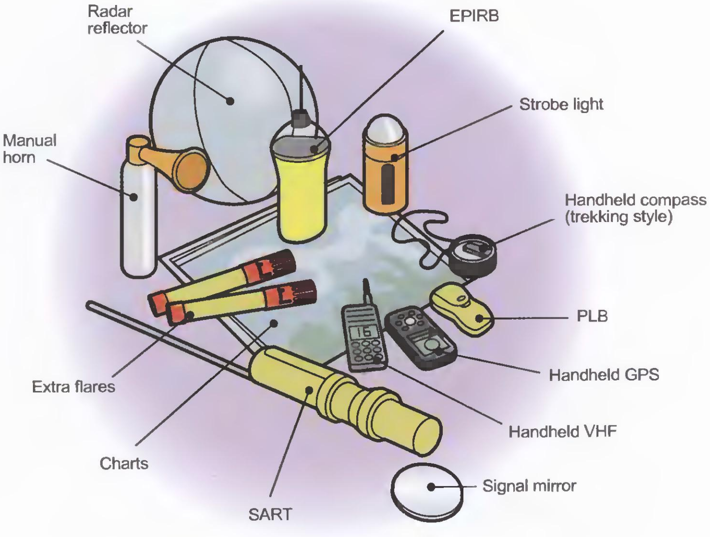
Radar
reflector
EPIRB
Strobe light
Manual
horn
Handheld compass
(trekking style)
PLB
Handheld GPS
Extra flares
Handheld VHF
Charts
Signal mirror
SART

If some items are normally in use on the boat, make up a laminated 'grab bag list' of what to take with you. Stow grab bag extras where you know you will be able to find them quickly.

If you have time, take the dinghy as well.

Two-tier system

Pack a waist-bag (bum-bag) with small items that will make your eventual return to shore easier: money, credit card, spare spectacles, personal medication, the boat's papers, passports, house- and car-keys etc. If rescued by helicopter, you will not be able to take a large case with you. It's bad enough losing your boat but not being able to get home, or having to break into your car and house will make it worse.

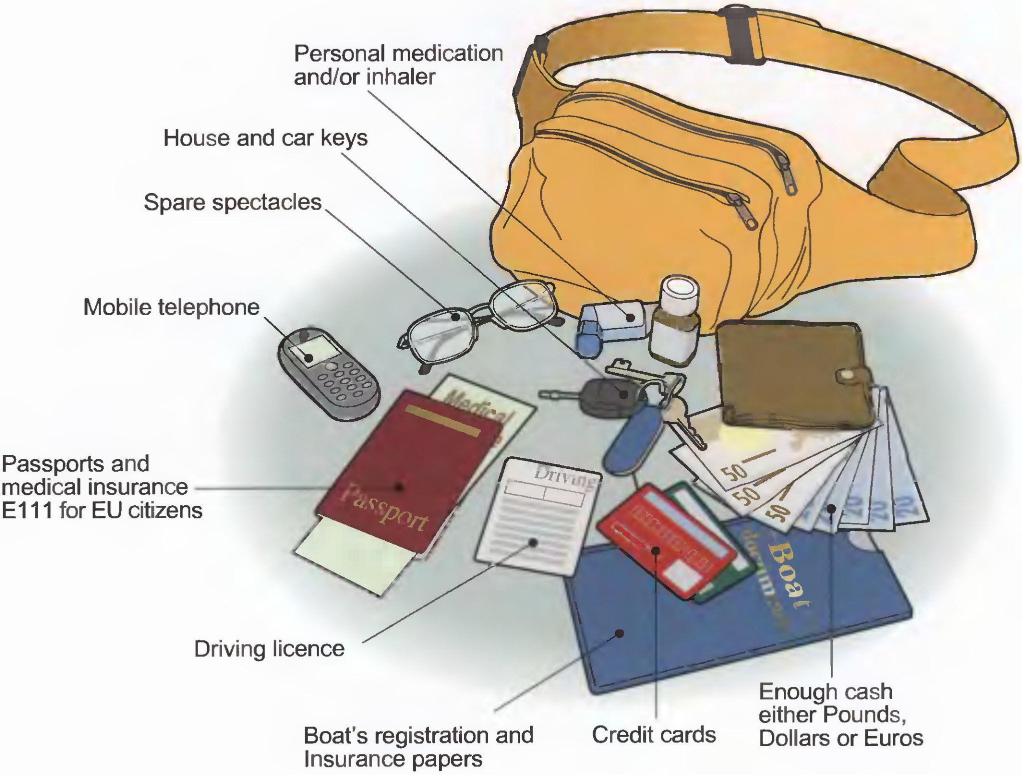
Personal medication and/or inhaler
House and car keys
Spare spectacles
Mobile telephone
Passports and medical insurance E111 for EU citizens
Medical
Passport
Driving
Driving licence
50
50
50
Boat documents
Boat's registration and Insurance papers
Credit cards
Enough cash either Pounds, Dollars or Euros

CHAPTER 9 : Fire Control

Fire prevention

- Keep the engine bay and electrics clean and tidy
- Install the correct size wiring
- Do not smoke below decks
- Take care with cooking fats and solvents
- Vent the engine compartment (petrol engines)
- Turn off the gas at source when not needed
- Check the gas system and use a gas alarm
- Ensure all crew know the gas routine
- Fit an automatic extinguisher in the engine compartment

Fire triangle

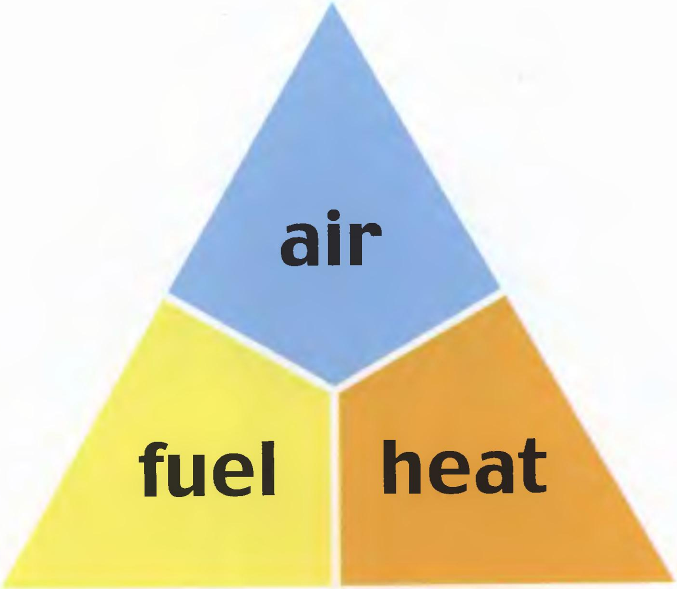

Fires require just three elements to burn. Remove just one of these and the fire will go out.

Fire blanket
Often overlooked but a very useful piece of safety equipment. Use to smother flames on liquid (cooking oil) or people, thereby depriving the fire of air. The blanket also makes a good protective shield when passing close to a fire. DO NOT store directly above a cooker.

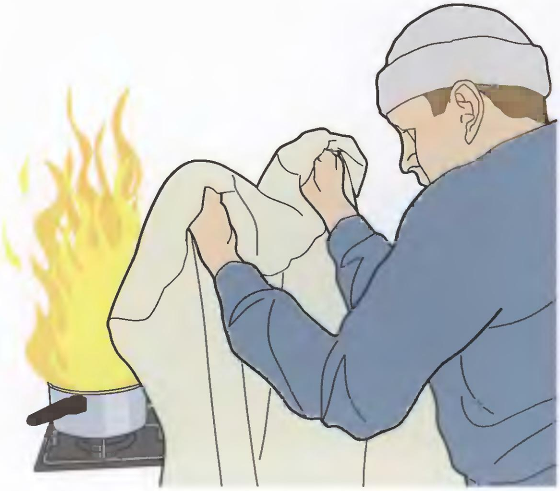

Fire extinguishers

All new extinguishers are red with a colour-coded area to show the type of extinguishant.

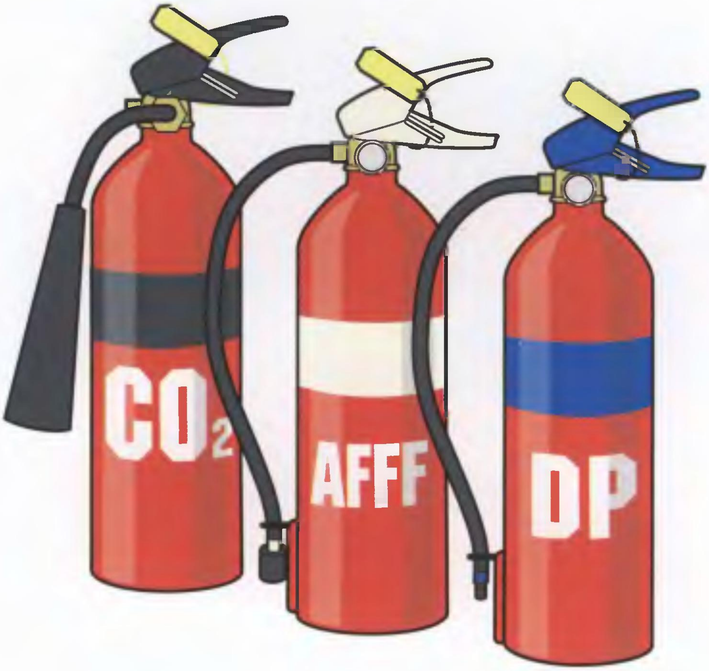

They are rated by the types and size of fire for which they are suitable.

A – carbonaceous (wood, glassfibre, upholstery)
B – flammable liquids
C – flammable gases

Sizes are related to a crib of wood for A-type fires and to a pan of flammable liquid for B-type fires, a typical rating is 5A/34B. The higher the number, the bigger the fire the extinguisher can tackle.

Water (A)

There is plenty of it around (sea) – collect it in a bucket (remembering to first tie a lanyard to the bucket). Water fire extinguishers are available, the water will cool the fire but they are large and heavy. Do not use water on liquid, gas, electrical or cooking-fat fires.

Dry powder (ABC) Blue

Use on solids, flammable liquid (petrol/diesel engine fires) and gas fires **but not cooking oil**. It is messy but very effective at knocking down flames, however it is suffocating when used in enclosed spaces, so care must be taken.

AFFF foam (AB) Cream

Use on solids, flammable liquid (petrol/diesel engine fires) **but not cooking-oil, gas or electrical fires**. Foam can run off solid objects and allow fire to reignite.

CO^2 (B) Black

Used in manual and automatic extinguishers although not often found on boats. Use on flammable liquid fires but not cooking-oil fires since the blast of gas can cause the oil to splash. **Do not use on people** – expanding gas is cold and can cause severe cold burns.

Automatic extinguishers for engine compartments

Use a single extinguisher of the correct size for the compartment.

Halocarbon gas

A number of environmentally friendly gas extinguishants are now available (FM 200, FE 36) for engine compartments. They are clean to use.

Micro-powder fine powder extinguishant

Chemically reacts with the fire.

Dry-powder (ABC)

Similar to a manual extinguisher. Can be used in naturally aspirated engine compartments. Dry powder will damage engines which have turbo - or super-chargers.

In the UK boats over 13.7 metres (45 feet) are required to fit minimum firefighting equipment, as prescribed by the Merchant Shipping Regulations Class XII Vessels.

Position extinguishers at exits from cabins so that they can be used to provide a means of escape. Fire blankets need to be easily accessible but not stored above a cooker. Fit an automatic extinguisher in the engine compartment.

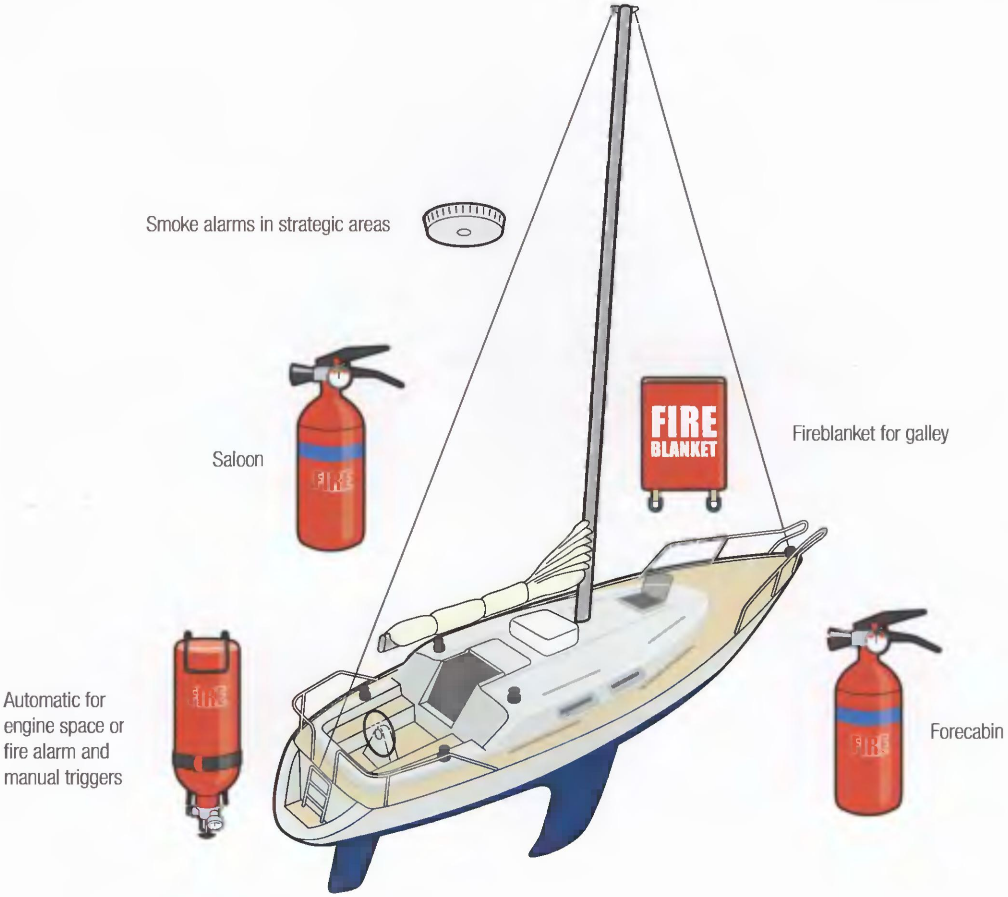
Smoke alarms in strategic areas
Saloon
FIRE
FIRE
BLANKET
Fireblanket for galley
Automatic for
engine space or
fire alarm and
manual triggers
FIRE
FIRE
Forecabin
FIRE

Small extinguishers provide a very limited operating time. A 1kg dry powder extinguisher will give about 5 to 6 seconds of extinguisher.

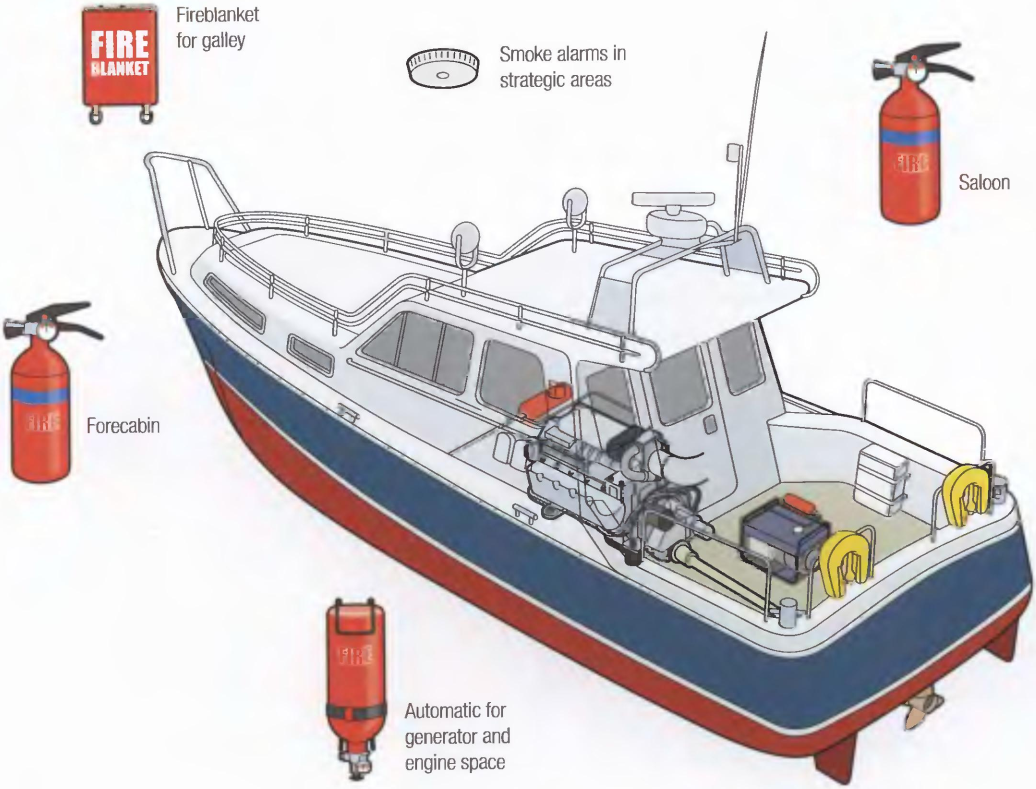
FIRE BLANKET
Fireblanket for galley
Smoke alarms in strategic areas
FIRE
Saloon
FIRE
Forecabin
FIRE
Automatic for generator and engine space

Maintenance

Regularly shake dry-powder extinguishers to prevent the powder clumping. Service all extinguishers at the prescribed periods.

Firefighting

Always keep a clear exit behind you when fighting a fire:

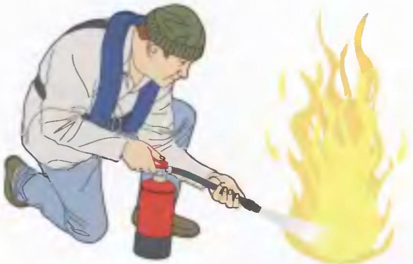

Aim the jet from a manual extinguisher at the base of the fire. Keep the extinguisher upright.

Splash rather than throw water. After putting out the fire, use water to cool the area and prevent re-ignition.

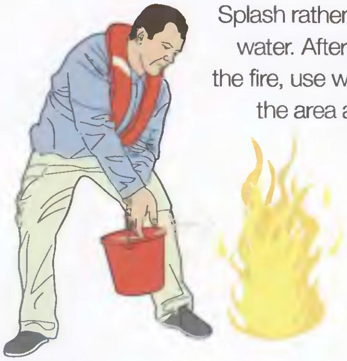

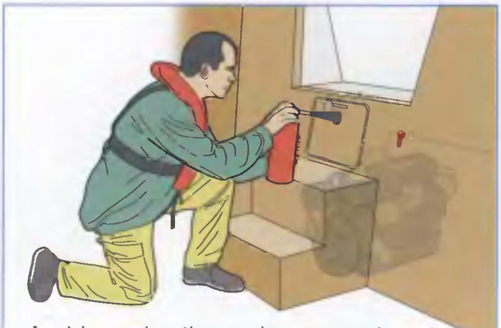

Avoid opening the engine compartment hatch unless absolutely necessary. If you have to, crack open the edge of the hatch and fire a manual extinguisher into the compartment.

Protect your hands behind the edges of the fire blanket. Smother clothing using a fire blanket.

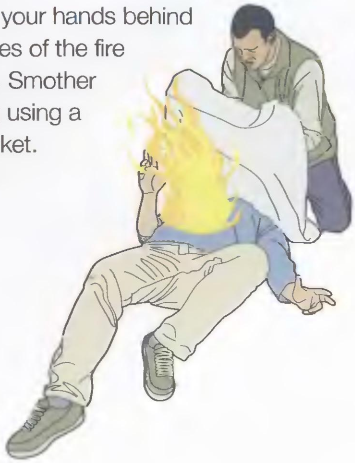

If you cannot extinguish the fire, prepare to abandon ship:

- If you are not already wearing lifejackets, put yours on and instruct the crew to do the same
- Send a Mayday
- Use flares
- Launch the liferaft

CHAPTER 10 : Raising the alarm

Are you in distress?
You are in distress when, in the opinion of the skipper, a vessel (boat, yacht, ship), or a person is in grave and imminent danger and requires immediate assistance.

Flares

Flares need to be readily accessible. In a sailing yacht, this usually means just inside the companionway (fig.1) ; in a motor cruiser, beneath or next to the helmsman's seat with some more in the wheelhouse and some on the flybridge (fig. 2). The number and type of flares to carry will depend on where you plan to sail. Race rules often specify a minimum pack that must be carried.

- Stow flares in a waterproof container lined with sponge foam or bubble wrap.
- Do not fasten the container's lid so tightly that others cannot open it.
- Handheld white anti-collision flares need to be immediately available and can be stowed in clips in the companionway or next to the helm. Keep flares out of reach of young children.

Fig. 2

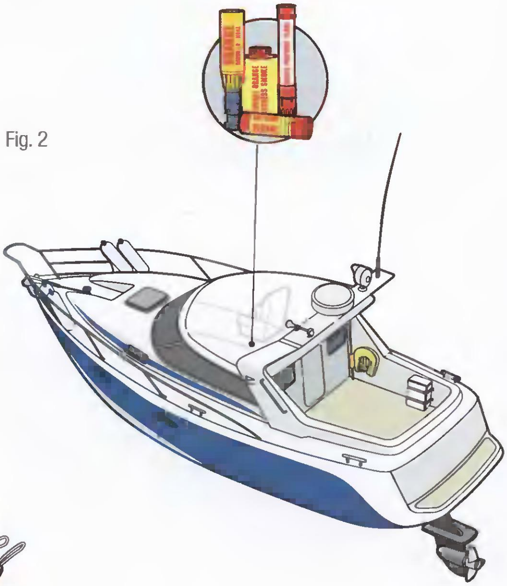

Fig. 1

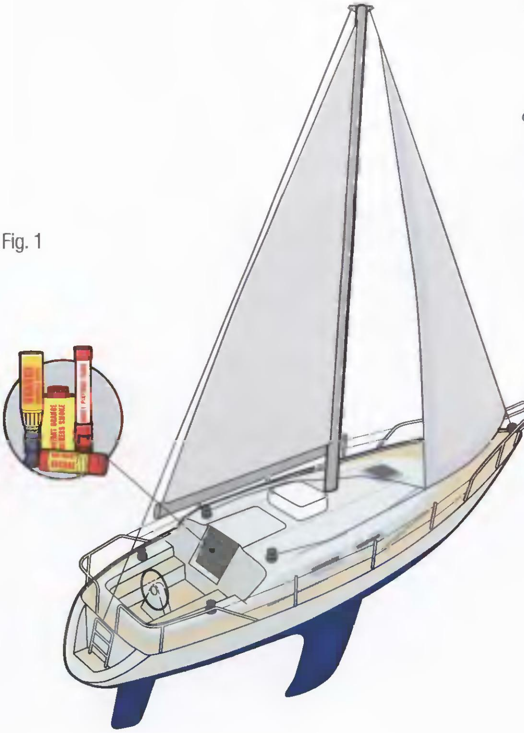

Stow flares where you can get to them quickly and easily.

Firing flares

Different makes of flares operate in different ways. Find out how to use your flares before you need them – Read Before You Need!

Which distress flare?

Red handheld flare

Burns for at least one minute at 15,000 candela. Visible up to 7 miles. Use day or night.

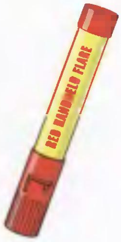

Red parachute rocket flare

Fires to a height of 300 metres or more and burns for at least 40 seconds at 30,000 candela. Visible for up to 28 miles. Use day or night.

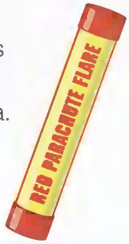

Handheld orange smoke

Produces bright orange smoke for at least one minute. Visible up to 7 miles. Some handheld smoke flares float and can be used to mark a MOB. Use during daylight only. **Not to SOLAS standard.**

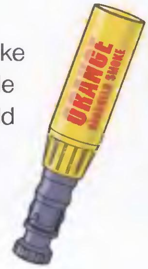

Buoyant orange smoke canister

Produces bright-orange smoke for over three minutes. Visible up to 7 miles. Use during daylight only. Can be used to mark a MOB.

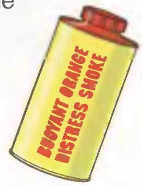

Day/night flare

Personal flare, waterproof. Used by divers and RNLI crew. Has a smoke flare at one end and a red flare at the other. Each end burns for 18 to 20 seconds. Visible up to 7 miles. **Not to SOLAS standard.**

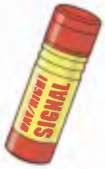

Mini-flare

Personal aerial flare fires up to a height of 60 metres. Comes with up to ten cartridges. Burns for up to 8 seconds. Fire two cartridges in succession. Visible up to 15 miles at night, 10 miles during day. **Not to SOLAS standard.**

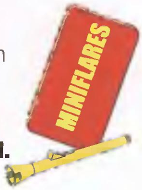

Aerial distress flares raise the alarm. Handheld distress flares can be used to raise the alarm but also to pinpoint your position.

Fire all flares with your back to the wind. Find a firm footing before operating the flare.

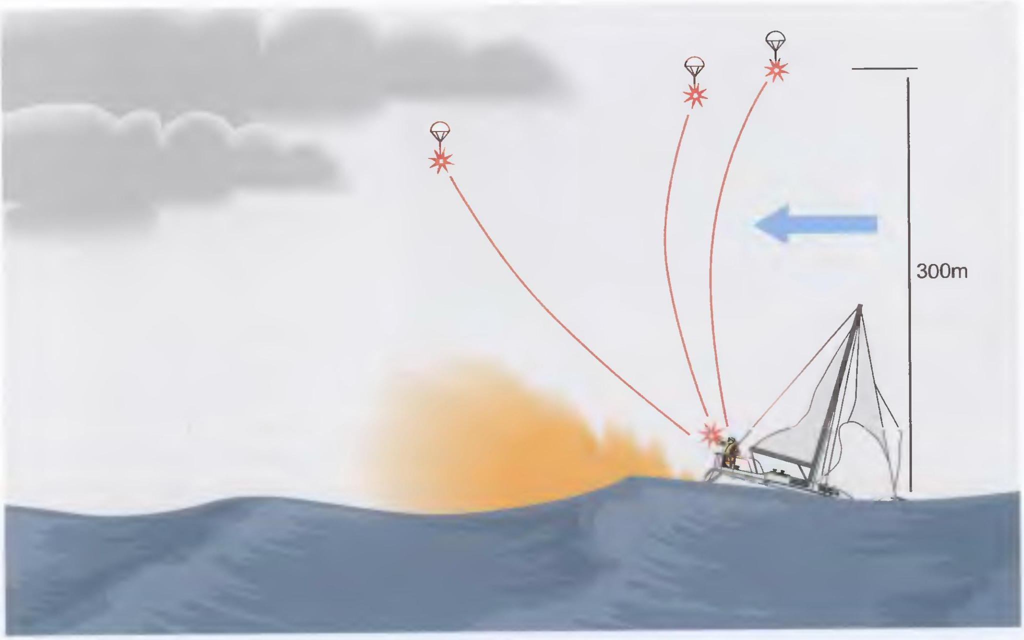

Parachute rocket flares reach a height of over 300m. For low cloud conditions it may be possible to fire the flare at an angle so that it deploys under the clouds. Orange smoke flares help to pinpoint your position.

Firing a parachute rocket flare:

1. Brace yourself in a firm position
2. Back to the wind
3. Remove any caps or covers
4. Check aloft to make sure it's clear of obstructions such as rigging, the flybridge or helicopters
5. Note which way up the flare needs to be fired
6. Remove the safety pin (if fitted)
7. Grip the flare firmly about two-thirds of the way up, the flare will recoil when fired
8. Gently squeeze the trigger upwards until the flare fires
9. Rocket flares tend to seek the wind. If the cloud level is low, fire at an angle downwind so that the flare ignites below cloud

Handheld flares

Hold handheld flares over the leeward side at an angle of 45 degrees to prevent hot ash or burning material from damaging the boat or liferaft. Leather (gardening) gloves can be worn to protect the hands. Flares do not extinguish in water. If you drop a flare it will quickly burn through a liferaft or even a glassfibre or wooden hull.

Buoyant orange smokes are activated and then dropped into the sea on the leeward side of the boat or raft to build up a cloud of smoke.

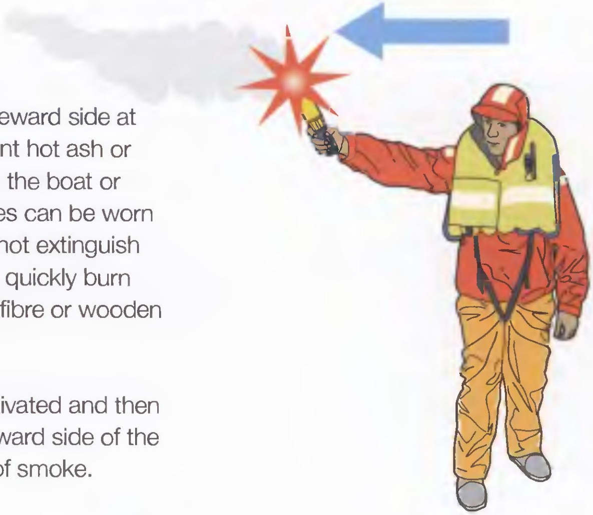

Non-distress flares

Handheld white flares raise awareness and pinpoint your position to other shipping to prevent collision.

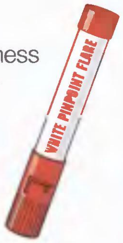

White parachute rocket flare

Used to illuminate the local area at night. Good for searching for MOB.

GMDSS

The Global Maritime Distress and Safety System was fully implemented in February 1999. It provides an International co-ordinated approach to calling for help and requires merchant vessels to carry at least two independent means of radio distress alerting. Leisure craft carry calling equipment voluntarily. It also provides for urgency and safety communications and for the provision of navigational and weather warnings.

The type of equipment suggested depends on where you sail. GMDSS divides the world into four areas:

Area A1 – within range of a shore-based VHF Coast Station fitted with DSC (up to 50 miles depending on antenna height).

Area A2 – within range of a shore-based MF Coast Station fitted with DSC (up to between 100 and 300 miles).

Area A3 – between latitudes 70 degrees N and 70 degrees S.

Area A4 – north of 70 degrees N and south of 70 degrees S (the polar regions).

Equipment covered by GMDSS includes – VHF, MF/HF SSB (radio tranceivers), Inmarsat A/B, C and M (satellite communications systems), Navtex, EPIRBs, PLBs and SARTs.

Raising the alarm

Mayday is the internationally recognised word to indicate distress.

DSC – Digital Selective Calling is a major part of the GMDSS. In a matter of seconds, pressing one button (correctly) will alert the rescue services and other shipping in the vicinity. The alert will tell them who you are, where you are and that you need help. DSC should also reduce routine radio traffic on Ch 16 making it easier to hear voice distress calls.

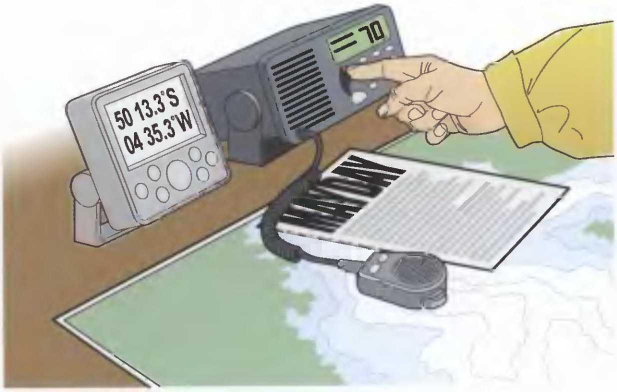

Using a VHF DSC radio

Make sure the radio is switched on and receiving position information from GPS. Different makes of radio transceiver operate in slightly different ways but the general approach shown below will operate most sets. However, make sure everyone on board knows how the radio works.

Lift the cover over the distress button and press and release the distress button once. This will (usually) provide a menu of types of distress.

If there's time, select the type of distress that suits your circumstances.

Press and hold the distress button again for five seconds (the radio will count down) until the call is sent. The radio may sound an alarm. Press CLR to stop the audio alarm. The radio will switch automatically to Ch 16. Make your voice Mayday call.

DSC distress calls will be sent automatically every four minutes, for as long as the radio can do so, until an acknowledgement is received.

Mayday by voice
Non-DSC VHF radios will need to be manually switched to Ch 16. Press the Ch 16 button and check that the radio is switched to high power. If not, push the H/L or 1/25 button.

Now make your voice Mayday call.

A reminder card next to the radio can help to make sure the right information is transmitted. In the panic of the moment it's easy to make mistakes. Try to speak slowly.

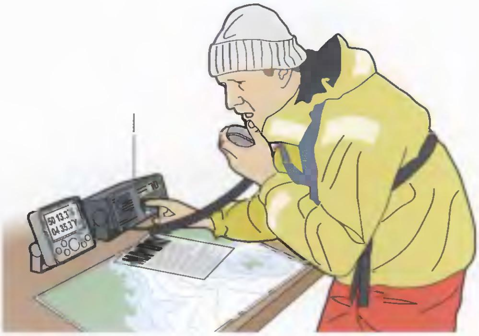

MAYDAY MAYDAY MAYDAY

THIS IS... yacht name spoken three times.

DSC - say your MMSI number.

MAYDAY... yacht name

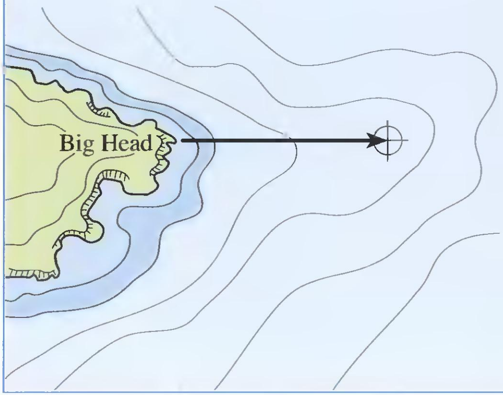

POSITION IS... give position in either Lat and Long or distance and bearing from a charted object

NATURE OF DISTRESS - describe briefly what the problem is, for example, sinking, MOB, boat on fire, stranded, broken down close to rocky lee shore etc

I REQUIRE IMMEDIATE ASSISTANCE

NUMBER OF PEOPLE ON BOARD
– don't forget to include yourself

FURTHER INFORMATION - anything else that may help rescuers, such as abandoning to liferaft, triggered EPIRB or PLB etc

OVER - the invitation to reply

You should receive a digital acknowledgement from the rescue services or ship, followed by a voice reply. If no acknowledgement or voice reply is received, check the batteries are on, the set is switched on and that Ch 16 and high power are selected. Repeat the procedure.

If still no reply, try a voice call on another Channel – Ch 6 or, if you are in shipping lanes, Ch 13. Prefixing the boat's name with the words 'Yacht' or 'Motor Cruiser' helps rescuers know what they are looking for.

VHF versus mobile phone

A mobile phone can be used to call for help but is a poor substitute for a marine VHF radio, the reasons being:

- VHF radios have a greater range.
- They raise the alarm with all in range who are listening.
- SAR services can determine and home in on VHF transmission, they have a longer battery life and can send distress calls in seconds (DSC).
- Mobile phones are designed for land use.
- They have poor coverage at sea and reduced range.
- They only alert the person you call. But in a real emergency a mobile phone is better than nothing.
- The emergency services operator will be the first one available and maybe located anywhere in the country.

Use the National Emergency Services number, in the UK, dial 999 (or 112 throughout Europe, 911 in the USA) and ask for the Coastguard.

Satellite mobile phones

Satellite phones are becoming a popular alternative to SSB radio.

In January 2006, experienced yachtsman Richard Wood and his partner Jetti were on passage from Nicaragua to Mexico aboard his catamaran *Eclipse* when they were caught in stormforce conditions. Wave heights were estimated at approaching 30ft (9m) with winds of over 70 knots. The sea anchor had been torn to shreds and they tried running downwind trailing warps and anchors but there was increasing danger of capsize. By late afternoon they decided they needed to call for help before things got worse and so set off their EPIRB and telephoned HM Coastguard in Falmouth (Cornwall, England) on their satellite telephone. The HM Coastguard contacted the Mexican authorities. Mr Woods continued to telephone the HM Coastguard every hour to check on progress and give a position and weather update. At 11pm, a helicopter from the USS *Ford* contacted *Eclipse* and the pair were lifted to safety.

Other Distress signals

Raising and lowering outstretched arms

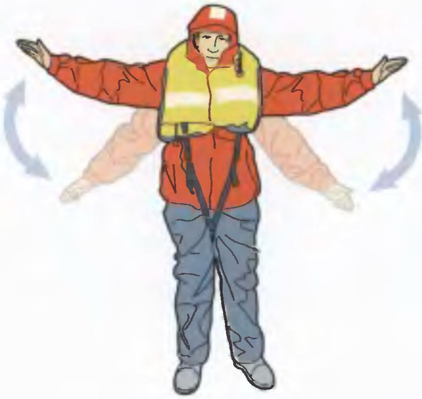

Continuous sounding of horn

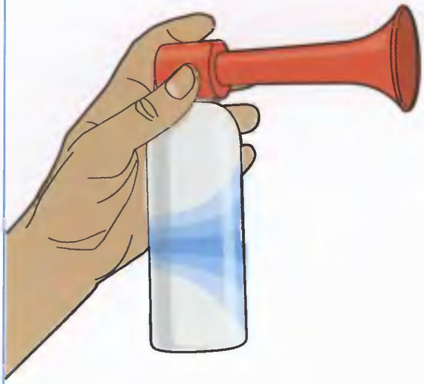

Morse SOS by light

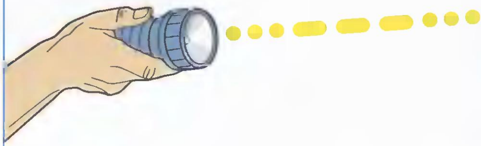

Black ball over a black square

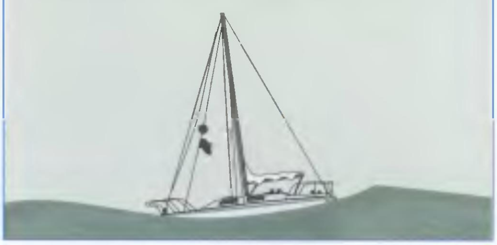

Smoke

Code flags N over C

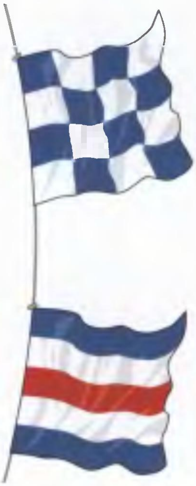

Upside down ensign

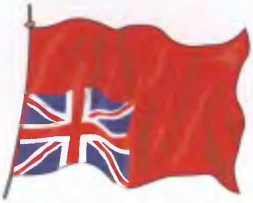

Divers

A diver on the surface will indicate distress by waving. They may also have raised their goggles onto the top of their head. Don't simply wave back and sail by – they are asking for help.

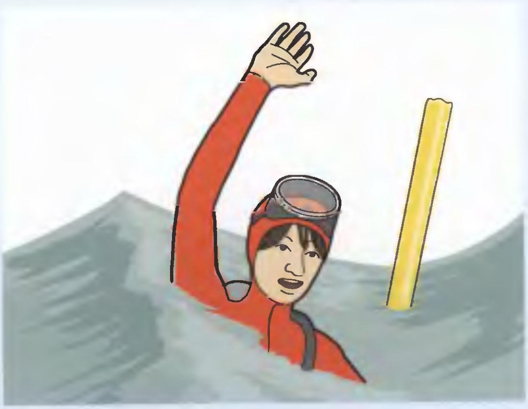

Using a heliograph (mirror or CD)

A heliograph is a simple way of drawing attention. Some come with a short stick and string but you can also use your hand. Using two fingers as a sight, reflect the light onto the two fingers. The target will then see the reflection off the mirror. Practise with a CD but be aware that its shiny surface will dissolve in water.

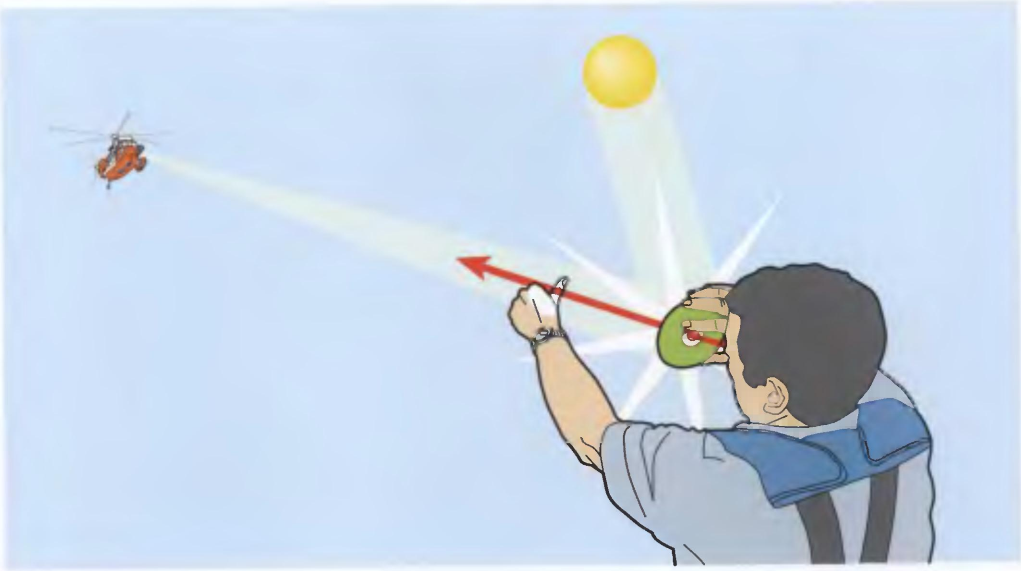

Need help but you are not in distress

You can also ask for assistance by making a Pan Pan call on the radio preceded by an Urgency Alert on DSC (if fitted).

By Voice

PAN PAN (Three times)
ALL SHIPS (Three times)
THIS IS… name of boat x 3 (+ MMSI if fitted with DSC)
POSITION IS… give position in either Latitude and Longditude or distance and bearing from a charted object
NATURE OF PROBLEM I am broken down and require a tow
NO OF PERSONS ON BOARD don't forget to include yourself
OVER

Let the SAR authorities know as soon as something goes wrong. Don't wait until the last minute.

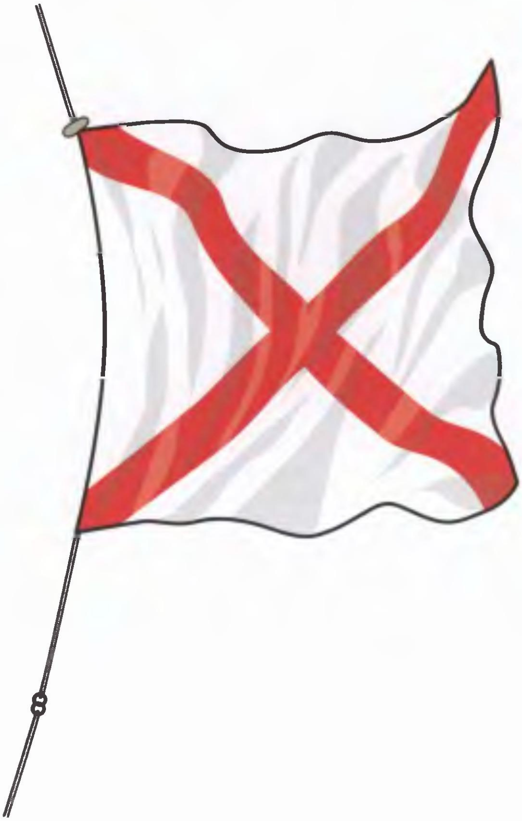

Code flag V indicates 'I require assistance'.

EPIRBs

An Emergency Position Indicating Radio Beacon will alert the Rescue Services by sending a distress signal via satellites. Two sets of satellites pick up the signals: Inmarsat and Cospas-Sarsat. Inmarsat satellites are in geostationary orbit. Cospas-Sarsat satellites are in a lower polar orbit and circle the earth approximately every 12 hours.

There are two types of EPIRB: standard and GPS. Both transmit a signal on 406MHz, which includes an identification code.

GPS-enabled EPIRBs also transmit position information that Inmarsat satellites will immediately download to an Earth station. The position information may come from a built-in receiver or from a link to the vessel's own GPS receiver.

Standard EPIRBs' positions are found using Doppler Frequency Shift theory by Cospas-Sarsat satellites. They require two satellite passes before an approximate position can be found. Each satellite will hold and then download data as soon as a ground station comes into range.

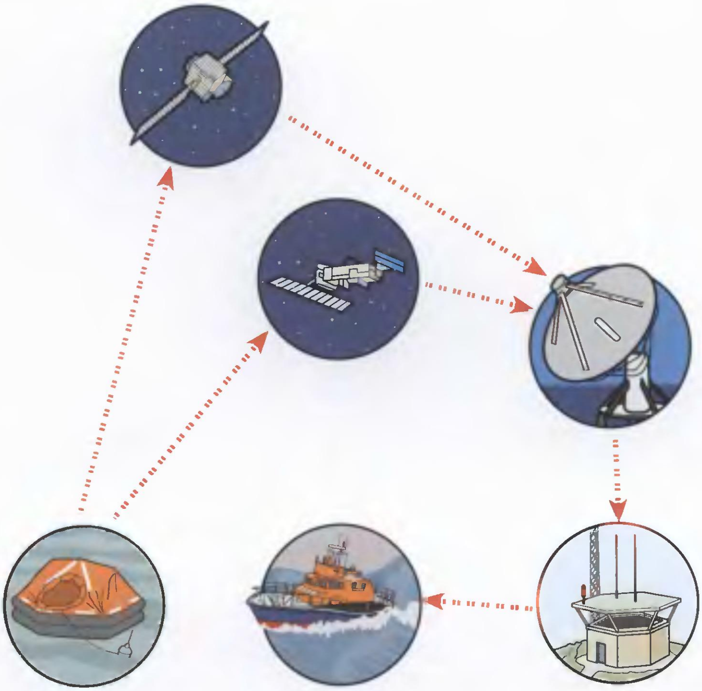

When the EPIRB is activated, it transmits a signal via satellite to an Earth station. The Earth station sends it to the appropriate rescue co-ordination centre, who will task a ship or local rescue services to your position.

GPS EPIRB – provides a distress alert immediately and a position within five minutes accurate to 100 metres.

Standard EPIRB – provides a distress alert immediately, if the Earth station is within the satellite range, and a position to within 3 nautical miles (5km) within 40 to 120 minutes depending on your location. EPIRBs can be activated manually or automatically on contact with the sea. Float-free versions are also available. Built to SOLAS standards, they have a battery life of 48 hours and will float upright.

Also built into the EPIRB is a 121.5MHz homing beacon and SAR craft use radio direction finders to home into the signal.

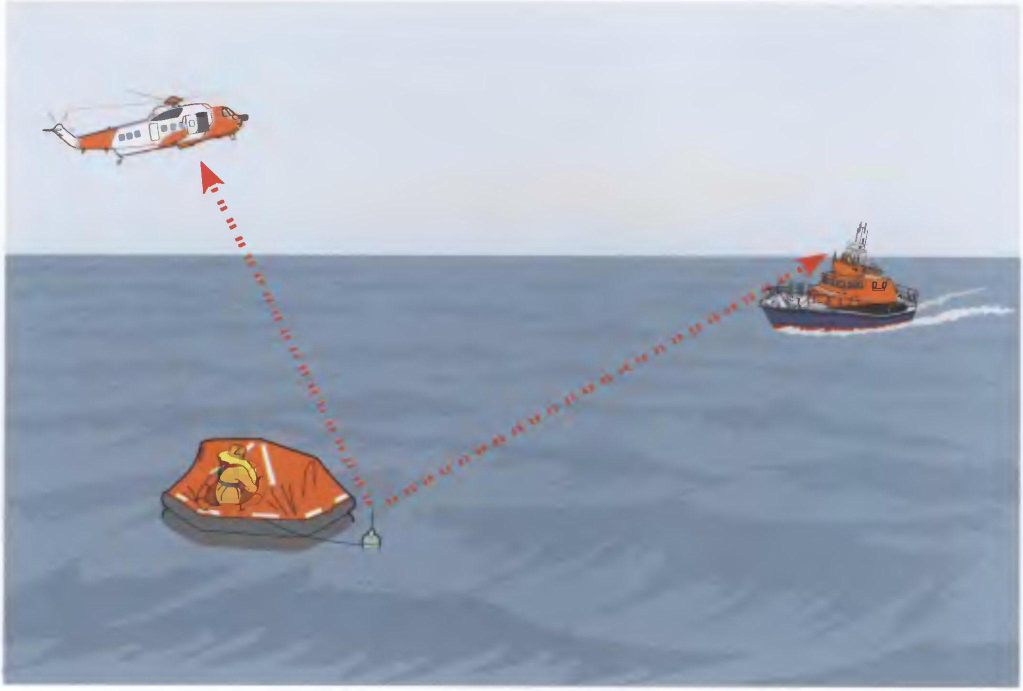

All 406MHz EPIRBs are required to be registered in the country of their vessel's flag. These details are used to check the authenticity of a distress alert. Batteries need to be replaced at the manufacturer's required date. Check the instructions and make a note of the date they need to be replaced - always replace the batteries.

PLBs
Personal Locator Beacons, sometimes referred to as PEPIRBs, are similar to EPIRBs but they are smaller and are designed to be worn by an individual crew member. Most countries require 406MHz PLBs to be registered.

As with EPIRBs, there are two 406MHz PLB types. Both operate with the Inmarsat and Cospas-Sarsat satellites in the same way as EPIRBs:

- GPS PLB – provides a distress alert immediately and a position within five minutes accurate to 100 metres.
- Standard PLB – provides distress alert immediately and a position to within 3 nautical miles (5km) within 40 to 120 minutes depending on your location.

Also built into the PLB is a 121.5MHz homing beacon. SAR craft use radio direction finders to home into the signal.

Unlike EPIRBs, PLBs do not float upright. They have a battery life of 24 hours and can only be activated manually.

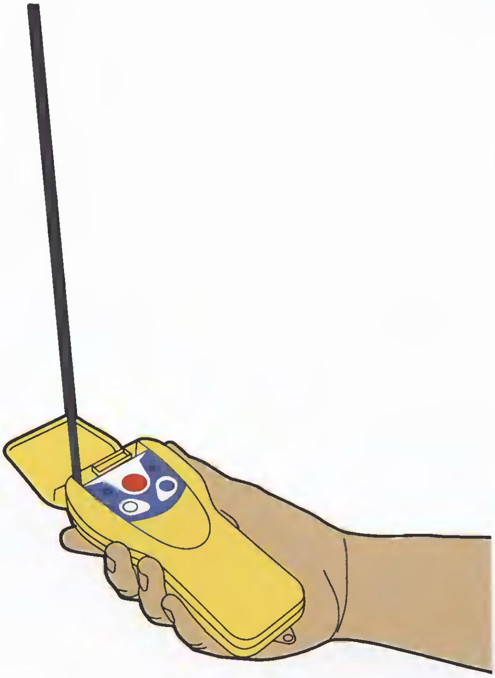

121.5 PLBs

Designed to be worn by individual crew members, 121.5 PLBs can trigger an onboard alarm to warn crew that somebody has gone over the side. A radio direction finder can also be used to home in on the MOB. Always tell the SAR services if a MOB may be using a 121.5 PLB.

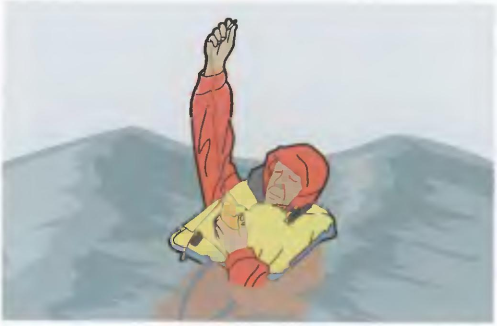

The MOB should hold the antenna as high as possible to give the greatest range.

MOB alerting devices

Proprietary MOB alerting devices that work on non-SAR rescue frequencies are also available. Some are capable of being linked to the GPS MOB button or an autopilot or may come with an appropriate radio direction finder.

RNLI MOB Guardian

This is a new worldwide system, developed by the UK-based Royal National Lifeboat Institution, which continually monitors boat and crew. An onboard transceiver sends regular position and condition data updates via the Iridium satellite system to the RNLI Operations Centre. If data is not received, the RNLI alerts the local rescue co-ordination centre to the vessel's last known position.

The transceiver also includes personal proximity alarms to be worn by each crew member. If crew goes out of range of the transceiver, it activates an alarm and alerts the RNLI Operations Centre.

SARTs

A Search-and-Rescue Radar Transponder is an alert and position-finding electronic device that produces a distinctive 'echo' on the screen of any 9GHz Radar. Previously only used on commercial vessels' liferafts, SARTs are now available sufficiently small enough to be fitted as an optional extra in most leisure liferafts.

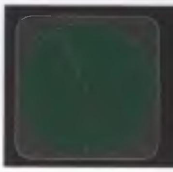

Fig. 1

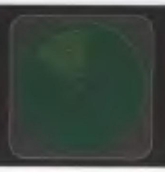

Fig. 2

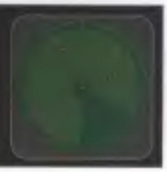

Fig. 3

On initial contact with a SART, the radar shows a line of dots giving the range and direction of the casualty (fig. 1). As the radar closes on the SART, the dots broaden to arcs (fig. 2). When the arcs make an almost complete circle the SART is within 1 mile (fig. 3).

Range will depend on the height of the SART and the height of the Radar scanner. A SAR helicopter at 1000m (3000ft) can pick up a SART 48 miles away. A radar scanner 7m above the waterline will 'see' a SART at about 6 miles.

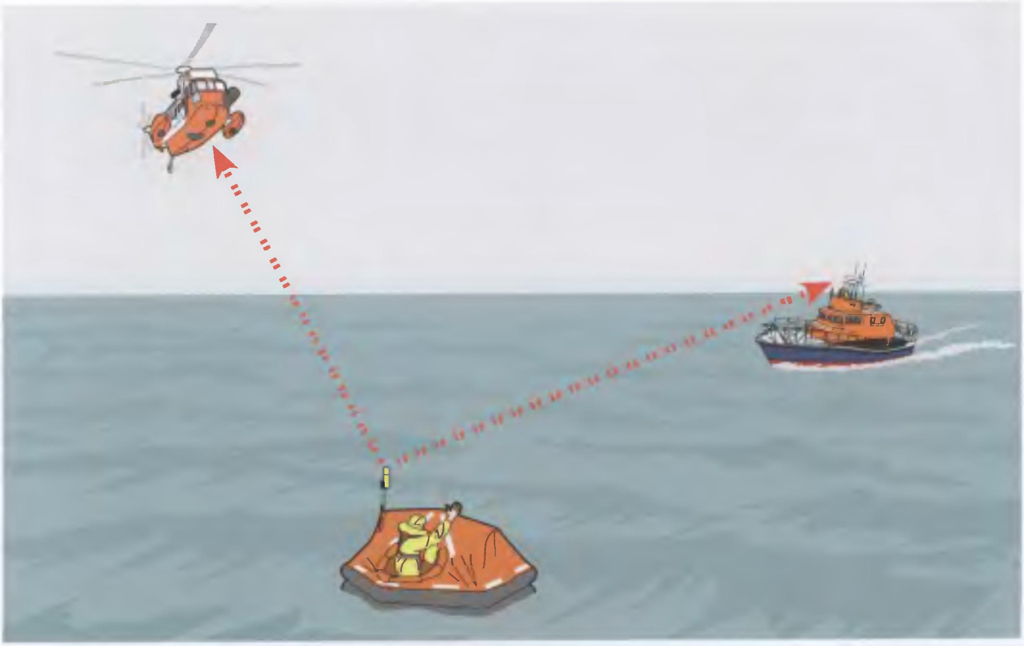

The SART starts transmitting when it receives a radar signal. Switch off your vessel's radar before abandoning ship, to prevent your SART from transmitting before rescuers are in range.

Position the SART as high as possible to achieve the greatest range.

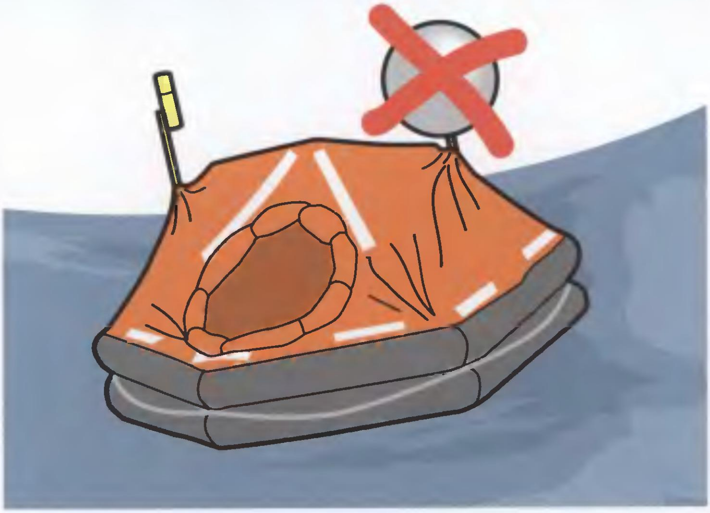

SARTs and inflatable radar reflectors conflict – use only one at a time.

CHAPTER 11 : When to abandon ship

There are two main reasons to abandon ship:

1. If your boat sinks.
2. If your boat catches fire and the fire cannot be controlled.

If there is no grave danger of the boat immediately sinking, then stay with your boat because:

- It carries far more supplies than your liferaft
- It will probably offer better shelter from the elements
- You may be able to find a way to jury-rig a repair and improve your conditions
- It makes a much larger target for rescuers to see

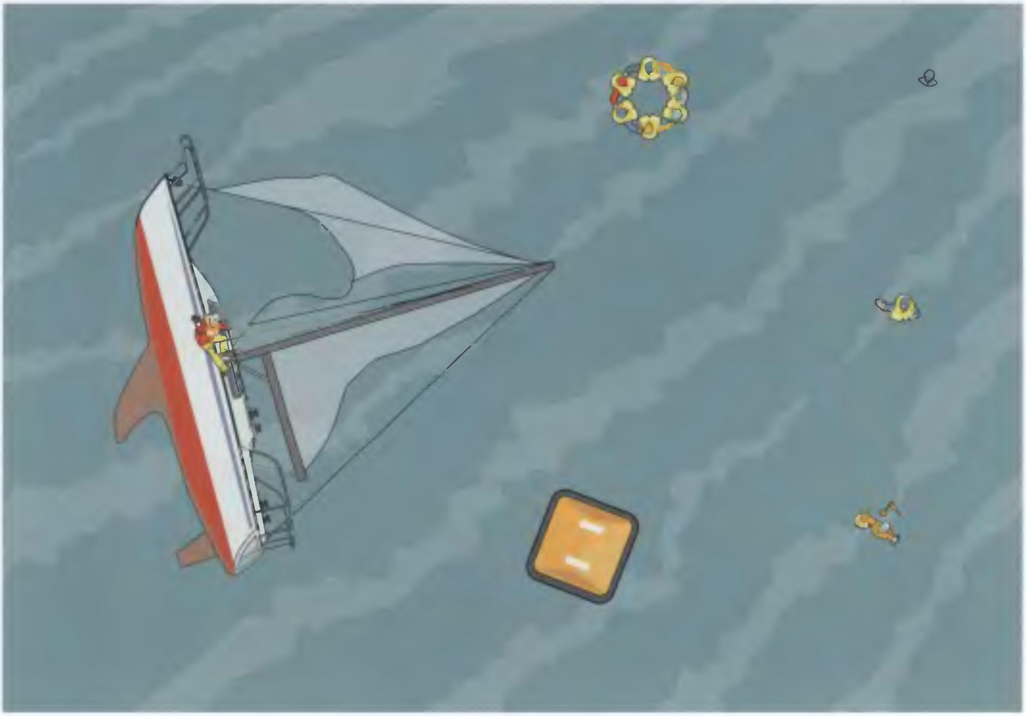

Your boat is full of supplies – only leave it if it sinks or catches fire. It makes a much bigger target for rescuers to find compared to a liferaft, a huddle of survivors, a single person with a lifejacket and/or a dan buoy or a person without a lifejacket.

What you need to survive

To ensure your survival you need the correct equipment with the right knowledge and, most importantly, a belief and will to survive. The four tenets of survival are protection, location, water and food. To this end, the survivor requires:

Equipment

- Personal survival aids
- Life-saving appliances
- Grab bag

Knowledge

- What equipment you have
- How to use it properly
- Have a strategy ready

Will to Survive

- Believe you will be rescued
- Avoid blame
- Positive attitude

I will survive!

The greatest factor in any survival situation is the positive mental attitude of the would-be survivor, some call it the will to survive. There are numerous examples where a sheer determination not to be beaten, to keep going despite the odds has made the difference between life and death. The belief that, no matter how bad the situation, you will pull through has to be emphasised to every casualty; a liferaft or semi-submerged boat is no place for negative thinking.

Obviously, a will to survive is not enough on its own. Training, preparation and a good understanding of the factors that will affect your survival will bolster that belief. Positive leadership will also improve a crew's chances of survival.

Be aware that tiredness, cold, seasickness and injury add to demoralising a crew and that the loss or death of a crew member can have devastating effects on the survivors' will to live.

Tony Bullimore's 60-foot yacht capsized in 60-knot winds in the Southern Ocean when it lost its keel during the Vendée Globe single-handed round-the-world race in January 1997, 1700 miles from Perth, Western Australia.

Without a keel, the boat remained inverted (upside down) with Bullimore caught inside the hull, waist-deep in water. Realising that he would have sufficient air to breathe and that the boat was unlikely to sink, he assessed his situation and put together a survival strategy.

He activated his EPIRB knowing that help would take several days to reach him. Although he was wearing a drysuit, he realised that he had to get out of the freezing water. In total darkness, he managed to jury-rig a hammock from cargo nets. He was aware that spotter planes may not realise that he was still alive inside the hull so he made several attempts to swim out of the cabin to release his liferaft so that it would float free next to the yacht. Each attempt sapped his strength and resulted in two hours of intense shivering back in his hammock. But his will to survive forced him to keep trying. For four days he lived on limited supplies of water and chocolate. The Royal Australian Navy rescued him, hypothermic and dehydrated but alive.

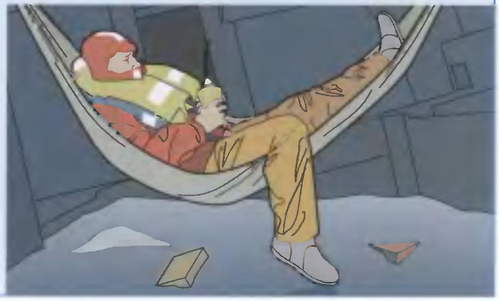

When disaster strikes

Crew will probably react in one of three ways when a yacht founders:

- 10 to 20% will remain calm and be aware of the situation and will respond appropriately
- 75% will be stunned and bewildered, they will be unable to judge what to do for the best and be unable to concentrate on a task
- 10 to 15% will react inappropriately and may not realise the seriousness of their predicament, they may scream, weep or be unable to move

Applied to a crew of six, these figures suggest that there will be;

- one person who is able to react effectively
- four who will need goading to undertake tasks
- one who may completely lose touch with reality and could endanger themself or their colleagues.

A good leader, who may or may not be the skipper, will stay positive, prevent recriminations, take stock of the situation and organise and allocate tasks to the survivors. Good planning and preparation, training and knowledge of what to expect will increase the number of crew who react appropriately.

CHAPTER 12 : Abandoning ship

Don't leave your boat until your boat leaves you! It is packed full of supplies and useful equipment that will aid your survival.

A few tasks, carried out before you abandon, may save your boat: emptying water tanks, therefore turning them into buoyancy tanks, closing the engine-cooling-water seacock, and disconnecting the raw-water feed and using the engine-cooling system to pump out the bilge.

Drills for abandoning ship

Prior to abandonment

1. Make everybody aware that you are preparing to abandon ship. **Stay calm.**
2. Activate the EPIRB. Press DSC distress button on VHF / HF radio. Make a voice distress call.
3. Fire parachute rockets if someone is likely to be within 30 miles.
4. Get everyone on board to put on layers of warm clothing. Extra clothing will not weigh you down in the water. Initially, it will help you float.
5. Waterproof clothing will reduce cold-water shock and heat-sapping water flow around your body. Use an immersion suit. **Keeping warm is a priority.**
6. Check everyone has donned lifejackets correctly – use a buddy system to speed things up. Inflate lifejackets before entering the water.
7. Have a drink (non-alcoholic) and take anti-seasickness tablets.
8. Find the grab bag and as many useful extras as you can lay your hands on.
9. Standby to launch the liferaft in case the vessel has to be abandoned quickly.

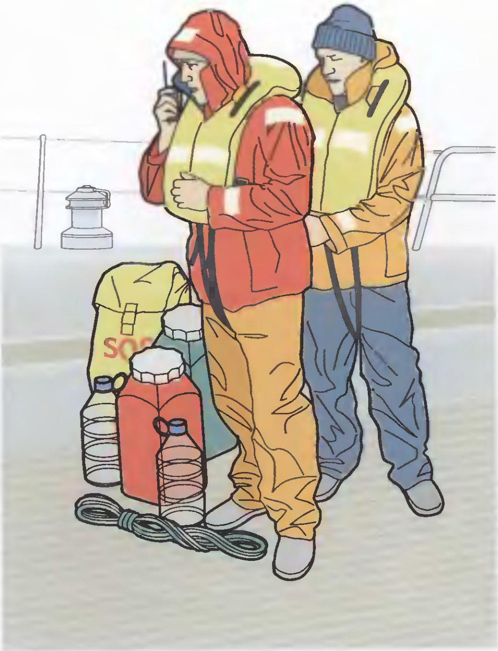

Priorities are donning lifejackets, sending Mayday, initiating the EPIRB and launching the liferaft. Anything else is a bonus.

Do not launch the liferaft earlier than you need it because it is difficult to hold a raft alongside in a rough sea.

Launching and entering liferaft

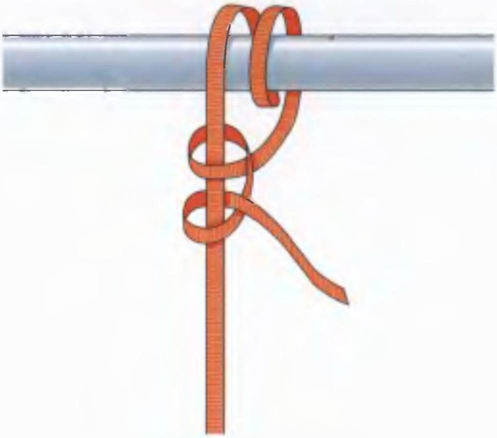

Prior to launching the liferaft

1. Secure the painter to a strongpoint – ask another crew member to check the knot. A round turn and two half-hitches is sufficient but any knot that holds will do.

2. Check that the water is clear of debris or the raft may be damaged as soon as it inflates.

3. Launch the liferaft to the leeward (downwind) side of boat.

Liferafts are heavy and difficult to manhandle – a six-man raft can weigh between 25kg (55lbs) and 75kg (165lbs) depending on its quality, type and contents. Launch them from as near to the stowage site as possible. It may need two people to lift the liferaft canister.

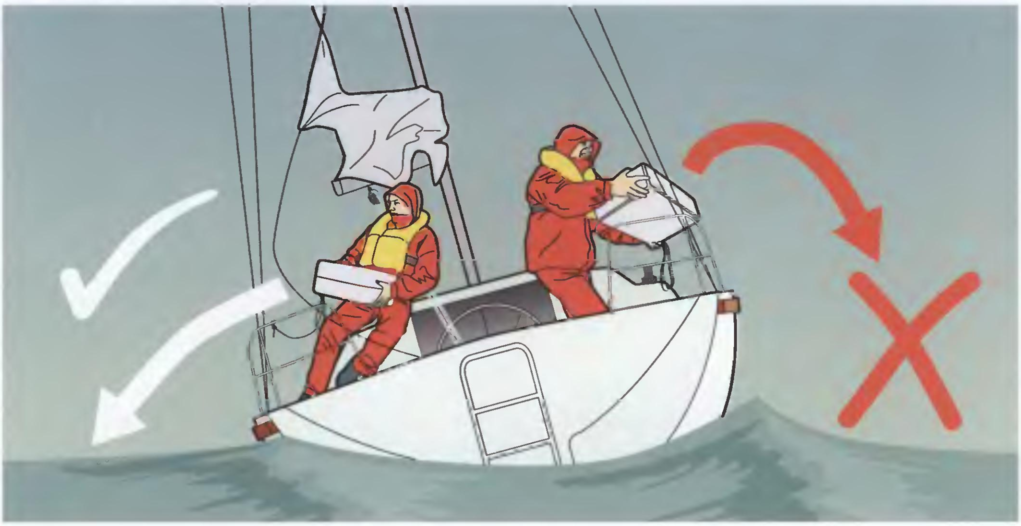

Launch the raft to leeward

Launching the raft to leeward will provide some protection from the prevailing conditions when boarding it.

The freeboard is likely to be lower on the leeward side, making the raft easier to board and reducing the chances of the raft damaging itself on the side of the boat.

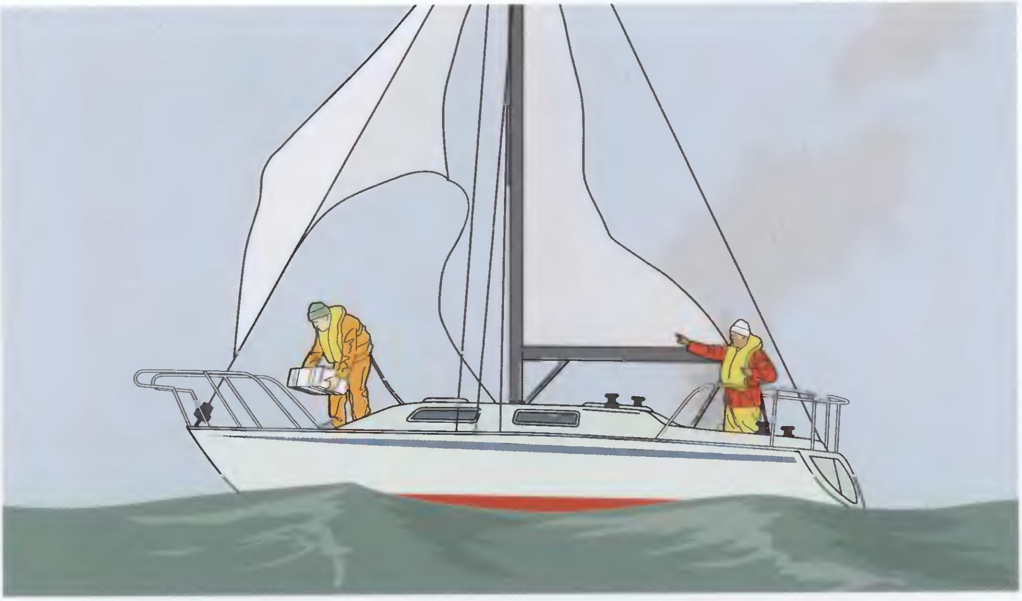

However, you may have to move the raft to a safer position – for example, because of a fire. Take care not to slip and injure yourself or lose yourself or the raft overboard. Be aware of other dangers such as flogging sails.

Launching the liferaft

4. Pull the painter. It's likely to be up to 10 metres (33ft) long.
5. When the painter is fully extended, a sharp tug will trigger the gas inflation mechanism.
6. The raft will inflate in 30 to 60 seconds.

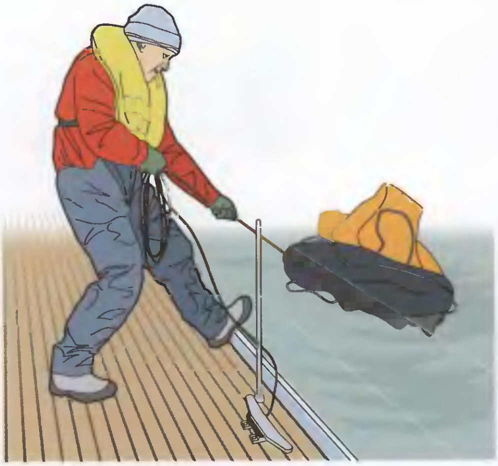

You may hear gas escaping during and shortly after inflation. This is excess CO_2 being expelled through the pressure-relief valves and is normal.

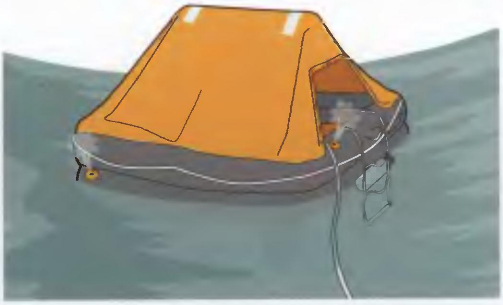

Launching the liferaft to windward may make it more difficult to board. Sharp barnacles on the bottom of the boat may puncture the liferaft tubes.

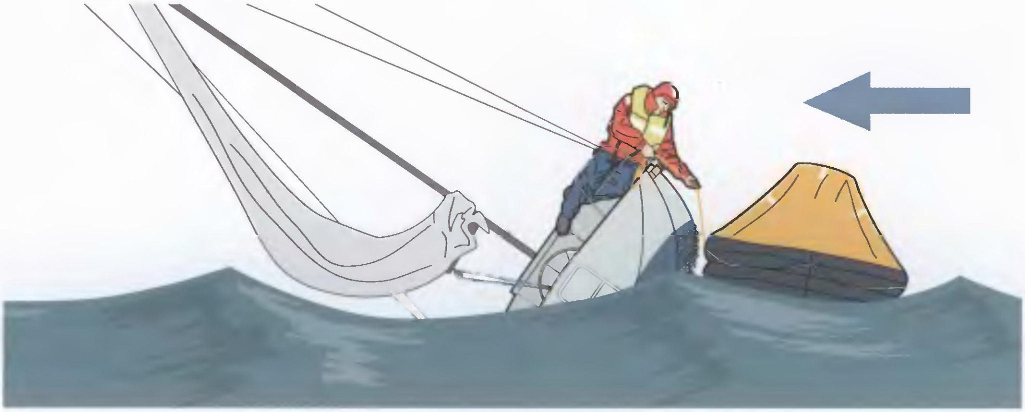

Don't let the liferaft drift away. In strong winds it may be too difficult to pull it or even winch it back to the boat, leaving you with no raft.

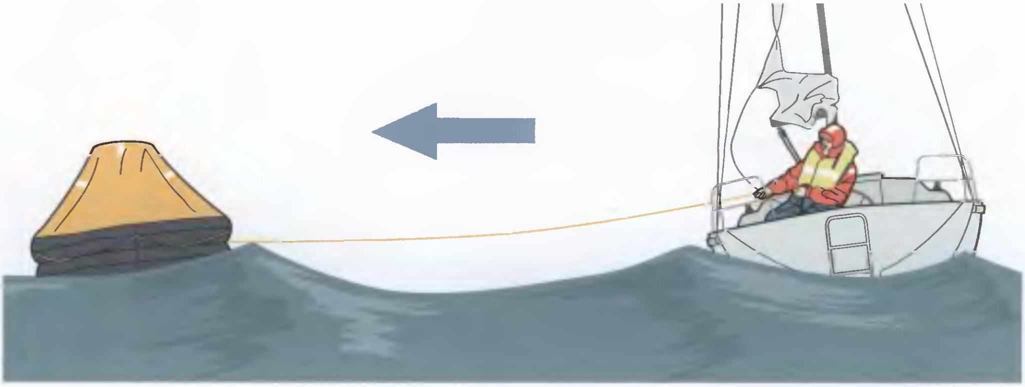

If the raft inflates upside down or capsizes before you can board it, try to right it while still onboard the vessel.

STAY OUT OF THE WATER – COLD KILLS

Boarding the liferaft

Remove sharp objects before entering the raft from your person such as keys attached to a belt clip.

Try to climb directly into the liferaft from the boat. The strongest and heaviest person should board the raft first to stabilise it and to help others in. As each person gets in they should move out of the way of the entrance and balance the raft as the others board.

Avoid jumping if at all possible. You risk injuring yourself or others already in the raft. Do not jump onto the canopy. If you have to jump, the maximum recommended height is 2 metres.

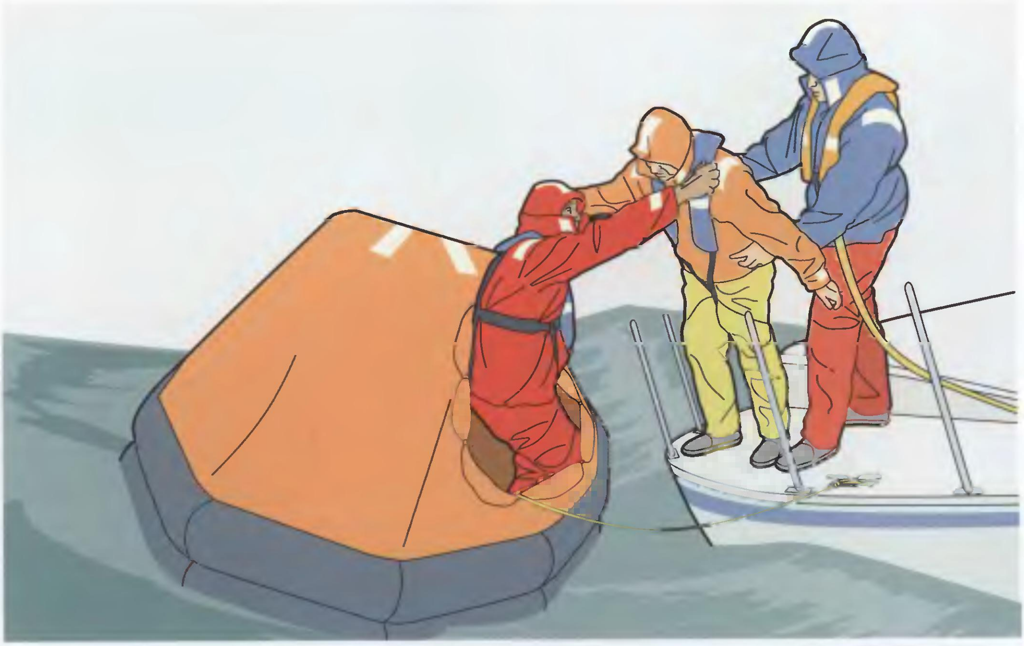

Spread the impact load by holding your feet slightly apart and your arms out.

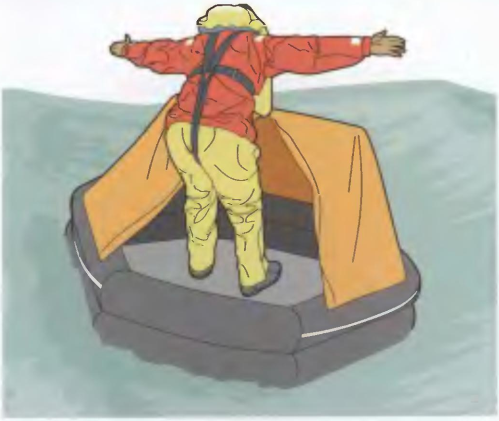

REMEMBER TO LOAD THE GRAB BAG AND EXTRAS

Leave any injured to the last but one. If they enter early, other people may make their injuries worse if they land on them. Get the injured aboard the raft before the last able person leaves the boat.

Entering the water

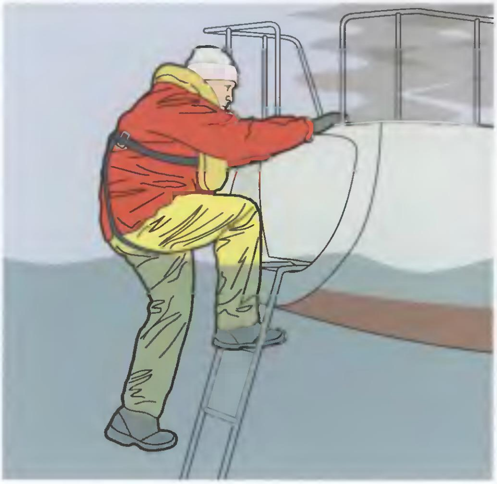

Only enter the water if you are unable to board the raft direct from the boat.

If possible, enter the water slowly, either by lowering yourself on a rope or by using the boat's fixed or emergency boarding ladder, this will minimise the effects of cold-water shock.

If a slow entry is not possible:

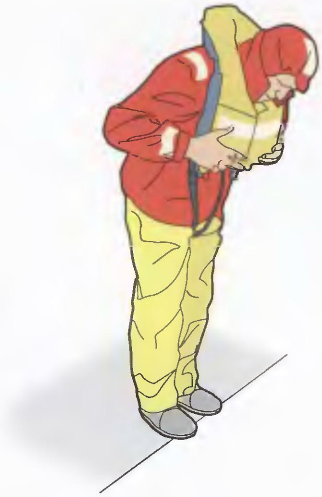

1. Go to the side of the boat where the freeboard is least or upwind of fire and smoke.
2. Steady yourself and check below for debris and other people.

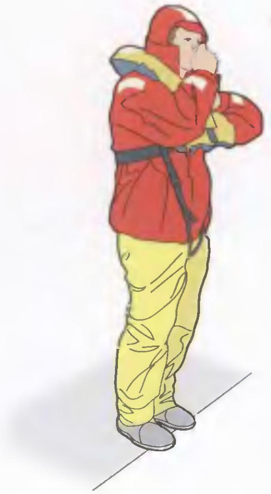

3. Inflate your lifejacket.
4. Place one arm over the top of the lifejacket to prevent it from jumping up when you enter the water.

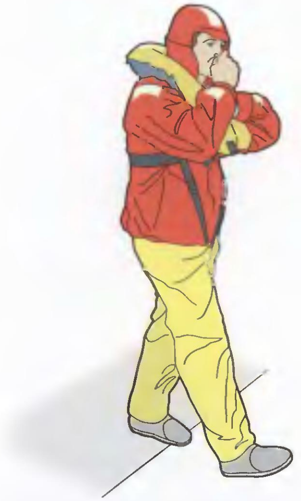

5. Use your other hand to cover your airway.

6. Look ahead to stop you from toppling forward – check the area is clear and step off the side of boat.

7. Put your feet together and enter the water in an upright position.

8. Hold this position until you have surfaced and regained control of your breathing.

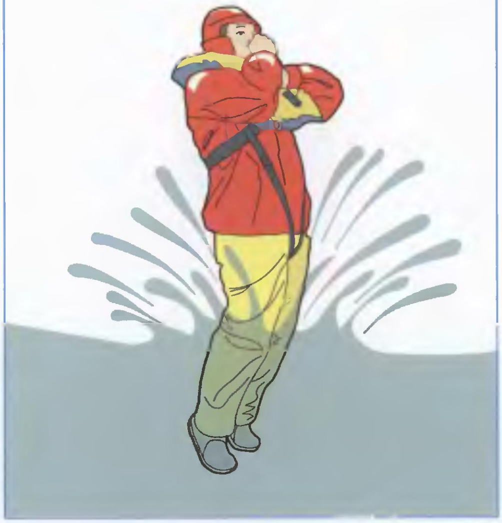

At night or in heavy weather, it may be prudent to clip your safety harness to the liferaft painter and pull yourself along it until you reach the raft.

While waiting to get into the raft, hook your arm through the lifelines fixed around the outside of the raft. Cold numb hands will be unable to grip the lifeline. Do not let go until you are on board the raft.

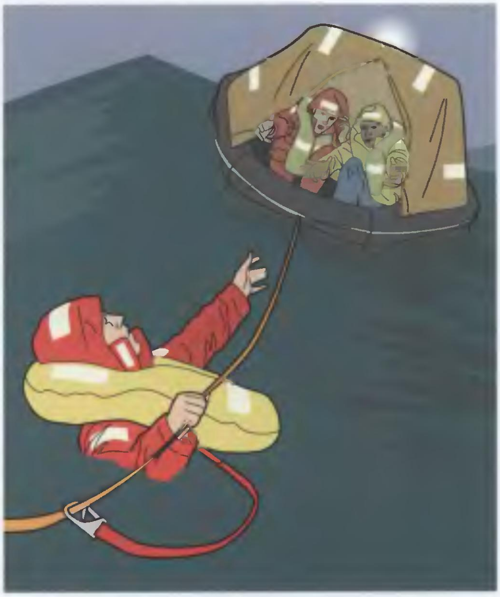

Getting into the liferaft from the water

The cumbersome shape of an inflated lifejacket, the weight of wet clothing and the strength-sapping effects of cold water make it very difficult to climb unaided into a liferaft from the water. The strongest and fittest person should enter the raft first. They can then help others to board.

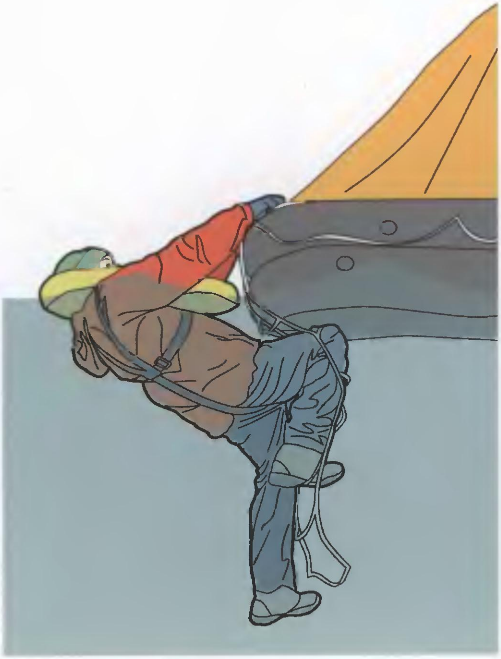

All liferafts have ramps or ladders to aid entry. Get a foothold on the ladder and a firm grip on the handhold on top or just inside the top tube.

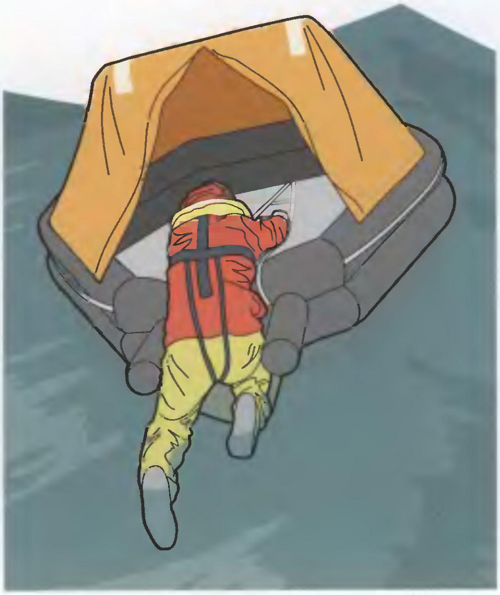

Partially deflating your lifejacket may make it easier to reach handholds inside the raft, especially if wearing a 275N lifejacket.

Rescuing survivors

Get casualties into the raft quickly. The two strongest survivors should be on either side of the entrance and grab hold of the casualty's lifejacket straps and pull them face-first up and into the raft.

GET EVERYONE OUT OF THE WATER FAST.

Make sure that semi-conscious casualties are not lying face-down in the water in the bottom of the raft. Look out for flailing legs.

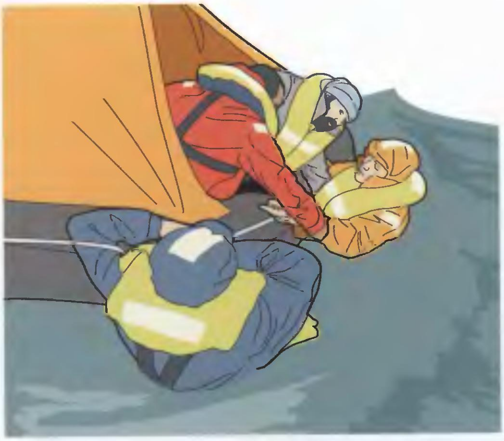

Once you are in the raft, move to the opposite side to help keep the raft balanced.

Keep a count of survivors. Continually check that none drift away. Communicate with those in the water. Help each other.

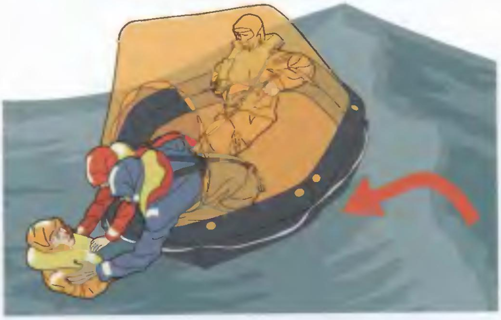

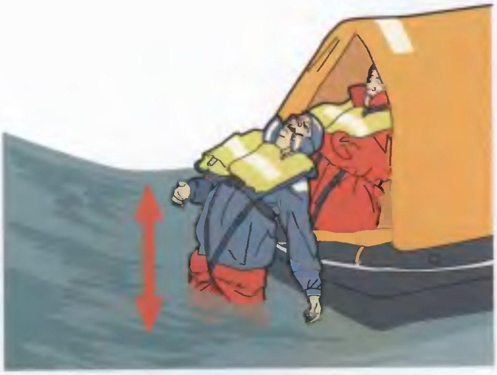

Pulling casualties in backwards by using their inherent buoyancy and dunking them first is slow and difficult and may also injure their back.

Righting a capsized raft

With the correct technique, one person can right any raft with a capacity of up to 12 persons.

Whenever possible right the liferaft while still on the boat

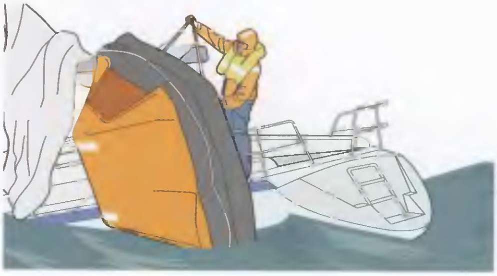

1. Using the lifelines, move around the outside of the raft to the gas bottle. There should be a sign or symbol saying 'right here'.
2. Reach up and find the line or webbing handles on the bottom of the raft.
3. Pull yourself up on the edge of the raft.
4. Draw up your knees and place them in the fold of the tubes. Use them as a fulcrum. Lean back while holding on the righting line.

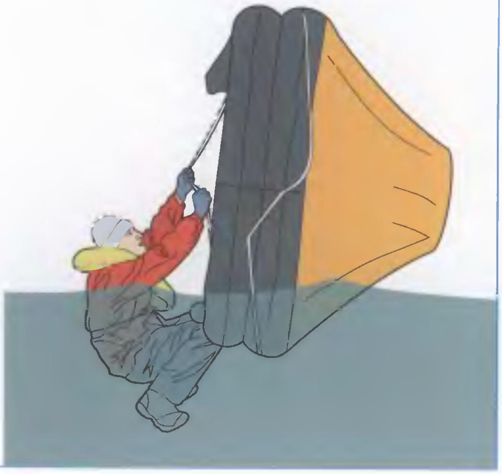

5. Pull the raft over on top of you. It's much easier if you can get the wind underneath the raft as you begin to lift.
6. Hold on to the line and stay on your back. As the raft comes over, keep your hand up to create an air pocket under the raft.

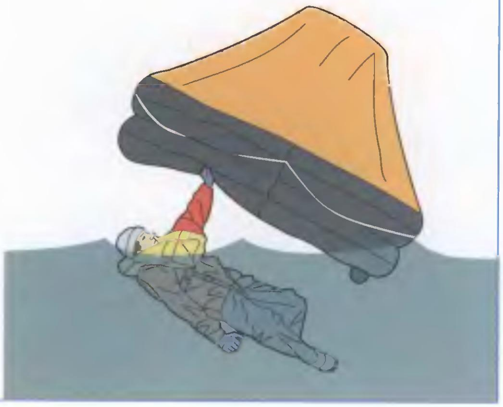

7. Use the line to pull and guide yourself out from under the raft. Mind your head on the gas bottle.

8. Do not let go of the raft. If the wind catches it, it will be blown away faster than you can swim.

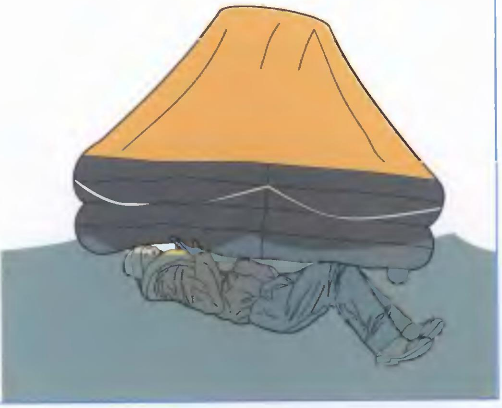

9. Do not turn on to your front when under the raft. The buoyancy in the lifejacket will trap you against the floor.

Note that self-righting rafts are also available.

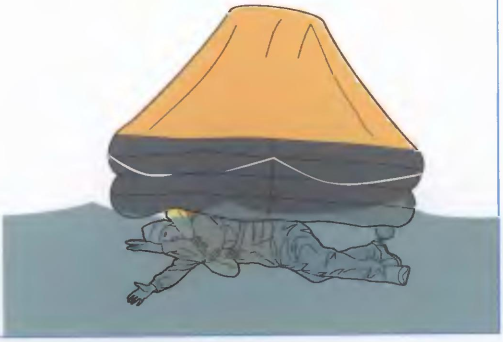

Initial actions

- Cut the painter with the buoyant safety knife (held in a sheath close to the liferaft entrance).
- Cut it as close to the point of attachment to the boat as possible.
- Pull in the line, it may prove to be useful later.

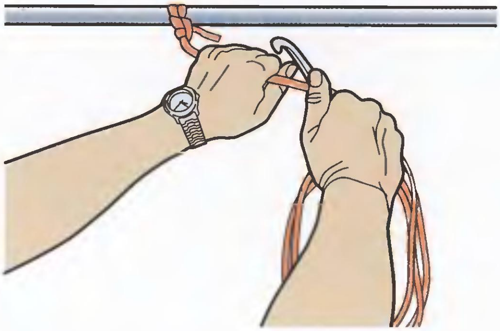

- Paddle clear of the sinking or burning vessel to prevent the raft from becoming damaged.
- Pick up other survivors from the water.
- Congregate with other liferafts and fasten them together.
- Salvage anything that might be useful.

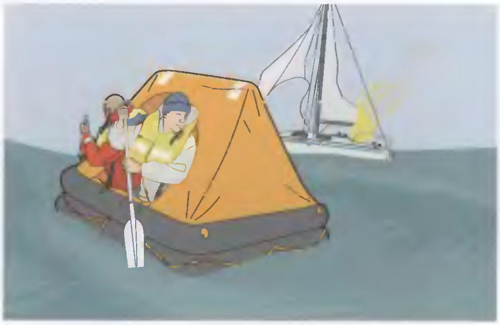

- Stream the sea anchor when you are clear of the vessel. It will turn the raft's entrance away from the wind and waves. It will also improve the raft's stability and slow its rate of drift, keeping you closer to the area where the rescuers will be searching.
- Retrieve the canister lid and any packaging.
- Pick up any useful flotsam.

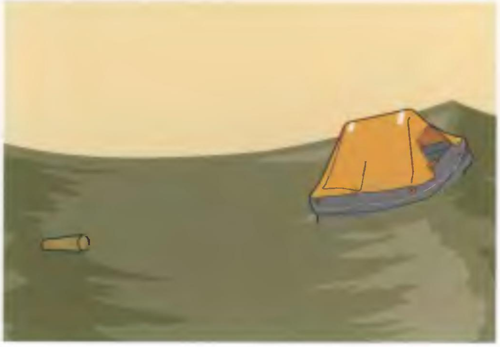

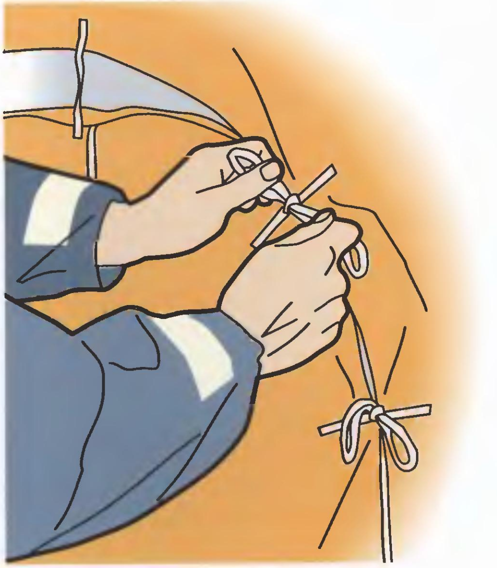

Close the raft's entrance to prevent further ingress of wind and water. It will also keep the warmth in. Entrance closures range from heavy-duty zips to Velcro fastening to webbing ties. Make sure that, whichever system is used, the raft entrance can be opened quickly. Use slipknots on ties.

Open the entrance every 20 minutes to allow fresh air in. Most pressure-relief valves vent outside the raft. If the PRVs vent inside the raft, open the door to let out the fumes. Inhaling CO_2 will give you a headache.

Maintain the raft by checking for leaks and bailing out. Check that the equipment pack is still secured inside the raft, if not check outside the raft; it may still be afloat and retrievable.

Remember...

1. CUT the painter
2. STREAM the sea anchor
3. CLOSE the door
4. MAINTAIN the raft

Secondary actions

What to do next

Be aware that there will be a great temptation to collapse into the liferaft and relax. Now's not the time to rest. Get organised before the cold saps your strength and your ability to use your hands.

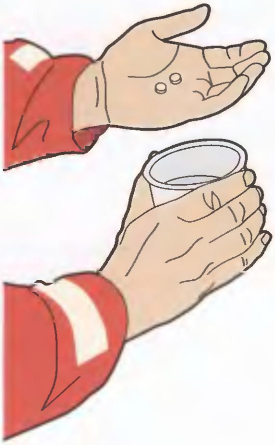

If anti-seasickness medication has not been taken before boarding the raft, open the liferaft pack, find anti-seasickness tablets and take them now. Everyone must take one. Even the hardiest of sailors is likely to be sick inside a raft.

Be prepared – take out one or two seasickness bags as well. Once someone is sick, everyone else is likely to be affected.

Seasickness will cause not only physical and psychological debility but also loss of valuable body heat and fluid. It may also mean the sufferer loses their medication before it takes effect.

The priority now is to get as warm and as dry as possible.

Bail out the raft. The bailer provided may be no more than a fabric scoop. Some rafts have a self-bailer fitted in the floor that will drain the water automatically.

If not, bail out by hand using the bailer and other containers – a boot, a bucket or the salvaged liferaft canister lid. Use the portable bilge pump from your grab bag. Be resourceful.

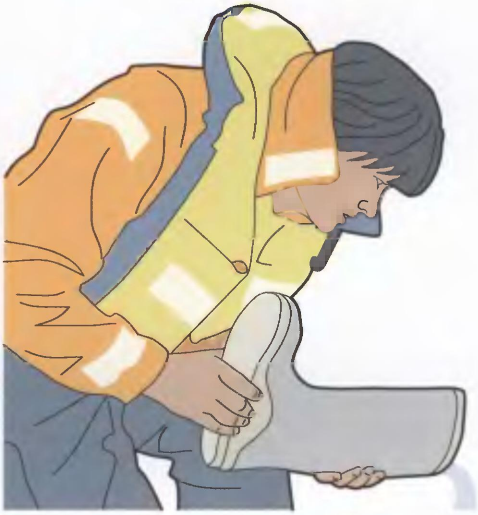

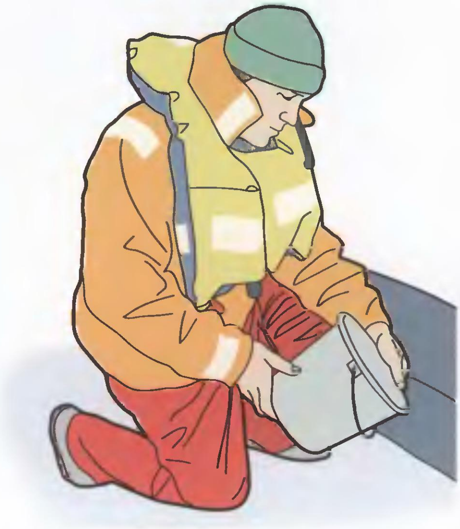

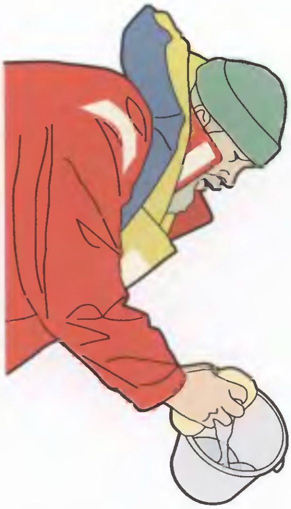

Use one of the sponges from the liferaft pack to dry the floor of the raft. Remember to keep another sponge clean for fresh-water collection.

Apply first-aid to those that require it. Everyone is likely to be suffering from varying degrees of hypothermia and shock in addition to injuries. Look out for the quiet ones – the quietest casualties are likely to be the worst-injured. Calm those that are acting inappropriately.

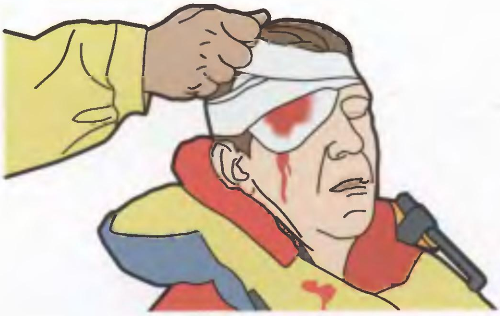

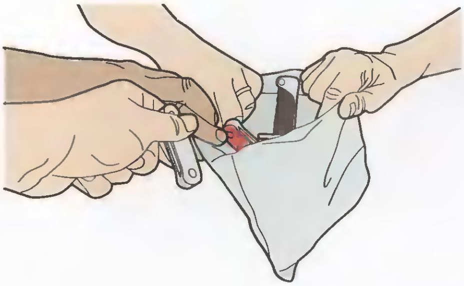

Collect sharp objects and weapons – knives, multi-tools etc – that could damage the raft or be used to harm or threaten anyone when rations become short and tempers fray at a later date.

Wring out wet clothingand put it back on. Huddle together for warmth – don't be shy!

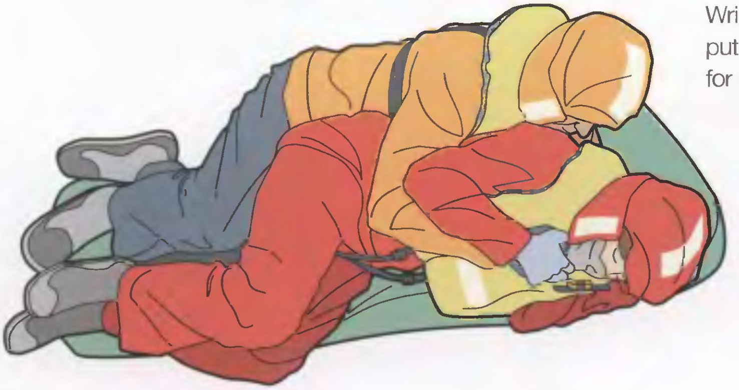

Your main heat loss is by conduction through the raft floor. Some floors have thermally reflective surfaces but others need to be inflated with the bellows. Take care not to pump water into the floor. Insulation can also be provided by sitting on salvaged bunk cushions, fenders or, conditions permitting, inflated lifejackets.

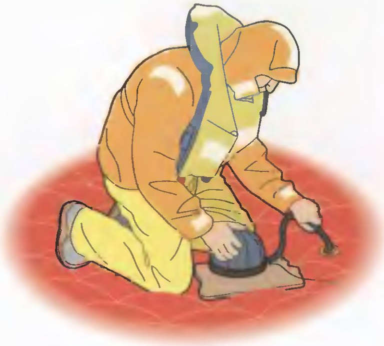

ISAF, ISO 9650 Part 1: Type 1 and SOLAS raft packs include a number of TPAs (thermal protective aids) that will reduce the body's evaporative heat losses. Thick plastic bags, large bin liners or the salvaged liferaft polythene wrapping could also be used.

KEEP YOUR HEAD WARM.

Locate the pressure-relief valve stoppers and put them in place to prevent leakage through the valves. Check for leaks. Top up the tubes with the pump if necessary. Repair kits will only work if you can dry the area to be repaired. Use liferaft repair clamps if the hole is large, and then reinflate the tube.

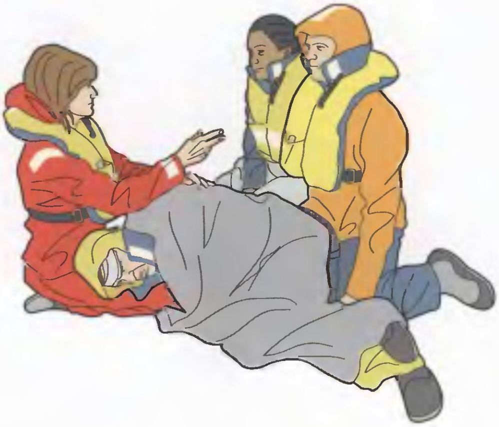

A leader, who may not be the skipper, will emerge. It may be the fittest person with the most sea survival knowledge. Their job is to make sure everyone believes they are going to be rescued and to organise the crew and resources effectively.

It's important that everyone works as part of a team to increase the chances of survival and keep each other's morale up.

No recriminations – there will be plenty of time for that after you've been rescued.

THE WILL TO SURVIVE IS PARAMOUNT.
KEEP MORALE HIGH.

Read the survival notes in the liferaft instruction booklet to refresh your memory. Stow equipment that needs to be kept dry in resealable bags. Some rafts will have stowage pockets on the canopy tube high above the water.

Establish a routine as soon as possible. If there are sufficient crew, put two people on watch for between 20 minutes and 2 hours depending on the weather conditions. Make sure the watch system is fair.

Outside watch should keep a lookout for ships, aircraft, other survivors and dangers. They must be fully briefed on signalling with flares, heliograph and VHF.

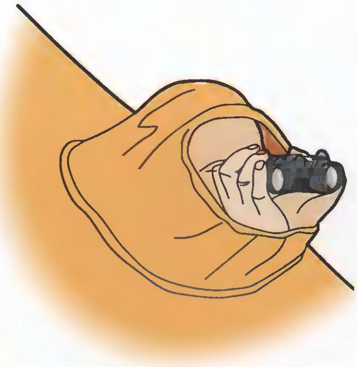

Inside watch should keep the raft inflated, treat and look after casualties, collect water, bail out etc.

Switch off the liferaft light during the day to preserve its power. It may seem very dim but to an SAR helicopter's or lifeboat's night-vision goggles it will stand out for miles. Switch off and save lifejacket lights – you may be able to use them when the liferaft light fails.

SOLAS rafts have an inflatable radar reflector. Wetting the canopy may also increase the radar reflection range.

Do not use a radar reflector and SART at the same time.

Look after the handheld VHF, EPIRB, PLB and flares since they are probably your best means of location by rescuers. Save the VHF's batteries – remember its range is limited. If conditions allow, stand up when using the VHF to increase its range.

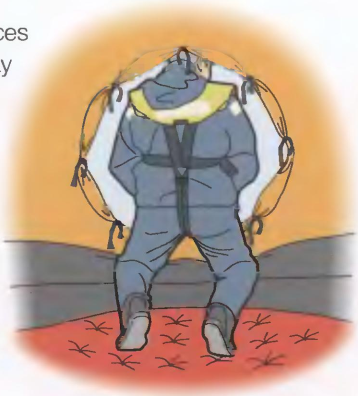

Avoid urine retention because it could have serious consequences later. Urinate within two hours of boarding. Female survivors may prefer to use the bailer. Take care not to fall in if urinating out of the entrance. Ask other survivors to hold your lifejacket straps.

You cannot reabsorb urine from the bladder. Urinating will not increase your rate of dehydration. Try to get rid of urine overboard. The smell can cause nausea. Avoid urinating in your clothes since cross-infection could cause problems later.

A bowel movement is not uncommon. You will probably not need to do it again if you are not ingesting food or fluid.

Protection

In northern European and southern Australian waters, the cold is your greatest enemy. The liferaft is designed to help save you from drowning and reduce heat loss by getting you out of the water as well as providing protection from wind chill.

As long as the canopy is providing a good seal from wind and waves, the air inside the raft will be warmed by the body heat of the occupants. Therefore the greatest heat loss is from conduction through the floor of the raft.

Dry the raft floor thoroughly. Pools of water will intensify conductive heat loss. Inflatable floors will need considerable air pressure before providing an air gap beneath seated survivors. Better insulation may be provided by sitting on lifejackets, fenders, bunk cushions or anything else you have salvaged. Only remove your lifejackets if conditions allow and you are confident that the raft is stable.

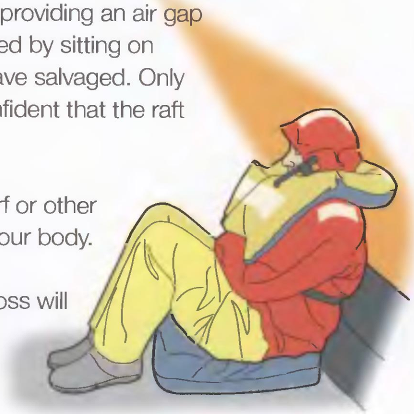

Put on a hat, raise your hood, cover your head with a scarf or other fabric. Your head loses more heat than any other part of your body.

Once you are insulated from the water, the greatest heat loss will be due to evaporation of water from wet clothes. To stop this, remove and wring dry your clothes. Put the damp clothes back on and don a thermal protective aid (TPA).

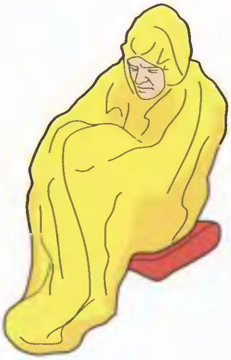

TPAs reduce evaporative heat losses by containing the water vapour in the bag. Once the air inside the bag reaches saturation, no more water can be absorbed and evaporation stops. If TPAs are not available, use bin liners or plastic sheeting.

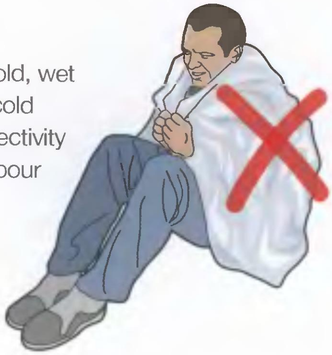

Reflective blankets are not effective in a cold, wet environment. Radiant heat losses from a cold casualty are minimal and the blanket's reflectivity is reduced to virtually nothing as water vapour condenses on its cool inner surface.

Survival or immersion suits are for extreme conditions and provide the best protection against cold. They tend to be bulky and awkward to put on, particularly in a hurry in a confined space, however many people have survived by using one.

Water and food rationing

For survival, the human body needs water more than food. Tests have shown that a person will live for only seven to ten days without water assuming there is no excessive fluid loss but can survive for 20 to 30 days without food.

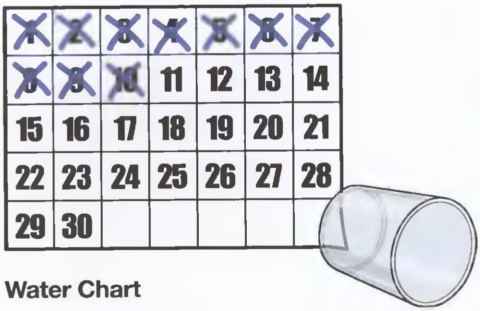

Water Chart

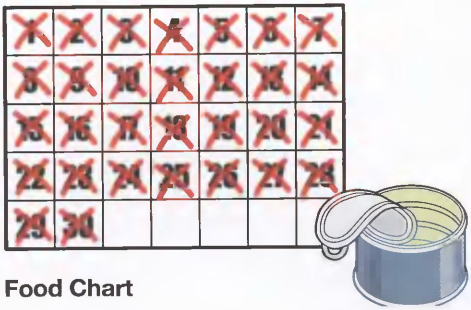

Food Chart

In busy waterways such as those found in northern Europe, it is unlikely a raft will be adrift for more than 48 hours before being rescued. The greatest dangers are drowning and hypothermia rather than dehydration or starvation.

Since the human body has a reserve of water and energy within its tissues, no food or water should be taken in the first 24 hours except by children or conscious injured casualties, who will experience greater fluid loss.

If only minimal water supplies are available, the ration for water, after 24 hours, is half a litre per person per day. (0.5lt/person/day = just under 1 pint/person/day)

Take a third of a ration at sunrise, a third at midday and a third at sunset. When drinking water, keep it in your mouth for as long as possible to moisten the membranes.

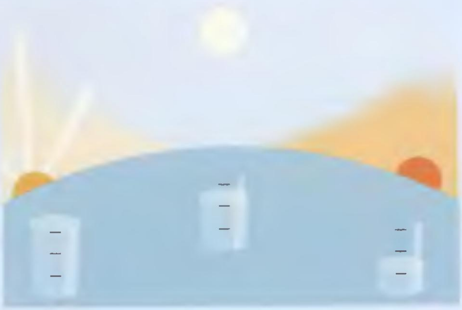

To maintain morale and good harmony, it is vital to ensure that food and water rations are issued fairly.

Water may be supplied in the liferaft pack. It will be in sealed sachets. Use the scissors in the first-aid kit and open the sachet carefully. Decant any leftover water into a clean bottle or sealable container. Stow an empty bottle in your grab bag to collect leftover water.

If you have plenty of water, each person may drink up to 1 litre per day.
(1lt/person/day = about 2 pints/person/day)

Whether you have plenty or virtually none, start to collect water from the outset – you don't know when it might rain again.

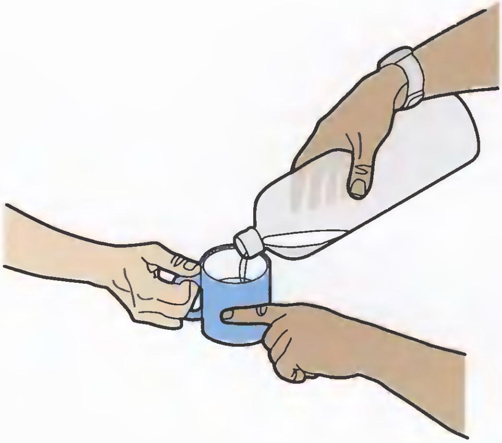

Drink collected water first – because bottled water and sealed-sachet water will stay fresh for longer than rainwater.

Do not drink urine. Do not drink seawater, even in a diluted state. Death has been found to occur quicker when you drink seawater rather than nothing at all.

Reduce the body's water loss by making the best use of the shade and cooling from the breeze.

Avoid eating protein-based food (such as fish or meat) because digesting them uses more fluid than they provide. Carbohydrates and sugars are better.

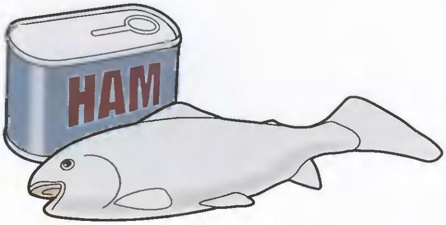

On 30th July 1945, the USS *Indianapolis* was attacked by a Japanese submarine. The ship sank in 12 minutes and many survivors ended up in the water. Rescuers took several days to reach them. Desperately thirsty, some survivors drank seawater.

They became delirious and started to hallucinate. Some thought that there was an island nearby and would try to swim off to it. Some claimed that the ship was not sunk but was just below the surface and convinced others to remove their lifejackets and swim down with them to drink from a water fountain.

Of a crew of 1196, it's estimated 900 went into the water. Four days later, only 316 men remained alive. While some were lost to sharks, many were lost due to the effects of drinking seawater.

Long-term survival techniques

Sustaining the will to survive and the belief that you will be rescued is essential.
Keep the survivors' morale high by running a disciplined routine. Fear, panic, despair and recriminations will undermine your belief that you will pull through. Knowledge of survival techniques and confidence in equipment will help you remain calm and positive.

Lack of water and food will cause fatigue and exhaustion and increase depression. Catching food can be a great morale-booster and will supply much-needed energy. Rest as much as you can but when you are not asleep, keep busy with routine raft duties. Stay optimistic and look forward to the future. Discuss what you plan to do when you get ashore.

Long-term survival techniques revolve around collecting or making water to drink, fishing, keeping the raft inflated and in good order and keeping watch for potential rescuers.

COLLECT RAINWATER AT EVERY OPPORTUNITY.

Better-quality liferafts have a small rain-catcher fitted to the canopy of the raft. It's important to prepare the canopy and the collection bottle before the rain arrives. Wash built-up salt crystals off the canopy and rinse containers with fresh seawater. Use the first downpour to wash off the remaining salt – anything you collect during the initial shower will be contaminated and undrinkable. Collect the rainwater once the salt has been washed off.

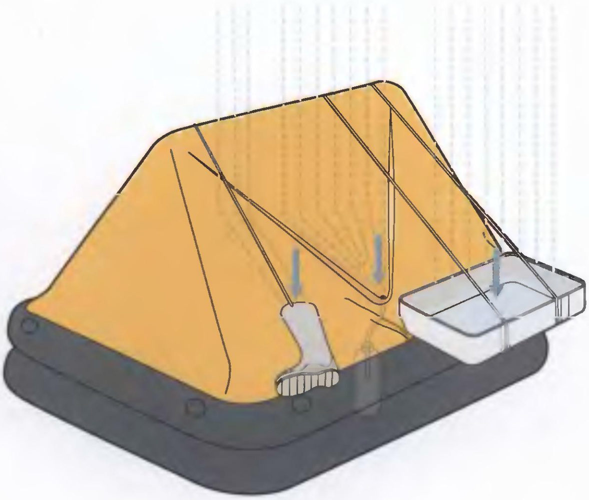

Improvise other means of collecting rainwater – the canopy's collection system is not large.

Unpalatable rainwater can be ingested by enema. Lyn Robertson, a qualified nurse, used the raft's bellows as a method for introducing poor-quality rainwater for absorption through the gut on her family when they were shipwrecked for 37 days in June 1972.

However, tests have shown that saltwater enemas are not a solution to dehydration. The gut does not filter salt out of the water – only use rainwater.

Solar still

An inflatable solar still can be filled and fastened alongside the raft. Salt water held in the bottom of the still evaporates and potable water condenses on the inside of the tent and runs down to a collecting bottle. It can produce about 0.75 to 1 litre per day in calm conditions. However, rough conditions can cause the seawater in the bottom of the still to splash into the distilled water making it undrinkable.

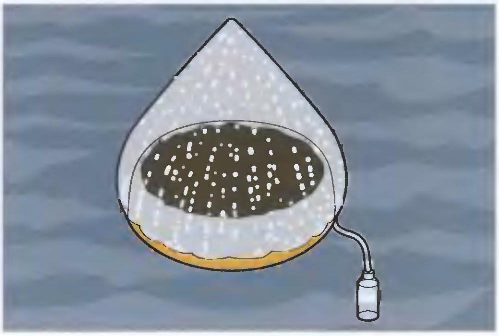

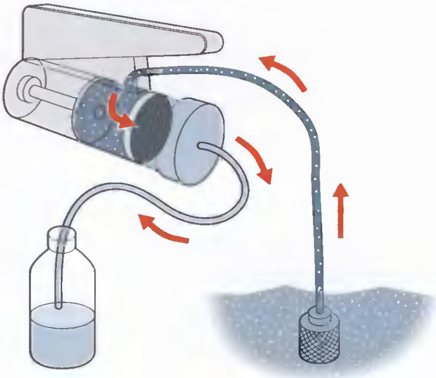

Hand-operated desalinator

Using reverse osmosis, a desalinator or water purifier pump will remove 98% of the salt from seawater. It can produce as much as 4 to 5 litres of drinking water per hour but is hard physical work to operate. It may, in the heat of the day, cause the operator to sweat out more water than they can make. To make the most of a desalinator, use it at night when the weather is cooler.

Lone sailor Steve Callahan's yacht sank after a collision with a whale while on a transatlantic passage from the Canaries. He abandoned ship into his liferaft. In his grab bag were 8 pints of water and two solar stills. Seventy-six days and 1500 miles later he was picked up by fishermen within sight of land.

Bill and Simone Butler survived for 66 days in a liferaft by using a PUR Surviva 34 manual reverse-osmosis water filter after whales sank their 38ft yacht *Siboney* 1200 miles west of Panama.

What's on the menu

Catching food boosts survivors' emotional and physical well-being. Foods high in complex carbohydrates are more suitable than protein food such as meat and fish. Protein will draw water from the body while it is being digested. Ideally, the body needs just over a litre of water a day to digest food and dispose of waste matter. If no water is available, the survivor should not eat, as this will accelerate dehydration. If food is contained in the liferaft pack it will be high-energy carbohydrate, similar to a block of dried porridge.

- Plankton can be caught using an improvised net made from a pair of stockings or tights.
- Barnacles will grow on the bottom of the raft and the meat can be extracted and eaten.
- Fish can be caught using a harpoon, spear or gaff, or by hook and line.

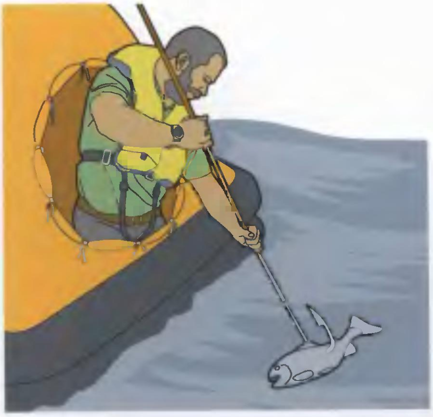

An improvised spear can be formed by lashing a knife to a paddle. Steve Callahan included a spear gun in his grab bag, but if you do the same, take care not to puncture the raft.

Flying fish may also land on or in the raft.

Maurice and Maralyn Bailey adapted the safety pins in their first-aid kit to make fish hooks. On average, they landed forty fish a day.

Alain Bombard created hooks from a bone found just behind the gill of the Dorado fish.

Initially, lures can be made from silver paper. After that, most survivors have used the heads of the fish they caught as their bait. Poon Lim, who survived for 133 days on a lifeboat, used a dried paste of biscuit and saliva for his initial bait.

Fluid can be extracted from large fish by sucking their bones and eyes. The fish guts may be more digestible than the flesh.

Turtles – Dougal and Lyn Robertson and their family and crew caught turtles. Taking care that the creature's beak didn't damage their inflatable, they slit its throat and drank its blood immediately to rehydrate. The meat was dried and the blood used as a 'sauce'.

Seabirds – Poon Lim, Steve Callahan and the Baileys all tell of catching and eating seabirds. Seagulls and boobys will often land on the liferaft or can be attracted by a baited hook.

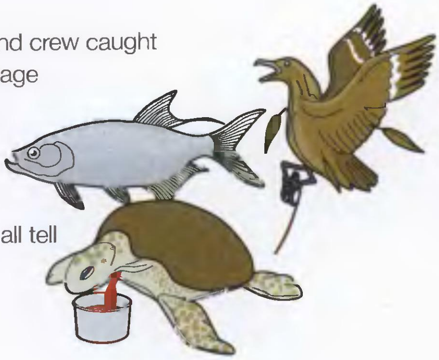

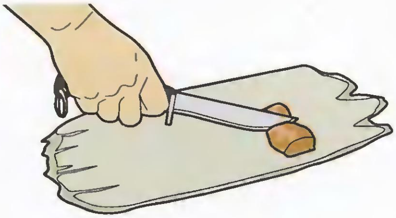

Some form of chopping board is useful and can be improvised from the liferaft canister, flare box or salvaged flotsam.

Keeping cool

While those in cold-water climates will be concerned about keeping warm, sailors in the tropics, are more concerned about staying cool and reducing dehydration caused by excessive sweating.

Methods of keeping cool

Obviously, stay under the canopy or create shade so that you can stay out of the sun. Rest during the heat of the day and undertake routine tasks in the morning and evening.

Cool the raft by wetting the canopy, and keep your clothes damp. Regularly rinse them in the sea to prevent a build-up of salt crystals, which would exacerbate sores.

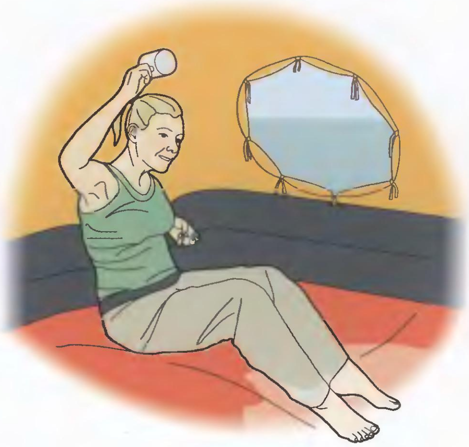

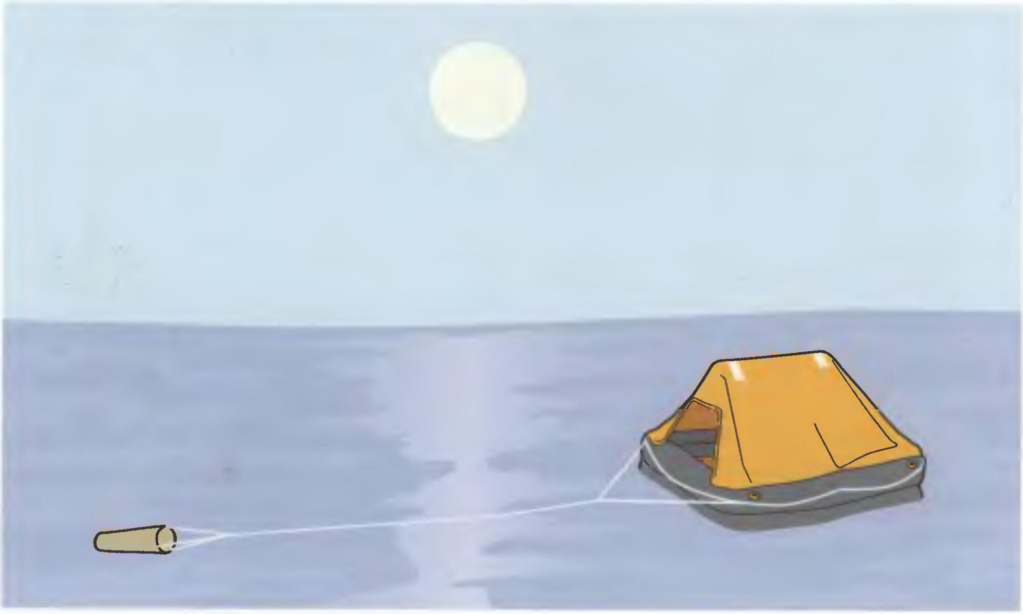

In hot, calm weather, reattach the sea anchor to the entrance-side of the raft so that the wind blows into the raft.

During the day, deflate the inflatable floor and sit directly on the raft floor. Reinflate it at night to prevent getting cold.

If you are in a group of two or more rafts, spread the survivors equally between them so that each individual has more space to stretch.

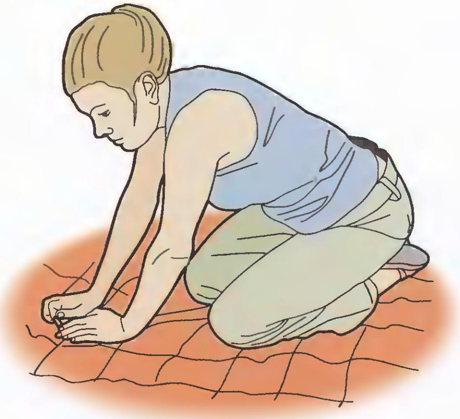

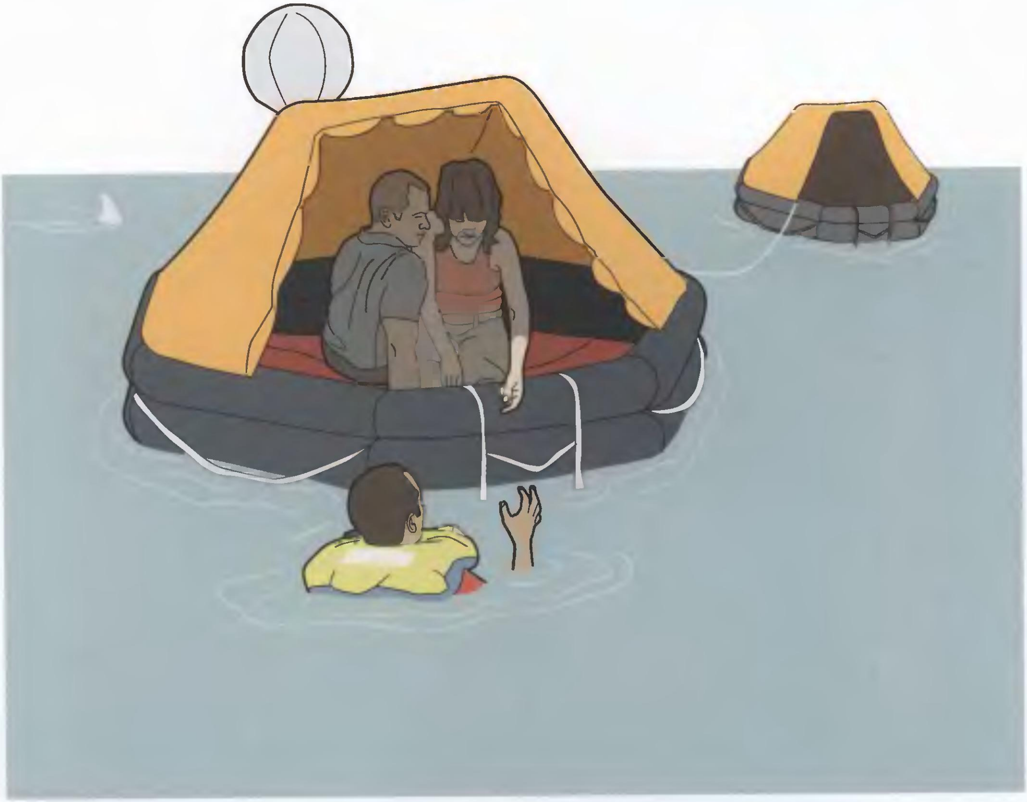

Don't get into the water to cool down; you may not be able to get back into the raft.

CHAPTER 13 : Survival in cold water

Research by Golden and Hervey shows that the body goes through four stages when immersed in cold water:

Length of Time Immersed	**Risks**
0–3 minutes	Diving reflex and cold shock
3–30 minutes	Swim failure
More than 30 minutes	Hypothermia
Post-immersion	Hydrostatic squeeze, secondary drowning, post-rescue collapse (during and after rescue)

Because the human body loses heat 26 times faster in water than in air, immersion in cold water can be extremely dangerous. The graph below shows the possible effects of immersion in 10 degrees C water. Around the UK, sea temperature varies between 5 degrees C and 18 degrees C. The temperature of the Mediterranean during the summer rarely gets above 26 degrees C.

Typical change in deep body temperature during immersion in stirred water at 10˚C *(50˚F)* for an average clothed individual. *(F. Golden)*

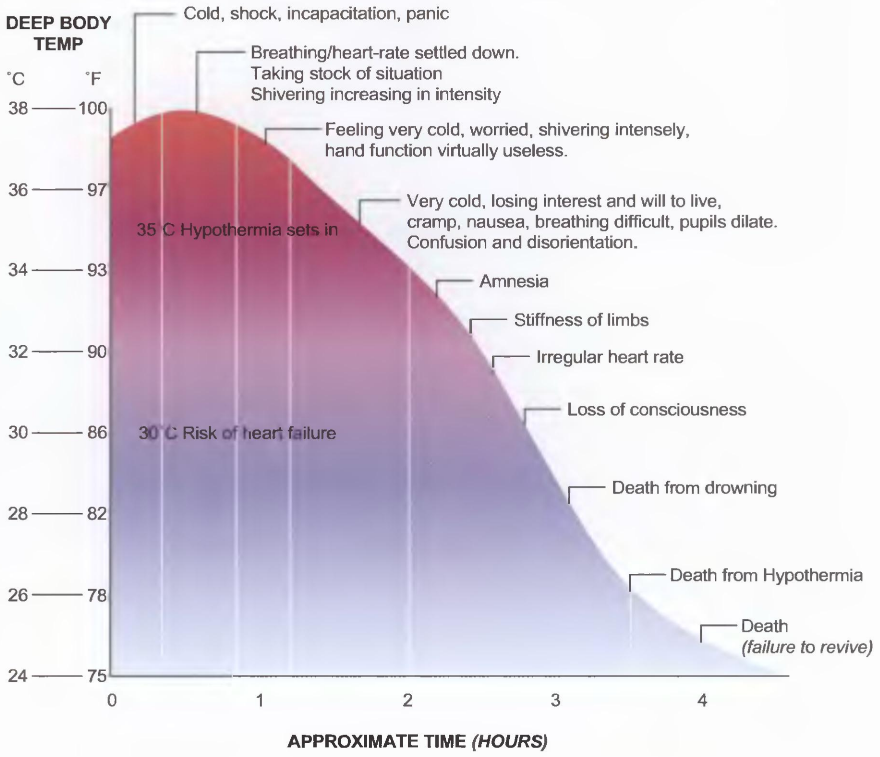

Diving reflex

The diving reflex occurs when you first make contact with the water. If the water is not too cold you involuntarily hold your breath and your blood circulation and heartbeat slows. However, in water 15 degrees C and below, cold water shock may overcome the diving reflex.

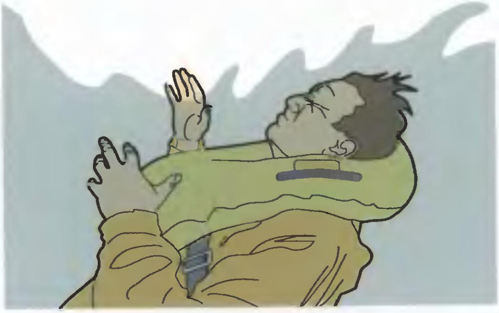

Cold shock

Cold shock takes place after thirty seconds to three minutes of immersion. Your breathing rate increases from around 10 breaths per minute to 60 breaths per minute (hyperventilation, which can cause dizziness and confusion). Breath-holding times are likely to reduce from over a minute to less than 10 seconds.

In water of less than 15 degrees C, it is probable that you will involuntarily inhale (gasp) even when underwater.

Blood vessels close to the skin shut down causing a sharp increase in blood pressure, which may be sufficient, depending on your fitness levels, to initiate a stroke or a heart attack.

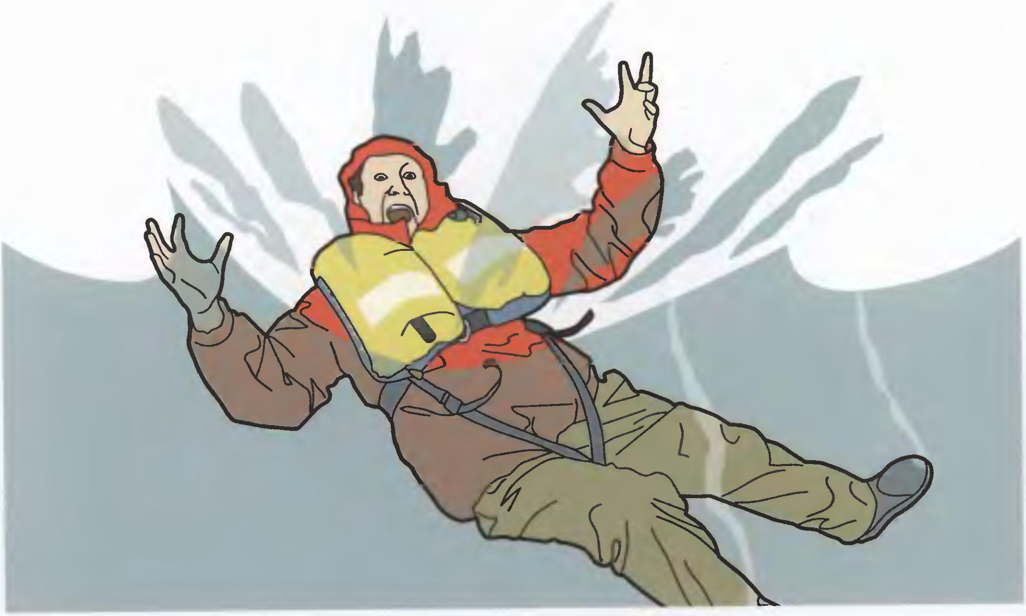

Protecting against cold shock
To reduce the likelihood of cold shock, wear a lifejacket, waterproof clothing and, if possible, enter the water slowly. Do not try to swim – adopt the HELP position (see p.66).

Regular cold showers, baths or sea swimming can help to prepare your body for sudden immersion in cold water. Tests have shown that after just one week of daily cold showers, the effects of cold-water shock can be reduced by 50%.

The fitter you are, the better able you will be to withstand cold-water shock.

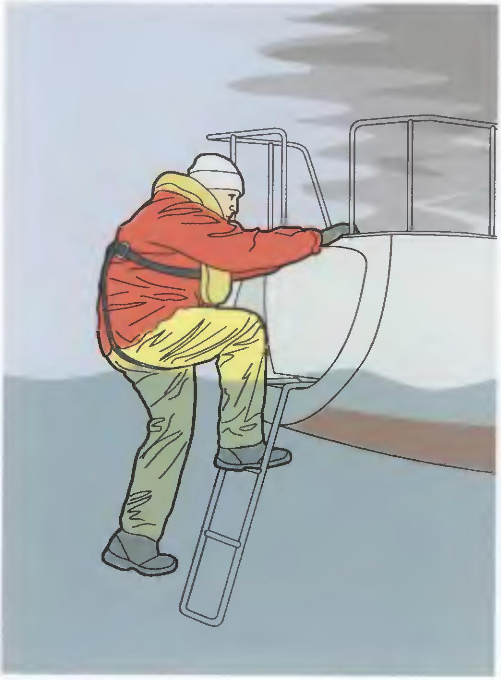

You are more likely to drown as a result of entering cold water quickly than you are from hypothermia.

Swim failure

After three to thirty minutes of being immersed in cold water, your arms and legs become numb and your muscles will not function properly. Shivering increases and your heart and breathing rate decreases.

Grip strength and co-ordination are significantly reduced. You may find it difficult to use your hands for firing flares, donning a spray hood, setting off a PLB or using a handheld VHF.

Even fit adult men can find it impossible to lift themselves up the side of a small boat and normally strong swimmers may only manage 100 metres before collapsing. This emphasises the importance of wearing a lifejacket and being realistic about your swimming ability.

Hypothermia

Hypothermia can occur in water of up to 24 degrees C and sets in as the core body temperature drops from 37 to 35 degrees C. In northern European waters in the summer, your survival time with clothing and lifejacket is between two and twelve hours. In winter, it ranges from several minutes to two hours. The exact length of time depends upon on the water temperature, sea state, clothing, gender, fitness, health, shivering rate and age of the person.

What happens?

The casualty will feel cold and their body becomes numb. Intense shivering may stop as the muscles become cramped and rigid. Speech will become slurred, nausea will set in and behaviour will become irrational (similar symptoms to being drunk). The casualty will slip into unconsciousness, increasing their chances of drowning. Heart and breathing rates decrease and the pupils will dilate. Heart failure is possible when body temperature drops below 30 degrees C.

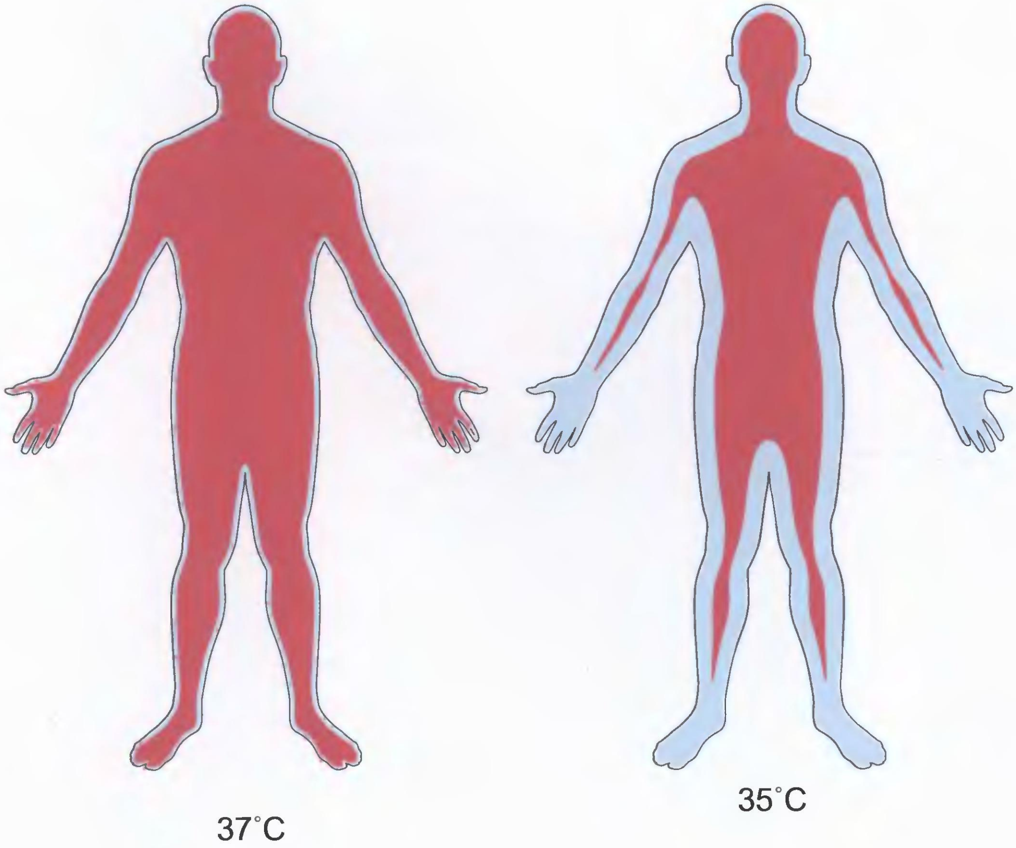

Methods to help prevent the onset of hypothermia

Before entering the water put on an immersion/survival suit, drysuit, wetsuit or more clothing and a lifejacket.

Wear a hat and cover your head with a hood (this also makes you more visible to rescuers). Once in the water, do not kick off boots and try to remain as still as possible, adopting the HELP position (see fig. 1).

Get out of the water if at all possible.

Avoid alcohol.

Heat Escape Lessening Posture (HELP position)

A static body position reduces heat loss and increases your survival time. Therefore, assuming the HELP position is strongly recommended. However, holding this position may not be possible in anything other than calm conditions.

Lie with ankles crossed, knees together and legs slightly bent and elbows held close to the body with one hand under the front of the lifejacket. Hold the other hand up with the palm towards your face, covering the mouth and nose to protect the airway from waves and spray.

In wind and waves, a lifejacket wearer will be turned to face the waves, causing water and spray to break continually into their face. The natural reaction is to stabilise their position using their arms and legs and to turn their body so that the back of the head faces the waves.

A spray hood helps protect the face when both conscious and unconscious and is highly recommended. Put it on as soon as possible.

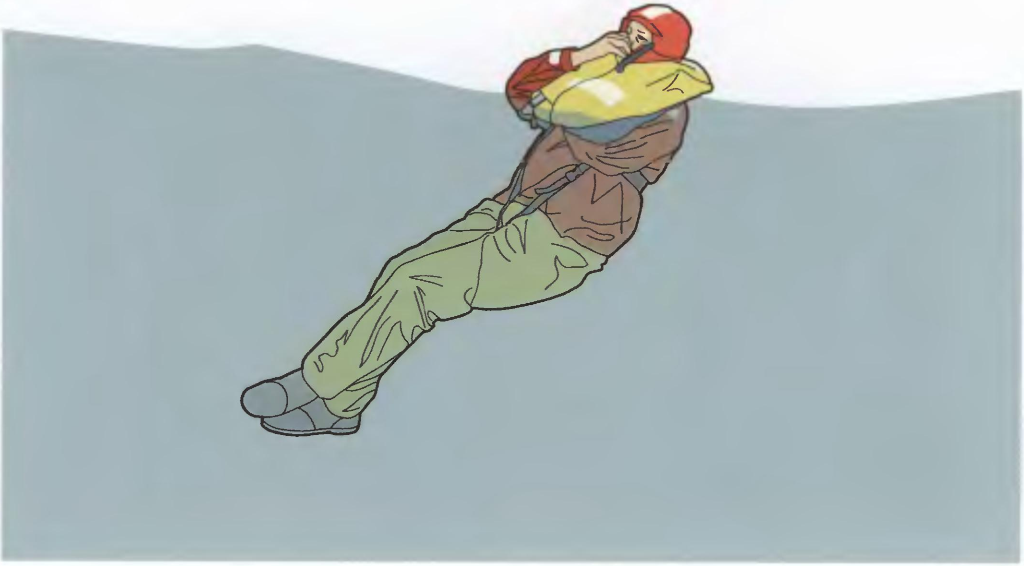

fig. 1

Swimming with a lifejacket

Avoid swimming if possible, since it increases heat loss, however if it is essential, swim on your back. Trying to swim on your front when wearing a lifejacket wastes energy. Swimming by kicking your legs loses less body heat than swimming with your arms but may not be as effective.

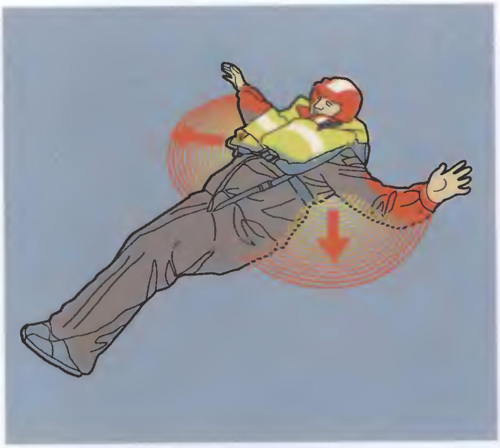

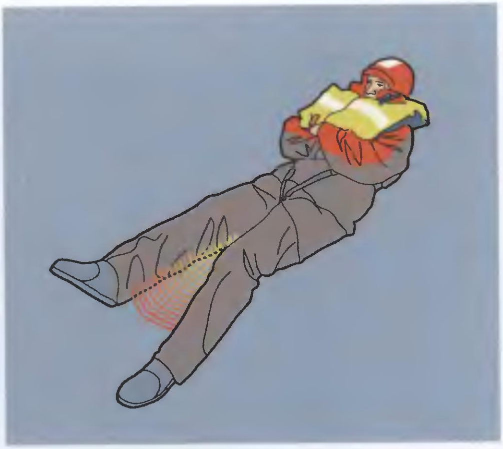

To reach other casualties, a liferaft or a survival craft in the water:

- Send a strong swimmer ahead, connected to the group by a line, or swim as a group.
- The 'crocodile' may be used to swim as a group but it can be very difficult to achieve in waves.
- If a casualty is injured or unconscious, they should be placed at the tail of the crocodile.

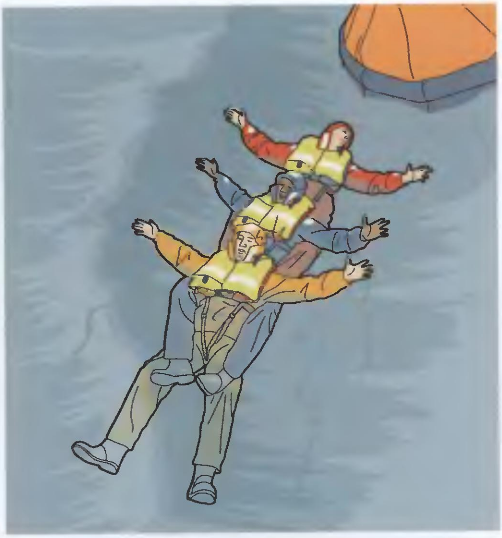

Huddle

The huddle shares body heat, improves morale, supports weaker members of the group and increases your chances of being seen by rescuers. Use safety harnesses or rope to clip yourselves together as soon as possible, while your hands are still functional.

Be aware that in waves some members of the huddle will be facing wind and waves, making it impossible for them to hold their position.

Two person huddle – one person places their legs around the outside of the other. Take turns to be the person on the outside.

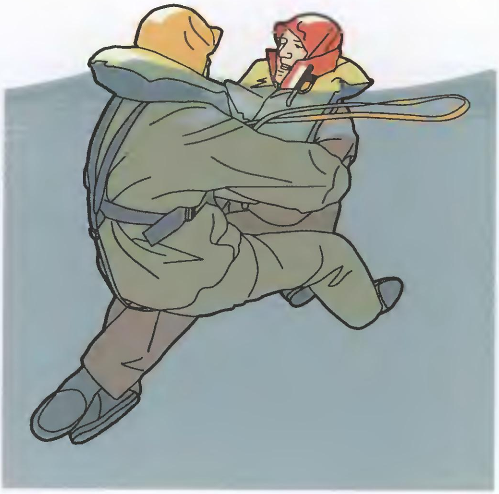

Group huddle – organise the group so that all use their right hand to hold on and their left hand to cover their airway or vice versa. Place injured or weak casualties in the middle of the huddle and rotate the huddle so that no one has to face wind and waves continuosly. Keep your ankles crossed and knees together to preserve body heat.

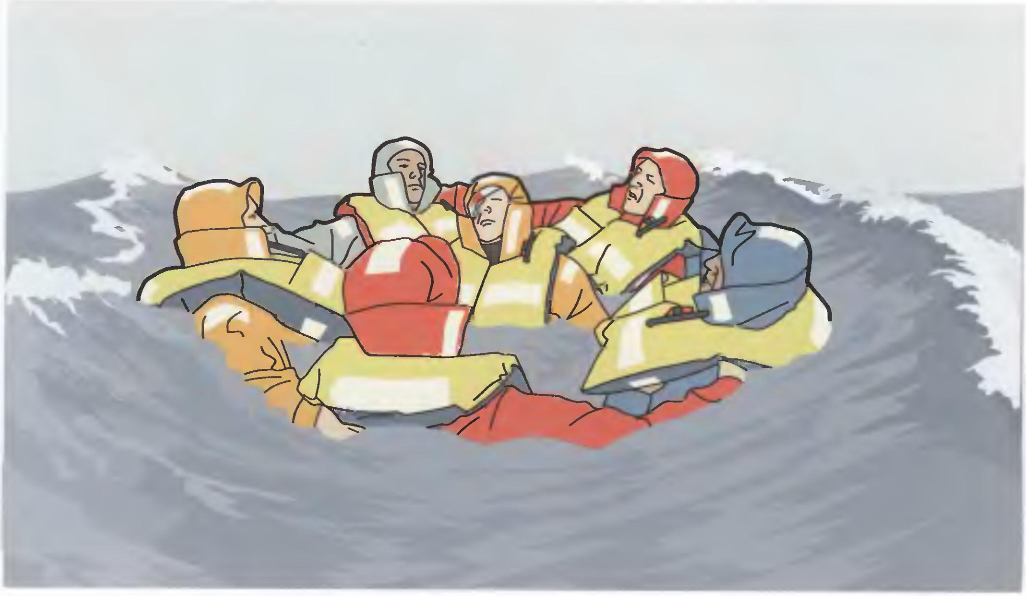

CHAPTER 14 : First Aid

The quality of the first-aid kit supplied will vary depending on the quality of the liferaft. The SOLAS C first-aid kit provides a broad range of medical items and will be found on many rafts, or can be specified for inclusion.

The contents are shown below.

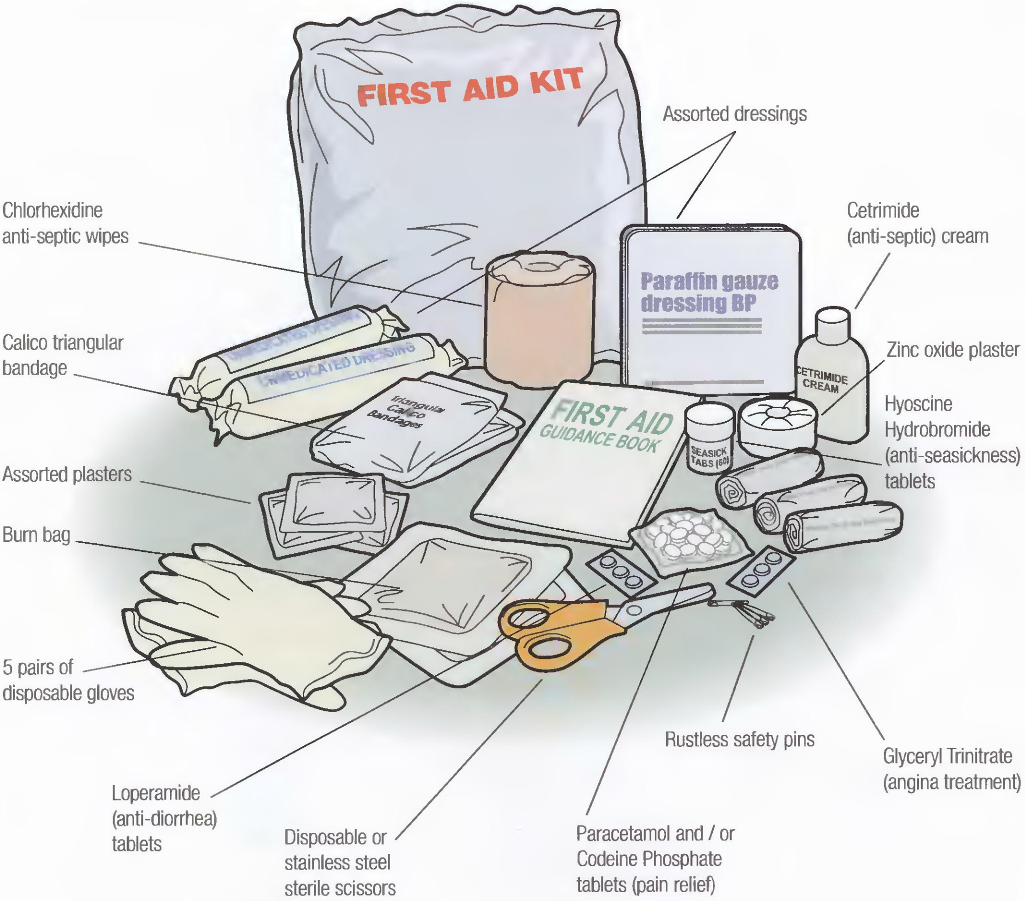
FIRST AID KIT
Assorted dressings
Chlorhexidine anti-septic wipes
Cetrimide (anti-septic) cream
Paraffin gauze dressing BP
UNMEDICATED DRESSING
UNMEDICATED DRESSING
Calico triangular bandage
Triangular Calico Bandages
CETRIMIDE CREAM
Zinc oxide plaster
FIRST AID GUIDANCE BOOK
SEASICK TABS (60)
Hyoscine Hydrobromide (anti-seasickness) tablets
Assorted plasters
Burn bag
5 pairs of disposable gloves
Rustless safety pins
Glyceryl Trinitrate (angina treatment)
Loperamide (anti-diorrhea) tablets
Disposable or stainless steel sterile scissors
Paracetamol and / or Codeine Phosphate tablets (pain relief)

Not shown: Laerdal-type pocket mask (for expelled air resusitation)

In addition to conventional first-aid equipment, consider what else may be improvised. A lifejacket, for example, can be made into an inflatable splint to immobilise the lower leg, or alternatively, use two paddles or a plank of salvaged wood.

For general advice on diagnosis and treatment of casualties refer to the St John's First Aid Book (available from the RYA webshop). The RYA also has a one-day first-aid course for yachtsmen.

Heat exhaustion

This is a condition caused by the loss of water and salt from the body, usually as a result of physical exercise in a hot, moist environment.

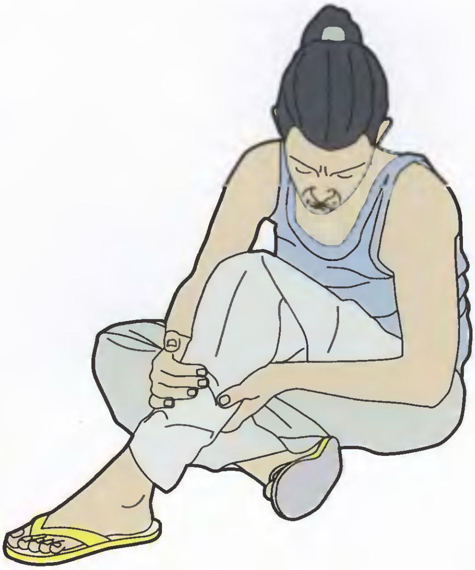

Symptoms
Fatigue, headache, dizziness, nausea, possibly vomiting and muscular cramps.

The skin will be cold, pale and clammy, the pulse weak and rapid, breathing fast and shallow.

Treatment
Remove the sufferer from direct heat and ventilate the liferaft. Sponge down their body, and give sips of cold water with a little salt.

Heat stroke

Caused by prolonged exposure to extreme heat or high humidity. The body temperature rises due to its inability to lose heat through sweating.

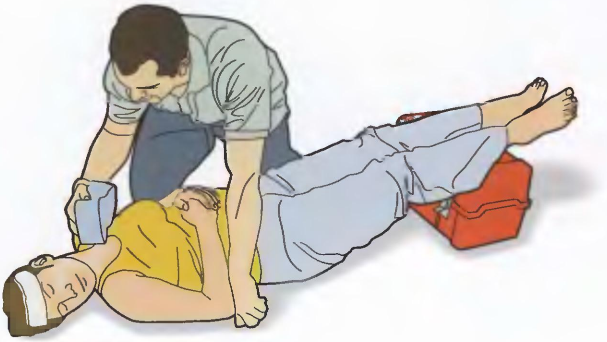

Symptoms
Similar to heat exhaustion except that the skin will look flushed and dry, the pulse is rapid and strong and breathing full and rapid.

Treatment
Sponge down the body, and give frequent sips of cool, slightly salted drinks. Help cool the sufferer by fanning or exposing them to a cooling breeze.

Hypothermia

You can become hypothermic in water of up to 24 degrees C. Around the UK, the water temperature varies between 5 degrees C and 18 degrees C. The temperature of the Mediterranean in the summer rarely rises above 26 degrees C.

Normal core body temperature is 37 degrees C. Hypothermia is defined to have occurred when the core temperature drops to 35 degrees C or below.

Hypothermia may occur in or out of the water. Liferaft occupants are susceptible due to the thin material insulating them from the cold water. Casualties that become cold relatively slowly – chronic hypothermia – such as those in a liferaft or those in water of temperatures between 20 and 28 degrees C will require different treatment from those who are suffering acute hypothermia from becoming cold quickly, such as falling into water below 15 degrees C.

Chronic hypothermic victims are more likely to be exhausted and unable to regain normal circulation on rewarming. Acute hypothermic casualties tend to respond well to rewarming and are soon back to normal.

Symptoms

The graph below shows the typical symptoms of a casualty who has fallen into 10-degree water as the body temperature falls.

Typical change in deep body temperature during immersion in stirred water at 10°C *(50°F)* for an average clothed individual. *(F. Golden)*

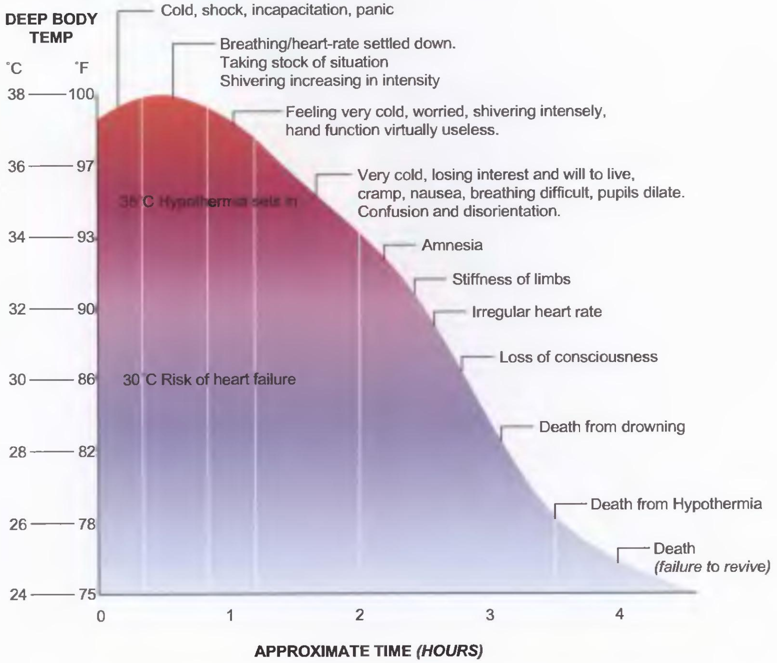

Without a thermometer it can be difficult to tell whether a person is cold or hypothermic. According to Golden and Tipton, one test is to feel the casualty's deep armpit; if it feels like cold marble, they are probably hypothermic.

Initially, the core temperature will rise as the blood vessels in the arms and legs contract, forcing blood back to the core. After the effects of cold-water shock have worn off, heart and breathing rates will slow and shivering will start and become more intense as the core temperature falls. Extremities become numb. Those in the water will suffer from swim failure as they become unable to control their limbs.

Speech will become slurred and the casualty may appear to be quiet and introverted. Nausea may be present and behaviour may become irrational. They will lose co-ordination and become mentally slow. Chronic hypothermics will stop shivering as the body runs out of energy, and may suffer cramps. As cooling continues, the victim will become unconscious and, if in water without a lifejacket, will drown. In a raft, they will continue to cool, the heart and breathing rate will slow and pupils dilate. When their body temperature drops below 30 degrees C, they are in danger of heart failure.

Treatment

Hypothermia is difficult to treat in a survival situation. Passive rewarming is the suggested treatment. The aim is to stop further heat loss and give the body a chance to warm up from the inside.

If the casualty is conscious and co-operative, remove wet clothing. Insulate them with blankets and sleeping bags and wrap in plastic or a TPA. Leave the face exposed. Ensure the casualty is well insulated from the ground, deck or the floor of the raft. The body will slowly rewarm itself as the internal organs start to get back to normal.

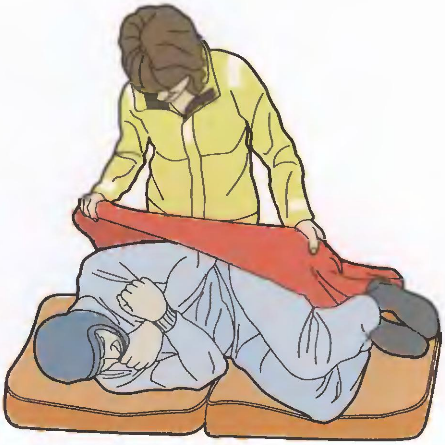

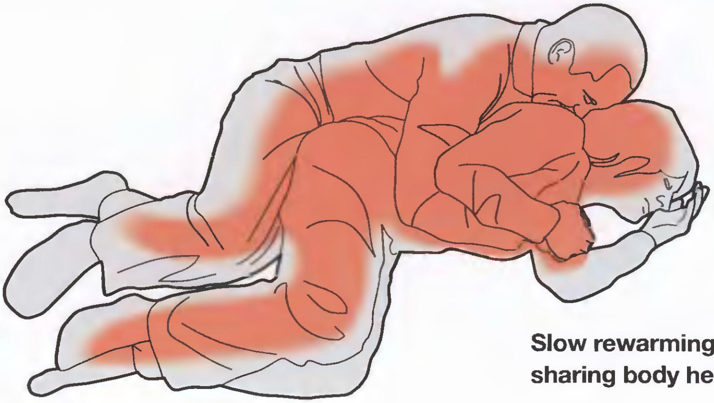

Slow rewarming may also be possible by sharing body heat in a 'buddy system'.

Warm drinks may be given to a conscious casualty. The hypothermic person can have lost as much as 2000 calories of heat.

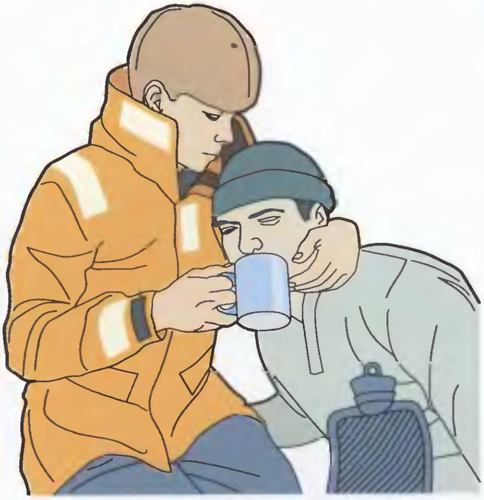

DO NOT:

- Give alcohol
- Use hot-water bottles
- Massage/rub areas
- Handle roughly
- Administer fluid to a semi-/ unconscious person

Unconscious hypothermic casualties must be handled very carefully – otherwise they may collapse and die.

Active rewarming should only be undertaken by medical professionals. Even with the right knowledge, it is unlikely to be possible in a liferaft or small yacht.

Note: it can be difficult to tell if a hypothermic casualty's heart has stopped. Attempting CPR may fibrillate the heart and cause death.

The risk of drowning is reduced if you are wearing a good lifejacket with a spray hood.

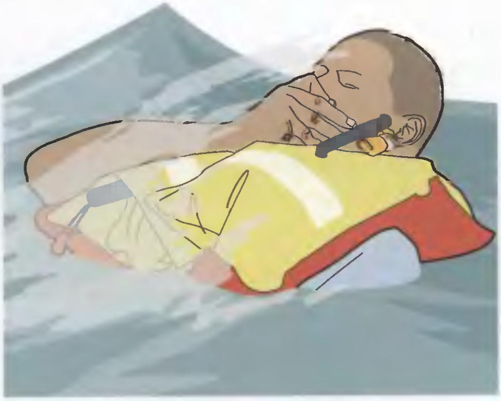

Near-drowning

Symptoms
Breathing may have stopped or be very shallow; lips blue, bluish pallor of the face. Froth around the mouth, vomiting. If conscious, the patient may complain of chest pains and may be coughing.

Treatment
Use Expelled Air Resuscitation as soon as possible (see p134). Water will be automatically coughed up from the lungs when breathing restarts. If available, apply oxygen. Seek further medical help.

Most diving boats carry oxygen and may be closer than medical services.

Secondary drowning

This occurs when a small amount of dirty water or seawater is inhaled into the lungs. A cupful is enough to do it. The water inflames the membranes of the lungs, which react by releasing fluid, filling the lungs thereby causing death by secondary drowning.

Symptoms

Increased chest pain and coughing (possibly with pink froth). Some people may show signs of asthma-type symptoms but many do not. It is likely to manifest itself up to 12 hours after the incident. Seek medical attention as soon as possible (and certainly before 12 hours) if you suspect a casulaty has ingested water into the lungs.

Heart attack

Heart attack is always possible for those in a stressful situation. It is also a possible effect of cold-water shock and hypothermia. It is difficult to tell if a hypothermic casualty's heart is beating, if necessary, use CPR or an automatic heart defibrillator.

Symptoms

Vice-like central chest pain and pain in left or both arms that does not ease when the casualty rests; breathlessness, gasping for air, collapse, sudden dizziness, grey skin, sweating.

Treatment

Make the casualty as comfortable as possible, apply oxygen if available, give angina medicine (glyceryl trinitrate) and/or aspirin (300mg). Monitor and record vital signs. Seek medical advice.

Panic attack

Caused when the casualty has a sudden bout of extreme anxiety. This may be caused by the situation the casualty is in or brought on by symptoms caused by other illness. Either way, the effects on the casualty are very real and frightening.

Symptoms

Rapid breathing (hyperventilation) and a feeling of a racing heart beat. Muscular tension leading to headache, backache and a feeling of tightness across the chest. The casualty may believe they are dying and experience trembling, sweating and a dry mouth.

Treatment

If possible remove the cause of the fear. Reassure them and explain that they are having a panic attack. Get them to slow their breathing. If they are hyperventilating ask them to breathe into a paper bag (use an unused sick bag). Continue to reassure the casualty until they are recovered.

Shock

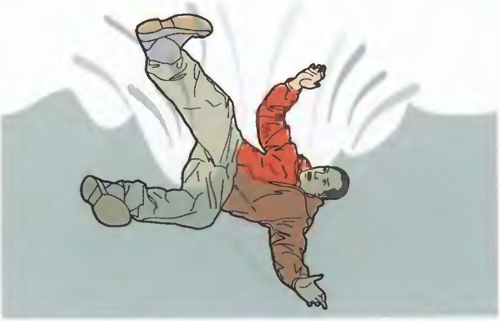

Caused by injury, burns, severe vomiting/ diarrhoea, fear, pain or traumatic experience.

- The effect of shock must not be underestimated, it can be fatal. It is caused by reduced blood flow to the vital organs. Movement can cause fainting and even heart failure.
- Watch out for delayed shock. MOB casualties may say they are OK but may go into shock 20 to 60 minutes after recovery.

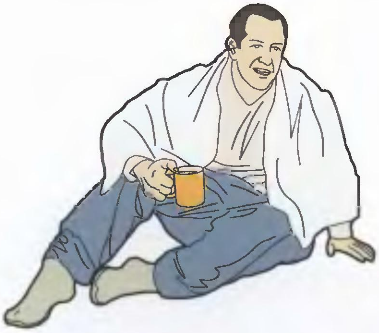

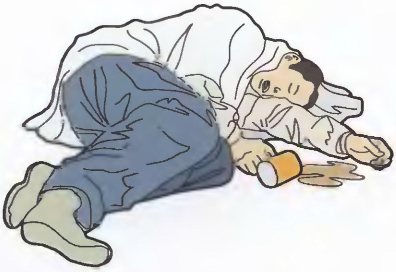

- Liferaft survivors are also susceptible – always check on quiet, introverted survivors, who may be suffering from shock.

Symptoms
Grey or pale skin that is cold but moist with sweat, feeling weak and faint, nausea, weak but rapid pulse, shallow breathing and perhaps gasping; thirst, possible unconsciousness.

Treatment
Most of the crew will have varying degrees of shock so there is little you can do in a liferaft.

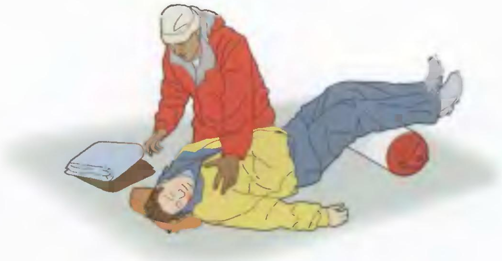

Treat obvious wounds such as external bleeding and broken limbs. Lie the casualty down with their feet higher than their head. Loosen their clothing and if possible put them into the recovery position. Moisten lips with water. Do not apply hot water bottles.

If the casualty stops breathing commence ABC of resuscitation.

Severe bleeding

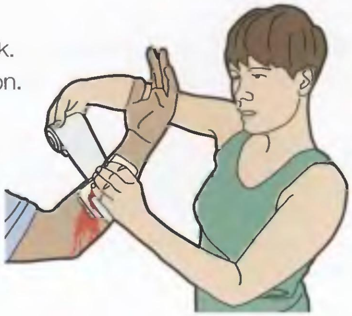

External bleeding is obvious and distressing, and can lead to shock. The aims are to stem the flow and minimise the chances of infection.

Treatment
Cover the wound with a dressing and apply direct pressure. Raise the wound to reduce blood loss, and bandage the area. Keep applying dressings until the bleeding stops. Support the injury. If an object is embedded in the wound, do not remove it. Provide padding either side of object. Apply dressings.

Frostbite

On watch, crew may be in danger of frostbite, where local tissue becomes frozen. The areas affected are usually the fingers, toes, ears or nose. Prevention is better than cure. Wear gloves, cover the face and ears and to be aware of the length of watch duties. Exercise and massage can delay the onset of cold injury.

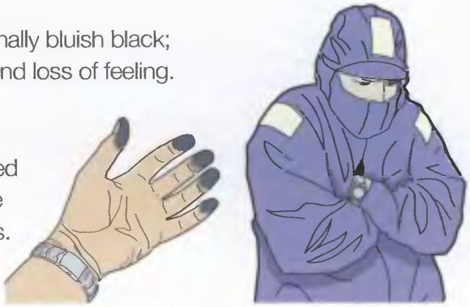

Symptoms
The area becomes pale then white, mottled blue and finally bluish black; there is swelling and fluid release from damaged cells and loss of feeling.

Treatment
Remove constricting garments, raise and dry the affected area. Warm the hands or feet by putting them under the armpits, in the groin or between another person's hands.

Do not massage or burst blisters or apply pressure.

Immersion foot

Known during World War One as Trench Foot, immersion foot is caused by continuous contact with a cold and wet environment.

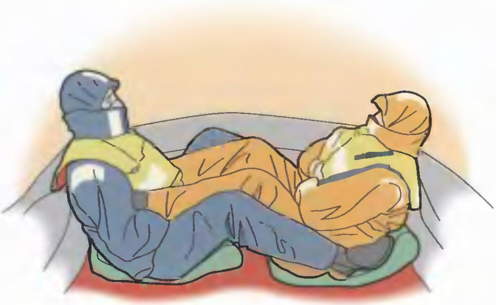

Symptoms
Feet become white as local circulation is reduced, causing swelling of tissues and numbness.

Treatment
Dry feet, use rapid rewarming, encourage gentle exercise and, if possible, give warm drinks.

As the foot warms, it will become painful.

Fractures and dislocations

Broken bones can be either open or closed fractures. If it is an open fracture, treat as for bleeding (p.133) and then immobilise the affected limb. If it is a closed fracture or a dislocation, the broad aim is to immobilise the limb to make it more comfortable.

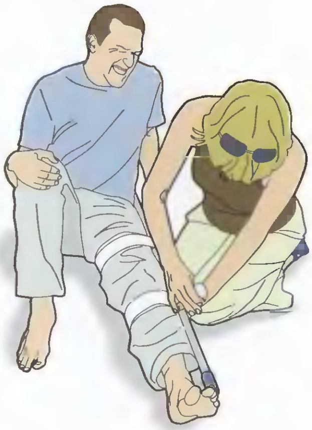

For leg fractures, the leg can be immobilised by improvising a splint from paddles and bandages, rope or strapping.

A lifejacket can be used to immobilise the lower leg. Place the ankle into the neck of the lifejacket with the lifejacket's body either side of the calf. Wrap it gently over the leg and apply strapping at the top, middle and bottom. Gently inflate the jacket by mouth until it is firm.

Seasickness

Seasickness is a debilitating illness that comes on rapidly, especially in the confines of a liferaft, at a time when the crew need to be as alert and able as they can be. If possible, take anti-seasickness medication before entering the raft or as soon as possible after boarding the raft.

Symptoms
Nausea and vomiting, pale clammy skin. Wishing never to go afloat again!

Treatment
Take anti-seasickness medication in the form of hyoscine hydrobromide. If vomiting has already started there is little point in taking more, because they are unlikely to be ingested. It's also possible that, if all the tablets are kept down, serious side effects will be experienced. Side effects can be drowsiness, dry mouth and blurred vision. Excessive doses of seasickness pills can produce hallucinations.

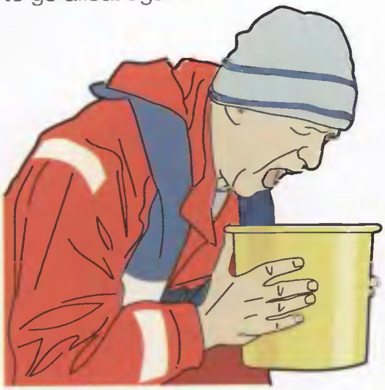

Do not attempt cardiac massage in a raft unless it has a wooden floor.

Resuscitation technique

Before attempting resuscitation, make the following checks:

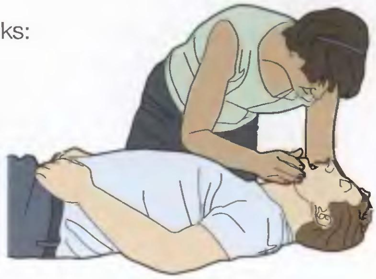

1. **Is the casualty responding to you?**

   If not, check the airway for breathing.

2. **Look at the casualty's chest. Is it moving?**

   If not, tilt the head back to open the casualty's airway. Check and remove any obstructions in the mouth.

Listen at the casualty's mouth for sounds of breathing. Hold your cheek close to their nose and mouth and feel for warm air movement. Alternatively, condensation forming on a cold mirror or metal spoon held close to their mouth and nose can also indicate breathing.

It is now accepted that if breathing is not present, circulation is not present either and that resuscitation should now be attempted. It is assumed that the casualty has suffered a cardiac arrest.

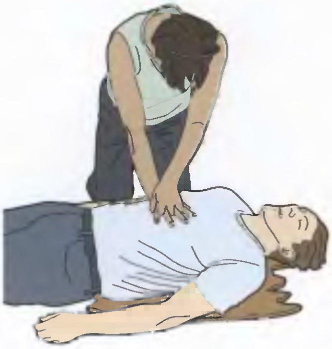

Place the heel of your hand in the centre of their chest. Place the heel of your other hand on top of the first hand. Interlock the fingers. Do not apply pressure over the upper abdomen or the bottom end of the breastbone (sternum).

Apply 30 chest compressions at the rate of 100 per minute.

Tilt the head back by placing a finger under the chin to open the casualty's airway. Allow the mouth to open but maintain chin lift.

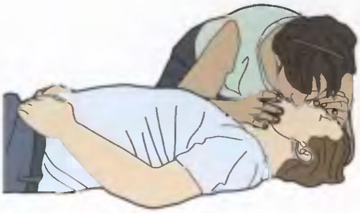

Place your mouth over casualty's mouth to achieve a good seal and blow into mouth.

Watch for the chest rising. Remove your mouth and allow the chest to fall.

Repeat the rescue breath. Start chest compressions again.

For non-drowning – generally cardiac arrest – casualties, give 30 chest compressions to two chest compressions.

For suspected drowning casualties: Check for breathing as for cardiac arrest. If not apparent, give five rescue breaths followed by one minute of chest compressions, continue until help arrives.

Pre-rescue collapse

Hypothermic casualties can suffer collapse at the thought of imminent rescue. Although not proven, it's believed that the feeling of overwhelming relief causes chemical changes within the body, which suddenly reduces blood pressure and so causes the casualty to collapse.

Circum-rescue collapse and hydrostatic squeeze

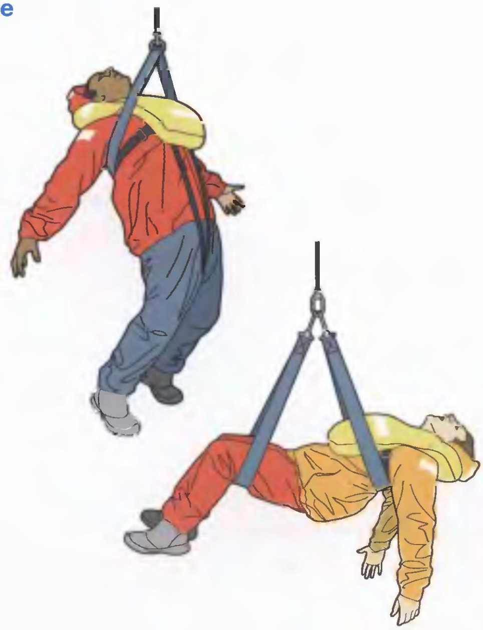

A combination of hypothermia with the sudden onset of physical action can result in some survivors collapsing and dying while being rescued.

Immersed casualties are at higher risk. In addition to the effects of hypothermia, water pressure on the lower limbs squeezes blood flow back into the body and is helping to support circulation.

When the casualty is lifted vertically from the water, the full effect of gravity creates extra strain on the heart. This may lead to unconsciousness or even death.

Immersed and hypothermic casualties should be treated with great care. If recovering from water they should be lifted horizontally to minimise the gravitational effects on the heart.

Post-rescue

Survivors are not survivors until they have survived.

Even after rescue there is a chance that the survivor will succumb to the effects of their ordeal.

This can be due to secondary drowning. Even those that show no immediate signs of aspirating seawater should be regularly checked during the hours immediately after immersion.

Rewarming survivors too quickly may result in a catastrophic drop in blood pressure. Active rewarming needs to be monitored professionally. Take care when taking hypothermic survivors into a warm cabin. Avoid warming by a shower or hot bath unless monitored by a medical professional.

Internal bleeding caused when the casualty fell into the water may not be obvious when a hypothermic MOB is recovered. If the MOB fell heavily, they should be monitored while the body rewarms. Seek medical advice.

CHAPTER 15 : Life-saving signals

These signals are used by ships, aircraft or persons in distress to communicate with rescue service stations, lifeboats, vessels and aircraft engaged in search-and-rescue operations. Use the most suitable signal for the situation and taking into account the prevailing conditions.

Search-and-rescue unit replies

These indicate that you have been seen and assistance will be given as soon as possible.

Orange smoke

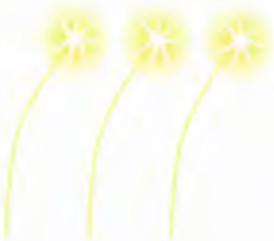

Three white pocket flares

Surface-to-air signals

These are shown by means of lights or flags or by laying out the symbol on the ground or deck in highly contrasting colours.

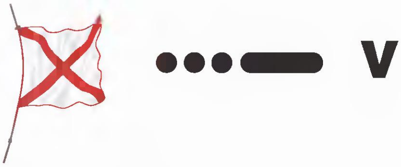

I require assistance

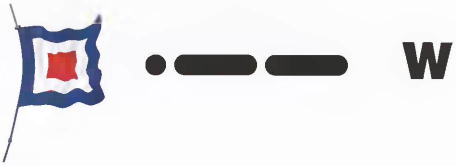

I require medical assistance

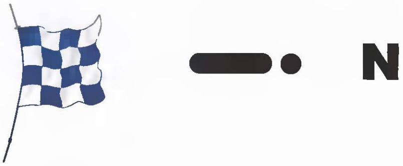

No or negative

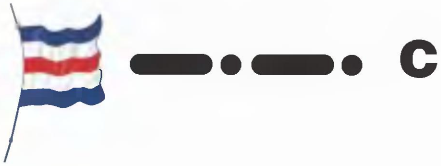

Yes or affirmative

Air-to-surface direction signals

Sequence of three manoeuvres meaning **'Go in this direction'**. May be used to show which way to go to assist another vessel or to indicate direction to a safe haven.

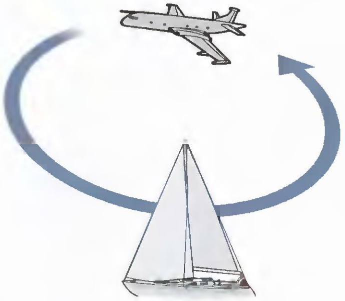

1. plane circles vessel at least once

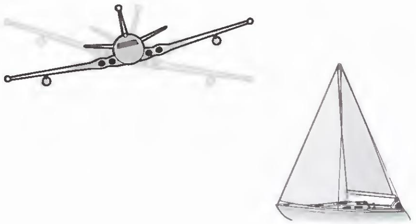

2. plane crosses low, ahead of boat, rocking wings

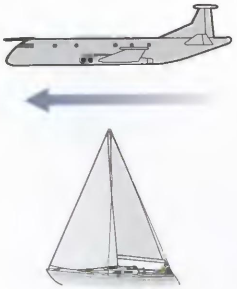

3. plane flies over boat in the direction to go

Your assistance is no longer required

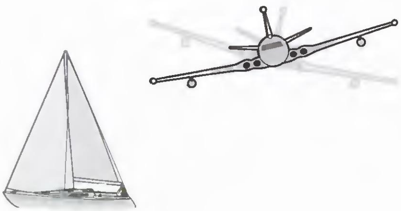

Plane crosses low, astern of vessel, rocking wings

Shore-to-ship signals

Safe to land here

Vertical waving of arms, white flag, light or flare.
Morse code letter K – dah dit dah

K – ▬ ● ▬

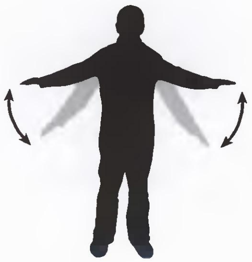

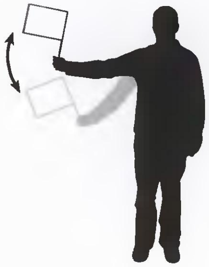

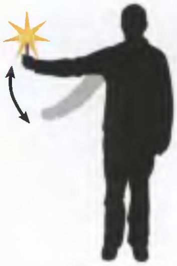

Landing here is dangerous with additional signals that indicate direction of safer landing place

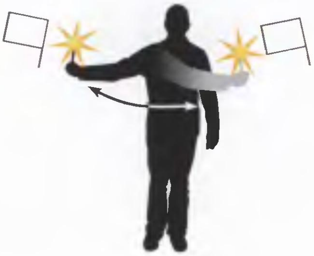

Horizontal waving of white flag, light or flare.

Go this way

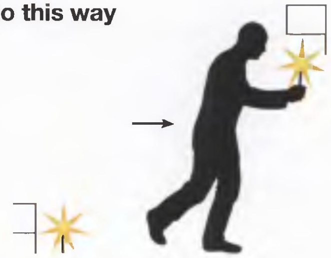

Putting one flag or flare on ground and moving in direction of safer landing area with the other indicates direction of safer landing

May also be shown by Morse code light or sound

S – ● ● ● = landing here is dangerous

R – ● ▬ ● = land to the right of your current heading

L – ● ▬ ● ● = land to the left of your current heading

Air-to-surface replies

Message understood

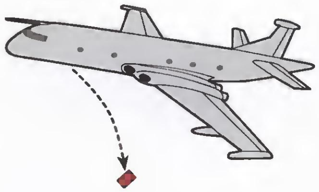

Drop a message

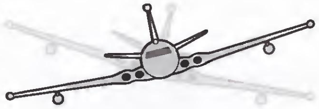

or rocking wings

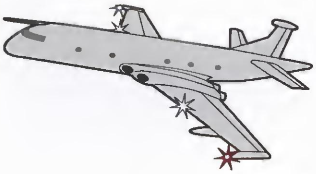

or flashing landing lights on and off twice

▬ ●▬●

T R

or Morse code by light T = dah or R = dit dah dit

Message not understood

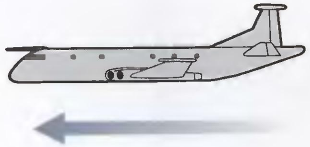

Straight and level flight

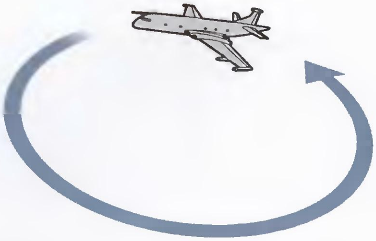

or Circling

Or Morse code by light R P T

●▬● ●▬▬● ▬

R P T

Surface-to-air replies

Message understood – I will comply
Change course to required direction
Or Morse code by light T = ▬ or code and answering pendant

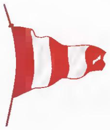

I am unable to comply
Morse code by light N = ▬● or code flag N

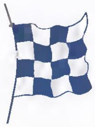

CHAPTER 16 : Rescue

Make yourself as visible as possible. An EPIRB will tell the SAR authorities where you are and who you are. But it's wise not to rely on any one system.

You will see potential rescuers before they see you. Try to make contact with them. Use flares only when there's a chance of rescuers seeing them. Use a handheld VHF and / or a signalling miror.

But be prepared for disappointment. A common theme of all survival stories is that they could have been rescued earlier if only the passing ship had seen them.

Don't celebrate early – they may not be able to pick you up and you might have to wait a few more hours. You haven't been rescued until you are safely on board the ship or helicopter.

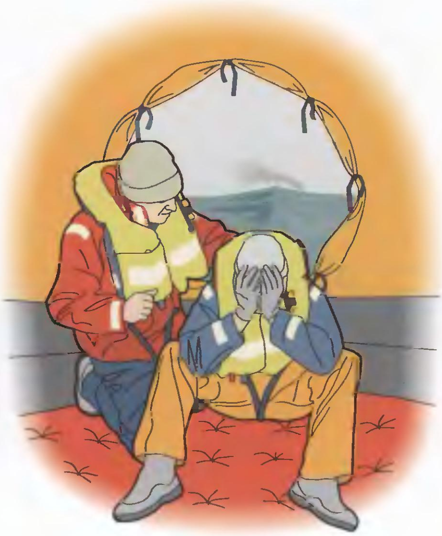

Rescue by lifeboat

If rescued by lifeboat, you'll probably see the boat searching for you before they see you. Use a handheld flare to help pinpoint your position.

If it's dark, switch on the liferaft light and use a torch to signal to them. Talk to them on a handheld VHF – they will use their direction finder to home in on you – but help confirm their bearing by telling them where you are using a hand held GPS or relative to their direction of travel. Use nautical terms. 'I am on your port bow, half a mile…' etc.

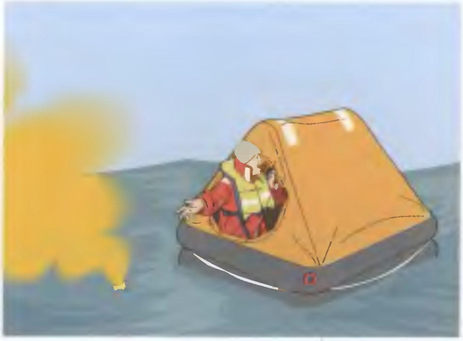

Tell them if you have injured casualties or children and the condition of the survivors. This will help the coxswain make the best plan for their evacuation. Tell them if there are any ropes or hazards around the raft – it may affect their approach.

As the lifeboat approaches, show the crew that you have a painter – assuming you cut it at the correct point when abandoning ship. The crew will then be able to secure the raft alongside during the rescue. If they throw you a heaving line, find a strongpoint and attach it – you will not have the strength to hold it while they pull the raft in.

The lifeboat will approach either head- or stern-to-wind to avoid becoming entangled in the sea anchor or other loose lines.

Rescue by ship

While many professional ships' crews practise emergency recovery, there are some that may have no idea how to go about retrieving survivors from a small boat or liferaft.

It's important to communicate effectively with them because it will be difficult for the captain and crew to appreciate the size and effects of the waves on a small vessel or liferaft.

Beware – the liferaft (or boat) can be sucked in to a lightly loaded ship's propellers.

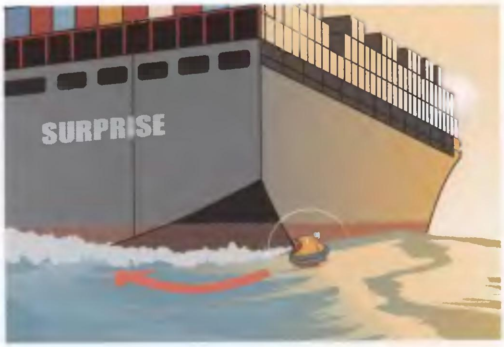

Due to exhaustion and the effects of the cold, you will not be in a fit state to climb a ship's ladder. In the excitement of the rescue, it's easy to think you can. There are many reported cases where survivors have tried to climb the ladder only to be lost when they fall off it after climbing only a few rungs.

The ship may be able to lower a basket or a cargo net to lift everyone in together. A large net can lift the whole raft with the survivors inside.

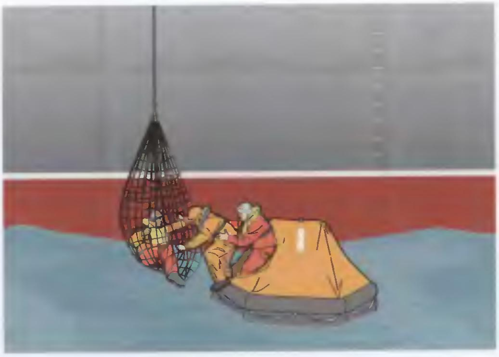

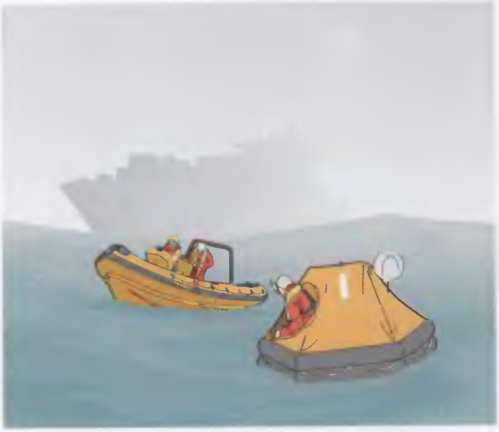

The best option is for the ship to lower a fast rescue craft that will come to the raft and pick up survivors. The ship will stand off and create a lee for the rescue boat to work. The rescue craft, its crew and the survivors will then be lifted back on board. This avoids exerting the survivors. Remember to take your small grab bag with ID documents etc.

Hypothermic casualties should lie down in the rescue boat with their heads towards the stern of the boat.

Rescue by helicopter

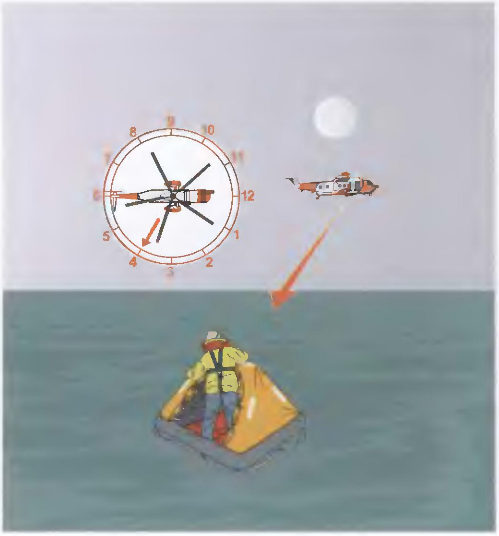

As with lifeboat rescue, the helicopter may have difficulty seeing you. If a 406/121.5 EPIRB or PLB is available, make sure it's switched on and operating. Switch on the liferaft lights – they may seem dim to you but a pilot using night-vision goggles will see them clearly, use your torch to signal to the helicopter.

If you have one, use a handheld VHF to communicate with the helicopter. Pilots use clock notation. For example, 'We are lying at your 4 o'clock'.

Use orange smoke – during the day – or handheld red flares to pinpoint your position.

Do not fire parachute rocket flares if the helicopter is within a short distance.
A rocket flare has the capability to down a helicopter.
At night, a bright flare can blind a pilot wearing night-vision goggles. If in radio contact, ask before firing a hand-held flare. It probably will not be necessary.

The helicopter crew will instruct you what to do. Do as they say – they are the experts.

Take care not to all crowd to one side of the raft or dinghy – the prevailing wind and the downdraught of the helicopter may be enough to turn the raft over.

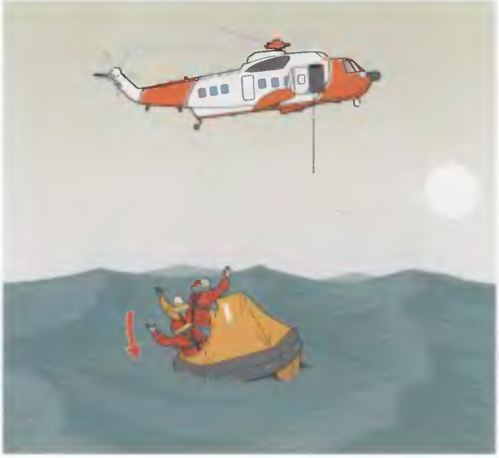

Most SAR helicopters will lower a winch man into the raft. Be aware that some countries' SAR units use different methods. Some may drop a rescue diver first, others may use a rescue basket.

> Helicopters quickly build a charge of static electricity. Do not grab the winch man until he has 'earthed' into the water.

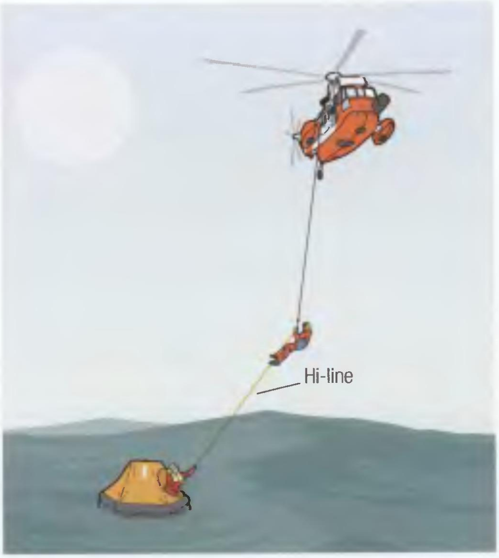

If the helicopter is using a 'hi-line' to help guide and steady the winch man, hold on to the line while the winch man is pulled back up to the helicopter. Do not tie it to the raft, and make sure it does not become tangled with the remaining casualties.

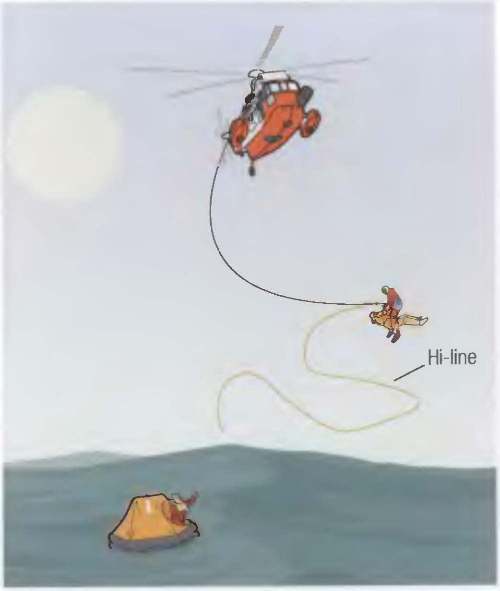

If the winch man suspects a casualty is hypothermic he will lift them in a horizontal position either in a stretcher or use a double strop – one underneath the arms and one under the back of the knees.

GLOSSARY

bear away	turn the boat downwind
bilge pump	pump for removing water from inside hull
bow thruster	an impellor mounted sideways in a tube below the waterline in the bow to assist manoeuvring
cleat	a fitting to which ropes are attached
coachroof	cabin roof
cold-water shock	physiological reaction to immersion in cold water
companionway	entrance to cabin, generally down steps
dan buoy	highly visible float thrown to a man overboard
datum point	marked position on which sector search is based
diving reflex	involuntary breathing reaction when falling into cold water
drogue	funnel shaped canvas device trailed from stern to help prevent craft from slewing sideways in following sea
DSC	Digital Selective Calling – automated VHF radio facility
EDR	Expected Detection Range
EPIRB	Emergency Position Indicating Radio Beacon – satellite-based location system
fairlead	metal fitting used to guide rope
fulcrum	pivot point
GMDSS	Global Maritime Distress and Safety System
GPS	Global Positioning System – satellite-based navigation system
grab bag	watertight buoyant bag for stowing essential items for emergency use
Granny bar	crew support bar around mast
gunwale	top edge of hull

halyard	rope for raising or lowering sail
handybilly	block and tackle
heaving to	bring boat to a standstill
heliograph	signalling system using mirror to reflect sun's rays
HELP position	Heat Escape Lessening Posture – position adopted in water
'hi-line'	winching technique used by SAR helicopters
HRU (hydrostatic release unit)	device triggered by immersion in water
hydrostatic squeeze	condition where water pressure on lower limbs squeezing blood back into body is removed, thereby placing strain on the heart
hypothermia	condition of having body temperature reduced to dangerously low level
immersion foot	condition caused by continuous contact with cold and wet environment
immersion suit	waterproof insulated emergency survival suit
ISAF	International Sailing Federation
ISO	International Standards Organisation
jackstay	line at deck level for attaching lifelines
jury-rig	makeshift repair, e.g. to sails or steering
kicker	control pulling boom downwards (also vang)
leeward	downwind direction
luffing	heading into wind
Mayday call	distress call
MMSI number	Maritime Mobile Service Identities number
MOB	man overboard

moment of inertia	force of rotation of boat dependent on weight of mast, keel etc.
ORC	Offshore Racing Congress
painter	mooring line attached to dinghy or liferaft
Pan Pan call	radio call seeking assistance
parbuckle	sling of canvas or rope used for raising objects
PEPIRB	Personal Emergency Position Indicating Radio Beacon – satellite-based location system (see PLB)
pitch-poling	capsizing with bow going over stern
PLB	Personal Locator Beacon – satellite-based or surface-based emergency location system
PRV	pressure-relief valve
reefing pennant	rope used to assist in reducing sail
RNLI	Royal National Lifeboat Institution
roller headsail	sail in front of mast set or reduced from a roller device
SAR	search and rescue
SART	Search-and-Rescue Radar Transponder – alert and position-finding electronic device
scandalise the boom	raise the outer end of the boom
sea anchor	parachute-like device deployed from bow to keep head-to-wind and reduce possibility of capsize or pitch-poling
seacock	valve in hull controlling seawater flow into boat
secondary drowning	physiological reaction caused by presence of water in lungs
Senhouse slip	release attachment for straps etc
shrouds	wires holding up the mast at sides of boat

signal card	card showing meanings of signals from ships and aircraft
snap shackle	fitting allowing quick attachment/removal of rope
solar still	solar-operated device for extracting potable water from seawater
SOLAS	Safety of Life at Sea Convention
sponson	inflated hull section of inflatable craft
spreaders	mast fittings guiding rigging from hull to mast head
stanchion	post supporting guardrail
steerage	steering effectiveness dependent on flow of water past rudder
storm jib	small sail set before mast for storm conditions
strum box	bilge pump filter
tack	change direction by bringing the wind around the front of the boat
topping lift	rope that holds the boom up when the sail is down
TPA	thermal protective aid – insulated bag-like suit for casualties
trysail	small loose-footed sail set in place of mainsail for storm conditions
turnbuckle	device for adjusting tension in rigging
vang	control pulling boom downwards (also kicker)
warp	mooring line
washboard	removable board at top of companionway to minimise ingress of water into cabin
Williamson turn	manoeuvre by powered craft to turn onto reciprocal track

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British Marine Federation
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The Radio Licensing Centre
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CHIRP - Confidential Human Factors Incident Reporting Programme
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United States Coast Guard Boating Safety
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EPIRB registration

International
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or by calling 1-888-212-SAVE

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Email: 406registry@msa.govt.nz

Useful Websites

Safety of Life at Sea Convention
Web: www.imo.org

Marine Accident Investigation Branch
Web: www.maib.gov.uk

First Aid
St John Ambulance
Web: www.sja.org.uk

BBC Health - First Aid
Web: www.bbc.co.uk/health/first_aid/index.shtml

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U.S. Department
of Transportation
FEDERAL AVIATION
ADMINISTRATION

Instrument Flying Handbook

2008

U.S. Department of Transportation
FEDERAL AVIATION ADMINISTRATION
Flight Standards Service

Preface

This Instrument Flying Handbook is designed for use by instrument flight instructors and pilots preparing for instrument rating tests. Instructors may find this handbook a valuable training aid as it includes basic reference material for knowledge testing and instrument flight training. Other Federal Aviation Administration (FAA) publications should be consulted for more detailed information on related topics.

This handbook conforms to pilot training and certification concepts established by the FAA. There are different ways of teaching, as well as performing, flight procedures and maneuvers and many variations in the explanations of aerodynamic theories and principles. This handbook adopts selected methods and concepts for instrument flying. The discussion and explanations reflect the most commonly used practices and principles. Occasionally the word "must" or similar language is used where the desired action is deemed critical. The use of such language is not intended to add to, interpret, or relieve a duty imposed by Title 14 of the Code of Federal Regulations (14 CFR).

All of the aeronautical knowledge and skills required to operate in instrument meteorological conditions (IMC) are detailed. Chapters are dedicated to human and aerodynamic factors affecting instrument flight, the flight instruments, attitude instrument flying for airplanes, basic flight maneuvers used in IMC, attitude instrument flying for helicopters, navigation systems, the National Airspace System (NAS), the air traffic control (ATC) system, instrument flight rules (IFR) flight procedures, and IFR emergencies. Clearance shorthand and an integrated instrument lesson guide are also included.

This handbook supersedes FAA-H-8081-15A, Instrument Flying Handbook, dated 2007.

This handbook may be purchased from the Superintendent of Documents, United States Government Printing Office (GPO), Washington, DC 20402-9325, or from GPO's web site.

http://bookstore.gpo.gov

This handbook is also available for download, in PDF format, from the Regulatory Support Division's (AFS-600) web site.

http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs600

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Page 2-3, correction to paragraph concerning induced drag.

Page 2-7, corrections made to Figure 2-8. Thrust and Power Required Curves.

Page 2-11, correction to paragraph concerning the coordination of rudder and aileron controls.

Page 2-12, correction to Figure 2-15. Adverse Yaw.

Page 3-4, correction to Figure 3-3. Sensitive Altimeter Components.

Page 3-5, correction to Figure 3-6. The loss of altitude experienced when flying into an area where the air is colder (more dense) than standard.

Page 4-2, correction to Figure 4-1. Control Instruments.

Page 4-3, correction to Figure 4-2. Performance Instruments.

Page 4-18, correction to Figure 4-25. Control Instruments.

Page 6-11, correction to Figure 6-12. Flight instrument indications in a stabilized constant-airspeed climb.

Page 6-12, correction to Figure 6-13. Flight Instrument Indications in a Stabilized Constant-Rate Climb.

Page 7-7, correction to Figure 7-7. ADF Tracking Inbound.

Page 7-9, corrections made to Figure 7-8. ADF Interception and Tracking Outbound.

Page 7-13, correction made to Figure 7-15. CDI Interpretation.

Page 7-15, correction made to Figure 7-16. Course Interception (VOR).

Page 7-18, correction made to Figure 7-18. Using DME and RMI to Maintain an Arc.

Page 7-27, correction made to paragraph concerning GPS Components.

Page 7-41, corrections made to Figure 7-37. Precision and Nonprecision ALS Configuration.

Page 10-12, correction made to paragraph concerning a parallel procedure.

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Introduction

Is an Instrument Rating Necessary?

The answer to this question depends entirely upon individual needs. Pilots may not need an instrument rating if they fly in familiar uncongested areas, stay continually alert to weather developments, and accept an alternative to their original plan. However, some cross-country destinations may take a pilot to unfamiliar airports and/or through high activity areas in marginal visual or instrument meteorological conditions (IMC). Under these conditions, an instrument rating may be an alternative to rerouting, rescheduling, or canceling a flight. Many accidents are the result of pilots who lack the necessary skills or equipment to fly in marginal visual meteorological conditions (VMC) or IMC and attempt flight without outside references.

Pilots originally flew aircraft strictly by sight, sound, and feel while comparing the aircraft's attitude to the natural horizon. As aircraft performance increased, pilots required more inflight information to enhance the safe operation of their aircraft. This information has ranged from a string tied to a wing strut, to development of sophisticated electronic flight information systems (EFIS) and flight management systems (FMS). Interpretation of the instruments and aircraft control have advanced from the "one, two, three" or "needle, ball, and airspeed" system to the use of "attitude instrument flying" techniques.

Navigation began by using ground references with dead reckoning and has led to the development of electronic navigation systems. These include the automatic direction finder (ADF), very-high frequency omnidirectional range (VOR), distance measuring equipment (DME), tactical air navigation (TACAN), long range navigation (LORAN), global positioning system (GPS), instrument landing system (ILS), microwave landing system (MLS), and inertial navigation system (INS).

Perhaps you want an instrument rating for the same basic reason you learned to fly in the first place—because you like flying. Maintaining and extending your proficiency, once you have the rating, means less reliance on chance and more on skill and knowledge. Earn the rating—not because you might need it sometime, but because it represents achievement and provides training you will use continually and build upon as long as you fly. But most importantly it means greater safety in flying.

Instrument Rating Requirements

A private or commercial pilot must have an instrument rating and meet the appropriate currency requirements if that pilot operates an aircraft using an instrument flight rules (IFR) flight plan in conditions less than the minimums prescribed for visual flight rules (VFR), or in any flight in Class A airspace.

You will need to carefully review the aeronautical knowledge and experience requirements for the instrument rating as outlined in Title 14 of the Code of Federal Regulations (14 CFR) part 61. After completing the Federal Aviation Administration (FAA) Knowledge Test issued for the instrument rating, and all the experience requirements have been satisfied, you are eligible to take the practical test. The regulations specify minimum total and pilot-in-command time requirements. This minimum applies to all applicants regardless of ability or previous aviation experience.

Training for the Instrument Rating

A person who wishes to add the instrument rating to his or her pilot certificate must first make commitments of time, money, and quality of training. There are many combinations of training methods available. Independent studies may be adequate preparation to pass the required FAA Knowledge Test for the instrument rating. Occasional periods of ground and flight instruction may provide the skills necessary to pass the required test. Or, individuals may choose a training facility that provides comprehensive aviation education and the training necessary to ensure the pilot will pass all the required tests and operate safely in the National Airspace System (NAS). The aeronautical knowledge may be administered by educational institutions, aviation-oriented schools, correspondence courses, and appropriately rated instructors. Each person must decide for themselves which training program best meets his or her needs and at the same time maintain a high quality of training. Interested persons should make inquiries regarding the available training at nearby airports, training facilities, in aviation publications, and through the FAA Flight Standards District Office (FSDO).

Although the regulations specify minimum requirements, the amount of instructional time needed is determined not by the regulation, but by the individual's ability to achieve a satisfactory level of proficiency. A professional pilot with diversified flying experience may easily attain a satisfactory level of proficiency in the minimum time required by regulation. Your own time requirements will depend upon a variety of factors, including previous flying experience, rate of learning, basic ability, frequency of flight training, type of aircraft flown, quality of ground school training, and quality of flight instruction, to name a few. The total instructional time you will need, the scheduling of such time, is up to the individual most qualified to judge your proficiency—the instructor who supervises your progress and endorses your record of flight training.

You can accelerate and enrich much of your training by informal study. An increasing number of visual aids and programmed instrument courses is available. The best course is one that includes a well-integrated flight and ground school curriculum. The sequential nature of the learning process requires that each element of knowledge and skill be learned and applied in the right manner at the right time.

Part of your instrument training may utilize a flight simulator, flight training device, or a personal computer-based aviation training device (PCATD). This ground-based flight training equipment is a valuable tool for developing your instrument cross-check and learning procedures, such as intercepting and tracking, holding patterns, and instrument approaches. Once these concepts are fully understood, you can then continue with inflight training and refine these techniques for full transference of your new knowledge and skills.

Holding the instrument rating does not necessarily make you a competent all-weather pilot. The rating certifies only that you have complied with the minimum experience requirements, that you can plan and execute a flight under IFR, that you can execute basic instrument maneuvers, and that you have shown acceptable skill and judgment in performing these activities. Your instrument rating permits you to fly into instrument weather conditions with no previous instrument weather experience. Your instrument rating is issued on the assumption that you have the good judgment to avoid situations beyond your capabilities. The instrument training program you undertake should help you to develop not only essential flying skills but also the judgment necessary to use the skills within your own limits.

Regardless of the method of training selected, the curriculum in Appendix B, Instrument Training Lesson Guide, provides guidance as to the minimum training required for the addition of an instrument rating to a private or commercial pilot certificate.

Maintaining the Instrument Rating

Once you hold the instrument rating, you may not act as pilot-in-command under IFR or in weather conditions less than the minimums prescribed for VFR, unless you meet the recent flight experience requirements outlined in 14 CFR part 61. These procedures must be accomplished within the preceding 6 months and include six instrument approaches, holding procedures, and intercepting and tracking courses through the use of navigation systems. If you do not meet the experience requirements during these 6 months, you have another 6 months to meet these minimums. If the requirements are still not met, you must pass an instrument proficiency check, which is an inflight evaluation by a qualified instrument flight instructor using tasks outlined in the instrument rating practical test standards (PTS).

The instrument currency requirements must be accomplished under actual or simulated instrument conditions. You may log instrument flight time during the time for which you control the aircraft solely by reference to the instruments. This can be accomplished by wearing a view-limiting device, such as a hood, flying an approved flight-training device, or flying in actual IMC.

It takes only one harrowing experience to clarify the distinction between minimum practical knowledge and a thorough understanding of how to apply the procedures and techniques used in instrument flight. Your instrument training is never complete; it is adequate when you have absorbed every foreseeable detail of knowledge and skill to ensure a solution will be available if and when you need it.

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Tubular ducts containing endolymph
Utricle
Saccule
Cochlea
Ampullae
Pilot capabilities
Margin of Safety
Effort
Task requirements
Time
Preflight
Takeoff
Cruise
Approach & Landing

Chapter 1

Human Factors

Introduction

Human factors is a broad field that examines the interaction between people, machines, and the environment for the purpose of improving performance and reducing errors. As aircraft became more reliable and less prone to mechanical failure, the percentage of accidents related to human factors increased. Some aspect of human factors now accounts for over 80 percent of all accidents. Pilots who have a good understanding of human factors are better equipped to plan and execute a safe and uneventful flight.

Flying in instrument meteorological conditions (IMC) can result in sensations that are misleading to the body's sensory system. A safe pilot needs to understand these sensations and effectively counteract them. Instrument flying requires a pilot to make decisions using all available resources.

The elements of human factors covered in this chapter include sensory systems used for orientation, illusions in flight, physiological and psychological factors, medical factors, aeronautical decision-making, and crew resource management (CRM).

Sensory Systems for Orientation

Orientation is the awareness of the position of the aircraft and of oneself in relation to a specific reference point. Disorientation is the lack of orientation, and spatial disorientation specifically refers to the lack of orientation with regard to position in space and to other objects.

Orientation is maintained through the body's sensory organs in three areas: visual, vestibular, and postural. The eyes maintain visual orientation. The motion sensing system in the inner ear maintains vestibular orientation. The nerves in the skin, joints, and muscles of the body maintain postural orientation. When healthy human beings are in their natural environment, these three systems work well. When the human body is subjected to the forces of flight, these senses can provide misleading information. It is this misleading information that causes pilots to become disoriented.

Eyes

Of all the senses, vision is most important in providing information to maintain safe flight. Even though the human eye is optimized for day vision, it is also capable of vision in very low light environments. During the day, the eye uses receptors called cones, while at night, vision is facilitated by the use of rods. Both of these provide a level of vision optimized for the lighting conditions that they were intended. That is, cones are ineffective at night and rods are ineffective during the day.

Rods, which contain rhodopsin (called visual purple), are especially sensitive to light and increased light washes out the rhodopsin compromising the night vision. Hence, when strong light is momentarily introduced at night, vision may be totally ineffective as the rods take time to become effective again in darkness. Smoking, alcohol, oxygen deprivation, and age affect vision, especially at night. It should be noted that at night, oxygen deprivation such as one caused from a climb to a high altitude causes a significant reduction in vision. A return back to the lower altitude will not restore a pilot's vision in the same transitory period used at the climb altitude.

The eye also has two blind spots. The day blind spot is the location on the light sensitive retina where the optic nerve fiber bundle (which carries messages from the eye to the brain) passes through. This location has no light receptors, and a message cannot be created there to be sent to the brain. The night blind spot is due to a concentration of cones in an area surrounding the fovea on the retina. Because there are no rods in this area, direct vision on an object at night will disappear. As a result, off-center viewing and scanning at night is best for both obstacle avoidance and to maximize situational awareness. [See the Pilot's Handbook of Aeronautical Knowledge and the Aeronautical Information Manual (AIM) for detailed reading.]

The brain also processes visual information based upon color, relationship of colors, and vision from objects around us. *Figure 1-1* demonstrates the visual processing of information. The brain assigns color based on many items to include an object's surroundings. In the figure below, the orange square on the shaded side of the cube is actually the same color as the brown square in the center of the cube's top face.

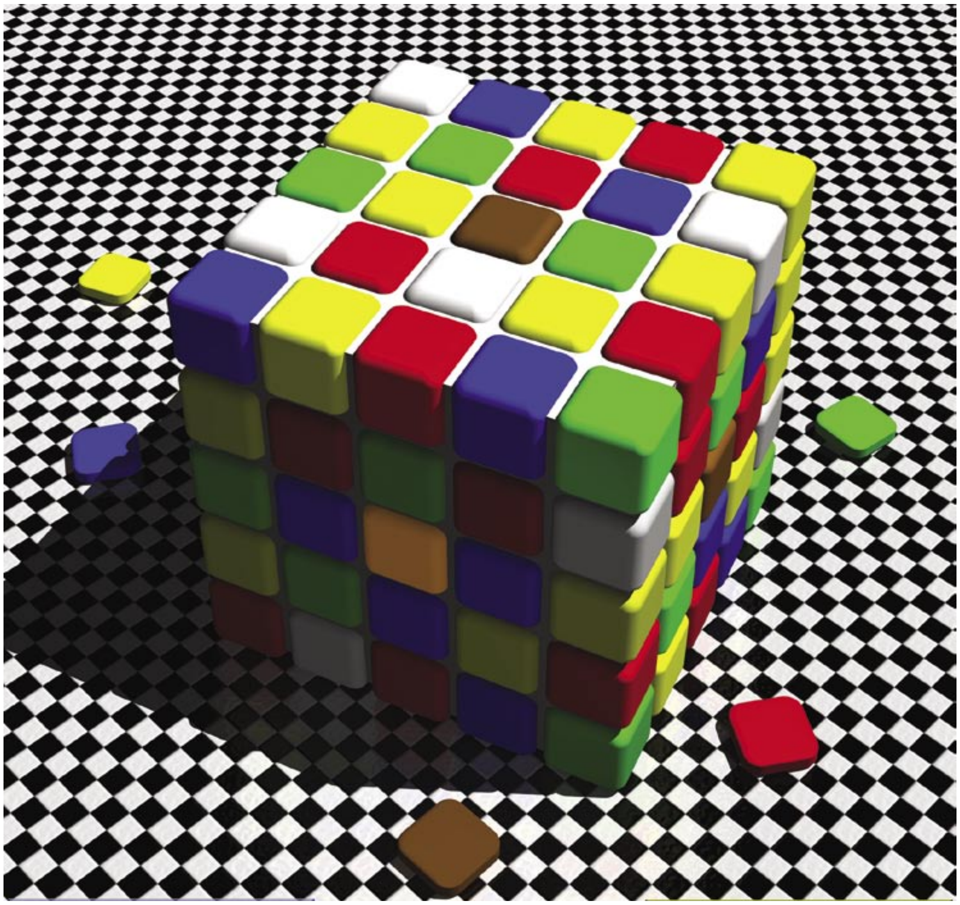

Figure 1-1. *Rubik's Cube Graphic.*

Isolating the orange square from surrounding influences will reveal that it is actually brown. The application to a real environment is evident when processing visual information that is influenced by surroundings. The ability to pick out an airport in varied terrain or another aircraft in a light haze are examples of problems with interpretation that make vigilance all the more necessary.

Figure 1-2 illustrates problems with perception. Both tables are the same lengths. Objects are easily misinterpreted in size to include both length and width. Being accustomed to a 75-foot-wide runway on flat terrain is most likely going to influence a pilot's perception of a wider runway on uneven terrain simply because of the inherent processing experience.

Vision Under Dim and Bright Illumination

Under conditions of dim illumination, aeronautical charts and aircraft instruments can become unreadable unless adequate flight deck lighting is available. In darkness, vision becomes more sensitive to light. This process is called dark adaptation. Although exposure to total darkness for at least 30 minutes is required for complete dark adaptation, a pilot can achieve a moderate degree of dark adaptation within 20 minutes under dim red flight deck lighting.

Red light distorts colors (filters the red spectrum), especially on aeronautical charts, and makes it very difficult for the eyes to focus on objects inside the aircraft. Pilots should use it only where optimum outside night vision capability is necessary. White flight deck lighting (dim lighting) should be available when needed for map and instrument reading, especially under IMC conditions.

Since any degree of dark adaptation is lost within a few seconds of viewing a bright light, pilots should close one eye when using a light to preserve some degree of night vision. During night flights in the vicinity of lightning, flight deck lights should be turned up to help prevent loss of night vision due to the bright flashes. Dark adaptation is also impaired by exposure to cabin pressure altitudes above 5,000 feet, carbon monoxide inhaled through smoking, deficiency of Vitamin A in the diet, and by prolonged exposure to bright sunlight.

During flight in visual meteorological conditions (VMC), the eyes are the major orientation source and usually provide accurate and reliable information. Visual cues usually prevail over false sensations from other sensory systems. When these visual cues are taken away, as they are in IMC, false sensations can cause the pilot to quickly become disoriented.

An effective way to counter these false sensations is to recognize the problem, disregard the false sensations, rely on the flight instruments, and use the eyes to determine the aircraft attitude. The pilot must have an understanding of the problem and the skill to control the aircraft using only instrument indications.

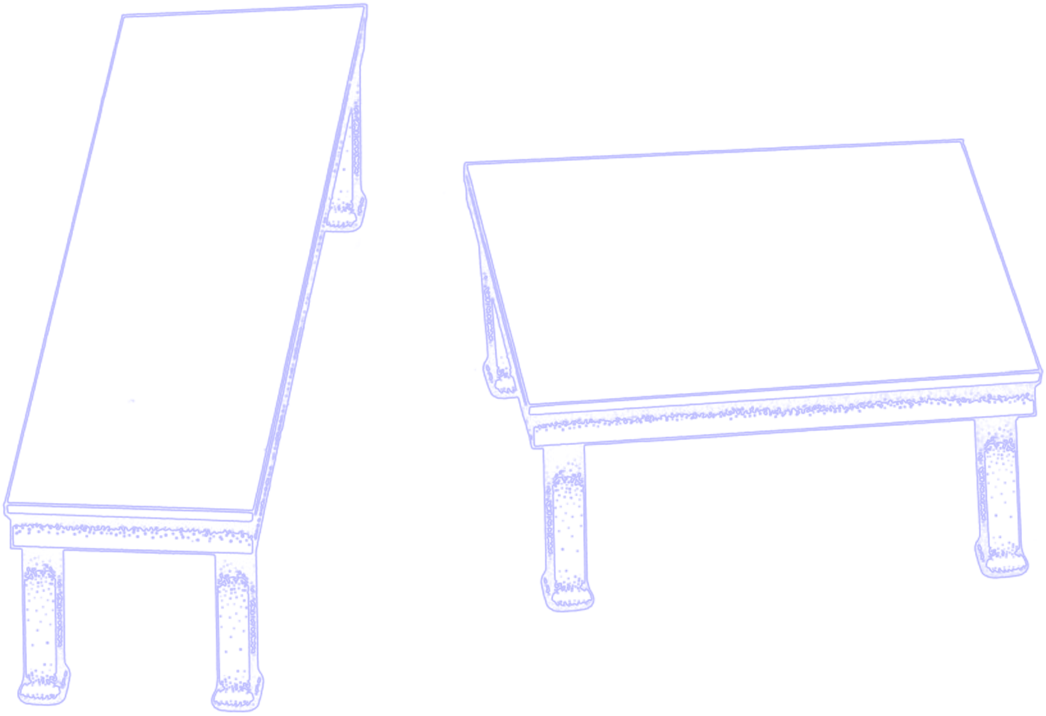

Figure 1-2. *Shepard's Tables.*

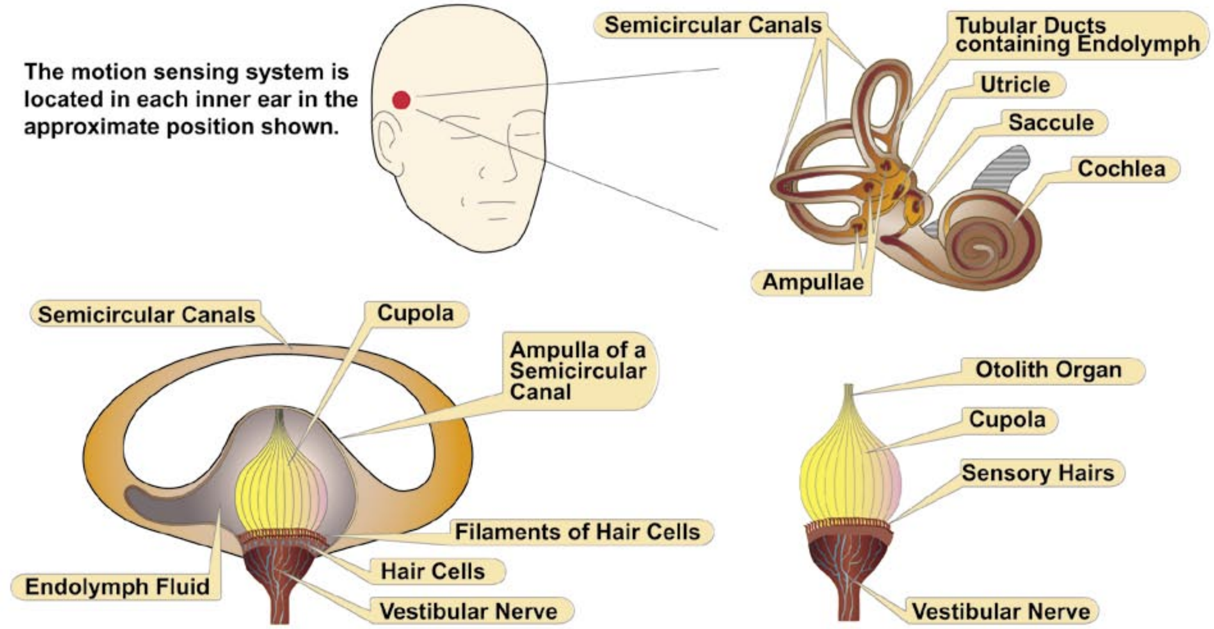
The motion sensing system is located in each inner ear in the approximate position shown.
Semicircular Canals
Tubular Ducts containing Endolymph
Utricle
Saccule
Cochlea
Ampullae
Semicircular Canals
Cupola
Ampulla of a Semicircular Canal
Filaments of Hair Cells
Hair Cells
Endolymph Fluid
Vestibular Nerve
Otolith Organ
Cupola
Sensory Hairs
Vestibular Nerve

Figure 1-3. *Inner Ear Orientation.*

Ears

The inner ear has two major parts concerned with orientation, the semicircular canals and the otolith organs. *[Figure 1-3]* The semicircular canals detect angular acceleration of the body while the otolith organs detect linear acceleration and gravity. The semicircular canals consist of three tubes at right angles to each other, each located on one of three axes: pitch, roll, or yaw as illustrated in *Figure 1-4*. Each canal is filled with a fluid called endolymph fluid. In the center of the canal is the cupola, a gelatinous structure that rests upon sensory hairs located at the end of the vestibular nerves. It is the movement of these hairs within the fluid which causes sensations of motion.

Because of the friction between the fluid and the canal, it may take about 15–20 seconds for the fluid in the ear canal to reach the same speed as the canal's motion.

To illustrate what happens during a turn, visualize the aircraft in straight and level flight. With no acceleration of the aircraft, the hair cells are upright and the body senses that no turn has occurred. Therefore, the position of the hair cells and the actual sensation correspond.

Placing the aircraft into a turn puts the semicircular canal and its fluid into motion, with the fluid within the semicircular canal lagging behind the accelerated canal walls.*[Figure 1-5]* This lag creates a relative movement of the fluid within the canal. The canal wall and the cupula move in the opposite direction from the motion of the fluid.

The brain interprets the movement of the hairs to be a turn in the same direction as the canal wall. The body correctly senses that a turn is being made. If the turn continues at a constant rate for several seconds or longer, the motion of the fluid in

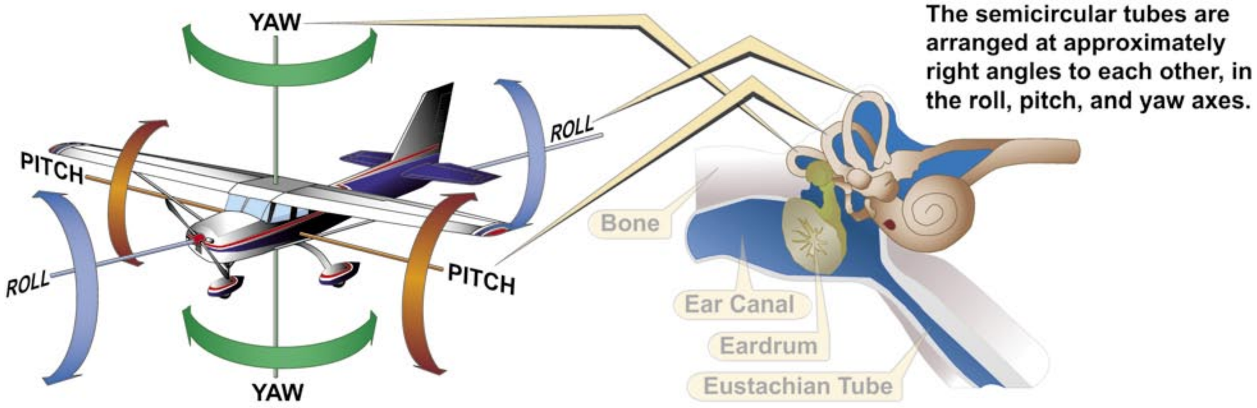
YAW
The semicircular tubes are arranged at approximately right angles to each other, in the roll, pitch, and yaw axes.
ROLL
PITCH
Bone
ROLL
PITCH
Ear Canal
Eardrum
Eustachian Tube
YAW

Figure 1-4. *Angular Acceleration and the Semicircular Tubes.*

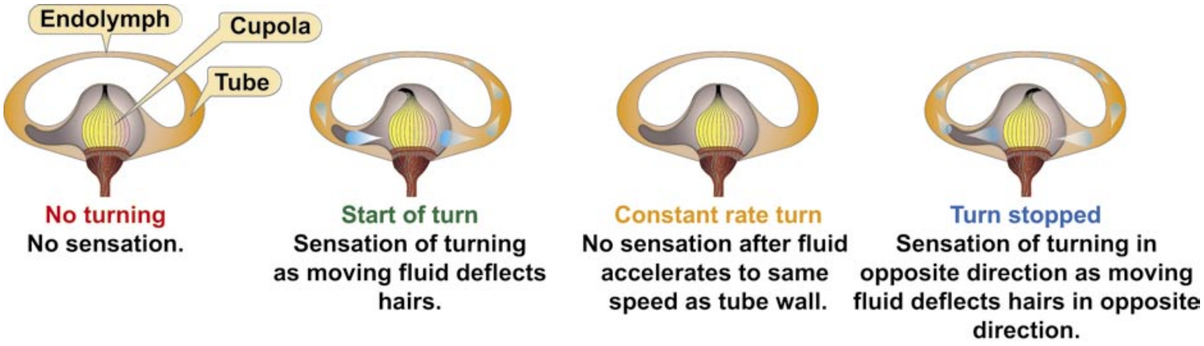
Endolymph
Cupola
Tube
No turning
No sensation.
Start of turn
Sensation of turning as moving fluid deflects hairs.
Constant rate turn
No sensation after fluid accelerates to same speed as tube wall.
Turn stopped
Sensation of turning in opposite direction as moving fluid deflects hairs in opposite direction.

Figure 1-5. *Angular Acceleration.*

the canals catches up with the canal walls. The hairs are no longer bent, and the brain receives the false impression that turning has stopped. Thus, the position of the hair cells and the resulting sensation during a prolonged, constant turn in either direction will result in the false sensation of no turn.

When the aircraft returns to straight-and-level flight, the fluid in the canal moves briefly in the opposite direction. This sends a signal to the brain that is falsely interpreted as movement in the opposite direction. In an attempt to correct the falsely perceived turn, the pilot may reenter the turn placing the aircraft in an out of control situation.

The otolith organs detect linear acceleration and gravity in a similar way. Instead of being filled with a fluid, a gelatinous membrane containing chalk-like crystals covers the sensory hairs. When the pilot tilts his or her head, the weight of these crystals causes this membrane to shift due to gravity and the sensory hairs detect this shift. The brain orients this new position to what it perceives as vertical. Acceleration and deceleration also cause the membrane to shift in a similar manner. Forward acceleration gives the illusion of the head tilting backward. *[Figure 1-6]* As a result, during takeoff and while accelerating, the pilot may sense a steeper than normal climb resulting in a tendency to nose-down.

Nerves

Nerves in the body's skin, muscles, and joints constantly send signals to the brain, which signals the body's relation to gravity. These signals tell the pilot his or her current position. Acceleration will be felt as the pilot is pushed back into the seat. Forces created in turns can lead to false sensations of the true direction of gravity, and may give the pilot a false sense of which way is up.

Uncoordinated turns, especially climbing turns, can cause misleading signals to be sent to the brain. Skids and slips give the sensation of banking or tilting. Turbulence can create motions that confuse the brain as well. Pilots need to be aware that fatigue or illness can exacerbate these sensations and ultimately lead to subtle incapacitation.

Illusions Leading to Spatial Disorientation

The sensory system responsible for most of the illusions leading to spatial disorientation is the vestibular system. Visual illusions can also cause spatial disorientation.

Vestibular Illusions

The Leans

A condition called the leans can result when a banked attitude, to the left for example, may be entered too slowly to set in motion the fluid in the "roll" semicircular tubes. *[Figure 1-5]* An abrupt correction of this attitude sets the fluid in motion, creating the illusion of a banked attitude to the right. The disoriented pilot may make the error of rolling the aircraft into the original left banked attitude, or if level flight is maintained, will feel compelled to lean in the perceived vertical plane until this illusion subsides.

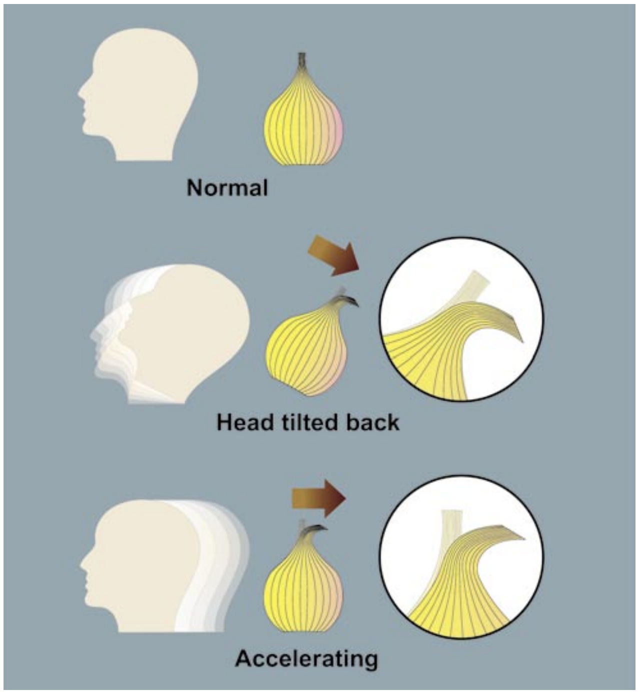
Normal
Head tilted back
Accelerating

Figure 1-6. *Linear Acceleration.*

Coriolis Illusion

The coriolis illusion occurs when a pilot has been in a turn long enough for the fluid in the ear canal to move at the same speed as the canal. A movement of the head in a different plane, such as looking at something in a different part of the flight deck, may set the fluid moving and create the illusion of turning or accelerating on an entirely different axis. This action causes the pilot to think the aircraft is doing a maneuver that it is not. The disoriented pilot may maneuver the aircraft into a dangerous attitude in an attempt to correct the aircraft's perceived attitude.

For this reason, it is important that pilots develop an instrument cross-check or scan that involves minimal head movement. Take care when retrieving charts and other objects in the flight deck—if something is dropped, retrieve it with minimal head movement and be alert for the coriolis illusion.

Graveyard Spiral

As in other illusions, a pilot in a prolonged coordinated, constant rate turn, will have the illusion of not turning. During the recovery to level flight, the pilot will experience the sensation of turning in the opposite direction. The disoriented pilot may return the aircraft to its original turn. Because an aircraft tends to lose altitude in turns unless the pilot compensates for the loss in lift, the pilot may notice a loss of altitude. The absence of any sensation of turning creates the illusion of being in a level descent. The pilot may pull back on the controls in an attempt to climb or stop the descent. This action tightens the spiral and increases the loss of altitude; hence, this illusion is referred to as a graveyard spiral. *[Figure 1-7]* At some point, this could lead to a loss of control by the pilot.

Somatogravic Illusion

A rapid acceleration, such as experienced during takeoff, stimulates the otolith organs in the same way as tilting the head backwards. This action creates the somatogravic illusion of being in a nose-up attitude, especially in situations without good visual references. The disoriented pilot may push the aircraft into a nose-low or dive attitude. A rapid deceleration by quick reduction of the throttle(s) can have the opposite effect, with the disoriented pilot pulling the aircraft into a nose-up or stall attitude.

Inversion Illusion

An abrupt change from climb to straight-and-level flight can stimulate the otolith organs enough to create the illusion of tumbling backwards, or inversion illusion. The disoriented pilot may push the aircraft abruptly into a nose-low attitude, possibly intensifying this illusion.

Elevator Illusion

An abrupt upward vertical acceleration, as can occur in an updraft, can stimulate the otolith organs to create the illusion of being in a climb. This is called elevator illusion. The disoriented pilot may push the aircraft into a nose-low attitude. An abrupt downward vertical acceleration, usually

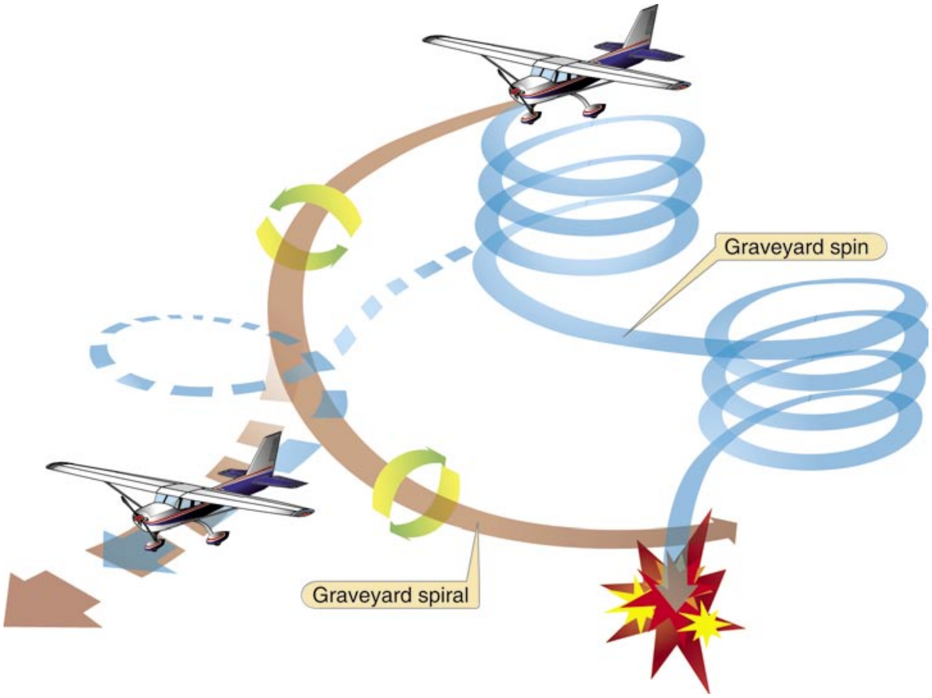

Figure 1-7. *Graveyard Spiral.*

in a downdraft, has the opposite effect, with the disoriented pilot pulling the aircraft into a nose-up attitude.

Visual Illusions

Visual illusions are especially hazardous because pilots rely on their eyes for correct information. Two illusions that lead to spatial disorientation, false horizon and autokinesis, are concerned with only the visual system.

False Horizon

A sloping cloud formation, an obscured horizon, an aurora borealis, a dark scene spread with ground lights and stars, and certain geometric patterns of ground lights can provide inaccurate visual information, or false horizon, for aligning the aircraft correctly with the actual horizon. The disoriented pilot may place the aircraft in a dangerous attitude.

Autokinesis

In the dark, a stationary light will appear to move about when stared at for many seconds. The disoriented pilot could lose control of the aircraft in attempting to align it with the false movements of this light, called autokinesis.

Postural Considerations

The postural system sends signals from the skin, joints, and muscles to the brain that are interpreted in relation to the Earth's gravitational pull. These signals determine posture. Inputs from each movement update the body's position to the brain on a constant basis. "Seat of the pants" flying is largely dependent upon these signals. Used in conjunction with visual and vestibular clues, these sensations can be fairly reliable. However, because of the forces acting upon the body in certain flight situations, many false sensations can occur due to acceleration forces overpowering gravity. *[Figure 1-8]* These situations include uncoordinated turns, climbing turns, and turbulence.

Demonstration of Spatial Disorientation

There are a number of controlled aircraft maneuvers a pilot can perform to experiment with spatial disorientation. While each maneuver will normally create a specific illusion, any false sensation is an effective demonstration of disorientation. Thus, even if there is no sensation during any of these maneuvers, the absence of sensation is still an effective demonstration in that it shows the inability to detect bank or roll. There are several objectives in demonstrating these various maneuvers.

1. They teach pilots to understand the susceptibility of the human system to spatial disorientation.
2. They demonstrate that judgments of aircraft attitude based on bodily sensations are frequently false.
3. They help lessen the occurrence and degree of disorientation through a better understanding of the relationship between aircraft motion, head movements, and resulting disorientation.
4. They help instill a greater confidence in relying on flight instruments for assessing true aircraft attitude.

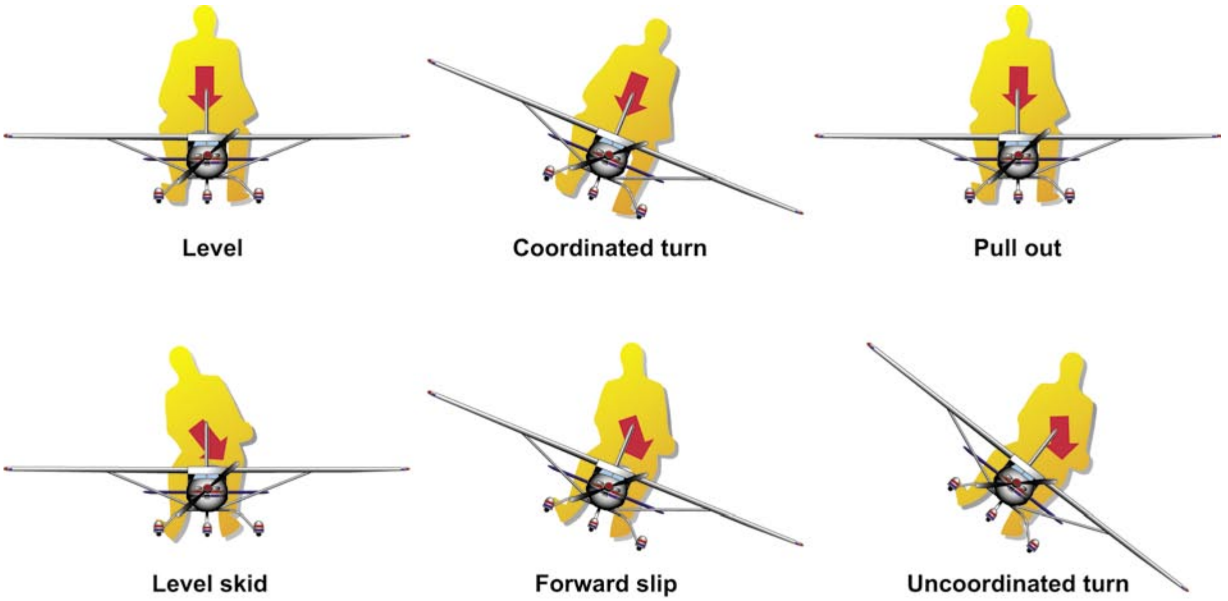

Skid, slip, and uncoordinated turns feel alike.
Pilots feel they are being forced sideways in their seat.

Figure 1-8. *Sensations From Centrifugal Force.*

A pilot should not attempt any of these maneuvers at low altitudes, or in the absence of an instructor pilot or an appropriate safety pilot.

Climbing While Accelerating

With the pilot's eyes closed, the instructor pilot maintains approach airspeed in a straight-and-level attitude for several seconds, and then accelerates while maintaining straight-and-level attitude. The usual illusion during this maneuver, without visual references, will be that the aircraft is climbing.

Climbing While Turning

With the pilot's eyes still closed and the aircraft in a straight-and-level attitude, the instructor pilot now executes, with a relatively slow entry, a well-coordinated turn of about 1.5 positive G (approximately 50° bank) for 90°. While in the turn, without outside visual references and under the effect of the slight positive G, the usual illusion produced is that of a climb. Upon sensing the climb, the pilot should immediately open the eyes and see that a slowly established, coordinated turn produces the same feeling as a climb.

Diving While Turning

Repeating the previous procedure, with the exception that the pilot's eyes should be kept closed until recovery from the turn is approximately one-half completed can create this sensation. With the eyes closed, the usual illusion will be that the aircraft is diving.

Tilting to Right or Left

While in a straight-and-level attitude, with the pilot's eyes closed, the instructor pilot executes a moderate or slight skid to the left with wings level. This creates the illusion of the body being tilted to the right.

Reversal of Motion

This illusion can be demonstrated in any of the three planes of motion. While straight and level, with the pilot's eyes closed, the instructor pilot smoothly and positively rolls the aircraft to approximately a 45° bank attitude while maintaining heading and pitch attitude. This creates the illusion of a strong sense of rotation in the opposite direction. After this illusion is noted, the pilot should open his or her eyes and observe that the aircraft is in a banked attitude.

Diving or Rolling Beyond the Vertical Plane

This maneuver may produce extreme disorientation. While in straight-and-level flight, the pilot should sit normally, either with eyes closed or gaze lowered to the floor. The instructor pilot starts a positive, coordinated roll toward a 30° or 40° angle of bank. As this is in progress, the pilot tilts his or her head forward, looks to the right or left, then immediately returns his or her head to an upright position. The instructor pilot should time the maneuver so the roll is stopped as the pilot returns his or her head upright. An intense disorientation is usually produced by this maneuver, and the pilot experiences the sensation of falling downward into the direction of the roll.

In the descriptions of these maneuvers, the instructor pilot is doing the flying, but having the pilot do the flying can also be a very effective demonstration. The pilot should close his or her eyes and tilt the head to one side. The instructor pilot tells the pilot what control inputs to perform. The pilot then attempts to establish the correct attitude or control input with eyes closed and head tilted. While it is clear the pilot has no idea of the actual attitude, he or she will react to what the senses are saying. After a short time, the pilot will become disoriented and the instructor pilot then tells the pilot to look up and recover. The benefit of this exercise is the pilot experiences the disorientation while flying the aircraft.

Coping with Spatial Disorientation

To prevent illusions and their potentially disastrous consequences, pilots can:

1. Understand the causes of these illusions and remain constantly alert for them. Take the opportunity to understand and then experience spatial disorientation illusions in a device such as a Barany chair, a Vertigon, or a Virtual Reality Spatial Disorientation Demonstrator.
2. Always obtain and understand preflight weather briefings.
3. Before flying in marginal visibility (less than 3 miles) or where a visible horizon is not evident such as flight over open water during the night, obtain training and maintain proficiency in airplane control by reference to instruments.
4. Do not continue flight into adverse weather conditions or into dusk or darkness unless proficient in the use of flight instruments. If intending to fly at night, maintain night-flight currency and proficiency. Include cross-country and local operations at various airfields.
5. Ensure that when outside visual references are used, they are reliable, fixed points on the Earth's surface.
6. Avoid sudden head movement, particularly during takeoffs, turns, and approaches to landing.
7. Be physically tuned for flight into reduced visibility. That is, ensure proper rest, adequate diet, and, if flying at night, allow for night adaptation. Remember that illness, medication, alcohol, fatigue, sleep loss, and mild hypoxia are likely to increase susceptibility to spatial disorientation.

8. Most importantly, become proficient in the use of flight instruments and rely upon them. Trust the instruments and disregard your sensory perceptions.

The sensations that lead to illusions during instrument flight conditions are normal perceptions experienced by pilots. These undesirable sensations cannot be completely prevented, but through training and awareness, pilots can ignore or suppress them by developing absolute reliance on the flight instruments. As pilots gain proficiency in instrument flying, they become less susceptible to these illusions and their effects.

Optical Illusions

Of the senses, vision is the most important for safe flight. However, various terrain features and atmospheric conditions can create optical illusions. These illusions are primarily associated with landing. Since pilots must transition from reliance on instruments to visual cues outside the flight deck for landing at the end of an instrument approach, it is imperative they be aware of the potential problems associated with these illusions, and take appropriate corrective action. The major illusions leading to landing errors are described below.

Runway Width Illusion

A narrower-than-usual runway can create an illusion the aircraft is at a higher altitude than it actually is, especially when runway length-to-width relationships are comparable. *[Figure 1-9A]* The pilot who does not recognize this illusion will fly a lower approach, with the risk of striking objects along the approach path or landing short. A wider-than-usual runway can have the opposite effect, with the risk of leveling out high and landing hard, or overshooting the runway.

Runway and Terrain Slopes Illusion

An upsloping runway, upsloping terrain, or both, can create an illusion the aircraft is at a higher altitude than it actually is. *[Figure 1-9B]* The pilot who does not recognize this illusion will fly a lower approach. Downsloping runways and downsloping approach terrain can have the opposite effect.

Featureless Terrain Illusion

An absence of surrounding ground features, as in an overwater approach, over darkened areas, or terrain made featureless by snow, can create an illusion the aircraft is at a higher altitude than it actually is. This illusion, sometimes referred to as the "black hole approach," causes pilots to fly a lower approach than is desired.

Water Refraction

Rain on the windscreen can create an illusion of being at a higher altitude due to the horizon appearing lower than it is. This can result in the pilot flying a lower approach.

Haze

Atmospheric haze can create an illusion of being at a greater distance and height from the runway. As a result, the pilot will have a tendency to be low on the approach. Conversely, extremely clear air (clear bright conditions of a high attitude airport) can give the pilot the illusion of being closer than he or she actually is, resulting in a high approach, which may result in an overshoot or go around. The diffusion of light due to water particles on the windshield can adversely affect depth perception. The lights and terrain features normally used to gauge height during landing become less effective for the pilot.

Fog

Flying into fog can create an illusion of pitching up. Pilots who do not recognize this illusion will often steepen the approach quite abruptly.

Ground Lighting Illusions

Lights along a straight path, such as a road or lights on moving trains, can be mistaken for runway and approach lights. Bright runway and approach lighting systems, especially where few lights illuminate the surrounding terrain, may create the illusion of less distance to the runway. The pilot who does not recognize this illusion will often fly a higher approach.

How To Prevent Landing Errors Due to Optical Illusions

To prevent these illusions and their potentially hazardous consequences, pilots can:

1. Anticipate the possibility of visual illusions during approaches to unfamiliar airports, particularly at night or in adverse weather conditions. Consult airport diagrams and the Airport/Facility Directory (A/FD) for information on runway slope, terrain, and lighting.
2. Make frequent reference to the altimeter, especially during all approaches, day and night.
3. If possible, conduct aerial visual inspection of unfamiliar airports before landing.

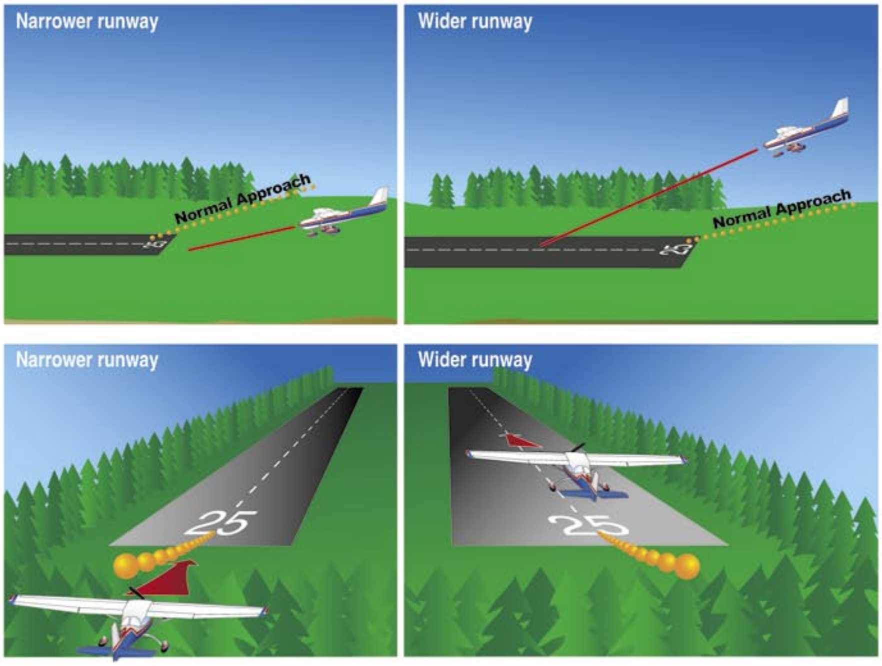
Narrower runway
Normal Approach
Wider runway
Normal Approach
Narrower runway
25
Wider runway
25

Figure 1-9A
Runway width illusion

- **A narrower-than-usual runway can created an illusion that the aircraft is higher than it actually is, leading to a lower approach.**
- **A wider-than-usual runway can create an illusion that the aircraft is lower than it actually is, leading to a higher approach.**

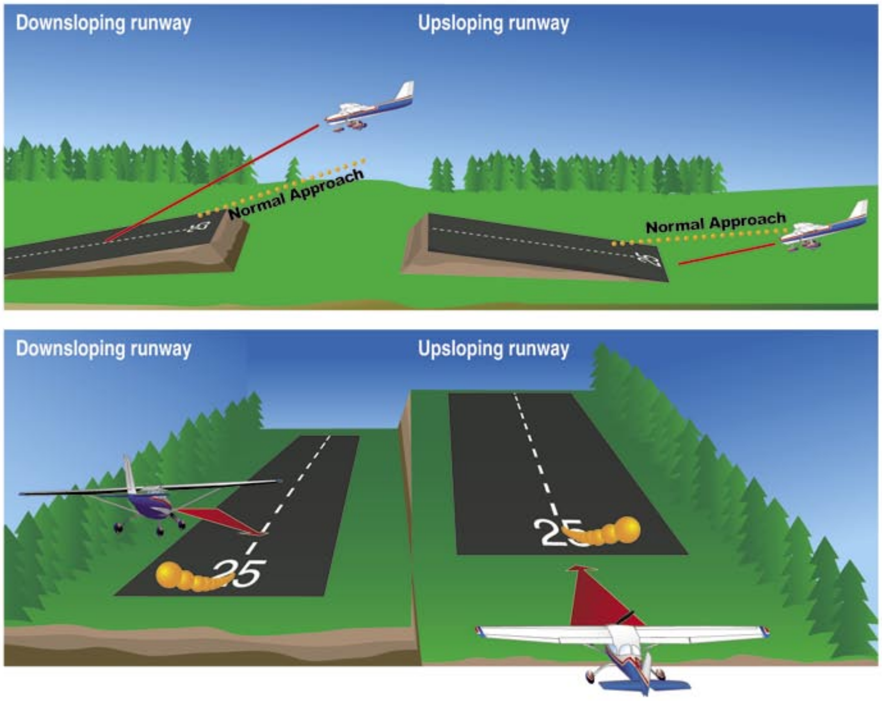
Downsloping runway
Normal Approach
Upsloping runway
Normal Approach
Downsloping runway
25
Upsloping runway
25

Figure 1-9B
Runway slope illusion

- **A downsloping runway can create the illusion that the aircraft is lower than it actually is, leading to a higher approach.**
- **An upsloping runway can create the illusion that the aircraft is higher than it actually is, leading to a lower approach.**

···· **Normal approach**
◀ **Approach due to illusion**

Figure 1-9. *Runway Width and Slope Illusions.*

4. Use Visual Approach Slope Indicator (VASI) or Precision Approach Path Indicator (PAPI) systems for a visual reference, or an electronic glide slope, whenever they are available.
5. Utilize the visual descent point (VDP) found on many nonprecision instrument approach procedure charts.
6. Recognize that the chances of being involved in an approach accident increase when some emergency or other activity distracts from usual procedures.
7. Maintain optimum proficiency in landing procedures.

Physiological and Psychological Factors

Physiological or psychological factors can affect a pilot and compromise the safety of a flight. These factors are stress, medical, alcohol, and fatigue. Any of these factors, individually or in combination, significantly degrade the pilot's decision-making or flying abilities.

Stress

Stress is the body's response to demands placed upon it. These demands can be either pleasant or unpleasant in nature. The causes of stress for a pilot can range from unexpected weather or mechanical problems while in flight, to personal issues unrelated to flying. Stress is an inevitable and necessary part of life; it adds motivation to life and heightens an individual's response to meet any challenge. The effects of stress are cumulative and there is a limit to a person's adaptive nature. This limit, called the stress tolerance level (or channel capacity), is based on the ability to cope with the situation.

At first, some amount of stress can be desirable and can actually improve performance. However, higher stress levels, particularly over long periods of time, can adversely affect performance. Performance will generally increase with the onset of stress, but will peak and then begin to fall off rapidly as stress levels exceed the ability to cope. *[Figure 1-10]*

At this point, a pilot's performance begins to decline and judgment deteriorates. Complex or unfamiliar tasks require higher levels of performance than simple or overlearned tasks. Complex or unfamiliar tasks are also more subject to the adverse effects of increasing stress than simple or familiar tasks. *[Figure 1-10]*

The indicators of excessive stress often show as three types of symptoms: (1) emotional, (2) physical, and (3) behavioral. Emotional symptoms may surface as over-compensation, denial, suspicion, paranoia, agitation, restlessness, or defensiveness. Physical stress can result in acute fatigue while behavioral degradation will be manifested as sensitivity to criticism, tendency to be argumentative, arrogance, and hostility. Pilots need to learn to recognize the symptoms of stress as they begin to occur.

There are many techniques available that can help reduce stress in life or help people cope with it better. Not all of the following ideas may be a solution, but some of them should be effective.

1. Become knowledgeable about stress.
2. Take a realistic self-assessment. (See the Pilot's Handbook of Aeronautical Knowledge).
3. Take a systematic approach to problem solving.
4. Develop a lifestyle that will buffer against the effects of stress.
5. Practice behavior management techniques.
6. Establish and maintain a strong support network.

Good flight deck stress management begins with good life stress management. Many of the stress coping techniques practiced for life stress management are not usually practical in flight. Rather, pilots must condition themselves to relax and think rationally when stress appears. The following checklist outlines some methods of flight deck stress management.

1. Avoid situations that distract from flying the aircraft.
2. Reduce flight deck workload to reduce stress levels. This will create a proper environment in which to make good decisions. Typically, flying involves higher stress levels during takeoff and landing phases. Between the two generally lies a period of low activity resulting in a lower stress level. Transitioning from the cruise phase to the landing phase is generally accompanied by a significant workload that, if not properly accommodated, will increase stress significantly. Proper planning and prioritization of flight deck duties are key to avoiding events that affect the pilot's capacity to maintain situational awareness.

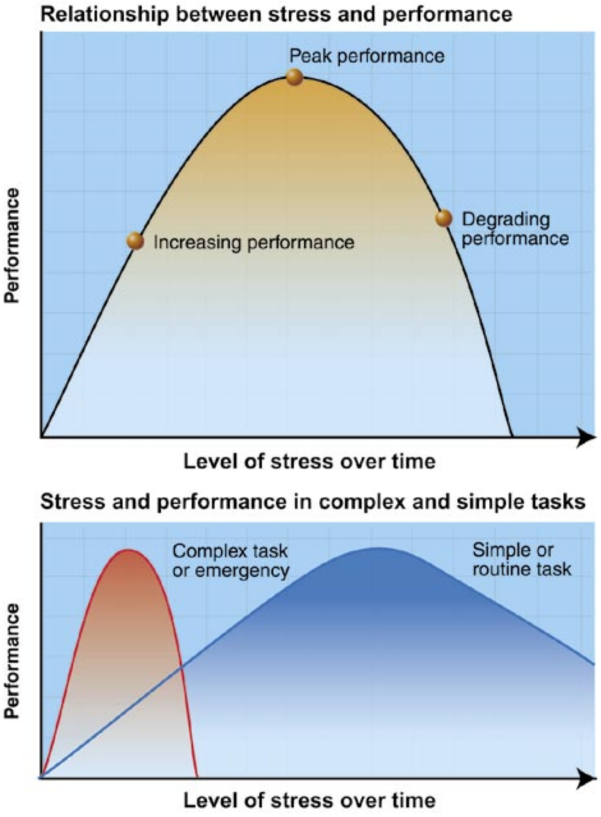

Figure 1-10. *Stress and Performance.*

3. If a problem occurs, remain calm. If time is not a pressing factor, follow the analytical approach to decision-making: think for a moment, weigh the alternatives, select and take an appropriate course of action, and then evaluate its effects.

   If an emergency situation occurs, remain calm and use the aeronautical decision-making (ADM) process to resolve the emergency. This process relies on the pilot's training and experience to accurately and automatically respond to an emergency situation. Constant training in handling emergency procedures will help reduce pilot stress when an emergency occurs.

4. Become thoroughly familiar with the aircraft, its operation, and emergency procedures. Also, maintain flight proficiency to build confidence.
5. Know and respect personal limits. Studies have suggested that highly experienced pilots have taken more chances when flying into potential icing conditions than low time or inexperienced pilots. Very low time pilots without experience may analyze and interpret the likelihood for "potential" flight into icing without the benefit of life experience, thereby making decisions closely aligned with the compilation of their training and recent academic knowledge. Highly experienced pilots may evaluate the current situation based upon the empirical information (sometimes diluted with time) coupled with their vast experience. This may lead to a level of greater acceptability of the situation because their experience has illustrated successful navigation of this problem before. Therefore, the automatic decision may be in error because not all salient facts are evaluated.
6. Do not allow small mistakes to be distractions during flight; rather, review and analyze them after landing.
7. If flying adds stress, either stop flying or seek professional help to manage stress within acceptable limits.

Medical Factors

A "go/no-go" decision based on a pilot's medical factors is made before each flight. The pilot should not only preflight check the aircraft, but also himself or herself before every flight. A pilot should ask, "Can I pass my medical examination right now?" If the answer is not an absolute "yes," *do not fly*. This is especially true for pilots embarking on flights in IMC. Instrument flying is much more demanding than flying in VMC, and peak performance is critical for the safety of flight.

Pilot performance can be seriously degraded by both prescribed and over-the-counter medications, as well as by the medical conditions for which they are taken. Many medications, such as tranquilizers, sedatives, strong pain relievers, and cough suppressants, have primary effects that impair judgment, memory, alertness, coordination, vision, and the ability to make calculations. Others, such as antihistamines, blood pressure drugs, muscle relaxants, and agents to control diarrhea and motion sickness, have side effects that impair the same critical functions. Any medication that depresses the nervous system, such as a sedative, tranquilizer, or antihistamine, makes a pilot much more susceptible to hypoxia.

Title 14 of the Code of Federal Regulations (14 CFR) prohibits pilots from performing crewmember duties while using any medication that affects the faculties in any way contrary to safety. The safest rule is not to fly as a crewmember while taking any medication, unless approved to do so by the Federal Aviation Administration (FAA). If there is any doubt regarding the effects of any medication, consult an Aviation Medical Examiner (AME) before flying.

Alcohol

14 CFR part 91 prohibits pilots from performing crewmember duties within 8 hours after drinking any alcoholic beverage or while under the influence. Extensive research has provided a number of facts about the hazards of alcohol consumption and flying. As little as one ounce of liquor, one bottle of beer, or four ounces of wine can impair flying skills and render a pilot much more susceptible to disorientation and hypoxia. Even after the body completely metabolizes a moderate amount of alcohol, a pilot can still be impaired for many hours. There is simply no way of increasing the metabolism of alcohol or alleviating a hangover.

Fatigue

Fatigue is one of the most treacherous hazards to flight safety, as it may not be apparent to a pilot until serious errors are made. Fatigue can be either acute (short-term) or chronic (long-term).

Acute Fatigue

A normal occurrence of everyday living, acute fatigue is the tiredness felt after long periods of physical and mental strain, including strenuous muscular effort, immobility, heavy mental workload, strong emotional pressure, monotony, and lack of sleep. Adequate rest, regular exercise, and proper nutrition prevent acute fatigue.

Indications of fatigue are generally subtle and hard to recognize because the individual being assessed is generally the person making the assessment, as in single pilot operations. Therefore, the pilot must look at small errors that occur to provide an indication of becoming fatigued. These include:

- Misplacing items during the preflight;
- Leaving material (pencils, charts) in the planning area;
- Missing radio calls;
- Answering calls improperly (read-backs); and
- Improper tuning of frequencies.

Chronic Fatigue

Chronic fatigue occurs when there is not enough time for a full recovery from repeated episodes of acute fatigue. Chronic fatigue's underlying cause is generally not "rest-related" and may have deeper points of origin. Therefore, rest alone may not resolve chronic fatigue.

Chronic fatigue is a combination of both physiological problems and psychological issues. Psychological problems such as financial, home life, or job related stresses cause a lack of qualified rest that is only resolved by mitigating the underpinning problems. Without resolution, performance continues to fall off, judgment becomes impaired, and unwarranted risks are taken. Recovery from chronic fatigue requires a prolonged and deliberate solution. In either case, unless adequate precautions are taken, personal performance could be impaired and adversely affect pilot judgment and decision-making.

IMSAFE Checklist

The following checklist, IMSAFE, is intended for a pilot's personal preflight use. A quick check of the items on this list will help a pilot make a good self-evaluation prior to any flight. If the answer to any of the checklist questions is yes, then the pilot should consider not flying.

Illness
Do I have any symptoms?

Medication
Have I been taking prescription or over-the-counter drugs?

Stress
Am I under psychological pressure from the job? Do I have money, health, or family problems?

Alcohol
Have I been drinking within 8 hours? Within 24 hours?

Fatigue
Am I tired and not adequately rested?

Eating
Have I eaten enough of the proper foods to keep adequately nourished during the entire flight?

Hazard Identification

In order to identify a hazard, it would be useful to define what a hazard is. The FAA System Safety course defines a hazard as: "a present condition, event, object, or circumstance that could lead or contribute to an unplanned or undesired event." Put simply, a hazard is a source of danger. Potential hazards may be identified from a number of internal and external sources. These may be based upon several concurrent factors that provide an indication and ultimate identification of a hazard. Consider the following situations:

Situation 1

The pilot has just taken off and is entering the clouds. Suddenly, there is an explosive sound. The sudden noise is disturbing and occurs as the pilot is given a new heading, a climb restriction, and the frequency for the departure control.

Situation 2

The pilot took off late in a rented aircraft (first time flying this model), and is now in night conditions due to the delay, and flying on an instrument flight rules (IFR) flight plan in IMC conditions. The radios do not seem to work well and develop static. They seem to be getting weaker. As the pilot proceeds, the rotating beacon stops flashing/rotating, and the lights become dimmer. As the situation progresses, the pilot is unaware of the problem because the generator warning light, (on the lower left of the panel) is obscured by the chart on the pilot's lap.

Both situations above represent hazards that must be dealt with differently and a level of risk must be associated with each depending on various factors affecting the flight.

Risk Analysis

Risk is defined as the future impact of a hazard that is not eliminated or controlled. It is the possibility of loss or injury. Risk analysis is the process whereby hazards are characterized by their likelihood and severity. Risk analysis evaluates the hazards to determine the outcomes and how abrupt that outcome will occur. The analysis applied will be qualitative to the degree that time allows resulting in either an analytical or automatic approach in the decision-making process.

In the first situation, the decision may be automatic: fly the airplane to a safe landing. Since automatic decision-making is based upon education and experience, an inexperienced pilot may react improperly to the situation which results in an inadequate action. To mitigate improper decision-making, immediate action items from emergency procedures should be learned. Training, education, and mentorship are all key factors in honing automatic decision-making skills.

In the second situation, if the pilot has a flashlight onboard, it can be used for illumination, although its light may degrade night vision. After changing the appropriate transponder code, and making calls in the blind, awareness of present location becomes imperative, especially if the pilot must execute a controlled descent to VMC conditions. Proper preflight planning conducted before departure and constant awareness of location provide an element of both comfort (reduces stress) and information from which the pilot can draw credible information.

In both cases, the outcomes can be successful through systems understanding, emergency procedures training, and correctly analyzing the risks associated with each course of action.

Crew Resource Management (CRM) and Single-Pilot Resource Management (SRM)

Crew resource management (CRM) and single-pilot resource management (SRM) is the ability for the crew or pilot to manage all resources effectively to ensure the outcome of the flight is successful. In general aviation, SRM will be most often used and its focus is on the single-pilot operation. SRM integrates the following:

- Situational Awareness
- Flight Deck Resource Management
- Task Management
- Aeronautical Decision-making (ADM) and Risk Management

SRM recognizes the need to seek proper information from these sources to make a valid decision. For instance, the pilot may have to request assistance from others and be assertive to resolve situations. Pilots should understand the need to seek information from other sources until they have the proper information to make the best decision. Once a pilot has gathered all pertinent information and made the appropriate decision, the pilot needs to perform an assessment of the action taken.

Situational Awareness

Situational awareness is the accurate perception of operational and environmental factors that affect the flight. It is a logical analysis based upon the machine, external support, environment, and the pilot. It is knowing what is going on.

Flight Deck Resource Management

CRM is the effective use of all available resources: human, equipment, and information. It focuses on communication skills, teamwork, task allocation, and decision-making. While CRM often concentrates on pilots who operate in crew environments, the elements and concepts also apply to single-pilot operations.

Human Resources

Human resources include everyone routinely working with the pilot to ensure flight safety. These people include, but are not limited to: weather briefers, flight line personnel, maintenance personnel, crew members, pilots, and air traffic personnel. Pilots need to effectively communicate with these people. This is accomplished by using the key components of the communication process: inquiry, advocacy, and assertion.

Pilots must recognize the need to seek enough information from these resources to make a valid decision. After the necessary information has been gathered, the pilot's decision must be passed on to those concerned, such as air traffic controllers, crew members, and passengers. The pilot may have to request assistance from others and be assertive to safely resolve some situations.

Equipment

Equipment in many of today's aircraft includes automated flight and navigation systems. These automatic systems, while providing relief from many routine flight deck tasks, present a different set of problems for pilots. The automation intended to reduce pilot workload essentially removes the pilot from the process of managing the aircraft, thereby reducing situational awareness and leading to complacency. Information from these systems needs to be continually monitored to ensure proper situational awareness. Pilots should be thoroughly familiar with the operation of and information provided by all systems used. It is essential that pilots be aware not only of equipment capabilities, but also equipment limitations in order to manage those systems effectively and safely.

Information Workload

Information workloads and automated systems, such as autopilots, need to be properly managed to ensure a safe flight. The pilot flying in IMC is faced with many tasks, each with a different level of importance to the outcome of the flight. For example, a pilot preparing to execute an instrument approach to an airport needs to review the approach chart, prepare the aircraft for the approach and landing, complete checklists, obtain information from Automatic Terminal Information Service (ATIS) or air traffic control (ATC), and set the navigation radios and equipment.

The pilot who effectively manages his or her workload will complete as many of these tasks as early as possible to preclude the possibility of becoming overloaded by last minute changes and communication priorities in the later, more critical stages of the approach. *Figure 1-11* shows the margin of safety is at the minimum level during this stage of the approach. Routine tasks delayed until the last minute can contribute to the pilot becoming overloaded and stressed, resulting in erosion of performance.

By planning ahead, a pilot can effectively reduce workload during critical phases of flight. If a pilot enters the final phases of the instrument approach unprepared, the pilot should recognize the situation, abandon the approach, and try it again after becoming better prepared. Effective resource management includes recognizing hazardous situations and attitudes, decision-making to promote good judgment and headwork, and managing the situation to ensure the safe outcome of the IFR flight.

Task Management

Pilots have a limited capacity for information. Once information flow exceeds the pilot's ability to mentally process the information any additional information will become unattended or displace other tasks and information already being processed. This is termed channel capacity and once reached only two alternatives exist: shed the unimportant tasks or perform all tasks at a less than optimal level. Like an electrical circuit being overloaded, either the consumption must be reduced or a circuit failure is experienced.

The pilot who effectively manages the tasks and properly prioritizes them will have a successful flight. For example, do not become distracted and fixate on an instrument light failure. This unnecessary focus displaces capability and prevents the pilot's ability to appreciate tasks of greater importance. By planning ahead, a pilot can effectively reduce workload during critical phases of a flight.

Aeronautical Decision-Making (ADM)

Flying safely requires the effective integration of three separate sets of skills. Most obvious are the basic stick-and-rudder skills needed to control the airplane. Next, are skills related to proficient operation of aircraft systems, and last, but not least, are ADM skills.

ADM is a systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances. The importance of learning effective ADM skills cannot be overemphasized. While progress is continually being made in the advancement of pilot training methods, airplane equipment and systems, and services for pilots, accidents still occur. Despite all the changes in technology to improve flight safety, one factor remains the same—the human factor. While the FAA strives to eliminate errors through training and safety programs, one fact remains: humans make errors. It is estimated that approximately 80 percent of all aviation accidents are human factors related.

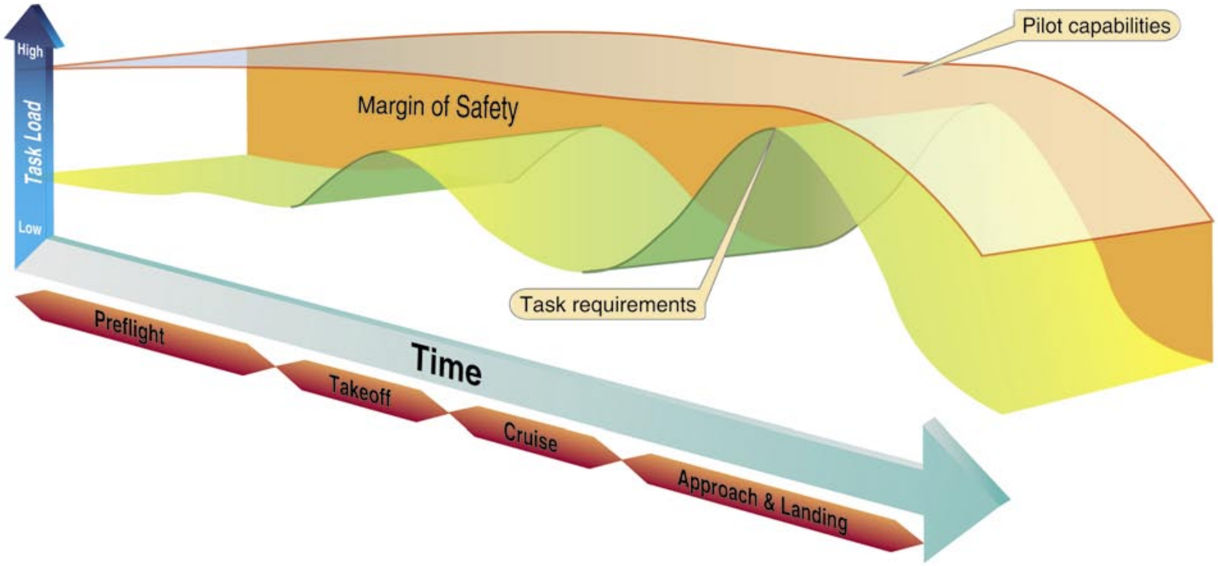

Figure 1-11. *The Margin of Safety.*

The ADM process addresses all aspects of decision making in the flight deck and identifies the steps involved in good decision making. While the ADM process will not eliminate errors, it will help the pilot recognize errors, and in turn enable the pilot to manage the error to minimize its effects. These steps are:

1. Identifying personal attitudes hazardous to safe flight;
2. Learning behavior modification techniques;
3. Learning how to recognize and cope with stress;
4. Developing risk assessment skills;
5. Using all resources; and
6. Evaluating the effectiveness of one's ADM skills.

Historically, the term "pilot error" has been used to describe the causes of these accidents. Pilot error means that an action or decision made by the pilot was the cause, or a contributing factor that led to the accident. This definition also includes the pilot's failure to make a decision or take action. From a broader perspective, the phrase "human factors related" more aptly describes these accidents since it is usually not a single decision that leads to an accident, but a chain of events triggered by a number of factors.

The poor judgment chain, sometimes referred to as the "error chain," is a term used to describe this concept of contributing factors in a human factors related accident. Breaking one link in the chain normally is all that is necessary to change the outcome of the sequence of events.

The Decision-Making Process

An understanding of the decision-making process provides a pilot with a foundation for developing ADM skills. Some situations, such as engine failures, require a pilot to respond immediately using established procedures with a little time for detailed analysis. This is termed automatic decision-making and is based upon training, experience, and recognition. Traditionally, pilots have been well trained to react to emergencies, but are not as well prepared to make decisions requiring a more reflective response where greater analysis is required. Typically during a flight, there is time to examine any changes that occur, gather information, and assess risk before reaching a decision. The steps leading to this conclusion constitute the decision-making process.

Defining the Problem

Problem definition is the first step in the decision-making process. Defining the problem begins with recognizing that a change has occurred or that an expected change did not occur. A problem is perceived first by the senses, then is distinguished through insight and experience. One critical error that can be made during the decision-making process is incorrectly defining the problem. For example, a low oil pressure reading could indicate that the engine is about to fail and an emergency landing should be planned, or it could mean that the oil pressure sensor has failed. The actions to be taken in each of these circumstances would be significantly different. One requires an immediate decision based upon training, experience, and evaluation of the situation; whereas the latter decision is based upon an analysis. It should be noted that the same indication could result in two different actions depending upon other influences.

Choosing a Course of Action

After the problem has been identified, the pilot must evaluate the need to react to it and determine the actions that may be taken to resolve the situation in the time available. The expected outcome of each possible action should be considered and the risks assessed before deciding on a response to the situation.

Implementing the Decision and Evaluating the Outcome

Although a decision may be reached and a course of action implemented, the decision-making process is not complete. It is important to think ahead and determine how the decision could affect other phases of flight. As the flight progresses, the pilot must continue to evaluate the outcome of the decision to ensure that it is producing the desired result.

Improper Decision-Making Outcomes

Pilots sometimes get in trouble not because of deficient basic skills or system knowledge, but rather because of faulty decision-making skills. Although aeronautical decisions may appear to be simple or routine, each individual decision in aviation often defines the options available for the next decision the pilot must make and the options, good or bad, they provide. Therefore, a poor decision early on in a flight can compromise the safety of the flight at a later time necessitating decisions that must be more accurate and decisive. Conversely, good decision-making early on in an emergency provide greater latitude for options later on.

FAA Advisory Circular (AC) 60-22, defines ADM as a systematic approach to the mental process of evaluating a given set of circumstances and determining the best course of action. ADM thus builds upon the foundation of conventional decision-making, but enhances the process to decrease the probability of pilot error. Specifically, ADM provides a structure to help the pilot use all resources to develop comprehensive situational awareness.

Models for Practicing ADM

Two models for practicing ADM are presented below.

Perceive, Process, Perform

The Perceive–Process–Perform (3P) model for ADM offers a simple, practical, and systematic approach that can be used during all phases of flight. *[Figure 1-12]* To use it, the pilot will:

- Perceive the given set of circumstances for a flight;
- Process by evaluating their impact on flight safety; and
- Perform by implementing the best course of action.

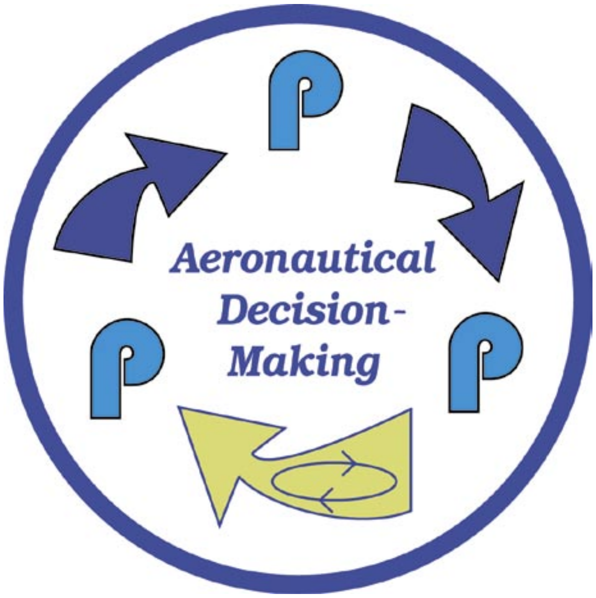

Figure 1-12. *The 3P Model for Aeronautical Decision-Making.*

In the first step, the goal is to develop situational awareness by perceiving hazards, which are present events, objects, or circumstances that could contribute to an undesired future event. In this step, the pilot will systematically identify and list hazards associated with all aspects of the flight: pilot, aircraft, environment, and external pressures. It is important to consider how individual hazards might combine. Consider, for example, the hazard that arises when a new instrument pilot with no experience in actual instrument conditions wants to make a cross-country flight to an airport with low ceilings in order to attend an important business meeting.

In the second step, the goal is to process this information to determine whether the identified hazards constitute risk, which is defined as the future impact of a hazard that is not controlled or eliminated. The degree of risk posed by a given hazard can be measured in terms of exposure (number of people or resources affected), severity (extent of possible loss), and probability (the likelihood that a hazard will cause a loss). If the hazard is low ceilings, for example, the level of risk depends on a number of other factors, such as pilot training and experience, aircraft equipment and fuel capacity, and others.

In the third step, the goal is to perform by taking action to eliminate hazards or mitigate risk, and then continuously evaluate the outcome of this action. With the example of low ceilings at destination, for instance, the pilot can perform good ADM by selecting a suitable alternate, knowing where to find good weather, and carrying sufficient fuel to reach it. This course of action would mitigate the risk. The pilot also has the option to eliminate it entirely by waiting for better weather.

Once the pilot has completed the 3P decision process and selected a course of action, the process begins anew because now the set of circumstances brought about by the course of action requires analysis. The decision-making process is a continuous loop of perceiving, processing and performing.

The DECIDE Model

Another structured approach to ADM is the DECIDE model, which is a six-step process intended to provide a logical way of approaching decision-making. As in the 3P model, the elements of the DECIDE model represent a continuous loop process to assist a pilot in the decision-making required when faced with a situational change that requires judgment. *[Figure 1-13C]* The model is primarily focused on the intellectual component, but can have an impact on the motivational component of judgment as well. If a pilot continually uses the DECIDE Model in all decision-making, it becomes natural and results in better decisions being made under all types of situations. The steps in this approach are listed in *Figure 1-13C*.

In conventional decision-making, the need for a decision is triggered by recognition that something has changed or an expected change did not occur. Recognition of the change, or lack of change, is a vital step in any decision making process. Not noticing change in a situation can lead directly to a mishap. *[Figure 1-13A]* The change indicates that an appropriate response or action is necessary in order to modify the situation (or, at least, one of the elements that comprise it) and bring about a desired new situation. Therefore, situational awareness is the key to successful and safe decision making. At this point in the process, the pilot is faced with a need to evaluate the entire range of possible responses to the detected change and to determine the best course of action.

Figure 1-13B illustrates how the ADM process expands conventional decision-making, shows the interactions of the

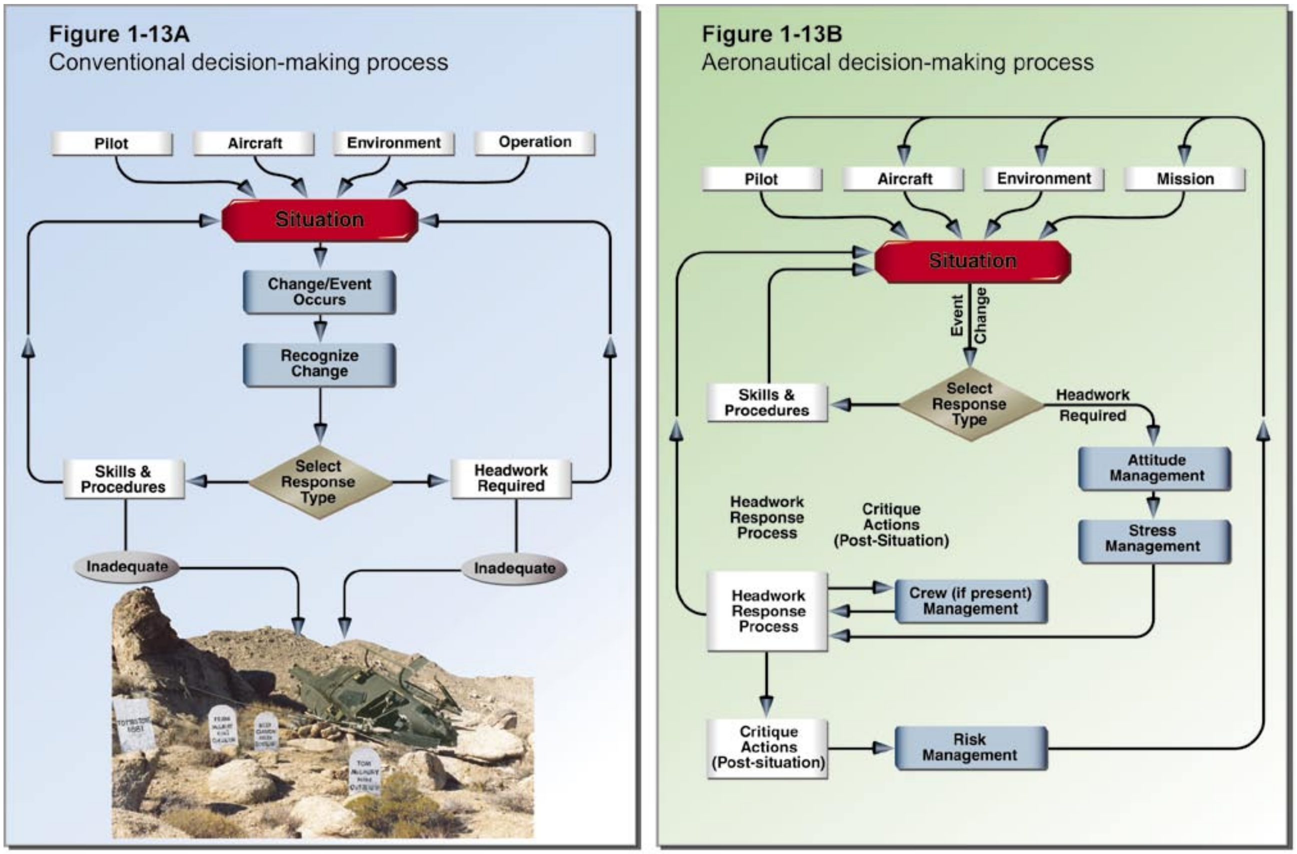

Figure 1-13A
Conventional decision-making process

Pilot
Aircraft
Environment
Operation
Situation
Change/Event Occurs
Recognize Change
Select Response Type
Skills & Procedures
Headwork Required
Inadequate
Inadequate

Figure 1-13B
Aeronautical decision-making process

Pilot
Aircraft
Environment
Mission
Situation
Event
Change
Skills & Procedures
Select Response Type
Headwork Required
Attitude Management
Stress Management
Headwork Response Process
Critique Actions (Post-Situation)
Headwork Response Process
Crew (if present) Management
Critique Actions (Post-situation)
Risk Management

Figure 1-13C
The DECIDE Model

1. **Detect.** The decision maker detects the fact that change has occurred.
2. **Estimate.** The decision maker estimates the need to counter or react to the change.
3. **Choose.** The decision maker chooses a desirable outcome (in terms of success) for the flight.
4. **Identify.** The decision maker identifies actions which could successfully control the change.
5. **Do.** The decision maker takes the necessary action.
6. **Evaluate.** The decision maker evaluates the effect(s) of his/her action countering the change.

Figure 1-13. *Decision-Making.*

ADM steps, and how these steps can produce a safe outcome. Starting with the recognition of change, and following with an assessment of alternatives, a decision to act or not act is made, and the results are monitored. Pilots can use ADM to enhance their conventional decision-making process because it:

1. Increases their awareness of the importance of attitude in decision-making;
2. Teaches the ability to search for and establish relevance of information; and
3. Increases their motivation to choose and execute actions that ensure safety in the situational timeframe.

Hazardous Attitudes and Antidotes

Hazardous attitudes, which contribute to poor pilot judgment, can be effectively counteracted by redirecting that hazardous attitude so that correct action can be taken. Recognition of hazardous thoughts is the first step toward neutralizing them. After recognizing a thought as hazardous, the pilot should label it as hazardous, then state the corresponding antidote. Antidotes should be memorized for each of the hazardous attitudes so they automatically come to mind when needed. Each hazardous attitude along with its appropriate antidote is shown in *Figure 1-14*.

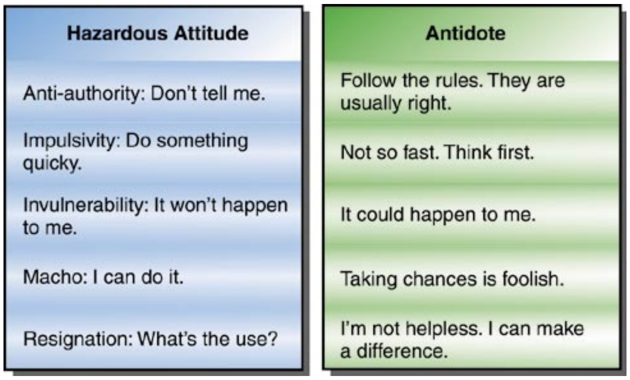

Hazardous Attitude	Antidote
Anti-authority: Don't tell me.	Follow the rules. They are usually right.
Impulsivity: Do something quicky.	Not so fast. Think first.
Invulnerability: It won't happen to me.	It could happen to me.
Macho: I can do it.	Taking chances is foolish.
Resignation: What's the use?	I'm not helpless. I can make a difference.

Figure 1-14. *The Five Antidotes to Hazardous Attitudes.*

Research has identified five hazardous attitudes that can affect a pilot's judgment, as well as antidotes for each of these five attitudes. ADM addresses the following:

1. Anti-authority ("Don't tell me!"). This attitude is found in pilots who do not like anyone telling them what to do. They may be resentful of having someone tell them what to do or may regard rules, regulations, and procedures as silly or unnecessary. However, there is always the prerogative to question authority if it is perceived to be in error.
2. Impulsivity ("Do something quickly!"). This attitude is found in pilots who frequently feel the need to do something—anything—immediately. They do not stop to think about what they are about to do, they do not select the best course of action, and they do the first thing that comes to mind.
3. Invulnerability ("It won't happen to me!"). Many pilots feel that accidents happen to others, but never to them. They know accidents can happen, and they know that anyone can be affected. They never really feel or believe that they will be personally involved. Pilots who think this way are more likely to take chances and increase risk.
4. Macho ("I can do it!"). Pilots who are always trying to prove that they are better than anyone else are thinking, "I can do it—I'll show them." Pilots with this type of attitude will try to prove themselves by taking risks in order to impress others. This pattern is characteristic in both men and women.
5. Resignation ("What's the use?"). These pilots do not see themselves as being able to make a great deal of difference in what happens to them. When things go well, these pilots are apt to think it is due to good luck. When things go badly, they may feel that someone is out to get them, or attribute it to bad luck. The pilot will leave the action to others, for better or worse. Sometimes, they will even go along with unreasonable requests just to be a "nice guy."

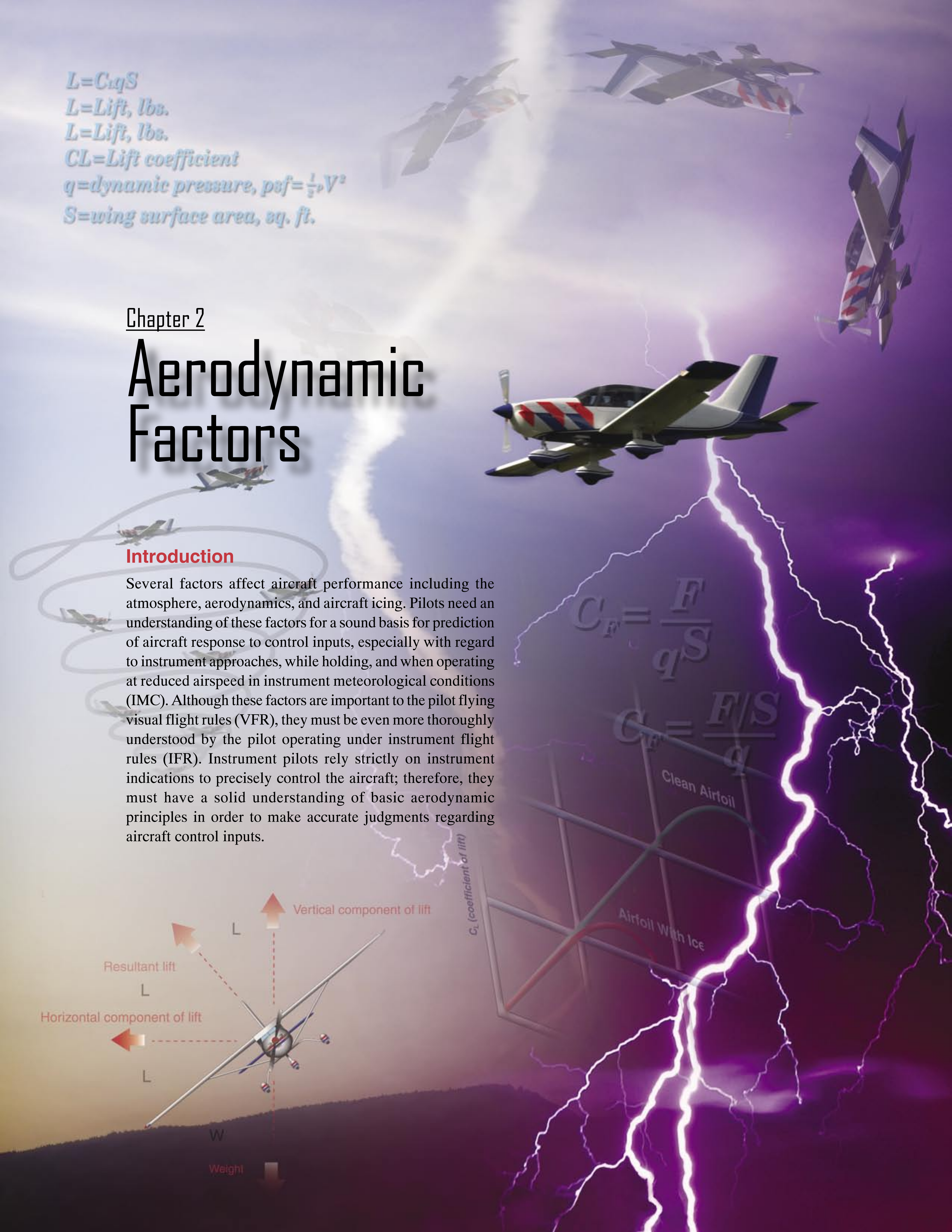
$L=C_LqS$
L=Lift, lbs.
L=Lift, lbs.
CL=Lift coefficient
q=dynamic pressure, psf=$\frac{1}{2}\rho V^2$
S=wing surface area, sq. ft.
$C_F=\frac{F}{qS}$
$C_F=\frac{F/S}{q}$
Clean Airfoil
C_L (coefficient of lift)
Airfoil With Ice
Vertical component of lift
L
Resultant lift
L
Horizontal component of lift
L
W
Weight

Chapter 2

Aerodynamic Factors

Introduction

Several factors affect aircraft performance including the atmosphere, aerodynamics, and aircraft icing. Pilots need an understanding of these factors for a sound basis for prediction of aircraft response to control inputs, especially with regard to instrument approaches, while holding, and when operating at reduced airspeed in instrument meteorological conditions (IMC). Although these factors are important to the pilot flying visual flight rules (VFR), they must be even more thoroughly understood by the pilot operating under instrument flight rules (IFR). Instrument pilots rely strictly on instrument indications to precisely control the aircraft; therefore, they must have a solid understanding of basic aerodynamic principles in order to make accurate judgments regarding aircraft control inputs.

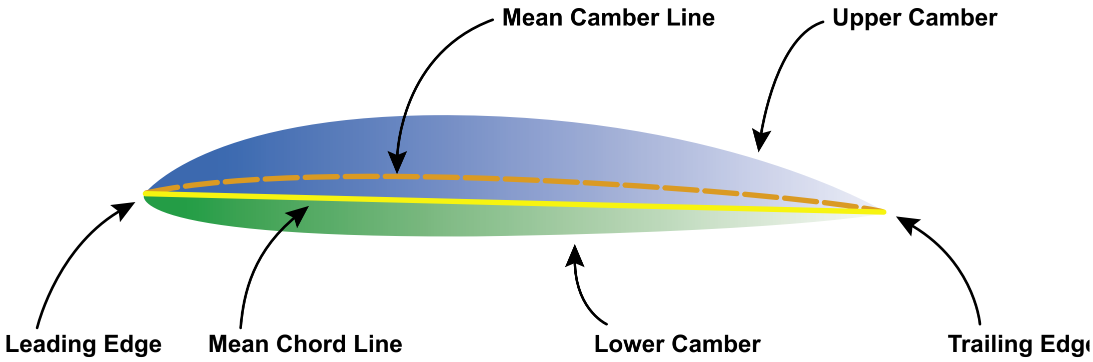

Figure 2-1. *The Airfoil.*

The Wing

To understand aerodynamic forces, a pilot needs to understand basic terminology associated with airfoils. *Figure 2-1* illustrates a typical airfoil.

The chord line is the straight line intersecting the leading and trailing edges of the airfoil, and the term chord refers to the chord line longitudinal length (length as viewed from the side).

The mean camber is a line located halfway between the upper and lower surfaces. Viewing the wing edgewise, the mean camber connects with the chord line at each end. The mean camber is important because it assists in determining aerodynamic qualities of an airfoil. The measurement of the maximum camber; inclusive of both the displacement of the mean camber line and its linear measurement from the end of the chord line, provide properties useful in evaluating airfoils.

Review of Basic Aerodynamics

The instrument pilot must understand the relationship and differences between several factors that affect the performance of an aircraft in flight. Also, it is crucial to understand how the aircraft reacts to various control and power changes, because the environment in which instrument pilots fly has inherent hazards not found in visual flying. The basis for this understanding is found in the four forces acting on an aircraft and Newton's Three Laws of Motion.

Relative Wind is the direction of the airflow with respect to an airfoil.

Angle of Attack is the acute angle measured between the relative wind, or flight path and the chord of the airfoil. *[Figure 2-2]*

Flight path is the course or track along which the aircraft is flying or is intended to be flown.

The Four Forces

The four basic forces *[Figure 2-3]* acting upon an aircraft in flight are lift, weight, thrust, and drag.

Lift

Lift is a component of the total aerodynamic force on an airfoil and acts perpendicular to the relative wind. Relative wind is the direction of the airflow with respect to an airfoil. This force acts straight up from the average (called mean) center of pressure (CP), which is called the center of lift. It should be noted that it is a point along the chord line of an airfoil through which all aerodynamic forces are considered to act. The magnitude of lift varies proportionately with speed, air density, shape and size of the airfoil, and angle of attack. During straight-and-level flight, lift and weight are equal.

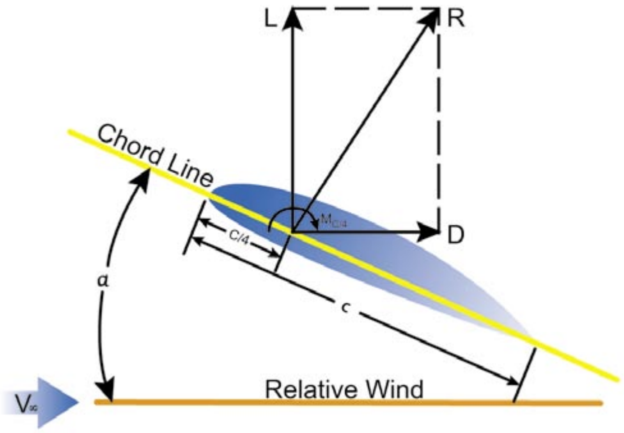

Figure 2-2. *Angle of Attack and Relative Wind.*

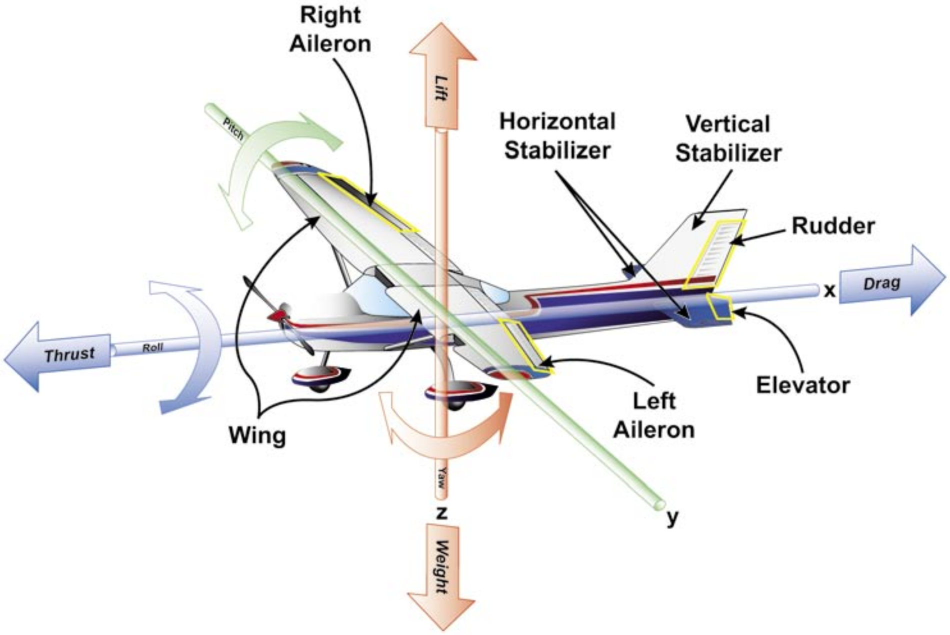

Figure 2-3. *The Four Forces and Three Axes of Rotation.*

Weight

Weight is the force exerted by an aircraft from the pull of gravity. It acts on an aircraft through its center of gravity (CG) and is straight down. This should not be confused with the center of lift, which can be significantly different from the CG. As an aircraft is descending, weight is greater than lift.

Thrust

Thrust is a force that drives an aircraft through the air and can be measured in thrust and/or horsepower. It is a component that is parallel to the center of thrust and overcomes drag providing the aircraft with its forward speed component.

Drag

Drag is the net aerodynamic force parallel to the relative wind and is generally a sum of two components: induced drag and parasite drag.

Induced drag

Induced drag is caused from the creation of lift and increases with angle of attack. Therefore, if the wing is not producing lift, induced drag is zero. Conversely, induced drag decreases with airspeed.

Parasite drag

Parasite drag is all drag not caused from the production of lift. Parasite drag is created by displacement of air by the aircraft, turbulence generated by the airfoil, and the hindrance of airflow as it passes over the surface of the aircraft or components. All of these forces create drag not from the production of lift but the movement of an object through an air mass. Parasite drag increases with speed and includes skin friction drag, interference drag, and form drag.

- Skin Friction Drag

Covering the entire "wetted" surface of the aircraft is a thin layer of air called a boundary layer. The air molecules on the surface have zero velocity in relation to the surface; however, the layer just above moves over the stagnant molecules below because it is pulled along by a third layer close to the free stream of air. The velocities of the layers increase as the distance from the surface increases until free stream velocity is reached, but all are affected by the free stream. The distance (total) between the skin surface and where free stream velocity is reached is called the boundary layer. At subsonic levels the cumulative layers are about the thickness of a playing card, yet their motion sliding over one another creates a drag force. This force retards motion due to the viscosity of the air and is called skin friction drag. Because skin friction drag is related to a large surface area its affect on smaller aircraft is small versus large transport aircraft where skin friction drag may be considerable.

- Interference Drag

Interference drag is generated by the collision of airstreams creating eddy currents, turbulence, or restrictions to smooth flow. For instance, the airflow around a fuselage and around the wing meet at some point, usually near the wing's root. These airflows interfere with each other causing a greater drag than the individual values. This is often the case when external items are placed on an aircraft. That is, the drag of each item individually, added to that of the aircraft, are less than that of the two items when allowed to interfere with one another.

- Form Drag

Form drag is the drag created because of the shape of a component or the aircraft. If one were to place a circular disk in an air stream, the pressure on both the top and bottom would be equal. However, the airflow starts to break down as the air flows around the back of the disk. This creates turbulence and hence a lower pressure results. Because the total pressure is affected by this reduced pressure, it creates a drag. Newer aircraft are generally made with consideration to this by fairing parts along the fuselage (teardrop) so that turbulence and form drag is reduced.

Total lift must overcome the total weight of the aircraft, which is comprised of the actual weight and the tail-down force used to control the aircraft's pitch attitude. Thrust must overcome total drag in order to provide forward speed with which to produce lift. Understanding how the aircraft's relationship between these elements and the environment provide proper interpretation of the aircraft's instruments.

Newton's First Law, the Law of Inertia

Newton's First Law of Motion is the Law of Inertia. It states that a body at rest will remain at rest, and a body in motion will remain in motion, at the same speed and in the same direction until affected by an outside force. The force with which a body offers resistance to change is called the force of inertia. Two outside forces are always present on an aircraft in flight: gravity and drag. The pilot uses pitch and thrust controls to counter or change these forces to maintain the desired flight path. If a pilot reduces power while in straight-and-level flight, the aircraft will slow due to drag. However, as the aircraft slows there is a reduction of lift, which causes the aircraft to begin a descent due to gravity. *[Figure 2-4]*

Newton's Second Law, the Law of Momentum

Newton's Second Law of Motion is the Law of Momentum, which states that a body will accelerate in the same direction as the force acting upon that body, and the acceleration will be directly proportional to the net force and inversely proportional to the mass of the body. Acceleration refers either to an increase or decrease in velocity, although deceleration is commonly used to indicate a decrease. This law governs the aircraft's ability to change flight path and speed, which are controlled by attitude (both pitch and bank) and thrust inputs. Speeding up, slowing down, entering climbs or descents, and turning are examples of accelerations that the pilot controls in everyday flight. *[Figure 2-5]*

Newton's Third Law, the Law of Reaction

Newton's Third Law of Motion is the Law of Reaction, which states that for every action there is an equal and opposite reaction. As shown in *Figure 2-6*, the action of the jet engine's thrust or the pull of the propeller lead to the reaction of the aircraft's forward motion. This law is also responsible for a portion of the lift that is produced by a wing, from the downward deflection of the airflow around it. This downward force of the relative wind results in an equal but opposite (upward) lifting force created by the airflow over the wing. *[Figure 2-6]*

Atmosphere

The atmosphere is the envelope of air which surrounds the Earth. A given volume of dry air contains about 78 percent nitrogen, 21 percent oxygen, and about 1 percent other gases such as argon, carbon dioxide, and others to a lesser degree. Although seemingly light, air does have weight and a one square inch column of the atmosphere at sea level weighs approximately 14.7 pounds. About one-half of the air by weight is within the first 18,000 feet. The remainder of the air is spread over a vertical distance in excess of 1,000 miles.

Air density is a result of the relationship between temperature and pressure. Air density is inversely related to temperature and directly related to pressure. For a constant pressure to be

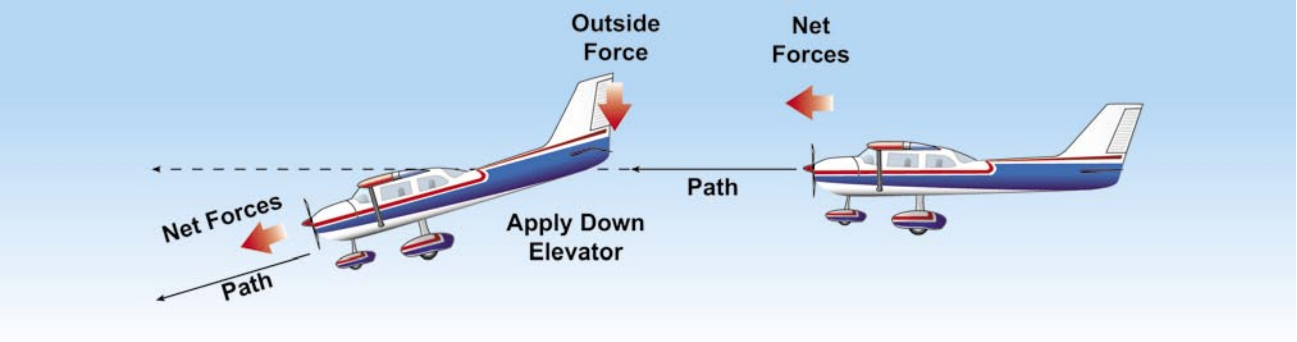

Figure 2-4. *Newton's First Law of Motion: the Law of Inertia.*

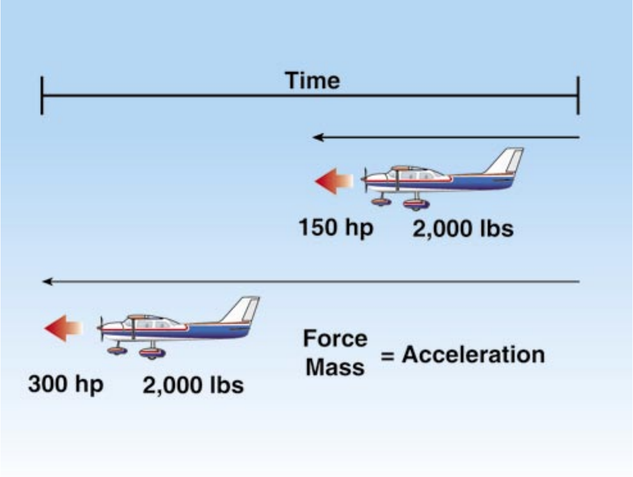

Figure 2-5. *Newton's Second Law of Motion: the Law of Momentum.*

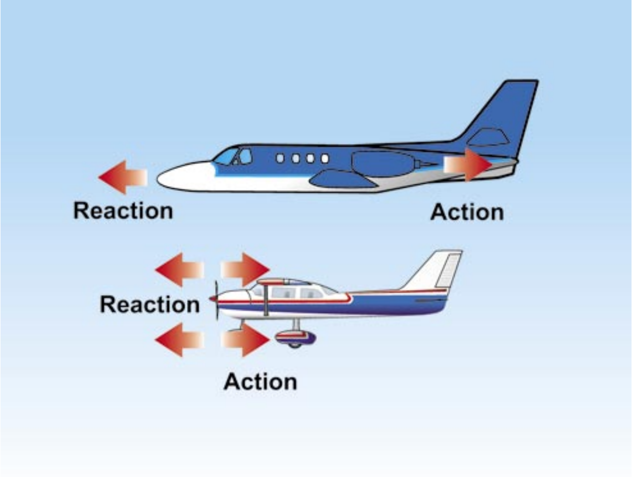

Figure 2-6. *Newton's Third Law of Motion: the Law of Reaction.*

maintained as temperature increases, density must decrease, and vice versa. For a constant temperature to be maintained as pressure increases, density must increase, and vice versa. These relationships provide a basis for understanding instrument indications and aircraft performance.

Layers of the Atmosphere

There are several layers to the atmosphere with the troposphere being closest to the Earth's surface extending to about 60,000 feet at the equator. Following is the stratosphere, mesosphere, ionosphere, thermosphere, and finally the exosphere. The tropopause is the thin layer between the troposphere and the stratosphere. It varies in both thickness and altitude but is generally defined where the standard lapse (generally accepted at 2° C per 1,000 feet) decreases significantly (usually down to 1° C or less).

International Standard Atmosphere (ISA)

The International Civil Aviation Organization (ICAO) established the ICAO Standard Atmosphere as a way of creating an international standard for reference and performance computations. Instrument indications and aircraft performance specifications are derived using this standard as a reference. Because the standard atmosphere is a derived set of conditions that rarely exist in reality, pilots need to understand how deviations from the standard affect both instrument indications and aircraft performance.

In the standard atmosphere, sea level pressure is 29.92" inches of mercury (Hg) and the temperature is 15° C (59° F). The standard lapse rate for pressure is approximately a 1" Hg decrease per 1,000 feet increase in altitude. The standard lapse rate for temperature is a 2° C (3.6° F) decrease per 1,000 feet increase, up to the top of the stratosphere. Since all aircraft performance is compared and evaluated in the environment of the standard atmosphere, all aircraft performance instrumentation is calibrated for the standard atmosphere. Because the actual operating conditions rarely, if ever, fit the standard atmosphere, certain corrections must apply to the instrumentation and aircraft performance. For instance, at 10,000 ISA predicts that the air pressure should be 19.92" Hg (29.92" - 10" Hg = 19.92") and the outside temperature at -5°C (15° C - 20° C). If the temperature or the pressure is different than the International Standard Atmosphere (ISA) prediction an adjustment must be made to performance predictions and various instrument indications.

Pressure Altitude

There are two measurements of the atmosphere that affect performance and instrument calibrations: pressure altitude and density altitude. Pressure altitude is the height above the standard datum pressure (SDP) (29.92" Hg, sea level under ISA) and is used for standardizing altitudes for flight levels (FL). Generally, flight levels are at or above 18,000 feet (FL 180), providing the pressure is at or above 29.92"Hg. For calculations involving aircraft performance when the altimeter is set for 29.92" Hg, the altitude indicated is the pressure altitude.

Density Altitude

Density altitude is pressure altitude corrected for nonstandard temperatures, and is used for determining aerodynamic performance in the nonstandard atmosphere. Density altitude increases as the density decreases. Since density varies directly with pressure, and inversely with temperature, a wide range of temperatures may exist with a given pressure altitude, which allows the density to vary. However, a known density occurs for any one temperature and pressure altitude combination. The density of the air has a significant effect on aircraft and engine performance. Regardless of the actual altitude above sea level an aircraft is operating at, its performance will be as though it were operating at an altitude equal to the existing density altitude.

If a chart is not available the density altitude can be estimated by adding 120 feet for every degree Celsius above the ISA. For example, at 3,000 feet pressure altitude (PA), the ISA prediction is 9° C (15° C - [lapse rate of 2° C per 1,000 feet x 3 = 6° C]). However, if the actual temperature is 20° C (11° C more than that predicted by ISA) then the difference of 11° C is multiplied by 120 feet equaling 1,320. Adding this figure to the original 3,000 feet provides a density altitude of 4,320 feet (3,000 feet + 1,320 feet).

Lift

Lift always acts in a direction perpendicular to the relative wind and to the lateral axis of the aircraft. The fact that lift is referenced to the wing, not to the Earth's surface, is the source of many errors in learning flight control. Lift is not always "up." Its direction relative to the Earth's surface changes as the pilot maneuvers the aircraft.

The magnitude of the force of lift is directly proportional to the density of the air, the area of the wings, and the airspeed. It also depends upon the type of wing and the angle of attack. Lift increases with an increase in angle of attack up to the stalling angle, at which point it decreases with any further increase in angle of attack. In conventional aircraft, lift is therefore controlled by varying the angle of attack and speed.

Pitch/Power Relationship

An examination of *Figure 2-7* illustrates the relationship between pitch and power while controlling flight path and airspeed. In order to maintain a constant lift, as airspeed is reduced, pitch must be increased. The pilot controls pitch through the elevators, which control the angle of attack. When back pressure is applied on the elevator control, the tail lowers and the nose rises, thus increasing the wing's angle of attack and lift. Under most conditions the elevator is placing downward pressure on the tail. This pressure requires energy that is taken from aircraft performance (speed). Therefore, when the CG is closer to the aft portion of the aircraft the elevator downward forces are less. This results in less energy used for downward forces, in turn resulting in more energy applied to aircraft performance.

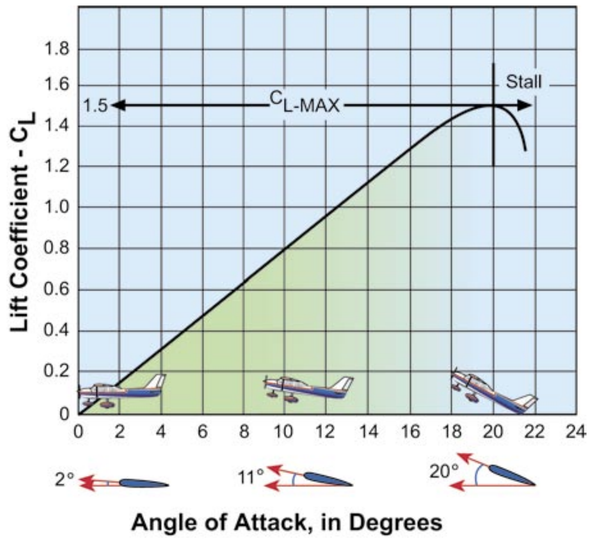

Figure 2-7. *Relationship of Lift to Angle of Attack.*

Thrust is controlled by using the throttle to establish or maintain desired airspeeds. The most precise method of controlling flight path is to use pitch control while simultaneously using power (thrust) to control airspeed. In order to maintain a constant lift, a change in pitch requires a change in power, and vice versa.

If the pilot wants the aircraft to accelerate while maintaining altitude, thrust must be increased to overcome drag. As the aircraft speeds up, lift is increased. To prevent gaining altitude, the pitch angle must be lowered to reduce the angle of attack and maintain altitude. To decelerate while maintaining altitude, thrust must be decreased to less than the value of drag. As the aircraft slows down, lift is reduced. To prevent losing altitude, the pitch angle must be increased in order to increase the angle of attack and maintain altitude.

Drag Curves

When induced drag and parasite drag are plotted on a graph, the total drag on the aircraft appears in the form of a "drag curve." Graph A of *Figure 2-8* shows a curve based on thrust versus drag, which is primarily used for jet aircraft. Graph B of *Figure 2-8* is based on power versus drag, and it is used for propeller-driven aircraft. This chapter focuses on power versus drag charts for propeller-driven aircraft.

Understanding the drag curve can provide valuable insight into the various performance parameters and limitations of the aircraft. Because power must equal drag to maintain a steady airspeed, the curve can be either a drag curve or a power required curve. The power required curve represents the amount of power needed to overcome drag in order to maintain a steady speed in level flight.

The propellers used on most reciprocating engines achieve peak propeller efficiencies in the range of 80 to 88 percent. As airspeed increases, the propeller efficiency increases until it reaches its maximum. Any airspeed above this maximum point causes a reduction in propeller efficiency. An engine that produces 160 horsepower will have only about 80 percent of that power converted into available horsepower,

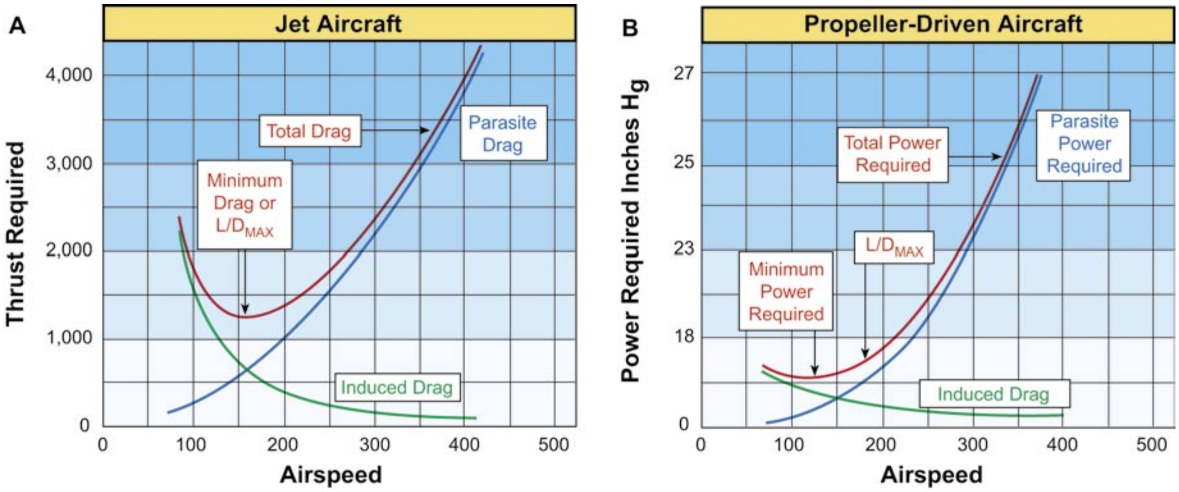

Figure 2-8. *Thrust and Power Required Curves.*

approximately 128 horsepower. The remainder is lost energy. This is the reason the thrust and power available curves change with speed.

Regions of Command

The drag curve also illustrates the two regions of command: the region of normal command, and the region of reversed command. The term "region of command" refers to the relationship between speed and the power required to maintain or change that speed. "Command" refers to the input the pilot must give in terms of power or thrust to maintain a new speed once reached.

The "region of normal command" occurs where power must be added to increase speed. This region exists at speeds higher than the minimum drag point primarily as a result of parasite drag. The "region of reversed command" occurs where additional power is needed to maintain a slower airspeed. This region exists at speeds slower than the minimum drag point (L/D_{MAX} on the thrust required curve, *Figure 2-8*) and is primarily due to induced drag. *Figure 2-9* shows how one power setting can yield two speeds, points 1 and 2. This is because at point 1 there is high induced drag and low parasite drag, while at point 2 there is high parasite drag and low induced drag.

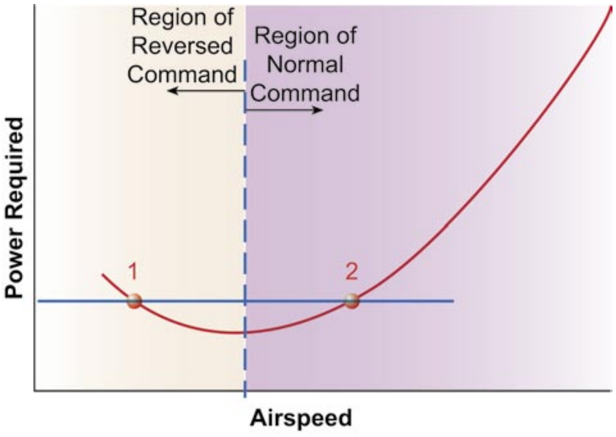

Figure 2-9. *Regions of Command.*

Control Characteristics

Most flying is conducted in the region of normal command: for example, cruise, climb, and maneuvers. The region of reversed command may be encountered in the slow-speed phases of flight during takeoff and landing; however, for most general aviation aircraft, this region is very small and is below normal approach speeds.

Flight in the region of normal command is characterized by a relatively strong tendency of the aircraft to maintain the trim speed. Flight in the region of reversed command is characterized by a relatively weak tendency of the aircraft to maintain the trim speed. In fact, it is likely the aircraft exhibits no inherent tendency to maintain the trim speed in this area. For this reason, the pilot must give particular attention to precise control of airspeed when operating in the slow-speed phases of the region of reversed command.

Operation in the region of reversed command does not imply that great control difficulty and dangerous conditions exist. However, it does amplify errors of basic flying technique—making proper flying technique and precise control of the aircraft very important.

Speed Stability

Normal Command

The characteristics of flight in the region of normal command are illustrated at point A on the curve in *Figure 2-10*. If the aircraft is established in steady, level flight at point A, lift is equal to weight, and the power available is set equal to the power required. If the airspeed is increased with no changes

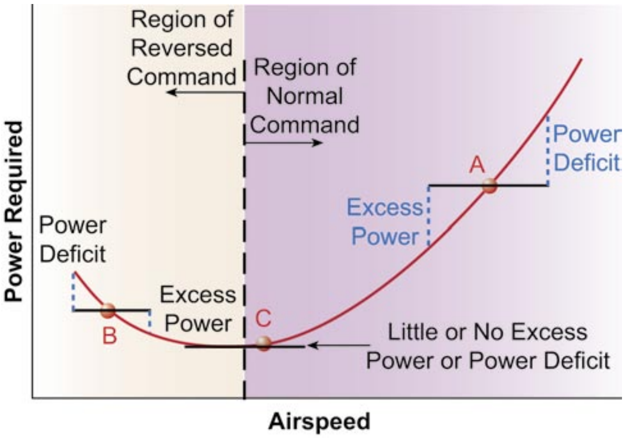

Figure 2-10. *Region of Speed Stability.*

to the power setting, a power deficiency exists. The aircraft has a natural tendency to return to the initial speed to balance power and drag. If the airspeed is reduced with no changes to the power setting, an excess of power exists. The aircraft has a natural tendency to speed up to regain the balance between power and drag. Keeping the aircraft in proper trim enhances this natural tendency. The static longitudinal stability of the aircraft tends to return the aircraft to the original trimmed condition.

An aircraft flying in steady, level flight at point C is in equilibrium. *[Figure 2-10]* If the speed were increased or decreased slightly, the aircraft would tend to remain at that speed. This is because the curve is relatively flat and a slight change in speed does not produce any significant excess or deficiency in power. It has the characteristic of neutral stability, i.e., the aircraft's tendency is to remain at the new speed.

Reversed Command

The characteristics of flight in the region of reversed command are illustrated at point B on the curve in *Figure 2-10*. If the aircraft is established in steady, level flight at point B, lift is equal to weight, and the power available is set equal to the power required. When the airspeed is increased greater than point B, an excess of power exists. This causes the aircraft to accelerate to an even higher speed. When the aircraft is slowed to some airspeed lower than point B, a deficiency of power exists. The natural tendency of the aircraft is to continue to slow to an even lower airspeed.

This tendency toward instability happens because the variation of excess power to either side of point B magnifies the original change in speed. Although the static longitudinal stability of the aircraft tries to maintain the original trimmed condition, this instability is more of an influence because of the increased induced drag due to the higher angles of attack in slow-speed flight.

Trim

The term trim refers to employing adjustable aerodynamic devices on the aircraft to adjust forces so the pilot does not have to manually hold pressure on the controls. One means is to employ trim tabs. A trim tab is a small, adjustable hinged surface, located on the trailing edge of the elevator, aileron, or rudder control surfaces. (Some aircraft use adjustable stabilizers instead of trim tabs for pitch trim.) Trimming is accomplished by deflecting the tab in the direction opposite to that in which the primary control surface must be held. The force of the airflow striking the tab causes the main control surface to be deflected to a position that corrects the unbalanced condition of the aircraft.

Because the trim tabs use airflow to function, trim is a function of speed. Any change in speed results in the need to re-trim the aircraft. An aircraft properly trimmed in pitch seeks to return to the original speed before the change. It is very important for instrument pilots to keep the aircraft in constant trim. This reduces the pilot's workload significantly, allowing attention to other duties without compromising aircraft control.

Slow-Speed Flight

Anytime an aircraft is flying near the stalling speed or the region of reversed command, such as in final approach for a normal landing, the initial part of a go around, or maneuvering in slow flight, it is operating in what is called slow-speed flight. If the aircraft weighs 4,000 pounds, the lift produced by the aircraft must be 4,000 pounds. When lift is less than 4,000 pounds, the aircraft is no longer able to sustain level flight, and consequently descends. During intentional descents, this is an important factor and is used in the total control of the aircraft.

However, because lift is required during low speed flight and is characterized by high angles of attack, flaps or other high lift devices are needed to either change the camber of the airfoil, or delay the boundary level separation. Plain and split flaps *[Figure 2-11]* are most commonly used to change the camber of an airfoil. It should be noted that with the application of flaps, the aircraft will stall at a lower angle of attack. The basic wing stalls at 18° without flaps but with the application of the flaps extended (to $C_{L\text{-}MAX}$ position) the new angle of attack at which point the aircraft will stall is 15°. However, the value of lift (flaps extended to the $C_{L\text{-}MAX}$ position) produces more lift than lift at 18° on the basic wing.

Delaying the boundary layer separation is another way to increase $C_{L\text{-}MAX}$. Several methods are employed (such as suction and use of a blowing boundary layer control), but the most common device used on general aviation light aircraft is the vortex generator. Small strips of metal placed along the wing (usually in front of the control surfaces) create turbulence. The turbulence in turn mixes high energy air from outside the boundary layer with boundary layer air. The effect is similar to other boundary layer devices. *[Figure 2-12]*

Small Airplanes

Most small airplanes maintain a speed well in excess of 1.3 times V_{SO} on an instrument approach. An airplane with a stall speed of 50 knots (V_{SO}) has a normal approach speed of 65 knots. However, this same airplane may maintain 90 knots (1.8 V_{SO}) while on the final segment of an instrument approach. The landing gear will most likely be extended at the beginning of the descent to the minimum descent altitude, or upon intercepting the glide slope of the instrument landing system. The pilot may also select an intermediate flap setting for this phase of the approach. The airplane at this speed has good positive speed stability, as represented by point A on *Figure 2-10*. Flying in this regime permits the pilot to make slight pitch changes without changing power settings, and accept minor speed changes knowing that when the pitch is returned to the initial setting, the speed returns to the original setting. This reduces the pilot's workload.

Aircraft are usually slowed to a normal landing speed when on the final approach just prior to landing. When slowed to 65 knots, (1.3 V_{SO}), the airplane will be close to point C. *[Figure 2-10]* At this point, precise control of the pitch and power becomes more crucial for maintaining the correct speed. Pitch and power coordination is necessary because the speed stability is relatively neutral since the speed tends to remain at the new value and not return to the original setting. In addition to the need for more precise airspeed control, the pilot normally changes the aircraft's configuration by extending landing flaps. This configuration change means the pilot must be alert to unwanted pitch changes at a low altitude.

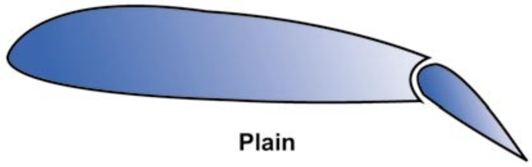

Plain

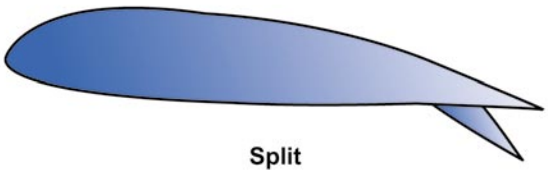

Split

Figure 2-11. *Various Types of Flaps.*

If allowed to slow several knots, the airplane could enter the region of reversed command. At this point, the airplane could develop an unsafe sink rate and continue to lose speed unless the pilot takes a prompt corrective action. Proper pitch and power coordination is critical in this region due to speed instability and the tendency of increased divergence from the desired speed.

Large Airplanes

Pilots of larger airplanes with higher stall speeds may find the speed they maintain on the instrument approach is near 1.3 V_{SO}, putting them near point C *[Figure 2-10]* the entire time the airplane is on the final approach segment. In this case, precise speed control is necessary throughout the approach. It may be necessary to temporarily select excessive, or deficient thrust in relation to the target thrust setting in order to quickly correct for airspeed deviations.

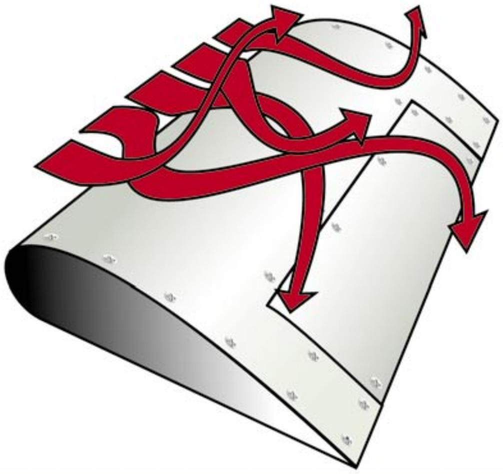

Uncontrolled Turbulence

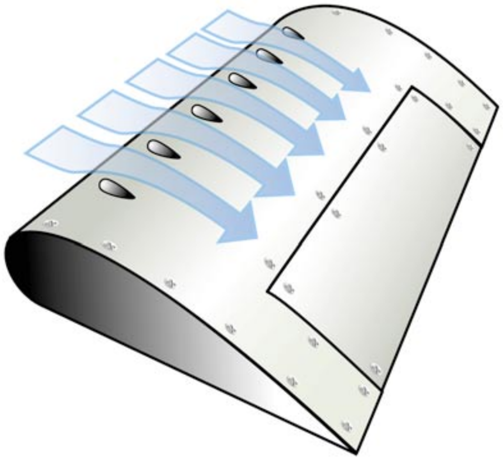

Controlled Vortices

Figure 2-12. *Vortex Generators.*

For example, a pilot is on an instrument approach at 1.3 V_{SO}, a speed near L/D_{MAX}, and knows that a certain power setting maintains that speed. The airplane slows several knots below the desired speed because of a slight reduction in the power setting. The pilot increases the power slightly, and the airplane begins to accelerate, but at a slow rate. Because the airplane is still in the "flat part" of the drag curve, this slight increase in power will not cause a rapid return to the desired speed. The pilot may need to increase the power higher than normally needed to maintain the new speed, allow the airplane to accelerate, then reduce the power to the setting that maintains the desired speed.

Climbs

The ability for an aircraft to climb depends upon an excess power or thrust over what it takes to maintain equilibrium. Excess power is the available power over and above that required to maintain horizontal flight at a given speed. Although the terms power and thrust are sometimes used interchangeably (erroneously implying they are synonymous), distinguishing between the two is important when considering climb performance. Work is the product of a force moving through a distance and is usually independent of time. Power implies work rate or units of work per unit of time, and as such is a function of the speed at which the force is developed. Thrust, also a function of work, means the force which imparts a change in the velocity of a mass.

During take off, the aircraft does not stall even though it may be in a climb near the stall speed. The reason is that excess power (used to produce thrust) is used during this flight regime. Therefore, it is important if an engine fails after take off, to compensate the loss of thrust with pitch and airspeed.

For a given weight of the aircraft, the angle of climb depends on the difference between thrust and drag, or the excess thrust. When the excess thrust is zero, the inclination of the flight path is zero, and the aircraft is in steady, level flight. When thrust is greater than drag, the excess thrust allows a climb angle depending on the amount of excess thrust. When thrust is less than drag, the deficiency of thrust induces an angle of descent.

Acceleration in Cruise Flight

Aircraft accelerate in level flight because of an excess of power over what is required to maintain a steady speed. This is the same excess power used to climb. Upon reaching the desired altitude with pitch being lowered to maintain that altitude, the excess power now accelerates the aircraft to its cruise speed. However, reducing power too soon after level off results in a longer period of time to accelerate.

Turns

Like any moving object, an aircraft requires a sideward force to make it turn. In a normal turn, this force is supplied by banking the aircraft in order to exert lift inward, as well as upward. The force of lift is separated into two components at right angles to each other. *[Figure 2-13]* The upward acting lift together with the opposing weight becomes the vertical lift component. The horizontally acting lift and its opposing centrifugal force are the horizontal lift component, or centripetal force. This horizontal lift component is the sideward force that causes an aircraft to turn. The equal and opposite reaction to this sideward force is centrifugal force, which is merely an apparent force as a result of inertia.

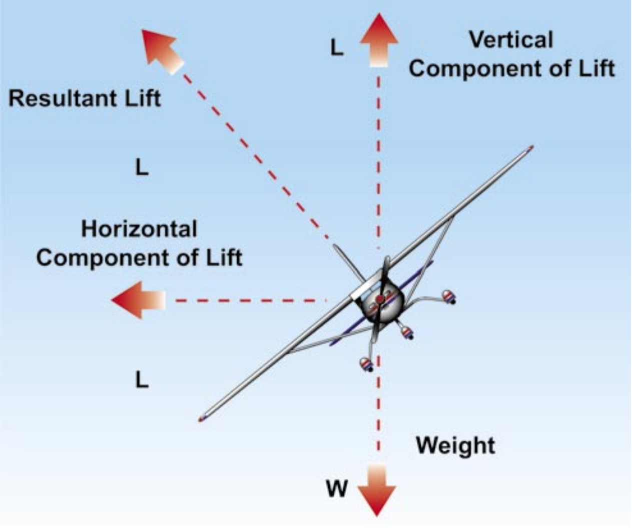

Figure 2-13. *Forces In a Turn.*

The relationship between the aircraft's speed and bank angle to the rate and radius of turns is important for instrument pilots to understand. The pilot can use this knowledge to properly estimate bank angles needed for certain rates of turn, or to determine how much to lead when intercepting a course.

Rate of Turn

The rate of turn, normally measured in degrees per second, is based upon a set bank angle at a set speed. If either one of these elements changes, the rate of turn changes. If the aircraft increases its speed without changing the bank angle, the rate of turn decreases. Likewise, if the speed decreases without changing the bank angle, the rate of turn increases.

Changing the bank angle without changing speed also causes the rate of turn to change. Increasing the bank angle without changing speed increases the rate of turn, while decreasing the bank angle reduces the rate of turn.

The standard rate of turn, 3° per second, is used as the main reference for bank angle. Therefore, the pilot must understand how the angle of bank varies with speed changes, such as slowing down for holding or an instrument approach. *Figure 2-14* shows the turn relationship with reference to a constant bank angle or a constant airspeed, and the effects on rate of turn and radius of turn. A rule of thumb for determining the standard rate turn is to divide the airspeed by ten and add 7. An aircraft with an airspeed of 90 knots takes a bank angle of 16° to maintain a standard rate turn (90 divided by 10 plus 7 equals 16°).

Radius of Turn

The radius of turn varies with changes in either speed or bank. If the speed is increased without changing the bank angle, the radius of turn increases, and vice versa. If the speed is constant, increasing the bank angle reduces the radius of turn, while decreasing the bank angle increases the radius of turn. This means that intercepting a course at a higher speed requires more distance, and therefore, requires a longer lead. If the speed is slowed considerably in preparation for holding or an approach, a shorter lead is needed than that required for cruise flight.

Coordination of Rudder and Aileron Controls

Any time ailerons are used, adverse yaw is produced. Adverse yaw is caused when the ailerons are deflected as a roll motion (as in turn) is initiated. In a right turn, the right aileron is deflected upward while the left is deflected downward. Lift is increased on the left side and reduced on the right, resulting in a bank to the right. However, as a result of producing lift on the left, induced drag is also increased on the left side. The drag causes the left wing to slow down, in turn causing the nose of the aircraft to initially move (left) in the direction opposite of the turn. Correcting for this yaw with rudder, when entering and exiting turns, is necessary for precise control of the airplane when flying on instruments. The pilot can tell if the turn is coordinated by checking the ball in the turn-and-slip indicator or the turn coordinator. *[Figure 2-15]*

As the aircraft banks to enter a turn, a portion of the wing's vertical lift becomes the horizontal component; therefore, without an increase in back pressure, the aircraft loses altitude during the turn. The loss of vertical lift can be offset by increasing the pitch in one-half bar width increments. Trim may be used to relieve the control pressures; however, if used, it has to be removed once the turn is complete.

In a slipping turn, the aircraft is not turning at the rate appropriate to the bank being used, and the aircraft falls to the inside of the turn. The aircraft is banked too much for the rate of turn, so the horizontal lift component is greater than the centrifugal force. A skidding turn results from excess of centrifugal force over the horizontal lift component, pulling the aircraft toward the outside of the turn. The rate of turn is too great for the angle of bank, so the horizontal lift component is less than the centrifugal force.

The ball instrument indicates the quality of the turn, and should be centered when the wings are banked. If the ball is off of center on the side toward the turn, the aircraft is slipping and rudder pressure should be added on that side to increase the rate of turn or the bank angle should be reduced. If the ball is off of center on the side away from the turn, the aircraft is skidding and rudder pressure toward the turn should be relaxed or the bank angle should be increased. If the aircraft is properly rigged, the ball should be in the center when the wings are level; use rudder and/or aileron trim if available.

The increase in induced drag (caused by the increase in angle of attack necessary to maintain altitude) results in a minor loss of airspeed if the power setting is not changed.

Load Factor

Any force applied to an aircraft to deflect its flight from a straight line produces a stress on its structure; the amount of this force is termed load factor. A load factor is the ratio of

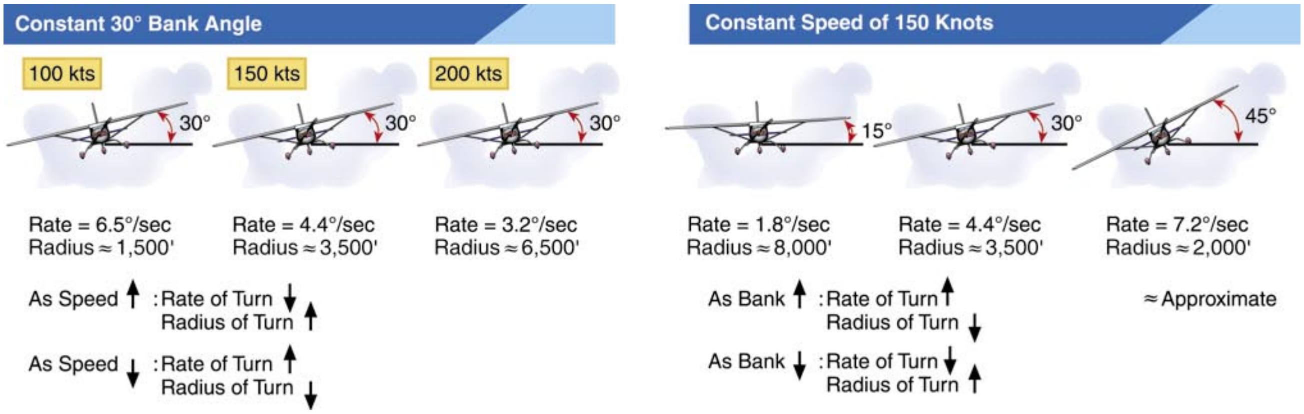

Figure 2-14. *Turns.*

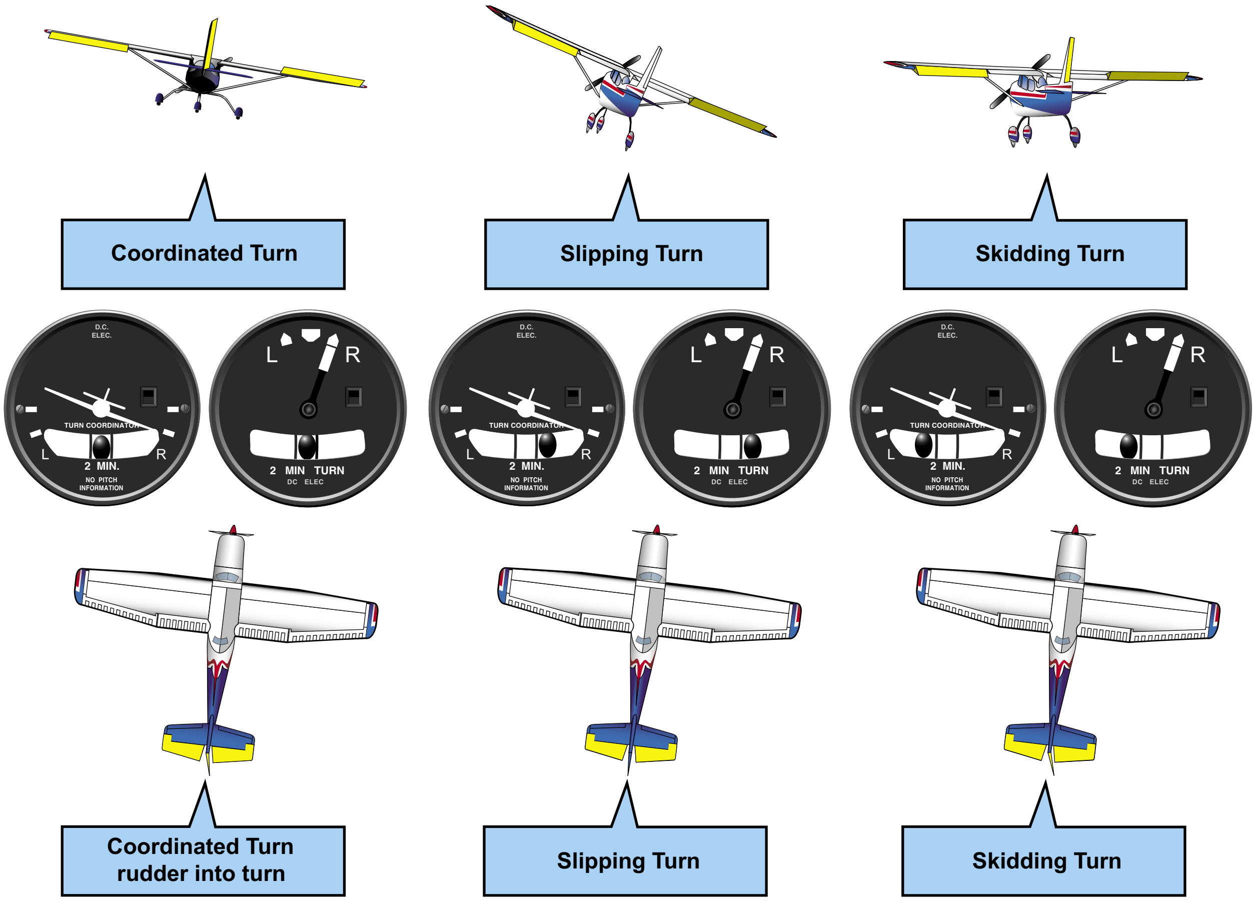

Note the slight differences in rudder placement.

Figure 2-15. *Adverse Yaw.*

the aerodynamic force on the aircraft to the gross weight of the aircraft (e.g., lift/weight). For example, a load factor of 3 means the total load on an aircraft's structure is three times its gross weight. When designing an aircraft, it is necessary to determine the highest load factors that can be expected in normal operation under various operational situations. These "highest" load factors are called "limit load factors."

Aircraft are placed in various categories, i.e., normal, utility, and acrobatic, depending upon the load factors they are designed to take. For reasons of safety, the aircraft must be designed to withstand certain maximum load factors without any structural damage.

The specified load may be expected in terms of aerodynamic forces, as in turns. In level flight in undisturbed air, the wings are supporting not only the weight of the aircraft, but centrifugal force as well. As the bank steepens, the horizontal lift component increases, centrifugal force increases, and the load factor increases. If the load factor becomes so great that an increase in angle of attack cannot provide enough lift to support the load, the wing stalls. Since the stalling speed increases directly with the square root of the load factor, the pilot should be aware of the flight conditions during which the load factor can become critical. Steep turns at slow airspeed, structural ice accumulation, and vertical gusts in turbulent air can increase the load factor to a critical level.

Icing

One of the greatest hazards to flight is aircraft icing. The instrument pilot must be aware of the conditions conducive to aircraft icing. These conditions include the types of icing, the effects of icing on aircraft control and performance, effects of icing on aircraft systems, and the use and limitations of aircraft deice and anti-ice equipment. Coping with the hazards of icing begins with preflight planning to determine where icing may occur during a flight and ensuring the aircraft is free of ice and frost prior to takeoff. This attention to detail extends to managing deice and anti-ice systems properly during the flight, because weather conditions may change rapidly, and the pilot must be able to recognize when a change of flight plan is required.

Types of Icing

Structural Icing

Structural icing refers to the accumulation of ice on the exterior of the aircraft. Ice forms on aircraft structures and surfaces when super-cooled droplets impinge on them and freeze. Small and/or narrow objects are the best collectors of droplets and ice up most rapidly. This is why a small protuberance within sight of the pilot can be used as an "ice evidence probe." It is generally one of the first parts of the airplane on which an appreciable amount of ice forms. An aircraft's tailplane is a better collector than its wings, because the tailplane presents a thinner surface to the airstream.

Induction Icing

Ice in the induction system can reduce the amount of air available for combustion. The most common example of reciprocating engine induction icing is carburetor ice. Most pilots are familiar with this phenomenon, which occurs when moist air passes through a carburetor venturi and is cooled. As a result of this process, ice may form on the venturi walls and throttle plate, restricting airflow to the engine. This may occur at temperatures between 20° F (-7° C) and 70° F (21° C). The problem is remedied by applying carburetor heat, which uses the engine's own exhaust as a heat source to melt the ice or prevent its formation. On the other hand, fuel-injected aircraft engines usually are less vulnerable to icing but still can be affected if the engine's air source becomes blocked with ice. Manufacturers provide an alternate air source that may be selected in case the normal system malfunctions.

In turbojet aircraft, air that is drawn into the engines creates an area of reduced pressure at the inlet, which lowers the temperature below that of the surrounding air. In marginal icing conditions (i.e., conditions where icing is possible), this reduction in temperature may be sufficient to cause ice to form on the engine inlet, disrupting the airflow into the engine. Another hazard occurs when ice breaks off and is ingested into a running engine, which can cause damage to fan blades, engine compressor stall, or combustor flameout. When anti-icing systems are used, runback water also can refreeze on unprotected surfaces of the inlet and, if excessive, reduce airflow into the engine or distort the airflow pattern in such a manner as to cause compressor or fan blades to vibrate, possibly damaging the engine. Another problem in turbine engines is the icing of engine probes used to set power levels (for example, engine inlet temperature or engine pressure ratio (EPR) probes), which can lead to erroneous readings of engine instrumentation operational difficulties or total power loss.

The type of ice that forms can be classified as clear, rime, or mixed, based on the structure and appearance of the ice. The type of ice that forms varies depending on the atmospheric and flight conditions in which it forms. Significant structural icing on an aircraft can cause serious aircraft control and performance problems.

Clear Ice

A glossy, transparent ice formed by the relatively slow freezing of super cooled water is referred to as clear ice. *[Figure 2-16]* The terms "clear" and "glaze" have been used for essentially the same type of ice accretion. This type of ice is denser, harder, and sometimes more transparent than rime ice. With larger accretions, clear ice may form "horns." *[Figure 2-17]* Temperatures close to the freezing point, large amounts of liquid water, high aircraft velocities, and large droplets are conducive to the formation of clear ice.

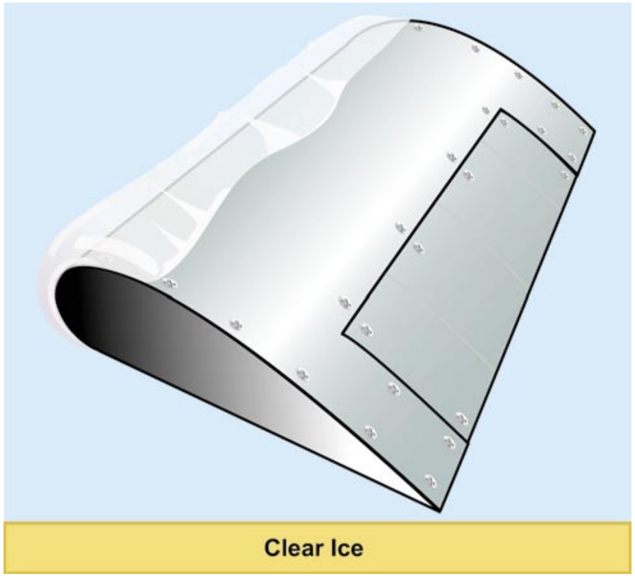

Figure 2-16. *Clear Ice.*

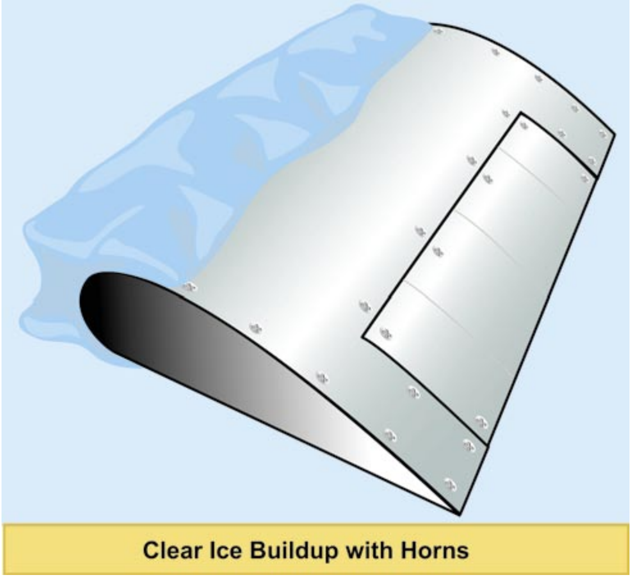
Clear Ice Buildup with Horns

Figure 2-17. *Clear Ice Buildup.*

Rime Ice

A rough, milky, opaque ice formed by the instantaneous or very rapid freezing of super cooled droplets as they strike the aircraft is known as rime ice. *[Figure 2-18]* The rapid freezing results in the formation of air pockets in the ice, giving it an opaque appearance and making it porous and brittle. For larger accretions, rime ice may form a streamlined extension of the wing. Low temperatures, lesser amounts of liquid water, low velocities, and small droplets are conducive to the formation of rime ice.

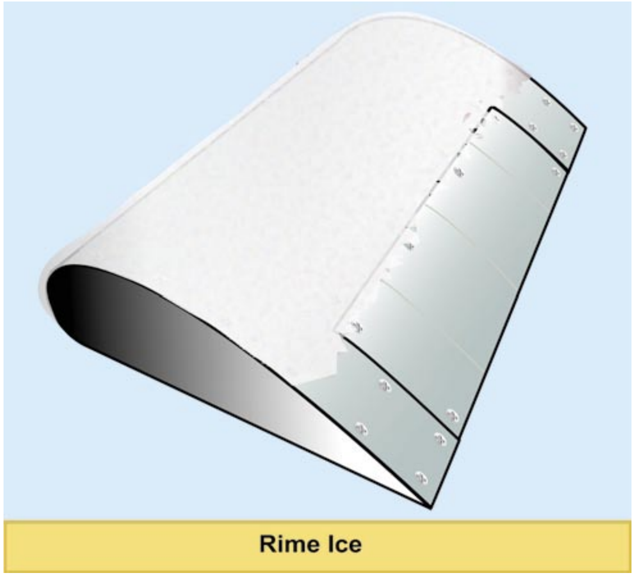

Figure 2-18. *Rime Ice.*

Mixed Ice

Mixed ice is a combination of clear and rime ice formed on the same surface. It is the shape and roughness of the ice that is most important from an aerodynamic point of view.

General Effects of Icing on Airfoils

The most hazardous aspect of structural icing is its aerodynamic effects. *[Figure 2-19]* Ice alters the shape of an airfoil, reducing the maximum coefficient of lift and angle of attack at which the aircraft stalls. Note that at very low angles of attack, there may be little or no effect of the ice on the coefficient of lift. Therefore, when cruising at a low angle of attack, ice on the wing may have little effect on the lift. However, note that the ice significantly reduces the $C_{L\text{-}MAX}$, and the angle of attack at which it occurs (the stall angle) is much lower. Thus, when slowing down and increasing the angle of attack for approach, the pilot may find that ice on the wing, which had little effect on lift in cruise now, causes stall to occur at a lower angle of attack and higher speed. Even a thin layer of ice at the leading edge of a wing, especially if it is rough, can have a significant effect in increasing stall speed. For large ice shapes, especially those with horns, the lift may also be reduced at a lower angle of attack. The accumulation of ice affects the coefficient of drag of the airfoil. *[Figure 2-19]* Note that the effect is significant even at very small angles of attack.

A significant reduction in $C_{L\text{-}MAX}$ and a reduction in the angle of attack where stall occurs can result from a relatively small ice accretion. A reduction of $C_{L\text{-}MAX}$ by 30 percent is not unusual, and a large horn ice accretion can result in reductions of 40 percent to 50 percent. Drag tends to increase steadily as ice accretes. An airfoil drag increase of 100 percent is not unusual, and for large horn ice accretions, the increase can be 200 percent or even higher.

Ice on an airfoil can have other effects not depicted in these curves. Even before airfoil stall, there can be changes in the pressure over the airfoil that may affect a control surface at the trailing edge. Furthermore, on takeoff, approach, and landing, the wings of many aircraft are multi-element airfoils with three or more elements. Ice may affect the different

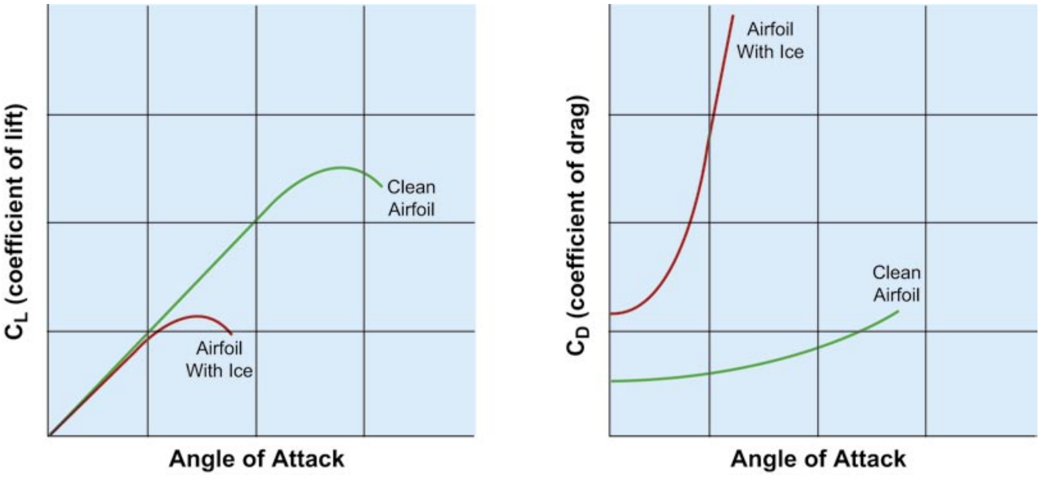

Figure 2-19. *Aerodynamic Effects of Icing.*

elements in different ways. Ice may also affect the way in which the air streams interact over the elements.

Ice can partially block or limit control surfaces, which limits or makes control movements ineffective. Also, if the extra weight caused by ice accumulation is too great, the aircraft may not be able to become airborne and, if in flight, the aircraft may not be able to maintain altitude. Therefore any accumulation of ice or frost should be removed before attempting flight.

Another hazard of structural icing is the possible uncommanded and uncontrolled roll phenomenon, referred to as roll upset, associated with severe in-flight icing. Pilots flying aircraft certificated for flight in known icing conditions should be aware that severe icing is a condition outside of the aircraft's certification icing envelope. Roll upset may be caused by airflow separation (aerodynamic stall), which induces self-deflection of the ailerons and loss of or degraded roll handling characteristics *[Figure 2-20]*. These phenomena can result from severe icing conditions without the usual symptoms of ice accumulation or a perceived aerodynamic stall.

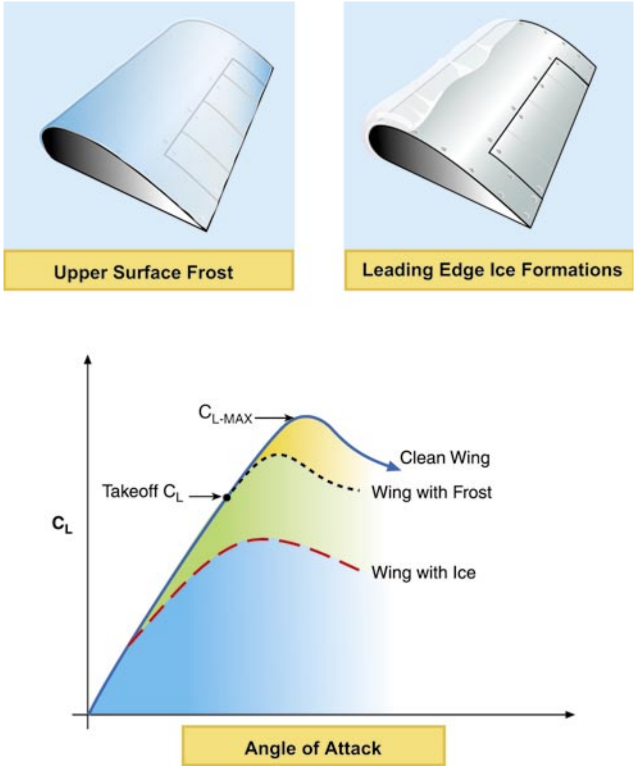

Figure 2-20. *Effect of Ice and Frost on Lift.*

Most aircraft have a nose-down pitching moment from the wings because the CG is ahead of the CP. It is the role of the tailplane to counteract this moment by providing a downward force. *[Figure 2-21]* The result of this configuration is that actions which move the wing away from stall, such as deployment of flaps or increasing speed, may increase the negative angle of attack of the tail. With ice on the tailplane, it may stall after full or partial deployment of flaps. *[Figure 2-22]*

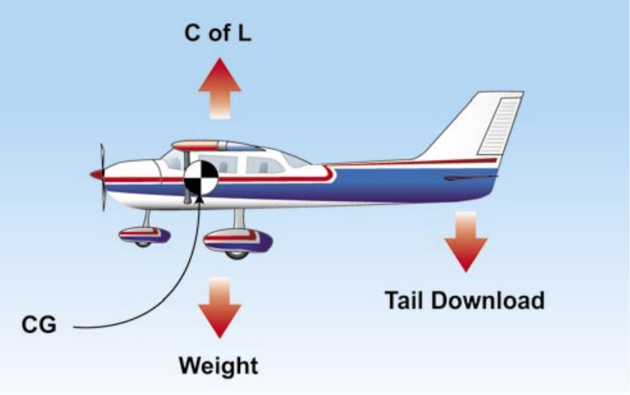

Figure 2-21. *Downward Force on the Tailplane.*

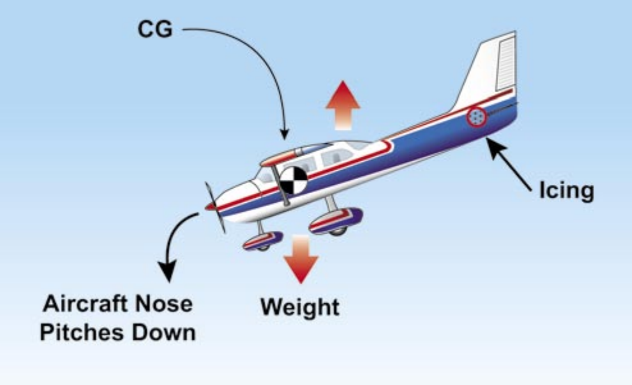

Figure 2-22. *Ice on the Tailplane.*

Since the tailplane is ordinarily thinner than the wing, it is a more efficient collector of ice. On most aircraft the tailplane is not visible to the pilot, who therefore cannot observe how well it has been cleared of ice by any deicing system. Thus, it is important that the pilot be alert to the possibility of tailplane stall, particularly on approach and landing.

Piper PA-34-200T (Des Moines, Iowa)

The pilot of this flight, which took place on January 9, 1996, said that upon crossing the runway threshold and lowering the flaps 25°, "the airplane pitched down." The pilot "immediately released the flaps and added power, but the airplane was basically uncontrollable at this point." The pilot reduced power and lowered the flaps before striking the runway on its centerline and sliding 1,000 feet before coming to a stop. The accident resulted in serious injury to the pilot, the sole occupant.

Examination of the wreckage revealed heavy impact damage to the airplane's forward fuselage, engines, and wings. Approximately one-half inch of rime ice was observed adhering to the leading edges of the left and right horizontal stabilizers and along the leading edge of the vertical stabilizer.

The National Transportation Safety Board (NTSB) determined the probable cause of the accident was the pilot's failure to use the airplane's deicing system, which resulted in an accumulation of empennage ice and a tailplane stall. Factors relating to this accident were the icing conditions and the pilot's intentional flight into those known conditions.

Tailplane Stall Symptoms

Any of the following symptoms, occurring singly or in combination, may be a warning of tailplane icing:

- Elevator control pulsing, oscillations, or vibrations;
- Abnormal nose-down trim change;
- Any other unusual or abnormal pitch anomalies (possibly resulting in pilot induced oscillations);
- Reduction or loss of elevator effectiveness;
- Sudden change in elevator force (control would move nose-down if unrestrained); and
- Sudden uncommanded nose-down pitch.

If any of the above symptoms occur, the pilot should:

- Immediately retract the flaps to the previous setting and apply appropriate nose-up elevator pressure;
- Increase airspeed appropriately for the reduced flap extension setting;
- Apply sufficient power for aircraft configuration and conditions. (High engine power settings may adversely impact response to tailplane stall conditions at high airspeed in some aircraft designs. Observe the manufacturer's recommendations regarding power settings.);
- Make nose-down pitch changes slowly, even in gusting conditions, if circumstances allow; and
- If a pneumatic deicing system is used, operate the system several times in an attempt to clear the tailplane of ice.

Once a tailplane stall is encountered, the stall condition tends to worsen with increased airspeed and possibly may worsen with increased power settings at the same flap setting. Airspeed, at any flap setting, in excess of the airplane manufacturer's recommendations, accompanied by uncleared ice contaminating the tailplane, may result in a tailplane stall and uncommanded pitch down from which recovery may not be possible. A tailplane stall may occur at speeds less than the maximum flap extended speed (VFE).

Propeller Icing

Ice buildup on propeller blades reduces thrust for the same aerodynamic reasons that wings tend to lose lift and increase drag when ice accumulates on them. The greatest quantity of ice normally collects on the spinner and inner radius of the propeller. Propeller areas on which ice may accumulate and be ingested into the engine normally are anti-iced rather than deiced to reduce the probability of ice being shed into the engine.

Effects of Icing on Critical Aircraft Systems

In addition to the hazards of structural and induction icing, the pilot must be aware of other aircraft systems susceptible to icing. The effects of icing do not produce the performance loss of structural icing or the power loss of induction icing but can present serious problems to the instrument pilot. Examples of such systems are flight instruments, stall warning systems, and windshields.

Flight Instruments

Various aircraft instruments including the airspeed indicator, altimeter, and rate-of-climb indicator utilize pressures sensed by pitot tubes and static ports for normal operation. When covered by ice these instruments display incorrect information thereby presenting serious hazard to instrument flight. Detailed information on the operation of these instruments and the specific effects of icing is presented in Chapter 3, Flight Instruments.

Stall Warning Systems

Stall warning systems provide essential information to pilots. These systems range from a sophisticated stall warning vane to a simple stall warning switch. Icing affects these systems in several ways resulting in possible loss of stall warning to the pilot. The loss of these systems can exacerbate an already hazardous situation. Even when an aircraft's stall warning system remains operational during icing conditions, it may be ineffective because the wing stalls at a lower angle of attack due to ice on the airfoil.

Windshields

Accumulation of ice on flight deck windows can severely restrict the pilot's visibility outside of the aircraft. Aircraft equipped for flight into known icing conditions typically have some form of windshield anti-icing to enable the pilot to see outside the aircraft in case icing is encountered in flight. One system consists of an electrically heated plate installed onto the airplane's windshield to give the pilot a narrow band of clear visibility. Another system uses a bar at the lower end of the windshield to spray deicing fluid onto it and prevent ice from forming. On high performance aircraft that require complex windshields to protect against bird strikes and withstand pressurization loads, the heating element often is a layer of conductive film or thin wire strands through which electric current is run to heat the windshield and prevent ice from forming.

Antenna Icing

Because of their small size and shape, antennas that do not lay flush with the aircraft's skin tend to accumulate ice rapidly. Furthermore, they often are devoid of internal anti-icing or deicing capability for protection. During flight in icing conditions, ice accumulations on an antenna may cause it to begin to vibrate or cause radio signals to become distorted and it may cause damage to the antenna. If a frozen antenna breaks off, it can damage other areas of the aircraft in addition to causing a communication or navigation system failure.

Summary

Ice-contaminated aircraft have been involved in many accidents. Takeoff accidents have usually been due to failure to deice or anti-ice critical surfaces properly on the ground. Proper deicing and anti-icing procedures are addressed in two other pilot guides, Advisory Circular (AC) 120-58, Pilot Guide: Large Aircraft Ground Deicing and AC 135-17, Pilot Guide: Small Aircraft Ground Deicing.

The pilot of an aircraft, which is not certificated or equipped for flight in icing conditions, should avoid all icing conditions. The aforementioned guides provide direction on how to do this, and on how to exit icing conditions promptly and safely should they be inadvertently encountered.

The pilot of an aircraft, which is certificated for flight in icing conditions can safely operate in the conditions for which the aircraft was evaluated during the certification process but should never become complacent about icing. Even short encounters with small amounts of rough icing can be very hazardous. The pilot should be familiar with all information in the Aircraft Flight Manual (AFM) or Pilot's Operating Handbook (POH) concerning flight in icing conditions and follow it carefully. Of particular importance are proper operation of ice protection systems and any airspeed minimums to be observed during or after flight in icing conditions. There are some icing conditions for which no aircraft is evaluated in the certification process, such as super-cooled large drops (SLD). These subfreezing water droplets, with diameters greater than 50 microns, occur within or below clouds and sustained flight in these conditions can be very hazardous. The pilot should be familiar with any information in the AFM or POH relating to these conditions, including aircraft-specific cues for recognizing these hazardous conditions within clouds.

The information in this chapter is an overview of the hazards of aircraft icing. For more detailed information refer to AC 91-74, Pilot Guide: Flight in Icing Conditions, AC 91-51A, Effect of Icing on Aircraft Control and Airplane Deice and Anti-Ice Systems, AC 20-73A, Aircraft Ice Protection and AC 23.143-1, Ice Contaminated Tailplane Stall (ICTS).

Chapter 3

Flight Instruments

Introduction

Aircraft became a practical means of transportation when accurate flight instruments freed the pilot from the necessity of maintaining visual contact with the ground. Flight instruments are crucial to conducting safe flight operations and it is important that the pilot have a basic understanding of their operation. The basic flight instruments required for operation under visual flight rules (VFR) are airspeed indicator (ASI), altimeter, and magnetic direction indicator. In addition to these, operation under instrument flight rules (IFR) requires a gyroscopic rate-of-turn indicator, slip-skid indicator, sensitive altimeter adjustable for barometric pressure, clock displaying hours, minutes, and seconds with a sweep-second pointer or digital presentation, gyroscopic pitch-and-bank indicator (artificial horizon), and gyroscopic direction indicator (directional gyro or equivalent).

Aircraft that are flown in instrument meteorological conditions (IMC) are equipped with instruments that provide attitude and direction reference, as well as navigation instruments that allow precision flight from takeoff to landing with limited or no outside visual reference.

The instruments discussed in this chapter are those required by Title 14 of the Code of Federal Regulations (14 CFR) part 91, and are organized into three groups: pitot-static instruments, compass systems, and gyroscopic instruments. The chapter concludes with a discussion of how to preflight these systems for IFR flight. This chapter addresses additional avionics systems such as Electronic Flight Information Systems (EFIS), Ground Proximity Warning System (GPWS), Terrain Awareness and Warning System (TAWS), Traffic Alert and Collision Avoidance System (TCAS), Head Up Display (HUD), etc., that are increasingly being incorporated into general aviation aircraft.

Pitot/Static Systems

Pitot pressure, or impact air pressure, is sensed through an open-end tube pointed directly into the relative wind flowing around the aircraft. The pitot tube connects to pressure operated flight instruments such as the ASI.

Static Pressure

Other instruments depend upon accurate sampling of the ambient still air atmospheric pressure to determine the height and speed of movement of the aircraft through the air, both horizontally and vertically. This pressure, called static pressure, is sampled at one or more locations outside the aircraft. The pressure of the static air is sensed at a flush port where the air is not disturbed. On some aircraft, air is sampled by static ports on the side of the electrically heated pitot-static head. *[Figure 3-1]* Other aircraft pick up the static pressure through flush ports on the side of the fuselage or the vertical fin. These ports are in locations proven by flight tests to be in undisturbed air, and they are normally paired, one on either side of the aircraft. This dual location prevents lateral movement of the aircraft from giving erroneous static pressure indications. The areas around the static ports may be heated with electric heater elements to prevent ice forming over the port and blocking the entry of the static air.

Three basic pressure-operated instruments are found in most aircraft instrument panels. These are the sensitive altimeter, ASI, and vertical speed indicator (VSI). All three receive pressures sensed by the aircraft pitot-static system. The static ports supply pressure to the ASI, altimeter, and VSI.

Blockage Considerations

The pitot tube is particularly sensitive to blockage especially by icing. Even light icing can block the entry hole of the pitot tube where ram air enters the system. This affects the ASI and is the reason most airplanes are equipped with a pitot heating system.

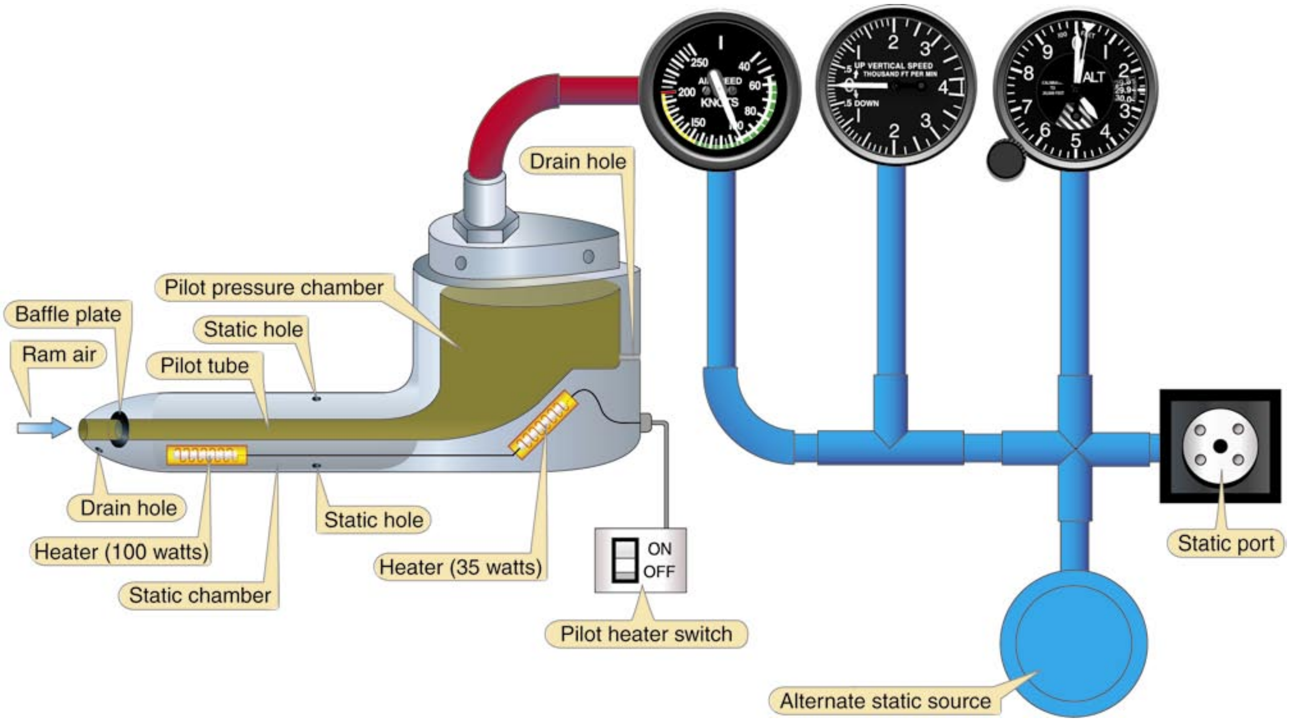

Figure 3-1. *A Typical Electrically Heated Pitot-Static Head.*

Indications of Pitot Tube Blockage

If the pitot tube becomes blocked, the ASI displays inaccurate speeds. At the altitude where the pitot tube becomes blocked, the ASI remains at the existing airspeed and doesn't reflect actual changes in speed.

- At altitudes above where the pitot tube became blocked, the ASI displays a higher-than-actual airspeed increasing steadily as altitude increases.
- At lower altitudes, the ASI displays a lower-than-actual airspeed decreasing steadily as altitude decreases.

Indications from Static Port Blockage

Many aircraft also have a heating system to protect the static ports to ensure the entire pitot-static system is clear of ice. If the static ports become blocked, the ASI would still function but could produce inaccurate indications. At the altitude where the blockage occurs, airspeed indications would be normal.

- At altitudes above which the static ports became blocked, the ASI displays a lower-than-actual airspeed continually decreasing as altitude is increased.
- At lower altitudes, the ASI displays a higher-than-actual airspeed increasing steadily as altitude decreases.

The trapped pressure in the static system causes the altimeter to remain at the altitude where the blockage occurred. The VSI remains at zero. On some aircraft, an alternate static air source valve is used for emergencies. *[Figure 3-2]* If the alternate source is vented inside the airplane, where static pressure is usually lower than outside static pressure, selection of the alternate source may result in the following erroneous instrument indications:

1. Altimeter reads higher than normal,
2. Indicated airspeed (IAS) reads greater than normal, and
3. VSI momentarily shows a climb. Consult the Pilot's Operating Handbook/Airplane Flight Manual (POH/AFM) to determine the amount of error.

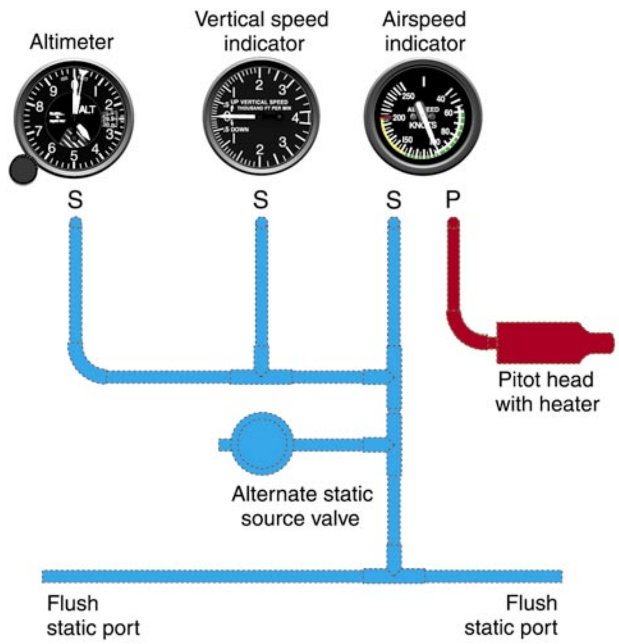

Figure 3-2. *A Typical Pitot-Static System.*

Effects of Flight Conditions

The static ports are located in a position where the air at their surface is as undisturbed as possible. But under some flight conditions, particularly at a high angle of attack with the landing gear and flaps down, the air around the static port may be disturbed to the extent that it can cause an error in the indication of the altimeter and ASI. Because of the importance of accuracy in these instruments, part of the certification tests for an aircraft is a check of position error in the static system.

The POH/AFM contains any corrections that must be applied to the airspeed for the various configurations of flaps and landing gear.

Pitot/Static Instruments

Sensitive Altimeter

A sensitive altimeter is an aneroid barometer that measures the absolute pressure of the ambient air and displays it in terms of feet or meters above a selected pressure level.

Principle of Operation

The sensitive element in a sensitive altimeter is a stack of evacuated, corrugated bronze aneroid capsules. *[Figure 3-3]* The air pressure acting on these aneroids tries to compress them against their natural springiness, which tries to expand them. The result is that their thickness changes as the air pressure changes. Stacking several aneroids increases the dimension change as the pressure varies over the usable range of the instrument.

Below 10,000 feet, a striped segment is visible. Above this altitude, a mask begins to cover it, and above 15,000 feet, all of the stripes are covered. *[Figure 3-4]*

Another configuration of the altimeter is the drum-type. *[Figure 3-5]* These instruments have only one pointer that makes one revolution for every 1,000 feet. Each number represents 100 feet and each mark represents 20 feet. A drum, marked in thousands of feet, is geared to the mechanism that drives the pointer. To read this type of altimeter, first look at

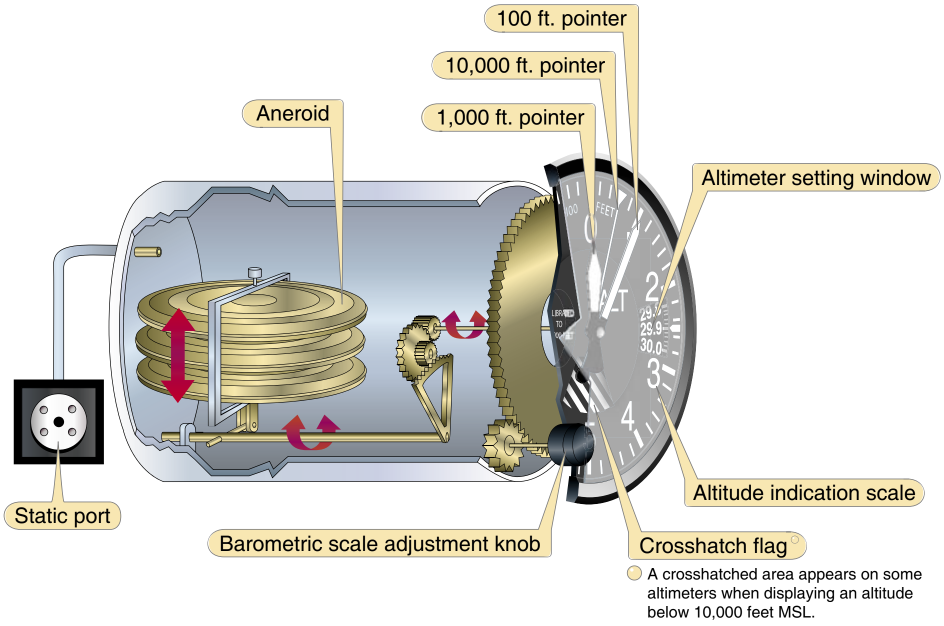
100 ft. pointer
10,000 ft. pointer
1,000 ft. pointer
Aneroid
Altimeter setting window
Static port
Barometric scale adjustment knob
Altitude indication scale
Crosshatch flag
A crosshatched area appears on some altimeters when displaying an altitude below 10,000 feet MSL.

Figure 3-3. *Sensitive Altimeter Components.*

the drum to get the thousands of feet, and then at the pointer to get the feet and hundreds of feet.

A sensitive altimeter is one with an adjustable barometric scale allowing the pilot to set the reference pressure from which the altitude is measured. This scale is visible in a small window called the Kollsman window. A knob on the instrument adjusts the scale. The range of the scale is from 28.00" to 31.00" inches of mercury (Hg), or 948 to 1,050 millibars.

Rotating the knob changes both the barometric scale and the altimeter pointers in such a way that a change in the barometric scale of 1" Hg changes the pointer indication by 1,000 feet. This is the standard pressure lapse rate below 5,000 feet. When the barometric scale is adjusted to 29.92" Hg or 1,013.2 millibars, the pointers indicate the pressure altitude. The pilot displays indicate altitude by adjusting the barometric scale to the local altimeter setting. The altimeter then indicates the height above the existing sea level pressure.

Altimeter Errors

A sensitive altimeter is designed to indicate standard changes from standard conditions, but most flying involves errors caused by nonstandard conditions and the pilot must be able to modify the indications to correct for these errors. There are two types of errors: mechanical and inherent.

Mechanical

A preflight check to determine the condition of an altimeter consists of setting the barometric scale to the local altimeter setting. The altimeter should indicate the surveyed elevation

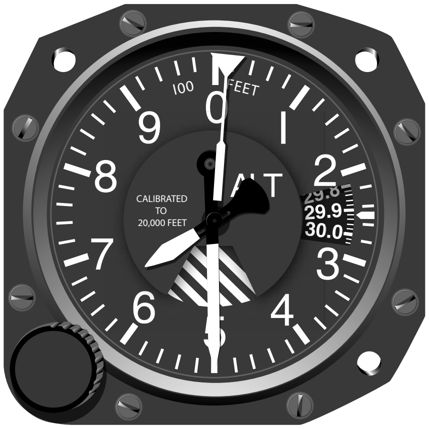
100
FEET
ALT
CALIBRATED TO 20,000 FEET
29.8
29.9
30.0

Figure 3-4. *Three-Pointer Altimeter.*

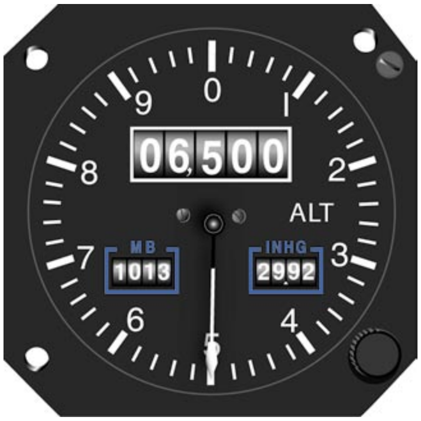
06,500
ALT
MB
1013
INHG
2992

Figure 3-5. *Drum-Type Altimeter.*

of the airport. If the indication is off by more than 75 feet from the surveyed elevation, the instrument should be referred to a certificated instrument repair station for recalibration. Differences between ambient temperature and/or pressure causes an erroneous indication on the altimeter.

Inherent Altimeter Error

When the aircraft is flying in air that is warmer than standard, the air is less dense and the pressure levels are farther apart. When the aircraft is flying at an indicated altitude of 5,000 feet, the pressure level for that altitude is higher than it would be in air at standard temperature, and the aircraft is higher than it would be if the air were cooler. If the air is colder than standard, it is denser and the pressure levels are closer together. When the aircraft is flying at an indicated altitude of 5,000 feet, its true altitude is lower than it would be if the air were warmer. *[Figure 3-6]*

Cold Weather Altimeter Errors

A correctly calibrated pressure altimeter indicates true altitude above mean sea level (MSL) when operating within the International Standard Atmosphere (ISA) parameters of pressure and temperature. Nonstandard pressure conditions are corrected by applying the correct local area altimeter setting.

Temperature errors from ISA result in true altitude being higher than indicated altitude whenever the temperature is warmer than ISA and true altitude being lower than indicated altitude whenever the temperature is colder than ISA. True altitude variance under conditions of colder than ISA temperatures poses the risk of inadequate obstacle clearance. Under extremely cold conditions, pilots may need to add an appropriate temperature correction determined from the chart in *Figure 3-7* to charted IFR altitudes to ensure terrain and obstacle clearance with the following restrictions:

- Altitudes specifically assigned by Air Traffic Control (ATC), such as "maintain 5,000 feet" shall not be corrected. Assigned altitudes may be rejected if the pilot decides that low temperatures pose a risk of inadequate terrain or obstacle clearance.
- If temperature corrections are applied to charted IFR altitudes (such as procedure turn altitudes, final approach fix crossing altitudes, etc.), the pilot must advise ATC of the applied correction.

ICAO Cold Temperature Error Table

The cold temperature induced altimeter error may be significant when considering obstacle clearances when temperatures are well below standard. Pilots may wish to increase their minimum terrain clearance altitudes with a corresponding increase in ceiling from the normal minimum when flying in extreme cold temperature conditions. Higher altitudes may need to be selected when flying at low terrain clearances. Most flight management systems (FMS) with air data computers implement a capability to compensate for cold temperature errors. Pilots flying with these systems should ensure they are aware of the conditions under which the system will automatically compensate. If compensation is applied by the FMS or manually, ATC must be informed that the aircraft is not flying the assigned altitude. Otherwise, vertical separation from other aircraft may be reduced creating a potentially hazardous situation. The table in *Figure 3-7*, derived from International Civil Aviation

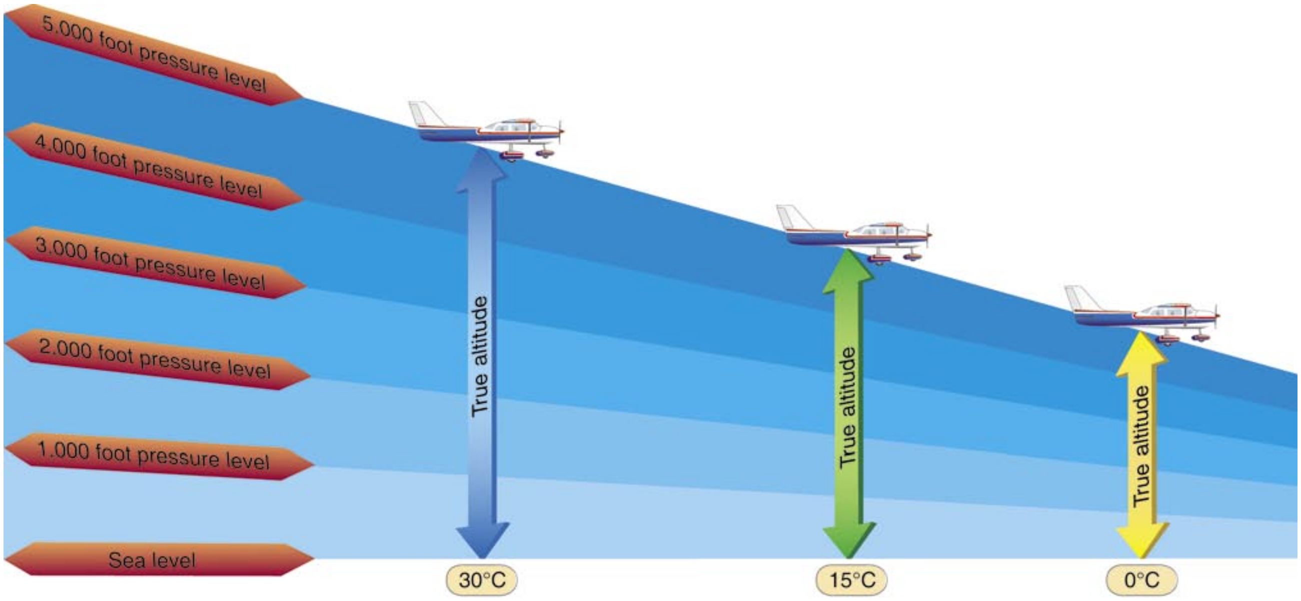
5,000 foot pressure level
4,000 foot pressure level
3,000 foot pressure level
2,000 foot pressure level
1,000 foot pressure level
Sea level
True altitude
True altitude
True altitude
30°C
15°C
0°C

Figure 3-6. *The loss of altitude experienced when flying into an area where the air is colder (more dense) than standard.*

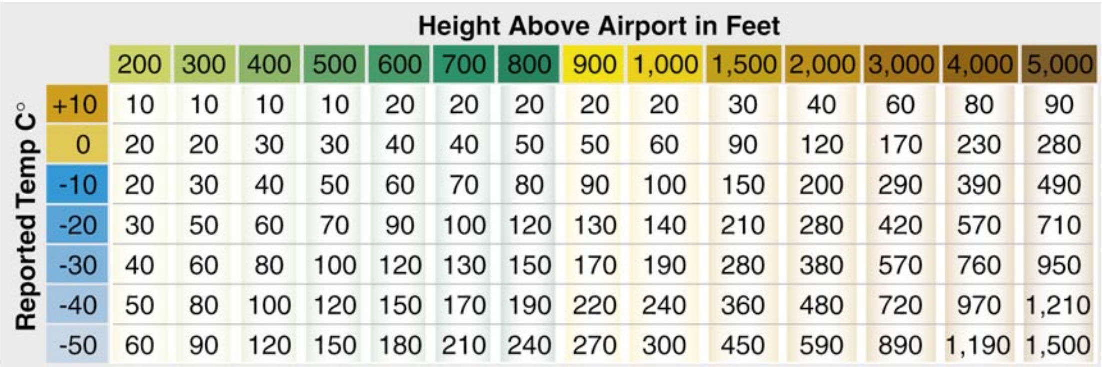

Reported Temp C°	Height Above Airport in Feet													
	200	300	400	500	600	700	800	900	1,000	1,500	2,000	3,000	4,000	5,000
+10	10	10	10	10	20	20	20	20	20	30	40	60	80	90
0	20	20	30	30	40	40	50	50	60	90	120	170	230	280
-10	20	30	40	50	60	70	80	90	100	150	200	290	390	490
-20	30	50	60	70	90	100	120	130	140	210	280	420	570	710
-30	40	60	80	100	120	130	150	170	190	280	380	570	760	950
-40	50	80	100	120	150	170	190	220	240	360	480	720	970	1,210
-50	60	90	120	150	180	210	240	270	300	450	590	890	1,190	1,500

Figure 3-7. *ICAO Cold Temperature Error Table.*

Organization (ICAO) standard formulas, shows how much error can exist when the temperature is extremely cold. To use the table, find the reported temperature in the left column, and then read across the top row to the height above the airport/reporting station. Subtract the airport elevation from the altitude of the final approach fix (FAF). The intersection of the column and row is the amount of possible error.

Example: The reported temperature is -10° Celsius and the FAF is 500 feet above the airport elevation. The reported current altimeter setting may place the aircraft as much as 50 feet below the altitude indicated by the altimeter.

When using the cold temperature error table, the altitude error is proportional to both the height above the reporting station elevation and the temperature at the reporting station. For IFR approach procedures, the reporting station elevation is assumed to be airport elevation. It is important to understand that corrections are based upon the temperature at the reporting station, not the temperature observed at the aircraft's current altitude and height above the reporting station and not the charted IFR altitude.

To see how corrections are applied, note the following example:

Airport Elevation	496 feet
Airport Temperature	- 50° C

A charted IFR approach to the airport provides the following data:

Minimum Procedure Turn Altitude	1,800 feet
Minimum FAF Crossing Altitude	1,200 feet
Straight-in Minimum Descent Altitude	800 feet
Circling MDA	1,000 feet

The Minimum Procedure Turn Altitude of 1,800 feet will be used as an example to demonstrate determination of the appropriate temperature correction. Typically, altitude values are rounded up to the nearest 100-foot level. The charted procedure turn altitude of 1,800 feet minus the airport elevation of 500 feet equals 1,300 feet. The altitude difference of 1,300 feet falls between the correction chart elevations of 1,000 feet and 1,500 feet. At the station temperature of -50°C, the correction falls between 300 feet and 450 feet. Dividing the difference in compensation values by the difference in altitude above the airport gives the error value per foot.

In this case, 150 feet divided by 500 feet = 0.33 feet for each additional foot of altitude above 1,000 feet. This provides a correction of 300 feet for the first 1,000 feet and an additional value of 0.33 times 300 feet, or 99 feet, which is rounded to 100 feet. 300 feet + 100 feet = total temperature correction of 400 feet. For the given conditions, correcting the charted value of 1,800 feet above MSL (equal to a height above the reporting station of 1,300 feet) requires the addition of 400 feet. Thus, when flying at an indicated altitude of 2,200 feet, the aircraft is actually flying a true altitude of 1,800 feet.

Minimum Procedure Turn Altitude
1,800 feet charted = 2,200 feet corrected
Minimum FAF Crossing Altitude
1,200 feet charted = 1,500 feet corrected
Straight-in MDA
800 feet charted = 900 feet corrected
Circling MDA
1,000 feet charted = 1,200 feet corrected

Nonstandard Pressure on an Altimeter

Maintaining a current altimeter setting is critical because the atmosphere pressure is not constant. That is, in one location the pressure might be higher than the pressure just a short distance away. Take an aircraft whose altimeter setting is set to 29.92" of local pressure. As the aircraft moves to an area of lower pressure (Point A to B in *Figure 3-8*) and the pilot fails to readjust the altimeter setting (essentially calibrating it to local pressure), then as the pressure decreases, the true altitude will be lower. Adjusting the altimeter settings compensates for this. When the altimeter shows an indicated altitude of 5,000 feet, the true altitude at Point A (the height above mean sea level) is only 3,500 feet at Point B. The fact that the altitude indication is not always true lends itself to the memory aid, "When flying from hot to cold or from a high to a low, look out below." *[Figure 3-8]*

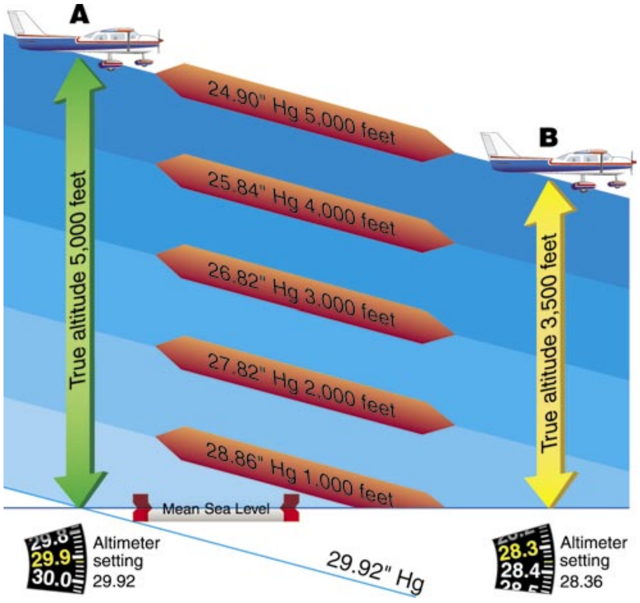

Figure 3-8. *Effects of Nonstandard Pressure on an Altimeter of an Aircraft Flown into Air of Lower Than Standard Pressure (Air is Less Dense).*

Altimeter Enhancements (Encoding)

It is not sufficient in the airspace system for only the pilot to have an indication of the aircraft's altitude; the air traffic controller on the ground must also know the altitude of the aircraft. To provide this information, the aircraft is typically equipped with an encoding altimeter.

When the ATC transponder is set to Mode C, the encoding altimeter supplies the transponder with a series of pulses identifying the flight level (in increments of 100 feet) at which the aircraft is flying. This series of pulses is transmitted to the ground radar where they appear on the controller's scope as an alphanumeric display around the return for the aircraft. The transponder allows the ground controller to identify the aircraft and determine the pressure altitude at which it is flying.

A computer inside the encoding altimeter measures the pressure referenced from 29.92" Hg and delivers this data to the transponder. When the pilot adjusts the barometric scale to the local altimeter setting, the data sent to the transponder is not affected. This is to ensure that all Mode C aircraft are transmitting data referenced to a common pressure level. ATC equipment adjusts the displayed altitudes to compensate for local pressure differences allowing display of targets at correct altitudes. 14 CFR part 91 requires the altitude transmitted by the transponder to be within 125 feet of the altitude indicated on the instrument used to maintain flight altitude.

Reduced Vertical Separation Minimum (RVSM)

Below 31,000 feet, a 1,000 foot separation is the minimum required between usable flight levels. Flight levels (FLs) generally start at 18,000 feet where the local pressure is 29.92" Hg or greater. All aircraft 18,000 feet and above use a standard altimeter setting of 29.92" Hg, and the altitudes are in reference to a standard hence termed FL. Between FL 180 and FL 290, the minimum altitude separation is 1,000 feet between aircraft. However, for flight above FL 290 (primarily due to aircraft equipage and reporting capability; potential error) ATC applied the requirement of 2,000 feet of separation. FL 290, an altitude appropriate for an eastbound aircraft, would be followed by FL 310 for a westbound aircraft, and so on to FL 410, or seven FLs available for flight. With 1,000-foot separation, or a reduction of the vertical separation between FL 290 and FL 410, an additional six FLs become available. This results in normal flight level and direction management being maintained from FL 180 through FL 410. Hence the name is Reduced Vertical Separation Minimum (RVSM). Because it is applied domestically, it is called United States Domestic Reduced Vertical Separation Minimum, or DRVSM.

However, there is a cost to participate in the DRVSM program which relates to both aircraft equipage and pilot training. For example, altimetry error must be reduced significantly and operators using RVSM must receive authorization from the appropriate civil aviation authority. RVSM aircraft must meet required altitude-keeping performance standards. Additionally, operators must operate in accordance with RVSM policies/procedures applicable to the airspace where they are flying.

The aircraft must be equipped with at least one automatic altitude control—

- Within a tolerance band of ±65 feet about an acquired altitude when the aircraft is operated in straight-and-level flight.
- Within a tolerance band of ±130 feet under no turbulent, conditions for aircraft for which application for type certification occurred on or before April 9, 1997 that are equipped with an automatic altitude control system with flight management/performance system inputs.

That aircraft must be equipped with an altitude alert system that signals an alert when the altitude displayed to the flight crew deviates from the selected altitude by more than (in most cases) 200 feet. For each condition in the full RVSM flight envelope, the largest combined absolute value for residual static source error plus the avionics error may not exceed 200 feet. Aircraft with TCAS must have compatibility with RVSM Operations. *Figure 3-9* illustrates the increase in aircraft permitted between FL 180 and FL 410. Most noteworthy, however, is the economization that aircraft can take advantage of by the higher FLs being available to more aircraft.

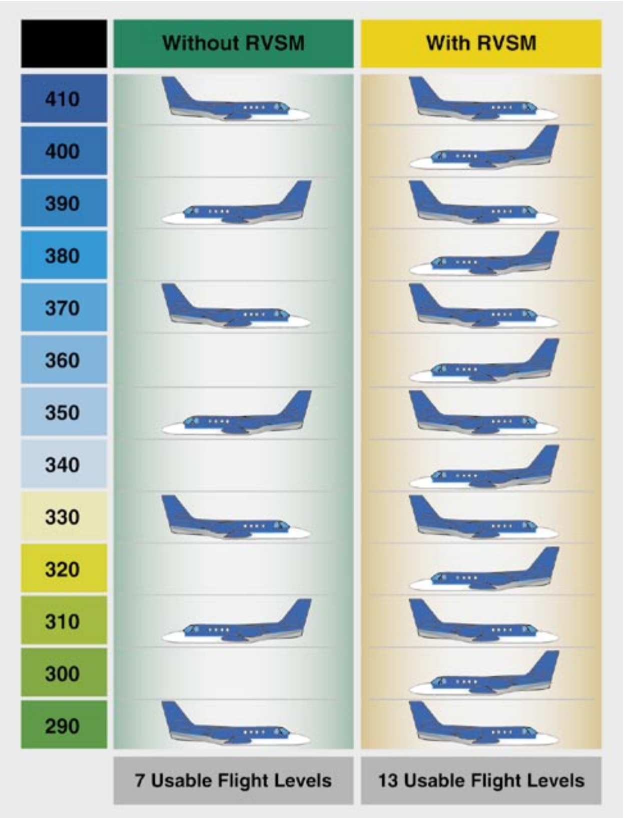

Figure 3-9. *Increase in Aircraft Permitted Between FL 180 and FL 410.*

Vertical Speed Indicator (VSI)

The VSI in *Figure 3-10* is also called a vertical velocity indicator (VVI), and was formerly known as a rate-of-climb indicator. It is a rate-of-pressure change instrument that gives an indication of any deviation from a constant pressure level.

Inside the instrument case is an aneroid very much like the one in an ASI. Both the inside of this aneroid and the inside of the instrument case are vented to the static system, but the case is vented through a calibrated orifice that causes the pressure inside the case to change more slowly than the pressure inside the aneroid. As the aircraft ascends, the static pressure becomes lower. The pressure inside the case compresses the aneroid, moving the pointer upward, showing a climb and indicating the rate of ascent in number of feet per minute (fpm).

When the aircraft levels off, the pressure no longer changes. The pressure inside the case becomes equal to that inside the aneroid, and the pointer returns to its horizontal, or zero, position. When the aircraft descends, the static pressure increases. The aneroid expands, moving the pointer downward, indicating a descent.

The pointer indication in a VSI lags a few seconds behind the actual change in pressure. However, it is more sensitive than an altimeter and is useful in alerting the pilot of an upward or downward trend, thereby helping maintain a constant altitude.

Some of the more complex VSIs, called instantaneous vertical speed indicators (IVSI), have two accelerometer-actuated air pumps that sense an upward or downward pitch of the aircraft and instantaneously create a pressure differential. By the time the pressure caused by the pitch acceleration dissipates, the altitude pressure change is effective.

Dynamic Pressure Type Instruments

Airspeed Indicator (ASI)

An ASI is a differential pressure gauge that measures the dynamic pressure of the air through which the aircraft is flying. Dynamic pressure is the difference in the ambient static air pressure and the total, or ram, pressure caused by the motion of the aircraft through the air. These two pressures are taken from the pitot-static system.

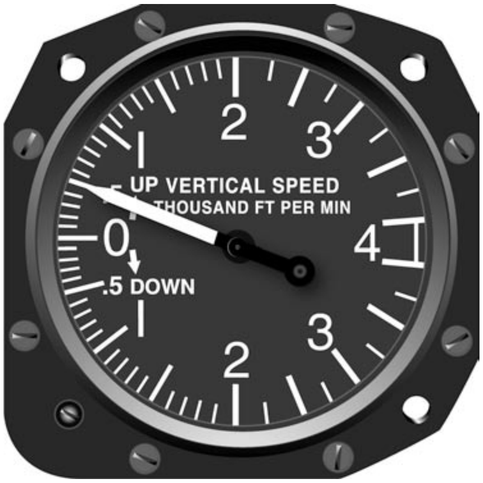

Figure 3-10. *Rate of Climb or Descent in Thousands of Feet Per Minute.*

The mechanism of the ASI in *Figure 3-11* consists of a thin, corrugated phosphor bronze aneroid, or diaphragm, that receives its pressure from the pitot tube. The instrument case is sealed and connected to the static ports. As the pitot pressure increases or the static pressure decreases, the diaphragm expands. This dimensional change is measured by a rocking shaft and a set of gears that drives a pointer across the instrument dial. Most ASIs are calibrated in knots, or nautical miles per hour; some instruments show statute miles per hour, and some instruments show both.

Types of Airspeed

Just as there are several types of altitude, there are multiple types of airspeed: Indicated Airspeed (IAS), Calibrated Airspeed (CAS), Equivalent Airspeed (EAS), and True Airspeed (TAS).

Indicated Airspeed (IAS)

IAS is shown on the dial of the instrument, uncorrected for instrument or system errors.

Calibrated Airspeed (CAS)

CAS is the speed at which the aircraft is moving through the air, which is found by correcting IAS for instrument and position errors. The POH/AFM has a chart or graph to correct IAS for these errors and provide the correct CAS for the various flap and landing gear configurations.

Equivalent Airspeed (EAS)

EAS is CAS corrected for compression of the air inside the pitot tube. EAS is the same as CAS in standard atmosphere at sea level. As the airspeed and pressure altitude increase, the CAS becomes higher than it should be, and a correction for compression must be subtracted from the CAS.

True Airspeed (TAS)

TAS is CAS corrected for nonstandard pressure and temperature. TAS and CAS are the same in standard atmosphere at sea level. Under nonstandard conditions, TAS is found by applying a correction for pressure altitude and temperature to the CAS.

Some aircraft are equipped with true ASIs that have a temperature-compensated aneroid bellows inside the instrument case. This bellows modifies the movement of the rocking shaft inside the instrument case so the pointer shows the actual TAS.

The TAS indicator provides both true and IAS. These instruments have the conventional airspeed mechanism, with an added subdial visible through cutouts in the regular dial. A knob on the instrument allows the pilot to rotate the subdial and align an indication of the outside air temperature with the pressure altitude being flown. This alignment causes the instrument pointer to indicate the TAS on the subdial. *[Figure 3-12]*

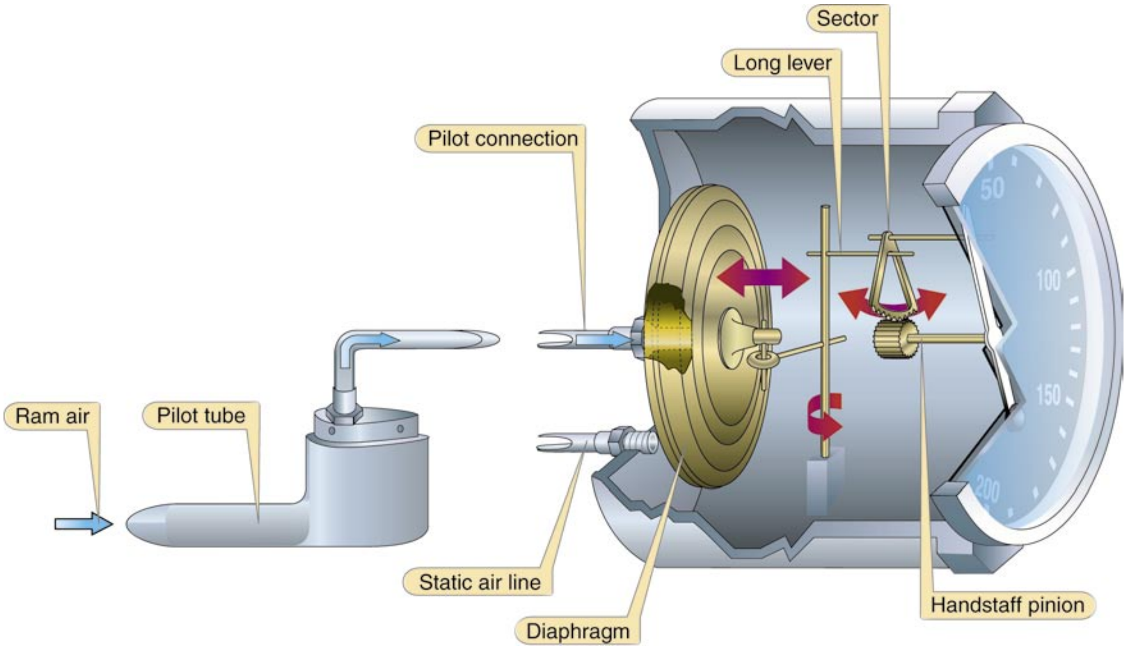

Figure 3-11. *Mechanism of an Airspeed Indicator.*

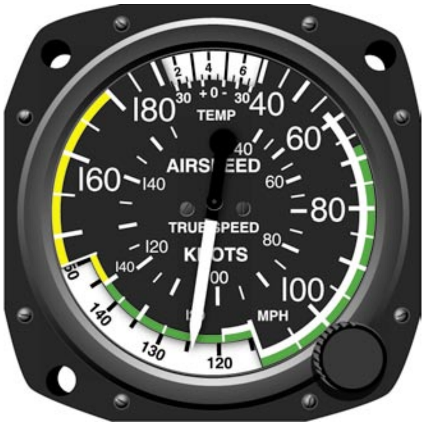

Figure 3-12. *A true airspeed indicator allows the pilot to correct IAS for nonstandard temperature and pressure.*

Mach Number

As an aircraft approaches the speed of sound, the air flowing over certain areas of its surface speeds up until it reaches the speed of sound, and shock waves form. The IAS at which these conditions occur changes with temperature. Therefore, in this case, airspeed is not entirely adequate to warn the pilot of the impending problems. Mach number is more useful. Mach number is the ratio of the TAS of the aircraft to the speed of sound in the same atmospheric conditions. An aircraft flying at the speed of sound is flying at Mach 1.0. Some older mechanical Machmeters not driven from an air data computer use an altitude aneroid inside the instrument that converts pitot-static pressure into Mach number. These systems assume that the temperature at any altitude is standard; therefore, the indicated Mach number is inaccurate whenever the temperature deviates from standard. These systems are called indicated Machmeters. Modern electronic Machmeters use information from an air data computer system to correct for temperature errors. These systems display true Mach number.

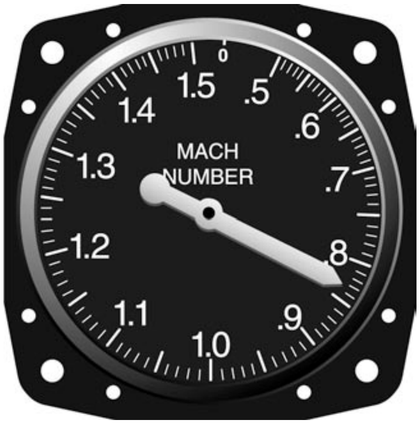

Figure 3-13. *A Machmeter shows the ratio of the speed of sound to the TAS the aircraft is flying.*

Most high-speed aircraft are limited to a maximum Mach number at which they can fly. This is shown on a Machmeter as a decimal fraction. *[Figure 3-13]* For example, if the Machmeter indicates .83 and the aircraft is flying at 30,000 feet where the speed of sound under standard conditions is 589.5 knots, the airspeed is 489.3 knots. The speed of sound varies with the air temperature. If the aircraft were flying at Mach .83 at 10,000 feet where the air is much warmer, its airspeed would be 530 knots.

Maximum Allowable Airspeed

Some aircraft that fly at high subsonic speeds are equipped with maximum allowable ASIs like the one in *Figure 3-14*. This instrument looks much like a standard air-speed indicator, calibrated in knots, but has an additional pointer colored red, checkered, or striped. The maximum airspeed pointer is actuated by an aneroid, or altimeter mechanism, that moves it to a lower value as air density decreases. By keeping the airspeed pointer at a lower value than the maximum pointer, the pilot avoids the onset of transonic shock waves.

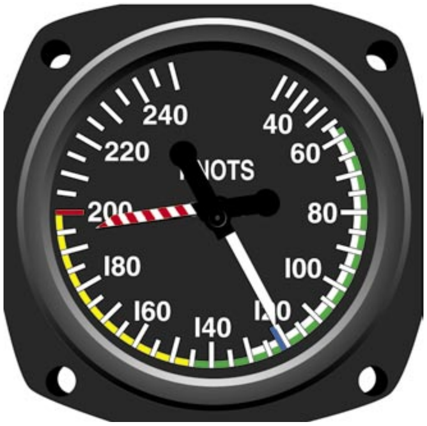

Figure 3-14. *A maximum allowable airspeed indicator has a movable pointer that indicates the never-exceed speed, which changes with altitude to avoid the onset of transonic shock waves.*

Airspeed Color Codes

The dial of an ASI is color coded to alert the pilot, at a glance, of the significance of the speed at which the aircraft is flying. These colors and their associated airspeeds are shown in *Figure 3-15*.

Magnetism

The Earth is a huge magnet, spinning in space, surrounded by a magnetic field made up of invisible lines of flux. These lines leave the surface at the magnetic north pole and reenter at the magnetic South Pole.

Lines of magnetic flux have two important characteristics: any magnet that is free to rotate will align with them, and

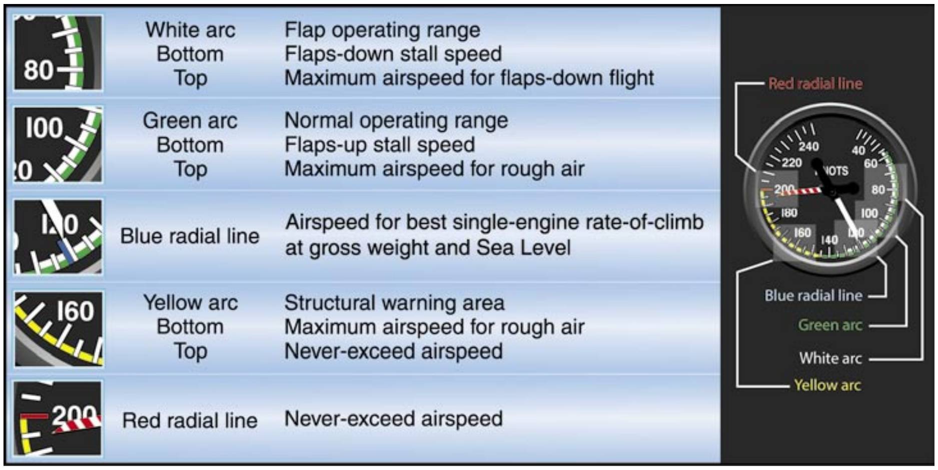

White arc	Flap operating range
Bottom	Flaps-down stall speed
Top	Maximum airspeed for flaps-down flight
Green arc	Normal operating range
Bottom	Flaps-up stall speed
Top	Maximum airspeed for rough air
Blue radial line	Airspeed for best single-engine rate-of-climb at gross weight and Sea Level
Yellow arc	Structural warning area
Bottom	Maximum airspeed for rough air
Top	Never-exceed airspeed
Red radial line	Never-exceed airspeed

Figure 3-15. *Color Codes for an Airspeed Indicator.*

an electrical current is induced into any conductor that cuts across them. Most direction indicators installed in aircraft make use of one of these two characteristics.

The Basic Aviation Magnetic Compass

One of the oldest and simplest instruments for indicating direction is the magnetic compass. It is also one of the basic instruments required by 14 CFR part 91 for both VFR and IFR flight.

Magnetic Compass Overview

A magnet is a piece of material, usually a metal containing iron, which attracts and holds lines of magnetic flux. Regardless of size, every magnet has two poles: a north pole and a south pole. When one magnet is placed in the field of another, the unlike poles attract each other and like poles repel.

An aircraft magnetic compass, such as the one in *Figure 3-16*, has two small magnets attached to a metal float sealed inside a bowl of clear compass fluid similar to kerosene. A graduated scale, called a card, is wrapped around the float and viewed through a glass window with a lubber line across it. The card is marked with letters representing the cardinal directions, north, east, south, and west, and a number for each 30° between these letters. The final "0" is omitted from these directions; for example, 3 = 30°, 6 = 60°, and 33 = 330°. There are long and short graduation marks between the letters and numbers, with each long mark representing 10° and each short mark representing 5°.

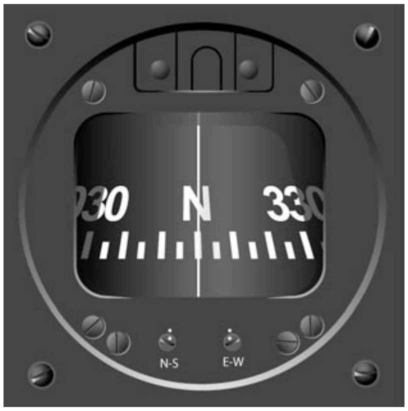

Figure 3-16. *A Magnetic Compass. The vertical line is called the lubber line.*

Magnetic Compass Construction

The float and card assembly has a hardened steel pivot in its center that rides inside a special, spring-loaded, hard-glass jewel cup. The buoyancy of the float takes most of the weight off the pivot, and the fluid damps the oscillation of the float and card. This jewel-and-pivot type mounting allows the float freedom to rotate and tilt up to approximately 18° angle of bank. At steeper bank angles, the compass indications are erratic and unpredictable.

The compass housing is entirely full of compass fluid. To prevent damage or leakage when the fluid expands and contracts with temperature changes, the rear of the compass case is sealed with a flexible diaphragm, or with a metal bellows in some compasses.

Magnetic Compass Theory of Operations

The magnets align with the Earth's magnetic field and the pilot reads the direction on the scale opposite the lubber line. Note that in *Figure 3-16*, the pilot sees the compass card from its backside. When the pilot is flying north as the compass shows, east is to the pilot's right, but on the card "33", which represents 330° (west of north), is to the right of north. The reason for this apparent backward graduation is that the card remains stationary, and the compass housing and the pilot turn around it, always viewing the card from its backside.

A compensator assembly mounted on the top or bottom of the compass allows an aviation maintenance technician (AMT) to create a magnetic field inside the compass housing that cancels the influence of local outside magnetic fields. This is done to correct for deviation error. The compensator assembly has two shafts whose ends have screwdriver slots accessible from the front of the compass. Each shaft rotates one or two small compensating magnets. The end of one shaft is marked E-W, and its magnets affect the compass when the aircraft is pointed east or west. The other shaft is marked N-S and its magnets affect the compass when the aircraft is pointed north or south.

Magnetic Compass Induced Errors

The magnetic compass is the simplest instrument in the panel, but it is subject to a number of errors that must be considered.

Variation

The Earth rotates about its geographic axis; maps and charts are drawn using meridians of longitude that pass through the geographic poles. Directions measured from the geographic poles are called true directions. The north magnetic pole to which the magnetic compass points is not collocated with the geographic north pole, but is some 1,300 miles away; directions measured from the magnetic poles are called magnetic directions. In aerial navigation, the difference between true and magnetic directions is called variation. This same angular difference in surveying and land navigation is called declination.

Figure 3-17 shows the isogonic lines that identify the number of degrees of variation in their area. The line that passes near Chicago is called the agonic line. Anywhere along this line the two poles are aligned, and there is no variation. East of this line, the magnetic pole is to the west of the geographic pole and a correction must be applied to a compass indication to get a true direction.

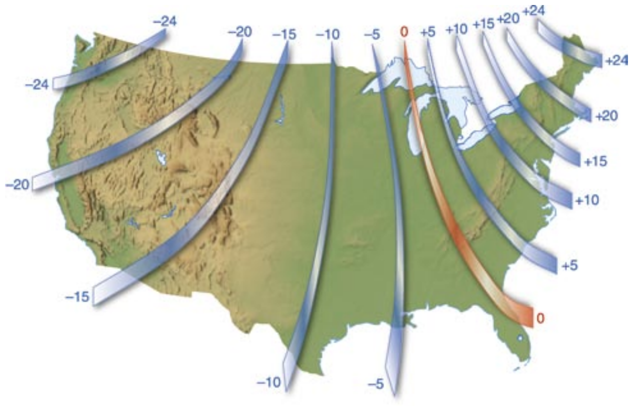

Figure 3-17. *Isogonic lines are lines of equal variation.*

Flying in the Washington, D.C. area, for example, the variation is 10° west. If the pilot wants to fly a true course of south (180°), the variation must be added to this resulting in a magnetic course to fly of 190°. Flying in the Los Angeles, CA area, the variation is 14° east. To fly a true course of 180° there, the pilot would have to subtract the variation and fly a magnetic course of 166°. The variation error does not change with the heading of the aircraft; it is the same anywhere along the isogonic line.

Deviation

The magnets in a compass align with any magnetic field. Local magnetic fields in an aircraft caused by electrical current flowing in the structure, in nearby wiring or any magnetized part of the structure, conflict with the Earth's magnetic field and cause a compass error called deviation.

Deviation, unlike variation, is different on each heading, but it is not affected by the geographic location. Variation error cannot be reduced or changed, but deviation error can be minimized when a pilot or AMT performs the maintenance task known as "swinging the compass."

Most airports have a compass rose, which is a series of lines marked out on a taxiway or ramp at some location where there is no magnetic interference. Lines, oriented to magnetic north, are painted every 30°, as shown in *Figure 3-18*.

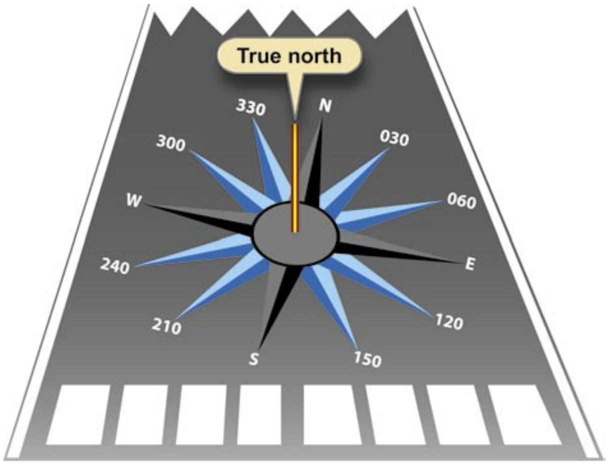

Figure 3-18. *Utilization of a Compass Rose Aids Compensation for Deviation Errors.*

The pilot or AMT aligns the aircraft on each magnetic heading and adjusts the compensating magnets to minimize the difference between the compass indication and the actual magnetic heading of the aircraft. Any error that cannot be removed is recorded on a compass correction card, like the one in *Figure 3-19*, and placed in a cardholder near the compass. If the pilot wants to fly a magnetic heading of 120° and the

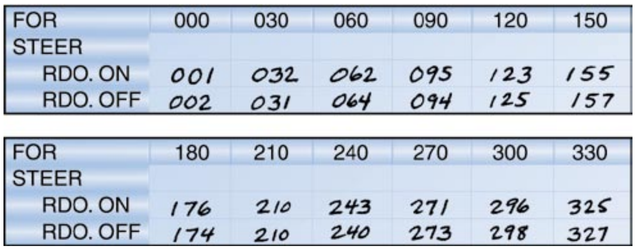

FOR	000	030	060	090	120	150
STEER						
RDO. ON	001	032	062	095	123	155
RDO. OFF	002	031	064	094	125	157

FOR	180	210	240	270	300	330
STEER						
RDO. ON	176	210	243	271	296	325
RDO. OFF	174	210	240	273	298	327

Figure 3-19. *A compass correction card shows the deviation correction for any heading.*

aircraft is operating with the radios on, the pilot should fly a compass heading of 123°.

The corrections for variation and deviation must be applied in the correct sequence and is shown below starting from the true course desired.

Step 1: Determine the Magnetic Course
True Course (180°) ± Variation (+10°) = Magnetic Course (190°)

The Magnetic Course (190°) is steered if there is no deviation error to be applied. The compass card must now be considered for the compass course of 190°.

Step 2: Determine the Compass Course
Magnetic Course (190°, from step 1) ± Deviation (-2°, from correction card) = Compass Course (188°)

NOTE: Intermediate magnetic courses between those listed on the compass card need to be interpreted. Therefore, to steer a true course of 180°, the pilot would follow a compass course of 188°.

To find the true course that is being flown when the compass course is known:
Compass Course ± Deviation = Magnetic Course ± Variation = True Course

Dip Errors

The lines of magnetic flux are considered to leave the Earth at the magnetic north pole and enter at the magnetic South Pole. At both locations the lines are perpendicular to the Earth's surface. At the magnetic equator, which is halfway between the poles, the lines are parallel with the surface. The magnets in a compass align with this field, and near the poles they dip, or tilt, the float and card. The float is balanced with a small dip-compensating weight, so it stays relatively level when operating in the middle latitudes of the northern hemisphere. This dip along with this weight causes two very noticeable errors: northerly turning error and acceleration error.

The pull of the vertical component of the Earth's magnetic field causes northerly turning error, which is apparent on a heading of north or south. When an aircraft flying on a heading of north makes a turn toward east, the aircraft banks to the right, and the compass card tilts to the right. The vertical component of the Earth's magnetic field pulls the north-seeking end of the magnet to the right, and the float rotates, causing the card to rotate toward west, the direction opposite the direction the turn is being made. *[Figure 3-20]*

If the turn is made from north to west, the aircraft banks to the left and the compass card tilts down on the left side. The magnetic field pulls on the end of the magnet that causes the card to rotate toward east. This indication is again opposite to the direction

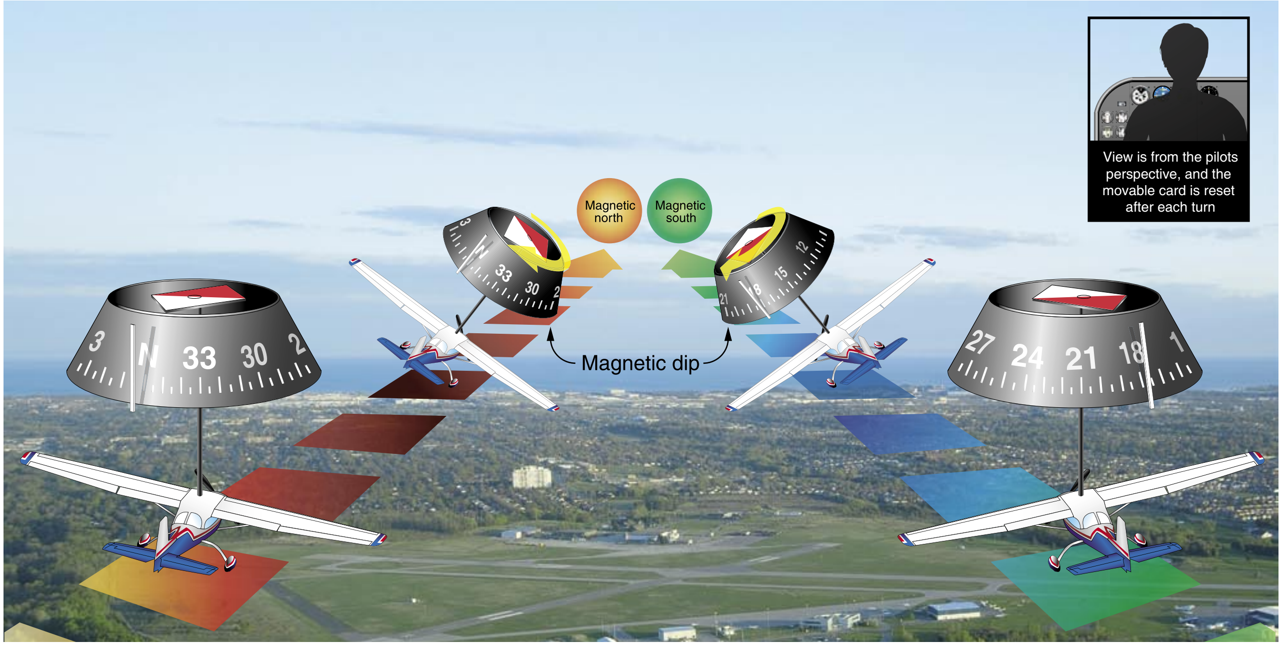
View is from the pilots perspective, and the movable card is reset after each turn
Magnetic north
Magnetic south
Magnetic dip
3
N
33
30
2
27
24
21
18
1
15
12

Figure 3-20. *Northerly Turning Error.*

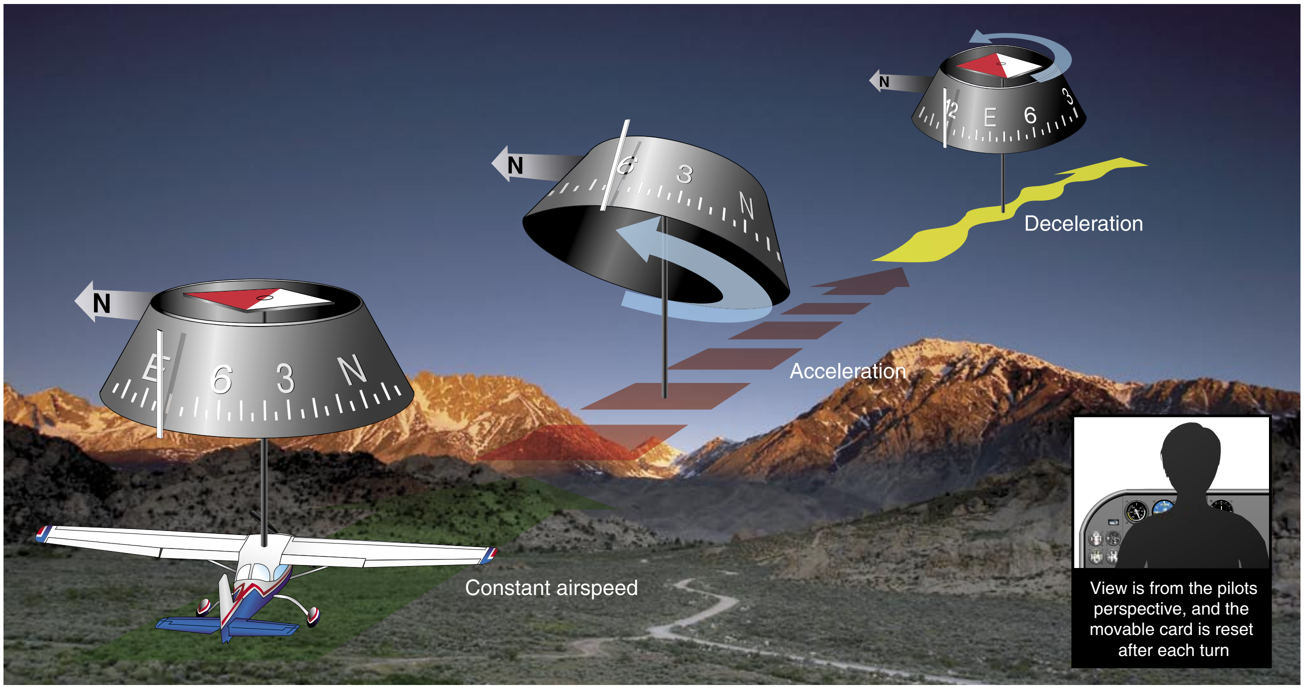
N
N
N
E 6 3 N
6 3 N
2 E 6 3
Deceleration
Acceleration
Constant airspeed
View is from the pilots perspective, and the movable card is reset after each turn

Figure 3-21. *The Effects of Acceleration Error.*

the turn is being made. The rule for this error is: when starting a turn from a northerly heading, the compass indication lags behind the turn.

When an aircraft is flying on a heading of south and begins a turn toward east, the Earth's magnetic field pulls on the end of the magnet that rotates the card toward east, the same direction the turn is being made. If the turn is made from south toward west, the magnetic pull starts the card rotating toward west—again, in the same direction the turn is being made. The rule for this error is: When starting a turn from a southerly heading, the compass indication leads the turn.

In acceleration error, the dip-correction weight causes the end of the float and card marked N (the south-seeking end) to be heavier than the opposite end. When the aircraft is flying at a constant speed on a heading of east or west, the float and card is level. The effects of magnetic dip and the weight are approximately equal. If the aircraft accelerates on a heading of east *[Figure 3-21]*, the inertia of the weight holds its end of the float back and the card rotates toward north. As soon as the speed of the aircraft stabilizes, the card swings back to its east indication. If, while flying on this easterly heading, the aircraft decelerates, the inertia causes the weight to move ahead and the card rotates toward south until the speed again stabilizes.

When flying on a heading of west, the same things happen. Inertia from acceleration causes the weight to lag, and the card rotates toward north. When the aircraft decelerates on a heading of west, inertia causes the weight to move ahead and the card rotates toward south.

Oscillation Error

Oscillation is a combination of all of the other errors, and it results in the compass card swinging back and forth around the heading being flown. When setting the gyroscopic heading indicator to agree with the magnetic compass, use the average indication between the swings.

The Vertical Card Magnetic Compass

The floating magnet type of compass not only has all the errors just described, but also lends itself to confused reading. It is easy to begin a turn in the wrong direction because its card appears backward. East is on what the pilot would expect to be the west side. The vertical card magnetic compass eliminates some of the errors and confusion. The dial of this compass is graduated with letters representing the cardinal directions, numbers every 30°, and marks every 5°. The dial is rotated by a set of gears from the shaft-mounted magnet, and the nose of the symbolic airplane on the instrument glass represents the lubber line for reading the heading of the aircraft from the dial. Eddy currents induced into an aluminum-damping cup damp oscillation of the magnet. *[Figure 3-22]*

The Flux Gate Compass System

As mentioned earlier, the lines of flux in the Earth's magnetic field have two basic characteristics: a magnet aligns with these lines, and an electrical current is induced, or generated, in any wire crossed by them.

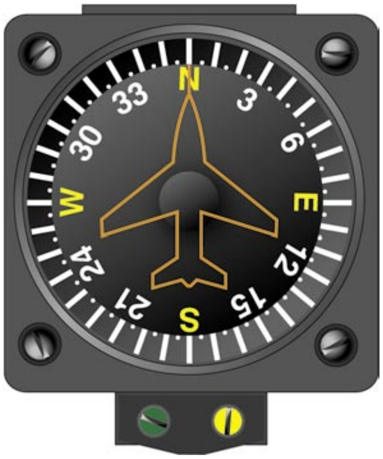

Figure 3-22. *Vertical Card Magnetic Compass.*

The flux gate compass that drives slaved gyros uses the characteristic of current induction. The flux valve is a small, segmented ring, like the one in *Figure 3-23*, made of soft iron that readily accepts lines of magnetic flux. An electrical coil is wound around each of the three legs to accept the current induced in this ring by the Earth's magnetic field. A coil wound around the iron spacer in the center of the frame has 400-Hz alternating current (A.C.) flowing through it. During the times when this current reaches its peak, twice during each cycle, there is so much magnetism produced by this coil that the frame cannot accept the lines of flux from the Earth's field.

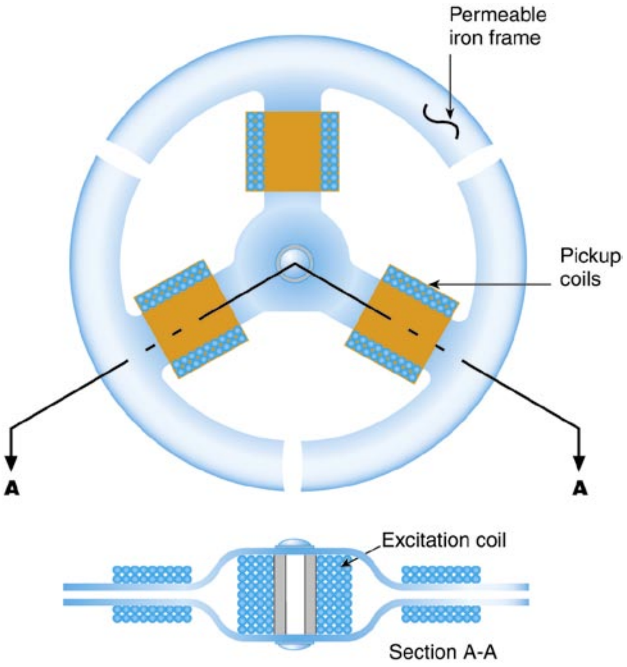

Figure 3-23. *The soft iron frame of the flux valve accepts the flux from the Earth's magnetic field each time the current in the center coil reverses. This flux causes current to flow in the three pickup coils.*

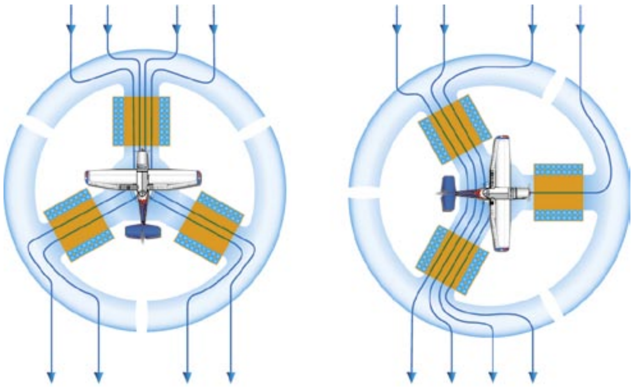

Figure 3-24. *The current in each of the three pickup coils changes with the heading of the aircraft.*

But as the current reverses between the peaks, it demagnetizes the frame so it can accept the flux from the Earth's field. As this flux cuts across the windings in the three coils, it causes current to flow in them. These three coils are connected in such a way that the current flowing in them changes as the heading of the aircraft changes. *[Figure 3-24]*

The three coils are connected to three similar but smaller coils in a synchro inside the instrument case. The synchro rotates the dial of a radio magnetic indicator (RMI) or a horizontal situation indicator (HSI).

Remote Indicating Compass

Remote indicating compasses were developed to compensate for the errors and limitations of the older type of heading indicators. The two panel-mounted components of a typical system are the pictorial navigation indicator and the slaving control and compensator unit. *[Figure 3-25]* The pictorial navigation indicator is commonly referred to as a HSI.

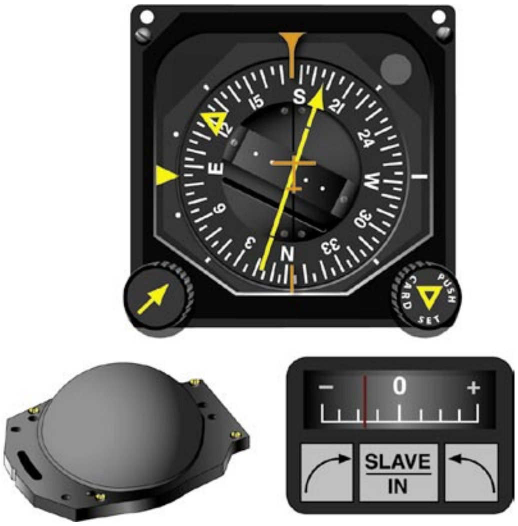

Figure 3-25. *Pictorial Navigation Indicator (HSI Top), Slaving Control and Compensator Unit.*

The slaving control and compensator unit has a pushbutton that provides a means of selecting either the "slaved gyro" or "free gyro" mode. This unit also has a slaving meter and two manual heading-drive buttons. The slaving meter indicates the difference between the displayed heading and the magnetic heading. A right deflection indicates a clockwise error of the compass card; a left deflection indicates a counterclockwise error. Whenever the aircraft is in a turn and the card rotates, the slaving meter shows a full deflection to one side or the other. When the system is in "free gyro" mode, the compass card may be adjusted by depressing the appropriate heading-drive button.

A separate unit, the magnetic slaving transmitter is mounted remotely; usually in a wingtip to eliminate the possibility of magnetic interference. It contains the flux valve, which is the direction-sensing device of the system. A concentration of lines of magnetic force, after being amplified, becomes a signal relayed to the heading indicator unit, which is also remotely mounted. This signal operates a torque motor in the heading indicator unit that processes the gyro unit until it is aligned with the transmitter signal. The magnetic slaving transmitter is connected electrically to the HSI.

There are a number of designs of the remote indicating compass; therefore, only the basic features of the system are covered here. Instrument pilots must become familiar with the characteristics of the equipment in their aircraft.

As instrument panels become more crowded and the pilot's available scan time is reduced by a heavier flight deck workload, instrument manufacturers have worked toward combining instruments. One good example of this is the RMI in *Figure 3-26*. The compass card is driven by signals from the flux valve, and the two pointers are driven by an automatic direction finder (ADF) and a very high frequency omnidirectional range (VOR).

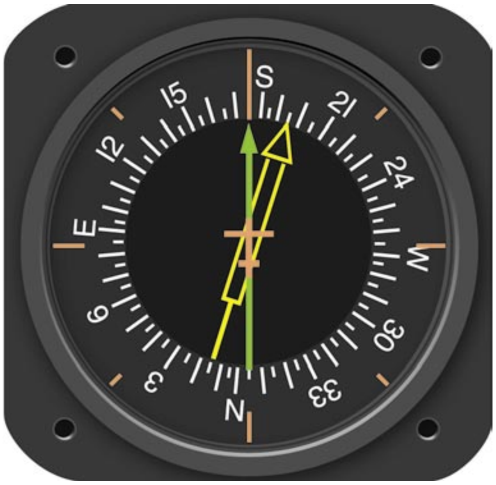

Figure 3-26. *Driven by signals from a flux valve, the compass card in this RMI indicates the heading of the aircraft opposite the upper center index mark. The green pointer is driven by the ADF.*

Gyroscopic Systems

Flight without reference to a visible horizon can be safely accomplished by the use of gyroscopic instrument systems and the two characteristics of gyroscopes, which are rigidity and precession. These systems include attitude, heading, and rate instruments, along with their power sources. These instruments include a gyroscope (or gyro) that is a small wheel with its weight concentrated around its periphery. When this wheel is spun at high speed, it becomes rigid and resists tilting or turning in any direction other than around its spin axis.

Attitude and heading instruments operate on the principle of rigidity. For these instruments, the gyro remains rigid in its case and the aircraft rotates about it. Rate indicators, such as turn indicators and turn coordinators, operate on the principle of precession. In this case, the gyro processes (or rolls over) proportionate to the rate the aircraft rotates about one or more of its axes.

Power Sources

Aircraft and instrument manufacturers have designed redundancy in the flight instruments so that any single failure will not deprive the pilot of the ability to safely conclude the flight. Gyroscopic instruments are crucial for instrument flight; therefore, they are powered by separate electrical or pneumatic sources.

Pneumatic Systems

Pneumatic gyros are driven by a jet of air impinging on buckets cut into the periphery of the wheel. On many aircraft this stream of air is obtained by evacuating the instrument case with a vacuum source and allowing filtered air to flow into the case through a nozzle to spin the wheel.

Venturi Tube Systems

Aircraft that do not have a pneumatic pump to evacuate the instrument case can use venturi tubes mounted on the outside of the aircraft, similar to the system shown in *Figure 3-27*. Air flowing through the venturi tube speeds up in the narrowest part and, according to Bernoulli's principle, the pressure drops. This location is connected to the instrument case by a piece of tubing. The two attitude instruments operate on approximately 4" Hg of suction; the turn-and-slip indicator needs only 2" Hg, so a pressure-reducing needle valve is used to decrease the suction. Air flows into the instruments through filters built into the instrument cases. In this system, ice can clog the venturi tube and stop the instruments when they are most needed.

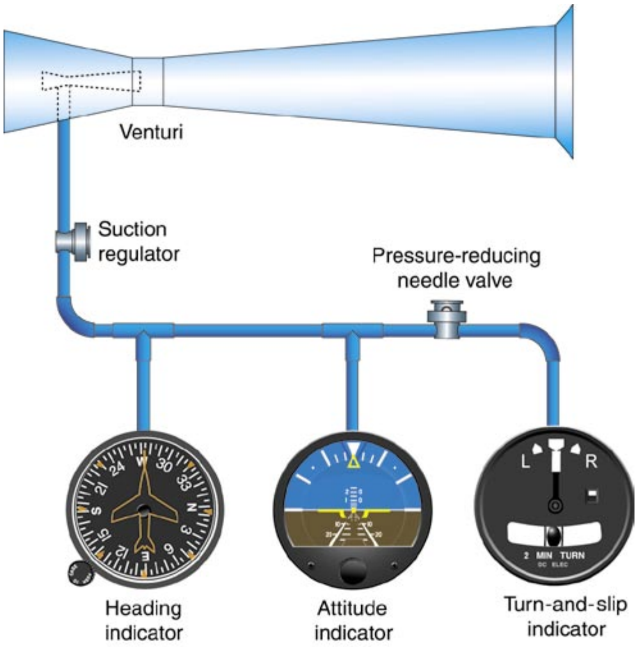
Venturi
Suction regulator
Pressure-reducing needle valve
L
R
2 MIN TURN
DC ELEC
Heading indicator
Attitude indicator
Turn-and-slip indicator

Figure 3-27. *A venturi tube system that provides necessary vacuum to operate key instruments.*

Vacuum Pump Systems

Wet-Type Vacuum Pump

Steel-vane air pumps have been used for many years to evacuate the instrument cases. The vanes in these pumps are lubricated by a small amount of engine oil metered into the pump and discharged with the air. In some aircraft the discharge air is used to inflate rubber deicer boots on the wing and empennage leading edges. To keep the oil from deteriorating the rubber boots, it must be removed with an oil separator like the one in *Figure 3-28*.

The vacuum pump moves a greater volume of air than is needed to supply the instruments with the suction needed, so a suction-relief valve is installed in the inlet side of the pump. This spring-loaded valve draws in just enough air to maintain the required low pressure inside the instruments, as is shown on the suction gauge in the instrument panel. Filtered air enters the instrument cases from a central air filter. As long as aircraft fly at relatively low altitudes, enough air is drawn into the instrument cases to spin the gyros at a sufficiently high speed.

Dry Air Vacuum Pump

As flight altitudes increase, the air is less dense and more air must be forced through the instruments. Air pumps that do not mix oil with the discharge air are used in high flying aircraft.

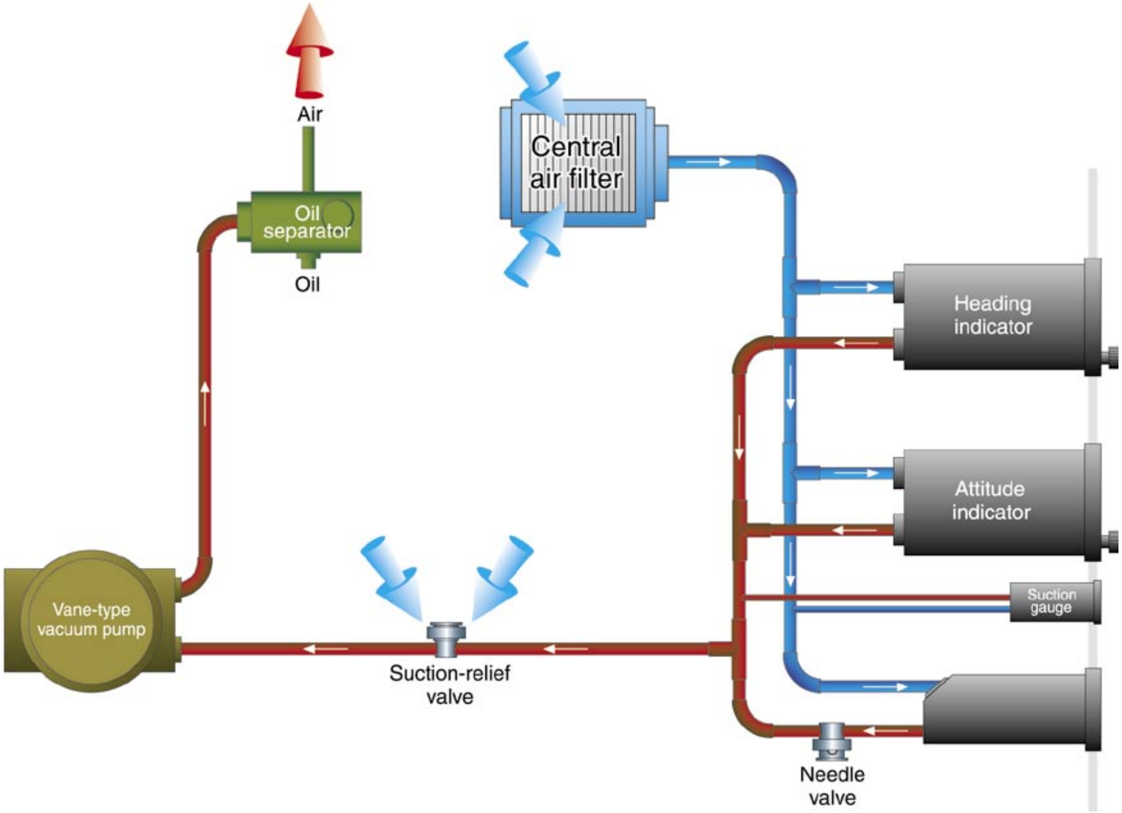
Air
Oil separator
Oil
Central air filter
Heading indicator
Attitude indicator
Suction gauge
Vane-type vacuum pump
Suction-relief valve
Needle valve

Figure 3-28. *Single-engine instrument vacuum system using a steel-vane wet-type vacuum pump.*

Steel vanes sliding in a steel housing need to be lubricated, but vanes made of a special formulation of carbon sliding inside carbon housing provide their own lubrication in a microscopic amount as they wear.

Pressure Indicating Systems

Figure 3-29 is a diagram of the instrument pneumatic system of a twin-engine general aviation airplane. Two dry air pumps are used with filters in their inlet to filter out any contaminants that could damage the fragile carbon vanes in the pump. The discharge air from the pump flows through a regulator, where excess air is bled off to maintain the pressure in the system at the desired level. The regulated air then flows through inline filters to remove any contamination that could have been picked up from the pump, and from there into a manifold check valve. If either engine should become inoperative or either pump should fail, the check valve isolates the inoperative system and the instruments are driven by air from the operating system. After the air passes through the instruments and drives the gyros, it is exhausted from the case. The gyro pressure gauge measures the pressure drop across the instruments.

Electrical Systems

Many general aviation aircraft that use pneumatic attitude indicators use electric rate indicators and/or the reverse. Some instruments identify their power source on their dial, but it is extremely important that pilots consult the POH/AFM to determine the power source of all instruments to know what action to take in the event of an instrument failure. Direct current (D.C.) electrical instruments are available in 14- or 28-volt models, depending upon the electrical system in the aircraft. A.C. is used to operate some attitude gyros and autopilots. Aircraft with only D.C. electrical systems can use A.C. instruments via installation of a solid-state D.C. to A.C. inverter, which changes 14 or 28 volts D.C. into three-phase 115-volt, 400-Hz A.C.

Gyroscopic Instruments

Attitude Indicators

The first attitude instrument (AI) was originally referred to as an artificial horizon, later as a gyro horizon; now it is more properly called an attitude indicator. Its operating mechanism is a small brass wheel with a vertical spin axis, spun at a high speed by either a stream of air impinging on buckets cut into its periphery, or by an electric motor. The gyro is mounted in a double gimbal, which allows the aircraft to pitch and roll about the gyro as it remains fixed in space.

A horizon disk is attached to the gimbals so it remains in the same plane as the gyro, and the aircraft pitches and rolls about it. On early instruments, this was just a bar that

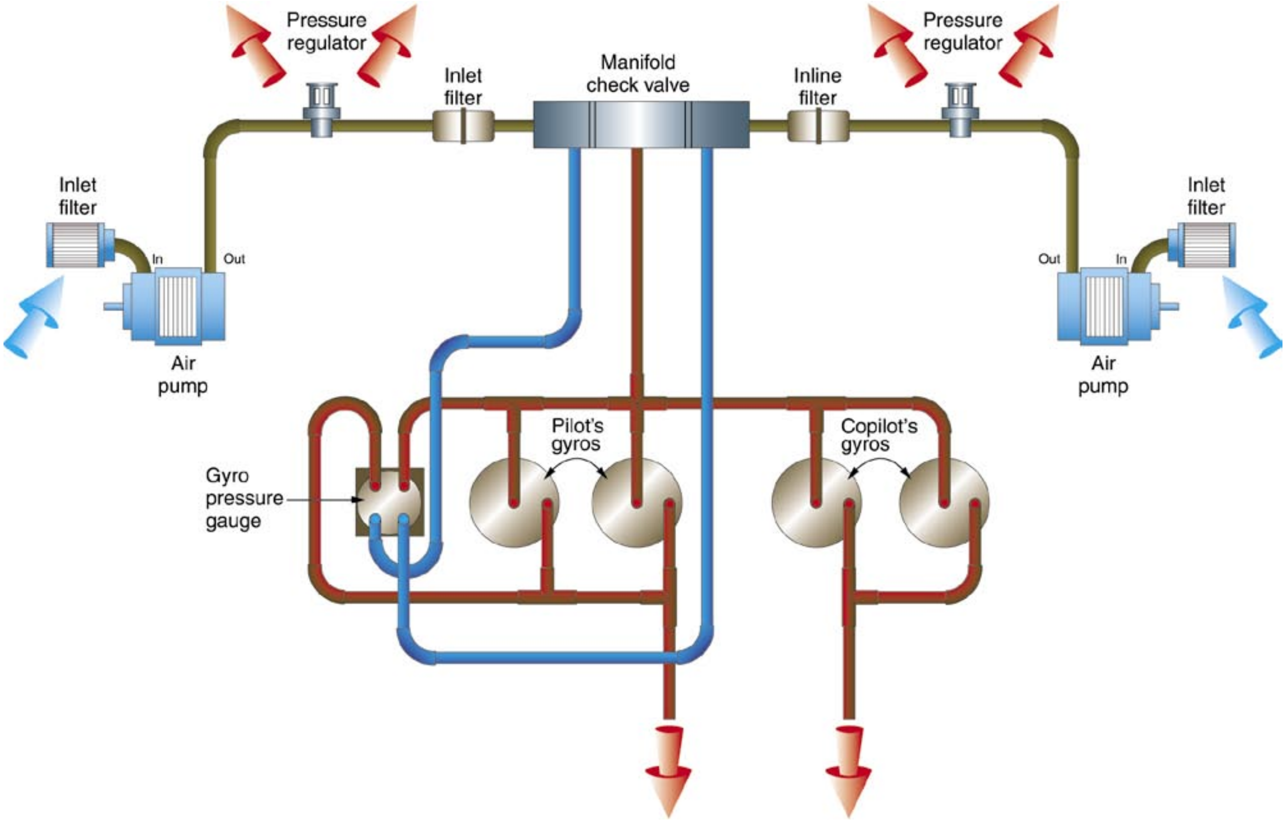

Figure 3-29. *Twin-Engine Instrument Pressure System Using a Carbon-Vane Dry-Type Air Pump.*

represented the horizon, but now it is a disc with a line representing the horizon and both pitch marks and bank-angle lines. The top half of the instrument dial and horizon disc is blue, representing the sky; and the bottom half is brown, representing the ground. A bank index at the top of the instrument shows the angle of bank marked on the banking scale with lines that represent 10°, 20°, 30°, 45°, and 60°. *[Figure 3-30]*

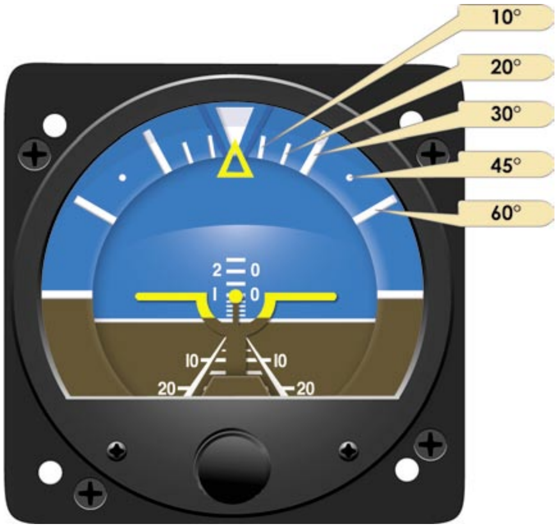

Figure 3-30. *The dial of this attitude indicator has reference lines to show pitch and roll.*

A small symbolic aircraft is mounted in the instrument case so it appears to be flying relative to the horizon. A knob at the bottom center of the instrument case raises or lowers the aircraft to compensate for pitch trim changes as the airspeed changes. The width of the wings of the symbolic aircraft and the dot in the center of the wings represent a pitch change of approximately 2°.

For an AI to function properly, the gyro must remain vertically upright while the aircraft rolls and pitches around it. The bearings in these instruments have a minimum of friction; however, even this small amount places a restraint on the gyro producing precession and causing the gyro to tilt. To minimize this tilting, an erection mechanism inside the instrument case applies a force any time the gyro tilts from its vertical position. This force acts in such a way to return the spinning wheel to its upright position.

The older artificial horizons were limited in the amount of pitch or roll they could tolerate, normally about 60° in pitch and 100° in roll. After either of these limits was exceeded, the gyro housing contacted the gimbals, applying such a precessing force that the gyro tumbled. Because of this limitation, these instruments had a caging mechanism that locked the gyro in its vertical position during any maneuvers that exceeded the instrument limits. Newer instruments do not have these restrictive tumble limits; therefore, they do not have a caging mechanism.

When an aircraft engine is first started and pneumatic or electric power is supplied to the instruments, the gyro is not erect. A self-erecting mechanism inside the instrument actuated by the force of gravity applies a precessing force, causing the gyro to rise to its vertical position. This erection can take as long as 5 minutes, but is normally done within 2 to 3 minutes.

Attitude indicators are free from most errors, but depending upon the speed with which the erection system functions, there may be a slight nose-up indication during a rapid acceleration and a nose-down indication during a rapid deceleration. There is also a possibility of a small bank angle and pitch error after a 180° turn. These inherent errors are small and correct themselves within a minute or so after returning to straight-and-level flight.

Heading Indicators

A magnetic compass is a dependable instrument used as a backup instrument. Although very reliable, it has so many inherent errors that it has been supplemented with gyroscopic heading indicators.

The gyro in a heading indicator is mounted in a double gimbal, as in an attitude indicator, but its spin axis is horizontal permitting sensing of rotation about the vertical axis of the aircraft. Gyro heading indicators, with the exception of slaved gyro indicators, are not north seeking, therefore they must be manually set to the appropriate heading by referring to a magnetic compass. Rigidity causes them to maintain this heading indication, without the oscillation and other errors inherent in a magnetic compass.

Older directional gyros use a drum-like card marked in the same way as the magnetic compass card. The gyro and the card remain rigid inside the case with the pilot viewing the card from the back. This creates the possibility the pilot might start a turn in the wrong direction similar to using a magnetic compass. A knob on the front of the instrument, below the dial, can be pushed in to engage the gimbals. This locks the gimbals allowing the pilot to rotate the gyro and card until the number opposite the lubber line agrees with the magnetic compass. When the knob is pulled out, the gyro remains rigid and the aircraft is free to turn around the card.

Directional gyros are almost all air-driven by evacuating the case and allowing filtered air to flow into the case and out through a nozzle, blowing against buckets cut in the periphery of the wheel. The Earth constantly rotates at 15° per hour while the gyro is maintaining a position relative to space, thus causing an apparent drift in the displayed heading of 15° per hour. When using these instruments, it is standard practice to compare the heading indicated on the directional gyro with the magnetic compass at least every 15 minutes and to reset the heading as necessary to agree with the magnetic compass.

Heading indicators like the one in *Figure 3-31* work on the same principle as the older horizontal card indicators, except that the gyro drives a vertical dial that looks much like the dial of a vertical card magnetic compass. The heading of the aircraft is shown against the nose of the symbolic aircraft on the instrument glass, which serves as the lubber line. A knob in the front of the instrument may be pushed in and turned to rotate the gyro and dial. The knob is spring loaded so it disengages from the gimbals as soon as it is released. This instrument should be checked about every 15 minutes to see if it agrees with the magnetic compass.

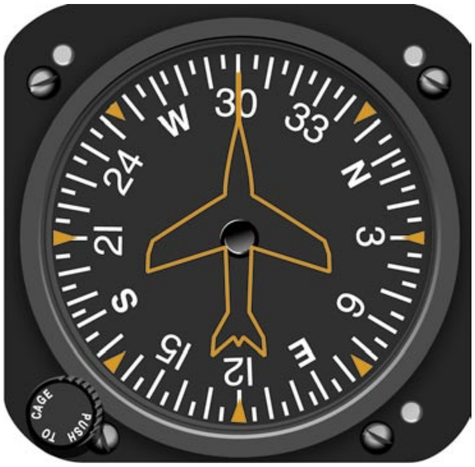

Figure 3-31. *The heading indicator is not north seeking, but must be set periodically (about every 15 minutes) to agree with the magnetic compass.*

Turn Indicators

Attitude and heading indicators function on the principle of rigidity, but rate instruments such as the turn-and-slip indicator operate on precession. Precession is the characteristic of a gyroscope that causes an applied force to produce a movement, not at the point of application, but at a point 90° from the point of application in the direction of rotation. *[Figure 3-32]*

Turn-and-Slip Indicator

The first gyroscopic aircraft instrument was the turn indicator in the needle and ball, or turn-and-bank indicator, which has more recently been called a turn-and-slip indicator. *[Figure 3-33]*

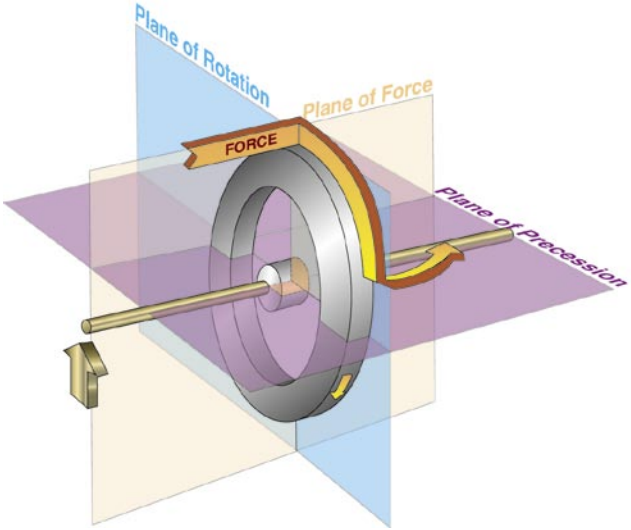

Figure 3-32. *Precession causes a force applied to a spinning wheel to be felt 90° from the point of application in the direction of rotation.*

The inclinometer in the instrument is a black glass ball sealed inside a curved glass tube that is partially filled with a liquid for damping. This ball measures the relative strength of the force of gravity and the force of inertia caused by a turn. When the aircraft is flying straight-and-level, there is no inertia acting on the ball, and it remains in the center of the tube between two wires. In a turn made with a bank angle that is too steep, the force of gravity is greater than the inertia and the ball rolls down to the inside of the turn. If the turn is made with too shallow a bank angle, the inertia is greater than gravity and the ball rolls upward to the outside of the turn.

The inclinometer does not indicate the amount of bank, nor does it indicate slip; it only indicates the relationship between the angle of bank and the rate of yaw.

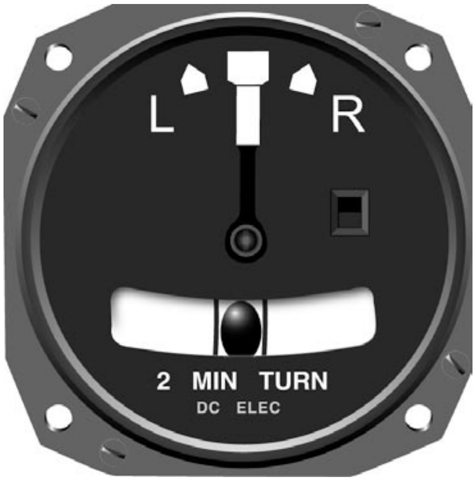

Figure 3-33. *Turn-and-Slip Indicator.*

The turn indicator is a small gyro spun either by air or by an electric motor. The gyro is mounted in a single gimbal with its spin axis parallel to the lateral axis of the aircraft and the axis of the gimbal parallel with the longitudinal axis. *[Figure 3-34]*

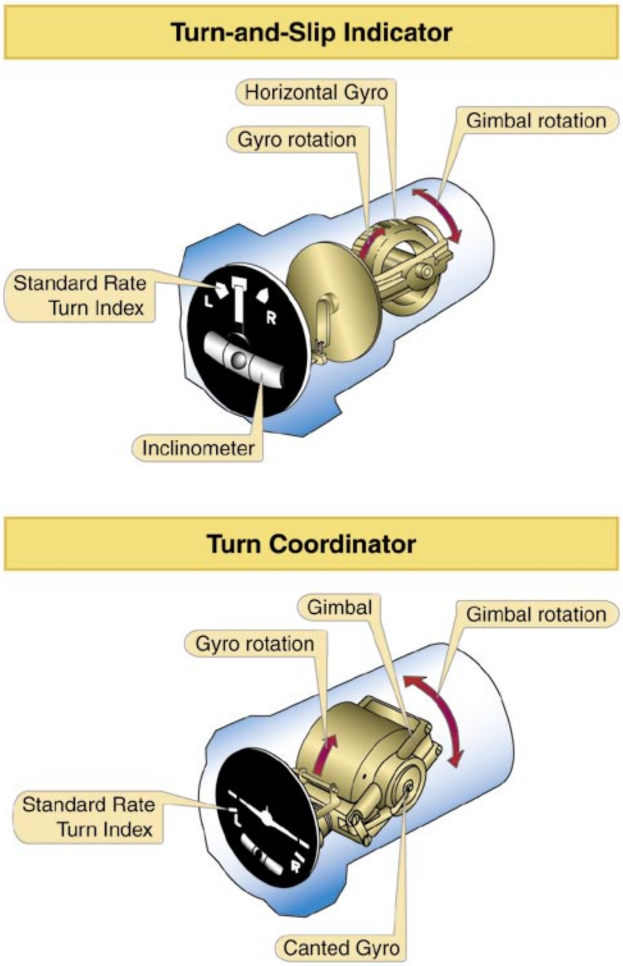

Figure 3-34. *The rate gyro in both turn-and-slip indicator and turn coordinator.*

When the aircraft yaws, or rotates about its vertical axis, it produces a force in the horizontal plane that, due to precession, causes the gyro and its gimbal to rotate about the gimbal's axis. It is restrained in this rotation plane by a calibration spring; it rolls over just enough to cause the pointer to deflect until it aligns with one of the doghouse-shaped marks on the dial, when the aircraft is making a standard rate turn.

The dial of these instruments is marked "2 MIN TURN." Some turn-and-slip indicators used in faster aircraft are marked "4 MIN TURN." In either instrument, a standard rate turn is being made whenever the needle aligns with a doghouse. A standard rate turn is 3° per second. In a 2 minute instrument, if the needle is one needle width either side of the center alignment mark, the turn is 3° per second and the turn takes 2 minutes to execute a 360° turn. In a 4 minute instrument, the same turn takes two widths deflection of the needle to achieve 3° per second.

Turn Coordinator

The major limitation of the older turn-and-slip indicator is that it senses rotation only about the vertical axis of the aircraft. It tells nothing of the rotation around the longitudinal axis, which in normal flight occurs before the aircraft begins to turn.

A turn coordinator operates on precession, the same as the turn indicator, but its gimbals frame is angled upward about 30° from the longitudinal axis of the aircraft. *[Figure 3-34]* This allows it to sense both roll and yaw. Therefore during a turn, the indicator first shows the rate of banking and once stabilized, the turn rate. Some turn coordinator gyros are dual-powered and can be driven by either air or electricity.

Rather than using a needle as an indicator, the gimbal moves a dial that is the rear view of a symbolic aircraft. The bezel of the instrument is marked to show wings-level flight and bank angles for a standard rate turn. *[Figure 3-35]*

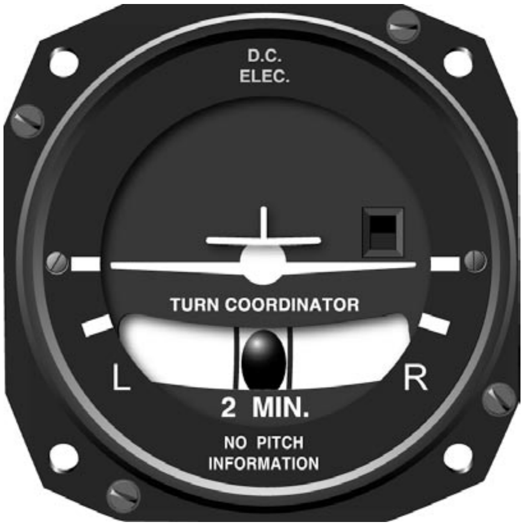

Figure 3-35. *A turn coordinator senses rotation about both roll and yaw axes.*

The inclinometer, similar to the one in a turn-and-slip indicator, is called a coordination ball, which shows the relationship between the bank angle and the rate of yaw. The turn is coordinated when the ball is in the center, between the marks. The aircraft is skidding when the ball rolls toward the outside of the turn and is slipping when it moves toward the inside of the turn. A turn coordinator does not sense pitch. This is indicated on some instruments by placing the words "NO PITCH INFORMATION" on the dial.

Flight Support Systems

Attitude and Heading Reference System (AHRS)

As aircraft displays have transitioned to new technology, the sensors that feed them have also undergone significant change. Traditional gyroscopic flight instruments have been replaced by Attitude and Heading Reference Systems (AHRS) improving reliability and thereby reducing cost and maintenance.

The function of an AHRS is the same as gyroscopic systems; that is, to determine which way is level and which way is north. By knowing the initial heading the AHRS can determine both the attitude and magnetic heading of the aircraft.

The genesis of this system was initiated by the development of the ring-LASAR gyroscope developed by Kearfott located in Little Falls, New Jersey. *[Figure 3-36]* Their development of the Ring-LASAR gyroscope in the 1960s/1970s was in support of Department of Defense (DOD) programs to include cruise missile technology. With the precision of these gyroscopes, it became readily apparent that they could be leveraged for multiple tasks and functions. Gyroscopic miniaturization has become so common that solid-state gyroscopes are found in products from robotics to toys.

Because the AHRS system replaces separate gyroscopes, such as those associated with an attitude indicator, magnetic heading indicator and turn indicator these individual systems are no longer needed. As with many systems today, AHRS itself had matured with time. Early AHRS systems used expensive inertial sensors and flux valves. However, today the AHRS for aviation and general aviation in particular are small solid-state systems integrating a variety of technology such as low cost inertial sensors, rate gyros, and magnetometers, and have capability for satellite signal reception.

Air Data Computer (ADC)

An Air Data Computer (ADC) *[Figure 3-37]* is an aircraft computer that receives and processes pitot pressure, static pressure, and temperature to calculate very precise altitude, IAS, TAS, and air temperature. The ADC outputs this information in a digital format that can be used by a variety of aircraft systems including an EFIS. Modern ADCs are small solid-state units. Increasingly, aircraft systems such as autopilots, pressurization, and FMS utilize ADC information for normal operations. NOTE: In most modern general aviation systems, both the AHRS and ADC are integrated within the electronic displays themselves thereby reducing the number of units, reducing weight, and providing simplification for installation resulting in reduced costs.

Analog Pictorial Displays

Horizontal Situation Indicator (HSI)

The HSI is a direction indicator that uses the output from a flux valve to drive the dial, which acts as the compass card. This instrument, shown in *Figure 3-38*, combines the magnetic compass with navigation signals and a glide slope. This gives the pilot an indication of the location of the aircraft with relationship to the chosen course.

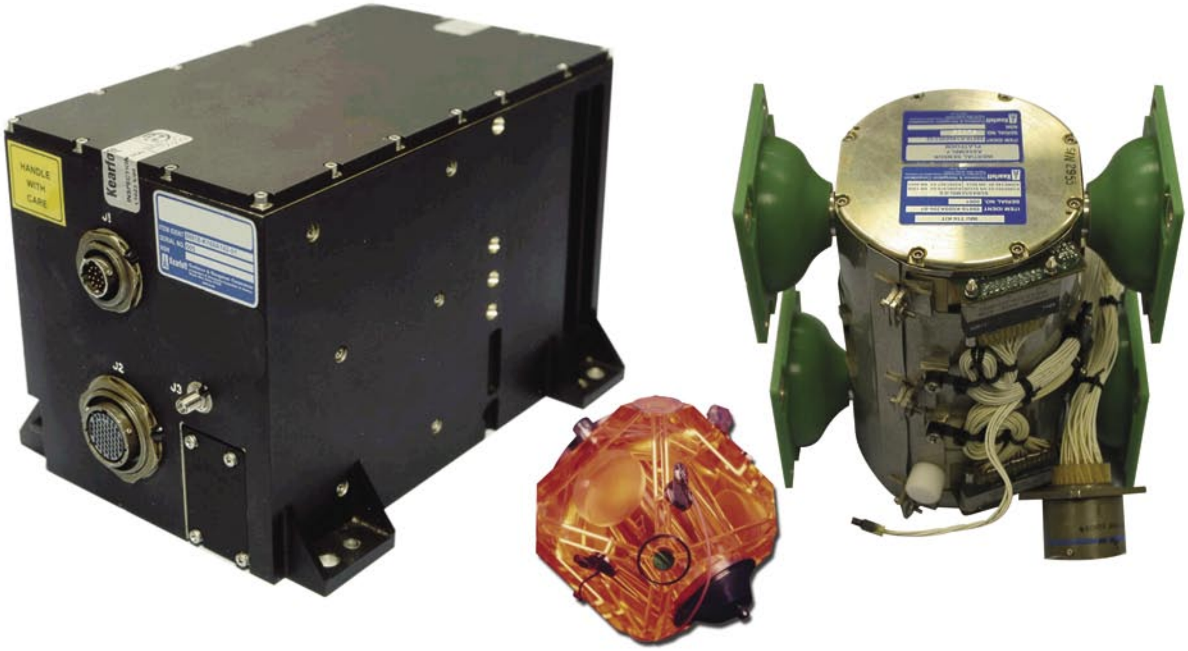

Figure 3-36. *The Kearfott Attitude Heading Reference System (AHRS) on the left incorporates a Monolithic Ring Laser Gyro (MRLG) (center), which is housed in an Inertial Sensor Assembly (ISA) on the right.*

Collins
PITOT STATIC
WARNING — FAA REGULATIONS REQUIRE QUALIFIED PERSONNEL TO WORK ON STATIC SYSTEM AND A PNEUMATIC TEST IF SYSTEM IS OPENED.
CAUTION — DO NOT BOTTOM TAPERED END OF ADJUSTABLE FITTINGS IN PORTS. USE ONLY MS28778-4 AND -6 GASKETS.
ADC-850
ALERT VALID TEST

Figure 3-37. *Air Data Computer (Collins).*

In *Figure 3-38*, the aircraft heading displayed on the rotating azimuth card under the upper lubber line is North or 360°. The course-indicating arrowhead shown is set to 020; the tail indicates the reciprocal, 200°. The course deviation bar operates with a VOR/Localizer (VOR/LOC) navigation receiver to indicate left or right deviations from the course selected with the course-indicating arrow, operating in the same manner that the angular movement of a conventional VOR/LOC needle indicates deviation from course.

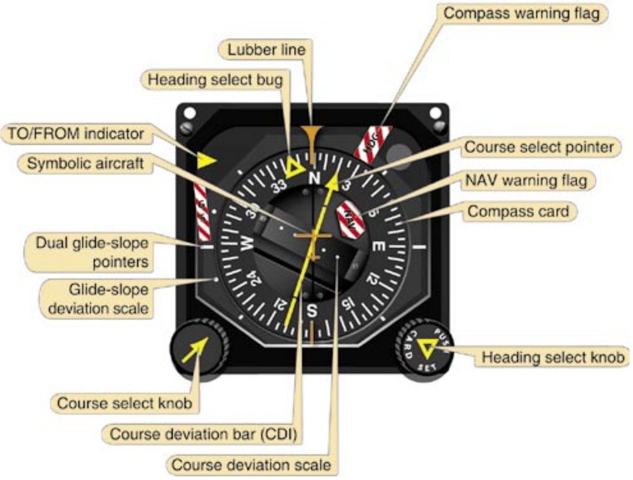
Compass warning flag
Lubber line
Heading select bug
TO/FROM indicator
Symbolic aircraft
Course select pointer
NAV warning flag
Compass card
Dual glide-slope pointers
Glide-slope deviation scale
Heading select knob
Course select knob
Course deviation bar (CDI)
Course deviation scale
N
3
E
12
15
S
21
24
W
30
33
HDG
NAV
PUSH
CARD
SET

Figure 3-38. *Horizontal Situation Indicator (HSI).*

The desired course is selected by rotating the course-indicating arrow in relation to the azimuth card by means of the course select knob. This gives the pilot a pictorial presentation: the fixed aircraft symbol and course deviation bar display the aircraft relative to the selected course, as though the pilot were above the aircraft looking down. The TO/FROM indicator is a triangular pointer. When the indicator points to the head of the course arrow, it shows that the course selected, if properly intercepted and flown, takes the aircraft to the selected facility. When the indicator points to the tail of the course arrow, it shows that the course selected, if properly intercepted and flown, takes the aircraft directly away from the selected facility.

The glide slope deviation pointer indicates the relation of the aircraft to the glide slope. When the pointer is below the center position, the aircraft is above the glide slope, and an increased rate of descent is required. In most installations, the azimuth card is a remote indicating compass driven by a fluxgate; however, in few installations where a fluxgate is not installed, or in emergency operation, the heading must be checked against the magnetic compass occasionally and reset with the course select knob.

Attitude Direction Indicator (ADI)

Advances in attitude instrumentation combine the gyro horizon with other instruments such as the HSI, thereby reducing the number of separate instruments to which the pilot must devote attention. The attitude direction indicator (ADI) is an example of such technological advancement. A flight director incorporates the ADI within its system, which is further explained below (Flight Director System). However, an ADI need not have command cues; however, it is normally equipped with this feature.

Flight Director System (FDS)

A Flight Director System (FDS) combines many instruments into one display that provides an easily interpreted understanding of the aircraft's flight path. The computed solution furnishes the steering commands necessary to obtain and hold a desired path.

Major components of an FDS include an ADI, also called a Flight Director Indicator (FDI), an HSI, a mode selector, and a flight director computer. It should be noted that a flight director in use does not infer the aircraft is being manipulated by the autopilot (coupled), but is providing steering commands that the pilot (or the autopilot, if coupled) follows.

Typical flight directors use one of two display systems for steerage. The first is a set of command bars, one horizontal and one vertical. The command bars in this configuration are maintained in a centered position (much like a centered glide slope). The second uses a miniature aircraft aligned to a command cue.

A flight director displays steerage commands to the pilot on the ADI. As previously mentioned, the flight director receives its signals from one of various sources and provides that to the ADI for steerage commands. The mode controller provides signals through the ADI to drive the steering bars, e.g., the pilot flies the aircraft to place the delta symbol in the V of the steering bars. "Command" indicators tell the pilot in which direction and how much to change aircraft attitude to achieve the desired result.

The computed command indications relieve the pilot of many of the mental calculations required for instrument flight. The yellow cue in the ADI *[Figure 3-39]* provides all steering commands to the pilot. It is driven by a computer that receives information from the navigation systems, the ADC, AHRS, and other sources of data. The computer processes this information, providing the pilot with a single cue to follow. Following the cue provides the pilot with the necessary three-dimensional flight trajectory to maintain the desired path.

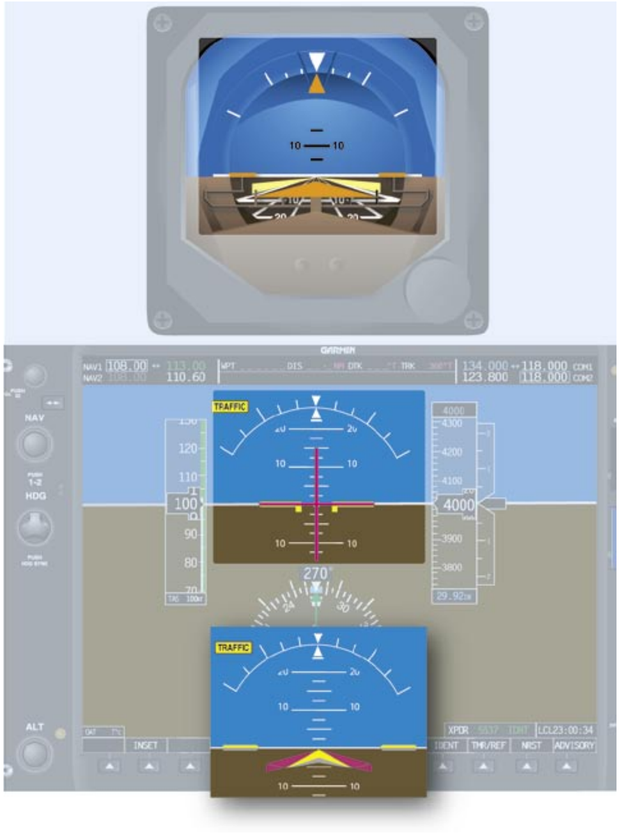

Figure 3-39. *A Typical Cue That a Pilot Would Follow.*

One of the first widely used flight directors was developed by Sperry and was called the Sperry Three Axis Attitude Reference System (STARS). Developed in the 1960s, it was commonly found on both commercial and business aircraft alike. STARS (with a modification) and successive flight directors were integrated with the autopilots and aircraft providing a fully integrated flight system.

The flight director/autopilot system described below is typical of installations in many general aviation aircraft.

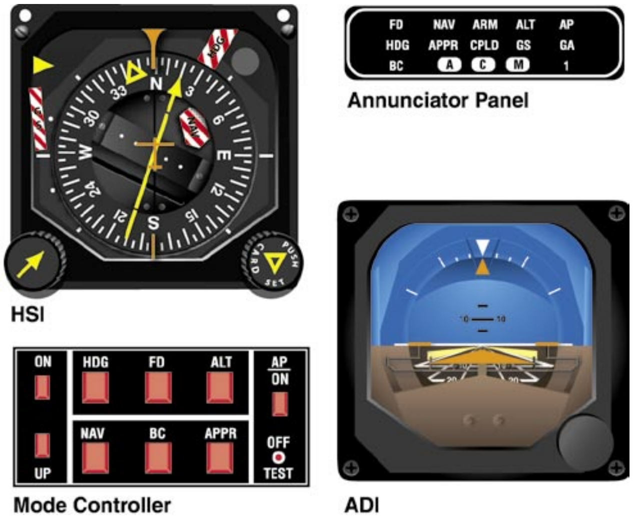

Figure 3-40. *Components of a Typical Flight Director System.*

The components of a typical flight director include the mode controller, ADI, HSI, and annunciator panel. These units are illustrated in *Figure 3-40*.

The pilot may choose from among many modes including the HDG (heading) mode, the VOR/LOC (localizer tracking) mode, or the AUTO Approach (APP) or G/S (automatic capture and tracking of instrument landing system (ILS) localizers and glide path) mode. The auto mode has a fully automatic pitch selection computer that takes into account aircraft performance and wind conditions, and operates once the pilot has reached the ILS glide slope. More sophisticated systems allow more flight director modes.

Integrated Flight Control System

The integrated flight control system integrates and merges various systems into a system operated and controlled by one principal component. *Figure 3-41* illustrates key components of the flight control system that was developed from the onset as a fully integrated system comprised of the airframe, autopilot, and flight director system. This trend of complete integration, once seen only in large commercial aircraft, are now becoming common in the general aviation field.

Autopilot Systems

An autopilot is a mechanical means to control an aircraft using electrical, hydraulic, or digital systems. Autopilots can control three axes of the aircraft: roll, pitch, and yaw. Most autopilots in general aviation control roll and pitch.

Autopilots also function using different methods. The first is position based. That is, the attitude gyro senses the degree of difference from a position such as wings level, a change in pitch, or a heading change.

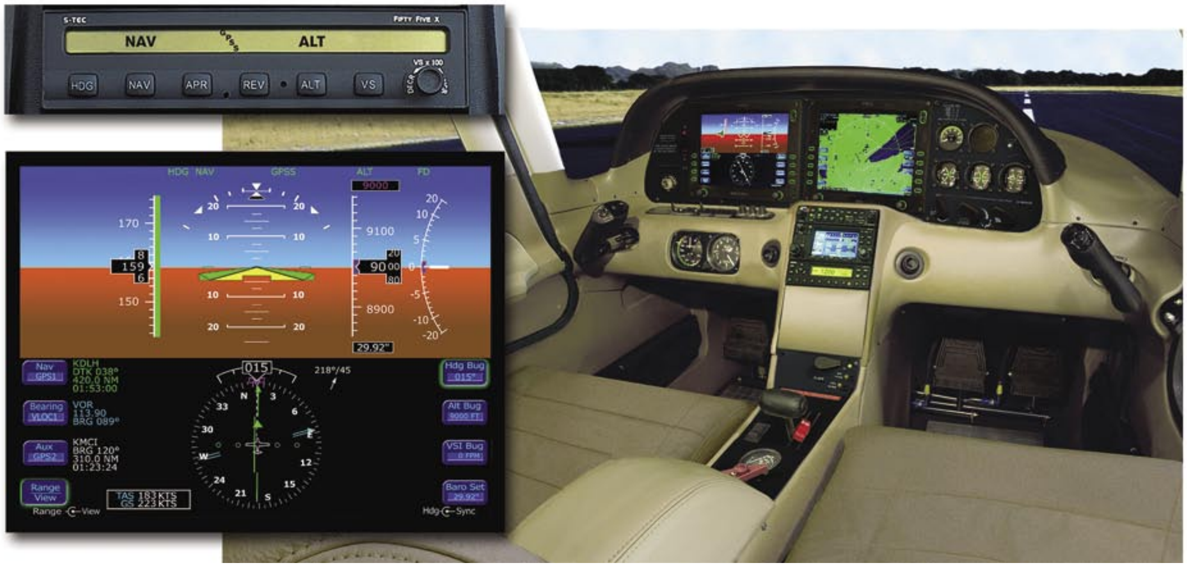
S-TEC
Fifty Five X
NAV
ALT
HDG
NAV
APR
REV
ALT
VS
VS x 100
HDG NAV
GPSS
ALT
FD
9000
9100
8900
170
159
150
29.92"
015
218°/45
Nav GPS1
KDLH DTK 038° 420.0 NM 01:53:00
Bearing VLOC1
VOR 113.90 BRG 089°
Aux GPS2
KMCI BRG 120° 310.0 NM 01:23:24
Range View
TAS 183 KTS GS 223 KTS
Hdg Bug 015°
Alt Bug 9000 FT
VSI Bug 0 FPM
Baro Set 29.92"
Hdg-Sync
Range-View

Figure 3-41. *The S-TEC/Meggit Corporation Integrated Autopilot Installed in the Cirrus.*

Determining whether a design is position based and/or rate based lies primarily within the type of sensors used. In order for an autopilot to possess the capability of controlling an aircraft's attitude (i.e., roll and pitch), that system must be provided with constant information on the actual attitude of that aircraft. This is accomplished by the use of several different types of gyroscopic sensors. Some sensors are designed to indicate the aircraft's attitude in the form of position in relation to the horizon, while others indicate rate (position change over time).

Rate-based systems use the turn-and-bank sensor for the autopilot system. The autopilot uses rate information on two of the aircraft's three axes: movement about the vertical axis (heading change or yaw) and about the longitudinal axis (roll). This combined information from a single sensor is made possible by the 30° offset in the gyro's axis to the longitudinal axis.

Other systems use a combination of both position and rate-based information to benefit from the attributes of both systems while newer autopilots are digital. *Figure 3-42* illustrates an autopilot by Century.

Figure 3-43 is a diagram layout of a rate-based autopilot by S-Tec, which permits the purchaser to add modular capability form basic wing leveling to increased capability.

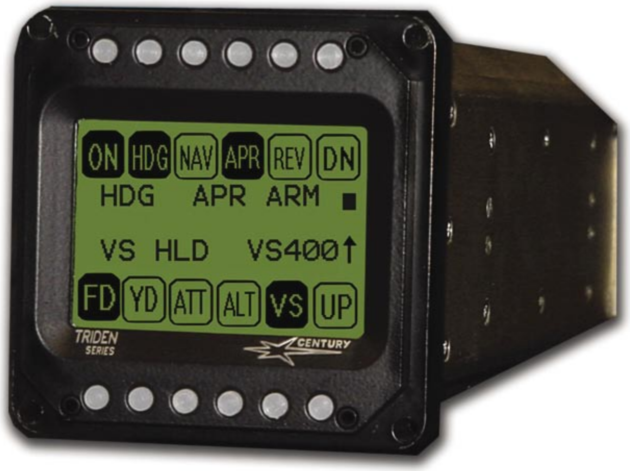
ON
HDG
NAV
APR
REV
DN
HDG APR ARM
VS HLD VS400↑
FD
YD
ATT
ALT
VS
UP
TRIDEN SERIES
CENTURY

Figure 3-42. *An Autopilot by Century.*

Flight Management Systems (FMS)

In the mid-1970s, visionaries in the avionics industry such as Hubert Naimer of Universal, and followed by others such as Ed King, Jr., were looking to advance the technology of aircraft navigation. As early as 1976, Naimer had a vision of a "Master Navigation System" that would accept inputs from a variety of different types of sensors on an aircraft and automatically provide guidance throughout all phases of flight.

At that time aircraft navigated over relatively short distances with radio systems, principally VOR or ADF. For long-range flight inertial navigation systems (INS), Omega, Doppler, and Loran were in common use. Short-range radio systems usually did not provide area navigation capability. Long-range systems were only capable of en route point-to-point navigation between manually entered waypoints described as longitude and latitude coordinates, with typical systems containing a limited number of waypoints.

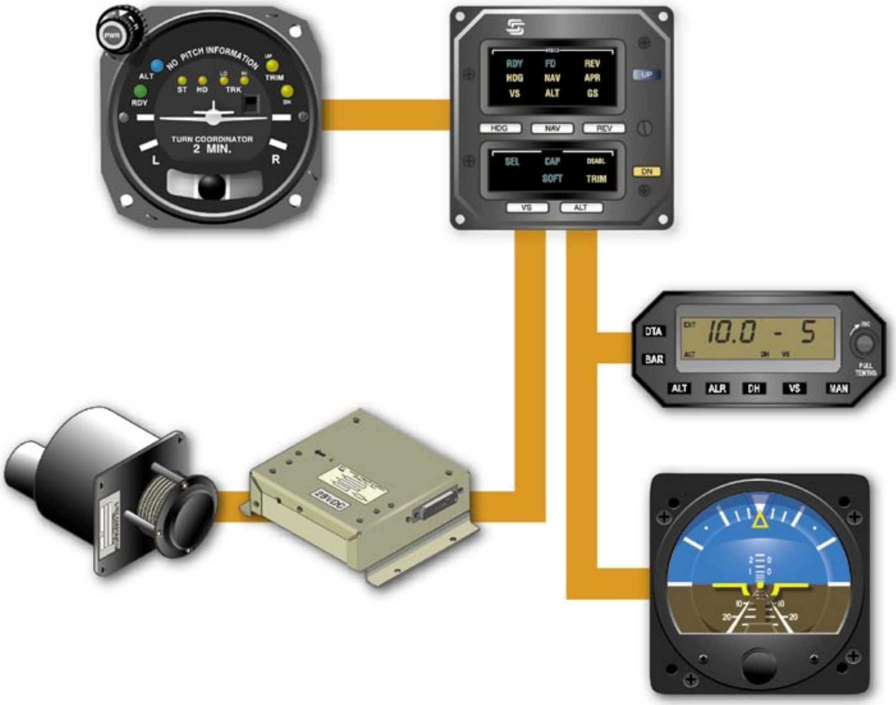
PWR
NO PITCH INFORMATION
ALT
RDY
ST
HD
TRK
TRIM
TURN COORDINATOR
2 MIN.
L
R
RDY
FD
REV
HDG
NAV
APR
VS
ALT
GS
UP
HDG
NAV
REV
SEL
CAP
DISBL
SOFT
TRIM
DN
VS
ALT
DTA
BAR
10.0 - 5
ALT
ALR
DH
VS
MAN
20
10

Figure 3-43. *A Diagram Layout of an Autopilot by S-Tec.*

The laborious process of manually entering cryptic latitude and longitude data for each flight waypoint created high crew workloads and frequently resulted in incorrect data entry. The requirement of a separate control panel for each long-range system consumed precious flight deck space and increased the complexity of interfacing the systems with display instruments, flight directors, and autopilots.

The concept employed a master computer interfaced with all of the navigation sensors on the aircraft. A common control display unit (CDU) interfaced with the master computer would provide the pilot with a single control point for all navigation systems, thereby reducing the number of required flight deck panels. Management of the various individual sensors would be transferred from the pilot to the new computer.

Since navigation sensors rarely agree exactly about position, Naimer believed that blending all available sensor position data through a highly sophisticated, mathematical filtering system would produce a more accurate aircraft position. He called the process output the "Best Computed Position." By using all available sensors to keep track of position, the system could readily provide area navigation capability. The master computer, not the individual sensors, would be integrated into the airplane, greatly reducing wiring complexity.

To solve the problems of manual waypoint entry, a preloaded database of global navigation information would be readily accessible by the pilot through the CDU. Using such a system a pilot could quickly and accurately construct a flight plan consisting of dozens of waypoints, avoiding the tedious typing of data and the error potential of latitude/longitude coordinates. Rather than simply navigating point-to-point, the master system would be able to maneuver the aircraft, permitting use of the system for terminal procedures including departures, arrivals, and approaches. The system would be able to automate any aspect of manual pilot navigation of the aircraft. When the first system, called the UNS-1, was released by Universal in 1982, it was called a flight management system (FMS). *[Figure 3-44]*

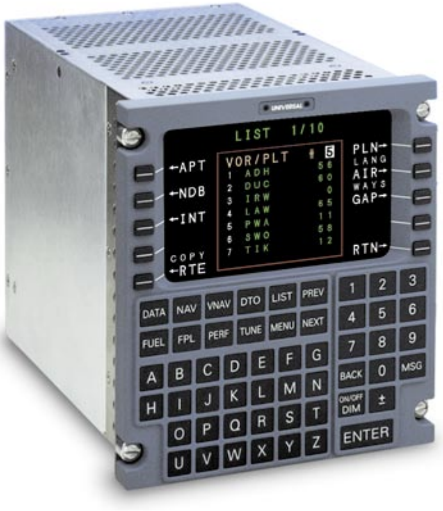
UNIVERSAL
LIST 1/10
←APT
←NDB
←INT
COPY
←RTE
VOR/PLT
1 ADH
2 DUC
3 IRW
4 LAW
5 PWA
6 SWO
7 TIK
PLN→
LANG
AIR→
WAYS
GAP→
RTN→
DATA
NAV
VNAV
DTO
LIST
PREV
FUEL
FPL
PERF
TUNE
MENU
NEXT
A B C D E F G
H I J K L M N
O P Q R S T
U V W X Y Z
1 2 3
4 5 6
7 8 9
BACK
0
MSG
ON/OFF DIM
±
ENTER

Figure 3-44. *A Control Display Unit (CDU) Used to Control the Flight Management System.*

An FMS uses an electronic database of worldwide navigational data including navigation aids, airways and intersections, Standard Instrument Departures (SIDs), Standard Terminal Arrival Routes (STARs), and Instrument Approach Procedures (IAPs) together with pilot input through a CDU to create a flight plan. The FMS provides outputs to several aircraft systems including desired track, bearing and distance to the active waypoint, lateral course deviation and related data to the flight guidance system for the HSI displays, and roll steering command for the autopilot/flight director system. This allows outputs from the FMS to command the airplane where to go and when and how to turn. To support adaptation to numerous aircraft types, an FMS is usually capable of receiving and outputting both analog and digital data and discrete information. Currently, electronic navigation databases are updated every 28 days.

The introduction of the Global Positioning System (GPS) has provided extremely precise position at low cost, making GPS the dominant FMS navigation sensor today. Currently, typical FMS installations require that air data and heading information be available electronically from the aircraft. This limits FMS usage in smaller aircraft, but emerging technologies allow this data from increasingly smaller and less costly systems.

Some systems interface with a dedicated Distance Measuring Equipment (DME) receiver channel under the control of the FMS to provide an additional sensor. In these systems, the FMS determines which DME sites should be interrogated for distance information using aircraft position and the navigation database to locate appropriate DME sites. The FMS then compensates aircraft altitude and station altitude with the aid of the database to determine the precise distance to the station. With the distances from a number of sites the FMS can compute a position nearly as accurately as GPS.

Aimer visualized three-dimensional aircraft control with an FMS. Modern systems provide Vertical Navigation (VNAV) as well as Lateral Navigation (LNAV) allowing the pilot to create a vertical flight profile synchronous with the lateral flight plan. Unlike early systems, such as Inertial Reference Systems (IRS) that were only suitable for en route navigation, the modern FMS can guide an aircraft during instrument approaches.

Today, an FMS provides not only real-time navigation capability but typically interfaces with other aircraft systems providing fuel management, control of cabin briefing and display systems, display of uplinked text and graphic weather data and air/ground data link communications.

Electronic Flight Instrument Systems

Modern technology has introduced into aviation a new method of displaying flight instruments, such as electronic flight instrument systems, integrated flight deck displays, and others. For the purpose of the practical test standards, any flight instrument display that utilizes LCD or picture tube like displays is referred to as "electronic flight instrument display" and/or a glass flight deck. In general aviation there is typically a primary flight display (PFD) and a multi-function display (MFD). Although both displays are in many cases identical, the PFD provides the pilot instrumentation necessary for flight to include altitude, airspeed, vertical velocity, attitude, heading and trim and trend information.

Glass flight decks (a term coined to describe electronic flight instrument systems) are becoming more widespread as cost falls and dependability continually increases. These systems provide many advantages such as being lighter, more reliable, no moving parts to wear out, consuming less power, and replacing numerous mechanical indicators with a single glass display. Because the versatility offered by glass displays is much greater than that offered by analog displays, the use of such systems will only increase with time until analog systems are eclipsed.

Primary Flight Display (PFD)

PFDs provide increased situational awareness to the pilot by replacing the traditional six instruments used for instrument flight with an easy-to-scan display that provides the horizon, airspeed, altitude, vertical speed, trend, trim, rate of turn among other key relevant indications. Examples of PFDs are illustrated in *Figure 3-45*.

Synthetic Vision

Synthetic vision provides a realistic depiction of the aircraft in relation to terrain and flight path. Systems such as those produced by Chelton Flight Systems, Universal Flight Systems, and others provide for depictions of terrain and course. *Figure 3-46* is an example of the Chelton Flight System providing both 3-dimensional situational awareness and a synthetic highway in the sky, representing the desired flight path. Synthetic vision is used as a PFD, but provides guidance in a more normal, outside reference format.

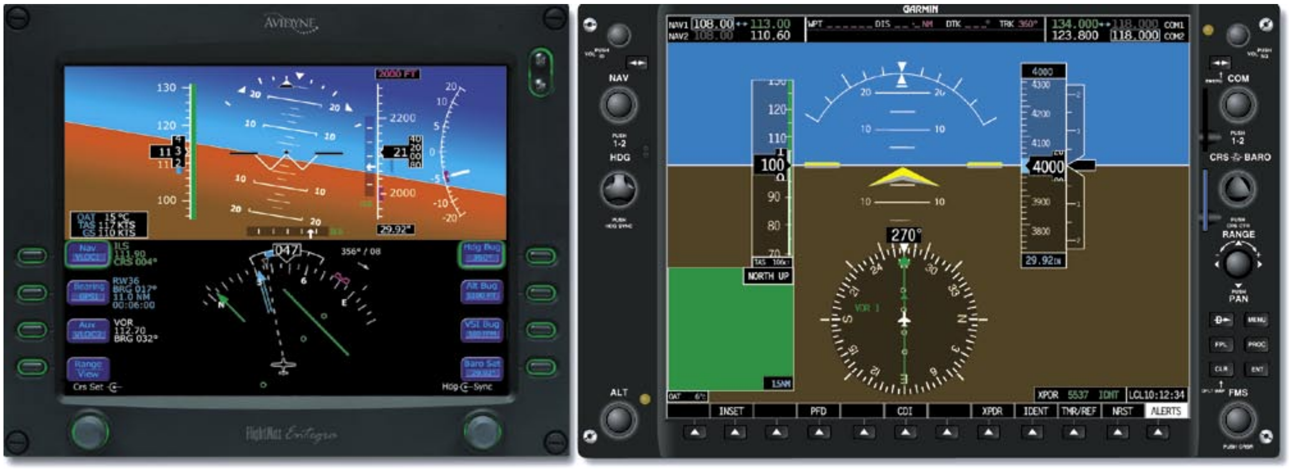

Figure 3-45. *Two Primary Flight Displays (Avidyne on the Left and Garmin on the Right).*

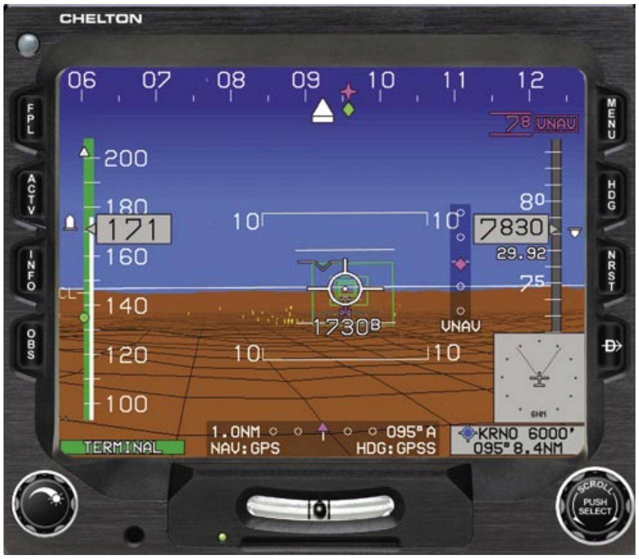

Figure 3-46. *The benefits of realistic visualization imagery, as illustrated by Synthetic Vision manufactured by Chelton Flight Systems. The system provides the pilot a realistic, real-time, three-dimensional depiction of the aircraft and its relation to terrain around it.*

Multi-Function Display (MFD)

In addition to a PFD directly in front of the pilot, an MFD that provides the display of information in addition to primary flight information is used within the flight deck. *[Figure 3-47]* Information such as a moving map, approach charts, Terrain Awareness Warning System, and weather depiction can all be illustrated on the MFD. For additional redundancy both the PFD and MFD can display all critical information that the other normally presents thereby providing redundancy (using a reversionary mode) not normally found in general aviation flight decks.

Advanced Technology Systems

Automatic Dependent Surveillance—Broadcast (ADS-B)

Although standards for Automatic Dependent Surveillance (Broadcast) (ADS-B) are still under continuing development, the concept is simple: aircraft broadcast a message on a regular basis, which includes their position (such as latitude, longitude and altitude), velocity, and possibly other information. Other aircraft or systems can receive this information for use in a wide variety of applications. The key to ADS-B is GPS, which provides three-dimensional position of the aircraft.

As an simplified example, consider air-traffic radar. The radar measures the range and bearing of an aircraft. The bearing is measured by the position of the rotating radar antenna when it receives a reply to its interrogation from the aircraft, and the range by the time it takes for the radar to receive the reply.

An ADS-B based system, on the other hand, would listen for position reports broadcast by the aircraft. *[Figure 3-48]* These position reports are based on satellite navigation systems. These transmissions include the transmitting aircraft's position, which the receiving aircraft processes into usable pilot information. The accuracy of the system is now determined by the accuracy of the navigation system, not measurement errors. Furthermore the accuracy is unaffected by the range to the aircraft as in the case of radar. With radar, detecting aircraft speed changes require tracking the data and changes can only be detected over a period of several position updates. With ADS-B, speed changes are broadcast almost instantaneously and received by properly equipped aircraft.

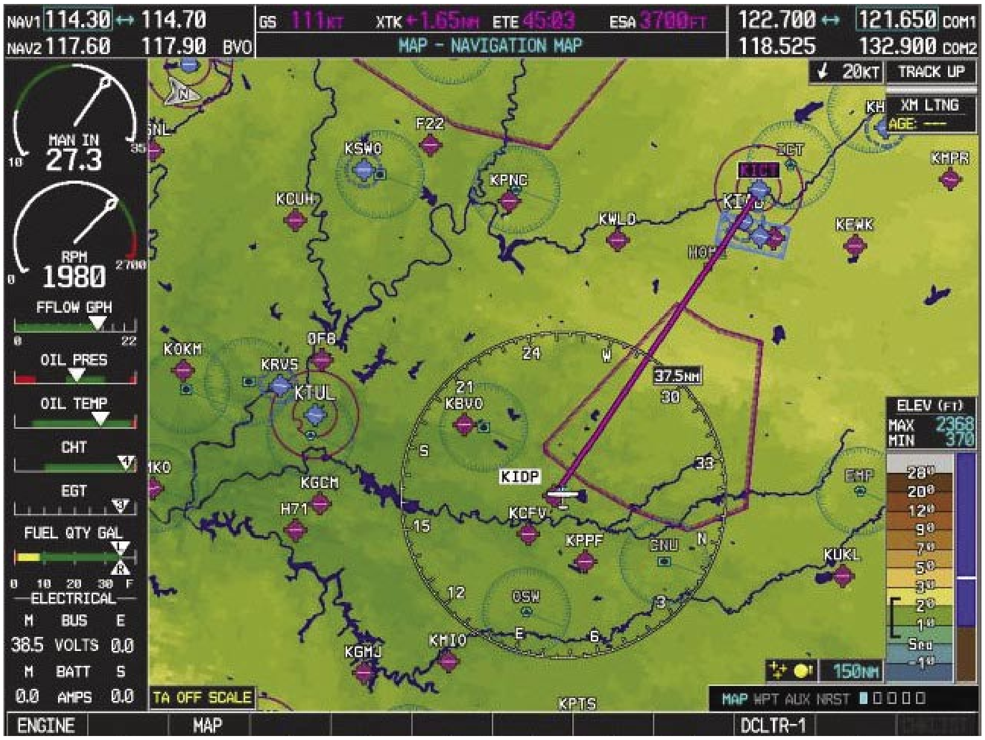
NAV1 114.30 ↔ 114.70
NAV2 117.60 117.90 BVO
GS 111KT
XTK 1.65NM
ETE 45:03
ESA 3700FT
MAP - NAVIGATION MAP
122.700 ↔ 121.650 COM1
118.525 132.900 COM2
20KT
TRACK UP
XM LTNG
AGE: ---
MAN IN
27.3
RPM
1980
FFLOW GPH
OIL PRES
OIL TEMP
CHT
EGT
FUEL QTY GAL
ELECTRICAL
M BUS E
38.5 VOLTS 0.0
M BATT S
0.0 AMPS 0.0
TA OFF SCALE
KIDP
37.5NM
ELEV (FT)
MAX 2368
MIN 370
150NM
MAP WPT AUX NRST
ENGINE
MAP
DCLTR-1

Figure 3-47. *Example of a Multi-Function Display (MFD).*

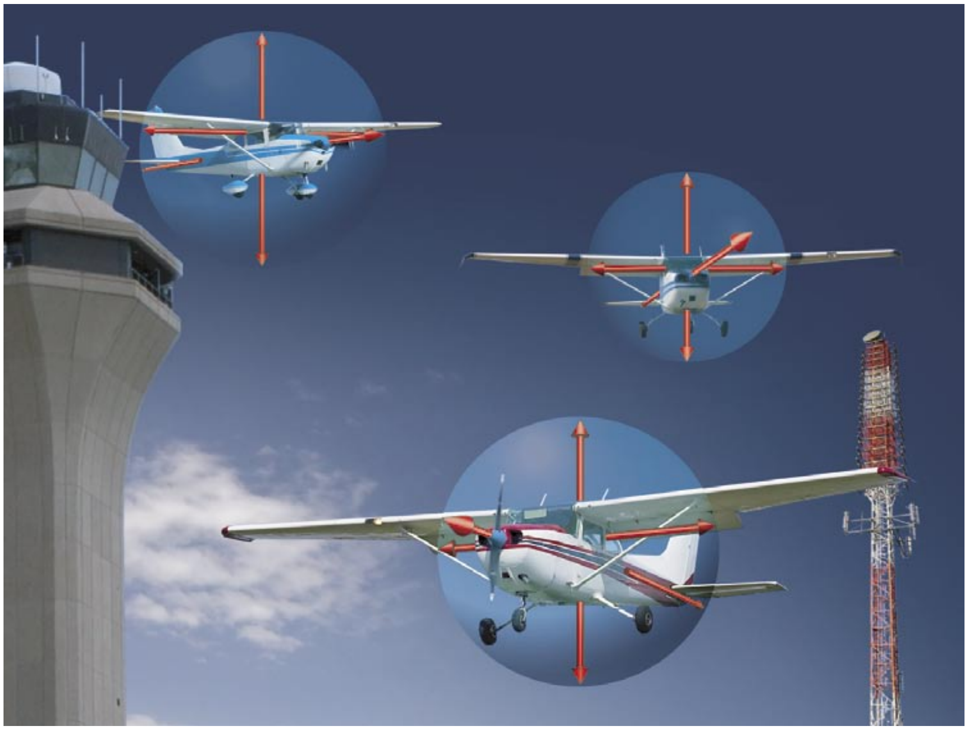

Figure 3-48. *Aircraft equipped with Automatic Dependent Surveillance—Broadcast (ADS-B) continuously broadcast their identification, altitude, direction, and vertical trend. The transmitted signal carries significant information for other aircraft and ground stations alike. Other ADS-equipped aircraft receive this information and process it in a variety of ways. It is possible that in a saturated environment (assuming all aircraft are ADS equipped), the systems can project tracks for their respective aircraft and retransmit to other aircraft their projected tracks, thereby enhancing collision avoidance. At one time, there was an Automatic Dependent Surveillance—Addressed (ADS-A) and that is explained in the Pilot's Handbook of Aeronautical Knowledge.*

Additionally, other information can be obtained by properly equipped aircraft to include notices to airmen (NOTAM), weather, etc. *[Figures 3-49* and *3-50]* At the present time, ADS-B is predominantly available along the east coast of the United States where it is matured.

Safety Systems

Radio Altimeters

A radio altimeter, commonly referred to as a radar altimeter, is a system used for accurately measuring and displaying the height above the terrain directly beneath the aircraft. It sends a signal to the ground and processes the timed information.

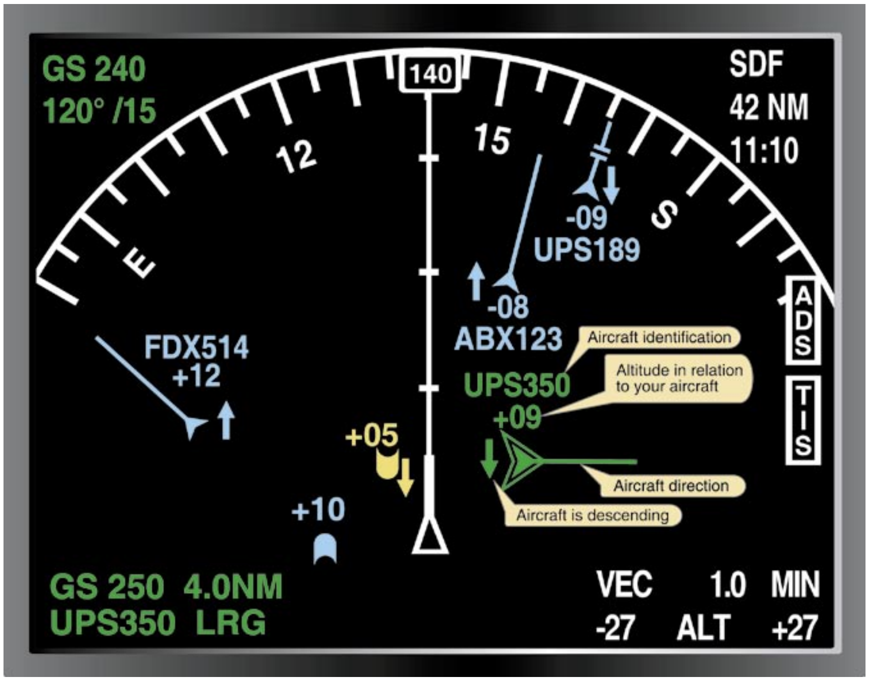
GS 240
120° /15
140
12
15
E
S
SDF
42 NM
11:10
-09
UPS189
-08
ABX123
Aircraft identification
UPS350
+09
Altitude in relation to your aircraft
Aircraft direction
Aircraft is descending
FDX514
+12
+05
+10
ADS
TIS
GS 250 4.0NM
UPS350 LRG
VEC 1.0 MIN
-27 ALT +27

Figure 3-49. *An aircraft equipped with ADS will receive identification, altitude in hundreds of feet (above or below using + or -), direction of the traffic, and aircraft descent or climb using an up or down arrow. The yellow target is an illustration of how a non-ADS equipped aircraft would appear on an ADS-equipped aircraft's display.*

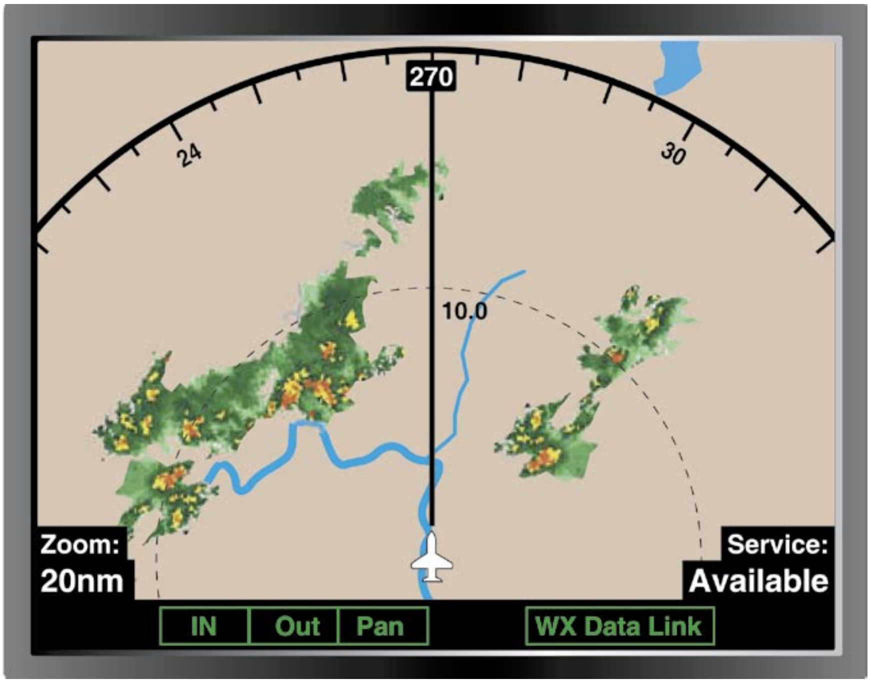
270
24
30
10.0
Zoom:
20nm
Service:
Available
IN
Out
Pan
WX Data Link

Figure 3-50. *An aircraft equipped with ADS has the ability to upload and display weather.*

Its primary application is to provide accurate absolute altitude information to the pilot during approach and landing. In advanced aircraft today, the radar altimeter also provides its information to other onboard systems such as the autopilot and flight directors while they are in the glide slope capture mode below 200-300 feet above ground level (AGL).

A typical system consists of a receiver-transmitter (RT) unit, antenna(s) for receiving and transmitting the signal, and an indicator. *[Figure 3-51]* Category II and III precision approach procedures require the use of a radar altimeter and specify the exact minimum height above the terrain as a decision height (DH) or radio altitude (RA).

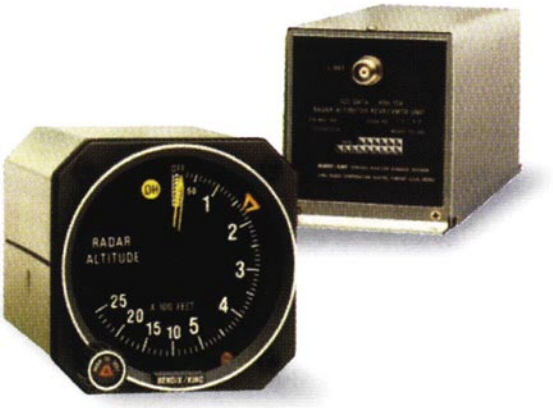

Figure 3-51. *Components of a Radar Altimeter.*

Traffic Advisory Systems

Traffic Information System

The Traffic Information Service (TIS) is a ground-based service providing information to the flight deck via data link using the S-mode transponder and altitude encoder. TIS improves the safety and efficiency of "see and avoid" flight through an automatic display that informs the pilot of nearby traffic. The display can show location, direction, altitude and the climb/descent trend of other transponder-equipped aircraft. TIS provides estimated position, altitude, altitude trend, and ground track information for up to several aircraft simultaneously within about 7 NM horizontally, 3,500 feet above and 3,500 feet below the aircraft. *[Figure 3-52]* This data can be displayed on a variety of MFDs. *[Figure 3-53]*

Figure 3-54 displays the pictorial concept of the traffic information system. Noteworthy is the requirement to have Mode S and that the ground air traffic station processes the Mode S signal.

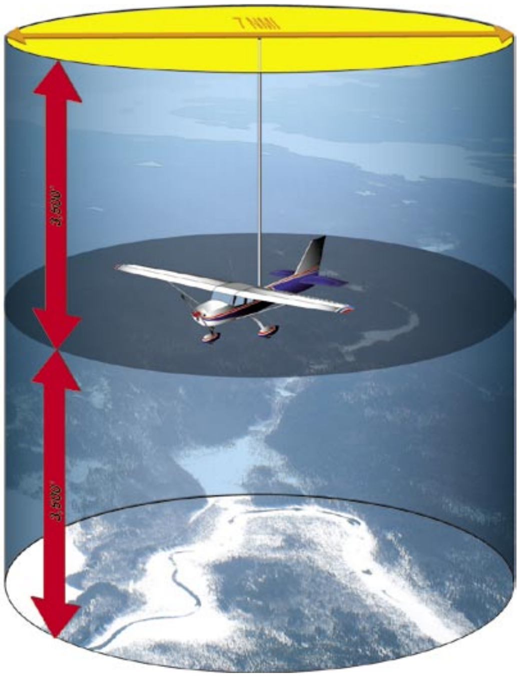

Figure 3-52. *Coverage Provided by a Traffic Information System.*

Traffic Alert Systems

Traffic alert systems receive transponder information from nearby aircraft to help determine their relative position to the equipped aircraft. They provide three-dimensional location of other aircraft *[Figures 3-55, 3-56,* and *3-57]* and are cost effective alternatives to TCAS equipage for smaller aircraft.

Traffic Avoidance Systems

Traffic Alert and Collision Avoidance System (TCAS)

The TCAS is an airborne system developed by the FAA that operates independently from the ground-based ATC system. TCAS was designed to increase flight deck awareness of proximate aircraft and to serve as a "last line of defense" for the prevention of mid-air collisions.

There are two levels of TCAS systems. TCAS I was developed to accommodate the general aviation (GA) community and the regional airlines. This system issues traffic advisories (TAs) to assist pilots in visual acquisition of intruder aircraft. TCAS I provides approximate bearing and relative altitude of aircraft with a selectable range. It provides the pilot with traffic advisory (TA) alerting him or her to potentially conflicting traffic. The pilot then visually acquires the traffic and takes appropriate action for collision avoidance.

TCAS II is a more sophisticated system which provides the same information of TCAS I. It also analyzes the projected flight path of approaching aircraft and issues resolution advisories (RAs) to the pilot to resolve potential mid-air collisions. Additionally, if communicating with another TCAS II equipped aircraft, the two systems coordinate the resolution alerts provided to their respective flight crews. *[Figure 3-58]*

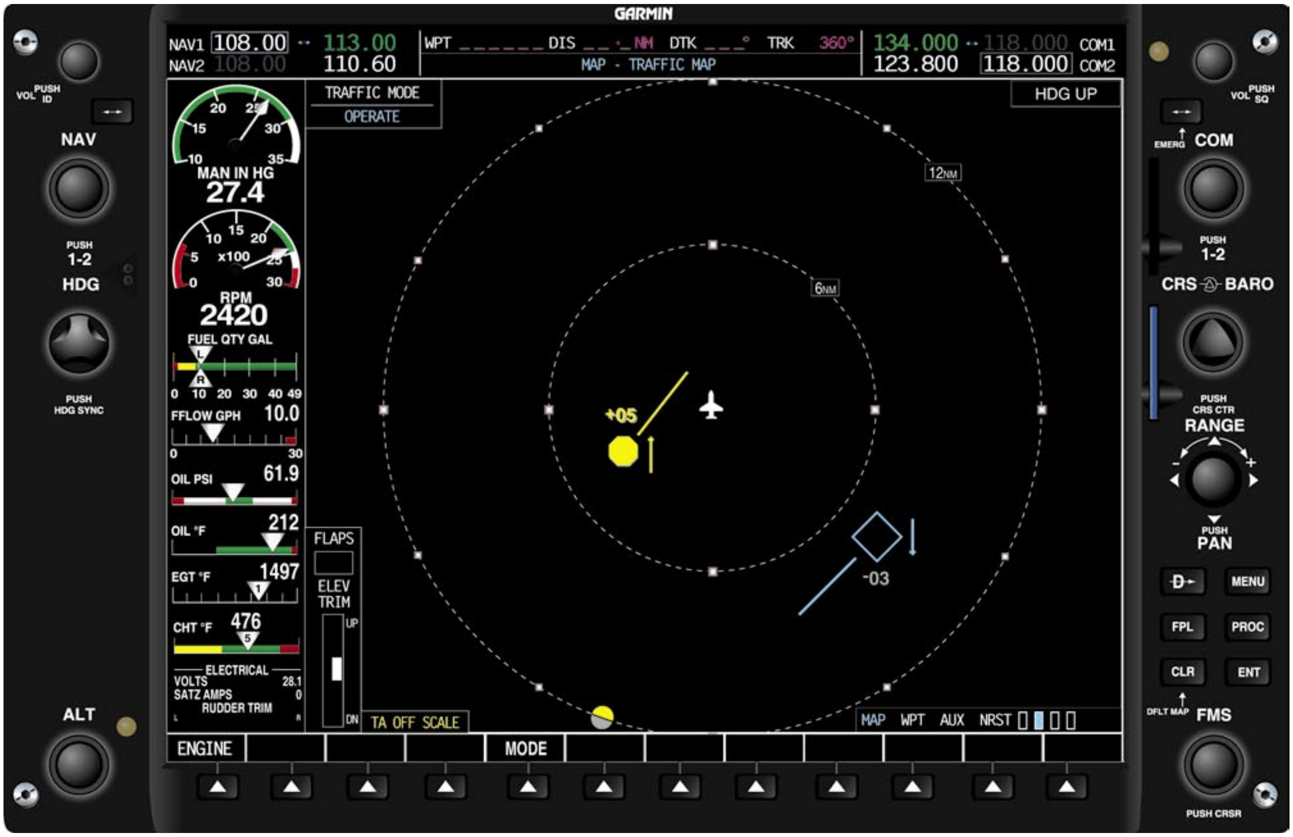
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
WPT DIS NM DTK TRK 360°
MAP - TRAFFIC MAP
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
TRAFFIC MODE
OPERATE
HDG UP
12NM
6NM
+05
-03
MAN IN HG
27.4
RPM
2420
FUEL QTY GAL
FFLOW GPH 10.0
OIL PSI 61.9
OIL °F 212
EGT °F 1497
CHT °F 476
ELECTRICAL
VOLTS 28.1
SATZ AMPS 0
RUDDER TRIM
FLAPS
ELEV TRIM
UP
DN
TA OFF SCALE
MAP WPT AUX NRST
ENGINE
MODE
NAV
HDG
ALT
PUSH HDG SYNC
COM
CRS BARO
RANGE
PAN
MENU
FPL
PROC
CLR
ENT
FMS
PUSH CRSR

Figure 3-53. *Multi-Function Display (MFD).*

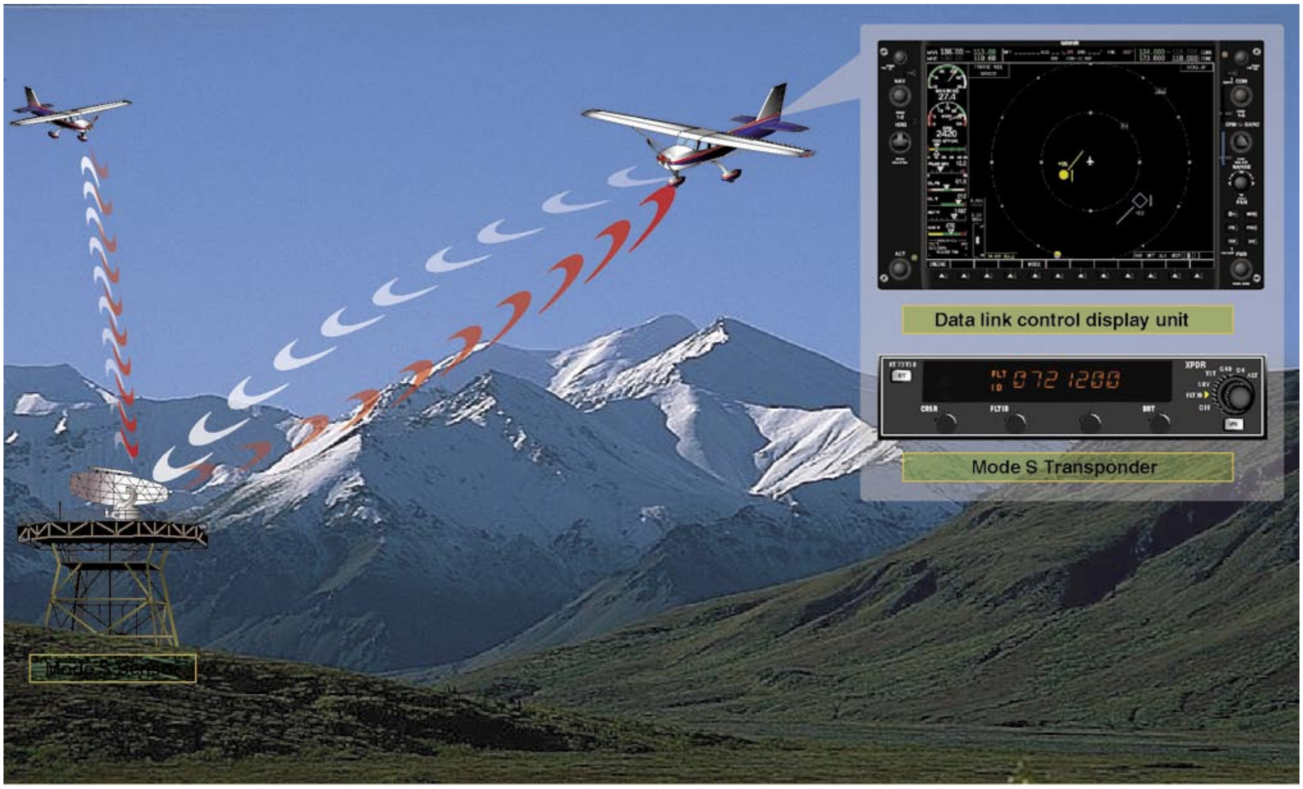
Data link control display unit
Mode S Transponder
Mode S Sensor

Figure 3-54. *Concept of the Traffic Information System.*

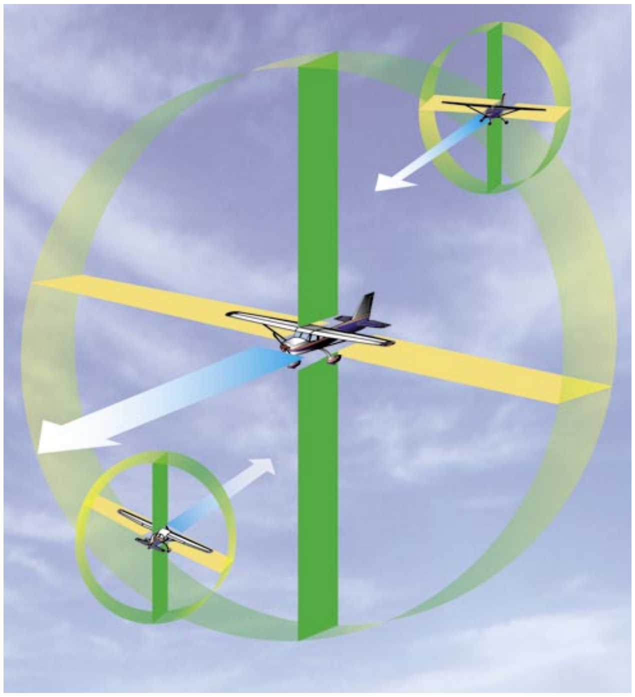

Figure 3-55. *Theory of a Typical Alert System.*

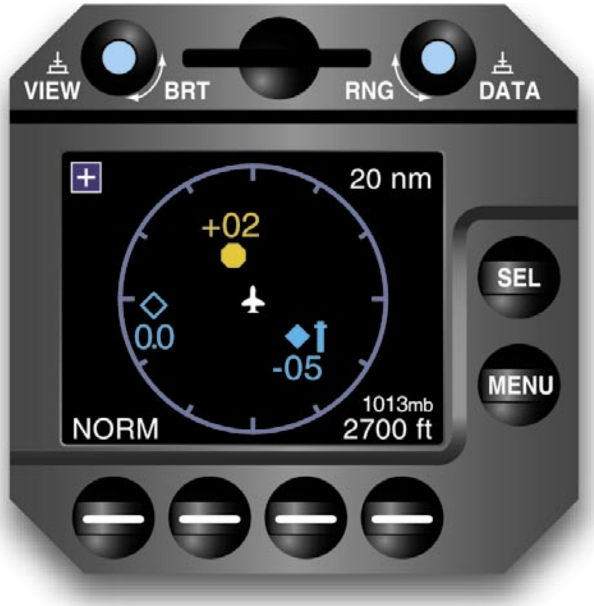
VIEW
BRT
RNG
DATA
20 nm
+02
0.0
-05
1013mb
2700 ft
NORM
SEL
MENU

Figure 3-56. *A Skywatch System.*

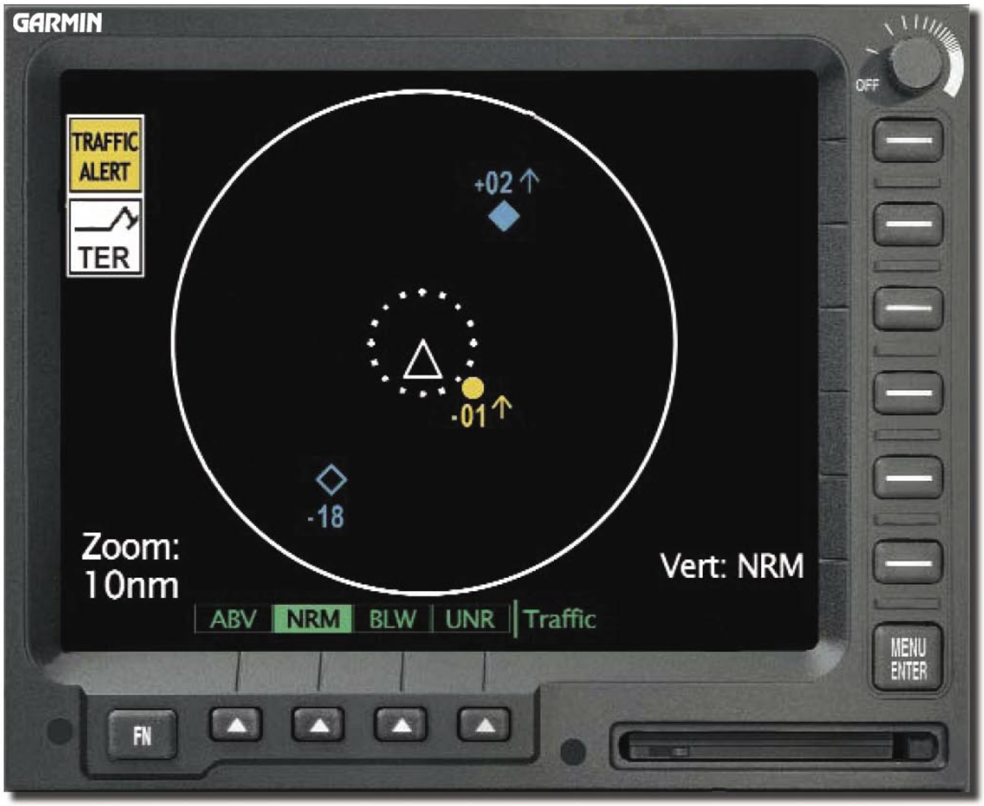
GARMIN
OFF
TRAFFIC ALERT
TER
+02
-01
-18
Zoom: 10nm
Vert: NRM
ABV
NRM
BLW
UNR
Traffic
MENU ENTER
FN

Figure 3-57. *Alert System by Avidyne (Ryan).*

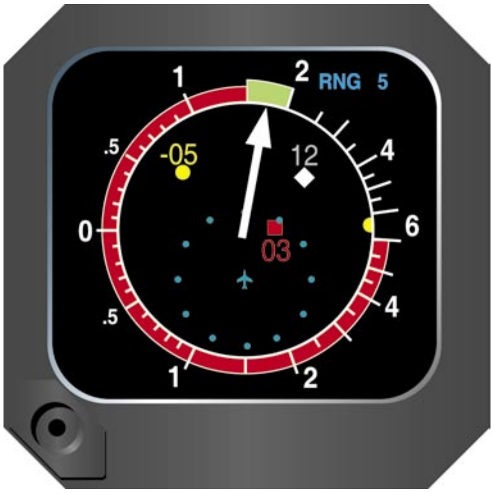

Figure 3-58. *An example of a resolution advisory being provided the pilot. In this case, the pilot is requested to climb, with 1,200 feet being the appropriate rate of ascent to avoid traffic conflict. This visual indication plus the aural warning provide the pilot with excellent traffic awareness that augments see and avoid practices.*

Terrain Alerting Systems

Ground Proximity Warning System (GPWS)

An early application of technology to reduce CFIT was the GPWS. In airline use since the early 1970s, GPWS uses the radio altimeter, speed, and barometric altitude to determine the aircraft's position relative to the ground. The system uses this information in determining aircraft clearance above the Earth and provides limited predictability about aircraft position relative to rising terrain. It does this based upon algorithms within the system and developed by the manufacturer for different airplanes or helicopters. However, in mountainous areas the system is unable to provide predictive information due to the unusual slope encountered.

This inability to provide predictive information was evidenced in 1999 when a DH-7 crashed in South America. The crew had a GPWS onboard, but the sudden rise of the terrain rendered it ineffective; the crew continued unintentionally into a mountain with steep terrain. Another incident involved Secretary of Commerce Brown who, along with all on board, was lost when the crew flew over rapidly rising terrain where the GPWS capability is offset by terrain gradient. However, the GPWS is tied into and considers landing gear status, flap position, and ILS glide slope deviation to detect unsafe aircraft operation with respect to terrain, excessive descent rate, excessive closure rate to terrain, unsafe terrain clearance while not in a landing configuration, excessive deviation below an ILS glide slope. It also provides advisory callouts.

Generally, the GPWS is tied into the hot bus bar of the electrical system to prevent inadvertent switch off. This was demonstrated in an accident involving a large four-engine turboprop airplane. While on final for landing with the landing gear inadvertently up, the crew failed to heed the GPWS warning as the aircraft crossed a large berm close to the threshold. In fact, the crew attempted without success to shut the system down and attributed the signal to a malfunction. Only after the mishap did the crew realize the importance of the GPWS warning.

Terrain Awareness and Warning System (TAWS)

A TAWS uses GPS positioning and a database of terrain and obstructions to provide true predictability of the upcoming terrain and obstacles. The warnings it provides pilots are both aural and visual, instructing the pilot to take specific action. Because TAWS relies on GPS and a database of terrain/obstacle information, predictability is based upon aircraft location and projected location. The system is time based and therefore compensates for the performance of the aircraft and its speed. *[Figure 3-59]*

Head-Up Display (HUD)

The HUD is a display system that provides a projection of navigation and air data (airspeed in relation to approach reference speed, altitude, left/right and up/down glide slope) on a transparent screen between the pilot and the windshield. The concept of a HUD is to diminish the shift between looking at the instrument panel and outside. Virtually any information desired can be displayed on the HUD if it is available in the aircraft's flight computer. The display for the HUD can be projected on a separate panel near the windscreen or as shown in *Figure 3-60* on an eye piece. Other information may be displayed, including a runway target in relation to the nose of the aircraft, which allows the pilot to see the information necessary to make the approach while also being able to see out the windshield.

Required Navigation Instrument System Inspection

Systems Preflight Procedures

Inspecting the instrument system requires a relatively small part of the total time required for preflight activities, but its importance cannot be overemphasized. Before any flight involving aircraft control by instrument reference, the pilot should check all instruments and their sources of power for proper operation. NOTE: The following procedures are appropriate for conventional aircraft instrument systems. Aircraft equipped with electronic instrument systems utilize different procedures.

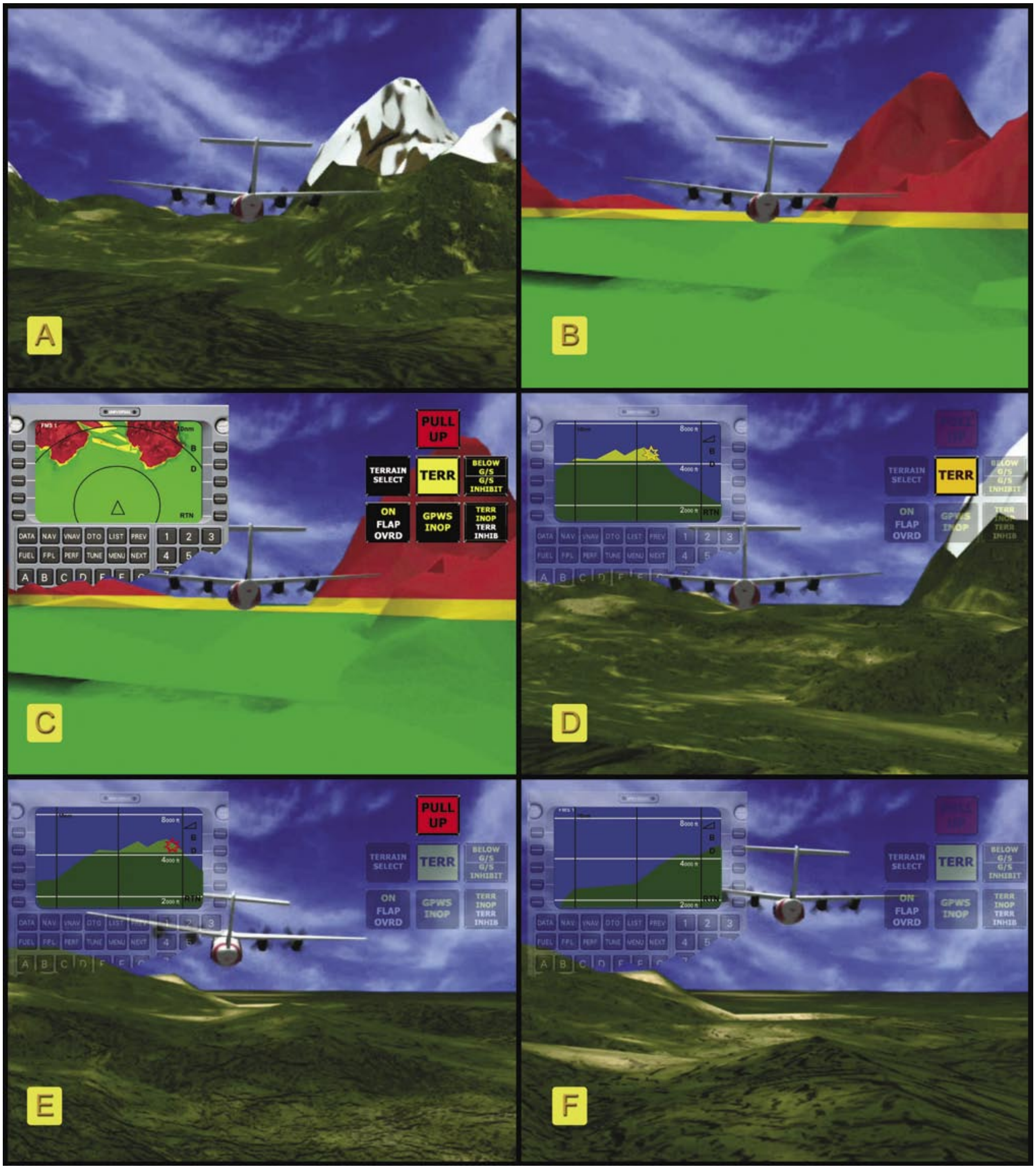
A
B
PULL UP
TERRAIN SELECT
TERR
BELOW G/S G/S INHIBIT
ON FLAP OVRD
GPWS INOP
TERR INOP TERR INHIB
DATA NAV VNAV DTO LIST PREV
FUEL FPL PERF TUNE MENU NEXT
RTN
C
D
E
F

Figure 3-59. *A six-frame sequence illustrating the manner in which TAWS operates. A TAWS installation is aircraft specific and provides warnings and cautions based upon time to potential impact with terrain rather than distance. The TAWS is illustrated in an upper left window while aircrew view is provided out of the windscreen.* A *illustrates the aircraft in relation to the outside terrain while* B *and* C *illustrate the manner in which the TAWS system displays the terrain.* D *is providing a caution of terrain to be traversed, while* E *provides an illustration of a warning with an aural and textural advisory (red) to pull up.* E *also illustrates a pilot taking appropriate action (climb in this case) while* F *illustrates that a hazard is no longer a factor.*

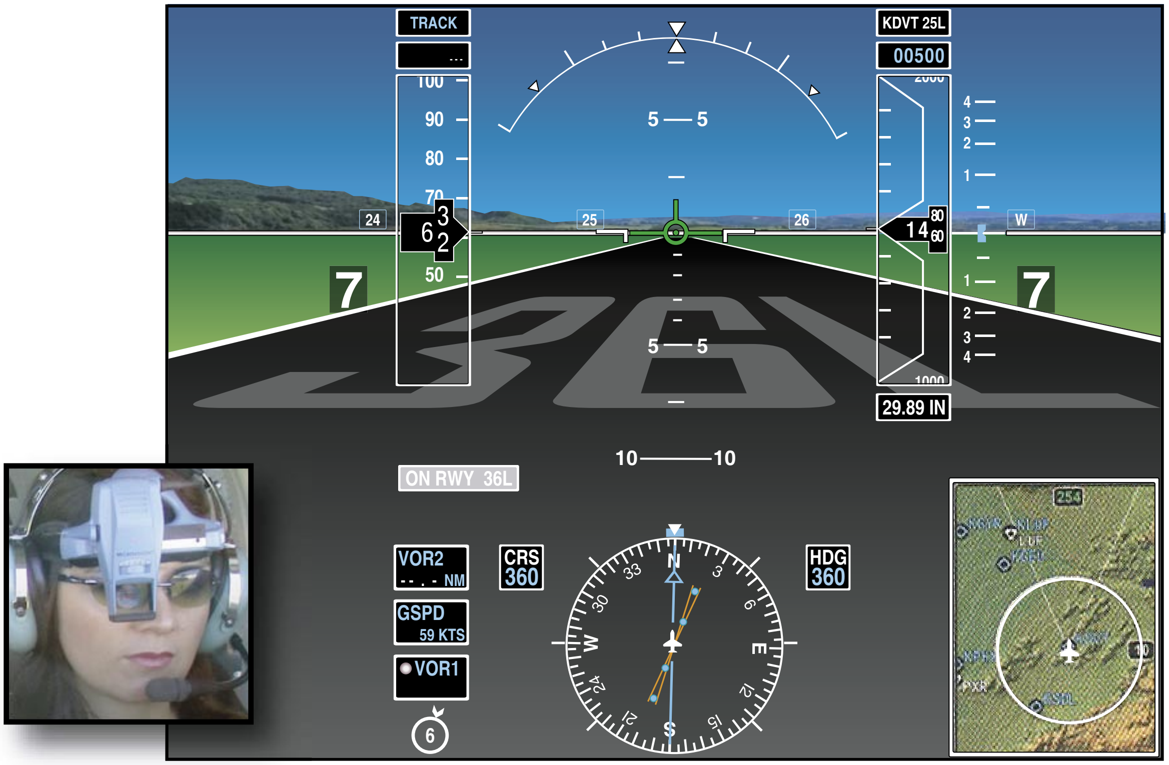

Figure 3-60. *A Head-Up Display.*

Before Engine Start

1. Walk-around inspection: Check the condition of all antennas and check the pitot tube for the presence of any obstructions and remove the cover. Check the static ports to be sure they are free from dirt and obstructions, and ensure there is nothing on the structure near the ports that would disturb the air flowing over them.
2. Aircraft records: Confirm that the altimeter and static system have been checked and found within approved limits within the past 24 calendar months. Check the replacement date for the emergency locator transmitter (ELT) batteries noted in the maintenance record, and be sure they have been replaced within this time interval.
3. Preflight paperwork: Check the Airport/Facility Directory (A/FD) and all Notices to Airmen (NOTAMs) for the condition and frequencies of all the navigation aid (NAVAIDs) that are used on the flight. Handbooks, en route charts, approach charts, computer and flight log should be appropriate for the departure, en route, destination, and alternate airports.
4. Radio equipment: Switches off.
5. Suction gauge: Proper markings as applicable if electronic flight instrumentation is installed.
6. ASI: Proper reading, as applicable. If electronic flight instrumentation is installed, check emergency instrument.
7. Attitude indicator: Uncaged, if applicable. If electronic flight instrumentation is installed, check emergency system to include its battery as appropriate.
8. Altimeter: Set the current altimeter setting and ensure that the pointers indicate the elevation of the airport.
9. VSI: Zero indication, as applicable (if electronic flight instrumentation is installed).
10. Heading indicator: Uncaged, if applicable.
11. Turn coordinator: If applicable, miniature aircraft level, ball approximately centered (level terrain).
12. Magnetic compass: Full of fluid and the correction card is in place and current.
13. Clock: Set to the correct time and running.
14. Engine instruments: Proper markings and readings, as applicable if electronic flight instrumentation is installed.
15. Deicing and anti-icing equipment: Check availability and fluid quantity.
16. Alternate static-source valve: Be sure it can be opened if needed, and that it is fully closed.

17. Pitot tube heater: Check by watching the ammeter when it is turned on, or by using the method specified in the POH/AFM.

After Engine Start

1. When the master switch is turned on, listen to the gyros as they spin up. Any hesitation or unusual noises should be investigated before flight.
2. Suction gauge or electrical indicators: Check the source of power for the gyro instruments. The suction developed should be appropriate for the instruments in that particular aircraft. If the gyros are electrically driven, check the generators and inverters for proper operation.
3. Magnetic compass: Check the card for freedom of movement and confirm the bowl is full of fluid. Determine compass accuracy by comparing the indicated heading against a known heading (runway heading) while the airplane is stopped or taxiing straight. Remote indicating compasses should also be checked against known headings. Note the compass card correction for the takeoff runway heading.
4. Heading indicator: Allow 5 minutes after starting engines for the gyro to spin up. Before taxiing, or while taxiing straight, set the heading indicator to correspond with the magnetic compass heading. A slaved gyrocompass should be checked for slaving action and its indications compared with those of the magnetic compass. If an electronic flight instrument system is installed, consult the flight manual for proper procedures.
5. Attitude indicator: Allow the same time as noted above for gyros to spin up. If the horizon bar erects to the horizontal position and remains at the correct position for the attitude of the airplane, or if it begins to vibrate after this attitude is reached and then slowly stops vibrating altogether, the instrument is operating properly. If an electronic flight instrument system is installed, consult the flight manual for proper procedures.
6. Altimeter: With the altimeter set to the current reported altimeter setting, note any variation between the known field elevation and the altimeter indication. If the indication is not within 75 feet of field elevation, the accuracy of the altimeter is questionable and the problem should be referred to a repair station for evaluation and possible correction. Because the elevation of the ramp or hangar area might differ significantly from field elevation, recheck when in the run-up area if the error exceeds 75 feet. When no altimeter setting is available, set the altimeter to the published field elevation during the preflight instrument check.
7. VSI: The instrument should read zero. If it does not, tap the panel gently. If an electronic flight instrument system is installed, consult the flight manual for proper procedures.
8. Engine instruments: Check for proper readings.
9. Radio equipment: Check for proper operation and set as desired.
10. Deicing and anti-icing equipment: Check operation.

Taxiing and Takeoff

1. Turn coordinator: During taxi turns, check the miniature aircraft for proper turn indications. The ball or slip/skid should move freely. The ball or slip/skid indicator should move opposite to the direction of turns. The turn instrument should indicate the direction of the turn. While taxiing straight, the miniature aircraft (as appropriate) should be level.
2. Heading indicator: Before takeoff, recheck the heading indicator. If the magnetic compass and deviation card are accurate, the heading indicator should show the known taxiway or runway direction when the airplane is aligned with them (within 5°).
3. Attitude indicator: If the horizon bar fails to remain in the horizontal position during straight taxiing, or tips in excess of 5° during taxi turns, the instrument is unreliable. Adjust the miniature aircraft with reference to the horizon bar for the particular airplane while on the ground. For some tricycle-gear airplanes, a slightly nose-low attitude on the ground gives a level flight attitude at normal cruising speed.

Engine Shut Down

When shutting down the engine, note any abnormal instrument indications.

100
FEET
ALT
CALIBRATED
29.8
29.9
30.0
UP VERTICAL SPEED
THOUSAND FT PER MIN
DOWN
L
R
OFF
2 MIN TURN
DC ELEC
STBY PWR
TEST
PULL TO CAGE

Chapter 4, Section I

Airplane Attitude Instrument Flying

Using Analog Instrumentation

Introduction

Attitude instrument flying is defined as the control of an aircraft's spatial position by using instruments rather than outside visual references. Today's aircraft come equipped with analog and/or digital instruments. Analog instrument systems are mechanical and operate with numbers representing directly measurable quantities, such as a watch with a sweep second hand. In contrast, digital instrument systems are electronic and operate with numbers expressed in digits. Although more manufacturers are providing aircraft with digital instrumentation, analog instruments remain more prevalent. This section acquaints the pilot with the use of analog flight instruments.

Any flight, regardless of the aircraft used or route flown, consists of basic maneuvers. In visual flight, aircraft attitude is controlled by using certain reference points on the aircraft with relation to the natural horizon. In instrument flight, the aircraft attitude is controlled by reference to the flight instruments. Proper interpretation of the flight instruments provides essentially the same information that outside references do in visual flight. Once the role of each instrument in establishing and maintaining a desired aircraft attitude is learned, a pilot is better equipped to control the aircraft in emergency situations involving failure of one or more key instruments.

Learning Methods

The two basic methods used for learning attitude instrument flying are "control and performance" and "primary and supporting." Both methods utilize the same instruments and responses for attitude control. They differ in their reliance on the attitude indicator and interpretation of other instruments.

Attitude Instrument Flying Using the Control and Performance Method

Aircraft performance is achieved by controlling the aircraft attitude and power. Aircraft attitude is the relationship of both the aircraft's pitch and roll axes in relation to the Earth's horizon. An aircraft is flown in instrument flight by controlling the attitude and power, as necessary, to produce both controlled and stabilized flight without reference to a visible horizon. This overall process is known as the control and performance method of attitude instrument flying. Starting with basic instrument maneuvers, this process can be applied through the use of control, performance, and navigation instruments, resulting in a smooth flight, from takeoff to landing.

Control Instruments

The control instruments display immediate attitude and power indications and are calibrated to permit those respective adjustments in precise increments. In this discussion, the term "power" is used in place of the more technically correct term "thrust or drag relationship." Control is determined by reference to the attitude and power indicators. Power indicators vary with aircraft and may include manifold pressure, tachometers, fuel flow, etc. *[Figure 4-1]*

Performance Instruments

The performance instruments indicate the aircraft's actual performance. Performance is determined by reference to the altimeter, airspeed or vertical speed indicator (VSI). *[Figure 4-2]*

Navigation Instruments

The navigation instruments indicate the position of the aircraft in relation to a selected navigation facility or fix. This group of instruments includes various types of course indicators, range indicators, glide-slope indicators, and bearing pointers. *[Figure 4-3]* Newer aircraft with more technologically advanced instrumentation provide blended information, giving the pilot more accurate positional information.

Procedural Steps in Using Control and Performance

1. Establish an attitude and power setting on the control instruments that results in the desired performance. Known or computed attitude changes and approximated power settings helps to reduce the pilot's workload.
2. Trim (fine tune the control forces) until control pressures are neutralized. Trimming for hands-off flight is essential for smooth, precise aircraft control.

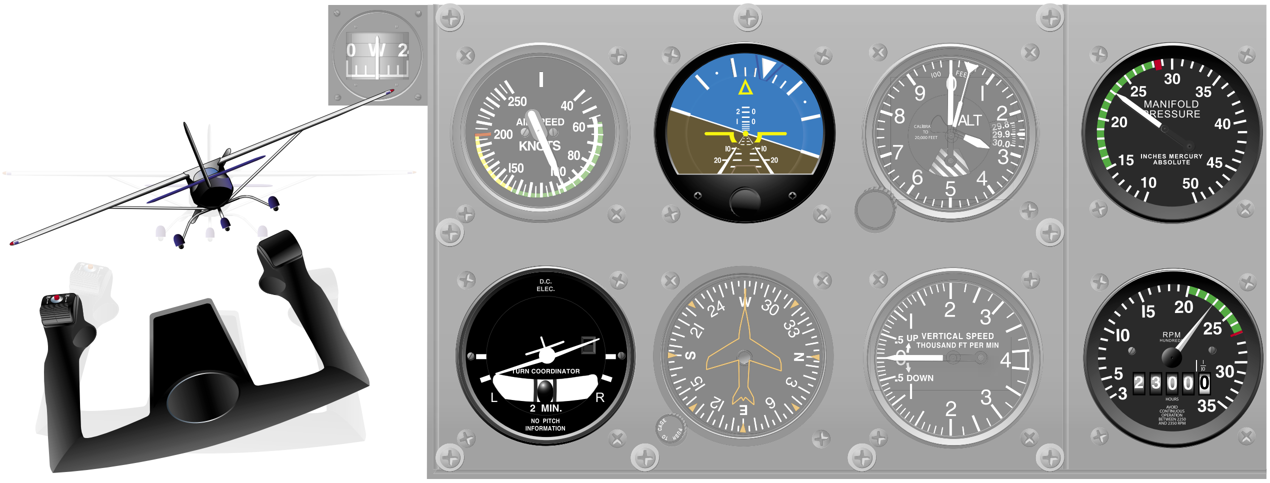

Figure 4-1. *Control Instruments.*

It allows a pilot to attend to other flight deck duties with minimum deviation from the desired attitude.

3. Cross-check the performance instruments to determine if the established attitude or power setting is providing the desired performance. The cross-check involves both seeing and interpreting. If a deviation is noted, determine the magnitude and direction of adjustment required to achieve the desired performance.

4. Adjust the attitude and/or power setting on the control instruments as necessary.

Aircraft Control During Instrument Flight

Attitude Control

Proper control of aircraft attitude is the result of proper use of the attitude indicator, knowledge of when to change the

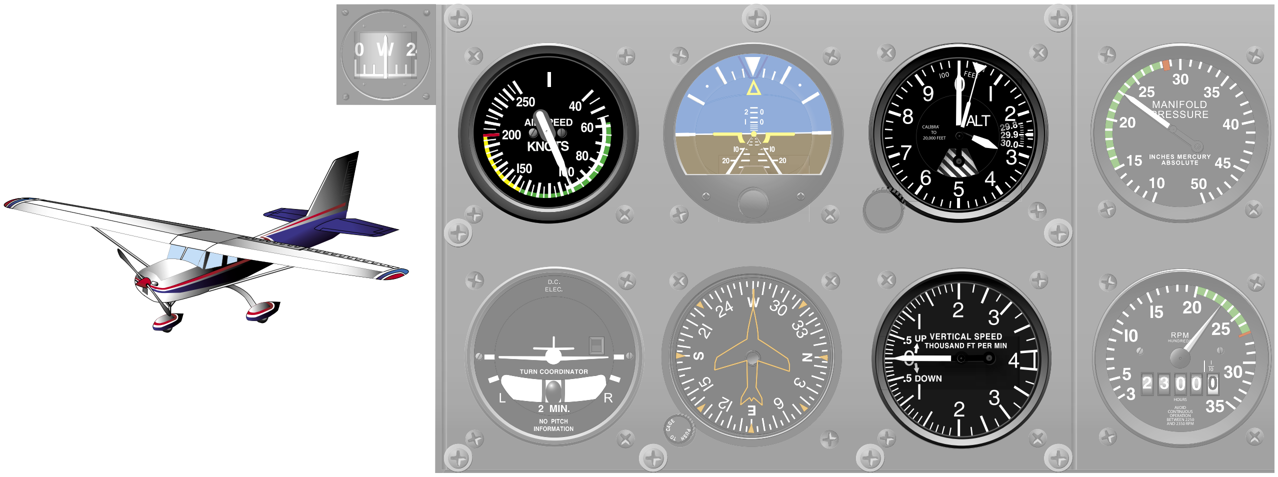
AIRSPEED KNOTS
ALT
MANIFOLD PRESSURE
INCHES MERCURY ABSOLUTE
D.C. ELEC.
TURN COORDINATOR
2 MIN.
NO PITCH INFORMATION
VERTICAL SPEED THOUSAND FT PER MIN
UP
DOWN
RPM
HOURS

Figure 4-2. *Performance Instruments.*

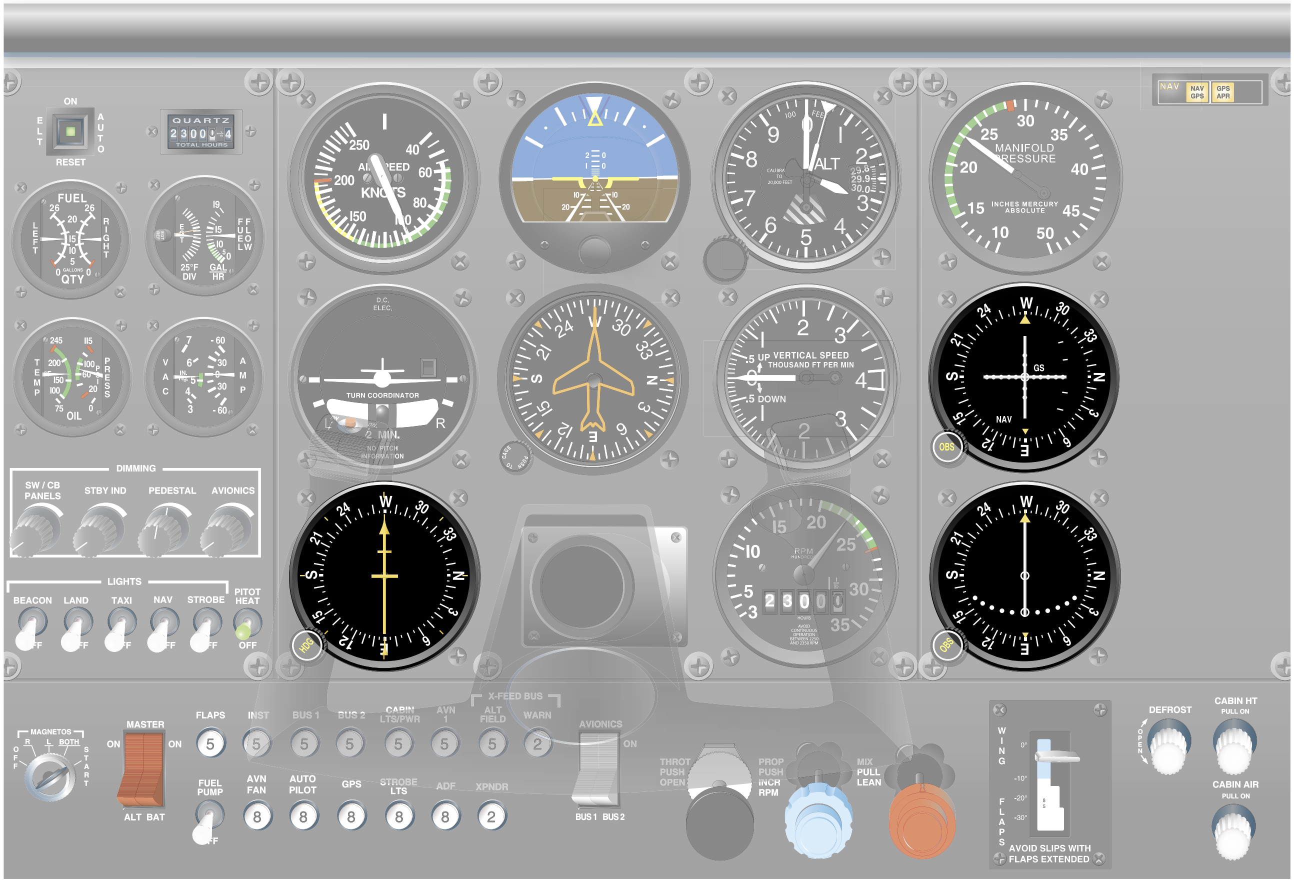
ELT
ON
AUTO
RESET
QUARTZ
TOTAL HOURS
FUEL
QTY
LEFT
RIGHT
FUEL FLOW
GAL HR
TEMP
PRESS
OIL
VAC
AMP
DIMMING
SW / CB PANELS
STBY IND
PEDESTAL
AVIONICS
LIGHTS
BEACON
LAND
TAXI
NAV
STROBE
PITOT HEAT
OFF
AIRSPEED KNOTS
ALT
MANIFOLD PRESSURE
INCHES MERCURY ABSOLUTE
TURN COORDINATOR
2 MIN.
NO PITCH INFORMATION
VERTICAL SPEED THOUSAND FT PER MIN
UP
DOWN
RPM
HOURS
HDG
OBS
GS
NAV
NAV GPS
GPS APR
MAGNETOS
OFF R L BOTH START
MASTER
ALT BAT
FLAPS
INST
BUS 1
BUS 2
CABIN LTS/PWR
AVN 1
ALT FIELD
WARN
X-FEED BUS
FUEL PUMP
AVN FAN
AUTO PILOT
GPS
STROBE LTS
ADF
XPNDR
AVIONICS
BUS 1 BUS 2
THROT PUSH OPEN
PROP PUSH INCH RPM
MIX PULL LEAN
WING FLAPS
AVOID SLIPS WITH FLAPS EXTENDED
DEFROST
CABIN HT PULL ON
CABIN AIR PULL ON

Figure 4-3. *Flight Panel Instrumentation.*

attitude, and then smoothly changing the attitude a precise amount. The attitude reference provides an immediate, direct, and corresponding indication of any change in aircraft pitch or bank attitude.

Pitch Control

Changing the "pitch attitude" of the miniature aircraft or fuselage dot by precise amounts in relation to the horizon makes pitch changes. These changes are measured in degrees or fractions thereof, or bar widths depending upon the type of attitude reference. The amount of deviation from the desired performance determines the magnitude of the correction.

Bank Control

Bank changes are made by changing the "bank attitude" or bank pointers by precise amounts in relation to the bank scale. The bank scale is normally graduated at 0°, 10°, 20°, 30°, 60°, and 90° and is located at the top or bottom of the attitude reference. Normally, use a bank angle that approximates the degrees to turn, not to exceed 30°.

Power Control

Proper power control results from the ability to smoothly establish or maintain desired airspeeds in coordination with attitude changes. Power changes are made by throttle adjustments and reference to the power indicators. Power indicators are not affected by such factors as turbulence, improper trim, or inadvertent control pressures. Therefore, in most aircraft little attention is required to ensure the power setting remains constant.

Experience in an aircraft teaches a pilot approximately how far to move the throttle to change the power a given amount. Power changes are made primarily by throttle movement, followed by an indicator cross-check to establish a more precise setting. The key is to avoid fixating on the indicators while setting the power. Knowledge of approximate power settings for various flight configurations helps the pilot avoid overcontrolling power.

Attitude Instrument Flying Using the Primary and Supporting Method

Another basic method for teaching attitude instrument flying classifies the instruments as they relate to control function as well as aircraft performance. All maneuvers involve some degree of motion about the lateral (pitch), longitudinal (bank/roll), and vertical (yaw) axes. Attitude control is stressed in this handbook in terms of pitch control, bank control, power control, and trim control. Instruments are grouped as they relate to control function and aircraft performance as pitch control, bank control, power control, and trim.

Pitch Control

Pitch control is controlling the rotation of the aircraft about the lateral axis by movement of the elevators. After interpreting the pitch attitude from the proper flight instruments, exert control pressures to effect the desired pitch attitude with reference to the horizon. These instruments include the attitude indicator, altimeter, VSI, and airspeed indicator. *[Figure 4-4]* The attitude indicator displays a direct indication of the aircraft's pitch attitude while the other pitch attitude control instruments indirectly indicate the pitch attitude of the aircraft.

Attitude Indicator

The pitch attitude control of an aircraft controls the angular relationship between the longitudinal axis of the aircraft and the actual horizon. The attitude indicator gives a direct and immediate indication of the pitch attitude of the aircraft. The aircraft controls are used to position the miniature aircraft in relation to the horizon bar or horizon line for any pitch attitude required. *[Figure 4-5]*

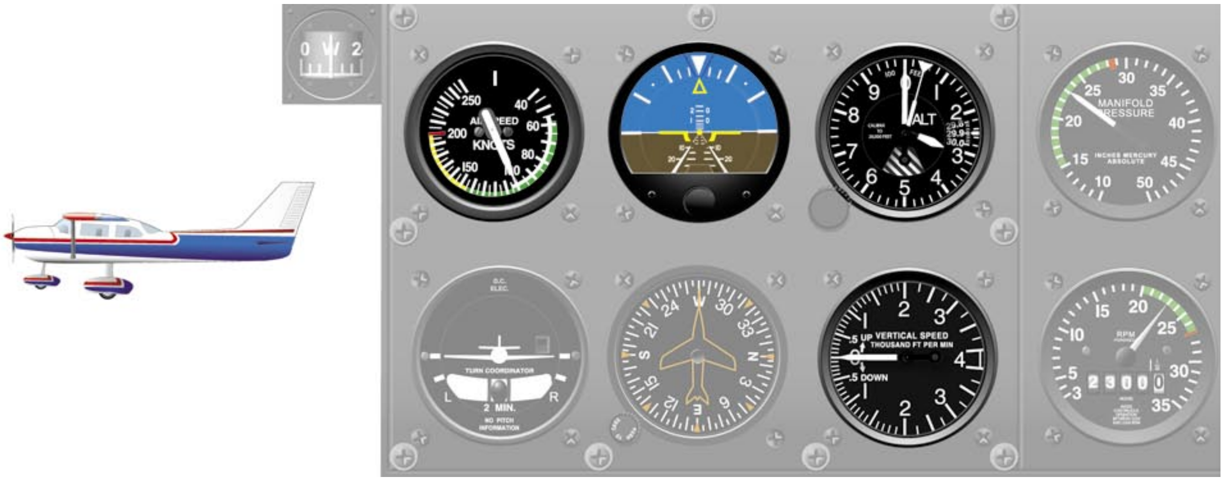

Figure 4-4. *Pitch Instruments.*

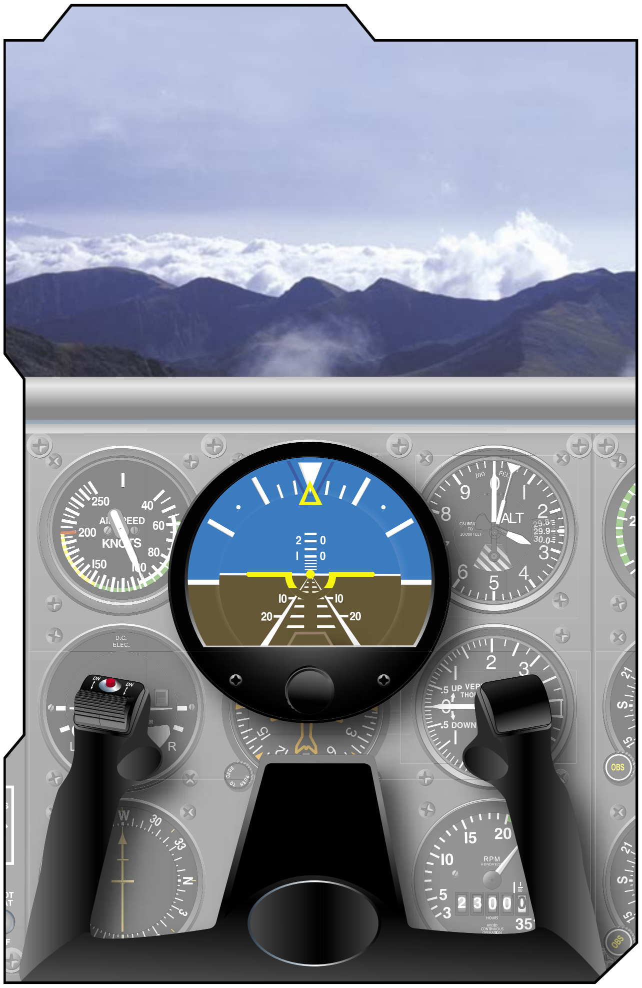

Figure 4-5. *Attitude Indicator.*

The miniature aircraft should be placed in the proper position in relation to the horizon bar or horizon line before takeoff. The aircraft operator's manual explains this position. As soon as practicable in level flight and at desired cruise airspeed, the miniature aircraft should be moved to a position that aligns its wings in front of the horizon bar or horizon line. This adjustment can be made anytime varying loads or other conditions indicate a need. Otherwise, the position of the miniature aircraft should not be changed for flight at other than cruise speed. This is to make sure that the attitude indicator displays a true picture of pitch attitude in all maneuvers.

When using the attitude indicator in applying pitch attitude corrections, control pressure should be extremely light. Movement of the horizon bar above or below the miniature aircraft of the attitude indicator in an airplane should not exceed one-half the bar width. *[Figure 4-6]* If further change is required, an additional correction of not more than one-half horizon bar wide normally counteracts any deviation from normal flight.

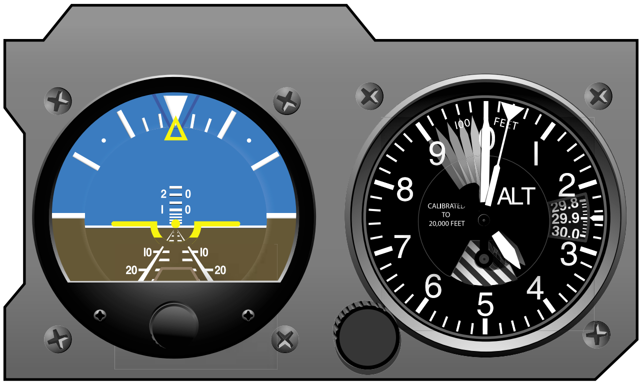

Figure 4-6. *Pitch Correction Using the Attitude Indicator.*

Altimeter

If the aircraft is maintaining level flight, the altimeter needles maintain a constant indication of altitude. If the altimeter indicates a loss of altitude, the pitch attitude must be adjusted upward to stop the descent. If the altimeter indicates a gain in altitude, the pitch attitude must be adjusted downward to stop the climb. *[Figure 4-7]* The altimeter can also indicate the pitch attitude in a climb or descent by how rapidly the needles move. A minor adjustment in pitch attitude may be made to control the rate at which altitude is gained or lost. Pitch attitude is used only to correct small altitude changes caused by external forces, such as turbulence or up and down drafts.

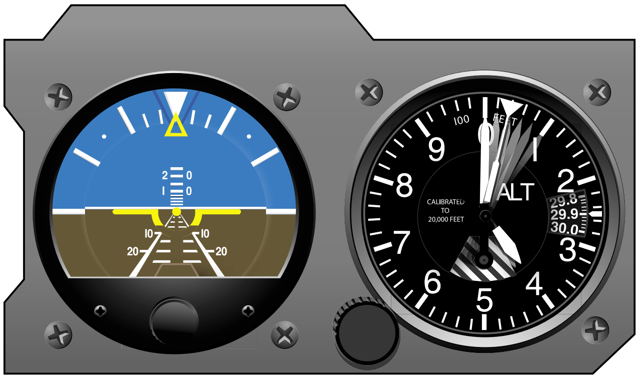

Figure 4-7. *Pitch Correction Using the Altimeter.*

Vertical Speed Indicator (VSI)

In flight at a constant altitude, the VSI (sometimes referred to as vertical velocity indicator or rate-of-climb indicator) remains at zero. If the needle moves above zero, the pitch attitude must be adjusted downward to stop the climb and return to level flight. Prompt adjustments to the changes in the indications of the VSI can prevent any significant change in altitude. *[Figure 4-8]* Turbulent air causes the needle to fluctuate near zero. In such conditions, the average of the fluctuations should be considered as the correct reading. Reference to the altimeter helps in turbulent air because it is not as sensitive as the VSI.

Vertical speed is represented in feet per minute (fpm). *[Figure 4-8]* The face of the instrument is graduated with numbers such as 1, 2, 3, etc. These represent thousands of feet up or down in a minute. For instance, if the pointer is aligned with .5 (1/2 of a thousand, or 500 fpm) the aircraft will climb 500 feet in one minute. The instrument is divided into two regions, one for climbing (up) and one for descending (down).

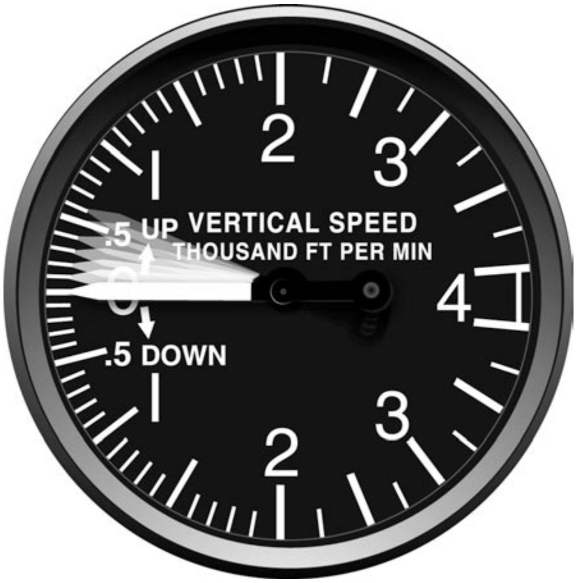

Figure 4-8. *Vertical Speed Indicator.*

During turbulence, it is not uncommon to see large fluctuations on the VSI. It is important to remember that small corrections should be employed to avoid further exacerbating a potentially divergent situation.

Overcorrecting causes the aircraft to overshoot the desired altitude; however, corrections should not be so small that the return to altitude is unnecessarily prolonged. As a guide, the pitch attitude should produce a rate of change on the VSI about twice the size of the altitude deviation. For example, if the aircraft is 100 feet off the desired altitude, a 200 fpm rate of correction would be used.

During climbs or descents, the VSI is used to change the altitude at a desired rate. Pitch attitude and power adjustments are made to maintain the desired rate of climb or descent on the VSI.

When pressure is applied to the controls and the VSI shows an excess of 200 fpm from that desired, overcontrolling is indicated. For example, if attempting to regain lost altitude at the rate of 500 fpm, a reading of more than 700 fpm would indicate overcontrolling. Initial movement of the needle indicates the trend of vertical movement. The time for the VSI to reach its maximum point of deflection after a correction is called lag. The lag is proportional to speed and magnitude of pitch change. In an airplane, overcontrolling may be reduced by relaxing pressure on the controls, allowing the pitch attitude to neutralize. In some helicopters with servo-assisted controls, no control pressures are apparent. In this case, overcontrolling can be reduced by reference to the attitude indicator.

Some aircraft are equipped with an instantaneous vertical speed indicator (IVSI). The letters "IVSI" appear on the face of the indicator. This instrument assists in interpretation by instantaneously indicating the rate of climb or descent at a given moment with little or no lag as displayed in a VSI.

Occasionally, the VSI is slightly out of calibration and indicates a gradual climb or descent when the aircraft is in level flight. If readjustments cannot be accomplished, the error in the indicator should be considered when the instrument is used for pitch control. For example, an improperly set VSI may indicate a descent of 100 fpm when the aircraft is in level flight. Any deviation from this reading would indicate a change in pitch attitude.

Airspeed Indicator

The airspeed indicator gives an indirect reading of the pitch attitude. With a constant power setting and a constant altitude, the aircraft is in level flight and airspeed remains constant. If the airspeed increases, the pitch attitude has lowered and should be raised. *[Figure 4-9]* If the airspeed decreases, the pitch attitude has moved higher and should be lowered. *[Figure 4-10]* A rapid change in airspeed indicates a large change in pitch; a slow change in airspeed indicates a small change in pitch. Although the airspeed indicator is used as a pitch instrument, it may be used in level flight for power control. Changes in pitch are reflected immediately by a change in airspeed. There is very little lag in the airspeed indicator.

Pitch Attitude Instrument Cross-Check

The altimeter is an important instrument for indicating pitch attitude in level flight except when used in conditions of exceptionally strong vertical currents, such as thunderstorms. With proper power settings, any of the pitch attitude instruments can be used to hold reasonably level flight attitude. However, only the altimeter gives the exact altitude information. Regardless of which pitch attitude control instrument indicates a need for a pitch attitude adjustment, the attitude indicator, if available, should be used to make the

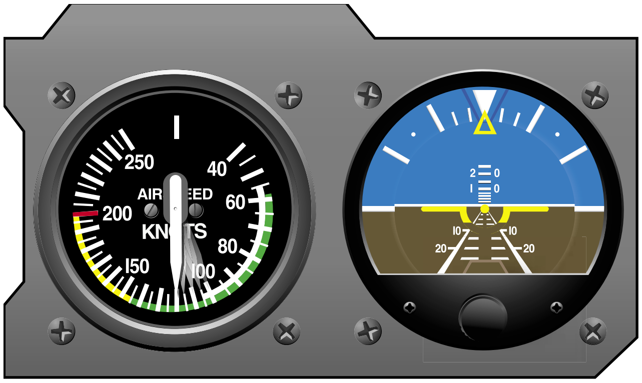
250
40
AIRSPEED
60
200
KNOTS
80
150
100
2 0
1 0
10
20

Figure 4-9. *Pitch attitude has lowered.*

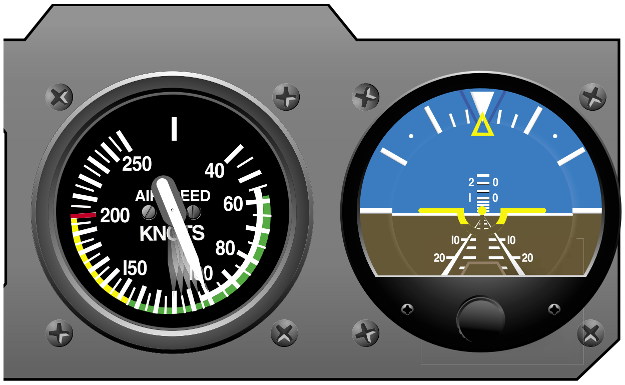
250
40
AIRSPEED
60
200
KNOTS
80
150
100
2 0
1 0
10
20

Figure 4-10. *Pitch attitude has moved higher.*

adjustment. Common errors in pitch attitude control are:

- Overcontrolling,
- Improperly using power, and
- Failing to adequately cross-check the pitch attitude instruments and take corrective action when pitch attitude change is needed

Bank Control

Bank control is controlling the angle made by the wing and the horizon. After interpreting the bank attitude from the appropriate instruments, exert the necessary pressures to move the ailerons and roll the aircraft about the longitudinal axis. As illustrated in *Figure 4-11*, these instruments include:

Attitude Indicator

As previously discussed, the attitude indicator is the only instrument that portrays both instantly and directly the actual flight attitude and is the basic attitude reference.

Heading Indicator

The heading indicator supplies the pertinent bank and heading information and is considered a primary instrument for bank.

Magnetic Compass

The magnetic compass provides heading information and is considered a bank instrument when used with the heading indicator. Care should be exercised when using the magnetic compass as it is affected by acceleration, deceleration in flight caused by turbulence, climbing, descending, power changes, and airspeed adjustments. Additionally, the magnetic compass indication will lead and lag in its reading depending upon the direction of turn. As a result, acceptance of its indication should be considered with other instruments that indicate turn information. These include the already mentioned attitude and heading indicators as well as the turn-and-slip indicator and turn coordinator.

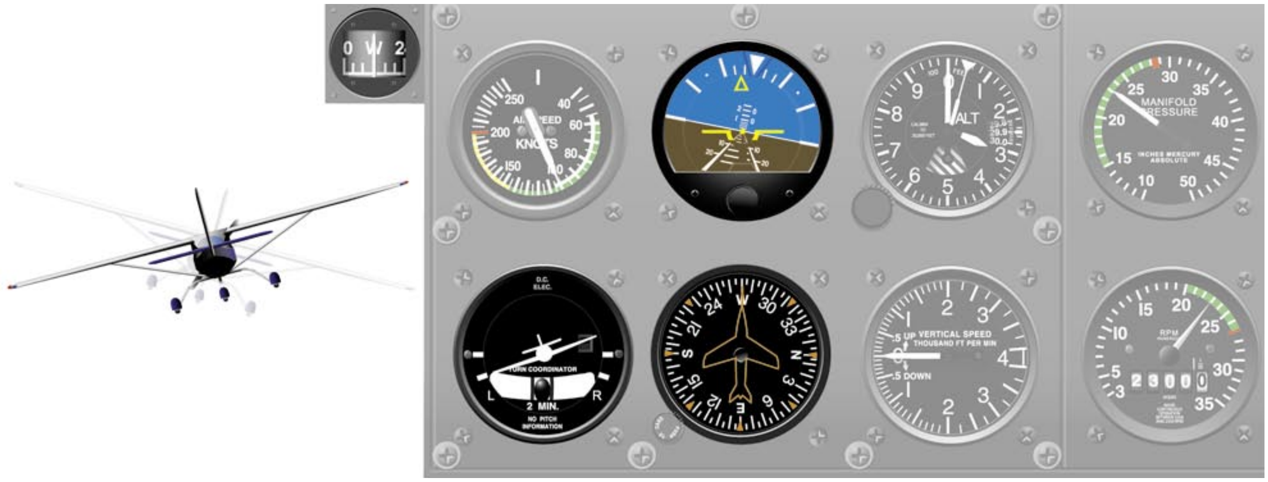
0 W 2
AIRSPEED KNOTS
ALT
MANIFOLD PRESSURE
INCHES MERCURY ABSOLUTE
D.C. ELEC.
TURN COORDINATOR
L
R
2 MIN.
NO PITCH INFORMATION
W
N
E
S
VERTICAL SPEED
THOUSAND FT PER MIN
UP
DOWN
RPM
2 3 0 0 0

Figure 4-11. *Bank Instruments.*

Turn Coordinator/Turn-and-Slip Indicator

Both of these instruments provide turn information. *[Figure 4-12]* The turn coordinator provides both bank rate and then turn rate once stabilized. The turn-and-slip indicator provides only turn rate.

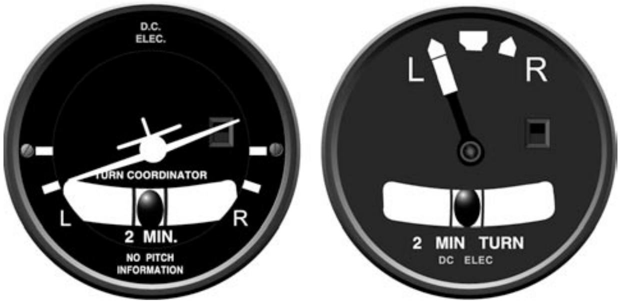

Figure 4-12. *Turn Coordinator and Turn-and-Slip Indicator.*

Power Control

A power change to adjust airspeed may cause movement around some or all of the aircraft axes. The amount and direction of movement depends on how much or how rapidly the power is changed, whether single-engine or multiengine airplane or helicopter. The effect on pitch attitude and airspeed caused by power changes during level flight is illustrated in *Figures 4-13* and *4-14*. During or immediately after adjusting the power control(s), the power instruments should be cross-checked to see if the power adjustment is as desired. Whether or not the need for a power adjustment is indicated by another instrument(s), adjustment is made by cross-checking the power instruments. Aircraft are powered by a variety of power plants, each power plant having certain instruments that indicate the amount of power being applied to operate the aircraft. During instrument flight, these instruments must be used to make the required power adjustments.

As illustrated in *Figure 4-15,* power indicator instruments include:

Airspeed Indicator

The airspeed indicator provides an indication of power best observed initially in level flight where the aircraft is in balance and trim. If in level flight the airspeed is increasing, it can generally be assumed that the power has increased, necessitating the need to adjust power or re-trim the aircraft.

Engine Instruments

Engine instruments, such as the manifold pressure (MP) indicator, provide an indication of aircraft performance for a given setting under stable conditions. If the power conditions are changed, as reflected in the respective engine instrument readings, there is an affect upon the aircraft performance, either an increase or decrease of airspeed. When the propeller rotational speed (revolutions per minute (RPM) as viewed on a tachometer) is increased or decreased on fixed-pitch propellers, the performance of the aircraft reflects a gain or loss of airspeed as well.

Trim Control

Proper trim technique is essential for smooth and accurate instrument flying and utilizes instrumentation illustrated in *Figure 4-16.* The aircraft should be properly trimmed while executing a maneuver. The degree of flying skill, which ultimately develops, depends largely upon how well the aviator learns to keep the aircraft trimmed.

Airplane Trim

An airplane is correctly trimmed when it is maintaining a desired attitude with all control pressures neutralized. By relieving all control pressures, it is much easier to maintain the aircraft at a certain attitude. This allows more time to devote to the navigation instruments and additional flight deck duties.

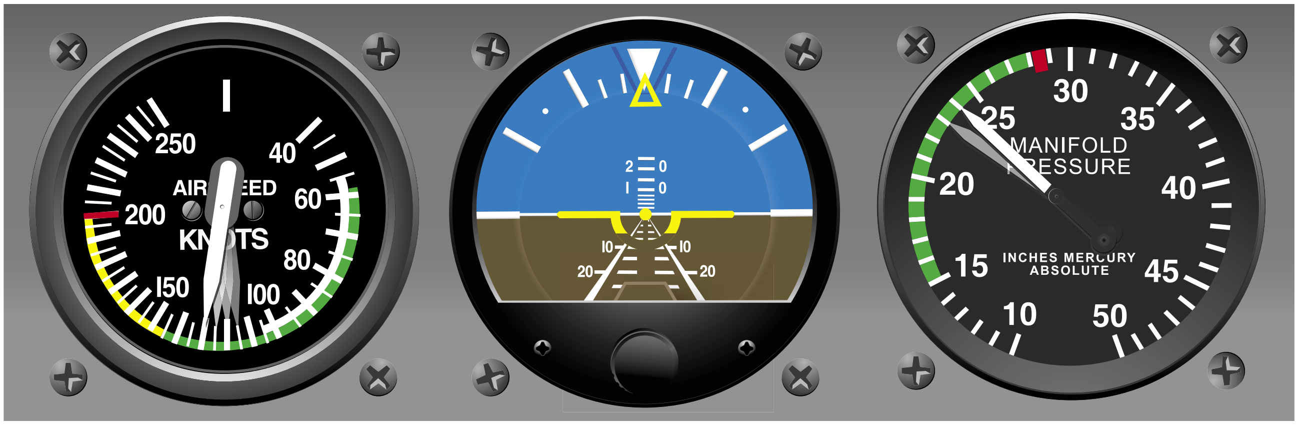

Figure 4-13. *An Increase in Power Inscreasing Airpseed Accordingly in Level Flight.*

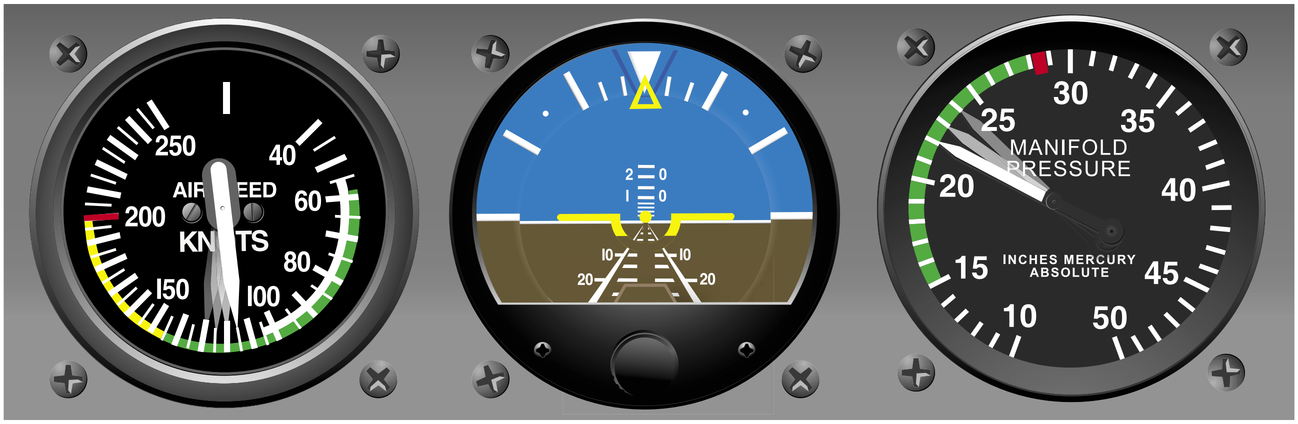
AIRSPEED
KNOTS
40
60
80
100
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250
20
10
MANIFOLD
PRESSURE
INCHES MERCURY
ABSOLUTE
10
15
20
25
30
35
40
45
50

Figure 4-14. *Pitch Control and Power Adjustment Required To Bring Aircraft to Level Flight.*

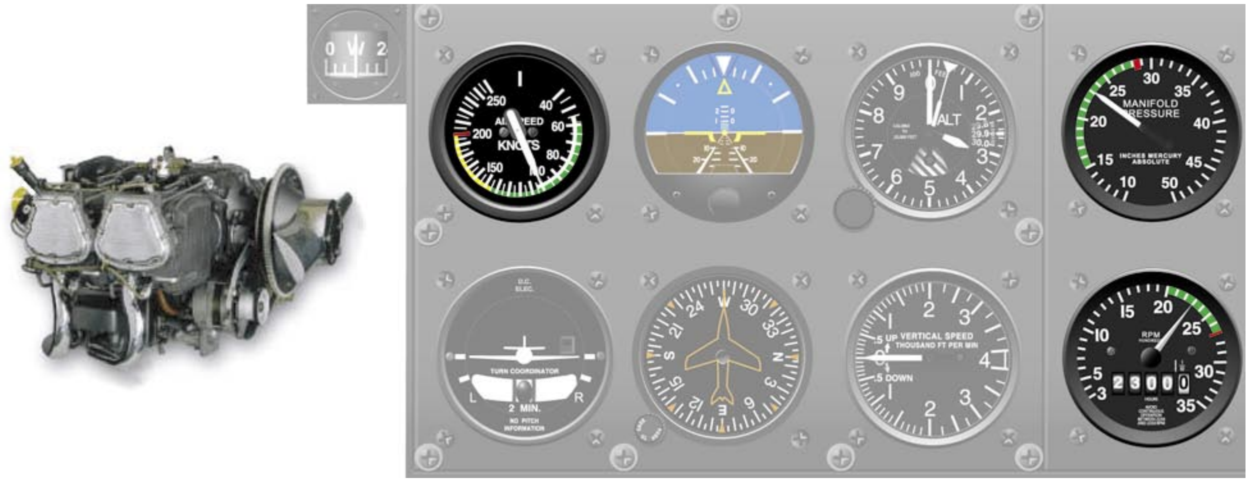
AIRSPEED
KNOTS
ALT
MANIFOLD
PRESSURE
INCHES MERCURY
ABSOLUTE
TURN COORDINATOR
2 MIN.
NO PITCH
INFORMATION
D.C.
ELEC.
L
R
VERTICAL SPEED
THOUSAND FT PER MIN
UP
DOWN
RPM
2 3 0 0 0

Figure 4-15. *Power Instruments.*

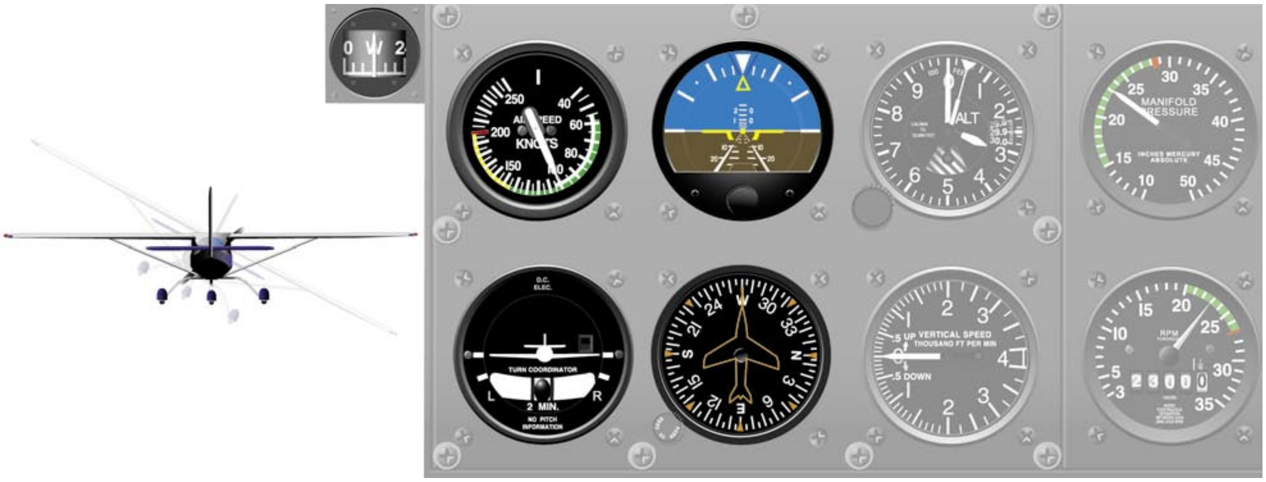
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D.C.
ELEC.
L
R
VERTICAL SPEED
THOUSAND FT PER MIN
UP
DOWN
RPM
2 3 0 0 0

Figure 4-16. *Trim Instruments.*

An aircraft is placed in trim by:

- Applying control pressure(s) to establish a desired attitude. Then, the trim is adjusted so that the aircraft maintains that attitude when flight controls are released. The aircraft is trimmed for coordinated flight by centering the ball of the turn-and-slip indicator.
- Moving the rudder trim in the direction where the ball is displaced from center. Aileron trim may then be adjusted to maintain a wings-level attitude.
- Using balanced power or thrust when possible to aid in maintaining coordinated flight. Changes in attitude, power, or configuration may require trim adjustments. Use of trim alone to establish a change in aircraft attitude usually results in erratic aircraft control. Smooth and precise attitude changes are best attained by a combination of control pressures and subsequent trim adjustments. The trim controls are aids to smooth aircraft control.

Helicopter Trim

A helicopter is placed in trim by continually cross-checking the instruments and performing the following:

- Using the cyclic centering button. If the helicopter is so equipped, this relieves all possible cyclic pressures.
- Using the pedal adjustment to center the ball of the turn indicator. Pedal trim is required during all power changes and is used to relieve all control pressures held after a desired attitude has been attained.

An improperly trimmed helicopter requires constant control pressures, produces tension, distracts attention from cross-checking, and contributes to abrupt and erratic attitude control. The pressures felt on the controls should be only those applied while controlling the helicopter.

Adjust the pitch attitude, as airspeed changes, to maintain desired attitude for the maneuver being executed. The bank must be adjusted to maintain a desired rate of turn, and the pedals must be used to maintain coordinated flight. Trim must be adjusted as control pressures indicate a change is needed.

Example of Primary and Support Instruments

Straight-and-level flight at a constant airspeed means that an exact altitude is to be maintained with zero bank (constant heading). The primary pitch, bank, and power instruments used to maintain this flight condition are:

- Altimeter—supplies the most pertinent altitude information and is primary for pitch.
- Heading Indicator—supplies the most pertinent bank or heading information and is primary for bank.
- Airspeed Indicator—supplies the most pertinent information concerning performance in level flight in terms of power output and is primary for power.

Although the attitude indicator is the basic attitude reference, the concept of primary and supporting instruments does not devalue any particular flight instrument, when available, in establishing and maintaining pitch-and-bank attitudes. It is the only instrument that instantly and directly portrays the actual flight attitude. It should always be used, when available, in establishing and maintaining pitch-and-bank attitudes. The specific use of primary and supporting instruments during basic instrument maneuvers is presented in more detail in Chapter 5, Airplane Basic Flight Maneuvers.

Fundamental Skills

During attitude instrument training, two fundamental flight skills must be developed. They are instrument cross-check and instrument interpretation, both resulting in positive aircraft control. Although these skills are learned separately and in deliberate sequence, a measure of proficiency in precision flying is the ability to integrate these skills into unified, smooth, positive control responses to maintain any prescribed flight path.

Instrument Cross-Check

The first fundamental skill is cross-checking (also called “scanning” or “instrument coverage”). Cross-checking is the continuous and logical observation of instruments for attitude and performance information. In attitude instrument flying, the pilot maintains an attitude by reference to instruments, producing the desired result in performance. Observing and interpreting two or more instruments to determine attitude and performance of an aircraft is called cross-checking. Although no specific method of cross-checking is recommended, those instruments that give the best information for controlling the aircraft in any given maneuver should be used. The important instruments are the ones that give the most pertinent information for any particular phase of the maneuver. These are usually the instruments that should be held at a constant indication. The remaining instruments should help maintain the important instruments at the desired indications, which is also true in using the emergency panel.

Cross-checking is mandatory in instrument flying. In visual flight, a level attitude can be maintained by outside references. However, even then the altimeter must be checked to determine if altitude is being maintained. Due to human error, instrument error, and airplane performance differences in various atmospheric and loading conditions, it is impossible to establish an attitude and have performance remain constant for a long period of time. These variables make it necessary for the pilot to constantly check the instruments and make appropriate changes in airplane attitude using cross-checking of instruments. Examples of cross-checking are explained in the following paragraphs.

Selected Radial Cross-Check

When the selected radial cross-check is used, a pilot spends 80 to 90 percent of flight time looking at the attitude indicator, taking only quick glances at the other flight instruments (for this discussion, the five instruments surrounding the attitude indicator are called the flight instruments). With this method, the pilot's eyes never travel directly between the flight instruments but move by way of the attitude indicator. The maneuver being performed determines which instruments to look at in the pattern. *[Figure 4-17]*

Inverted-V Cross-Check

In the inverted-V cross-check, the pilot scans from the attitude indicator down to the turn coordinator, up to the attitude indicator, down to the VSI, and back up to the attitude indicator. *[Figure 4-18]*

Rectangular Cross-Check

In the rectangular cross-check, the pilot scans across the top three instruments (airspeed indicator, attitude indicator, and altimeter) and then drops down to scan the bottom three instruments (VSI, heading indicator, and turn instrument). This scan follows a rectangular path (clockwise or counterclockwise rotation is a personal choice). *[Figure 4-19]*

This cross-checking method gives equal weight to the information from each instrument, regardless of its importance to the maneuver being performed. However, this method lengthens the time it takes to return to an instrument critical to the successful completion of the maneuver.

Common Cross-Check Errors

A beginner might cross-check rapidly, looking at the instruments without knowing exactly what to look for. With increasing experience in basic instrument maneuvers and familiarity with the instrument indications associated with them, a pilot learns what to look for, when to look for it, and what response to make. As proficiency increases, a pilot cross-checks primarily from habit, suiting scanning rate and sequence to the demands of the flight situation. Failure to maintain basic instrument proficiency through practice can result in many of the following common scanning errors, both during training and at any subsequent time.

Fixation, or staring at a single instrument, usually occurs for a reason, but has poor results. For example, a pilot may stare at the altimeter reading 200 feet below the assigned altitude, and wonder how the needle got there. While fixated on the

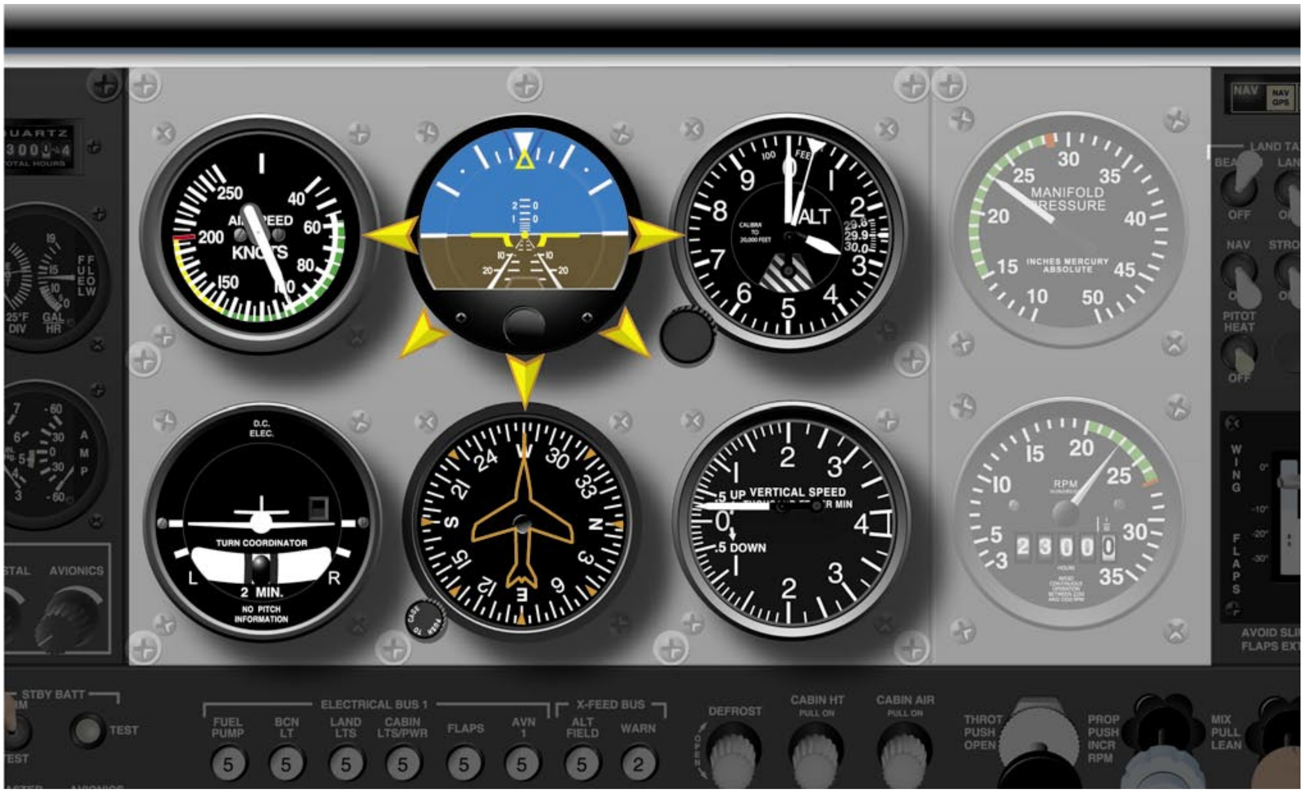
AIRSPEED
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MANIFOLD PRESSURE
INCHES MERCURY ABSOLUTE
TURN COORDINATOR
2 MIN.
NO PITCH INFORMATION
D.C. ELEC.
L
R
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UP
DOWN
RPM
FUEL PUMP
BCN LT
LAND LTS
CABIN LTS/PWR
FLAPS
AVN 1
ALT FIELD
WARN
ELECTRICAL BUS 1
X-FEED BUS
STBY BATT
TEST
DEFROST
CABIN HT
CABIN AIR
THROT PUSH OPEN
PROP PUSH INCR RPM
MIX PULL LEAN
PITOT HEAT

Figure 4-17. *Radial Cross-Check.*

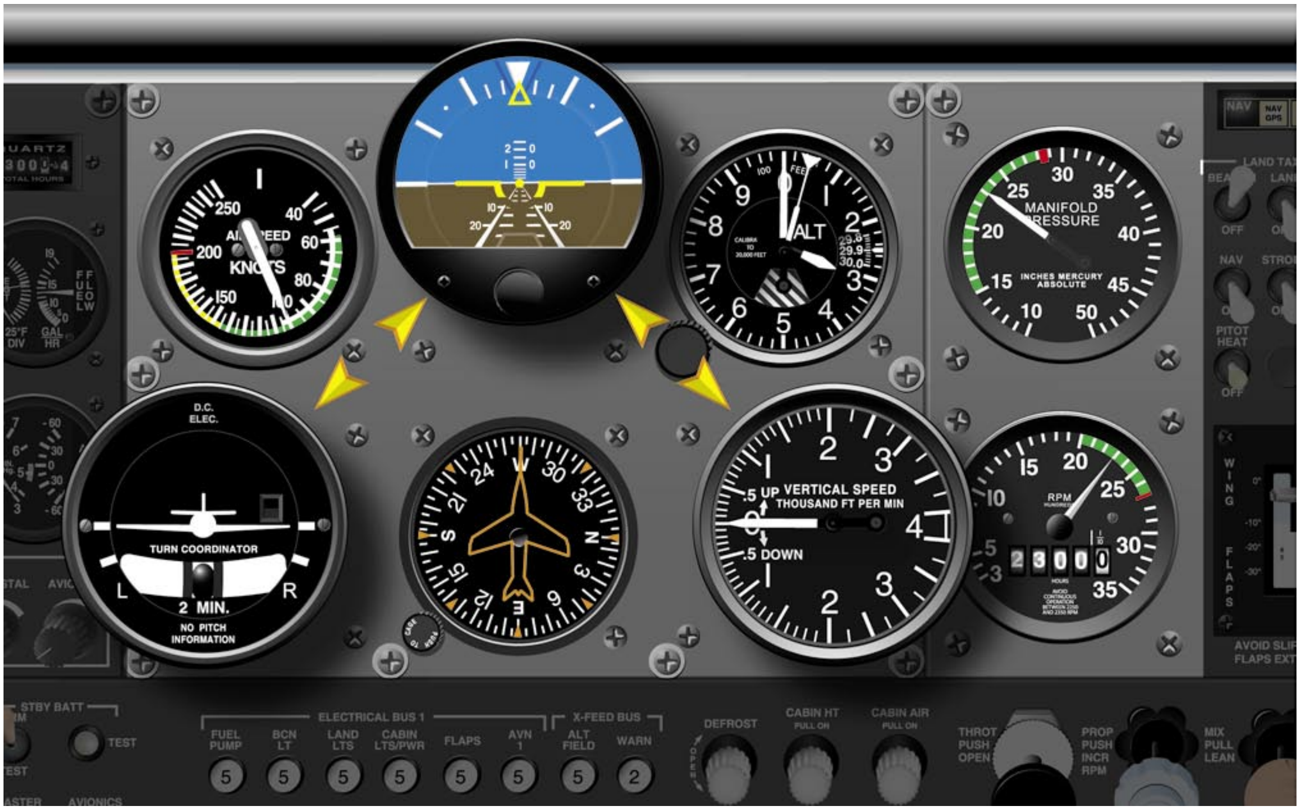
AIRSPEED
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ALT
CALIBRA TO 20,000 FEET
MANIFOLD PRESSURE
INCHES MERCURY ABSOLUTE
D.C. ELEC.
TURN COORDINATOR
2 MIN.
NO PITCH INFORMATION
L
R
VERTICAL SPEED
THOUSAND FT PER MIN
UP
DOWN
RPM
HUNDREDS
HOURS
AVOID CONTINUOUS OPERATION BETWEEN 2250 AND 2350 RPM
QUARTZ
TOTAL HOURS
FUEL FLOW
GAL HR
NAV
NAV GPS
LAND TAXI
BEACON
OFF
NAV
STROBE
PITOT HEAT
WING FLAPS
AVOID SLIPS FLAPS EXT
STBY BATT
TEST
ELECTRICAL BUS 1
FUEL PUMP
BCN LT
LAND LTS
CABIN LTS/PWR
FLAPS
AVN 1
X-FEED BUS
ALT FIELD
WARN
DEFROST
CABIN HT PULL ON
CABIN AIR PULL ON
THROT PUSH OPEN
PROP PUSH INCR RPM
MIX PULL LEAN
MASTER
AVIONICS

Figure 4-18. *Inverted-V Cross-Check.*

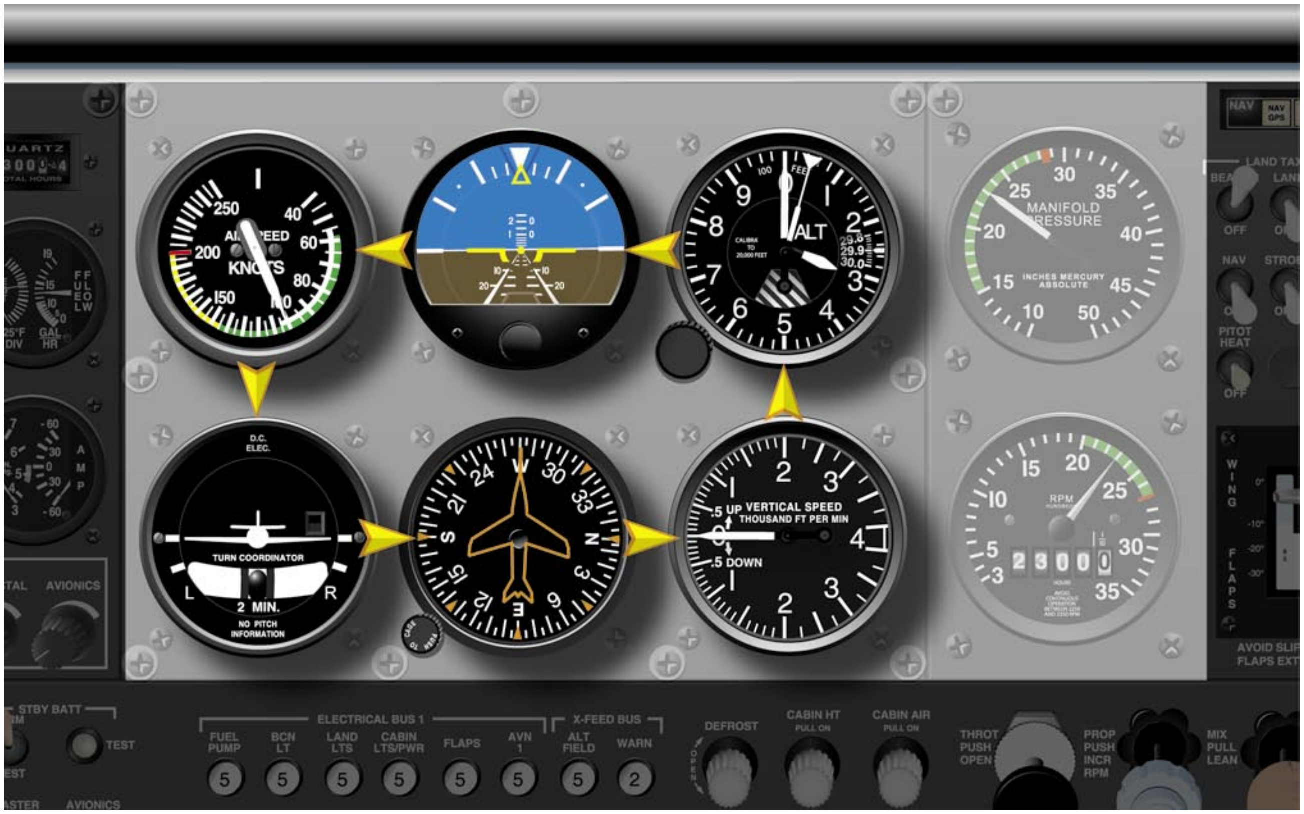
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MANIFOLD PRESSURE
INCHES MERCURY ABSOLUTE
D.C. ELEC.
TURN COORDINATOR
2 MIN.
NO PITCH INFORMATION
L
R
VERTICAL SPEED
THOUSAND FT PER MIN
UP
DOWN
RPM
STBY BATT
TEST
ELECTRICAL BUS 1
FUEL PUMP
BCN LT
LAND LTS
CABIN LTS/PWR
FLAPS
AVN 1
X-FEED BUS
ALT FIELD
WARN
DEFROST
CABIN HT PULL ON
CABIN AIR PULL ON
THROT PUSH OPEN
PROP PUSH INCR RPM
MIX PULL LEAN
AVOID SLIPS FLAPS EXT

Figure 4-19. *Rectangular Cross-Check.*

instrument, increasing tension may be unconsciously exerted on the controls, which leads to an unnoticed heading change that leads to more errors. Another common fixation is likely when initiating an attitude change. For example, a shallow bank is established for a 90° turn and, instead of maintaining a cross-check of other pertinent instruments, the pilot stares at the heading indicator throughout the turn. Since the aircraft is turning, there is no need to recheck the heading indicator for approximately 25 seconds after turn entry. The problem here may not be entirely due to cross-check error. It may be related to difficulties with instrument interpretation. Uncertainty about reading the heading indicator (interpretation) or uncertainty because of inconsistency in rolling out of turns (control) may cause the fixation.

Omission of an instrument from a cross-check is another likely fault. It may be caused by failure to anticipate significant instrument indications following attitude changes. For example, in a roll-out from a 180° steep turn, straight-and-level flight is established with reference only to the attitude indicator, and the pilot neglects to check the heading indicator for constant heading information. Because of precession error, the attitude indicator temporarily shows a slight error, correctable by quick reference to the other flight instruments.

Emphasis on a single instrument, instead of on the combination of instruments necessary for attitude information, is an understandable fault during the initial stages of training. It is a natural tendency to rely on the instrument that is most readily understood, even when it provides erroneous or inadequate information. Reliance on a single instrument is poor technique. For example, a pilot can maintain reasonably close altitude control with the attitude indicator, but cannot hold altitude with precision without including the altimeter in the cross-check.

Instrument Interpretation

The second fundamental skill, instrument interpretation, requires more thorough study and analysis. It begins by understanding each instrument's construction and operating principles. Then, this knowledge must be applied to the performance of the aircraft being flown, the particular maneuvers to be executed, the cross-check and control techniques applicable to that aircraft, and the flight conditions.

For example, a pilot uses full power in a small airplane for a 5-minute climb from near sea level, and the attitude indicator shows the miniature aircraft two bar widths (twice the thickness of the miniature aircraft wings) above the artificial horizon. *[Figure 4-20]* The airplane is climbing at 500 fpm as shown on the VSI, and at airspeed of 90 knots, as shown on the airspeed indicator. With the power available in this particular airplane and the attitude selected by the pilot, the performance is shown on the instruments. Now, set up the identical picture on the attitude indicator in a jet airplane. With the same airplane attitude as shown in the first example, the VSI in the jet reads 2,000 fpm and the airspeed indicator reads 250 knots.

As the performance capabilities of the aircraft are learned, a pilot interprets the instrument indications appropriately

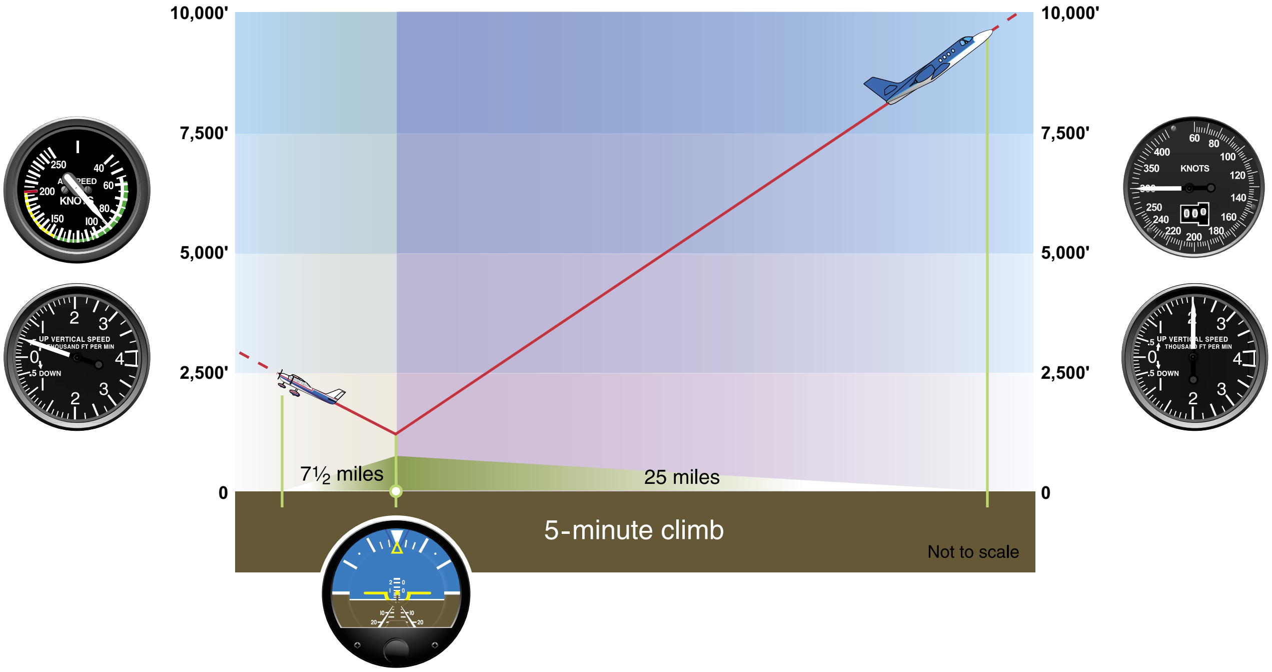

Figure 4-20. *Power and Attitude Equal Performance.*

in terms of the attitude of the aircraft. If the pitch attitude is to be determined, the airspeed indicator, altimeter, VSI, and attitude indicator provide the necessary information. If the bank attitude is to be determined, the heading indicator, turn coordinator, and attitude indicator must be interpreted. For each maneuver, learn what performance to expect and the combination of instruments to be interpreted in order to control aircraft attitude during the maneuver. It is the two fundamental flight skills, instrument cross-check and instrument interpretation, that provide the smooth and seamless control necessary for basic instrument flight as discussed at the beginning of the chapter.

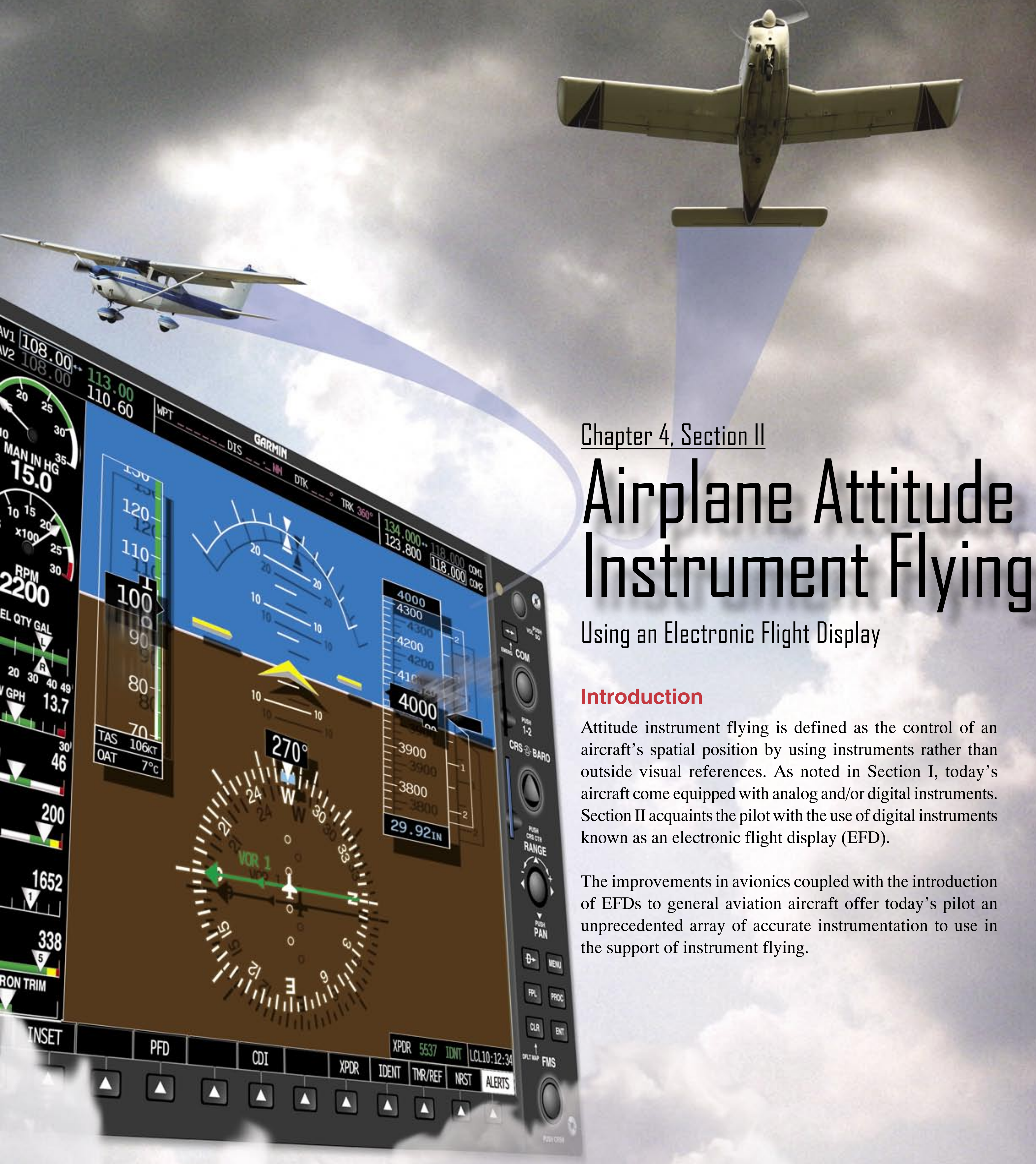
NAV1 108.00
NAV2 108.00
113.00
110.60
WPT
DIS NM
DTK
TRK 360°
GARMIN
134.000 118.000 COM1
123.800 118.000 COM2
MAN IN HG
15.0
RPM
2200
FUEL QTY GAL
GPH
13.7
46
200
1652
338
RON TRIM
TAS 106KT
OAT 7°C
100
4000
4300
4200
3900
3800
29.92IN
270°
VOR 1
COM
CRS BARO
RANGE
PAN
MENU
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PROC
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ENT
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XPDR
IDENT
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Chapter 4, Section II

Airplane Attitude Instrument Flying

Using an Electronic Flight Display

Introduction

Attitude instrument flying is defined as the control of an aircraft's spatial position by using instruments rather than outside visual references. As noted in Section I, today's aircraft come equipped with analog and/or digital instruments. Section II acquaints the pilot with the use of digital instruments known as an electronic flight display (EFD).

The improvements in avionics coupled with the introduction of EFDs to general aviation aircraft offer today's pilot an unprecedented array of accurate instrumentation to use in the support of instrument flying.

Until recently, most general aviation aircraft were equipped with individual instruments utilized collectively to safely maneuver the aircraft by instrument reference alone. With the release of the electronic flight display system, the conventional instruments have been replaced by multiple liquid crystal display (LCD) screens. The first screen is installed in front of the left seat pilot position and is referred to as the primary flight display (PFD). *[Figure 4-21]* The second screen is positioned in approximately the center of the instrument panel and is referred to as the multi-function display (MFD). *[Figure 4-22]* The pilot can use the MFD to display navigation information (moving maps), aircraft systems information (engine monitoring), or should the need arise, a PFD. *[Figure 4-23]* With just these two screens, aircraft designers have been able to de-clutter instrument panels while increasing safety. This has been accomplished through the utilization of solid-state instruments which have a failure rate far lower than those of conventional analog instrumentation.

However, in the event of electrical failure, the pilot still has emergency instruments as a backup. These instruments either do not require electrical power, or as in the case of many attitude indicators, they are battery equipped. *[Figure 4-24]*

Pilots flying under visual flight rules (VFR) maneuver their aircraft by reference to the natural horizon, utilizing specific reference points on the aircraft. In order to operate the aircraft in other than VFR weather, with no visual reference to the natural horizon, pilots need to develop additional skills. These skills come from the ability to maneuver the aircraft by reference to flight instruments alone. These flight instruments replicate all the same key elements that a VFR pilot utilizes during a normal flight. The natural horizon is replicated on the attitude indicator by the artificial horizon.

Understanding how each flight instrument operates and what role it plays in controlling the attitude of the aircraft is fundamental in learning attitude instrument flying. When the pilot understands how all the instruments are used in establishing and maintaining a desired aircraft attitude, the pilot is better prepared to control the aircraft should one or more key instruments fail or if the pilot should enter instrument flight conditions.

Learning Methods

There are two basic methods utilized for learning attitude instrument flying. They are "control and performance" and "primary and supporting." These methods rely on the same flight instruments and require the pilot to make the same adjustments to the flight and power controls to control aircraft attitude. The main difference between the two methods is the importance that is placed on the attitude indicator and the interpretation of the other flight instruments.

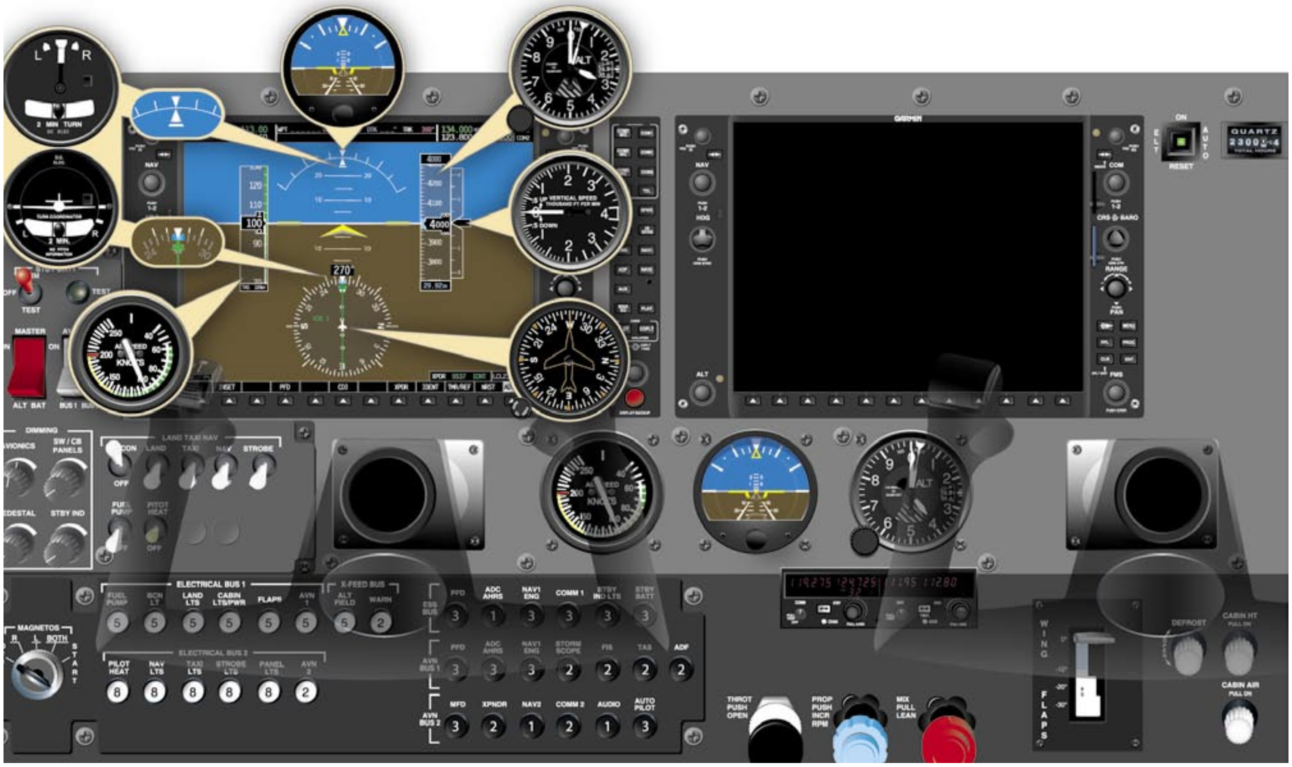

Figure 4-21. *Primary Flight Display (PFD) and Analog Counterparts.*

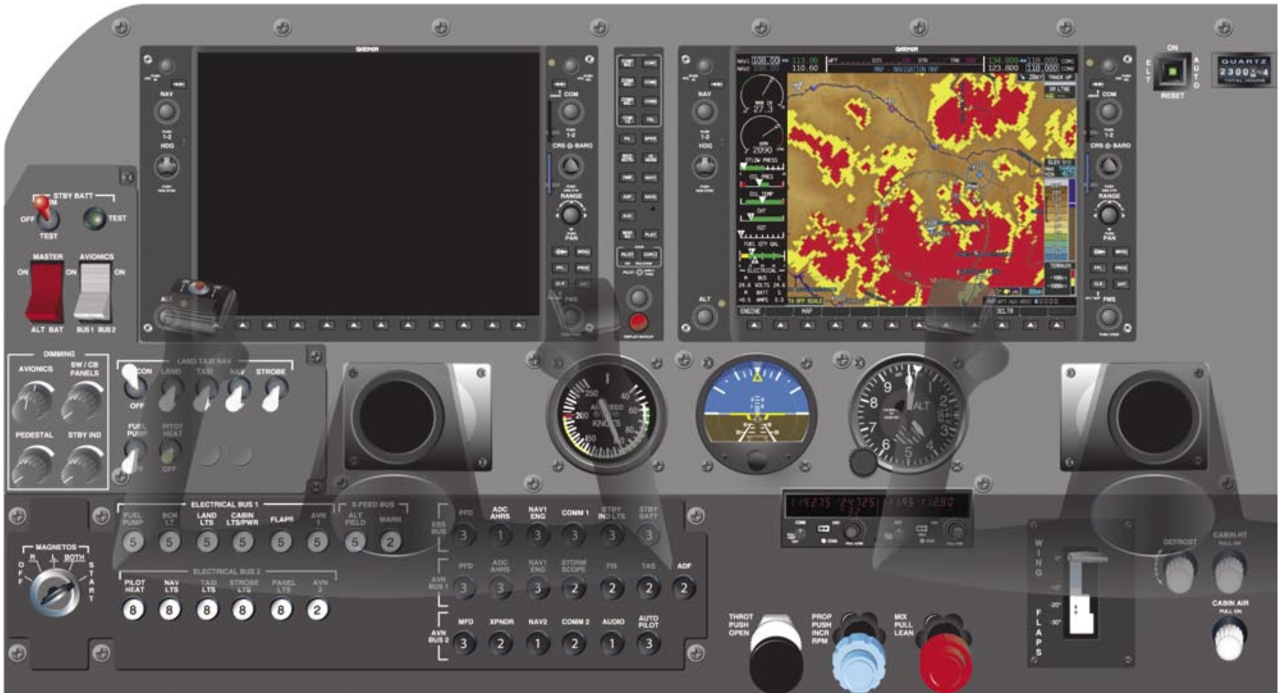

Figure 4-22. *Multifunction Display (MFD).*

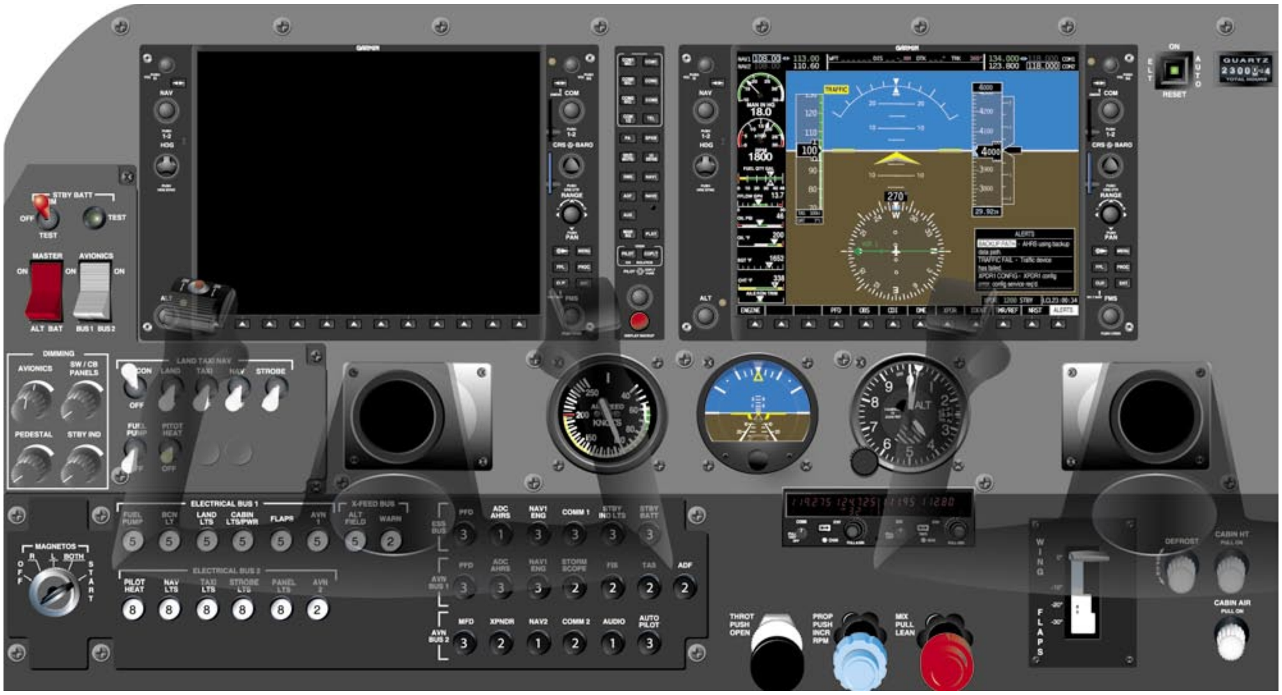

Figure 4-23. *Reversionary Displays.*

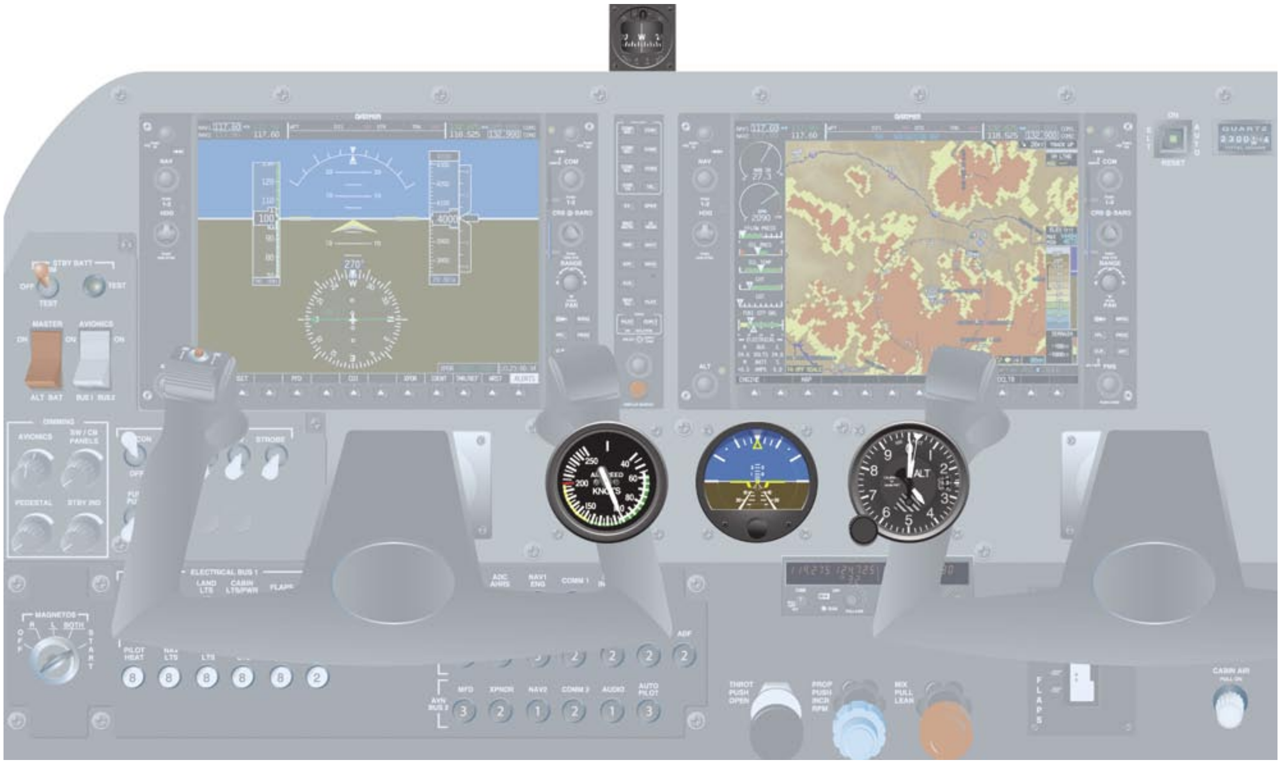

Figure 4-24. *Emergency Back-up of the Airspeed Indicator, Attitude Indicator, and Altitude Indicator.*

Control and Performance Method

Aircraft performance is accomplished by controlling the aircraft attitude and power output. Aircraft attitude is the relationship of its longitudinal and lateral axes to the Earth's horizon. When flying in instrument flight conditions, the pilot controls the attitude of the aircraft by referencing the flight instruments and manipulating the power output of the engine to achieve the performance desired. This method can be used to achieve a specific performance level enabling a pilot to perform any basic instrument maneuver.

The instrumentation can be broken up into three different categories: control, performance, and navigation.

Control Instruments

The control instruments depict immediate attitude and power changes. The instrument for attitude display is the attitude indicator. Power changes are directly reflected on the manifold pressure gauge and the tachometer. *[Figure 4-25]* All three of these instruments can reflect small adjustments, allowing for precise control of aircraft attitude.

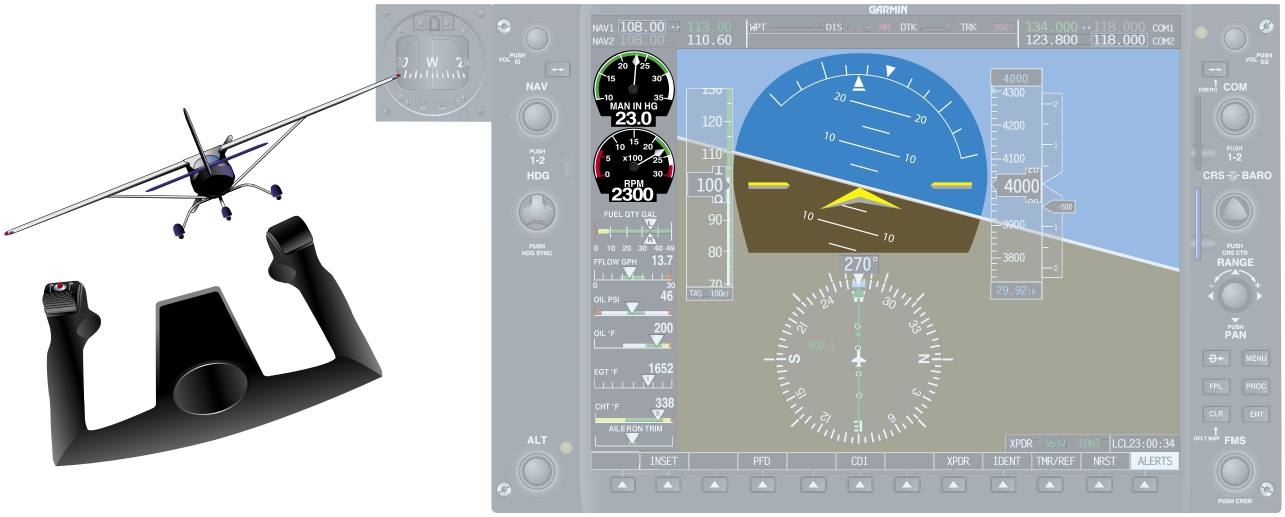
GARMIN
MAN IN HG
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RPM
2300
FUEL QTY GAL
FFLOW GPH 13.7
OIL PSI 46
OIL °F 200
EGT °F 1652
CHT °F 338
AILERON TRIM
270°
4000
29.92IN
INSET
PFD
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS
NAV
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ALT
COM
CRS BARO
RANGE
PAN
FMS

Figure 4-25. *Control Instruments.*

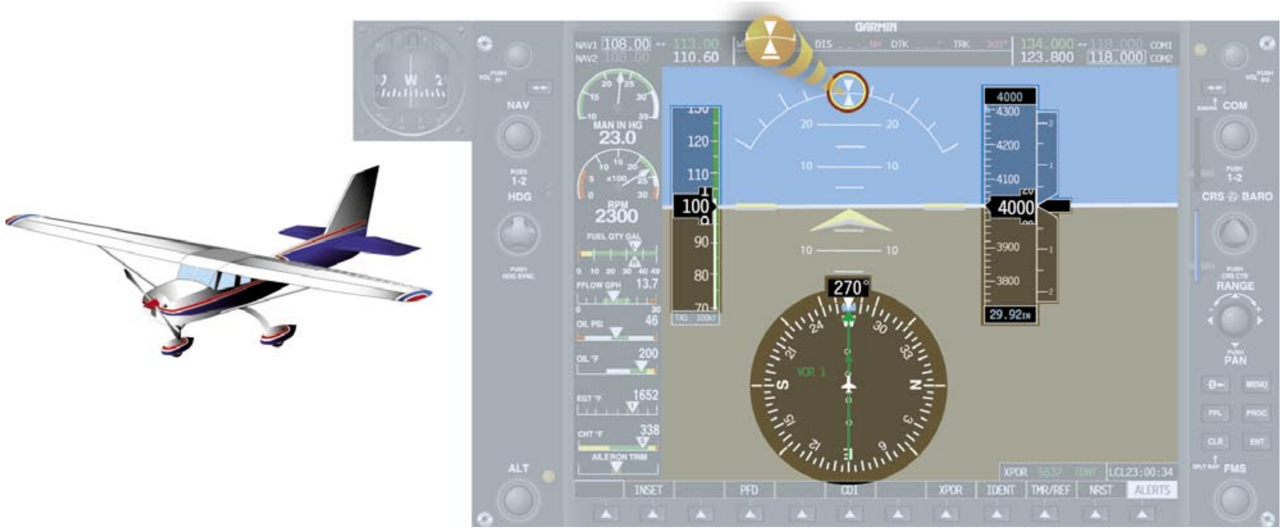
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
MAN IN HG 23.0
RPM 2300
100
4000
270°
29.92IN
INSET
PFD
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS
NAV
HDG
ALT
COM
CRS BARO
RANGE
PAN
FMS

Figure 4-26. *Performance Instruments.*

In addition, the configuration of the power indicators installed in each aircraft may vary to include the following types of power indicators: tachometers, manifold pressure indicator, engine pressure ratio indicator, fuel flow gauges, etc.

The control instruments do not indicate how fast the aircraft is flying or at what altitude it is flying. In order to determine these variables and others, a pilot needs to refer to the performance instruments.

Performance Instruments

The performance instruments directly reflect the performance the aircraft is achieving. The speed of the aircraft can be referenced on the airspeed indicator. The altitude can be referenced on the altimeter. The aircraft's climb performance can be determined by referencing the vertical speed indicator (VSI). *[Figure 4-26]* Other performance instruments available are the heading indicator, angle of attack indicator, and the slip/skid indicator.

The performance instruments will most directly reflect a change in acceleration, which is defined as change in velocity or direction. Therefore, these instruments indicate if the aircraft is changing airspeed, altitude, or heading, which are horizontal, vertical, or lateral vectors.

Navigation Instruments

The navigation instruments are comprised of global positioning system (GPS) displays and indicators, very high frequency omnidirectional range/nondirectional radio beacon (VOR/NDB) indicators, moving map displays, localizer, and glide slope (GS) indicators. *[Figure 4-27]* The instruments indicate the position of the aircraft relative to a selected navigation facility or fix. Navigation instruments allow the pilot to maneuver the aircraft along a predetermined path of ground-based or spaced-based navigation signals without reference to any external visual cues. The navigation instruments can support both lateral and visual inputs.

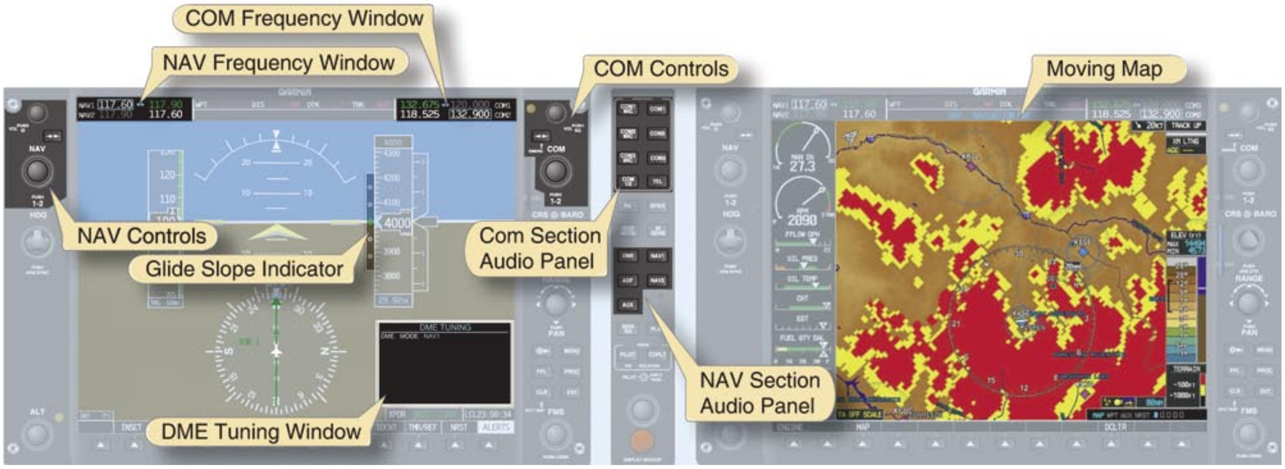
COM Frequency Window
NAV Frequency Window
COM Controls
Moving Map
NAV Controls
Glide Slope Indicator
Com Section Audio Panel
NAV Section Audio Panel
DME Tuning Window

Figure 4-27. *Navigation Instruments.*

The Four-Step Process Used to Change Attitude

In order to change the attitude of the aircraft, the pilot must make the proper changes to the pitch, bank, or power settings of the aircraft. Four steps (establish, trim, cross-check, and adjust) have been developed in order to aid in the process.

Establish

Any time the attitude of the aircraft requires changing, the pilot must adjust the pitch and/or bank in conjunction with power to establish the desired performance. The changes in pitch and bank require the pilot to reference the attitude indicator in order to make precise changes. Power changes should be verified on the tachometer, manifold pressure gauge, etc. To ease the workload, the pilot should become familiar with the approximate pitch and power changes necessary to establish a specified attitude.

Trim

Another important step in attitude instrument flying is trimming the aircraft. Trim is utilized to eliminate the need to apply force to the control yoke in order to maintain the desired attitude. When the aircraft is trimmed appropriately, the pilot is able to relax pressure on the control yoke and momentarily divert attention to another task at hand without deviating from the desired attitude. Trimming the aircraft is very important, and poor trim is one of the most common errors instructors note in instrument students.

Cross-Check

Once the initial attitude changes have been made, the pilot should verify the performance of the aircraft. Cross-checking the control and performance instruments requires the pilot to visually scan the instruments as well as interpret the indications. All the instruments must be utilized collectively in order to develop a full understanding of the aircraft attitude. During the cross-check, the pilot needs to determine the magnitude of any deviations and determine how much of a change is required. All changes are then made based on the control instrument indications.

Adjust

The final step in the process is adjusting for any deviations that have been noted during the cross-check. Adjustments should be made in small increments. The attitude indicator and the power instruments are graduated in small increments to allow for precise changes to be made. The pitch should be made in reference to bar widths on the miniature airplane. The bank angle can be changed in reference to the roll scale and the power can be adjusted in reference to the tachometer, manifold pressure gauge, etc.

By utilizing these four steps, pilots can better manage the attitude of their aircraft. One common error associated with this process is making a larger than necessary change when a deviation is noted. Pilots need to become familiar with the aircraft and learn how great a change in attitude is needed to produce the desired performance.

Applying the Four-Step Process

In attitude instrument flight, the four-step process is used to control pitch attitude, bank attitude, and power application of the aircraft. The EFD displays indications precisely enough that a pilot can apply control more accurately.

Pitch Control

The pitch control is indicated on the attitude indicator which spans the full width of the PFD. Due to the increased size of the display, minute changes in pitch can be made and corrected for. The pitch scale on the attitude indicator is graduated in 5-degree increments which allow the pilot to make correction with precision to approximately 1/2 degree. The miniature airplane utilized to represent the aircraft in conventional attitude indicators is replaced in glass panel displays by a yellow chevron. *[Figure 4-28]* Representing the nose of the aircraft, the point of the chevron affords the pilot a much more precise indication of the degree of pitch and allows the pilot to make small, precise changes should the desired aircraft performance change. When the desired performance is not being achieved, precise pitch changes should be made by referencing the point of the yellow chevron.

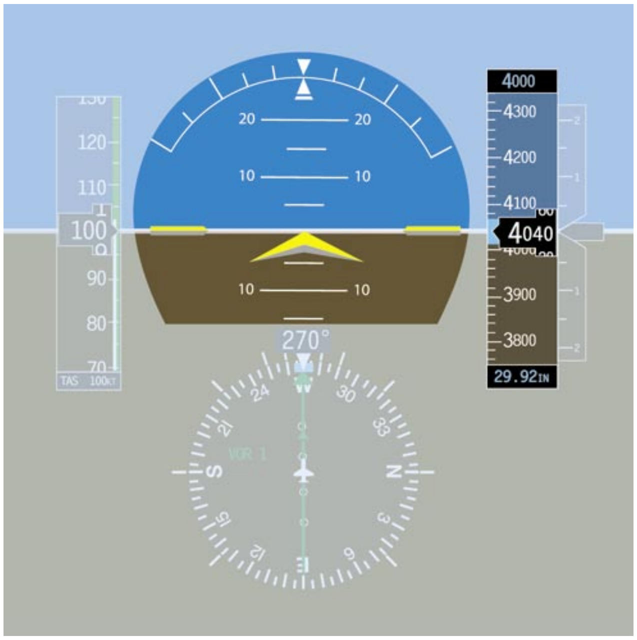

Figure 4-28. *The chevron's relationship to the horizon line indicates the pitch of the aircraft.*

Bank Control

Precise bank control can be developed utilizing the roll pointer in conjunction with the roll index displayed on the attitude indicator. The roll index is sectioned by hash marks at 0°, 10°, 20°, 30°, 45°, 60° and the horizon line which depicts 90° of bank. *[Figure 4-29]* The addition of the 45° hash mark is an improvement over conventional attitude indicators. In addition to the roll index, the instrument pilot utilizes the turn rate indicator to maintain the aircraft in a standard rate turn (3° per second). Most instrument maneuvers can be done comfortably, safely, and efficiently by utilizing a standard rate turn.

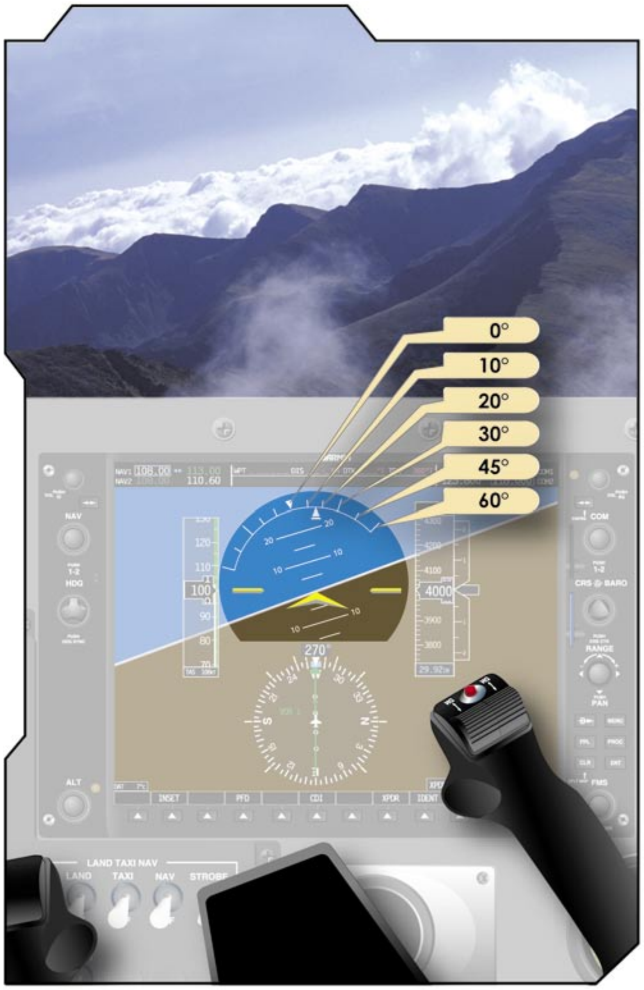

Figure 4-29. *Bank Control Index Lines.*

Power Control

The power instruments indicate how much power is being generated by the engine. They are not affected by turbulence, improper trim, or control pressures. All changes in power should be made with reference to power instruments and cross-checked on performance instruments.

Power control needs to be learned from the beginning of flight training. Attitude instrument flying demands increased precision when it comes to power control. As experience increases, pilots begin to know approximately how much change in throttle position is required to produce the desired change in airspeed. Different aircraft demand differing amounts of throttle change to produce specific performance. It is imperative that the pilot make the specific changes on the power instruments and allow the performance to stabilize. Avoid the tendency to overcontrol.

One common error encountered with glass panel displays is associated with the precision of the digital readouts. This precision causes pilots to focus too much attention on establishing the exact power setting.

Control and power instruments are the foundation for precise attitude instrument flying. The keys to attitude instrument flying are establishing the desired aircraft attitude on the attitude indicator and selecting the desired engine output on the power instruments. Cross-checking is the vital ingredient in maintaining precise attitude instrument flight.

Attitude Instrument Flying—Primary and Supporting Method

The second method for performing attitude instrument flight is a direct extension of the control/power method. By utilizing the primary and supporting flight instruments in conjunction with the control and power instruments, the pilot can precisely maintain aircraft attitude. This method utilizes the same instruments as the control/power method; however, it focuses more on the instruments that depict the most accurate indication for the aspect of the aircraft attitude being controlled. The four key elements (pitch, bank, roll, and trim) are discussed in detail.

Similar to the control/power method, all changes to aircraft attitude need to be made using the attitude indicator and the power instruments (tachometer, manifold pressure gauge, etc.). The following explains how each component of the aircraft attitude is monitored for performance.

Pitch Control

The pitch of the aircraft refers to the angle between the longitudinal axis of the aircraft and the natural horizon. When flying in instrument meteorological conditions, the natural horizon is unavailable for reference, and an artificial horizon is utilized in its place. *[Figure 4-30]* The only instrument capable of depicting the aircraft attitude is the attitude indicator displayed on the PFD. The attitude and heading reference system (AHRS) is the engine that drives the attitude display. The AHRS unit is capable of precisely tracking minute changes in the pitch, bank, and yaw axes, thereby making the PFD very accurate and reliable. The AHRS unit determines the angle between the aircraft's longitudinal axis and the horizon line on initialization. There is no need

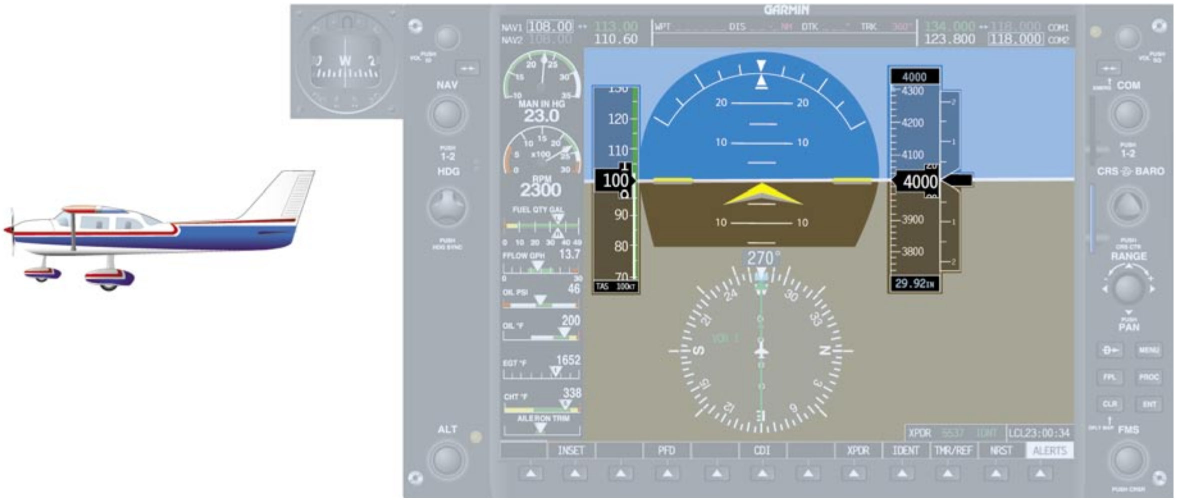

Figure 4-30. *Pitch of the Aircraft.*

or means for the pilot to adjust the position of the yellow chevron which represents the nose of the aircraft.

Straight-and-Level Flight

In straight-and-level flight, the pilot maintains a constant altitude, airspeed and, for the most part, heading for extended periods of time. To achieve this, three primary instruments need to be referenced in order to maintain these three variables.

Primary Pitch

When the pilot is maintaining a constant altitude, the primary instrument for pitch is the altimeter. As long as the aircraft maintains a constant airspeed and pitch attitude, the altitude should remain constant.

Two factors that cause the altitude to deviate are turbulence and momentary distractions. When a deviation occurs, a change in the pitch needs to be made on the attitude indicator. Small deviations require small corrections while large deviations require larger corrections. Pilots should avoid making large corrections that result in rapid attitude changes, for this may lead to spatial disorientation. Smooth, timely corrections should be made to bring the aircraft back to the desired attitude.

Pay close attention to indications on the PFD. An increase in pitch of 2.5° produces a climb rate of 450 feet per minute (fpm). Small deviations do not require large attitude changes.

A rule of thumb for correcting altitude deviations is to establish a change rate of twice the altitude deviation, not to exceed 500 fpm. For example, if the aircraft is off altitude by 40 feet, 2 x 40 = 80 feet, so a descent of approximately 100 fpm allows the aircraft to return to the desired altitude in a controlled, timely fashion.

In addition to the primary instrument, there are also supporting instruments that assist the pilot in cross-checking the pitch attitude. The supporting instruments indicate trend, but they do not indicate precise attitude indications. Three instruments (vertical speed, airspeed, and altitude trend tape) indicate when the pitch attitude has changed and that the altitude is changing. *[Figure 4-31]* When the altitude is constant, the VSI and altitude trend tape are not shown on the PFD. When these two trend indicators are displayed, the pilot is made aware that the pitch attitude of the aircraft has changed and may need adjustment.

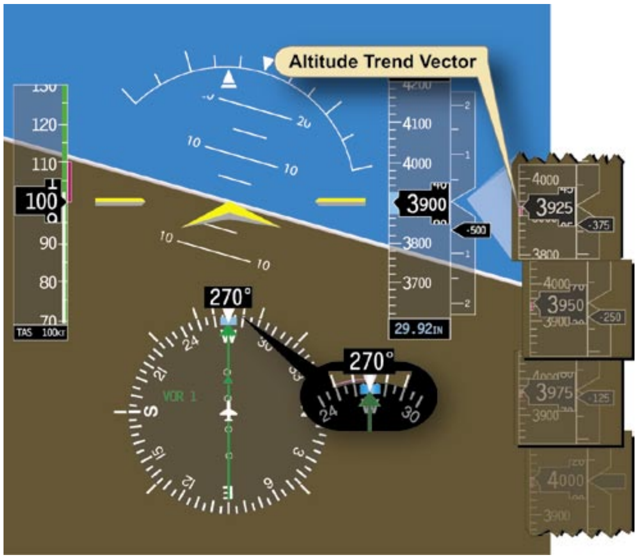

Figure 4-31. *Supporting Instruments.*

The instrument cross-check necessitates utilizing these supporting instruments to better manage altitude control. The VSI and trend tape provide the pilot with information regarding the direction and rate of altitude deviations. The pilot is thus able to make correction to the pitch attitude before a large deviation in altitude occurs. The airspeed indicator depicts an increase if the pitch attitude is lowered. Conversely, when the pitch attitude increases, the pilot should note a decrease in the airspeed.

Primary Bank

When flying in instrument meteorological conditions, pilots maintain preplanned or assigned headings. With this in mind, the primary instrument for bank angle is the heading indicator. Heading changes are displayed instantaneously. The heading indicator is the only instrument that displays the current magnetic heading, provided that it is matched to the magnetic compass with all deviation adjustments accounted for. *[Figure 4-32]*

There are supporting instruments associated with bank as well. The turn rate trend indicator shows the pilot when the aircraft is changing heading. The magnetic compass is also useful for maintaining a heading; however, it is influenced by several errors in various phases of flight.

Primary Yaw

The slip/skid indicator is the primary instrument for yaw. It is the only instrument that can indicate if the aircraft is moving through the air with the longitudinal axis of the aircraft aligned with the relative wind.

Primary Power

The primary power instrument for straight-and-level flight is the airspeed indicator. The main focus of power is to maintain a desired airspeed during level flight. No other instrument delivers instantaneous indication.

Learning the primary and supporting instruments for each variable is the key to successfully mastering attitude instrument flying. At no point does the primary and supporting method devalue the importance of the attitude indicator or the power instruments. All instruments (control, performance, primary, and supporting) must be utilized collectively.

Fundamental Skills of Attitude Instrument Flying

When first learning attitude instrument flying, it is very important that two major skills be mastered. Instrument cross-check and instrument interpretation comprise the foundation for safely maneuvering the aircraft by reference to instruments alone. Without mastering both skills, the pilot will not be able to maintain precise control of aircraft attitude.

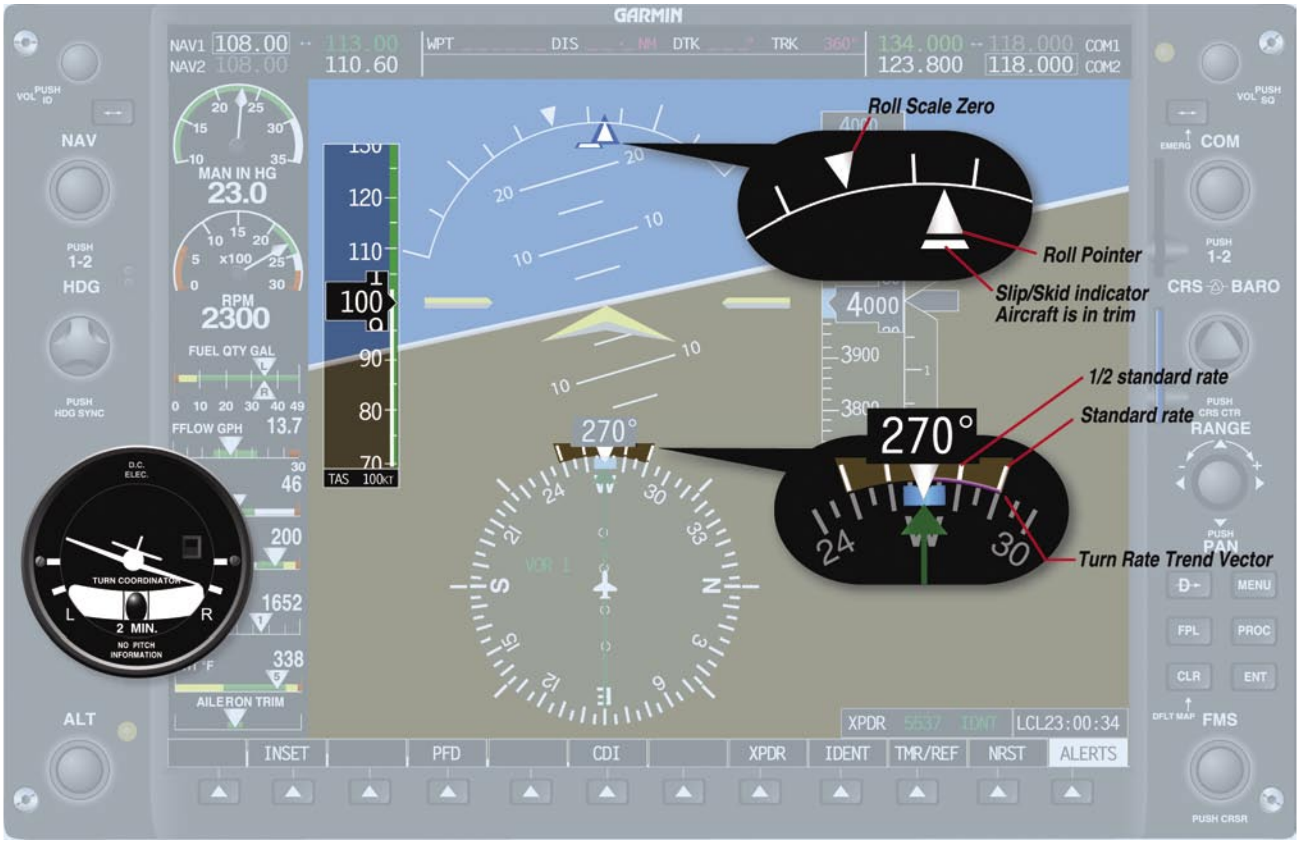
GARMIN
Roll Scale Zero
Roll Pointer
Slip/Skid indicator
Aircraft is in trim
1/2 standard rate
Standard rate
Turn Rate Trend Vector
270°
TURN COORDINATOR
2 MIN.
NO PITCH INFORMATION
NAV
HDG
ALT
COM
CRS BARO
RANGE
FMS
MAN IN HG
23.0
RPM
2300
INSET
PFD
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS

Figure 4-32. *Primary Bank.*

Instrument Cross-Check

The first fundamental skill is cross-checking (also call "scanning"). Cross-checking is the continuous observation of the indications on the control and performance instruments. It is imperative that the new instrument pilot learn to observe and interpret the various indications in order to control the attitude and performance of the aircraft. Due to the configuration of some glass panel displays such as the Garmin G1000, one or more of the performance instruments may be located on an MFD installed to the right of the pilot's direct forward line of sight. *[Figure 4-33]*

How a pilot gathers the necessary information to control the aircraft varies by individual pilot. No specific method of cross-checking (scanning) is recommended; the pilot must learn to determine which instruments give the most pertinent information for any particular phase of a maneuver. With practice, the pilot is able to observe the primary instruments quickly and cross-check with the supporting instruments in order to maintain the desired attitude. At no time during instrument flying should the pilot stop cross-checking the instrumentation.

Scanning Techniques

Since most of the primary and supporting aircraft attitude information is displayed on the PFD, standard scanning techniques can be utilized. It is important to remember to include the stand-by flight instruments as well as the engine indications in the scan. Due to the size of the attitude instrument display, scanning techniques have been simplified because the attitude indicator is never out of peripheral view.

Selected Radial Cross-Check

The radial scan is designed so that your eyes remain on the attitude indicator 80–90 percent of the time. The remainder of the time is spent transitioning from the attitude indicator to the various other flight instruments. *[Figure 4-34]*

The radial scan pattern works well for scanning the PFD. The close proximity of the instrument tape displays necessitates very little eye movement in order to focus in on the desired instrument. While the eyes move in any direction, the extended artificial horizon line allows the pilot to keep the pitch attitude in his or her peripheral vision. This extended horizon line greatly reduces the tendency to fixate on one instrument and completely ignore all others. Because of the size of the attitude display, some portion of the attitude indicator is always visible while viewing another instrument display on the PFD.

Starting the Scan

Start the scan in the center of the PFD on the yellow chevron. Note the pitch attitude and then transition the eyes upward to the slip/skid indicator. Ensure that the aircraft is coordinated

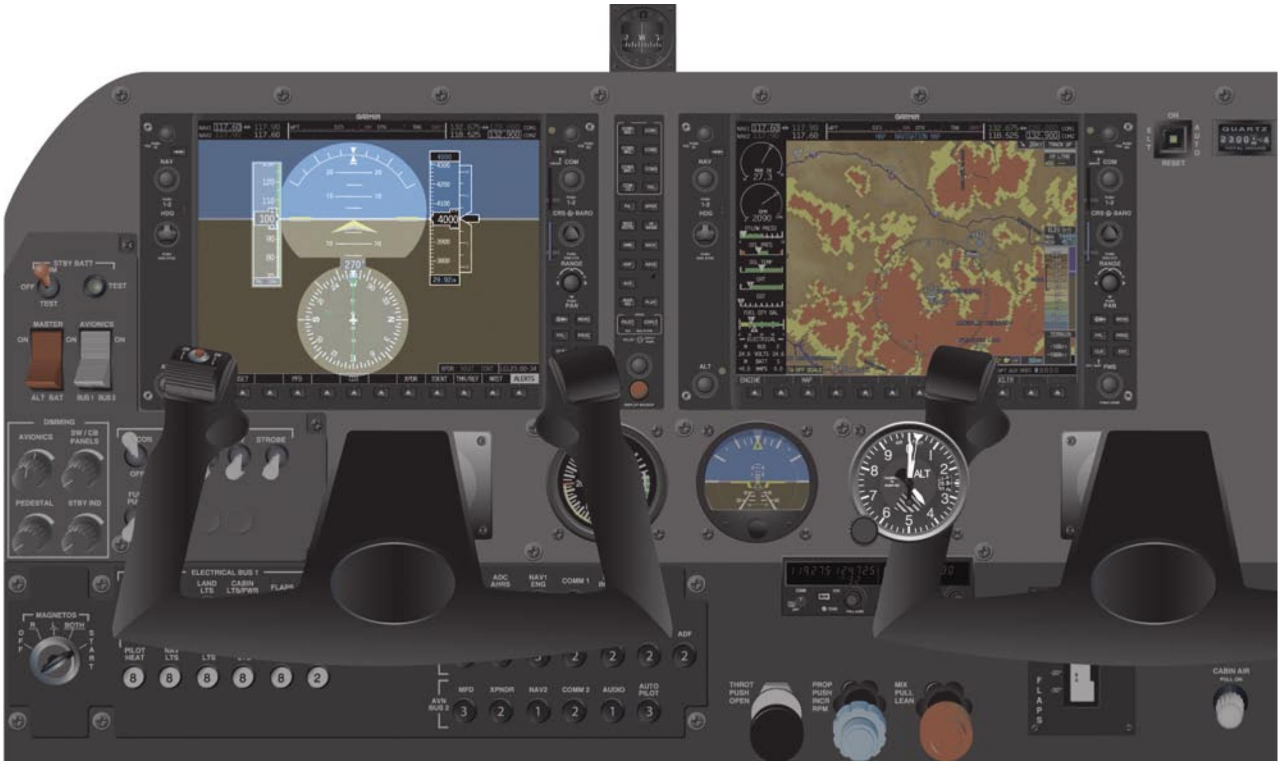

Figure 4-33. *Note that the altitude and vertical speed tapes are slightly to the right of the pilot's direct forward line of sight.*

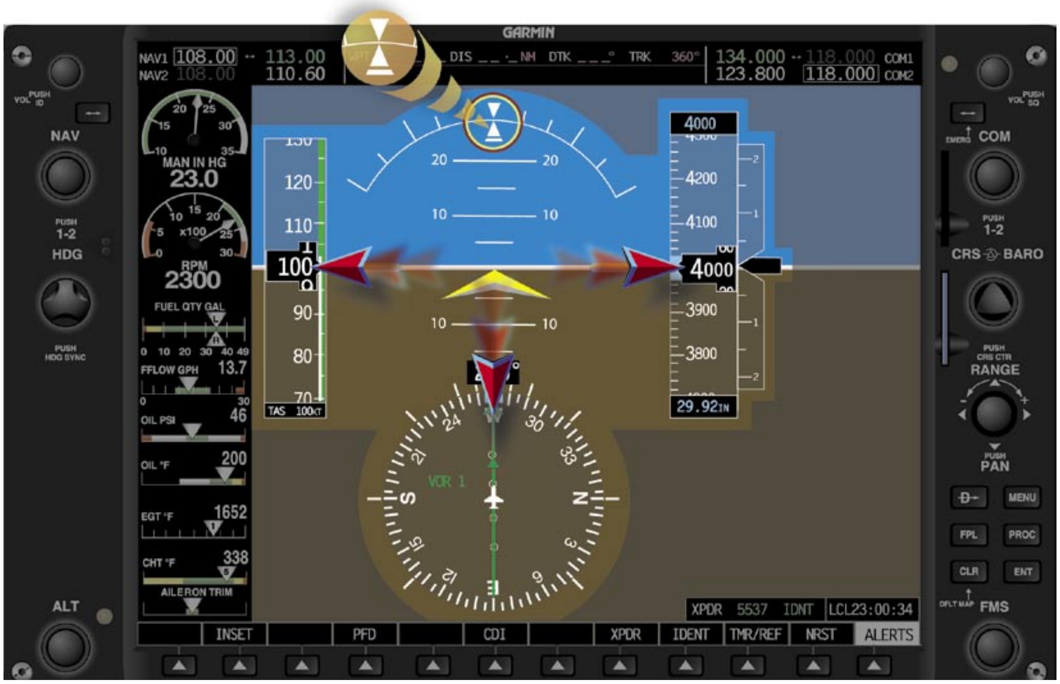
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
DIS ___._NM DTK ___° TRK 360°
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
MAN IN HG 23.0
RPM 2300
FUEL QTY GAL
FFLOW GPH 13.7
OIL PSI 46
OIL °F 200
EGT °F 1652
CHT °F 338
AILERON TRIM
100
4000
29.92IN
TAS 100KT
VOR 1
XPDR 5537 IDNT LCL23:00:34
INSET
PFD
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS
NAV
HDG
ALT
COM
CRS BARO
RANGE
PAN
MENU
FPL
PROC
CLR
ENT
FMS

Figure 4-34. *Selected Radial Cross-Check.*

by aligning the split triangle symbol. The top of the split triangle is referred to as the roll pointer. The lower portion of the split triangle is the slip/skid indicator. If the lower portion of the triangle is off to one side, step on the rudder pedal on the same side to offset it. *[Figure 4-35 NOTE: The aircraft is not changing heading. There is no trend vector on the turn rate indicator.]*

While scanning that region, check the roll pointer and assure that the desired degree of roll is being indicated on the bank scale. The roll index and the bank scale remain stationary at the top of the attitude indicator. The index is marked with angles of 10°, 20°, 30°, 45° and 60° in both directions. If the desired bank angle is not indicated, make the appropriate

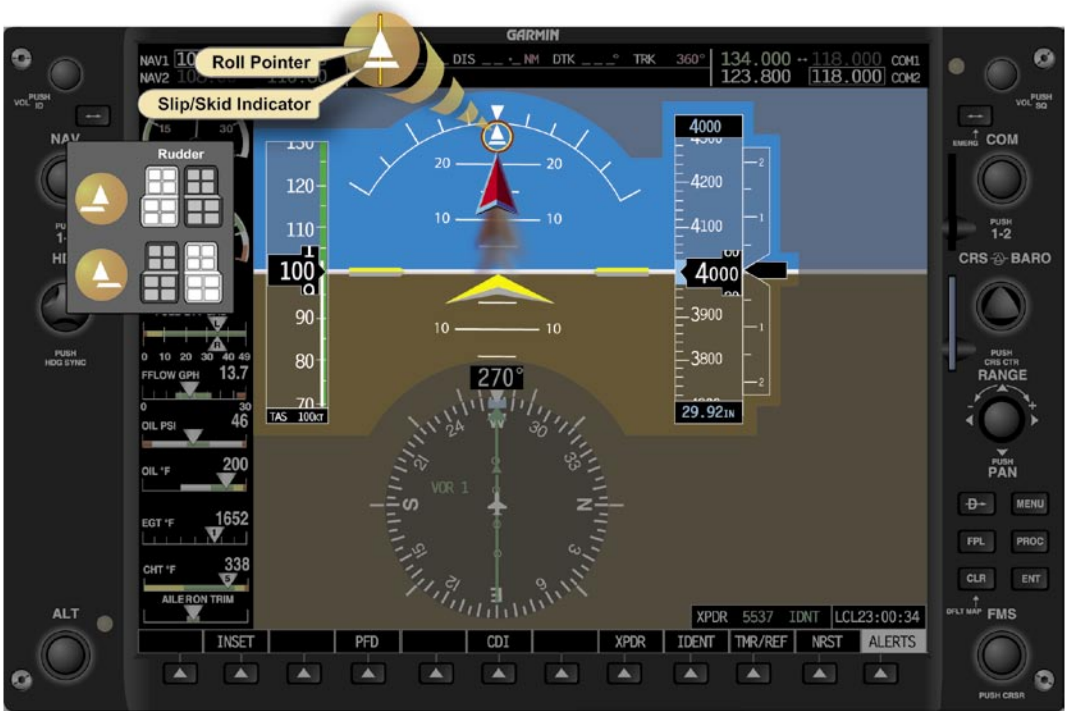
Roll Pointer
Slip/Skid Indicator
Rudder
GARMIN
DIS ___._NM DTK ___° TRK 360°
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
100
4000
270°
29.92IN
TAS 100KT
VOR 1
FFLOW GPH 13.7
OIL PSI 46
OIL °F 200
EGT °F 1652
CHT °F 338
AILERON TRIM
XPDR 5537 IDNT LCL23:00:34
INSET
PFD
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS
ALT
COM
CRS BARO
RANGE
PAN
MENU
FPL
PROC
CLR
ENT
FMS

Figure 4-35. *Roll Pointer and Slip/Skid Indicator.*

aileron corrections. Verify the bank angle is correct and continue scanning back to the yellow chevron.

Scan left to the airspeed tape and verify that the airspeed is as desired, then return back to the center of the display. Scan right to the altimeter tape. Verify that the desired altitude is being maintained. If it is not, make the appropriate pitch change and verify the result. Once the desired altitude has been verified, return to the center of the display. Transition down to the heading indicator to verify the desired heading. When the heading has been confirmed, scan to the center of the display.

It is also important to include the engine indications in the scan. Individualized scan methods may require adjustment if engine indications are presented on a separate MFD. A modified radial scan can be performed to incorporate these instruments into the scan pattern. Another critical component to include in the scan is the moving map display located on the MFD. To aid in situational awareness and facilitate a more centralized scan, a smaller inset map can be displayed in the lower left corner of the PFD screen.

Trend Indicators

One improvement the glass panel displays brought to the general aviation industry is the trend vector. Trend vectors are magenta lines that appear on the airspeed and altitude tapes as well as on the turn rate indicator. These magenta lines indicate what the associated airspeed, altitude, or heading will be in 6 seconds *[Figure 4-36]* if the current rate is maintained. The trend vector is not displayed if there is no change to the associated tape and the value remains constant *[Figure 4-37]* or if there is a failure in some portion of the system that would preclude the vector from being determined.

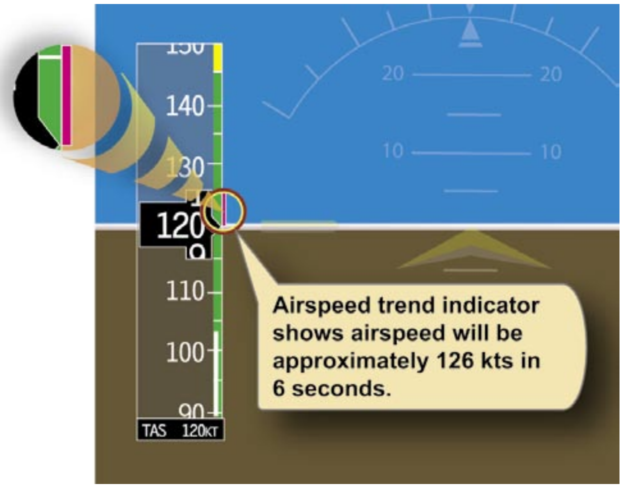

Airspeed trend indicator shows airspeed will be approximately 126 kts in 6 seconds.

Figure 4-36. *Airspeed Trend Indicators.*

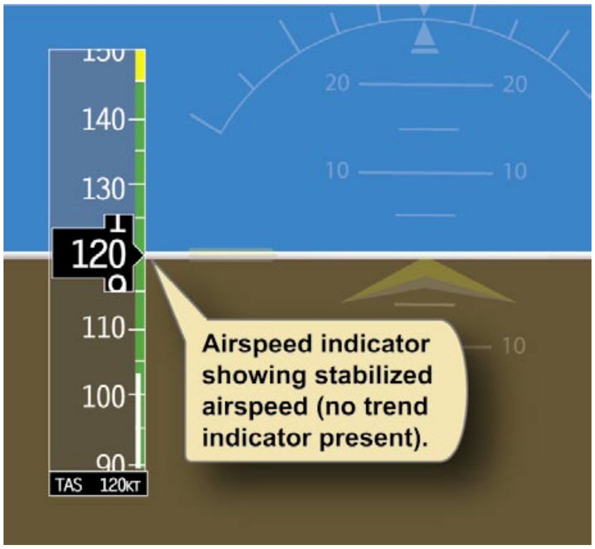

Airspeed indicator showing stabilized airspeed (no trend indicator present).

Figure 4-37. *Airspeed Indicators With No Trend Present.*

Trend vectors are a very good source of information for the new instrument flight rules (IFR) pilot. Pilots who utilize good scanning techniques can pick up subtle deviations from desired parameters and make small correction to the desired attitude. As soon as a trend is indicated on the PFD, a conscientious pilot can adjust to regain the desired attitude. *[Figure 4-38]*

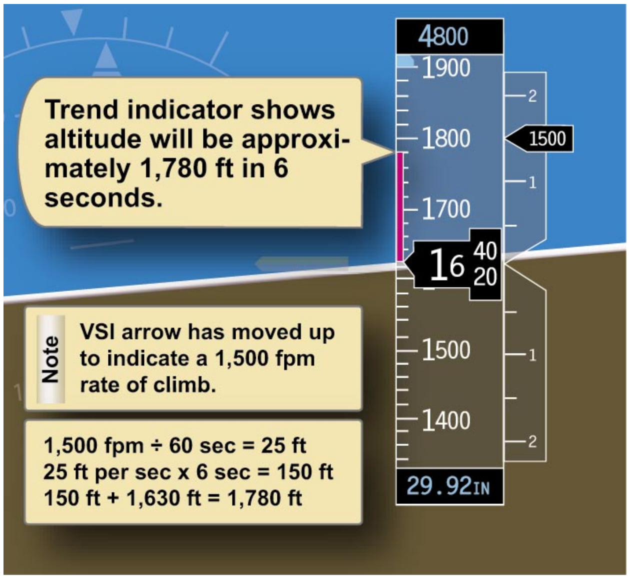

Trend indicator shows altitude will be approximately 1,780 ft in 6 seconds.

VSI arrow has moved up to indicate a 1,500 fpm rate of climb.

1,500 fpm ÷ 60 sec = 25 ft
25 ft per sec x 6 sec = 150 ft
150 ft + 1,630 ft = 1,780 ft

Figure 4-38. *Altimeter Trend Indicators.*

Another advancement in attitude instrument flying is the turn rate trend indicator. As in the cases of airspeed, altitude, and vertical speed trend indicators, the turn rate trend indicator depicts what the aircraft's heading will be in 6 seconds. While examining the top of the heading indicator, notice two white lines on the exterior of the compass rose. *[Figure 4-39]* These

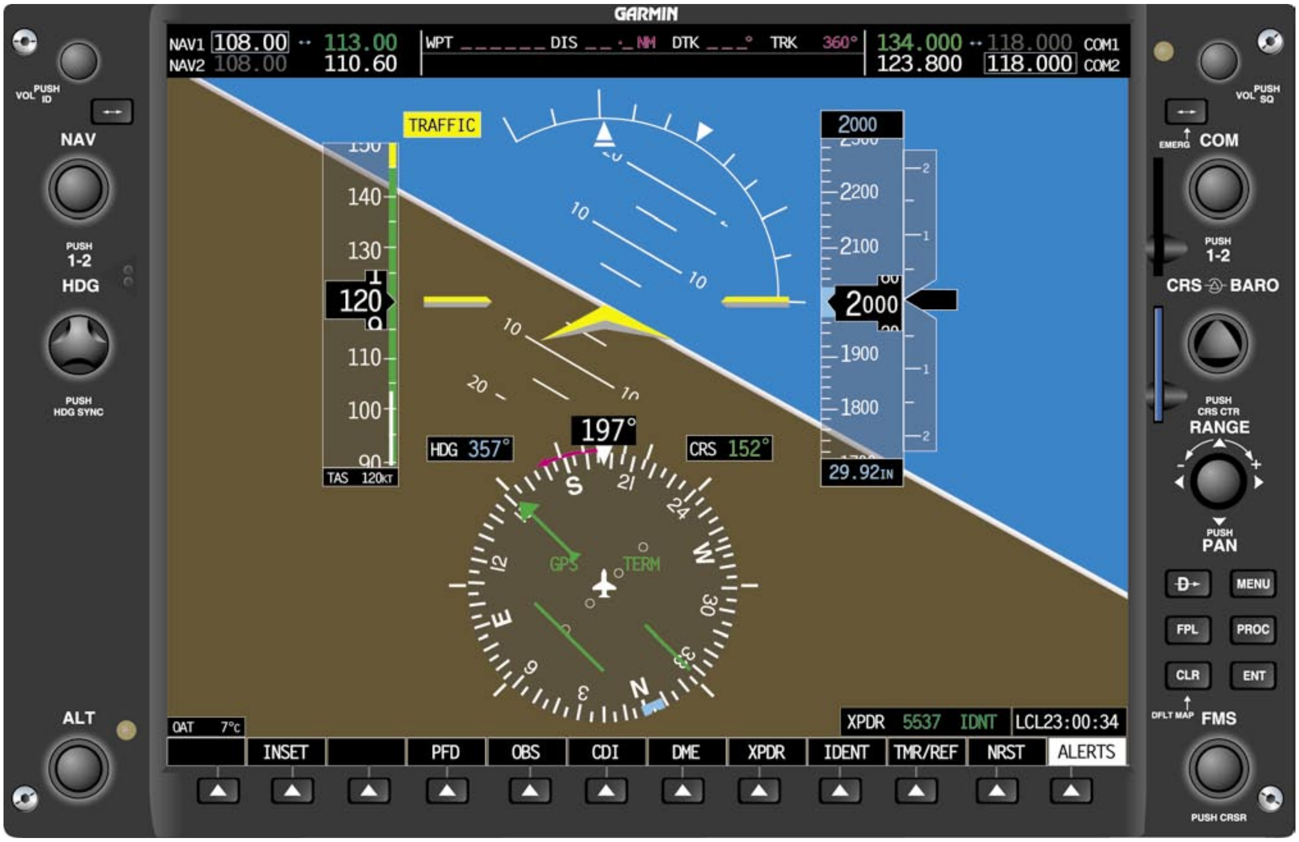
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
WPT ______ DIS __._ NM DTK ___° TRK 360°
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
VOL PUSH ID
NAV
PUSH 1-2
HDG
PUSH HDG SYNC
ALT
TRAFFIC
140
130
120
110
100
TAS 120KT
2000
2200
2100
2000
1900
1800
29.92IN
HDG 357°
197°
CRS 152°
GPS
TERM
OAT 7°C
XPDR 5537 IDNT LCL23:00:34
INSET
PFD
OBS
CDI
DME
XPDR
IDENT
TMR/REF
NRST
ALERTS
VOL PUSH SQ
EMERG COM
PUSH 1-2
CRS BARO
PUSH CRS CTR
RANGE
PUSH PAN
MENU
FPL
PROC
CLR
ENT
DFLT MAP
FMS
PUSH CRSR

Figure 4-39. *Horizontal Situation Indicator (HSI) Trend Indicator Elongates Proportionally With the Rate of Turn.*

two tick marks located on both sides of the top of the heading indicator show half-standard rate turns as well as standard rate turns.

In *Figure 4-40*, when the aircraft begins its turn to the left, the magenta trend indicator elongates proportionally with the rate of turn. To initiate a half-standard rate turn, position the indicator on the first tick mark. A standard rate turn would be indicated by the trend indicator extending to the second tick mark. A turn rate in excess of standard rate would be indicated by the trend indicator extending past the second tick mark. This trend indicator shows what the aircraft's heading will be in 6 seconds, but is limited to indicate no more than 24° in front of the aircraft, or 4° per second. When the aircraft exceeds a turning rate of 25° in 6 seconds, the trend indicator has an arrowhead attached to it.

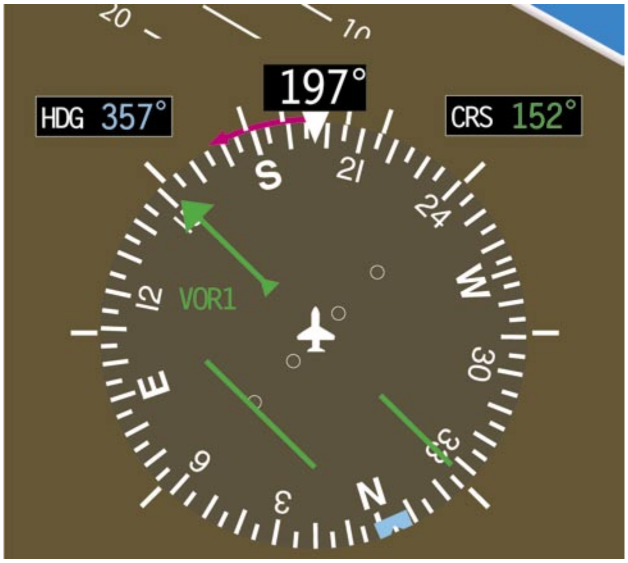
HDG 357°
197°
CRS 152°
S
21
24
W
30
33
N
3
6
E
12
VOR1

Figure 4-40. *HSI Indicator (enlargement).*

Trend indicators are very useful when leveling off at a specific altitude, when rolling out on a heading, or when stabilizing airspeed. One method of determining when to start to level off from a climb or descent is to start leveling at 10 percent of the vertical speed rate prior to the desired altitude.

As the aircraft approaches the desired altitude, adjust the pitch attitude to keep the trend indicator aligned with the target altitude. As the target approaches, the trend indicator gradually shrinks until altitude stabilizes. Trend indicators should be used as a supplement, not as a primary means of determining pitch change.

Common Errors

Fixation

Fixation, or staring at one instrument, is a common error observed in pilots first learning to utilize trend indicators. The pilot may initially fixate on the trend indicator and make adjustments with reference to that alone. Trend indicators are not the only tools to aid the pilot in maintaining the desired power or attitude; they should be used in conjunction with the primary and supporting instruments in order to better manage the flight. With the introduction of airspeed tapes, the pilot can monitor airspeed to within one knot. Fixation can lead to attempting to keep the airspeed to an unnecessarily tight tolerance. There is no need to hold airspeed to within one knot; the Instrument Rating Practical Test Standards (PTS) allows greater latitude.

Omission

Another common error associated with attitude instrument flying is omission of an instrument from the cross-check. Due to the high reliability of the PFD and associated components, pilots tend to omit the stand-by instruments as well as the magnetic compass from their scans. An additional reason for the omission is the position of the stand-by instruments. Pilots should continue to monitor the stand-by instruments in order to detect failures within those systems. One of the most commonly omitted instruments from the scan is the slip/skid indicator.

Emphasis

In initial training, placing emphasis on a single instrument is very common and can become a habit if not corrected. When the importance of a single instrument is elevated above another, the pilot begins to rely solely on that instrument for guidance. When rolling out of a 180° turn, the attitude indicator, heading indicator, slip/skid indicator, and altimeter need to be referenced. If a pilot omits the slip/skid indicator, coordination is sacrificed.

Chapter 5, Section I

Airplane Basic Flight Maneuvers

Using Analog Instrumentation

Introduction

Instrument flying techniques differ according to aircraft type, class, performance capability, and instrumentation. Therefore, the procedures and techniques that follow need to be modified to suit individual aircraft. Recommended procedures, performance data, operating limitations, and flight characteristics of a particular aircraft are available in the Pilot's Operating Handbook/Airplane Flight Manual (POH/AFM) for study before practicing the flight maneuvers.

The flight maneuvers discussed here in Chapter 5-I assume the use of a single-engine, propeller-driven small airplane with retractable gear and flaps and a panel with instruments representative of those discussed earlier in Chapter 3, Flight Instruments. With the exception of the instrument takeoff, all of the maneuvers can be performed on "partial panel," with the attitude gyro and heading indicator covered or inoperative.

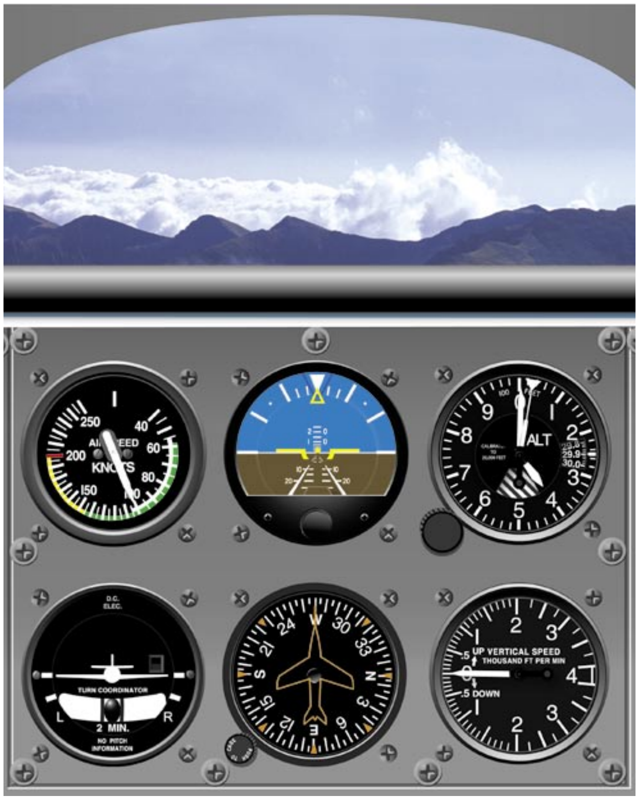

Figure 5-1. *Pitch Attitude and Airspeed in Level Flight, Slow Cruise Speed.*

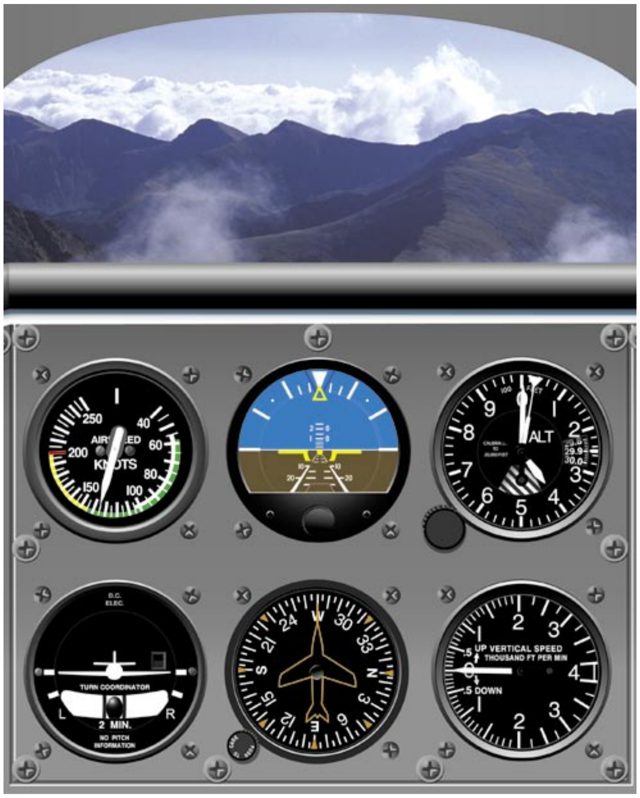

Figure 5-2. *Pitch Attitude and Airspeed in Level Flight, Fast Cruise Speed.*

Straight-and-Level Flight

Pitch Control

The pitch attitude of an airplane is the angle between the longitudinal axis of the airplane and the actual horizon. In level flight, the pitch attitude varies with airspeed and load. For training purposes, the latter factor can normally be disregarded in small airplanes. At a constant airspeed, there is only one specific pitch attitude for level flight. At slow cruise speeds, the level flight attitude is nose high with indications as in *Figure 5-1*; at fast cruise speeds, the level-flight attitude is nose low. *[Figure 5-2] Figure 5-3* shows the indications for the attitude at normal cruise speeds. The instruments used to determine the pitch attitude of the aircraft are the attitude indicator, the altimeter, the vertical speed indicator (VSI), and the airspeed indicator (ASI).

Attitude Indicator

The attitude indicator gives the direct indication of pitch attitude. The desired pitch attitude is gained by using the elevator control to raise or lower the miniature aircraft in relation to the horizon bar. This corresponds to the way pitch attitude is adjusted in visual flight by raising or lowering the nose of the airplane in relation to the natural horizon. However, unless the airspeed is constant, and until the level flight attitude for that airspeed has been identified and established, there is no way to know whether level flight as

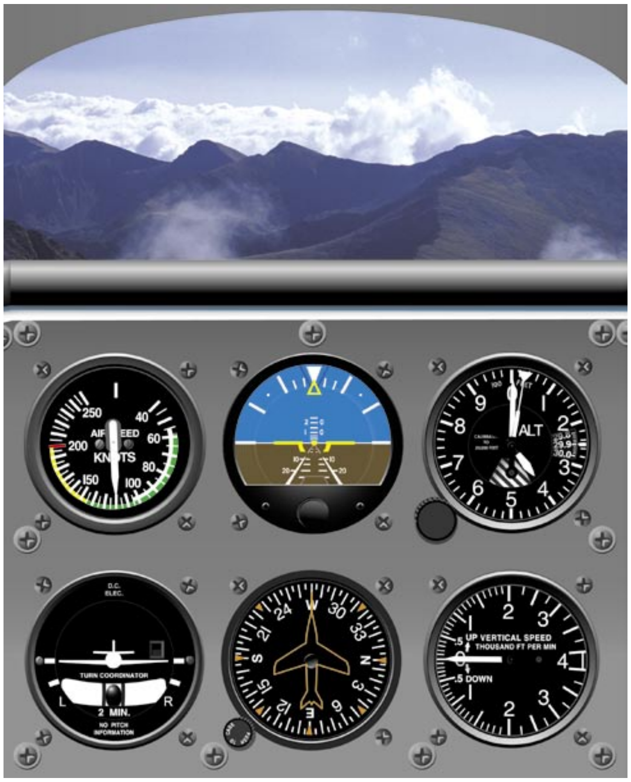

Figure 5-3. *Pitch Attitude and Airspeed in Level Flight, Normal Cruise Speed.*

indicated on the attitude indicator is resulting in level flight as shown on the altimeter, VSI, and ASI. If the miniature aircraft of the attitude indicator is properly adjusted on the ground before takeoff, it shows approximately level flight at normal cruise speed when the pilot completes the level off from a climb. If further adjustment of the miniature aircraft is necessary, the other pitch instruments must be used to maintain level flight while the adjustment is made.

To practice pitch control for level flight using only the attitude indicator, use the following exercise. Restrict the displacement of the horizon bar to a one-half bar width, a bar width up or down, then a one-and-one-half bar width. One-half, one, and one-and-one-half bar width nose-high attitudes are shown in *Figures 5-4, 5-5,* and *5-6*.

An instructor pilot can demonstrate these normal pitch corrections and compare the indications on the attitude indicator with the airplane's position to the natural horizon.

Pitch attitude changes for corrections to level flight by reference to instruments are much smaller than those commonly used for visual flight. With the airplane correctly trimmed for level flight, the elevator displacement and the control pressures necessary to effect these standard pitch changes are usually very slight. The following are a few helpful hints to help determine how much elevator control pressure is required.

First, a tight grip on the controls makes it difficult to feel control pressure changes. Relaxing and learning to control the aircraft usually takes considerable conscious effort during the early stages of instrument training.

Second, make smooth and small pitch changes with positive pressure. With practice, a pilot can make these small pitch corrections up or down, "freezing" (holding constant) the one-half, full, and one-and-one-half bar widths on the attitude indicator.

Third, with the airplane properly trimmed for level flight, momentarily release all pressure on the elevator control when becoming aware of tenseness. This is a reminder that the airplane is stable; except under turbulent conditions, it will maintain level flight if left alone. Even when no control change is called for, it will be difficult to resist the impulse to move the controls. This may be one of the most difficult initial training problems in instrument flight.

Altimeter

At constant power, any deviation from level flight (except in turbulent air) is the result of a pitch change. Therefore, the altimeter gives an indirect indication of the pitch attitude in level flight, assuming constant power. Since the altitude

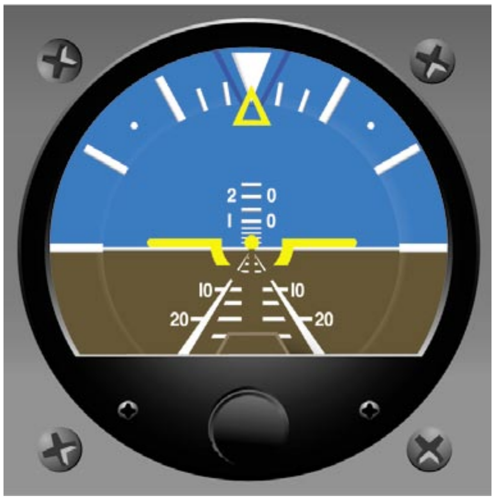

Figure 5-4. *Pitch Correction for Level Flight, One-Half Bar Width.*

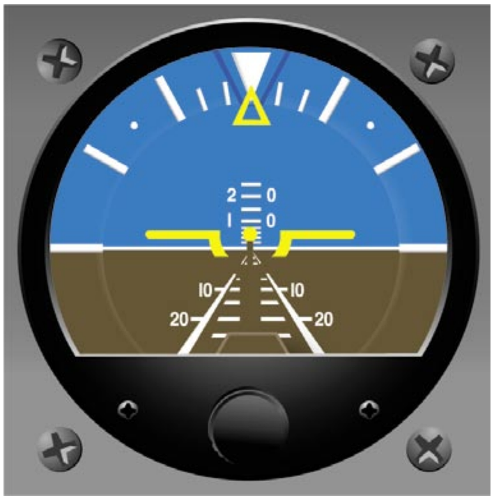

Figure 5-5. *Pitch Correction for Level Flight, One Bar Width.*

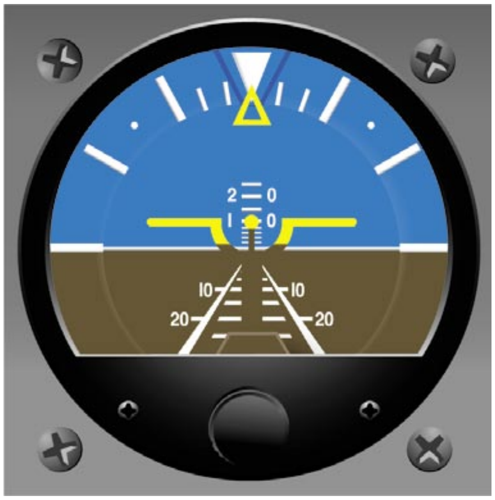

Figure 5-6. *Pitch Correction for Level Flight, One-and-One-Half Bar Width.*

should remain constant when the airplane is in level flight, any deviation from the desired altitude signals the need for a pitch change. If the aircraft is gaining altitude, the nose must be lowered. *[Figures 5-7* and *5-8]*

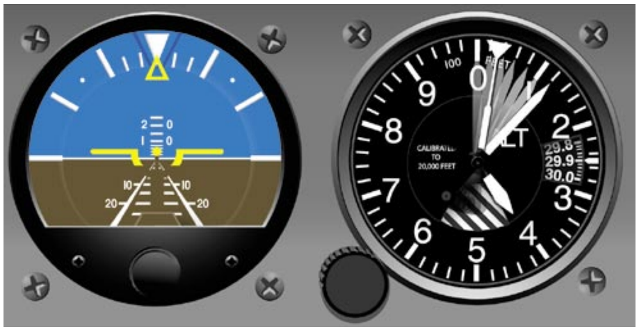

Figure 5-7. *Using the Altimeter for Pitch Interpretation, a High Altitude Means a Nose-High Pitch Attitude.*

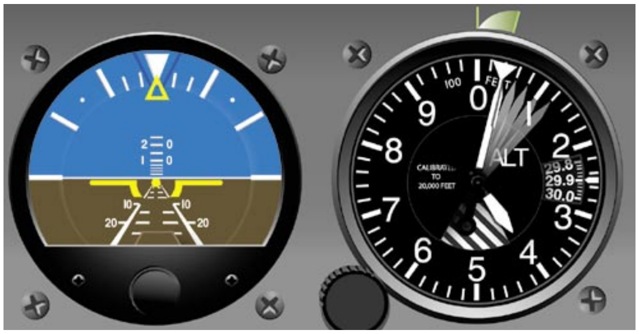

Figure 5-8. *Pitch Correction Following Altitude Increase—Lower Nose to Correct Altitude Error.*

The rate of movement of the altimeter needle is as important as its direction of movement in maintaining level flight without the use of the attitude indicator. An excessive pitch deviation from level flight results in a relatively rapid change of altitude; a slight pitch deviation causes a slow change. Thus, if the altimeter needle moves rapidly clockwise, assume a considerable nose-high deviation from level flight attitude. Conversely, if the needle moves slowly counterclockwise to indicate a slightly nose-low attitude, assume that the pitch correction necessary to regain the desired altitude is small. As the altimeter is added to the attitude indicator in a cross-check, a pilot will learn to recognize the rate of movement of the altimeter needle for a given pitch change as shown on the attitude indicator.

To practice precision control of pitch in an airplane without an attitude indicator, make small pitch changes by visual reference to the natural horizon, and note the rate of movement of the altimeter. Note what amount of pitch change gives the slowest steady rate of change on the altimeter. Then practice small pitch corrections by accurately interpreting and controlling the rate of needle movement.

An instructor pilot can demonstrate an excessive nose-down deviation (indicated by rapid movement of the altimeter needle) and then, as an example, show the result of improper corrective technique. The normal impulse is to make a large pitch correction in a hurry, but this inevitably leads to overcontrolling. The needle slows down, then reverses direction, and finally indicates an excessive nose-high deviation. The result is tension on the controls, erratic control response, and increasingly extreme control movements. The correct technique, which is slower and smoother, will return the airplane to the desired attitude more quickly, with positive control and no confusion.

When a pitch error is detected, corrective action should be taken promptly, but with light control pressures and two distinct changes of attitude: (1) a change of attitude to stop the needle movement and (2) a change of attitude to return to the desired altitude.

When the altimeter indicates an altitude deviation, apply just enough elevator pressure to decrease the rate of needle movement. If it slows down abruptly, ease off some of the pressure until the needle continues to move, but ease off slowly. Slow needle movement means the airplane attitude is close to level flight. Add slightly more corrective pressure to stop the direction of needle movement. At this point level flight is achieved; a reversal of needle movement means the aircraft has passed through it. Relax control pressures carefully, continuing to cross-check since changing airspeed will cause changes in the effectiveness of a given control pressure. Next, adjust the pitch attitude with elevator pressure for the rate of change of altimeter needle movement that is correlated with normal pitch corrections, and return to the desired altitude.

As a rule of thumb, for errors of less than 100 feet, use a half bar width correction. *[Figures 5-9* and *5-10]* For errors in excess of 100 feet, use an initial full bar width correction. *[Figures 5-11* and *5-12]* Practice predetermined altitude changes using the altimeter alone, then in combination with the attitude indicator.

Vertical Speed Indicator (VSI)

The VSI, like the altimeter, gives an indirect indication of pitch attitude and is both a trend and a rate instrument. As a trend instrument, it shows immediately the initial vertical movement of the airplane, which disregarding turbulence can be considered a reflection of pitch change. To maintain level flight, use the VSI in conjunction with the altimeter and attitude indicator. Note any positive or negative trend of the needle from zero and apply a very light corrective elevator

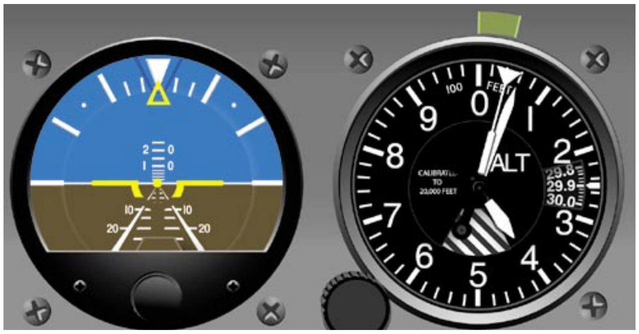

Figure 5-9. *Altitude Error, Less Than 100 Feet.*

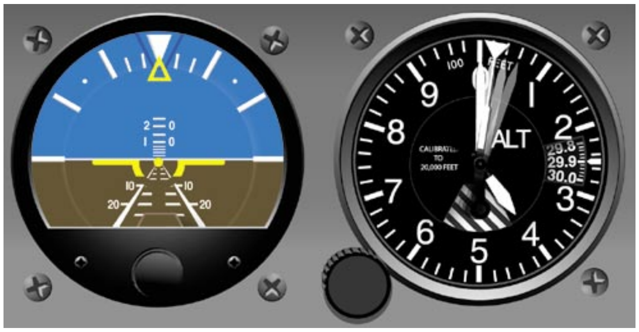

Figure 5-10. *Pitch Correction, Less Than 100 Feet—One-Half Bar Low to Correct Altitude Error.*

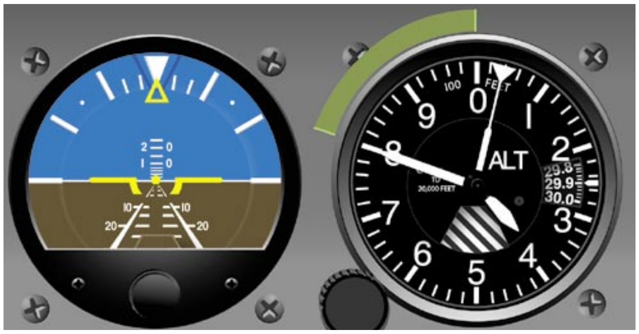

Figure 5-11. *Altitude Error, Greater Than 100 Feet.*

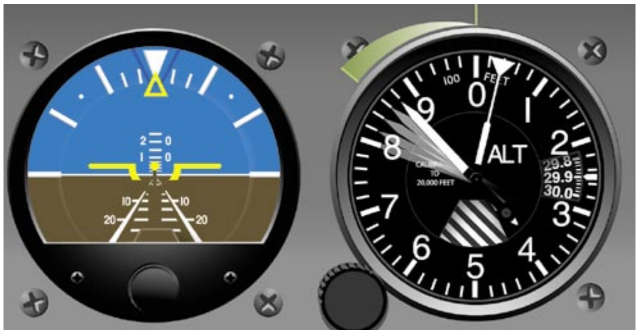

Figure 5-12. *Pitch Correction, Greater Than 100 Feet—One Bar Correction Initially.*

pressure. As the needle returns to zero, relax the corrective pressure. If control pressures have been smooth and light, the needle reacts immediately and slowly, and the altimeter shows little or no change of altitude. As a rate instrument, the VSI requires consideration of lag characteristics.

Lag refers to the delay involved before the needle attains a stable indication following a pitch change. Lag is directly proportional to the speed and magnitude of a pitch change. If a slow, smooth pitch change is initiated, the needle moves with minimum lag to a point of deflection corresponding to the extent of the pitch change, and then stabilizes as the aerodynamic forces are balanced in the climb or descent. A large and abrupt pitch change produces erratic needle movement, a reverse indication, and introduces greater time delay (lag) before the needle stabilizes. Pilots are cautioned not to chase the needle when flight through turbulent conditions produces erratic needle movements. The apparent lag in airspeed indications with pitch changes varies greatly among different airplanes and is due to the time required for the airplane to accelerate or decelerate when the pitch attitude is changed. There is no appreciable lag due to the construction or operation of the instrument. Small pitch changes, smoothly executed, result in an immediate change of airspeed.

When using the VSI as a rate instrument and combining it with the altimeter and attitude indicator to maintain level flight, a pilot should know that the amount the altimeter needle moves from the desired altitude governs the rate which should be used to return to that altitude. A rule of thumb is to make an attitude change that will result in a vertical-speed rate approximately double the error in altitude. For example, if altitude is off by 100 feet, the rate of return to the desired altitude should be approximately 200 feet per minute (fpm). If it is off by more than 100 feet, the correction should be correspondingly greater, but should never exceed the optimum rate of climb or descent for the airplane at a given airspeed and configuration.

A deviation of more than 200 fpm from the desired rate of return is considered overcontrolling. For example, if attempting to change altitude by 200 feet, a rate in excess of 400 fpm indicates overcontrolling.

When returning to an altitude, the VSI is the primary pitch instrument. Occasionally, the VSI is slightly out of calibration and may indicate a climb or descent when the airplane is in level flight. If the instrument cannot be adjusted, take the error into consideration when using it for pitch control. For example, if the needle indicates a descent of 200 fpm while in level flight, use this indication as the zero position.

Airspeed Indicator (ASI)

The ASI presents an indirect indication of the pitch attitude. In non-turbulent conditions with a constant power setting and pitch attitude, airspeed remains constant. *[Figure 5-13]* As the pitch attitude lowers, airspeed increases, and the nose should be raised. *[Figure 5-14]* As the pitch attitude rises, airspeed decreases, and the nose should be lowered. *[Figure 5-15]* A rapid change in airspeed indicates a large pitch change, and a slow change of airspeed indicates a small pitch change.

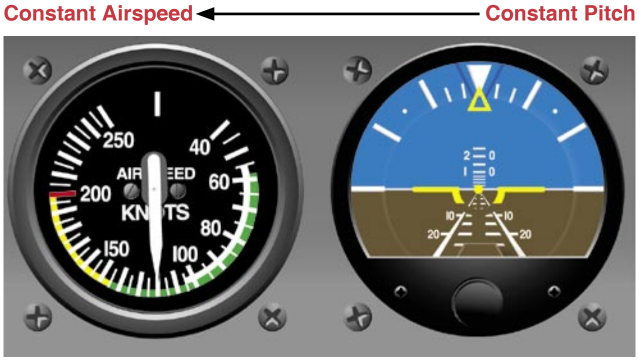

Figure 5-13. *Constant Power Plus Constant Pitch Equals Constant Speed.*

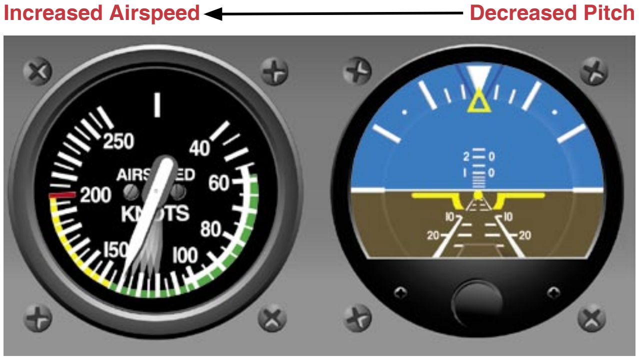

Figure 5-14. *Constant Power Plus Decreased Pitch Equals Increased Airspeed.*

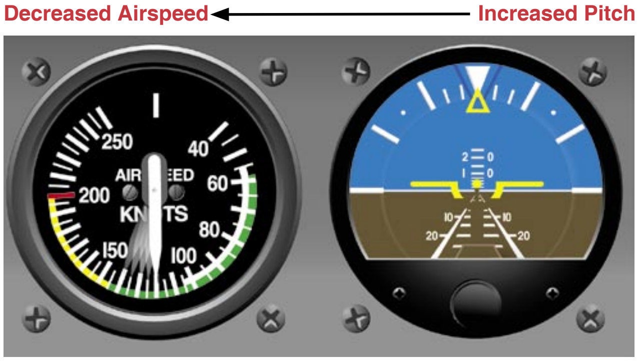

Figure 5-15. *Constant Power Plus Increased Pitch Equals Decreased Airspeed.*

Pitch control in level flight is a question of cross-check and interpretation of the instrument panel for the instrument information that enables a pilot to visualize and control pitch attitude. Regardless of individual differences in cross-check technique, all pilots should use the instruments that give the best information for controlling the airplane in any given maneuver. Pilots should also check the other instruments to aid in maintaining the primary instruments at the desired indication.

As noted previously, the primary instrument is the one that gives the most pertinent information for a particular maneuver. It is usually the one that should be held at a constant indication. Which instrument is primary for pitch control in level flight, for example? This question should be considered in the context of specific airplane, weather conditions, pilot experience, operational conditions, and other factors. Attitude changes must be detected and interpreted instantly for immediate control action in high-performance airplanes. On the other hand, a reasonably proficient instrument pilot in a slower airplane may rely more on the altimeter for primary pitch information, especially if it is determined that too much reliance on the attitude indicator fails to provide the necessary precise attitude information. Whether the pilot decides to regard the altimeter or the attitude indicator as primary depends on which approach will best help control the attitude. In this handbook, the altimeter is normally considered as the primary pitch instrument during level flight.

Bank Control

The bank attitude of an airplane is the angle between the airplane's wings and the natural horizon. To maintain a straight-and-level flight path, the wings of the airplane are kept level with the horizon (assuming the airplane is in coordinated flight). The instruments used for bank control are the attitude indicator, the heading indicator, and the turn coordinator. *Figure 5-16* illustrates coordinated flight. The aircraft is banked left with the attitude indicator and turn coordinator indicating the bank. The heading indicator indicates a left turn by apparent clockwise rotation of the compass card behind the airplane silhouette.

Attitude Indicator

The attitude indicator shows any change in bank attitude directly and instantly and is, therefore, a direct indicator. On the standard attitude indicator, the angle of bank is shown pictorially by the relationship of the miniature aircraft to the artificial horizon bar, and by the alignment of the pointer with the banking scale at the top of the instrument. On the face of the standard three-inch instrument, small angles of bank can be difficult to detect by reference to the miniature aircraft, especially if leaning to one side or changing a seating position

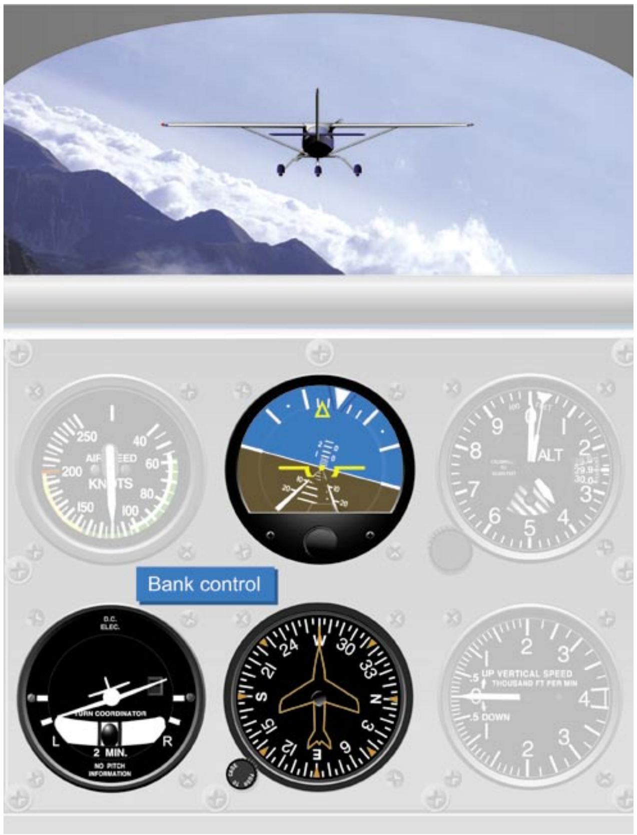

Figure 5-16. *Instruments Used for Bank Control.*

slightly. The position of the scale pointer is a good check against the apparent miniature aircraft position. Disregarding precession error, small deviations from straight coordinated flight can be readily detected on the scale pointer. The banking index may be graduated as shown in *Figure 5-17*, or it may be graduated in 30° increments.

The instrument depicted in *Figure 5-17* has a scale pointer that moves in the same direction of bank shown by the miniature aircraft. In this case, the aircraft is in a left 15° bank. Precession errors in this instrument are common and predictable, but the obvious advantage of the attitude indicator is an immediate indication of both pitch attitude and bank attitude in a single glance. Even with the precession errors associated with many attitude indicators, the quick attitude presentation requires less visual effort and time for positive control than other flight instruments.

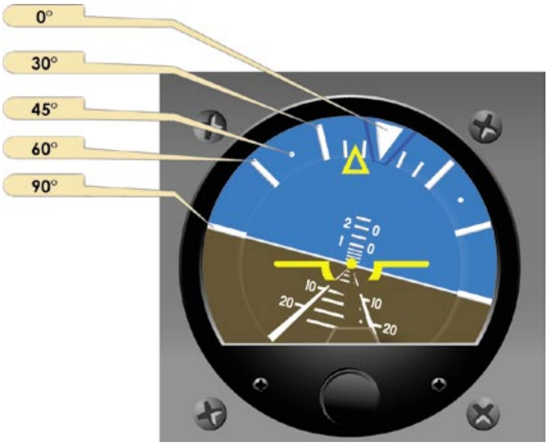

Figure 5-17. *Bank Interpretation with the Attitude Indicator.*

Heading Indicator

The bank attitude of an aircraft in coordinated flight is shown indirectly on the heading indicator, since banking results in a turn and change in heading. Assuming the same airspeed in both instances, a rapid movement of the heading indicator (azimuth card in a directional gyro) indicates a large angle of bank, whereas slow movement reflects a small angle of bank. Note the rate of movement of the heading indicator and compare it to the attitude indicator's degrees of bank. The attitude indicator's precession error makes a precise check of heading information necessary in order to maintain straight flight.

When deviations from straight flight are noted on the heading indicator, correct to the desired heading using a bank angle no greater than the number of degrees to be turned. In any case, limit bank corrections to a bank angle no greater than that required for a standard rate turn. Use of larger bank angles requires a very high level of proficiency, and normally results in overcontrolling and erratic bank control.

Turn Coordinator

The miniature aircraft of the turn coordinator gives an indirect indication of the bank attitude of the airplane. When the miniature aircraft is level, the airplane is in straight flight. When the miniature airplane is aligned with one of the alignment marks and the aircraft is rolling to the left or right the indication represents the roll rate, with the alignment marks indicating a roll of 3° per second in the direction of the miniature aircraft. This can be seen in level flight when a bank is introduced either to the left or the right. The turn coordinator's indicator will indicate the rolling motion although there is no turn being made. Conversely, a pedal input to the right or left causes the aircraft to turn momentarily about its vertical axis (with no rolling motion) with an indication of turn on the turn coordinator. After the turn becomes stabilized and the aircraft is no longer rolling, the turn coordinator displays the rate of turn with the alignment marks equaling a turn of 3° per second. The turn coordinator is able to display both roll and turn parameters because its electrically powered gyroscope is canted at an angle. As a result, the turn-and-slip indicator provides both roll and turn indications. Autopilots in general aviation today use this instrument in determining both roll and turn information. After the completion of a turn, return to straight flight is accomplished by coordinated aileron and rudder pressure to level the miniature aircraft. Include the miniature aircraft in the cross-check and correct for even the smallest deviations from the desired position. When this instrument is used to maintain straight flight, control pressures must be applied very lightly and smoothly.

The ball of the turn coordinator is actually a separate instrument, conveniently located under the miniature aircraft because the two instruments are used together. The ball instrument indicates the quality of the turn. If the ball is off center, the airplane is slipping or skidding. That is, if the coordinator's miniature airplane is tilted right and the ball is displaced to the right, the aircraft is in a skid. *[Figure 5-18]* If however, the miniature airplane is tilted to the right with the ball off-center to the left, the aircraft is in a slip. *[Figure 5-19]* If the wings are level and the airplane is properly trimmed, the ball will remain in the center, and the airplane will be in straight flight. If the ball is not centered, the airplane is improperly trimmed.

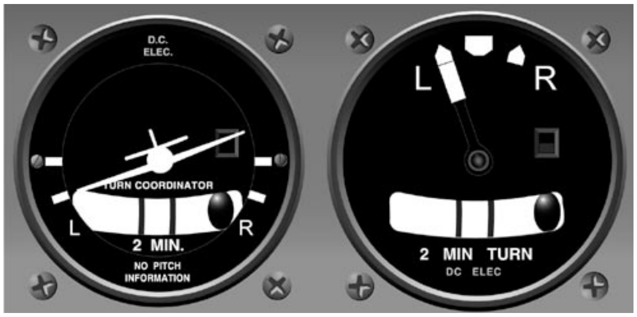

Figure 5-18. *Skid Indication.*

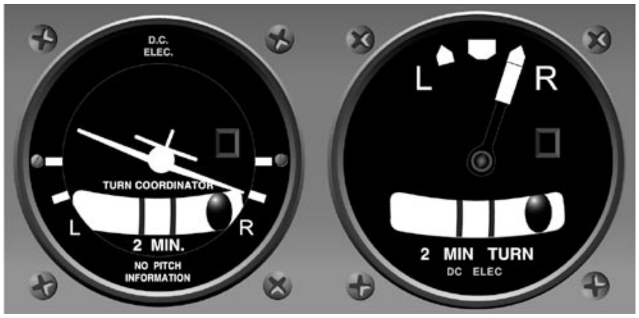

Figure 5-19. *Slip Indication.*

To maintain straight-and-level flight with proper trim, note the direction of ball displacement. If the ball is to the left of center and the left wing is low, apply left rudder pressure to center the ball and correct the slip. At the same time apply right aileron pressure as necessary to level the wings, cross-checking the heading indicator and attitude indicator while centering the ball. If the wings are level and the ball is displaced from the center, the airplane is skidding. Note the direction of ball displacement, and use the same corrective technique as for an indicated slip. Center the ball (left ball/left rudder, right ball/right rudder), use aileron as necessary for bank control, and retrim.

To trim the airplane using only the turn coordinator, use aileron pressure to level the miniature aircraft and rudder pressure to center the ball. Hold these indications with control pressures, gradually releasing them while applying rudder trim sufficient to relieve all rudder pressure. Apply aileron trim, if available, to relieve aileron pressure. With a full instrument panel, maintain a wings level attitude by reference to all available instruments while trimming the airplane.

Turn-and-Slip Indicator (Needle and Ball)

Unlike the turn coordinator that provides three indications (roll, turn, and trim), the turn-and-slip indicator provides two: turn-rate and trim. Although the turn-and-slip indicator needle provides an indication of turn only, it provides an indirect indication of aircraft attitude when used with roll indicators such as a heading indicator or magnetic compass. As with the turn coordinator (after stabilizing from a roll), when the turn-and-slip indicator's needle is aligned with the alignment marks the aircraft is in a standard turn of 3° per second or 360° in 2 minutes.

The ball of the turn-and-bank indicator provides important trim in the same manner that the ball in the turn coordinator does. *Figures 5-18* and *5-19* provide a comparison of the two instruments.

Power Control

Power produces thrust which, with the appropriate angle of attack of the wing, overcomes the forces of gravity, drag, and inertia to determine airplane performance.

Power control must be related to its effect on altitude and airspeed, since any change in power setting results in a change in the airspeed or the altitude of the airplane. At any given airspeed, the power setting determines whether the airplane is in level flight, in a climb, or in a descent. If the power is increased in straight-and-level flight and the airspeed held constant, the airplane climbs. If power is decreased while the airspeed is held constant, the airplane descends. On the other hand, if altitude is held constant, the power applied will determine the airspeed.

The relationship between altitude and airspeed determines the need for a change in pitch or power. If the airspeed is not the desired value, always check the altimeter before deciding that a power change is necessary. Think of altitude and airspeed as interchangeable; altitude can be traded for airspeed by lowering the nose, or convert airspeed to altitude by raising the nose. If altitude is higher than desired and airspeed is

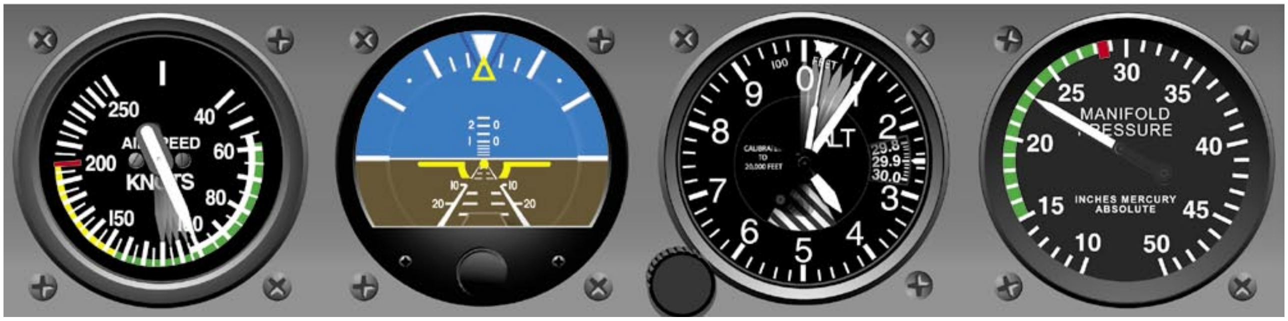

Figure 5-20. *Airspeed Low and Altitude High—Lower Pitch.*

low, or vice versa, a change in pitch alone may return the airplane to the desired altitude and airspeed. *[Figure 5-20]* If both airspeed and altitude are high or if both are low, then a change in both pitch and power is necessary in order to return to the desired airspeed and altitude. *[Figure 5-21]*

For changes in airspeed in straight-and-level flight, pitch, bank, and power must be coordinated in order to maintain constant altitude and heading. When power is changed to vary airspeed in straight-and-level flight, a single-engine, propeller-driven airplane tends to change attitude around all axes of movement. Therefore, to maintain constant altitude and heading, apply various control pressures in proportion to the change in power. When power is added to increase airspeed, the pitch instruments indicate a climb unless forward elevator control pressure is applied as the airspeed changes. With an increase in power, the airplane tends to yaw and roll to the left unless counteracting aileron and rudder pressures are applied. Keeping ahead of these changes requires increasing cross-check speed, which varies with the type of airplane and its torque characteristics, the extent of power and speed change involved.

Power Settings

Power control and airspeed changes are much easier when approximate power settings necessary to maintain various airspeeds in straight-and-level flight are known in advance. However, to change airspeed by any appreciable amount, the common procedure is to underpower or overpower on initial power changes to accelerate the rate of airspeed change. (For small speed changes, or in airplanes that decelerate or accelerate rapidly, overpowering or underpowering is not necessary.)

Consider the example of an airplane that requires 23" mercury (Hg) of manifold pressure to maintain a normal cruising airspeed of 120 knots, and 18" Hg of manifold pressure to maintain an airspeed of 100 knots. The reduction in airspeed from 120 knots to 100 knots while maintaining straight-and-level flight is discussed below and illustrated in *Figures 5-22, 5-23,* and *5-24*.

Instrument indications, prior to the power reduction, are shown in *Figure 5-22*. The basic attitude is established and maintained on the attitude indicator. The specific pitch, bank, and power control requirements are detected on these primary instruments:

Altimeter—Primary Pitch
Heading Indicator—Primary Bank
Airspeed Indicator—Primary Power

Supporting pitch-and-bank instruments are shown in *Figure 5-23*. Note that the supporting power instrument is the manifold pressure gauge (or tachometer if the propeller is fixed pitch). However, when a smooth power reduction to approximately 15" Hg (underpower) is made, the manifold pressure gauge becomes the primary power instrument. *[Figure 5-23]* With practice, power setting can be changed with only a brief glance at the power instrument, by sensing

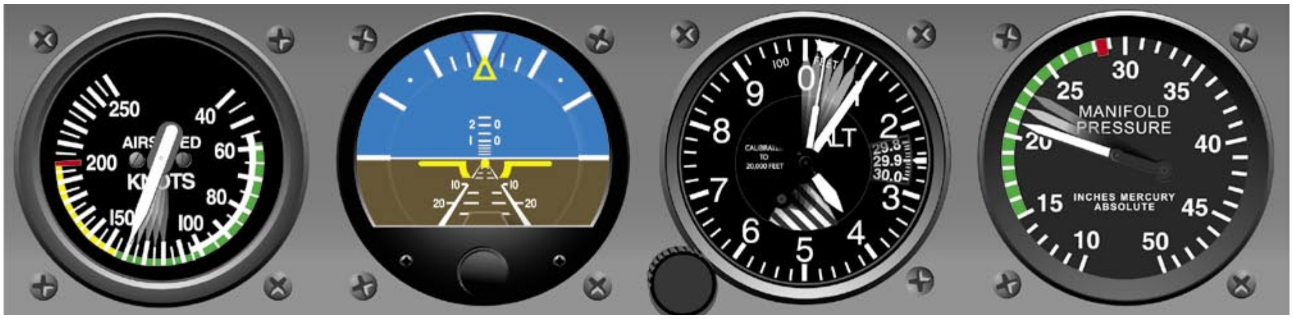

Figure 5-21. *Airspeed and Altitude High—Lower Pitch and Reduce Power.*

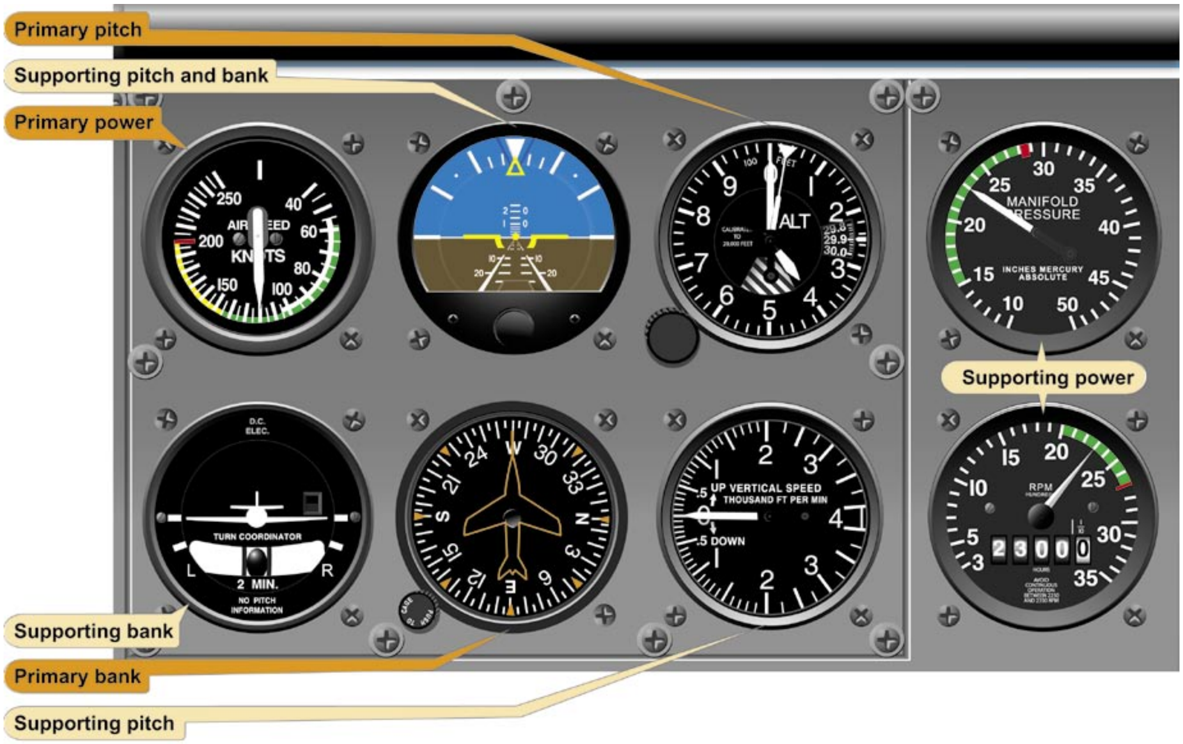
Primary pitch
Supporting pitch and bank
Primary power
AIRSPEED KNOTS
ALT
MANIFOLD PRESSURE
INCHES MERCURY ABSOLUTE
Supporting power
TURN COORDINATOR
2 MIN.
NO PITCH INFORMATION
UP VERTICAL SPEED THOUSAND FT PER MIN
DOWN
RPM
Supporting bank
Primary bank
Supporting pitch

Figure 5-22. *Straight-and-Level Flight (Normal Cruising Speed).*

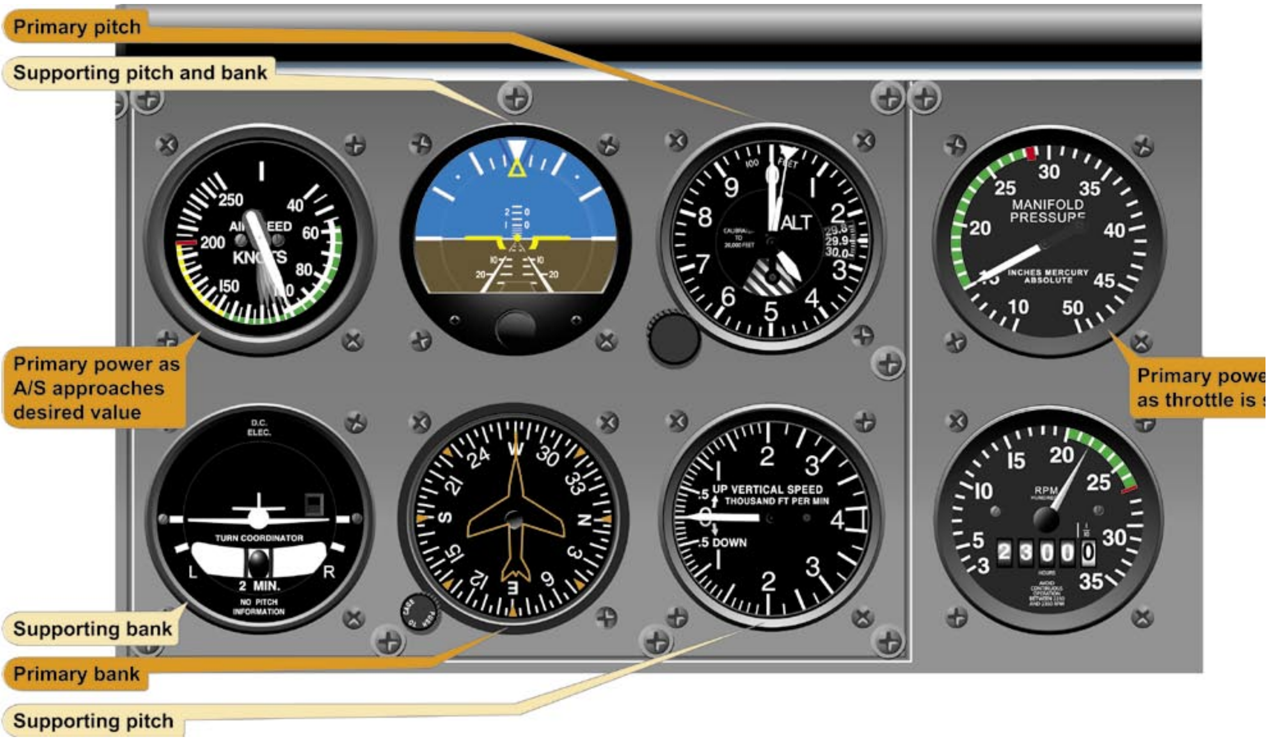
Primary pitch
Supporting pitch and bank
AIRSPEED KNOTS
ALT
MANIFOLD PRESSURE
INCHES MERCURY ABSOLUTE
Primary power as
A/S approaches
desired value
Primary powe
as throttle is
TURN COORDINATOR
2 MIN.
NO PITCH INFORMATION
UP VERTICAL SPEED THOUSAND FT PER MIN
DOWN
RPM
Supporting bank
Primary bank
Supporting pitch

Figure 5-23. *Straight-and-Level Flight (Airspeed Decreasing).*

the movement of the throttle, the change in sound, and the changes in the feel of control pressures.

As thrust decreases, increase the speed of the cross-check and be ready to apply left rudder, back-elevator, and aileron control pressure the instant the pitch-and-bank instruments show a deviation from altitude and heading. As proficiency is obtained, a pilot learns to cross-check, interpret, and control the changes with no deviation of heading and altitude. Assuming smooth air and ideal control technique, as airspeed decreases, a proportionate increase in airplane pitch attitude is required to maintain altitude. Similarly, effective torque control means counteracting yaw with rudder pressure.

As the power is reduced, the altimeter is primary for pitch, the heading indicator is primary for bank, and the manifold pressure gauge is momentarily primary for power (at 15" Hg in this example). Control pressures should be trimmed off as the airplane decelerates. As the airspeed approaches the desired airspeed of 100 knots, the manifold pressure is adjusted to approximately 18" Hg and becomes the supporting power instrument. The ASI again becomes primary for power. *[Figure 5-24]*

Airspeed Changes in Straight-and-Level Flight

Practice of airspeed changes in straight-and-level flight provides an excellent means of developing increased proficiency in all three basic instrument skills, and brings out some common errors to be expected during training in straight-and-level flight. Having learned to control the airplane in a clean configuration (minimum drag conditions), increase proficiency in cross-check and control by practicing speed changes while extending or retracting the flaps and landing gear. While practicing, be sure to comply with the airspeed limitations specified in the POH/AFM for gear and flap operation.

Sudden and exaggerated attitude changes may be necessary in order to maintain straight-and-level flight as the landing gear is extended and the flaps are lowered in some airplanes. The nose tends to pitch down with gear extension, and when flaps are lowered, lift increases momentarily (at partial flap settings) followed by a marked increase in drag as the flaps near maximum extension.

Control technique varies according to the lift and drag characteristics of each airplane. Accordingly, knowledge of the power settings and trim changes associated with different combinations of airspeed, gear and flap configurations will reduce instrument cross-check and interpretation problems.

For example, assume that in straight-and-level flight instruments indicate 120 knots with power at 23" Hg/2,300 revolutions per minute (rpm), gear and flaps up. After reduction in airspeed, with gear and flaps fully extended, straight-and-level flight at the same altitude requires 25" Hg manifold pressure/2,500 rpm. Maximum gear extension speed is 115 knots; maximum flap extension speed is 105

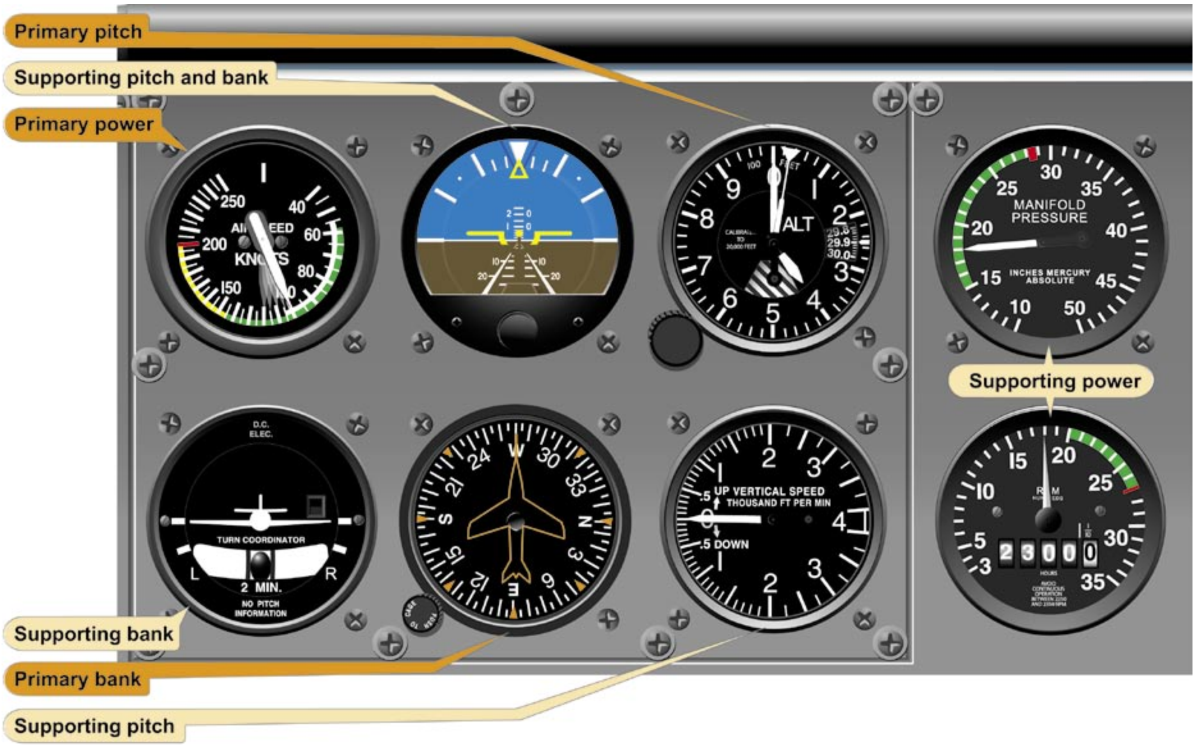

Figure 5-24. *Straight-and-Level Flight (Reduced Airspeed Stabilized).*

knots. Airspeed reduction to 95 knots, gear and flaps down, can be made in the following manner:

1. Maintain rpm at 2,500, since a high power setting will be used in full drag configuration.
2. Reduce manifold pressure to 10" Hg. As the airspeed decreases, increase cross-check speed.
3. Make trim adjustments for an increased angle of attack and decrease in torque.
4. Lower the gear at 115 knots. The nose may tend to pitch down and the rate of deceleration increases. Increase pitch attitude to maintain constant altitude, and trim off some of the back-elevator pressures. If full flaps are lowered at 105 knots, cross-check, interpretation, and control must be very rapid. A simpler technique is to stabilize attitude with gear down before lowering the flaps.
5. Since 18" Hg manifold pressure will hold level flight at 100 knots with the gear down, increase power smoothly to that setting until the ASI shows approximately 105 knots, and retrim. The attitude indicator now shows approximately two-and-a-half bar width nose-high in straight-and-level flight.
6. Actuate the flap control and simultaneously increase power to the predetermined setting (25" Hg) for the desired airspeed, and trim off the pressures necessary to hold constant altitude and heading. The attitude indicator now shows a bar width nose-low in straight-and-level flight at 95 knots.

Proficiency in straight-and-level flight is attained when a pilot can consistently maintain constant altitude and heading with smooth pitch, bank, power, and trim control during the pronounced changes in aircraft attitude.

Trim Technique

Proper trim technique is essential for smooth and precise aircraft control during all phases of flight. By relieving all control pressures, it is much easier to hold a given attitude constant, and devote more attention to other flight deck duties.

An aircraft is trimmed by applying control pressures to establish a desired attitude, then adjusting the trim so the aircraft will maintain that attitude when the flight controls are released. Trim the aircraft for coordinated flight by centering the ball of the turn-and-slip indicator, by using rudder trim in the direction the ball is displaced from the center. Differential power control on multiengine aircraft is an additional factor affecting coordinated flight. Use balanced power or thrust, when possible, to aid in maintaining coordinated flight.

Changes in attitude, power, or configuration will require a trim adjustment in most cases. Using trim alone to establish a change in aircraft attitude invariably leads to erratic aircraft control. Smooth and precise attitude changes are best attained by a combination of control pressures and trim adjustments. Therefore, when used correctly, trim adjustment is an aid to smooth aircraft control.

Common Errors in Straight-and-Level Flight

Pitch

Pitch errors usually result from the following faults:

1. Improper adjustment of the attitude indicator's miniature aircraft to the wings level attitude. Following the initial level off from a climb, check the attitude indicator and make any necessary adjustment in the miniature aircraft for level flight indication at normal cruise airspeed.
2. Insufficient cross-check and interpretation of pitch instruments. For example, the airspeed indication is low. The pilot, believing a nose-high attitude exists, applies forward pressure without noting that a low power setting is the cause of the airspeed discrepancy. Increase cross-check speed to include all relevant instrument indications before making a control input.
3. Uncaging the attitude indicator (if caging feature is present) when the airplane is not in level flight. The altimeter and heading indicator must be stabilized with airspeed indication at normal cruise before pulling out the caging knob, to obtain correct indications in straight-and-level flight at normal cruise airspeed.
4. Failure to interpret the attitude indicator in terms of the existing airspeed.
5. Late pitch corrections. Pilots commonly like to leave well enough alone. When the altimeter indicates a 20 foot error, there is a reluctance to correct it, perhaps because of fear of overcontrolling. If overcontrolling is the anticipated error, practice small corrections and find the cause of overcontrolling. If any deviation is tolerated, errors will increase.
6. Chasing the vertical speed indications. This tendency can be corrected by proper cross-check of other pitch instruments, as well as by increasing overall understanding of instrument characteristics.
7. Using excessive pitch corrections for the altimeter evaluation. Rushing a pitch correction by making a large pitch change usually aggravates the existing error, saving neither time nor effort.

8. Failure to maintain established pitch corrections, a common error associated with cross-check and trim errors. For example, having established a pitch change to correct an altitude error, there is a tendency to slow down the cross-check, waiting for the airplane to stabilize in the new pitch attitude. To maintain the attitude, continue to cross-check and trim off the pressures.
9. Fixations during cross-check. After initiating a heading correction, for example, there is a tendency to become preoccupied with bank control and miss errors in pitch attitude. Likewise, during an airspeed change, unnecessary gazing at the power instrument is common. A small error in power setting is of less consequence than large altitude and heading errors. The airplane will not decelerate any faster by staring at the manifold pressure gauge.

Heading

Heading errors usually result from the following faults:

1. Failure to cross-check the heading indicator, especially during changes in power or pitch attitude.
2. Misinterpretation of changes in heading, with resulting corrections in the wrong direction.
3. Failure to note and remember a preselected heading.
4. Failure to observe the rate of heading change and its relation to bank attitude.
5. Overcontrolling in response to heading changes, especially during changes in power settings.
6. Anticipating heading changes with premature application of rudder control.
7. Failure to correct small heading deviations. Unless zero error in heading is the goal, a pilot will tolerate larger and larger deviations. Correction of a 1° error takes a lot less time and concentration than correction of a 20° error.
8. Correcting with improper bank attitude. If correcting a 10° heading error with 20° of bank, the airplane will roll past the desired heading before the bank is established, requiring another correction in the opposite direction. Do not multiply existing errors with errors in corrective technique.
9. Failure to note the cause of a previous heading error and thus repeating the same error. For example, the airplane is out of trim, with a left wing low tendency. Repeated corrections for a slight left turn are made, yet trim is ignored.
10. Failure to set the heading indicator properly or failure to uncage it.

Power

Power errors usually result from the following faults:

1. Failure to know the power settings and pitch attitudes appropriate to various airspeeds and airplane configurations.
2. Abrupt use of throttle.
3. Failure to lead the airspeed when making power changes. For example, during airspeed reduction in level flight, especially with gear and flaps extended, adjust the throttle to maintain the slower speed before the airspeed actually reaches the desired speed. Otherwise, the airplane will decelerate to a speed lower than that desired, resulting in additional power adjustments. The amount of lead depends upon how fast the airplane responds to power changes.
4. Fixation on airspeed or manifold pressure instruments during airspeed changes, resulting in erratic control of both airspeed and power.

Trim

Trim errors usually result from the following faults:

1. Improper adjustment of seat or rudder pedals for comfortable position of legs and feet. Tension in the ankles makes it difficult to relax rudder pressures.
2. Confusion about the operation of trim devices, which differ among various airplane types. Some trim wheels are aligned appropriately with the airplane's axes; others are not. Some rotate in a direction contrary to what is expected.
3. Faulty sequence in trim technique. Trim should be used not as a substitute for control with the wheel (stick) and rudders, but to relieve pressures already held to stabilize attitude. As proficiency is gained, little conscious effort will be required to trim off the pressures as they occur.
4. Excessive trim control. This induces control pressures that must be held until the airplane is trimmed properly. Use trim frequently and in small amounts.
5. Failure to understand the cause of trim changes. Lack of understanding the basic aerodynamics related to basic instrument skills will cause a pilot to continually lag behind the airplane.

Straight Climbs and Descents

Climbs

For a given power setting and load condition, there is only one attitude that will give the most efficient rate of climb. The airspeed and climb power setting that will determine this climb attitude are given in the performance data found in the POH/AFM. Details of the technique for entering a climb vary according to airspeed on entry and the type of climb (constant airspeed or constant rate) desired. (Heading and trim control are maintained as discussed in Straight-and-Level Flight.)

Entry

To enter a constant-airspeed climb from cruising airspeed, raise the miniature aircraft to the approximate nose-high indication for the predetermined climb speed. The attitude will vary according to the type of airplane. Apply light back-elevator pressure to initiate and maintain the climb attitude. The pressures will vary as the airplane decelerates. Power may be advanced to the climb power setting simultaneously with the pitch change, or after the pitch change is established and the airspeed approaches climb speed. If the transition from level flight to climb is smooth, the VSI will show an immediate trend upward, continue to move slowly, and then stop at a rate appropriate to the stabilized airspeed and attitude. (Primary and supporting instruments for the climb entry are shown in *Figure 5-25*.)

Once the airplane stabilizes at a constant airspeed and attitude, the ASI is primary for pitch and the heading indicator remains primary for bank. *[Figure 5-26]* Monitor the tachometer or manifold pressure gauge as the primary power instrument to ensure the proper climb power setting is being maintained. If the climb attitude is correct for the power setting selected, the airspeed will stabilize at the desired speed. If the airspeed is low or high, make an appropriately small pitch correction.

To enter a constant airspeed climb, first complete the airspeed reduction from cruise airspeed to climb speed in straight-and-level flight. The climb entry is then identical to entry from cruising airspeed, except that power must be increased simultaneously to the climb setting as the pitch attitude is increased. Climb entries on partial panel are more easily and accurately controlled if entering the maneuver from climbing speed.

The technique for entering a constant rate climb is very similar to that used for entry to a constant-airspeed climb from climb airspeed. As the power is increased to the approximate setting for the desired rate, simultaneously raise the miniature aircraft to the climbing attitude for the desired airspeed and rate of climb. As the power is increased, the ASI is primary for pitch control until the vertical speed approaches the desired value. As the vertical speed needle stabilizes, it becomes primary for pitch control and the ASI becomes primary for power control. *[Figure 5-27]*

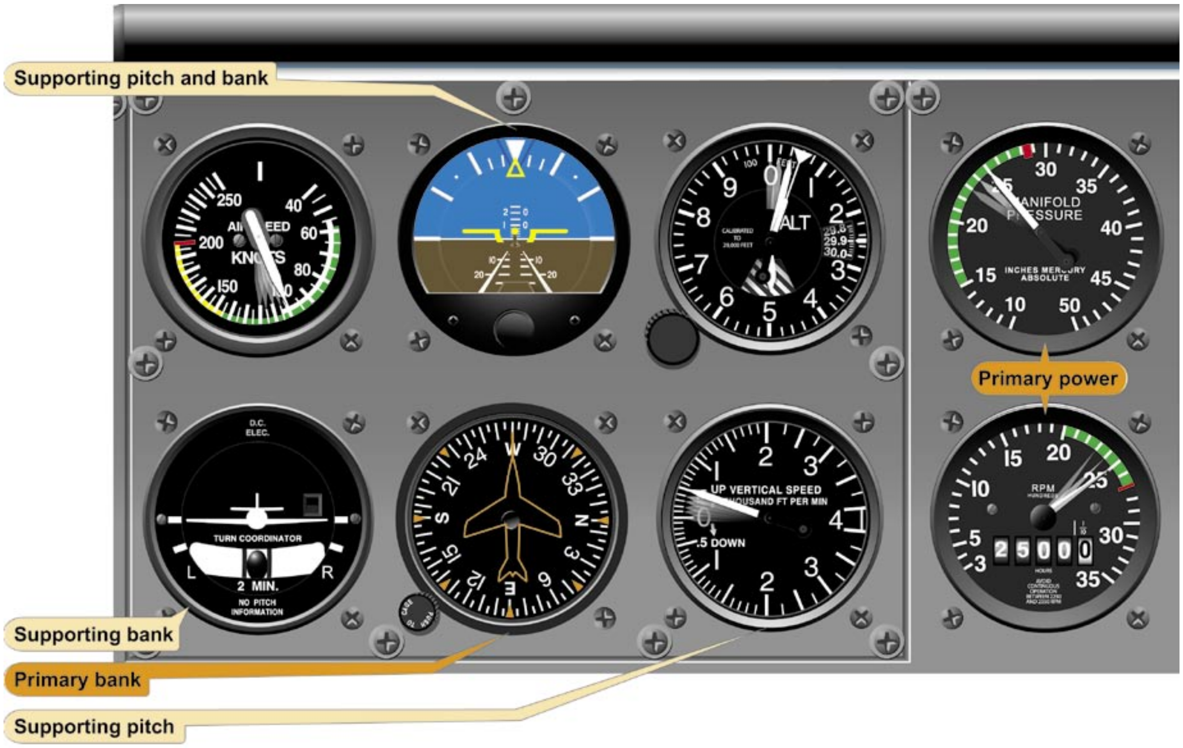

Figure 5-25. *Climb Entry for Constant Airspeed Climb.*

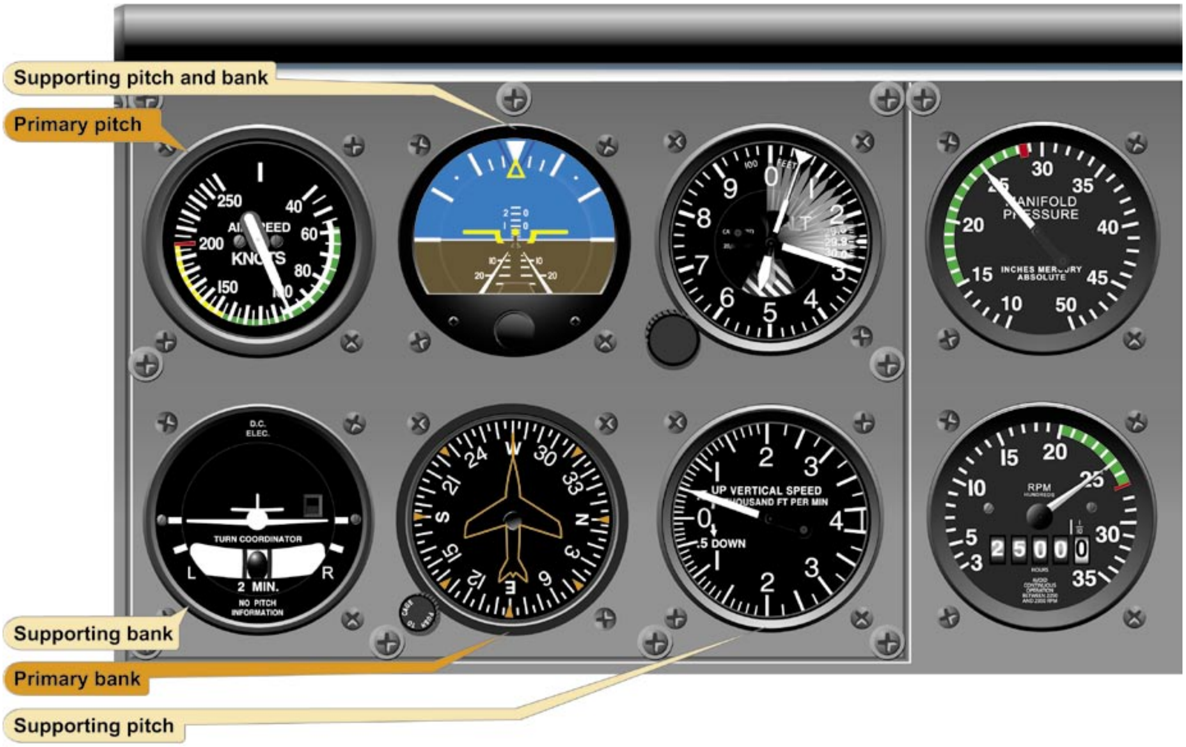
Supporting pitch and bank
Primary pitch
Supporting bank
Primary bank
Supporting pitch

Figure 5-26. *Stabilized Climb at Constant Airspeed.*

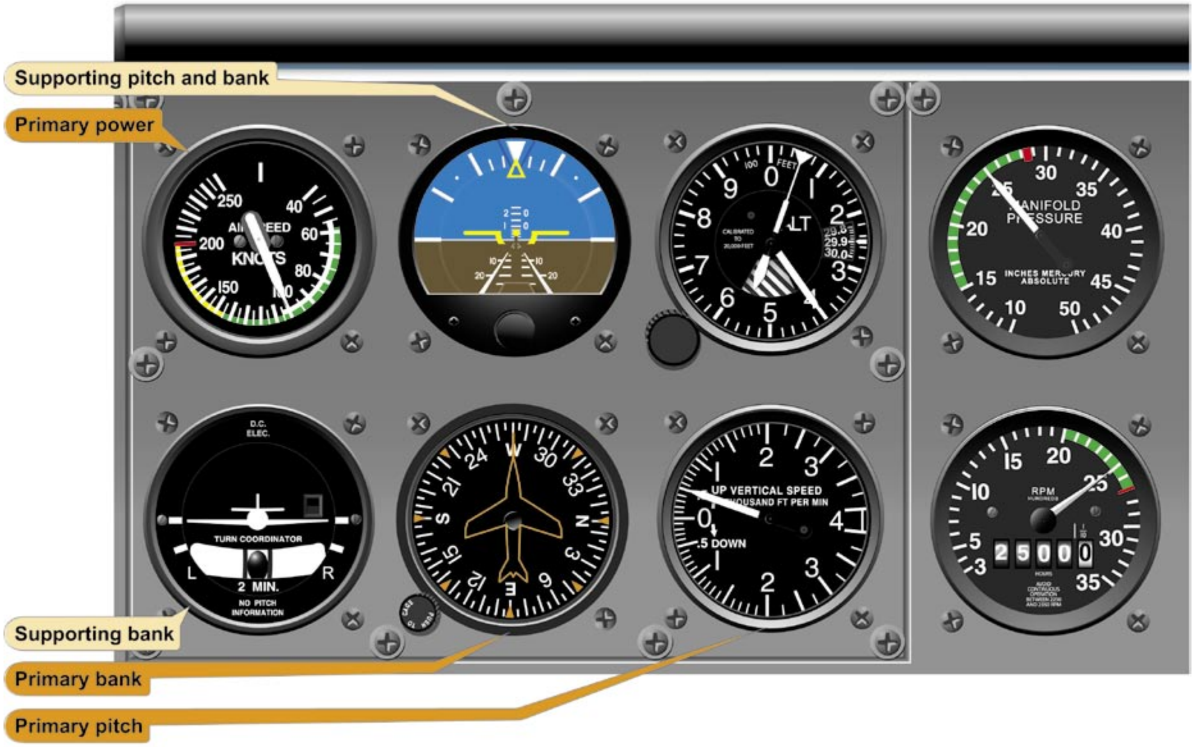
Supporting pitch and bank
Primary power
Supporting bank
Primary bank
Primary pitch

Figure 5-27. *Stabilized Climb at Constant Rate.*

Pitch and power corrections must be promptly and closely coordinated. For example, if the vertical speed is correct, but the airspeed is low, add power. As the power is increased, the miniature aircraft must be lowered slightly to maintain constant vertical speed. If the vertical speed is high and the airspeed is low, lower the miniature aircraft slightly and note the increase in airspeed to determine whether or not a power change is also necessary. *[Figure 5-28]* Familiarity with the approximate power settings helps to keep pitch and power corrections at a minimum.

Leveling Off

To level off from a climb and maintain an altitude, it is necessary to start the level off before reaching the desired altitude. The amount of lead varies with rate of climb and pilot technique. If the airplane is climbing at 1,000 fpm, it will continue to climb at a decreasing rate throughout the transition to level flight. An effective practice is to lead the altitude by 10 percent of the vertical speed shown (500 fpm/ 50-foot lead, 1,000 fpm/100-foot lead).

To level off at cruising airspeed, apply smooth, steady forward-elevator pressure toward level flight attitude for the speed desired. As the attitude indicator shows the pitch change, the vertical speed needle will move slowly toward zero, the altimeter needle will move more slowly, and the airspeed will show acceleration. *[Figure 5-29]* When the altimeter, attitude indicator, and VSI show level flight, constant changes in pitch and torque control will have to be made as the airspeed increases. As the airspeed approaches cruising speed, reduce power to the cruise setting. The amount of lead depends upon the rate of acceleration of the airplane.

To level off at climbing airspeed, lower the nose to the pitch attitude appropriate to that airspeed in level flight. Power is simultaneously reduced to the setting for that airspeed as the pitch attitude is lowered. If power reduction is at a rate proportionate to the pitch change, airspeed will remain constant.

Descents

A descent can be made at a variety of airspeeds and attitudes by reducing power, adding drag, and lowering the nose to a predetermined attitude. The airspeed will eventually stabilize at a constant value. Meanwhile, the only flight instrument providing a positive attitude reference, is the attitude indicator. Without the attitude indicator (such as during a partial panel descent), the ASI, the altimeter, and the VSI will show varying rates of change until the airplane decelerates to a constant airspeed at a constant attitude. During the transition, changes in control pressure and trim, as well as cross-check and interpretation, must be accurate to maintain positive control.

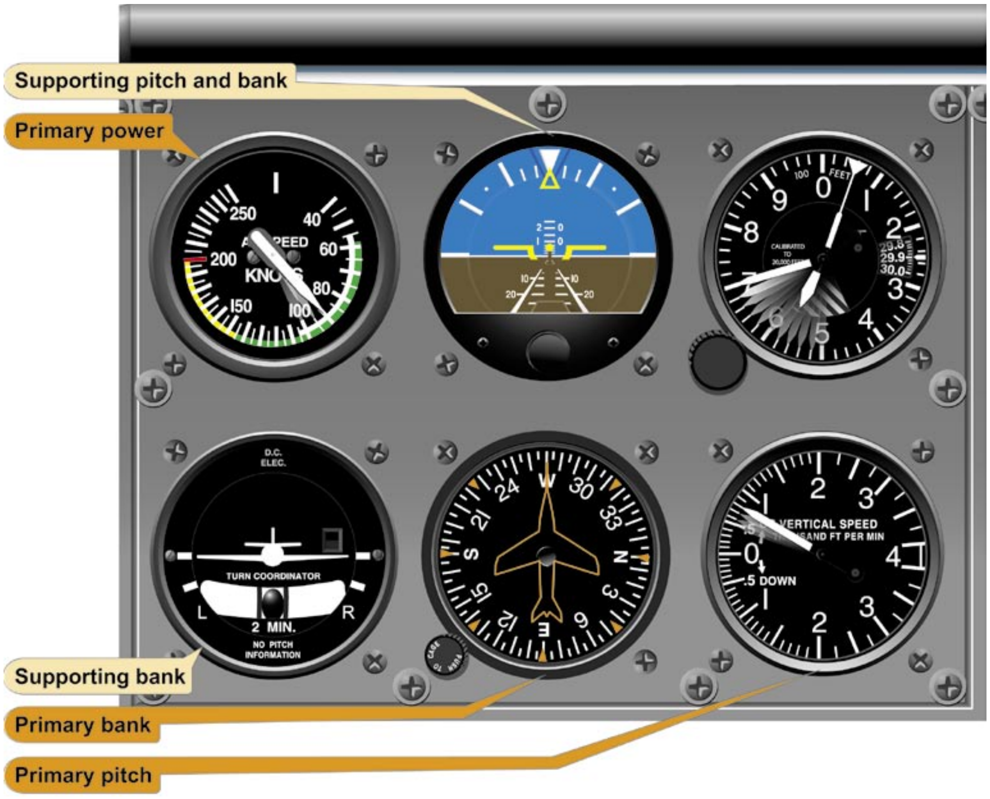

Figure 5-28. *Airspeed Low and Vertical Speed High—Reduce Pitch.*

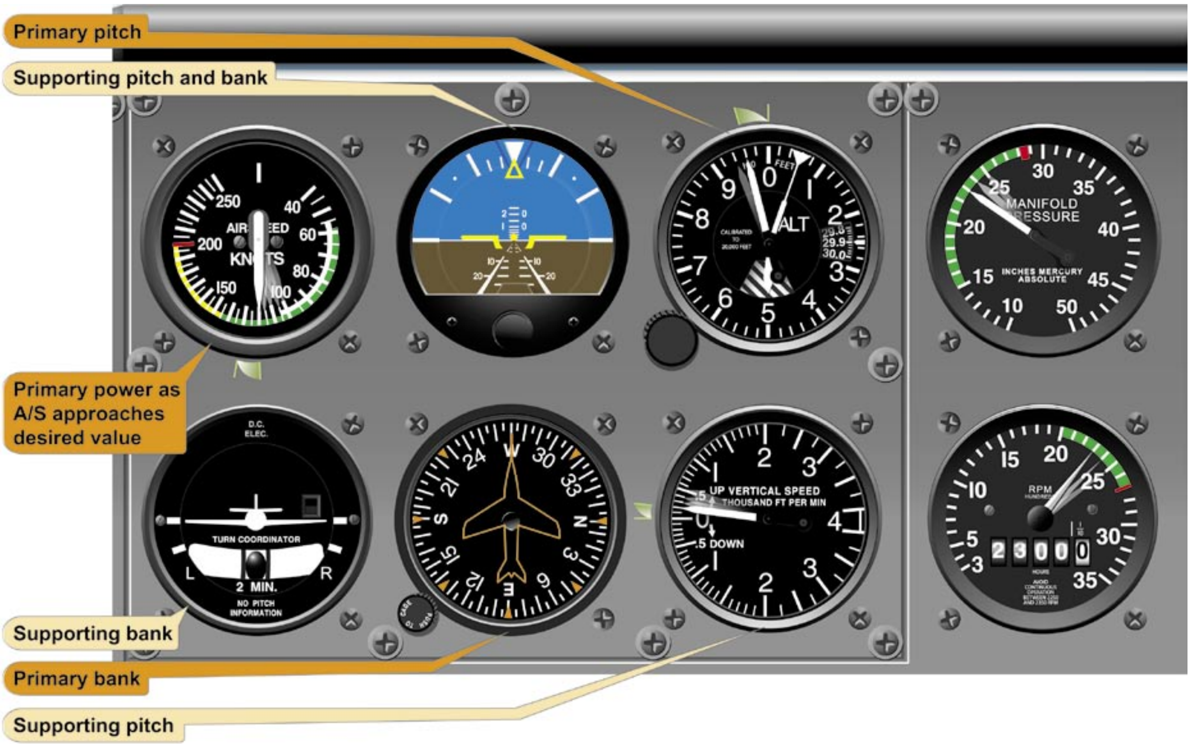
Primary pitch
Supporting pitch and bank
Primary power as A/S approaches desired value
Supporting bank
Primary bank
Supporting pitch

Figure 5-29. *Level Off at Cruising Speed.*

Entry

The following method for entering descents is effective with or without an attitude indicator. First, reduce airspeed to a selected descent airspeed while maintaining straight-and-level flight, then make a further reduction in power (to a predetermined setting). As the power is adjusted, simultaneously lower the nose to maintain constant airspeed, and trim off control pressures.

During a constant airspeed descent, any deviation from the desired airspeed calls for a pitch adjustment. For a constant rate descent, the entry is the same, but the VSI is primary for pitch control (after it stabilizes near the desired rate), and the ASI is primary for power control. Pitch and power must be closely coordinated when corrections are made, as they are in climbs. *[Figure 5-30]*

Leveling Off

The level off from a descent must be started before reaching the desired altitude. The amount of lead depends upon the rate of descent and control technique. With too little lead, the airplane will tend to overshoot the selected altitude unless technique is rapid. Assuming a 500 fpm rate of descent, lead the altitude by 100–150 feet for a level off at an airspeed higher than descending speed. At the lead point, add power to the appropriate level flight cruise setting. *[Figure 5-31]* Since the nose will tend to rise as the airspeed increases, hold forward elevator pressure to maintain the vertical speed at the descending rate until approximately 50 feet above the altitude, and then smoothly adjust the pitch attitude to the level flight attitude for the airspeed selected.

To level off from a descent at descent airspeed, lead the desired altitude by approximately 50 feet, simultaneously adjusting the pitch attitude to level flight and adding power to a setting that will hold the airspeed constant. *[Figure 5-32]* Trim off the control pressures and continue with the normal straight-and-level flight cross-check.

Common Errors in Straight Climbs and Descents

Common errors result from the following faults:

1. Overcontrolling pitch on climb entry. Until the pitch attitudes related to specific power settings used in climbs and descents are known, larger than necessary pitch adjustments are made. One of the most difficult habits to acquire during instrument training is to restrain the impulse to disturb a flight attitude until the result is known. Overcome the inclination to make a large control movement for a pitch change, and learn to apply small control pressures smoothly, cross-checking rapidly for the results of the change, and continuing with the pressures as instruments show the desired results. Small pitch changes can be easily controlled, stopped, and corrected; large changes are more difficult to control.

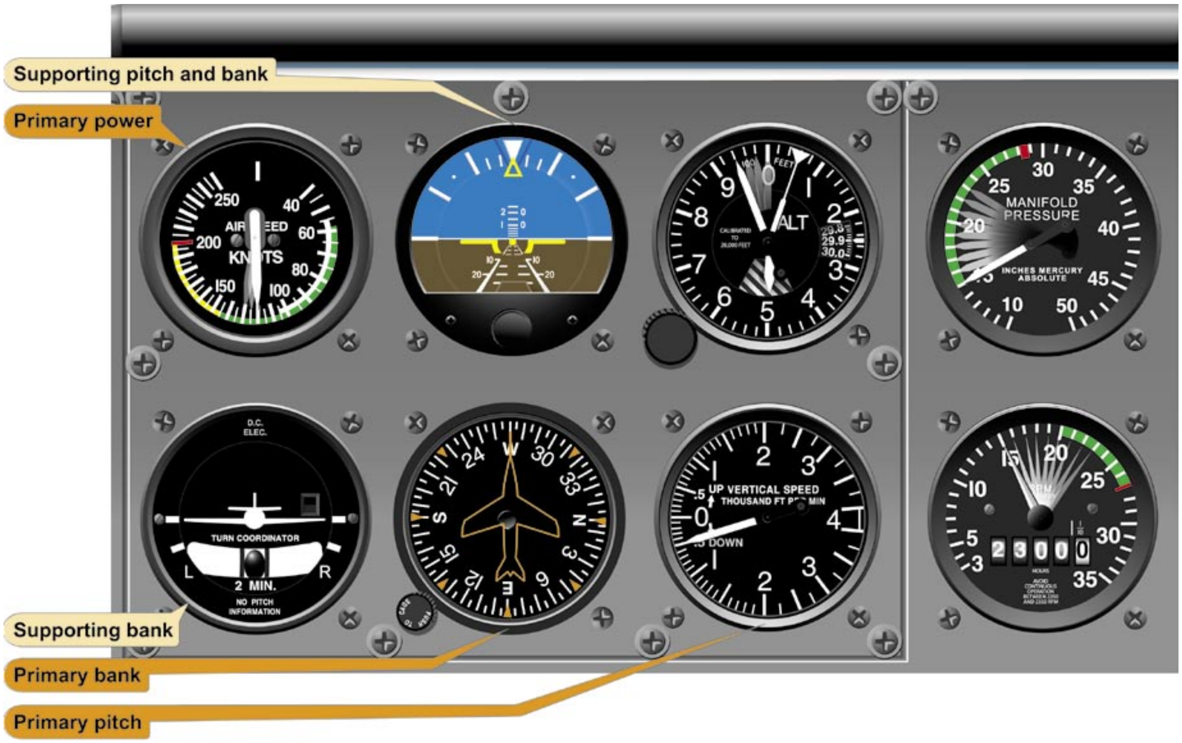
Supporting pitch and bank
Primary power
Supporting bank
Primary bank
Primary pitch

Figure 5-30. *Constant Airspeed Descent, Airspeed High—Reduce Power.*

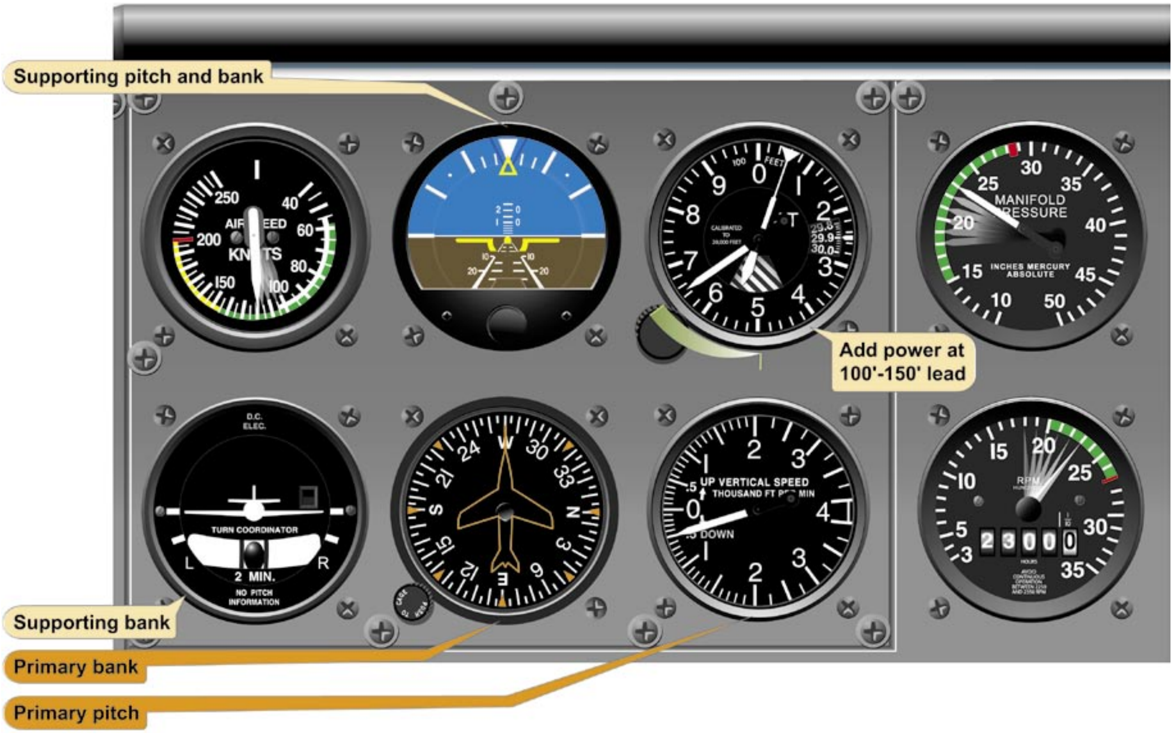
Supporting pitch and bank
Add power at
100'-150' lead
Supporting bank
Primary bank
Primary pitch

Figure 5-31. *Level Off Airspeed Higher Than Descent Airspeed.*

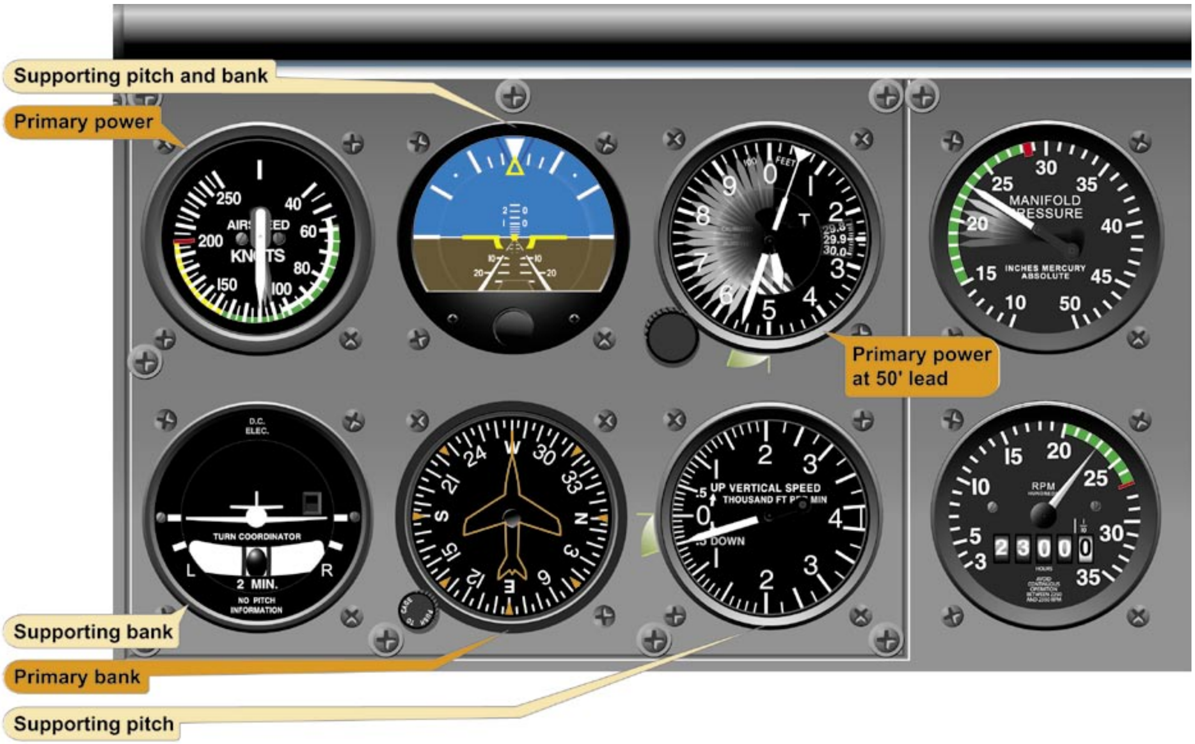

Figure 5-32. *Level Off at Descent Airspeed.*

2. Failure to vary the rate of cross-check during speed, power, or attitude changes or climb or descent entries.
3. Failure to maintain a new pitch attitude. For example, raising the nose to the correct climb attitude, and as the airspeed decreases, either overcontrol and further increase the pitch attitude, or allow the nose to lower. As control pressures change with airspeed changes, cross-check must be increased and pressures readjusted.
4. Failure to trim off pressures. Unless the airplane is trimmed, there will be difficulty in determining whether control pressure changes are induced by aerodynamic changes or by the pilot's own movements.
5. Failure to learn and use proper power settings.
6. Failure to cross-check both airspeed and vertical speed before making pitch or power adjustments.
7. Improper pitch and power coordination on slow-speed level offs, due to slow cross-check of airspeed and altimeter indications.
8. Failure to cross-check the VSI against the other pitch control instruments, resulting in chasing the vertical speed.
9. Failure to note the rate of climb or descent to determine the lead for level offs, resulting in overshooting or undershooting the desired altitude.
10. Ballooning (allowing the nose to pitch up) on level offs from descents, resulting from failure to maintain descending attitude with forward-elevator pressure as power is increased to the level flight cruise setting.
11. Failure to recognize the approaching straight-and-level flight indications as level off is completed. Maintain an accelerated cross-check until positively established in straight-and-level flight.

Turns

Standard Rate Turns

A standard rate turn is one in which the pilot will do a complete 360° circle in two minutes, or 3° per second. A standard rate turn, although always 3° per second, will require higher angles of bank as airspeed increases. To enter a standard rate level turn, apply coordinated aileron and rudder pressures in the desired direction of turn. Pilots commonly roll into turns at a much too rapid rate. During initial training in turns, base control pressures on the rate of cross-check and interpretation. Maneuvering an airplane faster than the capability to keep up with the changes in instrument indications only creates the need to make corrections.

A rule of thumb to determine the approximate angle of bank required for a standard rate turn is to use 15 percent of the true airspeed. A simple way to determine this amount is to divide the airspeed by 10 and add one-half the result. For example, at 100 knots, approximately 15° of bank is required (100 ÷ 10 = 10 + 5 = 15); at 120 knots, approximately 18° of bank is needed for a standard rate turn.

On the roll-in, use the attitude indicator to establish the approximate angle of bank, and then check the turn coordinator's miniature aircraft for a standard rate turn indication or the aircraft's turn-and-bank indicator. Maintain the bank for this rate of turn, using the turn coordinator's miniature aircraft as the primary bank reference and the attitude indicator as the supporting bank instrument. *[Figure 5-33]* Note the exact angle of bank shown on the banking scale of the attitude indicator when the turn coordinator indicates a standard rate turn.

During the roll-in, check the altimeter, VSI, and attitude indicator for the necessary pitch adjustments as the vertical lift component decreases with an increase in bank. If constant airspeed is to be maintained, the ASI becomes primary for power, and the throttle must be adjusted as drag increases. As the bank is established, trim off the pressures applied during pitch and power changes.

To recover to straight-and-level flight, apply coordinated aileron and rudder pressures opposite to the direction of the turn. Strive for the same rate of roll-out used to roll into the turn; fewer problems will be encountered in estimating the lead necessary for roll-out on exact headings, especially on partial panel maneuvers. Upon initiation of the turn recovery, the attitude indicator becomes the primary bank instrument. When the airplane is approximately level, the heading indicator is the primary bank instrument as in straight-and-level flight. Pitch, power, and trim adjustments are made as changes in vertical lift component and airspeed occur. The ball should be checked throughout the turn, especially if control pressures are held rather than trimmed off.

Some airplanes are very stable during turns, requiring only slight trim adjustments that permit hands-off flight while the airplane remains in the established attitude. Other airplanes require constant, rapid cross-check and control during turns to correct overbanking tendencies. Due to the interrelationship of pitch, bank, and airspeed deviations during turns, cross-check must be fast in order to prevent an accumulation of errors.

Turns to Predetermined Headings

As long as an airplane is in a coordinated bank, it continues to turn. Thus, the roll-out to a desired heading must be started before the heading is reached. The amount of lead varies with the relationship between the rate of turn, angle of bank, and rate of recovery. For small heading changes, use a bank angle that does not exceed the number of degrees to be turned. Lead the desired heading by one-half the number of degrees of bank used. For example, if a 10° bank is used during a change in heading, start the roll-out 5° before reaching the desired heading. For larger changes in heading, the amount

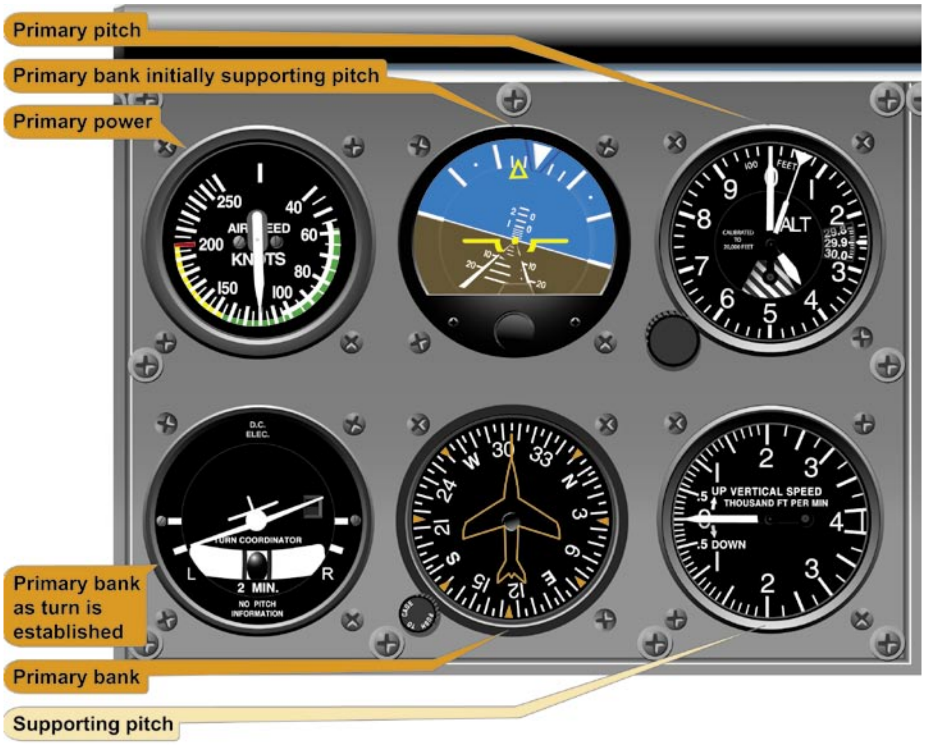

Figure 5-33. *Standard Rate Turn, Constant Airspeed.*

of lead varies since the angle of bank for a standard rate turn varies with the true airspeed.

Practice with a lead of one-half the angle of bank until the precise lead a given technique requires is determined. If rates of roll-in and roll-out are consistent, the precise amount of lead suitable to a particular roll-out technique can be determined.

Timed Turns

A timed turn is a turn in which the clock and the turn coordinator are used to change heading by a specific number of degrees in a given time. For example, in a standard rate turn (3° per second), an airplane turns 45° in 15 seconds; in a half standard rate turn, the airplane turns 45° in 30 seconds.

Prior to performing timed turns, the turn coordinator should be calibrated to determine the accuracy of its indications. *[Figure 5-34]* Establish a standard rate turn as indicated by the turn coordinator, and as the sweep-second hand of the clock passes a cardinal point (12, 3, 6, 9), check the heading on the heading indicator. While holding the indicated rate of turn constant, note the indicated heading changes at 10 second intervals. If the airplane turns more than or less than 30° in that interval, a respectively larger or smaller deflection of the miniature aircraft of the turn coordinator is necessary to produce a standard rate turn. After calibrating the turn coordinator during turns in each direction, note the corrected deflections, if any, and apply them during all timed turns.

The same cross-check and control technique is used in making a timed turn that is used to execute turns to predetermined headings, except the clock is substituted for the heading indicator. The miniature aircraft of the turn coordinator is primary for bank control, the altimeter is primary for pitch control, and the ASI is primary for power control. Start the roll-in when the clock's second hand passes a cardinal point, hold the turn at the calibrated standard rate indication (or half-standard rate for small heading changes), and begin the roll-out when the computed number of seconds has elapsed. If the rates of roll-in and roll-out are the same, the time taken during entry and recovery does not need to be considered in the time computation.

Practice timed turns with a full instrument panel and check the heading indicator for the accuracy of turns. If the turns are executed without the gyro heading indicator, use the magnetic compass at the completion of the turn to check turn accuracy, taking compass deviation errors into consideration.

Compass Turns

In most small airplanes, the magnetic compass is the only direction-indicating instrument independent of other airplane instruments and power sources. Because of its operating characteristics, called compass errors, pilots are prone to use it only as a reference for setting the heading indicator, but knowledge of magnetic compass characteristics permits full use of the instrument to turn the airplane to correct and maintain headings.

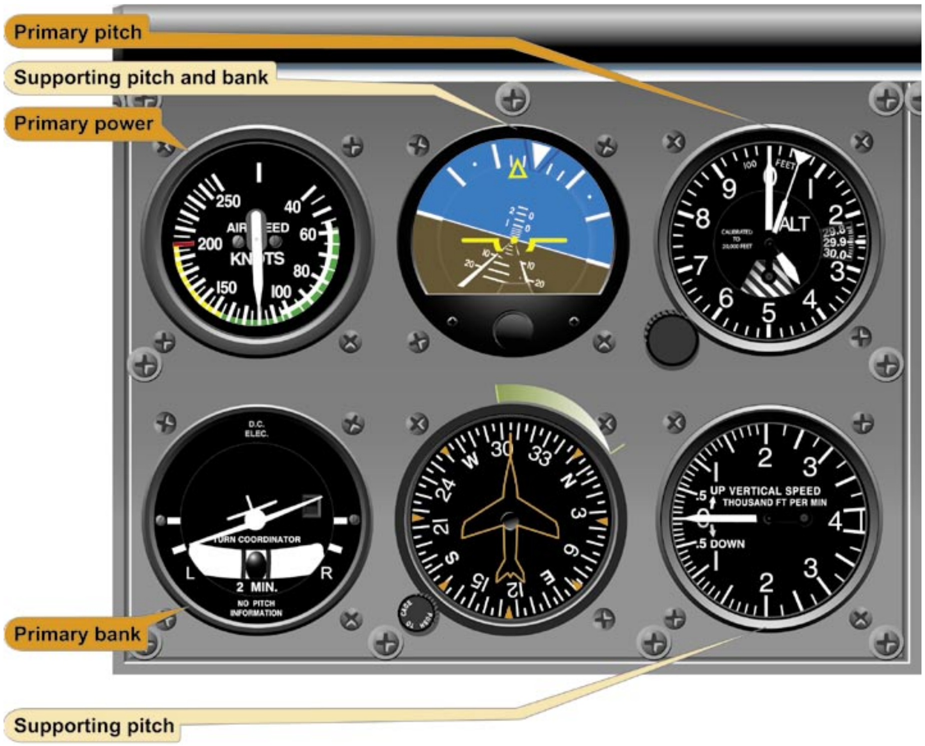

Figure 5-34. *Turn Coordinator Calibration.*

Remember the following points when making turns to magnetic compass headings or when using the magnetic compass as a reference for setting the heading indicator:

1. If on a north heading and a turn is started to the east or west, the compass indication lags, or indicates a turn in the opposite direction.
2. If on a south heading and a turn is started toward the east or west, the compass indication precedes the turn, indicating a greater amount of turn than is actually occurring.
3. When on an east or west heading, the compass indicates correctly when starting a turn in either direction.
4. If on an east or west heading, acceleration results in a north turn indication; deceleration results in a south turn indication.
5. When maintaining a north or south heading, no error results from diving, climbing, or changing airspeed.

With an angle of bank between 15° and 18°, the amount of lead or lag to be used when turning to northerly or southerly headings varies with, and is approximately equal to, the latitude of the locality over which the turn is being made. When turning to a heading of north, the lead for roll-out must include the number of degrees of change of latitude, plus the lead normally used in recovery from turns. During a turn to a south heading, maintain the turn until the compass passes south the number of degrees of latitude, minus normal roll-out lead. *[Figure 5-35]*

For example, when turning from an easterly direction to north, where the latitude is 30°, start the roll-out when the compass reads 37° (30° plus one-half the 15° angle of bank, or whatever amount is appropriate for the rate of roll-out). When turning from an easterly direction to south, start the roll-out when the magnetic compass reads 203° (180° plus 30° minus one-half the angle of bank). When making similar turns from a westerly direction, the appropriate points at which to begin the roll-out would be 323° for a turn to north, and 157° for a turn to south.

When turning to a heading of east or west from a northerly direction, start the roll-out approximately 10° to 12° before the east or west indication is reached. When turning to an east or west heading from a southerly direction, start the rollout approximately 5° before the east or west indication is reached. When turning to other headings, the lead or lag must be interpolated.

Abrupt changes in attitude or airspeed and the resulting erratic movements of the compass card make accurate interpretations of the instrument very difficult. Proficiency in compass turns depends on knowledge of compass characteristics, smooth control technique, and accurate bank-and-pitch control.

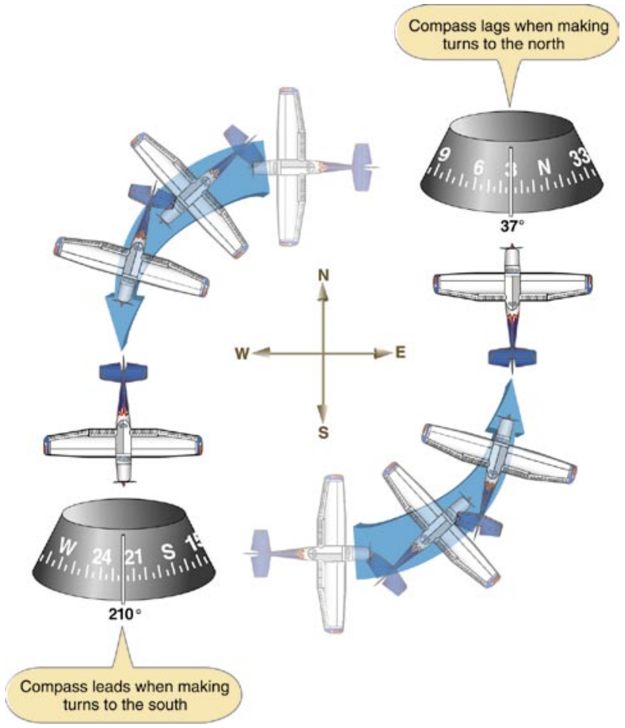
Compass lags when making turns to the north
9
6
3
N
33
37°
N
W
E
S
W
24
21
S
15
210°
Compass leads when making turns to the south

Figure 5-35. *North and South Turn Error.*

Steep Turns

For purposes of instrument flight training in conventional airplanes, any turn greater than a standard rate is considered steep. *[Figure 5-36]* The exact angle of bank at which a normal turn becomes steep is unimportant. What is important is learning to control the airplane with bank attitudes in excess of those normally used on instruments. Practicing steep turns will not only increase proficiency in the basic instrument flying skills, but also enable smooth, quick, and confident reactions to unexpected abnormal flight attitudes under instrument flight conditions.

Pronounced changes occur in the effects of aerodynamic forces on aircraft control at progressively greater bank attitudes. Skill in cross-check, interpretation, and control is increasingly necessary in proportion to the amount of these changes, though the techniques for entering, maintaining, and recovering from the turn are the same in principle for steep turns as for shallower turns.

Enter a steep turn in the same way as a shallower turn, but prepare to cross-check rapidly as the turn steepens. Because of the greatly reduced vertical lift component, pitch control is usually the most difficult aspect of this maneuver. Unless immediately noted and corrected with a pitch increase, the loss of vertical lift results in rapid movement of the altimeter, vertical speed, and airspeed needles. The faster the rate of bank change, the more suddenly the lift changes occur. If a cross-check is fast enough to note the immediate need for pitch changes, smooth, steady back elevator pressure will maintain constant altitude. However, overbanking to excessively steep angles without adjusting pitch as the bank changes occur, requires increasingly stronger elevator pressure. The loss of vertical lift and increase in wing loading finally reach a point at which further application of back-elevator pressure tightens the turn without raising the nose.

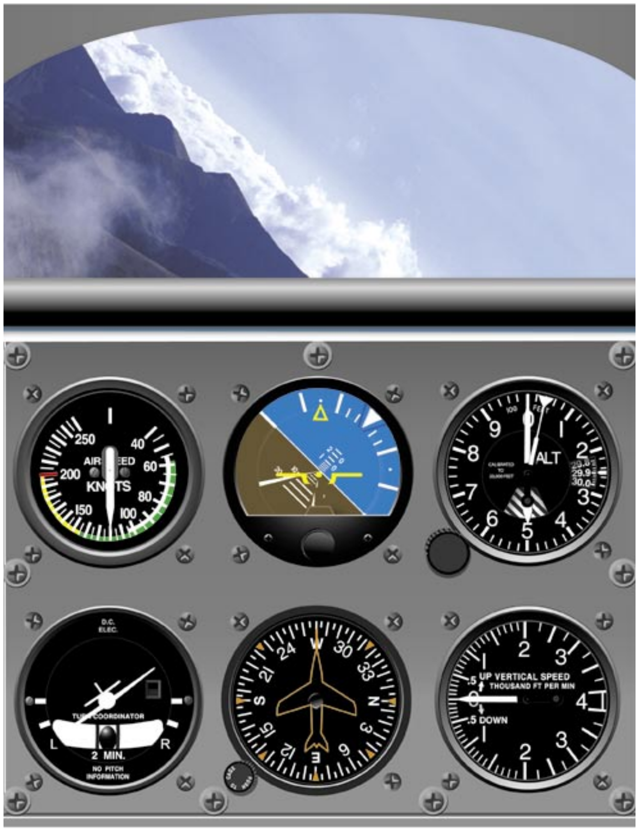
AIRSPEED
KNOTS
ALT
D.C. ELEC.
TURN COORDINATOR
L
R
2 MIN.
NO PITCH INFORMATION
UP VERTICAL SPEED THOUSAND FT PER MIN
DOWN

Figure 5-36. *Steep Left Turn.*

How does a pilot recognize overbanking and low pitch attitude? What should a pilot do to correct them? If a rapid downward movement of the altimeter needle or vertical speed needle, together with an increase in airspeed, is observed despite application of back elevator pressure, the airplane is in a diving spiral. *[Figure 5-37]* Immediately shallow the bank with smooth and coordinated aileron and rudder pressures, hold or slightly relax elevator pressure, and increase the cross-check of the attitude indicator, altimeter, and VSI. Reduce power if the airspeed increase is rapid. When the vertical speed trends upward, the altimeter needle will move slower as the vertical lift increases. When the elevator is effective in raising the nose, hold the bank attitude shown on the attitude indicator and adjust elevator control pressures smoothly for the nose-high attitude appropriate to the bank maintained. If pitch control is consistently late on entries to steep turns, rollout immediately to straight-and-level flight and analyze possible errors. Practice shallower turns initially and learn the attitude changes and control responses required, then increase the banks as a quicker and more accurate cross-check and control techniques are developed.

The power necessary to maintain constant airspeed increases as the bank and drag increase. With practice, the power

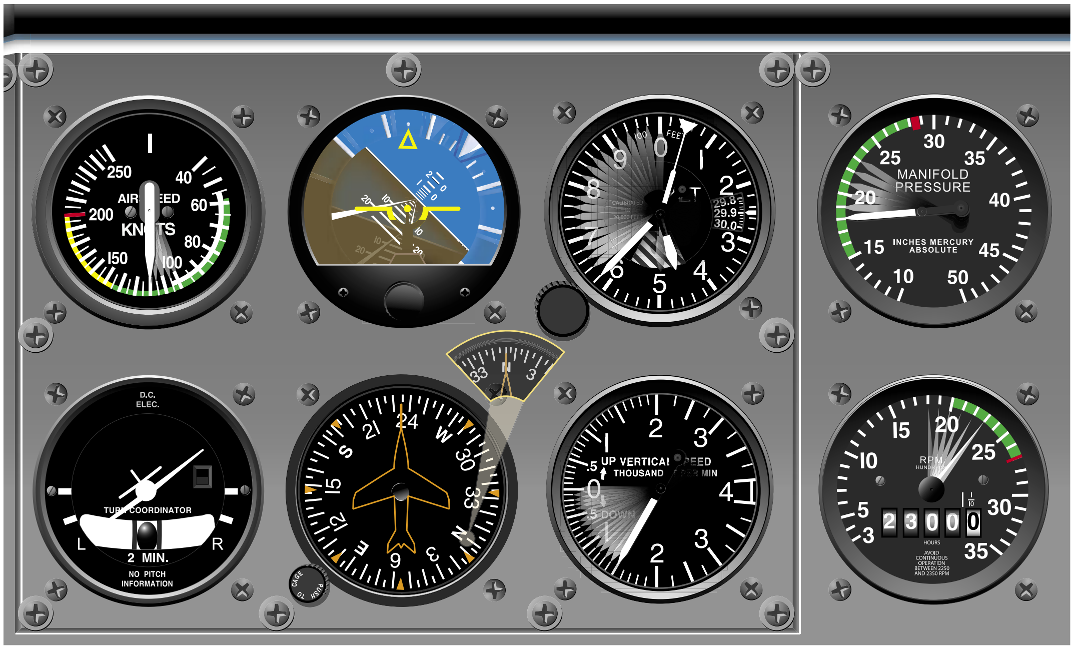
AIRSPEED
KNOTS
MANIFOLD PRESSURE
INCHES MERCURY ABSOLUTE
D.C. ELEC.
TURN COORDINATOR
L
R
2 MIN.
NO PITCH INFORMATION
UP VERTICAL SPEED THOUSAND FT PER MIN
DOWN
RPM
2 3 0 0 0
HOURS

Figure 5-37. *Diving Spiral.*

settings appropriate to specific bank attitudes are learned, and adjustments can be made without undue attention to airspeed and power instruments. During training in steep turns, as in any other maneuver, attend to the most important tasks first. Keep the pitch attitude relatively constant, and more time can be devoted to cross-check and instrument interpretation.

During recovery from steep turns to straight-and-level flight, elevator and power control must be coordinated with bank control in proportion to the changes in aerodynamic forces. Back elevator pressures must be released and power decreased. The common errors associated with steep turns are the same as those discussed later in this section. Remember, errors are more exaggerated, more difficult to correct, and more difficult to analyze unless rates of entry and recovery are consistent with the level of proficiency in the three basic instrument flying skills.

Climbing and Descending Turns

To execute climbing and descending turns, combine the technique used in straight climbs and descents with the various turn techniques. The aerodynamic factors affecting lift and power control must be considered in determining power settings, and the rate of cross-check and interpretation must be increased to enable control of bank as well as pitch changes.

Change of Airspeed During Turns

Changing airspeed during turns is an effective maneuver for increasing proficiency in all three basic instrument skills. Since the maneuver involves simultaneous changes in all components of control, proper execution requires rapid cross-check and interpretation as well as smooth control. Proficiency in the maneuver will also contribute to confidence in the instruments during attitude and power changes involved in more complex maneuvers. Pitch and power control techniques are the same as those used during changes in airspeed in straight-and-level flight.

The angle of bank necessary for a given rate of turn is proportional to the true airspeed. Since the turns are executed at a standard rate, the angle of bank must be varied in direct proportion to the airspeed change in order to maintain a constant rate of turn. During a reduction of airspeed, decrease the angle of bank and increase the pitch attitude to maintain altitude and a standard rate turn.

The altimeter and turn coordinator indications should remain constant throughout the turn. The altimeter is primary for pitch control and the miniature aircraft of the turn coordinator is primary for bank control. The manifold pressure gauge (or tachometer) is primary for power control while the airspeed is changing. As the airspeed approaches the new indication, the ASI becomes primary for power control.

Two methods of changing airspeed in turns may be used. In the first method, airspeed is changed after the turn is established. *[Figure 5-38]* In the second method, the airspeed change is initiated simultaneously with the turn entry. The first method is easier, but regardless of the method used, the rate of cross-check must be increased as power is reduced. As the airplane decelerates, check the altimeter and VSI for necessary pitch changes and the bank instruments for required bank changes. If the miniature aircraft of the turn coordinator indicates a deviation from the desired deflection, adjust the bank. Adjust

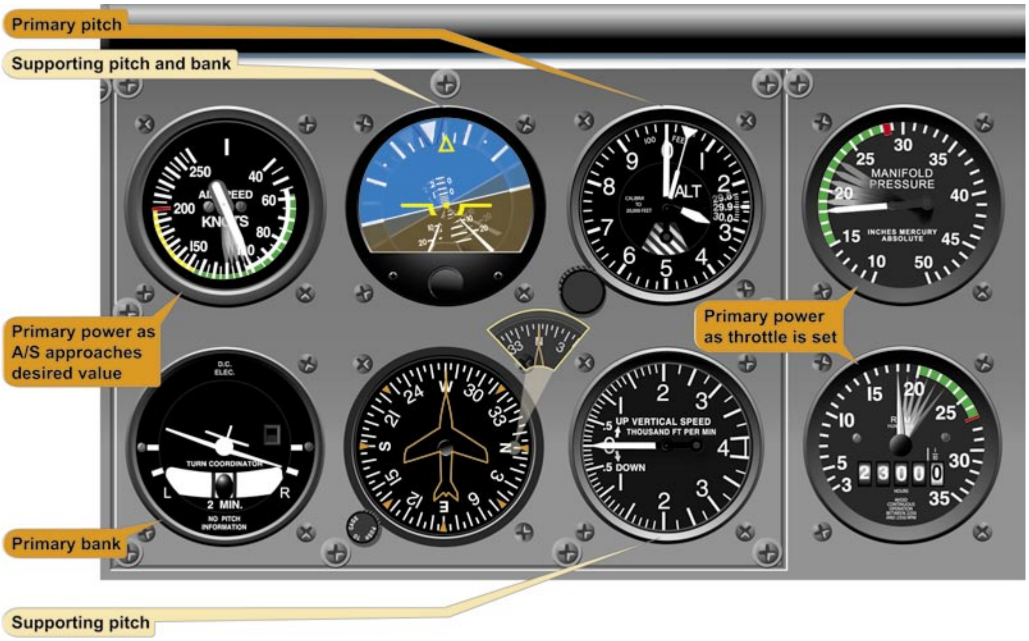

Figure 5-38. *Change of Airspeed During Turn.*

pitch attitude to maintain altitude. When approaching the desired airspeed, pitch attitude becomes primary for power control and the manifold pressure gauge (or tachometer) is adjusted to maintain the desired airspeed. Trim is important throughout the maneuver to relieve control pressures.

Until control technique is very smooth, frequent cross-check of the attitude indicator is essential to prevent overcontrolling and to provide approximate bank angles appropriate to the changing airspeeds.

Common Errors in Turns

Pitch

Pitch errors result from the following faults:

1. Preoccupation with bank control during turn entry and recovery. If 5 seconds are required to roll into a turn, check the pitch instruments as bank pressures are initiated. If bank control pressure and rate of bank change are consistent, a sense of the time required for an attitude change will be developed. During the interval, check pitch, power, and trim—as well as bank—controlling the total attitude instead of one factor at a time.
2. Failure to understand or remember the need for changing the pitch attitude as the vertical lift component changes, resulting in consistent loss of altitude during entries.
3. Changing the pitch attitude before it is necessary. This fault is very likely if a cross-check is slow and rate of entry too rapid. The error occurs during the turn entry due to a mechanical and premature application of back-elevator control pressure.
4. Overcontrolling the pitch changes. This fault commonly occurs with the previous error.
5. Failure to properly adjust the pitch attitude as the vertical lift component increases during the roll-out, resulting in consistent gain in altitude on recovery to headings.
6. Failure to trim during turn entry and following turn recovery (if turn is prolonged).
7. Failure to maintain straight-and-level cross-check after roll-out. This error commonly follows a perfectly executed turn.
8. Erratic rates of bank change on entry and recovery, resulting from failure to cross-check the pitch instruments with a consistent technique appropriate to the changes in lift.

Bank

Bank and heading errors result from the following faults:

1. Overcontrolling, resulting in overbanking upon turn entry, overshooting and undershooting headings, as well as aggravated pitch, airspeed, and trim errors.
2. Fixation on a single bank instrument. On a 90° change of heading, for example, leave the heading indicator out of the cross-check for approximately 20 seconds after establishing a standard rate turn, since at 3° per second the turn will not approach the lead point until that time has elapsed. Make the cross-check selective, checking only what needs to be checked at the appropriate time.
3. Failure to check for precession of the horizon bar following recovery from a turn. If the heading indicator shows a change in heading when the attitude indicator shows level flight, the airplane is turning. If the ball is centered, the attitude gyro has processed; if the ball is not centered, the airplane may be in a slipping or skidding turn. Center the ball with rudder pressure, check the attitude indicator and heading indicator, stop the heading change if it continues, and retrim.
4. Failure to use the proper degree of bank for the amount of heading change desired. Rolling into a 20° bank for a heading change of 10° will normally overshoot the heading. Use the bank attitude appropriate to the amount of heading change desired.
5. Failure to remember the heading to which the aircraft is being turned. This fault is likely when rushing the maneuver.
6. Turning in the wrong direction, due to misreading or misinterpreting the heading indicator, or to confusion regarding the location of points on the compass. Turn in the shortest direction to reach a given heading, unless there is a specific reason to turn the long way around. Study the compass rose and visualize at least the positions of the eight major points around the azimuth. A number of methods can be used to make quick computations for heading changes. For example, to turn from a heading of 305° to a heading of 110°, would a pilot turn right or left for the shortest way around? Subtracting 200 from 305 and adding 20, gives 125° as the reciprocal of 305°; therefore, execute the turn to the right. Likewise, to figure the reciprocal of a heading less than 180°, add 200 and subtract 20. Computations are done more quickly using multiples of 100s and 10s than by adding or subtracting 180° from the actual heading; therefore, the method suggested above may save time and confusion.

7. Failure to check the ball of the turn coordinator when interpreting the instrument for bank information. If the roll rate is reduced to zero, the miniature aircraft of the turn coordinator indicates only direction and rate of turn. Unless the ball is centered, do not assume the turn is resulting from a banked attitude.

Power

Power and airspeed errors result from the following faults:

1. Failure to cross-check the ASI as pitch changes are made.
2. Erratic use of power control. This may be due to improper throttle friction control, inaccurate throttle settings, chasing the airspeed readings, abrupt or overcontrolled pitch-and-bank changes, or failure to recheck the airspeed to note the effect of a power adjustment.
3. Poor coordination of throttle control with pitch-and-bank changes, associated with slow cross-check or failure to understand the aerodynamic factors related to turns.

Trim

Trim errors result from the following faults:

1. Failure to recognize the need for a trim change due to slow cross-check and interpretation. For example, a turn entry at a rate too rapid for a cross-check leads to confusion in cross-check and interpretation, with resulting tension on the controls.
2. Failure to understand the relationship between trim and attitude/power changes.
3. Chasing the vertical speed needle. Overcontrolling leads to tension and prevents sensing the pressures to be trimmed off.
4. Failure to trim following power changes.

Errors During Compass Turns

In addition to the faults discussed above, the following errors connected with compass turns should be noted:

1. Faulty understanding or computation of lead and lag.
2. Fixation on the compass during the roll-out. Until the airplane is in straight-and-level unaccelerated flight, it is unnecessary to read the indicated heading. Accordingly, after the roll-out, cross-check for straight-and-level flight before checking the accuracy of the turn.

Approach to Stall

Practicing approach to stall recoveries in various airplane configurations should build confidence in a pilot's ability to control the airplane in unexpected situations. Approach to stall should be practiced from straight flight and from shallow banks. The objective is to practice recognition and recovery from the approach to a stall.

Prior to stall recovery practice, select a safe altitude above the terrain, an area free of conflicting air traffic, appropriate weather, and the availability of radar traffic advisory service.

Approaches to stalls are accomplished in the following configurations:

1. Takeoff configuration—should begin from level flight near liftoff speed. Power should be applied while simultaneously increasing the angle of attack to induce an indication of a stall.
2. Clean configuration—should begin from a reduced airspeed, such as pattern airspeed, in level flight. Power should be applied while simultaneously increasing the angle of attack to induce an indication of a stall.
3. Approach or landing configuration—should be initiated at the appropriate approach or landing airspeed. The angle of attack should be smoothly increased to induce an indication of a stall.

Recoveries should be prompt in response to a stall warning device or an aerodynamic indication by smoothly reducing the angle of attack and applying maximum power, or as recommended by the POH/AFM. The recovery should be completed without an excessive loss of altitude, and on a predetermined heading, altitude, and airspeed.

Unusual Attitudes and Recoveries

An unusual attitude is an airplane attitude not normally required for instrument flight. Unusual attitudes may result from a number of conditions, such as turbulence, disorientation, instrument failure, confusion, preoccupation with flight deck duties, carelessness in cross-checking, errors in instrument interpretation, or lack of proficiency in aircraft control. Since unusual attitudes are not intentional maneuvers during instrument flight, except in training, they are often unexpected, and the reaction of an inexperienced or inadequately trained pilot to an unexpected abnormal flight attitude is usually instinctive rather than intelligent and deliberate. This individual reacts with abrupt muscular effort, which is purposeless and even hazardous in turbulent conditions, at excessive speeds, or at low altitudes. However, with practice, the techniques for rapid and safe recovery from unusual attitudes can be mastered.

When an unusual attitude is noted during the cross-check, the immediate problem is not how the airplane got there, but what it is doing and how to get it back to straight-and-level flight as quickly as possible.

Recognizing Unusual Attitudes

As a general rule, any time an instrument rate of movement or indication other than those associated with the basic instrument flight maneuvers is noted, assume an unusual attitude and increase the speed of cross-check to confirm the attitude, instrument error, or instrument malfunction.

Nose-high attitudes are shown by the rate and direction of movement of the altimeter needle, vertical speed needle, and airspeed needle, as well as the immediately recognizable indication of the attitude indicator (except in extreme attitudes). *[Figure 5-39]* Nose-low attitudes are shown by the same instruments, but in the opposite direction. *[Figure 5-40]*

Recovery from Unusual Attitudes

In moderate unusual attitudes, the pilot can normally reorient by establishing a level flight indication on the attitude indicator. However, the pilot should not depend on this instrument if the attitude indicator is the spillable type, because its upset limits may have been exceeded or it may have become inoperative due to mechanical malfunction. If it is the nonspillable-type instrument and is operating properly, errors up to 5° of pitch-and-bank may result and its indications are very difficult to interpret in extreme attitudes. As soon as the unusual attitude is detected, the recommended recovery procedures stated in the POH/AFM should be initiated. If there are no recommended procedures stated in the POH/AFM, the recovery should be initiated by reference to the ASI, altimeter, VSI, and turn coordinator.

Nose-High Attitudes

If the airspeed is decreasing, or below the desired airspeed, increase power (as necessary in proportion to the observed deceleration), apply forward elevator pressure to lower the nose and prevent a stall, and correct the bank by applying coordinated aileron and rudder pressure to level the miniature aircraft and center the ball of the turn coordinator. The corrective control applications are made almost simultaneously, but in the sequence given above. A level pitch attitude is indicated by the reversal and stabilization

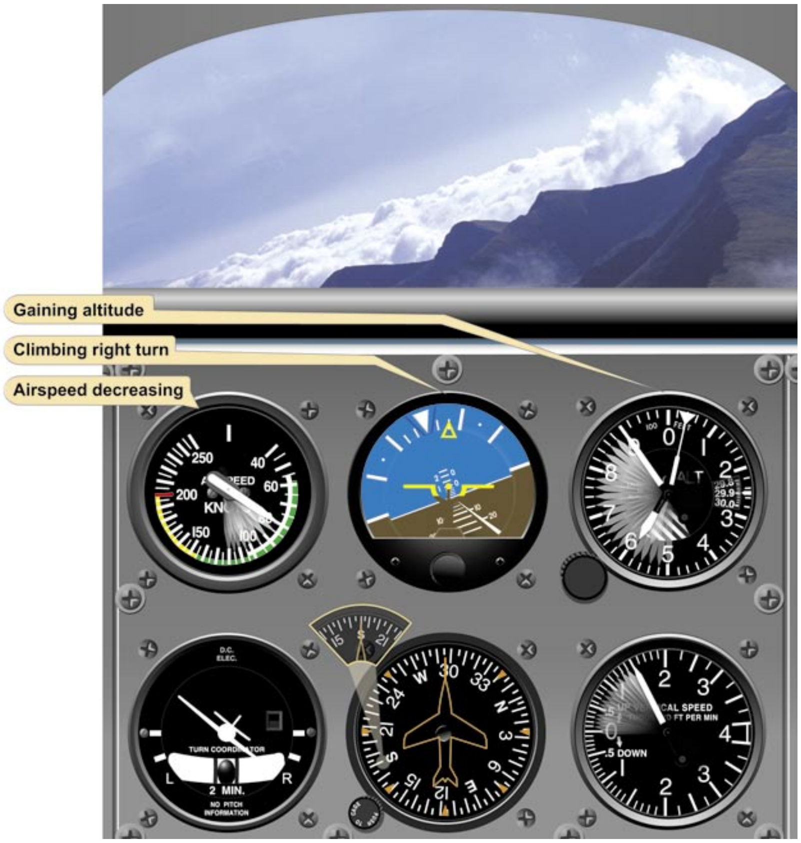

Figure 5-39. *Unusual Attitude—Nose-High.*

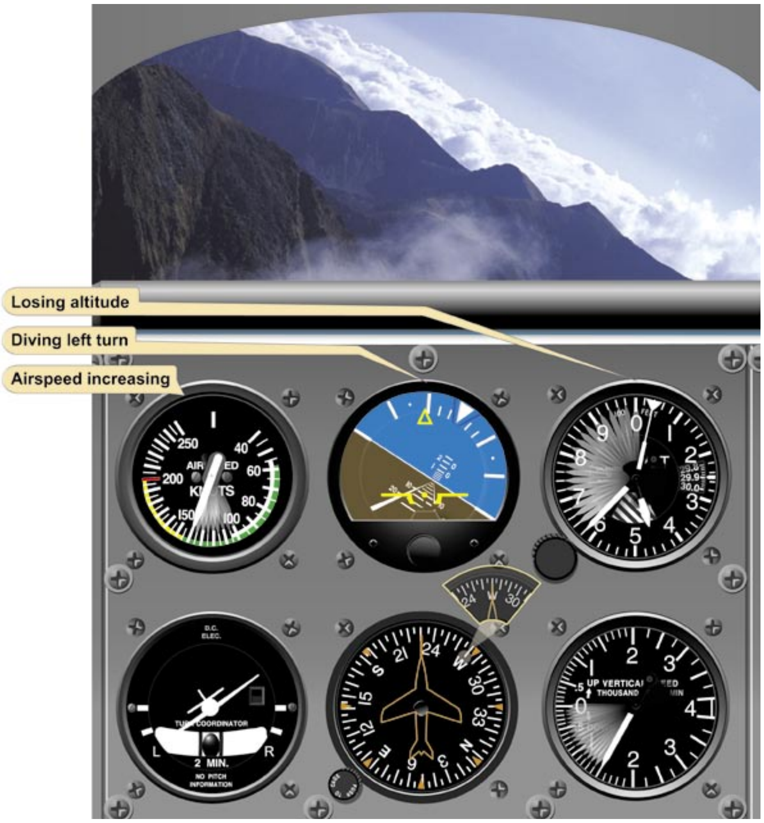

Figure 5-40. *Unusual Attitude—Nose-Low.*

of the ASI and altimeter needles. Straight coordinated flight is indicated by the level miniature aircraft and centered ball of the turn coordinator.

Nose-Low Attitudes

If the airspeed is increasing, or is above the desired airspeed, reduce power to prevent excessive airspeed and loss of altitude. Correct the bank attitude with coordinated aileron and rudder pressure to straight flight by referring to the turn coordinator. Raise the nose to level flight attitude by applying smooth back elevator pressure. All components of control should be changed simultaneously for a smooth, proficient recovery. However, during initial training a positive, confident recovery should be made by the numbers, in the sequence given above. A very important point to remember is that the instinctive reaction to a nose-down attitude is to pull back on the elevator control.

After initial control has been applied, continue with a fast cross-check for possible overcontrolling, since the necessary initial control pressures may be large. As the rate of movement of altimeter and ASI needles decreases, the attitude is approaching level flight. When the needles stop and reverse direction, the aircraft is passing through level flight. As the indications of the ASI, altimeter, and turn coordinator stabilize, incorporate the attitude indicator into the cross-check.

The attitude indicator and turn coordinator should be checked to determine bank attitude and then corrective aileron and rudder pressures should be applied. The ball should be centered. If it is not, skidding and slipping sensations can easily aggravate disorientation and retard recovery. If entering the unusual attitude from an assigned altitude (either by an instructor or by air traffic control (ATC) if operating under instrument flight rules (IFR)), return to the original altitude after stabilizing in straight-and-level flight.

Common Errors in Unusual Attitudes

Common errors associated with unusual attitudes include the following faults:

1. Failure to keep the airplane properly trimmed. A flight deck interruption when holding pressures can easily lead to inadvertent entry into unusual attitudes.
2. Disorganized flight deck. Hunting for charts, logs, computers, etc., can seriously distract attention from the instruments.
3. Slow cross-check and fixations. The impulse is to stop and stare when noting an instrument discrepancy unless a pilot has trained enough to develop the skill required for immediate recognition.

4. Attempting to recover by sensory sensations other than sight. The discussion of disorientation in Chapter 1, Human Factors, indicates the importance of trusting the instruments.
5. Failure to practice basic instrument skills. All of the errors noted in connection with basic instrument skills are aggravated during unusual attitude recoveries until the elementary skills have been mastered.

Instrument Takeoff

Competency in instrument takeoffs will provide the proficiency and confidence necessary for use of flight instruments during departures under conditions of low visibility, rain, low ceilings, or disorientation at night. A sudden rapid transition from "visual" to "instrument" flight can result in serious disorientation and control problems.

Instrument takeoff techniques vary with different types of airplanes, but the method described below is applicable whether the airplane is single- or multiengine; tricycle gear or conventional gear.

Align the airplane with the centerline of the runway with the nosewheel or tailwheel straight. Lock the tailwheel, if so equipped, and hold the brakes firmly to avoid creeping while preparing for takeoff. Set the heading indicator with the nose index on the 5° mark nearest the published runway heading to allow instant detection of slight changes in heading during the takeoff. Make certain that the instrument is uncaged (if it has a caging feature) by rotating the knob after uncaging and checking for constant heading indication. If using an electric heading indicator with a rotatable needle, rotate the needle so that it points to the nose position, under the top index. Advance the throttle to an rpm that will provide partial rudder control. Release the brakes, advancing the power smoothly to takeoff setting.

During the takeoff roll, hold the heading constant on the heading indicator by using the rudder. In multiengine, propeller-driven airplanes, also use differential throttle to maintain direction. The use of brakes should be avoided, except as a last resort, as it usually results in overcontrolling and extending the takeoff roll. Once the brakes are released, any deviation in heading must be corrected instantly.

As the airplane accelerates, cross-check both heading indicator and ASI rapidly. The attitude indicator may precess to a slight nose-up attitude. As flying speed is approached (approximately 15–25 knots below takeoff speed), smoothly apply elevator control for the desired takeoff attitude on the attitude indicator. This is approximately a two bar width climb indication for most small airplanes.

Continue with a rapid cross-check of heading indicator and attitude indicator as the airplane leaves the ground. Do not pull it off; let it fly off while holding the selected attitude constant. Maintain pitch-and-bank control by referencing the attitude indicator, and make coordinated corrections in heading when indicated on the heading indicator. Cross-check the altimeter and VSI for a positive rate of climb (steady clockwise rotation of the altimeter needle, and the VSI showing a stable rate of climb appropriate to the airplane).

When the altimeter shows a safe altitude (approximately 100 feet), raise the landing gear and flaps, maintaining attitude by referencing the attitude indicator. Because of control pressure changes during gear and flap operation, overcontrolling is likely unless the pilot notes pitch indications accurately and quickly. Trim off control pressures necessary to hold the stable climb attitude. Check the altimeter, VSI, and airspeed for a smooth acceleration to the predetermined climb speed (altimeter and airspeed increasing, vertical speed stable). At climb speed, reduce power to climb setting (unless full power is recommended for climb by the POH/AFM and trim).

Throughout the instrument takeoff, cross-check and interpretation must be rapid, and control positive and smooth. During liftoff, gear and flap retraction, power reduction, and the changing control reactions demand rapid cross-check, adjustment of control pressures, and accurate trim changes.

Common Errors in Instrument Takeoffs

Common errors during the instrument takeoff include the following:

1. Failure to perform an adequate flight deck check before the takeoff. Pilots have attempted instrument takeoffs with inoperative airspeed indicators (pitot tube obstructed), gyros caged, controls locked, and numerous other oversights due to haste or carelessness.
2. Improper alignment on the runway. This may result from improper brake application, allowing the airplane to creep after alignment, or from alignment with the nosewheel or tailwheel cocked. In any case, the result is a built-in directional control problem as the takeoff starts.
3. Improper application of power. Abrupt application of power complicates directional control. Add power with a smooth, uninterrupted motion.
4. Improper use of brakes. Incorrect seat or rudder pedal adjustment, with feet in an uncomfortable position, frequently cause inadvertent application of brakes and excessive heading changes.

5. Overcontrolling rudder pedals. This fault may be caused by late recognition of heading changes, tension on the controls, misinterpretation of the heading indicator (and correcting in the wrong direction), failure to appreciate changing effectiveness of rudder control as the aircraft accelerates, and other factors. If heading changes are observed and corrected instantly with small movement of the rudder pedals, swerving tendencies can be reduced.
6. Failure to maintain attitude after becoming airborne. If the pilot reacts to seat-of-the-pants sensations when the airplane lifts off, pitch control is guesswork. The pilot may either allow excessive pitch or apply excessive forward elevator pressure, depending on the reaction to trim changes.
7. Inadequate cross-check. Fixations are likely during trim changes, attitude changes, gear and flap retractions, and power changes. Once an instrument or a control input is applied, continue the cross-check and note the effect during the next cross-check sequence.
8. Inadequate interpretation of instruments. Failure to understand instrument indications immediately indicates that further study of the maneuver is necessary.

Basic Instrument Flight Patterns

Flight patterns are basic maneuvers, flown by sole reference to the instruments rather than outside visual clues, for the purpose of practicing basic attitude flying. The patterns simulate maneuvers encountered on instrument flights such as holding patterns, procedure turns, and approaches. After attaining a reasonable degree of proficiency in basic maneuvers, apply these skills to the various combinations of individual maneuvers. The following practice flight patterns are directly applicable to operational instrument flying.

Racetrack Pattern

1. Time 3 minutes straight-and-level flight from A to B. *[Figure 5-41]* During this interval, reduce airspeed to the holding speed appropriate for the aircraft.
2. Start a 180° standard rate turn to the right at B. Roll-out at C on the reciprocal of the heading originally used at A.
3. Time a 1 minute straight-and-level flight from C to D.
4. Start a 180° standard rate turn to the right at D, rolling-out on the original heading.
5. Fly 1 minute on the original heading, adjusting the outbound leg so that the inbound segment is 1 minute.

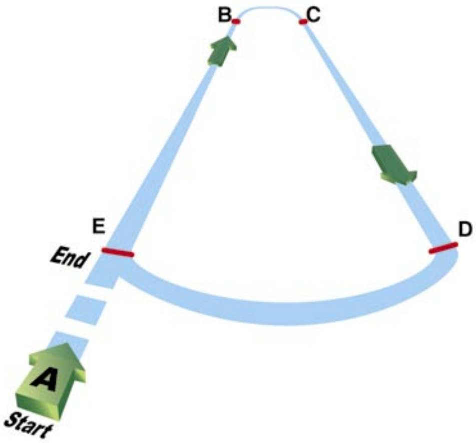

Figure 5-41. *Racetrack Pattern (Entire Pattern in Level Flight).*

NOTE*:* This pattern is an exercise combining use of the clock with basic maneuvers.

Procedure Turn

A procedure turn is a maneuver that facilitates:

- A reversal in flight direction.
- A descent from an initial approach fix or assigned altitude to a permissible altitude (usually the procedure turn altitude).
- An interception of the inbound course at a sufficient distance allowing the aircraft to become aligned with the final approach.

Procedure turn types include the 45° turn, the 80/260 turn, and the teardrop turn. All of these turns are normally conducted no more than 10 nautical miles (NM) from the primary airport. The procedure turn altitude generally provides a minimum of 1,000' obstacle clearance in the procedure turn area (not necessarily within the 10 NM arc around the primary airport). Turns may have to be increased or decreased but should not exceed 30° of a bank angle.

Standard 45° Procedure Turn

1. Start timing at point A (usually identified on approach procedures by a fix). For example, fly outbound on a heading of 360° for a given time (2 minutes, in this example). *[Figure 5-42]*
2. After flying outbound for 2 minutes (point B), turn left 45° to a heading of 315° using a standard rate turn. After roll-out and stabilizing, fly this new heading of 315° for 40 seconds and the aircraft will be at the approximate position of C.

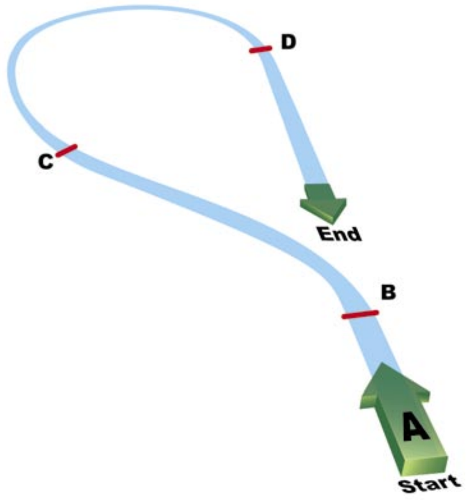

Figure 5-42. *Standard Procedure Turn (Entire Pattern in Level Flight).*

3. At point C, turn 225° right (using a standard rate turn) which will provide a heading of 180°. The timing is such that in a no wind environment, the pilot will be aligned with the final approach course of 180° at D. Wind conditions, however must be considered during the execution of the procedure turn. Compensating for wind may result in changes to outbound time, procedure turn heading and/or time and minor changes in the inbound turn.

80/260 Procedure Turn

1. Start timing at point A (usually identified on approach procedures by a fix). For example, fly outbound on a heading of 360° for 2 minutes. *[Figure 5-43]*

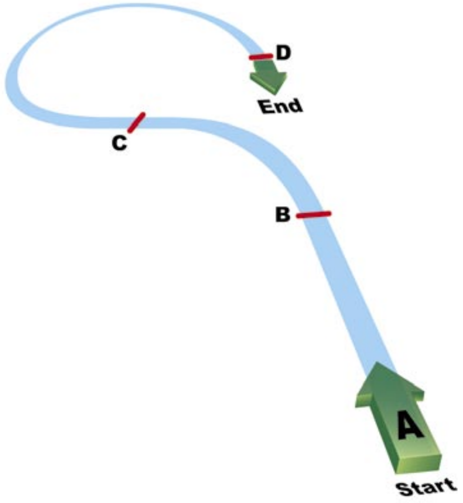

Figure 5-43. *80/260 Procedure Turn (Entire Pattern in Level Flight).*

2. At B, enter a left standard rate turn of 80° to a heading of 280°.
3. At the completion of the 80° turn to 280° (Point C), immediately turn right 260°, rolling-out on a heading of 180° (Point D) and also the reciprocal of the entry heading.

Teardrop Patterns

There are three typical teardrop procedure turns. A 30°, 20°, and a 10° teardrop pattern. The below steps indicate actions for all three starting on a heading of 360°. *[Figure 5-44]*

1. At point B (after stabilizing on the outbound course) turn left:
   - 30° to a heading of 330° and time for 1 minute
   - 20° to a heading of 340° and time for 2 minutes
   - 10° to a heading of 350° and time for 3 minutes
2. After the appropriate time above (Point C), make a standard rate turn to the right for:
   - 30° teardrop—210° to the final course heading of 180° (Point D)
   - 20° teardrop—200° to the final course heading of 180° (Point D)
   - 10° teardrop—190° to the final course heading of 180° (Point D)

By using the different teardrop patterns, a pilot is afforded the ability to manage time more efficiently. For instance, a 10° pattern for 3 minutes provides about three times the distance

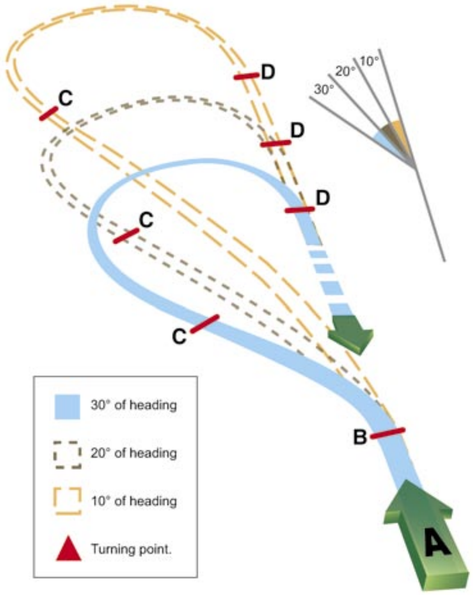

Figure 5-44. *Teardrop Pattern (Entire Pattern in Level Flight).*

(and time) than a 30° pattern. Pattern selection should be based upon an individual assessment of the procedure turn requirements to include wind, complexity, the individual preparedness, etc.

Circling Approach Patterns

Pattern I

1. At A, start timing for 2 minutes from A to B; reduce airspeed to approach speed. *[Figure 5-45]*
2. At B, make a standard rate turn to the left for 45°.
3. At the completion of the turn, time for 45 seconds to C.
4. At C, turn to the original heading; fly 1 minute to D, lowering the landing gear and flaps.
5. At D, turn right 180°, rolling-out at E on the reciprocal of the entry heading.
6. At E, enter a 500 fpm rate descent. At the end of a 500 foot descent, enter a straight constant-airspeed climb, retracting gear and flaps.

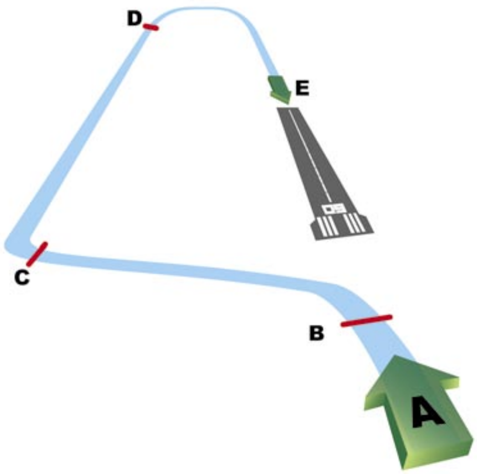

Figure 5-45. *Circling Approach Pattern I (Imaginary Runway).*

Pattern II

Steps:

1. At A, start timing for 2 minutes from A to B; reduce airspeed to approach speed. *[Figure 5-46]*
2. At B, make a standard rate turn to the left for 45°.
3. At the completion of the turn, time for 1 minute to C.
4. At C, turn right for 180° to D; fly for 1-1/2 minutes to E, lowering the landing gear and flaps.
5. At E, turn right for 180°, rolling-out at F.
6. At F, enter a 500 fpm rate descent. At the end of a 500 foot descent, enter a straight constant-airspeed climb, retracting gear and flaps.

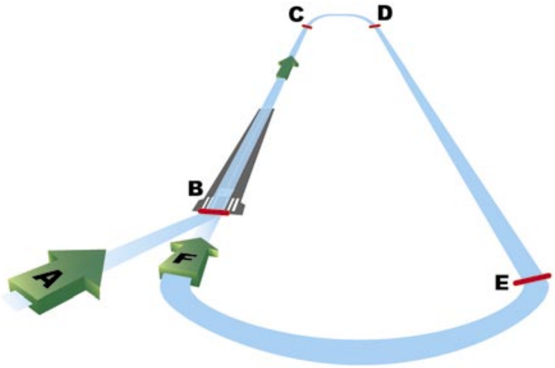

Figure 5-46. *Circling Approach Pattern II (Imaginary Runway).*

Chapter 5, Section II

Airplane Basic Flight Maneuvers

Using an Electronic Flight Display

270°
VOR 1
140
130
120
110
100
90
GARMIN
NAV
HDG
ALT
COM
CRS BARO
RANGE
PAN
MENU
FPL
PROC
STBY BATT
OFF
TEST
MASTER
AVIONICS
ON
ALT BAT
BUS 1 BUS 2
DIMMING
SW / CB PANELS
LAND TAXI NAV
LAND
TAXI
NORTH UP
INSET
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS
XPDR 5537 IDNT LCL10:12:34
4000
29.92IN

Introduction

The previous chapters have laid the foundation for instrument flying. The pilot's ability to use and interpret the information displayed and apply corrective action is required to maneuver the aircraft and maintain safe flight. A pilot must recognize that each aircraft make and model flown may require a different technique. Aircraft weight, speed, and configuration changes require the pilot to vary his or her technique in order to perform successful attitude instrument flying. A pilot must become familiar with all sections of the Pilot's Operating Handbook/Airplane Flight Manual (POH/AFM) prior to performing any flight maneuver.

Chapter 5–II describes basic attitude instrument flight maneuvers and explains how to perform each one by interpreting the indications presented on the electronic flight display (EFD). In addition to normal flight maneuvers, "partial panel" flight will be addressed. With the exception of the instrument takeoff, all flight maneuvers can be performed on "partial panel" with the Attitude Heading Reference System (AHRS) unit simulated or rendered inoperative.

Straight-and-Level Flight

Pitch Control

The pitch attitude of an airplane is the angle between the longitudinal axis of the airplane and the actual horizon. In level flight, the pitch attitude varies with airspeed and load. For training purposes, the latter factor can normally be disregarded in small airplanes. At a constant airspeed, there is only one specific pitch attitude for level flight. At slow cruise speeds, the level flight attitude is nose-high with indications as in *Figure 5-47*; at fast cruise speeds, the level flight attitude is nose-low. *[Figure 5-48] Figure 5-49* shows the indications for the attitude at normal cruise speeds.

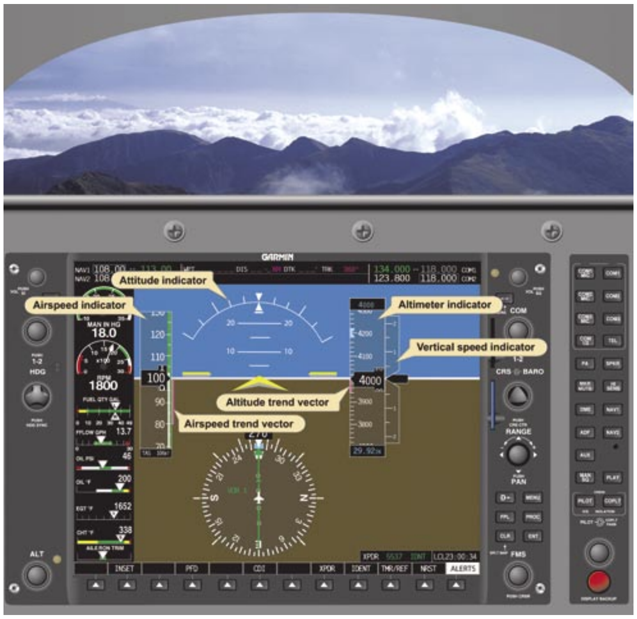

Figure 5-47. *Pitch Attitude and Airspeed in Level Flight, Slow Cruise Speed.*

The instruments that directly or indirectly indicate pitch on the Primary Flight Display (PFD) are the attitude indicator, altimeter, vertical speed indicator (VSI), airspeed indicator (ASI), and both airspeed and altitude trend indicators.

Attitude Indicator

The attitude indicator gives the pilot a direct indication of the pitch attitude. The increased size of the attitude display on the EFD system greatly increases situational awareness for the pilot. Most attitude indicators span the entire width of the PFD screen.

The aircraft pitch attitude is controlled by changing the deflection of the elevator. As the pilot pulls back on the control yoke causing the elevator to rise, the yellow chevron will begin to show a displacement up from the artificial horizon line. This is caused by the AHRS unit sensing the changing angle between the longitudinal plane of the earth and the longitudinal axis of the aircraft.

The attitude indicator displayed on the PFD screen is a representation of outside visual cues. Rather than rely on the natural horizon visible during visual flight rules (VFR) flight, the pilot must rely on the artificial horizon of the PFD screen.

During normal cruise airspeed, the point of the yellow chevron (aircraft symbol) will be positioned on the artificial horizon. Unlike conventional attitude indicators, the EFD attitude indicator does not allow for manipulating the position of the chevron in relationship to the artificial horizon. The position is fixed and therefore will always display the pitch angle as calculated by the AHRS unit.

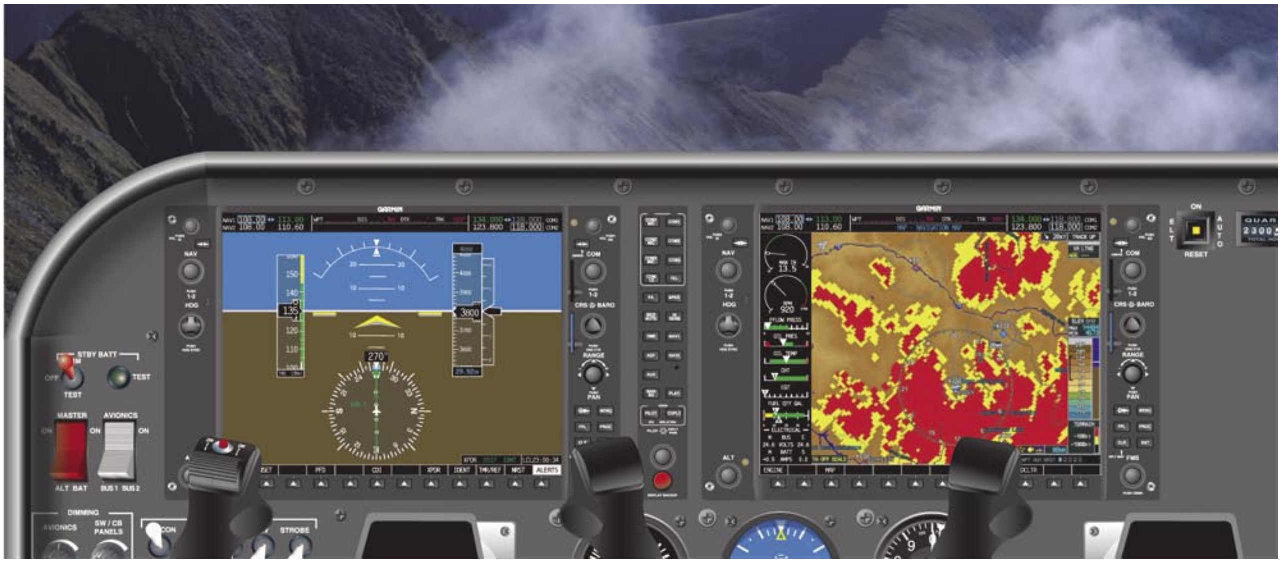

Figure 5-48. *Pitch Attitude Decreasing and Airspeed Increasing—Indicates Need to Increase Pitch.*

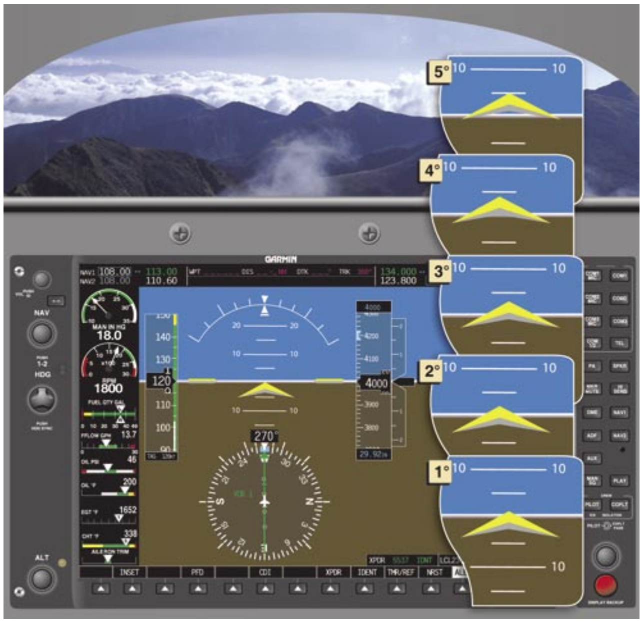

Figure 5-49. *Various Pitch Attitudes (Right), Aircraft Shown in Level Flight.*

The attitude indicator only shows pitch attitude and does not indicate altitude. A pilot should not attempt to maintain level flight using the attitude indicator alone. It is important for the pilot to understand how small displacements both up and down can affect the altitude of the aircraft. To achieve this, the pilot should practice increasing the pitch attitude incrementally to become familiar with how each degree of pitch changes the altitude. *[Figures 5-50* and *5-51]* In both cases, the aircraft will slow and gain altitude.

The full height of the chevron is approximately 5° and provides an accurate reference for pitch adjustment. It is imperative that the pilot make the desired changes to pitch by referencing the attitude indicator and then trimming off any excess control pressures. Relieving these pressures will allow for a more stabilized flight and will reduce pilot work load. Once the aircraft is trimmed for level flight, the pilot must smoothly and precisely manipulate the elevator control forces in order to change the pitch attitude.

To master the ability to smoothly control the elevator, a pilot must develop a very light touch on the control yoke. The thumb and two fingers are normally sufficient to move the control yoke. The pilot should avoid griping the yoke with a full fist. When a pilot grips the yoke with a full fist, there is a tendency to apply excess pressures, thus changing the aircraft attitude.

Practice making smooth, small pitch changes both up and down until precise corrections can be made. With practice a pilot will be able to make pitch changes in 1° increments, smoothly controlling the attitude of the aircraft.

The last step in mastering elevator control is trim. Trimming the aircraft to relieve any control pressures is essential for smooth attitude instrument flight. To accomplish this, momentarily release the control yoke. Note which way the aircraft pitch attitude wants to move. Grasp the control yoke again and then reapply the pressure to return the attitude to the previous position. Apply trim in the direction of the control pressure. Small applications of trim will make large changes in the pitch attitude. Be patient and make multiple changes to trim, if necessary.

Once the aircraft is in trim, relax on the control yoke as much as practicable. When pressure is held on the yoke, unconscious pressures are applied to the elevator and ailerons which displaces the aircraft from its desired flight path. If the aircraft is in trim, in calm, non-turbulent air, a pilot should be able to release the control yoke and maintain level flight for extended periods of time. This is one of the hardest skills to learn prior to successfully flying in instrument meteorological conditions (IMC).

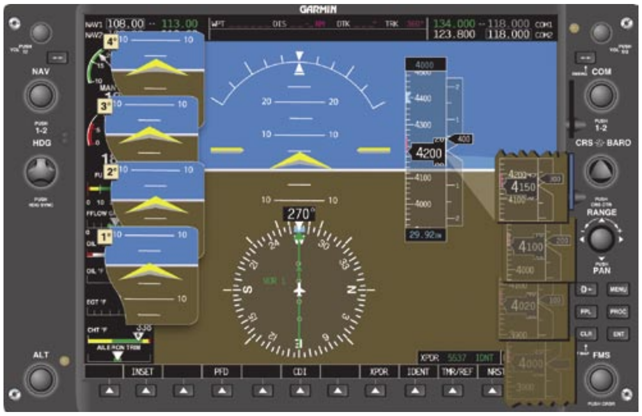

Figure 5-50. *Pitch Indications for Various Attitudes (1° through 5°).*

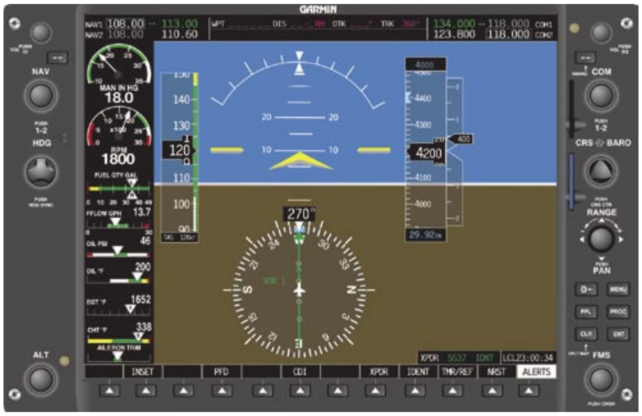

Figure 5-51. *Pitch Illustrated at 10°.*

Altimeter

At constant power, any deviation from level flight (except in turbulent air) must be the result of a pitch change. If the power is constant, the altimeter gives an indirect indication of the pitch attitude in level flight. Since the altitude should remain constant when the airplane is in level flight, any deviation from the desired altitude signals the need for a pitch change. For example, if the aircraft is gaining altitude, the nose must be lowered.

In the PFD, as the pitch starts to change, the altitude trend indicator on the altitude tape will begin to show a change in the direction of displacement. The rate at which the trend indicator grows and the altimeter numbers change aids the pilot in determining how much of a pitch change is necessary to stop the trend.

As a pilot becomes familiar with a specific aircraft's instruments, he or she learns to correlate pitch changes, altimeter tapes, and altitude trend indicators. By adding the altitude tape display and the altitude trend indicator into the scan along with the attitude indicator, a pilot starts to develop the instrument cross-check.

Partial Panel Flight

One important skill to practice is partial panel flight by referencing the altimeter as the primary pitch indicator. Practice controlling the pitch by referencing the altitude tape and trend indicator alone without the use of the attitude indicator. Pilots need to learn to make corrections to altitude deviations by referencing the rate of change of the altitude tape and trend indicator. When operating in IMC and in a partial panel configuration, the pilot should avoid abrupt changes to the control yoke. Reacting abruptly to altitude changes can lead to large pitch changes and thus a larger divergence from the initial altitude.

When a pilot is controlling pitch by the altitude tape and altitude trend indicators alone, it is possible to overcontrol the aircraft by making a larger than necessary pitch correction. Overcontrolling will cause the pilot to move from a nose-high attitude to a nose-low attitude and vice versa. Small changes to pitch are required to insure prompt corrective actions are taken to return the aircraft to its original altitude with less confusion.

When an altitude deviation occurs, two actions need to be accomplished. First, make a smooth control input to stop the needle movement. Once the altitude tape has stopped moving, make a change to the pitch attitude to start back to the entry altitude.

During instrument flight with limited instrumentation, it is imperative that only small and precise control inputs are made. Once a needle movement is indicated denoting a deviation in altitude, the pilot needs to make small control inputs to stop the deviation. Rapid control movements will only compound the deviation by causing an oscillation effect. This type of oscillation can quickly cause the pilot to become disoriented and begin to fixate on the altitude. Fixation on the altimeter can lead to a loss of directional control as well as airspeed control.

As a general rule of thumb, for altitude deviations less than 100 feet, utilize a pitch change of 1°, which equates to 1/5 of the thickness of the chevron. Small incremental pitch changes will allow the performance to be evaluated and will eliminate overcontrolling of the aircraft.

Instrumentation needs to be utilized collectively, but failures will occur which leave the pilot with only limited instrumentation. That is why partial panel flying training is important. If the pilot understands how to utilize each instrument independently, no significant change is encountered in carrying out the flight when other instruments fail.

VSI Tape

The VSI tape provides for an indirect indication of pitch attitude and gives the pilot a more immediate indication of a pending altitude deviation. In addition to trend information, the vertical speed also gives a rate indication. By using the VSI tape in conjunction with the altitude trend tape, a pilot will have a better understanding of how much of a correction needs to be made. With practice, the pilot will learn the performance of a particular aircraft and know how much pitch change is required in order to correct for a specific rate indication.

Unlike older analog VSIs, new glass panel displays have instantaneous VSIs. Older units had a lag designed into the system that was utilized to indicate rate information. The new glass panel displays utilize a digital air data computer that does not indicate a lag. Altitude changes are shown immediately and can be corrected for quickly.

The VSI tape should be used to assist in determining what pitch changes are necessary to return to the desired altitude. A good rule of thumb is to use a vertical speed rate of change that is double the altitude deviation. However, at no time should the rate of change be more than the optimum rate of climb or descent for the specific aircraft being flown. For example, if the altitude is off by 200 feet from the desired altitude, then a 400 feet per minute (fpm) rate of change would be sufficient to get the aircraft back to the original altitude. If the altitude has changed by 700 feet, then doubling that would necessitate a 1,400 fpm change. Most aircraft are not capable of that, so restrict changes to no more than optimum climb and descent. An optimum rate of change would vary between 500 and 1,000 fpm.

One error the instrument pilot encounters is overcontrolling. Overcontrolling occurs when a deviation of more than 200 fpm is indicated over the optimum rate of change. For example, an altitude deviation of 200 feet is indicated on the altimeter, a vertical speed rate of 400 feet should be indicated on the gauge. If the vertical speed rate showed 600 fpm (200 more than optimum), the pilot would be overcontrolling the aircraft.

When returning to altitude, the primary pitch instrument is the VSI tape. If any deviation from the desired vertical speed is indicated, make the appropriate pitch change using the attitude indicator.

As the aircraft approaches the target altitude, the vertical speed rate can be slowed in order to capture the altitude in a more stabilized fashion. Normally within 10 percent of the rate of climb or descent from the target altitude, begin to slow the vertical speed rate in order to level off at the target altitude. This will allow the pilot to level at the desired altitude without rapid control inputs or experiencing discomfort due to G-load.

Airspeed Indicator (ASI)

The ASI presents an indirect indication of the pitch attitude. At a constant power setting and pitch attitude, airspeed remains constant. As the pitch attitude lowers, airspeed increases, and the nose should be raised.

As the pitch attitude is increased, the nose of the aircraft will raise, which will result in an increase in the angle of attack as well as an increase in induced drag. The increased drag will begin to slow the momentum of the aircraft which will be indicated on the ASI. The airspeed trend indicator will show a trend as to where the airspeed will be in 6 seconds. Conversely, if the nose of the aircraft should begin to fall, the angle of attack as well as induced drag will decrease.

There is a lag associated with the ASI when using it as a pitch instrument. It is not a lag associated with the construction of the ASI, but a lag associated with momentum change. Depending on the rate of momentum change, the ASI may not indicate a pitch change in a timely fashion. If the ASI is being used as the sole reference for pitch change, it may not allow for a prompt correction. However, if smooth pitch changes are executed, modern glass panel displays are capable of indicating 1 knot changes in airspeed and also capable of projecting airspeed trends.

When flying by reference to flight instruments alone, it is imperative that all of the flight instruments be cross-checked for pitch control. By cross-checking all pitch related instruments, the pilot can better visualize the aircraft attitude at all times.

As previously stated, the primary instrument for pitch is the instrument that gives the pilot the most pertinent information for a specific parameter. When in level flight and maintaining a constant altitude, what instrument shows a direct indication of altitude? The only instrument that is capable of showing altitude is the altimeter. The other instruments are supporting instruments that are capable of showing a trend away from altitude, but do not directly indicate an altitude.

The supporting instruments forewarn of an impending altitude deviation. With an efficient cross-check, a proficient pilot will be better able to maintain altitude.

Bank Control

This discussion assumes the aircraft is being flown in coordinated flight which means the longitudinal axis of the aircraft is aligned with the relative wind. On the PFD, the attitude indicator shows if the wings are level. The turn rate indicator, slip/skid indicator, and the heading indicator also indicate whether or not the aircraft is maintaining a straight (zero bank) flight path.

Attitude Indicator

The attitude indicator is the only instrument on the PFD that has the capability of displaying the precise bank angle of the aircraft. This is made possible by the display of the roll scale depicted as part of the attitude indicator.

Figure 5-52 identifies the components that make up the attitude indicator display. Note that the top of the display is blue, representing sky, the bottom is brown, depicting dirt, and the white line separating them is the horizon. The lines parallel to the horizon line are the pitch scale which is marked in 5° increments and labeled every 10°. The pitch scale always remains parallel to the horizon.

The curved line in the blue area is the roll scale. The triangle on the top of the scale is the zero index. The hash marks on the scale represent the degree of bank. *[Figure 5-53]* The roll scale always remains in the same position relative to the horizon line.

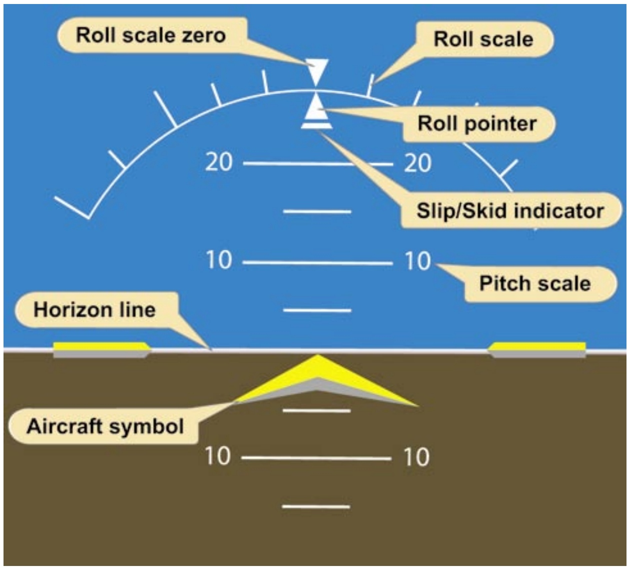

Figure 5-52. *Attitude Indicator.*

The roll pointer indicates the direction and degree of bank. *[Figure 5-53]* The roll pointer is aligned with the aircraft symbol. The roll pointer indicates the angle of the lateral axis of the aircraft compared to the natural horizon. The slip/skid indicator will show if the longitudinal axis of the aircraft is aligned with the relative wind, which is coordinated flight. With the roll index and the slip/skid indicator aligned, any deflection, either right or left of the roll index will cause the aircraft to turn in that direction. With the small graduations on the roll scale, it is easy to determine the bank angle within approximately 1°. In coordinated flight, if the roll index is aligned with the roll pointer, the aircraft is achieving straight flight.

An advantage of EFDs is the elimination of the precession error. Precession error in analog gauges is caused by forces being applied to a spinning gyro. With the new solid state instruments, precession error has been eliminated.

Since the attitude indicator is capable of showing precise pitch and bank angles, the only time that the attitude indicator will be a primary instrument is when attempting to fly at a specific bank angle or pitch angle. Other times, the attitude instrument can be thought of as a control instrument.

Horizontal Situation Indicator (HSI)

The HSI is a rotating 360° compass card that indicates magnetic heading. The HSI is the only instrument that is capable of showing exact headings. The magnetic compass can be used as a backup instrument in case of an HSI failure; however, due to erratic, unstable movements, it is more likely to be used a supporting instrument.

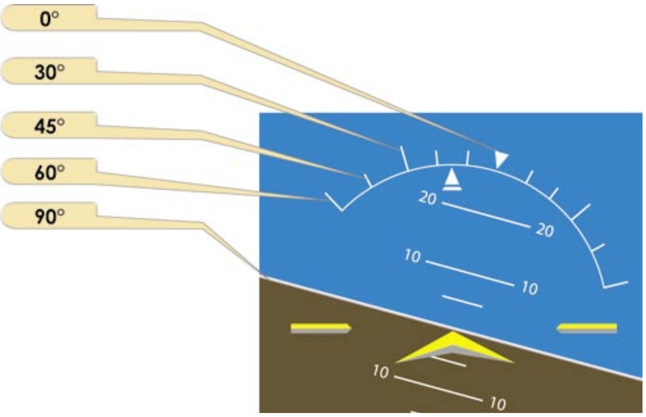

Figure 5-53. *Attitude Indicator Showing a 15° left bank.*

In order for the pilot to achieve the desired rate of change, it is important for him or her to understand the relationship between the rate at which the HSI changes heading displays and the amount of bank angle required to meet that rate of change. A very small rate of heading change means the bank angle is small, and it will take more time to deviate from the desired straight flight path. A larger rate of heading change means a greater bank angle will happen at a faster rate.

Heading Indicator

The heading indicator is the large black box with a white number that indicates the magnetic heading of the aircraft. *[Figure 5-54]* The aircraft heading is displayed to the nearest degree. When this number begins to change, the pilot should be aware that straight flight is no longer being achieved.

Turn Rate Indicator

The turn rate indicator gives an indirect indication of bank. It is a magenta trend indicator capable of displaying half-standard as well as standard rate turns to both the left and right. *[Figure 5-54]* The turn indicator is capable of indicating turns up to 4° per second by extending the magenta line outward from the standard rate mark. If the rate of turn has

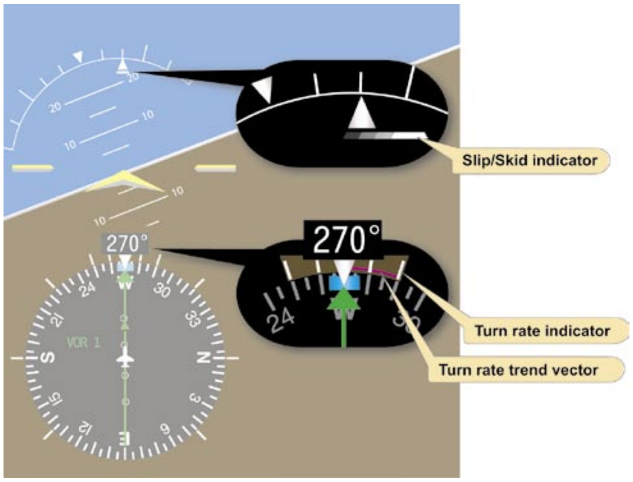

Figure 5-54. *Slip/Skid and Turn Rate Indicator.*

exceeded 4° per second, the magenta line can not precisely indicate where the heading will be in the next 6 seconds, the magenta line freezes and an arrowhead will be displayed. This alerts the pilot to the fact that the normal range of operation has been exceeded.

Slip/Skid Indicator

The slip/skid indicator is the small portion of the lower segmented triangle displayed on the attitude indicator. This instrument depicts whether the aircraft's longitudinal axis is aligned with the relative wind. *[Figure 5-54]*

The pilot must always remember to cross-check the roll index to the roll pointer when attempting to maintain straight flight. Any time the heading remains constant and the roll pointer and the roll index are not aligned, the aircraft is in uncoordinated flight. To make a correction, the pilot should apply rudder pressure to bring the aircraft back to coordinated flight.

Power Control

Power produces thrust which, with the appropriate angle of attack of the wing, overcomes the forces of gravity, drag, and inertia to determine airplane performance.

Power control must be related to its effect on altitude and airspeed, since any change in power setting results in a change in the airspeed or the altitude of the airplane. At any given airspeed, the power setting determines whether the airplane is in level flight, in a climb, or in a descent. If the power is increased in straight-and-level flight and the airspeed held constant, the airplane will climb; if power is decreased while the airspeed is held constant, the airplane will descend. On the other hand, if altitude is held constant, the power applied will determine the airspeed.

The relationship between altitude and airspeed determines the need for a change in pitch or power. If the airspeed is off the desired value, always check the altimeter before deciding that a power change is necessary. Think of altitude and airspeed as interchangeable; altitude can be traded for airspeed by lowering the nose, or convert airspeed to altitude by raising the nose. If altitude is higher than desired and airspeed is low, or vice versa, a change in pitch alone may return the airplane to the desired altitude and airspeed. *[Figure 5-55]* If both airspeed and altitude are high or if both are low, then a change in both pitch and power is necessary in order to return to the desired airspeed and altitude. *[Figure 5-56]*

For changes in airspeed in straight-and-level flight, pitch, bank, and power must be coordinated in order to maintain constant altitude and heading. When power is changed to vary airspeed in straight-and-level flight, a single-engine, propeller-driven airplane tends to change attitude around all axes of movement. Therefore, to maintain constant altitude and heading, apply various control pressures in proportion to the change in power. When power is added to increase airspeed, the pitch instruments indicate a climb unless forward-elevator control pressure is applied as the airspeed changes. With an increase in power, the airplane tends to yaw and roll to the left unless counteracting aileron and rudder pressures are applied. Keeping ahead of these changes requires increasing cross-check speed, which varies with the type of airplane and its torque characteristics, the extent of power and speed change involved.

Power Settings

Power control and airspeed changes are much easier when approximate power settings necessary to maintain various airspeeds in straight-and-level flight are known in advance. However, to change airspeed by any appreciable amount, the common procedure is to underpower or overpower on initial power changes to accelerate the rate of airspeed change. (For small speed changes, or in airplanes that decelerate or accelerate rapidly, overpowering or underpowering is not necessary.)

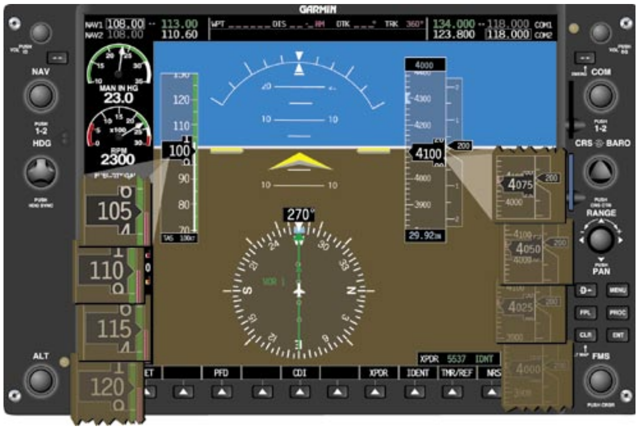

Figure 5-55. *An aircraft decreasing in airspeed while gaining altitude. In this case, the pilot has decreased pitch.*

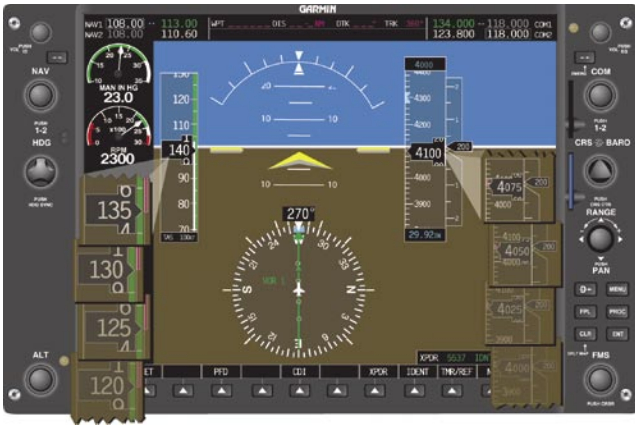

Figure 5-56. *Figure shows both an increase in speed and altitude where pitch adjustment alone is insufficient. In this situation, a reduction of power is also necessary.*

Consider the example of an airplane that requires 23" of manifold pressure (Hg) to maintain a normal cruising airspeed of 120 knots, and 18" Hg to maintain an airspeed of 100 knots. The reduction in airspeed from 120 knots to 100 knots while maintaining straight-and-level flight is discussed below and illustrated in *Figures 5-57, 5-58,* and *5-59*.

Instrument indications, prior to the power reduction, are shown in *Figure 5-57*. The basic attitude is established and maintained on the attitude indicator. The specific pitch, bank, and power control requirements are detected on these primary instruments:

Altimeter—Primary Pitch
Heading Indicator—Primary Bank
Airspeed Indicator—Primary Power

Supporting pitch and bank instruments are shown in *Figure 5-57*. Note that the supporting power instrument is the manifold pressure gauge (or tachometer if the propeller is fixed pitch). However, when a smooth power reduction to approximately 15" Hg (underpower) is made, the manifold pressure gauge becomes the primary power instrument. *[Figure 5-58]* With practice, power setting can be changed with only a brief glance at the power instrument, by sensing the movement of the throttle, the change in sound, and the changes in the feel of control pressures.

As the thrust decreases, increase the speed of the cross-check and be ready to apply left rudder, back-elevator, and aileron control pressure the instant the pitch-and-bank instruments show a deviation from altitude and heading. As proficiency is obtained, a pilot will learn to cross-check, interpret, and control the changes with no deviation of heading and altitude. Assuming smooth air and ideal control technique, as airspeed decreases, a proportionate increase in airplane pitch attitude is required to maintain altitude. Similarly, effective torque control means counteracting yaw with rudder pressure.

As the power is reduced, the altimeter is primary for pitch, the heading indicator is primary for bank, and the manifold pressure gauge is momentarily primary for power (at 15" Hg in *Figure 5-58*). Control pressures should be trimmed off as the airplane decelerates. As the airspeed approaches the desired airspeed of 100 knots, the manifold pressure is adjusted to approximately 18" Hg and becomes the supporting power instrument. The ASI again becomes primary for power. *[Figure 5-58]*

Airspeed Changes in Straight-and-Level Flight

Practice of airspeed changes in straight-and-level flight provides an excellent means of developing increased proficiency in all three basic instrument skills, and brings out some common errors to be expected during training in straight-and-level flight. Having learned to control the airplane in a clean configuration (minimum drag conditions), increase proficiency in cross-check and control by practicing speed changes while extending or retracting the flaps and landing gear. While practicing, be sure to comply with the airspeed limitations specified in the POH/AFM for gear and flap operation.

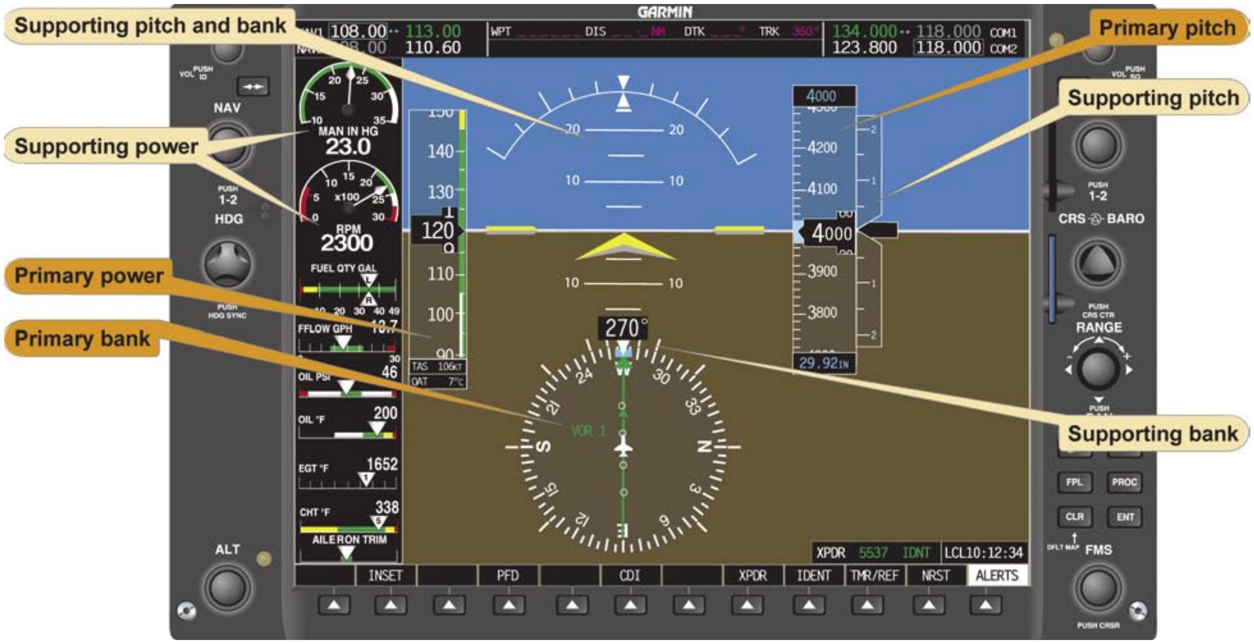

Figure 5-57. *Straight-and-Level Flight (Normal Cruising Speed).*

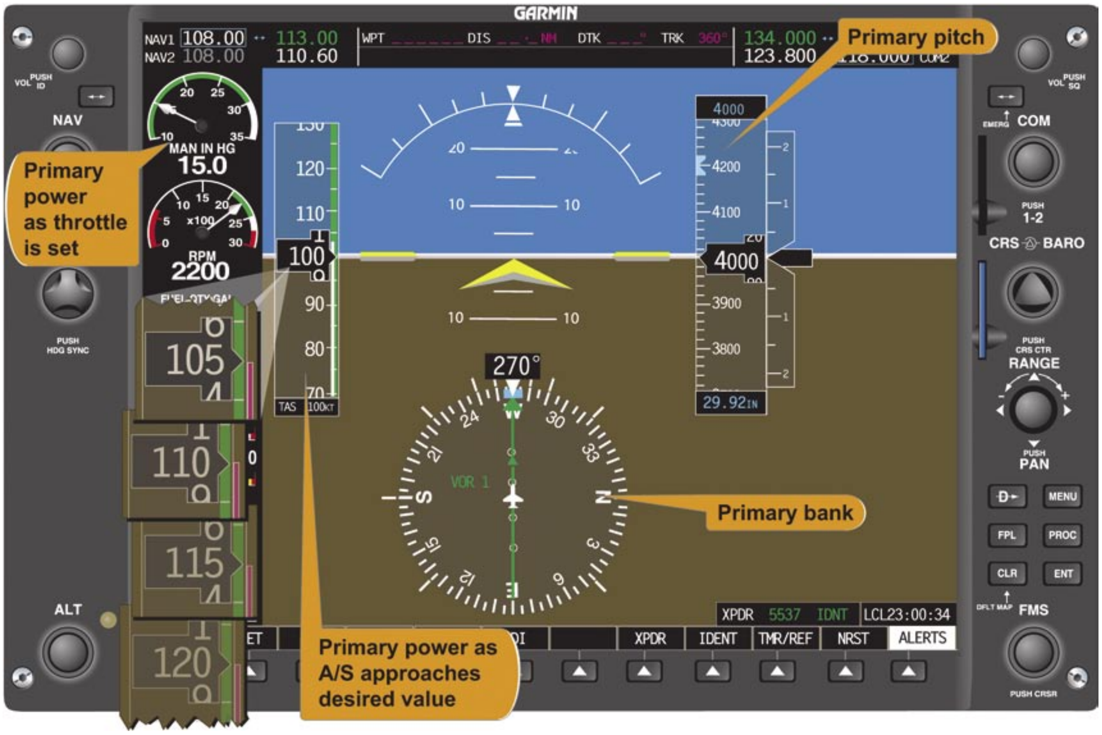
Primary pitch
Primary power as throttle is set
Primary bank
Primary power as A/S approaches desired value
GARMIN
MAN IN HG
15.0
RPM
2200
100
4000
270°
29.92IN

Figure 5-58. *Straight-and-Level Flight (Airspeed Decreasing).*

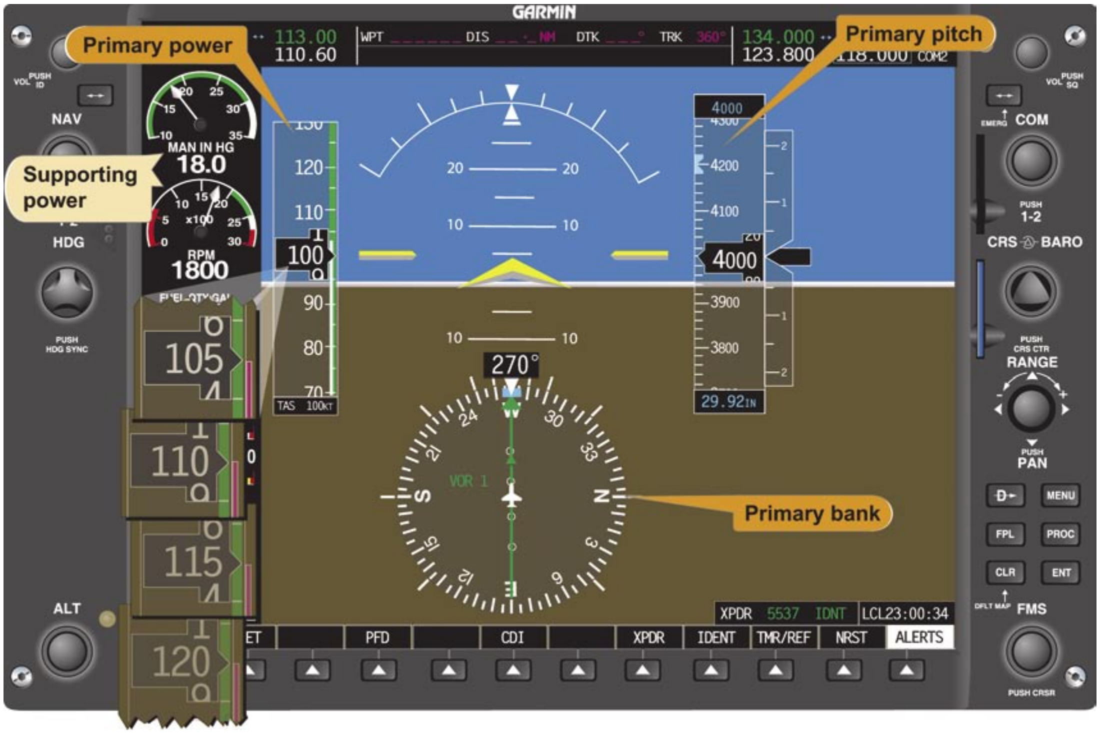
Primary power
Primary pitch
Supporting power
Primary bank
GARMIN
MAN IN HG
18.0
RPM
1800
100
4000
270°
29.92IN

Figure 5-59. *Straight-and-Level Flight (Reduced Airspeed Stabilized).*

Sudden and exaggerated attitude changes may be necessary in order to maintain straight-and-level flight as the landing gear is extended and the flaps are lowered in some airplanes. The nose tends to pitch down with gear extension, and when flaps are lowered, lift increases momentarily (at partial flap settings) followed by a marked increase in drag as the flaps near maximum extension.

Control technique varies according to the lift and drag characteristics of each airplane. Accordingly, knowledge of the power settings and trim changes associated with different combinations of airspeed, gear, and flap configurations will reduce instrument cross-check and interpretation problems. *[Figure 5-60]*

For example, assume that in straight-and-level flight instruments indicate 120 knots with power at 23" Hg manifold pressure/2,300 revolutions per minute (rpm), gear and flaps up. After reduction in airspeed, with gear and flaps fully extended, straight-and-level flight at the same altitude requires 25" Hg manifold pressure/2,500 rpm. Maximum gear extension speed is 115 knots; maximum flap extension speed is 105 knots. Airspeed reduction to 95 knots, gear and flaps down, can be made in the following manner:

1. Maintain rpm at 2,500, since a high power setting will be used in full drag configuration.
2. Reduce manifold pressure to 10" Hg. As the airspeed decreases, increase cross-check speed.
3. Make trim adjustments for an increased angle of attack and decrease in torque.
4. Lower the gear at 115 knots. The nose may tend to pitch down and the rate of deceleration increases. Increase pitch attitude to maintain constant altitude, and trim off some of the back-elevator pressures. If full flaps are lowered at 105 knots, cross-check, interpretation, and control must be very rapid. A simpler technique is to stabilize attitude with gear down before lowering the flaps.
5. Since 18" Hg manifold pressure will hold level flight at 100 knots with the gear down, increase power smoothly to that setting as the ASI shows approximately 105 knots, and retrim. The attitude indicator now shows approximately two-and-a-half bar width nose-high in straight-and-level flight.
6. Actuate the flap control and simultaneously increase power to the predetermined setting (25" Hg) for the desired airspeed, and trim off the pressures necessary to hold constant altitude and heading. The attitude indicator now shows a bar width nose-low in straight-and-level flight at 95 knots.

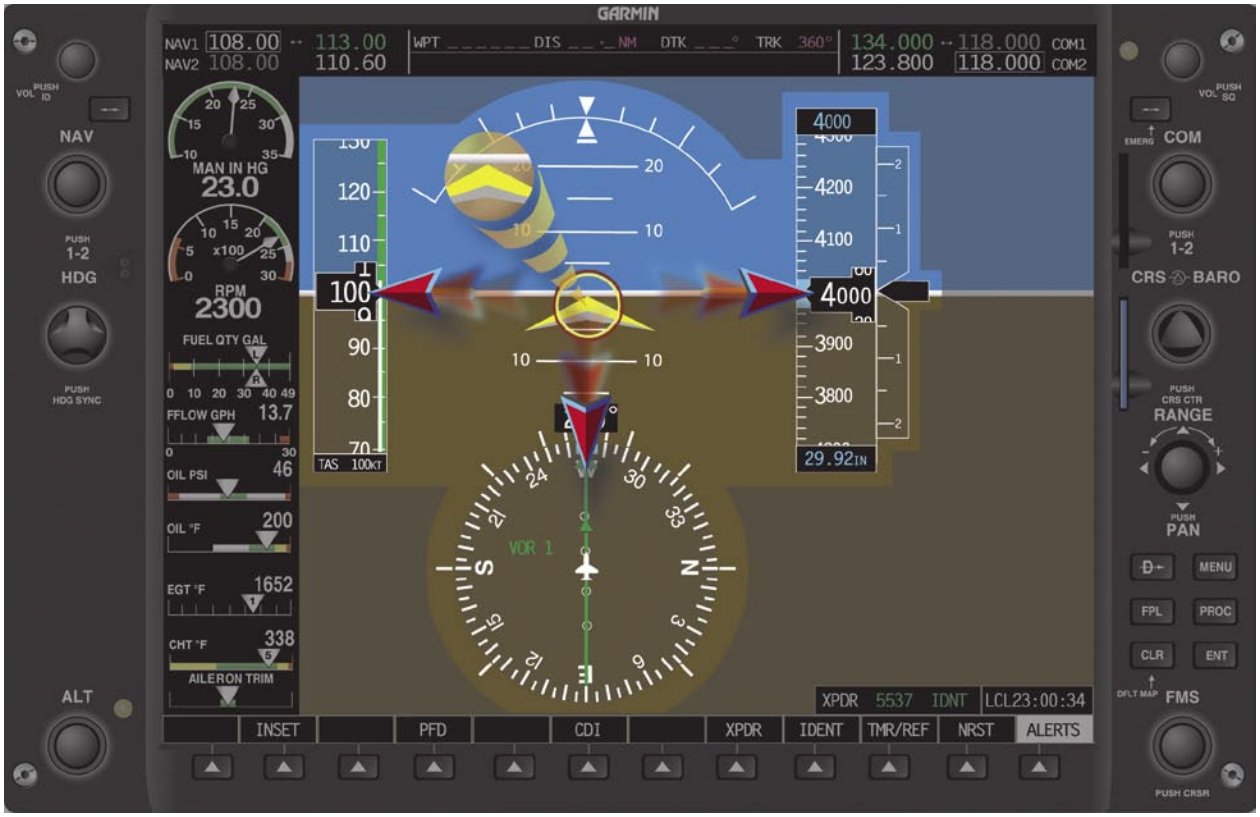
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
WPT ______ DIS __._ NM DTK ___° TRK 360°
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
VOL PUSH ID
NAV
PUSH 1-2
HDG
PUSH HDG SYNC
ALT
MAN IN HG
23.0
RPM
2300
FUEL QTY GAL
FFLOW GPH 13.7
OIL PSI 46
OIL °F 200
EGT °F 1652
CHT °F 338
AILERON TRIM
120
110
100
90
80
TAS 100KT
20
10
4000
4200
4100
3900
3800
29.92IN
VOR 1
XPDR 5537 IDNT LCL23:00:34
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NRST
ALERTS
VOL PUSH SQ
EMERG
COM
PUSH 1-2
CRS BARO
PUSH CRS CTR
RANGE
PUSH PAN
D→
MENU
FPL
PROC
CLR
ENT
DFLT MAP
FMS
PUSH CRSR

Figure 5-60. *Cross-check Supporting Instruments.*

Trim Technique

Trim control is one of the most important flight habits to cultivate. Trimming refers to relieving any control pressures that need to be applied by the pilot to the control surfaces to maintain a desired flight attitude. The desired result is for the pilot to be able to take his or her hands off the control surfaces and have the aircraft remain in the current attitude. Once the aircraft is trimmed for hands-off flight, the pilot is able to devote more time to monitoring the flight instruments and other aircraft systems.

In order to trim the aircraft, apply pressure to the control surface that needs trimming and roll the trim wheel in the direction pressure is being held. Relax the pressure that is being applied to the control surface and monitor the primary instrument for that attitude. If the desired performance is achieved, fly hands off. If additional trimming is required, redo the trimming steps.

An aircraft is trimmed for a specific airspeed, not pitch attitude or altitude. Any time an aircraft changes airspeed there is a need to re-trim. For example, an aircraft is flying at 100 knots straight-and-level. An increase of 50 rpm will cause the airspeed to increase. As the airspeed increases, additional lift will be generated and the aircraft will climb. Once the additional thrust has stabilized at some higher altitude, the airspeed will again stabilize at 100 knots.

This demonstrates how trim is associated with airspeed and not altitude. If the initial altitude is to be maintained, forward pressure would need to be applied to the control wheel while the trim wheel needs to be rolled forward to eliminate any control pressures. Rolling forward on the trim wheel is equal to increasing for a trimmed airspeed. Any time the airspeed is changed, re-trimming will be required. Trimming can be accomplished during any transitional period; however, prior to final trimming, the airspeed must be held constant. If the airspeed is allowed to change, the trim will not be adjusted properly and the altitude will vary until the airspeed for which the aircraft is trimmed is achieved.

Common Errors in Straight-and-Level Flight

Pitch

Pitch errors usually result from the following errors:

1. Improper adjustment of the yellow chevron (aircraft symbol) on the attitude indicator.

   Corrective Action: Once the aircraft has leveled off and the airspeed has stabilized, make small corrections to the pitch attitude to achieve the desired performance. Cross-check the supporting instruments for validation.

2. Insufficient cross-check and interpretation of pitch instruments. *[Figure 5-61]*

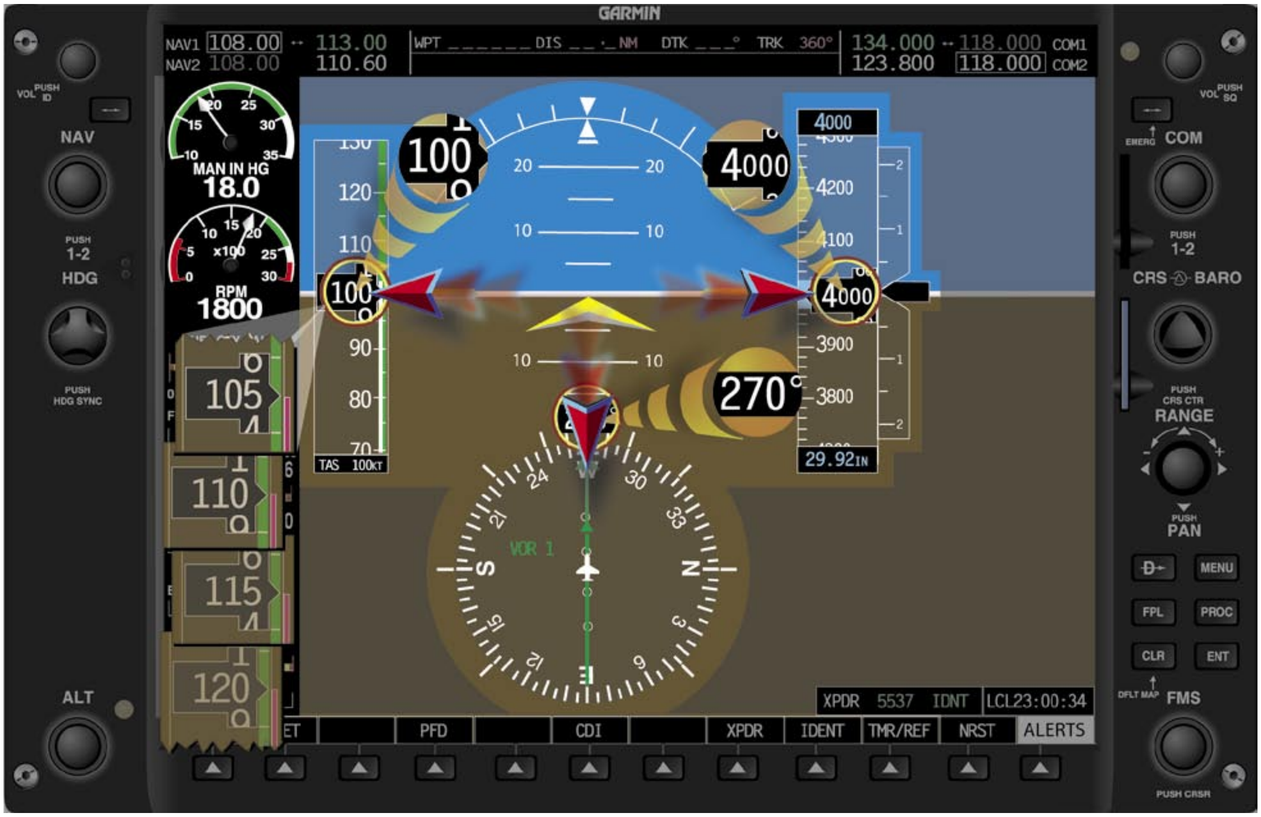

Figure 5-61. *Insufficient cross-check. The problem is power and not nose-high. In this case, the pilot decreased pitch inappropriately.*

Example: The airspeed indication is low. The pilot, believing a nose-high pitch attitude exists, applies forward pressure without noting that a low power setting is the cause of the airspeed discrepancy.

Corrective Action: Increase the rate of cross-check of all the supporting flight instruments. Airspeed and altitude should be stabilized before making a control input.

3. Acceptance of deviations.

   Example: A pilot has an altitude range of ±100 feet according to the practical test standards for straight-and level-flight. When the pilot notices that the altitude has deviated by 60 feet, no correction is made because the altitude is holding steady and is within the standards.

   Corrective Action: The pilot should cross-check the instruments and, when a deviation is noted, prompt corrective actions should be taken in order to bring the aircraft back to the desired altitude. Deviations from altitude should be expected but not accepted.

4. Overcontrolling—Excessive Pitch Changes.

   Example: A pilot notices a deviation in altitude. In an attempt to quickly return to altitude, the pilot makes a large pitch change. The large pitch change destabilizes the attitude and compounds the error.

   Corrective Action: Small, smooth corrections should be made in order to recover to the desired altitude (0.5° to 2° depending on the severity of the deviation). Instrument flying is comprised of small corrections to maintain the aircraft attitude. When flying in IMC, a pilot should avoid making large attitude changes in order to avoid loss of aircraft control and spatial disorientation.

5. Failure to Maintain Pitch Corrections.

   Pitch changes need to be made promptly and held for validation. Many times pilots will make corrections and allow the pitch attitude to change due to not trimming the aircraft. It is imperative that any time a pitch change is made; the trim is readjusted in order to eliminate any control pressures that are being held. A rapid cross-check will aid in avoiding any deviations from the desired pitch attitude.

   Example: A pilot notices a deviation in altitude. A change in the pitch attitude is accomplished but no adjustment to the trim is made. Distractions cause the pilot to slow the cross-check and an inadvertent reduction in the pressure to the control column commences. The pitch attitude then changes, thus complicating recovery to the desired altitude.

   Corrective Action: The pilot should initiate a pitch change and then immediately trim the aircraft to relieve any control pressures. A rapid cross-check should be established in order to validate the desired performance is being achieved.

6. Fixation During Cross-Check.

   Devoting an unequal amount of time to one instrument either for interpretation or assigning too much importance to an instrument. Equal amounts of time should be spent during the cross-check to avoid an unnoticed deviation in one of the aircraft attitudes.

   Example: A pilot makes a correction to the pitch attitude and then devotes all of the attention to the altimeter to determine if the pitch correction is valid. During this time, no attention is paid to the heading indicator which shows a turn to the left. *[Figure 5-62]*

   Corrective Action: The pilot should monitor all instrumentation during the cross-check. Do not fixate on one instrument waiting for validation. Continue to scan all instruments to avoid allowing the aircraft to begin a deviation in another attitude.

Heading

Heading errors usually result from but are not limited to the following errors:

1. Failure to cross-check the heading indicator, especially during changes in power or pitch attitude.
2. Misinterpretation of changes in heading, with resulting corrections in the wrong direction.
3. Failure to note and remember a preselected heading.
4. Failure to observe the rate of heading change and its relation to bank attitude.
5. Overcontrolling in response to heading changes, especially during changes in power settings.
6. Anticipating heading changes with premature application of rudder pressure.
7. Failure to correct small heading deviations. Unless zero error in heading is the goal, a pilot will tolerate larger and larger deviations. Correction of a 1° error takes far less time and concentration than correction of a 20° error.
8. Correcting with improper bank attitude. If correcting a 10° heading error with a 20° bank correction, the aircraft will roll past the desired heading before the bank is established, requiring another correction in the opposite direction. Do not multiply existing errors with errors in corrective technique.

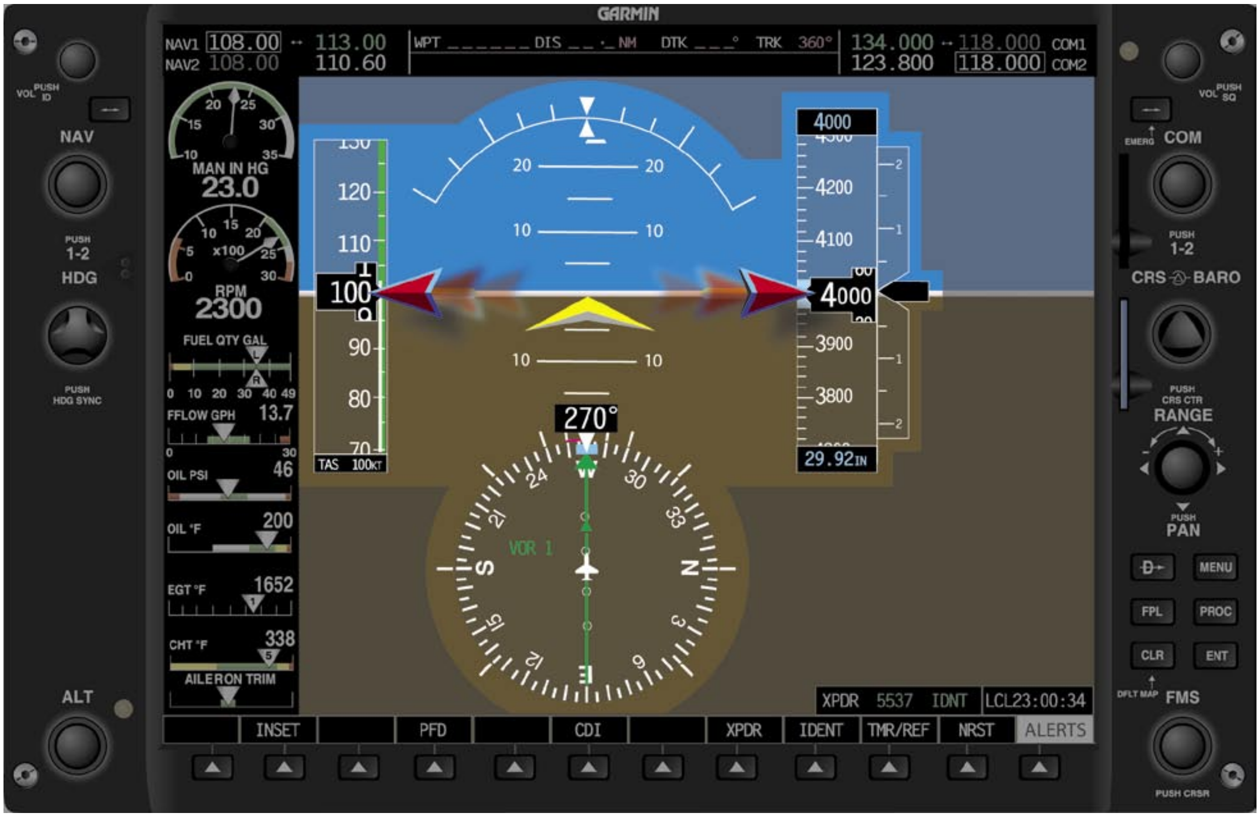
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
WPT DIS NM DTK TRK 360°
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
NAV
HDG
ALT
COM
CRS BARO
RANGE
PAN
MENU
FPL
PROC
CLR
ENT
FMS
MAN IN HG 23.0
RPM 2300
FUEL QTY GAL
FFLOW GPH 13.7
OIL PSI 46
OIL °F 200
EGT °F 1652
CHT °F 338
AILERON TRIM
100
TAS 100KT
4000
4200
4100
3900
3800
29.92IN
270°
VOR 1
XPDR 5537 IDNT LCL23:00:34
INSET
PFD
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS

Figure 5-62. *The pilot has fixated on pitch and altitude, leaving bank indications unattended. Note the trend line to the left.*

9. Failure to note the cause of a previous heading error and thus repeating the same error. For example, the airplane is out of trim, with a left wing low tendency. Repeated corrections for a slight left turn are made, yet trim is ignored.

Power

Power errors usually result from but are not limited to the following errors:

1. Failure to become familiar with the aircraft's specific power settings and pitch attitudes.
2. Abrupt use of throttle.
3. Failure to lead the airspeed when making power changes, climbs or descents.

   Example: When leveling off from a descent, increase the power in order to avoid the airspeed from bleeding off due to the decrease in momentum of the aircraft. If the pilot waits to bring in the power until after the aircraft is established in the level pitch attitude, the aircraft will have already decreased below the speed desired which will require additional adjustment in the power setting.
4. Fixation on airspeed tape or manifold pressure indications during airspeed changes, resulting in erratic control of airspeed, power, as well as pitch and bank attitudes.

Trim

Trim errors usually result from the following faults:

1. Improper adjustment of seat or rudder pedals for comfortable position of legs and feet. Tension in the ankles makes it difficult to relax rudder pressures.
2. Confusion about the operation of trim devices, which differ among various airplane types. Some trim wheels are aligned appropriately with the airplane's axes; others are not. Some rotate in a direction contrary to expectations.
3. Failure to understand the principles of trim and that the aircraft is being trimmed for airspeed, not a pitch attitude.
4. Faulty sequence in trim techniques. Trim should be utilized to relieve control pressures, not to change pitch attitudes. The proper trim technique has the pilot holding the control wheel first and then trimming to relieve any control pressures. Continuous trim changes will be required as the power setting is changed. Utilize the trim continuously, but in small amounts.

Straight Climbs and Descents

Each aircraft will have a specific pitch attitude and airspeed that corresponds to the most efficient climb rate for a specified weight. The POH/AFM contains the speeds that will produce the desired climb. These numbers are based on maximum gross weight. Pilots must be familiar with how the speeds will vary with weight so they can compensate during flight.

Entry

Constant Airspeed Climb From Cruise Airspeed

To enter a constant airspeed climb from cruise airspeed, slowly and smoothly apply aft elevator pressure in order to raise the yellow chevron (aircraft symbol) until the tip points to the desired degree of pitch. *[Figure 5-63]* Hold the aft control pressure and smoothly increase the power to the climb power setting. This increase in power may be initiated either prior to initiating the pitch change or after having established the desired pitch setting. Consult the POH/AFM for specific climb power settings if anything other than a full power climb is desired. Pitch attitudes will vary depending on the type of aircraft being flown. As airspeed decreases, control forces will need to be increased in order to compensate for the additional elevator deflection required to maintain attitude. Utilize trim to eliminate any control pressures. By effectively using trim, the pilot will be better able to maintain the desired pitch without constant attention. The pilot is thus able to devote more time to maintaining an effective scan of all instrumentation.

The VSI should be utilized to monitor the performance of the aircraft. With a smooth pitch transition, the VSI tape should begin to show an immediate trend upward and stabilize on a

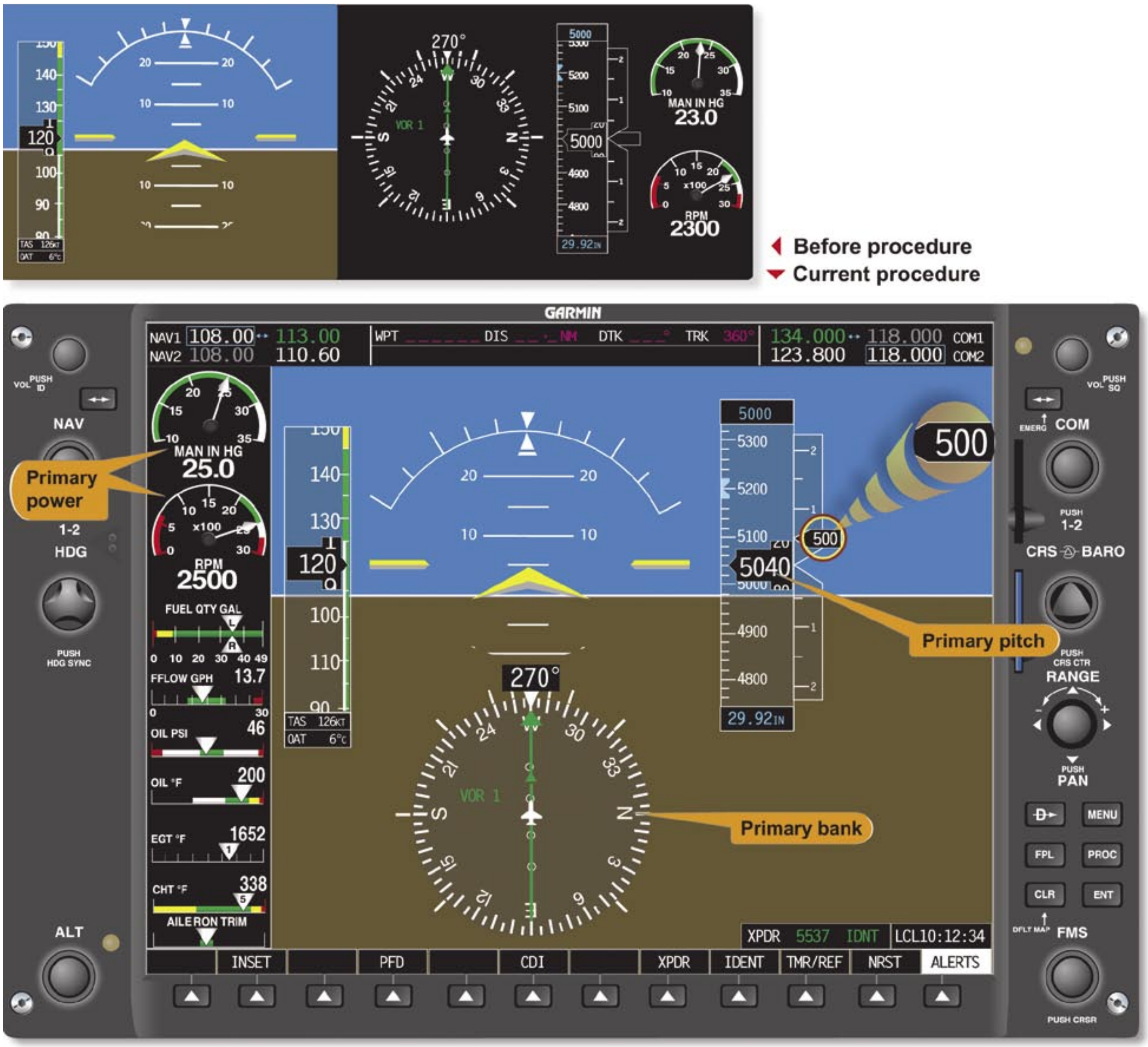

Figure 5-63. *Constant Airspeed Climb From Cruise Airspeed.*

rate of climb equivalent to the pitch and power setting being utilized. Depending on current weight and atmospheric conditions, this rate will be different. This will require the pilot to be knowledgeable of how weight and atmospheric conditions affect aircraft performance.

Once the aircraft is stabilized at a constant airspeed and pitch attitude, the primary flight instrument for pitch will be the ASI and the primary bank instrument will be the heading indicator. The primary power instrument will be the tachometer or the manifold pressure gauge depending on the aircraft type. If the pitch attitude is correct, the airspeed should slowly decrease to the desired speed. If there is any variation in airspeed, make small pitch changes until the aircraft is stabilized at the desired speed. Any change in airspeed will require a trim adjustment.

Constant Airspeed Climb from Established Airspeed

In order to enter a constant airspeed climb, first complete the airspeed reduction from cruise airspeed to climb airspeed. Maintain straight-and-level flight as the airspeed is reduced. The entry to the climb is similar to the entry from cruise airspeed with the exception that the power must be increased when the pitch attitude is raised. *[Figure 5-64]* Power added after the pitch change will show a decrease in airspeed due to the increased drag encountered. Power added prior to a pitch change will cause the airspeed to increase due to the excess thrust.

Constant Rate Climbs

Constant rate climbs are very similar to the constant airspeed climbs in the way the entry is made. As power is added,

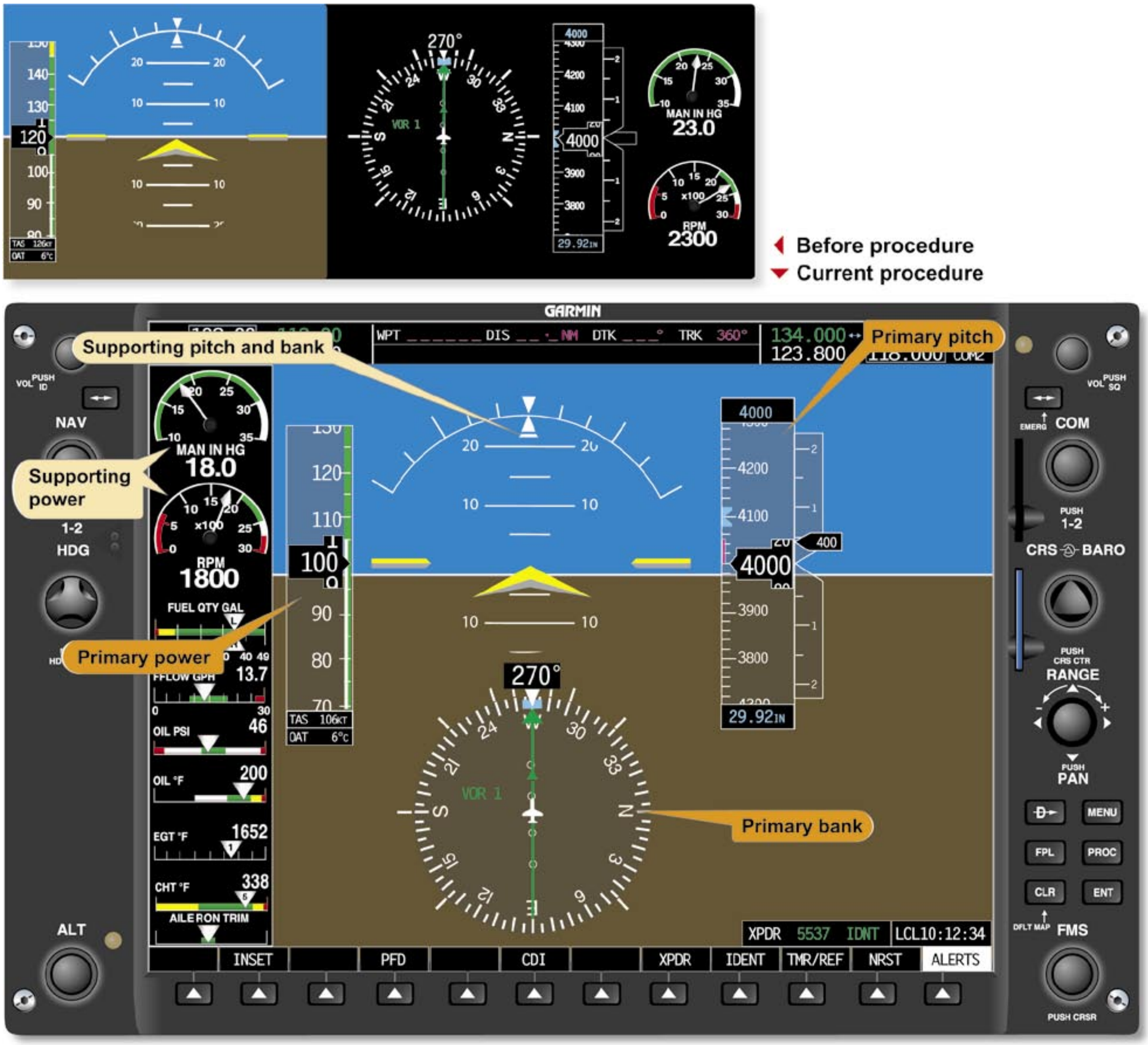

Figure 5-64. *Constant-Airspeed Climb From Established Airspeed.*

smoothly apply elevator pressure to raise the yellow chevron to the desired pitch attitude that equates to the desired vertical speed rate. The primary instrument for pitch during the initial portion of the maneuver is the ASI until the vertical speed rate stabilizes and then the VSI tape becomes primary. The ASI then becomes the primary instrument for power. If any deviation from the desired vertical speed is noted, small pitch changes will be required in order to achieve the desired vertical speed. *[Figure 5-65]*

When making changes to compensate for deviations in performance, pitch, and power, pilot inputs need to be coordinated to maintain a stable flight attitude. For instance, if the vertical speed is lower than desired but the airspeed is correct, an increase in pitch will momentarily increase the vertical speed. However, the increased drag will quickly start to degrade the airspeed if no increase in power is made. A change to any one variable will mandate a coordinated change in the other.

Conversely, if the airspeed is low and the pitch is high, a reduction in the pitch attitude alone may solve the problem. Lower the nose of the aircraft very slightly to see if a power reduction is necessary. Being familiar with the pitch and power settings for the aircraft aids in achieving precise attitude instrument flying.

Leveling Off

Leveling off from a climb requires a reduction in the pitch prior to reaching the desired altitude. If no change in pitch is made until reaching the desired altitude, the momentum of the aircraft causes the aircraft to continue past the desired altitude throughout the transition to a level pitch attitude. The amount of lead to be applied depends on the vertical speed rate. A higher vertical speed requires a larger lead for level off. A good rule of thumb to utilize is to lead the level off by 10 percent of the vertical speed rate (1,000 fpm ÷ 10 = 100 feet lead).

To level off at the desired altitude, refer to the attitude display and apply smooth forward elevator pressure toward the desired level pitch attitude while monitoring the VSI and altimeter tapes. The rates should start to slow and airspeed should begin to increase. Maintain the climb power setting until the airspeed approaches the desired cruise airspeed. Continue to monitor the altimeter to maintain the desired altitude as the airspeed increases. Prior to reaching the cruise airspeed, the power must be reduced to avoid overshooting the desired speed. The amount of lead time that is required depends on the speed at which the aircraft accelerates. Utilization of the airspeed trend indicator can assist by showing how quickly the aircraft will arrive at the desired speed.

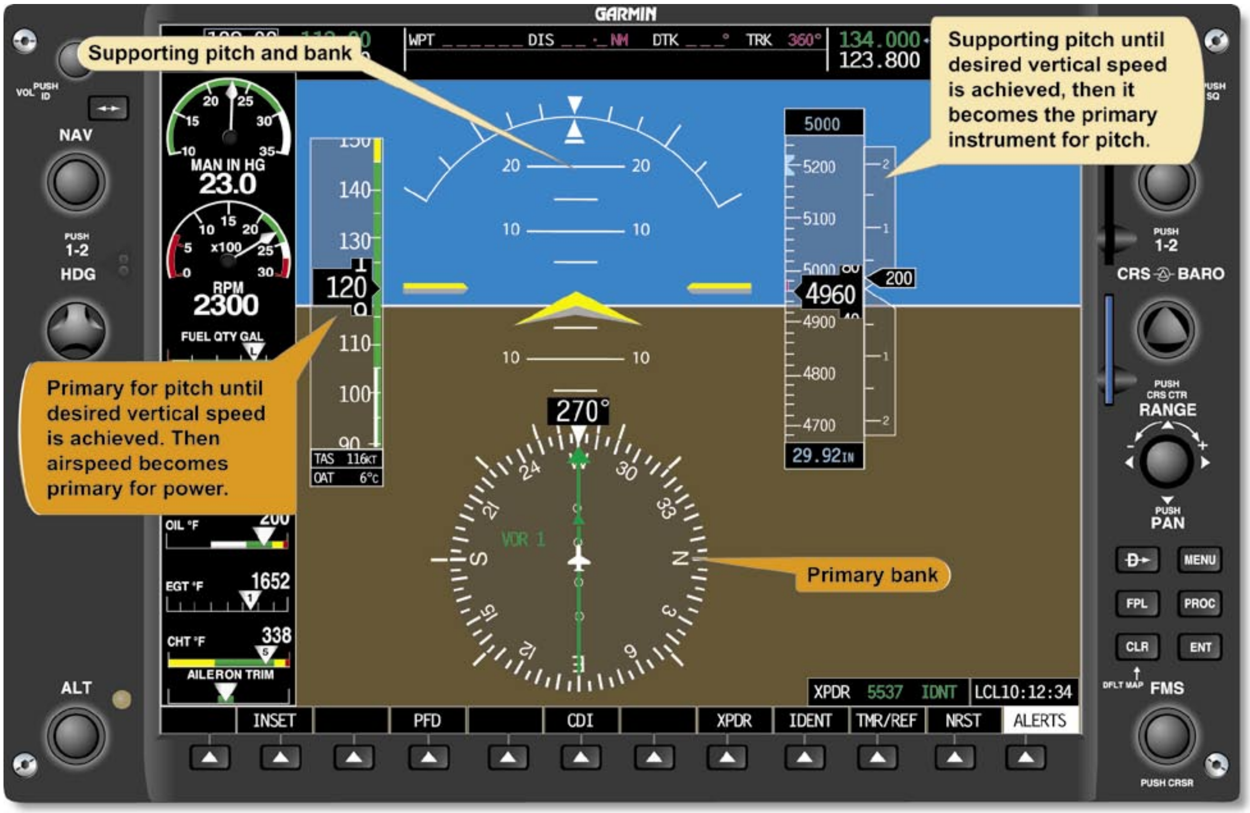
Supporting pitch and bank
Supporting pitch until desired vertical speed is achieved, then it becomes the primary instrument for pitch.
Primary for pitch until desired vertical speed is achieved. Then airspeed becomes primary for power.
Primary bank
GARMIN
MAN IN HG 23.0
RPM 2300
120
4960
270°
XPDR 5537 IDNT LCL10:12:34
INSET
PFD
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS

Figure 5-65. *Constant Rate Climbs.*

To level off at climbing airspeed, lower the nose to the appropriate pitch attitude for level flight with a simultaneous reduction in power to a setting that will maintain the desired speed. With a coordinated reduction in pitch and power there should be no change in the airspeed.

Descents

Descending flight can be accomplished at various airspeeds and pitch attitudes by reducing power, lowering the nose to a pitch attitude lower than the level flight attitude, or adding drag. Once any of these changes have been made, the airspeed will eventually stabilize. During this transitional phase, the only instrument that will display an accurate indication of pitch is the attitude indicator. Without the use of the attitude indicator (such as in partial panel flight), the ASI tape, the VSI tape, and the altimeter tape will show changing values until the aircraft stabilizes at a constant airspeed and constant rate of descent. The altimeter tape continues to show a descent. Hold pitch constant and allow the aircraft to stabilize. During any change in attitude or airspeed, continuous application of trim is required to eliminate any control pressures that need to be applied to the control yoke. An increase in the scan rate during the transition is important since changes are being made to the aircraft flight path and speed. *[Figure 5-66]*

Entry

Descents can be accomplished with a constant rate, constant airspeed or a combination. The following method can accomplish any of these with or without an attitude indicator. Reduce the power to allow the aircraft to decelerate to the desired airspeed while maintaining straight-and-level flight. As the aircraft approaches the desired airspeed, reduce the

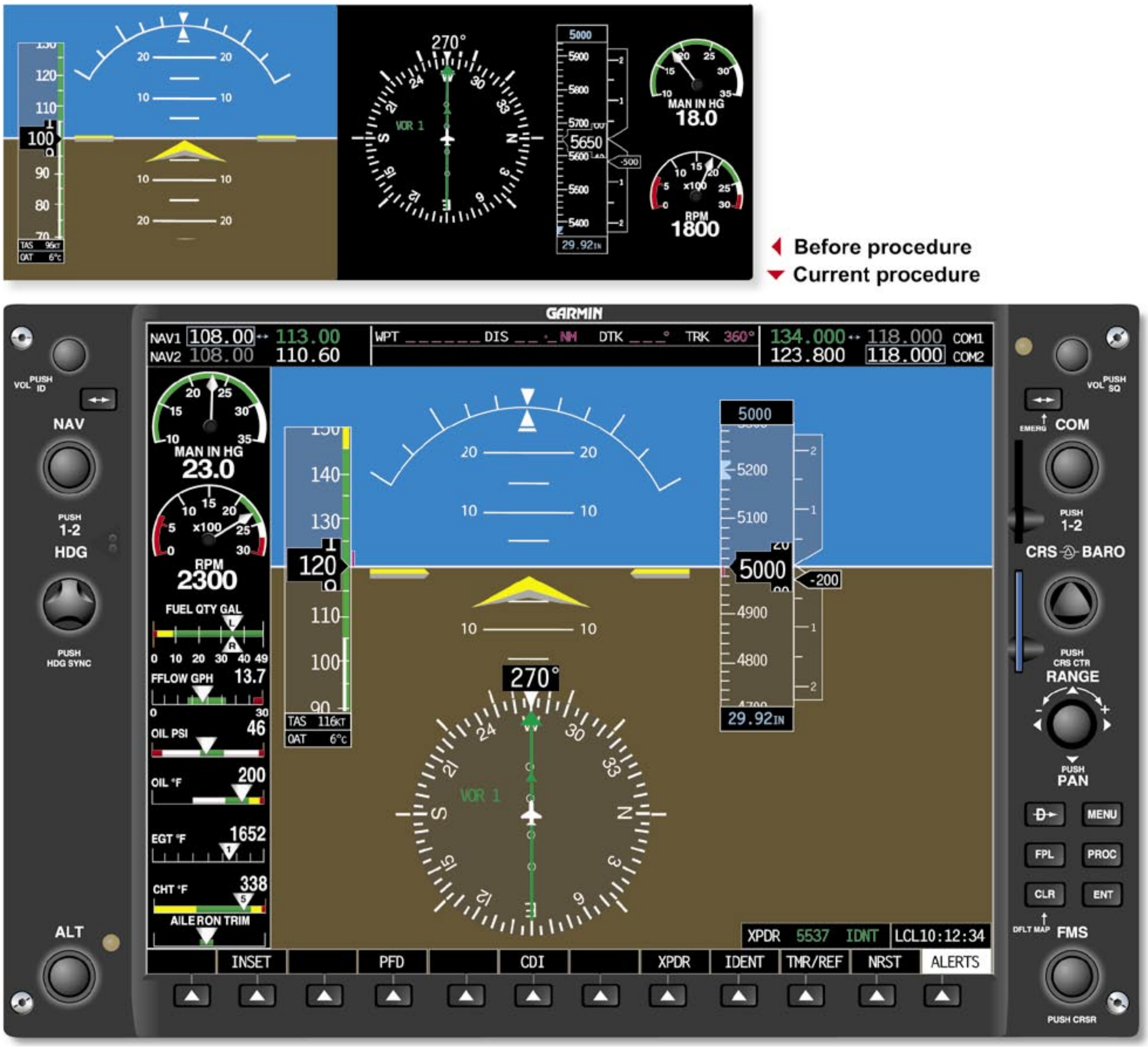

100
270°
5000
5650
-500
MAN IN HG
18.0
RPM
1800
29.92IN
TAS 96KT
OAT 6°C
◀ Before procedure
▼ Current procedure
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
WPT DIS NM DTK ° TRK 360°
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
MAN IN HG
23.0
RPM
2300
FUEL QTY GAL
FFLOW GPH 13.7
OIL PSI 46
OIL °F 200
EGT °F 1652
CHT °F 338
AILERON TRIM
120
270°
5000
-200
29.92IN
TAS 116KT
OAT 6°C
VOR 1
XPDR 5537 IDNT
LCL10:12:34
INSET
PFD
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS
NAV
HDG
PUSH HDG SYNC
ALT
COM
CRS BARO
RANGE
PUSH PAN
MENU
FPL
PROC
CLR
ENT
FMS
PUSH CRSR

Figure 5-66. *The top image illustrates a reduction of power and descending at 500 fpm to an altitude of 5,000 feet. The bottom image illustrates an increase in power and the initiation of leveling off.*

power to a predetermined value. The airspeed continues to decrease below the desired airspeed unless a simultaneous reduction in pitch is performed. The primary instrument for pitch is the ASI tape. If any deviation from the desired speed is noted, make small pitch corrections by referencing the attitude indicator and validate the changes made with the airspeed tape. Utilize the airspeed trend indicator to judge if the airspeed will be increasing and at what rate. Remember to trim off any control pressures.

The entry procedure for a constant rate descent is the same except the primary instrument for pitch is the VSI tape. The primary instrument for power will be the ASI. When performing a constant rate descent while maintaining a specific airspeed, coordinated use of pitch and power will be required. Any change in pitch directly affects the airspeed. Conversely, any change in airspeed will have a direct impact on vertical speed as long as the pitch is being held constant.

Leveling Off

When leveling off from a descent with the intention of returning to cruise airspeed, first start by increasing the power to cruise prior to increasing the pitch back toward the level flight attitude. A technique used to determine how soon to start the level off is to lead the level off by an altitude corresponding to 10 percent of the rate of descent. For example, if the aircraft is descending at 1,000 fpm, start the level off 100 feet above the level off altitude. If the pitch attitude change is started late, there is a tendency to overshoot the desired altitude unless the pitch change is made with a rapid movement. Avoid making any rapid changes that could lead to control issues or spatial disorientation. Once in level pitch attitude, allow the aircraft to accelerate to the desired speed. Monitor the performance on the airspeed and altitude tapes. Make adjustments to the power in order to correct any deviations in the airspeed. Verify that the aircraft is maintaining level flight by cross-checking the altimeter tape. If deviations are noticed, make an appropriate smooth pitch change in order to arrive back at desired altitude. Any change in pitch requires a smooth coordinated change to the power setting. Monitor the airspeed in order to maintain the desired cruise airspeed.

To level off at a constant airspeed, the pilot must again determine when to start to increase the pitch attitude toward the level attitude. If pitch is the only item that is changing, airspeed varies due to the increase in drag as the aircraft's pitch increases. A smooth coordinated increase in power will need to be made to a predetermined value in order to maintain speed. Trim the aircraft to relieve any control pressure that may have to be applied.

Common Errors in Straight Climbs and Descents

Climbing and descending errors usually result from but are not limited to the following errors:

1. Overcontrolling pitch on beginning the climb. Aircraft familiarization is the key to achieving precise attitude instrument flying. Until the pilot becomes familiar with the pitch attitudes associated with specific airspeeds, the pilot must make corrections to the initial pitch settings. Changes do not produce instantaneous and stabilized results; patience must be maintained while the new speeds and vertical speed rates stabilize. Avoid the temptations to make a change and then rush into making another change until the first one is validated. Small changes will produce more expeditious results and allow for a more stabilized flight path. Large changes to pitch and power are more difficult to control and can further complicate the recovery process.
2. Failure to increase the rate of instrument cross-check. Any time a pitch or power change is made, an increase in the rate a pilot cross-checks the instrument is required. A slow cross-check can lead to deviations in other flight attitudes.
3. Failure to maintain new pitch attitudes. Once a pitch change is made to correct for a deviation, that pitch attitude must be maintained until the change is validated. Utilize trim to assist in maintaining the new pitch attitude. If the pitch is allowed to change, it is impossible to validate whether the initial pitch change was sufficient to correct the deviation. The continuous changing of the pitch attitude delays the recovery process.
4. Failure to utilize effective trim techniques. If control pressures have to be held by the pilot, validation of the initial correction will be impossible if the pitch is allowed to vary. Pilots have the tendency to either apply or relax additional control pressures when manually holding pitch attitudes. Trim allows the pilot to fly without holding pressure on the control yoke.
5. Failure to learn and utilize proper power settings. Any time a pilot is not familiar with an aircraft's specific pitch and power settings, or does not utilize them, a change in flight paths will take longer. Learn pitch and power settings in order to expedite changing the flight path.
6. Failure to cross-check both airspeed and vertical speed prior to making adjustments to pitch and or power. It is possible that a change in one may correct a deviation in the other.

7. Uncoordinated use of pitch and power during level offs. During level offs, both pitch and power settings need to be made in unison in order to achieve the desired results. If pitch is increased before adding power, additional drag will be generated thereby reducing airspeed below the desired value.
8. Failure to utilize supporting pitch instruments which will lead to chasing the VSI. Always utilize the attitude indicator as the control instrument on which to change the pitch.
9. Failure to determine a proper lead time for level off from a climb or descent. Waiting too long can lead to overshooting the altitude.
10. Ballooning—Failure to maintain forward control pressure during level off as power is increased. Additional lift is generated causing the nose of the aircraft to pitch up.

Turns

Standard Rate Turns

The previous sections have addressed flying straight-and-level as well as climbs and descents. However, attitude instrument flying is not accomplished solely by flying in a straight line. At some point, the aircraft will need to be turned to maneuver along victor airways, global positioning system (GPS) courses, and instrument approaches. The key to instrument flying is smooth, controlled changes to pitch and bank. Instrument flying should be a slow but deliberate process that takes the pilot from departure airport to destination airport without any radical flight maneuvers.

A turn to specific heading should be made at standard rate. Standard rate is defined as a turning rate of 3° per second which will yield a complete 360° turn in 2 minutes. A turning rate of 3° per second will allow for a timely heading change, as well as allowing the pilot sufficient time to cross-check the flight instruments and avoid drastic changes to the aerodynamic forces being exerted on the aircraft. At no time should the aircraft be maneuvered faster than the pilot is comfortable cross-checking the flight instruments. Most autopilots are programmed to turn at standard rate.

Establishing A Standard Rate Turn

In order to initiate a standard rate turn, approximate the bank angle and then establish that bank angle on the attitude indicator. A rule of thumb to determine the approximate angle of bank is to use 15 percent of the true airspeed. A simple way to determine this amount is to divide the airspeed by 10 and add one-half the result. For example, at 100 knots, approximately 15° of bank is required (100/10 = 10 + 5 = 15); at 120 knots, approximately 18° of bank is needed for a standard-rate turn. Cross-check the turn rate indicator, located on the HSI, to determine if that bank angle is sufficient to deliver a standard rate turn. Slight modifications may need to be made to the bank angle in order to achieve the desired performance. The primary bank instrument in this case is the turn rate indicator since the goal is to achieve a standard rate turn. The turn rate indicator is the only instrument that can specifically indicate a standard rate turn. The attitude indicator is used only to establish a bank angle (control instrument) but can be utilized as a supporting instrument by cross-checking the bank angle to determine if the bank is greater or less than what was calculated.

As the aircraft rolls into the bank, the vertical component of lift will begin to decrease. *[Figure 5-67]* As this happens, additional lift must be generated to maintain level flight. Apply aft control pressure on the yoke sufficient to stop any altitude loss trend. With the increase in lift that needs to be generated, additional induced drag will also be generated. This additional drag will cause the aircraft to start to decelerate. To counteract this, apply additional thrust by adding power to the power lever. Once altitude and airspeed is being maintained, utilize the trim wheel to eliminate any control forces that need to be held on the control column.

When rolling out from a standard rate turn, the pilot needs to utilize coordinated aileron and rudder and roll-out to a wings level attitude utilizing smooth control inputs. The roll-out rate should be the same as the roll-in rate in order to estimate the lead necessary to arrive at the desired heading without over- or undershooting.

During the transition from the turn back to straight flight, the attitude indicator becomes the primary instrument for bank. Once the wings are level, the heading indicator becomes the primary instrument for bank. As bank decreases, the vertical component increases if the pitch attitude is not decreased sufficiently to maintain level flight. An aggressive cross-check keeps the altimeter stationary if forward control pressure is applied to the control column. As the bank angle is decreased, the pitch attitude should be decreased accordingly in order to arrive at the level pitch attitude when the aircraft reaches zero bank. Remember to utilize the trim wheel to eliminate any excess control forces that would otherwise need to be held.

Common Errors

1. One common error associated with standard rate turns is due to pilot inability to hold the appropriate bank angle that equates to a standard rate. The primary bank instrument during the turn is the turn rate indicator; however the bank angle varies slightly. With an

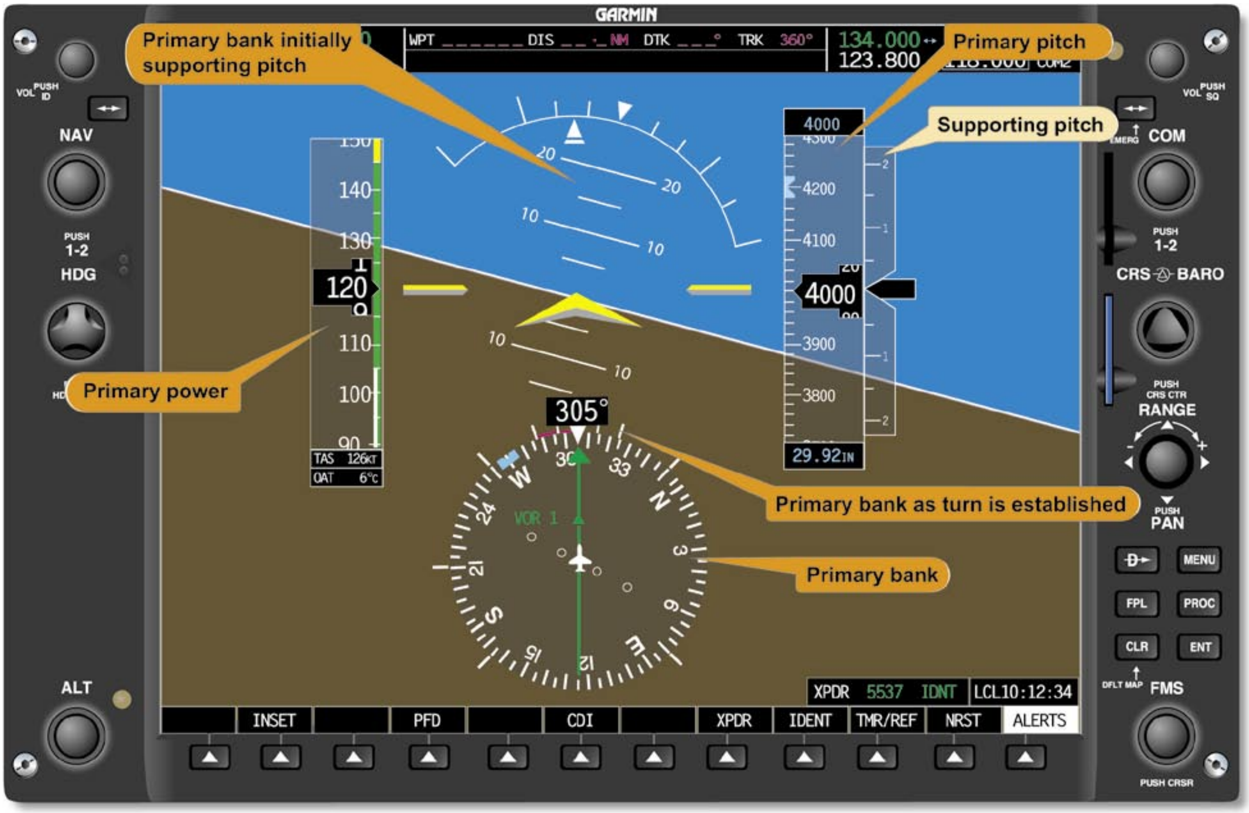

Figure 5-67. *Standard Rate Turn—Constant Airspeed.*

aggressive cross-check, a pilot should be able to minimize errors arising from over- or underbanking.

2. Another error normally encountered during standard rate turns is inefficient or lack of adequate cross-checking. Pilots need to establish an aggressive cross-check in order to detect and eliminate all deviations from altitude, airspeed, and bank angle during a maneuver.
3. Fixation is a major error associated with attitude instrument flying in general. Pilots training for their instrument rating tend to focus on what they perceive to be the most important task at hand and abandon their cross-check by applying all of their attention to the turn rate indicator. A modified radial scan works well to provide the pilot with adequate scanning of all instrumentation during the maneuver.

Turns to Predetermined Headings

Turning the aircraft is one of the most basic maneuvers that a pilot learns during initial flight training. Learning to control the aircraft, maintaining coordination, and smoothly rolling out on a desired heading are all keys to proficient attitude instrument flying.

EFDs allow the pilot to better utilize all instrumentation during all phases of attitude instrument flying by consolidating all traditional instrumentation onto the PFD. The increased size of the attitude indicator, which stretches the entire width of the PFD, allows the pilot to maintain better pitch control while the introduction of the turn rate indicator positioned directly on the compass rose aids the pilot in determining when to begin a roll-out for the desired heading.

When determining what bank angle to utilize when making a heading change, a general rule states that for a small heading change, do not use a bank angle that is greater than the total number of degrees of change needed. For instance, if a heading change of 20° is needed, a bank angle of not more than 20° is required. Another rule of thumb that better defines the bank angle is half the total number of degrees of heading change required, but never greater than standard rate. The exact bank angle that equates to a standard rate turn varies due to true airspeed.

With this in mind and the angle of bank calculated, the next step is determining when to start the roll-out process. For example:

An aircraft begins a turn from a heading of 030° to a heading of 120°. With the given airspeed, a standard rate turn has yielded a 15° bank. The pilot wants to begin a smooth coordinated roll-out to the desired heading when the heading indicator displays approximately 112°. The necessary calculations are:

15° bank (standard rate) ÷ 2 = 7.5°
120° – 7.5° = 112.5°

By utilizing this technique the pilot is better able to judge if any modifications need to be made to the amount of lead once the amount of over- or undershooting is established.

Timed Turns

Timed turns to headings are performed in the same fashion with an EFD as with an analog equipped aircraft. The instrumentation used to perform this maneuver is the turn rate indicator as well as the clock. The purpose of this maneuver is to allow the pilot to gain proficiency in scanning as well as to further develop the pilot's ability to control the aircraft without standard instrumentation.

Timed turns become essential when controlling the aircraft with a loss of the heading indicator. This may become necessary due to a loss of the AHRS unit or the magnetometer. In any case, the magnetic compass will still be available for navigation. The reason for timed turns instead of magnetic compass turns is the simplicity of the maneuver. Magnetic compass turns require the pilot to take into account various errors associated with the compass; timed turns do not.

Prior to initiating a turn, determine if the standard rate indication on the turn rate indicator will actually deliver a 3° per second turn. To accomplish this, a calibration must be made. Establish a turn in either direction at the indicated standard rate. Start the digital timer as the compass rolls past a cardinal heading. Stop the timer once the compass card rolls through another cardinal heading. Roll wings level and compute the rate of turn. If the turn rate indicator is calibrated and indicating correctly, 90° of heading change should take 30 seconds. If the time taken to change heading by 90° is more or less than 30 seconds, then a deflection above or below the standard rate line needs to be made to compensate for the difference. Once the calibration has been completed in one direction, proceed to the opposite direction. When both directions have been calibrated, apply the calibrated calculations to all timed turns.

In order to accomplish a timed turn, the amount of heading change needs to be established. For a change in heading from 120° to a heading of 360°, the pilot calculates the difference and divides that number by 3. In this case, 120° divided by 3° per second equals 40 seconds. This means that it would take 40 seconds for an aircraft to change heading 120° if that aircraft were held in a perfect standard rate turn. Timing for the maneuver should start as the aircraft begins rolling into the standard rate turn. Monitor all flight instruments during this maneuver. The primary pitch instrument is the altimeter. The primary power instrument is the ASI and the primary bank instrument is the turn rate indicator.

Once the calculated time expires, start a smooth coordinated roll-out. As long as the pilot utilizes the same rate of roll-in as roll-out, the time it takes for both will not need to be included in the calculations. With practice the pilot should level the wings on the desired heading. If any deviation has occurred, make small corrections to establish the correct heading.

Compass Turns

The magnetic compass is the only instrument that requires no other source of power for operation. In the event of an AHRS or magnetometer failure, the magnetic compass is the instrument the pilot uses to determine aircraft heading. For a more detailed explanation on the use of the magnetic compass, see page 5-21.

Steep Turns

For the purpose of instrument flight training, a steep turn is defined as any turn in excess of standard rate. A standard rate turn is defined as 3° per second. The bank angle that equates to a turn rate of 3° per second varies according to airspeed. As airspeed increases, the bank angle must be increased. The exact bank angle that equates to a standard rate turn is unimportant. Normal standard rate turn bank angles range from 10° to 20°. The goal of training in steep turn maneuvers is pilot proficiency in controlling the aircraft with excessive bank angles.

Training in excessive bank angles will challenge the pilot in honing cross-checking skills and improve altitude control throughout a wider range of flight attitudes. Although the current instrument flight check practical test standards (PTS) do not call for a demonstration of steep turns on the certification check flight, this does not eliminate the need for the instrument pilot-in-training to demonstrate proficiency to an instructor.

Training in steep turns teaches the pilot to recognize and to adapt to rapidly changing aerodynamic forces that necessitate an increase in the rate of cross-checking all flight instruments. The procedures for entering, maintaining and exiting a steep turn are the same as for shallower turns. Proficiency in instrument cross-check and interpretation is increased due to the higher aerodynamic forces and increased speed at which the forces are changing.

Performing the Maneuver

To enter a steep turn to the left, roll into a coordinated 45° bank turn to the left. An advantage that glass panel displays have over analog instrumentation is a 45° bank indication on the roll scale. This additional index on the roll scale allows the pilot to precisely roll into the desired bank angle instead of having to approximate it as is necessary with analog instrumentation. *[Figure 5-68]*

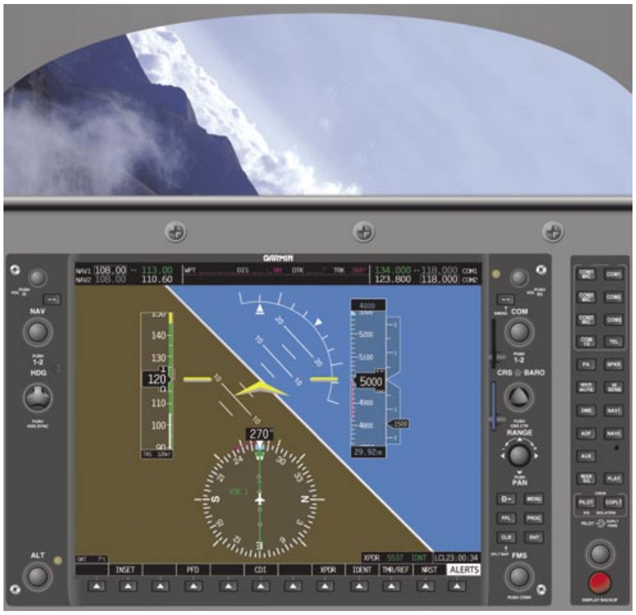

Figure 5-68. *Steep Left Turn.*

As soon as the bank angle increases from level flight, the vertical component of lift begins to decrease. If the vertical component of lift is allowed to continue to decrease, a pronounced loss of altitude is indicated on the altimeter along with the VSI tape, as well as the altitude trend indicator. Additionally, the airspeed will begin to increase due to the lowered pitch attitude. It is very important to have a comprehensive scan developed prior to training in steep turns. Utilization of all of the trend indicators, as well the VSI, altimeter, and ASI, is essential in learning to fly steep turns by reference to instruments alone.

In order to avoid a loss of altitude, the pilot begins to slowly increase back pressure on the control yoke in order to increase the pitch attitude. The pitch change required is usually no more than 3° to 5°, depending on the type of aircraft. As the pilot increases back pressure, the angle of attack increases, thus increasing the vertical component of lift. When a deviation in altitude is indicated, proper control force corrections need to be made. During initial training of steep turns, pilots have a tendency to overbank. Over banking is when the bank angle exceeds 50°. As the outboard wing begins to travel faster through the air it will begin to generate a greater and greater differential in lift compared to the inboard wing. As the bank angle continues to progress more and more steeply past 45°, the two components of lift (vertical and horizontal) become inversely proportionate.

Once the angle has exceeded 45°, the horizontal component of lift is now the greater force. If altitude should continue to decrease and the pilot only applies back yoke pressure, the aircraft's turn radius begins to tighten due to the increased horizontal force. If aft control pressure continues to increase, there will come a point where the loss of the vertical component of lift and aerodynamic wing loading prohibits the nose of the aircraft from being raised. Any increase in pitch only tightens the turning radius.

The key to successfully performing a steep turn by reference to instruments alone is the thorough understanding of the aerodynamics involved, as well as a quick and reliable cross-check. The pilot should utilize the trim to avoid holding control forces for any period of time. With time and practice, a flight instructor can demonstrate how to successfully fly steep turns with and without the use of trim. Once the aircraft is trimmed for the maneuver, accomplishing the maneuver will be virtually a hands-off effort. This allows additional time for cross-checking and interpreting the instruments.

It is imperative when correcting for a deviation in altitude, that the pilot modify the bank angle ±5° in order to vary the vertical component of lift, not just adjust back pressure. These two actions should be accomplished simultaneously.

During the recovery from steep turns to straight-and-level flight, aft control forces must be varied with the power control to arrive back at entry altitude, heading and airspeed.

Steps:

1. Perform clearing turns.
2. Roll left into a 45° bank turn and immediately begin to increase the pitch attitude by approximately 3° to 5°.
3. As the bank rolls past 30°, increase power to maintain the entry airspeed.
4. Apply trim to eliminate any aft control wheel forces.
5. Begin rolling out of the steep turn approximately 20° prior to the desired heading.
6. Apply forward control pressure and place the pitch attitude in the level cruise pitch attitude.
7. Reduce power to the entry power setting to maintain the desired airspeed.
8. Re-trim the aircraft as soon as practical or continue into a right hand steep turn and continue from step 3.

9. Once the maneuver is complete, establish cruise flight and accomplish all appropriate checklist items.

Unusual Attitude Recovery Protection

Unusual attitudes are some of the most hazardous situations for a pilot to be in. Without proper recovery training on instrument interpretation and aircraft control, a pilot can quickly aggravate an abnormal flight attitude into a potentially fatal accident.

Analog gauges require the pilot to scan between instruments to deduce the aircraft attitude. Individually, these gauges lack the necessary information needed for a successful recovery.

EFDs have additional features to aid in recognition and recovery from unusual flight attitudes. The PFD displays all the flight instruments on one screen. Each instrument is superimposed over a full-screen representation of the attitude indicator. With this configuration, the pilot no longer needs to transition from one instrument to another.

The new unusual attitude recovery protection allows the pilot to be able to quickly determine the aircraft's attitude and make a safe, proper and prompt recovery. Situational awareness is increased by the introduction of the large full-width artificial horizon depicted on the PFD. This now allows for the attitude indicator to be in view during all portions of the scan.

One problem with analog gauges is that the attitude indicator displays a complete blue or brown segment when the pitch attitude is increased toward 90° nose-up or nose-down.

With the EFDs, the attitude indicator is designed to retain a portion of both sky and land representation at all times. This improvement allows the pilot to always know the quickest way to return to the horizon. Situational awareness is greatly increased.

NOTE: The horizon line starts moving downward at approximately 47° pitch up. From this point on, the brown segment will remain visible to show the pilot the quickest way to return to the level pitch attitude. *[Figure 5-69]*

NOTE: The horizon line starts moving upward at approximately 27° pitch down. From this point on, the blue segment will remain visible to show the pilot the quickest way to return to the level pitch attitude. *[Figure 5-70]*

It is imperative to understand that the white line on the attitude indicator is the horizon line. The break between the blue and brown symbols is only a reference and should not be thought of as the artificial horizon.

Another important advancement is the development of the unusual attitude recovery protection that is built into the PFD software and made capable by the AHRS. In the case of a nose-high unusual attitude, the unusual attitude recovery protection displays red chevrons which point back to the horizon line.

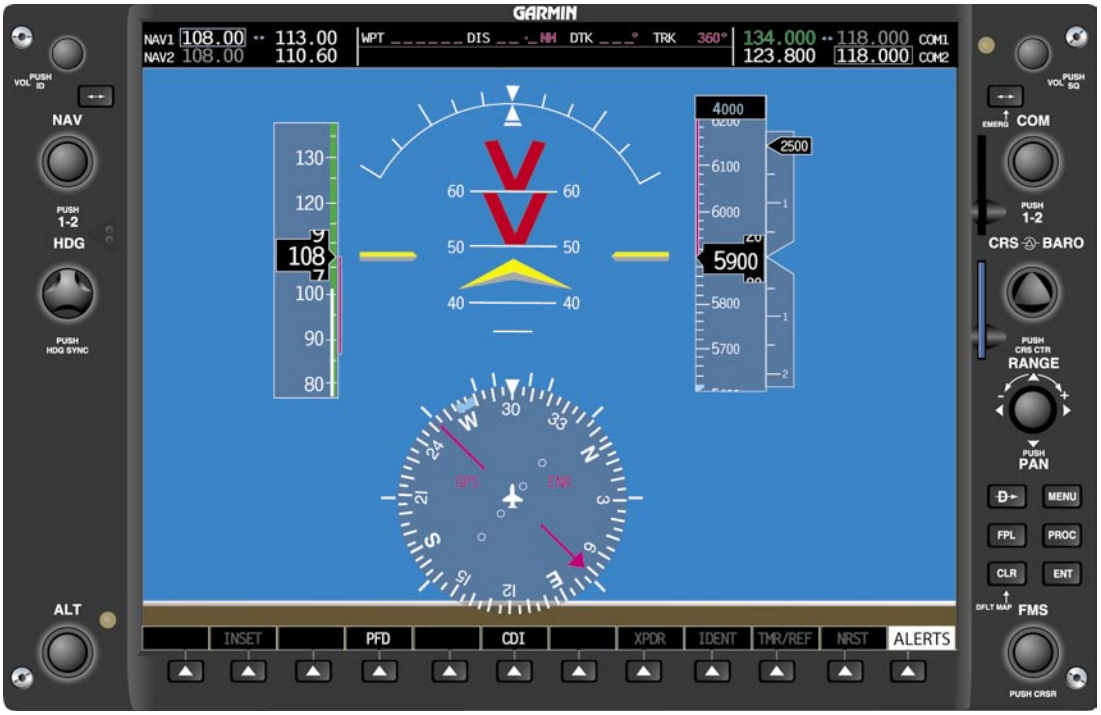

Figure 5-69. *Unusual Attitude Recovery Protection. Note the brown horizon line is visible at the bottom.*

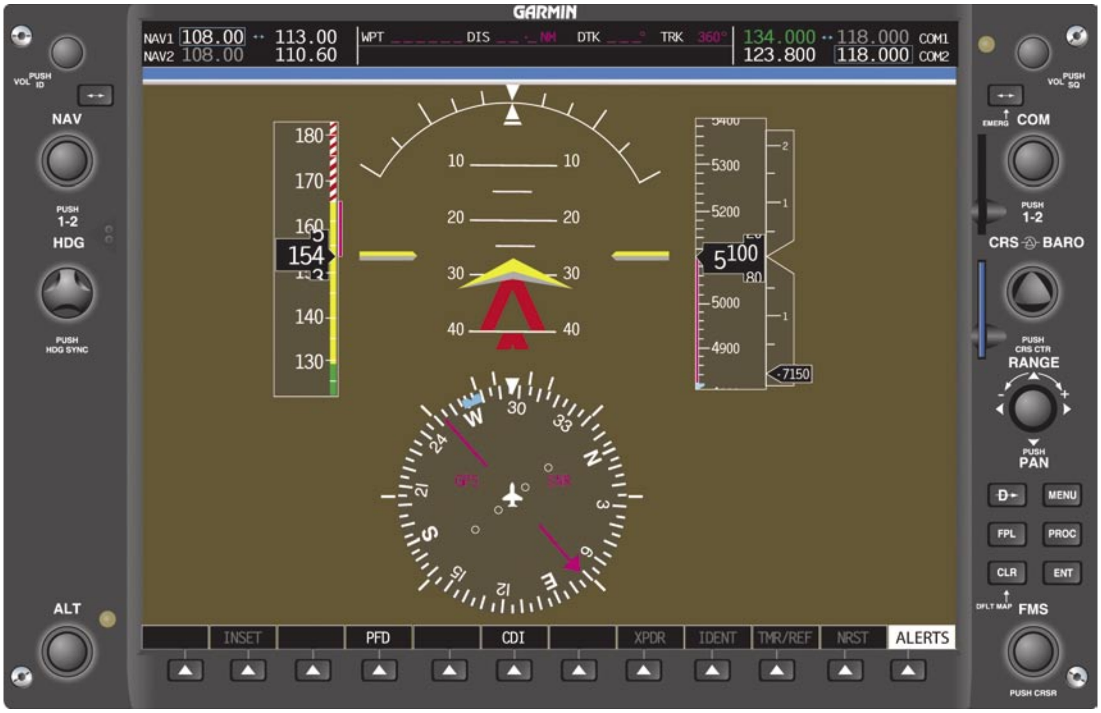
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IDENT
TMR/REF
NRST
ALERTS

Figure 5-70. *Horizon line starts moving upward at 27°. Note that the blue sky remains visible at 17° nose-down.*

These chevrons are positioned at 50° up on the attitude indicator. The chevrons appear when the aircraft approaches a nose-high attitude of 30°. The software automatically de-clutters the PFD leaving only airspeed, heading, attitude, altimeter, VSI tape, and the trend vectors. The de-cluttered information reappears when the pitch attitude falls below 25°.

For nose-low unusual attitudes, the chevrons are displayed when the pitch exceeds 15° nose-down. If the pitch continues to decrease, the unusual attitude recovery protection de-clutters the screen at 20° nose-down. The de-cluttered information reappears when the pitch increases above 15°.

Additionally, there are bank limits that trigger the unusual attitude protection. If the aircraft's bank increases beyond 60°, a continuation of the roll index occurs to indicate the shortest direction to roll the wings back to level. At 65°, the PFD de-clutters. All information reappears when the bank decreases below 60°.

In *Figure 5-71*, the aircraft has rolled past 60°. Observe the white line that continues from the end of the bank index. This line appears to indicate the shortest distance back to wings level.

When experiencing a failure of the AHRS unit, all unusual attitude protection is lost. The failure of the AHRS results in the loss of all heading and attitude indications on the PFD. In addition, all modes of the autopilot, except for roll and altitude hold, are lost.

The following picture series represents how important this technology is in increasing situational awareness, and how critical it is in improving safety.

Figure 5-72 shows the unusual attitude protection with valid AHRS and air data computer (ADC) inputs. The bright red chevrons pointing down to the horizon indicate a nose-high unusual attitude that can be easily recognized and corrected.

NOTE: The red chevrons point back to the level pitch attitude. The trend indicators show where the airspeed and altitude will be in 6 seconds. The trend indicator on the heading indicator shows which direction the aircraft is turning. The slip/skid indicator clearly shows if the aircraft is coordinated. This information helps the pilot determine which type of unusual attitude the aircraft has taken.

Now look at *Figure 5-73*. The display shows the same airspeed as the picture above; however, the AHRS unit has failed. The altimeter and the VSI tape are the only clear indications that the aircraft is in a nose-high attitude. The one key instrument that is no longer present is the slip/skid indicator. There is not a standby turn coordinator installed in the aircraft for the pilot to reference.

The magnetic compass indicates a heading is being maintained; however, it is not as useful as a turn coordinator or slip/skid indicator.

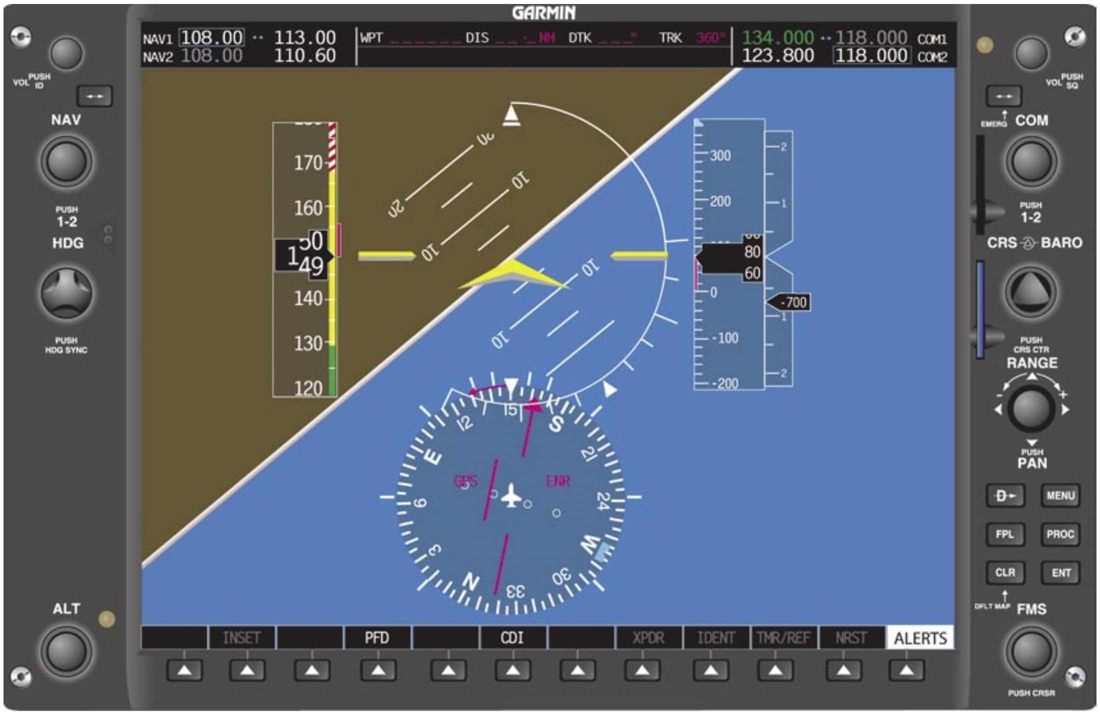
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DFLT MAP
FMS
PUSH CRSR

Figure 5-71. *Aircraft Rolled Past 60°.*

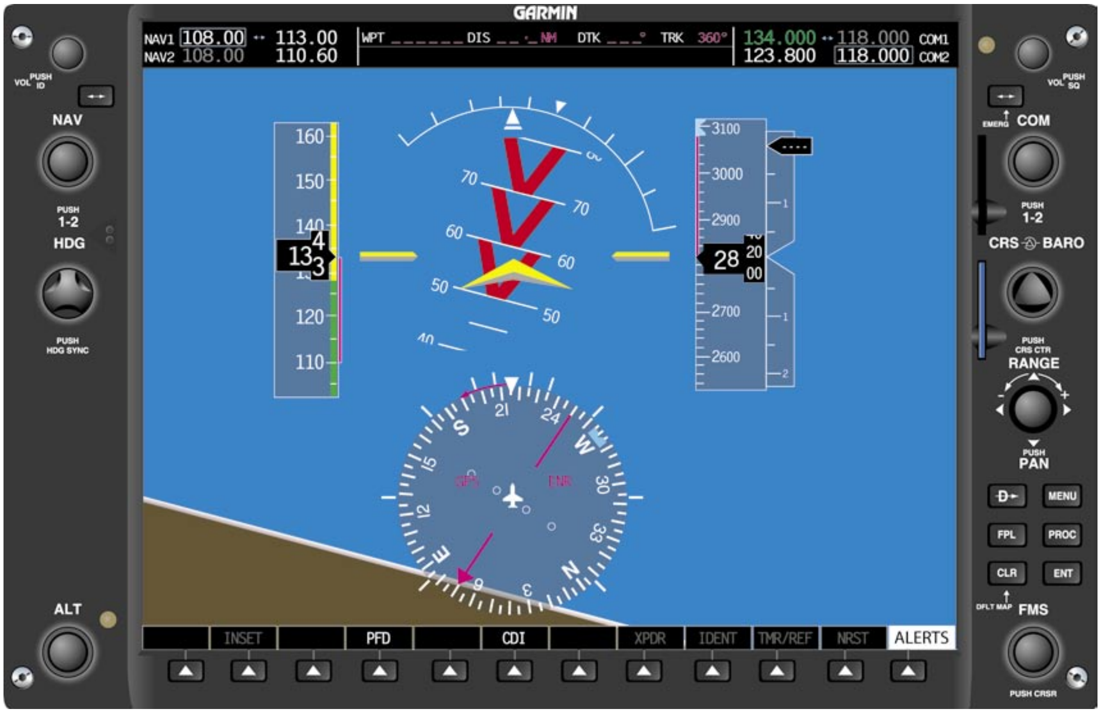
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PUSH 1-2
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PUSH CRS CTR
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Figure 5-72. *Unusual Attitude Protection With Valid AHRS.*

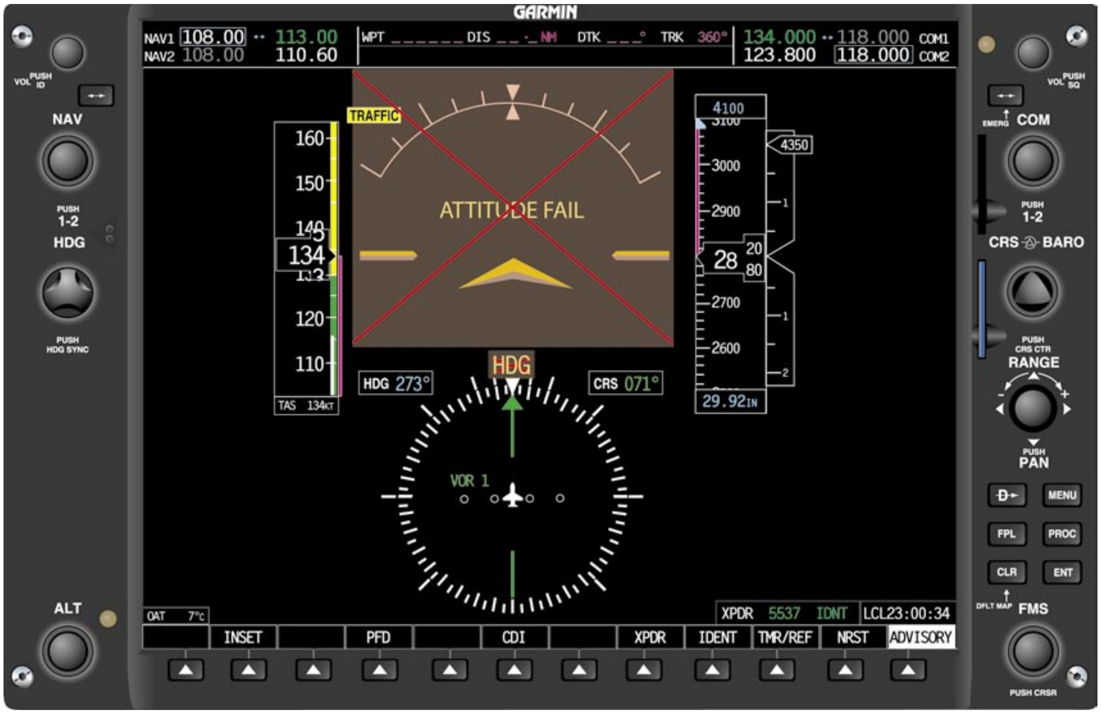
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PUSH HDG SYNC
ALT
COM
CRS BARO
RANGE
PAN
FMS
TRAFFIC
ATTITUDE FAIL
HDG 273°
CRS 071°
VOR 1
TAS 134KT
4100
4350
29.92IN
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XPDR 5537 IDNT LCL23:00:34
INSET
PFD
CDI
XPDR
IDENT
TMR/REF
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ADVISORY
MENU
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PROC
CLR
ENT

Figure 5-73. *AHRS Unit Failed.*

Figure 5-74 depicts an AHRS and ADC failure. In this failure scenario, there are no indications of the aircraft's attitude. The manufacturer recommends turning on the autopilot which is simply a wing leveler.

With a failure of the primary instrumentation on the PFD, the only references available are the stand-by instruments. The standby instrumentation consists of an analog ASI, attitude indicator, altimeter, and magnetic compass. There is no standby turn coordinator installed.

In extreme nose-high or nose-low pitch attitudes, as well as high bank angles, the analog attitude indicator has the potential to tumble, rendering it unusable.

Autopilot Usage

The autopilot is equipped with inputs from a turn coordinator installed behind the MFD screen. This turn coordinator is installed solely for the use of the autopilot to facilitate the roll mode. Roll mode, which is simply a wing leveler. This protection will always be available, barring a failure of the turn coordinator (to aid the pilot if the aircraft attains an unusual attitude).

NOTE: The pilot is not able to gain access to the turn coordinator. This instrument is installed behind the MFD panel. *[Figure 5-75]*

Most EFD equipped aircraft are coming from the factory with autopilots installed. However, the purchaser of the aircraft can specify if an autopilot is to be installed. Extreme caution should be utilized when flying an EFD equipped aircraft without an autopilot in IMC with an AHRS and ADC failure.

The autopilot should be utilized to reduce workload, which affords the pilot more time to monitor the flight. Utilization of the autopilot also decreases the chances of entry into an unusual attitude.

Flying an EFD equipped aircraft without the use of an autopilot has been shown to increase workload and decrease situational awareness for pilots first learning to flying the new system.

Common Errors Leading to Unusual Attitudes

The following errors have the potential to disrupt a pilot's situational awareness and lead to unusual attitudes.

1. Improper trimming techniques. A failure to keep the aircraft trimmed for level flight at all times can turn a momentary distraction into an emergency situation if the pilot stops cross-checking.
2. Poor crew resource management (CRM) skills. Failure to perform all single-pilot resource management duties efficiently. A major cause of CRM related accidents comes from the failure of the pilot to maintain an organized flight deck. Items that are being utilized for the flight portion should be neatly arranged for easy access. A disorganized flight deck

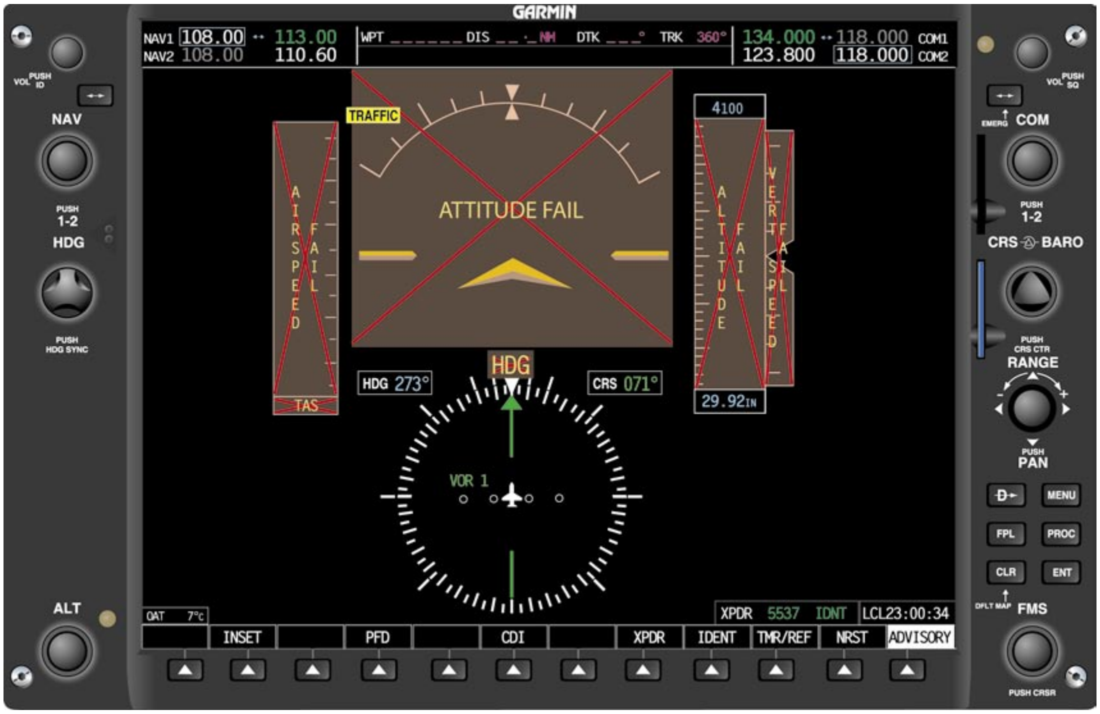
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CRS 071°
VOR 1
OAT 7°C
XPDR 5537 IDNT LCL23:00:34
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NRST
ADVISORY
VOL PUSH SQ
EMERG COM
PUSH 1-2
CRS BARO
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Figure 5-74. *AHRS ADC Failure.*

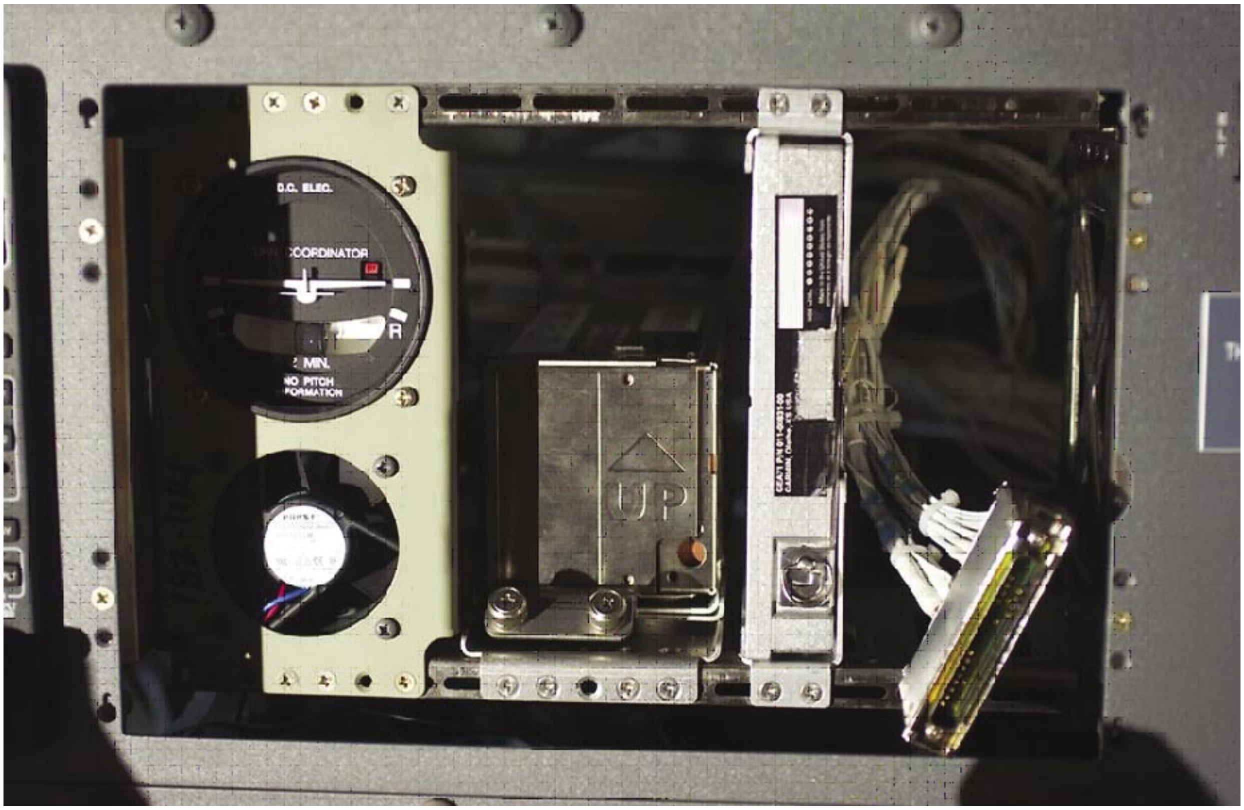
D.C. ELEC.
TURN COORDINATOR
R
2 MIN.
NO PITCH
FORMATION
UP

Figure 5-75. *This autopilot requires roll information from a turn coordinator.*

can lead to a distraction that causes the pilot to cease cross-checking the instruments long enough to enter an unusual attitude.

3. Fixation is displayed when a pilot focuses far too much attention on one instrument because he or she perceives something is wrong or a deviation is occurring. It is important for the instrument pilot to remember that a cross-check of several instruments for corroboration is more valuable than checking a single instrument.
4. Attempting to recover by sensory sensations other than sight. Recovery by instinct almost always leads to erroneous corrections due to the illusions that are prevalent during instrument flight.
5. Failure to practice basic attitude instrument flying. When a pilot does not fly instrument approach procedures or even basic attitude instrument flying maneuvers for long periods of time, skill levels diminish. Pilots should avoid flying in IMC if they are not proficient. They should seek a qualified instructor to receive additional instruction prior to entry into IMC.

Instrument Takeoff

The reason for learning to fly by reference to instruments alone is to expand a pilot's abilities to operate an aircraft in visibility less than VFR. Another valuable maneuver to learn is the instrument takeoff. This maneuver requires the pilot to maneuver the aircraft during the takeoff roll by reference to flight instruments alone with no outside visual reference. With practice, this maneuver becomes as routine as a standard rate turn.

The reason behind practicing instrument takeoffs is to reduce the disorientation that can occur during the transitional phase of quickly moving the eyes from the outside references inside to the flight instruments.

One EFD system currently offers what is trademarked as synthetic vision. Synthetic vision is a three-dimensional computer-generated representation of the terrain that lies ahead of the aircraft. The display shows runways as well as a depiction of the terrain features based on a GPS terrain database. Similar to a video game, the display generates a runway the pilot can maneuver down in order to maintain directional control. As long as the pilot tracks down the computer-generated runway, the aircraft will remain aligned with the actual runway.

Not all EFD systems have such an advanced visioning system. With all other systems, the pilot needs to revert to the standard procedures for instrument takeoffs. Each aircraft may require a modification to the maneuver; therefore, always obtain training on any new equipment to be used.

In order to accomplish an instrument takeoff, the aircraft needs to be maneuvered on the centerline of the runway facing the direction of departure with the nose or tail wheel straight. Assistance from the instructor may be necessary if the pilot has been taxiing while wearing a view limiting device. Lock the tail wheel, if so equipped, and hold the brakes firmly to prevent the aircraft from creeping. Cross-check the heading indicator on the PFD with the magnetic compass and adjust for any deviations noted on the compass card. Set the heading to the nearest 5° mark closest to the runway heading. This allows the pilot to quickly detect any deviations from the desired heading and allows prompt corrective actions during the takeoff roll. Using the omnibearing select (OBS) mode on the GPS, rotate the OBS selector until the needle points to the runway heading. This adds additional situational awareness during the takeoff roll. Smoothly apply power to generate sufficient rudder authority for directional control. Release the brakes and continue to advance the power to the takeoff setting.

As soon as the brakes are released, any deviation in heading needs to be corrected immediately. Avoid using brakes to control direction as this increases the takeoff roll, as well as provides the potential of overcontrolling the aircraft.

Continuously cross-check the ASI and the heading indicator as the aircraft accelerates. As the aircraft approaches 15-25 knots below the rotation speed, smoothly apply aft elevator pressure to increase the pitch attitude to the desired takeoff attitude (approximately 7° for most small airplanes). With the pitch attitude held constant, continue to cross-check the flight instruments and allow the aircraft to fly off of the runway. Do not pull the aircraft off of the runway. Pulling the aircraft off of the runway imposes left turning tendencies due to P-Factor, which will yaw the aircraft to the left and destabilize the takeoff.

Maintain the desired pitch and bank attitudes by referencing the attitude indicator and cross-check the VSI tape for an indication of a positive rate of climb. Take note of the magenta 6-second altimeter trend indicator. The trend should show positive. Barring turbulence, all trend indications should be stabilized. The airspeed trend indicator should not be visible at this point if the airspeed is being held constant. An activation of the airspeed trend indicator shows that the pitch attitude is not being held at the desired value and, therefore, the airspeed is changing. The desired performance is to be climbing at a constant airspeed and vertical speed rate. Use the ASI as the primary instrument for the pitch indication.

Once the aircraft has reached a safe altitude (approximately 100 feet for insufficient runway available for landing should an engine failure occur) retract the landing gear and flaps while referencing the ASI and attitude indicator to maintain the desired pitch. As the configuration is changed, an increase in aft control pressure is needed in order to maintain the desired pitch attitude. Smoothly increase the aft control pressure to compensate for the change in configuration. Anticipate the changes and increase the rate of cross-check. The airspeed tape and altitude tape increases while the VSI tape is held constant. Allow the aircraft to accelerate to the desired climb speed. Once the desired climb speed is reached, reduce the power to the climb power setting as printed in the POH/AFM. Trim the aircraft to eliminate any control pressures.

Common Errors in Instrument Takeoffs

Common errors associated with the instrument takeoff include, but are not limited to, the following:

1. Failure to perform an adequate flight deck check before the takeoff. Pilots have attempted instrument takeoff with inoperative airspeed indicators (pitot tube obstructed), controls locked, and numerous other oversights due to haste or carelessness. It is imperative to cross-check the ASI as soon as possible. No airspeed will be indicated until 20 knots of true airspeed is generated in some systems.
2. Improper alignment on the runway. This may result from improper brake applications, allowing the airplane to creep after alignment, or from alignment with the nosewheel or tailwheel cocked. In any case, the result is a built-in directional control problem as the takeoff starts.
3. Improper application of power. Abrupt applications of power complicate directional control. Power should be applied in a smooth and continuous manner to arrive at the takeoff power setting within approximately 3 seconds.
4. Improper use of brakes. Incorrect seat or rudder pedal adjustment, with feet in an uncomfortable position, frequently causes inadvertent application of brakes and excessive heading changes.
5. Overcontrolling rudder pedals. This fault may be caused by late recognition of heading changes, tension on the controls, misinterpretation of the heading indicator (and correcting in the wrong direction), failure to appreciate changing effectiveness of rudder control as the aircraft accelerates, and other factors. If heading changes are observed and corrected instantly with small movement of the rudder pedals, swerving tendencies can be reduced.
6. Failure to maintain attitude after becoming airborne. If the pilot reacts to seat-of-the-pants sensations when the airplane lifts off, pitch control is guesswork. The pilot may either allow excessive pitch or apply excessive forward-elevator pressure, depending on the reaction to trim changes.
7. Inadequate cross-check. Fixations are likely during the trim changes, attitude changes, gear and flap retractions, and power changes. Once an instrument or a control input is applied, continue the cross-check and note the effect control during the next cross-check sequence.
8. Inadequate interpretation of instruments. Failure to understand instrument indications immediately indicates that further study of the maneuver is necessary.

Basic Instrument Flight Patterns

After attaining a reasonable degree of proficiency in basic maneuvers, apply these skills to the various combinations of individual maneuvers. The practice flight patterns, beginning on page 5-30, are directly applicable to operational instrument flying.

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Chapter 6

Helicopter Attitude Instrument Flying

Introduction

Attitude instrument flying in helicopters is essentially visual flying with the flight instruments substituted for the various reference points on the helicopter and the natural horizon. Control changes, required to produce a given attitude by reference to instruments, are identical to those used in helicopter visual flight rules (VFR) flight, and pilot thought processes are the same. Basic instrument training is intended to be a building block toward attaining an instrument rating.

Flight Instruments

When flying a helicopter with reference to the flight instruments, proper instrument interpretation is the basis for aircraft control. Skill, in part, depends on understanding how a particular instrument or system functions, including its indications and limitations (see Chapter 3, Flight Instruments). With this knowledge, a pilot can quickly interpret an instrument indication and translate that information into a control response.

Instrument Flight

To achieve smooth, positive control of the helicopter during instrument flight, three fundamental skills must be developed. They are instrument cross-check, instrument interpretation, and aircraft control.

Instrument Cross-Check

Cross-checking, sometimes referred to as scanning, is the continuous and logical observation of instruments for attitude and performance information. In attitude instrument flying, an attitude is maintained by reference to the instruments, which produces the desired result in performance. Due to human error, instrument error, and helicopter performance differences in various atmospheric and loading conditions, it is difficult to establish an attitude and have performance remain constant for a long period of time. These variables make it necessary to constantly check the instruments and make appropriate changes in the helicopter's attitude. The actual technique may vary depending on what instruments are installed and where they are installed, as well as pilot experience and proficiency level. This discussion concentrates on the six basic flight instruments. *[Figure 6-1]*

At first, there may be a tendency to cross-check rapidly, looking directly at the instruments without knowing exactly what information is needed. However, with familiarity and practice, the instrument cross-check reveals definite trends during specific flight conditions. These trends help a pilot control the helicopter as it makes a transition from one flight condition to another.

When full concentration is applied to a single instrument, a problem called fixation is encountered. This results from a natural human inclination to observe a specific instrument carefully and accurately, often to the exclusion of other instruments. Fixation on a single instrument usually results in poor control. For example, while performing a turn, there is a tendency to watch only the turn-and-slip indicator instead of including other instruments in the cross-check. This fixation on the turn-and-slip indicator often leads to a loss of altitude through poor pitch-and-bank control. Look at each

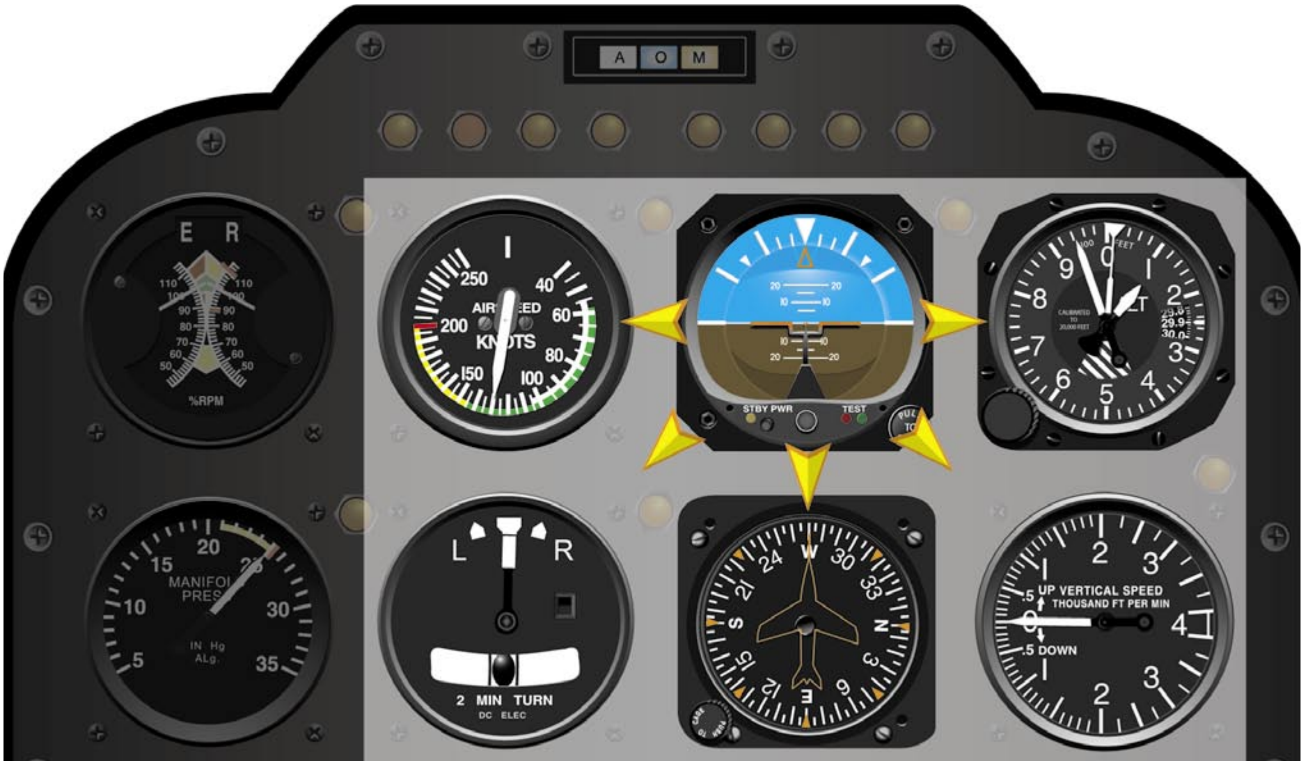

Figure 6-1. *In most situations, the cross-check pattern includes the attitude indicator between the cross-check of each of the other instruments. A typical cross-check might progress as follows: attitude indicator, altimeter, attitude indicator, vertical speed indicator, attitude indicator, heading indicator, attitude indicator, and so on.*

instrument only long enough to understand the information it presents, and then proceed to the next one. Similarly, too much emphasis can be placed on a single instrument, instead of relying on a combination of instruments necessary for helicopter performance information. This differs from fixation in that other instruments are included in a cross-check, but too much attention is placed on one particular instrument.

During performance of a maneuver, there is sometimes a failure to anticipate significant instrument indications following attitude changes. For example, during level off from a climb or descent, a pilot may concentrate on pitch control, while forgetting about heading or roll information. This error, called omission, results in erratic control of heading and bank.

In spite of these common errors, most pilots can adapt well to flight by instrument reference after instruction and practice. Many find that they can control the helicopter more easily and precisely by instruments.

Instrument Interpretation

The flight instruments together give a picture of what is happening. No one instrument is more important than the next; however, during certain maneuvers or conditions, those instruments that provide the most pertinent and useful information are termed primary instruments. Those which back up and supplement the primary instruments are termed supporting instruments. For example, since the attitude indicator is the only instrument that provides instant and direct aircraft attitude information, it should be considered primary during any change in pitch or bank attitude. After the new attitude is established, other instruments become primary, and the attitude indicator usually becomes the supporting instrument.

Aircraft Control

Controlling a helicopter is the result of accurately interpreting the flight instruments and translating these readings into correct control responses. Aircraft control involves adjustment to pitch, bank, power, and trim in order to achieve a desired flight path.

Pitch attitude control is controlling the movement of the helicopter about its lateral axis. After interpreting the helicopter's pitch attitude by reference to the pitch instruments (attitude indicator, altimeter, airspeed indicator, and vertical speed indicator (VSI)), cyclic control adjustments are made to affect the desired pitch attitude. In this chapter, the pitch attitudes depicted are approximate and vary with different helicopters.

Bank attitude control is controlling the angle made by the lateral tilt of the rotor and the natural horizon, or the movement of the helicopter about its longitudinal axis. After interpreting the helicopter's bank instruments (attitude indicator, heading indicator, and turn indicator), cyclic control adjustments are made to attain the desired bank attitude.

Power control is the application of collective pitch with corresponding throttle control, where applicable. In straight-and-level flight, changes of collective pitch are made to correct for altitude deviation if the error is more than 100 feet, or the airspeed is off by more than 10 knots. If the error is less than that amount, a pilot should use a slight cyclic climb or descent.

In order to fly a helicopter by reference to the instruments, it is important to know the approximate power settings required for a particular helicopter in various load configurations and flight conditions.

Trim, in helicopters, refers to the use of the cyclic centering button, if the helicopter is so equipped, to relieve all possible cyclic pressures. Trim also refers to the use of pedal adjustment to center the ball of the turn indicator. Pedal trim is required during all power changes.

The proper adjustment of collective pitch and cyclic friction helps a pilot relax during instrument flight. Friction should be adjusted to minimize overcontrolling and to prevent creeping, but not applied to such a degree that control movement is limited. In addition, many helicopters equipped for instrument flight contain stability augmentation systems or an autopilot to help relieve pilot workload.

Straight-and-Level Flight

Straight-and-level unaccelerated flight consists of maintaining the desired altitude, heading, airspeed, and pedal trim.

Pitch Control

The pitch attitude of a helicopter is the angular relation of its longitudinal axis to the natural horizon. If available, the attitude indicator is used to establish the desired pitch attitude. In level flight, pitch attitude varies with airspeed and center of gravity (CG). At a constant altitude and a stabilized airspeed, the pitch attitude is approximately level. *[Figure 6-2]*

Attitude Indicator

The attitude indicator gives a direct indication of the pitch attitude of the helicopter. In visual flight, attain the desired pitch attitude by using the cyclic to raise and lower the nose

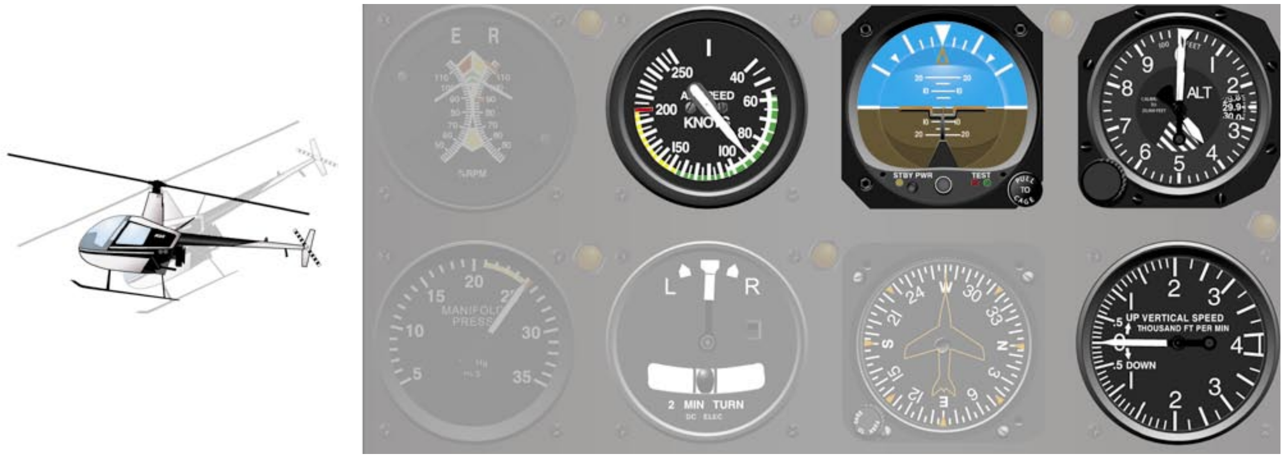

Figure 6-2. *The flight instruments for pitch control are the airspeed indicator, attitude indicator, altimeter, and vertical speed indicator.*

of the helicopter in relation to the natural horizon. During instrument flight, follow exactly the same procedure in raising or lowering the miniature aircraft in relation to the horizon bar.

There is some delay between control application and resultant instrument change. This is the normal control lag in the helicopter and should not be confused with instrument lag. The attitude indicator may show small misrepresentations of pitch attitude during maneuvers involving acceleration, deceleration, or turns. This precession error can be detected quickly by cross-checking the other pitch instruments.

If the miniature aircraft is properly adjusted on the ground, it may not require readjustment in flight. If the miniature aircraft is not on the horizon bar after level off at normal cruising airspeed, adjust it as necessary while maintaining level flight with the other pitch instruments. Once the miniature aircraft has been adjusted in level flight at normal cruising airspeed, leave it unchanged so it gives an accurate picture of pitch attitude at all times.

When making initial pitch attitude corrections to maintain altitude, the changes of attitude should be small and smoothly applied. The initial movement of the horizon bar should not exceed one bar width high or low. *[Figure 6-3]* If a further adjustment is required, an additional correction of one-half bar normally corrects any deviation from the desired altitude. This one-and-one-half bar correction is normally the maximum pitch attitude correction from level flight attitude.

After making the correction, cross-check the other pitch instruments to determine whether the pitch attitude change is sufficient. If additional correction is needed to return to altitude, or if the airspeed varies more than 10 knots from that desired, adjust the power.

Altimeter

The altimeter gives an indirect indication of the pitch attitude of the helicopter in straight-and-level flight. Since the altitude should remain constant in level flight, deviation from the desired altitude indicates a need for a change in pitch attitude and power as necessary. When losing altitude, raise the pitch attitude and adjust power as necessary. When gaining altitude, lower the pitch attitude and adjust power as necessary. Indications for power changes are explained in the next paragraph.

The rate at which the altimeter moves helps to determine pitch attitude. A very slow movement of the altimeter indicates a small deviation from the desired pitch attitude, while a

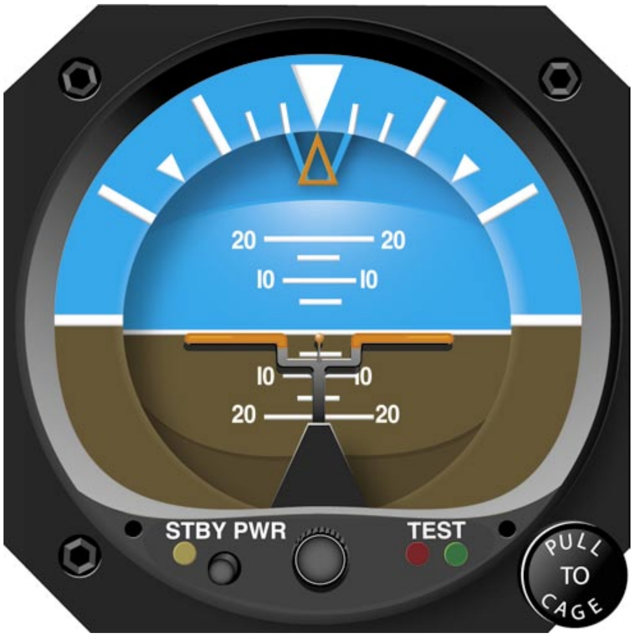

Figure 6-3. *The initial pitch correction at normal cruise is one bar width or less.*

fast movement of the altimeter indicates a large deviation from the desired pitch attitude. Make any corrective action promptly, with small control changes. Also, remember that movement of the altimeter should always be corrected by two distinct changes. The first is a change of attitude to stop the altimeter movement; the second is a change of attitude to return smoothly to the desired altitude. If altitude and airspeed are more than 100 feet and 10 knots low, respectively, apply power in addition to an increase of pitch attitude. If the altitude and airspeed are high by more than 100 feet and 10 knots, reduce power and lower the pitch attitude.

There is a small lag in the movement of the altimeter; however, for all practical purposes, consider that the altimeter gives an immediate indication of a change, or a need for change in pitch attitude. Since the altimeter provides the most pertinent information regarding pitch in level flight, it is considered primary for pitch.

Vertical Speed Indicator (VSI)

The VSI gives an indirect indication of the pitch attitude of the helicopter and should be used in conjunction with the other pitch instruments to attain a high degree of accuracy and precision. The instrument indicates zero when in level flight. Any movement of the needle from the zero position shows a need for an immediate change in pitch attitude to return it to zero. Always use the VSI in conjunction with the altimeter in level flight. If a movement of the VSI is detected, immediately use the proper corrective measures to return it to zero. If the correction is made promptly, there is usually little or no change in altitude. If the needle of the VSI does not indicate zero, the altimeter indicates a gain or loss of altitude.

The initial movement of the vertical speed needle is instantaneous and indicates the trend of the vertical movement of the helicopter. A period of time is necessary for the VSI to reach its maximum point of deflection after a correction has been made. This time element is commonly referred to as instrument lag. The lag is directly proportional to the speed and magnitude of the pitch change. When employing smooth control techniques and small adjustments in pitch attitude are made, lag is minimized, and the VSI is easy to interpret.

Overcontrolling can be minimized by first neutralizing the controls and allowing the pitch attitude to stabilize, then readjusting the pitch attitude by noting the indications of the other pitch instruments.

Occasionally, the VSI may be slightly out of calibration. This could result in the instrument indicating a slight climb or descent even when the helicopter is in level flight. If the instrument cannot be calibrated properly, this error must be taken into consideration when using the VSI for pitch control. For example, if a descent of 100 feet per minute (fpm) is the vertical speed indication when the helicopter is in level flight, use that indication as level flight. Any deviation from that reading would indicate a change in attitude.

Airspeed Indicator

The airspeed indicator gives an indirect indication of helicopter pitch attitude. With a given power setting and pitch attitude, the airspeed remains constant. If the airspeed increases, the nose is too low and should be raised. If the airspeed decreases, the nose is too high and should be lowered. A rapid change in airspeed indicates a large change in pitch attitude, and a slow change in airspeed indicates a small change in pitch attitude. There is very little lag in the indications of the airspeed indicator. If, while making attitude changes, there is some lag between control application and change of airspeed, it is most likely due to cyclic control lag. Generally, a departure from the desired airspeed, due to an inadvertent pitch attitude change, also results in a change in altitude. For example, an increase in airspeed due to a low pitch attitude results in a decrease in altitude. A correction in the pitch attitude regains both airspeed and altitude.

Bank Control

The bank attitude of a helicopter is the angular relation of its lateral axis to the natural horizon. To maintain a straight course in visual flight, keep the lateral axis of the helicopter level with the natural horizon. Assuming the helicopter is in coordinated flight, any deviation from a laterally level attitude produces a turn. *[Figure 6-4]*

Attitude Indicator

The attitude indicator gives a direct indication of the bank attitude of the helicopter. For instrument flight, the miniature aircraft and the horizon bar of the attitude indicator are substituted for the actual helicopter and the natural horizon. Any change in bank attitude of the helicopter is indicated instantly by the miniature aircraft. For proper interpretation of this instrument, imagine being in the miniature aircraft. If the helicopter is properly trimmed and the rotor tilts, a turn begins. The turn can be stopped by leveling the miniature aircraft with the horizon bar. The ball in the turn-and-slip indicator should always be kept centered through proper pedal trim.

The angle of bank is indicated by the pointer on the banking scale at the top of the instrument. *[Figure 6-5]* Small bank angles, which may not be seen by observing the miniature aircraft, can easily be determined by referring to the banking scale pointer.

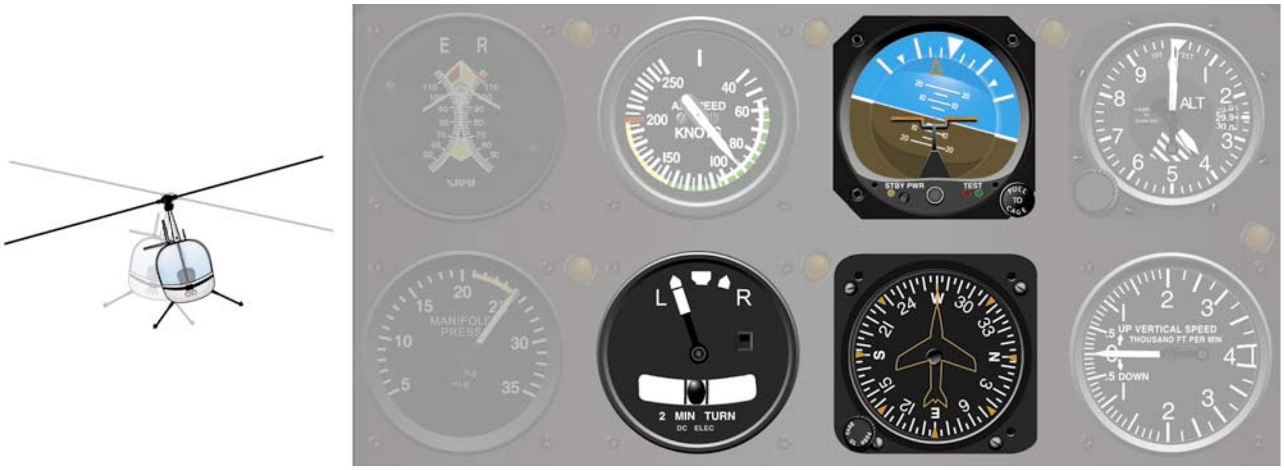

Figure 6-4. *The flight instruments used for bank control are the attitude, heading, and turn indicators.*

Pitch-and-bank attitudes can be determined simultaneously on the attitude indicator. Even though the miniature aircraft is not level with the horizon bar, pitch attitude can be established by observing the relative position of the miniature aircraft and the horizon bar.

The attitude indicator may show small misrepresentations of bank attitude during maneuvers that involve turns. This precession error can be detected immediately by closely cross-checking the other bank instruments during these maneuvers. Precession is normally noticed when rolling out of a turn. If, upon completion of a turn, the miniature aircraft is level and the helicopter is still turning, make a small change of bank attitude to center the turn needle and stop the movement of the heading indicator.

Heading Indicator

In coordinated flight, the heading indicator gives an indirect indication of a helicopter's bank attitude. When a helicopter is banked, it turns. When the lateral axis of a helicopter is level, it flies straight. Therefore, in coordinated flight when the heading indicator shows a constant heading, the helicopter is level laterally. A deviation from the desired heading indicates a bank in the direction the helicopter is turning. A small angle of bank is indicated by a slow change of heading; a large angle of bank is indicated by a rapid change of heading. If a turn is noticed, apply opposite cyclic until the heading indicator

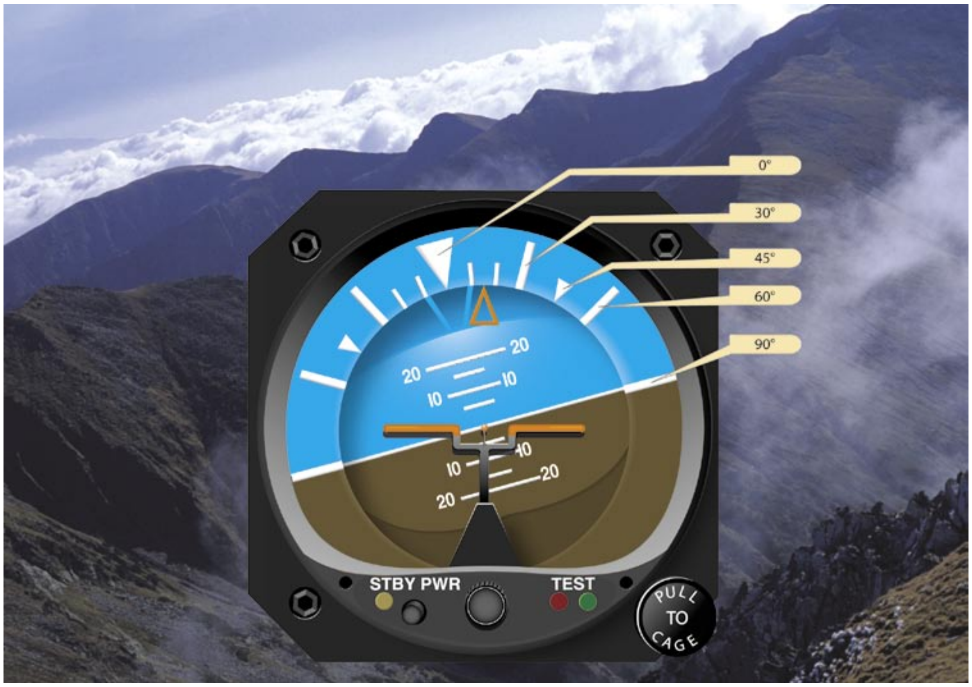

Figure 6-5. *The banking scale at the top of the attitude indicator indicates varying degrees of bank. In this example, the helicopter is banked approximately 15° to the right.*

indicates the desired heading, simultaneously ensuring the ball is centered. When making the correction to the desired heading, do not use a bank angle greater than that required to achieve a standard rate turn. In addition, if the number of degrees of change is small, limit the bank angle to the number of degrees to be turned. Bank angles greater than these require more skill and precision in attaining the desired results. During straight-and-level flight, the heading indicator is the primary reference for bank control.

Turn Indicator

During coordinated flight, the needle of the turn-and-slip indicator gives an indirect indication of the bank attitude of the helicopter. When the needle is displaced from the vertical position, the helicopter is turning in the direction of the displacement. Thus, if the needle is displaced to the left, the helicopter is turning left. Bringing the needle back to the vertical position with the cyclic produces straight flight. A close observation of the needle is necessary to accurately interpret small deviations from the desired position.

Cross-check the ball of the turn-and-slip indicator to determine if the helicopter is in coordinated flight. *[Figure 6-6]* If the rotor is laterally level and pedal pressure properly compensates for torque, the ball remains in the center. To center the ball, level the helicopter laterally by reference to the other bank instruments, then center the ball with pedal trim. Torque correction pressures vary as power changes are made. Always check the ball after such changes.

Common Errors During Straight-and-Level Flight

1. Failure to maintain altitude
2. Failure to maintain heading
3. Overcontrolling pitch and bank during corrections
4. Failure to maintain proper pedal trim
5. Failure to cross-check all available instruments

Power Control During Straight-and-Level Flight

Establishing specific power settings is accomplished through collective pitch adjustments and throttle control, where necessary. For reciprocating-powered helicopters, power indication is observed on the manifold pressure gauge. For turbine-powered helicopters, power is observed on the torque gauge. (Although most Instrument Flight Rules (IFR)-certified helicopters are turbine powered, depictions within this chapter use a reciprocating-powered helicopter as this is where training is most likely conducted.)

At any given airspeed, a specific power setting determines whether the helicopter is in level flight, in a climb, or in a descent. For example, cruising airspeed maintained with cruising power results in level flight. If a pilot increases the power setting and holds the airspeed constant, the helicopter climbs. Conversely, if the pilot decreases power and holds the airspeed constant, the helicopter descends.

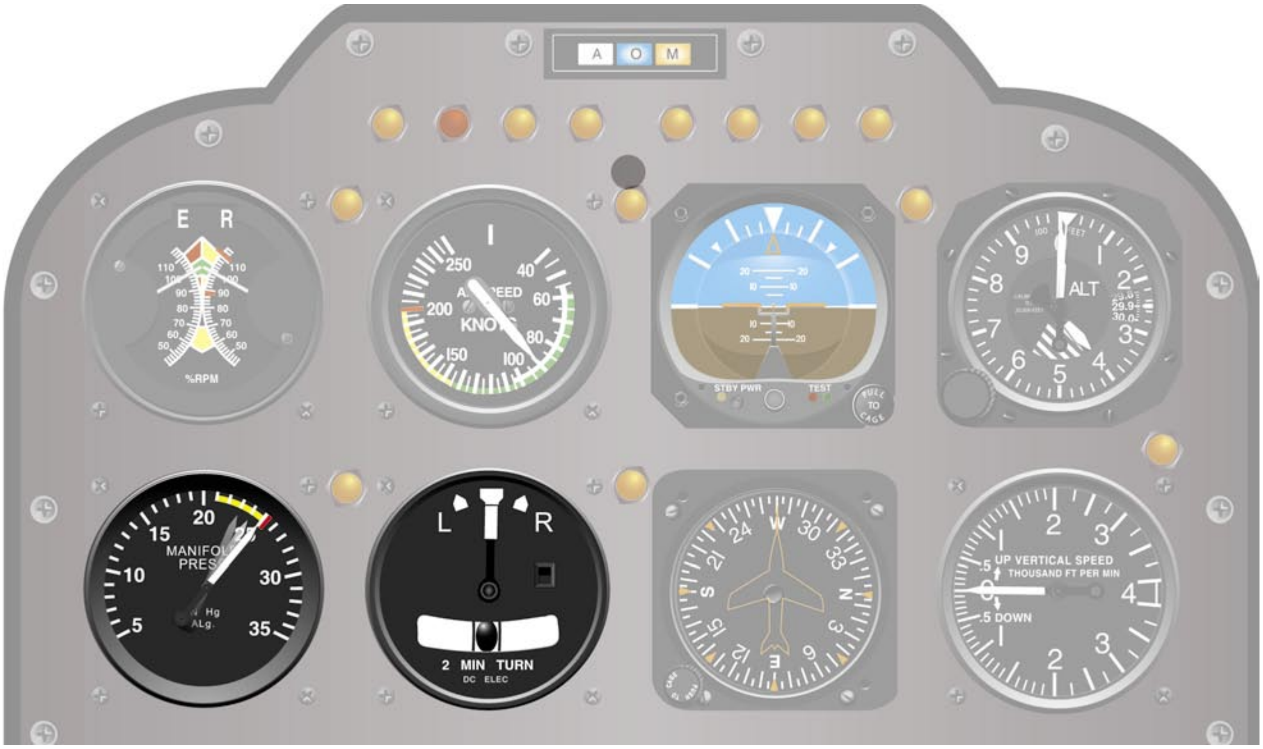

Figure 6-6. *Coordinated flight is indicated by centering of the ball.*

If the altitude is held constant, power determines the airspeed. For example, at a constant altitude, cruising power results in cruising airspeed. Any deviation from the cruising power setting results in a change of airspeed. When power is added to increase airspeed, the nose of the helicopter pitches up and yaws to the right in a helicopter with a counterclockwise main rotor blade rotation. *[Figure 6-7]* When power is reduced to decrease airspeed, the nose pitches down and yaws to the left. *[Figure 6-8]* The yawing effect is most pronounced in single-rotor helicopters, and is absent in helicopters with counter-rotating rotors. To counteract the yawing tendency of the helicopter, apply pedal trim during power changes.

To maintain a constant altitude and airspeed in level flight, coordinate pitch attitude and power control. The relationship between altitude and airspeed determines the need for a change in power and/or pitch attitude. If the altitude is constant and the airspeed is high or low, change the power to obtain the desired airspeed. During the change in power, make an accurate interpretation of the altimeter, then counteract any deviation from the desired altitude by an appropriate change of pitch attitude. If the altitude is low and the airspeed is high, or vice versa, a change in pitch attitude alone may return the helicopter to the proper altitude and airspeed. If both airspeed and altitude are low, or if both are high, changes in both power and pitch attitude are necessary.

To make power control easy when changing airspeed, it is necessary to know the approximate power settings for the various airspeeds at which the helicopter is flown. When the airspeed is to be changed by any appreciable amount, adjust the power so that it is over or under that setting necessary to maintain the new airspeed. As the power approaches the desired setting, include the manifold pressure in the cross-check to determine when the proper adjustment has been accomplished. As the airspeed is changing, adjust the pitch attitude to maintain a constant altitude. A constant heading should be maintained throughout the change. As the desired airspeed is approached, adjust power to the new cruising power setting and further adjust pitch attitude to maintain altitude. The instrument indications for straight-and-level flight at normal cruise and during the transition from normal cruise to slow cruise are illustrated in *Figures 6-9* and *6-10*. After the airspeed stabilizes at slow cruise, the attitude indicator shows an approximate level pitch attitude.

The altimeter is the primary pitch instrument during level flight, whether flying at a constant airspeed or during a change in airspeed. Altitude should not change during airspeed transitions, and the heading indicator remains the primary bank instrument. Whenever the airspeed is changed by an appreciable amount, the manifold pressure gauge is momentarily the primary instrument for power control. When the airspeed approaches the desired reading, the airspeed indicator again becomes the primary instrument for power control.

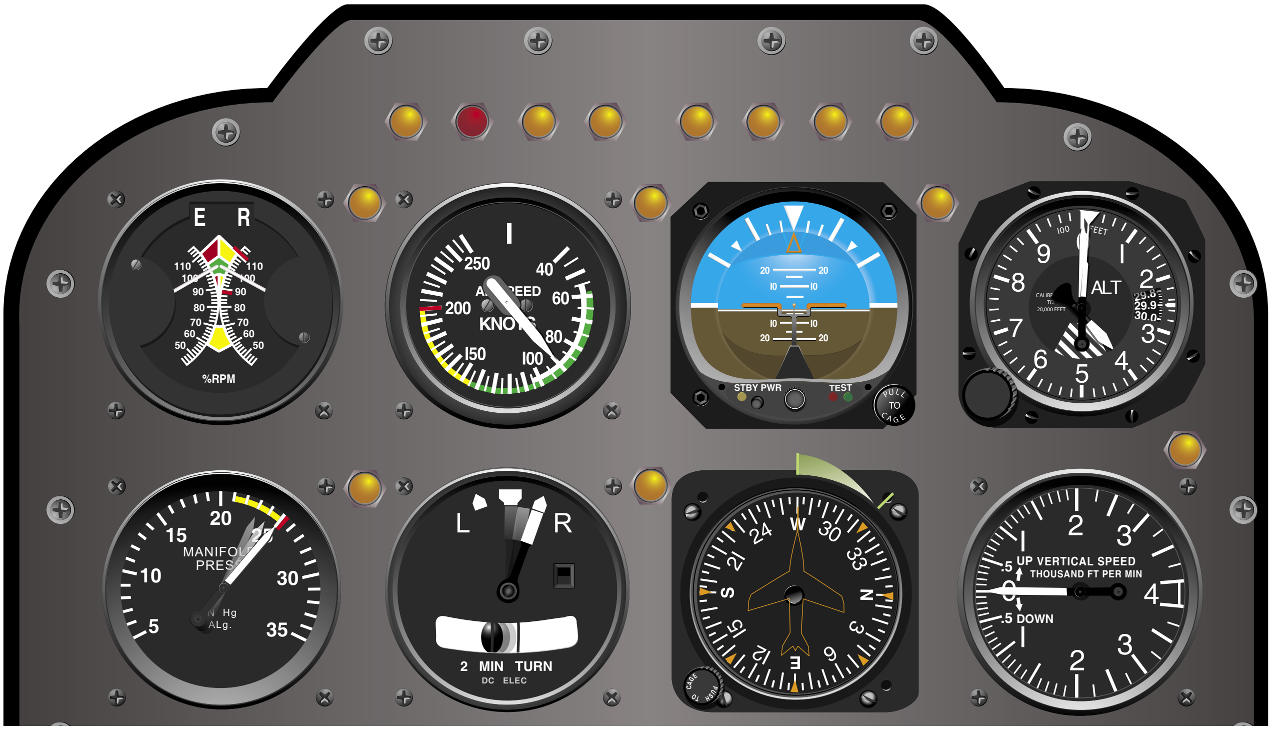

Figure 6-7. *Flight instrument indications in straight-and-level flight with power increasing.*

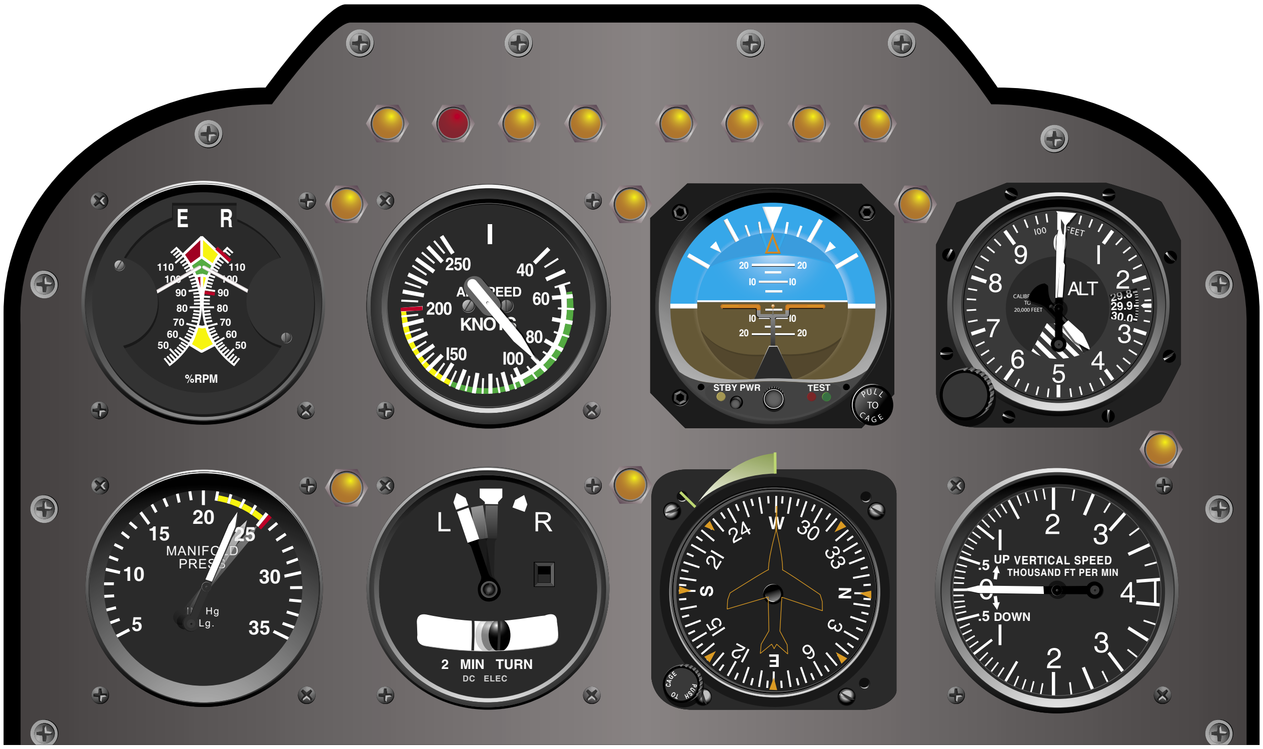
%RPM
AIRSPEED KNOTS
STBY PWR
TEST
PULL TO CAGE
ALT
MANIFOLD PRESS
2 MIN TURN
DC ELEC
UP VERTICAL SPEED THOUSAND FT PER MIN
DOWN

Figure 6-8. *Flight instrument indications in straight-and-level flight with power decreasing.*

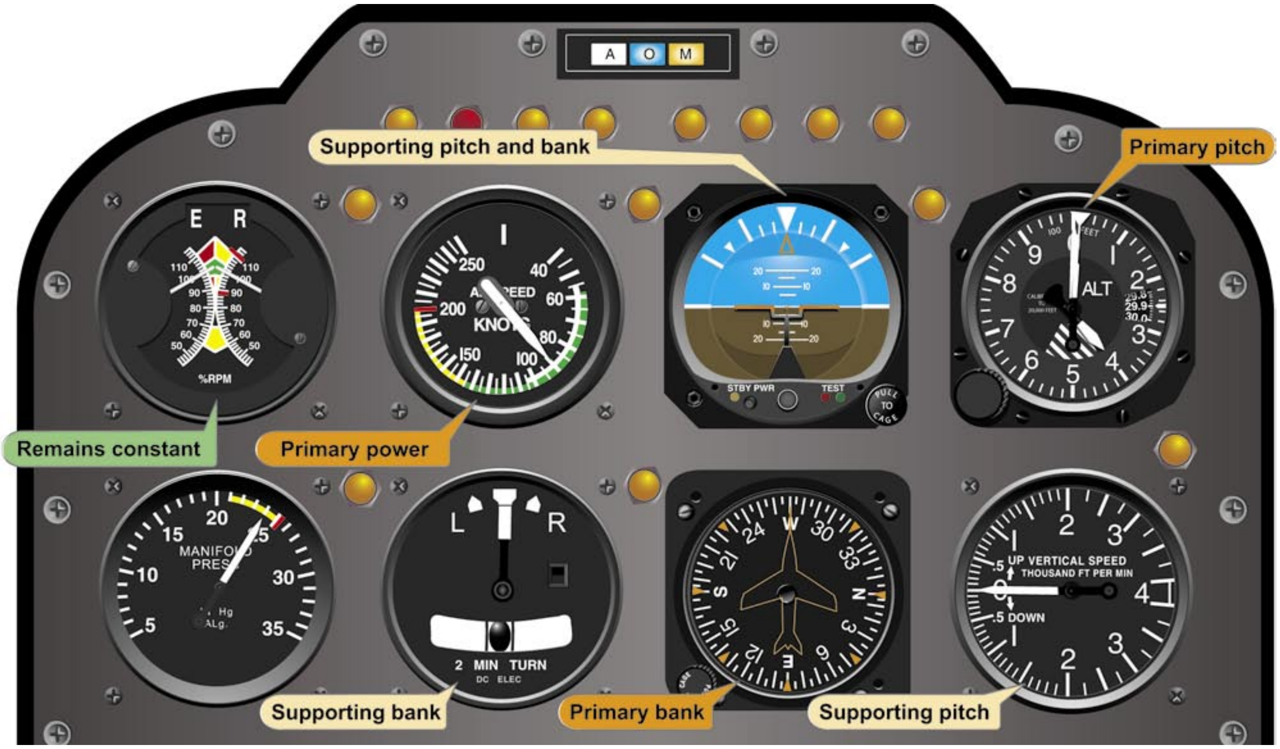
A O M
Supporting pitch and bank
Primary pitch
Remains constant
Primary power
Supporting bank
Primary bank
Supporting pitch

Figure 6-9. *Flight instrument indications in straight-and-level flight at normal cruise speed.*

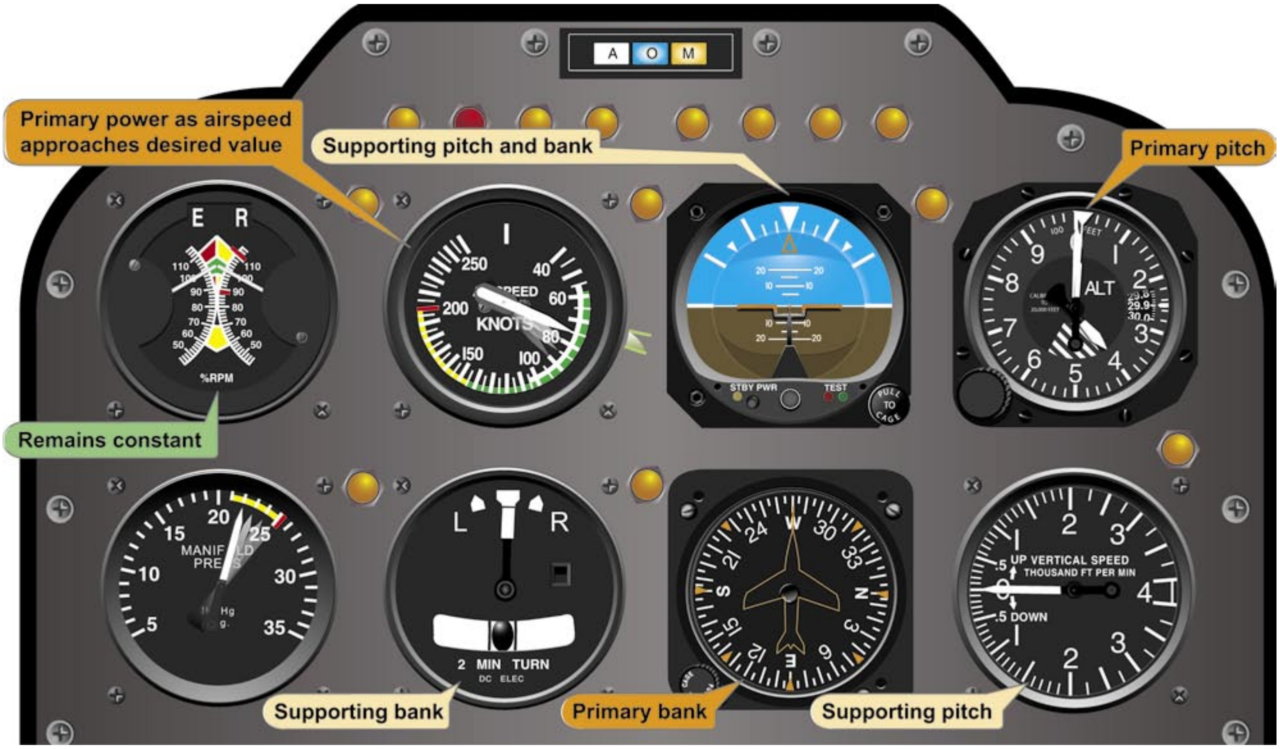
Primary power as airspeed approaches desired value
Supporting pitch and bank
Primary pitch
Remains constant
Supporting bank
Primary bank
Supporting pitch

Figure 6-10. *Flight instrument indications in straight-and-level flight with airspeed decreasing.*

To produce straight-and-level flight, the cross-check of the pitch-and-bank instruments should be combined with the power control instruments. With a constant power setting, a normal cross-check should be satisfactory. When changing power, the speed of the cross-check must be increased to cover the pitch-and-bank instruments adequately. This is necessary to counteract any deviations immediately.

Common Errors During Airspeed Changes

1. Improper use of power
2. Overcontrolling pitch attitude
3. Failure to maintain heading
4. Failure to maintain altitude
5. Improper pedal trim

Straight Climbs (Constant Airspeed and Constant Rate)

For any power setting and load condition, there is only one airspeed that gives the most efficient rate of climb. To determine this, consult the climb data for the type of helicopter being flown. The technique varies according to the airspeed on entry and whether a constant airspeed or constant rate climb is made.

Entry

To enter a constant airspeed climb from cruise airspeed when the climb speed is lower than cruise speed, simultaneously increase power to the climb power setting and adjust pitch attitude to the approximate climb attitude. The increase in power causes the helicopter to start climbing and only very slight back cyclic pressure is needed to complete the change from level to climb attitude. The attitude indicator should be used to accomplish the pitch change. If the transition from level flight to a climb is smooth, the VSI shows an immediate upward trend and then stops at a rate appropriate to the stabilized airspeed and attitude. Primary and supporting instruments for climb entry are illustrated in *Figure 6-11*.

When the helicopter stabilizes at a constant airspeed and attitude, the airspeed indicator becomes primary for pitch. The manifold pressure continues to be primary for power and should be monitored closely to determine if the proper climb power setting is being maintained. Primary and supporting instruments for a stabilized constant airspeed climb are shown in *Figure 6-12*.

The technique and procedures for entering a constant rate climb are very similar to those previously described for a constant airspeed climb. For training purposes, a constant

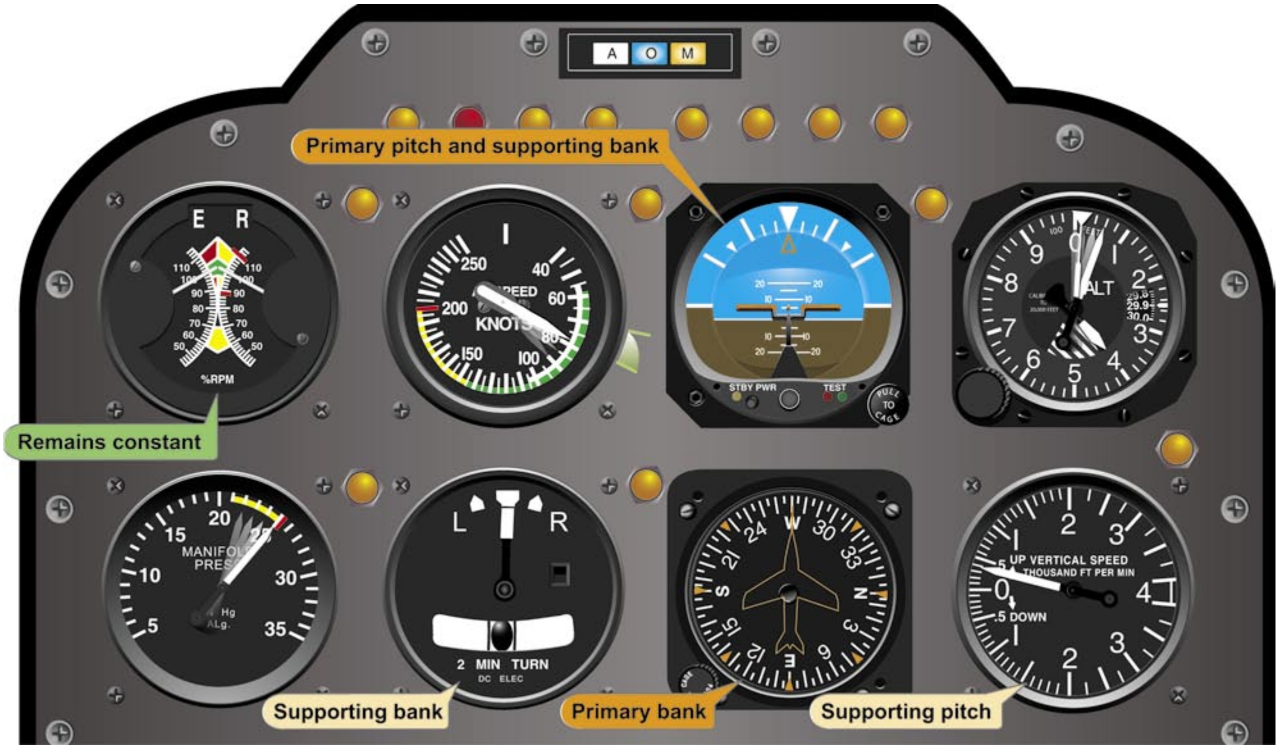
A O M
Primary pitch and supporting bank
Remains constant
Supporting bank
Primary bank
Supporting pitch

Figure 6-11. *Flight instrument indications during climb entry for a constant-airspeed climb.*

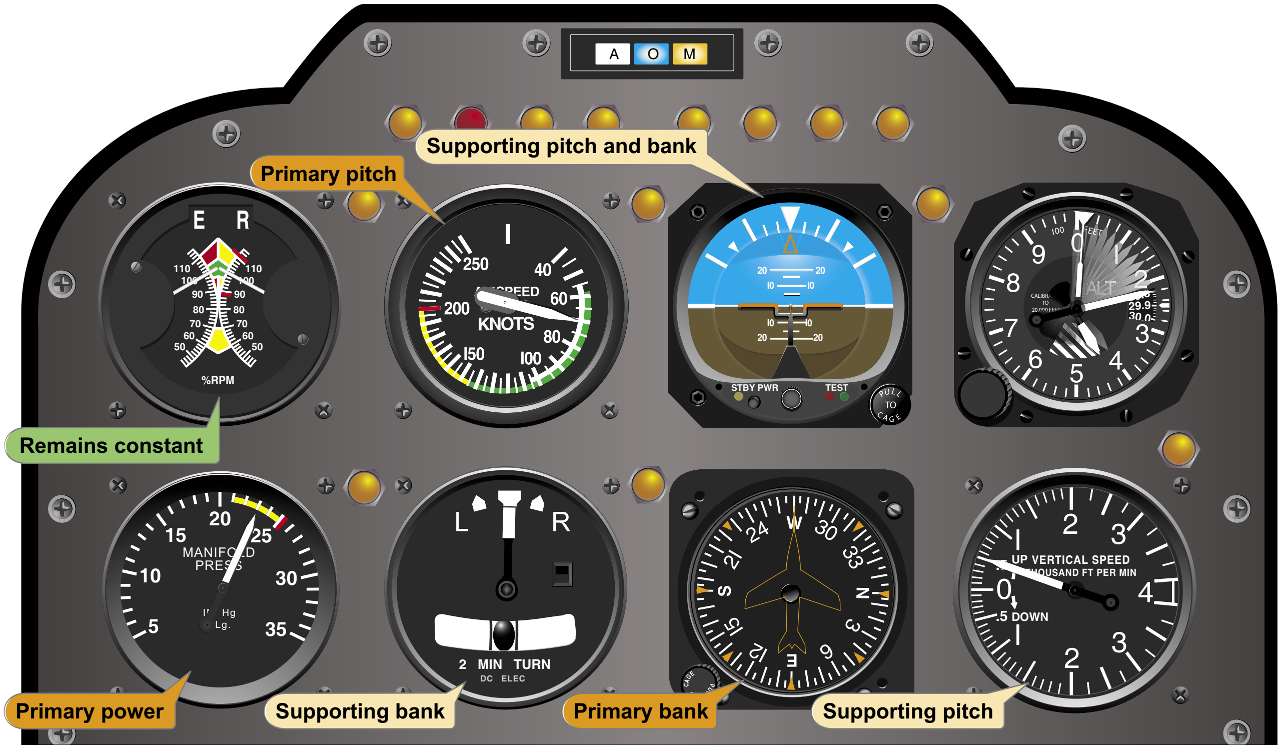
A O M
Primary pitch
Supporting pitch and bank
Remains constant
Primary power
Supporting bank
Primary bank
Supporting pitch

Figure 6-12. *Flight instrument indications in a stabilized constant-airspeed climb.*

rate climb is entered from climb airspeed. Use the rate appropriate for the particular helicopter being flown. Normally, in helicopters with low climb rates, 500 fpm is appropriate. In helicopters capable of high climb rates, use a rate of 1,000 fpm.

To enter a constant rate climb, increase power to the approximate setting for the desired rate. As power is applied, the airspeed indicator is primary for pitch until the vertical speed approaches the desired rate. At this time, the VSI becomes primary for pitch. Change pitch attitude by reference to the attitude indicator to maintain the desired vertical speed. When the VSI becomes primary for pitch, the airspeed indicator becomes primary for power. Primary and supporting instruments for a stabilized constant rate climb are illustrated in *Figure 6-13*. Adjust power to maintain desired airspeed. Pitch attitude and power corrections should be closely coordinated. To illustrate this, if the vertical speed is correct but the airspeed is low, add power. As power is increased, it may be necessary to lower the pitch attitude slightly to avoid increasing the vertical rate. Adjust the pitch attitude smoothly to avoid overcontrolling. Small power corrections are usually sufficient to bring the airspeed back to the desired indication.

Level Off

The level off from a constant airspeed climb must be started before reaching the desired altitude. Although the amount of lead varies with the type of helicopter being flown and pilot technique, the most important factor is vertical speed. As a rule of thumb, use 10 percent of the vertical velocity as the lead point. For example, if the rate of climb is 500 fpm, initiate the level off approximately 50 feet before the desired altitude. When the proper lead altitude is reached, the altimeter becomes primary for pitch. Adjust the pitch attitude to the level flight attitude for that airspeed. Cross-check the altimeter and VSI to determine when level flight has been attained at the desired altitude. If cruise airspeed is higher than climb airspeed, leave the power at the climb power setting until the airspeed approaches cruise airspeed, and then reduce it to the cruise power setting. The level off from a constant rate climb is accomplished in the same manner as the level off from a constant airspeed climb.

Straight Descents (Constant Airspeed and Constant Rate)

A descent may be performed at any normal airspeed the helicopter can attain, but the airspeed must be determined prior to entry. The technique is determined by the type of descent, a constant airspeed or a constant rate.

Entry

If airspeed is higher than descending airspeed, and a constant airspeed descent is desired, reduce power to a descent power setting and maintain a constant altitude using cyclic pitch control. This slows the helicopter. As the helicopter

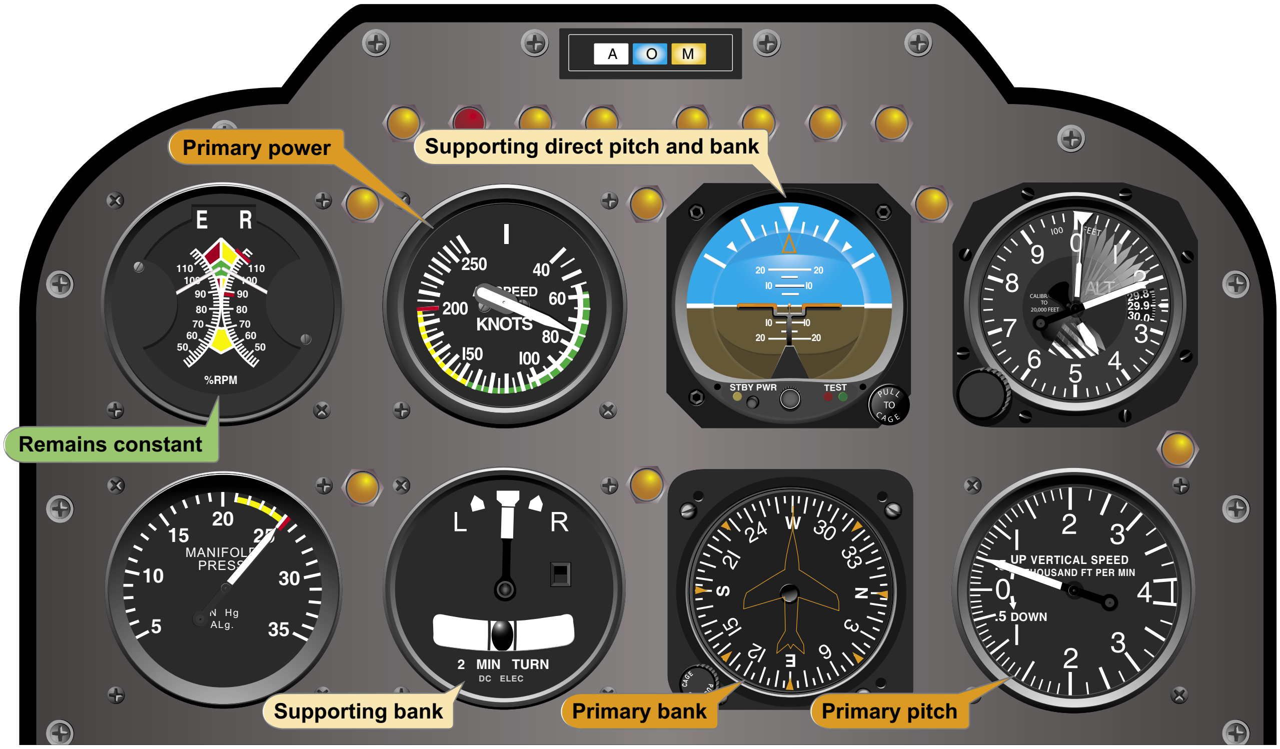

Figure 6-13. *Flight Instrument Indications in a Stabilized Constant-Rate Climb.*

approaches the descending airspeed, the airspeed indicator becomes primary for pitch and the manifold pressure is primary for power. Holding the airspeed constant causes the helicopter to descend. For a constant rate descent, reduce the power to the approximate setting for the desired rate. If the descent is started at the descending airspeed, the airspeed indicator is primary for pitch until the VSI approaches the desired rate. At this time, the VSI becomes primary for pitch, and the airspeed indicator becomes primary for power. Coordinate power and pitch attitude control as previously described on page 6-10 for constant rate climbs.

Level Off

The level off from a constant airspeed descent may be made at descending airspeed or at cruise airspeed, if this is higher than descending airspeed. As in a climb level off, the amount of lead depends on the rate of descent and control technique. For a level off at descending airspeed, the lead should be approximately 10 percent of the vertical speed. At the lead altitude, simultaneously increase power to the setting necessary to maintain descending airspeed in level flight. At this point, the altimeter becomes primary for pitch, and the airspeed indicator becomes primary for power.

To level off at an airspeed higher than descending airspeed, increase the power approximately 100 to 150 feet prior to reaching the desired altitude. The power setting should be that which is necessary to maintain the desired airspeed in level flight. Hold the vertical speed constant until approximately 50 feet above the desired altitude. At this point, the altimeter becomes primary for pitch and the airspeed indicator becomes primary for power. The level off from a constant rate descent should be accomplished in the same manner as the level off from a constant airspeed descent.

Common Errors During Straight Climbs and Descents

1. Failure to maintain heading
2. Improper use of power
3. Poor control of pitch attitude
4. Failure to maintain proper pedal trim
5. Failure to level off on desired altitude

Turns

Turns made by reference to the flight instruments should be made at a precise rate. Turns described in this chapter are those not exceeding a standard rate of 3° per second as indicated on the turn-and-slip indicator. True airspeed determines the angle of bank necessary to maintain a standard rate turn. A rule of thumb to determine the approximate angle of bank required for a standard rate turn is to use 15 percent of the airspeed. A simple way to determine this amount is to divide the airspeed by 10 and add one-half the result. For example, at 60 knots approximately 9° of bank is required (60 ÷ 10 = 6, 6 + 3 = 9); at 80 knots approximately 12° of bank is needed for a standard rate turn.

To enter a turn, apply lateral cyclic in the direction of the desired turn. The entry should be accomplished smoothly, using the attitude indicator to establish the approximate bank angle. When the turn indicator indicates a standard rate turn, it becomes primary for bank. The attitude indicator now becomes a supporting instrument. During level turns, the altimeter is primary for pitch, and the airspeed indicator is primary for power. Primary and supporting instruments for a stabilized standard rate turn are illustrated in *Figure 6-14*. If an increase in power is required to maintain airspeed, slight forward cyclic pressure may be required since the helicopter tends to pitch up as collective pitch is increased. Apply pedal trim, as required, to keep the ball centered.

To recover to straight-and-level flight, apply cyclic in the direction opposite the turn. The rate of roll-out should be the same as the rate used when rolling into the turn. As the turn recovery is initiated, the attitude indicator becomes primary for bank. When the helicopter is approximately level, the heading indicator becomes primary for bank as in straight-and-level flight. Cross-check the airspeed indicator and ball closely to maintain the desired airspeed and pedal trim.

Turn to a Predetermined Heading

A helicopter turns as long as its lateral axis is tilted; therefore, the recovery must start before the desired heading is reached. The amount of lead varies with the rate of turn and piloting technique.

As a guide, when making a 3° per second rate of turn, use a lead of one-half the bank angle. For example, if using a 12° bank angle, use half of that, or 6°, as the lead point prior to the desired heading. Use this lead until the exact amount required by a particular technique can be determined. The bank angle should never exceed the number of degrees to be turned. As in any standard rate turn, the rate of recovery should be the same as the rate of entry. During turns to predetermined headings, cross-check the primary and supporting pitch, bank, and power instruments closely.

Timed Turns

A timed turn is a turn in which the clock and turn-and-slip indicator are used to change heading a definite number of degrees in a given time. For example, using a standard rate turn, a helicopter turns 45° in 15 seconds. Using a half-

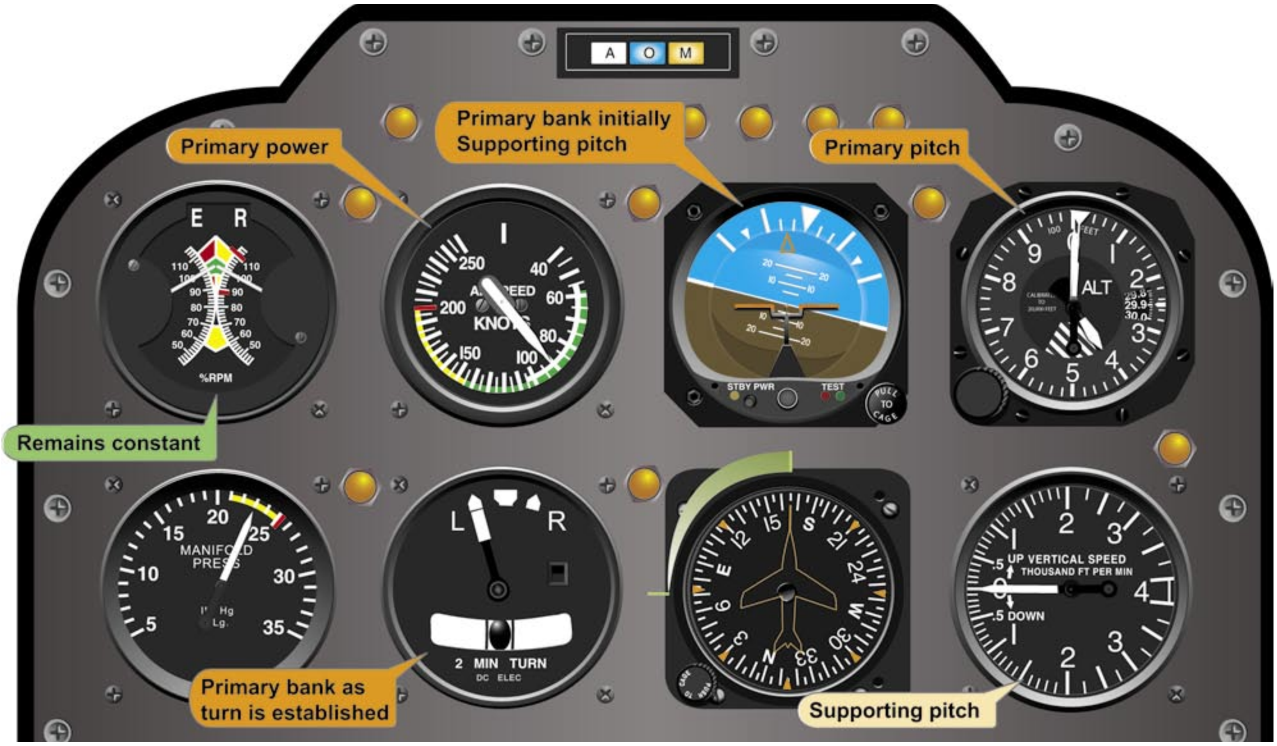

Figure 6-14. *Flight Instrument Indications in a Standard-Rate Turn to the Left.*

standard rate turn, the helicopter turns 45° in 30 seconds. Timed turns can be used if the heading indicator becomes inoperative.

Prior to performing timed turns, the turn coordinator should be calibrated to determine the accuracy of its indications. To do this, establish a standard rate turn by referring to the turn-and-slip indicator. Then, as the sweep second hand of the clock passes a cardinal point (12, 3, 6, or 9), check the heading on the heading indicator. While holding the indicated rate of turn constant, note the heading changes at 10-second intervals. If the helicopter turns more or less than 30° in that interval, a smaller or larger deflection of the needle is necessary to produce a standard rate turn. After the turn-and-slip indicator has been calibrated during turns in each direction, note the corrected deflections, if any, and apply them during all timed turns.

Use the same cross-check and control technique in making timed turns that is used to make turns to a predetermined heading, but substitute the clock for the heading indicator. The needle of the turn-and-slip indicator is primary for bank control, the altimeter is primary for pitch control, and the airspeed indicator is primary for power control. Begin the roll-in when the clock's second hand passes a cardinal point; hold the turn at the calibrated standard rate indication, or half-standard rate for small changes in heading; then begin the roll-out when the computed number of seconds has elapsed. If the roll-in and roll-out rates are the same, the time taken during entry and recovery need not be considered in the time computation.

If practicing timed turns with a full instrument panel, check the heading indicator for the accuracy of the turns. If executing turns without the heading indicator, use the magnetic compass at the completion of the turn to check turn accuracy, taking compass deviation errors into consideration.

Change of Airspeed in Turns

Changing airspeed in turns is an effective maneuver for increasing proficiency in all three basic instrument skills. Since the maneuver involves simultaneous changes in all components of control, proper execution requires a rapid cross-check and interpretation, as well as smooth control. Proficiency in the maneuver also contributes to confidence in the instruments during attitude and power changes involved in more complex maneuvers.

Pitch and power control techniques are the same as those used during airspeed changes in straight-and-level flight. As discussed previously, the angle of bank necessary for a given rate of turn is proportional to the true airspeed. Since the turns are executed at standard rate, the angle of bank must be varied in direct proportion to the airspeed change in order to maintain a constant rate of turn. During a reduction of airspeed, decrease the angle of bank and increase the pitch attitude to maintain altitude and a standard rate turn.

Altimeter and turn indicator readings should remain constant throughout the turn. The altimeter is primary for pitch control, and the turn needle is primary for bank control. Manifold pressure is primary for power control while the airspeed is changing. As the airspeed approaches the new indication, the airspeed indicator becomes primary for power control.

Two methods of changing airspeed in turns may be used. In the first method, airspeed is changed after the turn is established. In the second method, the airspeed change is initiated simultaneously with the turn entry. The first method is easier, but regardless of the method used, the rate of cross-check must be increased as power is reduced. As the helicopter decelerates, check the altimeter and VSI for needed pitch changes, and the bank instruments for needed bank changes. If the needle of the turn-and-slip indicator shows a deviation from the desired deflection, change the bank. Adjust pitch attitude to maintain altitude. When the airspeed approaches that desired, the airspeed indicator becomes primary for power control. Adjust the power to maintain the desired airspeed. Use pedal trim to ensure the maneuver is coordinated.

Until control technique is very smooth, frequently cross-check the attitude indicator to keep from overcontrolling and to provide approximate bank angles appropriate for the changing airspeeds.

Compass Turns

The use of gyroscopic heading indicators makes heading control very easy. However, if the heading indicator fails or the helicopter is not equipped with one, use the magnetic compass for heading reference. When making compass-only turns, a pilot needs to adjust for the lead or lag created by acceleration and deceleration errors so that the helicopter rolls out on the desired heading. When turning to a heading of north, the lead for the roll-out must include the number of degrees of latitude plus the lead normally used in recovery from turns. During a turn to a south heading, maintain the turn until the compass passes south the number of degrees of latitude, minus the normal roll-out lead. For example, when turning from an easterly direction to north, where the latitude is 30°, start the roll-out when the compass reads 37° (30° plus one-half the 15° angle of bank, or whatever amount is appropriate for the rate of roll-out). When turning from an easterly direction to south, start the roll-out when the magnetic compass reads 203° (180° plus 30° minus one-half the angle of bank). When making similar turns from a westerly direction, the appropriate points at which to begin the roll-out would be 323° for a turn to north, and 157° for a turn to south.

30° Bank Turn

A turn using 30° of bank is seldom necessary or advisable in instrument meteorological conditions (IMC), and is considered an unusual attitude in a helicopter. However, it is an excellent maneuver to practice to increase the ability to react quickly and smoothly to rapid changes of attitude. Even though the entry and recovery techniques are the same as for any other turn, it is more difficult to control pitch because of the decrease in vertical lift as the bank increases. Also, because of the decrease in vertical lift, there is a tendency to lose altitude and/or airspeed. Therefore, to maintain a constant altitude and airspeed, additional power is required. Do not initiate a correction, however, until the instruments indicate the need for one. During the maneuver, note the need for a correction on the altimeter and VSI, check the attitude indicator, and then make the necessary adjustments. After making a change, check the altimeter and VSI again to determine whether or not the correction was adequate.

Climbing and Descending Turns

For climbing and descending turns, the techniques described previously for straight climbs, descents, and standard rate turns are combined. For practice, simultaneously turn and start the climb or descent. The primary and supporting instruments for a stabilized constant airspeed left climbing turn are illustrated in *Figure 6-15*. The level off from a climbing or descending turn is the same as the level off from a straight climb or descent. To return to straight-and-level flight, stop the turn and then level off, or level off and then stop the turn, or simultaneously level off and stop the turn. During climbing and descending turns, keep the ball of the turn indicator centered with pedal trim.

Common Errors During Turns

1. Failure to maintain desired turn rate
2. Failure to maintain altitude in level turns
3. Failure to maintain desired airspeed
4. Variation in the rate of entry and recovery
5. Failure to use proper lead in turns to a heading
6. Failure to properly compute time during timed turns
7. Failure to use proper leads and lags during the compass turns
8. Improper use of power
9. Failure to use proper pedal trim

Unusual Attitudes

Any maneuver not required for normal helicopter instrument flight is an unusual attitude and may be caused by any one or combination of factors such as turbulence, disorientation, instrument failure, confusion, preoccupation with flight deck duties, carelessness in cross-checking, errors in instrument interpretation, or lack of proficiency in aircraft control. Due to the instability characteristics of the helicopter, unusual attitudes can be extremely critical. As soon as an unusual attitude is detected, make a recovery to straight-and-level flight as soon as possible with a minimum loss of altitude.

To recover from an unusual attitude, a pilot should correct bank-and-pitch attitude and adjust power as necessary. All components are changed almost simultaneously, with little lead of one over the other. A pilot must be able to perform this task with and without the attitude indicator. If the helicopter is in a climbing or descending turn, adjust bank, pitch, and power. The bank attitude should be corrected by referring to the turn-and-slip indicator and attitude indicator. Pitch attitude should be corrected by reference to the altimeter, airspeed indicator, VSI, and attitude indicator. Adjust power by referring to the airspeed indicator and manifold pressure.

Since the displacement of the controls used in recovery from unusual attitudes may be greater than those used for normal flight, make careful adjustments as straight-and-level flight is approached. Cross-check the other instruments closely to avoid overcontrolling.

Common Errors During Unusual Attitude Recoveries

1. Failure to make proper pitch correction
2. Failure to make proper bank correction
3. Failure to make proper power correction
4. Overcontrolling pitch and/or bank attitude
5. Overcontrolling power
6. Excessive loss of altitude

Emergencies

Emergencies during instrument flight are handled similarly to those occurring during VFR flight. A thorough knowledge of the helicopter and its systems, as well as good aeronautical knowledge and judgment, is the best preparation for emergency situations. Safe operations begin with preflight planning and a thorough preflight inspection. Plan a route of flight to include adequate landing sites in the event of an emergency landing. Make sure all resources, such as maps, publications, flashlights, and fire extinguishers are readily available for use in an emergency.

During any emergency, first fly the aircraft. This means ensure the helicopter is under control, and determine emergency

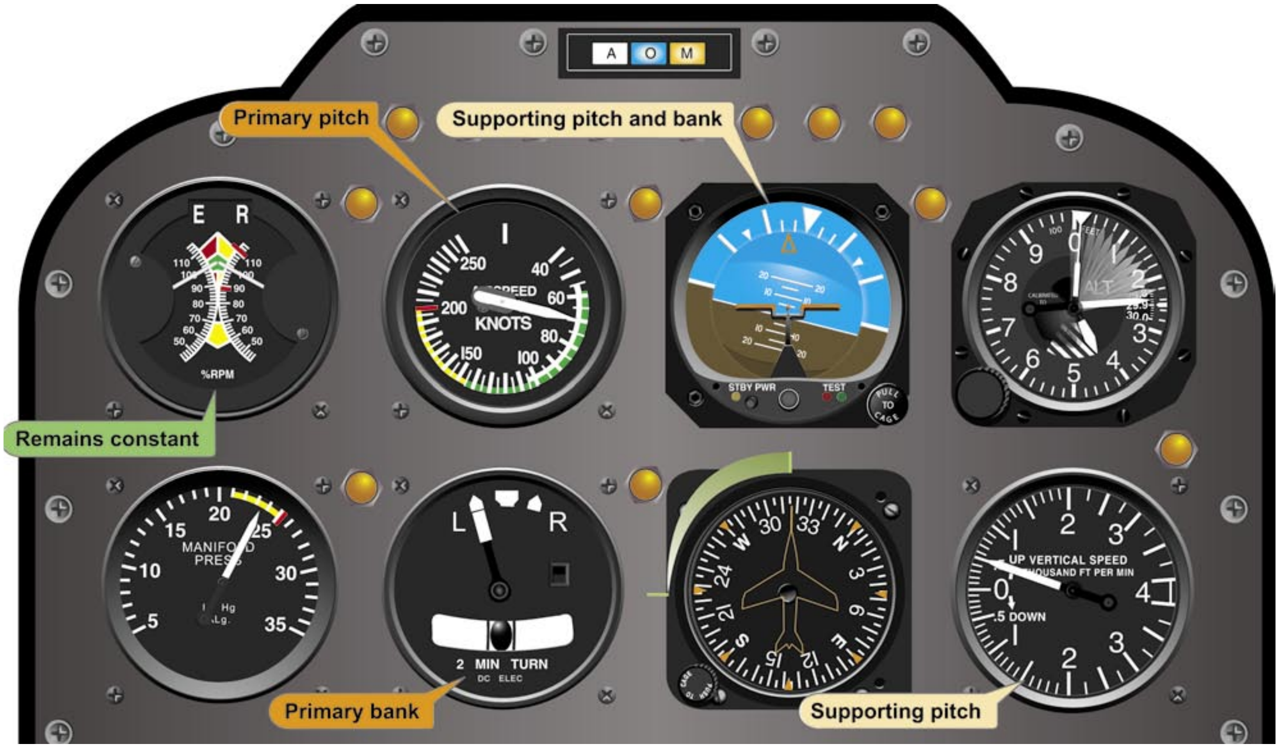

Figure 6-15. *Flight Instrument Indications for a Stabilized Left Climbing Turn at a Constant Airspeed.*

landing sites. Then perform the emergency checklist memory items, followed by items written in the rotorcraft flight manual (RFM). When all these items are under control, notify air traffic control (ATC). Declare any emergency on the last assigned ATC frequency. If one was not issued, transmit on the emergency frequency 121.5. Set the transponder to the emergency squawk code 7700. This code triggers an alarm or special indicator in radar facilities.

When experiencing most in-flight emergencies, such as low fuel or complete electrical failure, land as soon as possible. In the event of an electrical fire, turn off all nonessential equipment and land immediately. Some essential electrical instruments, such as the attitude indicator, may be required for a safe landing. A navigation radio failure may not require an immediate landing if the flight can continue safely. In this case, land as soon as practical. ATC may be able to provide vectors to a safe landing area. For specific details on what to do during an emergency, refer to the RFM for the helicopter.

Autorotations

Both straight-ahead and turning autorotations should be practiced by reference to instruments. This training ensures prompt corrective action to maintain positive aircraft control in the event of an engine failure.

To enter autorotation, reduce collective pitch smoothly to maintain a safe rotor RPM and apply pedal trim to keep the ball of the turn-and-slip indicator centered. The pitch attitude of the helicopter should be approximately level as shown by the attitude indicator. The airspeed indicator is the primary pitch instrument and should be adjusted to the recommended autorotation speed. The heading indicator is primary for bank in a straight-ahead autorotation. In a turning autorotation, a standard rate turn should be maintained by reference to the needle of the turn-and-slip indicator.

Common Errors During Autorotations

1. Uncoordinated entry due to improper pedal trim
2. Poor airspeed control due to improper pitch attitude
3. Poor heading control in straight-ahead autorotations
4. Failure to maintain proper rotor RPM
5. Failure to maintain a standard rate turn during turning autorotations

Servo Failure

Most helicopters certified for single-pilot IFR flight are required to have autopilots, which greatly reduces pilot workload. If an autopilot servo fails, however, resume manual control of the helicopter. The amount of workload increase depends on which servo fails. If a cyclic servo fails, a pilot may want to land immediately because the workload increases tremendously. If an antitorque or collective servo fails, continuing to the next suitable landing site might be possible.

Instrument Takeoff

The procedures and techniques described here should be modified as necessary to conform to those set forth in the operating instructions for the particular helicopter being flown. During training, instrument takeoffs should not be attempted except when receiving instruction from an appropriately certificated, proficient flight instructor pilot.

Adjust the miniature aircraft in the attitude indicator, as appropriate, for the aircraft being flown. After the helicopter is aligned with the runway or takeoff pad, to prevent forward movement of a helicopter equipped with a wheel-type landing gear, set the parking brakes or apply the toe brakes. If the parking brake is used, it must be unlocked after the takeoff has been completed. Apply sufficient friction to the collective pitch control to minimize overcontrolling and to prevent creeping. Excessive friction should be avoided since it limits collective pitch movement.

After checking all instruments for proper indications, start the takeoff by applying collective pitch and a predetermined power setting. Add power smoothly and steadily to gain airspeed and altitude simultaneously and to prevent settling to the ground. As power is applied and the helicopter becomes airborne, use the antitorque pedals initially to maintain the desired heading. At the same time, apply forward cyclic to begin accelerating to climbing airspeed. During the initial acceleration, the pitch attitude of the helicopter, as read on the attitude indicator, should be one- to two-bar widths low. The primary and supporting instruments after becoming airborne are illustrated in *Figure 6-16*. As the airspeed increases to the appropriate climb airspeed, adjust pitch gradually to climb attitude. As climb airspeed is reached, reduce power to the climb power setting and transition to a fully coordinated straight climb.

During the initial climb out, minor heading corrections should be made with pedals only until sufficient airspeed is attained to transition to fully coordinated flight. Throughout the instrument takeoff, instrument cross-check and interpretations must be rapid and accurate, and aircraft control positive and smooth.

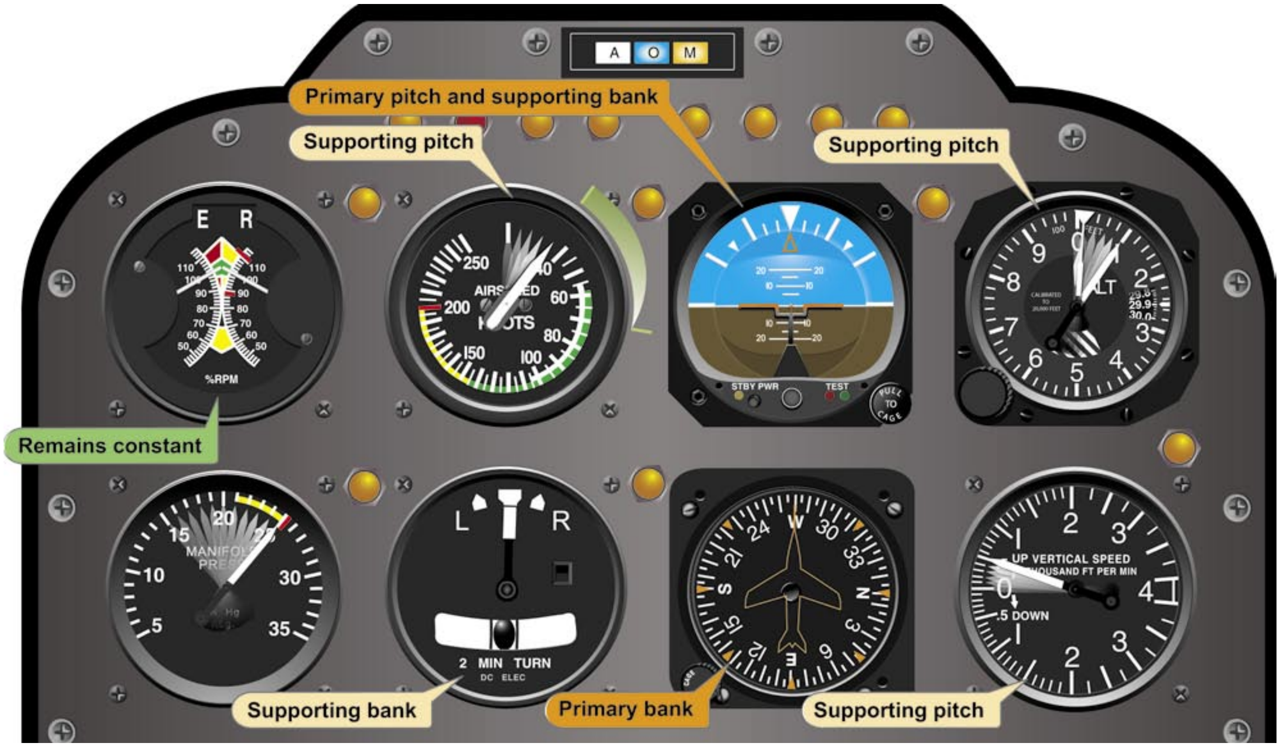
Primary pitch and supporting bank
Supporting pitch
Supporting pitch
Remains constant
Supporting bank
Primary bank
Supporting pitch

Figure 6-16. *Flight Instrument Indications During an Instrument Takeoff.*

Common Errors During Instrument Takeoffs

1. Failure to maintain heading
2. Overcontrolling pedals
3. Failure to use required power
4. Failure to adjust pitch attitude as climbing airspeed is reached

Changing Technology

Advances in technology have brought about changes in the instrumentation found in all types of aircraft, including helicopters. Electronic displays commonly referred to as "glass cockpits" are becoming more common. Primary flight displays (PFDs) and multi-function displays (MFDs) are changing not only what information is available to a pilot but also how that information is displayed.

Illustrations of technological advancements in instrumentation are described as follows. In *Figure 6-17,* a typical PFD depicts an aircraft flying straight-and-level at 3,000 feet and 100 knots. *Figure 6-18* illustrates a nose-low pitch attitude in a right turn. MFDs can be configured to provide navigation information such as the moving map in *Figure 6-19* or information pertaining to aircraft systems as in *Figure 6-20*.

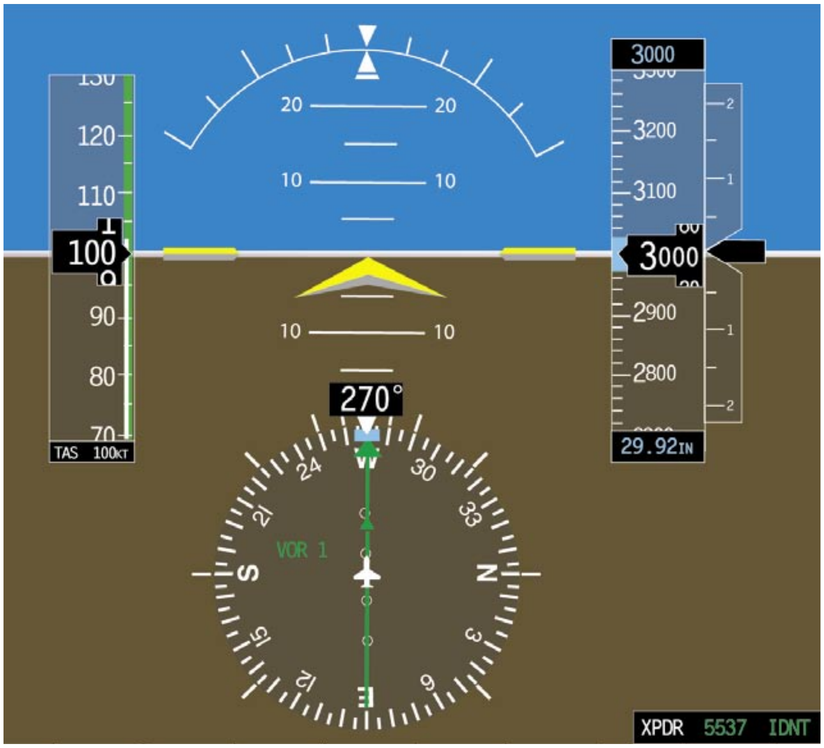
130
120
110
100
90
80
70
TAS 100KT
20
10
3000
3200
3100
2900
2800
29.92IN
270°
24
30
21
33
VOR 1
S
N
W
E
15
3
12
6
XPDR 5537 IDNT

Figure 6-17. *PFD Indications During Straight-and-Level Flight.*

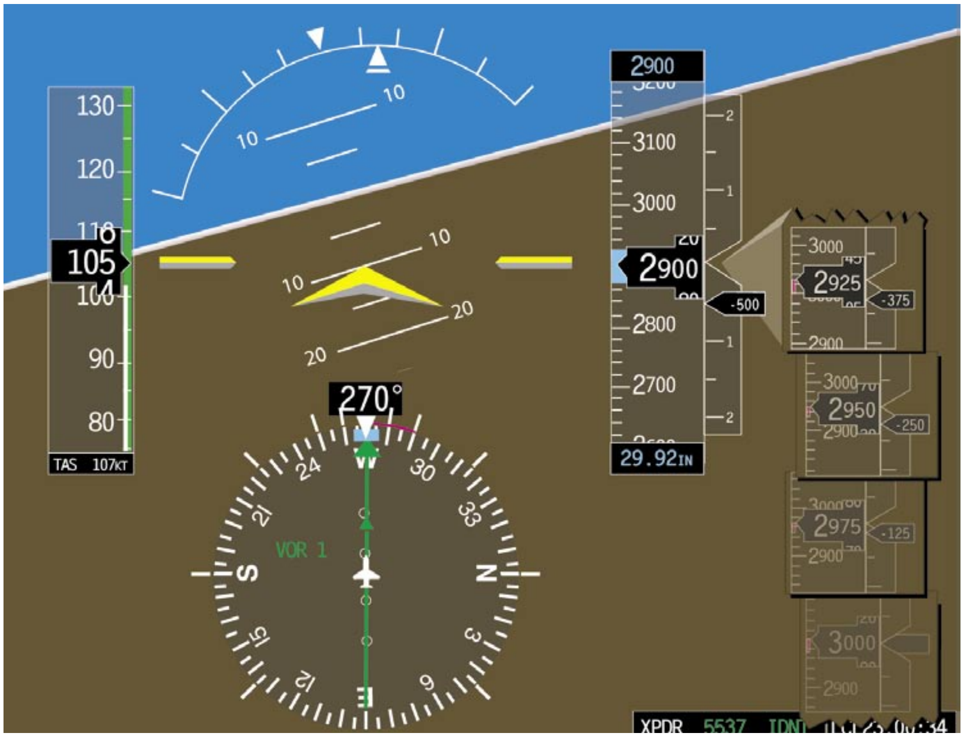
130
120
110
105
100
90
80
TAS 107KT
10
20
2900
3100
3000
2800
2700
-500
29.92IN
3000
2925
-375
2950
-250
2975
-125
270°
24
30
21
33
VOR 1
S
N
W
E
15
3
12
6
XPDR 5537

Figure 6-18. *PFD Indications During a Nose-Low Pitch Attitude in a Right Turn.*

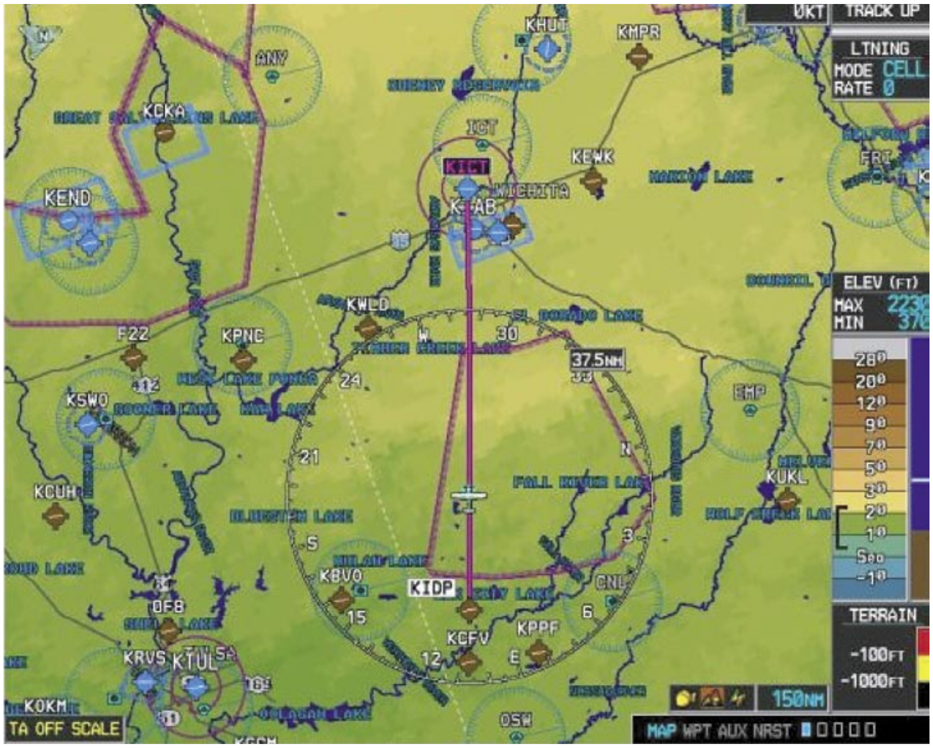
0KT
TRACK UP
LTNING
MODE CELL
RATE 0
KHUT
KMPR
ANY
KCKA
ICT
KEWK
KICT
WICHITA
KEND
ELEV (FT)
MAX 2230
MIN 370
KWLD
F22
KPNC
30
37.5NM
33
24
KSWO
EMP
21
N
KUKL
KCUH
S
3
KBVO
KIDP
CNU
15
6
0F8
KCFV
KPPF
KRVS
KTUL
12
E
TERRAIN
-100FT
-1000FT
KOKM
TA OFF SCALE
OSW
150NM
MAP WPT AUX NRST

Figure 6-19. *MFD Display of a Moving Map.*

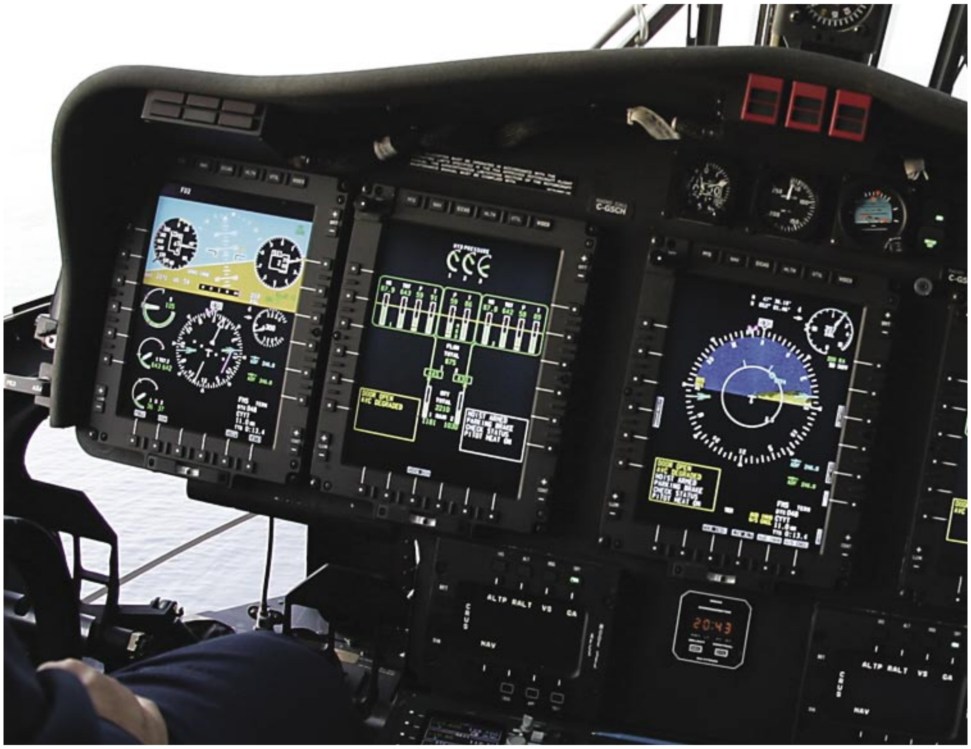
C-GSCN
ALTP RALT VS GA
NAV
20:43

Figure 6-20. *MFD Display of Aircraft Systems.*

W
24
21
S
9
6
3
N
33
025°
205°
015°
ADF
TO

Chapter 7

Navigation Systems

Introduction

This chapter provides the basic radio principles applicable to navigation equipment, as well as an operational knowledge of how to use these systems in instrument flight. This information provides the framework for all instrument procedures, including standard instrument departure procedures (SIDS), departure procedures (DPs), holding patterns, and approaches, because each of these maneuvers consists mainly of accurate attitude instrument flying and accurate tracking using navigation systems.

Basic Radio Principles

A radio wave is an electromagnetic (EM) wave with frequency characteristics that make it useful. The wave will travel long distances through space (in or out of the atmosphere) without losing too much strength. An antenna is used to convert electric current into a radio wave so it can travel through space to the receiving antenna, which converts it back into an electric current for use by a receiver.

How Radio Waves Propagate

All matter has a varying degree of conductivity or resistance to radio waves. The Earth itself acts as the greatest resistor to radio waves. Radiated energy that travels near the ground induces a voltage in the ground that subtracts energy from the wave, decreasing the strength of the wave as the distance from the antenna becomes greater. Trees, buildings, and mineral deposits affect the strength to varying degrees. Radiated energy in the upper atmosphere is likewise affected as the energy of radiation is absorbed by molecules of air, water, and dust. The characteristics of radio wave propagation vary according to the signal frequency and the design, use, and limitations of the equipment.

Ground Wave

A ground wave travels across the surface of the Earth. You can best imagine a ground wave's path as being in a tunnel or alley bounded by the surface of the Earth and by the ionosphere, which keeps the ground wave from going out into space. Generally, the lower the frequency, the farther the signal will travel.

Ground waves are usable for navigation purposes because they travel reliably and predictably along the same route day after day, and are not influenced by too many outside factors. The ground wave frequency range is generally from the lowest frequencies in the radio range (perhaps as low as 100 Hz) up to approximately 1,000 kHz (1 MHz). Although there is a ground wave component to frequencies above this, up to 30 MHz, the ground wave at these higher frequencies loses strength over very short distances.

Sky Wave

The sky wave, at frequencies of 1 to 30 MHz, is good for long distances because these frequencies are refracted or "bent" by the ionosphere, causing the signal to be sent back to Earth from high in the sky and received great distances away. *[Figure 7-1]* Used by high frequency (HF) radios in aircraft, messages can be sent across oceans using only 50 to 100 watts of power. Frequencies that produce a sky wave are not used for navigation because the pathway of the signal from transmitter to receiver is highly variable. The wave is "bounced" off of the ionosphere, which is always changing due to the varying amount of the sun's radiation reaching it (night/day and seasonal variations, sunspot activity, etc.). The sky wave is, therefore, unreliable for navigation purposes.

For aeronautical communication purposes, the sky wave (HF) is about 80 to 90 percent reliable. HF is being gradually replaced by more reliable satellite communication.

Space Wave

When able to pass through the ionosphere, radio waves of 15 MHz and above (all the way up to many GHz), are considered space waves. Most navigation systems operate with signals propagating as space waves. Frequencies above 100 MHz have nearly no ground or sky wave components. They are space waves, but (except for global positioning system (GPS)) the navigation signal is used before it reaches the ionosphere so the effect of the ionosphere, which can cause some propagation errors, is minimal. GPS errors caused by passage through the ionosphere are significant and are corrected for by the GPS receiver system.

Space waves have another characteristic of concern to users. Space waves reflect off hard objects and may be blocked if the object is between the transmitter and the receiver. Site and terrain error, as well as propeller/rotor modulation error in very high omnidirectional range (VOR) systems is caused by this bounce. Instrument landing system (ILS) course distortion is also the result of this phenomenon, which led to the need for establishment of ILS critical areas.

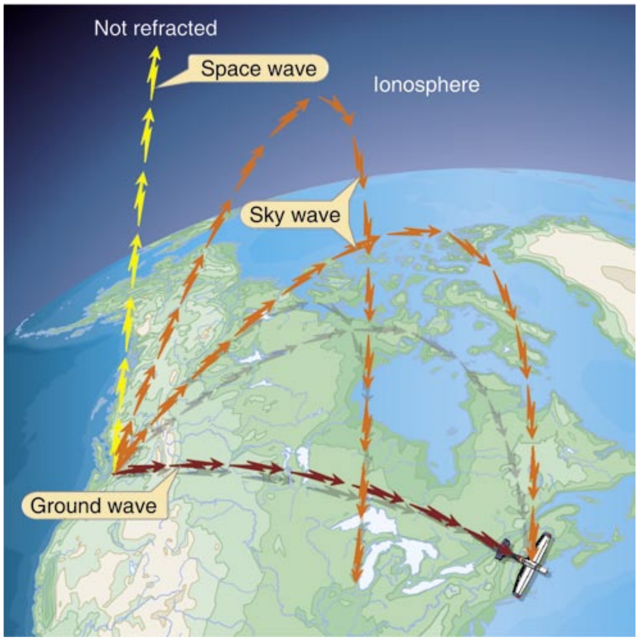

Figure 7-1. *Ground, Space, and Sky Wave Propogation.*

Generally, space waves are "line of sight" receivable, but those of lower frequencies will "bend" somewhat over the horizon. The VOR signal at 108 to 118 MHz is a lower frequency than distance measuring equipment (DME) at 962 to 1213 MHz. Therefore, when an aircraft is flown "over the horizon" from a VOR/DME station, the DME will normally be the first to stop functioning.

Disturbances to Radio Wave Reception

Static distorts the radio wave and interferes with normal reception of communications and navigation signals. Low-frequency airborne equipment such as automatic direction finder (ADF) and LORAN are particularly subject to static disturbance. Using very high frequency (VHF) and ultra-high frequency (UHF) frequencies avoids many of the discharge noise effects. Static noise heard on navigation or communication radio frequencies may be a warning of interference with navigation instrument displays. Some of the problems caused by precipitation static (P-static) are:

- Complete loss of VHF communications.
- Erroneous magnetic compass readings.
- Aircraft flying with one wing low while using the autopilot.
- High-pitched squeal on audio.
- Motorboat sound on audio.
- Loss of all avionics.
- Inoperative very-low frequency (VLF) navigation system.
- Erratic instrument readouts.
- Weak transmissions and poor radio reception.
- St. Elmo's Fire.

Traditional Navigation Systems

Nondirectional Radio Beacon (NDB)

The nondirectional radio beacon (NDB) is a ground-based radio transmitter that transmits radio energy in all directions. The ADF, when used with an NDB, determines the bearing from the aircraft to the transmitting station. The indicator may be mounted in a separate instrument in the aircraft panel. *[Figure 7-2]* The ADF needle points to the NDB ground station to determine the relative bearing (RB) to the transmitting station. It is the number of degrees measured clockwise between the aircraft's heading and the direction from which the bearing is taken. The aircraft's magnetic heading (MH) is the direction the aircraft is pointed with respect to magnetic north. The magnetic bearing (MB) is the direction to or from a radio transmitting station measured relative to magnetic north.

NDB Components

The ground equipment, the NDB, transmits in the frequency range of 190 to 535 kHz. Most ADFs will also tune the AM broadcast band frequencies above the NDB band (550 to 1650 kHz). However, these frequencies are not approved for navigation because stations do not continuously identify themselves, and they are much more susceptible to sky wave propagation especially from dusk to dawn. NDB stations are capable of voice transmission and are often used for transmitting the automated weather observing system (AWOS). The aircraft must be in operational range of the NDB. Coverage depends on the strength of the transmitting station. Before relying on ADF indications, identify the station by listening to the Morse code identifier. NDB stations are usually two letters or an alpha-numeric combination.

ADF Components

The airborne equipment includes two antennas, a receiver, and the indicator instrument. The "sense" antenna (non-directional) receives signals with nearly equal efficiency from all directions. The "loop" antenna receives signals better from two directions (bidirectional). When the loop and sense antenna inputs are processed together in the ADF radio, the result is the ability to receive a radio signal well in all directions but one, thus resolving all directional ambiguity. The indicator instrument can be one of four kinds: fixed-card ADF, rotatable compass-card ADF, or radio magnetic

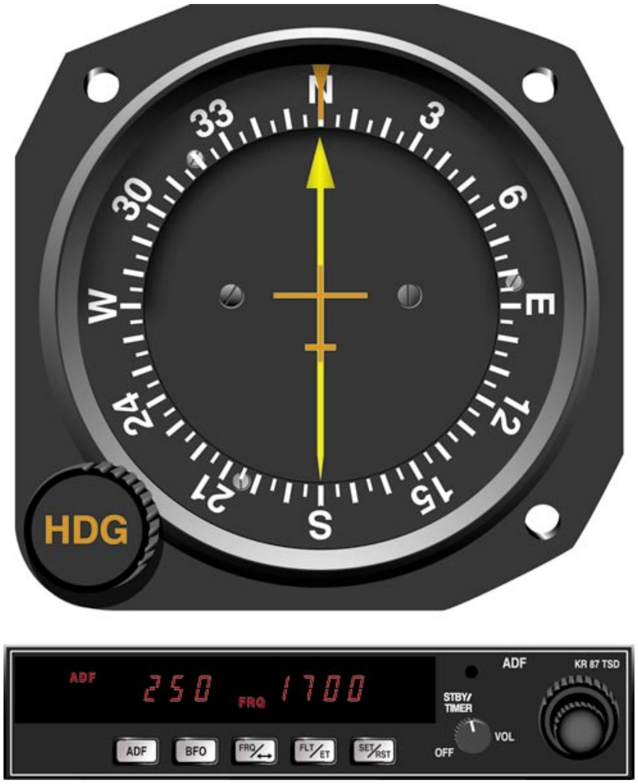

Figure 7-2. *ADF Indicator Instrument and Receiver.*

indicator (RMI) with either one needle or dual needle. Fixed-card ADF (also known as the relative bearing indicator (RBI)) always indicates zero at the top of the instrument, with the needle indicating the RB to the station. *Figure 7-3* indicates an RB of 135°; if the MH is 045°, the MB to the station is 180°. (MH + RB = MB to the station.)

The movable-card ADF allows the pilot to rotate the aircraft's present heading to the top of the instrument so that the head of the needle indicates MB to the station and the tail indicates MB from the station. *Figure 7-4* indicates a heading of 045°, MB to the station of 180°, and MB from the station of 360°.

The RMI differs from the movable-card ADF in that it automatically rotates the azimuth card (remotely controlled by a gyrocompass) to represent aircraft heading. The RMI has two needles, which can be used to indicate navigation information from either the ADF or the VOR receiver. When a needle is being driven by the ADF, the head of the needle indicates the MB TO the station tuned on the ADF receiver. The tail of the needle is the bearing FROM the station. When a needle of the RMI is driven by a VOR receiver, the needle indicates where the aircraft is radially with respect to the VOR station. The needle points to the bearing TO the station, as read on the azimuth card. The tail of the needle points to the radial of the VOR the aircraft is currently on or crossing. *Figure 7-5* indicates a heading of 005°, the MB to the station is 005°, and the MB from the station is 185°.

Function of ADF

The ADF can be used to plot your position, track inbound and outbound, and intercept a bearing. These procedures are used to execute holding patterns and nonprecision instrument approaches.

Orientation

The ADF needle points TO the station, regardless of aircraft heading or position. The RB indicated is thus the angular relationship between the aircraft heading and the station, measured clockwise from the nose of the aircraft. Think of the nose/tail and left/right needle indications, visualizing the ADF dial in terms of the longitudinal axis of the aircraft. When the needle points to 0°, the nose of the aircraft points directly to the station; with the pointer on 210°, the station is 30° to the left of the tail; with the pointer on 090°, the station is off the right wingtip. The RB alone does not indicate aircraft position. The RB must be related to aircraft heading in order to determine direction to or from the station.

Station Passage

When you are near the station, slight deviations from the desired track result in large deflections of the needle. Therefore, it is important to establish the correct drift correction angle as soon as possible. Make small heading corrections (not over 5°) as soon as the needle shows a deviation from course, until it begins to rotate steadily toward a wingtip position or shows erratic left/right oscillations. You

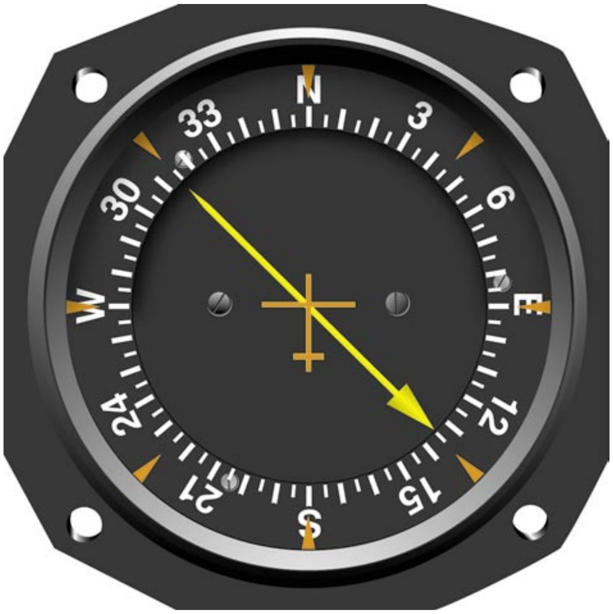

Figure 7-3. *Relative bearing (RB) on a fixed-card indicator. Note that the card always indicates 360°, or north. In this case, the relative bearing to the station is 135° to the right. If the aircraft were on a magnetic heading of 360°, then the magnetic bearing (MB) would also be 135°.*

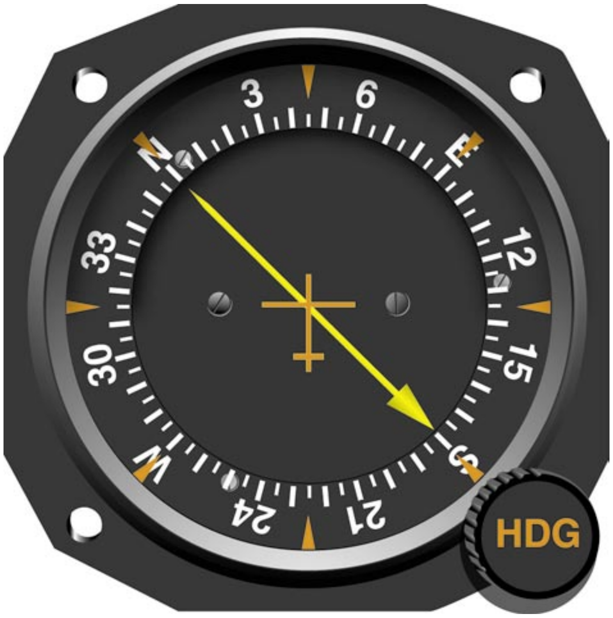

Figure 7-4. *Relative bearing (RB) on a movable-card indicator. By placing the aircraft's magnetic heading (MH) of 045° under the top index, the relative bearing (RB) of 135° to the right will also be the magnetic bearing (no wind conditions) which will take you to the transmitting station.*

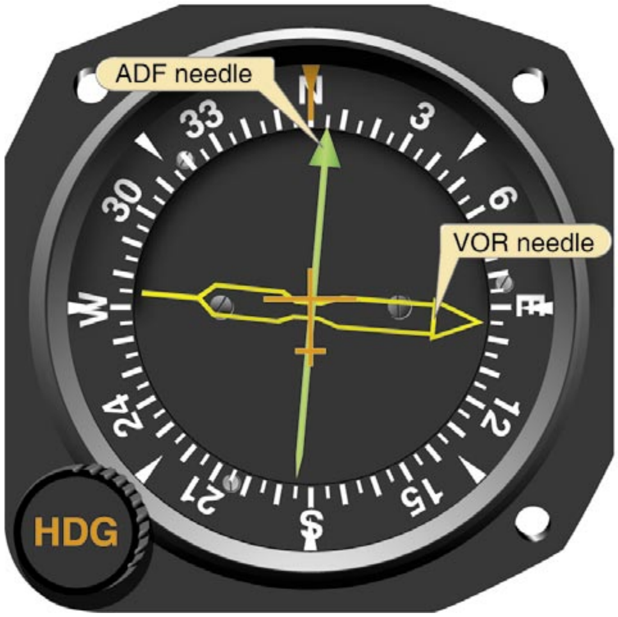

Figure 7-5. *Radio magnetic indicator (RMI). Because the aircraft's magnetic heading is automatically changed, the relative bearing (RB), in this case 095°, will indicate the magnetic bearing (095°) to the station (no wind conditions) and the magnetic heading that will take you there.*

are abeam a station when the needle points 90° off your track. Hold your last corrected heading constant and time station passage when the needle shows either wingtip position or settles at or near the 180° position. The time interval from the first indications of station proximity to positive station passage varies with altitude—a few seconds at low levels to 3 minutes at high altitude.

Homing

The ADF may be used to "home" in on a station. Homing is flying the aircraft on any heading required to keep the needle pointing directly to the 0° RB position. To home in on a station, tune the station, identify the Morse code signal, and then turn the aircraft to bring the ADF azimuth needle to the 0° RB position. Turns should be made using the heading indicator. When the turn is complete, check the ADF needle and make small corrections as necessary.

Figure 7-6 illustrates homing starting from an initial MH of 050° and an RB of 310°, indicating a 50° left turn is needed to produce an RB of zero. Turn left, rolling out at 50° minus 50° equals 360°. Small heading corrections are then made to zero the ADF needle.

If there is no wind, the aircraft will home to the station on a direct track over the ground. With a crosswind, the aircraft will follow a circuitous path to the station on the downwind side of the direct track to the station.

Tracking

Tracking uses a heading that will maintain the desired track to or from the station regardless of crosswind conditions. Interpretation of the heading indicator and needle is done to maintain a constant MB to or from the station.

To track inbound, turn to the heading that will produce a zero RB. Maintain this heading until off-course drift is indicated by displacement of the needle, which will occur if there is a crosswind (needle moving left = wind from the left; needle moving right = wind from the right). A rapid rate of bearing change with a constant heading indicates either a strong crosswind or close proximity to the station or both. When there is a definite (2° to 5°) change in needle reading, turn in the direction of needle deflection to intercept the initial MB. The angle of interception must be greater than the number of degrees of drift, otherwise the aircraft will slowly drift due to the wind pushing the aircraft. If repeated often enough, the track to the station will appear circular and the distance greatly increased as compared to a straight track. The intercept angle depends on the rate of drift, the aircraft speed, and station proximity. Initially, it is standard to double the RB when turning toward your course.

For example, if your heading equals your course and the needle points 10° left, turn 20° left, twice the initial RB. *[Figure 7-7]* This will be your intercept angle to capture the RB. Hold this heading until the needle is deflected 20° in the opposite direction. That is, the deflection of the needle equals the interception angle (in this case 20°). The track has been intercepted, and the aircraft will remain on track as long as the RB remains the same number of degrees as the wind correction angle (WCA), the angle between the desired track and the heading of the aircraft necessary to keep the aircraft tracking over the desired track. Lead the interception to avoid overshooting the track. Turn 10° toward the inbound course. You are now inbound with a 10° left correction angle.

NOTE: In *Figure 7-7*, for the aircraft closest to the station, the WCA is 10° left and the RB is 10° right. If those values do not change, the aircraft will track directly to the station. If you observe off-course deflection in the original direction, turn again to the original interception heading. When the desired course has been re-intercepted, turn 5° toward the inbound course, proceeding inbound with a 15° drift correction. If the initial 10° drift correction is excessive, as shown by needle deflection away from the wind, turn to parallel the desired course and let the wind drift you back on course. When the needle is again zeroed, turn into the wind with a reduced drift correction angle.

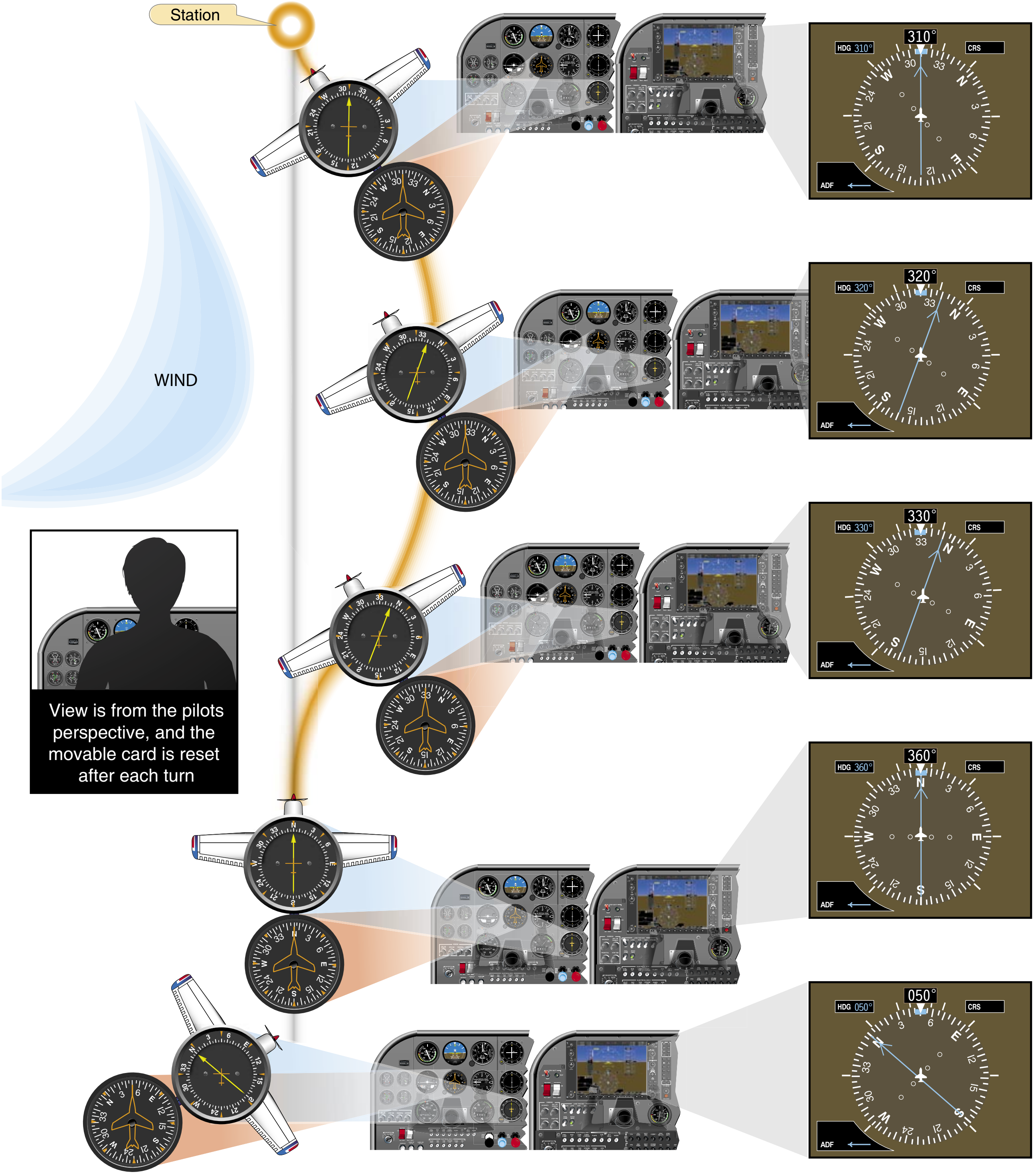
Station
WIND
View is from the pilots perspective, and the movable card is reset after each turn
310°
HDG 310°
320°
HDG 320°
330°
HDG 330°
360°
HDG 360°
050°
HDG 050°
CRS
ADF

Figure 7-6. *ADF Homing With a Crosswind.*

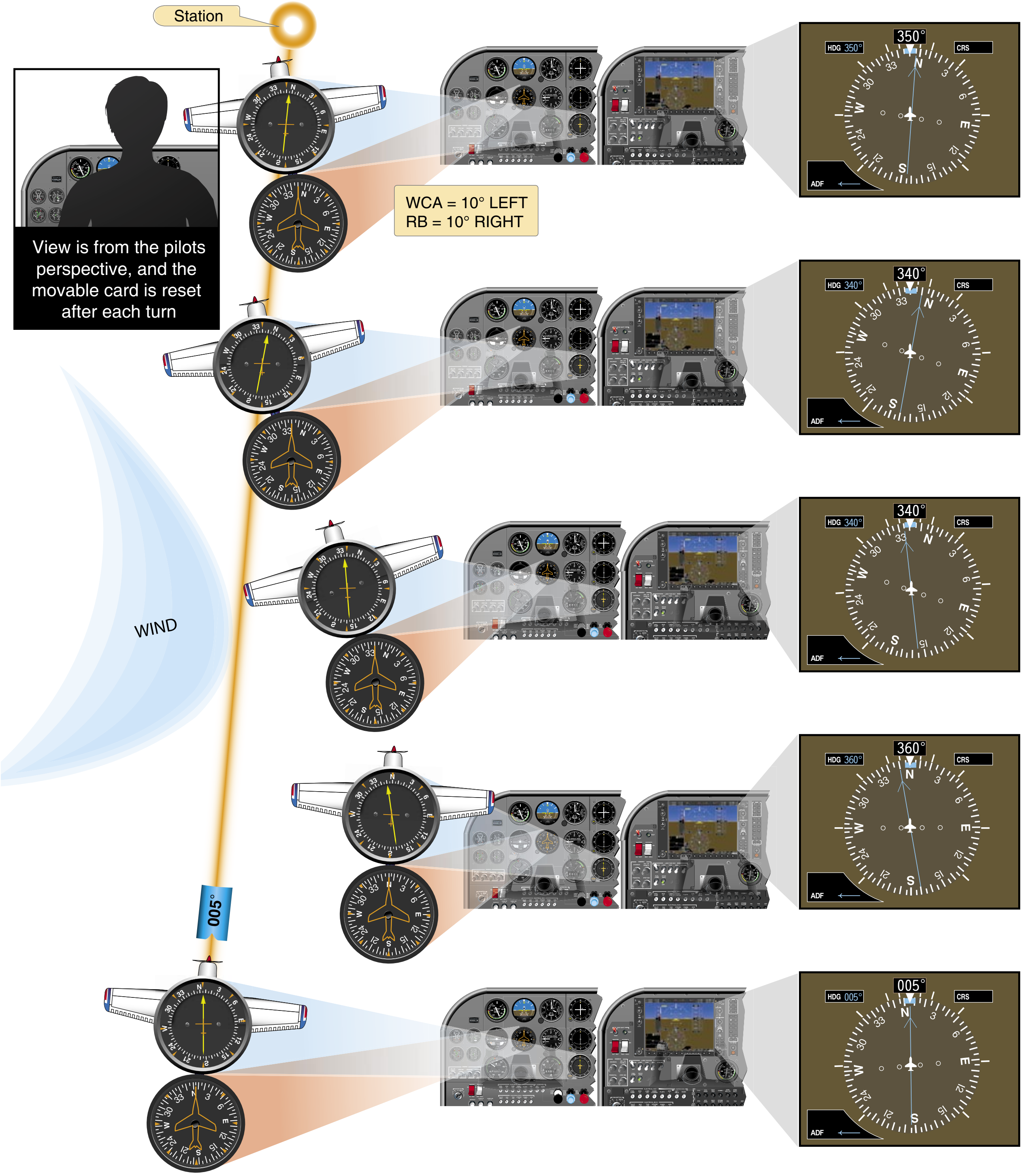
Station
View is from the pilots perspective, and the movable card is reset after each turn
WCA = 10° LEFT
RB = 10° RIGHT
WIND
005°
HDG 350°
350°
CRS
ADF
HDG 340°
340°
CRS
ADF
HDG 340°
340°
CRS
ADF
HDG 360°
360°
CRS
ADF
HDG 005°
005°
CRS
ADF

Figure 7-7. *ADF Tracking Inbound.*

To track outbound, the same principles apply: needle moving left = wind from the left, needle moving right = wind from the right. Wind correction is made toward the needle deflection. The only exception is while the turn to establish the WCA is being made, the direction of the azimuth needle deflections is reversed. When tracking inbound, needle deflection decreases while turning to establish the WCA, and needle deflection increases when tracking outbound. Note the example of course interception and outbound tracking in *Figure 7-8.*

Intercepting Bearings

ADF orientation and tracking procedures may be applied to intercept a specified inbound or outbound MB. To intercept an inbound bearing of 355°, the following steps may be used. *[Figure 7-9]*

1. Determine your position in relation to the station by paralleling the desired inbound bearing. In this case, turn to a heading of 355°. Note that the station is to the right front of the aircraft.
2. Determine the number of degrees of needle deflection from the nose of the aircraft. In this case, the needle's RB from the aircraft's nose is 40° to the right. A rule of thumb for interception is to double this RB amount as an interception angle (80°).
3. Turn the aircraft toward the desired MB the number of degrees determined for the interception angle which as indicated (in two above) is twice the initial RB (40°), or in this case 80°. Therefore, the right turn will be 80° from the initial MB of 355°, or a turn to 075° magnetic (355° + 80° + 075°).
4. Maintain this interception heading of 075° until the needle is deflected the same number of degrees "left" from the zero position as the angle of interception 080°, (minus any lead appropriate for the rate at which the bearing is changing).
5. Turn left 80° and the RB (in a no wind condition and with proper compensation for the rate of the ADF needle movement) should be 0°, or directly off the nose. Additionally, the MB should be 355° indicating proper interception of the desired course.

NOTE: The rate of an ADF needle movement or any bearing pointer for that matter will be faster as aircraft position becomes closer to the station or waypoint (WP).

Interception of an outbound MB can be accomplished by the same procedures as for the inbound intercept, except that it is necessary to substitute the 180° position for the zero position on the needle.

Operational Errors of ADF

Some of the common pilot-induced errors associated with ADF navigation are listed below to help you avoid making the same mistakes. The errors are:

1. Improper tuning and station identification. Many pilots have made the mistake of homing or tracking to the wrong station.
2. Positively identifying any malfunctions of the RMI slaving system or ignoring the warning flag.
3. Dependence on homing rather than proper tracking. This commonly results from sole reliance on the ADF indications, rather than correlating them with heading indications.
4. Poor orientation, due to failure to follow proper steps in orientation and tracking.
5. Careless interception angles, very likely to happen if you rush the initial orientation procedure.
6. Overshooting and undershooting predetermined MBs, often due to forgetting the course interception angles used.
7. Failure to maintain selected headings. Any heading change is accompanied by an ADF needle change. The instruments must be read in combination before any interpretation is made.
8. Failure to understand the limitations of the ADF and the factors that affect its use.
9. Overcontrolling track corrections close to the station (chasing the ADF needle), due to failure to understand or recognize station approach.
10. Failure to keep the heading indicator set so it agrees with the magnetic compass.

Very High Frequency Omnidirectional Range (VOR)

VOR is the primary navigational aid (NAVAID) used by civil aviation in the National Airspace System (NAS). The VOR ground station is oriented to magnetic north and transmits azimuth information to the aircraft, providing 360 courses TO or FROM the VOR station. When DME is installed with the VOR, it is referred to as a VOR/DME and provides both azimuth and distance information. When military tactical air navigation (TACAN) equipment is installed with the VOR, it is known as a VORTAC and provides both azimuth and distance information.

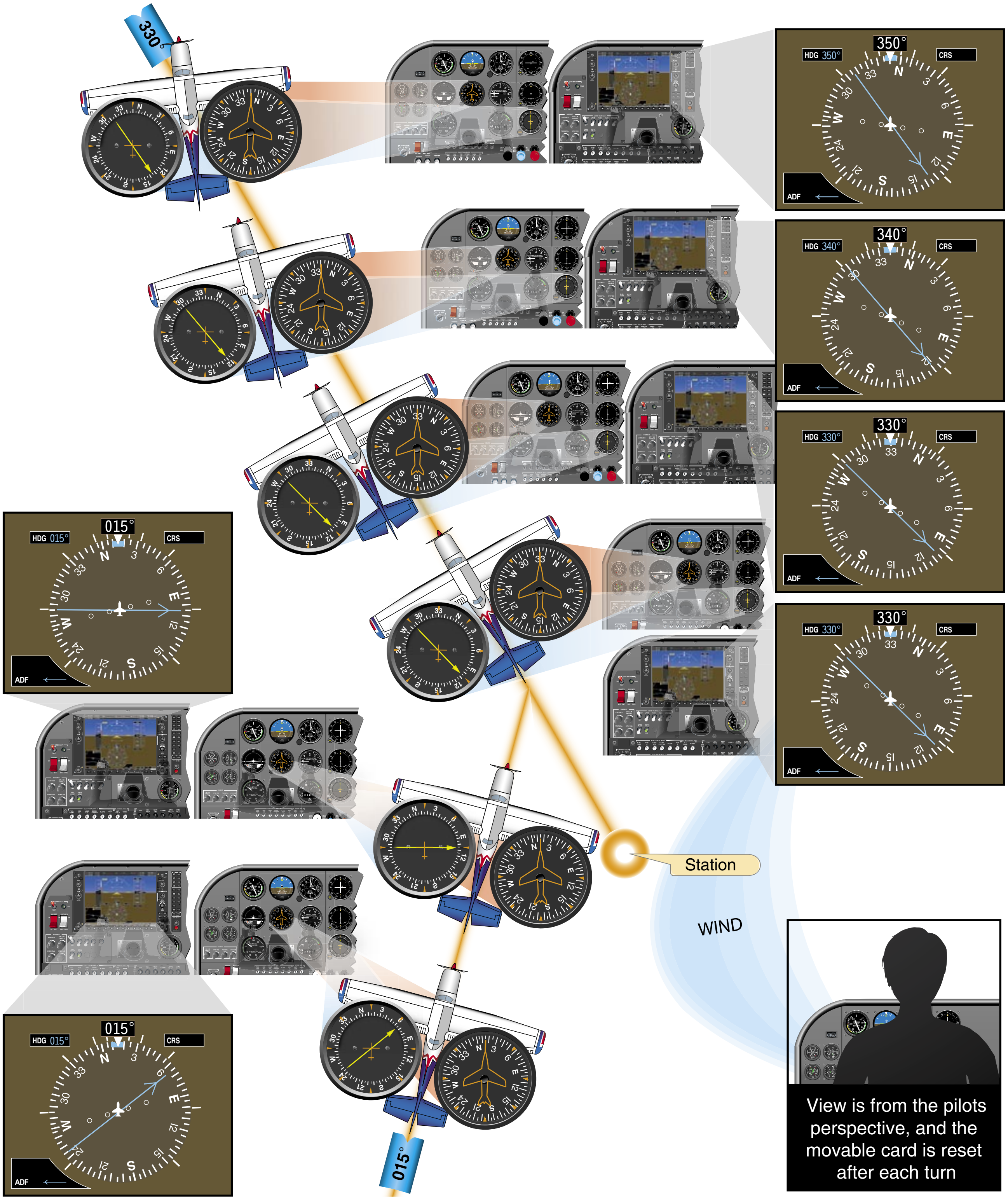
330°
350°
HDG 350°
CRS
ADF
340°
HDG 340°
330°
HDG 330°
015°
HDG 015°
Station
WIND
View is from the pilots perspective, and the movable card is reset after each turn
015°

Figure 7-8. *ADF Interception and Tracking Outbound.*

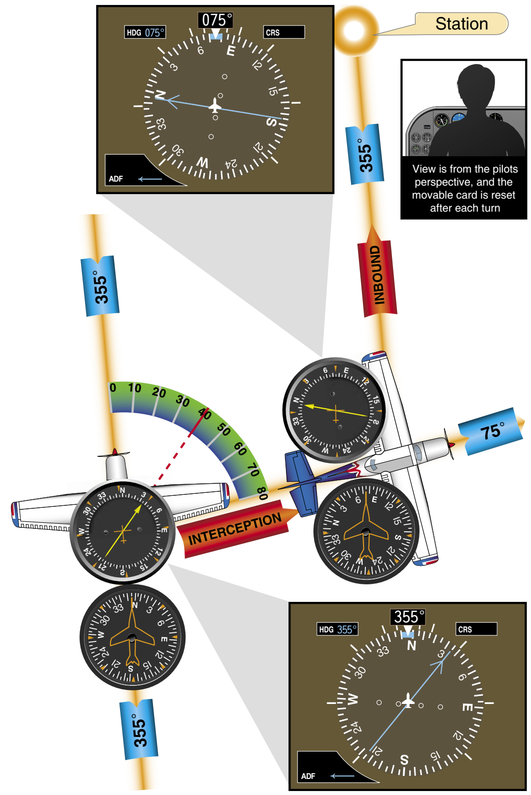

View is from the pilots perspective, and the movable card is reset after each turn

Figure 7-9. *Interception of Bearing.*

The courses oriented FROM the station are called radials. The VOR information received by an aircraft is not influenced by aircraft attitude or heading. *[Figure 7-10]* Radials can be envisioned to be like the spokes of a wheel on which the aircraft is on one specific radial at any time. For example, aircraft A (heading 180°) is inbound on the 360° radial; after crossing the station, the aircraft is outbound on the 180° radial at A1. Aircraft B is shown crossing the 225° radial. Similarly, at any point around the station, an aircraft can be located somewhere on a specific VOR radial. Additionally, a VOR needle on an RMI will always point to the course that will take you to the VOR station where conversely the ADF needle points to the station as a RB from the aircraft. In the example above, the ADF needle at position A would be pointed straight ahead, at A1 to the aircraft's 180° position (tail) and at B, to the aircraft's right.

The VOR receiver measures and presents information to indicate bearing TO or FROM the station. In addition to the navigation signals transmitted by the VOR, a Morse code signal is transmitted concurrently to identify the facility, as well as voice transmissions for communication and relay of weather and other information.

VORs are classified according to their operational uses. The standard VOR facility has a power output of approximately 200 watts, with a maximum usable range depending upon the aircraft altitude, class of facility, location of the facility, terrain conditions within the usable area of the facility, and other factors. Above and beyond certain altitude and distance limits, signal interference from other VOR facilities and a weak signal make it unreliable. Coverage is typically at least 40 miles at normal minimum instrument flight rules (IFR) altitudes. VORs with accuracy problems in parts of their service volume are listed in Notices to Airmen (NOTAMs) and in the Airport/Facility Directory (A/FD) under the name of the NAVAID.

VOR Components

The ground equipment consists of a VOR ground station, which is a small, low building topped with a flat white disc, upon which are located the VOR antennas and a fiberglass cone-shaped tower. *[Figure 7-11]* The station includes an automatic monitoring system. The monitor automatically turns off defective equipment and turns on the standby transmitter. Generally, the accuracy of the signal from the ground station is within 1°.

VOR facilities are aurally identified by Morse code, or voice, or both. The VOR can be used for ground-to-air communication without interference with the navigation signal. VOR facilities operate within the 108.0 to 117.95 MHz frequency band and assignment between 108.0 and 112.0

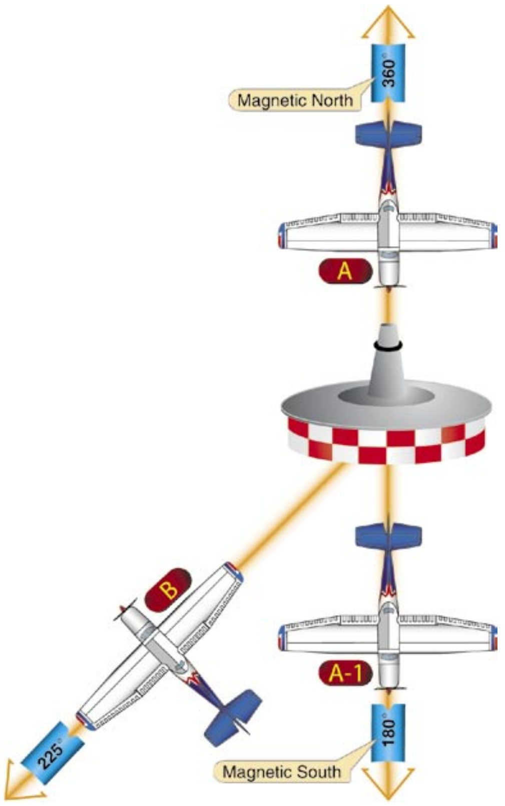

Figure 7-10. *VOR Radials.*

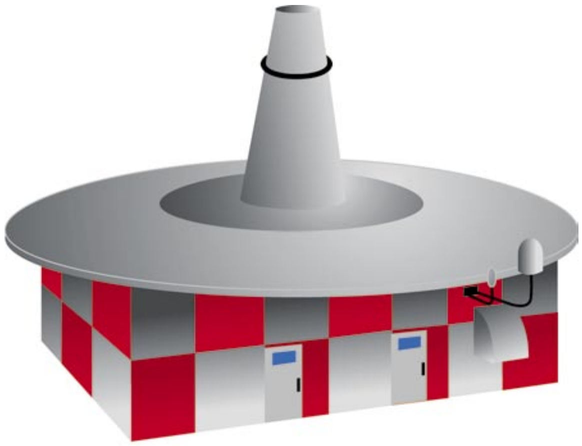

Figure 7-11. *VOR Transmitter (Ground Station).*

MHz is in even-tenth increments to preclude any conflict with ILS localizer frequency assignment, which uses the odd tenths in this range.

The airborne equipment includes an antenna, a receiver, and the indicator instrument. The receiver has a frequency knob to select any of the frequencies between 108.0 to 117.95 MHz. The On/Off/volume control turns on the navigation receiver and controls the audio volume. The volume has no effect on the operation of the receiver. You should listen to the station identifier before relying on the instrument for navigation.

VOR indicator instruments have at least the essential components shown in the instrument illustrated in *Figure 7-12.*

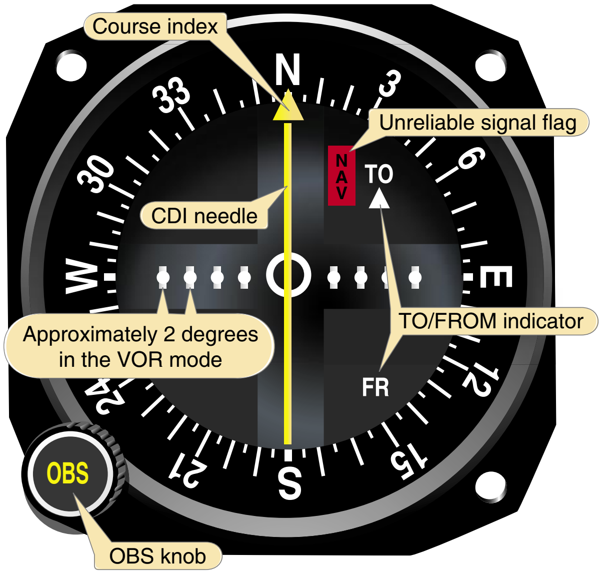
Course index
N
33
3
Unreliable signal flag
NAV
TO
30
6
CDI needle
W
E
Approximately 2 degrees in the VOR mode
TO/FROM indicator
FR
24
12
21
S
15
OBS
OBS knob

Figure 7-12. *The VOR Indicator Instrument.*

Omnibearing Selector (OBS)

The desired course is selected by turning the OBS knob until the course is aligned with the course index mark or displayed in the course window.

Course Deviation Indicator (CDI)

The deviation indicator is composed of an instrument face and a needle hinged to move laterally across the instrument face. The needle centers when the aircraft is on the selected radial or its reciprocal. Full needle deflection from the center position to either side of the dial indicates the aircraft is 12° or more off course, assuming normal needle sensitivity. The outer edge of the center circle is 2° off course; with each dot representing an additional 2°.

TO/FROM Indicator

The TO/FROM indicator shows whether the selected course if intercepted and flown will take the aircraft TO or FROM the station. It does not indicate whether the aircraft is heading to or from the station.

Flags or Other Signal Strength Indicators

The device that indicates a usable or an unreliable signal may be an "OFF" flag. It retracts from view when signal strength is sufficient for reliable instrument indications. Alternately, insufficient signal strength may be indicated by a blank or OFF in the TO/FROM window.

The indicator instrument may also be a horizontal situation indicator (HSI) which combines the heading indicator and CDI. *[Figure 7-13]* The combination of navigation information from VOR/Localizer (LOC) or from LORAN or GPS, with aircraft heading information provides a visual picture of the aircraft's location and direction. This decreases pilot workload especially with tasks such as course intercepts, flying a back-course approach, or holding pattern entry. (See

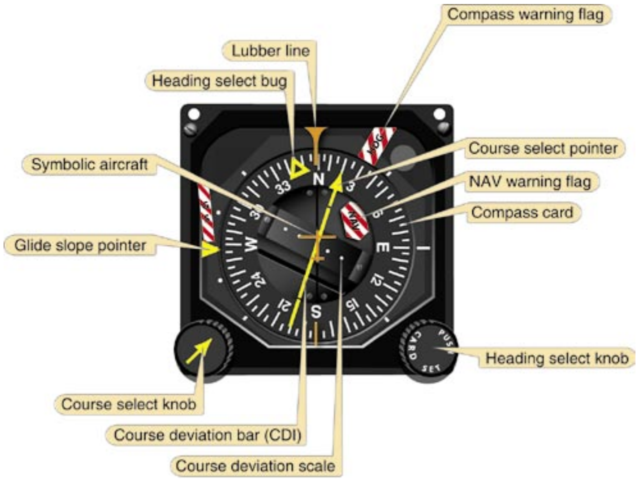
Compass warning flag
Lubber line
Heading select bug
Symbolic aircraft
Course select pointer
NAV warning flag
Compass card
Glide slope pointer
Heading select knob
Course select knob
Course deviation bar (CDI)
Course deviation scale

Figure 7-13. *A Typical Horizontal Situation Indicator (HSI).*

Chapter 3, Flight Instruments, for operational characteristics.) *[Figure 7-14]*

Function of VOR

Orientation

The VOR does not account for the aircraft heading. It only relays the aircraft direction from the station and will have the same indications regardless of which way the nose is pointing. Tune the VOR receiver to the appropriate frequency of the selected VOR ground station, turn up the audio volume, and identify the station's signal audibly. Then, rotate the OBS to center the CDI needle and read the course under or over the index.

In *Figure 7-12*, 360° TO is the course indicated, while in *Figure 7-15*, 180° TO is the course. The latter indicates that the aircraft (which may be heading in any direction) is, at this moment, located at any point on the 360° radial (line from the station) except directly over the station or very close to it, as in *Figure 7-15*. The CDI will deviate from side to side as the aircraft passes over or nearly over the station because of the volume of space above the station where the zone of confusion exists. This zone of confusion is caused by lack of adequate signal directly above the station due to the radiation pattern of the station's antenna, and because the resultant of the opposing reference and variable signals is small and constantly changing.

The CDI in *Figure 7-15* indicates 180°, meaning that the aircraft is on the 180° or the 360° radial of the station. The TO/FROM indicator resolves the ambiguity. If the TO indicator is showing, then it is 180° TO the station. The FROM indication indicates the radial of the station the aircraft is presently on. Movement of the CDI from center, if it occurs at a relatively constant rate, indicates the aircraft is moving or drifting off the 180°/360° line. If the movement is rapid or fluctuating, this is an indication of impending station passage (the aircraft is near the station). To determine the aircraft's position relative to the station, rotate the OBS until FROM appears in the window, and then center the CDI needle. The index indicates the VOR radial where the aircraft is located. The inbound (to the station) course is the reciprocal of the radial.

If the VOR is set to the reciprocal of the intended course, the CDI will reflect reverse sensing. To correct for needle deflection, turn away from the needle. To avoid this reverse sensing situation, set the VOR to agree with the intended course.

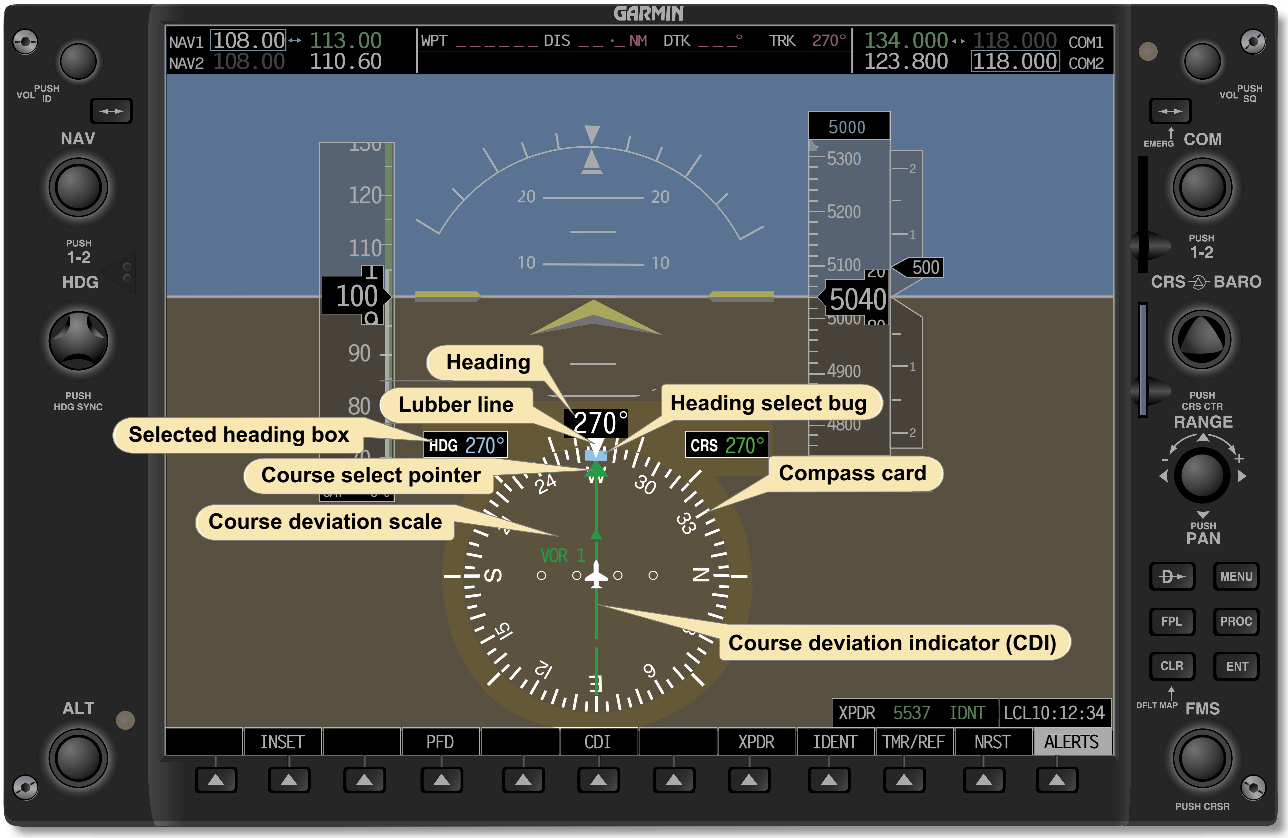
GARMIN
NAV1 108.00 113.00
NAV2 108.00 110.60
WPT DIS NM DTK TRK 270°
134.000 118.000 COM1
123.800 118.000 COM2
Heading
Lubber line
Heading select bug
Selected heading box
HDG 270°
270°
CRS 270°
Course select pointer
Compass card
Course deviation scale
VOR 1
Course deviation indicator (CDI)
NAV
HDG
ALT
COM
CRS BARO
RANGE
PAN
FMS
INSET
PFD
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS
XPDR 5537 IDNT LCL10:12:34

Figure 7-14. *An HSI display as seen on the pilot's primary flight display (PFD) on an electronic flight instrument. Note that only attributes related to the HSI are labeled.*

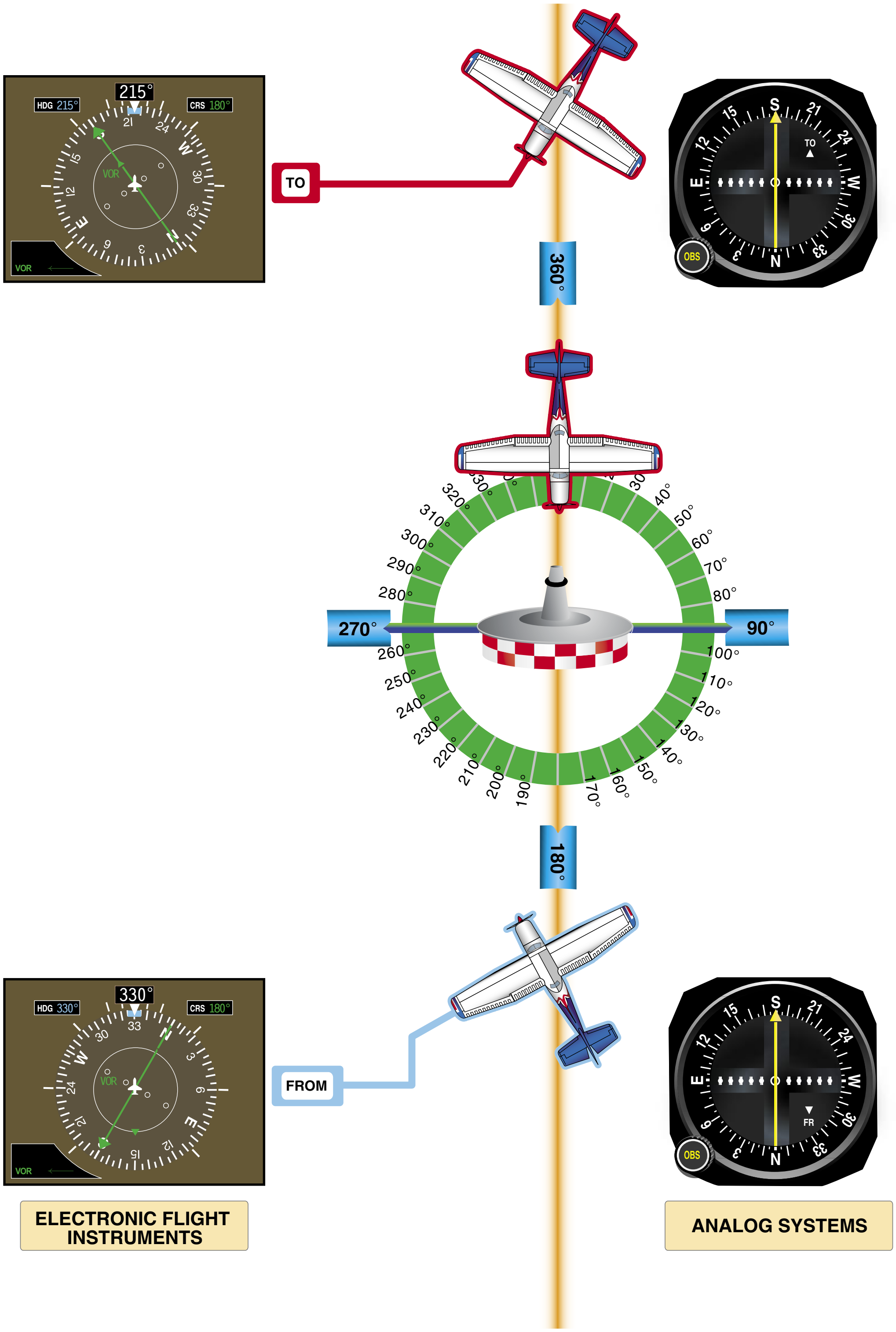
HDG 215°
215°
CRS 180°
VOR
TO
OBS
360°
270°
90°
180°
FROM
HDG 330°
330°
CRS 180°
VOR
FR
OBS
ELECTRONIC FLIGHT INSTRUMENTS
ANALOG SYSTEMS

Figure 7-15. *CDI Interpretation. The CDI as typically found on analog systems (right) and as found on electronic flight instruments (left).*

A single NAVAID will allow a pilot to determine the aircraft's position relative to a radial. Indications from a second NAVAID are needed in order to narrow the aircraft's position down to an exact location on this radial.

Tracking TO and FROM the Station

To track to the station, rotate the OBS until TO appears, then center the CDI. Fly the course indicated by the index. If the CDI moves off center to the left, follow the needle by correcting course to the left, beginning with a 20° correction.

When flying the course indicated on the index, a left deflection of the needle indicates a crosswind component from the left. If the amount of correction brings the needle back to center, decrease the left course correction by half. If the CDI moves left or right now, it should do so much more slowly, and smaller heading corrections can be made for the next iteration.

Keeping the CDI centered will take the aircraft to the station. To track to the station, the OBS value at the index is not changed. To home to the station, the CDI needle is periodically centered, and the new course under the index is used for the aircraft heading. Homing will follow a circuitous route to the station, just as with ADF homing.

To track FROM the station on a VOR radial, you should first orient the aircraft's location with respect to the station and the desired outbound track by centering the CDI needle with a FROM indication. The track is intercepted by either flying over the station or establishing an intercept heading. The magnetic course of the desired radial is entered under the index using the OBS and the intercept heading held until the CDI centers. Then the procedure for tracking to the station is used to fly outbound on the specified radial.

Course Interception

If the desired course is not the one being flown, first orient the aircraft's position with respect to the VOR station and the course to be flown, and then establish an intercept heading. The following steps may be used to intercept a predetermined course, either inbound or outbound. Steps 1–3 may be omitted when turning directly to intercept the course without initially turning to parallel the desired course.

1. Determine the difference between the radial to be intercepted and the radial on which the aircraft is located (205° – 160° = 045°).
2. Double the difference to determine the interception angle, which will not be less than 20° nor greater than 90° (45° x 2 = 090°). 205° + 090° = 295° for the intercept)
3. Rotate the OBS to the desired radial or inbound course.
4. Turn to the interception heading.
5. Hold this heading constant until the CDI center, which indicates the aircraft is on course. (With practice in judging the varying rates of closure with the course centerline, pilots learn to lead the turn to prevent overshooting the course.)
6. Turn to the MH corresponding to the selected course, and follow tracking procedures inbound or outbound.

Course interception is illustrated in *Figure 7-16*.

VOR Operational Errors

Typical pilot-induced errors include:

1. Careless tuning and identification of station.
2. Failure to check receiver for accuracy/sensitivity.
3. Turning in the wrong direction during an orientation. This error is common until visualizing position rather than heading.
4. Failure to check the ambiguity (TO/FROM) indicator, particularly during course reversals, resulting in reverse sensing and corrections in the wrong direction.
5. Failure to parallel the desired radial on a track interception problem. Without this step, orientation to the desired radial can be confusing. Since pilots think in terms of left and right of course, aligning the aircraft position to the radial/course is essential.
6. Overshooting and undershooting radials on interception problems.
7. Overcontrolling corrections during tracking, especially close to the station.
8. Misinterpretation of station passage. On VOR receivers not equipped with an ON/OFF flag, a voice transmission on the combined communication and navigation radio (NAV/COM) in use for VOR may cause the same TO/FROM fluctuations on the ambiguity meter as shown during station passage. Read the whole receiver—TO/FROM, CDI, and OBS—before you make a decision. Do not utilize a VOR reading observed while transmitting.
9. Chasing the CDI, resulting in homing instead of tracking. Careless heading control and failure to bracket wind corrections make this error common.

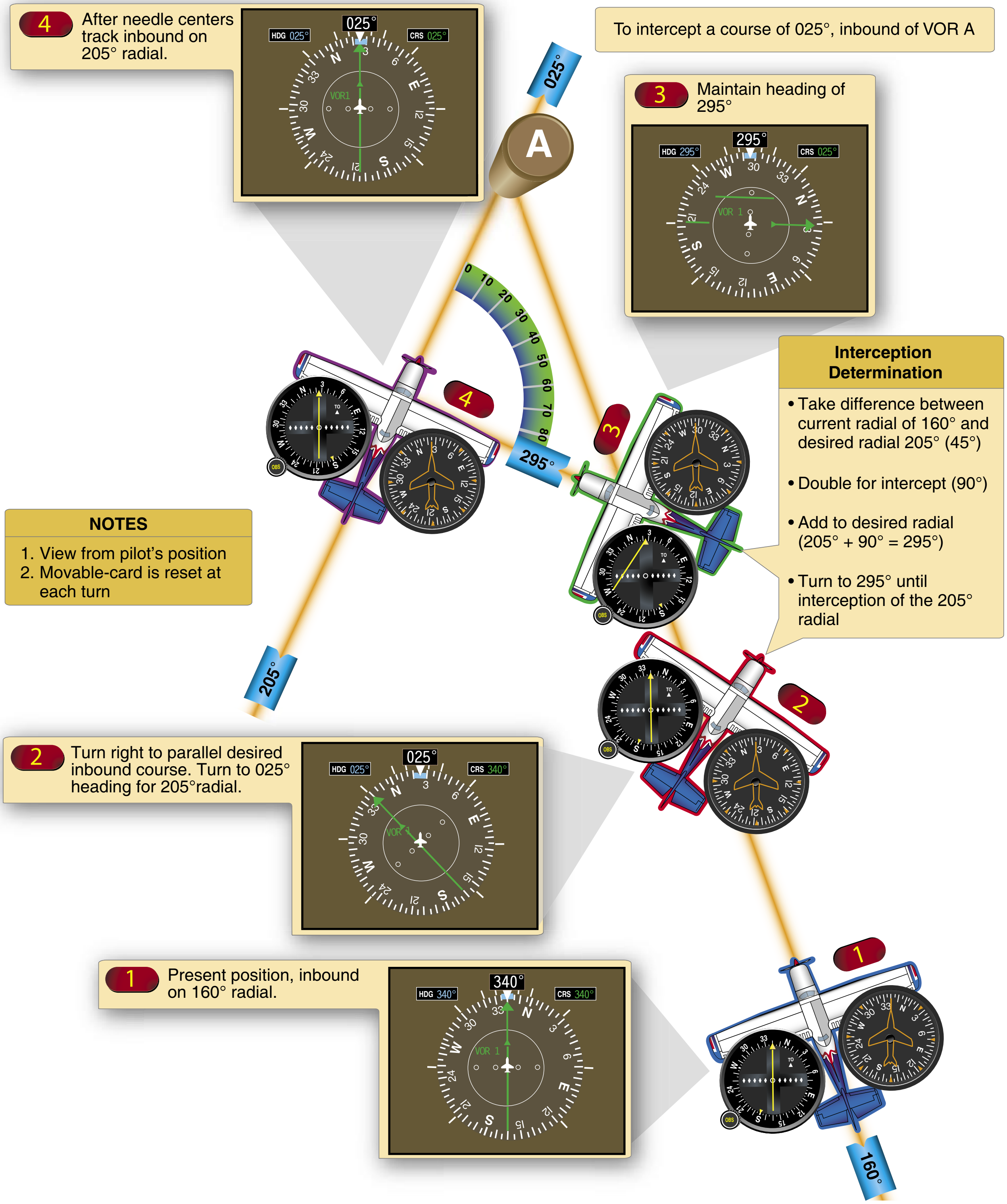

4 After needle centers track inbound on 205° radial.

To intercept a course of 025°, inbound of VOR A

3 Maintain heading of 295°

Interception Determination

- Take difference between current radial of 160° and desired radial 205° (45°)
- Double for intercept (90°)
- Add to desired radial (205° + 90° = 295°)
- Turn to 295° until interception of the 205° radial

NOTES

1. View from pilot's position
2. Movable-card is reset at each turn

2 Turn right to parallel desired inbound course. Turn to 025° heading for 205°radial.

1 Present position, inbound on 160° radial.

HDG 025°
025°
CRS 025°
VOR1
025°
A
HDG 295°
295°
CRS 025°
VOR 1
0
10
20
30
40
50
60
70
80
295°
4
3
2
1
205°
HDG 025°
025°
CRS 340°
VOR 1
HDG 340°
340°
CRS 340°
VOR 1
160°
OBS
TO

Figure 7-16. *Course Interception (VOR).*

VOR Accuracy

The effectiveness of the VOR depends upon proper use and adjustment of both ground and airborne equipment.

The accuracy of course alignment of the VOR is generally plus or minus 1°. On some VORs, minor course roughness may be observed, evidenced by course needle or brief flag alarm. At a few stations, usually in mountainous terrain, the pilot may occasionally observe a brief course needle oscillation, similar to the indication of "approaching station." Pilots flying over unfamiliar routes are cautioned to be on the alert for these vagaries, and in particular, to use the TO/FROM indicator to determine positive station passage.

Certain propeller revolutions per minute (RPM) settings or helicopter rotor speeds can cause the VOR CDI to fluctuate as much as plus or minus 6°. Slight changes to the RPM setting will normally smooth out this roughness. Pilots are urged to check for this modulation phenomenon prior to reporting a VOR station or aircraft equipment for unsatisfactory operation.

VOR Receiver Accuracy Check

VOR system course sensitivity may be checked by noting the number of degrees of change as the OBS is rotated to move the CDI from center to the last dot on either side. The course selected should not exceed 10° or 12° either side. In addition, Title 14 of the Code of Federal Regulations (14 CFR) part 91 provides for certain VOR equipment accuracy checks, and an appropriate endorsement, within 30 days prior to flight under IFR. To comply with this requirement and to ensure satisfactory operation of the airborne system, use the following means for checking VOR receiver accuracy:

1. VOR test facility (VOT) or a radiated test signal from an appropriately rated radio repair station.
2. Certified checkpoints on the airport surface.
3. Certified airborne checkpoints.

VOR Test Facility (VOT)

The Federal Aviation Administration (FAA) VOT transmits a test signal which provides users a convenient means to determine the operational status and accuracy of a VOR receiver while on the ground where a VOT is located. Locations of VOTs are published in the A/FD. Two means of identification are used. One is a series of dots and the other is a continuous tone. Information concerning an individual test signal can be obtained from the local flight service station (FSS.) The airborne use of VOT is permitted; however, its use is strictly limited to those areas/altitudes specifically authorized in the A/FD or appropriate supplement.

To use the VOT service, tune in the VOT frequency 108.0 MHz on the VOR receiver. With the CDI centered, the OBS should read 0° with the TO/FROM indication showing FROM or the OBS should read 180° with the TO/FROM indication showing TO. Should the VOR receiver operate an RMI, it would indicate 180° on any OBS setting.

A radiated VOT from an appropriately rated radio repair station serves the same purpose as an FAA VOT signal, and the check is made in much the same manner as a VOT with some differences.

The frequency normally approved by the Federal Communications Commission (FCC) is 108.0 MHz; however, repair stations are not permitted to radiate the VOR test signal continuously. The owner or operator of the aircraft must make arrangements with the repair station to have the test signal transmitted. A representative of the repair station must make an entry into the aircraft logbook or other permanent record certifying to the radial accuracy and the date of transmission.

Certified Checkpoints

Airborne and ground checkpoints consist of certified radials that should be received at specific points on the airport surface or over specific landmarks while airborne in the immediate vicinity of the airport. Locations of these checkpoints are published in the A/FD.

Should an error in excess of ±4° be indicated through use of a ground check, or ±6° using the airborne check, IFR flight shall not be attempted without first correcting the source of the error. No correction other than the correction card figures supplied by the manufacturer should be applied in making these VOR receiver checks.

If a dual system VOR (units independent of each other except for the antenna) is installed in the aircraft, one system may be checked against the other. Turn both systems to the same VOR ground facility and note the indicated bearing to that station. The maximum permissible variation between the two indicated bearings is 4°.

Distance Measuring Equipment (DME)

When used in conjunction with the VOR system, DME makes it possible for pilots to determine an accurate geographic position of the aircraft, including the bearing and distance TO or FROM the station. The aircraft DME transmits interrogating radio frequency (RF) pulses, which are received by the DME antenna at the ground facility. The signal triggers ground receiver equipment to respond to the interrogating aircraft. The airborne DME equipment measures the elapsed time between the interrogation signal sent by the aircraft and reception of the reply pulses from the ground station. This time measurement is converted into distance in nautical miles (NM) from the station.

Some DME receivers provide a groundspeed in knots by monitoring the rate of change of the aircraft's position relative to the ground station. Groundspeed values are accurate only when tracking directly to or from the station.

DME Components

VOR/DME, VORTAC, ILS/DME, and LOC/DME navigation facilities established by the FAA provide course and distance information from collocated components under a frequency pairing plan. DME operates on frequencies in the UHF spectrum between 962 MHz and 1213 MHz. Aircraft receiving equipment which provides for automatic DME selection assures reception of azimuth and distance information from a common source when designated VOR/DME, VORTAC, ILS/DME, and LOC/DME are selected. Some aircraft have separate VOR and DME receivers, each of which must be tuned to the appropriate navigation facility. The airborne equipment includes an antenna and a receiver.

The pilot-controllable features of the DME receiver include:

Channel (Frequency) Selector
Many DMEs are channeled by an associated VHF radio, or there may be a selector switch so a pilot can select which VHF radio is channeling the DME. For a DME with its own frequency selector, use the frequency of the associated VOR/DME or VORTAC station.

On/Off/Volume Switch
The DME identifier will be heard as a Morse code identifier with a tone somewhat higher than that of the associated VOR or LOC. It will be heard once for every three or four times the VOR or LOC identifier is heard. If only one identifier is heard about every 30 seconds, the DME is functional, but the associated VOR or LOC is not.

Mode Switch
The mode switch selects between distance (DIST) or distance in NMs, groundspeed, and time to station. There may also be one or more HOLD functions which permit the DME to stay channeled to the station that was selected before the switch was placed in the hold position. This is useful when you make an ILS approach at a facility that has no collocated DME, but there is a VOR/DME nearby.

Altitude
Some DMEs correct for slant-range error.

Function of DME

A DME is used for determining the distance from a ground DME transmitter. Compared to other VHF/UHF NAVAIDs, a DME is very accurate. The distance information can be used to determine the aircraft position or flying a track that is a constant distance from the station. This is referred to as a DME arc.

DME Arc

There are many instrument approach procedures (IAPs) that incorporate DME arcs. The procedures and techniques given here for intercepting and maintaining such arcs are applicable to any facility that provides DME information. Such a facility may or may not be collocated with the facility that provides final approach guidance.

As an example of flying a DME arc, refer to *Figure 7-17* and follow these steps:

1. Track inbound on the OKT 325° radial, frequently checking the DME mileage readout.
2. A 0.5 NM lead is satisfactory for groundspeeds of 150 knots or less; start the turn to the arc at 10.5 miles. At higher groundspeeds, use a proportionately greater lead.

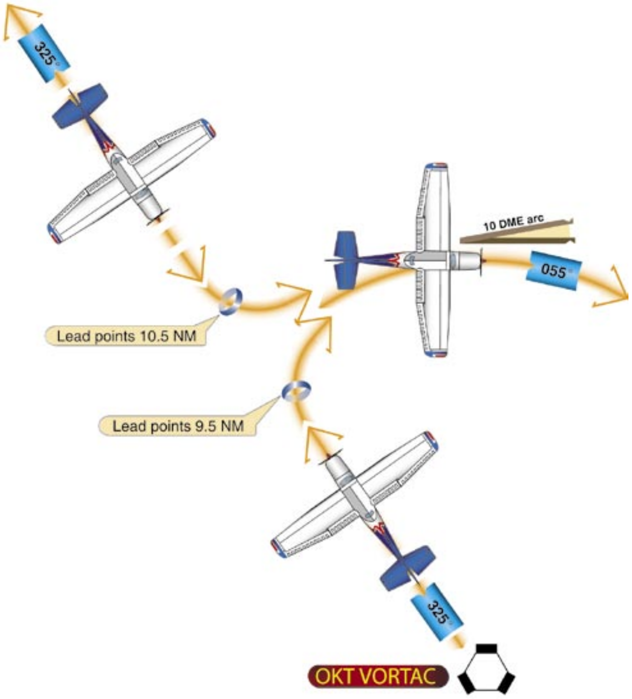

Figure 7-17. *DME Arc Interception.*

3. Continue the turn for approximately 90°. The roll-out heading will be 055° in a no wind condition.
4. During the last part of the intercepting turn, monitor the DME closely. If the arc is being overshot (more than 1.0 NM), continue through the originally planned roll-out heading. If the arc is being undershot, roll-out of the turn early.

The procedure for intercepting the 10 DME when outbound is basically the same, the lead point being 10 NM minus 0.5 NM, or 9.5 NM.

When flying a DME arc with wind, it is important to keep a continuous mental picture of the aircraft's position relative to the facility. Since the wind-drift correction angle is constantly changing throughout the arc, wind orientation is important. In some cases, wind can be used in returning to the desired track. High airspeeds require more pilot attention because of the higher rate of deviation and correction.

Maintaining the arc is simplified by keeping slightly inside the curve; thus, the arc is turning toward the aircraft and interception may be accomplished by holding a straight course. When outside the curve, the arc is "turning away" and a greater correction is required.

To fly the arc using the VOR CDI, center the CDI needle upon completion of the 90° turn to intercept the arc. The aircraft's heading will be found very near the left or right side (270° or 90° reference points) of the instrument. The readings at that side location on the instrument will give primary heading information while on the arc. Adjust the aircraft heading to compensate for wind and to correct for

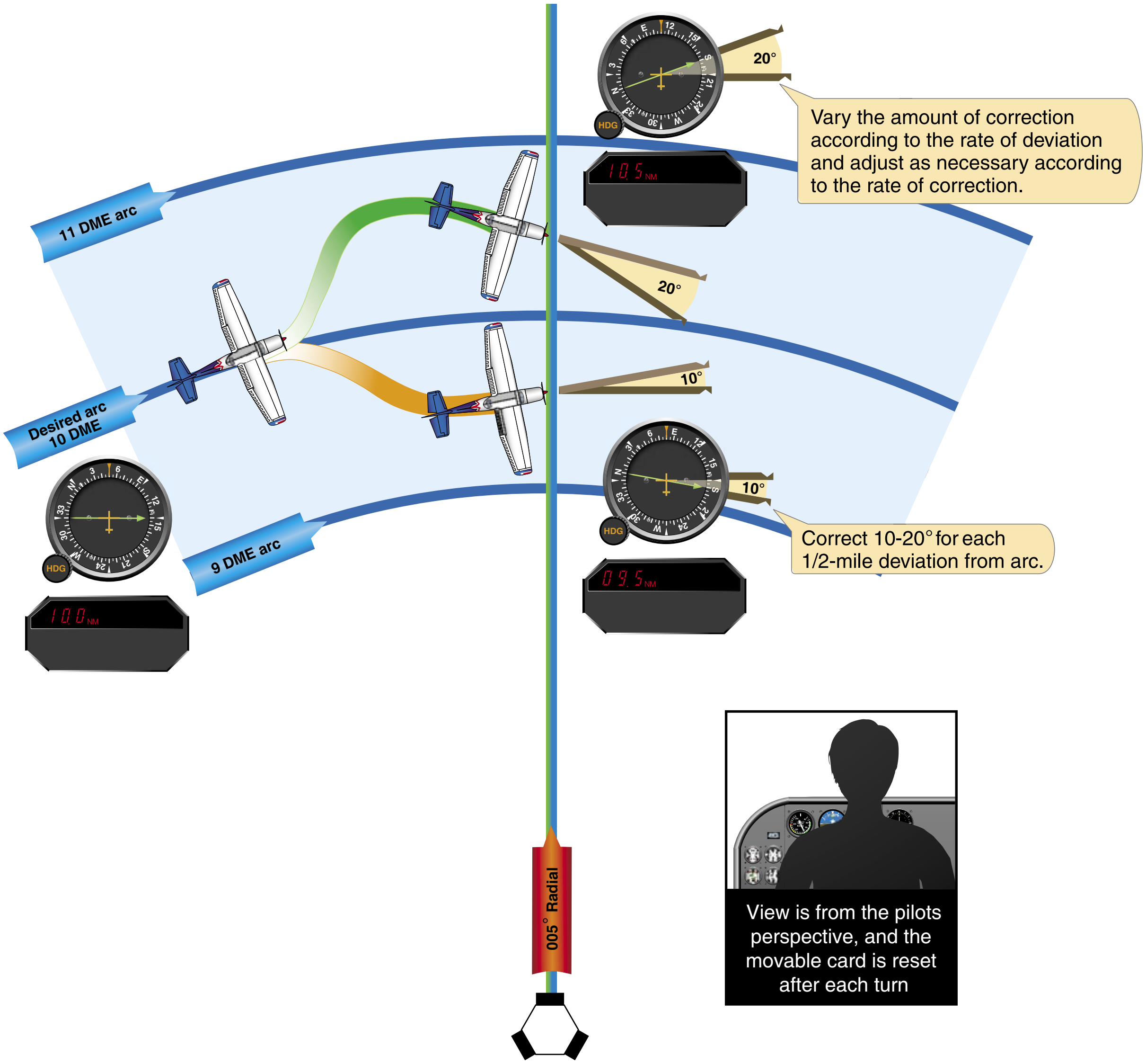

Vary the amount of correction according to the rate of deviation and adjust as necessary according to the rate of correction.

Correct 10-20° for each 1/2-mile deviation from arc.

View is from the pilots perspective, and the movable card is reset after each turn

Figure 7-18. *Using DME and RMI To Maintain an Arc.*

distance to maintain the correct arc distance. Recenter the CDI and note the new primary heading indicated whenever the CDI gets 2°–4° from center.

With an RMI, in a no wind condition, pilots should theoretically be able to fly an exact circle around the facility by maintaining an RB of 90° or 270°. In actual practice, a series of short legs are flown. To maintain the arc in *Figure 7-18*, proceed as follows:

1. With the RMI bearing pointer on the wingtip reference (90° or 270° position) and the aircraft at the desired DME range, maintain a constant heading and allow the bearing pointer to move 5°–10° behind the wingtip. This will cause the range to increase slightly.
2. Turn toward the facility to place the bearing pointer 5–10° ahead of the wingtip reference, and then maintain heading until the bearing pointer is again behind the wingtip. Continue this procedure to maintain the approximate arc.
3. If a crosswind causes the aircraft to drift away from the facility, turn the aircraft until the bearing pointer is ahead of the wingtip reference. If a crosswind causes the aircraft to drift toward the facility, turn until the bearing is behind the wingtip.
4. As a guide in making range corrections, change the RB 10°–20° for each half-mile deviation from the desired arc. For example, in no-wind conditions, if the aircraft is 1/2 to 1 mile outside the arc and the bearing pointer is on the wingtip reference, turn the aircraft 20° toward the facility to return to the arc.

Without an RMI, orientation is more difficult since there is no direct azimuth reference. However, the procedure can be flown using the OBS and CDI for azimuth information and the DME for arc distance.

Intercepting Lead Radials

A lead radial is the radial at which the turn from the arc to the inbound course is started. When intercepting a radial from a DME arc, the lead will vary with arc radius and ground speed. For the average general aviation aircraft, flying arcs such as those depicted on most approach charts at speeds of 150 knots or less, the lead will be under 5°. There is no difference between intercepting a radial from an arc and intercepting it from a straight course.

With an RMI, the rate of bearing movement should be monitored closely while flying the arc. Set the course of the radial to be intercepted as soon as possible and determine the approximate lead. Upon reaching this point, start the intercepting turn. Without an RMI, the technique for radial interception is the same except for azimuth information, which is available only from the OBS and CDI.

The technique for intercepting a localizer from a DME arc is similar to intercepting a radial. At the depicted lead radial (LR 223 or LR 212 in *Figures 7-19, 7-20,* and *7-21*), a pilot having a single VOR/LOC receiver should set it to the localizer frequency. If the pilot has dual VOR/LOC receivers, one unit may be used to provide azimuth information and the other set to the localizer frequency. Since these lead radials provide 7° of lead, a half-standard rate turn should be used until the LOC needle starts to move toward center.

DME Errors

A DME/DME fix (a location based on two DME lines of position from two DME stations) provides a more accurate aircraft location than using a VOR and a DME fix.

DME signals are line-of-sight; the mileage readout is the straight line distance from the aircraft to the DME ground facility and is commonly referred to as slant range distance. Slant range refers to the distance from the aircraft's antenna to the ground station (A line at an angle to the ground transmitter. GPS systems provide distance as the horizontal measurement from the WP to the aircraft. Therefore, at 3,000 feet and 0.5 miles the DME (slant range) would read 0.6 NM while the GPS distance would show the actual horizontal distance of .5 DME. This error is smallest at low altitudes and/or at long ranges. It is greatest when the aircraft is closer to the facility, at which time the DME receiver will display altitude (in NM) above the facility. Slant range error is negligible if the aircraft is one mile or more from the ground facility for each 1,000 feet of altitude above the elevation of the facility.

Area Navigation (RNAV)

Area navigation (RNAV) equipment includes VOR/DME, LORAN, GPS, and inertial navigation systems (INS). RNAV equipment is capable of computing the aircraft position, actual track, groundspeed, and then presenting meaningful information to the pilot. This information may be in the form of distance, cross-track error, and time estimates relative to the selected track or WP. In addition, the RNAV equipment installations must be approved for use under IFR. The Pilot's Operating Handbook/Airplane Flight Manual (POH/AFM) should always be consulted to determine what equipment is installed, the operations that are approved, and the details of equipment use. Some aircraft may have equipment that allows input from more than one RNAV source, thereby providing a very accurate and reliable navigation source.

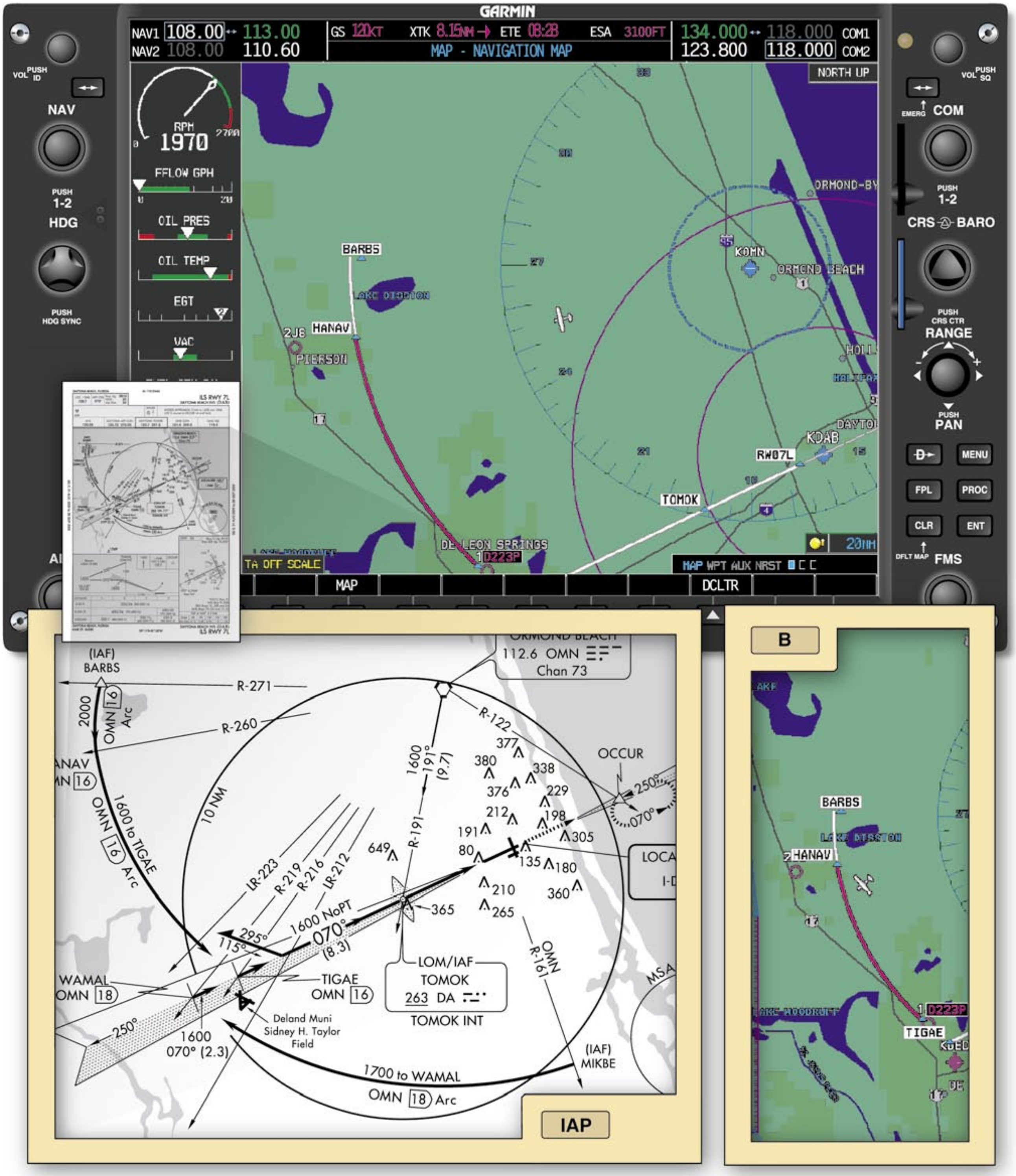
GARMIN
NAV1 108.00 113.00
NAV2 108.00 110.60
GS 120KT
XTK 8.15NM
ETE 08:28
ESA 3100FT
134.000 118.000 COM1
123.800 118.000 COM2
MAP - NAVIGATION MAP
NORTH UP
RPM
1970
FFLOW GPH
OIL PRES
OIL TEMP
EGT
VAC
BARBS
HANAV
2J6
PIERSON
LAKE DISSTON
KOMN
ORMOND BEACH
ORMOND-BY
HOLLY
HALIFAX
KDAB
DAYTONA
RW07L
TOMOK
DE LEON SPRINGS
1 D223P
TA OFF SCALE
20NM
MAP
DCLTR
MAP WPT AUX NRST
NAV
PUSH 1-2
HDG
PUSH HDG SYNC
COM
EMERG
CRS
BARO
PUSH CRS CTR
RANGE
PUSH PAN
MENU
FPL
PROC
CLR
ENT
DFLT MAP
FMS
VOL PUSH ID
VOL PUSH SQ
ILS RWY 7L
ORMOND BEACH
112.6 OMN
Chan 73
(IAF)
BARBS
R-271
R-260
2000
OMN 16 Arc
HANAV
OMN 16
1600 to TIGAE
OMN 16 Arc
10 NM
LR-223
R-219
R-216
LR-212
1600
191°
(9.7)
R-191
R-122
377
380
338
376
229
212
198
191
305
80
135
180
649
210
360
265
365
OCCUR
250°
070°
LOCA
I-D
1600 NoPT
070°
(8.3)
295°
115°
WAMAL
OMN 18
TIGAE
OMN 16
LOM/IAF
TOMOK
263 DA
TOMOK INT
OMN R-161
MSA
250°
1600
070° (2.3)
Deland Muni
Sidney H. Taylor
Field
1700 to WAMAL
OMN 18 Arc
(IAF)
MIKBE
IAP
B
BARBS
HANAV
LAKE DISSTON
LAKE WOODRUFF
1 D223P
TIGAE
KDED

Figure 7-19. *An aircraft is displayed heading southwest to intercept the localizer approach, using the 16 NM DME Arc off of ORM.*

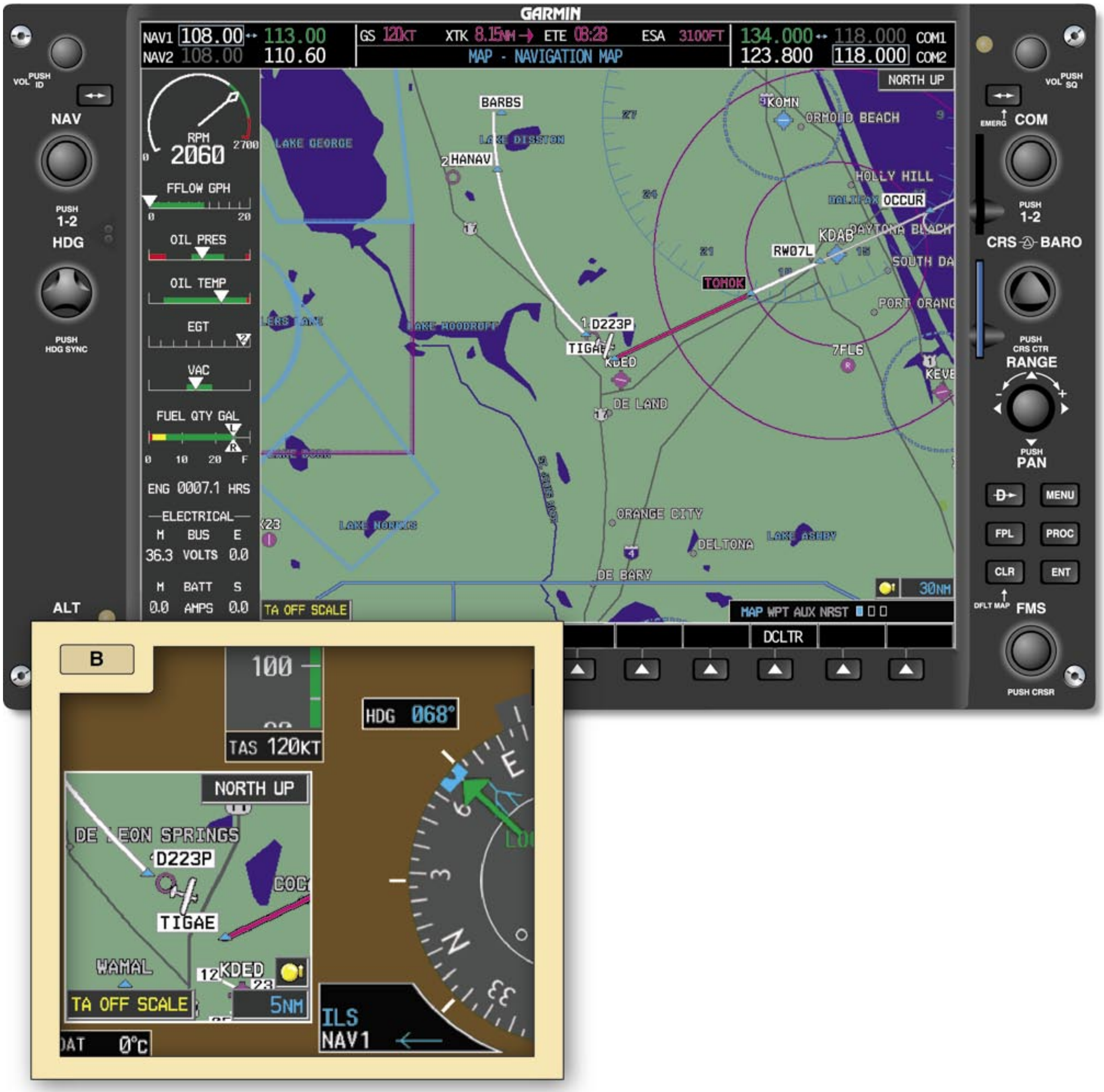
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
GS 120KT
XTK 8.15NM
ETE 08:28
ESA 3100FT
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
MAP - NAVIGATION MAP
NORTH UP
RPM 2060
FFLOW GPH
OIL PRES
OIL TEMP
EGT
VAC
FUEL QTY GAL
ENG 0007.1 HRS
ELECTRICAL
M BUS E
36.3 VOLTS 0.0
M BATT S
0.0 AMPS 0.0
BARBS
HANAV
LAKE GEORGE
LAKE DISSTON
KOMN
ORMOND BEACH
HOLLY HILL
OCCUR
KDAB
DAYTONA BEACH
RW07L
TOMOK
SOUTH DA
PORT ORANG
D223P
TIGAE
KDED
DE LAND
7FL6
ORANGE CITY
DELTONA
LAKE ASHBY
DE BARY
LAKE WOODRUFF
LAKE NORRIS
TA OFF SCALE
30NM
MAP WPT AUX NRST
DCLTR
NAV
HDG
ALT
COM
CRS BARO
RANGE
PAN
MENU
FPL
PROC
CLR
ENT
FMS
B
100
TAS 120KT
HDG 068°
NORTH UP
DE LEON SPRINGS
D223P
TIGAE
WAMAL
KDED
TA OFF SCALE
5NM
OAT 0°C
ILS
NAV1

Figure 7-20. *The same aircraft illustrated in Figure 7-19 shown on the ORM radial near TIGAE intersection turning inbound for the localizer.*

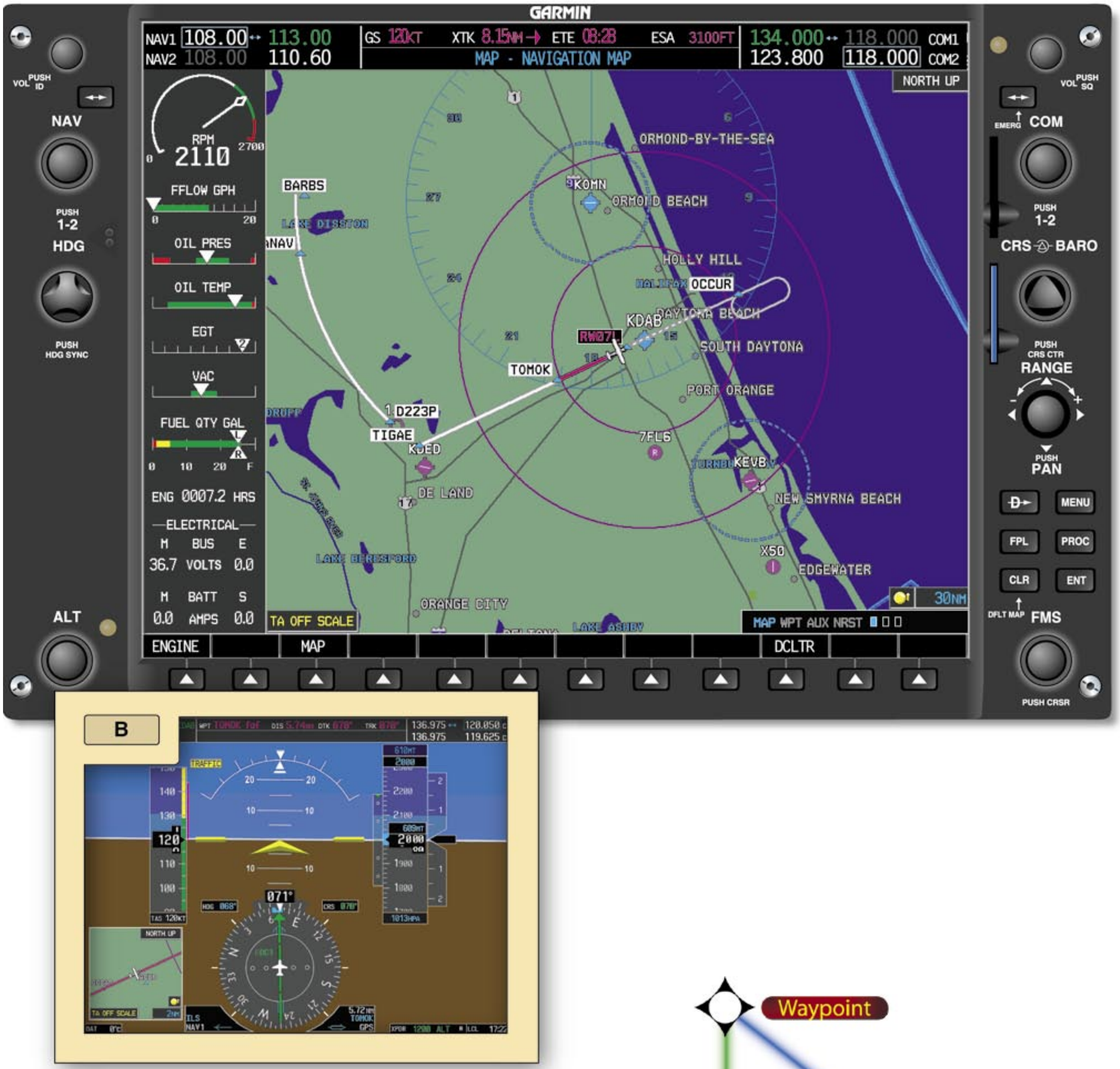
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
GS 120KT XTK 8.15NM → ETE 08:28 ESA 3100FT
MAP - NAVIGATION MAP
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
NORTH UP
RPM 2110
FFLOW GPH
OIL PRES
OIL TEMP
EGT
VAC
FUEL QTY GAL
ENG 0007.2 HRS
ELECTRICAL
M BUS E
36.7 VOLTS 0.0
M BATT S
0.0 AMPS 0.0
ORMOND-BY-THE-SEA
KOMN
ORMOND BEACH
BARBS
LAKE DISSTON
HOLLY HILL
OCCUR
KDAB
DAYTONA BEACH
RW07L
SOUTH DAYTONA
TOMOK
PORT ORANGE
D223P
TIGAE
KDED
DE LAND
7FL6
KEVB
NEW SMYRNA BEACH
X50
EDGEWATER
ORANGE CITY
TA OFF SCALE
30NM
MAP WPT AUX NRST
ENGINE
MAP
DCLTR
NAV
PUSH 1-2
HDG
PUSH HDG SYNC
ALT
COM
PUSH 1-2
CRS BARO
PUSH CRS CTR
RANGE
PUSH PAN
MENU
FPL
PROC
CLR
ENT
DFLT MAP
FMS
PUSH CRSR
B
TRAFFIC
120
2000
071°
HDG 068°
CRS 070°
TAS 120KT
NORTH UP
TA OFF SCALE
ILS
NAV1
5.72NM
TOMOK
GPS
XPDR 1200 ALT

Figure 7-21. *Aircraft is illustrated inbound on the localizer course.*

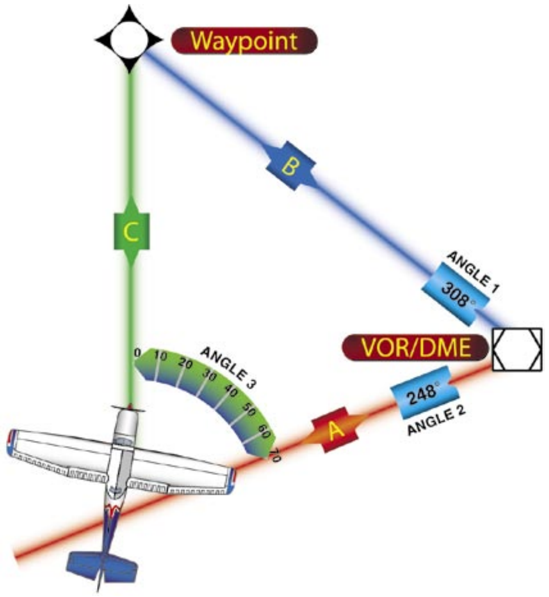
Waypoint
B
C
ANGLE 1
308°
VOR/DME
248°
ANGLE 2
A
ANGLE 3
0 10 20 30 40 50 60 70

Figure 7-22. *RNAV Computation.*

VOR/DME RNAV

VOR RNAV is based on information generated by the present VORTAC or VOR/DME system to create a WP using an airborne computer. As shown in *Figure 7-22*, the value of side A is the measured DME distance to the VOR/DME. Side B, the distance from the VOR/DME to the WP, and angle 1 (VOR radial or the bearing from the VORTAC to the WP) are values set in the flight deck control. The bearing from the VOR/DME to the aircraft, angle 2, is measured by the VOR receiver. The airborne computer continuously compares angles 1 and 2 and determines angle 3 and side C, which is the distance in NMs and magnetic course from the aircraft to the WP. This is presented as guidance information on the flight deck display.

VOR/DME RNAV Components

Although RNAV flight deck instrument displays vary among manufacturers, most are connected to the aircraft CDI with a switch or knob to select VOR or RNAV guidance. There is usually a light or indicator to inform the pilot whether VOR or RNAV is selected. *[Figure 7-23]* The display includes the WP, frequency, mode in use, WP radial and distance, DME distance, groundspeed, and time to station.

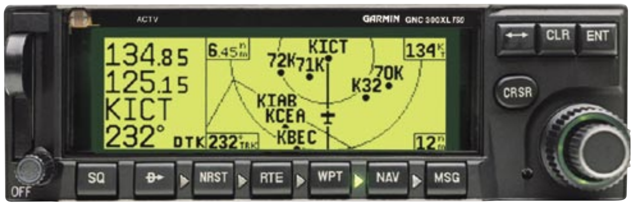

Figure 7-23. *Onboard RNAV receivers have changed significantly. Originally, RNAV receivers typically computed combined data from VOR, VORTAC, and/or DME. That is generally not the case now. Today, GPS such as the GNC 300 and the Bendix King KLS 88 LORAN receivers compute waypoints based upon embedded databases and aircraft positional information.*

Most VOR/DME RNAV systems have the following airborne controls:

1. Off/On/Volume control to select the frequency of the VOR/DME station to be used.
2. MODE select switch used to select VOR/DME mode, with:
    a. Angular course width deviation (standard VOR operation); or
    b. Linear cross-track deviation as standard (±5 NM full scale CDI).
3. RNAV mode, with direct to WP with linear cross-track deviation of ±5 NM.
4. RNAV/APPR (approach mode) with linear deviation of ±1.25 NM as full scale CDI deflection.
5. WP select control. Some units allow the storage of more than one WP; this control allows selection of any WP in storage.
6. Data input controls. These controls allow user input of WP number or ident, VOR or LOC frequency, WP radial and distance.

While DME groundspeed readout is accurate only when tracking directly to or from the station in VOR/DME mode, in RNAV mode the DME groundspeed readout is accurate on any track.

Function of VOR/DME RNAV

The advantages of the VOR/DME RNAV system stem from the ability of the airborne computer to locate a WP wherever it is convenient, as long as the aircraft is within reception range of both nearby VOR and DME facilities. A series of these WPs make up an RNAV route. In addition to the published routes, a random RNAV route may be flown under IFR if it is approved by air traffic control (ATC). RNAV DPs and standard terminal arrival routes (STARs) are contained in the DP and STAR booklets.

VOR/DME RNAV approach procedure charts are also available. Note in the VOR/DME RNAV chart excerpt shown in *Figure 7-24* that the WP identification boxes contain the following information: WP name, coordinates, frequency, identifier, radial distance (facility to WP), and reference facility elevation. The initial approach fix (IAF), final approach fix (FAF), and missed approach point (MAP) are labeled.

To fly a route or to execute an approach under IFR, the RNAV equipment installed in the aircraft must be approved for the appropriate IFR operations.

In vertical navigation (VNAV) mode, vertical guidance is provided, as well as horizontal guidance in some installations. A WP is selected at a point where the descent begins, and another WP is selected where the descent ends. The RNAV equipment computes the rate of descent relative to the groundspeed; on some installations, it displays vertical guidance information on the GS indicator. When using this type of equipment during an instrument approach, the pilot must keep in mind that the vertical guidance information provided is not part of the nonprecision approach. Published nonprecision approach altitudes must be observed and complied with, unless otherwise directed by ATC.

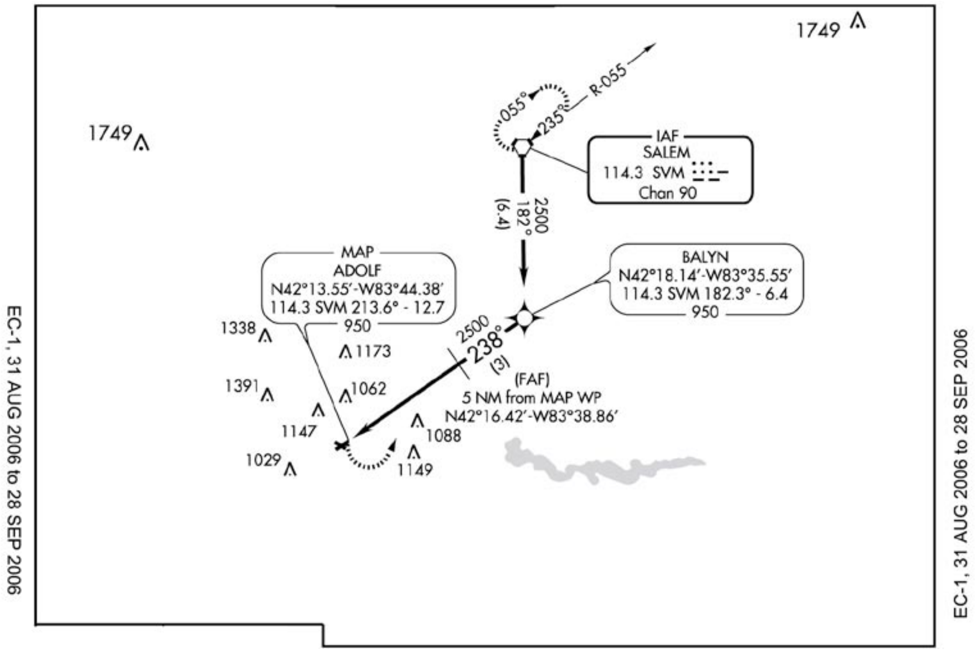
1749
1749
R-055
055°
235°
IAF
SALEM
114.3 SVM
Chan 90
2500
182°
(6.4)
BALYN
N42°18.14'-W83°35.55'
114.3 SVM 182.3° - 6.4
950
MAP
ADOLF
N42°13.55'-W83°44.38'
114.3 SVM 213.6° - 12.7
950
1338
1173
1391
1062
1147
1029
1149
1088
2500
238°
(3)
(FAF)
5 NM from MAP WP
N42°16.42'-W83°38.86'
EC-1, 31 AUG 2006 to 28 SEP 2006
EC-1, 31 AUG 2006 to 28 SEP 2006

Figure 7-24. *VOR/DME RNAV Rwy 25 Approach (Excerpt).*

To fly to a WP using RNAV, observe the following procedure *[Figure 7-25]*:

1. Select the VOR/DME frequency.
2. Select the RNAV mode.
3. Select the radial of the VOR that passes through the WP (225°).
4. Select the distance from the DME to the WP (12 NM).
5. Check and confirm all inputs, and center the CDI needle with the TO indicator showing.
6. Maneuver the aircraft to fly the indicated heading plus or minus wind correction to keep the CDI needle centered.
7. The CDI needle will indicate distance off course of 1 NM per dot; the DME readout will indicate distance in NM from the WP; the groundspeed will read closing speed (knots) to the WP; and the time to station (TTS) will read time to the WP.

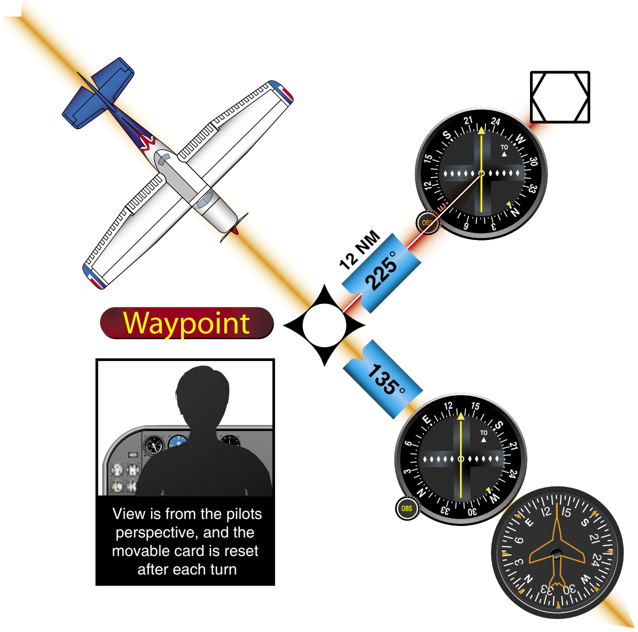
12 NM
225°
135°
Waypoint

View is from the pilots perspective, and the movable card is reset after each turn

Figure 7-25. *Aircraft/DME/Waypoint Relationship.*

VOR/DME RNAV Errors

The limitation of this system is the reception volume. Published approaches have been tested to ensure this is not a problem. Descents/approaches to airports distant from the VOR/DME facility may not be possible because, during the approach, the aircraft may descend below the reception altitude of the facility at that distance.

Long Range Navigation (LORAN)

LORAN uses a network of land-based transmitters to provide an accurate long-range navigation system. The FAA and the United States Coast Guard (USCG) arranged the stations into chains. The signal from station is a carefully structured sequence of brief RF pulses centered at 100 kHz. At that frequency, signals travel considerable distances as ground waves, from which accurate navigation information is available. The airborne receiver monitors all of the stations within the selected chain, then measures the arrival time difference (TD) between the signals. All of the points having the same TD from a station pair create a line of position

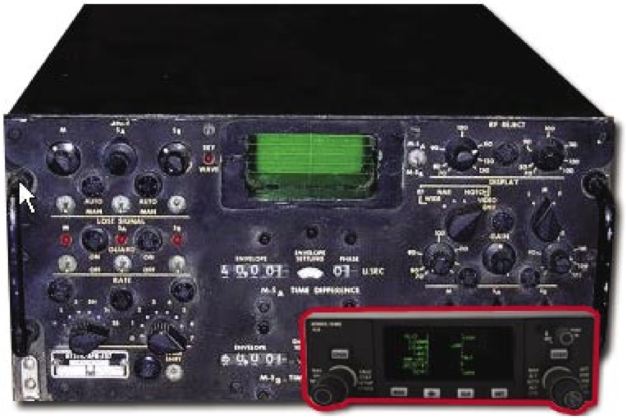

Figure 7-26. *A control panel from a military aircraft after LORAN was first put into use. The receiver is remotely mounted and weighs over 25 pounds. Its size is about six times that of the LORAN fully integrated receiver.*

(LOP). The aircraft position is determined at the intersection of two or more LOPs. Then the computer converts the known location to latitude and longitude coordinates. *[Figure 7-26]*

While continually computing latitude/longitude fixes, the computer is able to determine and display:

1. Track over the ground since last computation;
2. Groundspeed by dividing distance covered since last computation by the time since last computation (and averaging several of these);
3. Distance to destination;
4. Destination time of arrival; and
5. Cross-track error.

The Aeronautical Information Manual (AIM) provides a detailed explanation of how LORAN works. LORAN is a very accurate navigation system if adequate signals are received. There are two types of accuracy that must be addressed in any discussion of LORAN accuracy.

Repeatable accuracy is the accuracy measured when a user notes the LORAN position, moves away from that location, then uses the LORAN to return to that initial LORAN position. Distance from that initial position is the error. Propagation and terrain errors will be essentially the same as when the first position was taken, so those errors are factored out by using the initial position. Typical repeatable accuracy for LORAN can be as good as 0.01 NM, or 60 feet, if the second position is determined during the day and within a short period of time (a few days).

Absolute accuracy refers to the ability to determine present position in space independently, and is most often used by pilots. When the LORAN receiver is turned on and position is determined, absolute accuracy applies. Typical LORAN absolute accuracy will vary from about 0.1 NM to as much as 2.5 NM depending on distance from the station, geometry of the TD LOP crossing angles, terrain and environmental conditions, signal-to-noise ratio (signal strength), and some design choices made by the receiver manufacturer.

Although LORAN use diminished with the introduction of Global Navigation Satellite Systems such as the United States' GPS, its use has since increased. Three items aided in this resurgence:

- In 1996, a commission called the Gore Commission evaluated GPS' long-term use as a sole navigation aid. Although GPS was hailed originally as the eventual sole NAVAID, which would replace the need for most currently existing NAVAIDs by the year 2020, the Commission questioned single-link failure potential and its effect on the NAS. For this reason, the forecasted decommissioning of the VOR has been amended and their expectant lifecycle extended into the future. Additionally, the use of LORAN continues to be evaluated for facilitating carrying GPS corrective timing signals.
- The GPS is controlled by the DOD presenting certain unforecasted uncertainties for commercial use on an uninterrupted basis.

As a result of these and other key factors, it was determined that LORAN would remain. In recognition of GPS vulnerabilities as a GNSS, there are plans to maintain other systems that could provide en route and terminal accuracy such as LORAN. Therefore as LORAN is further modernized it's a possibility that it may be used to augment GPS and provide backup to GPS during unlikely but potential outages. Or if combined with GPS and other systems such as newer miniaturized low-cost inertial navigation systems (INS), superior accuracy and seamless backup will always be available.

LORAN Components

The LORAN receiver incorporates a radio receiver, signal processor, navigation computer, control/display, and antenna. When turned on, the receivers go through an initialization or warm-up period, then inform the user they are ready to be programmed. LORAN receivers vary widely in their appearance, method of user programming, and navigation information display. Therefore, it is necessary to become familiar with the unit, including programming and output interpretation. The LORAN operating manual should be in the aircraft at all times and available to the pilot. IFR-approved LORAN units require that the manual be aboard and that the pilot be familiar with the unit's functions, before flight.

Function of LORAN

After initialization, select for the present location WP (the airport), and select GO TO in order to determine if the LORAN is functioning properly. Proper operation is indicated by a low distance reading (0 to 0.5 NM). The simplest mode of navigation is referred to as GO TO: you select a WP from one of the databases and choose the GO TO mode. Before use in flight, verify that the latitude and longitude of the chosen WP is correct by reference to another approved information source. An updatable LORAN database that supports the appropriate operations (e.g., en route, terminal, and instrument approaches) is required when operating under IFR.

In addition to displaying bearing, distance, time to the WP, and track and speed over the ground, the LORAN receiver may have other features such as flight planning (WP sequential storage), emergency location of several nearest airports, vertical navigation capabilities, and more.

LORAN Errors

System Errors

LORAN is subject to interference from many external sources, which can cause distortion of or interference with LORAN signals. LORAN receiver manufacturers install "notch filters" to reduce or eliminate interference. Proximity to 60 Hz alternating current power lines, static discharge, P-static, electrical noise from generators, alternators, strobes, and other onboard electronics may decrease the signal-to-noise ratio to the point where the LORAN receiver's performance is degraded.

Proper installation of the antenna, good electrical bonding, and an effective static discharge system are the minimum requirements for LORAN receiver operation. Most receivers have internal tests that verify the timing alignment of the receiver clock with the LORAN pulse, and measure and display signal-to-noise ratio. A signal will be activated to alert the pilot if any of the parameters for reliable navigation are exceeded on LORAN sets certified for IFR operations.

LORAN is most accurate when the signal travels over sea water during the day and least accurate when the signal comes over land and large bodies of fresh water or ice at night; furthermore, the accuracy degrades as distance from the station increases. However, LORAN accuracy is generally better than VOR accuracy.

Operational Errors

Some of the typical pilot-induced errors of LORAN operation are:

1. Use of a nonapproved LORAN receiver for IFR operations. The pilot should check the aircraft's POH/AFM LORAN supplement to be certain the unit's functions are well understood (this supplement must be present in the aircraft for approved IFR operations). There should be a copy of FAA Form 337, Major Repair and Alteration, present in the aircraft's records, showing approval of use of this model LORAN for IFR operations in this aircraft.
2. Failure to double-check the latitude/longitude values for a WP to be used. Whether the WP was accessed from the airport, NDB, VOR, or intersection database, the values of latitude and longitude should still be checked against the values in the A/FD or other approved source. If the WP data is entered in the user database, its accuracy must be checked before use.
3. Attempting to use LORAN information with degraded signals.

Advanced Technologies

Global Navigation Satellite System (GNSS)

The Global Navigation Satellite System (GNSS) is a constellation of satellites providing a high-frequency signal which contains time and distance that is picked up by a receiver thereby. *[Figure 7-27]* The receiver which picks up multiple signals from different satellites is able to triangulate its position from these satellites.

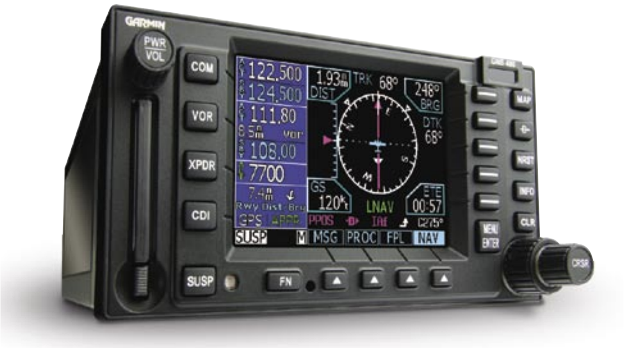

Figure 7-27. *A typical example (GNS 480) of a stand-alone GPS receiver and display.*

Three GNSSs exist today: the GPS, a United States system; the Russian GNSS (GLONASS); and Galileo, a European system.

1. GLONASS is a network of 24 satellites, which can be picked up by any GLONASS receiver, allowing the user to pinpoint their position.
2. Galileo planned to be a network of 30 satellites that continuously transmit high-frequency radio signals containing time and distance data that can be picked up by a Galileo receiver with operational expectancy by 2013.
3. The GPS came on line in 1992 with 24 satellites, and today utilizes 30 satellites.

Global Positioning System (GPS)

The GPS is a satellite-based radio navigation system, which broadcasts a signal that is used by receivers to determine precise position anywhere in the world. The receiver tracks multiple satellites and determines a measurement that is then used to determine the user location. *[Figure 7-28]*

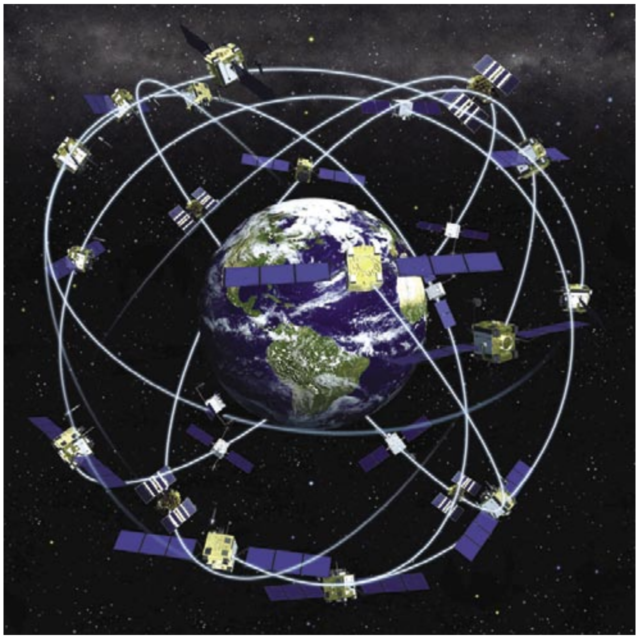

Figure 7-28. *Typical GPS Satellite Array.*

The Department of Defense (DOD) developed and deployed GPS as a space-based positioning, velocity, and time system. The DOD is responsible for operation of the GPS satellite constellation, and constantly monitors the satellites to ensure proper operation. The GPS system permits Earth-centered coordinates to be determined and provides aircraft position referenced to the DOD World Geodetic System of 1984 (WGS-84). Satellite navigation systems are unaffected by weather and provide global navigation coverage that fully meets the civil requirements for use as the primary means of navigation in oceanic airspace and certain remote areas. Properly certified GPS equipment may be used as a supplemental means of IFR navigation for domestic en route, terminal operations, and certain IAPs. Navigational values, such as distance and bearing to a WP and groundspeed, are computed from the aircraft's current position (latitude and longitude) and the location of the next WP. Course guidance is provided as a linear deviation from the desired track of a Great Circle route between defined WPs.

GPS may not be approved for IFR use in other countries. Prior to its use, pilots should ensure that GPS is authorized by the appropriate countries.

GPS Components

GPS consists of three distinct functional elements: space, control, and user.

The space element consists of over 30 Navstar satellites. This group of satellites is called a constellation. The space element consists of 24 Navigation System using Timing and Ranging (NAVSTAR) satellites in 6 orbital planes. The satellites in each plane are spaced 60° apart for complete coverage and are located (nominally) at about 11,000 miles above the Earth. The planes are arranged so that there are always five satellites in view at any time on the Earth. Presently, there are at least 31 Block II/IIA/IIR and IIR-M satellites in orbit with the additional satellites representing replacement satellites (upgraded systems) and spares. Recently, the Air Force received funding for procurement of 31 Block IIF satellites. The GPS constellation broadcasts a pseudo-random code timing signal and data message that the aircraft equipment processes to obtain satellite position and status data. By knowing the precise location of each satellite and precisely matching timing with the atomic clocks on the satellites, the aircraft receiver/processor can accurately measure the time each signal takes to arrive at the receiver and, therefore, determine aircraft position.

The control element consists of a network of ground-based GPS monitoring and control stations that ensure the accuracy of satellite positions and their clocks. In its present form, it has five monitoring stations, three ground antennas, and a master control station.

The user element consists of antennas and receiver/processors on board the aircraft that provide positioning, velocity, and precise timing to the user. GPS equipment used while operating under IFR must meet the standards set forth in Technical Standard Order (TSO) C-129 (or equivalent); meet the airworthiness installation requirements; be "approved" for that type of IFR operation; and be operated in accordance with the applicable POH/AFM or flight manual supplement.

An updatable GPS database that supports the appropriate operations (e.g., en route, terminal, and instrument approaches) is required when operating under IFR. The aircraft GPS navigation database contains WPs from the geographic areas where GPS navigation has been approved for IFR operations. The pilot selects the desired WPs from the database and may add user-defined WPs for the flight.

Equipment approved in accordance with TSO C-115a, visual flight rules (VFR), and hand-held GPS systems do not meet the requirements of TSO C-129 and are not authorized for IFR navigation, instrument approaches, or as a principal instrument flight reference. During IFR operations, these units (TSO C-115a) may be considered only an aid to situational awareness.

Prior to GPS/WAAS IFR operation, the pilot must review appropriate NOTAMs and aeronautical information. This information is available on request from an Automated Flight Service Station. The FAA will provide NOTAMs to advise pilots of the status of the WAAS and level of service available.

Function of GPS

GPS operation is based on the concept of ranging and triangulation from a group of satellites in space which act as precise reference points. The receiver uses data from a minimum of four satellites above the mask angle (the lowest angle above the horizon at which it can use a satellite).

The aircraft GPS receiver measures distance from a satellite using the travel time of a radio signal. Each satellite transmits a specific code, called a course/acquisition (CA) code, which contains information about satellite position, the GPS system time, and the health and accuracy of the transmitted data. Knowing the speed at which the signal traveled (approximately 186,000 miles per second) and the exact broadcast time, the distance traveled by the signal can be computed from the arrival time. The distance derived from this method of computing distance is called a pseudo-range because it is not a direct measurement of distance, but a measurement based on time. In addition to knowing the distance to a satellite, a receiver needs to know the satellite's exact position in space, its ephemeris. Each satellite transmits information about its exact orbital location. The GPS receiver uses this information to establish the precise position of the satellite.

Using the calculated pseudo-range and position information supplied by the satellite, the GPS receiver/processor mathematically determines its position by triangulation from several satellites. The GPS receiver needs at least four satellites to yield a three-dimensional position (latitude, longitude, and altitude) and time solution. The GPS receiver computes navigational values (distance and bearing to a WP, groundspeed, etc.) by using the aircraft's known latitude/longitude and referencing these to a database built into the receiver.

The GPS receiver verifies the integrity (usability) of the signals received from the GPS constellation through receiver autonomous integrity monitoring (RAIM) to determine if a satellite is providing corrupted information. RAIM needs a minimum of five satellites in view, or four satellites and a barometric altimeter baro-aiding to detect an integrity anomaly. For receivers capable of doing so, RAIM needs six satellites in view (or five satellites with baro-aiding) to isolate a corrupt satellite signal and remove it from the navigation solution.

Generally, there are two types of RAIM messages. One type indicates that there are not enough satellites available to provide RAIM and another type indicates that the RAIM has detected a potential error that exceeds the limit for the current phase of flight. Without RAIM capability, the pilot has no assurance of the accuracy of the GPS position.

Aircraft using GPS navigation equipment under IFR for domestic en route, terminal operations, and certain IAPs, must be equipped with an approved and operational alternate means of navigation appropriate to the flight. The avionics necessary to receive all of the ground-based facilities appropriate for the route to the destination airport and any required alternate airport must be installed and operational. Ground-based facilities necessary for these routes must also be operational. Active monitoring of alternative navigation equipment is not required if the GPS receiver uses RAIM for integrity monitoring. Active monitoring of an alternate means of navigation is required when the RAIM capability of the GPS equipment is lost. In situations where the loss of RAIM capability is predicted to occur, the flight must rely on other approved equipment, delay departure, or cancel the flight.

GPS Substitution

IFR En Route and Terminal Operations

GPS systems, certified for IFR en route and terminal operations, may be used as a substitute for ADF and DME receivers when conducting the following operations within the United States NAS.

1. Determining the aircraft position over a DME fix. This includes en route operations at and above 24,000 feet mean sea level (MSL) (FL 240) when using GPS for navigation.
2. Flying a DME arc.
3. Navigating TO/FROM an NDB/compass locator.

4. Determining the aircraft position over an NDB/compass locator.
5. Determining the aircraft position over a fix defined by an NDB/compass locator bearing crossing a VOR/LOC course.
6. Holding over an NDB/compass locator.

GPS Substitution for ADF or DME

Using GPS as a substitute for ADF or DME is subject to the following restrictions:

1. This equipment must be installed in accordance with appropriate airworthiness installation requirements and operated within the provisions of the applicable POH/AFM, or supplement.
2. The required integrity for these operations must be provided by at least en route RAIM, or equivalent.
3. WPs, fixes, intersections, and facility locations to be used for these operations must be retrieved from the GPS airborne database. The database must be current. If the required positions cannot be retrieved from the airborne database, the substitution of GPS for ADF and/or DME is not authorized
4. Procedures must be established for use when RAIM outages are predicted or occur. This may require the flight to rely on other approved equipment or require the aircraft to be equipped with operational NDB and/or DME receivers. Otherwise, the flight must be rerouted, delayed, canceled, or conducted under VFR.
5. The CDI must be set to terminal sensitivity (1 NM) when tracking GPS course guidance in the terminal area.
6. A non-GPS approach procedure must exist at the alternate airport when one is required. If the non-GPS approaches on which the pilot must rely require DME or ADF, the aircraft must be equipped with DME or ADF avionics as appropriate.
7. Charted requirements for ADF and/or DME can be met using the GPS system, except for use as the principal instrument approach navigation source.

NOTE: The following provides guidance, which is not specific to any particular aircraft GPS system. For specific system guidance, refer to the POH/AFM, or supplement, or contact the system manufacturer.

To Determine Aircraft Position Over a DME Fix:

1. Verify aircraft GPS system integrity monitoring is functioning properly and indicates satisfactory integrity.
2. If the fix is identified by a five-letter name which is contained in the GPS airborne database, select either the named fix as the active GPS WP or the facility establishing the DME fix as the active GPS WP. When using a facility as the active WP, the only acceptable facility is the DME facility which is charted as the one used to establish the DME fix. If this facility is not in the airborne database, it is not authorized for use.
3. If the fix is identified by a five-letter name which is not contained in the GPS airborne database, or if the fix is not named, select the facility establishing the DME fix or another named DME fix as the active GPS WP.
4. When selecting the named fix as the active GPS WP, a pilot is over the fix when the GPS system indicates the active WP.
5. If selecting the DME providing facility as the active GPS WP, a pilot is over the fix when the GPS distance from the active WP equals the charted DME value, and the aircraft is established on the appropriate bearing or course.

To Fly a DME Arc:

1. Verify aircraft GPS system integrity monitoring is functioning properly and indicates satisfactory integrity.
2. Select from the airborne database the facility providing the DME arc as the active GPS WP. The only acceptable facility is the DME facility on which the arc is based. If this facility is not in your airborne database, you are not authorized to perform this operation.
3. Maintain position on the arc by reference to the GPS distance instead of a DME readout.

To Navigate TO or FROM an NDB/Compass Locator:

1. Verify aircraft GPS system integrity monitoring is functioning properly and indicates satisfactory integrity.
2. Select the NDB/compass locator facility from the airborne database as the active WP. If the chart depicts the compass locator collocated with a fix of the same name, use of that fix as the active WP in place of the compass locator facility is authorized.
3. Select and navigate on the appropriate course to or from the active WP.

To Determine Aircraft Position Over an NDB/ Compass Locator:

1. Verify aircraft GPS system integrity monitoring is functioning properly and indicates satisfactory integrity.
2. Select the NDB/compass locator facility from the airborne database. When using an NDB/compass locator, the facility must be charted and be in the airborne database. If the facility is not in the airborne database, pilots are not authorized to use a facility WP for this operation.
3. A pilot is over the NDB/compass locator when the GPS system indicates arrival at the active WP.

To Determine Aircraft Position Over a Fix Made up of an NDB/Compass Locator Bearing Crossing a VOR/LOC Course:

1. Verify aircraft GPS system integrity monitoring is functioning properly and indicates satisfactory integrity.
2. A fix made up by a crossing NDB/compass locator bearing is identified by a five-letter fix name. Pilots may select either the named fix or the NDB/compass locator facility providing the crossing bearing to establish the fix as the active GPS WP. When using an NDB/compass locator, that facility must be charted and be in the airborne database. If the facility is not in the airborne database, pilots are not authorized to use a facility WP for this operation.
3. When selecting the named fix as the active GPS WP, pilot is over the fix when the GPS system indicates the pilot is at the WP.
4. When selecting the NDB/compass locator facility as the active GPS WP, pilots are over the fix when the GPS bearing to the active WP is the same as the charted NDB/compass locator bearing for the fix flying the prescribed track from the non-GPS navigation source.

To Hold Over an NDB/Compass Locator:

1. Verify aircraft GPS system integrity monitoring is functioning properly and indicates satisfactory integrity.
2. Select the NDB/compass locator facility from the airborne database as the active WP. When using a facility as the active WP, the only acceptable facility is the NDB/compass locator facility which is charted. If this facility is not in the airborne database, its use is not authorized.
3. Select nonsequencing (e.g., "HOLD" or "OBS") mode and the appropriate course in accordance with the POH/AFM, or supplement.
4. Hold using the GPS system in accordance with the POH/AFM, or supplement.

IFR Flight Using GPS

Preflight preparations should ensure that the GPS is properly installed and certified with a current database for the type of operation. The GPS operation must be conducted in accordance with the FAA-approved POH/AFM or flight manual supplement. Flightcrew members must be thoroughly familiar with the particular GPS equipment installed in the aircraft, the receiver operation manual, and the POH/AFM or flight manual supplement. Unlike ILS and VOR, the basic operation, receiver presentation to the pilot and some capabilities of the equipment can vary greatly. Due to these differences, operation of different brands, or even models of the same brand of GPS receiver under IFR should not be attempted without thorough study of the operation of that particular receiver and installation. Using the equipment in flight under VFR conditions prior to attempting IFR operation will allow further familiarization.

Required preflight preparations should include checking NOTAMs relating to the IFR flight when using GPS as a supplemental method of navigation. GPS satellite outages are issued as GPS NOTAMs both domestically and internationally. Pilots may obtain GPS RAIM availability information for an airport by specifically requesting GPS aeronautical information from an automated flight service station (AFSS) during preflight briefings. GPS RAIM aeronautical information can be obtained for a 3-hour period: the estimated time of arrival (ETA), and 1 hour before to 1 hour after the ETA hour, or a 24-hour time frame for a specific airport. FAA briefers will provide RAIM information for a period of 1 hour before to 1 hour after the ETA, unless a specific timeframe is requested by the pilot. If flying a published GPS departure, the pilot should also request a RAIM prediction for the departure airport. Some GPS receivers have the capability to predict RAIM availability. The pilot should also ensure that the required underlying ground-based navigation facilities and related aircraft equipment appropriate to the route of flight, terminal operations, instrument approaches for the destination, and alternate airports/heliports will be operational for the ETA. If the required ground-based facilities and equipment will not be available, the flight should be rerouted, rescheduled, canceled, or conducted under VFR.

Except for programming and retrieving information from the GPS receiver, planning the flight is accomplished in a similar manner to conventional NAVAIDs. Departure WP, DP, route, STAR, desired approach, IAF, and destination airport are entered into the GPS receiver according to the manufacturer's instructions. During preflight, additional information may be entered for functions such as ETA, fuel planning, winds aloft, etc.

When the GPS receiver is turned on, it begins an internal process of test and initialization. When the receiver is initialized, the user develops the route by selecting a WP or series of WPs, verifies the data, and selects the active flight plan. This procedure varies widely among receivers made by different manufacturers. GPS is a complex system, offering little standardization between receiver models. It is the pilot's responsibility to be familiar with the operation of the equipment in the aircraft.

The GPS receiver provides navigational values such as track, bearing, groundspeed, and distance. These are computed from the aircraft's present latitude and longitude to the location of the next WP. Course guidance is provided between WPs. The pilot has the advantage of knowing the aircraft's actual track over the ground. As long as track and bearing to the WP are matched up (by selecting the correct aircraft heading), the aircraft is going directly to the WP.

GPS Instrument Approaches

There is a mixture of GPS overlay approaches (approaches with "or GPS" in the title) and GPS stand-alone approaches in the United States.

NOTE: GPS instrument approach operations outside the United States must be authorized by the appropriate country authority.

While conducting these IAPs, ground-based NAVAIDs are not required to be operational and associated aircraft avionics need not be installed, operational, turned on, or monitored; however, monitoring backup navigation systems is always recommended when available.

Pilots should have a basic understanding of GPS approach procedures and practice GPS IAPs under visual meteorological conditions (VMC) until thoroughly proficient with all aspects of their equipment (receiver and installation) prior to attempting flight in instrument meteorological conditions (IMC). *[Figure 7-29]*

All IAPs must be retrievable from the current GPS database supplied by the manufacturer or other FAA-approved source. Flying point to point on the approach does not assure compliance with the published approach procedure. The proper RAIM sensitivity will not be available and the CDI sensitivity will not automatically change to 0.3 NM. Manually setting CDI sensitivity does not automatically change the RAIM sensitivity on some receivers. Some existing nonprecision approach procedures cannot be coded for use with GPS and will not be available as overlays.

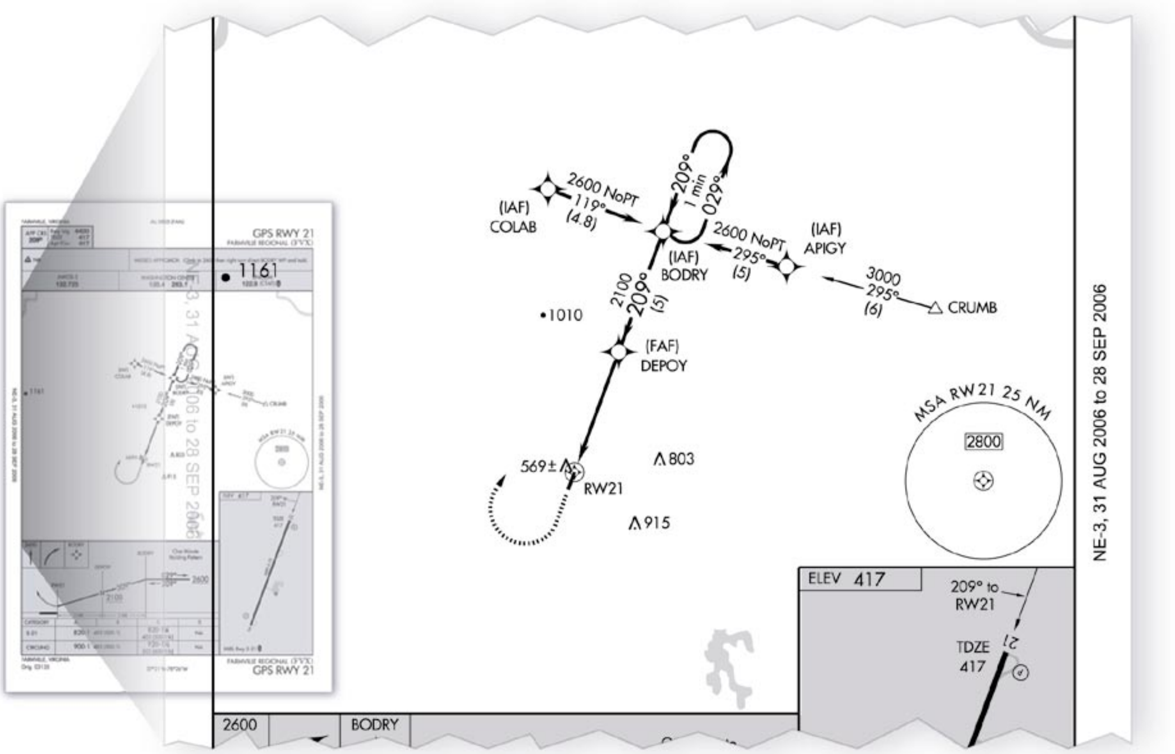

Figure 7-29. *A GPS Stand-Alone Approach.*

GPS approaches are requested and approved by ATC using the GPS title, such as "GPS RWY 24" or "RNAV RWY 35." Using the manufacturer's recommended procedures, the desired approach and the appropriate IAF are selected from the GPS receiver database. Pilots should fly the full approach from an initial approach waypoint (IAWP) or feeder fix unless specifically cleared otherwise. Randomly joining an approach at an intermediate fix does not ensure terrain clearance.

When an approach has been loaded in the flight plan, GPS receivers will give an "arm" annunciation 30 NM straight line distance from the airport/heliport reference point. The approach mode should be "armed" when within 30 NM distance so the receiver will change from en route CDI (±5 NM) and RAIM (±2 NM) sensitivity to ±1 NM terminal sensitivity. Where the IAWP is within 30 NM, a CDI sensitivity change will occur once the approach mode is armed and the aircraft is within 30 NM. Where the IAWP is beyond the 30 NM point, CDI sensitivity will not change until the aircraft is within 30 NM even if the approach is armed earlier. Feeder route obstacle clearance is predicated on the receiver CDI and RAIM being in terminal CDI sensitivity within 30 NM of the airport/heliport reference point; therefore, the receiver should always be armed no later than the 30 NM annunciation.

Pilots should pay particular attention to the exact operation of their GPS receivers for performing holding patterns and in the case of overlay approaches, operations such as procedure turns. These procedures may require manual intervention by the pilot to stop the sequencing of WPs by the receiver and to resume automatic GPS navigation sequencing once the maneuver is complete. The same WP may appear in the route of flight more than once and consecutively (e.g., IAWP, final approach waypoint (FAWP), missed approach waypoint (MAWP) on a procedure turn). Care must be exercised to ensure the receiver is sequenced to the appropriate WP for the segment of the procedure being flown, especially if one or more fly-over WPs are skipped (e.g., FAWP rather than IAWP if the procedure turn is not flown). The pilot may need to sequence past one or more fly-overs of the same WP in order to start GPS automatic sequencing at the proper place in the sequence of WPs.

When receiving vectors to final, most receiver operating manuals suggest placing the receiver in the nonsequencing mode on the FAWP and manually setting the course. This provides an extended final approach course in cases where the aircraft is vectored onto the final approach course outside of any existing segment which is aligned with the runway. Assigned altitudes must be maintained until established on a published segment of the approach. Required altitudes at WPs outside the FAWP or step-down fixes must be considered. Calculating the distance to the FAWP may be required in order to descend at the proper location.

When within 2 NM of the FAWP with the approach mode armed, the approach mode will switch to active, which results in RAIM and CDI sensitivity changing to the approach mode. Beginning 2 NM prior to the FAWP, the full scale CDI sensitivity will change smoothly from ±1 NM to ±0.3 NM at the FAWP. As sensitivity changes from ±1 NM to ±0.3 NM approaching the FAWP, and the CDI not centered, the corresponding increase in CDI displacement may give the impression the aircraft is moving further away from the intended course even though it is on an acceptable intercept heading. If digital track displacement information (cross-track error) is available in the approach mode, it may help the pilot remain position oriented in this situation. Being established on the final approach course prior to the beginning of the sensitivity change at 2 NM will help prevent problems in interpreting the CDI display during ramp-down. Requesting or accepting vectors, which will cause the aircraft to intercept the final approach course within 2 NM of the FAWP, is not recommended.

Incorrect inputs into the GPS receiver are especially critical during approaches. In some cases, an incorrect entry can cause the receiver to leave the approach mode. Overriding an automatically selected sensitivity during an approach will cancel the approach mode annunciation. If the approach mode is not armed by 2 NM prior to the FAWP, the approach mode will not become active at 2 NM prior to the FAWP and the equipment will flag. In these conditions, the RAIM and CDI sensitivity will not ramp down, and the pilot should not descend to minimum descent altitude (MDA), but fly to the MAWP and execute a missed approach. The approach active annunciator and/or the receiver should be checked to ensure the approach mode is active prior to the FAWP.

A GPS missed approach requires pilot action to sequence the receiver past the MAWP to the missed approach portion of the procedure. The pilot must be thoroughly familiar with the activation procedure for the particular GPS receiver installed in the aircraft and must initiate appropriate action after the MAWP. Activating the missed approach prior to the MAWP will cause CDI sensitivity to change immediately to terminal (±1 NM) sensitivity, and the receiver will continue to navigate to the MAWP. The receiver will not sequence past the MAWP. Turns should not begin prior to the MAWP. If the missed approach is not activated, the GPS receiver will display an extension of the inbound final approach course and the along track distance (ATD) will increase from the MAWP until it is manually sequenced after crossing the MAWP.

Missed approach routings in which the first track is via a course rather than direct to the next WP require additional action by the pilot to set the course. Being familiar with all of the required inputs is especially critical during this phase of flight.

Departures and Instrument Departure Procedures (DPs)

The GPS receiver must be set to terminal (±1 NM) CDI sensitivity and the navigation routes contained in the database in order to fly published IFR charted departures and DPs. Terminal RAIM should be provided automatically by the receiver. (Terminal RAIM for departure may not be available unless the WPs are part of the active flight plan rather than proceeding direct to the first destination.) Certain segments of a DP may require some manual intervention by the pilot, especially when radar vectored to a course or required to intercept a specific course to a WP. The database may not contain all of the transitions or departures from all runways and some GPS receivers do not contain DPs in the database. It is necessary that helicopter procedures be flown at 70 knots or less since helicopter departure procedures and missed approaches use a 20:1 obstacle clearance surface (OCS), which is double the fixed-wing OCS. Turning areas are based on this speed also. Missed approach routings in which the first track is via a course rather than direct to the next WP require additional action by the pilot to set the course. Being familiar with all of the required inputs is especially critical during this phase of flight.

GPS Errors

Normally, with 30 satellites in operation, the GPS constellation is expected to be available continuously worldwide. Whenever there are fewer than 24 operational satellites, GPS navigational capability may not be available at certain geographic locations. Loss of signals may also occur in valleys surrounded by high terrain, and any time the aircraft's GPS antenna is "shadowed" by the aircraft's structure (e.g., when the aircraft is banked).

Certain receivers, transceivers, mobile radios, and portable receivers can cause signal interference. Some VHF transmissions may cause "harmonic interference." Pilots can isolate the interference by relocating nearby portable receivers, changing frequencies, or turning off suspected causes of the interference while monitoring the receiver's signal quality data page.

GPS position data can be affected by equipment characteristics and various geometric factors, which typically cause errors of less than 100 feet. Satellite atomic clock inaccuracies, receiver/processors, signals reflected from hard objects (multi-path), ionospheric and tropospheric delays, and satellite data transmission errors may cause small position errors or momentary loss of the GPS signal.

System Status

The status of GPS satellites is broadcast as part of the data message transmitted by the GPS satellites. GPS status information is also available by means of the United States Coast Guard navigation information service: (703) 313-5907, or on the internet at http://www.navcen.uscg.gov/. Additionally, satellite status is available through the Notice to Airmen (NOTAM) system.

The GPS receiver verifies the integrity (usability) of the signals received from the GPS constellation through receiver autonomous integrity monitoring (RAIM) to determine if a satellite is providing corrupted information. At least one satellite, in addition to those required for navigation, must be in view for the receiver to perform the RAIM function; thus, RAIM needs a minimum of five satellites in view, or four satellites and a barometric altimeter (baro-aiding) to detect an integrity anomaly. For receivers capable of doing so, RAIM needs six satellites in view (or five satellites with baro-aiding) to isolate the corrupt satellite signal and remove it from the navigation solution.

RAIM messages vary somewhat between receivers; however, there are two most commonly used types. One type indicates that there are not enough satellites available to provide RAIM integrity monitoring and another type indicates that the RAIM integrity monitor has detected a potential error that exceeds the limit for the current phase of flight. Without RAIM capability, the pilot has no assurance of the accuracy of the GPS position.

Selective Availability. Selective Availability (SA) is a method by which the accuracy of GPS is intentionally degraded. This feature is designed to deny hostile use of precise GPS positioning data. SA was discontinued on May 1, 2000, but many GPS receivers are designed to assume that SA is still active. New receivers may take advantage of the discontinuance of SA based on the performance values in ICAO Annex 10, and do not need to be designed to operate outside of that performance.

GPS Familiarization

Pilots should practice GPS approaches under visual meteorological conditions (VMC) until thoroughly proficient with all aspects of their equipment (receiver and installation) prior to attempting flight by IFR in instrument meteorological conditions (IMC). Some of the tasks which the pilot should practice are:

1. Utilizing the receiver autonomous integrity monitoring (RAIM) prediction function;
2. Inserting a DP into the flight plan, including setting terminal CDI sensitivity, if required, and the conditions under which terminal RAIM is available for departure (some receivers are not DP or STAR capable);
3. Programming the destination airport;
4. Programming and flying the overlay approaches (especially procedure turns and arcs);
5. Changing to another approach after selecting an approach;
6. Programming and flying "direct" missed approaches;
7. Programming and flying "routed" missed approaches;
8. Entering, flying, and exiting holding patterns, particularly on overlay approaches with a second WP in the holding pattern;
9. Programming and flying a "route" from a holding pattern;
10. Programming and flying an approach with radar vectors to the intermediate segment;
11. Indication of the actions required for RAIM failure both before and after the FAWP; and
12. Programming a radial and distance from a VOR (often used in departure instructions).

Differential Global Positioning Systems (DGPS)

Differential global positioning systems (DGPS) are designed to improve the accuracy of global navigation satellite systems (GNSS) by measuring changes in variables to provide satellite positioning corrections.

Because multiple receivers receiving the same set of satellites produce similar errors, a reference receiver placed at a known location can compute its theoretical position accurately and can compare that value to the measurements provided by the navigation satellite signals. The difference in measurement between the two signals is an error that can be corrected by providing a reference signal correction.

As a result of this differential input accuracy of the satellite system can be increased to meters. The Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS) are examples of differential global positioning systems.

Wide Area Augmentation System (WAAS)

The WAAS is designed to improve the accuracy, integrity, and availability of GPS signals. WAAS allows GPS to be used, as the aviation navigation system, from takeoff through Category I precision approaches. The International Civil Aviation Organization (ICAO) has defined Standards for satellite-based augmentation systems (SBAS), and Japan and Europe are building similar systems that are planned to be interoperable with WAAS: EGNOS, the European Geostationary Navigation Overlay System, and MSAS, the Japanese Multifunctional Transport Satellite (MTSAT) Satellite-based Augmentation System. The result will be a worldwide seamless navigation capability similar to GPS but with greater accuracy, availability, and integrity.

Unlike traditional ground-based navigation aids, WAAS will cover a more extensive service area in which surveyed wide-area ground reference stations are linked to the WAAS network. Signals from the GPS satellites are monitored by these stations to determine satellite clock and ephemeris corrections. Each station in the network relays the data to a wide-area master station where the correction information is computed. A correction message is prepared and uplinked to a geostationary satellite (GEO) via a ground uplink and then broadcast on the same frequency as GPS to WAAS receivers within the broadcast coverage area. *[Figure 7-30]*

In addition to providing the correction signal, WAAS provides an additional measurement to the aircraft receiver, improving the availability of GPS by providing, in effect, an additional GPS satellite in view. The integrity of GPS is improved through real-time monitoring, and the accuracy is improved by providing differential corrections to reduce errors. *[Figure 7-31]* As a result, performance improvement is sufficient to enable approach procedures with GPS/WAAS glide paths. At this time the FAA has completed installation of 25 wide area ground reference systems, two master stations, and four ground uplink stations.

General Requirements

WAAS avionics must be certified in accordance with TSO-C145A, Airborne Navigation Sensors Using the GPS Augmented by the WAAS; or TSO-146A for stand-alone systems. GPS/WAAS operation must be conducted in accordance with the FAA-approved aircraft flight manual (AFM) and flight manual supplements. Flight manual supplements must state the level of approach procedure that the receiver supports.

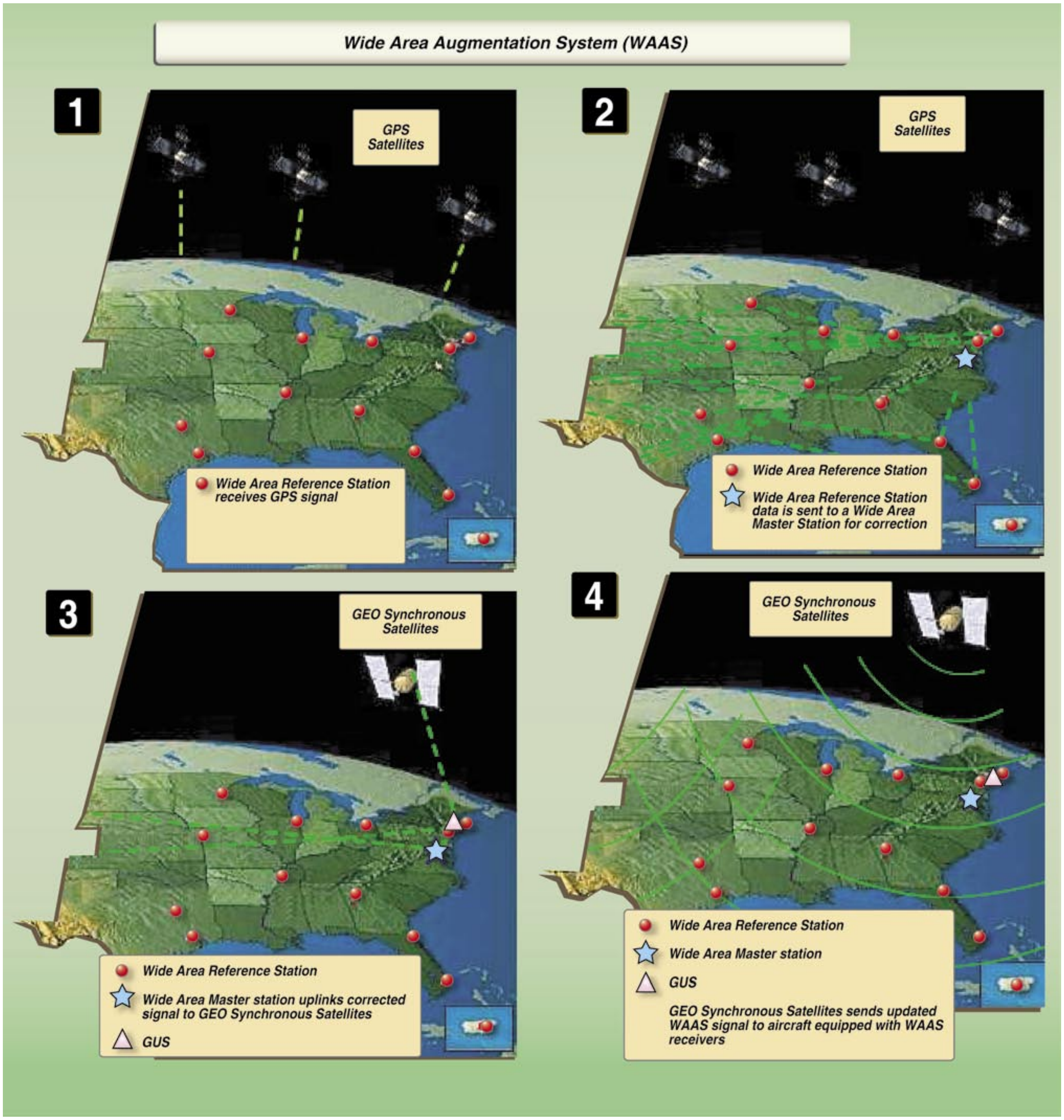
Wide Area Augmentation System (WAAS)
1
GPS Satellites
Wide Area Reference Station receives GPS signal
2
GPS Satellites
Wide Area Reference Station
Wide Area Reference Station data is sent to a Wide Area Master Station for correction
3
GEO Synchronous Satellites
Wide Area Reference Station
Wide Area Master station uplinks corrected signal to GEO Synchronous Satellites
GUS
4
GEO Synchronous Satellites
Wide Area Reference Station
Wide Area Master station
GUS
GEO Synchronous Satellites sends updated WAAS signal to aircraft equipped with WAAS receivers

Figure 7-30. *WAAS Satellite Representation.*

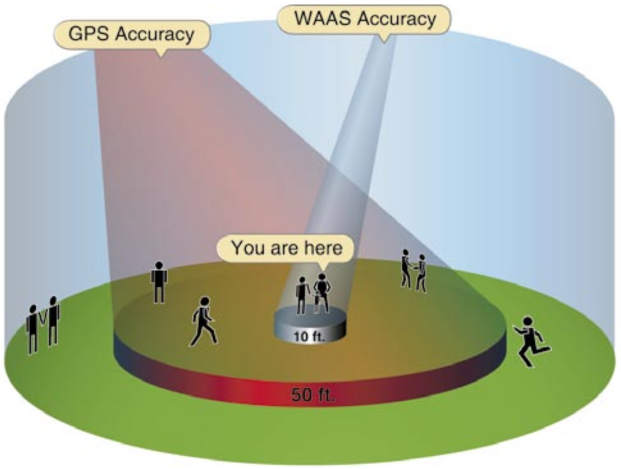
GPS Accuracy
WAAS Accuracy
You are here
10 ft.
50 ft.

Figure 7-31. *WAAS Satellite Representation.*

Instrument Approach Capabilities

WAAS receivers support all basic GPS approach functions and will provide additional capabilities with the key benefit to generate an electronic glide path, independent of ground equipment or barometric aiding. This eliminates several problems such as cold temperature effects, incorrect altimeter setting or lack of a local altimeter source, and allows approach procedures to be built without the cost of installing ground stations at each airport. A new class of approach procedures which provide vertical guidance requirements for precision approaches has been developed to support satellite navigation use for aviation applications. These new procedures called Approach with Vertical Guidance (APV) include approaches such as the LNAV/VNAV procedures presently being flown with barometric vertical navigation.

Local Area Augmentation System (LAAS)

LAAS is a ground-based augmentation system which uses a GPS reference facility located on or in the vicinity of the airport being serviced. This facility has a reference receiver that measures GPS satellite pseudo-range and timing and retransmits the signal. Aircraft landing at LAAS-equipped airports are able to conduct approaches to Category I level and above for properly equipped aircraft. *[Figures 7-32* and *7-33]*

Inertial Navigation System (INS)

Inertial Navigation System (INS) is a system that navigates precisely without any input from outside of the aircraft. It is fully self-contained. The INS is initialized by the pilot, who enters into the system the exact location of the aircraft on the ground before the flight. The INS is also programmed with WPs along the desired route of flight.

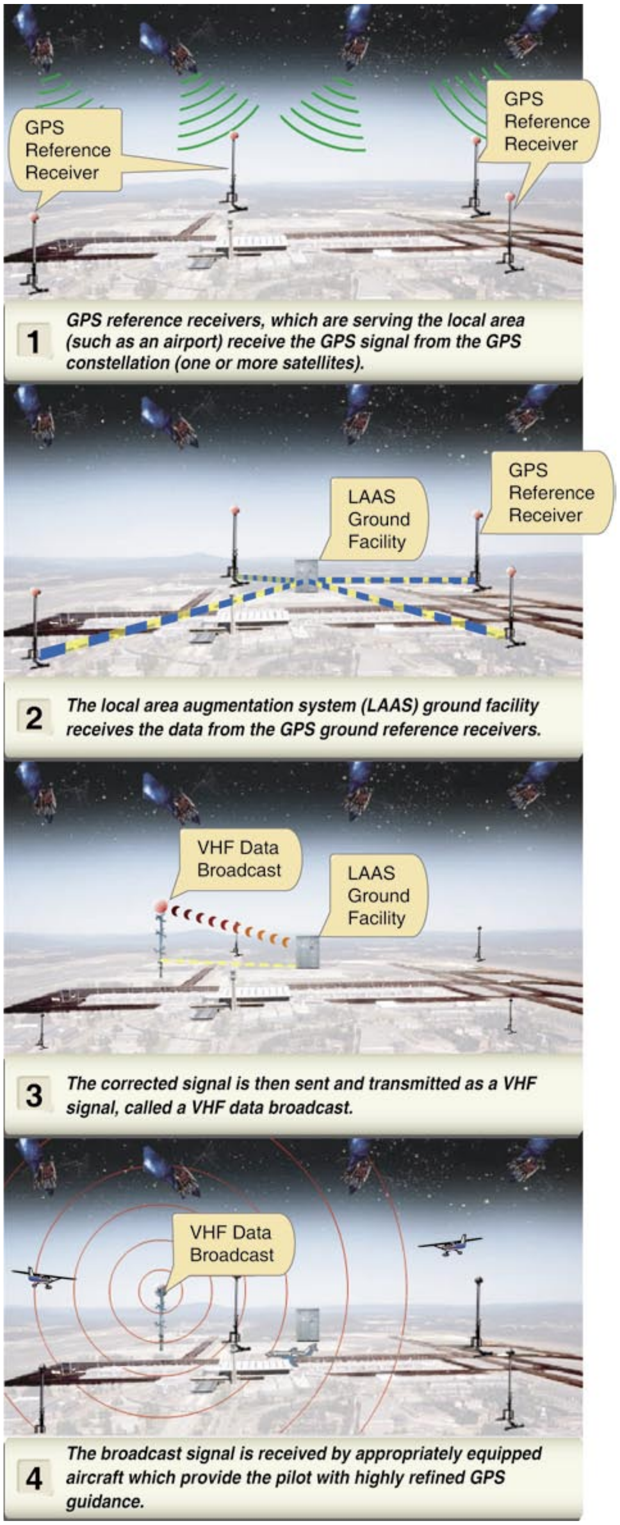
GPS Reference Receiver
GPS Reference Receiver
1
GPS reference receivers, which are serving the local area (such as an airport) receive the GPS signal from the GPS constellation (one or more satellites).
LAAS Ground Facility
GPS Reference Receiver
2
The local area augmentation system (LAAS) ground facility receives the data from the GPS ground reference receivers.
VHF Data Broadcast
LAAS Ground Facility
3
The corrected signal is then sent and transmitted as a VHF signal, called a VHF data broadcast.
VHF Data Broadcast
4
The broadcast signal is received by appropriately equipped aircraft which provide the pilot with highly refined GPS guidance.

Figure 7-32. *LAAS Representation.*

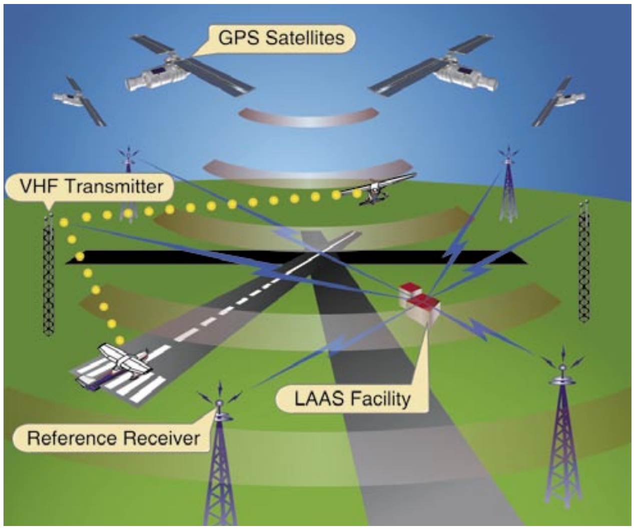

Figure 7-33. *LAAS Representation.*

INS Components

INS is considered a stand-alone navigation system, especially when more than one independent unit is onboard. The airborne equipment consists of an accelerometer to measure acceleration—which, when integrated with time, gives velocity—and gyros to measure direction.

Later versions of the INS, called inertial reference systems (IRS) utilize laser gyros and more powerful computers; therefore, the accelerometer mountings no longer need to be kept level and aligned with true north. The computer system can handle the added workload of dealing with the computations necessary to correct for gravitational and directional errors. Consequently, these newer systems are sometimes called strap down systems, as the accelerometers and gyros are strapped down to the airframe, rather than being mounted on a structure that stays fixed with respect to the horizon and true north.

INS Errors

The principal error associated with INS is degradation of position with time. INS computes position by starting with accurate position input which is changed continuously as accelerometers and gyros provide speed and direction inputs. Both accelerometers and gyros are subject to very small errors; as time passes, those errors probably accumulate.

While the best INS/IRS display errors of 0.1 to 0.4 NM after flights across the North Atlantic of 4 to 6 hours, smaller and less expensive systems are being built that show errors of 1 to 2 NM per hour. This accuracy is more than sufficient for a navigation system that can be combined with and updated by GPS. The synergy of a navigation system consisting of an INS/IRS unit in combination with a GPS resolves the errors and weaknesses of both systems. GPS is accurate all the time it is working but may be subject to short and periodic outages. INS is made more accurate because it is continually updated and continues to function with good accuracy if the GPS has moments of lost signal.

Instrument Approach Systems

Most navigation systems approved for en route and terminal operations under IFR, such as VOR, NDB, and GPS, may also be approved to conduct IAPs. The most common systems in use in the United States are the ILS, simplified directional facility (SDF), localizer directional aid (LDA), and microwave landing system (MLS). These systems operate independently of other navigation systems. There are new systems being developed, such as WAAS and LAAS. Other systems have been developed for special use.

Instrument Landing Systems (ILS)

The ILS system provides both course and altitude guidance to a specific runway. The ILS system is used to execute a precision instrument approach procedure or precision approach. *[Figure 7-34]* The system consists of the following components:

1. A localizer providing horizontal (left/right) guidance along the extended centerline of the runway.
2. A glide slope (GS) providing vertical (up/down) guidance toward the runway touchdown point, usually at a 3° slope.
3. Marker beacons providing range information along the approach path.
4. Approach lights assisting in the transition from instrument to visual flight.

The following supplementary elements, though not specific components of the system, may be incorporated to increase safety and utility:

1. Compass locators providing transition from en route NAVAIDs to the ILS system and assisting in holding procedures, tracking the localizer course, identifying the marker beacon sites, and providing a FAF for ADF approaches.
2. DME collocated with the GS transmitter providing positive distance-to-touchdown information or DME associated with another nearby facility (VOR or standalone), if specified in the approach procedure.

ILS approaches are categorized into three different types of approaches based on the equipment at the airport and the experience level of the pilot. Category I approaches provide for approach height above touchdown of not less than 200 feet. Category II approaches provide for approach to a height above

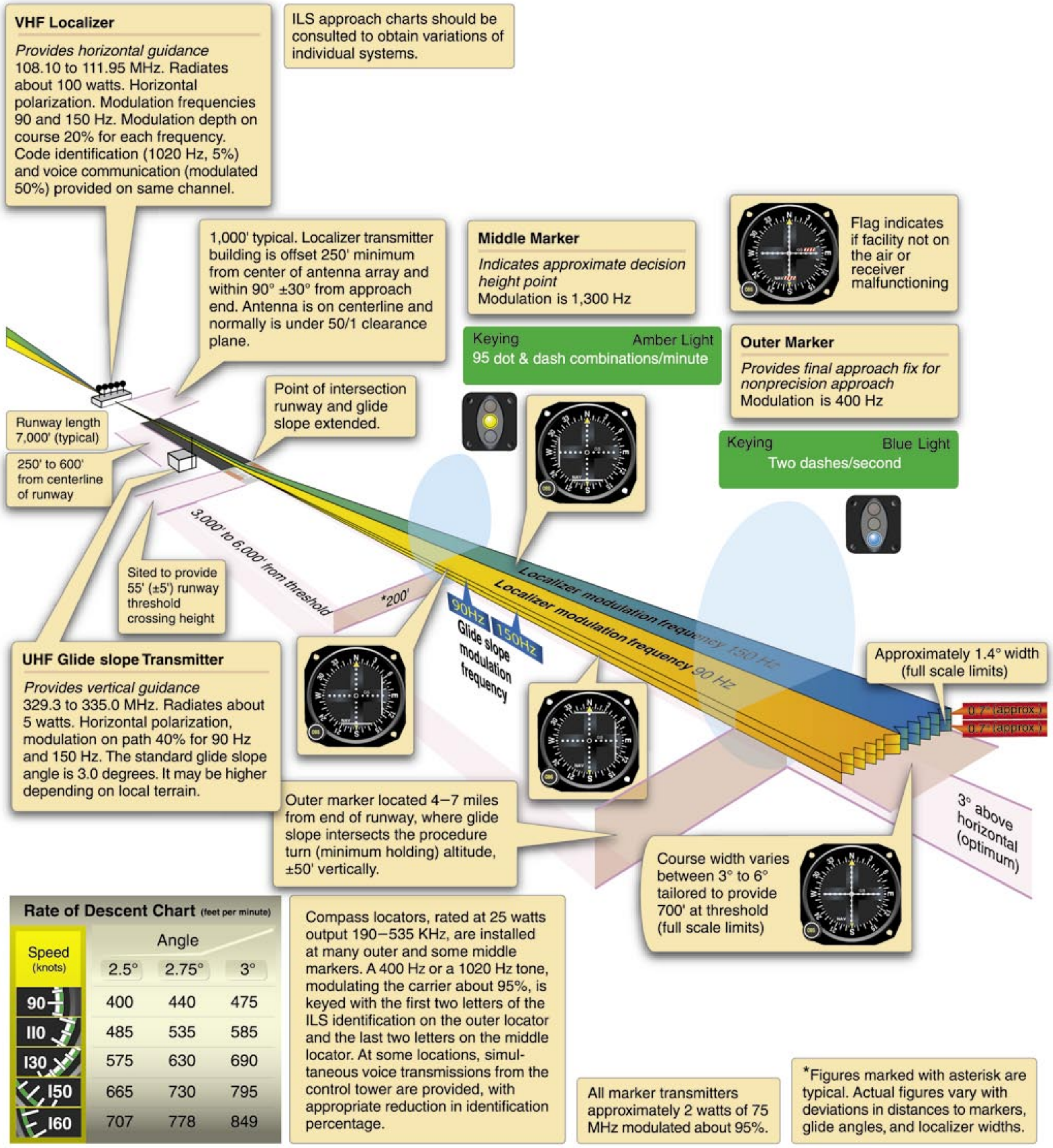

VHF Localizer

Provides horizontal guidance
108.10 to 111.95 MHz. Radiates about 100 watts. Horizontal polarization. Modulation frequencies 90 and 150 Hz. Modulation depth on course 20% for each frequency. Code identification (1020 Hz, 5%) and voice communication (modulated 50%) provided on same channel.

ILS approach charts should be consulted to obtain variations of individual systems.

1,000' typical. Localizer transmitter building is offset 250' minimum from center of antenna array and within 90° ±30° from approach end. Antenna is on centerline and normally is under 50/1 clearance plane.

Middle Marker

Indicates approximate decision height point
Modulation is 1,300 Hz

Keying — Amber Light
95 dot & dash combinations/minute

Flag indicates if facility not on the air or receiver malfunctioning

Outer Marker

Provides final approach fix for nonprecision approach
Modulation is 400 Hz

Keying — Blue Light
Two dashes/second

Runway length 7,000' (typical)

250' to 600' from centerline of runway

Point of intersection runway and glide slope extended.

Sited to provide 55' (±5') runway threshold crossing height

UHF Glide slope Transmitter

Provides vertical guidance
329.3 to 335.0 MHz. Radiates about 5 watts. Horizontal polarization, modulation on path 40% for 90 Hz and 150 Hz. The standard glide slope angle is 3.0 degrees. It may be higher depending on local terrain.

Approximately 1.4° width (full scale limits)

Outer marker located 4–7 miles from end of runway, where glide slope intersects the procedure turn (minimum holding) altitude, ±50' vertically.

Course width varies between 3° to 6° tailored to provide 700' at threshold (full scale limits)

3,000' to 6,000' from threshold
*200'
90Hz
150Hz
Glide slope modulation frequency
Localizer modulation frequency 150 Hz
Localizer modulation frequency 90 Hz
0.7° (approx.)
0.7° (approx.)
3° above horizontal (optimum)

Rate of Descent Chart (feet per minute)

Speed (knots)	Angle 2.5°	Angle 2.75°	Angle 3°
90	400	440	475
110	485	535	585
130	575	630	690
150	665	730	795
160	707	778	849

Compass locators, rated at 25 watts output 190–535 KHz, are installed at many outer and some middle markers. A 400 Hz or a 1020 Hz tone, modulating the carrier about 95%, is keyed with the first two letters of the ILS identification on the outer locator and the last two letters on the middle locator. At some locations, simultaneous voice transmissions from the control tower are provided, with appropriate reduction in identification percentage.

All marker transmitters approximately 2 watts of 75 MHz modulated about 95%.

*Figures marked with asterisk are typical. Actual figures vary with deviations in distances to markers, glide angles, and localizer widths.

Figure 7-34. *Instrument Landing Systems.*

touchdown of not less than 100 feet. Category III approaches provide lower minimums for approaches without a decision height minimum. While pilots need only be instrument rated and the aircraft be equipped with the appropriate airborne equipment to execute Category I approaches, Category II and III approaches require special certification for the pilots, ground equipment, and airborne equipment.

ILS Components

Ground Components

The ILS uses a number of different ground facilities. These facilities may be used as a part of the ILS system, as well as part of another approach. For example, the compass locator may be used with NDB approaches.

Localizer

The localizer (LOC) ground antenna array is located on the extended centerline of the instrument runway of an airport, located at the departure end of the runway to prevent it from being a collision hazard. This unit radiates a field pattern, which develops a course down the centerline of the runway toward the middle markers (MMs) and outer markers (OMs), and a similar course along the runway centerline in the opposite direction. These are called the front and back courses, respectively. The localizer provides course guidance, transmitted at 108.1 to 111.95 MHz (odd tenths only), throughout the descent path to the runway threshold from a distance of 18 NM from the antenna to an altitude of 4,500 feet above the elevation of the antenna site. *[Figure 7-35]*

The localizer course width is defined as the angular displacement at any point along the course between a full "fly-left" (CDI needle fully deflected to the left) and a full "fly-right" indication (CDI needle fully deflected to the right). Each localizer facility is audibly identified by a three-letter designator, transmitted at frequent regular intervals. The ILS identification is preceded by the letter "I" (two dots). For example, the ILS localizer at Springfield, Missouri transmits the identifier ISGF. The localizer includes a voice feature on its frequency for use by the associated ATC facility in issuing approach and landing instructions.

The localizer course is very narrow, normally 5°. This results in high needle sensitivity. With this course width, a full-scale deflection shows when the aircraft is 2.5° to either side of the centerline. This sensitivity permits accurate orientation to the landing runway. With no more than one-quarter scale deflection maintained, the aircraft will be aligned with the runway.

Glide Slope (GS)

GS describes the systems that generate, receive, and indicate the ground facility radiation pattern. The glide path is the straight, sloped line the aircraft should fly in its descent from where the GS intersects the altitude used for approaching the FAF, to the runway touchdown zone. The GS equipment is housed in a building approximately 750 to 1,250 feet down the runway from the approach end of the runway, and between 400 and 600 feet to one side of the centerline.

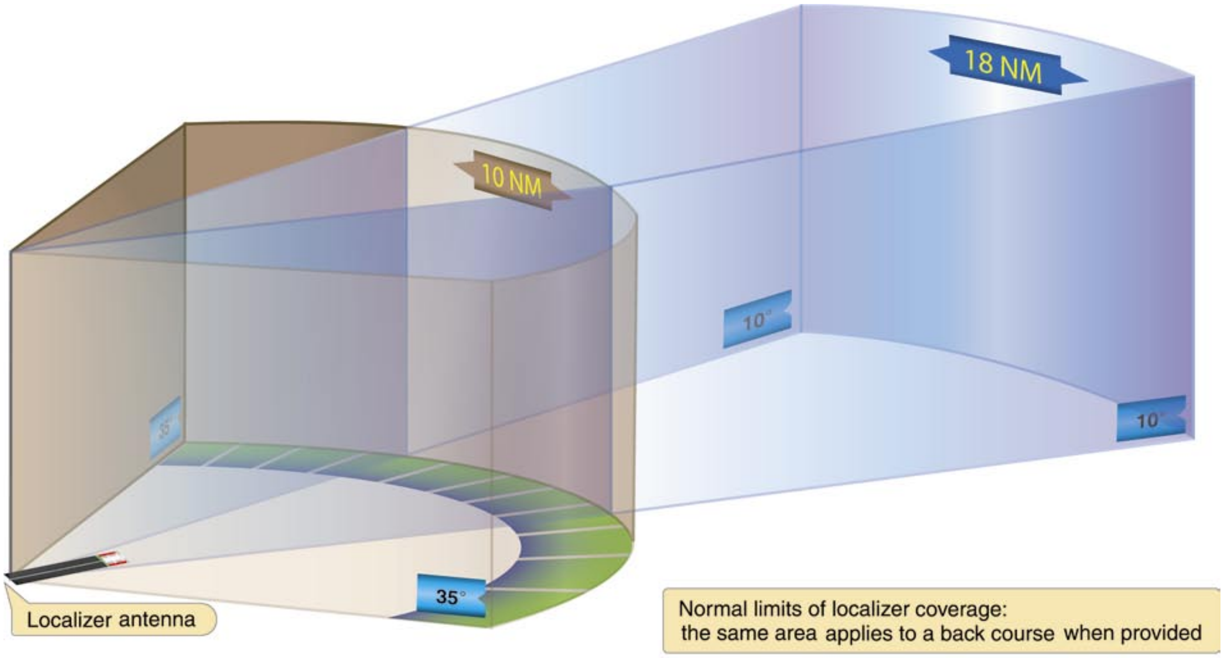
18 NM
10 NM
10°
10°
35°
35°
Localizer antenna
Normal limits of localizer coverage:
the same area applies to a back course when provided

Figure 7-35. *Localizer Coverage Limits.*

The course projected by the GS equipment is essentially the same as would be generated by a localizer operating on its side. The GS projection angle is normally adjusted to 2.5° to 3.5° above horizontal, so it intersects the MM at about 200 feet and the OM at about 1,400 feet above the runway elevation. At locations where standard minimum obstruction clearance cannot be obtained with the normal maximum GS angle, the GS equipment is displaced farther from the approach end of the runway if the length of the runway permits; or, the GS angle may be increased up to 4°.

Unlike the localizer, the GS transmitter radiates signals only in the direction of the final approach on the front course. The system provides no vertical guidance for approaches on the back course. The glide path is normally 1.4° thick. At 10 NM from the point of touchdown, this represents a vertical distance of approximately 1,500 feet, narrowing to a few feet at touchdown.

Marker Beacons

Two VHF marker beacons, outer and middle, are normally used in the ILS system. *[Figure 7-36]* A third beacon, the inner, is used where Category II operations are certified. A marker beacon may also be installed to indicate the FAF on the ILS back course.

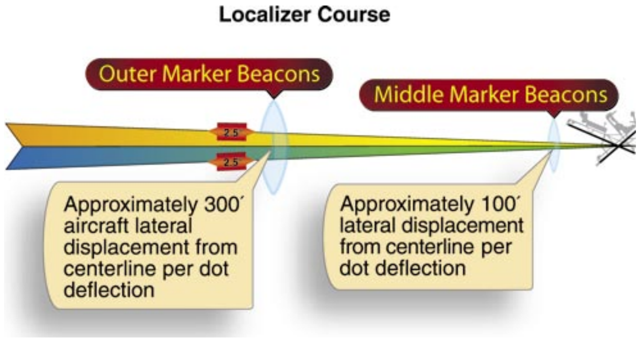
Localizer Course
Outer Marker Beacons
Middle Marker Beacons
2.5
2.5
Approximately 300´ aircraft lateral displacement from centerline per dot deflection
Approximately 100´ lateral displacement from centerline per dot deflection

Figure 7-36. *Localizer receiver indications and aircraft displacement.*

The OM is located on the localizer front course 4–7 miles from the airport to indicate a position at which an aircraft, at the appropriate altitude on the localizer course, will intercept the glide path. The MM is located approximately 3,500 feet from the landing threshold on the centerline of the localizer front course at a position where the GS centerline is about 200 feet above the touchdown zone elevation. The inner marker (IM), where installed, is located on the front course between the MM and the landing threshold. It indicates the point at which an aircraft is at the decision height on the glide path during a Category II ILS approach. The back-course marker, where installed, indicates the back-course FAF.

Compass Locator

Compass locators are low-powered NDBs and are received and indicated by the ADF receiver. When used in conjunction with an ILS front course, the compass locator facilities are collocated with the outer and/or MM facilities. The coding identification of the outer locator consists of the first two letters of the three-letter identifier of the associated LOC. For example, the outer locator at Dallas/Love Field (DAL) is identified as "DA." The middle locator at DAL is identified by the last two letters "AL."

Approach Lighting Systems (ALS)

Normal approach and letdown on the ILS is divided into two distinct stages: the instrument approach stage using only radio guidance, and the visual stage, when visual contact with the ground runway environment is necessary for accuracy and safety. The most critical period of an instrument approach, particularly during low ceiling/visibility conditions, is the point at which the pilot must decide whether to land or execute a missed approach. As the runway threshold is approached, the visual glide path will separate into individual lights. At this point, the approach should be continued by reference to the runway touchdown zone markers. The ALS provides lights that will penetrate the atmosphere far enough from touchdown to give directional, distance, and glide path information for safe visual transition.

Visual identification of the ALS by the pilot must be instantaneous, so it is important to know the type of ALS before the approach is started. Check the instrument approach chart and the A/FD for the particular type of lighting facilities at the destination airport before any instrument flight. With reduced visibility, rapid orientation to a strange runway can be difficult, especially during a circling approach to an airport with minimum lighting facilities, or to a large terminal airport located in the midst of distracting city and ground facility lights. Some of the most common ALS systems are shown in *Figure 7-37.*

A high-intensity flasher system, often referred to as "the rabbit," is installed at many large airports. The flashers consist of a series of brilliant blue-white bursts of light flashing in sequence along the approach lights, giving the effect of a ball of light traveling towards the runway. Typically, "the rabbit" makes two trips toward the runway per second.

Runway end identifier lights (REIL) are installed for rapid and positive identification of the approach end of an instrument runway. The system consists of a pair of synchronized flashing lights placed laterally on each side of the runway threshold facing the approach area.

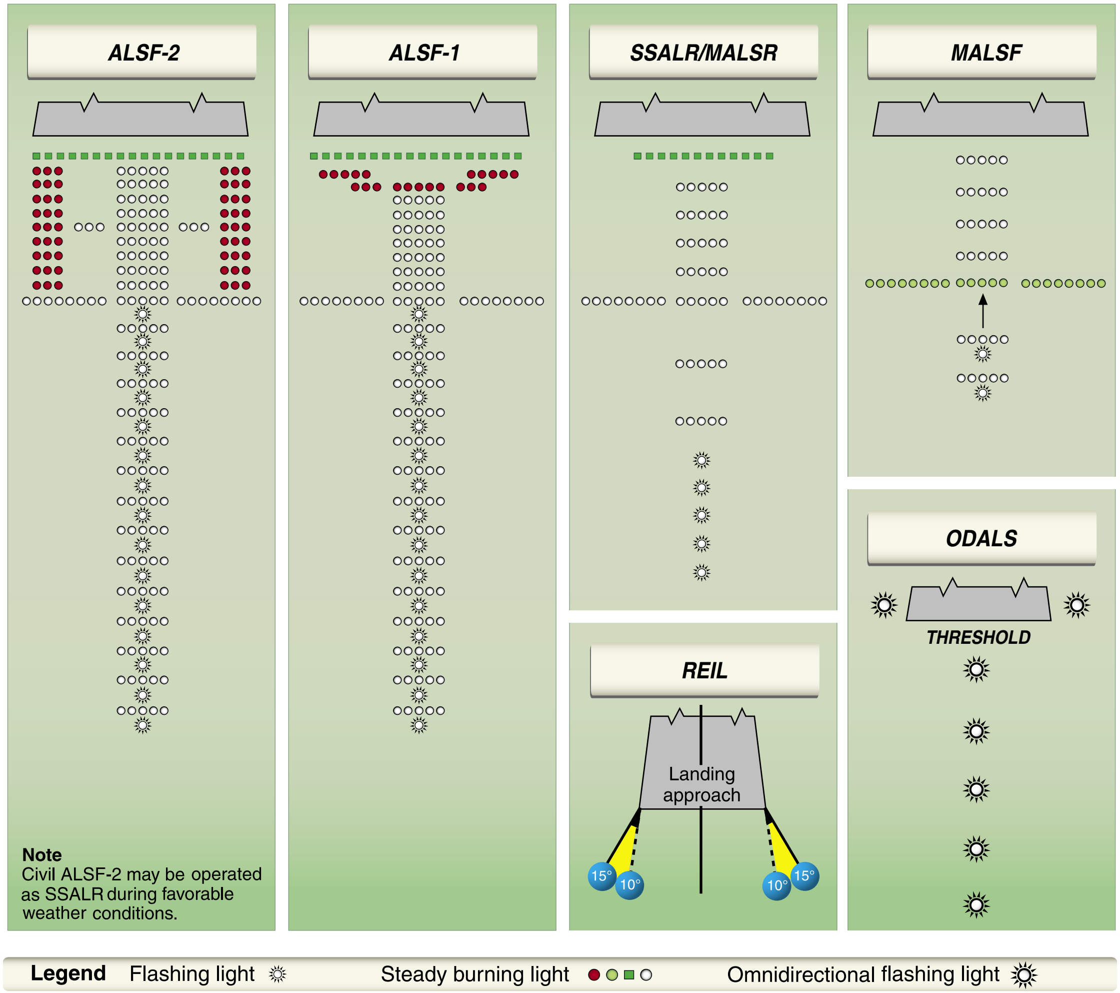
ALSF-2
ALSF-1
SSALR/MALSR
MALSF
Note
Civil ALSF-2 may be operated as SSALR during favorable weather conditions.
REIL
Landing approach
15°
10°
10°
15°
ODALS
THRESHOLD
Legend
Flashing light
Steady burning light
Omnidirectional flashing light

ALSF—Approach light system with sequenced flashing lights

SSALR—Simplified short approach light system with runway alignment indicator lights

MALSR—Medium intensity approach light system with runway alignment indicator lights

REIL—Runway end identification lights

MALSF—Medium intensity approach light system with sequenced flashing lights (and runway alignment)

ODALS—Omnidirectional approach light system

Figure 7-37. *Precision and Nonprecision ALS Configuration.*

The visual approach slope indicator (VASI) gives visual descent guidance information during the approach to a runway. The standard VASI consists of light bars that project a visual glide path, which provides safe obstruction clearance within the approach zone. The normal GS angle is 3°; however, the angle may be as high as 4.5° for proper obstacle clearance. On runways served by ILS, the VASI angle normally coincides with the electronic GS angle. Visual left/right course guidance is obtained by alignment with the runway lights. The standard VASI installation consists of either 2-, 3-, 4-, 6-, 12-, or 16-light units arranged in downwind and upwind light bars. Some airports serving long-bodied aircraft have three-bar VASIs which provide two visual glidepaths to the same runway. The first glide path encountered is the same as provided by the standard VASI. The second glide path is about 25 percent higher than the first and is designed for the use of pilots of long-bodied aircraft.

The basic principle of VASI is that of color differentiation between red and white. Each light projects a beam having a white segment in the upper part and a red segment in the lower part of the beam. From a position above the glide path the pilot sees both bars as white. Lowering the aircraft with respect to the glide path, the color of the upwind bars changes from white to pink to red. When on the proper glide path, the landing aircraft will overshoot the downwind bars and undershoot the upwind bars. Thus the downwind (closer) bars are seen as white and the upwind bars as red. From a position below the glide path, both light bars are seen as red. Moving up to the glide path, the color of the downwind

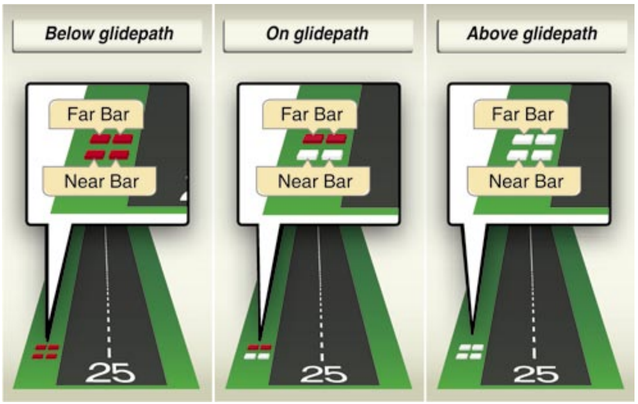

Figure 7-38. *Standard two-bar VASI.*

bars changes from red to pink to white. When below the glide path, as indicated by a distinct all-red signal, a safe obstruction clearance might not exist. A standard two-bar VASI is illustrated in *Figure 7-38*.

ILS Airborne Components

Airborne equipment for the ILS system includes receivers for the localizer, GS, marker beacons, ADF, DME, and the respective indicator instruments.

The typical VOR receiver is also a localizer receiver with common tuning and indicating equipment. Some receivers have separate function selector switches, but most switch between VOR and LOC automatically by sensing if odd tenths between 108 and 111.95 MHz have been selected. Otherwise, tuning of VOR and localizer frequencies is accomplished with the same knobs and switches, and the CDI indicates "on course" as it does on a VOR radial.

Though some GS receivers are tuned separately, in a typical installation the GS is tuned automatically to the proper frequency when the localizer is tuned. Each of the 40 localizer channels in the 108.10 to 111.95 MHz band is paired with a corresponding GS frequency.

When the localizer indicator also includes a GS needle, the instrument is often called a cross-pointer indicator. The crossed horizontal (GS) and vertical (localizer) needles are free to move through standard five-dot deflections to indicate position on the localizer course and glide path.

When the aircraft is on the glide path, the needle is horizontal, overlying the reference dots. Since the glide path is much narrower than the localizer course (approximately 1.4° from full up to full down deflection), the needle is very sensitive to displacement of the aircraft from on-path alignment. With the proper rate of descent established upon GS interception, very small corrections keep the aircraft aligned.

The localizer and GS warning flags disappear from view on the indicator when sufficient voltage is received to actuate the needles. The flags show when an unstable signal or receiver malfunction occurs.

The OM is identified by a low-pitched tone, continuous dashes at the rate of two per second, and a purple/blue marker beacon light. The MM is identified by an intermediate tone, alternate dots and dashes at the rate of 95 dot/dash combinations per minute, and an amber marker beacon light. The IM, where installed, is identified by a high-pitched tone, continuous dots at the rate of six per second, and a white marker beacon light. The back-course marker (BCM), where installed, is identified by a high-pitched tone with two dots at a rate of 72 to 75 two-dot combinations per minute, and a white marker beacon light. Marker beacon receiver sensitivity is selectable as high or low on many units. The low-sensitivity position gives the sharpest indication of position and should be used during an approach. The high-sensitivity position provides an earlier warning that the aircraft is approaching the marker beacon site.

ILS Function

The localizer needle indicates, by deflection, whether the aircraft is right or left of the localizer centerline, regardless of the position or heading of the aircraft. Rotating the OBS has no effect on the operation of the localizer needle, although it is useful to rotate the OBS to put the LOC inbound course under the course index. When inbound on the front course, or outbound on the back course, the course indication remains directional. (See *Figure 7-39,* aircraft C, D, and E.)

Unless the aircraft has reverse sensing capability and it is in use, when flying inbound on the back course or outbound on the front course, heading corrections to on-course are made opposite the needle deflection. This is commonly described as "flying away from the needle." (See *Figure 7-39*, aircraft A and B.) Back course signals should not be used for an approach unless a back course approach procedure is published for that particular runway and the approach is authorized by ATC.

Once you have reached the localizer centerline, maintain the inbound heading until the CDI moves off center. Drift corrections should be small and reduced proportionately as the course narrows. By the time you reach the OM, your drift correction should be established accurately enough on a well-executed approach to permit completion of the approach, with heading corrections no greater then 2°.

The heaviest demand on pilot technique occurs during descent from the OM to the MM, when you maintain the localizer course, adjust pitch attitude to maintain the

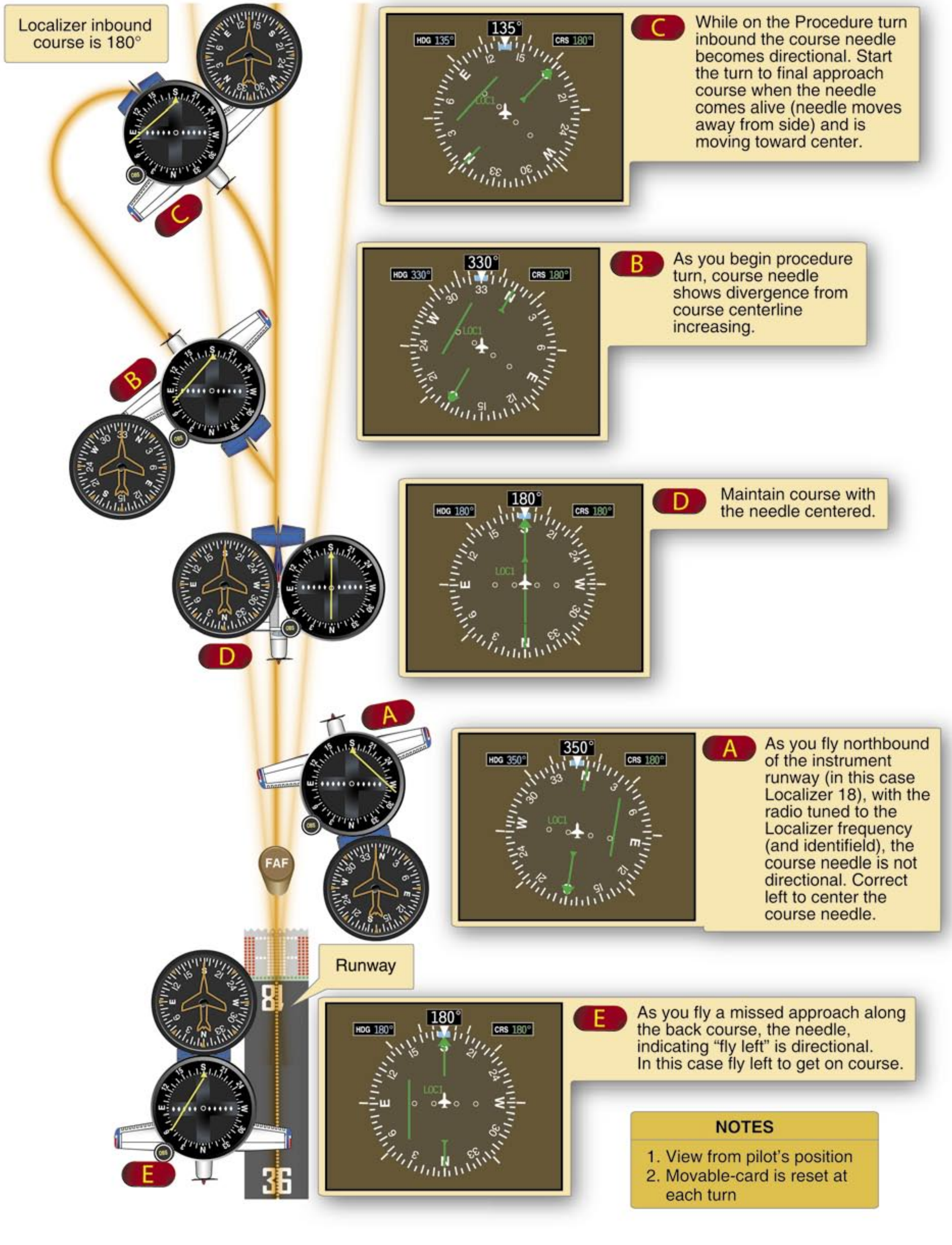

Localizer inbound course is 180°

C While on the Procedure turn inbound the course needle becomes directional. Start the turn to final approach course when the needle comes alive (needle moves away from side) and is moving toward center.

B As you begin procedure turn, course needle shows divergence from course centerline increasing.

D Maintain course with the needle centered.

A As you fly northbound of the instrument runway (in this case Localizer 18), with the radio tuned to the Localizer frequency (and identifield), the course needle is not directional. Correct left to center the course needle.

E As you fly a missed approach along the back course, the needle, indicating "fly left" is directional. In this case fly left to get on course.

NOTES

1. View from pilot's position
2. Movable-card is reset at each turn

Figure 7-39. *Localizer Course Indications. To follow indications displayed in the aircraft, start from A and proceed through E.*

proper rate of descent, and adjust power to maintain proper airspeed. Simultaneously, the altimeter must be checked and preparation made for visual transition to land or for a missed approach. You can appreciate the need for accurate instrument interpretation and aircraft control within the ILS as a whole, when you notice the relationship between CDI and glide path needle indications, and aircraft displacement from the localizer and glide path centerlines.

Deflection of the GS needle indicates the position of the aircraft with respect to the glide path. When the aircraft is above the glide path, the needle is deflected downward. When the aircraft is below the glide path, the needle is deflected upward. *[Figure 7-40]*

ILS Errors

The ILS and its components are subject to certain errors, which are listed below. Localizer and GS signals are subject to the same type of bounce from hard objects as space waves.

1. Reflection. Surface vehicles and even other aircraft flying below 5,000 feet above ground level (AGL) may disturb the signal for aircraft on the approach.
2. False courses. In addition to the desired course, GS facilities inherently produce additional courses at higher vertical angles. The angle of the lowest of these false courses will occur at approximately 9°–12°. An aircraft flying the LOC/GS course at a constant altitude would observe gyrations of both the GS needle and GS warning flag as the aircraft passed through the various false courses. Getting established on one of these false courses will result in either confusion (reversed GS needle indications) or in the need for a very high descent rate. However, if the approach is conducted at the altitudes specified on the appropriate approach chart, these false courses will not be encountered.

Marker Beacons

The very low power and directional antenna of the marker beacon transmitter ensures that the signal will not be received any distance from the transmitter site. Problems with signal reception are usually caused by the airborne receiver not being turned on, or by incorrect receiver sensitivity.

Some marker beacon receivers, to decrease weight and cost, are designed without their own power supply. These units utilize a power source from another radio in the avionics stack, often the ADF. In some aircraft, this requires the ADF to be turned on in order for the marker beacon receiver to function, yet no warning placard is required. Another

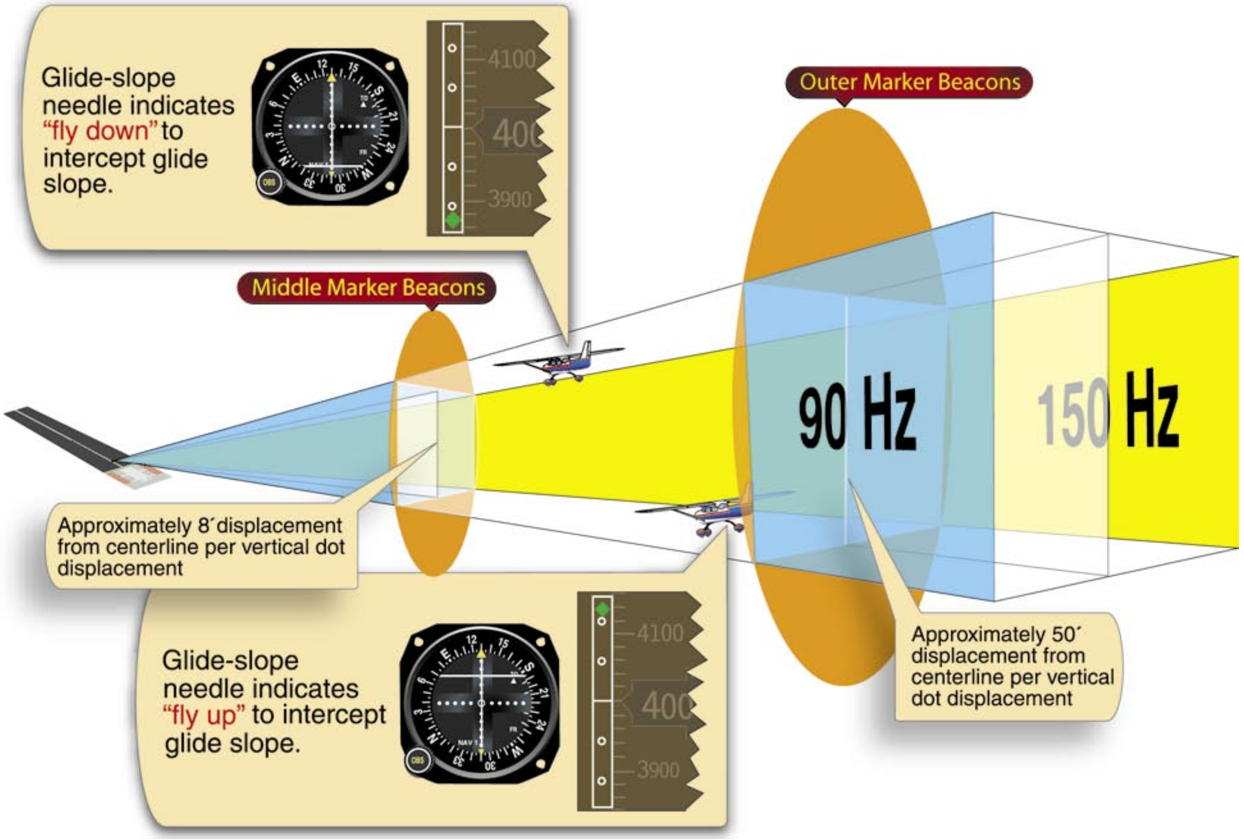
Glide-slope needle indicates "fly down" to intercept glide slope.

Approximately 8′ displacement from centerline per vertical dot displacement

Glide-slope needle indicates "fly up" to intercept glide slope.

Approximately 50′ displacement from centerline per vertical dot displacement

Figure 7-40. *Illustrates a GS receiver indication and aircraft displacement. An analog system is on the left and the same indication on the Garmin PFD on the right.*

source of trouble may be the "High/Low/Off" three-position switch, which both activates the receiver and selects receiver sensitivity. Usually, the "test" feature only tests to see if the light bulbs in the marker beacon lights are working. Therefore, in some installations, there is no functional way for the pilot to ascertain the marker beacon receiver is actually on except to fly over a marker beacon transmitter, and see if a signal is received and indicated (e.g., audibly, and visually via marker beacon lights).

Operational Errors

1. Failure to understand the fundamentals of ILS ground equipment, particularly the differences in course dimensions. Since the VOR receiver is used on the localizer course, the assumption is sometimes made that interception and tracking techniques are identical when tracking localizer courses and VOR radials. Remember that the CDI sensing is sharper and faster on the localizer course.
2. Disorientation during transition to the ILS due to poor planning and reliance on one receiver instead of on all available airborne equipment. Use all the assistance available; a single receiver may fail.
3. Disorientation on the localizer course, due to the first error noted above.
4. Incorrect localizer interception angles. A large interception angle usually results in overshooting, and possible disorientation. When intercepting, if possible, turn to the localizer course heading immediately upon the first indication of needle movement. An ADF receiver is an excellent aid to orient you during an ILS approach if there is a locator or NDB on the inbound course.
5. Chasing the CDI and glide path needles, especially when you have not sufficiently studied the approach before the flight.

Simplified Directional Facility (SDF)

The SDF provides a final approach course similar to the ILS localizer. The SDF course may or may not be aligned with the runway and the course may be wider than a standard ILS localizer, resulting in less precision. Usable off-course indications are limited to 35° either side of the course centerline. Instrument indications in the area between 35° and 90° from the course centerline are not controlled and should be disregarded.

The SDF must provide signals sufficient to allow satisfactory operation of a typical aircraft installation within a sector which extends from the center of the SDF antenna system to distances of 18 NM covering a sector 10° either side of centerline up to an angle 7° above the horizontal. The angle of convergence of the final approach course and the extended runway centerline must not exceed 30°. Pilots should note this angle since the approach course originates at the antenna site, and an approach continued beyond the runway threshold would lead the aircraft to the SDF offset position rather than along the runway centerline.

The course width of the SDF signal emitted from the transmitter is fixed at either 6° or 12°, as necessary, to provide maximum flyability and optimum approach course quality. A three-letter identifier is transmitted in code on the SDF frequency; there is no letter "I" (two dots) transmitted before the station identifier, as there is with the LOC. For example, the identifier for Lebanon, Missouri, SDF is LBO.

Localizer Type Directional Aid (LDA)

The LDA is of comparable utility and accuracy to a localizer but is not part of a complete ILS. The LDA course width is between 3° and 6° and thus provides a more precise approach course than an SDF installation. Some LDAs are equipped with a GS. The LDA course is not aligned with the runway, but straight-in minimums may be published where the angle between the runway centerline and the LDA course does not exceed 30°. If this angle exceeds 30°, only circling minimums are published. The identifier is three letters preceded by "I" transmitted in code on the LDA frequency. For example, the identifier for Van Nuys, California, LDA is I-BUR.

Microwave Landing System (MLS)

The MLS provides precision navigation guidance for exact alignment and descent of aircraft on approach to a runway. It provides azimuth, elevation, and distance. Both lateral and vertical guidance may be displayed on conventional course deviation indicators or incorporated into multipurpose flight deck displays. Range information can be displayed by conventional DME indicators and also incorporated into multipurpose displays. *[Figure 7-41]*

The system may be divided into five functions, which are approach azimuth, back azimuth, approach elevation, range; and data communications. The standard configuration of MLS ground equipment includes an azimuth station to perform functions as indicated above. In addition to providing azimuth navigation guidance, the station transmits basic data, which consists of information associated directly with the operation of the landing system, as well as advisory data on the performance of the ground equipment.

Approach Azimuth Guidance

The azimuth station transmits MLS angle and data on one of 200 channels within the frequency range of 5031 to 5091

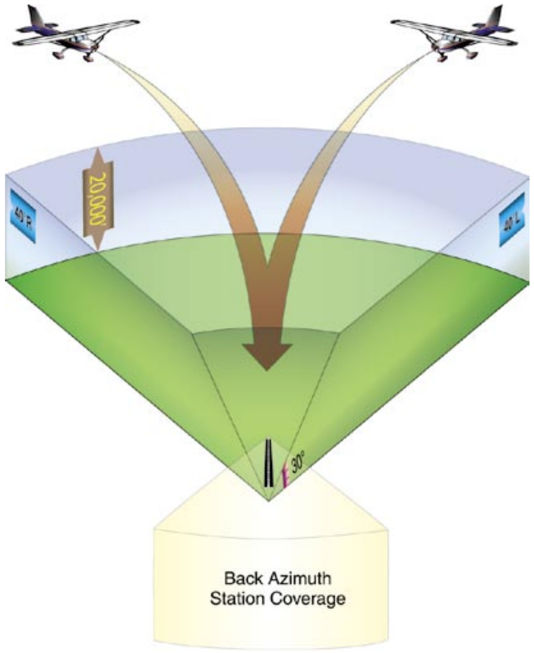

Figure 7-41. *MLS Coverage Volumes, 3-D Representation.*

MHz. The equipment is normally located about 1,000 feet beyond the stop end of the runway, but there is considerable flexibility in selecting sites. For example, for heliport operations the azimuth transmitter can be collocated with the elevation transmitter. The azimuth coverage extends laterally at least 40° on either side of the runway centerline in a standard configuration, in elevation up to an angle of 15° and to at least 20,000 feet, and in range to at least 20 NM.

MLS requires separate airborne equipment to receive and process the signals from what is normally installed in general aviation aircraft today. It has data communications capability, and can provide audible information about the condition of the transmitting system and other pertinent data such as weather, runway status, etc. The MLS transmits an audible identifier consisting of four letters beginning with the letter M, in Morse code at a rate of at least six per minute. The MLS system monitors itself and transmits ground-to-air data messages about the system's operational condition. During periods of routine or emergency maintenance, the coded identification is missing from the transmissions. At this time there are only a few systems installed.

Required Navigation Performance

RNP is a navigation system that provides a specified level of accuracy defined by a lateral area of confined airspace in which an RNP-certified aircraft operates. The continuing growth of aviation places increasing demands on airspace capacity and emphasizes the need for the best use of the available airspace. These factors, along with the accuracy of modern aviation navigation systems and the requirement for increased operational efficiency in terms of direct routings and track-keeping accuracy, have resulted in the concept of required navigation performance—a statement of the navigation performance accuracy necessary for operation within a defined airspace. RNP can include both performance and functional requirements, and is indicated by the RNP type. These standards are intended for designers, manufacturers, and installers of avionics equipment, as well as service providers and users of these systems for global operations. The minimum aviation system performance specification (MASPS) provides guidance for the development of airspace and operational procedures needed to obtain the benefits of improved navigation capability. *[Figure 7-42]*

The RNP type defines the total system error (TSE) that is allowed in lateral and longitudinal dimensions within a particular airspace. The TSE, which takes account of navigation system errors (NSE), computation errors, display errors and flight technical errors (FTE), must not exceed the specified RNP value for 95 percent of the flight time on any part of any single flight. RNP combines the accuracy standards laid out in the ICAO Manual (Doc 9613) with specific accuracy requirements, as well as functional and performance standards, for the RNAV system to realize a system that can meet future air traffic management requirements. The functional criteria for RNP address the need for the flight paths of participating aircraft to be both predictable and repeatable to the declared levels of accuracy. More information on RNP is contained in subsequent chapters.

The term RNP is also applied as a descriptor for airspace, routes, and procedures (including departures, arrivals, and IAPs). The descriptor can apply to a unique approach procedure or to a large region of airspace. RNP applies to navigation performance within a designated airspace, and includes the capability of both the available infrastructure (navigation aids) and the aircraft.

RNP type is used to specify navigation requirements for the airspace. The following are ICAO RNP Types: RNP-1.0, RNP-4.0, RNP-5.0, and RNP-10.0. The required performance is obtained through a combination of aircraft capability and the level of service provided by the corresponding navigation infrastructure. From a broad perspective:

Aircraft Capability + Level of Service = Access

In this context, aircraft capability refers to the airworthiness certification and operational approval elements (including avionics, maintenance, database, human factors, pilot procedures, training, and other issues). The level of service element refers to the NAS infrastructure, including published routes, signal-in-space performance and availability, and air

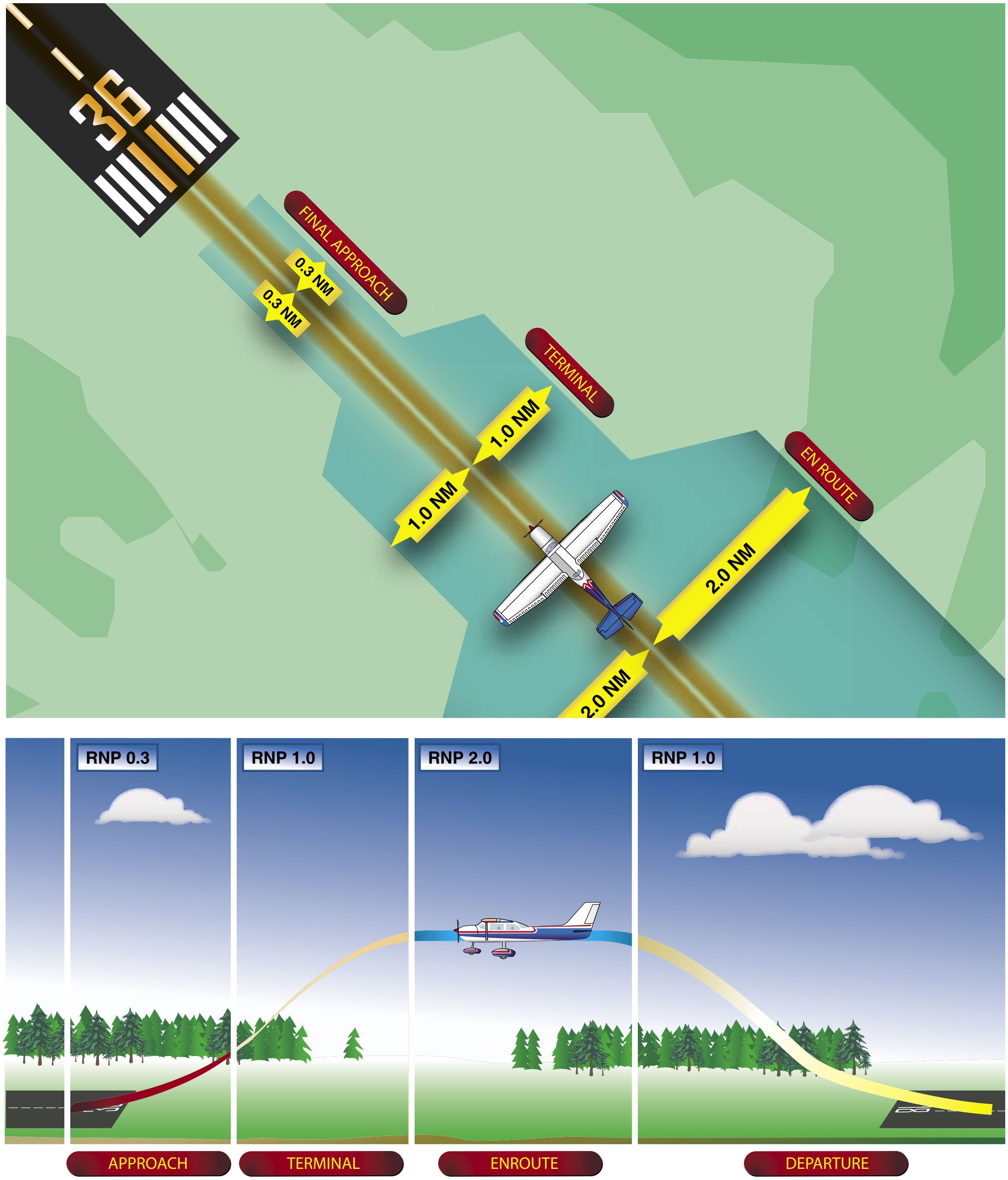
36
FINAL APPROACH
0.3 NM
0.3 NM
TERMINAL
1.0 NM
1.0 NM
EN ROUTE
2.0 NM
2.0 NM
RNP 0.3
RNP 1.0
RNP 2.0
RNP 1.0
APPROACH
TERMINAL
ENROUTE
DEPARTURE

Figure 7-42. *Required Navigation Performance.*

traffic management. When considered collectively, these elements result in providing access. Access provides the desired benefit (airspace, procedures, routes of flight, etc.). RNP levels are actual distances from the centerline of the flight path, which must be maintained for aircraft and obstacle separation. Although additional FAA-recognized RNP levels may be used for specific operations, the United States currently supports three standard RNP levels:

- RNP 0.3 – Approach
- RNP 1.0 – Departure, Terminal
- RNP 2.0 – En route

RNP 0.3 represents a distance of 0.3 NM either side of a specified flight path centerline. The specific performance that is required on the final approach segment of an instrument approach is an example of this RNP level. At the present time, a 0.3 RNP level is the lowest level used in normal RNAV operations. Specific airlines, using special procedures, are approved to use RNP levels lower than RNP 0.3, but those levels are used only in accordance with their approved operations specifications (OpsSpecs). For aircraft equipment to qualify for a specific RNP type, it must maintain navigational accuracy at least 95 percent of the total flight time.

Flight Management Systems (FMS)

A flight management system (FMS) is not a navigation system in itself. Rather, it is a system that automates the tasks of managing the onboard navigation systems. FMS may perform other onboard management tasks, but this discussion is limited to its navigation function.

FMS is an interface between flight crews and flight-deck systems. FMS can be thought of as a computer with a large database of airport and NAVAID locations and associated data, aircraft performance data, airways, intersections, DPs, and STARs. FMS also has the ability to accept and store numerous user-defined WPs, flight routes consisting of departures, WPs, arrivals, approaches, alternates, etc. FMS can quickly define a desired route from the aircraft's current position to any point in the world, perform flight plan computations, and display the total picture of the flight route to the crew.

FMS also has the capability of controlling (selecting) VOR, DME, and LOC NAVAIDs, and then receiving navigational data from them. INS, LORAN, and GPS navigational data may also be accepted by the FMS computer. The FMS may act as the input/output device for the onboard navigation systems, so that it becomes the "go-between" for the crew and the navigation systems.

Function of FMS

At startup, the crew programs the aircraft location, departure runway, DP (if applicable), WPs defining the route, approach procedure, approach to be used, and routing to alternate. This may be entered manually, be in the form of a stored flight plan, or be a flight plan developed in another computer and transferred by disk or electronically to the FMS computer. The crew enters this basic information in the control/display unit (CDU). *[Figure 7-43]*

Once airborne, the FMS computer channels the appropriate NAVAIDs and takes radial/distance information, or channels two NAVAIDs, taking the more accurate distance information. FMS then indicates position, track, desired heading, groundspeed and position relative to desired track. Position information from the FMS updates the INS. In more sophisticated aircraft, the FMS provides inputs to the HSI, RMI, glass flight deck navigation displays, head-up display (HUD), autopilot, and autothrottle systems.

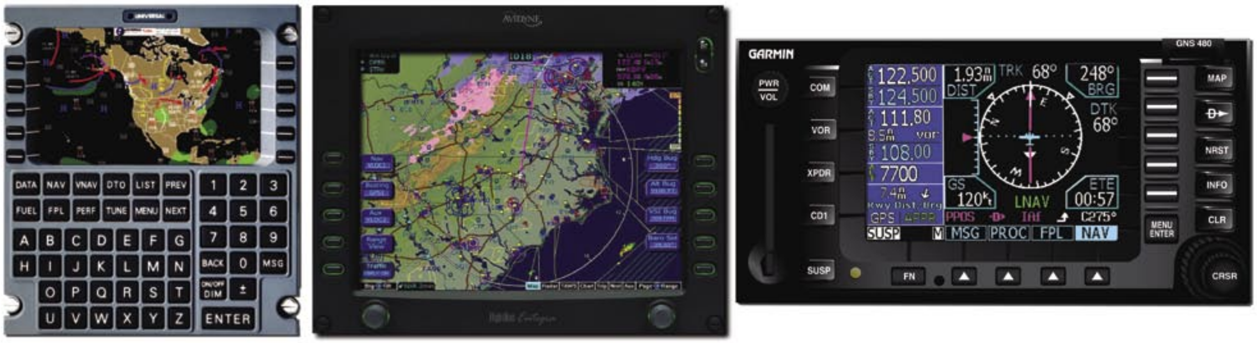

Figure 7-43. *Typical Display and Control Unit(s) in General Aviation. The Universal UNS-1 (left) controls and integrates all other systems. The Avidyne (center) and Garmin systems (right) illustrate and are typical of completely integrated systems. Although the Universal CDU is not typically found on smaller general aviation aircraft, the difference in capabilities of the CDUs and stand-alone sytems is diminishing each year.*

Head-Up Display (HUD)

The HUD is a display system that provides a projection of navigation and air data (airspeed in relation to approach reference speed, altitude, left/right and up/down GS) on a transparent screen between the pilot and the windshield. Other information may be displayed, including a runway target in relation to the nose of the aircraft. This allows the pilot to see the information necessary to make the approach while also being able to see out the windshield, which diminishes the need to shift between looking at the panel to looking outside. Virtually any information desired can be displayed on the HUD if it is available in the aircraft's flight computer, and if the display is user definable. *[Figure 7-44]*

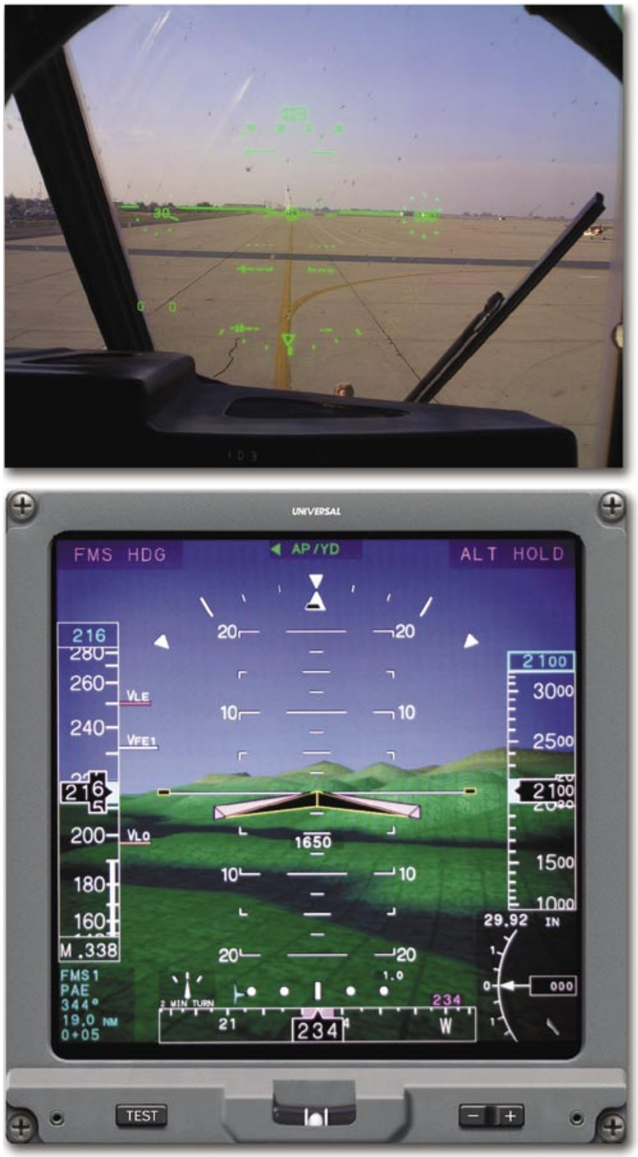

Figure 7-44. *Example of a Head-Up Display (top) and a Head-Down Display (bottom). The head-up display presents information in front of the pilot along his/her normal field of view while a head-down display may present information beyond the normal head-up field of view.*

Radar Navigation (Ground Based)

Radar works by transmitting a pulse of RF energy in a specific direction. The return of the echo or bounce of that pulse from a target is precisely timed. From this, the distance traveled by the pulse and its echo is determined and displayed on a radar screen in such a manner that the distance and bearing to this target can be instantly determined. The radar transmitter must be capable of delivering extremely high power levels toward the airspace under surveillance, and the associated radar receiver must be able to detect extremely small signal levels of the returning echoes.

The radar display system provides the controller with a map-like presentation upon which appear all the radar echoes of aircraft within detection range of the radar facility. By means of electronically generated range marks and azimuth-indicating devices, the controller can locate each radar target with respect to the radar facility, or can locate one radar target with respect to another.

Another device, a video-mapping unit, generates an actual airway or airport map and presents it on the radar display equipment. Using the video-mapping feature, the air traffic controller not only can view the aircraft targets, but can see these targets in relation to runways, navigation aids, and hazardous ground obstructions in the area. Therefore, radar becomes a NAVAID, as well as the most significant means of traffic separation.

In a display presenting perhaps a dozen or more targets, a primary surveillance radar system cannot identify one specific radar target, and it may have difficulty "seeing" a small target at considerable distance—especially if there is a rain shower or thunderstorm between the radar site and the aircraft. This problem is solved with the Air Traffic Control Radar Beacon System (ATCRBS), sometimes called secondary surveillance radar (SSR), which utilizes a transponder in the aircraft. The ground equipment is an interrogating unit, in which the beacon antenna is mounted so it rotates with the surveillance antenna. The interrogating unit transmits a coded pulse sequence that actuates the aircraft transponder. The transponder answers the coded sequence by transmitting a preselected coded sequence back to the ground equipment, providing a strong return signal and positive aircraft identification, as well as other special data such as aircraft altitude.

Functions of Radar Navigation

The radar systems used by ATC are air route surveillance radar (ARSR), airport surveillance radar (ASR), and precision approach radar (PAR) and airport surface detection equipment

(ASDE). Surveillance radars scan through 360° of azimuth and present target information on a radar display located in a tower or center. This information is used independently or in conjunction with other navigational aids in the control of air traffic.

ARSR is a long-range radar system designed primarily to cover large areas and provide a display of aircraft while en route between terminal areas. The ARSR enables air route traffic control center (ARTCC) controllers to provide radar service when the aircraft are within the ARSR coverage. In some instances, ARSR may enable ARTCC to provide terminal radar services similar to but usually more limited than those provided by a radar approach control.

ASR is designed to provide relatively short-range coverage in the general vicinity of an airport and to serve as an expeditious means of handling terminal area traffic through observation of precise aircraft locations on a radarscope. Nonprecision instrument approaches are available at airports that have an approved surveillance radar approach procedure. ASR provides radar vectors to the final approach course and then azimuth information to the pilot during the approach. In addition to range (distance) from the runway, the pilot is advised of MDA, when to begin descent, and when the aircraft is at the MDA. If requested, recommended altitudes will be furnished each mile while on final.

PAR is designed to be used as a landing aid displaying range, azimuth, and elevation information rather than as an aid for sequencing and spacing aircraft. PAR equipment may be used as a primary landing aid, or it may be used to monitor other types of approaches. Two antennas are used in the PAR array, one scanning a vertical plane, and the other scanning horizontally. Since the range is limited to 10 miles, azimuth to 20°, and elevation to 7°, only the final approach area is covered. The controller's scope is divided into two parts. The upper half presents altitude and distance information, and the lower half presents azimuth and distance.

PAR is a system in which a controller provides highly accurate navigational guidance in azimuth and elevation to a pilot. Pilots are given headings to fly to direct them to and keep their aircraft aligned with the extended centerline of the landing runway. They are told to anticipate glide path interception approximately 10–30 seconds before it occurs and when to start descent. The published decision height (DH) is given only if the pilot requests it. If the aircraft is observed to deviate above or below the glide path, the pilot is given the relative amount of deviation by use of terms "slightly" or "well" and is expected to adjust the aircraft's rate of descent/ascent to return to the glide path. Trend information is also issued with respect to the elevation of the aircraft and may be modified by the terms "rapidly" and "slowly" (e.g., "well above glide path, coming down rapidly"). Range from touchdown is given at least once each mile. If an aircraft is observed by the controller to proceed outside of specified safety zone limits in azimuth and/or elevation and continue to operate outside these prescribed limits, the pilot will be directed to execute a missed approach or to fly a specified course unless the pilot has the runway environment (runway, approach lights, etc.) in sight. Navigational guidance in azimuth and elevation is provided to the pilot until the aircraft reaches the published decision altitude (DA)/DH. Advisory course and glide path information is furnished by the controller until the aircraft passes over the landing threshold, at which point the pilot is advised of any deviation from the runway centerline. Radar service is automatically terminated upon completion of the approach.

Airport Surface Detection Equipment

Radar equipment is specifically designed to detect all principal features on the surface of an airport, including aircraft and vehicular traffic, and to present the entire image on a radar indicator console in the control tower. It is used to augment visual observation by tower personnel of aircraft and/or vehicular movements on runways and taxiways.

Radar Limitations

1. It is very important for the aviation community to recognize the fact that there are limitations to radar service and that ATC controllers may not always be able to issue traffic advisories concerning aircraft which are not under ATC control and cannot be seen on radar.
2. The characteristics of radio waves are such that they normally travel in a continuous straight line unless they are "bent" by abnormal atmospheric phenomena such as temperature inversions; reflected or attenuated by dense objects such as heavy clouds, precipitation, ground obstacles, mountains, etc.; or screened by high terrain features.
3. Primary radar energy that strikes dense objects will be reflected and displayed on the operator's scope, thereby blocking out aircraft at the same range and greatly weakening or completely eliminating the display of targets at a greater range.
4. Relatively low altitude aircraft will not be seen if they are screened by mountains or are below the radar beam due to curvature of the Earth.
5. The amount of reflective surface of an aircraft will determine the size of the radar return. Therefore, a small light airplane or a sleek jet fighter will be more difficult to see on primary radar than a large commercial jet or military bomber.

6. All ARTCC radar in the conterminous United States and many ASR have the capability to interrogate Mode C and display altitude information to the controller from appropriately equipped aircraft. However, a number of ASR do not have Mode C display capability; therefore, altitude information must be obtained from the pilot.

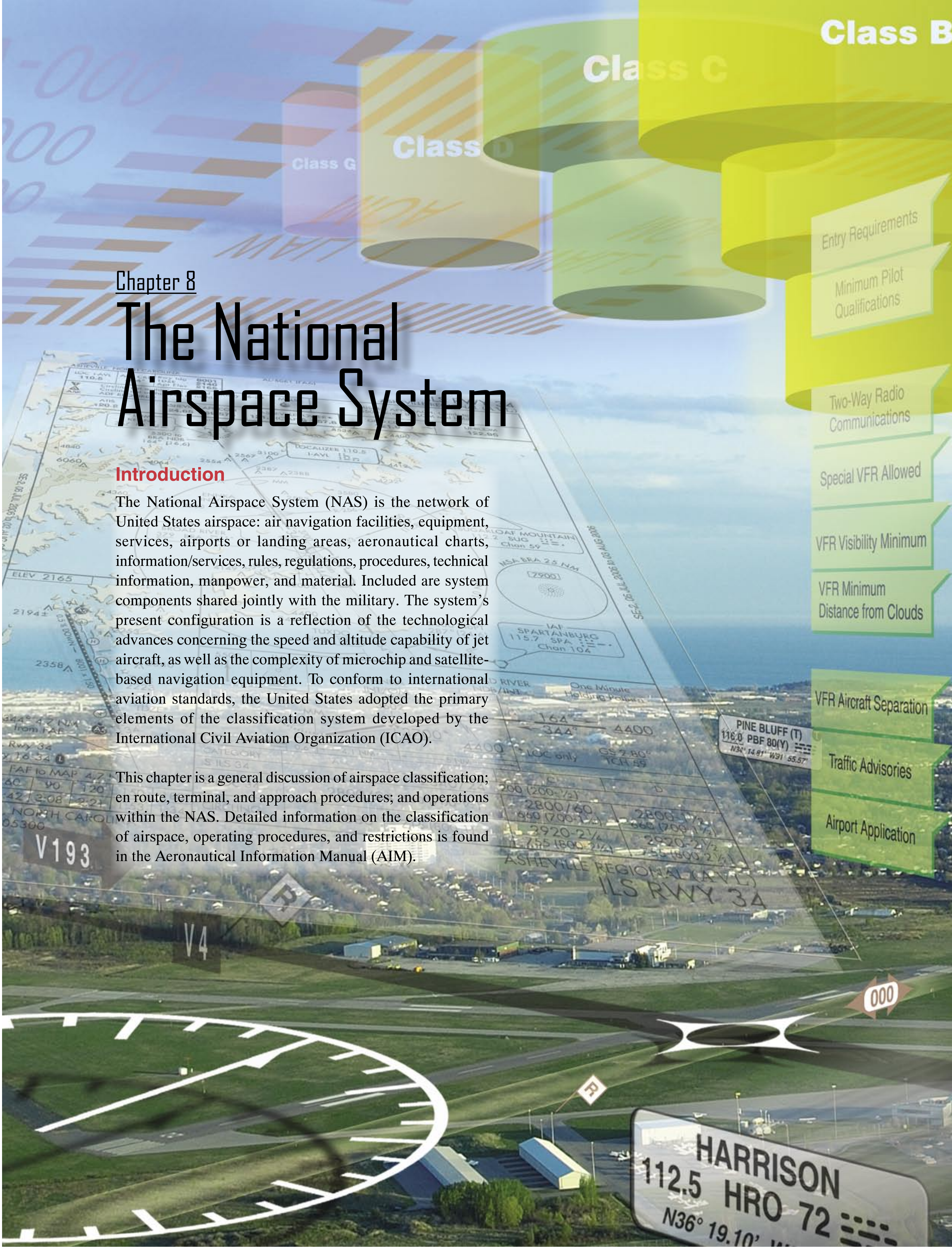
Class B
Class C
Class D
Class G
Entry Requirements
Minimum Pilot Qualifications
Two-Way Radio Communications
Special VFR Allowed
VFR Visibility Minimum
VFR Minimum Distance from Clouds
VFR Aircraft Separation
Traffic Advisories
Airport Application
PINE BLUFF (T)
116.0 PBF 80(Y)
V193
V4
ASHEVILLE REGIONAL (AVL)
ILS RWY 34
HARRISON
112.5 HRO 72
N36° 19.10'
000

Chapter 8

The National Airspace System

Introduction

The National Airspace System (NAS) is the network of United States airspace: air navigation facilities, equipment, services, airports or landing areas, aeronautical charts, information/services, rules, regulations, procedures, technical information, manpower, and material. Included are system components shared jointly with the military. The system's present configuration is a reflection of the technological advances concerning the speed and altitude capability of jet aircraft, as well as the complexity of microchip and satellite-based navigation equipment. To conform to international aviation standards, the United States adopted the primary elements of the classification system developed by the International Civil Aviation Organization (ICAO).

This chapter is a general discussion of airspace classification; en route, terminal, and approach procedures; and operations within the NAS. Detailed information on the classification of airspace, operating procedures, and restrictions is found in the Aeronautical Information Manual (AIM).

Airspace Classification

Airspace in the United States *[Figure 8-1]* is designated as follows:

1. Class A. Generally, airspace from 18,000 feet mean sea level (MSL) up to and including flight level (FL) 600, including the airspace overlying the waters within 12 nautical miles (NM) of the coast of the 48 contiguous states and Alaska. Unless otherwise authorized, all pilots must operate their aircraft under instrument flight rules (IFR).
2. Class B. Generally, airspace from the surface to 10,000 feet MSL surrounding the nation's busiest airports in terms of airport operations or passenger enplanements. The configuration of each Class B airspace area is individually tailored, consists of a surface area and two or more layers (some Class B airspace areas resemble upside-down wedding cakes), and is designed to contain all published instrument procedures once an aircraft enters the airspace. An air traffic control (ATC) clearance is required for all aircraft to operate in the area, and all aircraft that are so cleared receive separation services within the airspace.
3. Class C. Generally, airspace from the surface to 4,000 feet above the airport elevation (charted in MSL) surrounding those airports that have an operational control tower, are serviced by a radar approach control, and have a certain number of IFR operations or passenger enplanements. Although the configuration of each Class C area is individually tailored, the airspace usually consists of a surface area with a 5 NM radius, an outer circle with a 10 NM radius that extends from 1,200 feet to 4,000 feet above the airport elevation and an outer area. Each aircraft must establish two-way radio communications with the ATC facility providing air traffic services prior to entering the airspace and thereafter maintain those communications while within the airspace.
4. Class D. Generally, that airspace from the surface to 2,500 feet above the airport elevation (charted in MSL) surrounding those airports that have an operational control tower. The configuration of each Class D airspace area is individually tailored and when instrument procedures are published, the airspace will normally be designed to contain the procedures. Arrival extensions for instrument approach procedures (IAPs) may be Class D or Class E airspace. Unless otherwise authorized, each aircraft must establish two-way radio communications with the ATC facility providing air traffic services prior to entering the airspace and thereafter maintain those communications while in the airspace.
5. Class E. Generally, if the airspace is not Class A, B, C, or D, and is controlled airspace, then it is Class E airspace. Class E airspace extends upward from either the surface or a designated altitude to the overlying or adjacent controlled airspace. When designated as a surface area, the airspace will be configured to contain all instrument procedures. Also in this class are federal airways, airspace beginning at either 700 or 1,200 feet above ground level (AGL) used to transition to and from the terminal or en route environment, and en route domestic and offshore airspace areas designated below 18,000 feet MSL. Unless designated at a lower altitude, Class E airspace begins at 14,500 MSL over the United States, including that airspace overlying the waters within 12 NM of the coast of the 48 contiguous states and Alaska, up to but not including 18,000 feet MSL, and the airspace above FL 600.
6. Class G. Airspace not designated as Class A, B, C, D, or E. Class G airspace is essentially uncontrolled by ATC except when associated with a temporary control tower.

Special Use Airspace

Special use airspace is the designation for airspace in which certain activities must be confined, or where limitations may be imposed on aircraft operations that are not part of those activities. Certain special use airspace areas can create limitations on the mixed use of airspace. The special use airspace depicted on instrument charts includes the area name or number, effective altitude, time and weather conditions of operation, the controlling agency, and the chart panel location. On National Aeronautical Charting Group (NACG) en route charts, this information is available on one of the end panels.

Prohibited areas contain airspace of defined dimensions within which the flight of aircraft is prohibited. Such areas are established for security or other reasons associated with the national welfare. These areas are published in the Federal Register and are depicted on aeronautical charts. The area is charted as a "P" followed by a number (e.g., "P-123").

Restricted areas are areas where operations are hazardous to nonparticipating aircraft and contain airspace within which the flight of aircraft, while not wholly prohibited, is subject to restrictions. Activities within these areas must be confined because of their nature, or limitations may be imposed upon aircraft operations that are not a part of those activities, or both. Restricted areas denote the existence of unusual, often invisible, hazards to aircraft (e.g., artillery firing, aerial

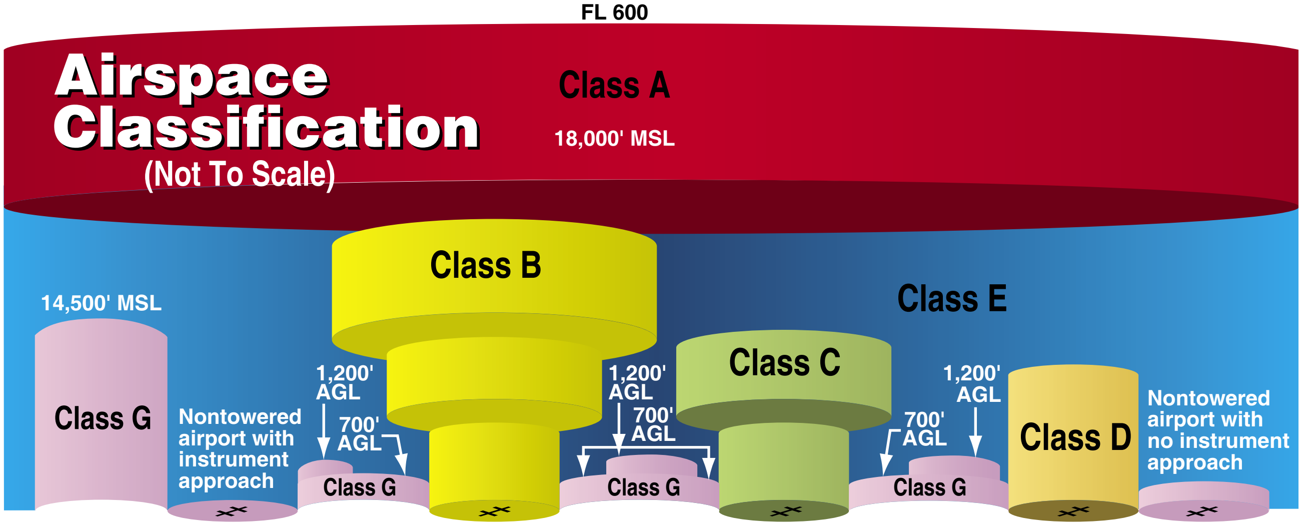
FL 600
Airspace Classification
(Not To Scale)
Class A
18,000' MSL
Class B
Class E
14,500' MSL
Class G
Nontowered airport with instrument approach
1,200' AGL
700' AGL
Class G
1,200' AGL
700' AGL
Class C
Class G
700' AGL
1,200' AGL
Class G
Class D
Nontowered airport with no instrument approach

	Class A	Class B	Class C	Class D	Class E	Class G
Entry Requirements	ATC clearance	ATC clearance	Prior two-way communications	Prior two-way communications	Prior two-way communications*	Prior two-way communications*
Minimum Pilot Qualifications	Instrument Rating	Private or Student certification—local restrictions apply.	Student certificate	Student certificate	Student certificate	Student certificate
Two-Way Radio Communications	Yes	Yes	Yes	Yes	Yes, under IFR flight plan*	Yes*
Special VFR Allowed	No	Yes	Yes	Yes	Yes	N/A
VFR Visibility Minimum	N/A	3 statute miles	3 statute miles	3 statute miles	3 statute miles**	1 statute mile†
VFR Minimum Distance from Clouds	N/A	Clear of clouds	500' below, 1,000' above, 2,000' horizontal	500' below, 1,000' above, 2,000' horizontal	500' below,** 1,000' above, 2,000' horizontal	Clear of clouds†
VFR Aircraft Separation	N/A	All	IFR aircraft	Runway operations	None	None
Traffic Advisories	Yes	Yes	Yes	Workload permitting	Workload permitting	Workload permitting
Airport Application	N/A	• Radar • Instrument approaches • Weather • Control tower • High density	• Radar • Instrument approaches • Weather • Control tower	• Instrument approaches • Weather • Control tower	• Instrument approaches • Weather	• Control tower

*Exception: temporary tower or control tower present
**True only below 10,000 feet
† True only during day at or below 1,200 feet AGL (see 14 CFR part 91)

AGL—above ground level
FL—flight level
MSL—mean sea level

Figure 8-1. *Airspace Classifications.*

gunnery, or guided missiles). IFR flights may be authorized to transit the airspace and are routed accordingly. Penetration of restricted areas without authorization from the using or controlling agency may be extremely hazardous to the aircraft and its occupants. ATC facilities apply the following procedures when aircraft are operating on an IFR clearance (including those cleared by ATC to maintain visual flight rules (VFR)-On-Top) via a route that lies within joint-use restricted airspace:

1. If the restricted area is not active and has been released to the Federal Aviation Administration (FAA), the ATC facility will allow the aircraft to operate in the restricted airspace without issuing specific clearance for it to do so.
2. If the restricted area is active and has not been released to the FAA, the ATC facility will issue a clearance which will ensure the aircraft avoids the restricted airspace.

Restricted areas are charted with an "R" followed by a number (e.g., "R-5701") and are depicted on the en route chart appropriate for use at the altitude or FL being flown.

Warning areas are similar in nature to restricted areas; however, the United States government does not have sole jurisdiction over the airspace. A warning area is airspace of defined dimensions, extending from 12 NM outward from the coast of the United States, containing activity that may be hazardous to nonparticipating aircraft. The purpose of such areas is to warn nonparticipating pilots of the potential danger. A warning area may be located over domestic or international waters or both. The airspace is designated with a "W" followed by a number (e.g., "W-123").

Military operations areas (MOAs) consist of airspace with defined vertical and lateral limits established for the purpose of separating certain military training activities from IFR traffic. Whenever an MOA is being used, nonparticipating IFR traffic may be cleared through an MOA if IFR separation can be provided by ATC. Otherwise, ATC will reroute or restrict nonparticipating IFR traffic. MOAs are depicted on sectional, VFR terminal area, and en route low altitude charts and are not numbered (e.g., "Boardman MOA").

Alert areas are depicted on aeronautical charts with an "A" followed by a number (e.g., "A-123") to inform nonparticipating pilots of areas that may contain a high volume of pilot training or an unusual type of aerial activity. Pilots should exercise caution in alert areas. All activity within an alert area shall be conducted in accordance with regulations, without waiver, and pilots of participating aircraft, as well as pilots transiting the area, shall be equally responsible for collision avoidance.

Military Training Routes (MTRs) are routes used by military aircraft to maintain proficiency in tactical flying. These routes are usually established below 10,000 feet MSL for operations at speeds in excess of 250 knots. Some route segments may be defined at higher altitudes for purposes of route continuity. Routes are identified as IFR (IR), and VFR (VR), followed by a number. MTRs with no segment above 1,500 feet AGL are identified by four number characters (e.g., IR1206, VR1207, etc.). MTRs that include one or more segments above 1,500 feet AGL are identified by three number characters (e.g., IR206, VR207). IFR Low Altitude En Route Charts depict all IR routes and all VR routes that accommodate operations above 1,500 feet AGL. IR routes are conducted in accordance with IFR regardless of weather conditions.

Temporary flight restrictions (TFRs) are put into effect when traffic in the airspace would endanger or hamper air or ground activities in the designated area. For example, a forest fire, chemical accident, flood, or disaster-relief effort could warrant a TFR, which would be issued as a Notice to Airmen (NOTAM).

National Security Areas (NSAs) consist of airspace with defined vertical and lateral dimensions established at locations where there is a requirement for increased security and safety of ground facilities. Flight in NSAs may be temporarily prohibited by regulation under the provisions of Title 14 of the Code of Federal Regulations (14 CFR) part 99 and prohibitions will be disseminated via NOTAM.

Federal Airways

The primary means for routing aircraft operating under IFR is the federal airways system.

Each federal airway is based on a centerline that extends from one NAVAID/waypoint/fix/intersection to another NAVAID/waypoint/fix/intersection specified for that airway. A federal airway includes the airspace within parallel boundary lines four NM to each side of the centerline. As in all instrument flight, courses are magnetic, and distances are in NM. The airspace of a federal airway has a floor of 1,200 feet AGL, unless otherwise specified. A federal airway does not include the airspace of a prohibited area.

Victor airways include the airspace extending from 1,200 feet AGL up to, but not including 18,000 feet MSL. The airways are designated on Sectional and IFR low altitude en route charts with the letter "V" followed by a number (e.g., "V23"). Typically, Victor airways are given odd numbers when oriented north/south and even numbers when oriented east/west. If more than one airway coincides on a route segment, the numbers are listed serially (e.g., "V287-495-500"). *[Figure 8-2]*

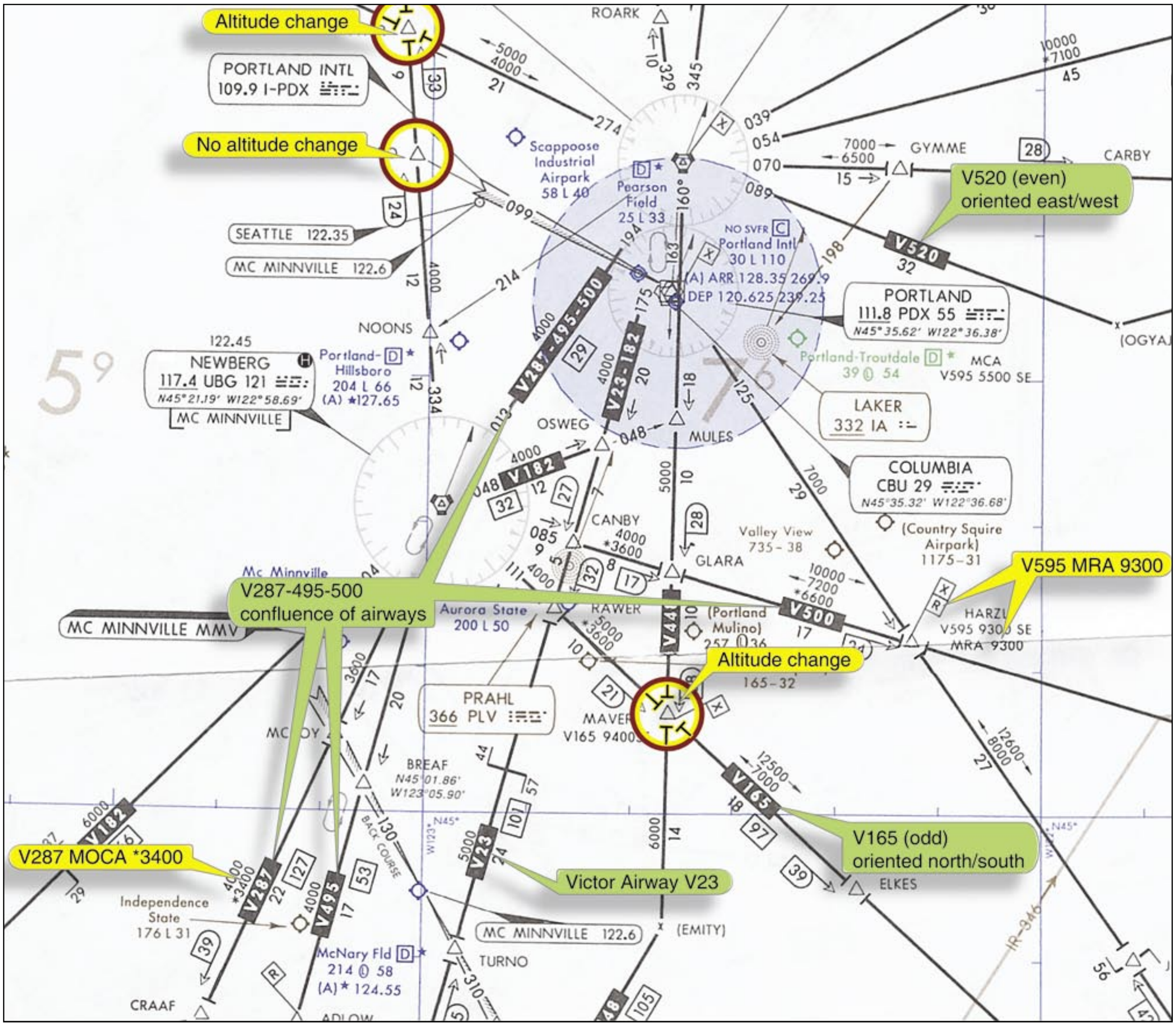
Altitude change
PORTLAND INTL
109.9 I-PDX
No altitude change
SEATTLE 122.35
MC MINNVILLE 122.6
NOONS
122.45
NEWBERG
117.4 UBG 121
N45°21.19' W122°58.69'
MC MINNVILLE
Portland-Hillsboro
204 L 66
(A) ★127.65
Scappoose Industrial Airpark
58 L 40
Pearson Field
25 L 33
ROARK
NO SVFR
Portland Intl
30 L 110
(A) ARR 128.35 269.9
DEP 120.625 239.25
GYMME
CARBY
V520 (even)
oriented east/west
PORTLAND
111.8 PDX 55
N45°35.62' W122°36.38'
(OGYA)
Portland-Troutdale
39 54
MCA
V595 5500 SE
LAKER
332 IA
COLUMBIA
CBU 29
N45°35.32' W122°36.68'
(Country Squire Airpark)
1175-31
Valley View
735-38
OSWEG
MULES
CANBY
GLARA
V595 MRA 9300
HARZL
V595 9300 SE
MRA 9300
V287-495-500
confluence of airways
Mc Minnville
MC MINNVILLE MMV
Aurora State
200 L 50
RAWER
(Portland Mulino)
257 36
Altitude change
165-32
PRAHL
366 PLV
MAVER
V165 9400
BREAF
N45°01.86'
W123°05.90'
MC COY
V287 MOCA *3400
Independence State
176 L 31
McNary Fld
214 58
(A) ★ 124.55
V165 (odd)
oriented north/south
ELKES
Victor Airway V23
MC MINNVILLE 122.6
(EMITY)
TURNO
CRAAF
ADLOW
IR-346

Figure 8-2. *Victor Airways and Charted IFR Altitudes.*

Jet routes exist only in Class A airspace, from 18,000 feet MSL to FL 450, and are depicted on high-altitude en route charts. The letter "J" precedes a number to label the airway (e.g., J12).

RNAV routes have been established in both the low-altitude and the high-altitude structures in recent years and are depicted on the en route low and high chart series. High altitude RNAV routes are identified with a "Q" prefix (except the Q-routes in the Gulf of Mexico) and low altitude RNAV routes are identified with a "T" prefix. RNAV routes and data are depicted in aeronautical blue.

In addition to the published routes, a random RNAV route may be flown under IFR if it is approved by ATC. Random RNAV routes are direct routes, based on area navigation capability, between waypoints defined in terms of latitude/longitude coordinates, degree-distance fixes, or offsets from established routes/airways at a specified distance and direction.

Radar monitoring by ATC is required on all random RNAV routes. These routes can only be approved in a radar environment. Factors that will be considered by ATC in approving random RNAV routes include the capability to provide radar monitoring, and compatibility with traffic volume and flow. ATC will radar monitor each flight; however, navigation on the random RNAV route is the responsibility of the pilot.

Other Routing

Preferred IFR routes have been established between major terminals to guide pilots in planning their routes of flight, minimizing route changes and aiding in the orderly management of air traffic on federal airways. Low and high altitude preferred routes are listed in the Airport/Facility Directory (A/FD). To use a preferred route, reference the departure and arrival airports; if a routing exists for your flight, then airway instructions will be listed.

Tower En Route Control (TEC) is an ATC program that uses overlapping approach control radar services to provide IFR clearances. By using TEC, a pilot is routed by airport control towers. Some advantages include abbreviated filing procedures and reduced traffic separation requirements. TEC is dependent upon the ATC's workload, and the procedure varies among locales.

The latest version of Advisory Circular (AC) 90-91, North American Route Program (NRP), provides guidance to users of the NAS for participation in the NRP. All flights operating at or above FL 290 within the conterminous United States and Canada are eligible to participate in the NRP, the primary purpose of which is to allow operators to plan minimum time/cost routes that may be off the prescribed route structure. NRP aircraft are not subject to route-limiting restrictions (e.g., published preferred IFR routes) beyond a 200 NM radius of their point of departure or destination.

IFR En Route Charts

The objective of IFR en route flight is to navigate within the lateral limits of a designated airway at an altitude consistent with the ATC clearance. Your ability to fly instruments safely and competently in the system is greatly enhanced by understanding the vast array of data available to the pilot on instrument charts. The NACG maintains and produces the charts for the United States government.

En route high-altitude charts provide aeronautical information for en route instrument navigation (IFR) at or above 18,000 feet MSL. Information includes the portrayal of Jet and RNAV routes, identification and frequencies of radio aids, selected airports, distances, time zones, special use airspace, and related information. Established Jet routes from 18,000 feet MSL to FL 450 use NAVAIDs not more than 260 NM apart. The charts are revised every 56 days.

To effectively depart from one airport and navigate en route under instrument conditions a pilot needs the appropriate IFR en route low-altitude chart(s). The IFR low altitude en route chart is the instrument equivalent of the Sectional chart. When folded, the cover of the NACG en route chart displays an index map of the United States showing the coverage areas. Cities near congested airspace are shown in black type and their associated area chart is listed in the box in the lower left-hand corner of the map coverage box. Also noted is an explanation of the off-route obstruction clearance altitude (OROCA). The effective date of the chart is printed on the other side of the folded chart. Information concerning MTRs is also included on the chart cover. The en route charts are revised every 56 days.

When the NACG en route chart is unfolded, the legend is displayed and provides information concerning airports, NAVAIDs, communications, air traffic services, and airspace.

Airport Information

Airport information is provided in the legend, and the symbols used for the airport name, elevation, and runway length are similar to the sectional chart presentation. Associated city names are shown for public airports only. FAA identifiers are shown for all airports. ICAO identifiers are also shown for airports outside of the contiguous United States. Instrument approaches can be found at airports with blue or green symbols, while the brown airport symbol denotes airports that do not have instrument approaches. Stars are used to indicate the part-time nature of tower operations, ATIS frequencies, part-time or on request lighting facilities, and part-time airspace classifications. A box after an airport name with a "C" or "D" inside indicates Class C and D airspace, respectively, per *Figure 8-3*. D

Charted IFR Altitudes

The minimum en route altitude (MEA) ensures a navigation signal strong enough for adequate reception by the aircraft navigation (NAV) receiver and obstacle clearance along the airway. Communication is not necessarily guaranteed with MEA compliance. The obstacle clearance, within the limits of the airway, is typically 1,000 feet in non-mountainous areas and 2,000 feet in designated mountainous areas. MEAs can be authorized with breaks in the signal coverage; if this is the case, the NACG en route chart notes "MEA GAP" parallel to the affected airway. MEAs are usually bidirectional; however, they can be single-directional. Arrows are used to indicate the direction to which the MEA applies.

The minimum obstruction clearance altitude (MOCA), as the name suggests, provides the same obstruction clearance as an MEA; however, the NAV signal reception is ensured only within 22 NM of the closest NAVAID defining the route. The MOCA is listed below the MEA and indicated on NACG charts by a leading asterisk (e.g., "*3400"—see *Figure 8-2*, V287 at bottom left).

The minimum reception altitude (MRA) identifies the lowest altitude at which an intersection can be determined from an off-course NAVAID. If the reception is line-of-sight based, signal coverage will only extend to the MRA or above. However, if the aircraft is equipped with distance measuring equipment (DME) and the chart indicates the intersection can

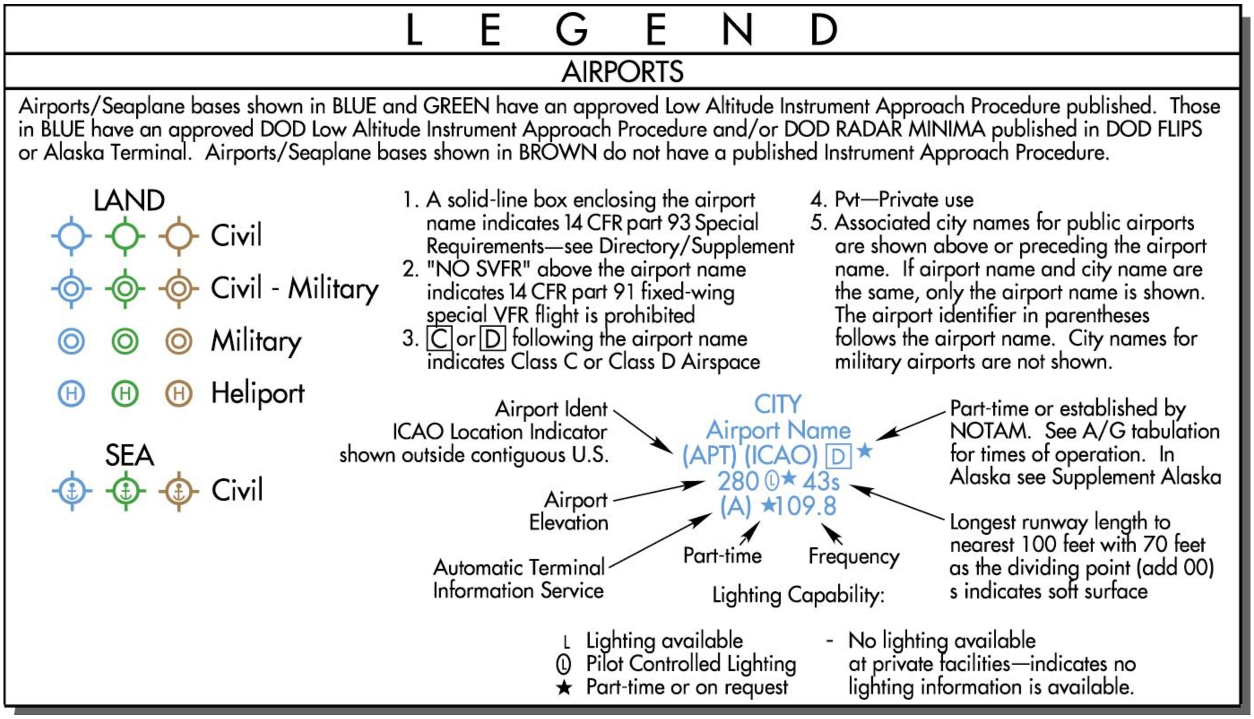
L E G E N D
AIRPORTS
LAND
Civil
Civil - Military
Military
Heliport
SEA
Civil
Airport Ident
ICAO Location Indicator shown outside contiguous U.S.
CITY
Airport Name
(APT) (ICAO) D ★
280 Ⓛ★ 43s
(A) ★109.8
Airport Elevation
Automatic Terminal Information Service
Part-time
Frequency
Lighting Capability:
Part-time or established by NOTAM. See A/G tabulation for times of operation. In Alaska see Supplement Alaska
Longest runway length to nearest 100 feet with 70 feet as the dividing point (add 00) s indicates soft surface
L Lighting available
Ⓛ Pilot Controlled Lighting
★ Part-time or on request
- No lighting available at private facilities—indicates no lighting information is available.

Airports/Seaplane bases shown in BLUE and GREEN have an approved Low Altitude Instrument Approach Procedure published. Those in BLUE have an approved DOD Low Altitude Instrument Approach Procedure and/or DOD RADAR MINIMA published in DOD FLIPS or Alaska Terminal. Airports/Seaplane bases shown in BROWN do not have a published Instrument Approach Procedure.

1. A solid-line box enclosing the airport name indicates 14 CFR part 93 Special Requirements—see Directory/Supplement
2. "NO SVFR" above the airport name indicates 14 CFR part 91 fixed-wing special VFR flight is prohibited
3. C or D following the airport name indicates Class C or Class D Airspace
4. Pvt—Private use
5. Associated city names for public airports are shown above or preceding the airport name. If airport name and city name are the same, only the airport name is shown. The airport identifier in parentheses follows the airport name. City names for military airports are not shown.

Figure 8-3. *En Route Airport Legend.*

be identified with such equipment, the pilot could define the fix without attaining the MRA. On NACG charts, the MRA is indicated by the symbol and the altitude preceded by "MRA" (e.g., "MRA 9300"). *[Figure 8-2]*

The minimum crossing altitude (MCA) will be charted when a higher MEA route segment is approached. The MCA is usually indicated when a pilot is approaching steeply rising terrain, and obstacle clearance and/or signal reception is compromised. In this case, the pilot is required to initiate a climb so the MCA is reached by the time the intersection is crossed. On NACG charts, the MCA is indicated by the symbol, and the Victor airway number, altitude, and the direction to which it applies (e.g. "V24 8000 SE").

The maximum authorized altitude (MAA) is the highest altitude at which the airway can be flown with assurance of receiving adequate navigation signals. Chart depictions appear as "MAA-15000."

When an MEA, MOCA, and/or MAA change on a segment other than at a NAVAID, a sideways "T" ⊣ is depicted on the chart. If there is an airway break without the symbol, one can assume the altitudes have not changed (see the upper left area of *Figure 8-2*). When a change of MEA to a higher MEA is required, the climb may commence at the break, ensuring obstacle clearance. *[Figure 8-4]*

Navigation Features

Types of NAVAIDs

Very high frequency omnidirectional ranges (VORs) are the principal NAVAIDs that support the Victor and Jet airways. Many other navigation tools are also available to the pilot. For example, nondirectional beacons (NDBs) can broadcast signals accurate enough to provide stand-alone approaches, and DME allows the pilot to pinpoint a reporting point on the airway. Though primarily navigation tools, these NAVAIDs can also transmit voice broadcasts.

Tactical air navigation (TACAN) channels are represented as the two- or three-digit numbers following the three-letter identifier in the NAVAID boxes. The NACG terminal procedures provide a frequency-pairing table for the TACAN-only sites. On NACG charts, very-high frequencies and ultra-high frequencies (VHF/UHF) NAVAIDs (e.g., VORs) are depicted in black, while low frequencies and medium frequencies (LF/MF) are depicted as brown. *[Figure 8-5]*

Identifying Intersections

Intersections along the airway route are established by a variety of NAVAIDs. An open triangle △ indicates the location of an ATC reporting point at an intersection. If the triangle is solid, ▲ a report is compulsory. *[Figure 8-4]*

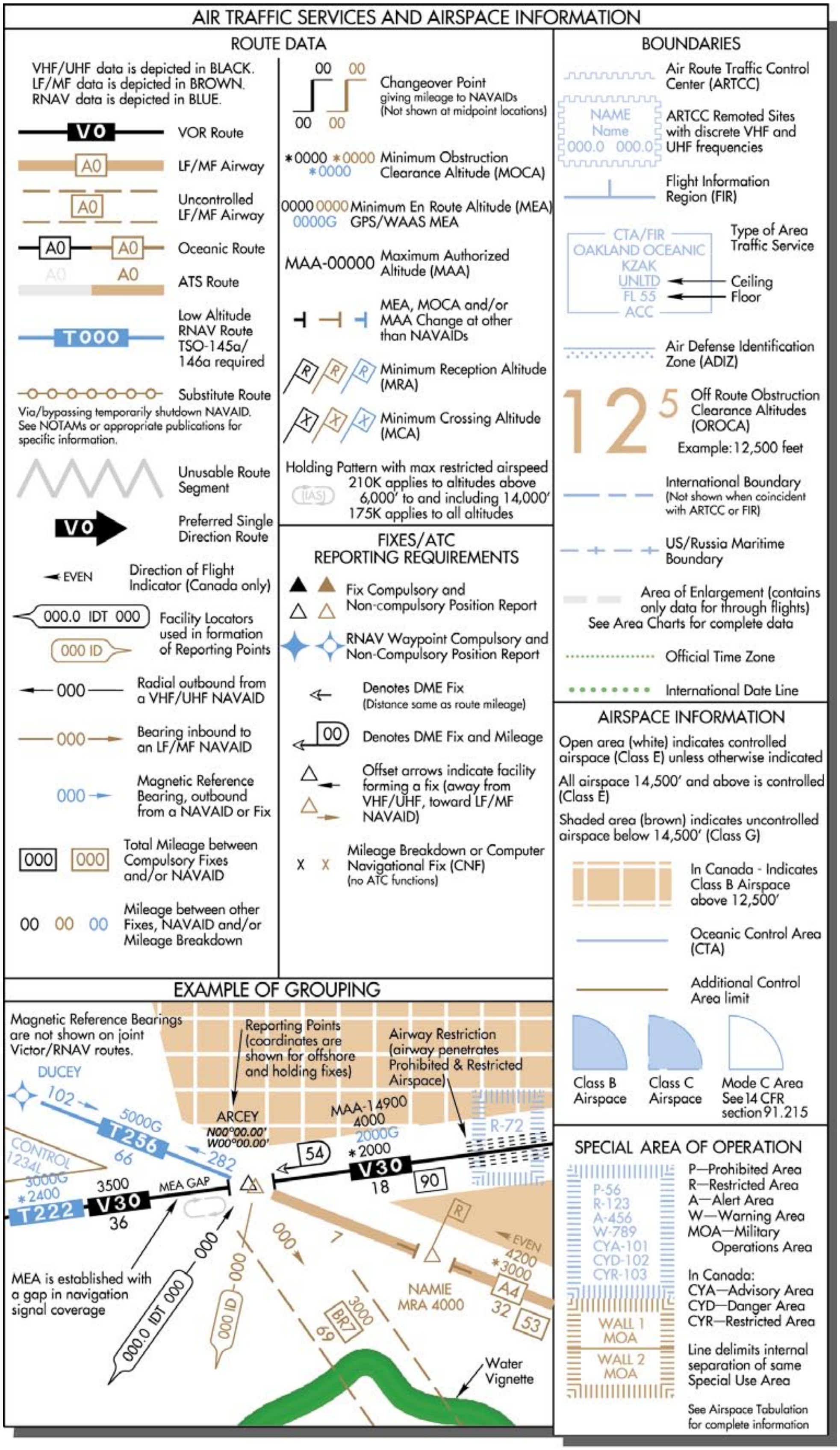
AIR TRAFFIC SERVICES AND AIRSPACE INFORMATION
ROUTE DATA
VHF/UHF data is depicted in BLACK.
LF/MF data is depicted in BROWN.
RNAV data is depicted in BLUE.
V0
VOR Route
A0
LF/MF Airway
A0
Uncontrolled LF/MF Airway
A0 A0
Oceanic Route
A0 A0
ATS Route
T000
Low Altitude RNAV Route TSO-145a/146a required
Substitute Route
Via/bypassing temporarily shutdown NAVAID. See NOTAMs or appropriate publications for specific information.
Unusable Route Segment
V0
Preferred Single Direction Route
EVEN
Direction of Flight Indicator (Canada only)
000.0 IDT 000
000 ID
Facility Locators used in formation of Reporting Points
000
Radial outbound from a VHF/UHF NAVAID
000
Bearing inbound to an LF/MF NAVAID
000
Magnetic Reference Bearing, outbound from a NAVAID or Fix
000 000
Total Mileage between Compulsory Fixes and/or NAVAID
00 00 00
Mileage between other Fixes, NAVAID and/or Mileage Breakdown
00 00
00 00
Changeover Point giving mileage to NAVAIDs (Not shown at midpoint locations)
*0000 *0000 *0000
Minimum Obstruction Clearance Altitude (MOCA)
0000 0000 Minimum En Route Altitude (MEA)
0000G GPS/WAAS MEA
MAA-00000
Maximum Authorized Altitude (MAA)
MEA, MOCA and/or MAA Change at other than NAVAIDs
R R R
Minimum Reception Altitude (MRA)
X X X
Minimum Crossing Altitude (MCA)
Holding Pattern with max restricted airspeed
IAS
210K applies to altitudes above 6,000′ to and including 14,000′
175K applies to all altitudes
FIXES/ATC REPORTING REQUIREMENTS
Fix Compulsory and Non-compulsory Position Report
RNAV Waypoint Compulsory and Non-Compulsory Position Report
Denotes DME Fix (Distance same as route mileage)
00
Denotes DME Fix and Mileage
Offset arrows indicate facility forming a fix (away from VHF/UHF, toward LF/MF NAVAID)
X X
Mileage Breakdown or Computer Navigational Fix (CNF) (no ATC functions)
BOUNDARIES
Air Route Traffic Control Center (ARTCC)
NAME
Name
000.0 000.0
ARTCC Remoted Sites with discrete VHF and UHF frequencies
Flight Information Region (FIR)
CTA/FIR
OAKLAND OCEANIC
KZAK
UNLTD
FL 55
ACC
Type of Area Traffic Service
Ceiling
Floor
Air Defense Identification Zone (ADIZ)
12 5
Off Route Obstruction Clearance Altitudes (OROCA)
Example: 12,500 feet
International Boundary (Not shown when coincident with ARTCC or FIR)
US/Russia Maritime Boundary
Area of Enlargement (contains only data for through flights)
See Area Charts for complete data
Official Time Zone
International Date Line
AIRSPACE INFORMATION
Open area (white) indicates controlled airspace (Class E) unless otherwise indicated
All airspace 14,500′ and above is controlled (Class E)
Shaded area (brown) indicates uncontrolled airspace below 14,500′ (Class G)
In Canada - Indicates Class B Airspace above 12,500′
Oceanic Control Area (CTA)
Additional Control Area limit
Class B Airspace
Class C Airspace
Mode C Area See 14 CFR section 91.215
SPECIAL AREA OF OPERATION
P-56
R-123
A-456
W-789
CYA-101
CYD-102
CYR-103
P—Prohibited Area
R—Restricted Area
A—Alert Area
W—Warning Area
MOA—Military Operations Area
In Canada:
CYA—Advisory Area
CYD—Danger Area
CYR—Restricted Area
WALL 1 MOA
WALL 2 MOA
Line delimits internal separation of same Special Use Area
See Airspace Tabulation for complete information
EXAMPLE OF GROUPING
Magnetic Reference Bearings are not shown on joint Victor/RNAV routes.
DUCEY
102
5000G
T256
66
282
CONTROL 1234L
3000G
*2400
T222
3500
V30
36
MEA GAP
Reporting Points (coordinates are shown for offshore and holding fixes)
ARCEY
N00°00.00′
W00°00.00′
54
MAA-14900
4000
2000G
*2000
V30
18
90
Airway Restriction (airway penetrates Prohibited & Restricted Airspace)
R-72
R
EVEN
4200
*3000
A4
32
53
7
000
000
000 ID
000.0 IDT 000
3000
BR7
69
NAMIE
MRA 4000
MEA is established with a gap in navigation signal coverage
Water Vignette

Figure 8-4. *Legend From En Route Low Attitude Chart, Air Traffic Services and Airspace Information Section.*

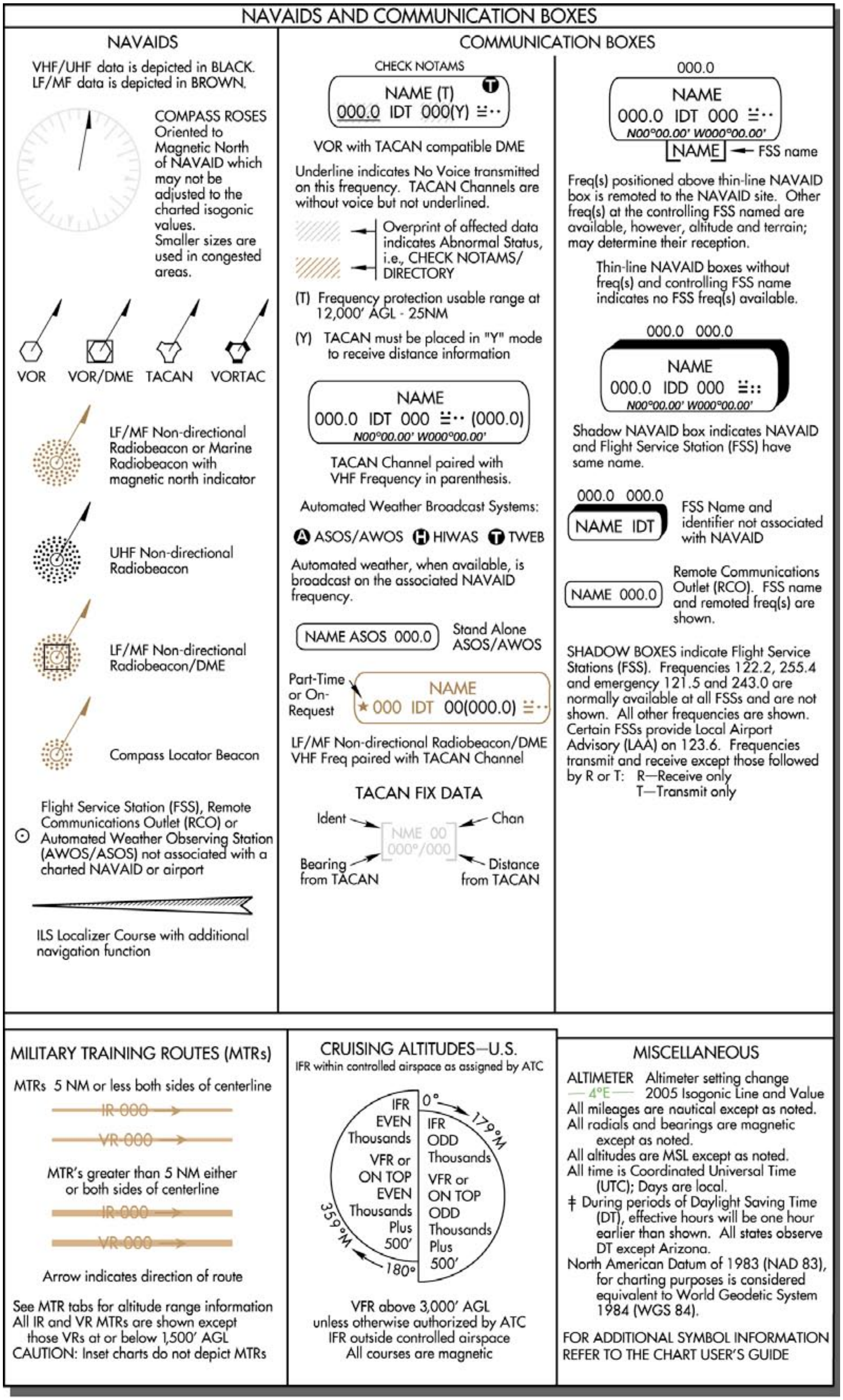
NAVAIDS AND COMMUNICATION BOXES

NAVAIDS

VHF/UHF data is depicted in BLACK.
LF/MF data is depicted in BROWN.

COMPASS ROSES Oriented to Magnetic North of NAVAID which may not be adjusted to the charted isogonic values. Smaller sizes are used in congested areas.

VOR
VOR/DME
TACAN
VORTAC

LF/MF Non-directional Radiobeacon or Marine Radiobeacon with magnetic north indicator

UHF Non-directional Radiobeacon

LF/MF Non-directional Radiobeacon/DME

Compass Locator Beacon

⊙ Flight Service Station (FSS), Remote Communications Outlet (RCO) or Automated Weather Observing Station (AWOS/ASOS) not associated with a charted NAVAID or airport

ILS Localizer Course with additional navigation function

COMMUNICATION BOXES

CHECK NOTAMS
NAME (T)
000.0 IDT 000(Y)

VOR with TACAN compatible DME

Underline indicates No Voice transmitted on this frequency. TACAN Channels are without voice but not underlined.

Overprint of affected data indicates Abnormal Status, i.e., CHECK NOTAMS/ DIRECTORY

(T) Frequency protection usable range at 12,000′ AGL - 25NM

(Y) TACAN must be placed in "Y" mode to receive distance information

NAME
000.0 IDT 000 (000.0)
N00°00.00′ W000°00.00′

TACAN Channel paired with VHF Frequency in parenthesis.

Automated Weather Broadcast Systems:

Ⓐ ASOS/AWOS Ⓗ HIWAS Ⓣ TWEB

Automated weather, when available, is broadcast on the associated NAVAID frequency.

NAME ASOS 000.0

Stand Alone ASOS/AWOS

Part-Time or On-Request
NAME
★000 IDT 00(000.0)

LF/MF Non-directional Radiobeacon/DME VHF Freq paired with TACAN Channel

TACAN FIX DATA

Ident
Chan
NME 00
000°/000
Bearing from TACAN
Distance from TACAN

000.0
NAME
000.0 IDT 000
N00°00.00′ W000°00.00′
NAME
FSS name

Freq(s) positioned above thin-line NAVAID box is remoted to the NAVAID site. Other freq(s) at the controlling FSS named are available, however, altitude and terrain; may determine their reception.

Thin-line NAVAID boxes without freq(s) and controlling FSS name indicates no FSS freq(s) available.

000.0 000.0
NAME
000.0 IDD 000
N00°00.00′ W000°00.00′

Shadow NAVAID box indicates NAVAID and Flight Service Station (FSS) have same name.

000.0 000.0
NAME IDT

FSS Name and identifier not associated with NAVAID

Remote Communications Outlet (RCO). FSS name and remoted freq(s) are shown.

SHADOW BOXES indicate Flight Service Stations (FSS). Frequencies 122.2, 255.4 and emergency 121.5 and 243.0 are normally available at all FSSs and are not shown. All other frequencies are shown. Certain FSSs provide Local Airport Advisory (LAA) on 123.6. Frequencies transmit and receive except those followed by R or T: R—Receive only
T—Transmit only

MILITARY TRAINING ROUTES (MTRs)

MTRs 5 NM or less both sides of centerline

IR-000
VR-000

MTR's greater than 5 NM either or both sides of centerline

IR-000
VR-000

Arrow indicates direction of route

See MTR tabs for altitude range information
All IR and VR MTRs are shown except those VRs at or below 1,500′ AGL
CAUTION: Inset charts do not depict MTRs

CRUISING ALTITUDES—U.S.

IFR within controlled airspace as assigned by ATC

0°
179°M
180°
359°M
IFR EVEN Thousands
VFR or ON TOP EVEN Thousands Plus 500′
IFR ODD Thousands
VFR or ON TOP ODD Thousands Plus 500′

VFR above 3,000′ AGL unless otherwise authorized by ATC
IFR outside controlled airspace
All courses are magnetic

MISCELLANEOUS

ALTIMETER Altimeter setting change
— 4°E — 2005 Isogonic Line and Value
All mileages are nautical except as noted.
All radials and bearings are magnetic except as noted.
All altitudes are MSL except as noted.
All time is Coordinated Universal Time (UTC); Days are local.
‡ During periods of Daylight Saving Time (DT), effective hours will be one hour earlier than shown. All states observe DT except Arizona.
North American Datum of 1983 (NAD 83), for charting purposes is considered equivalent to World Geodetic System 1984 (WGS 84).

FOR ADDITIONAL SYMBOL INFORMATION REFER TO THE CHART USER'S GUIDE

Figure 8-5. *Legend From En Route Low Attitude Chart.*

NDBs, localizers, and off-route VORs are used to establish intersections. NDBs are sometimes collocated with intersections, in which case passage of the NDB would mark the intersection. A bearing to an off-route NDB also can provide intersection identification. A localizer course used to identify an intersection is depicted by a feathered arrowhead symbol on the en route chart. 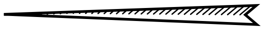 If feathered markings appear on the left-hand side of the arrowhead, 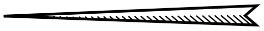 a back course (BC) signal is transmitted. On NACG en route charts, the localizer symbol is only depicted to identify an intersection.

Off-route VORs remain the most common means of identifying intersections when traveling on an airway. Arrows depicted next to the intersection indicate the NAVAID to be used for identification. Another means of identifying an intersection is with the use of DME. A hollow arrowhead indicates DME is authorized for intersection identification. If the DME mileage at the intersection is a cumulative distance of route segments, the mileage is totaled and indicated by a D-shaped symbol with a mileage number inside. 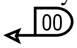

[Figure 8-4] Approved IFR GPS units can also be used to report intersections.

Other Route Information

DME and GPS provide valuable route information concerning such factors as mileage, position, and groundspeed. Even without this equipment, information is provided on the charts for making the necessary calculations using time and distance. The en route chart depicts point-to-point distances on the airway system. Distances from VOR to VOR are charted with a number inside of a box. 000 To differentiate distances when two airways coincide, the word "TO" with the three-letter VOR identifier appear to the left of the distance boxes. TO PDX 97

VOR changeover points (COPs) are depicted on the charts by this symbol: 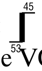

The numbers indicate the distance at which to change the VOR frequency. The frequency change might be required due to signal reception or conflicting frequencies. If a COP does not appear on an airway, the frequency should be changed midway between the facilities. A COP at an intersection may indicate a course change.

Occasionally an "x" will appear at a separated segment of an airway that is not an intersection. The "x" is a mileage breakdown or computer navigation fix and may indicate a course change.

Today's computerized system of ATC has greatly reduced the need for holding en route. However, published holding patterns are still found on charts at junctures where ATC has deemed it necessary to enable traffic flow. When a holding pattern is charted, the controller may provide the holding direction and the statement "as published." *[Figure 8-4]*

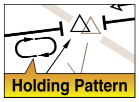

Boundaries separating the jurisdiction of Air Route Traffic Control Centers (ARTCC) are depicted on charts with blue serrations. 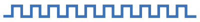 The name of the controlling facility is printed on the corresponding side of the division line. ARTCC remote sites are depicted as blue serrated boxes and contain the center name, sector name, and the sector frequency. *[Figure 8-4]*

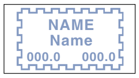

Weather Information and Communication Features

En route NAVAIDs also provide weather information and serve communication functions. When a NAVAID is shown as a shadowed box, an automated flight service station (AFSS) of the same name is directly associated with the facility. If an AFSS is located without an associated NAVAID, the shadowed box is smaller and contains only the name and identifier. The AFSS frequencies are provided above the box. (Frequencies 122.2 and 255.4, and emergency frequencies 121.5 and 243.0 are not listed.)

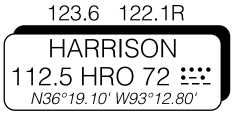

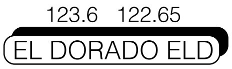

A Remote Communications Outlet (RCO) associated with a NAVAID is designated by a thin-lined box with the controlling AFSS frequency above the box, and the name under the box. Without an associated facility, the thin-lined RCO box contains the AFSS name and remote frequency.

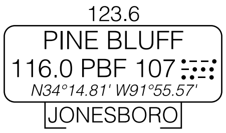

JONESBORO 122.55

Automated Surface Observing Station (ASOS), Automated Weather Observing Station (AWOS), Hazardous Inflight Weather Advisory Service (HIWAS) and Transcribed Weather Broadcast (TWEB) are continuously transmitted over selected NAVAIDs and depicted in the NAVAID box. ASOS/AWOS are depicted by a white "A", HIWAS by a "H" and TWEB broadcasts by a "T" in a solid black circle in the upper right or left corner.

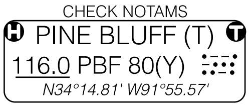

New Technologies

Technological advances have made multifunction displays and moving maps more common in newer aircraft. Even older aircraft are being retrofitted to include "glass" in the flight deck. *[Figure 8-6]* Moving maps improve pilot situational awareness by providing a picture of aircraft location in

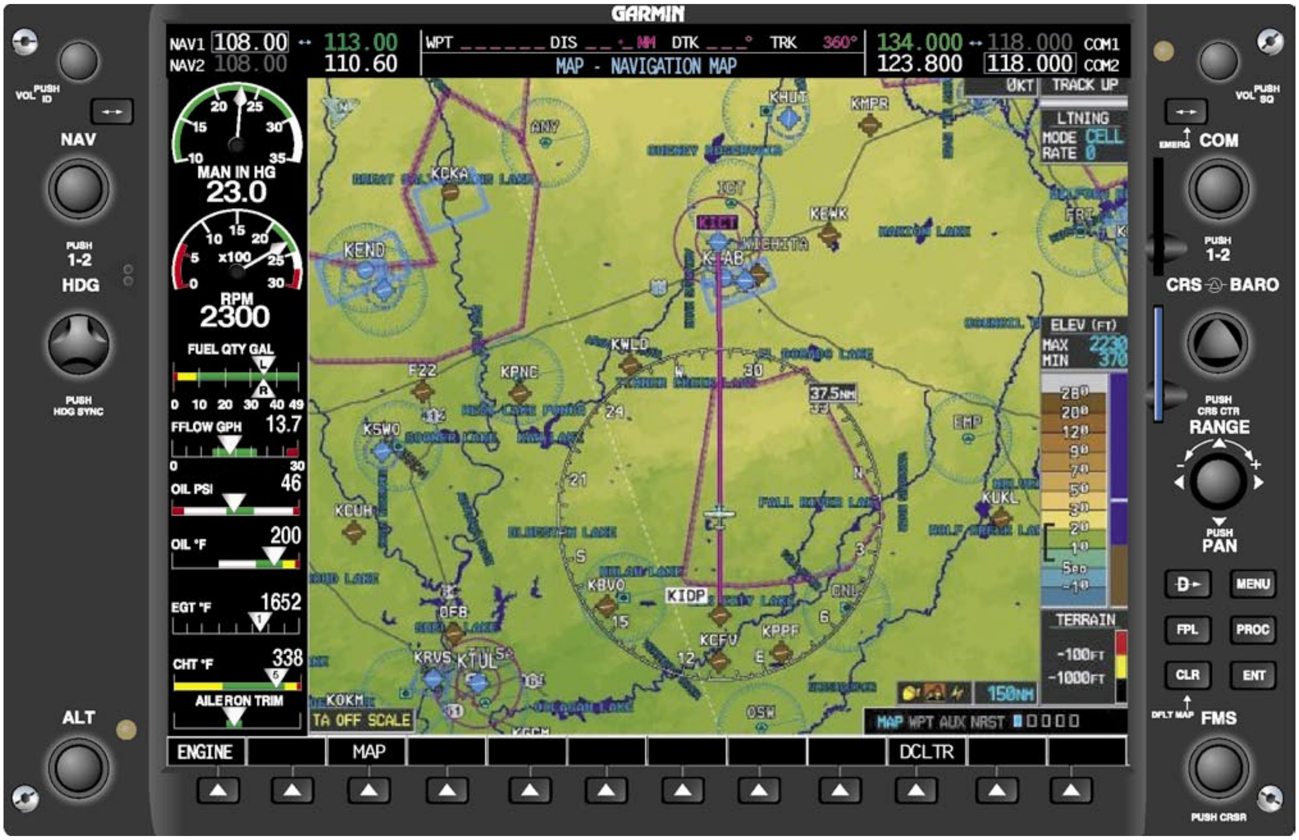
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
WPT DIS DTK TRK 360°
MAP - NAVIGATION MAP
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
NAV
COM
MAN IN HG 23.0
RPM 2300
FUEL QTY GAL
FFLOW GPH 13.7
OIL PSI 46
OIL °F 200
EGT °F 1652
CHT °F 338
AILERON TRIM
HDG
CRS BARO
RANGE
PAN
ALT
FMS
TRACK UP
LTNING
ELEV (FT)
TERRAIN
TA OFF SCALE
ENGINE
MAP
DCLTR
MENU
FPL
PROC
CLR
ENT

Figure 8-6. *Moving Map Display.*

relation to NAVAIDS, waypoints, airspace, terrain, and hazardous weather. GPS systems can be certified for terminal area and en route use as well as approach guidance.

Additional breakthroughs in display technology are the new electronic chart systems or electronic flight bags that facilitate the use of electronic documents in the general aviation flight deck. *[Figure 8-7]* An electronic chart or flight bag is a self-powered electronic library that stores and displays en route charts and other essential documents on a screen. These electronic devices can store the digitized United States terminal procedures, en route charts, the complete airport facility directory, in addition to Title 14 of the Code of Federal Regulations (14 CFR) and the AIM. Full touch-screen based computers allow pilots to view airport approach and area charts electronically while flying. It replaces paper charts as well as other paper materials including minimum equipment lists (MELs), standard operating procedures (SOPs), standard instrument departures (SIDs), standard terminal arrival routes (STARs), checklists, and flight deck manuals. As with paper flight publications, the electronic database needs to be current to provide accurate information regarding NAVAIDS, waypoints, and terminal procedures. Databases are updated every 28 days and are available from various commercial vendors. Pilots should be familiar with equipment operation, capabilities, and limitations prior to use.

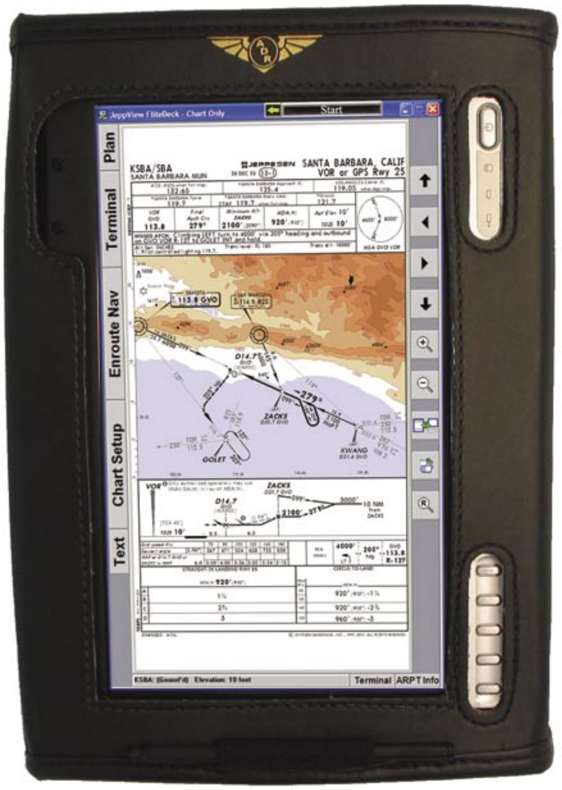
JeppView FliteDeck - Chart Only
Plan
Terminal
Enroute Nav
Chart Setup
Text
KSBA/SBA
SANTA BARBARA, CALIF
VOR or GPS Rwy 25

Figure 8-7. *Example of an Electronic Flight Bag.*

Terminal Procedures Publications

While the en route charts provide the information necessary to safely transit broad regions of airspace, the United States Terminal Procedures Publication (TPP) enables pilots to guide their aircraft in the airport area. Whether departing or arriving, these procedures exist to make the controllers' and pilots' jobs safer and more efficient. Available in booklets by region (published by NACG), the TPP includes approach procedures, STARs, Departure Procedures (DPs), and airport diagrams.

Departure Procedures (DPs)

There are two types of DPs, Obstacle Departure Procedures (ODP) and SIDs. *[Figure 8-8]* Both types of DPs provide obstacle clearance protection to aircraft in instrument meteorological conditions (IMC), while reducing communications and departure delays. DPs are published in text and/or charted graphic form. Regardless of the format, all DPs provide a way to depart the airport and transition to the en route structure safely. When possible, pilots are strongly encouraged to file and fly a DP at night, during marginal visual meteorological conditions (VMC) and IMC.

All DPs provide obstacle clearance provided the aircraft crosses the end of the runway at least 35 feet AGL; climbs to 400 feet above airport elevation before turning; and climbs at least 200 feet per nautical mile (FPNM), unless a higher climb gradient is specified to the assigned altitude. ATC may vector an aircraft off a previously assigned DP; however, the 200 FPNM or the FPNM specified in the DP is required.

Textual ODPs are listed by city and airport in the IFR Take-Off Minimums and DPs Section of the TPP. SIDs are depicted in the TPP following the approach procedures for the airport.

Standard Terminal Arrival Routes (STARs)

STARs depict prescribed routes to transition the instrument pilot from the en route structure to a fix in the terminal area from which an instrument approach can be conducted. If a pilot does not have the appropriate STAR, write "No STAR" in the flight plan. However, if the controller is busy, the pilot might be cleared along the same route and, if necessary, the controller will have the pilot copy the entire text of the procedure.

STARs are listed alphabetically at the beginning of the NACG booklet. *Figure 8-9* shows an example of a STAR, and the legend for STARs and DPs printed in NACG booklets.

Instrument Approach Procedure (IAP) Charts

The IAP chart provides the method to descend and land safely in low visibility conditions. The FAA establishes an IAP after thorough analyses of obstructions, terrain features, and navigational facilities. Maneuvers, including altitude changes, course corrections, and other limitations, are prescribed in the IAP. The approach charts reflect the criteria associated with the United States Standard for Terminal Instrument Approach Procedures (TERPs), which prescribes standardized methods for use in designing instrument flight procedures.

In addition to the NACG, other governmental and corporate entities produce approach procedures. The United States military IAPs are established and published by the Department of Defense and are available to the public upon request. Special IAPs are approved by the FAA for individual operators and are not available to the general public. Foreign country standard IAPs are established and published according to the individual country's publication procedures. The information presented in the following sections will highlight features of the United States Terminal Procedures Publications.

The instrument approach chart is divided into six main sections, which include the margin identification, pilot briefing (and notes), plan view, profile view, landing minimums, and airport diagram. *[Figure 8-10]* An examination of each section follows.

Margin Identification

The margin identification, at the top and bottom of the chart, depicts the airport location and procedure identification. The civil approach plates are organized by city, then airport name and state. For example, Orlando Executive in Orlando, Florida is alphabetically listed under "O" for Orlando. Military approaches are organized by airport name first.

The chart's amendment status appears below the city and state in the bottom margin. The amendment number is followed by the five-digit julian-date of the last chart change."05300" is read, "the 300th day of 2005". At the center of the top margin is the FAA chart reference number and the approving authority. At the bottom center, the airport's latitude and longitude coordinates are provided.

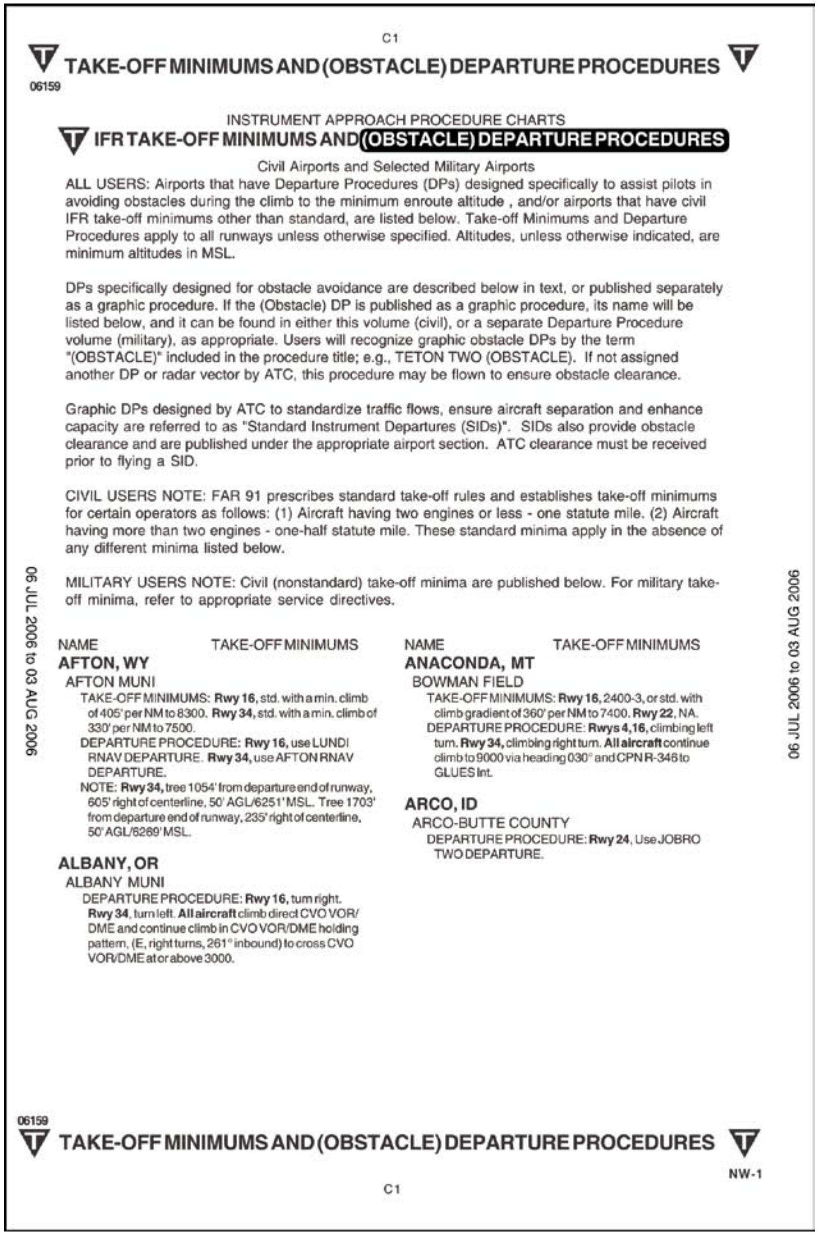

C1

TAKE-OFF MINIMUMS AND (OBSTACLE) DEPARTURE PROCEDURES

06159

INSTRUMENT APPROACH PROCEDURE CHARTS

IFR TAKE-OFF MINIMUMS AND (OBSTACLE) DEPARTURE PROCEDURES

Civil Airports and Selected Military Airports

ALL USERS: Airports that have Departure Procedures (DPs) designed specifically to assist pilots in avoiding obstacles during the climb to the minimum enroute altitude , and/or airports that have civil IFR take-off minimums other than standard, are listed below. Take-off Minimums and Departure Procedures apply to all runways unless otherwise specified. Altitudes, unless otherwise indicated, are minimum altitudes in MSL.

DPs specifically designed for obstacle avoidance are described below in text, or published separately as a graphic procedure. If the (Obstacle) DP is published as a graphic procedure, its name will be listed below, and it can be found in either this volume (civil), or a separate Departure Procedure volume (military), as appropriate. Users will recognize graphic obstacle DPs by the term "(OBSTACLE)" included in the procedure title; e.g., TETON TWO (OBSTACLE). If not assigned another DP or radar vector by ATC, this procedure may be flown to ensure obstacle clearance.

Graphic DPs designed by ATC to standardize traffic flows, ensure aircraft separation and enhance capacity are referred to as "Standard Instrument Departures (SIDs)". SIDs also provide obstacle clearance and are published under the appropriate airport section. ATC clearance must be received prior to flying a SID.

CIVIL USERS NOTE: FAR 91 prescribes standard take-off rules and establishes take-off minimums for certain operators as follows: (1) Aircraft having two engines or less - one statute mile. (2) Aircraft having more than two engines - one-half statute mile. These standard minima apply in the absence of any different minima listed below.

MILITARY USERS NOTE: Civil (nonstandard) take-off minima are published below. For military take-off minima, refer to appropriate service directives.

06 JUL 2006 to 03 AUG 2006

06 JUL 2006 to 03 AUG 2006

NAME TAKE-OFF MINIMUMS

AFTON, WY

AFTON MUNI

TAKE-OFF MINIMUMS: **Rwy 16**, std. with a min. climb of 405' per NM to 8300. **Rwy 34**, std. with a min. climb of 330' per NM to 7500.

DEPARTURE PROCEDURE: **Rwy 16**, use LUNDI RNAV DEPARTURE. **Rwy 34**, use AFTON RNAV DEPARTURE.

NOTE: **Rwy 34**, tree 1054' from departure end of runway, 605' right of centerline, 50' AGL/6251' MSL. Tree 1703' from departure end of runway, 235' right of centerline, 50' AGL/6269' MSL.

ALBANY, OR

ALBANY MUNI

DEPARTURE PROCEDURE: **Rwy 16**, turn right. **Rwy 34**, turn left. **All aircraft** climb direct CVO VOR/DME and continue climb in CVO VOR/DME holding pattern, (E, right turns, 261° inbound) to cross CVO VOR/DME at or above 3000.

NAME TAKE-OFF MINIMUMS

ANACONDA, MT

BOWMAN FIELD

TAKE-OFF MINIMUMS: **Rwy 16**, 2400-3, or std. with climb gradient of 360' per NM to 7400. **Rwy 22**, NA.

DEPARTURE PROCEDURE: **Rwys 4,16**, climbing left turn. **Rwy 34**, climbing right turn. **All aircraft** continue climb to 9000 via heading 030° and CPN R-346 to GLUES Int.

ARCO, ID

ARCO-BUTTE COUNTY

DEPARTURE PROCEDURE: **Rwy 24**, Use JOBRO TWO DEPARTURE.

06159

TAKE-OFF MINIMUMS AND (OBSTACLE) DEPARTURE PROCEDURES

NW-1

C1

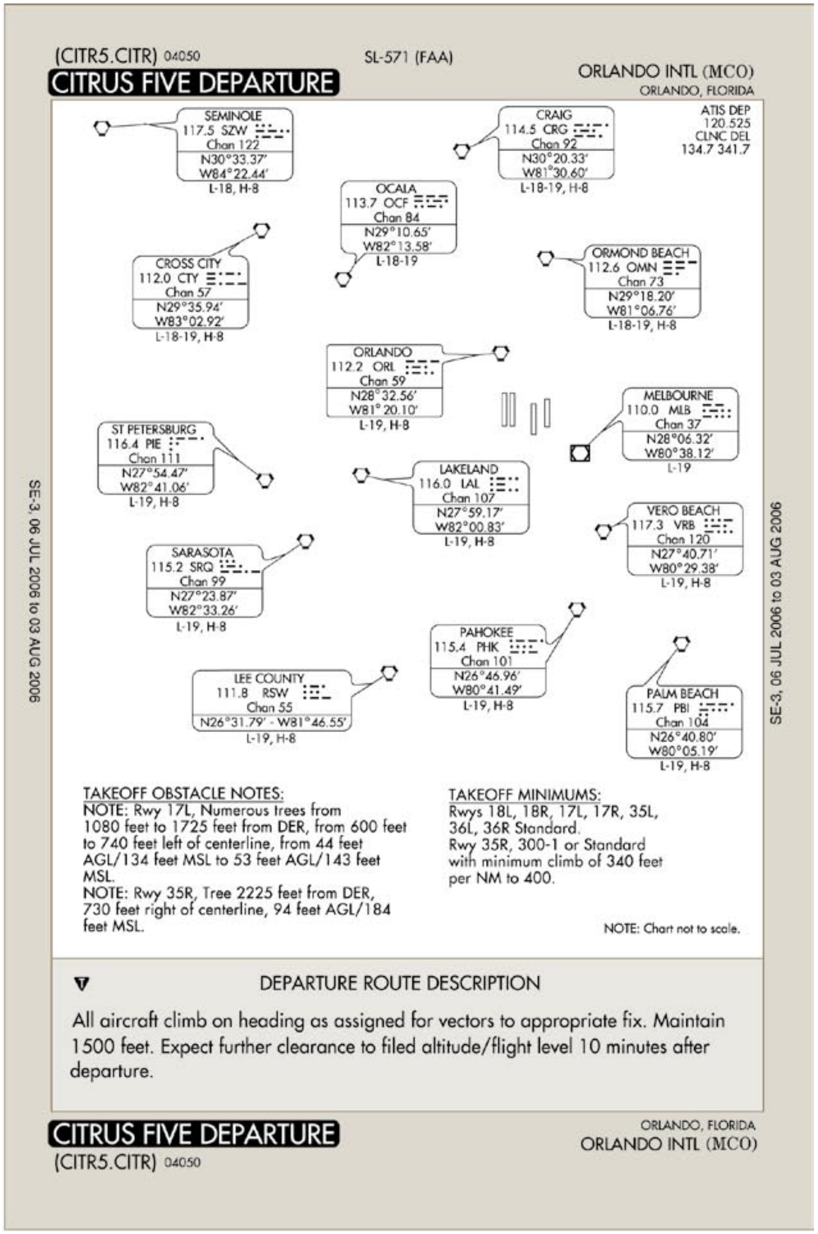

(CITR5.CITR) 04050

CITRUS FIVE DEPARTURE

SL-571 (FAA)

ORLANDO INTL (MCO)
ORLANDO, FLORIDA

SE-3, 06 JUL 2006 to 03 AUG 2006

SE-3, 06 JUL 2006 to 03 AUG 2006

ATIS DEP
120.525
CLNC DEL
134.7 341.7
SEMINOLE
117.5 SZW
Chan 122
N30°33.37'
W84°22.44'
L-18, H-8
CRAIG
114.5 CRG
Chan 92
N30°20.33'
W81°30.60'
L-18-19, H-8
OCALA
113.7 OCF
Chan 84
N29°10.65'
W82°13.58'
L-18-19
CROSS CITY
112.0 CTY
Chan 57
N29°35.94'
W83°02.92'
L-18-19, H-8
ORMOND BEACH
112.6 OMN
Chan 73
N29°18.20'
W81°06.76'
L-18-19, H-8
ORLANDO
112.2 ORL
Chan 59
N28°32.56'
W81°20.10'
L-19, H-8
MELBOURNE
110.0 MLB
Chan 37
N28°06.32'
W80°38.12'
L-19
ST PETERSBURG
116.4 PIE
Chan 111
N27°54.47'
W82°41.06'
L-19, H-8
LAKELAND
116.0 LAL
Chan 107
N27°59.17'
W82°00.83'
L-19, H-8
VERO BEACH
117.3 VRB
Chan 120
N27°40.71'
W80°29.38'
L-19, H-8
SARASOTA
115.2 SRQ
Chan 99
N27°23.87'
W82°33.26'
L-19, H-8
PAHOKEE
115.4 PHK
Chan 101
N26°46.96'
W80°41.49'
L-19, H-8
LEE COUNTY
111.8 RSW
Chan 55
N26°31.79' - W81°46.55'
L-19, H-8
PALM BEACH
115.7 PBI
Chan 104
N26°40.80'
W80°05.19'
L-19, H-8

TAKEOFF OBSTACLE NOTES:

NOTE: Rwy 17L, Numerous trees from 1080 feet to 1725 feet from DER, from 600 feet to 740 feet left of centerline, from 44 feet AGL/134 feet MSL to 53 feet AGL/143 feet MSL.

NOTE: Rwy 35R, Tree 2225 feet from DER, 730 feet right of centerline, 94 feet AGL/184 feet MSL.

TAKEOFF MINIMUMS:

Rwys 18L, 18R, 17L, 17R, 35L, 36L, 36R Standard.

Rwy 35R, 300-1 or Standard with minimum climb of 340 feet per NM to 400.

NOTE: Chart not to scale.

DEPARTURE ROUTE DESCRIPTION

All aircraft climb on heading as assigned for vectors to appropriate fix. Maintain 1500 feet. Expect further clearance to filed altitude/flight level 10 minutes after departure.

CITRUS FIVE DEPARTURE

(CITR5.CITR) 04050

ORLANDO, FLORIDA
ORLANDO INTL (MCO)

Figure 8-8. *Obstacle Departure Procedures (ODP) and Standard Instrument Departures (SID).*

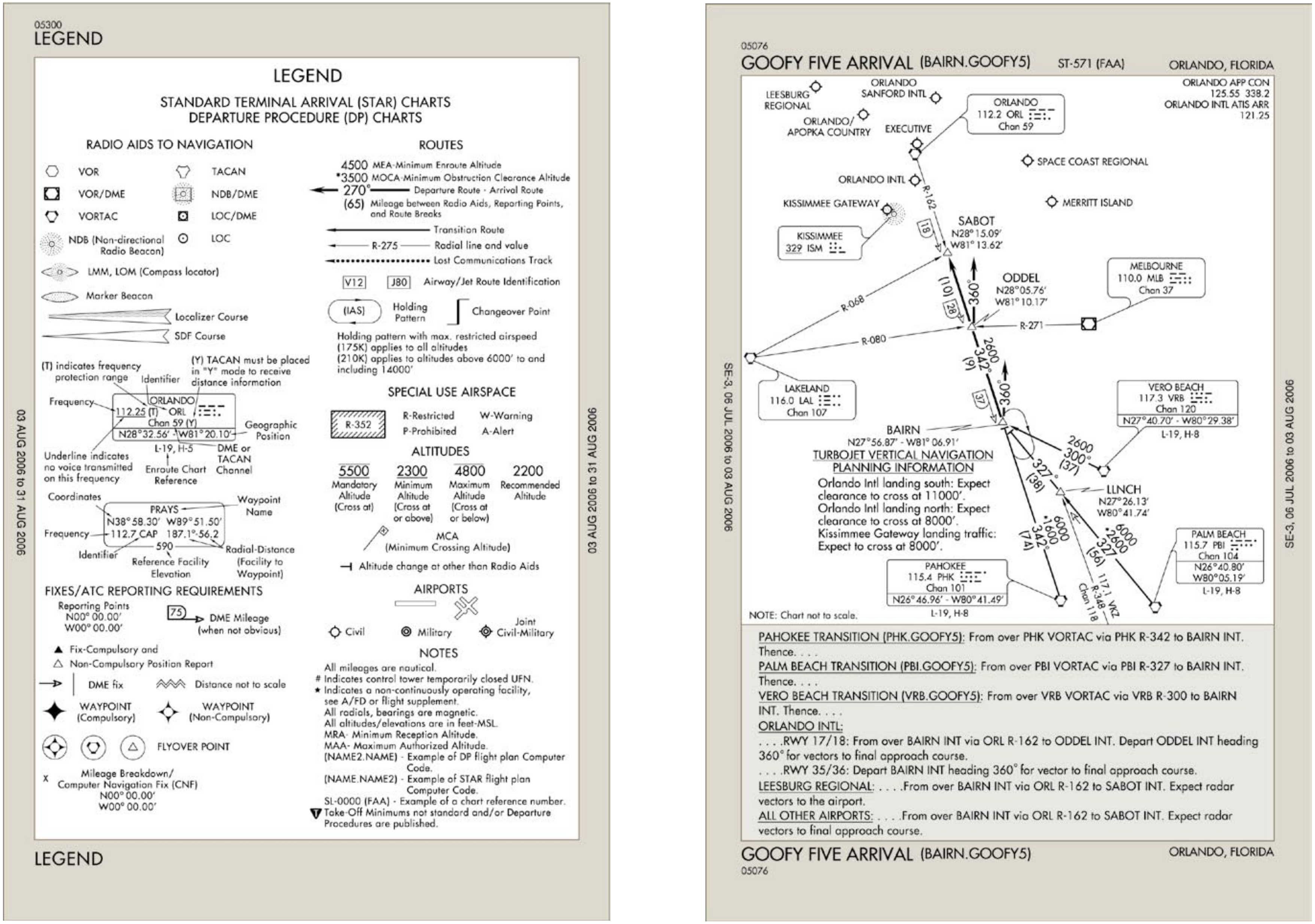
05300
LEGEND
LEGEND
STANDARD TERMINAL ARRIVAL (STAR) CHARTS
DEPARTURE PROCEDURE (DP) CHARTS
RADIO AIDS TO NAVIGATION
VOR
TACAN
VOR/DME
NDB/DME
VORTAC
LOC/DME
NDB (Non-directional Radio Beacon)
LOC
LMM, LOM (Compass locator)
Marker Beacon
Localizer Course
SDF Course
(T) indicates frequency protection range
Identifier
(Y) TACAN must be placed in "Y" mode to receive distance information
Frequency
ORLANDO
112.25 (T) ORL
Chan 59 (Y)
N28°32.56' W81°20.10'
Geographic Position
L-19, H-5
DME or TACAN Channel
Underline indicates no voice transmitted on this frequency
Enroute Chart Reference
Coordinates
Waypoint Name
PRAYS
N38°58.30' W89°51.50'
112.7 CAP 187.1°-56.2
590
Radial-Distance (Facility to Waypoint)
Identifier
Reference Facility Elevation
FIXES/ATC REPORTING REQUIREMENTS
Reporting Points
N00° 00.00'
W00° 00.00'
75
DME Mileage (when not obvious)
▲ Fix-Compulsory and
△ Non-Compulsory Position Report
DME fix
Distance not to scale
WAYPOINT (Compulsory)
WAYPOINT (Non-Compulsory)
FLYOVER POINT
x Mileage Breakdown/ Computer Navigation Fix (CNF)
N00° 00.00'
W00° 00.00'
ROUTES
4500 MEA-Minimum Enroute Altitude
*3500 MOCA-Minimum Obstruction Clearance Altitude
270° Departure Route - Arrival Route
(65) Mileage between Radio Aids, Reporting Points, and Route Breaks
Transition Route
R-275 Radial line and value
Lost Communications Track
V12
J80
Airway/Jet Route Identification
(IAS)
Holding Pattern
Changeover Point
SPECIAL USE AIRSPACE
R-352
R-Restricted
P-Prohibited
W-Warning
A-Alert
ALTITUDES
5500
Mandatory Altitude (Cross at)
2300
Minimum Altitude (Cross at or above)
4800
Maximum Altitude (Cross at or below)
2200
Recommended Altitude
MCA
(Minimum Crossing Altitude)
Altitude change at other than Radio Aids
AIRPORTS
Civil
Military
Joint Civil-Military
NOTES
03 AUG 2006 to 31 AUG 2006
LEGEND
05076
GOOFY FIVE ARRIVAL (BAIRN.GOOFY5)
ST-571 (FAA)
ORLANDO, FLORIDA
ORLANDO APP CON
125.55 338.2
ORLANDO INTL ATIS ARR
121.25
LEESBURG REGIONAL
ORLANDO SANFORD INTL
ORLANDO/ APOPKA COUNTRY
EXECUTIVE
ORLANDO
112.2 ORL
Chan 59
SPACE COAST REGIONAL
ORLANDO INTL
MERRITT ISLAND
KISSIMMEE GATEWAY
KISSIMMEE
329 ISM
R-162
18
SABOT
N28°15.09'
W81°13.62'
(10)
28
360°
ODDEL
N28°05.76'
W81°10.17'
MELBOURNE
110.0 MLB
Chan 37
R-068
R-080
R-271
2600
342°
(9)
37
360°
LAKELAND
116.0 LAL
Chan 107
VERO BEACH
117.3 VRB
Chan 120
N27°40.70' - W80°29.38'
L-19, H-8
BAIRN
N27°56.87' - W81°06.91'
2600
300°
(37)
327°
(38)
LLNCH
N27°26.13'
W80°41.74'
6000
•1600
342°
(74)
6000
•2600
327°
(56)
117.1 VKZ
R-348
Chan 118
PALM BEACH
115.7 PBI
Chan 104
N26°40.80'
W80°05.19'
L-19, H-8
PAHOKEE
115.4 PHK
Chan 101
N26°46.96' - W80°41.49'
L-19, H-8
SE-3, 06 JUL 2006 to 03 AUG 2006
GOOFY FIVE ARRIVAL (BAIRN.GOOFY5)
ORLANDO, FLORIDA
05076

Holding pattern with max. restricted airspeed
(175K) applies to all altitudes
(210K) applies to altitudes above 6000' to and including 14000'

All mileages are nautical.
# Indicates control tower temporarily closed UFN.
★ Indicates a non-continuously operating facility, see A/FD or flight supplement.
All radials, bearings are magnetic.
All altitudes/elevations are in feet-MSL.
MRA- Minimum Reception Altitude.
MAA- Maximum Authorized Altitude.
(NAME2.NAME) - Example of DP flight plan Computer Code.
(NAME.NAME2) - Example of STAR flight plan Computer Code.
SL-0000 (FAA) - Example of a chart reference number.
▼ Take-Off Minimums not standard and/or Departure Procedures are published.

TURBOJET VERTICAL NAVIGATION PLANNING INFORMATION
Orlando Intl landing south: Expect clearance to cross at 11000'.
Orlando Intl landing north: Expect clearance to cross at 8000'.
Kissimmee Gateway landing traffic: Expect to cross at 8000'.

NOTE: Chart not to scale.

PAHOKEE TRANSITION (PHK.GOOFY5): From over PHK VORTAC via PHK R-342 to BAIRN INT. Thence. . . .
PALM BEACH TRANSITION (PBI.GOOFY5): From over PBI VORTAC via PBI R-327 to BAIRN INT. Thence. . . .
VERO BEACH TRANSITION (VRB.GOOFY5): From over VRB VORTAC via VRB R-300 to BAIRN INT. Thence. . . .
ORLANDO INTL:
. . . .RWY 17/18: From over BAIRN INT via ORL R-162 to ODDEL INT. Depart ODDEL INT heading 360° for vectors to final approach course.
. . . .RWY 35/36: Depart BAIRN INT heading 360° for vector to final approach course.
LEESBURG REGIONAL: . . . .From over BAIRN INT via ORL R-162 to SABOT INT. Expect radar vectors to the airport.
ALL OTHER AIRPORTS: . . . .From over BAIRN INT via ORL R-162 to SABOT INT. Expect radar vectors to final approach course.

Figure 8-9. *DP Chart Legend and STAR.*

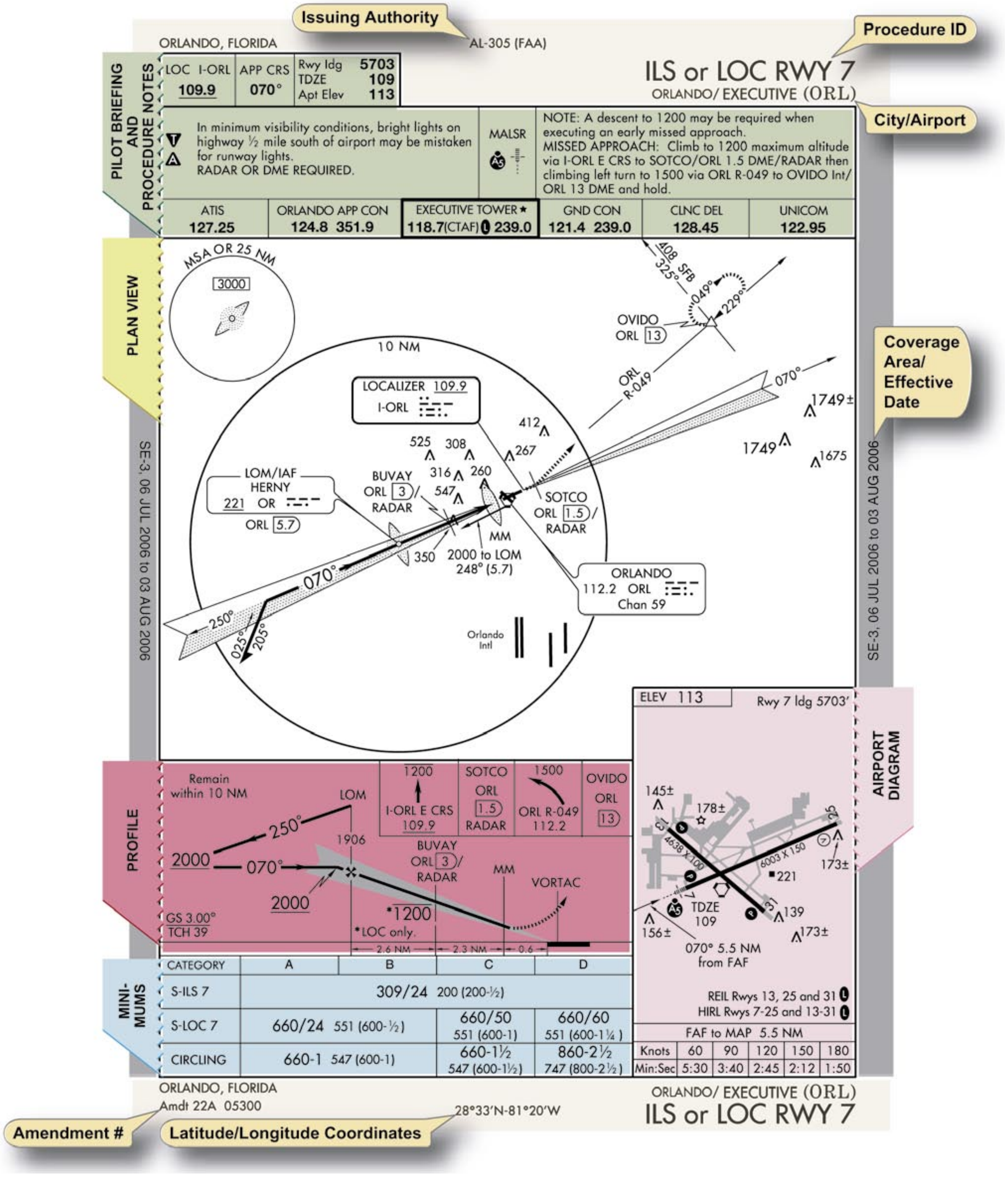
Issuing Authority
Procedure ID
City/Airport
Coverage Area/ Effective Date
Amendment #
Latitude/Longitude Coordinates
PILOT BRIEFING AND PROCEDURE NOTES
PLAN VIEW
PROFILE
MINI-MUMS
AIRPORT DIAGRAM
ORLANDO, FLORIDA
AL-305 (FAA)
ILS or LOC RWY 7
ORLANDO/ EXECUTIVE (ORL)
LOC I-ORL 109.9
APP CRS 070°
Rwy ldg 5703
TDZE 109
Apt Elev 113
In minimum visibility conditions, bright lights on highway ½ mile south of airport may be mistaken for runway lights.
RADAR OR DME REQUIRED.
MALSR
NOTE: A descent to 1200 may be required when executing an early missed approach.
MISSED APPROACH: Climb to 1200 maximum altitude via I-ORL E CRS to SOTCO/ORL 1.5 DME/RADAR then climbing left turn to 1500 via ORL R-049 to OVIDO Int/ ORL 13 DME and hold.
ATIS 127.25
ORLANDO APP CON 124.8 351.9
EXECUTIVE TOWER ★ 118.7(CTAF) 239.0
GND CON 121.4 239.0
CLNC DEL 128.45
UNICOM 122.95
MSA OR 25 NM
3000
10 NM
LOCALIZER 109.9
I-ORL
LOM/IAF HERNY
221 OR
ORL 5.7
BUVAY ORL 3 / RADAR
SOTCO ORL 1.5 / RADAR
OVIDO ORL 13
ORL R-049
408 SFB 325°
049°
229°
070°
250°
025°
205°
525
308
316
547
260
412
267
350
1749±
1749
1675
MM
2000 to LOM 248° (5.7)
ORLANDO 112.2 ORL Chan 59
Orlando Intl
SE-3, 06 JUL 2006 to 03 AUG 2006
Remain within 10 NM
LOM
1906
2000
2000
GS 3.00°
TCH 39
*1200
*LOC only.
1200 I-ORL E CRS 109.9
SOTCO ORL 1.5 RADAR
1500 ORL R-049 112.2
OVIDO ORL 13
BUVAY ORL 3 / RADAR
MM
VORTAC
2.6 NM
2.3 NM
0.6
ELEV 113
Rwy 7 ldg 5703'
145±
178±
4638 X 100
6003 X 150
221
173±
TDZE 109
139
156±
173±
070° 5.5 NM from FAF
REIL Rwys 13, 25 and 31
HIRL Rwys 7-25 and 13-31
ORLANDO, FLORIDA
Amdt 22A 05300
28°33'N-81°20'W

CATEGORY	A	B	C	D
S-ILS 7	309/24 200 (200-½)			
S-LOC 7	660/24 551 (600-½)		660/50 551 (600-1)	660/60 551 (600-1¼)
CIRCLING	660-1 547 (600-1)		660-1½ 547 (600-1½)	860-2½ 747 (800-2½)

FAF to MAP 5.5 NM

Knots	60	90	120	150	180
Min:Sec	5:30	3:40	2:45	2:12	1:50

Figure 8-10. *Instrument Approach Chart.*

The procedure chart title (top and bottom margin area of *Figure 8-10*) is derived from the type of navigational facility providing final approach course guidance. A runway number is listed when the approach course is aligned within 30º of the runway centerline. This type of approach allows a straight-in landing under the right conditions. The type of approach followed by a letter identifies approaches that do not have straight-in landing minimums. Examples include procedure titles at the same airport, which have only circling minimums. The first approach of this type created at the airport will be labeled with the letter A, and the lettering will continue in alphabetical order (e.g., "VOR-A or "LDA-B"). The letter designation signifies the expectation is for the procedure to culminate in a circling approach to land. As a general rule, circling-only approaches are designed for one of the two following reasons:

- The final approach course alignment with the runway centerline exceeds 30º.
- The descent gradient is greater than 400 feet per NM from the FAF to the threshold crossing height (TCH). When this maximum gradient is exceeded, the circling-only approach procedure may be designed to meet the gradient criteria limits.

Further information on this topic can be found in the Instrument Procedures Handbook, Chapter 5, under Approach Naming Conventions.

To distinguish between the left, right, and center runways, an "L," "R," or "C" follows the runway number (e.g., "ILS RWY 16R"). In some cases, an airport might have more than one circling approach, shown as VOR-A, VOR/DME-B, etc.

More than one navigational system separated by a slash indicates more than one type of equipment is required to execute the final approach (e.g., VOR/DME RWY 31). More than one navigational system separated by "or" indicates either type of equipment may be used to execute the final approach (e.g., VOR or GPS RWY 15). Multiple approaches of the same type, to the same runway and using the same guidance, have an additional letter from the end of the alphabet, number, or term in the title (e.g., ILS Z RWY 28, SILVER ILS RWY 28, or ILS 2 RWY 28). VOR/DME RNAV approaches are identified as VOR/DME RNAV RWY (runway number). Helicopters have special IAPs, designated with COPTER in the procedure identification (e.g., COPTER LOC/DME 25L). Other types of navigation systems may be required to execute other portions of the approach prior to intercepting the final approach segment or during the missed approach.

The Pilot Briefing

The pilot briefing is located at the top of the chart and provides the pilot with information required to complete the published approach procedure. Included in the pilot briefing are the NAVAID providing approach guidance, its frequency, the final approach course, and runway information. A notes section contains additional procedural information. For example, a procedural note might indicate restrictions for circling maneuvers. Some other notes might concern a local altimeter setting and the resulting change in the minimums. The use of RADAR may also be noted in this section. Additional notes may be found in the plan view.

When a triangle containing a "T" (T) appears in the notes section, it signifies the airport has nonstandard IFR takeoff minimums. Pilots should refer to the DPs section of the TPP to determine takeoff minimums.

When a triangle containing an "A" (A) appears in the notes section, it signifies the airport has nonstandard IFR alternate minimums. Civil pilots should refer to the Alternate Minimums Section of the TPP to determine alternate minimums. Military pilots should refer to appropriate regulations.

When a triangle containing an "A" NA (ANA) appears in the notes area, it signifies that Alternate Minimums are Not Authorized due to unmonitored facility or the absence of weather reporting service.

Communication frequencies are listed in the order in which they would be used during the approach. Frequencies for weather and related facilities are included, where applicable, such as automatic terminal information service (ATIS), automated surface observing system (ASOS), automated weather observation system (AWOS), and AFSSs.

The Plan View

The plan view provides a graphical overhead view of the procedure, and depicts the routes that guide the pilot from the en route segments to the initial approach fix (IAF). *[Figure 8-10]* During the initial approach, the aircraft has departed the en route phase of flight and is maneuvering to enter an intermediate or final segment of the instrument approach. An initial approach can be made along prescribed routes within the terminal area, which may be along an arc, radial, course, heading, radar vector, or a combination thereof. Procedure turns and high altitude teardrop penetrations are initial approach segments. Features of the plan view, including the procedure turn, obstacle elevation, minimum safe altitude (MSA), and procedure track, are depicted in *Figure 8-11*. Terrain will be depicted in the plan view portion of all IAPs if the terrain within the plan view exceeds 4,000 feet above the airport elevation, or if within a 6 nautical mile radius of the airport reference point the terrain rises at least 2,000 feet above the airport elevation.

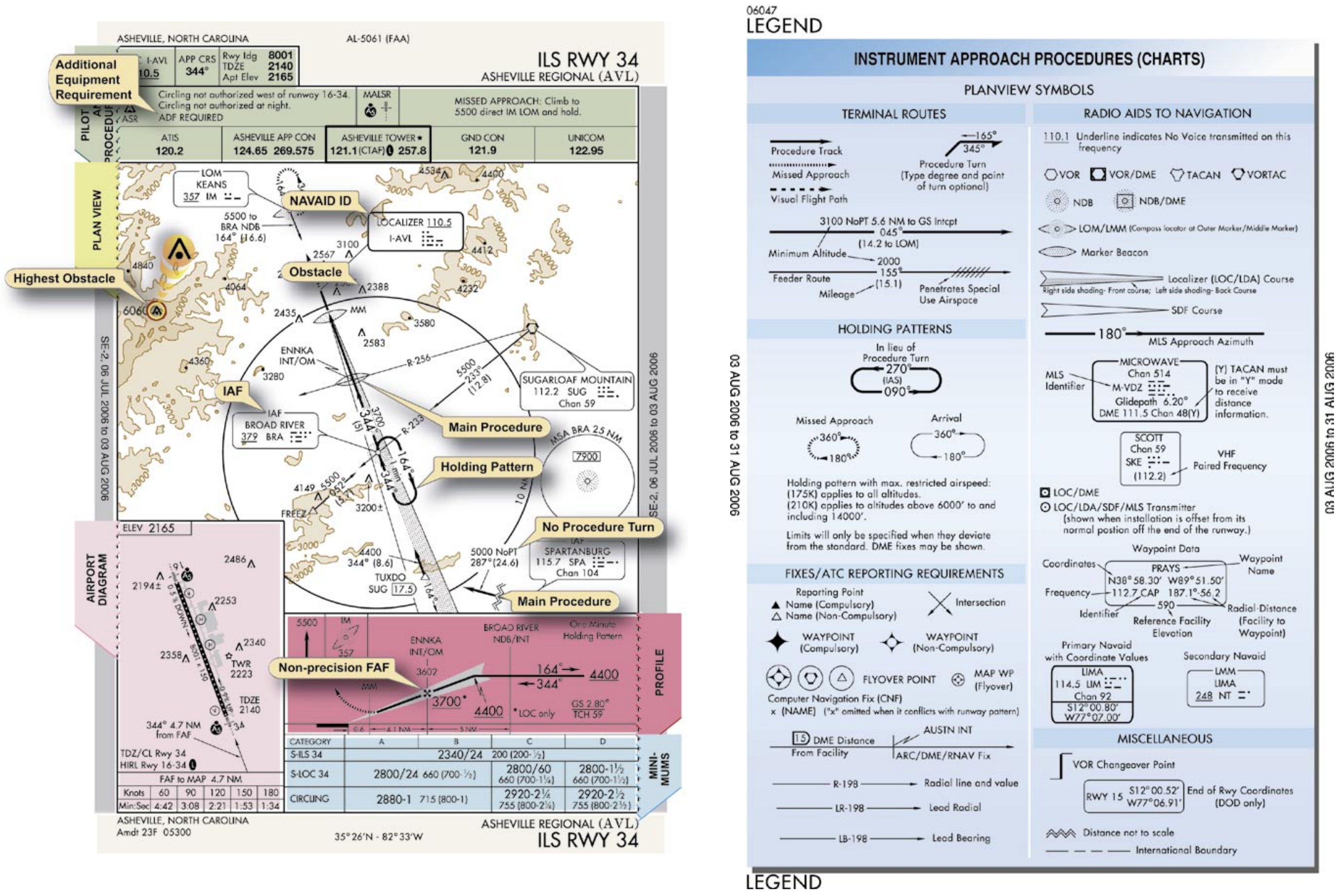
Additional Equipment Requirement
Highest Obstacle
NAVAID ID
Obstacle
IAF
Main Procedure
Holding Pattern
No Procedure Turn
Main Procedure
Non-precision FAF
PILOT PROCEDURE
PLAN VIEW
AIRPORT DIAGRAM
PROFILE
MINIMUMS
ASHEVILLE, NORTH CAROLINA
AL-5061 (FAA)
ILS RWY 34
ASHEVILLE REGIONAL (AVL)
Circling not authorized west of runway 16-34.
Circling not authorized at night.
ADF REQUIRED
MISSED APPROACH: Climb to 5500 direct IM LOM and hold.
ATIS 120.2
ASHEVILLE APP CON 124.65 269.575
ASHEVILLE TOWER 121.1 (CTAF) 257.8
GND CON 121.9
UNICOM 122.95
SE-2, 06 JUL 2006 to 03 AUG 2006
Amdt 23F 05300
35°26'N - 82°33'W
06047
LEGEND
INSTRUMENT APPROACH PROCEDURES (CHARTS)
PLANVIEW SYMBOLS
TERMINAL ROUTES
RADIO AIDS TO NAVIGATION
HOLDING PATTERNS
FIXES/ATC REPORTING REQUIREMENTS
MISCELLANEOUS
03 AUG 2006 to 31 AUG 2006

Figure 8-11. *IAP Plan View and Symbol Legends.*

Some NACG charts contain a reference or distance circle with a specified radius (10 NM is most common). Normally, approach features within the plan view are shown to scale; however, only the data within the reference circle is always drawn to scale.

Concentric dashed circles, or concentric rings around the distance circle, are used when the information necessary to the procedure will not fit to scale within the limits of the plan view area. They serve as a means to systematically arrange this information in its relative position outside and beyond the reference circle. These concentric rings are labeled en route facilities and feeder facilities.

The primary airport depicted in the plan view is drawn with enough detail to show the runway orientation and final approach course alignment. Airports other than the primary approach airport are not normally depicted in the NACG plan view.

Known spot elevations are indicated on the plan view with a dot in MSL altitude. The largest dot and number combination indicates the highest elevation. An inverted "V" with a dot in the center depicts an obstacle. Λ The highest obstacle is indicated with a bolder, larger version of the same symbol. *[Figure 8-11]*

The MSA circle appears in the plan view, except in approaches for which the Terminal Arrival Area (TAA) format is used or appropriate NAVAIDs (e.g., VOR or NDB) are unavailable. The MSA is provided for emergency purposes only and guarantees 1,000 feet obstruction clearance in the sector indicated with reference to the bearings in the circle. For conventional navigation systems, the MSA is normally based on the primary omnidirectional facility (NAVAID) on which the IAP is predicated. The MSA depiction on the approach chart contains the facility identifier of the NAVAID used to determine the MSA altitudes. For RNAV approaches, the MSA is based on the runway waypoint for straight-in approaches, or the airport waypoint for circling approaches. For GPS approaches, the MSA center header will be the missed approach waypoint. The MSL altitudes appear in boxes within the circle, which is typically a 25 NM radius unless otherwise indicated. The MSA circle header refers to the letter identifier of the NAVAID or waypoint that describes the center of the circle.

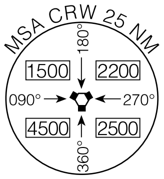

NAVAIDs necessary for the completion of the instrument procedure include the facility name, letter identifier, and Morse code sequence. They may also furnish the frequency, Morse code, and channel. A heavy-lined NAVAID box depicts the primary NAVAID used for the approach. An "I" in front of the NAVAID identifier (in *Figure 8-11*, "I-AVL") listed in the NAVAID box indicates a localizer. The requirement for an ADF, DME, or RADAR in the approach is noted in the plan view.

Intersections, fixes, radials, and course lines describe route and approach sequencing information. The main procedure or final approach course is a thick, solid line. ▬▬▬ A DME arc, which is part of the main procedure course, is also represented as a thick, solid line. ▬▬▬ A feeder route is depicted with a medium line ——— and provides heading, altitude, and distance information. (All three components must be designated on the chart to provide a navigable course.) Radials, such as lead radials, are shown by thin lines. ——— The missed approach track is drawn using a thin, hash marked line with a directional arrow. ||||||||||||||||||||||||► A visual flight path segment appears as a thick dashed line with a directional arrow. - - - - - - - → Visual Flight Path IAFs are charted IAF when associated with a NAVAID or when freestanding.

The missed approach holding pattern track is represented with a thin-dashed line. When collocated, the missed approach holding pattern and procedure turn holding pattern are indicated as a solid, black line. Arrival holding patterns are depicted as thin, solid lines.

Terminal Arrival Area (TAA)

The design objective of the TAA procedure is to provide a transition method for arriving aircraft with GPS/RNAV equipment. TAAs will also eliminate or reduce the need for feeder routes, departure extensions, and procedure turns or course reversal. The TAA is controlled airspace established in conjunction with the standard or modified RNAV approach configurations.

The standard TAA has three areas: straight-in, left base, and right base. The arc boundaries of the three areas of the TAA are published portions of the approach and allow aircraft to transition from the en route structure direct to the nearest IAF. When crossing the boundary of each of these areas or when released by ATC within the area, the pilot is expected to proceed direct to the appropriate waypoint IAF for the approach area being flown. A pilot has the option in all areas of proceeding directly to the holding pattern.

The TAA has a "T" structure that normally provides a NoPT for aircraft using the approach. *[Figure 8-12]* The TAA provides the pilot and air traffic controller with an efficient method for routing traffic from the en route to the terminal structure. The basic "T" contained in the TAA normally aligns the procedure on runway centerline, with the missed

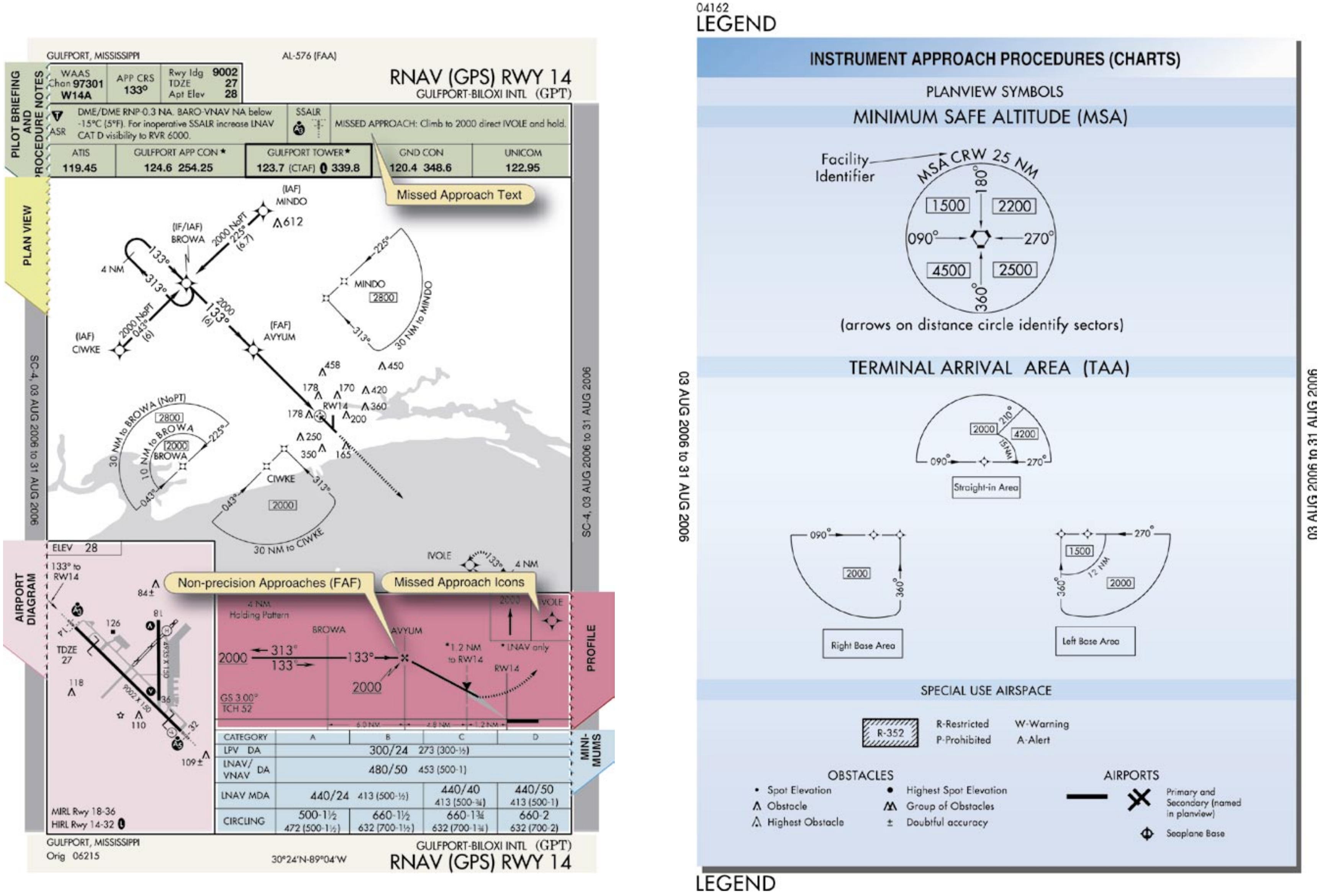
PILOT BRIEFING AND PROCEDURE NOTES
PLAN VIEW
AIRPORT DIAGRAM
PROFILE
MINI-MUMS
GULFPORT, MISSISSIPPI
AL-576 (FAA)
RNAV (GPS) RWY 14
GULFPORT-BILOXI INTL (GPT)
WAAS Chan 97301 W14A
APP CRS 133°
Rwy Idg 9002
TDZE 27
Apt Elev 28
DME/DME RNP-0.3 NA. BARO-VNAV NA below -15°C (5°F). For inoperative SSALR increase LNAV CAT D visibility to RVR 6000.
ASR
SSALR
MISSED APPROACH: Climb to 2000 direct IVOLE and hold.
ATIS 119.45
GULFPORT APP CON ★ 124.6 254.25
GULFPORT TOWER★ 123.7 (CTAF) 339.8
GND CON 120.4 348.6
UNICOM 122.95
Missed Approach Text
(IAF) MINDO
612
(IF/IAF) BROWA
2000 NoPT 225° (6.7)
4 NM
133°
313°
2000 133° (6)
(IAF) CIWKE
2000 NoPT 043° (6)
(FAF) AVYUM
MINDO 2800
225°
313°
30 NM to MINDO
458
450
178
170
420
RW14
360
200
250
350
165
30 NM to BROWA (NoPT)
2800
10 NM to BROWA
2000
BROWA
225°
043°
CIWKE
2000
043°
313°
30 NM to CIWKE
SC-4, 03 AUG 2006 to 31 AUG 2006
ELEV 28
133° to RW14
84±
TDZE 27
126
118
110
109±
9002 X 150
4935 X 150
18
36
14
32
MIRL Rwy 18-36
HIRL Rwy 14-32
IVOLE
133°
4 NM
Non-precision Approaches (FAF)
Missed Approach Icons
4 NM Holding Pattern
BROWA
AVYUM
2000
313°
133°
1.2 NM to RW14
LNAV only
RW14
2000
GS 3.00° TCH 52
6.0 NM
4.8 NM
1.2 NM
IVOLE
CATEGORY A B C D
LPV DA 300/24 273 (300-½)
LNAV/VNAV DA 480/50 453 (500-1)
LNAV MDA 440/24 413 (500-½) 440/40 413 (500-¾) 440/50 413 (500-1)
CIRCLING 500-1½ 472 (500-1½) 660-1½ 632 (700-1½) 660-1¾ 632 (700-1¾) 660-2 632 (700-2)
GULFPORT, MISSISSIPPI
Orig 06215
30°24'N-89°04'W
04162
LEGEND
INSTRUMENT APPROACH PROCEDURES (CHARTS)
PLANVIEW SYMBOLS
MINIMUM SAFE ALTITUDE (MSA)
Facility Identifier
MSA CRW 25 NM
180°
1500
2200
090°
270°
4500
2500
360°
(arrows on distance circle identify sectors)
TERMINAL ARRIVAL AREA (TAA)
2000
210°
4200
15NM
090°
270°
Straight-in Area
090°
2000
360°
Right Base Area
1500
12 NM
270°
2000
360°
Left Base Area
SPECIAL USE AIRSPACE
R-352
R-Restricted
P-Prohibited
W-Warning
A-Alert
OBSTACLES
Spot Elevation
Obstacle
Highest Obstacle
Highest Spot Elevation
Group of Obstacles
± Doubtful accuracy
AIRPORTS
Primary and Secondary (named in planview)
Seaplane Base
03 AUG 2006 to 31 AUG 2006
LEGEND

Figure 8-12. *Basic "T" Design of Terminal Arrival Area (TAA) and Legend.*

approach point (MAP) located at the threshold, the FAF 5 NM from the threshold, and the intermediate fix (IF) 5 NM from the FAF.

In order to accommodate descent from a high en route altitude to the initial segment altitude, a hold in lieu of a procedure turn provides the aircraft with an extended distance for the necessary descent gradient. The holding pattern constructed for this purpose is always established on the center IAF waypoint. Other modifications may be required for parallel runways, or special operational requirements. When published, the RNAV chart will depict the TAA through the use of icons representing each TAA associated with the RNAV procedure. These icons are depicted in the plan view of the approach, generally arranged on the chart in accordance with their position relative to the aircraft's arrival from the en route structure.

Course Reversal Elements in Plan View and Profile View

Course reversals included in an IAP are depicted in one of three different ways: a 45°/180° procedure turn, a holding pattern in lieu of procedure turn, or a teardrop procedure. The maneuvers are required when it is necessary to reverse direction to establish the aircraft inbound on an intermediate or final approach course. Components of the required procedure are depicted in the plan view and the profile view. The maneuver must be completed within the distance and at the minimum altitude specified in the profile view. Pilots should coordinate with the appropriate ATC facility relating to course reversal during the IAP.

Procedure Turns

A procedure turn barbed arrow 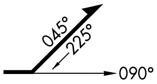

indicates the direction or side of the outbound course on which the procedure turn is made. *[Figure 8-13]* Headings are provided for course reversal using the 45° procedure turn. However, the point at which the turn may be commenced, and the type and rate of turn is left to the discretion of the pilot. Some of the options are the 45° procedure turn, the racetrack pattern, the teardrop procedure turn, or the 80°/260° course reversal. The absence of the procedure turn barbed arrow in the plan view indicates that a procedure turn is not authorized for that procedure. A maximum procedure turn speed of not greater than 200 knots indicated airspeed (KIAS) should be observed when turning outbound over the IAF and throughout the procedure turn maneuver to ensure staying within the obstruction clearance area. The normal procedure turn distance is 10 NM. This may be reduced to a minimum of 5 NM where only Category A or helicopter aircraft are operated, or increased to as much as 15 NM to accommodate high performance aircraft. Descent below the procedure turn altitude begins after the aircraft is established on the inbound course.

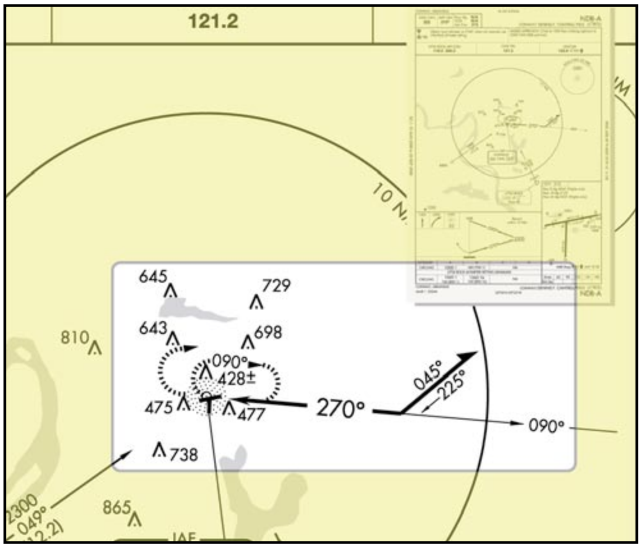

Figure 8-13. *45° Procedure Turn.*

The procedure turn is *not* required when the symbol "NoPT" appears, when radar vectoring to the final approach is provided, when conducting a timed approach, or when the procedure turn is not authorized. Pilots should contact the appropriate ATC facility when in doubt if a procedure turn is required.

Holding in Lieu of Procedure Turn

A holding pattern in lieu of a procedure turn may be specified for course reversal in some procedures. *[Figure 8-14]* In such cases, the holding pattern is established over an intermediate fix or a final approach fix (FAF). The holding pattern distance

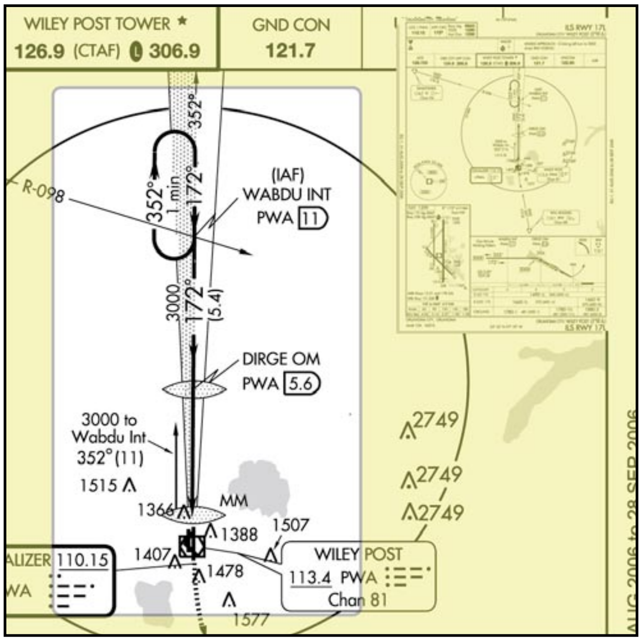

Figure 8-14. *Holding in Lieu of Procedure Turn.*

or time specified in the profile view must be observed. Maximum holding airspeed limitations as set forth for all holding patterns apply. The holding pattern maneuver is completed when the aircraft is established on the inbound course after executing the appropriate entry. If cleared for the approach prior to returning to the holding fix and the aircraft is at the prescribed altitude, additional circuits of the holding pattern are neither necessary nor expected by ATC. If pilots elect to make additional circuits to lose excessive altitude or to become better established on course, it is their responsibility to advise ATC upon receipt of their approach clearance. When holding in lieu of a procedure turn, the holding pattern must be followed, except when RADAR VECTORING to the final approach course is provided or when NoPT is shown on the approach course.

Teardrop Procedure

When a teardrop procedure turn is depicted and a course reversal is required, unless otherwise authorized by ATC, this type of procedure must be executed. *[Figure 8-15]* The teardrop procedure consists of departure from an IAF on the published outbound course followed by a turn toward and intercepting the inbound course at or prior to the intermediate fix or point. Its purpose is to permit an aircraft to reverse direction and lose considerable altitude within reasonably limited airspace. Where no fix is available to mark the beginning of the intermediate segment, it shall be assumed to commence at a point 10 NM prior to the FAF. When the facility is located on the airport, an aircraft is considered to be on final approach upon completion of the penetration turn. However, the final approach segment begins on the final approach course 10 NM from the facility.

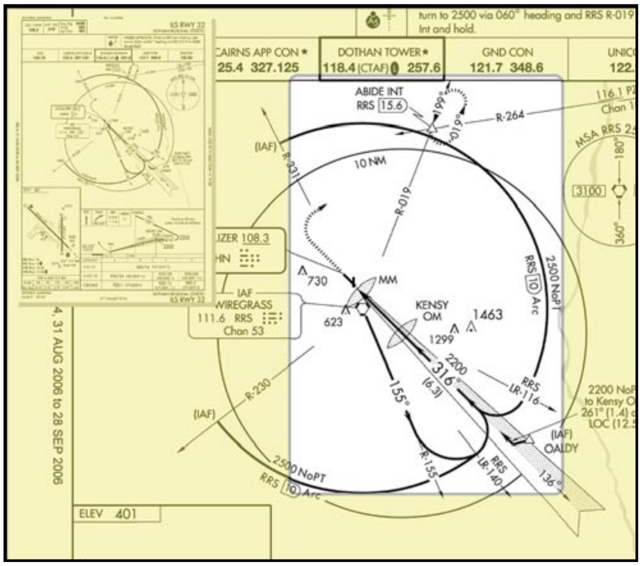

Figure 8-15. *Teardrop Procedure.*

The Profile View

The profile view is a depiction of the procedure from the side and illustrates the vertical approach path altitudes, headings, distances, and fixes. *[Figures 8-10, 8-11,* and *8-12]* The view includes the minimum altitude and the maximum distance for the procedure turn, altitudes over prescribed fixes, distances between fixes, and the missed approach procedure. The profile view aids in the pilot's interpretation of the IAP. The profile view is not drawn to scale. *[Figures 8-10, 8-11, 8-12,* and *8-16]*

The precision approach glide slope (GS) intercept altitude is a minimum altitude for GS interception after completion of the procedure turn, illustrated by an altitude number and "zigzag" line. It applies to precision approaches, and except where otherwise prescribed, also applies as a minimum altitude for crossing the FAF when the GS is inoperative or not used. Precision approach profiles also depict the GS angle of descent, threshold-crossing height (TCH), and GS altitude at the outer marker (OM).

For nonprecision approaches, a final descent is initiated and the final segment begins at either the FAF or the final approach point (FAP). The FAF is identified by use of the Maltese cross symbol in the profile view. ✖ *[Figure 8-11]* When no FAF is depicted, the final approach point is the point at which the aircraft is established inbound on the final approach course. *[Figure 8-16]*

Stepdown fixes in nonprecision procedures are provided between the FAF and the airport for authorizing a lower minimum descent altitude (MDA) after passing an obstruction. Stepdown fixes can be identified by NAVAID, NAVAID fix, waypoint or radar, and are depicted by a hash marked line. ¦ Normally, there is only one stepdown fix between the FAF and the MAP, but there can be several. If the stepdown fix cannot be identified for any reason, the minimum altitude at the stepdown fix becomes the MDA for the approach. However, circling minimums apply if they are higher than the stepdown fix minimum altitude, and a circling approach is required.

The visual descent point (VDP) is a defined point on the final approach course of a nonprecision straight-in approach procedure. A normal descent from the MDA to the runway touchdown point may be commenced, provided visual reference is established. The VDP is identified on the profile view of the approach chart by the symbol "V." *[Figure 8-12]*

The MAP varies depending upon the approach flown. For the ILS, the MAP is at the decision altitude/decision height (DA/DH). For nonprecision procedures, the pilot determines

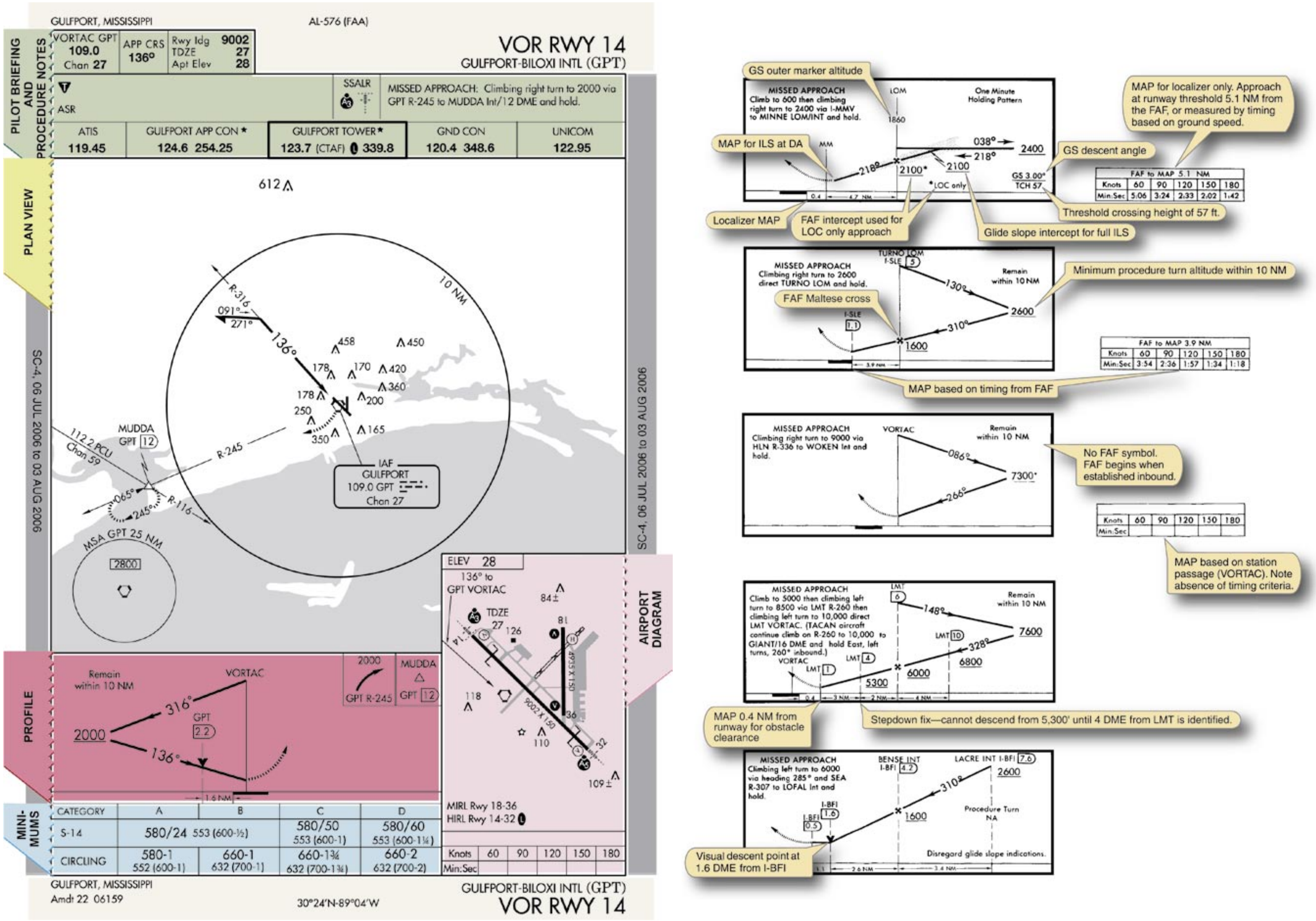
GULFPORT, MISSISSIPPI
AL-576 (FAA)
VOR RWY 14
GULFPORT-BILOXI INTL (GPT)
VORTAC GPT 109.0 Chan 27
APP CRS 136°
Rwy ldg 9002
TDZE 27
Apt Elev 28
PILOT BRIEFING AND PROCEDURE NOTES
ASR
SSALR
MISSED APPROACH: Climbing right turn to 2000 via GPT R-245 to MUDDA Int/12 DME and hold.
ATIS 119.45
GULFPORT APP CON ★ 124.6 254.25
GULFPORT TOWER★ 123.7 (CTAF) 339.8
GND CON 120.4 348.6
UNICOM 122.95
PLAN VIEW
SC-4, 06 JUL 2006 to 03 AUG 2006
10 NM
R-316
091°
271°
136°
R-245
MUDDA GPT 12
112.2 PCU Chan 59
065°
245°
R-116
MSA GPT 25 NM
2800
IAF GULFPORT 109.0 GPT Chan 27
AIRPORT DIAGRAM
ELEV 28
136° to GPT VORTAC
TDZE 27
9002 X 150
4935 X 150
MIRL Rwy 18-36
HIRL Rwy 14-32
PROFILE
Remain within 10 NM
VORTAC
2000
316°
136°
GPT 2.2
1.6 NM
GPT R-245
MUDDA
GPT 12
MINI-MUMS
CATEGORY
A
B
C
D
S-14
580/24 553 (600-½)
580/50 553 (600-1)
580/60 553 (600-1¼)
CIRCLING
580-1 552 (600-1)
660-1 632 (700-1)
660-1¾ 632 (700-1¾)
660-2 632 (700-2)
Knots 60 90 120 150 180
Min:Sec
GULFPORT, MISSISSIPPI
Amdt 22 06159
30°24'N-89°04'W
GS outer marker altitude
MISSED APPROACH Climb to 600 then climbing right turn to 2400 via I-MMV to MINNE LOM/INT and hold.
LOM
1860
One Minute Holding Pattern
MAP for ILS at DA
MM
218°
2100*
038°
2400
2100
*LOC only
GS 3.00° TCH 57
GS descent angle
MAP for localizer only. Approach at runway threshold 5.1 NM from the FAF, or measured by timing based on ground speed.
FAF to MAP 5.1 NM
Knots 60 90 120 150 180
Min:Sec 5:06 3:24 2:33 2:02 1:42
Threshold crossing height of 57 ft.
Localizer MAP
FAF intercept used for LOC only approach
Glide slope intercept for full ILS
MISSED APPROACH Climbing right turn to 2600 direct TURNO LOM and hold.
TURNO LOM I-SLE 5
Remain within 10 NM
130°
310°
2600
1600
I-SLE 1.1
FAF Maltese cross
Minimum procedure turn altitude within 10 NM
FAF to MAP 3.9 NM
Knots 60 90 120 150 180
Min:Sec 3:54 2:36 1:57 1:34 1:18
MAP based on timing from FAF
MISSED APPROACH Climbing right turn to 9000 via HLN R-336 to WOKEN Int and hold.
VORTAC
Remain within 10 NM
086°
266°
7300'
No FAF symbol. FAF begins when established inbound.
Knots 60 90 120 150 180
Min:Sec
MAP based on station passage (VORTAC). Note absence of timing criteria.
MISSED APPROACH Climb to 5000 then climbing left turn to 8500 via LMT R-260 then climbing left turn to 10,000 direct LMT VORTAC. (TACAN aircraft continue climb on R-260 to 10,000 to GIANT/16 DME and hold East, left turns, 260° inbound.)
LMT 6
148°
328°
LMT 10
LMT 4
LMT 1
7600
6800
6000
5300
Remain within 10 NM
MAP 0.4 NM from runway for obstacle clearance
Stepdown fix—cannot descend from 5,300' until 4 DME from LMT is identified.
MISSED APPROACH Climbing left turn to 6000 via heading 285° and SEA R-307 to LOFAL Int and hold.
BENSE INT I-BFI 4.2
LACRE INT I-BFI 7.6
310°
2600
1600
I-BFI 1.6
I-BFI 0.5
Procedure Turn NA
Disregard glide slope indications.
Visual descent point at 1.6 DME from I-BFI

Figure 8-16. *More IAP Profile View Features.*

the MAP by timing from FAF when the approach aid is away from the airport, by a fix or NAVAID when the navigation facility is located on the field, or by waypoints as defined by GPS or VOR/DME RNAV. The pilot may execute the MAP early, but pilots should, unless otherwise cleared by ATC, fly the IAP as specified on the approach plate to the MAP at or above the MDA or DA/DH before executing a turning maneuver.

A complete description of the missed approach procedure appears in the pilot briefing section. *[Figure 8-16]* Icons indicating what is to be accomplished at the MAP are located in the profile view. When initiating a missed approach, the pilot will be directed to climb straight ahead (e.g., "Climb to 2,000") or commence a turning climb to a specified altitude (e.g., "Climbing right turn to 2,000"). In some cases, the procedure will direct the pilot to climb straight ahead to an initial altitude, then turn or enter a climbing turn to the holding altitude (e.g., "Climb to 900, then climbing right turn to 2,500 direct ABC VOR and hold").

When the missed approach procedure specifies holding at a facility or fix, the pilot proceeds according to the missed approach track and pattern depicted on the plan view. An alternate missed approach procedure may also be issued by ATC. The textual description will also specify the NAVAID(s) or radials that identify the holding fix.

The profile view also depicts minimum, maximum, recommended, and mandatory block altitudes used in approaches. The minimum altitude is depicted with the altitude underscored. $\underline{2500}$ On final approach, aircraft are required to maintain an altitude at or above the depicted altitude until reaching the subsequent fix. The maximum altitude will be depicted with the altitude overscored, $\overline{4300}$ and aircraft must remain at or below the depicted altitude. Mandatory altitudes will be depicted with the altitude both underscored and overscored, $\overline{\underline{5500}}$ and altitude is to be maintained at the depicted value. Recommended altitudes are advisory altitudes and are neither over- nor underscored. When an over- or underscore spans two numbers, a mandatory block altitude is indicated, and aircraft are required to maintain altitude within the range of the two numbers. *[Figures 8-11* and *8-12]*

The Vertical Descent Angle (VDA) found on nonprecision approach charts provides the pilot with information required to establish a stabilized approach descent from the FAF or stepdown fix to the threshold crossing height (TCH). *[Figure 8-17]* Pilots can use the published angle and estimated or actual ground speed to find a target rate of descent using the rate of descent table in the back of the TPP.

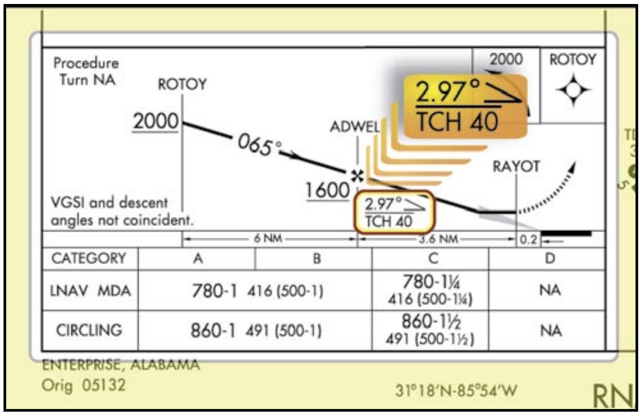

Figure 8-17. *Vertical Descent Angle (VDA).*

Landing Minimums

The minimums section sets forth the lowest altitude and visibility requirements for the approach, whether precision or nonprecision, straight-in or circling, or radar vectored. When a fix is incorporated in a nonprecision final segment, two sets of minimums may be published, depending upon how the fix can be identified. Two sets of minimums may also be published when a second altimeter source is used in the procedure. The minimums ensure that final approach obstacle clearance is provided from the start of the final segment to the runway or MAP, whichever occurs last. The same minimums apply to both day and night operations unless different minimums are specified in the Notes section of the pilot briefing. Published circling minimums provide obstacle clearance when pilots remain within the appropriate area of protection. *[Figure 8-18]*

Minimums are specified for various aircraft approach categories based upon a value 1.3 times the stalling speed of the aircraft in the landing configuration at maximum certified gross landing weight. If it is necessary to maneuver at speeds in excess of the upper limit of a speed range for a category, the minimums for the next higher category should be used. For example, an aircraft that falls into category A, but is circling to land at a speed in excess of 91 knots, should use approach category B minimums when circling to land. *[Figure 8-19]*

The minimums for straight-in and circling appear directly under each aircraft category. *[Figure 8-19]* When there is no solid division line between minimums for each category on the rows for straight-in or circling, the minimums apply to the two or more categories.

The terms used to describe the minimum approach altitudes differ between precision and nonprecision approaches.

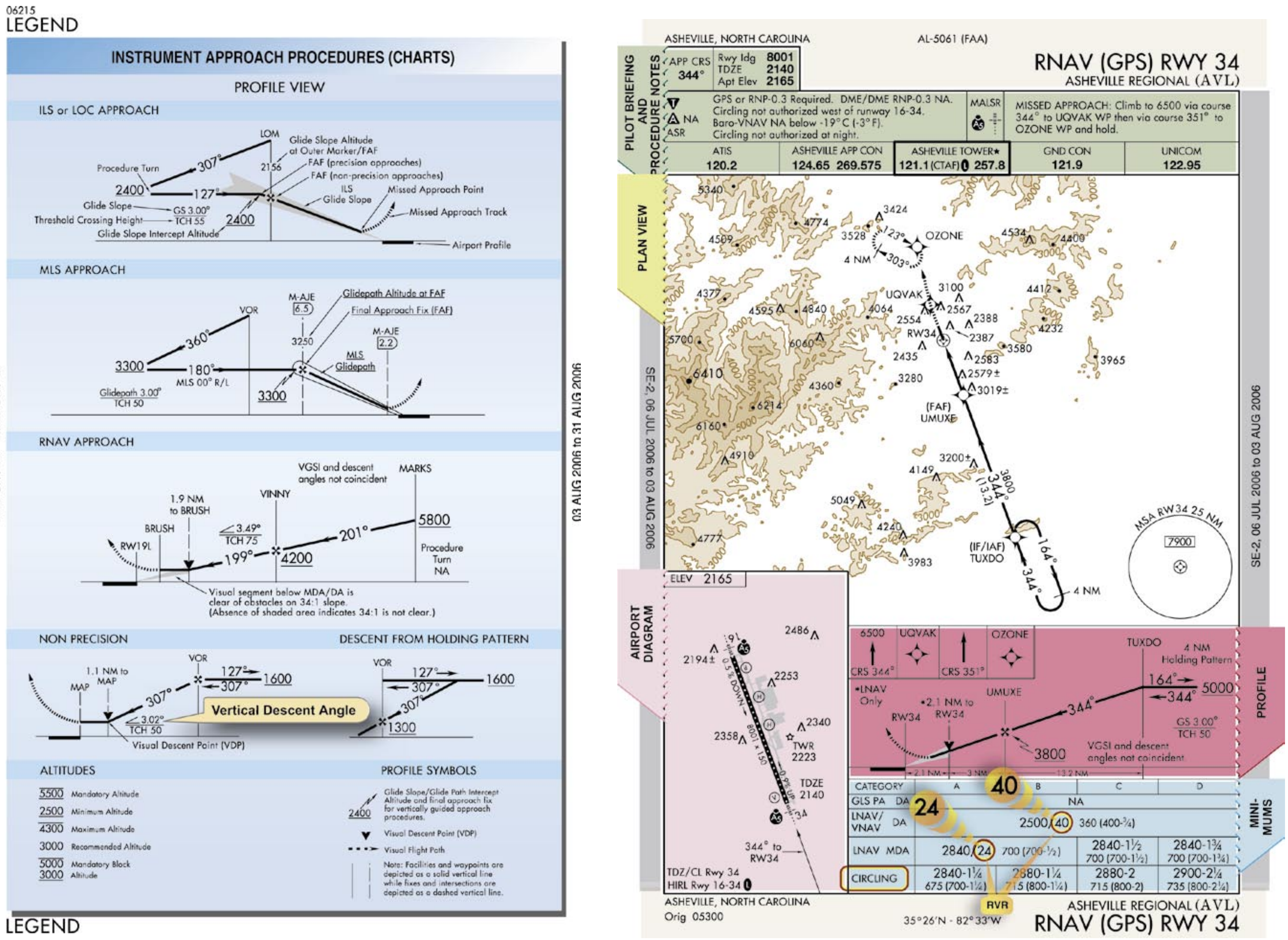
06215
LEGEND
INSTRUMENT APPROACH PROCEDURES (CHARTS)
PROFILE VIEW
ILS or LOC APPROACH
LOM
Glide Slope Altitude at Outer Marker/FAF
FAF (precision approaches)
FAF (non-precision approaches)
ILS Glide Slope
Missed Approach Point
Missed Approach Track
Airport Profile
Procedure Turn
2400
307°
127°
2156
Glide Slope
GS 3.00°
Threshold Crossing Height
TCH 55
Glide Slope Intercept Altitude
MLS APPROACH
VOR
M-AJE
6.5
Glidepath Altitude at FAF
Final Approach Fix (FAF)
M-AJE
2.2
3250
MLS Glidepath
3300
360°
180°
MLS 00° R/L
Glidepath 3.00°
TCH 50
RNAV APPROACH
VGSI and descent angles not coincident
MARKS
VINNY
1.9 NM to BRUSH
BRUSH
RW19L
3.49°
TCH 75
199°
4200
201°
5800
Procedure Turn NA
Visual segment below MDA/DA is clear of obstacles on 34:1 slope. (Absence of shaded area indicates 34:1 is not clear.)
NON PRECISION
DESCENT FROM HOLDING PATTERN
1.1 NM to MAP
MAP
VOR
307°
127°
1600
3.02°
TCH 50
Vertical Descent Angle
Visual Descent Point (VDP)
1300
ALTITUDES
5500 Mandatory Altitude
2500 Minimum Altitude
4300 Maximum Altitude
3000 Recommended Altitude
5000 3000 Mandatory Block Altitude
PROFILE SYMBOLS
2400 Glide Slope/Glide Path Intercept Altitude and final approach fix for vertically guided approach procedures.
Visual Descent Point (VDP)
Visual Flight Path
Note: Facilities and waypoints are depicted as a solid vertical line while fixes and intersections are depicted as a dashed vertical line.
LEGEND
03 AUG 2006 to 31 AUG 2006
ASHEVILLE, NORTH CAROLINA
AL-5061 (FAA)
RNAV (GPS) RWY 34
ASHEVILLE REGIONAL (AVL)
PILOT BRIEFING AND PROCEDURE NOTES
APP CRS 344°
Rwy Idg 8001
TDZE 2140
Apt Elev 2165
A NA
ASR
GPS or RNP-0.3 Required. DME/DME RNP-0.3 NA.
Circling not authorized west of runway 16-34.
Baro-VNAV NA below -19° C (-3° F).
Circling not authorized at night.
MALSR
MISSED APPROACH: Climb to 6500 via course 344° to UQVAK WP then via course 351° to OZONE WP and hold.
ATIS 120.2
ASHEVILLE APP CON 124.65 269.575
ASHEVILLE TOWER★ 121.1 (CTAF) 257.8
GND CON 121.9
UNICOM 122.95
PLAN VIEW
OZONE
UQVAK
RW34
(FAF) UMUXE
(IF/IAF) TUXDO
123°
303°
4 NM
3800
344°
(13.2)
164°
344°
MSA RW34 25 NM
7900
SE-2, 06 JUL 2006 to 03 AUG 2006
AIRPORT DIAGRAM
ELEV 2165
2194±
2486
2253
2340
TWR 2223
2358
0.5% DOWN
8001 x 150
0.9% UP
TDZE 2140
344° to RW34
TDZ/CL Rwy 34
HIRL Rwy 16-34
PROFILE
6500
CRS 344°
UQVAK
CRS 351°
OZONE
TUXDO
4 NM Holding Pattern
164°
344°
5000
•LNAV Only
•2.1 NM to RW34
RW34
UMUXE
3800
GS 3.00°
TCH 50
VGSI and descent angles not coincident
2.1 NM
3 NM
13.2 NM
MINI-MUMS
CATEGORY
A
B
C
D
GLS PA DA
NA
LNAV/VNAV DA
2500/40 360 (400-¾)
LNAV MDA
2840/24 700 (700-½)
2840-1½ 700 (700-1½)
2840-1¾ 700 (700-1¾)
CIRCLING
2840-1¼ 675 (700-1¼)
2880-1¼ 715 (800-1¼)
2880-2 715 (800-2)
2900-2¼ 735 (800-2¼)
24
40
RVR
ASHEVILLE, NORTH CAROLINA
Orig 05300
35°26'N - 82°33'W
ASHEVILLE REGIONAL (AVL)
RNAV (GPS) RWY 34

Figure 8-18. *IAP Profile Legend.*

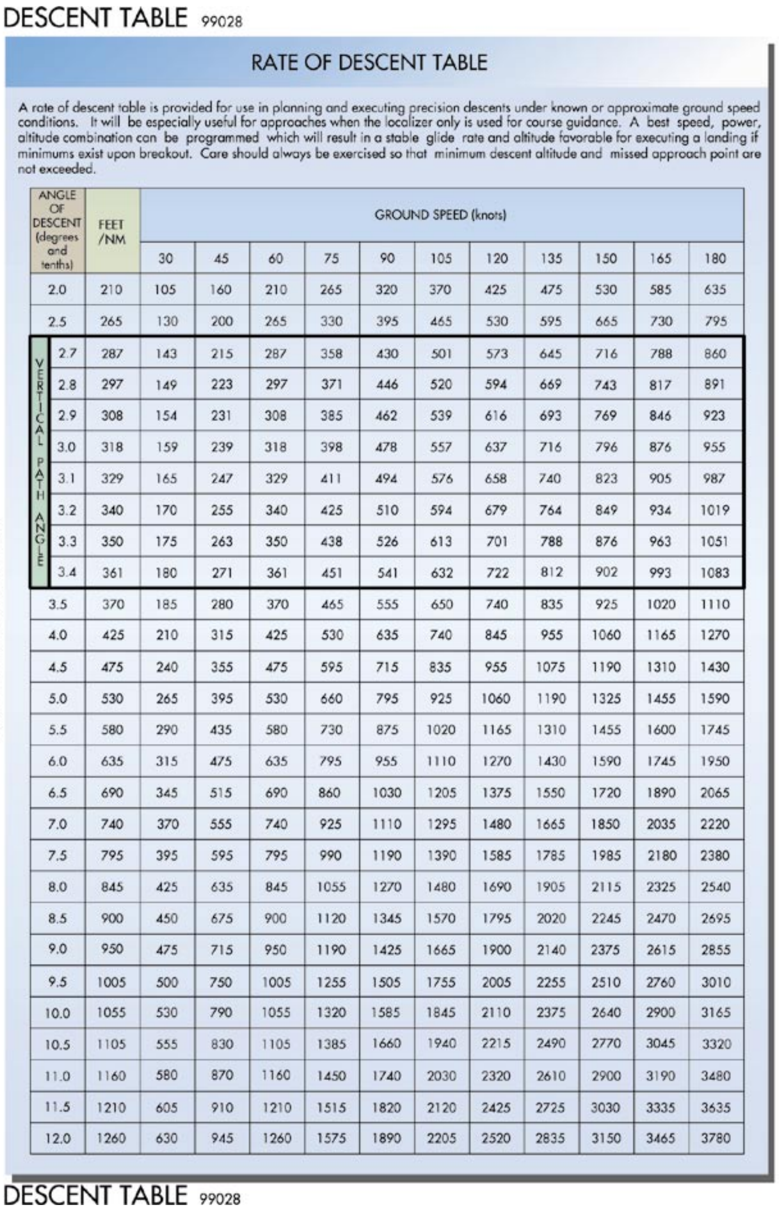

DESCENT TABLE 99028

RATE OF DESCENT TABLE

A rate of descent table is provided for use in planning and executing precision descents under known or approximate ground speed conditions. It will be especially useful for approaches when the localizer only is used for course guidance. A best speed, power, altitude combination can be programmed which will result in a stable glide rate and altitude favorable for executing a landing if minimums exist upon breakout. Care should always be exercised so that minimum descent altitude and missed approach point are not exceeded.

	ANGLE OF DESCENT (degrees and tenths)	FEET /NM	GROUND SPEED (knots)										
			30	45	60	75	90	105	120	135	150	165	180
	2.0	210	105	160	210	265	320	370	425	475	530	585	635
	2.5	265	130	200	265	330	395	465	530	595	665	730	795
VERTICAL PATH ANGLE	2.7	287	143	215	287	358	430	501	573	645	716	788	860
	2.8	297	149	223	297	371	446	520	594	669	743	817	891
	2.9	308	154	231	308	385	462	539	616	693	769	846	923
	3.0	318	159	239	318	398	478	557	637	716	796	876	955
	3.1	329	165	247	329	411	494	576	658	740	823	905	987
	3.2	340	170	255	340	425	510	594	679	764	849	934	1019
	3.3	350	175	263	350	438	526	613	701	788	876	963	1051
	3.4	361	180	271	361	451	541	632	722	812	902	993	1083
	3.5	370	185	280	370	465	555	650	740	835	925	1020	1110
	4.0	425	210	315	425	530	635	740	845	955	1060	1165	1270
	4.5	475	240	355	475	595	715	835	955	1075	1190	1310	1430
	5.0	530	265	395	530	660	795	925	1060	1190	1325	1455	1590
	5.5	580	290	435	580	730	875	1020	1165	1310	1455	1600	1745
	6.0	635	315	475	635	795	955	1110	1270	1430	1590	1745	1950
	6.5	690	345	515	690	860	1030	1205	1375	1550	1720	1890	2065
	7.0	740	370	555	740	925	1110	1295	1480	1665	1850	2035	2220
	7.5	795	395	595	795	990	1190	1390	1585	1785	1985	2180	2380
	8.0	845	425	635	845	1055	1270	1480	1690	1905	2115	2325	2540
	8.5	900	450	675	900	1120	1345	1570	1795	2020	2245	2470	2695
	9.0	950	475	715	950	1190	1425	1665	1900	2140	2375	2615	2855
	9.5	1005	500	750	1005	1255	1505	1755	2005	2255	2510	2760	3010
	10.0	1055	530	790	1055	1320	1585	1845	2110	2375	2640	2900	3165
	10.5	1105	555	830	1105	1385	1660	1940	2215	2490	2770	3045	3320
	11.0	1160	580	870	1160	1450	1740	2030	2320	2610	2900	3190	3480
	11.5	1210	605	910	1210	1515	1820	2120	2425	2725	3030	3335	3635
	12.0	1260	630	945	1260	1575	1890	2205	2520	2835	3150	3465	3780

DESCENT TABLE 99028

03 AUG 2006 to 31 AUG 2006

03 AUG 2006 to 31 AUG 2006

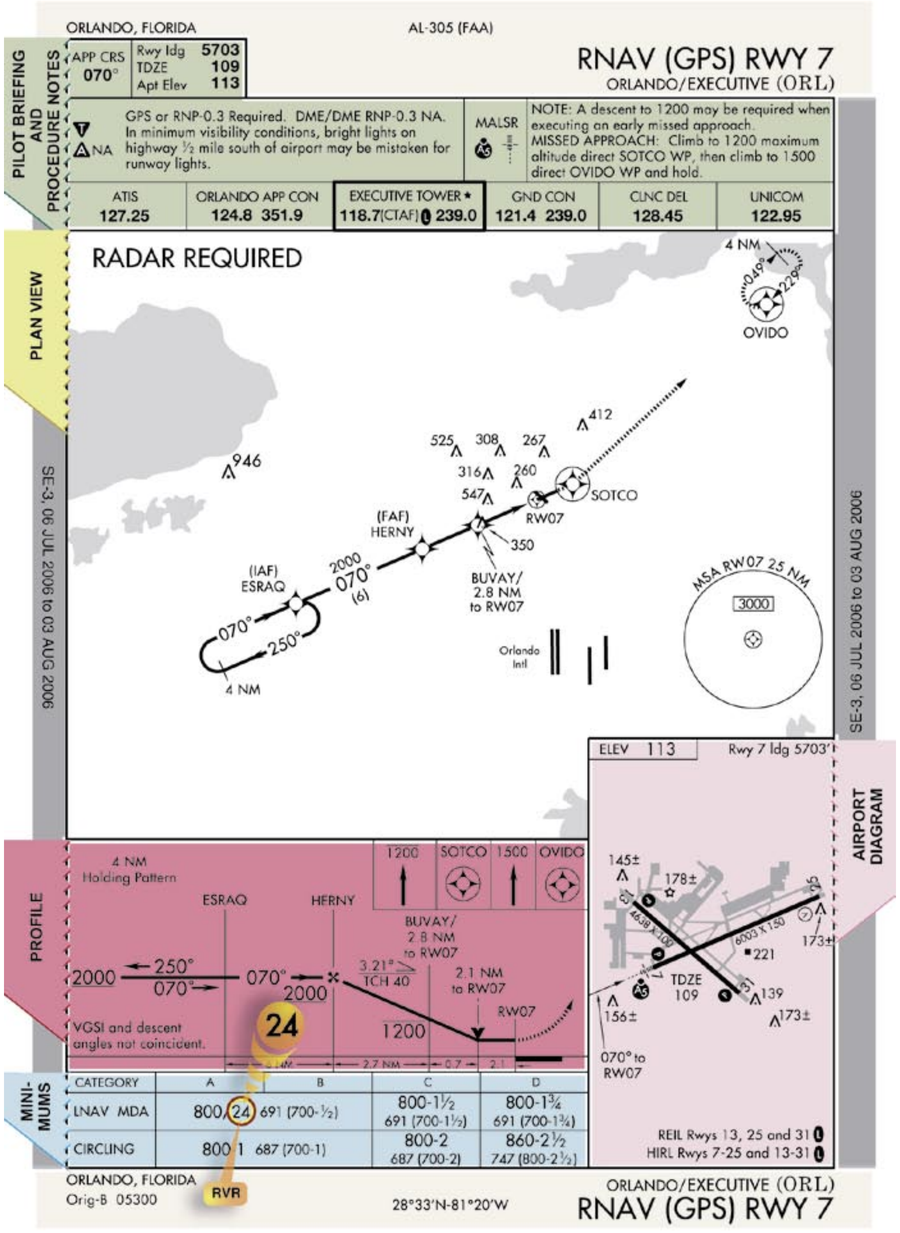

ORLANDO, FLORIDA

AL-305 (FAA)

RNAV (GPS) RWY 7

ORLANDO/EXECUTIVE (ORL)

NOTE: A descent to 1200 may be required when executing an early missed approach.

MISSED APPROACH: Climb to 1200 maximum altitude direct SOTCO WP, then climb to 1500 direct OVIDO WP and hold.

GPS or RNP-0.3 Required. DME/DME RNP-0.3 NA.

In minimum visibility conditions, bright lights on highway ½ mile south of airport may be mistaken for runway lights.

ATIS	ORLANDO APP CON	EXECUTIVE TOWER ★	GND CON	CLNC DEL	UNICOM
127.25	124.8 351.9	118.7(CTAF) Ⓛ 239.0	121.4 239.0	128.45	122.95

CATEGORY	A	B	C	D
LNAV MDA	800/24 691 (700-½)		800-1½ 691 (700-1½)	800-1¾ 691 (700-1¾)
CIRCLING	800-1 687 (700-1)		800-2 687 (700-2)	860-2½ 747 (800-2½)

REIL Rwys 13, 25 and 31 Ⓛ
HIRL Rwys 7-25 and 13-31 Ⓛ

ORLANDO, FLORIDA
Orig-B 05300

28°33'N-81°20'W

ORLANDO/EXECUTIVE (ORL)
RNAV (GPS) RWY 7

PILOT BRIEFING AND PROCEDURE NOTES
APP CRS 070°
Rwy ldg 5703
TDZE 109
Apt Elev 113
ANA
MALSR
PLAN VIEW
RADAR REQUIRED
SE-3, 06 JUL 2006 to 03 AUG 2006
4 NM
049°
229°
OVIDO
946
412
525
308
267
316
260
547
SOTCO
RW07
350
(FAF) HERNY
2000
070°
(6)
(IAF) ESRAQ
070°
250°
4 NM
BUVAY/ 2.8 NM to RW07
Orlando Intl
MSA RW07 25 NM
3000
ELEV 113
Rwy 7 ldg 5703'
AIRPORT DIAGRAM
145±
178±
4638 X 100
6003 X 150
221
173±
TDZE 109
139
173±
156±
070° to RW07
PROFILE
4 NM Holding Pattern
ESRAQ
HERNY
1200
SOTCO
1500
OVIDO
BUVAY/ 2.8 NM to RW07
3.21°
TCH 40
2.1 NM to RW07
2000
250°
070°
070°
2000
1200
RW07
VGSI and descent angles not coincident.
2.7 NM
0.7
2.1
24
MINI-MUMS
RVR

Figure 8-19. *Descent Rate Table.*

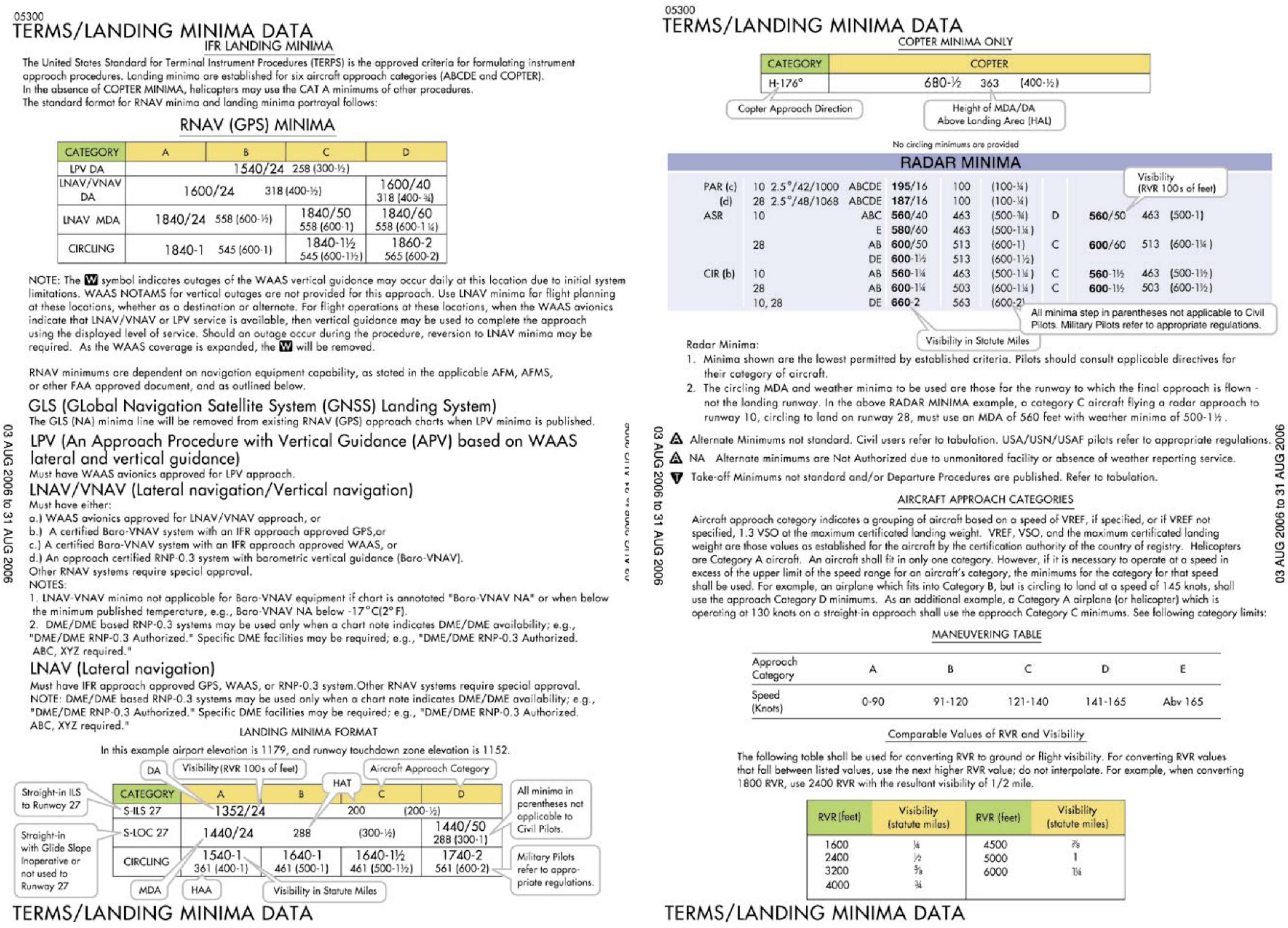

05300

TERMS/LANDING MINIMA DATA

IFR LANDING MINIMA

The United States Standard for Terminal Instrument Procedures (TERPS) is the approved criteria for formulating instrument approach procedures. Landing minima are established for six aircraft approach categories (ABCDE and COPTER). In the absence of COPTER MINIMA, helicopters may use the CAT A minimums of other procedures. The standard format for RNAV minima and landing minima portrayal follows:

RNAV (GPS) MINIMA

CATEGORY	A	B	C	D
LPV DA	1540/24 258 (300-½)			
LNAV/VNAV DA	1600/24 318 (400-½)			1600/40 318 (400-¾)
LNAV MDA	1840/24 558 (600-½)		1840/50 558 (600-1)	1840/60 558 (600-1 ¼)
CIRCLING	1840-1 545 (600-1)		1840-1½ 545 (600-1½)	1860-2 565 (600-2)

NOTE: The W symbol indicates outages of the WAAS vertical guidance may occur daily at this location due to initial system limitations. WAAS NOTAMS for vertical outages are not provided for this approach. Use LNAV minima for flight planning at these locations, whether as a destination or alternate. For flight operations at these locations, when the WAAS avionics indicate that LNAV/VNAV or LPV service is available, then vertical guidance may be used to complete the approach using the displayed level of service. Should an outage occur during the procedure, reversion to LNAV minima may be required. As the WAAS coverage is expanded, the W will be removed.

RNAV minimums are dependent on navigation equipment capability, as stated in the applicable AFM, AFMS, or other FAA approved document, and as outlined below.

GLS (GLobal Navigation Satellite System (GNSS) Landing System)

The GLS (NA) minima line will be removed from existing RNAV (GPS) approach charts when LPV minima is published.

LPV (An Approach Procedure with Vertical Guidance (APV) based on WAAS lateral and vertical guidance)

Must have WAAS avionics approved for LPV approach.

LNAV/VNAV (Lateral navigation/Vertical navigation)

Must have either:

a.) WAAS avionics approved for LNAV/VNAV approach, or

b.) A certified Baro-VNAV system with an IFR approach approved GPS,or

c.) A certified Baro-VNAV system with an IFR approach approved WAAS, or

d.) An approach certified RNP-0.3 system with barometric vertical guidance (Baro-VNAV).

Other RNAV systems require special approval.

NOTES:

1. LNAV-VNAV minima not applicable for Baro-VNAV equipment if chart is annotated "Baro-VNAV NA" or when below the minimum published temperature, e.g., Baro-VNAV NA below -17°C(2°F).

2. DME/DME based RNP-0.3 systems may be used only when a chart note indicates DME/DME availability; e.g., "DME/DME RNP-0.3 Authorized." Specific DME facilities may be required; e.g., "DME/DME RNP-0.3 Authorized. ABC, XYZ required."

LNAV (Lateral navigation)

Must have IFR approach approved GPS, WAAS, or RNP-0.3 system.Other RNAV systems require special approval.
NOTE: DME/DME based RNP-0.3 systems may be used only when a chart note indicates DME/DME availability; e.g., "DME/DME RNP-0.3 Authorized." Specific DME facilities may be required; e.g., "DME/DME RNP-0.3 Authorized. ABC, XYZ required."

LANDING MINIMA FORMAT

In this example airport elevation is 1179, and runway touchdown zone elevation is 1152.

CATEGORY	A	B	C	D
S-ILS 27	1352/24 200 (200-½)			
S-LOC 27	1440/24 288 (300-½)			1440/50 288 (300-1)
CIRCLING	1540-1 361 (400-1)	1640-1 461 (500-1)	1640-1½ 461 (500-1½)	1740-2 561 (600-2)

DA

Visibility (RVR 100s of feet)

HAT

Aircraft Approach Category

Straight-in ILS to Runway 27

Straight-in with Glide Slope Inoperative or not used to Runway 27

All minima in parentheses not applicable to Civil Pilots.

Military Pilots refer to appropriate regulations.

MDA

HAA

Visibility in Statute Miles

TERMS/LANDING MINIMA DATA

03 AUG 2006 to 31 AUG 2006

05300

TERMS/LANDING MINIMA DATA

COPTER MINIMA ONLY

CATEGORY	COPTER
H-176°	680-½ 363 (400-½)

Copter Approach Direction

Height of MDA/DA Above Landing Area (HAL)

No circling minimums are provided

RADAR MINIMA

PAR (c)	10	2.5°/42/1000	ABCDE	**195**/16	100	(100-¼)				
(d)	28	2.5°/48/1068	ABCDE	**187**/16	100	(100-¼)				
ASR	10		ABC	**560**/40	463	(500-¾)	D	**560**/50	463	(500-1)
			E	**580**/60	463	(500-1¼)				
	28		AB	**600**/50	513	(600-1)	C	**600**/60	513	(600-1¼)
			DE	**600**-1½	513	(600-1½)				
CIR (b)	10		AB	**560**-1¼	463	(500-1¼)	C	**560**-1½	463	(500-1½)
	28		AB	**600**-1¼	503	(600-1¼)	C	**600**-1½	503	(600-1½)
	10, 28		DE	**660**-2	563	(600-2)				

Visibility (RVR 100s of feet)

All minima step in parentheses not applicable to Civil Pilots. Military Pilots refer to appropriate regulations.

Visibility in Statute Miles

Radar Minima:

1. Minima shown are the lowest permitted by established criteria. Pilots should consult applicable directives for their category of aircraft.
2. The circling MDA and weather minima to be used are those for the runway to which the final approach is flown - not the landing runway. In the above RADAR MINIMA example, a category C aircraft flying a radar approach to runway 10, circling to land on runway 28, must use an MDA of 560 feet with weather minima of 500-1½.

▲ Alternate Minimums not standard. Civil users refer to tabulation. USA/USN/USAF pilots refer to appropriate regulations.

▲ NA Alternate minimums are Not Authorized due to unmonitored facility or absence of weather reporting service.

▼ Take-off Minimums not standard and/or Departure Procedures are published. Refer to tabulation.

AIRCRAFT APPROACH CATEGORIES

Aircraft approach category indicates a grouping of aircraft based on a speed of VREF, if specified, or if VREF not specified, 1.3 VSO at the maximum certificated landing weight. VREF, VSO, and the maximum certificated landing weight are those values as established for the aircraft by the certification authority of the country of registry. Helicopters are Category A aircraft. An aircraft shall fit in only one category. However, if it is necessary to operate at a speed in excess of the upper limit of the speed range for an aircraft's category, the minimums for the category for that speed shall be used. For example, an airplane which fits into Category B, but is circling to land at a speed of 145 knots, shall use the approach Category D minimums. As an additional example, a Category A airplane (or helicopter) which is operating at 130 knots on a straight-in approach shall use the approach Category C minimums. See following category limits:

MANEUVERING TABLE

Approach Category	A	B	C	D	E
Speed (Knots)	0-90	91-120	121-140	141-165	Abv 165

Comparable Values of RVR and Visibility

The following table shall be used for converting RVR to ground or flight visibility. For converting RVR values that fall between listed values, use the next higher RVR value; do not interpolate. For example, when converting 1800 RVR, use 2400 RVR with the resultant visibility of 1/2 mile.

RVR (feet)	Visibility (statute miles)	RVR (feet)	Visibility (statute miles)
1600	¼	4500	⅞
2400	½	5000	1
3200	⅝	6000	1¼
4000	¾		

TERMS/LANDING MINIMA DATA

03 AUG 2006 to 31 AUG 2006

Figure 8-20. *Terms/Landing Minima Data.*

Precision approaches use decision height (DH), which is referenced to the height above threshold elevation (HAT). Nonprecision approaches use MDA, referenced to "feet MSL." The MDA is also referenced to HAT for straight-in approaches, or height above airport (HAA) for circling approaches. On NACG charts, the figures listed parenthetically are for military operations and are not used in civil aviation.

Visibility figures are provided in statute miles or runway visual range (RVR), which is reported in hundreds of feet. RVR is measured by a transmissometer, which represents the horizontal distance measured at points along the runway. It is based on the sighting of either high intensity runway lights or on the visual contrast of other targets, whichever yields the greater visual range. RVR is horizontal visual range, not slant visual range, and is used in lieu of prevailing visibility in determining minimums for a particular runway. It is illustrated in hundreds of feet if less than a mile (i.e., "24" is an RVR of 2,400 feet). *[Figures 8-19* and *8-20]*

Visibility figures are depicted after the DA/DH or MDA in the minimums section. If visibility in statute miles is indicated, an altitude number, hyphen, and a whole or fractional number appear; for example, 530-1, which indicates "530 feet MSL' and 1 statute mile visibility. This is the descent minimum for the approach. The RVR value is separated from the minimum altitude with a slash, such as "1065/24," which indicates 1,065 feet MSL and an RVR of 2,400 feet. If RVR is prescribed for the procedure, but not available, a conversion table is used to provide the equivalent visibility in this case, of 1/2 statute mile visibility. *[Figure 8-20]* The conversion table is also available in the TPP.

When an alternate airport is required, standard IFR alternate minimums apply. For aircraft other than helicopters, precision approach procedures require a 600-feet ceiling and two statute miles visibility; nonprecision approaches require an 800-feet ceiling and two statute miles visibility. Helicopter alternate minimums are a ceiling that is 200 feet above the minimum for the approach to be flown and visibility of at least one statute mile, but not less than the minimum visibility for the approach to be flown. When a black triangle with a white "A" appears in the notes section of the pilot briefing, it indicates non-standard IFR alternate minimums exist for the airport. If an "NA" appears after the "A," ANA then alternate minimums are not authorized. This information is found in the beginning of the TPP.

In addition to the COPTER approaches, instrument-equipped helicopters may fly standard approach procedures. The required visibility minimum may be reduced to one-half the published visibility minimum for category A aircraft, but in no case may it be reduced to less than 1/4 mile or 1,200 feet RVR.

Two terms are specific to helicopters. Height above landing (HAL) means height above a designated helicopter landing area used for helicopter IAPs. "Point in space approach" refers to a helicopter IAP to a MAP more than 2,600 feet from an associated helicopter landing area.

Airport Sketch /Airport Diagram

The airport sketch, located on the bottom right side of the chart, includes many helpful features. IAPs for some of the larger airports devote an entire page to an airport diagram. Airport sketch information concerning runway orientation, lighting, final approach bearings, airport beacon, and obstacles all serve to guide the pilot in the final phases of flight. See *Figure 8-21* for a legend of airport diagram/airport sketch features (see also *Figure 8-10* for an example of an airport diagram).

The airport elevation is indicated in a separate box at the top left of the airport sketch. The touchdown zone elevation (TDZE), which is the highest elevation within the first 3,000 feet of the runway, is designated at the approach end of the procedure's runway.

Beneath the airport sketch is a time and speed table when applicable. The table provides the distance and the amount of time required to transit the distance from the FAF to the MAP for selected groundspeeds.

The approach lighting systems and the visual approach lights are depicted on the airport sketch. White on black symbols V are used for identifying pilot-controlled lighting (PCL). Runway lighting aids are also noted (e.g., REIL, HIRL), as is the runway centerline lighting (RCL). *[Figure 8-22]*

The airport diagram shows the paved runway configuration in solid black, while the taxiways and aprons are shaded gray. Other runway environment features are shown, such as the runway identification, dimensions, magnetic heading, displaced threshold, arresting gear, usable length, and slope.

Inoperative Components

Certain procedures can be flown with inoperative components. According to the Inoperative Components Table, for example, an ILS approach with a malfunctioning Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights (MALSR = MALS with RAIL) can be flown if the minimum visibility is increased by 1/4 mile. *[Figure 8-23]* A note in this section might read, "Inoperative Table does not apply to ALS or HIRL Runway 13L."

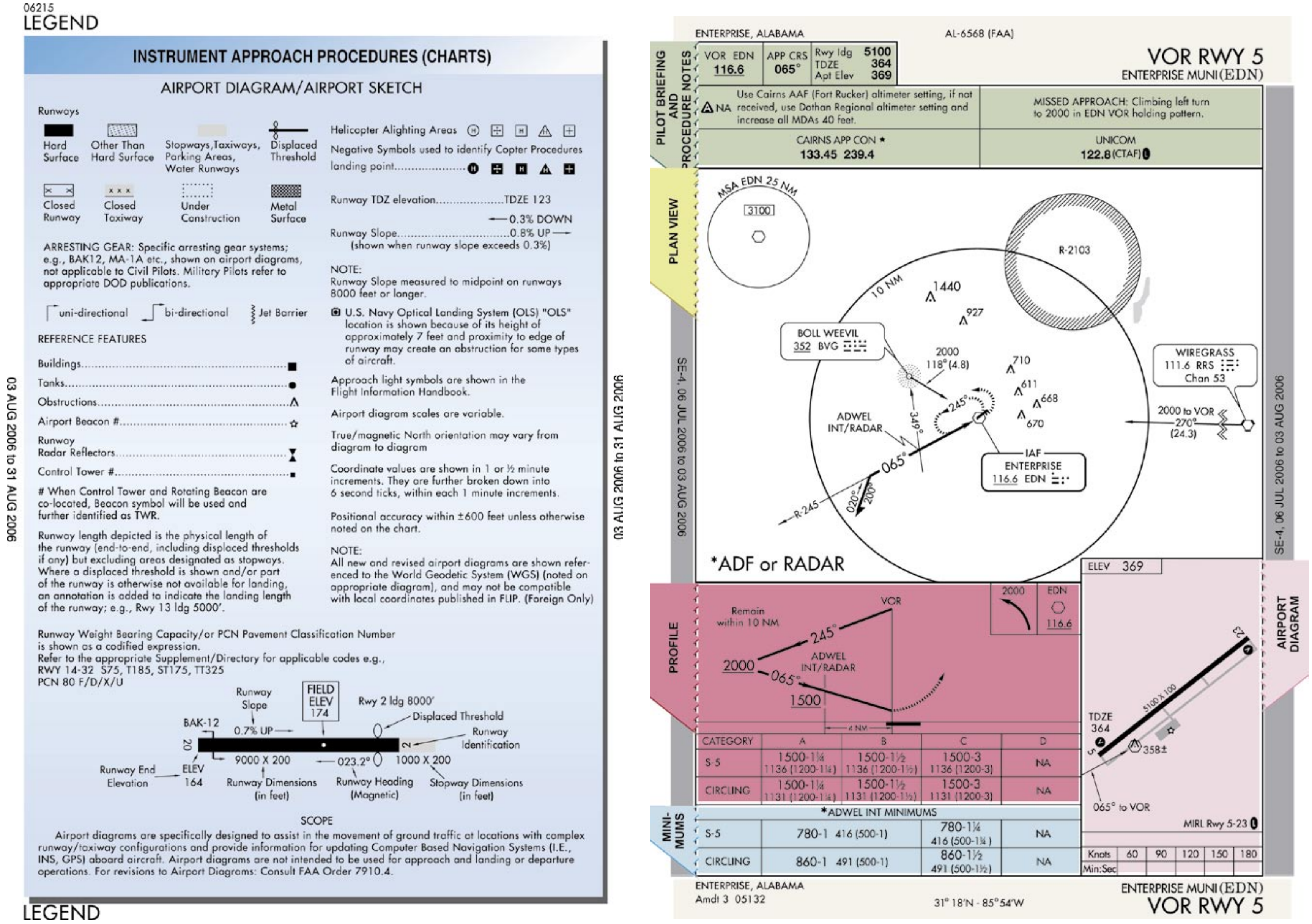

06215
LEGEND

INSTRUMENT APPROACH PROCEDURES (CHARTS)

AIRPORT DIAGRAM/AIRPORT SKETCH

Runways

Hard Surface
Other Than Hard Surface
Stopways, Taxiways, Parking Areas, Water Runways
Displaced Threshold
Closed Runway
Closed Taxiway
Under Construction
Metal Surface

ARRESTING GEAR: Specific arresting gear systems; e.g., BAK12, MA-1A etc., shown on airport diagrams, not applicable to Civil Pilots. Military Pilots refer to appropriate DOD publications.

uni-directional
bi-directional
Jet Barrier

REFERENCE FEATURES

Buildings...■
Tanks...●
Obstructions...Λ
Airport Beacon #...☆
Runway Radar Reflectors..................................⧗
Control Tower #..▪

When Control Tower and Rotating Beacon are co-located, Beacon symbol will be used and further identified as TWR.

Runway length depicted is the physical length of the runway (end-to-end, including displaced thresholds if any) but excluding areas designated as stopways. Where a displaced threshold is shown and/or part of the runway is otherwise not available for landing, an annotation is added to indicate the landing length of the runway; e.g., Rwy 13 ldg 5000'.

Helicopter Alighting Areas

Negative Symbols used to identify Copter Procedures landing point....................

Runway TDZ elevation....................TDZE 123

Runway Slope.................................0.8% UP ⟶ ⟵ 0.3% DOWN
(shown when runway slope exceeds 0.3%)

NOTE:
Runway Slope measured to midpoint on runways 8000 feet or longer.

U.S. Navy Optical Landing System (OLS) "OLS" location is shown because of its height of approximately 7 feet and proximity to edge of runway may create an obstruction for some types of aircraft.

Approach light symbols are shown in the Flight Information Handbook.

Airport diagram scales are variable.

True/magnetic North orientation may vary from diagram to diagram

Coordinate values are shown in 1 or ½ minute increments. They are further broken down into 6 second ticks, within each 1 minute increments.

Positional accuracy within ±600 feet unless otherwise noted on the chart.

NOTE:
All new and revised airport diagrams are shown referenced to the World Geodetic System (WGS) (noted on appropriate diagram), and may not be compatible with local coordinates published in FLIP. (Foreign Only)

Runway Weight Bearing Capacity/or PCN Pavement Classification Number is shown as a codified expression.
Refer to the appropriate Supplement/Directory for applicable codes e.g.,
RWY 14-32 S75, T185, ST175, TT325
PCN 80 F/D/X/U

Runway Slope
FIELD ELEV 174
Rwy 2 ldg 8000'
BAK-12
0.7% UP
Displaced Threshold
Runway Identification
20
2
9000 X 200
023.2°
1000 X 200
Runway End Elevation
ELEV 164
Runway Dimensions (in feet)
Runway Heading (Magnetic)
Stopway Dimensions (in feet)

SCOPE

Airport diagrams are specifically designed to assist in the movement of ground traffic at locations with complex runway/taxiway configurations and provide information for updating Computer Based Navigation Systems (I.E., INS, GPS) aboard aircraft. Airport diagrams are not intended to be used for approach and landing or departure operations. For revisions to Airport Diagrams: Consult FAA Order 7910.4.

LEGEND

03 AUG 2006 to 31 AUG 2006

ENTERPRISE, ALABAMA
AL-6568 (FAA)

VOR RWY 5
ENTERPRISE MUNI(EDN)

VOR EDN 116.6
APP CRS 065°
Rwy ldg 5100
TDZE 364
Apt Elev 369

NA Use Cairns AAF (Fort Rucker) altimeter setting, if not received, use Dothan Regional altimeter setting and increase all MDAs 40 feet.

MISSED APPROACH: Climbing left turn to 2000 in EDN VOR holding pattern.

CAIRNS APP CON * 133.45 239.4

UNICOM 122.8 (CTAF)

PILOT BRIEFING AND PROCEDURE NOTES
PLAN VIEW
SE-4, 06 JUL 2006 to 03 AUG 2006
MSA EDN 25 NM
3100
10 NM
1440
927
R-2103
BOLL WEEVIL
352 BVG
2000
118° (4.8)
710
611
668
670
WIREGRASS
111.6 RRS
Chan 53
2000 to VOR
270°
(24.3)
ADWEL
INT/RADAR
349°
245°
065°
IAF
ENTERPRISE
116.6 EDN
R-245
020°
200°
*ADF or RADAR
PROFILE
Remain within 10 NM
VOR
245°
ADWEL
INT/RADAR
2000
065°
1500
4 NM
2000
EDN
116.6
AIRPORT DIAGRAM
ELEV 369
23
5100 X 100
358±
TDZE 364
5
065° to VOR
MIRL Rwy 5-23
MINI-MUMS

CATEGORY	A	B	C	D
S-5	1500-1¼ 1136 (1200-1¼)	1500-1½ 1136 (1200-1½)	1500-3 1136 (1200-3)	NA
CIRCLING	1500-1¼ 1131 (1200-1¼)	1500-1½ 1131 (1200-1½)	1500-3 1131 (1200-3)	NA

*ADWEL INT MINIMUMS

CATEGORY	A	B	C	D
S-5	780-1 416 (500-1)		780-1¼ 416 (500-1¼)	NA
CIRCLING	860-1 491 (500-1)		860-1½ 491 (500-1½)	NA

Knots	60	90	120	150	180
Min:Sec					

ENTERPRISE, ALABAMA
Amdt 3 05132

31° 18'N - 85° 54'W

ENTERPRISE MUNI(EDN)
VOR RWY 5

03 AUG 2006 to 31 AUG 2006

Figure 8-21. *Airport Legend and Diagram.*

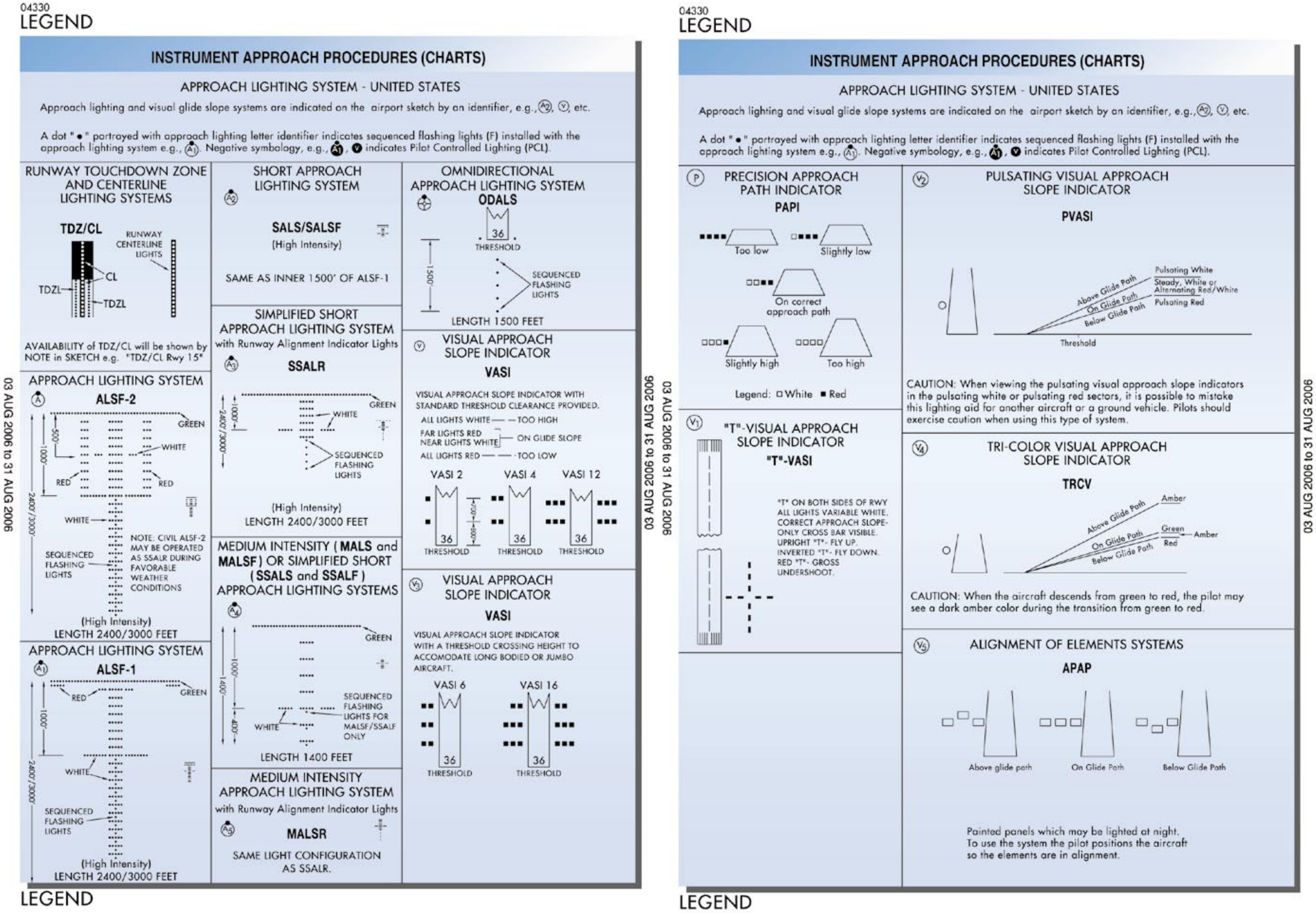

04330
LEGEND

INSTRUMENT APPROACH PROCEDURES (CHARTS)

APPROACH LIGHTING SYSTEM - UNITED STATES

Approach lighting and visual glide slope systems are indicated on the airport sketch by an identifier, e.g., Ⓐ2, Ⓥ, etc.

A dot "•" portrayed with approach lighting letter identifier indicates sequenced flashing lights (F) installed with the approach lighting system e.g., Ⓐ1. Negative symbology, e.g., Ⓐ1, Ⓥ indicates Pilot Controlled Lighting (PCL).

RUNWAY TOUCHDOWN ZONE AND CENTERLINE LIGHTING SYSTEMS

TDZ/CL

AVAILABILITY of TDZ/CL will be shown by NOTE in SKETCH e.g. "TDZ/CL Rwy 15"

Ⓐ APPROACH LIGHTING SYSTEM

ALSF-2

NOTE: CIVIL ALSF-2 MAY BE OPERATED AS SSALR DURING FAVORABLE WEATHER CONDITIONS

(High Intensity)
LENGTH 2400/3000 FEET

Ⓐ1 APPROACH LIGHTING SYSTEM

ALSF-1

(High Intensity)
LENGTH 2400/3000 FEET

Ⓐ2 SHORT APPROACH LIGHTING SYSTEM

SALS/SALSF
(High Intensity)

SAME AS INNER 1500' OF ALSF-1

Ⓐ3 SIMPLIFIED SHORT APPROACH LIGHTING SYSTEM with Runway Alignment Indicator Lights

SSALR

(High Intensity)
LENGTH 2400/3000 FEET

Ⓐ4 MEDIUM INTENSITY (MALS and MALSF) OR SIMPLIFIED SHORT (SSALS and SSALF) APPROACH LIGHTING SYSTEMS

LENGTH 1400 FEET

Ⓐ5 MEDIUM INTENSITY APPROACH LIGHTING SYSTEM with Runway Alignment Indicator Lights

MALSR

SAME LIGHT CONFIGURATION AS SSALR.

OMNIDIRECTIONAL APPROACH LIGHTING SYSTEM

ODALS

LENGTH 1500 FEET

Ⓥ VISUAL APPROACH SLOPE INDICATOR

VASI

VISUAL APPROACH SLOPE INDICATOR WITH STANDARD THRESHOLD CLEARANCE PROVIDED.

ALL LIGHTS WHITE — TOO HIGH
FAR LIGHTS RED, NEAR LIGHTS WHITE — ON GLIDE SLOPE
ALL LIGHTS RED — TOO LOW

Ⓥ3 VISUAL APPROACH SLOPE INDICATOR

VASI

VISUAL APPROACH SLOPE INDICATOR WITH A THRESHOLD CROSSING HEIGHT TO ACCOMODATE LONG BODIED OR JUMBO AIRCRAFT.

LEGEND

04330
LEGEND

INSTRUMENT APPROACH PROCEDURES (CHARTS)

APPROACH LIGHTING SYSTEM - UNITED STATES

Approach lighting and visual glide slope systems are indicated on the airport sketch by an identifier, e.g., Ⓐ2, Ⓥ, etc.

A dot "•" portrayed with approach lighting letter identifier indicates sequenced flashing lights (F) installed with the approach lighting system e.g., Ⓐ1. Negative symbology, e.g., Ⓐ1, Ⓥ indicates Pilot Controlled Lighting (PCL).

Ⓟ PRECISION APPROACH PATH INDICATOR

PAPI

Legend: □ White ■ Red

Ⓥ1 "T"-VISUAL APPROACH SLOPE INDICATOR

"T"-VASI

"T" ON BOTH SIDES OF RWY
ALL LIGHTS VARIABLE WHITE.
CORRECT APPROACH SLOPE-ONLY CROSS BAR VISIBLE.
UPRIGHT "T"- FLY UP.
INVERTED "T"- FLY DOWN.
RED "T"- GROSS UNDERSHOOT.

Ⓥ2 PULSATING VISUAL APPROACH SLOPE INDICATOR

PVASI

CAUTION: When viewing the pulsating visual approach slope indicators in the pulsating white or pulsating red sectors, it is possible to mistake this lighting aid for another aircraft or a ground vehicle. Pilots should exercise caution when using this type of system.

Ⓥ4 TRI-COLOR VISUAL APPROACH SLOPE INDICATOR

TRCV

CAUTION: When the aircraft descends from green to red, the pilot may see a dark amber color during the transition from green to red.

Ⓥ5 ALIGNMENT OF ELEMENTS SYSTEMS

APAP

Painted panels which may be lighted at night. To use the system the pilot positions the aircraft so the elements are in alignment.

LEGEND

03 AUG 2006 to 31 AUG 2006

RUNWAY CENTERLINE LIGHTS
CL
TDZL
TDZL
500'
1000'
2400'/3000'
GREEN
WHITE
RED
RED
WHITE
SEQUENCED FLASHING LIGHTS
1500'
THRESHOLD
SEQUENCED FLASHING LIGHTS
1000'
2400'/3000'
1400'
400'
36
VASI 2
VASI 4
VASI 12
VASI 6
VASI 16
700'
800'
Too low
Slightly low
On correct approach path
Slightly high
Too high
Pulsating White
Steady, White or Alternating Red/White
Pulsating Red
Above Glide Path
On Glide Path
Below Glide Path
Threshold
Amber
Green
Red
Above glide path
On Glide Path
Below Glide Path

Figure 8-22. *Approach Lighting Legend.*

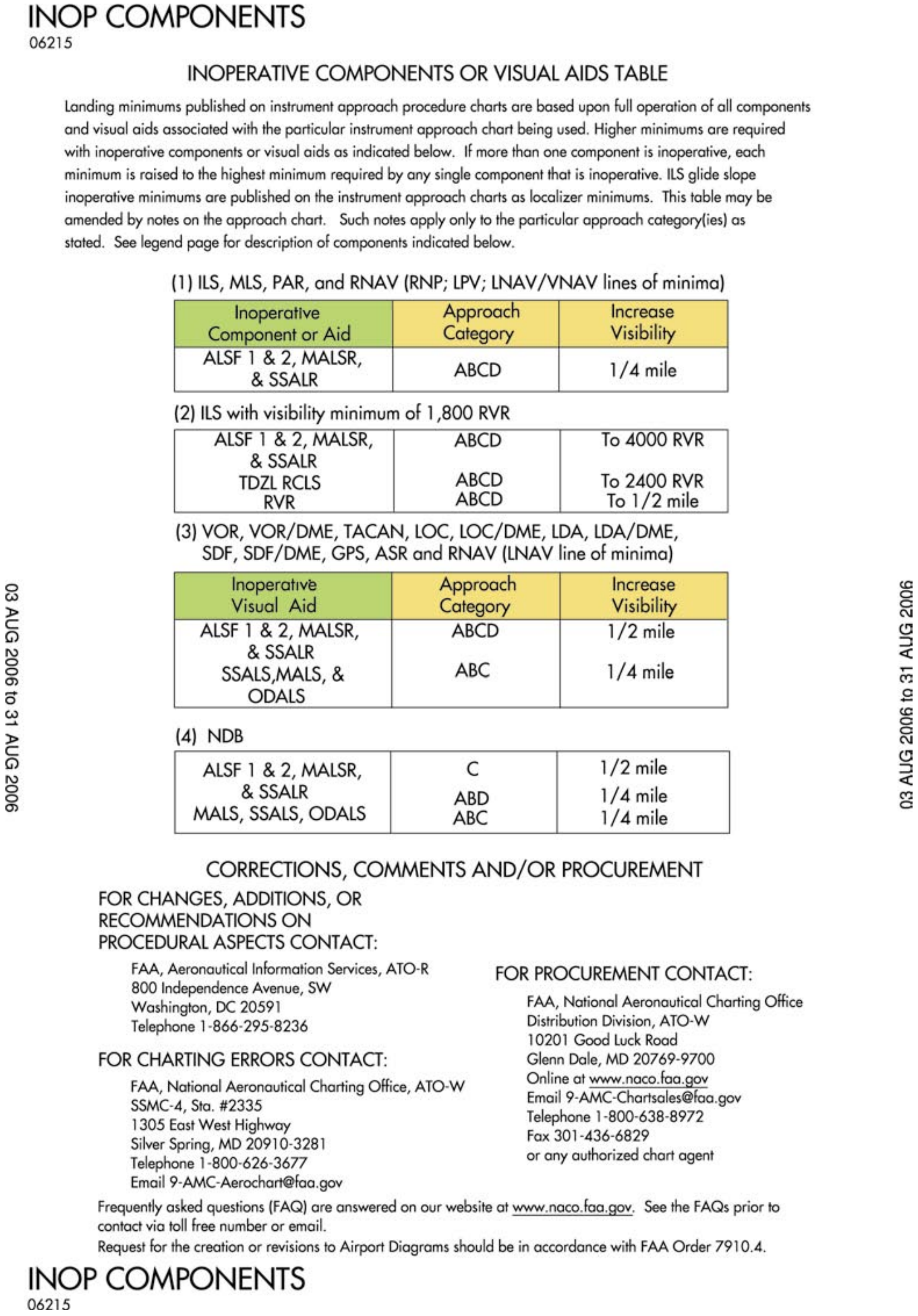

INOP COMPONENTS

06215

INOPERATIVE COMPONENTS OR VISUAL AIDS TABLE

Landing minimums published on instrument approach procedure charts are based upon full operation of all components and visual aids associated with the particular instrument approach chart being used. Higher minimums are required with inoperative components or visual aids as indicated below. If more than one component is inoperative, each minimum is raised to the highest minimum required by any single component that is inoperative. ILS glide slope inoperative minimums are published on the instrument approach charts as localizer minimums. This table may be amended by notes on the approach chart. Such notes apply only to the particular approach category(ies) as stated. See legend page for description of components indicated below.

(1) ILS, MLS, PAR, and RNAV (RNP; LPV; LNAV/VNAV lines of minima)

Inoperative Component or Aid	Approach Category	Increase Visibility
ALSF 1 & 2, MALSR, & SSALR	ABCD	1/4 mile

(2) ILS with visibility minimum of 1,800 RVR

ALSF 1 & 2, MALSR, & SSALR	ABCD	To 4000 RVR
TDZL RCLS	ABCD	To 2400 RVR
RVR	ABCD	To 1/2 mile

(3) VOR, VOR/DME, TACAN, LOC, LOC/DME, LDA, LDA/DME, SDF, SDF/DME, GPS, ASR and RNAV (LNAV line of minima)

Inoperative Visual Aid	Approach Category	Increase Visibility
ALSF 1 & 2, MALSR, & SSALR	ABCD	1/2 mile
SSALS,MALS, & ODALS	ABC	1/4 mile

(4) NDB

ALSF 1 & 2, MALSR, & SSALR	C	1/2 mile
	ABD	1/4 mile
MALS, SSALS, ODALS	ABC	1/4 mile

03 AUG 2006 to 31 AUG 2006

03 AUG 2006 to 31 AUG 2006

CORRECTIONS, COMMENTS AND/OR PROCUREMENT

FOR CHANGES, ADDITIONS, OR RECOMMENDATIONS ON PROCEDURAL ASPECTS CONTACT:

FAA, Aeronautical Information Services, ATO-R
800 Independence Avenue, SW
Washington, DC 20591
Telephone 1-866-295-8236

FOR CHARTING ERRORS CONTACT:

FAA, National Aeronautical Charting Office, ATO-W
SSMC-4, Sta. #2335
1305 East West Highway
Silver Spring, MD 20910-3281
Telephone 1-800-626-3677
Email 9-AMC-Aerochart@faa.gov

FOR PROCUREMENT CONTACT:

FAA, National Aeronautical Charting Office
Distribution Division, ATO-W
10201 Good Luck Road
Glenn Dale, MD 20769-9700
Online at www.naco.faa.gov
Email 9-AMC-Chartsales@faa.gov
Telephone 1-800-638-8972
Fax 301-436-6829
or any authorized chart agent

Frequently asked questions (FAQ) are answered on our website at www.naco.faa.gov. See the FAQs prior to contact via toll free number or email.

Request for the creation or revisions to Airport Diagrams should be in accordance with FAA Order 7910.4.

INOP COMPONENTS

06215

Figure 8-23. *IAP Inoperative Components Table.*

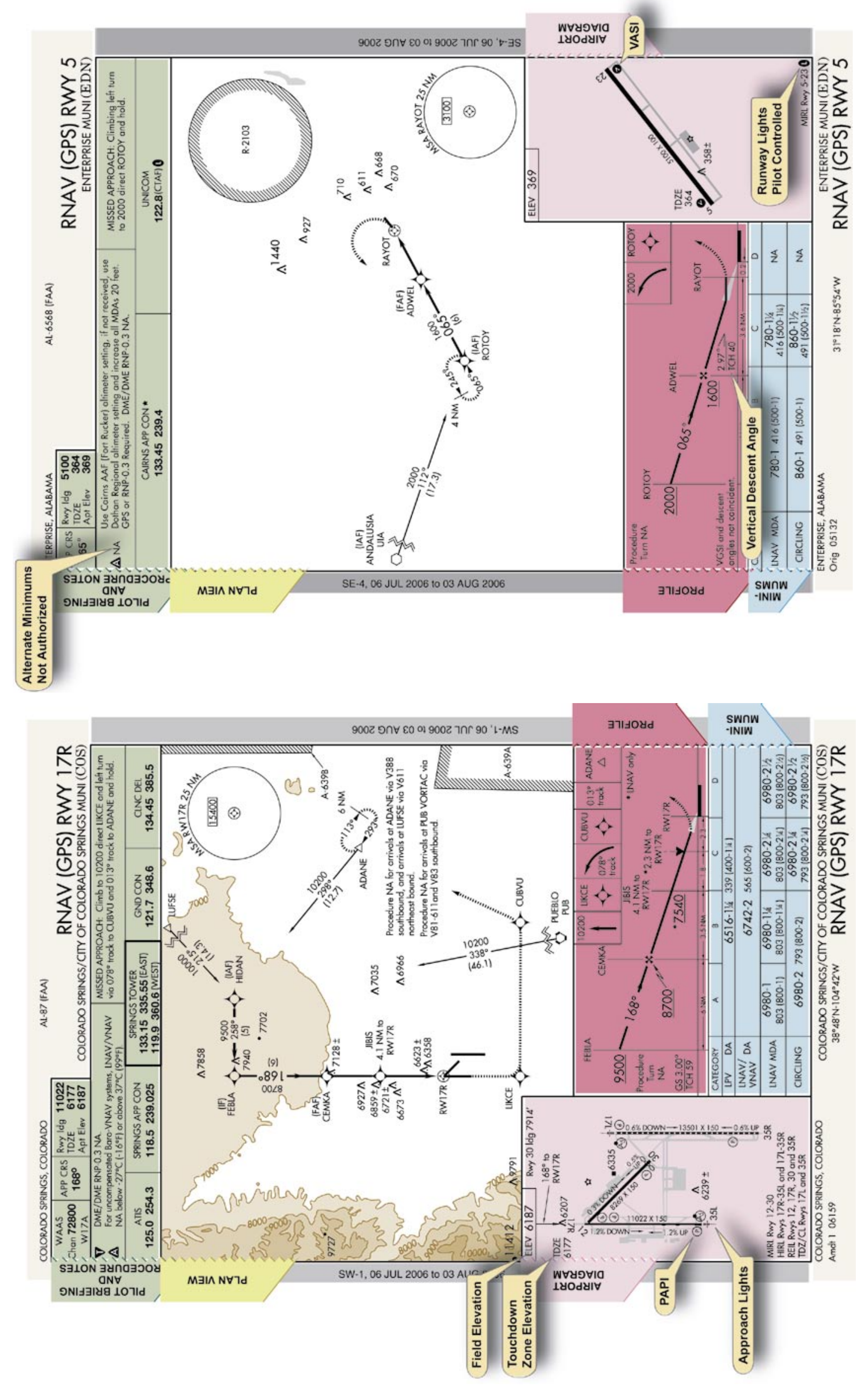
RNAV (GPS) RWY 17R
COLORADO SPRINGS/CITY OF COLORADO SPRINGS MUNI (COS)
COLORADO SPRINGS, COLORADO
AL-87 (FAA)
PILOT BRIEFING AND PROCEDURE NOTES
PLAN VIEW
PROFILE
MINIMUMS
AIRPORT DIAGRAM
Field Elevation
Touchdown Zone Elevation
PAPI
Approach Lights
ELEV 6187
TDZE 6177
SW-1, 06 JUL 2006 to 03 AUG 2006
RNAV (GPS) RWY 5
ENTERPRISE MUNI (EDN)
ENTERPRISE, ALABAMA
AL-6568 (FAA)
Alternate Minimums Not Authorized
Vertical Descent Angle
VASI
Runway Lights Pilot Controlled
ELEV 369
TDZE 364
SE-4, 06 JUL 2006 to 03 AUG 2006

Figure 8-24. *RNAV Instrument Approach Charts.*

RNAV Instrument Approach Charts

To avoid unnecessary duplication and proliferation of approach charts, approach minimums for unaugmented GPS, Wide Area Augmentation System (WAAS), Local Area Augmentation System (LAAS), will be published on the same approach chart as lateral navigation/vertical navigation (LNAV/VNAV). Other types of equipment may be authorized to conduct the approach based on the minima notes in the front of the TPP approach chart books. Approach charts titled "RNAV RWY XX" may be used by aircraft with navigation systems that meet the required navigational performance (RNP) values for each segment of the approach. *[Figure 8-24]*

The chart may contain as many as four lines of approach minimums: global landing system (GLS), WAAS and LAAS, LNAV/VNAV, LNAV, and circling. LNAV/VNAV is an instrument approach with lateral and vertical guidance with integrity limits similar to barometric vertical navigation (BARO VNAV).

RNAV procedures that incorporate a final approach stepdown fix may be published without vertical navigation on a separate chart also titled RNAV. During a transition period when GPS procedures are undergoing revision to a new title, both RNAV and GPS approach charts and formats will be published. ATC clearance for the RNAV procedure will authorize a properly certificated pilot to utilize any landing minimums for which the aircraft is certified.

Chart terminology will change slightly to support the new procedure types:

1. DA replaces the term DH. DA conforms to the international convention where altitudes relate to MSL and heights relate to AGL. DA will eventually be published for other types of IAPs with vertical guidance, as well. DA indicates to the pilot that the published descent profile is flown to the DA (MSL), where a missed approach will be initiated if visual references for landing are not established. Obstacle clearance is provided to allow a momentary descent below DA while transitioning from the final approach to the missed approach. The aircraft is expected to follow the missed approach instructions while continuing along the published final approach course to at least the published runway threshold waypoint or MAP (if not at the threshold) before executing any turns.
2. MDA will continue to be used only for the LNAV and circling procedures.
3. Threshold crossing height (TCH) has been traditionally used in precision approaches as the height of the GS above threshold. With publication of LNAV/VNAV minimums and RNAV descent angles, including graphically depicted descent profiles, TCH also applies to the height of the "descent angle," or glide path, at the threshold. Unless otherwise required for larger type aircraft, which may be using the IAP, the typical TCH will be 30 to 50 feet.

The minima format changes slightly:

1. Each line of minima on the RNAV IAP will be titled to reflect the RNAV system applicable (e.g., GLS, LNAV/VNAV, and LNAV). Circling minima will also be provided.
2. The minima title box will also indicate the nature of the minimum altitude for the IAP. For example: DA will be published next to the minima line title for minimums supporting vertical guidance, and MDA will be published where the minima line supports only lateral guidance. During an approach where an MDA is used, descent below MDA is not authorized.
3. Where two or more systems share the same minima, each line of minima will be displayed separately.

For more information concerning government charts, the NACG can be contacted by telephone, or via their internet address at:

National Aeronautical Charting Group
Telephone 800-626-3677
http://naco.faa.gov/

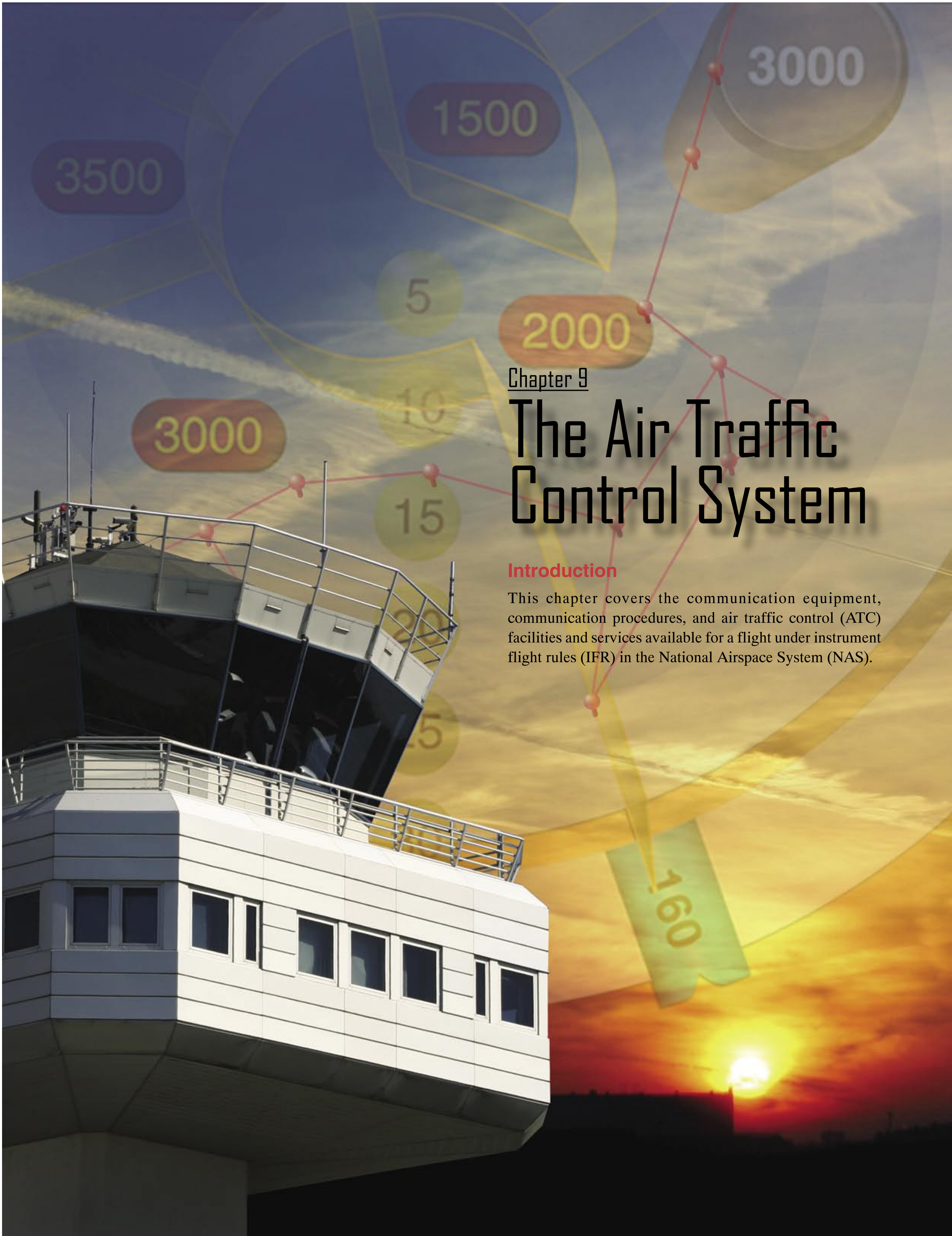
3000
1500
3500
5
2000
10
3000
15
20
25
160

Chapter 9

The Air Traffic Control System

Introduction

This chapter covers the communication equipment, communication procedures, and air traffic control (ATC) facilities and services available for a flight under instrument flight rules (IFR) in the National Airspace System (NAS).

Communication Equipment

Navigation/Communication (NAV/COM) Equipment

Civilian pilots communicate with ATC on frequencies in the very high frequency (VHF) range between 118.000 and 136.975 MHz. To derive full benefit from the ATC system, radios capable of 25 kHz spacing are required (e.g., 134.500, 134.575, 134.600). If ATC assigns a frequency that cannot be selected, ask for an alternative frequency.

Figure 9-1 illustrates a typical radio panel installation, consisting of a communications transceiver on the left and a navigational receiver on the right. Many radios allow the pilot to have one or more frequencies stored in memory and one frequency active for transmitting and receiving (called simplex operation). It is possible to communicate with some automated flight service stations (AFSS) by transmitting on 122.1 MHz (selected on the communication radio) and receiving on a VHF omnidirectional range (VOR) frequency (selected on the navigation radio). This is called duplex operation.

An audio panel allows a pilot to adjust the volume of the selected receiver(s) and to select the desired transmitter. *[Figure 9-2]* The audio panel has two positions for receiver selection, cabin speaker, and headphone (some units might have a center "off" position). Use of a hand-held microphone and the cabin speaker introduces the distraction of reaching for and hanging up the microphone. A headset with a boom microphone is recommended for clear communications. The microphone should be positioned close to the lips to reduce

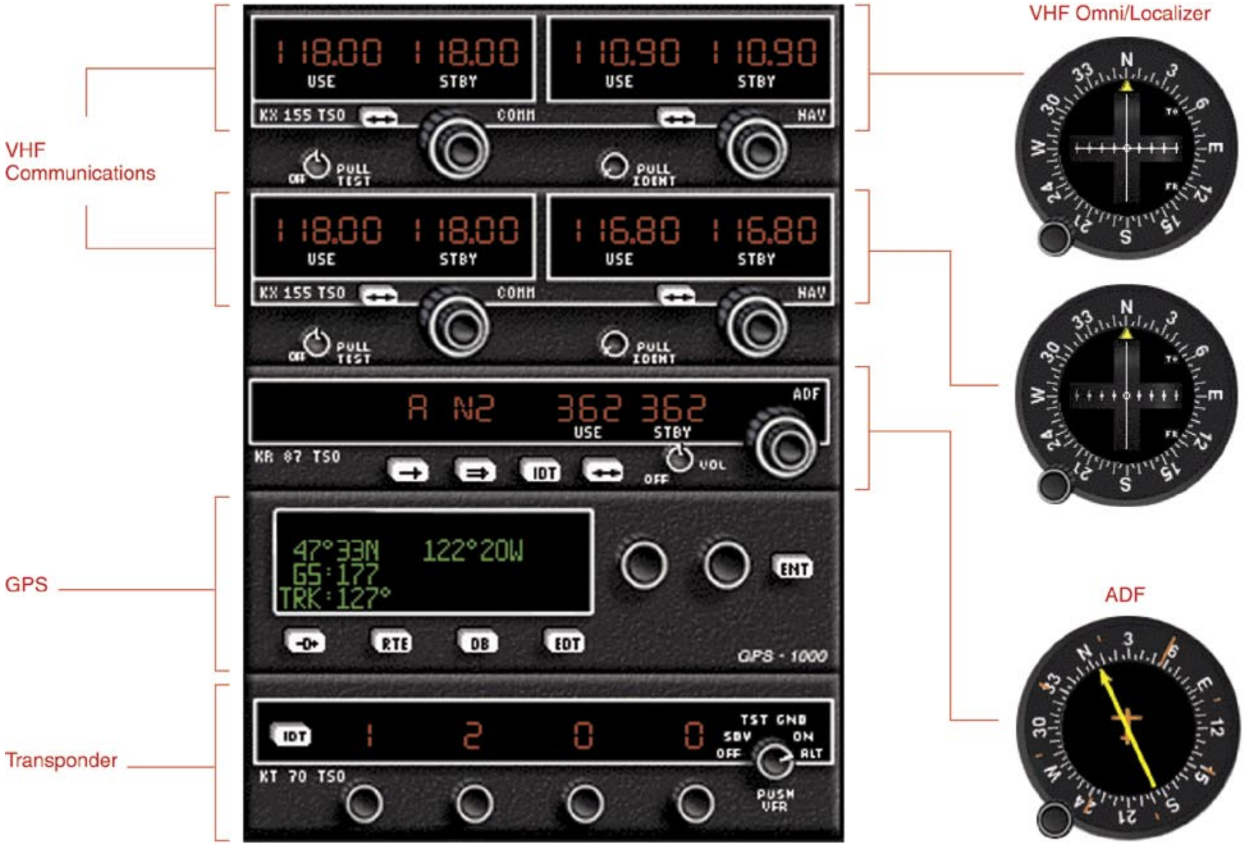
VHF Communications
GPS
Transponder
VHF Omni/Localizer
ADF
118.00 USE 118.00 STBY
KX 155 TSO
COMM
110.90 USE 110.90 STBY
NAV
PULL TEST
PULL IDENT
118.00 USE 118.00 STBY
116.80 USE 116.80 STBY
A N2 362 USE 362 STBY
ADF
KR 87 TSO
IDT
VOL
OFF
47°33N 122°20W
GS:177
TRK:127°
ENT
RTE
DB
EDT
GPS - 1000
IDT 1 2 0 0
TST GND
SBY ON
OFF ALT
KT 70 TSO
PUSH VFR

Figure 9-1. *Typical NAV/COM Installation.*

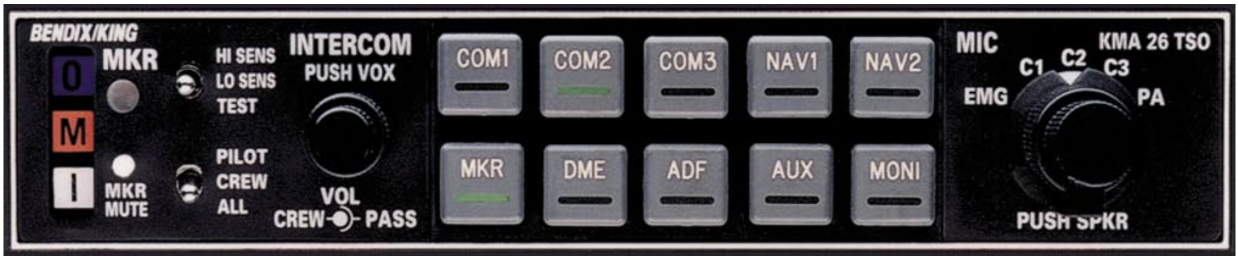
BENDIX/KING
MKR
O
M
I
MKR MUTE
HI SENS
LO SENS
TEST
PILOT
CREW
ALL
INTERCOM
PUSH VOX
VOL
CREW PASS
COM1
COM2
COM3
NAV1
NAV2
MKR
DME
ADF
AUX
MONI
MIC
KMA 26 TSO
C1 C2 C3
EMG
PA
PUSH SPKR

Figure 9-2. *Audio Panel.*

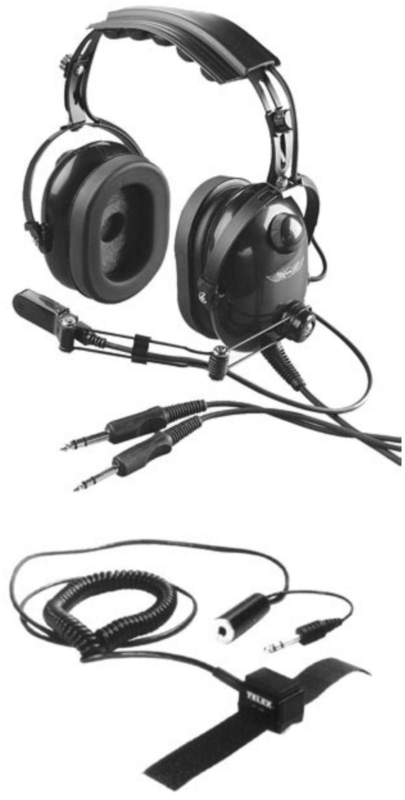

Figure 9-3. *Boom Microphone, Headset, and Push-To-Talk Switch.*

the possibility of ambient flight deck noise interfering with transmissions to the controller. Headphones deliver the received signal directly to the ears; therefore, ambient noise does not interfere with the pilot's ability to understand the transmission. *[Figure 9-3]*

Switching the transmitter selector between COM1 and COM2 changes both transmitter and receiver frequencies. It is necessary only when a pilot wants to monitor one frequency while transmitting on another. One example is listening to automatic terminal information service (ATIS) on one receiver while communicating with ATC on the other. Monitoring a navigation receiver to check for proper identification is another reason to use the switch panel.

Most audio switch panels also include a marker beacon receiver. All marker beacons transmit on 75 MHz, so there is no frequency selector.

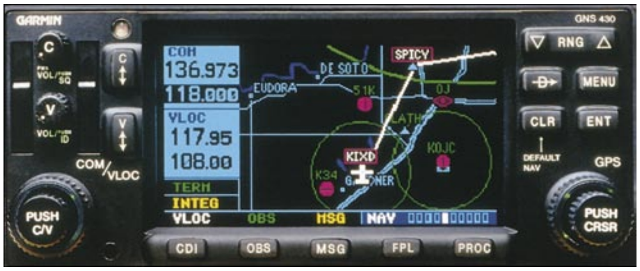

Figure 9-4. *Combination GPS-Com Unit.*

Figure 9-4 illustrates an increasingly popular form of NAV/COM radio; it contains a global positioning system (GPS) receiver and a communications transceiver. Using its navigational capability, this unit can determine when a flight crosses an airspace boundary or fix and can automatically select the appropriate communications frequency for that location in the communications radio.

Radar and Transponders

ATC radars have a limited ability to display primary returns, which is energy reflected from an aircraft's metallic structure. Their ability to display secondary returns (transponder replies to ground interrogation signals) makes possible the many advantages of automation.

A transponder is a radar beacon transmitter/receiver installed in the instrument panel. ATC beacon transmitters send out interrogation signals continuously as the radar antenna rotates. When an interrogation is received by a transponder, a coded reply is sent to the ground station where it is displayed on the controller's scope. A reply light on the transponder panel flickers every time it receives and replies to a radar interrogation. Transponder codes are assigned by ATC.

When a controller asks a pilot to "ident" and the ident button is pushed, the return on the controller's scope is intensified for precise identification of a flight. When requested, briefly push the ident button to activate this feature. It is good practice for pilots to verbally confirm that they have changed codes or pushed the ident button.

Mode C (Altitude Reporting)

Primary radar returns indicate only range and bearing from the radar antenna to the target; secondary radar returns can display altitude, Mode C, on the control scope if the aircraft is equipped with an encoding altimeter or blind encoder. In either case, when the transponder's function switch is in the ALT position the aircraft's pressure altitude is sent to the controller. Adjusting the altimeter's Kollsman window has no effect on the altitude read by the controller.

Transponders, when installed, must be ON at all times when operating in controlled airspace; altitude reporting is required by regulation in Class B and Class C airspace and inside a 30-mile circle surrounding the primary airport in Class B airspace. Altitude reporting should also be ON at all times.

Communication Procedures

Clarity in communication is essential for a safe instrument flight. This requires pilots and controllers to use terms that are understood by both—the Pilot/Controller Glossary in the Aeronautical Information Manual (AIM) is the best source of terms and definitions. The AIM is revised twice a year and new definitions are added, so the glossary should be reviewed frequently. Because clearances and instructions are comprised largely of letters and numbers, a phonetic pronunciation guide has been developed for both. *[Figure 9-5]*

ATCs must follow the guidance of the Air Traffic Control Manual when communicating with pilots. The manual presents the controller with different situations and prescribes precise terminology that must be used. This is advantageous for pilots because once they have recognized a pattern or format they can expect future controller transmissions to follow that format. Controllers are faced with a wide variety of communication styles based on pilot experience, proficiency, and professionalism.

Pilots should study the examples in the AIM, listen to other pilots communicate, and apply the lessons learned to their own communications with ATC. Pilots should ask for clarification of a clearance or instruction. If necessary, use plain English to ensure understanding, and expect the controller to reply in the same way. A safe instrument flight is the result of cooperation between controller and pilot.

Communication Facilities

The controller's primary responsibility is separation of aircraft operating under IFR. This is accomplished with ATC facilities which include the AFSS, airport traffic control tower (ATCT), terminal radar approach control (TRACON), and air route traffic control center (ARTCC).

Automated Flight Service Stations (AFSS)

A pilot's first contact with ATC is usually through AFSS, either by radio or telephone. AFSSs provide pilot briefings, receive and process flight plans, relay ATC clearances, originate Notices to Airmen (NOTAMs), and broadcast aviation weather. Some facilities provide En Route Flight Advisory Service (EFAS), take weather observations, and advise United States Customs and Immigration of international flights.

Telephone contact with Flight Service can be obtained by dialing 1-800-WX-BRIEF. This number can be used anywhere in the United States and connects to the nearest AFSS based on the area code from which the call originates. There are a variety of methods of making radio contact: direct transmission, remote communication outlets (RCOs), ground communication outlets (GCOs), and by using duplex transmissions through navigational aids (NAVAIDs). The best source of information on frequency usage is the Airport/Facility Directory (A/FD) and the legend panel on sectional charts also contains contact information.

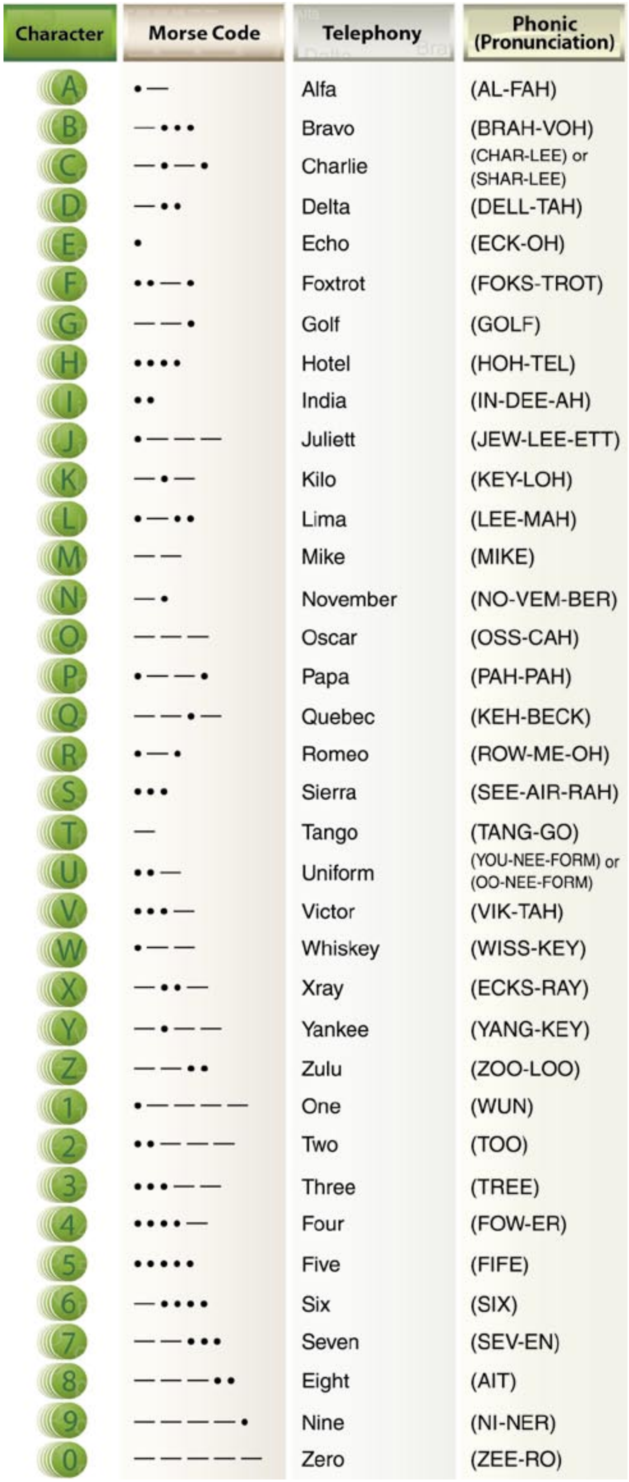

Character	Morse Code	Telephony	Phonic (Pronunciation)
A	•—	Alfa	(AL-FAH)
B	—•••	Bravo	(BRAH-VOH)
C	—•—•	Charlie	(CHAR-LEE) or (SHAR-LEE)
D	—••	Delta	(DELL-TAH)
E	•	Echo	(ECK-OH)
F	••—•	Foxtrot	(FOKS-TROT)
G	——•	Golf	(GOLF)
H	••••	Hotel	(HOH-TEL)
I	••	India	(IN-DEE-AH)
J	•———	Juliett	(JEW-LEE-ETT)
K	—•—	Kilo	(KEY-LOH)
L	•—••	Lima	(LEE-MAH)
M	——	Mike	(MIKE)
N	—•	November	(NO-VEM-BER)
O	———	Oscar	(OSS-CAH)
P	•——•	Papa	(PAH-PAH)
Q	——•—	Quebec	(KEH-BECK)
R	•—•	Romeo	(ROW-ME-OH)
S	•••	Sierra	(SEE-AIR-RAH)
T	—	Tango	(TANG-GO)
U	••—	Uniform	(YOU-NEE-FORM) or (OO-NEE-FORM)
V	•••—	Victor	(VIK-TAH)
W	•——	Whiskey	(WISS-KEY)
X	—••—	Xray	(ECKS-RAY)
Y	—•——	Yankee	(YANG-KEY)
Z	——••	Zulu	(ZOO-LOO)
1	•————	One	(WUN)
2	••———	Two	(TOO)
3	•••——	Three	(TREE)
4	••••—	Four	(FOW-ER)
5	•••••	Five	(FIFE)
6	—••••	Six	(SIX)
7	——•••	Seven	(SEV-EN)
8	———••	Eight	(AIT)
9	————•	Nine	(NI-NER)
0	—————	Zero	(ZEE-RO)

Figure 9-5. *Phonetic Pronunciation Guide.*

The briefer sends a flight plan to the host computer at the ARTCC (Center). After processing the flight plan, the computer will send flight strips to the tower, to the radar facility that will handle the departure route, and to the Center controller whose sector the flight first enters. *Figure 9-6* shows a typical strip. These strips are delivered approximately 30 minutes prior to the proposed departure time. Strips are delivered to en route facilities 30 minutes before the flight is expected to enter their airspace. If a flight plan is not opened, it will "time out" 2 hours after the proposed departure time.

When departing an airport in Class G airspace, a pilot receives an IFR clearance from the AFSS by radio or telephone. It contains either a clearance void time, in which case an aircraft must be airborne prior to that time, or a release time. Pilots should not take-off prior to the release time. Pilots can help the controller by stating how soon they expect to be airborne. If the void time is, for example, 10 minutes past the hour and an aircraft is airborne at exactly 10 minutes past the hour, the clearance is void—a pilot must take off prior to the void time. A specific void time may be requested when filing a flight plan.

ATC Towers

Several controllers in the tower cab are involved in handling an instrument flight. Where there is a dedicated clearance delivery position, that frequency is found in the A/FD and on the instrument approach chart for the departure airport. Where there is no clearance delivery position, the ground controller performs this function. At the busiest airports, pre-taxi clearance is required; the frequency for pre-taxi clearance can be found in the A/FD. Taxi clearance should be requested not more than 10 minutes before proposed taxi time.

It is recommended that pilots read their IFR clearance back to the clearance delivery controller. Instrument clearances can be overwhelming when attempting to copy them verbatim, but they follow a format that allows a pilot to be prepared when responding "Ready to copy." The format is: clearance limit (usually the destination airport); route, including any departure procedure; initial altitude; frequency (for departure control); and transponder code. With the exception of the transponder code, a pilot knows most of these items before engine start. One technique for clearance copying is writing C-R-A-F-T.

Assume an IFR flight plan has been filed from Seattle, Washington to Sacramento, California via V-23 at 7,000 feet. Traffic is taking off to the north from Seattle-Tacoma (Sea-Tac) airport and, by monitoring the clearance delivery frequency, a pilot can determine the departure procedure being assigned to southbound flights. The clearance limit is the destination airport, so write "SAC" after the letter C. Write "SEATTLE TWO – V23" after R for Route, because departure control issued this departure to other flights. Write "7" after the A, the departure control frequency printed on the approach charts for Sea-Tac after F, and leave the space after the letter T blank—the transponder code is generated by computer and can seldom be determined in advance. Then, call clearance delivery and report "Ready to copy."

As the controller reads the clearance, check it against what is already written down; if there is a change, draw a line through that item and write in the changed item. Chances are the changes are minimal, and most of the clearance is copied before keying the microphone. Still, it is worthwhile to develop clearance shorthand to decrease the verbiage that must be copied (see Appendix 1).

Pilots are required to have either the text of a departure procedure (DP) or a graphic representation (if one is available), and should review it before accepting a clearance. This is another reason to find out ahead of time which DP is in use. If the DP includes an altitude or a departure control frequency, those items are not included in the clearance.

The last clearance received supersedes all previous clearances. For example, if the DP says "Climb and maintain 2,000 feet, expect higher in 6 miles," but upon contacting the departure controller a new clearance is received: "Climb and maintain 8,000 feet," the 2,000 feet restriction has been canceled. This rule applies in both terminal and Center airspace.

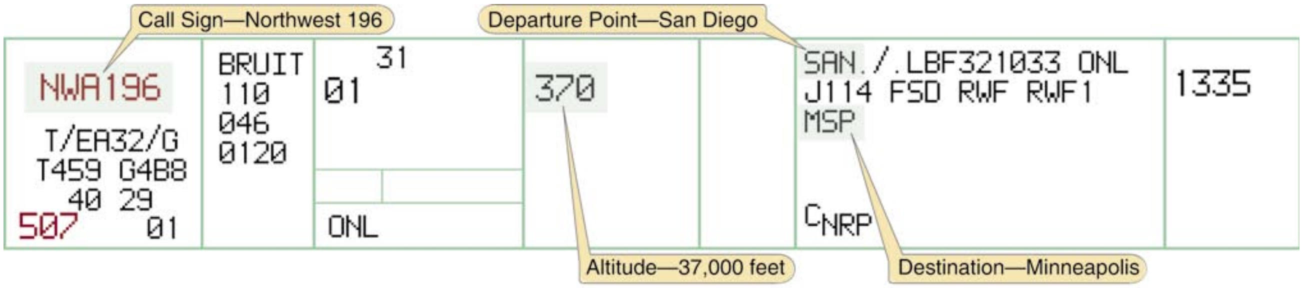

Figure 9-6. *Flight Strip.*

When reporting ready to copy an IFR clearance before the strip has been received from the Center computer, pilots are advised "clearance on request." The controller initiates contact when it has been received. This time can be used for taxi and pre-takeoff checks.

The local controller is responsible for operations in the Class D airspace and on the active runways. At some towers, designated as IFR towers, the local controller has vectoring authority. At visual flight rules (VFR) towers, the local controller accepts inbound IFR flights from the terminal radar facility and cannot provide vectors. The local controller also coordinates flights in the local area with radar controllers. Although Class D airspace normally extends 2,500 feet above field elevation, towers frequently release the top 500 feet to the radar controllers to facilitate overflights. Accordingly, when a flight is vectored over an airport at an altitude that appears to enter the tower controller's airspace, there is no need to contact the tower controller—all coordination is handled by ATC.

The departure radar controller may be in the same building as the control tower, but it is more likely that the departure radar position is remotely located. The tower controller will not issue a takeoff clearance until the departure controller issues a release.

Terminal Radar Approach Control (TRACON)

TRACONs are considered terminal facilities because they provide the link between the departure airport and the en route structure of the NAS. Terminal airspace normally extends 30 nautical miles (NM) from the facility, with a vertical extent of 10,000 feet; however, dimensions vary widely. Class B and Class C airspace dimensions are provided on aeronautical charts. At terminal radar facilities the airspace is divided into sectors, each with one or more controllers, and each sector is assigned a discrete radio frequency. All terminal facilities are approach controls and should be addressed as "Approach" except when directed to do otherwise (e.g., "Contact departure on 120.4").

Terminal radar antennas are located on or adjacent to the airport. *Figure 9-7* shows a typical configuration. Terminal controllers can assign altitudes lower than published procedural altitudes called minimum vectoring altitudes (MVAs). These altitudes are not published or accessible to pilots, but are displayed at the controller's position, as shown in *Figure 9-8*. However, when pilots are assigned an altitude that seems to be too low, they should query the controller before descending.

When a pilot accepts a clearance and reports ready for takeoff, a controller in the tower contacts the TRACON for a release. An aircraft is not cleared for takeoff until the departure controller can fit the flight into the departure flow. A pilot may have to hold for release. When takeoff clearance is received, the departure controller is aware of the flight and is waiting for a call. All of the information the controller needs is on the departure strip or the computer screen there is no need to repeat any portion of the clearance to that controller. Simply establish contact with the facility when instructed to do so by the tower controller. The terminal facility computer picks up the transponder and initiates tracking as soon as it detects the

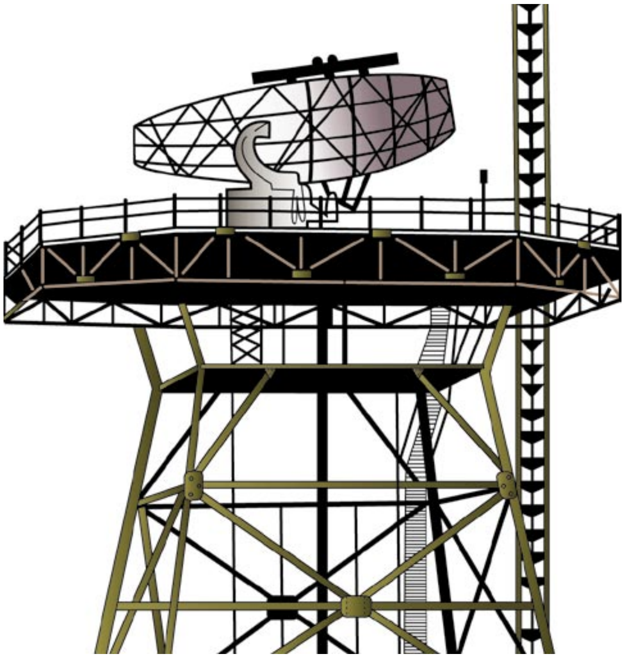

Figure 9-7. *Combined Radar and Beacon Antenna.*

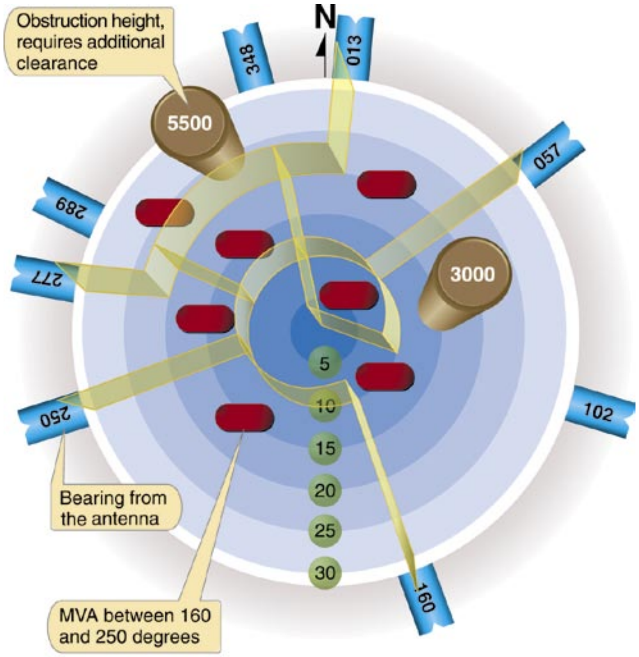
Obstruction height, requires additional clearance
N
348
013
5500
057
289
277
3000
5
10
15
20
25
30
250
102
160
Bearing from the antenna
MVA between 160 and 250 degrees

Figure 9-8. *Minimum Vectoring Altitude Chart.*

assigned code. For this reason, the transponder should remain on standby until takeoff clearance has been received.

The aircraft appears on the controller's radar display as a target with an associated data block that moves as the aircraft moves through the airspace. The data block includes aircraft identification, aircraft type, altitude, and airspeed.

A TRACON controller uses Airport Surveillance Radar (ASR) to detect primary targets and Automated Radar Terminal Systems (ARTS) to receive transponder signals; the two are combined on the controller's scope. *[Figure 9-9]*

At facilities with ASR-3 equipment, radar returns from precipitation are not displayed as varying levels of intensity, and controllers must rely on pilot reports and experience to provide weather avoidance information. With ASR-9 equipment, the controller can select up to six levels of intensity. Light precipitation does not require avoidance tactics but precipitation levels of moderate, heavy or extreme should cause pilots to plan accordingly. Along with precipitation the pilot must additionally consider the temperature, which if between -20° and +5° C will cause icing even during light precipitation. The returns from higher levels of intensity may obscure aircraft data blocks, and controllers may select the higher levels only on pilot request. When uncertainty exists about the weather ahead, ask the controller if the facility can display intensity levels—pilots of small aircraft should avoid intensity levels 3 or higher.

Tower En Route Control (TEC)

At many locations, instrument flights can be conducted entirely in terminal airspace. These TEC routes are generally for aircraft operating below 10,000 feet, and they can be found in the A/FD. Pilots desiring to use TEC should include that designation in the remarks section of the flight plan.

Pilots are not limited to the major airports at the city pairs listed in the A/FD. For example, a tower en route flight from an airport in New York (NYC) airspace could terminate at any airport within approximately 30 miles of Bradley International (BDL) airspace, such as Hartford (HFD). *[Figure 9-10]*

A valuable service provided by the automated radar equipment at terminal radar facilities is the Minimum Safe Altitude Warnings (MSAW). This equipment predicts an aircraft's position in 2 minutes based on present path of flight—the controller issues a safety alert if the projected path encounters terrain or an obstruction. An unusually rapid descent rate on a nonprecision approach can trigger such an alert.

Air Route Traffic Control Center (ARTCC)

ARTCC facilities are responsible for maintaining separation between IFR flights in the en route structure. Center radars (Air Route Surveillance Radar (ARSR)) acquire and track transponder returns using the same basic technology as terminal radars. *[Figure 9-11]*

Earlier Center radars display weather as an area of slashes (light precipitation) and Hs (moderate rainfall), as illustrated in *Figure 9-12*. Because the controller cannot detect higher levels of precipitation, pilots should be wary of areas showing moderate rainfall. Newer radar displays show weather as three levels of blue. Controllers can select the level of weather to be displayed. Weather displays of higher levels of intensity can make it difficult for controllers to see aircraft data blocks, so pilots should not expect ATC to keep weather displayed continuously.

Center airspace is divided into sectors in the same manner as terminal airspace; additionally, most Center airspace is divided by altitudes into high and low sectors. Each sector has a dedicated team of controllers and a selection of radio frequencies, because each Center has a network of remote transmitter/receiver sites. All Center frequencies can be found in the back of the A/FD in the format shown in *Figure 9-13;* they are also found on en route charts.

Each ARTCC's area of responsibility covers several states; when flying from the vicinity of one remote communication site toward another, expect to hear the same controller on different frequencies.

Center Approach/Departure Control

The majority of airports with instrument approaches do not lie within terminal radar airspace, and when operating to or from these airports pilots communicate directly with the Center controller. Departing from a tower-controlled airport, the tower controller provides instructions for contacting the appropriate Center controller. When departing an airport without an operating control tower, the clearance includes instructions such as "Upon entering controlled airspace, contact Houston Center on 126.5." Pilots are responsible for terrain clearance until reaching the controller's MVA. Simply hearing "Radar contact" does not relieve a pilot of this responsibility.

If obstacles in the departure path require a steeper-than-standard climb gradient (200 FPNM), then the controller advises the pilot. However, it is the pilot's responsibility to check the departure airport listing in the A/FD to determine if there are trees or wires in the departure path. When in doubt, ask the controller for the required climb gradient.

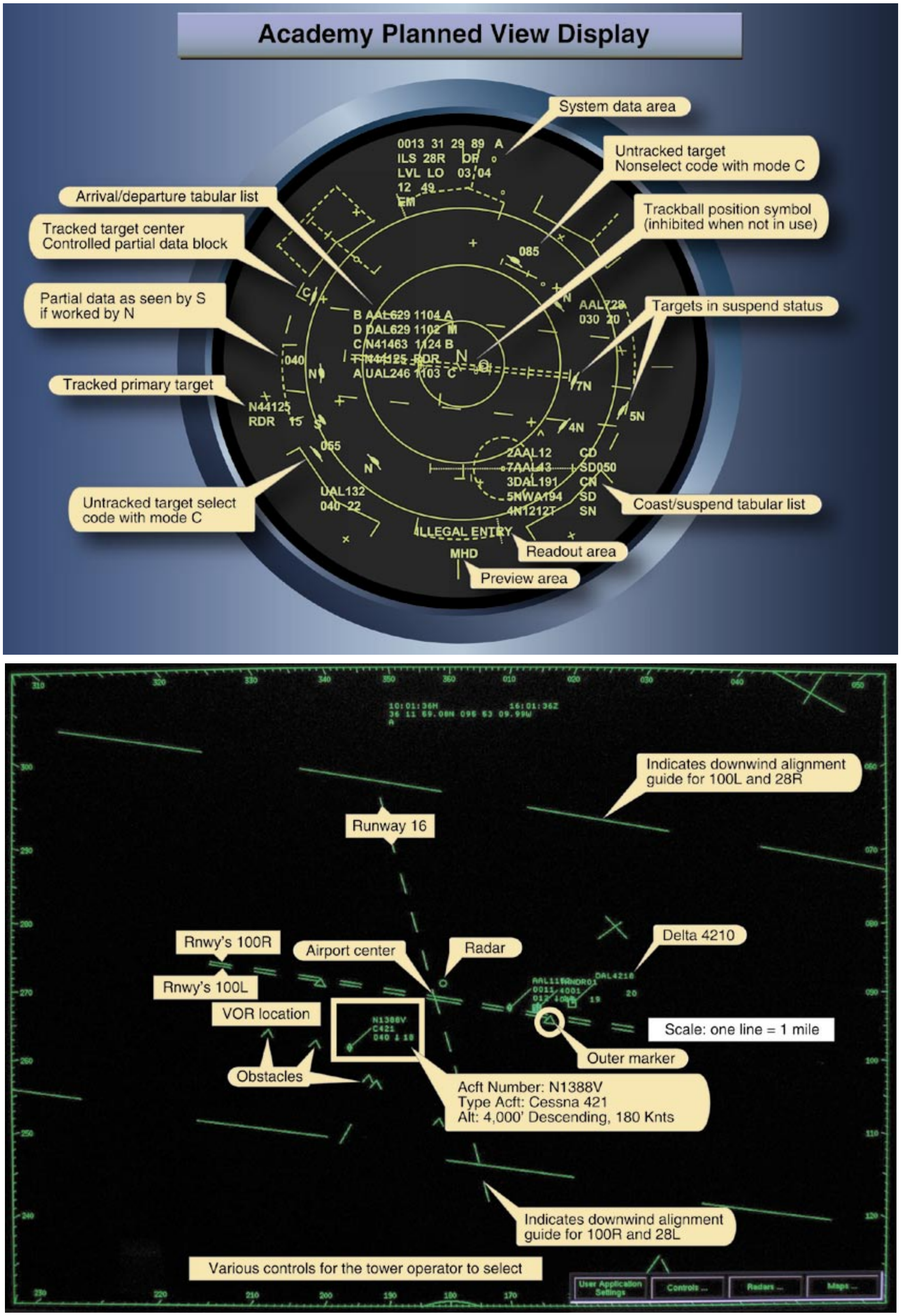
Academy Planned View Display
System data area
Untracked target
Nonselect code with mode C
Arrival/departure tabular list
Trackball position symbol
(inhibited when not in use)
Tracked target center
Controlled partial data block
Partial data as seen by S
if worked by N
Targets in suspend status
Tracked primary target
Untracked target select
code with mode C
Coast/suspend tabular list
Readout area
Preview area
0013 31 29 89 A
ILS 28R DR
LVL LO 03/04
12 49
EM
085
AAL729
030 20
B AAL629 1104 A
D DAL629 1102 M
C N41463 1124 B
T N44125 RDR
A UAL246 1103 C
040
N44125
RDR 15
055
7N
5N
4N
2AAL12 CD
7AAL43 SD050
3DAL191 CN
5NWA194 SD
4N1212T SN
UAL132
040 22
ILLEGAL ENTRY
MHD
Indicates downwind alignment
guide for 100L and 28R
Runway 16
Rnwy's 100R
Airport center
Radar
Delta 4210
Rnwy's 100L
VOR location
Scale: one line = 1 mile
Outer marker
Obstacles
Acft Number: N1388V
Type Acft: Cessna 421
Alt: 4,000' Descending, 180 Knts
Indicates downwind alignment
guide for 100R and 28L
Various controls for the tower operator to select
User Application Settings
Controls ...
Radars ...
Maps ...

Figure 9-9. *The top image is a display as seen by controllers in an Air Traffic Facility. The one illustrated is an ARTS III (Automated Radar Terminal System). The display shown provides an explanation of the symbols in the graphic. The lower figure is an example of the Digital Bright Radar Indicator Tower Equipment (DBRITE) screen as seen by tower personnel. It provides tower controllers with a visual display of the airport surveillance radar, beacon signals, and data received from ARTS III. The display shown provides an explanation of the symbols in the graphic.*

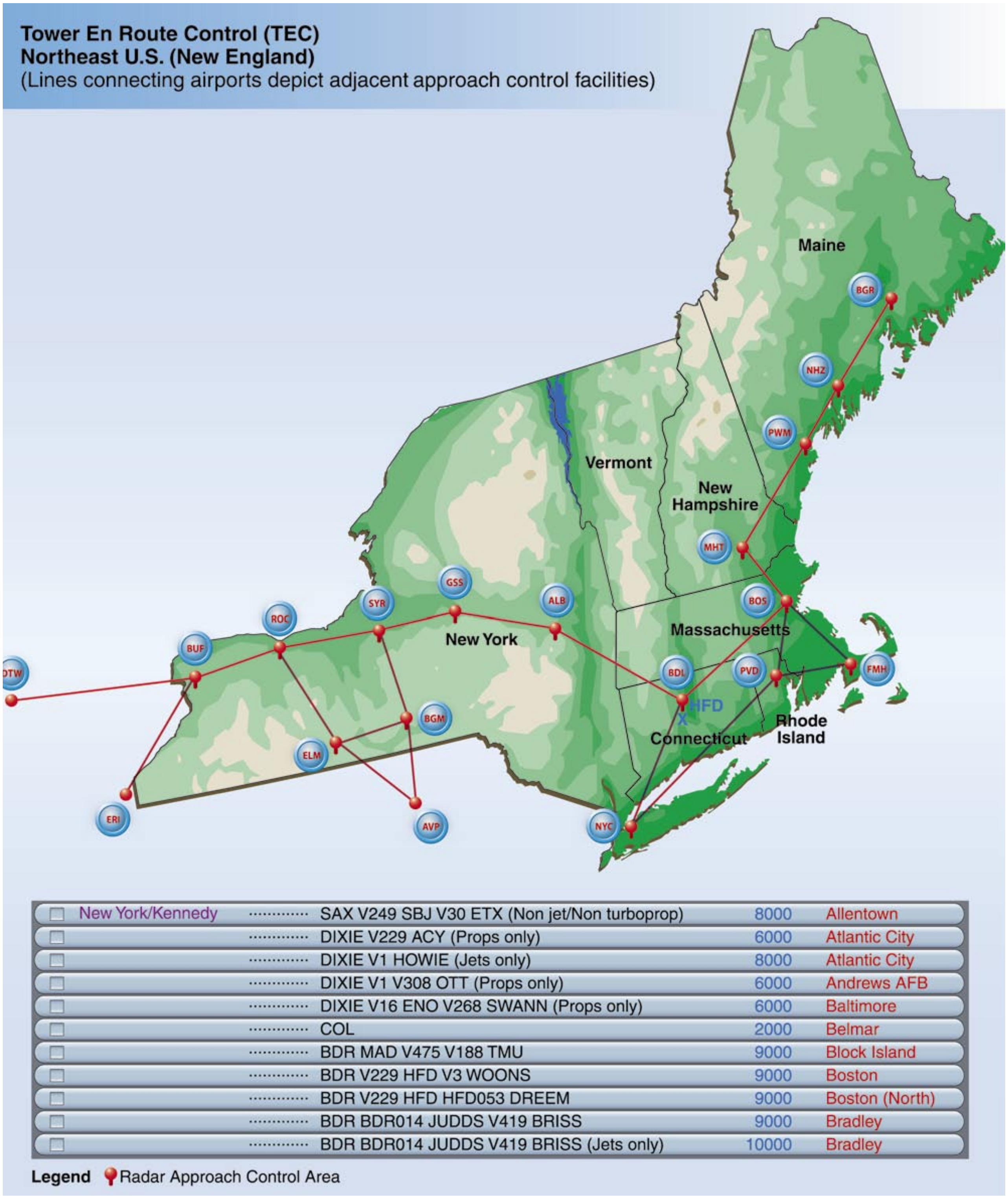
Tower En Route Control (TEC)
Northeast U.S. (New England)
(Lines connecting airports depict adjacent approach control facilities)
Maine
BGR
NHZ
PWM
Vermont
New Hampshire
MHT
BOS
GSS
SYR
ROC
BUF
DTW
ALB
New York
Massachusetts
BDL
PVD
FMH
HFD
Connecticut
Rhode Island
BGM
ELM
ERI
AVP
NYC
Legend
Radar Approach Control Area

☐	New York/Kennedy	SAX V249 SBJ V30 ETX (Non jet/Non turboprop)	8000	Allentown
☐		DIXIE V229 ACY (Props only)	6000	Atlantic City
☐		DIXIE V1 HOWIE (Jets only)	8000	Atlantic City
☐		DIXIE V1 V308 OTT (Props only)	6000	Andrews AFB
☐		DIXIE V16 ENO V268 SWANN (Props only)	6000	Baltimore
☐		COL	2000	Belmar
☐		BDR MAD V475 V188 TMU	9000	Block Island
☐		BDR V229 HFD V3 WOONS	9000	Boston
☐		BDR V229 HFD HFD053 DREEM	9000	Boston (North)
☐		BDR BDR014 JUDDS V419 BRISS	9000	Bradley
☐		BDR BDR014 JUDDS V419 BRISS (Jets only)	10000	Bradley

Figure 9-10. *A Portion of the New York Area Tower En Route List. (From the A/FD)*

Figure 9-11. *Center Radar Displays.*

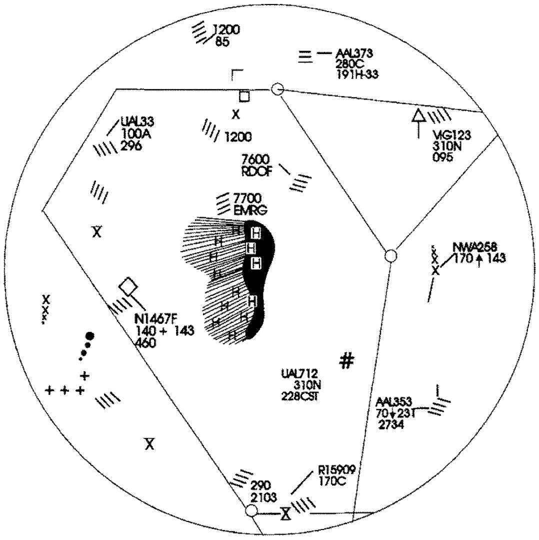

Figure 9-12. *A Center Controller's Scope.*

A common clearance in these situations is "When able, proceed direct to the Astoria VOR…" The words "when able" mean to proceed to the waypoint, intersection, or NAVAID when the pilot is able to navigate directly to that point using onboard available systems providing proper guidance, usable signal, etc. If provided such guidance while flying VFR, the pilot remains responsible for terrain and obstacle clearance. Using the standard climb gradient, an aircraft is 2 miles from the departure end of the runway before it is safe to turn (400 feet above ground level (AGL)). When a Center controller issues a heading, a direct route, or says "direct when able," the controller becomes responsible for terrain and obstruction clearance.

Another common Center clearance is "Leaving (altitude) fly (heading) or proceed direct when able." This keeps the terrain/obstruction clearance responsibility in the flight deck until above the minimum IFR altitude. A controller cannot issue an IFR clearance until an aircraft is above the minimum IFR altitude unless it is able to climb in VFR conditions.

On a Center controller's scope, 1 NM is about 1/28 of an inch. When a Center controller is providing Approach/Departure control services at an airport many miles from the radar antenna, estimating headings and distances is very difficult. Controllers providing vectors to final must set the range on their scopes to not more than 125 NM to provide the greatest possible accuracy for intercept headings. Accordingly, at locations more distant from a Center radar antenna, pilots should expect a minimum of vectoring.

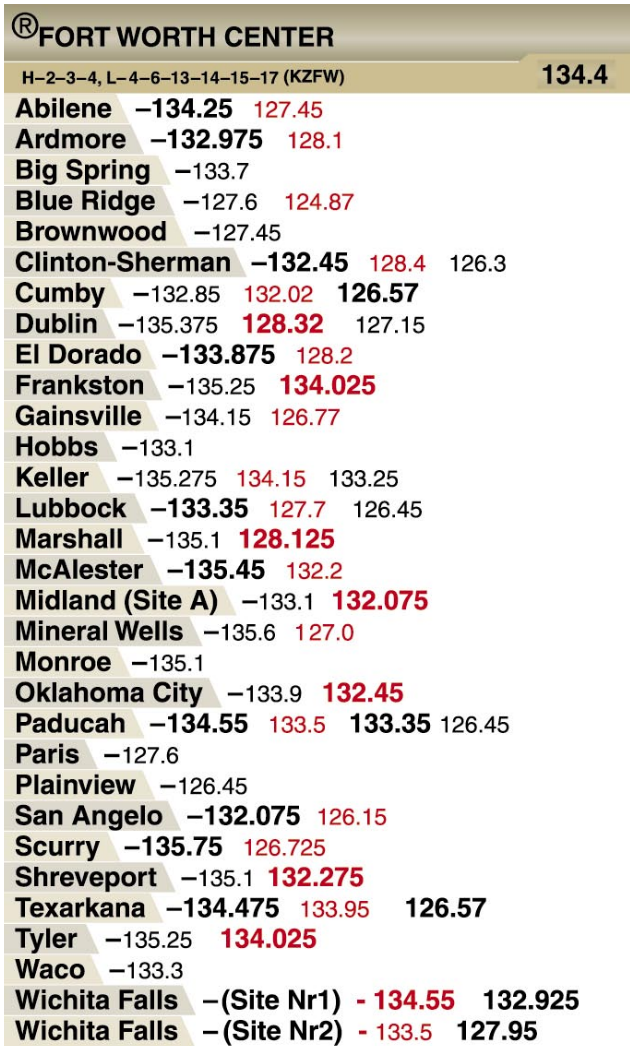

®FORT WORTH CENTER

H–2–3–4, L–4–6–13–14–15–17 (KZFW) **134.4**

Abilene	**–134.25**	127.45		
Ardmore	**–132.975**	128.1		
Big Spring	–133.7			
Blue Ridge	–127.6	124.87		
Brownwood	–127.45			
Clinton-Sherman	**–132.45**	128.4	126.3	
Cumby	–132.85	132.02	**126.57**	
Dublin	–135.375	**128.32**	127.15	
El Dorado	**–133.875**	128.2		
Frankston	–135.25	**134.025**		
Gainsville	–134.15	126.77		
Hobbs	–133.1			
Keller	–135.275	134.15	133.25	
Lubbock	**–133.35**	127.7	126.45	
Marshall	–135.1	**128.125**		
McAlester	**–135.45**	132.2		
Midland (Site A)	–133.1	**132.075**		
Mineral Wells	–135.6	127.0		
Monroe	–135.1			
Oklahoma City	–133.9	**132.45**		
Paducah	**–134.55**	133.5	**133.35**	126.45
Paris	–127.6			
Plainview	–126.45			
San Angelo	**–132.075**	126.15		
Scurry	**–135.75**	126.725		
Shreveport	–135.1	**132.275**		
Texarkana	**–134.475**	133.95	**126.57**	
Tyler	–135.25	**134.025**		
Waco	–133.3			
Wichita Falls	**–(Site Nr1)**	**- 134.55**	**132.925**	
Wichita Falls	**–(Site Nr2)**	- 133.5	**127.95**	

Figure 9-13. *Center Symbology.*

ATC Inflight Weather Avoidance Assistance

ATC Radar Weather Displays

ATC radar systems are able to display areas of precipitation by sending out a beam of radio energy that is reflected back to the radar antenna when it strikes an object or moisture which may be in the form of rain drops, hail, or snow. The larger the object, or the denser its reflective surface, the stronger the return will be. Radar weather processors indicate the intensity of reflective returns in terms of decibels with respect to the radar reflectively factor (dBZ).

ATC systems cannot detect the presence or absence of clouds. ATC radar systems can often determine the intensity of a precipitation area, but the specific character of that area (snow, rain, hail, VIRGA, etc.) cannot be determined. For this reason, ATC refers to all weather areas displayed on ATC radar scopes as “precipitation.”

All ATC facilities using radar weather processors with the ability to determine precipitation intensity describes the intensity to pilots as:

1. “LIGHT” (< 30 dBZ)
2. “MODERATE” (30 to 40 dBZ)
3. “HEAVY” (>40 to 50 dBZ)
4. “EXTREME” (>50 dBZ)

ARTCC controllers do not use the term “LIGHT” because their systems do not display “LIGHT” precipitation intensities. ATC facilities that, due to equipment limitations, cannot display the intensity levels of precipitation, will describe the location of the precipitation area by geographic position, or position relative to the aircraft. Since the intensity level is not available, the controller states, “INTENSITY UNKNOWN.”

ARTCC facilities normally use a Weather and Radar Processor (WARP) to display a mosaic of data obtained from multiple NEXRAD sites. The WARP processor is only used in ARTCC facilities.

There is a time delay between actual conditions and those displayed to the controller. For example, the precipitation data on the ARTCC controller’s display could be up to 6 minutes old. When the WARP is not available, a secondary system, the narrowband ARSR is utilized. The ARSR system can display two distinct levels of precipitation intensity that is described to pilots as “MODERATE” (30 to 40 dBZ) and “HEAVY to EXTREME” (>40 dBZ).

ATC radar systems cannot detect turbulence. Generally, turbulence can be expected to occur as the rate of rainfall or intensity of precipitation increases. Turbulence associated with greater rates of rainfall/precipitation is normally more severe than any associated with lesser rates of rainfall/precipitation. Turbulence should be expected to occur near convective activity, even in clear air. Thunderstorms are a form of convective activity that implies severe or greater turbulence. Operation within 20 miles of thunderstorms should be approached with great caution, as the severity of turbulence can be markedly greater than the precipitation intensity might indicate.

Weather Avoidance Assistance

ATC’s first duty priority is to separate aircraft and issue safety alerts. ATC provides additional services to the extent possible, contingent upon higher priority duties and other factors including limitations of radar, volume of traffic, frequency congestion, and workload. Subject to the above factors/limitations, controllers issue pertinent information on weather or chaff areas; and if requested, assist pilots, to the extent possible, in avoiding areas of precipitation. Pilots should respond to a weather advisory by acknowledging the advisory and, if desired, requesting an alternate course of action, such as:

1. Request to deviate off course by stating the direction and number of degrees or miles needed to deviate from the original course;
2. Request a change of altitude; or
3. Request routing assistance to avoid the affected area. Because ATC radar systems cannot detect the presence or absence of clouds and turbulence, such assistance conveys no guarantee that the pilot will not encounter hazards associated with convective activity. Pilots wishing to circumnavigate precipitation areas by a specific distance should make their desires clearly known to ATC at the time of the request for services. Pilots must advise ATC when they can resume normal navigation.

IFR pilots shall not deviate from their assigned course or altitude without an ATC clearance. Plan ahead for possible course deviations because hazardous convective conditions can develop quite rapidly. This is important to consider because the precipitation data displayed on ARTCC radar scopes can be up to 6 minutes old and thunderstorms can develop at rates exceeding 6,000 feet per minute (fpm). When encountering weather conditions that threaten the safety of the aircraft, the pilot may exercise emergency authority as stated in 14 CFR part 91, section 91.3 should an immediate deviation from the assigned clearance be necessary and time does not permit approval by ATC.

Generally, when weather disrupts the flow of air traffic, greater workload demands are placed on the controller. Requests for deviations from course and other services should be made as far in advance as possible to better assure the controller's ability to approve these requests promptly. When requesting approval to detour around weather activity, include the following information to facilitate the request:

1. The proposed point where detour commences;
2. The proposed route and extent of detour (direction and distance);
3. The point where original route will be resumed;
4. Flight conditions (IMC or VMC);
5. Whether the aircraft is equipped with functioning airborne radar; and
6. Any further deviation that may become necessary.

To a large degree, the assistance that might be rendered by ATC depends upon the weather information available to controllers. Due to the extremely transitory nature of hazardous weather, the controller's displayed precipitation information may be of limited value.

Obtaining IFR clearance or approval to circumnavigate hazardous weather can often be accommodated more readily in the en route areas away from terminals because there is usually less congestion and, therefore, greater freedom of action. In terminal areas, the problem is more acute because of traffic density, ATC coordination requirements, complex departure and arrival routes, and adjacent airports. As a consequence, controllers are less likely to be able to accommodate all requests for weather detours in a terminal area. Nevertheless, pilots should not hesitate to advise controllers of any observed hazardous weather and should specifically advise controllers if they desire circumnavigation of observed weather.

Pilot reports (PIREPs) of flight conditions help define the nature and extent of weather conditions in a particular area. These reports are disseminated by radio and electronic means to other pilots. Provide PIREP information to ATC regarding pertinent flight conditions, such as:

1. Turbulence;
2. Visibility;
3. Cloud tops and bases; and
4. The presence of hazards such as ice, hail, and lightning.

Approach Control Facility

An approach control facility is a terminal ATC facility that provides approach control service in the terminal area. Services are provided for arriving and departing VFR and IFR aircraft and, on occasion, en route aircraft. In addition, for airports with parallel runways with ILS or LDA approaches, the approach control facility provides monitoring of the approaches.

Approach Control Advances

Precision Runway Monitor (PRM)

Over the past few years, a new technology has been installed at airports that permits a decreased separation distance between parallel runways. The system is called a Precision Runway Monitor (PRM) and is comprised of high-update radar, high-resolution ATC displays, and PRM-certified controllers. *[Figure 9-14]*

Figure 9-14. *High Resolution ATC Displays Used in PRM.*

Precision Runway Monitor (PRM) Radar

The PRM uses a Monopulse Secondary Surveillance Radar (MSSR) that employs electronically scanned antennas. Because the PRM has no scan rate restrictions, it is capable of providing a faster update rate (up to 0.5 second) over conventional systems, thereby providing better target presentation in terms of accuracy, resolution, and track prediction. The system is designed to search, track, process, and display SSR-equipped aircraft within airspace of over 30 miles in range and over 15,000 feet in elevation. Visual and audible alerts are generated to warn controllers to take corrective actions.

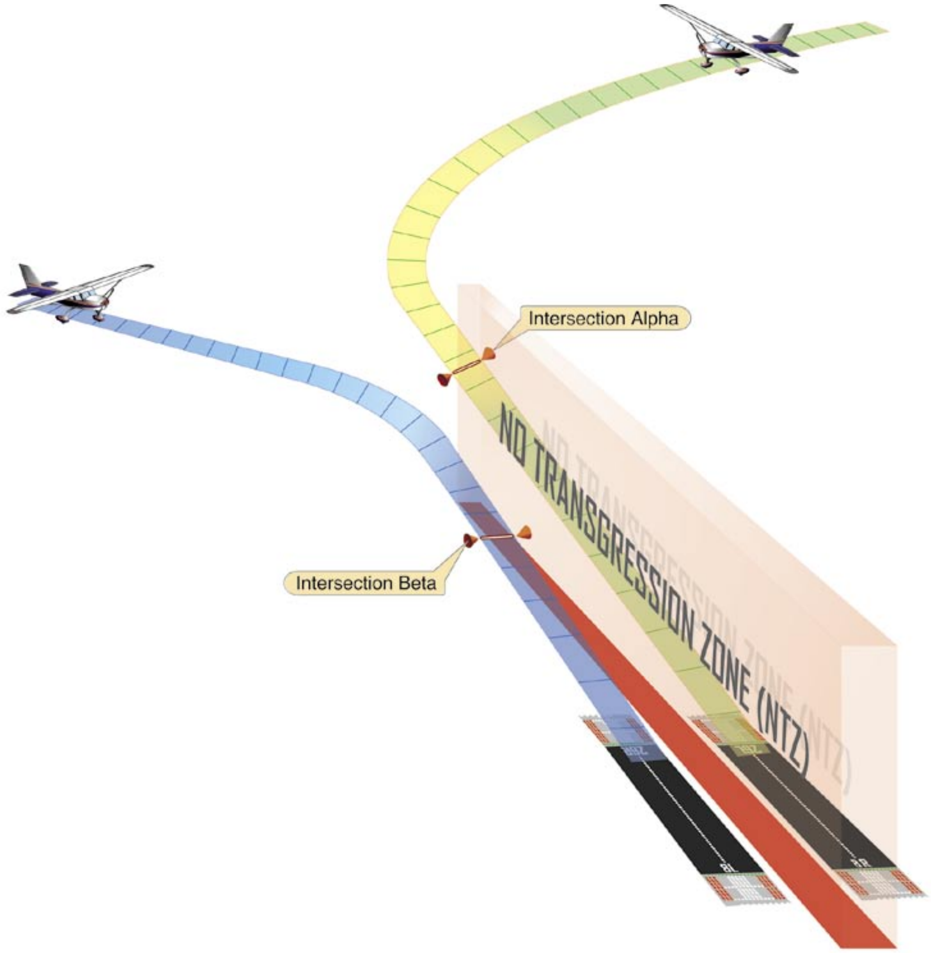

Figure 9-15. *Aircraft Management Using PRM. (Note the no transgression zone (NTZ) and how the aircraft are separated.)*

PRM Benefits

Typically, PRM is used with dual approaches with centerlines separated less than 4,300 feet but not less than 3,000 feet (under most conditions). *[Figure 9-15]* Separating the two final approach courses is a No Transgression Zone (NTZ) with surveillance of that zone provided by two controllers, one for each active approach. The system tracking software provides PRM monitor controllers with aircraft identification, position, speed, projected position, as well as visual and aural alerts.

Control Sequence

The IFR system is flexible and accommodating if pilots do their homework, have as many frequencies as possible written down before they are needed, and have an alternate in mind if the flight cannot be completed as planned. Pilots should familiarize themselves with all the facilities and services available along the planned route of flight. *[Figure 9-16]* Always know where the nearest VFR conditions can be found, and be prepared to head in that direction if the situation deteriorates.

A typical IFR flight, with departure and arrival at airports with control towers, would use the ATC facilities and services in the following sequence:

1. AFSS: Obtain a weather briefing for a departure, destination and alternate airports, and en route conditions, and then file a flight plan by calling 1-800-WX-BRIEF.
2. ATIS: Preflight complete, listen for present conditions and the approach in use.
3. Clearance Delivery: Prior to taxiing, obtain a departure clearance.
4. Ground Control: Noting that the flight is IFR, receive taxi instructions.
5. Tower: Pre-takeoff checks complete, receive clearance to takeoff.
6. Departure Control: Once the transponder "tags up" with the ARTS, the tower controller instructs the pilot to contact Departure to establish radar contact.

7. ARTCC: After departing the departure controller's airspace, aircraft is handed off to Center, who coordinates the flight while en route. Pilots may be in contact with multiple ARTCC facilities; they coordinate the hand-offs.
8. EFAS/HIWAS: Coordinate with ATC before leaving their frequency to obtain inflight weather information.
9. ATIS: Coordinate with ATC before leaving their frequency to obtain ATIS information.
10. Approach Control: Center hands off to approach control where pilots receive additional information and clearances.
11. Tower: Once cleared for the approach, pilots are instructed to contact tower control; the flight plan is canceled by the tower controller upon landing.

A typical IFR flight, with departure and arrival at airports without operating control towers, would use the ATC facilities and services in the following sequence:

1. AFSS: Obtain a weather briefing for departure, destination, and alternate airports, and en route conditions, and then file a flight plan by calling 1-800-WX-BRIEF. Provide the latitude/longitude description for small airports to ensure that Center is able to locate departure and arrival locations.
2. AFSS or UNICOM: ATC clearances can be filed and received on the UNICOM frequency if the licensee has made arrangements with the controlling ARTCC; otherwise, file with AFSS via telephone. Be sure all preflight preparations are complete before filing. The clearance includes a clearance void time. Pilots must be airborne prior to the void time.
3. ARTCC: After takeoff, establish contact with Center. During the flight, pilots may be in contact with multiple ARTCC facilities; ATC coordinates the hand-offs.
4. EFAS/HIWAS: Coordinate with ATC before leaving their frequency to obtain in-flight weather information.
5. Approach Control: Center hands off to approach control where pilots receive additional information and clearances. If a landing under visual meteorological conditions (VMC) is possible, pilots may cancel their IFR clearance before landing.

Letters of Agreement (LOA)

The ATC system is indeed a system, and very little happens by chance. As a flight progresses, controllers in adjoining sectors or adjoining Centers coordinate its handling by telephone or by computer. Where there is a boundary between the airspace controlled by different facilities, the location and altitude for hand-off is determined by Letters of Agreement (LOA) negotiated between the two facility managers. This information is not available to pilots in any Federal Aviation Administration (FAA) publication. For this reason, it is good practice to note on the en route chart the points at which hand-offs occur. Each time a flight is handed-off to a different facility, the controller knows the altitude and location—this was part of the hand-off procedure.

Communications Facility	Description	Frequency
Airport Advisory Area "[AFSS name] RADIO"	AFSS personnel provide traffic advisories to pilots operating within 10 miles of the airport.	123.6 MHz.
UNICOM "[airport name] UNICOM"	Airport advisories from an airport without an operating control tower or AFSS.	Listed in A/FD under the city name; also on sectional charts in airport data block.
Air Route Traffic Control Center (ARTCC) "CENTER"	En route radar facilities that maintain separation between IFR flights, and between IFR flights and known VFR flights. Centers provide VFR traffic advisories on a workload permitting basis.	Listed in A/FD and on instrument enroute charts.
Approach/Departure Control "[airport name] APPROACH" (unless otherwise advised)	Positions at a terminal radar facility responsible for handling of IFR flights to and from the primary airport (where Class B airspace exists).	Listed in A/FD; also on sectional charts in the communications panel and on terminal area charts.
Automatic Terminal Information Service (ATIS)	Continuous broadcast of audio tape prepared by ATC controller containing wind direction and velocity, temperature, altimeter setting, runway and approach in use, and other information of interest to pilots.	Listed in A/FD under the city name; also on sectional charts in airport data block and in the communications panel, and on terminal area charts.
Clearance Delivery "[airport name] CLEARANCE"	Control tower position responsible for transmitting departure clearances to IFR flights.	Listed on instrument approach procedure charts.
Common Traffic Advisory Frequency (CTAF)	CTAF provides a single frequency for pilots in the area to use for contacting the facility and/or broadcasting their position and intentions to other pilots.	Listed in A/FD; also on sectional charts in the airport data block (followed by a white C on a blue or magenta background). At airports with no tower, CTAF is 122.9, the "MULTICOM" frequency.
Automated Flight Service Station (AFSS) "[facility name] RADIO"	Provides information and services to pilots, using remote communications outlets (RCOs) and ground communications outlets (GCOs).	Listed in A/FD and sectional charts, both under city name and in a separate listing of AFSS frequencies. On sectional charts, listed above the VOR boxes, or in separate boxes when remote.
Ground Control "[airport name] GROUND"	At tower-controlled airports, a position in the tower responsible for controlling aircraft taxiing to and from the runways.	Listed in A/FD under city name.
Hazardous Inflight Weather Advisory Service (HIWAS)	Continuous broadcast of forecast hazardous weather conditions on selected NAVAIDs. No communication capability.	Black circle with white "H" in VOR frequency box; notation in A/FD airport listing under "Radio Aids to Navigation."
MULTICOM "[airport name] TRAFFIC"	Intended for use by pilots at airports with no radio facilities. Pilots should use self-announce procedures given in the AIM.	122.9 MHz. A/FD shows 122.9 as CTAF; also on sectional charts 122.9 is followed by a white C on a dark background, indicating CTAF.
Tower "[airport name] TOWER"	"Local" controller responsible for operations on the runways and in Class B, C, or D airspace surrounding the airport.	Listed in A/FD under city name; also on sectional and terminal control area charts in the airport data block and communications panel.
En Route Flight Advisory Service (EFAS) "FLIGHT WATCH"	For inflight weather information.	122.0 MHz (0600-2200 local time)

Figure 9-16. *ATC Facilities, Services, and Radio Call Signs.*

IFR Flight

Introduction

This chapter is a discussion of conducting a flight under instrument flight rules (IFR). It also explains the sources for flight planning, the conditions associated with instrument flight, and the procedures used for each phase of IFR flight: departure, en route, and approach. The chapter concludes with an example of an IFR flight which applies many of the procedures discussed in the chapter.

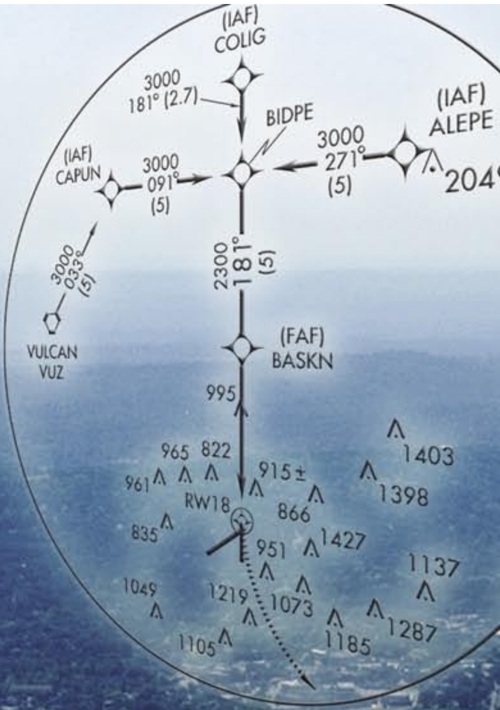
(IAF)
COLIG
3000
181° (2.7)
BIDPE
(IAF)
ALEPE
3000
271°
(5)
(IAF)
CAPUN
3000
091°
(5)
2300
181°
(5)
3000
033°
(5)
VULCAN
VUZ
(FAF)
BASKN
995
965
822
961
915±
1403
1398
866
RW18
835
951
1427
1137
1049
1219
1073
1287
1105
1185

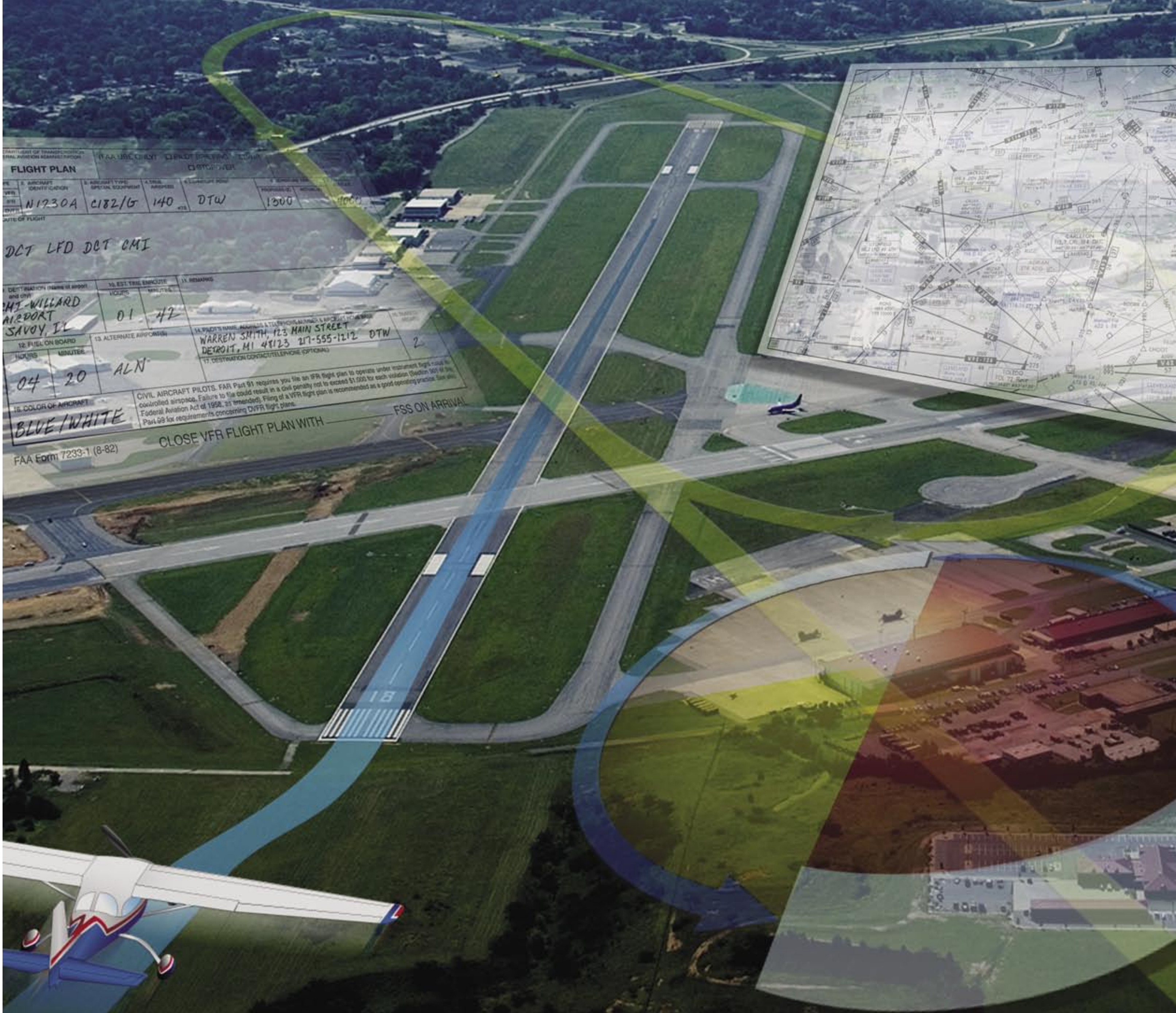
FLIGHT PLAN
N1230A
C182/G
140
DTW
1300
DCT LFD DCT CMI
CMI-WILLARD
AIRPORT
SAVOY, IL
01
42
WARREN SMITH, 123 MAIN STREET
DETROIT, MI 48123 217-555-1212 DTW
2
12. FUEL ON BOARD
HOURS
MINUTES
04
20
13. ALTERNATE AIRPORT(S)
ALN
17. DESTINATION CONTACT/TELEPHONE (OPTIONAL)
15. COLOR OF AIRCRAFT
BLUE/WHITE
CIVIL AIRCRAFT PILOTS. FAR Part 91 requires you file an IFR flight plan to operate under instrument flight rules in controlled airspace. Failure to file could result in a civil penalty not to exceed $1,000 for each violation (Section 901 of the Federal Aviation Act of 1958, as amended). Filing of a VFR flight plan is recommended as a good operating practice. See also Part 99 for requirements concerning DVFR flight plans.
CLOSE VFR FLIGHT PLAN WITH
FSS ON ARRIVAL
FAA Form 7233-1 (8-82)
18

Sources of Flight Planning Information

The following resources are available for a pilot planning a flight conducted under instrument flight rules (IFR).

National Aeronautical Charting Group (NACG) publications:

- IFR en route charts
- area charts
- United States (U.S.) Terminal Procedures Publications (TPP)

The Federal Aviation Administration (FAA) publications:

- AIM
- Airport/Facility Directory (A/FD)
- Notices to Airmen Publication (NTAP) for flight planning in the National Airspace System (NAS)

Pilots should also consult the Pilot's Operating Handbook/Airplane Flight Manual (POH/AFM) for flight planning information pertinent to the aircraft to be flown.

A review of the contents of all the listed publications will help determine which material should be referenced for each flight. As a pilot becomes more familiar with these publications, the flight planning process becomes quicker and easier.

Aeronautical Information Manual (AIM)

The AIM provides the aviation community with basic flight information and air traffic control (ATC) procedures used in the United States NAS. An international version called the Aeronautical Information Publication contains parallel information, as well as specific information on the international airports used by the international community.

Airport/Facility Directory (A/FD)

The A/FD contains information on airports, communications, and navigation aids pertinent to IFR flight. It also includes very-high frequency omnidirectional range (VOR) receiver checkpoints, automated flight service station (AFSS), weather service telephone numbers, and air route traffic control center (ARTCC) frequencies. Various special notices essential to flight are also included, such as land-and-hold-short operations (LAHSO) data, the civil use of military fields, continuous power facilities, and special flight procedures.

In the major terminal and en route environments, preferred routes have been established to guide pilots in planning their routes of flight, to minimize route changes, and to aid in the orderly management of air traffic using the federal airways. The A/FD lists both high and low altitude preferred routes.

Notices to Airmen Publication (NTAP)

The NTAP is a publication containing current Notices to Airmen (NOTAMs) which are essential to the safety of flight, as well as supplemental data affecting the other operational publications listed. It also includes current Flight Data Center (FDC) NOTAMs, which are regulatory in nature, issued to establish restrictions to flight or to amend charts or published instrument approach procedures (IAPs).

POH/AFM

The POH/AFM contain operating limitations, performance, normal and emergency procedures, and a variety of other operational information for the respective aircraft. Aircraft manufacturers have done considerable testing to gather and substantiate the information in the aircraft manual. Pilots should refer to it for information relevant to a proposed flight.

IFR Flight Plan

As specified in Title 14 of the Code of Federal Regulations (14 CFR) part 91, no person may operate an aircraft in controlled airspace under IFR unless that person has filed an IFR flight plan. Flight plans may be submitted to the nearest AFSS or air traffic control tower (ATCT) either in person, by telephone (1-800-WX-BRIEF), by computer (using the direct user access terminal system (DUATS)), or by radio if no other means are available. Pilots should file IFR flight plans at least 30 minutes prior to estimated time of departure to preclude possible delay in receiving a departure clearance from ATC. The AIM provides guidance for completing and filing FAA Form 7233-1, Flight Plan. These forms are available at flight service stations (FSSs), and are generally found in flight planning rooms at airport terminal buildings. *[Figure 10-1]*

Filing in Flight

IFR flight plans may be filed from the air under various conditions, including:

1. A flight outside controlled airspace before proceeding into IFR conditions in controlled airspace.
2. A VFR flight expecting IFR weather conditions en route in controlled airspace.

In either of these situations, the flight plan may be filed with the nearest AFSS or directly with the ARTCC. A pilot who files with the AFSS submits the information normally entered during preflight filing, except for "point of departure," together with present position and altitude. AFSS then relays this information to the ARTCC. The ARTCC will then clear the pilot from present position or from a specified navigation fix.

A pilot who files directly with the ARTCC reports present position and altitude, and submits only the flight plan information normally relayed from the AFSS to the ARTCC. Be aware that traffic saturation frequently prevents ARTCC personnel from accepting flight plans by radio. In such cases, a pilot is advised to contact the nearest AFSS to file the flight plan.

Cancelling IFR Flight Plans

An IFR flight plan may be cancelled any time a pilot is operating in VFR conditions outside Class A airspace by stating "cancel my IFR flight plan" to the controller or air-to-ground station. After cancelling an IFR flight plan, the pilot should change to the appropriate air-to-ground frequency, transponder code as directed, and VFR altitude/flight level.

ATC separation and information services (including radar services, where applicable) are discontinued when an IFR flight plan is cancelled. If VFR radar advisory service is desired, a pilot must specifically request it. Be aware that other procedures may apply when cancelling an IFR flight plan within areas such as Class C or Class B airspace.

When operating on an IFR flight plan to an airport with an operating control tower, a flight plan is cancelled automatically upon landing. If operating on an IFR flight plan to an airport without an operating control tower, the pilot is responsible for cancelling the flight plan. This can be done by telephone after landing if there is no operating FSS or other means of direct communications with ATC. When there is no FSS or air-to-ground communications are not possible below a certain altitude, a pilot may cancel an IFR flight plan while still airborne and able to communicate with ATC by radio. If using this procedure, be certain the remainder of the flight can be conducted under VFR. It is essential that IFR flight plans be cancelled expeditiously. This allows other IFR traffic to utilize the airspace.

Clearances

An ATC clearance allows an aircraft to proceed under specified traffic conditions within controlled airspace for the purpose of providing separation between known aircraft.

Examples

A flight filed for a short distance at a relatively low altitude in an area of low traffic density might receive a clearance as follows:

> "Cessna 1230 Alpha, cleared to Doeville airport direct, cruise 5,000."

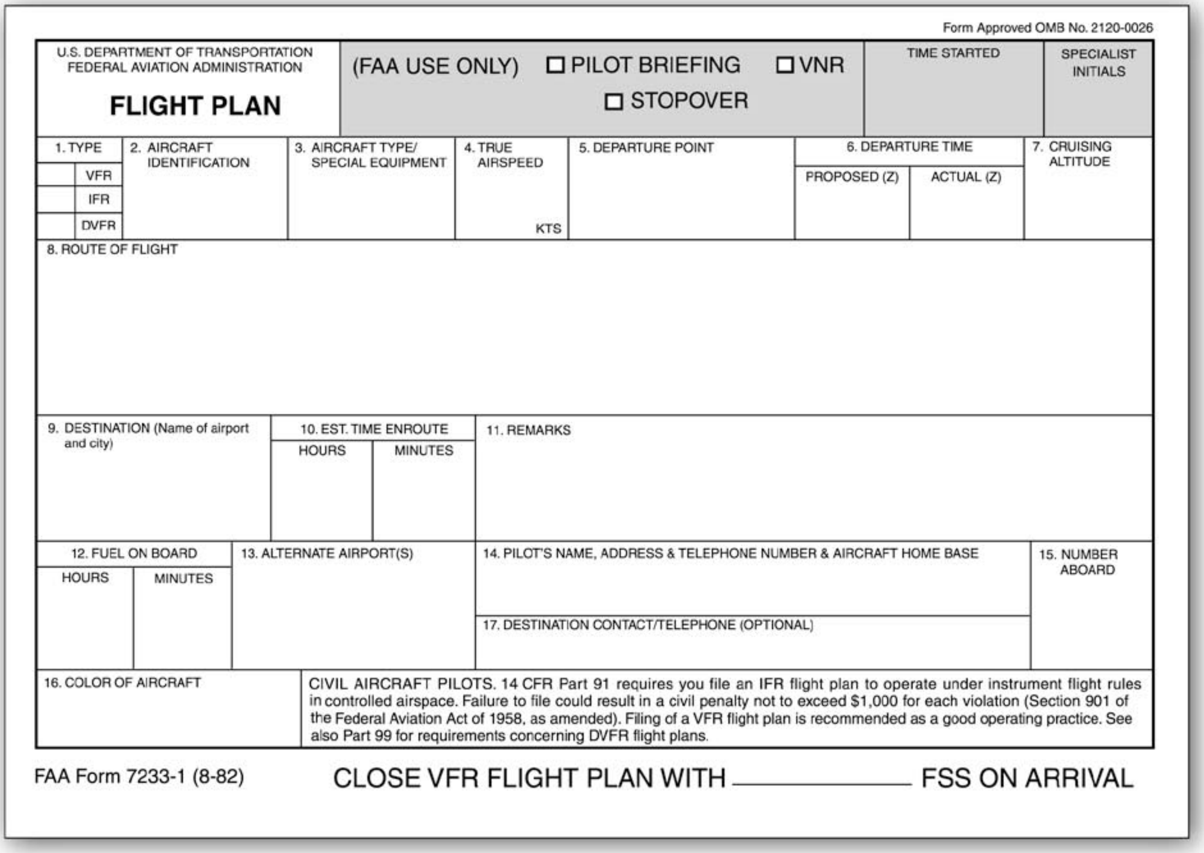

Form Approved OMB No. 2120-0026

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

FLIGHT PLAN

(FAA USE ONLY) ☐ PILOT BRIEFING ☐ VNR ☐ STOPOVER

TIME STARTED

SPECIALIST INITIALS

1. TYPE ☐ VFR ☐ IFR ☐ DVFR

2. AIRCRAFT IDENTIFICATION

3. AIRCRAFT TYPE/ SPECIAL EQUIPMENT

4. TRUE AIRSPEED KTS

5. DEPARTURE POINT

6. DEPARTURE TIME PROPOSED (Z) ACTUAL (Z)

7. CRUISING ALTITUDE

8. ROUTE OF FLIGHT

9. DESTINATION (Name of airport and city)

10. EST. TIME ENROUTE HOURS MINUTES

11. REMARKS

12. FUEL ON BOARD HOURS MINUTES

13. ALTERNATE AIRPORT(S)

14. PILOT'S NAME, ADDRESS & TELEPHONE NUMBER & AIRCRAFT HOME BASE

15. NUMBER ABOARD

17. DESTINATION CONTACT/TELEPHONE (OPTIONAL)

16. COLOR OF AIRCRAFT

CIVIL AIRCRAFT PILOTS. 14 CFR Part 91 requires you file an IFR flight plan to operate under instrument flight rules in controlled airspace. Failure to file could result in a civil penalty not to exceed $1,000 for each violation (Section 901 of the Federal Aviation Act of 1958, as amended). Filing of a VFR flight plan is recommended as a good operating practice. See also Part 99 for requirements concerning DVFR flight plans.

FAA Form 7233-1 (8-82)

CLOSE VFR FLIGHT PLAN WITH ______________ FSS ON ARRIVAL

Figure 10-1. *Flight Plan Form.*

The term “cruise” in this clearance means a pilot is authorized to fly at any altitude from the minimum IFR altitude up to and including 5,000 feet, and may level off at any altitude within this block of airspace. A climb or descent within the block may be made at the pilot’s discretion. However, once a pilot reports leaving an altitude within the block, the pilot may not return to that altitude without further ATC clearance.

When ATC issues a cruise clearance in conjunction with an unpublished route, an appropriate crossing altitude will be specified to ensure terrain clearance until the aircraft reaches a fix, point, or route where the altitude information is available. The crossing altitude ensures IFR obstruction clearance to the point at which the aircraft enters a segment of a published route or IAP.

Once a flight plan is filed, ATC will issue the clearance with appropriate instructions, such as the following:

> “Cessna 1230 Alpha is cleared to Skyline airport via the Crossville 055 radial, Victor 18, maintain 5,000. Clearance void if not off by 1330.”

Or a more complex clearance, such as:

> “Cessna 1230 Alpha is cleared to Wichita Mid-continent airport via Victor 77, left turn after takeoff, proceed direct to the Oklahoma City VORTAC. Hold west on the Oklahoma City 277 radial, climb to 5,000 in holding pattern before proceeding on course. Maintain 5,000 to CASHION intersection. Climb to and maintain 7,000. Departure control frequency will be 121.05, Squawk 0412.”

Clearance delivery may issue the following “abbreviated clearance” which includes a departure procedure (DP):

> “Cessna 1230 Alpha, cleared to La Guardia as filed, RINGOES 8 departure Phillipsburg transition, maintain 8,000. Departure control frequency will be 120.4, Squawk 0700.”

This clearance may be readily copied in shorthand as follows:

> “CAF RNGO8 PSB M80 DPC 120.4 SQ 0700.”

The information contained in this DP clearance is abbreviated using clearance shorthand (see appendix 1). The pilot should know the locations of the specified navigation facilities, together with the route and point-to-point time, before accepting the clearance.

The DP enables a pilot to study and understand the details of a departure before filing an IFR flight plan. It provides the information necessary to set up communication and navigation equipment and be ready for departure before requesting an IFR clearance.

Once the clearance is accepted, a pilot is required to comply with ATC instructions. A clearance different from that issued may be requested if the pilot considers another course of action more practicable or if aircraft equipment limitations or other considerations make acceptance of the clearance inadvisable.

A pilot should also request clarification or amendment, as appropriate, any time a clearance is not fully understood or considered unacceptable for safety of flight. The pilot is responsible for requesting an amended clearance if ATC issues a clearance that would cause a pilot to deviate from a rule or regulation or would place the aircraft in jeopardy.

Clearance Separations

ATC will provide the pilot on an IFR clearance with separation from other IFR traffic. This separation is provided:

1. Vertically—by assignment of different altitudes.
2. Longitudinally—by controlling time separation between aircraft on the same course.
3. Laterally—by assignment of different flight paths.
4. By radar—including all of the above.

ATC does not provide separation for an aircraft operating:

1. Outside controlled airspace.
2. On an IFR clearance:
    a) With “VFR-On-Top” authorized instead of a specific assigned altitude.
    b) Specifying climb or descent in “VFR conditions.”
    c) At any time in VFR conditions, since uncontrolled VFR flights may be operating in the same airspace.

In addition to heading and altitude assignments, ATC will occasionally issue speed adjustments to maintain the required separations. For example:

> “Cessna 30 Alpha, slow to 100 knots.”

A pilot who receives speed adjustments is expected to maintain that speed plus or minus 10 knots. If for any reason the pilot is not able to accept a speed restriction, the pilot should advise ATC.

At times, ATC may also employ visual separation techniques to keep aircraft safely separated. A pilot who obtains visual contact with another aircraft may be asked to maintain visual separation or to follow the aircraft. For example:

> "Cessna 30 Alpha, maintain visual separation with that traffic, climb and maintain 7,000."

The pilot's acceptance of instructions to maintain visual separation or to follow another aircraft is an acknowledgment that the aircraft will be maneuvered as necessary, to maintain safe separation. It is also an acknowledgment that the pilot accepts the responsibility for wake turbulence avoidance.

In the absence of radar contact, ATC will rely on position reports to assist in maintaining proper separation. Using the data transmitted by the pilot, the controller follows the progress of each flight. ATC must correlate the pilots' reports to provide separation; therefore, the accuracy of each pilot's report can affect the progress and safety of every other aircraft operating in the area on an IFR flight plan.

Departure Procedures (DPs)

Instrument departure procedures are preplanned instrument flight rule (IFR) procedures, which provide obstruction clearance from the terminal area to the appropriate en route structure and provide the pilot with a way to depart the airport and transition to the en route structure safely. Pilots operating under 14 CFR part 91 are strongly encouraged to file and fly a DP when one is available. *[Figure 10-2]*

There are two types of DPs, Obstacle Departure Procedures (ODP), printed either textually or graphically, and Standard Instrument Departures (SID), always printed graphically. All DPs, either textual or graphic, may be designed using either conventional or RNAV criteria. RNAV procedures will have RNAV printed in the title, e.g., SHEAD TWO DEPARTURE (RNAV).

Obstacle Departure Procedures (ODP)

ODPs provide obstruction clearance via the least onerous route from the terminal area to the appropriate en route structure. ODPs are recommended for obstruction clearance and may be flown without ATC clearance unless an alternate departure procedure (SID or radar vector) has been specifically assigned by ATC. Graphic ODPs will have (OBSTACLE) printed in the procedure title, e.g., GEYSR THREE DEPARTURE (OBSTACLE), CROWN ONE DEPARTURE (RNAV)(OBSTACLE).

Standard Instrument Departures

Standard Instrument Departures (SID) are air traffic control (ATC) procedures printed for pilot/controller use in graphic form to provide obstruction clearance and a transition from the terminal area to the appropriate en route structure. SIDs are primarily designed for system enhancement and to reduce pilot/controller workload. ATC clearance must be received prior to flying a SID.

ODPs are found in section C of each booklet published regionally by the NACG, TPP, along with "IFR Take-off Minimums" while SIDs are collocated with the approach procedures for the applicable airport. Additional information on the development of DPs can be found in paragraph 5-2-7 of the AIM. However, the following points are important to remember.

1. The pilot of IFR aircraft operating from locations where DP procedures are effective may expect an ATC clearance containing a DP. The use of a DP requires pilot possession of at least the textual description of the approved DP.
2. If a pilot does not possess a preprinted DP or for any other reason does not wish to use a DP, he or she is expected to advise ATC. Notification may be accomplished by filing "NO DP" in the remarks section of the filed flight plan, or by advising ATC.
3. If a DP is accepted in a clearance, a pilot must comply with it.

Radar Controlled Departures

On IFR departures from airports in congested areas, a pilot will normally receive navigational guidance from departure control by radar vector. When a departure is to be vectored immediately following takeoff, the pilot will be advised before takeoff of the initial heading to be flown. This information is vital in the event of a loss of two-way radio communications during departure.

The radar departure is normally simple. Following takeoff, contact departure control on the assigned frequency when advised to do so by the control tower. At this time departure control verifies radar contact, and gives headings, altitude, and climb instructions to move an aircraft quickly and safely out of the terminal area. A pilot is expected to fly the assigned headings and altitudes until informed by the controller of the aircraft's position with respect to the route given in the clearance, whom to contact next, and to "resume own navigation."

Departure control will provide vectors to either a navigation facility, or an en route position appropriate to the departure clearance, or transfer to another controller with further radar surveillance capabilities. *[Figure 10-2]*

A radar controlled departure does not relieve the pilot of responsibilities as pilot-in-command. Be prepared before takeoff to conduct navigation according to the ATC clearance, with navigation receivers checked and properly tuned. While under radar control, monitor instruments to ensure continuous orientation to the route specified in the clearance, and record the time over designated checkpoints.

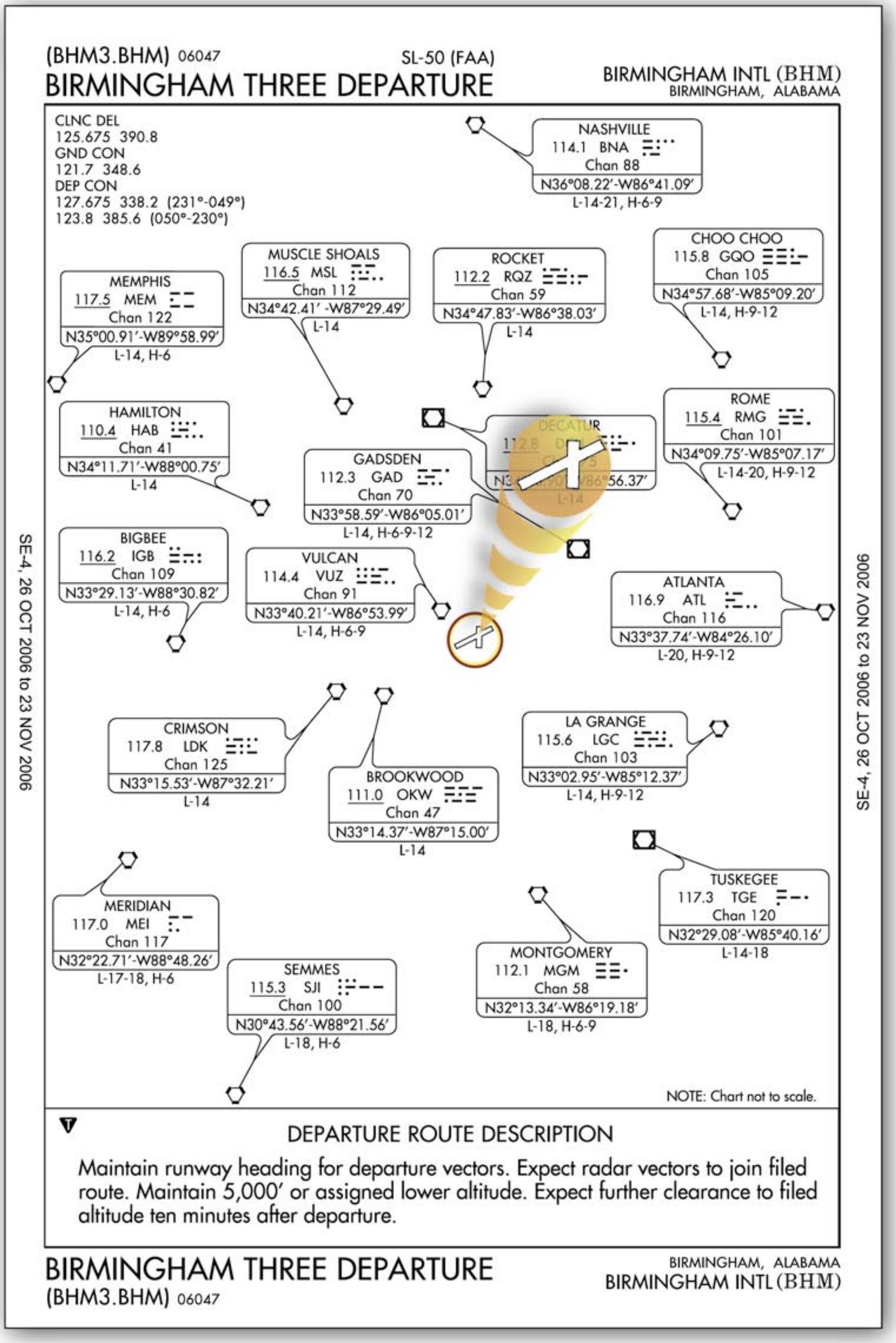

(BHM3.BHM) 06047 SL-50 (FAA)

BIRMINGHAM THREE DEPARTURE

BIRMINGHAM INTL (BHM)
BIRMINGHAM, ALABAMA

CLNC DEL
125.675 390.8
GND CON
121.7 348.6
DEP CON
127.675 338.2 (231°-049°)
123.8 385.6 (050°-230°)

NASHVILLE
114.1 BNA
Chan 88
N36°08.22'-W86°41.09'
L-14-21, H-6-9

MUSCLE SHOALS
116.5 MSL
Chan 112
N34°42.41' -W87°29.49'
L-14

ROCKET
112.2 RQZ
Chan 59
N34°47.83'-W86°38.03'
L-14

CHOO CHOO
115.8 GQO
Chan 105
N34°57.68'-W85°09.20'
L-14, H-9-12

MEMPHIS
117.5 MEM
Chan 122
N35°00.91'-W89°58.99'
L-14, H-6

HAMILTON
110.4 HAB
Chan 41
N34°11.71'-W88°00.75'
L-14

DECATUR
112.8 D
N3 56.37'
L-14

ROME
115.4 RMG
Chan 101
N34°09.75'-W85°07.17'
L-14-20, H-9-12

GADSDEN
112.3 GAD
Chan 70
N33°58.59'-W86°05.01'
L-14, H-6-9-12

BIGBEE
116.2 IGB
Chan 109
N33°29.13'-W88°30.82'
L-14, H-6

VULCAN
114.4 VUZ
Chan 91
N33°40.21'-W86°53.99'
L-14, H-6-9

ATLANTA
116.9 ATL
Chan 116
N33°37.74'-W84°26.10'
L-20, H-9-12

CRIMSON
117.8 LDK
Chan 125
N33°15.53'-W87°32.21'
L-14

BROOKWOOD
111.0 OKW
Chan 47
N33°14.37'-W87°15.00'
L-14

LA GRANGE
115.6 LGC
Chan 103
N33°02.95'-W85°12.37'
L-14, H-9-12

TUSKEGEE
117.3 TGE
Chan 120
N32°29.08'-W85°40.16'
L-14-18

MERIDIAN
117.0 MEI
Chan 117
N32°22.71'-W88°48.26'
L-17-18, H-6

SEMMES
115.3 SJI
Chan 100
N30°43.56'-W88°21.56'
L-18, H-6

MONTGOMERY
112.1 MGM
Chan 58
N32°13.34'-W86°19.18'
L-18, H-6-9

NOTE: Chart not to scale.

SE-4, 26 OCT 2006 to 23 NOV 2006

SE-4, 26 OCT 2006 to 23 NOV 2006

DEPARTURE ROUTE DESCRIPTION

Maintain runway heading for departure vectors. Expect radar vectors to join filed route. Maintain 5,000' or assigned lower altitude. Expect further clearance to filed altitude ten minutes after departure.

BIRMINGHAM THREE DEPARTURE
(BHM3.BHM) 06047

BIRMINGHAM, ALABAMA
BIRMINGHAM INTL (BHM)

Figure 10-2. *Departure Procedure (DP).*

Departures From Airports Without an Operating Control Tower

When departing from airports that have neither an operating tower nor an FSS, a pilot should telephone the flight plan to the nearest ATC facility at least 30 minutes before the estimated departure time. If weather conditions permit, depart VFR and request IFR clearance as soon as radio contact is established with ATC.

If weather conditions make it undesirable to fly VFR, telephone clearance request. In this case, the controller would probably issue a short-range clearance pending establishment of radio contact, and might restrict the departure time to a certain period. For example:

> "Clearance void if not off by 0900."

This would authorize departure within the allotted period and permit a pilot to proceed in accordance with the clearance. In the absence of any specific departure instructions, a pilot would be expected to proceed on course via the most direct route.

En Route Procedures

Procedures en route will vary according to the proposed route, the traffic environment, and the ATC facilities controlling the flight. Some IFR flights are under radar surveillance and controlled from departure to arrival, and others rely entirely on pilot navigation.

Where ATC has no jurisdiction, it does not issue an IFR clearance. It has no control over the flight, nor does the pilot have any assurance of separation from other traffic.

ATC Reports

All pilots are required to report unforecast weather conditions or other information related to safety of flight to ATC. The pilot-in-command of each aircraft operated in controlled airspace under IFR shall report as soon as practical to ATC any malfunctions of navigational, approach, or communication equipment occurring in flight:

1. Loss of VOR, tactical air navigation (TACAN) or automatic direction finder (ADF) receiver capability.
2. Complete or partial loss of instrument landing system (ILS) receiver capability.
3. Impairment of air-to-ground communications capability.

The pilot-in-command shall include within the report (1) Aircraft identification, (2) Equipment affected, (3) Degree to which the pilot to operate under IFR within the ATC system is impaired, and (4) Nature and extent of assistance desired from ATC.

Position Reports

Position reports are required over each compulsory reporting point (shown on the chart as a solid triangle) along the route being flown regardless of altitude, including those with a VFR-on-top clearance. Along direct routes, reports are required of all IFR flights over each point used to define the route of flight. Reports at reporting points (shown as an open triangle) are made only when requested by ATC. A pilot should discontinue position reporting over designated reporting points when informed by ATC that the aircraft is in "RADAR CONTACT." Position reporting should be resumed when ATC advises "RADAR CONTACT LOST" or "RADAR SERVICE TERMINATED."

Position reports should include the following items:

1. Identification
2. Position
3. Time
4. Altitude or flight level (include actual altitude or flight level when operating on a clearance specifying VFR-on-top)
5. Type of flight plan (not required in IFR position reports made directly to ARTCCs or approach control)
6. ETA and name of next reporting point
7. The name only of the next succeeding reporting point along the route of flight
8. Pertinent remarks

En route position reports are submitted normally to the ARTCC controllers via direct controller-to-pilot communications channels, using the appropriate ARTCC frequencies listed on the en route chart.

Whenever an initial contact with a controller is to be followed by a position report, the name of the reporting point should be included in the call-up. This alerts the controller that such information is forthcoming. For example:

> "Atlanta Center, Cessna 1230 Alpha at JAILS intersection."
>
> "Cessna 1230 Alpha Atlanta Center."
>
> "Atlanta Center, Cessna 1230 Alpha at JAILS intersection, 5,000, estimating Monroeville at 1730."

Additional Reports

In addition to required position reports, the following reports should be made to ATC without a specific request.

1. At all times:
    - a) When vacating any previously assigned altitude or flight level for a newly assigned altitude or flight level
    - b) When an altitude change will be made if operating on a clearance specifying VFR-on-top
    - c) When unable to climb/descend at a rate of at least 500 feet per minute (fpm)
    - d) When an approach has been missed (Request clearance for specific action (to alternative airport, another approach, etc.))
    - e) Change in average true airspeed (at cruising altitude) when it varies by 5 percent or ten knots (whichever is greater) from that filed in the flight plan
    - f) The time and altitude upon reaching a holding fix or point to which cleared
    - g) When leaving any assigned holding fix or point

      NOTE - The reports in (f) and (g) may be omitted by pilots of aircraft involved in instrument training at military terminal area facilities when radar service is being provided.
    - h) Any loss in controlled airspace of VOR, TACAN, ADF, low frequency navigation receiver capability, GPS anomalies while using installed IFR-certified GPS/GNSS receivers, complete or partial loss of ILS receiver capability, or impairment of air/ground communications capability. Reports should include aircraft identification, equipment affected, degree to which the capability to operate under IFR in the ATC system is impaired, and the nature and extent of assistance desired from ATC.
    - i) Any information relating to the safety of flight.
2. When not in radar contact:
    - a) When leaving the final approach fix inbound on final approach (nonprecision approach), or when leaving the outer marker or fix used in lieu of the outer marker inbound on final approach (precision approach).
    - b) A corrected estimate at any time it becomes apparent that an estimate as previously submitted is in error in excess of 3 minutes.

Any pilot who encounters weather conditions that have not been forecast, or hazardous conditions which have been forecast, is expected to forward a report of such weather to ATC.

Planning the Descent and Approach

ATC arrival procedures and flight deck workload are affected by weather conditions, traffic density, aircraft equipment, and radar availability.

When landing at an airport with approach control services and where two or more IAPs are published, information on the type of approach to expect will be provided in advance of arrival or vectors will be provided to a visual approach. This information will be broadcast either on automated terminal information service (ATIS) or by a controller. It will not be furnished when the visibility is 3 miles or more and the ceiling is at or above the highest initial approach altitude established for any low altitude IAP for the airport.

The purpose of this information is to help the pilot plan arrival actions; however, it is not an ATC clearance or commitment and is subject to change. Fluctuating weather, shifting winds, blocked runway, etc., are conditions that may result in changes to the approach information previously received. It is important for a pilot to advise ATC immediately if he or she is unable to execute the approach or prefers another type of approach.

If the destination is an airport without an operating control tower, and has automated weather data with broadcast capability, the pilot should monitor the automated surface observing system/automated weather observing system (ASOS/AWOS) frequency to ascertain the current weather for the airport. ATC should be advised that weather information has been received and what the pilot's intentions are.

When the approach to be executed has been determined, the pilot should plan for and request a descent to the appropriate altitude prior to the initial approach fix (IAF) or transition route depicted on the IAP. When flying the transition route, a pilot should maintain the last assigned altitude until ATC gives the instructions "cleared for the approach." Lower altitudes can be requested to bring the transition route altitude closer to the required altitude at the initial approach fix. When ATC uses the phrase "at pilot's discretion" in the altitude information of a clearance, the pilot has the option to start a descent at any rate, and may level off temporarily at any intermediate altitude. However, once an altitude has been vacated, return to that altitude is not authorized without a clearance. When ATC has not used the term "at pilot's discretion" nor imposed any descent restrictions, initiate descent promptly upon acknowledgment of the clearance.

Descend at an optimum rate (consistent with the operating characteristics of the aircraft) to 1,000 feet above the assigned altitude. Then attempt to descend at a rate of between 500 and

1,500 fpm until the assigned altitude is reached. If at anytime a pilot is unable to maintain a descent rate of at least 500 fpm, advise ATC. Also advise ATC if it is necessary to level off at an intermediate altitude during descent. An exception to this is when leveling off at 10,000 feet mean sea level (MSL) on descent, or 2,500 feet above airport elevation (prior to entering a Class B, Class C, or Class D surface area) when required for speed reduction.

Standard Terminal Arrival Routes (STARs)

Standard terminal arrival routes (as described in Chapter 8) have been established to simplify clearance delivery procedures for arriving aircraft at certain areas having high density traffic. A STAR serves a purpose parallel to that of a DP for departing traffic. *[Figure 10-3]* The following points regarding STARs are important to remember:

1. All STARs are contained in the TPP, along with the IAP charts for the destination airport. The AIM also describes STAR procedures.
2. If the destination is a location for which STARs have been published, a pilot may be issued a clearance containing a STAR whenever ATC deems it appropriate. To accept the clearance, a pilot must possess at least the approved textual description.
3. It is the pilot's responsibility to either accept or refuse an issued STAR. If a STAR will not or cannot be used, advise ATC by placing "NO STAR" in the remarks section of the filed flight plan or by advising ATC.
4. If a STAR is accepted in a clearance, compliance is mandatory.

Substitutes for Inoperative or Unusable Components

The basic ground components of an ILS are the localizer, glide slope, outer marker, middle marker, and inner marker (when installed). A compass locator or precision radar may be substituted for the outer or middle marker. Distance measuring equipment (DME), VOR, or nondirectional beacon (NDB) fixes authorized in the standard IAP or surveillance radar may be substituted for the outer marker.

Additionally, IFR-certified global positioning system (GPS) equipment, operated in accordance with Advisory Circular (AC) 90-94, Guidelines for Using Global Positioning System Equipment for IFR En Route and Terminal Operations and for Nonprecision Instrument Approaches in the United States National Airspace System, may be substituted for ADF and DME equipment, except when flying NDB IAP. Specifically, GPS can be substituted for ADF and DME equipment when:

1. Flying a DME arc;
2. Navigating TO/FROM an NDB;
3. Determining the aircraft position over an NDB;
4. Determining the aircraft position over a fix made up of a crossing NDB bearing;
5. Holding over an NDB;
6. Determining aircraft position over a DME fix.

Holding Procedures

Depending upon traffic and weather conditions, holding may be required. Holding is a predetermined maneuver which keeps aircraft within a specified airspace while awaiting further clearance from ATC. A standard holding pattern uses right turns, and a nonstandard holding pattern uses left turns. The ATC clearance will always specify left turns when a nonstandard pattern is to be flown.

Standard Holding Pattern (No Wind)

In a standard holding pattern with no winds, *[Figure 10-4]* the aircraft follows the specified course inbound to the holding fix, turns 180° to the right, flies a parallel straight course outbound for 1 minute, turns 180° to the right, and flies the inbound course to the fix.

Standard Holding Pattern (With Wind)

A standard symmetrical holding pattern cannot be flown when winds exist. In those situations, the pilot is expected to:

1. Compensate for the effect of a known wind except when turning.
2. Adjust outbound timing to achieve a 1-minute (1-1/2 minutes above 14,000 feet) inbound leg.

Figure 10-5 illustrates the holding track followed with a left crosswind. The effect of wind is counteracted by applying drift corrections to the inbound and outbound legs and by applying time allowances to the outbound leg.

Holding Instructions

If an aircraft arrives at a clearance limit before receiving clearance beyond the fix, ATC expects the pilot to maintain the last assigned altitude and begin holding in accordance with the charted holding pattern. If no holding pattern is charted and holding instructions have not been issued, enter a standard holding pattern on the course on which the aircraft approached the fix and request further clearance as soon as possible. Normally, when no delay is anticipated, ATC will issue holding instructions at least 5 minutes before the

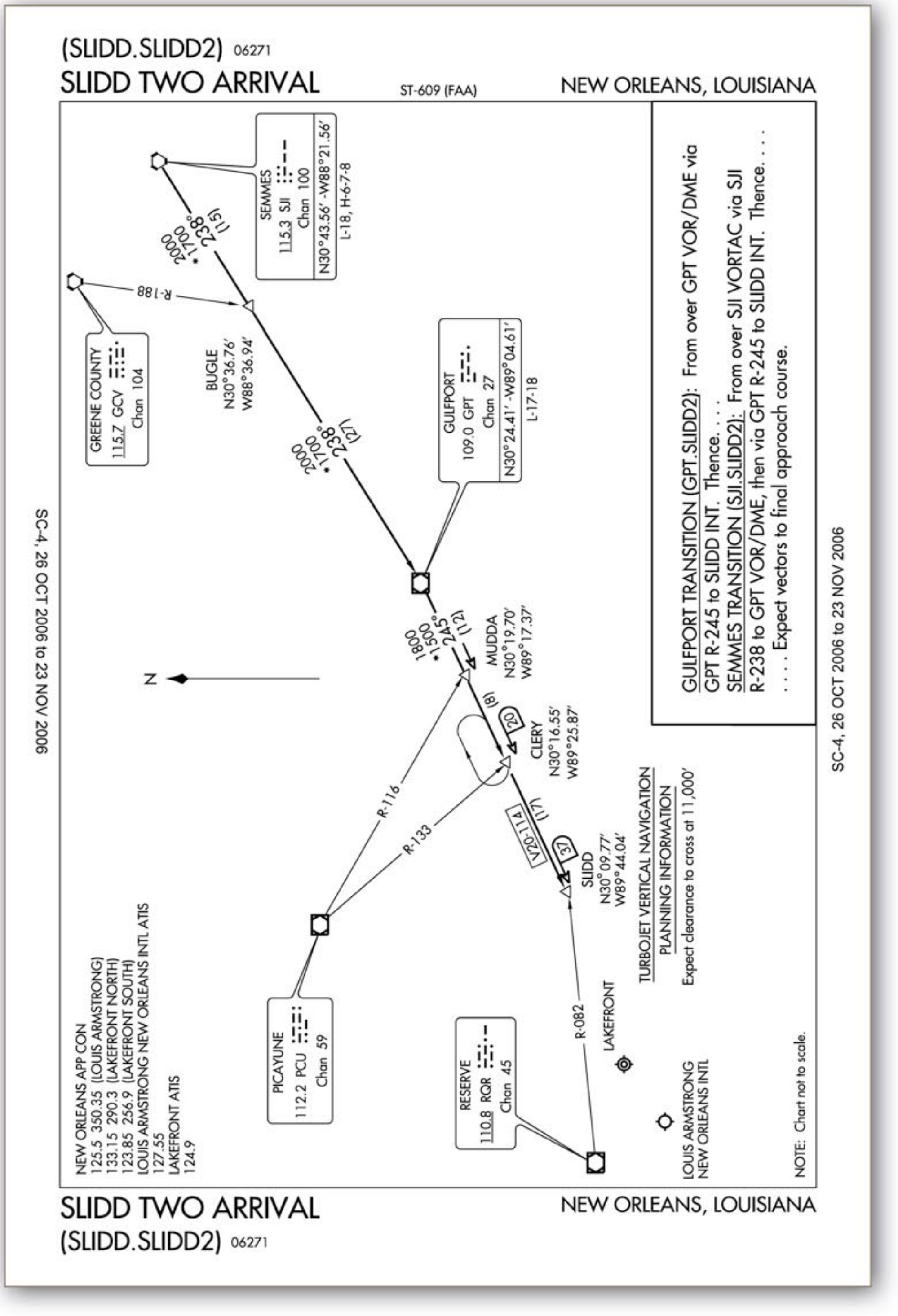
(SLIDD.SLIDD2) 06271
SLIDD TWO ARRIVAL
ST-609 (FAA)
NEW ORLEANS, LOUISIANA
SEMMES
115.3 SJI
Chan 100
N30°43.56′ -W88°21.56′
L-18, H-6-7-8
2000
*1700
238°
(15)
R-188
GREENE COUNTY
115.7 GCV
Chan 104
BUGLE
N30°36.76′
W88°36.94′
2000
*1700
238°
(27)
GULFPORT
109.0 GPT
Chan 27
N30°24.41′ -W89°04.61′
L-17-18
1800
*1500
245°
(12)
MUDDA
N30°19.70′
W89°17.37′
N
(8)
20
CLERY
N30°16.55′
W89°25.87′
R-116
R-133
V20-114
(17)
37
SLIDD
N30°09.77′
W89°44.04′
PICAYUNE
112.2 PCU
Chan 59
RESERVE
110.8 RQR
Chan 45
R-082
LAKEFRONT
LOUIS ARMSTRONG
NEW ORLEANS INTL
NEW ORLEANS APP CON
125.5 350.35 (LOUIS ARMSTRONG)
133.15 290.3 (LAKEFRONT NORTH)
123.85 256.9 (LAKEFRONT SOUTH)
LOUIS ARMSTRONG NEW ORLEANS INTL ATIS
127.55
LAKEFRONT ATIS
124.9
SC-4, 26 OCT 2006 to 23 NOV 2006
SC-4, 26 OCT 2006 to 23 NOV 2006
SLIDD TWO ARRIVAL
(SLIDD.SLIDD2) 06271
NEW ORLEANS, LOUISIANA

GULFPORT TRANSITION (GPT.SLIDD2): From over GPT VOR/DME via GPT R-245 to SLIDD INT. Thence. . . .

SEMMES TRANSITION (SJI.SLIDD2): From over SJI VORTAC via SJI R-238 to GPT VOR/DME, then via GPT R-245 to SLIDD INT. Thence. . . .

. . . . Expect vectors to final approach course.

TURBOJET VERTICAL NAVIGATION PLANNING INFORMATION

Expect clearance to cross at 11,000′

NOTE: Chart not to scale.

Figure 10-3. *Standard Terminal Arrival Route (STAR).*

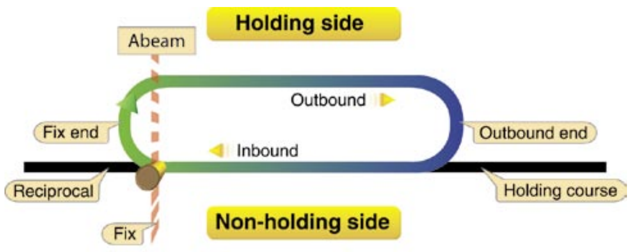

Standard pattern: Right turns (illustrated)
Non-standard pattern: Left turns

Figure 10-4. *Standard Holding Pattern—No Wind.*

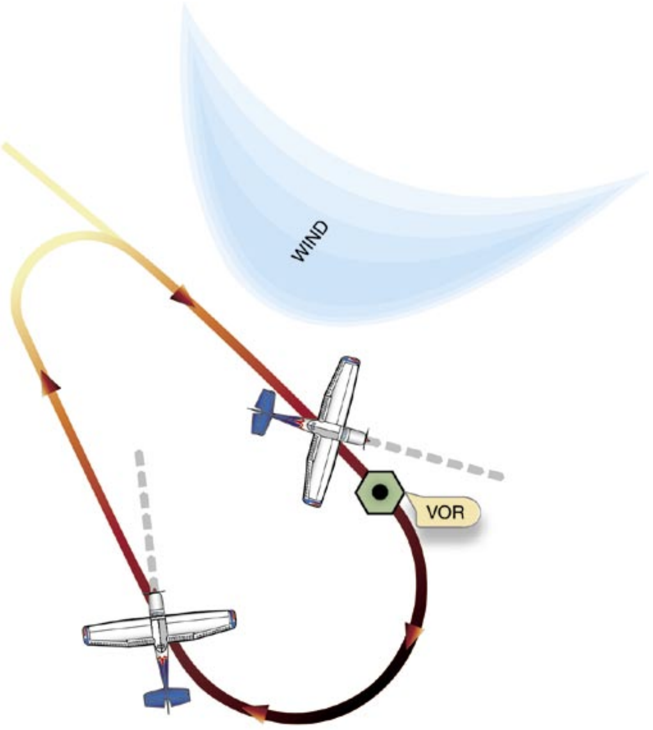

Figure 10-5. *Drift Correction in Holding Pattern.*

estimated arrival at the fix. Where a holding pattern is not charted, the ATC clearance will specify the following:

1. Direction of holding from the fix in terms of the eight cardinal compass points (N, NE, E, SE, etc.)
2. Holding fix (the fix may be omitted if included at the beginning of the transmission as the clearance limit)
3. Radial, course, bearing, airway, or route on which the aircraft is to hold.
4. Leg length in miles if DME or area navigation (RNAV) is to be used (leg length will be specified in minutes on pilot request or if the controller considers it necessary).
5. Direction of turn, if left turns are to be made, because the pilot requests or the controller considers it necessary.
6. Time to expect-further-clearance (EFC) and any pertinent additional delay information.

ATC instructions will also be issued whenever:

1. It is determined that a delay will exceed 1 hour.
2. A revised EFC is necessary.
3. In a terminal area having a number of navigation aids and approach procedures, a clearance limit may not indicate clearly which approach procedures will be used. On initial contact, or as soon as possible thereafter, approach control will advise the pilot of the type of approach to expect.
4. Ceiling and/or visibility is reported as being at or below the highest "circling minimums" established for the airport concerned. ATC will transmit a report of current weather conditions and subsequent changes, as necessary.
5. An aircraft is holding while awaiting approach clearance, and the pilot advises ATC that reported weather conditions are below minimums applicable to the operation. In this event, ATC will issue suitable instructions to aircraft desiring either to continue holding while awaiting weather improvement or proceed to another airport.

Standard Entry Procedures

The entry procedures given in the AIM evolved from extensive experimentation under a wide range of operational conditions. The standardized procedures should be followed to ensure that an aircraft remains within the boundaries of the prescribed holding airspace.

When a speed reduction is required, start the reduction when 3 minutes or less from the holding fix. Cross the holding fix initially at or below the maximum holding airspeed (MHA). The purpose of the speed reduction is to prevent overshooting the holding airspace limits, especially at locations where adjacent holding patterns are close together.

All aircraft may hold at the following altitudes and maximum holding airspeeds:

Altitude Mean Sea Level (MSL)	*Airspeed (KIAS)*
Up to 6,000 feet	200
6,001 – 14,000 feet	230
14,001 feet and above	265

The following are exceptions to the maximum holding airspeeds:

1. Holding patterns from 6,001 to 14,000 feet may be restricted to a maximum airspeed of 210 knots indicated airspeed (KIAS). This nonstandard pattern is depicted by an icon.
2. Holding patterns may be restricted to a maximum airspeed of 175 KIAS. This nonstandard pattern is depicted by an icon. Holding patterns restricted to 175 KIAS are generally found on IAPs applicable to category A and B aircraft only.
3. Holding patterns at Air Force airfields only—310 KIAS maximum, unless otherwise depicted.
4. Holding patterns at Navy airfields only—230 KIAS maximum, unless otherwise depicted.
5. The pilot of an aircraft unable to comply with maximum airspeed restrictions should notify ATC.

While other entry procedures may enable the aircraft to enter the holding pattern and remain within protected airspace, the parallel, teardrop, and direct entries are the procedures for entry and holding recommended by the FAA. Additionally, paragraph 5-3-7 in the AIM should be reviewed. *[Figure 10-6]*

1. Parallel Procedure. When approaching the holding fix from anywhere in sector (a), fly to the fix. Afterwards, turn to a heading to parallel the holding course outbound. Fly outbound for 1 minute, turn in the direction of the holding pattern through more than 180°, and return to the holding fix or intercept the holding course inbound.
2. Teardrop Procedure. When approaching the holding fix from anywhere in sector (b), the teardrop entry procedure would be to fly to the fix, turn outbound to a heading for a 30° teardrop entry within the pattern (on the holding side) for a period of 1 minute, then turn in the direction of the holding pattern to intercept the inbound holding course.
3. Direct Entry Procedure. When approaching the holding fix from anywhere in sector (c), the direct entry procedure would be to fly directly to the fix and turn to follow the holding pattern.

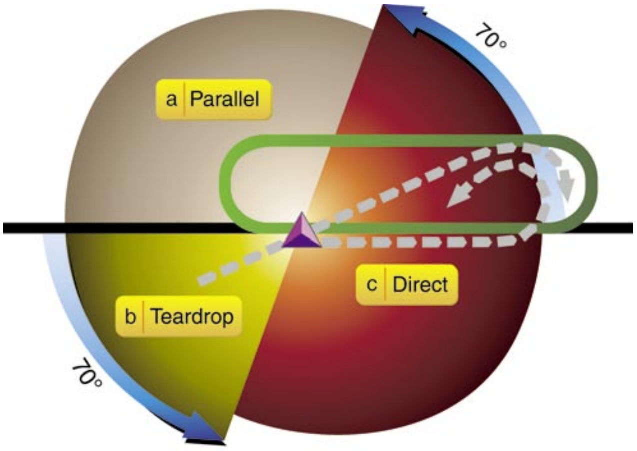

Figure 10-6. *Holding Pattern Entry Procedures.*

A pilot should make all turns during entry and while holding at:

1. 3° per second, or
2. 30° bank angle, or
3. A bank angle provided by a flight director system.

Time Factors

The holding pattern entry time reported to ATC is the initial time of arrival over the fix. Upon entering a holding pattern, the initial outbound leg is flown for 1 minute at or below 14,000 feet MSL, and for 1-1/2 minutes above 14,000 feet MSL. Timing for subsequent outbound legs should be adjusted as necessary to achieve proper inbound leg time. The pilot should begin outbound timing over or abeam the fix, whichever occurs later. If the abeam position cannot be determined, start timing when the turn to outbound is completed. *[Figure 10-7]*

Time leaving the holding fix must be known to ATC before succeeding aircraft can be cleared to the vacated airspace. Leave the holding fix:

1. When ATC issues either further clearance en route or approach clearance;
2. As prescribed in 14 CFR part 91 (for IFR operations; two-way radio communications failure, and responsibility and authority of the pilot-in-command); or
3. After the IFR flight plan has been cancelled, if the aircraft is holding in VFR conditions.

DME Holding

The same entry and holding procedures apply to DME holding, but distances (nautical miles) are used instead of time values. The length of the outbound leg will be specified by the controller, and the end of this leg is determined by the DME readout.

Approaches

Compliance With Published Standard Instrument Approach Procedures

Compliance with the approach procedures shown on the approach charts provides necessary navigation guidance information for alignment with the final approach courses,

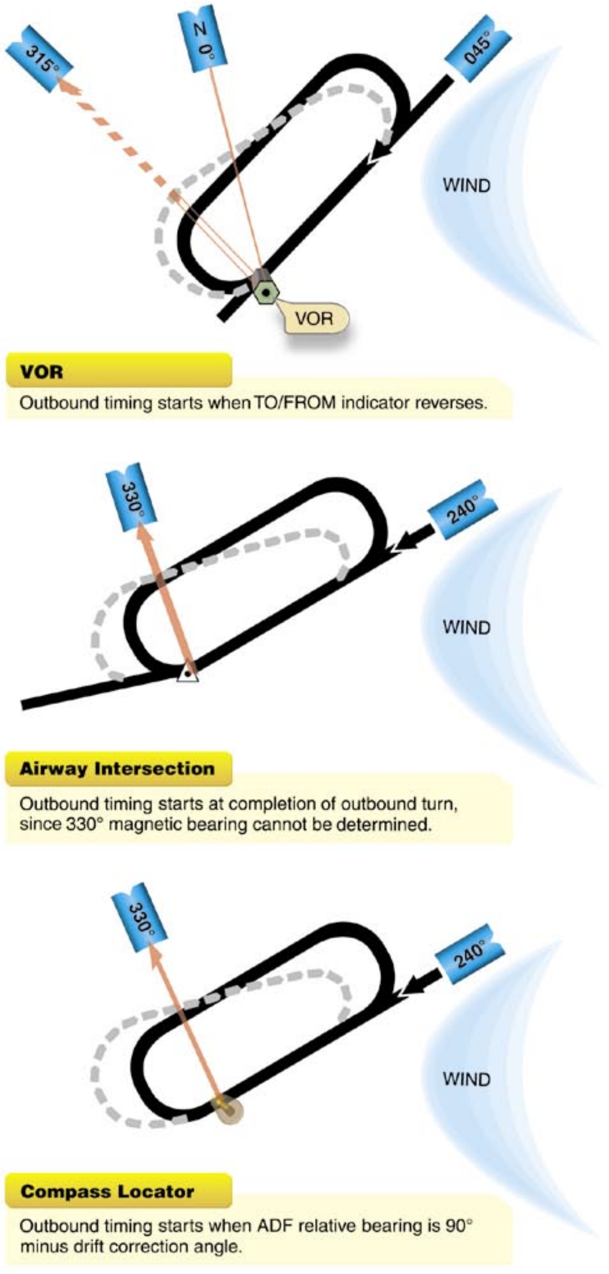

VOR

Outbound timing starts when TO/FROM indicator reverses.

Airway Intersection

Outbound timing starts at completion of outbound turn, since 330° magnetic bearing cannot be determined.

Compass Locator

Outbound timing starts when ADF relative bearing is 90° minus drift correction angle.

Figure 10-7. *Holding—Outbound Timing.*

as well as obstruction clearance. Under certain conditions, a course reversal maneuver or procedure turn may be necessary. However, this procedure is not authorized when:

1. The symbol "NoPT" appears on the approach course on the plan view of the approach chart.
2. Radar vectoring is provided to the final approach course.
3. A holding pattern is published in lieu of a procedure turn.
4. Executing a timed approach from a holding fix.
5. Otherwise directed by ATC.

Instrument Approaches to Civil Airports

Unless otherwise authorized, when an instrument letdown to an airport is necessary, the pilot should use a standard IAP prescribed for that airport. IAPs are depicted on IAP charts and are found in the TPP.

ATC approach procedures depend upon the facilities available at the terminal area, the type of instrument approach executed, and the existing weather conditions. The ATC facilities, navigation aids (NAVAIDs), and associated frequencies appropriate to each standard instrument approach are given on the approach chart. Individual charts are published for standard approach procedures associated with the following types of facilities:

1. Nondirectional beacon (NDB)
2. Very-high frequency omnirange (VOR)
3. Very-high frequency omnirange with distance measuring equipment (VORTAC or VOR/DME)
4. Localizer (LOC)
5. Instrument landing system (ILS)
6. Localizer-type directional aid (LDA)
7. Simplified directional facility (SDF)
8. Area navigation (RNAV)
9. Global positioning system (GPS)

An IAP can be flown in one of two ways: as a full approach or with the assistance of radar vectors. When the IAP is flown as a full approach, pilots conduct their own navigation using the routes and altitudes depicted on the instrument approach chart. A full approach allows the pilot to transition from the en route phase, to the instrument approach, and then to a landing with minimal assistance from ATC. This type of procedure may be requested by the pilot but is most often used in areas without radar coverage. A full approach also provides the pilot with a means of completing an instrument approach in the event of a communications failure.

When an approach is flown with the assistance of radar vectors, ATC provides guidance in the form of headings and altitudes which position the aircraft to intercept the final approach. From this point, the pilot resumes navigation, intercepts the final approach course, and completes the approach using the IAP chart. This is often a more expedient method of flying the approach, as opposed to the full approach, and allows ATC to sequence arriving traffic. A pilot operating in radar contact can generally expect the assistance of radar vectors to the final approach course.

Approach to Airport Without an Operating Control Tower

Figure 10-8 shows an approach procedure at an airport without an operating control tower. When approaching such a facility, the pilot should monitor the AWOS/ASOS if available for the latest weather conditions. When direct communication between the pilot and controller is no longer required, the ARTCC or approach controller will issue a clearance for an instrument approach and advise "change to advisory frequency approved." When the aircraft arrives on a "cruise" clearance, ATC will not issue further clearance for approach and landing.

If an approach clearance is required, ATC will authorize the pilot to execute his or her choice of standard instrument approach (if more than one is published for the airport) with the phrase "Cleared for the approach" and the communications frequency change required, if any. From this point on, there will be no contact with ATC. The pilot is responsible for closing the IFR flight plan before landing, if in VFR conditions, or by telephone after landing.

Unless otherwise authorized by ATC, a pilot is expected to execute the complete IAP shown on the chart.

Approach to Airport With an Operating Tower, With No Approach Control

When an aircraft approaches an airport with an operating control tower, but no approach control, ATC will issue a clearance to an approach/outer fix with the appropriate information and instructions as follows:

1. Name of the fix
2. Altitude to be maintained
3. Holding information and expected approach clearance time, if appropriate
4. Instructions regarding further communications, including:
    a) facility to be contacted
    b) time and place of contact
    c) frequency/ies to be used

If ATIS is available, a pilot should monitor that frequency for information such as ceiling, visibility, wind direction and velocity, altimeter setting, instrument approach, and runways in use prior to initial radio contact with the tower. If ATIS is not available, ATC will provide weather information from the nearest reporting station.

Approach to an Airport With an Operating Tower, With an Approach Control

Where radar is approved for approach control service, it is used to provide vectors in conjunction with published IAPs. Radar vectors can provide course guidance and expedite traffic to the final approach course of any established IAP. *Figure 10-9* shows an IAP chart with maximum ATC facilities available.

Approach control facilities that provide this radar service operate in the following manner:

1. Arriving aircraft are either cleared to an outer fix most appropriate to the route being flown with vertical separation and, if required, given holding information; or,
2. When radar hand-offs are effected between ARTCC and approach control, or between two approach control facilities, aircraft are cleared to the airport, or to a fix so located that the hand-off will be completed prior to the time the aircraft reaches the fix.
    a) When the radar hand-offs are utilized, successive arriving flights may be handed off to approach control with radar separation in lieu of vertical separation.
    b) After hand-off to approach control, an aircraft is vectored to the appropriate final approach course.
3. Radar vectors and altitude/flight levels are issued as required for spacing and separating aircraft; do not deviate from the headings issued by approach control.
4. Aircraft are normally informed when it becomes necessary to be vectored across the final approach course for spacing or other reasons. If approach course crossing is imminent and the pilot has not been informed that the aircraft will be vectored across the final approach course, the pilot should query the controller. The pilot is not expected to turn inbound on the final approach course unless an approach clearance has been issued. This clearance is normally issued with the final vector for interception of the final approach course, and the vector enables the pilot to establish the aircraft on the final approach course prior to reaching the final approach fix.
5. Once the aircraft is established inbound on the final approach course, radar separation is maintained with other aircraft, and the pilot is expected to complete the approach using the NAVAID designated in the clearance (ILS, VOR, NDB, GPS, etc.) as the primary means of navigation.

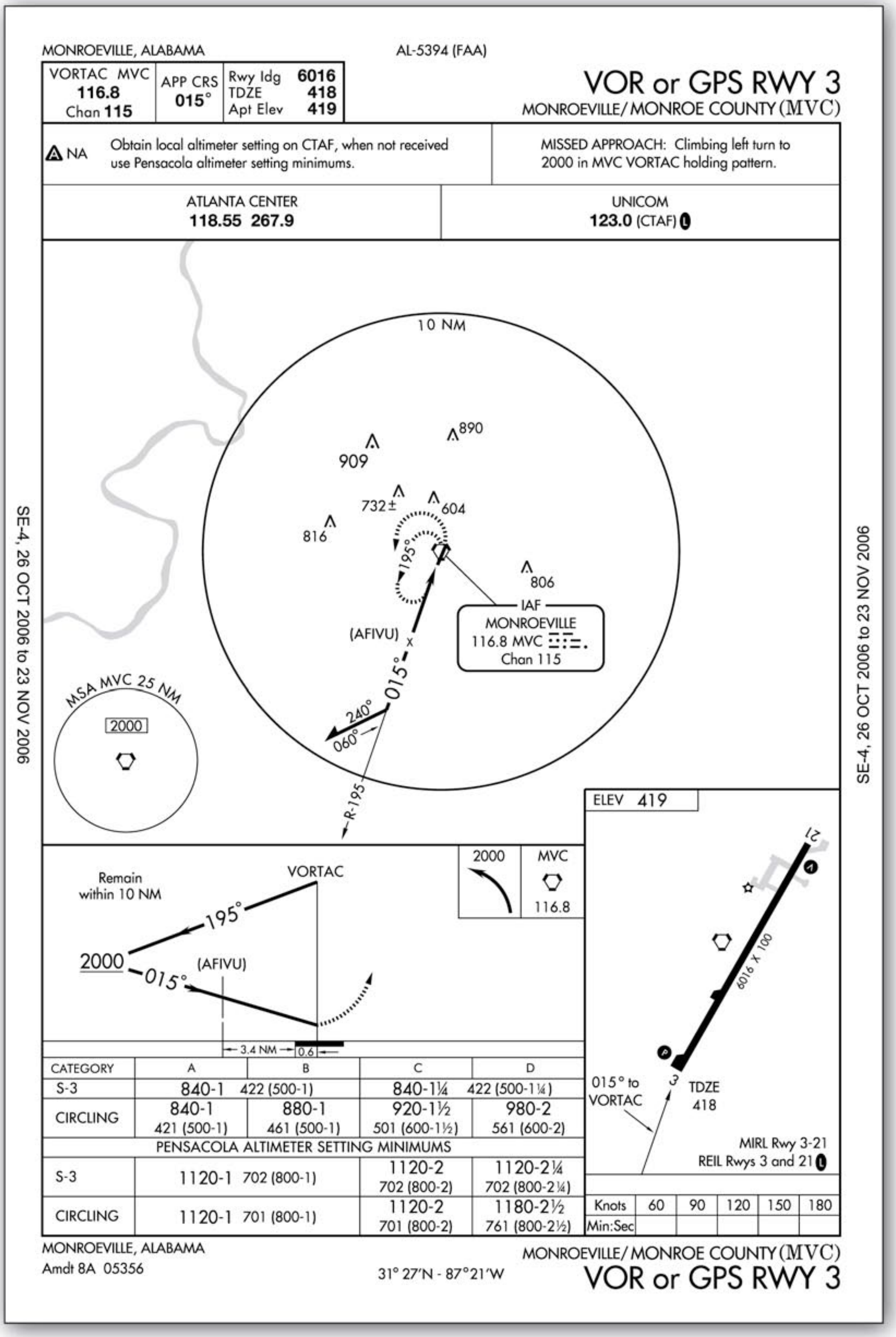
MONROEVILLE, ALABAMA
AL-5394 (FAA)
VORTAC MVC
116.8
Chan 115
APP CRS
015°
Rwy ldg 6016
TDZE 418
Apt Elev 419
VOR or GPS RWY 3
MONROEVILLE/ MONROE COUNTY (MVC)
NA
ATLANTA CENTER
118.55 267.9
UNICOM
123.0 (CTAF)
10 NM
890
909
732±
604
816
806
195°
IAF
MONROEVILLE
116.8 MVC
Chan 115
(AFIVU)
015°
240°
060°
R-195
MSA MVC 25 NM
2000
SE-4, 26 OCT 2006 to 23 NOV 2006
ELEV 419
21
6016 X 100
3
TDZE
418
015° to
VORTAC
MIRL Rwy 3-21
REIL Rwys 3 and 21
Remain
within 10 NM
VORTAC
195°
2000
015°
(AFIVU)
3.4 NM
0.6
2000
MVC
116.8
MONROEVILLE, ALABAMA
Amdt 8A 05356
31° 27′N - 87°21′W
MONROEVILLE/ MONROE COUNTY (MVC)
VOR or GPS RWY 3

Obtain local altimeter setting on CTAF, when not received use Pensacola altimeter setting minimums.

MISSED APPROACH: Climbing left turn to 2000 in MVC VORTAC holding pattern.

CATEGORY	A	B	C	D
S-3	840-1 422 (500-1)		840-1¼ 422 (500-1¼)	
CIRCLING	840-1 421 (500-1)	880-1 461 (500-1)	920-1½ 501 (600-1½)	980-2 561 (600-2)
PENSACOLA ALTIMETER SETTING MINIMUMS				
S-3	1120-1 702 (800-1)		1120-2 702 (800-2)	1120-2¼ 702 (800-2¼)
CIRCLING	1120-1 701 (800-1)		1120-2 701 (800-2)	1180-2½ 761 (800-2½)

Knots	60	90	120	150	180
Min:Sec					

Figure 10-8. *Monroeville, AL (MVC) VOR or GPS Rwy 3 Approach: An Approach Procedure at an Airport Without an Operating Control Tower.*

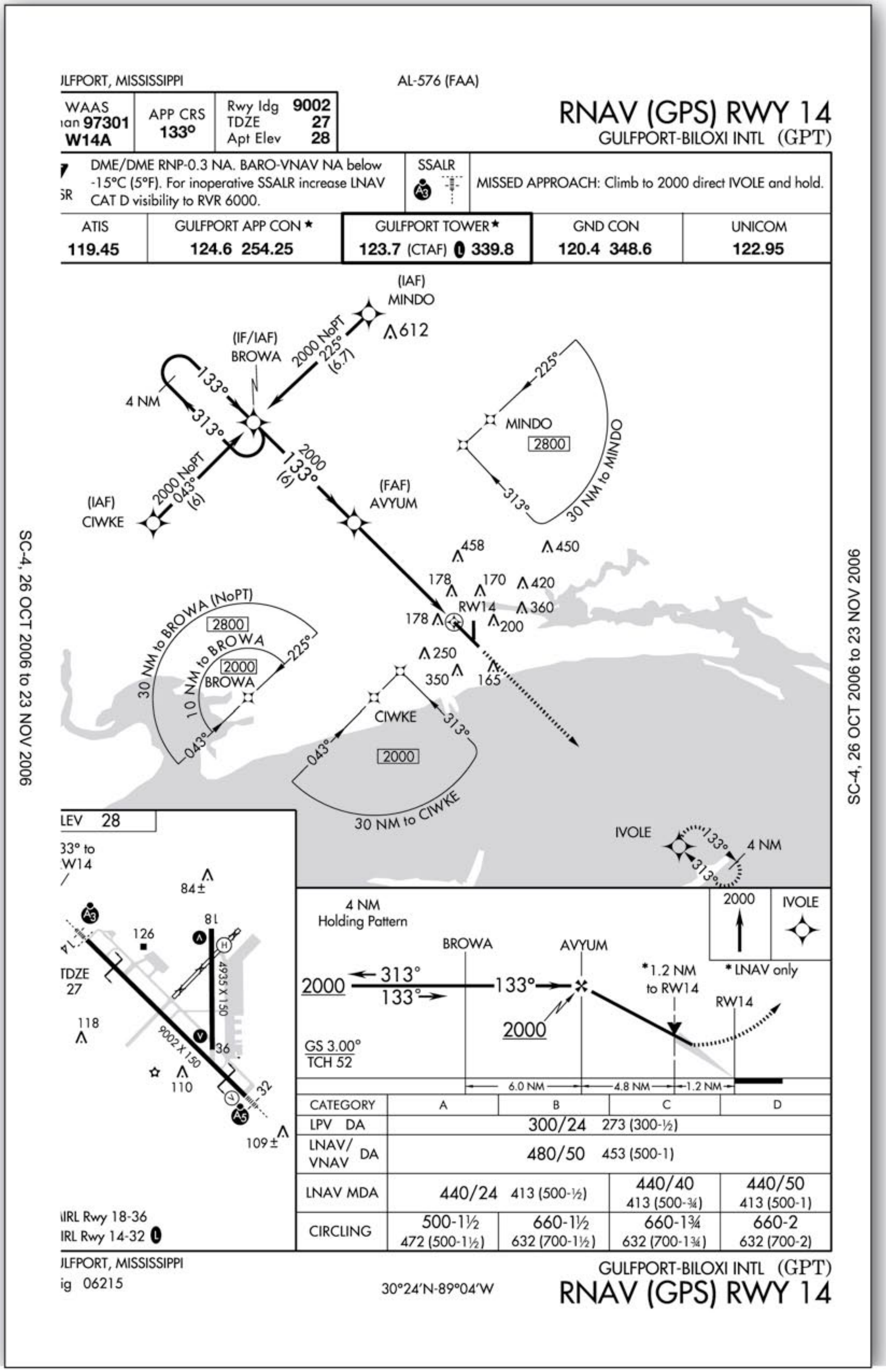
JLFPORT, MISSISSIPPI
AL-576 (FAA)
WAAS
ian 97301
W14A
APP CRS 133°
Rwy Idg 9002
TDZE 27
Apt Elev 28
RNAV (GPS) RWY 14
GULFPORT-BILOXI INTL (GPT)
DME/DME RNP-0.3 NA. BARO-VNAV NA below -15°C (5°F). For inoperative SSALR increase LNAV CAT D visibility to RVR 6000.
SSALR
MISSED APPROACH: Climb to 2000 direct IVOLE and hold.
ATIS 119.45
GULFPORT APP CON ★ 124.6 254.25
GULFPORT TOWER★ 123.7 (CTAF) 339.8
GND CON 120.4 348.6
UNICOM 122.95
(IAF) MINDO
612
(IF/IAF) BROWA
2000 NoPT 225° (6.7)
4 NM
133°
313°
2000 NoPT 043° (6)
(IAF) CIWKE
2000 133° (6)
(FAF) AVYUM
MINDO 2800
225°
313°
30 NM to MINDO
458
450
178
170
420
RW14
360
178
200
250
350
165
30 NM to BROWA (NoPT)
2800
10 NM to BROWA
2000
BROWA
225°
043°
CIWKE
313°
043°
2000
30 NM to CIWKE
IVOLE
133°
313°
4 NM
SC-4, 26 OCT 2006 to 23 NOV 2006
LEV 28
33° to W14
84±
126
18
4935 X 150
TDZE 27
118
9002 X 150
36
110
32
109±
IRL Rwy 18-36
IRL Rwy 14-32
4 NM Holding Pattern
BROWA
AVYUM
2000 ← 313°
133° →
133° →
2000
*1.2 NM to RW14
RW14
*LNAV only
2000
IVOLE
GS 3.00°
TCH 52
6.0 NM
4.8 NM
1.2 NM
CATEGORY A B C D
LPV DA 300/24 273 (300-½)
LNAV/VNAV DA 480/50 453 (500-1)
LNAV MDA 440/24 413 (500-½) 440/40 413 (500-¾) 440/50 413 (500-1)
CIRCLING 500-1½ 472 (500-1½) 660-1½ 632 (700-1½) 660-1¾ 632 (700-1¾) 660-2 632 (700-2)
JLFPORT, MISSISSIPPI
ig 06215
30°24′N-89°04′W
GULFPORT-BILOXI INTL (GPT)
RNAV (GPS) RWY 14

Figure 10-9. *Gulfport, MS (GPT) ILS or LOC Rwy 14 Approach: An Instrument Procedure Chart With Maximum ATC Facilities Available.*

6. After passing the final approach fix inbound, the pilot is expected to proceed direct to the airport and complete the approach, or to execute the published missed approach procedure.
7. Radar service is automatically terminated when the landing is completed or when the pilot is instructed to change to advisory frequency at uncontrolled airports, whichever occurs first.

Radar Approaches

With a radar approach, the pilot receives course and altitude guidance from a controller who monitors the progress of the flight with radar. This is an option should the pilot experience an emergency or distress situation.

The only airborne radio equipment required for radar approaches is a functioning radio transmitter and receiver. The radar controller vectors the aircraft to align it with the runway centerline. The controller continues the vectors to keep the aircraft on course until the pilot can complete the approach and landing by visual reference to the surface. There are two types of radar approaches: Precision (PAR) and Surveillance (ASR).

A radar approach may be given to any aircraft upon request and may be offered to pilots of aircraft in distress or to expedite traffic; however, an ASR might not be approved unless there is an ATC operational requirement, or in an unusual or emergency situation. Acceptance of a PAR or ASR by a pilot does not waive the prescribed weather minimums for the airport or for the particular aircraft operator concerned. The decision to make a radar approach when the reported weather is below the established minimums rests with the pilot.

PAR and ASR minimums are published on separate pages in the FAA Terminal Procedures Publication (TPP). *Figure 10-10*.

Precision Approach (PAR) is one in which a controller provides highly accurate navigational guidance in azimuth and elevation to a pilot.

The controller gives the pilot headings to fly that direct the aircraft to, and keep the aircraft aligned with, the extended centerline of the landing runway. The pilot is told to anticipate glide path interception approximately 10 to 30 seconds before it occurs and when to start descent. The published decision height (DH) will be given only if the pilot requests it. If the aircraft is observed to deviate above or below the glide path, the pilot is given the relative amount of deviation by use of terms "slightly" or "well" and is expected to adjust the aircraft's rate of descent/ascent to return to the glide path. Trend information is also issued with respect to the elevation of the aircraft and may be modified by the terms "rapidly" and "slowly"; e.g., "well above glide path, coming down rapidly."

Range from touchdown is given at least once each mile. If an aircraft is observed by the controller to proceed outside of specified safety zone limits in azimuth and/or elevation and continue to operate outside these prescribed limits, the pilot will be directed to execute a missed approach or to fly a

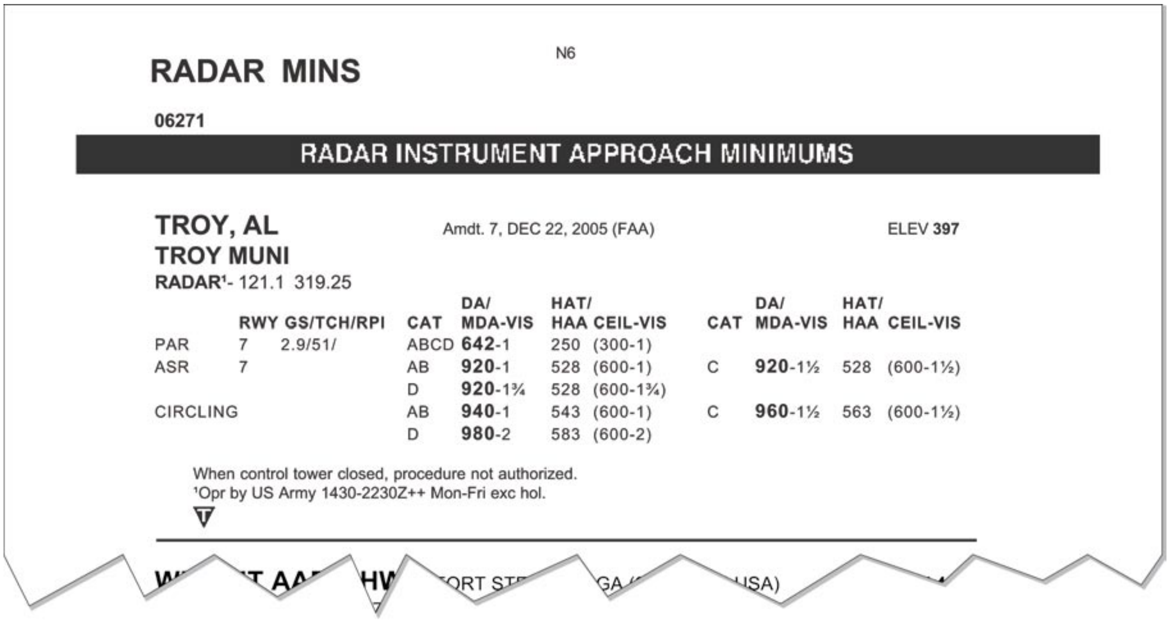

RADAR MINS N6

06271

RADAR INSTRUMENT APPROACH MINIMUMS

TROY, AL Amdt. 7, DEC 22, 2005 (FAA) ELEV **397**

TROY MUNI

RADAR[1]- 121.1 319.25

	RWY	GS/TCH/RPI	CAT	DA/ MDA-VIS	HAT/ HAA	CEIL-VIS	CAT	DA/ MDA-VIS	HAT/ HAA	CEIL-VIS
PAR	7	2.9/51/	ABCD	**642**-1	250	(300-1)				
ASR	7		AB	**920**-1	528	(600-1)	C	**920**-1½	528	(600-1½)
			D	**920**-1¾	528	(600-1¾)				
CIRCLING			AB	**940**-1	543	(600-1)	C	**960**-1½	563	(600-1½)
			D	**980**-2	583	(600-2)				

When control tower closed, procedure not authorized.
[1] Opr by US Army 1430-2230Z++ Mon-Fri exc hol.

Figure 10-10. *Radar Instrument Approach Minimums for Troy, AL.*

specified course unless the pilot has the runway environment (runway, approach lights, etc.) in sight. Navigational guidance in azimuth and elevation is provided to the pilot until the aircraft reaches the published DH. Advisory course and glide path information is furnished by the controller until the aircraft passes over the landing threshold. At this point the pilot is advised of any deviation from the runway centerline. Radar service is automatically terminated upon completion of the approach.

Surveillance Approach (ASR) is one in which a controller provides navigational guidance in azimuth only.

The controller furnishes the pilot with headings to fly to align the aircraft with the extended centerline of the landing runway. Since the radar information used for a surveillance approach is considerably less precise than that used for a precision approach, the accuracy of the approach will not be as great and higher minimums will apply. Guidance in elevation is not possible but the pilot will be advised when to commence descent to the Minimum Descent Altitude (MDA) or, if appropriate, to an intermediate step-down fix Minimum Crossing Altitude and subsequently to the prescribed MDA. In addition, the pilot will be advised of the location of the Missed Approach Point (MAP) prescribed for the procedure and the aircraft's position each mile on final from the runway, airport or heliport or MAP, as appropriate.

If requested by the pilot, recommended altitudes will be issued at each mile, based on the descent gradient established for the procedure, down to the last mile that is at or above the MDA. Normally, navigational guidance will be provided until the aircraft reaches the MAP.

Radar service is automatically terminated at the completion of a radar approach.

No-Gyro Approach is available to a pilot under radar control who experiences circumstances wherein the directional gyro or other stabilized compass is inoperative or inaccurate. When this occurs, the pilot should so advise ATC and request a no-gyro vector or approach. The pilot of an aircraft not equipped with a directional gyro or other stabilized compass who desires radar handling may also request a no-gyro vector or approach. The pilot should make all turns at standard rate and should execute the turn immediately upon receipt of instructions. For example, "TURN RIGHT," "STOP TURN." When a surveillance or precision approach is made, the pilot will be advised after the aircraft has been turned onto final approach to make turns at half standard rate.

Radar Monitoring of Instrument Approaches

PAR facilities operated by the FAA and the military services at some joint-use (civil and military) and military installations monitor aircraft on instrument approaches and issue radar advisories to the pilot when weather is below VFR minimums (1,000 and 3), at night, or when requested by a pilot. This service is provided only when the PAR Final Approach Course coincides with the final approach of the navigational aid and only during the operational hours of the PAR. The radar advisories serve only as a secondary aid since the pilot has selected the navigational aid as the primary aid for the approach.

Prior to starting final approach, the pilot will be advised of the frequency on which the advisories will be transmitted. If, for any reason, radar advisories cannot be furnished, the pilot will be so advised.

Advisory information, derived from radar observations, includes information on:

1. Passing the final approach fix inbound (nonprecision approach) or passing the outer marker or fix used in lieu of the outer marker inbound (precision approach).
2. Trend advisories with respect to elevation and/or azimuth radar position and movement will be provided.
3. If, after repeated advisories, the aircraft proceeds outside the PAR safety limit or if a radical deviation is observed, the pilot will be advised to execute a missed approach unless the prescribed visual reference with the surface is established.

Radar service is automatically terminated upon completion of the approach. *[Figure 10-11]*

Timed Approaches From a Holding Fix

Timed approaches from a holding fix are conducted when many aircraft are waiting for an approach clearance. Although the controller will not specifically state "timed approaches are in progress," the assigning of a time to depart the FAF inbound (nonprecision approach), or the outer marker or fix used in lieu of the outer marker inbound (precision approach), indicates that timed approach procedures are being utilized.

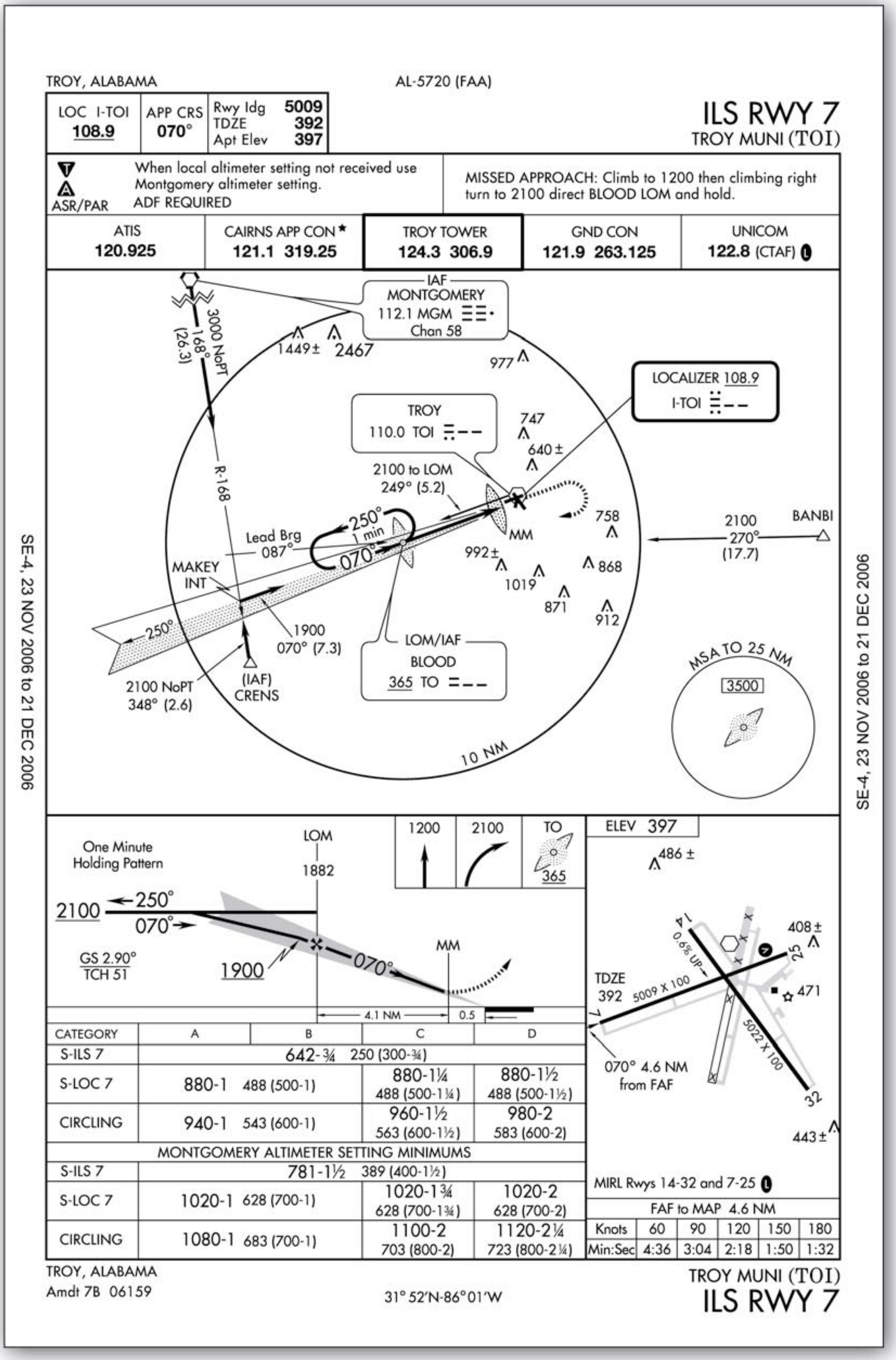

TROY, ALABAMA AL-5720 (FAA)

LOC I-TOI	APP CRS	Rwy ldg	5009
108.9	070°	TDZE	392
		Apt Elev	397

ILS RWY 7

TROY MUNI (TOI)

When local altimeter setting not received use Montgomery altimeter setting.
ADF REQUIRED
ASR/PAR

MISSED APPROACH: Climb to 1200 then climbing right turn to 2100 direct BLOOD LOM and hold.

ATIS	CAIRNS APP CON ★	TROY TOWER	GND CON	UNICOM
120.925	121.1 319.25	124.3 306.9	121.9 263.125	122.8 (CTAF) 🅛

IAF
MONTGOMERY
112.1 MGM
Chan 58
3000 NoPT
168°
(26.3)
1449±
2467
977
LOCALIZER 108.9
I-TOI
TROY
110.0 TOI
747
640±
2100 to LOM
249° (5.2)
R-168
758
2100
270°
(17.7)
BANBI
Lead Brg
087°
250°
1 min
070°
MM
992±
1019
868
MAKEY
INT
871
912
250°
1900
070° (7.3)
LOM/IAF
BLOOD
365 TO
2100 NoPT
348° (2.6)
(IAF)
CRENS
10 NM
MSA TO 25 NM
3500
SE-4, 23 NOV 2006 to 21 DEC 2006
One Minute
Holding Pattern
LOM
1882
2100
250°
070°
GS 2.90°
TCH 51
1900
070°
MM
4.1 NM
0.5
1200
2100
TO
365
ELEV 397
486±
408±
14
0.6% UP
25
471
TDZE
392
5009 X 100
7
5022 X 100
070° 4.6 NM
from FAF
32
443±

CATEGORY	A	B	C	D
S-ILS 7	642-¾ 250 (300-¾)			
S-LOC 7	880-1 488 (500-1)		880-1¼ 488 (500-1¼)	880-1½ 488 (500-1½)
CIRCLING	940-1 543 (600-1)		960-1½ 563 (600-1½)	980-2 583 (600-2)
MONTGOMERY ALTIMETER SETTING MINIMUMS				
S-ILS 7	781-1½ 389 (400-1½)			
S-LOC 7	1020-1 628 (700-1)		1020-1¾ 628 (700-1¾)	1020-2 628 (700-2)
CIRCLING	1080-1 683 (700-1)		1100-2 703 (800-2)	1120-2¼ 723 (800-2¼)

MIRL Rwys 14-32 and 7-25 🅛

FAF to MAP 4.6 NM

Knots	60	90	120	150	180
Min:Sec	4:36	3:04	2:18	1:50	1:32

TROY, ALABAMA
Amdt 7B 06159

31°52′N-86°01′W

TROY MUNI (TOI)
ILS RWY 7

Figure 10-11. *ILS RWY 7 Troy, AL.*

In lieu of holding, the controller may use radar vectors to the final approach course to establish a distance between aircraft that will ensure the appropriate time sequence between the FAF and outer marker, or fix used in lieu of the outer marker and the airport. Each pilot in the approach sequence will be given advance notice of the time they should leave the holding point on approach to the airport. When a time to leave the holding point is received, the pilot should adjust the flight path in order to leave the fix as closely as possible to the designated time.

Timed approaches may be conducted when the following conditions are met:

1. A control tower is in operation at the airport where the approaches are conducted.
2. Direct communications are maintained between the pilot and the Center or approach controller until the pilot is instructed to contact the tower.
3. If more than one missed approach procedure is available, none require a course reversal.
4. If only one missed approach procedure is available, the following conditions are met:
    a) Course reversal is not required; and
    b) Reported ceiling and visibility are equal to or greater than the highest prescribed circling minimums for the IAP.
5. When cleared for the approach, pilots should not execute a procedure turn.

Approaches to Parallel Runways

Procedures permit ILS instrument approach operations to dual or triple parallel runway configurations. A parallel approach is an ATC procedure that permits parallel ILS approach to airports with parallel runways separated by at least 2,500 feet between centerlines. Wherever parallel approaches are in progress, pilots are informed that approaches to both runways are in use.

Simultaneous approaches are permitted to runways:

1. With centerlines separated by 4,300 to 9,000 feet;
2. That are equipped with final monitor controllers;
3. That require radar monitoring to ensure separation between aircraft on the adjacent parallel approach course.

The approach procedure chart will include the note "simultaneous approaches authorized RWYS 14L and 14R," identifying the appropriate runways. When advised that simultaneous parallel approaches are in progress, pilots must advise approach control immediately of malfunctioning or inoperative components.

Parallel approach operations demand heightened pilot situational awareness. The close proximity of adjacent aircraft conducting simultaneous parallel approaches mandates strict compliance with all ATC clearances and approach procedures. Pilots should pay particular attention to the following approach chart information: name and number of the approach, localizer frequency, inbound course, glide slope intercept altitude, DA/DH, missed approach instructions, special notes/procedures, and the assigned runway location and proximity to adjacent runways. Pilots also need to exercise strict radio discipline, which includes continuous monitoring of communications and the avoidance of lengthy, unnecessary radio transmissions.

Side-Step Maneuver

ATC may authorize a side-step maneuver to either one of two parallel runways that are separated by 1,200 feet or less, followed by a straight-in landing on the adjacent runway. Aircraft executing a side-step maneuver will be cleared for a specified nonprecision approach and landing on the adjacent parallel runway. For example, "Cleared ILS runway 7 left approach, side-step to runway 7 right." The pilot is expected to commence the side-step maneuver as soon as possible after the runway or runway environment is in sight. Landing minimums to the adjacent runway will be based on nonprecision criteria and therefore higher than the precision minimums to the primary runway, but will normally be lower than the published circling minimums.

Circling Approaches

Landing minimums listed on the approach chart under "CIRCLING" apply when it is necessary to circle the airport, maneuver for landing, or when no straight-in minimums are specified on the approach chart. *[Figure 10-11]*

The circling minimums published on the instrument approach chart provide a minimum of 300 feet of obstacle clearance in the circling area. *[Figure 10-12]* During a circling approach, the pilot should maintain visual contact with the runway of intended landing and fly no lower than the circling minimums until positioned to make a final descent for a landing. It is important to remember that circling minimums are only minimums. If the ceiling allows it, fly at an altitude that more nearly approximates VFR traffic pattern altitude. This will make any maneuvering safer and bring the view of the landing runway into a more normal perspective.

Figure 10-13 shows patterns that can be used for circling approaches. Pattern "A" can be flown when the final approach

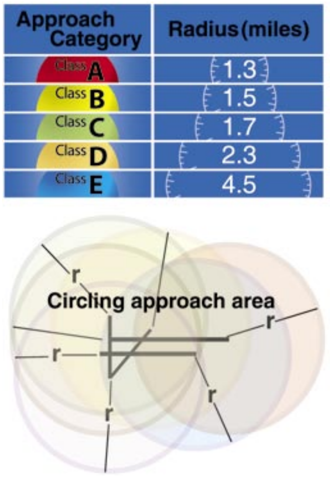

Approach Category	Radius (miles)
Class A	1.3
Class B	1.5
Class C	1.7
Class D	2.3
Class E	4.5

Defining size of areas, radii (r) vary with the approach category

Figure 10-12. *Circling Approach Area Radii.*

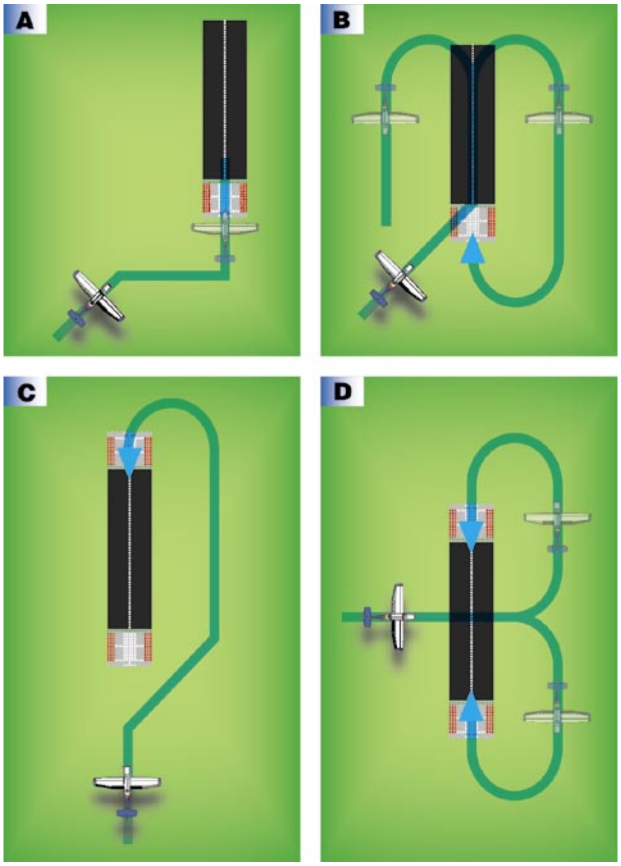

Figure 10-13. *Circling Approaches.*

course intersects the runway centerline at less than a 90° angle, and the runway is in sight early enough to establish a base leg. If the runway becomes visible too late to fly pattern "A," circle as shown in "B." Fly pattern "C" if it is desirable to land opposite the direction of the final approach, and the runway is sighted in time for a turn to downwind leg. If the runway is sighted too late for a turn to downwind, fly pattern "D." Regardless of the pattern flown, the pilot must maneuver the aircraft to remain within the designated circling area. Refer to section A ("Terms and Landing Minima Data") in the front of each TPP for a description of circling approach categories.

The criteria for determining the pattern to be flown are based on personal flying capabilities and knowledge of the performance characteristics of the aircraft. In each instance, the pilot must consider all factors: airport design, ceiling and visibility, wind direction and velocity, final approach course alignment, distance from the final approach fix to the runway, and ATC instructions.

IAP Minimums

Pilots may not operate an aircraft at any airport below the authorized MDA or continue an approach below the authorized DA/DH unless:

1. The aircraft is continuously in a position from which a descent to a landing on the intended runway can be made at a normal descent rate using normal maneuvers;
2. The flight visibility is not less than that prescribed for the approach procedure being used; and
3. At least one of the following visual references for the intended runway is visible and identifiable to the pilot:
    a) Approach light system
    b) Threshold
    c) Threshold markings
    d) Threshold lights
    e) Runway end identifier lights (REIL)
    f) Visual approach slope indicator (VASI)
    g) Touchdown zone or touchdown zone markings
    h) Touchdown zone lights
    i) Runway or runway markings
    j) Runway lights

Missed Approaches

A missed approach procedure is formulated for each published instrument approach and allows the pilot to return to the airway structure while remaining clear of obstacles. The procedure is shown on the approach chart in text and graphic form. Since the execution of a missed approach occurs when the flight deck workload is at a maximum, the procedure should be studied and mastered before beginning the approach.

When a missed approach procedure is initiated, a climb pitch attitude should be established while setting climb power. Configure the aircraft for climb, turn to the appropriate heading, advise ATC that a missed approach is being executed, and request further clearances.

If the missed approach is initiated prior to reaching the missed approach point (MAP), unless otherwise cleared by ATC, continue to fly the IAP as specified on the approach chart. Fly to the MAP at or above the MDA or DA/DH before beginning a turn.

If visual reference is lost while circling-to-land from an instrument approach, execute the appropriate missed approach procedure. Make the initial climbing turn toward the landing runway and then maneuver to intercept and fly the missed approach course.

Pilots should immediately execute the missed approach procedure:

1. Whenever the requirements for operating below DA/DH or MDA are not met when the aircraft is below MDA, or upon arrival at the MAP and at any time after that until touchdown;
2. Whenever an identifiable part of the airport is not visible to the pilot during a circling maneuver at or above MDA; or
3. When so directed by ATC.

Landing

According to 14 CFR part 91, no pilot may land when the flight visibility is less than the visibility prescribed in the standard IAP being used. ATC will provide the pilot with the current visibility reports appropriate to the runway in use. This may be in the form of prevailing visibility, runway visual value (RVV), or runway visual range (RVR). However, only the pilot can determine if the flight visibility meets the landing requirements indicated on the approach chart. If the flight visibility meets the minimum prescribed for the approach, then the approach may be continued to a landing. If the flight visibility is less than that prescribed for the approach, then the pilot must execute a missed approach, regardless of the reported visibility.

The landing minimums published on IAP charts are based on full operation of all components and visual aids associated with the instrument approach chart being used. Higher minimums are required with inoperative components or visual aids. For example, if the ALSF-1 approach lighting system were inoperative, the visibility minimums for an ILS would need to be increased by one-quarter mile. If more than one component is inoperative, each minimum is raised to the highest minimum required by any single component that is inoperative. ILS glide slope inoperative minimums are published on instrument approach charts as localizer minimums. Consult the "Inoperative Components or Visual Aids Table" (printed on the inside front cover of each TPP), for a complete description of the effect of inoperative components on approach minimums.

Instrument Weather Flying

Flying Experience

The more experience a pilot has in VFR and IFR flight, the more proficient a pilot becomes. VFR experience can be gained by flying in terminal areas with high traffic activity. This type of flying forces the pilot to polish the skill of dividing his or her attention between aircraft control, navigation, communications, and other flight deck duties. IFR experience can be gained through night flying which also promotes both instrument proficiency and confidence. The progression from flying at night under clear, moonlit conditions to flying at night without moonlight, natural horizon, or familiar landmarks teaches a pilot to trust the aircraft instruments with minimal dependence upon what can be seen outside the aircraft. It is a pilot's decision to proceed with an IFR flight or to wait for more acceptable weather conditions.

Recency of Experience

Currency as an instrument pilot is an equally important consideration. No person may act as pilot in command of an aircraft under IFR or in weather conditions less than VFR minimums unless he or she has met the requirements of part 91. Remember, these are minimum requirements.

Airborne Equipment and Ground Facilities

Regulations specify minimum equipment for filing an IFR flight plan. It is the pilot's responsibility to determine the adequacy of the aircraft and navigation/communication (NAV/COM) equipment for the proposed IFR flight. Performance limitations, accessories, and general condition of the equipment are directly related to the weather, route, altitude, and ground facilities pertinent to the flight, as well as to the flight deck workload.

Weather Conditions

In addition to the weather conditions that might affect a VFR flight, an IFR pilot must consider the effects of other weather phenomena (e.g., thunderstorms, turbulence, icing, and visibility).

Turbulence

Inflight turbulence can range from occasional light bumps to extreme airspeed and altitude variations that make aircraft control difficult. To reduce the risk factors associated with turbulence, pilots must learn methods of avoidance, as well as piloting techniques for dealing with an inadvertent encounter.

Turbulence avoidance begins with a thorough preflight weather briefing. Many reports and forecasts are available to assist the pilot in determining areas of potential turbulence. These include the Severe Weather Warning (WW), SIGMET (WS), Convective SIGMET (WST), AIRMET (WA), Severe Weather Outlook (AC), Center Weather Advisory (CWA), Area Forecast (FA), and Pilot Reports (UA or PIREPs). Since thunderstorms are always indicative of turbulence, areas of known and forecast thunderstorm activity will always be of interest to the pilot. In addition, clear air turbulence (CAT) associated with jet streams, strong winds over rough terrain, and fast moving cold fronts are good indicators of turbulence.

Pilots should be alert while in flight for the signposts of turbulence. For example, clouds with vertical development such as cumulus, towering cumulus, and cumulonimbus are indicators of atmospheric instability and possible turbulence. Standing lenticular clouds lack vertical development but indicate strong mountain wave turbulence. While en route, pilots can monitor hazardous inflight weather advisory service (HIWAS) broadcast for updated weather advisories, or contact the nearest AFSS or En Route Flight Advisory Service (EFAS) for the latest turbulence-related PIREPs.

To avoid turbulence associated with strong thunderstorms, circumnavigate cells by at least 20 miles. Turbulence may also be present in the clear air above a thunderstorm. To avoid this, fly at least 1,000 feet above the top for every 10 knots of wind at that level, or fly around the storm. Finally, do not underestimate the turbulence beneath a thunderstorm. Never attempt to fly under a thunderstorm. The possible results of turbulence and wind shear under the storm could be disastrous.

When moderate to severe turbulence is encountered, aircraft control is difficult, and a great deal of concentration is required to maintain an instrument scan. *[Figure 10-14]* Pilots should immediately reduce power and slow the aircraft to the recommended turbulence penetration speed as described in the POH/AFM. To minimize the load factor imposed on the aircraft, the wings should be kept level and the aircraft's pitch attitude should be held constant. The aircraft is allowed to fluctuate up and down, because maneuvering to maintain a constant altitude only increases the stress on the aircraft. If necessary, the pilot should advise ATC of the fluctuations and request a block altitude clearance. In addition, the power should remain constant at a setting that will maintain the recommended turbulence penetration airspeed.

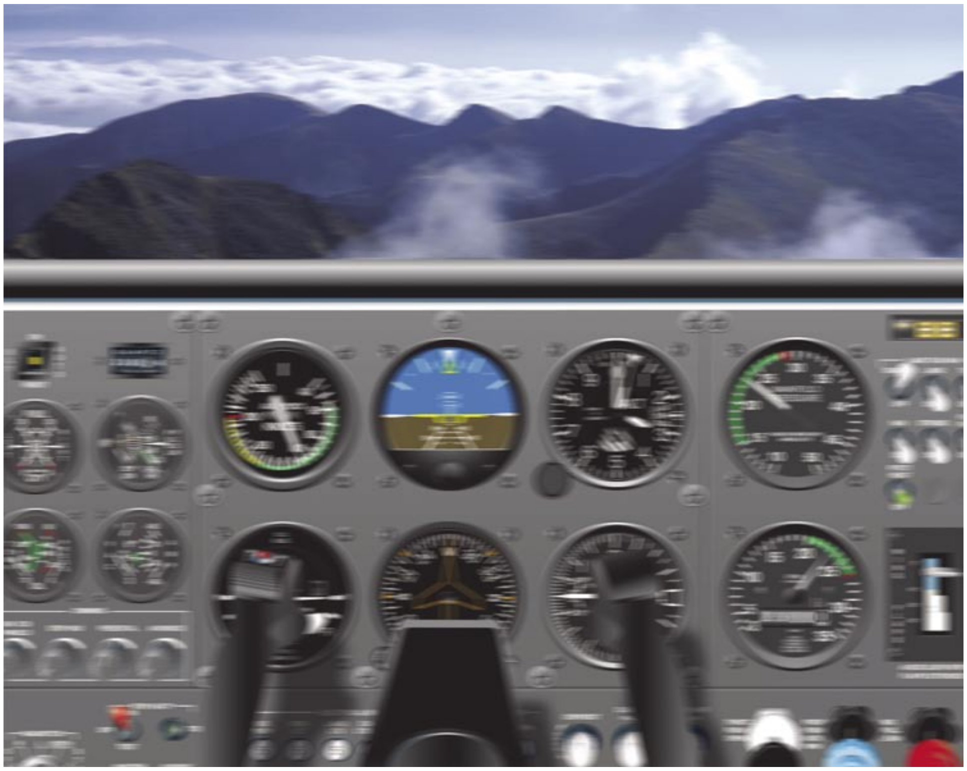

Figure 10-14. *Maintaining an instrument scan in severe turbulence can be difficult.*

The best source of information on the location and intensity of turbulence are PIREPs. Therefore, pilots are encouraged to familiarize themselves with the turbulence reporting criteria found in the AIM, which also describes the procedure for volunteering PIREPs relating to turbulence.

Structural Icing

The very nature of flight in Instrument Meteorological Conditions means operating in visible moisture such as clouds. At the right temperatures, this moisture can freeze on the aircraft, causing increased weight, degraded performance, and unpredictable aerodynamic characteristics. Understanding, avoidance, and early recognition followed by prompt action are the keys to avoiding this potentially hazardous situation.

Structural icing refers to the accumulation of ice on the exterior of the aircraft and is broken down into three classifications: rime ice, clear ice, and mixed ice. For ice to form, there must be moisture present in the air, and the air must be cooled to a temperature of 0° C (32° F) or less. Aerodynamic cooling can lower the surface temperature of an airfoil and cause ice to form on the airframe even though the ambient temperature is slightly above freezing.

Rime ice forms if the droplets are small and freeze immediately when contacting the aircraft surface. This type of ice usually forms on areas such as the leading edges of wings or struts. It has a somewhat rough-looking appearance and a milky-white color.

Clear ice is usually formed from larger water droplets or freezing rain that can spread over a surface. This is the most dangerous type of ice since it is clear, hard to see, and can change the shape of the airfoil.

Mixed ice is a mixture of clear ice and rime ice. It has the bad characteristics of both types and can form rapidly. Ice particles become embedded in clear ice, building a very rough accumulation. The table in *Figure 10-15* lists the temperatures at which the various types of ice will form.

Outside Air Temperature Range	Icing Type
0 °C to -10 °C	Clear
-10 °C to -15 °C	Mixed clear and rime
-15 °C to -20°C	Rime

Figure 10-15. *Temperature Ranges for Ice Formation.*

Structural icing is a condition that can only get worse. Therefore, during an inadvertent icing encounter, it is important the pilot act to prevent additional ice accumulation. Regardless of the level of anti-ice or deice protection offered by the aircraft, the first course of action should be to leave the area of visible moisture. This might mean descending to an altitude below the cloud bases, climbing to an altitude that is above the cloud tops, or turning to a different course. If this is not possible, then the pilot must move to an altitude where the temperature is above freezing. Pilots should report icing conditions to ATC and request new routing or altitude if icing will be a hazard. Refer to the AIM for information on reporting icing intensities.

Fog

Instrument pilots must learn to anticipate conditions leading to the formation of fog and take appropriate action early in the progress of the flight. Before a flight, close examination of current and forecast weather should alert the pilot to the possibility of fog formation. When fog is a consideration, pilots should plan adequate fuel reserves and alternate landing sites. En route, the pilot must stay alert for fog formation through weather updates from EFAS, ATIS, and ASOS/AWOS sites.

Two conditions will lead to the formation of fog. Either the air is cooled to saturation, or sufficient moisture is added to the air until saturation occurs. In either case, fog can form when the temperature/dewpoint spread is 5° or less. Pilots planning to arrive at their destination near dusk with decreasing temperatures should be particularly concerned about the possibility of fog formation.

Volcanic Ash

Volcanic eruptions create volcanic ash clouds containing an abrasive dust that poses a serious safety threat to flight operations. Adding to the danger is the fact that these ash clouds are not easily discernible from ordinary clouds when encountered at some distance from the volcanic eruption.

When an aircraft enters a volcanic ash cloud, dust particles and smoke may become evident in the cabin, often along with the odor of an electrical fire. Inside the volcanic ash cloud, the aircraft may also experience lightning and St. Elmo's fire on the windscreen. The abrasive nature of the volcanic ash can pit the windscreens, thus reducing or eliminating forward visibility. The pitot-static system may become clogged, causing instrument failure. Severe engine damage is probable in both piston and jet-powered aircraft.

Every effort must be made to avoid volcanic ash. Since volcanic ash clouds are carried by the wind, pilots should plan their flights to remain upwind of the ash-producing volcano. Visual detection and airborne radar are not considered a reliable means of avoiding volcanic ash clouds. Pilots witnessing volcanic eruptions or encountering volcanic ash should immediately pass this information along in the form of a pilot report. The National Weather Service monitors volcanic eruptions and estimates ash trajectories. This information is passed along to pilots in the form of SIGMETs.

As for many other hazards to flight, the best source of volcanic information comes from PIREPs. Pilots who witness a volcanic eruption or encounter volcanic ash in flight should immediately inform the nearest agency. Volcanic Ash Forecast Transport and Dispersion (VAFTAD) charts are also available; these depict volcanic ash cloud locations in the atmosphere following an eruption, and also forecast dispersion of the ash concentrations over 6- and 12-hour time intervals. See AC 00-45, Aviation Weather Services.

Thunderstorms

A thunderstorm packs just about every weather hazard known to aviation into one vicious bundle. Turbulence, hail, rain, snow, lightning, sustained updrafts and downdrafts, and icing conditions are all present in thunderstorms. Do not take off in the face of an approaching thunderstorm or fly an aircraft that is not equipped with thunderstorm detection in clouds or at night in areas of suspected thunderstorm activity. *[Figure 10-16]*

There is no useful correlation between the external visual appearance of thunderstorms and the severity or amount of turbulence or hail within them. All thunderstorms should be considered hazardous, and thunderstorms with tops above 35,000 feet should be considered extremely hazardous.

Figure 10-16. *A thunderstorm packs just about every weather hazard known to aviation into one vicious bundle.*

Weather radar, airborne or ground based, will normally reflect the areas of moderate to heavy precipitation (radar does not detect turbulence). The frequency and severity of turbulence generally increases with the radar reflectivity closely associated with the areas of highest liquid water content of the storm. A flight path through an area of strong or very strong radar echoes separated by 20 to 30 miles or less may not be considered free of severe turbulence.

The probability of lightning strikes occurring to aircraft is greatest when operating at altitudes where temperatures are between -5 ° C and +5 ° C. In addition, an aircraft flying in the clear air near a thunderstorm is also susceptible to lightning strikes. Thunderstorm avoidance is always the best policy.

Wind Shear

Wind shear can be defined as a change in wind speed and/or wind direction in a short distance. It can exist in a horizontal or vertical direction and occasionally in both. Wind shear can occur at all levels of the atmosphere but is of greatest concern during takeoffs and landings. It is typically associated with thunderstorms and low-level temperature inversions; however, the jet stream and weather fronts are also sources of wind shear.

As *Figure 10-17* illustrates, while an aircraft is on an instrument approach, a shear from a tailwind to a headwind causes the airspeed to increase and the nose to pitch up with a corresponding balloon above the glide path. A shear from a headwind to a tailwind has the opposite effect, and the aircraft will sink below the glide path.

A headwind shear followed by a tailwind/downdraft shear is particularly dangerous because the pilot has reduced power and lowered the nose in response to the headwind shear. This leaves the aircraft in a nose-low, power-low configuration when the tailwind shear occurs, which makes recovery more difficult, particularly near the ground. This type of wind shear scenario is likely while making an approach in the face of an oncoming thunderstorm. Pilots should be alert for indications of wind shear early in the approach phase and be ready to initiate a missed approach at the first indication. It may be impossible to recover from a wind shear encounter at low altitude.

To inform pilots of hazardous wind shear activity, some airports have installed a Low-Level Wind Shear Alert System (LLWAS) consisting of a centerfield wind indicator and several surrounding boundary-wind indicators. With

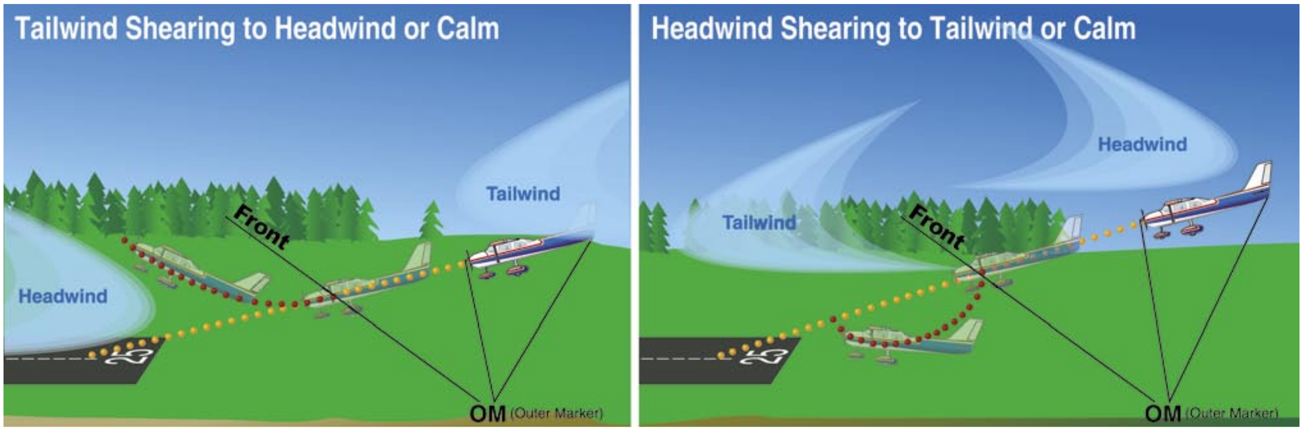

Figure 10-17. *Glide slope Deviations Due to Wind Shear Encounter.*

this system, controllers are alerted of wind discrepancies (an indicator of wind shear possibility) and provide this information to pilots. A typical wind shear alert issued to a pilot would be:

> "Runway 27 arrival, wind shear alert, 20 knot loss 3 mile final, threshold wind 200 at 15"

In plain language, the controller is advising aircraft arriving on runway 27 that at about 3 miles out they can expect a wind shear condition that will decrease their airspeed by 20 knots and possibly encounter turbulence. Additionally, the airport surface winds for landing runway 27 are reported as 200° at 15 knots.

Pilots encountering wind shear are encouraged to pass along pilot reports. Refer to AIM for additional information on wind shear PIREPs.

VFR-On-Top

Pilots on IFR flight plans operating in VFR weather conditions may request VFR-on-top in lieu of an assigned altitude. This permits them to select an altitude or flight level of their choice (subject to any ATC restrictions).

Pilots desiring to climb through a cloud, haze, smoke, or other meteorological formation and then either cancel their IFR flight plan or operate VFR-on-top may request a climb to VFR-on-top. The ATC authorization will contain a top report (or a statement that no top report is available) and a request to report upon reaching VFR-on-top. Additionally, the ATC authorization may contain a clearance limit, routing, and an alternative clearance if VFR-on-top is not reached by a specified altitude.

A pilot on an IFR flight plan, operating in VFR conditions, may request to climb/descend in VFR conditions. When operating in VFR conditions with an ATC authorization to "maintain VFR-on-top/maintain VFR conditions," pilots on IFR flight plans must:

1. Fly at the appropriate VFR altitude as prescribed in 14 CFR part 91.
2. Comply with the VFR visibility and distance-from-cloud criteria in 14 CFR part 91.
3. Comply with instrument flight rules applicable to this flight (minimum IFR altitudes, position reporting, radio communications, course to be flown, adherence to ATC clearance, etc.).

Pilots operating on a VFR-on-top clearance should advise ATC before any altitude change to ensure the exchange of accurate traffic information.

ATC authorization to "maintain VFR-on-top" is not intended to restrict pilots to operating only above an obscuring meteorological formation (layer). Rather, it permits operation above, below, between layers, or in areas where there is no meteorological obstruction. It is imperative pilots understand, however, that clearance to operate "VFR-on-top/VFR conditions" does not imply cancellation of the IFR flight plan.

Pilots operating VFR-on-top/VFR conditions may receive traffic information from ATC on other pertinent IFR or VFR aircraft. However, when operating in VFR weather conditions, it is the pilot's responsibility to be vigilant to see and avoid other aircraft.

This clearance must be requested by the pilot on an IFR flight plan. VFR-on-top is not permitted in certain areas, such as Class A airspace. Consequently, IFR flights operating VFR-on-top must avoid such airspace.

VFR Over-The-Top

VFR over-the-top must not be confused with VFR-on-top. VFR-on-top is an IFR clearance that allows the pilot to fly VFR altitudes. VFR over-the-top is strictly a VFR operation in which the pilot maintains VFR cloud clearance requirements while operating on top of an undercast layer. This situation might occur when the departure airport and the destination airport are reporting clear conditions, but a low overcast layer is present in between. The pilot could conduct a VFR departure, fly over the top of the undercast in VFR conditions, then complete a VFR descent and landing at the destination. VFR cloud clearance requirements would be maintained at all times, and an IFR clearance would not be required for any part of the flight.

Conducting an IFR Flight

To illustrate some of the concepts introduced in this chapter, follow along on a typical IFR flight from the Birmingham International Airport (BHM), Birmingham, Alabama to Gulfport-Biloxi International Airport (GPT), Gulfport, Mississippi. *[Figure 10-18]* For this trip, a Cessna 182 with a call sign of N1230A will be flown. The aircraft is equipped with dual navigation and communication radios, a transponder, and a GPS system approved for IFR en route, terminal, and approach operations.

Preflight

The success of the flight depends largely upon the thoroughness of the preflight planning. The evening before the flight, pay close attention to the weather forecast and begin planning the flight.

The Weather Channel indicates a large, low-pressure system has settled in over the Midwest, pulling moisture up from the Gulf of Mexico and causing low ceilings and visibility with little chance for improvement over the next couple of days. To begin planning, gather all the necessary charts and materials, and verify everything is current. This includes en route charts, approach charts, DPs, STAR charts, the GPS database, as well as an A/FD, some navigation logs, and the aircraft's POH/AFM. The charts cover both the departure and arrival airports and any contingency airports that will be needed if the flight cannot be completed as planned. This is also a good time for the pilot to consider recent flight experience, pilot proficiency, fitness, and personal weather minimums to fly this particular flight.

Check the A/FD to become familiar with the departure and arrival airport, and check for any preferred routing between BHM and GPT. Next, review the approach charts and any DP or STAR that pertains to the flight. Finally, review the en route charts for potential routing, paying close attention to the minimum en route and obstacle clearance altitudes.

After this review, select the best option. For this flight, the Birmingham Three Departure *[Figure 10-2]* to Brookwood VORTAC, V 209 to Kewanee VORTAC, direct to Gulfport using GPS would be a logical route. An altitude of 4,000 feet meets all the regulatory requirements and falls well within the performance capabilities of the aircraft.

Next, call 1-800-WX-BRIEF to obtain an outlook-type weather briefing for the proposed flight. This provides forecast conditions for departure and arrival airports, as well as the en route portion of the flight including forecast winds aloft. This also is a good opportunity to check the available NOTAMs.

The weather briefer confirms the predictions of the weather channel giving forecast conditions that are at or near minimum landing minimums at both BHM and GPT for the proposed departure time. The briefer provides NOTAM information for GPT indicating that the localizer to runway 32 is scheduled to be out of service and that runway 18/36 is closed until further notice. Also check for temporary flight restrictions (TFRs) along the proposed route.

After receiving a weather briefing, continue flight planning and begin to transfer some preliminary information onto the navigation log, listing each fix along the route and the distances, frequencies, and altitudes. Consolidating this information onto an organized navigation log will keep the workload to a minimum during the flight.

Next, obtain a standard weather briefing online for the proposed route. A check of current conditions indicates low IFR conditions at both the departure airport and the destination, with visibility of one-quarter mile:

SURFACE WEATHER OBSERVATIONS
METAR KBHM 111155Z VRB04KT ¼ SM FG –RA VV004 06/05 A2994 RMK A02 SLP140

METAR KGPT 111156Z 24003KT ¼ SM FG OVC001 08/07 A2962 RMK A02 SLP033

The small temperature/dewpoint spread is causing the low visibility and ceilings. Conditions should improve later in the day as temperatures increase. A check of the terminal forecast confirms this theory:

TERMINAL FORECASTS
TAF KBHM 111156Z 111212 VRB04KT ¼ SM FG VV004 TEMPO1316 ¾ SM OVC004

FM1600 VRB05KT 2SM BR OVC007 TEMPO 1720 3SM DZ BKN009

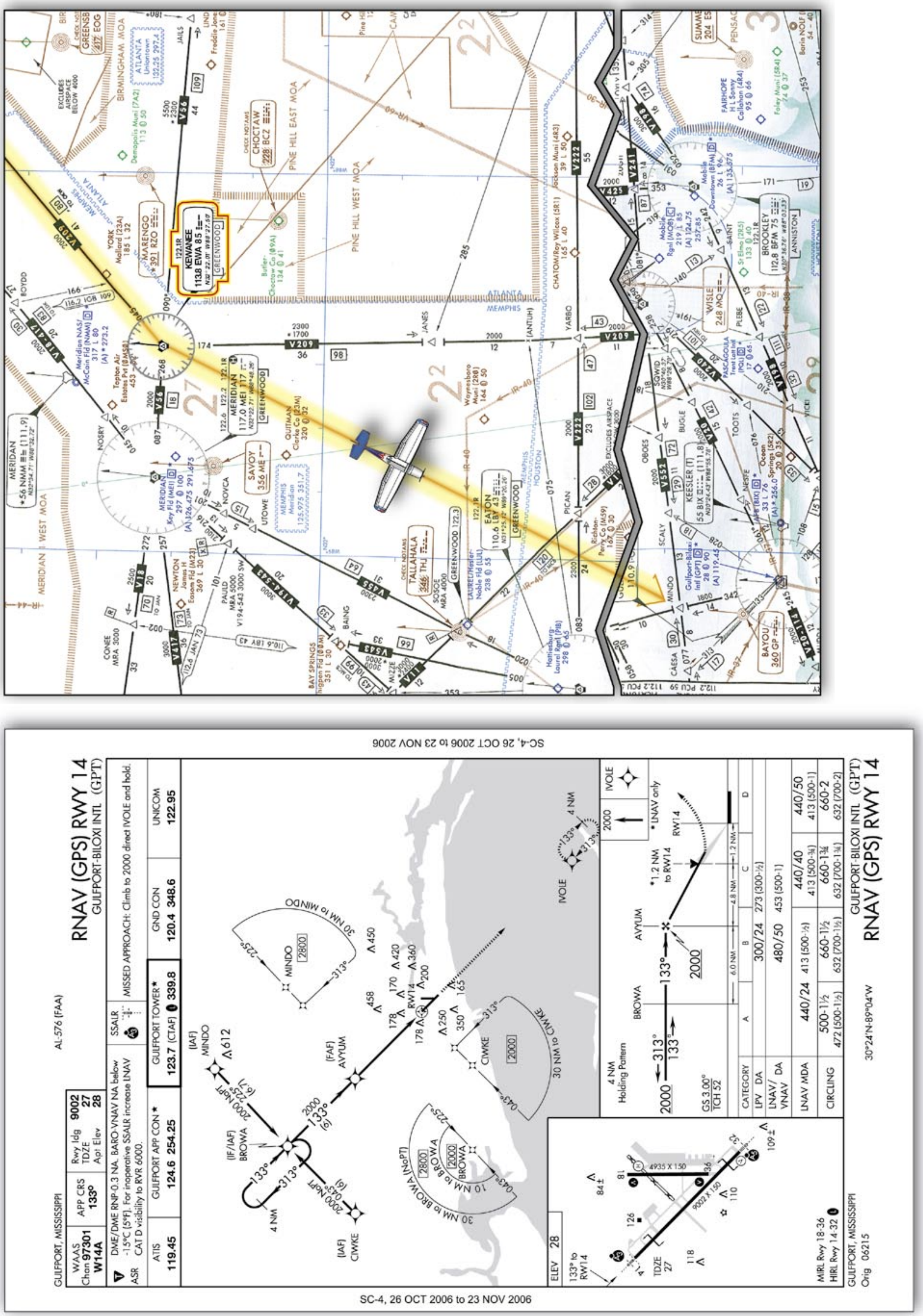
RNAV (GPS) RWY 14
GULFPORT-BILOXI INTL (GPT)
GULFPORT, MISSISSIPPI
AL-576 (FAA)
WAAS Chan 97301 W14A
APP CRS 133°
Rwy ldg 9002
TDZE 27
Apt Elev 28
MISSED APPROACH: Climb to 2000 direct IVOLE and hold.
ATIS 119.45
GULFPORT APP CON 124.6 254.25
GULFPORT TOWER 123.7 (CTAF) 339.8
GND CON 120.4 348.6
UNICOM 122.95
CIWKE
BROWA
AVYUM
MINDO
IVOLE
RW14
SC-4, 26 OCT 2006 to 23 NOV 2006
30°24'N-89°04'W
Orig 06215
MERIDIAN
KEWANEE
EATON
GREENWOOD
V209
V222
V56
V18
V11
V417
V194-543
V20-114
BROOKLEY
KEESLER
SAVOY
TALLAHALA
ATLANTA
MEMPHIS
HOUSTON
PINE HILL EAST MOA
PINE HILL WEST MOA
MERIDIAN 1 WEST MOA
BIRMINGHAM MOA

Figure 10-18. *Route Planning.*

FM2000 22008KT 3SM –RA OVC015 TEMP 2205 3SM –RA OVC025 FM0500 23013KT P6SM OVC025

FM0800 23013KT P6SM BKN030 PROB40 1012 2SM BR OVC030

TAF KGPT 111153Z 111212 24004KT ¼ SM FG OVC001 BECMG 1317 3SM BR 0VC004

FM1700 24010KT 4SM –RA OVC006 FM0400 24010 5SM SCT080 TEMPO 0612 P6SM SKC

In addition to the terminal forecast, the area forecast also indicates gradual improvement along the route. Since the terminal forecast only provides information for a 5-mile radius around a terminal area, checking the area forecast provides a better understanding of the overall weather picture along the route, as well as potential hazards:

SYNOPSIS AND VFR CLOUDS/WEATHER FORECASTS SYNOPSIS… AREA OF LOW PRESSURE CNTD OV AL RMNG GENLY STNRY BRNGNG MSTR AND WD SPRD IFR TO E TN. ALF…LOW PRES TROF ACRS CNTR PTN OF THE DFW FA WILL GDLY MOV EWD DURG PD.

NRN LA, AR, NRN MS
SWLY WND THRUT THE PD. 16Z CIG OVC006. SCT –SHRA. OTLK… IFR SRN ½ … CIG SCT – BKN015 TOPS TO FL250 SWLY WND THRUT THE PD. 17Z AGL BKN040. OTLK…MVFR CIG VIS.

LA MS CSTL WTRS
CIG OVC001 – OVC006. TOPS TO FL240. VIS ¼ - ¾ SM FG. SWLY WND. 16Z CIG OVC010 VIS 2 SM BR. OCNL VIS 3-5SM –RN BR OVC009. OTLK…MVFR CIG VIS.

FL
CIG BKN020 TOPS TO FL180. VIS 1–3 SM BR. SWLY WND. 18Z BRK030. OTLK…MVFR CIG.

At this time, there are no SIGMETs or PIREPs reported. However, there are several AIRMETs, one for IFR conditions, one for turbulence that covers the entire route, and another for icing conditions which covers an area just north of the route:

WAUS44 KKCI 111150

DFWS WA 0111150

AIRMET SIERRA FOR IFR VALID UNTIL 111800

AIRMET IFR...OK TX LA AR MS AL FL

TS IMPLY SEV OR GTR TURB SEV ICE LLWS AND IFR CONDS.

NON MSL HGHTS DENOTED BY AGL OR CIG.

A recheck of NOTAMs for Gulfport confirms that the localizer to runway 32 is out of service until further notice and runway 18/36 is closed. If runway 6 is planned for the departure, confirm that the climb restriction for the departure can be met.

GPT 12/006 GPT LOC OS UFN

GPT 12/008 GPT MIRL RWY 18/36 OS UFN

Since the weather is substantially better to the east, Pensacola Regional Airport is a good alternate with current conditions and a forecast of marginal VFR.

METAR KPNS 111150Z 21010Z 3SM BKN014 OVC025 09/03 A2973

TAF KPNS 111152Z 111212 22010KT 3 SM BR OVC020 BECMG 1317 4 SM BR OVC025

FM1700 23010KT 4SM –RA OVC030

FM 0400 25014KT 5SM OVC050 TEMPO1612 P6SM OVC080

If weather minimums are below a pilot's personal minimums, a delay in departure to wait for improved conditions is a good decision. This time can be used to complete the navigation log which is the next step in planning an IFR flight. *[Figure 10-19]*

Use the POH/AFM to compute a true airspeed, cruise power setting, and fuel burn based on the forecast temperatures aloft and cruising pressure altitude. Also, compute weight-and-balance information and determine takeoff and landing distances. There will be a crosswind if weather conditions require a straight-in landing on runway 14 at GPT. Therefore, compute the landing distance assuming a 10-knot crosswind and determine if the runway length is adequate to allow landing. Determine the estimated flight time and fuel burn using the winds aloft forecast and considering Pensacola Regional Airport as an alternate airport. With full tanks, the flight can be made nonstop with adequate fuel for flight to the destination, alternate, and the reserve requirement.

Next, check the surface analysis chart which shows where the pressure systems will be found. The weather depiction chart shows areas of IFR conditions and can be used to find areas

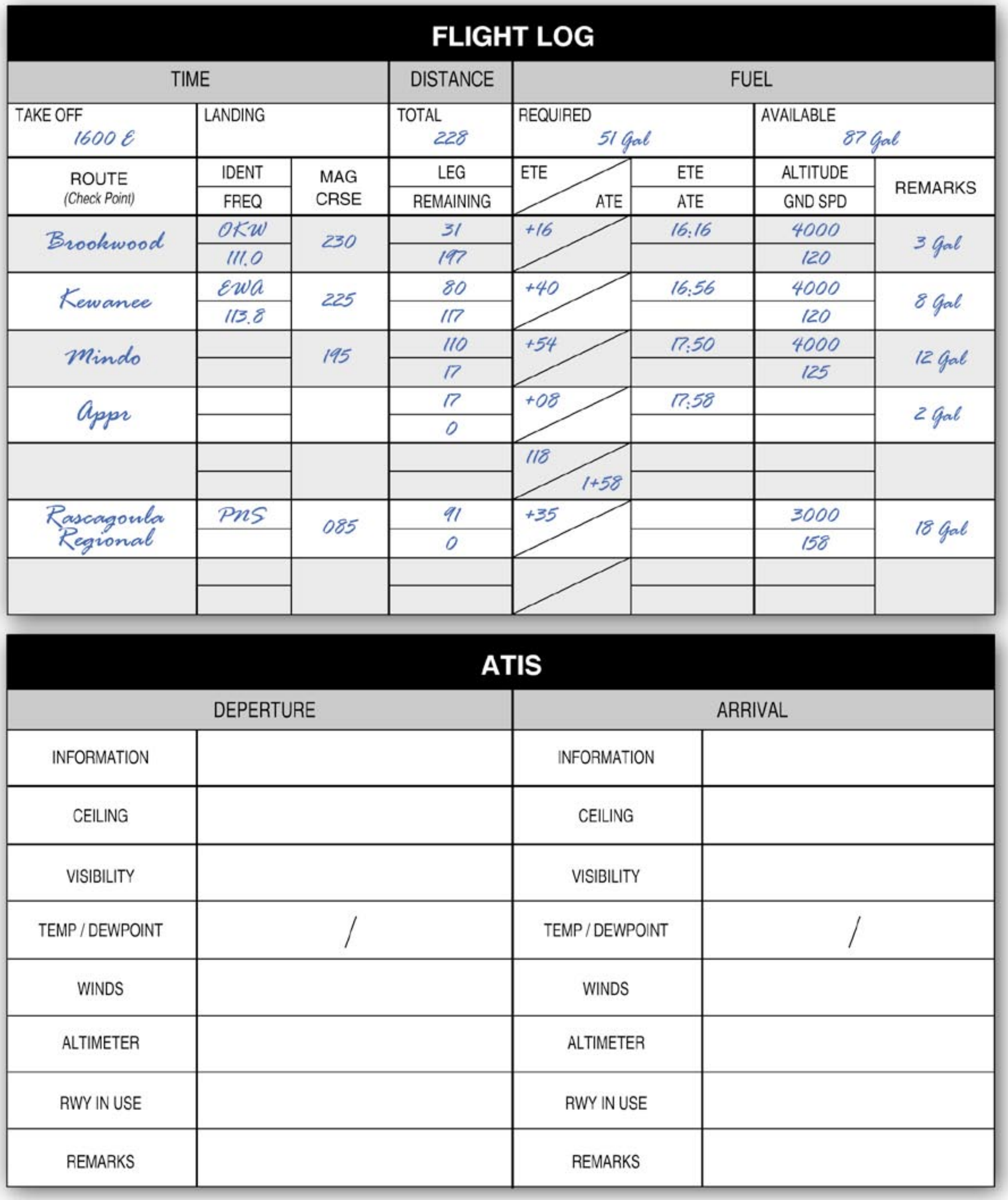

FLIGHT LOG

TIME		DISTANCE	FUEL	
TAKE OFF 1600 E	LANDING	TOTAL 228	REQUIRED 51 Gal	AVAILABLE 87 Gal

ROUTE (Check Point)	IDENT FREQ	MAG CRSE	LEG REMAINING	ETE ATE	ETE ATE	ALTITUDE GND SPD	REMARKS
Brookwood	OKW 111.0	230	31 197	+16	16:16	4000 120	3 Gal
Kewanee	EWA 113.8	225	80 117	+40	16:56	4000 120	8 Gal
Mindo		195	110 17	+54	17:50	4000 125	12 Gal
Appr			17 0	+08	17:58		2 Gal
				118 1+58			
Rascagoula Regional	PNS	085	91 0	+35		3000 158	18 Gal

ATIS

DEPERTURE		ARRIVAL	
INFORMATION		INFORMATION	
CEILING		CEILING	
VISIBILITY		VISIBILITY	
TEMP / DEWPOINT	/	TEMP / DEWPOINT	/
WINDS		WINDS	
ALTIMETER		ALTIMETER	
RWY IN USE		RWY IN USE	
REMARKS		REMARKS	

Figure 10-19. *Navigation Log.*

of improving conditions. These charts provide information a pilot will need should a diversion to VFR conditions be required. For this flight, the radar depicts precipitation along the route, and the latest satellite photo confirms what the weather depiction chart showed.

When the navigation log is finished, complete the flight plan in preparation for filing with flight service. *[Figure 10-20]*

Call an AFSS for an updated weather briefing, Birmingham INTL airport is now reporting 700 overcast with 3 miles visibility, and Gulfport-Biloxi is now 400 overcast with 2 miles visibility. The alternate, Pensacola Regional Airport, continues to report adequate weather conditions with 2,000 overcast and 3 miles visibility in light rain.

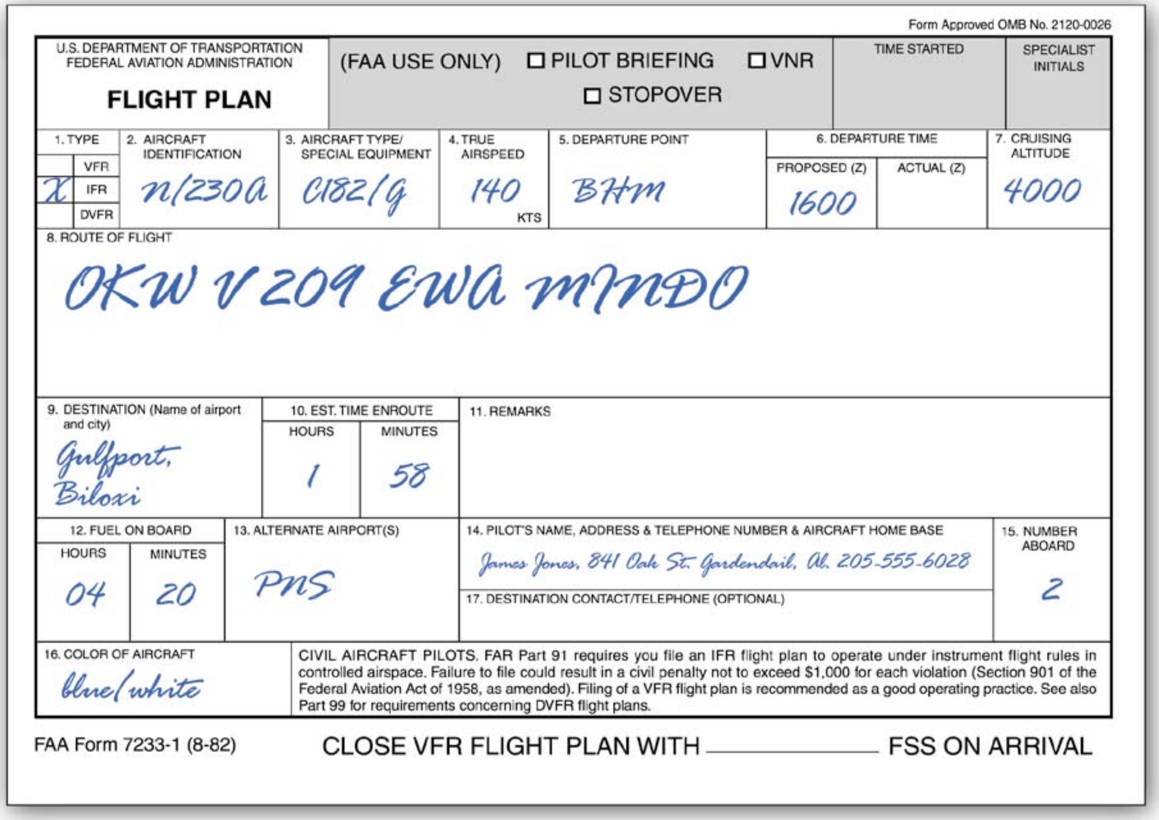

Form Approved OMB No. 2120-0026

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

FLIGHT PLAN

(FAA USE ONLY) ☐ PILOT BRIEFING ☐ VNR ☐ STOPOVER

TIME STARTED

SPECIALIST INITIALS

1. TYPE	2. AIRCRAFT IDENTIFICATION	3. AIRCRAFT TYPE/ SPECIAL EQUIPMENT	4. TRUE AIRSPEED	5. DEPARTURE POINT	6. DEPARTURE TIME PROPOSED (Z)	6. DEPARTURE TIME ACTUAL (Z)	7. CRUISING ALTITUDE
VFR X IFR DVFR	n1230a	C182/G	140 KTS	BHM	1600		4000

8. ROUTE OF FLIGHT: OKW V 209 EWA MINDO

9. DESTINATION (Name of airport and city)	10. EST. TIME ENROUTE HOURS	10. EST. TIME ENROUTE MINUTES	11. REMARKS
Gulfport, Biloxi	1	58	

12. FUEL ON BOARD HOURS	12. FUEL ON BOARD MINUTES	13. ALTERNATE AIRPORT(S)	14. PILOT'S NAME, ADDRESS & TELEPHONE NUMBER & AIRCRAFT HOME BASE	15. NUMBER ABOARD
04	20	PNS	James Jones, 841 Oak St. Gardendail, Al. 205-555-6028	2
			17. DESTINATION CONTACT/TELEPHONE (OPTIONAL)	

16. COLOR OF AIRCRAFT: blue/white

CIVIL AIRCRAFT PILOTS. FAR Part 91 requires you file an IFR flight plan to operate under instrument flight rules in controlled airspace. Failure to file could result in a civil penalty not to exceed $1,000 for each violation (Section 901 of the Federal Aviation Act of 1958, as amended). Filing of a VFR flight plan is recommended as a good operating practice. See also Part 99 for requirements concerning DVFR flight plans.

FAA Form 7233-1 (8-82) CLOSE VFR FLIGHT PLAN WITH ____________ FSS ON ARRIVAL

Figure 10-20. *Flight Plan Form.*

Several pilot reports have been submitted for light icing conditions; however, all the reports are north of the route of flight and correspond to the AIRMET that was issued earlier. No pilot reports have included cloud tops, but the area forecast predicted cloud tops to flight level 240. Since the weather conditions appear to be improving, a flight plan can be filed using the completed form.

Analyze the latest weather minimums to determine if they exceed personal minimums. With the absence of icing reported along the route and steadily rising temperatures, structural icing should not be a problem. Make a note to do an operational check of the pitot heat during preflight and to take evasive action immediately should even light icing conditions be encountered in flight. This may require returning to BHM or landing at an intermediate spot before reaching GPT. The go/no-go decision will be constantly reevaluated during the flight.

Once at the airport, conduct a thorough preflight inspection. A quick check of the logbooks indicates all airworthiness requirements have been met to conduct this IFR flight including an altimeter, static, and transponder test within the preceding 24 calendar months. In addition, a log on the clipboard indicates the VOR system has been checked within the preceding 30 days. Turn on the master switch and pitot heat, and quickly check the heating element before it becomes too hot. Then, complete the rest of the walk-around procedure. Since this will be a flight in actual IFR conditions, place special emphasis on IFR equipment during the walk-around, including the alternator belt and antennas. After completing the preflight, organize charts, pencils, paper, and navigation log in the flight deck for quick, easy access. This is also the time to enter the planned flight into the GPS.

Departure

After starting the engine, tune in ATIS and copy the information to the navigation log. The conditions remain the same as the updated weather briefing with the ceiling at 700 overcast, and visibility at 3 miles. Call clearance delivery to receive a clearance:

> "Clearance Delivery, Cessna 1230A IFR to Gulfport Biloxi with information Kilo, ready to copy."
>
> "Cessna 1230A is cleared to Gulfport-Biloxi via the Birmingham Three Departure, Brookwood, Victor 209 Kewanee then direct Mindo, Gulfport. Climb and maintain 4,000. Squawk 0321."

Read back the clearance and review the DP. Although a departure frequency was not given in the clearance, note that on the DP, the departure control frequency is listed as 123.8 for the southern sector. Since a departure from runway 24 is anticipated, note the instruction to climb to 2,100 prior to turning. After tuning in the appropriate frequencies and setting up navigation equipment for the departure routing, contact ground control (noting that this is IFR) and receive the following clearance:

> "Cessna 1230A taxi to runway 24 via taxiway Mike."

Read back the clearance and aircraft call sign. After a review of the taxi instructions on the airport diagram, begin to taxi and check the flight instruments for proper indications.

Hold short of runway 24 and complete the before takeoff checklist and engine run-up. Advise the tower when ready for takeoff. The tower gives the following clearance:

> "Cessna 30A cleared for takeoff runway 24. Caution wake turbulence from 737 departing to the northwest."

Taxi into position. Note the time off on the navigation log, verify that the heading indicator and magnetic compass are in agreement, the transponder is in the ALT position, all the necessary lights, equipment, and pitot heat are on. Start the takeoff roll. To avoid the 737's wake turbulence, make note of its lift off point and take off prior to that point.

En Route

After departure, climb straight ahead to 2,100 feet as directed by the Birmingham Three Departure. While continuing a climb to the assigned altitude of 4,000 feet, the following instructions are received from the tower:

> "Cessna 30A contact Departure."

Acknowledge the clearance and contact departure on the frequency designated by the DP. State the present altitude so the departure controller can check the encoded altitude against indicated altitude:

> "Birmingham Departure Cessna 1230A climbing through 2,700 heading 240."

Departure replies:

> "Cessna 30A proceed direct to Brookwood and resume own navigation. Contact Atlanta Center on 134.05."

Acknowledge the clearance, contact Atlanta Center and proceed direct to Brookwood VORTAC, using the IFR-approved GPS equipment. En route to Kewanee, VORTAC Atlanta Center issues the following instructions:

> "Cessna 1230A contact Memphis Center on 125.975."

Acknowledge the instructions and contact Memphis Center with aircraft ID and present altitude. Memphis Center acknowledges contact:

> "Cessna 1230A, Meridian altimeter is 29.87. Traffic at your 2 o'clock and 6 miles is a King Air at 5,000 climbing to 12,000."

Even when on an IFR flight plan, pilots are still responsible for seeing and avoiding other aircraft. Acknowledge the call from Memphis Center and inform them of negative contact with traffic due to IMC.

> "Roger, altimeter setting 29.87. Cessna 1230A is in IMC negative contact with traffic."

Continue the flight, and at each fix note the arrival time on the navigation log to monitor progress.

To get an update of the weather at the destination and issue a pilot report, contact the FSS servicing the area. To find the nearest AFSS, locate a nearby VOR and check above the VOR information box for a frequency. In this case, the nearest VOR is Kewanee VORTAC which lists a receive-only frequency of 122.1 for Greenwood FSS. Request a frequency change from Memphis and then attempt to contact Greenwood on 122.1 while listening over the Kewanee VORTAC frequency of 113.8:

> "Greenwood Radio Cessna 1230A receiving on frequency 113.8, over."

> "Cessna 30A, this is Greenwood, go ahead."

> "Greenwood Radio, Cessna 30A is currently 30 miles south of the Kewanee VORTAC at 4,000 feet en route to Gulfport. Requesting an update of en route conditions and current weather at GPT, as well as PNS."

> "Cessna 30A, Greenwood Radio, current weather at Gulfport is 400 overcast with 3 miles visibility in light rain. The winds are from 140 at 7 and the altimeter is 29.86. Weather across your route is generally IFR in light rain with ceilings ranging from 300 to 1,000 overcast with visibilities between 1 and 3 miles. Pensacola weather is much better with ceilings now at 2,500 and visibility 6 miles. Checking current NOTAMs at GPT shows the localizer out of service and runway 18/36 closed."

> "Roger, Cessna 30A copies the weather. I have a PIREP when you are ready to copy."

> "Cessna 30A go ahead with your PIREP."

> "Cessna 30A is a Cessna 182 located on the Kewanee 195° radial at 30 miles level at 4,000 feet. I am currently in IMC conditions with a smooth ride. Outside air temperature is plus 1° Celsius. Negative icing."

> "Cessna 30A thank you for the PIREP."

With the weather check and PIREP complete, return to Memphis Center:

> "Memphis Center, Cessna 1230A is back on your frequency."

> "Cessna 1230A, Memphis Center, roger, contact Houston Center now on frequency 126.8."

> "Roger, contact Houston Center frequency 126.8, Cessna 1230A."

> "Houston Center, Cessna 1230A level at 4,000 feet."

> "Cessna 30A, Houston Center area altimeter 29.88."

Arrival

40 miles north of Gulfport, tune in ATIS on number two communication radio. The report reveals there has been no change in the weather and ATIS is advertising ILS runway 14 as the active approach.

Houston Center completes a hand off to Gulfport approach control with instructions to contact approach:

> "Gulfport Approach, Cessna 1230A level 4,000 feet with information TANGO. Request GPS Runway 14 approach."

> "Cessna 30A, Gulfport Approach, descend and maintain 3,000 feet."

> "Descend to 3,000, Cessna 30A."

Begin a descent to 3,000 and configure your navigation radios for the approach. The GPS will automatically change from the en route mode to the terminal mode. This change will affect the sensitivity of the CDI. Tune in the VORTAC frequency of 109.0 on the number one navigation radio, and set in the final approach course of 133° on the OBS. This setup will help with situational awareness should the GPS lose signal.

> "Cessna 30A your position is 7 miles from MINDO, maintain 3,000 feet until MINDO, cleared for the GPS runway 14 approach."

Read back the clearance and concentrate on flying the aircraft. At MINDO descend to 2,000 as depicted on the approach chart. At BROWA turn to the final approach course of 133°. Just outside the Final Approach Way Point (FAWP) AVYUM, the GPS will change to the approach mode and the CDI will become even more sensitive. Gulfport approach control issues instructions to contact Gulfport tower:

> "Cessna 30A contact Tower on 123.7."

> "123.7, Cessna 30A."

> "Tower, Cessna 1230A outside AVYUM on the GPS runway 14."

> "Cessna 30A Gulfport Tower, the ceiling is now 600 overcast and the visibility is 4 miles."

> "Cleared to land runway 14, Cessna 30A."

Continue the approach, complete the appropriate checklists, cross AVYUM, and begin the final descent. At 700 feet MSL visual contact with the airport is possible. Slow the aircraft and configure it to allow a normal descent to landing. As touch down is completed, Gulfport Tower gives further instructions:

> "Cessna 30A turn left at taxiway Bravo and contact ground on 120.4."

> "Roger, Cessna 30A."

Taxi clear of the runway and complete the appropriate checklists. The Tower will automatically cancel the IFR flight plan.

ATTITUDE FAIL
AIRSPEED FAIL
TRAFFIC
HDG
NORTH UP
INSET
PFD
OBS
CDI
DME
XPDR
IDENT
MAN IN
27.3
RPM
1930
FFLOW GPH
OIL PRES
OIL TEMP
CHT
EGT
FUEL QTY GAL
ELECTRICAL
BUS
VOLTS
BATT
AMPS
ENGINE
COLORADO
ALBUQUERQUE
NEW MEXICO
111.30
117.90
BVO
110.70
117.90
117.60
HDG 293°

Chapter 11

Emergency Operations

Introduction

Changing weather conditions, air traffic control (ATC), the aircraft, and the pilot are all variables that make instrument flying an unpredictable and challenging operation. The safety of the flight depends upon the pilot's ability to manage these variables while maintaining positive aircraft control and adequate situational awareness. This chapter discusses the recognition and suggested remedies for such abnormal and emergency events related to unforecasted, adverse weather; aircraft system malfunctions; communication/navigation system malfunctions; and loss of situational awareness.

Unforecast Adverse Weather

Inadvertent Thunderstorm Encounter

A pilot should avoid flying through a thunderstorm of any intensity. However, certain conditions may be present that could lead to an inadvertent thunderstorm encounter. For example, flying in areas where thunderstorms are embedded in large cloud masses may make thunderstorm avoidance difficult, even when the aircraft is equipped with thunderstorm detection equipment. Therefore, pilots must be prepared to deal with an inadvertent thunderstorm penetration. At the very least, a thunderstorm encounter subjects the aircraft to turbulence that could be severe. The pilot and passengers should tighten seat belts and shoulder harnesses and secure any loose items in the cabin.

As with any emergency, the first order of business during an inadvertent thunderstorm encounter must be to fly the aircraft. The pilot workload is heavy; therefore, increased concentration is necessary to maintain an instrument scan. If a pilot inadvertently enters a thunderstorm, it is better to maintain a course straight through the thunderstorm rather than turning around. A straight course minimizes the amount of time in the thunderstorm and turning maneuvers only increase structural stress on the aircraft.

Reduce power to a setting that maintains a speed at the recommended turbulence penetration speed as described in the Pilot's Operating Handbook/Airplane Flight Manual (POH/AFM), and try to minimize additional power adjustments. Concentrate on maintaining a level attitude while allowing airspeed and altitude to fluctuate. Similarly, if using the autopilot, disengage the altitude hold and speed hold modes, as they only increase the aircraft's maneuvering—thereby increasing structural stress.

During a thunderstorm encounter, the potential for icing also exists. As soon as possible, turn on anti-icing/deicing equipment and carburetor heat, if equipped. Icing can be rapid at any altitude and may lead to power failure and/or loss of airspeed indication.

Lightning is also present in a thunderstorm and can temporarily blind a pilot. To reduce this risk, turn up flight deck lights to the highest intensity, concentrate on the flight instruments, and resist the urge to look outside.

Inadvertent Icing Encounter

Because icing is unpredictable in nature, pilots may find themselves in icing conditions even though they have done everything practicable to avoid it. In order to stay alert to this possibility while operating in visible moisture, pilots should monitor the outside air temperature (OAT).

The effects of ice on aircraft are cumulative—thrust is reduced, drag increases, lift lessens, and weight increases. The results are an increase in stall speed and a deterioration of aircraft performance. In extreme cases, two to three inches of ice can form on the leading edge of the airfoil in less than 5 minutes. It takes only 1/2 inch of ice to reduce the lifting power of some aircraft by 50 percent and increases the frictional drag by an equal percentage.

A pilot can expect icing when flying in visible precipitation, such as rain or cloud droplets, and the temperature is between +02 and -10° Celsius. When icing is detected, a pilot should do one of two things, particularly if the aircraft is not equipped with deicing equipment: leave the area of precipitation or go to an altitude where the temperature is above freezing. This "warmer" altitude may not always be a lower altitude. Proper preflight action includes obtaining information on the freezing level and the above-freezing levels in precipitation areas.

If neither option is available, consider an immediate landing at the nearest suitable airport. Even if the aircraft is equipped with anti-icing/deicing equipment, it is not designed to allow aircraft to operate indefinitely in icing conditions. Anti-icing/deicing equipment gives a pilot more time to get out of the icing conditions. Report icing to ATC and request new routing or altitude. Be sure to report the type of aircraft, and use the following terms when reporting icing to ATC:

1. Trace. Ice becomes perceptible. Rate of accumulation is slightly greater than sublimation. Deicing/anti-icing equipment is not utilized unless encountered for an extended period of time (over 1 hour).
2. Light. The rate of accumulation may create a problem if flight is prolonged in this environment (over 1 hour). Occasional use of deicing/anti-icing equipment removes/prevents accumulation. It does not present a problem if deicing/anti-icing equipment is used.
3. Moderate. The rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or flight diversion is necessary.
4. Severe. The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate flight diversion is necessary.

Early ice detection is critical and is particularly difficult during night flight. Use a flashlight to check for ice accumulation on the wings. At the first indication of ice accumulation, take action to get out of the icing conditions. Refer to the POH/AFM for the proper use of anti-icing/deicing equipment.

Figure 11-1. *St. Elmo's Fire is harmless but may affect both communication and navigation radios, especially the lower frequencies such as those used on the ADF.*

Precipitation Static

Precipitation static, often referred to as P-static, occurs when accumulated static electricity is discharged from the extremities of the aircraft. This discharge has the potential to create problems for the instrument pilot. These problems range from the serious, such as erroneous magnetic compass readings and the complete loss of very high frequency (VHF) communications to the annoyance of high-pitched audio squealing and St. Elmo's fire. *[Figure 11-1]*

Precipitation static is caused when an aircraft encounters airborne particles during flight (e.g., rain or snow), and develops a negative charge. It can also result from atmospheric electric fields in thunderstorm clouds. When a significant negative voltage level is reached, the aircraft discharges it, which can create electrical disturbances. This electrical discharge builds with time as the aircraft flies in precipitation. It is usually encountered in rain, but snow can cause the same effect. As the static buildup increases, the effectiveness of both communication and navigation systems decreases to the point of potential unusability.

To reduce the problems associated with P-static, the pilot should ensure the aircraft's static wicks are properly maintained and accounted for. Broken or missing static wicks should be replaced before an instrument flight. *[Figure 11-2]*

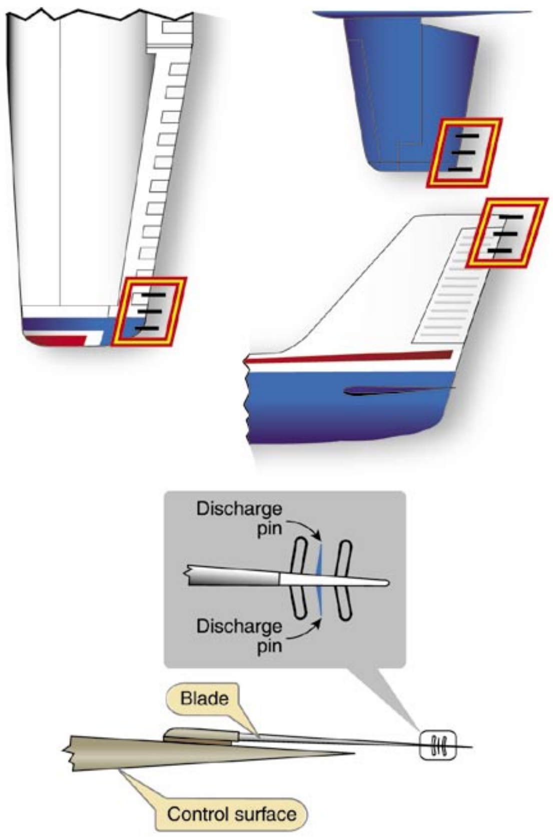

Figure 11-2. *One example of a static wick installed on aircraft control surface to bleed off static charges built up during flight. This will prevent static buildup and St. Elmo's fire by allowing the static electricity to dissipate harmlessly.*

Aircraft System Malfunctions

Preventing aircraft system malfunctions that might lead to an inflight emergency begins with a thorough preflight inspection. In addition to those items normally checked prior to a visual flight rules (VFR) flight, pilots intending to fly under instrument flight rules (IFR) should pay particular attention to the alternator belt, antennas, static wicks, anti-icing/deicing equipment, pitot tube, and static ports.

During taxi, verify the operation and accuracy of all flight instruments. In addition, during the run-up, verify that the operation of the pneumatic system(s) is within acceptable parameters. It is critical that all systems are determined to be operational before departing into IFR conditions.

Electronic Flight Display Malfunction

When a pilot becomes familiar and comfortable with the new electronic displays, he or she also tends to become more reliant on the system. The system then becomes a primary source of navigation and data acquisition instead of the supplementary source of data as initially intended.

Complete reliance on the moving map for navigation becomes a problem during a failure of one, more, or all of the flight display screens. Under these conditions, the systems revert to a composite mode (called reversionary), which eliminates the moving map display and combines the PFD with the engine indicating system. *[Figure 11-3]* If a pilot has relied on the display for navigation information and situational awareness, he or she lacks any concept of critical data such as the aircraft's position, the nearest airport, or proximity to other aircraft.

The electronic flight display is a supplementary source of navigation data and does not replace en route charts. To maintain situational awareness, a pilot must follow the flight on the en route chart while monitoring the PFD. It is important for the pilot to know the location of the closest airport as well as surrounding traffic relative to the location of his or her aircraft. This information becomes critical should the electronic flight display fail.

For the pilot who utilizes the electronic database as a substitute for the Airport Facilities Directory, screen failure or loss of electrical power can mean the pilot is no longer able to access airport information. Once the pilot loses the ability to call up airport information, aeronautical decision-making is compromised.

Alternator/Generator Failure

Depending upon the aircraft being flown, an alternator failure is indicated in different ways. Some aircraft use an ammeter

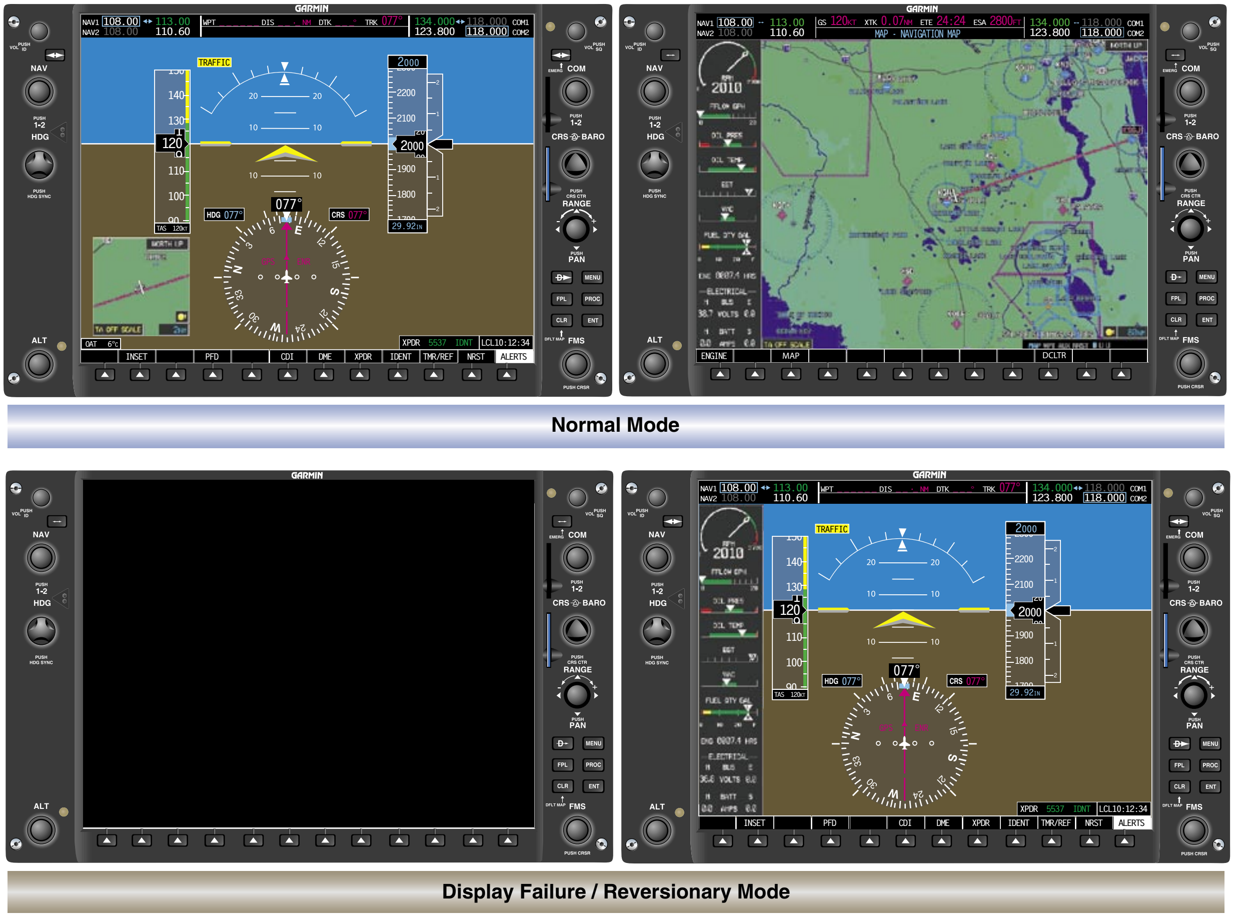

Figure 11-3. *G1000 PFD display in normal mode and in the reversionary mode activated upon system failure.*

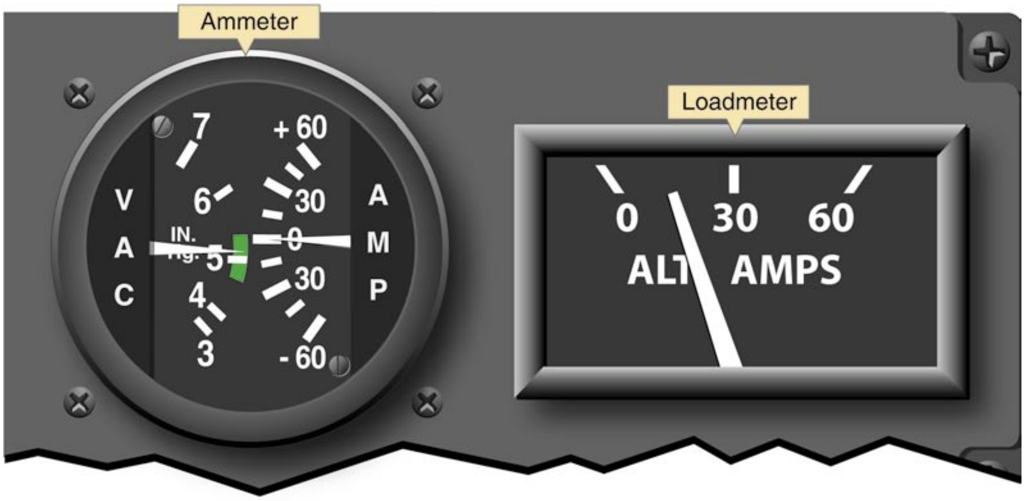

Figure 11-4. *Ammeter (left) and Loadmeter (right).*

that indicates the state of charge or discharge of the battery. *[Figure 11-4]* A positive indication on the ammeter indicates a charge condition; a negative indication reveals a discharge condition. Other aircraft use a load meter to indicate the load being carried by the alternator. *[Figure 11-4]*

Sometimes an indicator light is also installed in the aircraft to alert the pilot to an alternator failure. On some aircraft such as the Cessna 172, the light is located on the lower left side making it difficult to see its illumination if charts are open Ensure that these safety indicators are visible during flight.

When a loss of the electrical charging system is experienced, the pilot has approximately 40 minutes of battery life remaining before the system fails entirely. The time mentioned is an approximation and should not be relied upon as specific to all aircraft. In addition, the battery charge that exists in a battery may not be full, altering the time available before electrical exhaustion occurs. At no time should a pilot consider continuing a flight once the electrical charging system has failed. Land at the nearest suitable airport.

Techniques for Electrical Usage

Master Battery Switch

One technique for conserving the main battery charge is to fly the aircraft to the airport of intended landing while operating with minimal power. If a two-position battery master/alternator rocker switch *[Figure 11-5]* is installed, it can be utilized to isolate the main battery from the electrical system and conserve power.

Operating on the Main Battery

While en route to the airport of intended landing, reduce the electrical load as much as practical. Turn off all unnecessary electrical items such as duplicate radios, non-essential lighting, etc. If unable to turn off radios, lights, etc. manually, consider pulling circuit breakers to isolate those pieces of equipment from the electrical system. Maximum time of useful voltage may be between 30 and 40 minutes and is influenced by many factors, which degrade the useful time.

Loss of Alternator/Generator for Electronic Flight Instrumentation

With the increase in electrical components being installed in modern technically advanced aircraft, the power supply and the charging system need increased attention and understanding. Traditional round dial aircraft do not rely as heavily on electrical power for the primary six-pack instrumentation. Modern electronic flight displays utilize the electrical system to power the AHRS, ADC, engine indicating system (EIS), etc. A loss of an alternator or generator was considered an abnormality in traditionally equipped aircraft;

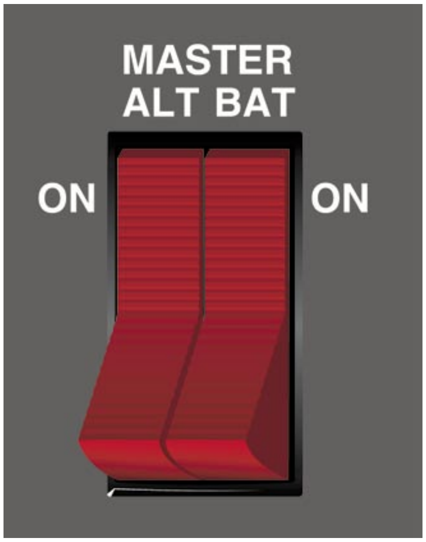

Figure 11-5. *Double Rocker Switch Seen on Many Aircraft.*

however, a failure of this magnitude is considered an emergency in technically advanced aircraft.

Due to the increased demand for electrical power, it is necessary for manufacturers to install a standby battery in conjunction with the primary battery. The standby battery is held in reserve and kept charged in case of a failure of the charging system and a subsequent exhaustion of the main battery. The standby battery is brought online when the main battery voltage is depleted to a specific value, approximately 19 volts. Generally, the standby battery switch must be in the ARM position for this to occur but pilots should refer to the aircraft flight manual for specifics on an aircraft's electrical system. The standby battery powers the essential bus and allows the primary flight display (PFD) to be utilized.

The essential bus usually powers the following components:

1. AHRS (Attitude and Heading Reference System)
2. ADC (Air Data Computer)
3. PFD (Primary Flight Display)
4. Navigation Radio #1
5. Communication Radio #1
6. Standby Indicator Light

Techniques for Electrical Usage

Standby Battery

One technique for conserving the main battery charge is to fly the aircraft to the airport of intended landing while using the standby battery. A two-position battery master/alternator rocker switch is installed on most aircraft with electronic flight displays, which can be utilized to isolate the main battery from the electrical system. By switching the MASTER side off, the battery is taken offline and the standby battery comes online to power the essential bus. However, the standby battery switch must be in the ARM position for this to occur. *[Figure 11-6]* Utilization of the standby battery first reserves the main battery for use when approaching to land. With this technique, electrical power may be available for the use of flaps, gear, lights, etc. Do not rely on any power to be available after the standby battery has exhausted itself. Once the charging system has failed, flight with a powered electrical system is not guaranteed.

Operating on the Main Battery

While en route to the airport of intended landing, reduce the electrical load as much as practical. Turn off all unnecessary electrical items such as duplicate radios, non-essential lighting, etc. If unable to turn off radios, lights, etc., manually, consider pulling circuit breakers to isolate those pieces of equipment from the electrical system. Keep in mind that once the standby battery has exhausted its charge, the flight deck may become very dark depending on what time of day the failure occurs. The priority during this emergency situation is landing the aircraft as soon as possible without jeopardizing safety.

A standby attitude indicator, altimeter, airspeed indicator (ASI) and magnetic compass are installed in each aircraft for use when the PFD instrumentation is unavailable. *[Figure 11-7]* These would be the only instruments left available to the pilot. Navigation would be limited to pilotage and dead reckoning unless a hand-held transceiver with a GPS/navigation function is onboard.

Once an alternator failure has been detected, the pilot must reduce the electrical load on the battery and land as soon as practical. Depending upon the electrical load and condition of the battery, there may be sufficient power available for 45 minutes of flight—or for only a matter of minutes. Pilots should also know which systems on the aircraft are electric and those that continue to operate without electrical power. Pilots can attempt to troubleshoot alternator failure by following the established alternator failure procedure published in the POH/AFM. If the alternator cannot be reset, advise ATC of the situation and inform them of the impending electrical failure.

Analog Instrument Failure

A warning indicator or an inconsistency between indications on the attitude indicator and the supporting performance

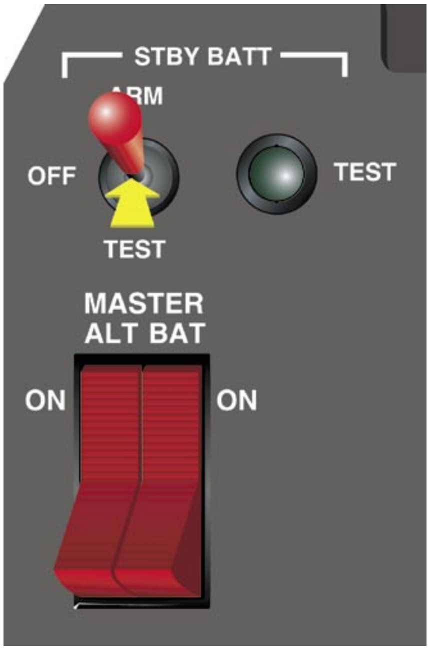

Figure 11-6. *Note the double rocker switch and the standby battery switch in this aircraft. The standby battery must be armed to work correctly; arming should be done prior to departure.*

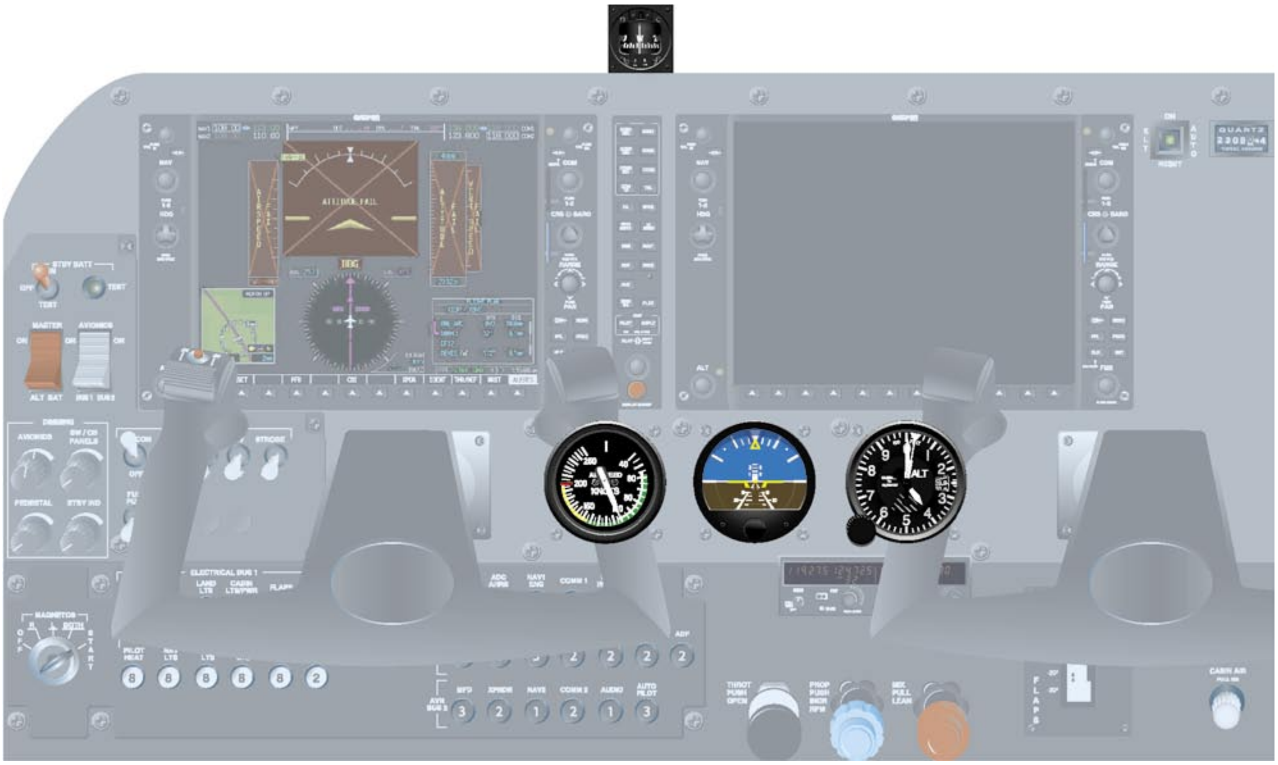

Figure 11-7. *Emergency Instrumentation Available to the Pilot on Electronic Flight Instrumented Aircraft.*

instruments usually identifies system or instrument failure. Aircraft control must be maintained while identifying the failed component(s). Expedite the cross-check and include all flight instruments. The problem may be individual instrument failure or a system failure affecting multiple instruments.

One method of identification involves an immediate comparison of the attitude indicator with the rate-of-turn indicator and vertical speed indicator (VSI). Along with providing pitch-and-bank information, this technique compares the static system with the suction or pressure system and the electrical system. Identify the failed component(s) and use the remaining functional instruments to maintain aircraft control.

Attempt to restore the inoperative component(s) by checking the appropriate power source, changing to a backup or alternate system, and resetting the instrument if possible. Covering the failed instrument(s) may enhance a pilot's ability to maintain aircraft control and navigate the aircraft. Usually, the next step is to advise ATC of the problem and, if necessary, declare an emergency before the situation deteriorates beyond the pilot's ability to recover.

Pneumatic System Failure

One possible cause of instrument failure is a loss of the suction or pressure source. This pressure or suction is supplied by a vacuum pump mechanically driven off the engine. Occasionally these pumps fail, leaving the pilot with inoperative attitude and heading indicators.

Figure 11-8 illustrates inoperative vacuum driven attitude and heading indicators which can fail progressively. As the gyroscopes slow down they may wander, which, if connected to the autopilot and/or flight director, can cause incorrect movement or erroneous indications. In *Figure 11-8,* the aircraft is actually level and at 2,000 feet MSL. It is not in a turn to the left which the pilot may misinterpret if he or she fails to see the off or failed flags. If that occurs, the pilot may transform a normally benign situation into a hazardous situation. Again, good decision-making by the pilot only occurs after a careful analysis of systems.

Many small aircraft are not equipped with a warning system for vacuum failure; therefore, the pilot should monitor the system's vacuum/pressure gauge. This can be a hazardous situation with the potential to lead the unsuspecting pilot into a dangerous unusual attitude which would require a partial panel recovery. It is important that pilots practice instrument flight without reference to the attitude and heading indicators in preparation for such a failure.

Pitot/Static System Failure

A pitot or static system failure can also cause erratic and unreliable instrument indications. When a static system

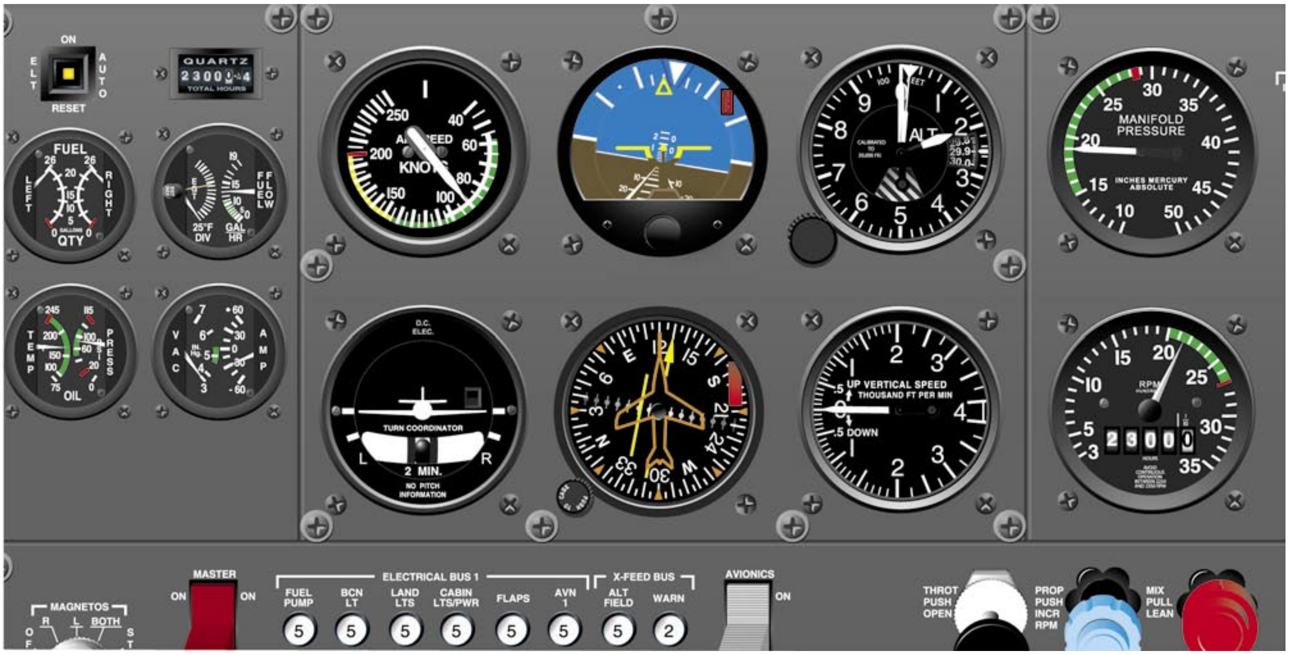
ON
ELT
AUTO
RESET
QUARTZ
TOTAL HOURS
FUEL
QTY
LEFT
RIGHT
EGT
FUEL FLOW
25°F DIV
GAL HR
AIRSPEED KNOTS
ALT
MANIFOLD PRESSURE
INCHES MERCURY ABSOLUTE
TEMP
OIL
PRESS
VAC
AMP
D.C. ELEC.
TURN COORDINATOR
L
R
2 MIN.
NO PITCH INFORMATION
UP VERTICAL SPEED THOUSAND FT PER MIN
DOWN
RPM
MASTER
ON
ON
MAGNETOS
R
L
BOTH
OFF
START
ELECTRICAL BUS 1
FUEL PUMP
BCN LT
LAND LTS
CABIN LTS/PWR
FLAPS
AVN 1
X-FEED BUS
ALT FIELD
WARN
AVIONICS
ON
THROT PUSH OPEN
PROP PUSH INCR RPM
MIX PULL LEAN

Figure 11-8. *Vacuum Failure.*

problem occurs, it affects the ASI, altimeter, and the VSI. In most aircraft, provisions have been made for the pilot to select an alternate static source. Check the POH/AFM for the location and operation of the alternate static source. In the absence of an alternate static source, in an unpressurized aircraft, the pilot could break the glass on the VSI. The VSI is not required for instrument flight, and breaking the glass provides the altimeter and the ASI a source of static pressure. This procedure could cause additional instrument errors.

Communication/Navigation System Malfunction

Avionics equipment has become very reliable, and the likelihood of a complete communications failure is remote. However, each IFR flight should be planned and executed in anticipation of a two-way radio failure. At any given point during a flight, the pilot must know exactly what route to fly, what altitude to fly, and when to continue beyond a clearance limit. Title 14 of the Code of Federal Regulations (14 CFR) part 91 describes the procedures to be followed in case of a two-way radio communications failure. If operating in VFR conditions at the time of the failure, the pilot should continue the flight under VFR and land as soon as practicable. If the failure occurs in IFR conditions, or if VFR conditions cannot be maintained, the pilot must continue the flight:

1. Along the route assigned in the last ATC clearance received;
2. If being radar vectored, by the direct route from the point of radio failure to the fix, route, or airway specified in the vector clearance;
3. In the absence of an assigned route, by the route that ATC has advised may be expected in a further clearance; or
4. In the absence of an assigned route or a route that ATC has advised may be expected in a further clearance, by the route filed in the flight plan.

The pilot should maintain the highest of the following altitudes or flight levels for the route segment being flown:

1. The altitude or flight level assigned in the last ATC clearance received;
2. The minimum altitude (converted, if appropriate, to minimum flight level as prescribed in part 91 for IFR operations); or
3. The altitude or flight level ATC has advised may be expected in a further clearance.

In addition to route and altitude, the pilot must also plan the progress of the flight to leave the clearance limit.

1. When the clearance limit is a fix from which an approach begins, commence descent or descent and approach as close as possible to the expect-further-clearance time if one has been received. If an expect-further-clearance time has not been received, commence descent or descent and approach as close as possible to the estimated time of arrival as calculated from the filed or amended (with ATC) estimated time en route.

2. If the clearance limit is not a fix from which an approach begins, leave the clearance limit at the expect-further-clearance time if one has been received. If no expect-further-clearance time has been received, leave the clearance limit upon arrival over it, and proceed to a fix from which an approach begins and commence descent or descent and approach as close as possible to the estimated time of arrival as calculated from the filed or amended (with ATC) estimated time en route. *[Figure 11-8]*

While following these procedures, set the transponder to code 7600 and use all means possible to reestablish two-way radio communication with ATC. This includes monitoring navigational aids (NAVAIDs), attempting radio contact with other aircraft, and attempting contact with a nearby automated flight service station (AFSS).

GPS Nearest Airport Function

Procedures for accessing the nearest airport information vary by the type of display installed in an aircraft. Pilots can obtain information relative to the nearest airport by using the PFD, MFD, or the nearest function on the GPS receiver. The following examples are based on a popular system. Pilots should become familiar with the operational characteristics of the equipment to be used.

Nearest Airports Using the PFD

With the advancements in electronic databases, diverting to alternate airports has become easier. Simply by pressing a soft key on the PFD, pilots can access information for up to 25 of the nearest airports that meet the criteria set in the systems configuration page. *[Figure 11-9]* Pilots are able to specify what airports are acceptable for their aircraft requirements based on landing surface and length of runway.

When the text box opens, the flashing cursor is located over the nearest airport that meets the criteria set in the auxiliary setup page as shown in *Figure 11-10*. Scrolling through the 25 airports is accomplished by turning the outer FMS knob, which is located on the lower right corner of the display screen. Turning the FMS knob clockwise moves the blinking cursor to the next closest airport. By continuing to turn the knob, the pilot is able to scroll through all 25 nearest airports. Each airport box contains the information illustrated in *Figure 11-11,* which the pilot can utilize to determine which airport best suits their individual needs.

Additional Information for a Specific Airport

In addition to the information that is presented on the first screen, the pilot can view additional information as shown in *Figure 11-12* by highlighting the airport identifier and then pressing the enter key.

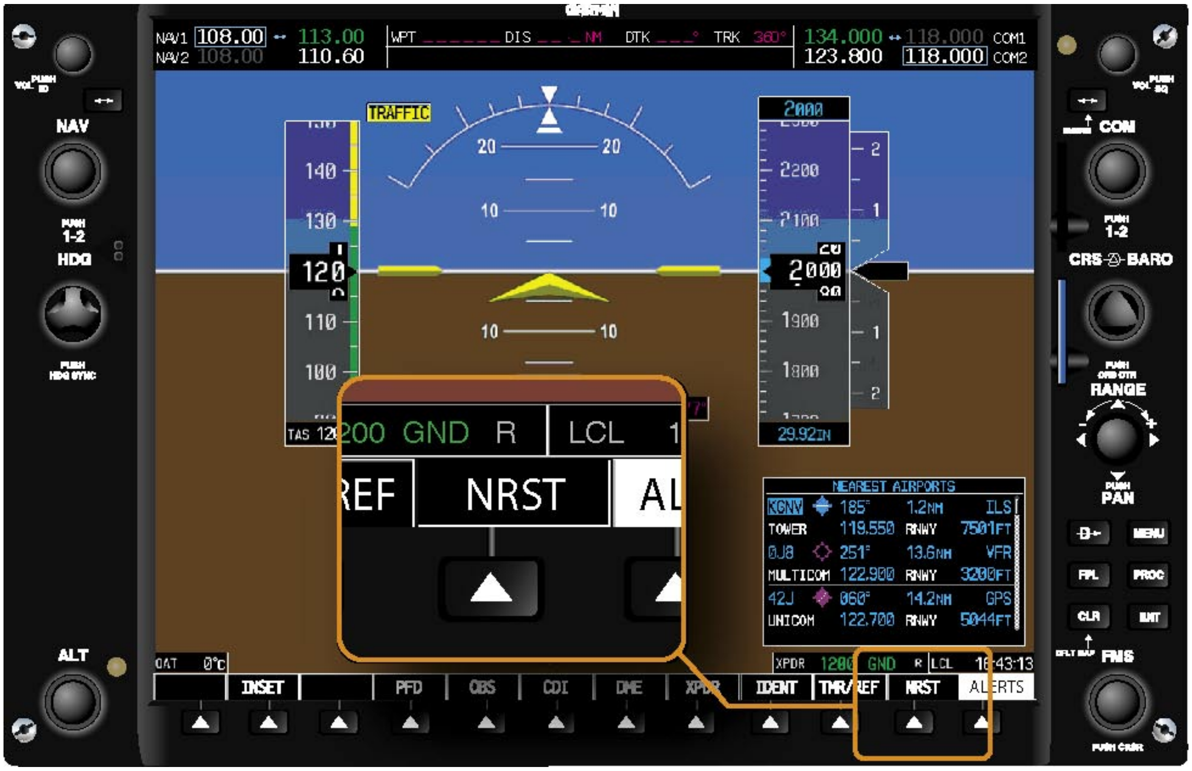
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
WPT DIS NM DTK ° TRK 360°
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
NAV
HDG
ALT
COM
CRS BARO
RANGE
PAN
FMS
TRAFFIC
2000
29.92IN
200 GND R LCL
REF NRST AL
NEAREST AIRPORTS
KGNV 185° 1.2NM ILS
TOWER 119.550 RNWY 7501FT
0J8 251° 13.6NM VFR
MULTICOM 122.900 RNWY 3200FT
42J 060° 14.2NM GPS
UNICOM 122.700 RNWY 5044FT
OAT 0°C
XPDR 1200 GND R LCL 18:43:13
INSET PFD OBS CDI DME XPDR IDENT TMR/REF NRST ALERTS
MENU FPL PROC CLR ENT

Figure 11-9. *The default soft key menu that is displayed on the PFD contains a "NRST" (Nearest Airport) soft key. Pressing this soft key opens a text box which displays the nearest 25 airports.*

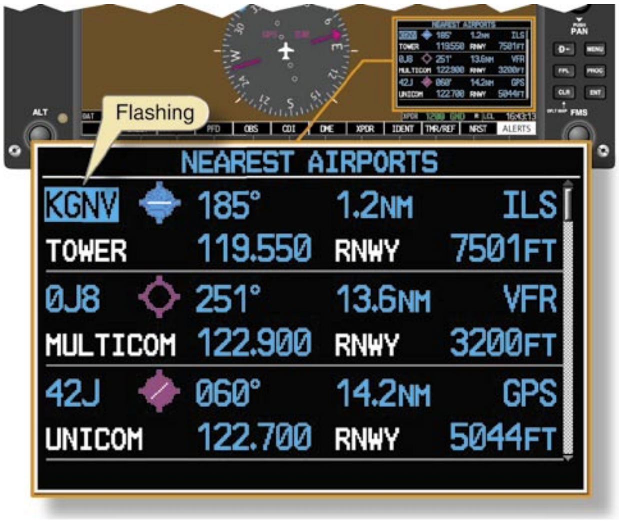

NEAREST AIRPORTS

KGNV	185°	1.2NM	ILS
TOWER	119.550	RNWY	7501FT
0J8	251°	13.6NM	VFR
MULTICOM	122.900	RNWY	3200FT
42J	060°	14.2NM	GPS
UNICOM	122.700	RNWY	5044FT

Figure 11-10. *An enlargement of the box shown in the lower right of Figure 11-9. Note that KGNV would be flashing.*

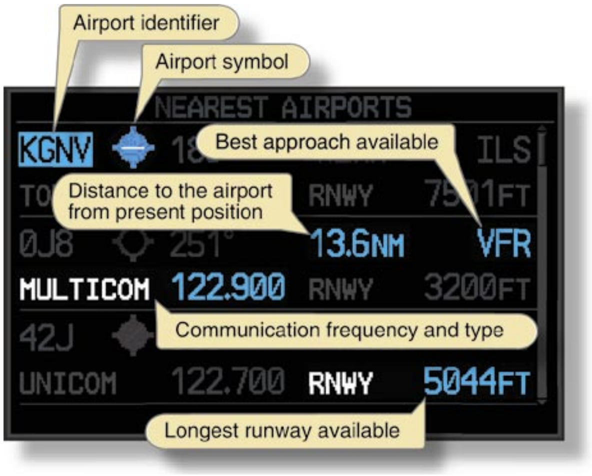
Airport identifier
Airport symbol
NEAREST AIRPORTS
Best approach available
Distance to the airport from present position
Communication frequency and type
Longest runway available

Figure 11-11. *Information shown on the nearest airport page.*

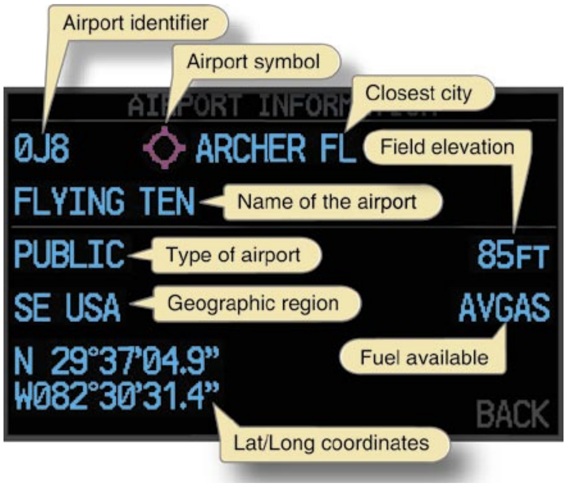
Airport identifier
Airport symbol
Closest city
Field elevation
Name of the airport
Type of airport
Geographic region
Fuel available
Lat/Long coordinates
BACK

AIRPORT INFORMATION

0J8 ARCHER FL
FLYING TEN
PUBLIC 85FT
SE USA AVGAS
N 29°37'04.9"
W082°30'31.4"

Figure 11-12. *Information shown on the additional information page that will aid the pilot in making a more informed decision about which airport to choose when diverting.*

From this menu or the previous default nearest airport screen, the pilot is able to activate the Direct-To function, which provides a direct GPS course to the airport. In addition, the pilot can auto-tune communication frequencies by highlighting the appropriate frequency and then pressing the enter key. The frequency is placed in the stand-by box of either COM1 or COM2, whichever frequency has the cyan box around it.

Nearest Airports Using the MFD

A second way to determine the nearest airport is by referencing the NRST Page Group located on the MFD. This method provides additional information to the pilot; however, it may require additional steps to view. *[Figure 11-13]*

Navigating the MFD Page Groups

Most display systems are designed for ease of navigation through the different screens on the MFD. Notice the various page groups in the lower right-hand corner of the MFD screen. Navigation through these four page groups is accomplished by turning the outer FMS knob clockwise. *[Figure 11-14]*

Within each page group are specific pages that provide additional information pertaining to that specific group. Once the desired page group and page is selected, the MFD remains in that configuration until the page is changed or the CLR button is depressed for more than 2 seconds. Holding the CLR button returns the display to the default moving map page.

Nearest Airport Page Group

The nearest airport page contains specific areas of interest for the airport selected. *[Figure 11-15]* The pilot is furnished information regarding runways, frequencies, and types of approaches available.

Nearest Airports Page Soft Keys

Figure 11-16 illustrates four specific soft keys that allow the pilot to access independent windows of the airport page. Selection of each of these windows can also be accomplished by utilizing the MENU hard key.

The soft keys and functions are as follows: Scroll through each section with the cursor, then press enter to accept the selection.

1. APT. Allows the user access to scroll through the 25 nearest airports. The white arrow indicates which airport is selected. The INFORMATION window is slaved to the white arrow. The INFORMATION window decodes the airport identifier. Scroll through the 25 airports by turning the outer FMS knob.

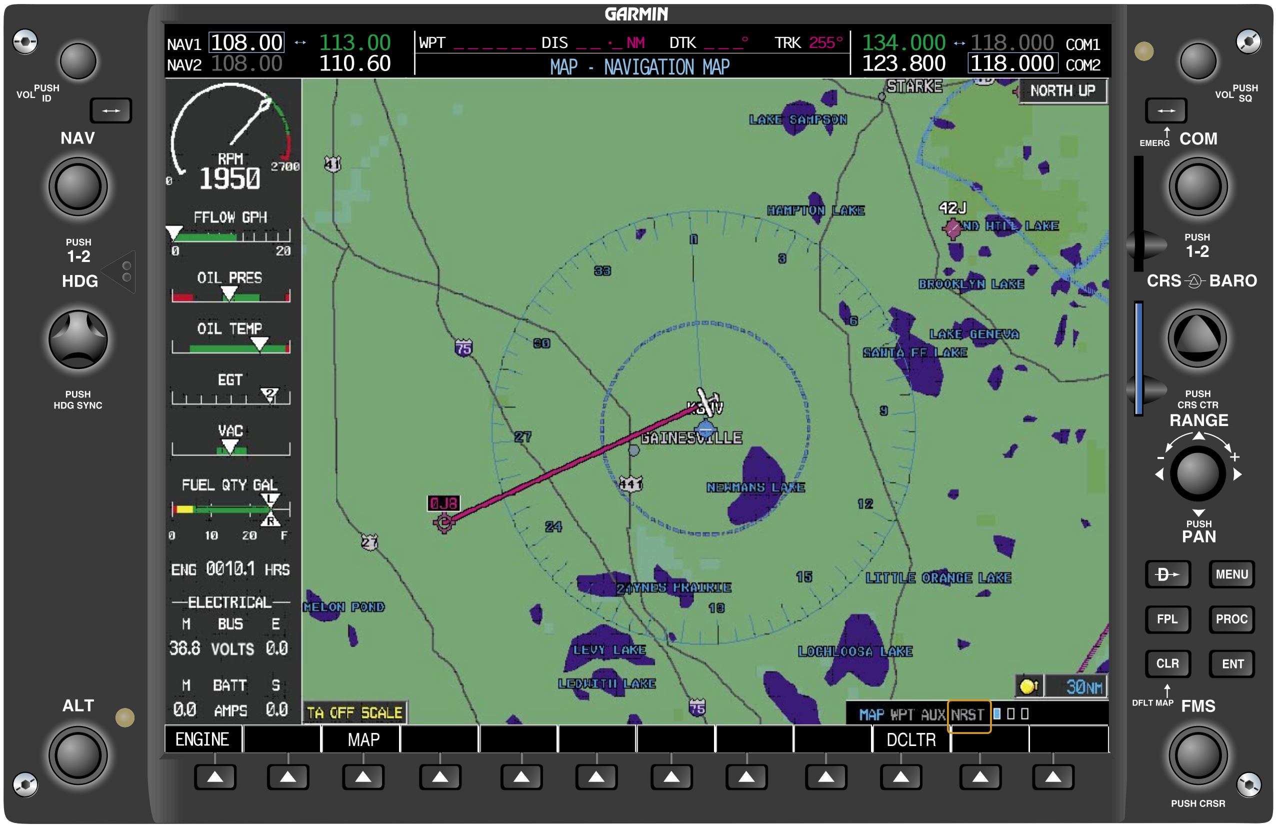
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
WPT ______ DIS __._ NM DTK ___° TRK 255°
MAP - NAVIGATION MAP
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
NORTH UP
RPM 1950
FFLOW GPH
OIL PRES
OIL TEMP
EGT
VAC
FUEL QTY GAL
ENG 0010.1 HRS
ELECTRICAL
M BUS E
38.8 VOLTS 0.0
M BATT S
0.0 AMPS 0.0
TA OFF SCALE
MAP WPT AUX NRST
30NM
ENGINE
MAP
DCLTR
NAV
1-2
HDG
PUSH HDG SYNC
ALT
COM
CRS BARO
RANGE
PAN
MENU
FPL
PROC
CLR
ENT
DFLT MAP
FMS
PUSH CRSR
GAINESVILLE
NEWMANS LAKE
LITTLE ORANGE LAKE
LOCHLOOSA LAKE

Figure 11-13. *The MFD is another means of viewing the nearest airports.*

2. RNWY. Moves the cursor into the Runways section and allows the user to scroll through the available runways at a specific airport that is selected in conjunction with the APT soft key. A green arrow indicates additional runways to view.
3. FREQ. Moves the cursor into the Frequencies section and allows the pilot to highlight and auto-tune the frequency into the selected standby box.
4. APR. Moves the cursor into the Approach section and allows the pilot to review approaches and load them into the flight plan. When the APR soft key is selected, an additional soft key appears. The LD APR (Load Approach) soft key must be pressed once the desired instrument approach procedure has been highlighted. Once the soft key is pressed, the screen changes to the PROC Page Group. From this page the pilot is able to choose the desired approach, the transition, and choose the option to activate the approach or just load it into the flight plan.

Situational Awareness

Situational awareness (SA) is not simply a mental picture of aircraft location; rather, it is an overall assessment of each element of the environment and how it affects a flight. On one end of the SA spectrum is a pilot who is knowledgeable of every aspect of the flight; consequently, this pilot's decision-making is proactive. With good SA, this pilot is able to make decisions well ahead of time and evaluate several different options. On the other end of the SA spectrum is a pilot who is missing important pieces of the puzzle: "I knew exactly where I was when I ran out of fuel." Consequently, this pilot's decision-making is reactive. With poor SA, a pilot

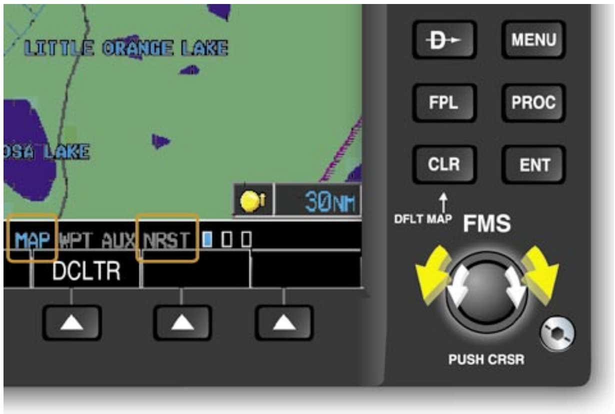
LITTLE ORANGE LAKE
OSA LAKE
30NM
MAP WPT AUX NRST
DCLTR
MENU
FPL
PROC
CLR
ENT
DFLT MAP
FMS
PUSH CRSR

Figure 11-14. *Page Groups. As the FMS outer knob is rotated, the current page group is indicated by highlighting the specific group indicator. Notice that the MAP page group is highlighted.*

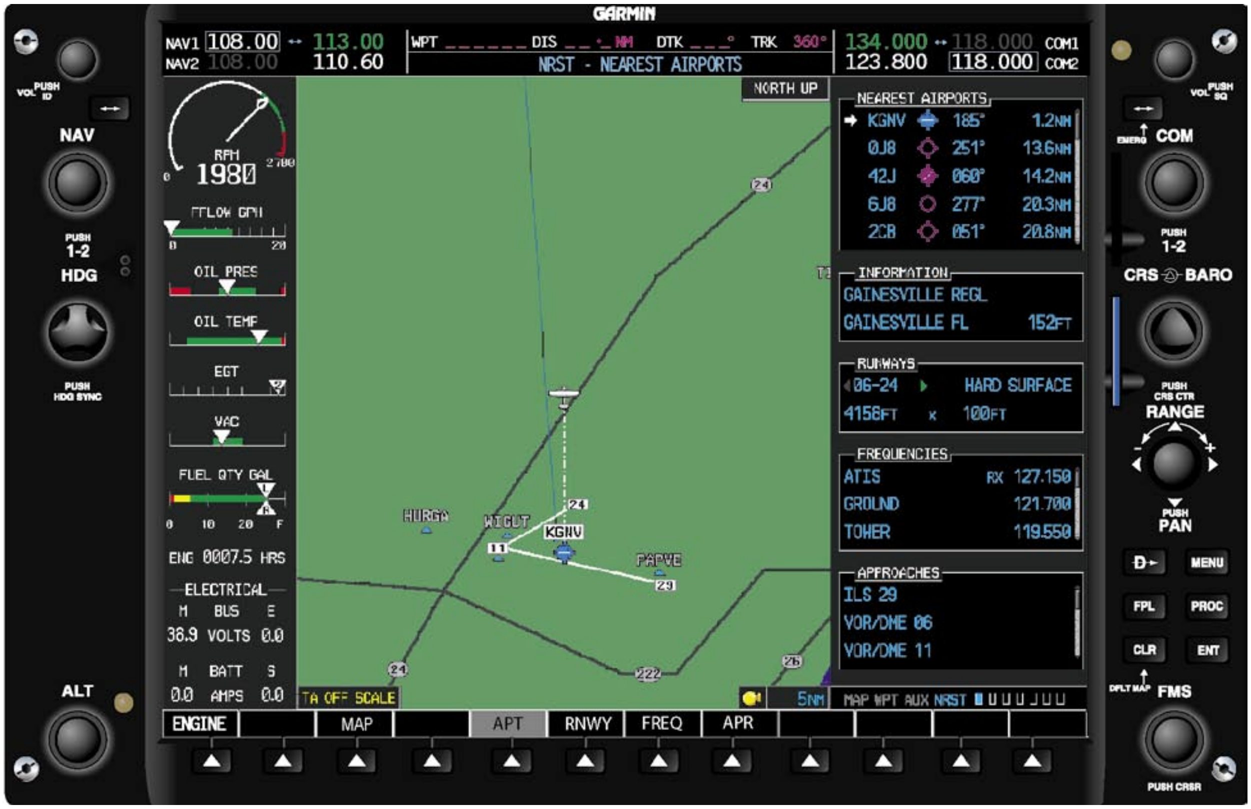
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
WPT _ _ _ _ _ _ DIS _ _ . _ NM DTK _ _ _° TRK 360°
NRST - NEAREST AIRPORTS
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
NORTH UP
NEAREST AIRPORTS
KGNV 185° 1.2NM
0J8 251° 13.6NM
42J 060° 14.2NM
6J8 277° 20.3NM
2CB 051° 20.8NM
INFORMATION
GAINESVILLE REGL
GAINESVILLE FL 152FT
RUNWAYS
06-24 HARD SURFACE
4158FT x 100FT
FREQUENCIES
ATIS RX 127.150
GROUND 121.700
TOWER 119.550
APPROACHES
ILS 29
VOR/DME 06
VOR/DME 11
RPM
1980
2700
FFLOW GPH
OIL PRES
OIL TEMP
EGT
VAC
FUEL QTY GAL
ENG 0007.5 HRS
ELECTRICAL
M BUS E
30.9 VOLTS 0.0
M BATT S
0.0 AMPS 0.0
HURGA
WIGUT
KGNV
PAPVE
TA OFF SCALE
5NM
MAP WPT AUX NRST
ENGINE
MAP
APT
RNWY
FREQ
APR
NAV
PUSH 1-2
HDG
PUSH HDG SYNC
ALT
VOL PUSH ID
COM
EMERG
VOL PUSH SQ
PUSH 1-2
CRS BARO
PUSH CRS CTR
RANGE
PUSH PAN
MENU
FPL
PROC
CLR
ENT
DFLT MAP
FMS
PUSH CRSR

Figure 11-15. *The page group of nearest airports has been selected.*

lacks a vision of future events and is forced to make decisions quickly, often with limited options.

During a typical IFR flight, a pilot operates at varying levels of SA. For example, a pilot may be cruising to his or her destination with a high level of SA when ATC issues an unexpected standard terminal arrival route (STAR). Since the pilot was not expecting the STAR and is not familiar with it, SA is lowered. However, after becoming familiar with the STAR and resuming normal navigation, the pilot returns to a higher level of SA.

Factors that reduce SA include: distractions, unusual or unexpected events, complacency, high workload, unfamiliar situations, and inoperative equipment. In some situations, a loss of SA may be beyond a pilot's control. For example, a pneumatic system failure and associated loss of the attitude and heading indicators could cause a pilot to find his or her aircraft in an unusual attitude. In this situation, established procedures must be used to regain SA.

Pilots should be alert to a loss of SA anytime they are in a reactive mindset. To regain SA, reassess the situation and seek additional information from other sources, such as the navigation instruments or ATC.

Traffic Avoidance

Electronic flight displays have the capability of displaying transponder-equipped aircraft on the MFD as well as the inset map on the PFD. However, due to the limitations of the systems, not all traffic is displayed. Some TIS units display only eight intruding targets within the service volume. The normal service volume has altitude limitations of 3,500 feet below the aircraft to 3,500 feet above the aircraft. The lateral limitation is 7 NM. *[Figure 11-17]* Pilots unfamiliar with the limitations of the system may rely on the aural warnings to alert them to approaching traffic.

In addition to an outside visual scan of traffic, a pilot should incorporate any Traffic Information electronically displayed such as TIS. This innovation in traffic alerting reinforces and adds synergy to the ability to see and avoid. However, it is an aid and not a replacement for the responsibilities of the pilot. Systems such as TIS provide a visual representation of nearby traffic and displays a symbol on the moving map display with relative information about altitude, vertical trends, and direction of flight. *[Figure 11-18]*

It is important to remember that most systems display only a specific maximum number of targets allowed. Therefore, it

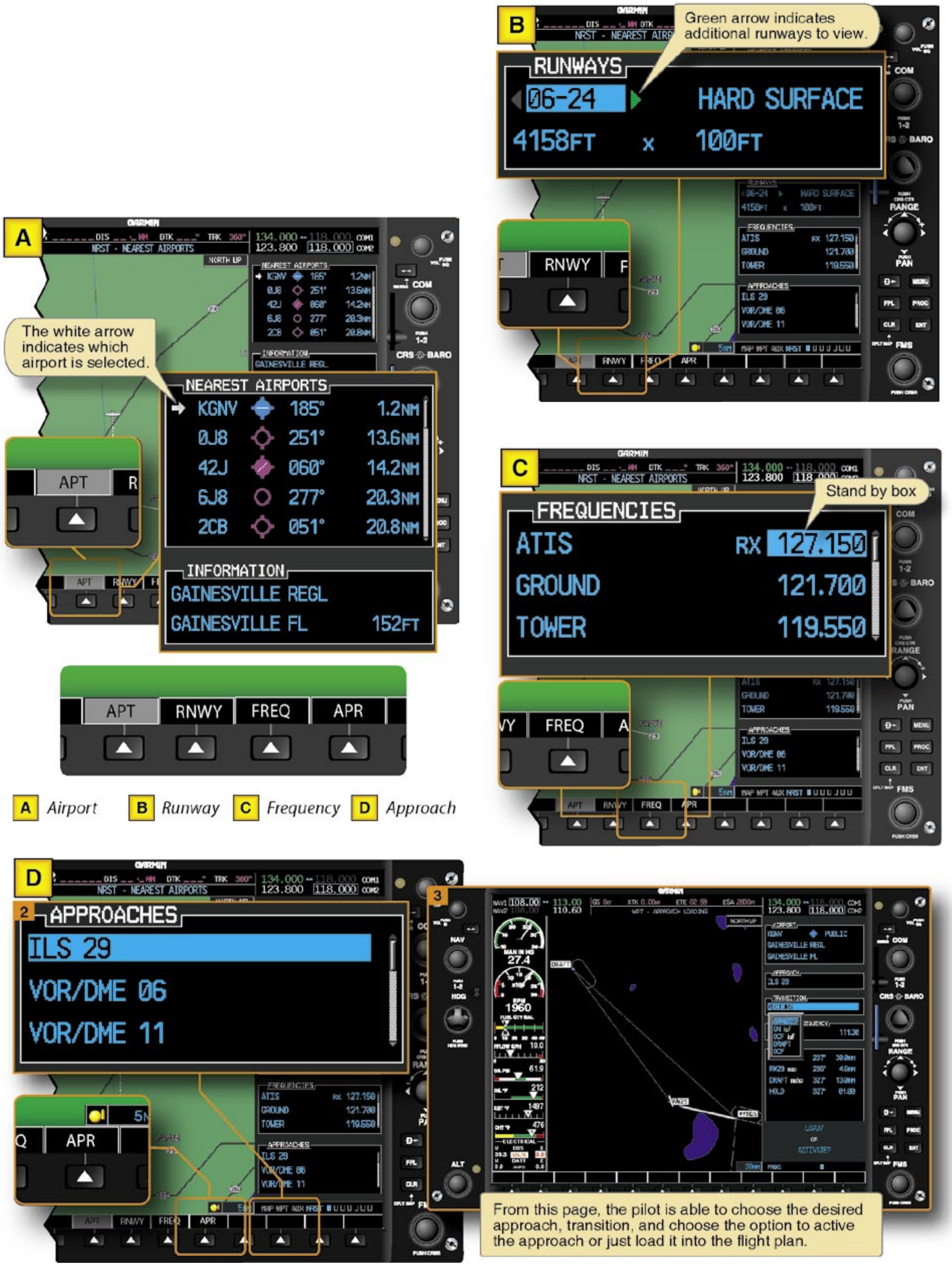

Green arrow indicates additional runways to view.

RUNWAYS

06-24 HARD SURFACE

4158FT x 100FT

The white arrow indicates which airport is selected.

NEAREST AIRPORTS

KGNV	185°	1.2NM
0J8	251°	13.6NM
42J	060°	14.2NM
6J8	277°	20.3NM
2CB	051°	20.8NM

INFORMATION

GAINESVILLE REGL

GAINESVILLE FL 152FT

Stand by box

FREQUENCIES

ATIS	RX 127.150
GROUND	121.700
TOWER	119.550

APPROACHES

ILS 29

VOR/DME 06

VOR/DME 11

From this page, the pilot is able to choose the desired approach, transition, and choose the option to active the approach or just load it into the flight plan.

A
B
C
D
2
3
GARMIN
APT
RNWY
FREQ
APR
A Airport
B Runway
C Frequency
D Approach

Figure 11-16. *The four soft keys at the bottom of the MFD are airport (A), runway (B), frequency (C), and approach (D).*

does not mean that the targets displayed are the only aircraft in the vicinity. The system displays only the closest aircraft. In addition, the system does not display aircraft that are not equipped with transponders. The display may not show any aircraft; however, a Piper Cub with no transponder could be flying in the area. TIS coverage can be sporadic and is not available in some areas of the United States. Traffic advisory software is to be utilized only for increased situational awareness and not the sole means of traffic avoidance. There is no substitute for a good visual scan of the surrounding sky.

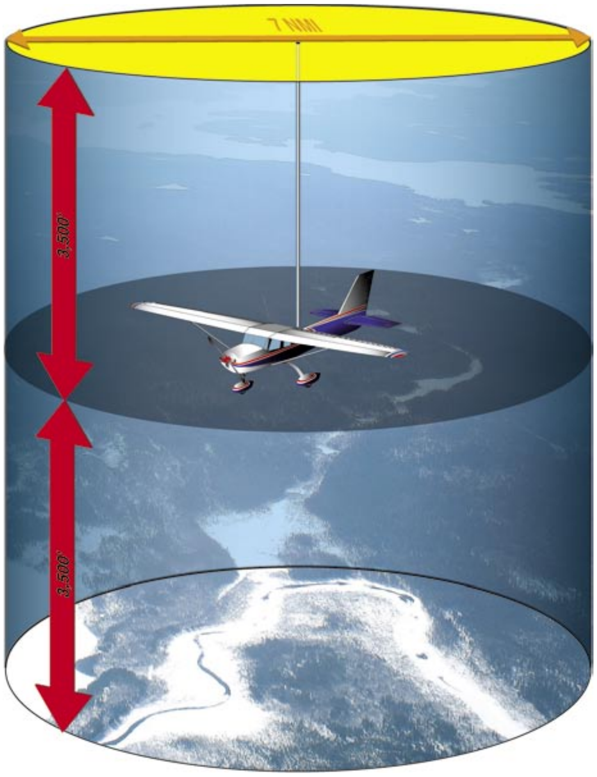
7 NM
3,500'
3,500'

Figure 11-17. *The Area Surrounding the Aircraft for Coverage Using TIS.*

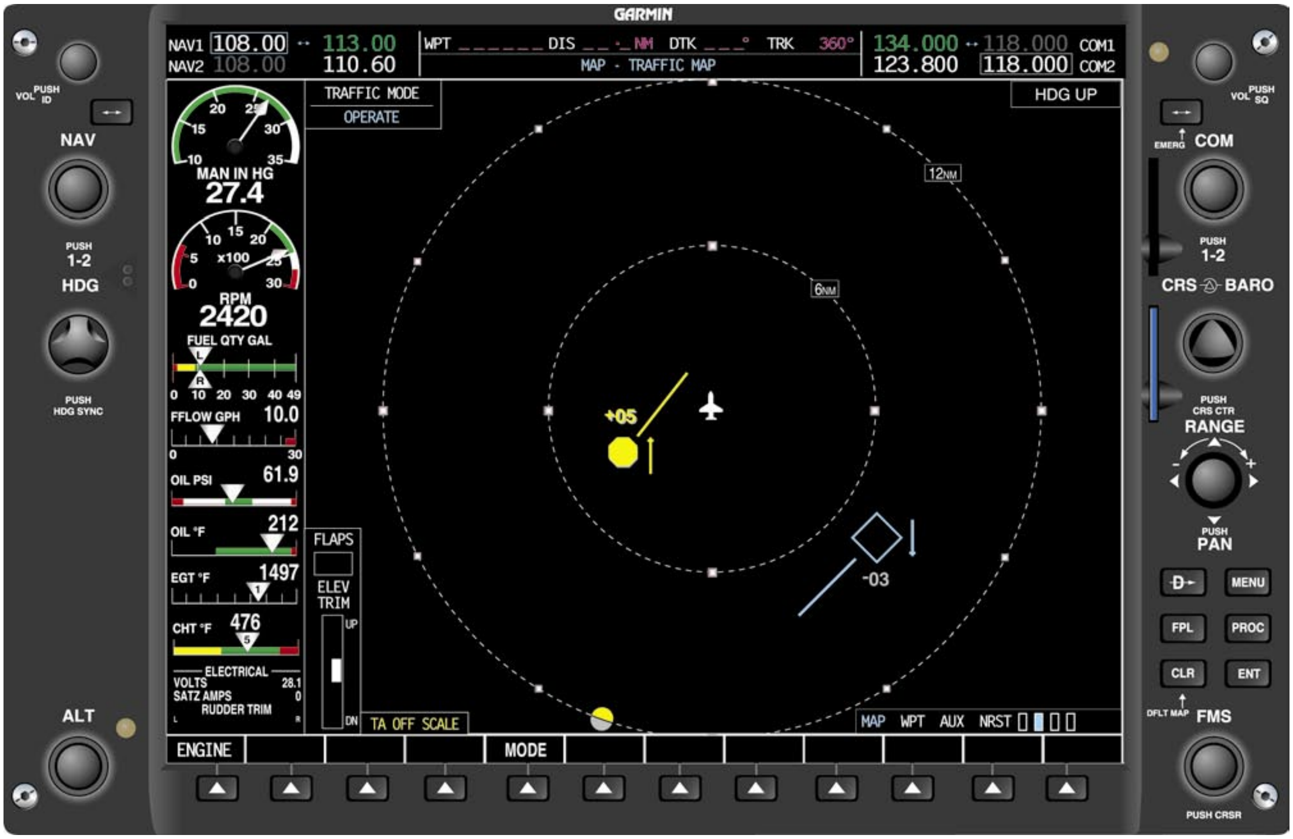
GARMIN
NAV1 108.00 ↔ 113.00
NAV2 108.00 110.60
WPT _ _ _ _ _ _ DIS _ _ . _ NM DTK _ _ _° TRK 360°
MAP - TRAFFIC MAP
134.000 ↔ 118.000 COM1
123.800 118.000 COM2
TRAFFIC MODE
OPERATE
HDG UP
12NM
6NM
+05
-03
MAN IN HG
27.4
RPM
2420
FUEL QTY GAL
FFLOW GPH 10.0
OIL PSI 61.9
OIL °F 212
EGT °F 1497
CHT °F 476
ELECTRICAL
VOLTS 28.1
SATZ AMPS 0
RUDDER TRIM
FLAPS
ELEV TRIM
UP
DN
TA OFF SCALE
MAP WPT AUX NRST
ENGINE
MODE
NAV
HDG
ALT
COM
CRS BARO
RANGE
PAN
MENU
FPL
PROC
CLR
ENT
FMS
PUSH CRSR

Figure 11-18. *A Typical Display on Aircraft MFD When Using TIS.*

Appendix A

Clearance Shorthand

The following shorthand system is recommended by the Federal Aviation Administration (FAA). Applicants for the instrument rating may use any shorthand system, in any language, which ensures accurate compliance with air traffic control (ATC) instructions. No shorthand system is required by regulation and no knowledge of shorthand is required for the FAA Knowledge Test; however, because of the vital need for reliable communication between the pilot and controller, clearance information should be unmistakably clear.

The following symbols and contractions represent words and phrases frequently used in clearances. Most are used regularly by ATC personnel. By practicing this shorthand, omitting the parenthetical words, you will be able to copy long clearances as fast as they are read.

Example: CAF ~~M~~→ RH RV V18 ↑40 SQ 0700 DPC 120.4
Cleared as filed, maintain runway heading for radar vector to Victor 18, climb to 4,000, squawk 0700, departure control frequency is 120.4.

Words and Phrases	**Shorthand**
Above	ABV
Above (Altitude, Hundreds of Feet)	$\underline{70}$
Adjust speed to 250 knots	250 K
Advise	ADZ
After (Passing)	<
Airway (Designation)	V26
Airport	A
Alternate Instructions	( )
Altitude 6,000–17,000	60-170
And	&
Approach	AP
Approach Control	APC
Area Navigation	RNAV
Arriving	↓
At	@
At or Above	$\underline{\uparrow}$
At or Below	$\overline{\downarrow}$
(ATC) Advises	CA
(ATC) Clears or Cleared	C
(ATC) Requests	CR
Back Course	BC
Bearing	BR
Before (Reaching, Passing)	>
Below	BLO
Below (Altitude, Hundreds of Feet)	$\overline{70}$
Center	CTR
Clearance Void if Not Off By (Time)	v<
Cleared as Filed	CAF
Cleared to Airport	A
Cleared to Climb/Descend at Pilot's Discretion	PD
Cleared to Cross	X
Cleared to Depart From the Fix	D
Cleared to the Fix	F
Cleared to Hold and Instructions Issued	H
Cleared to Land	L
Cleared to the Outer Marker	O
Climb to (Altitude, Hundreds of Feet)	↑70
Contact Approach	CT
Contact (Denver) Approach Control	(den
Contact (Denver) Center	(DEN
Course	CRS
Cross	X
Cruise	→
Delay Indefinite	DLI
Depart (Direction, if Specified)	T→( )
Departure Control	DPC
Descend To (Altitude, Hundreds of Feet)	↓70
Direct	DR
Direction (Bound)	
Eastbound	EB
Westbound	WB
Northbound	NB
Southbound	SB
Inbound	IB
Outbound	OB
DME Fix (Mile)	$\boxed{21}$
Each	EA
Enter Control Area	△
Estimated Time of Arrival	ETA
Expect	EX
Expect-Further-Clearance	EFC

Fan Marker	FM
Final	F
Final Approach	FA
Flight Level	FL
Flight Planned Route	FPR
For Further Clearance	FFC
For Further Headings	FFH
From	FM
Ground	GND
GPS Approach	GPS
Heading	HDG
Hold (Direction)	H-W
Holding Pattern	⬭
ILS Approach	ILS
Increase Speed 30 Knots	+30 K
Initial Approach	I
Instrument Departure Procedure	DP
Intersection	XN
Join or Intercept Airway/Jet Route/Track or Course	$\overline{>}$
Left Turn After Takeoff	↰
Locator Outer Marker	LOM
Magnetic	M
Maintain	~~M~~>
Maintain VFR Conditions On Top	$\underline{\text{VFR}}$
Middle Compass Locator	ML
Middle Marker	MM
Missed Approach	MA
Nondirectional Beacon Approach	NDB
Out of (Leave) Control Area	△↗
Outer Marker	OM
Over (Station)	$\underline{\text{OKC}}$
On Course	OC
Precision Approach Radar	PAR
Procedure Turn	PT
Radar Vector	RV
Radial (080° Radial)	080R
Reduce Speed 20 Knots	-20 K
Remain This Frequency	RTF
Remain Well to Left Side	LS
Remain Well to Right Side	RS
Report Crossing	RX
Report Departing	RD
Report Leaving	RL
Report on Course	R-CRS
Report Over	RO
Report Passing	RP
Report Reaching	RR
Report Starting Procedure Turn	RSPT
Reverse Course	RC
Right Turn After Takeoff	↱
Runway Heading	RH
Runway (Number)	RY18
Squawk	SQ
Standby	STBY
Straight-in Approach	SI
Surveillance Radar Approach	ASR
Takeoff (Direction)	T→N
Tower	Z
Turn Left	TL
Turn Right	TR
Until	/
Until Advised (By)	UA
Until Further Advised	UFA
VFR Conditions On Top	OTP
Via	VIA
Victor (Airway Number)	V14
Visual Approach	VA
VOR	⊙
VOR Approach	VR
VORTAC	Ⓣ
While in Control Area	△

Appendix B

Instrument Training Lesson Guide

Introduction

Flight instructors may use this guide in the development of lesson plans. The lessons are arranged in a logical learning sequence and use the building-block technique. Each lesson includes ground training appropriate to the flight portion of the lesson. It is vitally important that the flight instructor brief the student on the objective of the lesson and how it will be accomplished. Debriefing the student's performance is also necessary to motivate further progress. To ensure steady progress, student pilots should master the objective of each lesson before advancing to the next lesson. Lessons should be arranged to take advantage of each student's knowledge and skills.

Flight instructors must monitor progress closely during training to guide student pilots in how to properly divide their attention. The importance of this division of attention or "cross-check" cannot be overemphasized. Cross-check and proper instrument interpretation are essential components of "attitude instrument flying" that enables student pilots to accurately visualize the aircraft's attitude at all times.

When possible, each lesson should incorporate radio communications, basic navigation, and emergency procedures so the student pilot is exposed to the entire IFR experience with each flight. Cross-reference the Instrument Training Lesson Guide with this handbook and the Instrument Practical Test Standards for a comprehensive instrument rating training program.

Lesson 1—Ground and flight evaluation of student's knowledge and performance

Aircraft systems
Aircraft performance
Preflight planning
Use of checklists
Basic flight maneuvers
Radio communications procedures
Navigation systems

Lesson 2—Preflight preparation and flight by reference to instruments

Ground Training

Instrument system preflight procedures
Attitude instrument flying
Fundamental instrument skills
Instrument cross-check techniques

Flight Training

Aircraft and instrument preflight inspection
Use of checklists
Fundamental instrument skills
Basic flight maneuvers
Instrument approach (demonstrated)
Postflight procedures

Lesson 3—Flight instruments and human factors

Ground Training

Human factors
Flight instruments and systems
Aircraft systems
Navigation instruments and systems

Flight Training

Aircraft and instrument preflight inspection
Radio communications
Checklist procedures
Attitude instrument flying
Fundamental instrument skills
Basic flight maneuvers
Spatial disorientation demonstration
Navigation systems
Postflight procedures

Lesson 4—Attitude instrument flying

Ground Training

Human factors
Flight instruments and systems

Aircraft systems
Navigation instruments and systems
Attitude instrument flying
Fundamental instrument skills
Basic flight maneuvers

Flight Training

Aircraft and instrument preflight inspection
Checklist procedures
Radio communications
Attitude instrument flying
Fundamental instrument skills
Basic flight maneuvers
Spatial disorientation
Navigation
Postflight procedures

Lesson 5—Aerodynamic factors and basic flight maneuvers

Ground Training

Basic aerodynamic factors
Basic instrument flight patterns
Emergency procedures

Flight Training

Aircraft and instrument preflight inspection
Checklist procedures
Radio communications
Basic instrument flight patterns
Emergency procedures
Navigation
Postflight procedures

Lesson 6—Partial panel operations

Ground Training

ATC system
Flight instruments
Partial panel operations

Flight Training

Aircraft and instrument preflight inspection
Checklist procedures
Radio communications
Basic instrument flight patterns
Emergency procedures
Partial panel practice
Navigation
Postflight procedures

Lesson 7—Recovery from unusual attitudes

Ground Training

Attitude instrument flying
ATC system
NAS overview

Flight Training

Preflight
Aircraft and instrument preflight inspection
Checklist procedures
Radio communications
Instrument takeoff
Navigation
Partial panel practice
Recovery from unusual attitudes
Postflight procedures

Lesson 8—Navigation systems

Ground Training

ATC clearances
Departure procedures
IFR en route charts

Flight Training

Aircraft and instrument preflight inspection
Checklist procedures
Radio communications
Intercepting and tracking
Holding
Postflight procedures

Lesson 9—Review and practice

Ground Training

Aerodynamic factors
Flight instruments and systems
Attitude instrument flying
Navigation systems
NAS
ATC
Emergency procedures

Flight Training

Aircraft and instrument preflight inspection
Checklist procedures
Radio communications
Review and practice as determined by the flight instructor

Instrument takeoff
Radio communications
Navigation systems
Emergency procedures
Postflight procedures

Lessons 10 through 19—Orientation, intercepting, tracking, and holding using each navigation system installed in the aircraft

Ground Training

Preflight planning
Navigation systems
NAS
ATC
Emergencies

Flight Training

Aircraft and instrument preflight inspection
Checklist procedures
Radio communications
Departure procedures
En route navigation
Terminal operations
Partial panel operation
Instrument approach
Missed approach
Approach to a landing
Postflight procedures

Lessons 20 and 21—Cross-country flights

Ground Training

Preflight planning
Aircraft performance
Navigation systems
NAS
ATC
Emergencies

Flight Training

Emergency procedures
Partial panel operation
Aircraft and instrument preflight inspection
Checklist procedures
Radio communications
Departure procedures
En route navigation
Terminal operations
Instrument approach
Missed approach
Approach to a landing
Postflight procedures

Lessons 22 and 23—Review and practice

Ground Training

Human factors
Aerodynamic factors
Flight instruments and systems
Attitude instrument flying
Basic flight maneuvers
Navigation systems
NAS
ATC
Emergency operations

Flight Training

Aircraft and instrument preflight inspection
Checklist procedures
Radio communications
Review and practice as determined by the flight instructor
Instrument takeoff
Partial panel operations
Unusual attitude recoveries
Radio communications
Navigation systems
Emergency procedures
Postflight procedures

Lessons 24 and subsequent—Practical test preparation

Ground Training

Title 14 of the Code of Federal Regulations (14 CFR) parts 61, 71, 91, 95, and 97
Instrument Flying Handbook
Practical test standards
Administrative requirements
Equipment requirements
Applicant’s requirements

Flight Training

Review and practice until the student can consistently perform all required tasks in accordance with the appropriate practical test standards.

NOTE: It is the recommending instructor’s responsibility to ensure that the applicant meets 14 CFR part 61 requirements and is prepared for the practical test, including: training, knowledge, experience, and the appropriate instructor endorsements.

Glossary

Absolute accuracy. The ability to determine present position in space independently, and is most often used by pilots.

Absolute altitude. The actual distance between an aircraft and the terrain over which it is flying.

Absolute pressure. Pressure measured from the reference of zero pressure, or a vacuum.

A.C. Alternating current.

Acceleration error. A magnetic compass error apparent when the aircraft accelerates while flying on an easterly or westerly heading, causing the compass card to rotate toward North.

Accelerometer. A part of an inertial navigation system (INS) that accurately measures the force of acceleration in one direction.

ADF. See automatic direction finder.

ADI. See attitude director indicator.

ADM. See aeronautical decision-making.

ADS–B. See automatic dependent surveillance–broadcast.

Adverse yaw. A flight condition at the beginning of a turn in which the nose of the aircraft starts to move in the direction opposite the direction the turn is being made, caused by the induced drag produced by the downward-deflected aileron holding back the wing as it begins to rise.

Aeronautical decision-making (ADM). A systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances.

A/FD. See Airport/Facility Directory.

Agonic line. An irregular imaginary line across the surface of the Earth along which the magnetic and geographic poles are in alignment, and along which there is no magnetic variation.

Aircraft approach category. A performance grouping of aircraft based on a speed of 1.3 times the stall speed in the landing configuration at maximum gross landing weight.

Air data computer (ADC). An aircraft computer that receives and processes pitot pressure, static pressure, and temperature to calculate very precise altitude, indicated airspeed, true airspeed, and air temperature.

AIRMET. Inflight weather advisory issued as an amendment to the area forecast, concerning weather phenomena of operational interest to all aircraft and that is potentially hazardous to aircraft with limited capability due to lack of equipment, instrumentation, or pilot qualifications.

Airport diagram. The section of an instrument approach procedure chart that shows a detailed diagram of the airport. This diagram includes surface features and airport configuration information.

Airport/Facility Directory (A/FD). An FAA publication containing information on all airports, communications, and NAVAIDs.

Airport surface detection equipment (ASDE). Radar equipment specifically designed to detect all principal features and traffic on the surface of an airport, presenting the entire image on the control tower console; used to augment visual observation by tower personnel of aircraft and/or vehicular movements on runways and taxiways.

Airport surveillance radar (ASR). Approach control radar used to detect and display an aircraft's position in the terminal area.

Airport surveillance radar approach. An instrument approach in which ATC issues instructions for pilot compliance based on aircraft position in relation to the final approach course and the distance from the end of the runway as displayed on the controller's radar scope.

Air route surveillance radar (ARSR). Air route traffic control center (ARTCC) radar used primarily to detect and display an aircraft's position while en route between terminal areas.

Air route traffic control center (ARTCC). Provides ATC service to aircraft operating on IFR flight plans within controlled airspace and principally during the en route phase of flight.

Airspeed indicator. A differential pressure gauge that measures the dynamic pressure of the air through which the aircraft is flying. Displays the craft's airspeed, typically in knots, to the pilot.

Air traffic control radar beacon system (ATCRBS). Sometimes called secondary surveillance radar (SSR), which utilizes a transponder in the aircraft. The ground equipment is an interrogating unit, in which the beacon antenna is mounted so it rotates with the surveillance antenna. The interrogating unit transmits a coded pulse sequence that actuates the aircraft transponder. The transponder answers the coded sequence by transmitting a preselected coded sequence back to the ground equipment, providing a strong return signal and positive aircraft identification, as well as other special data.

Airway. An airway is based on a centerline that extends from one navigation aid or intersection to another navigation aid (or through several navigation aids or intersections); used to establish a known route for en route procedures between terminal areas.

Alert area. An area in which there is a high volume of pilot training or an unusual type of aeronautical activity.

Almanac data. Information the global positioning system (GPS) receiver can obtain from one satellite which describes the approximate orbital positioning of all satellites in the constellation. This information is necessary for the GPS receiver to know what satellites to look for in the sky at a given time.

ALS. See approach lighting system.

Alternate airport. An airport designated in an IFR flight plan, providing a suitable destination if a landing at the intended airport becomes inadvisable.

Alternate static source valve. A valve in the instrument static air system that supplies reference air pressure to the altimeter, airspeed indicator, and vertical speed indicator if the normal static pickup should become clogged or iced over.

Altimeter setting. Station pressure (the barometric pressure at the location the reading is taken) which has been corrected for the height of the station above sea level.

AME. See aviation medical examiner.

Amendment status. The circulation date and revision number of an instrument approach procedure, printed above the procedure identification.

Ammeter. An instrument installed in series with an electrical load used to measure the amount of current flowing through the load.

Aneroid. The sensitive component in an altimeter or barometer that measures the absolute pressure of the air. It is a sealed, flat capsule made of thin disks of corrugated metal soldered together and evacuated by pumping all of the air out of it.

Aneroid barometer. An instrument that measures the absolute pressure of the atmosphere by balancing the weight of the air above it against the spring action of the aneroid.

Angle of attack. The acute angle formed between the chord line of an airfoil and the direction of the air striking the airfoil.

Anti-ice. Preventing the accumulation of ice on an aircraft structure via a system designed for that purpose.

Approach lighting system (ALS). Provides lights that will penetrate the atmosphere far enough from touchdown to give directional, distance, and glide path information for safe transition from instrument to visual flight.

Area chart. Part of the low-altitude en route chart series, this chart furnishes terminal data at a larger scale for congested areas.

Area navigation (RNAV). Allows a pilot to fly a selected course to a predetermined point without the need to overfly ground-based navigation facilities, by using waypoints.

ARSR. See air route surveillance radar.

ARTCC. See air route traffic control center.

ASDE. See airport surface detection equipment.

ASOS. See automated surface observing station.

ASR. See airport surveillance radar.

ATC. Air Traffic Control.

ATCRBS. See air traffic control radar beacon system.

ATIS. See automatic terminal information service.

Atmospheric propagation delay. A bending of the electromagnetic (EM) wave from the satellite that creates an error in the GPS system.

Attitude and heading reference systems (AHRS). System composed of three-axis sensors that provide heading, attitude, and yaw information for aircraft. AHRS are designed to replace traditional mechanical gyroscopic flight instruments and provide superior reliability and accuracy.

Attitude director indicator (ADI). An aircraft attitude indicator that incorporates flight command bars to provide pitch and roll commands.

Attitude indicator. The foundation for all instrument flight, this instrument reflects the airplane's attitude in relation to the horizon.

Attitude instrument flying. Controlling the aircraft by reference to the instruments rather than by outside visual cues.

Autokinesis. Nighttime visual illusion that a stationary light is moving, which becomes apparent after several seconds of staring at the light.

Automated Weather Observing System (AWOS). Automated weather reporting system consisting of various sensors, a processor, a computer-generated voice subsystem, and a transmitter to broadcast weather data.

Automated Surface Observing Station (ASOS). Weather reporting system which provides surface observations every minute via digitized voice broadcasts and printed reports.

Automatic dependent surveillance–broadcast (ADS-B). A device used in aircraft that repeatedly broadcasts a message that includes position (such as latitude, longitude, and altitude), velocity, and possibly other information.

Automatic direction finder (ADF). Electronic navigation equipment that operates in the low- and medium-frequency bands. Used in conjunction with the ground-based nondirectional beacon (NDB), the instrument displays the number of degrees clockwise from the nose of the aircraft to the station being received.

Automatic terminal information service (ATIS). The continuous broadcast of recorded non-control information in selected terminal areas. Its purpose is to improve controller effectiveness and relieve frequency congestion by automating repetitive transmission of essential but routine information.

Aviation medical examiner (AME). A physician with training in aviation medicine designated by the Civil Aerospace Medical Institute (CAMI).

AWOS. See automated weather observing system.

Azimuth card. A card that may be set, gyroscopically controlled, or driven by a remote compass.

Back course (BC). The reciprocal of the localizer course for an ILS. When flying a back-course approach, an aircraft approaches the instrument runway from the end at which the localizer antennas are installed.

Baro-aiding. A method of augmenting the GPS integrity solution by using a non-satellite input source. To ensure that baro-aiding is available, the current altimeter setting must be entered as described in the operating manual.

Barometric scale. A scale on the dial of an altimeter to which the pilot sets the barometric pressure level from which the altitude shown by the pointers is measured.

BC. See back course.

Block altitude. A block of altitudes assigned by ATC to allow altitude deviations; for example, "Maintain block altitude 9 to 11 thousand."

Cage. The black markings on the ball instrument indicating its neutral position.

Calibrated. The instrument indication compared with a standard value to determine the accuracy of the instrument.

Calibrated orifice. A hole of specific diameter used to delay the pressure change in the case of a vertical speed indicator.

Calibrated airspeed. The speed at which the aircraft is moving through the air, found by correcting IAS for instrument and position errors.

CAS. Calibrated airspeed.

CDI. Course deviation indicator.

Changeover point (COP). A point along the route or airway segment between two adjacent navigation facilities or waypoints where changeover in navigation guidance should occur.

Circling approach. A maneuver initiated by the pilot to align the aircraft with a runway for landing when a straight-in landing from an instrument approach is not possible or is not desirable.

Class A airspace. Airspace from 18,000 feet MSL up to and including FL 600, including the airspace overlying the waters within 12 NM of the coast of the 48 contiguous states and Alaska; and designated international airspace beyond 12 NM of the coast of the 48 contiguous states and Alaska within areas of domestic radio navigational signal or ATC radar coverage, and within which domestic procedures are applied.

Class B airspace. Airspace from the surface to 10,000 feet MSL surrounding the nation's busiest airports in terms of IFR operations or passenger numbers. The configuration of each Class B airspace is individually tailored and consists of a surface area and two or more layers, and is designed to contain all published instrument procedures once an aircraft enters the airspace. For all aircraft, an ATC clearance is required to operate in the area, and aircraft so cleared receive separation services within the airspace.

Class C airspace. Airspace from the surface to 4,000 feet above the airport elevation (charted in MSL) surrounding those airports having an operational control tower, serviced by radar approach control, and having a certain number of IFR operations or passenger numbers. Although the configuration of each Class C airspace area is individually tailored, the airspace usually consists of a 5 NM radius core surface area that extends from the surface up to 4,000 feet above the airport elevation, and a 10 NM radius shelf area that extends from 1,200 feet to 4,000 feet above the airport elevation.

Class D airspace. Airspace from the surface to 2,500 feet above the airport elevation (charted in MSL) surrounding those airports that have an operational control tower. The configuration of each Class D airspace area is individually tailored, and when instrument procedures are published, the airspace is normally designed to contain the procedures.

Class E airspace. Airspace that is not Class A, Class B, Class C, or Class D, and is controlled airspace.

Class G airspace. Airspace that is uncontrolled, except when associated with a temporary control tower, and has not been designated as Class A, Class B, Class C, Class D, or Class E airspace.

Clean configuration. A configuration in which all flight control surfaces have been placed to create minimum drag. In most aircraft this means flaps and gear retracted.

Clearance. ATC permission for an aircraft to proceed under specified traffic conditions within controlled airspace, for the purpose of providing separation between known aircraft.

Clearance delivery. Control tower position responsible for transmitting departure clearances to IFR flights.

Clearance limit. The fix, point, or location to which an aircraft is cleared when issued an air traffic clearance.

Clearance on request. An IFR clearance not yet received after filing a flight plan.

Clearance void time. Used by ATC, the time at which the departure clearance is automatically canceled if takeoff has not been made. The pilot must obtain a new clearance or cancel the IFR flight plan if not off by the specified time.

Clear ice. Glossy, clear, or translucent ice formed by the relatively slow freezing of large, supercooled water droplets.

Compass course. A true course corrected for variation and deviation errors.

Compass locator. A low-power, low- or medium-frequency (L/MF) radio beacon installed at the site of the outer or middle marker of an ILS.

Compass rose. A small circle graduated in 360° increments, printed on navigational charts to show the amount of compass variation at different locations, or on instruments to indicate direction.

Computer navigation fix. A point used to define a navigation track for an airborne computer system such as GPS or FMS.

Concentric rings. Dashed-line circles depicted in the plan view of IAP charts, outside of the reference circle, that show en route and feeder facilities.

Cone of confusion. A cone-shaped volume of airspace directly above a VOR station where no signal is received, causing the CDI to fluctuate.

Control and performance. A method of attitude instrument flying in which one instrument is used for making attitude changes, and the other instruments are used to monitor the progress of the change.

Control display unit. A display interfaced with the master computer, providing the pilot with a single control point for all navigations systems, thereby reducing the number of required flight deck panels.

Controlled airspace. An airspace of defined dimensions within which ATC service is provided to IFR and VFR flights in accordance with the airspace classification. It includes Class A, Class B, Class C, Class D, and Class E airspace.

Control pressures. The amount of physical exertion on the control column necessary to achieve the desired attitude.

Convective weather. Unstable, rising air found in cumiliform clouds.

Convective SIGMET. Weather advisory concerning convective weather significant to the safety of all aircraft, including thunderstorms, hail, and tornadoes.

Coordinated flight. Flight with a minimum disturbance of the forces maintaining equilibrium, established via effective control use.

COP. See changeover point.

Coriolis illusion. The illusion of rotation or movement in an entirely different axis, caused by an abrupt head movement, while in a prolonged constant rate turn that has ceased stimulating the brain's motion sensing system.

Crew resource management (CRM). The effective use of all available resources—human, hardware, and information.

Critical areas. Areas where disturbances to the ILS localizer and glide slope courses may occur when surface vehicles or aircraft operate near the localizer or glide slope antennas.

CRM. See crew resource management.

Cross-check. The first fundamental skill of instrument flight, also known as "scan," the continuous and logical observation of instruments for attitude and performance information.

Cruise clearance. An ATC clearance issued to allow a pilot to conduct flight at any altitude from the minimum IFR altitude up to and including the altitude specified in the clearance. Also authorizes a pilot to proceed to and make an approach at the destination airport.

Current induction. An electrical current being induced into, or generated in, any conductor that is crossed by lines of flux from any magnet.

DA. See decision altitude.

D.C. Direct current.

Dark adaptation. Physical and chemical adjustments of the eye that make vision possible in relative darkness.

Deceleration error. A magnetic compass error that occurs when the aircraft decelerates while flying on an easterly or westerly heading, causing the compass card to rotate toward South.

Decision altitude (DA). A specified altitude in the precision approach, charted in feet MSL, at which a missed approach must be initiated if the required visual reference to continue the approach has not been established.

Decision height (DH). A specified altitude in the precision approach, charted in height above threshold elevation, at which a decision must be made either to continue the approach or to execute a missed approach.

Deice. The act of removing ice accumulation from an aircraft structure.

Density altitude. Pressure altitude corrected for nonstandard temperature. Density altitude is used in computing the performance of an aircraft and its engines.

Departure procedure (DP). Preplanned IFR ATC departure, published for pilot use, in textual and graphic format.

Deviation. A magnetic compass error caused by local magnetic fields within the aircraft. Deviation error is different on each heading.

DGPS. Differential global positioning system.

DH. See decision height.

Differential Global Positioning System (DGPS). A system that improves the accuracy of Global Navigation Satellite Systems (GNSS) by measuring changes in variables to provide satellite positioning corrections.

Direct indication. The true and instantaneous reflection of aircraft pitch-and-bank attitude by the miniature aircraft, relative to the horizon bar of the attitude indicator.

Direct User Access Terminal System (DUATS). A system that provides current FAA weather and flight plan filing services to certified civil pilots, via personal computer, modem, or telephone access to the system. Pilots can request specific types of weather briefings and other pertinent data for planned flights.

Distance circle. See reference circle.

Distance measuring equipment (DME). A pulse-type electronic navigation system that shows the pilot, by an instrument-panel indication, the number of nautical miles between the aircraft and a ground station or waypoint.

DME. See distance measuring equipment.

DME arc. A flight track that is a constant distance from the station or waypoint.

DOD. Department of Defense.

Doghouse. A turn-and-slip indicator dial mark in the shape of a doghouse.

Domestic Reduced Vertical Separation Minimum (DRVSM). Additional flight levels between FL 290 and FL 410 to provide operational, traffic, and airspace efficiency.

Double gimbal. A type of mount used for the gyro in an attitude instrument. The axes of the two gimbals are at right angles to the spin axis of the gyro, allowing free motion in two planes around the gyro.

DP. See departure procedure.

Drag. The net aerodynamic force parallel to the relative wind, usually the sum of two components: induced drag and parasite drag.

Drag curve. The curve created when plotting induced drag and parasite drag.

DUATS. See direct user access terminal system.

Duplex. Transmitting on one frequency and receiving on a separate frequency.

Eddy currents. Current induced in a metal cup or disc when it is crossed by lines of flux from a moving magnet.

EFAS. See En Route Flight Advisory Service.

EFC. See expect-further-clearance.

Electronic flight display (EFD). For the purpose of standardization, any flight instrument display that uses LCD or other image-producing system (Cathode Ray Tube [CRT], etc.)

Elevator illusion. The sensation of being in a climb or descent, caused by the kind of abrupt vertical accelerations that result from up- or downdrafts.

Emergency. A distress or urgent condition.

Emphasis error. The result of giving too much attention to a particular instrument during the cross-check, instead of relying on a combination of instruments necessary for attitude and performance information.

EM wave. Electromagnetic wave.

Encoding altimeter. A special type of pressure altimeter used to send a signal to the air traffic controller on the ground, showing the pressure altitude the aircraft is flying.

En route facilities ring. Depicted in the plan view of IAP charts, a circle which designates NAVAIDs, fixes, and intersections that are part of the en route low altitude airway structure.

En Route Flight Advisory Service (EFAS). An en route weather-only AFSS service.

En route high-altitude charts. Aeronautical charts for en route instrument navigation at or above 18,000 feet MSL.

En route low-altitude charts. Aeronautical charts for en route IFR navigation below 18,000 feet MSL.

Equivalent airspeed. Airspeed equivalent to CAS in standard atmosphere at sea level. As the airspeed and pressure altitude increase, the CAS becomes higher than it should be, and a correction for compression must be subtracted from the CAS.

Expect-further-clearance (EFC). The time a pilot can expect to receive clearance beyond a clearance limit.

FAA. Federal Aviation Administration.

FAF. See final approach fix.

False horizon. Inaccurate visual information for aligning the aircraft, caused by various natural and geometric formations that disorient the pilot from the actual horizon.

Federal airways. Class E airspace areas that extend upward from 1,200 feet to, but not including, 18,000 feet MSL, unless otherwise specified.

Feeder facilities. Used by ATC to direct aircraft to intervening fixes between the en route structure and the initial approach fix.

Final approach. Part of an instrument approach procedure in which alignment and descent for landing are accomplished.

Final approach fix (FAF). The fix from which the IFR final approach to an airport is executed, and which identifies the beginning of the final approach segment. An FAF is designated on government charts by a Maltese cross symbol for nonprecision approaches, and a lightning bolt symbol for precision approaches.

Fixating. Staring at a single instrument, thereby interrupting the cross-check process.

FL. See flight level.

Flight configurations. Adjusting the aircraft control surfaces (including flaps and landing gear) in a manner that will achieve a specified attitude.

Flight director indicator (FDI). One of the major components of a flight director system, it provides steering commands that the pilot (or the autopilot, if coupled) follows.

Flight level (FL). A measure of altitude (in hundreds of feet) used by aircraft flying above 18,000 feet with the altimeter set at 29.92" Hg.

Flight management system (FMS). Provides pilot and crew with highly accurate and automatic long-range navigation capability, blending available inputs from long- and short-range sensors.

Flight path. The line, course, or track along which an aircraft is flying or is intended to be flown.

Flight patterns. Basic maneuvers, flown by reference to the instruments rather than outside visual cues, for the purpose of practicing basic attitude flying. The patterns simulate maneuvers encountered on instrument flights such as holding patterns, procedure turns, and approaches.

Flight strips. Paper strips containing instrument flight information, used by ATC when processing flight plans.

FMS. See flight management system.

Form drag. The drag created because of the shape of a component or the aircraft.

Fundamental skills. Pilot skills of instrument cross-check, instrument interpretation, and aircraft control.

Glide slope (GS). Part of the ILS that projects a radio beam upward at an angle of approximately 3° from the approach end of an instrument runway. The glide slope provides vertical guidance to aircraft on the final approach course for the aircraft to follow when making an ILS approach along the localizer path.

Glide slope intercept altitude. The minimum altitude of an intermediate approach segment prescribed for a precision approach that ensures obstacle clearance.

Global landing system (GLS). An instrument approach with lateral and vertical guidance with integrity limits (similar to barometric vertical navigation (BRO VNAV).

Global navigation satellite systems (GNSS). Satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. It allows small electronic receivers to determine their location (longitude, latitude, and altitude) to within a few meters using time signals transmitted along a line of sight by radio from satellites.

GNSS. See global navigation satellite systems.

Global positioning system (GPS). Navigation system that uses satellite rather than ground-based transmitters for location information.

Goniometer. As used in radio frequency (RF) antenna systems, a direction-sensing device consisting of two fixed loops of wire oriented 90° from each other, which separately sense received signal strength and send those signals to two rotors (also oriented 90°) in the sealed direction-indicating instrument. The rotors are attached to the direction-indicating needle of the instrument and rotated by a small motor until minimum magnetic field is sensed near the rotors.

GPS. See global positioning system.

GPS Approach Overlay Program. An authorization for pilots to use GPS avionics under IFR for flying designated existing nonprecision instrument approach procedures, with the exception of LOC, LDA, and SDF procedures.

Graveyard spiral. The illusion of the cessation of a turn while still in a prolonged, coordinated, constant rate turn, which can lead a disoriented pilot to a loss of control of the aircraft.

Great circle route. The shortest distance across the surface of a sphere (the Earth) between two points on the surface.

Ground proximity warning system (GPWS). A system designed to determine an aircraft's clearance above the Earth and provides limited predictability about aircraft position relative to rising terrain.

Groundspeed. Speed over the ground, either closing speed to the station or waypoint, or speed over the ground in whatever direction the aircraft is going at the moment, depending upon the navigation system used.

GS. See glide slope.

GWPS. See ground proximity warning system.

HAA. See height above airport.

HAL. See height above landing.

HAT. See height above touchdown elevation.

Hazardous attitudes. Five aeronautical decision-making attitudes that may contribute to poor pilot judgment: antiauthority, impulsivity, invulnerability, machismo, and resignation.

Hazardous Inflight Weather Advisory Service (HIWAS). Service providing recorded weather forecasts broadcast to airborne pilots over selected VORs.

Head-up display (HUD). A special type of flight viewing screen that allows the pilot to watch the flight instruments and other data while looking through the windshield of the aircraft for other traffic, the approach lights, or the runway.

Height above airport (HAA). The height of the MDA above the published airport elevation.

Height above landing (HAL). The height above a designated helicopter landing area used for helicopter instrument approach procedures.

Height above touchdown elevation (HAT). The DA/DH or MDA above the highest runway elevation in the touchdown zone (first 3,000 feet of the runway).

HF. High frequency.

Hg. Abbreviation for mercury, from the Latin hydrargyrum.

HIWAS. See Hazardous Inflight Weather Advisory Service.

Holding. A predetermined maneuver that keeps aircraft within a specified airspace while awaiting further clearance from ATC.

Holding pattern. A racetrack pattern, involving two turns and two legs, used to keep an aircraft within a prescribed airspace with respect to a geographic fix. A standard pattern uses right turns; nonstandard patterns use left turns.

Homing. Flying the aircraft on any heading required to keep the needle pointing to the 0° relative bearing position.

Horizontal situation indicator (HSI). A flight navigation instrument that combines the heading indicator with a CDI, in order to provide the pilot with better situational awareness of location with respect to the courseline.

HSI. See horizontal situation indicator.

HUD. See head-up display.

Human factors. A multidisciplinary field encompassing the behavioral and social sciences, engineering, and physiology, to consider the variables that influence individual and crew performance for the purpose of optimizing human performance and reducing errors.

Hypoxia. A state of oxygen deficiency in the body sufficient to impair functions of the brain and other organs.

IAF. See initial approach fix.

IAP. See instrument approach procedures.

IAS. See indicated airspeed.

ICAO. See International Civil Aviation Organization.

Ident. Air Traffic Control request for a pilot to push the button on the transponder to identify return on the controller's scope.

IFR. See instrument flight rules.

ILS. See instrument landing system.

ILS categories. Categories of instrument approach procedures allowed at airports equipped with the following types of instrument landing systems:

> **ILS Category I:** Provides for approach to a height above touchdown of not less than 200 feet, and with runway visual range of not less than 1,800 feet.
>
> **ILS Category II:** Provides for approach to a height above touchdown of not less than 100 feet and with runway visual range of not less than 1,200 feet.
>
> **ILS Category IIIA:** Provides for approach without a decision height minimum and with runway visual range of not less than 700 feet.
>
> **ILS Category IIIB:** Provides for approach without a decision height minimum and with runway visual range of not less than 150 feet.
>
> **ILS Category IIIC:** Provides for approach without a decision height minimum and without runway visual range minimum.

IMC. See instrument meteorological conditions.

Indicated airspeed (IAS). Shown on the dial of the instrument airspeed indicator on an aircraft. Directly related to calibrated airspeed (CAS), IAS includes instrument errors and position error.

Indirect indication. A reflection of aircraft pitch-and-bank attitude by the instruments other than the attitude indicator.

Induced drag. Drag caused by the same factors that produce lift; its amount varies inversely with airspeed. As airspeed decreases, the angle of attack must increase, in turn increasing induced drag.

Induction icing. A type of ice in the induction system that reduces the amount of air available for combustion. The most commonly found induction icing is carburetor icing.

Inertial navigation system (INS). A computer-based navigation system that tracks the movement of an aircraft via signals produced by onboard accelerometers. The initial location of the aircraft is entered into the computer, and all subsequent movement of the aircraft is sensed and used to keep the position updated. An INS does not require any inputs from outside signals.

Initial approach fix (IAF). The fix depicted on IAP charts where the instrument approach procedure (IAP) begins unless otherwise authorized by ATC.

Inoperative components. Higher minimums are prescribed when the specified visual aids are not functioning; this information is listed in the Inoperative Components Table found in the United States Terminal Procedures Publications.

INS. See inertial navigation system.

Instantaneous vertical speed indicator (IVSI). Assists in interpretation by instantaneously indicating the rate of climb or descent at a given moment with little or no lag as displayed in a vertical speed indicator (VSI).

Instrument approach procedures (IAP). A series of predetermined maneuvers for the orderly transfer of an aircraft under IFR from the beginning of the initial approach to a landing or to a point from which a landing may be made visually.

Instrument flight rules (IFR). Rules and regulations established by the Federal Aviation Administration to govern flight under conditions in which flight by outside visual reference is not safe. IFR flight depends upon flying by reference to instruments in the flight deck, and navigation is accomplished by reference to electronic signals.

Instrument landing system (ILS). An electronic system that provides both horizontal and vertical guidance to a specific runway, used to execute a precision instrument approach procedure.

Instrument meteorological conditions (IMC). Meteorological conditions expressed in terms of visibility, distance from clouds, and ceiling less than the minimums specified for visual meteorological conditions, requiring operations to be conducted under IFR.

Instrument takeoff. Using the instruments rather than outside visual cues to maintain runway heading and execute a safe takeoff.

Interference drag. Drag generated by the collision of airstreams creating eddy currents, turbulence, or restrictions to smooth flow.

International Civil Aviation Organization (ICAO). The United Nations agency for developing the principles and techniques of international air navigation, and fostering planning and development of international civil air transport.

International standard atmosphere (IAS). A model of standard variation of pressure and temperature.

Inversion illusion. The feeling that the aircraft is tumbling backwards, caused by an abrupt change from climb to straight-and-level flight while in situations lacking visual reference.

Inverter. A solid-state electronic device that converts D.C. into A.C. current of the proper voltage and frequency to operate A.C. gyro instruments.

Isogonic lines. Lines drawn across aeronautical charts to connect points having the same magnetic variation.

IVSI. See instantaneous vertical speed indicator.

Jet route. A route designated to serve flight operations from 18,000 feet MSL up to and including FL 450.

Jet stream. A high-velocity narrow stream of winds, usually found near the upper limit of the troposphere, which flows generally from west to east.

KIAS. Knots indicated airspeed.

Kollsman window. A barometric scale window of a sensitive altimeter used to adjust the altitude for the altimeter setting.

LAAS. See local area augmentation system.

Lag. The delay that occurs before an instrument needle attains a stable indication.

Land as soon as possible. ATC instruction to pilot. Land without delay at the nearest suitable area, such as an open field, at which a safe approach and landing is assured.

Land as soon as practical. ATC instruction to pilot. The landing site and duration of flight are at the discretion of the pilot. Extended flight beyond the nearest approved landing area is not recommended.

Land immediately. ATC instruction to pilot. The urgency of the landing is paramount. The primary consideration is to ensure the survival of the occupants. Landing in trees, water, or other unsafe areas should be considered only as a last resort.

LDA. See localizer-type directional aid.

Lead radial. The radial at which the turn from the DME arc to the inbound course is started.

Leans, the. A physical sensation caused by an abrupt correction of a banked attitude entered too slowly to stimulate the motion sensing system in the inner ear. The abrupt correction can create the illusion of banking in the opposite direction.

Lift. A component of the total aerodynamic force on an airfoil and acts perpendicular to the relative wind.

Lines of flux. Invisible lines of magnetic force passing between the poles of a magnet.

L/MF. See low or medium frequency.

LMM. See locator middle marker.

Load factor. The ratio of a specified load to the total weight of the aircraft. The specified load is expressed in terms of any of the following: aerodynamic forces, inertial forces, or ground or water reactions.

Loadmeter. A type of ammeter installed between the generator output and the main bus in an aircraft electrical system.

LOC. See localizer.

Local area augmentation system (LAAS). A differential global positioning system (DGPS) that improves the accuracy of the system by determining position error from the GPS satellites, then transmitting the error, or corrective factors, to the airborne GPS receiver.

Localizer (LOC). The portion of an ILS that gives left/right guidance information down the centerline of the instrument runway for final approach.

Localizer-type directional aid (LDA). A NAVAID used for nonprecision instrument approaches with utility and accuracy comparable to a localizer but which is not a part of a complete ILS and is not aligned with the runway. Some LDAs are equipped with a glide slope.

Locator middle marker (LMM). Nondirectional radio beacon (NDB) compass locator, collocated with a middle marker (MM).

Locator outer marker (LOM). NDB compass locator, collocated with an outer marker (OM).

LOM. See locator outer marker.

Long range navigation (LORAN). An electronic navigational system by which hyperbolic lines of position are determined by measuring the difference in the time of reception of synchronized pulse signals from two fixed transmitters. LORAN A operates in the 1750 to 1950 kHz frequency band. LORAN C and D operate in the 100 to 110 kHz frequency band.

LORAN. See long range navigation.

Low or medium frequency. A frequency range between 190–535 kHz with the medium frequency above 300 kHz. Generally associated with nondirectional beacons transmitting a continuous carrier with either a 400 or 1,020 Hz modulation.

Lubber line. The reference line used in a magnetic compass or heading indicator.

MAA. See maximum authorized altitude.

Mach number. The ratio of the true airspeed of the aircraft to the speed of sound in the same atmospheric conditions, named in honor of Ernst Mach, late 19th century physicist.

Mach meter. The instrument that displays the ratio of the speed of sound to the true airspeed an aircraft is flying.

Magnetic bearing (MB). The direction to or from a radio transmitting station measured relative to magnetic north.

Magnetic heading (MH). The direction an aircraft is pointed with respect to magnetic north.

Mandatory altitude. An altitude depicted on an instrument approach chart with the altitude value both underscored and overscored. Aircraft are required to maintain altitude at the depicted value.

Mandatory block altitude. An altitude depicted on an instrument approach chart with two underscored and overscored altitude values between which aircraft are required to maintain altitude.

MAP. See missed approach point.

Margin identification. The top and bottom areas on an instrument approach chart that depict information about the procedure, including airport location and procedure identification.

Marker beacon. A low-powered transmitter that directs its signal upward in a small, fan-shaped pattern. Used along the flight path when approaching an airport for landing, marker beacons indicate both aurally and visually when the aircraft is directly over the facility.

Maximum altitude. An altitude depicted on an instrument approach chart with overscored altitude value at which or below aircraft are required to maintain altitude.

Maximum authorized altitude (MAA). A published altitude representing the maximum usable altitude or flight level for an airspace structure or route segment.

MB. See magnetic bearing.

MCA. See minimum crossing altitude.

MDA. See minimum descent altitude.

MEA. See minimum en route altitude.

Mean sea level. The average height of the surface of the sea at a particular location for all stages of the tide over a 19-year period.

MFD. See multi-function display.

MH. See magnetic heading.

MHz. Megahertz.

Microwave landing system (MLS). A precision instrument approach system operating in the microwave spectrum which normally consists of an azimuth station, elevation station, and precision distance measuring equipment.

Mileage breakdown. A fix indicating a course change that appears on the chart as an "x" at a break between two segments of a federal airway.

Military operations area (MOA). Airspace established for the purpose of separating certain military training activities from IFR traffic.

Military training route (MTR). Airspace of defined vertical and lateral dimensions established for the conduct of military training at airspeeds in excess of 250 knots indicated airspeed (KIAS).

Minimum altitude. An altitude depicted on an instrument approach chart with the altitude value underscored. Aircraft are required to maintain altitude at or above the depicted value.

Minimum crossing altitude (MCA). The lowest allowed altitude at certain fixes an aircraft must cross when proceeding in the direction of a higher minimum en route altitude (MEA).

Minimum descent altitude (MDA). The lowest altitude (in feet MSL) to which descent is authorized on final approach, or during circle-to-land maneuvering in execution of a nonprecision approach.

Minimum en route altitude (MEA). The lowest published altitude between radio fixes that ensures acceptable navigational signal coverage and meets obstacle clearance requirements between those fixes.

Minimum obstruction clearance altitude (MOCA). The lowest published altitude in effect between radio fixes on VOR airways, off-airway routes, or route segments, which meets obstacle clearance requirements for the entire route segment and which ensures acceptable navigational signal coverage only within 25 statute (22 nautical) miles of a VOR.

Minimum reception altitude (MRA). The lowest altitude at which an airway intersection can be determined.

Minimum safe altitude (MSA). The minimum altitude depicted on approach charts which provides at least 1,000 feet of obstacle clearance for emergency use within a specified distance from the listed navigation facility.

Minimum vectoring altitude (MVA). An IFR altitude lower than the minimum en route altitude (MEA) that provides terrain and obstacle clearance.

Minimums section. The area on an IAP chart that displays the lowest altitude and visibility requirements for the approach.

Missed approach. A maneuver conducted by a pilot when an instrument approach cannot be completed to a landing.

Missed approach point (MAP). A point prescribed in each instrument approach at which a missed approach procedure shall be executed if the required visual reference has not been established.

Mixed ice. A mixture of clear ice and rime ice.

MLS. See microwave landing system.

MM. Middle marker.

MOA. See military operations area.

MOCA. See minimum obstruction clearance altitude.

Mode C. Altitude reporting transponder mode.

MRA. See minimum reception altitude.

MSA. See minimum safe altitude.

MSL. See mean sea level.

MTR. See military training route.

Multi-function display (MFD). Small screen (CRT or LCD) in an aircraft that can be used to display information to the pilot in numerous configurable ways. Often an MFD will be used in concert with a Primary Flight Display.

MVA. See minimum vectoring altitude.

NACG. See National Aeronautical Charting Group.

NAS. See National Airspace System.

National Airspace System (NAS). The common network of United States airspace—air navigation facilities, equipment and services, airports or landing areas; aeronautical charts, information and services; rules, regulations and procedures, technical information; and manpower and material.

National Aeronautical Charting Group (NACG). A Federal agency operating under the FAA, responsible for publishing charts such as the terminal procedures and en route charts.

National Route Program (NRP). A set of rules and procedures designed to increase the flexibility of user flight planning within published guidelines.

National Security Area (NSA). Areas consisting of airspace of defined vertical and lateral dimensions established at locations where there is a requirement for increased security and safety of ground facilities. Pilots are requested to voluntarily avoid flying through the depicted NSA. When it is necessary to provide a greater level of security and safety, flight in NSAs may be temporarily prohibited. Regulatory prohibitions are disseminated via NOTAMs.

National Transportation Safety Board (NTSB). A United States Government independent organization responsible for investigations of accidents involving aviation, highways, waterways, pipelines, and railroads in the United States. NTSB is charged by congress to investigate every civil aviation accident in the United States.

NAVAID. Naviagtional aid.

NAV/COM. Navigation and communication radio.

NDB. See nondirectional radio beacon.

NM. Nautical mile.

NOAA. National Oceanic and Atmospheric Administration.

No-gyro approach. A radar approach that may be used in case of a malfunctioning gyro-compass or directional gyro. Instead of providing the pilot with headings to be flown, the controller observes the radar track and issues control instructions “turn right/left” or “stop turn,” as appropriate.

Nondirectional radio beacon (NDB). A ground-based radio transmitter that transmits radio energy in all directions.

Nonprecision approach. A standard instrument approach procedure in which only horizontal guidance is provided.

No procedure turn (NoPT). Term used with the appropriate course and altitude to denote that the procedure turn is not required.

NoPT. See no procedure turn.

Notice to Airmen (NOTAM). A notice filed with an aviation authority to alert aircraft pilots of any hazards en route or at a specific location. The authority in turn provides means of disseminating relevant NOTAMs to pilots.

NRP. See National Route Program.

NSA. See National Security Area.

NTSB. See National Transportation Safety Board.

NWS. National Weather Service.

Obstacle departure procedures (ODP). Obstacle clearance protection provided to aircraft in instrument meteorological conditions (IMC).

ODP. See obstacle departure procedures.

OM. Outer marker.

Omission error. The failure to anticipate significant instrument indications following attitude changes; for example, concentrating on pitch control while forgetting about heading or roll information, resulting in erratic control of heading and bank.

Optical illusion. A misleading visual image. For the purpose of this handbook, the term refers to the brain’s misinterpretation of features on the ground associated with landing, which causes a pilot to misread the spatial relationships between the aircraft and the runway.

Orientation. Awareness of the position of the aircraft and of oneself in relation to a specific reference point.

Otolith organ. An inner ear organ that detects linear acceleration and gravity orientation.

Outer marker. A marker beacon at or near the glide slope intercept altitude of an ILS approach. It is normally located four to seven miles from the runway threshold on the extended centerline of the runway.

Overcontrolling. Using more movement in the control column than is necessary to achieve the desired pitch-and bank condition.

Overpower. To use more power than required for the purpose of achieving a faster rate of airspeed change.

P-static. See precipitation static.

PAPI. See precision approach path indicator.

PAR. See precision approach radar.

Parasite drag. Drag caused by the friction of air moving over the aircraft structure; its amount varies directly with the airspeed.

PFD. See primary flight display.

PIC. See pilot-in-command.

Pilot-in-command (PIC). The pilot responsible for the operation and safety of an aircraft.

Pilot report (PIREP). Report of meteorological phenomena encountered by aircraft.

Pilot's Operating Handbook/Airplane Flight Manual (POH/AFM). FAA-approved documents published by the airframe manufacturer that list the operating conditions for a particular model of aircraft.

PIREP. See pilot report.

Pitot pressure. Ram air pressure used to measure airspeed.

Pitot-static head. A combination pickup used to sample pitot pressure and static air pressure.

Plan view. The overhead view of an approach procedure on an instrument approach chart. The plan view depicts the routes that guide the pilot from the en route segments to the IAF.

POH/AFM. See Pilot's Operating Handbook/Airplane Flight Manual.

Point-in-space approach. A type of helicopter instrument approach procedure to a missed approach point more than 2,600 feet from an associated helicopter landing area.

Position error. Error in the indication of the altimeter, ASI, and VSI caused by the air at the static system entrance not being absolutely still.

Position report. A report over a known location as transmitted by an aircraft to ATC.

Precession. The characteristic of a gyroscope that causes an applied force to be felt, not at the point of application, but 90° from that point in the direction of rotation.

Precipitation static (P-static). A form of radio interference caused by rain, snow, or dust particles hitting the antenna and inducing a small radio-frequency voltage into it.

Precision approach. A standard instrument approach procedure in which both vertical and horizontal guidance is provided.

Precision approach path indicator (PAPI). A system of lights similar to the VASI, but consisting of one row of lights in two- or four-light systems. A pilot on the correct glide slope will see two white lights and two red lights. See VASI.

Precision approach radar (PAR). A type of radar used at an airport to guide an aircraft through the final stages of landing, providing horizontal and vertical guidance. The radar operator directs the pilot to change heading or adjust the descent rate to keep the aircraft on a path that allows it to touch down at the correct spot on the runway.

Precision runway monitor (PRM). System allows simultaneous, independent Instrument Flight Rules (IFR) approaches at airports with closely spaced parallel runways.

Preferred IFR routes. Routes established in the major terminal and en route environments to increase system efficiency and capacity. IFR clearances are issued based on these routes, listed in the A/FD except when severe weather avoidance procedures or other factors dictate otherwise.

Pressure altitude. Altitude above the standard 29.92" Hg plane.

Prevailing visibility. The greatest horizontal visibility equaled or exceeded throughout at least half the horizon circle (which is not necessarily continuous).

Primary and supporting. A method of attitude instrument flying using the instrument that provides the most direct indication of attitude and performance.

Primary flight display (PFD). A display that provides increased situational awareness to the pilot by replacing the traditional six instruments used for instrument flight with an easy-to-scan display that provides the horizon, airspeed, altitude, vertical speed, trend, trim, rate of turn among other key relevant indications.

PRM. See precision runway monitor.

Procedure turn. A maneuver prescribed when it is necessary to reverse direction to establish an aircraft on the intermediate approach segment or final approach course.

Profile view. Side view of an IAP chart illustrating the vertical approach path altitudes, headings, distances, and fixes.

Prohibited area. Designated airspace within which flight of aircraft is prohibited.

Propeller/rotor modulation error. Certain propeller RPM settings or helicopter rotor speeds can cause the VOR course deviation indicator (CDI) to fluctuate as much as ±6°. Slight changes to the RPM setting will normally smooth out this roughness.

Rabbit, the. High-intensity flasher system installed at many large airports. The flashers consist of a series of brilliant blue-white bursts of light flashing in sequence along the approach lights, giving the effect of a ball of light traveling towards the runway.

Radar. Radio Detection And Ranging.

Radar approach. The controller provides vectors while monitoring the progress of the flight with radar, guiding the pilot through the descent to the airport/heliport or to a specific runway.

Radials. The courses oriented from a station.

Radio or radar altimeter. An electronic altimeter that determines the height of an aircraft above the terrain by measuring the time needed for a pulse of radio-frequency energy to travel from the aircraft to the ground and return.

Radio frequency (RF). A term that refers to alternating current (AC) having characteristics such that, if the current is input to antenna, an electromagnetic (EM) field is generated suitable for wireless broadcasting and/or communications.

Radio magnetic indicator (RMI). An electronic navigation instrument that combines a magnetic compass card with two bearing pointers (typically). Generally, one pointer is for the ADF while the other is for an RNAV or VOR navigation system. The pointers are typically different colors and of different widths for ease of identification. Sometimes a function switch is provided to allow the #2 pointer to be slaved to either a VOR or RNAV system. The card of the RMI acts as a gyro-stabilized magnetic compass (usually corrected for north via a flux valve) and shows the magnetic heading the aircraft is flying.

Radio wave. An electromagnetic wave (EM wave) with frequency characteristics useful for radio transmission.

RAIM. See receiver autonomous integrity monitoring.

Random RNAV routes. Direct routes, based on area navigation capability, between waypoints defined in terms of latitude/longitude coordinates, degree-distance fixes, or offsets from established routes/airways at a specified distance and direction.

Ranging signals. Transmitted from the GPS satellite, these allow the aircraft's receiver to determine range (distance) from each satellite.

RB. See relative bearing.
RBI. See relative bearing indicator.

RCO. See remote communications outlet.

Receiver autonomous integrity monitoring (RAIM). A system used to verify the usability of the received GPS signals and warns the pilot of any malfunction in the navigation system. This system is required for IFR-certified GPS units.

Recommended altitude. An altitude depicted on an instrument approach chart with the altitude value neither underscored nor overscored. The depicted value is an advisory value.

Receiver-transmitter (RT). A system that permits selection of a unique channel or frequency whereupon a signal (typically communication) can be transmitted and received.

Reduced vertical separation minimum (RVSM). Reduces the vertical separation between flight level (FL) 290–410 from 2,000 feet to 1,000 feet and makes six additional FLs available for operation. Also see DRVSM.

Reference circle (also, distance circle). The circle depicted in the plan view of an IAP chart that typically has a 10 NM radius, within which chart the elements are drawn to scale.

Regions of command. The "regions of normal and reversed command" refers to the relationship between speed and the power required to maintain or change that speed in flight.

REIL. See runway end identifier lights.

Relative bearing (RB). The angular difference between the aircraft heading and the direction to the station, measured clockwise from the nose of the aircraft.

Relative bearing indicator (RBI). Also known as the fixed-card ADF, zero is always indicated at the top of the instrument and the needle indicates the relative bearing to the station.

Relative wind. Direction of the airflow produced by an object moving through the air. The relative wind for an airplane in flight flows in a direction parallel with and opposite to the direction of flight; therefore, the actual flight path of the airplane determines the direction of the relative wind.

Remote communications outlet (RCO). An unmanned communications facility that is remotely controlled by air traffic personnel.

Required navigation performance (RNP). A specified level of accuracy defined by a lateral area of confined airspace in which an RNP-certified aircraft operates.

Restricted area. Airspace designated under 14 CFR part 73 within which the flight of aircraft, while not wholly prohibited, is subject to restriction.

Reverse sensing. The VOR needle appearing to indicate the reverse of normal operation.

RF. Radio frequency.

Rhodopsin. The photosensitive pigments that initiate the visual response in the rods of the eye.

Rigidity. The characteristic of a gyroscope that prevents its axis of rotation tilting as the Earth rotates.

Rime ice. Rough, milky, opaque ice formed by the instantaneous freezing of small supercooled water droplets.

Risk. The future impact of a hazard that is not eliminated or controlled.

RMI. See radio magnetic indicator.

RNAV. See area navigation.

RNP. See required navigation performance.

Runway end identifier lights (REIL). A pair of synchronized flashing lights, located laterally on each side of the runway threshold, providing rapid and positive identification of the approach end of a runway.

Runway visibility value (RVV). The visibility determined for a particular runway by a transmissometer.

Runway visual range (RVR). The instrumentally derived horizontal distance a pilot should be able to see down the runway from the approach end, based on either the sighting of high-intensity runway lights, or the visual contrast of other objects.

RVR. See runway visual range.

RVV. See runway visibility value.

SA. See selective availability.

St. Elmo's Fire. A corona discharge which lights up the aircraft surface areas where maximum static discharge occurs.

Satellite ephemeris data. Data broadcast by the GPS satellite containing very accurate orbital data for that satellite, atmospheric propagation data, and satellite clock error data.

Scan. The first fundamental skill of instrument flight, also known as "cross-check;" the continuous and logical observation of instruments for attitude and performance information.

SDF. See simplified directional facility.

Selective availability (SA). A satellite technology permitting the Department of Defense (DOD) to create, in the interest of national security, a significant clock and ephemeris error in the satellites, resulting in a navigation error.

Semicircular canal. An inner ear organ that detects angular acceleration of the body.

Sensitive altimeter. A form of multipointer pneumatic altimeter with an adjustable barometric scale that allows the reference pressure to be set to any desired level.

SIDS. See standard instrument departure procedures.

SIGMET. The acronym for Significant Meteorological information. A weather advisory issued concerning weather significant to the safety of all aircraft.

Signal-to-noise ratio. An indication of signal strength received compared to background noise, which is a measure of how adequate the received signal is.

Simplex. Transmission and reception on the same frequency.

Simplified directional facility (SDF). A NAVAID used for nonprecision instrument approaches. The final approach course is similar to that of an ILS localizer; however, the SDF course may be offset from the runway, generally not more than 3°, and the course may be wider than the localizer, resulting in a lower degree of accuracy.

Single-pilot resource management (SRM). The ability for crew or pilot to manage all resources effectively to ensure the outcome of the flight is successful.

Situational awareness. Pilot knowledge of where the aircraft is in regard to location, air traffic control, weather, regulations, aircraft status, and other factors that may affect flight.

Skidding turn. An uncoordinated turn in which the rate of turn is too great for the angle of bank, pulling the aircraft to the outside of the turn.

Skin friction drag. Drag generated between air molecules and the solid surface of the aircraft.

Slant range. The horizontal distance from the aircraft antenna to the ground station, due to line-of-sight transmission of the DME signal.

Slaved compass. A system whereby the heading gyro is "slaved to," or continuously corrected to bring its direction readings into agreement with a remotely located magnetic direction sensing device (usually this is a flux valve or flux gate compass).

Slipping turn. An uncoordinated turn in which the aircraft is banked too much for the rate of turn, so the horizontal lift component is greater than the centrifugal force, pulling the aircraft toward the inside of the turn.

Small airplane. An airplane of 12,500 pounds or less maximum certificated takeoff weight.

Somatogravic illusion. The misperception of being in a nose-up or nose-down attitude, caused by a rapid acceleration or deceleration while in flight situations that lack visual reference.

Spatial disorientation. The state of confusion due to misleading information being sent to the brain from various sensory organs, resulting in a lack of awareness of the aircraft position in relation to a specific reference point.

Special use airspace. Airspace in which flight activities are subject to restrictions that can create limitations on the mixed use of airspace. Consists of prohibited, restricted, warning, military operations, and alert areas.

SRM. See single-pilot resource management.

SSR. See secondary surveillance radar.

SSV. See standard service volume.

Standard holding pattern. A holding pattern in which all turns are made to the right.

Standard instrument departure procedures (SIDS). Published procedures to expedite clearance delivery and to facilitate transition between takeoff and en route operations.

Standard rate turn. A turn in which an aircraft changes its direction at a rate of 3° per second. The turn indicators are typically 2 minute or 4 minute instruments. In a 2 minute instrument, if the needle is one needle width either side of the center alignment mark, the turn is 3° per second and the turn takes 2 minutes to execute a 360° turn. In a 4 minute instrument, the same turn takes two widths deflection of the needle to achieve 3° per second. The 4 minute turn instrument is usually found on high performance aircraft.

Standard service volume (SSV). Defines the limits of the volume of airspace which the VOR serves.

Standard terminal arrival route (STAR). A preplanned IFR ATC arrival procedure published for pilot use in graphic and/or textual form.

STAR. See standard terminal arrival route.

Static longitudinal stability. The aerodynamic pitching moments required to return the aircraft to the equilibrium angle of attack.

Static pressure. Pressure of air that is still, or not moving, measured perpendicular to the surface of the aircraft.

Steep turns. In instrument flight, any turn greater than standard rate; in visual flight, anything greater than a 45° bank.

Stepdown fix. The point after which additional descent is permitted within a segment of an IAP.

Strapdown system. An INS in which the accelerometers and gyros are permanently "strapped down" or aligned with the three axes of the aircraft.

Stress. The body's response to demands placed upon it.

Structural icing. The accumulation of ice on the exterior of the aircraft.

Suction relief valve. A relief valve in an instrument vacuum system required to maintain the correct low pressure inside the instrument case for the proper operation of the gyros.

Synchro. A device used to transmit indications of angular movement or position from one location to another.

Synthetic vision. A realistic display depiction of the aircraft in relation to terrain and flight path.

TAA. See terminal arrival area.

TACAN. See tactical air navigation.

Tactical air navigation (TACAN). An electronic navigation system used by military aircraft, providing both distance and direction information.

TAWS. See terrain awareness and warning system.

TCAS. See traffic alert collision avoidance system.

TCH. See threshold crossing height.

TDZE. See touchdown zone elevation.

TEC. See Tower En Route Control.

Technique. The manner in which procedures are executed.

Temporary flight restriction (TFR). Restriction to flight imposed in order to:

1. Protect persons and property in the air or on the surface from an existing or imminent flight associated hazard;
2. Provide a safe environment for the operation of disaster relief aircraft;
3. Prevent an unsafe congestion of sightseeing aircraft above an incident;
4. Protect the President, Vice President, or other public figures; and,
5. Provide a safe environment for space agency operations.

Pilots are expected to check appropriate NOTAMs during flight planning when conducting flight in an area where a temporary flight restriction is in effect.

Tension. Maintaining an excessively strong grip on the control column, usually resulting in an overcontrolled situation.

Terminal Instrument Approach Procedure (TERP). Prescribes standardized methods for use in designing instrument flight procedures.

Terminal arrival area (TAA). A procedure to provide a new transition method for arriving aircraft equipped with FMS and/or GPS navigational equipment. The TAA contains a "T" structure that normally provides a NoPT for aircraft using the approach.

TERP. See terminal instrument approach procedure.

Terrain Awareness and Warning System (TAWS). A timed-based system that provides information concerning potential hazards with fixed objects by using GPS positioning and a database of terrain and obstructions to provide true predictability of the upcoming terrain and obstacles.

TFR. See temporary flight restriction.

Threshold crossing height (TCH). The theoretical height above the runway threshold at which the aircraft's glide slope antenna would be if the aircraft maintains the trajectory established by the mean ILS glide slope or MLS glide path.

Thrust (aerodynamic force). The forward aerodynamic force produced by a propeller, fan, or turbojet engine as it forces a mass of air to the rear, behind the aircraft.

Time and speed table. A table depicted on an instrument approach procedure chart that identifies the distance from the FAF to the MAP, and provides the time required to transit that distance based on various groundspeeds.

Timed turn. A turn in which the clock and the turn coordinator are used to change heading a definite number of degrees in a given time.

TIS. See traffic information service.

Title 14 of the Code of Federal Regulations (14 CFR). The federal aviation regulations governing the operation of aircraft, airways, and airmen.

Touchdown zone elevation (TDZE). The highest elevation in the first 3,000 feet of the landing surface, TDZE is indicated on the instrument approach procedure chart when straight-in landing minimums are authorized.

Tower En Route Control (TEC). The control of IFR en route traffic within delegated airspace between two or more adjacent approach control facilities, designed to expedite traffic and reduce control and pilot communication requirements.

TPP. See United States Terminal Procedures Publication.

Tracking. Flying a heading that will maintain the desired track to or from the station regardless of crosswind conditions.

Traffic Alert Collision Avoidance System (TCAS). An airborne system developed by the FAA that operates independently from the ground-based Air Traffic Control system. Designed to increase flight deck awareness of proximate aircraft and to serve as a "last line of defense" for the prevention of mid-air collisions.

Traffic information service (TIS). A ground-based service providing information to the flight deck via data link using the S-mode transponder and altitude encoder to improve the safety and efficiency of "see and avoid" flight through an automatic display that informs the pilot of nearby traffic.

Transcribed Weather Broadcast (TWEB). Meteorological and aeronautical data recorded on tapes and broadcast over selected NAVAIDs. Generally, the broadcast contains route-oriented data with specially prepared NWS forecasts, inflight advisories, and winds aloft. It also includes selected current information such as weather reports (METAR/SPECI), NOTAMs, and special notices.

Transponder. The airborne portion of the ATC radar beacon system.

Transponder code. One of 4,096 four-digit discrete codes ATC assigns to distinguish between aircraft.

Trend. Immediate indication of the direction of aircraft movement, as shown on instruments.

Trim. Adjusting the aerodynamic forces on the control surfaces so that the aircraft maintains the set attitude without any control input.

TWEB. See Transcribed Weather Broadcast.

True airspeed. Actual airspeed, determined by applying a correction for pressure altitude and temperature to the CAS.

UHF. See ultra-high frequency.

Ultra-high frequency (UHF). The range of electromagnetic frequencies between 962 MHz and 1213 MHz.

Uncaging. Unlocking the gimbals of a gyroscopic instrument, making it susceptible to damage by abrupt flight maneuvers or rough handling.

Underpower. Using less power than required for the purpose of achieving a faster rate of airspeed change.

United States Terminal Procedures Publication (TPP). Booklets published in regional format by the NACO that include DPs, STARs, IAPs, and other information pertinent to IFR flight.

Unusual attitude. An unintentional, unanticipated, or extreme aircraft attitude.

User-defined waypoints. Waypoint location and other data which may be input by the user, this is the only GPS database information that may be altered (edited) by the user.

Variation. Compass error caused by the difference in the physical locations of the magnetic north pole and the geographic north pole.

VASI. See visual approach slope indicator.

VDP. See visual descent point.

Vectoring. Navigational guidance by assigning headings.

Venturi tube. A specially shaped tube attached to the outside of an aircraft to produce suction to allow proper operation of gyro instruments.

Vertical speed indicator (VSI). A rate-of-pressure change instrument that gives an indication of any deviation from a constant pressure level.

Very-high frequency (VHF). A band of radio frequencies falling between 30 and 300 MHz.

Very-high frequency omnidirectional range (VOR). Electronic navigation equipment in which the flight deck instrument identifies the radial or line from the VOR station, measured in degrees clockwise from magnetic north, along which the aircraft is located.

Vestibule. The central cavity of the bony labyrinth of the ear, or the parts of the membranous labyrinth that it contains.

VFR. See visual flight rules.

VFR-on-top. ATC authorization for an IFR aircraft to operate in VFR conditions at any appropriate VFR altitude.

VFR over-the-top. A VFR operation in which an aircraft operates in VFR conditions on top of an undercast.

Victor airways. Airways based on a centerline that extends from one VOR or VORTAC navigation aid or intersection, to another navigation aid (or through several navigation aids or intersections); used to establish a known route for en route procedures between terminal areas.

Visual approach slope indicator (VASI). A visual aid of lights arranged to provide descent guidance information during the approach to the runway. A pilot on the correct glide slope will see red lights over white lights.

Visual descent point (VDP). A defined point on the final approach course of a nonprecision straight-in approach procedure from which normal descent from the MDA to the runway touchdown point may be commenced, provided the runway environment is clearly visible to the pilot.

Visual flight rules (VFR). Flight rules adopted by the FAA governing aircraft flight using visual references. VFR operations specify the amount of ceiling and the visibility the pilot must have in order to operate according to these rules. When the weather conditions are such that the pilot can not operate according to VFR, he or she must use instrument flight rules (IFR).

Visual meteorological conditions (VMC). Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling meeting or exceeding the minimums specified for VFR.

VMC. See visual meteorological conditions.

VOR. See very-high frequency omnidirectional range.

VORTAC. A facility consisting of two components, VOR and TACAN, which provides three individual services: VOR azimuth, TACAN azimuth, and TACAN distance (DME) at one site.

VOR test facility (VOT). A ground facility which emits a test signal to check VOR receiver accuracy. Some VOTs are available to the user while airborne, while others are limited to ground use only.

VOT. See VOR test facility.

VSI. See vertical speed indicator.

WAAS. See wide area augmentation system.

Warning area. An area containing hazards to any aircraft not participating in the activities being conducted in the area. Warning areas may contain intensive military training, gunnery exercises, or special weapons testing.

Waypoint. A designated geographical location used for route definition or progress-reporting purposes and is defined in terms of latitude/longitude coordinates.

WCA. See wind correction angle.

Weather and radar processor (WARP). A device that provides real-time, accurate, predictive and strategic weather information presented in an integrated manner in the National Airspace System (NAS).

Weight. The force exerted by an aircraft from the pull of gravity.

Wide area augmentation system (WAAS). A differential global positioning system (DGPS) that improves the accuracy of the system by determining position error from the GPS satellites, then transmitting the error, or corrective factors, to the airborne GPS receiver.

Wind correction angle (WCA). The angle between the desired track and the heading of the aircraft necessary to keep the aircraft tracking over the desired track.

Work. A measurement of force used to produce movement.

Zone of confusion. Volume of space above the station where a lack of adequate navigation signal directly above the VOR station causes the needle to deviate.

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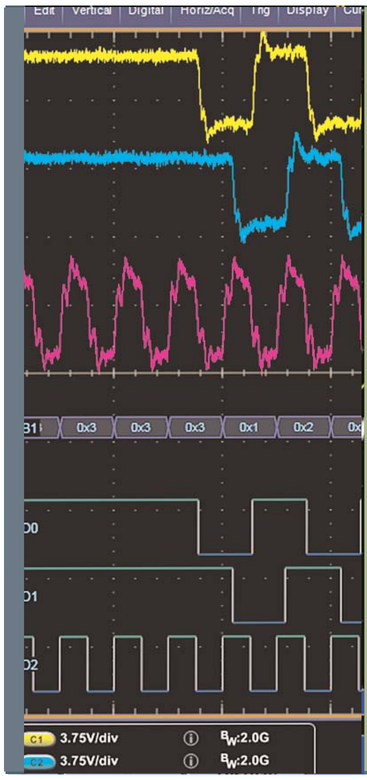
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Horiz/Acq
Trig
Display
B1
0x3
0x3
0x3
0x1
0x2
D0
D1
D2
C1 3.75V/div
C2 3.75V/div
BW:2.0G
BW:2.0G

XYZs of Oscilloscopes

Primer

Tektronix®

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Introduction

Nature moves in the form of a sine wave, be it an ocean wave, earthquake, sonic boom, explosion, sound through air, or the natural frequency of a body in motion. Energy, vibrating particles and other invisible forces pervade our physical universe. Even light – part particle, part wave – has a fundamental frequency, which can be observed as color.

Sensors can convert these forces into electrical signals that you can observe and study with an oscilloscope. Oscilloscopes enable scientists, engineers, technicians, educators and others to "see" events that change over time.

Oscilloscopes are indispensable tools for anyone designing, manufacturing or repairing electronic equipment. In today's fast-paced world, engineers need the best tools available to solve their measurement challenges quickly and accurately. As the eyes of the engineer, oscilloscopes are the key to meeting today's demanding measurement challenges.

The usefulness of an oscilloscope is not limited to the world of electronics. With the proper sensor, an oscilloscope can measure all kinds of phenomena. A sensor is a device that creates an electrical signal in response to physical stimuli, such as sound, mechanical stress, pressure, light, or heat. A microphone is a sensor that converts sound into an electrical signal. Figure 1 shows an example of scientific data that can be gathered by an oscilloscope.

Oscilloscopes are used by everyone from physicists to repair technicians. An automotive engineer uses an oscilloscope to correlate analog data from sensors with serial data from the engine control unit. A medical researcher uses an oscillscope to measure brain waves. The possibilities are endless.

The concepts presented in this primer will provide you with a good starting point in understanding oscilloscope basics and operation.

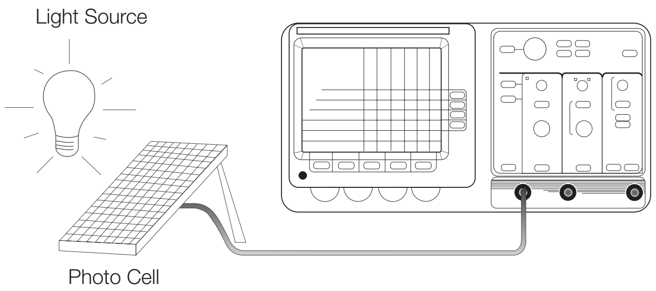

Figure 1. An example of scientific data gathered by an oscilloscope.

The glossary in the back of this primer will give you definitions of unfamiliar terms. The vocabulary and multiple-choice written exercises on oscilloscope theory and controls make this primer a useful classroom aid. No mathematical or electronics knowledge is necessary.

After reading this primer, you will be able to:

- Describe how oscilloscopes work
- Describe the differences between various oscilloscopes
- Describe electrical waveform types
- Understand basic oscilloscope controls
- Take simple measurements

The manual provided with your oscilloscope will give you more specific information about how to use the oscilloscope in your work. Some oscilloscope manufacturers also provide a multitude of application notes to help you optimize the oscilloscope for your application-specific measurements.

Should you need additional assistance, or have any comments or questions about the material in this primer, simply contact your Tektronix representative, or visit **www.tektronix.com**.

Signal Integrity

The Significance of Signal Integrity

The key to any good oscilloscope system is its ability to accurately reconstruct a waveform – referred to as signal integrity. An oscilloscope is analogous to a camera that captures signal images that we can then observe and interpret. Two key issues lie at the heart of signal integrity.

- When you take a picture, is it an accurate picture of what actually happened?
- Is the picture clear or fuzzy?
- How many of those accurate pictures can you take per second?

Taken together, the different systems and performance capabilities of an oscilloscope contribute to its ability to deliver the highest signal integrity possible. Probes also affect the signal integrity of a measurement system.

Signal integrity impacts many electronic design disciplines. But until a few years ago, it wasn't much of a problem for digital designers. They could rely on their logic designs to act like the Boolean circuits they were. Noisy, indeterminate signals were something that occurred in high-speed designs – something for RF designers to worry about. Digital systems switched slowly and signals stabilized predictably.

Processor clock rates have since multiplied by orders of magnitude. Computer applications such as 3D graphics, video and server I/O demand vast bandwidth. Much of today's telecommunications equipment is digitally based, and similarly requires massive bandwidth. So too does digital high-definition TV. The current crop of microprocessor devices handles data at rates up to 2, 3 and even 5 GS/s (gigasamples per second), while some DDR3 memory devices use clocks in excess of 2 GHz as well as data signals with 35 ps rise times.

Importantly, speed increases have trickled down to the common IC devices used in automobiles, consumer electronics, and machine controllers, to name just a few applications.

A processor running at a 20 MHz clock rate may well have signals with rise times similar to those of an 800 MHz processor. Designers have crossed a performance threshold that means, in effect, almost every design is a high-speed design.

Without some precautionary measures, high-speed problems can creep into otherwise conventional digital designs. If a circuit is experiencing intermittent failures, or if it encounters errors at voltage and temperature extremes, chances are there are some hidden signal integrity problems. These can affect time-to-market, product reliability, EMI compliance, and more. These high-speed problems can also impact the integrity of a serial data stream in a system, requiring some method of correlating specific patterns in the data with the observed characteristics of high-speed waveforms.

Why is Signal Integrity a Problem?

Let's look at some of the specific causes of signal degradation in today's digital designs. Why are these problems so much more prevalent today than in years past?

The answer is speed. In the "slow old days," maintaining acceptable digital signal integrity meant paying attention to details like clock distribution, signal path design, noise margins, loading effects, transmission line effects, bus termination, decoupling and power distribution. All of these rules still apply, but…

Bus cycle times are up to a thousand times faster than they were 20 years ago! Transactions that once took microseconds are now measured in nanoseconds. To achieve this improvement, edge speeds too have accelerated: they are up to 100 times faster than those of two decades ago.

This is all well and good; however, certain physical realities have kept circuit board technology from keeping up the pace. The propagation time of inter-chip buses has remained almost unchanged over the decades. Geometries have shrunk, certainly, but there is still a need to provide circuit board real estate for IC devices, connectors, passive components, and of course, the bus traces themselves. This real estate adds up to distance, and distance means time – the enemy of speed.

It's important to remember that the edge speed – rise time – of a digital signal can carry much higher frequency components than its repetition rate might imply. For this reason, some designers deliberately seek IC devices with relatively "slow" rise times.

The lumped circuit model has always been the basis of most calculations used to predict signal behavior in a circuit. But when edge speeds are more than four to six times faster than the signal path delay, the simple lumped model no longer applies.

Circuit board traces just six inches long become transmission lines when driven with signals exhibiting edge rates below four to six nanoseconds, irrespective of the cycle rate. In effect, new signal paths are created. These intangible connections aren't on the schematics, but nevertheless provide a means for signals to influence one another in unpredictable ways.

Sometimes even the errors introduced by the probe/instrument combination can provide a significant contribution to the signal being measured. However, by applying the "square root of the sum of the squares" formula to the measured value, it is possible to determine whether the device under test is approaching a rise/fall time failure. In addition, recent oscilloscope tools use special filtering techniques to de-embed the measurement system's effects on the signal, displaying edge times and other signal characteristics.

At the same time, the intended signal paths don't work the way they are supposed to. Ground planes and power planes, like the signal traces described above, become inductive and act like transmission lines; power supply decoupling is far less effective. EMI goes up as faster edge speeds produce shorter wavelengths relative to the bus length. Crosstalk increases.

In addition, fast edge speeds require generally higher currents to produce them. Higher currents tend to cause ground bounce, especially on wide buses in which many signals switch at once. Moreover, higher current increases the amount of radiated magnetic energy and with it, crosstalk.

Viewing the Analog Origins of Digital Signals

What do all these characteristics have in common? They are classic analog phenomena. To solve signal integrity problems, digital designers need to step into the analog domain. And to take that step, they need tools that can show them how digital and analog signals interact.

Digital errors often have their roots in analog signal integrity problems. To track down the cause of the digital fault, it's often necessary to turn to an oscilloscope, which can display waveform details, edges and noise; can detect and display transients; and can help you precisely measure timing relationships such as setup and hold times. Modern oscilloscopes can help to simplify the troubleshooting process by triggering on specific patterns in parallel or serial data streams and displaying the analog signal that corresponds in time with a specified event.

Understanding each of the systems within your oscilloscope and how to apply them will contribute to the effective application of the oscilloscope to tackle your specific measurement challenge.

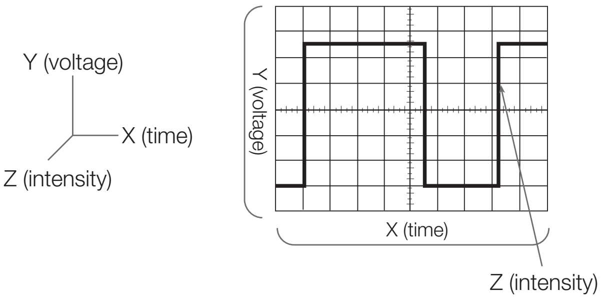

Figure 2. X, Y, and Z components of a displayed waveform.

The Oscilloscope

What is an oscilloscope and how does it work? This section answers these fundamental questions.

The oscilloscope is basically a graph-displaying device – it draws a graph of an electrical signal. In most applications, the graph shows how signals change over time: the vertical (Y) axis represents voltage and the horizontal (X) axis represents time. The intensity or brightness of the display is sometimes called the Z axis, as shown in Figure 2. In DPO oscilloscopes, the Z axis can be represented by color grading of the display, as seen in Figure 3.

This simple graph can tell you many things about a signal, such as:

- The time and voltage values of a signal
- The frequency of an oscillating signal
- The “moving parts” of a circuit represented by the signal
- The frequency with which a particular portion of the signal is occurring relative to other portions
- Whether or not a malfunctioning component is distorting the signal
- How much of a signal is direct current (DC) or alternating current (AC)
- How much of the signal is noise and whether the noise is changing with time

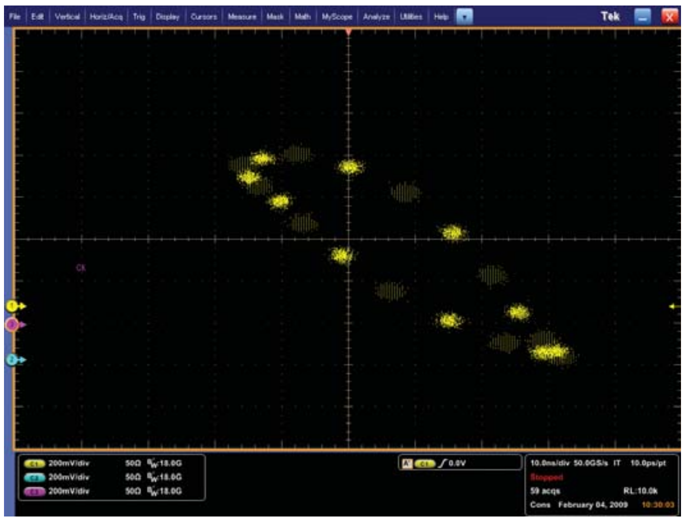

C1 200mV/div 50Ω B_W:18.0G
C2 200mV/div 50Ω B_W:18.0G
C3 200mV/div 50Ω B_W:18.0G

A C1 ∫ 0.0V

10.0ns/div 50.0GS/s IT 10.0ps/pt
Stopped
59 acqs RL:10.0k
Cons February 04, 2009 10:30:03

Figure 3. Two offset clock patterns with Z axis intensity grading.

Understanding Waveforms and Waveform Measurements

The generic term for a pattern that repeats over time is a wave – sound waves, brain waves, ocean waves, and voltage waves are all repetitive patterns. An oscilloscope measures voltage waves. Remember as mentioned earlier, that physical phenomena such as vibrations or temperature or electrical phenomena such as current or power can be converted to a voltage by a sensor. One cycle of a wave is the portion of the wave that repeats. A waveform is a graphic representation of a wave. A voltage waveform shows time on the horizontal axis and voltage on the vertical axis.

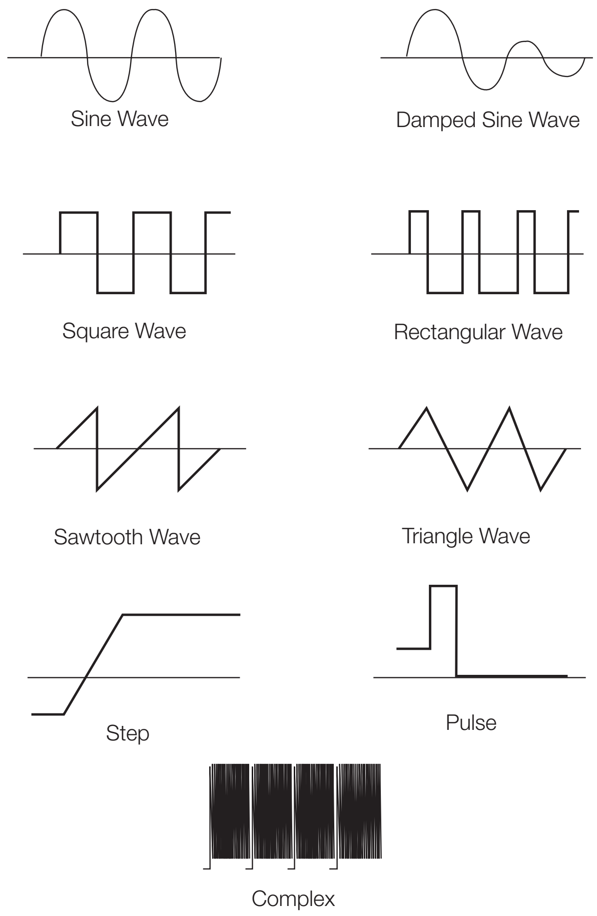
Sine Wave
Damped Sine Wave
Square Wave
Rectangular Wave
Sawtooth Wave
Triangle Wave
Step
Pulse
Complex

Figure 4. Common waveforms.

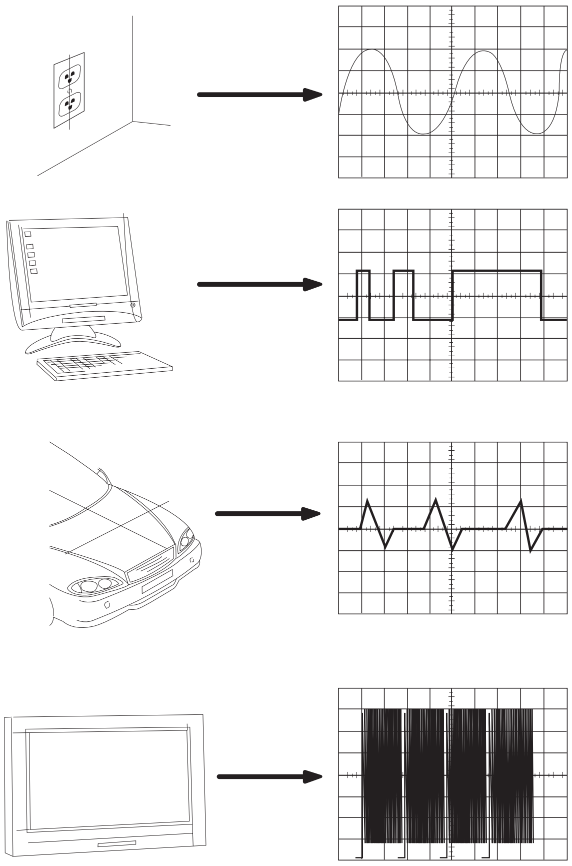

Figure 5. Sources of common waveforms.

Waveform shapes reveal a great deal about a signal. Any time you see a change in the height of the waveform, you know the voltage has changed. Any time there is a flat horizontal line, you know that there is no change for that length of time. Straight, diagonal lines mean a linear change – rise or fall of voltage at a steady rate. Sharp angles on a waveform indicate sudden change. Figure 4 shows common waveforms and Figure 5 displays sources of common waveforms.

Types of Waves

You can classify most waves into these types:

- Sine waves
- Square and rectangular waves
- Sawtooth and triangle waves
- Step and pulse shapes
- Periodic and non-periodic signals
- Synchronous and asynchronous signals
- Complex waves

Sine Waves

The sine wave is the fundamental wave shape for several reasons. It has harmonious mathematical properties – it is the same sine shape you may have studied in trigonometry class. The voltage in your wall outlet varies as a sine wave. Test signals produced by the oscillator circuit of a signal generator are often sine waves. Most AC power sources produce sine waves. (AC signifies alternating current, although the voltage alternates too. DC stands for direct current, which means a steady current and voltage, such as a battery produces.)

The damped sine wave is a special case you may see in a circuit that oscillates, but winds down over time.

Square and Rectangular Waves

The square wave is another common wave shape. Basically, a square wave is a voltage that turns on and off (or goes high and low) at regular intervals. It is a standard wave for testing amplifiers – good amplifiers increase the amplitude of a square wave with minimum distortion. Television, radio and computer circuitry often use square waves for timing signals.

The rectangular wave is like the square wave except that the high and low time intervals are not of equal length. It is particularly important when analyzing digital circuitry.

Sawtooth and Triangle Waves

Sawtooth and triangle waves result from circuits designed to control voltages linearly, such as the horizontal sweep of an analog oscilloscope or the raster scan of a television. The transitions between voltage levels of these waves change at a constant rate. These transitions are called ramps.

Step and Pulse Shapes

Signals such as steps and pulses that occur rarely, or non-periodically, are called single-shot or transient signals. A step indicates a sudden change in voltage, similar to the voltage change you would see if you turned on a power switch.

A pulse indicates sudden changes in voltage, similar to the voltage changes you would see if you turned a power switch on and then off again. A pulse might represent one bit of information traveling through a computer circuit or it might be a glitch, or defect, in a circuit. A collection of pulses traveling together creates a pulse train. Digital components in a computer communicate with each other using pulses. These pulses may be in the form of serial data stream or multiple signal lines may be used to represent a value in a parallel data bus. Pulses are also common in x-ray, radar, and communications equipment.

Periodic and Non-periodic Signals

Repetitive signals are referred to as periodic signals, while signals that constantly change are known as non-periodic signals. A still picture is analogous to a periodic signal, while a moving picture can be equated to a non-periodic signal.

Synchronous and Asynchronous Signals

When a timing relationship exists between two signals, those signals are referred to as synchronous. Clock, data and address signals inside a computer are an example of synchronous signals.

Asynchronous is a term used to describe those signals between which no timing relationship exists. Because no time correlation exists between the act of touching a key on a computer keyboard and the clock inside the computer, these are considered asynchronous.

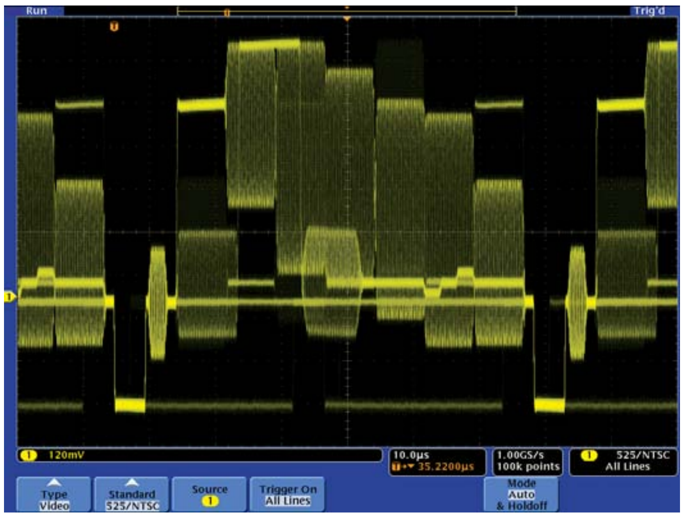
Run
Trig'd
1 120mV
10.0µs
35.2200µs
1.00GS/s
100k points
1 525/NTSC
All Lines
Type
Video
Standard
525/NTSC
Source
1
Trigger On
All Lines
Mode
Auto
& Holdoff

Figure 6. An NTSC composite video signal is an example of a complex wave.

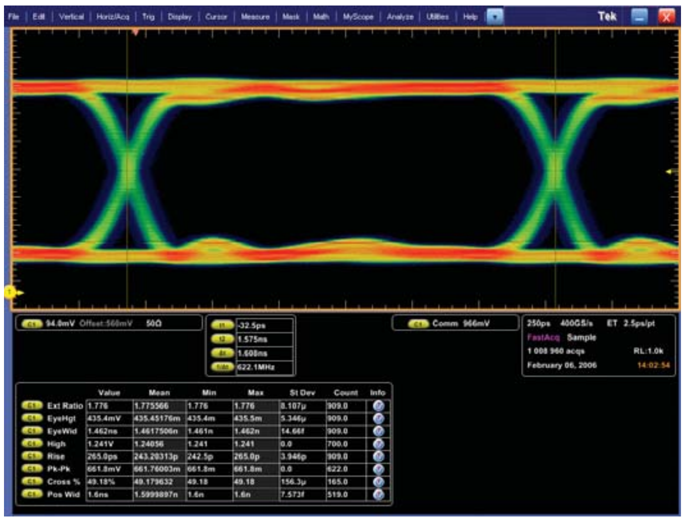
File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursor
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
C1 94.0mV Offset:566mV 50Ω
t1 -32.5ps
t2 1.575ns
Δt 1.608ns
1/Δt 622.1MHz
C1 Comm 966mV
250ps 400GS/s ET 2.5ps/pt
FastAcq Sample
1 008 960 acqs RL:1.0k
February 06, 2006 14:02:54

	Value	Mean	Min	Max	St Dev	Count	Info
C1 Ext Ratio	1.776	1.775566	1.776	1.776	8.107µ	909.0	
C1 EyeHgt	435.4mV	435.45176m	435.4m	435.5m	5.346µ	909.0	
C1 EyeWid	1.462ns	1.4617506n	1.461n	1.462n	14.66f	909.0	
C1 High	1.241V	1.24056	1.241	1.241	0.0	700.0	
C1 Rise	265.0ps	243.20313p	242.5p	265.0p	3.946p	909.0	
C1 Pk-Pk	661.8mV	661.76003m	661.8m	661.8m	0.0	622.0	
C1 Cross %	49.18%	49.179632	49.18	49.18	156.3µ	165.0	
C1 Pos Wid	1.6ns	1.5999897n	1.6n	1.6n	7.573f	519.0	

Figure 7. 622 Mb/s serial data eye pattern.

Complex Waves

Some waveforms combine the characteristics of sines, squares, steps, and pulses to produce complex waveshapes. The signal information may be embedded in the form of amplitude, phase, and/or frequency variations. For example, although the signal in Figure 6 is an ordinary composite video signal, it is composed of many cycles of higher-frequency waveforms embedded in a lower-frequency envelope.

In this example, it is usually most important to understand the relative levels and timing relationships of the steps. To view this signal, you need an oscilloscope that captures the low-frequency envelope and blends in the higher-frequency waves in an intensity-graded fashion so that you can see their overall combination as an image that can be visually interpreted. Digital phosphor oscilloscopes are most suited to viewing complex waves, such as video signals, illustrated in Figure 6. Their displays provide the necessary frequency-of-occurrence information, or intensity grading, that is essential to understanding what the waveform is really doing.

Some oscilloscopes allow for displaying certain types of complex waveforms in special ways. For example, telecommunications data may be displayed as an eye pattern or a constellation diagram.

Telecommunications digital data signals can be displayed on an oscilloscope as a special type of waveform referred to as an eye pattern. The name comes from the similarity of the waveform to a series of eyes, as seen in Figure 7. Eye patterns are produced when digital data from a receiver is sampled and applied to the vertical input, while the data rate is used to trigger the horizontal sweep. The eye pattern displays one bit or unit interval of data with all possible edge transitions and states superimposed in one comprehensive view.

A constellation diagram is a representation of a signal modulated by a digital modulation scheme such as quadrature amplitude modulation or phase-shift keying.

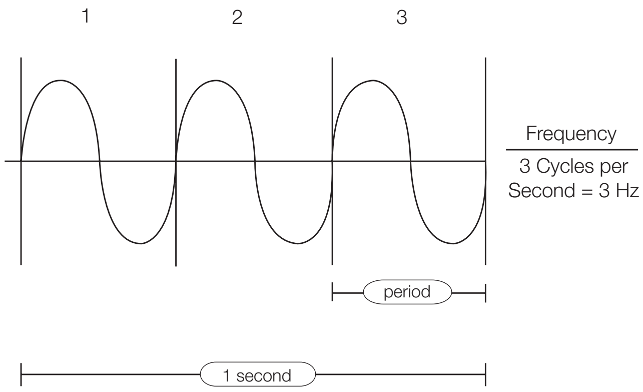

Figure 8. Frequency and period of a sine wave.

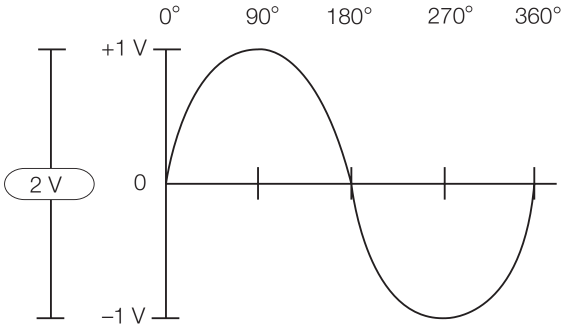

Figure 9. Amplitude and degrees of a sine wave.

Waveform Measurements

Many terms are used to describe the types of measurements that you make with your oscilloscope. This section describes some of the most common measurements and terms.

Frequency and Period

If a signal repeats, it has a frequency. The frequency is measured in Hertz (Hz) and equals the number of times the signal repeats itself in one second, referred to as cycles per second. A repetitive signal also has a period, which is the amount of time it takes the signal to complete one cycle. Period and frequency are reciprocals of each other, so that 1/period equals the frequency and 1/frequency equals the period. For example, the sine wave in Figure 8 has a frequency of 3 Hz and a period of 1/3 second.

Voltage

Voltage is the amount of electric potential, or signal strength, between two points in a circuit. Usually, one of these points is ground, or zero volts, but not always. You may want to measure the voltage from the maximum peak to the minimum peak of a waveform, referred to as the peak-to-peak voltage.

Amplitude

Amplitude refers to the amount of voltage between two points in a circuit. Amplitude commonly refers to the maximum voltage of a signal measured from ground, or zero volts. The waveform shown in Figure 9 has an amplitude of 1 V and a peak-to-peak voltage of 2 V.

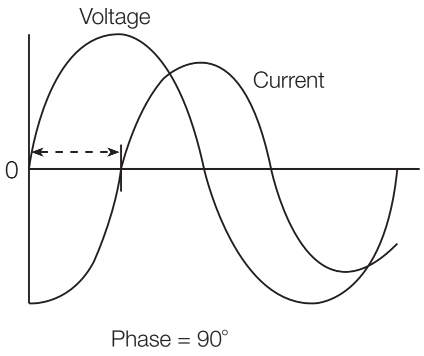

Figure 10. Phase shift.

Phase

Phase is best explained by looking at a sine wave. The voltage level of sine waves is based on circular motion. Given that a circle has 360°, one cycle of a sine wave has 360°, as shown in Figure 9. Using degrees, you can refer to the phase angle of a sine wave when you want to describe how much of the period has elapsed.

Phase shift describes the difference in timing between two otherwise similar signals. The waveform in Figure 10 labeled “current” is said to be 90° out of phase with the waveform labeled “voltage,” since the waves reach similar points in their cycles exactly 1/4 of a cycle apart (360°/4 = 90°). Phase shifts are common in electronics.

Waveform Measurements with Digital Oscilloscopes

Modern digital oscilloscopes have functions that make waveform measurements easier. They have front-panel buttons and/or screen-based menus from which you can select fully automated measurements. These include amplitude, period, rise/fall time, and many more. Many digital instruments also provide mean and RMS calculations, duty cycle, and other math operations. Automated measurements appear as on-screen alphanumeric readouts. Typically these readings are more accurate than is possible to obtain with direct graticule interpretation.

Examples of fully automated waveform measurements:

- Period
- Frequency
- Width +
- Width -
- Rise time
- Fall time
- Amplitude
- Extinction ratio
- Mean optical power
- Duty Cycle +
- Duty Cycle -
- Delay
- Phase
- Burst width
- Peak-to-peak
- Mean
- Cycle mean
- Cycle area
- High
- Low
- Minimum
- Maximum
- Overshoot +
- Overshoot -
- RMS
- Cycle RMS
- Jitter

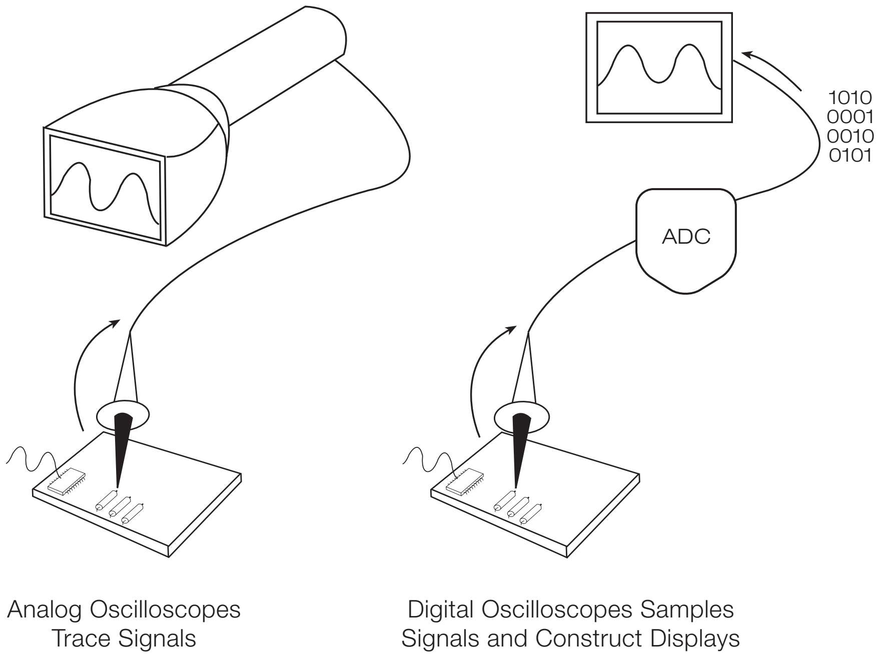
1010
0001
0010
0101
ADC
Analog Oscilloscopes Trace Signals
Digital Oscilloscopes Samples Signals and Construct Displays

Figure 11. Analog oscilloscopes trace signals, while digital oscilloscopes sample signals and construct displays.

The Types of Oscilloscopes

Electronic equipment can be classified into two categories: analog and digital. Analog equipment works with continuously variable voltages, while digital equipment works with discrete binary numbers that represent voltage samples. A conventional phonograph is an analog device, while a compact disc player is a digital device.

Oscilloscopes can be classified similarly – as analog and digital types. In contrast to an analog oscilloscope, a digital oscilloscope uses an analog-to-digital converter (ADC) to convert the measured voltage into digital information. It acquires the waveform as a series of samples, and stores these samples until it accumulates enough samples to describe a waveform. The digital oscilloscope then re-assembles the waveform for display on the screen, as seen in Figure 11.

Digital oscilloscopes can be classified into digital storage oscilloscopes (DSOs), digital phosphor oscilloscopes (DPOs), mixed signal oscilloscopes (MSOs), and digital sampling oscilloscopes.

The digital approach means that the oscilloscope can display any frequency within its range with stability, brightness, and clarity. For repetitive signals, the bandwidth of the digital oscilloscope is a function of the analog bandwidth of the front-end components of the oscilloscope, commonly referred to as the –3 dB point. For single-shot and transient events, such as pulses and steps, the bandwidth can be limited by the oscilloscope's sample rate. Please refer to the Sample Rate section under Performance Terms and Considerations for a more detailed discussion.

Digital Storage Oscilloscopes

A conventional digital oscilloscope is known as a digital storage oscilloscope (DSO). Its display typically relies on a raster-type screen rather than the luminous phosphor found in an older analog oscilloscope.

Digital storage oscilloscopes (DSOs) allow you to capture and view events that may happen only once – known as transients. Because the waveform information exists in digital form as a series of stored binary values, it can be analyzed, archived, printed, and otherwise processed, within the oscilloscope itself or by an external computer. The waveform need not be continuous; it can be displayed even when the signal disappears. Unlike analog oscilloscopes, digital storage oscilloscopes provide permanent signal storage and extensive waveform processing. However, DSOs typically have no real-time intensity grading; therefore, they cannot express varying levels of intensity in the live signal.

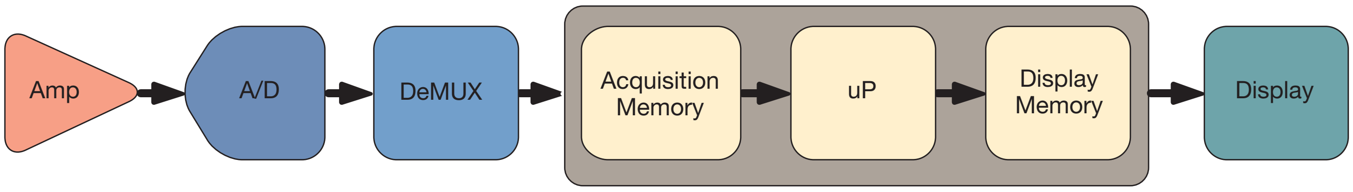

Figure 12. The serial-processing architecture of a digital storage oscilloscope (DSO).

Some of the subsystems that comprise DSOs are similar to those in analog oscilloscopes. However, DSOs contain additional data-processing subsystems that are used to collect and display data for the entire waveform. A DSO employs a serial-processing architecture to capture and display a signal on its screen, as shown in Figure 12. A description of this serial-processing architecture follows.

Serial-processing Architecture

Like an analog oscilloscope, a DSO's first (input) stage is a vertical amplifier. Vertical controls allow you to adjust the amplitude and position range at this stage. Next, the analog-to-digital converter (ADC) in the horizontal system samples the signal at discrete points in time and converts the signal's voltage at these points into digital values called sample points. This process is referred to as digitizing a signal.

The horizontal system's sample clock determines how often the ADC takes a sample. This rate is referred to as the sample rate and is expressed in samples per second (S/s).

The sample points from the ADC are stored in acquisition memory as waveform points. Several sample points may comprise one waveform point. Together, the waveform points comprise one waveform record. The number of waveform points used to create a waveform record is called the record length. The trigger system determines the start and stop points of the record.

The DSO's signal path includes a microprocessor through which the measured signal passes on its way to the display. This microprocessor processes the signal, coordinates display activities, manages the front panel controls, and more. The signal then passes through the display memory and is displayed on the oscilloscope screen.

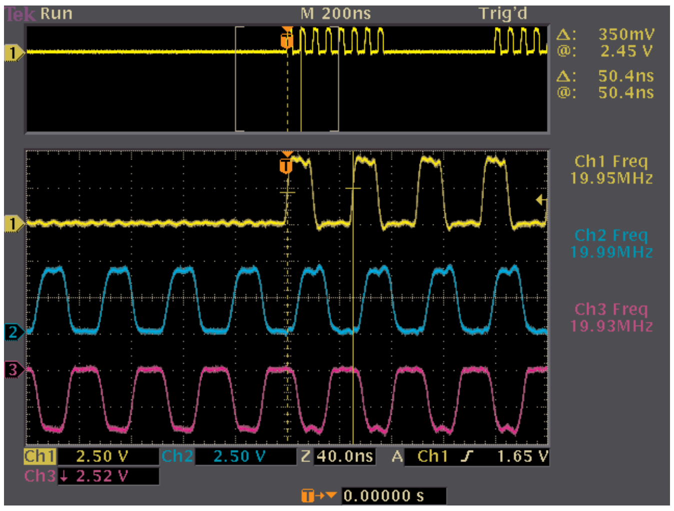

Figure 13. The digital storage oscilloscope delivers high-speed, single-shot acquisition across multiple channels, increasing the likelihood of capturing elusive glitches and transient events.

Depending on the capabilities of your oscilloscope, additional processing of the sample points may take place, which enhances the display. Pre-trigger may also be available, enabling you to see events before the trigger point. Most of today's digital oscilloscopes also provide a selection of automatic parametric measurements, simplifying the measurement process.

As shown in Figure 13, a DSO provides high performance in a single-shot, multi-channel instrument. DSOs are ideal for low-repetition-rate or single-shot, high-speed, multi-channel design applications. In the real world of digital design, an engineer usually examines four or more signals simultaneously, making the DSO a critical companion.

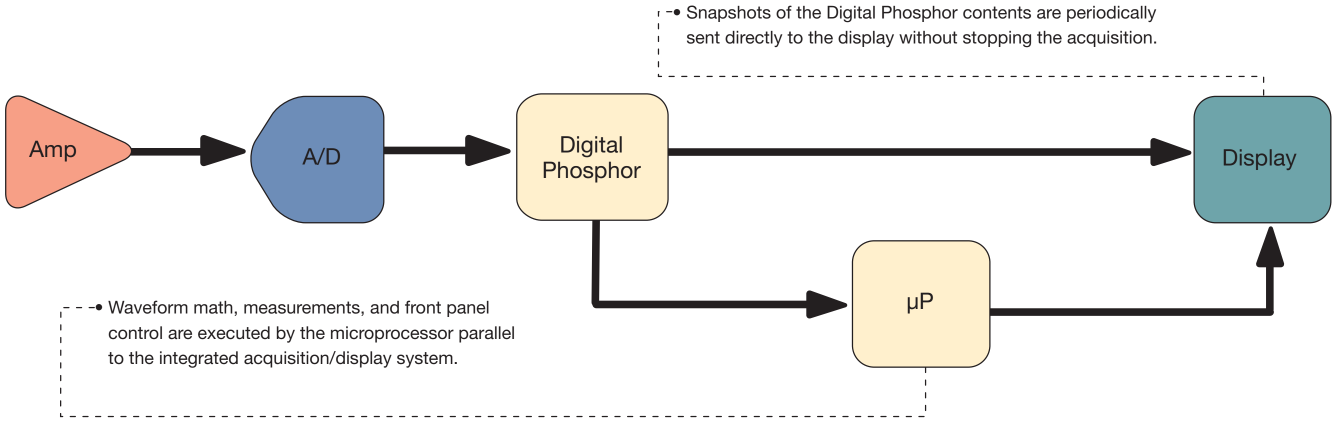
Snapshots of the Digital Phosphor contents are periodically sent directly to the display without stopping the acquisition.
Amp
A/D
Digital Phosphor
Display
µP
Waveform math, measurements, and front panel control are executed by the microprocessor parallel to the integrated acquisition/display system.

Figure 14. The parallel-processing architecture of a digital phosphor oscilloscope (DPO).

Digital Phosphor Oscilloscopes

The digital phosphor oscilloscope (DPO) offers a new approach to oscilloscope architecture. This architecture enables a DPO to deliver unique acquisition and display capabilities to accurately reconstruct a signal.

While a DSO uses a serial-processing architecture to capture, display and analyze signals, a DPO employs a parallel-processing architecture to perform these functions, as shown in Figure 14. The DPO architecture dedicates unique ASIC hardware to acquire waveform images, delivering high waveform capture rates that result in a higher level of signal visualization. This performance increases the probability of witnessing transient events that occur in digital systems, such as runt pulses, glitches and transition errors, and enables additional analysis capability. A description of this parallel-processing architecture follows.

Parallel-processing Architecture

A DPO's first (input) stage is similar to that of an analog oscilloscope – a vertical amplifier – and its second stage is similar to that of a DSO – an ADC. But, the DPO differs significantly from its predecessors following the analog-to-digital conversion.

For any oscilloscope – analog, DSO or DPO – there is always a holdoff time during which the instrument processes the most recently acquired data, resets the system, and waits for the next trigger event. During this time, the oscilloscope is blind to all signal activity. The probability of seeing an infrequent or low-repetition event decreases as the holdoff time increases.

It should be noted that it is impossible to determine the probability of capture by simply looking at the display update rate. If you rely solely on the update rate, it is easy to make the mistake of believing that the oscilloscope is capturing all pertinent information about the waveform when, in fact, it is not.

The digital storage oscilloscope processes captured waveforms serially. The speed of its microprocessor is a bottleneck in this process because it limits the waveform capture rate.

The DPO rasterizes the digitized waveform data into a digital phosphor database. Every 1/30th of a second – about as fast as the human eye can perceive it – a snapshot of the signal image that is stored in the database is pipelined directly to the display system. This direct rasterization of waveform data, and direct copy to display memory from the database, removes the data-processing bottleneck inherent in other architectures. The result is an enhanced "real-time" and lively display update. Signal details, intermittent events, and dynamic characteristics of the signal are captured in real-time. The DPO's microprocessor works in parallel with this integrated acquisition system for display management, measurement automation and instrument control, so that it does not affect the oscilloscope's acquisition speed.

A DPO faithfully emulates the best display attributes of an analog oscilloscope, displaying the signal in three dimensions: time, amplitude and the distribution of amplitude over time, all in real-time.

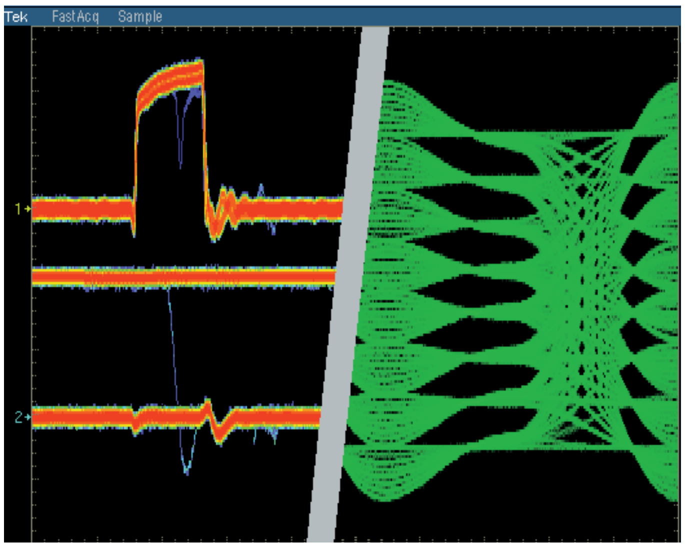

Figure 15. Some DPOs can acquire millions of waveform in just seconds, significantly increasing the probability of capturing intermittent and elusive events and revealing dynamic signal behavior.

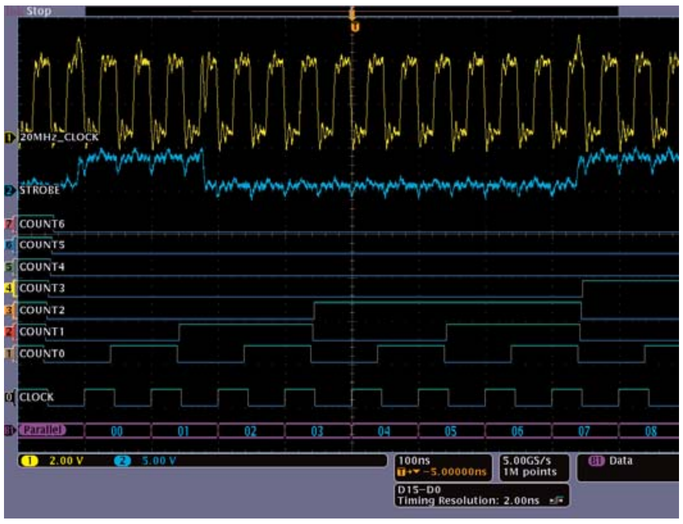

Figure 16. The MSO provides 16 integrated digital channels, enabling the ability to view and analyze time-correlated analog and digital signals.

Unlike an analog oscilloscope's reliance on chemical phosphor, a DPO uses a purely electronic digital phosphor that's actually a continuously updated database. This database has a separate "cell" of information for every single pixel in the oscilloscope's display. Each time a waveform is captured – in other words, every time the oscilloscope triggers – it is mapped into the digital phosphor database's cells. Each cell that represents a screen location and is touched by the waveform is reinforced with intensity information, while other cells are not. Thus, intensity information builds up in cells where the waveform passes most often.

When the digital phosphor database is fed to the oscilloscope's display, the display reveals intensified waveform areas, in proportion to the signal's frequency of occurrence at each point – much like the intensity grading characteristics of an analog oscilloscope. The DPO also allows the display of the varying frequency-of-occurrence information on the display as contrasting colors, unlike an analog oscilloscope. With a DPO, it is easy to see the difference between a waveform that occurs on almost every trigger and one that occurs, say, every 100th trigger.

Digital phosphor oscilloscopes (DPOs) break down the barrier between analog and digital oscilloscope technologies. They are equally suitable for viewing high and low frequencies, repetitive waveforms, transients, and signal variations in real-time. Only a DPO provides the Z (intensity) axis in real-time that is missing from conventional DSOs.

A DPO is ideal for those who need the best general-purpose design and troubleshooting tool for a wide range of applications, as seen in Figure 15. A DPO is exemplary for advanced analysis, communication mask testing, digital debug of intermittent signals, repetitive digital design and timing applications.

Mixed Signal Oscilloscopes

The mixed signal oscilloscope (MSO) combines the performance of a DPO with the basic functionality of a 16-channel logic analyzer, including parallel/serial bus protocol decoding and triggering. The MSO's digital channels view a digital signal as either a logic high or logic low, just like a digital circuit views the signal. This means as long as ringing, overshoot and ground bounce do not cause logic transitions, these analog characteristics are not of concern to the MSO. Just like a logic analyzer, a MSO uses a threshold voltage to determine if the signal is logic high or logic low.

The MSO is the tool of choice for quickly debugging digital circuits using its powerful digital triggering, high resolution acquisition capability, and analysis tools. The root cause of many digital problems is quicker to pinpoint by analyzing both the analog and digital representations of the signal, as shown in Figure 16, making a MSO ideal for verifying and debugging digital circuits.

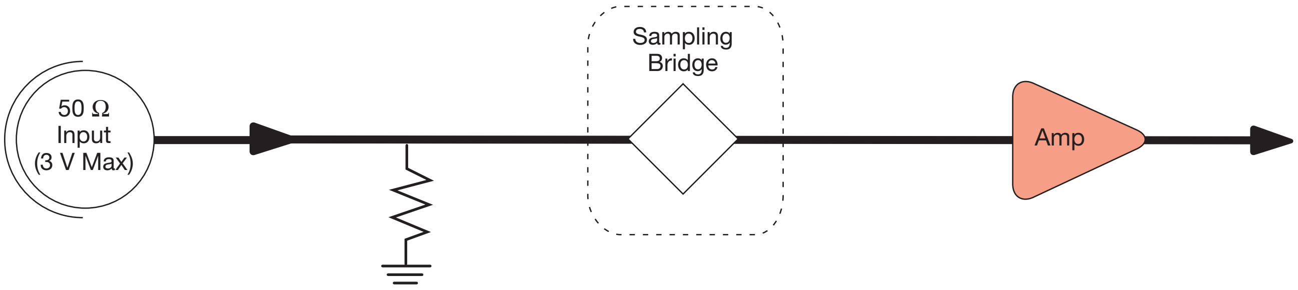

Figure 17. The architecture of a digital sampling oscilloscope.

Digital Sampling Oscilloscopes

In contrast to the digital storage and digital phosphor oscilloscope architectures, the architecture of the digital sampling oscilloscope reverses the position of the attenuator/amplifier and the sampling bridge, as shown in Figure 17. The input signal is sampled before any attenuation or amplification is performed. A low bandwidth amplifier can then be utilized after the sampling bridge because the signal has already been converted to a lower frequency by the sampling gate, resulting in a much higher bandwidth instrument.

The tradeoff for this high bandwidth, however, is that the sampling oscilloscope's dynamic range is limited. Since there is no attenuator/amplifier in front of the sampling gate, there is no facility to scale the input. The sampling bridge must be able to handle the full dynamic range of the input at all times. Therefore, the dynamic range of most sampling oscilloscopes is limited to about 1 V peak-to-peak. Digital storage and digital phosphor oscilloscopes, on the other hand, can handle 50 to 100 volts.

In addition, protection diodes cannot be placed in front of the sampling bridge as this would limit the bandwidth. This reduces the safe input voltage for a sampling oscilloscope to about 3 V, as compared to 500 V available on other oscilloscopes.

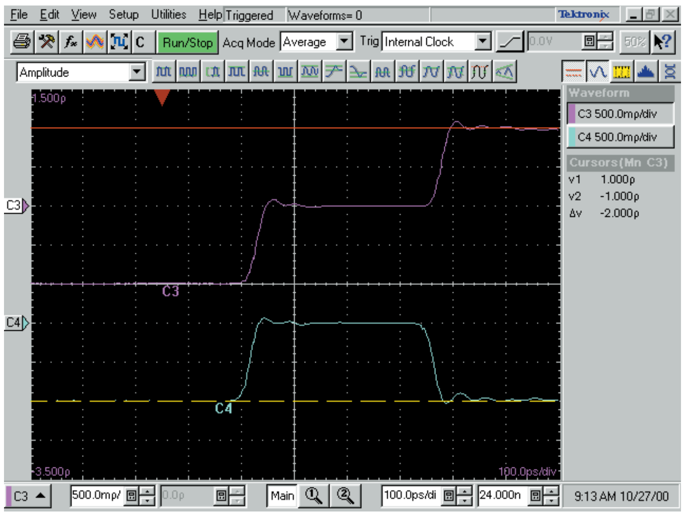

Triggered Waveforms= 0

Acq Mode Average

Trig Internal Clock

0.0V

50%

Amplitude

Waveform

C3 500.0mρ/div

C4 500.0mρ/div

Cursors(Mn C3)

v1 1.000ρ

v2 -1.000ρ

Δv -2.000ρ

C3 500.0mρ/ 0.0ρ Main 100.0ps/di 24.000n 9:13 AM 10/27/00

Figure 18. Time domain reflectometry (TDR) display from a digital sampling oscilloscope.

When measuring high-frequency signals, the DSO or DPO may not be able to collect enough samples in one sweep. A digital sampling oscilloscope is an ideal tool for accurately capturing signals whose frequency components are much higher than the oscilloscope's sample rate, as seen in Figure 18. This oscilloscope is capable of measuring signals of up to an order of magnitude faster than any other oscilloscope. It can achieve bandwidth and high-speed timing ten times higher than other oscilloscopes for repetitive signals. Sequential equivalent-time sampling oscilloscopes are available with bandwidths to 80 GHz.

The Systems and Controls of an Oscilloscope

This section briefly describes the basic systems and controls found on analog and digital oscilloscopes. Some controls differ between analog and digital oscilloscopes; your oscilloscope probably has additional controls not discussed here.

A basic oscilloscope consists of four different systems – the vertical system, horizontal system, trigger system, and display system. Understanding each of these systems will enable you to effectively apply the oscilloscope to tackle your specific measurement challenges. Recall that each system contributes to the oscilloscope's ability to accurately reconstruct a signal.

The front panel of an oscilloscope is divided into three main sections labeled vertical, horizontal, and trigger. Your oscilloscope may have other sections, depending on the model and type. See if you can locate these front-panel sections in Figure 19, and on your oscilloscope, as you read through this section.

When using an oscilloscope, you need to adjust three basic settings to accommodate an incoming signal:

- Vertical: The attenuation or amplification of the signal. Use the volts/div control to adjust the amplitude of the signal to the desired measurement range.
- Horizontal: The time base. Use the sec/div control to set the amount of time per division represented horizontally across the screen.
- Trigger: The triggering of the oscilloscope. Use the trigger level to stabilize a repeating signal, or to trigger on a single event.

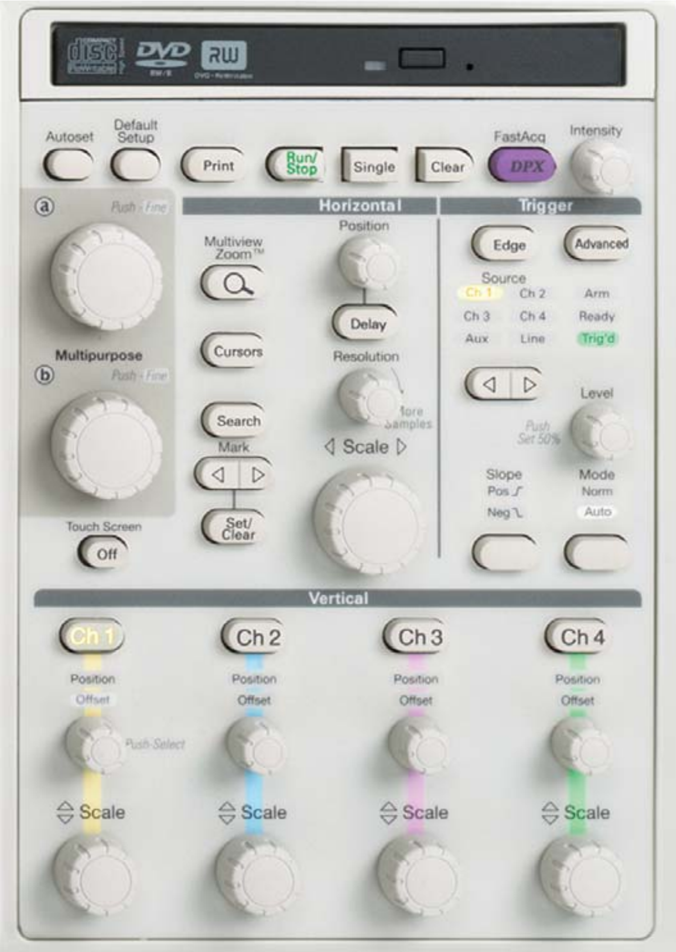
DVD RW
Autoset
Default Setup
Print
Run/Stop
Single
Clear
FastAcq
DPX
Intensity
Push - Fine
Horizontal
Trigger
Multiview Zoom™
Position
Edge
Advanced
Source
Ch 1
Ch 2
Arm
Ch 3
Ch 4
Ready
Aux
Line
Trig'd
Delay
Cursors
Multipurpose
Resolution
Level
Search
Mark
More Samples
Scale
Push Set 50%
Slope
Pos
Neg
Mode
Norm
Auto
Set/Clear
Touch Screen
Off
Vertical
Ch 1
Ch 2
Ch 3
Ch 4
Position
Offset
Push-Select
Scale

Figure 19. Front-panel control section of an oscilloscope.

Common vertical controls include:

- Termination
  - 1M ohm
  - 50 ohm
- Coupling
  - DC
  - AC
  - GND
- Bandwidth
  - Limit
  - Enhancement
- Position
- Offset
- Invert – On/Off
- Scale
  - Fixed steps
  - Variable

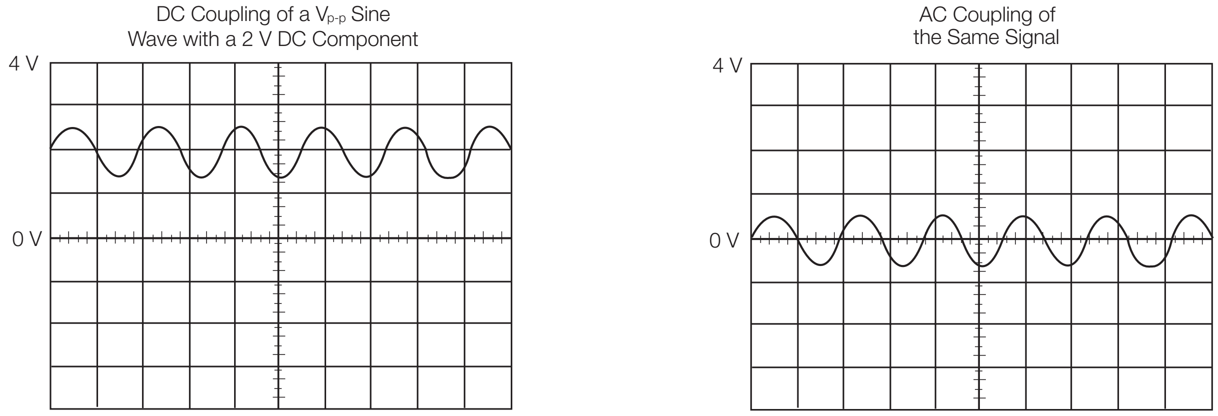
DC Coupling of a V_{p-p} Sine Wave with a 2 V DC Component
4 V
0 V
AC Coupling of the Same Signal
4 V
0 V

Figure 20. AC and DC input coupling.

Vertical System and Controls

Vertical controls can be used to position and scale the waveform vertically, set the input coupling, and adjust other signal conditioning.

Position and Volts per Division

The vertical position control allows you to move the waveform up and down exactly where you want it on the screen.

The volts-per-division setting (usually written as volts/div) is a scaling factor that varies the size of the waveform on the screen. If the volts/div setting is 5 volts, then each of the eight vertical divisions represents 5 volts and the entire screen can display 40 volts from bottom to top, assuming a graticule with eight major divisions. If the setting is 0.5 volts/div, the screen can display 4 volts from bottom to top, and so on. The maximum voltage you can display on the screen is the volts/div setting multiplied by the number of vertical divisions. Note that the probe you use, 1X or 10X, also influences the scale factor. You must divide the volts/div scale by the attenuation factor of the probe if the oscilloscope does not do it for you.

Often the volts/div scale has either a variable gain or a fine gain control for scaling a displayed signal to a certain number of divisions. Use this control to assist in taking rise time measurements.

Input Coupling

Coupling refers to the method used to connect an electrical signal from one circuit to another. In this case, the input coupling is the connection from your test circuit to the oscilloscope. The coupling can be set to DC, AC, or ground. DC coupling shows all of an input signal. AC coupling blocks the DC component of a signal so that you see the waveform centered around zero volts. Figure 20 illustrates this difference. The AC coupling setting is useful when the entire signal (alternating current + direct current) is too large for the volts/div setting.

The ground setting disconnects the input signal from the vertical system, which lets you see where zero volts is located on the screen. With grounded input coupling and auto trigger mode, you see a horizontal line on the screen that represents zero volts. Switching from DC to ground and back again is a handy way of measuring signal voltage levels with respect to ground.

Bandwidth Limit

Most oscilloscopes have a circuit that limits the bandwidth of the oscilloscope. By limiting the bandwidth, you reduce the noise that sometimes appears on the displayed waveform, resulting in a cleaner signal display. Note that, while eliminating noise, the bandwidth limit can also reduce or eliminate high-frequency signal content.

Bandwidth Enhancement

Some oscilloscopes may provide a DSP arbitrary equalization filter which can be used to improve the oscilloscope channel response. This filter extends the bandwidth, flattens the oscilloscope channel frequency response, improves phase linearity, and provides a better match between channels. It also decreases rise time and improves the time domain step response.

Horizontal System and Controls

An oscilloscope's horizontal system is most closely associated with its acquisition of an input signal – sample rate and record length are among the considerations here. Horizontal controls are used to position and scale the waveform horizontally.

Acquisition Controls

Digital oscilloscopes have settings that let you control how the acquisition system processes a signal. Look over the acquisition options on your digital oscilloscope while you read this description. Figure 21 shows you an example of an acquisition menu.

Acquisition Modes

Acquisition modes control how waveform points are produced from sample points. Sample points are the digital values derived directly from the analog-to-digital converter (ADC). The sample interval refers to the time between these sample points. Waveform points are the digital values that are stored in memory and displayed to construct the waveform. The time value difference between waveform points is referred to as the waveform interval.

Common horizontal controls include:

- Time Base
- XY
- Scale
- Trace Separation
- Record Length
- Resolution
- Sample Rate
- Trigger Position
- Zoom/Pan
- Search

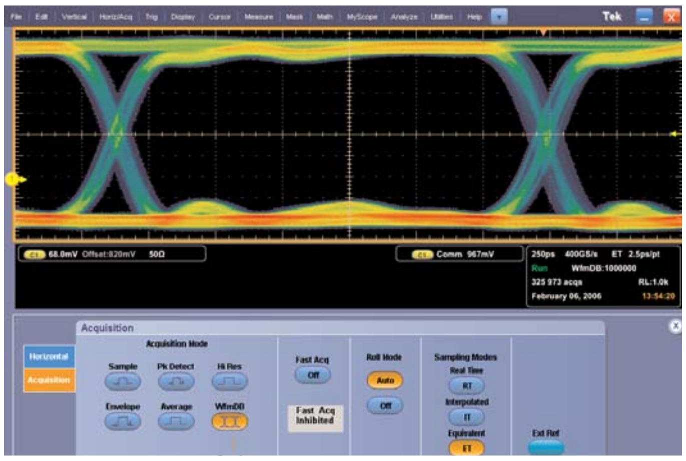
File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursor
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
C1 68.0mV Offset:820mV 50Ω
C1 Comm 967mV
250ps 400GS/s ET 2.5ps/pt
Run WfmDB:1000000
325 973 acqs RL:1.0k
February 06, 2006 13:54:20
Horizontal
Acquisition
Acquisition
Acquisition Mode
Sample
Pk Detect
Hi Res
Envelope
Average
WfmDB
Fast Acq
Off
Fast Acq Inhibited
Roll Mode
Auto
Off
Sampling Modes
Real Time
RT
Interpolated
IT
Equivalent
ET
Ext Ref

Figure 21. Example of an acquisition menu.

The sample interval and the waveform interval may, or may not, be the same. This fact leads to the existence of several different acquisition modes in which one waveform point is comprised of several sequentially acquired sample points.

Additionally, waveform points can be created from a composite of sample points taken from multiple acquisitions, which provides another set of acquisition modes. A description of the most commonly used acquisition modes follows.

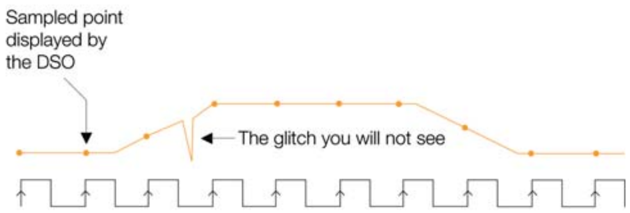
Sampled point displayed by the DSO
The glitch you will not see

Figure 22. Sample rate varies with time base settings - the slower the time based setting, the slower the sample rate. Some digital oscilloscopes provide peak detect mode to capture fast transients at slow sweep speeds.

Types of Acquisition Modes

- Sample Mode: This is the simplest acquisition mode. The oscilloscope creates a waveform point by saving one sample point during each waveform interval.
- Peak Detect Mode: The oscilloscope saves the minimum and maximum value sample points taken during two waveform intervals and uses these samples as the two corresponding waveform points. Digital oscilloscopes with peak detect mode run the ADC at a fast sample rate, even at very slow time base settings (slow time base settings translate into long waveform intervals) and are able to capture fast signal changes that would occur between the waveform points if in sample mode, as shown in Figure 22. Peak detect mode is particularly useful for seeing narrow pulses spaced far apart in time, as demonstrated in Figure 23.
- Hi-Res Mode: Like peak detect, hi res mode is a way of getting more information in cases when the ADC can sample faster than the time base setting requires. In this case, multiple samples taken within one waveform interval are averaged together to produce one waveform point. The result is a decrease in noise and an improvement in resolution for low-speed signals. The advantage of Hi Res Mode over Average is that Hi-Res Mode can be used even on a single shot event.
- Envelope Mode: Envelope mode is similar to peak detect mode. However, in envelope mode, the minimum and maximum waveform points from multiple acquisitions are combined to form a waveform that shows min/max accumulation over time. Peak detect mode is usually used to acquire the records that are combined to form the envelope waveform.

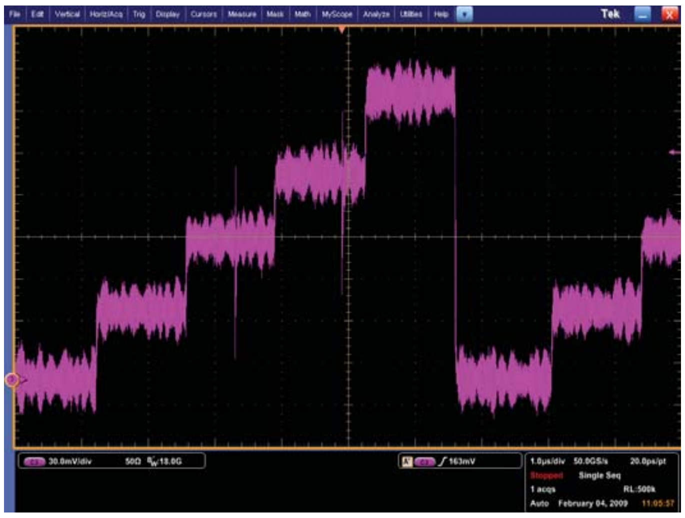

Figure 23. Peak detect mode enables the oscilloscope to capture extremely brief transient anomalies.

- Average Mode: In average mode, the oscilloscope saves one sample point during each waveform interval as in sample mode. However, waveform points from consecutive acquisitions are then averaged together to produce the final displayed waveform. Average mode reduces noise without loss of bandwidth, but requires a repeating signal.
- Waveform Database Mode: In waveform database mode, the oscillocope accumulates a waveform database that provides a three-dimensional array of amplitude, time, and counts.

Starting and Stopping the Acquisition System

One of the greatest advantages of digital oscilloscopes is their ability to store waveforms for later viewing. To this end, there are usually one or more buttons on the front panel that allow you to start and stop the acquisition system so you can analyze waveforms at your leisure. Additionally, you may want the oscilloscope to automatically stop acquiring after one acquisition is complete or after one set of records has been turned into an envelope or average waveform. This feature is commonly called single sweep or single sequence and its controls are usually found either with the other acquisition controls or with the trigger controls.

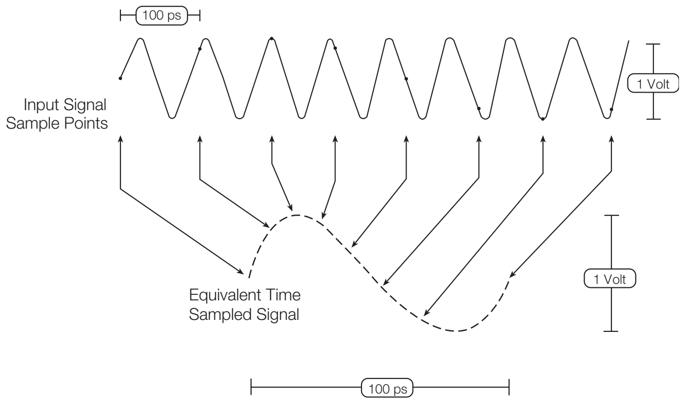

Figure 24. Basic sampling, showing sample points are connected by interpolation to produce a continuous waveform.

Sampling

Sampling is the process of converting a portion of an input signal into a number of discrete electrical values for the purpose of storage, processing and/or display. The magnitude of each sampled point is equal to the amplitude of the input signal at the instant in time in which the signal is sampled.

Sampling is like taking snapshots. Each snapshot corresponds to a specific point in time on the waveform. These snapshots can then be arranged in the appropriate order in time so as to reconstruct the input signal.

In a digital oscilloscope, an array of sampled points is reconstructed on a display with the measured amplitude on the vertical axis and time on the horizontal axis, as illustrated in Figure 24.

The input waveform in Figure 24 appears as a series of dots on the screen. If the dots are widely spaced and difficult to interpret as a waveform, the dots can be connected using a process called interpolation. Interpolation connects the dots with lines, or vectors. A number of interpolation methods are available that can be used to produce an accurate representation of a continuous input signal.

Sampling Controls

Some digital oscilloscopes provide you with a choice in sampling method – either real-time sampling or equivalent-time sampling. The acquisition controls available with these oscilloscopes will allow you to select a sample method to acquire signals. Note that this choice makes no difference for slow time base settings and only has an effect when the ADC cannot sample fast enough to fill the record with waveform points in one pass. Each sampling method has distinct advantages, depending on the kind of measurements being made.

Controls are typically available on modern oscilloscopes to give you the choice of three horizontal time base modes of operations. If you are simply doing signal exploration and want to interact with a lively signal, you will use the Automatic or interactive default mode that provides you with the liveliest display update rate. If you want a precise measurement and the highest real-time sample rate that will give you the most measurement accuracy, then the Constant Sample Rate mode is for you. It will maintain the highest sample rate and provide the best real-time resolution. The last mode is called the Manual mode because it ensures direct and independent control of the sample rate and record length.

Real-time Sampling Method

Real-time sampling is ideal for signals whose frequency range is less than half the oscilloscope's maximum sample rate. Here, the oscilloscope can acquire more than enough points in one "sweep" of the waveform to construct an accurate picture, as shown in Figure 25. Real-time sampling is the only way to capture fast, single-shot, transient signals with a digital oscilloscope.

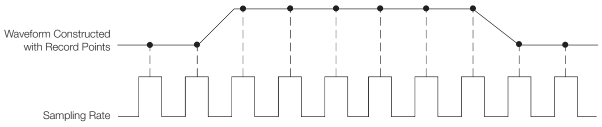

Figure 25. Real-time sampling method.

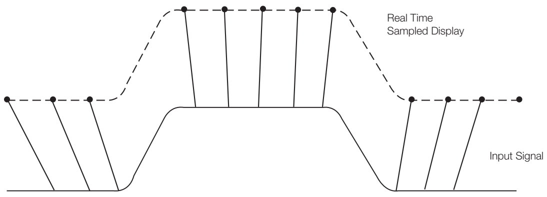

Figure 26. In order to capture this 10 ns pulse in real-time, the sample rate must be high enough to accurately define the edges.

Real-time sampling presents the greatest challenge for digital oscilloscopes because of the sample rate needed to accurately digitize high-frequency transient events, as shown in Figure 26. These events occur only once, and must be sampled in the same time frame that they occur.

If the sample rate isn't fast enough, high-frequency components can "fold down" into a lower frequency, causing aliasing in the display, as demonstrated in Figure 27. In addition, real-time sampling is further complicated by the high-speed memory required to store the waveform once it is digitized. Please refer to the Sample Rate and Record Length sections under Performance Terms and Considerations for additional detail regarding the sample rate and record length needed to accurately characterize high-frequency components.

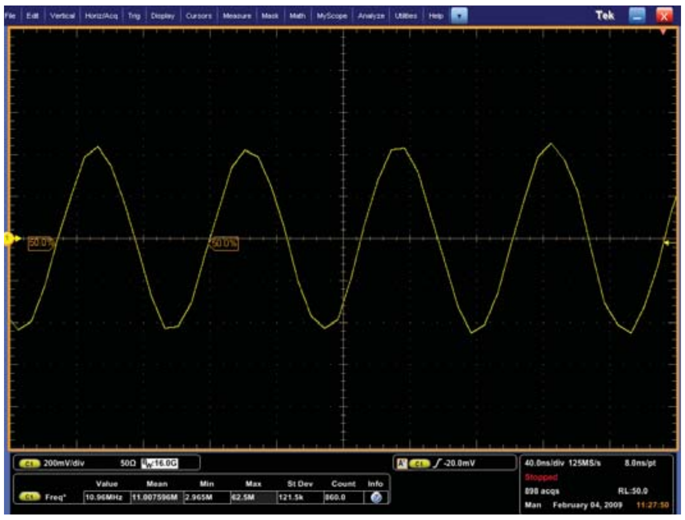

C1 200mV/div 50Ω BW:16.0G

A C1 ∫ -20.0mV

	Value	Mean	Min	Max	St Dev	Count	Info
C1 Freq*	10.96MHz	11.007596M	2.965M	62.5M	121.5k	860.0	

40.0ns/div 125MS/s 8.0ns/pt
Stopped
898 acqs RL:50.0
Man February 04, 2009 11:27:50

Figure 27. Undersampling of a 100 MHz sine wave introduces aliasing effects.

Real-time sampling with interpolation, dgital oscilloscopes take discrete samples of the signal that can be displayed. However, it can be difficult to visualize the signal represented as dots, especially because there can be only a few dots representing high-frequency portions of the signal. To aid in the visualization of signals, digital oscilloscopes typically have interpolation display modes.

In simple terms, interpolation "connects the dots" so that a signal that is sampled only a few times in each cycle can be accurately displayed. Using real-time sampling with interpolation, the oscilloscope collects a few sample points of the signal in a single pass in real-time mode and uses interpolation to fill in the gaps. Interpolation is a processing technique used to estimate what the waveform looks like based on a few points.

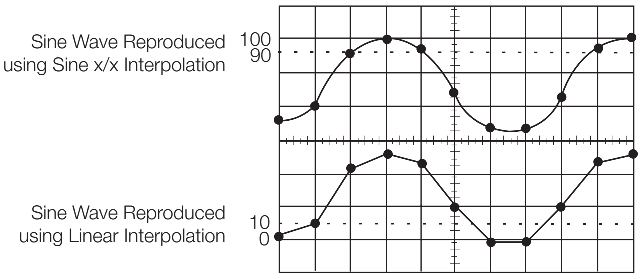

Figure 28. Linear and sin x/x interpolation.

Linear interpolation connects sample points with straight lines. This approach is limited to reconstructing straight-edged signals, as illustrated in Figure 28, which better lends itself to square waves.

The more versatile sin x/x interpolation connects sample points with curves, as shown in Figure 28. Sin x/x interpolation is a mathematical process in which points are calculated to fill in the time between the real samples. This form of interpolation lends itself to curved and irregular signal shapes, which are far more common in the real world than pure square waves and pulses. Consequently, sin x/x interpolation is the preferred method for applications where the sample rate is 3 to 5 times the system bandwidth.

Equivalent-time Sampling Method

When measuring high-frequency signals, the oscilloscope may not be able to collect enough samples in one sweep. Equivalent-time sampling can be used to accurately acquire signals whose frequency exceeds half the oscilloscope's sample rate, as illustrated in Figure 29. Equivalent-time digitizers (samplers) take advantage of the fact that most naturally occurring and man-made events are repetitive. Equivalent-time sampling constructs a picture of a repetitive signal by capturing a little bit of information from each repetition. The waveform slowly builds up like a string of lights, illuminating one-by-one. This allows the oscilloscope to accurately capture signals whose frequency components are much higher than the oscilloscope's sample rate.

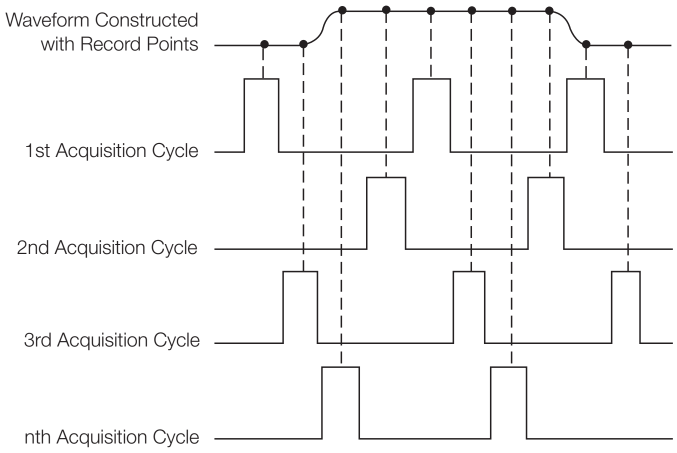

Figure 29. Some oscilloscopes use equivalent-time sampling to capture and display very fast, repetitive signals.

There are two types of equivalent-time sampling methods: random and sequential. Each has its advantages. Random equivalent-time sampling allows display of the input signal prior to the trigger point, without the use of a delay line. Sequential equivalent-time sampling provides much greater time resolution and accuracy. Both require that the input signal be repetitive.

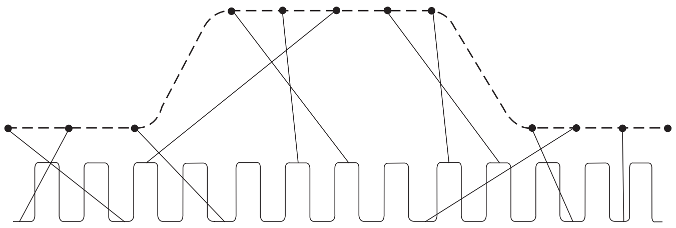

Figure 30. In random equivalent-time sampling, the sampling clock runs asynchronously with the input signal and the trigger.

Random Equivalent-time Sampling

Random equivalent-time digitizers (samplers) utilize an internal clock that runs asynchronously with respect to the input signal and the signal trigger, as illustrated in Figure 30. Samples are taken continuously, independent of the trigger position, and are displayed based on the time difference between the sample and the trigger. Although samples are taken sequentially in time, they are random with respect to the trigger – hence the name "random" equivalent-time sampling. Sample points appear randomly along the waveform when displayed on the oscilloscope screen.

The ability to acquire and display samples prior to the trigger point is the key advantage of this sampling technique, eliminating the need for external pretrigger signals or delay lines. Depending on the sample rate and the time window of the display, random sampling may also allow more than one sample to be acquired per triggered event. However, at faster sweep speeds, the acquisition window narrows until the digitizer cannot sample on every trigger. It is at these faster sweep speeds that very precise timing measurements are often made, and where the extraordinary time resolution of the sequential equivalent-time sampler is most beneficial. The bandwidth limit for random equivalent-time sampling is less than for sequential-time sampling.

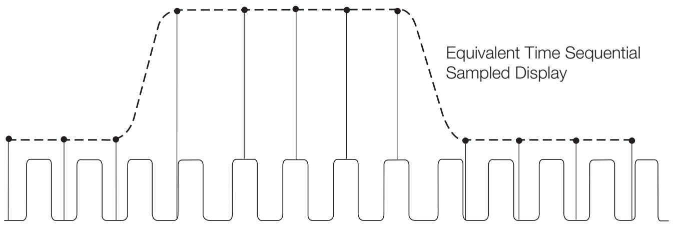

Figure 31. In sequential equivalent-time sampling, the single sample is taken for each recognized trigger after a time delay which is incremented after each cycle.

Sequential Equivalent-time Sampling

The sequential equivalent-time sampler acquires one sample per trigger, independent of the time/div setting, or sweep speed, as illustrated in Figure 31. When a trigger is detected, a sample is taken after a very short, but well-defined, delay. When the next trigger occurs, a small time increment – delta t – is added to this delay and the digitizer takes another sample. This process is repeated many times, with "delta t" added to each previous acquisition, until the time window is filled. Sample points appear from left to right in sequence along the waveform when displayed on the oscilloscope screen.

Technologically speaking, it is easier to generate a very short, very precise "delta t" than it is to accurately measure the vertical and horizontal positions of a sample relative to the trigger point, as required by random samplers. This precisely measured delay is what gives sequential samplers their unmatched time resolution. Since, with sequential sampling, the sample is taken after the trigger level is detected, the trigger point cannot be displayed without an analog delay line, which may, in turn, reduce the bandwidth of the instrument. If an external pretrigger can be supplied, bandwidth will not be affected.

Position and Seconds per Division

The horizontal position control moves the waveform left and right to exactly where you want it on the screen.

The seconds-per-division setting (usually written as sec/div) lets you select the rate at which the waveform is drawn across the screen (also known as the time base setting or sweep speed). This setting is a scale factor. If the setting is 1 ms, each horizontal division represents 1 ms and the total screen width represents 10 ms, or ten divisions. Changing the sec/div setting enables you to look at longer and shorter time intervals of the input signal.

As with the vertical volts/div scale, the horizontal sec/div scale may have variable timing, allowing you to set the horizontal time scale between the discrete settings.

Time Base Selections

Your oscilloscope has a time base, which is usually referred to as the main time base. Many oscilloscopes also have what is called a delayed time base – a time base with a sweep that can start (or be triggered to start) relative to a pre-determined time on the main time base sweep. Using a delayed time base sweep allows you to see events more clearly and to see events that are not visible solely with the main time base sweep.

The delayed time base requires the setting of a time delay and the possible use of delayed trigger modes and other settings not described in this primer. Refer to the manual supplied with your oscilloscope for information on how to use these features.

Zoom/Pan

Your oscilloscope may have special horizontal magnification settings that let you display a magnified section of the waveform on-screen. Some oscilloscopes add pan functions to the zoom capability. Knobs are used to adjust zoom factor or scale and the pan of the zoom box across the waveform.

Search

Some oscilloscopes offer search and mark capabilities, enabling you to quickly navigate through long acquisitions looking for user-defined events.

XY Mode

Most oscilloscopes have an XY mode that lets you display an input signal, rather than the time base, on the horizontal axis. This mode of operation opens up a whole new area of phase shift measurement techniques, explained in the Measurement Techniques section of this primer.

Z Axis

A digital phosphor oscilloscope (DPO) has a high display sample density and an innate ability to capture intensity information. With its intensity axis (Z axis), the DPO is able to provide a three-dimensional, real-time display similar to that of an analog oscilloscope. As you look at the waveform trace on a DPO, you can see brightened areas – the areas where a signal occurs most often. This display makes it easy to distinguish the basic signal shape from a transient that occurs only once in a while – the basic signal would appear much brighter. One application of the Z axis is to feed special timed signals into the separate Z input to create highlighted “marker” dots at known intervals in the waveform.

XYZ Mode with DPO and XYZ Record Display

Some DPOs can use the Z input to create an XY display with intensity grading. In this case, the DPO samples the instantaneous data value at the Z input and uses that value to qualify a specific part of the waveform. Once you have qualified samples, these samples can accumulate, resulting in an intensity-graded XYZ display. XYZ mode is especially useful for displaying the polar patterns commonly used in testing wireless communication devices – a constellation diagram, for example. Another method of displaying XYZ data is XYZ record display. In this mode the data from the acquisition memory is used rather than the DPO database.

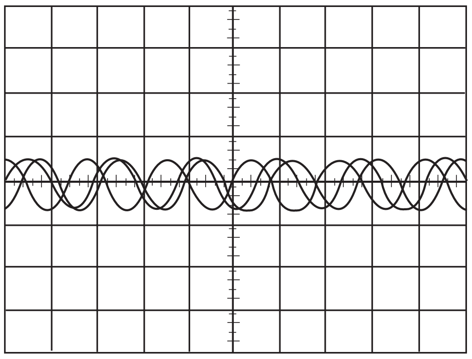

Figure 32. Untriggered display.

Trigger System and Controls

An oscilloscope's trigger function synchronizes the horizontal sweep at the correct point of the signal, essential for clear signal characterization. Trigger controls allow you to stabilize repetitive waveforms and capture single-shot waveforms.

The trigger makes repetitive waveforms appear static on the oscilloscope display by repeatedly displaying the same portion of the input signal. Imagine the jumble on the screen that would result if each sweep started at a different place on the signal, as illustrated in Figure 32.

Edge triggering, available in analog and digital oscilloscopes, is the basic and most common type. In addition to threshold triggering offered by both analog and digital oscilloscopes, many digital oscilloscopes offer numerous specialized trigger settings not offered by analog instruments. These triggers respond to specific conditions in the incoming signal, making it easy to detect, for example, a pulse that is narrower than it should be. Such a condition would be impossible to detect with a voltage threshold trigger alone.

Advanced trigger controls enable you to isolate specific events of interest to optimize the oscilloscope's sample rate and record length. Advanced triggering capabilities in some oscilloscopes give you highly selective control. You can trigger on pulses defined by amplitude (such as runt pulses), qualified by time (pulse width, glitch, slew rate, setup-and-hold, and time-out), and delineated by logic state or pattern (logic triggering).

Other advanced trigger functions include:

- **Pattern Lock Triggering:** Pattern lock triggering adds a new dimension to NRZ serial pattern triggering by enabling the oscilloscope to take synchronized acquisitions of a long serial test pattern with outstanding time base accuracy. Pattern lock triggering can be used to remove random jitter from long serial data patterns. Effects of specific bit transitions can be investigated, and averaging can be used with mask testing.
- **Serial Pattern Triggering:** Serial pattern triggering can be used to debug serial architectures. It provides a trigger on the serial pattern of an NRZ serial data stream with built-in clock recovery and correlates events across the physical and link layer. The instrument can recover the clock signal, identify transitions, and allow you to set the desired encoded words for the serial pattern trigger to capture.
- **A & B Triggering:** Some trigger systems offer multiple trigger types only on a single event (A event), with delayed trigger (B event) selection limited to edge type triggering and often do not provide a way to reset the trigger sequence if the B event doesn't occur. Modern oscilloscopes can provide the full suite of advanced trigger types on both A and B triggers, logic qualification to control when to look for these events, and reset triggering to begin the trigger sequence again after a specified time, state, or transition so that even events in the most complex signals can be captured.
- **Search & Mark Triggering:** Hardware triggers watch for one event type at a time, but Search can scan for multiple event types simultaneously. For example, scan for setup or hold time violations on multiple channels. Individual marks can be placed by Search indicating events that meet search criteria.
- **Trigger Correction:** Since the trigger and data acquisition systems share different paths there is some inherent time delay between the trigger position and the data acquired. This results in skew and trigger jitter. With a trigger correction system the instrument adjusts the trigger position and compensates for the difference of delay there is between the trigger path and the data acquisition path. This will eliminate virtually any trigger jitter at the trigger point. In this mode, the trigger point can be used as a measurement reference.

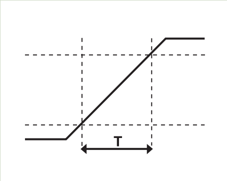

Slew Rate Triggering. High frequency signals with slew rates faster than expected or needed can radiate troublesome energy. Slew rate triggering surpasses conventional edge triggering by adding the element of time and allowing you to selectively trigger on fast or slow edges.

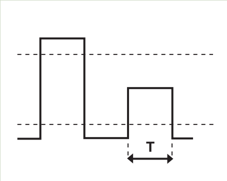

Runt Pulse Triggering. Runt triggering allows you to capture and examine pulses that cross one logic threshold, but not both.

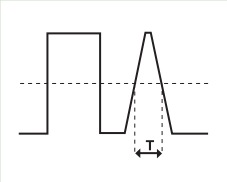

Glitch Triggering. Glitch triggering allows you to trigger on digital pulses when they are shorter or longer than a user-defined time limit. This trigger control enables you to examine the causes of even rare glitches and their effects on other signals

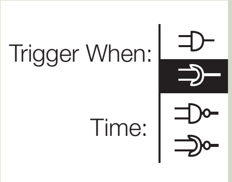

Logic Triggering. Logic triggering allows you to trigger on any logical combination of available input channels – especially useful in verifying the operation of digital logic.

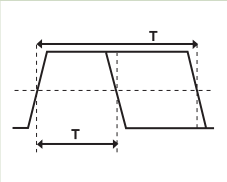

Pulse Width Triggering. Using pulse width triggering, you can monitor a signal indefinitely and trigger on the first occurrence of a pulse whose duration (pulse width) is outside the allowable limits.

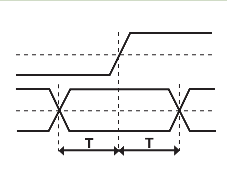

Setup-and-Hold Triggering. Only setup-and-hold triggering lets you deterministically trap a single violation of setup-and-hold time that would almost certainly be missed by using other trigger modes. This trigger mode makes it easy to capture specific signal quality and timing details when a synchronous data signal fails to meet setup-and-hold specifications.

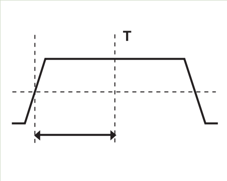

Time-out Triggering. Time-out triggering lets you trigger on an event without waiting for the trigger pulse to end, by triggering based on a specified time lapse.

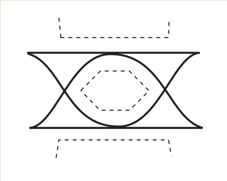

Communication Triggering. Optionally available on certain oscilloscope models, these trigger modes address the need to acquire a wide variety of Alternate-Mark Inversion (AMI), Code-Mark Inversion (CMI), and Non-Return to Zero (NRZ) communication signals.

Figure 33. Common trigger types.

- **Serial Triggering on Specific Standard Signals I^{2}C, CAN, LIN, etc.)** - Some oscilloscopes provide the ability to trigger on specific signal types for standard serial data signals such as CAN, LIN, I^{2}C, SPI, and others. The decode of these signal types is also available on many oscilloscopes today.
- **Parallel Bus Triggering** - Multiple parallel buses can be defined and displayed at one time to easily view decoded parallel bus data over time. By specifying which channels are the clock and data lines, you can create a parallel bus display on some oscilloscopes that automatically decodes bus content. Countless hours can be saved by using parallel bus triggers to simplify capture and analysis.

Optional trigger controls in some oscilloscopes are designed specifically to examine communications signals as well. Figure 33 highlights a few of these common trigger types in more detail. The intuitive user interface available in some oscilloscopes also allows rapid setup of trigger parameters with wide flexibility in the test setup to maximize your productivity.

Trigger Position

Horizontal trigger position control is only available on digital oscilloscopes. The trigger position control may be located in the horizontal control section of your oscilloscope. It actually represents the horizontal position of the trigger in the waveform record.

Varying the horizontal trigger position allows you to capture what a signal did before a trigger event, known as pre-trigger viewing. Thus, it determines the length of viewable signal both preceding and following a trigger point.

Digital oscilloscopes can provide pre-trigger viewing because they constantly process the input signal, whether or not a trigger has been received. A steady stream of data flows through the oscilloscope; the trigger merely tells the oscilloscope to save the present data in memory.

In contrast, analog oscilloscopes only display the signal – that is, write it on the CRT – after receiving the trigger. Thus, pre-trigger viewing is not available in analog oscilloscopes, with the exception of a small amount of pre-trigger provided by a delay line in the vertical system.

Pre-trigger viewing is a valuable troubleshooting aid. If a problem occurs intermittently, you can trigger on the problem, record the events that led up to it and, possibly, find the cause.

Trigger Level and Slope

The trigger level and slope controls provide the basic trigger point definition and determine how a waveform is displayed, as illustrated in Figure 34.

The trigger circuit acts as a comparator. You select the slope and voltage level on one input of the comparator. When the trigger signal on the other comparator input matches your settings, the oscilloscope generates a trigger.

The slope control determines whether the trigger point is on the rising or the falling edge of a signal. A rising edge is a positive slope and a falling edge is a negative slope. The level control determines where on the edge the trigger point occurs.

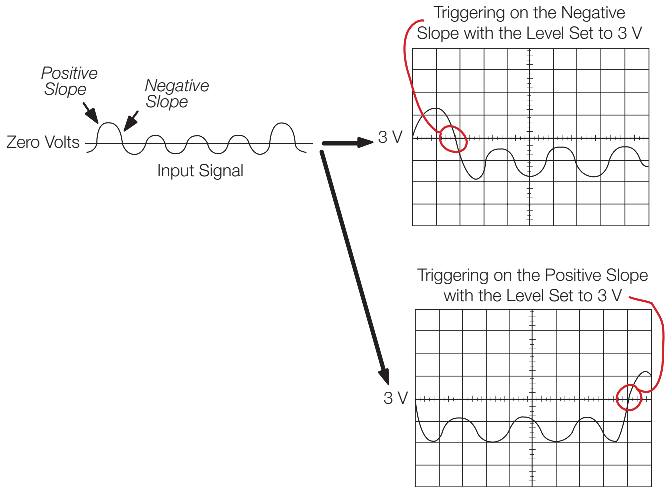
Triggering on the Negative Slope with the Level Set to 3 V
Positive Slope
Negative Slope
Zero Volts
Input Signal
3 V
Triggering on the Positive Slope with the Level Set to 3 V
3 V

Figure 34. Positive and negative slope triggering.

Trigger Sources

The oscilloscope does not necessarily need to trigger on the signal being displayed. Several sources can trigger the sweep:

- Any input channel
- An external source other than the signal applied to an input channel
- The power source signal
- A signal internally defined by the oscilloscope, from one or more input channels

Most of the time, you can leave the oscilloscope set to trigger on the channel displayed. Some oscilloscopes provide a trigger output that delivers the trigger signal to another instrument.

The oscilloscope can use an alternate trigger source, whether or not it is displayed, so you should be careful not to unwittingly trigger on channel 1 while displaying channel 2, for example.

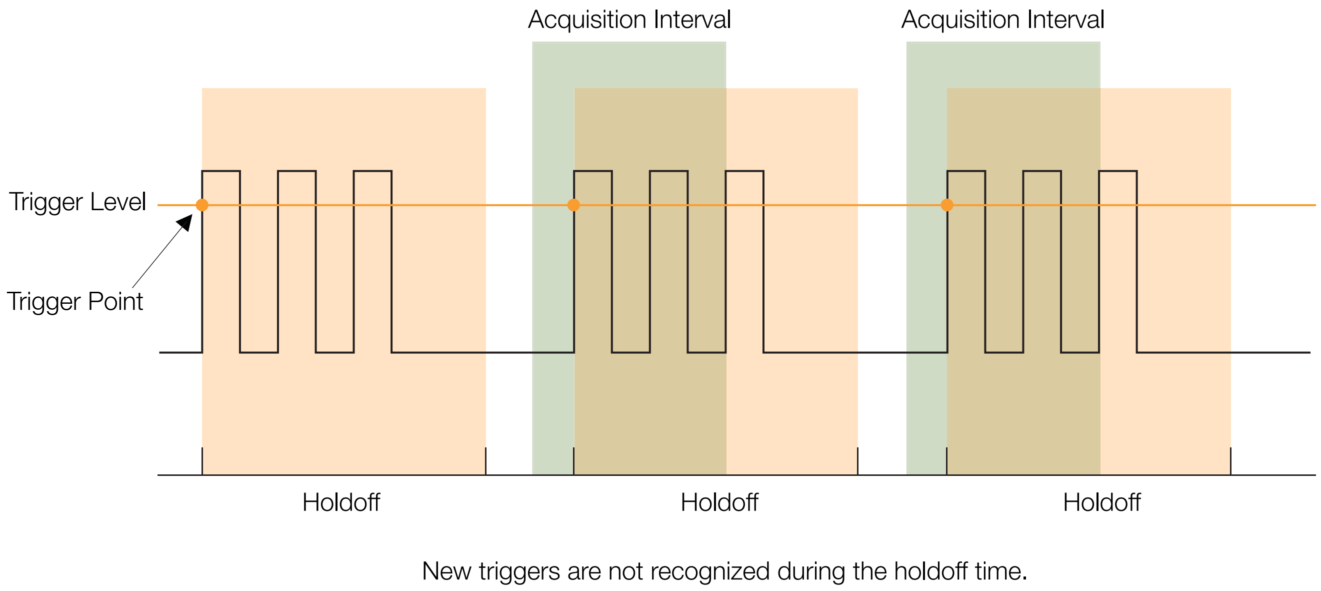

Figure 35. Trigger holdoff.

Trigger Modes

The trigger mode determines whether or not the oscilloscope draws a waveform based on a signal condition. Common trigger modes include normal and auto.

In normal mode the oscilloscope only sweeps if the input signal reaches the set trigger point; otherwise (on an analog oscilloscope) the screen is blank or (on a digital oscilloscope) frozen on the last acquired waveform. Normal mode can be disorienting since you may not see the signal at first if the level control is not adjusted correctly.

Auto mode causes the oscilloscope to sweep, even without a trigger. If no signal is present, a timer in the oscilloscope triggers the sweep. This ensures that the display will not disappear if the signal does not cause a trigger.

In practice, you will probably use both modes: normal mode because it lets you see just the signal of interest, even when triggers occur at a slow rate, and auto mode because it requires less adjustment.

Many oscilloscopes also include special modes for single sweeps, triggering on video signals, or automatically setting the trigger level.

Trigger Coupling

Just as you can select either AC or DC coupling for the vertical system, you can choose the kind of coupling for the trigger signal.

Besides AC and DC coupling, your oscilloscope may also have high frequency rejection, low frequency rejection, and noise rejection trigger coupling. These special settings are useful for eliminating noise from the trigger signal to prevent false triggering.

Trigger Holdoff

Sometimes getting an oscilloscope to trigger on the correct part of a signal requires great skill. Many oscilloscopes have special features to make this task easier.

Trigger holdoff is an adjustable period of time after a valid trigger during which the oscilloscope cannot trigger.
This feature is useful when you are triggering on complex waveform shapes, so that the oscilloscope only triggers on an eligible trigger point. Figure 35 shows how using trigger holdoff helps create a usable display.

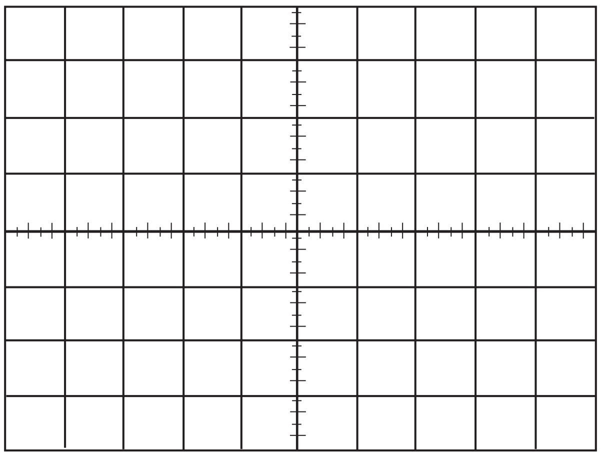

Figure 36. An oscilloscope graticule.

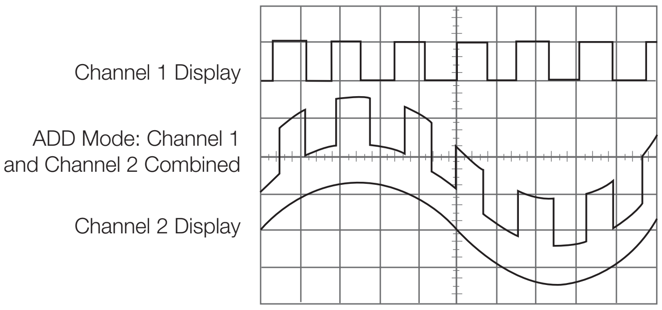

Figure 37. Adding channels.

Display System and Controls

An oscilloscope's front panel includes a display screen and the knobs, buttons, switches, and indicators used to control signal acquisition and display. As mentioned at the front of this section, front-panel controls are usually divided into vertical, horizontal and trigger sections. The front panel also includes input connectors.

Take a look at the oscilloscope display. Notice the grid markings on the screen – these markings create the graticule. Each vertical and horizontal line constitutes a major division. The graticule is usually laid out in an 8-by-10 or 10-by-10 division pattern. Labeling on the oscilloscope controls (such as volts/div and sec/div) always refers to major divisions. The tick marks on the center horizontal and vertical graticule lines, as shown in Figure 36, are called minor divisions. Many oscilloscopes display on the screen how many volts each vertical division represents and how many seconds each horizontal division represents.

Other Oscilloscope Controls

Math and Measurement Operations

Your oscilloscope may also have operations that allow you to add waveforms together, creating a new waveform display. Analog oscilloscopes combine the signals while digital oscilloscopes create new waveforms mathematically. Subtracting waveforms is another math operation. Subtraction with analog oscilloscopes is possible by using the channel invert function on one signal and then using the add operation. Digital oscilloscopes typically have a subtraction operation available. Figure 37 illustrates a third waveform created by combining two different signals.

Using the power of their internal processors, digital oscilloscopes offer many advanced math operations: multiplication, division, integration, Fast Fourier Transform, and more. This advanced signal processing capability can also perform functions such as the insertion of a filter block which can be used de-embed the characteristics of the fixture on the device under test or implement a filter block with desired frequency response such as a low pass filter. The processing block is flexible – not dedicated; it can perform as an arbitrary filter instead, for example for simulation of pre-emphasis/de-emphasis schemes.

Digital Timing and State Acquisitions

Digital channels provided by a mixed signal oscilloscope enable acquisition capabilities similar to those found on logic analyzers. There are two major digital acquisition techniques. The first technique is timing acquisition in which the MSO samples the digital signal at uniformly spaced times determined by the MSO's sample rate. At each sample point, the MSO stores the signal's logic state and creates a timing diagram of the signal. The second digital acquisition technique is state acquisition. State acquisition defines special times that the digital signal's logic state is valid and stable. This is common in synchronous and clocked digital circuits. A clock signal defines the time when the signal state is valid. For example, the input signal stable time is around the rising clock edge for a D-Flip-Flop with rising edge clocking. The output signal stable time is around the falling clock edge for a D-Flip-Flop with rising edge clocking. Since the clock period of a synchronous circuit may not be fixed, the time between state acquisitions may not be uniform as it is in a timing acquisition.

A mixed signal oscilloscope's digital channels acquire signals similar to how a logic analyzer acquires signals in timing acquisition mode. The MSO then decodes the timing acquisition into a clocked bus display, and event table which is similar to the logic analyzer's state acquisition display, providing you with important information during debug.

We have described the basic oscilloscope controls that a beginner needs to know about. Your oscilloscope may have other controls for various functions. Some of these may include:

- Automatic parametric measurements
- Measurement cursors
- Keypads for mathematical operations or data entry
- Printing capabilities
- Interfaces for connecting your oscilloscope to a computer or directly to the Internet

Look over the other options available to you and read your oscilloscope’s manual to find out more about these other controls.

The Complete Measurement System

Probes

Even the most advanced instrument can only be as precise as the data that goes into it. A probe functions in conjunction with an oscilloscope as part of the measurement system. Precision measurements start at the probe tip. The right probes matched to the oscilloscope and the device-under-test (DUT) not only allow the signal to be brought to the oscilloscope cleanly, they also amplify and preserve the signal for the greatest signal integrity and measurement accuracy.

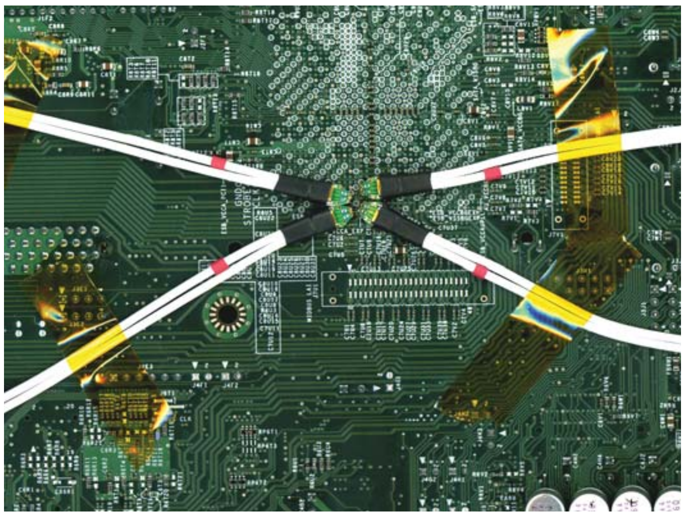

Figure 38. Dense devices and systems require small form factor probes.

To ensure accurate reconstruction of your signal, try to choose a probe that, when paired with your oscilloscope, exceeds the signal bandwidth by 5 times.

Probes actually become part of the circuit, introducing resistive, capacitive and inductive loading that inevitably alters the measurement. For the most accurate results, the goal is to select a probe with minimal loading. An ideal pairing of the probe with the oscilloscope will minimize this loading, and enable you to access all of the power, features and capabilities of your oscilloscope.

Another connectivity consideration is the probe’s form factor. Small form factor probes provide easier access to today’s densely packed circuitry, as shown in Figure 38.

A brief description of the types of probes follows. Please refer to the Tektronix ABCs of Probes primer for more information about this essential component of the overall measurement system.

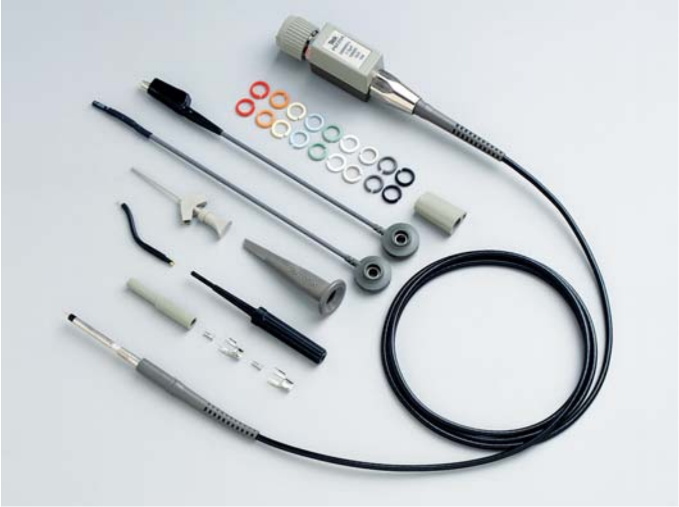

Figure 39. A typical passive probe with accessories.

Passive Probes

For measuring typical signal and voltage levels, passive probes provide ease-of-use and a wide range of measurement capabilities at an affordable price. The pairing of a passive voltage probe with a current probe will provide you with an ideal solution for measuring power.

Most passive probes have some attenuation factor, such as 10X, 100X, and so on. By convention, attenuation factors, such as for the 10X attenuator probe, have the X after the factor. In contrast, magnification factors like X10 have the X first.

The 10X (read as “ten times”) attenuator probe reduces circuit loading in comparison to a 1X probe and is an excellent general-purpose passive probe. Circuit loading becomes more pronounced for higher frequency and/or higher impedance signal sources, so be sure to analyze these signal/probe loading interactions before selecting a probe. The 10X attenuator probe improves the accuracy of your measurements, but also reduces the signal’s amplitude at the oscilloscope input by a factor of 10.

Because it attenuates the signal, the 10X attenuator probe makes it difficult to look at signals less than 10 millivolts peak-to-peak. The 1X probe is similar to the 10X attenuator probe but lacks the attenuation circuitry. Without this circuitry, more interference is introduced to the circuit being tested.

Use the 10X attenuator probe as your general-purpose probe, but keep the 1X probe accessible to measure slow-speed, low-amplitude signals. Some probes have a convenient feature for switching between 1X and 10X attenuation at the probe tip. If your probe has this feature, make sure you are using the correct setting before taking measurements.

Many oscilloscopes can automatically detect whether you are using a 1X or 10X probe and adjust their screen readouts accordingly. However with some oscilloscopes, you must set the type of probe you are using or read from the proper 1X or 10X marking on the volts/div control.

The 10X attenuator probe works by balancing the probe’s electrical properties against the oscilloscope’s electrical properties. Before using a 10X attenuator probe you need to adjust this balance for your particular oscilloscope. This adjustment is known as compensating the probe and is described in more detail in the Operating the Oscilloscope section of this primer.

Passive probes, such as the one shown in Figure 39, provide excellent general-purpose probing solutions. However, general-purpose passive probes cannot accurately measure signals with extremely fast rise times, and may excessively load sensitive circuits. The steady increase in signal clock rates and edge speeds demands higher speed probes with less loading effects. High-speed active and differential probes provide ideal solutions when measuring high-speed and/or differential signals.

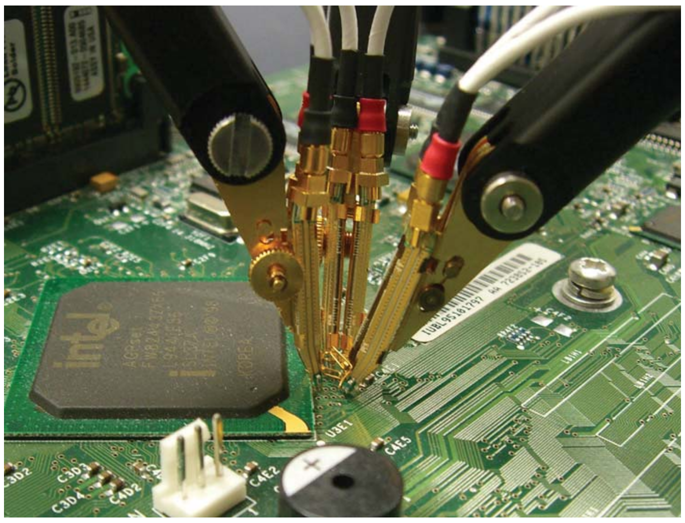

Figure 40. High-performance probes are critical when measuring the fast clocks and edges found in today's computer buses and data transmission lines.

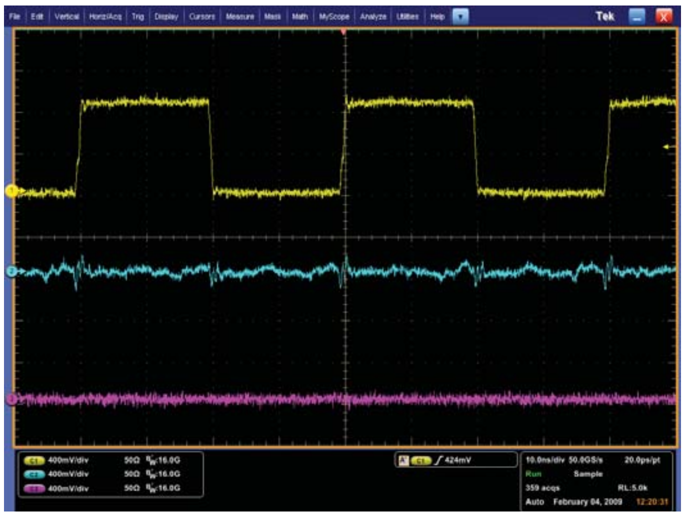
File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursors
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
C1 400mV/div 50Ω 16.0G
C2 400mV/div 50Ω 16.0G
C3 400mV/div 50Ω 16.0G
C1 424mV
10.0ns/div 50.0GS/s 20.0ps/pt
Run Sample
359 acqs RL:5.0k
Auto February 04, 2009 12:20:31

Figure 41 Differential probes can separate common-mode noise from the signal content of interest in today's fast, low-voltage applications - especially important as digital signals continue to fall below typical noise thresholds found in integrated circuits.

Active and Differential Probes

Increasing signal speeds and lower-voltage logic families make accurate measurement results difficult to achieve. Signal fidelity and device loading are critical issues. A complete measurement solution at these high speeds includes high-speed, high-fidelity probing solutions to match the performance of the oscilloscope, as shown in Figure 40.

Active and differential probes use specially developed integrated circuits to preserve the signal during access and transmission to the oscilloscope, ensuring signal integrity. For measuring signals with fast rise times, a high-speed active or differential probe will provide more accurate results, as highlighted in Figure 41.

Newer probe types provide the advantage of being able to use one setup, and get three types of measurements without adjusting probe tip connections. These probes can make differential, single-ended and common mode measurements from the same probe setup.

Logic Probes

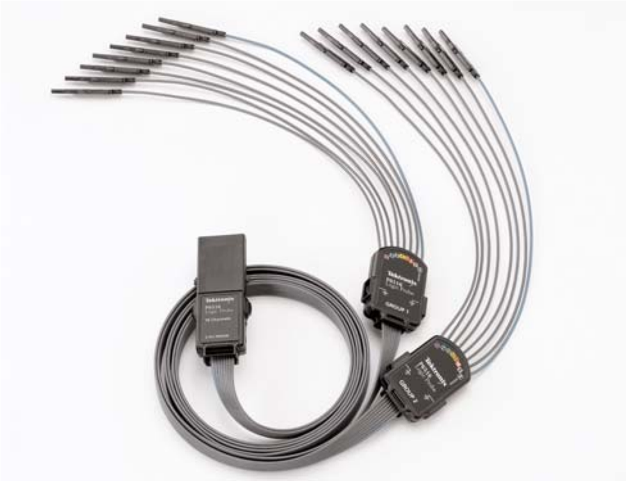

Figure 42. Logic probes for a mixed signal oscilloscope (MSO) simplify digital connectivity to your device.

The logic probe shown in Figure 42 offers two eight-channel pods. Each channel ends with a probe tip featuring a recessed ground for simplified connection to the device-under-test. The coax on the first channel of each pod is colored blue making it easy to identify. The common ground uses an automotive style connector making it easy to create custom grounds for connecting to the device-under-test. When connecting to square pins, you can use an adapter that attaches to the probe head extending the probe ground flush with the probe tip so you can attach to a header. These probes offer outstanding electrical characteristics with minimal capacitive loading.

Specialty Probes

In addition to the previously mentioned probe types, there are also a variety of other specialty probes and probing systems. These include current, high-voltage, and optical probes, just to name a few.

Probe Accessories

Many modern oscilloscopes provide special automated features built into the input and mating probe connectors. In the case of intelligent probe interfaces, the act of connecting the probe to the instrument notifies the oscilloscope about the probe's attenuation factor, which in turn scales the display so that the probe's attenuation is figured into the readout on the screen. Some probe interfaces also recognize the type of probe – that is, passive, active or current. The interface may act as a DC power source for probes. Active probes have their own amplifier and buffer circuitry that requires DC power.

Ground lead and probe tip accessories are also available to improve signal integrity when measuring high-speed signals. Ground lead adapters provide spacing flexibility between probe tip and ground lead connections to the DUT, while maintaining very short lead lengths from probe tip to DUT.

Please refer to the Tektronix ABCs of Probes primer for more information about probes and probe accessories.

Performance Terms and Considerations

As previously mentioned, an oscilloscope is analogous to a camera that captures signal images that we can observe and interpret. Shutter speed, lighting conditions, aperture and the ASA rating of the film all affect the camera's ability to capture an image clearly and accurately.

Like the basic systems of an oscilloscope, the performance considerations of an oscilloscope significantly affect its ability to achieve the required signal integrity.

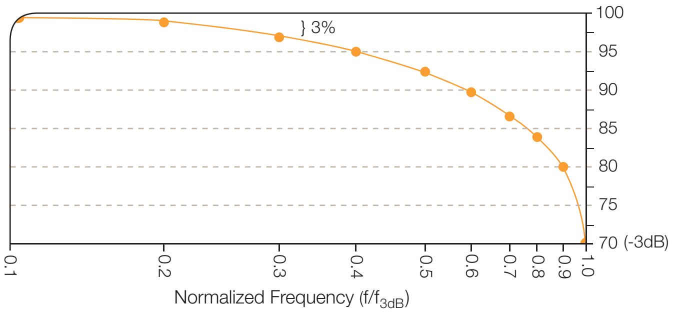

Figure 43. Oscilloscope bandwidth is the frequency at which a sinusoidal input signal is attenuated to 70.7% of the signal's true amplitude, known as the -3 dB point.

Learning a new skill often involves learning a new vocabulary. This idea holds true for learning how to use an oscilloscope. This section describes some useful measurement and oscilloscope performance terms. These terms are used to describe the criteria essential to choosing the right oscilloscope for your application. Understanding these terms will help you to evaluate and compare your oscilloscope with other models.

Bandwidth

Bandwidth determines an oscilloscope's fundamental ability to measure a signal. As signal frequency increases, the capability of the oscilloscope to accurately display the signal decreases. This specification indicates the frequency range that the oscilloscope can accurately measure.

Oscilloscope bandwidth is specified as the frequency at which a sinusoidal input signal is attenuated to 70.7% of the signal's true amplitude, known as the –3 dB point, a term based on a logarithmic scale, as seen in Figure 43.

Without adequate bandwidth, your oscilloscope will not be able to resolve high-frequency changes. Amplitude will be distorted. Edges will vanish. Details will be lost. Without adequate bandwidth, all the features, bells and whistles in your oscilloscope will mean nothing.

To determine the oscilloscope bandwidth needed to accurately characterize signal amplitude in your specific application, apply the "5 Times Rule."

$$\text{Oscilloscope Bandwidth} \geq \begin{matrix}\text{Highest Frequency}\\ \text{Component of Signal}\end{matrix} \; x \;\; 5$$

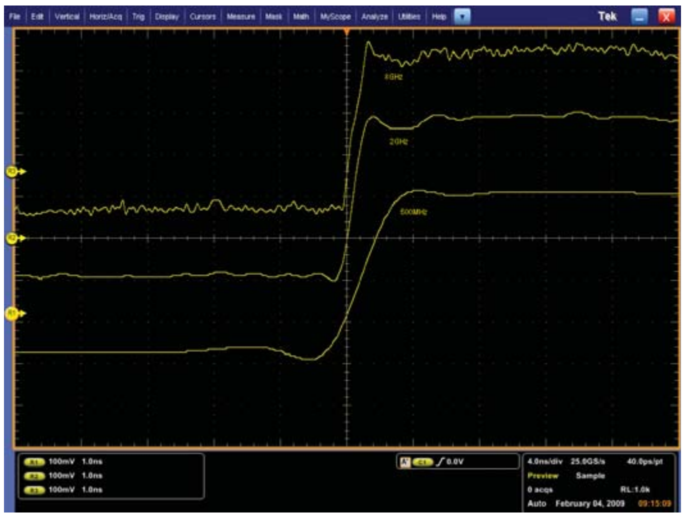
File
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Vertical
Horiz/Acq
Trig
Display
Cursors
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
4GHz
2GHz
500MHz
R1 100mV 1.0ns
R2 100mV 1.0ns
R3 100mV 1.0ns
C1 0.0V
4.0ns/div 25.0GS/s 40.0ps/pt
Preview Sample
0 acqs RL:1.0k
Auto February 04, 2009 09:15:09

Figure 44. The higher the bandwidth, the more accurate the reproduction of your signal, as illustrated with a signal captured at 250 MHz, 1 GHz and 4 GHz bandwidth levels.

An oscilloscope selected using the 5 Times Rule will give you less than ±2% error in your measurements – typically sufficient for today's applications. However, as signal speeds increase, it may not be possible to achieve this rule of thumb. Always keep in mind that higher bandwidth will likely provide more accurate reproduction of your signal, as demonstrated in Figure 44.

Some oscilloscopes provide a method of enhancing the bandwidth through digital signal processing. A DSP arbitrary equalization filter can be used to improve the oscilloscope channel response. This filter extends the bandwidth, flattens the oscilloscope's channel frequency response, improves phase linearity, and provides a better match between channels. It also decreases rise time and improves the time-domain step response.

Rise Time

In the digital world, rise time measurements are critical. Rise time may be a more appropriate performance consideration when you expect to measure digital signals, such as pulses and steps. As shown in Figure 45, your oscilloscope must have sufficient rise time to accurately capture the details of rapid transitions.

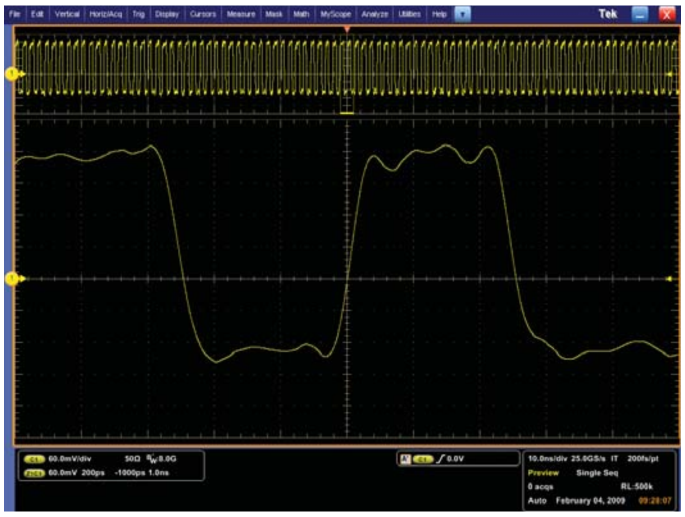
File
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Math
MyScope
Analyze
Utilities
Help
Tek
C1 60.0mV/div 50Ω BW:8.0G
Z(C1) 60.0mV 200ps -1000ps 1.0ns
C1 0.0V
10.0ns/div 25.0GS/s IT 200fs/pt
Preview Single Seq
0 acqs RL:500k
Auto February 04, 2009 09:28:07

Figure 45. Rise time characterization of a high-speed digital signal.

Rise time describes the useful frequency range of an oscilloscope. To calculate the oscilloscope rise time required for your signal type, use the following equation:

$$\text{Oscilloscope Rise Time} \leq \text{Fastest Rise Time of Signal} \;\; x \;\; \frac{1}{5}$$

Note that this basis for oscilloscope rise time selection is similar to that for bandwidth. As in the case of bandwidth, achieving this rule of thumb may not always be possible given the extreme speeds of today's signals. Always remember that an oscilloscope with faster rise time will more accurately capture the critical details of fast transitions.

In some applications, you may know only the rise time of a signal. A constant allows you to relate the bandwidth and rise time of the oscilloscope, using the equation:

$$\text{Bandwidth} = \frac{k}{\text{Rise Time}}$$

where k is a value between 0.35 and 0.45, depending on the shape of the oscilloscope's frequency response curve and pulse rise time response. Oscilloscopes with a bandwidth of <1 GHz typically have a 0.35 value, while oscilloscopes with a bandwidth of > 1 GHz usually have a value between 0.40 and 0.45.

Logic Family	Typical Signal Rise Time	Calculated Signal Bandwidth
TTL	2 ns	175 MHz
CMOS	1.5 ns	230 MHz
GTL	1 ns	350 MHz
LVDS	400 ps	875 MHz
ECL	100 ps	3.5 GHz
GaAs	40 ps	8.75 GHz

Figure 46. Some logic families produce inherently faster rise times than others.

Some logic families produce inherently faster rise times than others, as illustrated in Figure 46.

Sample Rate

Sample rate – specified in samples per second (S/s) – refers to how frequently a digital oscilloscope takes a snapshot or sample of the signal, analogous to the frames on a movie camera. The faster an oscilloscope samples (i.e., the higher the sample rate), the greater the resolution and detail of the displayed waveform and the less likely that critical information or events will be lost, as shown in Figure 47. The minimum sample rate may also be important if you need to look at slowly changing signals over longer periods of time. Typically, the displayed sample rate changes with changes made to the horizontal scale control to maintain a constant number of waveform points in the displayed waveform record.

How do you calculate your sample rate requirements? The method differs based on the type of waveform you are measuring, and the method of signal reconstruction used by the oscilloscope.

In order to accurately reconstruct a signal and avoid aliasing, the Nyquist theorem states that the signal must be sampled at least twice as fast as its highest frequency component. This theorem, however, assumes an infinite record length and a continuous signal. Since no oscilloscope offers infinite record length and, by definition, glitches are not continuous, sampling at only twice the rate of highest frequency component is usually insufficient.

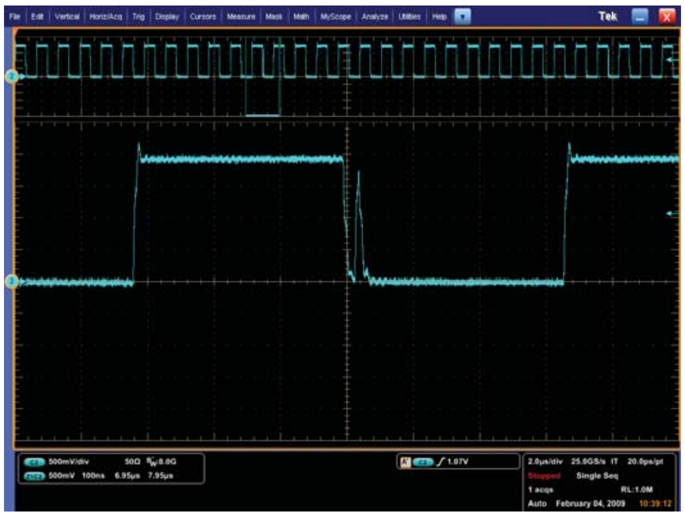

Figure 47. A higher sample rate provides greater signal resolution, ensuring that you'll see intermittent events.

In reality, accurate reconstruction of a signal depends on both the sample rate and the interpolation method used to fill in the spaces between the samples. Some oscilloscopes let you select either sin (x)/x interpolation for measuring sinusoidal signals, or linear interpolation for square waves, pulses and other signal types.

> For accurate reconstruction using sin(x)/x interpolation, your oscilloscope should have a sample rate at least 2.5 times the highest frequency component of your signal. Using linear interpolation, the sample rate should be at least 10 times the highest frequency signal component.

Some measurement systems with sample rates to 50 GS/s and bandwidths to 20 GHz have been optimized for capturing very fast, single-shot and transient events by oversampling up to 5 times the bandwidth.

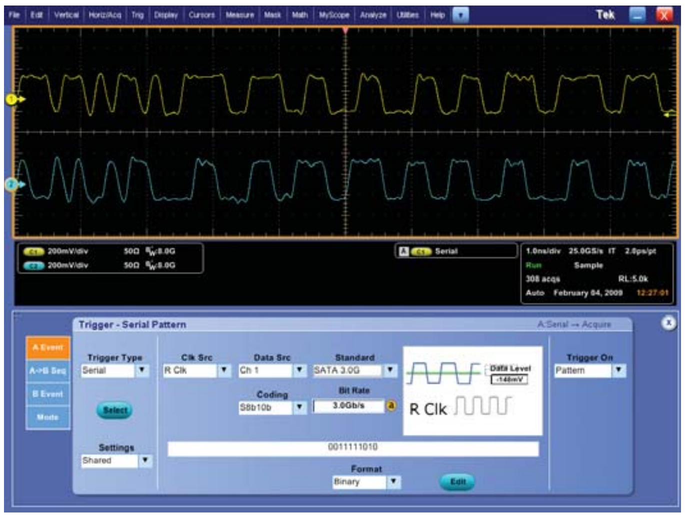
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Trig
Display
Cursors
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
200mV/div 50Ω 8.0G
200mV/div 50Ω 8.0G
Serial
1.0ns/div 25.0GS/s IT 2.0ps/pt
Run Sample
308 acqs RL:5.0k
Auto February 04, 2009 12:27:01
A Event
A->B Seq
B Event
Mode
Select
Edit
A:Serial → Acquire
R Clk

Trigger - Serial Pattern

Trigger Type: Serial
Clk Src: R Clk
Data Src: Ch 1
Standard: SATA 3.0G
Coding: S8b10b
Bit Rate: 3.0Gb/s
Data Level: -148mV
Trigger On: Pattern
Settings: Shared
0011111010
Format: Binary

Figure 48. A DPO provides an ideal solution for non-repetitive, high-speed, multi-channel digital design applications.

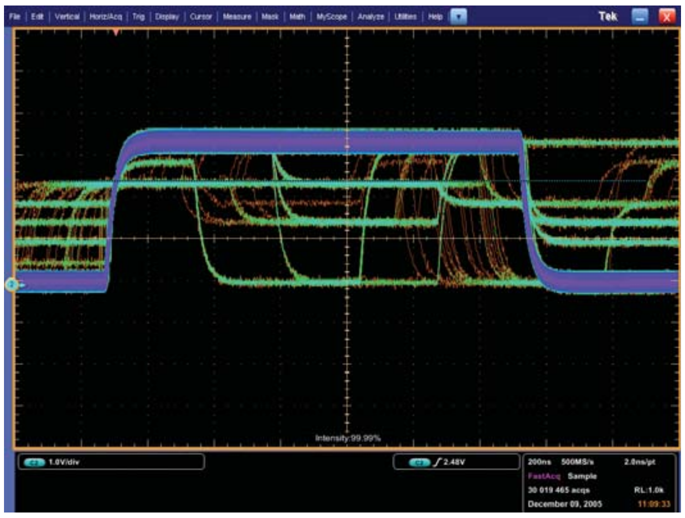
File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursor
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
Intensity:99.99%
1.0V/div
2.48V
200ns 500MS/s 2.0ns/pt
FastAcq Sample
30 019 465 acqs RL:1.0k
December 09, 2005 11:09:33

Figure 49. A DPO enables a superior level of insight into signal behavior by delivering vastly greater waveform capture rates and three-dimensional display, making it the best general-purpose design and troubleshooting tool for a wide range of applications.

Waveform Capture Rate

All oscilloscopes blink. That is, they open their eyes a given number of times per second to capture the signal, and close their eyes in between. This is the waveform capture rate, expressed as waveforms per second (wfms/s). While the sample rate indicates how frequently the oscilloscope samples the input signal within one waveform, or cycle, the waveform capture rate refers to how quickly an oscilloscope acquires waveforms.

Waveform capture rates vary greatly, depending on the type and performance level of the oscilloscope. Oscilloscopes with high waveform capture rates provide significantly more visual insight into signal behavior, and dramatically increase the probability that the oscilloscope will quickly capture transient anomalies such as jitter, runt pulses, glitches and transition errors.

Digital storage oscilloscopes (DSOs) employ a serial-processing architecture to capture from 10 to 5,000 wfms/s. Some DSOs provide a special mode that bursts multiple captures into long memory, temporarily delivering higher waveform capture rates followed by long processing dead times that reduce the probability of capturing rare, intermittent events.

Most digital phosphor oscilloscopes (DPOs) employ a parallel-processing architecture to deliver vastly greater waveform capture rates. As seen in Figure 48, some DPOs can acquire millions of waveforms in just seconds, significantly increasing the probability of capturing intermittent and elusive events and allowing you to see the problems in your signal more quickly. Moreover, the DPO's ability to acquire and display three dimensions of signal behavior in real time – amplitude, time and distribution of amplitude over time – results in a superior level of insight into signal behavior, as shown in Figure 49.

Record Length

Record length, expressed as the number of points that comprise a complete waveform record, determines the amount of data that can be captured with each channel. Since an oscilloscope can store only a limited number of samples, the waveform duration (time) will be inversely proportional to the oscilloscope's sample rate.

$$\text{Time Interval} = \frac{\text{Record Length}}{\text{Sample Rate}}$$

Modern oscilloscopes allow you to select record length to optimize the level of detail needed for your application. If you are analyzing an extremely stable sinusoidal signal, you may need only a 500 point record length, but if you are isolating the causes of timing anomalies in a complex digital data stream, you may need a million points or more for a given record length, as demonstrated in Figure 50.

Triggering Capabilities

An oscilloscope's trigger function synchronizes the horizontal sweep at the correct point of the signal, essential for clear signal characterization. Trigger controls allow you to stabilize repetitive waveforms and capture single-shot waveforms.

Please refer to the Trigger section under Performance Terms and Considerations for more information regarding triggering capabilities.

Effective Bits

Effective bits represent a measure of a digital oscilloscope's ability to accurately reconstruct a sinewave signal's shape. This measurement compares the oscilloscope's actual error to that of a theoretical "ideal" digitizer. Because the actual errors include noise and distortion, the frequency and amplitude of the signal must be specified.

Frequency Response

Bandwidth alone is not enough to ensure that an oscilloscope can accurately capture a high frequency signal. The goal of oscilloscope design is a specific type of frequency response: Maximally Flat Envelope Delay (MFED). A frequency response of this type delivers excellent pulse fidelity with minimum overshoot and ringing. Since a digital oscilloscope is composed of real amplifiers, attenuators, ADCs, interconnects, and relays, MFED response is a goal that can only be approached. Pulse fidelity varies considerably with model and manufacturer.

Vertical Sensitivity

Vertical sensitivity indicates how much the vertical amplifier can amplify a weak signal – usually measured in millivolts (mV) per division. The smallest voltage detected by a general-purpose oscilloscope is typically about 1 mV per vertical screen division.

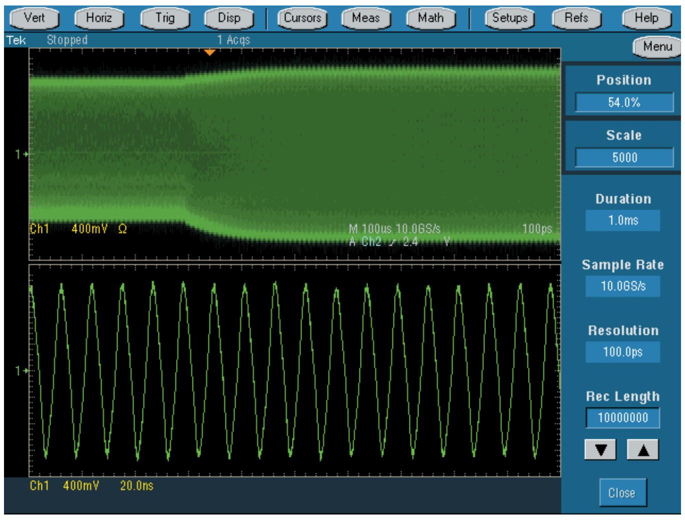

Position 54.0%

Scale 5000

Duration 1.0ms

Sample Rate 10.0GS/s

Resolution 100.0ps

Rec Length 10000000

Figure 50. Capturing the high frequency detail of this modulated 85 MHz carrier requires high resolution sampling (100 ps). Seeing the signal's complete modulation envelope requires a long time duration (1 ms). Using long record length (10 MB), the oscilloscope can display both.

Sweep Speed

Sweep speed indicates how fast the trace can sweep across the oscilloscope screen, enabling you to see fine details. The sweep speed of an oscilloscope is represented by time (seconds) per division.

Gain Accuracy

Gain accuracy indicates how accurately the vertical system attenuates or amplifies a signal, usually represented as a percentage error.

Horizontal Accuracy (Time Base)

Horizontal, or time base, accuracy indicates how accurately the horizontal system displays the timing of a signal, usually represented as a percentage error.

Vertical Resolution (Analog-to-Digital Converter)

Vertical resolution of the ADC, and therefore, the digital oscilloscope, indicates how precisely it can convert input voltages into digital values. Vertical resolution is measured in bits. Calculation techniques can improve the effective resolution, as exemplified with hi-res acquisition mode.

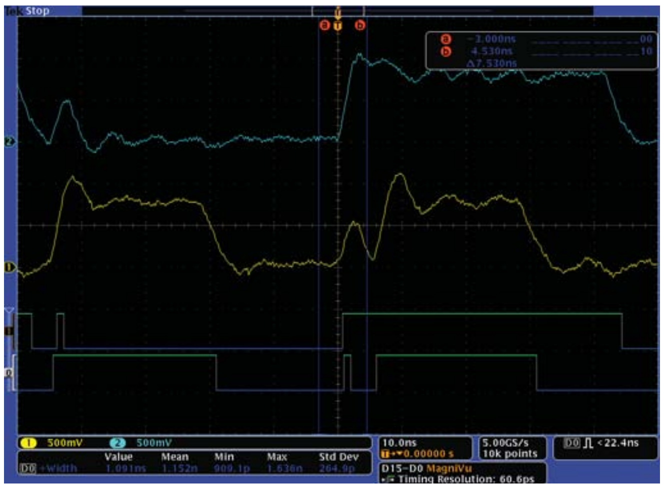
Stop
-3.000ns
4.530ns
Δ7.530ns
500mV
500mV
Value Mean Min Max Std Dev
D0 +Width 1.091ns 1.152n 909.1p 1.636n 264.9p
10.0ns
0.00000 s
5.00GS/s
10k points
D0 <22.4ns
D15–D0 MagniVu
Timing Resolution: 60.6ps

Figure 51. The MSO provides 16 integrated digital channels, enabling the ability to view and analyze time-correlated analog and digital signals. A high speed timing acquisition provides more resolution to reveal narrow events such as glitches.

Timing Resolution (MSO)

An important MSO acquisition specification is the timing resolution used for capturing digital signals. Acquiring a signal with better timing resolution provides a more accurate timing measurement of when the signal changes. For example, a 500 MS/s acquisition rate has 2 ns timing resolution and the acquired signal edge uncertainty is 2 ns. A smaller timing resolution of 60.6 ps (16.5 GS/s) decreases the signal edge uncertainty to 60.6 ps and captures faster changing signals.

Some MSOs internally acquire digital signals with two types of acquisitions at the same time. The first acquisition is with standard timing resolution, and the second acquisition uses a high speed resolution. The standard resolution is used over a longer record length while the high speed timing acquisition offers more resolution around a narrow point of interest, as shown in Figure 51.

Connectivity

The need to analyze measurement results remains of utmost importance. The need to document and share information and measurement results easily and frequently has also grown in importance. The connectivity of an oscilloscope delivers advanced analysis capabilities and simplifies the documentation and sharing of results. As shown in Figure 52, standard interfaces (GPIB, RS-232, USB, Ethernet) and network communication modules enable some oscilloscopes to deliver a vast array of functionality and control.

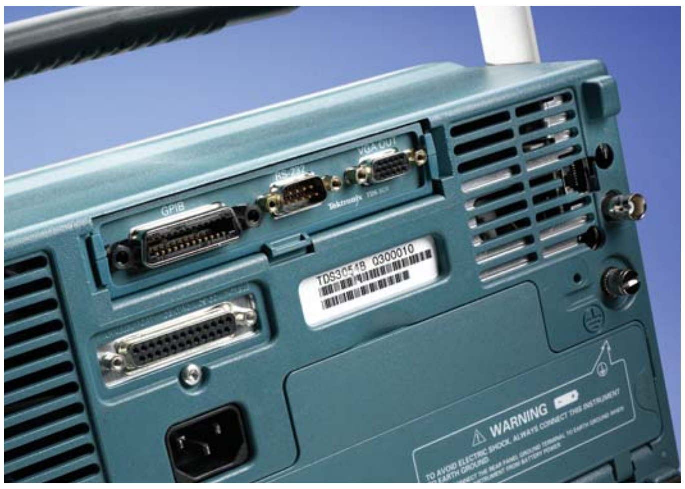
GPIB
RS-232
VGA OUT
Tektronix
TDS3054B 0300010
WARNING

Figure 52. Today's oscilloscopes provide a wide array of communications interfaces, such as a standard Centronics port and optional Ethernet/RS-232, GPIB/RS-232, and VGA/RS-232 modules. There is even a USB port (not shown) on the front panel.

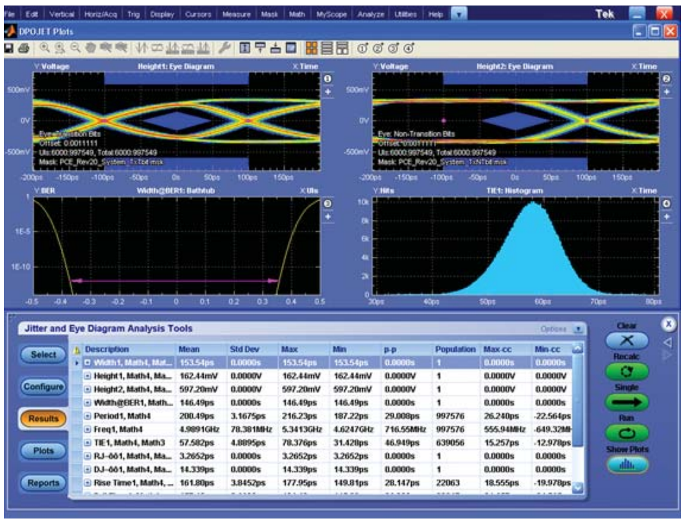
DPOJET Plots
Height1: Eye Diagram
Height2: Eye Diagram
Width@BER1: Bathtub
TIE1: Histogram
Select
Configure
Results
Plots
Reports
Clear
Recalc
Single
Run
Show Plots

Jitter and Eye Diagram Analysis Tools

Description	Mean	Std Dev	Max	Min	p-p	Population	Max-cc	Min-cc
Width1, Math4, Mat...	153.54ps	0.0000s	153.54ps	153.54ps	0.0000s	1	0.0000s	0.0000s
Height1, Math4, Ma...	162.44mV	0.0000V	162.44mV	162.44mV	0.0000V	1	0.0000V	0.0000V
Height2, Math4, Ma...	597.20mV	0.0000V	597.20mV	597.20mV	0.0000V	1	0.0000V	0.0000V
Width@BER1, Math...	146.49ps	0.0000s	146.49ps	146.49ps	0.0000s	1	0.0000s	0.0000s
Period1, Math4	200.49ps	3.1675ps	216.23ps	187.22ps	29.008ps	997576	26.240ps	-22.564ps
Freq1, Math4	4.9891GHz	78.381MHz	5.3413GHz	4.6247GHz	716.55MHz	997576	555.94MHz	-649.32MH
TIE1, Math4, Math3	57.582ps	4.8895ps	78.376ps	31.428ps	46.949ps	639056	15.257ps	-12.978ps
RJ-δδ1, Math4, Ma...	3.2652ps	0.0000s	3.2652ps	3.2652ps	0.0000s	1	0.0000s	0.0000s
DJ-δδ1, Math4, Ma...	14.339ps	0.0000s	14.339ps	14.339ps	0.0000s	1	0.0000s	0.0000s
Rise Time1, Math4, ...	161.80ps	3.8452ps	177.95ps	149.81ps	28.147ps	22063	18.555ps	-19.978ps

Figure 53. Analysis software packages are specifically designed to meet jitter and eye measurement needs of today's high-speed digital designers.

Some advanced oscilloscopes also let you:

- Create, edit and share documents on the oscilloscope – all while working with the instrument in your particular environment
- Access network printing and file sharing resources
- Access the Windows® desktop
- Run third-party analysis and documentation software
- Link to networks
- Access the Internet
- Send and receive e-mail

Expandability

An oscilloscope should be able to accommodate your needs as they change. Some oscilloscopes allow you to:

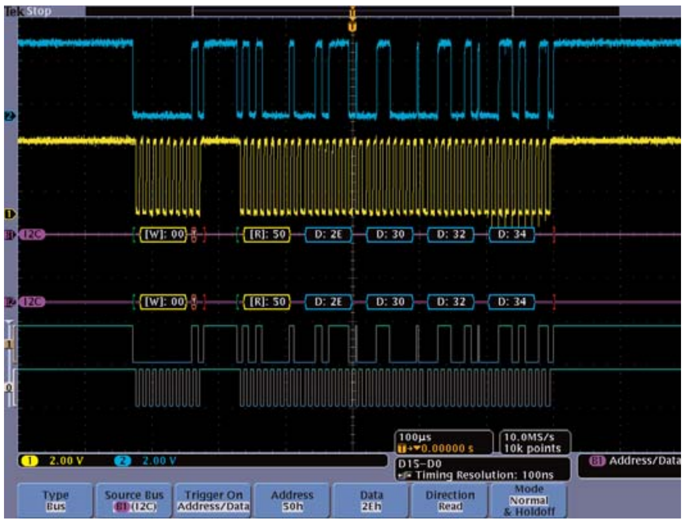
Stop
I2C
[W]: 00
[R]: 50
D: 2E
D: 30
D: 32
D: 34
100µs
0.00000 s
10.0MS/s
10k points
D15–D0
Timing Resolution: 100ns
B1 Address/Data
2.00 V
Type
Bus
Source Bus
B1 (I2C)
Trigger On
Address/Data
Address
50h
Data
2Eh
Direction
Read
Mode
Normal
& Holdoff

Figure 54. Serial bus analysis is accelerated with automated trigger, decode, and search on serial packet context.

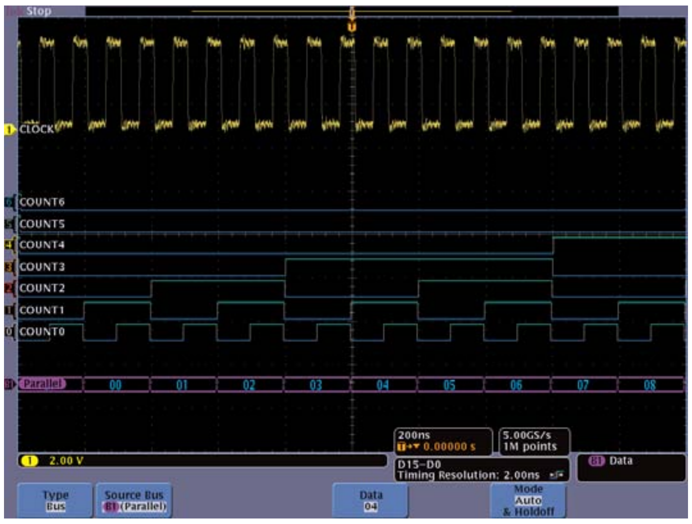
Stop
CLOCK
COUNT6
COUNT5
COUNT4
COUNT3
COUNT2
COUNT1
COUNT0
Parallel
00
01
02
03
04
05
06
07
08
200ns
0.00000 s
5.00GS/s
1M points
D15–D0
Timing Resolution: 2.00ns
B1 Data
2.00 V
Type
Bus
Source Bus
B1 (Parallel)
Data
04
Mode
Auto
& Holdoff

Figure 55. Automatically trigger, decode, and search on clocked or unclocked parallel bus data.

- Add memory to channels to analyze longer record lengths
- Add application-specific measurement capabilities
- Complement the power of the oscilloscope with a full range of probes and modules
- Work with popular third-party analysis and productivity Windows-compatible software
- Add accessories, such as battery packs and rackmounts

Application modules and software may enable you to transform your oscilloscope into a highly specialized analysis tool capable of performing functions such as jitter and timing analysis, microprocessor memory system verification, communications standards testing, disk drive measurements, video measurements, power measurements and much more. Figures 53 - 58 highlight a few of these examples.

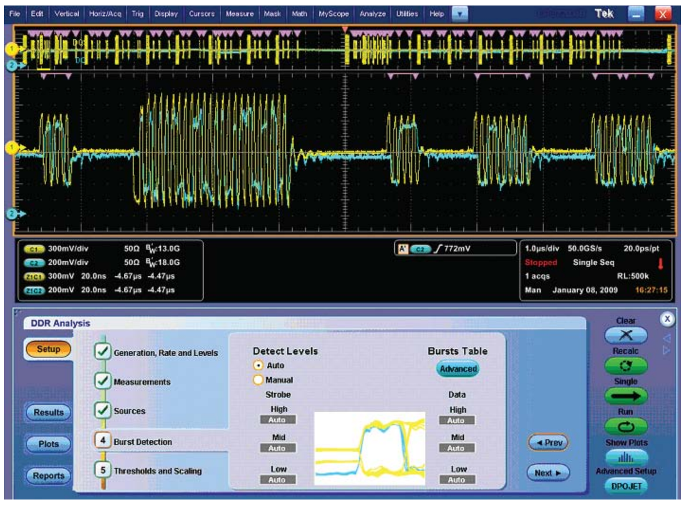
Tek
DDR Analysis
Setup
Results
Plots
Reports
Generation, Rate and Levels
Measurements
Sources
Burst Detection
Thresholds and Scaling
Detect Levels
Auto
Manual
Bursts Table
Advanced
Strobe
Data
High
Mid
Low
Prev
Next
Clear
Recalc
Single
Run
Show Plots
Advanced Setup
DPOJET

Figure 56. Advanced DDR analysis tools automate complex memory tasks like separating read/write bursts and performing JEDEC measurements.

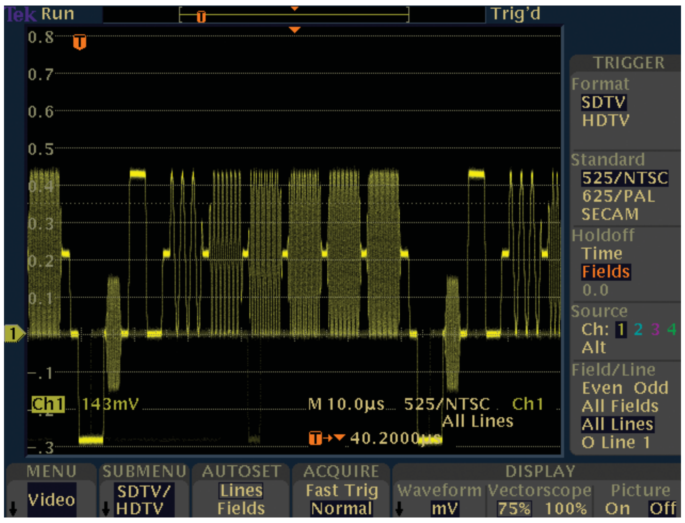
Run
Trig'd
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-.1
-.3
Ch1 143mV
M 10.0µs
525/NTSC
Ch1
All Lines
40.2000µs
TRIGGER
Format
SDTV
HDTV
Standard
525/NTSC
625/PAL
SECAM
Holdoff
Time
Fields
0.0
Source
Ch: 1 2 3 4
Alt
Field/Line
Even Odd
All Fields
All Lines
0 Line 1
MENU
Video
SUBMENU
SDTV/HDTV
AUTOSET
Lines
Fields
ACQUIRE
Fast Trig
Normal
DISPLAY
Waveform
Vectorscope
mV
75%
100%
Picture
On
Off

Figure 57. Video application modules make the oscilloscope a fast, tell-all tool for video troubleshooting.

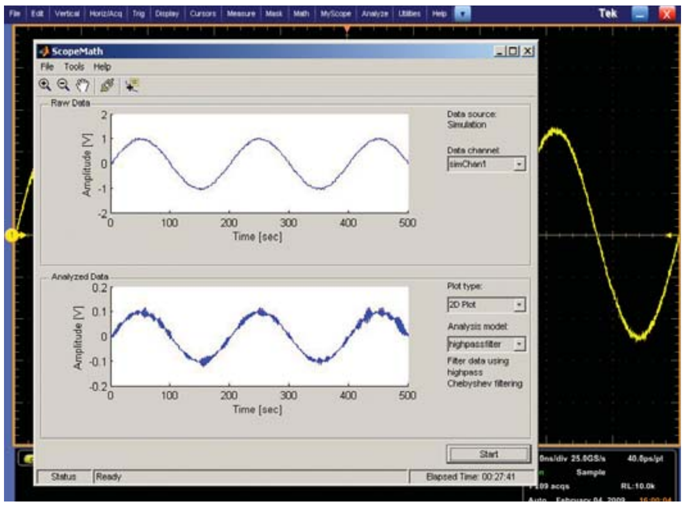
ScopeMath
File
Tools
Help
Raw Data
Amplitude [V]
Time [sec]
Data source:
Simulation
Data channel:
simChan1
Analyzed Data
Plot type:
2D Plot
Analysis model:
highpassfilter
Filter data using highpass Chebyshev filtering
Start
Status
Ready
Elapsed Time: 00:27:41

Figure 58. Advanced analysis and productivity software, such as MATLAB®, can be installed in Windows-based oscilloscopes to accomplish local signal analysis.

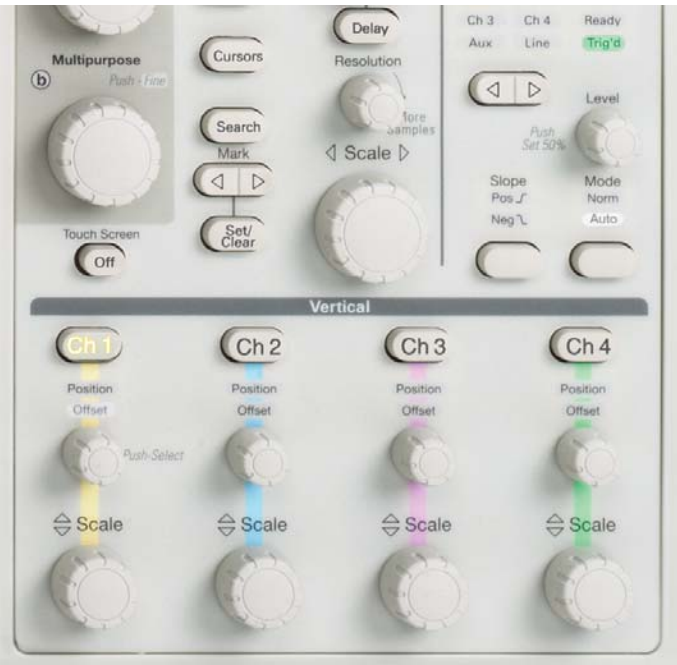
Multipurpose
Push - Fine
Cursors
Delay
Resolution
More Samples
Search
Mark
Scale
Set/Clear
Touch Screen
Off
Ch 3
Ch 4
Ready
Aux
Line
Trig'd
Level
Push Set 50%
Slope
Pos
Neg
Mode
Norm
Auto
Vertical
Ch 1
Ch 2
Ch 3
Ch 4
Position
Offset
Push-Select
Scale

Figure 59. Traditional, analog-style knobs control position, scale, intensity, etc. – precisely as you would expect.

Ease-of-Use

Oscilloscopes should be easy to learn and easy to use, helping you work at peak efficiency and productivity. Allowing you to focus on your design, rather than the measurement tools. Just as there is no one typical car driver, there is no one typical oscilloscope user. Regardless of whether you prefer a traditional instrument interface, or that of a Windows® interface, it is important to have flexibility in your oscilloscope's operation.

Many oscilloscopes offer a balance between performance and simplicity by providing the user with many ways to operate the instrument. A front-panel layout, in Figure 59, provides dedicated vertical, horizontal and trigger controls. An icon-rich graphical user interface, as shown in Figure 60, helps you understand and intuitively use advanced capabilities. Touch-sensitive displays solve issues with cluttered benches and carts, while providing access to clear, on-screen buttons, as seen in Figure 61. Online help provides a convenient, built-in reference manual. Intuitive controls allow even occasional oscilloscope users to feel as comfortable driving the oscilloscope as they do driving a car, while giving full-time users easy access to the oscilloscope's most advanced features. In addition, many oscilloscopes are portable, such as the one shown in Figure 62, making the oscilloscope efficient in many different operating environments – in the lab or in the field.

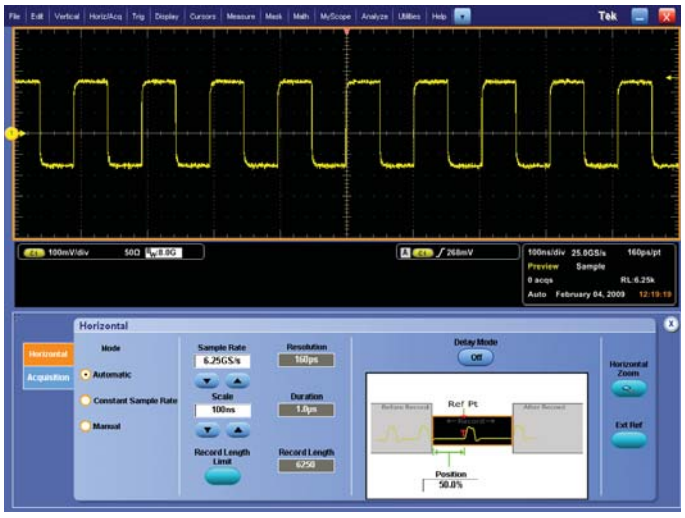
File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursors
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
100mV/div
50Ω
268mV
100ns/div
25.0GS/s
160ps/pt
Preview
Sample
0 acqs
RL:6.25k
Auto
February 04, 2009
Horizontal
Acquisition
Mode
Automatic
Constant Sample Rate
Manual
Sample Rate
6.25GS/s
Scale
100ns
Record Length Limit
Resolution
160ps
Duration
1.0µs
Record Length
6250
Delay Mode
Off
Ref Pt
Position
50.0%
Horizontal Zoom
Ext Ref

Figure 60. Use graphical control windows to access even the most sophisiticated functions with confidence and ease.

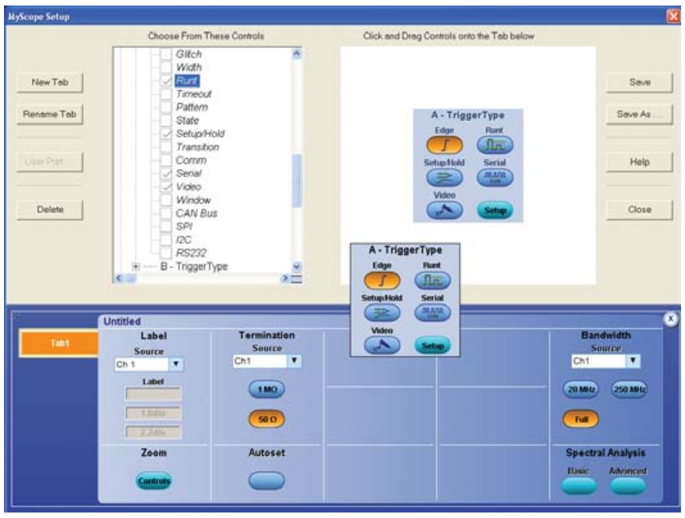
MyScope Setup
Choose From These Controls
Click and Drag Controls onto the Tab below
New Tab
Rename Tab
Delete
Save
Save As
Help
Close
Glitch
Width
Runt
Timeout
Pattern
State
Setup/Hold
Transition
Comm
Serial
Video
Window
CAN Bus
SPI
I2C
RS232
B - TriggerType
A - TriggerType
Edge
Runt
Setup/Hold
Serial
Video
Setup
Untitled
Tab1
Label
Source
Ch 1
Termination
1 MΩ
50 Ω
Autoset
Zoom
Controls
Bandwidth
20 MHz
250 MHz
Full
Spectral Analysis
Basic
Advanced

Figure 61. Touch-sensitive display naturally solves issues with cluttered benches and carts, while providing access to clear, on-screen buttons.

Figure 62. The portability of many oscilloscopes makes the instrument efficient in many operating environments.

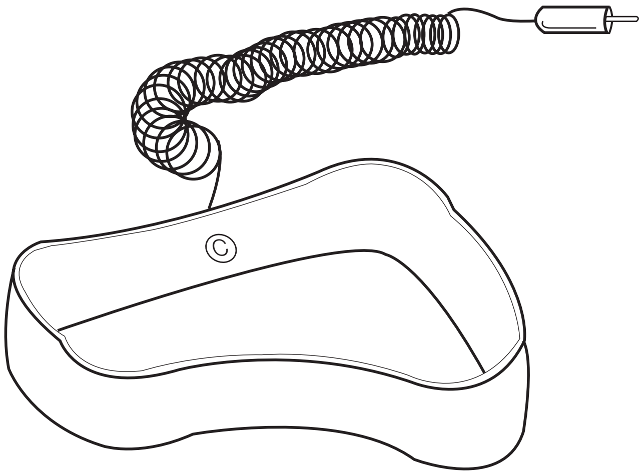

Figure 63. Typical wrist-type grounding strap.

Operating the Oscilloscope

This section briefly describes how to set up and start using an oscilloscope – specifically, how to properly ground the oscilloscope and yourself, set the oscilloscope controls, calibrate the oscilloscope, connect the probes, and compensate the probes.

Proper grounding is an important step when setting up to take measurements or work on a circuit. Proper grounding of the oscilloscope protects you from a hazardous shock and grounding yourself protects your circuits from damage.

Proper Grounding

To ground the oscilloscope means to connect it to an electrically neutral reference point, such as earth ground. Ground your oscilloscope by plugging its three-pronged power cord into an outlet grounded to earth ground.

Grounding the oscilloscope is necessary for safety. If a high voltage contacts the case of an ungrounded oscilloscope – any part of the case, including knobs that appear insulated – it can give you a shock. However, with a properly grounded oscilloscope, the current travels through the grounding path to earth ground rather than through you to earth ground.

Grounding is also necessary for taking accurate measurements with your oscilloscope. The oscilloscope needs to share the same ground as any circuits you are testing.

Some oscilloscopes do not require separate connection to earth ground. These oscilloscopes have insulated cases and controls, which keeps any possible shock hazard away from the user.

If you are working with integrated circuits (ICs), you also need to ground yourself. Integrated circuits have tiny conduction paths that can be damaged by static electricity that builds up on your body. You can ruin an expensive IC simply by walking across a carpet or taking off a sweater and then touching the leads of the IC. To solve this problem, wear a grounding strap, as shows in Figure 63. This strap safely sends static charges on your body to earth ground.

Setting the Controls

After plugging in the oscilloscope, take a look at the front panel. As described previously, the front panel is typically divided into three main sections labeled vertical, horizontal, and trigger. Your oscilloscope may have other sections, depending on the model and type.

Notice the input connectors on your oscilloscope – this is where you attach the probes. Most oscilloscopes have at least two input channels and each channel can display a waveform on the screen. Multiple channels are useful for comparing waveforms. As mentioned earlier, MSOs also have digital inputs as well.

Some oscilloscopes have AUTOSET and/or DEFAULT buttons that can set up the controls in one step to accommodate a signal. If your oscilloscope does not have this capability, it is helpful to set the controls to standard positions before taking measurements.

General instructions to manually set up the oscilloscope in standard positions are as follows:

- Set the oscilloscope to display channel 1
- Set the vertical volts/division scale and position controls to mid–range positions
- Turn off the variable volts/division
- Turn off all magnification settings
- Set the channel 1 input coupling to DC
- Set the trigger mode to auto
- Set the trigger source to channel 1
- Turn trigger holdoff to minimum or off
- Set the horizontal time/division and position controls to mid-range positions
- Adjust channel 1 volts/division such that the signal occupies as much of the 10 vertical divisions as possible without clipping or signal distortion

Calibrating the Instrument

In addition to proper oscilloscope setup, periodic instrument self-calibration is recommended for accurate measurements. Calibration is needed if the ambient temperature has changed more than 5° C (9° F) since the last self-calibration or once a week. In the oscilloscope menu this can sometimes be initiated as “Signal Path Compensation”. Refer to the manual that accompanied your oscilloscope for more detailed instructions.

Connecting the Probes

Now you are ready to connect a probe to your oscilloscope. A probe, if well-matched to the oscilloscope, will enable you to access all of the power and performance in the oscilloscope and will ensure the integrity of the signal you are measuring.

Measuring a signal requires two connections: the probe tip connection and the ground connection. Probes often come with a clip attachment for grounding the probe to the circuit under test. In practice, you attach the grounding clip to a known ground in the circuit, such as the metal chassis of a product you are repairing, and touch the probe tip to a test point in the circuit

Compensating the Probes

Passive attenuation voltage probes must be compensated to the oscilloscope. Before using a passive probe, you need to compensate it – to balance its electrical properties to a particular oscilloscope.

You should get into the habit of compensating the probe every time you set up your oscilloscope. A poorly adjusted probe can make your measurements less accurate. Figure 64 illustrates the effects on a 1 MHz test signal when using a probe that is not properly compensated.

Most oscilloscopes have a square wave reference signal available at a terminal on the front panel used to compensate the probe. General instructions to compensate the probe are as follows:

- Attach the probe to a vertical channel
- Connect the probe tip to the probe compensation, i.e. square wave reference signal
- Attach the ground clip of the probe to ground
- View the square wave reference signal
- Make the proper adjustments on the probe so that the corners of the square wave are square

03W-8605-5.qxd 12/10/09 10:24 AM Page 45

Probe Undercompensated.

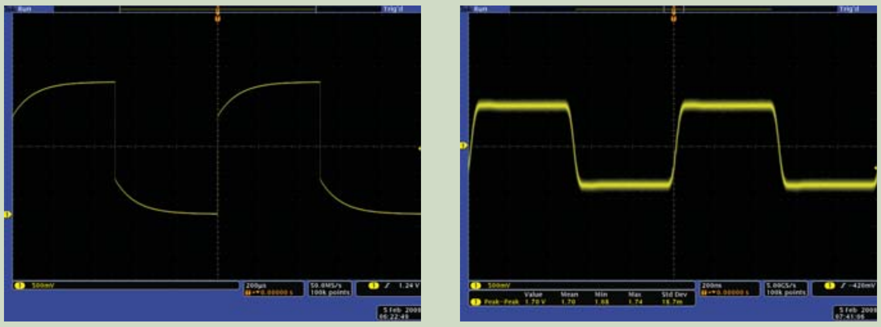

Probe Adjustment Signal

Note Reduced Amplitude

Probe Compensated Correctly.

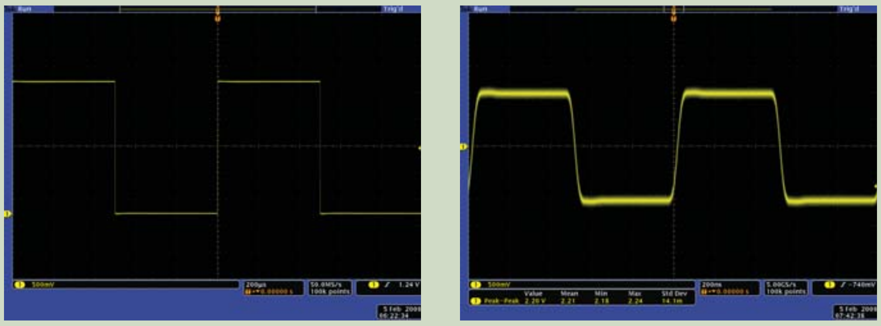

Probe Adjustment Signal

Note Proper Amplitude

Probe Overcompensated.

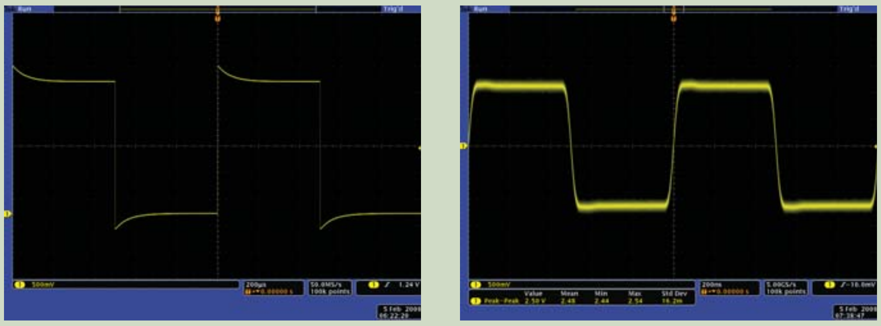

Probe Adjustment Signal

Note Increased Amplitude

Figure 64. The effects of improper probe compensation.

When you compensate the probe, always attach any accessory tips you will use and connect the probe to the vertical channel you plan to use. This will ensure that the oscilloscope has the same electrical properties as it does when you take measurements.

Oscilloscope Measurement Techniques

This section reviews basic measurement techniques. The two most basic measurements you can make are voltage and time measurements. Just about every other measurement is based on one of these two fundamental techniques.

This section discusses methods for taking measurements visually with the oscilloscope screen. This is a common technique with analog instruments, and also may be useful for "at-a-glance" interpretation of digital oscilloscope displays.

Note that most digital oscilloscopes include automated measurement tools that simplify and accelerate common analysis tasks, thus improving the reliability and confidence of your measurements. However, knowing how to make measurements manually as described here will help you understand and check the automatic measurements.

Voltage Measurements

Voltage is the amount of electric potential, expressed in volts, between two points in a circuit. Usually one of these points is ground (zero volts), but not always. Voltages can also be measured from peak-to-peak – from the maximum point of a signal to its minimum point. You must be careful to specify which voltage you mean.

The oscilloscope is primarily a voltage-measuring device. Once you have measured the voltage, other quantities are just a calculation away. For example, Ohm's law states that voltage between two points in a circuit equals the current times the resistance. From any two of these quantities you can calculate the third using the following formula:

$$\text{Voltage} = \text{Current } x \text{ Resistance}$$

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

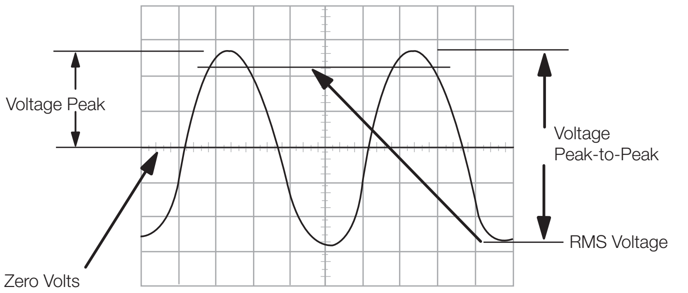

Figure 65. Voltage peak (V_p) and peak-to-peak voltage ($V_{p\text{-}p}$)

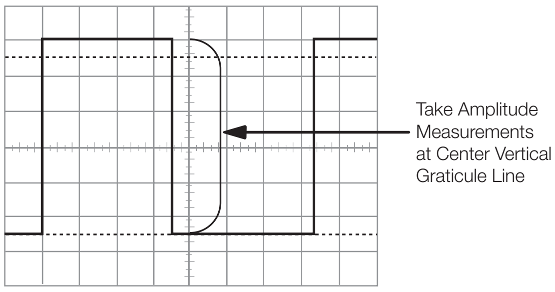
Take Amplitude Measurements at Center Vertical Graticule Line

Figure 66. Measure voltage on the center vertical graticule line.

Another handy formula is the power law, which states that the power of a DC signal equals the voltage times the current. Calculations are more complicated for AC signals, but the point here is that measuring the voltage is the first step toward calculating other quantities. Figure 65 shows the voltage of one peak (V_p) and the peak-to-peak voltage ($V_{p\text{-}p}$).

The most basic method of taking voltage measurements is to count the number of divisions a waveform spans on the oscilloscope's vertical scale. Adjusting the signal to cover most of the display vertically makes for the best voltage measurements, as shown in Figure 66. The more display area you use, the more accurately you can read the measurement.

Many oscilloscopes have cursors that let you make waveform measurements automatically, without having to count graticule marks. A cursor is simply a line that you can move across the display. Two horizontal cursor lines can be moved up and down to bracket a waveform's amplitude for voltage measurements, and two vertical lines move right and left for time measurements. A readout shows the voltage or time at their positions.

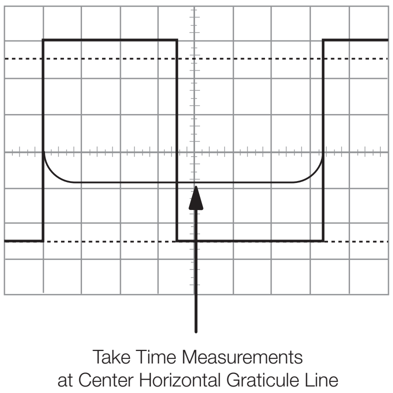

Figure 67. Measure time on the center horizontal graticule line.

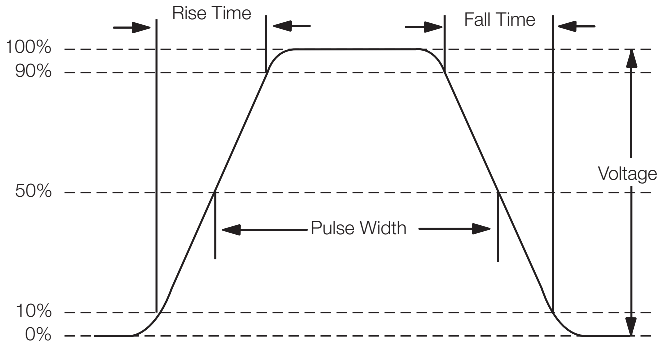

Figure 68. Rise time and pulse width measurement points.

Time and Frequency Measurements

You can make time measurements using the horizontal scale of the oscilloscope. Time measurements include measuring the period and pulse width of pulses. Frequency is the reciprocal of the period, so once you know the period, the frequency is one divided by the period. Like voltage measurements, time measurements are more accurate when you adjust the portion of the signal to be measured to cover a large area of the display, as illustrated in Figure 67.

Pulse Width and Rise Time Measurements

In many applications, the details of a pulse's shape are important. Pulses can become distorted and cause a digital circuit to malfunction, and the timing of pulses in a pulse train is often significant.

Standard pulse measurements are pulse rise time and pulse width. Rise time is the amount of time a pulse takes to go from a low to high voltage. By convention, the rise time is measured from 10% to 90% of the full voltage of the pulse. This eliminates any irregularities at the pulse's transition corners. Pulse width is the amount of time the pulse takes to go from low to high and back to low again. By convention, the pulse width is measured at 50% of full voltage. Figure 68 illustrates these measurement points.

Pulse measurements often require fine-tuning the triggering. To become an expert at capturing pulses, you should learn how to use trigger holdoff and how to set the digital oscilloscope to capture pretrigger data, as described in the Systems and Controls of an Oscilloscope section. Horizontal magnification is another useful feature for measuring pulses, since it allows you to see fine details of a fast pulse.

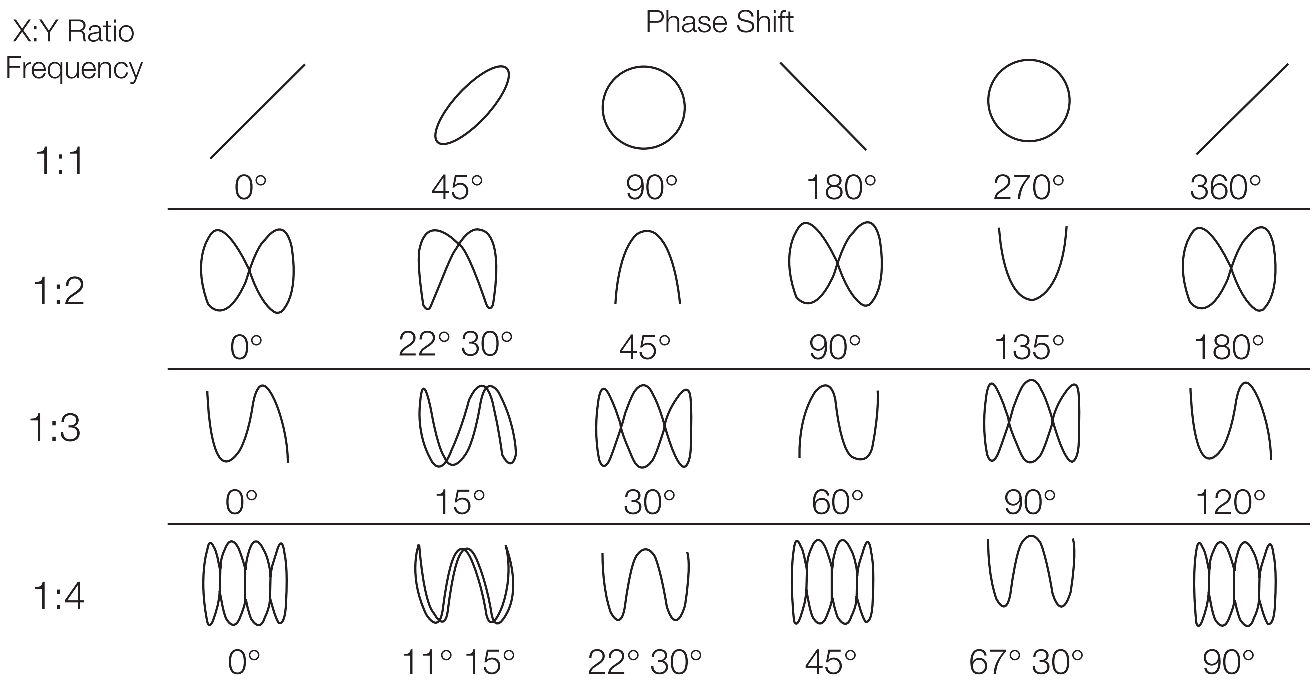

Figure 69. Lissajous patterns.

Phase Shift Measurements

One method for measuring phase shift – the difference in timing between two otherwise identical periodic signals – is to use XY mode. This measurement technique involves inputting one signal into the vertical system as usual and then another signal into the horizontal system – called an XY measurement because both the X and Y axis are tracing voltages. The waveform that results from this arrangement is called a Lissajous pattern (named for French physicist Jules Antoine Lissajous and pronounced LEE–sa–zhoo). From the shape of the Lissajous pattern, you can tell the phase difference between the two signals. You can also tell their frequency ratio. Figure 69 shows Lissajous patterns for various frequency ratios and phase shifts.

The XY measurement technique originated with analog oscilloscopes. DSOs may have difficulty creating real-time XY displays. Some DSOs create an XY image by accumulating triggered data points over time, then displaying two channels as an XY display.

DPOs, on the other hand, are able to acquire and display a genuine XY mode image in real-time, using a continuous stream of digitized data. DPOs can also display an XYZ image with intensified areas. Unlike XY displays on DSOs and DPOs, these displays on analog oscilloscopes are typically limited to a few megahertz of bandwidth.

Other Measurement Techniques

This section has covered basic measurement techniques. Other measurement techniques involve setting up the oscilloscope to test electrical components on an assembly line, capturing elusive transient signals, and many others. The measurement techniques you will use will depend on your application, but you have learned enough to get started. Practice using your oscilloscope and read more about it. Soon its operation will be second nature to you.

Written Exercises

This section contains written exercises that cover information in this primer. These are divided into two parts, Part I and Part II, with vocabulary and application exercises for each.

Check how well you have absorbed the information in these sections by verifying your responses against the answer key at the end of this section on page 54.

Part I covers information presented in these sections:

- The Oscilloscope
- Performance Terms and Considerations

Part II covers information presented in sections:

- The Systems and Controls of an Oscilloscope
- Operating the Oscilloscope
- Measurement Techniques

Part I A: Vocabulary Exercise

Write the letter of the definitions in the right column next to the correct words in the left column.

	Term		Definition
1. ___	Acquisition	**A**	The unit of electric potential difference.
2. ___	Analog	**B**	A performance measurement indicating the precision of an ADC, measured in bits.
3. ___	Bandwidth	**C**	Term used when referring to degree points of a signal's period.
4. ___	Digital Phosphor	**D**	The number of times a signal repeats in one second.
5. ___	Frequency	**E**	The amount of time it takes a wave to complete one cycle.
6. ___	Glitch	**F**	A stored digital value that represents the voltage of a signal at a specific point in time on the display.
7. ___	Period	**G**	A common waveform shape that has a rising edge, a width, and a falling edge.
8. ___	Phase	**H**	A performance measurement indicating the rising edge speed of a pulse.
9. ___	Pulse	**I**	Oscilloscope circuitry that controls the timing of the sweep.
10. ___	Waveform Point	**J**	An intermittent spike in a circuit.
11. ___	Rise Time	**K**	A signal measured by an oscilloscope that only occurs once.
12. ___	Sample Point	**L**	The oscilloscope's process of collecting sample points from the ADC, processing them, and storing them in memory.
13. ___	Digital Storage	**M**	Something that operates with continuously changing values.
14. ___	Time Base	**N**	Digital oscilloscope that captures 3 dimensions of signal information in real-time.
15. ___	Transient	**O**	Digital oscilloscope with serial processing.
16. ___	ADC Resolution	**P**	A sine wave frequency range, defined by the – 3 dB point.
17. ___	Volt	**Q**	The raw data from an ADC used to calculate and display waveform points.

Part I B: Application Exercise

Circle the best answers for each statement. Some statements have more than one right answer.

.1. With an oscilloscope you can:

a. Calculate the frequency of a signal.

b. Find malfunctioning electrical components.

c. Analyze signal details.

d. All the above.

2. The difference between analog and digitizing oscilloscopes is:

a. Analog oscilloscopes do not have on-screen menus.

b. Analog oscilloscopes apply a measurement voltage directly to the display system, while digital oscilloscopes first convert the voltage into digital values.

c. Analog oscilloscopes measure analogs, whereas digitizing oscilloscopes measure digits.

d. Analog oscilloscopes do not have an acquisition system.

3. An oscilloscope's vertical section does the following:

a. Acquires sample points with an ADC.

b. Starts a horizontal sweep.

c. Lets you adjust the brightness of the display.

d. Attenuates or amplifies the input signal.

4. The time base control of the oscilloscope does the following:

a. Adjusts the vertical scale.

b. Shows you the current time of day.

c. Sets the amount of time represented by the horizontal width of the screen.

d. Sends a clock pulse to the probe.

5. On an oscilloscope display:

a. Voltage is on the vertical axis and time is on the horizontal axis.

b. A straight diagonal trace means voltage is changing at a steady rate.

c. A flat horizontal trace means voltage is constant.

d. All the above.

6. All repeating waves have the following properties:

a. A frequency measured in Hertz.

b. A period measured in seconds.

c. A bandwidth measured in Hertz.

d. All the above.

7. If you probe inside a computer with an oscilloscope, you are likely to find the following types of signals:

a. Pulse trains.

b. Ramp waves.

c. Sine waves.

d. All the above.

8. When evaluating the performance of an analog oscilloscope, some things you might consider are:

a. The bandwidth.

b. The vertical sensitivity.

c. The ADC resolution.

d. The sweep speed.

9. The difference between digital storage oscilloscopes (DSO) and digital phosphor oscilloscopes (DPO) is:

a. The DSO has a higher bandwidth.

b. The DPO captures three dimensions of waveform information in real-time.

c. The DSO has a color display.

d. The DSO captures more signal details.

Part II A: Vocabulary Exercise

Write the letter of the definitions in the right column next to the correct words in the left column.

	Term		**Definition**
1. ___	Averaging Mode	**A**	The unintentional interaction of the probe and oscilloscope with the circuit being tested which distorts a signal.
2. ___	Circuit Loading	**B**	A conductor that connects electrical currents to the Earth.
3. ___	Compensation	**C**	A sampling mode in which the digital oscilloscope collects as many samples as it can as the signal occurs, then constructs a display, using interpolation if necessary.
4. ___	Coupling	**D**	A sampling mode in which the digital oscilloscope constructs a picture of a repetitive signal by capturing a little bit of information from each repetition.
5. ___	Earth Ground	**E**	A device that converts a specific physical quantity such as sound, pressure, strain, or light intensity into an electrical signal.
6. ___	Equivalent-Time	**F**	A test device for injecting a signal into a circuit input.
7. ___	Graticule	**G**	A processing technique used by digital oscilloscopes to eliminate noise in a displayed signal.
8. ___	Interpolation	**H**	The method of connecting two circuits together.
9. ___	Real Time	**I**	A “connect-the-dots” processing technique to estimate what a fast waveform looks like based on only a few sampled points.
10. ___	Signal Generator	**J**	The grid lines on a screen for measuring oscilloscope traces.
11. ___	Single Sweep	**K**	A trigger mode that triggers the sweep once, must be reset to accept another trigger event.
12. ___	Sensor	**L**	A probe adjustment for 10X attenuator probes that balances the electrical properties of the probe with the electrical properties of the oscilloscope.

Part II B: Application Exercise

Circle the best answers for each statement. Some statements have more than one right answer.

1. **To operate an oscilloscope safely, you should:**
   - a. Ground the oscilloscope with the proper three-pronged power cord.
   - b. Learn to recognize potentially dangerous electrical components.
   - c. Avoid touching exposed connections in a circuit being tested even if the power is off.
   - d. All the above.
2. **Grounding an oscilloscope is necessary:**
   - a. For safety reasons.
   - b. To provide a reference point for making measurements.
   - c. To align the trace with the screen's horizontal axis.
   - d. All the above.
3. **Circuit loading is caused by:**
   - a. An input signal having too large a voltage.
   - b. The probe and oscilloscope interacting with the circuit being tested.
   - c. A 10X attenuator probe being uncompensated.
   - d. Putting too much weight on a circuit.
4. **Compensating a probe is necessary to:**
   - a. Balance the electrical properties of the 10X attenuator probe with the oscilloscope.
   - b. Prevent damaging the circuit being tested.
   - c. Improve the accuracy of your measurements.
   - d. All the above.
5. **The trace rotation control is useful for:**
   - a. Scaling waveforms on the screen.
   - b. Detecting sine wave signals.
   - c. Aligning the waveform trace with the screen's horizontal axis on an analog oscilloscope.
   - d. Measuring pulse width.
6. **The volts per division control is used to:**
   - a. Scale a waveform vertically.
   - b. Position a waveform vertically.
   - c. Attenuate or amplify an input signal.
   - d. Set the numbers of volts each division represents.
7. **Setting the vertical input coupling to ground does the following:**
   - a. Disconnects the input signal from the oscilloscope.
   - b. Causes a horizontal line to appear with auto trigger.
   - c. Lets you see where zero volts is on the screen.
   - d. All the above.
8. **The trigger is necessary to:**
   - a. Stabilize repeating waveforms on the screen.
   - b. Capture single-shot waveforms.
   - c. Mark a particular point of an acquisition.
   - d. All the above.
9. **The difference between auto and normal trigger mode is:**
   - a. In normal mode the oscilloscope only sweeps once and then stops.
   - b. In normal mode the oscilloscope only sweeps if the input signal reaches the trigger point; otherwise the screen is blank.
   - c. Auto mode makes the oscilloscope sweep continuously even without being triggered.
   - d. All the above.
10. **The acquisition mode that best reduces noise in a repeating signal is:**
    - a. Sample mode.
    - b. Peak detect mode.
    - c. Envelope mode.
    - d. Averaging mode.

11. The two most basic measurements you can make with an oscilloscope are:

a. Time and frequency measurements.

b. Time and voltage measurements.

c. Voltage and pulse width measurements.

d. Pulse width and phase shift measurements.

12. If the volts/division is set at 0.5, the largest signal that can fit on the screen (assuming an 8 x 10 division screen) is:

a. 62.5 millivolts peak-to-peak.

b. 8 volts peak-to-peak.

c. 4 volts peak-to-peak.

d. 0.5 volts peak-to-peak.

13. If the seconds/division is set at 0.1 ms, the amount of time represented by the width of the screen is:

a. 0.1 ms.

b. 1 ms.

c. 1 second.

d. 0.1 kHz.

14. By convention, pulse width is measured:

a. At 10% of the pulse's peak-to-peak (pk-pk) voltage.

b. At 50% of the pulse's peak-to-peak (pk-pk) voltage.

c. At 90% of the pulse's peak-to-peak (pk-pk) voltage.

d. At 10% and 90% of the pulse's peak-to-peak (pk-pk) voltage.

15. You attach a probe to your test circuit but the screen is blank. You should:

a. Check that the screen intensity is turned up.

b. Check that the oscilloscope is set to display the channel that the probe is connected to.

c. Set the trigger mode to auto since norm mode blanks the screen.

d. Set the vertical input coupling to AC and set the volts/division to its largest value since a large DC signal may go off the top or bottom of the screen.

e. Check that the probe isn't shorted and make sure it is properly grounded.

f. Check that the oscilloscope is set to trigger on the input channel you are using.

g. All of the above.

Answer Key

This section provides the answers to all written exercises in the previous section.

Part IA: Vocabulary Exercise Answers

1. L	5. D	9. G	13. O
2. M	6. J	10. F	14. I
3. P	7. E	11. H	15. K
4. N	8. C	12. Q	16. B
			17. A

Part IB: Application Exercise Answers

1. D	3. D	5. D	7. A
2. B,D	4. C	6. A,B	8. A,B,D
			9. B

Part IIA: Vocabulary Exercise Answers

1. G	4. H	7. J	10. F
2. A	5. B	8. I	11. K
3. L	6. D	9. C	12. E

Part IIB: Application Exercise Answers

1. D	5. C	9. B,C	13. B
2. A,B	6. A,C,D	10. D	14. B
3. B	7. D	11. B	15. G
4. A,C	8. D	12. C	

Glossary

A

Acquisition Mode – Modes that control how waveform points are produced from sample points. Some types include sample, peak detect, hi res, envelope, average, and waveform data base.

Alternating Current (AC) – A signal in which the current and voltage vary in a repeating pattern over time. Also used to indicate signal coupling type.

Amplification – An increase in signal amplitude during its transmission from one point to another.

Amplitude – The magnitude of a quantity or strength of a signal. In electronics, amplitude usually refers to either voltage or power.

Analog-to-Digital Converter (ADC) – A digital electronic component that converts an electrical signal into discrete binary values.

Analog Oscilloscope – An instrument that creates a waveform display by applying the input signal (conditioned and amplified) to the vertical axis of an electron beam moving across a cathode-ray tube (CRT) screen horizontally from left to right. A chemical phosphor coated on the CRT creates a glowing trace wherever the beam hits.

Analog Signal – A signal with continuously variable voltages.

Attenuation – A decrease in signal amplitude during its transmission from one point to another.

Averaging – A processing technique used by digital oscilloscopes to reduce noise in a displayed signal.

B

Bandwidth – A frequency range, usually limited by –3 dB.

C

Circuit Loading – The unintentional interaction of the probe and oscilloscope with the circuit being tested, distorting the signal.

Compensation – A probe adjustment for passive attenuation probes that balances the capacitance of the probe with the capacitance of the oscilloscope.

Coupling – The method of connecting two circuits together. Circuits connected with a wire are directly coupled (DC); circuits connected through a capacitor or transformer are indirectly (AC) coupled.

Cursor – An on–screen marker that you can align with a waveform to make more accurate measurements.

D

Delayed Time Base – A time base with a sweep that can start (or be triggered to start) relative to a pre-determined time on the main time base sweep. Allows you to see events more clearly and to see events that are not visible solely with the main time base sweep.

Digital Signal – A signal whose voltage samples are represented by discrete binary numbers.

Digital Oscilloscope – A type of oscilloscope that uses an analog-to-digital converter (ADC) to convert the measured voltage into digital information. Types include: digital storage, digital phosphor, mixed signal, and digital sampling oscilloscopes.

Digital Phosphor Oscilloscope (DPO) – A type of digital oscilloscope that closely models the display characteristics of an analog oscilloscope while providing traditional digital oscilloscope benefits (waveform storage, automated measurements, etc.) The DPO uses a parallel-processing architecture to pass the signal to the raster-type display, which provides intensity-graded viewing of signal characteristics in real time. The DPO displays signals in three dimensions: amplitude, time and the distribution of amplitude over time.

Digital Sampling Oscilloscope – A type of digital oscilloscope that employs equivalent-time sampling method to capture and display samples of a signal, ideal for accurately capturing signals whose frequency components are much higher than the oscilloscope's sample rate.

Digital Signal Processing – The application of algorithms to improve the accuracy of measured signals.

Digital Storage Oscilloscope (DSO) – A digital oscilloscope that acquires signals via digital sampling (using an analog-to-digital converter). It uses a serial-processing architecture to control acquisition, user interface, and the raster display.

Digitize – The process by which an analog-to-digital converter (ADC) in the horizontal system samples a signal at discrete points in time and converts the signal's voltage at these points into digital values called sample points.

Direct Current (DC) – A signal with a constant voltage and/or current. Also used to indicate signal coupling type.

Division – Measurement markings on the oscilloscope graticule indicating major and minor marks.

E

Earth Ground – A conductor that will connect electrical currents to the Earth.

Effective Bits – A measure of a digital oscilloscope's ability to accurately reconstruct a sine wave signal's shape. This measurement compares the oscilloscope's actual error to that of a theoretical "ideal" digitizer.

Envelope – The outline of a signal's highest and lowest points acquired over many displayed waveform repetitions.

Equivalent-time Sampling – A sampling mode in which the oscilloscope constructs a picture of a repetitive signal by capturing a little bit of information from each repetition. Two types of equivalent-time sampling: random and sequential.

F

Focus – The analog oscilloscope control that adjusts the cathode-ray tube (CRT) electron beam to control the sharpness of the display.

Frequency – The number of times a signal repeats in one second, measured in Hertz (cycles per second). The frequency equals 1/period.

Frequency Response – Frequency response curves of an oscilloscope define the accuracy in amplitude representation of the input signal in function of the signals frequency. In order to obtain maximum signal fidelity, it is important that the oscilloscope has a flat (stable) frequency response across the entire specified oscilloscopes bandwidth.

G

Gain Accuracy – An indication of how accurately the vertical system attenuates or amplifies a signal, usually represented as a percentage error.

Gigahertz (GHz) – 1,000,000,000 Hertz; a unit of frequency.

Glitch – An intermittent, high-speed error in a circuit.

Graticule – The grid lines on a display for measuring oscilloscope traces.

Ground –

1. A conducting connection by which an electric circuit or equipment is connected to the earth to establish and maintain a reference voltage level.
2. The voltage reference point in a circuit.

H

Hertz (Hz) – One cycle per second; the unit of frequency.

Horizontal Accuracy (Time Base) – An indication of how accurately the horizontal system displays the timing of a signal, usually represented as a percentage error.

Horizontal Sweep – The action of the horizontal system that causes a waveform to be drawn.

I

Intensity Grading – Frequency-of-occurrence information that is essential to understanding what the waveform is really doing.

Interpolation – A "connect-the-dots" processing technique to estimate what a fast waveform looks like based on only a few sampled points. Two types: linear and sin x/x.

K

Kilohertz (kHz) – 1,000 Hertz; a unit of frequency.

L

Loading – The unintentional interaction of the probe and oscilloscope with the circuit being tested which distorts a signal.

Logic Analyzer – An instrument used to make the logic states of many digital signals visible over time. It analyzes the digital data and can represent the data as real-time software execution, data flow values, state sequences, etc.

M

Megahertz (MHz) – 1,000,000 Hertz; a unit of frequency.

Megasamples per second (MS/s) – A sample rate unit equal to one million samples per second.

Microsecond (µs) – A unit of time equivalent to 0.000001 seconds.

Millisecond (ms) – A unit of time equivalent to 0.001 seconds.

Mixed Signal Oscilloscope (MSO) – A type of digital oscilloscope that combines the basic functionality of a 16-channel logic analyzer with the trusted performance of a 4-channel digital phosphor oscilloscope.

N

Nanosecond (ns) – A unit of time equivalent to 0.000000001 seconds.

Noise – An unwanted voltage or current in an electrical circuit.

O

Oscilloscope – An instrument used to make voltage changes visible over time. The word oscilloscope comes from “oscillate,” since oscilloscopes are often used to measure oscillating voltages.

P

Peak (V_p) – The maximum voltage level measured from a zero reference point.

Peak Detection – An acquisition mode available with digital oscilloscopes that enables you to observe signal details that may otherwise be missed, particularly useful for seeing narrow pulses spaced far apart in time.

Peak-to-peak ($V_{p\text{-}p}$) – The voltage measured from the maximum point of a signal to its minimum point.

Period – The amount of time it takes a wave to complete one cycle. The period equals 1/frequency.

Phase – The amount of time that passes from the beginning of a cycle to the beginning of the next cycle, measured in degrees.

Phase Shift – The difference in timing between two otherwise similar signals.

Pre-trigger Viewing – The ability of a digital oscilloscope to capture what a signal did before a trigger event. Determines the length of viewable signal both preceding and following a trigger point.

Probe – An oscilloscope input device, usually having a pointed metal tip for making electrical contact with a circuit element, a lead to connect to the circuit’s ground reference, and a flexible cable for transmitting the signal and ground to the oscilloscope.

Pulse – A common waveform shape that has a fast rising edge, a width, and a fast falling edge.

Pulse Train – A collection of pulses traveling together.

Pulse Width – The amount of time the pulse takes to go from low to high and back to low again, conventionally measured at 50% of full voltage.

R

Ramps – Transitions between voltage levels of sine waves that change at a constant rate.

Raster – A type of display.

Real-time Sampling – A sampling mode in which the oscilloscope collects as many samples as possible from one triggered acquisition. Ideal for signals whose frequency range is less than half the oscilloscope’s maximum sample rate.

Record Length – The number of waveform points used to create a record of a signal.

Rise Time – The time taken for the leading edge of a pulse to rise from its low to its high values, typically measured from 10% to 90%.

S

Sampling – The conversion of a portion of an input signal into a number of discrete electrical values for the purpose of storage, processing and/or display by an oscilloscope. Two types: real-time sampling and equivalent-time sampling.

Sample Point – The raw data from an ADC used to calculate waveform points.

Sample Rate – Refers to how frequently a digital oscilloscope takes a sample of the signal, specified in samples per second (S/s).

Sensor – A device that converts a specific physical quantity such as sound, pressure, strain, or light intensity into an electrical signal.

Signal Integrity – The accurate reconstruction of a signal, determined by the systems and performance considerations of an oscilloscope, in addition to the probe used to acquire the signal.

Signal Source – A test device used to inject a signal into a circuit input; the circuit’s output is then read by an oscilloscope. Also known as a signal generator.

Sine Wave – A common curved wave shape that is mathematically defined.

Single Shot – A signal measured by an oscilloscope that only occurs once (also called a transient event).

Single Sweep – A trigger mode to display one triggered screen of a signal and then stop.

Slope – On a graph or an oscilloscope display, the ratio of a vertical distance to a horizontal distance. A positive slope increases from left to right, while a negative slope decreases from left to right.

Square Wave – A common wave shape consisting of repeating square pulses.

Sweep – One horizontal pass of an anlog oscilloscope's electron beam from left to right across the CRT screen.

Sweep Speed – Same as the time base.

T

Time Base – Oscilloscope circuitry that controls the timing of the sweep. The time base is set by the seconds/division control.

Trace – The visible shapes drawn on a CRT by the movement of the electron beam.

Transient – A signal measured by an oscilloscope that only occurs once (also called a single–shot event).

Trigger – The circuit that references a horizontal sweep on an oscilloscope.

Trigger Holdoff – A control that allows you to adjust the period of time after a valid trigger during which the oscilloscope cannot trigger.

Trigger Level – The voltage level that a trigger source signal must reach before the trigger circuit initiates a sweep.

Trigger Mode – A mode that determines whether or not the oscilloscope draws a waveform if it does not detect a trigger. Common trigger modes include normal and auto.

Trigger Slope – The slope that a trigger source signal must reach before the trigger circuit initiates a sweep.

V

Vertical Resolution (Analog-to-Digital Converter) – An indication of how precisely an analog-to-digital converter (ADC) in a digital oscilloscope can convert input voltages into digital values, measured in bits. Calculation techniques, such as hi res acquisition mode, can improve the effective resolution.

Vertical Sensitivity – An indication of how much the vertical amplifier can amplify a weak signal – usually measured in millivolts (mV) per division.

Volt – The unit of electric potential difference.

Voltage – The difference in electric potential, expressed in volts, between two points.

W

Wave – The generic term for a pattern that repeats over time. Common types include: sine, square, rectangular, sawtooth, triangle, step, pulse, periodic, non-periodic, synchronous, asynchronous.

Waveform – A graphic representation of a voltage varying over time.

Waveform Capture Rate – Refers to how quickly an oscilloscope acquires waveforms, expressed as waveforms per second (wfms/s).

Waveform Point – A digital value that represents the voltage of a signal at a specific point in time. Waveform points are calculated from sample points and stored in memory.

Writing Speed – The ability of an analog oscilloscope to provide a visible trace of the movement of a signal from one point to another. This ability is restrictive for low-repetition signals that have fast-moving details, such as digital logic signals.

XY Mode – A measuremenbt technique that involves inputting one signal into the vertical system, as usual, and one into the horizontal system to trace voltages on both the X and Y axis.

Z

Z Axis – The display attribute on an oscilloscope that shows brightness variations as the trace is formed.

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Our Zapper Kit contains all the parts necessary to build either a 30,000 Hz or a 1,000 Hz Positive Offset Square Wave Frequency Generator Unit. This breadboard kit is based on Dr. Hulda Clark's zapper circuit design that was recently updated and published in 2003. Copper Pipes and 9 Volt Battery are not included in kit. For copper pipes and individual electronic parts, click the links in the right column.

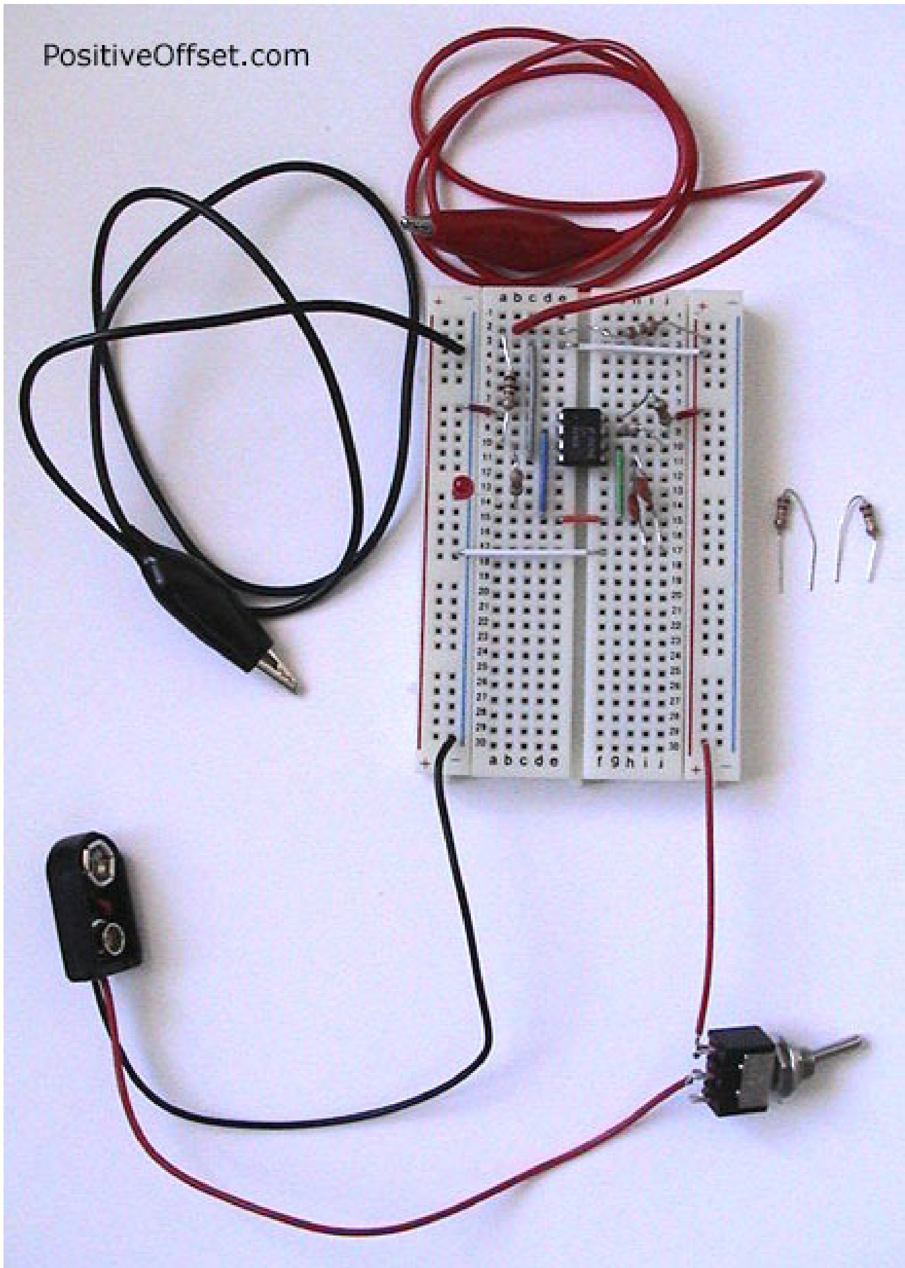

Hulda Clark Zapper Kit with Color Illustrated Instructions
$50.00 Add to Cart

Zapper Kit includes: Breadboard, 555 CMOS Timer, (2) 1K Ohm resistors, 2.2K Ohm resistor, 4.7K Ohm resistor, 39K Ohm resistor, (2) 270K Ohm

www.PositiveOffset.com

- 30 kHz/1 kHz Zapper Kit
- .0047 uF Capacitors
- 1 uH Inductors
- 1K Ohm Resistors
- 2.2K Ohm Resistors
- 3.9K Ohm Resistors
- 4.7K Ohm Resistors
- 39K Ohm Resistors
- 270K Ohm Resistors
- 555 CMOS Timer
- 8 Pin Wire Wrap Socket
- 9 Volt Battery Snap
- Alligator Clip Converter
- Alligator Leads
- Aluminum Square
- Banana to Alligator Leads
- Breadboard
- Color Coded Jump Wires
- Copper Pipes
- Nuts and Bolts
- On/Off Toggle Switch
- Red Mini LED
- Switching diode 1N914
- Video Instructions

Dual Frequency
1KHz 30KHz
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resistors, (2) .0047 uF Capacitors, Mini Red LED, (9) Color Coded Jump Wires, 9-Volt Battery Snap, (2) Alligator leads, and an On/Off Switch. All this comes in a sturdy little cardboard box you can use to house your finished circuit. The full-color instructions will help you build either a 30,000 Hz or 1,000 Hz circuit.

It's so easy to build. No soldering required! Watch the video instructions right here (36 minutes).

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Breadboard
555 CMOS Timer
Jump Wires (9)
1 long red, 2 white, 1 gray, 2 red,
1 blue, 1 orange, 1 green
On/Off Switch
9-volt Battery Clip
.0047 uF Capacitors
Two 6" Wires 1 red, 1 black
1/4 Watt Resistors (7)
1K
2.2K
4.7K
39K
270K
Red LED
Alligator Leads (2)
Instructions
23:54
HD
vimeo

- YouTube video instructions: 9 easy steps to build this circuit
- Build a zapper Frequently Asked Questions and Answers
- Already have electronic parts? Download PDF Instructions

Remember the Hulda Clark Zapper has not been licensed as a medical device by the US FDA. Zapper Kit is sold as an educational tool only, no medical claims are intended by the sale of these electronic parts. Our Zapper Kit is a great project for a school science fair, or to learn the basics of building simple electronics.

Please note that when ordering electronic parts and kits we can assume no liability on the customer's ability to use them. Safety, craftsmanship, experience, and ability are the user's responsibility.

Electronic parts are small and fragile. We can not offer refunds or replacements on electronic parts. Buy electronic parts and kits only if you believe you can accomplish the work. If you experience difficulty with your build, or have little experience in electronics, please order replacement parts along with your kit.

The 555 CMOS Timer is the most likely part to need replacement, so it may be smart to order extras when building a kit.

The 555 CMOS Timer is vulnerable to static electricity. If you walk on a carpeted floor and the 555 receives a static shock it may burn out and need replacement.

555 CMOS Timers are sold separately for those who want to have several at hand during a kit build, or to troubleshoot a circuit that is not working.

If you are new to electronics, or just want to be cost effective, you may want to purchase extra 555 CMOS Timers when building your first kit. We can not offer refunds or replacements on electronic parts.

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Hulda Clark 30 kHz / 1 kHz Zapper Kit
with Color Illustrated Instructions
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Hulda Clark Zapper Kit includes: Breadboard, 555 CMOS Timer, 7 resistors: (2) 1K Ohm, 2.2K Ohm, 4.7K Ohm, 39K, (2) 270K Ohm, (2) .0047 uF Capacitors, Red LED, (8) Color Jump Wires, (2) Alligator Leads, and Soldered Battery Snap/On-Off Switch. All this comes in a sturdy little cardboard box you can use to house your finished circuit. The full-color instructions will help you build either a 30,000 Hz or 1,000 Hz circuit. Kit does not include copper pipes. Click here to order copper pipes.

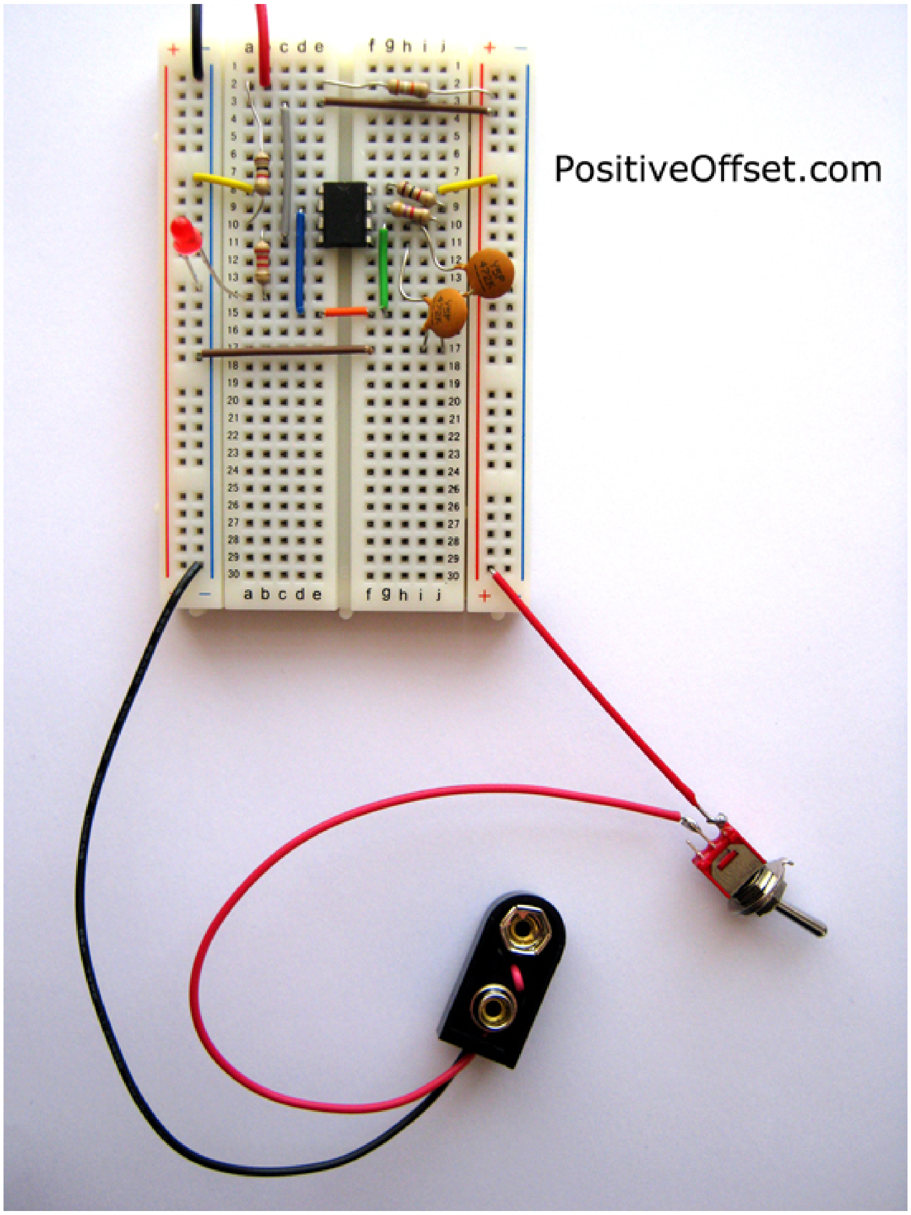

Hulda Clark Zapper Kit with Color Illustrated Instructions
Order Zapper Kit Here

If you are new to building electronics, you may also want to watch the instruction video. The 'Build A Zapper Video' shows how to build this Clark Zapper breadboard kit. Watch the video below. (Note: There are minor updates to the "Build Your Own Zapper" Kit. We have adjusted the jump wires for a

www.PositiveOffset.com

- 30 kHz/1 kHz Zapper Kit
- 555 CMOS Timer
- Switching diode 1N914
- Mini Alligator Leads
- Copper Pipes
- Dial-A-Zap
- Chair Zappicator
- Pet Zappicator
- Video Instructions

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better fit. We have also pre-soldered the 9-volt battery snap to the on/off switch. These updates are not shown in this video, but are clearly described in the kit instructions.)

It's so easy to build. No soldering required! Watch the video instructions right here (36 minutes).

More Video Instructions

- Build a Zapper, Plate Zapper, Food Zappicator, and Toothbrush Zappicator
- Zapper Kit Frequently Asked Questions and Answers
- Already have electronic parts? Download PDF Instructions

The Hulda Clark Zapper has not been licensed as a medical device by the US FDA. Zapper Kit is sold as an educational tool only, no medical claims are intended by the sale of these electronic parts. Our Zapper Kit is a great project for a school science fair, or to learn the basics of building simple electronics.

Please note that when ordering electronic parts and kits we can assume no liability on the customer's ability to use them. Safety, craftsmanship, experience, and ability are the user's responsibility.

Electronic parts are small and fragile. We can not offer refunds or replacements on electronic parts. Buy electronic parts and kits only if you believe you can accomplish the work.

The 555 CMOS Timer is the most likely part to need replacement, so it may be smart to order extras when building a kit.

The 555 CMOS Timer is vulnerable to static electricity. If you walk on a carpeted floor and the 555 receives a static shock it may burn out and need replacement. If you ever touch the 9 volt battery backwards to the battery snap, it may burn out the 555. You may want to protect your 555 by adding a 1N914 Switching Diode to your kit (diode sold separately).

555 CMOS Timers are sold separately for those who want to have several at hand during a kit build, or to troubleshoot a circuit that is not working. If you are new to electronics, or just want to be cost effective, you may want to purchase extra 555 CMOS Timers when building your first kit. We can not offer refunds or replacements on electronic parts.

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www.ZapperLab.com

Order A Hulda Clark Zapper - **Order Dr. Clark's Books** - **Order Electrical Supplies**

Welcome to the Zapper Lab. Here we have the step-by-step instructions for building your very own Hulda Clark Zapper, reprinted with permission from the books by Dr. Hulda Clark. Dr. Clark has improved her original zapper circuit and published this update in 2003. Knowing her readers have varying experience with building electronics, this recent update released several different sets of instructions on how to build a zapper, depending on one's electronic expertise.

- The original published Zapper instructions require soldering or twisting the parts together. It is best when soldered, which does require some special tools and skill. These instructions are found reprinted below from Dr. Clark's 2003 update.
- A newer, easier to build design employs the use of an electronic *breadboard*. A breadboard does not require soldering, as one can push the electronic components into place onto the breadboard to easily build a circuit. Dr. Clark published designs for the 30 kHz Zapper, and the 1000 Hz Zappicator to be built on a breadboard. The instructions for building both breadboard zapper circuits are at ClarkZapper.net along with a nifty on-line video to help guide you through the process.
- And last, for advanced electricians, Dr. Hulda Clark published a schematic for building the updated Zapper (see photo below).

If you do not know anyone who could put one together for you, you can order a pre-built Zapper at the web site, www.ClarkZapper.com. Remember, the Hulda Clark Zapper is not a licensed medical device. It has not been tested by the FDA or AMA for use on humans or animals. The Clark Zapper can be sold and used only as an experimental device, and no claim can be made as to a diagnosis, cure or treatment for any medical condition or disease. Dr. Clark's book states to not experiment with a zapper if you are either pregnant or wearing an electronic pacemaker. Please be sure to read one of Dr. Clark's books before using a Hulda Clark Zapper.

Order A Hulda Clark Zapper - **Order Dr. Clark's Books** - **Order Electrical Supplies**

How To Build A Hulda Clark Zapper

click here to print the 2003 schematic for building a zapper

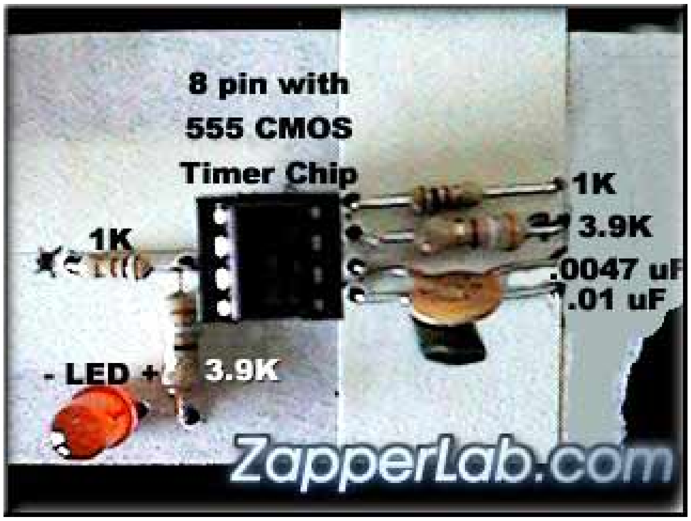

Order A Hulda Clark Zapper

Instructions for building your very own zapper can be found reprinted below from the books by Dr. Hulda Clark. You can get all the parts you need at online electrical supply stores such as: PositiveOffset.com. If you would rather order a pre-built zapper, just click: Clark Zapper.

Dr. Clark has released new devices called the *Food Zappicator* and the *Toothbrush Zappicator.* For the instructions on how to build this new type of zapper, visit: FoodZappicator.com and ToothZappicator.com

NEW! Build A Hulda Clark Zapper Video Instructions
Nine short videos that take you step-by-step through the process of building a Hulda Clark Zapper.

How To Build A Hulda Clark Zapper

***The Cure For All Cancers* © Copyright 1993 by Hulda Regehr Clark, Ph.D., N.D.**
Zapper instructions have been updated for 2003 by Dr. Hulda Clark

Hints for absolute novices: Don't let unusual vocabulary deter you. A "lead" is just a piece of wire used to make connections. When you remove a component from its package, label it with a piece of tape. A serrated kitchen knife works best, as does a large safety pin. Practice using the micro clips. If the metal ends are L-shaped bend them into a U with the long-nose pliers so they grab better. Chips and chip holders (wire wrap sockets) are very fragile. It is wise to purchase an extra one of each in case you break the connections. The "555" timer is a widely used component; if you can't locate this one, try another electronics shop.

The Shoebox Way

This circuit has been improved since the one given in earlier books. A resistor has been added that gives every pulse an added Positive Offset of 1/4 volt. You no longer need to operate your zapper so daringly close to a Negative voltage.

Get from Radio Shack, (serial number included to make it easy). Order these parts from their web site at: www.RadioShack.com. If any electrical parts are unavailable at Radio Shack, visit another on-line electrical supplier of these items, such as: www.PositiveOffset.com to buy your electrical parts.

Parts List for the 30,000 Hz Zapper Circuit

Item	Radio Shack Catalog Number
Use Shoebox or Buy a Plastic Project Box	270-1809
9 volt battery	
9 volt battery snap connector	270-324 (set of 5 you need 1)
on-off toggle switch	275-624A micro mini toggle switch
If not available, choose any toggle switch with holes in the contact points or Radio Shack 275-612	
1 K Ohm resistor, brown-black-red-gold	271-312 (500 piece assortment) use 2
3.9 K Ohm resistor, orange-white-red-gold	Use 2 from 500 piece assortment
39 K Ohm resistor, orange-white-orange-gold	From 500 piece assortment
low-current red LED	276-044
.0047 uF capacitor	272-130 (set of 2, you need 1)
.01 uF capacitor	272-131 (set of 2, you need 1)
555 CMOS timer chip (TLC 555)	276-1718 (you may wish to buy a spare)
8 pin wire-wrapping socket for the chip	900-7242
If only 16 pin sockets are available, cut one in half OR leave half empty. Editor's Note: These parts have been discontinued at most Radio Shacks. 8 pin wire wrap sockets are available at many other electrical supply stores such as: www.PositiveOffset.com	
short (12") alligator clip leads	any electronics shop, get 10
If not available, use 14" length from Radio Shack, 278-1156	
Micro clip jumper wires	278-017 (you need 2 packages of 2)
If not available, use mini-clip jumper wires 278-016	
2 bolts, about 1/8" diameter, 2" long, with 4 nuts and 4 washers	hardware store
2 copper pipes, 3/4" diameter, 4" long	hardware store
Sharp knife, pin, long-nose pliers, tape, 4 twist ties or rubber bands.	

Editor's Note:

The 8 pin wire-wrapping socket has been discontinued at many Radio Shacks and readers have asked what to do. We know a great electrical supply store where 8 pin wire wrap sockets are available, as well as easy-to-build science kits for making a 30,000 Hz Frequency Generator with all the parts listed above in one simple package.

A Hulda Clark zapper is basically just a common Frequency Generator set at 30,000 Hz, with a 100% positive offset square wave. The cost for the electrical parts to build one is about $30-$40 for them all. Visit the electrical suppliers at PositiveOffset.com for all your electrical needs. They have everything you'd need to build a basic 30,000 Hz Positive Offset Square Wave Frequency Generator, and their kit is much easier to build than the instructions given below, because it uses a breadboard so there is no need to twist or solder wires, you simply push the electrical parts into place on the breadboard. **-editor.**

Assembling The Zapper

If you have tools such as a drill, needle nose pliers, and small drill bits, buy one of the plastic project boxes on the list, otherwise build your zapper in a shoe box, or a box half the size of a shoe box.

1. You will be using the lid of the shoe box or plastic lid of the project box to mount the components. Save the box to enclose the finished project.

2. Pierce two holes near the ends of the lid. Enlarge the holes with a pen or pencil until the bolts would fit through. Mount the bolts on the outside about half way through the holes so there is a washer and nut holding it in place on both sides. Tighten. Label one hole "grounding bolt" on the inside and outside.

3. Mount the 555 chip in the wire wrap socket. Find the "top end" of the chip by searching the outside surface carefully for a cookie-shaped bite or hole taken out of it. Align the chip with the socket and very gently squeeze the pins of the chip into the socket until they click in place.

4. Make 8 pinholes to fit the wire wrap socket. Enlarge them slightly with a sharp pencil. Mount it on the outside. Write in the numbers of the pins (connections) on both the outside and inside, starting with number one to the left of the "cookie bite" as seen from outside. After number 4, cross over to number 5 and continue. Number 8 will be across from number 1. The pins are numbered like this:

1	8
2	7
3	6
4	5

5. Pierce two holes ½ inch apart very near to pins 5,6,7, and 8. They should be less than 1/8 inch away. (Or, one end of each component can share a hole with the 555 chip.) Mount the .01 uF capacitor near pin 5 on the outside. On the inside connect pin 5 to one end of this capacitor by simply twisting them together. Loop the capacitor wire around the

pin first; then twist with the long-nose pliers until you have made a tight connection. Bend the other wire from the capacitor flat against the inside of the shoe box lid. Label it .01 on the outside and inside. Mount the .0047 uF capacitor near pin 6. On the inside twist the capacitor wire around the pin. Flatten the wire from the other end and label it .0047. Mount the 3.9 K Ohm resistor near pin 7, connecting it on the inside to the pin. Flatten the wire on the other end and label it 3.9. Mount the 1 K Ohm resistor and connect it similarly to pin 8 and label it 1K.

6. Pierce two holes ½ inch apart next to pin 3 (again, you can share the hole for pin 3 if you wish), in the direction of the bolt. Mount the other 1 K Ohm resistor and label inside and outside. Twist the connections together and flatten the remaining wire. This resistor protects the circuit if you should accidentally short the terminals. Mount the 3.9 K Ohm resistor downward. One end can go in the same hole as the 1K resistor near pin 3. Twist that end around pin 3 which already has the 1K resistor attached to it. Flatten the far end. Label.

7. Next to the 3.9 K Ohm resistor pierce two holes ¼ inch apart for the LED. Notice that the LED has a positive and a negative connection. The longer wire is the positive (anode). Mount the LED on the outside and bend back the wires, labeling them + and - on the inside.

8. Near the top pierce a hole for the toggle switch. Enlarge it until the shaft fits through from the inside. Remove nut and washer from switch before mounting. You may need to trim away some paper with a serrated knife before replacing washer and nut on the outside. Tighten.

9. Next to the switch pierce two holes for the wires from the battery holder and poke them through. Do not attach the battery yet.

10. An inch away from the switch pierce two holes 1/4 inch apart. Mount the 39 K Ohm resistor on the outside and label it inside and outside as "39 K, Positive offset." Flatten the wires on the inside.

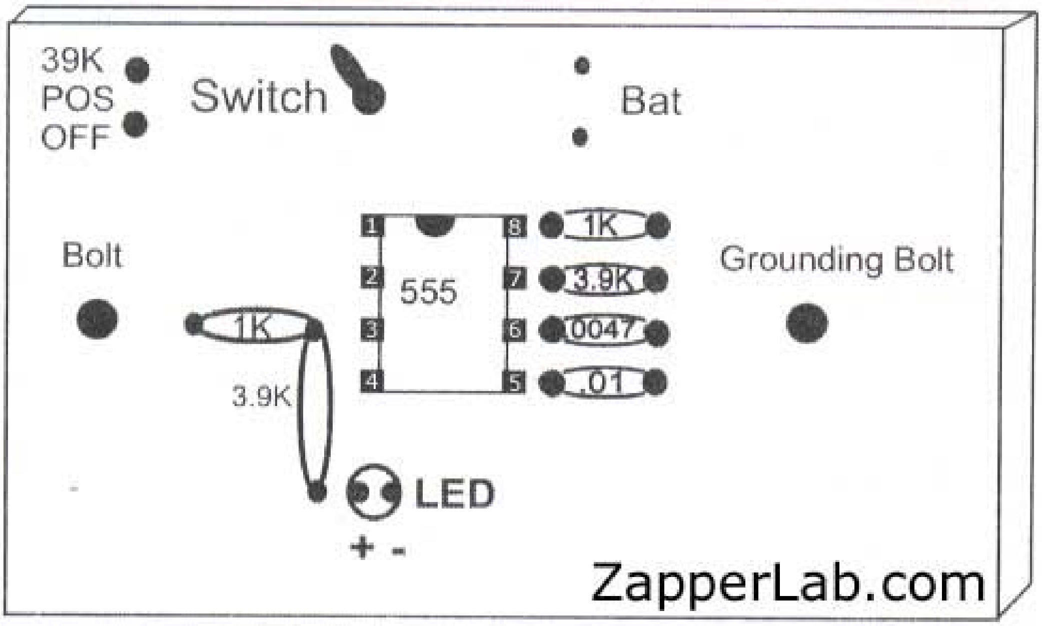

Now To Connect Everything

1. Twist free ends of the two capacitors .01 and .0047 together. Connect this to the Grounding Bolt using an alligator clip.

2. Bend the top ends of pin 2 and pin 6 (which already has a connection) inward towards each other in an L shape. Catch them both with an alligator clip and attach the other end of the alligator clip to the free end of the 3.9 K Ohm resistor by pin 7.

3. Using an alligator clip connect pin 7 to the free end of the 1 K Ohm resistor attached to pin 8.

4. Using three micro clips connect pin 8 to one end of the switch, pin 4 to the same end of the switch, and one end of the offset resistor to the same end of the switch. (Put one hook inside the hole and the other hooks around the whole connection. Check to make sure they are securely connected.) Connect the free end of the offset resistor to the bolt using an alligator clip.

5. Use an alligator clip to connect the free end of the 1 K Ohm resistor (by pin 3) to the bolt. It is the **output resistor**.

6. Twist the free end of the 3.9 K Ohm resistor by pin 3 around the plus end of the LED. Connect the minus end of the LED to the grounding bolt using an alligator clip.

7. Connect pin number 1 on the chip to the grounding bolt with an alligator clip.

8. Attach an alligator clip to the outside of one of the bolts. Attach the other end to a handhold (copper pipe). Do the same for the other bolt and handhold.

9. Connect the minus end of the battery snap connector (black wire) to the grounding bolt with an alligator clip.

10. Connect the plus end of the battery snap connector (red wire) to the free end of the switch using a micro clip lead. Attach the battery very carefully. Before attaching the battery to its snap connector, cover one terminal with tape. After snapping in one terminal, remove the tape to attach the other terminal. This is to prevent accidental touching of terminals in a backwards direction. If the LED lights up you know the switch is ON. If it does not, flip the switch and see if the LED lights. Label the switch clearly. If you cannot get the LED to light in either switch position, double-check all of your connections, and make sure you have a fresh battery. Even if it does light up, check every connection again.

11. Finally tie up the bunches of wire with twist-ties or rubber bands

and replace the lid on the box. Slip a couple of rubber bands around the box to keep it securely shut. For safer storage, place it inside a larger box.

Note: Having gained this much experience, you may prefer to build your next zapper on a piece of cardboard folded and able to fit inside a shoebox or plastic electronic project box for more protection.

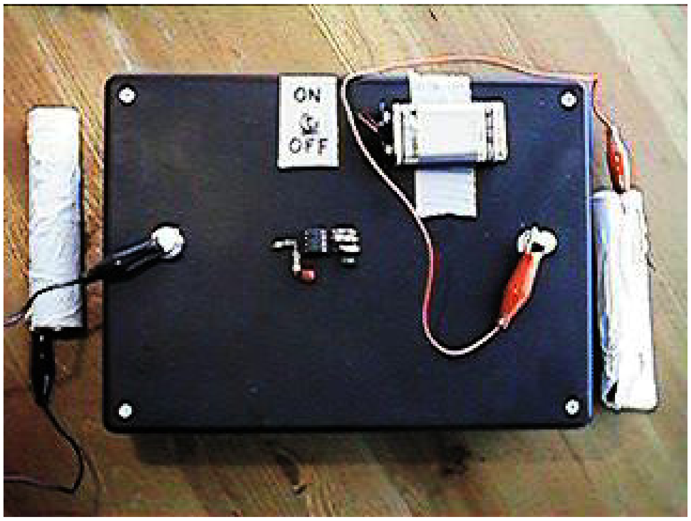

- Optional: measure the frequency of your zapper by connecting an oscilloscope or frequency counter to the handholds. Any electronics shop can do this. It should read between 20 and 40 kHz. The shop can also read the voltage (peak to peak) and the amount of Positive offset (on the .5 volt-per-division scale). The voltage output should be about 8 volts.
- Note: a voltage meter will only read 4 to 5 volts because it displays an average voltage.

Using The Zapper

1. Wrap handholds in one layer of wet paper towel before using. More will reduce the current. Grasp securely and turn the switch on to zap. Keep a bottle of water handy to keep them wet.

2. Zap for seven minutes, let go of the handholds, turn off the zapper, and rest for 20 minutes. Then seven minutes on, 20 minutes rest, and a final seven minutes on. This is the routine for **regular** zapping.

Tell us about your zapper experience at the zapper message board.

To Visit The Zapper Museum - Click Here!

Order A Hulda Clark Zapper - Click Here!

See The *'Build A Zapper'* Video - Click Here!

Learn about Dr Clark's latest zapping technique called: Plate Zapping

Learn about Dr Clark's latest inventions:
The Food Zappicator and The Toothbrush Zappicator

Order Electronic Parts at RadioShack.com and Frequency Generator Kits at PositiveOffset.com

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Simple Zapper Schematic

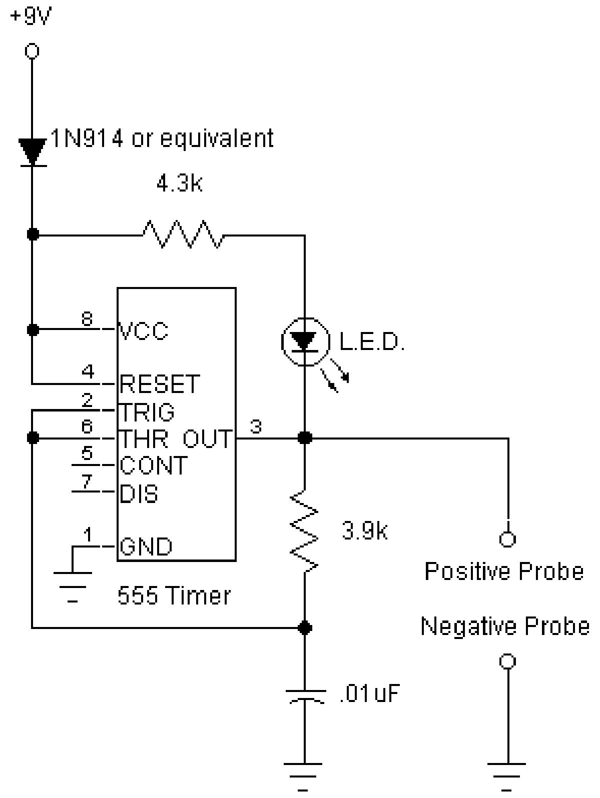
+9V
1N914 or equivalent
4.3k
8
VCC
4
RESET
2
TRIG
6
THR OUT
3
5
CONT
7
DIS
1
GND
555 Timer
L.E.D.
3.9k
Positive Probe
Negative Probe
.01uF

The Research of Dr. Hulda Regehr Clark, Ph. D., N.D.

I have recently (9/15/2000) come across the research of Dr. Hulda Regehr Clark, Ph. D., N.D. In her books, she states that many diseases, among which are cancer and HIV/AIDS, can be cured by the use of, among other things, certain herbs and a frequency generator called a "Zapper" that was invented by her and her son.

Speaking of mothers :), my mother, 62, had fatigue and arthritic symptoms in her hands before I found out about and told her about Dr. Hulda Clark. She is a seamstress, so the arthritic symptoms hindered her work. After doing the Parasite Cleanses and using the Zapper, she doesn't have to take naps like before and her hands are flexible again. She has done the complete Parasite Cleanse only twice but she Zaps practically every day.

Simple Zapper Information

Schematic updated on 12/21/2001

Simple Zapper Information text updated on 12/21/2001.

I forgot to mention that the Simple Zapper that I'm using has a 1 Megohm potentiometer instead of the 2.2k ohm resistor in order to vary the output frequency. If you use a potentiometer with the circuit put it in series with the 2.2k ohm resistor because the chip gets hot when there is too little resistance.

The duty-cycle is pretty consistent with a range of 51% to 57%. With the oscilloscope's frequency analyzer in storage mode, I hold the Zapper probes and put the oscilloscope probes somewhere on my body and then I vary the frequency of the Zapper using the 1 Megohm potentiometer.

When testing my body on a spectrum analyzer while using the Simple Zapper with an output of around 5 Volts (tested on a DC voltmeter), I noticed that the frequencies around 4,000 hz to around 18,000 hz had larger peaks telling me that my body at the time was more conductive (less reactive?) and/or less resistive to frequencies in this range at the given voltage.

With my body being more conductive (less reactive?) at these frequencies, I believe that there is a better dispersal of the Simple Zapper's output within my body. I did this recent test with one Zapper probe in each hand (as opposed to both in one hand) and the oscilloscope probes (RCA to 1/4" phone plug adaptor) in my mouth near my wisdom teeth with my lips around the RCA ground (like a lollipop).

The oscilloscope's frequency analyzer was in storage mode. With the Simple Zapper circuit on this page, change the 2.2k ohm resistor to 4.3k ohm if you want a ~15,000 hz frequency. I have recently built a couple of Zappers with optimized output frequencies of around 11,000 hz. I haven't tested anyone using the Simple Zapper other than myself, so there is the possibility that your body's response may differ.

For more information, check out my Simple Zapper webpage at:

www.members.aol.com/mas1911/index.html

or for really interesting free circuit schematics:

www.members.tripod.com/~mas1911/zappers20011221tripod.html

You can write the Author of Simple Zapper if you have comments or questions.

The following document, written by Luke Parrish, provides instructions on building an astable multivibrator in DC pulse mode, identical in output to the Zapper, described in The Cure For All Diseases by Dr. Hulda Clark.

Plans For Zapper

This page tells how to make a Hulda Clark-style "Parasite Zapper". It's a simpler and more efficient version, but works just as well. We make no theraputic claims for this device. It is for experimental purposes only. We provide a ready made version for those who prefer not to spend so much time building it.

Materials

- A CD4069 hex inverter (Radio Shack link)
- 1 1M resistor, 1 10k resistor, and 1 1k resistor (Radio Shack link) (Resistor color code)
- 1 1000 pF capacitor (Radio Shack link)

NOTE: The size of the resistors and capacitors can vary, because they determine the frequency of the zapper, which doesn't really matter much according to Hulda Clark.

The following parts may be substituted according to preference, though something similar will be needed:
- Solderless breadboard (Radio Shack link)
- 9-volt battery
- 4 alligator clip-leads sets Radio Shack link
- 2 copper pipes (hand-holds)

Instructions

Plug the components into the solderless breadboard according to the following schematic. Make sure none of the wires touch each other. To hook up the power, attach an alligator clip-lead to each side of the capacitor that stretches from hot to ground. Clip the one that goes to hot to the positive terminal on the battery and the one that goes to ground to the negative terminal. The two hand-holds are attached with the other two clip-leads. (One goes to ground, the other to the end of a resistor that goes to pin 12.)

Schematic

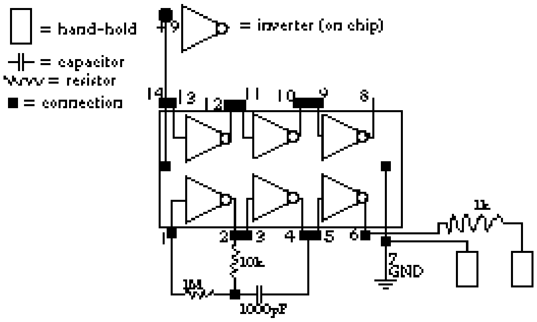

Schematic most recently updated 5-17-2001

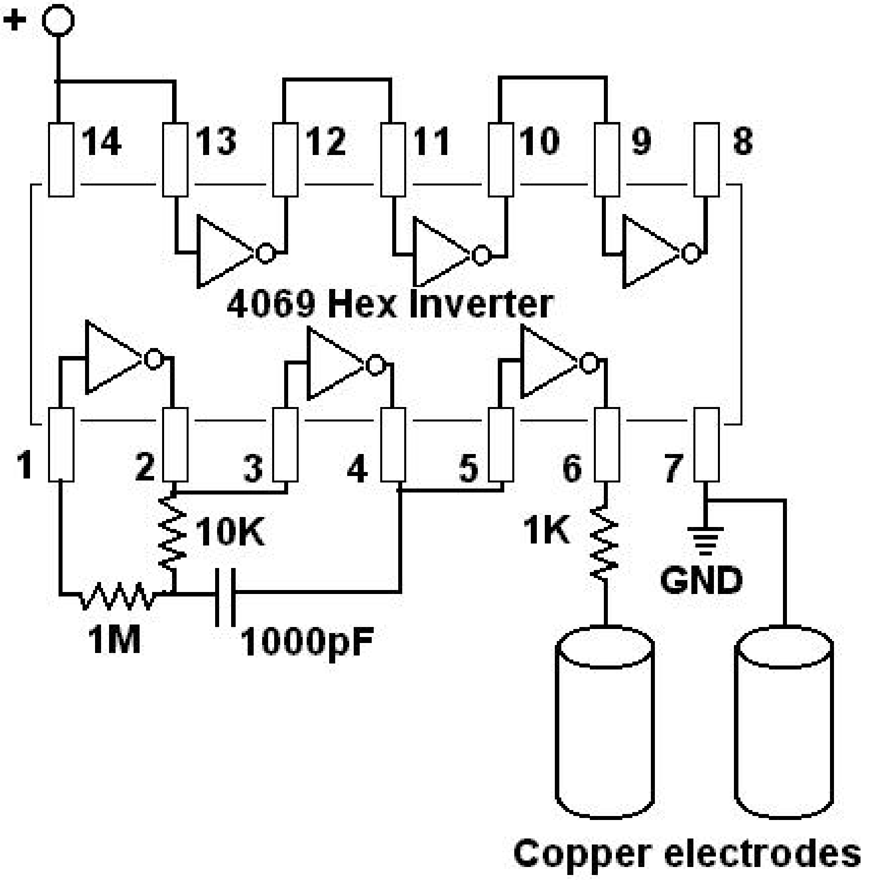

The above instructions are not the only way to do it. You can, for example, solder all the components directly to a 14-pin socket, like we do in our ready made version. This is a lot more trouble and more time-consuming for most people, which is why we recommend a breadboard. The resistors and capacitor don't all have to be the exact sizes mentioned here to make a working Zapper. However, any variation in capacitance or resistivity will change the frequency. (There are certain limits on how high of frequencies the chip can handle, so don't stray too far from the specified values.) If you have an oscilliscope, that's handy to check if it's working.

[Ready made Zappers]

Free plans from [Zapperlab.com]

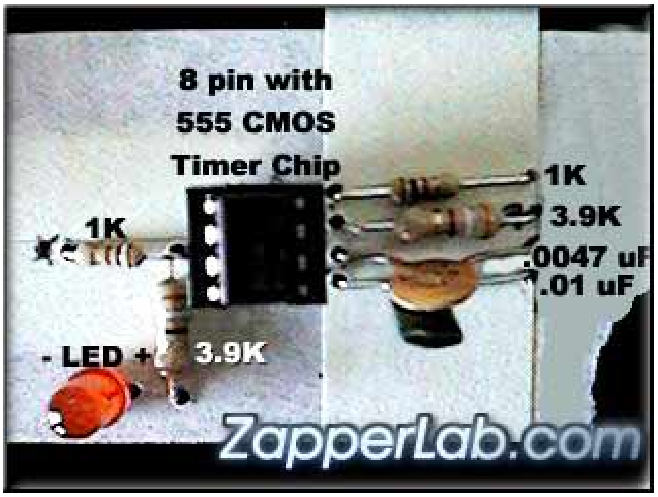

Here we have the easy step-by-step instructions for building your very own Hulda Clark Zapper reprinted with permission from her books (provided below). For advanced electricians there is a schematic for building a Hulda Clark Zapper as well. If you do not know anyone that could put one together for you, you can now order the zapper Hulda Clark uses as described in "The Cure For All Cancers" and "The Cure For All Diseases" at: www.SyncroZap.com. The Dr. Clark Zapper can be sold only as an experimental device, and no claim can be made by us legally as to a diagnosis, cure or treatment for any medical condition or disease.

Build A Dr. Clark Zapper

Order A Dr. Clark Zapper

Instructions for building your very own zapper can be found reprinted below from the books by Dr. Hulda Clark. If you would rather order a pre-built zapper, just click here.

How To Build A Zapper from *The Cure For All Cancers*:

The Cure For All Cancers © Copyright 1993 by Hulda Regehr Clark, Ph.D., N.D.

Get from Radio Shack, (serial number included to make it easy).
Order these parts from their web site at:
www.RadioShack.com

___ Black plastic Project Box Radio Shack # 270-1809

___ 9 volt battery

___ 9 volt battery clips: Radio Shack # 270-325

___ On off switch: Radio Shack # 275-624A

___ 1K Ohm resistor: RS# 271-1321

___ 3.9K Ohm resistor: RS# 271-1123

___ low current red LED: RS# 276-044

___ .0047 uF capacitor: RS# 272-130

___ .01 uF capacitor: RS# 272-1065

___ 555 CMOS timer chip: RS# 276-1723

___ 8 pin wire wrapping socket for CMOS chip: RS# 276-1988

___ two packs of Microclip test jumpers: RS# 278-017

___ one pack of 14" alligator clip leads RS# 278-1156C

Get from any Hardware Store:

2 Bolts 1/8" diameter, 2" long with 4 nuts and washers.

2 pieces of ¾" copper pipe, cut to 4 inches long each.

Editor's Note:

Remove 8 Pins From A
16 Pin Wire Wrap Socket

The **8 pin wire-wrapping socket** has been discontinued at many Radio Shacks and readers have asked what to do. Some say it is still available on their website at www.RadioShack.com, if not:

There are a couple options. One can still get the **16 pin wire-**

wrapping socket. Pull out the bottom grouping of 8 pins, and you now have an 8 pin socket. Just make sure when you plug the 555 Timer into it, you line it up with the remaining 8 pins. Very simple.

There is also a **Low Profile 8 pin socket**. The pins are so small one must solder to them.

The wire-wrap socket has long pins for easy twisting onto other wires. The low profile is for those that solder electronics.

If you are soldering your zapper together get the low profile 8 pin socket. Since the socket is just a saddle for the 555 Timer, it is not a vital part of the circuit. It's just a way to put long or short pins on the 555 Timer for easy twisting. If you cannot find one at your local Radio Shack, simply get the 16 pin wire-wrap socket, and pull out 8 pins. -editor.

Assembling The Zapper

If you have tools such as a drill, needle nose pliers, and small drill bits, buy one of the plastic project boxes on the list, otherwise build your zapper in a shoe box, or a box half the size of a shoe box.

1. You will be using the lid of the shoe box or plastic lid of the project box to mount the components. Save the box to enclose the finished project.

2. Pierce two holes near the ends of the lid. Enlarge the holes with a pen or pencil until the bolts would fit through. Mount the bolts on the outside about half way through the holes so there is a washer and nut holding it in place on both sides. Tighten. Label one hole "grounding bolt" on the inside and outside.

3. Mount the 555 chip in the wire wrap socket. Find the "top end" of the chip by searching the outside surface carefully for a cookie-shaped bite or hole taken out of it. Align the chip with the socket and very gently squeeze the pins of the chip into the socket until they click in place.

4. Make 8 pinholes to fit the wire wrap socket. Enlarge them slightly with a sharp pencil. Mount it on the outside. Write in the numbers of the pins (connections) on both the outside and inside, starting with number one to the left of the "cookie bite" as seen from outside. After number 4, cross over to number 5 and continue. Number 8 will be across from number 1. The pins are numbered like this:

1	8
2	7

3 6

4 5

5. Pierce two holes ½ inch apart very near to pins 5,6,7, and 8. They should be less than 1/8 inch away. (Or, one end of each component can share a hole with the 555 chip.) Mount the .01 uF capacitor near pin 5 on the outside. On the inside connect pin 5 to one end of this capacitor by simply twisting them together. Loop the capacitor wire around the pin first; then twist with the long-nose pliers until you have made a tight connection. Bend the other wire from the capacitor flat against the inside of the shoe box lid. Label it .01 on the outside and inside. Mount the .0047 uF capacitor near pin 6. On the inside twist the capacitor wire around the pin. Flatten the wire from the other end and label it .0047. Mount the 3.9 K Ohm resistor near pin 7, connecting it on the inside to the pin. Flatten the wire on the other end and label it 3.9. Mount the 1 K Ohm resistor and connect it similarly to pin 8 and label it 1K.

6. Pierce two holes ½ inch apart next to pin 3 (again, you can share the hole for pin 3 if you wish), in the direction of the bolt. Mount the other 1 K Ohm resistor and label inside and outside. Twist the connections together and flatten the remaining wire. This resistor protects the circuit if you should accidentally short the terminals. Mount the 3.9 K Ohm resistor downward. One end can go in the same hole as the 1K resistor near pin 3. Twist that end around pin 3 which already has the 1K resistor attached to it. Flatten the far end. Label.

7. Next to the 3.9 K Ohm resistor pierce two holes ¼ inch apart for the LED. Notice that the LED has a positive and a negative connection. The longer wire is the positive (anode). Mount the LED on the outside and bend back the wires, labeling them + and - on the inside.

8. Near the top pierce a hole for the toggle switch. Enlarge it until the shaft fits through from the inside. Remove nut and washer from switch before mounting. You may need to trim away some paper with a serrated knife before replacing washer and nut on the outside. Tighten.

9. Next to the switch pierce two holes for the wires from the battery holder and poke them through. Attach the battery and tape it to the outside.

Now To Connect Everything

Twist free ends of the two capacitors .01 and .0047 together. Connect to Grounding Bolt using an alligator clip.

Bend pin 2 and pin 6 together inward, using an alligator clip, catch them and connect to free end of 3.9K Ohm (by pin 7).

Alligator clip Pin 7 to free end 1K Ohm (near pin 8)

Using two microclips Pin 8 and pin 4 to one end of switch (use hole to attach both microclips).

Free end of 1K Ohm (by pin 3) to the Bolt using an alligator clip.

Alligator clip the free end of 3.9K Ohm (by pin 3) to plus end (long) of LED.

Minus end (short) of LED to Grounding Bolt with an alligator clip.

Alligator clip pin 1 to the Grounding Bolt.

Alligator clip Black battery wire to Grounding Bolt.

Micro clip the Red battery wire to free end of switch.

Hook up the battery, and the light should turn on, click the switch if it does not, check connections if LED does not light up.

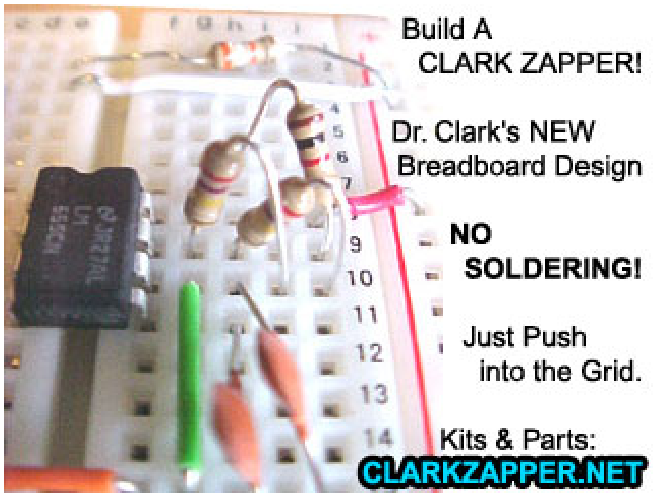
Build A
CLARK ZAPPER!
Dr. Clark's NEW
Breadboard Design
NO
SOLDERING!
Just Push
into the Grid.
Kits & Parts:
CLARKZAPPER.NET
LM 555CN
9
10
11
12
13
14

Attach a long lead wire to the grounding bolt & bolt, and then to the copper handles. Wrap handles in paper towel, clip with lead wire, wet handle when you are ready to zap.)

How To Zap

Wrap handles in wet paper towel, or wet cotton sleeves, and hold in each hand. If you have wrist cuffs, run them under water to wet them, attach to each wrist.

Attach handles or wrist cuffs to zapper.

Turn zapper on, zapping for 7 minutes.

At end of 7 minute zapping rest 20 minutes.

Do this a minimum of three 7 minute zapping sessions, with a 20 minute break in between each session. Some people zap five times in extreme cases.

Order A Dr. Hulda Clark Zapper - Click Here!

Learn about Dr Clark's latest zapping technique at: www.PlateZapping.com

All information is for educational purposes only. These statements have not been evaluated by the FDA. Not intended to diagnose, treat, prevent, mitigate or cure disease.

This Circuit designed by Geoff Clark and approved by Dr. Hulda Clark

SOTA Instruments Inc. presents...
"The Zapper" as per Dr. Hulda Clark, Ph.D., N.D.

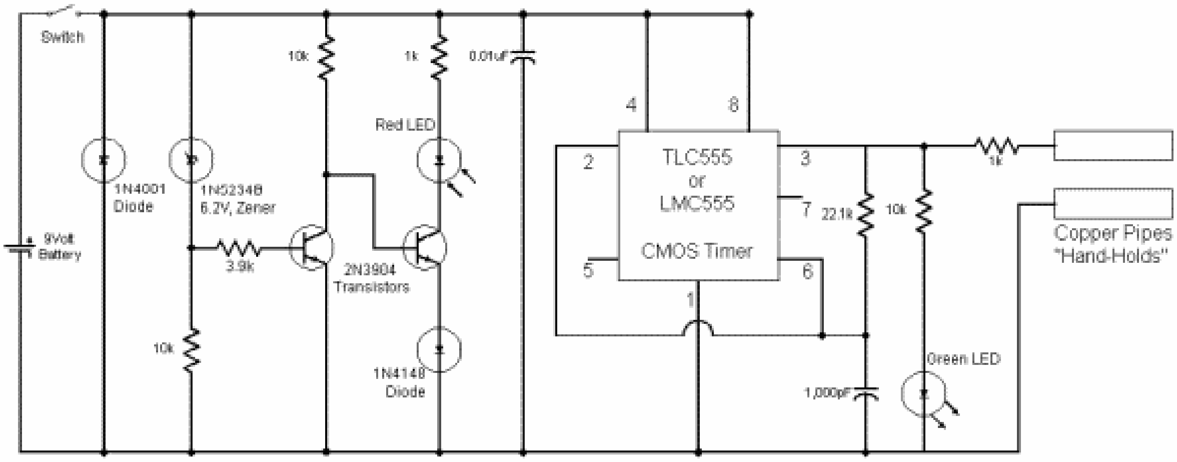
Switch
10k
1k
0.01uF
4
8
Red LED
2
TLC555
or
LMC555
CMOS Timer
3
1k
7
22.1k
10k
5
6
1
Copper Pipes
"Hand-Holds"
1N4001
Diode
1N5234B
6.2V, Zener
9Volt
Battery
3.9k
2N3904
Transistors
10k
1N4148
Diode
1,000pF
Green LED

Low Battery Warning
<7.2 Volts DC

~30kHZ Square-Wave Output,
50% Duty Cycle, Positive Offset

Output LED

Certified and Approved by Dr. Clark's son Geoff Clark.
Designed & Drawn by Russell J. Torlage, CTech, President, SOTA Instruments Inc.
Model: ZHC3 Rev 4.0
Revised: June 9, 1999

All Resitors are 1/4W, 5% Tol. 22.1k resistor is 1%.

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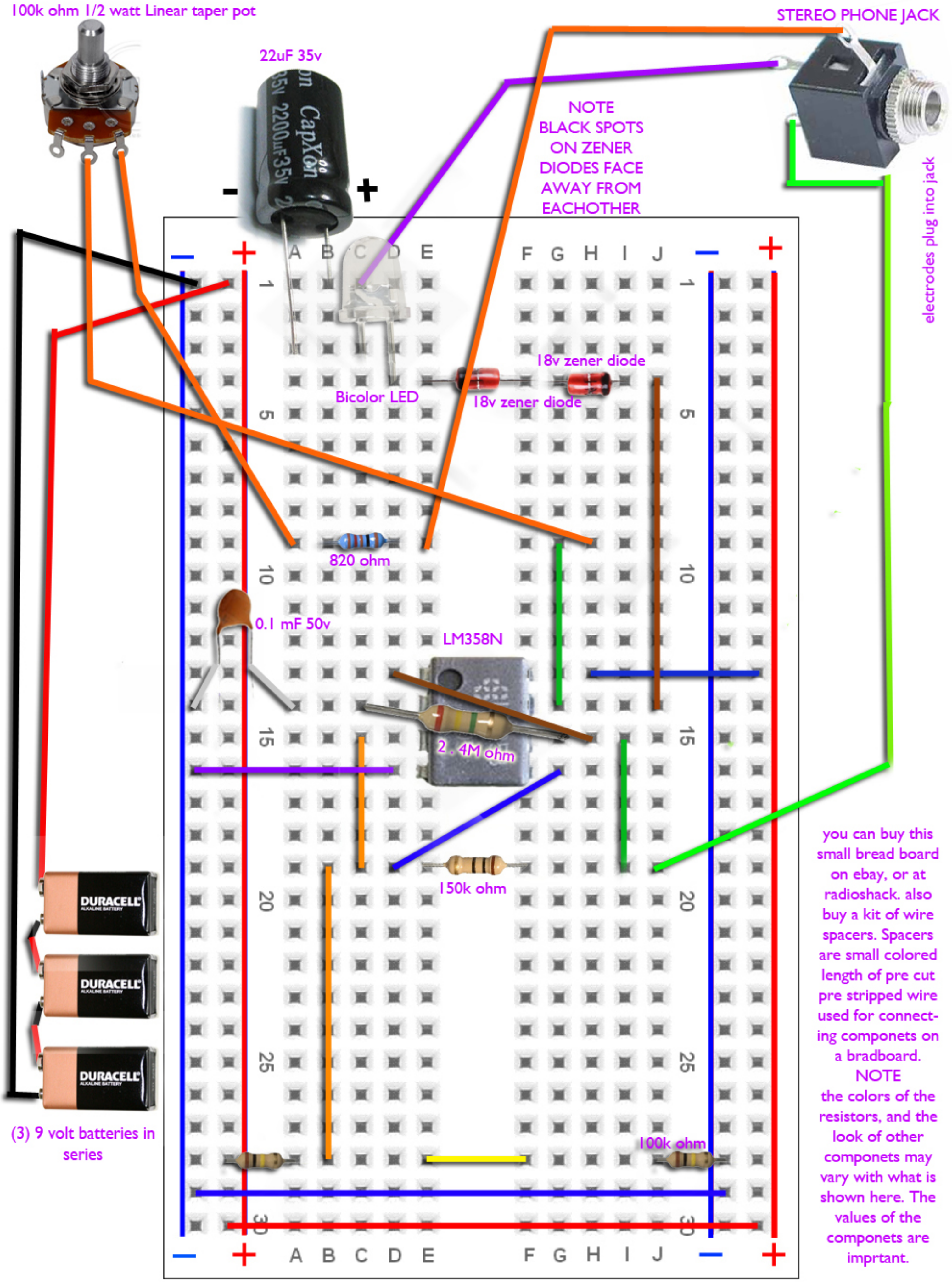
100k ohm 1/2 watt Linear taper pot
22uF 35v
-
+
2200uF 35V
CapXon
STEREO PHONE JACK
electrodes plug into jack
A B C D E F G H I J
−
+
1
5
10
15
20
25
30
Bicolor LED
18v zener diode
18v zener diode
820 ohm
0.1 mF 50v
LM358N
2 . 4M ohm
150k ohm
100k ohm
DURACELL
ALKALINE BATTERY
(3) 9 volt batteries in series

NOTE
BLACK SPOTS
ON ZENER
DIODES FACE
AWAY FROM
EACHOTHER

you can buy this small bread board on ebay, or at radioshack. also buy a kit of wire spacers. Spacers are small colored length of pre cut pre stripped wire used for connecting componets on a bradboard.

NOTE

the colors of the resistors, and the look of other componets may vary with what is shown here. The values of the componets are imprtant.

COMPONENT DESCRIPTIONS, SOURCES, AND CURRENT PRICES

Revision November 24, 1996. Copyright (c) 1991/1999 Robert C. Beck, D.Sc.

Note: These data are for theoretical, informational and instructional purposes only and are not to be construed as medical advice. Consult with your licensed medical practitioner. Hundreds have been built successfully if duplicated exactly as shown.

LM358 CMOS Operational Amplifier (OP-AMP) chip (generic)		U1	$ 1.00
2.4 megohm 1/4 watt 5% resistor		R1	0.07
150 kohm 1/4 watt 5% resistor		R2	0.07
100 k ohm 1/4w 5% resistor	2 required @ 0.15	R3, R4	0.14
100 kohm linear taper pot, 1/2 watt Cattronics P-68		R5	2.56
150 ohm 1/4 watt 5% resistor		R6	0.07
820 ohm 1/4 watt 5% resistor 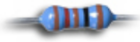		R7	0.07
0.1 mF 50 V (or higher) ceramic capacitor		C1	0.45
22 mF 35 V (or higher) electrolytic capacitor		C2	0.25
18 Volt Zener diodes (NTE5027A)	% Watt, 2 @ 0.79	D1 & D2	1.58
Bulb, 6.3V 0.075 A	Type 7377	B1	1.34
Bicolor LED Red/Green	RS# 276-012	LED 1	$ 1.19
Jack for electrode leads (3.5mm or 1/8" mono-phone jack)	RS# 274-251 3/$1.59	J1	0.53
Jack for silver wire leads (2.5mm or 3/32" mono-phone jack)	RS# 274-292 3/$1.59	J2	0.53
3 Alkaline 9 V batteries, type 1604 etc.	3 for		3.75
3 x 9 V battery snaps (clip-on connectors)	RS# 270-325 pkg.	5/$1.29	1.29
Misc. wire, solder, etc.			0.50
Box, if used			2.29
Lead wire with 3.5 mm plug, 6 ft., Mouser or Calrad Electronics			0.35
Electrodes, stretch elastic, Velcro, cotton flannel, alligator clips, etc.		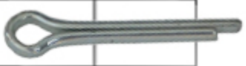	
Total Cost **for all** components for improved **do-it-yourself** project			**$22.47**

All components listed above check your local electronics store.

Ensure the IC chip U 1 (LM358) is wired correctly. The location of Pin #1 is shown below:

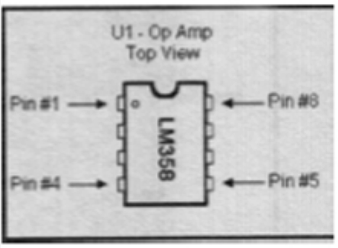

NOTE RESISTOR COLORS NOT TO SPEC. CHECK RESISTOR COLOR VALUES

electrodes: 3/32 x 1 stainless steel cotter pins -hardware store- Snap pins in half across the curve. and wrap the headphone wires comming from the mono plug around the curve of each half of the pin. then hou glue into place.

The Lakhovsky Multiple Wave Oscillator Handbook

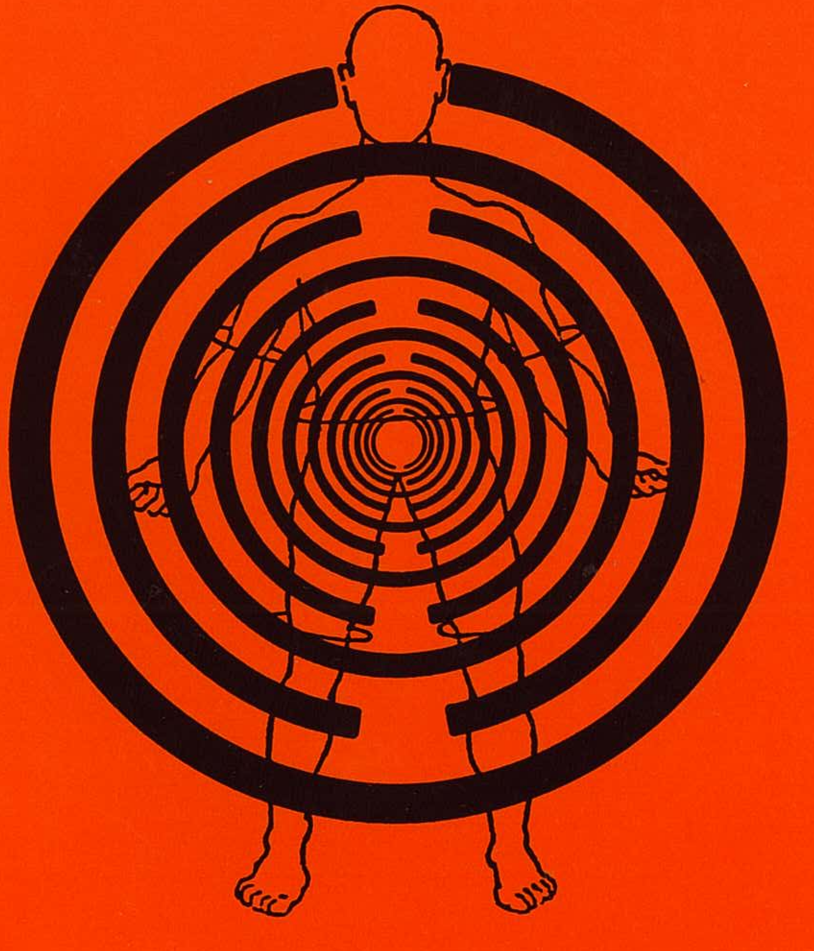

Compiled and Edited by

Thomas J. Brown

The Lakhovsky Multiple Wave Oscillator Handbook

Comprising the
Borderland Sciences Research Foundation
Lakhovsky Multiple Wave Oscillator
&
Radio-Cellular Oscillator
Research Files

Compiled and Edited by
Thomas J. Brown
Executive Director of
Borderland Sciences Research Foundation

Published May 31, 1992
in the Light of further research,
in the interests of BSRF Associates by:

P.O. BOX 429 ★ GARBERVILLE, CA 95440-0429 ★ U.S.A.

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DISCLAIMER

This book is a research publication of Borderland Sciences Research Foundation. It consists of our MWO and RCO files which have been put into some semblance of order to preserve the records of many people with new and different ideas on how to study the energetic states of living systems and how these systems may be influenced by externally applied energies, and also to allow for further experimentation in this field by competent researchers. Read this book thouroughly before undertaking any experiments becasue you will find many different opinions, some conflicting, as to how to proceed. High frequency electrical apparatus can cause serious shock injury and should only be handled by knowledgable, competent people. All experiments are conducted solely at your own risk. We disclaim any responsibility for the use or misuse of any information in this book. While this book touches on the subject of human health, all information should be considered as anecdotal and should not in any way be construed as medical advice. We are not qualified to give medical advice and the use of the experimental equipment and research techniques described in this book may provide a false sense of security wherein one may neglect professional medical care. Use your brains. Thanks.

Tom Brown
Editor/Publisher

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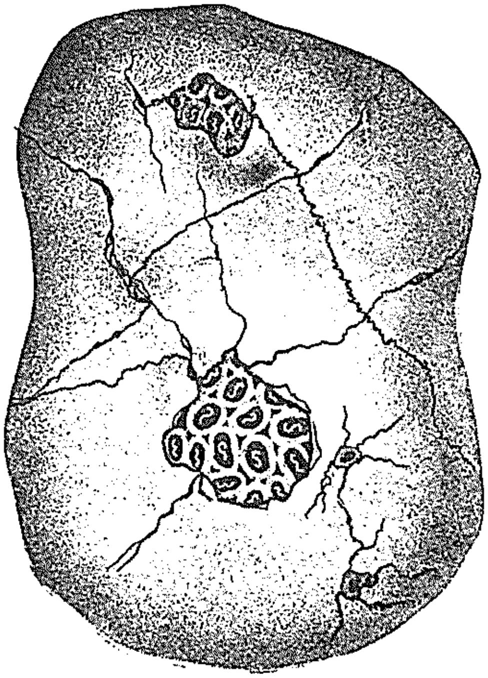

A dead cell. This diagram shows a cell where the chromosomes have stopped oscillating, and for this reason have ceased to live. But the chondromes, visible through the opening, continue to live an independent life. They are surrounded by a tough membrane and are multiplying so as to burst open the outside of the cell, as a baby chick, when it comes to maturity, breaks through the egg shell to come out.

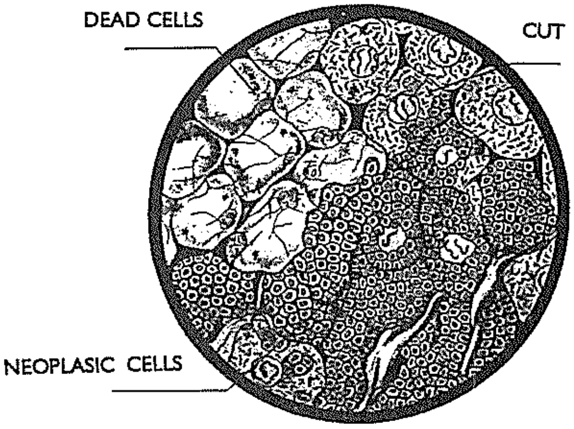

A group of dead cells, but not yet destroyed, in which the neoplasic cells are forming. One can see the transformation in the neoplasic tissue.

Photograph taken during the treatment of Mrs S..., who sits between the MWO antennas at Calvary. Behind the patient is Dr. Marquer, head physician of the hospital, to the left is Dr Z..., assistant, three voluntary Nurses, & to the right is Georges Lakhovsky.

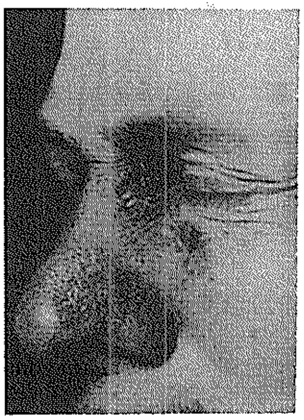

At left, Madame C... *Before Treatment.* Rodent Ulcer in inner angle of left eye.

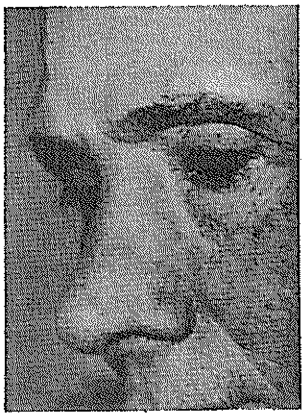

At right, Madame C... *After Treatment.*

Excerpts from:

RADIATIONS AND WAVES

Source of Our Life

by Georges Lakhovsky, 1941

THEORY OF CELLULAR OSCILLATION

Before presenting the therapeutic results obtained with my multiple short wave oscillator and presented at the International Congress of Short Waves in Vienna (July, 1937) it may be useful to give a rapid survey of my theory of cellular oscillation which I have developed fully in a number of books.*

All living cells are composed of two essential elements; the nucleus and the protoplasm in which it is bathed. This nucleus is itself composed of many tubular filaments: the chromosomes. In addition, hundreds of much smaller filaments or chondromes are present in the cytoplasm.

Chromosomes and chondromes are sheathed in an insulating substance (cholesterine, resin, fat, plastrin, etc.) and contain a liquid-like serum with the same mineral content as sea water, and consequently a conductor of electricity. Thus, these filaments constitute ultramicroscopic oscillating circuits capable of oscillating electrically over a wide scale of very short wavelengths.

I have demonstrated in my works that these cellular oscillating circuits, chromosomes and chondromes, vibrate electrically under the stimulus of electro-magnetic waves: cosmic, atmospheric and telluric.

Now, many internal and external influences may upset the oscillating equilibrium of these cells. For instance, a variation or change in the field of cosmic, telluric or atmospheric waves, a demineralization of the organic matter constituting the cellular substance, traumas causing the destruction by shock of the protoplasm or the nucleus.

I have shown in my books, **The Secret of Life** and especially in **The Earth and Ourselves**, that every living cell draws its oscillatory energy from the field of secondary radiations resulting from the ionization of the geological substances of the earth by cosmic radiations.

But certain natural radiations are particularly toxic, especially those originating in geologically-induced geopathic zones. Many cancer cases have been attributed to these toxic radiations which has been proven experimentally, notably in Germany by Dr. Rambeau of Marburg. Therefore, earth radiations sometimes cause disturbance of the cellular oscillatory equilibrium of the organism.

Under these varied circumstances cellular oscillation may cease; the cell is then dead. But within the dead cell, the chondromes sometimes continue to oscillate electrically on their own natural frequencies. Fortunately, this phenomenon occurs rarely, or all humanity would already have perished from cancer.

The chondromes then envelope themselves in a membrane and continue to oscillate and multiply independently of the cell. They may then become neoplasic cells.

THE RADIO CELLULAR OSCILLATOR

To re-establish this equilibrium, I thought of creating, in 1923, a constant compensating field of very short radiations (2 to 10 metre wavelengths) to neutralize the action of the disturbing rays, and give the living cell the necessary stimulation for a return to its normal oscillation.

To this end, in 1923, I constructed my short-wave oscillator, using two triode tubes for very short waves made especially for this apparatus. I tried several cross leakages for this machine using one or more tubes and then multiple triodes with a tube containing oscillatory circuits within the bulb. Finally I adopted the oscillator with symmetrical cross leakage comprising two triodes. The oscillating circuits formed a single spiral, branched between the two grilles and the two anodes. It was fed directly by alternating current from the local supply circuit.

With this short-wave apparatus I was able to cure plants inoculated with cancer. For six years at the Saltpetriere I observed and checked the effects of these short waves.

Using very low power, from 10 to 12 watts, and a limited duration of treatment, I succeeded in curing cancer in human beings, but also had to record some failures.

The news of the success of my experiments became widespread. In many countries, as early as 1928, they began to build short-wave oscillators of considerable power producing thermal effects.

But here was great danger that the chromosomes and

*** The Secret of Life; Contribution to the Etiology of Cancer; The Earth and Ourselves; Cellular Oscillation; Nature and Her Wonders.**

chondromes, which are barely a ten-thousandth or twenty-thousandth of a millimeter in thickness, might not survive under a high frequency current. They offer much resistance, even to a low current which is sufficient to dissolve and destroy them.

It is simple to prove this by bringing a small bulb of from 2 to 5 volts with a filament of several hundredths of a millimeter, inserted between metal rods forming antennas, within the radius of a short wave transmitter. The bulb will light up and sometimes burn out, if it is brought too near the apparatus.

Moreover, the chondromes and chromosomes of all living cells, which are infinitely finer than the filaments of the bulbs, are sensitive centers of thermal phenomena, which may provoke their fusion. Undoubtedly this method is effective in killing microbes in the organism and in neoplasic cells. But it can also destroy millions of cells of healthy tissue in every irradiation.

THE MULTIPLE WAVE OSCILLATOR

On the other hand, I thought it possible to obtain better results by administering an oscillatory shock to all the cells in the organism simultaneously. Such a shock, very brief, produced by dampened or weakened electrostatic waves, does not provoke thermal and prolonged effects and involves no risk of burning living cells.

I therefore sought to produce an artificial oscillatory shock causing a periodic oscillation of the weak or dead cells.

At first glance this problem seems physically insoluble as there are approximately 200 quintillion cells in our bodies, each oscillating on its own natural wavelength. Theoretically, therefore, we would have to have a different wave length for each cell, so that every cell in the organism would oscillate in resonance on its own wavelength.

After much research I was able to construct an apparatus creating an electrostatic field covering all frequencies from 3 metres to the infra-red, so that every cell can find its natural frequency and vibrate in resonance.

We know that in physics, a circuit fed by damped or weakened high frequency currents creates many harmonics. Consequently, I conceived an oscillator of multiple wavelengths with a broad scale in which every organ, every gland, every tissue, every nerve, could find its natural frequency.

To obtain this result I set up a transmitter composed of a series of circular concentric oscillating circuits linked by a silk cord but not contiguous. These circuits are stimulated by damped high frequency currents from a spark gap. Thus each circuit of the transmitter vibrates not only on its natural frequency, but also on numerous harmonics.

Thus, I built an oscillator with all the basic wavelengths from 10 centimetres to 400 metres, that is, all frequencies from 750,000 to 3,000,000,000 cycles per second. But each circuit also emits many harmonics, which, with their basic waves, their interferences and their effluvia can reach the scale of infra-red and even that of visible light (1 to 3000 trillion vibrations per second.)

Since all the cells as well as the chondromes oscillate precisely at frequencies in that range, they can therefore find, in the output of such an oscillator, the frequencies which cause them to vibrate in resonance.

You know the results I obtained with continuous very short waves using triode tubes at a distance, with no contact electrode....

As early as 1931, I began using this multiple wave oscillator in various Paris hospitals: the Saint Louis, Val-de-Grace, Calvary, Necker, etc... Among the many cures with this treatment, I will mention especially those of various cases of cancer which X-ray and radium treatments failed to improve. These patients, cured six years ago, have had no recurrence and are in perfect health at this date. In all pathogenic cases this treatment gives very good results. As it does not attack the microbes directly, it does not destroy live tissue, but reinforces the vitality of the organism by accelerating cellular oscillation. It is therefore the reinforced organism that successfully resists the microbes and all pathogenic causes.

So, while X-rays and radium destroy microbes, neoplasic cells and healthy tissue at the same time -- which accounts for the serious accidents which occur during and after such treatments -- high frequency radiations (short waves) applied at a distance and without thermal effect cure diseases of all kinds, even those of the prostate to a considerable degree.

Whatever the pathogenic cause, the multiple wave oscillator reproduced the frequencies necessary to re-establish the cellular oscillatory equilibrium.

In general, it is sufficient to seat the patient, or to have him stand in the radius of the apparatus, before the transmitter. The duration of the treatment is usually from five to ten minutes, every other day. These figures are purely arbitrary, since these radiations reinforcing cellular oscillation do not produce organic disturbances, whatever the duration of the treatment may be.

Despite the many cases successfully treated, almost without exception, it must be understood that my oscillator cannot cure all types of cancer in all its stages of development. In many cases, when the cancerous tumor has already destroyed important blood vessels, my apparatus is powerless to rebuild that tissue before the fatal haemorrhage.

INFLUENCE OF COSMIC WAVES ON THE OSCILLATION OF LIVING CELLS

Part 3, Chapter 1, From La Science et le Bonheur, by Georges Lakhovsky, Paris 1930

Translated by Brigitte Donvez, Edited by Tom Brown

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This part of my study is devoted to the trials, experimentation and applications of the theory of the oscillation of living beings.

I have assembled here short technical reports about the processes and methods employed, as well as a collection of all the papers read at the French Sciences Academy and at various French and foreign Scientific Societies about oscillatory therapeutics and all its domains of application.

We intend first to examine successively the influence of cosmic waves on the oscillation of living cells, taking as a concrete example the influence of solar activity upon the quality of wine and vintage. Then we will examine the construction of an electromagnetic short-wave generator, such as the radio-cellular-oscillator for the treatment of animal and plant organisms.

We will later consider the applications of the radio-cellular-oscillator, particularly in the experimental treatment of plant cancer, diathermy and the artificial production of fever.

Concurrently, we will introduce the application of open oscillating circuits to the treatment of diseases in various living beings, in the absence of any other oscillations but those produced by the natural cosmic and atmospheric waves. We will also review in this chapter the observations of scientists and practitioners who clinically applied my oscillating circuits.

Finally we will take up the very latest applications of oscillating circuits to water and liquid sterilization, and to the activation of the germinative power of plants.

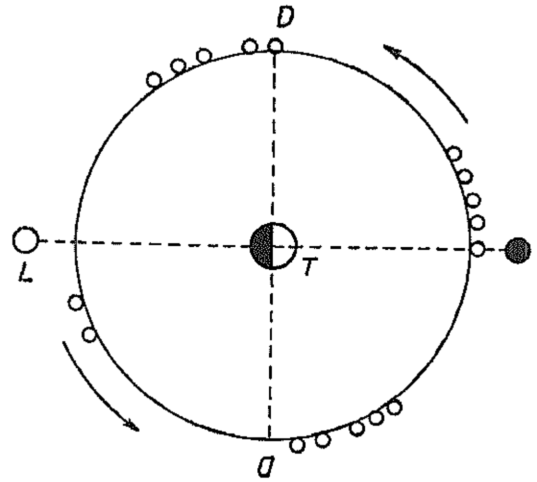

Fig. I -- Distribution of the highest intensity of electromagnetic waves observed by Mr. Vincent, as a function of the moon phases.

Obviously, the number of these applications, presently limited to certain domains, tends to rapidly expand and touch upon the various problems presented by therapeutics, biology, agriculture and zoology.

I have discussed elsewhere the role played by cosmic radiations in the development of living beings, due to the very oscillatory nature of the cell. Now, as a consequence of the earth's rotation and the stars' reciprocal motion, the cosmic and atmospheric radiation field is not constant, but rather variable. Living beings are subsequently under the influence of these variable cosmic radiations, whose nature either weakens or strengthens the cell's oscillatory balance.

I have mentioned elsewhere[1] that the lunar radiation interferes with the waves of radioelectric stations. Every week, the recurrence of moon phases enables us to obtain highest and lowest intensities in the reception of electromagnetic waves (see Fig. 1).

On the other hand, the sun does not only send light, heat and actinic (ultra-violet) radiations, but also electromagnetic waves, especially during the eruptive periods of its prominences (sunspots). The influence of the sun's electromagnetic radiation becomes obvious if we consider the variations in the earth's magnetic field and the spinning of a compass' magnetic needle during magnetic storms, under the influence of the telluric currents induced in the ground. The ionization produced by the sun's radiation also generates atmospherics and statics which disturb radioelectric receptions.

Astrophysicists, notably those of the Meudon Observatoire under the direction of Mr. Deslandres, have been able to establish a correlation between the periodicity of cataclysms on earth (tidal waves, tides, earthquakes) and that of the recurrence of sun-spots in the earth plane (about 27 days).

We can observe that the graphs which render geophysical, electric (ionization, gas conductivity, aurora borealis -- northern lights), magnetic (variations of the earth field, compass spinning) and electromagnetic (disturbance in wave propagation, atmospherics and telluric parasites) phenomena, as a function of time, are very appreciably parallel to each other and to the curve of solar activity. An 11½ year periodicity appears on these graphs, confirmed by numerous, previous observations in the domain of meteorology. In particular certain tropical rainfall patterns show a 33 to 35 year periodicity, three times longer than the previous one.

I researched the extent to which cosmic radiations which condition physical and meteorological phenomena, also influence biological phenomena and the development of living beings.

As early as 1801, while cosmic radiations were not even suspected, Hershel pointed out: "the scarcity of vegetation when the sun has no spots". Starvations recur every eleven years in India with alternances of heat and rain. From 1901 to 1909, the canon Th. Moreux noticed that the wheat crop in France and in the world more or less followed the solar activity, so did arthritic conditions, and the nervousness of students and teachers.

I compared the graphs of the solar activity, as recorded at the Meudon Observatory, with the statistics of wine production in the Bourgogne and Beaujolais regions, and I noticed that the outstanding vintages coincided precisely with the year of recrudescent solar activity.

On this topic, Professor d'Arsonval agreed to present in my name at the Academie des Sciences (Academy of Sciences) on March 28, 1927, an original report entitled Influence of Cosmic Waves On The Oscillations Of Living Cells which is entirely reproduced here.

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[1] L'universion, p.127, Gauthiers Villars publishers

INFLUENCE OF COSMIC WAVES ON THE OSCILLATION OF LIVING CELLS

(Paper by Mr. Georges Lakhovsky, presented on March 28, 1927 to the Academie des Sciences (Academy of Science) by Professor d'Arsonval.)

In my book The Origin of Life, Radiation and Living Beings, that Professor D'Arsonval did me the honor to present to the Academie des Sciences (Academy of Science), at the sitting of the 15th of February 1926, I exposed my theory about the influence of (cosmic) penetrating radiations on living beings. As a matter of fact, I demonstrated that the nucleus of each living cell, having the form of a tubular filament made of a dielectric matter filled with a conductive substance, could be compared to an oscillating circuit, equipped with self-inductances, electric resistance and capacity. The living cells can thus oscillate at very high frequencies under the influence of cosmic radiation emitted by stars.

I made certain to verify the exactness of this theory by studying the influence of cosmic radiations (sun-spots, comets, interferences of stars' radiations, etc...) on biological matter.

My observations were based on the curves recorded by the astrophysicists of the Meudon Observatoire, curves which revealed since 1845 the activities of the sun-spots, the frequency of magnetic disturbances, and the frequency of aurora borealis -- northern lights.

These three curves are appreciably parallel. I endeavored to study the existing correlation between these cosmic radiations, on the one hand, and the development of vital activity in the plant and animal domains, on the other. As for any given individual, periods of fatigue and illness alternate with periods of health, in the same way there is, for fruit and crops in general, for each species, years of good quality and years of rather mediocre quality.

As to what concerns wine, according to the documentation established by the Chambers of Commerce of the Bordeaux and Bourgogne regions, I observed that, from 1845 until 1915, the outstanding vintages corresponded exactly to the highest activity of the sun-spots, as shown by the curves on Figure 2.

The results for red Bordeaux wines are:

Maximum of 1848: outstanding vintages of 1847 and 1848;

Maximum of 1858: outstanding vintages of 1857 and 1858;

Maximum of 1869: outstanding vintages of 1869 and 1870;

From 1880 to 1889: period of phylloxera.

Maximum of 1893: rather good vintages of 1890 and 1893;

Maximum of 1906: good vintages of 1906 and 1907.

In addition, let's point out that the wine of 1811 was called the wine of the comet, and we could ascribe its excellent quality to this comet's radiation. It is the same with white Bordeaux and Bourgogne wines.

I am sure that there are many other biological phenomena which recur periodically after a few years or a few centuries as a function of the relative revolution of the earth around the stars. I am convinced that all the scourges which ravaged humanity during the Middle-Ages: plague, leprosy, cholera, etc... and disappeared thereafter without traces in other regions will reappear some day, when the earth shall once more occupy the same position as then in relation to the stars, producing thus by interference with the cosmic waves the same oscillatory imbalances of the cells, which at that time, had produced these same diseases.

Fortunately till then, thanks to the oscillating circuits and the new methods that scientific discoveries will put to our disposal without delay, we'll be in a position to fight victoriously against these illnesses provoked by the interference of the stars' radiations.

Figure 2
RED BORDEAUX WINES

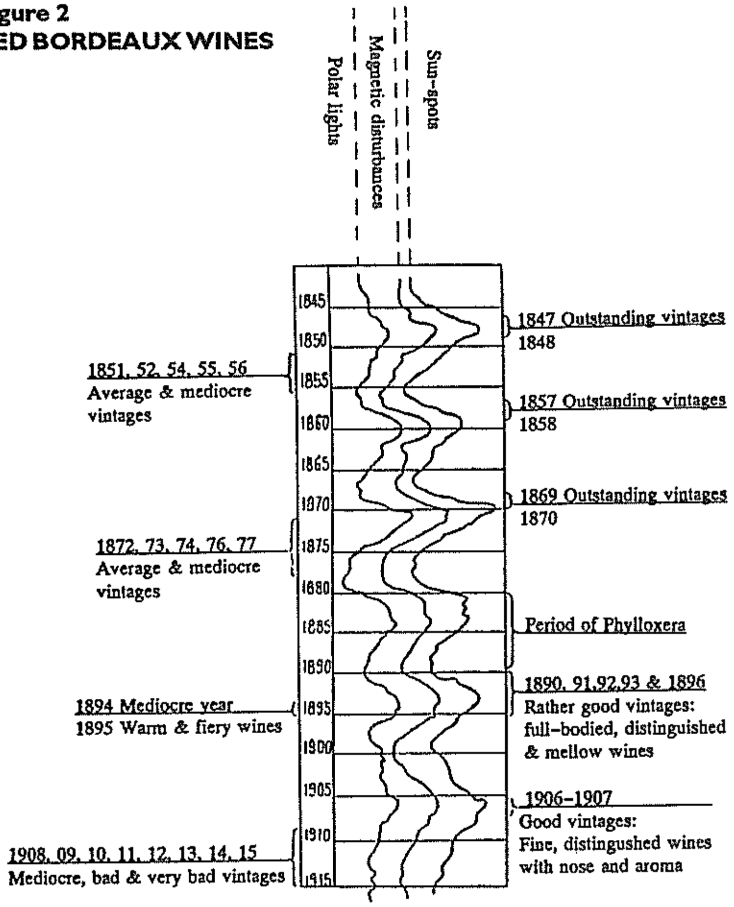

Figure 2 -- Graph showing the coincidence of outstanding vintages with the intensity of the waves emitted by the sun and corresponding to the variation in intensity: 1) of sun-spots, 2) of earth magnetic disturbances, 3) of polar lights. The graph has been established for red Bordeaux wines; the greatest intensities correspond to the outstanding vintages, the lesser intensities correspond to the years of mediocre wines. We can establish a similar graph for the other vintages, notably Bourgogne and Beaujolais wines.

THE RADIO-CELLULAR-OSCILLATOR AND ITS APPLICATIONS

by Georges Lakhovsky

Part 3, Chapter 2, from La Science et le Bonheur, Paris 1930

I demonstrated in the last chapter, how, according to my cellular oscillation theory, alteration in organic tissues came from a variation in the intensity of the cosmic waves' radiations and from these waves' frequency, thus causing the oscillation of the cells.

To reestablish the balance of these natural astral fields, the radiation of which we can no more directly influence, than a meteorologist can influence the weather, I thought of using a local oscillator, generating waves and creating an artificial and auxiliary magnetic field.

Incidentally, I should add that this method is analogous to the methods used in radiotelegraphy, known as heterodyne and super-heterodyne methods. These methods use the interferences produced between the waves received and the waves generated by the local generator at the required frequency and intensity.

About 40 years ago (1890) Professor D'Arsonval advocated the treatment of certain illnesses by high frequency electrical currents, that were at the time produced in waves strongly damped by means of a Ruhmkorff coil and a spark gap (arrester).

My radio-cellular-oscillator is a generator of continuous waves of very high frequencies, the first application of triode lamps to biological research and pathological treatments.

We know the difficulty of obtaining very short waves, because of the parasitic capacitance present in electronic lamps due to the electrodes themselves and, within the bulbs, to tube sockets and connective wires.

In 1924, when I studied the possible construction of a triode lamp oscillator for very short waves, shorter than 2 meters, the radioelectrical technique, in France and abroad, was still at the stage of long-waves and the length of the so-called short-waves was in fact from 200 to 500 meters.

Therefore, I had to do my own research in view of studying a type of lamp appropriate to the generation of very short waves. Thus, I have been led to design lamps with multiple electrodes enclosed in the same bulb. These multiple lamps have been patented in France[1] and in Germany[2].

Later, I intentionally abandoned the idea of working this patent and preferred to give it up to the public domain, in a scientific aim, so that no patent claim could oppose disinterested researches undertaken for the radioelectric prophylaxis of diseases, especially cancer.

However, if the French industry did not engage in the construction of these multiple lamps, the problem was reconsidered in Germany three years later and partly resolved as the double or triple "multi-valve" by Dr. Siegmund Loewe[3].

To reduce connections to a minimum, as well as the parasitic capacity between electrodes, to achieve the generation of waves of less than 1.5 meters while avoiding low efficiency, deformation, or distortion of the wave which would jeopardize the purity of the transmission and particularly alter the modulation, I proposed in my patent to enclose the oscillating circuit and its connections within the bulb. This invention, which cannot conveniently be applied to long waves is, on the contrary, easy to carry out for very short wave circuits, of which the bobbins are reduced to several turns of coil, even to a fraction of a turn, and of which the condensers have a very small capacity (Fig. 3).

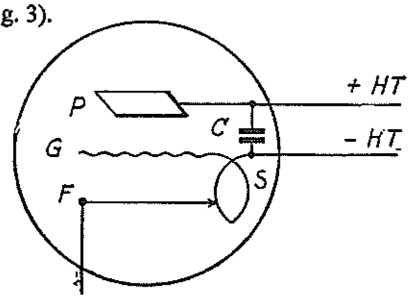

Fig. 3 -- Triode generator of very short waves, after the original drawing of Lakhovsky's patent.

Practically, the oscillating circuit only includes a turn of several centimeters in diameter. The only connections getting out of the tube are the feeders, bringing in the plate voltage (anode voltage) and the heating current (thermo-current).

These tubes can generate oscillations and transmit them by induction to outer circuits (aerials, loops, antennas).

Beside the practical simplification, the improvement of the efficiency comes from the fact that all electronic elements work with the same degree of vacuum. This is what I observed when I grouped within one same glass tubing the bulbs of a 4 triode lamp device (Fig. 4). The equal distribution of the vacuum among the various electrodes increases the purity and stabilizes the functioning.

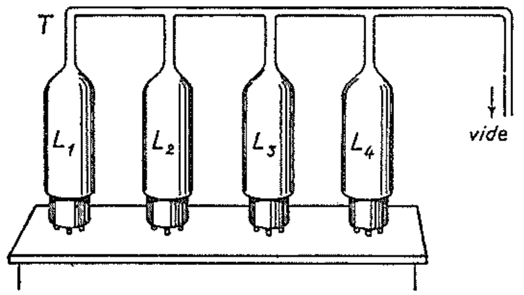

Fig. 4-- Glass tube T helps maintain the same vacuum pressure inside the four triodes of a classic resonance receiver. Author's realization.

According to this principle, I indicated the possibility of constructing not only a certain number of simple or multiple electrical cell oscillators but also all kinds of triodes or electronic lamps contained in a same bulb. Figure 5, quoted from my patent, shows the diagram of a symmetrical oscillator, with double electrodes and filaments connected in parallel. This oscillator is completely enclosed in a same casing.

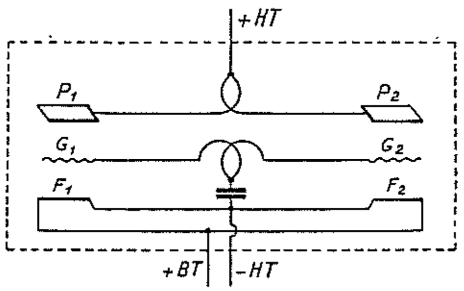

Fig. 5 -- According to the original drawing of the author's patent. Multiple triode including inside the bulb the connections of a symmetrical short-wave transmitter, with filaments set up in parallel.

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1. G. Lakhvosky. French patent #601,155 of October 18, 1924
2. G. Lakvhosky. German patent #427,596 of May 26, 1925
3. Patent application in France on May 7, 1927

Figure 6, also taken from my patent, presents a double, symmetrical oscillator of which the filaments are connected in series. A possible tuning condenser is anticipated, which would be placed in the same vacuumed bulb as the electrodes and turns of the circuit.

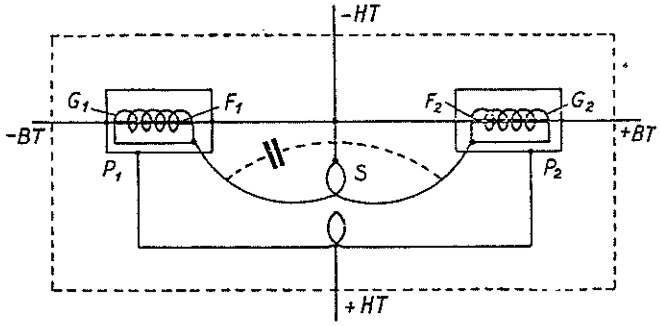

Fig. 6 – Multiple triode symmetrically connected with filaments in series, according to the original drawing of the author's patent.

Figure 7 shows the case of a double oscillator with a unique filament.

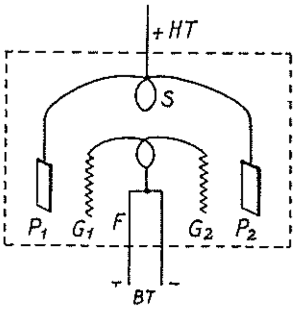

Fig. 7 – Double triode multiple lamp with symmetrical connections and a single filament, according to the original drawing of the author's patent.

For long-waves, moreover, I indicated the possibility of putting together the circuits outside the bulb.

These various constructions are extremely general. We know that for all practical purposes Dr. Loewe has only introduced resistances and capacitances inside his multiple lamps, reducing therefore its use to low and high frequencies amplifications of long waves. These lamps' efficiency is bound to be rather mediocre for the following reasons: great connection resistances, strong plate voltage (about 160 to 200 volts), and impossibility to stabilize the circuits and cause a resonance.

On the contrary, I always anticipated inner couplings through bobbins and capacitances ensuring the greatest efficiency. The resonance is obtained through a variable condenser inside the lamp and commanded from outside without any mechanical element. For example, if you use the gravity field, it suffices to place a counterweight on the sliding condenser and to direct the lamp in space. Or you can use a magnetic field produced by a magnet or an electromagnet. (Fig. 8).

I indicated the means of building an oscillator of good efficiency for ultra-short waves, with the possibility to tune it into a whole range of frequencies.

To resolve this problem on a practical level, before people started to produce multiple lamps, I used a symmetrical oscillator including two triode lamps. It is the radio-cellular-oscillator which I used in 1924, at the wards of the Saltpetriere Hospital in Paris, to treat and heal geraniums inoculated with experimental plant cancer.

Fig. 8 – Variable sliding condenser M, balanced with a counterweight W within a triode lamp, according to the original drawing in author's patent.

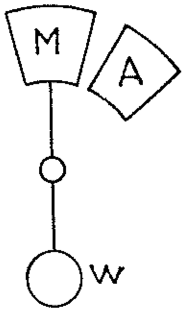

The simplified diagram of the radio-cellular-oscillator is indicated in Figure 9 (Mesny set-up).

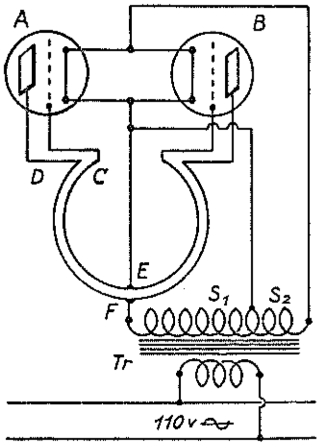

Fig. 9 – Simplified diagram of the Lakhovsky radio-cellular-oscillator.

Plates, grids and filaments parallel connected. The grids and plates circuits all comprise one turn. These two turns are variably coupled between them. Plates and filaments are directly supplied with alternating current of the mains by means of the appropriate transformer. In these conditions, the transmission of waves starts as soon as the plug is connected onto the mains. By using a tuning condenser, one can produce the entire range of waves of a length comprised between 2 and 10 meters. The supply of alternating current creates a great number of harmonics with which the oscillations of the various cells can enter into resonance. The fundamental wave length can moreover be regulated according to the nature of the cells to be treated.

The biological role of the radio-cellular-oscillator is to reestablish the oscillatory equilibrium of the living cell, threatened by any alteration, and in particular by neighboring microbes. When it resumes its normal vigor, thanks to the auxiliary radiation of the radio-cellular-oscillator, the cell can destroy the microbe itself by damping down its pernicious radiations.

The fundamental experiment I presented at the Saltpetriere Hospital demonstrates the functioning of the radio-cellular-oscillator. It dealt with cancerous plants inoculated according to Erwin Smith's method.

This fundamental experiment was the subject, on the 26th of July 1924, of a report to the Societe de Biologie (Society of Biology) and it is reproduced here in extenso, from the society's newsletter.

ATTEMPT AT TREATMENT OF EXPERIMENTAL PLANT CANCER

Report to the Society of Biology

by A. Gosset, A. Gutmann, G. Lakhovsky, J. Magrou

We know that we can produce tumors comparable to animal cancer (Erwin F. Smith)[1] on various plants, by inoculating them with the Bacterium tumefaciens. Using this method[2], one of us obtained experimentally a great number of tumors. These tumors have an indefinite growth; they might partially necrotize but they only die completely when the entire plant or at least the branch infected by the tumor has succumbed to the cachexia. Even when surgically removed, these tumors continued to proliferate.

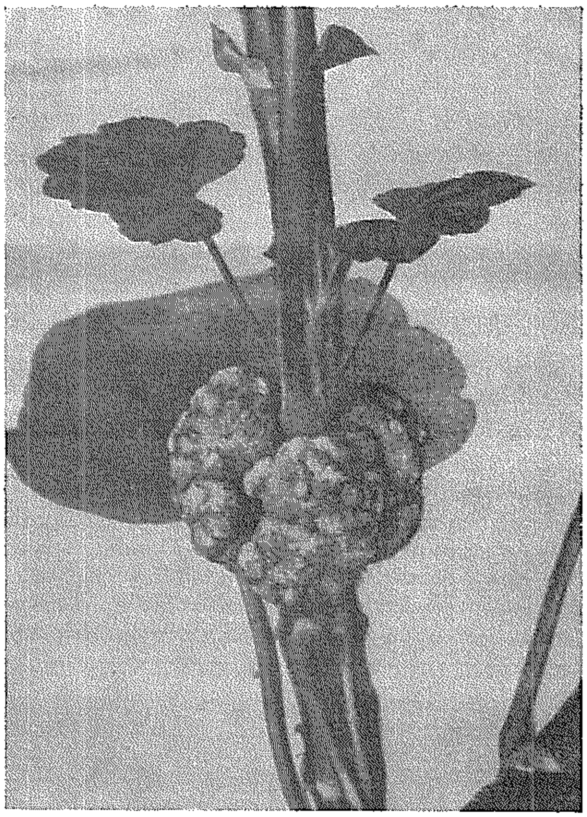

Fig. 10 -- Sight of the tumor of an untreated witness check sample. -- Subject: Pelargonium zonatum inoculated April 10, 1924. We see the growth of the cancerous tumor on the stalk. (*Clinique Chirurgicale de la Saltpetriere*).

We intend to study, in this present report, the influence of magnetic waves of great frequencies, obtained by means of a device built by one of us, for therapeutic applications and following his theoretical views[3]: the Georges Lakhovsky Radio-Cellular-Oscillator. This device generates oscillations of a λ wave length = about 2 meters, and corresponds to 150 millions (150,000,000) vibrations per second.

A first plant (Pelargonium zonatum) has been experimented with a month after its inoculation with Bacterium tumefaciens; it showed at that point several, small, white tumors, of the approximate volume of a cherry kernel. The plant has been exposed twice to the radiation, with a 24-hour break and during three hours each time.

In the days following the treatment, the tumor continued to grow rapidly, like the check sample tumors, forming a great plurilobate mass. About sixteen days later, after the first treatment day, the tumor suddenly started to necrotize. A few days later (about 15 days) the necrosis was complete; the lobes of the tumor, retracted and completely dried out, separated from the stalk bearing them, through furrows of elmination, and the tumor could be taken off by the slightest traction. The necrosis effect of the radiation was extremely elective, limited only to the cancerous tissues which it followed into the very depth and root of the tumor; the healthy parts, stalk and leaves remained unhurt and retained all their vigor.

A second Pelargonium was treated in the like manner, but the time of exposure to the radiations was lengthened (eleven 3-hour sessions); 16 days after the first session, the tumor it carried started to necrotize and several days later it dried out completely. As in the first case, the healthy part remained unhurt.

With a third Pelargonium which underwent nine hours of radiation (three 3-hour sessions) the necrosis of the tumor's lobes followed the same path.

Sixteen control Pelargoniums remained untreated. All bore tumors in full activity which often became enormous.

As a summary, we may say that the Pelargonium which became cancerous after inoculation of the bacterium tumefaciens and for which a surgical intervention could not prevent recurrence seemed to heal under the influence of the magnetic waves indicated above. *(Clinique Chirurgicale de la Saltpetriere.)*

A very clear conclusion can be drawn from this experiment and its counterpart.

On the one side, we observe that, on the control subjects, inoculated with the *Bacterium tumefaciens* and left untreated, enormous tumors grew which by absorbing the plants' vital energy lead them to a quick and certain death.

On the other hand, the plants treated by the radio-cellular-oscillator, and moreover taken at random from among the inoculated subjects, have been healed quickly and acquired a considerable vitality, as is proven by their growth, their continual development and abundant flowering.

We can see it in the photograph (Figure 12), taken one year after the healing of the geranium.

My theory of cellular oscillation, that I had moreover proposed before I realized this experiment, enables us to understand cancer pathology and to direct its therapy onto a new path.

Cancer, mostly reaching older people, comes from the ageing of tissues as a result of the cells and blood decay. This impairing of the cells results from a modification of the

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[1] Erwin F. Smith, *An Introduction to Bacterial Diseases of Plants*, 1st vol., Philadelphia and London 1920.

[2] J. Magrou, *Revue de pathologie comparee*, March 1924. Two other reports will be soon published in the *Revue de pathologie vegetale et d'entolmologie agricole* and in the *Annales de l'Institut Pasteur*.

[3] Georges Lakhovsky, *Radio-revue*, November 1923 and Conference to *L'Ecole Superieure des P.T.T.*, June 2nd, 1924.

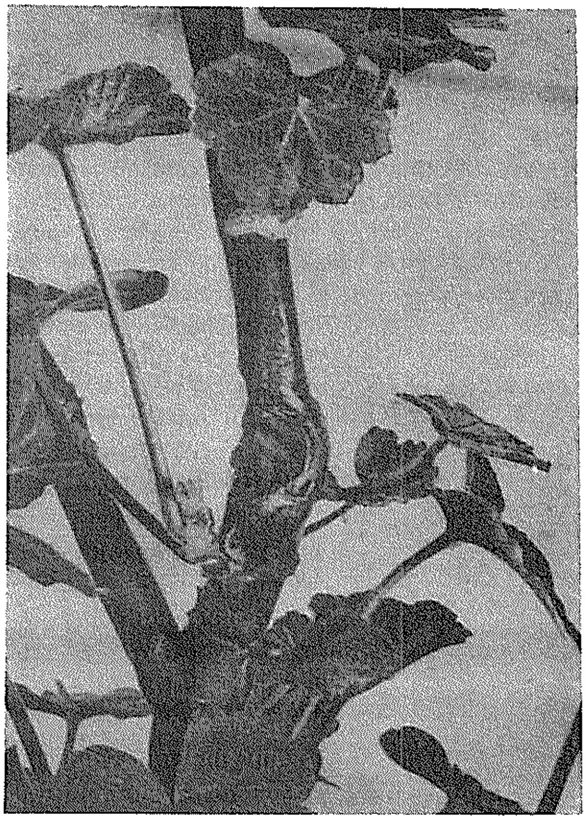

Fig. 11 Sight of the scar of the treated subject. Subject: Pelargonium zonatum, inoculated April 10, 1924 with the Bacterium tumefaciens, treated from May 24, to June 14, 1924, during eleven three-hour sessions with the Lakhovsky oscillator with antennas, photographed after it healed on July 24, 1924. *(Clinique Chirurgicale de la Saltpetriere).*

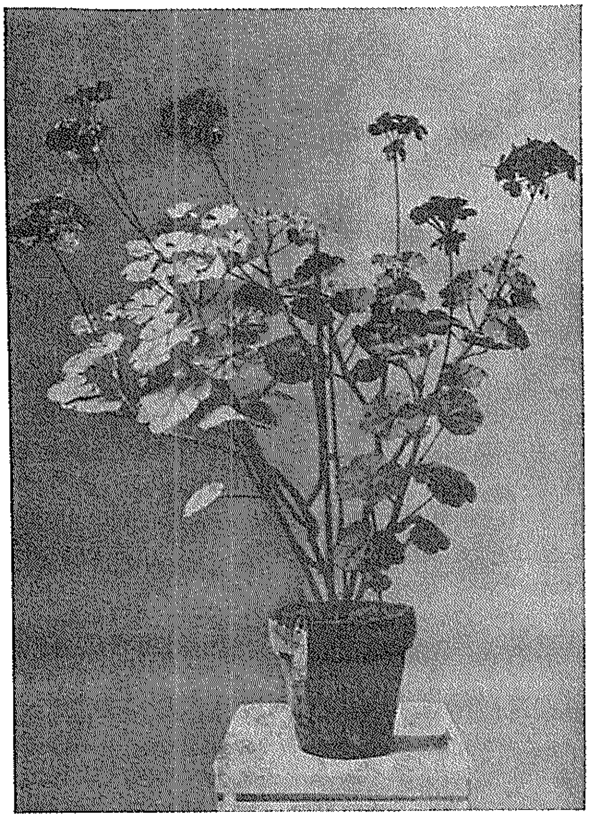

Figure 12 Sight of the treated subject after healing. -- This pelargonium is no other than the one of Figure 10, treated by the Lakhovsky oscillator, on May 24, 1924, healed on the 4th of June, 1924, and photographed in July 1925. As you can see, this plant is in perfect health and abundantly flowered. On the other hand, the sixteen inoculated but untreated check samples died long ago.

chemical composition due to the contribution of foreign bodies which appear as residues of the organism. Such are, for instance, blood haematoblasts, rich in iron and phosphorus, produced by residues of fibrin, leucocytes, and hematites. Each cell destruction brings with it a small mass of cholesterol, an insulating substance forming the armature of the nuclear filament, which later clogs the nucleus. Therefore older people first experience a decrease in the number of active cells and of the white and red corpuscles, which is reflected in the regression of the blood count, and on the other hand, an increase of the quantity of mineral (iron, phosphorus, haematoblasts) and organic (cholesterol) residues. These chemical modifications of the cell result in the variation of the cellular oscillation both in intensity, as a consequence of the changes of electric conductivity and resistance, and in the radiation frequency, because of the changes of capacitance and inductance.

The decayed cell appears like a pendulum with a pendulum-bob one could have lengthened, shortened or damaged. This oscillatory disorder provokes, because of the excess of cosmic waves, a too rapid cellular division, which results in the formation of neoplasms, or cells vibrating at a different frequency from the regular frequency of the tissue.

For long years, it has been wondered whether cancer is contagious and hereditary, or whether it is caused by a microbe. Histological analyses seem to invalidate the existence of a microbe. On the other hand, inoculations of cancer only succeed, and moreover very rarely, with impaired tissues composed of abnormal cells, such as certain moles and this would seen to ruin the hypothesis of contagion and heredity.

In fact, I believe that the true cancer microbe is the neoplastic cell which forces the neighboring cells into oscillating at its own frequency, thus transforming by electromagnetic induction, the healthy cells into neoplasms. To prevent cancer, is to prevent this neoplastic induction and to give back the healthy cell enough vigor to reestablish its oscillatory equilibrium.

I was pleased to observe that, apart from the skepticism of a few, my experiments have been taken up again with great success in France and abroad by various scientists and practitioners who understood the future of oscillation therapeutics.

It seems appropriate to quote the works pursued in Germany by Professor Esau at the Technisch-Psychaliches Institut of Iena.

Although directed toward paths sometimes very different from mine, these works present a very clear analogy with those I have conducted from the use of a very short wave oscillator similar to my radio-cellular-oscillator.

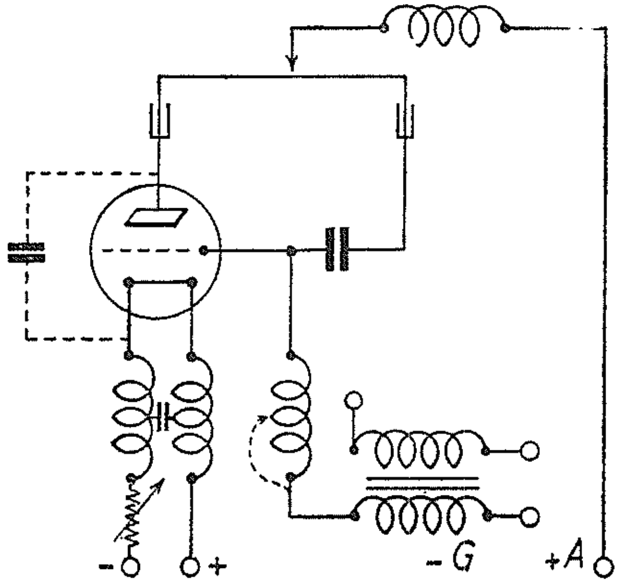

Fig. 13 -- Simplified diagram of Dr. Esau's very short wave oscillator.

The transmitter-receivers used by Professor Esau do not essentially differ from the devices I advocated. I indicated moreover that connections were irrelevant as long as they produced the desired very short waves. Professor Esau's connections, which were described in the technical magazines of Dr. Ernest Busse, assistant at the Ieana Institute[4], are characterized by the use of a single triode lamp, functioning in direct current. The transmitter's filament (Fig. 13) is supplied through a filter preventing high frequency back currents. The coilings are simple fractions of turns, as in the radio-cellular-oscillator, which only includes about half a turn for each oscillating circuit.

A test receiver (Fig. 14) is provided with square loop circuits on which variable plugs can be installed. Another device is provided with a circular turn, of which a radial cursor allows connection to the necessary position.

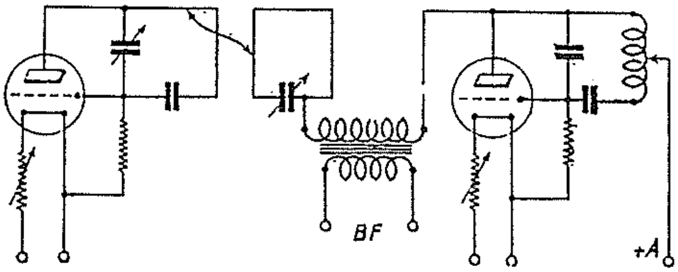

Fig. 14 -- Simplified diagram of Dr. Esau's very short wave receiver.

The works of Professor Esau in the biological domain are rather recent, for during the Radio-electric Symposium in Bremen (August 1928)[5], he stated that he had been doing research, for only a year, on the physiological effects of *ultra-short* waves, or, according to his definition, very high frequency waves comprised between a length of 1.50 and 3 meters, of which I indicated the use in 1924 in my report addressed to the Societe de Biologie, reproduced here. He indicated then that since July 1928, he successfully constructed a very short wave receiver.

About this subject Professor Esau pointed to the fact that the main difficulties came from the electronic lamps, and that he had to use foreign lamps, particularly French lamps, which are more appropriate for very short waves techniques. I indicated earlier that, 4 years before, I had studied and had these special short-wave lamps built, which were designed for my radio-cellular-oscillator.

I shall also point out that a very short transmitter has recently been used by Dr. Frantz Seidel from Vienna, for the destruction of bacteria, particularly in the sterilization of milk.[6] This subject will be investigated at a later time.

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[4] Dr. Ernest Busse, *Die Erzeugung ultrakurzer Wellen.* (*Radio-Welt,* No. 49, 1928, p. 77. Vienna.)

[5] Oscar Gadamer. *The ultra-short waves and their field of application.* (*Der Deutsche Rundfunk,* August 31, 1928, t. VI, p. 240, Berlin.)

[6] *Les ondes ultra-courte contre les bacteries.* (*Radio-Welt,* January 27, 1929, No. 4, p. 108, Vienna.)

THE LAKHOVSKY RADIO-CELLULAR OSCILLATOR

a synopsis by Jorge Resines

What you are about to read is my resume of the book La Science et le Bonheur, Longevite et Immortalite par les vibrations -- *Science and Good Health, Longevity and Immortality Through Vibrations* -- by Georges Lakhovsky. More specifically, this synopsis encompasses Part III, chapters 1 and 2, being pages from 137-171 of said work, and whatever I translate from it will be forwarded by the words "Lakhovsky said:".

Mr. Lakhovsky begins by indicating the influence of heavenly bodies upon all facets of everyday life, from their influence upon the cells up to how magnetic compasses are affected by magnetic storms originating in the Sun (he refers the readership to his book L'Universion, published by Gauthier-Villars of Paris, France). He says that the French Astronomer Mr. Deslandres with his collaborators at the Observatory of Meudon have established a cycle of about 27 days for sunspots affecting both tides and earthquakes. This lapse is part of another larger cycle of 11½ years (or about) that most usually forms in turn part of another, larger, cycle of 33 to 35 years.

Mr. Lakhovsky also discovered, as indicated by the small circles at the lunar orbit of Figure 1, that lunar radiations provoke interferences with the waves broadcasted from radioelectric stations at said marked positions.

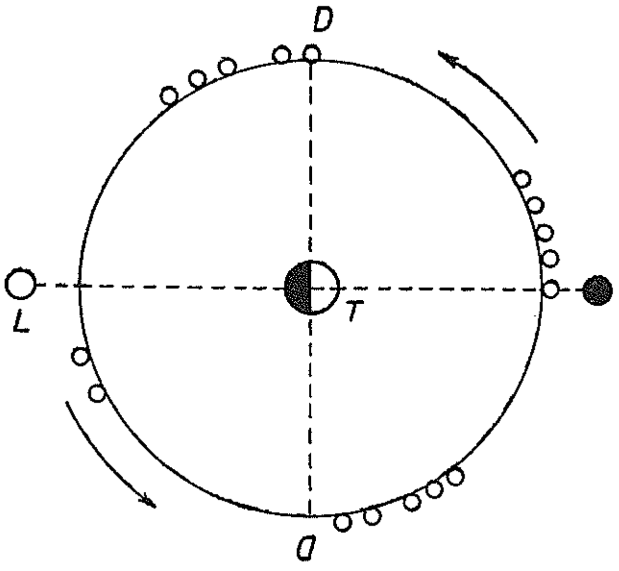

Figure 1

T = Earth
L1 = Full Moon
L2 = Waning Moon
L3 = New (Dark) Moon
L4 = Waxing Moon

Carrying his researches a step further, helped also by the people at the Observatory of Meudon, he correlated the highs-and-lows of three different factors (to wit: a. Sunspot activity, b. Perturbations of Terrestrial Magnetism, and c. Polar Aurora) with the type of wines collected at different French regions. For a single zone and type of wine, his findings are shown in Figure 2 (next page). You will easily notice how the highs of the three factors are in coincidence with the best collections of wines, with a single exception: the 1880-1889 period when the grape-wines were massively attacked at France by the "Phylloxera" plague. Though Mr. Lakhovsky does not explain the reason for this adverse period (when the opposite was expected), he does voice his opinion that cellular and biological phenomena is periodically affected by the same type of radiations (and the generated-sicknesses they produce), proposing at the same time to destroy the scourges by overriding the "astrally-produced radiations" (his words) with this "Radio-Cellular Oscillator."

About the basic concept behind his devices, Lakhovsky said: "To re-establish the balance of these heavenly fields from nature, upon which variations we are able to act directly, unlike Meteorology which cannot make weather change, I will resort to a local oscillating-generator of waves creating an auxiliary artificial electromagnetic field.

"By the way, I must add this method is analogous to that employed in radiotelegraphy and known under the names of heterodyning and superheterodyning. These procedures employ the interferences generated between the received and generated waves by a local generator, at the necessary frequency and intensity."

Mr. Lakhovsky states that his inspiration came from Professor Arsene D'Arsonval, who in 1890 had put forth the opinion that different sicknesses could be eliminated by means of high-frequency currents. He continues on, explaining that by about 1924 he studied the possibility of generating waves under 2 meters in length, but that the electronics of said period considered "short" only those waves from 200 to 500 meters.

To overcome such a hindrance, Lakhovsky developed a vacuum tube with multiple-electrodes and received two patents for it -- French Patent No. 601,155 granted in October 18, 1924 and German Patent No. 427,596 granted in May 26th, 1925 -- afterwards another scientist of that time, Dr. Siegmund Loewe, improved on his ideas and demanded a French Patent on May 07, 1927 (this Patent is not indicated as either granted or not; further investigation is needed here).

Figure 3

+HT = Positive High Voltage
-HT = Negative High Voltage
G = Grid
P = Plate
C = Condenser
S = Loop of Coil
F = Filament

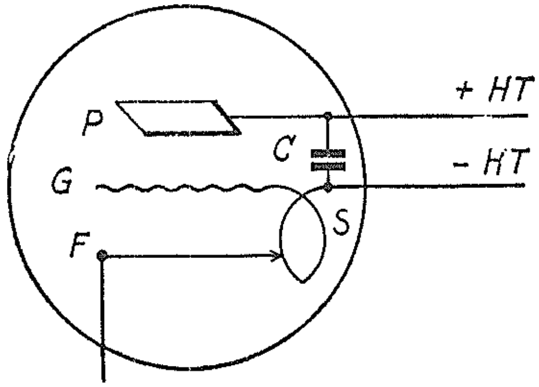

Figure 2 -- RED BORDEAUX WINES

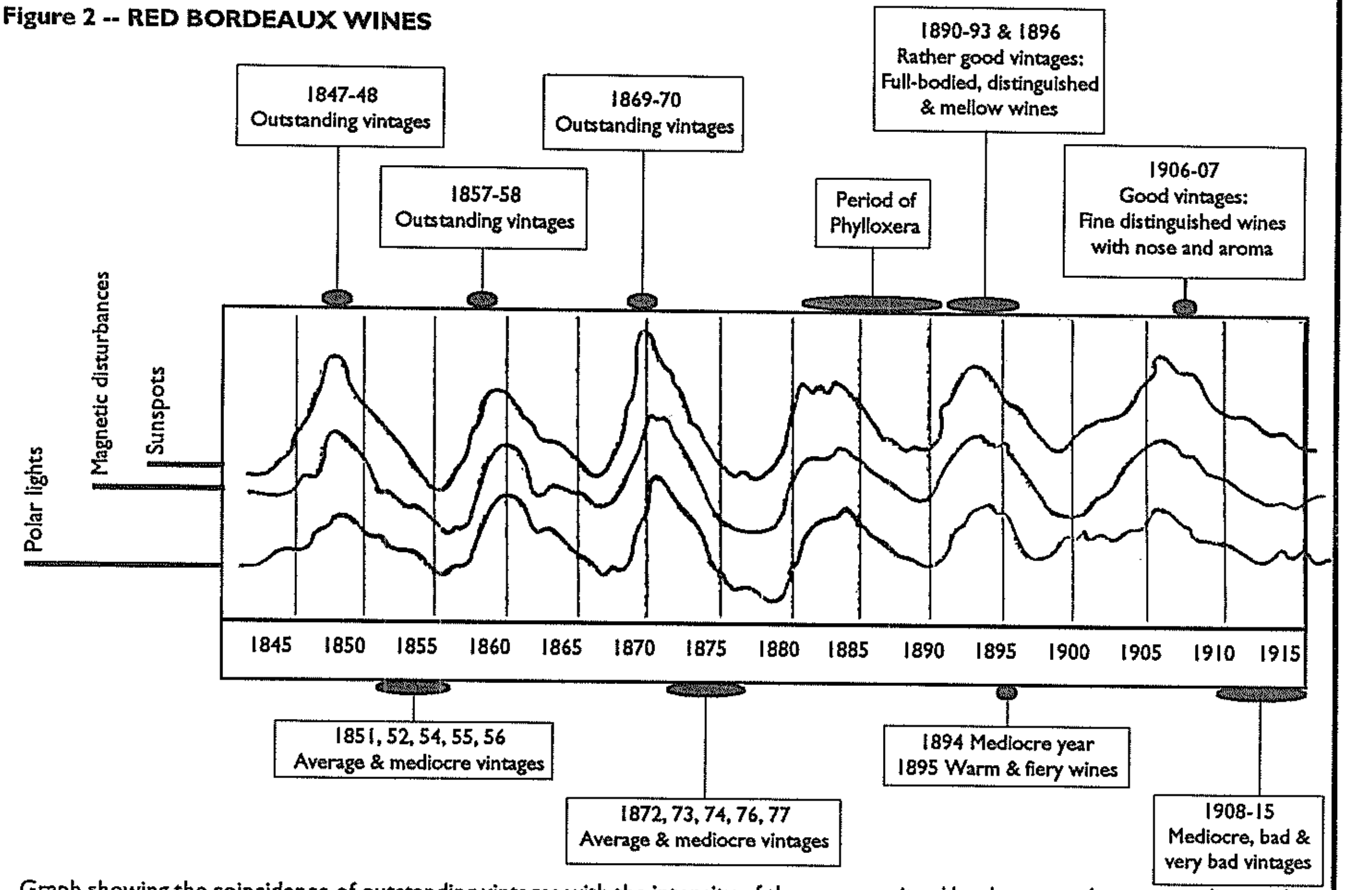

Graph showing the coincidence of outstanding vintages with the intensity of the waves emitted by the sun and corresponding to the variation in the intensity: 1) of sun-spots, 2) of earth magnetic disturbances, 3) of polar lights. The graph has been established for red Bordeaux wines; the greatest intensities correspond to the outstanding vintages, the lesser intensities correspond to the years of mediocre wines. We can establish a similar graph for the other vintages, notably Bourgogne and Beaujolais wines.

To produce waves "under 1½ meters" (his words), Mr. Lakhovsky enclosed within a vacuum tube's glass vessel different elements, as is seen in Figure 3. About this new type of tube, Lakhovsky said: "The oscillating circuit does not involve but a loop with a diameter of several centimeters. The only connections going out of the tube are the supply-wires, leading the plate-voltage and the heating current. These tubes can generate oscillations and transmit them to external circuits (square-loop antennas) by induction."

I will stop now the synopsis to introduce a personal comment: It is not clear on the illustration of Figure 3, WHY the filament is connected -- in a controllable fashion as the schematic indicates -- to the loop "S"; neither do I see clearly indicated whether the tube is one of direct or indirect heating and which type of vacuum tube -- existing at the time, with its specifications of that era -- served as the foundation to develop the tube of Figure 3, and how this was made in both constituents, procedure of manufacture, etc.

Neither is it indicated if there was a constitutional modification involving a change of material(s) for the new type of tube Mr. Lakhovsky first employed. I do not want to spoil anybody's fun in experimentation, I am just suggesting caution... Let's go on with Mr. Lakhovsky.

Another feature employed to ensure a high-quality when in use by Mr. Lakhovsky was to put a group of electronic tubes, as illustrated in Figure 4, directly over these lines, in the same vacuum pump. As all the tubes were connected in series, when the apparatus was made to work it produced the same degree of vacuum within them all.

Figure 4

L_1, L_2, L_3, L_4 = Identical Vacuum Tubes
T = joining tube

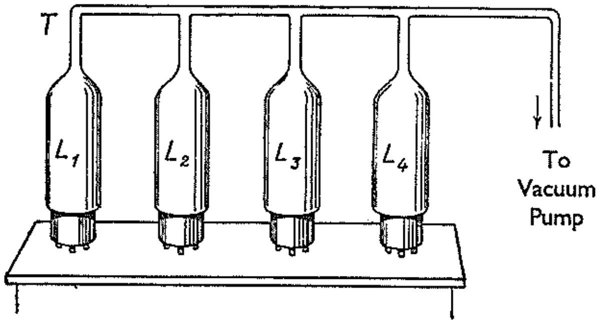

A further development of his idea, "extracted from his patent" he claims without indicating which one (French or German) this is, is the multiple triode illustrated in Figure 5. From its analysis we notice that Mr. Lakhovsky adhered to electronic theory, which says that electricity is a flow of electrons, and in a semiconducting device as the usual vacuum tube there is only a single direction of flow, from the "Cathode" (or negative pole) to the "Anode" (or positive pole). In the multiple triode of Figure 5, the filaments are connected in parallel.

Figure 5

+BT = Positive Filament Voltage
+HT = Positive High Voltage
-HT = Negative High Voltage
P_1 = Plate Tube No. 1
G_1 = Grid Tube No. 1
F_1 = Filament Tube No. 1
P_2, G_2, F_2 = Same for Tube #2
C = Condenser

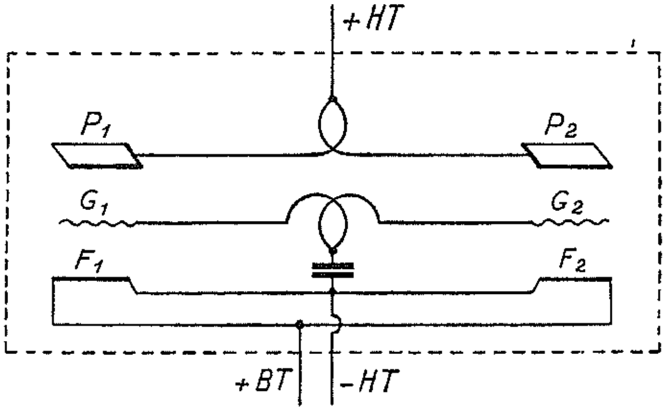

A further improvement of the device is seen in Figure 6, of which Lakhovsky says: "This illustration, also taken from my patent, shows a double and symmetrical oscillator where the filaments are mounted in series. It is also provided for, eventually, to place within a condenser so located as the electrodes and the loops of the oscillating circuit, within the same evacuated glass-vessel".

Figure 6

P_1 = Plate Tube No. 1
G_1 = Grid Tube No. 1
F_1 = Filament Tube No. 1
P_2, G_2, F_2, = Same for Tube #2
C = Condenser
-HT = Negative High Voltage
+HT = Positive High Voltage
-BT = Negative Filament Voltage
+BT = Positive Filament Voltage

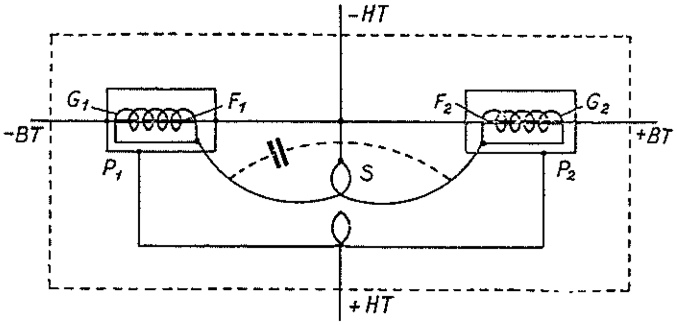

Figure 7 shows us a double-oscillator with a single filament, that is the two lamps of Figure 6 within a single vessel and with just one heat-source.

Figure 7

+HT = Positive High Voltage
+/- BT = Positive and Negative Filament Voltage
F = Filament
S = Loop of Coil
G_1 = Grid No. 1
P_1 = Plate No. 1
G_2 = Grid No. 2
P_2 = Plate No. 2

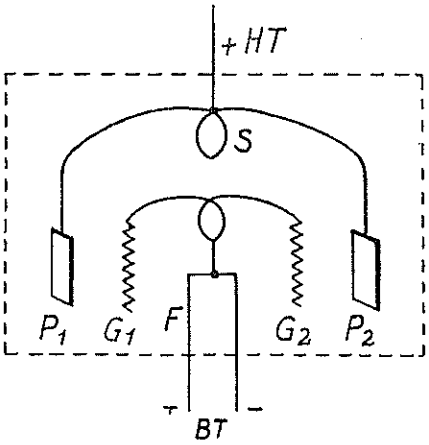

I remind the readership that all the models of vacuum tubes shown so far are for short waves under 2 meters. Lakhovsky indicated that to obtain long waves it sufficed to place the same elements outside a vacuum tube.

After saying that everything so far shown were just "extremely general things" Lakhovsky said: "One can, almost, say that Dr. Loewe just introduced resistances and capacities within his multiple-tubes, where performance is just reduced to amplifying low and high frequencies upon long waves. The performance of these tubes is very mediocre because of the following reasons: a) Heavy linking resistances, b) Strong plate-voltages (about 160 to 200 volts), c) impossibility of coupling circuits and thus producing a resonance."

Figure 8

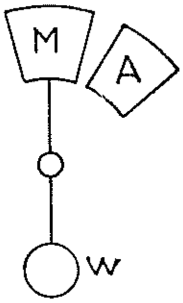

M = Mobile blade of condenser
A = Fixed blade of condenser
W = Weight to move blade "M"
H = Turning point for the combination of "M" with "W"

Here, in the former comment, is an apparent contradiction: Lakhovsky criticized Dr. Loewe for including resistances and capacities within his multiple-tubes, while at the

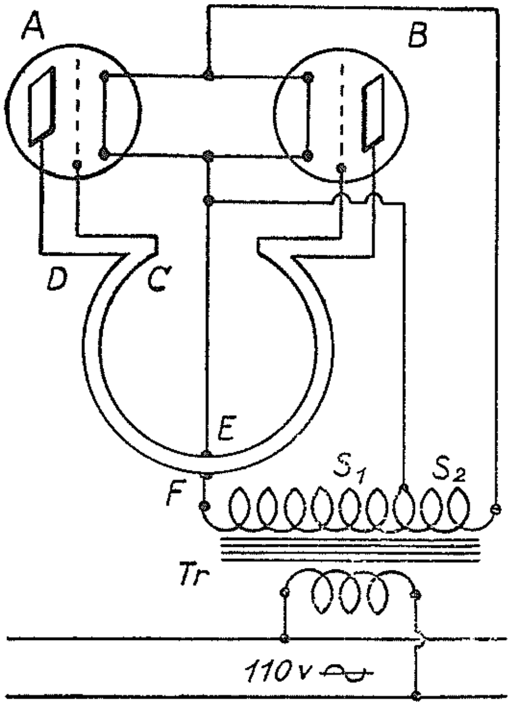

Figure 9
A = a Lakhovsky Triode
B = another Lakhovsky Triode
C = Loop associated to Grids
D = Loop associated to Plates
E = Connection to Filament
F = Connection to High Voltage of Transformer secondary tap S_1
S_1 = High Voltage tap of AC Transformer secondary
S_2 = Filament Voltage tap of AC Transformer secondary
Tr= AC step-up Tranformer with a tapped secondary winding

same time he did the same! But Lakhovsky's capacitors are different to the common types.

What he did was to "separate" a variable condenser's blades and to "counterweight" the moving blades, as indicated in Figure 8, so that the blades would move within the fixed armature of the condenser as the whole tube was rotated and weight "W" responded to gravity! He does not indicate, thus making it an object of personal experimentation on the part of the readership, if there was just one or more of these special variable condensers.

Now, in order to produce a wide range of frequencies with only two of his special triodes, Lakhovsky built the "Radio-Cellular Oscillator" that is shown in schematic form in Figure 9, which he used at the Clinic of Salpetriere in 1924 to treat and heal Geranium plants which he experimentally inoculated with the disease of cancer; it was mounted, he says, according to the "Montage Mesny," thus indicating that one man called Mesny originated the setup at that time (this is another source for research, try finding in old books from either the '20s or '30s anything made by a Mr. Mesny).

This is what, on the device, Lakhovsky says: "Plates, grids and filaments are connected in parallel. The circuits of grid and plate have each a single loop. These two loops are coupled variably between themselves. Plates and filaments are fed directly from the Alternating Current of the place by means of the appropriated transformer. Within these conditions, it is produced the emission of waves because it is branched the intake of current upon the electrified section.

"Using, accordingly, a condenser it is possible to produce the whole spectrum of waves between 2 and 10 meters of wavelength. The supply from AC produces a large number of harmonics upon which can enter into resonance the oscillations of different cells. Therefore, the fundamental wavelength can be regulated according to the nature of those cells to treat.

"The biological role of the Radio-Cellular Oscillator is to re-establish the oscillatory equilibrium in the living cell, under threat by any alteration, particularly by a close microbe. When recovering its normal strength thanks to the auxiliary irradiation from the Radio-Cellular Oscillator, the cell can all-by-itself destroy the microbe by counter-acting its deleterious radiation."

Mr. Lakhovsky goes on indicating that he established the aforementioned concept as the foundation of his device by first inoculating several plants of *Pelargonium zonatum* with the *Bacterium tumefaciens* in order to generate tumors similar to those of animals in plants (his source was: An Introduction to Bacterial Diseases of Plants by Erwin F. Smith, London and Philadelphia, 1920). He was helped with inoculating the plants by Mr. A. Gosset, Mr. A. Gutmann and Mr. J. Magrou, the latter being the one who had more articles published on the subject of plant-inoculation (see the Revue de Pathol. Vegetale et d'entomologie agricole and within that the Annales de L'Institut Pasteur, by this author).

He then applied his Radio-Cellular Oscillator, using waves of about 2 meters, which he equated with a vibration of 150,000,000 cycles per common-second. He broadcasted the oscillator's output upon the infected plants and got them all back to health after a given time. He had already explained how his oscillator worked to his fellow Frenchmen in an article (Radio-Revue, November 1923) and a conference (given at the Ecole Superieur des Postes, Telegraphes and Telephones

Figure 10

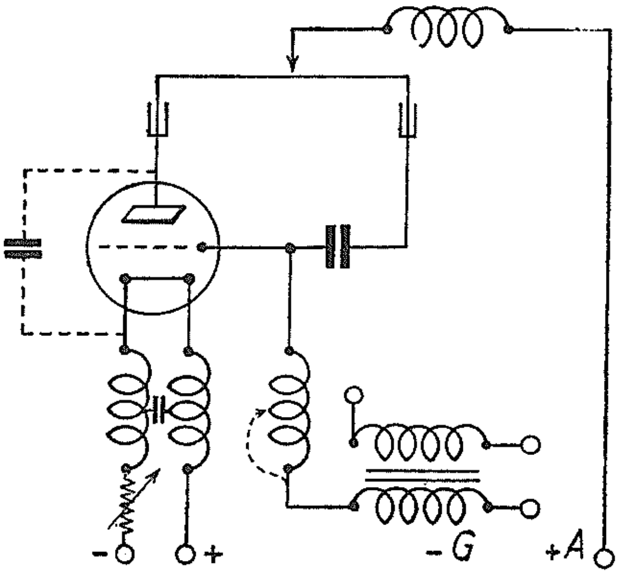

on June 2nd, 1924).

After detailing how the experiment in plant-healing progressed and how the plants were healed, he goes on to explain that -- in his conception -- cancer is provoked by an "aging" of the cells that makes them both reproduce at a slower rate and to evacuate a higher amount of wastes. This, in combination with radiations coming from space at different times, produces an oscillatory disequilibrium in the cells resulting in cancer of different types. Mr. Lakhovsky rejects, on the ground of histological examinations he performed, both the "microbial" theory of cancer and its hereditary transmission.

If you have followed all of the writing up to this point, carefully noting the concepts involved in Lakhovsky's procedures, you will remember that:

(1) His Radio-Cellular Oscillator created an auxiliary electromagnetic field capable of restoring balance to the diseased cell(s) and body.

(2) This was done by means of very short waves (during the period he experimented) of about 2 meters and 150,000,000 cycles per second.

(3) To achieve the necessary shortness of wave he introduced different elements within an evacuated glass-vessel, thus creating a different type of vacuum tube.

(4) He purposely indicated that external elements created long waves that did NOT comply with what he needed for therapy.

(5) He included, within his special tubes, a variable condenser that could be tuned to the desired capacity by moving the tube in space so that the internal variable capacity could generate the coupling needed in therapy.

If all of this has been, so far, an essential group of conditions necessary to produce the short waves of about 2 meters, then why -- as seen in Figure 9 -- does he place two electrified loops OUTSIDE the vacuum tubes of his special design????

In compliance with this "loops outside" line, he goes on quoting the works by one of many foreign scientists who, he claims, have followed his line of research:

Lakhovsky says: "It is convenient to quote the works made by Professor Esau at Jena's Technisch-Physicalishes Institut (Germany). If they are directed by ways somewhat different to mine, his works show the similitude of using an oscillator of very short waves similar to my Radio-Cellular Oscillator. Professor Esau's emitters and receivers do not differ essentially from the apparatus I champion. I have already indicated that the arrangements of constituents are indifferent, because they produce the very short waves needed.

"The setups by Professor Esau -- described in the Institute's technical magazines by Dr. Ernest Busse (see Die Erzeugung Ultakurzer Wellen -- *Research on Ultrashort Waves* -- in Radio Welt, No. 49, page 77, Vienna, 1928), secretary to the Institute of Jena, are characteristic because they employ a single triode working with DC.

"The emitter's filament -- as seen in Figure 10 -- is fed by a filter preventing the return of high-frequency currents. Windings are made with simple fractions of turns, as in the Radio-Cellular Oscillator, which does not involve but a half-turn per oscillating circuit.

"An experimental receiver (see Figure 11) is supplied with a circuit possessing a single square-loop, upon which can be made variable taps. Another apparatus is possessed of a single circular-loop upon which a radial cursor allows to take just the necessary fraction of circuit.

"Works by Professor Esau in the realm of Biology are very recent, because at the August 1928 Radioelectric Con-

Figure 11

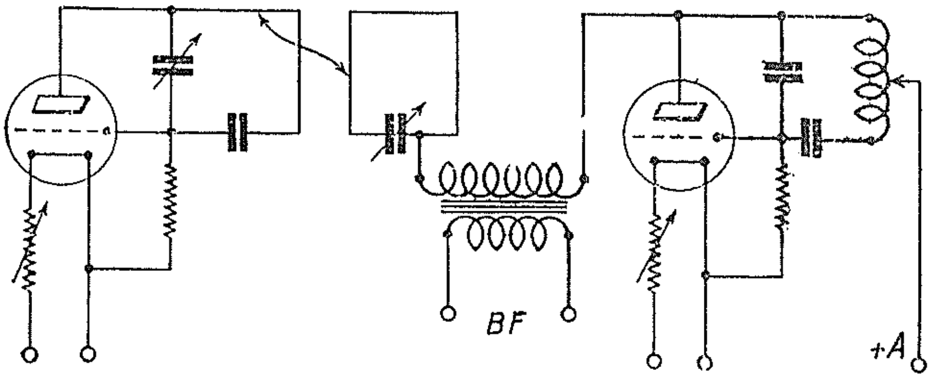

gress of Bremen (see Les ondes ultra-courtes et leur champ d'application -- *Ultrashort-waves and Their Field of Application* -- by Oscar Gadamer in Der Deutsche Rundfunk -- *German Radio* -- of August 31st, 1928, volume VI, page 240, Berlin) this author states that after about a year he investigated the physiological effects of ultrashort-waves that is, according to his definition, waves of very high frequencies between 1½ and 3 meters in length, of which I have indicated how I employ them in a 1924 communication to the Society of Biology (Note: It is on the inoculation and healing of the *Pelargonium zonatum*, as explained on page four of this writing). Prof. Esau then indicated that, since July 1928, he built a receiver of very short waves.

"About this subject, Professor Esau remarked that the main difficulties come from electronic tubes, for he was forced to use foreign tubes, particularly French ones, that are better fitted to the technology of very short waves. I must remind (the readership) that four years before him I studied and had built these special lamps for short waves, to be used in my Radio-Cellular Oscillator.

"I will also point out that an emitter of very short waves has recently been employed by Dr. Franz Seidel of Vienna for destroying bacteria, particularly to sterilize milk (see Les ondes ultra-courtes contre les bacteries -- *Ultra-short Waves Against Bacteria* -- in Radio Welt -- *Radio World*, January 27th, 1929, No. 4, page 108, Vienna)."

We have two definitely contradictory positions in the same chapter dealing with the same type of device:

(1st) In the paragraph translated under Figure 3 of this paper, Lakhovksy emphasized that the elements to produce ultrashort waves (under 2 meters) must be inside the tube. Figures 3 to 8 are dedicated to showing specific constituents for this special type of tube. Though he only speaks on Triodes, there is no reason to suppose he did not experiment with Tetrode and Pentode tubes (plus others of his own design not usually covered in publicly available technical literature).

(2nd) The formerly-indicated conditions change radically when he speaks of his experimental device employed to eliminate tumors affecting inoculated plants, this being the device of Figure 9 of this paper. Notice how the emitting elements in this apparatus are outside the vacuum tube; furthermore Mr. Lakhovsky claims that other, similar, devices developed by Professor Esau at Jena's Technisch-Physicalysches Institut are based in his "internal" design when the opposite is quite true!

(3rd) In order to make a better synopsis, I went back to read my copy of The Secret of Life, a translation into Spanish by M. Aquilar (Madrid, 1929). Therein are explained the basics of the Multi-Wave Oscillator but the Radio-Cellular Oscillator is NOT shown. It is reproduced in the 1924 communication to the Society of Biology. Neither source mentioned here reproduced the special vacuum tubes, with internal constituents, as explained in La Science et le Bonheur, the subject of this synopsis.

(4th) In Mark Clement's The Waves that Heal, the Multi-Wave Oscillator is explained as: "The apparatus consists of a transmitter and a receiving resonator, both arranged so as to set up an electromagnetic field in their immediate vicinity." The Multi-Wave Oscillator seems, in my opinion, derived from the "experimental receiver" of Figure 11 plus those of Heinrich Hertz (as I have indicated in my Some Free Energy Devices, a BSRF publication, quoting directly from The Secret of Life and introducing complementary information from other sources), rather than from the multiple-tubes shown in Figures 3 through 8 of this paper.

(5th) Considering everything explained from (1st) to (4th), it is my opinion Mr. Lakhovsky produced several types of apparati, along different lines of research, while pretending in his books that only a single-line of investigation was being pursued.

What are the reasons for doing this? There are many:

(*) Trying to disorient his fellow scientists by covering up his actual intentions and actions, so that the actual secret of the apparati rested with him.

(*) Trying to foil any attempt by the "organised medical profession" to steal his "secret" -- whatever this could actually be.

(*) Having discovered something that he wanted to keep for himself in the course of his researches. This is, in my opinion, the most likely possibility, for Mr. Lakhovsky's researches were well-received in Europe, South America and Asia before WWII began. Even more, he was outspokenly backed by men of science and Academies of great reputation and his enemies were very few (outside of the USA, of course....).

I do not mean to slander him and his researches, I just want to indicate the necessity for greater and deeper research into what he did from all possible sources of information.

VERY IMPORTANT NOTE

In order to facilitate the understanding of the illustrations, I have taken a few liberties to aid the non-French speaking associates:

(1) All the "lateral letterings" from Figure 3 to Figure 9 are of my doing, they did not exist in the original text.

(2) I changed into English, keeping the true meaning in translation, the writing in Figure 2.

(3) I made some additional lettering in some illustrations for greater understanding: L1 to L4 in Figure 1; I added the "C" in Figure 5, the same "C" was added in Figure 6; Finally, I added the "H" in Figure 8 for greater clarity.

(4) In French the letters "HT" are the abbreviation of "Haute Tension" that means in English "High Voltage"; in Spanish we also use the word "Tension" in electricity meaning "Voltage," as the French do. The letters "BT" stand for "Basse Tension" which I translate not as "Low Tension" but as "Filament Voltage" for this is the actual meaning.

Patented June 12, 1943 Georges Lakhovsky 1,962,565

UNITED STATES PATENT OFFICE

1,962,565

APPARATUS WITH CIRCUITS OSCILLATING UNDER MULTIPLE WAVE LENGTHS

Application November. 13, 1931, Serial No. 574,907

In France, May 2, 1931

7 Claims. (Cl. 250-23)

Fig. 1.

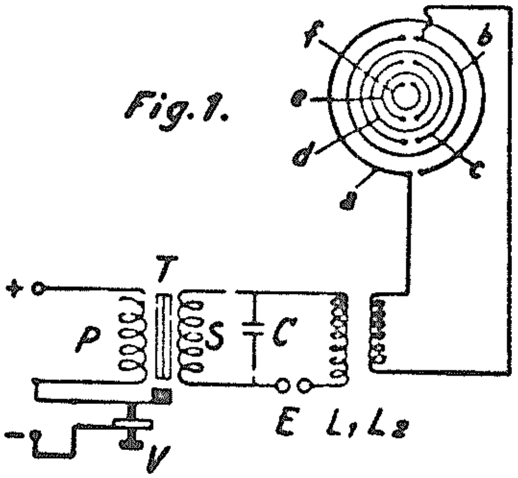

Fig. 2.

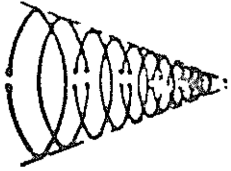

Fig. 3.

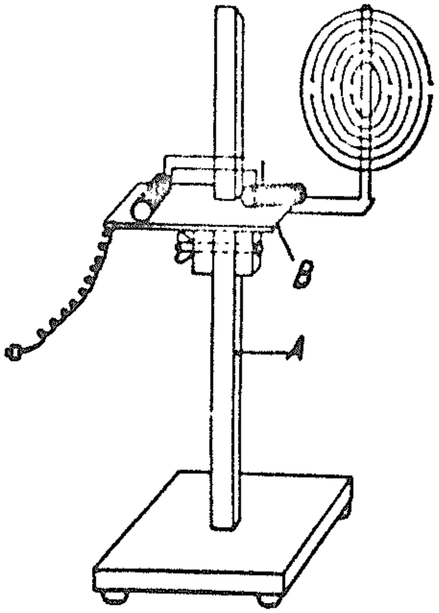

The present invention has for its object an apparatus capable of sending out simultaneously different wave lengths so that among these waves or their harmonics there is found almost always one or several capable of producing the best effect sought for any application whatever.

There is used for that purpose the property of open circuits having well determined wave length if they are excited by electric impulses emanating from discharges of any source.

The radiating part of the system, producing waves of various lengths, is therefore constituted by a certain number of concentric open rings of different diameters, which are maintained insulated by any appropriate means. These rings may or may not be terminated by small spheres forming capacities.

These rings may be arranged either in the same plane or in different planes so as to form any surfaces, such as portions of cones, spheres, paraboloids, ellipsoids, etc..., these surfaces being of a nature to concentrate the waves in a determined direction in the manner of a reflector, for example.

These rings may be fed by any producing device whatever of high frequency, for example, a combination comprising a trembler coil (or any other transformer) and a high frequency circuit provided with a self-induction coil and a capacity.

One of several points of this high frequency circuit is or are connected to the end of one or several of the rings forming the radiating apparatus. The other rings not connected are excited by induction.

The complete apparatus (coil, high frequency circuits, rings, etc....), may be mounted in a box or upon a small board capable of sliding along a guide or rocking so as to be able to be placed in the most convenient position.

In the accompanying drawing, by way of example, not limitative, there is shown:

Fig. 1 a diagram of the system.

Fig. 2 the position of the rings in the form of a cone.

Fig. 3 the apparatus mounted upon a foot or base.

In Fig. 1 there is seen at T the transformer or coil (P the primary, S the secondary of this coil), V the screw of the trembler, C the condenser the discharge of which across the spark gap E produces oscillations in the self-induction coil L1, which in its turn acts by induction upon the self-induction coil L1; this self-induction coil L2 is connected on one side to the first exterior ring a, on the other side to the following ring b. It thus forms an electrostatic field of high frequency which induces oscillations in the other rings c, d, e, f.

As a modification, L2 may be suppressed and the rings a and b may be connected each to one of the ends of L1.

One of the ends, or even any point of the self-induction coils L1 or L2 may likewise be connected to any one of the rings.

Fig. 2 shows the arrangement of the rings in the form of a cone. The open circuits a, b, c....f can be constituted by solid conductors. They can also be tubular circuits, this being advantageous, since, for the same bulk, the radiating surface is larger. Finally, the area of the cross section of each of these various circuits can vary from one circuit to the other for instance, this area can decrease from the periphery (ring a) to the center (ring f) of the radiating system.

Fig. 3 shows the apparatus mounted upon a foot A along which it can slide, in order to be placed at any desired height and upon a hinge B which allows it to be oriented upon the horizon.

I claim:--

1. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits constituted by concentric insulated split rings of different diameters, the split ends being spaced from each other and terminating with small spheres.

2. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits constituted by concentric insulated split rings of different diameters and terminated by small spheres forming capacities.

3. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits constituted by concentric insulated split rings of different diameters and arranged in one and the same plane the split ends being spaced from each other and terminating with small spheres, in staggered position as regards adjacent rings.

4. An apparatus of the type described comprising a base, a plate slidably mounted on said base, a support pivoted to the said plate, a series of open and insulated, high frequency radiating circuits mounted on the pivoted support, and a high frequency producing device for the excitation of the said circuits.

5. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits, said circuits being open, insulated, and having dimensions different from each other.

6. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits arranged in the same plane, said circuits being open, insulated, and having dimensions different from each other.

7. An apparatus of the type described comprising a transformer, a high frequency energizing circuit fed by the said transformer and provided with a self-induction coil and a capacity, a series of open and insulated high-frequency radiating circuits having dimensions different from each other, and inductive connection between two of these radiating circuits and respectively each of the poles of the outgoing element of the high frequency energizing circuit.

G. Lakhovsky
INVENTOR

By: Marks & Clerk
Attys.

June 13, 1944. **G. LAKHOVSKY** **2,351,055**

TUBE FOR PRODUCING MULTIPLE WAVE LENGTHS

Filed Nov. 21, 1941

Fig. 1.

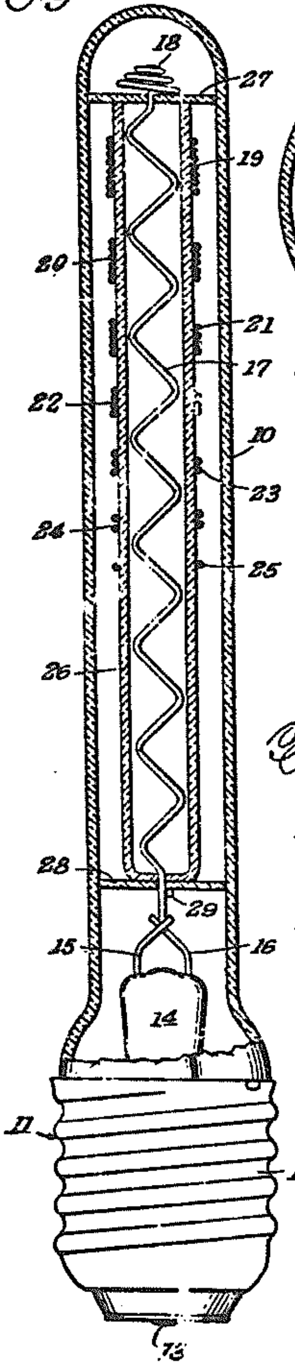
18
27
19
20
21
17
22
10
23
24
25
26
28
29
15
16
14
11
12
13

Fig. 2.

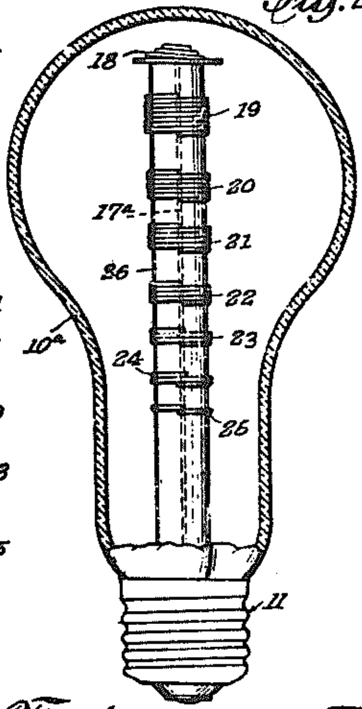
18
19
20
17a
21
26
22
10a
23
24
25
11

Fig. 3.

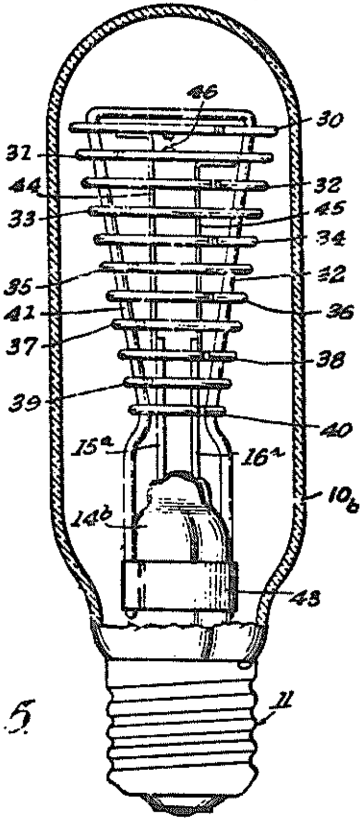
46
30
31
44
32
33
45
34
35
32
41
36
37
38
39
40
15a
16a
10b
14b
43
11

Fig. 4.

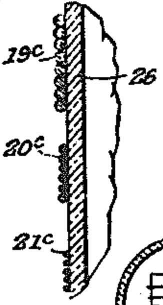
19c
26
20c
21c

Fig. 5.

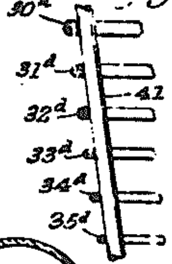
30d
31d
41
32d
33d
34d
35d

Fig. 6.

Fig. 7.

Fig. 8.

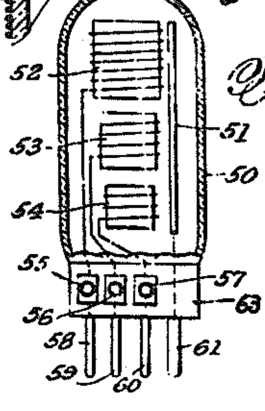
52
51
53
50
54
55
57
63
56
58
61
59
60

Fig. 9.

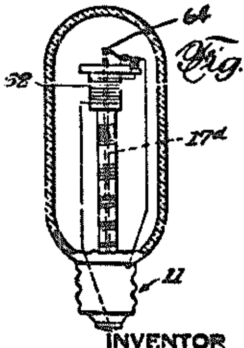

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GEORGE LAKHOVSKY
BY
Leon M. Strauss
ATTY.

Patented June 13, 1944

2,351,055

UNITED STATES PATENT OFFICE

2,351,055

TUBE FOR PRODUCING MULTIPLE WAVE LENGTHS

George Lakhovsky, New York, N. Y.; Anne-Marie Louise Lakhovsky, administratrix of said George Lakhovsky, deceased, assignor to Henry S. Blum, Chicago, Ill.

Application November 21, 1941, Serial No. 420,006

11 Claims. (Cl. 250—33)

This invention relates generally to electric devices excited by electric impulses and more particularly to multiple wave length conducting and/or producing means. This invention has for its primary object the provision of such means disposed within a vacuum tube or a tube containing rare gas or gases.

My work over a period of more than 20 years has led me to the belief that there is great need for means conducting and/or producing multiple wave lengths which may be employed in many industrial and medical fields. Suitable apparatus for producing waves of various lengths is disclosed in my U. S. Letters Patent No. 1,962,565, dated June 12, 1934. Embodiments of this apparatus have been in use the world over. Because of the need for simplification in such apparatus so that it may be handy and easily used by persons lacking skill in electrical matters, I have concluded that by providing one unit which incorporates oscillation generating means and another in which the wave lengths are produced, the apparatus may be more universally used in the treatment of cellular life in therapy, in the aging or treating of liquids and in other industrial fields.

The present invention deals with those units, preferably combined with one another and constructed as a portable device and as stated above, has for its major object the provision of a unitary multiple wave length producing and/or conducting device in the form of a vacuum tube.

The present invention further contemplates the incorporation in such a tube, of means for varying the effect of wave lengths, or selectively employing the means therefor enclosed in or forming part of said tube.

This invention further seeks to provide a tube of the indicated type incorporating means for generating oscillations.

Another object of the invention is to provide a single unit which contains an oscillation generator, which produces waves of definite frequency, and further inductance means each permitting emanation of wave lengths of various values.

The structural features of my invention also form a material part of this disclosure, the objects and advantages being attained in structures such as shown in the accompanying drawing, which exemplifies the invention. The following specification, based on said drawing, more clearly points out the purposes and advantages of my invention.

In the drawing:

Fig. 1 is a vertical, partial sectional, partial elevational view of a tube incorporating features of my invention.

Fig. 2 is a similar view of an alternate form thereof.

Fig. 3 illustrates in a similar manner a modified form of my invention.

Fig. 4 is a fragmentary sectional view of a modification made in accordance with the invention.

Fig. 5 is a similar view of another modification.

Figs. 6 and 7 are sectional views illustrating types of wires used in either of the forms of my invention as shown in Figs. 1, 2 and 3.

Fig. 8 is a partial sectional, partial elevational view illustrating a tube incorporating a plurality of grids and selective capacity means for varying the effects of said grids.

Fig. 9 is a similar view of a tube, such as shown in Figs. 1 or 2 and incorporating oscillating or vibrating means.

In that form of my invention shown in Fig. 1, there is provided a sealed preferably transparent envelope 10 made of glass or like material affixed in the usual manner to a screw or Edison plug 11. The latter is conventionally provided with a shell terminal 12 and a central terminal 13. The support or seal 14 of the tube serves to hold wires such as 15 and 16 which connect to the terminals 12 and 13.

Connected to the wires 15 and 16 is a primary inductance member in the form of a loose coil 17 which may be disposed axially of the envelope 10, as shown. The upper end of said member 17 forms a tight wound coil 18 which serves to radiate the strongest induced wave lengths.

Surrounding the primary inductance member 17, there are arranged a plurality of separate coils of wire each being of different length and capacity. Thus, I provide a coil 19 having greatest capacity and successive coils 20, 21, 22, 23, 24, and 25, each having less capacity than the preceding coil. These coils 19 to 25 form secondary inductance means each permitting emanation of a wave length of different magnitude and value than the other.

I may support the secondary coils in several ways. As shown, I prefer to provide a dielectric member such as a glass sleeve 26 surrounding the primary inductance wire member 17 and to mount the secondary coils 19 to 25 on the outer surface of said sleeve, leaving the coil 18 exposed at the top thereof. In order to effectively support and centralize the glass sleeve 26, I provide spacing washers 27 and 28 of mica or the like, top and bottom, and provide a supporting crosspiece 29 on the lower portion of the wire 17.

The tube above described may be employed as indicated for the treatment of cellular structures by connecting it to any one of the rings in the electrostatic field of high frequency, such as shown in said U. S. Letters Patent No. 1,962,565, each of the coils 18 to 25 producing by induction a different wave length, as can be understood.

In the form of my invention shown in Fig. 2, the envelope 10*a* is somewhat differently shaped, and the wire 17*a* straight instead of arranged as an open coil. In other respects, the structure follows that described with reference to Fig. 1.

As shown in Fig. 3, there may be arranged a plurality of open rings 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, and 40 in frustro-conical form, for instance, with the largest of said rings at the top and the smallest one adjacent the bottom. I have shown said rings as supported, for instance, by glass posts 41 and 42, said posts being supported on the seal 14*b*, as by a band 43. I provide extensions for the terminal wires 15*a* and 16*a* and connect said extensions 44 and 45 to the upper ring 30 and the next lower ring 31, respectively.

The rings 30 and 31 may become the primary inductance members, whereas the remaining rings constitute the secondary inductance members as before set forth. Electric current conducted to the suitably spaced rings 30, 31 will cause a spark 48 to be drawn between the rings 30 and 31 providing oscillations emanating from electrical discharges therebetween and causing the radiation of waves of various lengths within the envelope 10*b* and affecting the remaining rings.

In Figs. 1 and 2, I have shown the secondary coils as formed of wires having uniform cross-section. Fig. 4 illustrates how such wires may be made progressively smaller in the succeeding coils 19*c*, 20*c*, and 21*c*, etc. Similarly, I have shown the rings of Fig. 3 made progressively smaller in Fig. 5, said rings being designated by numerals 30*d*, 31*d*, 32*d*, 33*d*, 34*d* and 35*d*, etc. In such various manners, the wave length producing effect of the secondary coils or rings may be arrived at.

The secondary coils or rings may be round or somewhat flattened wire as shown in Fig. 6 or tubular as in Fig. 7, offering a yet greater flexibility of design.

The devices of Figs. 1 and 2 above described may be incorporated in the system shown in said U. S. Letters Patent by connecting one of the rings *a*, *b*, *c*, *d*, *e*, or *f* with plug 11 of Fig. 1, since either terminal 15, 16 is in contact with primary inductance member 17. To this end a conductor (not shown) connects such a ring with said plug or socket.

In Fig. 8, I have shown a modification of the invention which comprises a vacuum tube 50 containing a plate 51 and a plurality of different wave lengths producing grids 52, 53, and 54. I connect each grid with a variable capacity device, such as 55, 56, and 57 carried by said tube 50 and preferably by its base support 63, whereby the grids may be selectively connected into an operating circuit (not shown) by means of the respective prongs 58, 59, and 60, and the plate prong 61. Heating or other exciting means may be incorporated in the tube in a well-known manner. This combination tube 50 is designed to replace a plurality of known tubes each operating with different and variable wave length effect, mere exterior manipulation at said base support brings about change of the capacities 55, 56, and 57 and cutting in one or more of the grids 52, 53, and 54.

The effect of the spark as produced in the form of the invention depicted in Fig. 3 may be further utilized in Fig. 9 in which I also incorporate a vibrator 62 which produces electrical oscillations by a spark intermittently generated between the end of the primary inductance member 17*d* and vibrator armature 64. In other respects the structure follows that of Fig. 1.

It may be noted that any type of spark producing or oscillation generating means may be substituted for the vibrator shown. The tubes shown in Figs. 3 and 9 may be used in the manner described for Fig. 1 by connecting one terminal of the base as set forth to produce an induction effect. These tubes may be also connected across both terminals with a suitable potential to obtain the spark effect.

From the foregoing it may be seen that I have provided tubes in various forms for the purpose of generating and conducting multiple wave lengths. Other forms of the invention may be produced within the spirit and scope of the invention as claimed.

Having thus described my invention, what I claim as new and desire to be secured by Letters Patent, is:

1. A device of the character described comprising a vacuum tube having an envelope and base, primary inductance means, and a plurality of separate secondary inductance means of different length for radiating waves of various lengths extending above said primary inductance means, all said inductance means being arranged within said envelope.

2. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member axially arranged in said envelope, and a plurality of secondary inductance members spaced apart and independent from each other each member surrounding a respective portion of said primary inductance member and within the field of influence thereof.

3. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member axially arranged in said envelope, and a plurality of secondary inductance members each surrounding the primary inductance member and within the field of influence thereof, each of said secondary inductance members having a different wave length effect than the others.

4. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member comprising a pair of split rings in inductive relation, and a plurality of secondary inductance members each comprising split rings.

5. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member comprising a pair of split rings in inductive relation, and a plurality of secondary inductance members each comprising split rings, said latter rings being arranged in different planes and being of different length to produce a different wave length effect.

6. In a device of the character described, means for producing multiple wave lengths comprising a wire member, enclosing dielectric means for said member, and a plurality of separate wire coils of different lengths on said dielectric means and in the field of inductance of said wire member.

7. In a device of the character described,

means for producing multiple wave lengths comprising a wire member, enclosing dielectric means for said member, and a plurality of wire coils on said dielectric means and in the field of inductance of said wire member, each coil extending over said wire member and having a different number of convolutions than the others.

8. In a device of the character described, means for producing multiple wave lengths comprising two split rings in inductive relation, and a plurality of split rings in inductive relation to the two split rings.

9. In a device of the character described, means for producing multiple wave lengths comprising two split rings in inductive relation, and a plurality of split rings in inductive relation to the two split rings, the plurality of rings being of smaller diameter than the mentioned two rings and each progressively smaller than the others.

10. In a device of the character described, means for producing multiple wave lengths comprising two split rings in inductive relation, and a plurality of split rings in inductive relation to the two split rings, the plurality of rings being of smaller diameter than the mentioned two rings and each progressively smaller than the others, all of the rings being arranged in frusto-conical disposition.

11. In a vacuum tube having a primary inductance member and secondary inductance members, a vibrator arranged in the field of influence of said primary inductance member and secondary inductance members, a vibrator arranged in the field of influence of said primary inductance member for affecting the induction of said secondary members.

GEORGE LAKHOVSKY.

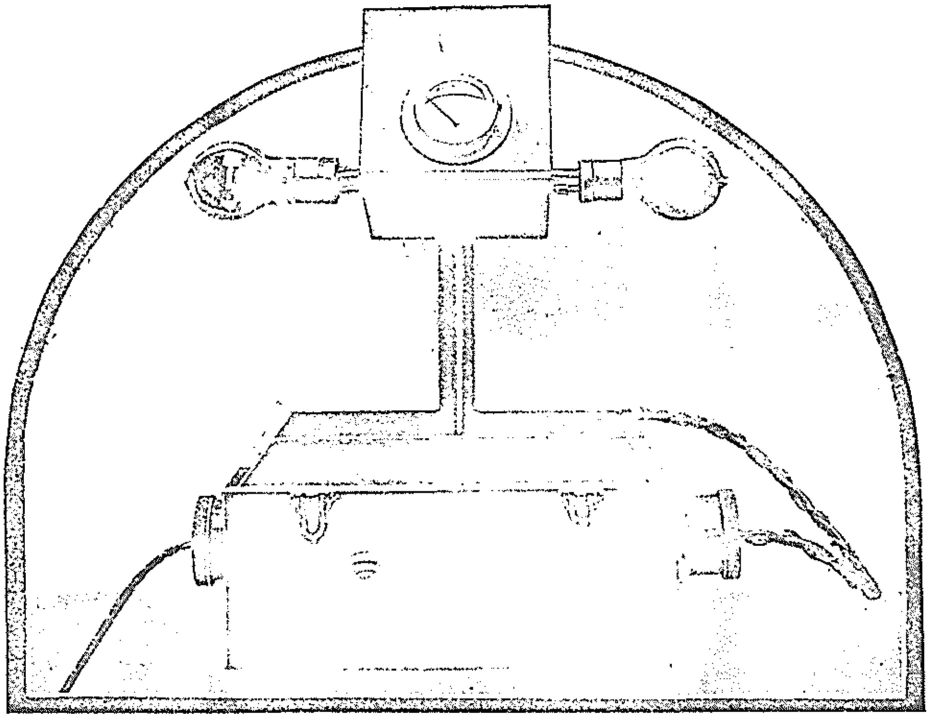

The two-meter oscillator used by the author in his experiments with the supply box containing the necessary controls and transformers.

Picture from *Radio News* for February 1925

Curing Cancer with Ultra Radio Frequencies

by George Lakhovsky

LAKHOVSKY'S VIBRATORY CIRCLE

Author Unknown, Source: BSRF files
Translated from the German by Bodo Capeller, 1988

"We owe to magic all progress in physics and chemistry."
(Jules Lermina, 1915)

The Paris professor with the Russian name Georges Lakhovsky claims to capture, with so called open vibratory circuits (circuits oscillants), cosmic waves and pass them on to humans (neck antenna) and plants. Healing of people has been verified by French and Italian medical practitioners, healing of Cancer injected plants has been proven through photographic records.

The vibratory circles are manufactured from heavy copper wire with a diameter of 5-10 millimeters. Those wires 5-8 millimeters in diameter had a more pronounced effect than the much thinner variety. The spiral (of the open ended circle), which can be single or double, is guided around the plant and is supposed to be insulated against its support by "Ebonit" (1).

Instead of copper wire medical practitioner Dr. Ernst Busse (Garmisch, Germany) recommends the use of thin copper tubing: "because of the short wave length of cosmic vibration only the surface effect (skin effect) is effective (that means electricity is only present on the surface of a conductor, not in the middle) which requires the use of maximum surface area. Besides this the tubing is easier to work with and has less weight. (Private Correspondence 1/10/1953)

Helmut Friedensdorff (Berlin, Germany) did report already in 1932, from himself as well as others, on the effectiveness of an open vibratory circuit against lumbago among other ailments. He inserted a simple isolated copper wire into surgical tubing and positioned it at the problem spot in a manner that both wire ends did not touch (2).

Canon Smythe of Great Britain did proceed in a similar manner: "The only tools required are a one meter length of flexible electrical wire and a sidereal pendulum. The insulation is removed at both ends for a length of 2 centimeters, the wire is stripped and the wire strands are removed except a single strand. Then the wire is laid out on a table and the pendulum is positioned over the wire ends. It will rotate over the positive end in a clockwise motion, over the negative end in reverse. Then one proceeds to make a knot at the negative end for identification purposes. It should be positioned on the left side of the body or in the vicinity of the leg, the bare wire pointing to the left. The wire may be installed over the clothing and can be braided or fastened with safety pins, the ends should point into the proper direction.

"Arthritis in one toe should be treated by using the wire like a stocking holder wound around the leg where the knotted end will point to the left. The author makes no claims for the healing arthritis but reports a lessening of pain.

"With severe headaches the wire is wound just above the eye level around the head so that the negative end rests over the left temple.

"Severe coughing is treated with one wire around the throat, another one around the abdomen."

A just started cold is removed by our associate in a few hours with two wires, one with the positive connected to the negative end of the next wire joined as a 2 meter long wire. "I wound the wire over the shirt under a sweater around the chest until I reached under the arm pits and made sure that the negative end is on left side of the chest pointing to the left, the positive end pointing the opposite way."

Smythe published this in a paper many years ago called "The Other Half of Medicine". He is supported by the research of a recently deceased friend, Dr. Martin of Airaines, France who had been promoted to the medical faculty in Paris in 1932 with a dissertation "Diagnostic Radiesthesique en medecine veterinaire" under the tutelage of professor Nathering--without an examination! In 1935 a Dr. Girard presented a similar thesis before the University at Lyon.

Medical practitioner Arnold Mannlicher (1880-1958) from Salzburg carried in his rear pocket an open vibratory circuit which also acted as a cell detector.

Vibratory circuits proliferated after the announcements by Lakhovsky's discovery as "throat antennas, broadcast jewelry and healing chains" in the market place. I cannot say at the moment if they were of the open or closed kind. Apparently between the two kinds exists a fundamental difference in their effectiveness, open circuits reduce the tension within the body, closed circuits raise it. A closed broadcast chain can easily be transformed into an open one when it is opened and is closed with an insulator inbetween (rubber band, silk thread).

The open circuit is nothing new at all. Dr. Beck, former head of the municipal children's clinic in Bayreuth says: "the open bronze rings of the Hallstadt area from grave sites can be understood as protection against radiation effects very similar to the rings worn by the Negro tribes around the arms, legs and throat." The ancient Germans wore "broadcast jewelry"--in order to coin a modern word--an open solar spiral. Dr. Heermann has revived this. He writes: "invigorating liver and intestines the solar wheel acts like a plated iron spiral with the windings running from the center clockwise."

Smaller--sown into green material--is my usual aid in stomach ulcers and swollen glands. Underneath his illustration (not shown) the researcher explains: "a spiral ending growth rays to the abdomen" (3).

The never tired Dr. Busse since 1954 has also tried out open rings beside vibratory chains and belts. Earlier he replaced acupuncture needles with metal foil band aids and states now in a letter dated 4/19/1954: "instead of metal foil one may arrive at the same effect by wearing open copper rings on certain fingers and joints. When you put a ring that is cut open or manufactured from heavy copper wire on the corresponding finger an immediate change of pulse at the radial pulsation can be observed".

One of his associates who experimented with these open finger rings was surprised by the achieved results.

I am very much indebted to this versatile medical practitioner.

Because copper rings are a tuner (strengthening, invigorating) it was required to find a second metal which reduces organic functions. It turned out to be aluminum. On closed rings it was already reported in the chapter "Amulets". As far as the application of aluminum is concerned the welder Herbert Bauer (born 1921) from Freiburg, Germany has manufactured many years ago the so called "Zelemente".

According to the description it was recently manufactured from a three metal alloy which reminds of the "seven metal (electrum magicum)" of Hermetic fame. We are dealing here with closed chains that are supposed to protect from dangerous radiations of technical and cosmic nature and are therefore named radiation protective antennas. They look flat and are meant to be moistened in the morning and evening.

Whatever the effect is of the vibratory circuit on the world of plants has been shown in 1905 when sick elm trees were healed on a Hamburg street.

The Vienna engineer Lambert Binder (born 1905) caused, during a growth experiment in 1944 on orange trees, accelerated growth by surrounding the tree with an isolated wire spool.

R.E. Esspiau tried out in 1954 the following experiment with the Lakhovsky antenna arrangement. He connected the first on a three stalk head of cabbage to free standing antenna, the second to ground the third one to water which was replaced every 24 hours. In less than a week the first buds began to form, within four weeks other stalks were formed and developed leaves while a control plant withered away (4).

PHOTO TEXT:

Illustration A: This illustration shows a Lakhovsky experiment on a Cancer infected geranium plant. The cancerous growth is clearly visible. Pelargonium zonatum (Geranium) inoculated with Bacterium tumefaciens on April 10th, 1924 and photographed June 6th, 1924. It will be observed that the stem of the plant bears a massive tumour.

Illustration B: An astounding discovery by Prof. Lakhovsky: a free standing antenna ring manufactured from copper that surrounds the geranium caused the plant to drop the cancerous growth (resting on the rim of the container) and made the plant whole again. Photographed June 1925.

Illustration C: The test plant three years later. The antenna ring has completely healed the plant and protected it from other damage. To the side are two unprotected similar control plants of same age that became victims of the same disease. Photographed on March 13, 1928.

Picture credits: These three illustrations are designated tables II, V, and VII in Lakhovsky's Secret of Life.

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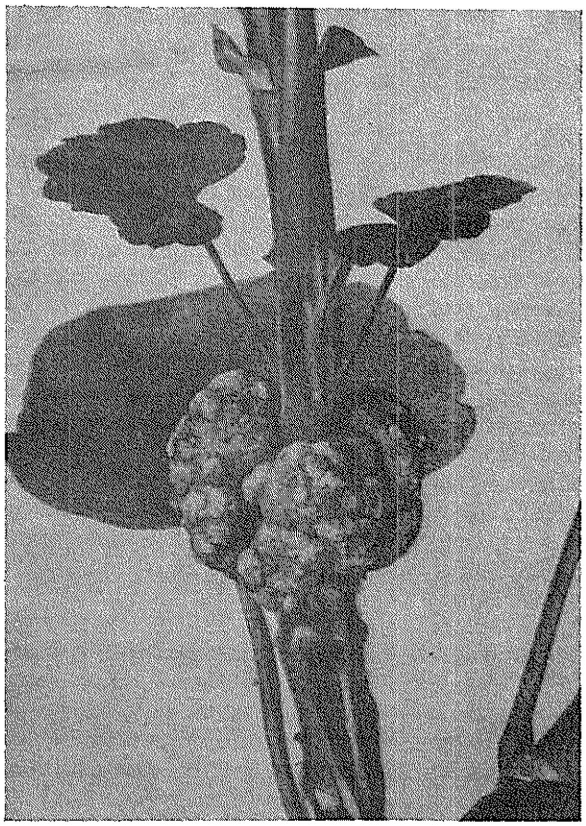

Illustration A

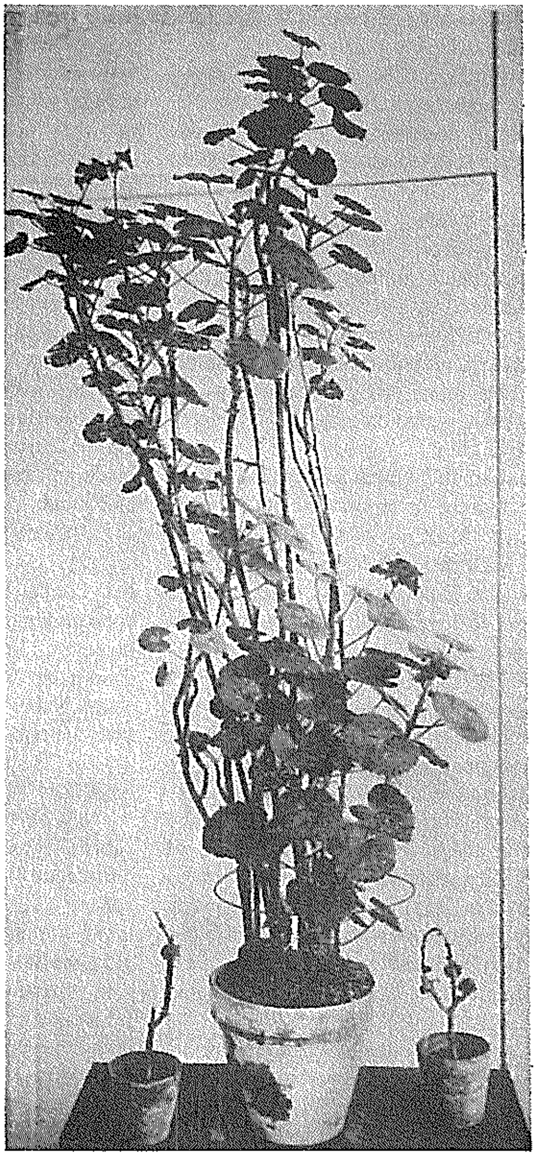

Illustration C

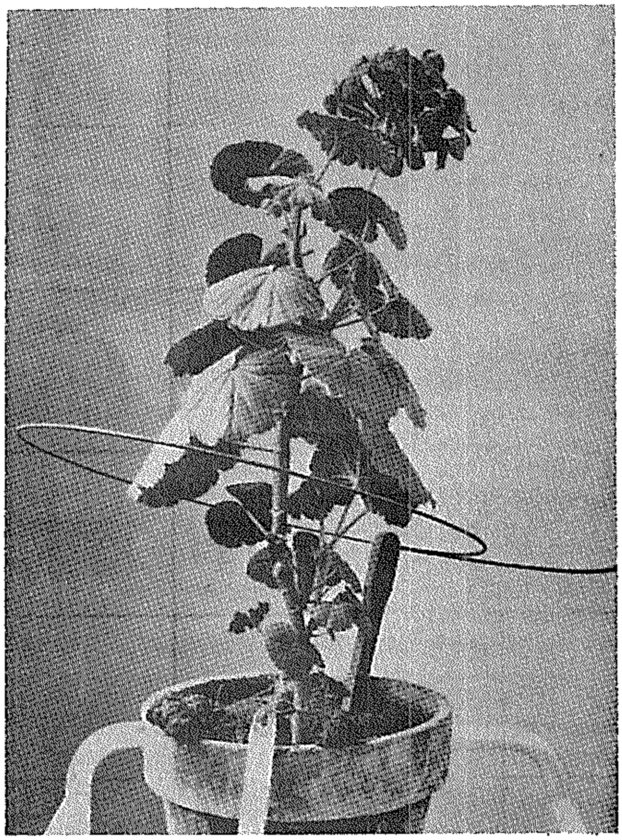

Illustration B

THE RUSSIAN LAKHOVSKY REJUVENATION MACHINE

by Bob Beck

from the November 1963 Journal of Borderland Research

In September 1963, Dr. L.O. Anderson, Anderson Research Center Director and BSR Associate, phoned me about a "marvelous electronic machine" purported to "cure" almost any human ailment. I've looked into dozens of these "modalities" every year; so with extreme skepticism I gathered instruments and took off to check another possible hoax.

I found a heavy spark-gap Tesla Coil inside a four-foot cabinet. This console was rigged to circular "antennas" and was partially shielded inside a home-built Faraday cage in the living room of Dr. Anderson's friend. It hadn't functioned in over a decade, and had been given up by some twenty-odd medical instrument repairmen and engineers as unfathomable.

The machine, which had no nameplate or other identification, turned out to be a Lakhovsky "Multiple Wave Oscillator", or MWO. Fortunately the present owner had found patents and two books describing its operation. We were able to reconstruct the circuits and after several hours had it operating perfectly. The machine was not a hoax.

Lakhovsky did his research prior to world War II and died in 1942. No infringement can be involved in duplicating Lakhovsky's work, since his U.S. Patent #1,962,565 expired in 1951 and is in public domain. I have found from the book **The Waves that Heal** by Mark Clements that MWOs are extensively used in hospitals in France, Germany and Italy, and although tested in a New York Hospital with fantastic success, MWOs remain practically unknown in the United States.

MDs testing Multiple Wave Oscillators reported up to 98% cures of terminal cancer, arthritis and other "hopeless" conditions. Case histories were complete with before-and-after photos. Often rejuvenation was demonstrated, not only in human beings but in plants and animals as well!

So, on Sept. 18, 1963, I designed and built a modern MWO based on Nikola Tesla and Lakhovsky's original work and patents. The transistorized instrument fits into a brief case and weighs under 14 lbs. Experiments with the MWO on some eighteen volunteers have demonstrated almost unbelievable results. At this writing, Oct 20th, every single subject, including myself, reports fantastic gains.

My mother, age 72, who has suffered from hypertension and glaucoma for many years, measured absolutely normal blood pressure the morning after her first treatment. And the eye tension, tested by her MD the week following, had dropped to a lower point than in the previous two years. Another woman with a long-standing back condition says she was permanently relieved in one 15 minute exposure. An asthmatic with chronic bronchial complications claims he is now symptom-free after two exposures and her husband with a bad dermatological condition of seven years history appears to be very definitely improved. Perhaps the most dramatic is Mr. N.V.C. who had broken his leg skiing last December. Because of an old polio complication the broken leg had never healed and flesh surrounding the fracture was in a very poor, waxy condition. After one exposure he phoned to say he had regained feeling in the area. The next day we made an "after" photo slide of nearly normal tissue.

A friend suffering allergies of long standing says she can now eat anything and her MD admits he as startled by her youthful appearance and new vitality. The Lakhovsky literature illustrated many such rejuvenations as an unexpected side effect of cancer cases. Subject's wrinkles disappeared along with the tumors!

THEORY OF OPERATION

Lakhovsky pointed out that all cells capable of reproduction contain in their nuclei "filaments" of highly conductive material surrounded by insulating media. This filament, which may be the RNA-DNA complex, is always in the form of a spiral or helix -- in other words, a coil. Therefore, each will react as a tuned circuit if its resonant frequency can be approximated by an external oscillating coil.

Lakhovsky didn't carry this to it's conclusion; however, I postulate that by exciting the nuclei with electromagnetic energy a "charge" can be induced by the long established principle of electromagnetic induction. This demonstratively raises the energy level and perhaps the vitality of every cell in the field simultaneously. Since each cell is an individual, and of slightly different physical dimensions, the exciting wavelengths must be multiple, and must span a broad frequency spectrum. Diathermy machines, limited to crystal-controlled single frequencies in the 27.255 MC region, can do nothing but heat the tissue; and yet this approach, abandoned by Lakhovsky in the 1930s, can still be found in "modern" doctor's offices!

The Electromotive Force (EMF) produced by the MWO and induced in the cell nucleus, can raise the cell's metabolic rate by Electrolysis, and perhaps jog the RNA-DNA "memory" and reproductive capabilities to their level at an earlier, younger age, thus the rejuvenation. Even more subtle changes might be postulated, such as magnetic "progression" effects as evidenced by heavy water in magnetic fields.

By contrast, any chemical taken into one's system by mouth or by injection -- such as vitamins, food or medicine -- must first be absorbed in proper solution and ratio with unknown tract elements, then be transported by the blood to affected tissue only to be possibly rejected by the target areas.

Perhaps in cancer the EMF induced by the MWO raises the vitality and memory of marginal cells to normal reproduction levels. In the case of other disease, perhaps a cell's given higher energy levels can more readily throw off affliction.

A WAVE FOR EVERY BODY CELL

The Multiple Wave Oscillator described here radiates a bandwidth of radio frequency (RF) energy from the audio frequencies up beyond microwave frequencies. By actual measurement with standard field strength meters, this vast bandwidth of frequencies and harmonics can be shown. In fact, a bluish glow of "brush discharge" surrounds the antenna when operating. A fluorescent lamp held anywhere within several feet of the subject glows brilliantly. Within this multiple-wave range of frequencies, every cell in the body can find its ONE resonant frequency and absorb energy at its own natural wavelength.

Obviously the Electrostatic energy cannot penetrate the body. This is known as the "skin effect". However, the Electromagnetic component of the energy can and does permeate and will induce an EMF in each cell. It is precisely this energy to which Lakhovsky attributes his almost miraculous "cures".

A word of warning, although no deleterious side effects have ever been reported for human reactions, the MWO has input power exceeding 35 watts. It radiates RF interference over a bandpass of 15 Kilocycles to well beyond 250 Megacycles. The Federal Communications Commission has stiff penalties for unlicensed transmitters and radio and TV interference -- not to mention making all your neighbors very unhappy. We operate our machine in a shielded room, and the battery input prevents RF interference from feeding back into the power line.

The deluxe MWO diagrammed here can be built by any intelligent 16-year old with readily available electronic parts. I do not plan to build, manufacture, sell or otherwise exploit this device, as my interest is purely in research. Several Associates given this circuit have successfully constructed MWOs. We would certainly like to hear from any BSR Associates who undertake this project, but please do not communicate until after building the unit. I cannot correspond over details which any intelligent person would be able to thresh out with his or her own technical friends.

At one stage we had planned constructing a much higher-powered unit but the results with the "portable" are so gratifying that Model Two was shelved. Extensive tests are scheduled with plants and animals, and every effort is being made to remove any element of "suggestion" from results. A physician friend is cooperating with the project by sending a few "problem" patients for test. It is much too soon, however, to make a finished statement concerning the MWO's potential. No cures can be claimed even if obviously demonstrated, since our laws are controlled by medical unions forbidding the use of the word except by MDs. But I have satisfied myself with nearly twenty miracles in these few weeks of tests that the MWO might well be the most promising device to come to light in many years.

I have one request, that no one building this device ever be tempted to charge a fee, donation, or reimbursement of any kind whatsoever for its use. I feel most strongly that any device potentially helpful to suffering humanity should be available completely free of charge to anyone needing it.

CONSTRUCTION TIPS

My MWO is built on an 11 x 11½ inch plastic panel. Components extend 3½ in. below this, so the unit fits nicely into a small attache case. The 6 volt battery was a Sonotone lifetime Nickel Cadmium unit; however, five war-surplus NiCads (1.2 v each) wired in series would be less expensive.

My first unit used a transistorized driver for the Tesla Coil but the Ford coil works equally well, is far cheaper, but has the disadvantage of making a buzzing noise. The Ford Model T coils may still be available at Pep Boys stores in California, or can possibly still be purchased from J.C. Whitney & Co., 1917 Archer Ave., Chicago, IL 60616. The spark gap was made from salvaged tungsten relay contact points about 1/4 in. in diameter. (Chevrolet Six timer points, 1950, do very well). The relay spring arm can be tuned by a Nylon 6-32 screw adjusting its natural spring tension. The gap must be carefully tuned for maximum output for every individual, since the subject's absorption seems dependent on his body fluids and weight. *Adjust for maximum sparking at random times and intervals between several of the inner antenna rings.*

The automatic timer, zero to 15 minutes, the meter, the internal battery charger, the RFC circuits, etc. are all simply conveniences and may be left out of the circuit without in any way subtracting from results. By not building in these deluxe features, the entire MWO will cost much less to build. Use plastic instead of metal screws around the high voltage coils. High voltage capacitors can be tracked down at surplus stores or well stocked electronics parts sources. The Tesla Coil must be hand wound as it is not available commercially.

We have determined experimentally that a workable pair of antennas, radiator and resonator, can consist of 16 concentric rings, ranging from an outside diameter of 10-3/4 inches down to 1/2 inch. These were constructed by cementing a one-foot square of

BECK ADAPTATION OF LAKHOVSKY MULTIPLE-WAVE OSCILLATOR, U.S. Patent #1,962,565

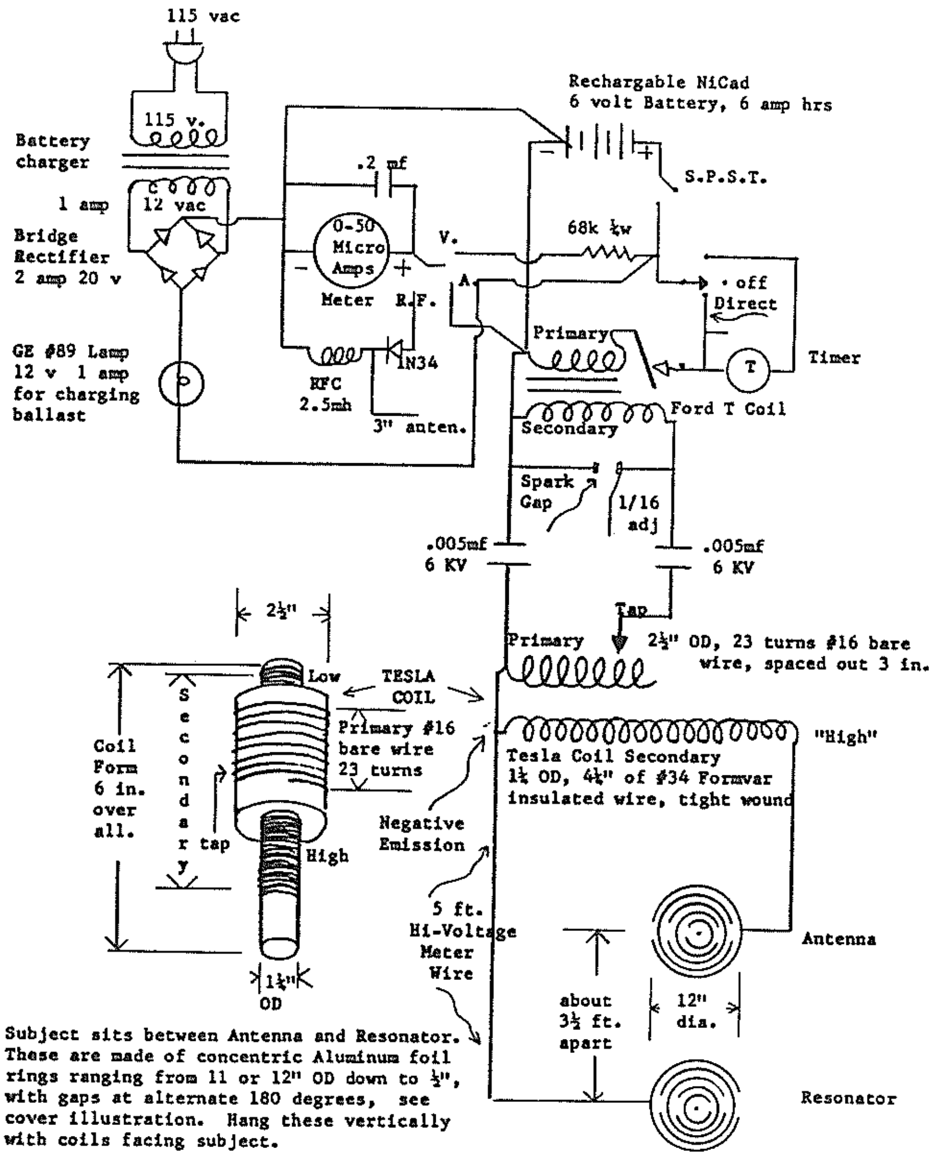
115 vac
115 v.
Battery charger
12 vac
1 amp
Bridge Rectifier 2 amp 20 v
GE #89 Lamp 12 v 1 amp for charging ballast
.2 mf
0-50 Micro Amps
−
+
Meter
R.F.
V.
A
RFC 2.5mh
IN34
3" anten.
Rechargable NiCad 6 volt Battery, 6 amp hrs
−
+
S.P.S.T.
68k ¼w
• off
Direct
Timer
T
Primary
Ford T Coil
Secondary
Spark Gap
1/16 adj
.005mf 6 KV
.005mf 6 KV
Tap
Primary
2½" OD, 23 turns #16 bare wire, spaced out 3 in.
2½"
Low
TESLA COIL
Secondary
Coil Form 6 in. over all.
Primary #16 bare wire 23 turns
tap
High
1¼"
OD
Negative Emission
"High"
Tesla Coil Secondary 1¼ OD, 4¼" of #34 Formvar insulated wire, tight wound
5 ft. Hi-Voltage Meter Wire
Antenna
about 3½ ft. apart
12" dia.
Resonator

Subject sits between Antenna and Resonator. These are made of concentric Aluminum foil rings ranging from 11 or 12" OD down to ½", with gaps at alternate 180 degrees, see cover illustration. Hang these vertically with coils facing subject.

Original cover providing template for aluminum MWO antenna.

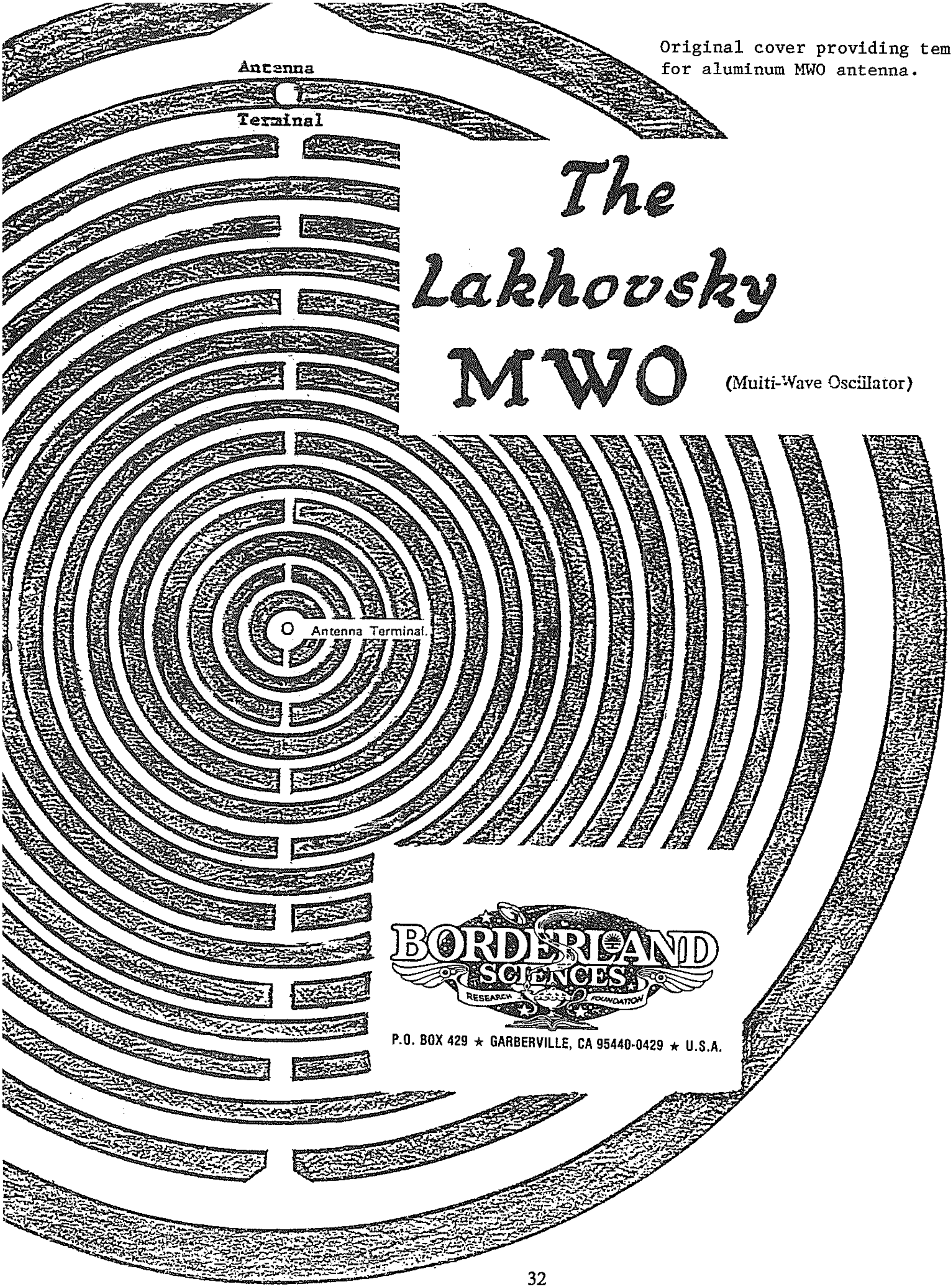
Antenna Terminal
Antenna Terminal.

The Lakhovsky MWO

(Multi-Wave Oscillator)

BORDERLAND SCIENCES RESEARCH FOUNDATION
P.O. BOX 429 ★ GARBERVILLE, CA 95440-0429 ★ U.S.A.

Reynolds kitchen aluminum foil to an 11-inch square of thin fiberglass. The outline of each set of circles was carefully scribed with a sharpened compass, razor or Scripto blade. By scoring or cutting the aluminum foil was cut through to the plastic backing and the waste area strips pulled away before the cement hardened. Excess cement was removed with a solvent. The gaps were then cut with the razor. Note that gaps are alternated in position each 180°, as per drawing on original cover page. This was drawn from an actual antenna and you can set your compass distances for each ring from it. Keep gaps between inner rings narrow to encourage random arcing between rings. Trim the corners from the gaps of the three or four outside rings to discourage fixed arcing at these places. Also be sure to clean away any bits of foil between rings. These also will cause fixed arcing.

In use, the ring second from the outside is connected to the high side of the Tesla secondary. (Refer to "antenna terminal" on original cover page illustration) This is the radiator coil. The arcing from this ring to the outside ring causes the "shock excitation" of the fourteen other antenna elements. Since each radiator is of different diameter, the array spans a broad, multiple-wave segment of the Radio Frequency (RF) spectrum. The other antenna element, called the Resonator, is connected with a five-foot, high-voltage meter wire to the ground side of the Tesla coil secondary.

PUTTING THE MWO TO USE

The antenna and resonator are suspended from non-conductive supports about three feet apart, such as wooden chairs with no nails or screws. The subject of the experiment, preferably with all metal removed from their person, including belt buckles, zippers, hooks, fasteners, coins, hairpins, earrings, rings, etc, is seated on a wooden or plastic rest between the antenna and resonator (hung vertically, the foil rings toward the subject. Unless the Resonator is powered by a separate Tesla Coil it will not arc. Metal on the subject will produce eddy currents in the field of radio frequencies, reducing their effectiveness.) Experiments should last from nine to over 15 minutes. A four-day interval between experiments is recommended. Four such experiments over 16 days should suffice to demonstrate anything.

Warning, two-inch sparks can be drawn from antenna; so keep subject at least three inches away. If touched a mild and harmless sting can be felt. HF effects can be demonstrated in a darkened room by holding a fluorescent lamp anywhere near the subject. The RF energy will cause the lamp to light although no wires are touching it. Field strength measurements read several watts of power from the audio frequency spectrum to beyond 250 megacycles.

The illustration to the right is from Clement's **Waves That Heal**, Lakhovsky's illustration of a living cell. "In the centre is a twisted filament which, possessing self-inductance and capacity, constitutes an oscillating circuit. The similarity to a short-wave circuit is manifest; the filament shown here oscillates like a coil having a very small number of spirals." He quotes Lakhovsky: "Every living being emits radiations", and adds: "the living cell can thus play the part of a transmitter or receiver of exceedingly short radio-electric waves which give rise to high frequency currents in the circuits of the cellular nucleus."

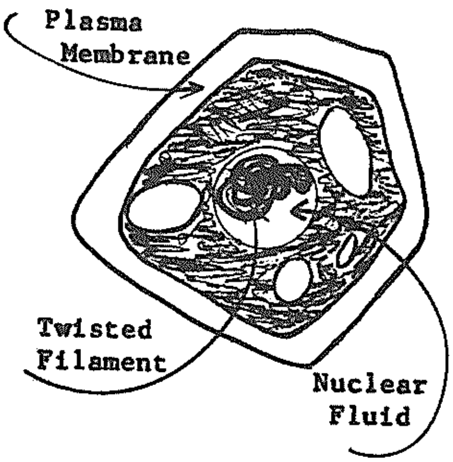

THE FOLLOWING PHOTOS were kindly furnished by Borderland Sciences Research Associates from their own experimental work with the MWO during the years of 1964 and 1965.

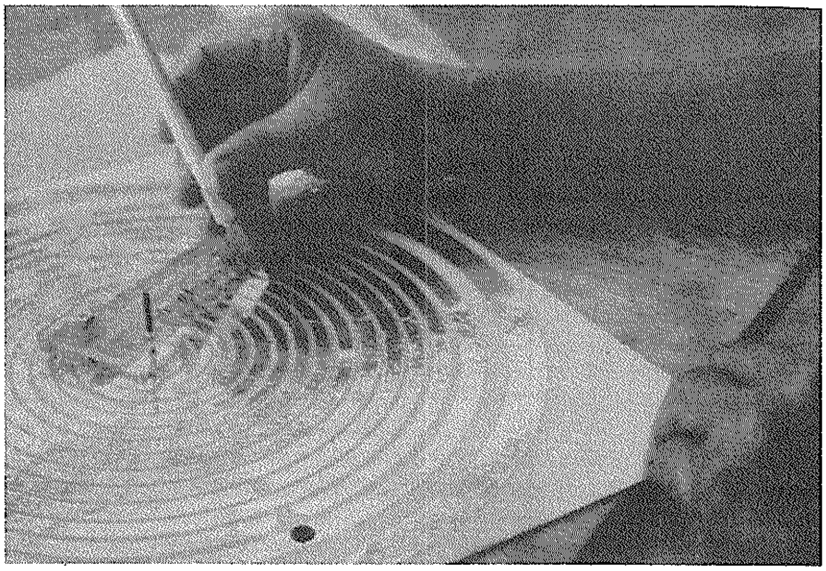

THE PRINTED-CIRCUIT ANTENNA foil is glued to an 11-inch square of 1/16th inch thick fiberglass. Spray one surface of the fiberglass with Hobby Shop spray glue and stretch smooth-surfaced kitchen aluminum foil across it. Press the foil on firmly from the center out, smoothing out repeatedly with a soft cloth. Any remaining air bubbles can be released through a small pin hole. The circles are more easily cut if you make a jig with a 16-inch square of plywood with a headless nail for a center post. Using the antenna pictured on the front cover as a pattern, mark and notch an old ruler or stick where each circular cut is to be made. This marked guide ruler is mounted over the antenna on the plywood jig as shown at right. The foil-covered surface is then turned clockwise with the left hand against the Scripto blade held firmly in the successive notches by the right hand. Be careful to cut through the foil. If you don't, in lifting the cutouts afterward, you may also lift or tear the rings. If a metal grommet is placed in the terminal hole in the second ring this will prevent the high-frequency arc from burning the foil and fiberglass during operation. Copper foil can be used for the printed-circuit antenna rings but deposits build up on it from arcing, wherever it occurs. There is no deposit buildup on aluminum foil.

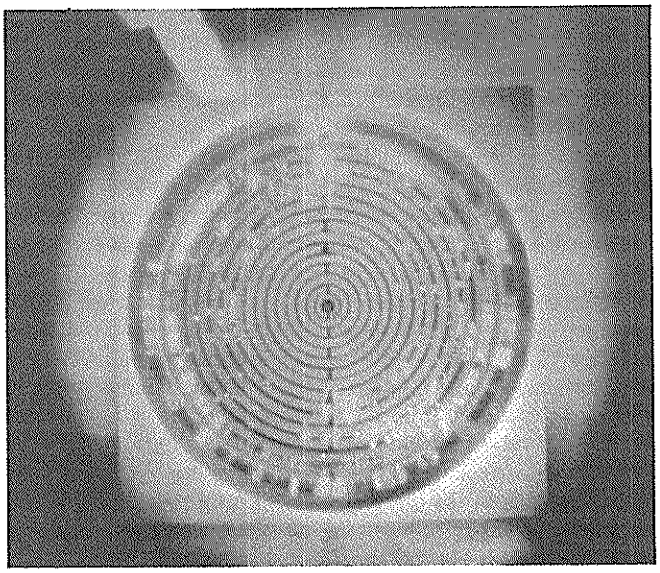

THE RADIANT ENERGY of the MWO is obvious in this three-minute time exposure during operation in a darkened room. Note the brush discharge of etheric energy all along the edge of the outside ring, going three or four inches. Look at the random arcing between the antenna rings, down to the eighth ring! This antenna received full power by being mounted on the MWO case, directly at the positive end of the Tesla Coil.

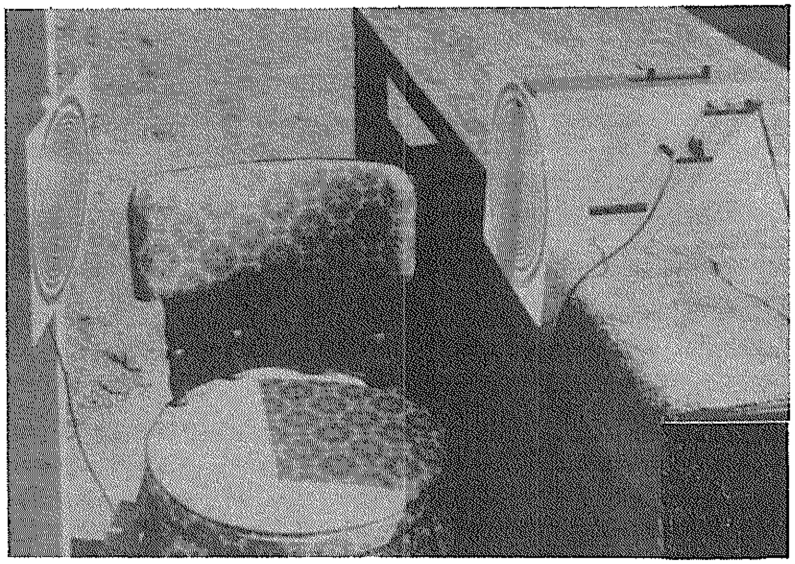

AT LEFT IS A TYPICAL EXPERIMENTAL SETUP, with a chair for "guinea pig" between antenna and resonator. Beck's original equipment called for an 18-inch lead wire from the positive end of the Tesla coil to the antenna. It was found that there was too much loss of power along this wire. The later development shown above has the MWO set upright, with the antenna mounted directly against the positive end of the Tesla Coil in the case.

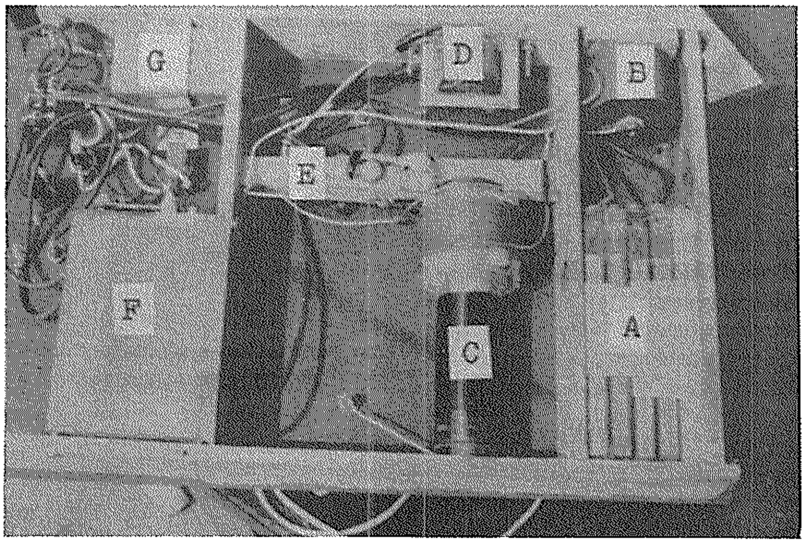

THE INTERIOR HARDWARE LAYOUT is shown at right in this photo of another MWO, neatly packaged for an attache case. A. The five Ni-Cad batteries, 1-1/4 volts each at full power. B. Timer. C. Tesla Coil. D. 115VAC transformer (for house current operation if desired). E. Spark-gap using modified Chevy Six points. F. Model T Ford Coil. G. Battery Charger.

RECTIFYING THE FORD COIL OUTPUT using a 1B3GT or 1G3GT high-voltage tube.

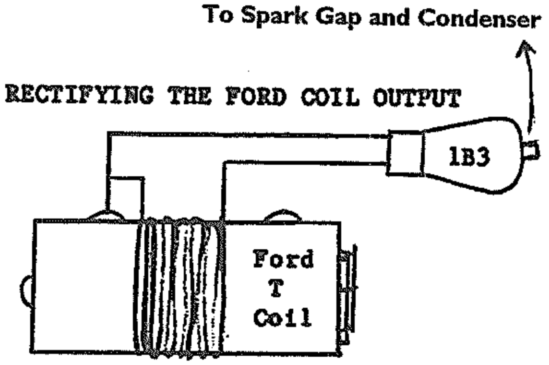

Wind 15 or more turns of fairly heavy insulated copper wire around the middle of the Model T Ford Coil. One lead from the winding goes to the Hi-voltage output of the Coil, and to pin 2 or 7 of the 1B3 tube. The other lead goes to the other pin, as only two pins of the tube, 2 and 7, are used in this hookup. The souped-up or rectified voltage is drawn off the top of the tube to the spark gap and condenser.

MODIFIED VERSION OF THE BECK TESLA COIL

115 volt house current into the black leads of the 6 volt transformer, one green lead to the T Coil negative terminal, the other to an SCR 45 amp Diode to make direct current to the Plus terminal of the T Coil. A 12-volt current to the T Coil heats it up and will not increase the spark. Radio Shack's 6.3 volt, 3 amp transformer does very well for a power supply.

Wrap 16 turns of insulated hookup wire around the middle of the T Coil and feed to pins 2 and 7 of the 1B3 rectifier tube. Feed the plus output of the T Coil into pin 2 or 7 of the 1B3 also.

Hi-voltage from the top of 1B3 goes to Spark plug. Widen gap of plug to 1/8 inch or more for maximum output of Secondary coil to Antenna.

One 10,000 WVDC (Working Volts Direct Current) commercial-type Capacitor, on the plus side, will do very well in this circuit. Capacity can be from .0015 to .005 microfarads.

Beck's tunable Tesla Primary called for 20 or more turns of bare wire for his movable contact but experience shows that 16 turns of insulated #19 wire for a Primary and adjust one turn more or less for maximum spark at Plus end Secondary coil. This is 4-1/4 inches of #34 insulated wire, or 4-3/4 inches of #32 insulated wire, for 420 turns more or less on 1-1/4 inch coil form 6 in. long. The Primary is wound on a 2 or 2½ in. coil form. There should be heavy insulation between Primary and Secondary to prevent power-loss arcing between Coils.

REMEMBER, the goal is a thin blue, or blue-white spark at least 3/4 inch long at the plus end of the Secondary. When fed into the center hole of the Antenna it should light up like a Christmas tree, with arcing between every ring. Feeding the coil output into the center hole gives more power to the shorter wave lengths. We get plenty of the longer wave-lengths from other electrical apparatus and from power lines.

This coil would be a good high-frequency power supply for Kirlian Photography.

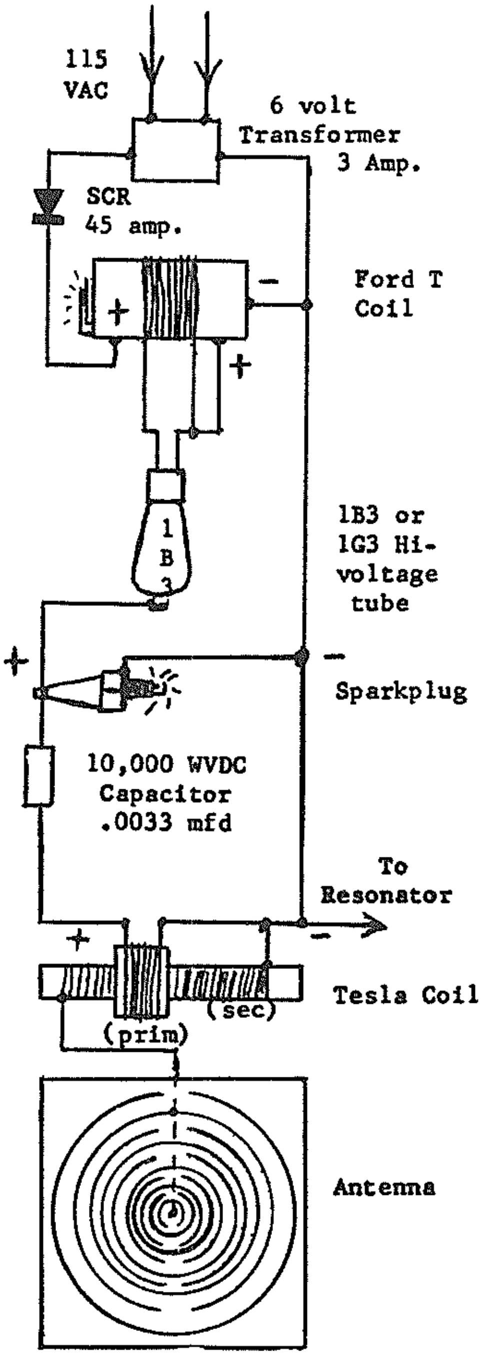

THE TRANSISTORIZED MWO

By Gerald W. Steele

Here is tentative information on the solid-state MWO. I say tentative since this is the 3rd version I've built. The first used an automobile spark coil for T2 but I found this undesirable since it lacked higher frequency harmonics. Even worse, the lower frequency ones could be harmful to living systems.

Version 2 was with a small black and white TV flyback transformer running at a slow (100 pulses per sec.) pulse rate. I eventually sped it up but could never get the required 1" spark from the Tesla coil.

This version uses a color TV flyback and a higher power discharge circuit. Nominal lowest frequency is 1.5 Khz though it could go as low as 270 Hz.

All diodes, SCR, and transistor can be substituted with universal replacement types available at electric part outlets.

As you can see, electronically it is simple. The power metering circuitry in the original MWO can also be used here if desired. I've had enough trouble maximizing the output of this device to worry about monitoring the power.

This device is excellent for use in Kirlian photography several ways: A modified circuit could be used for A, for a wide range of pulse rate settings.

There are two possible voltage sources for Kirlian use, each with unique characteristics. First is the output directly from T2 with or without the Tesla coil circuitry connected. Second is the Tesla coil output itself.

Other modifications include rectifying T2's output. The old MWO manual recommended the use of a tube rectifier out there are solid state types available.

Be sure it is a color TV high voltage rectifier. Connect as shown:

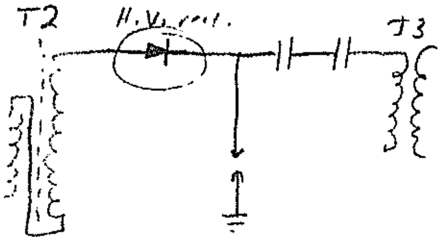

One question may arise in the builders mind: the need to heatsink SCR. No need. Not much heat generated.

Be sure R3 (or combination of resistors forming it) get ventilation. They get hot.

Always short C1 just after turning off power to work on the device. Remove short before reapplying power. The device is perfectly safe if you exercise care. R6 is a safety feature, it discharges C1 when turned off - but still short C1 when servicing, a standard safety procedure.

I am making constant improvements. The alternate values given for R3, C5 may give greater power at a higher pulse rate. I have yet to try them since 225 watt resistors are hard to find and apply. Besides it seems to work quite well as it stands. The only complaint one might have is the cost of construction principally due to the flyback transformer T2. But scavenging could help here.

Enclosing the spark gap in a plastic box could reduce its audible noise level. Ventilation of the spark gap gives more consistent operation. If the spark gap can be physically constructed above R3 the heat will produce air currents giving natural ventilation.

As I said, I am making constant improvements. Its too early to finalize it, but perhaps other associates may be interested in constructing and improving it. The lack of interrupter contacts gives a high level of reliability and consistent output.

Its too early in use for me to comment on its effects except that I think it is quite positive.

CIRCUIT DESCRIPTION:

The circuit consists of: low voltage oscillator, high voltage capacitive discharge generator, and Tesla coil.

The low voltage oscillator consists of Q1 a unijunction transistor operating as a relaxation oscillator. Frequency is variable from 270 Hz to 26 Khz with most power generated at 1500 Hz. VR1 controls this frequency. The DC Power for this circuit comes from a voltage doubler on the power transformer low voltage windings. The low voltage DC value was chosen to be as low as possible with consistent firing of the SCR.

The high DC voltage is rectified and filtered in C1. R1 is surge protection. The high DC voltage charges C5 through R3 until Q1 fires SCR1 whereby C5 is discharged through the primary of flyback transformer T2. D5 protects the SCR from high reverse voltage transients.

The secondary of T2 feeds the adjustable shunt spark gap and then through the Tesla coil resonating capacitors. Two capacitors are used here due to voltage requirements though one 15Kv capacitor could be used. From this point on it is all standard MWO fare.

Transformer T2 is expensive although any used color TV flyback could be tried. In all experimentation or adjustment the goal is maximum spark output at the Tesla coil secondary.

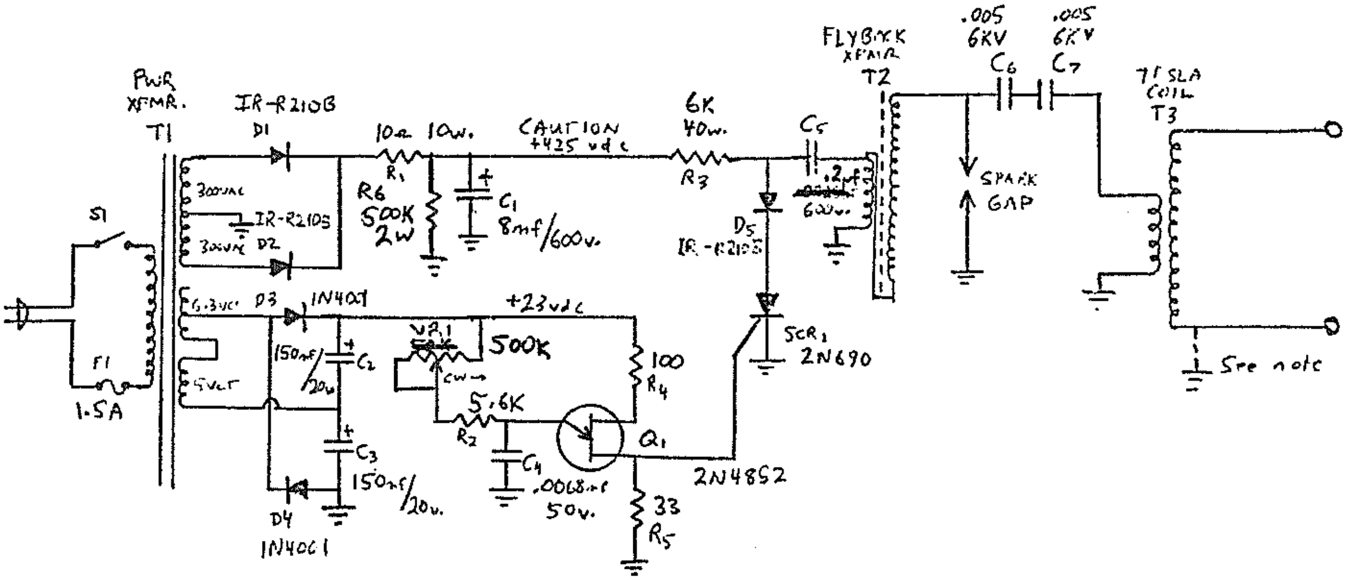
PWR XFMR. T1
IR-R210B D1
10Ω 10w. R1
CAUTION +425 vdc
6K 40w. R3
300vac
IR-R210S
300vac D2
R6 500K 2W
C1 8mf/600v.
S1
F1 1.5A
6.3vac D3 1N4001
+23vdc
VR1 500K
CW
5.6K R2
150mf/20v C2
5vac
C3 150mf/20v.
D4 1N4001
C4 .0068mf 50v.
100 R4
Q1 2N4852
33 R5
C5 .2mf 600v.
D5 IR-R210S
SCR1 2N690
FLYBACK XFMR. T2
.005 6KV C6
.005 6KV C7
SPARK GAP
TESLA COIL T3
See note

Note: Optional ground for Tesla coil secondary, if it reduces output do not use.
R3 made from four 25K 10w resistors in parallel. VR1 linear taper. C1 may or may not be polarized. C6, C7 could be single .0025/15KV capacitor. SCR1, Q1 and all diodes can be standard replacement equivelants.
MFR Type: T1 - TRIAD. T2 - Stancor HO 6246, Thordarson fly.
Alternate values: R3 - 1K ohm, 225 watts; C5 - 1 microfarad, 600v.

THE LAKHOVSKY MULTI-WAVE POWER SUPPLY

by KLARK KENT

Many of us have read the Borderland Sciences Research Foundation (BSRF) publication "The Lakhovsky MWO" in which electrical wizard Bob Beck astounds us with tales of wonder. He tells how he was informed of the location of an old Lakhovsky Multi-Wave Oscillator that had been declared "unfathomable". He was able to reconstruct the circuits and after several hours the machine worked perfectly!

Mr. Beck and fellow experimenter Ed Skilling designed and built a modern version of the MWO based upon Nikola Tesla's and Lakhovsky's original works and patents. Georges Lakhovsky, a herald of the New Age, was no doubt a skilled experimenter and investigator of the Life Energy. This is evident by his practical application of Nikola Tesla's famous coil.

Super Science has updated both Lakhovksy's original and Bob Beck's adaptation of the Multi-Wave Oscillator. Looking at the schematic diagram in Bob Beck's article, we will eliminate everything but the 12 volt battery (or 12 volt power supply), switch, Model T Ford Coil, high voltage capacitors, and the Tesla Coil. A large high voltage diode is added to rectify the output of the Model T Ford coil which leaves us with a stripped down but thoroughly functional MWO power supply.

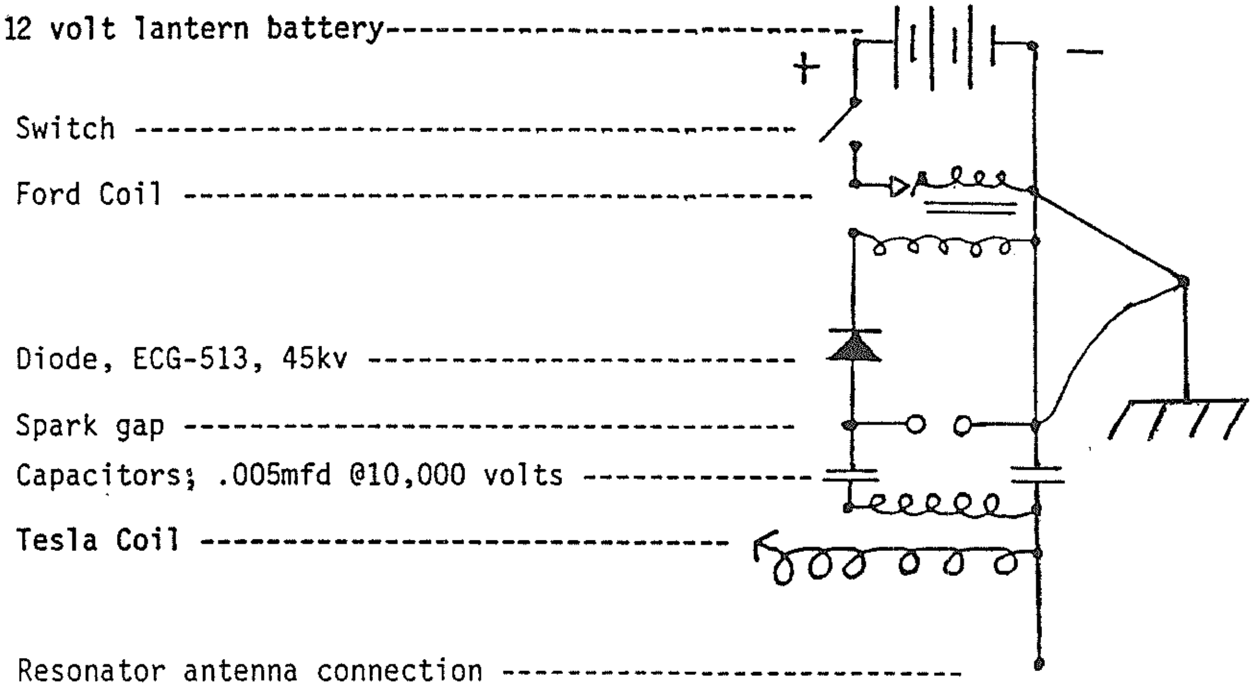

Before proceeding further, let's remember that the MWO is an experimental device and not for any healing or medical purposes! All experimenters should be in at least reasonably good health when building or experimenting with this high voltage, high frequency Tesla Coil Multi-Wave Oscillator power supply.

LET'S BUILD!

To begin our MWO Tesla Coil power supply project, we can round up the needed parts and components. Basic parts list:

-12 volt power supply; this can be a 12 volt lantern battery available from Radio Shack or any plug in power supply rated from approx 2 to 7 amperes.

-Model T Ford Coil; these old time induction coils are still available from J.C. Whitney Co, 1917 Archer Ave, PO Box 8410, Chicago, IL 60680. The MWO power supply will work adequately with the Model T Ford coil but a transistorized driver for a modern "hot rod" auto ignition coil will produce a Tesla Coil power supply with far more power!

-Switch; the on/off switch can be of any type. There is a switch already present on the plug in 12 volt power supply. I prefer to add a second switch of the key type, which prevents unauthorized use of the unit and a piece of vinyl tubing can be fitted over the metal key to create an insulated switch (this is important when turning the unit off).

-Diode, ECG-513 at 45 KV. The diode rectifies the output from the Model T Ford coil or the auto ignition coil by taking out the stray ac signals. This diode is a high voltage device rated at 45 Kilovolts (45 KV) peak inverse voltage.

-Spark Gap; an ordinary spark plug works adequately in this application. Try wrapping the spark plug in a large piece of vinyl tubing to insulate the spark gap. For a better spark gap, use a set of tungsten points. Chevy 6 cylinder 1965 model year works well to fabricate an adjustable gap.

-Capacitors; .005 mfd and rated at least at 10 KV (20 KV is better). We buy our capacitors or make them ourselves. I prefer to buy them. Check with your local electronic supply house to special order these high voltage capacitors; they will not be cheap... An alternative is to scrounge the local surplus stores to fabricate high voltage capacitors from several capacitors of a lower rating. It is easy to round up some 2500 wvdc capacitors with a 5000 volt test rating and .005 mfd capacitance. Wire the capacitors together in a series/parallel arrangement to arrive at the desired value. Series connections add the voltage rating and lessen the capacitance by division of the total number of capacitors in the series. Thus four capacitors rated at 5000 volts wired together in series yield one 20,000 volt capacitor. If the capacitance was originally .005 mfd each, now it will be .00125 mfd for the series. Thus we need to connect four of the series capacitors together in a parallel arrangement to create one 20 KV capacitor at .005 mfd. Parallel connections have no effect on the voltage rating but parallel connections add the capacitance of each individual capacitor.

CAUTION! Capacitors store electrical energy and can shock even when unit is turned off. Be sure to discharge the capacitors before touching them...

TESLA COIL

We make the Tesla Coil ourselves using the basic parameters worked out by Bob Beck in his original MWO adaptation from Georges Lakhovsky. The Super Science Tesla Coil is a close coupled, liquid filled coil that produces a 3" spark discharge when driven by a Darlington transistor and "hot rod" auto ignition coil setup.
For making the Tesla Coil, I like to use pvc pipe for the secondary coil form and acrylic tube for the primary coil form. The acrylic is transparent which permits visual inspection of the interior of the coil to observe any corona leakage or malfunction.

For the secondary winding: cut a 1 1/4" outside diameter piece of pvc pipe seven inches long. For the primary winding: cut a 2 1/2" outside diameter piece of clear acrylic tubing (1/4" wall thickness) seven inches long. Wind the secondary coil form with #32 gauge bare enameled copper wire so that the turns are tightly packed to create a winding approx six inches long with a 1/2" gap at either end. Wind the primary coil form with #14 gauge stranded and insulated copper wire. Wind exactly 18 turns and tightly pack them together. The vinyl insulation on the #14 gauge stranded wire will provide the correct spacing between turns.

Place the secondary winding inside the primary winding and use Super glue to hold the windings in place. For the terminals of the windings, use ordinary banana jacks to create a modular coil with a standard banana plug connector system. There will be tremendous electrical stress between the primary and secondary windings. We could reduce this dialetric stress by using a pancake style primary winding, but the pancake style primary takes up a lot of room. To solve the dialetric breakdown between the two windings, we insulate the space with liquid mineral oil. The liquid mineral oil is self healing should a dialetric breakdown occur. Solid forms of insulation such as paraffin wax are useless once a short circuit path has been created between the two windings.

To use the mineral oil insulation system, finish the coil first. Then drill a small hole in one end and squirt the oil in using a squeeze bottle. Then seal the hole using a piece of acrylic and Super glue. A word about Super Glue! This stuff is quite remarkable and is sold in hobby shops that specialize in flying, gas powered, model airplanes. Use accelerator to fast dry the glue. The brand name of the Super glue is "Gap Filler" and the accelerator is "Insta Set" both made by Bob Smith Industries.

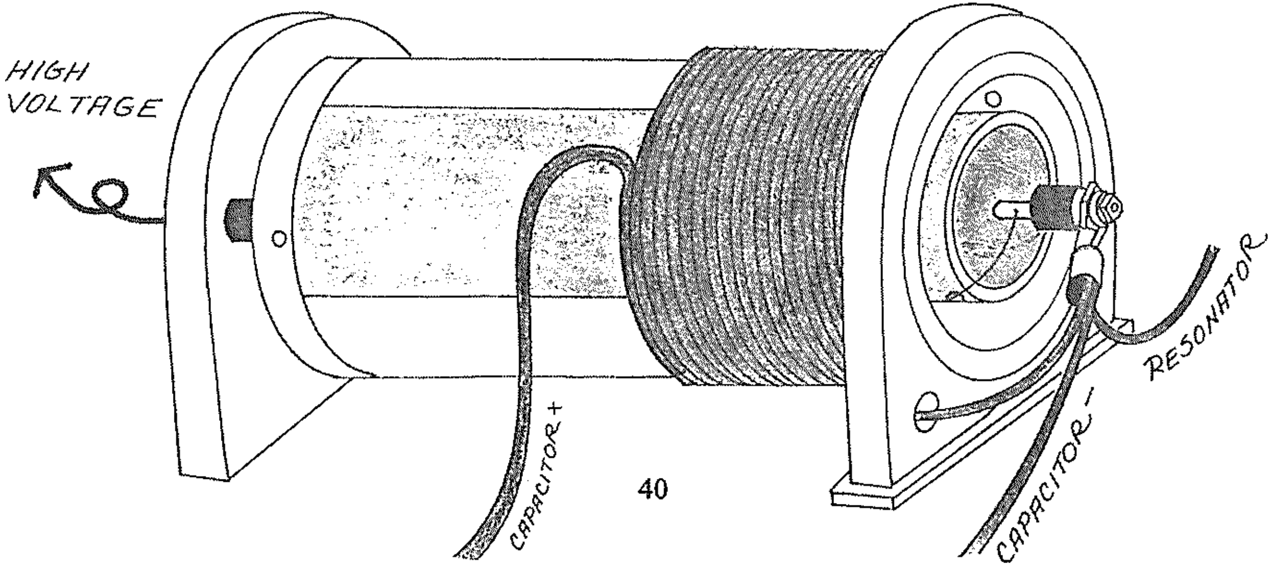

SPARK GAP

Even though an ordinary spark plug will work for a spark gap, we can do much better with an adjustable spark gap made from a set of tungsten auto ignition points. Chevy six cylinder, vintage 1960's are fine. To fabricate the adjustable spark gap, cut the base plate of the point assembly into two parts; make the cut near the spot where the two tungsten contacts normally meet. You should now have two base sections, with a contact point on each section. The reason we cut the base plate is to prevent the high voltage from jumping from the connections to the base and bypassing the breaker points. File down any sharp points where the base was cut. Mount the two tungsten points in such a way that the contact points barely touch each other and the base sections are as far apart as possible. Mount the spark gap assembly on a small piece of acrylic sheet. Wood is not suitable to mount the spark gap because the high voltage current will pass right through the wood base, possibly setting it on fire! Use a large nylon bolt to mechanically adjust the points. Mount the nylon bolt (Toilet seat bolts work well) in the side of the briefcase so that it butts against the spring loaded contact arm; this acts as a spark gap adjuster.

The advantage with an adjustable spark gap is that we can tune the gap while the MWO is in operation. The closer the two tungsten points are to each other, the faster the frequency of the spark jumping the gap. The further apart, the slower the frequency of the spark jumping the gap. Typically the Violet Ray Bulb Assembly calls for a fast frequency spark gap setting; while the High Power Radiator Antenna or Golden Ratio Antenna call for a wider gap spark setting to produce more power.

One side of the spark gap points will be at "ground" potential; while the other side will be at "high voltage" potential. Leave a metal discharge point exposed on the high voltage side of the spark gap assembly. We do this so that the entire MWO power supply may be discharged with a test wire running from the Ground Bus to the high voltage point. This provides a quick way to discharge the capacitors before troubleshooting the unit. Also, cover the spark gap assembly with a visual block made from translucent acrylic. This visual screen will block the ultraviolet light emitted by the spark jumping the gap. Leave the sides of the spark gap assembly open to allow circulation of air around the points; this will "quench" the spark gap and prevent the jumping spark from turning into a constant arc. Also, mount the cooling fan air intake near or directly above the spark gap assembly; this will serve to further quench the gap for better, more bouncy performance...

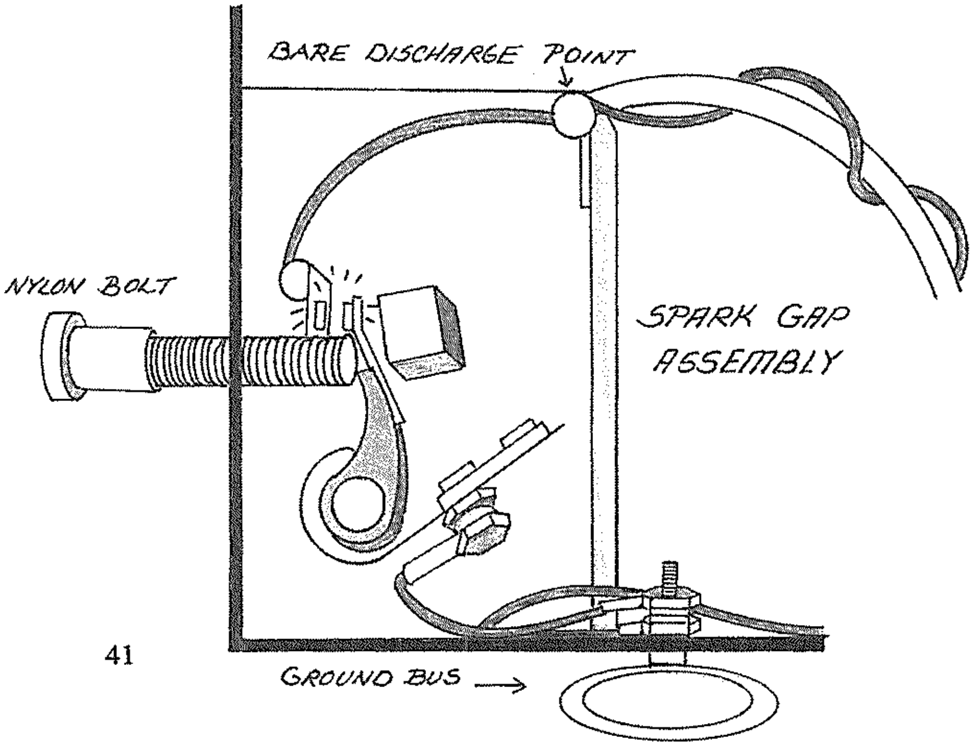

555 TIMER AND TRANSISTORIZED DRIVER

Even though the Model T Ford coil works adequately to power the MWO Tesla Coil power supply, we can really do better with a modern "hot rod" auto ignition coil. Mallory makes an aftermarket coil for drag racing that puts out approx 45 KV. The "MSD Blaster" is another aftermarket auto ignition coil that really gets the job done. Even an ordinary UC-15 replacement coil with its 30 KV rating will outperform the Model T Ford coil.

However there is one consideration to using an auto ignition coil as the primary high voltage source. Since we are working with 12 volts direct current, we need to interrupt or chop the 12 volts going into the auto coil to enable it to function as a transformer. The Model T Ford coil had a built in interrupter for this purpose. We will make a much better interrupter from a 555 timer chip and a high power Darlington transistor. The 555 timer chip will chop or interrupt the 12 volts going into the auto ignition coil from 130 times per second to 1300 times per second while the Darlington transistor handles the power. With the Model T Ford coil we were stuck with the fixed frequency of the interrupter (approx 200 Hz). With the 555 timer system, we can tune the frequency of the primary high voltage from 130 Hz to 1300 Hz. This really makes a difference when we try to get maximum performance from our Tesla Coil when it is driving the MWO Golden Ratio Radiator Antenna or driving the Violet Ray Bulb Assembly for direct stimulation.

Below is the schematic for the 555 Timer/Transistor Assembly. It is shown hooked up to the auto ignition coil. You can hardwire this circuit using a Radio Shack #276-162 project board. I use a large heatsink to mount the Darlington transistor (RCA 8766) and to mount the 50K ohm tuning potentiometer. When the MWO power supply is housed in a briefcase, the shaft of the 50K ohm potentiometer can extend through a hole in the side of the case. Go ahead & slip a short piece of vinyl tubing over the potentiometer shaft both to extend the shaft and to insulate it from high voltage.

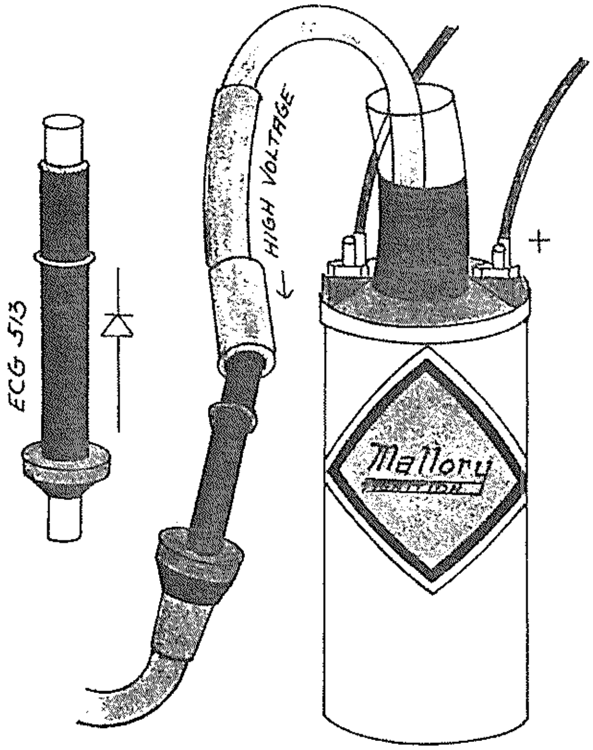

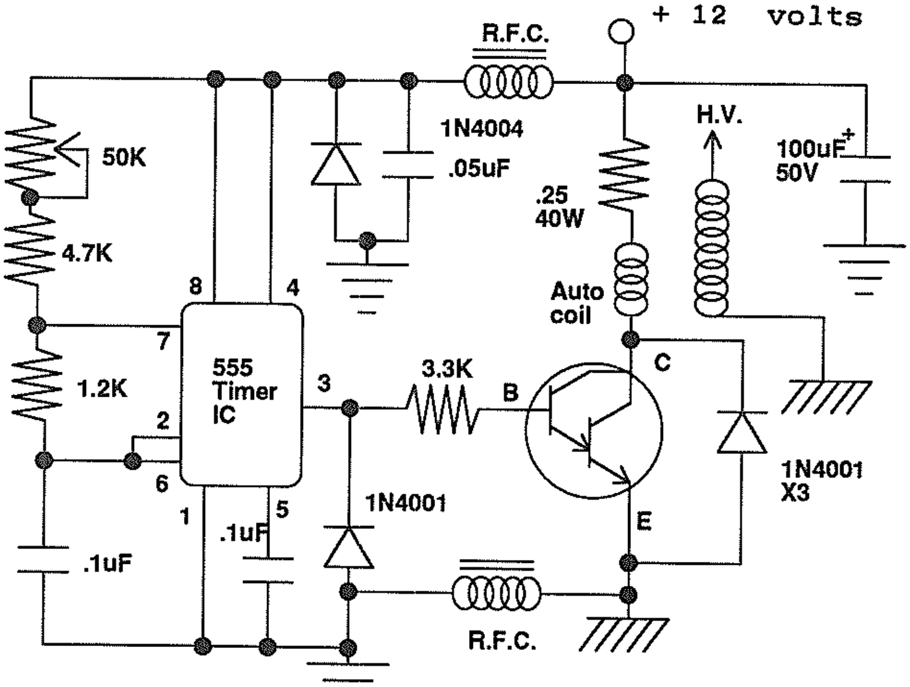

GROUND BUS

An external Ground Bus is important because it lets us reference the high voltage to the zero potential of the Earth itself. Without a true Earth ground, the negative side of the circuit can pick up a substantial voltage by induction from the high voltage potentials in the circuit. This condition is known as a "floating ground" and could result in the experimenter getting shocked. The shock itself is harmless, but the surprise that an accidental shock causes may lead the experimenter to jump back and bump his head! The Ground Bus may be connected by a long wire to a cold water pipe or to a steel fence post or to a piece of rebar driven into the ground. The Ground Bus is a handy reference point when discharging the circuit before troubleshooting.

SAFETY

Try to follow the "one hand rule" when actively adjusting the live high voltage circuit. This means keep one hand in your pocket or one hand behind your back. If an accidental shock should occur, then the electrical current does not travel across the heart when the experimenter follows the "one hand rule". Another safety procedure is to use a 12 volt lantern battery to power the circuit while it is still under construction. Once all the problems have been solved, then a more powerful 12 volt supply can be used.

TESTING THE CIRCUIT

Let the circuit run in darkness and try to observe any corona leaking from exposed high voltage points. There are two good and easy ways to stop high voltage leaks. One method is ordinary vinyl tubing: wrap wires carrying high voltage in vinyl tubing to absolutely stop them from leaking power robbing corona. Auto parts store sell expensive spark plug wire which will withstand the high voltages we are dealing with. If you use spark plug wire, be sure that it is metal wire, not "radio suppressor" wire (it's carbon fiber and impossible to solder or connect to).

Another good method of insulating high voltage is 100% silicone clear caulk! With your caulking gun, apply some 100% silicone clear caulking to exposed wires, exposed high voltage points and other places where you can observe leaking high voltage corona.

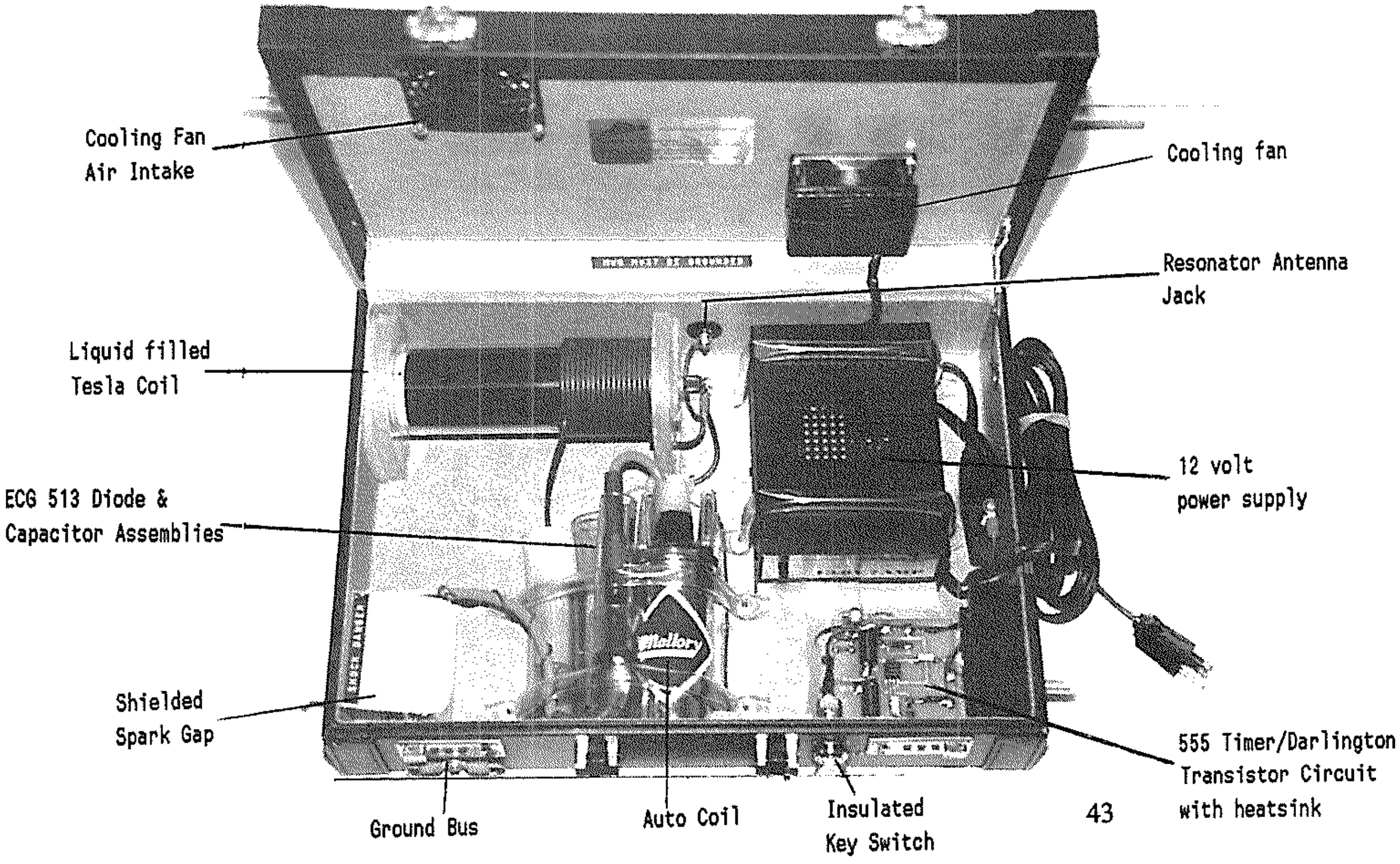
Cooling Fan Air Intake
Cooling fan
Resonator Antenna Jack
Liquid filled Tesla Coil
12 volt power supply
ECG 513 Diode & Capacitor Assemblies
Shielded Spark Gap
555 Timer/Darlington Transistor Circuit with heatsink
Ground Bus
Auto Coil
Insulated Key Switch

LAKHOVSKY MULTI-WAVE OSCILLATOR.

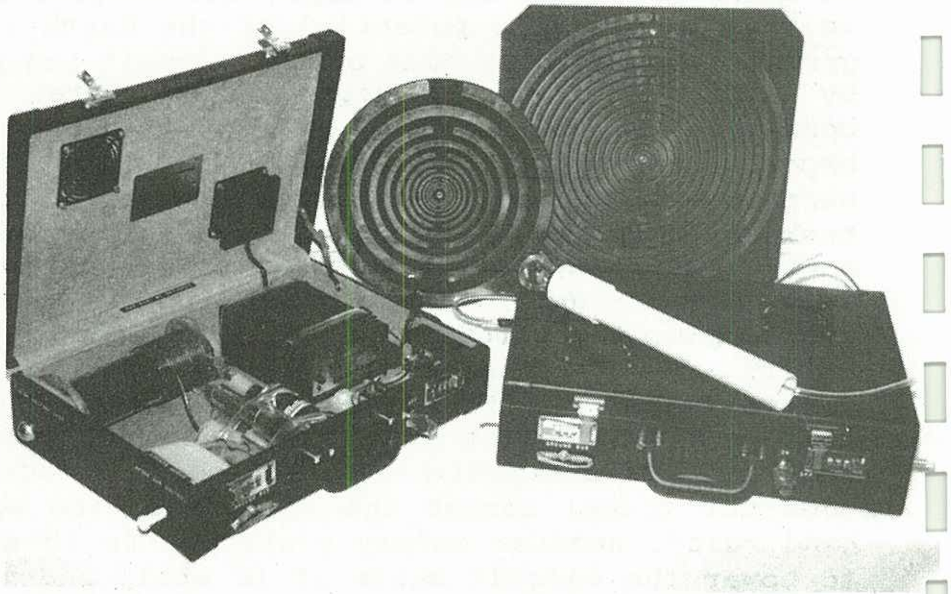

HOW IT WORKS:
The MWO sets up a high voltage oscillating electromagnetic field between the two antennas. Experimental subject sits or stands in this field and every cell in the body is exposed to the resonant effect of the multiple waves. Just as one guitar string will sound when exposed to its resonant tone; so will each cell vibrate to its own natural frequency!

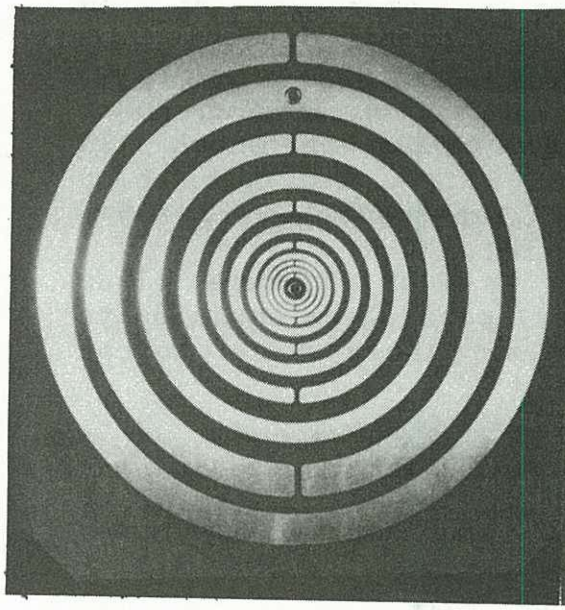

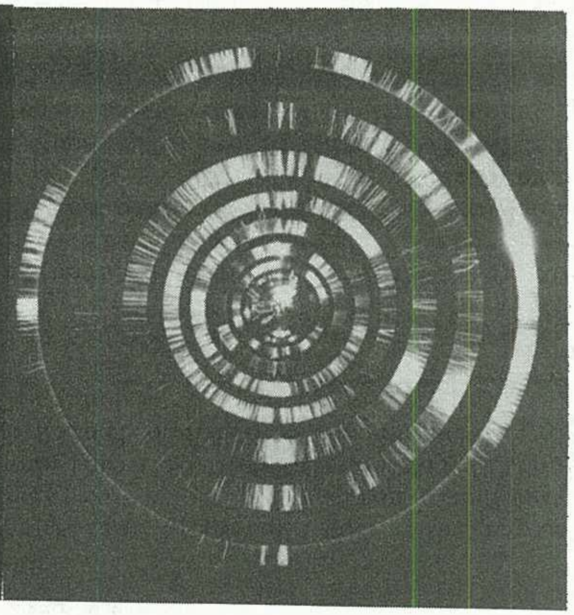

In this time lapse photo, we can see the dramatic effect of the high voltage excitation of each ring of the MWO antenna! Each ring radiates at its characteristic wavelength and frequency to cover a range from approx 200 Hz to 14 Giga Hz!

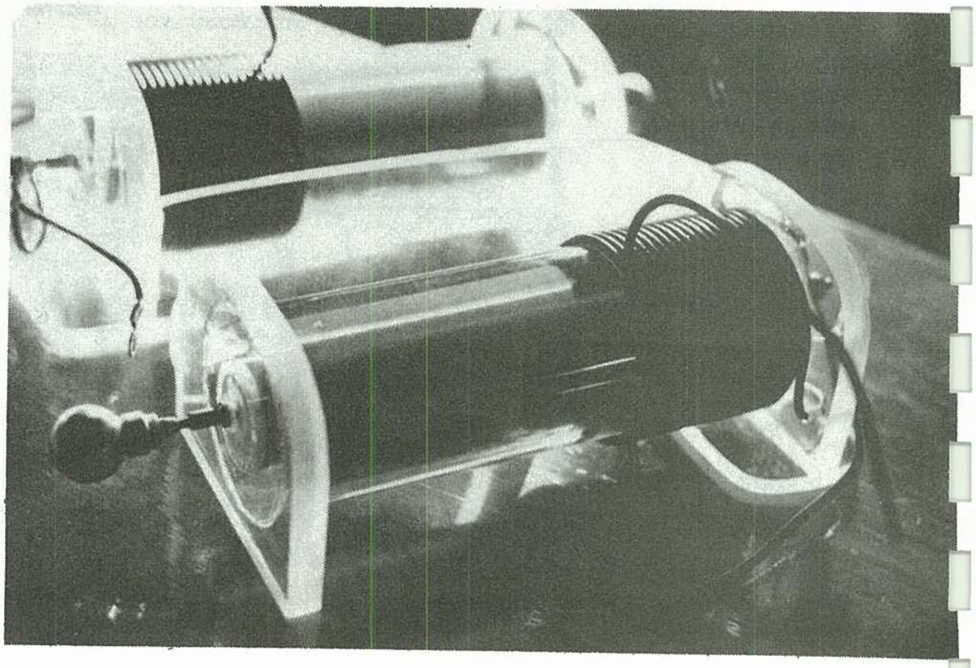

Modular construction works well for the Tesla Coil in the Super Science MWO power supply. This high voltage Tesla Coil can produce a 3" spark discharge from the smooth HV Discharge Terminal! The unit is a versatile experimenter's kit that can be used for Kirlian photography, or to create a plasma of Argon gas in the Violet Ray Bulb Assembly.

SUPER SCIENCE
P.O. Box 392
Dayton, Ohio 45409
(513) 298-7116

ANTENNA HOOKUP

Experimental subject is placed within the oscillating electrostatic field between the two antennas which are approx 4 to 6 feet apart. All metal such as heavy belt buckles is removed from the body. Clothes are optional. Sessions should last approx 20 minutes; skip at least one day between sessions to allow the body a chance to detoxify.
With the Golden Ratio Radiator Antenna, the use of the second Resonator is not required due to the unique "Scalar" properties of this design.

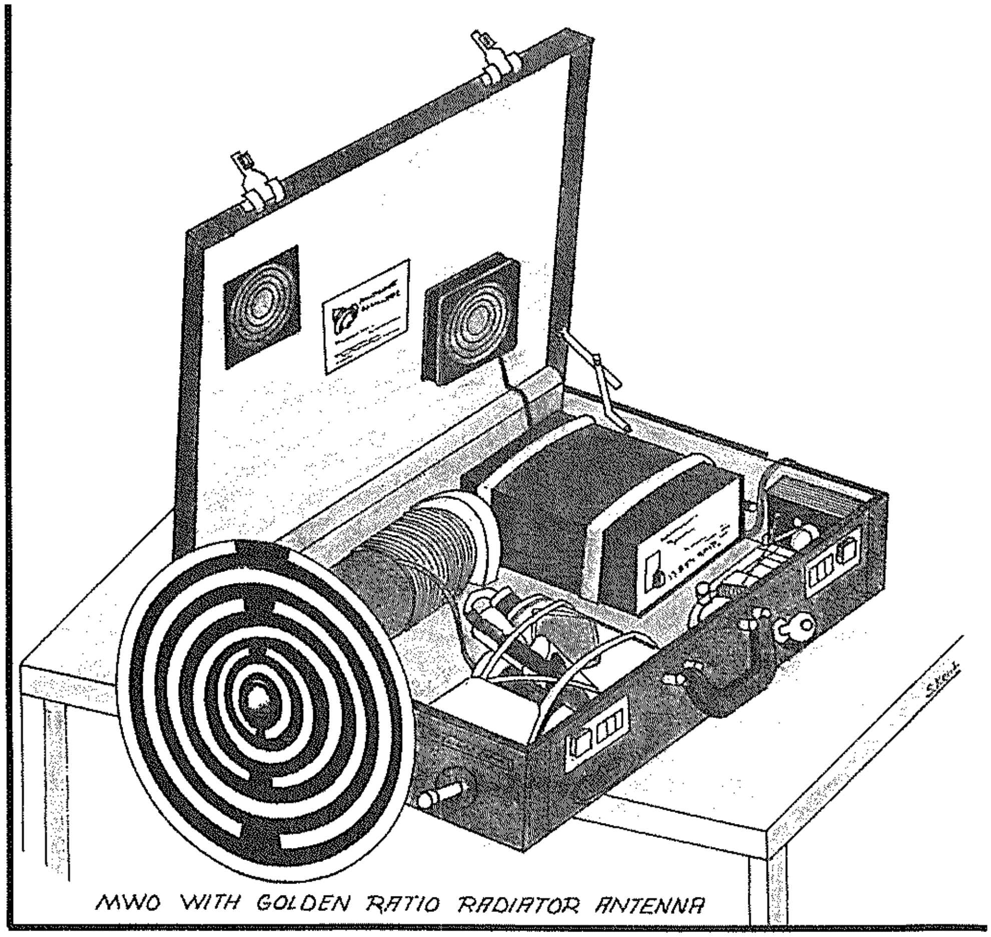

MWO WITH GOLDEN RATIO RADIATOR ANTENNA

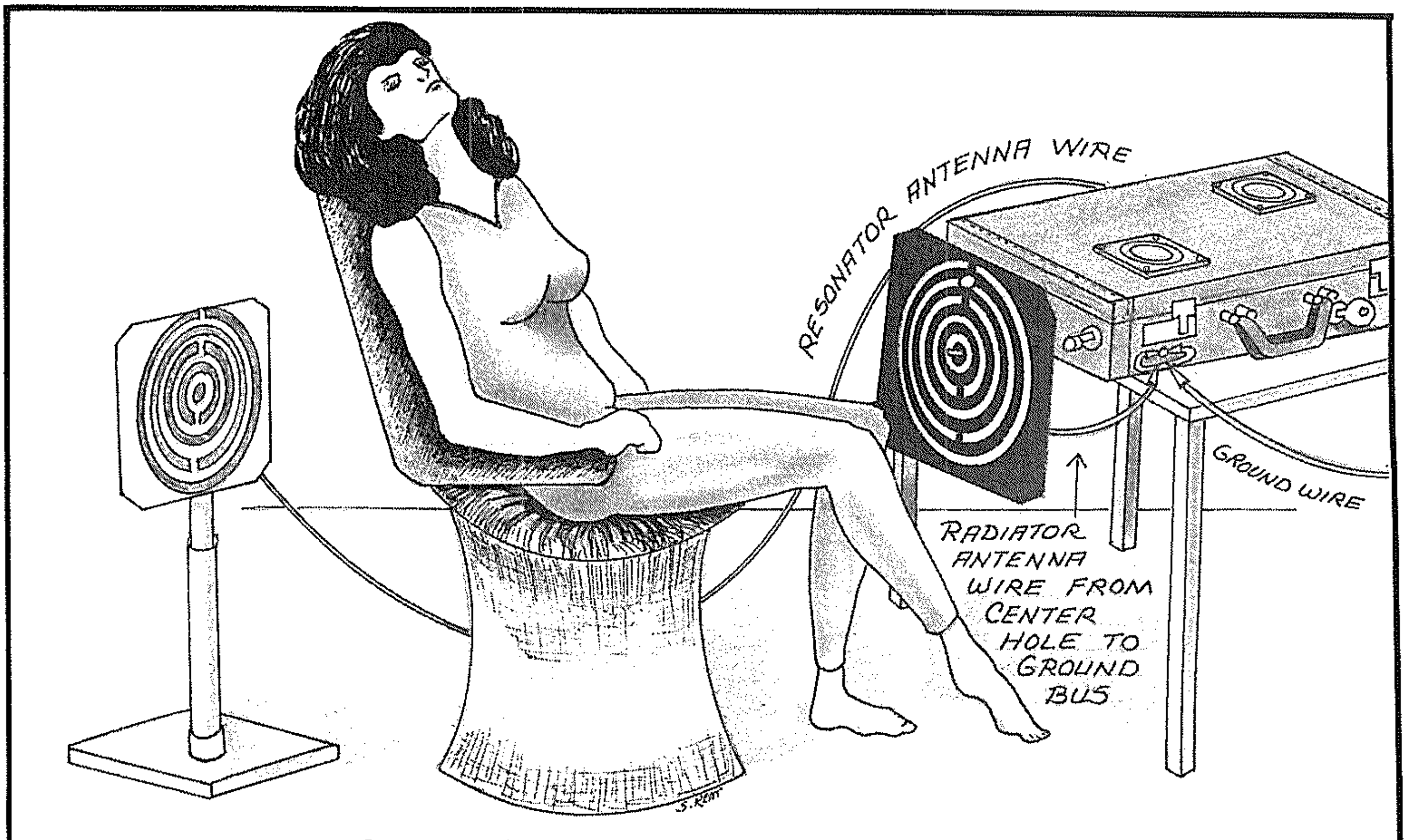
RESONATOR ANTENNA WIRE
GROUND WIRE
RADIATOR ANTENNA WIRE FROM CENTER HOLE TO GROUND BUS

MWO WITH HIGH POWER RADIATOR ANTENNA AND RESONATOR ANTENNA

From the December 1963 Journal of Borderland Research
Excerpts from:

THE WAVES THAT HEAL

The New Science of Radiobiology

by Mark Clement

edited with commentary by Riley Hansard Crabb

Bob Beck has loaned us a copy of the late Mark Clement's brief, illustrated review of Georges Lakhovsky's Multiple Wave Oscillator showing pictures of antennas, before-and-after skin cancers apparently cured by the Oscillator, and of cancerous plants returned to normal health by two means: 1. Radio-Cellular Oscillator, and 2. Single Wire Oscillating Circuits.

"On the day Hitler's mechanized hordes drove into Prague a book was published in London entitled **The Secret of Life** by Georges Lakhovsky, a Russian-born engineer resident of Paris. The book had previously appeared in French, German, Italian and Spanish translations and Lakhovsky's theories were well known on the Continent long before the English Translation was published.

"The evil designs of the Nazis soon gave rise to depressing repercussions in all spheres of human activity and Lakhovsky's remarkable work was left virtually unnoticed in this country (England) by the medical profession and the public alike. A few discerning critics, however, expressed their views with appreciative understanding. The Hospital said 'Lakhovsky's theories are so interesting from the point of view of future developments that it will repay any keen hospital officer to give them his close attention.' Science Forum said 'The admirable translation of Lakhovsky's **The Secret of Life** will be heartily welcomed in progressive circles. The general theory is one which physicists, biologists and medical men cannot afford to ignore.' But these were voices in the wilderness and the field for experimental investigation was left open to a few amateurs devoid of scientific training and lacking the necessary resources.

"The impartial investigation of claims of cure of various diseases by un-orthodox methods demands high qualities of mind and character possessed by very few men indeed. Scientific truth is no respecter of persons or of vested interests, and Lakhovsky's spectacular results in the treatment of plants and animals and human beings were inevitably bound to antagonize orthodox practitioners and exponents of popular medical cults.

"On the Continent Lakhovsky's work attracted a great deal of attention in scientific circles, particularly in Germany and Italy. Italian investigators were among the first to study Lakhovsky's theories and put them to the test in laboratories and clinics. It was, of course, to be expected that the new science of Radiobiology should make a special appeal to the intellectual heirs of Galvani, Volta and Marconi. It is somewhat depressing to observe that in England, the country of Faraday and Clerk Maxwell, Lakhovsky's theories have not yet received the attention they deserve.

REGENERATING OSCILLATING CIRCUITS

"Lakhovsky has been criticized by physicists ignorant of biology and by biologists ignorant of physics! These self-appointed censors of knowledge soon found they were confronted with a redoubtable opponent who fully realized the value of experimental evidence. Its publication resulted in causing annoyance to the custodians of infallible doctrines who made up with carping verbiage what they lacked in clarity of vision. But Lakhovsky's achievements with his oscillating circuits supported by astonishing photographs of regenerated tissues in plants and human beings could not be exploded by mere verbal fireworks, and as evidence accumulated the skepticism of hostile critics relapsed into morose silence.

"The indisputable fact remains that Lakhovsky was the first experimenter to make use of high frequency electro-magnetic waves in the domain of biology. Thus out of the application of radio-electricity to biology his work developed and gradually established the foundations of the new science of Radiobiology. The first international Congress of Radiobiology was held in Venice in 1934. A leading authority on electro-therapy, the late Dr. E.P. Cumberbatch, wrote: 'Although it had been frequently observed that the short Hertzian waves could produce heat at a distance from the transmitter the first scientific investigation from a biological point of view was made by Lakhovsky and his colleagues who published a paper in 1924 on the effects of very short waves on cancer in plants...'

"When France was occupied by German troops, Lakhovsky, being a prominent anti-Nazi, decided to leave Paris and made his way to New York where he died in 1942 at the age of 73.

"In the United States Lakhovsky's theories were put to the practical test with typical American speed. Noticing that patients treated with Lakhovsky's Multiple Wave Oscillator showed signs of rejuvenating appearance, the possibility of exploiting this side-effect proved irresistible to an enterprising 'beautician'. A film was made featuring cases after treatment with Lakhovsky's MWO, which proved to be both interesting and convincing.

"In New York Lakhovsky was approached by several hospitals with a view to testing his apparatus experimentally. The remarkable results obtained . . . in a large New York City hospital, and also by a prominent Brooklyn urologist are fully set out in the text.

"In this country (England), owing mainly to the inauspicious time at which Lakhovsky's major work was published, very little interest has been shown on the part of those best qualified to judge its merits. The medical profession, whose conservatism is the most formidable barrier to progress, has been notoriously slack in investigating the new radio-electrical methods of treating disease as originated by Lakhovsky...."

Mark Clement's observation on the formidable conservatism of the medical profession in 1949 is still true today. Effective electronic diagnosis and treatment of disease is still a closed door here in America as far as the AMA is concerned. Those brave MDs who have tried to keep medical practice abreast of developments in electronic science have been discouraged, if not actually driven out of practice. Dr Abrams is a good example, with his Oscilloclast, developed and proven effective in San Francisco about the time Lakhovsky was developing the MWO in Paris in the 1920s. Radical innovations in any line of endeavor are usually thought up and proven by rank outsiders. Georges Lakhovsky was no doctor, but an electrical engineer!

Doctors, with their own pharmacies and with massive investments in the drug industry, are not likely to show much interest in radical new ways for treating human ailments, especially if the new way is a threat to profitable practice; and, as long as Americans think they can buy health in a pill or a shot in the fanny, doctors will continue to treat them with poisonous drugs at top prices. This is good business.

BORDERLAND RESEARCH

But for those of us who would like to keep our bodies as uncontaminated -- and as healthy -- as possible, Lakhovsky's theories

It is highly significant that about the only rays and ray machines approved for general use by the American Medical Association are the destructive ones of X-rays and atomic radiation for the mis-treatment of cancer.

“Since Lakhovsky's oscillating circuits were first used for the treatment of cancerous geraniums, an experiment fully described in communications to the French Academy of Science, the same method has been successfully applied in Continental hospitals and nursing homes.”

Photos of the successful treatment of cancerous geranium plants are included in Clement's book, along with the pictures of the disappearing skin cancers in human beings. So Clement describes the major features of Lakhovsky's work in this first chapter, the simple, one-coil Oscillating Circuit powered by cosmic rays, and the electric-powered Multiple Wave Oscillator. There are photos of the Multiple Wave Oscillator, showing clearly the unique circular antennas. These were made of metal tubing, separated and suspended with silk thread. The simpler, aluminum-foil printed circuit in Bob Beck's adaptation is an easy way to experiment with the idea.

THE OSCILLATING CIRCUIT

“The diagram on this page shows where the oscillating circuits should be worn, i.e. round the neck, waist, and above the elbows and knees. The effect is intensified if more than one circuit is worn. Generally speaking, the neck and waist are the favoured sites and likely to bring about the best results.

“In the light of Lakhovsky's theories the fight between the living organism and microbes is fundamentally a ‘war of radiations’. If the radiations of the microbe win the cell ceases to oscillate and death is the ultimate result. If, on the other hand, radiations of the cell gain the ascendant the microbe is killed and health is preserved.

THE SECRET OF LIFE (AT THE FORM LEVEL)

“Broadly speaking, health is equivalent to oscillatory equilibrium of living cells whereas disease is characterized by oscillatory dis-equilibrium. This general principle has given rise to a vast number of experiments covering the whole field of biology. Plants, animals and human beings have been successfully treated by the application of Lakhovsky's oscillating circuits and the reader is referred to his major work The Secret of Life for a full discussion of this important subject.

Those of you who have been studying the Kabala with Mrs. Crabb and me must have been struck immediately by the metaphysical soundness of Lakhovsky's basic theory expressed above. One wonders if this Russian escapee from Communism, and from Naziism, wasn't indeed a student of the Western Mystery Tradition, perhaps even an Initiate! The Tree of Life is the groundplan of our Tradition. On the Tree we show the descent and the ascent of power, oscillating back and forth from left to right and right to left across the Middle Pillar, or balance point.

Now for the final paragraph of Chapter One. “During recent years observations on the part of several investigators have established the fact that most animals, including insects and birds, emit radiations while they are also sensitive to the influence of external electromagnetic waves. These radiations emitted by all living beings cover an indefinite range (infinite range?) and are characterized by a multitude of different wave lengths. In the immense range of existing radiations we can only perceive the luminous octave (visible light) but we know that whole gamuts of radiations exist beyond the narrow limits of the visible spectrum. The limitations of our senses prevent us from perceiving radiations of living beings and this sensory incapacity also excludes from the field of direct awareness the vast gamut of electromagnetic waves traversing our atmosphere. Yet all these radiations and waves exist and affect all forms of organic life in various ways.”

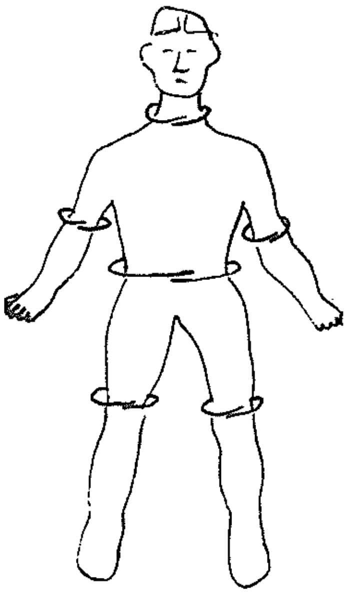

Single wire oscillating circuits around subject's neck, arms, waist and knees.

DR. RAUL ARAUJO'S REPORT

In Chapter Two Mark Clement gives “Medical Reports on Lakhovsky's Oscillating Circuits.” We'll give only one, by Dr. Araujo, Physician at the Prophylactic Institute, Montevideo Uruguay. “In 1929, Dr. Araujo was suffering from a long-standing infection of the larynx which his eminent colleagues had failed to cure. While in Paris he met Lakhovsky who advised him to wear one of his oscillating circuits in the form of a collar. Although feeling rather skeptical about this unorthodox method of treatment Dr. Araujo wore the oscillating circuit for several months with the result that he fully recovered and has had no relapse since. This personal experience led him to treat his own patients with Lakhovsky's oscillating circuits. Having treated over 300 patients suffering from a wide variety of diseases Dr. Araujo succeeded in curing or greatly improving cases of rheumatism, asthma, anemia, neuralgia, gastric ulcer, colitis, glandular disturbances, sterility, genito-urinary affections, general weakness and even cancer. Dr. Araujo observed that in cases in which Lakhovsky's oscillating circuits appeared to give no definite results there was invariably a latent infection which required special treatment such as syphilis, cholecystitus, sinusitis, pyelitis, dental sepsis, etc...A full account of Dr. Araujo's Report appeared in a monograph entitled ‘Cosmic Rays and Oscillating Circuits’ by Dr. P. Rigaux, Paris, 1932.”

CHAPTER THREE, THE MULTIPLE WAVE OSCILLATOR

Most of this has been well explained by Bob Beck in his article in the November Journal, though we might quote again in Clement's own words: “After many experiments Lakhovsky succeeded in constructing an apparatus generating an electrostatic field in which all frequencies from 3 metres to the infra-red region could be produced. Hence in this field every cell could find its own frequency in resonance... Thus a type of oscillator was obtained giving all fundamental wave lengths from 10 cms. to 400 metres, corresponding to frequencies of 750,000 to 3 milliards per second. . .

“Since 1931 the Multiple Wave Oscillator has been used in most European countries and in America for the treatment of many diseases including cancer. No contra-indications for the use of the apparatus nor any harmful effects on patients have ever been reported. This is in striking contrast with short-wave therapy in general, X-rays and radium whose application in the hands of experts has not infrequently been followed by the most serious consequences. . .”

Then follow several pages of photos of before-and-after cancer cures and medical reports from doctors. This one is typical, from Dr. Nicholas Gentile, Chief Radiologist of the Clinic for Incurables of the Apostolic Ladies of the Sacred Heart of Jesus, offer a way out of the clutches of the medical trust. There is little likelihood that the AMA will support research in this area of electronic science for years to come. There is every probability that there will be murderous opposition to any attempt to exploit the MWO on a national scale. This means that you will have to build and test your own equipment, or make friends with some electronic technician -- engineer, TV or radio repairman -- and prevail upon him or her to build it for you. This is the active kind of borderland research which requires that you get up out of your easy chair and get to work! If you live in an isolated spot, take a mail order course in basic radio construction. If you live near a high school that has an adult education program, sign up for the evening class in radio theory and bench work. I did at Barstow in 1958, so can you. If you want to be a citizen of the New Age you should make some effort to keep up to date, even if the sick industry doesn't!

What are Lakhovsky's general theories? Mark Clement sums them up neatly in Chapter One of **The Waves That Heal**:

"The fundamental principle of Lakhovsky's scientific system may be summed up in the axiom 'Every living being emits radiation'. Guided by this principle Lakhovsky was able to explain such diverse phenomena as instinct in animals, migration in birds, health, disease, and, in general, all the manifestations of organic life.

"According to Lakhovsky the nucleus of a living cell may be compared to an electrical oscillating circuit. This nucleus consists of tubular filaments and chromosomes made up of insulating material and filled with a conducting fluid containing all the mineral salts found in sea water. These filaments constitute minute oscillating circuits endowed with capacity and inductance and capable of oscillating according to a specific frequency. They are comparable to the circuits, coils and windings of radio receivers."

I believe Clement's comparison of a body cell with a radio receiver is only half-true. The cell can also be compared with a radio transmitter when it is releasing energy. We are both radio-receptive and radio-active! Lakhovsky's theory should be acceptable to any occult scientist. The push-pull idea, the positive and the negative, the Law of Opposites, is basic to all forms and to all life at this level of existence. By inductance Clement means that radio-electricity can be induced or put into every cell of your body. By capacity he means that each body cell can hold a charge of radio-electricity, just as the battery of your car can carry a charge of electricity. In the case of your body, the charge is put in through invisible but very real radio waves. These can travel unimpeded through any solid object!

"The living cell can thus play the part of a transmitter or receiver of exceedingly short radio-electric waves which give rise to high frequency currents in the circuits of the cellular nucleus. Now the vibration of an oscillating circuit is maintained by radiated energy. But where does it come from.

COSMIC RAYS

"Scientists have established the existence of highly penetrating waves to which, by reason of their universality, they have given the name of cosmic rays. These rays, generated by the interference of astral radiations, are capable of traversing dense metals and soils to a great depth. Lakhovsky has demonstrated the cellular oscillation of living organisms is maintained by cosmic radiation. According to him disease may be said to result from oscillatory dis-equilibrium due to either a deficiency or an excess of cellular radiation. An important factor in this connection is the nature of the soil. A reinforcement of cosmic rays takes place on soils which are good conductors of electricity such as clay, ferruginous and carboniferous soils.

RESONATE IN HARMONY WITH THE UNIVERSE

"To avoid the harmful effects of loss of oscillatory equilibrium it is necessary to ensure the regularization of the cosmic field round the living organism by filtration. Lakhovsky's own explanation of the problem of filtration is as follows: 'The terrestrial atmosphere is known to be impregnated by a vast range of electro-magnetic oscillations of all wave lengths and intensities as a result of unceasing electrical discharges (thunder, etc.). Besides that we know that electric motors and other electrical machines create in the atmosphere a field of auxiliary waves. Moreover, during the past 25 years the earth has been flooded with radio-telegraphic, radio-telephonic and other waves. Under such conditions it is easy to understand why any oscillating circuit of any form or dimensions is likely to find in this vast field of waves its own resonance with which it can vibrate harmoniously. It is therefore obvious that to make any oscillating circuit oscillate there is no need to have recourse to a local generator such as the Radio Cellular Oscillator used by Lakhovsky in 1924 when he first treated and cured geraniums inoculated with cancer. The oscillating circuit utilized by Lakhovsky in his second series of experiments -- a circuit having no artificial source of excitation -- proved equally effective in curing geraniums rendered cancerous by inoculation."

Yes, in 1924 Lakhovsky 'graduated' from electronics to radionics! He discovered and proved to his own satisfaction that in some ways a simple, one-turn coil of wire or fibre was as effective as the electric powered Multiple Wave Oscillator. The simple Oscillating Circuit, as Lakhovsky called it, has two advantages over the MWO. It doesn't have to be plugged in to a battery or 110 volt home power supply, and it broadcasts no interference with radio and TV sets. It acts as a step down transformer for life-positive cosmic radiation.

Clement says that "it must be particularly stressed that only Circuits made in strict accordance with Lakhovsky's directions should be used, otherwise the results will prove to be entirely negative." Unfortunately we do not have Lakhovsky's directions, and Clement certainly doesn't give them. You are still free to investigate this type of research and many have. If you want to experiment in this area then get yourself some copper wire (solid or stranded, research should be done on both) in various lengths, (8 inches is one wave length which has worked well on tomato plants) and make them into a circle with the ends overlapping, but with the metal ends insulated or separated from each other. Lengths can be determined through radiesthetic means (that is, by dowsing) or perhaps in geometric relationship with the structure of the plant. Considering the radionic and radiesthetic viewpoint geometric shapes would also have an influence and can be experimented with. Always use control samples in your experiments to see what works and what doesn't.

To get back to Clement's text: "Through the action of this constant field of radio-electric waves which emanates from the surrounding atmosphere the oscillating circuit is made to resonate like an instrument in tune with certain sounds. Thus the oscillating circuit creates a field which canalizes and filters, so to speak, the cosmic waves necessary for cellular oscillation.

THE DANGER OF BURNING X-RAYS

"Furthermore, this filtration is a general phenomenon. It has been discovered, through the investigations of Lakhovsky, that radiations such as those associated with light, ultra-violet rays, X-rays, etc., have the property of making cosmic rays act, as it were, to the advantage or disadvantage of the cells. Now the field created by an oscillating circuit is constant and emits a steady and sustained force. It invariably acts in a favorable manner on the oscillation of the body cells, facilitating by the filtration of cosmic rays, regular cellular division, a fact which explains the immunity imparted to the cells and their consequent capacity of resistance to diseases and microbes.

Rome, published in the medical review Medicina Nuova XXVI, N.5., 1935, Rome: "**Effects On The Nervous System.** Generally speaking I have observed a marked analgesic action following the application of the Multiple Wave Oscillator in all affections associated with pain, particularly in the classical cases typical of such affections. For example, a patient suffering from cephalagia, resulting from violent cranial trauma, for a duration of 10 years, was subjected to a great variety of treatments, but all in vain. The patient was definitely cured after 2 months' treatment with the MWO. Improvement was manifest after only 3 applications."

Dr. Gentile also reported the effects of the MWO on the Central Nervous System, on Chronic Inflammations, on Metabolism, on Disorders of the Cardio-Vascular System, and on miscellaneous cases. He says he adopted the "technique of localized irradiation. Generally speaking, treatment is given every 4 days for a duration of 5-15 minutes per session. This is the technique which has given me the best results after having experimented with many forms of application. For children, old people and debilitated women, a relatively weaker application is indicated. If results are not apparent after 7 or 8 applications, I continue until 15-30 applications are given at the rate of a single treatment once a week. I have never observed any ill-effects from the MWO treatment, whatever the number of applications was in any given case. Moreover, the general condition of patients is always improved, even if only temporarily, so much so that the patients themselves sometimes insist on having further treatments. . ."

This chapter on the MWO concludes with four pages of reports of notable improvement or cure by American doctors. Chapter Five is concerned with the remarkable results obtained by using the Multiple Wave Oscillator on animals. Chapter Six contains Lakhovsky's prophecy that some time in the future diagnosis of disease would be obtained by television! This is something which Dr. Ruth Drown's Radio-Vision and Homo-Vibra Ray instruments have already accomplished.

THE NOVEMBER CONVENTION TESTING PROGRAM

There were two Multiple Wave Oscillators available. These were generously furnished by Bob Beck and Ed Skilling, and were set up in the shielded seance room. Only short exposures of from 2 to 5 minutes were given, during the lunch and dinner hours on Saturday and Sunday. In that time perhaps 100 people volunteered for tests. Until a follow up inquiry is made, no statistical conclusion can be made, or even begun!

A few individual cases reported to your Director are worthy of note, including my own. By mid-morning on Saturday a spinal injury from my old, hockey-playing days was acting up. Doctors have called it a spasm in the sacro-iliac area. Ed Skilling invited me to sit in the rays from the MWO for a couple of minutes while the seance room was being readied for testing. Within a minute the spasm relaxed completely and the pain was gone. This was not a permanent change, of course, but the analgesic effect was certainly noticeable.

Mrs. Fred Rannenberg, financial secretary of Harmony Grove and a BSR Associate, told me she had had a sharp pain in the area of her left hip for over two weeks at the time of the Convention. One 3-minute exposure to the rays of the MWO removed this completely. When I attended the Grove Board meeting a week later she said the pain had still not returned.

One Associate did report a negative reaction to the MWO. She attributed it to arsenic poisoning. She had a severe case of this earlier in the year. When the machine was turned on she felt a severe pain through her right side, as though someone had jabbed a knife into her. It could be that some of the lead poison was still in her system and the stirring of the cells in the mid-section produced this reaction. It was endurable, however, and she sat out the exposure without a murmur. The pain persisted that night and she had to put cold compresses on her side to get to sleep. The next morning she felt fine and was eager to take another exposure to the multiple waves. This time there was no negative reaction.

The most startling subject of all was the woman who had been awake all Saturday night with a migraine headache, an old and recurring ailment. By Sunday morning, Nov. 10th, she was sick and nauseated. It was suggested that before taking her to a doctor or hospital she be given a short exposure to MWO rays. Within minutes all pain was gone and she returned to her cottage to lay down and sleep like a baby.

THE PSYCHEDELIC EFFECT

Ed Skilling is the only I know who has stayed in the MWO field or rays for longer than 15 minutes. While testing and adjusting his equipment at his microphone factory several weeks ago he deliberately stayed between the antennas for an hour. At the end of that time he was beginning to feel lightheaded and dreamy he thought it a good idea to get out before losing consciousness altogether.

An even more spectacular possibility is the Time-Machine effect in connection with rejuvenation. If, as Bob Beck suggested in his article, the MWO tends to take the body cell back down the time-track to a more youthful, more vital period, what would happen to a person who stayed in the field of the machine for four hours? Would his vibratory rate be speeded up to where he would disappear completely? Like the hero of H.G. Wells' "Time Machine"? Anybody want to try it? It seems, from hints George Van Tassel has been dropping over the years, that his Integratron at Giant Rock, California might do something like this -- if and when he gets it working! As I recall, both George and the Canadian Saucerian, the late W.B. Smith, spoke of the four dimensions of electricity: 1. is the electricity moving in one direction along a copper wire, 2. is the magnetic field around the wire, 3. is the static charge created by the first two effects, and 4. is Time -- or the "tempic field" as Smith called it. The Time Field equates with Space, where consciousness is everywhere present. Seems to me Lakhovsky's Multiple Wave Oscillator is a gadget which gives us the opportunity -- for the first time -- of approaching the Time Field with scientifically acceptable equipment, operating in known frequencies. Remember, that with its circular antennas it operates on the vortex principle. Each individual antenna in the group is a segment of a 60 degree cone. The 1/2 inch gaps, at alternate 180 degrees from each other, conform to the alternating principle and give a damped or pulsed wave.

THE SPACE AGE EFFECT

Copies of our November 1963 **Journal** have gone all over the world. Each day's mail brings new orders. We are confident that Lakhovsky's invention, far ahead of its time in the 1920s and 30s, has been given a new lease on life and will be pushed to its ultimate development on every continent. There will be vigorous opposition from the right-wing conservatives and reactionaries. Their resistance will furnish the platform from which electronic "medicine" will eventually sweep the world.

I see the day when a device, similar to the MWO, will be a standard part of every home bathroom or cleansing center. You will consider it as necessary and as routine to take an electronic showerbath, as to take a water bath. Home from work, tired, dirty and discouraged, you strip, flip on the MWO switch, and while shaving, doing your hair or whatever, re-balance your whole system with a two or three minutes exposure to the pulsing waves from the oscillator as they flood the whole room. For the sale of the house of the future it will be as important for the ad to say "shielded bath with MWO" as it will to say "tile bath with radiant heat."

Mr. Skilling told me he was tired and

"dragged out" after processing dozens of volunteer "guinea pigs" late Saturday afternoon. Before shutting down the equipment he sat in the nail-less wooden chair between the antennas and gave himself a three minute shot of pulsed waves. Refreshed and revived he looked forward to a good dinner and the full evening program.

I don't know of a better Christmas gift we could have given the Associates than the idea and the plans for the Lakhovsky MWO, researched and so generously offered us by Bob Beck in the true borderland science tradition. Now it is up to you to carry it forward in your own individual way. We welcome your comments, observations and research data as you develop equipment and a testing program.

AND NOTHING HAPPENED!

"No doubt you are deluged with correspondence about your articles on the Lakhovsky Rejuvenation Machine. Since you said it is possible for any intelligent 16-year-old to build one that is exactly that which I have had to rely on. Fortunately, my son is fairly well informed on electronics but obviously no expert at his age, 16. He followed your diagram but instead of battery power he used an electric train transformer, which he assures me, is equally efficient. He also found he had to make one change in the hookup of the Tesla Coil. I have taken four exposures and the results! Nil!"

Maybe this lady expected to be rejuvenated back to her early twenties. As far as we know, no such claims have ever been made for the Lakhovsky gadgets -- though it would be interesting if it happened! As for power supply to the Model T Ford coil, any 6, 8, 10 or 12 volt battery or transformer should do, depending on what you have available and where you intend to do your experimenting. We understand the old Model T magneto delivered as high as 18 volts to the four coils. One handy source of 6 or 12 volt electricity is the cigarette lighter on the dash of the car. Plug in there for power when you want to expose yourself while driving or out in the country.

"I had been fighting a virus for several days and the day after the first exposure I felt a great deal better, but the second day I was right back where I had been. But that was the pattern the virus had been taking. One day I'd feel fairly normal, the next miserable again. So it is difficult to know if the Lakhovsky machine could be credited with the temporary improvement."

That's right, ma'am, some people show little or no reaction to the mytogenic waves put out by the Lakhovsky instrument. The results are unpredictable. Perhaps that's why the research was pushed no further in the 1930s by authorities here in the United States. You, like most people, think that health can be bought in a package. Lakhovsky didn't agree with this erroneous conclusion. His theory was that health is a condition of balance of all the forces of the body. Ill health is a condition of imbalance caused by your misbehavior. If you continue to misbehave, any force applied from the outside, whether it be mytogenic waves, manipulation, drugs, medicine or surgery, will only bring temporary relief. Pain is an insistent teacher, urging you to change your mind; but if you can't change your mind, how can you change your body?

"One possible reaction to the exposure I can report is that I took the first one just before going to bed at night. It took me three hours to get to sleep. Several things puzzle me about the machine we have constructed. First of all, although we have experimented with a Tesla coil of the size your diagram calls for, as well as one almost twice the size and strength, we cannot get a two-inch spark from the antenna or resonator, 1/2 to 3/4 of an inch is the absolute maximum."

The mention of the two-inch spark was Mr. Beck's error. 1/2 to 3/4 inch arcing is all this circuitry will produce and that is adequate to affect notable changes in many forms of cell life. More power might produce faster changes, and much harm! Be reasonable, a living cell is so small as to be invisible without a microscope. Only minute amounts of energy are necessary to affect a cell, to stimulate it or to kill it.

"Second, under no conditions do we get the 'bluish glow of brush discharge' from the antenna that you mention; although we have no trouble lighting up a two-foot fluorescent lamp."

Operate your Oscillator in total darkness and you should see some brush discharge at some points on the antenna. True this redesigned equipment puts out nothing like the five-inch brush discharge visible in the photo of some of the original Lakhovsky equipment in Mark Clement's book, "Waves That Heal", and Lakhovsky's antenna appears to be at least two feet across.

But power is not the answer to balanced cell life! Dr. Abrams discovered this with his early electronic experiments in San Francisco in the 1920s. It is the quality and the variety of the pulsed waves that counts! In any event weaker equipment can be compensated by longer exposure, and this may be more beneficial to living matter.

"And thirdly, since we have not constructed any outer shield for the machine, such as a Faraday cage of copper screen, I have been monitoring the operation on our radios and television. On the radio, one notes an annoying and loud buzz, but on T.V. except for a couple of light horizontal lines and a very slight hum, there is no serious effect. So I doubt that we're bothering our neighbors very much. In any case, we try to use the oscillator very early or very late in the day, when few people are using their radios or TV. I have sent for Clement's book, 'Waves That Heal,' and Lakhovsky's 'The Secret of Life', not only to better understand what we are trying to work with but also in the anxious hope that I will find out why our machine does not have the affect it apparently should have."

Let me assure you, good lady, there is no single cure-all for man's ills. The clue to better health is in the profound statement of the Savior of our race: "As a man thinketh in his heart, so is he." Pain is still the great teacher in the world and will be for a long, long time to come. I don't know what your physical condition is and it's none of my business; that's between you and your doctor. If you have a long history of frustration and thwarted ambition, going back to childhood and even into past lives, this mass of energy of crystallized thought-forms, is not going to be broken up and dissipated overnight. If you have consciously and willfully flouted Cosmic laws, or have turned them to your own selfish ends, the consequences of this misbehavior will have to be worked out at this level. The occult scientist calls this Fixed Karma. In this connection, one of my favorite teachers, Dion Fortune, reminds us: "What cannot be cured must be endured."

If the Lakhovsky oscillator does have an analgesic affect -- as it appears to have had in some cases -- it has this advantage over pain-relieving drugs; it does not leave a residue of poison in our already over-loaded liver and kidneys!

WORD OF A SIMILAR INSTRUMENT UNDER DEVELOPMENT

We have a second letter from this same lady Associate, also worthy of note in connection with the Lakhovsky Multi-Wave Oscillator.

"First off, when my brother received the machine we had built for him, using the battery indicated in the schematic, he felt the power source might be too weak. It so happens he has a business contact with one of the largest electronic instrument companies in the area where he lives. He decided to go straight to the president and seek his advice. With the whole idea placed before him this gentleman said, 'This is very interesting. I want you to meet one of our physicists who is working on a very similar instrument.' A meeting with the physicist revealed two interesting pieces of information: first, the physicist had never heard of Lakhovsky or his machine; second as soon as this new instrument was completed, arrangements had been made to test it in a large nearby hospital! Is this latter not a cheering bit of news?"

Both cheering and discouraging. The basic principle discovered by Lakhovsky is certainly available to the mental probing of other sincere researchers, so let us keep it alive by all means. But barring a revolution in the ultra-conservative leadership of the American Medical Association, no electronic developments will be allowed to threaten the high-profit position of the drug industry.

"In their discussion of the power source, the physicist suggested my brother use a wet-cell car battery, #50, 39 plates, 70 A.H. We are using one too and it makes a much better spark from the antenna, although it still is no greater than 1/2 to 3/4 inch. It does seem stronger. Of course the machine is not so readily portable with such a heavy battery. My brother had only one exposure at this writing but he reports a noticeable improvement in the arthritic pain bothering him in his right arm for months. On the other hand, the report on the use of my own machine is somewhat less encouraging. The only positive results concern my husband. After his first ten-minute exposure, within a few hours, a painful bursur in his shoulder cleared up. He has been subject to off-again, on-again attacks of bursitis there for some 15 years; for which he had taken medication, short wave, and even X-ray treatments, when the attacks were severe. He has since taken another exposure, but neither this nor the first one seemed to help an itching-skin allergy which has bothered him for some years.

NOT THE FOUNTAIN OF YOUTH SHE EXPECTED!

"As for myself, I have taken at least a half-dozen exposures and cannot in all honesty detect the slightest difference from them. I'm not sure if it is a matter of 'suggestion' or a desire to prove the capabilities of the machine. On the contrary, I notice such strange contradictions as the fact that although I took an exposure yesterday morning, in the evening the fourth and fifth fingers on my right hand were painful, from some kind of arthritis or rheumatism. I had never had anything like this before. Does it not seem odd that it should develop on the day of the exposure?"

Not at all! Any positive reaction to exposure to the mytogenic rays of the Lakhovsky oscillator indicates that it is working! Mr. Lakhovsky's theory is that the waves or oscillations excite the cell, causing it to release mor energy, also to shake off accumulated poisons and/or tensions. If your system is loaded down with tensions from daily living in America, if your system is loaded down with poisons from processed foods and contaminated air and water, you can expect painful reactions when the junk breaks free. I believe that is what sickness is the body struggling to get rid of poison. For you, things may get worse before they get better!

HOW OFTEN AND HOW LONG?

"With the mention of two successive exposures in two days I get to what is the most important question in the use of the MWO. No one has explained why exposures are suggested at four-day intervals. Is it harmful or useless to take them more frequently? When one is uncomfortable or in pain, one is anxious to rid oneself of the discomfort as quickly as possible. And to have to wait four more days for additional improvement seems unnecessary if there is no harm in the exposures. I have exposed myself at more frequent intervals and still have observed no reactions?"

The suggested exposure rate of fifteen minutes every four days came from Dr. Gentile's extensive researches with Lakhovsky equipment in Rome in the 1930s. This is a typical professional approach to treatment of disease by doctors. From long experience with drugs and other proven forms of therapy, they know that it takes time for the human organism to adjust itself to radical changes -- without harming the organism.

Whether or not this holds true for the operation and effect of the Lakhovsky machine remains to be proven and you'll have to be your own guinea pig. It's your machine; it's your body; it's your life. You can take an exposure every hour on the hour if you like; stay in all day. Who's going to stop you? This is borderland research and you are a borderland scientist, looking for new knowledge which may be of benefit to yourself and the human race, judging from the last lines of your letter.

"I am so excited and hopeful of the efficacy of this MWO machine that I do not want to leave any avenue unexplored that may possibly help in understanding its use and making it freely available to anybody I can possibly help. May I take this opportunity to tell you how tremendously enthusiastic and interested I am in BSRA, not only what you are trying to do but what you are accomplishing, too. From what you imply of the financial situation, it seems to be largely a labor of love and service on your part, for which you deserve great praise and the heartfelt thanks of every BSRA member and others whose lives they touch. Please accept this very, very small donation of the enclosed check, as a symbol of my appreciation."

The donation is most welcome and will be put toward the expenses of carrying on this work, also the words of appreciation. The lady was also most curious about the Lakhovsky circuits, those single bands of wire which are placed around the waist, or knees, or ankles, wrist or neck, and seem to have a subtle but very real affect on the wearers. We have some information on the Lakhovsky Circuits or Belts from Associate A.E. Powell, a retired lieutenant colonel of the British Indian Army:

THE OSCILLATING CIRCUIT

"The Belts can be made by almost anyone, for a few cents. At most hardware stores, for a few cents per foot, one can buy twin electric cable insulated with white rubber, used for lamps, etc. Get the smaller size 1/4 inch wide, having 42 strands of copper wire. Slit an end with a knife and the two wires easily tear apart.

"For the button, get white sheet plastic about 1/8th inch thick, saw it into pieces about 1½ by 5/8th inches, and drill near each end a hole large enough to take two wires. Round the corners of the plastic and bevel edges. Thread the wires, from opposite directions, up through one hold and down through the other, leaving about half an inch projecting beyond each end of the button. Where a circuit can be slipped off the body without unbuttoning, you may overlap the ends of the wire belt an inch or two, bind with fine string and smear with Duco cement for strength.

"Parallelism and overlap of the ends are important. This builds up capacitance, produces inductance and generates an alternating current. Circuits may be worn, as many as you please, round chest, waist, neck, arms, wrists, legs, ankles, neck or head continuously. Water will do them no harm.

"Gladly will I supply Circuits, in any quantity, with buttons or bound ends. To avoid trouble with the Food and Drug people, I make no charge. Donations, however, are acceptable, and go intact into my Fund for the Sick. For long this has been doing fine work and I'm sure you will approve. For reasons stated I make no claims whatsoever for the Circuits, and no guarantee or promise of any kind. If you want to give them a trial, that is wholly your affair." Col. A.E. Powell (Col. Powell died in March 1969).

MWO USED TWENTY YEARS AGO

"The recent article in the BSRA Journal pertaining to the Lakhovsky Oscillator is of special interest to me. First, I am an engineer, Physician and Surgeon, and a Scientific Consultant for the U.S. Government. (Technical Intelligence). I am not in any manner snooping for the government. This is completely personal. We built several oscillators in 1944. These were used in my sanatorium in Dallas where we had some startling results. As we did not have the proper facilities to research the instruments adequately, we became more and more conservative. Many patients would show reactions, resembling the old fashioned Flu, after a few days following exposure to the oscillator. I realized we were using too much power, so cut the level several times with good results; but we did not completely eliminate the side effects. In 1946 I was sent to Germany for the Government to explore Electro-biology and Biophysics in its application to electro-medical equipment. I felt it wise to destroy the machines so injudicious use would not be indulged. The possibilities have intrigued me ever since. It looks as though you have solved most if not all of the problems involved. Hence my renewed interest. The excess power upset the enzyme complex of the body, or as some felt, distorted the double electric layers of charge carried on the cells, hence allowing for the penetration of virii directly into the cells (virii operate within the cells -- bacteria operate between the cells). Cells as well as organs function in a force field so mild oscillating currents not only work through resonance but seem to regenerate these force fields. Here is where application to cancer can be optimistically explored."

Speak for your own state, Doc! Here in California the medical association has decreed that only four forms of treatment for cancer are legal; drugs, surgery, burning rays and death.

"Proof of energy flow from the fingers and thumb is here and must be recognized. We have demonstrated it by its effect on Yeast cells, viewed under the microscope (Girwich research). Whether it comes from the conscious rather than the subconscious mind is harder to prove, but I am impelled to believe it does. This may interest you. Years ago we experimented with crystallization. Precipitated water vapor to snowflakes in a chamber with electrodes planted in two sides. When we threw a current into the chamber at a given frequency the flakes were all the same. Changing the wave length changed the crystallization pattern. Each frequency had its own pattern. Here is the explanation of energy absorption by the chemical used, and the control of the crystalline patterns by the nature of the energy flowing."

Naturopaths are in 100% disagreement with the doctor's above explanation of the side affects of his use of the MWO on his patients. If I understand the theory correctly, according the natural view of colds, flu, virus infections, etc., these are attempts by the human organism to throw off mucous, to eliminate intolerable accumulations of poison from the system. Exposure to the field created by the MWO tends to raise the general tone of the whole system by stimulation. The raised vibrations release an unusual amount of mucous and other junk into the elimination channels, and until this is eliminated one would have a cold or flu and the usual aches and pains which generally go with such a condition.

Another doctor stopped by here not long ago to tell of his sad experience in trying to use spark-gap electronic equipment in his medical practice "for those suffering patients not helped by drugs." This powerful, high-frequency machine produced a two-inch spark! Every time he turned it on, everyone in town seemed to know it and the phone would ring. Even a Faraday cage didn't shield the output of this monster. Finally he was called before the county medical board to explain what he was doing. The board presented a staggering combination of fatuous conceit and stubborn ignorance. "They didn't want to know anything about the affects of radio waves on the body and didn't care!"

CURING CANCEROUS PLANTS WITH ULTRA RADIO FREQUENCIES

by Georges Lakhovsky

From Radio News February 1925

"The new application of short wave-length oscillations described in the following article" wrote the Editor of Radio News, "is one of the most important ever found, and we are pleased to present to our readers this article by Mr. Georges Lakhovsky, the well known French scientist. The experiments described were carried out in collaboration with several doctors and scientists of high standing and it seems from results obtained, that the very high frequency treatments will play an important role in the future. We shall publish in a later issue another article on this new system together with the effects of ultra radio frequencies in the treatment of diseases in human beings."

Since November 1923 I have published in various technical and radio publications, several papers in which I explained my theory that the instinct or special feeling, which permits birds to direct themselves in space, is only the results of the emission and reception of rays by living beings. While developing this theory, I explained how thoroughly I was convinced that science will discover, some day, not only the nature of microbes by the radiation which they produce, but also a method of killing disease bacilli within the human body by means of the proper radiations.

The researches I have made by means of special apparatus have shown such results, that I believe my theory is correct. This theory is that life is born from radiations, kept going by radiation and suppressed by any accident producing the destruction of the oscillatory equilibrium, especially by the radiations of certain microbes, which suppress those of the weaker cells.

Before going any further in our reasoning, it is necessary, in order to present the facts to the uninitiated reader, to imagine what oscillations really are. The motion of a pendulum will be used for this explanation. When a pendulum is displaced from the position of equilibrium, it moves back and forth producing what are known as ochrone oscillations, until the energy stored is entirely exhausted. By means of a motor, a spring, or an electro-magnet, it is possible to keep the motion of the pendulum of constant amplitude, producing undamped oscillations. If, on the contrary, the source of power is removed, the oscillations die down and it is necessary not only to re-apply the power sustaining the oscillations, but also to furnish additional energy to start the pendulum in motion. This oscillation of a pendulum reproduces exactly what happens in the cells of a living being.

Our organs are composed of cells formed of protoplasm containing various mineral matters and acids, such as iron, chloride, phosphorous, etc. It is by the combination of these elements that the cells detect outside waves and vibrate continuously at a very high frequency, probably higher than the period of X-rays or over all other vibrations known and measured today (1925). The amplitude of cell oscillations must reach a certain value, in order that the organism be strong enough to repulse the destructive vibrations from certain microbes.

COSMIC RAYS AND CELL LIFE

The astrophysicians are actually carrying out experiments of great interest on the existence of vibrations, which have been called penetration rays and of which the frequency is higher than that of X-rays and of the alpha, beta and gamma rays of radium. Such rays, according to the theory, are produced by the earth itself and some others come from outer space. Some accurate measurements have proved the correctness of this theory. Therefore, it is quite permissible to believe that these penetration rays, or at least some of them, produce the vibratory motion of living cells and consequently their life.

For instance, let us suppose a cell vibrates at a certain frequency and a microbe vibrates at a different frequency; the microbe begins to fight the cell, and sickness is started. If the cell cannot repel the stronger vibrations and if the amplitude of its own vibration decreases, the microbe gains and its vibrations in decreasing and stopping those of the cells, bring dangerous sickness or death. If, on the contrary, the living cell is started vibrating with the proper amplitude by inside or outside causes, the oscillatory attack is repulsed. Such is my theory.

The problem is somewhat similar to the situation in which a rescuer finds himself when, coming to help a friend in a dangerous situation, finds himself fighting hand to hand against strong aggressors. The rescuer does not dare to fire his gun; fearing to harm his friend mixed up with the aggressors in the melee. Similarly, microbes and healthy cells are exposed to electric or radio-active action, which could be used to destroy the unwanted rays and it is difficult to suppress them without harming or killing at the same time, the cells which are to be treated. In fact, since Pasteur, scientists have been constantly searching for means of destroying microbes. The great difficulty with all methods found was that in destroying the bacillae, the cell was attacked too. The experience gained in cancer and tuberculosis treated with radium, X-ray, or ultra-violet rays, shows how difficult is the work of the investigators.

A RADICALLY NEW METHOD

The remedy in my opinion is not to kill the microbes in contact with the healthy cells, but to reinforce the oscillations of the cell either directly by reinforcing the radio activity of the blood or in producing on the cells a direct action by means of the proper rays. During January 1924 I began to build, according to this theory, and with the purpose of therapeutic applications, an apparatus which I have called Radio-Cellular-Oscillator, with the firm belief that the cells vibrating at extremely short wave-lengths would find their own in the Hertzian waves, which have the properties of producing extremely short harmonics. The cell with very weak vibrations, when placed in the field of multiple radiations, finds its own frequency and starts again to oscillate normally through the phenomenon of resonance. This type of vibration which I propose to use, is harmless, unlike those of X-rays and radium. Their application, therefore, does not present any danger to the operator.

I exposed in front of my apparatus, during long periods, a certain number of microbes in culture, which developed themselves normally. I, myself, have never felt the effect of these ultra radio frequencies, although I remained for a great many days near the apparatus, during the treatment applied to the living cells. It is only when two living beings such as a cell and a microbe, are in contact, that the rays produced by the Radio-Cellular-Oscillator have any direct effect upon cellular structure.

WORK IN A FRENCH HOSPITAL

The experiments which I carried out at the Salpetriere Hospital in Paris, in the service and with the collaboration of Prof. Gosset, were made with plants inoculated with cancer, and the results were described in a paper presented on July 26, last year, before the Biological Society. The text of this paper follows.

"One knows that it is possible to produce by inoculation of Bacterium tumefaciens in plants tumors similar to those of cancer in animals. One of us obtained experimentally by this method, a great number of tumors. These had various degrees of development. Some of them dry up partially, but do not die entirely until the entire plant or at least the limb bearing the tumor dies. Even removed by surgical methods, these grew again on a sick limb.

"We propose to describe in this paper, the action of electromagnetic waves of very high frequency obtained by means of the Radio-Cellular-Oscillator of Georges Lakhovsky. This apparatus produces wavelengths of the order of two meters and less, corresponding to 150 million cycles per second. A first plant was submitted to the effect of radiation one month after being inoculated with cancer; at this time small tumors of the size of a cherry stone were visible upon it. This plant was submitted to the rays twice, for three hours each time. During the following days, the tumors continued to grow rapidly in the same way as those on plants, which had not been submitted to the effect of radiations. However, 16 days after the first treatment, the tumors began to shrink and dry up. A few days later the tumors were entirely dried up and could be very easily detached from the limb of the plant by merely touching them. The drying action of the radio frequency radiations is selective and affects only the sick part of the plant. Even the inside sick tissues were destroyed, although they were next to healthy cells in the center of the limb, showing that the radiations had not affected the healthy parts.

"Another plant was treated in the same way, except that it was exposed 11 times for three hours each time, to the radiations of the oscillator. Sixteen days after the first exposure the tumors, which were rather large as shown in one of the photographs, began to shrink and dry up and were easily detached from the limb exactly as in the first case. Again in this case, the healthy parts of the plant were not affected in the least. A third plant exposed to the radiations for nine hours, that is, three treatments of three hours each, was cured in the same manner as the two others. Sixteen plants also inoculated with cancer, were left without treatment. They have tumors in full activity, several of which are very large. These experiments show conclusively that plants inoculated with cancer can be treated and cured by means of the ultra radio frequency vibrations, whereas surgical treatment fails.

"Such are the results of my researches with plants. At the present time, similar experiments are being carried out with animals and it seems that the effect on cancerous animals is the same as on cancerous plants.

"I am highly pleased to present my theory and the results of my work in a scientific review of the United States, this great country, which has always been in the lead in the fight against this horrible sickness, cancer, and whose sympathy and help I would greatly appreciate.

"In conclusion I wish to call the attention of the reader to the fact that I have obtained very conclusive results not only with a wave length of two meters, but with longer and shorter wave-lengths. The main thing is to produce the greatest number of harmonics possible."

* * *

This February 1925 article from Radio News magazine shows how long some of Lakhovsky's theories have been known in America. This article was furnished to BSRA by an Associate who had met the Russian-French scientist in New York. He claims also to have visited several times the New York hospital which set up a research program on the Multi-Wave Oscillator and saw the Lakhovsky-type equipment. No information on the machine or its effects could be elicited from the hospital authorities and in the early 1950s the shielded room was dismantled and equipment destroyed.

We feel that Lakhovsky's theories and early researches should be followed up. It should be publicly proven that high-frequency waves, in the proper concentrations, do affect living organisms in a beneficial way, or that Lakhovsky be declared an idle dreamer. Since research of this kind falls within the purposes of Borderland Sciences Research Foundation, Inc., members are encouraged to build their own equipment and, in a suitably shielded or isolated environment, carry on their own research program. If you cannot obtain the necessary materials, BSRF may be able to put you in touch with another borderlander who can be of help. Until the medical authorities come forth with official approval of this radical approach to the state of imbalance or un-health attributed to disease, no one but a fool would go into commercial production of this kind of equipment in America today. It is now said to take a minimum of $300,000 in research money and three years of testing to develop medically acceptable data.

HOW DR. JAMISON WAS TRAPPED

In a letter dated Aug. 29, 1967, Dr. Jamison enclosed this news clip from the **Modesto Bee**: "Turlock — Veterinarian Stanton L. Jamison yesterday was fined $249 in Turlock Judicial District Court after being convicted of three charges stemming from his use of an electronic machine to treat human patients for cancer. A jury of nine women and three men returned a verdict of guilty on one count of practicing medicine without a license and two counts of advertising a device represented to have effect on cancer, stomach ulcers or bone diseases. The decision followed a two day trial in which Jamison defended himself...

"They (Jamison and his assistant, Martha Ann Davis) were arrested last December following a lengthy investigation by Turlock police officers and agents of the State Bureau of Food and Drug Inspection. The investigation began when Police Chief John Viarengo requested assistance from the bureau after learning 'the cancer-curing machine' was being operated here.

"During the investigation, Food and Drug agents Willis Worley and Harvey Lee arranged several meetings with Jamison on the pretense they were interested in purchasing machines similar to his. Jamison reportedly organized a church as a front for his operation. The facility, located at 200 West Main St., was known as the Life Aquarium Center. Worley and Lee became bishops of the church as did deputy District Attorney Frank Damrell, Jr., who prosecuted the case. At the time of the investigation, Damrell was employed in the State Attorney General's office.

"Worley said Jamison's intention was to open other treatment centers throughout the state, using his bishops to set up facilities under protection of the church. 'This was the most fantastic investigation I've ever been involved in,' said the agent this morning.

(Yes, it is fantastic to think anyone would want to give or donate healing services free when there are billions to be made on the four kinds of cancer treatment authorized by the California Medical Association: Drugs, Surgery, Radiation and Death. RHC.)

"Worley points out the manufacturer of Jamison's machine was convicted of grand theft two weeks ago in Los Angeles after selling a similar machine to a Food and Drug agent under false pretenses. (This was probably Ralph Bergstresser, Burbank, Calif., who was manufacturing and selling the Bob Beck MWO for $250.)

"After Jamison's conviction yesterday, Damrell called for imposition of a prison term for the veterinarian. If he had received the maximum penalty, he could have been sentenced to 18 months in jail and fined $1,500.

"We felt very strongly on this," said Worley, "because Jamison could easily become a menace to many innocent victims throughout the state."

MWO IN USE AT INDIAN CLINIC

"I am continuing my experiments with the MWO and my experience is that in practically all cases there is an aggravation of the existing symptoms, and previous symptoms are brought to the surface. Hemorrhage was seen in another case and treatment was stopped forthwith. This is one problem which has to be tackled before MWO can be used with confidence. I think MWO treatment should not be given to tubercular cases. Also in cases where there is a hemorrhagic tendency this would do more harm than good.

"Neuritis seems to respond nicely to this treatment. Sciatica is definitely cured by this. Some cases of Rheumatism and Arthritis are benefited, responding at first but the improvement does not last much longer. I cannot understand the reason for this eccentric behavior. I think there must be something with the frequencies."

Don't blame it on the frequencies, Doc, blame it on the patients who stubbornly clings to their fixed ideas and rigid unyielding mental patterns. We have no evidence that the radio frequencies of the MWO reach into the mental world. Each person's aura is loaded with "signatures", national, family and religious concepts hammered into him over the years. His creative energies, flowing freely down from the higher worlds, channel through these deeply cut "grooves" in mind and emotions. The health or illth of the physical body indicate whether the person's ideas are in tune or out of tune with Creation. As a man thinketh in his heart, so is he.

"Can you please let me know what are the ranges of frequencies these machines have? Have they been measured and are they the same in all instruments? Is there any difference in the models prepared in the USA and France? Which model was tried by Lakhovsky in the New York hospital? What are the actual frequencies used by him?"

The only frequency readings we have on an MWO were those submitted by Bob Beck originally, from the output of his own machine. "It radiates RF interference over a bandpass of 15 Kilocycles to well beyond 250 Megacycles. This blocks AM, FM and Television reception for hundreds of yards" But so does my electric razor, and I've been using one for years. I was told by a sailor that electric razors are very effective as "scramblers" for knocking out the electronic brains of guided missiles, and have been so used as defensive equipment during missile exercises on aircraft carriers at sea. No one has furnished us with RF output figures from original Lakhovsky equipment, either at the New York hospital or from Europe. If anyone has these figures I hope they will be kind enough to forward them to you. Lakhovsky's available technical record is very slim.

"An Associate writes 'A very good psychic in Florida gave the following, in a sitting devoted to the MWO. It is not anywhere near developed to its potential. It has unlimited amplifications to be made. The use of the MWO can change the auric field, thus spiritually it can change the individual. This is done with the work of the seven rays of life. The MWO should be used in conjunction with the radionics instrument.' What about this radionics instrument? I would appreciate it if you can throw some light on this."

Sorry Doc, the punitive hand of the American Medical Association has driven radionics builders and users underground here in the United States. No one but a fool like me would stand up on the firing line. England isn't quite the police state America is and you can get information on radionics and radionics equipment from the Delawarre Laboratories, in England, and from Bruce Copen, in Sussex, England. Radionics experts have developed rates for every organ in the body. Equilibrating those rates with specific radio frequencies offers an interesting field for borderland research.

"I have tried both the Vitic and the Eeman Screens. I am still continuing my experiments with the Eeman Screens. Only a couple of days back I gave a set of screens to a patient who is having an encyclopedia of complaints. The MWO did not give her much improvement hence the change. I have one set of Vitic with me and whenever I feel a bit out of sorts I sit for ten minutes and get back my vigor. I am using a very strong pair of magnets and a carbon rod 1½ inch in diameter. After I received the MWO my interest in the other two flagged. I think I will have to cultivate them again."

Dr. A.K. Bhattacharya

From the March 1964 Journal of Borderland Research

ARMY MEDICAL RESEARCH SUPPORTS LAKHOVSKY THEORY!

That's our headline, and it's derived from news clips loaned to us by an Associate. One especially is from the New York "Times" for Friday, Aug. 19, 1960 by John Osmundsen.

The heading says that Radio Microwaves Produce Molecular Changes in Human Beings. This is merely a repetition of what Georges Lakhovsky proved with his pioneering work in Paris hospitals in the 1920s!

"New and possibly important biological effects of radio and radar waves were reported at a three-day scientific meeting that concluded here yesterday. One scientist told of producing 'a profound molecular change' in human gamma globulin with specific wave lengths of radio waves in the high frequency to very high frequency, or VHF range.

"Alterations so created in the molecules that constitute an important part of the body's defense apparatus were accompanied by at least a fourfold increase in their biological activity, the scientist said. 'The changes can be produced under widely varying conditions of voltage, power, pulse width, and pulse repetition rate, provided the frequency is suitable,' according to Lieut. Col. Sven A. Bach of the Army Medical Research Laboratory in Fort Knox, Ky."

If Col. Bach had been working from Lakhovsky's original theories and equipment, he wasn't saying. This is obvious in reporter Osmundsen's next paragraph.

"This is believed to be the first report of a proven frequency-specific effect of radio waves on human chemistry. Dr. Bach's report appeared to cause more comment at the conference than almost any other, for the effect of radio frequencies on human gamma globulin in the test tube were clearly not a result of heating.

It was suggested by Dr. Bach that the increased biological activity of the molecules as measured against a rabbit serum sensitized to them might have resulted from an unfolding of their structure, thus exposing more active spots."

YUP, THEY MIGHT EVEN CURE CANCER

Later in 1960 an electronics magazine revealed even more about the proceedings of this Fourth Annual Tri-Service Microwave Conference held in New York. Our news clip is only half a page which reveals neither the magazine nor the writer, but about Dr. Bach's claim of a four-fold increase in the production of gamma globulin, he says:

"What does this mean to you? Gamma globulin plays an important part in the body's defenses against disease. Speed up its activity fourfold and it may be four times as effective a disease fighter. Some day your doctor may give you 'a shot of microwave' to keep you well.

Dr. Joe Howland of the University of Rochester found that dogs which had been exposed to microwaves were able to withstand heavy doses of X-rays far better than dogs not so treated. No specific application for this technique is now known, but such discoveries frequently lead to undreamed-of advances.

"And finally, some evidence has been gathered to indicate that certain kinds of cells, under the right conditions, will simply disintegrate -- fly to pieces -- in the presence of the right radiation. But surrounding cells are unaffected. Could such a selective beam ever be used to destroy cancer cells while leaving healthy tissue unaffected? Scientists don't yet know."

The writer didn't say which scientists he is speaking for, certainly not for Georges Lakhovsky, who died in that very same New York City 17 years before the Microwave Conference. Before-and-after photos of skin cancer cures effected by the Lakhovsky Multi-Wave Oscillator in Paris hospitals in the 1930s show that the Russian inventor did know just how selective radio microwaves can be. These pictures are reproduced in Lakhovsky's book, "The Secret of Life".

To continue with the magazine article: "said Col. George M. Knauf, one of the foremost experts on the biological effects of microwaves, speaking of these recent advances, 'Our work has progressed sufficiently for us to be fairly certain that the beneficial uses to which this energy may be put will greatly outweigh any harmful results it may produce in men.' All this of course does not mean we should forget that uncontrolled microwave energy can be dangerous. But like fire or W-rays, microwaves can, when used intelligently and with understanding and respect for the hazards involved, be among man's most valuable tools."

MULTI-WAVE OSCILLATOR USE IN A NEW YORK HOSPITAL

Georges Lakhovsky crossed the Atlantic to New York City in 1941, there to observe the effects of his MWO under controlled, technical conditions in a New York Hospital. A brief report of the positive and beneficial results of MWO treatments is appended to the English translation of his book, "The Secret of Life", by Mark Clement, on page 201. These treatments were given from July 1st to Aug. 21st and the name of the hospital and of each patient are withheld for ethical reasons.

Patient	Illness	Treatments	Results
X.	Arthritis, both knees	14	Good improvement
O.P.	Endocervicitis. Abdominal pain	6	Condition good
F.T.	Periarthritis of shoulder	12	Marked improvement after first treatment, condition good
M.M.	Osteoarthritis	7	Marked improvement after two treatments, stiffness diminished
M.K.	General Chronic Arthritis	11	Slight improvement
M.O.	Arthritis of ankle	3	Results good
A.E.	Post-operative fracture	6	Results good
C.V.	Arthritis, both knees	14	Marked improvement
M.D.	General arthritis	8	Marked improvement
J.H.	Epicondylitis of elbow	7	Results good
D.G.	Chronic arthritis	10	No cough, no soreness, marked improvement
S.L.	General arthritis	10	Marked improvement
B.M.	Arthritis and circulatory disturbances	6	Improving
M.L.	Arthritis of ankle and knee	7	Improvement, no recurrence
M.B.	Arthritis of shoulder	7	Marked improvement
M.O.	Tenosynovitis, hand	6	Improvement
S.S.	Arthritis, both knees	7	Improvement

S.C.N.	Congenital hip dislocation	3	Marked improvement
R.L.	Fracture, both ulnae.		
	Synovitis, both knees	5	No pain

Additional Cases

Case 1. G.D., female, aged 25: Patient complained of pain in the chest and muscles of the right arm and back, and constant cough. She did not respond to medical treatment and massage. Treatment with Lakhovsky Multiple Wave Oscillator was instituted. After the fourth treatment coughing stopped, pain in the chest became infrequent, and the tired feeling in the back disappeared. At the end of 12 treatments the patient no longer complained of previous symptoms.

Case 2. M.M., female, aged 51: Patient complained of pain and stiffness in the right hip. X-ray examination disclosed a marked narrowing of this articulation associated with large spurs at the margin of the acetablum which appeared to ankylose the joint. There were proliferative changes in the upper margin of the femoral head. Diathermy and massage failed to relieve the pain and stiffness. After 10 treatments with Lakhovsky's M.W.O. the stiffness markedly reduced.

Case 3. F.T., female, aged 38: For two months the patient complained of pain in both shoulders. Abduction of the right humerus was limited to 45 degrees. A diagnosis of periarthritis was made and treatment with Lakhovsky's M.W.O. was started. After three treatments the patient said she felt much better. The improvement continued. After a series of 11 treatments the patient did not return. Apparently permanent relief had been obtained.

Case 4. A.B., male, aged 60: Patient gave history of pain in both knees beginning in 1940. Diathermy and massage for one year gave only slight relief. Treatment with Lakhovsky's M.W.O. was instituted. After one treatment patient stated that he felt better. After four treatments patient felt so much better that he took only one treatment in two weeks.

Case 5. M.M., female, aged 42: Patient complained of pain in lower left back and hip. X-ray examination of the lumbar spine and pelvis showed calcification at the anterior margins of the inter-vertebral discs between the ninth and tenth and the tenth and eleventh vertebrae. There was also a slight scoliosis of the lumbar spine. Treatment with Lakhovsky's M.W.O. was instituted. After the first treatment patient felt better. After the fifth treatment improvement was very marked. Patient did not return after nine treatments.

Case 6. S.N., female, aged 59: Patient complained of pain in the right shoulder and inability to extend the arm more than 5-10 degrees, accompanied by severe pain. X-ray examination disclosed irregular calcification in the region of the greater tuberosity of the right humerus. Treatment with Lakhovsky's M.W.O. was instituted. After one treatment patient said she felt much better. The improvement continued steadily until 10 treatments were completed.

Case 7. C.P., female, aged 38: Gynecological examination showed uterus slightly enlarged and hard. Right para-metrium tender. Diagnosis --Parametritis. Treatment with Lakhovsky's M.W.O. was instituted on July 17, 1941. After four treatments patient felt better, and after 12 treatments patient was found to be much improved. Examination on Oct. 7th showed the adnexa and parametrium to be painless. Patient was considered cured.

REPORT OF CASES TREATED WITH LAKHOVSKY'S MULTIPLE WAVE OSCILLATOR BY A PROMINENT BROOKLYN UROLOGIST

The following results were obtained by a prominent Brooklyn urologist whose name must be omitted for ethical reasons. He is a Fellow of the American College of Surgeons and enjoys a great reputation as a skilled specialist. He treated hundreds of patients with Lakhovsky's MWO but only a few typical cases can be given here.

H.G.	Acute urinary retention due to enlarged prostate	2	Retention ceased
R.B.	Bleeding from uterine fibroids of two years standing	3	Bleeding ceased
S.M.	Mild multiple sclerosis with halting gate	6	Marked improvement, was able to run on several occasions
R.R.	Cellulitis of nose with pain	2	Cleared completely after two treatments of ten minutes each in one day.
B.T.	Acute urinary retention due to enlarged prostate	2	Retention ceased.
S.B.	Bleeding from cancer of the bladder	3	Bleeding checked. The tumor cleared up nicely and was reduced in size when seen again on cystoscopy three weeks later.
J.G.	Chronic aczema of Axilla	2	Cleared entirely.
L.G.	Severe pains form duodenal ulcer	2	Greatly improved.

In addition to the above cases this Brooklyn specialist treated six cases of enlarged prostate with nocturnal frequency (three to five times per night). After two treatments with Lakhovsky's M.W.O. frequency was reduced "to only once a night or did not occur at all..."

The above American reports were not included in the first edition of Georges Lakhovsky's "The Secret of Life", published in 1935, but were added by the English translator, Mark Clement, to later editions. We are quoting from the 1963 edition published by Health Science Press, Sussex, England. Health Research, (P.O.Box 70 Mokelumne Hill, California 95245) offers this same book.

This early (1941) research with the Lakhovsky equipment seems to nave been ignored by the American medical authorities, who are still concentrating on cure by surgery or medicine. If you want to discover the effects of weak radio waves on living organisms you'll have to dig for yourself. Our BSRA brochure, "The Lakhovsky Multi-Wave Oscillator", will give you some hints about setting up your own research program, and is available from headquarters.

'DOCTORS SAY RADIO TREATMENT IS EFFECTIVE AGAINST ARTHRITIS'

Apparently some doctors didn't ignore the research work done by Georges Lakhovsky. Take this news item from the New York "Post" for Feb. 8, 1962, with an Associated Press dateline from Washington, D.C. "A device theoretically capable of bouncing radio signals off the moon has yielded highly effective results in the treatment of stubborn cases of arthritis and certain other ills, a group of doctors reported today. The machine generates high-frequency, short-wave-length radio waves and emits them as pulses lasting only 1/17,000th of a second each. The pulsed currents are directed into a patient's body, with a maximum achievable penetration of eight inches.

"Use of the technique in treating arthritis, bone infection after hip operations, inflammation of the female pelvis due to gonorrhea and other conditions, and in speeding the healing of surgical wounds was described in reports by Dr. Euclid M. Smith of Hot Springs, Ark.; Dr. Dana Street of the University of Arkansas; Dr. Bruce Camern of Baylor University; Dr. Marshall Lobell of Harlem Hospital, N.Y.; and Dr. Solon N. Blackberg of Chicago. The reports were made last night at a private conference to which several Congressmen and Public Health Service doctors were invited. Blackberg later told reporters the researchers would like to enlist government support for expanded research by themselves and their investigators.

"Smith, in his report on arthritis, said the technique had been employed with "highly "effective results in 99 out of a series of 100 cases treated by him. Declaring that some of the patients treated had arthritis for up to 25 years before receiving radioactive treatment. Smith told reporters that "marked improvement" was achieved in all cases in from three to six months.

PUBLIC RECOGNITION OF RADIOWAVE TREATMENT

This sensational advance in the treatment of human ailments should have been welcomed from coast to coast in every newspaper. Dr. Blackberg and his distinguished fellow scientists from Baylor, Arkansas and Harlem should have received public acclaim from President Kennedy's Dept. of Health and Welfare and from the American Medical Association. But only a thunderous silence followed that early 1962 news item ion the private meeting in Washington -- until the Aug. 24, 1963 edition of the Saturday evening Post! In this national magazine, radiowave treatment of arthritis was branded medical quackery in the article "Hucksters of Pain". There Drs. Smith, Street, Camern, Lobell and Blackberg had their answer to "government support for expanded research". Fortunately, not every American is going to take this kind of libel without striking back at the mouthpieces of the vested interests who lend themselves so readily to control of the mass mind. Read this news clip from the Los Angeles "Times" for Nov. 1, 1963.

"SATURDAY EVENING POST SUED FOR $7.5 MILLION"

"New York -- The Saturday Evening Post, still smarting from one of the largest libel awards in history, was hit Thursday with another libel suit demanding $7.5 million.

"The suit was filed in Federal District Court here by the Diapulse Corp. of America, manufacturer of a machine that employs high-frequency waves in the treatment of infections and inflammations, including arthritis. The company said it was defamed in an article, "The Hucksters of Pain", which appeared in the Aug. 24 edition of the magazine. The article dealt with quack remedies for arthritis. The suit seeks $2.5 million in compensatory damages and $5 million in exemplary damages."

From the June 1964 Journal of Borderland Research

LAKHOVSKY OSCILLATING CIRCUITS

"About eight years ago I sent to the Health Science Press, Sussex, England for a little book, "Quick and Free Healing", and also "The Waves That Heal" and found that there are healing waves in the air we breathe. I am a sensitive with the pendulum. The book told to take an insulated copper wire and find the positive and negative ends with the pendulum, so I would know which end to put to the left side of my body --positive to the right and the ends overlapping. If you can't keep them in place, wrap an elastic band around them. For me, the pendulum swings clockwise for negative and back and forth for positive. First use of the wire came when I skinned my shin with a five-inch gash. The bleeding made me sick and I had to lie down. I thought of my wire circuit, got up and put it on just above the knee. It always had taken a long time for sores to heal on my body but this healed in three days time and showed only a narrow line about the width of small yarn. This convinced me that the oscillating circuit wasn't foolish.

"I loaned my little books to a high school student that was taking science. I thought they would interest him but he made all manner of fun of me, for believing such a thing. None of my family are interested in the good things that I have learned. I have been a member of BSRA since 1951 and think your journal is the best magazine I have ever read. Anyone wanting to learn more about the Lakhovsky circuits can write to Col. A.E. Powell. (Now deceased)

"Forty years ago I was taking treatments from an osteopathic doctor who sometimes diagnosed with the pendulum. When I became pregnant he told me he was going to discover the sex of my unborn child. He took his gold band ring off, tied a string to it and held it over me. It didn't seem to have any definite swing, maybe around once and back and forth. 'That's strange,' he said, 'I've never missed yet!' When the baby came there were two, a boy and a girl! I didn't ask him then where he learned about the pendulum or what it meant. Years afterward I sent to New York for one and found that I could ask questions and get yes or no answers that satisfied me. A medium told me that the pendulum is spirit controlled and mine was controlled by a young girl who was rather mischievous. If you want to put my experiences in the BSRF Journal it is all right with me. I got my education in the little red schoolhouse. I am 73 years old and still learning. They say you never get too old to learn and I find it is very true." Mrs. Earl Holfinger, Piqua, Ohio

A "HOPPED UP MWO" IS DANGEROUS!

"It is far too early to draw final conclusions regarding my experiences with the higher powered Multi-Wave Oscillator, a word of warning is in order. I powered mine with a 250 VA, 10 KV oil burner transformer. This is DYNAMITE and could, in my opinion, be fatal if too much power is used and I didn't miss it by much. My equipment sparks the antenna down to the 4th ring and the resonator to the second, with occasionally a week spark to the third. 10 hours after the first high-power exposure I felt like running instead of walking (age 72) and walked all around town and back, about six miles and no tiredness, whereas two miles would tire me before. That first exposure was about ten minutes for me and four for the wife (age 75). Immediate reaction for me was a moderately strong sensation of tingling from head to foot for about three hours before I could get back to sleep. None of this for the wife. Then, as aforementioned, I felt on top of the world. 24 hours after that, however, the wife and I developed the grandaddy of all colds and flu symptoms that we'd ever had. I hadn't had any real cold or flu in 15 years. This one dredged such an amount of mucus and toxic waste as I'd never seen before in my life. It was rough. It lasted two days before it wore off.

"This all had me guessing until your brochure arrived, with the experience of your Engineer-Physician Associate. He told that many of his patients developed flu symptoms after MWO exposure. His increasing conservatism was well founded. I decided to find out if the doctor's hypothesis of viral penetration would hold up. If so, a second high-powered treatment of equal strength and duration should produce much the same flu symptoms. But, having wound another coil, I used more power than the first time, sparking antenna and resonator down to the fourth and fifth rings. Results: no more flu, only a very slight tingling sensation, no feeling of exhilaration as before. Five days later I took another exposure, of seven minutes, with a little less power. This one did it. No tingle, no exhilaration, only a feeling of rapidly increasing depression, no sleep that night, a rather severe pain in the chest and heart region, extremely weak pulse, hardly pep enough to life an arm, and a nervous shaking all over. For a while I thought, this is it. It took five days for this to wear off and it isn't all gone yet. One night I lay awake until three a.m. figuring out how to pep up the MWO still more. Out of the blue, a voice clear and distinct and very emphatic: 'This is dangerous!' Again very emphatically, "Yes!" Normally I am not the least psychic, clairvoyant or clairaudient; so I choose to heed this as a warning from a discarnate guide or guardian."

Let this Associate's experience be a warning to you, if you feel the urge to build a hopped-up Oscillator, to transform yourself overnight! Bob Beck's original article cautions against this and his original equipment falls well within the safety tolerances set by the Air Force and the telephone companies for personnel working around radar and micro-wave broadcasting and relay equipment. Most of you taking part in this research program have built your equipment only in the last two or three months. It would be wise to stick closely to the original design for a year before altering it for further research.

LAKHOVSKY'S ORIGINAL THEORIES ARE SOUND!

With one or two exceptions all reports in to date show beyond question that Georges Lakhovsky's theories are sound: Radio waves do effect living organisms. In certain concentrations these waves appear to benefit cell growth, even to stimulate it. This BSR Associates have proven to their own satisfaction in only six months from the publication of our first article. Now it is up to others to exploit this knowledge while we turn our attention to other projects.

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From the July-August 1964 Journal of Borderland Research

LAKHOVKSY OSCILLATING CIRCUITS

"The danger of strong reaction to a hopped up MWO, as told in the June Journal, reminds me of my experience with the single circuits. Months ago I wrote to Col. A.E. Powell and he sent me single circuits to wear around waist, neck etc. This I did for two months or so, daily. I'd been under the weather enough to hope for benefit. Instead, I had three successive colds -- something I never, never had in my life before, even during the worst of my catarrh years. It never once dawned on me it could have been the Lakhovsky oscillating circuits; now I wonder?"

A California Associate

Yes, it had been the experience of others that the apparently powerless Oscillating circuit, of only one wire looped around the body, can produce a strong reaction on living tissue. A San Fransisco Associate told us during our May trip north that she received a wire loop from Co. Powell and wore it to bed that night, and forgot about it. Early in the morning she awoke with such a violent pain through her middle she thought she'd die! She lay there and stuck it out until the pain left and went back to sleep. In the morning she awoke refreshed and ready to go, with the oscillating circuit still around her middle. It began to dawn on her that this was the cause of the pain, but it also had affected the healing of a long-suffered condition. At the time we were there, weeks later, the condition had not returned. Certainly no permanent cure of any condition can be expected unless the original cause in mind, emotions or spirit is changed, and if a person insists on indulging his vices, use of oscillating circuits may only cause needless pain!

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From the OCTOBER 1964 Journal of Borderland Research

HE PREFERS VITIC TO MWO

"Personally, while feeling the passage of the high tension flow from the antenna of the Multi-Wave Oscillator, I found no beneficial effect. On the other hand, the Associate with whom I obtained the MWO realized definite improvement. He has kept up the use and told me lately that he is feeling steadily better and lays the improvement to the use of the outfit. Some years ago I had frequent conferences (thru a medium) with one who was said to be Madame Blavatsky. During the course of these talks she dismissed the subject of electricity as of little value in comparison with a study of magnetism. That in the study of magnetism lay the secrets of many valuable matters. I am led to refer to this because I recently obtained relief, and apparent cure, from a troublesome irritability of the bladder by the use of a magnet. Other treatments had been of no value. I made no report of this until the fact was definite. The use of the magnet was experimental and came from the suggestions of a Chicago University specialist in the subject, relayed to me via various Biomagnetic reports and some correspondence."

Associate A.N. Onymous, Dixie, U.S.A.

This letter from an elderly Associate was dated Sept. 3, 1964. It certainly provides an interesting and stimulating commentary on the material in the preceding pages of the Journal. Interestingly enough, we've had many reports of successful and continued relief of irritating bladder and prostate conditions from exposure to the MWO. In the Vitic device we now have a borderland gadget that is far less troublesome to build and to operate. How effective it is remains to be proven.

THOSE LAKHOVSKY CIRCUITS AT WORK

"About the Lakhovsky wire circuits, there is no other way to account for the consistently maintained energy I receive. I wear one all the time as do several others I know, all of whom report amazing results. One man past 80 finds it peps him up too much, so he wears it intermittently."

Howard D. Clark, Yucca Valley, Calif.

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From Jan-Feb 1965 Journal of Borderland Research

HE WORKED WITH GEORGES LAKHOVSKY

"A friend of mine sent me your pamphlet describing the Lakhovsky Multiple Wave Oscillator. I was the first man that bought this instrument in New York in 1940, on the advice of a physician who saw it at a medical congress in Vienna. My young son had developed a face lesion. It was diagnosed as tubercular. I was having a joint office at that time with a progressive MD. I was practicing dentistry. Her success with the MWO was phenomenal, but when she began to treat cancer cases the American Medical Association got after her and me and revoked our licenses. I had translated some of Lakhovsky's works into English from the French. Professor Lakhovsky came often to my New York office. He told me the Pope was using one of his instruments. The success obtained in the hospitals was excellent but the reports were suppressed. The good professor died of a broken heart. Our case was a regular frameup by the AMA, the lawyers and the courts. I was foolish enough to fight the case and spend lots of money, not knowing that the AMA controls even the courts and judges. I still have some copies of the booklet and a photo of my Lakhovsky instrument. If I can locate them I'll send them to you. I sold my instrument to a doctor in Texas and left New York state in 1945. I am a licensed Naturopath in Florida and Chiropractor in California. Am enclosing $ for membership. I belonged to BSRA several years ago."

Dr. N.S. Hanoka, Miami Beach, Florida

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From March 1965 Journal Borderland Research

"THE SECRET OF LIFE"

"I loaned my copy of Lakhovsky's 'The Secret of Life' to my chiropractor, also your Journal. He had one build and I've been taking treatments from him on the Multi-Wave Oscillator. After two treatments I got an awful cold and I have never blown so much bloody mucous out of my nose. Also, after each treatment, it would leave me weak. I would have to lie down several times a day. There always was a reaction but my bad sinus condition has cleared up considerable. I also had trouble with my liver and there were so many things that I hadn't been able to eat, for 15 years or more. Now I can eat them and enjoy them. The MWO is certainly worth having and I am improving."

Mrs. A.N. Onymous, Somewhere, Indiana.

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From the October 1966 Journal of Borderland Research

HITTING THE HEALING TRAIL WITH THE MWO

"It would be appreciated if you would put an announcement in the Journal that Dr. S.L. Jamison, D.V.M., N.D. (Gr.Br.) announces the opening of a practice of naturopathy in Santa Cruz, California.

"The climate has changed greatly from the old burning-of-books days by the FDA. We cannot all stand back and wait for "George" to do something. I have the advantage of a lot of training in a legitimate field of allopathic medicine. Only a veterinarian would be able to make such a move and escape retribution for it. A regular M.D. would be branded a traitor to his fellows.

"I have moved to Santa Cruz to set up practice as a naturopath, using the M.W.O. unit, spiritual healing and diet -- along with naturopathy measures for the healing of old injuries and chronic degenerative diseases. There will be no charge if there are no results. Since my fees will have no legal status, this will be made clear to the people using the service so they will be under no compulsion to pay, even if results are satisfactory!

"There are no incurable diseases but there are incurable patients!

"With the MWO we have not gotten uniform results classified by the disease the patient had. About two out of ten people do not respond to the MWO unit at all. You had just as well breathe on them. I strongly suspect that these people should consult an allopathic physician, M.D., as they would be helped better by conventional medicine. You might say our cases were selected, as people came to us in the last stages of sheer desperation -- conventional methods (including chiropractic) having failed.

"Some of these (not many) also do not respond to the MWO. They usually respond to spiritual healing methods when this happens. This I have not figured out good as yet. Once in awhile an arthritic will claim to have been worsened by the unit. This occurs usually in an arthritic with arthritis in a number of joints. One treatment seems to break the poison loose in their body, and they fall like the wrath of hell about two days after. Get them in immediately and run them again, and everything is alright.

"To sum it all up, I have got so I do not care what disease a person has got as long as it is not an acute infectious disease, or a recent stroke case. I have been afraid to try it on either of these as all we would need is for somebody to fall over dead while on the unit and we would be wearing striped suits or breathing HCN in a gasper chamber. . . The unit regenerates the whole body." S.L. Jamison, D.V.M.

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From the July-Aug 1967 Journal of Borderland Research

A TRANSISTORIZED MWO

"I would like to compare operational notes with some one who has built one of these MWOs because I question some of the statements made in the original article. I'll just give a brief description of mine and some of the things I ended up doing. I started with aluminum elements but had trouble with the gluing process so ended up with using printed circuit boards so my elements (antennas) are copper. I have good arcing between first four rings. Can make 'em all arc if I bring point of wooden pencil near the smallest, but pencil must be held certain way or I'll get knocked on my haunches.

"I ended up with a 9 in. Tesla coil. Tried 7, 6 and 5 but ended up with nine. The trouble here was with leakage between primary and secondary. It was terrific until I took means to reduce to a minimum. The transistorized drive I use is partially a hangover from the days of when I used transistorized ignition in my one vehicle. The ignition coil was modified to increase the step-up ratio and since the coil was mounted originally in oil, it was a 'slippery as an eel' project. The driver uses 5 transistors plus diode and operates on a source power supply which can supply up to 20 volts d.c. The drive seems to function best at about 15 - 16 volts.

"Now for a question. If Mr. Beck, as he indicated in his original article, 'reconstructed the circuits' of an original MWO in a certain man's house, why didn't you people publish a diagram and dimensional data on that original piece of equipment? That would be a project a man could sink his teeth in. Instead this pee-wee MWO which you now say is not much good unless everything arcs. You mean arcing all the way down to the smallest ring?????? When you get your up-dated MWO data published, let me know as I would like a copy. R.A. Rieck, Rochester, Minn.

Arcing between the first four rings, from the outside in on the MWO antenna, is about as good as any we saw when we were researching the instrument in 1964; so it sounds as though your transistorized MWO -- the first we've heard of --is doing very well and should be putting out enough energy to affect living cells. You any wish you had cut aluminum antenna rings after all. For some reason, the arcing between copper rings builds up deposits which must be cleaned off periodically. Bob Beck didn't offer us a schematic of the original Lakhovsky equipment he saw. He said it was housed in a 300 lb. cabinet. The antennas were of circular-formed pipe rings. The outside ring was two feet in diameter. There was a large, separate Tesla Coil driving each antenna. This is a professional model designed to impress the patient. It also probably puts out enough static to antagonize the neighbors for blocks around. We believe Bob Beck deserves all credit for grasping the principle of multiple wave propagation developed by Lakhovsky during radio's infancy in the 1920s and redesigning it into a simpler, smaller device for present-day borderland research.

LATER COMMENT ON THE MWO BY MR. BECK

"The key factor is that the rings MUST arc profusely all around the circumference of the outside and THIRD ring simultaneously. There is no effect, either on a calibrated Hewlett-Packard field strength meter, or physiologically, at the target frequencies if this arcing does not shock-excite the rings. And yet I have seen at least three machines that did not have sufficient voltage from the Tesla Coil to even drive the outside ring, let alone the third element! It would be a shame to invalidate the device because of this. Some of the machines I've seen drive the Model T Coil from an A.C. transformer! The obvious fallacy here is that the coil's vibrator is a resonant device supplying the make-and-break voltages (and magnetic field) to the T coil primary at the designed frequency. Since the transformer is on and off 120 times a second, the chances of the T coil points 'breaking' at the precise instant that the 60-cycle house current is at a POSITIVE peak is about one in fifty. And even if it fires 'sometimes', the T coil is modulated with the 120 cycle line (twice the 60 cycle frequency, since each cycle has two peaks, both a positive and a negative).

"Try it at 300 mc. and 10 kmc. on a field-strength meter some time. You'll see what I mean. The Tesla Coil, incidentally, is just a convenient supply of free electrons. The cascade of electrons or 'high voltage' breaks down the air's resistance (by arcing) and then drives the antenna rings. But if the drive is interrupted, the rings may not absorb and resonate properly. At any rate, it is difficult to kid the Hewlett-Packard meter, and I'd like to see the original design followed, at least for the first year."

AN IMPORTANT MODIFICATION

"The greatest modification to date was the discovery of a box of war surplus very high voltage rectifiers in a bin at a Burbank electronics store. The 30,000 to 60,000 volt selenium stack rectifiers.....eliminates the necessity for a tuneable gap, and roughly quadruples the output of the Tesla Coil, also lowers battery drain to half."

BEWARE THE PUNITIVE HAND OF THE AMA

Turlock, Calif. "Daily Journal", Dec. 2, 1966: "Dr. Stanton L. Jamison, formerly in charge of the state Poultry Pathological Lab here, was arrested yesterday for practicing medicine without a license. The veterinarian is charged with using an electronic device -- with high voltage sparks crackling and jumping about on either side of a patient --with the claim it was beneficial in cancer and bone diseases.

"After posting $1100 bail, Dr. Jamison defended his machine. He said parts for the machine cost less than $50. If someone followed up on the apparatus, he claimed, it would be a 'blessing to humanity'. Police Chief John Viarengo, Lt. Bill Ladd and investigators for the California Bureau of Food and Drug Inspection took Dr. Jamison into custody in the offices of his Life Aquarian Center in the Mercantile Building. Lt. Ladd said a sign reading 'Universal Life Church, Inc.' was prominently displayed in the front office. He said four or five agents had been 'ordained' as ministers in the church by telling Dr. Jamison they wanted to become preachers. Soon their official ordination certificates arrived in the mail, said Lt. Ladd.

"Police described the apparatus as similar to an electric chair, with four-inch metal rings looking like handcuffs hanging over doors to the room. The theory was to determine polarity of a patient with a pendulum and then proceed to change negative polarity to positive with the 70,000 volt device. Chief Viarengo said patients were being treated for a variety of diseases, including stomach ulcers and cancer. Investigation into Dr. Jamison's operations started in May, when police began receiving complaints from relatives of patients. No money was charged for treatment, according to Lt. Ladd, but patients were expected to make donations to the church. Dr. Jamison headed the state poultry lab here for a decade. He will be arraigned on the charges in Turlock Judicial Court next Friday morning.

"In a statement released following his arrest, Dr. Jamison said the 'multiple wave oscillator' picked up by police resembles many electronic gadgets used, usually ineffectively, in the past for treatment of many complaints. However, he insisted, his oscillator appears to be the exception that proves the rule.

"'The unit suffers from a sort of 'guilt by association' with other electronic gadgets to the point where serious doubt would be the reaction of any trained scientist on first observing it,' he admitted. 'I know that this was my reaction.' However, he said he suffered continuous pain following a 1962 automobile accident and, willing to try anything, tried the unit. It helped him, he insisted, and has helped many others. He said the unit had been tested and checked by qualified medical men in Europe in the late 1930s. 'Some progressive healer will follow up my lead in continuing to develop the electronic unit,' he said."

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From the November 1968 Journal of Borderland Research

AN MWO PHENOMENON

"Please find enclosed $ for another year's subscription to your wonderful Journal. It has been very enlightening, and I always look forward to receiving it. I have taken treatments on the MWO for a long time and have been puzzled. Soon after I started to take treatments, the hair stopped growing under my arms. I have wondered about this and if anyone else has had the same reactions?"

Mrs. E.H. Piqua, Ohio

This is new to us! If any of you researchers have experienced or observed a similar phenomenon, we'd be glad to hear about it and share it with the rest through the pages of the Journal. The Tesla Coil problem has been solved with the discovery of a good commercial coil made by Master Appliances, Marion Indiana. This coil will drive one antenna very well.

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From the Jan-Feb 1971 Journal of Borderland Research

THE PASSING OF CYRIL SCOTT

"Cyril Scott, born Sept. 27. 1879 in England, died first week of 1971, so two friends here inform me. I'm always happy to see one who writes so intelligently regarding diet and health, vindicates his ideas by living that long. Not many do! BUT, I read in our local paper yesterday of the death of a former neighbor who died on 11th January at 93, and she knew nothing regarding diet, positive thinking, etc. So, where are we? I can't ever make 2 & 2 come to four, woe is me.

"Two small books come from Muriel Archdale, England, by Cyril Scott, 'Safe and Saner Remedies', and 'Health, Diet and Common Sense'. On page 162 of the latter he mentions the George Lakhovsky book, 'The Secret of Life', memory of which caused Mr. Scott to suggest using a copper wire around his middle to a man who was too breathless to walk far or uphill. The man wore the Lakhovsky loop for twelve hours, had a copious and offensive bowel movement, then on following day and another uphill walk, the man was able to keep up with Scott! I found my copper flex soon after but it is awkward to keep in place to make sure the negative end is to the left. Cyril Scott gives the homeopathic remedies needed, particularly emphasizes potassium for cancer."

A.F., Santa Cruz, California

COPPER BRACELET CURES "TENNIS ELBOW"

News Item from Crosby Golf Tournament at Pebble Beach, California a year ago. 1/24/70: "Bert Yancey one had to give up golf because of a nervous breakdown. He also came close to quitting the professional tour last year because of a 'tennis elbow'. But he didn't mainly because he found a remedy endorsed by Australian tennis pros John Newcombe and Tony Roche. The so-called remedy is a $7.50 copper bracelet, otherwise known as 'The Absorber' or a 'Voodoo Bracelet".

"Yancey wears one on his right wrist to correct an arthritic condition in his elbow and he has worn it for the past five tournaments, including the $150,000 Bing Crosby National Pro-Am, which he leads by two strokes at 137 going into today's third round.

"'I don't know why it works, but it does,' said Yancey, a 31-year old former West Point cadet who finished third in the 1967 and 1968 Masters and won the Atlanta Classic last year. He said a tennis pro in Napa Valley suggested last summer that he wear the bracelet and got confirmation from Newcombe and Roche, who have suffered from similar ailments, that it would work.

"Yancey strained his right elbow two summers ago lifting a concrete birdbath in the backyard of his home in Tallahassee, Fla. He took a pain-killing drug that enabled him to compete in the U.S. Open at Rochester (where he finished third), but he was warned that the drug w 'dangerous...that it gives you ulcers'. 'I never got ulcers, but I felt a pull in my stomach. That's when I quit using the drug.'

"He said he hasn't needed the pills anyway, since wearing the bracelet. The therapeutic effect of the copper, he said, has to do with chemical displacement within the body. 'I majored in chemistry while taking pre-med courses in college and I think I know enough about copper deficiency in the body to believe that, somehow, the bracelet can help me.'

"Somebody then pressed Yancey for an answer about what makes the bracelet such an effective remedy. 'I don't know for sure,' he drawled, 'maybe it's all psychological.'"

YANCEY WINS THE CROSBY OPEN

Sports writers are always looking for a new angle for stories and Bert Yancey withstood a spectacular charge by Jack Nicklaus on the final round, with a 65, and came in with a hot round of his own a 69, to win the tournament and a cash prize of $25,000. Yancey and his Voodoo Bracelet were headlined all over the country. The LA "Times" called it a "Copper Caper" in its Jan. 26, 1970 story.

As was to be expected, the medical authorities in desperation had to prepare an immediate counter blast of propaganda to keep the public hypnotized. The sales of medical snakeoil went down as arthritis sufferers flocked to buy non-medical copper bracelets! The "Times" and other metropolitan newspapers willingly cooperated. After all, patent medicine advertising is a big source of revenue, and who knows how much profitable pharmaceutical stock is owned by the publishers of the papers?

The "Times medical writer, Harry Nelson, dutifully wrote: "The Arthritis Foundation, a legitimate group interested in getting better treatment for arthritis sufferers (There is a contradiction here, Harry, for medical authorities claim there is no cure for arthritis!) refers to copper bracelets as 'an age-old fraud which has no scientific basis whatsoever'. Yancey is the latest sports figure to get taken by the 'copper caper', which the attorney general of New York last summer called 'one of the oldest and most vicious swindles'."

These opinions by the Arthritic Foundation and the attorney general are of course; utterly worthless. They are not based on the results of intelligent scientific research, but are based on the profit motive of the medical trust. The electrical nature of living cells was established beyond any shadow oaf doubt two generations ago, by the sound theories and research of Dr. Abrams in San Fransisco and Georges Lakhovsky in Paris. Thousands of supporting tests since then have proven conclusively that body cells have polarity, and that in an unbalanced or unpolarized condition, disease or injury, the subtle oscillations of a wire coil or loop will restore polarity. Sad to say, there is nothing of this in the training of medical students today and it is left to Borderland science to carry the torch. The honest, straightforward testimony of public figures like Bert Yancey, Tony Roche and John Newcombe is ridiculed by the witch doctors of authority for medicine.

JUST KEEP TAKING YOUR EXPENSIVE PILLS!

Under orders from above Harry Nelson interviewed Dr. John Calabro, the arthritis authority at University of California in Los Angeles, "He points out that the bracelets may seem to work because arthritis can improve spontaneously and it is easy for the person to associate his improvement with the bracelet.

"'I tell patients it's OK to wear the bracelet providing they do all the other things I ask them to do,' said Dr. Calabro." Including, of course, the purchase of poisonous pain killers at fancy prices. How much scientific integrity does Dr. Calabro have when he and his university accepts fat research contracts from the medical trust? Is it any wonder that today's Aquarian Age students are publicly questioning the morals and ethics of their professors? They are told that the goal of a university is the search for truth -- at least that is what the Chancellors say in their public speeches. But when the student gets to the laboratory he finds that the search is for profitable products for industry -- or help maintain a well-established profit position.

LAKHOVSKY BELTS, LOOPS or OPEN CIRCUITS

"Thank you for the clarification of the Lakhovsky belts described by the late Col. Powell in his publication. I tried what you suggested and after some thought I finally understood what he meant and I believe the belts should look like this:

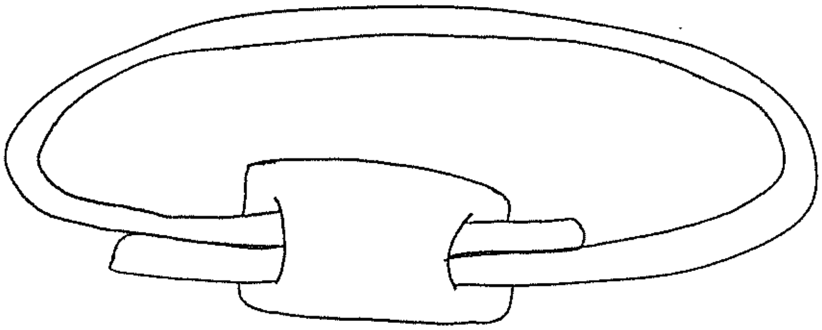

You might want to try experimenting with flat ribbon cable for these belts or coils. It can be bought at most electronic stores and it comes in different widths or colors. I am wondering also, is it really necessary to separate the lamp cord and use only half of it? Could it not be used as it is, with two strands of copper wire, insulated, side by side?" G.B.F., San Fernando, California

Yes, in our one-loop coils of white insulated lamp cord, we now use it just as it comes from the store, without separating the two strands. But you plastic 'buckle' or 'button' shown above may allow too much slippage; so the ones we make for ourselves and for research-minded Associates have separate entrance and exit holes for each end of the insulated wire. The white insulated wire seems preferable from the hygiene angle, seeing that it is usually worn next to the skin.

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From the March-April 1971 Journal of Borderland Research

OUR LOOP-THE LOOP PROJECT

"It looks to me like the Lakhovsky loops work homeopathically. It's not the copper element, per se, but the loop the loops it makes, throwing back into the body forces which the body is throwing off. It's an automatic homeopathic prescription, each body being its own pharmacist!

"The Yogi does it when he goes into suspended animation, re-breathing his own air. Urine therapy, drinking one's own urine, as described by Armstrong, is homeopathic. An ostrich putting his head in the sand breathes his own air. Breathing into a paper bag and re-breathing the contents is a specific cure for old age pains and hiccoughs. Dianetics was mental homeopathy, i.e., the original book but not no more. Dianetics is re-thinking one's own thoughts. You imbibe your own aberrations, attaching like with like. Homeopathy is like a feedback system. Gods ate their own offspring. It's Isis picking up the pieces. The smaller the dose the more potent the cure. Etc. Etc.

"Send me two kits of three experimental loops. Maybe I can fatten up on them."
P.F., Florence, Arizona

HE FEELS LIKE A NEW PERSON

"I read that part in the Journal about the copper wire loop; so today I did loop one around me and sure enough the oscillating motion calmed me down. It sure was a sensational feeling because lately at times it got so bad I though I would spin off, even though I do the five Rites nightly. On occasion I also experience a terrific pain in my left side which forces me to sit down, just a great pressure especially after standing over the stove preparing meals for maybe three to four hours at a time. The customers just couldn't understand how I stood up under pressure of serving so many people. Seems like mass production.

"So with this new item I feel like a new person! And I'm going to have you send me one of your experimental kits, to see how it compares to what I hooked up on myself. Of course I just taped the wire on and this is only about six hours since I put it on." J.M.S., Charleston, South Carolina

A DEDICATED BORDERLANDER

"Enclosed is a check for membership renewal and for five sets of experimental loops. I want to compare the effects of the Lakhovsky coil with the Japanese-made magnetic health bands which I sell to my tennis customers. I am very active in tennis playing and teaching. The results with this band are very good."

A.M., Miami, Florida

BEYOND THE PHYSICAL

An Associate writes that she had success in "curing" and arthritic elbow by wearing a copper bracelet on her wrist. Then the pesky condition showed up in her knee! From there is moved to another part of her body. Then it began to dawn on her that their Higher Self was trying to tell her something, that the swollen and painful joints were an outward manifestation of an inner mento-emotional condition of resentment and bitterness over an unhappy marriage. With the cooperation of an understanding doctor and more orthodox heat treatments, etc., and a more positive and cheerful attitude on her part, the condition was finally eliminated. It took months to cleanse the system of the accumulated poisons, physical, emotional and mental.

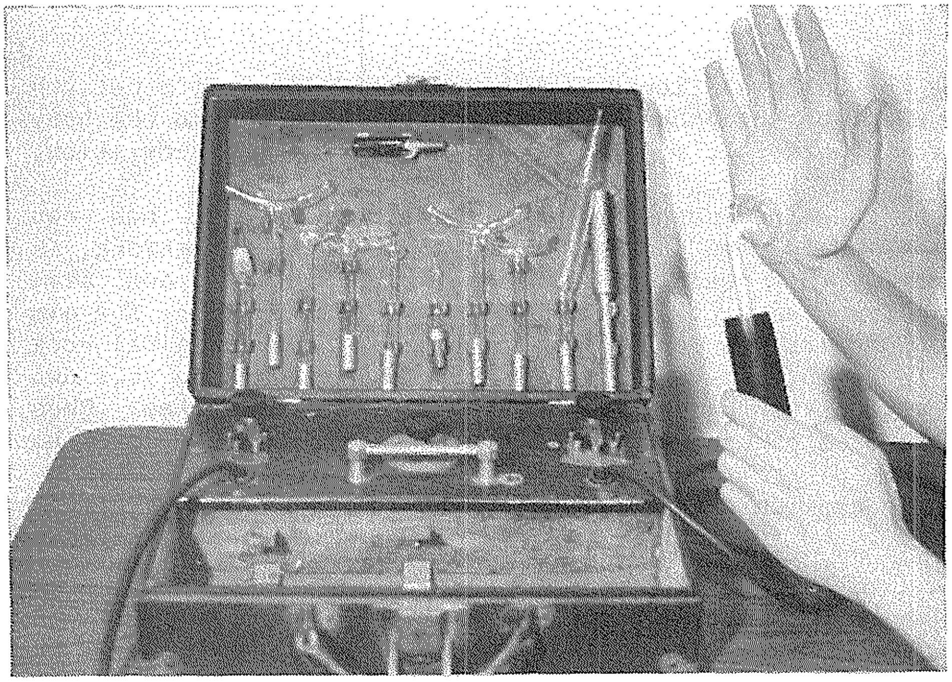

1920's era Violet Ray Massager. From the BSRF Collection.

From the Jan-Feb 1966 Journal of Borderland Research

THE LAKHOVSKY MWO IN INDIA

"The MWO is giving wonderful service and days are passing and I am gaining some new experiences which have not been recorded in the book. I will appreciate if you kindly clear some of my doubts. In practically all the cases I am finding aggravation after three or four sittings. Do you think that it is due to a sudden oscillatory shock that is given to the patient as it so happens when Homeopathic medicine is given? I feel that it should have at least been recorded by some one. One more question. What is the reason for metals being removed from the person of the patient? In case they are not removed will there be any adverse effect? This is very vital because here in Bengal there is a custom that the married ladies must wear one Iron bangle. They will not remove it under any circumstances. What is the remedy for this?

"I find that the appetite improves in practically all cases. Rheumatism and Arthritis cases are definitely benefitted. In one case a Tumour which is there since about 20 years has definitely gone down with only 4 sittings. I am watching the case carefully and if the Tumour disappears it will be a great achievement for the MWO. Debility is markedly reduced in nearly all cases. In a recent case of Spondylitis the MWO has done wonderful work. The flexibility was 8-1/2" from the floor which has come to 6" after 7 treatments and all the pains have practically disappeared. Due to the New Moon and Eclipse there is an aggravation but I hope it will gradually go. Asthma cases have not responded so well but I am not yet disappointed with the results. It is as yet too early for me to assess the capabilities of the MWO on various diseases. As you say I also believe that this instrument will work on all persons irrespective of their complaints but still there must be some specific organs on which there is more influence of this.

"Something which I forgot to mention previously, can you tell me whether you have seen Hemorrhage as a result of MWO treatment? In at least 3 cases I have seen bleeding start where there was no previous history of bleeding. What is it due to? In one case there was profuse bleeding after 2 sittings and that has made me a bit nervous. Just now a patient reported that he was getting blood in the sputum even though there is nothing in the lungs. In the third case blood appeared in the urine. Please give a thought to this as this is a very serious complication if it is caused by the MWO." Dr. A.K. Bhattacharya, West Bengal, India.

The above is a portion of a letter to Associate Al Goeke, Redmond, Washington, which Al passed on to me for comment. I thought the rest of you would be pleased to know that this East Indian doctor has gotten very encouraging results from the very beginning in the use of the Multi-Wave Oscillator. If by aggravation the doctor means a sudden release of mucous, heavy cold or flu, this is a sure indication that the MWO is working and affecting a release of accumulated poisons in the body. This is touched on in our brochure, in the comment from a midwestern doctor which built and used such equipment in the 1940's. When he began producing mild flue -- as he called it -- in his patients, he got scared off! The hemorrhaging by the doctor's East Indian patients is more serious but we believe it is still a result of the same thing, a sudden releasing of accumulated poisons through the shedding of bad blood. We know one oriental who had a heavy nose bleed after the first exposure to the MWO field. Apparently orientals, some of them at least, are more sensitive to the soft radio wavers than Caucasians living in America; so the doctor's prescribed treatments should probably be somewhat shorter in duration and spaced further apart.

Yet I well remember the radio technicians in Honolulu, Hawaii. I was an announcer and producer there for several years. Some of them were of Chinese and Japanese ancestry. When repairs were needed on the radio towers, these men wouldn't hesitate to jump on, climb up and work for hours while the station was putting out a steady five to ten thousand watts of power. I don't recall any of them suffering any ill effects such as internal bleeding. Yet their tools would get so hot because of the strong field that they would have to wear gloves in handling them! It was these eddy currents caused by an inert piece of metal in the pulsing field that Bob Beck was concerned about. There isn't enough power in the MWO to cause heating in bits of metal about the body, if one can't strip down for an exposure. The piece of metal, say a zipper or a ring, might reduce the efficiency of the field in that area but we didn't worry about this when testing the equipment we had for a short while in 1964. I don't think Dr. Bhattacharya should either. The machine seems to produce results anyhow.

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From the March 1966 Journal of Borderland Research

BASIC NEW AGE PHYSICS

by Trevor Constable

(Publication of Dr. Bhattacharya's letter in the Journal, page 20, Jan-Feb 1966 issue, elicited the following significant comments by Mr. Constable.)

A word on Dr A.K. Bhattacharya's reports concerning the Lakhovsky Multi-Wave Oscillator he is using successfully at his West Bengal, India clinic. The results are indistinguishable from those systematically recorded and published over a long period by the late Dr. Wilhelm Reich, M.D., concerning his "orgone therapy". Reich was the discoverer of Primary Energy -- pre-material and mass-free -- which he named Orgone.

The improvement of the appetite, the reversal of rheumatism and arthritis even to structural changes, the rapid reduction of tumors and the hemorrhage effects are all to be found in Reich's massive clinical literature on orgone therapy. Dr Bhattacharya's reports, plus others any my own experiences with the MWO serve to confirm my previous evaluation of this unit as published in the Journal over two years ago. In essence, the MWO is a device for orgone therapy. It achieves its startling results because it is a generator of primary energy, or at least a focus for primary energy.

Any person with a modest extension of physical vision who will observe an operating MWO under conditions of indirect, rather dim fluorescent lighting, will see for himself that primary energy from the earth's atmosphere (the Orgone of Reich) condenses prolifically between the coils of the unit. The concentration is many times that which normally surrounds a living organism.

The basic New Age physics involved, for which we are indebted to Reich, are as follows: Wherever secondary energy, i.e. energy obtained from matter in some way, is released, primary energy tends to concentrate to extinguish this energy. Secondary energy is life-negative, i.e. inimical to the living, a fact which is illustrated, in its ultimate extension, in the lethality of atomic energy. Where so-called "soft" radio waves are involved, the antagonism of primary energy to their emission is evidently considerably diminished over the violent effects that accompany radioactive substances in the presence of primary energy accumulators.

In the case of the MWO, the tremendous band of frequencies covered results in an extreme concentration of primary energy, which also has its frequencies and correspondences (the Rates of radionics) with the secondary, electromagnetic spectrum. That this effect is achieved with minimal secondary emission is the beauty of the Lakhovsky unit.

TWO-FOLD FUNCTION OF THE MWO

In my view, the dramatic results obtained are due to a two-fold function of the unit. First, there is the undeniable concentration of primary energy around the body of the patient, particularly potent where a limb or other readily accessible member may be exposed. Secondly, there is the reaction of the specific biological energy of the individual organism, from within, to the stimulus of the secondary waves, which it rushes to combat.

Under the laws of primary energy first discovered by Reich, the patient, as a living organism, is a stronger vital system than the MWO. Accordingly the patient attracts and withdraws the charge of primary energy produced by the device. This is in direct contradiction to formal electrical laws, and as such is typical of the criteria that rule primary energy. The continued emissions of the Lakhovsky unit provide a continuous concentration of primary energy on which the patient draws. Just how long this process should be allowed to continue, per treatment, is where we run afoul of allopathic (MD) thinking.

The acquisition of a strong primary energy charge by the ailing organism results in a reversal, or at least in the reduction of life-negative, i.e. diseased, processes. Reich found with his orgone accumulators that the reduction of tumors was not as great a problem as the auto-infection resulting from the overloading of the excretory apparatus. The debris and bacilli from the diminishing tumors must be eliminated, and unfortunately, because the excretory apparatus is frequently involved in the general putrefaction of which the tumor is the end result, this was the major problem in managing such cases, in Reich's experience.

The medical lectures of Rudolf Steiner, Ph.D., contain one of the master keys to successful therapy, particularly appropriate to the use of the MWO. Steiner points out that what the ailing organism needs is the significant, vital impulse in the right direction, then careful nursing and management as it recovers out of its own forces. This was also the view of another genius, the late Dr Ruth Drown, who knew from experience how important the first impulse back to health is for the sick individual.

Hence, it seems that the old allopathic urge to convulse the patient with therapy, to repeat the massive dose again and again, is something that should be resisted in using the MWO, at least where tumors are being dealt with. The idea of applying the MWO in daily doses may stand in need of modification. We are all to some degree creatures of gross, non-vital thinking that stands behind our allopathic medical civilization, and we will need to carefully train and think ourselves out of the absurdity that the massive dose is the sine qua non of therapeutic success.

THE TRUE-BLUE ROOT CAUSE OF DIS-EASE

As far as unexpected hemorrhaging from the lungs and similar manifestations are concerned, I think the problem is essentially that diagnosis is so inept and inaccurate that the physician does not have a true blueprint of his patient. After my years of association with Dr Drown I am sharply aware of the fact that nobody just has one ailment or problem, but that we are all bearers of a veritable plexus of malfunctions which usually proceed from one primary and obscure root cause. What happens with the MWO is that the injection of primary energy into an ailing organism results in multiple manifestations of the healing impulse, and not just a direct effect upon the object of our attention --which may be a tumor, ulcer or other extreme symptom.

All the effects produced by exposure to MWO units are identical to those experienced in orgone accumulator. The healing agency in both cases is primary energy, and I hold that this is so no matter what plausible arguments might be advanced to reconcile the MWO with formal theories and thus win the neurotically-desired approval of physicists and doctors. It perhaps seems incredible that one can obtain the same effects produced by the MWO by sitting in an orgone accumulator, with absolutely no electronic apparatus connected to is, but it happens to be so. Try it and see!

MWO experimenters owe it to themselves to study Reich's work in full. As long as they wander in these fields, they may as well build into themselves the realization that electromagnetic energy has an inevitable and unavoidable and inescapable concomitant -- primary energy, life-positive, mass-free energy whose criteria and laws are the exact opposite of the energy accepted by formal physics. The best testimony to Reich's tremendous contribution to human advancement is that he died in a U.S. Federal Prison. As all Borderlanders know, innocent bumblers die in bed in their own homes, untroubled by the status quo.

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From the April 1966 Journal of Borderland Research

MWO SURGERY AT SHASTRI VILLAGE AND RELATED MATTERS

by Al Goeke

I believe you and the Associates would like to hear the latest comments from Dr. A.K. Bhattacharya, Naihati, West Bengal, India on the Beck adaptation of the Lakhovsky Multi-Wave Oscillator he is using in his clinic there.

"The other day I had an unique experience with the MWO. I think this should be published. I was treating a lady for rheumatism. After four sittings, once a week, she had a pain under the tongue and there was some inflammation with pus coming out. I asked her to take a further sitting. After about five minutes all of a sudden the thing burst inside the mouth and five pieces of stone came out. When I took her medical history I found that she had an operation two years before and a bit of Salivary Calculi was extracted, but the surgeon had told her that some still remained behind. The MWO treatment eliminated the foreign matter which would not have come out without an operation. This then paves the way for research with Gall Stones and Kidney Stones. I would like to know if anyone else had an experience like mine.

"This time I can give you some reports about the special attachment you sent. A patient was having much pain in the knee and there was swelling. I held the Bulb against the knee for five minutes, and after that it was found that the swelling had reduced and the pain also was much less. In an asthma case I applied the Bulb on the chest for ten minutes. The report is the patient had no recurring attack for two days. Yesterday I was having pain in my thigh so I applied the Bulb. In five minutes I got wonderful relief. Gradually I am getting the hang of it and I think I will be using it more and more."

I, too, am using the Argon more and more, and the more I experiment with it, the greater I think it is, also the MWO. I have had two test cases of young men who, after five minutes in the MWO, said they could feel something happening inside their heads. Both cases had a history of head injuries. I take it that the MWO reactivates a dormant, abnormal condition that perhaps one day would cause trouble. Another test case was a mental patient in Texas. The use of the MWO was part of the test program which brought about a marked improvement in only nine days.

Some time ago a BSRA associate spent an evening with me and told of an interesting borderland gadget. People came from miles around to sit in its healing radiations. I built one for experimentation and found the results good. A Texas Associate says that it works! The original was set in the ground, but I wanted it in the house where it would be more convenient, and figured on running a ground wire outside; but this is not necessary. I have found that it corrects polarity of anyone sitting in the same room. The one I built radiates out 25 ft. One length of 6" stovepipe is used, filled with alternate 2" layers of crushed granite, and of charcoal. For a quick charge of energy, touch your foot on wire at lower end and hand on wire or rod sticking out of the upper end. I have checked the walls and ceilings or rooms (with pendulum) and found them negative. After a few minutes with this borderland gadget in a room, the walls and ceilings check positive! Here is something that should be shared with Associates.

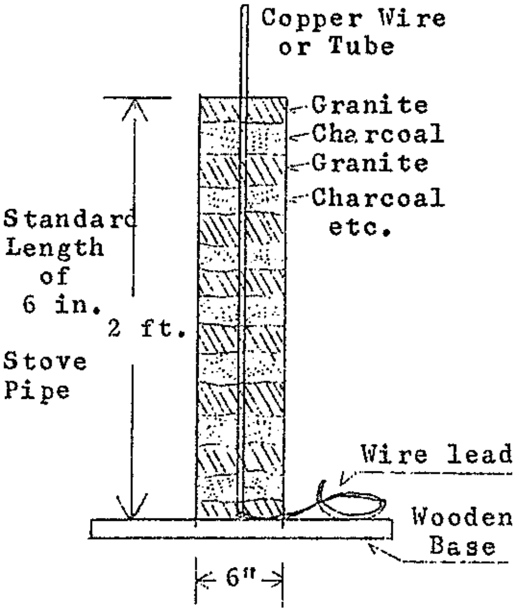

ETHERIC CONDENSER

(Here is our drawing from the rough sketch in Goeke's letter, of the borderland gadget explained above. This is just another of many simple devices which concentrate or condense etheric energies of the higher physical sublevels into a field or vortex of force available or useful in beneficial amounts to a living organism within that field. The drawing is not to scale. The dimensions are not critical. It is the relation of the parts that is important. You can consider the upper end of the copper wire as positive and the lower end coming out of the base as negative, but with the alternating layers of crushed granite and charcoal there must be an alternating or pulsating effect. Remember, charcoal is carbon, so this Etheric Condenser is a Vitic device, but not nearly so concentrated as the field between the Alnico magnets of Vitic. Iron filings sifted in the crushed granite would probably increase the power of this thing. This gadget would augment the power of your Eeman Screens, if you are using them, by adding extra etheric vitality to the circuit. Add long wire leads to the upper and lower ends of the Condenser, so you can hold one in each hand while holding the handles of the Eeman Screen leads. Which Condenser lead should go to each hand? I dunno! This is borderland research and you'll have to experiment on yourself, and be you own authority! This is one of the first principles of the Aquarian Age into which we are moving at breakneck speed. Now to continue Al Goeke's article. RHC)

GERMICIDAL EFFECT OF ULTRA-VIOLET LIGHT

The use of the Argon bulb (General Electric AR-1) as a pain-killer and infection reducer is not a new idea. Nikola Tesla used a gas-filled tube or bulb, excited by high-frequency current to rejuvenate himself every day in his laboratory. 40 years ago the RenuLife Electric Co. of Detroit was making and selling such a treating device to doctors all over the country. The offered a choice selection of vacuum tubes for getting into the body to release rejuvenating, purifying ultra-violet rays. I don't know that their tubes were filled with Argon gas, as is the current General Electric bulb. Maybe this is why the GE bulb is so effective. There is a greater concentration of ultra-violet light in the most beneficial wave-lengths, from pure, excited Argon gas.

We visited one chiropractor on a trip last year who used an MWO machine on his patients, and also uses the Tesla Coil of the MWO to drive the Argon bulb. General Electric designed this little gas-filled bulb for use on the regular 115 volt house current. As a very dimly burning, ultra-violet night light it is a good spook-chaser and can be left on all the time because it uses only pennies worth of electricity in a month! The little bulb has a curved metal plate inside it, as shown here, on which you can see a faint, ultra-violet luminescence when it is turned on, in a standard light socket.

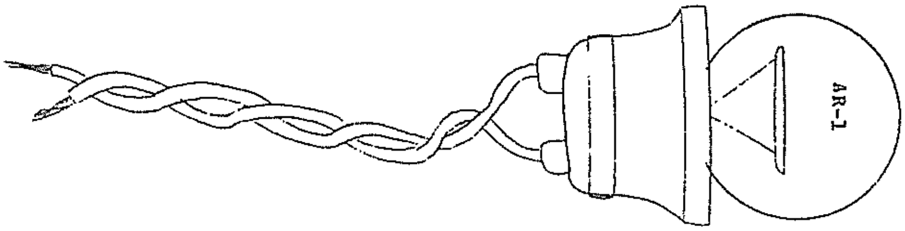

BUT, when you put a hundred thousand volts through it from the MWO Tesla Coil, that Argon gas gets real excited and throws off powerful ultra-violet energy which can penetrate into the body and destroy infection and break up tension, inflammation. Showers of sparks jump from the surface of the clear glass to the skin unless the bulb is held so it touches. Sparks will also jump into your hand unless the socket mounting is well insulated. The mounting or socket shown here is the standard rubber base with heavy, six-inch leads for outdoor lighting. Our local hardware store sells the socket for 39 cents. The Argon bulb needs only one connection -- to the antenna lead of your MWO. The black and white leads from the socket can be twisted together and soldered to a female Banana Plug. This will take the male connection from the Antenna lead. The twisted socket leads can be wrapped with heavy, insulating tape if any of the ultra-high voltage gets through to tickle your hand.

The chiropractor who makes use of this in his work asks his patients if they have any infected teeth, or a toothache. One five-minute treatment over an aching tooth, rubbing the Argon bulb on the cheek over the infected area, stopped a toothache for us. It also relieved a throat, sore from too much lecturing.

General Electric also makes an identical Neon bulb. This gas throws off an orange radiation, which would probably give off more of a surface, heating effect because of the longer wave-length. You won't find these special bulbs in your local stores, probably, but will have to order them through some wholesale dealer, say an electric contractor and builder who has the GE catalog of special bulbs. A compact, professionally built Tesla Coil can be bought from Edmond Scientific Co, Barrington, New Jersey. It doesn't put out as much energy as the MWO coil designed by Bob Beck, but it will cause the GE Argon bulb to emit considerably more ultra-violet radiation than the 115 volt house current.

From the MAY-JUNE 1971 Journal of Borderland Research

A HIGH-POWERED MULTI-WAVE OSCILLATOR

A HIGH-POWER MULTI-WAVE OSCILLATOR

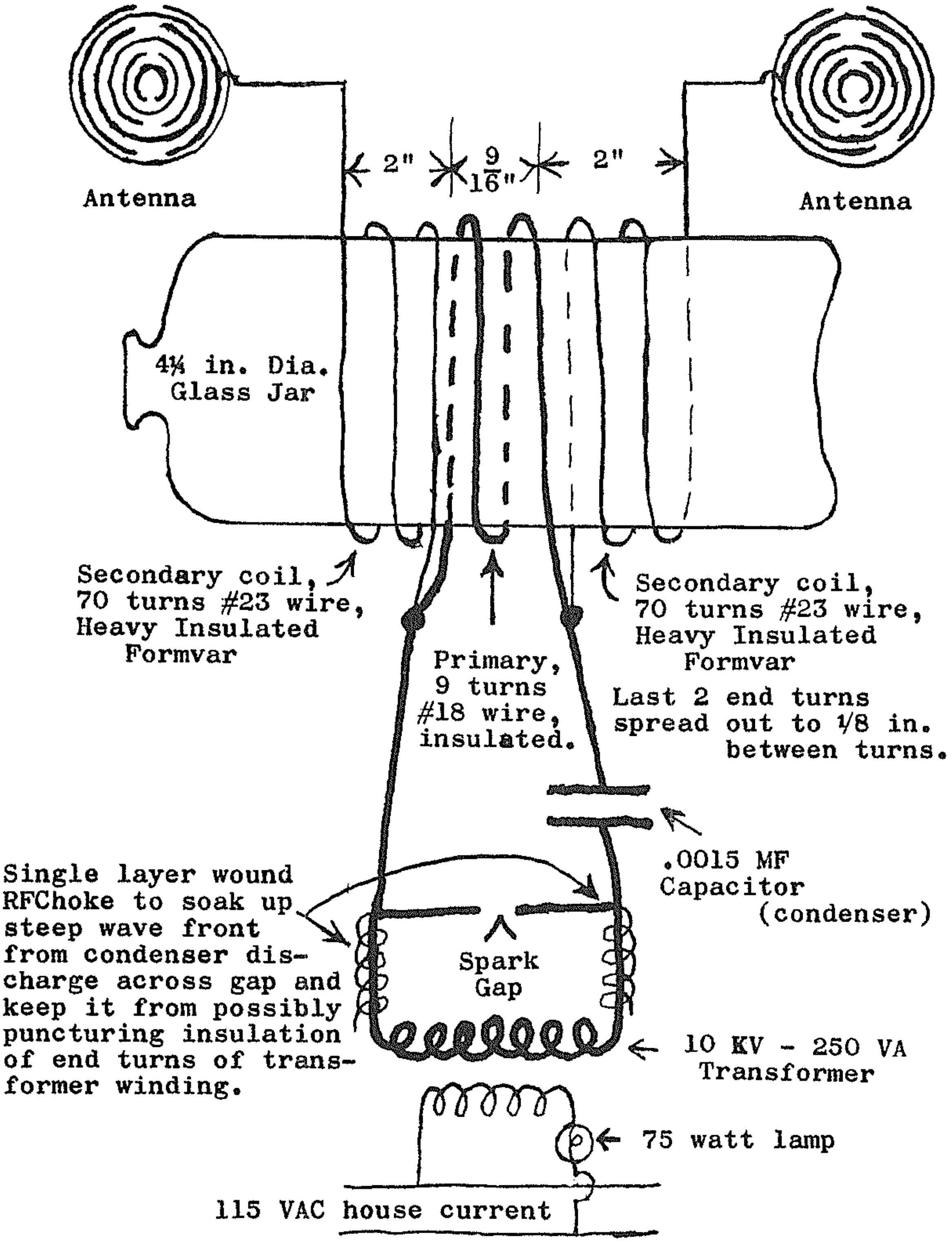
Antenna
Antenna
2"
9/16"
2"
4¼ in. Dia. Glass Jar
Secondary coil, 70 turns #23 wire, Heavy Insulated Formvar
Primary, 9 turns #18 wire, insulated.
Secondary coil, 70 turns #23 wire, Heavy Insulated Formvar
Last 2 end turns spread out to 1/8 in. between turns.
.0015 MF Capacitor (condenser)
Single layer wound RFChoke to soak up steep wave front from condenser discharge across gap and keep it from possibly puncturing insulation of end turns of transformer winding.
Spark Gap
10 KV - 250 VA Transformer
75 watt lamp
115 VAC house current

"Your brochure article stating that Georges Lakhovsky's original MWO had a separate Tesla coil driving each antenna is most interesting. This is in line with my experience here in Manila. I find that when livening up both antennas to full voltage, to spark each antenna down to the 3rd ring with an occasional slop-over to the 4th ring, it is much more effective than when keeping one antenna (or resonator) down to near ground potential; and it is least effective when actually grounding this antenna -- as Mr. Beck does --through a 1/10 MF capacitor!

"One five minute treatment a week is enough for me and the equivalent of two 15 minute treatments with only one antenna up to full voltage. However, I drive both antennas up to full voltage with only one Tesla coil. It has rather tightly coupled primary and secondary windings, wound as an auto-transformer, on a 4-1/4 in. diameter glass jar, as per enclosed sketch.

"The present spark gap is 1/8 inch, a fixed, constant gap, needs no turning with variable distances between antennas, subject or no subject. The sparking is much the same and the gap is not at all critical, 1/32nd, plus or minus, works just as well. Gap electrodes are 1/4 inch tungsten. The present primary circuit capacitor is .0015 Micro Farads, but this also is not at all critical, can be varied up to .0025 and still give much the same sparking and effect on subject.

"I tried using #28 Formvar wire, heavy insulated, 70 turns each on the secondaries, to shorten coil and get tighter coupling, primary to secondary, but coil was too short and flashed over from end to end.

"Just plug it in and use it, no tuning manipulation of any kind required. The input of 115 VAC to the 10,000 volt oil burner ignition transformer is only 17 VA through the 75 watt lamp as a limiting resistor. Never use more than a 100 watt lamp. This is all I can take. More power becomes rapidly depressing. And the full 250 VA out put of the transformer I once used, with a 5/8 inch spark gap, was nearly fatal. It took me four months to get over the effects of it. Pass this info on to your Associates."

J. Gilbert E. Wright

Associates can benefit from this dedicated borderlander's experience, which confirms Lakhovsky's warning that healthy cells can be over-stimulated and killed by powerful high-frequency waves -- as well by X-ray and radium waves. It may be easier to locate Neon Sign transformers of 5,000 to 7,500 volts output as power supplies for this MWO, at a cost of $15 to $20. In this case the wattage of the "limiting resistor" electric light could be increased to 150 or 200 watts, or eliminated altogether, if it is necessary to get enough power to cause random arcing down to the third and fourth rings on both antennae. The good doctor says nothing about shielding but care should be taken to prevent radio interference from this powerful spark.

"No data is given in the drawing (May-June 71 Journal) on the size of the antennas. I would suggest that the outer ring be about 18 inches in diameter with a 3 inch gap. Alternate down through the rings separating them about 2 inches apart and held together with plastic electrical tape. Wire should be #10 bare. The secondary leads connects to the second ring from the largest diameter outside ring."

George Van Tassel, Giant Rock, California

An even more spectacular possibility is the Time-Machine effect in connection with rejuvenation. If, as Bob Beck suggested in his article, the MWO tends to take the body cell back down the time-track to a more youthful, more vital period, what would happen to a person who stayed in the field of the machine for four hours? Would his vibratory rate be speeded up to where he would disappear completely? Like the hero of H.G. Wells' 'Time Machine'? Anybody want to try it? It seems, from hints George Van Tassel has been dropping over the years, that his Integratron at Giant Rock, California might do something like this -- if and when he gets it working! As I recall, both George and the Canadian Saucerian, the late W.B. Smith, spoke of the four dimensions of electricity: 1. is the electricity moving in one direction along a copper wire, 2. is the magnetic field around the wire, 3. is the static charge created by the first two effects, and 4. is Time -- or the 'tempic field' as Smith called it. The Time Field equates with Space, where consciousness is everywhere present. Seems to me Lakhovksy's Multiple Wave Oscillator is a gadget which gives us the opportunity -- for the first time -- of approaching the Time Field with scientifically acceptable equipment, operating in known frequencies.

BIOPHYSICIST CONFIRMS LAKHOVSKY'S THEORIES!

LA "Times", March 28, 1971: "The 'magnetic resonance' of the nuclei of atoms (in living cells) has been used to tell the difference between cancer and normal tissues. This resonance is the reaction of the nuclei to electromagnetic energy --first its absorption and then its emission. The process can be timed.

"Raymond Damadian, a biophysicist at the State University of New York's Manhattan Medical Center, said his achievement may open the way to major advances in the diagnosis of cancer in humans... Like other attempts to find a way of making early diagnosis of cancer, Damadian's research began with a hunt for significant differences between cancer and normal cells.

"He relied on a law of physics on which nuclear magnetic resonance is based -- that the atoms in each element in the periodic table absorb and then emit electromagnetic energy on an individual wavelength that is different from that absorbed and emitted by the atoms of any other element. In his system, radio waves are aimed at atoms in strong magnetic fields. If the wavelength is the right one for that atom, the atom will absorb the energy and then emit it, returning to a 'resting' state afterwards.

"The reactions differ according to the kind of molecule the various atoms are incorporated in. They also differ when very subtle changes have taken place in the molecules. The measure Damadian uses is what is called the 'relaxation time' of hydrogen atoms in water molecules within the (body) cells... He found that it takes longer for protons (nuclei) in cancerous tissue to 'relax' than it does for protons in normal tissue... The relaxation time of protons in normal liver tissue, as one example, was .25 of a second, compared with .86 of a second for cancerous tissue.

"Damadian's findings confirm the theory proposed by several scientists that water molecules in a normal cell are held in a fairly well organized structure by electromagnetic attraction exerted by the molecules in the cell. But, it was theorized, when a cell begins the uncontrolled growth of cancer, the structure begins to collapse because of the cell's increasing disorganization.

"Damadian thinks the device for detecting cancer in humans (his experiments were conducted on mice and mouse tissue) that may come out of his work would be a radio frequency coil to emit the electromagnetic waves to be aimed at the atoms in the water molecules under study. The device also would include a magnet to create the field required for measurement.

"The coil would be wrapped around the patient while the magnet would be moved back and forth over his body. The reading of how long it takes the atomic nuclei to relax would be made and then computers would do the matching up and make the diagnosis."

Interesting, isn't it, how the 1970s researches of biophysicist Damadian parallel the pioneering work of electrical engineer Georges Lakhovsky in the 1920s? The goals are quite different, of course, in that Damadian only wants to prove the existence of cancer so the victim can go on to be drugged, operated or radiated with destructive X-rays or Cobalt rays, at fancy prices, a procedure inspired by the soulless monsters who guide the American Medical Association from the Lower Astral plane.

The irony of Damadian's proposed diagnostic technique is that it combines two electro-magnetic healing procedures. If it is used on sick people, sooner or later someone is going to be healed of cancer while being diagnosed! Can you imagine the disagreeable shock this would cause in orthodox medical circles? Extensive surgery would have to be cancelled. The sale of drugs would be lost. Under these circumstances it isn't likely that his diagnostic technique will ever receive the approval of the AMA.

So, borderland science will have to continue to carry the torch of research on electro-magnetics in this area, as George Van Tassel is doing with his Integratron up at Giant Rock, California. In his newsletter "Proceedings" he gives more details of his research program there. We learn that in addition to creating a field of soft, high frequency radio waves, and a magnetic field, the Integratron will also bathe the subject in an atmosphere charged with negative ions.

HOPPING UP THE HIGHER FREQUENCIES

"There is one thing you may wish to try on the MWO. Close the center hole in the driven antenna with a washer and screw. Connect this to the driven ring (second ring from the outside) with a 500 mmf condenser, 10,000 volt rating. This increases the power of the higher frequencies. I think you will be pleased with the results. Mount the condenser at the back of the antenna. Mankind has been saturated with the lower frequencies for years; 60 cycles and their first few harmonics are almost everywhere in more than adequate power. Radio, TV, radar, etc. also saturate our world but the amount of power available to the average person is very small. In 1942 I used to cure my sinus trouble in minutes by getting close to the transmitter section of a radar transmitter. Few get that close, though, and it is a good thing as this power can kill. I have seen birds and larger animals killed instantly. It can happen to humans, too." H.B., Melbourne, Florida

SEND A FEW BUTTONS

"Received the Lakhovsky loops and am pleased to feel the response to the body. I wear my belt only at night. I gave one to a friend who was having a problem with her leg and anticipating hospital treatment for same and the response was also to the good... So all I want now is for you to send me a few buttons so I can make some more loops myself and help to lessen some misery around here, for someone. I tried to have some buttons made here, but no success." J.M.S., Charleston, S.C.

The non-slip loop buttons we make are of 1/16 inch thick, white fiber glass plastic.

MORE POWER NEEDED

"Enclosed is $. Please send me the magnet assembly with carbon rod (March-April 71 Journal). Have not had the hoped for results with the loops. Possibly the assembly, which can be used more directly over the research area, will be more effective." M.S., Ellensburg, Washington

If we've proven one thing in our borderland research, there is no single cure for any or all of mankind's ailments. Injury and disease are outward manifestations of an invisible cause, which may involve three or four levels of consciousness and extend back two or three lives. You Director has found in over thirty years of counselling people on their borderland problems, half of them don't really want to get well, they just want to be free of pain so they can go on indulging their vices. And by the time the hidden vice surfaces as a disease in some target organ of the body, an unhealthy trend has been established in the cell life there. It usually requires a strong jolt or shock to reverse this trend, such as a powerful magnetic field, a drug, chiropractic, even surgery -- anything to break the negative pattern which created the condition. One of the simplest and most effective methods, and cheapest, is fasting for a week or two. This gives the system a chance to purge itself of all filth.

OPEN ENDED COPPER BRACELETS

"Your article on copper bracelets sent me to the typewriter! It is quite well known in England and has figured on TV as anklets for racehorses! Open-ended copper bracelets sold freely in shops for some years here, but not recently. However, I have a copper bracelet from Rhodesia which I wear always, never take it off, and of course no arthritis or rheumatism. But I'd like your experimental loops for throat, waist and wrist.

J.G., London, England

THE PRO AND THE CON

"Thanks for the wire rings. Sorry to report no favorable results. My husband refused to try. I wore them several nights but seemed to feel even worse afterward. It was a good experiment. I guess my trouble is psychosomatic."

Mrs. A.H., Enid, Oklahoma

"I want to thank you for sending me the kit of Lakhovsky coils. I especially appreciate your taking the time to prepare a larger-than-usual coil for my chest. I guess I'm, too young to have any really serious physical ailments -- except for insomnia! And the coils eliminated that the first night I wore them to bed!"

J.T.D, Venice, California

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From the September-October 1971 Journal of Borderland Research

UPGRADING CELLULAR ACTIVITY WITH ELECTRO-MAGNETISM

By Aaron H. Steinberg, Ph.D.

For too many years now the scientific knowledge of electro-magnetics and its positive effects on cell life has been collecting dust and cobwebs on the shelves of ignorance, brought on by those special interests who fear the Truth. We are now seeing a rebirth, if you will, with scientists both professional and amateur, who are reviewing the work of their predecessors and making improvements in the mechanical application of magnetic fields.

In 1969 I visited the USSR to see for myself what and how they were utilizing Electro-magnetism. In several country homes for retirees I was most pleasantly surprised to see electro-magnetism used daily on most of the old folks. I should say young folks since may who claimed to be over 100 years young, looked and acted like most people at 50! The main object of the E-M was to reverse the ageing process by altering the cellular structure. I was most anxious to purchase a piece of the equipment, but alas no sale.

Seek and you shall find has always been one of my dominant characteristics. So when I learned that Japan was truly advanced in this field, having been using such equipment since 1936, I decided to go there in 1970. I sought out the one company that had been most productive in this field. They were most kind and cooperative. I was introduced to several scientists who had done much useful research. Their claims were backed up by scientific facts and I was convinced that they had a well constructed instrument, simple to use by anyone so desirous. They named their equipment The Magnetizer.

I returned to the U.S. with a Magnetizer and immediately began a research program. I can report that the results obtained to date have been most favorable, after nine months of experimentation. The magnetic flux generated by the coils can be measured accurately over any part of the body, thus determining those areas where the flux is penetrating as well as those where it is weak.

Chemicals and pollution are surely contributing to an unhealthy alteration in our cellular activity and human magnetic filed. It will be many years, if at all, before this mess can be rectified and controlled. But in the meantime, those who are aware and see the danger signals, will not sit by and wait for the clean up, which may never happen. Instead they will seek to upgrade their cellular activity so that the body's natural resistance may be at peak ohms. There is some indication that the aura force centers known as chakras or vortexes are stimulated by electro-magnetism.

From the Japanese scientists I learned the following about the effects of magnetic flux. It is different from ordinary electric current, which only flows along the surface of matter. It is different from X-rays, which do not penetrate the bones. The magnetic flux of ultra-long wave generated by the Magnetizer penetrates deeply in muscles, fat and bones and has an intensive effect on the nerves.

Magnetic flux never causes unpleasant sensations in the body, such as pain or shock, but instead produces comfortable, warm sensations. These sensations are also known as Joule's heat, which strengthens the function of the cell, corrects spasms and inflammations. When magnetic flux passes through tissues, a secondary electric current called the eddy current is created around the magnetic lines of force in the tissue cells, which ionized the protoplasm and rejuvenates the tissues as a result of activating metabolism. Furthermore, magnetic flux, in the process of penetrating the tissues, works to increase hormone secretions. These maintain youth by providing energy as a result of normalizing function of the internal organs.

Flux strongly stimulates magnetic substances in the blood, like iron. Accordingly, the hemoglobin in the blood vessels moves actively, accompanying the lymph circulation, when the Magnetizer is turned on. The therapeutic effect is not singular but collective, thus eliminating constitutional weakness.

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From the May-June 1971 Journal of Borderland Research Clips, Quotes & Comments

OSCILLATING LOOPS AND COILS

"I have a necklace which is definitely an oscillating circuit. I'm sure you have seen them. They are a wire around the neck instead of a chain. The only thing is that they come with a hook arrangement to clasp them. I cut the ends off, and rounded them to make a real oscillating circuit. Then, too, I got a pair of earrings which are simply coiled wires, like this:

One of these days maybe I'll have a headache (this is rare), and I will try either or both of these. Mrs. C.M., Watertown, Wisconsin

REMEDIES, HOMEOPATHIC AND ELECTRO-MAGNETIC

"You might spread the word around that the Copen Vibro-Potentizer actually can make any Homeopathic remedy in any potency from 1X to 10M.

"Since the medical-industrial complex is trying to destroy Homeopathy and its pharmacists, those who know of it and are doing research on its remedies would do well to get such a machine. It can also make a remedy from a radionic rate. I made Skull-Staphylococcus 10M and reduced an intractable sinus infection. The possibilities are fantastic and open up a new field in healing. One can make color remedies and aura remedies with greater power than radionic treatment of the same."

From his own research this Associate is suggesting that homeopathic remedies, being closer to physical matter than radionic treatment rates, may bring physical body changes more effectively. A hundred years ago in Philadelphia, Dr. Pancoast was curing practically every known human disease with colored light, either blue or red. But he (she?) also prepared color-treated dosages of oil or water for internal use, to back up or augment the shining of colored light on the outside of the body.

"May I remind you that the Multi-Wave Oscillator requires an antenna without any edges, to give efficient radiation. Lakhovsky's original had round bars or tubing with spherical ends. Edges lose most of the radiation. In addition the largest ring should be based on that fundamental resonance of the human organism, 3.66 meters as discovered by Bell Laboratories. This could be a quarter-wave antenna length of .91 meters or a circle of pi diameter.

"However, this should be doubled so that the human organism resonance is the first octave. Individual resonances vary slightly above and below 3.66 meters. By giving lower octave and with the variations supplied by the spark gap all wavelengths would be reached. Therefore, the outer ring should be 1.82/pi meters.

"The relative size of the outer rings could be determined by examining one of Lakhovsky's original antennas. The outer ring should be fed current at both ends, quarter wave style, I believe (to a H.V. Coil) not at the middle of the second ring as the Beck antenna does. The frequency of human resonance, 3.66 meters or approximately 84.6 megacycles is the key to radionics. [By my calculations, using the formula wavelength in meters (3.66 meters) equals (=) the speed of light in meters per second (300,000,000 m/s) divided by the frequency in cycles per second, I figure the frequency to be 81.97 megacycles. T.B.] The human sample or witness -- blood spot, etc. radiates around that frequency, varying according to the disease and the person, I believe. The homeopathic remedy also has a resonant frequency and alters the human frequency for better (or worse). In addition there are harmonics and possibly sub-harmonics.

"The resistance rates discovered by Dr. Abrams, followed by Guyon Richards, are still valid even though this work was done 50 years ago. The rate for Aqua Marina (sea water) put on a Copen V.P. produces a very effective remedy good for almost everyone. This rate comes from Richards' book 'Chain of Life', 1934."

S.M.S., Chicago, Illinois

We welcome this Associate's observations on the MWO antenna, radionics rates and homeopathic remedies.

Riley Hansard Crabb, editor JBR 1959-1985

BSRF MWO Update - Issued May 31, 1988

Compiled by Tom Brown from the BSRF Files
In consultation with Eric Dollard & other BSRF Associates
(Contains the complete 1986-87 MWO Update materials)

As there has been a continuing strong interest in the Lakhovsky Multi-Wave Oscillator we felt the need to compile this information into the present book. This documentation is the result of a wide variety of analysis and experimentation with the MWO and covers many years of active research.

There have been many comments made concerning the inherent healing effects of the MWO, but as it cannot be stated enough, the device is merely a tool of research, of which one may draw their own conclusions as to whether or not the device actually has any healing properties. It may be interesting to note that in a personal conversation with Dr. Ita Wegman, Rudolf Steiner stated that electricity, magnetism, and the force upon which nuclear phenomena is based, are all corrupted ethers.

We have found through studying Goethe's indications on the phenomenon of Light and Color in conjunction with Eric Dollard's high frequency researches that electricity is a reflection of the Light Ether. This matter is being discussed further in The Journal of Borderland Research, so it is sufficient for present reference to say that Light has its two poles, red-yellow and blue-violet. The red-yellow pole in nature is longitudinal (direct rays from sun) and the blue-violet pole is a progressive type of transverse wave (rounded sky, Reich's KRW wave/blue orgone). Electricity has its two poles, electro-magnetism: red-yellow-hot, (retarded transverse); and dielectricity: blue-violet-cold (longitudinal). Hence, there are experimental indications that electricity really is a reflection of the Light Ether.

In light of this trail of thought we quote with permission from a 1986 private communication with Trevor James Constable: "The MWO I regard as a false path. The cellular stimulation theories sound and seem good because they are mechanistic, and therefore sympathetic with the mechanistic weltanschaung. With the MWO you can avoid the etheric--or so it seems--and therefore those who feel adrift in the etheric ocean cling to things like this. Healing is one hundred percent an etheric problem. Any dysfunction or hyperfunction not caused by direct trauma has to be tackled via the ether body, and even the direct traumas respond best to etheric correction, such as getting the displaced double back into occlusion through the use of arnica compresses, etc., etc. In between the MWO antennas, there is a general marshaling or focus of light and chemical ethers. Its quite evident even with a minor extension of vision. This is the healing agency, not the sparks. The ether rushes to suppress the EM activity, and because it is low power, the ether accumulates around the spirals and in between them. Any stricken area placed in such a high concentration of formative energy, is going to respond with a return towards normal. BUT, why go to all that trouble when a simple orgone blanket--a layered structure that can be directly applied to a traumatized or dysfunctional area--does a much more efficient, controllable job without that infernal juice. In my time with Ruth Drown, I heard it over and over again, and I pass it on to you: keep that 115V juice away from the organism. The post material EM energy is life negative, but no one seems to feel that they can get results unless they INJECT the alien EM activity into the stricken carcass. It's pure ignorance really. My own experience with orgone accumulators and blankets leaves me with no other choice but to regard the MWO as superfluous. A good rule for any experimenter: If it gets simpler, you are on the right track. Remember always Steiner's dictum: "the spirit of man is always healthy!.....it is the obstruction or dysfunction in the lower sheaths that distorts the manifestation of the spirit and personality via the body."

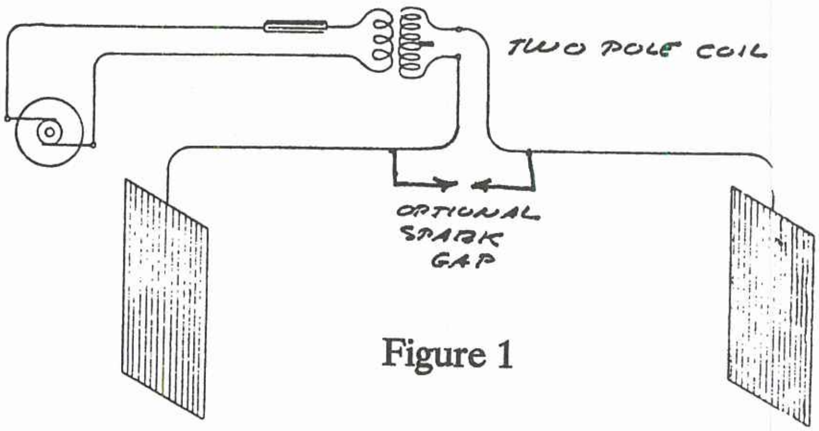
TWO POLE COIL
OPTIONAL
SPARK
GAP

Figure 1

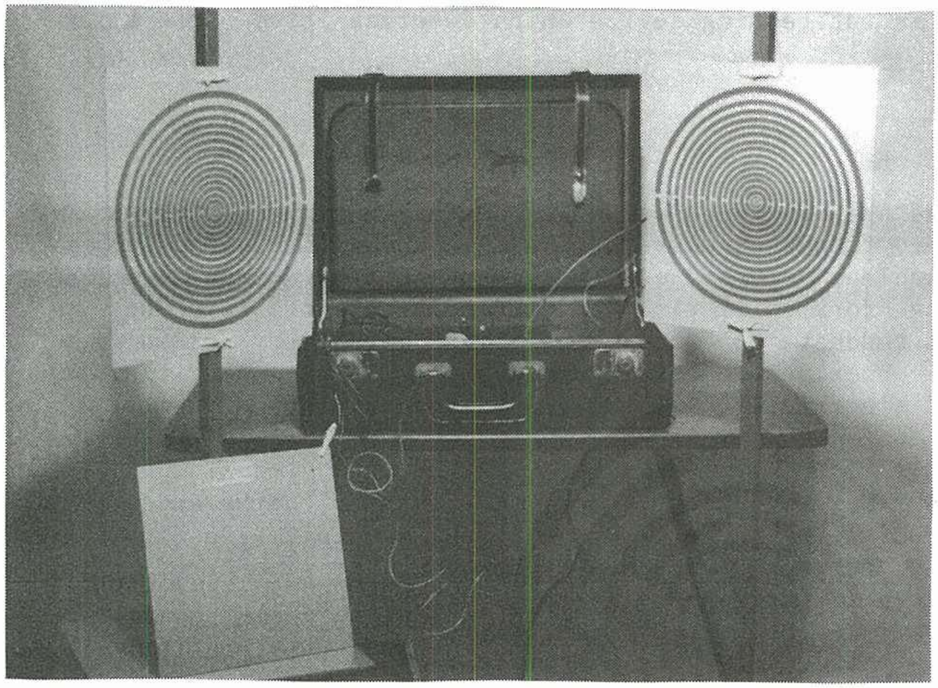

Photo 1
"Beck" style MWO from
the BSRF collection
(note: foot plate at lower
left goes to ground)

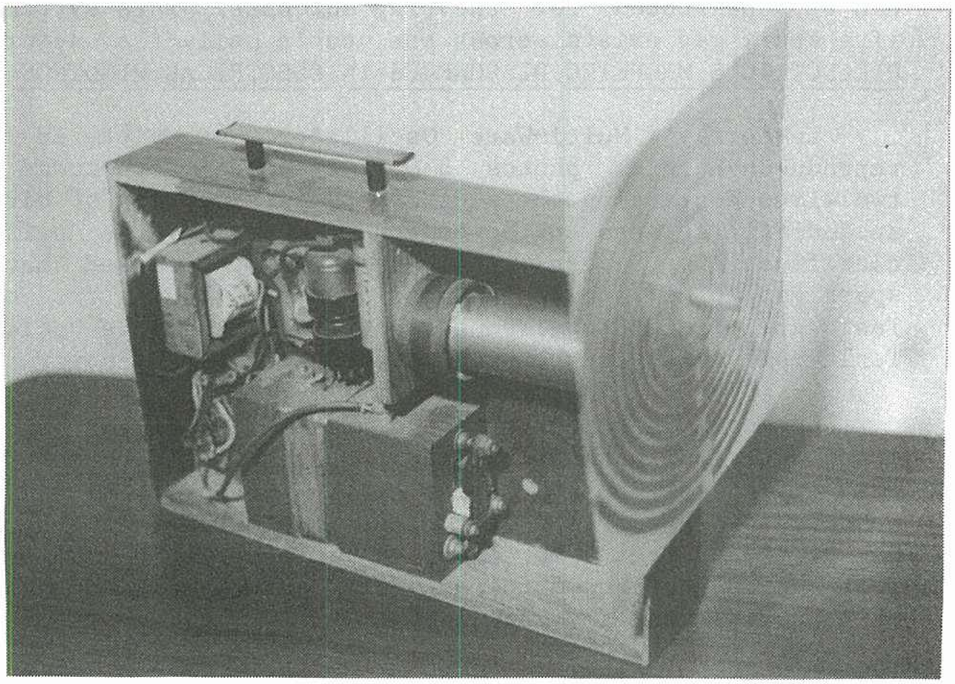

Photo 2
Single antenna version
from the BSRF collection
(Resonator antenna can
be attached at ground)

Not much more need be said in that vein except that of a reinforcement of Trevor's comment. Our present society is not on the path of Nature so therefore some people feel the need for a device such as this. Wilhelm Reich discovered how to concentrate the living energy of the universe, which he termed the Orgone. The Yogic sciences teach us how to accumulate this energy without any outside apparatus, so therefore the simpler and more passive a device is, the closer it resembles Nature.

In the following pages you will find some of the results of MWO experimentation and consideration by BSRF and Associates. We hope the information proves useful, but again it is for research purposes only. We do not recommend the MWO for medical use because we are not qualified to give medical advice, nor do we want to create any false hope where one may neglect professional health care. We do fully support a persons right to investigate and research with devices such as the MWO. No one has all the answers and the MWO is an interesting device which deserves true scientific verification or rejection.

THE BASICS

The general theory behind the MWO is to excite a concentric ring antenna which produces a wide spectrum of radio frequency waves. In this theory it is understood that the RNA-DNA coil in the nucleus of every cell has a resonant frequency within this range. Just as a tuning fork will ring when an identical fork is struck in close proximity, the cells will resonate to their individual frequency pulled from the frequency ocean of the MWO. Most people don't consider that there are different types of waves and two poles of electricity, and these distinction have not generally been noted.

The antennas on the currently popular "Beck" MWO system, serve as simple capacitor plates which transmit dielectric waves out of the Tesla Coil (see figure 1 and photos 1 and 2). The second MWO plate in such a system must be connected to a second Tesla coil or to a double pole (half wave) Tesla coil (May-June 1971 JBR), not a single pole (quarter wave) Tesla coil as per the Bob Beck/Klark Kent style MWO. Action in the MWO antenna is neutralized by the fact that capacitor currents flow radially inward and little electron current flows around the loops. Copper plates can be substituted for the ring antennas. This system operates 1000 times stronger if a spark gap exists across the double coil. A description of the action is in DIELECTRIC & MAGNETIC DISCHARGES IN ELECTRICAL WINDINGS by Eric Dollard from BSRF.

Lakhovsky's Multi-Wave Oscillator, as pictured in THE SECRET OF LIFE and reproduced here as photos 3 & 4, created a structured electro-magnetic field fed by two wires contacting the ends of the outside ring of his antennas. This is obviously an end-fire antenna so the component reaching the person is a novel energy needing clarification. Several researchers have expressed that Lakhovsky used a quenched spark gap which creates damped waves allowing free oscillation in the antenna. A Tesla coil is not required since the Multiple Wave Oscillator IS THE COIL. However a Tesla coil still can be used as the high voltage power supply.

Lakhovsky's patents will cover both types of units so it seems as though he experimented with both, but the pictures in THE SECRET OF LIFE are an indicator as to what he actually used. After having gone over the patents I'm beginning to think that Lakhovsky buried his secret to mislead copycats. That is the purpose for a patent, to protect the inventor. The Tube MWO Patent 2,351,055 gives some interesting insights into the overall picture of Lakhovsky's work and study of it will provide many research leads.

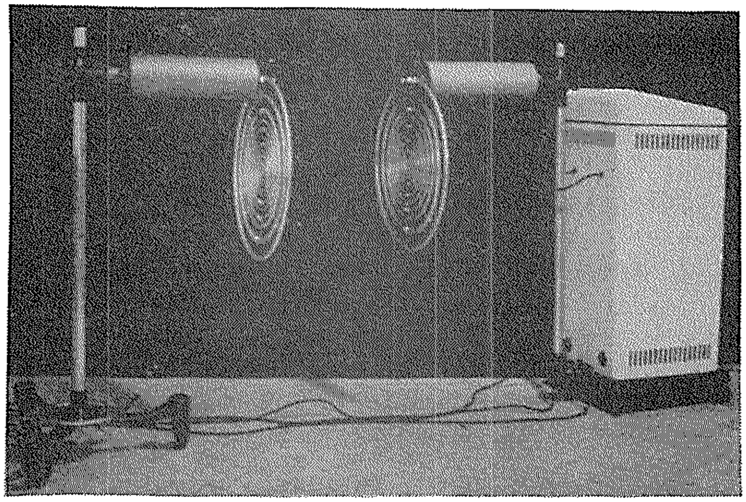

Photo 3
Lakhovsky's Multiple Wave Oscillator

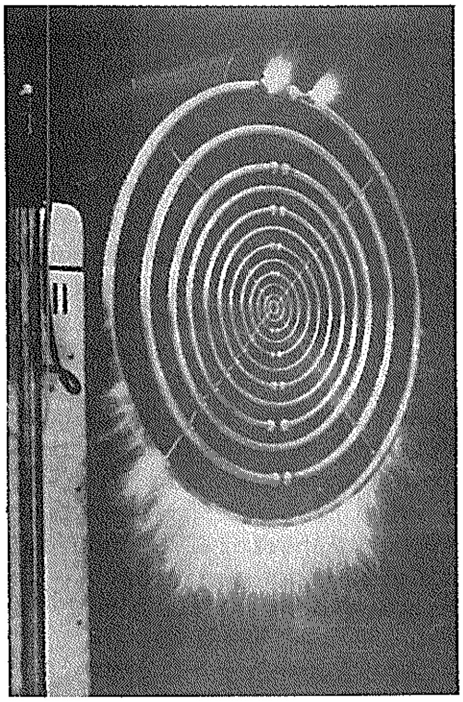

Photo 4
Lakhovsky's MWO. Close-up of transmitter in action, showing *effluve* (electric brush). Note this is end-fire antenna. Regeneration may have come from novel component at 90° to antenna plane.

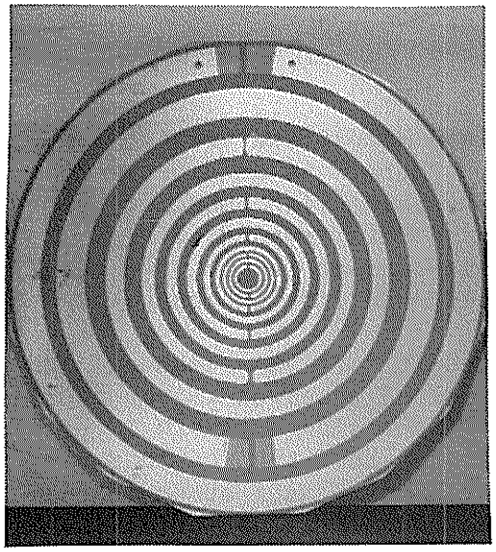

Photo 5
Yagi MWO antenna

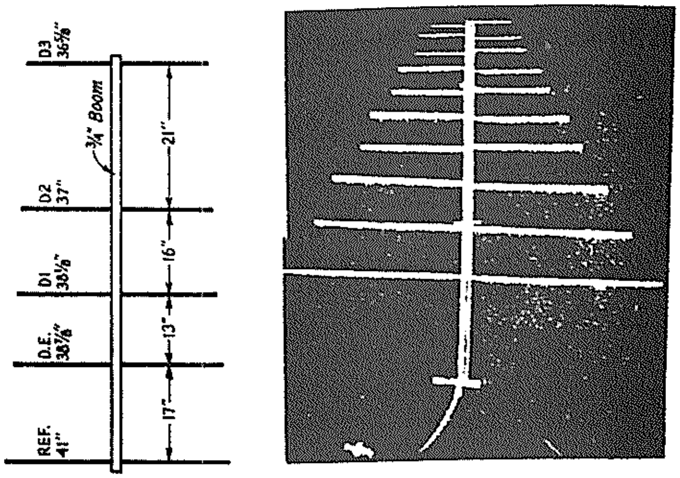

D3 36⅝"
¾" Boom
21"
D2 37"
16"
D1 38⅛"
13"
D.E. 38⅞"
17"
REF. 41"

Yagi antenna Log periodic antenna

Figure 2

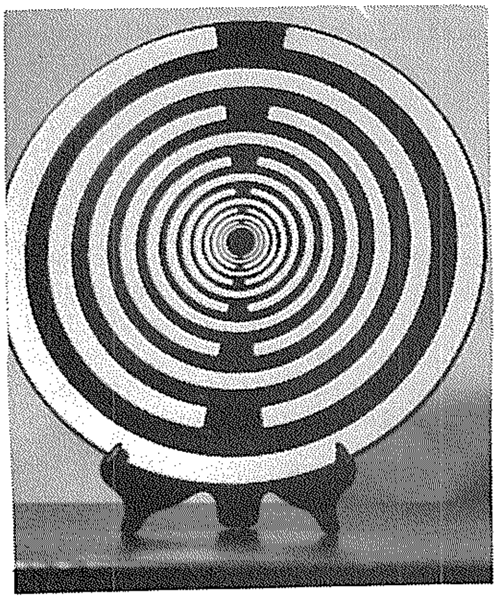

Photo 6
Golden Ratio – Log Periodic
MWO antenna

LOG PERIODIC ANTENNAS

Our research indicates that Lakhovsky worked with log periodic antennas and may have been the first to use them. The antenna will create a harmonious structure in the ether. The Beck style MWO produces a dielectric field 90 degrees out of phase with this, and utilizes the dielectric breakdown (arcing) of the field. This is basically a radio frequency noise generator and the most popular derivation of Lakhovsky's first MWO patent.

Scaling the rings non-uniformly using correction factors is not needed according to log periodic antenna theory (see figure 2 and photos 5 & 6). Lakhovsky states that any high frequency radiating circuit will drive the antennas. We are striving for waveforms mirroring the harmonic laws of nature. As an example the old Yagi antenna has non-uniform distribution of the elements. Log periodic design uses the uniform distribution of the elements such as is found everywhere in nature. This presents superior MWO performance. Lakhovsky's Speaker and Microphone Patent indicates that the log periodic design can be applied to sound as well as radio frequency energy.

LAKHOVSKY'S MWO

Figures 3 & 4 are a preliminary attempt by Eric Dollard to accurately reproduce the MWO system as pictured in SECRET OF LIFE. Figure 3 is a simplified version for a single antenna, figure 4 is a double antenna system. Photo 7 is an experimental setup utilizing this design. We feel that Lakhovsky was working with quenched spark gaps which produce damped waves in the form of the antenna. This type of circuit is needed to power log periodic antennas to create their structure in the ether harmonious with the Golden Ratio structure of the human body and life in general.

This information is not definitive, but is the result of experimental and theoretical considerations. We present this so that Borderland researchers can carry on with new input. We are not saying that the "Beck/Kent" models do not work. There are many claims that they do, but based on Tesla's theories, rather than Lakhovsky's. Figure 1 unit works off of longitudinal dielectric waves (displacement current). Figs 3 & 4 work off of Transverse electromagnetic waves (Hertzian) and residual scalar waves.

Figure 5 is a low power driver based on the Steinmetz lightning wave, a reproduction of the wave naturally occurring in the atmosphere. Values given need to be experimented on for optimum pulse formation. A mathematical analysis of this wave by Steinmetz is included as an addendum to this book. See DISTRIBUTED SERIES CAPACITY.

GOLDEN RATIO ANTENNA

Eric Dollard has designed a log periodic antenna based on the Golden Proportion, as found in living systems such as plants and animals. These antennas are two sided, the first side looking somewhat similar to currently used MWO antennas, the second side being capacitive loading (as Lakhovsky mentions, he used spheres on the ends of his antenna rings) based on the Golden Ratio. This design can be seen in photo 8. These antennas are gold plated to provide direct contact with the ether. Their actual size is 12" in diameter.

Figure 3

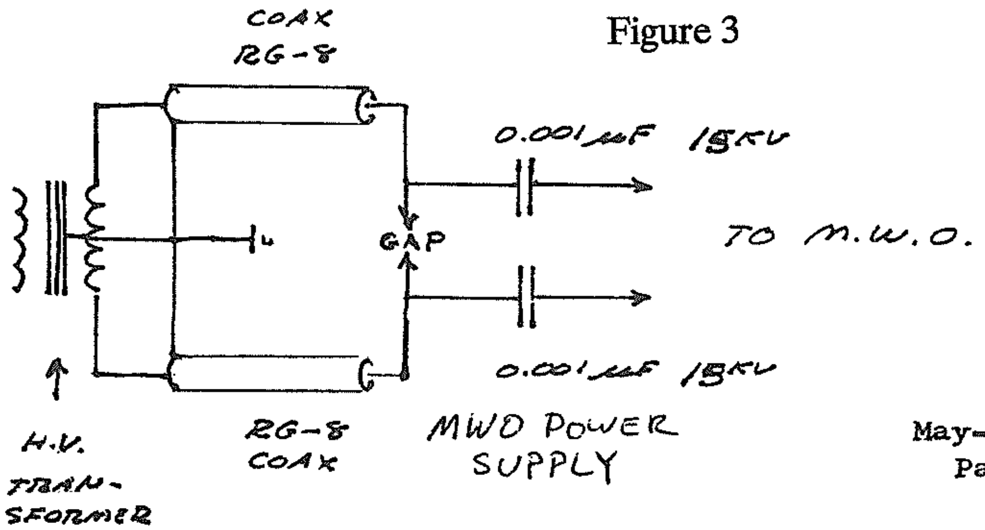
COAX
RG-8
0.001µF 15KV
GAP
TO M.W.O.
0.001µF 15KV
H.V. TRANSFORMER
RG-8 COAX
MWO POWER SUPPLY

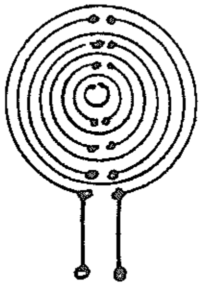

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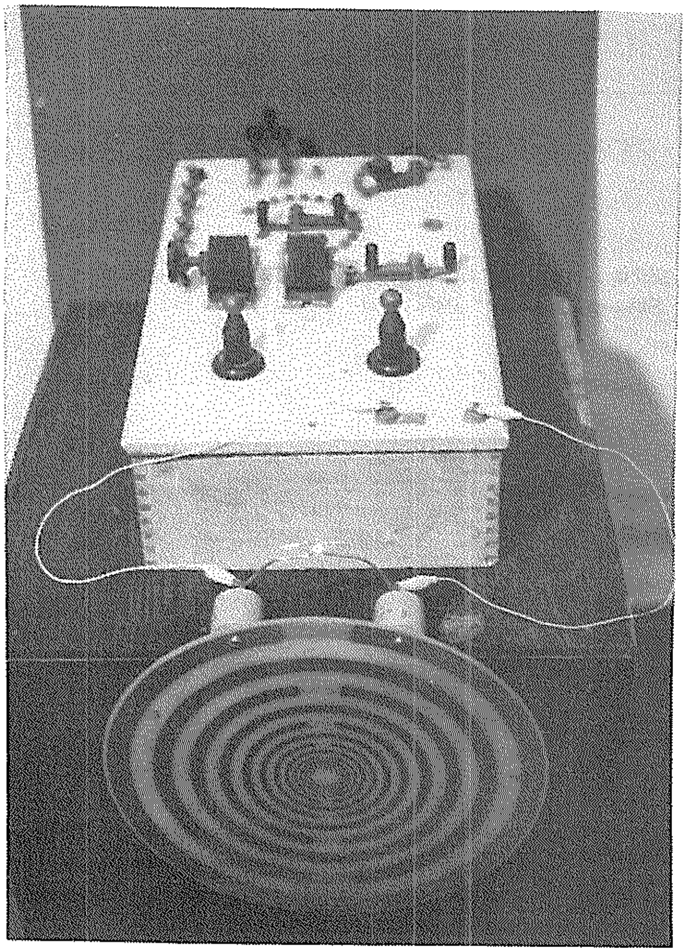

Photo 7
Golden Ratio antenna driven by 1919 era double-phase marble-top medical Tesla Coil. Mid-frequency D'Arsonval currents are utilized in this arrangement. Setup is as per Figure 3 (above), and is our understanding of the arrangement as utilized in THE SECRET OF LIFE. Coil donated to BSRF by John Crane from laboratory of Royal R. Rife.

Action of Lakhovsky setup

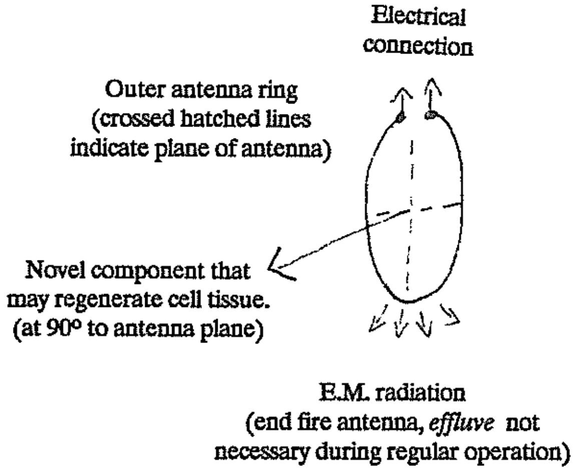
Electrical connection
Outer antenna ring (crossed hatched lines indicate plane of antenna)
Novel component that may regenerate cell tissue. (at 90° to antenna plane)
E.M. radiation (end fire antenna, *effluve* not necessary during regular operation)

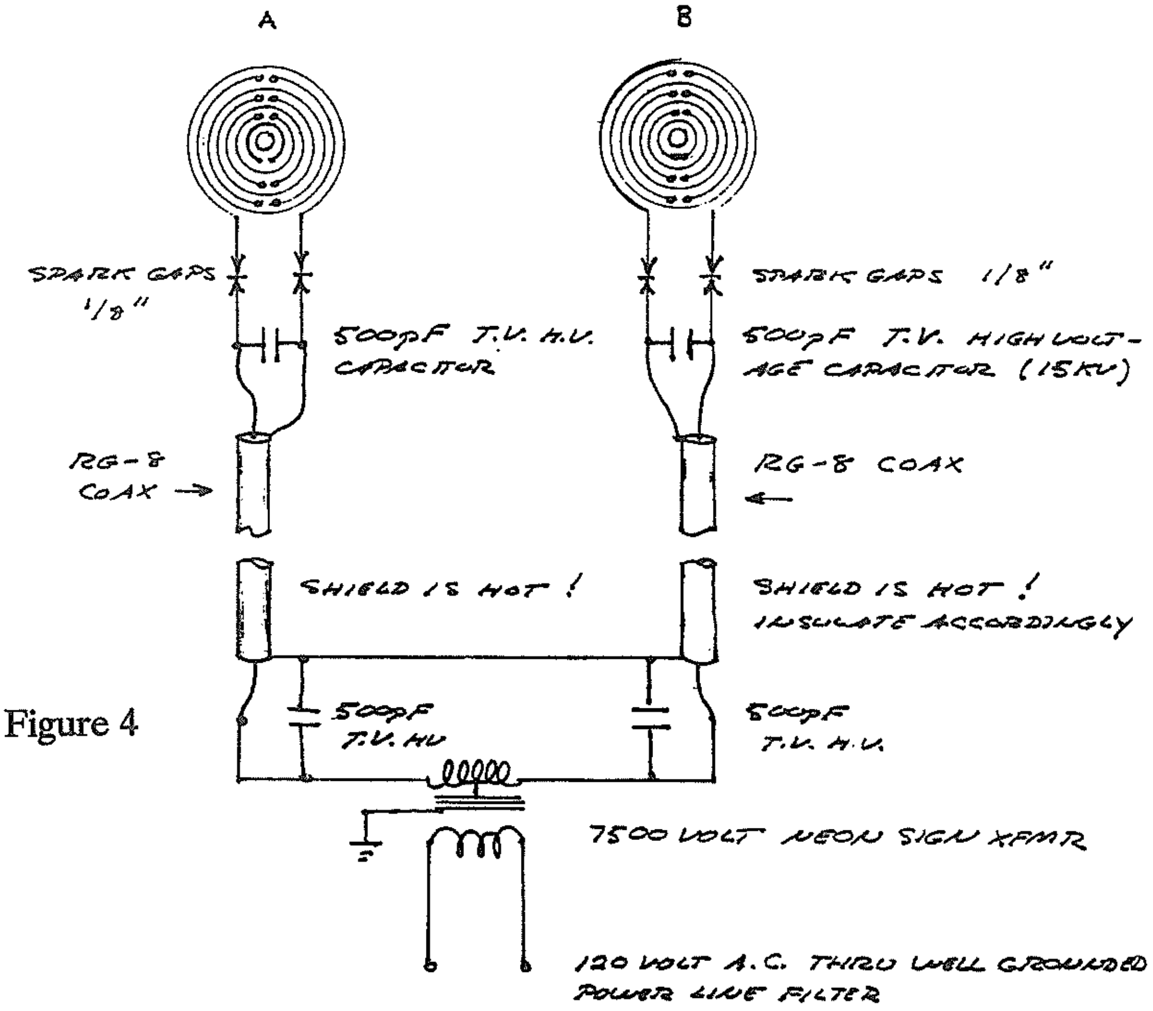
A
B
SPARK GAPS 1/8"
500pF T.V. H.V. CAPACITOR
SPARK GAPS 1/8"
500pF T.V. HIGH VOLTAGE CAPACITOR (15KV)
RG-8 COAX
RG-8 COAX
SHIELD IS HOT!
SHIELD IS HOT! INSULATE ACCORDINGLY
500pF T.V. HV
500pF T.V. H.V.
7500 VOLT NEON SIGN XFMR
120 VOLT A.C. THRU WELL GROUNDED POWER LINE FILTER

Figure 4

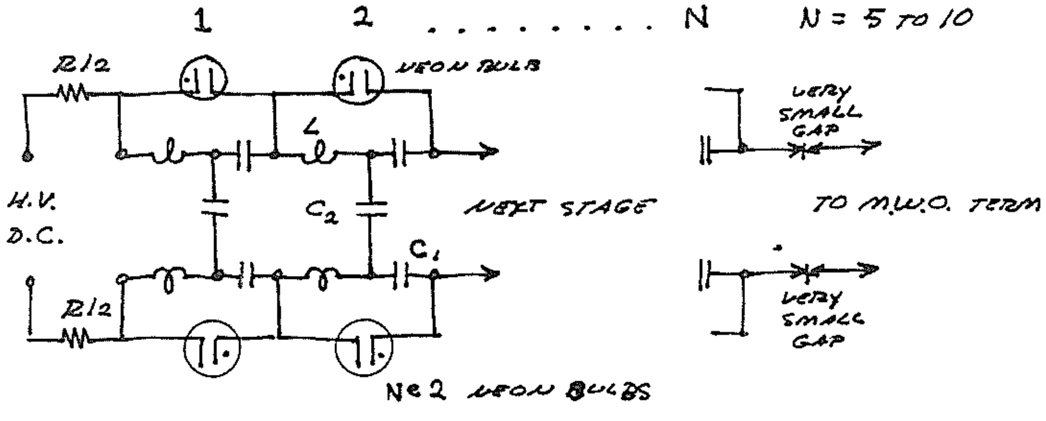
1
2
. . . .
N
N = 5 TO 10
R/2
NEON BULB
L
H.V. D.C.
C2
C1
NEXT STAGE
R/2
VERY SMALL GAP
TO M.W.O. TERM
VERY SMALL GAP
Ne 2 NEON BULBS

Figure 5

D.C. INPUT = 240V / STAGE   ALL C_1 RATED 600V

R = 100KΩ / STAGE   1 WATT / STAGE

L = 1 µH / STAGE C_1 = 100pF X № OF STAGES

C_2 = 0.02 µF / STAGE   600V X № OF STAGES

The term Golden Mean, Ratio or Section refers to the mathematics of life, which is a logarithmic function. This ratio can be found everywhere in nature. It is the Sacred Geometry used in the architecture of ancient Greek and Roman temples, the Great Pyramid, etc. It has also been concluded by certain Orgonomists that "the Golden Ratio is a basic mathematical property of the orgone energy" discovered by Dr. Wilhelm Reich. (Journal of Orgonomy, V.8, N.2, Rosenblum, THE GOLDEN SECTION). It is evident from Lakhovsky's MWO Tube patent that he was aware of the Log Periodic design.

The MWO has usually been understood as having to be driven by a high-frequency source such as Tesla Coils and neon transformers generate. However, those who have looked into Lakhovsky's work know that he used simple wire circles to cure plants of cancers, and to make plants grow better in general. The Golden Ratio Antenna is a series of Lakhovsky rings because the rear conjugate strips on the antenna close the loops and in effect make Lakhovsky oscillating rings which are a complete circuit for focusing the ethers. The log periodic (following a logarithmic pattern) antenna design carries this effect further and preliminary indications are that the log periodic design creates a structure in the ether even without power, in may be an orgone accumulator of sorts. Futher experimentation in this vein is being undertaken.

Log periodic antennae have the interesting property of creating a virtual (non existent but functioning) antenna extending about 1-1/2 times beyond the actual. It is also frequency independent and is an excellent antenna for Amateur Radio communications.

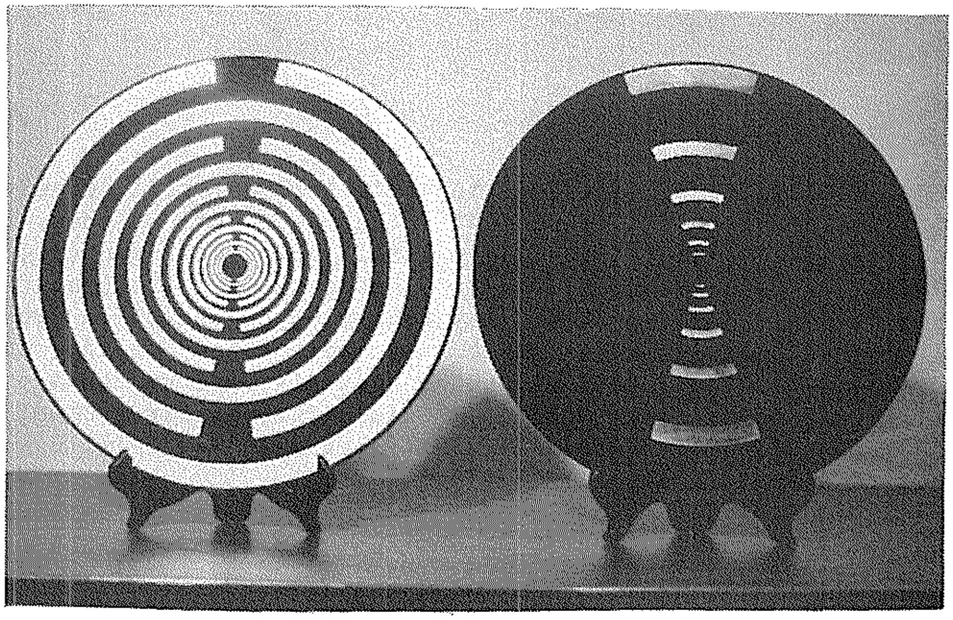

Photo 8
Golden Ratio antennas designed for MWO use by Eric Dollard. Forward side similar to Lakhovsky antenna. Reverse side provides capacitance as did metal spheres at ends of original Lakhovsky antennas. (see Photo 4)

The ethers harmonize to Golden Section Mathematics, (as demonstrated by Trevor Constable in his PRIMARY ENERGY WEATHER ENGINEERING ON THE HIGH SEAS video), so it can be understood that a living organism is a discharge of energy into the Golden Section space. We have observed the discharge of sprout energy into living sprouts when one of these antennas is directed at them. We found that it makes the sprouts grow better. Then we found that simply the pattern makes the sprouts grow better. So here we present you with the Golden Ratio Pattern that you can photocopy and use for experiments. This pattern may be copied as many times as you like for experimentation. We have reports that this pattern keeps the scale out of water heaters and fish tanks.

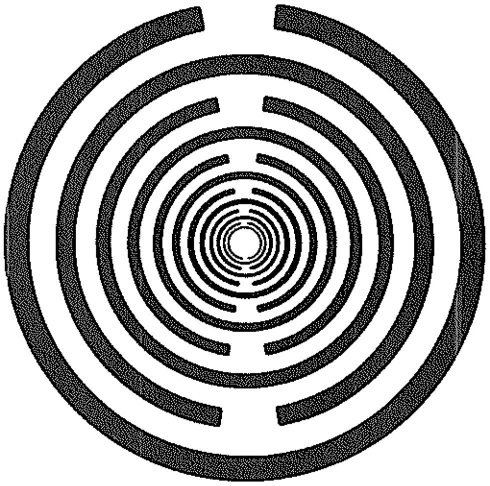

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Log Periodic -- Golden Ratio design for research into the subtle vibrations from patterns.

In 1986 Borderland produced a limited amount of Golden Ratio Antennas in copper and gold. These were precision engineered Log Periodic antennas, and were quickly absorbed into the research network. They can be reproduced if sufficient interest is generated through this book. There is an appendix on log periodic antennas in this book for those who wish to pursue this interesting subject directly related to MWO research.

BUT - DO THEY WORK?

For all the material in this book we still haven't personally seen any solid documentation on the results of either type of MWO that could be re-verified as true to any investigator. I've seen listings and testimonials, but even the photos in THE SECRET OF LIFE look doctored to enhance the cancers (tar can be seen on the wound and the hair!). What was Lakhovsky really up to and which type of device works better? If anyone reading this knows any more than we do then please drop a line. In Lakhovsky's Tube patent he states that his instruments are in use the world over. It is important to check out one of his originals first hand, if any readers have access to such please drop Borderland Sciences a line. We'll make the information available for research. Thanks.

CONCLUSIONS

There are no conclusions at this point in time. Borderland has been publishing MWO information for 25 years now. This book marks the beginning of a new phase of research and development. Perhaps in 1995 after people do some serious research into the subject of the Multi-Wave Oscillator can some conclusions be drawn.

It is important to keep in mind during these researches that just because a frog leg will jump when electricity is applied it doesn't necessarily mean that electricity and life are the same thing. If we labor under this (quite common) delusion we may as well hope for our television sets to "heal" us of our ills. Rather, as astute phenomenological observers, we see that there is a relationship between electricity and life and in the understanding of that relationship we can come to a clearer comprehension of our place in this manifest universe.

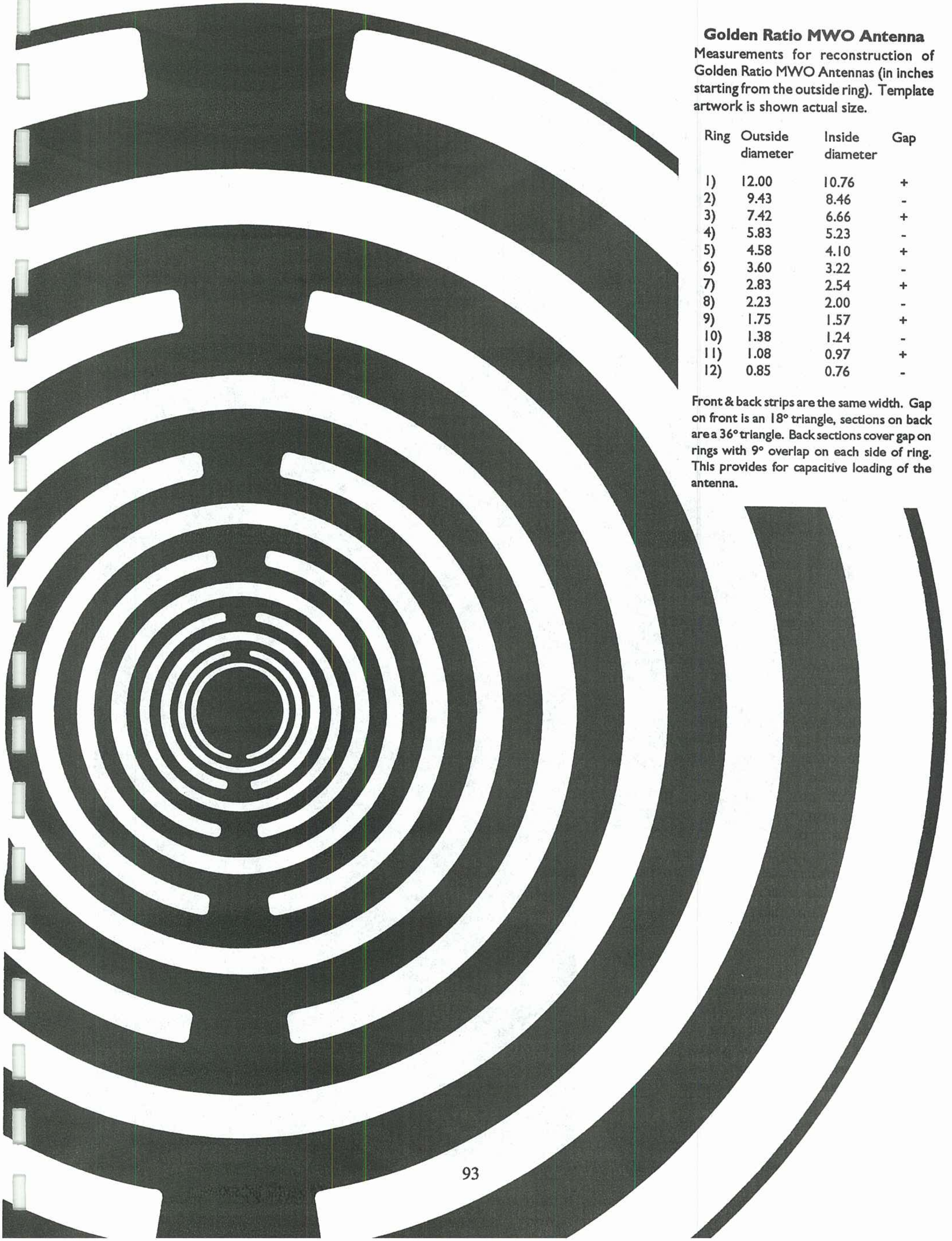

Golden Ratio MWO Antenna

Measurements for reconstruction of Golden Ratio MWO Antennas (in inches starting from the outside ring). Template artwork is shown actual size.

Ring	Outside diameter	Inside diameter	Gap
1)	12.00	10.76	+
2)	9.43	8.46	-
3)	7.42	6.66	+
4)	5.83	5.23	-
5)	4.58	4.10	+
6)	3.60	3.22	-
7)	2.83	2.54	+
8)	2.23	2.00	-
9)	1.75	1.57	+
10)	1.38	1.24	-
11)	1.08	0.97	+
12)	0.85	0.76	-

Front & back strips are the same width. Gap on front is an 18° triangle, sections on back are a 36° triangle. Back sections cover gap on rings with 9° overlap on each side of ring. This provides for capacitive loading of the antenna.

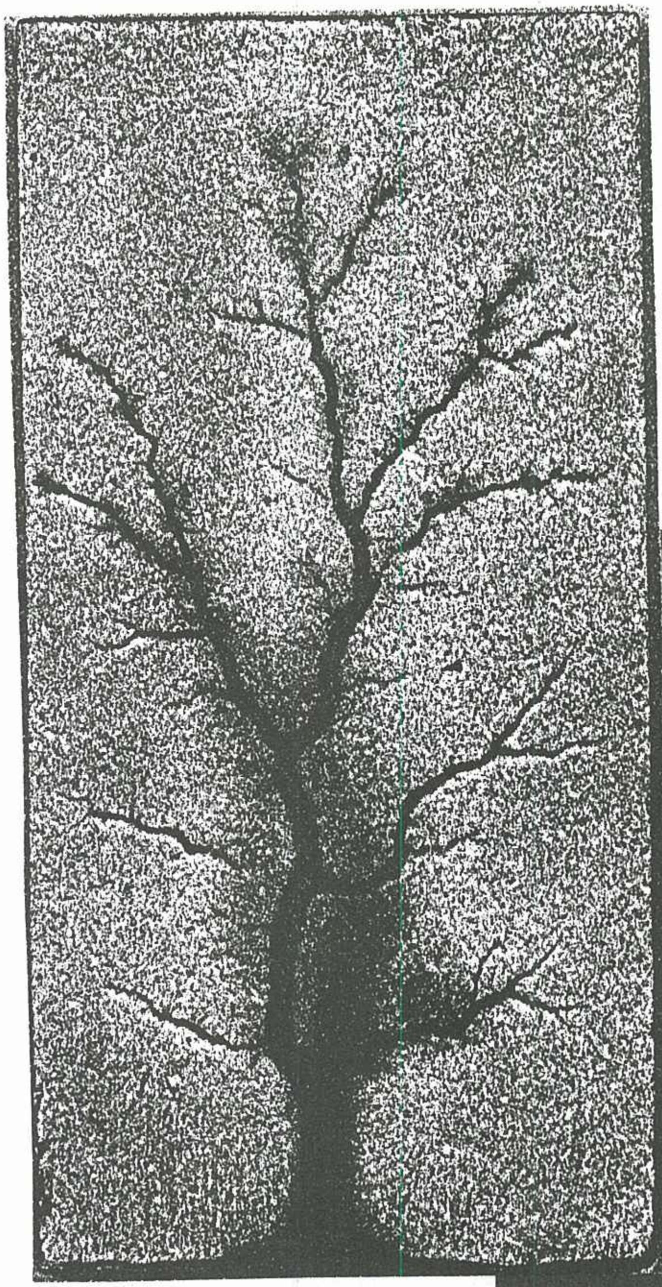

At left is a Golden Ratio pattern burned into particle board using Tesla Coil pictured below, seen here discharging into free space. Scientist Eric Dollard, builder of this coil, has deduced that the Golden Ratio is a property of space itself. The proportions are decided by the amount and type of discharge.

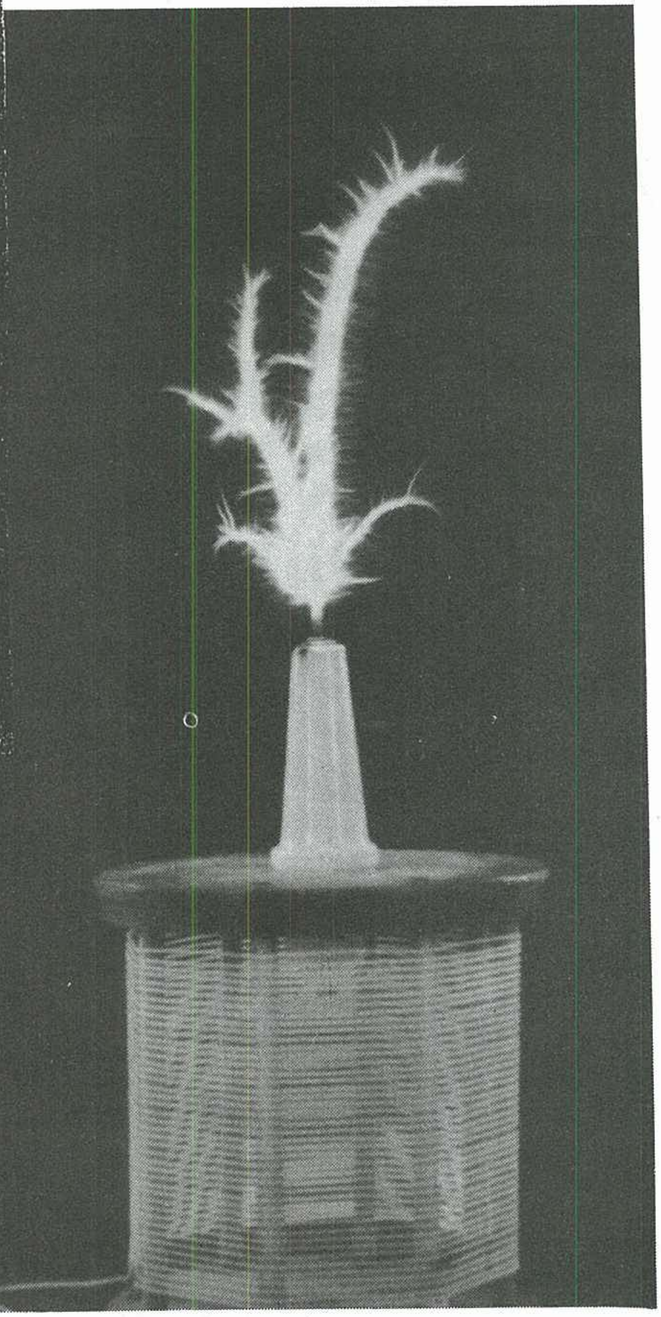

THE SPIRAL COIL MULTI-WAVE OSCILLATOR

Louis A. Schad

DISCLAIMER

Let me make it perfectly clear, I present this information for information and research purposes only and I make no suggestions or recommendations as to its use for healing or medical purposes whatsoever. If you are sick see your doctor. I present to you only what I have learned in my research and observations. I am not a medical doctor and the information I give should be used for education and research only.

To preface this, I have been interested in and studied and collected articles on the unusual sciences for over 30 years and have built many unusual devices. My attention was directed to the Lakhovsky M.W.O. by an article given to me by a friend. I read it several times and studied it and then put it away, (punched holes in it and put it in a notebook). I don't know why -- I can't tell you -- but I couldn't get it out of my mind, so I got it out again and read it some more -- this time going through it sentence by sentence digesting it -- now I was hooked!

I tried to gather all the information I could on the M.W.O., and as usual it wasn't easy -- I had to dig. Bottom line, I started to build Bob Beck's high power multi-wave oscillator -- I still haven't finished it, but I will. The more I studied the M.W.O. (being an average person -- not an electrical engineer, but a mechanical engineer) it seemed to me, complicated, difficult, and had to be adjusted for each person and circumstance. Looking at it now I see that isn't all true -- it was me. Back to square one -- I search for some way simpler, and out of it came the spiral coil M.W.O.

I am a recent member of Borderland Sciences and I have read many fine articles published in this Journal. Many of the articles are very high-tech and delve into the how, where, when and why, and that is how it should be if one is to research. Questions have to be asked and answers have to be found. I am not a professional writer and it isn't one of my greatest talents, so I ask that you have patience with me and I will do my best to tell you about my spiral coil M.W.O.

When I was trying to develop this spiral coil M.W.O. all I wanted was results and I didn't really care how or why it worked, my goal was results, and in doing so I tried many things that I wouldn't have normally tried had I planned each step and tried to fight my way through with pure brain power. In retrospect, I can see that I approached this project with a more light hearted attitude and I have enjoyed developing and building this M.W.O. But at times I did have problems to work out.

I experimented by winding coils, and coils, and coils. I got to be the electric supply house's best copper wire customer, or at least it seemed that way. After boxes and boxes of copper coils, I was ready to throw in the towel and give up -- but having the handicap of being stubborn like I am, I decided to wind one more coil, so I went out to the garage and wouldn't you know it, no more wire. I looked around and all I could find was some old solid strand 16 gauge house wire. It was too light and flimsy for what I wanted, so in desperation I decided to take 2 pieces and twist them together to make 1 heavy piece of wire. Well -- bingo -- I made a coil and got a tingle, that did it. After winding more coils and more coils and experimenting I got to where I am now, so I present to you the Spiral Coil Multi-Wave-Oscillator.

Warning -- this unit is deceiving (it just sits there and looks innocent like it couldn't do much), in fact some of my friends upon first seeing it have laughed at it, and commented you have to be kidding. Another friend of mine asked me to help him build one -- which I did -- and he was lying on his bed in his shorts with a sheet over him and had the unit about 2 foot above the bed and he fell asleep for about 3 hours (he had an infection from a wound in his leg). When he woke up he had a white blister on him about the size of a nickel -- he has done this twice. I warn you, use it with care, it is more powerful than it seems. I think he percolated the infection up out of his leg, as he is fine now.

Now, I know someone is going to say -- I made mine from an old coat hanger and hung it off the coiling with a piece of string, and I'll say -- gee that's nice, do what you wish -- but if you want it to work and work properly build it as it is, use it, experiment with it, and then change it as you wish.

Warning -- persons who have or are diabetic should not use this unit, as it may change the blood sugar level in some people. Diabetes is one of the few things that a M.W.O. will not correct or help. Lakhovsky states this in his book **THE SECRET OF LIFE**. I think I know why but I won't get into it now.

NOTE -- The spiral coils of this unit work all the time -- that is -- they never stop -- they work with or without the vibrator. Who said there is no free energy? If you put it over a bed with an electric blanket, it will charge the blanket and you will probably have difficulty sleeping. If you do not swing it far enough away from the bed at night it will cause unusual dreaming.

As near as I can tell this coil broadcasts at about 120° angle, although its peak energy is centered straight down from the small coil.

Question: is it patented or am I going to patent it? Answer: NO -- as far as I'm concerned it's free to everybody and that's as it should be.

The advantage of using a spiral is that one should get all the frequencies up to the maximum diameter of the outer diameter (O.D.) of the spiral. If you draw a spiral on a paper and place one point of a compass at the center, you can choose any diameter you wish up to the coil O.D. diameter and the scribing diameter will fall some place on the spiral.

This unit can be operated in 6 modes:

1. The coil only.
2. The coil plus the vibrator.
3. The coil plus the vibrator plus the coil shocker.
4. The coil plus the vibrator plus constant coil charge.
5. The coil (no vibrator) plus the coil shocker.
6. The coil (no vibrator) plus the constant coil charge.

So as one can see there is plenty to experiment with here.

NOTE -- I also tried connecting a ion generator to mine -- that really blows me away -- try it if you have one.

If you are experimenting with magnets -- be careful if you use them with this unit as some people get bad reactions. I personally have used magnetic water and this M.W.O. and have had no bad reactions.

Warning -- although I have -- I suggest you do not use this on the head or above the neck.

Warning -- if you have a heart problem do not use this unit as in some people it tends to reduce blood pressure and lower the pulse or heart rate.

Well -- now that I've scared the hell out of you, if you still want to build it I'll tell you the good side. In most all people who have used it or tried it they get a tingle or a feeling of heat (light). Most people get a boost of energy when they use it and it seems to help circulation. I am not sure why. I don't know if it tends to dilate the blood vessels of not. One man that used it can now wiggle his toes and he hadn't been able to do that for about 3 to 4 years.

I know someone will ask what type or kind and amount of energy is emitted by these coils and the answer is I do not know, but I do know that it works. I will leave that to someone who has the proper instruments and the know how to check it, so there is still a lot of work to be done here if someone wishes to do it. Now, before someone starts climbing my ladder, let me say that I give the credit to Lakhovsky -- what I did was to modify, update and expand upon the base of some of his work.

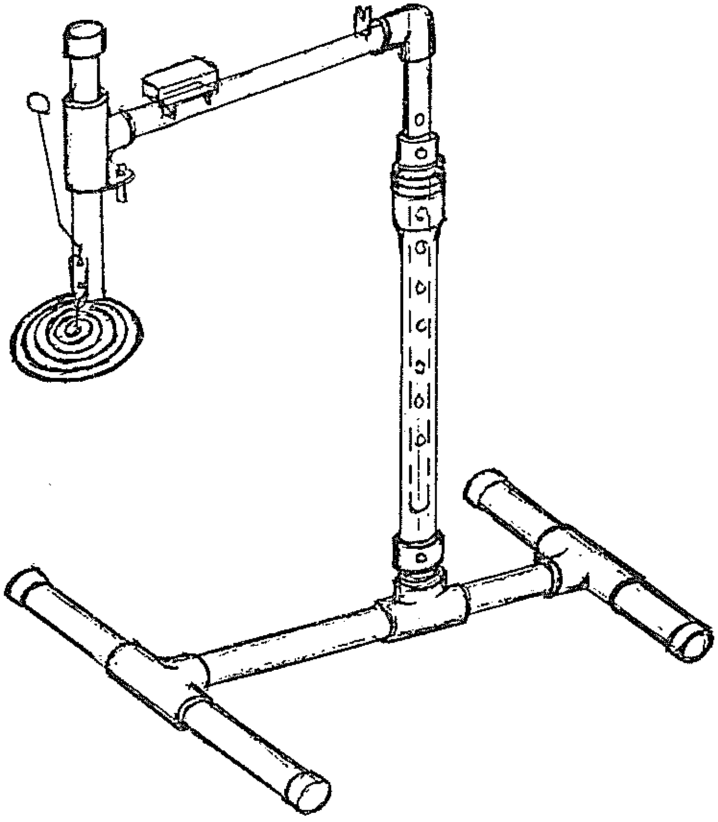

Spiral Coil Multiple Wave Oscillator

You do not have to be gifted in the knowledge of the sciences to build this M.W.O. and do not need special equipment or tools. However, there are little tricks that I have learned that make it easier to build that I will give in another article. The body or base of this unit is made of P.V.C. pipe, also the vertical and swing arm, the vibrator base and also the drop tube that hangs the coils. We want a unit that is low in cost, tough and durable, light in weight, corrosion resistant, portable, easy to fabricate (and repair if necessary) and looks nice, so we will build our unit out of P.V.C. pipe.

ALL COILS ON THIS M.W.O. MUST BE RIGHT HAND COILS, IN RELATION TO THE UNIT AND EACH OTHER. If they are not you will get negative energy. (I'm not speaking of polarity here.)

I use a fish tank air pump (modified) -- (Challenger 1) about $8.50. This provides the oscillatory motion to the coils. I'm not in love with it and would like to find something better -- something of higher frequency, but it works. If anyone has any suggestions on this I would like to hear from them.

I chose to design the unit so it can access any part of the body freely without a lot of excess adjustments. The body when lying down is in one plane or height (approximately), so I built the unit so it would extend over a bed or table, added a swing arm, and a vertical adjustment (holes in the vertical tube arm and a wood dowel or pin stop) -- that seemed simple enough, remember we're trying not to get complicated here.

If you are going to build this M.W.O. I strongly suggest that you read Lakhovsky's book, THE SECRET OF LIFE. When I finally decided to try to build an alternative type of M.W.O., I read everything I could get my hands on about the subject. I read carefully and took notes of key points, functions etc., then I put my books away and studied my notes -- the basics.

M.W.O. -- MULTI-WAVE OSCILLATOR

MULTI -- meaning more than one or many.

WAVE -- energy (given off)

OSCILLATOR -- I looked this up in Webster's -- and simply stated it says -- motion deflected from center to one side -- back to center -- deflected to the opposite side -- back to center, OR -- Vibration.

Now, Lakhovsky in his book stated he made an oscillator of 1 loop or coil of wire errata: This page was inadvertantly left out of the book.

electrical supply house. If you cannot get bare wire, you will have to get plastic coated and strip the coating with a sharp jackknife, taking care not to nick the wire, or yourself.

2. You need a piece of aluminum bar 3/16 x 1-1/2 inces, 20 to 24 inches long.
3. You need a medium size pair of pliers.
4. Soldering iron and acid core solder.
5. Small coil of 19 gauge coated (shellacked) copper wire.

Now – we have 17-1/2 ft. of 10 gauge copper wire, lay it out on a flat clean surface and straighten it out taking the curve out of it and the kinks and bends. Next we need a secure and strong place to fasten the ends of the wire to – like a trailer hitch or bumper of a car or truck etc. After you have found a place to secure your wire, fasten both ends of the wire to it as shown in Fig. 1.

Slowly pull the center of the wire so that you have 2 pieces of wire, put your aluminum bar in the loop and pull tight. With a pair of pliers close the wire down on the bar tight so that it passes between the screws. Pull hard on the wire with the bar – it won't break. Start twisting as shown in Fig. 1 – always keep tension on the wire – do not let go of the bar. (COUNTER CLOCKWISE). Twist the wire, stopping at time, give the wire a couple of good yanks. NO, it won't break. Twist the wire until you have a good tight twist on it. When you think you have twisted it enough – twist it a little more. When you get it where you like it – SLOWLY back the pressure off of the bar.

Remove 1 screw on the bar and slide the loop out or off of the bar. Unfasten the wire where you secured it and cut the spiral wire as close as possible at secured end. Lay the twisted wire down flat. Measure 3" down from the top of the loop as shown in Fig. 2 and mark it with a pencil or pen. Hard or tight bend the wires as shown in Fig 2, 90 degrees. Grip the twisted wire at the bend point with a pair of pliers, and start forming the spiral. Continue forming 1 or 2 loops. Remove the pliers, grip the wire and hand form the spiral as shown in the drawing #2. When you have formed about 4 loops of the spiral, stop and apply light heat to the coil with a hair dryer or similar device to relieve some of the stress in the wire, so that the loops that you have formed will stay where you have bent them. Repeat the operations and continue forming until you have your spiral.

DO NOT BEND END OR TIP IN YET.

Put your spiral in the freezer of your refrigerator for 30 to 45 minutes, and freeze it. This will tend to stabilize the copper some and relieve some more of the stress.

In Fig. 4 we can see that if we bend a piece of metal the inside of the curve is compressed and the outside is stretched, this stress is what we are trying to get rid of. About now some of you will be thinking – GAD – he even tells us how to hold the hammer. I am sure that some of your who are pro's at metal forming and fabrication can build this thing – WHAM-BANG, but please have patience, not all are gifted in some of these skills.

When you have formed your spiral and it is shaped as you want it, hold the loop of the spiral with your thumb and point fingers at eye level height and sight across the spiral, it should hang so that all coils are level and even with each other, so that it is flat – if not form it so it is. Put the coil in the freezer again, repeat freezing operation several times, this tends to age harden the coil some.

With a very hot soldering iron solder the end of the coil, wash it in warm water, dry it, and bend end in as on drawing #2. After you bend the tip in, bend it down a little bit so the bent in tip clears the crossed coil by about 1/4 inch.

Drill 2 small holes in the spiral at points marked on Fig. 6, taking care not to break the drill, use light pressure. Cut 1 piece of coated coil wire (19 ga.) about 4 1/2 feet long. Push one end of wire (about 1-1/2 inches) up through bottom of hole in spiral, and wrap wind (twisted) loops of wire to second hole. Straight wrap 1 loop at hole area, this locks the standing wire. Pull standing wires tight with pliers and cut standing wires to about 1-1/4 inches.

Refreeze spiral and warm to room temperature. Sand or remove shellac from standing wires down about 3/4 of an inch, this makes electrical contact for the coil shocker. You have finished the main spiral coil. You have just done the hardest part, the rest of it is easy. Save your aluminum bar; you may want to build other types and shapes of coils and spirals to experiment with. I have wound and tried 2 wire coils, 3 wire coils, cone shaped spirals, step spirals, spirals with wires attached and hanging down with soldered tips etc. There is no end – you can experiment to your heart's delight, it's only limited by your imagination.

In closing, I would like to tell you a story – a true story about a close relative who gave me permission to tell of his experience with my M.W.O., but prefers to remain anonymous. I will not elaborate, but just state the facts as told to me by him and his nurse.

This relative took a trip by car to the southwest part of the U.S. with some friends. Before he left he called me and said that he would come to California and would stop to visit with me. This was in the late summer of 1990. After arriving at his destination in the southwest, the weather turned very hot for the whole western U.S. Due to this extreme hot spell, he phoned me and said he was returning home and would not come to California.

When I talked to him on the phone before he left, I told him I had built a Multi Wave Oscillator for him and I would give it to him when he came to see me, and he could take it back with him. He did not make it to Calif. but returned to his home in the midwest. After returning home he became ill and went to see his doctor. After being checked by his doctor, he had tests, and the doctors discovered that he had cancer of the large intestine. When I phoned him and found that he had cancer, I asked him if he wanted to try my M.W.O. I told him that I could not guarantee that it would help him – but I said – what do you have to lose. He said yes, he wanted to try it, so I sent it to him.

When he received the M.W.O., it was assembled from instructions I sent him. He used it twice a day for approximately 6 weeks. He had additional medical problems, he had diabetes and congestive heart failure plus the cancer plus a back problem. I had made the M.W.O. for him in hopes that it might help his back. When he went back in 6 weeks to see a cancer specialist doctor they gave him extensive tests and could not find any traces of

of a given diameter that overlapped. Also, I have read that it isn't the intensity or power of the unit that is desired, but the quality of the signal and also the number of frequencies, signals or waves, as the power can be offset by a longer exposure time. It seemed obvious that a spiral should produce all or most of the waves or signals desired and that it would be better than one loop with a limited signal effect. If Lakhovsky could cure cancer in plants and people with one loop it is logical that a spiral should be even better. OSCILLATION -- how about inducing it artificially -- vibrate or agitate the coil or coils.

This unit produces it's peak energy at 12 o'clock at night, but it can be used during the daylight hours too; it's energy diminishes some toward mid-day. Lakhovsky stated this and he is right. I've got to give it to him, he did his homework. Exposure rates or time of treatment with an electronic double screen M.W.O. is said to be 10 to 15 minutes every 3 to 4 days. Exposure time for a spiral coil M.W.O. (rule of thumb) is about 20 to 25 minutes or 45 minutes maximum per day, or less, depending on what is treated.

Lakhovsky also stated that he treated plants, animals and people with belts, collars, bracelets etc., consisting of a single loop of copper wire. From what I can gather, if a subject was wearing a Lakhovsky coil they never took it off.

My spiral coil M.W.O. is half and half -- part 1 loop + of wire, and part electronic. If a subject got 1 exposure every 3 to 4 days with a conventional M.W.O., it means that the subject's system was hit hard or shocked, and it needs time to adjust. A spiral coil M.W.O. requires a longer or more often exposure and this can be an advantage as it gives us more control of the research subject's requirements. The negative side is that the subject has to spend more time more often.

There is one unusual thing that I and others have experienced with this unit. When you first use it the sensation of heat or tingling is light and you require longer exposure time, like about 25 minutes before you feel that you have had enough. After you use it for about 1 to 2 weeks you will find that after 10 to 15 minutes you feel that you have had enough. Simply stated Lakhovsky said that a M.W.O. activates or excites the cells. It's kind of like pushing a car, it takes a lot of energy to get it started, but once it's rolling it's easier to push. Maybe the body just becomes more sensitized to the energy after the M.W.O. is used for a while. In Lakhovsky's THE SECRET OF LIFE on page 75, "The circuit is subjected to any kind of electric or magnetic shock it is then said that it vibrates according to its natural period." So, now what do we have?

1. A spiral coil (Providing Multiple Frequencies)
2. Vibrator (artificial oscillation).
3. Electric current (D.C.) (shock to the coil) provided by a small transformer limited by bulbs turned on and off by a Christmas light blinker or winker.

Now I said previously that most of the unit is made of P.V.C. schedule 40 pipe (white). P.V.C. pipe being what it is has the tendency to sag if placed in a horizontal position, fastened at one end with weight suspended at the other end. We can correct this by inserting a piece of 1 inch diameter .050 aluminum tubing inside the P.V.C. and gluing it with an adhesive or simply by drilling a 1/8 inch hole through both pieces and inserting a #8 sheet metal screw. Remember also I said there were little tricks you can use to build it as given above, so before you get too anxious to build, wait till I can write the HOW TO BUILD article, it may make your job easier and you will not have to change or rebuild the second time. I am trying to save some of you all the mistakes I made.

The heart of this M.W.O. is the large main spiral coil. This coil is in simple terms an antenna. It is a dual antenna, that is, 2 in 1 as it is a receiving antenna and also a broadcasting antenna. The antenna can be shaped in many forms and still retain the right hand spiral. Do we wind it tight toward the center and increase the spacing as we go out? This configuration I have found best, but other configurations can be formed to achieve different effects. I have experimented with different shapes and some have given unusual results. There is still a lot of work that could be done here also. I wound a 3 wire coil that was very effective but I had problems twisting the copper wire and lost several of them. I would suggest that the first coil you make be a 2 wire twist coil. If you want to build the M.W.O. complete you will have a total of 4 coils.

1 large main spiral coil.
1 small spiral coil (that is mounted under the large coil).
2 straight tube coils.

We use these coils because they all have independent functions. We are going to squeeze it and milk it for all we can, to get everything we can out of it. The main spiral coil produces most of the waves or energy, however, due to its design and nature the inside of the spiral cannot be wound tight to create small loops in the coil, so we will add another smaller spiral coil under the large main-spiral, this will give us the higher waves or frequencies we desire. We drill 2 small holes in the main spiral and tight wind a piece of 19 gauge coated coil wire around the twisted copper wire, and pull the wire up through the holes, leaving 2 standing 19 gauge wires. We sand the ends of these and fasten spring clips that hold the tube coils. The other end of the tube coil wire is connected to a banana plug -- into a receptacle, we connect our coil shock to these.

I know there are some of you out there who are like I am, (impatient) and are curious and would like to try this to see if this guy is telling the truth or if he is just full of it. I am aware that the Journal is published every 2 months and maybe some of you don't want to wait 2 months, so for those of you who are like I am -- let me tell you how to build the main spiral coil. This one coil in and of itself won't knock you over -- but you can get started, and you can play with it until I can write the HOW TO BUILD article. This coil will emit energy by itself if suspended horizontally. Fasten it to something, a piece of plastic tube or wood dowel etc. Try it on your feet as the feet seem to be sensitive to these energies. Well -- here we go.

HOW TO BUILD THE MAIN SPIRAL COIL

You will need to purchase a few things.

1. You need 17-1/2 feet of 10 gauge (solid) bare copper wire (cost about 14 cents per foot). You can get this at any

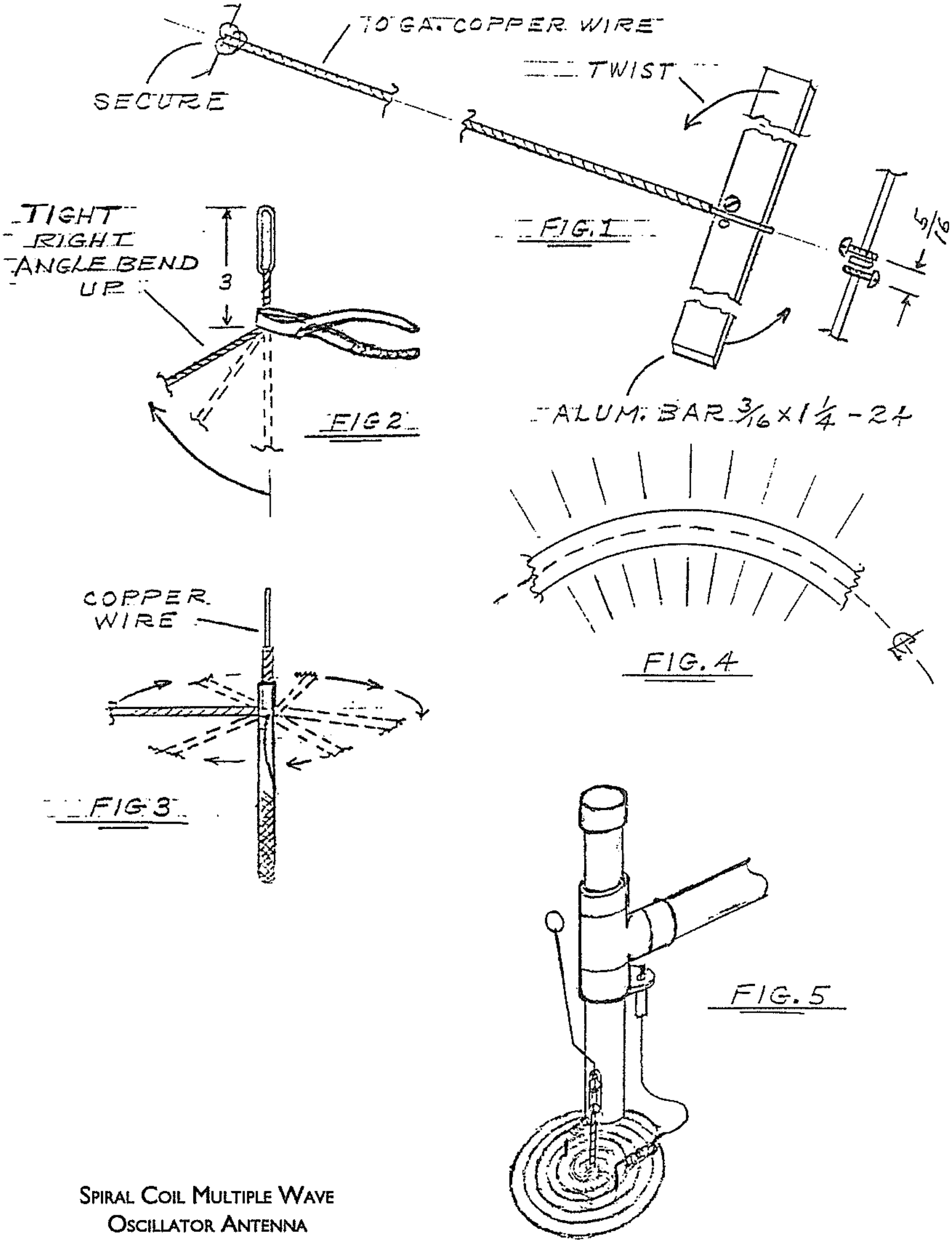

10 GA. COPPER WIRE
SECURE
TWIST
FIG. 1
5/16
ALUM. BAR 3/16 × 1 1/4 - 24
TIGHT RIGHT ANGLE BEND UP
3
FIG 2
FIG. 4
COPPER WIRE
FIG 3
FIG. 5

Spiral Coil Multiple Wave
Oscillator Antenna
Construction Drawings
Figures 1-5

cancer. After his tests he phoned me and said the doctors could find NO traces of cancer whatsoever. I asked him -- did you take any medications whatsoever for your cancer? -- he said NO. I asked him -- did you take any radiation treatments for you cancer? -- he said NO. I asked him -- did you take anything at all for your cancer? -- he said NO. To this date he has not had any return of his cancer.

Now, where does this leave us? He either had spontaneous remission or he was helped by the M.W.O. As I understand and have been told, some forms of cancer in the upper stomach are inoperable. My relative is the 3rd person who seemingly has had remission from cancer from using my M.W.O. I do not like to use the word cured when speaking of cancer, and I say seemingly as this is all in the experimental stages of research.

Then there is Al Mills who built and used a copy of my M.W.O. He had prostate cancer; he's fine now, but we can't count him as he has taken medications for it. I have heard that doctors have said that prostate cancer is very difficult to treat. Then there also is Simon Lucas who built my M.W.O. and loaned it to a lady who has LUPUS (a cutaneous disease due to the tubercle bacillus). He said she is feeling and doing much better now. I also built a M.W.O. for my mother who lives in So. Sioux City, Nebraska, across the river from Sioux City, Iowa. I sent it to her -- she could not assemble it so I flew back to do it for her.

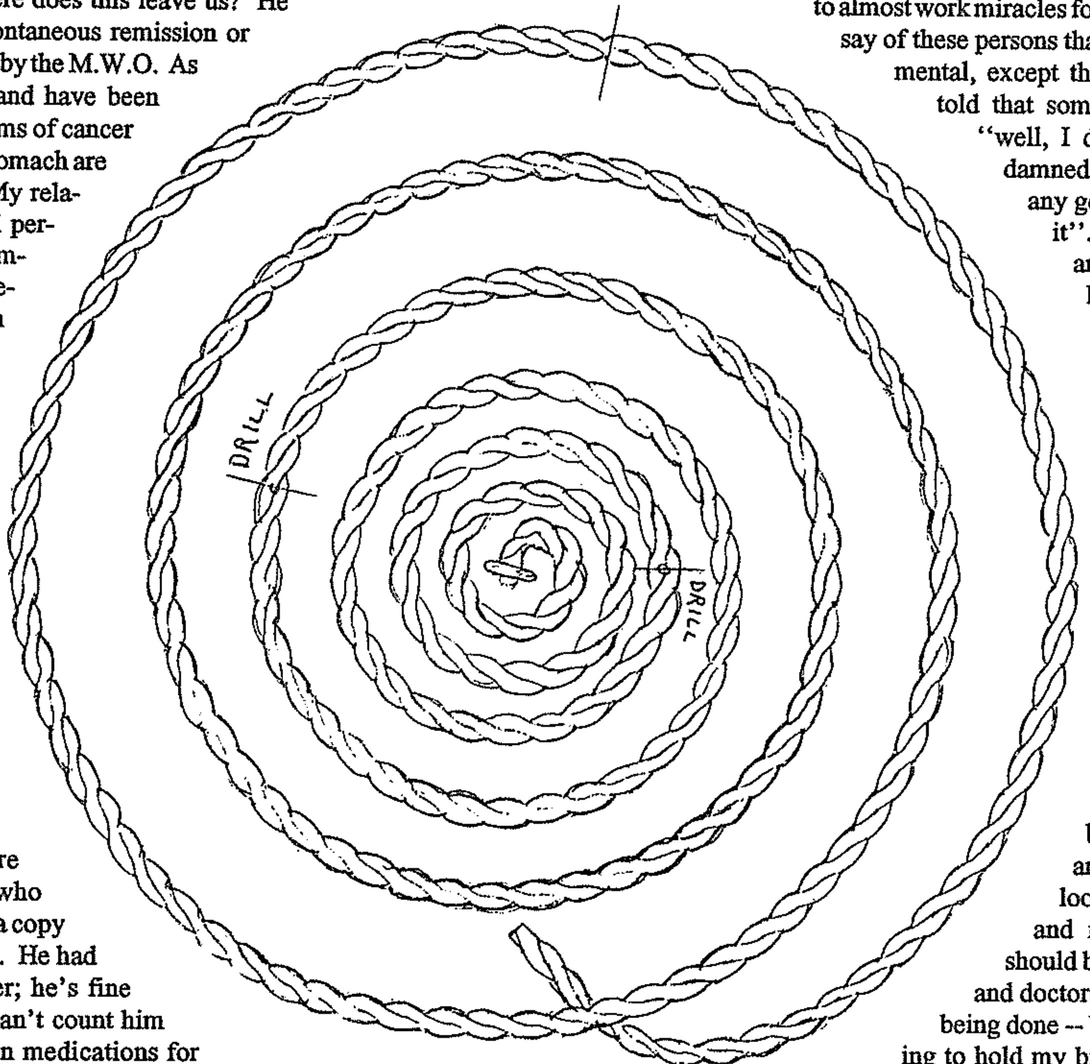

FIGURE 6

Several years back she was leaving a market and caught her foot in a disposed plastic bag on the sidewalk, fell and broke her hip and leg. The doctors repaired it by wrapping screen around the bone and added a few screws and pins here and there. She was OK for several years and then she got to the point where the pain was so bad she could walk only a short distance. She has used the M.W.O. for about 2 months. She called me the other day and said she took the bus all over town, did shopping, came back, took her pull cart and did her food shopping -- 6 blocks up and 6 blocks back -- and then walked up to the restaurant and got her dinner, all in 1 day and she said she feels fine. The doctors gave her the choice of pain shots or cutting off her leg -- (some choice). NOTE -- She does not have a coil shocker on her unit.

In all honesty I have to say that my spiral coil M.W.O. does not affect all people the same. I have had no negative or bad reports to date from anyone using it with good common sense and discretion. There are a few people that it does not seem to help to any great degree. There are also some people that it seems to almost work miracles for them. I would say of these persons that maybe it was mental, except that I have been told that some have said -- "well, I don't think the damned thing will do any good, but I'll try it". I could go on and on but we'll leave it at that.

If you decide to build my M.W.O. I would welcome any serious and honest experimental input as this unit still has many areas that need to be explored. Sometimes I back way off and just stop and look at all this -- and realize that it should be the scientists and doctors doing what is being done -- but I'm not going to hold my breath until that happens. I guess the only way it's going to get done is for people like you and me getting off our backsides and getting it done. If enough will work at it and add a little bit, it'll get done. I sometimes wonder what the end-run potential of my M.W.O. is. I love the doctors (God Bless them!), we need them, but I wish they were more open minded and that they were not so profit orientated and stigmatized by their organizations. I think these ideas I present here will help.

THE SPIRAL COIL M.W.O.

PART II - HOW TO BUILD

by Lou Schad

In Part One I explained how the spiral coil M.W.O. evolved and how I came to build it and notes on things I have learned about it and its use. I also explained with drawings how to build the main spiral coil. For those of you who wish to build this unit, I have added additional drawings and notes so you can build the rest of the coils, base, etc.

Before I begin I would like to address an issue that has bothered me for some time, it pertains to my M.W.O. and maybe other M.W.O's in general. It is a situation or function that has been ignored by many or all but a few. In my article in Part I, I said all coils on this unit must be right hand coils. What I am referring to is what I call RIGHT HAND SPIN. In my study of Lakhovsky's and others work, I have not been able to find any information pertaining to direction of spin, although he gave very precise directions -- how collars, belts, bracelets etc. were to be made. Did he know and was it his secret? Was he not telling? Lakhovsky stated that his M.W.O. stimulated the twisted filament or nucleus of the cell, and the cell oscillated according to its natural frequency. A weak oscillating cell would increase its oscillations back to normal. The question is, do certain oscillations cause the cell to spin right hand or left hand, or clockwise or counter-clockwise, if the frequencies spin right hand or left hand? Some might say -- what difference does it make. The people who use or practice the Five Tibetan Rites always spin right -- never left. Sir Lawrence Bragg (Nobel Prize winner) discovered that healthy people have "RIGHT HAND" spinning blood. And physicist Dr. E. Mersmann discovered that people exposed to electronic smog have "LEFT HAND" spinning blood, the same as people who have cancer -- they also have "LEFT HAND" spin blood. Maybe if the earth spun in the opposite direction, left hand spin blood would be normal. So, is left hand spin or right hand spin important? Yes, I think so. I have purposely made and used left hand coils and they made me feel sick and ill. There is an instrument that has been built that emits weak pulsed electromagnetic waves that causes the blood to spin right hand in people who have left hand spin blood, however if the unit is removed the blood will go back to abnormal left hand spin.

If you put your hand in a bucket of water you can spin it to the right or to the left -- is this polarity? Does magnetic polarity have an effect on matter causing right or left spin? Yes, it seems to. But how about induced spin direction on a non-magnetic or non-electrical energy or wave? If I hold a magnetic compass near the spiral coil of my M.W.O., I get nothing -- no needle movement. If I hold a pocket radio under the coil with vibrator and tune it off station, I get static on A.M. from about 80 on down, none above 90 and up, but I don't think that static is coming from the vibrator. Warning: I damaged my radio by using if for testing. At first I thought it was the battery, but a new battery did not correct it. Sometimes when I turn it on now it doesn't want to come on, by flipping the switch on and off several times it then works. I had no problem with this radio before I used it for testing.

Whatever the answers are, I would suggest you use right hand coils. Look very carefully on pages 113 and 114, these are right hand coils in relation to the subject, (ref. The Secret of Life). If you build the spiral coil M.W.O. you will have the basic unit. You can experiment and try all types of coils and spirals, as I said in Part I, it is only limited by your imagination. I find it fun and interesting to try unusual and weird coils, it's not expensive and you only have to remove a couple of screws, no big deal.

I have been thinking of building a cheap copy of Lakhovsky's coil of tube and wire, also a foil coil of equal size, to test if the coils when vibrated emit equal energies etc., and what the differences would be. It may answer the question why some of the foil coils don't seem to produce the results as good as some would like. In Lakhovsky's book there are pictures of, and he speaks of, the oscillator coils of Hertz. There is a striking resemblance of Lakhovsky's coils on his oscillator antenna to Hertz's coil. Could he have been influenced by or borrowed the Hertz oscillator coil for his unit -- did he expand upon the base of Hertz's work for his antenna coil? (interesting thought)

Enough digression -- back to our spiral coil building project. If you look at drawing #3 you will see that it is self descriptive, giving diameters, lengths etc. We make most all of our unit out of schedule 40 PVC plastic pipe. Take enough care to make your cuts square and clean, debur the ends of the tubes so they will slide into the glued slip fittings correctly. Now, here comes the stinky part. If you want your unit to look nice, you will have to clean the tube, (after cutting), taking off all the dirt, the ink lettering etc. I use a laundry tub, a small amount of water, laundry detergent, Comet, and some wet or dry #200 sandpaper and a lot of elbow grease.

Warning: PVC glue sets fast, in a matter of seconds. I put glue on the female fittings only -- none on the male side, slide it together firmly and whack it with a short piece of 2 x 4. Glue part #7 to part #8 and drill a 5/16 hole through fitting -- this is so you can tighten or remove the threaded fitting by inserting a phillips screw driver or rod in the hole. This makes your unit portable.

Glue pieces 1-1-5-4-4, also 3-3-5-4-4.

Now glue part 2 to part 6, also part 3 to part 6.

Thread assembly 7-8 (large vertical tube) into assemble 2-6-3.

We will slide assembly 11-5-44 onto tube #2, but we will not glue it. Place this on a flat table, and adjust tube 8 so it is vertical.

When you get it where you like it, glue assembly 33-5-44 to loose tube 3, let this dry for 20 minutes.

Now remove assembly 11-5-44, apply glue to fitting #5 and glue it to tube #2 on your flat table. You now have the base finished.

Glue the rest of the tubes and fittings together on your table. NOTE: Do not glue parts #19 and #20, we leave these loose and just set them in place, as we may add something additional here later.

NOTE: Before you glue tubes #11 and #15, cut some one inch diameter .050 aluminum tube full length of tubes and slide them inside of plastic tubes, this eliminates sag. Drill a 1/8 inch hole through plastic tube and aluminum tube, screw a #8 sheet metal screw through both tubes. Tube #11 has holes in it so we can adjust the height, drill these 2 inches apart, 5/16 inch holes. We insert a 1/4 inch wood dowel through fitting #10 and through tube #11.

We drill 2 holes in tube #21 and thread them 10-24, we fasten our spiral coils and antenna to these. The first hole is drilled 5/16 of an inch up from the bottom edge of the tube and the second hole is drilled 3/4 of an inch from the first hole.

When you buy your 1-1/2 PVC tube, get a piece with a flared end, as we set a reducer fitting in it to make a sleeve for the #11 one inch tube. To keep tube #11 guided at the bottom of tube #8, drill 3 holes at the bottom of tube #11 equally spaced around the diameter and insert 3 #8 sheet metal screws.

Parts #9 and #10 will have to be filed out or machined out so the one inch tube will slide through them.

Part #16, the vibrator base, is made of flat stock PVC. If you cannot buy it from a plastic supply house, cut a couple pieces of 1-1/2 PVC tube about 3-1/2 inches long, cut them again length wise, so you have half tube pieces. Place the half tube pieces between two - 1/8 inch aluminum plates and heat in a stove oven with a brick or weight on top. Let them cool and the plastic will come out flat. Layout and mark parts on flat sheet and cut out.

Glue all the pieces of vibrator base together and fit to tube #15 and glue it tight. A wood match works wood to lay glue in joints.

Make and fit your metal brace from aluminum or non-corrosive metal and fasted with two - #8 sheet metal screws. Cut out part #23, fit it to T - #22, drill two holes for banana receptacles and glue securely, also cord holder #14.

Make your small spiral coil from .0625 low carbon stainless steel heli-arc welding rod -- 36 inches long, do not twist wire, use as is. You can get this from any welding supply; get 4 or 5 pieces. Also make antenna from same wire. To make small spiral use the full length or rod. Start by forming an eye on one end for the 10-24 screw. Move down 3 1/4 inches and form spiral same as large spiral coil, also bending end tip in. Put an offset kink in the stem so it will pass through the main coil.

The tube coils are made from #19 shellac insulated coil wire, 12 to 14 turns. I tight bend a 90 degree bend, so I have a 1 inch long tail. I place this parallel on a pencil or wood dowel and tight wind the coil. Grip the wire tail and dowel with a pair of pliers. Remove the dowel and freeze for 30 minutes, warm to room temperature. Grip the ends of the coil with your thumb and middle finger nails and stretch the coil to the desired length, refreeze for 30 minutes. Bend long tail of coil 90 degrees and fit to banana plug. Trim short end to 3/4 inch, clean and solder pinch clip to coil. The pinch clip is made from light gauge hard stainless or brass. Blank size is 7/32 x 1-1/4.

After you have everything glued and finished put a coat of auto polish on PVC tubes, as this keeps them clean and they will not finger mark or get dirty. Also put a coat of vaseline on the threaded fittings so they can be removed easily as they tend to stick.

If you are, or want to be, the serious experimenter type, buy a note book and keep records and notes. Keeping a log with dates, exposure times, etc. can be a very useful tool to compare results of different coils etc. I would welcome hearing from you on the use of the spiral coil M.W.O., i.e. your success and problems. NOTE: Don't expect results in 2 or 3 exposures, as this unit is more gentle and may require a longer time of weeks or several months to get permanent results. To this date I have not had a single report from anyone for over-exposure if used with common discretion. I have used belts, collars, wire loops etc. with the M.W.O., this seems to multiply the energy. I also have used a spin magnetic unit with a reticular energy filter before and after M.W.O. exposure. This seems to work well for joint problems.

Please Note: Lou Schad does not manufacture or sell this MWO. He is giving his knowledge and experience as a gift to the world. He may be written c/- BSRF.

LEGEND

USE P.V.C. (WHITE) SCHEDULE 40

KEY

L=LENGTH D=DIAMETER C=CUT
T=TUBE T.F.=THREADED FITTING

PART #	**DESCRIPTION** (in inches)
1.	T-D=1-1/2, CL=10
2.	T-D=1-1/2, CL=15-1/2
3.	T-D=1-1/2, CL=8-1/4
4.	CAP-D=1-1/2 (4)
5.	TEE-D=1-1/2 (2)
6.	TEE-D=1-1/2 THD'D
7.	NIPPLE-D=1-1/2 THD'D
8.	T-D=1-1/2, CL=28-1/2
9.	REDUCER - D=1-1/2 TO 1
10.	REDUCER - D=1-1/2 TO 1 INV.
11.	T-D=1, CL=28-1/2
12.	T.F.-D=1 NIPPLE
13.	ELBOW - D=1 - T.F.
14.	CORD HOLDER (ELEC.)
15.	T-D=1, CL=20-1/2
16.	VIBRATOR BASE
17.	METAL BRACE
18.	TEE-D=1
19.	T-D=1, CL=3-1/4
20.	CAP - D=1
21.	T-D=1, CL=5-1/2
22.	ANTENNA
23.	F.T.G. BANANA RECP.

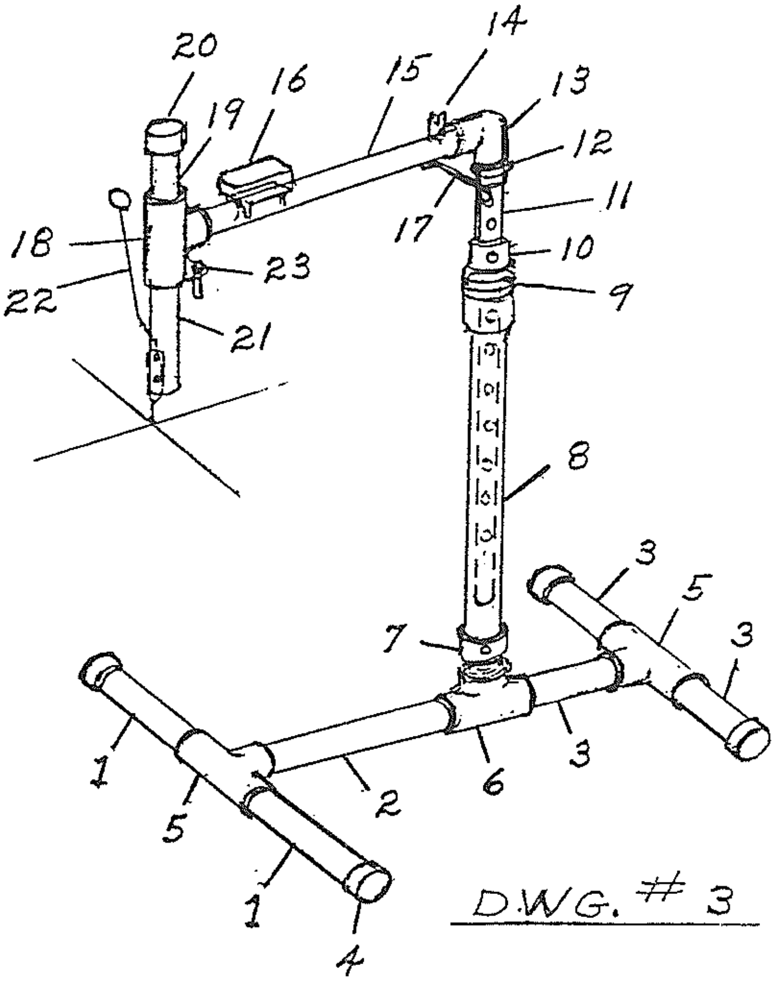

D.W.G. # 3

COIL SHOCKER FOR SCHAD SPIRAL COIL M.W.O.

This unit provides a D.C. shock to the spiral coil. It should be built in a wood box, or grounded metal box for safety sake as we use 115V A.C. power source. All the parts can be purchased from an electrical supply, except auto bulb and socket. Get these from an auto parts supply house.

The Leviton dimmer is not necessary, but it gives more control. I use a ceramic base for 40 watt bulb. A smaller transformer can be used, but I find the 3A-12V best. It is nice to add a handle to the box. I dropped mine once. Put ventilation holes in the box, and rubber bumper feet on the bottom.

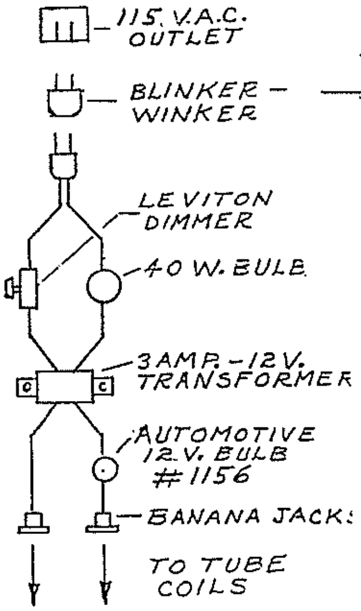
115 V.A.C. OUTLET
BLINKER – WINKER
LEVITON DIMMER
40 W. BULB
3 AMP. – 12 V. TRANSFORMER
AUTOMOTIVE 12 V. BULB #1156
BANANA JACKS
TO TUBE COILS

POOR MANS COIL SHOCKER

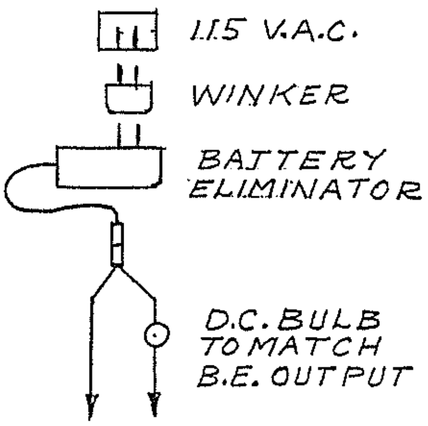
115 V.A.C.
WINKER
BATTERY ELIMINATOR
D.C. BULB TO MATCH B.E. OUTPUT

DWG. # 4

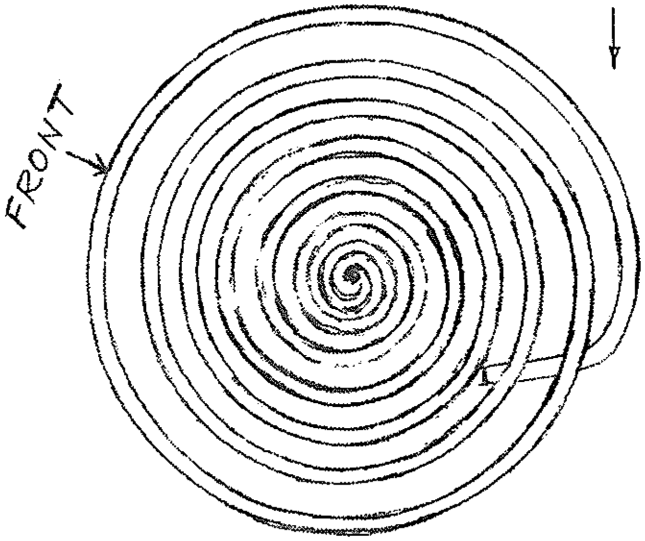

TRACING OF SMALL SPTRAL

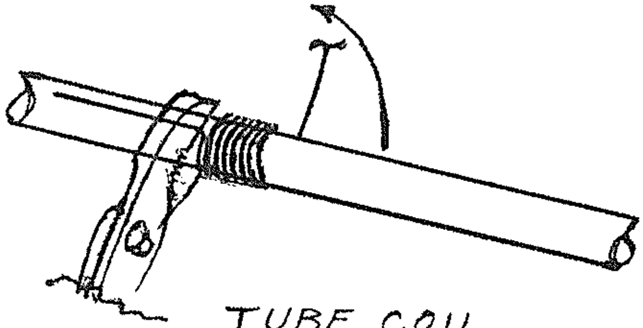

TUBE COIL
#19 COIL WIRE 2 REQ.

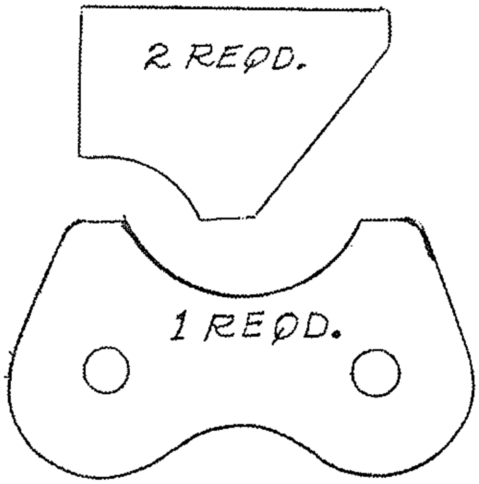
2 REQD.
1 REQD.

DWG. # 5

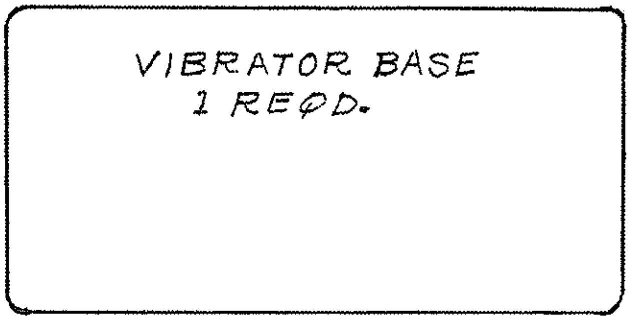
VIBRATOR BASE
1 REQD.

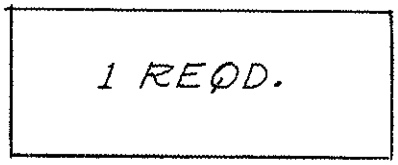

SPIRAL COIL M.W.O. UPDATE

Lou Schad

This is an update on the work I have done on the spiral coil MWO. I have built and tested several new coils and made changes in design of shapes and twist of the wire and different size of wires etc. I have experimented on plants and myself for the past several months.

In my article in the Journal of Borderland Research of March-April 1991, page 15, figure 1, I stated, to twist the wire counter clockwise, as I was told by someone of authority that this was best. I now find after experimenting and testing that this is not so. I now twist the wire clockwise, causing a left hand spin of the wire when viewed -- or counter clockwise. If the wire is twisted in this manner it more than doubles the energy and the plants and I both seem to like it better. If the wire is twisted as stated it will produce energy not only in a spiral shape but also in single loop rings (overlapped) and also in just a straight length of twisted wire.

I made a coil like a target or a series of one loop rings of twisted wire of different diameters and wire sizes, from about 1 inch to 8 inch and overlapped them about ¾ inch and wired them to a X shaped piece of thin plywood, and it produces more energy than I need. I can stay under it only about 7 to 10 minutes. If I stay under it longer than this, I get over exposure or too much energy in my body, and it makes my feet and hands tingle.

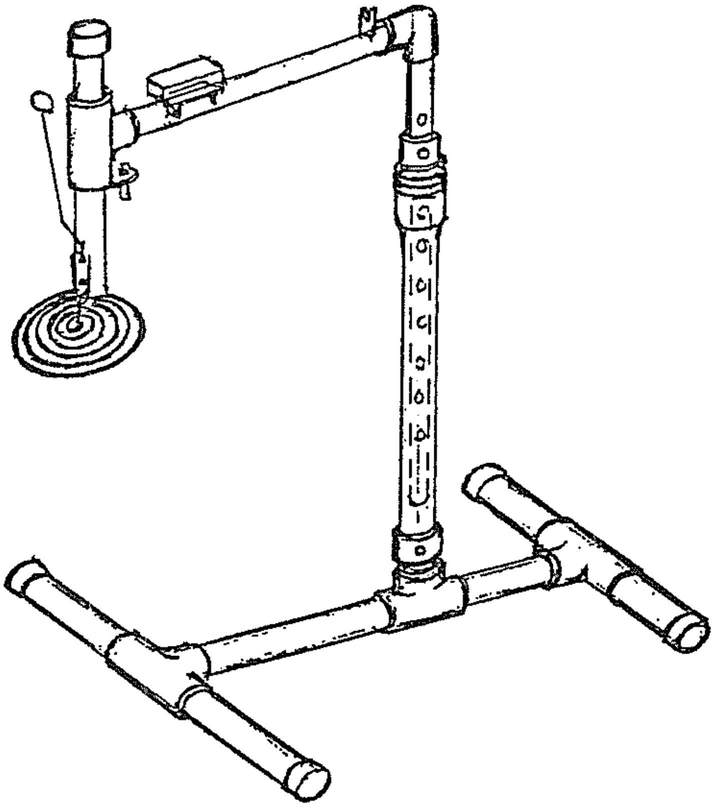

Spiral Coil Multiple Wave Oscillator

I made a spiral coil from 1/8 inch copper tubing, twisting it like a solid wire, and it produces more energy than a like spiral made from solid wire. I do not know if the energy travels on the inside of the tube and the outside also, but the energy produced is much more than is required for normal use.

I also have been experimenting with new and different ways to pump or project the energy. In my original design I used a vibrator to increase the output. I now find that with the new coils (twisted as stated) that they develop as much or more energy without the vibrator as the old coils did with the vibrator. It seems that the field or energy pattern given off by a straight (twisted) wire is different than those of a single loop (twisted wire) shape or spiral shape.

I am building a new coil that uses both and looks like a spider with 8 legs of different length. It has 2 single loops (overlapped). One loop is 2-3/8 in diameter and the other is 4-1/8 in diameter. The small loop is centered in the large loop and in the same plane. I made a wood jig with nails for pins to hold them in place and soldered twisted straight lengths of wire pointing from the center outward. I will bend the tips of the straight twisted wires down 90° producing a shape like a spider. I'll let you know if it is different from the spiral coil shape in energy output.

It now becomes obvious that a spiral is not the only configuration that will generate or collect and broadcast energy of unknown origin. If other shapes or designs will also produce energy, is their output different? If so, what are the differences? Are the wave lengths different, are there different patterns to the waves or energy? How does it affect the living organism?

When a spiral or coil is placed in front of a reticular energy field it produces unusual results. Coils can be combined with many other forms of energy, magnetics, light, audio, vibration etc.

In my article I said you can design and build coils of all shapes and types, as it is only limited by your imagination. It is my personal belief that someday someone will design and develop a coil of a nature that will be highly beneficial to humanity, we need your input, ideas and help.

If a coil of twisted wire was built in a target configuration of a series of overlapping loops so as to be similar in design to a Lakhovsky coil, and was powered by a Beck MWO output, what would be the results? If a twisted wire coil will produce and project energy, connecting it to the field of a Beck type unit should be interesting. Are there any takers?

ELECTROSTATIC M.W.O.

INTRODUCTION TO A NEW PHASE OF RESEARCH

by Peter A. Lindemann

Lakhovsky's multiple wave oscillator has always intrigued me. I tried to build my first one in 1976 based on Bob Beck's schematics. These early experiments failed miserably, but I remained interested. In 1987, I had the opportunity to see one of Bob Beck's MWOs at a meeting of the Los Angeles Psychotronics Association. I am a healer and a sensitive by nature, and I was looking forward to finally seeing the mythical machine in action. Bob had said that is was a very high power model and he was right about that.

The unit was of the design that has been popular since the 60s; a high voltage spark-gap transmitter driving an antenna of concentric rings. Bob turned it on and ran it for about three minutes. It made a loud zapping noise as hundred of sparks jumped from ring to ring on the antenna.

I was standing in the back of the room, about 30 feet from Bob's MWO. As soon as he turned it on I felt a blast of irritation hit my aura. I could handle the etheric frying of my energy field for only about thirty seconds before I had to leave the room. When I came back in, everyone's energy had been fried. The meeting quickly digressed into a break, with everyone talking to their neighbor. It was quite a sensation!

In thirty seconds I had become convinced of two things. First, this MWO was extremely damaging to the subtle energy field and therefore must be incapable of promoting systemic healing. And second, this MWO must be unrelated to what Georges Lakhovsky was reporting in his book Secret of Life.

Since I drew those conclusions back in 1987, I have been confronted with numerous testimonials of people gaining benefit from this style of MWO. While I do not doubt the accuracy of these stories, I must admit, I do not understand by what process the benefit is derived.

Here is where the MWO languished in my mind until Lou Schad's articles appeared in the March/April and May/June 1991 issues of this journal. Intuitively I felt Lou was on to something very important. On a visit to Borderland Headquarters, I had a chance to evaluate a unit Lou had given to Tom. The energy coming from the antenna was gentle but very penetrating. I was excited. I went home with the intention of building one of Lou's units to experiment with.

After considering Lou's design carefully, I decided to make a few changes and by late May 1991 I had my first unit. As it turned out, my unit did not look at all like Lou's, but it did embody the fundamental principles that he innovated. These included a spiral main antenna that was charged with static electricity and physically vibrated. Lou's antenna was complicated to build. I decided to use an antenna design that I had been developing uses for for three years, a spiral based on the phi ratio that I could have printed right onto a circuit board. That solved the problem of antenna fabrication. Another thing I changed was the method to induce the physical vibrations. Lou had used an aquarium pump. It worked well but was limited to only one rate of vibration. I decided that the rate of vibration might be important to look at so my unit was made with a variable rate of vibration from 2½ vibrations per second up to about 14 vibrations per second. The last change I made was the vertical antenna. Not knowing the height I needed for the optimum effect, I simply used a retractable replacement antenna from Radio Shack, the kind you usually see on portable radios. This gave me a way to vary the electrostatic charge on the spiral, by raising or lowering the antenna.

By early June 1991 I had made an arrangement with a local acupuncturist in town to run some clinical trials with the unit. This medical professional has asked to remain anonymous and so for the purposes of this article, I will refer to this person as "John". John is a gifted sensitive and an advanced bioenergetic diagnostician using equipment from Germany called the VegaTest. John also has had assistance in this evaluation by another gifted sensitive who can see auras in vivid color and detail. I will refer to this second person as "Pam". As of this writing in early November, their evaluation has been on-going for 4½ months or since mid-June. The results are preliminary. No cures are claimed. However, all indications point to systemic detoxification, energizing and rejuvenation, just what you would expect to see from a broadly stimulated natural healing process.

The VegaTest procedure is very sophisticated. It uses a bio-feedback mechanism to establish baselines for toxicity level, systemic stress and specific organ stress as well as the presence and location of specific pathogens and types of toxic substances. Toxicity level is measured on a scale of 0 to 21, where 21 is the most toxic. A "Biological Score" is developed from the toxicity values that come up and can have from 1 to 6 numbers ranging from 1 to 21, 6 numbers being the most toxic. An "Ideal Score" is determined on a scale from 1 to 15 where normal for adults on first testing range from 7 to 11. Stress on the immune system and endocrine system is measured on a scale from 0 to 5.

CASE A is a 21-year old female who has never been treated with other remedies. The patient was VegaTested, then received one 20 minute session with the MWO and then was retested. (See box insert) These scores suggest that even one session can temporarily reduce stress levels significantly and promote detoxification.

SCORES BEFORE SESSION	SCORES AFTER SESSION
Ideal Score: 8	Ideal Score: 6
Biological Score: 19-16-14-12-9 *5 scores with high numbers is considered very toxic.*	Biological Score: 12-10-8
Immune System Stress: 3	Immune System Stress: 1
Endocrine System Stress: 5	Endocrine System Stress: 0

CASE B is a 72-year old male with extreme intraocular pressure. The patient received only three sessions with the MWO. The pressure within the eyes lessened with each session. Pam reported that before the MWO sessions, the region of the eyes and head was completely dark and devoid of life force. After the first session, the darkness cleared about 40%. With the second session, the darkness cleared about 80% and with the third session, the energy around the eyes was completely vibrant.

Without going into a lot of specific case histories, or naming disease conditions treated, John and Pam are consistently seeing the following:

1. The MWO expands the energy field around the body 3 to 6 feet.
2. It functions to reduce accumulated stress on many levels.
3. It clears the energetic imprints of illnesses.
4. It fills in breaks and cracks in the aura.
5. It builds vitality at a very deep level and combats fatigue.
6. It promotes the drainage of stale and stagnant life energy down the arms and legs and out the hands and feet. Several times

Pam has seen dark yellow or dark green energy drain out of acupuncture points or organs, to be replaced by cleaner and clearer colors.

7. Everyone experienced improvement, regardless of their condition.

METHOD OF USE FOR THE MWO, (developed by John and Pam during this testing period) is as follows:

1. A person using the MWO should sit in a comfortable chair with their feet flat on the floor and their hands apart, laying on their thighs, palms up is best. The chair should be about 6 feet from the MWO. During the session they should periodically rotate their wrists and ankles to help promote the draining.
2. The MWO should be started at slow vibration rates (2-3) and slowly moved to higher vibration rates (5-9) and then at the end, moved to slower ones again. Sessions can be from 10 to 25 minutes.
3. After the MWO is turned off, the person should remain seated for 10-15 minutes to continue to drain while the energy field slowly shrinks back from its highly expanded state.
4. Rooms where the MWO is used may need to be cleared after its use due to the stale energies that drain out. Sun light, fresh air, toning, sage or other means may need to be employed to keep the MWO session room clear.

THE BSRF MWO PROJECT continues to develop, as this and other articles in this issue clearly show. A special thanks to Lou Schad for his brilliant and original departure from the errors of the past and showing us the true Borderland spirit in action.

One final note. We at Borderland are constantly railing against people who invoke the name of some famous researcher, like Rife, Tesla or Lakhovsky, and then sell the public a piece of equipment unrelated to the original work. This is no better than bait-and-switch hucksterism and we deplore it. Therefore, let us state for the record from the outset, that this new Electrostatic MWO is not what Georges Lakhovsky was doing. Neither is it a direct attempt to duplicate his work. Lakhovsky claimed to have had his units in use around the world, but after years of research we have found no physical evidence of this. He never published detailed schematics of any complete devices. This new MWO is a modern attempt to address the same problems that Lakhovsky was grappling with. We call it a multiple wave oscillator because it is, clearly, a device that produces a wide spectrum of oscillatory emissions simultaneously. Lakhovsky pioneered this line of research. This unit is not a "Lakhovsky MWO" but, strictly speaking, no other unit sold in the last 30 years has been either.

As this MWO is part of an ongoing research project, a limited number of these units will be produced and made available to the public.

The new BSRF Electrostatic MWO is for investigational purposes only. It is not a substitute for professional medical care and is not indicated as a specific cure for any disease condition. Any such use goes directly against the intent of the manufacturer. The performance characteristics of this device have not been established.

MULTIPLE WAVE OSCILLATOR

Borderland Sciences Research Foundation is proud to announce that their new Electrostatic Multiple Wave Oscillator is now available for investigational purposes.

TOTALLY NEW APPROACH

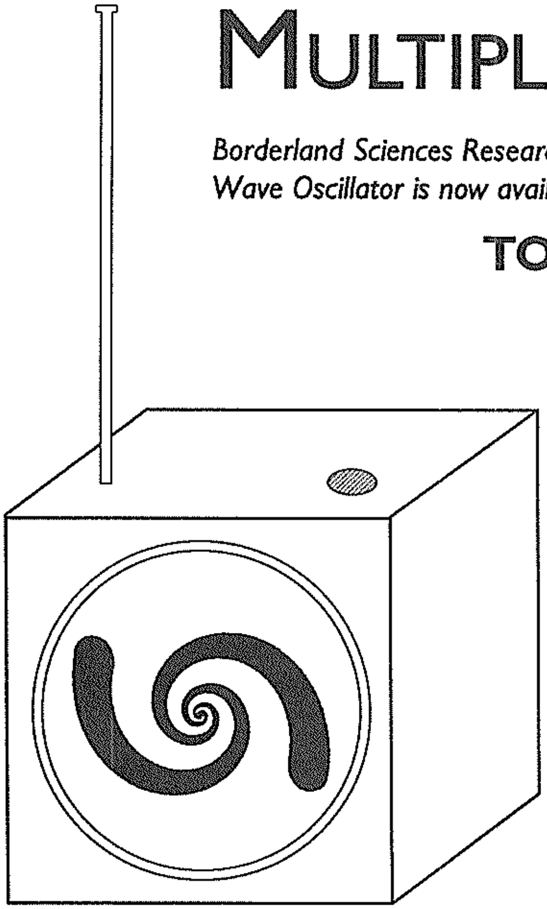

This unique Multiple Wave Oscillator uses a specially designed spiral coil that is both physically vibrated and simultaneously charged with a safe quantity of static potential, unlike designs using high voltage discharges between concentric rings. The result is a wide-spectrum wavefront of electromagnetic and etheric vibrations. It also provides a means to introduce a wide variety of other subtle influences into the broadcast much like a substance biocircuit. The Electrostatic MWO from Borderland Sciences is a versatile investigational tool.

The MWO has a wide range of vibratory rates and charge intensities. It is a one square foot cube with a Golden Mean Spiral MWO antenna on the front and a retractable antenna on the top for tuning. Powered with standard AC. Constructed using no toxic materials.

ELECTROSTATIC MWO

The Electrostatic MWO is a high quality device produced in limited quantity for our research network. Interested researchers may inquire with BSRF as to current availability of units.

SUN-ETHER DISC
By Albert Zock

The German inventor Oscar Korschelt based his cosmic ether accumulator, German Patent #69340, dated July 14, 1891, on the teaching of Wilhelm Weber not realizing that it incorporated the implosion principle as well. Weber professed that all particles of the ether, having an electrical charge, are circling around solid objects without touching them, the molecular particles being negative and the ether particles being positive, according to the law of attraction and repulsion. Since a solid body attracts ether particles, Korschelt searched for a way to collect, condense and to rectify them.

On a wooden disc with a hole in its center, Korschelt fastened spirals of copper wire, on both sides, one wound clockwise and the other, as a mirror image, counter clockwise, and connected the ends together through the hole in the center. His assumption was that the collected energy would be condensed in the center and then be beamed off at a right angle to the disc. He termed the side facing the light positive and the other negative. To increase the condensation and lengthen the antenna, Korschelt wound small coils like key rings and assembled them like links in a chain. He was convinced this device would give additional life energy if the beam was directed at the neck of a person in the height where the 18 cranial nerves are leaving the skull, (medulla oblongata). Such a spiral resembles a Nornen coil, which is stretched out and is used to eliminate undesirable emanations.

An application of a Korschelt coil seems to have its merits. In one case a relative of an elderly man suffering an acute pneumonia, being already unconscious and according to his physician, beyond hope, hung a Sun-Ether Disc over his bed. From this moment, his condition improved rapidly. Fourteen days later, he was almost normal again. In another case, a Sun-Ether Disc hangs over the door in the waiting room of a Naturopath. Every one walking in is amazed over its warmth, and the flowers are flourishing like in a green house, even though it is not heated and faces north. When asked for the reason, the owner points smilingly to the disc and gladly explains how it works and how to build one.

On a plywood disc with a diameter of 50 cm (20-3/4 in.) are two coils, one on each side, wound in a mirror image, the front one counter-clockwise and the other clockwise, almost on top of each other. Both are connected through the hole in the center which has a diameter of 10 mm (6/8 in.). The space between each winding is 15 mm (5/8 in.). Aluminum wire is best. To make the key rings, take a 4 mm (3/16 in.) thick wire, fasten it into an electric drill and wind the armature wire around it tightly, by allowing the rotating wire in the drill to do the spinning. Make sure to wind the links for the front counter-clockwise and for the back clockwise. Then separate every fourth winding and cut it to get the links shaped like key rings. Now attach the rings onto one another like a chain. Each link will lengthen the antenna and work like an oscillator. Fasten the chain onto the board, using nails or screws, but to be accurate, give the chain a light tension so it will not slip off. Twist the ends in the hole together, or better, solder them. The counter-clockwise winding for the front applies to people living in the northern hemisphere; in the southern hemisphere it might need to be reversed.

In Korschelt's time, some made "beam-handbags" carried on a shoulder strap. The material had to be framed to it could not move, then the spiral was embroidered and fasted to the inside of the bag, the whole bag measuring about 20 x 20 cm (8 x 8 in.) and the windings being 1 cm (3/8 in.) apart. Such bags were more powerful than the disc.

From Mar-Apr 1988 Journal of Borderland Research

ETHER RADIATING APPARATUS

An Apparatus For Therapeutic Use Without Direct Or Indirect Suggestion
Oscar Korschelt of Leipzig. German Patent #69340, July 14, 1891
Translated from the German by Bodo Capeller, 1986

This apparatus utilizes the living forces of the ethers for healing purposes. The electro dynamic theory of Wilhelm Weber concerning the structure of smallest parts results in the insight that all ether is identical with Webers electric particles, that all solids rotate around it at a certain distance because of attraction of positive to negative ether particles in relation to solids. Through a corresponding arrangement of solids it ought to be possible to condense the diffuse ether and redirect it. A similar arrangement has been utilized in the following described apparatus which has been named by the inventor "Ether Radiating Apparatus".

This apparatus can be used for the purpose of increasing the intensity of the power of living ether. The difference between several versions of this apparatus is that of shape of materials used. In order to get increased power electric current may be used. Since the same appears to consist of positive and negative particles that try to find equilibrium, the amount of liberated ether particles within the wiring of the apparatus and the diameter of the wire formed ether vortex will increase with the spun off ether particles.

In drawings 1 through 5 an ether radiating device is shown. Within the apparatus the arrangement of the metal wiring is formed in a spiral that will cause ether particles to spin in a predetermined direction so that the living force can be utilized in many ways.

The version in drawing #3 shows the wire is formed in spiral configuration on both sides of plate E and is connected in the center. Through this arrangement the ether particles will accumulate in the center of the disk and be thrown forward. In order to achieve a longer path for the ether vortex one may utilize a chain instead of a simple wire which consists of horizontal displaced links (drawing #5). The disk is intended to cause physiological changes in humans (see drawing #1).

Patent request: An apparatus for therapeutic purposes with direct or indirect suggestion consisting of a non conductive disk (E), free standing or installed in a tube, where both sides of the disk contain spiral wound wire with the side toward the light exposed as the collector and the opposite the radiating portion.

Fig. 1

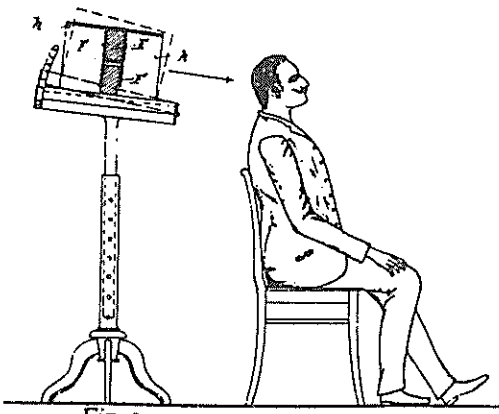

Fig. 2.

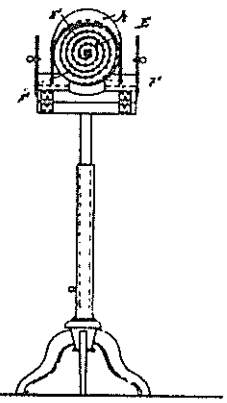

Fig. 3.

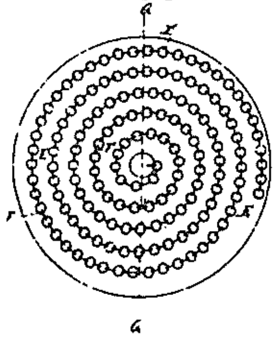

Fig. 4.

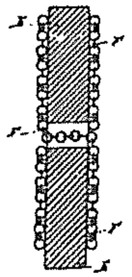

Fig. 5.

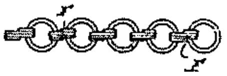

Fig. 6.

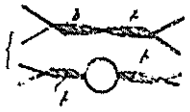

March-April 1988 JBR, VIEW FROM THE BORDERLANDS

by Tom Brown

NATURAL ELECTRICITY

Ernst Lehrs, writing in **MAN OR MATTER** about early views by Volta and Galvani on electric fish, provides insight into the nature of animal electricity. "The electric organ of such a fish consists of many thousands of little piles, each made up of a very great number of plates of two different kinds, arranged in alternating layers. The two kinds differ in substance: in one case the plate is made from a material similar to that present in the nervous system of animals: in the other the resemblance is to a substance present in the muscular system, though only when the muscles are in a state of decay. In this way the two opposing systems of the animal body seem to be brought here into direct contact, repeated many thousands of times.

"In the electric fishes, accordingly, sensation and will are brought into a peculiar interrelation. For as a result of the spatial fixation and the state of deterioration of its bodily foundation the animal's will-pole is related to its bodily foundation in a manner which otherwise obtains only between the nervous system and the psychological processes co-ordinated with it. These fishes have the capacity to send out force-currents which produce in other animals and in man 'concussion of the limbs', or in extreme cases paralysis and even death. When contemplated with pure observation this phenomenon tells us that in cases of minor strength, this force causes processes of a volitional character in bodies affected by it. Through stronger effects the organic system which serves the will of the creature involved passes into disuse, either for a time or for good. By describing the process in this way we realize that electricity appears here as metamorphosed animal will, which takes this peculiar form because part of the animals' volitional system is assimilated to its sensory system in an exceptional manner.

"It is known today that what nature reveals so strikingly in the case of the electric fish is nothing but the manifestation of a principle at work in the bodies of all beings endowed with sensation and volition -- in corporeal terms, with the duality of a nervous and a muscular system -- and therefore at work also in the human body. Observation has shown that the activities of these two systems in man and animal are accompanied by the occurrence of different electric potential in different parts of the body. Manifold in detail though the relevant observations are, they all confirm a definite correlation of negative electricity with the nerve-and-sense pole (sensation) and of positive electricity with the blood-and-muscle pole (volition)." From **MAN OR MATTER**, © 1958 Ernst Lehrs, Rudolf Steiner Press, London.

Thus we see that natural electricity is formed by processes which can be mirrored in non-living matter. But if we can have access to the primary form of the energy why pursue the secondary, and seek out that "magic frequency" that will cure AIDS, cancer, and assorted body clogs that go under fancy medical names? The answer is that everyone has their individual path to travel. Spiritual healing sometimes takes a long time, while an electronic device may get the person back on the track of their day-to-day life. The spiritual lesson of the sickness is buried for the future. Electricity is the subsensible force, but it is a real force with the ability to alter the functioning of the human body.

November-December 1989 JBR, VIEW FROM THE BORDERLANDS

by Tom Brown

MWO NOTES

The work of Georges Lakhovsky continues to be of strong interest. I have been investigating the Lakhovsky MWO for about four years now and my views have consistently changed with new information. BSRF's MWO Handbook is getting quite popular! However, my views have changed somewhat since doing that book, and eventually a new edition will have to be put out to keep up with the new data.

What was Lakhovsky really up to? Well, his basic experiments were with copper wires which were circled around plants. Lakhovsky felt that these rings were activated by cosmic radiation. Lakhovsky was extremely interested in subtle energies, such as those that guided birds on their migrations. The copper rings, when placed around plants, would heal cancers in the plants. THE SECRET OF LIFE, Lakhovsky's best known book in English shows pictures of these experiments. Lakhovsky then moved to bring these healing energies to humans.

Lakhovsky also intuited the DNA spiral coil in the center of every cell long before anyone "discovered" it. He felt that a properly generated multiple wave electrical field would make the coil in each cell resonate at its proper frequency, just as a tuning fork resonates when its frequency is struck on a nearby similar fork.

Today's conceptions of a Multiple Wave Oscillator (MWO) are quite different from what Lakhovsky was really doing. Lakhovsky tried to reproduce the healing energies of the cosmos by electrically energizing coils to produce energy fields which apparently regenerated aberrant cells along the lines of his theories. Lakhovsky first did this by producing an antenna, comprised of concentric copper tubes, the outer one being energized with two wires from his power source. Our impression of his antennas is that they were log periodic, that is logarithmic in nature (Lakhovsky doesn't come right out and say this, but his patents are definitely worded to cover such an arrangement). New data coming in (but not yet verified) tells us that these copper tubes were filled with one or more of the noble gasses (also called rare, or inert gasses).

As anyone could guess, these antennas would be somewhat hard to manufacture. Lakhovsky then miniaturized the antenna and inserted it in a gas bulb. His US patent #2,351,055 says vacuum bulb, but also covers low pressure gasses. There are two main keys here. One is the log periodic antenna. All higher forms of life are based on logarithmic patterns, from ferns to humans. Lakhovsky was creating a structure in the ether which would bring cells into proper functioning. The other is the vacuum / low pressure gas effect. For those who wish to understand the potent effect of the vacuum on life then the reading of The Nature Of Substance by Rudolf Hauschka is required. According to Walter Russell the noble gasses are the octave markers in the harmonic spiral of the elements, which also exists in a logarithmic pattern.

I recently visited with Dr. Norman McVea of Stinson Beach, California. Norman has several high frequency gas tubes built trying to understand what Lakhovsky and Royal R. Rife were up to. Norman has a MWO built of 12 glass concentric rings with various noble gasses inserted in them. When we checked it out it was running at 60 cycles, pulsed at 7.8 cycles. My recommendation to Norman was to run the unit with a radio-frequency oscillator which can be tuned from 1 to 30 megacycles, and modulated with a variety of sources for research. Norman has produced the most unique MWO I've seen in our modern times, and he is certainly on the right track. He is also working to reproduce Rife's high-frequency gas bulbs.

The key to Royal R. Rife's frequency instrument is also the use of the noble gasses energized at high frequency (possibly 4.5 megacycles), which were then modulated with specific musical tones. Lakhovsky's units were energized similarly, but used the frequency-independent log periodic antennas, giving a broad band of treatment, rather than the specifics of Rife's units. In many ways these two pioneers were working with the same keys.

WHO DUNNIT?

Rife and Lakhovsky have another similarity, that is, that people today are building equipment obliquely related to their work and offering them as original, or "improvements." This needs serious examination. The last two years has brought on an underground cult of so called "Rife Frequency Generators." There are hordes of these so-called "Rife" units being sold which are merely fancy variations of TENS (Transcutaneous Electrical Nerve Stimulation) devices. The conception for these units, usually producing square audio waves, comes from John Crane who knew and worked with Rife in his later years. John has affidavits from people who swear that they were healed from cancers and such by his square wave units in the early 1960's. It is extremely important to note that Rife's work in the 1930's through the 1950's was with high frequency gas tubes and all his documentation covers those units. History is rapidly becoming blurred in the race to cash in on people's poor health.

Modern purveyors of the so-called "Rife" equipment are making several errors: The first is that they claim that Rife developed the use of the square wave generators with electrodes. That is incorrect, it was John Crane (which makes Crane a pioneer of TENS research!). The second is that they claim that Crane's equipment was junk and would never work. Maybe the equipment wasn't of the highest quality (we have an original unit in our collection!) but Crane does have a lot of signed affidavits, several of them in our files, claiming that the units worked on specific diseases. In general, people are being misled in order to sell them equipment they probably don't need. That is a bad reflection on the field of electrotherapeutic research.

Perhaps these modern "Rife" (TENS) units have some merit in killing certain types of pathogens. I've spoken with many people who were completely dissatisfied with their so-called "Rife" units, and I've spoken with two people who have claimed that they have killed infections such as foot rot and herpes. Maybe they do, but for all of the thousands of devices being put out where is the documentation? Where is the proof? I have seen Crane's affidavits of the early 1960's, but have seen no medical studies from anyone, not even basic notes!!! There is obviously a very important bit of work to do in researching the effects of pulsed DC on the human body. TENS units kill pain, that has been clinically documented. The claims of the so-called "Rife" units are just that -- claims, *and unsubstantiated to boot.* Until any substantial research work is done in this area I would recommend that people do not follow the mob hysteria which shrewd hucksters have instigated over Royal R. Rife's work.

Lakhovsky's story is similar. All the units being built today are based on Bob Beck's early 1960's interpretation of Lakhovsky's first patent (#1,962,565). After four years of looking at these devices and reading Lakhovsky's patents and books I've come to the conclusion that Bob was misled by the patent. From an electrical engineer's viewpoint Bob's units make sense. From the standpoint of understanding subtle energies within and surrounding the body the units are merely RF noise generators which have questionable effects on the body, and most likely interfere with natural energetic processes (chi flow, etc.). The Beck MWO is a variation of one of Tesla's electrotherapeutic devices, the variation being that Tesla went to great pains to make the antennas spark-proof, and Beck's antennas spark away. Lakhovsky's units didn't spark either!

What makes this more interesting is an article which appeared some months ago in the **Health Freedom News**, titled Who Dunnit? by Mike Brown. Mike gives a weak case for his view that Lakhovsky was inept, that his earlier units didn't work, and who needed Tesla to fix them up and make them work. Perhaps Mike didn't notice that Lakhovsky's SECRET OF LIFE, which he sells to promote his units (in the ad following the article), is based on the units he claims in the article didn't work! Mike refers readers to Tesla's article High Frequency Oscillators For Electro-Therapeutic And Other Purposes (**Lectures, Patents, Articles** by Nikola Tesla, Beograd, 1956), but fails to notice that Tesla's article contradicts what he is doing with his units. I wonder how that article got past the editors?

CORRECT DIRECTIONS

Lakhovsky was a brilliant scientist, highly regarded on the European continent. His name comes up in many books, most recently I found him referenced in Lilly Kolisko's **AGRICULTURE OF TOMORROW.** If he and Tesla met, I'm sure it was for more than to fix poorly engineered units. There are three types of units that I feel should be built for research into this area: One is Tesla's oscillator circuit. The higher quality Beck MWO units, such as those built by Klark Kent, can be converted fairly easily. Use the unit's power supply as is, but for antennas use insulated copper plates (or spheres, as Tesla preferred for maximum effect) coated with heavy dielectric material such as beeswax. Eliminate the sparking! A necessary design change for future units will be to change the ¼ wave coil to ½ wave.

The second is a reproduction of Lakhovsky's Tube MWO. It will take miniaturizing the Golden Ratio antennas that Eric Dollard designed for the MWO and inserting them into low-pressure rare gas bulbs, which will then be driven at high frequencies. It is my estimation that this is the best way to pursue Lakhovsky's high frequency researches. The mathematics for the antenna, along with further reference materials on log periodic antennas, are in The Lakhovsky MWO Handbook.

The third is a reproduction of Rife's original type of equipment being a rare gas bulb driven at high frequencies, modulated with musical tones. This will take RF broadcast equipment and a rare gas tube. No electrodes!

It is time that researchers in this area begin to go in the correct direction. Bob Beck made a noble effort in the early 1960's with his conception of the MWO, and gave people something to work with for 25 years. That phase is definitely over and a new one beginning.

The "Rife generator" craze should be stopped now before it takes people another 25 years to find they've been misled. Serious research into the effects of pulsed DC should be undertaken by those with the wherewithal.

And keep it uppermost in your mind that electricity is a sub-sensible force. In the borderland sciences one should look to the supersensible, such as Dr. Wilhelm Reich's orgone energy (which, by the way, reacts to electricity in such a way that makes it detrimental to the human body), and the human vital energy such as is utilized in Biocircuit research (as begun by L.E. Eeman).

January-February 1990 JBR,

VIEW FROM THE BORDERLANDS

by Tom Brown

THE WONDROUS ELECTRICAL FORCES

Electrical research is a primary area of borderland research. While the term "occult" puts many people off, it should be realized that electricity is an occult force whose effects we only see when equipment is properly engineered. Four to five hundred years ago one would probably be burned at the stake if it would have been possible for them to demonstrate electrical devices.

Electricity is considered by some to be a degraded form of the Light Ether, that the etheric force gets bound up in matter in a way that it can be used. But being bound up in matter it provides mankind with the option of using it properly or improperly. Many articles on the detrimental effects of electric fields have been published, and more studies are no doubt underway on this important topic. There are also some records of electro-therapeutic devices that used this force for healing. Tesla envisioned a worldwide electrical power system and did the basic testing to show himself that it was viable, and needed but to be built. Tesla was a man of great intellect and was a reader of Goethe and other great minds. One would feel that he was in some way familiar with Goethe's *Farbenlehre* (color theory). The type of electricity being sent around our globe on wires is of a different, lower form that that of Tesla's transmission of electricity without wires. It is quite possible that Tesla's electricity was of a beneficial nature. Tesla did research into electrotherapeutics and was no doubt aware of both beneficial and detrimental effects. With the power system he envisioned on line we may not have ended up with the electrical problem we are just beginning to see the "tip of the iceberg" of.

This point needs clarification and elaboration beyond what most people now imagine. We periodically mention certain aspects of Dr. Lilly Kolisko's experiments with the crystallization of metallic salts rising *contra* gravity. These experiments were done to establish whether or not the planets had any direct connection to the metals as alchemical lore supposed.

The connections she investigated are Gold-Sun, Silver-Moon, Mercury-Mercury, Copper-Venus, Iron-Mars, Tin-Jupiter, Lead-Saturn. For example Dr. Kolisko would take a gold chloride solution (1%) and allow a portion of it in a laboratory dish to *climb* a segment of blotter paper. As it dried the fine details of crystalline form could be seen. After many experiments the characteristic form of each metal's salt could be comprehended. It was scientifically established that the actions of cosmic bodies would have direct effects upon the crystallizing actions in the lab. Gold chloride would not crystallize properly during several solar eclipses that Dr. Kolisko reported on (1927, 1947). A darkening effect was noticed on these slides.

Just recently I came across this in the recollections of Dr. Rudolf Hauschka, founder of Wala Pharmaceuticals: "In the course of researches into the delicate changes in matter which are revealed in the capillary-dynamic method, an alarming symptom came to the fore. At one of the Easter conferences of the Anthroposophical Doctors' Working Group in Comburg in 1964, Frau Kolisko, the past-master of the capillary-dynamic method, spoke on 'Gold and the Signs of the Times.' In earlier years she had demonstrated by means of the *Steigbild* (literally rising pictures, also known as chromatograms) the connections between the metals and the planets, and in particular the effect on gold of an eclipse of the sun. During an eclipse of the sun the gold *Steigbild* which normally glows with beautiful colors, shows a darkening and the emergence of grey formations. Frau Kolisko now showed a series of gold *Steigbild* produced in the last years almost hourly and at all times of the day and of the year. Without exception all of them showed the same sinister dark formations which had appeared earlier, in the first half of the century, only at the time of a sun eclipse. She closed her lecture with a question to the doctors, namely whether, considering the change now in gold, they could still be answerable for its use as a medicine. There was no doubt about it: since the middle of the century gold had become different -- it was sick. Or, to express it differently, the connection between the spheres of the sun which stream down and the metal which they permeate is disturbed."

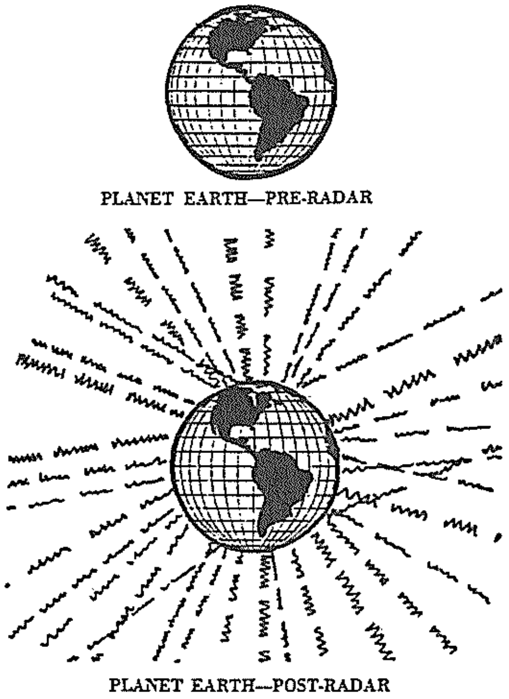

Entire planetary environment permeated with pulsed electromagnetic radiation—an unprecedented condition.

ELECTRICITY: THE MAIN CULPRIT

The main culprit in this sickness of earthly matter is none other than the electrical environment that has manifested on this planet. Certainly there were radio communications going during Dr. Kolisko's early experiments, but as this chart from Trevor Constable's *COSMIC PULSE OF LIFE* shows, the post WWII environment was heavy with these signals, culminating in today's total saturation point. Imagine what the *Steigbild* would have shown in previous centuries before the electrical force began its manifestation.

Nuclear proliferation must also be considered as adding to this phenomenon, but electricity is the degraded form of the light ether, whose source the sun is related to gold. Walter Russell, in ATOMIC SUICIDE, indicates that the spread of nuclear energy will destroy the atmosphere surrounding this planet and now scientists are scratching their heads as the hole in the planetary ozone layer gets larger. (Of course chlorofluorocarbons and New Zealand sheep farts have all been blamed for the ozone depletion, but nuclear energy is a primary cause.) This atmospheric destruction could well aid in cutting off gold from its cosmic wellspring of life.

Rudolf Steiner had many insights into the true nature of electricity, its relationship to humanity and its role in our future. Pertinent to the matter at hand let us consider the following remarks, a portion of his answer to a question about electrical treatment of animal fodder:

"You must consider the whole part played by electricity in Nature ... to the effect that human beings cannot go on developing in the same way in an atmosphere permeated on all sides by electric currents and radiations. It has an influence on the whole development of man. This is quite true; man's inner life will become different if these things are carried as far as is now intended. It makes a difference whether you simply supply a certain district with steam-engines or electrify the railway lines. Steam works more consciously, whereas electricity has an appallingly unconscious influence; people simply do not know where certain things are coming from. Without a doubt there is a trend of evolution in the following direction. Consider how electricity is now being used above the earth as radiant and as conducted electricity, to carry the news as quickly as possible from one place to another. This life of men in the midst of electricity, notably radiant electricity, will presently affect them in such a way that they will no longer be able to understand the news which they receive so rapidly. The effect is to damp down their intelligence. Such effects are already to be seen today. Even today you can notice how people understand the things that come to them with far greater difficulty than they did a few decades ago.

"It is a remarkable fact that whenever something new appears, as a rule in the early stages it is heralded as a remedy--a means of healing. Then the prophets get hold of it. It is strange, where a new thing appears, clairvoyant perception is often reduced to a very human level! Here is a man who makes all sorts of prophecies about the healing powers of electricity, where no such thing would previously have occurred to him. Things become fashionable! No one was able to imagine healing people by electricity so long as electricity was not there. Now--not because it is there, but because it has become the fashion--now it is suddenly proclaimed as a means of healing. Electricity--applied as radiant electricity--is often no more a means of healing than it would be to take tiny little needles and prick the patient all over with them. It is not the electricity--it is the shock that has the healing effect.

"Now you must not forget that electricity always works on the higher organization, the head-organization both of man and animal; and correspondingly, on the root-organization in the plant. It works very strongly there. If... you pour electricity through the foodstuffs--you create foodstuffs which will gradually cause the animal that feeds on them to grow sclerotic. It is a slow process; it will not be observed at once. Electricity will not at first be recognized as the cause; it will be ascribed to all manner of other things.

"Electricity, once and for all, is not intended to work into the realm of the living--it is not meant to help living things especially; it cannot do so. You must know that electricity is at a lower level than that of living things." (from **Agriculture** by Rudolf Steiner)

How pertinent and timely these words are today on many levels of borderland research. Electrical/electronic medicine has the glamorous position on stage at most of the conferences, and in many people's minds, in today's 'borderland' field. People are racing to buy instruments which are designed by electronic engineers with little or no training in the comprehensive constitution of humans. *It is the fashion!* There is no consideration that true healing comes from the spiritual realms, that the spirit is always healthy, and that dis-ease comes from a condition where the various subtle levels of the body are not aligned properly with the physical.

These electrical instruments have the potential to produce apparent results in treating disease symptoms. But what of the long term effects of the subsensible electric current? Considering the alarming state of affairs viewed through the information just presented I pose the question to the reader, "Do you prefer the natural or the unnatural forms of treatment?" Many people flock to electronic medicine because they feel that the petro-chemical drugs that are prescribed by the medical establishment are detrimental to their long term health. Very possibly so, but will electricity be any better? What about your own vital energy and its relation to cosmic life forces?

Electrical stimulation of the body treats a symptom and fails to allow for the body's natural healing process. As electricity is an externalized part of humanity's inner volitional force we can see that there will be definite effects from the subsensible current. But the effects will be relative and the inner healing process put on secondary mode. Electro-therapy, while emerging as a viable medicine of the future, still ignores the natural healing process.

This does not mean that we should not research electro-therapy. In what may seem a contradiction to many readers, I am 100% for further research into this area. It will no doubt be of benefit to many. Our relationship with electricity is one of the greatest questions of our time. People unconsciously use this force, and the results are such as those noted by Lilly Kolisko. Electricity is intimately connected to the Life Force, but great care must be taken not to confuse the two. Electro-therapeutic research helps define the boundaries, and thus is of interest to Borderland Researchers, but it certainly does not mean I recommend it!

Mar-Apr 1990 JBR, BSRF Bulletin Board

MWO QUESTIONS

Your comments re the MWO in the Nov-Dec 89 JBR are of much interest and raise the following questions in my mind:
1. Will you be publishing any information by Dr. Norman McVea?
2. How can the Kent units now in circulation be converted to produce a 1/2 wave? Perhaps Klark would be willing to publish an article on this or be willing to do the converting for a price.
3. Has any member ever tried to obtain any information on the circumstances of Lakhovsky's death? About three years ago a reference librarian made a serious effort for me to obtain any information re Lakhovsky, with absolutely no success. Perhaps there was an obit in the NY Times at the time he died, assuming that is where he was at the time.
4. Where in the world would we obtain copper spheres like Tesla used? Perhaps a member can suggest a source.
P.V.P.
California

In answer to your questions:
1. Norman McVea has sent us in a bit of material on his latest oxygen researches. He has opted for the oxygenation approach instead of the electrical.
2. I don't know about conversion of Kent's units to 1/2 wave, you should check with him on that. It will probably be easier to use it as it is -- they are good power supplies for experimentation -- and in the future engineer units with more refined outputs. After reading my column Klark added a rare gas tube assembly to his "Rife" units. He has always listened to other people and has constantly worked to improve his units.
3. If any readers have info on Lakhovsky's death, or his life for that matter, these pages are open to pursue the matter.
4. Anybody know where to get copper spheres? Tesla also used copper plates coated with a heavy dielectric.

September-October 1990 JBR BSRF Bulletin Board

MWO EXPERIMENTS

I have been very fascinated with your Journal. Thank you for the new world you have opened up to me. For the last few months I have begun to work on an MWO.

I have completed the antennas but did not do as well with the Tesla-coil. I decided to buy the ready made coil from

"Edmonds". I connected the secondary to the center of my antennas and did get some action in the form of a purple glow around the third and fourth smaller rings. I can only assume that I need more power to this unit although I was "Quite" pleased at the limited reaction on my first attempt. I would like to reach out to a fellow member who might be able to help me with some advice at this point.

Any advice you would send my way would be greatly appreciated.
P.D.
New York

Naturally, the quality of output of any electrical device is dependent on not only the quality of materials, but also the geometry of structure and arrangement. The better the coil, the better the antenna, the more refined the fields will be that are put out around the device. As I have pointed out in the article mentioned above in my remarks about the "Rife" devices, the types of "Lakhovsky" MWO's being built today vary quite a bit from what Lakhovsky was actually building and using himself.

Lakhovsky used very refined electrical designs and probably log-periodic antennas with both poles of a Tesla coil feeding the outside ring in such a manner that there was a logarithmic, electro-magnetic structure oscillating in space which apparently had quite beneficial effects on living organisms.

The modern variations, based on Bob Beck's schematic of 1963, feed one pole into an antenna (and the other into a second antenna), creating a dielectric field, which when it collapses, due to the rings on the antennas, creates unnecessary sparking and random radio-frequency noise with questionable effects. It is an organic system alterant, but is quite different electrically from Lakhovsksy's original equipment.

Nov-Dec 1990 JBR.

BSRF Bulletin Board

THAT MWO AGAIN

I recently purchased your MWO HANDBOOK. In the book are many references to the "Golden Ratio". I was unable to determine what the mathematical basis for the Golden Ratio is. I have other material which describe the Golden Section, and it is a ratio of .618 to 1. The closest I came to a value for the Golden Ratio is from the MWO antenna data on page 188 of your book the ratio appears to be 1.27:1. Could you please clarify the mathematics of the Golden Ratio antenna?
B.C.S., California

*** I recently purchased THE LAKHOVSKY MWO HANDBOOK. I am in the process of building an oscillator. I have all the parts except 6Kv .005mf capacitors. No electronic store in Alaska has them, or knows how to get them. I would appreciate it if you would send the address of either the manufacturer or an electronic store that carries 6Kv .005μf capacitors. I have one more question. Do you know of a meter or electronic apparatus that measures the amount of energy level the human body produces? It seems that like fingerprints, all human bodies are different in the amount of energy they use or produce. If one can coordinate the energy level of the oscillator to that of the body far less damage would be done and far greater healing potential be made.**
S.N.
Alaska

For the first question, the Golden Ratio antenna uses the golden ratio as a base, but it was engineered to conform to other considerations of antenna propagation. It is what is called a log periodic antenna. These antennas are based on the square root of phi, that is the inner ring is multiplied by the square root of phi to get the next ring, or inversely the outer ring is multiplied by one over the square root of phi to get the next inner, etc. This provides the Golden Ratio mathematics (every other ring is phi related).

MWO NEWS FROM FRANCE

I'd like to mention with regard to "Electricity the Main Culprit" that just after the war, Gurdjieff wrote a chapter in his book ALL AND EVERYTHING entitled "Beelzebub says that man's capture and subsequent destruction of electricity from nature is one of the main causes of the reduction in the human lifespan." And you are lucky in the US. In Europe we have a 230V system that is far more harmful than yours.

A final comment on the MWO which seems as popular as ever. When I lived in Paris I made the acquaintance of Lakhovsky's son and saw two of the MWO's built by his father in operation. The demonstration was very impressive but it didn't last too long because the old units interfered seriously with radio and television reception in the area. They were very big units, about as large as an early TV set. I don't know where they are now since he later loaned them to friends living in the country.
R.C.
France

Very curious quote from Gurdjieff as it concurs with what Steiner indicated, that electricity makes living things sclerotic. If perhaps you wouldn't mind searching your memory a bit more I have a question about Lakhovsky's device: You say it interfered with radio and television reception. Was this from internal spark gaps, or did any unit you see arc between antenna coils. The pictures in THE SECRET OF LIFE indicate that the then necessary spark gaps were interior to the unit, and the pictures of the effluvia coming off the antenna are obviously pictures of corona discharge and not arcing as in the units built in the US today. Bob Beck, in his 1963 article on MWO's claims he built a unit from an original, but his antenna hook-up is quite different from Lakhovsky's pictures. Many years of searching have failed to produce an original unit. The modern units are derived from the most obvious derivation of Lakhovsky's first MWO patent, which is written to both protect his design and cover infinite variations thereof. A detailed account of an original MWO in action would be of great value in this research.

SOUTH OF THE BORDERLAND

I have read Mark Clement's THE WAVES THAT HEAL and discovered a little piece of information not included in the current edition to THE LAKHOVSKY M.W.O. HANDBOOK. In WAVES I noted a short sentence indicating that one set of rings transmits energy through space which falls upon the patient's body and (it must be ascertained through experiment whether this is as I tell here or otherwise) later absorbed by the receiving resonator which resonates it for rebroadcasting into the patient's body. Thus the true Lakhovsky MWO, and UNLIKE the Beck-reconstructed model, would be a more-complex device involving features so-far unthought of. It must be ascertained what KIND of "receiving resonator" Lakhovsky employed, if it had or not special constituents not described at any of his patents included in the MWO HANDBOOK and what other features could be complementary to both.

Another feature to be considered, and which I discovered in the photo on page 30 of Clement's book is that there are two protruding spheres connected to the outermost ring of the Lakhovsky setup. In the copy of the BSRF publication I have, these two photographs are reduced and with not the same kind of resolution of the work by Clement. Each protruding sphere is connected to a cable and following the path of least resistance

the electrostatic current flows both along the metallic path of the outermost ring and the excesses accumulated from attracting ether from the environment are projected towards the patient (in the case of the transmitter) and collected for resonating (in the instance of the receiving resonator). Also notice that there are two "bracing wires" to both keep the rings in place and at the same time to fulfill the 90° division determined for Earth by the metric theorems which are the foundation of the Energy Grid! This adds another feature of complexity to the duplication of the MWO, which carries the Lakhovsky invention, again, farther from the Beck-built model.

Please mention my paper SOME FREE-ENERGY DEVICES for the MWO analysis I made is at best very incomplete, not including the feature of non-uniformity the true MWO does possess.

Jorge Resines
Buenos Aires, Argentina

Thanks for your further insights into the MWO. I feel that a continuing dialogue will eventually produce more evidence as to what type of equipment Lakhovsky used in his successful researches into cell regeneration and how to best reproduce it. The resonator antenna setup on Lakhovsky's original is more complex than the Beck MWO, as, like the primary antenna, it also has two feeder wires. The two spheres you mention, from which brush discharges can be seen, have always struck me as the nuts that held the heavy antenna onto its stand. Some mechanical contrivance was necessary and the mini-spheres fit the bill with the possibility that they may have been further configured to produce a specific capacitance, as our evidence indicates that Lakhovsky's antennas were very precisely built, probably log periodic. We have heard that Lakhovsky was a radiethesiest and would dowse the sites where he set his equipment up. He was certainly into the subtle energies, and the French school was very precise in its radiesthetic work, being the source material for much of Christopher Hills Supersensonics work. We have an unconfirmed report that the original tube antennas were filled with a rare gas such as argon. This would seem to be the case as in Lakhovsky's second MWO patent he reduced the antennas and puts them into vacuum or low pressure gas bulbs (as the first, this patent is written to be very specifically vague). This was meant to be an improvement over the original units, and probably was. What it tells us is that the "Beck" units appear to be far from what Lakhovsky was doing and where he was going, though because of more than 25 years of people building and using Beck models it is hard find information on the original. The "bracing wires" are supposedly silk. Their angle was probably determined solely by mechanical function.

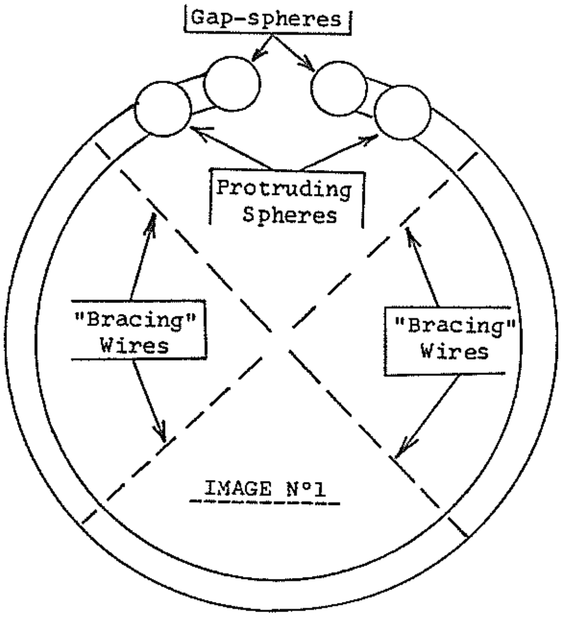

Detail of outer ring on Lakhovsky's original MWO antenna. Front view above, side view below

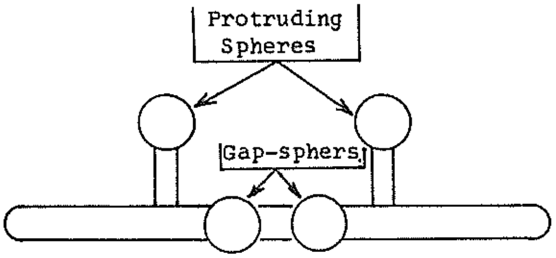

We have actually come under attack for our attempts to clarify the MWO story! In a brochure put out by MWO salesman Mike Brown, Box 25, Pleasant Hope, MO 65725, we come in for the following treatment: "Then there are the characters who, with no formal training whatsoever, denigrate tings [sic] they know less than nothing about. One outfit calling itself Borderland Research sent out a bulletin claiming that no-one today is manufacturing a Lakhovsky Multiple Wave Oscillator. These characters arrived at their conclusion by comparing photos of a 1935 unit to ones being made today. The units don't have the same external appearance. Quite often people with no formal training in electronics or electricity don't understand that an electronic device and how it operates are determined by the circuitry contained within the unit, not by the box it comes in." My comments are that there are perhaps *tings* we don't know but we do know that what is inside counts as much as the outside on the MWO. I have put five years of serious investigation into the MWO and would have to say that what we published is the result of serious consideration by a number of intelligent people--some highly trained electrical and mechanical engineers--interacting and exchanging ideas. We have published the evidence to support our contention, and have in fact stated that if we can be shown to be wrong then we would like to know, that we have no final conclusions, just some of the facts. A crude attempt to belittle BSRF's research by ignoring the main facts does not change the facts and the facts are that the units pictured in Lakhovsky's book **THE SECRET OF LIFE** are quite a bit different than the units being built today, indicated specifically by the antenna hookups, from which basic logic would indicate the need for a different interior setup. A thorough analysis of the basic differences between the two types of units can be found in The Lakhovsky Multiple Wave Oscillator Handbook, edited by myself, Tom Brown (no relation to Mike). Mike's brochure then goes on to claim that "the equipment necessary to regrow arms and legs can be purchased at Radio Shack for about $10", that is a "metal plate, copper wire, battery, and 100 K-ohm to 1.5 Megohm resistor." Heck, if you can regenerate an amputated limb with a only battery and a resistor then why do we need all the electronics in a MWO just to drive out mere cancerous tissue?!

As a final note on this, I would like to point out that electricity is a system alterant. Whether it alters the system for better or worse depends on many other factors, including mental status and diet. As Trevor Constable pointed out back in the 1960s in this Journal, the healing powers attributed to the MWO could be caused by the etheric force rushing to suppress the life-negative electro-magnetic activity. It is also possible that any benefits coming from modern day MWOs are psycho-tronic in nature -- that is the mind is doing the cure and the instrument provides a physical anchor for the psychic energies. The actual operation of the equipment, the sparking and gross electrical output, is superfluous to the matter, other than in convincing the mind that *someting* is happening.

Jan-Feb 1991 JBR,

BSRF Bulletin Board

LAKHOVSKY'S ORIGINAL

You ask whether the original Lakhovsky MWO had any arc between antenna coils. I don't remember any but to make sure I checked up with a friend who has worked on the MWO and knows it inside out. He was also present when I saw the device working. He tells me that there is definitely no arc between coils. The arc occurs inside the machine after the "Ruhmkorff coil". He also says that there are two tungsten plates which are drawn apart and brought together manually.

The other thing I remember is a sort of metal wand with a knob at one end which is used between the two units to treat people. At the time I saw it, one of the persons present had a bad back. The two MWO antennas were turned on and were facing each other about 6 ft apart. The "wand" was applied to the sore back. I seem to remember that it kind of gave off sparks, but I'm not sure of this. I touched the wand and I could clearly feel something coming through. My knowledge of electricity is nil, however, if you have further questions, I could always try my friend who should be able to answer them for you.

R.C., France

Many thanks, as this confirms the evidence of Lakhovsky's own pictures used in his books. Would you be so kind as to ask your friend if it is possible to get a schematic (even a rough drawing from memory) of the basic layout of the MWO, which we could reproduce on these pages, also any antenna construction details. Many questions remain such as what components are in the metallic tubes holding the antennas up, and such (Eric Dollard finger-dowsed the pictures of the tubes and felt it was an arrangement of capacitors and spark gaps -- his basic MWO diagram, an intelligent guess of what Lakhovsky was doing, is in this Handbook). A basic schematic would probably be the most important piece of information to date. Please read on, pot has been stirred.....

LAKHOVSKY ANTENNAS

I got my Nov-Dec 89 Journal where it shows an update on Lakhovsky's antennas. On page 181 of SECRET OF LIFE it also shows the same thing. Take a magnifying glass and you can see it. I disagree with all the experts, it seems that they are chasing a phantom ghost. Lakhovsky gave us all his secrets in his book, all we have to do is read carefully.

He could cure cancer and other ailments with a simple piece of copper wire. Lakhovsky wasn't dumb, can you see him telling doctors to cure with a piece of wire they would tell him to get lost, so he built a very complex machine to impress them, also he would have something to sell. I think Beck's machine is close except the antenna. Who came up with this aluminum foil glued to plastic? That's where they fell on their face. If you read page 75 of the same book he repeats VIBRATES 3 times. That's why he hung his rings with silk thread, so it wouldn't damp the VIBRATIONS.

Can you imagine a pipe organ with copper strips glued to a board? I have designed an antenna using copper tube of varying sizes held by fish leader that I think would work fine. I'd bet a penny to 10 bucks that George used thin wall bronze tube as it will resonate better -- but it's expensive to fabricate.

Louis A. Schad
California

Yup, I agree that Georges was no dummy. His book shows plant cancers that have been cured via use of a single copper wire single-coiled around the plant. He felt that the pre-matter cosmic rays (or what I would call the material pole of the etheric instreams) were "ringing" the copper coil, in effect creating a tone that would heal the plant. I got the impression, from studying Lakhovsky's progress towards the vacuum (or low pressure rare gas) patent, that in his equipment Georges tried to invert the process -- exciting the ring with a post-material high frequency current that would create a healing tone. By using log periodic antennas (as would be allowed under the MWO patents) a vibrant chorus would ring in the ether, the tones, via the structure of the antenna, would be such that they could harmonize the functioning of the human body.

The aluminum foil antennas were developed by Riley Crabb, as a low cost way for experimenters to make their own antennas without having to have printed circuit boards made, and many folks were quite happy with the results. The physical evidence now clearly indicates that the Beck unit is quite different from the original Lakhovsky unit for which the cell regeneration results were recorded. What I have termed the "BECK MWO" must stand on its own merits and it can lay no claim to Lakhovsky's recorded results. As stated several times in the past Beck's device is more like one of Tesla's electro-therapeutic oscillators, except Tesla used copper sphere antennas, coated with a heavy dielectric to suppress sparking. Beck's unit would be covered under Lakhovsky's original (and very generalized) patent, but research of Lakhovsky's own material shows it is not what he used for electro-therapeutic researches. To excite the antennas in the Beck manner will not create the same vibrating field that Lakhovsky's antennas excitation circuit will. But it does create an electrical field that some claim is beneficial to a live body placed in its proximity.

It makes much sense that the antenna should also vibrate physically as well as electrically. Ah... if we simply had an original unit to weigh and measure...

Lou has sent us in a MWO of his own design with a single spiral antenna made of two twisted bare copper wires. We will be running a several part article on construction and use starting next issue. This unit is reminiscent of the Sun-Ether disc of Oscar Korschelt, circa 1891. Having sat in front of a number of different operating MWO's over the last six years I have to say that Lou's unit is the most exciting thing I've ever seen like this. I could strongly feel the effect 10-12 inches away, and there was no electrical excitation of the antenna, rather it is physically vibrated. There is a low voltage shocker that can drive the antenna through two smaller copper coils. It's easy to build and use, simpler than the Beck units, and should provide borderlanders with years of workable ideas. Lou will not be selling these devices but will provide complete building plans in the JBR.

We received a call from Patrick Flanagan. He reports that he has a MWO unit built by Lakhovsky's son in Paris. It is a little box with a one tube white noise generator and it has a multi-stranded cable which wraps around the body. It shows that the evolution of Lakhovsky's device has taken a different turn among those who actually knew what he was doing. This unit is based on the Radio-Cellular Oscillator.

Also, Klark Kent (of Super Science, Box 392, Dayton OH 45409) just called to say that he has completed a run of Golden Ratio antennas from the original B.S.R.F. artwork. These are double sided (with inverse gap strips, to simulate the ball capacitance on the original tube antennas, on back) gold plated and are available from Klark for $100 each. (These antennas have produced beneficial effects on plants without any electrical excitation. Many experiments can be done and the results quantified with various protocols such as those used by Rudolf Hauschka and Lilly Kolisko.)

There is no doubt that there is a new phase of MWO research being undertaken. For 25 years people built Beck's model, with many people claiming beneficial results, and others experiencing nothing but no one keeping track of results for evaluation. Thanks to Bob Beck's schematic (published by B.S.R.F. in 1963) the idea was kept alive and now people will have many ideas to choose from in their search for measurable effects from energies ranging from the gross electrical to the fine etheric. Thanks to everyone who has interacted on this ongoing aspect of our researches!

EVEN MORE LAKHOVSKY STUFF

Some time ago I bought your excellent handbook of the Lakhovsky Multi Wave Oscillator and due to pressure of other things have only just found time to read it. Interesting because it parallels some research done by myself and friends, or should I say we duplicated some of the original. This was only to be expected as the entire principle is so outrageously simple, too simple for establishment minds to comprehend.

I should like to offer a few ideas which might be of interest and in return I would be grateful for some additional information.

I helped develop the Betatron now sold by All-Source Systems, PO Box 596, Morton, WA 98356. The Betatron uses a TV Flyback transformer and is very similar to the Master Violet Ray devices. The nicest feature is that the applicator is an ordinary clear light bulb. Even a burnt out one will do. There are differences; some makes of bulb will not work at all, perhaps due to different gas fillings. The Betatron can also be used with the Lakhovsky concentric antenna with spectacular results. This of course has been done in the book's articles although as far as I know it was not actually copied, but was an obvious choice of experiment.

I have tried out an improvement which I did not see in the Handbook or anywhere else, perhaps you will be interested. The Standard circuit whilst apparently covering a very wide range of frequencies, must, because of its inherent fixed inductance and capacitance have its own natural fundamental frequency. Our Betatron is around 21 Kilocycles (I refuse to use the meaningless term Kilo Hertz), and other units seem to be basically tuned to one fundamental even though they do stray and produce an almost infinite range of harmonics.

My first improvement is to substitute a "Jacob's Ladder" for the spark gap. This consists of two 1/4" copper tubes spaced 5/32" apart at the bottom and tapering outwards to 1" at the top then abruptly turning out at 1" radius. The spark travels up the ladder from bottom to top and is extinguished by the sudden increase of gap, then begins again at the bottom. This sequence takes place at about 2 second intervals. The whole point of this is, as the spark progresses up the ladder, the length of the tuned circuit is progressively increased, then suddenly decreased again ditto repeato. As the ladder is about 9" long the length of the tuned primary of the Tesla coil is progressively made 18" longer, then back to its original length. Thereby resonating at infinite numbers of frequencies within its range and delivering virtually the same power at all those frequencies.

A further improvement on this feature is to make the ladder a Spiral Staircase by using a solid rigid central electrode, say a ½" copper tube and the spiral be wound in an ever increasing diameter on the outside, the start being about 5/32" gap and vertical to begin with.

Alternatively the spiral can be the inside element wound on a porcelain former such as is used in radiant "bowl" heaters with a plain copper tube surrounding it or perhaps a perforated tube as used in decorative lighting fixtures. The spark winds its way around the spiral staircase and alters the frequency accordingly. The Spiral Staircase provides a much longer path and more variation in frequency range. I have not yet perfected this and ruined a few porcelain formers in the process. It requires some exact progressive increases in the travelling spark gap but there are no serious obstacles.

Both the Jacobs Ladder and the Spiral Staircase have the advantage of easily cooling the spark gap. We had experienced problems due to overheating of the electrodes in a fixed gap, even spark plugs transmitted the heat to other parts and carbonized insulation. The addition of a cooling fan (the low power kind used in computers) provides a current of air which accelerated the progress of the spark up the Jacobs Ladder and more importantly up the Spiral Staircase. The spark is sometimes reluctant to leave its easy path at the base of the ladder and even more reluctant to wend its winding way up the coil, but the air flow does the trick and keeps everything cool.

The fan also helps remove Ozone from the enclosure. Ozone has the delightful habit of attacking insulation. It has also been blamed for respiratory illnesses. I am skeptical of the latter as I have breathed plenty of Ozone and found it exhilarating.

Master Violet Ray even included an Ozone Inhaler with its de-luxe model!!!, recommended for asthma, bronchitis etc. What's more M.D.s used it on their patients. Certainly Ozone is about the only thing which will quickly digest Carbon Monoxide in a hurry and it deodorizes a room when the cat has misbehaved.

The Betatron and Lakhovsky machine both can be used to destroy troublesome warts and moles, by simply wrapping a wire around the electrode and applying the point of the wire to the offending growth. I had some troublesome warts removed in this way by a Dermatologist. It was not until I got involved with this project that I realized the Dermatologist was using a Lakhovsky device.

He anesthetized the area first but I have since got rid of warts and moles without this. It caused some "Discomfort" which as any mother knows is worse than mere pain, but it was tolerable.

I hope the foregoing will be useful and will not be in the least surprised it has not already been done, but I would like to know what you think of it.

Regarding Spark Coils. I recently found at the local Flea Market, a small spark coil about 3½" overall length 2" dia. with a sturdy vibrator assembly and a turret mounted sideways. It looked like a small steam boiler in fact. It is labelled "Coil, Booster, Battery Operated. Type C1, (24 Volts DC) Spec. #94-32182, Serial #96082, order #A,C 27073, Eclipse Aviation Bendix, N.J. Division of Bendix Corp. I don't know what it is for but on 12 volts it delivers a lively 3/8" spark. The absence of a Zip Code suggests it is fairly old, but this is the ideal driver for a compact tesla coil. I do not know if it contains condensers but I added some anyway. The adjusting screw has a click stop adjustment. Have you come across

one of these? It works well on 6 volts which is just as well as it draws a lot of juice and 8 D cells won't fire it.

Now a request for information about Lakhovsky Treatment and parts. Please Please. On my knees!! Where can I obtain High Voltage Capacitors as used in the Lakhovsky Machine?????? I have tried all the surplus stores I know of in this area but the highest voltage they have is 450. I recently paid over $50 for a 660 volt one for a 12 v trailer power supply and that was ordered specially from New York. HELP!!! I even tried making one from instructions in the Boy Electrician, a Sunday School prize from the 1930s. I used Acrylic 1/8" dielectrics instead of glass. They worked well for a time but soon tracked and failed. I don't fancy using glass plates any way but I desperately need some H V Capacitors at less than Pentagon prices.

Re Treatments. One of the contributors to the Handbook reports that treatment with the Lakhovsky Machine resulted in the dis-appearance of underarm hair. (The report of decreasing underarm hair is from the Nov. 1968 Journal of Borderland Research by Mrs. E.H., Piqua, Ohio.) This is very interesting as I am a heavy construction worker, and after a hard day at the office I like to drop in for a cool beer and fraternize with nice hot ladies. However, underarm odor which results from my daily exertion and defies Right Guard AFTER for 2 hours, is a Repellant. I did find that shaving the offending fuzz helped a lot. Tearing it out by the roots was even better; it seemed to de-activate the sweat glands.

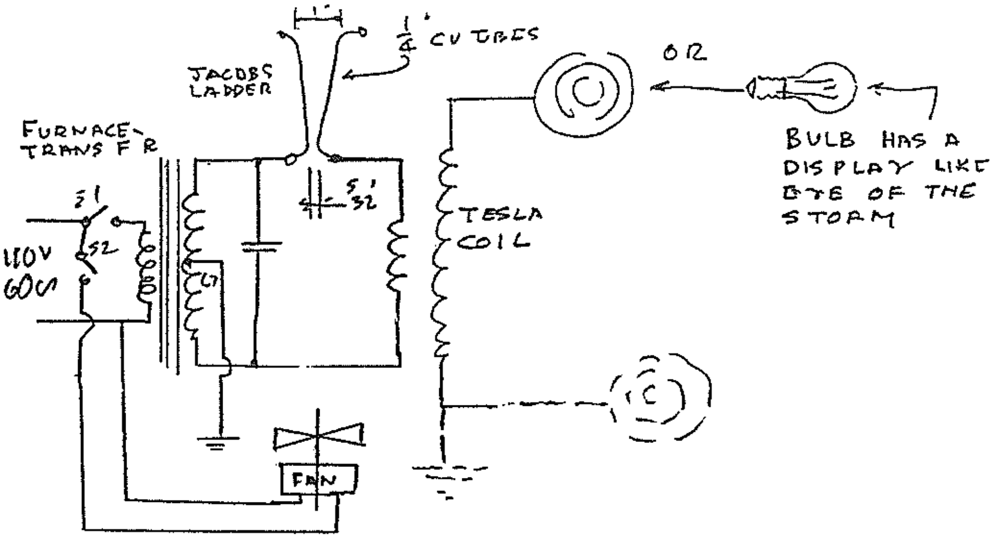

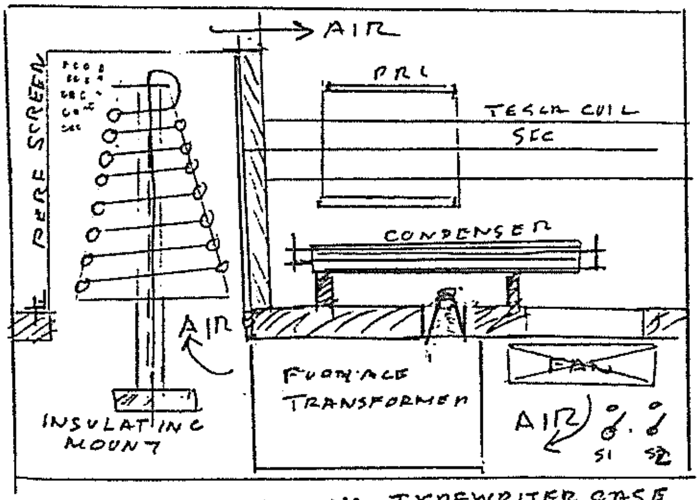

UNIT MOUTED IN TYPEWRITER CASE WITH ACRYLIC FRONT COVER TO DIRECT AIR FLOW

After I sprained my shoulder I used the Betatron all around the joint and have noticed that underarm hair now grows much more slowly, and I have much less trouble with B.O. I used the Betatron frequently and the Ozone removes any residual stink...

NOW the Big question. Has anyone succeeded in using the Lakhovsky machine to stimulate hair growth??? I have hair like Yul Brynner. Maybe some folks think its sexy but I find it repulsive and worst of all it makes me look and feel 20 years older at least without a hat. It seems to me that the machine could well be used to rejuvenate hair cells since it can reverse most other degenerative processes. Its a strange thing that men who are short on top have an overabundance of superfluous body hair in places where it is utterly wasted.

Has anyone done any research on this subject with the Lakhovsky Machine??? If so please let me know. I will be most grateful for any information and will of course inform you of the results of my own experiments.

It occurs to me that such a phenomenon could well dispense with the daily chore of shaving and make Gillette obsolete. I am forever disgusted that such a lot of life force is wasted growing hair on my face instead of where it belongs, On Top! Would be most grateful for your ideas.

I remember the Master Violet ray being demonstrated in a department store in the 1930s, I must have been about 7 years old. My mother who was with me watched the demonstration and I, of course, was fascinated. I said, "Oh Mom do buy one, it's just what you need for your rheumatism". Mother replied, "Oh no, You just want it to play with". How right she was. Well, in spite of all the quack devices which come and go, Lakhovsky in all his forms is still with us. That's recommendation enough. The AMA persecution of course confirms its effectiveness.

A Naturopathic Doctor saw me wearing a copper bracelet. He was treating me for arthritis, effectively with electro therapy etc. and asked if I really believed in the copper. I said "No", then he said "Why wear it?" "Because it works." He laughed and said,

"Look at that green stain on your wrist. That's copper salts and they are being ingested; maybe that's how it works, you might have a copper deficiency, well it's cheaper than pills."
Very Sincerely,
K.V.A.R., Washington

First off, without further ado, let me congratulate you on taking a stand on refusing to use the word Hertz to designate cycles per second. Why use mumbo-jumbo designators when simple English will do. Tesla said that the acceptance of the Hertzian theory would come to be seen by future generations as the greatest aberration of the scientific mind. Of course Tesla is probably rolling in his grave (at 3600 rpm?) at the modern etherless explanations of electricity. He, and others of his day, regarded the (transverse) Hertzian waves as the "waste" put off by coils. The Tesla (longitudinal) wireless system would have been worldwide (including radio and power), with the transverse waves engineered to a minimum, whereas the radio we have today, with the transverse waves engineered to a peak, fades out as one goes around a hill or a decent distance from the emitting source. This is dealt with much more specifically in THE THEORY OF WIRELESS POWER by Eric Dollard. Regarding use of the Jacobs Ladder as a spark gap, that is an interesting idea and thanks for sending it in. As far as your hair growth problems go, perhaps our other readers have further comments. You have provided a lot of food for thought, thanks!

HIGH VOLTAGE SOURCES:
Re: Nov/Dec Journal and inquiry of S.N. Capacitor 6KV (6000V) .0047 uF (which is the standard value, not .005!) available ($4.90) from: Antique Electronic Supply, 6221 S. Maple Ave., Tempe, Arizona 85283. (602) 820-5411.
A.A.
Massachusetts

Source for high voltage equipment: Plastic Capacitors, Inc., 2623 N. Pulaski Rd., Chicago IL 60639-2190. Write for catalog (Dealer for above is Newark Electronics). Also recommended is Homemade Lightning: Creative Experiments in Electricity by R.A. Ford, ISBN 0-8306-3576-9, TAB Books, Blue Ridge Summit, PA 17294-0850. Can be ordered through your bookstore.
Simplified Tech Service
PO Box 2140A, Champaign IL 61825

In the Nov-Dec 90 issue S.N. of Alaska asks about a 6Kv .005 uf capacitor. Radio Shack sells a 2Kv .01 capacitor #272-160. Three connected in series will be 6Kv .003 uf, another 3 connected in parallel across the first three will be 6Kv .006 uf. Six of these costs about $3.

Regarding the MWO, when Hieronymus lived near me in Ft. Lauderdale I asked him about the MWO. He didn't recommend it because the broad spectrum of frequencies had both beneficial and harmful frequencies which could not be separated.
R.B.
Florida

Thanks for all the input on where to get HV capacitors. Also, thanks Ron, for Hieronymus' viewpoint. With the Beck style MWOs I would agree. A mass of radio frequency noise is generated. With Lakhovsky's original units driving structured antennas one could produce multiple wavelengths of a more refined nature. We don't recommend the MWO to anyone, that is not our purpose. This Journal acts as a forum to ideas such as these to be explored, and the MWO refuses to go away, rather interest is growing and it is time we closely examine the field. Read on...

THE BECK MWO
My MWO is a Beck model. It has successfully killed a skin cancer on the back of my hand. Yet I am wondering about its resonator. There seems to be no action, it's of no use and is as if dead. I did not realize that we are having trouble establishing a real Georges Lakhovsky MWO. This [enclosed] information from Europe may help clear up our need.
D.M.
Bryte,

A good puzzle truly has many pieces, so thanks for your experiences. I never said that the Beck MWOs didn't work, but that they are not the same as Lakhovsky built. The enclosed ad was for radionic and related equipment including MWOs from Radionic Instrumentation & Research, Dorset, England. It may be that this is the radionic type of MWO originally sold by Copen Labs. I honestly don't know a thing about these MWOs, so any info would be greatly appreciated especially a schematic. Years ago I had heard them spoken of disparagingly by people who claimed that they wouldn't work because there wasn't enough power, an argument I never bought. It would seem that the more subtle and refined the energy the more beneficial it is to the human organism. The field is still open for new ideas and fresh impulses...

KLARK KENT CHECKS IN!
Just a note to say thanks for the mention in the Journal about the availability of the Golden Ratio Antennas from Super Science. And also to say that the articles on the continuing developments of the MWO are most welcome. Especially interesting is the comparison of the Beck MWO to the Lakhovsky original!

I have never seen an original Lakhovsky MWO. Only from the patent information can we really get schematic information, circuit diagrams, antenna structures, etc. As you know from all of the free energy patents circulating around, a patent wrapper and drawing is not really enough to produce the claimed device. If it were, then we should have many free energy devices in production today!

Several months ago a contact in New York made a generous offer to procure an original Lakhovsky MWO. I passed this information along to you and to others. So far no one has come forth to my knowledge with information leading to the whereabouts of an original Lakhovsky MWO. What this means is that we must grope our own way in replicating the technology first developed by Lakhovsky.

So I guess I owe Bob Beck a word of thanks because he was the one who made it possible for researchers to actually build a MWO. The information left to the world by Lakhovsky is (in my opinion) wholly inadequate to build and construct the device. The patent information is, like most patents, just not adequate to enable someone to replicate the device. And this brings up the question: Just what constitutes the original Lakhovsky MWO? We don't have an original device (and a bounty of $100,000 has so far failed to produce one). The information given in the patents doesn't really tell us enough.

Borderland Sciences can help out by continuing to publish articles about the MWO which emphasize circuit diagrams and construction details. In this way, Borderland researchers can redevelop this important technology.

I enclose a letter we received from a customer. Since the letter is of the testimonial variety, it is best not to reference it in the Journal. But the point is that even a Beck adaptation MWO can seem to produce positive experimental results!
Klark Kent, Super Science,
P.O. Box 392, Dayton, OH 45409

Glad to hear you are open to new research. Lakhovsky left much information -- it just never got translated into English. BSRF will continually publish the results of ongoing MWO research, and will always be on the lookout for the best information available. Here is the letter submitted to Klark, from a person known to us here also:

Dear Mr. Kent,

At long last I get around writing to you and share some of my experiences with the MWO I bought from you.

The unit arrived on May 17, 1990 in excellent condition. Your packaging is superb. I inspected the unit superficially but, because of some professional problems, was not able to make use of it until October.

Let me comment first on general appearance and workmanship. While obviously not industrially produced, this is a well-built high quality machine, using fine components. Having been an electronics engineer part of my life (before I became a philosopher), I feel well qualified to make that judgement.

The instructions are generally adequate but I was glad that I did order your audio cassette, done by you with a fine dramatic flair, worthy of Christopher Reeve, who does resemble you. My suggestion: include the cassette with the MWO as a matter of course.

I used the machine about thirty times, sometimes daily, sometimes skipping a day or two for 35 min. per session, mostly in the High Power Radiator mode.

I suffered over a period of about fifteen years from a mild chronic bronchitis, some coughing in the morning with some phlegm, rest of the day just fine. The medicine men told me that I "just have to live with it". Though I am 70, I judge myself being in great health.

Now, your machine has definitely improved my condition. I know, of course, that my testimonial is worthless to you, since you cannot make, and do not make, any health claims. But still I thought you might want to know.

I do have several radionics machines (De la Warr and Copen) but we all realize that this is sympathetic magic; great stuff, though!

With best wishes, faithfully yours,
NAME WITHHELD

ELECTRONIC ENTITY REMOVAL

Judging by the letters you receive and print in the BULLETIN BOARD people are still experimenting and building MWOs. It should be accepted that no two MWOs will be identical due to different components, circuits, etc. Also, Lakhovsky did not have some mystical secret that is exclusive to his particular instruments; he built one that generated his required multi-frequencies and there are no doubt many ways to effect this.

The large MWO I built in 1966 worked as well as I could expect and, although I never use it now, its circuit can be regarded as a basic Tesla coil, starting out with a 12KV neon transformer. Other circuits I have experimented with unfortunately appeared not to give the same results. Your MWO Handbook should be the starting point for would-be experimenters keeping in mind that most of the 'transistorized' models do not have enough energy to effect the desired results.

A major point that never seems to be mentioned is that the subject should be seated ON AN INSULATED PLATFORM with the antenna about six inches from the back. In this way all the cells of the body are raised to their full potential for, say, ten minutes during which each cell can absorb energy at its one resonant frequency. The subject should ground himself for an instant before stepping off the platform. Then switch off the instrument. I found this procedure mandatory to obtaining positive results and have found it odd that this point has never been mentioned in the literature.

I might also bring up the very real possibility (discussed with Riley Crabb in the past) that at least part of the positive results obtained with the MWO could be attributed to the removal of spirit entities by the high voltage involved. Regrettably, Borderland appears to skirt this issue.

As I have stated before, the Journal is an important platform for the meeting of the minds and I wish you well in your efforts.

R.M.
Nevada

Appreciate your input and valuable ideas. I'm certainly open to the possibility that the results obtained from the MWO could be attributed to the removal of spirit entities. This should also bring up the question of whether or not what is perceived as spirit entities (negative in this sense) could be also related to their potential physical anchors, i.e. virus and bacteria. Maybe we see the same thing but interpret differently.

As far as using different configurations to achieve multiple wavelengths, different arrangements will produce qualitatively different results. A French horn and a clarinet will show the same frequency for the same note played, but the difference in quality of sound should be obvious to all. The major difference between the hookup of Lakhovsky's and Beck's units makes them fall into quite separate categories. A silver bell rings finer than tin.

MWO REPORT FROM FRANCE

I finally managed to get hold of my friend (see BSRF Bulletin Board, Jan-Feb 1991) but he is very, very busy and only gave me some of the information I wanted.

Firstly, he declined to provide any basic layout of the MWO because he say no two units were the same. Apparently Lakhovsky experimented all the time and each machine was a "one-off" model, different from the others.

The origins of the MWO are in Tesla's work. A French professor, Mr. D'Arsonval took some of Tesla's equipment and modified it. Lakhovsky used D'Arsonval's work to build his machine. Tesla heard about D'Arsonval's experiments and, convinced that D'Arsonval was stealing his patents, came to France with the idea of starting legal proceedings against the professor. However, he found D'Arsonval so courteous and charming that he returned to America having dropped the idea of court action.

My friend tells me that the whole secret of the MWO is in the "diffuseur". He further indicated two sources of information, both in French. A series of books have been written and published by the Study Group "Arkall" called "L'Emergence de l'Enel" dealing with all aspects of the MWO. The second source is George Lakhovsky's book "L'oscillation cellulaire" which has been re-edited in Belgium. Unfortunately, my friend did not know the editor, so I suggest you will have to contact the American Embassy in Belgium and they should be able to give you addresses of bookshops where it can be obtained. Apparently, this book gives all the references concerning the people I have mentioned.

I'm sorry I can't be more helpful but the whole question seems to be much more complicated that I at first thought. In short, I'm afraid you will have to wade through "L'oscillation cellulaire" and the "L'Emergence de Enel" to see how Lakhovsky himself worked out the idea of the first MWO's.

R.C.
France

Thank you, your input has been most valuable and stimulating. The "diffuseur" (literally: loudspeaker or nozzle) would probably be the antenna, so the "secret" could very well be (as we have intimated over the years) in his mathematical arrangement -- a much more important consideration under Lakhovsky's antenna feed arrangement than with Beck's.

Jul-Aug 1991 JBR,
BSRF Bulletin Board

MWO CORNER

Received the Journal yesterday and was very excited about the Spiral Coil MWO. I congratulate Mr. Schad on doing a very good job and would submit the following input for future models.

1) No aluminium tubing should be used. Copper or steel tubing should be used instead. Aluminium is wholly negative. It attracts negative radiation like honey attracts files. In this connection, I heard this morning on the British radio that a "mobile home" site had just been devastated in the USA. If I'm right, "mobile home" site means trailer park, in which there is a huge quantity of Al. These are prime targets for tornadoes and all kinds of negative influence. My chief reference for this is Dr. Starbard Webb, Box 200, Orangevale, CA 95662. She has been studying the subject since 1956 and has accumulated a mass of data. Be patient for she travels a lot in the States doing seminars etc.

2) The rest is from a Tibetan lama to whom I showed the drawing. If you're wondering what a lama would know about the MWO I would say that they seem to know about everything that matters. For instance, in my own field (medicinal plants), their knowledge is not great, it is simply colossal, far beyond anything known in the West. The Lama tells me that there should be 12 coils, no more no less (Fig. 6). The "up" wire (see illustration) should be five times longer than the diameter of the coil. No doubt further information will be forthcoming when the whole of the MWO is described.

Yours sincerely,
R.C.
France.

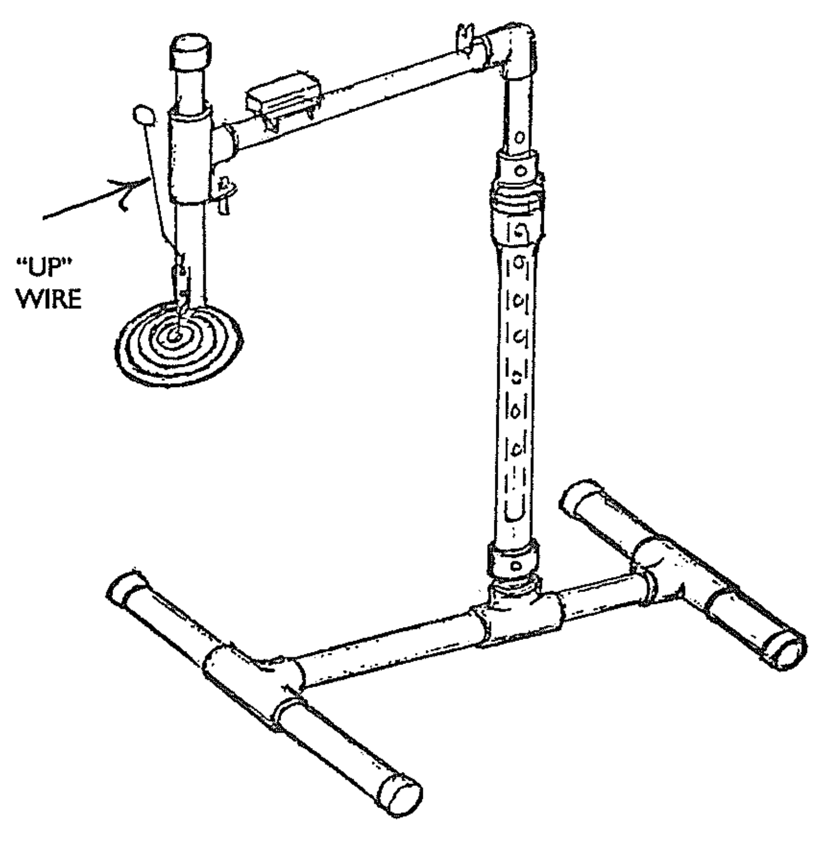

Spiral Coil Multi-Wave Oscillator

Glad to hear of your suggestions for further research on Lou's spiral coil MWO. His articles have stimulated a lot of work that should provide a lot of new ideas over time. Peter Lindemann has taken Lou's concept of physical vibration and is experimenting with phi ratioed antennas that are stimulated with sub-audible sound. Also, Lou called to make sure that it was clear that the antenna side facing the subject is a counterclockwise spiral. It is clockwise from the top.

Interesting thoughts on the mobile homes, which are reverse orgone accumulators. A few items congruent with your comments have showed up over the years and perhaps we can get more on that in an upcoming issue.

LAKHOVSKY COIL INFORMATION

The following was forwarded to us from Health Research, Box 70, Mokelumne Hill CA 95245:

On Health Research's flyer for THE HANDBOOK OF UNUSUAL ENERGIES, the artist shows the copper wire positioned incorrectly through the wood support.

I have made a number of discoveries which I even find hard to believe by using this COILED COPPER WIRE. I expect to write a booklet on my findings and you may want to represent it in your sales catalog. I have proven over and over again what I have done but, to date, have not shared anything with anyone else. I had to be ABSOLUTELY CERTAIN before I 'went public'.

When I first received the books THE SECRET OF LIFE and THE WAVES THAT HEAL from you about 4 years ago, I noted carefully just how the copper wire was COILED around the plant. Please note that the copper wire STARTS from INSIDE THE EBONITE and MOVES COUNTER CLOCKWISE and then ends ABOVE the ebonite... This is shown on page 14 of THE WAVES THAT HEAL and page 110 of THE SECRET OF LIFE.

In the past four years I have made dozens of experiments and I've gone far beyond what even Lakhovsky did or thought of. NOW, to prove my point about the proper way the copper MUST be coiled, I deliberately experimented by coiling the wire the way you have shown it and NOTHING HAPPENED in all my experiments. That's why I KNOW THAT

I AM RIGHT and it is imperative that you change your picture to show the correct way. I am not a scientist of a professional person, but I KNOW what I have done and you will have to take my word for it unless you want to YOURSELF, conduct the same experiments I have and PROVE it to yourself... I have not the slightest idea WHY the copper wire MUST be coiled this way but I DO KNOW THAT IT MUST.

You know as well as I that EVERYTHING in the COSMOS is perfect, exact, precise and absolute that the LAWS, FORCES, ENERGIES, POWERS, FREQUENCIES, RAYS... and all the rest function flawlessly and cannot allow any variations even for an instant. Life as we know it will cease forever if even an INSTANT change is made by whatever cause.

I would dearly love to see one of Lakhovsky's BELTS, COLLARS, BRACELETS he calls them OSCILLATING CIRCUITS, of course, and although the picture on page 63 of WAVES THAT HEAL is interesting, I am wondering if there is more to it that what this artist concept shows. I have yet to experiment with a HUMAN BODY as I will need to be very careful to use the RIGHT PERSON who will not think that I have gone off the deep end and headed for the 'funny farm'. But Lakhovsky certainly has plenty of evidence to show. If you know of anyone who has one of the ORIGINAL Lakhovsky oscillating circuits, let me know. It is imperative that the 'human' circuits MUST be done, and applied, correctly.
A.P.
Nebraska

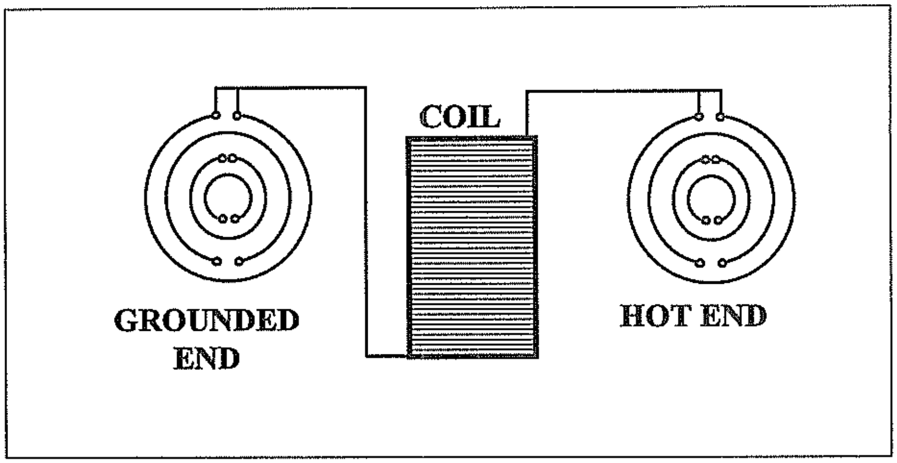

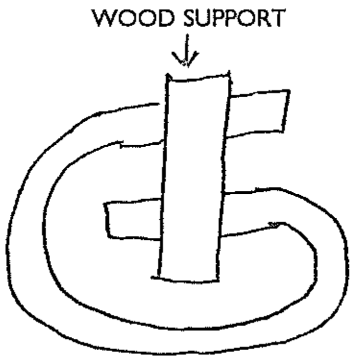

WRONG

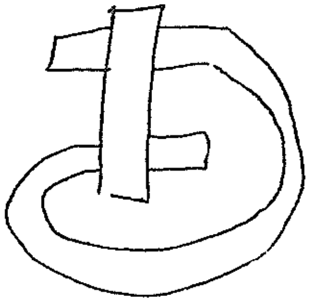

RIGHT

Nov-Dec 1991 JBR,
BSRF Bulletin Board

MWO RESEARCH
Five years ago I duplicated the MWO as best I could with my limited knowledge. I scaled up the antennas from the book WAVES THAT HEAL using copper tubing of all different sizes and soldering brass hex caps of various sizes on the ends after I rounded them off with a grinder. The outside ring was about 2 ft. across.

I was able to duplicate the exact brush discharge pattern in the picture with Tesla coil 4" diameter with about 1,000 turns of regular hook up wire. 500 turns gave a discharge of 2"-3" evenly all around the outer ring. 1,000 turns gave a discharge of 5"-6" at the bottom with less and less towards the top except for some off the two balls at the top, like in the picture.

I found it necessary to run two connections from the feed wire otherwise with one connection the spark would travel around the ring and out the other end burning anything used to suspend the ring. Two connections eliminated this problem forcing all energy towards the bottom of the ring like in the picture.

The resonator was grounded just like the Beck model to the ground end although I used two wires one going to each end of the outer ring. Even so, at this power you could draw a small spark off the outer ring and if you turned the unit off and on you could hear the resonator ring just like it was struck by a small hammer.

I used a 30mA 15,000 volt sign transformer or stronger. These tend to burn out unless you put the primaries of two in series to share the load and restrict current. Actually, I started using half burned out transformers using mid point ground and the good half for 7,500 volts which is much safer for the capacitors. I used two .005 uf 20,000 volt capacitors in parallel for .010. The stationary spark gap was air cooled with a small blower fan.

There was no spark between rings. The side effects from this unit were too strong to continue treatments so I am now working on smaller units. After 15 minutes your head would be full of mucus. The closer the antennas were to each other the stronger the effect to the point of making one very nauseous.

Also, did anyone else purchase and test Dr. Charles T. Turley's square wave sound MWO two printed antennas powered by a sound generator?
J.A.
Ohio

Thanks for your most helpful input. Would be most interested in Dr. Turley's MWO as it may very well relate to Lou Schad's spiral coil MWO, presented several issues back, which worked on physically vibrating the coil. Peter Lindemann has picked up on this and is experimenting with vibrating the antennas with sound waves and through other mechanical means. A whole new field of MWO research is opening up and it sounds like Dr. Turley is working in the same direction. Please send us any information you may have on this. Thanks.

From the March-April 1992 JBR
BSRF Bulletin Board

MWO CORNER!

Here is a nice present for you and your readers. Some tidbits about George Lakhovsky. I phoned my knowledgeable friend on Sat, 14th Dec. To my surprise not only was he at home but he invited me to spend the afternoon with him the following day.

Firstly, it is comforting to know that there are still about four original MWO's within a radius of 200 miles from Paris, and the people who have them are likely to take good care of them.

Secondly, from what I can gather, L. took very great pains with each MWO. I understand now what my friend meant when he said that each one was different. L. would calculate all sorts of parameters relating to the place where the MWO was to be used. He would then do the "fine tuning" with the help, sometimes, of an unusual cleric Abbe Breuil.

L. arrived in France around 1896. He was a friend of Tesla and when the latter came to France the first person he wanted to see was L. I don't know anything about this early period but two episodes occurred later which gave L. quite a bit of money and enabled him to finance his future research himself. 1) During the 1914 war, there was a dearth of methylated spirits in France and L. negotiated supplies, on behalf of the French government, with the Russians. 2) He invented a gadget which was used everywhere on the French railways and which brought in tidy sums in royalties. He was thus able to invite titled people to his table, the Count of this and the Duke of that and, of course, Abbe Breuil. This curious cleric was very well known in France, not for saintly endeavors on behalf of the Church but for his exploration of caves in search of traces of early man. He became the High Priest of Pre-history. However, what interests us here is that he was an extraordinary medium. For instance, L. at table, would say something like this: "Abbe, I've just thought up a new design for the MWO (passing him the drawings) what do you think of it?" And the Abbe might reply: "The antenna's too thick here, you should take 1 millimetre off and here, you are using the wrong kind of metal." In this way, L. gradually refined each model, using the Abbe's intuition to verify his own findings, until he got it as near perfect as possible.

What follows is a translation of the notes scribbled down by my friend yesterday. I offer no comments because I wouldn't know a Hertz dipole if I fell over one in the dark.

These are some of the parameters taken into consideration by L.

1) Diameter: D.

2) Thickness of the wire of the tube (not to be confused with the section).

3) Distance "e" between the two ends.

4) Orientation of the circuit with respect to the horizontal plane (29° 70 N).

5) Kind of circuit. Should it be made of metal or hollow glass containing chemical salts.

6) Orientation of the distance "e" with respect to the magnetic North.

7) Study of the terrain: the mineralogical, geological, geodesic and tectonic factors.

8) Study of the nature of the surface of the circuit and whether and how it should be covered.

I see now that what I had taken for solid rods making up the antenna were in reality hollow tubes.

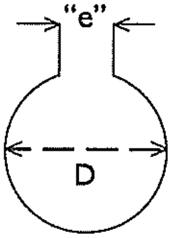

Hertz dipole

MWO antenna

I hope that you and your readers will find this information interesting. It sheds a new light on how L. operated. He used the pendulum a lot and, as we have seen, the mediumistic talents of his friend Abbe Breuil. My best wishes to yourself and to BSRF in 1992.

R.C.
France

Your input on the MWO project has been most helpful to everyone trying to find the truth of the story, and I offer my thanks and I'm sure the thanks of BSRF members the world around. Georges Lakhovsky was a complex individual whose ideas on cell regeneration have ignited many a seeking mind. It seems as though he had some rather interesting friends also, Nikola Tesla, Professor D'Arsonval, and the curious Abbe Breuil! Your friend's comments indicate some important factors in Lakhovsky's considerations: He was very concerned about the orientation towards the natural energetic lines of the earth, even considering latitude (what you have termed the horizontal plane) as a determining factor in the energetic output of his devices. He must have been aware of the interaction of the electric output with the planetary magnetic, electrostatic and etheric fields. He was also concerned about the underlying earth itself. In his **Secret of Life** he proposes his theory that cancers are more predominant in areas where the soils (such as clays) reflect the cosmic radiation back to the surface, causing interference patterns that disrupt the body's energetic flows. It is interesting to note that his antennas were constructed with all these factors involved. It is also very interesting that he relied on the pendulum and the mediumship of Abbe Breuil for his refinements. Lakhovsky was a true borderland scientist! Also of note is your point #5 mentioning the hollow glass circuit containing chemical salts. Something new to figure in our researches. We also have the open question of whether or not some of his tube antennas contained rare gases, which his MWO Tube Patent implies by its refinements in miniaturization. This has been an exciting period of discovering what Lakhovsky was really up to in his vast researches. Please read on....

A REAL LAKHOVSKY SCHEMATIC!

This schematic is from a Lakhovsky Radio Cellular Oscillator manufactured by Lakhovsky's son in Paris long after the untimely death his father in the early 1940s. It shows that the Lakhovsky's own family followed the path of the radio-cellular oscillator and not that suggested by Lakhovsky's turn to damped electrostatic power supplies in his MWO. Our many thanks go to Patrick Flanagan for providing this information to BSRF. Patrick obtained the unit, removed the seal at risk of voiding the warranty, and provided us with the circuit description you see here. Also, a special thanks to Roger Modjeski of RAM Tube Works of Santa Barbara, California for providing the pinouts and tube conversion info. As far as our extensive research notes show, this is the first real, complete schematic of an working Lakhovsky device that has been published in the US!

This unit, which fits in a small box that can be held in the hand, is a very powerful white noise generator with a treatment coil comprising of coax cable which is looped around the subject when in use. The treatment coil loop is 1 meter in length, the center wire and shield are connected. This unit will interfere with electronic communication devices up to the satellite TV range, and may be illegal to operate under FCC rules. The tube is an EL83, a French tube (Telefunken manual gives the German number as PL83) whose US equivalent is given as a 6CK6 video output pentode, but GE never made them. It is very similar in function to a 6CL6 which has a different

Lakhovsky MWO/Radio Cellular Oscillator submitted by Patrick Flanagan

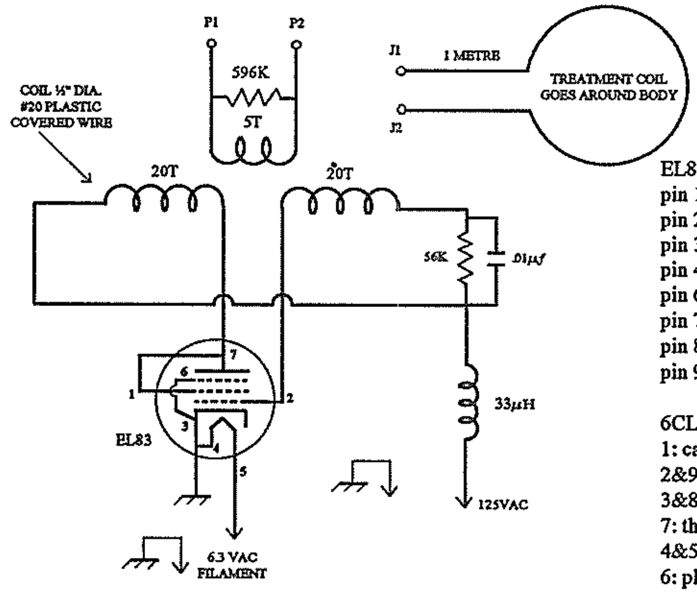

EL83/6CK6 PINOUT
pin 1: grid 2
pin 2: grid 1
pin 3: cathode
pin 4&5: filament 6.3V
pin 6: grid 3
pin 7: plate/anode
pin 8: internal shield
pin 9: not used

6CL6 PINOUT
1: cathode
2&9: first grid
3&8: second grid
7: third grid
4&5: filament
6: plate/anode

pinout. We provide the pinouts for both.

The 5 and 20 turn coils are ½ inch diameter tightly wound with #20 plastic coated wire. They are air core and all three are wound in the same right hand direction. They are spaced tightly and arranged exactly as shown. Varying the physical distance between the primary and secondary coils would vary the output strength. The resistors are ½ watt. The .01 capacitor is ceramic at 500 volts. The choke is 33 µH. The power supply is not shown, but is implied by the circuit.

We have no exact details of the interaction of this generation of Lakhovsky device with the human system, only that suggested by Lakhovsky's original RCO research and its extension through time. This data is provided for research purposes and to record yet another development in radio-biological research.

We would still be most interested in finding the schematic of one of the original MWOs pictured in Lakhovsky's various publications such as that pictured below from his book **La Terre Et Nous (The Earth and Ourselves)**, Fasquelle Editeurs, Paris, 1933, as it would provide the exact antenna feed for the concentric ring antennas and other pertinent details. Note that the antennas on this unit stand above the arm, unlike the well publicized pictures from **The Waves that Heal** and **Secret of Life.** This indicates that the protruding spheres seen in the detail on those pictures have a mechanical function, perhaps more important than their electrical function, though with Lakhovsky's methodology, he would certainly incorporate the optimum characteristics for the main antenna feeds.

We have discovered the basic construction of the Radio-Cellular Oscillator and know that Lakhovsky moved from them to the MWOs with damped electrostatic power supplies and concentric ring antennas because of the potential for thermal shortwave damage from continuous-wave radio frequencies. But then we see that Lakhovsky's son was still manufacturing RCOs after the death of his father! So we can see that the final conclusion has yet to be drawn as to exactly how the original MWOs were built, and of course we would also like to see some actual MWO Tube units that Lakhovsky patented. We also see the RCO as a potential low-cost method of researching Lakhovsky's basic theory of radio-frequency cell regeneration. This MWO Handbook contains the essential keys to all our questions and more. Much research has to be done and Borderland Sciences is willing to help any serious researcher who wishes to pursue these streams of activity.

The Journal of Borderland Research is the publication of record in the English language for these and many other research subjects. Please join in and exchange information with us. Without the help of the many borderland researchers sending us their ideas for over a quarter of a century this book would not exist. Thanks to all and best wishes on your researches -- may they be serious, straightforward, and well documented for others to learn from.

Tom Brown

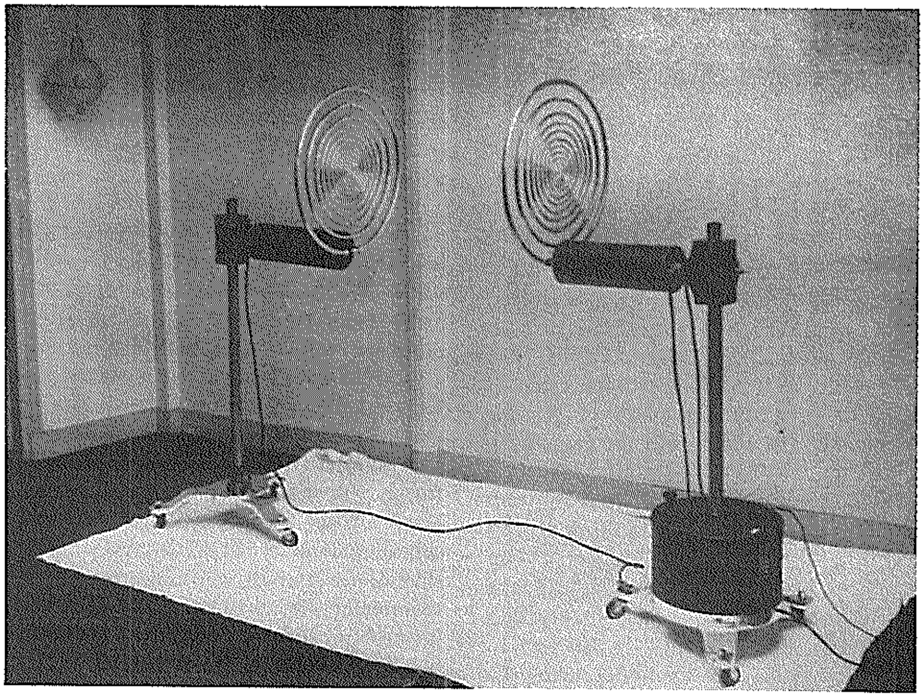

The complete Lakhovsky Multiple Wave Oscillator apparatus which creates an ambient electromagnetic field between its two *resonateurs.*

5

HIGH FREQUENCY OSCILLATORS FOR ELECTRO-THERAPEUTIC AND OTHER PURPOSES*

by Nikola Tesla

Some theoretical possibilities offered by currents of very high frequency and observations which I casually made while pursuing experiments with alternating currents, as well as the stimulating influence of the work of Hertz and of views boldly put forth by Oliver Lodge, determined me some time during 1889 to enter a systematic investigation of high frequency phenomena, and the results soon reached were such as to justify further efforts towards providing the laboratory with efficient means for carrying on the research in this particular field, which has proved itself so fruitful since. As a consequence alternators of special design were constructed and various arrangements for converting ordinary into high frequency currents perfected, both of which were duly described and are now — I assume — familiar.

One of the early observed and remarkable features of the high frequency currents, and one which was chiefly of interest to the physician, was their apparent harmlessness which made it possible to pass relatively great amounts of electrical energy through the body of a person without causing pain or serious discomfort. This peculiarity which, together with other mostly unlooked-for properties of these currents I had the honor to bring to the attention of scientific men first in an article in a technical journal in February, 1891, and in subsequent contributions to scientific societies, made it at once evident, that these currents would lend themselves particularly to electro-therapeutic uses.

With regard to the electrical actions in general, and by analogy it was reasonable to infer that the physiological effects, however complex, might be resolved in three classes. First the statical, that is, such as are chiefly dependent on the magnitude of electrical potential; second, the dynamical, that is, those principally dependent on the quality of electrical movement or current's strength through the body, and third, effects of a distinct nature due to electrical waves or oscillations, that is, impulses in which the electrical energy is alternately passing in more or less rapid succession through the static and dynamic forms.

Most generally in practice these different actions are coexistent, but by a suitable selection of apparatus and observance of conditions the experimenter may make one or other of these effects predominate. Thus he may pass through the body, or any part of the same, currents of comparatively large volume under a small electrical pressure, or he may subject the body to a high electrical pressure while the current is negligibly small, or he may put the patient under the influence of electrical waves transmitted, if desired, at considerable distance through space.

While it remained for the physician to investigate the specific actions on the organism and indicate proper methods of treatment, the various ways of applying these currents to the body of a patient suggested themselves readily to the electrician.

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* Read at the eighth annual meeting of The American Electro-Therapeutic Association, Buffalo, N. Y., Sept. 13 to 15, 1898

As one cannot be too clear in describing a subject, a diagrammatic illustration of the several modes of connecting the circuits which I will enumerate, though obvious for the majority, is deemed of advantage.

The first and simplest method of applying the currents was to connect the body of the patient to two points of the generator, be it a dynamo or induction coil. Fig. 1 is intended to illustrate this case. The alternator G may be one giving from five to ten thousand complete vibrations per second, this number being still within the limit of practicability. The electromotive force — as measured by a hot wire instrument — may be from fifty to one hundred volts. To enable strong currents to be passed through the tissues, the terminals T T, which serve to establish contact with the patient's body should, of course, be of large area, and covered with cloth saturated with a solution of electrolyte harmless to the skin, or else the contacts are made by immersion. The regulation of the currents is best effected by means of an insulating trough A provided with two metal terminals T' T' of considerable surface, one of which, at least, should be movable. The trough is filled with water, and an electrolytic solution is added to the same, until a degree of conductivity is obtained suitable for the experiments.

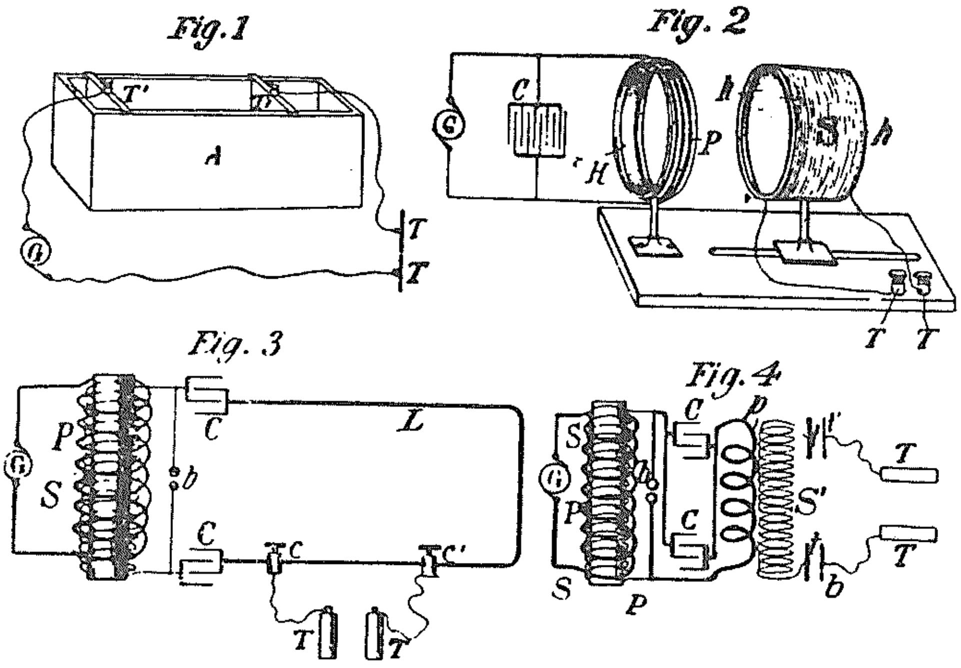

Figs. 1, 2, 3, 4.

When it is desired to use small currents of high tension, a secondary coil is resorted to, as illustrated in Fig. 2. I have found it from the outset convenient to make a departure from the ordinary ways of winding the coils with a considerable number of small turns. For many reasons the physician will find it better to provide a large hoop H of not less than, say, three feet in diameter and preferably more, and to wind upon it a few turns of stout cable P. The secondary coil S is easily prepared by taking two wooden hoops h h and joining them with stiff cardboard. One single layer of ordinary magnet wire, and not too thin at that, will be generally sufficient, the number of turns necessary for the particular use for which the coil is intended being easily ascertained by a few trials. Two plates of large surface, forming an adjustable condenser, may be used for the purpose of synchronizing the secondary with the primary circuit, but this is generally not necessary. In this manner a cheap coil is obtained, and one which cannot be easily injured. Additional advantages, however, will be found in the perfect regulation which is effected merely by altering the distance between the primary and secondary, for which adjustment provision should be made, and, furthermore, in the occurrence of harmonics which are more pronounced in such large coils of thick wire, situated at some distance from the primary.

The preceding arrangements may also be used with alternating or interrupted currents of low frequency, but certain peculiar properties of high frequency currents make it possible to apply the latter in ways entirely impracticable with the former.

One of the prominent characteristics of high frequency or, to be more general, of rapidly varying currents, is that they pass with difficulty through stout conductors of high self-induction. So great is the obstruction which self-induction offers to their passage that it was found practicable, as shown in the early experiments to which reference has been made, to maintain differences of potential of many thousands of volts between two points — not more than a few inches apart — of a thick copper bar of inappreciable resistance. This observation naturally suggested the disposition illustrated in Fig. 3. The source of high frequency impulses is in this instance a familiar type of transformer which may be supplied from a generator G of ordinary direct or alternating currents. The transformer comprises a primary P, a secondary S, two condensers C C which are joined in series, a loop or coil of very thick wire L and a circuit interrupting device or break b. The currents are derived from the loop L by two contacts c c', one or both of which are capable of displacement along the wire L. By varying the distance between these contacts, any difference of potential, from a few volts to many thousands, is readily obtained on the terminals or handles T T. This mode of using the currents is entirely safe and particularly convenient, but it requires a very uniform working of the break b employed for charging and discharging the condenser.

Another equally remarkable feature of high frequency impulses was found in the facility with which they are transmitted through condensers, moderate electromotive forces and very small capacities being required to enable currents of considerable volume to pass. This observation made it practicable to resort to a plan such as indicated in Fig. 4. Here the connections are similar to those shown in the preceding case, except that the condensers C C are joined in parallel. This lowers the frequency of the currents, but has the advantage of allowing the working with a much smaller difference of potential on the terminals of the secondary S. Since the latter is the chief item of expense of such apparatus and since its price rapidly increases with the number of turns required, the experimenter will find it generally cheaper to make a sacrifice in the frequency, which, however, will be high enough for most purposes. However, he only needs to reduce proportionately the number of turns or the length of primary p to obtain the same frequency as before, but the economy of transformation will be somewhat reduced in so doing and the break b will require more attention. The secondary S' of the high frequency coil has two metal plates t t of considerable surface connected to its terminals, and the current for use is derived from two similar plates t' t' in proximity to the former. Both the tension and volume of the currents taken from terminals T T may be easily regulated and in a continuous manner by simply varying the distance between the two pairs of plates t t and t' t' respectively.

A facility is also afforded in this disposition for raising or lowering the potential of one of the terminals T, irrespective of the changes produced on the other terminal, this making it possible to cause a stronger action on one or other part of the patient's body.

The physician may find it for some or other reason convenient to modify the arrangements in Figs. 2, 3 and 4 by connecting one terminal of the high frequency source to the ground. The effects will be in most respects the same, but certain peculiarities will be noted in each case. When a ground connection is made it may be of some consequence which of the terminals of the secondary is connected to the ground, as in high frequency discharges the impulses of one direction are generally preponderating.

Among the various noteworthy features of these currents there is one which lends itself especially to many valuable uses. It is the facility which they afford for conveying large amounts of electrical energy to a body entirely insulated in space. The practicability of this method od energy transmission, which is already receiving useful applications and promises to become of great importance in the near future, has helped to dispel the old notion assuming the necessity of a return circuit for the conveyance of electrical energy in any considerable amount. With novel appliances we are enabled to pass through a wire, entirely insulated on one end, currents strong enough to fuse it, or to convey through the wire any amount of energy to an insulated body. This mode of applying high frequency currents in medical treatment appears to me to offer the greatest possibilities at the hands of the physician. The effects produced in this manner possess features entirely distinct from those observed when the currents are applied in any of the before mentioned or similar ways.

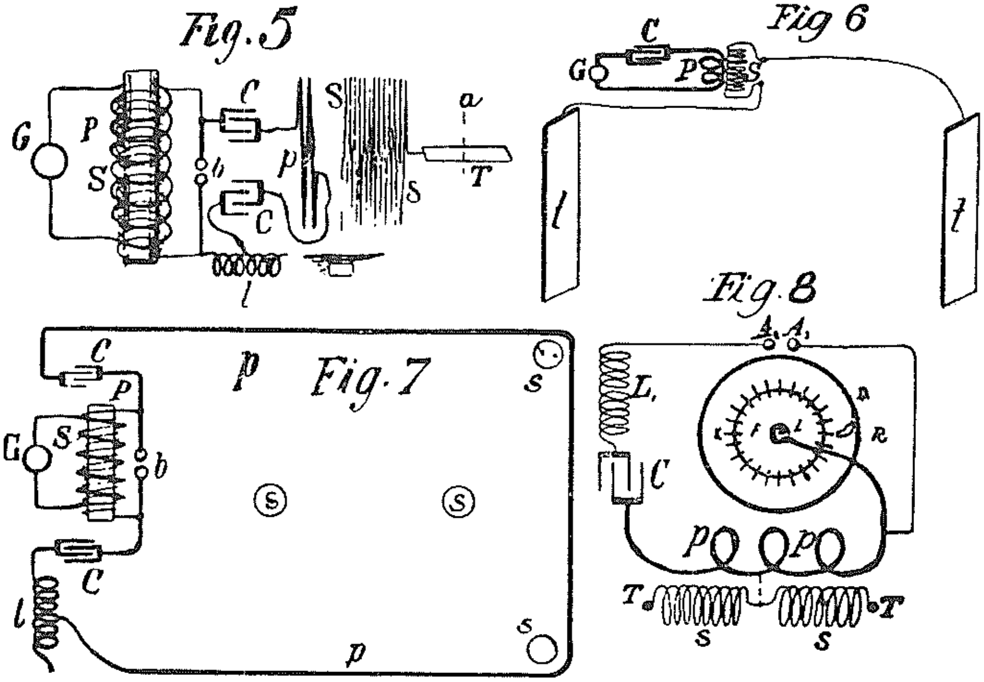

Figs. 5, 6, 7, 8.

The circuit connections as usually made are illustrated schematically in Fig. 5, which, with reference to the diagrams before shown, is self-explanatory. The condensers C C, connected in series, are preferably charged by a step-up transformer, but a high frequency alternator, static machine, or a direct current generator, if it be of sufficiently high tension to enable the use of small condensers, may be used with more or less success. The primary p, through which the high frequency discharges of the condensers are passed, consists of very few turns of cable of as low resistance as possible, and the secondary s, preferably at some distance from the primary to facilitate free oscillation, has one of its ends — that is the one which is nearer to the primary — connected to the ground, while the other end leads to on insulated terminal T, with which the body of the patient is connected. It is of importance in this case to establish synchronism between the oscillations in the primary and secondary circuits p and s respectively. This will be as a rule best effected by varying the self-induction of the circuit including the primary loop or coil p, for which purpose an adjustable self-induction e is provided; but in cases when the electromotive force of the generator is exceptionally high, as when a static machine is used and a condenser consisting of merely two plates offers sufficient capacity, it will be simpler to attain the same object by varying the distance of the plates.

The primary and secondary oscillations being in close synchronism, the points of highest potential will be on a part of terminal T, and the consumption of energy will occur chiefly there. The attachment of the patient's body to the terminal will in most cases very materially affect the period of oscillation in the secondary, making it longer, and a readjustment of the primary circuit will have to be made in each case to suit the capacity of the body connected with terminal T. Synchronism should always be preserved, and the intensity of the action varied by moving the secondary coil to or from the primary, as may be desired. I know of no method which would make it possible to subject the human body to such excessive electrical pressures as are practicable with this, or of one which would enable the conveying to and giving off from the body without serious injury amounts of electrical energy approximating even in a remote degree those which are entirely practicable when this manner of applying the energy is resorted to. This is evidently due to the fact that action is chiefly superficial, the largest possible section being offered to the transfer of the current, or, to say more correctly, of the energy. With a very rapidly and smoothly working break I would not think it impossible to convey to the body of a person and to give off into the space energy at the rate of several horse power with impunity, while a small part of this amount applied in other ways could not fail to produce injury.

When a person is subjected to the action of such a coil, the proper adjustments being carefully observed, luminous streams are seen in the dark issuing from all parts of the body. These streams are short and of delicate texture when the number of breaks is very great and the action of the device b (Fig. 5) free of any irregularities, but when the number of breaks is small or the action of the device imperfect, long and noisy streams appear which cause some discomfort. The physiological effects produced with apparatus of this kind may be graduated from a hardly perceptible action when the secondary is at a great distance from the primary, to a most violent one when both coils are placed at a small distance. In the latter case only a few seconds are sufficient to cause a feeling of warmth all over the body, and soon after the person perspires freely. I have repeatedly, in demonstrations to friends, exposed myself longer to the action of the oscillations, and each time, after the lapse of an hour or so, an immense fatigue, of which it is difficult to give an idea, would take hold of me. It was greater than I experienced on some occasions after the most straining and prolonged bodily exertion. I could scarcely make a step and could keep the eyes open only with the greatest difficulty. I slept soundly afterward, and the after-effect was certainly beneficial, but the medicine was manifestly too strong to be used frequently.

One should be cautious in performing such experiments for more than one reason. At or near the surface of the skin, where the most intense action takes place, various chemical products are formed, the chief being ozone and nitrogen compounds. The former is itself very destructive, this feature being illustrated by the fact that the rubber insulation of a wire is destroyed so quickly as to make the use of such insulation entirely impracticable. The compounds of nitrogen, when moisture is present, consist largely of nitric acid which might, by excessive application, prove hurtul to the skin. So far, I have not noted injuries which could be traced directly to this cause, though on several occasions burns were produced in all respects similar to those which were later observed and attributed to the Röntgen rays. This view is seemingly being abandoned, having not been substantiated by experimental facts, and so also is the notion that these rays are transverse vibrations. But while investigation is being turned in what appears to be the right direction, scientific men are still at sea. This state of things impedes the progress of the physicist in these new regions and makes the already hard task of the physician still more difficult and uncertain.

One or two observations made while pursuing experiments with the apparatus described might be found as deserving mention here. As before stated, when the oscillations in the primary and secondary circuits are in synchronism, the points of highest potential are on some portion of the terminal T. The synchronism being perfect and the length of the secondary coil just equal to one-quarter of the wave length, these points will be exactly on the free end of terminal T, that is, the one situated farthest from the end of the wire attached to the terminal. If this be so and if now the period of the oscillations in the primary be shortened, the points of highest potential will recede towards the secondary coil, since the wave-length is reduced and since the attachment of one end of the secondary coil to the ground determines the position of the nodal points, that is, the points of least potential. Thus, by varying the period of vibration of the primary circuit in any manner, the points of highest potential may be shifted accordingly along the terminal T, which has been shown, designedly, long to illustrate this feature. The same phenomenon is, of course, produced if the body of a patient constitutes the terminal, and an assistant may by the motion of a handle cause the points of highest potential to shift along the body with any speed he may desire. When the action of the coil is vigorous, the region of highest potential is easily and unpleasantly located by the discomfort or pain experienced, and it is most curious to feel how the pain wanders up and down, or eventually across the body, from hand to hand, if the connection to the coil is accordingly made — in obedience to the movement of the handle controlling the oscillations. Though I have not observed any specific action in experiments of this kind, I have always felt that this effect might be capable of valuable use in electro-therapy.

Another observation which promises to lead to much more useful results is the following: As before remarked, by adopting the method described, the body of a person may be subjected without danger to electrical pressures vastly in excess of any producible by ordinary apparatus, for they may amount to several million volts, as has been shown in actual practice. Now, when a conducting body is electrified to so high a degree, small particles, which may be adhering firmly to its surface, are torn off with violence and thrown to distances which can be only conjectured. I find that not only firmly adhering matter, as paint, for instance, is thrown off, but even the particles of the toughest metals are torn off. Such actions have been thought to be restricted to a vacuous inclosure, but with a powerful coil they occur also in the ordinary atmosphere. The facts mentioned would make it reasonable to expect that this extraordinary effect which, in other ways, I have already usefully applied, will likewise prove to be of value in electro-therapy. The continuous improvement of the instruments and the study of the phenomenon may shortly lead to the establishment of a novel mode of hygienic treatment which would permit an instantaneous cleaning of the skin of a person, simply by connecting the same to, or possibly, by merely placing the person in the vicinity of a source of intense electrical oscillations, this having the effect of throwing off, in a twinkle of the eye, dust or particles of any extraneous matter adhering to the body. Such a result brought about in a practicable manner would, without doubt, be of incalculable value in hygiene and would be an efficient and time-saving substitute for a water bath, and particularly appreciated by those whose contentment consists in undertaking more than they can accomplish.

High frequency impulses produce powerful inductive actions and in virtue of this feature they lend themselves in other ways to the uses of the electro-therapeutist. These inductive effects are either electrostatic or electrodynamic. The former diminish much more rapidly with the distance — with the square of the same — the latter are reduced simply in proportion to the distance. On the other hand, the former grow with the square of intensity of the source, while the latter increase in a simple proportion with the intensity. Both of these effects may be utilized for establishing a field of strong action extending through considerable space, as through a large hall, and such an arrangement might be suitable for use in hospitals or institutions of this kind, where it is desirable to treat a number of patients at the same time.

Fig. 6 illustrates the manner, as I have shown it originally, in which such a field of electrostatic action is established. In this diagram G is a generator of currents of very high frequency, C a condenser for counteracting the self-induction of the circuit which includes the primary P of an induction coil, the secondary S of which has two plates t t of large surface connected to its terminals. Well known adjustments being observed, a very strong action occurs chiefly in the space between the plates, and the body of a person is subjected to rapid variations of potential and surgings of current, which produce, even at a great distance, marked physiological effects. In my first experiments I used two metal plates as shown, but later I found it preferable to replace them by two large hollow spheres of brass covered with wax of a thickness of about two inches. The cables leading to the terminals of the secondary coil were similarly covered, so that any of them could be approached without danger of the insulation breaking down. In this manner the unpleasant shocks, to which the experimenter was exposed when using the plates, were prevented.

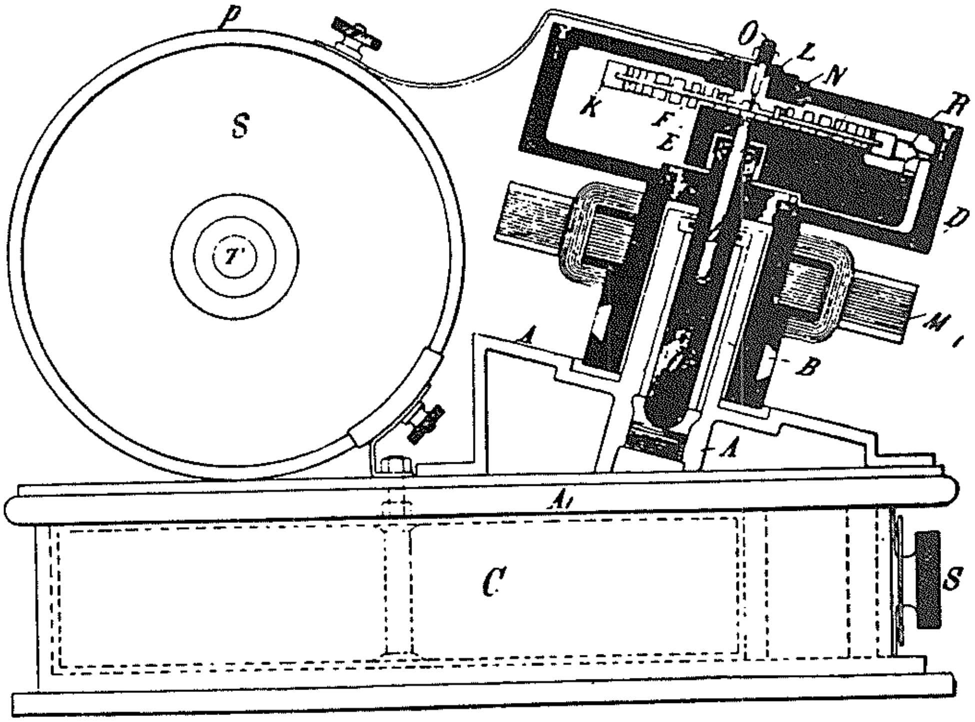

Fig. 9.

In Fig. 7 a plan for similarly utilizing the dynamic inductive effects of high frequency currents is illustrated. As the frequencies obtainable from an alternator are not as high as is desired, conversion by means of condensers is resorted to. The diagram will be understood at a glance from the foregoing description. It only need be stated that the primary p, through which the condensers are made to discharge, is formed by a thick stranded cable of low self-induction and resistance, and passes all around the hall. Any number of secondary coils s s s, each consisting generally of a single layer of rather thick wire, may be provided. I have found it practicable to use as many as one hundred, each being adjusted for a definite period and responding to a particular vibration passed through the primary. Such a plant I have had in use in my laboratory since 1892, and many times it has contributed to the pleasure of my visitors and also proved itself of practical utility. On a latter occasion I had the pleasure of entertaining some of the members with experiments of this kind, and this opportunity I cannot let pass without expressing my thanks for the interest which was awakened in me by their visit, as well as for the generous acknowledgment of the courtesy by the Association. Since that time my apparatus has been very materially improved, and now I am able to create a field of such intense induction in the laboratory that a coil three feet in diameter, by careful adjustment, will deliver energy at the rate of one-quarter of a horse power, no matter where it is placed within the area inclosed by the primary loops. Long sparks, streamers and all other phenomena obtainable with induction coils are easily producible anywhere within the space, and such coils, though not connected to anything, may be utilized exactly as ordinary coils, and what is still more remarkable, they are more effective. For the past few years I have often been urged to show experiments in public, but, though I was desirous to comply with such requests, pressing work has so far made it impossible. These advances have been the result of slow but steady improvement in the details of the apparatus which I hope to be able to describe connectedly in the near future.

However remarkable the electrodynamic inductive effects, which I have mentioned, may appear, they may be still considerably intensified by concentrating the action upon a very small space. It is evident that since, as before stated, electromotive forces of many thousand volts are maintained between two points of a conducting bar or loop only a few inches long, electromotive forces of approximately the same magnitude will be set up in conductors situated near by. Indeed, I found that it was practicable in this manner to pass a discharge through a highly exhausted bulb, although the electromotive force required amounted to as much as ten or twenty thousand volts, and for a long time I followed up experiments in this direction with the object of producing light in a novel and more economical way. But the tests left no doubt that there was great energy consumption attendant to this mode of illumination, at least with the apparatus I had then at command, and, finding another method which promised a higher economy of transformation, my efforts turned in this new direction. Shortly afterward (some time in June, 1891), Prof. J. J. Thomson described experiments which were evidently the outcome of long investigation, and in which he supplied much novel and interesting information, and this made me return with renewed zeal to my own experiments. Soon my efforts were centered upon producing in a small space the most intense inductive action, and by gradual improvement in the apparatus I obtained results of a surprising character. For instance, when the end of a heavy bar of iron was thrust within a loop powerfully energized, a few moments were sufficient to raise the bar to a high temperature. Even heavy lumps of other metals were heated as rapidly as though they were placed in a furnace. When a continuous band formed of a sheet of tin was thrust into the loop, the metal was fused instantly, the action being comparable to an explosion, and no wonder, for the frictional losses accumulated in it at the rate of possibly ten horse power. Masses of poorly conducting material behaved similarly, and when a highly exhausted bulb was pushed into the loop, the glass was heated in a few seconds nearly to the point of melting.

When I first observed these astonishing actions, I was interested to study their effects upon living tissues. As may be assumed, I proceeded with all the necessary caution, and well I might, for I had the evidence that in a turn of only a few inches in diameter an electromotive force of more than ten thousand volts was produced, and such high pressure would be more than sufficient to generate destructive currents in the tissue. This appeared all the more certain as bodies of comparatively poor conductivity were rapidly heated and even partially destroyed. One may imagine my astonishment when I found that I could thrust my hand or any other part of the body within the loop and hold it there with impunity. More than on one occasion, impelled by a desire to make some novel and useful observation, I have willingly or unconsciously performed an experiment connected with some risk, this being scarcely avoidable in laboratory experience, but have always believed, and do so now, that I have never undertaken anything in which, according to my own estimation, the chances of being injured were so great as when I placed my head within the space in which such terribly destructive forces were at work. Yet I have done so, and repeatedly, and have felt nothing. But I am firmly convinced that there is great danger attending such experiment, and some one going just a step farther than I have gone may be instantly destroyed. For, conditions may exist similar to those observable with a vacuum bulb. It may be placed in the field of the loop, however intensely energized, and so long as no path for the current is formed, it will remain cool and consume practically no energy. But the moment the first feeble current passes, most of the energy of the oscillations rushes to the place of consumption. If by any action whatever, a conducting path were formed within the living tissue or bones of the head, it would result in the instant destruction of these and death of the foolhardy experimenter. Such a method of killing, if it were rendered practicable, would be absolutely painless. Now, why is it that in a space in which such violent turmoil is going on living tissue remains uninjured? One might say the currents cannot pass because of the great self-induction offered by the large conducting mass. But this it cannot be, because a mass of metal offers a still higher self-induction and is heated just the same. One might argue the tissues offer too great a resistance. But this again cannot be the reason, for all evidence shows that the tissues conduct well enough, and besides, bodies of approximately the same resistance are raised to a high temperature. One might attribute the apparent harmlessness of the oscillations to the high specific heat of the tissue, but even a rough quantitative estimate from experiments with other bodies shows that this view is untenable. The only plausible explanation I have so far found is that the tissues are condensers. This only can account for the absence of injurious action. But it is remarkable that, as soon as a heterogeneous circuit is constituted, as by taking in the hands a bar of metal and forming a closed loop in this manner, the passage of the currents through the arms is felt, and other physiological effects are distinctly noted. The strongest action is, of course, secured when the exciting loop makes only one turn, unless the connections take up a considerable portion of the total length of the circuit, in which case the experimenter should settle upon the least number of turns by carefully estimating what he loses by increasing the number of turns, and what he gains by utilizing thus a greater proportion of the total length of the circuit. It should be borne in mind that, when the exciting coil has a considerable number of turns and is of some length, the effects of electrostatic induction may preponderate, as there may exist a very great difference of potential — a hundred thousand volts or more — between the first and last turn. However, these latter effects are always present even when a single turn is employed.

When a person is placed within such a loop, any pieces of metal, though of small bulk, are perceptibly warmed. Without doubt they would be also heated — particularly if they were of iron — when embedded in living tissue, and this suggests the possibility of surgical treatment by this method. It might be possible to sterilize wounds, or to locate, or even to extract metallic objects, or to perform other operations of this kind within the sphere of the surgeon's duties in this novel manner.

Most of the results enumerated, and many others still more remarkable, are made possible only by utilizing the discharges of a condenser. It is probable that but a very few — even among those who are working in these identical fields — fully appreciate what a wonderful instrument such a condenser is in reality. Let me convey an idea to this effect. One may take a condenser, small enough to go in one's vest pocket, and by skilfully using it he may create an electrical pressure vastly in excess — a hundred times greater if necessary — than any producible by the largest static machine ever constructed. Or, he may take the same condenser and, using it in a different way, he may obtain from it currents against which those of the most powerful welding machine are utterly insignificant. Those who are imbued with popular notions as to the pressure of static machines and currents obtainable with a commercial transformer, will be astonished at this statement — yet the truth of it is easy to see. Such results are obtainable, and easily, because the condenser can discharge the stored energy in an inconceivably short time. Nothing like this property is known in physical science. A compressed spring, or a storage battery, or any other form of device capable of storing energy, cannot do this; if they could, things udreamt of at present might be accomplished by their means. The nearest approach to a charged condenser is a high explosive, as dynamite. But even the most violent explosion of such a compound bears no comparison with the discharge or explosion of a condenser. For, while the pressures which are produced in the detonation of a chemical compound are measured in tens of tons per square inch, those which may be caused by condenser discharges may amount to thousands of tons per square inch, and if a chemical could be made which would explode as quickly as a condenser can be discharged under conditions which are realizable — an ounce of it would quite certainly be sufficient to render useless the largest battleship.

That important realizations would follow from the use of an instrument possessing such ideal properties I have been convinced since long ago, but I also recognized early that great difficulties would have to be overcome before it could replace less perfect implements now used in the arts for the manifold transformations of electrical energy. These difficulties were many. The condensers themselves, as usually manufactured, were inefficient, the conductors wasteful, the best insulation inadequate, and the conditions for the most efficient conversion were hard to adjust and to maintain. One difficulty, however, which was more serious than the others, and to which I called attention when I first described this system of energy transformation, was found in the devices necessarily used for controlling the charges and discharges of the condenser. They were wanting in efficiency and reliability and threatened to prove a decided drawback, greatly restricting the use of the system and depriving it of many valuable features. For a number of years I have tried to master this difficulty. During this time a great number of such devices were experimented upon. Many of them promised well at first, only to prove inadequate in the end. Reluctantly, I came back upon an idea on which I had worked long before. It was to replace the ordinary brushes and commutator segments by fluid contacts. I had encountered difficulties then, but the intervening years in the laboratory were not spent in vain, and I made headway. First it was necessary to provide for a circulation of the fluid, but forcing it through by a pump proved itself impractical. Then the happy idea presented itself to make the pumping device an integral part of the circuit interrupter, inclosing both in a receptacle to prevent oxydation. Next some simple ways of maintaining the circulation, as by rotating a body of mercury, presented themselves. Then I learned how to reduce the wear and losses which still existed. I fear that these statements, indicating how much effort was spent in these seemingly insignificant details will not convey a high idea of my ability, but I confess that my patience was taxed to the utmost. Finally, though, I had the satisfaction of producing devices which are simple and reliable in their operation, which require practically no attention and which are capable of effecting a transformation of considerable amounts of energy with fair economy. It is not the best that can be done, by any means, but it is satisfactory, and I feel that the hardest task is done.

The physician will now be able to obtain an instrument suitable to fulfil many requirements. He will be able to use it in electro-therapeutic treatment in most of the ways enumerated. He will have the facility of providing himself with coils such as he may desire to have for any particular purpose, which will give him any current or any pressure he may wish to obtain. Such coils will consist of but a few turns of wire, and the expense of preparing them will be quite insignificant. The instrument will also enable him to generate Röntgen rays of much greater power than obtainable with ordinary apparatus. A tube must still be furnished by the manufacturers which will not deteriorate and which will allow to concentrate larger amounts of energy upon the electrodes. When this is done, nothing will stand in the way of an extensive and efficient application of this beautiful discovery which must ultimately prove itself of the highest value, not only at the hands of the surgeon, but also of the electro-therapist and, what is most important, of the bacteriologist.

To give a general idea of an instrument in which many of the latter improvements are embodied, I would refer to Fig. 9, which illustrates the chief parts of the same in side elevation and partially in vertical cross-section. The arrangement of the parts is the same as in the form of instrument exhibited on former occasions, only the exciting coil with the vibrating interrupter is replaced by one of the improved circuit breakers to which reference has been made.

This device comprises a casting A with a protruding sleeve B, which in a bushing supports a freely rotatable shaft a. The latter carries an armature within a stationary field magnet M and on the top, a hollow iron pulley D, which contains the break proper. Within the shaft a, and concentrically with the same, is placed a smaller shaft b, likewise freely movable on ball-bearings and supporting a weight E. This weight being on one side and the shafts a and b inclined to the vertical, the weight remains stationary as the pulley is rotated. Fastened to the weight E is a device R in the form of a scoop with very thin walls, narrow on the end nearer to the pulley and wider on the other end. A small quantity of mercury being placed in the pulley and the latter rotated against the narrow end of the scoop, a portion of the fluid is taken up and thrown in a thin and wide stream towards the centre of the pulley. The top of the latter is hermetically closed by an iron washer, as shown, this washer supporting on a steel rod L a disk F of the same metal provided with a number of thin contact blades K. The rod L is insulated by washers N from the pulley, and for the convenience of filling in the mercury a small screw o is provided. The bolt L forming one terminal of the circuit breaker is connected by a copper strip to the primary p. The other end of the primary coil leads to one of the terminals of the condenser C, contained in a compartment of a box A, another compartment of the same being reserved for switch S and terminals of the instrument. The other terminal of the condenser is connected to the casting A and through it to pulley D. When the pulley is rotated, the contact blades K are brought rapidly in and out of contact with the stream of mercury, thus closing and opening the circuit in quick succession. With such a device it is easy to obtain ten thousand makes and breaks per second and even more. The secondary a is made of two separate coils and so arranged that it can be slipped out, and a metal strip in its middle connects it to the primary coil. This is done to prevent the secondary from breaking down when one of the terminals is overloaded, as it often happens in working Röntgen bulbs. This form of coil will withstand a very much greater difference of potential than coils as ordinarily constructed.

The motor has both field and armature built of plates, so that it can be used on alternating as well as direct current supply circuits, and the shafts are as nearly as possible vertical, so as to require the least care in oiling. Thus, the only thing which really requires some attention is the commutator of the motor, but where alternating currents are always available, this source of possible trouble is easily done away with.

The circuit connections of the instrument have been already shown and the mode of operation explained in periodicals. The usual manner of connecting is illustrated in Fig. 8, in which A_2 A_2 are the terminals of the supply circuit, L, a self-induction coil for raising the pressure, which is connected in series with condenser C and primary P P. The remaining letters designate the parts correspondingly marked in Fig. 9 and will be understood with reference to the latter.

THE MAGNETIC-ARC INSTRUMENT OF S.S. KNIGHT

by Mark L. Gallert

Reprinted from
NEW LIGHT ON THERAPEUTIC ENERGIES, 1976

Mr. Knight, a chemical and electrical engineer of Walnut Creek, California, was impressed with the severity and persistence of pain suffered in certain types of cancer. Realizing that pain is a sensation representative of an electrical phenomenon of excessive nerve-current flow, he decided to experiment to see if there was some way of interfering with that nerve flow through artificial impulses, in the effort to stop or alleviate the pain.

Towards this end, he developed an instrument combining several features of electro-therapy:

1. A wave pulsed at 90 times per minute, taking advantage of data obtained from experience with the older types Faradic machines.
2. A rest interval exceeding 75% of the duration of each pulsing cycle - enhances the beneficial effect.
3. Breaking the treatment by mechanical opening of contacts in such a way as to create an arc at each of the pulsing intervals. An arc produces a very wide band of frequencies, from those of very low frequency, to the highest that can be measured. The multiplicity of frequencies seems to play a part in masking or interrupting the sensation of pain.
4. A unique feature of the Knight instrument is that the arc is broken in a strong magnetic field produced by a large, powerful, permanent magnet. This introduces what is called the "Zeeman effect", that is, a magnification of the arc impulses, and a spreading of frequencies.
5. Use of very low power output - below 1/100 of a watt, so that there will be no perceptible heating of tissue when the complex of impulses from the instrument are fed to the patient through electrodes applied to the skin.

Experiments on cases which had been declared terminal cancer by medical doctors, showed that this device not only brought outstanding relief of pain in the majority of instances, but also produced some surprising "remissions" characterized by shrinking of tumour masses, and restoration of general health to the patient.

Dr. C.P. Bryant of Seattle, Washington, who used these instruments extensively in his practice over a period of years, declared that with their use he was able to restore to health 75% of all cancer cases which had not undergone surgery, X-ray or radium, and 25% of those cancer cases which had been subjected to surgery, X-ray or radium.

The Knight family has never represented these instruments as a "cancer cure". The original aim was to find some way to relieve the pain of cancer. Reports from doctors of apparent cures through use of the instruments were received with interest, as well as reports of benefits from the application of the instrument to conditions other than cancer.

Mr. S.S. Knight, a man with pronounced humanitarian ideals, made the circuit of the instrument available to all inquirers and encouraged the building of instruments by anyone who wished to copy his circuit and specifications. He was keenly disappointed when reports reached him of failure, or lack of therapeutic effect from instruments constructed by others. It developed that adjustments were quite critical, particularly concerning the making and breaking of the arc. Mr. Knight could tell by looking at the arc and listening to it, when it was "right". It was difficult to develop objective criteria for adjustment of the equipment.

A puzzling circumstance, was that the maximum effect from Mr. Knight's instruments was obtained when they were new; after a few weeks of use the effect began to diminish; after some months it was perceptibly weaker, and after a year or more, of very little use. Several years ago, the reason for the lessening of effect was determined. The isolation transformer used to block the direct flow of the arc frequencies from the electric line supply (an isolation required to eliminate radio interference) was being saturated by the magnetism from the large magnet surrounding the arc. The more saturated the transformer became, the less electricity it passed. The equipment was re-designed to place the transformer out of range of the field of the magnet.

The instrument can be classed with experimental devices, as there have not been sufficient tests made under controlled conditions to establish with certainty the percentage of cases of various types of cancer that can be alleviated, arrested, and perhaps cured, but the tests to date indicate at least that this is a promising approach, which should be explored further.

An imitation instrument has been marketed by others, using an electro-magnet instead of a permanent magnet. Mr. Knight was opposed to this substitution, having a number of reasons for believing that the permanent magnet was preferable. Other changes have also been made in constructing these imitation instruments, including the type of electrodes. So far as your compiler has been able to determine, the instruments using electro-magnets have some value in relieving pain in a variety of conditions, but the effect on cancer seems to be slower and less pronounced than that obtained from the genuine Knight instruments when the latter are functioning properly and are in adjustment.

electronics

April 20, 1962

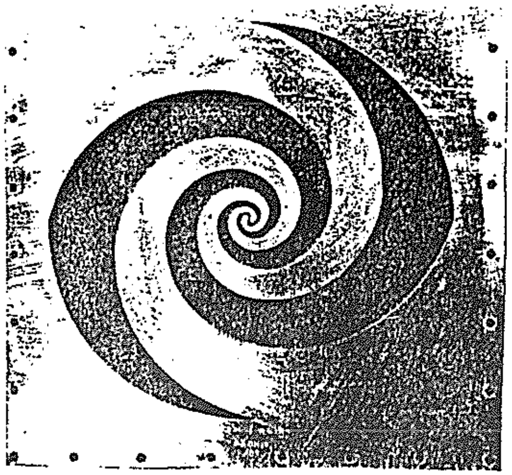

FIG. 1—Balanced planar equiangular or logarithmic spiral-slot antenna (left) radiates a broad circularly polarized beam on each side of, and perpendicular to, the plane of the antenna

Frequency-Independent Antennas

SURVEY OF DEVELOPMENT

Antennas now provide continuous coverage of large portions of the frequency spectrum. These very-wide-band antennas offer a challenge to the systems engineer to design equipment that will match bandwidths now available

By JOHN D. DYSON
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THE NECESSITY of providing continuous coverage of large portions of the electromagnetic frequency spectrum for defense purposes has exerted great pressure on the antenna engineer to produce antennas that could be used over wider and wider bands of frequencies. Such requirements have led to an important breakthrough in the antenna field. The conception of the frequency-independent antennas at the University of Illinois and their development at this and at other laboratories has produced advances in the state of the art that now puts pressure on the electronics and system engineer to design equipment that will match the available antenna bandwidths. The purpose of this survey is to outline the development of these antennas.

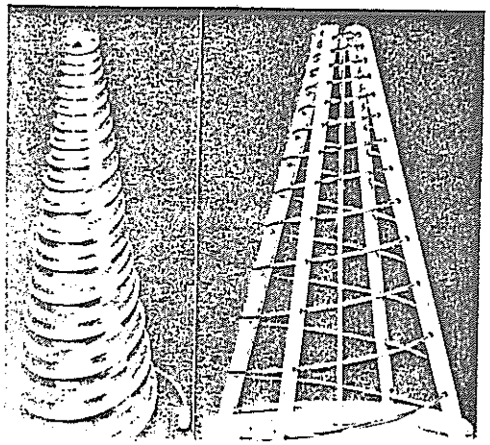

FIG. 2—Balanced conical logarithmic spiral antenna (left) with feed cable carried along one arm; wire version of balanced conical logarithmic spiral antenna (right), fed with coaxial line and balun along axis of cone

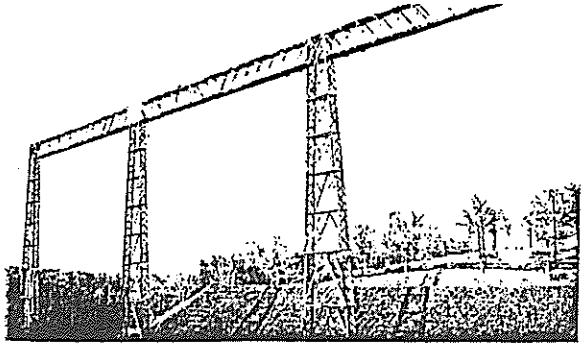

FIG. 3—The University of Illinois radio telescope. The focal line array, 153 feet above the 400-by-600-foot parabolic reflector, is visible below the wooden truss

As of 1945, antenna research and development had led to a few structures that operated over a 2 to 1 or slightly greater range of frequencies, with acceptable radiation and impedance characteristics. In a majority of cases, it was the radical changes in the radiation pattern with changes in operating frequency which limited the usefulness of antennas to somewhat less than this 2 to 1 range, since antennas had been developed with an input impedance that remained relatively constant with a change in frequency.

The discone antenna[1] introduced in 1946 was one of the first antennas that could be used over approximately a 4-to-1 range of frequencies. Advances during the next 7 or 8 years were limited, mainly, to increasing the bandwidth of existing antennas by a few percent. The one exception during this period was a modified helical antenna[2, 3, 4]. These unbalanced conical helical structures, fed against a ground plane, had acceptable pattern bandwidths of 4 or 5 to 1.

The spiral antenna introduced in 1953 was a major step forward in wide band antenna design. This construction consists of two flat, narrow, constant-width metallic arms, wound in an Archimedean spiral.[5] Fed at the center in a balanced manner, it radiates a broad circularly polarized lobe on each side of the plane of the antenna. Subsequent development of this configuration produced forms that had stable pattern and impedance characteristics over bandwidths up to 10 to 1.[6-8]

Arrays of the Archimedes spiral antenna provide variable polarization of the radiated field[9] and beam scanning by simple rotation of the antennas.[10-12]

In 1954 a major breakthrough occurred when V. H. Rumsey suggested that an infinite length structure based upon the equiangular or logarithmic spiral could be specified completely in terms of angles, and hence it should have characteristics independent of frequency. A study of balanced planar antennas based on these curves disclosed the equiangular spiral antenna to be the first antenna of practical size that had characteristics associated with an infinite structure.[13, 14] This structure became the first of a class now called frequency-independent antennas.[15]

This descriptive term is applied to antennas set apart from the usual concepts of operating bandwidth. The upper and lower frequencies at which these antennas may be operated are determined by independent paramters, and hence the bandwidth over which the radiation pattern and input characteristics are essentially constant is theoretically unlimited. Actually, the bandwidth is limited only by practical considerations of construction, and such antennas have been built to operate over a bandwidth of more than 42 to 1. There is no fundamental reason why this bandwidth cannot be extended.

The general philosophy behind the frequency-independent antennas is to design a radiating structure such that successive applications of a scaling factor result in structures identical with the original, or which at most, differ by some rotation about an axis through the origin of the original structure. Although the structure must be infinite in size to fulfill the scaling condition of exact equivalence, forms based upon the equiangular, or logarithmic, spiral curve may be truncated to a finite size and still retain, over an extremely wide range of frequencies, characteristics associated with the infinite structure.

A second breakthrough occurred in 1955 when R. H. Du Hamel proposed to force radiation from otherwise angular structures by periodic discontinuities. This led to a linearly polarized antenna with pattern and impedance characteristics that repeat periodically with the logarithm of frequency.[16-18] Although these logarithmic-periodic antennas scale exactly at only certain discrete frequencies, they can be designed so that the radiation characteristics do not change appreciably over the period between these frequencies. Hence they also exhibit nearly frequency-independent characteristics.

Many versions of the log-spiral and log-periodic antennas have been developed. The planar log-spiral antenna shown in Fig. 1 is bidirectional, radiating a broad circularly polarized beam on each side of, and perpendicular to, the antenna plane.[19] This spiral antenna may be made unidirectional, and hence more useful, by an orthogonal projection of the balanced spiral arms upon the surface of a cone (see Fig. 2 left).[20-22] For included cone angles less than about 45 degrees, radiation is confined to one broad circularly polarized lobe with maximum radiation off the apex of the cone. The antenna is balanced, with the feed voltage applied between the two arms at the apex of the cone. This feed voltage may be supplied by a conventional balanced line carried along the axis of the cone, or by a coaxial line and balun.

The characteristics of equiangu-

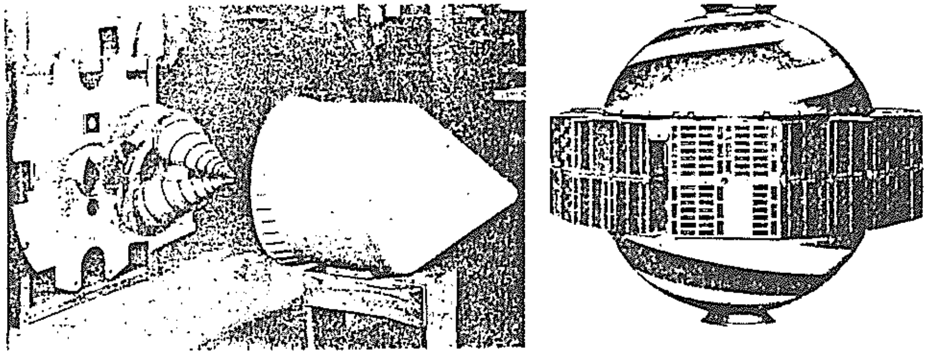

FIG. 4—First production of Dynatronics 500-to-4,000-Mc dual conical spiral Autorack feed for 40-foot diameter parabolic reflector (left); Transit 3B satellite (right) by Applied Physics Lab. of the Johns Hopkins University. The logarithmic spiral antenna projected onto the spherical surface provides for transmission at 54, 108, 162 and 216 Mc

lar spiral antennas permit a third method. The feed line, a coaxial cable, may be carried along and soldered in contact with one of the arms. The amplitude of the antenna currents on the arms, and also on the outside of the cable, fall off rapidly with distance from the apex, so the ends of the arms where the cable enters carry negligible antenna current. This optional feed, conveniently and automatically, provides a frequency-independent balun, permitting feeding the balanced antenna by means of an unbalanced line.

Conical log-spiral antennas have been constructed to operate over more than 40-to-1 bandwidths. The upper usable frequency is determined by the truncated region at the apex which must remain less than 1/4 wavelength at the highest frequency of operation. The lowest usable frequency is determined by the base diameter of the cone which, for tightly wrapped antennas, must be approximately 3/8 wavelength at lowest operating frequency.

A highly practical conical log-spiral antenna can be constructed by allowing the exponentially expanding arms to degenerate into narrow constant width structures following the logarithmic spiral curve (see Fig. 2 right).[illegible] For tightly wrapped spirals this version has characteristics similar to the original antenna. This wire version, simple to construct, may be excited by bringing the feed cable up the axis of the cone. If the infinite balun feed is desired, the feed cable itself can become one of the arms, with a dummy cable becoming the second arm of a balanced structure.

The balanced conical log-spiral antenna has characteristics other than bandwith that are attractive. The electromagnetic fields radiated by these antennas are essentially circularly polarized over very wide angles off the axis of the antenna. In addition, the phase of the far field of the two-arm antenna has essentially a one-to-one relationship with the azimuthal angle around the antenna. These two properties were utilized in the line feed for the University of Illinois radio telescope shown in Fig. 3. The focal-line array for this 400-by-600-foot parabolic reflector consists of a linear array of 286 conical logspiral antennas.[illegible] The beam is steerable in declination ±30 degrees and the phase adjustment to provide this scan is secured by a physical rotation of each element of the array to a prescribed orientation. Thus it is of importance that the beam of each element be circularly polarized over at least a sector ±30 degrees from the axis and that the phase of the radiated field be linearly related to the angle of orientation around the antenna.

Multiarm versions of the balanced conical log-spiral antenna operate in several distinct modes.[illegible] Thus a four-arm symmetrical structure may be excited to radiate an axial beam with an $e^{j\phi}$ variation, that is, the phase of the far field varies linearly with the azimuthal angle ϕ, around the antenna. It can be excited to produce a conical beam with an $e^{j\phi}$ and a conical beam with an $e^{j\phi}$ variation. Since orientation of the maximum of the conical beam may be controlled by varying the rate of spiral of the antenna arms, it can be positioned perpendicular to the axis of the antenna to provide a simple very-wide-band circularly polarized omnidirectional source. The well-behaved phase characteristics of these antennas suggest the basis for many variations of phase-comparison direction-finding systems.[illegible]

The conical log-spiral antennas have been developed as feeds for dishes used in tracking applications.[illegible] A modernization program is now under way to equip many of the large parabolic reflector antennas on the Atlantic Missile Range with dual conical spiral feeds designed to cover a 10-to-1 range of frequencies.[illegible] The first production model of one of these feeds is shown in Fig. 4 (left).

In an interesting modification of the log-spiral geometry, the planar antenna, was projected upon a spherical surface and used on the Transit satellites[illegible] shown in Fig. 4 (right). Although this geometry is no longer frequency independent, the antenna operates well over four frequencies, spaced from 54 to 216 Mc. Similarly, the planar antenna can be projected upon a myriad of surfaces. However, it can be shown that the conical surface, which includes the plane, is the only surface satisfying the required scaling principles for unlimited bandwidth.

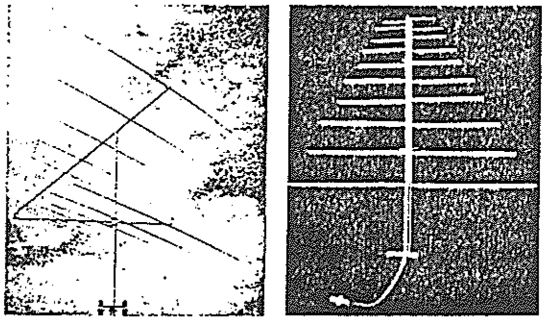

FIG. 5—Trapezoidal tooth nonplanar log-periodic antenna (left) designed by Collins Radio Company to cover 6.5 to 60 Mc; and logarithmic periodic dipole array (right)

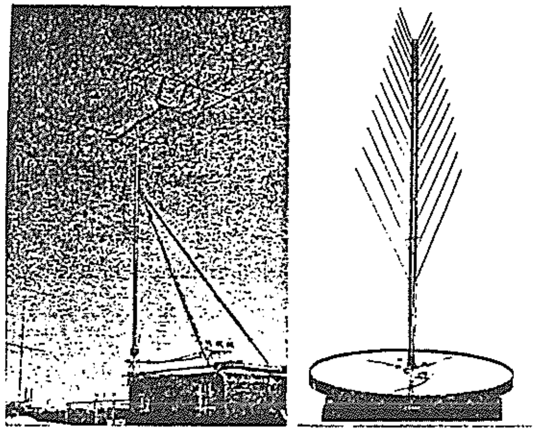

FIG. 6—Militarized version of the log-periodic dipole array (left) by Collins Radio Company; and log-periodic resonant-V array (right), an adaption of the log-periodic dipole array, designed to operate in several different modes

The log-periodic antennas have been extensively investigated. The planar antenna can be modified to provide unidirectional patterns by forming the two elements of the antenna into a V, that is, a nonplanar arrangement.[illegible] A wire version of the log-periodic elements (see Fig. 5 left), and omnidirectional horizontally polarized, and unidirectional circularly polarized log-periodic antennas have been described.[illegible] Multielement arrays have been described,[illegible] and design information for log-periodic antennas as feeds for dishes, and as point-to-point h-f communications antennas has been given.[illegible]

The dipole array of Fig. 5 (right) is a simple log-periodic structure.[illegible] The length of each element in this array bears a fixed ratio to the length of the preceding element, and the adjacent element spacings bear the same ratio one to another. The pattern and impedance characteristics of the array at frequency f_n, such that the nth element is resonant, will be repeated at a higher frequency f_{n+1}, which makes the $(n + 1)$th element resonant. The characteristics repeat periodically at all frequencies given by $\tau^n f$, where n is an integer and τ the ratio of the lengths of adjacent elements. The geometry shown in this figure provides an excitation with a 180-deg phase shift between elements. Thus it radiates a single-lobe, linearly polarized beam, directed toward the apex of the array. Analysis and design information for this array has been presented.[illegible] A militarized version of the antenna is shown in Fig. 6 (left).

In an extension of this work, a log-periodic monopole array has been described in which simple reactive networks produce the proper monopole current amplitude and phase distribution for unidirectional frequency-independent operation.[illegible] A slot complement of the log-periodic dipole array has also been investigated.[illegible]

The log-periodic resonant-V array[illegible] (Fig. 6 right) is an adaptation of the log-periodic dipole array, designed to operate in several modes. In the lowest order mode, the performance approximates the log-periodic array. The active portion of the antenna centers around elements whose lengths are near a half-wavelength at the frequency of operation. As the operating frequency is increased, this active region moves toward the apex. The antenna may be designed so that as the $\lambda/2$ region moves off the apex of the antenna the large elements on the other end approach a $3\lambda/2$ resonance. Thus, as the operating frequency is increased, the active region moves through the array in the $3\lambda/2$ wave mode, then in the $5\lambda/2$ mode, etc. Forward tilt of the individual elements insures a unidirectional beam and provides increased directivity. This antenna has transition regions between modes where the characteristics deteriorate, but it can provide a gain of approximately 18 db over an isotropic radiator in the higher modes.

Triangular or zig-zag log-periodic structures have received considerable attention. A flush-mounted sinuous structure, fed by a waveguide, has been studied, and a balanced zig-zag antenna has been proposed. A vertically polarized log-periodic zig-zag antenna is shown in Fig. 7. The teeth bent parallel to the ground plane serve as a delay line to phase the vertical radiating portions.

Tapering structures, not constructed in a logarithmic periodic manner, have led to antennas of appreciable bandwidth. One tapered ladder antenna consists of symmetrical elements excited by a balanced line. In addition long slot, tapered feed, structures that can be used over a 10-to-1 bandwidth have been proposed. A radiating horn with side walls of periodically spaced wires, when fed from a ridged waveguide, can be operated over a 4-to-1 range of frequencies.

The frequency-independent antennas have opened up a new era in wide-band antennas. However, in view of their complex geometry, the experimental and empirical development of these antennas have outstripped their theoretical analysis.

The theoretical problem of the log-spiral antenna has received considerable attention. This problem has been attacked by calculating the fields due to a logarithmic spiral filament, and the fields produced by an infinite number of planar logarithmic spiral filaments. An approximate analysis for the radiation patterns of a filamentary log-spiral antenna with an assumed current distribution has been published.

A recent comprehensive analysis of the log-periodic dipole array has been reported.

A new and promising approach considers the log-periodic antenna as a locally periodic structure whose period varies slowly, increasing linearly with distance to the origin or apex. This approach indicates that the basic ingredients for a frequency-independent antenna are a slow-wave transmission medium and a series of radiating elements, satisfying the similarity condition, coupled to the transmission medium at points spaced in geometric progression. Such a structure produces a wave substantially radiated toward the feed point with characteristics that vary little as the operating frequency is varied over extremely wide bandwidths.

A general consideration of the log periodic zig-zag antennas and the conical log-spiral antennas as locally periodic, slow wave structures has led to a better understanding of their operation and to some useful design criteria.

This survey has covered the work of many people. It has been impossible to acknowledge the work of many others, however an extensive list of references has been included.

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Medical Aspects of Ultra Short Waves

By C. H. West

U. S. Public Health Service

Mr. West here describes some of the effects and also some of the dangers of subjecting the human body to powerful ultra short wave fields

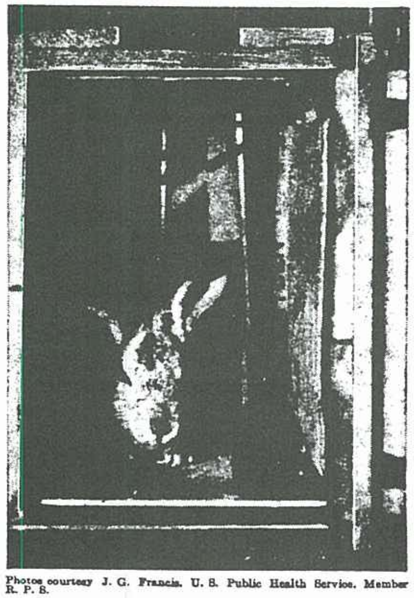

Photos courtesy J. G. Francis. U. S. Public Health Service. Member R. P. S.

Above—A rabbit about to be exposed to a powerful ultra short wave field; the sides as well as the top and bottom linings of the cabinet are of metal.

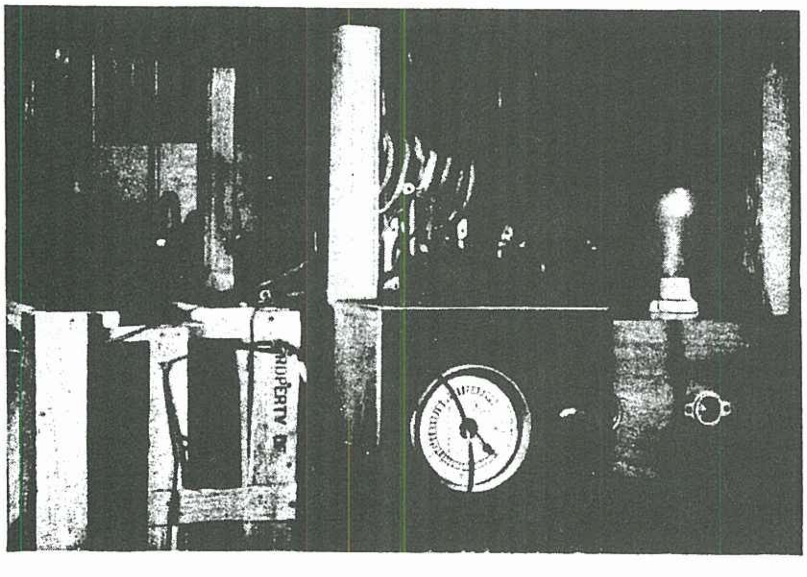

At left—The appearance of the ultra short-wave apparatus built and tested by Mr. West in his experiments.

● IT SEEMS that the general public is once again taking to radio and the art of building as a pastime. The amateurs are busy developing the five meter band, while the engineers are devoting a goodly portion of their time to dabbling in the mysteries that the ultra short waves have created.

On the other hand, medical-scientific personages are making use of their medical knowledge, plus a large portion of electronics, in efforts to make the world a better place to live in with less aches and pains to bother us.

Many engineers employed in large electrical laboratories have made valuable use of their knowledge pertaining to the ultra short waves, and have constructed oscillators of high power for the purpose of producing fever in the human body at will. It is a known fact that fever is nature's doctor to a certain degree. If it can be produced in cases where there is no cause for a high fever, the patient's chance for recovery and cure is far better than combatting disease by injection of malaria germs, etc., which may produce reactions worse than the disease itself.

Unknown Qualities

However, the production of fever by an oscillator is a simple procedure, but the application of these high wave speeds to the human body is an entirely different matter. Secondly, the output or radiation of an ultra high frequency oscillator has never been completely identified.

It seems that for every known element discovered there are many others within—undiscovered. An illustration of this fact was brought to light very recently, in which the writer witnessed a demonstration of photo-electric cell work.

A double-cell apparatus manufactured by the Weston Electrical Instrument Corporation produced readings in foot-candles from the output of a 10 k. w. X-ray tube in which the cells were completely covered by ⅛ inch lead sheet.

The roentgen rays do not penetrate lead, and as the tube was quite a distance from the cells, the reaction in the sensitive meter was not due to heat waves, but simply a current output which registered through the lead upon the faces of the cells. The X-ray is noted for producing very bad burns if not handled properly, and the deflection from the *target* is called and identified as the *roentgen ray* after the name of the discoverer. How does science know whether the burns are caused from this additional element as registered in *foot candles*, for want of a better name?

U. S. W. "Fever" Apparatus

Recently, the writer constructed and put into practice an *ultra short wave oscillator* for the production of fever or temperature. This apparatus consisted of two UX-852 tubes arranged in push-pull, but with the "back-to-back" arrangement of *Mesny-Valuri*. It is a persistent oscillator and is capable of running long hours on wavelengths from 2 to 10 meters.

An auxiliary cabinet was constructed with two leads to couple across the plate inductance. This cabinet has one adjustable side; the top and bottom being one lead, and the two sides the other and forming a large condenser.

Rabbits were used in experiments and their temperature reached 41 degrees (Centigrade) from the usual 38 degrees (normal). However, after a few weeks severe burns were noticed. Since that time research has been carried on by other factions in an effort to ascertain the direct cause of the burns, which do not seem to be due to collections of moisture, or from coming in contact with the condenser plates.

This brings to mind that experiments by the writer with the very short waves disclose the fact that some sort of a photo-electric ray could be produced and would highly expose small dental films. It is believed this elementary action was first discovered by Mr. John Reinartz, the noted radio amateur, who perceived a bluish glow within an auxiliary indicator at a certain frequency.

Before any actual application to humans may be applied, it is our duty to ascertain accurately whether other elements are prevailing. To all indications there are many, and one of them is severe burns, which may be caused by an unidentified element.

Constructional Data and Summary

As will be noted in the photographs, the apparatus is entirely enclosed and surrounded by glass sides to better view the "works" in case things tend to go the "hay-wire" route. The lower portion of the cabinet contains the necessary plate and filament transformers, which operate direct from the 110 volt, 60 cycle line. The plate power is raw A. C. at a potential of 2600 volts, the filament transformer being the customary 10 volt affair. Inductances are removable; the ones shown are at present used for 30,000 kc. work. The circuit is shown in Fig. 1, which is the conventional push-pull method.

However, the auxiliary cabinet is for purpose of holding an animal within the field and without strapping him and causing discomfort. The condenser plates are of sheet metal and insulated, the schematic diagram appearing in Fig. 2.

When a rabbit is placed in this pen and the power applied, he fails to react immediately; but as he "warms" up to the situation the veins in the ears show dilation, and in 20 minutes his temperature starts to rise and keeps going. It is only at a much later date that burns are noticed.

From the foregoing it would hardly seem advisable to subject a human to any lengthy treatment, at least, for the present; but the value of high frequency in various forms have proved essential in many cases. Secondly, the natural heavy perspiration that is produced is essential in one degree in opening the pores (some of which have probably never been opened before) and allowing the natural poisons of the body to escape more quickly than could have been accomplished with potent medicines.

The majority of high frequency apparatus produces this result. In the case of pulsating currents, which produce a series of reactions or "jumps" within the muscular system, this often is very beneficial in activating those muscles which could not have been manipulated manually without a great degree of pain.

Probably the first reaction noticed with reference to the ultra high frequencies were from early experimenters while conducting transmission tests with high power. It was noticed that the body temperature tended to rise at various times, due entirely to their proximity to a powerful oscillator. Science has been looking for a long time for some method to raise the temperature in the human body *quickly*. Ultra high frequency oscillators have solved that problem but have brought many other matters to light. Secondly, to produce the desired results the patient must be enclosed between two or more condenser plates of large proportions. The oscillator must be of high power, capable of delivering 500 watts output and the patient must be wrapped in a suitable covering to prevent his contact with any portion of the charged plates.

Various research workers who have volunteered their services as "trial patients" have received a goodly portion of burns as compensation, and are quite satisfied that ultra high frequency currents are "hot stuff!" Where heat is concerned, one could get equivalent results by setting on a hot steam radiator. The writer knows this to be true, and has experienced many a painful burn which he would have been willing to trade for a shock from a quarter kw. closed-core transformer.*

It could hardly seem probable that burns would prevail where the body is not in contact with any metallic object; but an examination under darkness of a large condenser tapped from the oscillator, will disclose a bluish aurora between the two elements, which is similar to that noted in Tesla coil experiments. Within this bluish discharge there can be many components not yet identified, which have a tendency to attack tender portions of the body and produce an internal burn, which does not come to the surface for identification until some days have passed.

It is open to discussion whether one-half of the electrical apparatus in present use actually cures the patient of pains, or whether it is the psychology of the matter in which the patient is surrounded by many cabinets of mysteries, of which he knows absolutely nothing. What cures one man does not seem to cure another with the identical complaint.

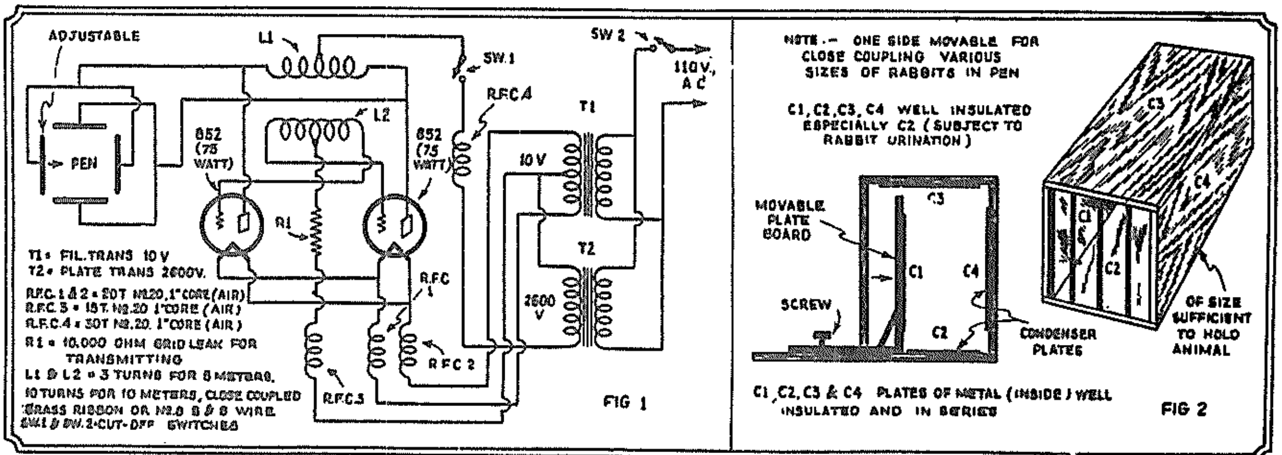
ADJUSTABLE
L1
SW 2
SW.1
110V., A C
RFC 4
T1
L2
852 (75 WATT)
852 (75 WATT)
PEN
10 V
R1
T2
R.F.C 1
2600 V
RFC 2
R.F.C.3
T1 = FIL. TRANS 10 V
T2 = PLATE TRANS 2600V.
R.F.C. 1 & 2 = 20T No.20, 1" CORE (AIR)
R.F.C. 3 = 15T. No.20 1" CORE (AIR)
R.F.C. 4 = 30T No.20. 1" CORE (AIR)
R1 = 10,000 OHM GRID LEAK FOR TRANSMITTING
L1 & L2 = 3 TURNS FOR 5 METERS.
10 TURNS FOR 10 METERS, CLOSE COUPLED
BRASS RIBBON OR No.8 B & S WIRE
SW.1 & SW.2-CUT-OFF SWITCHES
FIG 1
NOTE.— ONE SIDE MOVABLE FOR CLOSE COUPLING VARIOUS SIZES OF RABBITS IN PEN
C1, C2, C3, C4 WELL INSULATED ESPECIALLY C2 (SUBJECT TO RABBIT URINATION)
MOVABLE PLATE BOARD
SCREW
C3
C1
C4
C2
CONDENSER PLATES
OF SIZE SUFFICIENT TO HOLD ANIMAL
C1, C2, C3 & C4 PLATES OF METAL (INSIDE) WELL INSULATED AND IN SERIES
FIG 2

The drawings above provide details of the circuit used by Mr. West in building his ultra short-wave physiological apparatus, together with details of the apparatus itself.

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*Yes—but it is generally understood we believe, that the high frequency currents or field causes heat to be developed inside the body; even in organs such as the liver, etc., without heating up the whole body, which is not the case with direct application of heat as when seated on a hot radiator, etc.—Editor.

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Short Waves in Medicine

ULTRA SHORT WAVES IN *MEDICINE*

By Dr. FRITZ NOACK
(*Berlin*)

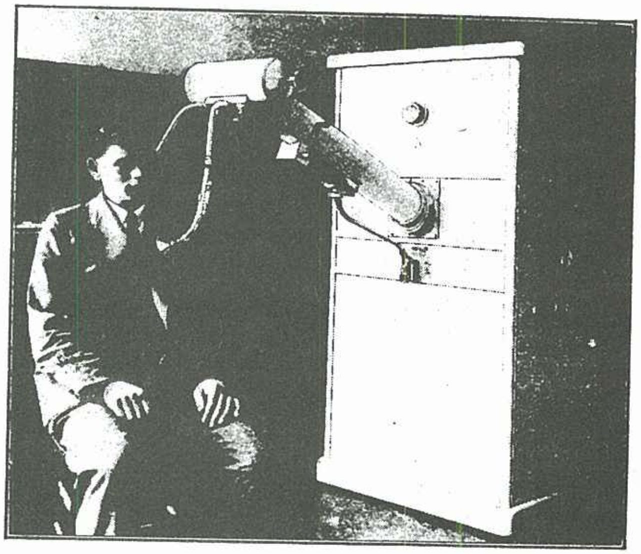

PROFESSOR ESAU, of the University of Jena, the well-known pioneer in the field of ultra short waves, was the one who nearly two years ago pointed out that very evidently the ultra short wave exercised beneficial medicinal effects.

For further investigation of this effect, small mice were put between the condenser plates of the sender; and Lo! after some time the mice fell victims to a sort of tetanus, which eventually led to death. The result of this fact was that Prof. Esau resolved to commission a physician to make a further study of the physiological effect of these ultra short waves. Naturally the serious investigation of medicinal effects requires experience in physical measurements, likewise an apparatus operating in a constant and easily controlled manner.

Siemens and Halske Interested

It is gratifying that a manufacturer which already possesses very great experience in constructing electro-medical apparatus and which also has the requisite experience in physical measurements, the prominent firms of Siemens and Halske took up the matter. Now this company has manufactured a first ultra-short wave *radiation apparatus* and recently exhibited it to a picked group of scientists and to the press.

The pictures show the new set which, of course, has to be considered as the first of an evolutionary series. There will still be necessary all sorts of experiments to produce the set in such form that it will correspond to all the needs of the medical profession. The present set will, for the time being, be used for the further study of the physiological effect of ultra short waves. It will be the problem of the doctors to investigate the fields of use and the conditions under which the set may be used.

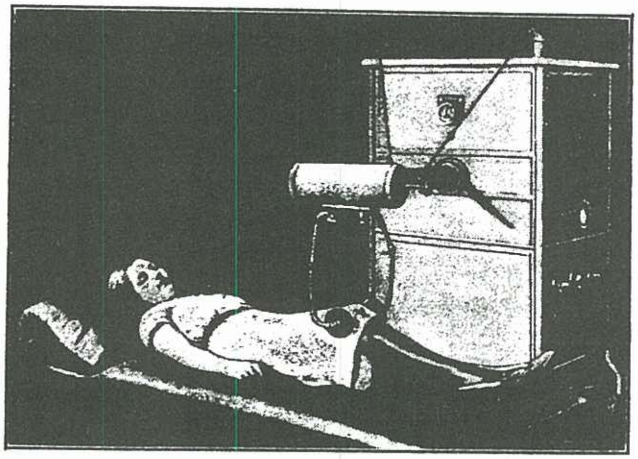

One of the "fair sex" receiving a treatment through the knee by ultra-short waves. Several treatments are given for the average ailment.

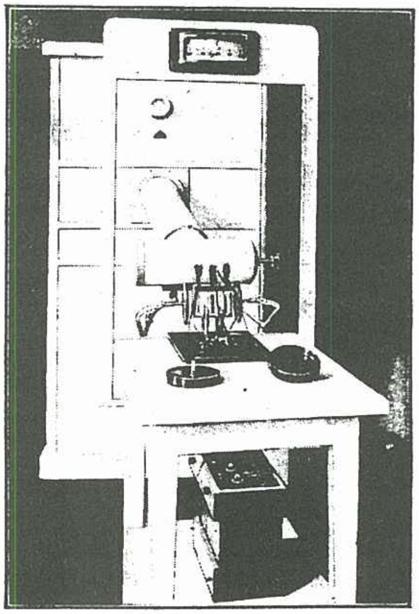

The ultra-short wave medical apparatus with its electrode arm adjusted to permit the waves passing through a solution for experiment.

Arrangement of U. S. W. Generator

In the large shielded box are the real ultra short wave generator—(actually resembling a radio transmitter) and the parts needed for its operation. The generator can work on two waves, four and eight meters. The wavelength is adjusted by inserting the proper tuning coils. The arm which projects out of the apparatus has inside it two lead wires which convey the oscillations outward; they are led to the two electrodes, which are placed at the ends of the two visible supports.

In the cross-beam at the end of the arm is a "tuning" device, which tunes the electrode oscillatory circuit exactly to the wavelength of the generator. The exact tuning can be read on a meter, which is above the arm on the box; this shows the direct plate current of the transmitter, which, with correct tuning of the electrode circuit, adjusts to a minimum; the value then indicated by the meter gives, after calibration of the a value for the electrode energy.

To be able to adjust the electrodes, as is necessary from one case to another, the electrode arms are set in ball-joints. To ascertain whether oscillations are actually present in the electrode oscillatory circuit, there is on one electrode arm a little *glow lamp* (Neon tube), which lights up in the presence of oscillations.

Electrodes Swing on Giant Arm

The arm projecting out of the apparatus can be swung in all directions, for the better use of the whole unit. To accomplish this, it is fixed to the box in a universal joint. The end cross-piece of the arm can furthermore be turned, so that the electrodes can assume any desired direction. The right side wall of the box contains the main current switch, as well as a resistor with which the filaments of the tubes are regulated. The apparatus is in fact constructed just like a vacuum tube radio transmitter. The electrodes may take various forms; in accordance with the most recent experiences, they are so shaped that they do not have to be put firmly against the body, but exercise their effect even in the presence of a layer of air between body and electrode. At the same time, the remarkable fact may be determined, that the thickness of the layer of air and the "depth effect" are dependent on each other.

Advantages of Ultra Short Waves

According to all experiences thus far, the medicinal ultra-short wave radiator is a sort of *diathermal* apparatus; therefore it serves to conduct to the part of the body, or the organ to be treated, electric wave energy, which is converted into heat and thereby exercises a healing effect. As compared with the usual diathermal sets (which operate on a wavelength of about 600 meters, using leaden electrodes, which have to be put right on the body), the *ultra-short wave set* offers a considerably better control of the direction in which the heat is to be applied, so that one can better reach any desired organ than was possible before. Furthermore, by changing the wavelength, one can also adjust for a definite deep-lying stratum. Unpleasant accompanying phenomena, which result with the usual diathermal sets, where the electrodes do not rest firmly on the body, do not occur in the case of the ultra short wave radiator. It is especially important to note that one can now, for the first time, perform a "therapy" or treatment directly on the head. The operation of the set is very simple.

Whether, besides the warming of the different strata in the body, still other biological effects occur or can be accomplished, with the new ultra short wave radiator, is, at the present time, still a matter of question.

HUMAN BEINGS *as* ANTENNAS

By DR. ERWIN SCHLIEPHAKE, M.D.
Of the Jena University Medical Clinic

IF human beings remain in the vicinity of powerful radio transmitters, they are exposed to a very strong electromagnetic field. One must therefore ask what significance these radiations have for the internal organs, and how the body reacts to them. This question is justified by the fact that all other kinds of electromagnetic rays influence the human body more or less strongly.

The character, however, of the reaction is different, according to the wavelengths. Radium rays and X-rays, for example, because of the extraordinary shortness of the waves and the high effectiveness of energy under these conditions, exercise a very strong effect on the structure of atoms; so that serious injuries to the organism can arise (for instance, under certain conditions, cancer). Less serious are the effects of light rays which, however, in the ultraviolet part of the spectrum, can still occasion serious injuries; while the visible light which we perceive is of too low a frequency to injure healthy persons. There are, however, subjects, made sensitive by illness, who suffer serious affections of the skin from strong illumination. Above the optical spectrum, there follow the infra-red and heat waves, whose effect on atoms is relatively slight; in the case of still longer waves only molecular effects are to be expected. Here we are entering

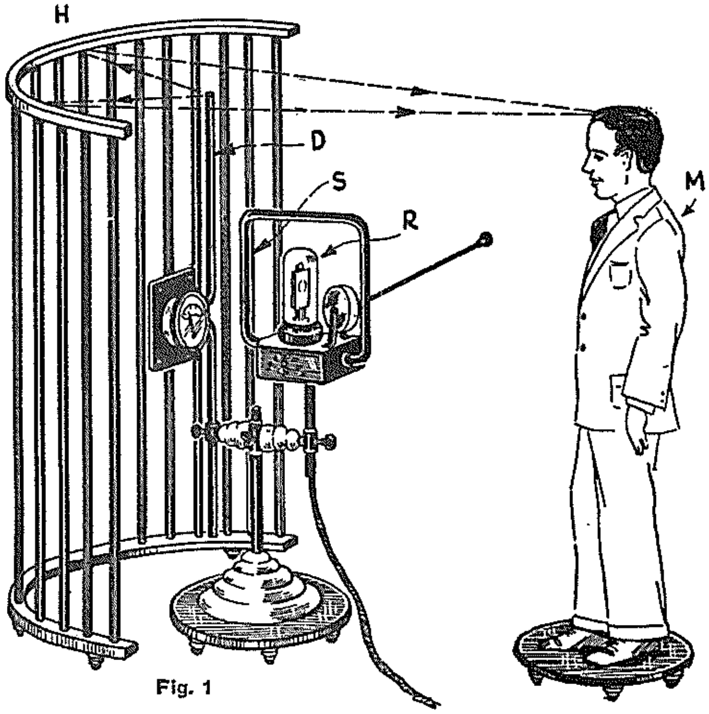

Fig. 1

Arrangement of the apparatus used by Dr. Schliephake in measuring and observing the effects of short waves on the human body, absorption, et cetera. H, parabolic reflector formed of wires; D, antenna, charged inductively by the coil S; vacuum tube at R, and beside it wave changing condenser; subject at M.

the range of the Hertzian waves, electric waves in the stricter sense. Of these, the shortest are about half a millimeter (.02-inch) long, and therefore just above the heat radiations.

From direct analogy, it is to be assumed that the shortest of these waves must be absorbed by human bodies, as in the case of heat rays, and this absorption can be actually demonstrated.

DO YOU KNOW —

¶ What effect short waves have on the hair and scalp in general?

¶ Whether the current in the exciting antenna increases or decreases when a person stands in its field? Why?

¶ If the person stoops will this affect the reading of the antenna current meter?

¶ Whether 'cold" or "heat" is produced inside the body by an overdose of the high frequency waves?

¶ The effect of short waves on the nervous system?

Absorption of Radio by the Body

With specially-built transmitters, especially such as those which have been described by Kohl, electric waves only a few centimeters in length can be produced; these waves can be reflected by mirrors, exactly like light rays. If one puts the antenna in the focus of a concave mirror, then there is formed a parallel beam of radiation which can be concentrated again in another concave mirror. By means of a lens placed in the course of the radiation, the ray is made very sharp. If a person steps into this path, reception ceases. Since no reflection by the human body or only a very slight one is demonstrable, absorption of the radiation must have occurred; this effect is, moreover, demonstrable in the case of other organic substances or water. Unfortunately, not much can yet be said about the physiological effects of these radiations; the power of the transmitters of extremely short waves is still too low to produce perceptible changes.

It is otherwise with the wavelengths from three meters up, to the production of which powers of several kilowatts can be applied. Here the above described optical phenomena cannot be so well demonstrated, because the diffraction is much greater; but absorption by the human body can be very well shown.

When an antenna is inductively coupled to a 3-meter transmitter, the oscillations can be indicated by a detector even at a considerable distance away. If however, a person puts himself in the place of the antenna, the detector responds much more weakly, although the power consumed by the transmitter remains the same. Accordingly, a part of the power must have been used up in the body. The same phenomenon can be demonstrated as follows: a closed or open oscillation circuit is inductively coupled with the transmitter (see Fig. 1). The ammeter in the circuit shows a definite current strength. If a person places himself on an insulating stool beside it, the current in the oscillation circuit is reduced. This withdrawal of energy, however, depends on the length of the body; for if the subject stoops, or changes to a sitting position, the current in the other circuit increases (Fig. 2). Therefore, it appears as though, by the tuning of the subject, *to about half the wavelength, the power transmitted to him becomes much greater.*

Concentrating Power by Means of a Reflector

By means of a large concave mirror one can also collect the transmitted power to a focus. Such a mirror need consist only of parallel wires stretched between two wooden frames. Its height must be equal to the wavelength, the opening one and one-half times the wavelength. It is best to use elliptical reflectors, with the transmitting antenna at one focus; then the reflected radiation is at the other focus of the ellipse. With a "dipole" ("Hertzian" antenna) containing an ammeter, especially strong concentration of energy at this point can be demonstrated. Here a lessening of the current in the dipole is instantly shown if a person steps into the vicinity. Since the human body is to be regarded essentially as an electrolytic system, with regard to the electric wave, and I have tried to demonstrate the effect in the following manner in a model experiment.

A glass tube, of half the wave's length, was filled with an 0.5% sodium chloride (salt) solution, to which gelatine was added to prevent convection. In this jelly the temperature was measured, at different places, by thermo-elements. It was shown that the heating was greatest in the middle and least at the ends; being half as strong at the quarter points of entire length as it was in the middle. Since the maximum strength of the current is at the middle, the greatest heating is therefore connected with this.

Physiological Effect of Short Waves

Especially noteworthy, also, was a feeling of vibration, which was particularly evident if the hand was raised in front. We could establish this sensation only at our transmitter, which is operated with 50-cycle alternating current. There must be, therefore, a direct influence on the nervous system. Here too we have, therefore, another proof that the ultra-short radio waves exercised an effect on the nerves.

These vibrations are also felt if the hand is placed in a condenser's field. Many persons who remain close to the transmitter also experience remarkable sensations on the head, near the roots of the hair; these are like a peculiar prickling, the hair likewise standing up a little. In many subjects we could also observe slight increases in bodily temperature, which however did not exceed 0.5 of a degree, Centigrade (0.9 degree Fahrenheit). Since the body contains extremely fine regulators, by which the temperature is always kept constant, and since also the amounts of energy which can be conveyed into the body, even by powerful radio transmitters, give (when translated into heat units) only a relatively low number of calories, this increase in heat is probably not attributable to the received energy alone. As is to be shown later, nervous effects may play an important part in this.

The effect on the nervous system is

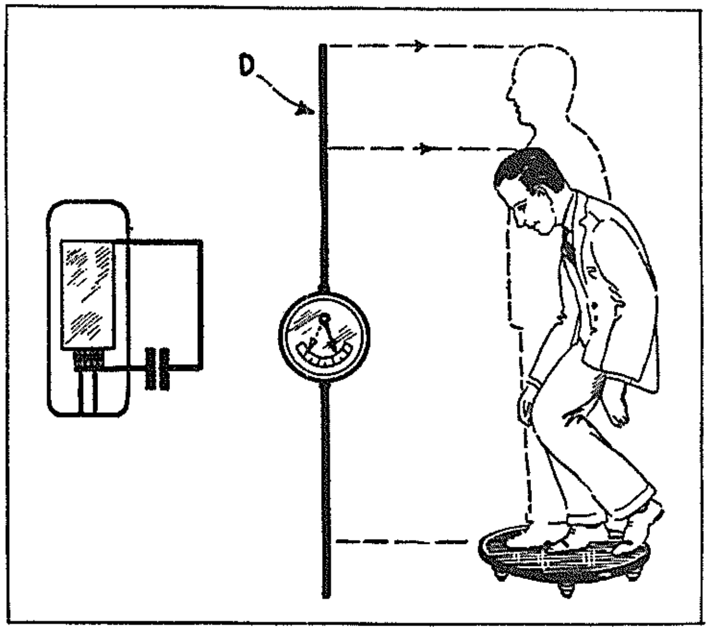

Fig. 2. One of the most interesting effects of placing a human being in the field of a short wave (high frequency) oscillator is that of absorption. The antenna "D" is excited by the power tube and loop circuit at the left. Do you think the antenna current is increased or decreased by bending the body?

Human Beings As Antennas

By Dr. Erwin Schliephake, M.D.

plainly felt by all persons who work a fairly long time with short waves. The sensations are different with the individuals; there are persons who are relatively insensitive, and others who very soon complain about the disturbances of their health. Usually there is first an increasing sleepiness; they are very tired by day, but at night they sleep badly. Several times a night they start out of their sleep, and they are tired and sleepy in the morning.

These phenomena increase more and more. Often there are also intensive headaches, particularly covering the back of the head. Many persons complain of digestive disturbances and pressure on the stomach. Most of them are furthermore easily excited and irritated, being inclined to complaining and to violence. This increased excitability of the nervous system can also be shown by electrical tests of the nerves.

Effects of the Electrostatic Field

It is much easier to study these changes by using the condenser field. Here it is not the electromagnetic wave which is used, but the electrostatic field, which always accompanies it. Here, however, the effect may be much more strongly concentrated. I have generally used plates four inches in diameter, between which the parts of the body in question were treated. The field between these plates suffices to heat 100 cc. of a 0.5% sodium chloride (salt) solution 5 degrees C. (9° F.) in one minute. If parts of the human body are introduced into this field, and the blood is then taken from some part of the body (for instance, from the earlobe) on investigation obvious changes are found.

The number of red corpuscles per cubic millimeter is very greatly increased; i. e., if they formerly amounted to 5 million, the number has risen to 6 million. The same is true of the haemoglobin (a constituent of the blood) and the white corpuscles, the number of which likewise increases. But this is not always true to the same extent, depending upon the strength of the radiation and the place treated. One frequently sees instead a lessening of these amounts, which would therefore correspond to a thinning of the blood. Likewise, the albumens of the blood undergo certain changes which I cannot discuss here.

In the case of these strong effects it is to be assumed that the tissues of the body also undergo changes; which, however, cannot be directly proved in a subject.

Results of Experiments on Animals

In experiments with animals, on the contrary, such changes are plainly recognizable. They occur particularly strong in projecting parts of the animals, such as in the ears and tips of the tails; since there the electric field is distorted. Very often, one sees, some time after the treatment, that the parts in question are dying and falling off. In the case of a rabbit whose leg had been too strongly exposed to the electrostatic field, I noticed a complete disintegration of the flesh in a ring-shaped region, so that only the bone remained; but then, after a while, that also fell off.

That the nervous sytem of the animals is also influenced is shown by the fact that many of them shudder on the switching on or off of the field, at a time when there can be no question of a strong heating effect.

Also very interesting are the disturbances of the internal heat regulation, which one can produce in animals. If the region of the neck and the back of the head of a rabbit are exposed to a limited capacitative field and the temperature is afterward measured, one can soon note a permanently increased temperature, which often lasts for some weeks. If a very powerful dose of "irradiation" is administered the opposite can occur: the bodily heat falls more and more, often below 35 degrees C. (95° F.), until these low temperatures are no longer compatible with life. At the same time, it is interesting to observe that almost all animals which have had such disturbances of their heat regulation after a few weeks developed inflammation of the lungs and pleurisy, afterward dying. It seems as though, by the disturbance of the heat regulation, the resistance of the animals to disease had suffered greatly; so that in this path throughout the central nervous system there was created a special susceptibility to colds. On investigating the spinal marrow of such animals microscopically, serious injuries to the nerve cells have been observed.

Dangers and Beneficial Possibilities

After these experiences, I have not dared to expose entire human beings to a condenser field and in this way produce artificial rises in temperature. The responsibility seemed too great. At the same time, effective heating of the body can be accomplished equally well in other ways; such as with the well-known Apostoli "condenser bed," which can be connected to any diathermal apparatus. With the method previously described, only serious dangers for the patients treated would have been conjured up, without the possibility of producing a fundamentally new effect.

On the other hand, the disturbances of the physical health, which we could observe in the field of free radiation of powerful transmitters, have never been serious. After a period of recovery of a few weeks, with no irradiation, all effects have been observed to vanish. For four years now, I have almost daily worked for several hours at a transmitter with 1½ kw. plate dissipation; and the effects, often very unpleasant, have always gone back to normal on stopping the work.

In these things the wavelength is also certainly of importance, and in fact we have the impression that the disturbances to health became stronger as the wave was shortened. Anyway, the unpleasant sensations appear much quicker with a three-meter wave than with longer ones.

From all these experiences, it is at any rate clear that treatment with electric waves can in no way be regarded as always harmless for the human body. It is plain that their incorrect use can cause serious injuries to health. Certainly such injuries are to be expected only when the frequencies are very high; that is, with ultra-short waves; even then there is nothing to fear except with fairly high transmitter power.

On the other hand, with proper use, the short electric waves seem to be a valuable means of treatment. According to our experiments to date, with bacteria cultures and infected animals, the germs of disease can be killed. There is the added point that certain defensive processes are stimulated in the body. I have also already repeatedly treated human beings; and, in about a hundred cases, I have been able to attain an extraordinarily quick cure of suppuration (pus formation).

Ills Treated by Short Waves

● IN a dispatch to the N. Y. Times, a report from London states that cures for various ailments by the use of short radio waves were claimed by Dr. Erwin Schliephake, a German physician and scientist.

Writing in the *British Medical Journal* he described how he succeeded in treating deep-seated abscess in the human body by passing ultra-short wireless waves through the patient, who was not in immediate contact with any instrument. He found, he said, that various tissues exhibit different degrees of conductivity in the presence of these waves.

Dr. Schliephake declared he has used waves to treat pulmonary abscesses after pneumonia, in pleural empyema, pneumonic tuberculosis, in certain forms of peritonitis, in migraine and acute tonsilitis.

Dr. Willis R. Whitney, research director of the General Electric Company, revealed in April, 1930, that he had developed a radio type of apparatus for killing bacteria in the body.

From THEORY AND CALCULATION OF TRANSIENT PHENOMENON &
ELECTRIC OSCILLATIONS by Charles Proteus Steinmetz, 1920

CHAPTER V.

DISTRIBUTED SERIES CAPACITY.

43. The capacity of a transmission line, cable, or high-potential transformer coil is shunted capacity, that is, capacity from conductor to ground, or from conductor to return conductor, or shunting across a section of the conductor, as from turn to turn or layer to layer of a transformer coil.

In some circuits, in addition to this shunted capacity, distributed series capacity also exists, that is, the circuit is broken at frequent and regular intervals by gaps filled with a dielectric or insulator, as air, and the two faces of the conductor ends thus constitute a condenser in series with the circuit. Where the elements of the circuit are short enough so as to be represented, approximately, as conductor differentials, the circuit constitutes a circuit with distributed series capacity.

An illustration of such a circuit is afforded by the so-called "multi-gap lightning arrester," as shown diagrammatically in Fig. 90, which consists of a large number of metal cylinders p, q . . . , with small spark gaps between the cylinders, connected between line L and ground G. This arrangement, Fig. 90, can be represented diagrammatically by Fig. 91. Each cylinder has a capacity C_0 against ground, a capacity C against the adjacent cylinder, a resistance r,— usually very small,— and an inductance L.

The series of insulator discs of a high voltage suspension — or strain — insulator also forms such a circuit.

If such a series of n equal capacities or spark gaps is connected across a constant supply voltage e_0, each gap has a voltage $e = \frac{e_0}{n}$. If, however, the supply voltage is alternating, the voltage does not divide uniformly between the gaps, but the potential difference is the greater, that is, the potential gradient steeper the nearer the gap is to the line L, and this distribution of potential becomes the more non-uniform the higher the frequency; that is, the greater the charging current of the capacity of the cylinder against the ground. The charging currents against ground, of all

the cylinders from q to the ground G, Figs. 90 and 91, must pass the gap between the adjacent cylinders p and q; that is, the charging current of the condenser represented by two adjacent cylinders p and q is the sum of all the charging currents from q to G; and as the potential difference between the two cylinders p and q is proportional to the charging current of the condenser formed by these two cylinders, C, this potential difference increases towards L, being, at each point proportional to the vector sum of all the charging currents, against ground, of all the cylinders between this point and ground.

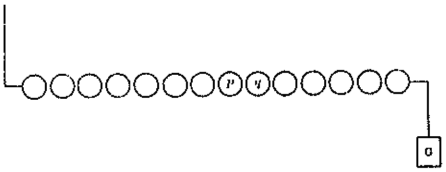

Fig. 90. Multi-gap lightning arrester.

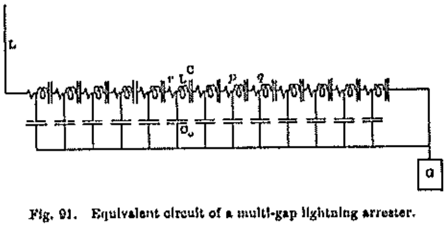

Fig. 91. Equivalent circuit of a multi-gap lightning arrester.

The higher the frequency, the more non-uniform is the potential gradient along the circuit and the lower is the total supply voltage required to bring the maximum potential gradient, near the line L, above the disruptive voltage, that is, to initiate the discharge. Thus such a multigap structure is discriminating regarding frequency; that is, the discharge voltage with increasing frequency, does not remain constant, but decreases with increase of frequency, when the frequency becomes sufficiently high to give appreciable charging currents. Hence high frequency oscillations discharge over such a structure at lower voltage than machine frequencies.

For a further discussion of the feature which makes such a multigap structure useful for lightning protection, see A. I. E. E. Transactions, 1906, pp. 431, 448, 1907, p. 425, etc.

44. Such circuits with distributed series capacity are of great interest in that it is probable that lightning flashes in the clouds are discharges in such circuits. From the distance traversed by lightning flashes in the clouds, their character, and the disruptive strength of air, it appears certain that no potential difference can exist in the clouds of such magnitude as to cause a disruptive discharge across a mile or more of space. It is probable that as the result of condensation of moisture, and the lack of uniformity of such condensation, due to the gusty nature of air currents, a non-uniform distribution of potential is produced between the rain drops in the cloud; and when the potential gradient somewhere in space exceeds the disruptive value, an oscillatory discharge starts between the rain drops, and gradually, in a number of successive discharges, traverses the cloud and equalizes the potential gradient. A study of circuits containing distributed series capacity thus leads to an understanding of the phenomena occurring in the thunder cloud during the lightning discharge.*

Only a general outline can be given in the following.

45. In a circuit containing distributed resistance, conductance, inductance, shunt, and series capacity, as the multigap lightning arrester, Fig. 90, represented electrically as a circuit in Fig. 91, let r = the effective resistance per unit length of circuit, or per circuit element, that is, per arrester cylinder; g = the shunt conductance per unit length, representing leakage, brush discharge, electrical radiation, etc.; L = the inductance per unit length of circuit; C = the series capacity per unit length of circuit, or circuit element, that is, capacity between adjacent arrester cylinders, and C_0 = the shunt capacity per unit length of circuit, or circuit element, that is, capacity between arrester cylinder and ground. If then f = the frequency of impressed e.m.f., the series impedance per unit length of circuit is

$$Z = r + j(x - x_c); \tag{1}$$

the shunt admittance per unit length of circuit is

$$Y = g + jb, \tag{2}$$

where

$$\left.\begin{aligned} x &= 2\pi f L, \\ x_c &= \frac{1}{2\pi f C}, \\ b &= 2\pi f C_0; \end{aligned}\right\} \tag{3}$$

or the absolute values are

$$\left.\begin{aligned} z &= \sqrt{r^2 + (x - x_c)^2} \\ \text{and} \quad y &= \sqrt{g^2 + b^2}. \end{aligned}\right\} \tag{4}$$

If the distance along the circuit from line L towards ground G is denoted by l, the potential difference between point l and ground by $\dot{E}$, and the current at point l by $\dot{I}$, the differential equations of the circuit are *

$$\frac{d\dot{E}}{dl} = Z\dot{I} \tag{5}$$

and

$$\frac{d\dot{I}}{dl} = Y\dot{E}. \tag{6}$$

Differentiating (5) and substituting (6) therein gives

$$\frac{d^2\dot{E}}{dl^2} = YZ\dot{E}. \tag{7}$$

Equation (7) is integrated by

$$\dot{E} = A_1 \epsilon^{-al} + A_2 \epsilon^{+al}, \tag{8}$$

where

$$a = \sqrt{YZ} = \alpha + j\beta, \tag{9}$$

and

$$\left.\begin{aligned} \alpha &= \sqrt{\tfrac{1}{2}\{yz + gr - b(x - x_c)\}} \\ \beta &= \sqrt{\tfrac{1}{2}\{yz - gr + b(x - x_c)\}}. \end{aligned}\right\} \tag{10}$$

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* See paper, "Lightning and Lightning Protection," N.E.L.A., 1907. Reprinted and enlarged in "General Lectures on Electrical Engineering," by Author.

* Section III, Chapter II, paragraph 7.

Substituting (10) in (8) and eliminating the imaginary exponents by the substitution of trigonometric functions,

$$\underset{.}{E} = A_1\varepsilon^{-\alpha l}(\cos\beta l - j\sin\beta l) + A_2\varepsilon^{+\alpha l}(\cos\beta l + j\sin\beta l). \quad (11)$$

46. However, if n = the total length of circuit from line L to ground G, or total number of arrester cylinders between line and ground, for $l = n$,

$$\underset{.}{E} = 0, \tag{12}$$

and for $l = 0$,

$$\underset{.}{E} = e_0 = \text{the impressed e.m.f.} \tag{13}$$

Substituting (12) and (13) into (11) gives

$$0 = A_1\varepsilon^{-\alpha n}(\cos\beta n - j\sin\beta n) + A_2\varepsilon^{+\alpha n}(\cos\beta n + j\sin\beta n)$$

and

$$e_0 = A_1 + A_2;$$

hence,

$$\left.\begin{aligned} A_1 &= \frac{e_0}{1 - \varepsilon^{-2\alpha n}(\cos 2\beta n - j\sin 2\beta n)}, \\ A_2 &= -A_1\varepsilon^{-2\alpha n}(\cos 2\beta n - j\sin 2\beta n), \end{aligned}\right\} \tag{14}$$

and the potential difference against ground is

$$\underset{.}{E} = e_0 \frac{\varepsilon^{-\alpha l}(\cos\beta l + j\sin\beta l) - \varepsilon^{-\alpha(2n-l)}[\cos\beta(2n-l) - j\sin\beta(2n-l)]}{1 - \varepsilon^{-2\alpha n}(\cos 2\beta n - j\sin 2\beta n)} \tag{15}$$

From equation (5), substituting (15) and (9), we have

$$\underset{.}{I} = -\sqrt{\frac{Y}{Z}}\, e_0 \frac{\varepsilon^{-\alpha l}(\cos\beta l - j\sin\beta l) + \varepsilon^{-\alpha(2n-l)}[\cos\beta(2n-l) - j\sin\beta(2n-l)]}{1 - \varepsilon^{-2\alpha n}(\cos 2\beta n - j\sin 2\beta n)}. \tag{16}$$

Reduced to absolute terms this gives the potential difference against ground as

$$e = e_0\sqrt{\frac{\varepsilon^{-2\alpha l} + \varepsilon^{-2\alpha(2n-l)} - 2\varepsilon^{-2\alpha n}\cos 2\beta(n-l)}{1 + \varepsilon^{-4\alpha n} - 2\varepsilon^{-2\alpha n}\cos 2\beta n}}, \tag{17}$$

the current as

$$i = e_0\sqrt{\frac{y}{z}}\sqrt{\frac{\varepsilon^{-2\alpha l} + \varepsilon^{-2\alpha(2n-l)} + 2\varepsilon^{-2\alpha n}\cos 2\beta(n-l)}{1 + \varepsilon^{-4\alpha n} - 2\varepsilon^{-2\alpha n}\cos 2\beta n}}, \tag{18}$$

and the potential gradient, or potential difference between adjacent cylinders, is

$$e' = x_c i = e_0 x_c\sqrt{\frac{y}{z}}\sqrt{\frac{\varepsilon^{-2\alpha l} + \varepsilon^{-2\alpha(2n-l)} + 2\varepsilon^{-2\alpha n}\cos 2\beta(n-l)}{1 + \varepsilon^{-4\alpha n} - 2\varepsilon^{-2\alpha n}\cos 2\beta n}}. \tag{19}$$

For an infinite length of line, $n = \infty$, that is, for a very large number of lightning arrester cylinders, where $\varepsilon^{-2\alpha n}$ is negligible, as in the case where the discharge passes from the line into the arrester without reaching the ground, equations (17), (18), (19) simplify to

$$e = e_0\varepsilon^{-\alpha l}, \tag{20}$$

$$i = e_0\sqrt{\frac{y}{z}}\,\varepsilon^{-\alpha l}, \tag{21}$$

and

$$e' = e_0 x_c\sqrt{\frac{y}{z}}\,\varepsilon^{-\alpha l}; \tag{22}$$

that is, are simple exponential curves.

Substituting (4) and (3) in (21) and (22) gives

$$e' = e_0\varepsilon^{-\alpha l}\sqrt[4]{\frac{C_0^2 + \left(\frac{g}{2\pi f}\right)^2}{C^2\{[1 - (2\pi f)^2 CL]^2 + (2\pi f C r)^2\}}} \tag{23}$$

and

$$i = 2\pi f C e'; \tag{24}$$

or, approximately, if r and g are negligible, we have

$$e' = e_0\varepsilon^{-\alpha l}\sqrt{\frac{C_0}{C\{1 - (2\pi f)^2 CL\}}} \tag{25}$$

and

$$i = 2\pi f e_0\varepsilon^{-\alpha l}\sqrt{\frac{CC_0}{1 - (2\pi f)^2 CL}}. \tag{26}$$

47. Assume, as example, a lightning arrester having the following constants: $L = 2 \times 10^{-8}$ henry; $C_0 = 10^{-13}$ farads;

$C = 4 \times 10^{-11}$ farads; $r = 1$ ohm; $g = 4 \times 10^{-6}$ mho; $f = 10^8$ = 100 million cycles per second; $n = 300$ cylinders, and $e_0 = 30{,}000$ volts; then from equation (3), $x = 12.6$ ohms, $x_c = 39.7$ ohms, and $b = 62.8 \times 10^{-6}$ mhos;

from equation (1),

$$Z = 1 - 27.1\,j \text{ ohms};$$

from equation (2),

$$Y = (4 + 62.8\,j)\,10^{-6} \text{ mho};$$

from equation (4),

$$z = 27.1 \text{ ohms and } y = 62.9 \times 10^{-6} \text{ mho};$$

from equation (10),

$$\alpha = 0.0021 \text{ and } \beta = 0.0412;$$

from equation (17),

$$e = 35{,}500\sqrt{\varepsilon^{-0.0042\,l} + 0.08\,\varepsilon^{+0.0042\,l} - 0.568\cos(24.72 - 0.0824\,l)};$$

from equation (18),

$$i = 54\sqrt{\varepsilon^{-0.0042\,l} + 0.08\,\varepsilon^{+0.0042\,l} + 0.568\cos(24.72 - 0.0824\,l)},$$

and from equation (19),

$$e' = 2140\sqrt{\varepsilon^{-0.0042\,l} + 0.08\,\varepsilon^{+0.0042\,l} + 0.568\cos(24.72 - 0.0824\,l)}.$$

Hence, at $l = 0$, $e = 30{,}000$ volts, $i = 64.6$ amperes, and $e' = 2560$ volts; and at $l = 300$, $e = 0$, $i = 57.5$ amperes, and $e' = 2280$ volts.

With voltages per gap varying from 2280 to 2560, 300 gaps would, by addition, give a total voltage of about 730,000, while the actual voltage is only about one-twenty-fourth thereof; that is, the sum of the voltages of many spark-gaps in series may be many times the resultant voltage, and a lightning flash may pass possibly for miles through clouds with a total potential of only a few hundred million volts. In the above example the 300 cylinders include 7.86 complete wave-lengths of the discharge.

Los Angeles Times

Jan 3, 1988

Ham Radio Operators' High Cancer Rate Poses a Puzzle

TACOMA, Wash. (AP)—Amateur radio operators in Washington and California appear to die at abnormally high rates from several forms of cancer, suggesting a possible link between cancer and electromagnetic fields, according to data collected by a state epidemiologist.

Others cautioned that evidence of such a link has been inconsistent and that other factors may be involved.

Dr. Samuel Milham Jr. of the Washington Department of Social and Health Services studied the deaths of 2,485 Washington and California ham operators between 1979 and 1984.

He reported in the American Journal of Epidemiology that 29 leukemia deaths would be expected in a group of people that size, but he found 36 deaths. Statistically, he expected to find 72 lymphatic and blood-forming organ cancers, but found 89. And he expected to find 67.6 deaths from prostate cancer, but found 78.

'Excess Mortality'

The study "indicates that amateur radio operator licensees in Washington state and California have significant excess mortality due to acute myloid leukemia, multiple myeloma and perhaps certain types of malignant lymphoma," Milham reported.

Leonard Sagan, program manager for radiation studies at the Electric Power Research Institute in Palo Alto, Calif., warned that studies like Milham's can be misinterpreted. Milham's findings could be simple associations that have nothing to do with cancer causes among people who work with electricity, he said.

Sagan said his own research hasn't shown whether electricity causes cancer. But he predicted that if it does, it's rare.

"I think it would be unfortunate for people with children to become overly concerned about this," he said. "Evidence is weak and inconsistent and in a few years we will have better evidence."

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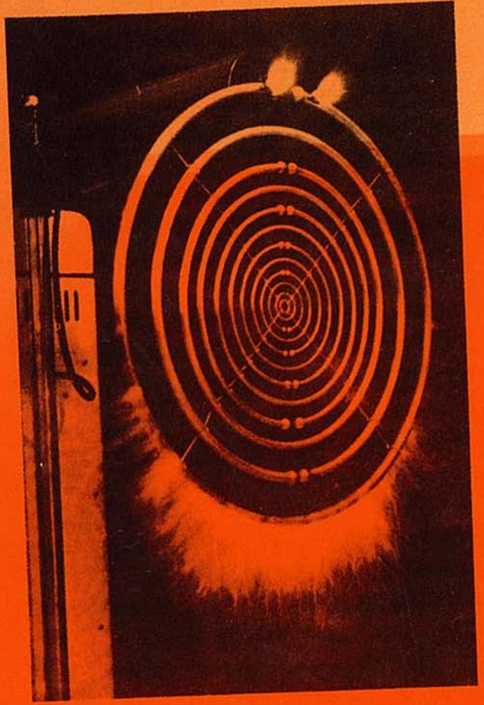

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This book describes researches such as the enhancement of plant grown through the amplification of cosmic waves with simple wire coils, and the neutralization of cancerous tissue with radio waves. This was done with cosmic radiations ringing wires coiled around plants, and with refined electrical fields ringing specially designed antennas. Lakhovsky's original work into the dramatic impact of the subtle forces of nature included the effects of sunspot cycles on plant and animal health, the nature of cancer and how it appears in clusters over areas which have soils that reflect cosmic radiations, thereby causing interference patters, and how diseased cells would turn to a state of health when specific natural or electrical fields were applied in a proper manner.

Nikola Tesla provided some of the early electro-therapeutic research and Lakhovsky was introduced to this through Professor D'arsonval. Lakhovsky, a brilliant scientist, combined this knowledge with his original work and produced a device known as the Multiple Wave Oscillator.

The Multiple Wave Oscillator is an ongoing research project of Borderland Sciences Research Foundation, begun in 1963. This book is the published record of our search for Lakhovsky's secrets and the potential for reversing the aging process.

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Notice to the Reader:

The opinions and conclusions expressed in this book are mine, and unless expressed otherwise, mine alone. The opinions expressed herein are based on my scientific research and on specific case studies involving my patients. Be advised that every person is unique and may respond differently to the treatments described in this book. On occasion we have provided dosage recommendations where appropriate. Again, remember that we are all different and any new treatment should be applied in a cautious, common sense fashion.

The treatments outlined herein are not intended to be a replacement or substitute for other forms of conventional medical treatment. Please feel free to consult with your physician or other health care provider.

I have indicated throughout this book the existence of pollutants in food and other products. These pollutants were identified using a testing device of my invention known as the Syncrometer.™ Complete instructions for building and using this device are contained in this book. Therefore anyone can repeat the tests described and verify the data.

The Syncrometer is more accurate and versatile than the best existing testing methods. A method for determining the degree of precision is also presented. However at this point it only yields positive or negative results, it does not quantify. The chance of a false positive or a false negative is about 5%, which can be lessened by test repetition.

It is in the public interest to know when a single bottle of a single product tests positive to a serious pollutant. If one does, the safest course is to avoid all bottles of that product entirely, which is what I repeatedly advise. These recommendations should be interpreted as an intent to warn and protect the public, not to provide a statistically significant analysis. It is my fervent hope that manufacturers use the new electronic techniques in this book to make purer products than they ever have before.

Dedication

I would like to dedicate this book to all the persons who visited me professionally, from the very first person in 1963, **Mrs. R. Biehl**, to the present. I learned so much from each of you and I appreciate your confidence, your intelligence and your reluctance to be defeated.

Acknowledgments

I would like to express my gratitude to my son, **Geoffrey**, who always listened to my "crazy ideas" on Sundays, right at supper time. He was patient, kind, helpful and willing to share his expertise in electronics and computers. Without him, this book could not have been written.

A big thank you goes to **Frank Jerome, DDS**. Without the loan of his parasite slide collection many of my discoveries could not have been make, and without his development of metal-free dentistry, many of these patient histories could not have ended happily. Thank you to **Linda Jerome** for nurturing us both with personal interest and patience. And thank you to **Edna Bernstein** for her resourceful assistance.

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Preface

The sick have been held hostage for their money or intangible assets since time immemorial. Doctors, even primitive and natural healers, surround themselves with mystery as they use herbs or chemicals and incantations or “prognoses” to help the sick recover. Today, the medical industry (doctors and their suppliers and insurers) take a significant amount of the worker's earnings. Wouldn't it be nice if they could all go back to gardening or some other primitive and useful endeavor? Wouldn't it be wonderful if the sick could join them?

The most promising discovery in this book is the effectiveness of electricity to kill viruses, bacteria and parasites. Does this mean you can cancel your appointment with your clinical doctor? No it does not. Killing your invaders does not make you well instantly. But happily, at your next doctor visits she or he will be removing drugs, not adding them.

You might think that such an invention should be quickly patented. That was my universal advice. But I chose not to. It helps me, my children, and my grandchildren, if you are well. The whole world needs to come out of the dark ages of medicine and illness. And to learn the true causes of infection and disease. We must and can usher in the **new age of disease-free living.**

No diabetes, no high blood pressure, no cancer, no HIV/AIDS, no migraines, no lupus and so on!

Not a single disease is left unconquerable with this new understanding!

The Promise

Step into a new world.

A world without chronic diseases.

Step out of your old world.

It has kept you a prisoner.

Try something new.

The prison has no walls. It has only lines. Lines that mark the ground around you. Inside the lines are your old ideas. Outside are new ideas that invite you to step over and escape your prison. Dare to try these new ideas and your illness promises to recede. In a few weeks it can be gone.

If you are very ill or chronically ill you must have asked yourself many times: why have these problems chosen me? Will there never be a way to conquer them?

You may be quite familiar with your doctor's explanation of your illness or your child's illness. A *Coxsackie* virus has entered your child's brain causing inflammation (encephalitis) there. You pray that your child's immunity will overcome it. You may be familiar, but so very helpless against this microscopic invader.

If you had the proverbial 3 wishes they would be: 1) please spare my child's life; 2) please make it so my child doesn't have permanent damage; 3) please bless and guide the wonderful doctors and nurses who are keeping the oxygen tent going, and are watching my child's temperature and vital signs.

What if you could turn a dial and in 3 minutes kill every Coxsackie virus in your child's body?

What if this had no side effects?

What if the virus never came back?

In this book you will learn how to do that. You will also learn why your child got encephalitis or other disease and how to prevent it forever.

If this is too mind boggling, just take it a step at a time: First, learn about the radio-type broadcasting that all living animals do. Second, find the “station frequencies” that your particular invader(s) broadcast at. Third, learn how to “jam” their frequency until they **expire**: it takes only minutes!

Finally, learn how to make your own diagnostic and treatment devices. The instructions are simple enough for anyone. Only by putting this power in your hands will it be safe from government regulation, however well intended.

Only Two Health Problems

No matter how long and confusing is the list of symptoms a person has, from chronic fatigue to infertility to mental problems, I am sure to find only two things wrong: they have in them **pollutants** and/or **parasites**. I never find lack of exercise, vitamin deficiencies, hormone levels or anything else to be a primary causative factor. So the solution to good health is obvious:

Problem	**Simplest Cure**
Parasites	Electronic and herbal treatment
Pollution	Avoidance

It's a valiant quest: The quest for health. With optimism in one hand and determination in the other, you too can work the miracles for yourself that my clients accomplished in the case histories.

More good news is that it is not expensive. The cost will range from a few hundred dollars to only a few thousand in order to eliminate both problems and cure your chronic diseases.

Be A Health Detective

After curing your own diseases, teach your friends and family how it's done. Families are related and their problems are related. This should make the task easier. Keep a small notebook to become part of the treasured family legacy as much as photographs do. If your aunt, father and brother had diabetes as well as yourself and all were cured after introducing them to this concept and technology, isn't this worthy of notes in your family's history?

Notice what a strong line of inheritance there can be, **not due to sharing genes** but due to sharing a roof, a table, a supermarket, and a dentist!

Many problems can be disinherited. Cure yourself of retinitis pigmentosa, Muscular dystrophy (the “inherited” kind), and break down your family's faith in the gene-concept for these diseases. Bring hope to your family by proving diseases' true etiology. Bring respect back for your loyal genes that bring you hair color, and texture, not hair loss. That bring you eye color, not eye disease. Your genes brought you the good things about your ancestors, not the bad things. Parasites and pollution brought you the bad things.

Killing all your invaders is just the first step, though. It is indeed the life-saving step. But getting well is more than saving your life. Next comes the more tedious task of finding their sources. Where did they come from? Why did they invade you so massively. Why you?

The story of your personal pollution unfolds as in a book. Look closely and you see the whole panorama of your numerous tiny invaders being held at bay by your valiant immune system, your white blood cells. You can see what they are fighting besides the invaders. Your ill-chosen diet and lifestyle products!

Your heart may go out to those tiny white blood cells. Never again, you may say, will you give them arsenic and mercury and lead. Never again, cobalt and asbestos and freon.

That great body of wisdom, your body, the same as listened to your three wishes, will reward you over and over as you co-operate with it, until you have had not 3 but 30 wishes granted, each one seemingly as impossible as climbing Mt. Everest.

- Your chronic yeast infection can go away.
- Your hair can stop falling out–might even grow back.
- Your body can become pregnant–when you had already given up.
- Your fatigue can vanish.
- Your insomnia can be gone.
- Your warts can fall off.
- Your sight and hearing can sharpen.
- Your constant hunger can disappear.

Health isn't just being free of sickness. Health is feeling great, feeling like laughing at funny things. Health is feeling grateful to be alive. It is feeling happy to see the sky and to see growing things and to feel confident in human society's progress. Health is remembering the good parts of childhood and believing you still have a lot of them.

The Discovery

What makes me think I can find things in the human body that a blood test can not? What new technology makes this possible? Why is electronic testing superior in many ways to chemical methods? What are my claims of electrically killing parasites based on?

In 1988 I discovered a new way to scan a body organ. It was electronic. We already can "see" an organ with a sonogram, X-rays, computerized tomography (CAT) scan, or with magnetic resonance imagery (MRI). These techniques can identify abnormal shapes in an organ without having to explore or guess. But my new electronic technique can check for viruses, bacteria, fungi, parasites, solvents and toxins, and in addition is simple, cheap, fast and infallible. Electricity can do many magical things; now we can add detecting substances in our body to that list.

The method rests on radio electronic principles.

If you match, very precisely, the capacitance and inductance properties of an external circuit so that its resonant frequency is the same as the emitted frequency coming from somewhere else, the circuit will oscillate. This means there will be positive feedback in an amplifier circuit. You can hear it. Like when a public address system squeals.

The external circuit I use is called an *audio oscillator*, quite easy to build or buy. Your body provides the emitted frequencies. When you combine the audio oscillator circuit with your body, and you hear *resonance*, then you have detected a match! Something in your body matches something in the circuit on the test plate. By putting a laboratory sample of, say, a virus on the test plate, you can determine if your body has that virus by listening for resonance. Hearing resonance is easy if you're a radio technician or musician. Others must patiently practice. The details are given in the Bioelectronics chapter (page 457).

You do not have to be an expert in anything to learn the electronic detection method. But a keen sense of hearing helps.

In 1988 I learned a way to put anything on my skin, blindfolded, and identify it electronically in a few minutes. I could taste something without flavor and identify it electronically. The system worked fine for detecting things in the skin and tongue. Would it be reliable for internal organs, too?

A whole world of discovery lay ahead of me. I wanted to know what was in my inner ear causing tinnitus, in my eyes causing pain, in my stomach causing indigestion and a thousand other things.

But behind the daily excitement of new discoveries, a gnawing question lingered in my mind. How is this possible without some pretty high frequency energy source, radio frequency in fact, running through my circuit? My audio oscillator was only 1000 Hz (*hertz*, or cycles per second); radio frequency is hundreds of thousands of Hz. And the phenomenon could be produced with an old-fashioned *dermatron*[1], too, that only puts out DC (direct current)–no frequencies at all!

A high frequency energy had to be coming from somewhere. Was it me? *Ridiculous*!

But there was a way to test. If my own body was putting forth the high frequency energy, it could be bled off and diverted into the ground with a correct size capacitor. This should stop the feedback oscillations. This turned out to be true; it was stopped. But *ridiculous* kept ringing in my ears and I tried another test. If there was indeed radio frequency (RF) running through my circuit I should be able to block it with the right snap-on choke. It did block. I thought of a third test. If this was truly a resonance phenomenon I should be able to add a capacitance to this circuit and see the resonance destroyed. Then add an inductance and see the resonance return. It did just that. I made graphs of the relationship between capacitance and inductance. They were entirely reproducible.

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[1] The dermatron was invented decades ago and made famous by Dr. Voll. Establishment science disdained it!

Then why couldn't I see the RF on my RF oscilloscope? Probably because it was high frequency energy, not high energy frequency, and I didn't know how to amplify it above the background noise level. It was nevertheless not convincing. Yet much too tantalizing to ignore.

I thought of yet a fourth test. If I was really producing RF radiation that could be channeled through a circuit, I should be able to interfere with it by adding another RF radiation from an outside source. I added a frequency from my frequency generator, first at 1,000 Hz. Now there was no resonance. It interfered. Did this mean that my body was not producing radiation at 1,000 Hz? Or was my 1,000 Hz radiation being matched and canceled? I raised the frequency gradually, from 1,000 to 10,000 to 100,000 to 1,000,000 Hz. There was no resonance anywhere, and I couldn't draw any conclusions. It was 5 o'clock on Sunday afternoon. Quitting time. But one last look at my generator reminded me that it could reach 2,000,000 Hz and I was just at 1,000,000. One more quick experiment wouldn't take much time. I cranked it to 1,800,000 Hz. And now a resonance screamed out! Was I “hearing things?” No more interference. I did it over and over. Why was it resonating now and not before? Had I arrived at my body's own *bandwidth* (transmission range), and this was the reason it no longer interfered?

I found the lowest frequency that resonated to be 1,562,000 Hz. All frequencies that I checked (about 2,000) from there up to 2,000,000 (my frequency generator would go no higher) also resonated.

A year later I purchased a better frequency generator to search for the upper end of my bandwidth. Any frequency between 1,562,000 and 9,457,000 Hz could be added to the circuit and produce resonance.

It seemed obvious, then, that the human body broadcasts electrically, just like a radio station, but over a wide band of frequencies and very low voltages, which is why it has not been detected and measured until now.

Everything Has A Unique Frequency

It was a busy year, now 1989. I was determined to find a bandwidth for other living things: I found them for flies, beetles, spiders, fleas, ants. They were between 1,000,000 Hz and 1,500,000 Hz; cockroaches were highest amongst insects I tested.

Then came a dismaying finding. A dead insect had a bandwidth too! Much narrower, and near the top end of the same range it had when living, but distinctly present. So it wasn't altogether a living phenomenon.

But if dead things had a resonant bandwidth, then maybe a prepared microscope slide of a dead creature could be used, and my trips to the garden and telephone calls to abattoirs (for meat parasites) could cease. That was a lucky thought. My first slide was of the *human intestinal fluke*, a huge parasite, scourge of humanity. I had just found it to be present in the liver (not intestine) of every cancer sufferer I saw. The (dead) adult parasite had a resonant frequency around 434,000 Hz. Slides of that parasite's redia resonated nearby (432,000 Hz), as did its other stages.

Dead things still resonated! The entire catalog of biological supply companies, hundreds of specimens of viruses, bacteria, parasites, molds, and even toxins, were now available to research with this new technique!

Suddenly an idea bolted out of the blue. If a person were to hold on to the frequency generator while it was generating 434,000 Hz, what would happen to the adult fluke, if you were infected with it?

I tested this plan that same week on myself, not with the fluke but with *Salmonella* bacteria and *Giardia* and *Herpes* that I carried chronically. After a 3 minute treatment, I retested myself. I could no longer find them in my organs! There were no emissions at their characteristic frequencies. I repeated and repeated. Were they really dead? Maybe they were just numbed or were suddenly hiding. But symptoms were gone quickly too. My *Herpes* lesion stopped tingling. It was all too simple and unbelievable.

But was it safe? Within three weeks I had reliable data regarding the necessary level of electrical treatment. It only took 5 volts for three minutes at the specific frequency. It is not as if you had to use house current which would kill you, along with the parasite.

Selective Electrocution

In twenty minutes (three minutes at six different frequencies) a whole family could get rid of this parasite. Cancer cases showed that in a few hours the universal cancer marker, *ortho-phospho-tyrosine* could be banished from their bodies by killing this same parasite.

"Incurable" HIV cases lost their virus in a few hours, too. Laboratory retesting for HIV came back negative! Most cases of pain got immediate relief if I could identify the correct "bug" and have its frequency found by the next office visit. This seemed to be absolute proof that living things had an essential high frequency output of some kind of energy.

What was actually happening to the bacteria or parasites? If I could kill something as large as an *Ascaris* worm or intestinal fluke, then perhaps I could kill something even larger, like an earthworm or flea, something I could see with my own eyes instead of having to imagine its demise inside my body.

Ten minutes at a frequency chosen near the top of their broadcast range seemed to anesthetize them. But they didn't die. Later I checked the body bandwidth (the range of frequencies they emit) of each. The earthworms had lost a lot of their bandwidth, both at the top and bottom. The fleas seemed hardier; they had only lost a little. However they did not recover, even weeks later, from this loss.

Could it harm humans to douse them with RF frequencies **in their own bandwidth?** Quite probably, if the voltage were high enough. There was no need to experiment, though, because the parasites we want to kill have characteristic frequencies that **do not overlap** the characteristic frequencies of a human. In fact, they are far away (see the chart on page 17).

So my electronic method attacking illness was born. Find the resonant frequency of a bacterium, virus or parasite using a slide or dead bit. Treat the living invaders inside the human body with this frequency and in a matter of minutes they are no longer transmitting their own bandwidths—they are dead or sick and will be removed by our white blood cells.

It was a worrisome truth. Perhaps the department of defense would use this knowledge and develop super high voltage devices to kill people ("enemies") somewhere in the world. But I couldn't let sick people suffer. Besides, it would probably require a voltage much like lightning to kill people from a distance. Possibly a way could be found to shield yourself from frequencies harmful to humans by wearing a choke (inductor) coil which suppresses these frequencies. Remember, there was no recovery, just a slow death for my experimental animals. It must not happen to humans!

Meanwhile, people must be alerted that they can safely kill their invaders and heal their chronic illnesses. Invaders that have been increasing exponentially due to lowered immunity in recent decades. Possibly this is true for all species on our planet. The pollution of the entire biosphere has been increasing and with it the prospect of acquired immune deficiency syndrome (AIDS) for all of us.

Remember, though, that the true challenge is not to kill our invaders but to regain our health and immunity.

More than just parasites are making us sick! Pollution is too. Selective electrocution rarely makes people completely well. Sick people always have an environmental factor that must be corrected also.

How do we do that? The ship of “progress”, of increasingly complex, processed foods and products, must be turned around and simplicity become our goal. Survival is in simplicity of food intake, simplicity of life habits. Did Ralph Waldo Emerson foresee this when he said “To be simple is to be great”? Or will daily parasite and pathogen electrocution become another crutch that makes us just enough better that we can continue a detrimental lifestyle? Yet another “Band-Aid” treatment for our poisoned planet?

Bioradiation

Strange as it appears, it now seems obvious that every living creature broadcasts its presence like a radio station, the sun, or the stars. I have named it *bioradiation*.

Perhaps it is the same energy as the Asian *chi*; perhaps it is merely related to it. Perhaps it is the energy that runs along the meridians discovered eons ago by Asian practitioners.

Perhaps it is the energy that faith healers and religious teachers know how to harness, perhaps not.

Perhaps it is the energy that psychics perceive and that drives occult phenomena, perhaps not.

What is truly amazing is that ordinary persons have discovered such energy well ahead of scientists. Persons using the “art” of kinesiology, pendulums, radionics, dousing rods and many other forms of “strange energy” have no doubt harnessed a part of this bioradiation. It is a tribute to the generally high intelligence of common people and to their open-mindedness that they discovered this energy, **in spite of** opposition from scientists of today.

Over a century ago the scientists of Europe proposed the existence of a “life force” called “élan vitale.” They were scorned out of existence (and out of jobs). Young scientists, (including myself) were systematically taught to scorn this idea. Of course we were also taught that a good scientist was unemotional, does not scorn ideas, has a completely open mind, and does not rule something out until it is disproved to their satisfaction. The youthfulness of college years is so susceptible to prejudices of all kinds, and the desire for acceptance is so great, that special effort needs to be made to teach neutrality. Or at least to distinguish between emotion and fact. Where have these basic pedagogic principles gone? I was indeed inspired with the phrase “search for truth” but then promptly led down the path of “search for acceptance.”

I do not know what bioradiation, this electrical broadcast from our cells, is made of. Only its frequency was noticed and caught (modulated) in such a way as to be measurable. And this frequency, 1,520,000 to 9,460,000 Hz (for a human infant) is in the radio frequency (RF) range[2].

Anyone who is experienced with RF knows its strange behavior. Not strange in the "unknown" sense but in the amazing sense. Circuits don't need to be complete or closed for it to travel. Bodies and objects can "pick it up" without being in the circuit. These amazing properties are due to the capacitive and inductive properties of objects all around us, including ourselves.

Zapping Bugs

By *zapping* I mean selectively electrocuting pathogens. For years I used a commercial frequency generator to "zap" one pathogen after another.

First I made a chart of the frequencies for most of the bacteria and viruses in my collection (over 80, see page 561). Then I would test the sick client for each one of these, and hope they did not have one for which I didn't have a sample. Even persons with a simple cold typically had a dozen they tested positive to (not just *Adenovirus*).

Next it was time to tune in the frequency generator to a dozen frequencies for three minutes each. The total process, testing and treatment, would take about two hours. They frequently got immediate relief. But often the relief would be temporary. What I didn't know at that time was that viruses could infect a larger parasite such as a roundworm. Until you killed your roundworm and your virus, you would keep getting the virus back promptly.

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[2] AM radio broadcasts are from 540,000 Hz to 1,600,000 Hz (slight overlap with lower end of human band), FM is 88,000,000 to 108,000,000 Hz (out of the human range).

In 1993 my son, Geoffrey, joined me and we tried a new approach. He programmed a computer controlled frequency generator to automatically cover all the frequencies populated by all the parasites, viruses, and bacteria, from 290,000 Hz to 470,000 Hz. It spent about three minutes for every 1000 Hz it covered. This was more efficient, but it meant spending ten hours being zapped.

Again, the results were disappointing. Arthritis pain, eye pain, colds were improved, but not completely cured overnight. Months later I would find that organisms were transmitting as low as 170,000, and as high as 690,000 Hz. My specimen collection was obviously incomplete. To cover this larger range, spending three minutes for every 1000 Hz, would take 26 hours. Still worth doing if it would indeed help all our illnesses. But even this method of zapping was not 100% effective for reasons yet to become clear.

In 1994 my son built a hand held, battery operated, accurate frequency generator. The purpose was to enable everyone to kill the intestinal fluke at 434,000 Hz with a low cost device. Enough benefit would be derived from zapping at various frequencies that I thought everyone should know how to make one. When I tested it on one of my own bacteria, however, **three others at much different frequencies died also!** This had never happened before. When I tested it on others, even though they had dozens of pathogens, all were killed!

Subsequent testing showed it was not due to some unique design, or special wave form produced by the device. It was due to battery operation!

Any positively offset frequency kills all bacteria, viruses and parasites simultaneously

given sufficient voltage (5 to 10 volts), duration (seven minutes), and frequency (anything from 10 Hz to 500,000 Hz).

Before this I had always set my commercial frequency generator to alternate between positive and negative voltage. Now I tried setting it to alternate between positive and zero voltage (*positive offset*). It was just as effective as the battery operated frequency generator my son designed.

Generating positive offset frequencies is the best way to kill all pathogens quickly.

But it takes more than one treatment.

It takes three treatments to kill everything. Why? The first zapping kills viruses, bacteria and parasites. But a few minutes later, bacteria and viruses (different ones) often recur. I conclude they had been infecting the parasites, and killing the parasites released them. The second zapping kills the released viruses and bacteria, but soon a few viruses appear again. They must have been infecting some of the last bacteria. After a third zapping I never find any viruses, bacteria or parasites, even hours later.

Why didn't the virus inside the parasite die with the first zapping? It may be because electricity travels on the exterior of things. The body of the parasite shielded the interior. This is why my earlier, promising work spending hours on a frequency generator gave only partial or temporary improvement—it was only done once, not three times. And it explains why a single treatment with a frequency generator or zapper frequently gives you a cold!

Zapping does not kill shielded organisms

such as those that may be in the middle of your stomach or intestines. The electricity travels along the stomach or intestine wall, not through their contents.

So zapping is still not perfect, but can bring such manifest relief that everyone should buy or make one. Parts cost less than $25.00; the plans are in the next chapter.

The Bioradiation Spectrum

Everything emits a characteristic range of frequencies (bandwidth). In general, the more primitive the organism, the lower its bandwidth. Advanced animals have higher frequencies and the range is wider.

BANDWIDTH OF BIORADIATION OF ANIMALS

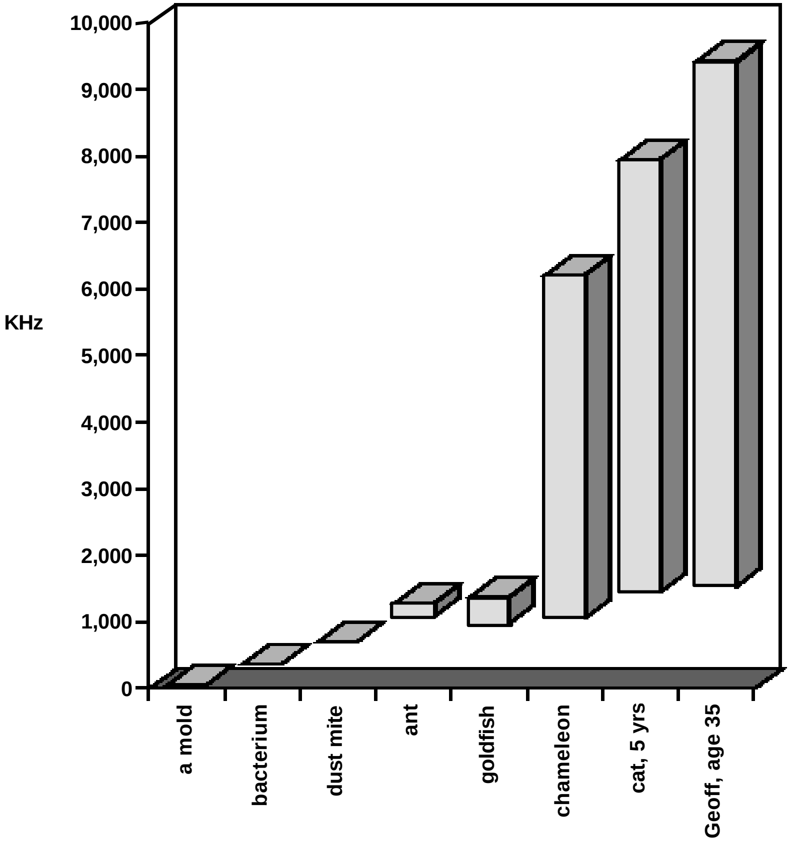

Fig. 1 Selected animal bandwidths.

The human range is from 1520 KHz to 9460 KHz. Pathogens (molds, viruses, bacteria, worms, mites) range from 77 KHz to 900 KHz. Fortunately for us we can work on zapping pathogens in the lower ranges without affecting humans in the upper range.

BIORADIATION OF TYPICAL PATHOGENS

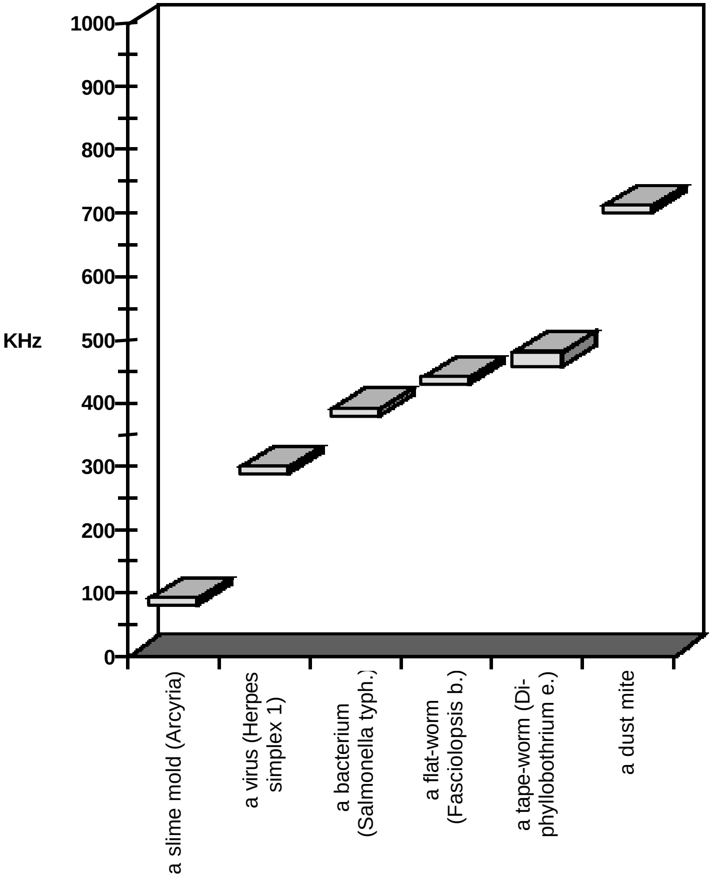

Fig 2 Selected pathogen bandwidths.

Applying an alternating electrical voltage within an organism's bandwidth injures it. Small organisms with narrow bandwidths are extinguished quite readily (three minutes at five volts).

Positively offset frequencies can kill the entire range of small organisms (viruses, bacteria, parasites) in just seven minutes.

Building A Zapper

Being able to kill your bacteria and other invaders with electricity becomes much more of a panacea when you can do it all in three 7 minute sessions. No need to single out specific frequencies or to sweep through a range of frequencies one KHz at a time. No matter what frequency it is set at (within reason), it kills large and small invaders: flukes, roundworms, mites, bacteria, viruses and fungi. It kills them all at once, in 7 minutes, even at 5 volts.

How does it work? I suppose that a positive voltage applied anywhere on the body attracts negatively charged things such as bacteria. Perhaps the battery voltage tugs at them, pulling them out of their locations in the cell doorways (called *conductance channels*). But doorways can be negatively charged too. Does the voltage tug at them so they disgorge any bacteria stuck in them? How would the positive voltage act to kill a large parasite like a fluke? None of these questions can be answered yet.

Other fascinating possibilities are that the intermittent positive voltage interferes with electron flow in some key metabolic route, or straightens out the ATP molecule disallowing its breakdown. Such biological questions could be answered by studying the effects of positive frequencies on bacteria in a lab.

The most important question, of course, is whether there is a harmful effect on you. I have seen no effects on blood pressure, mental alertness, or body temperatures. It has never produced pain, although it has often stopped pain instantly. This does not prove its safety. Even knowing that the voltage comes from a small 9 volt battery does not prove safety, although it is reassuring. The clotting of red blood cells, platelet aggregation and functions that depend on surface charges on cells need to be investigated. But not before you can use it. Your safety lies in the short period of exposure that is necessary. Viruses and bacteria disappear in 3 minutes; tapeworm stages, flukes, roundworms in 5; and mites in 7. One need not go beyond this time, although no bad effects have been seen at any length of treatment.

The first seven minute zapping is followed by an intermission, lasting 20 to 30 minutes. During this time, bacteria and viruses are released from the dying parasites and start to invade you instead.

The second seven minute session is intended to kill these newly released viruses and bacteria. If you omit it, you could catch a cold, sore throat or something else immediately. Again, viruses are released from the dying bacteria. The third session kills the last viruses released.

Do Not Zap If You Are Pregnant
Or Wearing A Pacemaker.

These situations have not been explored yet. Don't do these experiments yourself. Children as young as 8 months have been zapped with no noticeable ill effects. For them, you should weigh the possible benefits against the unknown risks.

That is all there is to it. Almost all. The zapping current does not reach deep into the eyeball or testicle or bowel contents. It does not reach into your gallstones, or into your living cells where *Herpes* virus lies latent or *Candida* fungus extends its fingers. But by zapping 3 times a day for a week or more you can deplete these populations, too, often to zero.

Killing The Surviving Pathogens

The interior of gallstones may house parasites inaccessible to the zapping. Eliminate this source of reinfection by flushing them out with liver cleanses (page 552).

Although the center of the bowel contents is often unaffected by electric current, which lets bowel bacteria like *Shigella, Escherichia coli (E. coli)* and parasite stages survive, sometimes it is nearly all sterilized by zapping. This results in considerable shrinkage of the bowel movement. Eliminate remaining parasites and bacteria with a single dose (2 tsp.) of Black Walnut Hull Tincture, Extra Strength (see page 543).

There is no way of distinguishing between "good" and "bad" bacteria with either of these methods. However even good bacteria are bad if they come through the intestinal wall, so zapping targets mostly "bad" bacteria. The good news is that perfect bowel habits often result in a few days. Evidently, the good bacteria are benefited by killing the invasive ones. Home-made yogurt and buttermilk (see *Recipes*) are especially good at recolonizing the bowel. But it does not seem wise to culture yourself with special commercial preparations and risk getting parasite stages again when you can become normal so soon anyway. If you do decide to take some *acidophilus* bacteria to replenish your intestinal flora make sure you test for parasites like *Eurytrema* first.

When a large number of parasites, bacteria and viruses are killed, it can leave you fatigued. Try to give yourself a low-stress day after your initial zapping. But there are no significant side effects. I believe this is due to the second and third zapping which mops up bacteria and viruses that would otherwise be able to go on a feeding frenzy with so much dead prey available.

To build your zapper you may take this list of components to any electronics store (Radio Shack part numbers are given for convenience).

Zapper Parts List

Item	**Radio Shack Catalog Number**
large shoe box	
9 volt battery	

9 volt battery clips	270-325 (set of 5, you need 1)
On-Off toggle switch	275-624A micro mini toggle switch
1 KΩ resistor	271-1321 (set of 5, you need 2)
3.9 KΩ resistor	271-1123 (set of 2, you need 2)
low-current red LED	276-044 or 276-041 or 276-045
.0047 uF capacitor	272-130 (set of 2, you need 1)
.01 uF capacitor	272-1065 (set of 2, you need 1)
555 CMOS timer chip	276-1723 (set of 2, you need 1)
8 pin wire-wrapping socket for the chip	276-1988 (set of 2, you need 1) Note: Radio Shack is discontinuing all wire wrap sockets. Find another parts store or use 276-1995 (but the legs are much shorter and harder to attach clips to).
short (12”) alligator clip leads	any electronics shop, get 6
Microclip test jumpers	278-017 (you need 2 packages of 2)
2 bolts, about 1/8” diameter, 2” long, with 4 nuts and 4 washers	hardware store
2 copper pipes, ¾diameter, 4” long	hardware store
sharp knife, pin, long-nose pliers	

Hints for absolute novices: Don't let unusual vocabulary deter you. A “lead” is just a piece of wire used to make connections. When you remove a component from its package, label it with a piece of tape. A serrated kitchen knife works best as does a large safety pin. Practice using the microclips. If the metal ends are L-shaped bend them into a U with the long-nose pliers so they grab better. Chips and chip holders are very fragile. It is wise to purchase an extra of each in case you break the connections.

R1	1K
R2	3.9K
R3	1K
R4	3.9K
C1	.01ì f
C2	.0047ì f
U3	MC1455
LED1	2 ma LED Red
Pin 1	ground
pin 8	power

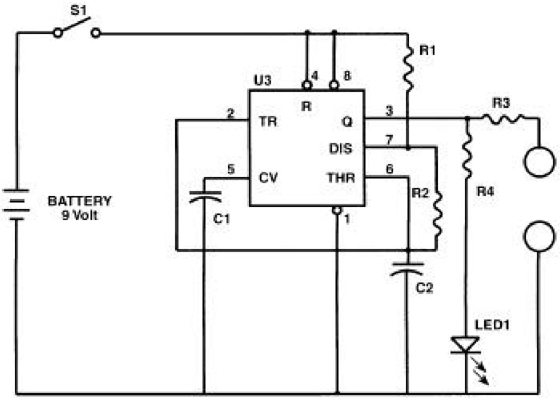

Give this to an electronics person or make it yourself in a shoebox by using the following instructions.

Fig. 3 Zapper schematic.

Assembling The Zapper

1. You will be using the lid of the shoe box to mount the components. Save the box to enclose the finished project.
2. Pierce two holes near the ends of the lid. Enlarge the holes with a pen or pencil until the bolts would fit through. Mount the bolts on the outside about half way through the holes so there is a washer and nut holding it in place on both sides. Tighten. Label one hole “grounding bolt” on the inside and outside.

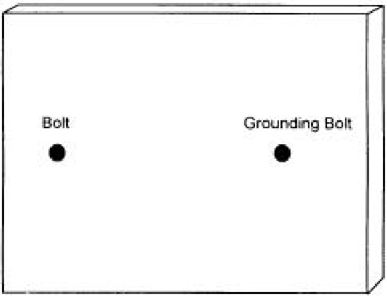

3. Mount the 555 chip in the wire wrap socket. Find the “top end” of the chip by searching the outside surface carefully for a cookie-shaped bite or hole taken out of it. Align the chip with the socket and very gently squeeze the pins of the chip into the socket until they click in place.
4. Make 8 pinholes to fit the wire wrap socket. Enlarge them slightly with a sharp pencil. Mount it on the outside. Write in the numbers of the pins (connections) on both the outside and inside, starting with number one to the left of the “cookie bite” as seen from outside. After number 4, cross over to number 5 and continue. Number 8 will be across from number 1.

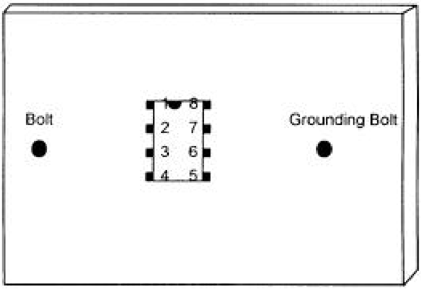

5. Pierce two holes ½ inch apart very near to pins 5, 6, 7, and 8. They should be less than 1/8 inch away. (Or, one end of each component can share a hole with the 555 chip.) Mount the .01 uF ca-

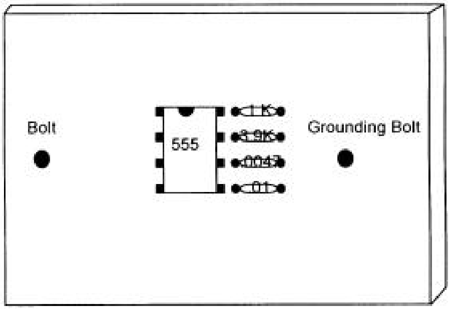

pacitor near pin 5 on the outside. On the inside connect pin 5 to one end of this capacitor by simply twisting them together. Loop the capacitor wire around the pin first; then twist with the long-nose pliers until you have made a tight connection. Bend the other wire from the capacitor flat against the inside of the shoe box lid. Label it .01 on the outside and inside. Mount the .0047 uF capacitor near pin 6. On the inside twist the capacitor wire around the pin. Flatten the wire from the other end and label it .0047. Mount the 3.9 KΩ resistor near pin 7, connecting it on the inside to the pin. Flatten the wire on the other end and label it 3.9. Mount the 1 KΩ resistor and connect it similarly to pin 8 and label it 1K.

6. Pierce two holes ½inch apart next to pin 3 (again, you can share the hole for pin 3 if you wish), in the direction of the bolt. Mount the other 1 KΩ resistor and label inside and outside. Twist the connections together and flatten the remaining wire. This resistor protects the circuit if you should accidentally short the terminals. Mount the 3.9KΩ resistor downward. One end can go in the same hole as the 1K resistor near pin 3. Twist that end around pin 3 which already has the 1K resistor attached to it. Flatten the far end. Label.

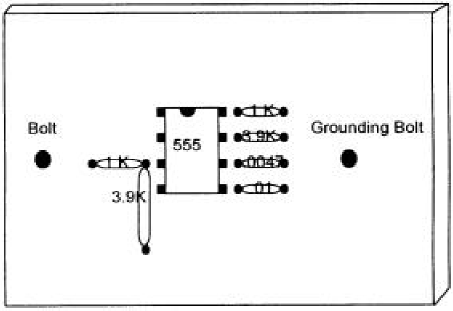

7. Next to the 3.9KΩ resistor pierce two holes ¼ inch apart for the LED. No-

tice that the LED has a positive and negative connection. The longer wire is the anode (positive). Mount the LED on the outside and bend back the wires, labeling them + and - on the inside.

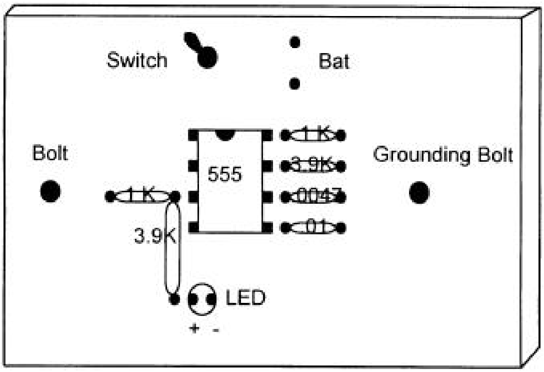

8. Near the top pierce a hole for the toggle switch. Enlarge it until the shaft fits through from the inside. Remove nut and washer from switch before mounting. You may need to trim away some paper with a serrated knife before replacing washer and nut on the outside. Tighten.
9. Next to the switch pierce two holes for the wires from the battery holder and poke them through. Attach the battery and tape it to the outside.

NOW TO CONNECT EVERYTHING

First, make holes at the corners of the lid with a pencil. Slit each corner to the hole. They will accommodate extra loops of wire that you get from using the clip leads to make connections. After each connection gently tuck away the excess wire.

1. Twist the free ends of the two capacitors (.01 and .0047) together. Connect this to the grounding bolt using an alligator clip.
2. Bend the top ends of pin 2 and pin 6 (which already has a connection) inward towards each other in an L shape. Catch them both with an alligator clip and attach the other end of the alligator clip to the free end of the 3.9KΩ resistor by pin 7.

3. Using an alligator clip connect pin 7 to the free end of the 1KΩ resistor attached to pin 8.
4. Using two microclips connect pin 8 to one end of the switch, and pin 4 to the same end of the switch. (Put one hook inside the hole and the other hook around the whole connection. Check to make sure they are securely connected.)
5. Use an alligator clip to connect the free end of the other 1KΩ resistor (by pin 3) to the bolt.
6. Twist the free end of the 3.9KΩ resistor around the plus end of the LED. Connect the minus end of the LED to the grounding bolt using an alligator clip.
7. Connect pin number 1 on the chip to the grounding bolt with an alligator clip.

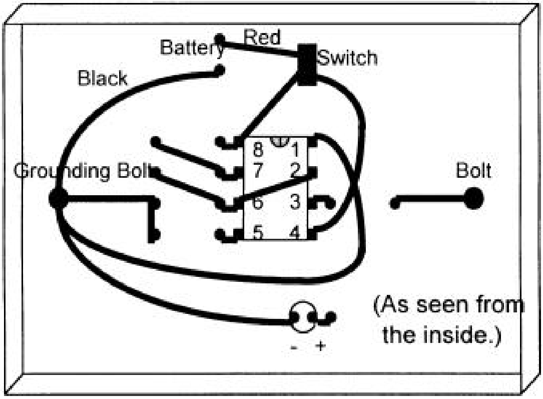

(As seen from the inside.)

8. Attach an alligator clip to the outside of one of the bolts. Attach the other end to a handhold (copper pipe). Do the same for the other bolt and handhold.
9. Connect the minus end of the battery (black wire) to the grounding bolt with an alligator clip.
10. Connect the plus end of the battery (red wire) to the free end of the switch using a microclip lead. If the LED lights up you know the switch is ON. If it does not, flip the switch and see if the LED lights. Label the switch clearly. If you cannot get the LED to light in either switch position, you must double-check all of your connections, and make sure you have a fresh battery.

11. Finally replace the lid on the box, loosely, and slip a couple of rubber bands around the box to keep it securely shut.

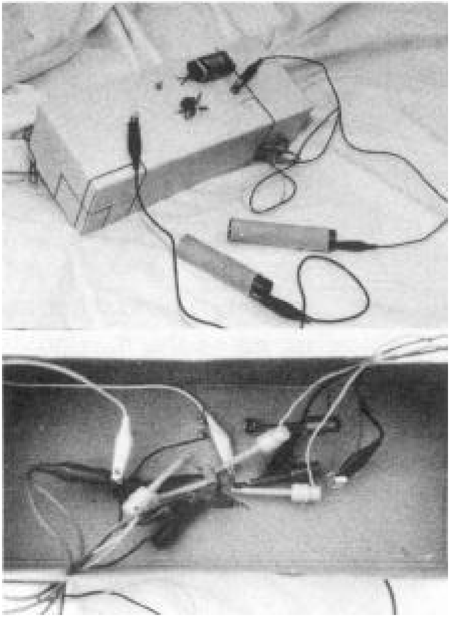

Fig. 4 Finished zapper, outside and inside.

- Optional: measure the frequency of your zapper by connecting an oscilloscope or frequency counter to the handholds. Any electronics shop can do this. It should read between 20 and 40 kHz.
- Optional: measure the voltage output by connecting it to an oscilloscope. It should be about 8 to 9 volts. **Note: a voltage meter will only read 4 to 5 volts.**
- Optional: measure the current that flows through you when you are getting zapped. You will need a 1 KΩ resistor and oscilloscope. Connect the grounding bolt on the zapper to one end of the resistor. Connect the other end of the resistor to a handhold. (Adding this resistor to the circuit decreases the current slightly, but not significantly.)

The other handhold is attached to the other bolt. Connect the scope ground wire to one end of the resistor. Connect the scope probe to the other end of the resistor. Turn the zapper ON and grasp the handholds. Read the voltage on the scope. It will read about 3.5 volts. Calculate current by dividing voltage by resistance. 3.5 volts divided by 1 KΩ is 3.5 ma (milliamperes).

Using The Zapper

1. Wrap handholds in one layer of wet paper towel before using. Grasp securely and turn the switch on to zap.
2. Zap for 7 minutes, let go of the handholds, turn off the zapper, and rest for 20 minutes. Then 7 minutes on, 20 minutes rest, and a final 7 minutes on.

Trying the zapper on an illness to see “if it works” is not useful. Your symptoms may be due to a non-parasite. Or you may reinfect within hours of zapping. The best way to test your device is to find a few invaders that you currently have (see Lesson Twelve, page 492, or Lesson Twenty Seven, page 509). This gives you a starting point. Then zap yourself. After the triple zapping, none of these invaders should be present.

Simple Pulser

If you are ill or want a reliable zapping, make the first model. However, there is another way to make a zapper if you can not afford to build the first model.

An ordinary battery is a source of positive voltage. It is the positive voltage that eliminates so many parasites at once, not a specific frequency. So although the zapper's frequency is about 30 kHz (thirty thousand “zaps” per second), even 5 Hz (five "zaps" per second), **about as fast as you can tap the battery with your hand, is moderately effective!**

You must be connected to both terminals. One will be marked + (positive) and the other – (negative). If you simply touch these terminals with your wet fingers, nothing much happens. That is because your resistance to the current starts going up right away, so less and less current passes through you.

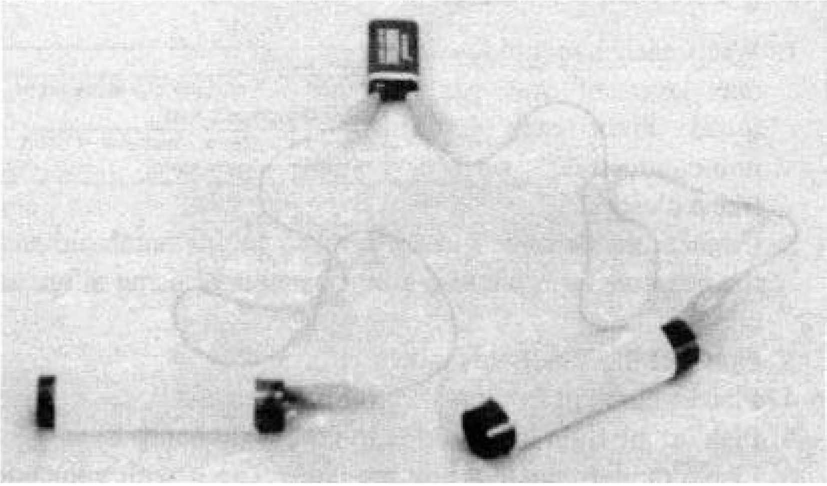

Fig. 5 Simple pulser.

However if you tap the positive terminal with your wet hand, and tap it at a fairly high rate, your body's capacitors come into play. Capacitors only take part in the flow of electricity when they are charged and discharged. Tapping the terminal starts and stops the voltage so capacitors charge and discharge. This kind of resistance to current flow is much smaller.

The faster you tap, the greater the frequency of current pulses and the lower this kind of resistance becomes. Now you can have a considerable sustained current flow through your body.

If you can tap even twice per second (2 Hz) for ten minutes without interruption you can give yourself a zapping that is moderately effective. Remember to take an intermission of twenty minutes and then repeat to avoid catching new viruses. After a second twenty minute intermission repeat zapping a third time.

Using The Simple Pulser

9 volt battery
2 short (12”) alligator clip leads (from any electronics shop)
2 copper pipes, ¾” diameter, 4” long (from a hardware store)

1. Wrap each handhold with one layer of wet paper towel. Place each on a non-conductive surface, like a plastic bag.
2. Connect the positive battery terminal to one handhold and the negative terminal to the other handhold using alligator clip leads.
3. Don't let the handholds touch.
4. Place a clock in front of you to time yourself.
5. Pick up the right handhold with your right hand.
6. Leave the left handhold on the table. Tap it with your left hand, preferably the fleshy part of the palm. You may brace yourself with your fingers on the plastic. Keep up a steady pace as fast as you are able.
7. When you get tired pick up the left handhold with your left hand and tap with your right hand. Keep changing off with the least interruption.
8. Repeat a second time 20 minutes later, and a third time 20 minutes after that.

A single 9 volt battery will wear out rather quickly used this way. Put two together, in parallel, for longer lasting power. This requires two more short alligator clips. Connect positive terminals of the batteries to each other, and the negatives also.

Parasites & Pollution

The word "parasites" is used in two senses. Everything living on you or in you, not just to perch, but to take its food from you is a *parasite*. No matter what its size, it can be called a parasite.

But in some way the big worms need to be distinguished from the medium-sized amoebae, the even smaller bacteria and the smallest of all—viruses. So often the term parasite is reserved for the bigger things, from amoebae on up. In this book, the word parasite will be used in both ways as usual. You can easily guess what is meant.

Parasitic worms are divided into *roundworms* and *flatworms*. Roundworms are round like earthworms even though they may be as thin as hairs (threadworms, *filaria*) or microscopically small (like *Trichinella*). Flatworms are more like leeches. They have a way to attach themselves sometimes with the head (*scolex*) like *tapeworms*, sometimes with a special sucker like *flukes*.

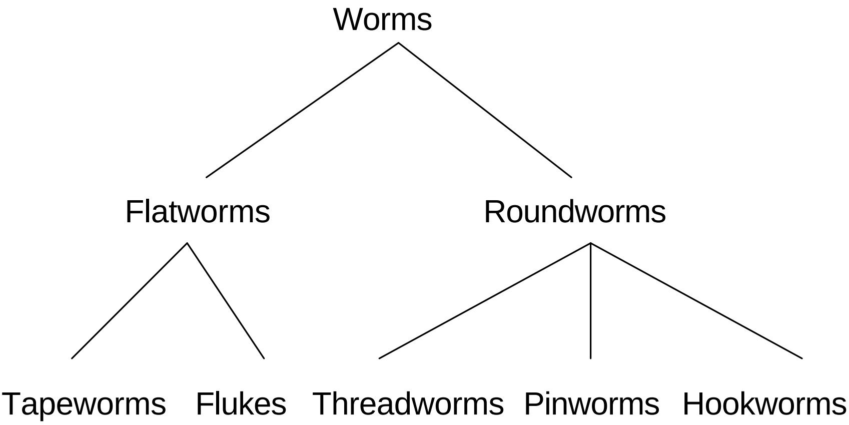

Worm parasites go through stages of development that can look very, very different from the adult.

Roundworms like *Ascaris* (common cat and dog roundworm), are simplest. The **eggs** are swallowed by licking or eating a bit of filth. They hatch into a tiny *larva*. The larva treks to the lungs. You cough it up and swallow it. Meanwhile it has molted a few times. It then crawls to the intestine where it becomes an adult, shedding eggs in your stool.

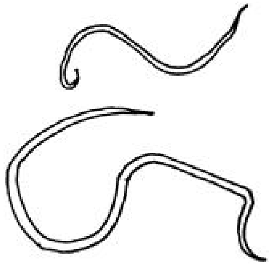

Fig. 6 Ascaris.

Worms usually have preferred locations. The favorite organ for *Dirofilaria* (dog heartworm) is the heart (even human heart). Sometimes the rules can be broken. My tests show *Dirofilaria* can live in other organs, too, if they are sufficiently polluted with solvents, metals and other toxins.

Flatworms like **tapeworms** are much more complicated in their life history. You could eat the eggs accidentally with dirt. After hatching, the tiny larva burrows into its favorite organ. Your body encases it with a cyst. The white blood cells have been taught never to attack your body...and the cyst case is your body! So the tapeworm stage has safe residence for some time. If you are a meat eater, you could eat such a cyst if it happens to be lodged in the meat you are eating! Your teeth break it apart as you crunch. The little larva is swallowed and tries to attach itself to your intestine with its head. Then it grows longer by making segment after segment. The segments with their eggs leave with the bowel contents. I often see dog tapeworm of the small variety in their human family.

Flatworms like **flukes** are also very complicated. The eggs, passed out with bowel contents were not meant to be eaten as such. They were meant to hatch in a pond where snails and minnows eat them. The larva grows up in these new "secondary" hosts. Later, the snail sheds them and they attach themselves to foliage near the pond. They over-winter in a tough *metacercarial* cyst. An unsuspecting browsing animal now eats them. They come out of their metacercarial cyst as a small adult and quickly attach themselves to the intestine with a sucker. They now have "safe haven" and can go about maturing and laying eggs.

Four common flukes are: **human intestinal fluke, human liver fluke, sheep liver fluke, pancreatic fluke of cattle.** Don't let the terms sheep and cattle mislead you. They are all found in humans.

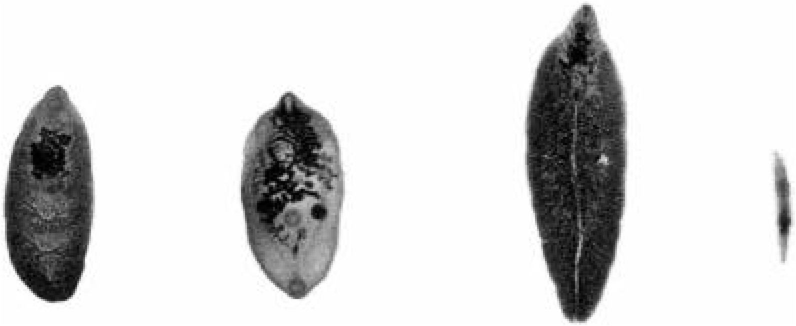

Fig. 7 (L to R) Human intestinal fluke, pancreatic fluke, sheep liver fluke, and human liver fluke.

The Worst Parasite

Fasciolopsis buskii is the fluke (flatworm) that I find in every case of cancer, HIV infection, Alzheimer's, Crohn's disease, Kaposi's, endometriosis, and in many people without these diseases. Its life cycle involves six different stages:

Stage	**Normal Life Cycle**	
1 Egg	Expelled with bowel movement onto soil. Washed by rain into ponds.	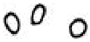
2 Miracidia	Hatches from egg in water. Has cilia, can swim vigorously and must find intermediate snail host in one to two hours or may be too exhausted to invade.	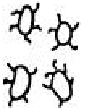
3 Redia	Develop inside miracidia as little balls until expelled. Those are "mother" redia, and each one bears "daughter" redia for up to 8 months, all still inside the snail, and living on the fluids in the lymphatic spaces. Similarly, daughter redia are continually developing cercaria.	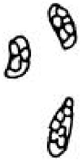
4 Cercaria	Have a tail, use it to exit from snail and swim to a plant. If the snail is feeding on a plant, cercaria can latch onto plant with sucker mouth and start to encyst (form a "cocoon") within minutes. Tail breaks off and swims away to dissolve.	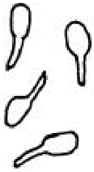
5 Metacercaria	Two-walled cyst. The outer wall is very sticky. But as you eat the plant it is stuck to, the least pressure will break it, leaving the cyst in the mouth. The "almost unbreakable" inner cyst wall protects it from chewing, and the keratin-like coat prevents digestion by stomach juices. However when it reaches the duodenum, contact with intestinal juices dissolves away the cyst-wall and frees it. It then fastens itself to the intestinal lining and begins to develop into an adult.	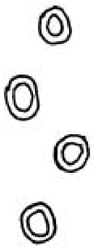

6 Adult	Lives in your intestine and can produce 1000 eggs per bowel movement and live many years.	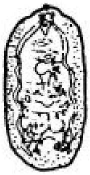

Fig. 8 Fasciolopsis' normal life cycle.

Note that the adult is the only stage that “normally” lives in the human (and then only in the intestine). *Fasciolopsis* depends on a snail, called a *secondary host*, for part of its life cycle. **But when your body has solvents in it, the other five stages can develop in you!**

If **propyl alcohol** is the solvent, the intestinal fluke is invited to use another organ as a secondary host—this organ will become cancerous. If **benzene** is the solvent, the intestinal fluke uses the thymus for its secondary host, setting the stage for AIDS. **Wood alcohol** invites pancreatic flukes to use the pancreas as a secondary host. This leads to pancreatic dysfunction which we call *diabetes*. If **xylene** (or **toluene**) are the solvents, I typically see any of four flukes using the brain as a secondary host. If **methyl ethyl ketone** (MEK) or **methyl butyl ketone** (MBK) are the solvents, the uterus becomes a secondary host and endometriosis a likely result.

This is a new kind of parasitism, based on pollution. I call the diseases caused by fluke stages in inappropriate locations **Fluke Disease**; it is discussed in more detail later (page 249).

Are tapeworms and roundworms affected by solvents this way, too? This is a fascinating and very important question. Search for the answer and help others search for the answer. I do not know yet.

Pollution

Pollutants are all the dead things around us that should not get into your body because they interfere with its work. As long as they don't penetrate your tissues, they won't interfere, like plastic eyeglasses and clothing. But if they are invasive, your body must fight to remove them.

Pollutants can invade your body via the air you breath, the foods and beverages you eat, and the products you put on your skin.

The biggest tragedy is not recognizing when a pollutant is harming you.

Two people can use the same face cream. One develops a rash, the other does not. The one who did not assumes the cream is not harmful to them…that they are like a bank vault, impregnable to that product. A better assumption is that the face cream is somewhat toxic, as evidenced by the rash that can develop, and they escaped the rash only because they had a stronger immune system. The immune system is like money, paid out of the bank vault, for every toxic invasion. When the money is gone, the bank (your health) fails.

Solvent Pollution

Solvents are compounds that dissolve things. Water is a useful, life giving solvent. Most other solvents dissolve fats and are life threatening, because fats form the membrane wall around each of our cells, especially our nerve cells.

The solvent that does the most harm is **benzene**. It goes to the thymus, ruins our immune system, and causes AIDS. The next worst solvent is **propyl alcohol**. It goes to the liver and causes cancer in some distant organ. Other major culprits of disease are **xylene**, **toluene**, **wood alcohol**, **methylene chloride**, and **trichloroethane** (TCE). I'll discuss each one later, with the ailment it's associated with.

Metal Pollution

Biochemists know that a mineral in raw element form always inhibits the enzyme using that mineral. Copper from the meat and vegetables you eat is essential. Inorganic copper, like you would get from a copper bottomed kettle or copper plumbing, is carcinogenic[3]. Unfortunately, the inorganic form of metals is what pervades our environment. We put metal jewelry on our skin, eat bread baked in metal pans, and drink water from metal plumbing.

Another obvious metallic threat is tooth fillings. **Mercury amalgam fillings**, despite the assurances of the American Dental Association, are not safe. And sometimes the mercury is polluted with **thallium**, even more toxic than mercury! **Gold** and **silver** seem to have fewer harmful effects, but no one should have any pure metal in or on their body.

Other prevalent toxic metals include **lead** and **cadmium** from soldered and galvanized plumbing, **nickel** and **chromium** from dentalware and cosmetics, and **aluminum** from food and drink cans, and cooking pots.

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[3] Haleem J. Issaq, The Role of Metals in Tumor Development and inhibition. From *Carcinogenicity and Metal Ions*, volume 10, page 61, of a series called *Metal Ions in Biological Systems*, edited by Helmut Sigel, 1980.

Mycotoxins

Molds produce some of the most toxic substances known, called *mycotoxins*. One small moldy fruit or vegetable can pollute a huge batch of juice, jam or other product. Although molds are alive, and can be killed by zapping, mycotoxins are not, and must be detoxified by your liver.

But because mycotoxins are so extremely poisonous, a tiny amount can incapacitate a part of the liver for days!

Aflatoxin is the most common mycotoxin I detect. It is produced by molds that grow on quite a variety of plants. For that reason I am always cautioning people to eat only perfect citrus fruit, and never drink commercial fruit juice. Of the thousands of oranges that go into the batch of orange juice you drink, one is sure to be moldy, and that is all it takes to give your liver a setback.

A heavy dose of vitamin C helps the liver recover quickly. It also helps get rid of aflatoxin before it is consumed, right in the food container. So keep a plastic shaker of vitamin C powder handy and use it like salt on all your food.

There are thirteen other mycotoxins I have searched for in our foods. They are described in the section on moldy food (page 381).

Physical Toxins

Breathing in dust is quite bad for you so your body rejects it by sneezing, coughing, spitting up and out. Imagine breathing in broken glass particles. They cut into the lungs in a thousand places and couldn't be coughed up. They would travel. Imagine swallowing a needle or open pin. If the tip was blunt it could move through the intestine. But because it is sharp it gets caught in your tissue, then works its way deeper and deeper.

Would we ever knowingly breathe in broken glass? We are justifiably afraid of it in our food or under our bare feet. We are unaware that it fills our homes when **fiberglass** insulation is left imperfectly sealed off. Any hole made through the ceiling or wall, even if covered with cloth, lets swarms of broken glass bits into the house air. Air currents flow inward, into your living space. So all holes leading to the attic or insulated spaces must be sealed airtight. Of course, fiberglass should never be used in home construction, draperies, or around water heaters. The best advice is to have it all removed while you are away and then vacuum and dust.

Occasional exposures by house builders working outdoors does much less harm. Chronic exposure from a single small hole in the ceiling does a lot of harm, leading to cyst formation. And that cyst is a perfect place for parasites and bacteria to settle and multiply. When the intestinal fluke settles there it becomes malignant!

Cancer patients with *solid tumors* have either fiberglass or asbestos in them.

Asbestos is another tiny bit, sharp as glass, that moves through your body like a swordfish, impaling your cells until it, too, gets routed into a cyst.

We have been led to believe that we no longer have asbestos in our homes because we have outlawed the fireproofing materials it was used in. While that may be true, the source I find most often is all too prevalent: the clothes dryer belt. As it gets hot the belt releases a blast of asbestos particles that are forced through the seams of your dryer, and also openings in your exhaust hose, by the high pressure formed inside. It is now in your air.

Chemical Toxins

Chlorofluorocarbons (**CFCs**) or **freon** is the refrigerant in your air conditioner and refrigerator coils. CFCs are suspected of causing the ozone hole above the South Pole. All cancer sufferers test positive for CFCs in their cancerous organ! I have preliminary evidence that it is CFCs that attract other pollutants–fiberglass, metals, PCBs–to form a growing tumor instead of allowing their excretion. This would make it a "super carcinogen.". How could you detect CFCs leaking in your home? By the time your air conditioner or refrigerator needs recharging, you have been exposed for a long time. We desperately need an inexpensive, in-home test for this unsuspected killer.

Arsenic is used in pesticide. Why would we poison ourselves along with the cockroaches? Is it because we can't see it happening? Just as we couldn't see the fiberglass floating in the air? Our diligent scientists have studied the mechanism of arsenic poisoning in great detail. Then why are we allowed to put it on our lawns to be carried into our carpets via shoes?

Polychlorinated biphenyls (PCBs), oily compounds with wonderfully useful electrical properties, were originally used in transformers until their inability to break down into less toxic substances in our environment was spotlighted. Banned from use, I find them in most commercial soap and detergents! Is transformer oil being disposed of by selling it to soap makers?

Formaldehyde is used to cure foam. As a result, foam furniture, pillows and mattresses give off formaldehyde for about two years after manufacturing. If you sleep with your nose buried in a new foam pillow all night, you are risking major lung problems.

Every cleanser in your house probably has a toxic warning on its label. Every fluid your automobile uses is toxic. Every pesticide, herbicide and fertilizer you put on your lawn is probably toxic. Every paint, varnish, wax, lubricant, bleach and detergent will send you to the hospital if even a small amount is ingested. Why do we keep them around? See *Recipes* (page 513) for safe, old-fashioned, alternatives.

If you are ill even after zapping, it is toxins still at work. Getting rid of them is a major step toward being well.

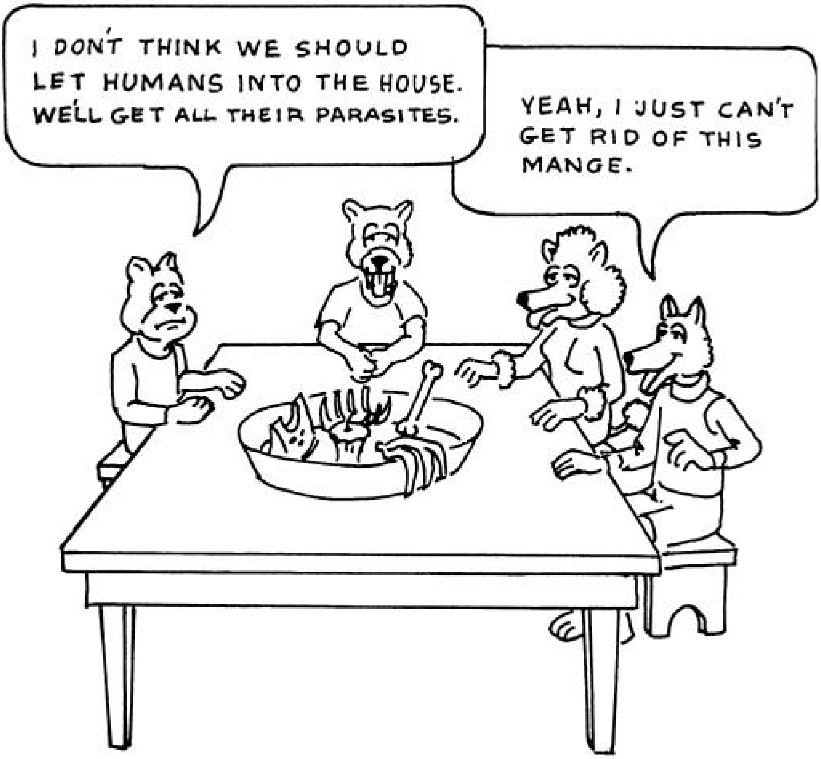
I DON'T THINK WE SHOULD LET HUMANS INTO THE HOUSE. WE'LL GET ALL THEIR PARASITES.
YEAH, I JUST CAN'T GET RID OF THIS MANGE.

How We Really Get Sick

What if you invented a device that could search people for the presence of mycotoxins (extremely toxic substances made by food molds)? And what if you found that although many people had them, those who were sick with a cold always had at least one of them. Would you ask whether a sudden buildup of mycotoxins is what really lets colds develop? Why do some people in the same family get the cold while others do not?

- What if you found everyone with **cancer** had the human intestinal fluke in their liver, and no one else did?
- What if you found everyone with **diabetes** had the pancreatic fluke of cattle in their pancreas, and few others did?
- What if you found everyone with **environmental illness** tested positive for Fasciola (sheep liver fluke) in their liver?
- What if you found everyone with **asthma** tested positive for Ascaris in their lungs?

What if you always found every mysteriously ill person had some unsuspected parasite or pollutant?

The device is the Syncrometer™, and these "what ifs" are all true. They forced me to alter my entire outlook on what really causes some of our "incurable", mysterious diseases.

We used to believe that diabetes was caused by over consumption of sugars, a cold by a virus you caught from somebody, cancer from carcinogen exposure, depression from poor parenting. This multicausal concept is what made the study of medicine so difficult that only a few could undertake it. And every year new syndromes are added to the list of human illnesses.

But these diagnoses are based on a description of what is happening at a particular place in your body. This is like calling a mosquito bite behind the ears by one name and a mosquito bite behind the knee by another name. If you never see the true cause, a mosquito at work, this system could be excused as somewhat sensible.

And, until now, the profession of medicine has made some sense. The new truths, however, make the old descriptive system obsolete. You can now find the true causes of all your illnesses. And you can find them yourself by building the electronic diagnostic circuit (page 457)!

Once you have seen a mosquito at work on your body you no longer need to go to the doctor for a red, itchy bump. You don't need to search for the correct diagnosis and an appropriate drug. **You put up screen doors and windows!**

Once you have seen how common house dust is implicated in the common cold you get rid of the house dust. Once you have seen the mold in your food facilitate the cold virus you throw out that moldy food. But only seeing is believing. Nothing is left to faith. The electronic resonance method described in this book will let you see all these things for yourself.

You are not a hapless pawn attacked by bacteria and viruses that dart at you from nowhere to make you ill. You are not at the mercy of diseases all around you, hoping, by chance, to escape, like a soldier hoping to come home from the war. Nature and your body make good sense.

There is no disease that can outwit you if you know enough about it. Not even Lou Gehrig's disease! Nor asthma or diabetes. Read how the people in the case histories made themselves well. Read why some people failed. You have an advantage they did not have. Their instructions were hard to carry out because they had to have faith in them. You don't. You can replace faith with your own hard headed observations by building the diagnostic circuit (Syncrometer). The great convincer is seeing it yourself. When you personally find the mold in your peanut butter, or *Shigella* in your cheese, you have the knowledge, not faith, that convinces and guides you.

All illness comes from two causes, PARASITES and POLLUTANTS.

Only two causes! This is what simplifies the picture to make it possible for you to cure yourself.

We have been taught that illness is largely our own fault. That it is due to “catching something”, not eating what we should, like roughage or vitamins, or not doing what we should, like dressing properly, exercising or going to bed on time. Somehow, it's our own fault. Either by doing something we shouldn't or not doing something we should. When absolutely no fault can be found we are told it's in our genes! True inherited diseases are extremely rare. Our genes have evolved over millions of years to produce healthy humans. Nor are genes that mutate during your lifetime at fault. Pollutants, which are known to be mutagens, are the real culprits.

Neither the parasites nor the pollutants in you are “your fault”. Notice that other people all around us are doing the same things or not doing the same things, and even share our genes and don't have our illness. The current concepts on disease causation blaming our actions and our genes are simply not logical.

But until now they appeared logical. Suppose 1000 people were bitten by a mosquito or flea, it would always be in a different place, and if you were using the location and effect system to diagnose the problem you could have a thousand diagnoses listed for them, including a defective gene. Could you be persuaded to accept a gene replacement for your red itchy bumps? The new gene might be for antihistamine production so the welts don't become large, red and hot, or lead to impetigo. If you were the research doctor, you might be tempted to alleviate a thousand persons' distress with a new gene. Fortunately, you are not and only need to solve your own problems. You can be more logical.

After you have found the parasite interlopers hiding in your body you can kill them electronically. And after you have identified the pollutants stuck in your organs you can stop eating them, breathing them or putting them on yourself. In response, your body will begin to heal, just as surely as a mosquito bite heals.

Heal from multiple sclerosis, emphysema, myasthenia? Yes!! Some healing will be swift. Some healing will be slow. Healing is not understood. It is much faster in young persons. But fast or slow you know it has begun. It will be an exciting adventure to watch yourself lose your symptoms and get stronger.

Self Health

The entire purpose of this book is to enable you to diagnose and treat yourself for any disease. You have three new approaches that make this wish a reality: the understanding that only pollution and parasites make you sick, the quick and inexpensive diagnostic circuit that lets you find which pollutants and parasites they are, and the zapper or herbal recipe that kills the parasites.

Wouldn't it be nice not to have to go to the doctor for your aches and pains? And not to be dependent on the doctor to diagnose and treat you?

Self health means keeping yourself healthy. Doing it **yourself**.

Suppose your doctor has already diagnosed you as having “Atypical Lateral Sclerosis” or “Shoulder-Hip Girdle Metastable Aplasia.” Could you re-diagnose this for yourself so as to treat and cure it? And be successful? Why not? You have already succeeded in many enterprises. You learned to talk, walk, read, get along with people. These skills took a few years to master. Learning to keep well is a new skill. It may take a few years too. After you have learned these skills you may pass them on to your children. And so a new gift is given to humanity, like the gift of music or the art of cooking.

How To Heal

Your body has been trying to rid itself of its parasites and pollutants all your life! It had its own ways. It made stones, it made mucus secretions, it made itself toxic dumpsites. These were good tactics but now of course, they are no longer necessary. Can you help your body get rid of these accumulations and sweep itself clean again?

Sweeping your liver clean is the most powerful way of helping your body to heal itself after the parasites are gone. There are thousands of bits of “trash” accumulated in the liver bile ducts. They will turn into stones (gallstones) if left in place.

The kidney, too, has made numerous small stones in its effort to keep your body clear of lead, cadmium, mercury and other impassable pollutants. You can assist the kidney to expel all these.

In days, not weeks or months, you can feel the healing effects of clearing gallstones and kidney stones from your body. But there are miles of bile ducts (50,000 ducts) in the liver; the herbal recipes that do this are used over and over, patiently, until all, the "trash" is removed. This can take several years.

So, although you can stop your disease very quickly from progressing, the healing process may not be complete for years.

Nevertheless, you are healthy again. This means your pains are either gone or greatly reduced. Your organs are functioning better. You have a new sense of well being. Your energy is up. Your desire to live and accomplish something is back.

Organs that have been damaged beyond the ability of our simple methods to reverse can be treated with the magic of modern surgery. Cataracts, bunions, old injuries are examples. Possibly, these too, are "stone" formations. But no recipe has been found to clear them up simply and in a useful time frame.

Killing parasites, removing pollutants and clearing gallstones and kidney stones from your body is a powerful combination of treatments. It is so powerful you can change yourself into a new person in half a year. And then go on improving for years more.

Should you stop taking your prescription medicine while you are treating yourself? NO. Wait until you have cured yourself of the condition that required the medicine. Reduce your medicine and eventually go off it. Will your doctor approve? Find one that will. Remember that the medicine is buying you the time to cure yourself, something to be grateful for.

The Road To Wellness

To review our new understanding of health vs. disease:

- We have only two problems: parasites and pollutants. Parasites are things that live on us, using up our food and giving us their wastes. Pollutants are toxic things in us making it difficult for our organs to do their work. These two things are responsible for all our other problems.
- Our bodies have been trying to rid us of these by making stones, making secretions, giving us swellings, inflammations and benign tumors. We develop deficiencies and disabilities.
- Finally, some permanent damage is done. Our hair turns gray, we develop cataracts, the spine bends, nerves and muscles die. We weaken.

Our strategy to undo all this will be a logical one.

First, we will kill all parasites, bacteria, viruses and fungi.

Second, we will remove the toxic molds, metals and chemicals in our foods and body products.

Third, we will clear away and wash away the stones, secretions and debris already formed, that hinder healing.

Fourth, we will use herbs and special food factors to hasten healing, being very careful to use pure products. (These act more quickly when given intravenously but the emphasis in this book will be on oral consumption.)

Finally, for repairs that are beyond our abilities, we will seek help from health and medical professionals.

What could be more exciting than finding the tremor is out of your arm or the pain is out of your shoulder? Won't it be admirable to correct your pulse and your high blood pressure, by yourself? What an adventure it could be to get rid of all your warts.

But getting rid of pain seems like a first priority to me, since pain often undermines our morale, our initiative to do things, even our interest in getting well!

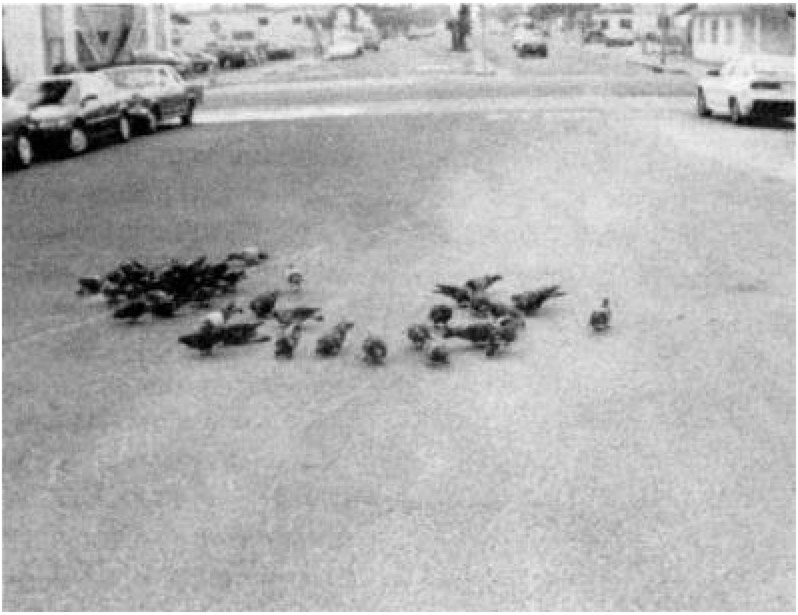

Many of our illnesses are caused by unsuspected sources. I have found pigeon tapeworm in humans, for instance.

Fig. 9 Feed animals out of your yard and away from where children play. Their wastes contain pathogens.

Pain From Toe To Head

I would rather die than endure excruciating, unrelievable pain. That puts **pain** at the very top of my priority list.

Fortunately for us, pain killers are at hand to get us through it and buy us the time it takes to solve the real problem behind it.

The pain killing industry also brought us the addiction industry. As we turn to electrical pain killing the need for addicting drugs should decline. There are other very useful pain killers: acupuncture, massage, listening to music, feedback devices, contemplation, hypnotism, and prayer.

But we will focus on getting rid of the cause of pain and healing the organs that are in pain so none of these methods are needed.

I am not talking about the pain of a broken bone, twisted ankle, bee sting or sunburn. I am not talking about the pain of a misaligned vertebra or stretch trauma in your leg muscles or arm muscles. I am referring to pain that is in one of your organs and refuses to go away. For example, arthritis. Other pains are headache, foot pain, elbow pain, hip pain, chest pain. All of these may have special names like rheumatoid arthritis, cluster headache, fibromyalgia, bursitis, tennis elbow and so on, but they are all the same phenomenon.

Knowing that parasites and pollutants are the real culprits, let us get right down to the job of finding out which they are, where they come from, and how to get rid of them.

The parasites that cause pain are not the large ones, like worms or amoebas. Nor are they the very tiny viruses. They are *bacteria*. Bacteria are the right size to get into the doorways of our cells. Our cells try to keep their doorways tight-shut but, of course, they have to open to let food in, or hormones, or other life-signals. If bacteria are swarming around the outside of cells, some will manage to slip into a doorway while it is open. A battle begins. The cells refuse to let the bacteria in. The bacteria refuse to let go of the door latch. There is probably a specific electrical attraction between them and an exact physical fit. The body's extra forces, the immune system, are called in to help quell the invasion. The bacteria multiply as fast as they can. There is swelling. There is heat produced. There is pressure against other organs. All together it is called inflammation and infection.

The answer is not to deinflame with drugs (like the cortisone variety). The answer is not to reduce swelling or body temperature. **The answer is certainly not pain killer.** The answer is to kill the bacteria. (Even this is not the ultimate answer. We must stop the source of the bacteria and your body's invitation to be invaded. We will get to this later.)

So **Step One** is to search for the bacteria nibbling at our painful regions and identify them. This gives us the clue to finding their source. **Step Two** is to exterminate them electrically. Within minutes they fall out of the doorways to our cells. Your white blood cells are waiting for them, and will gobble them up in a grand feast.

But, remember, there is another cause of pain, pollutants. **Step Three** is to find the pollutants and identify them because this gives us a clue as to their source. **Step Four** is to eliminate our pollution sources. **And the job is done. Pain is gone.**

An intriguing question will pop into your head as you search your organs for parasites and pollutants. Which came first? Pollutants can jam their way into your cell's doorways too. Does this allow the bacteria to swim in? Or do the bacteria come first, jamming open the doorways so the pollutants can enter? Both seem possible. Maybe both events go on simultaneously. Perhaps that is why bacteria and pollutants are always seen together. Viruses can land on your cell's doorways, too, and cause viral diseases, but they are not as often pain producing.

You will also notice something, as you keep testing and watching over your health. **Your body is very good at killing bacteria and viruses**. Your body kills them faster than a wave of a magic wand! The only ones that get away are those that are stuck in doorways and ‘channels with pollutants in them! This seems like evidence that pollutants do the gate-opening. But it isn't proof and we must keep all possibilities in mind.

Fortunately we do not have to know exactly how parasites and pollution make us sick in order to get well.

Searching For Bacteria

In order to find which organs have the bacteria and which bacteria are present you will need to learn the new technology that makes all of this possible. This technology is a simple electronic circuit that is capable of trapping frequencies in such a way that you can hear them. Your body's frequencies, the frequencies of bacteria, viruses and parasites are all different and can be heard as distinctly as a **mooo**, **baah**, **tweet**, or **oink** coming from a farm yard.

But do you have to do all that?

No! You don't. You could simply electrocute all these tiny invaders. But how would you know what to avoid in the future? If your pain returned how would you know if it was the same old bacteria or a new one?

Learning to test takes the guesswork out of diagnosis.

My hope is that you will find it all so intriguing, so absolutely fascinating, that in spite of some chronic pain, you will feel compelled to make the searches yourself. Find someone willing to help. Trade your information. It is less difficult than learning to use a computer.

What You Will Find

First we will study and cure pains of all kinds, starting with the toes and working our way up the body. We don't need to be very specific about the location of the pain since bacteria and toxins flow over to nearby locations anyway.

For each kind of pain, we will look into the causes so you can eliminate them. Pain could come back in an hour if you didn't know the bacteria were coming from cheese and you had a cheese sandwich after *zapping* (killing parasites electrically). In fact, the pain may not have had time to go away before the next onslaught begins and you might conclude, wrongly, that this method doesn't work.

Parasites might also come back to your specially painful place from a few far away places that are hard to reach by your zapper's electrical current. The inside of your eyeball, the testicle, the interior of gallstones, the middle of a tooth abscess or the bowel contents are such places. Your zapper current, because it is high frequency, prefers to “go around” these items, rather than through them. But with repeated zapping, and herbal parasite treatment, you can decimate them, too, and stop reinfecting the rest of your body.

In fact, it is such knowledge about reinfection and sources of our pollutants that is the most important contribution of the case histories.

After dealing with pains we will turn our attention to the diseases that aren't pain producing, like diabetes, myasthenia gravis and so on.

Toe Pain

The ends of your feet get the poorest “service” from your blood supply. They are the furthest away. The blood here has the most accumulated acid and the least oxygen supply. The body produces quite a bit of *uric acid* and this should, of course, be excreted into the bladder by the kidneys. But if the kidneys are doing a poor job of this, levels in the body and blood stream rise. The blood can only hold so much. It holds even less in acid conditions such as the ends of your feet experience. Uric acid begins to settle out or precipitate at our feet.

Hippuric acid, too, is found where pain is found. Hippuric acid is made in large amounts (about 1 gram/day) by the liver because it is a detoxification product. It makes no sense to consume *benzoic acid*, the common preservative, since this is what the body detoxifies into hippuric acid. Read all labels on food you buy. Don't buy any beverages or baked goods preserved with benzoic acid. *Citric acid* is fine. The joints of the big toes are favorite places for pain to develop. This is made even worse when circulation is poor. Take a *cayenne* capsule with each meal to improve circulation. If you cannot find your pulse just below your inner ankle your circulation is poor.

The accumulation of uric and hippuric acid invites bacteria to feed on them. As bacteria multiply the tissue fights back with

inflammation. Now the stage has been set for **pain**. Some people do not have pain although these acids and other deposits are present making their joints knobby and unbending. Bacteria have not found them yet or haven't multiplied sufficiently in them to invade your tissues. Perhaps there are other reasons as well.

If you have **toe pain** your course of action is this:

1. Kill all bacteria possible with your zapper. Repeat daily until no further benefit is seen.
2. Dissolve the deposits away. An herbal recipe, quite elaborate, is capable of doing this. It is called the Kidney Cleanse (page 549). Toe deposits are made of the same crystals as kidney stones, which is why the Kidney Cleanse works for toe pain. But because these deposits are far away from the kidney, it takes longer than merely cleaning up kidneys. It may take six months to make a significant dent on these deposits. This will at the same time remove kidney crystals so that these are no longer a source of bacteria.
3. Get teeth cavitations cleaned (cavitations are bone infections in the jaw where a tooth was pulled; it never healed; see Dental Cleanup page 409). This can "magically" stop the toe pain the same day as they are cleaned. The effect lasts for days afterward showing it is not the dental anesthetic that is responsible. It also teaches you that the bacteria in the toes can come from the teeth. But pain may return as other bacteria find the deposits.
4. Clean the liver of stones using the Liver Cleanse (page 552). This, too, can give immediate pain relief in the toes showing you they are a source for bacteria. Liver cleaning may take you two years to complete! Meanwhile your toe pain is receding. And, of course, this pays extra dividends in health for your body.

5. Reduce the acidity in your toes. First, check your acidity with pH paper meant for testing urinary pH, called Nitrazine^{TM} paper. Ordinary pH paper, as for fish tanks, is almost as accurate and will serve as well. Tear a ½inch piece and hold it in the urine stream. Early morning is the time your urine is most acid. If this reads below 5.5 your feet must have been even lower in the night (lower is more acid).

Once deposits start, it is hard to stop them. If they start forming at 2 a.m., they are likely to continue for several hours even if the pH goes back up to normal. Your tactic will be to go to bed with an alkalizing action. Taking a calcium and magnesium supplement at bedtime, drinking milk at bedtime, using baking soda at bedtime are all remedies to be tried. They should raise your urinary pH to 6 in the morning.

Balance Your pH

Most persons with painful deposits anywhere in their feet have a morning urine pH of 4.5! At 4.5 it is safe to guess that a lot has precipitated again in the night. During the day, your body's pH swings back and forth. The urine gets quite alkaline right after a meal; this is called the *alkaline tide*. Three meals a day would bring you three alkaline tides. During these periods, lasting about an hour, you have an opportunity to dissolve some of your foot deposits. But if you allow your pH to drop too low in the night you put the deposits back again. The net effect decides whether your deposits grow or shrink.

To alkalinize yourself at bedtime, choose one of these options:

1. Two oyster shell tablets, equaling 750 mg. of calcium plus a magnesium oxide tablet, 300 mg (see *Sources*). The magnesium helps the calcium dissolve and stay in solu-

tion. Taking more calcium at one time is not advised because it cannot be dissolved and absorbed anyway and might constipate you. For the elderly only one calcium tablet is advised. Take calcium tablets with vitamin C or lemon water to help dissolve (¼ tsp. vitamin C powder; adding honey is fine).

2. One cup of sterilized milk or buttermilk, drunk hot or cold, plus 1 magnesium oxide tablet, 300 mg. (adding cinnamon is fine).

   If these two remedies work for you, your morning urinary pH will come up to 6.0 but if for some reason they don't, you need to take more drastic measures. Take the supplements and milk earlier in the day and reserve bedtime for:

3. ½tsp. baking soda in water. This is *sodium bicarbonate*. But don't use baking soda from a store because most brands I have tested are polluted with benzene! (See *Sources* for safe baking soda.) Using a combination of sodium and potassium bicarbonate in a ratio of 2:1 is actually a much more healthful potion. You can make your own or ask a pharmacist to make it for you. Mix two parts baking soda and one part potassium bicarbonate (see *Sources*) in a jar. Keep tightly closed. Label it **sodium potassium bicarbonate alkalizer** (this potion is also very useful in allergic reactions of all kinds). Take 1 level tsp. in water at bedtime. If your pH reaches 6 in the morning continue each night at this dose. If it does not, take 1½tsp. Keep watching your pH, since it will gradually normalize and you will require less and less. If you are using plain baking soda, instead of the mixture, watch your pH each morning, also, so you can cut back when the pH goes higher than 6.

Persons with a limit on their daily sodium intake must carefully count the grams of baking soda consumed in this way.

Each tsp. weighs about 2 grams, of which half (1 gram or 1000 milligrams is sodium. The sodium/potassium mixture would only give you half as much sodium (½gram per tsp.). By comparison, the usual daily intake of sodium is about 5 gm., although salt eaters consume twice that amount.

You have done five things to pull the rug out from under the bacteria living in and around the deposits in your toes. Now when you kill bacteria with your zapper, you can expect the pain to go away and stay away.

Locations at the base of toes may be painful due to a *neuroma*. Deposits and bacteria here are even more painful because this is the location of nerve centers. If the build-up is large, you may prefer some surgical help or a cortisone shot rather than wait several years for solid relief.

Foot Pain

This kind of pain does not involve as much deposits as toe pain and is therefore easier to clear up. But trauma to the foot is more important. First, even though your shoes are comfortable, change them. Get wider shoes, longer shoes, lower heels. Alternate two pairs of shoes in a single day. In your home take shoes off.

Keep feet very warm. Wear natural fiber socks, not synthetics. If your circulation is poor, take a *cayenne* capsule with each meal. When circulation is moderately poor, your feet get cold easily. When circulation is very poor, the heart pulse cannot be felt in your feet (take your pulse just below your inner ankle). Again:

- Get teeth cavitations cleaned (Dental Cleanup, page 409).
- Do the herbal Kidney Cleanse (page 549).
- Kill parasites and bacteria with a zapper.

- Then clean the liver (page 552).
- Check body pH in the morning upon rising using Nitrazine™ or other pH paper. Correct it as discussed in Toe Pain. If the urinary pH is 7 or higher, it means you have a bladder infection. Treat it immediately (page 101).

If there is any swelling around the foot or ankle, you are "holding water." It may be called *edema*. This is due to poor adrenal and kidney function. The adrenals are located on top of the kidneys and together they regulate how much salt and water stays in your body. Because they are situated so close together, they share their parasites and pollution. When the kidneys form *kidney crystals* the flow through the kidney tubes is hindered, and less water and salt can leave the body. It stays in your tissues as edema.

The kidney herb recipe will dissolve the crystals. But you must remove toxins such as metal from tooth fillings and kill parasites. Continue doing the Kidney Cleanse after the original six weeks is up until all foot pain and edema are gone. Continue killing your tiny invaders with a zapper twice a week. You may need to cleanse the liver several times, too, before all the pain and edema are gone.

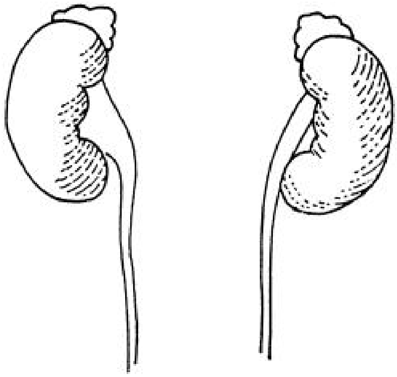

Fig. 10 Your kidneys with the adrenal glands sitting like hats on top. The ureters lead to the bladder.

The supplement, *pantothenic acid* (see *Sources*), is particularly good for feet. Take 500 mg three times a day for several weeks to see if it helps. Massage and reflexology are also good for them.

Heel Pain

Sometimes heel pain is due to heel spurs, sometimes it is not. Heel spurs are due to deposits. The usual heel deposits are *uric acid* and various *phosphates*. Uric acid deposits become a breeding ground for bacteria. The phosphates give the deposits a rigid structure that is hard to dissolve. You may have to choose a pain killer, get specially built "orthopedic" shoes, or stop your daily walks to get relief from the piercing pains. These will not cure the problem but may "buy you some time" while you make basic changes in your lifestyle.

Stop drinking tea and cocoa because they contain *oxalic acid*. Stop drinking coffee, decafs, fruit juice and soda pop because they are contaminated with solvents. All of these must be detoxified by your body and eliminated by your kidneys. We should spare the kidneys these extra tasks when we wish them to clean up heel spur deposits. You must first dissolve the deposits, then help the kidneys eliminate them.

To dissolve them, you alkalinize your body's pH, watching over it carefully with pH paper or Nitrazine paper. To help kidneys eliminate them, use the Kidney Cleanse and drink lots of water. Only water, not a beverage, helps the kidneys to eliminate.

Drink a pint of water upon rising in the morning, and a pint of water between meals.

Do not buy "special" water. Use your cold tap water only. If you don't like the taste of your own tap water, get it from somebody else's tap. Use only glass or reused polyethylene jugs. Polyethylene is opaque, not clear. It has already lost its plasticizer into the water that stood in it earlier. (Somebody drank it!) Purchased water has traces of solvents from machinery and sterilizing equipment used in its bottling. Your own tap water is not pure (indeed it may have 500 toxic elements), but it never contains solvents in amounts I can detect.

Traces of solvents are worse than traces of other toxins.

Water filters are not the solution. They trap the pollutants and then allow a tiny amount to enter the water on a daily basis. Chronic toxin consumption is much worse for your health than periodic surges of toxins. You can use a small filter, that gets changed every month without much risk. This would dechlorinate the water, at least, and improve the flavor. The pitcher variety (it should be made of hard, inflexible plastic) and the faucet variety are listed in *Sources*.

Bottled water is popular,

and tasty, and has appealing advertising, but it is just not safe.

Why is it easier for everyone to spend dollars per day, for the rest of their life, buying water instead of insisting that their water pipes are metal-free?

Another reason not to drink water from bottles, however convenient, is that it is stagnant and is soon contaminated with our own bacteria from contact with mouth or hands. *Staphylococcus (Staph)* and *E. coli* are commonly seen. The solution is not to add still more chemical disinfectants, the solution is to drink from a flowing source, such as our faucets. If you must carry water, use glass containers; plastic is porous and much more difficult to wash clean (sterilizing in a dishwasher is effective, though).

By drinking a total of four pints of water in a day, the kidneys will notice the assistance. (Any single herb tea without added salt or sweetener counts as water.) The urine will stop having any odor and will become very light colored. This is especially important while you are dissolving the heel deposits since your body is now carrying these in the circulation.

Killing bacteria with a zapper may give you instant pain relief and is, of course, beneficial to your body. But you can't expect the pain to stay away until the deposits are gone and the source of bacteria is also removed. Go after the usual sources: teeth and stones. Another source is dairy food contaminated with *Salmonella* and *Shigella* bacteria. Sterilize all of it by boiling. Even the amount put on cereal in the morning or used in scrambled eggs is enough to reinfect you! Butter and heavy whipping cream also need boiling. Stop eating yogurt and cheese which can't be boiled.

Phosphate deposits are a mixture of three phosphates: *monocalcium phosphate* (CaH_2 PO_4), *dicalcium phosphate* (Ca_2H PO_4) and *tricalcium phosphate* (Ca_3 PO_4). They are formed by eating too much (way too much) phosphate relative to calcium.

Our high phosphate foods are meats, carbonated beverages and grain products like rice, cereals, breads, pastas and nuts.

The body's normal elimination tactic for phosphate is to combine it with calcium and magnesium in order to neutralize it first. Unneutralized phosphate is very acidic and would burn the delicate kidneys. But where shall the calcium and magnesium be taken from? Magnesium is often in very short supply since it comes from green vegetables in the diet and is not stored up in any special organ. So it falls on calcium to be used for this purpose since it is stored up (in your bones and teeth).

The acid condition created by phosphates dissolves your bones and allows large amounts of bone structure to be washed out with the urine: this can be directly seen with an analysis of urine (you can ask your doctor to order this at a lab). If you catch all the urine in a 24 hour period you can measure all the calcium you have wasted. You should not lose more than 150 mg calcium in a day because this is all you can absorb in a day![4] If you do lose more than 150 mg in a day, you are dissolving your bones at a fast clip. This also means there is too much calcium in your blood and lymph, from dissolving so much bone so quickly.

Once you have dissolved your bones it is not so easy to put the calcium back into them. Your body will try to put it back as soon as possible—as soon as your acid condition is gone. But your bones can't do this without *vitamin D*. Vitamin D may "come from" sunshine and from vitamin D in milk but it isn't that simple. Vitamin D must be activated by your kidneys before it can go to work! Remember, though, it was the kidneys that had a problem in the first place, allowing deposits to form! With old kidneys, clogged with crystals, hampered by heavy metal and mold toxins, and beleaguered by bacteria and parasites, is it any wonder that sunshine and vitamin D fortified milk don't supply large amounts of activated vitamin D? It takes large amounts to put back into your bones the large amount of calcium that dissolved out during the acid state you put yourself in by over consuming phosphate food.

If you can't put the calcium back into your bones promptly where is it to go? It may attach itself to tissues that were never meant to be used this way. Your arteries fill with "scale," your kidneys form calcium phosphate crystals, heels form spurs, joints become knobby with deposits.

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[4] You absorb 5 to 10% of what you eat. If you eat 1 gram (1000 mg) you absorb 50 to 100 mg. But you absorb 25-40% if it comes from milk!

Young persons and children, with healthy unclogged kidneys, make–that is, activate–ample vitamin D, so even if they consume too much phosphate and develop an acid condition that dissolves their teeth and bones, **they can put the dissolved calcium back in its proper place.** They don't develop hardened arteries, heel spurs, and knobby joints, at least not at first. Their bodies can take a considerable amount of abuse without showing it.

In general, people eat way too much phosphate. Meat eaters eat too much meat. Vegetarians eat too much grain. Most everyone drinks phosphated beverages. In this way we set the stage for hardened arteries, joint disease, calcified tissues that no longer have flexibility. We all get kidney crystals that become stones. This is *aging*. All these deposits invite bacteria to live in them and on them, creating pain.

Old age and pain go together as if they were true partners. Yet it is just the result of bad food choices.

Try to undo as much of this false aging as possible.

1. Reduce your meat consumption. Switch to fish which supplies calcium in the tiny bones. It is true, these bones are made of calcium phosphate and one might expect, logically, to be getting a less effective calcium source. Logic isn't necessarily biologically correct. The bones of fish work nicely as a calcium source and their phosphate content is not too great. Such a diet has worked for many primitive societies. Further, I have never seen a case of mercury toxicity from eating fish; amalgam tooth fillings are our truly significant source.

2. Reduce your grain consumption. Instead of cereal for breakfast, add fruit and reduce the cereal to half. Cut bread consumption in half. Cut pasta consumption in half. Cut rice and corn consumption in half. Eat more bananas and other fruits. Eat more vegetables; always choose potato (not potato chips) instead of rice or macaroni. Always choose a leafy salad instead of pasta salad. At any restaurant or salad bar ask yourself: is this wheat, rice or corn? If so, choose potatoes or other vegetables. Choose coleslaw. Choose mixed fruit. You don't need to go off the grains, only reduce them to improve your condition.
3. Take vitamin D as a supplement. Nothing less than 40,000 units has any real impact by the time there are problems. This strength is available by prescription only (usually 50,000 units, which is close enough). To avoid getting a polluted product, ask your pharmacist to follow the recipe on page 560. (In the past some cases of poisoning by overdosing resulted in this regulation. If you overdose you will get joint and muscle pain and nausea but it is reversible.) Take one a day (not more), for the first three weeks, then two a week forever after.
4. Finally, toss the carbonated beverages right out of your diet or make your own (see *Recipes*). It is not the carbonation that is harmful, it is the added phosphate. Drink water, herb teas, homemade fruit and vegetable juices, milk or buttermilk.

Milk, like fish, is full of calcium in the form of calcium phosphate. Again, logic might speak against the effectiveness of this form of calcium. Again, logic is wrong. Evidently, the calcium and phosphate story must be much more complex than I am depicting here.

Milk works best as a calcium source, in spite of its phosphate content. Possibly the *lactose* and other complexities of its composition contribute to this. My recommendation when deposits have formed anywhere in the body, such as heel, toe, arteries, joints, is to switch to milk as a beverage. Compare the calcium level of your urine before and after the switch (allowing several weeks first). Also compare calcium levels in your blood serum. It should move towards normal. This means **up** if it is too low (below 9.2). It means **down** if it is too high (10). If you are monitoring the effectiveness of the kidney herb recipe in dissolving away your phosphate crystals, notice that drinking milk keeps them from reforming. Taking calcium tablets does not! Taking nothing lets them reform the quickest.

The milk must be 2% or higher in butter fat to be effective.

With your body fluids at their proper acid level, with your kidneys able to flush out acids, with heavy metal toxins no longer settling in, with your bone-dissolving stopped, your heel deposits can shrink. Bacteria have no place to feed and breed. You can kill them several times more with your zapper to catch stragglers. And your heel pain becomes history. Be careful not to bruise the sensitive tissue with too much walking or running immediately after the pain is gone. Wear cushioning socks and well cushioned shoes.

Names in the case histories have been changed to ones of the same sex, picked at random from a telephone directory. Other facts may have been altered in non-essential ways.

Walter Jones, a man of 67, was diabetic for 14 years. His feet and upper legs hurt so much for the past 13 years he could barely shuffle along now. They were also cold and clammy. The herb, juniper berry was added to the Kidney Cleanse recipe to make it even more effective for him and he was advised to stop smoking, using alcohol, and caffeine. He also started the parasite killing program (at that time an herbal parasite program was being used instead of a zapper) and a liver cleanse that yielded several hundred small gallstones. Three months from his first visit his legs were better and feet OK, although he still had some trouble walking due to pain in upper thighs.

Dinah Sagun, a minister's wife, had a lot of walking and standing to do besides traveling a lot. She had knee surgery 15 years ago to remove deposits but now they were getting bad again. Also her heels were sore. My tests showed she had phosphate and oxalate deposits in her kidneys. She was started on the Kidney Cleanse followed by the parasite program. She stopped using benzene polluted items, especially her Chap Stick™. Her diet was changed to include milk and leave out store-bought beverages. In 4½ months her heel pain was gone along with the bad headaches we had not even started to work on.

Julie Fernandez came with a list of 10 serious problems including foot pain and ankle swelling. Her urinalysis showed crystals. My test showed they were uric acid crystals. Her parasites included *Trichinella*. There was a house cat. Her toxic metal test showed tellurium and platinum accumulation from metal dentalware and arsenic from pesticide. She was to start on a Kidney Cleanse and add the parasite program two weeks later. She was to remove all roach hives and other pest killers from her house and arrange for dental metal replacement. At her third visit, four weeks later, she could walk without pain although she still had *Trichinella* and arsenic problems. Two months later she was aching all over again and her kidneys hurt. She still had *Trichinella* and some dental work to do. She was to do a 5-day high dose parasite treatment and treat the cat also and repeat the kidney cleanse. This relieved her pain.

Dorothy Shelley had numerous pains including foot pain in the arch, lower back pain and cramps with her period. She had oxalate and uric acid crystals in the kidneys so was started on kidney herbs. Three weeks later her foot pain and low back pain were gone.

Paul Longtin had toe cramps, calf cramps, and heel pain. After cutting down on smoking, quitting caffeine and soda pop and taking niacin (250 mg time release; 1 capsule each meal and upon rising in morning) and doing a kidney cleanse, all in three weeks, he was much improved and didn't even need his arch supports.

Juan Onley, age 58, came for his gout in both feet and one hand. He could hardly walk, in spite of soft shoes and pain killer. It started 7 years ago. He also had prostate pain and couldn't sit comfortably. My tests showed his kidneys were full of uric acid, oxalate and cystine stones. His prostate was full of *Gardnerella* and *Campylobacter* bacteria. His wisdom teeth were harboring *plantar wart #4 virus* and *Coxsackie B4* virus. *Gardnerella* often comes with fluke parasites and indeed he had intestinal flukes in his kidney! He began with the kidney herb program, then the parasite killing program. It took five months to clear them all. Then he could walk and sit without pain.

Leg Pain In Children

It is commonly accepted as normal(!) in children to have pain in the shins or calves of the leg. They may even be called "growing pains." Children may cry with the pain and never tell anyone the reason for crying. It happens mostly after napping. This may be caused by cramping of the leg or spasms of the blood vessels. *Lead toxicity* is a common cause of both. Test for the presence of both **lead** and **cadmium** in the tap water. Only your own electronic tests are helpful. Water department tests are much too crude.

ULTRAS
ULTRA
Pampers
Pamper
Pampers
ular Thickness
Pamper
Pampers
HUGGIES
HUGGIES

Fig. 11 All disposable diapers I tested had mercury and thallium! These toxins can be absorbed through babies' skin.

If either poison is

found, test the water supply from each faucet in the house, in the morning, before it has been run. Find the offending sources, change the water pipes to polyvinyl chloride (PVC).

Also search for thallium or mercury in the child's saliva. If it is there, remove all dental metal. Stop using all commercial disposable diapers, dental floss, cotton swabs and bandages; they are polluted with mercury and thallium probably from manufacturing them in foreign countries where it is legal to sterilize with mercuric chloride. Test again, several times, after plumbing or dental work has been completed. To relieve pain:

- immerse legs in warm water
- massage legs gently
- give 25-50 mg niacin, not time-release, to dilate blood vessels.

Leg Pain In Adults

Leg pain in adults is usually associated with *cadmium* or *thallium*. Cadmium is present in tap water that runs through corroded galvanized pipes. The cadmium is probably a contaminant of the zinc used for galvanizing. Test the water, electronically, for cadmium. If you have all copper pipes but there is cadmium in the water, there must be a short piece (a **Y** or a **T** joint) made of old galvanized pipe lurking somewhere. Track it down by testing water from all your faucets.

Cadmium causes the blood vessels to spasm and it is made worse by smoking, that's why the condition is sometimes called **Smoker's Leg**. But extremely painful legs are due to chronic thallium poisoning more than any other cause!

It is very important to know exactly how toxic thallium is. Read the clipping on page 417 right now!

Where would you ever get thallium? From your very own mouth! The mercury in fillings is often itself polluted with thallium! Replace your amalgam fillings with composite.

Bandages

Sanitary napkins and tampons

Cotton swabs

limpiecitos

Cotton balls

ACE
First Aid
First Aid

Floss

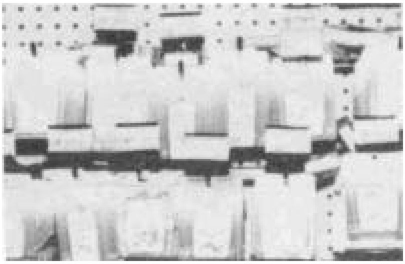

Toothpicks (the one on the right is ten years old and had no mercury or thallium)

TOOTH PICKS
TOOTHPICKS
Forster

Fig. 12 Do not use any commercial personal products, the risk of pollution is too great.

Thallium has another source: it is riding along as a pollutant in cotton swabs, cotton balls, commercial bandages, toothpicks, floss, gauze, sanitary napkins, tampons, disposable diapers, and paper towels. Evidently these are being sterilized with mercuric chloride which, in turn, has thallium pollution.

- Line **disposable diapers** with a tissue
- Line **sanitary napkins** and pads with a tissue
- Use the **polyester puff** in the top of vitamin bottles in place of cotton balls. Twirl some around a plastic stirrer for a swab.
- Use pieces of **tissue and masking tape** for bandages.

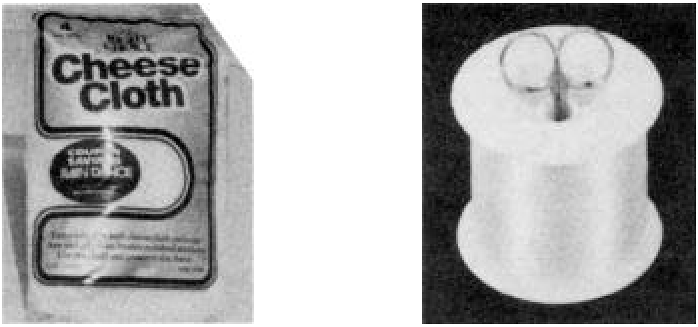

Use cheesecloth in place of gauze.

Use monofilament fish line (2 or 4 lb. test) for floss

Fig. 13 Safe substitutes for personal products.

If you do have thallium in your white blood cells and you haven't used toothpicks, etc. earlier in the day, then it is in your tooth fillings and **you have no higher priority than getting the**

amalgams out. Find a dentist immediately who will remove them, drilling deeply and widely not to miss a speck of it, thereby getting the thallium out, too. You cannot cure your leg pains without removing thallium.

Leg Pain Protocol

1. Stop smoking.
2. Repair plumbing.
3. Do dental cleanup and chelate out the mercury and thallium that has gotten into your tissues with EDTA (see *Sources*). You will need to find a chelating doctor; ask a friendly chiropractor to help you locate one. Or at least take thioctic acid 100 mg, (2 three times a day) and vitamin C (5 gm or one teaspoon) daily for a month.
4. Take magnesium oxide 300 mg (take 1 twice a day).
5. Take niacin, as much as you tolerate—time release varieties are less effective. Try 50 mg with each meal.
6. Change your diet to reduce phosphate and include milk (sterilized).
7. Do the herbal Kidney Cleanse (page 549) followed by a Liver Cleanse (page 552).
8. Zap yourself on alternate days at bedtime. If this zapping makes no difference whatever, your problem is purely spasms. But if you get relief, even if it's very short lived, you must have killed something. Bacteria must come from somewhere. Concentrate your efforts on dental health and better diet.

Jean Booth, age 30, had sore, tired legs and severe three-day headaches. She would get stabbing pains in back of her thighs. After we found thallium and mercury in her kidneys she did a Kidney Cleanse and got all her metal tooth fillings replaced. She then felt fine for one year. Suddenly she got fatigue and heavy legs again with stabbing pain at the outer thigh. She had seen a neurologist. Her chiropractor suggested it was leftover mercury so she came back to us. Indeed, she was toxic with lead, mercury, thallium, but her dentist could not find the leftover metal in her mouth. Three cavitations were cleaned; she was put on thioctic acid; eight varieties of bacteria and viruses were killed with a frequency generator and her legs became well again. Our test showed thallium at 4 teeth, but it was not a big enough deposit to show up on dental X-ray. She may eventually choose to have these redrilled.

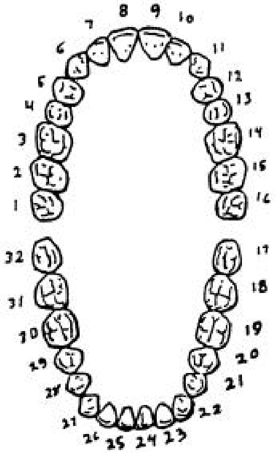

Fig. 14 Tooth numbering system.

Charlie Snelling was a picture of pain: pain in arms, elbows, shoulders, wrist, hands, chest, low back, legs, knees, and feet. He was started on kidney herbs and a few pains were reduced. He was toxic with cadmium so he changed his plumbing to plastic. However, he continued to be toxic with cadmium and thallium throwing suspicion on his numerous old tooth fillings. He got them all replaced and cavitations cleaned. He used our frequency generator to kill *beta Streptococcus*, *Pseudomonas*, *Troglodytella* and *Staphylococcus aureus* all of which were under one tooth (#15). A year later he still had bouts of leg pain. He still had numerous bacteria under his teeth because the jaw bone was not healing. He had not been taking vitamin D, nor magnesium nor drinking milk for the necessary calcium. But he had improved enough to go back to work full time.

Victor Abhay, age 16, could no longer play in high school sports because of knee pain. It began “with a virus” and high temperature two years ago. His knee started to bother him after that. He had *cysteine* kidney crystals and four parasites: *Cryptocotyl*, human liver fluke, *Echinococcus granulosus* cyst and *Echinostomum revolutum* in his white blood cells. He was to start the kidney herb recipe and follow this with the parasite program. Five months later, when we next saw him, his knee was fine.

Kim Murphy, 45, had painful legs, feet and knees. They also were swollen and itched. She was parasitized by *Trichuris*, (dog whipworm). She also had tapeworm stages (*Taenia pisiformis*) and intestinal fluke in the intestine. She started on the kidney herbs, followed by the parasite program. She stopped using zirconium-containing products (deodorant) and barium (lipstick). She stayed out of bus exhaust. (She knew she was allergic to diesel exhaust.) In one month her leg pain and itching were gone; slight swelling remained.

Nancy Tong, 80's, had edematous legs. In fact she could get no stockings on. They appeared like pillars with no taper at all. She was on diuretic medicine from her doctor. It kept her blood pressure down but she was losing ground with water excretion. This raised her general toxicity (blood BUN[5]) which made her feel bad most of the time. Yet she drank enough water, curtailed her salt, used no caffeine and had no really bad habits. She had to wear several pads for incontinence. We found she was toxic with cadmium and lead, which were probably responsible for her huge accumulation of kidney stones. The metals were in her tap water and she was unable to resolve this problem since she lived in a senior citizen center. We advised her to move, or to have her tap water carried in, but she could do none of these. Although the situation was hopeless, she did the kidney cleanse, parasite killing program and changed her metal rimmed glasses and wrist watch to plastic. She gained enough ground from these improvements to be able to wear elastic hose and thereby give some physical assistance to her body. This encouraged her to do a liver cleanse. She had a headache with the cleanse but immediately afterwards she fit into a smaller size “Keds” (elasticized stockings). A half a year from the beginning, her legs had taper to them; she didn't even mind wearing a dress.

Fibromyositis and Fibromyalgia

When pain is widespread, not just in joints or legs but in many muscles and soft tissues of your body your doctor may call it *fibromyositis* or *fibromyalgia*.

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[5] BUN stands for blood urea nitrogen. It is a body waste and is normally kept low by the kidneys.

For bacteria to get all over your body, they must be riding along with parasites that get all over your body. Microscopically tiny roundworms can do this.

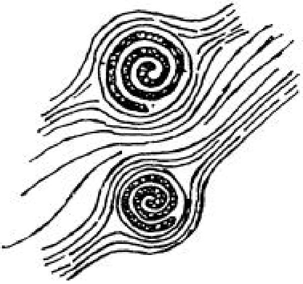

Fig. 15 Trichinella larvae settled in muscles.

Trichinella is the most common cause of these diseases, but sometimes *Ascaris* larvae or *hookworms* or *strongyle* larvae are the main culprits. These wormlets bring hosts of **bacteria** with them, mainly *"Streps"* (*Streptococcus* varieties) and *"Staphs"* (*Staphylococcus* varieties), but also *"Clostridiums"* (*Clostridium* varieties) and "Campyls" (*Campylobacter* varieties). The bacteria are probably the pain causers. By killing all bacteria—*Staphs*, *Streps*, *Clostridiums* and *Campyls*—using a zapper, you may get relief for one hour!

By killing *Trichinella* and *Ancylostomas* (worms) first, followed by the bacteria, you may get relief for several hours. By killing the parasites and bacteria in every household member and the pets at the same time and by never putting your fingers to your mouth, you can expect permanent pain relief. It is interesting to speculate why the other family members, who are also infected with these tiny roundworms don't develop *fibromyalgia*. Perhaps the larvae stay in the intestine or go to the diaphragm (causing coughing) or the eyes (causing "lazy" eye muscles). Perhaps they merely cause **anemia**. *Trichinella,* hookworms and *strongyles* are extremely difficult to get rid of in a family.

These roundworm larvae undoubtedly cross the placenta into the unborn child during pregnancy, too. So they can be "inherited." Try to clear up the whole family before the next pregnancy.

Clearing up pets of these parasites is even harder. The best advice is to give your pets away. They will continue to harbor them even though they are on a pet parasite program. It is impossible to stay free of the parasites your pets have: they will move to your soft tissues immediately, giving you the bacteria and inflammation again.

The next most important advice is to keep fingers out of your mouth (read Hands, page 397). None of these parasites enter through your skin (this is in spite of teachings that hook-worms enter this way), you must put them into your mouth somehow! Consider your mouth off limits to anything but food and kissing.

Finally, if there is a baby in diapers in the family, be patient. When diapering days are over you will have less bowel contact, giving you an opportunity to finish your own treatment. Meanwhile, wash fingernails in Skin Sanitizer (see *Recipes*) after cleaning up children's bowel movements, diapers and yourself. Use borax liquid for soap to leave an antibacterial residue on the skin.

Try to identify your parasites before killing them so you can be on the lookout for them in the future. Get slides or dead cultures of various pathogens and search in your white blood cells. If you can't do this, at least save a saliva sample of your own; keep it frozen or preserved. Also make a saliva sample for your pet. This gives you specimens to test yourself for later. You won't know which parasite is in this saliva specimen, but if you ever test positive for it again you will know you got it back. Then zap yourself.

Brenda Byrd was diagnosed with myofibrositis two years earlier at the age of 36. Her blood test showed triglycerides slightly high (152 mg./DL), indicating the beginnings of urinary tract problems. Her urinalysis stated “hazy” (hazy with bacteria or crystals) instead of clear urine. It also listed white blood cells, red blood cells, and a few bacteria present in her urine. Our tests revealed mercury and numerous other heavy metals distributed in her thyroid, stomach, kidney, lungs, bones and bone marrow. She was also full of beryllium (usually from "coal oil") contained in the hurricane lamps she kept in every room. She had numerous parasites, including *Strongyloides* and hookworms spread through her body tissues. She was thrilled to learn how to get her health back and started with the dental problem.

Marcia Cochran, 36, had muscles twitching all over her body. It was diagnosed as fibromyalgia. Her joints were tender and her chest felt "tight." She had bronchitis twice a year. She was on Amytryptaline™ for muscle twitching and Bentyl™ to calm the intestine (spastic colon). She had depression with it and was on medicine for that. It all started with fever and chills that she thought was the flu but after they went away, she was left with a tremor. Sometimes she felt that little electric shocks were going through her. She had *Ascaris* and hookworm larvae widespread in her body. She had sheep liver flukes in her liver. She was started on the parasite program. She was also toxic with PVC and tellurium (dental metal). The PVC was traced to plastic storm windows applied to the inside of the window and to new shower curtains. Two months passed and she had not solved any of her problems. Then she did her first liver cleanse and got over 100 stones out. This instantly reduced her fibromyalgia to occasional attacks. She was so encouraged she decided to go ahead with dental cleanup.

Joint Pain or Arthritis

Two main kinds of arthritis are recognized clinically, *osteoarthritis* and *rheumatoid arthritis*. In osteoarthritis the joints have bacteria living on the deposits left there. In rheumatoid arthritis the bacteria come from larger parasites—wormlets actually living in these joints. The worms are the common little roundworms whose eggs hatch into microscopic wormlets that travel.

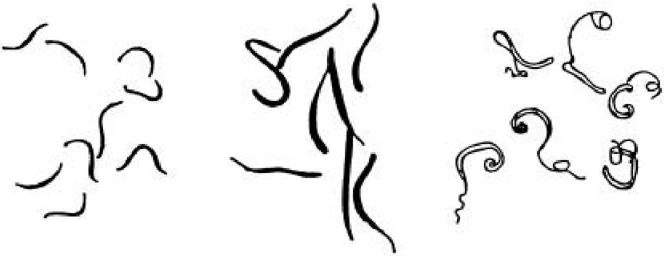

Fig. 16 Hookworms, strongyles, and whipworms.

We have four common roundworms: *Ascaris, hookworm, Strongyloides, Trichinella*. Their life cycle normally directs them to travel to the lungs but in some people they travel through the entire body, including brain, muscles and joints. More research is necessary to explain this. My suspicion is that there are toxins, like **mercury**, **thallium**, **cadmium**, **lead**, as well as **solvents**, distributed through the body, lowering immunity and allowing the tiny larvae to reside there. Once the pathway (routing) to these organs has been established, it continues to be used by other parasites as well. Soon a variety of parasites, their bacteria and viruses, and pollutants are all headed toward these organs.

Osteo or Common Arthritis

When joints are painful it is a simple matter to kill the bacteria with an electronic zapper. Treat yourself with a zapper daily until the pain is gone. Maybe it will stay away, but chances are the bacteria have a steady source.

The most common source for *Staphs* and *Streps* are small abscesses in the jaw bone, under and beside old extractions, root canals and mercury fillings. You may get immediate pain relief just from a dental cleanup, and again disappointment may follow. *Staphs* and *Streps* are such ubiquitous bacteria, they may come not only from jaw bone infections but from gallstones, kidney stones and other parasites. The correct treatment for arthritis is a complete overhaul of body health: a diet cleanup, a body cleanup, and environmental cleanup.

Start with the herbal parasite program and zapping. Follow this with a kidney cleanse, then liver cleanse. If any toxin is overlooked, especially asbestos and fiberglass, it is sure to find your joints and permit bacteria to return and cause pain. Make sure to correct your body acid levels after doing pH measurements of the urine (page 57).

Arthritic deposits contain a large amount of phosphates combined with calcium. This calcium came from some other bone, such as the base of your spine or the wrist. Here the bones are getting weaker due to this calcium loss. Calcium was taken out of your bones for the simple purpose of neutralizing the excess phosphate in your diet. Reduce phosphate consumption (meats, soda pop, grains) by half, eating fish, milk, vegetables and fruit instead. Drink three cups of milk a day. If you are allergic to milk, do several liver cleanses, switch brands of milk, use milk digestant, and use it in cooking and baking. Cheese and cottage cheese are not substitutes for milk (the calcium stayed in the whey). Dairy products must be boiled before consuming and should be no less than 2% butter fat. It takes bile to make calcium absorbable, yet milk with less than 2% butterfat does not trigger the gallbladder to empty it's bile at mealtime.

If you are not used to dairy products, start slowly and work up gradually to the 3 cups a day needed.

Carol Lachance was diagnosed with arthritis of her back and knees. (She had spurs in both places.) She was positive for *Trichinella*, *Ascaris* and *Dirofilaria* (she also had pain over the heart). They had an outdoor dog. Her blood test showed a high phosphate and alkaline phosphatase level showing she was dissolving her bones. After changing her diet to include milk, extra oyster shell calcium (one a day), magnesium oxide and vitamin B_6, and reducing her meat and grain consumption her phosphate level went down to normal (below 4). She did the kidney cleanse and liver cleanse as well as parasite program but still had pain. A toxic element test revealed lead in her bones. It was traced to a drugstore variety multivitamin tablet she had taken daily for years. When she stopped these and added prescription vitamin D (50,000 units) for three weeks to help her bones heal she got relief.

Gail Hildebrand, age 62, had painful arthritic hands and gum disease. She had 12 parasites free-loading on her and was toxic with asbestos. This was traced to her clothes dryer. Four months later, after killing parasites, her hand pain and gums were much better. She had the dryer vent taped up tighter and this got rid of her asbestos problem. She started on kidney herbs and in one month saw that her enlarged knuckles were beginning to go down.

Norma Littrell, age 53, came in for her severe arthritis of six years. Her knees, shoulders and hands were painful. I explained to her that painful shoulders did not belong to the arthritis picture but had a gallstone etiology which she could easily fix in a single night at a later time (liver cleanse). She also had mid-back, upper back and lower back pain; again the upper back pain belonged to the liver problem. She had tricalcium phosphate kidney crystals as well as uric acid crystals. She was told to go off coffee (no decaf either), decrease her meat and grain consumption (phosphate) and increase milk and use stone ground cornmeal products (genuine stone ground tortillas as well as pickled pigs' feet are high in utilizable calcium). She started on the kidney herbs. In 33 days her low back pain had improved a lot, she could wash her own hair again and she could sit down and get up from her living room floor without pain. She was elated but we recommended less stress than such exercises for her joints.

TORTILLAS
Santa Fe
Santa Fe

Fig. 17 Stone ground corn tortillas, high in calcium.

Patricia Robinson, age 76, had pain in her knees, feet, lower back, hands and wrists. Also in her shoulders and upper back which is not part of the arthritis picture. She had swollen puffy eyelids which is a telltale sign of Ascaris. She had heartburn, cold feet and insomnia as well as high blood pressure. She was on several medicines. We started her on the kidney recipe and ornithine (four to eight as needed at bedtime) for sleep. We hoped she could stop her Ativan™ drug soon. She was to go off coffee, tea and decafs. Her hands were knotted and misshapen at the joints, also tender. Two months later there was little change; her doctor had put her on Prozac™ and she hoped that would do a lot for her (so she stopped the kidney herbs) but it didn't. The parasite test still showed *Ascaris* and she was started on the parasite program. We also found fluoride (from toothpaste), iridium, samarium and palladium, all from her tooth implants. She was to remove as much metal as the dentist could replace, clean cavitations, and take thioctic acid, 2 a day, to help clear metal from her body. In four weeks the sharp pain in her back was gone and in three more weeks the pain in her hands was gone.

Lynne Snyder, 72, had pain in every joint and had to be on pain medicine to keep moving. Her potassium level was very low (3.6—an adrenal/kidney problem), and she was started on kidney herbs, carrot juice, vegetable juice and bananas. In ten days she could feel some new energy but her pains were terrible, especially her knees. She was taken off tomato juice, cranberry juice, citrus, pepper (she was using a lot), and given buttermilk as a beverage which she enjoyed. After three weeks of kidney herbs she was started on parasite killing herbs. In another month her arthritis was much better. She was not on any pain medicine and could get to sleep without it. She thought it was mostly going off pepper that helped.

Rheumatoid Arthritis

When inflammation and swelling affect your joints, besides pain, it is called *rheumatoid arthritis*. In addition, a blood test may reveal “rheumatoid factor” to be present. In this case, the common tiny round worms have invaded your joints. These are *Ascaris*, *Ancylostomas*, *Strongyloides*, and *Trichinella*. Their eggs are everywhere around us, in dust and dirt and the filth under fingernails and our own bowel movements.

Superior sanitation is your first defense. Rinse fingernails in alcohol after cleaning up bowel movements or changing diapers. Never, never, tolerate long fingernails in any family member. If this discipline can't be enforced, do not allow food preparation by "long nails" unless gloves are worn. He or she may not be getting ill (yet) from the family parasites, but you are. Of course, you can kill them with a zapper (internally, not the ones under the nails) but that is after you have been infected. They are easily picked up again. It would be wise to zap for roundworms every week, just in case.

Make sure your pet is treated with parasite herbs or by zapper as well. A pet that goes outdoors will quickly (the very next day) bring these roundworms into the house again. Give away your pets if possible.

Check for dental problems. Do the Dental Clean-Up (page 409). Then do a Kidney Cleanse and Liver Cleanse.

You may relieve your pain and begin to heal immediately after zapping but it is wise to do all the health programs, anyway. Change your diet. Reduce phosphate, start using sterilized milk for calcium. Switch to fish from meats. Drink much more water. Use only harmless beverages (see *Recipes*) and foods. Switch to toxin-free body products. Live in a non-toxic house. Stay on a maintenance parasite program of herbs, and zap regularly. Stay on the kidney cleanse for three to six weeks and repeat a one-week session every few months to keep removing deposits which may also choose these sick joints to settle in. Knees are a favorite location for rheumatoid arthritis. Knees are very dependent on kidneys.

To summarize, do everything as for osteoarthritis, emphasizing the roundworm parasites for elimination.

Allergic Arthritis

A prominent food toxin that is said to affect knees is *piperine*, found in the pepper family which includes black and white pepper (not cayenne). The *Solanaceae* family of plants (potatoes, tomatoes, eggplant, tobacco!) also has a common "allergen" that produces joint pain. Try going off these for two weeks to see if it helps. Two more chemicals that can trigger arthritis-like pain are *hippuric acid* and *phenylisothiocyanate* (PIT).

Your body makes large amounts of hippuric acid, up to a gram a day. It is the product of benzoic acid detoxification by the liver. Quite a few fruits contain natural benzoic acid. But we can easily triple and quadruple our benzoic acid intake by consuming commercial beverages and pastries where benzoic acid is used as a preservative. It is indeed a "natural" preservative. All of it must be detoxified, though, and this gives us way too much hippuric acid. The kidneys are unable to excrete such overloads of hippuric acid, so it distributes itself in our organs. I suspect a simple mechanism could explain its pain-triggering action: hippuric acid molecules could attach themselves to our cell's conductance channels keeping the gates jammed open. This might invite bacteria and viruses to enter there. But there are also hippuric acid-loving bacteria that feed on it. Perhaps hippuric acid can cause pain without the help of bacteria. This requires further study. It is only sensible for persons with chronic pain not to consume benzoic acid (or benzoate) preserved foods.

PIT is a food chemical found especially in chicken, eggs, the cabbage family, peas. PIT is also part of the body's own chemistry, taking place in the liver, and involving detoxification of *cyanide*-containing foods. Many vegetables, notably the cabbage family, contain such cyanides, giving them protection from insects, disease, and grazing animals. It can take the liver a week to detoxify a meal full of these cyanides: in the meantime, PIT levels are higher in the body. PIT is very reactive. In fact, it is the chemical used as a general reactant with amino acids in the well known **Edman degradation** reaction. But now, your body is the reaction flask, supplying the amino acids. Since all organs supply amino acids, it is no wonder they can all react to PIT, giving you multiple allergic reactions and pains.

If you have any kind of arthritis, stop eating the high-PIT foods and clean the liver until you are free of all allergies you are aware of. This suggests that the liver is capable, again, of detoxifying the cyanides for you in a reasonable time and you may eat them again. These foods do have many benefits, of course.

Joint pain, or arthritis, was known in antiquity long before dogs and cats were household pets and giving us their parasites. Pigs and horses harbor these roundworms too and may have been the source at that time.

Herbs and treatments that help arthritis are, therefore, plentiful. Maybe they act by killing roundworms, bacteria, and viruses, or help metabolize hippuric acid and PIT. Homeopathic treatments, as well as massage, heat and electronic devices also help. With this wide range of effective treatments dating to the distant past, why is none of them a permanent cure? The answer is simple. The common roundworms are everywhere about us, sanitation is poor, and our civilized lifestyle leads to deposit formation that invites bacteria. But knowing this, you can stop your pain and remove the causes to become one of the first humans to achieve a permanent cure.

Verna Plumb, age 46, was diagnosed with rheumatoid arthritis four years earlier. Since then she had been continuously on methotrexate™ and prednisone.™ This had caused her to gain a lot of weight from water retention. The drugs were no longer effective and she would need to do something else very soon. She had the typical causes: her body was toxic with mercury and nickel from tooth fillings. Her kidneys were full of five kinds of stones. She had numerous roundworm parasites including two kinds of *Ascaris*, two kinds of hookworm, *Strongyloides* and *Trichinella*. She would have to clean everything up to get relief. She started on the kidney herbs, killed parasites with a frequency generator and in two months noticed her swelling was receding.

Camille Franklin had hands that were swollen and hot and painful. She also had "arthritis" in shoulders and knees. We explained that shoulders were not part of the arthritis picture. She could deal with that in a single evening, soon. She also had bone spurs at sinuses which needed surgical removal. Her kidneys revealed tricalcium phosphate crystals. She was given a diet change; onto milk, fruits and vegetables, off other beverages, less meat and grains. She was started on kidney herbs. In five weeks all the swelling and redness and heat was out of her finger joints.

Thigh Pain

Inner thigh pain often stems from the *sciatic nerve* which is suffering pressure at the lower back. If this is so, chiropractic adjustments should help. The correct treatment, after killing bacteria electronically, is to clean up the entire kidney area using the kidney herb recipe.

If this is not the correct explanation, (and you're not getting pain relief) you may have a trauma—perhaps you overstretched your leg in some exercise. The minor trauma invited bacteria to settle there and give you pain.

If the pain recurs after clearing it several times, there must be a chronic source of bacteria. Since the kidneys are already cleaned, consider the teeth, as well as recurring parasites, and the liver. Clean the liver every two weeks until 2000 or more stones have appeared and no more appear. This could take 1-2 years. Be patient. Do a dental clean up. Keep killing the bacteria so they can't spread. And, of course, let the painful leg rest.

Hip Pain

Hip pain is always due to bacteria. In fact, these bacteria regularly come from two sources: the kidneys and the teeth. This simplifies the treatment since neither of these places takes a long time to clear.

Start yourself immediately on the kidney cleanse (page 549) to clean your kidneys. Continue on the recipe until the dental cleanup has been completed. Both must be clean together to stop exporting bacteria to the hip.

The dental cleanup could take several weeks if extensive work is required. During this time, kill all parasites electronically. Keep killing bacteria, especially *Staphs*, *Streps*, *Clostridia*, *Campyls*.

The dental problem is not always on the same side as the hip pain. The jaw may be very fragile and porous, full of invading bacteria. Cleaning these cavitations may give immediate pain relief in the hip (proving the bacterial source). But getting the jaw bone to heal by taking up calcium again is not guaranteed by the cleaning process.

Give your jaw bone every chance to heal:

- Start taking vitamin D (40,000 to 50,000 u.), every day for three weeks from the day of the dental work or before. After this, take it twice a week forever. **Do not take more.**
- Take vitamin C (1+ gm a day) and B_6 (250-500 mg a day) for healthy gums.
- Get one gram of usable calcium in your daily diet.

Bone Strengthening

Vegetable calcium can't be dissolved by our stomachs (*ruminants*, like cows, can dissolve it—they have an extra stomach loaded with special bacteria who do the actual retrieving of calcium). Tablet-form calcium can't be dissolved well either, especially as we age. We need predissolved calcium if a little is to go a long way.

Primitive people who lived on fish or stone-ground meal ate 4-6 grams of calcium a day.[6] Even if only 20% of this got dissolved, they would still have about 1 gram of utilizable calcium for themselves. Chances are good they dissolved even more, since they were young (life expectancy was less than 50 years). Their skull remains show beautiful, cavity-free teeth. They lived outdoors, mainly, so getting enough sunshine-derived vitamin D was not a problem. Their natural diet supplied enough vitamin B_2 to protect them from UV (ultraviolet) damage from sunshine exposure.

But these are civilized times. Our lives are stretched into old age, when our stomachs no longer produce enough acid to kill bacteria, nor to dissolve the minerals in our food. So they need to be dissolved for us. Milk is a beverage where the calcium has already been dissolved by the other ingredients. The lactic acid in milk formed during digestion gives the calcium the correct chelated structure for absorption by the intestine. Even the bile participates in calcium absorption. Milk also contains phosphate, but not too much to be useful. I recommend milk as a calcium-source to heal the jaw bone after and before dental work. You need 1+ grams a day. One quart of milk has 1 gm (1000 mg) of utilizable calcium. You absorb only 250-400 mg. The rest is excreted and eliminated. Only the absorbed calcium can heal your jaw bone. Use milk in cooking as well as a beverage. The calcium in it is indestructible.

Bones are not made of calcium alone. **Magnesium** is essential. Since magnesium is more soluble and easy to assimilate than calcium, the tablet form (magnesium oxide, 300 mg, see

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[6] Read Nutrition and Physical Degeneration by Weston A. Price, DDS first published in 1939. At least, gaze at the pictures. Ask your library to buy a copy, available from Price-Pottenger Nutrition Foundation, (800) 366-3748.

Sources) will do. If you are not absorbing the magnesium it will stay in your intestine and act as a laxative. If this happens acidify your stomach during meals: always add fresh lemon, vinegar, or vitamin C to your food or drink to help digest milk and dissolve minerals for you. **Boron** (3 mg. once a day) and **manganese** (15 mg. once a day) are additional bone hardeners.

When your diet is improved, your dental problem is cleared, and your kidneys are clean, your hip pain will stay away and you can stop thinking about hip replacement surgery.

Mary Hammond, 48, had two painful hips. She was diabetic and drinking five cups of coffee a day. She had *Staphylococcus aureus* infections under three teeth that she no longer had. After going off caffeine (caffeine may spread bacteria by making tissues more permeable) and getting some dental work done, her right hip stopped hurting. When cavitations were cleaned, her left hip stopped hurting too, but after a week the pain returned. She still had parasites and their bacteria to kill. She had solvents to eliminate and a kidney cleanse to do but she was quite enthusiastic and enjoyed showing off how well she walked.

Groin Pain

Lymph nodes are situated here, as well as in armpits and around the neck. Lymph nodes are your best friends. They are hives of activity. Your white blood cells “nest” here. Lymph nodes sample your body fluids (lymph) at these locations, much like the water department and health department sample our milk and water, making sure they are pure and sterile. Of course, they never really are. But your white blood cells keep working at it. They are busy removing impurities like zirconium and titanium and pathogens like bacteria and viruses.

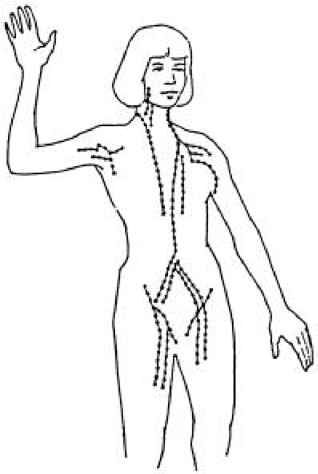

Fig. 18 Your lymph nodes are your best friends.

When an especially challenging dose of parasite or pollution arrives at the node, it enlarges, in order to handle the bigger sized task. This enlargement can be felt. It may press against other organs and you feel the pain of pressure in the groin. This should alert you, of course, to the danger. Kill the parasites and pathogens immediately with your zapper. Start the kidney cleanse. Stop using toxic products and eating toxic food. If you are being effective, the lymph nodes will begin to shrink in a few days, relieving the groin pain. If it does not come back, you probably eliminated the main cause. But if it recurs, try to diagnose it accurately. Test yourself for HIV and AIDS and then to pet saliva, dairy products and other disease specimens. Stop reinfecting from humans or pets or dairy food. Assist your body by cleaning up your dentalware, and environment. Check all supplements for toxins before using them on a daily basis. (If they show up in your white blood cells a few minutes after eating them, there is a toxin.) If your groin pain doesn't go away, you probably missed something!

There are other causes of groin pain, though, such as **hernia**. A physician will help you identify it. Have it surgically repaired. The Shouldice Hospital[7] has the best surgical record and will disclose their statistics! You won't even need full anesthesia there.

Pain from the **ovaries** is often felt near the groin. Sometimes a large cyst in the ovary puts pressure on the sensitive nearby organs. The formation of cysts, *cystic ovaries*, is a common condition of cats, too. Obviously, something is not right in the ovaries.

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[7] Shouldice Hospital, 7750 Bayview Ave. Box 370, Thornhill, Ontario, Canada L3T-4A3, telephone (416) 889-1125.

Ovaries make hormones: **progesterone** and **estrogen**. If bacteria (like *Gardnerella, syphilis, gonorrhea*) are living there, the ovaries are handicapped and may under-produce or over-produce some hormone. The first treatment should be to kill parasites, especially the flukes. Then kill all other parasites and bacteria, especially *Gardnerella* and enteric bacteria which can migrate easily from intestine to ovary. In spite of all this, the cyst may not shrink. In order to shrink the cyst you must determine what is filling the cyst. Then stop filling it. The cyst will eliminate itself and shrink.

Many kinds of pollution can fill an ovarian cyst. Test for CFCs and PCBs. Gold is another favorite. Particulate pollutants like asbestos and fiberglass are often put into cysts by your body. Your body is wise. If these can't be eliminated through the kidneys or bile, it will at least keep them all together (in the form of a cyst) the same way a toxic dump spares the rest of the landscape. As long as you are adding to it, it cannot get smaller. Fortunately, your loyal white blood cells are trucking toxins away from your cysts every minute of every day and night. All you need to do is stop adding. Remove dental mental, clean up your body, diet, and environment.

You will notice shrinking of cysts in three weeks. What you actually notice is absence of pain, implying shrinkage. Meanwhile pain relief by killing bacteria, herbal ovarian assistance (try wild yam), chiropractic, pain killers are all useful. Decongest the area by means of a kidney cleanse. If your cyst does not shrink you have missed the pollutants. After it does shrink, stay on a regular program of parasite killing, herbal or electronic, and improved lifestyle.

Ovaries may be giving you pain even without a cyst present. By cleaning up parasites and pollutants you can eliminate it quickly; much more quickly than when a cyst has formed.

Synthetic hormones (Provera,™ Premarin,™ Ogen,™ etc.) are often used to clear up ovary problems of various kinds. Don't continue to use them when the need no longer exists. Although they have low toxicity, there are disadvantages such as the need for liver detoxification, and risk of heavy metal pollutants. Cancer acceleration has been seen when taking estrogens.

Low Back Pain

We have been told that lower back pain originates in an inherited weakness of the spine at its base because we humans walk upright instead of on four legs. And we have been told that the bony hooks that keep the spine aligned are flatter in some families, making it harder for them to hold the spine together. We are also told that "proper exercises" could have kept this part of our bodies strong so lower back pain could be avoided.

These theories become obsolete when, without surgery or exercise or change in posture, lower back pain can be made to disappear quickly and permanently.

Acupressure massage and chiropractic can bring "miraculous" relief. The most severely crippled lower back pain sufferer can shuffle lamely into a chiropractor's office and walk out normally, without pain or painkiller after treatments. So although there has been slippage of disc or spine, apparently it goes back into place rather easily.

If muscle relaxation is the clue, we must ask why these muscles spasm so easily. Any muscle spasms if you irritate or injure it suddenly. In fact, your whole body spasms and flinches if a sliver or bit of broken glass is in your shoe. If you remove these objects, the leg can walk normally.

Oxalic acid crystals are as sharp as broken glass. Use the kidney cleanse (page 549) to dissolve them and other stones. All lower back pain can be cured by removing the sharp crystals in the kidneys. It takes about three weeks to dissolve them. In some very severe cases, it may take six weeks.

Whether you have suffered a year or 20 years, the permanent cure is only weeks away.

Our bodies make eight or more different kinds of kidney "stones." The oxalic acid variety is associated with sharp stabbing pains. In its effort to eliminate this extremely vicious acid your body neutralizes it with calcium first to make calcium oxalate. Your kidneys can keep a bit of calcium oxalate in solution but not a lot. The excess hardens into crystals. A glass of regular or iced tea (not herb tea or green tea) has about 20 mg[8] of oxalic acid—way too much for kidneys to excrete. Tea is a toxic drink, not to be considered a beverage. Chocolate is very high in oxalate, too, and should not be used as a beverage (as cocoa).

Children should never drink tea or cocoa. Their delicate kidneys should not be faced with the daily burden of excreting large amounts of oxalic acid. And calcium used to neutralize oxalic acid is wasted. Calcium is a precious nutrient. It should be conserved for children's bone development.

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[8] Taken from Food Values 14th ed. by Pennington and Church, 1985.

It isn't necessary to find which variety of kidney crystals are causing your muscle spasms. Different herbs dissolve different kinds. And by combining them into a grand herbal mixture you can be dissolving all varieties at the same time.

Wherever oxalate crystals have formed, a particular bacterium, *Proteus vulgaris*, can be found. Does that bacterium somehow thrive on oxalate crystals? Or even help them form? Does *Proteus* itself contribute to lower back pain? Is lower back pain in reality two pains in one—the sharp jabbing of glass-like particles plus the inflammatory effect of bacteria? Fortunately, you can kill *Proteus vulgaris* electronically.

By using your new diagnostic skills, you can test your kidneys for crystals. The kidney stone varieties I have tested for are: **calcium oxalate, uric acid, cysteine, cystine, monocalcium phosphate, dicalcium phosphate, tricalcium phosphate.** All these varieties can be dissolved by the herbal mixture. But all can be formed again in a week!

To prevent **oxalate** formation stop drinking oxalic acid (eating oxalate rich vegetables is not significant—spinach, chard, rhubarb and sorrel all have their place in the diet). Also take magnesium and B_6 supplements (as directed in the kidney cleanse).

To prevent **phosphate** crystals from forming, reduce phosphate consumption and drink milk as a calcium source. Keep your kidneys squeaky clean with herbs and copious water drinking. After drinking one quart of sterilized milk, two pints of water, one-half glass of homemade fruit juice and one-half glass of vegetable juice, there is little desire for additional beverages.

I have no understanding of what may cause **cysteine** or **cystine** stones (the genetic theory does not explain them either, considering that people without *cystinuria* make these stones).

Since they are sulfur-containing, and I have seen them appear after taking sulfa-drugs, it may be wise to avoid use of sulfa-drugs if you have a choice, or go on the kidney cleanse afterward.

If you have severe lower back pain you probably have several kinds of stones. Some persons have all seven kinds!

Rosie Zakar, age 30, came to see us because her mother was cured of lower back pain so severe she could do no housework for 30 years. Rosie had the usual crystals in her kidneys: oxalate, urate and phosphates. She was started on the kidney herb recipe. In three weeks she was so much better she would have missed her appointment if she had not wanted to cure her digestive problem and fatigue too.

Vera Vigneault, age 32, came mainly for help in getting pregnant but she already had lower back pain and mid-back pain. If she had gotten pregnant before clearing this up, she might have developed eclampsia and high blood pressure which are kidney-related disorders. She was started on kidney herbs for these. She chewed gum a lot and had bleeding gums. She stated her bad teeth were hereditary (meaning other family members had bad teeth also). For this she was instructed to stop chewing gum, start drinking three glasses of 2% milk a day and take a vitamin A&D perle. She was to floss her teeth once a day. (All floss varieties are polluted with mercury and thallium. Use monofilament fish line, 2 to 4 lb. weight.) Immediately after flossing she was to brush them with a new very soft toothbrush with five drops of 17½% food grade hydrogen peroxide. She was to avoid brushing teeth with metal fillings to reduce erosion. She was to brush them a second time without flossing first, this time with five drops of white iodine (potassium iodide) made up by the pharmacist, again avoiding the metal. She had only oxalate kidney stones and was to stop drinking regular tea, replacing it with single-herb teas. In five weeks her gums were better although she was still chewing a little gum and the "peroxy" had been too painful for her to use. Her low back and mid-back pains were gone too.

Gerhard Rogers, age 39, came for his lower back pain and leg cramps. He had mono, di and tricalcium phosphate crystals in his kidneys. His diet was changed to reduce phosphate (meat, cereal, breads, pasta, carbonated beverage) and increase calcium and minerals. He was to drink three glasses of 2% milk a day and to start the kidney herb recipe. In 25 days he had only minor improvement. He still had phosphate crystals. He was afraid to drink milk because he had heard so many bad things about it. He was told to boil it first to eliminate these “bad things”. A toxic element test showed a buildup of copper, arsenic, cobalt, cadmium, lead, thallium, vanadium and radon. This could easily explain his leg cramps, headaches and sleep problem, too. The arsenic came from pesticide, cobalt from detergent, thallium and copper from tooth fillings. The vanadium was fixed by having the gas pipes tightened, and radon could be reduced by improving ventilation under the house. He was thankful for the information and set about cleaning up his body and environment.

Alberta Mellos age 52, came in for lower back pain and upper back pain. It was explained to her that lower back pain was simply due to tiny stones cutting into her tissues but upper back pain was due to gallstones. She could clear her low back pain first. The kidney test showed she had oxalate and cysteine crystals. She was started on the kidney herb recipe. Nineteen days later she arrived with a cold but stated that her low back pain was gone.

Glenn Dirk, age 62, called on the telephone to say his urination had stopped, probably due to kidney stones. This had happened once before and now he was in a panic. He started our kidney herb recipe the same day and passed 117 stones the same night without bleeding or enough pain to need painkiller. After this, he could focus on his prostate enlargement and pain with sitting. He had intestinal flukes and other stages in his prostate gland as well as in his intestine. He also had *Clonorchis* (human liver flukes and their eggs) in his prostate. He had carbon tetrachloride methyl butyl ketone and TC Ethylene from food pollution accumulated there too. After stopping grocery store beverages and killing parasites with a frequency generator, he could urinate normally, freely and without pain.

Lower Abdominal Pain

The lower abdomen on the left side has the sigmoid colon as it comes down and bends. This is a favorite location for larger parasites to settle permanently. Flukes, roundworms, parasites of all kinds and their attendant bacteria and viruses can be felt if they produce gas and pain. Sometimes they live perfectly quietly, seemingly in harmony with us.

Moving the bowel more frequently expels them repeatedly and prevents their numbers from getting very high. Nature may help you with this by setting up diarrhea. Diarrhea is your clue that intestinal freeloaders are present.

The small intestine leads into the colon at your lower abdomen on the right side. At the junction is the ileocaecal valve that prevents backwash, and the appendix. The ascending colon goes up your right side then becomes the transverse colon that crosses your abdomen at the belly button level. The colon descends on your left side, leading into the sigmoid.

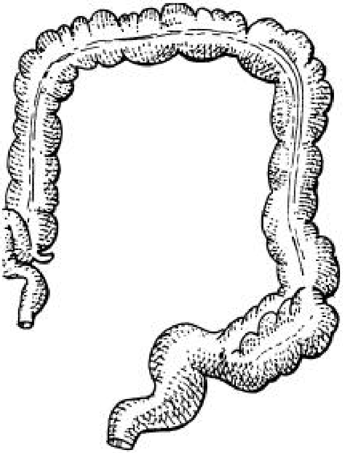

Fig. 19 Colon.

E. coli and *Salmonella* and *Shigella* are “enteric” (they live in your bowel) bacteria that can give you severe abdominal distress and pain. In fact, you can become a chronic sufferer. They can live on hands and under your fingernails, so reinfection from yourself is the most important source. Never, never touch your fingers to your lips. Most importantly, don't try to stop your frequent bowel movements. They will stop on a dime when your parasites and bacteria are dead and gone.

Other sources of *E. coli* are personal water bottles, other people's hands, hands that have changed baby diapers or cleaned bathrooms.

Hands do everything. To eliminate their threat of reinfection, cut out the section on hands (page 397) and paste it on your refrigerator.

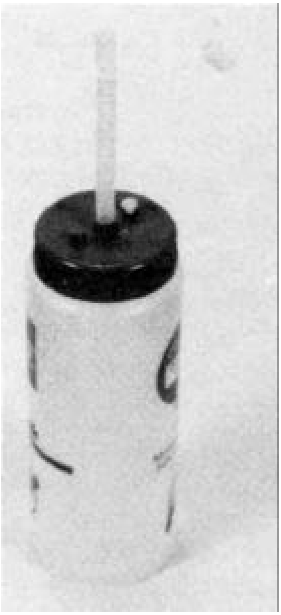

Fig. 20 Keep personal water bottles sterile.

Stomach Pain

Our dairy foods are polluted with *Salmonella* and *Shigella* bacteria. It is impossible to operate a dairy without getting some cow manure into the milk. Although udder wash contains antiseptic it does not kill all manure bacteria. Later, when milk is pasteurized, many heat sensitive bacteria are killed like the “friendly” *streps* and *staphs*, but not all the harmful *Salmonellas* and *Shigellas*. Some survive to colonize the milk, then later infect the consumer. Only milk that is sterilized is safe. A commercial source of sterilized (safe) milk can sometimes be found on the shelf (unrefrigerated). If it had any bacteria, it would not survive shelf life for more than one day!

You may not notice any discomfort from drinking milk, buttermilk, or eating yogurt without sterilizing it. Your stomach acids may be strong enough to kill them, or your liver able to strain them out of your body fluids and dump them, dead, into your bile ducts. Or they may live quietly in some part of the bowel where you feel no effects. Sterilize all your dairy foods by heating at the boiling point for 10 seconds, even if you have no symptoms.

If you are intolerant of milk it doesn't mean that you are lactase deficient, but that you are unable to kill any *Salmonellas* and *Shigellas*. These, in turn, can make you lactase deficient via frequent diarrheas. You can correct this situation by not eating any more bacteria. Give your body clean food, as intended by nature. Don't eat any deli foods, don't eat salad bar food or restaurant food unless it has been baked or cooked. Never eat chicken or red meat at restaurants. They are not thoroughly cooked.

As soon as a new abdominal pain or discomfort, or a gassy condition appears, zap bacteria and try to eliminate your bowel contents. Use the herb, *Cascara sagrada* (follow directions on label) as a laxative, or Epsom salts if necessary. Also start the Bowel Program (page 546).

If you have chronic abdominal problems, make sure you eliminate the bowel contents two or three times a day. There are herbs that can kill enteric bacteria, known to our ancestors of various cultures. **Echinacea** was a treasured herb of American Indians. **Goldenseal** is another favorite. **Turmeric** can kill *E. coli* and some *Shigellas*. **Fennel** can also kill some. But a single dose of Black Walnut Tincture Extra Strength seems to do the most. Make it yourself if possible (see *Recipes*, page 543).

If your body has lost its ability to kill *Salmonellas* and *Shigellas*, all the antibiotics and herbs and good bowel habits cannot protect you from these ubiquitous bacteria. You could ask how you lost your natural protection from them. There is evidence that common **antibiotics** that kill *Streptococcus* and *Staphylococcus* varieties are responsible.

A fraction of your bowel bacteria should be the friendly *Strep. lactis* and *Staph. epidermidis*. After repeated doses of penicillin-like antibiotics (that you may be taking for your strep throat) they are eradicated along with the "bad" *Strep. pneumoniae* bug. No amount of acidophilus culture (which contains active *Lactobacillus*) can replace these *Streps* or *Staphs*.

In mice, it takes a million Salmonella bacteria to start an infection. After giving them streptomycin, it only took 10 bacteria to infect them![9] Your intestines are similarly handicapped after antibiotics, and allow even very small amounts of *Salmonella* and *Shigella* to escape and multiply!

Try to get some natural killing power back. This means improving the stomach's ability to produce acid and the liver's ability to make bile. In turn, this means getting the toxins out of the stomach and cleaning the liver. Certain toxins accumulate in the stomach when the liver and kidneys can't keep up with elimination. Arsenic is a prominent stomach toxin. Get all sources of arsenic removed. Freon is another stomach toxin. Switch to a non-Freon containing refrigerator.

The metals from dentalware: mercury, silver, copper, thallium, first are swallowed and then land in the stomach. Clean up your dentalware. Toxins you inhale such as asbestos, formaldehyde, fiberglass, also are coughed up and swallowed to accumulate in the stomach. Test for them and clean up your environment. Any stomach can recover a significant part of its function by cleaning it up. Even though you regain your tolerance toward minute bits of filth in dairy products, do not go back to unsterilized milk products.

Appendicitis

The lower abdomen on the right side has the valve that separates the small intestine (*ileum*) from the large intestine

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[9] Sherwood L. Gorbach, M.D., Perturbation of Intestinal Microflora, Vet Human Toxicol 35 (Supplement 1) 1993.

(*caecum*) called the *ileocaecal* valve. It is a common trouble spot because large parasites can attach themselves behind it and keep themselves safe from elimination. (A parasite's biggest worry is your elimination.) It is a favorite location for pinworms in children. It is near this point where the appendix attaches and this, too, is a favorite location of pinworms. With an appendix full of pinworms and their bacteria, is it any wonder when it gets inflamed and causes pain?

Appendicitis refers to inflammation of the appendix. Often, the pain isn't felt over the appendix but over the navel (this is an example of pain being caused at one location but felt at another; it is called *referred pain*). If there are any suspicions of appendicitis, zap pinworms and all enteric parasites and bacteria immediately. Because the current does not penetrate the bowel contents very well, zap every day for two weeks and take 2 tsp. (½tsp. for children) Black Walnut Hull Tincture Extra Strength one time. Make sure bowel movements are regular after this (see the Bowel Program, page 546, for hints) and hands are washed after bathroom use and before eating. Keep fingernails short for the whole family.

If appendicitis does not clear up it can lead to a burst appendix, spewing the dreadful contents into the abdomen. Kill pinworms and roundworms and enteric parasites regularly (once a week) in children. Keep pets on a regular diet of parasite-killing herbs.

Urinary Tract Pain

Urinary tract infections, including bladder, kidney, and urethral infections, are easier to clear up than to test for. Start by drinking a half gallon of water a day. Put yourself on the kidney herb recipe (page 549). This will dissolve the tiny crystals where bacteria hide and multiply.

Common urinary tract pathogens are *Gardnerella*, *Proteus*, *Trichomonas*, *Campylobacters*, *E. coli*, and *Salmonellas*. Sex will give you an instant dose of your partner's urinary tract bacteria. Make sure both of you clean up the urinary tract by zapping and doing the Kidney Cleanse.

Irritable Bowel Syndrome(IBS), Colitis, and Spastic Colon

are all conditions that combine parasite and bacterial problems plus an allergic trigger. If dairy foods trigger yours, you can guess it is not allergic at all but simply *Salmonella* or *Shigella* infection. Boil all dairy foods, stop eating ice cream, cheese and yogurt which you cannot boil. If eating lettuce triggers your intestinal attack, but other roughage does not, it may be a true allergen and cleaning the liver will eventually cure it. Apples, cinnamon and other “allergic” foods can be salvaged the same way. Wheat “allergy” is due to the pancreas being full of pancreatic flukes, wood alcohol, Kojic acid (a mycotoxin), and gold.

All these bowel diseases are quite easily cured by killing all parasites, bacteria, and viruses. Since reinfection is such a big problem, give your pet away until you are completely cured. Have your pet on the herbal parasite program before bringing it back. Clean up your diet, dentalware and environment. Your abdomen will be happy once more and grateful to you for your kind attention. Remember that zapping does not penetrate into the bowel contents. It kills only the outside layer of pathogens. For this reason you should zap daily for several weeks. For this reason, too, I recommend the Bowel Program (page 546) and Black Walnut Hull Tincture Extra Strength even though you may have gotten immediate relief from zapping alone.

Crohn's Disease

is somewhat more serious because the sores are higher up in the digestive tract. This is because sheep liver fluke and pancreatic fluke are commonly the main parasites and these live in the pancreas and liver. They often spill over into the upper intestine. *Salmonella* and *Shigella* are always part of the picture, too, as are various amoebae and fungi. The treatment is the same, kill all parasites and remove all pollutants, especially wood alcohol in commercial beverages. Healing of the digestive tract is very quick, often in a week. Reinfection is very quick too, if the rule about cooking dairy foods is not observed. Keep up meticulous hand sanitation.

Michelle Whorton had stomach pain at the middle of her abdomen, not related to eating. She had occasional very bad diarrhea and also daily headaches. She was started on the kidney herbs for other reasons. Her diarrhea disappeared! We found she had *Ascaris* (probably in her stomach where they cause indigestion and inflammation). She zapped them with a frequency generator set to 408 KHz for three minutes at 10 volts. She was to be very careful with sanitation since they owned a number of farm dogs. Next seen after six weeks, she stated that all her previous problems were gone but she had a different pain in the mid-lower abdomen that got worse during her period and sent pain shooting down both legs.

This turned out to be uterine in origin, but not endometriosis. Her uterus was full of asbestos, arsenic, gold, silver, titanium, propyl alcohol, benzene, styrene, toluene and carbon tetrachloride. This would invite any bacteria toward it!

Mark Lippman, age 51, came in for his irritable bowel syndrome, hoping we would find *Giardia* and put an end to it quickly. Actually, he had intestinal flukes, beginning to invade the liver. He also had propyl alcohol built up in his body giving him a precancerous condition that needed immediate attention. The flukes were killed in twenty minutes, along with *Ascaris* (he had swollen eyelids). He was allergic to milk as could be expected with so much interference with digestion. He was immediately better and did not need to come back.

Billy Henry, a 9-year-old boy, had diarrhea daily and stomach aches. He also wet the bed. There was an indoor pet dog and a bird. Electronic testing showed he had two kinds of *Ascaris* and pinworms. His young body also had a buildup of benzene, moth balls and carbon tetrachloride that he was eating, drinking, and breathing. His bed wetting stopped after killing parasites with the herbal program. His other problems recurred until he was older and could stop licking his fingers when eating.

Tom Ochs, age 36, had chronic stomach problems, alternating constipation and diarrhea, was labeled “lactose intolerant” after an elaborate test, and finally had been diagnosed with irritable bowel syndrome. Actually, he had *Ascaris*, besides other smaller parasites. He was also toxic with cesium from drinking beverages out of clear plastic bottles. This frequently causes depression and he was happy to understand his mood changes. After changing to purer food and products and killing his parasites, he did not need to come back. Five months later he was able to drink all the milk he wanted, no longer had sinus problems and lost his IBS.

Rex Callahan, age 5, had dark circles under his eyes, numerous ear infections until tonsils were removed and tubes put in, and many strep throat infections. Clinically, he was found allergic to dust mites, pollens, and animal dander. His skin got “rashy” if he drank too much fruit juice. He had frequent diarrhea. We found he had *Ascaris* parasites. They were not difficult to clear and he was soon a new person.

David Falls, age 52, had stomach pain and numerous health problems stemming, no doubt, from his diagnosed Crohn's disease. He became allergic to the sulfa drugs commonly used in this disease. We found he had sheep liver flukes and all their developmental stages in his blood and intestine. He was put on the herbal parasite program which he found difficult to follow. Nevertheless, in three months his bowel was nearly normal and the pain in his intestine much less.

Edward Marsili age 7, had bouts of stomach pain. He had intestinal flukes and a build-up of benzene in his body. This would seriously lower his immunity and ability to fight off tiny parasites. He was using a product containing an herbal oil that was polluted with benzene. His parasites were quickly killed with a frequency generator and he was put on the herbal parasite program. One month later his stomach felt much better, but he still had an occasional stomach ache. Testing showed hookworm and rabbit fluke. His benzene was now gone so the tendency to “pick up everything” was gone too. Staying on a child's maintenance parasite program would protect him.

Kim Johnson, almost two years old, had lots of ear infections. It started at eight months so the mother took her off cow's milk and wheat. This stopped her ear infections until mid-winter. She had to be back on antibiotics and a few months ago the doctor began discussing tube implants with her since she was still on antibiotics (six months). Another ear, nose and throat doctor agreed with this opinion, but was willing to wait until Autumn. The baby had been passing a lot of undigested food and was unhappy. They were vegetarians. The baby nursed. Our test showed pancreatic fluke infestation; this would easily lead to bad digestion, especially of milk and gluten in wheat. Fortunately, she was nursed throughout, in spite of going to daycare. Simply killing the parasites (in both mother and baby) solved both problems and she did not need to come back. The ear infections were probably caused by bacteria and viruses brought in by the parasites.

Cynthia Prout, age 36, brought her three children because of their poor health. They all, including herself, had stomach problems, a lot of allergies, asthma, ear infections, and milk intolerance. One boy, age 8, was intolerant of both milk and wheat and hadn't had them for years. He was infested with two kinds of *Ascaris* and pancreatic flukes. His sister, Nola, had itching legs and headaches besides; she was toxic with bismuth and antimony (from shampoo fragrance and laundry fragrance). She also showed a build up of vanadium, implying a gas leak in the home. The youngest, age 5, had frequent stomach aches and vomiting. It was a simple matter to kill *Ascaris* electronically at 408 KHz and the pancreatic fluke with all its stages (421 through 434) after which the children did fine.

Sofia Sobel had extreme ulcerative colitis although she came for her headache. She had been on Prednisone for a month with no relief. We found she had the three large flukes plus *Chilomastix*, dog whip worm, and amoebas in her intestine (but not in body organs).

There were several house dogs. Her stomach and intestines were much too sensitive to accept parasite herbs, or in fact, anything—anything except slippery elm powder. This herb (1 tbs. made into a paste first with water and then drunk as a beverage three times a day) paved the way for acceptance of two oyster shell calcium, one magnesium and one zinc tablet. Her blood test showed high phosphate levels since she was dissolving her bones to get calcium. She added sodium alginate (¼ tsp. to a cup of vegetable broth soup) twice a day to help her tolerate the parasite killing herbs. Her children were given VMF (vermifuge or parasite killing) syrup. By the 12th day of the parasite program she no longer needed colitis medicine; her bowel movements were down to twice a day, soft and formed, but still with a little blood streaking. She loved the alginate mixed with slippery elm. She was able to eat fruits and vegetables but agreed to stay off wheat and corn until her liver was cleansed. In another week she was free from all abdominal complaints except a heaviness over the uterus, possibly due to two missed periods. The thought of pregnancy put her in a panic. She was instructed to induce her period (Emmenagogue, see *Recipes*). She was sure she wanted her period, not a pregnancy and this seemed to be her God-given right. Three weeks later she had a flare up of colitis due to *Salmonella* in food; it also gave her a urinary tract infection. This time she took Quassia herb to kill invaders in addition to the maintenance parasite program which she had begun to neglect. She had been very busy, had lots of energy and wasn't on medications. She treated her urinary tract infection with betaine-hydrochloride (to acidify the stomach), began using plastic utensils to reduce her nickel intake (see Prostate Pain, page 124)) and drank a lot of water. This experience taught her valuable lessons that she was eager to learn, benefiting her family and herself immensely.

Rebecca Goetz, age 53, had ulcerative colitis and her husband had Crohn's disease. She had been on Azulfidine™ and Flagyl™ frequently. Her parasites were only intestinal flukes and their stages, and *Endolimax*, an amoeba. It was a simple task for her to clear her problems by killing them and by sterilizing her dairy foods. Wes, her husband, had three surgeries to remove sections of bowel due to Crohn's disease. He now had a colostomy but was on Advil™ for pain in the rectal area. He could hardly sit. He had been tried on anti parasitic medicine (Cypril™ and Flagyl™) but they did no good. He had intestinal flukes and all their reproductive stages in his body, also pancreatic flukes, *Capillaria* roundworm, and *Diphyllobothrium erinacea* scolex. We interrupted his testing at that point. His kidneys were full of phosphate crystals— he ate no dairy products. He was started on half-doses of kidney herbs and only part of the parasite program in view of his colostomy and possible diarrhea. Two weeks later we continued testing, finding pinworms, *Haemonchus*, *Leishmania tropica*, *Paragonimus*, *Sarcocystis*, *Stephanuris* and *Trichuris* (whip worm.) Quassia was added and doses increased. His blood test showed a high thyroid hormone level (T4), contributory to over activity of his bowel He was started on goat milk, vitamin C (3 gm. daily) and B_{12} shots. He was given magnets to sit on for pain. He was toxic with cadmium, from his old tooth fillings. But in five weeks he could sit comfortably without pain pills. There was less blood in the stool. Dental work would bring him his next big improvement.

Benito Villamar, a middle age man, had severe side pain for several weeks. He was also gassy. He had sheep liver fluke and stages in his thymus and intestine. The thymus is under the top of the breastbone and is a very important organ of immune function. It is easily damaged by benzene. He did, indeed, have benzene accumulated there. He was given a list of benzene-polluted products to avoid and was started on the parasite killing herbs after killing the flukes instantly with the frequency generator. Two weeks later his side was very much better, his benzene was gone and he was eager to rid himself of lower back pain, which he also had.

Al Vickers, age 9, had stomach aches, headaches, a constantly runny nose and asthma. He was on Slo-Bid™ medicine and allergy treatment. He had a sleep problem. He also had two dogs, one rat and two hamsters. The dogs and he had high levels of *Ascaris*. He was zapped for *Ascaris* and the four common flukes (without testing). He was put on vermifuge syrup and Rascal capsules. This ended his problems and began a new chapter of better care for his health by his parents.

Tim Melton, age 16, had several colitis attacks yearly, requiring hospitalization, from third grade to the present. He also drooled constantly, needing to spit a lot. (This is due to mercury toxicity from amalgam fillings. It is better to spit out the mercury than to swallow it.) He had intestinal flukes at a high level for which he was started on the parasite program. One month later he was very much better. He had only one diarrhea session since the last visit. But he still had sharp pains under both buttocks (probably due to kidney stones). He had been an iced tea drinker and had numerous oxalate and cysteine crystals deposited. He was appalled that a common beverage could be so harmful.

Central Abdominal Pain

can be coming from the uterus, bladder, or bowel. It is difficult to tell which is the source. The first step is to simply kill enteric (bowel) free-loaders and get into good bowel habits. Gas and bloating should be gone. If this isn't the solution to the pain there may be special bladder parasites with their bacteria. *Schistosomes* prefer to invade the bladder wall. In fact, very many parasites temporarily invade the bladder because the body is trying to excrete many of them. The whole family should be cleared of these same parasites. Kill them by zapping. Pets should not be kept indoors since they have many of these parasites, too, and they are easily transmitted to us.

Interstitial Cystitis

is one of the most painful conditions described by clients. *Schistosomes* are the real perpetrators but after the bladder wall is weakened, other parasites and their bacteria and viruses accumulate here too. To regain your bladder's health all toxins must be cleared as well. Dental metal, environmental toxins, including radon, asbestos, formaldehyde, must be cleaned up. The diet, body products and home should be carefully searched for toxins. *Schistosomes* are easily zapped but easily picked up off toilet seats and doorknobs. Always wash hands after toileting: a single droplet reinfects you!

Uterine Pain

Endometriosis

Many a woman's dreams have been shattered by her inability to have a child. Endometriosis is often the cause. It starts with painful cramps at period times. They get worse and worse until pain killers are necessary just to get out of bed and move about the house. There are flukes in the uterus! Large intestinal flukes in a rather small organ! Did they migrate to the uterus from the intestine or did they develop there from eggs?

Sometimes sheep liver fluke is seen there. Once an avenue to the uterus is established, numerous other parasites move in the same direction: *Clonorchis*, the human liver fluke and even *Eurytrema*, the pancreatic fluke, can invade the uterus wall. Why have they taken up so abnormal a living place? Because the uterus has solvents in it! This is the green light for flukes. This disarms your organs so they are left helpless against fluke stages left there by the blood and lymph. Stop eating solvent-polluted foods. There are solvents in all cold cereals. Make cooked cereal. There are solvents in purchased drinking water. Drink from your cold kitchen faucet. There are solvents in grocery store bread, grocery baked goods and cholesterol-reduced foods. Eat none of these. Buy baked goods and bread at your local bakery. Stay away from “low cholesterol” foods. There are solvents in decaffeinated and other powdered mixes for beverages. Drink nothing except milk from the grocery store (sterilize it). Milk does not have solvent pollution. The hormones, antibiotics and udder wash can be tolerated—solvents cannot.

Beverages and powdered mixtures sold at health food stores are no exception. Use no powdered mixture intended for weight loss or weight gain, nor vitality supports, nor dietary supplements. They are all polluted. Some solvents (I often see methyl ethyl ketone and methyl butyl ketone) choose the uterus to accumulate in. This sets the stage for endometriosis and fertility problems. Where there are large parasites, smaller ones soon crowd in. All bring their own bacteria and viruses. *Gardnerella*, especially, is found in cases of endometriosis, ovarian cysts and menstrual problems. The flukes evidently travel from the uterus to other parts of your body cavity, distributing bits of the uterine lining as they go. Once this distribution has occurred, can the bleeding (regular menstrual bleeding) at these extra sites ever be stopped?

It stops immediately when the flukes are dead!

Your body knows how to clean up after dead flukes and does the job perfectly. You can be free of pain in time for your next period. Zap to kill the four common flukes, *Gardnerella*, all other common parasites, and urinary tract bacteria (common ones include *Proteus*, *Salmonella*, *Campylobacter*, *Chlamydia*, *Trichomonas*). Avoid reinfection by avoiding solvents! It is impossible not to pick up parasites. If your uterus has solvent in it, they will find their way to it in a day. Without solvent, they will not.

The solvents will leave by themselves. Help your body get rid of them with vitamin C and B_2 (3 grams and 300 mg. respectively, daily, see *Sources*).

To heal the uterus so it no longer attracts parasites, clear up its internal pollution besides solvents. This means mainly the dental metal that has piled up and environmental toxins such as asbestos, arsenic, fiberglass, and formaldehyde. Gold and silver are especially attracted to the uterus. Don't wear gold rings or any metal jewelry touching your skin anymore, and, of course, get all metal out of your teeth. Never try to get pregnant before you have cleared up endometriosis.

The advice given by obstetricians to get pregnant to solve your pain problem is most unwise. Indeed, pregnancy changes your body's metabolism and without periods you get pain relief. But it seems much too risky to grow a baby in an infested, polluted uterus. Fear of birth defects is an intelligent fear. Be careful not to get pregnant while you are killing parasites and getting mercury removed from your teeth.

Healing starts as soon as all the parasites and pollutants are gone.

Joanne Biro, age 22, had severe cramping pain with her periods, diagnosed as endometriosis. She had adult intestinal flukes and the *cercaria* stage in her uterus. She had a xylene (solvent) buildup in both her brain (cerebrum and cerebellum) and uterus. She was started on the herbal parasite program following the kidney cleanse. Her next period was pain free. A check up showed she was free of flukes but had thallium in her immune system. Dental cleanup was next on her agenda.

Denise Leyva, 22, was on birth control pills to control the growth of endometrial tissue. She had laser surgery previously. She had hexanedione and methyl butyl ketone buildup in her uterus supporting the intestinal fluke and its eggs in the uterus. There were also some sheep liver flukes and human liver fluke stages there! She was advised to stop eating cold cereals and commercial beverages and kill the parasites immediately. She had no recurrence.

Anita Pierce, age 32, had numerous surgeries for her endometriosis. She also had chronic fatigue syndrome, and several allergies. She had two beautiful poodles in her home. She could not part with them so she gave them the pet parasite herbs faithfully. She had intestinal flukes, tapeworm stages, *Ascaris* and various other flukes in the uterus. She had all her dental metal removed and home detoxified. Her body was teeming with *Nocardia* and Epstein Barre Virus (EBV). In spite of repeatedly killing the flukes and bacteria with a frequency generator and making herculean efforts she was no better off eight months later. She was unable to solve the problem of reinfection from her dogs.

Christine Solton, age 27, had extremely heavy and painful periods and didn't stop bleeding between periods. A large cyst had been seen by X-ray in the uterine wall. She also had constant bladder pain. Both problems kept her in the bathroom most of the time (90 visits/day). She had the intestinal fluke in her uterus (probable cause of cyst) and *Schistosoma haematobium* (bladder parasite) throughout her body. She was started on the parasite program and in one week her bladder pain was under control but bleeding (from the cyst in uterine wall) continued. *Schistosomes* are very contagious, probably even from toilet seats and the house dust of an infected person. She had them again three weeks later. This time she zapped them and got instant relief. Her bladder and uterus were both full of propyl alcohol, tooth metal, fluoride, cobalt, zirconium, aluminum, antimony, cadmium, and formaldehyde. She was delighted, though, to understand her problem and made the dental appointment.

Contraception

There is an excellent pamphlet available at health food stores, called Wild Yam for Birth Control Without Fear[10] that informs that 3 capsules taken two times a day provides reliable (perfect) contraception provided you give it a two month head start. Also, an emmenagogue recipe is on page 546.

The Silent Cervix

The cervix is a big “trouble spot” for women just as the prostate is for men. It seldom lets you know with pain, however, that bacteria or parasites or toxins are present. Sometimes a brief needle-like pain does alert you to something going on there, but it is easy to miss. The cervix is constantly secreting a little bit of mucous and this helps it stay clean but why give it mercury and copper and gold to secrete? Many a fertility problem has been solved by stopping the toxic pollution of uterus, ovaries, and cervix. Clean up your dentalware and clean up your diet and environment.

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[10] Willa Shaffer, published by Woodland Health Books, PO Box 1422, Provo, Utah 84603.

Kill parasites and bacteria regularly, every week, with the herbal recipe or by zapping. You should have no pain with menstruation, no bloating, fatigue or headaches. A PAP smear test should always be “good”. If it isn't, hurry to the rescue of your cervix.

Menopausal Symptoms, Hot Flushes, PMS

Insomnia, irritability, PMS (pre-menstrual syndrome), depression, anxiety, nervousness, are all not to be expected at and after menopause. They may certainly be caused by hormone imbalances. It is these imbalances that are not normal.

NO menopausal symptoms are normal

After the ovaries are done with their cycles of estrogen and progesterone production, the **adrenal glands'** hormone production was meant to “kick in” and make up any deficit.

During your fertile years, you were meant to have a peak of 100 picograms/milliliter (pg./ml) of estrogen on day 9 and day 22 of your cycle. Progesterone, on the other hand, only peaks once, on day 22, and it should reach a level 20 to 100 times as high as estrogen! After this ends, your adrenals can still keep your hormone levels regulated. Typical values are 20 pg./ml estrogen and, again, 20 to 100 times as much progesterone. Keeping these two hormones in balance is just as important as the actual amounts. **20 pg./ml estrogen is enough to prevent menopausal symptoms** including hot flushes, and to give you heart protection and bone density protection. Taking synthetic hormones usually gives you exactly such levels. But if your own adrenal glands can supply them, surely it is a better approach. (A blood test can tell you your levels; do it on day 21, 22 or 23 before menopause, after menopause the day is not critical.)

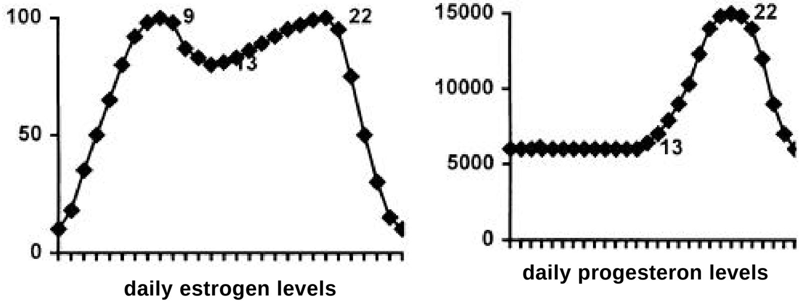

Fig. 21 Estrogen and progesterone levels (pg./ml).

Why aren't your adrenals producing them? Because they are hampered by parasites and pollutants! Kill all the parasites, bacteria and viruses, especially *Gardnerella*, *Proteus*, *Chlamydia*, *Campylobacter*, *Neisseria*, *Treponema*, *Salmonella*. Use the zapper.

Notice that these are also the favorite urinary tract bacteria! This makes good sense, because the adrenal glands sit right on the kidneys and would be geographically close to the kidney bacteria. To avoid getting them back, do a kidney cleanse (page 549) to remove all crystals where they might hide.

After this, hot flushes can be suddenly gone. If not, continue the cleanse. Meanwhile, do some permanent lifestyle improvement. Start drinking two pints of water between meals plus water and milk (sterilized) at mealtime.

Don't drink cranberry juice with its copious *hippuric acid* and its solvent pollutants. You won't need such insufficient help after cleaning up your body, dentalware, and environment. Besides giving you a better hormone supply, your newly revitalized adrenals will get you through stress in better shape and keep your blood pressure normal.

If bacteria are not kept down they will begin to invade other organs. *Gardnerella* goes to ovaries to feast on the corpus luteum after ovulation. This keeps the corpus luteum from making enough progesterone and PMS results.

Menstrual problems and PMS, in general, although they may not be pain-causers, are a sign that all is not well with the uterus and ovaries. Go on a cleanup program. Kill your invaders with herbs or the zapper. Clear up your toxic accumulations from dental metal and environmental sources.

Don't be surprised by a pregnancy! This is not the time to get pregnant, though. If you wish to get pregnant, clean up your body first, being very careful to prevent pregnancy during this time. If this is not under your control do your dental work first. Since every cleanup job increases your fertility, it is best to get the mercury, thallium, copper and nickel out of your body before your risk of conception is raised further by making other improvements. Many an amalgam replacement job had to be halted in the middle due to pregnancy! Couples just couldn't believe they could have a child as a result of cleaning up their bodies so they were careless in spite of my warnings! **A dentist will not take out mercury during pregnancy.**

Nicole Truett, 40ish, had PMS before her periods. She was a returning student and couldn't afford to feel emotionally upset. She also had recurrent yeast infections, *Herpes* and panic attacks. She complained that her thinking was weird, although she was an excellent student (she got her birth date wrong on our office forms!) She had high levels of mercury and we suggested dental work immediately. Two months later she was feeling much better and had all metal removed but was experiencing a slight return of symptoms which panicked her. She still had *E. coli* and *Bacillus anthracus* at four tooth locations, giving her chronic sinus symptoms. She needed her cavitations cleaned. Four weeks later she described how she had gotten immediate emotional relief after two cavitations were done. Our solvent test showed methyl butyl ketone, benzene and carbon tetrachloride (which we found in her Mountain Valley Arkansas Spring Water). They were lowering her immunity giving recurrent Herpes and yeast problems. These disappeared in a week. She was so happy to find the cause of her problems and yet so angry at the nature of the cause that she planned to write to the water company. We need more such environmental activists.

Monica Koziol was on Ibuprofen™ for menstrual cramps. She also got a severe sugar craving and minor depression and headache with her period. She was toxic with silver, copper, platinum, mercury and lead. She also had hookworms, pinworms, human liver fluke and cat liver flukes infesting her. A hormone test showed very low estrogen (57.6 pg/ml) probably due to all these interfering factors. She had all the metal from her fillings replaced and killed parasites with the herbal recipe. This gave her regular normal periods for several months. She decided to get pregnant but couldn't. A follow-up showed she was full of parasites again. She had stopped the maintenance parasite program. She resumed it and began kidney and liver cleanses to get longer lasting benefits.

Barbara Ashby, age 43, had suffered for 1½ years from menstrual pain. She had oxalate crystals in her kidneys and was started on the kidney cleanse. She followed this with the parasite program and dental metal replacement. Then she cleaned her liver and after three cleanses (she got over 1,000 stones the first time!) she said she felt great again.

Terri Entzminger, age 16, had a long list of health problems including painful ovaries and painful periods for which she was put on birth control pills by her doctor. She had several bacteria in her genital tract: *Neisseria gonorrhea*, *Plasmodium cyano*, *Staphylococcus* *aureus* (also at tooth #28 which had a plastic filling), *Streptococcus pyogenes* (also at tooth #28). A parasite test showed intestinal fluke adults in the uterus, not in the intestine or liver. There were also fluke *cercaria* here. She was started on the parasite herbs. Three weeks later there was no improvement. She had a rabbit, a dog and a hamster. She was to get them all onto the pet parasite program. Her diet was changed to exclude solvents. Six weeks later her periods were "great", she did not need the pill and she was keeping the whole household on a maintenance program killing parasites. Three weeks later she had cramps again. This time it was sheep liver fluke in the uterus. She probably got them from the snails in her fish tanks. She was off the maintenance program and drinking caffeine free cola again. This would fill her with solvents that make fluke disease possible. She killed them all with a frequency generator and decided to be more vigilant over parasites as long as she was such an ardent animal lover.

Azar Moya, 57, was on Premarin™ and Provera™ for hot flushes and emotional extremes, Synthroid™ for the thyroid, Xanax™ for nerves and sleep problems, something for diarrhea and something for depression. In five months she needed none of it. She had done a liver cleanse by then and got a commode-full of stones (about 1,000), she had changed her plumbing, got rid of the water softener, killed parasites and cleansed her kidneys. She still had sinus problems and some arthritis and was planning dental metal replacement and cavitation cleaning to clear them up too.

Infertility

An ominous sign in any species, infertility is not just another disease or "problem."

When birds' eggs don't hatch their species is doomed. So we learned from the DDT experiment humans did with birds in the 1960's. The DDT changed the thickness of their egg shells so they cracked when the mother bird sat on them. All changes are experiments whether intentional or unintentional. Nature by itself produces sweeping changes, too, such as droughts, wind storms, fires, ice ages, but usually living things had time or mobility to adapt to them. When there wasn't time, and they couldn't run away, the species went extinct.

Are we humans an exception to this rule of adapt or perish? Nobody feels more helpless and hopeless than the infertile couple. They can not run away, time is limited, and obviously adaptation is not occurring. More likely their lineage will perish. The couples' only wish is "Give us one child, now." Surely, it is their birthright, as it is any living creatures', to reproduce.

Can we relax with the assurance that our intelligence, through the arm of science, will always rescue us? Are test tube fertilizations, fertility drugs, Cesarean sections, incubators for premature babies all triumphs for science? No, they are signs of reproductive failure for the human species.

When the concern is overpopulation of this planet, reproductive failure might seem less ominous. Maybe it's no worse than the natural way any species curbs its growth rate. Maybe only those who can survive parasitism, pollution and immune deficiency should survive in order to strengthen the species. But when reproductive intervention becomes a necessity, not an option, surely the danger signal is present as it was for the DDT'd birds who saw cracks develop in their eggs. The solution to our reproductive failure is not to find ever more artificial ways to conceive, to give birth, and to care for damaged babies. The solution is to fix the old fashioned way; to safeguard the natural way.

If you are unable to conceive or to provide viable sperms use an intelligent approach. Remove the obstacles. **The obstacles are parasites and pollutants, the same enemies of health we have seen before.**

Kill all large and small parasites with a zapper and the herbal parasite killing program. Don't try to keep a pet parasite free, give it away. Living close to another species is a luxury you can't afford at present. The pet can live with its parasites, you can't. Remember to kill bacteria and viruses too, especially *Gardnerella, Neisseria, Treponema*, the ancient enemies of human reproduction.

Is it safe to kill parasites if you might be pregnant?

The electronic way of killing parasites is safe if you use a frequency generator. The frequencies of parasites and bacteria are far away from human frequencies. The treatment with each frequency is short. There are no side effects.

The zapper has not been tested and should not be used during pregnancy.

The herbal way of killing parasites has been used by pregnant women without bad effects but this is not enough safeguard. I recommend waiting until the baby is born if at all possible. The treatment is long and intense. The growing baby is exposed continuously to herbs. Perhaps this is preferable to the toxins produced by parasites. You must use your own judgment. Obviously it is wiser to take a chance on herbs than to take a chance on inheriting AIDS or “genetic” diseases.

Part two of regaining your reproductive freedom to have a child is removing pollutants. Gold, silver, copper and mercury can accumulate in the reproductive organs, wrecking the delicate hormone balance between estrogen and progesterone, or wrecking the motility of sperm. Research has not been done to search for dental metal in the uterus, ovaries and testicle of infertile couples. You can do this research yourself. Slides of ovary tissue cost less than $10.00 as do other parts of the reproductive system. Search for dental metal yourself. Remove all dental metal from your mouth, and replace it with metal-free composite. Extract teeth with root canals.

A Word Of Warning!

Be extra careful with contraception during the dental cleanup. You could get pregnant the very next day! **This is no joke.** It is a serious hazard to conceive a child while mercury is loose and rampant in your body from the removal process. It may be a higher risk than leaving it untouched. If you are pregnant no dentist will want to finish the job of mercury removal! **Don't try to get pregnant yet.**

You may have tried fertility pills, in vitro fertilization, and other methods for getting pregnant over a ten year time period, all to no avail. Then you start cleaning up your body and taking your mercury out and suddenly you are pregnant before the job is complete! It may seem unreasonable and illogical to have to be careful after ten years of no worries, but play it safe.

If you fail to observe this warning and do get pregnant too soon, you may pray for miscarriage. Otherwise, take vitamin C and thioctic acid and hope for the best. Men should add daily zinc and arginine (60 mg. and 450 mg, respectively) to their diets. Both men and women should add vitamin E (200 mg.), a prenatal multivitamin and multimineral tablet, eat freshly grown vegetables for folic acid, and add vitamin C (at least a gram daily, see *Sources*). **No other supplements**! Supplements polluted with heavy metals or solvents do more harm than good. If you are not sure of their purity, test one by eating it and searching for it in your immune system five minutes later. If it is there, it is harmful; eat no more.

Nausea

of pregnancy is the scourge of expectant parents. After waiting hard and long for the desired pregnancy, the mother-to-be feels rotten, salivates and gags at the thought of food, and wants no more sex. Maybe sex is ill-advised during pregnancy, no matter how reassuring the male or male-oriented obstetrician is! Maybe salivation is actually mercury excretion being attempted by the body. Maybe nausea is all about keeping toxins out of the body and away from the developing child. These are intriguing possibilities, worthy of your research expertise.

A few decades ago the treatment for nausea was a weekly B_6 and B_{12} shot. Ask your obstetrician for this to see if it helps.

An older, herbal remedy was cinnamon tea: 2 tbs. cinnamon (bark or powder) in 2½cups boiling water, steeped for 10 minutes. Strain and add honey to taste. Dose: ¼ cup three times a day before meals.

Nausea invites starch eating—pasta, potatoes, rice and bread. Starches can absorb. Perhaps they absorb the noxious substances causing nausea. Make sure you add vitamin C to grains. In any case you must still eat additional nutritious food to grow your baby. In spite of craving a pickles/chocolate pudding/carbonated beverage lifestyle, you must eat mainly good food. Craving can take strange turns. Search for the taste you crave in good food and in long forgotten childhood foods.

These are all the fertility cases I saw in a year's time. None were left out in order to hide failure. Assess the success rate yourself:

Domilita Renshaw and her husband had been trying for six years to get pregnant. Both had been tested and treated in assorted ways. Domilita's period was irregular, a sure sign that all is not well in the area of reproduction. I gave them the usual warning about not risking pregnancy during their deparasitizing and depolluting procedures they both would be going through. Her hormone test showed slightly high (125 pg/ml) estrogen levels for day 22 (if it really was day 22!) and higher still if it was not yet day 22! Obviously, something was irritating the ovaries into overproduction of estrogen. She had oxalate and urate crystals and was put on the kidney herb recipe. She was switched to milk (3 glasses 2% a day) as her primary beverage besides water. She was toxic with nickel (dental metal) which would invite hordes of urinary tract bacteria, dangerously close to the ovaries. She made her dental appointment. She had sheep liver flukes and was started on the parasite program. She broke out in hives from a new hair spray polluted with praseodymium which got into her ovaries. She prepared to clean her liver for her frequent hives. Then she called to cancel her next appointment because she was pregnant (four months from first visit). Fortunately she had one visit with dentist completed. Nine months later she had a beautiful perfect baby.

Lindy Maloy and her husband had been trying for eight years to have their second child. They all had *Ascaris*, including, of course, their house dog. They wormed the dog monthly and did not want to part with it since they did not believe it mattered. They used the pet parasite program, but five months later she had higher *Ascaris* loads than ever. She also could not rid her uterus of intestinal fluke stages in spite of killing them with a frequency generator and using the parasite herbs. She remained full of solvents, bacteria and platinum from dentalware. Her endometriosis continued. They gave up.

Rosemary Peterson, age 33, had been trying to get pregnant for fourteen years. She had seven laparoscopies for endometriosis and very hard cramps with her period. She had intestinal flukes and sheep liver flukes in her uterus. There were sheep liver flukes and human liver flukes in her liver. There were intestinal fluke redia and cercaria in her saliva. The solvents in her uterus were methyl butyl ketone, acetone, carbon tetrachloride (from drinking store bought water), styrene (from drinking out of styrofoam cups), xylene (from carbonated beverages) and decane (from cholesterol-reduced foods). She also had a chronic yeast infection, treating it constantly with Nystatin™. She killed the flukes and yeast electronically before leaving the office and started herself on the parasite program and diet restriction. She got pregnant immediately, and did not return.

Elisabeth Tran, age 37, had tried to get pregnant for five years. She did get pregnant recently, on a special “gift” surgery program, but lost it. Her ovaries and uterus were toxic with mercury and thallium from polluted dental alloy. She also had barium and titanium in them, probably from lipstick. We did not see her again, we hope she solved these problems.

Christopher Gravely, a young man of 26 and Frederica, 22, promised faithfully not to get pregnant until their cleanup was complete. He was found by his doctor to have slow moving (low motility) sperm. He was robust and healthy looking but suffered a lot from low back pain—a clue to swarms of bacteria in the lower abdomen. An electronic search of his testicles and prostate (which had been infected once) revealed iridium, platinum and yttrium. This implicated tooth metal. He was also started on kidney herbs. Eight months later he had completed all his tasks, his low back and pain with urination had stopped, and this encouraged him to continue with his fertility program. We started him on thioctic acid two a day and zinc (60 mg.) two a day, switched him to an electric razor so he wouldn't have to use any chemicals on his face, and recommended that he ventilate his garage which was attached to the house, to reduce fumes in his home.

Meanwhile, Frederica, his wife, was also checked for toxic elements. She had antimony (from mascara) in her ovaries and breasts. She had sensitive painful breasts during her periods which were quite irregular. She also had indium and gallium, dental alloys in the ovaries and breasts. She, too, was started on the kidney herbs and instructed to get metal tooth fillings replaced. After two months they canceled their appointment. Frederica was pregnant! Not for long, though, and a wiser couple returned a few months later. Frederica finished her dental work. Both started the parasite program. Frederica's periods became regular. She was started on thioctic acid (one a day) plus zinc, (one a day), until her first missed period. Twelve months later they sent me their baby's picture: he was two months old.

Ginger Hart had been trying for three years to get pregnant. After an endometrial biopsy, a D&C,[11] and laparoscopy she was diagnosed with "inadequate corpus luteum." We found her ovaries toxic with nickel and europium from tooth fillings and strontium from toothpaste. She was delighted to understand her problem and set about correcting it.

Marjory Davis, age 28, had been on the "pill" (synthetic hormones) a long time but was off now and couldn't get pregnant. She actually got pregnant about one year ago but lost it at one month. A toxic element test showed her ovaries and uterus were full of beryllium (gasoline and coal oil), gadolinium and gallium. The metals are alloys of gold used in dentistry. She wore a lot of jewelry, just loved her chains, necklaces, rings, etc. But she agreed to go off all except two rings which did not have these alloys. To reduce fossil fuel fumes in the house she removed all gas cans and the lawn mower from the attached garage. They parked the cars outside. She was started on kidney herbs and promised to use contraception until she was done. She was to drink three glasses of 2% milk a day and take a magnesium tablet and stop drinking other beverages. Three weeks later her husband canceled her appointment because she was too embarrassed and delighted to call herself.

Prostate Problems

If urination is not complete, so you must soon go again, especially in the night, it is suggestive of pressure on the urethra from an enlarged prostate gland. Keeping a little urine from being voided is conducive to bladder and kidney infection, too, because bacteria soon find this "free food."

The prostate collects toxins as if it were a designated dump site, especially for nickel. Urinary tract bacteria quickly find "their" metal, nickel. Any supply of nickel will attract bacteria as quickly as crumbs and cheese attract mice. Urinary tract bacteria are making use of your urea as their food. To digest it, they first break the urea molecule apart into two ammonia molecules. It is the ammonia smell of the urine that gives away their presence. The urine should have no ammonia smell. Our bodies do not make ammonia. Only bacteria can do this! Their digestive enzyme is called *urease*. In order to do its job, this enzyme requires the element nickel.

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[11] A surgical procedure, called *dilation and curettage*, meaning dilate the bladder with air and scrape away the inner lining.

Nickel is plentiful in the soil which is undoubtedly where these bacteria belong, breaking up and utilizing the urine and droppings left there by animals. They perform an essential task in our environment, destroying animal excrement and thereby cleaning-up the soil around us. What folly it is to load ourselves up with nickel so that in one short hop from the earth they are residing in us! Bacteria are all around us doing their valuable jobs. We cannot stop associating with bacteria. We were not meant to feed them, however. If we did not supply them with nickel, as if we were just another patch of earth, they could not gain a foothold in our urinary tract and then to the prostate.

How can we rid our bodies of nickel? This is the challenge. Are we eating dirt? A small amount of dirt can't be avoided on our food. But we can stop sucking on nickel as if it were a lollipop. Our spoons, forks and knives are made of nickel! Stainless steel is 8% nickel! Does it really come off as you eat? When you stick a knife into the mayonnaise jar, it is stained in a few minutes. Try it. The mayonnaise has reacted with the metal loosening the nickel. When you smear the knife over your bread, this film comes off and you eat it. If you were to put the knife in your mouth, now, you could taste the metal. You will later wash the knife but not before you have eaten enough nickel to supply all the bacteria in your body with the daily allowance of their essential element, nickel. Nickel is not our essential mineral. Even plants keep their nickel levels very low. But due to pollution of animal feed with it, even a hen's egg now has 3 mcg/100 gm of nickel in it.[12] To produce a nickel-polluted egg, the chicken must be polluted.

Especially infants and children should never be given metal cups or cutlery. They need all their immune power to combat the barrage of new bacteria and viruses that is emerging in this age of AIDS. Nickel is part of dirt and belongs there, not in our pots and cutlery.

Another large source of nickel is metal dentalware. It is used to harden gold! If you suffer from prostate problems, remove metal from your dentalware. Nickel is used to make bridges, gold crowns, retainers, amalgams. Exchange it all for plastic ware and composite buildups (see *Sources* for more dental information). Stop eating and cooking with metal utensils; use old fashioned wooden or sturdy plastic cutlery instead. Always use a plastic knife for butter or mayonnaise. Never buy foil-wrapped butter.

Nickel is fat soluble and is stored in your skin fat temporarily when a surge of it enters the body. Your skin oils may be loaded with nickel causing “allergies” in the skin. Male pattern baldness is such an allergy. The sweat tries to excrete it for you. Always wash off your scalp sweat to help with this excretion. The skin oils dissolve nickel from metal jewelry (sometimes leaving your skin with a greenish black color) and transport it into your body. Don't wear metal jewelry. Earring posts should be plastic. Metal watches and metal rimmed glasses should be replaced with all plastic types. Metal rings should be replaced. After lowering your total body nickel levels and your prostate disease is only a memory, you might notice scalp hair returning to sparse areas. Search around the edge of the hair line for the first returnees.

Bacteria cannot live in the prostate without nickel being present. You can cure your prostate problems with the simple tactic of stopping nickel pollution of your body. Notice that you get a fresh attack after accidentally using metal cutlery in a restaurant or eating mayonnaise-style salad with a metal spoon stuck in it. It might be wise to take a **histidine** capsule (about 500 mg., one a day for three weeks, see *Sources*) when this happens. Histidine is a nickel chelator. Taking **zinc** is helpful too (60 mg. two times a day for a month). Possibly, the nickel was poisoning zinc enzymes. Read about the benefits of **flaxseed**, too, but remember to test every product for pollutants before accepting it as a supplement.

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[12] Food Values by Pennington and Church, 1985

Prostate problems of all kinds clear up when bacteria are zapped, the Kidney Cleanse is done, dental cleanup is done, and the Bowel Program is followed.

Richard Traylor, age 71, had suffered from prostate and urinary tract disease for three years. Scar tissue had to be removed occasionally from prior treatments of them. He was started on the kidney herbs and in two weeks (13 days) he had a considerable improvement in urine flow. At his follow-up visit we searched for toxins. He had radon, chromate, yttrium and strontium in his genital and urinary tract. He got rid of his water softener (such salts are polluted with chromate), toothpaste (strontium source) and opened the crawl space vents (source of radon). This cured these problems in less than two months. It also cured his stomach ulcers for which he had to take medicine. He was so pleased he decided to install a crawl space fan and pursue a parasite program and dental health just to see what extra health improvements he might get.

Omer Whitney, age 45, had always been a strong, healthy, hard worker. He could now barely walk, due to weakness and pains of several kinds; his prostate problems began several years ago. Our tests showed 4 kinds of kidney stones. He was started on only half a dose of the herbal recipe to give them a chance to dissolve more slowly. One month later he still had some stones although his leg cramps were already gone. At this time we found *Ascaris* (both kinds) which he killed with a frequency generator. We also found carbon tetrachloride and pentane (in decaf beverages) built up in him; also gasoline and TCE. He was considerably improved five weeks later and was quite eager to improve further. A toxic element test showed he was full of copper, antimony (from mineral ice massages), cobalt (aftershave), zirconium (deodorant), thulium (vitamin C fortified orange drink) and mercury (very high, from tooth fillings). He planned on cleaning all of it out of his body and regaining his lost strength.

Harvey Van Til, age 35, came in for his prostate and testicle swelling which began shortly after a vasectomy. He ached over the front right side of his abdomen. He was started on the kidney herbs and in four weeks he had eliminated his oxalate crystals and felt considerably better. We next found the adult intestinal flukes and human liver flukes in his prostate gland! After killing them immediately with a frequency generator and getting instant relief of pain, he got his own device and did not need to return.

Clayton Gamino, 26, had pain during urination which he interpreted as a left-over from a prostate infection he once had. He got all the metal out of his mouth, and did a kidney cleanse. A half year later he had no remaining pains and was able to father his first child.

Side Pain

Pain on the right side can come from problems at the ileocaecal valve or the appendix or the large intestine itself. It can also come from the liver which is higher up but is sending its pain message to your side. Pursue it as an intestinal problem first, killing parasites and bacteria and normalizing bowel movements with the Bowel Program. If the pain persists, especially if it reaches up the side to the

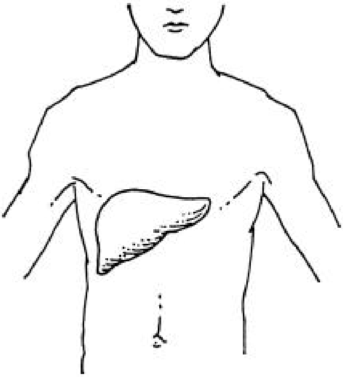

Fig. 22 The liver has a large lobe on your right side with the gallbladder tucked inside. The left lobe is smaller.

middle of the waist, it is probably due to the liver.

The liver is a large organ, mostly on the right side of the body, but with a smaller lobe on the left side. It is the chemical manufacturing plant for the body. It pulls in the food from the intestine (that you ate hours ago) and makes your body's chemicals from them. Toxic items are changed chemically into non-toxic items that the kidney is able to excrete into the bladder. Fatty things must be made water soluble for them to leave with the urine. The liver also makes bile and sends toxic items along with it to the intestine through the bile ducts. The bile enables calcium and fat to be absorbed. If the liver isn't getting much bile to the intestine, fat is left in the bowel contents and the feces will float in the toilet bowl. That is your clue to bile duct blockage.

Bile is bright green. Mixed with intestinal contents it turns the bowel movement dark brown. If the bile is not arriving in the intestine the bowel movement will stay light colored, even yellow or orange. This is another clue to bile duct blockage. Over a quart of bile should exit the body each day. Since bile is loaded with cholesterol this daily excretion of bile is a major method of keeping cholesterol levels low. If the bile ducts are choked with debris so only half as much (often only a cup instead of a quart!) bile is produced and excreted you can expect cholesterol levels to rise, and digestion to be bad. When food isn't promptly digested and absorbed the ever present, ever-ready bacteria will grab it for themselves.

Taking cholesterol-lowering drugs should be reserved for cases where natural excretion cannot be regained.

E. coli and other intestinal bacteria, which do no harm in moderate numbers, can overgrow in a few hours to give you bloating, gas and pain. Your body produces no gas. Only bacteria can produce gas. If your side pain is accompanied by bloating and gas, you know you have a digestive problem. And that this digestive problem stems from a congested liver if the pain is directly under it or over it, or if the feces are light colored or your cholesterol levels are high. Not everybody has all the symptoms.

To clear the clogged passages of the bile ducts, you simply do the liver cleanse (page 552) over and over until the problem is gone. There is one catch. If there are living parasites in the bile ducts, they will not let the bile ducts clear themselves. They are stuck fast to your ducts as a tick can be to your skin. They must be killed before they will let go. Zap them all, or you may use the herbal parasite program, staying on a twice a week maintenance program. Only after parasites are dead (after day 20 if using the herbal program) will you get a lot of “green stuff” and be able to clear “stones” out of your bile ducts. Only one large duct at a time will clean itself. We have hundreds of larger ducts and thousands of tiny ducts feeding into the larger ones! Stay on a schedule of cleansing the liver every two weeks (unless you are ill) until your side pain is gone, your digestion is normal, and you are bouncing with energy. You may also lose some weight, but only if you are overweight.

Remember that a clogged liver does not necessarily give you pain by itself. It is more likely the bacteria in the gall bladder and bile ducts, causing inflammation there and in your intestine, that cause pain. Don't wait till pain occurs over the liver. Use whatever clues you can to diagnose your clogged condition. Or just assume it is clogged. Do the cleanse, and see if you get any stones out. It can never hurt and can help a lot.

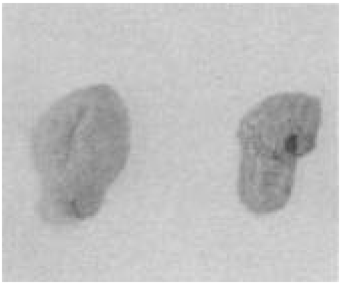

Fig. 23 Gallstones.

Bruce Hearn, 40ish, had severe side pain for several weeks and was rather gassy. He had seen a clinical doctor who found him in good health. But we found sheep liver flukes in the intestine and in the thymus! The thymus is an immunity-giving gland, so anything in the thymus is a very serious matter. He also had benzene in his thymus (inviting AIDS). He quickly switched from drinking soda to drinking milk. He went off everything in the benzene list. He killed the flukes electronically and started on the parasite program. Three weeks later the benzene was gone, his side was very much better and he could begin a kidney cleanse for his low back pain. He hadn't cleansed his liver yet! His improvement was probably due to improving his immunity which then controlled the bacteria.

Midabdomen Pain, Stomach Pain

The colon crosses over from your right side to the left side at the midabdomen. This is also the location for the bile duct to join your small intestine. Most midabdomen pain comes from either the colon or the bile duct connections. Kill parasites and bacteria by zapping or with the herbal recipe. Improve your digestion with diet clean up (off moldy food, boil dairy products). Sometimes the midabdomen pain stems from the stomach itself. The valves at the top and bottom of the stomach are meant to keep the food in. The valve at the top where the stomach joins the esophagus is a favorite location for bacteria.

You seldom feel them here though. This is just under your breastbone. They do their work quietly. Eventually, the tissue there is so weakened, the valve can't shut tightly and food is allowed to go back up the esophagus. This is called *reflux* and you may be told to sleep with your head elevated and to eat small meals, especially at bedtime. You may be given Reglan,^{TM} a drug to help empty the stomach faster. Digestive enzymes will help empty the stomach, too, but may harbor molds. The real solution is to kill the bacteria in this area and keep them from reinvading it. Start by killing the *Salmonellas* and *Campylobacters* (zap them).

Within a day or so, however, the area can be re-invaded. Some bacteria are coming from your teeth! Some come from the liver! Often both sources are supplying bacteria to the stomach. The stomach allows a little bile to enter at the end of each meal, this is normal. But if the bile is full of live parasite stages and bacteria they may try to colonize the stomach, too. If there is insufficient stomach acid to kill them or if there is an accumulation of toxin in the stomach, they will get a foothold. Then they can burrow down deep to escape acid. Eventually, an ulcer can develop.

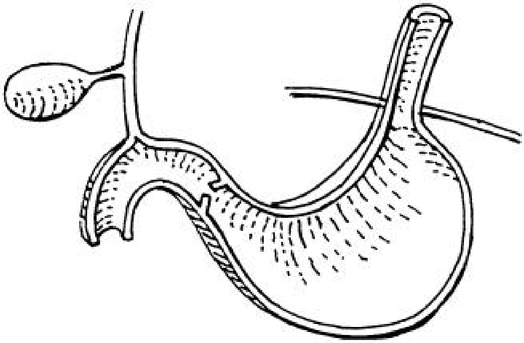

Fig. 24 Stomach, esophagus, diaphragm, gallbladder.

Stomach Ulcer

Often, such an ulcer is painless.

You are, therefore, not alerted to the parasites' presence until they have established themselves in good hiding places. Taking antacids, of course, works in their favor. The solution for both stomach pain and stomach ulcers is to kill parasites and bacteria, followed by dental and liver clean ups. One very common toxin that accumulates in the stomach is the pesticide **arsenic**. You inhale it right along with the flies and roaches you may be trying to kill with arsenic-laced pesticides.

Other inhaled toxins are fiberglass, asbestos, formaldehyde and freon. Your nose and mouth mucous traps a lot of these whereupon you swallow them and they glide into the stomach. Tooth bacteria and tooth metal get into the stomach the same way. You simply swallow them.

Clean up your air, don't use any pesticides (see other methods in *Recipes*). Your dentalware may be cleaned up in a few dental visits but the liver cleanses must go on for a year or two before it is reasonably clean. You may get pain relief in a few weeks but this should not derail your intention to revitalize yourself completely with a cleaned liver and stomach.

Hiatal Hernia

When bacteria have spread to the diaphragm and weakened it, along with the upper-stomach valve, food is allowed to get pushed up right through the diaphragm. Pressure in the abdomen from overeating or sitting in an easy chair pushes it up. Walk after eating. Empty the stomach before going to bed. Don't sit in recliners. Very many of us, about 25%, have a small hiatal hernia. It only hurts if it is inflamed. Work at clearing the inflammation first, to get pain relief. In time, the area will strengthen and the hernia itself may get smaller.

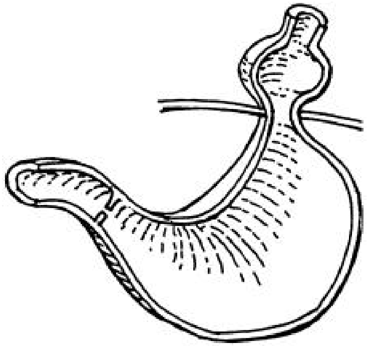

Fig. 25 Hiatal hernia.

Jeffy, 3½ months, had been screaming a lot ever since birth. He was very gassy. He could not be put down without starting to cry. He was congested and had colds. He was on mother's milk exclusively so his chronic *Salmonella* infection must have come from someone who was a carrier, possibly his mother, although she had no symptoms. The mother had platinum and tellurium in her milk (*Salmonella* can be transmitted in milk but this was not checked). The solution was to clean up the mother's milk by getting the dental metal out of her mouth, and washing hands before nursing. Jeffy's father had an *Ascaris* and intestinal fluke infestation. It is quite possible the baby had these also, giving him a nasty tummy ache in addition to the gas pains. The baby's older sister had screamed and cried the first nine months, too, so the parents were told it was a “familial thing.” She also had ear infections, colds and a flaky patch of skin occasionally. She, too, had *Ascaris*. They were very pleased to be able to clear up the whole family's problems by killing parasites and removing toxins.

Ruby Adair, age 14, filled a page with her symptoms. She was also chronically fatigued and had consumed enough antibiotic “to fill a room.” She had shooting pains from under her feet up her legs. A quick check revealed mercury and thallium in her immune system. Instead of being dismayed, this news filled her with hope for recovery. She arranged for dental metal replacement. Then she related her stomach “story”. While at a wedding, a year ago, she began vomiting with diarrhea. She thought it was the stomach “flu” but she didn't recover for six months and had to miss school. The psychologist thought it was emotional. She was still only attending school one hour a day. We found *Fasciolopsis*, the intestinal fluke, in her stomach wall as well as in her intestine. She started the parasite program and in three weeks her appetite was back, insomnia was gone, fatigue was better and a significant improvement was evident.

Respiratory Illness

Asthma

is a very old disease described in the ancient literature. The only progress we have made to date with this disease is to give drugs to soothe the symptoms.

Asthma is associated in **all** (100%) cases with tiny *Ascaris* larvae. As soon as eggs hatch (in the stomach, immediately after swallowing filth) the microscopic larvae travel to the lungs, not the intestines. Imagine the distress of lungs full of tiny worms! One tries to cough them up, of course, but in our misguided effort to be polite we teach children to swallow anything they cough up! Some swallowing is inevitable and the young worms are back in the stomach, this time to set up their housekeeping in the intestine. Some never leave the stomach, causing children stomach aches and, of course, a large entourage of bacteria which, in turn, have their viruses.

Most cases of *Ascaris* infestation also show *Bacteroides fragilis* bacteria which, in turn, carry the *Coxsackie* viruses (brain viruses). Whether or not these bacteria or viruses will thrive in you depends on whether you make a good home for them, namely have low immunity in some organ. The preferred organs for *Bacteroides* are liver and brain (brain tumors always show *Bacteroides*). The preferred organs for *Coxsackie* viruses appear to be tooth abscesses and brain.

Not everybody with *Ascaris* develops asthma, even though they always go through a lung stage. Does it depend on the age of the person when the infection develops? Or how many *Ascaris* are present? Or the time of year when lung infection is present?

That innocent cough of early childhood should not be neglected, as simply "croup." At the first sign of a cough, use a frequency generator set to 408 KHz, the frequency for *Ascaris*, or use a zapper. Pay extra attention to washing hands before meals. Pay extra attention to the animals nearby. Kill their *Ascaris* with a zapper and keep it up daily or put parasite killing herbs in their food.

Asthma sufferers become **allergic** to many air pollutants such as pollen, animal dander, smoke. The production of histamine in the lungs and the vast interconnectedness of histamine to allergies has been well studied scientifically. Although invasion by worms is known to result in both histamine production and high eosinophil counts (over 3), and **asthma clients typically have both**, they are not routinely checked for worms clinically! They are simply given drugs to enable better breathing. More and better (though toxic) drugs have been developed.

But you can put an end to your asthma by terminating your *Ascaris* infection. Then wash your hands and fingernails with grain alcohol, and let no more filth past your lips. Wear plastic gloves for a week to break a nail biting or finger sucking habit. For children wash hands before eating anything, even between meals; keep fingernails short.

Dogs, cats, pigs and horses all get *Ascaris*. Never, never let a child clean up any vomit or mess left by an animal. This could lead to massive infection, the kind that could result not only in asthma but **seizures**. Kill the worms in animal messes before you clean them up too. Never use your dustpan or broom. Use cardboard, newspaper or anything that you can afford to throw away with the mess. Squirt povidone iodine (available at drug stores) on the mess–even if it's outside–and cover with salt before cleaning up. Discard it in outside trash. Wash your hands with grain alcohol, paying special attention to fingernails. If you are a food preparer, you could infect the whole family if you don't wash carefully.

If there is an asthmatic in your family, the whole family should be treated for *Ascaris* with a zapper or with the herbal parasiticides. Even after everybody including the pets have been treated, pets should not be allowed in the bedroom of the asthmatic person. Asthma is more than parasitism. It is also an allergic reaction, to the pet and to other inhaled bits of matter.

Clean the air. Smoke of any kind, fragrance and chemicals of any kind, all household cleaners, polishes, and so forth should be removed. Store essentials in the garage, not the basement, since basement air rises. Clean up the whole house. Persons who must use hair spray or nail polish should do so outside in the summer and in their own rooms with the doors closed in winter. Use a chlorine filter for the water, especially at the shower. Install central air conditioning if possible, with maximum filtering (but never with chemicals added to the filter and never with a fiberglass filter) at the furnace. A room air filter (not fiberglass) is next best. Use it for an hour in the bedroom ahead of bedtime so the air currents can cease. Just moving dust around is worse than leaving it there. Never do dusting when an asthmatic is in the house. Lungs heal quickly when the air is clean and there is no reinfection. The best place to recover is outdoors away from trees and bushes or indoors with total pollution-free air conditioning (free of asbestos, formaldehyde, arsenic, fiberglass, pet dander).

As your asthma lessens, reduce your inhalers, but always keep them on hand. When you suddenly need them, try to identify your source of reinfection or allergens. Use this experience wisely. Try to understand the recurrence of your asthma. Keep notes. It may take half a year with a dozen recurrences to finally learn and conquer! It will feel great to breathe without spraying yourself and taking medicine. If it comes back a year later, figure out what is happening that's seasonal. A pine tree near the house, a flowering bush, the first mown grass? Stay away from these until you are completely healed.

There are traditional herbs for helping lungs. Grow your own **comfrey** and **garlic**. Make **mullein** tea from the dried herb (see *Sources*). Read herb books for more help. Dry some for winter use, being careful to do it right and not let it mold.

Suzanne Carlyle, 45, had asthma from infancy. She was currently on Albutesol™ spray and tablets daily. Now she was beginning to have arthritis too. She was given arginine to replace caffeine. She had two species of *Ascaris* and was allergic to cats and other animals. She was started on the herbal parasite program after killing *Ascaris*, *Bacteroides* and *Coxsackie* viruses with a frequency generator. Her lungs showed kerosene, carbon tetrachloride, mineral oil, benzalkonium (from udder wash, she was also milk sensitive), aluminum from her cookware, and aluminum silicate from her salt. She had two extra lung parasites: *Paragonimus*, a lung fluke, and *Pneumocystis*. She was immediately improved after cleaning up these sources and canceled her future appointment.

Cay Wenkert, 63, had asthma for many years for which she took Proventil™, but this gave her such bad side effects she had to stay home now and not venture out. Her lungs were full of benzalkonium (toothpaste), arsenic (ant poison under kitchen sink), zirconium (deodorant), and nickel from tooth metal. She had dog heartworm in her lungs(!), in addition to her heart where she sometimes felt pain. She had *Ascaris* and *Naegleria*, *mycoplasma*, *Endolimax* and the intestinal fluke in her lungs! She coughed up blood, after her doctor had diagnosed *bronchiestasis* recently, meaning her lungs were not capable of sweeping out the daily refuse we all breathe in. In spite of killing these and cleaning up her environment she got no improvement. She repeatedly got parasitized. She had four or five root canal teeth which she was unwilling to have pulled. Hopefully, the tradeoff between teeth and health will soon begin to look poor.

Amy Newberry, 41, had recently begun to have asthma attacks. She had been on cortisone but now was on inhalers through the day (two puffs Ventillin™ 3x/day, plus three puffs Intel™ 3x/day plus four puffs Asthmacort™ 3x/day). She was often hospitalized for attacks. She also had stomach trouble and sinus problems (had pneumonia recently). She had *Ascaris* larvae, *Endolimax*, *Naegleria* and *Acanthocephala* in her lungs! She also had arsenic and palladium (tooth metal). Going onto homeopathic medicine for stuffiness helped her avoid some hospital visits. It took several months (5 visits) to track her arsenic source to the bedroom carpets (stain resistance!). After steam cleaning it herself and doing a liver cleanse (after first killing parasites) she was amazed at her improvement. She had not been to the hospital in a month and was only using inhalers preventively. She planned to get dental work done. She got all her former health back.

Laura Brewster, 25, lived in a very old house. The slightest exertion would give her an asthma attack. She frequently got pneumonia, too. Her lungs had beryllium (coal oil) and asbestos, and two parasites, *Paragonimus* (lung fluke) and *Ascaris*. She got rid of all the old fashioned lamps and candles in the house, but could not find the source of asbestos. She got rid of the attacks but her cough and pneumonia bouts will continue until she moves from that house.

Brett Wilsey, 70, was congested most of the time, had chronic sinus problems, was getting allergy shots for dust and mold, and was on several inhalers for his asthma plus emphysema. He had asthma for eight years. He had oxalate, urate, and all three phosphate variety crystals in his kidneys. He was started on kidney herbs. His blood test showed high "total carbon dioxide" or "carbonate" showing that his air exchange was not good. His potassium was low, showing that his adrenals couldn't keep his electrolytes (sodium, potassium and chloride) regulated, in turn, giving him muscle weakness. His LDH was very high, showing that his heart muscle) was in distress, too. Fortunately, his RBC was slightly elevated, to help with oxygen delivery. (See Anemia page 285). His eosinophil count was high, as is the rule for asthmatics since they all have *Ascaris* worms. Besides *Ascaris* he had pancreatic and intestinal flukes in his lungs(!) plus *Heterakis* (a chicken roundworm), human hookworm, and *Prosthogonimus*, another fluke. He was started on the parasite herbs. Two weeks later he felt a lot better although he still had some *Ascaris*. He was toxic with barium and hafnium (which were traced to his dentures) nickel, tin, rhenium. He stopped using commercial "denture-soak." His wife stopped using hair spray and they started leaving the car out of the garage and walked around to the front door, instead of using the attached garage. He also started drinking homemade comfrey tea. This made him feel still better.

When he removed his watch he got rid of his nickel source. Nickel has an affinity for lungs (as well as prostate and skin). He was now down to one puff of inhaler instead of two, only four times a day instead of hourly. He could breathe deeper than before. Then the lead in his water was found and traced to a single "sweated" joint in the pipes. He was started on food grade hydrogen peroxide, working up a drop at a time; now his cough became "productive", he was coughing up a lot.

He got the plumbing fixed and did a liver cleanse after which his fatigue lifted. He couldn't stop laughing and joking about the "emphysema" he was so worried over earlier.

Bea Karnes, 49, had asthma from childhood when she also had eczema. She was presently on several medicines plus allergy shots and antibiotics for it. She was toxic with antimony although she used no eye makeup and europium, tantalum, and gadolinium from dental metal. She also had hand swelling in the morning and was started on kidney herbs. She killed her intestinal flukes (in the intestine) and *Ascaris* in her lungs and was not seen for half a year. When we eventually saw her, she said her asthma had been "wonderful." She was faithfully controlling parasites with the maintenance program and occasionally drinking kidney herb tea.

Cynthia Prout's whole family (mentioned previously) had asthma. She was told it was inherited. The three young children and herself were on inhalers, nose sprays, cough syrups and antibiotics. Nola, age 10, also had ear infections and numerous allergies. Lewis, age 8, was a slight, nervous boy; he had been off wheat and milk for many years due to intolerance. Irwin, age 5, seldom went with the family due to his frequent stomach aches and the fact he could vomit without notice. The mother and two children who were with her (Irwin stayed home) had *Ascaris* infection and Lewis also had pancreatic flukes. Their home was toxic with vanadium, namely, a gas leak. The parasites were quickly killed and gas leak repaired. The whole family got well and canceled their next appointment. Some inherited disease!

Asthma is just one of our common respiratory problems. The causes are always a combination of *Ascaris* and other parasites with pollutants (allergies).

Bronchitis, Croup, Chronic Cough

- In **bronchitis** the bronchioles are the site of the problem.
- In **croup** it's further down.
- In cases of **chronic little hacky coughs** it may be heartworm!

Bud Portillo, 62, worked on earth moving machines. He frequently had a "bronchial virus" or "bronchial infection." He was always coughing. He had *Ascaris* infestation and arsenic pollution in his home. He also had palladium toxicity from tooth fillings. As soon as they removed the mouse bait from their home, tore down the hallway wallpaper (arsenic source) and changed wells (the well water had arsenic in it from seepage!) and killed parasites, his cough was gone. He also finished his dental work. All this took six months.

Gene Mizell, age 4, was constantly clearing his throat. His parents wondered if it was a “nervous habit.” He had two species of *Ascaris* living inside his small body. He was started on a small dose of parasite herbs immediately, stirred into a daily dose of VMF syrup (see *Sources*). He also had PCBs, aluminum silicate, lutetium from recent painting in the house and xylene and toluene solvents. He was switched off soda pop and onto milk. We saw him five weeks later. He had gone through three treatments with vermifuge syrup. His throat clearing was gone, as well as his hacky cough and the blue circles around his eyes. He still had PCBs, which they later cleared by switching off detergent.

Carmen Castro, 30ish, had a chronic cough without being ill. She also had some heart irregularity. She had *Dirofilaria* (dog heartworm) and *Loa loa*. There were no indoor pets. After killing the parasites with a frequency generator and starting on the parasite herbs she was still coughing a bit but her pulse was down to 80 (from 120). She still had toluene, TC Ethylene solvents and mercury, platinum and lead in her body. Then a gas leak developed in their home. She used moth balls and painted a room. After this she had to be on antibiotics for her extreme cough. This time she had *mycoplasma*, *Haemophilus* and *influenza*. She killed these electronically and her coughing stopped. Until she gets the dental work done she will continue to pick up new infections.

Hope Feldman, 57, had been coughing for half a year. She had seen many doctors including a reflexologist. She had *mycoplasma* and *alpha strep* at tooth #17 (lower left wisdom tooth). As soon as these were killed with a frequency generator her cough stopped. She was advised to wear turtleneck sweaters for extra warmth over her bronchii and get a cavitation cleaned at tooth #17.

Teresa White, 37, had bronchitis several times each winter and was put on antibiotic for the whole season to keep it from breaking out. Her lungs were loaded with tantalum from dental metal, cobalt from detergent and thulium from her vitamin C. She had taken herself off milk, thinking it might be a factor, and used an air cleaner but without results. As soon as she had the tooth metal replaced with plastic (in less than a month) she could go off antibiotics and also was rid of a chronic sinus condition, but still had a bronchitis bout. She had *Ascaris* larvae in her lungs and phosphate and oxalate crystals in her kidneys. Her diet was changed to include milk and fish, magnesium, lysine (500 mg one a day), vitamin B_6 and a vitamin A+D capsule. She started on the kidney cleansing herbs and then the parasite program. In another month the whole problem was gone. Wisely, she got ready to cleanse her liver.

Craig Stewart, 2, had a history of respiratory problems. He had been on Ceclor™ and Ventilin™ for a long time; he had pneumonia the previous year. He had whip worm (*Trichuris*) infesting his intestine which was promptly killed with parasite herbs (as much as his parents could get down him was effective). He was toxic with asbestos. When the clothes dryer belt was changed to a U.S. variety (imported belts contain asbestos which flies into the air when the dryer is used), Craig's health turned around.

Doris Gumb, 26, was on Isoniazid™, Tussionex™ and Rifodin™ for tuberculosis. It started with coughing. She was down to 98 lb. in weight. Her lungs were toxic with beryllium (coal oil fuel), mercury, uranium, and tellurium. She began by clearing all toxic items from her house and basement and then bringing an air sample for testing. She also had *Ascaris* larvae in her lungs and pancreatic fluke in her pancreas. In three weeks she was coughing less and producing less with each cough. The “clean” air sample still had uranium, tellurium, mercury and beryllium. She had no metal tooth fillings, though. In the next three weeks she found a hole in the floor to the crawl space. It was letting up uranium dust and radon. The mercury was traced to the carpet in a child's bedroom. After throwing it out, her sputum cleared up and she was on the way to recovery, although we never found the source of tellurium.

Breast Pain

Although lumps and cancer in the breast produce no pain, they sometimes do give you little warning twinges. These twinges cross into the breast from the armpit or from any direction. It is gone in a second, leading one to believe it couldn't be serious. If the breast has any unusual sensations, painful or not, investigate immediately.

Test yourself for cancer. (You may use a specimen of mother's milk as a cancer test since this has mitotic stimulants in it—see Curing Cancer page 331). If you have purchased a slide of breast tissue (mammary gland) you can search your breast for cancer. If not, but you find “mother's milk” in your white blood cells, assume it is cancer and clear it up immediately.

If you don't have cancer, search for the pollutants giving you these twinges of pain. Search for your deodorant, cosmetics, and soap in your white blood cells. Search for dental metal. The breasts are often full of nickel. Nickel is quite soluble in fat and the breast is mainly fat. Nickel is one of the top carcinogens listed by researchers. It could even explain the high incidence of breast cancer. But titanium and barium from cosmetics, as well as asbestos and fiberglass are also quickly accumulated in the breast. Clean up your dentalware and body products. Check for exposed fiberglass. Change your dryer belt. Buy a new non-CFC refrigerator. Never try to get rid of these pains with pain killers; let the pains show you whether the clean up has been complete.

Breast Sensitivity

Breast sensitivity can be quite uncomfortable to the point of not being able to wear a bra, especially near period time. It may be due to high estrogen levels; this is also conducive to breast lumps and breast cancer. Most of your estrogen is produced by the ovaries before menopause and later by the adrenal glands. Too high estrogen levels plague the modern woman. Certain food molds, particularly **zearalenone**, causes over-estrogenization. It affects men too. I have found it in popcorn and corn chips! And brown rice. Stop eating these. Eat white rice. If you make cooked cereals be sure to add vitamin C to them before cooking (1/8 tsp. per cup), to detoxify food molds. I do not know whether taking vitamin C with your popcorn would detoxify zearalenone. Don't risk it. The excess estrogen compounds must be detoxified by the liver. Yet, the liver may be incapable of this because you ate yet another food mold! See the section on moldy food (page 381).

Over-estrogenized women are over-emotional, seemingly on a roller coaster of enthusiasm and despondence. They can develop a high pitched voice, that almost sounds squeaky. High enough estrogen levels are important for fertility but too high levels can cause infertility. Your body is eager to set the level just right, if only you will clean up the ovaries of parasites and pollution. Don't stop your clean up until the breast feels normal again throughout your cycle and you don't feel over-emotional, even just before your period.

Breast Lumps

Breast lumps may or may not be painful. If you feel one, don't wait to be more certain, don't wait to analyze it with tests, don't wait for a doctor's diagnosis or a mammogram. Obtain a frequency generator or zapper and zap yourself immediately. Also do the herbal parasite program immediately (page 338).

Your body often turns the breast into a collecting station for toxic wastes that have been drawn downward from the top of your body. From your head where shampoo and hair spray and cosmetics leave their daily deposits, from your dentalware with its constant supply of heavy metals, from neck and armpits where cologne, deodorant and soap leave their toxic residues. The lymph nodes under the armpit and the region above the breast, collect it all and let it slip into the breast where it is bundled up in a cyst. Perhaps the kidneys are clogged so toxins are forced to go to a designated dump site instead of out through the bladder. Do a kidney cleanse. Don't rest until all your breast lumps are gone. They will begin to shrink in three weeks if you are removing the correct toxins. Even radon and asbestos go to the breast, so be meticulous with your cleanup.

When the platelet count (in a blood test) is very high (over 400) there is quite a tendency to form cysts or lumps since platelets make your blood clot. The platelet count goes up when parasites are present. Maybe your blood is attempting to clot them! These clots make “nests” for fluke stages which may be why breast lumps often become cancerous. If yours is over 300, (it should be 250,000/cu mm) start patrolling parasites regularly. Stopping the use of caffeine and taking vitamin E (400 u. a day) are helpful in recovery but don't rely on these minor measures. Breast lumps definitely invite breast cancer.

Leslie Yeager, age 37, had breast soreness and "fibrocystic lumps”. She had cerium and nickel accumulated in her breasts. They cleared up in weeks after her dental metal was gone (she simply took out her retainer). Later she replaced it with a partial made of plastic.

Kari Pfeifer, age 36, had numerous cysts in both breasts and uterus. Her estrogen level was too high (187 pg/ml on day 22 of her cycle; the day of testing is important since it varies through the cycle). Her breasts were full of beryllium (coal oil from hurricane lamps) and radon. After these toxins were removed, all her breast lumps got smaller. After she did the kidney and Liver Cleanse, the lumps got softer and breasts were no longer painful. She had several root canals which filled her breasts with numerous bacteria, mainly *Histoplasma cap* (root canals develop infection around themselves). After starting her dental cleanup and killing bacteria with a frequency generator, all her breast lumps disappeared.

Claudia Davis, age 41, had breast soreness ever since a mammogram two years earlier. She had numerous other pains and indigestion. She had intestinal flukes in her intestine and fluke eggs in her blood: a dangerous situation. They might land in the breasts and start developing there. This is how cancer begins. But she did not have cancer yet. She had a buildup of niobium from polluted pain killer drugs and thulium from her vitamin C. She had *Salmonella* and several other bacteria in her white blood cells, which accounted for digestive problems. In eight weeks she had cleaned kidneys, killed parasites and gotten rid of her heavy metals. Her breast pain was better and a lump on her eyelid had also disappeared.

Stephanie Nakamura, 68, had six surgeries to remove breast lumps, going back to youth. Her recent mammogram was O.K. Her breasts were toxic with cadmium, lead, gold, radon, uranium, gallium, silver. Our tests showed she had kidney crystals and she was started on the kidney cleanse. She was given vitamin E, (400 units daily), sodium selenite (150 mcg daily) and vitamin C (1 or more grams daily). Her triglycerides were also very high showing again that she had kidney problems. She was given magnesium (300 mg daily), vitamin B_6 (250 mg daily) and lysine (500 mg daily). She killed parasites and cleaned up everything except gallium, silver, mercury, gold, cadmium. These must have come from her gold crowns. Her dentist advised against removing these and proclaimed they had nothing to do with her developing glaucoma, arthritis and stomach ulcers. It was a tough decision for her and she made the wrong choice. Perhaps if she had been up for the next breast surgery she would have gotten those “gold” crowns replaced with composite too.

Heart Pain

Pain over the heart region is usually quite real, even though an EKG does not find any abnormality. The most common cause is *Dirofilaria*, heartworm of dogs. It often begins as a pain just above the heart but spreads itself over the whole heart region. Kill it with your zapper. Parasite herbs can also be effective. If you did kill them, the pain often intensifies for a day before it leaves. Then the pain should be completely gone.

Heartworm is very easy to pick up again. If you have had heartworm, you should no longer keep a dog for a pet. Give it away.

Another heart parasite, *Loa loa*, is also a filarial worm and may be the causative factor. Both *Dirofilaria* and *Loa loa* can be obtained as slide specimens to use for testing yourself. Heart muscle can also be obtained as a slide specimen, but a chicken heart from the grocery store or snippets of beef heart (make sure to sample all 4 chambers) will do.

Follow up on your heart, even when no pain remains. These tiny heart parasites have stages that you may not be able to purchase in slide form and therefore can't test for. These stages, if not killed, will become adults so a maintenance parasite killing program, herbal or electronic, is essential. Virtually all dogs have *Dirofilaria* in spite of monthly medicine to kill it. They pick it up immediately after their last treatment for it and can give it to you again. The only way to live safely with pets is to give them parasite killing herbs daily in the feed.

Other heart problems such as irregular beat and mitral valve prolapse can clear up along with the pain. Or they may be due to bacteria (see Heart Disease, page 318).

Meredith Zackman, age 53, came for her diagnosed cardiomyopathy (heart disease). She owned a beautiful, old, very big dog, and of course she would never part from him. We knew she would lose her battle against heart disease. She had both *Dirofilaria* and *Loa loa* which we killed instantly with a frequency generator. She was on Lanoxin™, Furosemide™, Captopril™ and Metoprolol.™ We found she also had *Cytomegalovirus*, *Staphylococcus aureus*, *Streptococcus pneumonia* in her heart. The *Staph* bugs were also in tooth #17. She had copper in her heart (from tooth fillings) and cobalt and PCB from her detergent. There was zirconium from her deodorant and fiberglass from somewhere. Her pulse was typically in the 90's. Eight days later, after her dental work to replace metal was done her pulse was normal (low 70's), both worms were gone and she felt much better. But she still carried four bacteria, five viruses and two tapeworm stages: *Taenia solium* scolex in the spleen (she had chronic pain there) and *Taenia pisiformis* in the liver. She was started on Rascal (an herbal combination) for these. Six days later she had all of her problems back including *Loa loa*. She repeated everything, then she had to go off her heart medications because they lowered her blood pressure and pulse too much. She started the dog on the parasite program but continued to be heavily laden with parasites and bacteria that always found their way to her heart. She purchased her own frequency generator and was quite faithful with dog treatments. She may outlive her dog and then regain her health, finally.

Bruce Walby, age 42, had chest pain for three years. We found he had *Dirofilaria* and *Loa loa* in all four chambers of his heart. When he zapped them, the pain left a day or so later.

D'Ann Fonties, age 22, had a lot of chest pain but was told by her doctor it was simply “gas bubbles”. She also had a serious digestion problem. She had *Dirofilaria*, high levels of styrene (from styrofoam drinking cups) and benzene. This information delighted her and she planned to change her habits.

Sheila Osborn, age 27, had chest pain when she lifted objects. Her pulse was slightly elevated (81) and slightly irregular. She had *Dirofilaria*. Five weeks after starting the parasite program she was feeling much better but still had the chest pain. This time she had *Loa loa* (but not *Dirofilaria*).

Wendy Lewellen, age 28, had a chronic cough and chest pain at midsternum (the sternum is the bone attached to the ribs and runs up the middle of the chest). She had *Dirofilaria* in one chamber of her heart (right auricle). She had xylene and toluene solvents which came from her daily beverage, Mountain Dew.™ She was also full of asbestos from her trips to do laundry nearby (this could not be proved, but when she switched laundromats, the asbestos went away). Two months later, after killing parasites, she was free of heartworm and her cough and chest pain were almost gone. She was probably healing very slowly due to the asbestos which was still present.

Lupita Cline, a young mother, had a chronic hacky cough and irregular heart beat. She had *Dirofilaria* in all chambers of her heart and *Loa loa* in her blood but not in her heart. She had carbon tetrachloride, propyl alcohol, hexanedione, toluene, and TC Ethylene buildup from drinking Pepsi™ and Mountain Dew.™ Her pulse was slightly elevated at 80. There were no pets in the house. She was started on the parasite program and two months later was rid of her heartworm but now had *Loa loa* in her heart and was still coughing a bit. She was full of platinum, mercury and palladium from tooth metal as well as vanadium from a gas leak in her home and paradichlorobenzene from using moth balls. She was on antibiotics for a “bronchial infection” and was happy to learn about a better solution.

Slow Pulse/Syncope (Passing Out)

Mason Heckler, 30s, was a mechanic by trade and could not afford to pass out on the job. Yet, it had been happening off and on for 10 years. He had acquired high blood pressure in his teens! This was soon followed by an extremely slow pulse (50 beats/mm). No medicine worked (he had been tried on many) so he was on none. Then he got high blood pressure, it was 160/80 currently. He also had constant chest pain around the left nipple. He had heartworm and was started on the herbal parasite program. He never had a dog. In five weeks his pulse was 72; the parasite was gone. I presume his syncopes were due to sudden blood pressure changes or missing a few heart beats in a row. He began the kidney cleanse next to lower his blood pressure.

Chest Pain

When there is a tightness or just a little pain at the middle of the chest, especially under the breastbone, you may be merely having an allergic reaction. You might be feeling little spasms coming from the esophagus, and reaching up toward the throat from gallstones. You might also have HIV/AIDS disease which has a similar symptom over the sternum. So it is very important to pay attention to even a minor symptom in the chest.

Ruling out HIV disease ranks first in importance. Search for its emission at 365 KHz, or purchase a microscope slide with the dead virus on it as a test specimen (see *Sources*). Or purchase a set of slides representing all the stages of *Fasciolopsis buskii*. Without this parasite you can't get the HIV virus. Purchase a slide of the thymus gland or make your own specimen of throat sweetbreads. Check yourself for benzene buildup in the thymus. (See Using The Syncrometer page 462.)

If you have neither the benzene nor the parasite stages, you have no risk. Your chest distress is due to something else. Improve your air quality so that your lungs are not in distress. This includes radon, chlorine (from the bleach bottle under the sink), colognes, room fresheners as well as the usual pollutants (asbestos, arsenic, formaldehyde, fiberglass, freon).

If you feel waves of pain reaching up to your throat, you probably have a gallstone stuck in a bile duct. Epsom salts can relax that bile duct in 20 minutes. Take a tablespoon in ¾ cup water but only on an empty stomach or you may feel quite ill. Taking a large dose of valerian herb (6 to 8 capsules) may also buy you a little time by relaxing the duct. If you do get relief, you can be sure it was a spasm of some kind. The magnesium in Epsom salts relaxes spasms. I would recommend cleaning the liver (page 552) a number of times to try to dislodge the sticking gallstone. The instructions for liver cleansing advise you to kill parasites and cleanse the kidneys first. But if your throat pain is severe enough, you might just zap and go ahead with it at once.

Upper Back Pain

The main pain may be a dull ache over a shoulder blade, or between the shoulder blades or running right through you from the front to the back of the chest. These are all gallstone pains coming from the liver! Get yourself ready to clean them out. Clean the kidneys first, kill all the parasites that might be residing in the bile ducts and blocking them (flukes, pinworms and roundworms) and get onto a maintenance parasite program. Then mark your calendar for your first liver cleanse. Even if your first cleanse gives you only a dozen bits of green "stuff" you have done well; you have accessed the bile ducts. The pains will probably be "magically" gone the next day, but they might start to return in two days. The bile ducts are having spasms again due to the remaining stones.

After you have cleaned out 1,000 or more, you will get permanent relief. Repeat every two weeks, unless ill, until the upper back pains are gone, permanently. If chest pain or upper back pain is severe, try going off your favorite high fat food (ice cream, butter, cheese). Also try taking 6 valerian capsules, 4 times a day including bedtime to relieve the spasms.

Shoulder Pain

Some shoulder pain is called *bursitis* and some is called *arthritis*. But it always derives from stuck gallstones in the bile ducts of the liver! You can prove this by taking a tablespoon of Epsom salts in ¾cup water at 6 p.m. instead of supper and on an empty stomach (or you may feel quite ill). If some of the pain subsides then you have evidence as to its true cause, because Epsom salts relax the bile duct valves.

Get started cleaning the liver (page 552). By the time you have chronic or acute shoulder pain you have about 3,000 Stones! Count them roughly, as they float in the toilet after the liver cleanse so you know how much progress you have made toward the final goal. Don't start cleaning the liver until you have killed parasites and spent three weeks cleaning the kidneys though. This improves elimination of liquid toxins so a liver cleanse is promptly cleaned up for you.

What emerges from the liver is the most contaminated mess imaginable, full of bacteria and viruses and parasite eggs and stages (all dead we hope) of every kind. It needs prompt clearing from your body. The diarrhea sees to the bowel elimination. But some toxins can only pass through the kidneys. Kidneys should be clean and capable of doing the job. Remember it is unwise to clean the liver before all parasites are dead, especially flukes, because they produce a substance that inhibits any action of the bile ducts!

You are only one day away from freedom of shoulder motion and sleeping on your side again. Permanent improvement, though, depends on progress with your total stone count. Your bursitis can return in a few days or a few weeks. Be patient. You may only cleanse once in two weeks, and not if you are ill. After six cleanses you can be quite sure of being relatively pain free.

Between cleanses use valerian capsules to stop the spasms. It takes 6 capsules 4 times a day to be effective.

Typically only some bile ducts are spasming, and typically those ducts have a single fatty food trigger. Stop eating the high fat food you consume the most (it's probably your favorite). If that hasn't helped in two days choose a different high fat food to omit. The most common culprits are ice cream, potato chips, salad dressings, cheese, butter, cream, and milk.

Perhaps the pain is actually caused by bacteria living in the blocked bile ducts and invading the shoulder. This point has not been clarified. Using your zapper or frequency generator does no good for this pain. Only liver cleaning brings your shoulders back to their youthful mobility.

Upper Arm Pain

Excruciating pain in the upper arm soft tissues can keep your arm hanging straight down for fear of worsening it with motion.

Magnets of high strength (2x5000 gauss) taped to your arm, under your sleeve, can get you through the day. Also try valerian capsules (6 capsules four times a day). Go off all fat in the diet to let the spasm subside. Then start your liver cleanse at 6 p.m. If you used pain killer drugs during the day, the cleanse may not yield anything but it's worth a try anyway. You might be lucky and pop out the chief culprit stone. If not, you should wait several days before trying again; this time avoid pain killers the day of the cleanse. Be sure to zap parasites the day before or earlier.

Peggy Patton, age 60, had shoulder pain and painful feet in addition to aching all over. The aching was due to *Trichinella* which both she and her husband had. It took six months on the parasite program before it stayed away. She had clay colored stools, evidence of bile duct blockage. Then two liver cleanses cured her shoulder pain, nausea and remaining pains. She started gardening again and immediately picked up hookworms and *Trichinella* again. But she learned to sanitize her hands with grain alcohol after washing away dirt and this kept her parasites in check.

Jessica Atkinson, a middle age school teacher, developed a pain in the right cheek quite suddenly. She also had pain over the right mid abdomen and right side at the waist but X-rays and scans showed nothing (she had been X-rayed three times). She struggled for seven years to stay employed. She was having severe pain attacks over the liver and described her stool as almost white after these attacks. She cleaned her liver at least 30 times before she related, one day, that her joy in living had returned. Her gallstones were exceptionally large (½ x ¾ inch). Eventually the abscesses in her upper teeth were found, clearing up her cheek pain and protecting the liver from recurrent infections from these bacteria. Only then did she get permanent and complete pain relief.

Lisa Mattie, 72, had her right arm hanging limply by her side. It was so painful she bent forward to let it hang straight down. But in seven months she had done 6 liver cleanses, getting over 3,000 stones out. All pain was gone although some numbness in that arm persisted. She could also stop using Tums™, stop coughing, and no longer was bothered by her hiatal hernia.

Elbow Pain

One variety of elbow pain is due to an inflamed tendon there; it is sometimes called “tennis elbow.” It is not due to playing tennis or any other arm use. The inflammation is caused by a liver full of stones and parasites, especially flukes which manufacture a chemical that affects tendons. Kill all flukes and cleanse the liver for quick relief. Using your elbows while they are inflamed is traumatic to them, like working with a sore thumb. Don't play tennis or do other arm exercises until they are pain free.

Parasites consume large amounts of your vitamins and minerals. Give yourself vitamin A (25,000 u daily), zinc (60 mg. daily), and B_6 (250 mg twice a day) until the pain is gone.

Wrist Pain

Tendons passing through the wrist can become inflamed from the unnatural chemicals produced by fluke parasites in the liver. Using the wrists to work further traumatizes them (injures them) making it harder for them to heal. A small hole between the tendons lets the nerve and blood vessels through into the hand. Fluke parasites also make chemicals that thicken tendons. When tendons at the wrist thicken, they can squeeze down on the nerves and blood vessels until the hand or fingers feel numb. If you have pain at the wrist or numbness in your hands, killing parasites and cleaning the liver may give you the permanent cure. Wearing a wrist bandage or support can help reduce trauma damage to the wrist while it is healing.

Numbness of hands, without wrist pain, is more often due to a brain problem with parasites and pollutants. Lead, mercury, fluke parasites are the usual culprits.

Thumb Pain and Hand Pain

can be due to liver parasites. Get yourself ready for a liver cleanse. If the pain goes away beforehand, while you are on the kidney cleanse, it shows you had deposits in your joints. You were headed for arthritis in your hands. Read the information on arthritis (page 78) to protect yourself.

Finger Pain

This is pain in a joint, often accompanied by some enlargement or knobbyness of the joint. It is not hard to recognize these as deposits of the same kind as we saw in the toes. You can test yourself to identify the variety. **Uric acid** and **phosphates** are the commonest types. Read the section on toe pain (page 55) for detailed instructions. You can greatly reduce your finger joint deposits and the size of the knobs. In six weeks after starting the kidney cleanse and changing your diet, the knobs may already be shrinking. A large magnet (5000 gauss—used only as directed) may bring pain relief but only dental cleanup and environmental cleanup will give you lasting improvement.

Back Of Neck Pain

The back sides of the neck seem to be highways that run between the teeth and liver. Both contribute to pain at the back of the neck. Pulling an infected tooth or cleaning a cavitation can bring complete relief, only to return the next time a tooth is extracted. Extractions should be followed by cleaning out the cavity created so an infection can't start here. Cleaning the liver can also bring immediate relief, only to find pain and stiffness to return months later. You must cleanse many times for permanent relief.

An allergic reaction to potatoes and tomatoes can express itself in neck pain too. When the liver can no longer detoxify the chemicals (solanine, etc.) in this food family they are free to roam the body with the circulation. Perhaps they prefer to attach themselves at a particular neck site and cause inflammation here. Perhaps an injury was already there, beforehand. Whiplash is often blamed for back-neck pain and indeed chiropractic adjustments can bring total relief. Perhaps the trauma of whiplash first invited all of these contributors. Merely killing bacteria with a zapper is not long lasting. But dental cleanup plus liver cleansing is.

Front Neck Pain

Lymph nodes under the jaw strain your body fluids of the head, removing bacteria and toxins. They are sometimes called “neck glands.” If the stream of bacteria is endless such as when they are coming from a hidden tooth infection, the lymph nodes will enlarge to do a better job. They will also try to remove toxic metals, mouthwash, and toothpaste for you.

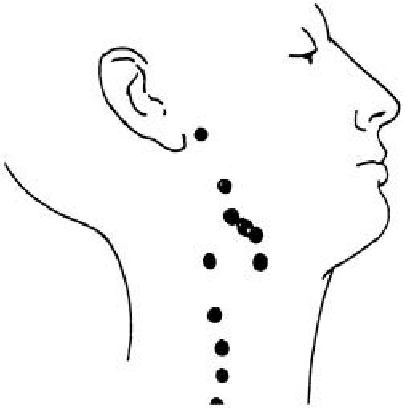

Fig. 26 Lymph node neck glands

To see what is affecting your lymph nodes, purchase a slide of lymph nodes. Since we have lymph nodes in many locations in the body, you can't single out the neck nodes for study. So you will get to see all the toxins affecting lymph nodes everywhere: PCBs in your underwear being removed by groin lymph nodes, lead in your intestinal lymph nodes from the water you are drinking, mercury in your neck lymph nodes from amalgam fillings. Eliminate all these. Don't rest as long as any of your glands are enlarged.

Roland Sanford, 23, had minor pain and a lot of stiffness along the sides of his neck. His arms had some numbness. He only had one metal tooth filling but his whole body was toxic with samarium, beryllium, indium, copper, cesium, and mercury. When it was replaced, his neck pain and numbness got better.

Audrey Doyle had severe neck pains she attributed to sitting all day and sleeping in her wheelchair. She had to take pain killers to get to sleep at night because they were so bad. She knew eating cream and butter made it worse but she had no will power, she said. After a liver cleanse, getting “thousands” of tiny stones, she was free of it.. for one day! But it was enough to convince her and she was determined to be off pain killers.

Temporal Mandibular Joint (TMJ) Problems

Pain at the angle of your jaw is not due to a poorly fitting joint. It fits perfectly but the muscles nearby are pulling it out of joint with their frequent spasms. There is always a hidden tooth infection present. Ask the dentist to search for hidden tooth infections and to clean your cavitations (you will need to find an alternative dentist, and read Dental Cleanup, page 409). Begin immediately to heal these bone lesions with vitamin D (40,000 to 50,000 units once a day for 3 weeks, followed by 2 such doses per week forever), milk-consumption for calcium, and a magnesium oxide tablet. (See bone healing, page 87).

Kill pinworms with a zapper or frequency generator in yourself and family members twice a week and keep everyone's fingernails short for extra hygiene in the family for a month to prevent reinfection. Pinworms can cause tooth grinding and contribute to TMJ dysfunction. For extra muscle relaxation, take two magnesium tablets at bedtime and valerian capsules.

Tooth Ache

Before the pain becomes acute and excruciating, kill bacteria of the mouth, including “tooth decay” and “tooth plaque” frequencies (see frequency list, page 561). Make your dental appointment immediately. If zapping bacteria several times in a few hours relieves pain enough to get you through the night or past the weekend, do not delay a single day. Zapping does not reach into the middle of an abscess—it circles around, so some bacteria are left to repopulate.

Try to understand the problem. If there are teeth with root canals near the location of pain, extract them. The toxic materials of the root canal jeopardize your total body health. Removing them always helps and may let the jaw heal normally where they were extracted. Since the pain is caused by a bulging infection pressing on a jaw nerve, and because each tooth has a related organ(s) it is especially important to clear up all infections to protect these organs.

These relationships are not understood yet. Finding that teeth have the same tissue frequency as some distant organ sheds a little light on the situation. Until the meaning and function of these frequencies is understood we can only guess that they interact somehow. Bacteria have taken advantage of this common resonance and have invaded both organs.

Heart infection by *Staphylococcus aureus* is an example. It is a common heart bacterium, causing much of our heart ailments, particularly mitral valve disease and irregularity problems. They always derive from teeth, whether present or missing! After wisdom teeth are extracted, the hole left in the jaw frequently does not heal, it picks up *Staphylococcus aureus* from the mouth and a chronic infection is started. For this reason it seems ill advised to pull wisdom teeth if it isn't necessary.

Another heart bacterium, *Nocardia*, can originate in the teeth. *Nocardia* can also invade the brain and nerves. Persons with Parkinson's disease always harbor quite a population of *Nocardia*. Zap all these bacteria before and after your dental visits. Remember that killing bacteria in itself is not a panacea. Pain and body damage will return unless you do the proper repair and cleanup work.

Throat Pain

Recurring sore throats are always improved by removing dental metal and root canals, and by cleaning up hidden tooth infections. This is essential for a permanent solution. Bacteria and viruses that cause sore throats are thriving in hiding places under and around dental metal. It is quite difficult to reach the center of such places (abscesses) with electric currents. Even if you could, you would reinfect the very next time you ate non-sterile food! Zapping is not a substitute for cleaning up your dentalware.

Keep your neck warmer than would be perfectly comfortable, gargle with hot water to bring in extra circulation. Use zinc tablets (60 mg. see *Sources*) twice a day; suck on them before swallowing. After cleaning up dentalware you may never have another sore throat!

Children with recurrent sore throats usually do not have a dental problem. They invariably have an air pollution problem. Asbestos, formaldehyde, fiberglass, Freon and arsenic are the chief culprits. Clean these out of the house. Eating moldy food is especially conducive to respiratory illness. The immunity drop can last for weeks! Go off the moldy suspects to raise your family's resistance.

Eye Pain

is caused by parasites.

The eye is a favorite location for many parasites, including *Giardia, amoebas, hookworm, schistosomes, Toxoplasma*, and innumerable others. The eye has two large bodies of watery fluid: the *aqueous humor* and *vitreous humor*, where no blood traverses to bring in extra white blood cells when the need arises. It has its own protective devices, like tears, but some parasites, like *Toxoplasma*, have overcome all the body's

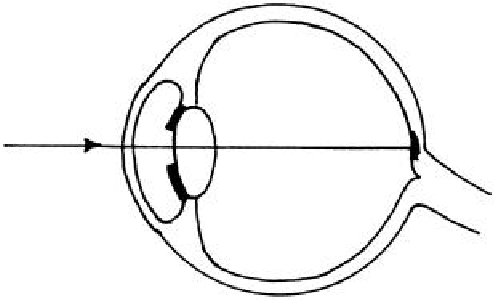

Light travels through the cornea, through the aqueous liquid, the lens, and then the vast vitreous humor, finally striking the super sensitive spot on the retina, called the macula.

Fig. 27 Eye.

defenses and regularly invade the eye if they get into the body somewhere.

We get *Toxoplasma* from cats; the infectious stage is in cat feces.

Toxoplasma infection could be the beginning of a lifetime of eye disease due to weakening of the eyes at an early age. *Toxoplasma* also invades the brain, frequently causing a dull ache or pressure at the back of the head. *Trichinella* is another common eye parasite, invading the eye muscles, so that a muscle is weakened and doesn't allow perfect alignment of the two eyes. Dogs and cats are the source of these.

**There should never be a cat box in the house.
Never let a child near a cat box.**

By killing all the large parasites plus a few bacteria (*Staphylococci*, *Chlamydias*, *Neisserias*) the eye can become pain free in a few days. If pain returns, you missed something or reinfected yourself. Everyone in the family including pets needs to be treated for all the parasites. No indoor pets should be kept by a person of low immunity, since infecting yourself daily and then killing parasites daily is not a solution.

Herpes of the eye is not a single actor. The true host of this virus is a larger parasite, possibly a tapeworm stage. Tapeworm stages should be killed with an herbal preparation, Rascal, or with a zapper. (Not with a frequency generator. Only a zapper can kill all the segments and eggs at once, leaving nothing alive to wander about and find a new tissue to invade.)

Mary Rauch, age 60, filled a page with different pains and problems. Even her eyes had a dull ache around and behind them, sometimes reaching to the back of the head. Her teeth hurt when she ate and she had been getting B_{12} shots once a week for 36 years for pernicious anemia. She was full of *Ascaris*, amoebas and pinworms which kept her legs twitching and jerking in bed at night, even waking her up. She was so much better after the kidney cleanse and parasite program she was eager to cleanse her liver. Before two months had passed her eye pain was gone.

Jessie Healy, middle aged and in good health otherwise, had carried the anxiety of having inherited *retinitis pigmentosa* for forty years. Now her drivers' license was in jeopardy due to fast progression of her disease. Numerous heavy metals had accumulated in her retina, including cerium from dental floss, arsenic from pesticide, tin from health food brand deodorant, PCB from skin salve, cobalt from dish detergent and indium from tooth metal. She had eight parasites in the retina including *Toxoplasma* from association with cats years ago. Removal of dental metal alone arrested the disease process. Two years later she was slightly improved and still driving her car.

Macular Degeneration

Dolores Bollapragada, 50ish, had suffered from clinical ergot poisoning in the past which put her in a coma for several weeks. Ergot is a grain (especially rye) fungus, very toxic to the liver. Its byproducts are used in migraine medicine. She had overdosed, somehow. Perhaps her liver never recovered. It no longer detoxified solvents for her, allowing them to accumulate in her retina. There she had propyl alcohol, benzene, carbon tetrachloride acetone, butyl nitrite, styrene, gasoline, wood alcohol, paradichlorobenzene (moth balls), pentane, methylene chloride and decane. She stopped snacking on cold cereal through the day. She had many habits and products to change. But she was determined to salvage her sight. She did.

Headache and Migraines

Headaches can take the joy out of living. They can lower your motivation level so low that you don't even want to do anything about them! People with daily headache deserve our deepest sympathy since they must carry on with life's daily duties in spite of it. Often, no medicine helps. Although there are common headaches, sinus headaches, migraines, and others, the causes of all overlap a great deal.

Tooth infection, urinary tract infection, bowel problems, and a wormlet, *Strongyloides* are the common causes.

There are also allergic connections which include milk, eggs, citrus and salty foods. But the allergy-approach is difficult to put into practice. It is almost impossible to stay off these foods for long time periods. Eliminating bacteria and *Strongyloides* leads to a permanent solution.

Possibly the parasite wormlet comes first, since even young children can suffer with migraines. *Strongyloides* is a microscopically small threadworm that horses are plagued with, but humans and our pets pick it up easily. Every migraine sufferer (100%) has high levels of this tiny worm. Perhaps it is really the special bacteria it brings with it that cause the blood vessels to seep or to spasm in the brain, causing pain. Zap it immediately.

Bacteria hidden under a tooth filling or root canal or in a space where once a tooth was pulled can be the cause. *Staphylococcus aureus* is a favorite, but various *Clostridia*, *Streps* and others are often seen, too. You don't feel pain from this small abscess because the pressure isn't building up inside it. It has found a way into your body–namely, your brain!–so no pressure builds up to alert you. Find an alternative dentist with experience cleaning cavitations and finding small hidden abscesses. If you get immediate relief from dental work, only to lose ground again later, the abscess may have formed again (they are notorious for forming again). Go back to the dentist. Irrigate the dental wound site with white iodine (potassium iodide, 12 drops) or Lugol’s (6 drops) to ¼ cup water using a curved-tip syringe.

Do not use iodine if you know you are allergic to it.

The colon is always a thriving mass of bacteria. It should be emptied at least twice a day to keep their levels down. Use the simple herb, *Cascara sagrada*, senna tea, or magnesium oxide tablets (2 to 3 a day) to help you eliminate frequently if your own regularity is lacking.

Gallstones in the liver and a congested liver are sources of bacteria, too. Do several liver cleanses and note the effect.

Is it the toxins made by bacteria or the inflammation from the bacteria or wormlets themselves that produces the headache? Certainly, one can eat the toxins by themselves in foods like yogurt, cheese, wine, sour cream and develop "royal" headaches. Stay away from these **tyramine** containing foods. Boil all your dairy foods to prevent *Salmonellas* and *Shigellas* from swimming into your beleaguered brain. Don't eat dairy foods that can't be boiled for ten seconds.

Begin by killing all *Strongyloides* and other parasites, bacteria and viruses with a zapper. Hopefully, this will only leave a few stragglers behind in abscesses, gallstones and the colon contents. If the colon bacterium, *E. coli*, is your headache cause, start the Bowel Program. Search for the source of your *E. coli* in food or polluted water. Stop reusing water bottles. Most people get their *Strongyloides* back in a few days from pets, other family members, and themselves! Zap every day for three weeks. Try to "clean up" family members and pets. Never let a horse or pet salivate on you. Never put your fingers in your mouth. Always sanitize your hands with grain alcohol after using the bathroom.

To summarize the steps to cure migraine headaches:

1. Kill *Strongyloides* and bacteria by zapping.
2. Do the herbal kidney cleanse.
3. Clean up dentalware.
4. Do the Bowel Program.

5. Boil all dairy foods.
6. Do liver cleanses.

This has never failed to substantially reduce migraine intensity and frequency.

Headaches are also caused by toxins in your environment; especially things you breathe in. Household gas is the most common offender. You don't smell it after you get used to it! Gas pipes are notoriously leaky. Conducting gases through pipes with joints in them, where gases could escape, must be the most ludicrous of all modern "conveniences". Would you try to conduct water through pipes with holes in them? You would soon see the water on your kitchen or bathroom floor. But gas doesn't land on the floor, it doesn't make a puddle, so you, the consumer, are left helplessly believing you don't have leaks. Every gas pipe that has a seam should have a clear plastic boot around it containing indicator compound to let it be known when gas is escaping. Other methods could be invented to make the gas utility safe. As you will see from the case histories, very many persons are living in a cloud of poisonous gas.

The telltale element is **vanadium**. When your vanadium test is positive, you have a gas leak that your body found, even though the gas company may not. Many gas companies use outmoded equipment to search for it. Four out of five gas companies miss the gas leak. Health Departments and building contractors use modern equipment that detects even the tiniest leak; call them.

If you are a headache sufferer, fixing the pipes is not good enough. Switch from fossil fuels to electric. There will be many dividends. (Remember not to use candles as part of your lifestyle, nor to be a smoker.) Your air needs to be clean: clean of perfumes and colognes, clean of potpourri and air fresheners, clean of air sprays, pesticides, formaldehyde, freon, carpet and car odor, fireplace lighter, and of wood smoke.

Janette Donovan, age 52, had migraines every day but could not tolerate any medication for it. She walked about "like a zombie" most of the time. She frequently had vomiting with them. She was gassy, had pain in her right groin for many years and chronic bladder leakage. Our kidney stone test showed urate crystals. Her urinalysis also showed urate crystals and a slight amount of blood, obviously chronic urinary tract infection. The parasite test showed *Strongyloides*, *Trichuris* and *Fasciolopsis buskii* in the intestines. Her heavy metal test showed beryllium. This was tracked down to hurricane lamps that once held coal-oil in them— it filled her house air unbeknownst to her. Thirty five days later she had done an herbal parasite killing program, done the kidney cleanse, cleared out the hurricane lamps and all fuel containers. Her headaches were "more like pressure" now than pain. She still had *Strongyloides*. Four months later she had some headaches still but not migraines. They were down to once a week. Three months after that she had done a liver cleanse and gotten abut 3,000 stones out! She was still getting some headaches. She tested positive to *Histoplasma* and *Coxsackie virus #4* (a common brain virus) probably stemming from dentalware. She had many root canals and couldn't decide what to do. Keep her teeth and risk return of migraines; or get partial dentures. After eight months of indecisiveness she was back up to ten headaches per month, although not migraines.

Patsy Olsen, age 30, had migraines daily, frequently with vomiting. She had *Strongyloides* as well as *Ascaris*, and other bowel parasites as did her husband and two children. She couldn't tolerate any medication and had to give herself an enema daily for constipation. The whole family was put on parasite killing herbs. A gas leak was found and fixed and the baby's diapers were changed to non fragrant. Ten months later, the whole family still had *Strongyloides*. By one year she was experiencing a couple of good days a month although she still had *Ascaris*, *Coxsackie* viruses, and various tooth-related bacteria. Her two and a half year old had swollen neck glands, was toxic with bismuth from disposable diapers but did not have *Strongyloides*. The eight year old was also toxic with the lotions and fragrance of baby-stuff in the home; she was constantly congested and coughing but became free of *Strongyloides* in six months. After another ten months (the baby had been potty-trained meanwhile) the mother began to have headache-free days.

Donald Schaible, age 14, had migraines, learning disabilities and severe acne. The parasite test showed *Strongyloides*, *hookworm* and *Ascaris*. In spite of being on the parasite program two weeks and zapping, he still had *Strongyloides*.

Kenneth Jones had migraines for thirty five years and had tried all the new medications. They worked for a while, then stopped helping, but he continued taking them anyway. He usually went to the emergency room for the really bad ones, once a week but lived with the constant daily variety. There were two house dogs. They and the whole family had *Strongyloides*. After cleaning up an asbestos problem, killing parasites for five months and clearing kidneys of urate stones, he was down to two to three mere headaches a week. Two months later, he was getting migraines again; they all had *Strongyloides* again. With renewed efforts, one month later his bad headaches were down to one a month, although his low level chronic headache persisted: they had the dogs on a strict schedule of parasite killing herbs as well as themselves. He had not been to the emergency room for a month.

Angelina Gander, age 46, had daily headaches, not migraines. She also had persistent urinary tract infection and sinus infection. She was put on the herbal parasite program and four weeks later was much better. She also lost her chest pain due to heartworm and regained her milk tolerance.

Gracie Arlington had a boy age 6 who wet the bed, a girl age 8 with a behavior problem at school. She was stressed by an unfaithful spouse and thought she should go back to school for a Nursing degree so she could support the family. But she was getting two or three migraines a week in addition to colitis attacks which she feared would make her unable to study. The two cats, a dog, the children and herself all had *Strongyloides*, *Ascaris*, and a variety of other intestinal parasites. The humans were promptly zapped for parasites and the boy was dry that night for the first time in his life. A few nights later he was wet again. This time the animals were zapped and put on the pet parasite program and the children's toileting was carefully supervised. When she dropped her extreme vigilance over all, they all relapsed. After a year of trying, they gave away their beloved dog, put the cat box in the porch

> and the mother did the cleaning herself but nothing prevented relapses. A half year later, her six year old son asked if he could launder his own sheets and blankets. This request broke her heart and she planned to give away one cat. Even with only one cat, the girl's behavior and grades fluctuated extremely, the mother had a migraine a week and the boy wet. During a vacation the mother loaned the last cat, (her cat) to which she was very endeared, to a friend, to see if it made a difference. The boy never wet again, the girl made straight A's, and the mother's headaches became sinus headaches. Some intensive dental work cleared these up. She brought her Nursing diploma to our office two years after beginning. She should have had another diploma for **Intelligent Parenting.**

Earache

Earache is particularly common in children. Bacteria, mainly *Streptococcus pneumoniae,* have built up to a high level. Zap them. They were probably introduced by some larger parasite. But why did they multiply and thrive in your child's ear? There must have been food for them and protection from the immune system. Probably the Eustachian tubes are full of mucous, providing habitat. The mucous is present because some air toxin is irritating the sensitive linings. Clean up the air: not just asbestos, fiberglass, formaldehyde, freon, and arsenic, but perfumes, fragrant school supplies, potpourri.

Being housebound, as in winter, makes the air-toxin problem worse. Use summer time to strengthen your child for the winter—spend summer outdoors. Always wash hands a lot. Stay away from moldy food. Give small doses of niacin (25 mg., niacin thins mucous so it can run away) along with vitamin C (250 mg.) at bedtime.

Putting in “tubes” is a short term solution that is better than perpetually staying on antibiotics, but neither should be necessary.

To hasten healing, as soon as earache is suspected put room temperature olive oil in both ears, tug the earlobe to let bubbles out, and stopper them with cotton wool salvaged from vitamin bottles (other types are polluted with mercury). Put on a light bat that covers the ears.

When adults get earache, the *Streps* are hiding under tooth fillings and in gallstones. Clean up these two sources and zap.

Drinking non sterile milk adds *Salmonellas* and *Shigellas* to the *Strep* ear infection! Small wonder milk is thought to make people mucousy. The ears must now battle them, too. Even a few bacteria consumed in milk can start a whole colony if bowel bacteria have been disturbed by antibiotics. If your child has become “allergic” to milk or gets mucousy, remove cheese and ice cream–not milk–from the diet. Even cheese can be eaten if baked as in pizza or casseroles. Milk must be boiled. Try to reduce the child's *Salmonella* sensitivity by avoiding unnecessary antibiotics. Keep immunity high by avoiding moldy food!

Ear Noises And Ringing

This is also called *tinnitus*. A hissing or buzzing sound is heard in one or both ears. It can be continuous or pulsing off and on. It can be as loud as roaring.

Tinnitus is caused by three things acting in partnership: toxic elements, an allergy to *salicylates* (the aspirin family) and a bacterium *Streptococcus pneumoniae* (the pneumonia bug). This “bug” can be carried in the chronic state after a bout of pneumonia or what seems to be a head-cold. It is always present in earache. It is easily activated by exposure to cold wind or drafts and certain toxic substances. For this reason I recommend keeping the ears warm in winter by keeping them covered or wearing a cotton plug or ear-muffs. The *Strep* bug can also cause *Meniere's syndrome*, congestion, loss of balance and chronic sinus problems. Often an antibiotic of the penicillin family helps immediately, then loses its effectiveness. This shows you that bacteria are involved but cannot be truly vanquished with antibiotics.

Streptococcus pneumoniae often hides in pockets under infected teeth and in holes left where teeth have been pulled—especially wisdom teeth. These can be found by alternative dentists who clean these cavitations. *Strep* also resides in the liver; clean them out with liver flushes.

Certain foods and many medicines, especially cough medicine and lozenges contain salicylate.

To cure the tinnitus we must stop using aspirin or any high level source of salicylates. We must also stop the exposure to certain toxic elements—lead, beryllium, zirconium, benzalkonium. They are present in the air at gas stations and in many of our body lotions, soaps and salves. Switch to safe varieties. Niacin tablets, such as 100 mg, taken three times daily is another treatment, intended to increase the blood supply to the inner ear. Taking a thyroid tablet, by prescription, often helps too.

These methods never fail to improve tinnitus but a complete cure is seldom possible.

William Thall, 47, had a headache daily and was on pain medicine for it daily. He had tinnitus, a loud humming noise in the right ear. He had *Shigella* (producing nerve toxins) and *Borellia* (Lyme disease virus). He had *Gaffkya*, a respiratory bacterium under two wisdom teeth (right side). He also had *Campylobacter* and *Anaplasma* growing on him somewhere. He had *Strongyloides* too. He was toxic with vanadium (gas leak) and asbestos. After ten weeks he had two cavitations on the right side of his jaw cleaned, he had been on the parasite program and his tinnitus was gone, (he still had occasional headaches indicating he still had some *Strongyloides*).

Billie Scott, 26, had a history of ear problems, and lots of headaches. She was started on the kidney cleanse. Then she added the parasite program including their two dogs. She had a cyst in her left buttock, due to PCBs traced to the well water. She stopped using this well and switched off detergents for laundry and dishes. She switched off soda pop, onto milk. In 3½ months her tinnitus was gone and the cyst was shrinking.

Larry Pelegrini, 59, had tinnitus in both ears but was otherwise a strong, tall, intelligent person, who cared for sick people, whether family or not. As soon as he saw how simple it was to kill invaders with a frequency generator, he bought one. Preventing their recurrence was his big challenge since he had neither the means nor insurance to do dental work. He was toxic with aluminum, copper and PCBs. After switching to borax for all washing purposes, he got rid of aluminum and could feel his memory improve. The kidney herbs cleared him of uric acid and oxalate and he felt more supple. He had to go off his favorite beverage to get rid of pentane and methyl ethyl ketone. Twice a week he killed two dozen parasites and bacteria, that just seemed to pop up from nowhere, in order to feel better and reduce his tinnitus. But he lived alone, had to cook, garden, take care of animals and his sick friends which gave him a lot of parasite exposure. Sometimes he would be toxic with arsenic (a new pesticide he tried out) or vanadium (gas leak) but mainly it was tooth filling metal. If only this wonderful man could afford his dental work: what a blessing to society he could be for a long time to come.

Scalp Pain

Infection anywhere in the head can cause sensitive scalp and scalp pain. Even a common cold can cause bouts of scalp pain. Clean up your dentalware and environment.

Lumps on the scalp are often called *sebaceous cysts*, actually this is where your body has sequestered PCBs (polychlorinated biphenyls, extremely hazardous, now banned in the U.S., but often a pollutant in detergents.) Get rid of them by switching off detergents for all purposes. See *Recipes* for dishwasher liquid, dishwasher detergent, and laundry detergent replacements.

Non-Painful Diseases

Explanations for many of these “mysterious” diseases become rather obvious when you see a **common parasite, or pollutant, or both** consistently show up in case after case.

Diabetes

All diabetics have a common fluke parasite, *Eurytrema pancreaticum*, the pancreatic fluke of cattle, in their own pancreas. It seems likely that we get it from cattle, repeatedly, by eating their meat or dairy products in a raw state. It is not hard to kill with a zapper but because of its infective stages in our food supply we can immediately be reinfected.

Eurytrema will not settle and multiply in our pancreas without the presence of **wood alcohol** (methanol). Methanol pollution pervades our food supply—it is found in processed food including bottled water, artificial sweetener, soda pop, baby formula and powdered drinks of all kinds including health food varieties. I presume wood alcohol is used to wash equipment used in manufacturing. If your child has diabetes, **use nothing out of a can, package or bottle** except regular milk, and no processed foods.

By killing this parasite and removing wood alcohol from the diet, the need for insulin can be cut in half in three weeks (or sooner!)

Be vigilant with your blood sugar checks. The pancreas with its tiny islets that produce insulin recovers very quickly. Even if 90% of them were destroyed, requiring daily insulin shots, half of them can recover or regenerate so insulin is no longer necessary. The insulin shot itself may be polluted with wood alcohol (this is an especially cruel irony—the treatment itself is worsening the condition). Test it yourself, using the wood alcohol in automotive fluids (windshield washer) or from a paint store, as a test substance. Try different brands of insulin until you find one that is free of methanol.

Artificial sweeteners are polluted with wood alcohol! Instead of helping you cope with diabetes, they are actually promoting it! Do not use them.

Drugs that stimulate your pancreas to make more insulin may also carry solvent pollution; test them for wood alcohol and switch brands and bottles until you find a pure one. You may not need them much longer, so the extra expense now may soon reward you.

Many persons can detoxify the amount of wood alcohol that pollutes our foods. They do not have a food mold, **Kojic acid**, built up in their bodies as diabetics do. I have found Kojic acid in coffee, and potatoes with gray areas inside. Do not eat discolored potatoes or peels, even if cooked or baked. Being able to detoxify a poisonous substance like wood alcohol should not give us the justification for consuming it. All poisons are bad for us. Do not consume them.

All diabetic persons also carry a virus, *HA virus* in the pancreas. This virus grows in the skin as a wart but is spread quite widely in the body such as in the spleen or liver besides pancreas. It is not necessary to kill this virus since it disappears when the pancreatic fluke is gone. The HA virus undoubtedly belongs to the pancreatic fluke. The question can be asked: Does the fluke or its virus cause diabetes? There might even be a bacterium, so far missed in our observations, that is the real perpetrator.

While recovering from diabetes, it is very important to check your blood sugar every day. Improvement is so rapid, you may suddenly be over-insulinized by your next shot. Cut down your dose to suit your actual need.

There are additional aspects to diabetes that have been studied by alternative physicians. For instance, allergy to wheat and other grains containing gluten is common. Perhaps the pancreas and its islets would heal much faster if grains were out of the diet for a while. Perhaps the 50% improvement that is consistently possible just by killing parasites and stopping wood alcohol consumption could be improved further by a month of grain-free diet. Eating **fenugreek seeds** has been reported to greatly benefit (actually cure) diabetes cases. Are they a specific fluke killer, virus killer, or neither? It seems like a good idea to add this to your diet if you are a diabetic. Wood alcohol also accumulates in the eyes, and there is a connection between diabetes and eye disease. **Bilberry leaves** are an herbal treatment for both diabetes and weak eyes. Do they help by counteracting wood alcohol or detoxifying Kojic acid? Make a tea for yourself, using ¼ cup leaves to three cups water. Drink ½ cup a day. Chromium is another must for diabetics (200 mcg three times a day). It helps insulin enter your cells.

Gold is attracted to the pancreas. Heavy metals should be removed from dentalware including all gold crowns and no metal should be worn next to the skin as jewelry, including all gold items.

Blythe Jenkins was on Micronase™ (5 mg) daily for her diabetes but she still had a morning blood sugar of 183. She had pancreatic flukes and sheep liver flukes in her pancreas, vanadium (a gas leak) in her home and cadmium in her water (old pipes). After killing parasites and cleaning kidneys her morning blood sugar was down to 148. She also got rid of her hot flushes, groin and leg pain. This encouraged her so much she did the rest of her body cleanup and could go off her medicine completely.

Robert Greene, age 65, had been on insulin five years already, getting two shots a day (25 u each), and even this was not controlling his blood sugar which was 288 in the morning. He was raised to 30 units without much improvement. His legs and feet were too painful to walk without a walker to lean on. He had *Loa loa* in his pancreas. (This is another example of a parasite going to the "wrong" location, this time the pancreas instead of the heart. I believe the solvent makes this possible.) Also *mumps virus*, *HA wart virus*, *mycoplasma*, *flu virus*, *chicken pox virus*, *Adenovirus* and *Shigella*, all making their home in his pancreas! This was possible because he had wood alcohol accumulated there, from drinking various beverages and using artificial sweetener. As soon as he stopped this practice and killed everything with a frequency generator his blood sugar fell below 100 in the morning and he had to reduce his insulin to 20 units. He was also on chromium 200 mcg (2 three times a day). Meanwhile, he cleared 2,000 stones out of his liver. He could now walk well again and decided to take a part time job. The whole process took one year.

Ralph Dixon, age 72, had been switched to 30 units of insulin, once a day, after six years on pills for his diabetes. He still had a fasting blood sugar of 242. He had the pancreatic fluke and a host of bacteria and viruses in his pancreas. He had a poodle. After killing the pathogens and cleaning his kidneys, his blood sugar dropped so he cut his insulin to 25 units (blood sugar was at 111) Soon he had to cut it to 20 units. He was also on chromium 200 mcg (2 three times a day), manganese 50 mg. (one a day), fenugreek capsules (2 a day), and bilberry leaves, each supplement by itself. He also lost his angina and fatigue with all this body-cleaning. But if he went off the maintenance parasite program he would promptly get a spike in his blood sugar, showing how easy it was for him to reinfect and how new parasites would immediately find his pancreas.

Melissa Bird, 54, had major illnesses including heart disease (2 angioplasties), numerous other surgeries and diabetes. She took 15-18 units of insulin once a day. Besides pancreatic flukes in her pancreas, she also had intestinal flukes there(!) plus widespread *Ascaris*. She also had warts and candidiasis. Fortunately there were no pets. Her parasites were instantly eliminated with a frequency generator and she was started on kidney herbs for her other problems. Seven weeks later she stated she had to cut down her insulin because her morning blood sugar had dropped to 90. Then she eliminated the decafs and artificial sweetener that were giving her wood alcohol, started the parasite herbs and did a liver cleanse. The day after the liver cleanse her blood sugar went up to 164 but was completely normal after that (under 100) and she did not dare take any more insulin or pills. We advised her to keep monitoring her blood sugar and be very, very vigilant and to please stop smoking.

John Angert, 65, was not on any medicine in spite of his diabetes. He was too embarrassed to tell us his blood sugar. He had a long list of other health problems, too. He was toxic with thulium (vitamin C) and palladium (from tooth fillings). He had a variety of parasites. After doing some dental work and parasite killing his fasting blood sugar dropped to a normal 98. But his leg cramps kept returning in spite of doing a kidney cleanse. Only after changing his diet to include milk did the phosphate crystals stay away and eliminate his cramps.

Cornelius Edens, age 33, came for his diabetes, although he also had fatigue, digestion problems, and headaches. He had numerous other minor symptoms like chest pain over the heart, soreness in testicles, etc. His diabetes was only diagnosed one year ago. he was on insulin (Humulin™ 20 long acting plus 6 regular units) in the morning. He often omitted the evening dose which should be 14 long plus 6 regular. This brought his fasting blood sugar down to 166 in the morning.

He had pancreatic flukes in his testicles besides in his pancreas. His aflatoxin level was very high; he was told to stop eating grocery store bread, eat bakery bread only. He had silver, nickel and very high levels of gold–probably all three coming from his gold crowns–he was to have them all replaced with composite. He had fiberglass in his pancreas. Wood alcohol was present in large amounts in his pancreas as expected. He was to stop drinking all store bought beverages, whether frozen, powdered, or ready to drink. He did not test positive to benzene, propyl alcohol, *Salmonellas*, *Shigellas*, or *E. coli*. But he had *Staph aureus* growing at high levels in his pancreas. The usual source for this is in teeth, so he was told to ask his dentist to search for cavitations and clean up hidden tooth infections while replacing the gold crowns. He was to find the exposed fiberglass and seal it off. He was to zap parasites every other day for 1 month. His supplements were vitamin C (1 tsp. with each meal for constipation; then 1 tsp. daily), vitamin B-50 complex (2 per day), thioctic acid (2 per day). He was to start the Kidney Cleanse recipe for his testicle problem, and after 6 weeks do a Liver Cleanse. He was to follow up with us in 3 weeks, after dental work was completed. He never returned. Four months later we received a phone call he was too embarrassed to make himself. He needed no insulin and was doing fine. Another 3 months later he was still doing well, and off insulin.

Prediabetic

Alyce Dold, 64, came because she was worried about her blood sugar and chest pain. Indeed, a blood test showed her fasting blood sugar to be 136, just beginning to show insufficient insulin production by her pancreas. She had pancreatic flukes and wood alcohol there. Also *mumps virus* and *HA virus*. She had six more solvents accumulated due to eating raisin bran and other cold cereals each day. She was glad to be forced off this routine: she switched to 2 eggs every other day with biscuits or bread (not toast) and cooked cereal in between. Her chest pain was due to dog heartworm and *Staphylococcus aureus* bacteria that originated at teeth #16, 17, 1, 32. The worms and *Staph* were killed with a frequency generator. She was referred to a dentist for cavitations and started on kidney herbs. Two weeks later, there was still a little residual heart pain due to *Staph*; dental work was not yet done. She was given chromium (600 mcg per day) to help her insulin regulate sugar. Her LDH (See tests) was still high from the recent heart stress, no doubt. But she had accomplished a lot and planned to get it all done.

Diabetes Of Childhood

The problem is the same for diabetes of childhood as for diabetes of later onset, but much easier to clear up, provided the whole family cooperates.

Wesley Evanco, age 6, had his onset at age 11 months. Prior to that he had chicken pox and his baby shots. He had pancreatic flukes and their reproductive stages in his pancreas as well as wood alcohol. He had no other solvents accumulated. The problem was clearly due to these two enemies of his small body. Wesley's father did not have pancreatic flukes but his mother had very high levels, along with wood alcohol. She had to clear hers up before Wesley could recover. She chose not to. She couldn't believe the connection. Our most persuasive efforts were not successful. We hope Wesley can forgive us all in due time.

Herpes

The *Herpes* family of viruses includes *Herpes Simplex Virus* (HSV) 1 and 2, *Epstein Barre Virus* (EBV), *shingles or Chicken Pox* (*Varicella zoster*), *Cytomegalovirus* (CMV) and some newly discovered ones.

Herpes simplex virus 1 is the virus that breaks out around or inside the mouth. We call it a cold sore because it often follows a cold in childhood. As children, we may get HSV 1 once or twice each winter. When they come more often the child's immunity is low. Adults who get repeated attacks also have low immunity (this is obvious from a blood test where the white blood cell count is less than 5,000 per cu mm).

Herpes simplex virus 2 breaks out in the genital area. It is often blamed on promiscuous sex but I believe it has quite different origins.

I believe the virus is introduced to our bodies by another large parasite. Perhaps it is pinworms, or *Ascaris*. Perhaps it is a tapeworm stage, picked up from dust and dirt.

I have some evidence that it is released from dog tapeworm stages when these are being killed by your immune system. It is probably the same tapeworm stage as releases the *Adenovirus* (cold virus) which would explain why children frequently get "cold sores" during or after a cold. (See Curing The Common Cold, page 357.)

Nevertheless, you would not get sick from these viral releases unless your immunity was lowered.

Herpes lives in your nerve centers (*ganglia*) and it is from here that you can be attacked after the initial infection. Evidently your immune system can destroy them as quickly as they emerge. But a meal of **aflatoxin** or other **moldy food** suddenly "gags" your white blood cells and lets a viral attack happen.

The viruses can also be "triggered" which lets them out of hibernation (latency) to multiply and travel along the nerve fiber to the skin. Triggers are things that put these nerve centers to work: sudden cold and heat, trauma from chafing and friction. Never drink water with ice cubes in it. Never eat hot soup with a metal spoon. Don't tweeze hairs.

Begin your prevention program by raising the immunity of your skin; this means removing all toxins from the skin. Use only natural lotions, softeners, cleansers on your skin made from recipes in this book. Health food brands are not superior. This will get rid of nickel, chromate, titanium, zirconium, aluminum, and benzalkonium from your skin and probably your whole body! Do laundry with borax and washing soda, only, to eliminate commercial detergent as a source, too.

As soon as you feel that warning tingle or sensation of *Herpes*, zap or use a frequency generator at 293 and 345 KHz (HSV 1) or 360 and 355 KHz (for HSV 2). Immediately take a **cayenne** capsule and 8 **lysine** tablets (500 mg each). The cayenne slows down travel of the virus along the nerve.

Attacks probably occur when the triggers act at the same time as an immune drop occurs. Immune drops happen frequently due to eating moldy food. Of course, mercury in amalgam tooth fillings keeps immunity chronically lowered. Many persons report they stopped breaking out with *Herpes 1* after replacing their amalgams. Stopping wearing tight synthetic underpants helps reduce *Herpes 2* out breaks.

When you get an outbreak, mop up a droplet of the blister fluid and prepare it as a specimen for yourself. If you search for it in your white blood cells when your attack is over, it will not be found because it is in hiding inside your nerve cells. Zapping does not reach them inside your own cells. Nevertheless, you can totally eliminate them by repeated zapping provided you kill them at their earliest warning. Evidently, they haven't multiplied yet, so gradually their numbers go down.

Even after you have been *Herpes* free for a long time, stick to your preventive principles. Avoid the trigger foods, peanuts, and chocolate, or be ready to zap. Avoid cold wind or direct sunlight on your face. Don't eat abrasive or acid foods like popcorn, nuts, toast, crackers, candy, citrus. Although you may stop the virus in its tracks by zapping, healing the lesion takes time. Keep the skin softened with a cornstarch or sodium alginate recipe (see *Recipes*).

A lysine mush helps too: crush a lysine table with a large wooden spoon, add a pinch of vitamin C powder and a pinch of zinc oxide. Save part of this mixture for later use. Wet a small bit of it with a few drops of water to make a paste. Apply to lesions.

Bazezew Hailey, 38, started breaking out in the genital area after a period of antibiotic use. She was started on lysine (500 mg, 8 a day), cayenne caps (one with each meal). She was to fill her prescription for Zovirax™ from her doctor, though. By the time she had it filled, the next day, her lesion had stopped enlarging, and she could reduce her supplements. Her skin was full of mercury, lead, strontium, aluminum. Her white blood cell count was low, showing low immunity. Her ratio of segmental to lymphocyte white blood cells was low, evidence for a chronic viral condition. Her bone marrow contained lead and radon. She stopped using toothpaste (strontium), salt, deodorant, detergents (aluminum). She got the metal out of her mouth and eliminated her radon problem by opening crawl space vents. The lead source was never found, but after she moved to a new house it went away. *Herpes 2* stayed away. A year later she still hadn't opened the Zovirax™ bottle.

Fatigue

Fatigue, whether minor or extreme, is always associated with blood sugar disturbances. The more disturbance, the more fatigue. We have three organs that do most of the sugar regulating: our **adrenals**, the **liver**, and the **islets in the pancreas**. In severe fatigue, that keeps you partly bedridden, all three organs are heavily parasitized. *Epstein Barre Virus* (EBV) is running amok in your body, as a rule, even when clinical culture techniques cannot find it. With your frequency generator and Syncrometer you can find it emitting at 380 KHz. Killing the viruses is not as important as killing the larger parasites and getting your organs functioning for you again. The viruses will go away by themselves.

The liver's role in blood sugar regulation is to get it out of storage when needed. When sheep liver flukes have taken up residence they're spewing their chemicals as well as their own bacteria and viruses into your circulation; it is surprising that the liver has any sugar in reserve and can function at all. Sheep liver flukes are commonly seen in fatigue syndrome cases.

The adrenals (the outer layer called the cortex) help to regulate the blood sugar in a complex way. Some adrenal factors influence the thyroid which is another energy-related organ. Both adrenals and thyroid have toxic buildups in fatigue cases! Their work is hampered.

The heart of sugar regulation is in your pancreas in the tiny islands of cells that secrete insulin, called the *islets of Langerhans*. Here we always find the pancreatic fluke in residence. It actually breeds there when wood alcohol accumulates in it. Wood alcohol is a common pollutant of food, even in artificial sugar which is often recommended to replace real sugar and spare the pancreas. There is wood alcohol in store-bought drinking water, fruit juice, powders meant to be stirred into beverages, even if they are health food varieties. It's probably being used to clean tubes and hoses in the manufacturing plant. The only beverage you can safely buy (not safe unless you sterilize it, though) at a grocery store is milk. Make your own beverages using recipes in this book.

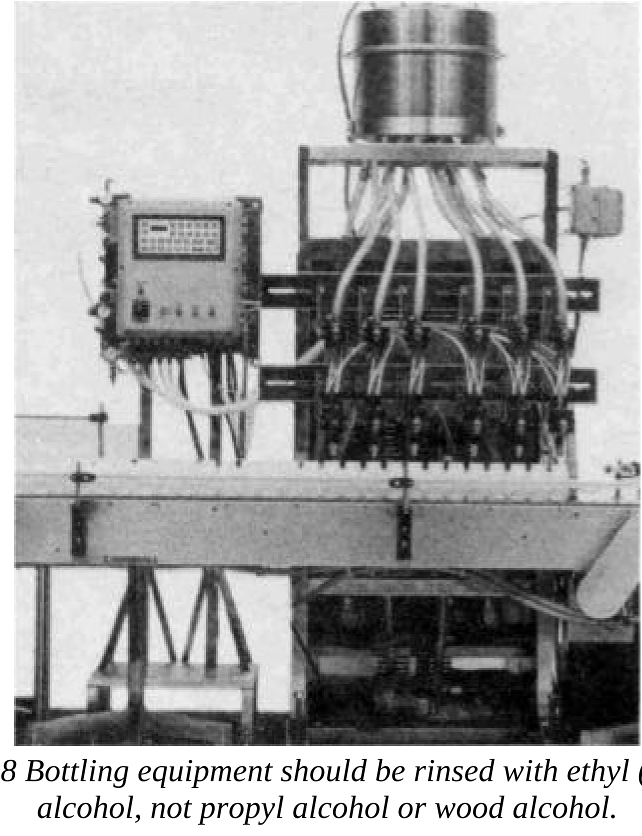

Fig. 28 Bottling equipment should be rinsed with ethyl (grain) alcohol, not propyl alcohol or wood alcohol.

Your first step toward curing your fatigue syndrome is to kill the pancreatic fluke and all other living invaders of the pancreas, liver, adrenals and thyroid. Use a zapper. Drink milk or buttermilk for several days afterward to provide lactic acid for the "good" bacteria to feed and recover on.

Your second step is removing metal from your mouth, particularly gold. Gold from teeth and jewelry readily goes to the pancreas! Do everything in the *Easy Lifestyle Improvements* chapter.

Your energy can bounce back in a few weeks by attending your liver, adrenals and pancreas. Help these organs heal and grow strong again. Avoid food molds (read Moldy Food, page 381). The most powerful assistance to the liver is a cleanse. This will eliminate liver viruses such as EBV and *Cytomegalovirus* (CMV). Be patient. Do it on a schedule until you have over 2,000 stones out. Take **vitamin C** at least 3 gm/day, to help both liver and adrenals. Take **B_2** and **B_6** to help adrenals and kidneys. Take glucose tolerance factor, **chromium** (two 200 mcg tablets 3x/day). See *Sources* for all of these. Take these supplements for three weeks, then cut the dose in half, and take on alternate days only, as a hedge against possible pollution in these.

Although your energy may be normal in three weeks, you are at higher risk for fatigue than the average person. Reinfection with anything will put the new parasites right back where the old ones were. Other bacteria, solvents and toxins will head for the pancreas, liver and adrenals again because these are weakened organs. It could take two years to build your health to its previous level, but is well worth it to have youth, initiative, and a beautiful appearance again. Going back to school is a good use of your time when your initiative has returned but your physical strength is still not up to housework or a job. When your energy comes back to you, it is tempting to overwork: to clean the whole house or to get into some gardening.

It is better to be moderate today than in bed tomorrow.

Anyone who has suffered from Chronic Fatigue Syndrome (CFS) or recurrent EBV has learned that lesson well.

June Timony, age 38, was diagnosed with Chronic Fatigue Syndrome), EBV and *Candida* around 1½ years ago by her family doctor. She also had a thyroid problem and a high estrogen level (165 pg/ml). She had severe depression at times. Our test showed her body was full of bismuth (fragrance) and silver (tooth fillings) especially in the ovaries. She cleansed her kidneys and killed parasites but could not make up her mind to do the expensive dental work.

Janice Brown, age 21, had EBV with chronic fatigue and depression along with a dozen more symptoms. Her skin, kidneys, breasts, brain, ovaries and pancreas were all loaded with mercury, platinum and other metals. She was full of radon and bus exhaust and the plumbing was shedding cadmium. Rather than do all this she and her husband decided to move. Before the moving date arrived she had cleansed kidneys, killed parasites and done dental work and was feeling noticeably better. Then they moved. She immediately was very fatigued again and worried that the move had been in vain. This time she had a liver full of Salmonella and a return of phosphate crystals in her kidneys. But it was easy to clear up and it was a very useful lesson to her to avoid unsterilized dairy products. She was much more careful after this.

Dee Safian, age 36, came especially for her low energy. She had EBV once. It left her extremely nervous. We advised going off caffeine but not substituting for it by drinking decafs. Her tissues were full of arsenic from pesticide; her urinalysis showed kidney crystals and her eosinophil count was high 5.5% (parasites). She had sheep liver flukes and stages in her pancreas due to a buildup of wood alcohol there. In four months after killing parasites and doing a kidney cleanse she was much improved.

Josefina Linzer, age 32, came for her fatigue and depression. Her tissues were full of arsenic, PCBs, chromate (eye makeup), mercury, yttrium, radon and terbium. She needed tooth metal replacement but could not schedule it immediately. She had *Ascaris* and pancreatic flukes in her pancreas and reacted to sugar in her diet quite strongly, so avoided it. She also had *Strongyloides* and *Trichinella*. She killed all these with a frequency generator and started on the kidney herbs. Her wood alcohol buildup was coming from carbonated beverages. She went off. In 6 weeks she had done everything except the mercury removal and was feeling much better.

Brigette Dawn, age 21, had Chronic Fatigue Syndrome with EBV, along with other problems. She cleaned her home and cleansed kidneys, killed parasites, and did two liver cleanses. Still the fatigue would return two days later. Meanwhile, though, her infertility problem got solved (she got pregnant) and this encouraged her to continue the battle against fatigue after the baby was born.

Hector Garcia, age 14, was getting gamma globulin injections every three weeks for his chronic fatigue syndrome. He had pancreatic flukes in his pancreas, sheep and human liver flukes in his liver and intestinal fluke in his intestine. He had a buildup of benzene, propanol, and carbon tetrachloride as well as aflatoxin from his granola breakfasts. He also had *Candida* and measles in his white blood cells. He killed parasites with a frequency generator and went off the solvent polluted items in the propyl alcohol and benzene lists. He immediately (in 20 days) felt much better.

Dana Levi, age 16, had chronic fatigue syndrome and dizziness; he was not in school. He had pancreatic fluke in his pancreas, sheep, human and intestinal flukes in his liver! Both benzene and propyl alcohol were present in his immune system. As soon as the parasites were killed (with a frequency generator) and he changed a lot of his products, he felt better but soon lost his improvement. At the next visit, our tests showed a buildup of vanadium (from burning candles in his bedroom). When he stopped this, he was better again for a while only to relapse again. His propyl alcohol level was up as was aflatoxin. But getting a taste of normal energy gave him the determination to get himself well! He embarked on a liver cleanse program and still more careful food selection.

Dennis Dillard, age 16, was beginning to do poorly at school due to fatigue. He had to stop athletics although his regular doctor pronounced him well. He was also getting chronic sinus infections. His lungs and trachea had accumulated seven heavy metals: vanadium, palladium, cerium, barium, tin, europium, beryllium. His fasting blood sugar was low (73 mg/DL) and LDH very low (90 u/L; it should have been 160). The body makes LDH in response to lactic acid levels. When the muscles aren't making much lactic acid from their normal metabolism, LDH levels will fall too. Was he developing a muscle disease? The gas leak was fixed (vanadium), the garage was sealed off from the house to eliminate barium and beryllium but the other toxic elements came from his dental retainer. As soon as his retainer came out, and they stopped using flea powder on their dog, his energy became normal and sinuses cleared up. A year later he still had not been ill.

Evelina Rojas, age 12, was having extreme fatigue with mood problems and sudden fevers. She killed *Ascaris* and sheep liver flukes with the parasite program but promptly got them back due to a benzene buildup I believe due to using products containing an herbal oil. Her high levels of *Streptococcus pneumoniae* (cause of fevers), *Staphylococcus aureus* and *Nocardia* could not be eliminated until her three baby teeth (with root canals) were pulled. After that, she was well.

Elaine Perkins, 48, came specifically for her low energy and nervousness. She was toxic with arsenic, a substance that replaces energy with nervous excitement and exhaustion. She also had a backlog of antimony (using baby oil), aluminum, rhenium (hair spray), benzalkonium (toothpaste) and radon. In four months, she had the arsenic and three other toxins eliminated and already had more energy.

Neil Youngblood, 53, was so fatigued, he had to brace himself even while sitting. A blood thyroxin level (T_4) of 1.0 instead of the normal 7.5 mcg/DL explained his fatigue. He had a mouthful of assorted dental metals which were accumulating in the thyroid, inviting viruses, particularly CMV, into it. He had to be on four grains of thyroid to feel near normal. After he had all his tooth metal removed, he only needed one grain to feel O.K. This encouraged him to clean up more of his body.

Scott Pennington, 50ish, was on thyroid medicine for his hyperthyroidism. He had been on iodine-radium earlier. He had the *miracidia* of the intestinal fluke, sheep liver fluke, and pancreatic fluke in his thyroid! Adult human liver flukes were also there! His thyroid was toxic with iridium, nickel, tellurium and mercury (metal tooth fillings) and decane, TC Ethylene and pentane solvents. He had been drinking a great deal of regular tea, which let oxalate crystals deposit in his kidney and slow down the excretion of toxins. The parasites were killed with a frequency generator, he changed his diet to get rid of solvents. In two weeks he was feeling better, had more energy and better sleep. This encouraged him to do the dental work.

Skin Problems

Sebaceous Cysts

Your body, in its wisdom, keeps toxins together and out of harm's way by making a cyst out of it. All the *sebaceous cysts* I have seen are filled with *polychlorinated biphenyls* (PCBs).

Get rid of PCB sources in order to clear PCBs from your body. This can take 6 to 12 months. Change all detergents (for dishes, laundry, and body use) to borax and/or washing soda.

Commercial detergents are wonderful cleaners...

but are unquestionably toxic. Whether you have cysts or not, it is always a good idea to use borax and washing soda instead.

If you have a particularly visible cyst, try to poultice it to the surface. Washing away some of it would be a great help to your body. Read herb books on poultices or just take whatever wild leaves you can gather; make a mush out of them with a blender, mix with honey or homemade skin softener to make it spread like peanut butter and cover the cyst with it night and day, covered with a piece of plastic. The wetness has drawing power. The plant juices have other benefits. If you can't poultice and must rely on kidney excretion, be sure to take kidney herbs at the same time.

Skin Rash

Rashes can be caused by many things. To find the cause, follow a logical pattern. It may be due to:

- HIV
- Yeast and Fungus
- Allergy
- Childhood Diseases (rubella, etc.)

HIV is the most alarming possibility. Eliminate it first by testing for it. It's often too early for a clinical test to be positive for HIV, so use the Syncrometer (page 457). I often see the rash disappear within days of eliminating the virus.

Probably the most common cause of rash is **yeast**. *Candida* has a resonant frequency of 384-388 KHz. If you test positive for it, stop all commercial soap and detergent for all possible uses. Zapping *Candida* may drive it away for a few days. The fungus is hosted by another parasite but finds your skin quite satisfactory for a home, at least while your skin immunity is low. It may be low from wearing metal jewelry, having metal tooth fillings, aluminum (from lotions and soaps), cobalt (from shaving supplies), and zirconium (from deodorant.). When all these are removed, the skin will dry up quickly in open air or under a heat lamp.

In babies' skin, immunity is low from diaper chemicals (mercury and thallium), wipes, and soap and detergent chemicals. Tight fitting, mercury treated diapers are a modern atrocity. Always line them with a tissue and keep them loose fitting.

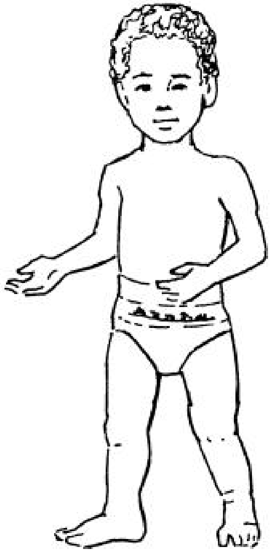

Fig. 29 Tight diapers are a modern atrocity, forcing mercury and thallium into the baby's sponge-like skin.

The skin that has rash or fungus should be dried with paper towels, unfragranced and uncolored, in order not to contaminate the cloth towels, and thereby transport the tiny infectious spores to other skin locations. You may use skin healers.

Only the skin healers given in *Recipes* are safe to use. Keep them refrigerated when not in daily use. Commercial lotions, including health varieties, all contain toxic ingredients.

Many adult rashes are due to **allergies**. Allergy to nickel is common, the reaction is easiest to see under rings or watches. The metal is pulled into the body for elimination. Since nickel is used by so many bacteria, especially urinary tract bacteria, it doesn't get eliminated, it gets taken up by bacteria. It also piles up in kidneys, adrenals, bladder and prostate where bacteria thrive on it. Strangely, it also accumulates in the male scalp (and in women's scalps who have male pattern baldness).

Allergy to strawberries, perfume, deodorant or chlorinated water, however different they are, can all be expressed the same way, in a rash. The liver has refused (been unable) to detoxify the chemicals in these items and allows them to circulate in the body. Not for long, though, since great damage could be done to brain and other tissues. Mercifully, the skin grabs these chemicals into itself. Ultimately, it must still be removed. The allergic reaction and your immune system come to your skin's rescue, although bringing you discomfort.

Why didn't the liver detoxify the chemicals given to it? The answer is based on a simple experiment. Try cleaning your liver (page 552) several times or until 1,000 bits of refuse have been washed out of the bile ducts. This relieves the back pressure on that part of the liver, and allows it to do its work again. The physiological details are not understood. Fortunately, the results are instantaneous. The day before the liver cleanse you would never eat a strawberry or peanut for fear of a reaction. A few days after the cleanse, your body "knows" which food it might tolerate and as you try a bit, you notice no reaction, no rash This simple experiment suggests that the liver couldn't detoxify these foods because of the refuse in its ducts.

Each liver cleanse "cures" a different set of allergies suggesting that the liver is compartmentalized—different parts having different duties. It follows that by getting all the stones out all your allergies will disappear. Experience shows this to be true, although it can take two years to carry out such a program.

Meanwhile, avoiding the offensive food or product is very important. It is quite destructive to bathe the brain in strawberry chemicals or your toes in maple syrup chemicals. Stay off allergy-producing foods and products even if you can tolerate a little or can be "desensitized" to them with shots or homeopathic methods. Use these methods for relief, not license to continue using items that tax your body.

Certain **childhood diseases** produce a rash and this can be diagnosed by testing for the suspected disease with a slide or culture of it. Then use a zapper to kill both the bug and any larger parasites that may have brought it in.

Hives

Sometimes your body will break out in hives instead of a rash. Again, gallstones in the liver and gallbladder are responsible. Do the Liver Cleanse.

Acne

The more severe cases of acne cover parts of the body as well as face and can pit the face so badly there is hardly any clear skin left.

In ten days you can reverse this, so most of the skin is beautifully clear. There are bacteria involved and skin oils of youth feed these bacteria. Acne has been extensively studied by scientists. Perhaps the true culprit was too big to be seen with a microscope or too small (antigen) to be recognized or just too unimaginable. I inevitably find *Trichinella*, one of the four common roundworms that infect humans.

Test yourself to *Trichinella* with the slide called "larvae in tissue." Search for it in your skin. It is generally believed to reside in muscles, especially the diaphragm, but in acne cases it is in the skin.

If you only have a frequency generator, set it at 404.5 KHz and at neighboring numbers, extending 5 KHz on each side, to be sure to include all eggs and other molt stages. Or zap.

Psoriasis, Eczema

Psoriasis and eczema are both caused by *Ascaris*. Their molting chemicals are quite allergenic; perhaps it is these that are affecting the skin. Since pets pick these worms up daily, there is chronic reinfection in families with pets. Keep zapping.

Bernadette McNutt, 34, had acne on her back, chest and face. She had been treated since teen age with ultraviolet light, Retin A, and antibiotics. She already had a history of shingles and fungus, two more skin conditions. Her skin was toxic with strontium and her kidneys had cadmium, silver and beryllium deposits inhibiting excretion. She had only one parasite, extremely high levels of *Trichinella*. Her children were also infected as was the cat. In spite of using parasite herbs for months she got no improvement until the baby was out of diapers. Then she cleared up.

Royce Hamilton, 17, had acne so dense on his face there was no good spot the size of a dime anywhere. He had it about one year. His urinalysis showed “amorphous” crystals (stones of all kinds) and a trace of protein. He had *Trichinella* worms throughout his organs. He was very fatigued. He was started on kidney herbs so there would be good excretion after killing the *Trichinella*. His thyroid and kidneys were full of zirconium and titanium from all the lotions he used for his skin. He didn't need deodorant. Evidently even his armpit bacteria had been affected. It took four months to clear his *Trichinella* although there were no young children or pets in the house. His face was beginning to heal, but three months later he had a recurrence, although his parent was not a carrier. After this, he cleared it up again and his face looked as beautiful as a child's.

Evan Knight, 36, had psoriasis at elbows and knees from age 9 but now it was spreading to his fingers and scalp. He occasionally had bronchitis and puffy eyelids, indicative of *Ascaris* but at the time of his visit he had *Trichinella* fluke stages and *Echinostomum* in his skin. He was started on the parasite program and in three weeks it was clearing instead of advancing. He switched to milk for his beverage to raise his immunity and removed the arsenic, formaldehyde and thulium (from his vitamin C) by doing the necessary cleanups.

Gerry Chastain, 41, had a red nose, erupted along the sides. He had been on sulfa drugs and Emycin.™ He had *Leishmania tropica*. He killed it in the office with a frequency generator and got immediate improvement but four weeks later it was back. He had four solvents built up in his body: benzene, TCE, TC Ethylene and hexanedione. This situation would make recovery impossible since he was no doubt reinfecting himself. He also had titanium, platinum and silver accumulated in his tissues and needed to replace his dentalware before expecting a permanent cure.

Floyd Oldham, 50s, was getting pimples on his nose. His whole face was red and flushed looking. His bowels were loose and he had some urinary urgency. He harbored two kinds of *Leishmania* (*braziliensis* and *tropica*). He killed the *Leishmanias* with a frequency generator and started himself on the kidney herb program. Five weeks later the pimples were gone but general redness had reappeared. The *Leishmanias* were still gone but this time he was toxic with cobalt.

Cobalt is known to promote skin cancers and also heart disease. This was discovered decades ago when an outbreak of heart disease occurred in England. It was traced to a pub (where they all partook) where cobalt was added to the beer to make the foam rise higher! In fact, the foam will just stay in place like a hairdo, if you add cobalt. It was made an illegal additive. Gradually, it has crept back into consumer's products: first toilet cake (blue), then window washer (blue), then dishwasher detergent, and now even mouthwash. If you see a blue colored product, **stay away from it**. It accumulates in the heart and skin. People with skin cancers often have cobalt build up.

Floyd stopped using all these products and cleared up again.

Grethe Driscoll, middle aged, wore tons of make up, so skillfully applied that scars from a face lift could never be detected. When she had minor breakouts, which usually occurred while away on a trip, it seemed like a catastrophe. She tried everything available but could not get to her parasite herbs until she was back home several weeks later. After one week on them (5 day high dose plus maintenance) her complexion was perfect again.

Crofton Thornton, 15, had an embarrassing case of acne. He had *Ascaris*, hookworm and *Strongyloides* (he also had migraines) all reacting in the skin. He stopped drinking commercial beverages that gave him solvents. He killed parasites electronically and with herbs and got a considerable improvement. But he still had *Strongyloides* one month later. Nevertheless, he had seen the connection and he knew it was just a matter of persistence to a clear complexion. Note, he should have had *Trichinella*—did I miss testing for it?

Warts

Could we get warts from playing with toads in childhood? We don't play with toads anymore. Yet we get warts. We don't know how we get them. But after learning how to get rid of them, you will probably know how you got them. Not all warts are the same. In fact, they might all be different: each one is made up of 5 or 6 different viruses, not just one as we had believed.

Peel a tiny fragment off one of your warts. Prepare it for testing by placing it in a small bottle. Add a few tsp. filtered water and a ¼ tsp. grain alcohol, Label it with the location you got it from: like "left middle finger knuckle. "First, search your body for other locations of this wart (organs that test positive to your sample). You can easily find them in your skin, of course. But also search electronically in your liver, spleen, muscles, stomach, heart, pancreas. **Notice how often they are present in the pancreas**. The pancreas seems to be a wart-virus heaven. Are they in the islets or the rest of the pancreas?

Without a zapper, you will need to find the frequency of each virus to completely destroy it. Attach your frequency generator and search between 400 and 290 KHz. When you find its resonant frequency, kill it by treating yourself for three minutes at 10 volts from a frequency generator. Will your warts fall off?

In a few days one or two of your warts will begin to shred. After a week you may lose one or two completely, and find that several more have become smaller. The remainder are unchanged. Continue to identify and kill them. Notice that they are not necessarily gone from the pancreas or other organs at the same time as they are gone from the skin. Perhaps warts are not the benign entities we have believed them to be. They may, in fact, ride into the body on some common bacteria, like *Salmonella*, or common parasite like pinworms or tapeworm stages.

Zapping doesn't reach all the viruses in a wart either. It takes repeated zappings to start the shredding and gradual killing of warts.

Guy Laird, age 11, had warts on his lips besides fingers. His job was feeding the three outdoor dogs. He was full of *Ascaris*. He had *Taenia pisiformis* and *Taenia solium* bladder cysts in his liver. These were shedding viruses into Guy. He was started on Rascal for six weeks (this was before the zapper was invented). Maybe his benzene buildup was responsible for letting so many parasites (and their viruses) survive and multiply in his body. He stopped using toothpaste, killed *Ascaris* (408 KHz) and some flukes (434 to 421 KHz) and improved his diet. All except one wart came off (without bleeding). He was given different chores, too, to reduce his contact with animals and their parasites.

Georgianna Mills, a middle age music teacher, broke out with warts all over her hands, at least 30 in total. A few months later she was diagnosed with bone cancer; she always wondered if there was a connection. She cleared up her cancer and killed her viruses and bacteria with a frequency generator. Nearly all her warts disappeared. But her indoor pet brought new parasites daily, especially *Moniezia* tapeworm stages. With each *Moniezia* infection (about once a month) she got new warts. She was never able to clear them completely.

I concluded that each wart is actually composed of 3 to 6 viruses and these viruses are distributed throughout our bodies! How satisfying to be able to rid our bodies of them, once and for all even in internal organs. There is a catch. Small remnants of some warts do not disappear in spite of killing most of them. More accurately, they disappear and then reappear in our internal organs. Could this suggest to us their true origin? Could it be a tapeworm stage?

Tapeworm Stages

Our bodies harbor numerous stages of tapeworms. But not the tapeworm itself, which may belong to a dog, cow, or pigeon. Tapeworms lead complicated lives, much like insects with their caterpillars, larvae, larval molts, pupae and eventual adults. Tapeworms shed eggs with the bowel movement of the animal host. The eggs blow in the dust and reside in the earth. A vegetarian animal nibbling vegetation near this filth, or licking dirt and dust off its coat, swallows the eggs. Humans, too, eat plenty of filth by licking their fingers. As children we all eat dirt simply by eating with unwashed hands.

The Jewish society discovered the great importance of washing hands before eating, thousands of years ago. But many of us choose to ignore truths that seem old fashioned. In our own relatively short life times we cannot see the whole picture as well as the prophets and seers of ancient cultures could. We eat plenty of dirt and along with it, the eggs of tape-worms. Dog and cat tapeworms are most prevalent, but sheep, cow, pig, and seagull tapeworms are also common.

There is hardly a predator species in existence that doesn't have its own characteristic tapeworm. Whatever animal species you live near, or once lived near, you probably swallowed some of its filth and some tape eggs. The **eggs** hatch in your stomach and the tiny **larvae** burrow into a neighboring organ without any consideration that this is your stomach wall or spleen or muscle. The larva's plan is not to grow into a long worm— that can wait. The larva must simply

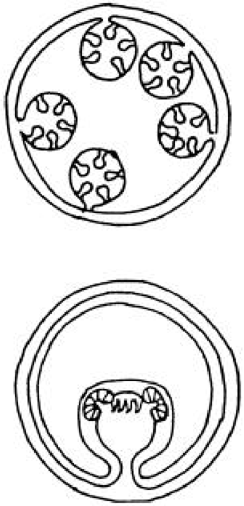

Fig. 30 Some cysticercus varieties (types) have multiple heads.

survive until you can be conveniently eaten! A wolf or a tiger will surely come along! In bygone days it did.

The larva is about ¼ inch long, surrounded by a “sac of waters,” like a tiny water balloon. Looking very closely at this sac, called a **cysticercus**, we see a head (scolex), complete with hooks and suckers, turned inside out, inside a bladder.

As the tiger's teeth bite down on the cysticercus, the pressure pops it out. The head is now right side out with hooks and suckers ready for action. Now it grows in the tiger!

It quickly hooks into a loop of intestinal wall so it can't be swept away and begins its growth into a regular long **adult** tapeworm. The tiger is the true or **primary host**. We were merely the secondary or **intermediate host**. Why does the adult tapeworm prefer the tiger instead of us? Only Mother Nature knows. But the best way to get to a carnivore is through its prey.

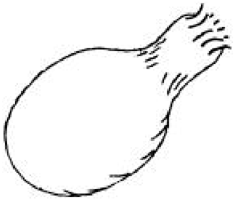

Fig. 31 Emerged cysticercus.

You can find these larval cysts in your organs using slides of the *cysticercus* stage of various common tapeworms. Search in your muscles, liver, stomach, pancreas, spleen, intestine and even brain. **You will not find even little bits of them in your white blood cells**. My explanation for this curious finding is that the tapeworm leaves no debris to be cleaned up by your white blood cells. Evidently your body builds a cyst wall around the larva to tightly encase it and prevent toxins and debris from entering your body. Thus your white blood cells are not alerted in any way. Of course, the larva is much too big to be devoured by tiny white blood cells anyway. Yet, it seems that if a pack of white blood cells had attacked the larva just as soon as it hatched from the egg they would have been able to devour it. Perhaps it enlarges too rapidly. Perhaps our white blood cells are preoccupied. In any case, we begin to load up on tapeworm stages from infancy and by the time we are middle aged we have dozens tucked away in our organs.

Some do die in the course of time. Perhaps their true secondary host is a rabbit or a mouse instead of a human. The short life span of these other hosts might mean that the life span of the *cysticercus* is also quite short, not 40 years! When they die, the white blood cells do clean them up and we can see them in our white blood cells at this time. It can take several weeks for the *cysticercus* to be completely gone by this natural method. During this time, we become ill! Numerous bacteria and viruses spring up, as if from nowhere, in our organs.

Don't be surprised if you are testing yourself during illness to find a tapeworm or two in your white blood cells! It is well worth searching for at such a time. Help your body dispatch the tapeworm stages all together with your zapper. A frequency generator is bound to miss some. Some cysticercus varieties consist of many heads, and each head has even more heads inside it! These might have different resonant frequencies. Only killing them together has the desired effect. Remember bacteria and viruses are released by killing tapeworms, so always follow with a second zapping in 20 minutes, and a third zapping 20 minutes after that. Only then can your tapeworm-related illness disappear.

If you do nothing, your body will be kept busy killing bacteria and viruses as the tape cysticercus wears down and eventually dies. You may not wish to identify all of them (but at least search for *Adenovirus*, the common cold) and just note where you are being attacked: your nose, throat, ears, lungs, bronchi. Internal organs are attacked too. It seldom takes more than three weeks, though, for your body to clean up a tape stage even without any help from a zapper. The attendant illness will be gone by then, too.

Watching these events in your body gives you insight into the very powerful forces at work, called immunity or body defense. The body "knows" a great deal more than we have surmised. There is yet so much to discover.

What initiated the death or dying process of the tapeworm stage in the first place? Has your body been trying all along and finally succeeded? Has the *cysticercus* reached the end of its life span naturally? Have its (the tapeworm's) own viruses and bacteria gotten the upper hand and killed it? Did it accidentally absorb something that killed it?

By taking a herbal combination, Rascal, you can soon find a tapeworm stage in your white blood cells where you could not find it earlier. It is now dead or dying. This proves the effectiveness of Rascal, even though it is slow.

Since we all eat dirt and inhale dust that is laden with dog feces or other animal excrement, we all harbor tapeworm stages, although none may be present in our white blood cells. **Are they harming us?** Perhaps they are living out their lives as quietly as they can in our organs, the way mice or ants try to live in our dwellings. Yet, when tapeworm stages are being killed, either spontaneously by your body or with a zapping device, we see an assortment of bacteria and viruses spread through the body, including the common cold.

Getting rid of the tapeworm stages in your organs seems a very worthwhile goal. Since each of us has been associated with dozens of animal species in our past, we probably have dozens of varieties of tapeworm stages in us. I cannot identify more than a handful due to lack of prepared slides. You can find them without identifying first, though, by listening to their emission frequencies. Their emissions are often extremely weak, possibly due to being encased in a cyst. Search between 510 KHz and 410 KHz. You may wish to "track" them for a while before killing them. You may wish to search for identical frequencies in your pet's saliva. Or you may wish to dispatch them as rapidly as possible. Use the zapper, not a frequency generator. Remember to "mop up" after your tapeworm killing by zapping again to kill bacteria and viruses that have been released from the tapeworm.

You may be disappointed not to feel any different after ridding yourself of numerous tapeworms and their pathogens. Evidently, the tapeworm stage itself doesn't make you sick; it is simply there like a wart is there, without making you sick. Its viruses can make you sick. Depending on which virus it is, it can make you very sick or not sick at all. Different viruses invade different organs. And some of these turn into warts!

The Flu

Influenza is a virus that can cause “the flu.” Does it belong to us as humans or to a larger parasite we are hosting? It is easily transmitted from person to person and in less than a year can spread across the planet. Some flu examples are Influenza A, B, C and Swine flu.

However, much that is called “flu” is actually caused by a bacterium, either *Salmonella* or *Shigella*. If someone in your family is “catching” a flu, test their saliva for the presence of dairy products, implicating the *Salmonellas* and *Shigellas*. Also test for influenza A, B, and C. Children's “flus”, especially when there is a fever, are usually due to *Salmonellas*. Even after zapping it can take an hour for the symptoms and fever to go away.

Go straight to the refrigerator and throw away all dairy products. Throw away all milk, cheesecakes, buttermilk, cream, butter, yogurt and cottage cheese, deli food and leftovers. You may wish to identify the food source of your family's bacteria first, and save the uncontaminated food. Use the sick person as a subject, searching for foods that appear in her white blood cells (or search their saliva sample for the food offender). If the flu is “going around” your neighborhood, you might wish to tell some of your neighbors which foods you found were contaminated. They may have purchased the same food! Obviously, when a contaminated shipment of dairy products arrives in your grocery stores, quite a few people will be consuming it, setting the stage for a "bad flu" that "goes around".

Why can some people eat contaminated food without getting sick? Maybe their *Salmonellas* don't multiply rapidly. Maybe their stomach acid is strong enough to kill most of them. Maybe their bowel movements are frequent enough to expel them quickly. Maybe they haven't been on frequent treatments with anti-strep antibiotics. The answer is not known yet. After a serious bout with *Salmonellas* or *Shigellas* the body does not completely clear itself of them. They stay in hiding somewhere. When a new batch of bacteria arrives, even though very sparse, as in 1 tbs. of milk, the two subtypes can hybridize and produce a much more vigorous offspring. This is called *virulence*. You are made much sicker by more virulent subtypes of bacteria. You may have diarrhea, vomiting, illness. Especially if you believe you have "lactose intolerance," pay attention to *Salmonella* and *Shigella*.

If your flu is due to an influenza virus, kill it with your zapper. Some family members may prefer to take a homeopathic flu "remedy" such as Oscillococcinum™ or Flusolution.™ Others may take herbs. These probably act by prying the viruses out of your cells' gateways and channels so the white blood cells can easily devour them.

But flu due to *Salmonella* is not easily zapped away. Remember, the zapper current does not penetrate the bowel contents, which is exactly where *Salmonella* lives! Besides zapping to clear them from your tissues, you must eliminate them from the bowel by using the Bowel Program (page 546).

Lugol's iodine solution (see *Recipes*) can quite quickly get rid of Salmonella throughout the body. Use 6 drops (small drops from an eyedropper) in ½glass of water four times a day. If no more *Salmonella* is consumed, it will be vanquished in a day or two.

If your flu brings you a fever, use Lugol’s.

Fever

Fevers are there to help your body fight the invaders...up to a point. Don't use a fever medication unless the body temperature goes over 102°F, and then only enough to bring the fever down a bit.

Most fevers, especially **“fevers of unknown origin”** are due to *Salmonellas* and *Shigellas*. Your body may be young and strong enough to kill them but not strong enough to kill an everlasting supply of them coming from dairy foods you eat on a daily basis. Stop eating salads at restaurants immediately. Stop eating food made by others' hands unless it is sterilized. Stop eating dairy foods until you have cooked them. Stop eating those that can't be cooked.

Sam Ellis, age 7, had two episodes of severe abdominal pain with fever lasting two weeks. He got hyperactive with milk products, had a frequent cough and stuffy nose. (Here the picture is quite clear. The milk products were bringing him *Salmonellas*, *Shigellas* and other bacteria which grew in his intestine to produce pain. But why only Sam and not his brothers?) Sam had a buildup of benzene from using bathroom soap containing a special herbal oil. Sam also had hookworms, intestinal fluke, and rabbit fluke, probably due to his lowered immunity from the benzene. Then his mother boiled Sam's milk, removed the polluted soap (she planned to use it herself!) and killed his parasites with the parasite herbs. His fever went away and stayed away. He said he enjoyed all this because now he “could play after school” without a stomach ache and he wasn't being sent to the nurse's office because of a fever. Notice the bacteria causing the temperature went away by themselves, probably due to the return of his normally strong immune system.

Jalene McCormick, 46, had been passing lots of kidney stones (hundreds) for years and had a temperature most of the time for which she was on antibiotics. It took her six months on our kidney herb recipe to dissolve and pass so many they no longer showed up on X-ray, and to stop making them. Then her fever left, not to return.

Kristen Jane Johnson, a young mother, had recurrent fevers and fatigue but, besides EBV, her doctors found no cause. We found HIV virus and a lot of bacteria and parasites. The fever-causing bacterium was *Salmonella*. To stop her *Salmonella* attacks she had to raise her immunity besides boiling all dairy products. Moldy foods (pasta) and lunch meats (benzopyrenes) were the source of liver toxicity. Each new *Salmonella* attack immediately invaded the liver so a vicious cycle was set up. When she stayed meticulously on the parasite program, meticulously off unsterilized dairy products, and meticulously off benzene-polluted items, she cured herself of fevers and night sweats and the HIV infection. Perhaps in two years the liver will have recovered enough to kill *Salmonella* that enter it, but she is not taking any chances till then.

Although Kristen was eating food polluted with both *Salmonellas* and *Shigellas* she only “picked up” *Salmonella*, never *Shigella*! Why is that? In contrast, people with multiple sclerosis “pick up” *Shigellas*, not *Salmonellas*.

Multiple Sclerosis & Amyotropic Lateral Sclerosis

Multiple sclerosis (MS) is a disease of the brain and spinal cord. It is called *lateral sclerosis* if the disease is mainly in the spinal cord.

It is caused by fluke parasites reaching the brain or spinal cord and attempting to multiply there. Any of the four common flukes may be responsible. Kill them immediately with your zapper or a frequency generator (434 KHz to 421 KHz). They cannot return unless you reinfect yourself. Stop eating meats, except fish and seafood. All meats are a source of fluke parasite stages unless canned or very well cooked. Pets and family members are undoubtedly carriers of the same flukes, although they do not show the same symptoms. Give away your house pets. Don't kiss your loved ones on the mouth. Make sure your sex partner has also been freed of fluke parasites.

The most important question you must be able to answer is why did these parasites enter your brain and spinal cord? When the brain contains solvents, it allows flukes to multiply there. The solvents, **xylene** and **toluene** are common brain solvents always seen in MS cases. Evidently these solvents accumulate first in the motor and sensory regions of the brain, inviting the parasites to these locations.

Xylene and toluene are industrial solvents used in paint and thinners. It is also a pollutant of certain carbonated beverages (I found it in 7-Up,™ ginger ale and others that I tested). Stop drinking them.

All MS cases I have seen also harbor *Shigella* bacteria in the brain and spinal cord. These come from dairy products. They are manure bacteria. Be absolutely meticulous about sterilizing dairy products. Even one tsp. unsterilized milk added to scrambled eggs could reinfect you. Not even heavy whipping cream or butter is safe without boiling. Kill bacteria every day with a zapper. *Shigellas* produce chemicals that are toxic to the brain and spinal cord. Eliminating *Shigellas* brings immediate improvement.

All large parasites like flukes have their own entourage of bacteria and viruses. Perhaps it is these that initiate the brain's reaction, which is inflammation and scar tissue formation in the outer covering of brain cells and nerve fibers. Perhaps it is the fluke stages themselves. Your brain is trying desperately to heal these lesions, only to be assailed by a fresh batch of solvent and *Shigellas* and another generation of parasites and pathogens.

The other pollutant associated with MS is **mercury** from dental metal. The mercury that is constantly released in the mouth does not all get excreted by the kidneys or eliminated by the bowels. Some of it travels up to the brain and gets into the spinal cord as well. You will be able to eliminate and excrete more mercury by doing a kidney and liver cleanse. The mercury may itself be polluted with **thallium** which is even more toxic. For this reason mercury removal should be done extra thoroughly to be sure no thallium has been left behind.

If you are concerned about MS-like symptoms, purchase slides of the brain regions, cerebrum, and cerebellum. Or purchase pork brains at the grocery store and snip out a portion of the sensory lobe and cerebellum. Prepare these as test substances (sterilize your hands afterward). Test your daily foods and body products for their presence in these brain areas. Also test for parasites, bacteria (especially *Nocardia* and *Shigella*) and other pollutants such as arsenic and pesticides. If the disease (tremor and lack of sensation) has not progressed too far, you can cure it. In all cases you can stop it from progressing further by cleaning up dentalware, the environment and diet.

Brandi Rainey, age 34, of Amish religious culture, was diagnosed with MS four months earlier after an MRI confirmed it although she had symptoms for many years. She was told she had inherited a gene for it and that Amish folk are particularly susceptible to MS for reasons of inbreeding. She had a constant pain running down the side of her neck, and headache. Her legs were getting too heavy to get up stairs. Our tests showed her brain was full of scandium (tooth metal alloy) and fluoride (toothpaste). Her vision was getting worse; her eyes were full of wood alcohol. She lost no time in getting dentures: there were no teeth that could be saved. She had several bacteria growing in her jaw bone: *Strep G* (sore throat bacteria), *Staphylococcus aureus* (this was raising her pulse to over 100), *Clostridium tetani* (causes great stiffness), and *Shigella* (produces nerve toxins). She killed these with a frequency generator. Five weeks later the pain and stiffness in her neck were gone, her pulse was down to 100, her periods were free of pain and her hands seemed to shake less. She was put on the parasite program plus thioctic acid (2 a day) and histidine (500 mg, one a day to keep nickel levels down)and advised to cook and eat with non metal. Four weeks later her pulse was down to 80, her legs were much better. She zapped four remaining bacteria. Two months later the numbness and tremor had left; her legs still felt tired and her hands sometimes shook but she was quite reassured that MS would not claim her life. Nor had a gene betrayed her. A half year later she was walking and working normally, doing liver cleanses and keeping up her vigilance against parasites and pollutants.

Kendra Welch, 56, was diagnosed with MS a year ago, by MRI. She went to a chelating doctor and this cleared up her temporary ischemic attacks (T.I.A's) which were occurring daily. But she had lost her balance, eyesight was getting worse, her feet and hands stung. Her sister also had MS but nobody else in the family did which baffled her doctor. Her brain tissue was full of barium, europium, gadolinium, and platinum. These are dental alloys, although barium could come from bus exhaust (she wore no lipstick). She was advised to have all metal removed from her mouth immediately. Two days afterward she came into the office without any neurological symptoms. She stated she was afraid to stop her new health program, though, and this was good policy.

Lynne Ceretto, age 15, was diagnosed with an “MS-like syndrome” by MRI. She had intestinal flukes and stages, human liver flukes and *Trichinella* in the brain. She had no tooth fillings. But there was benzene in her thymus keeping her immunity low. She also had propane and asbestos in her brain from leaky pipes and a worn washing machine belt. She, too, was told she had a “bad” gene. She was barely able to walk with help. It took several months to track down the source of benzene—the drinking water. Sometimes it was polluted; sometimes it was not! When the pump was oiled, some of it dripped onto the cement platform. Rain washed it to the center and down the pipe in the well. They eagerly removed the platform, found the oil on the water surface, cleaned everything up carefully, until no benzene could be found which put her on the road to recovery. A year later she had recovered further.

Norma Luellen, a young mother, had tingling, numbness and weakness on the entire left side of her body. She was in process of clinical tests for MS. Her body was full of pentane, possibly from her workplace since 12 other persons working there also had MS (such a situation should make our government eager to jump at investigations)! She had intestinal flukes and their stages, not in the intestine or liver or thymus, but in her brain! We found her home air toxic with bismuth too, probably from cosmetics. In spite of staying on the parasite program she got reinfected with sheep liver fluke, probably from eating hamburgers. She was not able to stop her carbonated beverage habit and frequently showed xylene, acetone, methylene chloride in addition to pentane in her white blood cells.

Shannon Synder, age 44, had been getting more numb over her whole body for several years and was presently considered by her doctor to have MS. Her muscles twitched all night, making sleep impossible, and her hands shook. She had intestinal flukes in the brain (cerebrum and cerebellum) but none in the intestine! The brain also had wood alcohol from drinking Diet Coke.™ She also had bismuth (cosmetics), palladium, copper, samarium, and tellurium (tooth alloys) in her brain. She began to improve enough to be off Prednisone by her 10th day of the parasite program.

Erica Blake, age 41, was diagnosed with MS two years earlier although her symptoms went back 13 years. She was on Prednisone™ but her balance was getting so bad she had to be in a wheelchair. Chelation treatments kept her from deteriorating further. Her brain was full of gasoline; she used to work at a gas station and now was getting it from the attached garage. Her hands and feet were completely numb. She had 5 root canals extracted and a few days later was able to stand. She could now walk with a cane. She had human liver flukes, sheep liver fluke and *Trichinellas* and dog tapeworm stages in her cerebellum (motor control center). After killing parasites and starting to take thioctic acid (4 a day) and cleaning up her environment she improved enough to drive a car again, walk without a cane in her home. She regained enough feeling in her hands and legs to do her housework, too.

Kurt Nielsen, age 43, was told he had peripheral neuropathy. His feet were so numb he had to look at the clutch to drive. Also both hands were numb. He was full of kerosene and benzene possibly from fuel oil that he pumped for a living. There were fluke stages in his brain and a dozen bacteria and viruses. He also had mercury and thallium in his immune system which came from tooth fillings. However, he had all his metal fillings replaced two years earlier! He thought there was no mercury left in his mouth! Actually, he had little bits (called tattoos) left somewhere. And they were giving him the classical symptoms: numbness of hands and feet and gradual destruction of his nervous system. His peripheral neuropathy was due to thallium poisoning. The dentist couldn't find tattoos, and he was left in his predicament. (This was before I found mercury and thallium sources in many personal products.)

Duncan Wood, a middle age father of 5 young children, could still slowly shuffle along when he arrived. He could not raise his arms to eat. He had uncontrolled inappropriate laughter every minute. He was diagnosed with MS two years earlier and told he had a “bad” gene. The fact that one child was beginning to show similar symptoms strengthened their belief in the gene theory. Ten days later his inappropriate laughter stopped; he could get his right hand to his face, he walked twice as fast and had very little tremor remaining. Strong chelating treatments obtained at a Mexican clinic had drawn much of the mercury and thallium out of his brain. He killed the flukes and *Shigella* bacteria electronically and stopped consuming unboiled milk. The brain solvents, xylene and toluene were removed quickly, too, as well as asbestos. His fast improvement showed them how important it was to remove the source of these pollutants in his home.

Two days later he regressed considerably which made him feel quite depressed, since his chelating treatments had not stopped. Was there still an unknown factor? It was a return of *Shigella* bacteria! He had inadvertently eaten a non-sterile dairy food: milk added to soup when it was already done cooking! This was a valuable lesson. Nothing else had returned. He was away from the asbestos and xylene from the workshop at home. He zapped the bacteria again and applied greater vigilance to eating only sterilized dairy foods. He recouped his losses in one day.

Then they scheduled their dental work, which had already been done once two years ago! He had leftover mercury and thallium. Now, selecting a dentist with experience in finding tattoos and cleaning cavitations made much more sense to him than it had before. He also planned to do a kidney and liver cleanse after returning home. And to stay out of the workshop until the asbestos-containing belt had been replaced and the furniture painting had been moved to a different building.

Shigella also causes irritability and depression, a frequent problem for MS cases.

High Blood Pressure

High blood pressure is one of the easiest problems to correct without resorting to drugs.

The most important change to make is to stop using caffeine as in coffee, tea, or carbonated beverages. Don't use decaffeinated coffee or tea either because of the solvent pollution in them. Switch to hot milk or hot water if a hot beverage is desired, or any of the beverages given in the recipe section. If being without caffeine leaves you fatigued, take an arginine tablet in the morning (500 mg).

Blood pressure is mainly controlled by the adrenal glands which sit like little caps on top of the kidneys. Whatever is affecting the kidneys is probably affecting the adrenals, too, since they're so close to each other. You must find out what it is.

You could do your search in the kidneys since kidney tissue is available in grocery stores. Adrenal tissue is available on microscope slides. What will you find? Probably **cadmium**.

Search for the cadmium source in your drinking water! Cadmium comes from the metal pipes. In fact, you could scrape a galvanized pipe to get a cadmium test substance. Conducting or storing drinking water in containers of metal is as foolish a practice as eating food off the floor. Water picks up everything it touches simply because it is wet! You may not see what it picked up any more than you can see if it has picked up sugar or salt. The cadmium and other metal is dissolved in the water. The older the pipes the softer, more corroded they are, and the more metal is picked up as the water rushes by. If you find cadmium in your hot or cold water, you will never be able to filter it out. Nor should you switch to bottled water. The amount of cadmium in your clothing from doing laundry with this water is already too much for your adrenals and kidneys.

Change your galvanized pipes to PVC plastic. If you believe you already have plastic pipes or all copper (which leads to leukemia, schizophrenia and fertility problems) you will need to search every inch of plumbing for a very short piece of galvanized pipe left in the system! A piece as short as a 2 inch T or Y can be causing all the trouble.

The toxicity of cadmium, in fact, the high blood pressure connection, has been known a long time. After finding the cadmium start on the kidney cleanse. You might miss the cadmium problem if you don't attend to it first. Also remove all metal from your mouth.

All (100%) cases of high blood pressure I have seen could be easily cured by eliminating cadmium and other pollutants, followed by cleansing the kidneys.

To test whether you still need your blood pressure medicine, wait until your pressure is down to 140/90 or better. Then cut the dose in half. Check it again next day. If it has climbed back up you are not ready; go back to ¾or a full dose of medicine. Try again a few days later. If your blood pressure stays down, cut your medicine in half again (you are now down to ¼ the regular dose) and see if your blood pressure stays improved.

When you are down to 130/80 go off completely. But stay on the kidney herb recipe. At 120/80 try yourself on a few shakes of sea salt. The amount of salt eaten, once the pressure is down, has little influence. In fact increasing salt intake improves energy without raising blood pressure. Take no more than one teaspoon a day (2,000 mg sodium), total, including cooking. Better yet, make a salt that is a mixture of sodium and potassium chlorides (see *Sources*). Mix it for yourself in a 1 to 1 ratio or whatever your taste can accept. The sodium portion could be sterilized sea salt (test and make sure it has no aluminum silicate in it first).

Mold toxins have specific kidney effects! Especially **T-2 toxin**, found mostly in dried peas, beans and lentils. Rinse these thoroughly first, throw away shriveled ones, and add vitamin C to the cooking water. All cases of serious kidney disease show a build up of T-2 toxin. Be extra careful to avoid moldy food (read Moldy Food, page 381).

Bala Cuzmin, age 72, had high blood pressure for ten years but the upper (systolic) pressure remained high in spite of various medicines that were tried. She had three kinds of kidney stones and only one functional kidney. She stopped using caffeine, switching to arginine tablets to get over the let-down. Her diet was changed to reduce phosphate and add calcium, and she took magnesium and Vitamin B_6 to assist the kidneys. She was very anemic and her mean cell volume (MCV) was high due to *Ascaris* infestation. She killed parasites, cleansed kidneys but saw no drop in blood pressure which stayed at 150 to 170 systolic. Her adrenal glands were choked with copper and platinum. She had all the metal in her mouth replaced and promptly saw a blood pressure drop to 145-1 50. Three months later it was at 128 to 133 on half her medicine. She had not been tested for T-2 toxin yet, nor changed her copper water pipes.

Sabrina Patton, 66, had a long list of health problems, including high blood pressure for six years. She was on Corgard™ and diazide drugs which kept it down to 140-160/74-80. She had phosphate crystals in her kidneys and was started on kidney herbs and a diet change to include milk and exclude soda pop. She had high levels of mercury and copper in her immune system. She was feeling so much better after the kidney cleanse that she decided to remove her last fillings and replace her bridge, too, since it was shedding ruthenium. On her way home from the dentist, her ears stopped ringing and soon her blood pressure was down to 126/68. She was still on half a dose of drugs because she was too afraid to go off entirely. But when her pressure stayed down she found the courage to go off completely. This gave her the energy she wanted to play basketball with the grandchildren again.

Rolf Ehrhart, 61, had 80% blockage of heart arteries and high blood pressure for which he was on a Hydropres™ patch, Tenormin™, and Logol™ (diuretic). He had phosphate and uric acid crystals in his kidneys. He was started on kidney herbs followed by the parasite herbs. His *Ascaris* and flukes were zapped. He stopped using store-bought beverages. Then he could cut back on his medicines, measuring his blood pressure daily to guide him. After seven weeks it was down to 140/85, so he decided to do without medicine, a bit early. He was also getting chelation therapy and was now able to walk 2-4 miles a day. His next chore, which he approached gladly, was removal of all metal from his mouth.

Len Gerald, 45, was on Vasotec™ for high blood pressure. He was constantly sleepy; his blood test showed a low thyroid level in spite of being on Euthyroid.™ He was started on kidney herbs followed by parasite herbs. In two weeks, barely into his program, his blood pressure dropped. He had to go off his blood pressure medicine. It stayed at 126/80. He still had some *Ascaris* and other health problems but was highly motivated to clean them up, too.

Glaucoma

In glaucoma the pressure in the eyeball gets too high, putting pressure on fragile retina cells that do your seeing. The first question to ask is: "Is my blood pressure too high?," because there is a link between high blood pressure and elevated eyeball pressure.

Your blood pressure should be 120/80. Your doctor may say 140/85 is "not high." He or she is kindly refraining from giving you drugs until this level of pressure is reached. It is your tip-off, though, that something is not right and you should correct it now, when it is easy, and before other damage is done. Read the section on high blood pressure (page 210) to learn how to reduce it by going off caffeine, checking for cadmium poisoning from your water pipes, and cleansing the kidneys (page 549). Even though your doctor has explained how the tiny tube draining your eyeball is too narrow, you should ask: was it not too narrow before high blood pressure struck? Simply getting your blood pressure to normal is sufficient help for beginning glaucoma.

Antonia Guerrero, age 51, had glaucoma for five years and was deteriorating rapidly. She cleansed her kidneys, killed parasites and changed her diet to the anti-arthritic one since she also suffered from arthritis in her hands for ten years with painful enlarged knuckles. She didn't get relief from taking aspirin. She got rid of her asbestos toxins by bringing her own hair blower with her to the hairdresser. After seven months she had pain relief for her arthritis (without aspirin) and her glaucoma was pronounced stable by her ophthalmologist.

Tooth Decay

The strongest part of our body structure is our bones. The strongest bones are our teeth. How can they decay? We must look at the **enamel**, **dentine** and **root** of the tooth as well as the bone they rest in for some answers.

Scientists have already searched very hard and long for answers. But their work is hampered by commercial interests that try to shape the results. Since commerce determines which research can be done (that is, paid for) sacred territory can be ignored. For example, the effects of sugar-eating, gum-chewing, tooth brushing, fluoridation, tooth filling materials and diet can be ignored if it interferes with product sales. Trivial studies such as comparing shapes of toothbrushes, studying the chemical composition of plaque, and studies of bacterial structure and genes are done instead. Studies “at the molecular level” do not threaten existing industries.

Important research has lapsed since the 40's and 50's. Perspective on tooth health was sound and clear in the mind of Dr. Weston Price in the 1930's. His scientific studies stand as a beacon even today because truths, once found, do not change. He traveled the world over in search of good teeth. Anywhere and anytime he found them, he described the people who had them. This is excellent science. It lets you draw the conclusions. He described what he saw in a book, titled Nutrition and Physical Degeneration.[13] They came to these conclusions from the following observable facts:

1. Skulls of primitive peoples who lived along coastlines, such as Peruvians, Scandinavians and various islanders, and whose staple foods included fish daily, showed perfect teeth; not a single cavity in a lifetime. They had strong bones that didn't break even once in a lifetime of 45 years. Skeletal structure was fully developed, meaning the jaw bone was not undershot or cheek bones squeezed together, forcing the teeth to grow into a smaller than ideal space. Consequently, there was room for the wisdom teeth, and no need to crowd the remainder. They saw no crooked teeth or unerupted wisdom teeth. The authors estimated a daily consumption of **4 to 5 grams of calcium** in their fish containing diet.

Our daily consumption of less than 1 gram calcium daily is small by comparison. Our wisdom teeth erupt poorly, our other teeth are often crooked. But today bad teeth go shamefully unheeded because we don't need to chew our food, we can lap it (ice cream) or suck it, or gum it (applesauce).

2. These primitive peoples got all the calcium, magnesium, phosphate, boron and other bone builders they needed simply from eating (fish) bones. Mexican peoples got 4 to 6 grams of calcium a day from **stone-grinding** of corn for their staple, tortillas, instead of from fish.

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[13] It is still available from the Price-Pottenger Nutrition Foundation, a non-profit organization that seeks to keep his observations alive. Their address is PO Box 2614, La Mesa, California 91943, (800) 366-3748.

Where do we get our calcium? Milk is our only supply. One quart supplies one gram. There is little excuse for a carnivorous society like ours to regularly throw away the bones of its food animals in view of our dire shortage. It leaves us dependent on milk alone. Milk has so many disadvantages. It is impossible to milk a cow by machine and not get a few manure bacteria, *Salmonellas* and *Shigellas*, into the milk. These bacteria are not completely killed by pasteurization the way more susceptible bacteria are. It takes boiling temperature to kill all of them. Why isn't milk sterilized? Water was sterilized for human consumption in distant decades. Chlorination of water is not ideal but it did sterilize the water. Milk could be sterilized by boiling or flash-heating.

Milk has other disadvantages: dozens of antibiotics, both by feed and by shot, bovine growth hormone, chemicals added in milk processing, the bad effects of homogenization, and allergy to milk. Yet, in a choice between milk drinking and bone loss, one must choose the milk. This would not be necessary if bones were properly salvaged–ground to powder and added back to the meat where it belongs–to offset the acidifying effect of the phosphate in meat. One gram of calcium is not much bone (½tsp.) but it requires a whole quart of milk. Bone powder added back to ground meat, soups, stews could greatly improve our tooth decay problem, bone density problem, and skeletal growth problems.

Softened teeth set the stage for decay; bacteria do the dirty work.

Zapping bacteria does not kill them all. The zapper current does not reach into abscesses under metal filled teeth or around root canals. *Staphylococcus aureus*, which we are constantly stuffing in our mouths as we lick our fingers, finds an immediate hiding place in a crevice where it can't be zapped. Many other bacteria hide here, too: those that cause ear ache, sore throats, bronchitis, stiff knees, joint disease. You can try zapping all the *Clostridia*, *Streps* and tooth decay or plaque bacteria. But the only way to successfully eliminate them is to pry them out of hiding and wash them away. This is a job for the dentist (see Dental Cleanup page 409).

Strep. mutans is considered to be the bacterium that causes tooth cavities. I have found it in milk, evidently another pasteurization escapee. All the more reason to sterilize dairy products.

Frannie LaSalle, 52, was getting compression fractures in her spine, but the weak bone condition was evident in her mouth (many teeth were loose—they could be jiggled!). Her gums were red and inflamed. A low thyroid condition (she needed 2½ grains a day of thyroid—in one day the normal body goes through 5 grains of thyroid products) contributed to this. Her blood phosphate level was high (4.7 mg/DL—should be below 4.0) and her alkaline phosphatase was 205, also high, showing she was dissolving her bones (including tooth sockets) at a rapid pace. Her whole system was too acid, as could be seen in elevated CO_2 levels (28, when 23-30 is normal).

Only the major minerals, sodium, potassium, calcium and magnesium can have an impact on this major disturbance. The dentist said she had to have all her teeth pulled and replaced with dentures. Her kidneys showed all three types of calcium phosphate crystals. She drank no milk. She had only three weeks before her oral surgery appointment. She was started on ½ cup 2% milk, 6 times a day plus 50,000 units of vitamin D (a prescription dose) to make sure she absorbed all the calcium. She also took magnesium oxide (300 mg. once a day) and vitamin B_6 500 mg (one a day).

She was started on the kidney cleanse to help activate the vitamin D and to help the adrenal glands make *estrogen*. Her estrogen level (5.2 pg/ml) was too low to get the calcium deposited back into her bones. She was also given licorice herb for their estrogen-like action to help with this and vitamin C, 1 gram (1,000 mg) 2 to 3 a day.

Her mouth care was to be as follows: potassium iodide (white iodine, made up by dissolving 88 gm potassium iodide in one liter/quart water). Purchase a new very soft toothbrush. Use no toothpaste or store bought floss. Use 2 lb. or 4 lb. (the 4 lb. is coarser) fish line (rinse first). Brush twice a day; floss only once at bedtime before brushing. Use 6 drops of food grade hydrogen peroxide for daytime brushing. Use 6 drops of potassium iodide for nighttime brushing. Use no mouthwash, chewing gum, candy. In three weeks her teeth could not be jiggled. Her dentist was astonished (but was not interested in how she achieved this). In six weeks her mouth looked normal and she could chew some foods. Her vitamin D was tapered as follows: Take 6 a week for the first week (miss one day). Take 5 a week for the second week (miss two days). Take 4 a week for the third week. Then 2 a week indefinitely. She never lost a tooth.

Muscle Diseases

There are a variety of muscle wasting diseases, thought to be genetic in their cause. Yet, what could be more easily inherited than a parasite? Persons living together share food, living habits. refrigerators, and parasites. Their shared genes indeed give them similar susceptibilities but if we take muscle parasites away, muscle diseases “magically” disappear.

Of course, there is no magic involved. It is actually hard work. Hard work to rid the whole family of parasites that are shared and possibly were present even at birth. Parasites that normally don't go to the muscles. For example liver flukes and intestinal flukes. They belong in the liver and intestine! Yet, in muscle disease they show up and reproduce themselves in the muscles. The reason for this becomes clearer when you see that certain solvents have accumulated there. Heavy metals, bacteria, and viruses have accumulated there, too. The host's muscles, instead of kidney and bowel, have taken on the duties of toxic dumping grounds. Could it be that the regular routes of elimination were overwhelmed? Or did the muscles, traumatized by these unusual parasites, invite the toxins? A tantalizing question.

But in seven minutes you can methodically kill everything and anything that is alive in your muscles and shouldn't be there. Zap until you are free of all parasite invaders. Your muscles will feel lighter afterward.

Muscular Dystrophy

In muscular dystrophy the solvents, **xylene** and **toluene** are seen to accumulate in muscles. These also accumulate in brain and nervous tissue! (See Alzheimer's page 269 and multiple sclerosis, page 204). Could it be that these solvents are actually present in the nerves of the muscles?

Fortunately these solvents will leave your body, by themselves, in five days after you stop consuming them! Stop drinking all store bought beverages, including water and powders that you mix, and including health food varieties. Water claims and health food powder claims sound as convincing and strong as a twelve inch plank to walk on. But if the plank leads out over the side of a ship, would you walk it?

Throw all your possible sources of solvents out. Flavored foods are the chief offenders (cold cereals, sweets and candy too). But of course, you should check in your basement or attached garage for cleaning solvents. Places where painting is done or automobiles are worked on should be off limits to you.

If you've been wondering whether you have muscular dystrophy, which I consider to be a fluke disease, search your muscles electronically. Use prepared slides of flukes along with a sample of hamburger meat to represent your muscles. If flukes have already taken up residence in them, you should diagnose yourself as “Positive”. If not, but other parasites and toxins are present, you have pre-muscular dystrophy.

Also, the likelihood of finding thallium is quite high, judging by the case histories.

Mel Rickling, age 18, had been seeing a specialist for bouts of muscular weakness for several years, but no diagnosis was given. His condition was not yet severe enough although it was difficult for him to raise an empty glass or get upstairs. It began at puberty, not too long after his first mercury tooth filling. He had asthma in childhood. The flukes attacking his muscles were liver fluke, intestinal fluke, and pancreatic fluke. Other parasites in his muscles were *Leishmanias*, several dog tapeworm cysts, and pinworm.

He also had assorted bacteria in his muscles. The solvents propyl alcohol, benzene, toluene, and xylene were accumulated there too. Ortho-phospho-tyrosine (cancer test) was already positive. His doctors had not searched for cancer in their biopsies. His drinking water contained lead and since he had lived in one house since birth he was probably drinking lead every day of his life. He also had high levels of mercury and some thallium accumulated in his muscles; these came from the tooth fillings in his mouth and could explain why his problems began after his first filling was put in.

His flukes and other large parasites were killed immediately with a frequency generator. He was started on the herbal parasite program to prevent reinfection. His diet and body products were changed to exclude solvent pollution. He could have no commercially prepared beverages except milk which needed to be boiled to kill bacteria. In twelve days his daily stomach pains were gone, so he was able to eat more and gain some much needed weight. The rash on his face was gone, the pain at his right side was gone, his muscle twitches were gone, his joints no longer ached and his mood was much better. The whole family was put on the parasite program and Mel was scheduled for dental cleanup. The plumbing repairs removed lead from the water and he was soon able to walk upstairs, in fact run upstairs.

A young man, seeing himself regain normalcy, wants nothing more than to lead a normal life” which includes reckless behavior. But after several warnings from his muscles he stuck to his restrictions and gained the weight he wanted in order to participate in athletics.

Myasthenia Gravis

is probably a fluke disease. Some chemical, possibly coming from the fluke, may affect the acetylcholine receptors, thereby causing an allergic reaction so they become inefficient. This is most noticeable in the eyelids. They droop from lack of strength to lift them.

The thymus is often involved, too. The thymus is extremely sensitive to benzene and with so much benzene pollution in our products and foods (pollution from gasoline is negligible by comparison), you will probably find benzene accumulated there. Search the thymus and the muscles for parasites, bacteria and tooth metal as well as toxins in the foods eaten daily. Kill invaders twice a week with a zapper or stay on an herbal parasite program until all danger of recurrence is past (one to two years).

Clean up dentalware, diet and environment. Keep no indoor pets since any new parasite, however tiny, will surely find the niche left behind by the flukes and give you a new myasthenia gravis-like disease. The whole family must be parasite-free to protect the member with myasthenia gravis. But it is a task easily accomplished and desirable in its own right, so discuss your plan immediately with family members. Don't delay. The flukes don't waste a single minute. They go right on feeding and breeding.

Carmen Opsal, age 37, was told by her specialist she had her myasthenia from birth since she didn't have the strength to nurse. She had pancreatic fluke stages throughout her body. Her plan was to start on the parasite killing program, clean her kidneys, remove toxic elements, kill bacteria and clean her liver. Long before she accomplished this, in one month, she was feeling better and had return of her strength on some days. She still had the solvent, methylene chloride, from drinking “pure” orange juice and praseodymium from eating foil-packaged foods, also thulium from her brand of vitamin C. She was full of auto exhaust and nickel from dental metal. There was hafnium from nail polish and hair spray and zirconium from deodorant. She planned to get rid of it all, and never need to return.

Universal Allergies

If minor allergies are due to a disabled liver, then extreme allergies must be due to an extremely disabled liver. This is the case for persons suffering from "universal" allergies, namely "everything", like the lacquer on floors, plastic chairs, the neighbor's flowers, and the grocery store.

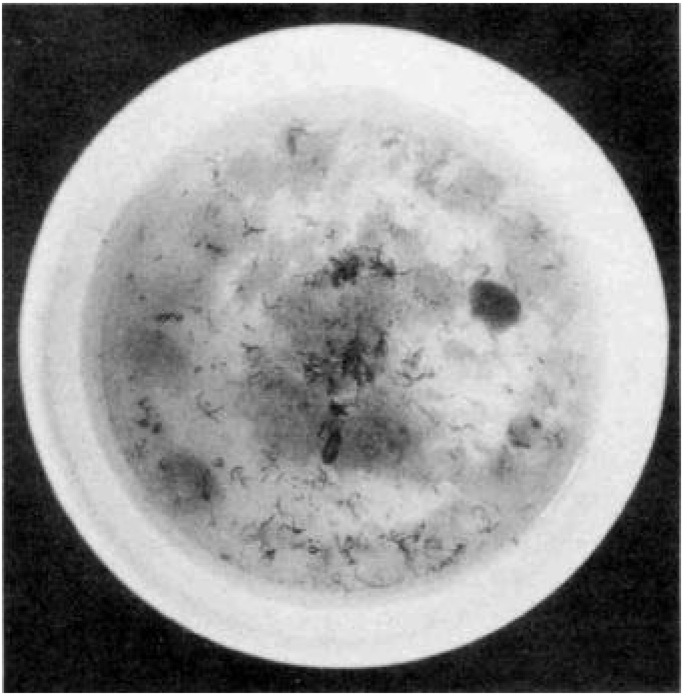

Fig. 32 Sheep liver flukes. Black threads in toilet are indicative of fluke remains.

They have more than merely clogged bile ducts. They have the sheep liver fluke living in the bile ducts! A tip-off to this situation is allergy to wool and wool fat (lanolin). A few flukes might not be noticed but a liver full of flukes that spill over into the intestine can give the worst case of allergy imaginable.

Sometimes the body manages to kill them with its own resources (maybe you ate something even too toxic for them!) They come through the bowel in a torrent. In the water of the toilet bowel they explode, spewing their infectious eggs all over in little black threads. Because these look like hairs, you may believe you passed "things with black hairy legs." These are actually burst flukes with black strings of highly infectious eggs. Why some people are literally taken over by these flukes is unclear. Amongst sheep, only certain sheep will be severely affected, being called "liver-rot." The disease in animals has been extensively studied.

Kill flukes with a frequency generator (434-421 KHz) or zapper. Come to the aid of the liver by avoiding food molds, removing dental metals, stopping chronic *Salmonella* infection and finally cleaning the kidneys and liver.

Environmental Illness

is another name for "universal" allergies. When more than a few flukes are present in the liver, they keep the liver from doing its major job: detoxifying all the food and chemicals that are taken into your body.

Different parts of the liver have different detoxifying jobs. One part detoxifies plastics and solvents, another part detoxifies perfumes and another newsprint ink, and so on. Foods have natural chemicals that need detoxification. By changing our food constantly we avoid overburdening any one of our detoxifying mechanisms. This is probably the basis for wanting different food at each meal and different meals each day. We somehow "know" when we're ready for the same food again.

Less extreme forms of allergy can be due to other flukes in the liver, such as human liver fluke (*Clonorchis*), or just plain clogging with numerous cholesterol crystals.

Anything that is lodged in the bile ducts obstructs the flow of bile. This causes back pressure in that part of the liver so it produces less bile.

The bile duct system is a gigantic tree with lots of interconnecting branches. Remember how "stringy" liver can be when you buy it in the grocery store. These strings are bile ducts. When one is obstructed, others take over its job. But when a whole section of the liver gets obstructed and it can't detoxify a whole set of chemicals you dare not get those chemicals into you again.

What if you do? These chemicals go coursing all over your body! They are taken up by various organs. The brain has special protection, called the *blood brain barrier*. But this can get broken by parasites that burrow. Now chemicals can roam through the brain. Some attach themselves and cause an "allergic reaction". Beryllium, from "coal oil," kerosene and gasoline attaches itself to the brain easily. Then other things attach themselves to the beryllium!

The extreme form of allergies simply requires killing the sheep liver fluke and other flukes inhabiting the liver. They tend to overflow the liver and inhabit the intestine, too. In this case, you might actually see some in the bowel movement after killing them. They won't let go of you as long as they are alive.

They have two attachments to hold onto you, yet, they are not difficult to kill, even with herbs. Use the herbal parasite recipe (page 338), zapper, or a frequency generator.

Sheep liver flukes might actually be breeding, that is, multiplying in the liver of the hyperallergic person. This is not normal. Sheep liver flukes "should" only spend their adulthood in our bodies. When the baby stages are also found in our bodies, (instead of in minnows or snails) there is undoubtedly a specific solvent involved. Environmentally ill persons have quite a few solvents accumulated in their organ tissues. Which one enables the sheep liver fluke to go through all of its development in the human is not known yet.

Obviously, the extremely allergic person, should remove all solvents from their diet and environment. Begin with eliminating propyl alcohol and benzene. The same products have other solvents too. It is processing of foods that puts solvents into them. Go completely natural. Dairy products are free of solvents, except for some cheeses. Remember to boil them to get rid of bacteria. Salt, olive oil, butter, and honey are free of solvents. With electronic technology, you can find solvent free products. Otherwise, if it didn't grow or you didn't make it from scratch, you must assume it has solvents! Cook from scratch, make your own pasta, bread, fruit juices, beverages.

Often, but not always, persons with sheep liver fluke, have a specific allergy to lanolin, a sheep product. Since lanolin is widely used in other products, this becomes a very broad range allergy. Such persons "can get no fat" at mealtimes or wear no wool without a considerable reaction. The allergy to lanolin does not disappear the day the flukes are all dead. But cleaning the liver with several liver cleanses (page 552) after killing parasites will start the recovery process.

Which comes first, the flukes or the solvents? That can't be answered. But what happens next is easily seen. The more flukes, the less able the liver is to detoxify solvents. The more solvents the better able the fluke is to multiply. A vicious cycle is set up that accelerates the illness.

Perhaps neither of these came first. Perhaps something else poisoned the liver so both solvents and flukes are given a home in your liver! Such a powerful liver poison would be a food mold: *aflatoxin*, *cytochalasin B*, *sterigmatocystin*, *zearalenone*, *ochratoxin, sorghum mold, griseofulvin, citrinin, T-2 toxin, Kojic acid, ergot* and others. Avoid food molds—see Mold Free Diet, page 365. The diet must be quite limited at first, to allow the liver time to "regain" its detoxifying capability.

Of course, it is assumed that environmentally ill persons have had their dental metal replaced by metal free composite. This includes gold. Gold accumulates in the pancreas, another organ of digestion. This may mean choosing partial dentures. Read the section on healing the jaw and Bone Strengthening (page 87) to ensure this move brings you success.

The liver is a versatile organ. It can regenerate itself but it won't if food molds block regeneration. Given half a chance it will become like new. After killing parasites do the liver cleanse (page 552). If it has been a month or more since you killed parasites, then go on a high dose parasite herb treatment the week before, or zap. Don't use the herbs the day of the cleanse. With one major allergy gone after each cleanse and by timing liver cleanses two weeks apart, it takes only six months to have a reasonably normal life again. You can endure indoor air again, sit on plastic chairs, read newspapers, wear cotton clothing and leather shoes without reacting. You must still be patient and careful as you take back the world for you to live in.

Delores Flores, 53, was brought by her husband to the driveway in front of the office. There she put on her mask and advanced to the outdoor bench. She did not dare to come in. Without doing any testing her condition was obvious. She must start killing liver parasites. But it seemed too simple to be believable. And she knew she'd be allergic to the parasite killing herbs (this was before the zapper). She decided to do nothing.

Patricia Humphry arrived wearing an industrial painters' mask. It smelled rubbery. Her winter boots smelled moldy. And a faint scent of mothballs came from somewhere. Even her car had an engine problem, spewing exhaust fumes into the driveway. I suggested she begin with some basic reading material on allergies. She did not return either.

Arlene Kelly, 50ish, could eat no fat—not the tiniest snippet. But at Thanksgiving she allowed herself a little gravy. The consequences were swollen eyelids, swollen face, swollen throat: quite a dangerous situation. After killing *Ascaris* and the flukes, and cleansing the liver (all in time for Christmas) she dared a little pie—and got along quite well!

Alcoholism

When the portion of liver that detoxifies ethyl alcohol (the drinking kind) is hampered you are at risk for alcoholism. The other contributors to alcoholism are **beryllium** and **ergot**. Perhaps there are even more contributors.

Beryllium is plentiful in coal products such as “coal oil”, and in gasoline to which kerosene or coal oil has been added. Fuel for “hurricane lamps” is a common offender, filling the air with beryllium. Liver blockage can force beryllium to circulate through the body; if it happens to attach itself to the addiction center of the brain, you're in a heap of trouble. Beryllium is very reactive. Any other allergen coursing by can react with it. If this happens to be alcohol–the drinking kind–you will be alcoholic unbeknownst to you.

When the liver is quite disabled, there may still be alcohol coursing through your body the day after you drank even a little bit! It is bound to find the beryllium stuck to the addiction center. Together, they turn the brain into a uncontrolled machine. Neurotransmitters are released that shouldn't be; others not released that should be. Mood is affected in a typically “alcoholic” way. Depression may be lifted—or caused!

Alcoholic persons should remove all fossil fuels from their environment, and never choose a career that exposes them to paint, cleaners, or automotive products. They should do liver cleanses until 2,000 stones or more are out.

Of course, they should never touch a drop of alcohol: not even the Black Walnut Hull Tincture in the herbal parasite program. The aqueous recipe should be made for them. Since alcohol is produced anyway, in the body, the liver should never be poisoned by molds, especially ergot: the very mold that is so abundant in alcoholic beverages! Alcohol and ergot interact to make each more toxic.

To help the brain recover its neurotransmitter status, take glutamine (500 mg.), a B-50 complex, and niacinamide (500 mg—to help detoxify ergot), with each meal.

To prevent alcoholism, protect your liver from food molds, especially ergot. Add vitamin C to nuts, pasta cereals, grains and even alcoholic beverages! Avoid fossil fuel pollution of your home by switching to all electric utilities.

Alcohol Addiction

There are many definitions of addiction. My definition is based on the special brain toxins, *beryllium* and *ergot*.

The brain has a region called the addiction center. If this center is stimulated it produces pleasure-chemicals. It is carefully controlled so that not too much pleasure or happiness can be experienced.

When a toxic substance, beryllium, is inhaled it circulates with the blood to the brain and may land at the addiction center. The more beryllium is inhaled the bigger the chance that it will occupy the addiction center. The brain cells in the addiction center have receptor sites for *glutamate* (the same glutamic acid that comes from the protein in our food). Normally, glutamate activates the addiction center. But when beryllium has "stolen" these seats, the glutamate is powerless to activate the joy and happiness center. The result is a low level chronic depression. The more beryllium there is to clog the receptors the worse the depression. Giving glutamic acid does not help but giving **glu-**

tamine does! Addicted or depressed persons should take glutamine, no less than 3 grams (3000 mg) a day. It comes in 500 mg. tablets. It is completely harmless.

When we drink alcohol or put it on the skin (as in mouthwash, tinctures, medicine) or produce it by fermentation in the intestines (*Candida* produces alcohol) a substance, *salsol,* is formed. Salsol reacts with beryllium. If the beryllium is in the pleasure center it reacts with it there. This reaction has the effect of activating the cells! Now a large amount of pleasure-chemical can be released. The amount is larger than normal because so many clogged cells are activated together. This explains the alcohol “high”. In all the alcohol-addicted persons I studied, salsol was present, along with beryllium, on the receptor sites normally activated by glutamate (or NMDA or kainate). As we removed the beryllium we saw that the salsol also disappeared.

The solution to alcoholism is to avoid ergot contaminated food and avoid beryllium inhalation. We also remove the brain beryllium using **thioctic acid**. Stopping the use of alcohol may save a life or career but does not correct the problem. Even after 30 years of abstinence, I still see the beryllium present in the addiction center and the salsol, derived no doubt from endogenous sources, still attached to the beryllium. This is why the addiction is never gone even after years of abstinence.

If any member of the family is, or was, addicted to alcohol the house should be searched for beryllium sources. Hurricane lamps or antique lamps are the most common sources. Remove them permanently. Washing does not clean them. Remove all solvents, cleaners, lighters. Switch to a butane lighter. The air should be tested for beryllium. The garage door to the house should be permanently closed, and the car and lawnmower kept out of it. Addicted persons should not be painters! Nor walk into a dry-cleaning business. Soon you will see a more cheerful disposition in the addicted person and this will be rewarding for the whole family.

Miguel Alcorn's wife cleaned up the environment for Miguel, whose alcoholism was 30 years long. Even lighter fluid was removed. The garage was sealed off from the house. She added vitamin C to his meals so he didn't have to “take anything”. She was very careful about moldy grains. He lost his preoccupation with drinking after killing parasites. She believes he is not sneaking any. Our hats are off to her.

Seizures

are always caused by tiny *Ascaris* larvae in the brain.

I suppose they find their way to the seizure center by accident. It is not normal for them to be in the brain, they typically travel between the stomach and lungs. *Ascaris* eggs are present everywhere in animal filth. Dogs, cats, horses and pigs all get *Ascaris*. Their excrement dries and flies about in the dust, but mostly it resides in the soil. Children playing in the dirt cannot help but pick up *Ascaris* eggs. The eggs hatch in the stomach and the tiny larvae, microscopic in size, travel first to the lungs. Here they go through a *molt*. This causes some coughing.

Whenever a child coughs for part of the day do not assume it is harmless. Use a frequency generator set to 408 KHz, or use a zapper. Children should be treated for *Ascaris* anyway, whether coughing or not, once a week. The tiny larvae are in the cough up. Children should not be taught to politely swallow this. They could be swallowing their own future seizures, asthma, or eczema. Teach children to use tissues for all spit up. The lungs are doing what they can to rid the body of these invaders. Your intelligence must cooperate with your lungs.

Ascaris do not come sweet and clean in themselves. They bring their own bacteria and viruses. One of these bacteria is *Bacteroides fragilis*. *Bacteroides* needs a host like *Ascaris* so it can be oxygen-free. Such a requirement is termed *obligatory anaerobic* meaning “must have absence of air.”

Being transported to the brain inside *Ascaris* larvae is probably the means by which *Bacteroides* gets into the brain. Brain abscesses and brain tumors usually have *Bacteroides fragilis* growing there. Brain tumors will not shrink unless all the parasites, bacteria and viruses are dead. *Bacteroides,* in turn, are big enough to house thousands of viruses. Two common viruses seen with *Ascaris* are *Coxsackie* B_1 and *Coxsackie* B_4. Perhaps it is the toxins of the *Ascaris* larvae or *Bacteroides* or *Coxsackies* that induces the seizures. Maybe it is something else about the infestation that induces them. But by killing *Ascaris, Bacteroides* and *Coxsackies* (zapper or frequency generator at 408, 325, 364, 362.5 KHz) you have eliminated the first essential link in the chain of developments that causes seizures.

The brain does not quietly tolerate these invaders. It fights back with its immune system. But the wormlets are already too big to be eaten by white blood cells. The brain fights back by producing **inflammation**.

Inflammations are intended to attract calcium so a wall can be built around the intruders. Inflammations are negatively charged regions so the positively charged calcium can find its way to the inflamed site. But lead and mercury are also positively charged! Perhaps this is how these **toxic metals** are attracted to the brain. All metals are positively charged. Perhaps this is their fateful poisonous attraction to living things. Perhaps they do not poison when no inflammations are present! In seizure cases we see many tooth metals in the brain. These must be removed so the inflamed site can heal.

Other toxic substances have also found their way to the inflammation at the seizure center: **vanadium** from leaking household gas; **PVC** from new carpets; **titanium** from face powder; **zirconium** from deodorant; **asbestos** from the clothes dryer belt or hair blower; **lead** from tainted drinking water. Do a good clean up of your environment.

Solvents accumulate here, too. Especially **toluene** and **xylene**. These are found in paint (persons with seizures should never be around fresh paint) but are also found in trace amounts in carbonated beverages. A person with seizures should drink no commercial beverages: see the Recipe section for homemade carbonated and other beverages. There are several other specific brain irritants that accumulate at the seizure center.

The food fungus, **ergot**, is always seen in seizure cases. Perhaps it can act alone to produce seizures. After all, seizures are an ancient malady, existing long before chemicals and solvents were manufactured.

MSG, which is *monosodium glutamate* should never be used in food. It was already banned in infant food in Europe a decade ago. Why are we still allowing it? Are our children not as precious? Healthy adults may tolerate it better than young children. But what about sick adults? Specifically, adults with a brain illness? Glutamic acid is a natural constituent of protein in our foods. And the sodium glutamate it must form in the body does no harm. But MSG is not biologically produced. It is lab-made. Lab-made amino acids are not the same as biologically made. Perhaps it is these “isomers”, perhaps it is the simple overdose of a natural thing that is brain-toxic. Whatever the mechanism, MSG should not be consumed by anyone, let alone a seizure sufferer. Fortunately, you can ask at restaurants, where (not whether) MSG is used so you can avoid these foods.

BHT and **BHA**, standing for *bishydroxytoluene* and *bishydroxyanisole* are food preservatives and also seizure triggers. They are often put on the boxes of cereals, rather than the cereals themselves, so the cereals can be pronounced preservative-free. Imagine how much the box must be drenched with to prevent oxygen leakage into the interior?

A more insidious seizure trigger is a perfectly natural substance, **malvin**. Malvin is the natural dye found in grapes, strawberries, plums and blueberries. Stop eating strawberry and grape jam or juice. Chickens and the eggs they lay, have lots of malvin too, stop eating chicken and eggs.

Here are foods relatively free of malvin: artichokes, asparagus, almonds, barley, beans of all kinds, green beans, broccoli, Brussels sprouts, cantaloupe, celery, nectarines, citrus, dates, mango, pears, kiwi, pineapple, Granny Smith apples.[14]

To Summarize

To stop your seizures on a dime, and not have another one:

1. Avoid malvin in food. Eat nothing colored red or blue, chicken, eggs, MSG, BHA & BHT. Boil all dairy products or don't eat them.
2. Avoid ergot in food. Eat no whole grain products; take niacinamide 500 mg three times a day to help the liver detoxify tiny bits in other foods.
3. Kill *Ascaris*, *Bacteroides* and *Coxsackie* virus and stay on a maintenance program of killing them. Avoid reinfection. It would be wise to have only outdoor pets.
4. Replace dental metal with metal-free plastic (See Dental Clean-up).
5. Clean up the home environment and body products of toxic substances.
6. Keep your fingers sanitary: spray them with 10% grain alcohol or vodka after bathroom use.

You can often tell by how you feel whether you are near to having a seizure. But some people get no warning. Don't take chances. Keep your drugs with you, even though you no longer need to take them. Drugs like Tegretol™ and Phenobarbital™ are not harmless. Once you can tell that you're better, try reducing your drug dosage slightly. See how you manage. If you have a breakthrough seizure you could fall and break a bone. Don't take chances. Even a year after your last seizure you should carry your medicine with you and have some in your house. This is because it is so easy to pick up *Ascaris* again. The highway to the brain–its seizure center–is still open. They will travel it again. It might only take two days from the time of accidental swallowing of animal filth, to having little larvae in the brain. Use a frequency generator every day at first, or zap daily to guard against this. Notice that killing parasites the first time may actually start a seizure coming. Simply stop zapping if you feel one coming. Do shortened zapping until you can tolerate a regular treatment. Have someone with you while zapping.

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[14] Taken from *A Guide to the Identification and Treatment of Biocatalyst and Biochemical Intolerances*, 1988 by J. A. Krohn, Los Alamos Medical Center, 3917 West Road Suite 136, Los Alamos, NM 87544.

Say good-bye to seizures forever. But don't forget your susceptibility. I believe you should be extra careful for two years. If you have a recurrence, repeat the whole procedure. This time it should be curable in a single day.

Doug's mother was distraught when she brought him, age 8 months. Her doctor only seemed sympathetic with her purpose to keep the baby's temperature down the next time he catches a cold. But her doctor had referred her to the county social worker. She had been completely honest with her doctor, because she was that kind of trusting person. Since her baby had only experienced one seizure (which was during a fever), she didn't see why her beautiful first born child should be on medicine "the rest of his life". She wanted her baby to be perfect. But the social worker had called her, talked about "the law" and being an unfit mother. She was all apart. The baby was supposed to be on Phenobarbital™ twice a day. Our tests showed Doug had *Ascaris* plus lead toxicity. He was also getting home made strawberry and grape juice. She promised to put the three cats outdoors, keep the baby off the floor, keep Doug's fingernails short and always wash his hands before eating. The parasites were easily killed. The lead was sporadically present in the water. She planned to move, and until then would filter all the drinking water so her breast milk would be free of it too. His diet was changed to eliminate eggs, chicken and the red and blue fruits. We recommended leaving the state in order to be able to peacefully raise her child. We promised to treat her child free of charge if another seizure should occur. Two years passed and we heard she was doing fine with her child.

Clara Scruggs, 50ish was losing control over her seizures and had to be hospitalized while a new medicine was tried. It changed her personality (again!) which upset her husband, too. She was started on the herbal parasite program but could only increase by one drop of Black Walnut Hull Tincture a week, instead of daily, since each new increase would give her a seizure. In half a year she was fairly free of seizures in spite of being off drugs. After each seizure, a checkup showed she had picked up *Ascaris* again sometimes with additional parasites. She could not bear to put her cat outside; Boots had been a friend in need many times. When she finally got Boots onto a regular parasite program she improved enough to go to church and church events again. When Boots finally “wanted out” she didn't mind. She decided to do a liver cleanse—this, too, gave her two seizures the next day but paid big dividends in other ways. She eventually improved to an incidence of one small seizure (“spacey” time or incoherent speech) in two weeks.

Chun Yee, age 28, has been on Dilantin™ from age 15. Now he was up to five pills a day and it didn't control his seizures. Any activity would trigger it. He was put on a low malvin diet and started on the kidney cleanse. His blood test showed he was anemic with a high MCV (104 cu microns), suggesting the *Ascaris* worms were using up all his vitamin B_{12} too. In six weeks he was down to one or two seizures per week, although he had not yet started the parasite program. He had beryllium built up in him, probably from a kerosene heater. When the pets and family were all treated for parasites he had no more breakthrough seizures and could cut his medicine in half which gave him much more energy. He was no longer in danger of losing his job.

Shiresse Nobel, age 7, was having minimal seizures but the mother did not want to start her on medicine. Shiresse had high levels of mercury in her body, although she had no tooth fillings. The whole family cleared their Ascaris infestation and in three weeks the seizures were gone but aggressive behavior remained. There was mercury in the air of some rooms but it was not in the paint. The bathroom was the worst. When everything in the bathroom was removed, the air cleared and so did Shiresse's behavior problem.

Drew Seaton, age 8, had his first seizure lasting nearly a minute. The parents were very fastidious and extremely conscientious about diet and habits. They were distraught. They all had *Ascaris*. A baby was still being diapered. Drew had arsenic (pesticide under kitchen sink), formaldehyde (some remodeling) and PVC (a new carpet) accumulated in his body. The carpets had to be steam cleaned to get rid of the arsenic. He was started on parasite herbs at once, since he was on medication that would shield him from having another seizure while killing *Ascaris*. Two weeks later everybody, except the mother, was free of *Ascaris*. In another two weeks they were all free and had cleaned up house toxins. They dared to stop his medicine. This let Drew's former happy personality come back to everyone's delight. Two years later there was still no recurrence.

Cosmo Maser, 30ish, was in a hospital across the country. He was having continuous seizures, although he had been there a week. It seemed impossible to transport him but, against doctor's orders, they got him into a station wagon. He had nothing to eat or drink that had any malvin in it (he ate four very well done hamburgers, plain, with lettuce on his trip) and his seizures stopped immediately. They felt a bit sheepish upon arrival 20 hours later since he could sit up, could tell his own story and no longer looked ill. He was without medication, too. They had left in a hurry. They immediately removed all the metal from his mouth; this cleared his mercury problem. He was started on parasite medicine and weathered the small seizures each increase gave him. He could return home in five days with his new diet and thioctic acid daily as a supplement. He occasionally had a seizure (2 a month) until they moved away from the busy street below their apartment. About a year later he could hold a job and go off Social Security support.

Weight Problems

Overweight is not the same problem as *obesity*. In fact, I do not have the answer to either problem, only a part of the answer.

In **obese** women, the ovaries, pancreas and thyroid are all involved. Perhaps the adrenals, the brain satiety center, and the liver are also involved. Maybe it's as simple as gold accumulation in all these places. Perhaps it is bacteria in all these places. When you weigh close to 300 pounds obviously some organ isn't working right. Try several things, but not a starvation diet.

The cause is not eating too much. Try removing all gold: gold teeth, gold jewelry and gold rings. Replace them with non metal varieties. After removing the gold, pull the remaining gold out of your tissues with thioctic acid (2 or 3 a day for several months). Make sure kidneys are able to excrete the gold instead of making crystals by doing a kidney cleanse. Gold accumulates in the pancreas, the brain (possibly in a control center here) and the ovaries (causes some infertility here). Also try clearing the body of all bacteria and parasites by regularly using a zapper. Use the Bowel Program (page 546) to evict the last of the *Shigellas*. Be very careful to avoid nonsterile dairy products. Try cleansing your liver by doing liver cleanses. Get 3,000 stones out.

Make sure you are getting enough nutritious food; make carrot and vegetable juice; use no commercial beverages. Avoid moldy food—don't take risks. If all these measures bring your weight down to the level of mere overweight give yourself good grades.

Overweight is a low energy condition. Your food is being turned into fat instead of energy. The decision not to make energy is being made in the liver mainly, but perhaps other organs as well.

Try cleaning the liver (page 552) until no more stones come out: get at least 2,000 stones. Notice that as the liver gets cleaner you get more and more energy right after each cleanse. Some cleanses have a dramatic effect. Others do not. This suggests that a certain part of the liver is the responsible part. Soon after the cleanse–within a week–the same old lassitude sets in. But during these few days notice how your body feels. It feels light. Your abdomen feels tight, like it's a part of you again. You're mind isn't on food throughout the day. It's very easy to lose weight, in fact you may lose five pounds in these few days without dieting or exercising. Definitely, your long-lost weight regulation is back in force. But then it vanishes. Fortunately, a bit of the weight loss stays with you, and by repeating cleanses (only once in 2 weeks, though) you can shed the pounds you want and gain energy in a permanent way. It is probably the way nature intended.

Try increasing your bowel movements. Notice how cats and dogs seem to derive energy from emptying their bowels. A cat walks to its litter box; after emptying its bowels and carefully covering it up, it jumps from the box and runs away. It now has its playful mood. A body chemical, *acetylcholine*, plays a role in emptying the bowels. Acetylcholine is a necessary operator for many of our muscles. Is there a disturbance in our acetylcholine metabolism in overweight conditions?

Coax your body to release more acetylcholine, at least in the intestines, by using a herbal laxative like Cascara sagrada. Other varieties are useful, too, but don't use a drug laxative: it burdens the liver more. Try to have three bowel movements a day.

Shigella bacteria can cause dreadful constipation. Immediately, the body feels sluggish, abdomen feels disconnected or hanging out. A nameless hunger sets in. Keep a close watch on dairy foods to make sure they are sterile. Zap when in doubt and do the Bowel Program.

Exercise helps as long as you keep at it. Strict dieting works as long as you keep doing it. But there's the problem. When you stop, you lose ground. It doesn't solve the problem of an inefficient body metabolism.

Raising thyroid levels helps but this can be dangerous. Raising thyroid levels naturally, by removing toxins is a very effective method—provided it was low to begin with. Overweight people often have a low body temperature, showing that the thyroid is involved: it is under producing. **But giving the body extra thyroid doesn't solve the thyroid's problem. It only temporarily solves the rest of the body's problem.** The thyroid will have viruses and heavy metals in it. The metal in your mouth drains downward to the stomach passing very close to the thyroid. Perhaps its iodine uptake is inhibited. The chlorine in water and bromine in bread may inhibit iodine uptake by the thyroid, too. After all, they are all halogens. Stop eating bleached bread and filter out the chlorine in your water. If this raises your body temperature you could expect better weight control.

The traditional herb, *Fucus*, was used to treat thyroid problems (and overweight) in days when herbs ruled medicine. Herbalists made a point of discouraging use of plain iodine. Fucus, they said, was much more effective. See *Recipes*.

If all these measures don't work for you, at least you have improved your health trying.

There are some advantages of being overweight. Overweight people seem to weather illness better. They laugh more. But one look in the mirror or at the scales ruins it. Put away the long mirror and scales. Don't ruin your whole life over it. Make a reasonable effort and then let go. Enjoy your stay on this planet.

Underweight can be just as difficult as overweight to correct. Once the stomach has been trained to say “full” or “full enough,” even after a few mouthfuls, it is difficult to heal. *Salmonellas* in the stomach wall are often seen. *Giardia* and other common parasites, that don't belong in the stomach, are seen here in cases of underweight.

The stomach is invaded by bacteria and parasites when its immunity is low. The common culprit is tooth metal draining down continuously into the stomach. Remove every bit of mouth metal. Don't cook or eat with metal. Stimulate your appetite with B-vitamins. And, again, the liver plays a role. If it is toxic with mold, it may say "eat no more" and the body obeys.

A stage of cancer illness is weight loss. This is called *cachexia*. The victim believes he or she is eating enough. They may not even have a poor appetite. Yet weight drops steadily. This metabolic problem has been studied scientifically. A chemical, **hydrazine sulfate** (prescription only), can reverse it to some degree. Use 65 mg three times a day for 30 days. Perhaps a lesson taken from cachexia metabolism could be applied to obesity. For the cachexia sufferer, life would end sooner if high calorie supplements were not used. But don't use canned "calorie boosters". They are polluted—often with the very solvent that makes the condition worse. Instead, make an eggnog: ½cup boiled milk, ¼ cup boiled whipping cream, a raw egg (exterior carefully washed), 1 tsp. olive oil, a banana, honey, cinnamon, cloves, nutmeg to taste. Mix all in a blender. Drink 1 cup a day. Vary it daily to keep it interesting.

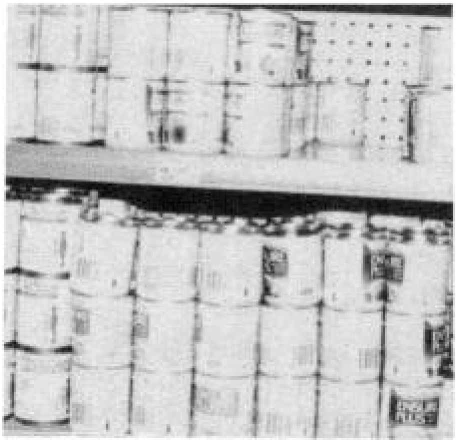

Fig. 33 I found all calorie boosters to be polluted with wood alcohol. Make your own.

If all this fails, give yourself credit for achieving health improvement and shift your focus to a different project. Underweight is not all bad either.

Sleep Problems

All big animals sleep, but some sleep by day instead of night. When humans do this, that is, work the night shift, they don't feel as well. Humans need about seven hours of sleep out of the twenty-four. Younger ones sleep more; newborns sleep much more. When we are deprived of sleep we are grouchy, think less clearly next day and have less energy. In spite of lots of research at "sleep labs" sleep problems are not understood, except for sleep *apnea*. Breathing should be even. When breaths are missed it is called apnea. It is especially disturbing when a baby shows apnea.

Sleep Apnea

Since breathing is regulated by acid levels in the blood and this is influenced by air quality, air toxins should be searched for first. **Cigarette smoke** is an air toxin. **Vanadium** from a gas leak is a very serious air toxin and can go unnoticed. Do your own checking since gas companies give wrong answers four out of five times. Ask a home construction company to check for gas leaks or the Health Department. **PVC** from new carpeting may be polluting the air. **Arsenic** from "treated" carpets and drapes and furniture also pollutes. **Asbestos** from clothes and hair dryers may be the toxin responsible. Perhaps even **fiberglass**, **formaldehyde**, or **freon**.

Adults with sleep apnea show swollen throat tissues: not necessarily pain. This makes the air passage smaller; long gasps of air are taken to try to make up for the missed oxygen and the carbon dioxide build up.

Swelling of the throat is a common allergic reaction. The possibility of allergy should get second consideration after air quality. Drug reactions, even in a nursing baby, where only the mother is using a medicine could be the problem. Allergy to food, chemicals has been suggested, as well as a simple lack of vitamin C (implicating mold and medicine which consume vitamin C in the detoxification process).

A third possibility is infection. Many bacteria and viruses can cause throat swelling. Redness of the throat is a telltale sign. It doesn't necessarily hurt. Kill all invaders with a zapper and try to understand the basis of low immunity in the throat.

Keeping metal in the mouth constantly, is a cause of low throat immunity since it must drain past the throat.

If you snore, you can deduce that your throat is swollen, even if you don't have sleep apnea. Pursue all three possible causes (air toxin, allergy, infection).

Overweight and obesity have been emphasized as causes. This may apply to some cases but certainly not to babies.

Whatever you do, don't do nothing. Keep removing bad things until you find the cause of irregular breathing.

Chester Fannon, 5Oish, was quite overweight and wore a mask at night with an air blower to assist his breathing. He had been referred to a sleep center for sleep apnea. He had extreme dryness of his throat at night and some hearing loss in one ear. He was toxic with arsenic (roach killer), bismuth (cologne), tin (toothpaste), and thallium (polluted dentalware). He was infested with both species of *Ascaris* and had a hacky cough. He had four solvents accumulated in his tissues. He was growing nine pathogens: *Mycoplasma*, *Haemophilus inf.*, *Streptococcus pneu*, *A-strep*, *Nocardia*, *Staphylococcus aureus*, *Bacillus cereus* and Flu virus, over half of them in his throat. These were killed with a frequency generator and a general cleanup was done. After two teeth were pulled he no longer needed his mask, he no longer had apnea.

Peter Day, middle age, was set for throat surgery in a few days. He had a couple of scary nights when he thought he was dying and couldn't risk many more nights with his obstructed airways. He was overweight. His throat was red and swollen, although he felt nothing. He never even had colds. His diet was completely changed, to things he rarely ate (bananas, milk, soup, oatmeal) and off things he ate daily (hamburgers, fries, tea, pancakes with genuine maple syrup). In two days, his throat was quite clear, the tissues having become unswollen. Maybe it was the molds in the maple syrup, maybe it was the oxalic acid in the tea, or something else he could not detoxify in these foods. He was certainly happy not to live the rest of his life with an artificial voice box.

Insomnia

Another sleep disturbance is waking in the night and not being able to go back to sleep for hours. Or not being able to get to sleep.

I believe these problems are caused by a high ammonia level in the brain. This belief is based on two observations. **Ornithine**, an ammonia reducer, induces a wonderful sleep in sleep-deprived persons. It is also observed that after killing parasites, which produce ammonia, sleep is much improved. Our metabolism does not produce ammonia. We produce urea which is excreted by the kidneys along with water and then called urine. When we are parasitized, our metabolism is burdened with ammonia, though, made by the parasites. We have to turn it into urea in the liver and kidneys so we can excrete for them. But this can't be done in the brain! The brain lacks an essential enzyme, *ornithine carbamyl-transferase*, for this bit of biochemistry. The brain was never meant to be parasitized or infected and has no defense. Most of our parasites come from animals we associate with. We weren't meant to live with horses, cows, sheep, pigs, monkeys, guinea pigs, cats, dogs and chickens nor to come in contact with dozens more at a zoo. We do so at our own peril.

It is known that ammonia is a strong brain irritant. In fact, a person can be awakened from a coma by being made to smell ammonia "smelling salts." Ornithine reacts with ammonia, mopping it up like a sponge. **Arginine**, another amino acid, also reacts with ammonia, but does not put you to sleep. So there is more to insomnia than mere inability to reduce ammonia levels. Arginine results in alertness and therefore should be used in the morning, when needed. Ornithine, given at bedtime, may take ½ hour to do its magic. Both are perfectly safe, since they are natural to your body, and a food constituent.

Start by taking two ornithine capsules (each 500 mg.) on the first night. Take four the next night. Take six the night after and choose the dose you like best. Sometimes it takes five days to "catch up" on everything that needs to be done for the brain and get you sleeping. Meanwhile, of course, you are planning to kill your parasites and be done with insomnia in the most effective way of all.

Another sleep aid is herbal. A couple of herbs, **valerian** and **skullcap**, are known for such action. The mechanisms are not understood and this makes for nonuniform action. Some persons sleep well with them, others do not. Simply try them to find out. We are all so different in our metabolism details, we respond differently to herbs. But it is a blessing that the mechanism is not understood. Herbs, a tradition that precedes civilization, need to be forever off limits for intervention by government agencies.

Tryptophane, another amino acid, is about twice as powerful as ornithine, but was taken off the market a few years ago. Some persons taking it daily were seen to become quite ill and some deaths ensued. Since tryptophane had been used in prior years without noticing toxicity, something unusual should have been suspected. My tests showed extreme pollution of tryptophane capsules. They contained PCBs, mercury, ruthenium, strontium, praseodymium, aluminum, and benzalkonium. I can only speculate that a mixing vat broke, dumping its precious load onto the floor—but it was salvaged. Or that the mixing vat wasn't cleaned thoroughly from it's last use.

Persons with illness due to taking tryptophane developed an extremely high eosinophil count in their blood test—an index of parasitism, too. Parasitism, that would have led to insomnia in the first place! Were these unfortunate victims seeing the cause or the result of their tryptophane use? This tragic event should have led to a discovery of the heavy pollution, a revelation of the industrial manufacturing process, and a safeguarding against any repetition. It has not been done (certainly not publicly).

Foreign countries' manufacturing processes do not come under U.S. scrutiny or jurisdiction, although some imported products must pass tests. There are no safeguards against repetition of the tryptophane experience. It behooves us to demand safe supplements and medicines. It is not the list of ingredients that informs. Lot analysis, after bottling, would give us the necessary safeguard. The presence of filth contamination and toxins cannot be completely avoided but the consumer can make informed choices if he or she knows it is there. Disclosure, of course, is the bane of the manufacturing business. Interest rate disclosure was the bane of the money lending business. Such important matters can't be left to “self-regulation” policies. The consumers must simply demand to know what they are consuming.

Ruby Adair, 14, ached all over, had ringing in her ears, sinus problems and chronic fatigue. She couldn't get to sleep, ever; and had been half a year out of school already. She had intestinal flukes in her stomach. In three weeks she had eliminated them with parasite herbs and she could go to sleep naturally.

Yeast Infections

The most common yeast in humans is *Candida albicans*. *Candida* has always been around. It flies in the air, searching for a place to land and reproduce. It can invade a variety of human tissues like the mouth (called thrush), skin (including some kinds of diaper rash), vagina, and the digestive tract. We all have some yeast in our digestive tract, but when it gets out of hand, it's called *candidiasis*.

Yeast is a **fungus**. It needs dampness to survive and sugar to grow.

Our immune system, white blood cells, are capable of eradicating yeast provided it isn't growing too fast. And provided the white blood cells aren't immobilized or preoccupied with something else.

Diaper Rash

A baby's rash is an example of the white blood cells being preoccupied. When chemicals are used in the diaper, the white blood cells go after the chemicals and let the yeast grow. Drying the baby's skin helps since the yeast must have dampness. This should be done with air, sunlight and a heat lamp, not with more chemicals! Certainly not with cortisone containing salves that further reduce the immune competence of white blood cells.

Use a heat lamp for five minutes at a time, several times a day. Switch to cloth diapers; do not bleach them with chlorine bleach, the residual chlorine trapped in the cloth is a chronic irritant, setting the stage for another rash and future chlorine-allergy. Cloth diapers should be sterilized, not bleached. Use the hottest water your laundry system is capable of producing. Add ½ cup borax for the washing process. If you have homemade Lugol’s iodine (made by your pharmacist or by yourself, see *Recipes*), add a tsp. to the wash or rinse. Vinegar is a yeast inhibitor, add it to the rinse. Dry diapers at the hottest setting. Dry to kill. Kill all the yeast spores in the diapers.

To strengthen the baby's skin against future infection, do not put chemicals on the skin. Do not use any soap, fragrance, bath oil, ointment or lotion. Do not use cotton balls or baby wipes. Do not give a daily bath. Wash bottoms gently, with borax followed by a vitamin C rinse. Vitamin C is acid and is our natural healing agent but it will sting on a broken skin surface. Use it as dilute as necessary to be tolerated. Zinc oxide is another natural healer because it competes away the iron that fungus and bacteria need for their reproduction. Never use commercially available zinc compounds though, simply purchase your own zinc oxide powder, mix it with cornstarch and keep in a large old salt shaker, dust it wherever there is moisture or fungus growth.

Treat Yeast or Fungus the Same

Other fungus growths, like *Tinea* (crotch itch), ringworm (not a worm at all), athlete's foot, along with *Candida*, can be similarly eradicated:

1. Deprive the fungus of moisture.
2. Deprive the invaders of iron.
3. Deprive the fungus of sugar.
4. Strengthen the skin's immune power.
5. Strengthen the skin's healing ability.

It may be impossible to deprive the fungus of moisture, for example if your feet sweat and you must wear socks. Take your socks off as soon as you are at home, treat your feet with a heat lamp. Use zinc oxide or cornstarch to powder and dry the skin. Boil your socks when laundering. Dry them to tinder-heat (too hot to touch). Launder with borax only (soaps and detergents contain aluminum which pollutes the skin). Rinse skin with vitamin C water. It takes all these measures used simultaneously to clear up athlete's foot fungus. And great persistence. They may have developed a foothold underneath the toe nail where a steady supply of moisture, iron and sugar is available to them. Nevertheless, your white blood cells will eventually gobble them up if you let them.

In thrush (yeast infection of the mouth) you must again outwit its growth by doing everything possible at one time. Eat no sugar, drink no fruit juice, stay off antibiotic. Avoid trauma like eating abrasive foods (crusts, popcorn, nuts, lozenges) or sucking on things. Floss teeth only once a day (using monofilament fish line), followed immediately by brushing with white iodine (or Lugol’s, but this may temporarily stain). Hydrogen peroxide is not strong enough. Remember to sterilize your toothbrush with grain alcohol or iodine. You may also rinse your mouth with Lugol’s (6 drops to ¼ cup of water). Or apply 6 drops directly to the tongue and rub it in lightly with your lips.

Do not use Lugol’s iodine if you have been told you are allergic to iodine.

Kill *Candida* daily with a frequency generator or zapper. Since reinfection is constant, you must continue to do all the treatments given to permanently cure yourself of fungus disease.

Since *Candida* grows right into your living cells (which you are not attacking!) you cannot kill it all at once. Only surface fungus can be accessed by either Lugol’s or electrical “zapping”. But as the top layer is killed, exposing the next layer, you will make progress. It will take a month of daily treatment to clear it.

Clearing up fungus at one location but not another will not bring you a permanent cure, either. Damp locations like under the breasts, under the belly fold, groin and crotch need to be kept dry with cornstarch daily. Keep it up long after it seems to be cured.

Fluke Disease

Flukes, or flatworms, have a complex life cycle with many stages. Although sheep, cattle, pigs and humans can be "natural" hosts to the **adult** stage, the other stages are meant to develop outdoors and in secondary hosts. When fluke stages other than the adult are able to develop in us, I call it *fluke disease*.

Or, when an adult that "normally belongs" to another species is able to develop in us, I also call that fluke disease. Or even with adult flukes in their "normal" host, when they move from the organ that they "normally" colonize to other organs in the body I call this fluke disease, too.

Four fluke varieties engaged in this extra territorial pursuit are the **intestinal fluke**, **sheep liver fluke**, **pancreatic fluke**, and **human liver fluke**.

As you can see from their names, scientists have studied them well, and know exactly which animals are the "normal" hosts, and which organ in that animal is the adult fluke's "normal" home. Fluke disease is when any of these is "wrong."

Flukes don't have eyes to see with or legs to walk with, so how can they find and travel to the organ they want in the middle of your body? Scientists do not know for sure. However it's concluded from many scientific studies that the liver fluke, *Fasciola*, for example, has no trouble seeking out and colonizing the liver.

Here are some examples of what can happen when flukes go "wrong:"

- Adult flukes (any of the four mentioned) in the uterine wall causes cramping and bleeding when it is not menstrual period time. If an adult crosses the wall to the inside and then manages to get out through the fallopian tubes to the abdominal cavity it takes some endometrium with it—causing **endometriosis**.

- If adults develop in the kidneys, it can cause **lupus** or **Hodgkin's disease**.
- If adults complete their cycle in the brain, **Alzheimer's** disease and **multiple sclerosis** result.
- If the intestinal fluke (*Fasciolopsis buskii*) becomes adult in the liver it causes **cancers** of many (hundreds) kinds.
- If the pancreatic fluke completes its cycle in the pancreas it leads to **diabetes**. This is not an example of flukes straying into the wrong organs, but of having its stages reproducing where they never could before.
- If flukes develop in the thymus, immunity is lowered. If it happens to be the intestinal fluke, **HIV** (Human Immunodeficiency Virus) is released there. In turn, HIV invades other tissues, like penis and vagina.
- These four flukes can also invade the muscles, causing **dystrophies**.

As dissimilar as we always thought these diseases to be, it's obvious to me that they are but one disease—fluke disease

Considering the size of these flukes (adults are easily visible), it is not surprising that they can quickly lay waste a human's organs. Yet a human is big and makes a valiant effort to kill the stages, block access to tissues and otherwise battle them.

But only the human's intelligence can be counted on to defeat them. The intelligent approach is to discover what enables these mighty monsters to do their reproducing in our bodies instead of the pond with its snail/minnow secondary hosts.

Flukes and Solvents

The explanation I have found for two of these flukes is the presence of solvents in our bodies. The presence of *isopropyl alcohol* is associated in 100% of cancer cases (over 500 cases) with reproduction of the intestinal fluke stages in a variety of organs causing cancers in these organs.

The presence of *benzene* is associated in 100% of HIV cases (over 100 cases) with reproduction of intestinal fluke stages in the thymus.

The presence of *wood alcohol* is associated in 100% of diabetes cases (over 50 cases) with reproduction of pancreatic fluke stages in the pancreas.

The presence of *xylene* and *toluene* is associated in 100% of Alzheimer cases (over 10 cases) with the reproduction of intestinal fluke stages in the brain.

Much more work needs to be done to examine the relationship between fluke reproduction, the solvent and the chosen organ. But it seems probable that the solvent allows it all to happen. And our intelligence, to save us, must find a solution.

Stopping use of these solvents seems to me to be the most urgent advice. Finding which foods and products are polluted with them is the first step. It is imperative that you test everything you use or eat for solvent pollution. The Syncrometer makes that an easy task. Ideally, we should all pool our results, adding to the body of knowledge I have begun.

In my observations, when the big sources of solvents are stopped, the body's levels go back to zero. In other words, the minute amounts that we inhale here and there do not accumulate to the point of serious damage. We have to eat, drink or absorb them on a daily basis to injure us! So where can they come from?

The sources of benzene and propyl alcohol that I found are given in special lists (page 354 and 335). The sources of wood alcohol are not as well known, but include commercial beverages, cold cereals, artificial sweetener, vitamins, and drugs. Other solvents are even less studied. But a pattern is emerging: foods and products that require sterilization of bottles and machinery to fill these bottles are polluted with propyl alcohol or wood alcohol. Foods and products containing flavorings or oils are polluted with benzene. Let the buyer (you) be wary! Test your own products if possible. If not, do not purchase them.

There are many other flukes and many other diseases. Are there other fluke/solvent/disease trios? Has fluke disease been going on for a long time or is it a recent phenomenon? Certainly cancer is 100 years old, so is the use of propyl alcohol. Diabetes is quite old as an illness, too, and so is its associated solvent, wood alcohol. But HIV, AIDS and Alzheimer's are recent diseases. Should we conclude that benzene, xylene and toluene were used much less in the past?

Fluke diseases could be eradicated with some simple actions: monitoring of solvents in foods, feeds and products. Hopefully, this will begin. It is in the interest of the consumer to have her or his own independent way of monitoring too. Chemical ways can be devised, besides the electronic way presented in this book. Imagine a small test strip like a flat toothpick which turns color when in contact with propyl alcohol. Keep a pack in your pocket and never be unknowingly dosed again...all in tomorrow's world.

Flukes Not Alone

There are other families of parasites. The roundworms and tapeworms are gaining ground too. Are they associated with solvents? Or with yet undiscovered factors? Are they changing their life cycles to take advantage of our lowered immunity? These are important questions. But you are armed with excellent technology. The answers will be found.

And along with answers there will surely develop a new industry. An industry that not only proclaims purity for its products but provides the proof to your satisfaction.

Burning And Numbness

Burning sensations in the skin let you know that nerves are involved. Mercury is the most common offender. Mercury may have started the trek of a host of other toxins as well into your nervous system: pesticide, automotive chemicals, household chemicals, fragrance and even food chemicals. Some people can get a burning sensation after a car trip, some when exposed to perfume, some when walking down the soap aisle in a grocery store. When the affected nerves don't go to skin but instead go to an organ like toes, you might feel a toe cramp or finger cramp instead. Remove your mercury sources.

Burning skin is an ancient malady—maybe even the basis of concepts like “hell.” St. Anthony's fire was caused by *ergot* (food fungus) ingestion. Molds don't necessarily come singly. Maybe other mold toxins can go to your nerves, too (see Moldy Food, page 381). Maybe the mold toxins interfere with **pantothenic acid** used by your body, because giving pantothenate (500 mg three times a day) can sometimes relieve the condition and, of course, this is good for your body.

Monosodium glutamate (MSG) can cause burning, especially of the face and lips. Sometimes swelling occurs too. MSG is used as a flavor enhancer. It was found decades ago to be a brain toxin and was taken out of baby food. But what about adults? Especially those who already have a brain problem. Throw it all out of your kitchen. Ask at restaurants which foods have it.

Numbness has a similar cause. Numbness of fingers or feet has become quite common since thallium and mercury toxicity has spread so widely.

If you have burning and numbness, can multiple sclerosis (MS) be far away? Remove all the metal in your dentalware immediately, replacing with composite (see Dental Cleanup, page 409). Hopefully, your immune system is still strong enough to clear the bacteria growing around the metal and in pockets in the jaw. Check and clean cavitations. Start your jaw healing with the milk, magnesium, vitamin D diet. Use thioctic acid to help clear your tissues of remaining metal (3 to 6 a day).

The most common nervous system bacterium is *Shigella*. Its beginning can already be seen in cases of burning and numbness. It is deeply entrenched in cases of MS. Three kinds of *Shigella* are readily obtainable on slides: *Shigella dysenteriae*, *Shigella flexneri*, *Shigella sonnei*. *Shigella flex* causes depression and irritability. All can cause gas and bloating. Zapping doesn't kill all of them because they inhabit the bowel. You must empty your bowels frequently, two or three times a day. And do the Bowel Program until all symptoms are gone. Be very careful not to put contaminated dairy food in your mouth again. Boil all milk products. They must be at boiling point for 10 seconds. This includes cheese, cottage cheese, buttermilk and regular milk. Eat only home made yogurt or home made buttermilk. Butter and whipping cream need this treatment, too. Never use raw dairy products.

Nana Hughes, 48, had numbness of the whole right arm, hand and right side of her head; it was particularly bad in the last four months. She was toxic with PCBs, titanium and dysprosium (paint). She was on thyroid, Xantac™ (for stomach) and chlorazipate medicines. We also found dog heartworm (she had chest pain over the heart). She started on the parasite program, stopped using nail polish, and stopped all detergents for dishes or laundry. In three weeks her numbness was greatly reduced. She still had titanium buildup from dental metal (a partial bridge). Seeing she was on the right track, she stopped use of MSG in her food, switched from concocted beverages to milk and cut down on her smoking. She brought her arm pretty near to normal.

Maria Santana, 45, had numbness in both arms; they would tingle and "go to sleep" a lot. It was spreading to one leg. Her muscles were toxic with thallium. It was in some very old pesticide, still effective and still in use in the house. It was also in the well water, probably, from pesticide seepage. She went off all commercial body products, did a kidney cleanse and killed parasites. She had difficulty getting rid of *Prosthogonimus* but in two months she had everything cleaned up. Her legs, arms, sleep problem, urinary tract problems were all gone and she could focus on her last problem, digestion.

Candy Donaldson, 44, had numbness from her shoulder to the wrist of one arm, it started a year ago. She was toxic with iridium, lithium and vanadium from a gas leak. She was advised to stop caffeine use and switch to milk (her calcium level was low: 9.0 mg/DL) and a magnesium tablet (300 mg daily). Her triglycerides were high, implying a kidney problem. She had urate and phosphate crystals in her kidney. She decreased the phosphate in her diet (meat, nuts, grains, soda pop) and started the kidney cleanse. When the gas leak was fixed, both her lithium and vanadium toxicity disappeared. In six weeks she had also killed parasites and her periods became regular for the first time. An ovarian cyst had disappeared, too, as checked by ultrasound. Soon her PMS was gone, including hot flushes. After four months she had done three liver cleanses and suddenly her numbness improved. After a few more there was no numbness at all.

If cleaning cavitations brings you immediate improvement you know that these bacteria were part of the problem. Have them checked again if problems return; dental bacteria are notorious for returning. If kidney cleansing makes it worse for a day and then better, you know kidney bacteria are partly responsible. If liver cleanses (page 552) make matters worse for a day and then better, you know bacteria are entrenched in the liver. Continue cleansing until none of these sources exist any longer. Kill all bacteria at least once a week electronically. Burning and numbness can be cured, not just arrested. In other words, your nerves can be cleaned up and healed.

Depression

All persons I have seen with clinical depression had small roundworms in the brain. Is it any wonder the brain can't make enough neurotransmitters or gets them out of balance? The usual worms are hookworms (*Ancylostoma*), *Ascaris* of cats and dogs, *Trichinellas* and *Strongyloides*.

Although it is commonly believed that hookworms penetrate the skin when walking barefoot on earth, this appears to be a negligible route. The important routes are eating animal filth and inhaling filthy dust. Our pets pick these worms up daily. We get them and give them in constant exchange with our pets and family members. Diapering babies is an especially hazardous, though necessary, business. Letting little children clean up after their own bowel movements is even more hazardous. Hands should be sanitized with grain alcohol after dealing with bowel contents, whether your own, your child's, or an animal's. If you clean up a messy diaper and then your hands well with soap, then go to make the chopped salad for dinner, you're sure to give each family member a dose of whatever the baby has. It was hiding under the fingernails. Animals clean up the easy way: they simply lick the youngster's bottom. But, we humans are not strong enough to take on a dose of bottom with each meal. **We must sanitize our hands**.

Cleaning bathrooms is also dangerous. Wear gloves. If nobody suffers from depression, you can use bleach (stored in the garage) to disinfect the stool, otherwise use alcohol (50% grain alcohol). Keep doorknobs and faucet handles wiped with alcohol, too.

If you suffer from depression use your zapper to immediately kill these four roundworm species: *Ancylostoma*, *Ascaris*, *Trichinella* and *Strongyloides*.

Other family members should be cleared of these four worms on the same day or as close to it as possible. Reinfection always occurs. In the depressed person, the microscopic parasites travel immediately to the brain. In others, they may simply reside in the intestine or lungs or liver, or other organs. Pathways (routes) to the brain have become established for the depressed person. These must heal before there is any tolerance to reinfection.

Solvents and other toxins, also in the brain, slow down or prevent healing. For this reason the depressed person should do the *Four Clean-ups*.

The bacteria of the *Shigella* family are always seen in depression cases. Kill all *Shigellas* and avoid reinfection by boiling dairy products and not eating those that can't be boiled. Go on the Bowel Program (page 546). Do not eat deli food or hand prepared salads at salad bars. Finally, do the Liver Cleanse, repeating every two weeks. Depression, even of long standing, can lift within days after the brain finally has its territory to itself. Look in the mirror and smile at yourself for your success in vanquishing your invaders. Never again, let these creepy crawlers into the happiness-center of your brain.

Manic Depression

This variety of depression is associated with *Strongyloides*, as the main parasite in the brain. Plus **chlorine** as an allergen! *Strongyloides* is the same worm that causes migraines and other severe types of recurrent headache. It probably depends on where these tiny worms have set up their “housekeeping” which symptoms you get: manic depression or migraines. Maybe chlorine is the deciding factor.

These tiny wormlets can pass the placenta into the unborn fetus. Is it any wonder that these brain disturbances seem to be inherited? Of course, there is ample opportunity to simply eat them off hands, other people's hands, and off floors during childhood. The amazing truth is that some family members do not get infected with it or at least do not get brain symptoms! It is very difficult to eradicate *Strongyloides* in a whole family and thereby let the depressed person get well. It is, in fact, impossible if there is a pet or other animal connection. Getting rid of the chlorine allergy is also very challenging. Step one is to zap all parasites.

I usually see an accumulation of **bromine** as well. Since bromine, fluorine and chlorine are all *halogens,* maybe getting too much of any one could saturate the liver's ability to detoxify chlorine. Stop eating brominated (bleached) bread. Stop taking drugs containing bromides. That is the easy part. You must also stop even washing your face in chlorinated water (use a pure carbon filter system). You inhale it as you wash. Never drink it or use it for any purpose. Of course, there should be no bleach container in the house, even when tightly closed; nor should bleached clothing be worn.

Do the *Four Clean-ups*. Sometimes the cloud lifts and the mind clears on the way home from the dentist. Recovery can be very rapid—less than a week. And recurrence just as rapid when a tiny bit of chlorine is inhaled or drunk. But your careful vigilance pays off. In half a year you can expect no recurrence.

Humans, it seems, must lick fingers with the same compulsion that cows lick their noses and cats lick their rears. The single, most significant advance in human hygiene would most assuredly be stopping the hand to mouth habit. We must always eat with utensils. And never leave a bathroom without washing. These are difficult changes but the new age of parasitism makes it necessary. Together with the new pollutants, solvents, and heavy metals, parasites will overtake us unless we change.

Don't go off lithium and other medicines until your doctor agrees you are ready, about a half year. After this, make sure you still keep it handy. Although you may be free of manic depression in a day, reinfecting yourself weeks later will attack your brain like a hurricane; it has not yet healed, the routes are open. Be patient; healing will happen as it did for these happy persons.

Lena Constantine, age 39, had a history of migraine, TMJ, heavy clotting with periods and numerous pains but it shouldn't have made her try suicide 1½ years ago. She was put on Prozac^{TM} afterward. She was parasitized by intestinal flukes (in the intestine), dog whipworm, *Strongyloides* and human liver flukes. She was started on a parasite program and kidney cleanse. This made her feel so good she took herself off Prozac^{TM} and landed in the hospital for reasons she couldn't remember. After 42 days spent there she got out, wiser than before. She set to work again, leaving no detail undone, because she could remember how good it felt to be free of depression (not drugged out of it). Three months later she still had *Strongyloides* (she had a cat) but she did her first liver cleanse anyway. She got over 500 stones out. Her depression was gone. She substituted 4 ornithine and 2 ginseng capsules daily (more if tension was not relieved) for Prozac and cured her problem.

Mona Zabala, 33, was extremely depressed over her job. She was full of mercury, arsenic, PCBs, chromate from eye liner, wood alcohol from drinking colas and she had *Ascaris*, pancreatic flukes, *Trichinellas* and *Strongyloides*. She thought she was a hopeless case. But in less than three months, when only half her clean-up chores were done, she was already saying positive things about her job.

Acey O'Hara, a young graduate student, was very careful to avoid junk food, caffeine, fragrance, and body products because he had learned the hard way that he didn't tolerate them. When “crying” depression hit him he was not only surprised but angry that his good health habits “hadn't paid off.” He was buying his drinking water; it came in clear plastic containers. He had cesium in his tissues and brain. When he switched back to plain tap water (filtered in small quantities) the depression lifted in a week and he was no longer crying over anything.

Leisa Underwood, 46, was clinically depressed and in therapy. She believed it was due to going through menopause. She had a heavy burden of *Strongyloides* but no other worms. Only one of her two dogs had *Strongyloides* (saliva test) and the cat was free of them also. She was full of cesium (from drinking refrigerator water) and vanadium (from a gas leak). In two months she had accomplished the impossible: all pets and herself were free of *Strongyloides*, they had repaired three gas leaks and her depression was just a memory.

Roland Greeley was diagnosed as manic depressive a few years ago and was put on Ativan™ and Prozac.™ This controlled him but did not relieve depression. He had a prominent tremor. He had *Ascaris* and sheep liver fluke stages in the brain. Also *Trichinella*, *Strongyloides* and human liver fluke stages. Styrene (from styrofoam cups), methyl ethyl ketone (beverage) and carbon tetrachloride were in his brain also, probably setting the stage for parasite reproduction. He had high levels of mercury and silver but highest of all–throughout his body–was chlorine (from bleach and tap water). In four weeks he had all the metal removed from his mouth. He stated that this “unchained” him. He could already tell on his way home from the dentist that something special had happened. His depression was simply gone “the way you lift a blanket off a bed”. He resolved to clean up his whole body and recover from his illness using logical methods, like ours. Staying away from regular chlorinated water was a fine challenge to his resolve but with whole house filtering now available he may have done it.

Darren Knox, age 48, had been on Thorazine™ for 36 years but was recently changed to Desyral™ and Valium™ and lithium. He had *Ascaris* and hookworm and two dozen more assorted parasites including fluke stages. His brain was also hosting *Bacteroides* and *Nocardia*. All parasites were killed in half an hour by frequency generator at his first visit whereupon he immediately announced himself free of depression; better than the last eight years. He had many metals in his brain, also chlorine. In four weeks his tremor was way down, after dechlorinating his tap water. His depression never came back after dental work was done.

Schizophrenia

Much more mold toxin was seen in schizophrenic families than in other kinds of illness. They usually had four or more kinds of mold toxins at the same time, meaning that one toxin was not detoxified before the next was already eaten. It may reflect on the liver as much as the food selected. The initial injury, though, to the liver may have occurred in early childhood.

Schizophrenia does not require mercury or other dental metal pollution for its expression. This pattern is logical when it is seen that young children can have schizophrenia. Schizophrenia is an ancient illness, being described in some very old literature, before dentistry existed. But parasites existed. And moldy food existed. And copper existed!

Ergot is always seen in sick persons. Other mycotoxins are also present, including *sterigmatocystin*, *cytochalasin B*, and *aflatoxin*. As the mycotoxin panorama changes, brain symptoms can change from compulsive hand washing to paranoia or from hearing voices to meanness in disposition.

It is my belief that the current increase in violent crime in U.S. society can be attributed to the especially high levels of mold consumption in foods and beverages, with the resultant effect that behavior erupts into violence with almost no provocation, merely some frustration. It would not be difficult or expensive to experiment with a mold-free diet in our prisons.

A bacterium, *Mycobacterium phlei*, may also be a cause because I have seen a high correlation between it and schizophrenia cases. What its specific effects are, I don't yet know. This bacterium may be hiding under teeth. It is also seen in dogs.

Shigella bacteria from nonsterile dairy foods are part of the problem, too. They produce brain and nerve toxins resulting in irritability, depression, anger. In fact, anger can be so intense, it erupts in violence.

Lead and copper are commonly seen in schizophrenia sufferers. The usual source for these is the household water (household plumbing may have lead solder joints). Change plumbing to PVC, then take thioctic acid (100 mg, twice a day).

Parasites always found in schizophrenia are hookworms (4 *Ancylostoma* varieties) in the brain.

Instructions:

1. Stop eating all grain products, nut products and syrups immediately.
2. Sterilize all dairy products.
3. Search for lead and copper in the water.
4. Stop drinking commercial beverages, including bottled water.
5. Zap the parasites in the whole family for three days, followed by repetitions twice a week.
6. Eliminate *Shigellas* with the Bowel Program (page 546).
7. Give away pets. Schizophrenia is too serious to risk reinfection.
8. Do the dental cleanup (page 409).

The need to zap repeatedly arises from reinfection. Nothing needs to be killed twice. But reinfection from self, family members, pets and food happens every hour. One cannot rely on zapping to stay well. Do a thorough diagnostic search of all foods eaten at the last meal, the water drunk, the air breathed. Only when all these are clean, will the brain heal.

When can you eat grains again? When you are well. Find a cereal or pasta that has no mold. Test it for the mold frequencies (77, 88, 100, 126, 131, 177, 188, 232, 242, 277, 281, 288, 295

KHz). Search especially for ergot (295). Remember, ergot makes *lysergic acid diethylamide* (LSD), not a good thing for a schizophrenic brain. Honeys, too, have ergot. Ergot takes longer (up to 20 minutes) to detoxify with added vitamin C. (Read the section on Moldy Food, page 381). If you become ill again after starting grains, go off again. Take 500 mg. niacinamide 3 times a day to speed up ergot detoxification by the liver. Avoidance is much easier.

Healing of the brain is very rapid; in less than one week feelings and behavior are more normal. Perhaps there are herbs that hasten healing; considering how old the illness is, there must surely be several useful herbs. But considering that herbs, too, can be moldy, be very careful to search for molds electronically before using any herbs. Blue vervain, sage, and ginseng are herbs worth trying.

A question may have popped into your mind as well as mine. If the whole family is eating moldy food, why aren't they all schizophrenic? In fact, family members usually do suffer from some symptoms that are similar to the victim. But every person's collection of parasites and pollutants is unique. Certainly, the whole family should obey the moldy food rules, in order to function better.

Autism

Childhood brain disorders suggest an inherited genetic defect. Yet numerous parasites and pollutants are able to pass into the unborn child through the placenta. Even some bacteria and viruses can.

Lead accumulation is always seen in children with autism. Was it acquired before birth?

Mercury can be transmitted from mother to child, too. If mercury fillings were not removed before pregnancy, have them replaced as soon after delivery as possible (never during pregnancy since the removal itself causes a surge of heavy metal to enter the body).

The common tiny worms such as *Ascaris*, hookworm, *Strongyloides* and *Trichinellas* easily enter the brain. They are present in dirt. Dirt enters buildings via shoes. Shoes carry animal filth. Don't let children put their own shoes on until they have learned to avoid touching the soles. Don't let your child crawl on the floor of a public building, even though it looks glossy. Don't set shoes on furniture or table! A preferred habit is to leave shoes at the door.

Once wormlets have found a pathway to the child's brain it is difficult to reroute them. They must all be killed repeatedly since there is daily reinfection from putting hands in mouths. All family members should kill these parasites weekly to protect the child with autism. When lead and parasites are gone consistently for several weeks the pathway to the brain heals and reinfection no longer sends them to the brain and your child can resume a normal life.

I have not treated enough cases to point to a particular parasite or pollutant. For this reason you must do a total cleanup: body, environment, dental, diet (especially solvents and molds).

Leon Dickson, age 10, appeared normal at birth but he crawled and walked late. At age 3½ he began having seizures and was also diagnosed with autism. (Seizures are caused by *Ascaris* larvae, they probably began the routing to the brain). He was started on Phenobarbital™ by his clinical doctor; switched to Dilantin™ then two other drugs were tried. Now he was on Tegretol™ plus Depacote.™ The mother used no anti nausea medicine during pregnancy, no caffeine, no alcohol or nicotine, not even a single aspirin. In spite of his medicines he seemed to have headaches, continued to have seizures which disturbed his sleep and he wasn't trying to talk. He vomited a lot. He would take no pills or drops (no herbs even mixed with honey) and our frequency generator method was not discovered at that time. He couldn't kill his parasites and *Shigellas*. His brain was full of thallium (not mercury!)

besides the roundworm larvae. He must have gotten this from Q-tips™ or cotton balls or some other mercury-sterilized product. Leon's favorite food was grilled chicken which he ate nearly every day, as well as two eggs a day.

His diet was changed to exclude chicken, eggs, bacon, chips, preservatives and colors in foods, grape jelly and strawberry jam. One month later he had not improved, nor had they been able to kill his parasites with the herbal recipe. The diet change was extremely difficult; he was screaming for his favorite junk food and the whole family was upset over his restrictions. But we encouraged the mother to stick to her purpose, get a different baby-sitter who would obey her, and to try to get some parasite herbs and thioctic acid (100 mg. daily, stirred into honey, to take out lead) down him. The first week the new baby-sitter succeeded in getting him to take thioctic acid. He had only one seizure that week. This encouraged the mother to enforce the parasite program and the diet rules. He became attentive in one month and tried to voice sounds.

The problem with eggs is that they are contaminated with *Salmonellas*. I find, however that it is the outside of the eggshell and the carton that is contaminated. The safe way to handle eggs is to remove them and return the carton to the refrigerator, then wash the eggs and your hands before cracking them. Eggs also contain malvin, a known seizure trigger.

Kirk Peeples, age 5, did not have any words yet but he would point to something and voice M-M-M to mean he wanted it (usually food). He was in a special school and “doing well.” He had the brain toxin MSG, and antioxidants BHT and BHA accumulated in him. In other words, his liver was not able to detoxify these common food chemicals. At that time, I had not found the mold toxins yet; I would now surmise that they were responsible for the liver's disability. Besides going off these food additives he was “desensitized” to them with homeopathic drops by an alternative allergist. The result was immediate. In one week he tried several new sounds and managed his first word: “box.” After killing parasites with the herbal program over a four week time period he could speak 19 words. The parents were bewildered with joy. They cleaned the toxins out of their home so thoroughly, there was no place to sit and nothing familiar to eat. But their son could say things and the parents loved each new sound as if it came from a newborn baby. In two months he was saying two-syllable words and putting phrases together. He needed us no more (he was on homeopathic thyroid drops, too).

Geoff Berkely was diagnosed autistic. He went about his business of examining everything in the office without a word. He was infested with both species of *Ascaris* (there was a pet dog) and was started on the herbal parasite program: just a little less than the adult doses. (Children's' syrups are not as effective.) He was toxic with mercury, too. He had 2 or 3 “baby” root canals. These were to be pulled out. He was also taken off food color, MSG, chicken and eggs. The parents accomplished all this very quickly and called to say their child had become normal but they didn't want us to spread the good news to the “autism” club they attended for fear of criticism for doing unorthodox things. Only in the USA could such thinking occur!

Digestion Problems

Burping, bloating, and being gassy are signs that your digestion isn't perfect. What has gone wrong? Burps are gases escaping upward. Bloating is due to bubbles of gas causing pressure. Your body does not make gas! Gas can only be made by bacteria. The immediate conclusion is that bacteria are growing in your digestive tract (stomach and intestines) that should not be allowed to do so. They are likely to be the common enteric (digestive tract) bacteria: *Salmonellas*, *Shigellas*, *E. coli*, *Bacteroides fragilis*.

You may wish to identify them before killing them with the zapper. Or you can sweep through the whole bacterial and viral range killing all with a frequency generator. The good effects can be felt in an hour, although the last gases may take days to get rid of. *Salmonella* and *Bacteroides fragilis* are two bacteria that can eat bile, and can do without oxygen, so they are commonly seen in the liver. *Bacteroides* probably escaped from its roundworm host, *Ascaris*. *Salmonella* probably came with non-sterile dairy food.

If you have an intestinal problem involving digestion or pain, start immediately to boil all dairy foods. Stop eating those that can't be boiled: cheese sandwiches, yogurt, ice cream. It must be boiled for 10 seconds. The bacteria are in the liver because your liver attempted to strain them out of your blood and lymph in order to kill them with bile. Instead, they turned around and “ate” the bile, turning it brown as evidence. Now, every time the liver lets down bile into the intestine (and stomach), a population of these bacteria goes with it. The intestine becomes a seething mass of bacteria, bubbling away as they produce CO_2, SO_2, H_2S, CO (carbon dioxide, sulfur dioxide, hydrogen sulfide, carbon monoxide). Some of these gases are quite toxic.

Help your liver expel its bacterial overload with liver cleanses (page 552) until all the bile is a beautiful bright green. This is evident as dark brown bowel movements. Without the green color of bile added to your intestine, the bowel movement remains light colored, such as tan, yellow or orange! By stopping eating polluted food, killing bacteria and cleansing the liver, digestion becomes normal again.

Of course, there must be enough acid in the stomach and digestive enzymes produced to make good digestion possible. Otherwise, leftover food goes to feed the waiting bacteria.

Persons with a chronic digestion problem may also find they harbor lead, cadmium, or mercury in the intestine! This is very good in a sense. Your body has kept these toxins in the intestine, preventing it from getting into your vital organs. The bad news is that their presence in the intestine could start an intestinal disease. Toxins in the intestine would inhibit your immune system (here the white blood cells are in clumps called *Peyer's patches*), from gobbling up the “bad” enteric bacteria. Maybe the "good" bacteria found your intestine too toxic to live there. Clean up your dentalware. Search for lead and cadmium in your drinking water. After improving your lifestyle, continue to do liver cleanses. Keep your goals high: a flat tummy that feels energetic, no burps or gas.

Stomach ache (page 98) and **hiatal hernia** (page 133) are also digestive problems but are dealt with under pain. (See also lower abdominal pains, page 97, and appendicitis, page 100).

Alan Barth had his two young sons with him. One of them had a very sensitive stomach, a poor appetite, wanting nothing but sweets or chips to eat. The 16 year old had aches and pains that were keeping him out of sports. The father had a tonsil problem; they swelled if he drank milk. One problem was obvious. Their milk was tainted with *Salmonellas* and *Shigellas*, setting up throat problems for the father, stomach problems for one child and a pain syndrome for the other child. Boiling all their milk, not bringing raw chicken into the house (*Salmonella* Source) and stopping eating yogurt and cheese was the solution. There were traces of lead in their tap water and the house air had vanadium in it, announcing a gas leak. They were all heavily parasitized. When these problems were cleaned up, the whole family's health improved.

Kae Nakajima, middle age, had a history of ulcers and stomach problems. She took a lot of Zantac™ and Tagamet™ over the years. She was drinking coffee, tea and colas. She had *Ascaris* and cadmium in her stomach. Five months later she had cleaned up everything except dentalware and was feeling very good. She didn't need any medicines. She still had arthritis and sinus problems but felt so encouraged she had the dental work scheduled.

Sven Lippencott, age 4, had been tube fed for several years due to weak stomach action. He was quite underweight for his age. He had a population of intestinal fluke in his stomach along with arsenic (pesticide). The rest of the family also had intestinal flukes. After killing parasites and washing the upholstered furniture, Sven's appetite went up so he ate more by mouth and grew immediately. But he soon picked up *Ascaris* and cat liver fluke (there was an indoor cat). Then the whole family got intestinal flukes again. They all, including Sven, drank carbonated beverages *ad* *libitum* (whenever they wished). With both parents working it would not be possible to discipline the habit. Sven had wood alcohol, methyl butyl ketone, hexanedione, methylene chloride and toluene buildup making his recovery hopeless.

Alzheimer's

What was once a rare disease has become a household word because it now affects so many. Two new pollutants of the brain, inviting an old parasite to a location it would not normally be, is the explanation. The new pollutants are solvents that seek the brain.

Xylene and **toluene** are pollutants of popular beverages, decaffeinated powders and carbonated drinks. At first, the body can detoxify these but with a steady stream of solvent arriving, detoxification slows down and parasites begin to build up in the brain. Common fluke parasites which we eat in undercooked meat and perhaps get from our pets, can now reach the brain and multiply there.

Other toxins are also present, such as aluminum, mercury, freon, thallium, cadmium. Aluminum buildup is seen in all Alzheimer's sufferers (100%). This is undoubtedly part of the true cause. Did it come before or after the parasites?

Whatever the answer, your job is clear. Remove every bit of aluminum from the food and environment. Throw out the pots, the aluminum foil, the cookie sheets, the tea ball. Throw out the kitchen salt, the pickles, the baking powder. Buy things made with baking soda (not baking powder), use a plastic salt shaker, buy salt without added aluminum. Stop using commercial soaps and lotions. Make the soap recipes in this book. Finally, tape over all aluminum handles in the bathroom and elsewhere (e.g. the walker) with masking tape. Then find a chelating doctor to help remove aluminum from the brain. Also use thioctic acid (100 mg; take 2 three times a day).

Kill the four common flukes with the first frequency genrator or zapper you can get your hands on. Prevent reinfection from meats and pets. Stop all commercial beverages, including water. The processing has left xylene and toluene in them. They are not put in intentionally. For the same reason, health food beverages are similarly polluted. Only milk is safely bought from the store. You must still sterilize it, however. Make your own fruit juices. Select beverages from the list of recipes given. Drink water from your cold water tap, filtering it with a small pure carbon filter as in a filter pitcher (see *Sources*).

As much as xylene and toluene are brain-seeking solvents, *Shigella* is a brain-seeking bacterium. The symptoms it causes are not always the same since they depend on the location of infection. Sometimes they cause tremor, sometimes loss of balance, sometimes speech problems. But they are very serious problems. Kill *Shigellas* every day at bedtime with your zapper. Start the Bowel Program (page 546). When improvement is lasting you know you have stopped reinfecting from your own bowel or from polluted dairy products.

Remove dental metal and use thioctic acid as a help to clear tissues of metal. Use vitamin C (3 grams) and B_2 (300 mg) to assist the liver with detoxification. Use B complex (2 a day) to assist the liver generally. Avoid food molds; ergot especially has strong mental effects (see Moldy Food, page 381).

Start a kidney cleanse (page 549) as soon as you can. Follow this with a liver cleanse (page 552). Clean up environment and diet. Your beloved family member or friend with Alzheimer's can regain her or his mental function to a considerable degree. **Most important is stopping the mental deterioration** before it is not reversible.

Lisa Anne Reed, 60ish, was tentatively diagnosed with Alzheimer's 10 years ago. She needed complete care at present but was able to walk (could disappear quickly) and eat. She could occasionally say her name. Her brain had intestinal flukes and their eggs and was toxic with aluminum (cooking pots) and aluminum silicate (salt). One week later she still had the parasites because nobody could skillfully give her the parasite program. She was also toxic with benzene so reinfection was occurring. In addition she was toxic with bromine (from brominated bread?), chlorine (chlorinated water?) lithium, bismuth, vanadium, and tungsten, all known to have strong brain effects. She was also toxic with moth balls and iridium. She harbored *Naegleria*, another brain parasite. In another week there still were no changes due to inability to administer the treatment.

Isabelita Ufford, 77, was in a wheelchair, brought by her two daughters who took turns caring for her. She was on Clanopin™ medicine, did not try to speak and needed total care, including feeding. She had been ill about seven years. She had intestinal flukes and their stages in her brain (the cerebrum) as well as intestine. She also had isopropanol solvent, aluminum, chromate and high levels of arsenic in her body. She was given the parasite herbs plus instruction to get rid of solvents and metals but the plans could not be carried out. The parasites could not be killed without considerably more help than was available. She was a dear, sweet person. The daughters were highly motivated but were overwhelmed with the size of the task.

Beth Hamm, 60ish, arrived led by her ever-vigilant, ever-caring husband. She was started by medical doctors on EDTA chelation to remove aluminum from her brain. My tests showed aluminum, toluene, sheep liver flukes, asbestos and *Shigella* bacteria. The parasites and bacteria were zapped immediately and her husband began the difficult task of excluding non-sterile dairy products from the diet provided. In four days she was able to walk by herself, knowing where she was going. She could finish a short sentence and comply with directions to sit down and get up. Then she had a set back—she had acquired *Salmonellas* in the brain from a bit of dairy food that had slipped by his attention. She was given Lugol's and she improved further. In ten days she was a new person; an interview of twenty minutes length did not reveal Alzheimer symptoms. Will she be able to hold on to her gains? Only if the aluminum and asbestos are removed from her home environment, his vigilance with dairy food keeps up, and she stays on a maintenance parasite program. But her husband appeared intent on her recovery. She is a person again. And there seems to be a delightful companionship.

Ruben Camberos was brought by his wife and a friend for Alzheimer's. The first day he arrived, the intestinal flukes in his brain were found and killed. He was started on EDTA chelation. They were warned about non sterile dairy foods. His *Shigella* was zapped. Four days later he spoke his first meaningful sentence: it was three words long. He could pay attention to the appointment proceedings. Two days after that he was reading a newspaper. This was utterly shocking to his wife. In another three days, he could hold a conversation consisting of very short sentences. Larger ones became hopelessly garbled. He was started on ornithine (4) and valerian capsules (6) at bedtime: this produced a beautiful nights sleep (especially for his caretakers!) and his days were less agitated. There were still setbacks later but his wife was determined to get him well.

Dementias, Memory Loss

Memory loss is progressive with age but not due to aging. There are plenty of nonagenarians and centenarians with clear minds and good memories to prove that age is not the deciding factor in the dementias. Why do some people deteriorate much sooner? Could you prevent personal deterioration of mental abilities? You probably can. You will know it by noticing memory improvement. Telephone numbers that left you with no recall, unless you wrote them down, number by number, now form groups as you hear them, and you can jot them down the way you always did! This is a good sign of memory improvement. Your writing can improve. The jagged, crooked, misaligned words can be smoothly written again! You can remember things that happened earlier in the day and talk about it later, at mealtime. You can finish your thoughts in conversation.

Mental deterioration of the elderly is not as complicated as is generally believed. Although circulation and blood pressure play a role, **the effect of toxins is much greater**. The action of toxins is greater in age than in youth. The same polluted water and food causes disorientation in the elderly when it only gives a young person a stomach ache.

The liver's detoxification capability may be the real issue. Indeed, the liver may age, in accordance with the calendar date. Perhaps the liver is the only truly aging organ. It may even determine your life span. The answer, then, is to stop giving it toxic substances and shortening your life span.

As the liver is less able to detoxify them, common toxins are allowed to roam the body with the circulation, doing harm to all the organs. The brain feels disoriented or dizzy; there is memory loss. At first, the liver can “catch up” its work and finally clear the toxin for excretion. But, eventually, it can't catch up or keep up. The body, notably the brain, is bathed in toxic chemicals that interfere with its functioning. Now, the elderly person must use a cane for stability, must walk very carefully not to fall, must write everything down to remember it, calls people by their wrong names, can't “find” the right words to speak with, can't finish sentences, must write on a calendar to keep the days straight, starts talking to themselves to help think of things, develops tremors and unsteady gait, acquires a passive personality, loses weight, gets stooped, stops reading the newspaper.

All these signs of aging (dementias) can be reversed by simply removing the common toxins with which we are already familiar.

Of primary significance are food molds. These cause brain hemorrhages. Clean up diet, mouth, body, environment, very meticulously.

Of course, an elderly person cannot bring these changes to herself or himself. If you have a loved one with symptoms of aging, and this person is willing to cooperate with you, you can honestly promise them numerous improvements. Spend a good deal of your effort on persuasion since living longer or being healthier may not seem worth giving up a coffee and doughnut breakfast. On the other hand, they might respond to the goal of needing fewer pills, getting into their own apartment again or becoming freed from a walker.

Walter Heffern, 64, had been to various neurologists but could not find any help. He appeared to have the same kind of mental deterioration as his mother, but at a much earlier age. He couldn't understand an ordinary conversation; he constantly spoke about winning money, walked hesitantly and had to be left undisturbed to accomplish anything—even eating and dressing. He needed a lot of care. We found he had *Ascaris* larvae in the brain—in the cerebrum, where you think. He also had *Acanthocephala*, *Dipetalonema* (a chicken roundworm), amoeba (*Entamoeba histolytica*) and *Fischoedrius* in the thinking part of his brain. He had been in the poultry business all his life: his mother probably shared this exposure, as well as other lifestyle habits that gave them solvents and pollutants besides parasites. He had constant ringing in his ears, this could affect hearing an ordinary conversation. He had a water softener that would have supplied a daily dose of aluminum to the brain, too. There always were dogs in the house. Perhaps the marvel is that he was no worse off, a tribute to human strength in general.

Pushing Back Age

This chapter is a tribute to Jimmy, Nazy, Michele, Suzanne, Marlena and all the others who achieved excellence with daily care-taking of Mary Austin, deceased at 97.

It's true that we have to die sometime. But why die before our life span is up? If many people can live to 100 years, then surely this is the human life span, not three score and ten. Some scientists think the true human life span is closer to 140 years! And that we all lead shortened lives. The shortening is due to failure of some organ in us. Other organs are dependent on the failing organ and begin to fail also. When the brain fails, death occurs, sometimes in five minutes.

If we knew which organ is failing, we could come to its assistance and prevent the collapse of the whole body. Often it is easy to see which organ is failing. But whether this is the true beginning of the body's problems we cannot know. Before death there may have been appetite loss. Before the appetite loss there may have been a broken hip. Before the broken hip, dizziness. Before the dizziness a blood pressure or blood sugar problem. Before these, an episode of “flu” or a dental “repair.” Sometimes we know what started it all. But often we don't. Just make a guess and begin somewhere.

Diet

If your aging friend or relative is in a home for the elderly, you may be able to persuade him or her to choose a diet that is wiser than the average diet people eat there. This can help a lot. Just stopping drinking the coffee, decaf, iced tea and carbonated beverages that are served, and switching to the recipes in this book could get them off some of their medicines.

The beverages to encourage are sterilized milk and hot water—delicious with whipping cream, honey and cinnamon. This gets them away from solvents, oxalic acid and caffeine.

Old age is not a time when you "no longer need milk." Calcium losses increase in old age. Milk has the organic form of calcium, chelated with lactic acid, and it has the cream to promote absorption. For this reason, milk should never be reduced in fat content (not less than 2%). The cream is necessary to improve calcium absorption.

In old age it is downright dangerous to be taking many calcium tablets. The stomach does not have the acid necessary to dissolve them. They pass into the intestine, disturbing its function and acid levels. With tablets, too, one must be careful with dosages, while food is self limiting. No elderly person would be able to drink more than one cup of milk at a time. This contains 250 mg. of calcium.

Milk, however, requires stomach acid to curdle it as the first step in digestion. If there is not sufficient acid, it will pass undigested into the intestine, causing new problems. We must listen to the elderly when they say milk gives them gas or other troubles.

Having the milk warm to hot helps in getting digestion started in the stomach. Milk served hot with cinnamon accomplishes two purposes: it will stimulate acid secretion and the cinnamon is an insulin aid. Milk served hot with honey adds the nutritive value of honey, displacing the need for other unnatural sweets. The meal should always include something sour to curdle the milk. It does not have to be added to the milk; it can simply be included with the meal somewhere.

Lemon juice or vinegar can be put in certain foods but the most reliable way to get it into the diet is to put 1 tablespoon into the water glass along with a teaspoon of honey. This gives the water a "sweet and sour" flavor, enough to make it interesting throughout the meal. The fresh lemon juice or white distilled vinegar and a honey dispenser that is easy to use should always be on the table. Bring these two items to your loved one at the "home" if it cannot be provided regularly and reliably. Pop in at mealtime to check up on it. Powdered vitamin C (¼ tsp.) is another useful acid if the first two are not effective enough.

The lemon and honey habit, alone, can add years (healthier years) to an elderly person. The extra acid taken with lunch and supper (the stomach has its own best supply of acid in the morning, for breakfast) improves overall digestion and helps dissolve the calcium, magnesium, iron, zinc, manganese, and other minerals in the food so they can be absorbed.

The habit of using vinegar and honey in water as a beverage was made famous by Dr. Jarvis in his book *Folk Medicine,* circa 1960. He recommended apple cider vinegar for its extra potassium. In those days, vinegar was made of good apples. Now, all the regular vinegars have mold in them. The toxin, *patulin,* in moldy apples has been carefully studied by scientists. It taints the vinegar as well as apple juice and concentrate made from them. I have not tested patulin to see if it can be detoxified by vitamin C. We must use only white distilled vinegar, even though it lacks potassium, aroma and popularity. Using a variety of honeys can make up for the need to vary the flavor. Get orange blossom, linden blossom, buckwheat, wildflower, and sage honey, besides clover blossom.

But honey is not perfect food. It usually has *ergot* mold, a very serious toxin. To detoxify the ergot, you simply add vitamin C to the honey as soon as it arrives from the supermarket. This gives it plenty of time to react with the ergot before you eat it. Bring your "fixed" honeys to the home.

If your elderly loved one has not tolerated milk in years, start with the vinegar and honey beverage, or lemon and honey, and be patient until that is accepted. Then add only ¼ cup milk to the day's diet, (in the morning, on homemade cereal). Go up very gradually and only when digestion allows it. Of course, the milk must be sterile.

If it is not sterile, the final warming will only increase the bacterial count. You must be sure of its sterility. Boil the milk yourself. Near-boiling is not hot enough. It must be heated until it bubbles up and almost goes over the container for ten seconds. Use a non-metal pot that holds one to two quarts. You may throw away the skin. Then cool and refrigerate. Supply it to the home, too.

Milk that is marketed in paper containers that need no refrigeration has been sterilized; it is safe.

Once the body, even an aged body, finds a nutritious food that does not cause troubles of its own, it asks for more. Your loved one will accept it and drink it without forceful coaxing, if there is no problem with it. As long as your loved one tries to avoid drinking it, your challenge is to find the problem and solve it. It is not a matter of taste or habit. It is a matter of digestibility and lack of toxicity. When your loved one is drinking three cups of milk (or buttermilk or whey) a day and three cups of water, there will be no room (nor request) for the usual coffee and tea and other bad beverages.

We all must die of something. But it needn't be a stroke, or heart failure, or cancer. Choose what seems to be the most pressing problem to work on. Common problems that plague the aged are brain problems, incontinence, bad digestion, diabetes, tremor, weakness, feeling cold, sensitivity to noise, losing the sense of taste and smell, hearing loss, insomnia, kidney and heart failure.

Increase Oxygen

Brain problems include memory loss, communication deficit, dementia (calling things by inappropriate names and saying inappropriate things). The brain is simply not getting enough oxygen and food to work right. It is like having a pocket calculator with rundown batteries: it will give you wrong answers (without telling you they are wrong). Not enough oxygen to the brain is the main cause of memory loss, inability to find the right words, getting words mixed up and not being able to speak in sentences. You can prove this by providing oxygen from a tank; modern equipment is very easy to use and inexpensive. If your loved one responds well to a few hours of oxygen, you have proof of the problem.

How can you increase oxygen in the brain?

1. Open the blood vessels wider.
2. Increase pressure of blood running through the blood vessels.
3. Raise the oxygen level in the air that is breathed. Less carbon dioxide, tobacco smoke and auto exhaust. All these, including a gas leak from the pipes in the house, compete with oxygen.
4. Increase the oxygen delivery system to the brain by raising hemoglobin levels. Cure anemia and low iron levels.
5. Raise oxygen saturation of blood by keeping body acidity down.
6. Correct a slow and irregular heart beat.

Niacin

Open blood vessels wider by giving **niacin**. Give it early in the morning, upon rising, as soon as the feet are set on the floor. Keep it at the bedside, use small capsules or tablets and combine this chore with water drinking. The water should not be cold and should have nothing added to make it a beverage. (Drinking water within minutes of sitting upright may also move the bowels soon.) A 250 mg. time-release niacin tablet (see *Sources*) is a good choice. The elderly have little side effects. Even the niacin-flush, which reddens the face and neck is welcomed since it gives a sensation of warmth.

The flush is intensified by giving hot liquids or acids (even vitamin C) to drink. The flush is reduced by giving cold liquids. The opening of blood vessels by niacin only lasts a few hours. If you see it has a good effect on your loved one, give several a day. Do not use a prescription variety, since they are polluted with heavy metals; use only the brand in *Sources*, or a brand that you have tested pure. You can freely experiment with niacin to find the best dosage and variety; it is not toxic in this amount; but the size of the tablet should not turn it into an unpleasant chore. Reduce it if it seems too large to swallow. Don't cut tablets in half, the rough edges can scratch the throat.

Hawthorn berry is an herb that opens blood vessels, particularly to the heart. Carefully watch the effect on blood pressure when using it.

Food mold, particularly ergot, has the opposite effect of niacin. Brain blood vessels are made narrower, cutting down the oxygen supply. Ergot is a common contaminant of grains: don't provide rye or pumpernickel breads or crackers. Don't provide wine or other alcoholic beverages; they are too contaminated with ergot and aflatoxin. Narrowing the blood vessels in the brain can lead to stroke. If you notice an attack of dementia coming, try a niacin tablet (100 mg, not timed release) immediately.

Fig. 34 Alcoholic beverages contain ergot and aflatoxin. Add vitamin C (1/8 tsp.) upon opening and wait 10 minutes for it to act.

TIA's, Strokes and Purpura

Sometimes, the elderly person is aware of the onset of a brain attack; they may see stars or peculiar shapes or lose vision temporarily. These are called *temporary ischemic attacks* (TIA's). Immediately give a 100 mg tablet of niacin, 1 gram vitamin C, and a B-complex in this order of importance.

TIA's are caused by spasming in the brain blood vessels. If this causes them to spring a tiny leak somewhere, a part of the brain will not get its usual oxygen and nourishment. A stroke results.

The spasming was probably caused by sorghum molds. Cooking during the manufacturing of sorghum syrup kills the mold but its toxic byproducts (mycotoxins) are still present. Other syrups may have sorghum added, polluting them. Brown sugar is also polluted with sorghum molds, but fortunately you can detoxify this mold with vitamin C as usual. Mix well ¼ tsp. powdered vitamin C with each new (1 lb.) box of brown sugar.

Purple patches, like bruises, on the hands or arms of an elderly person are called *purpura*, and is also caused by sorghum molds. It weakens blood vessels so they break easily.

When an elderly person has purpura or TIA's and the mold source isn't obvious, you must track it down. Test in a saliva sample for all the sweetenings used recently (at least an hour ago). At the very least, keep notes on all the sweeteners being used. Look for a common one at the next attack. Never let the trigger food be eaten again.

Blood Pressure

Increase blood pressure if it is habitually too low. Blood pressures below 110 may prevent strokes but ruin the quality of life. Low blood pressures are often due to toxins from foods. But severe salt deprivation in the diet can also cause this. If the adrenal glands are not conserving salt properly, too much sodium is allowed to leave the body with the urine, resulting in low sodium levels in the blood and a blood pressure drop. Adrenal performance is improved by taking the kidney herb recipe.

The kidney herbs (page 549), at half dose level (½cup a day instead of a whole cup) can be given daily for three weeks and then on alternate days indefinitely. Be very careful to keep the herbal tea sterile by reheating. Elderly people seem to sense the improvement given by kidney herbs. Try other kidney herbs from time to time: **shave grass, cedar berries, juniper berries, butcher's broom, cornsilk**. None interfere with drugs. Remember, they also have a diuretic effect. Be prepared to use extra paper padding in underwear to help catch the extra urine output. The first few nights may be disturbed by extra urination. Interpret this positively.

After the blood pressure comes up to 115 (systolic) mental performance will be greatly improved. Don't try to bring it up to 120 since this raises the stroke potential without giving you much improvement in performance. Use an electronic device to measure blood pressure, one with a finger cuff, not an arm cuff which can itself induce broken blood vessels. Purchase a device that needs no adjustments of any kind and has automatic cuff tension control (see mail order catalogs if your pharmacy does not have one).

Air Pollution

Improve the quality of the air by lowering the pollution level. Check into carbon dioxide, carbon monoxide, fumes from a gas stove pilot light, auto exhaust from an attached garage or nearby highway, arsenic from household pesticide, PVC from new plastic curtains or carpeting, formaldehyde from wearing new clothing before washing it, asbestos from hair dryers, freon from a refrigerator, fiberglass, and chlorine from running tap water. Some of these displace oxygen, some are simply toxic to the body and lungs. Clean up the air according to the general principles of environmental cleanup (see Four Clean-ups, page 409).

For the elderly pay special attention to **chlorine** in the air. Shower water puts a lot of chlorine into the bathroom air which then distributes itself through the rest of the house. Notice whether your elderly person goes into the bathroom in fair shape mentally but comes out confused, unreasonable. Not every day's chlorine exposure will have the same effect. Trust your judgment. Attach a carbon filter to the shower head (see *Sources*). Purchase a variety that has very simple-to-replace cartridges. Figure out how long it should last and write the date for replacement on the outside of it for your own convenience.

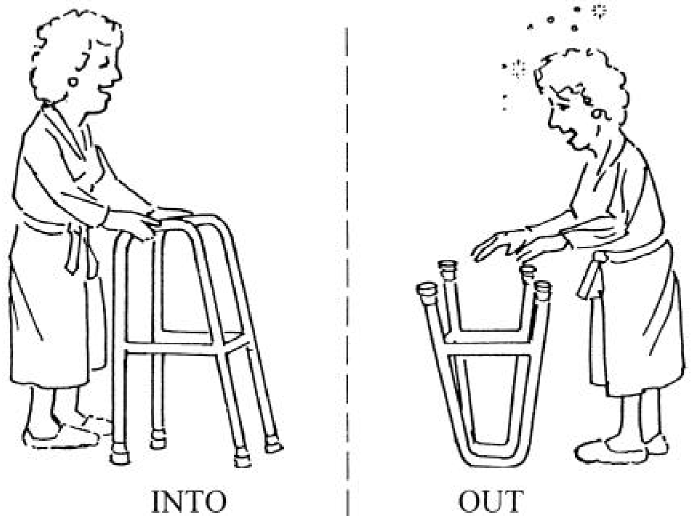

When into and out of the bathroom is a different performance suspect chlorine. Put a filter on your faucets.

Fig. 35 Chlorinated water can cause mental problems.

Washing hands and face in chlorinated water can give off enough chlorine to trigger a manic episode in a manic-depressive person. Certainly, it is enough to cause mental effects in an elderly person. Of course, the chlorine bleach bottle should not be kept under the sink. It should be kept in a closed plastic bag in the garage. It should not be used while the elderly person is in the house and never for his or her laundry. Use chlorine-free bleach.

Don't pollute the air with fresh flowers, potpourris, or room fresheners. These can induce a dizzy spell.

Room air conditioners may have a fiberglass filter! This fills the house with tiny particles of glass to be breathed by everybody. The body makes tumors out of them in order to stop them from cutting through your tissue. Replace the filter with a foam sheet. This sheet is 1/8 inch thick and washable. I have not found these types of foam filters to emit formaldehyde.

Room air filters are not the answer to polluted air. Removing the pollution source is. Air filters may remove some of the toxic elements but by blowing the air (and dust) around vigorously the remaining toxins are made much more vicious in their effect. The noise of a filter motor and fumes it may put out itself adds misery to the simple job of breathing. Using a non-fiberglass filter at the furnace is a better idea.

Make sure all fragrances are removed from the air, even though family members “like” them. They don't belong in air. The lungs treat them like toxins to be coughed up or removed by the kidneys and immune system. This includes colognes, scented tissues, soap and shampoo and shaving supplies. If you can walk into the bathroom blindfolded and know you're in the bathroom, it's not clean enough. Everything in the bathroom pollutes the air of the whole house. People who must use fragrance should apply it outdoors to keep the indoor air less polluted.

Anemia

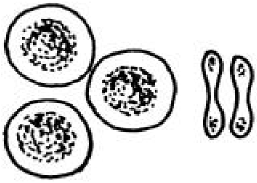

Fig. 36 Red blood cells, top and side view.

Oxygen gets to the brain on a carrier system of tiny rafts called *red blood cells*. They were meant to be an exact shape and size to fit the most oxygen molecules onto them.

Each red blood cell is shaped like a doughnut without the hole. This fits a lot more oxygen, O_2, than round balls would. Yet, if there isn't enough vitamin B_{12}, the dimple isn't put into them to make them doughnut shaped. This reduces the body's oxygen supply and the disorder is called *"pernicious" anemia*. The changed shape of the red blood cells is reflected in a bigger volume called *mean cell volume* (MCV). The correct volume for red blood cells is about 90 cubic microns. Many elderly persons have a MCV over 100!

I have seen pernicious anemia to be associated with *Ascaris* infestation. Kill *Ascaris* on a frequency generator (408 KHz) or zap. The source of *Ascaris* is usually a pet, owned in the past. Once infected, the tiny worms do not leave your body on their own. The infestation may date back to childhood. What a relief for the bone marrow whose job it is to make red blood cells to have enough vitamin B_{12} again! What does *Ascaris* do with your B_{12}? B_{12} is a beautiful rose colored vitamin. Some worms are actually pink from absorbing your B_{12}! Giving B_{12} shots is the current clinical treatment for B_{12} deficiency. Killing *Ascaris* twice a week by zapping and taking B_{12} lozenges (see *Sources*) is a better solution. (If your loved one is getting shots, make sure that no isopropyl alcohol is used on the skin beforehand. Provide vodka yourself in a small pocket flask or 70% grain alcohol for this purpose. Unfortunately, the shot itself may contain traces of this harmful solvent—take a sample home for testing.)

Other kinds of “anemia” can deprive your elderly person of oxygen. A low red blood cell count (under 4.4 million/mm^3) is the “garden” variety. Sometimes iron levels are low and can explain the low red blood cell count. Sometimes they are not.

Most regular anemias, including low iron levels, are associated with hookworm infestations.

Kill all *Ancylostomas* along with *Ascaris* twice a week. It is not wise to take iron pills, even if they do raise hemoglobin levels, except in life-threatening situations. Remove the tiny creatures that cause microscopic bleeding instead. Iron in the form of pills is too easily snatched up by bacteria who also need it, making them more virulent to the body. Use grain alcohol rinse in the bathroom to kill *Ascaris* and hookworm eggs under fingernails. Don't have pets in the house or keep them on daily parasite killing herbs.

It takes nutritious food to build the blood back up to its normal hemoglobin level. Eggs and meats (all very well cooked) are the richest sources of iron and other minerals used in blood building. B_6 and other vitamins are also involved and can be given as a B-complex (see *Sources*). Do not use black strap molasses as an iron source, or any molasses, since it contains toxic molds. (The molds could be detoxified with vitamin C the same way as honey. However, I have not tested enough molasses for solvents and you cannot risk these.) In the past, when the nutrient properties of molasses were discovered, the molasses manufacturing was a small, carefully conducted business. Now it has molds which cause platelet destruction, (purpuric spots) internal bleeding, and immune failure.

Acid Levels

Oxygen must first jump onto its raft, the hemoglobin, in the lungs. Later, in the brain, oxygen must jump off again to enter the brain cells. A difference in acid levels makes this possible. Acid levels operate the latching system that decides whether oxygen will be attached to hemoglobin or let go! Acidity unlatches oxygen. There should be no acidity in the lungs so oxygen can attach here. Sometimes, the entire body is too acid! Diabetics, asthmatics, arthritics, especially, suffer from total body acidity.

Acid was meant to be removed from the blood and loaded into the stomach at mealtime for digestion. When this isn't happening, it was meant to be shipped out of the body with the urine. But the kidneys may be doing a poor job because they are clogged with tiny crystals and because not enough water is drunk, so the body's acid levels rise. You can test total body acidity by measuring the pH of the morning urine. It should not be under (more acid than) 5.5. If the body acid level is too high, help the kidneys excrete it by adding more water to the diet and more minerals to neutralize the acid. The main minerals for this purpose are calcium and magnesium.

Increase Minerals

Adding water to the diet could be the most difficult of tasks if your elderly loved one “doesn't like it.” Calcium should be in the form of milk, magnesium as a tablet. When tablets cannot be swallowed; use magnesium oxide powder (see *Sources*). Use 1/8 tsp. added to cooked cereal, soup, stew, pudding. Magnesium, being a mineral, does not get destroyed as vitamins may. You can add it anywhere in the diet where it won't be tasted. Notice how calming it is to have extra magnesium in this gradual way. And how much better the sleep is at night.

When water "doesn't taste good," there is probably a valid reason. The body may be trying to reject chlorine or other toxins in it. In this case, filter it with a small all-carbon unit that is changed right on schedule. A plastic pitcher (not clear plastic or flexible plastic) with a carbon pack fitted into the top is best. Sterilize it once a week by putting a cup of water and one tbs. of grain alcohol in it and turning it upside down so the filter can soak for 15 minutes. Flush out the alcohol with two pitchers of water. Make sure the temperature suits the person. Temperature can mean everything to the never-thirsty person. Don't allow ice cubes, however, nor beverage making, with the essential water. Adding lemon or vinegar (white distilled) and 1 tsp. honey is probably the best way to stimulate both thirst and appetite.

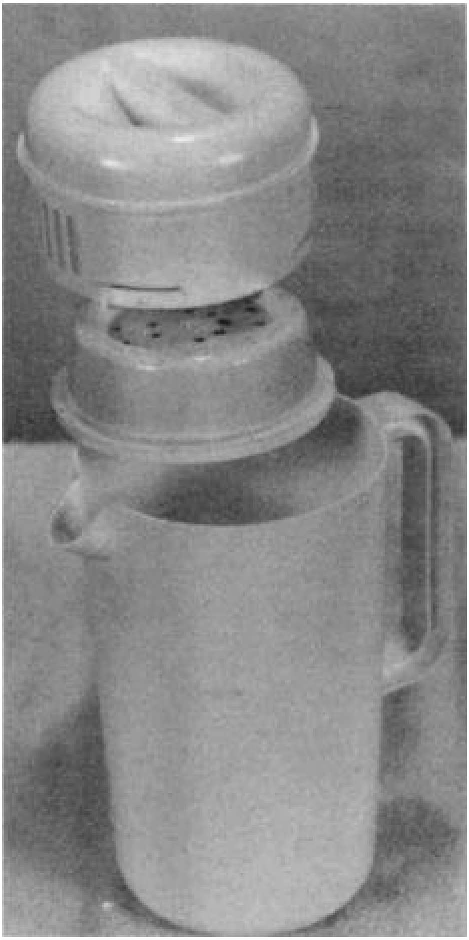
Fig. 37 Water pitcher with filter.

When blood is properly oxygenated it takes on a bright red color, unoxygenated blood is more purple. A chelation doctor can easily see the state of oxygenation.

Chelation

Chelation is a powerful way to quickly improve oxygenation of blood. The most important rule to observe, though, is to take the treatment slowly. Especially if *ethylene diamine tetra acetate* (EDTA) is being used to remove heavy metals, it is important to take the treatment over a two hour time period. Mini doses may be given in a shorter time. Generally, you are in charge of the flow rate. Discuss it with the nurse. Weekly chelations can correct many problems of the elderly that no other treatment could.

Because of hostility from insurance companies who do not wish to add another cost to their ledger and doctors indoctrinated with misinformation, bad publicity is given to this wonderful, life-prolonging mode of treatment. Clinical doctors who have no time to really investigate the statistics of chelation treatments and for whom this is purely competition may feel antagonistic to these treatments. Your loved one should not be the one who must suffer from medical politics. Go to see for yourself what chelation is all about. The receptionist should be glad to show you around. The secret is to talk to the patients themselves. They are usually sitting around a room, eating their lunch and reading as their IV's drip. The pulse, blood pressure and blood chemistry is also carefully monitored. Sit down with them to find out their stories. Get a realistic picture of benefits and costs.

Pulse

The pulse reflects the heartbeat. A **slow pulse** can give weird brain symptoms besides great fatigue. The cause is usually a drug that is being taken to correct a **fast pulse**! Check with the nurse. Read the insert included with packaging for all drugs used. The drugs responsible are usually “beta blockers”, used for the purpose of smoothing out the heart beat, that is, making it regular. Often the drug can be changed.

Less than 60 beats per minute will lead to trouble. For a young person it is a good sign to be as low as 60, provided no drug is involved. But for the elderly it does not reflect a strong athletic heart beat.

The heart is made of four separate “chambers” or compartments each pulsing in turn. They are like four horses pulling a wagon. Unless they pull evenly, the wagon feels jerky, and irregular. The wagon will wear out sooner with jerky pulling. To smooth them out you simply slow them down. Apparently they sense each other better and can pull evenly now.

A heart that is beating 100 times per minute, not unusual for a weak old heart, can be so irregular that it misses every fourth beat. That creates a terrible deficiency of oxygen. Imagine your four cylinder car or lawnmower missing one out of four engine strokes! Beta-blockers have some quite undesirable side effects but heart regularity has a higher priority. So drugs are the immediate choice. Later, when heart health is improved, the heart will beat regularly without drug use. In the meantime, watch over the pulse. When the pulse drops below 60 the new danger is slowness. Take the pulse daily when a new drug has been added, or when you are working on heart health, without getting your loved one anxious about it.

Heart Health

To improve heart health, the first steps of course would be to go off caffeine and to kill parasites and bacteria. This alone could drop the pulse from 120 to 80 in a few days. Obviously, the need for a drug is gone. Cut the drug dosage in half immediately. Don't wait for a doctor's appointment to O.K. it. If you waited another day the pulse could be below 60.

Many common bacteria, especially *Staphylococcus aureus*, choose the heart as their favorite location. Their nesting place, though, will be under a missing tooth in the jaw (cavitation). Heartworm and *Loa loa* are two very common heart parasites. You can have all these killed in a day, without side effects and your heart is once more free to beat regularly. Don't take a chance on over-medicating. As soon as the beat is regular and under 100 per minute, reduce your heart drugs. Stop them when you are regular and under 80. Fatigue will leave and the brain will work better.

Raising potassium levels slows the pulse. Try to do this with diet by eating more potassium rich food and by conserving on potassium losses. The adrenals are in control of losses. Give them a thorough cleaning. The adrenals are situated right on top of the kidneys where all toxic things are being excreted. Being this near to the urinary tract will result in shared toxins. Urinary tract bacteria, small kidney stones, moldy foods and metal from dentalware are the chief offenders. Switch to composite tooth fillings. Use non-metal jewelry. Cook and eat with non-metal ware. Don't handle metal unconsciously throughout the day. Aluminum objects that must be touched should be wrapped in masking tape: this includes walker, shower door, bathroom supports.

Door knobs, taped walker handles, and cane handles should be wiped daily with a grain alcohol solution.

Treat the adrenal glands to 5 supplements

1. **Vitamin C:** shake some into all foods that can absorb a bit of the sour taste, even cooked cereal and vinegar water.
2. **Pantothenic acid:** 500 mg., one daily.
3. **B_6:** 250-500 mg. daily.

4. **Folic acid:** 800 mcg. daily.
5. **B_2:** 150 mg. daily. These are minimum dosages.

If no capsules or tablets can be swallowed put a three day supply in a heavy plastic bag. Pound with a hammer; then roll finer with a big glass jar. Use about 1/3 of the mix each day. If you are trying to do all this in a nursing home, feed it to your loved one while visiting. Put the powder mix in a plastic (not styrofoam) cup, add honey and stir until you get a paste. Feed the paste directly by spoon. Often the elderly prefer it this way in order not to bother with pill taking at meal time. Remind them it will turn the urine yellow.

When the brain problems are corrected for an elderly person, be sure to relate the improvement to him or her. Improvements should not be dismissed lightly. Keep notes. This encourages the elderly, letting them know their existence and quality of life is important to you. Improvements are not merely steps to yet further improvements. Enjoy each bit of progress; it is often too subtle for your loved one to notice even when it is glaringly obvious to you. Before and after a chelation treatment can show a dramatic change in mood, energy, appetite and communication ability, yet get no comment from your loved one. Point it out explicitly so your loved one can look forward to it, too.

Aging is no fun. The elderly long for a brisk gait, laughter, and a picnic at a park again. They dwell on dying, though, because they know it isn't far away and wonder what to do about it. They dare not talk about it because it is too painful a subject for the loved ones. And the immediate problems are too pressing to allow much contemplation of future problems. Talk about aging in its positive aspects. Let your loved one express feelings about it.

Incontinence

plagues most elderly persons. It begins to plague women much earlier—after childbirth, for instance. Surgically shortening the bands that hold the bladder in position (called bladder "lifting") can give temporary relief, but the surgeon may be the first to tell you that it is a temporary fix. Still, it is so shocking not to be able to run a few steps or sneeze or cough without wetting the underwear, that anything seems better than doing nothing. Surgeons will tell you that the bands have been "overstretched."

The real reason why nothing, not even surgery, is permanent is that the support bands are weak. Bacterial invasion causes most of this weakness. Low potassium levels (due to excess potassium losses by the adrenals) causes more weakness. When you kill bacteria (and *Schistosomes* and *Ascaris* and other parasites that bring in bacteria) and blood potassium levels go up, the problem is solved. Overnight you may throw those pads away. Even though you needed three pads to be "safe" you will not need any. Whether you have killed bacteria permanently determines whether you have permanently cured the condition. Make sure all dairy foods are absolutely sterile. Ask that the milk be boiled for ten seconds and other foods that can't be sterilized are not on the menu, like sour cream. Sour cream has too much *tyramine* to be safe. Tyramine is a bacterial by product that is quite toxic; it is rather high in aged cheese, also. With the food bacteria, *Salmonellas* and *Shigella*, out of the way and parasites being killed regularly, you can focus attention on the adrenals which control potassium levels.

Be careful not to rave about the foods that your loved one cannot eat.

Eating more potassium in food is a good nutrition project. Bananas are the top choice. Fresh fruit salad and baked potatoes and soup also provides a lot. Mixing potassium salt with regular salt, half and half, for the shaker is another easy trick, even if you only use it in cooking where the taste cannot be detected. Potassium by prescription is often used by clinicians to conserve body potassium during diuretic use. This need not be stopped (if the pills are not polluted) although taking potassium pills is less useful than salting it in because the adrenals will let any big dose escape anyway. A sign of too much potassium is a slow pulse.

It may be necessary to wear some kind of incontinence underwear. Try to avoid them at night, though, so the skin can breathe freely. Bring a commode near the bed for the night, rather than diapering your loved one (but don't call them diapers; say “underwear”). Absorbent pants of all kinds are heavily chemicalized. This is absorbed by the skin and adds to the toxin level. Less will be absorbed if you powder the skin with cornstarch first. Use them minimally and line them with tissue or paper towel. Chair and bed pads, too, are chemicalized. Don't sit on them with bare skin. To facilitate getting to the commode quickly in the night, dress the elderly in a short night shirt, no pajamas or long gown. Bed socks on the feet help with warmth.

Wash the body parts daily, around the urinary and rectal outlet, using borax water. Follow with 5% grain alcohol. Put washcloth in laundry after a single use. Nothing, not even brain improvement, impresses and encourages an elderly person as much as seeing the incontinence lessen. This bit of progress will put him or her solidly on your side. When they believe in you, it makes your task more rewarding. Remember to enjoy and celebrate your achievements together; don't make a grim business out of it.

Bad Digestion

with its excessive gas and burping is another plague of the elderly. They would rather not go to church nor visit a friend than embarrass themselves in that way.

Chewing

It all begins with the stomach although chewing food well is essential for really good digestion. Dentures should fit perfectly so the mouth does not develop sores. Using denture cream is not a good substitute for correct fit and is toxic. Denture plastic is often toxic, even containing mercury in its composition! Toxins in plastic can seep! Such toxins lower the immunity of the mouth and throat and stomach since it all flows down into the stomach. Low immunity in the mouth permits throat infections to be chronic. If your elderly loved one has a red-looking mouth or throat, instead of pink, an infection is going on in spite of no coughs and no complaints.

It will do no good to keep zapping bacteria when reinfection is so easy. First kill the bacteria in the dentures by soaking in 70% grain alcohol. Then test the dentures for toxins. Soak the dentures in water for several hours. Rinse and soak again in fresh water. Repeat a third time to insure that any toxin found came from the dentures, not the saliva. Save this water for testing. Search for heavy metals in the denture water. If you find any, you know the dentures are toxic! Get new ones, made of uncolored methacrylate (see Dental Cleanup, page 409).

The denture-soak should kill bacteria each night. Plastic has tiny pores where bacteria can hide. Use 70% grain alcohol which you make yourself or plain vodka which is about 50% alcohol. Since alcohol evaporates and is expensive, use a wide mouth jar with close fitting non-metal lid for all this. Fish them out with your toothbrush so it gets sterilized too. It only takes minutes to kill everything. Commercial denture cleaners are much more toxic than grain alcohol; don't use them.

Use food grade hydrogen peroxide or salt water to brush teeth in your mouth, never **toothpaste**. Toothpaste has toxic metals (tin, fluoride, strontium) besides benzene pollution. See the section on brushing teeth (page 532) for details and sources. If you are responsible for this daily chore, use homemade floss (2 pound to 4 pound nylon fish line) first; then brush. If your loved one is seated they may be able to handle the brush by themselves, giving them pride in the achievement.

If an elderly person refuses or can't wear dentures, provide food that is soft and without chunks since this decides whether the stomach can digest it. The stomach is the weak point of the digestive process for the elderly because nearly all don't produce enough acid to get the job done.

Stomach Acid

The body produces hydrochloric acid (HCL) which gets pushed into the stomach from the blood! The enzyme, *carbonic anhydrase*, a zinc enzyme, is involved. Not many ways are known to stimulate this whole process. Drinking water before meals stimulates it in unknown ways but is hard to do for the elderly. Next best is to provide acid.

Because strong HCL would dissolve teeth it is not available as a solution to aid digestion. Ask a pharmacist to make a 1% HCL solution and use 10 drops of it in a beverage at mealtime once a day. HCL as a tablet (“Betaine HCL”) is available but doesn't have enough HCL in it.

Using a lemon or vinegar and honey beverage helps with digestion although this provides citric or acetic acid, not hydrochloric. These acids are completely metabolized so they don't add to the body acid level. But the fact that it is not hydrochloric means that it can't kill bacteria and parasites in the stomach like regular hydrochloric acid could. The stomach becomes a haven for *Salmonellas* and other bacteria and this is **the biggest digestive plague of the elderly**. *Salmonellas* dig deep into the stomach wall, safe from antibiotics and stomach acid and aren't washed away with the food. When they take over the region near the top of the stomach, it weakens the esophageal sphincter and food keeps coming back up a bit—a most uncomfortable development, especially after supper or when lying down.

When the Salmonellas spread out further to invade the diaphragm around the sphincter, the diaphragm weakens, and lets a bit of the stomach up through the hole.

This causes *hiatal hernia* distress. Don't settle your loved one in an easy chair after supper. This presses the stomach upward and the food up, too. Leave them sitting at the table a while, then walk a bit, to get the food down lower. The food will sink lower if some of it can leave the stomach at the lower pyloric end. But if *Salmonellas* are entrenched here, too, the lower end does not have enough action to push the food through the valve. Drugs like Reglan™ are given to speed this up.

What helps most is getting digestion completed. This sets up the natural cues for emptying. Digestive enzyme tablets have been in popular use to help digestion. But they may not be safe since they have not been sterilized. Always try the vinegar and honey method first. Coughing during eating is a sign that the diaphragm is irritated (by a hiatal hernia). If drinking water starts the coughing, omit it at the beginning of meals. Work in sips during the meal.

Salmonella and Shigella

Some *Salmonella* infections can bring dizziness to your elderly person. Dizziness is another plague of the elderly, keeping them from going shopping, getting to church and even from getting around their own homes. Drugs such as Antivert™ are given but only take the edge off the problem. Feeling dizzy can make your loved one home bound and stuck to a walker for every move.

Salmonellas, along with *Shigellas*, produce very toxic substances that cause dizziness. There are three common *Salmonella* varieties: *Salmonella enteriditis*, *Salmonella paratyphi*, and *Salmonella typhimurium* (386, 380, 354 KHz). Kill *Salmonellas* daily for a month by taking Lugol's iodine (6 drops in a half cup water, after meals and bedtime, see *Recipes*). Unfortunately, this will not kill *Shigellas*; follow the Bowel Program (page 546) to get them.

During this time set up a system of sterilizing all dairy products (see Milk, page 425) since this is the source of reinfection. Set up a system of rinsing fingers (and fingernails) in 10% grain alcohol in the bathroom. Deli food and restaurant salads carry *Salmonellas* and *Shigellas*, too. Kill them, routinely, after eating such food due to necessity. A warm stomach full of food at a neutral pH is just the right culture condition for these bacteria. It's like putting yeast into a bowl of warm water, flour and sugar. In half an hour it is overflowing with growth.

Once *Salmonella* is entrenched in an organ it is difficult to eliminate. Only an electric zapper can kill them all (in an organ, not the bowel). If your body has the right conditions (like a low acid stomach) to let them grow you dare not swallow another one! *Shigellas* arrive with dairy foods, too, but prefer the lower intestine as their headquarters. Indigestion that starts right after eating is probably due to *Salmonellas*. If your indigestion comes in the night, this suggests *Shigellas*, since they've had time to reach their favorite place further down.

Campylobacter and *E. coli*, other digestive bacteria, are sometimes the culprits. The Bowel Program is effective against these also. Besides getting digestive improvement you get mental improvement, less depression, less dizziness, less irritability after clearing these up. Remember that eating bacteria and killing them later will not solve the problem. Stopping eating them will.

Other Clues

Digestion problems that remain after eliminating bacteria can be diagnosed in a rational way. Ask these questions:

- Is the stool orangish-yellow, or very pale, instead of greenish brown? If so, bile isn't getting delivered to the small intestine from the liver.
- Is there abdominal pain? (More about this on page 97). It may be due to *Ascaris*, flukes, or other parasites.
- Is there constipation? This will let wastes accumulate, all the longer for bacteria to thrive on them.
- Is there bloating? This is due to gas made by bacteria.
- Does the stool float? If so, it must be lighter than water and contain fat or a great deal of undigested material.

Liver Bile

Bile is necessary for digestion. Absorption of fat and calcium depends on bile mixing with the food. When fat isn't absorbed, it stays in the intestine. Fat is lighter than water; it makes the stool float. Feces should not float. When the stool floats you can assume that calcium isn't being absorbed either, leaving the blood in a deficit which will be taken from the bones.

If the stool floats or is orangish in color prepare your elderly person for a liver cleanse (page 552) to clear a bile duct of obstruction. They get quite fond of these cleanses and will ask to have one. Liver cleanses are completely safe, even for persons in their 80's. One of the stones pictured on page 554 came from a woman age 97. The general rules apply to the extremely elderly: kill all parasites first by zapper if possible, otherwise by herbal parasite killing. Do a kidney cleanse (page 549) first, using half a dose instead of the regular dose, for three to six weeks. Attend your loved one in person for the liver cleanse, have a commode at bedside, protect bedding from accident: use paper underwear if necessary. Share the joy of getting gallstones out painlessly with your loved one; let them see and count them if they wish before you flush them (use a flashlight).

Be extra careful with the skin cleansing. Hot water soothes and heals. Use starch skin soother to dispense onto the wet paper towel, besides borax solution and alcohol. Don't use ordinary soap. The starch skin softener gives the smoothness of soap, and prevents the pain of friction. An elderly person may have no diarrhea at all with the Epsom salts! Evidently the body absorbs all the magnesium so eagerly, none is left in the intestine to absorb water and create diarrhea. It is especially important though to rehydrate your elderly person after a diarrhea. This time they do not balk at water consumption. The liver cleanse, it seems, gives them new thirst as well as new appetite. But it doesn't last long. As the stones from the far corners of the liver move forward, they compact into larger stones and plug the ducts again. Their previous symptoms return. Try to give a cleanse once a month until the dark color of the stool returns and it no longer floats.

The benefits of a liver cleanse will last longer if **valerian herb** is taken the day after the cleanse and from then forward. It may be preventing spasm of the bile ducts. Use 2 oz. of the herb (cut) in 3 cups water. Simmer for 5-10 minutes, let settle or strain. Add honey to sweeten. Give a few tbs. every 4 hours (or 6 capsules) for several days followed by a daily dose at bedtime.

Constipation

If constipation is a problem, use an herbal product rather than a drug until you have removed the cause. **Cascara sagrada** (half dosage) or **prunes** work for many people. Adding **roughage** to the diet is a good solution but often doesn't work. If you try bran, you should add vitamin C and boil it, first, because it is very moldy. But even eating tree branches for supper won't move a bowel that has the wrong bacteria in it.

Bacteria are part of the cause; and part of the result! Constipation increases the bacteria level which causes further constipation! You may solve the constipation problem immediately by zapping. Even though this kills some “good” with some “bad” bacteria, no harm is done. The stool is recolonized in one to two days.

Poop Your Troubles Away

Two bowel movements a day are the minimum necessary for good health. The first one should be in the morning. The morning cup of water, drunk at the bedside has the magical ability to move the bowels. Cold water may fail. But the water effect only works in the early morning. Waiting until after breakfast may not work. Notice the energy lift your loved one gets from this most primitive body cleanse. Take advantage of this to exercise them. Go immediately for the morning walk. This might be the only time of day they can enjoy their walk.

Walking and **liver cleansing** are the most health-promoting activities you can do for your loved one.

Make walking as essential as eating. Walking is not merely walking about the house or shopping. Walking should be done outdoors. Walking is a brisk exercise, done as speedily as possible and lasting at least ½hour. Only if the weather doesn't allow outdoor walking can an indoor walk be substituted. Don't let your elderly person choose whether they will walk that day. To overcome resistance, find a cheerful neighborhood person willing to do this task for pay. The need to respond to a new stranger energizes the elderly more than your persuasion can.

Sugar Regulation

Diabetes is a common development in the elderly. If your loved one is already on a pill for beginning diabetes, take this as your challenge never to let it get worse. It is not a chronic metabolic deterioration. It is a destruction of the pancreas (specifically the islets) by the pancreatic fluke which is attracted to the pancreas by wood alcohol. Zap flukes and eliminate wood alcohol as described in the section on diabetes (page 173).

Use no artificial sweetener and no beverages besides milk, water and the recipes given in this book. This is one regimen your loved one will not resent. They are well motivated to prevent the need for giving themselves daily shots of insulin. Use this motivation to acquire the taste for new foods and beverages.

Elderly Person’s 7 Day Diabetic Diet

Daily supplements: 4 chromium (200 mcg. each), 1 or 2 B-50 complex, vitamin C (1,000 mg. or ¼ tsp.). Take with food.

Breakfast

Choose any one; they need not be in order.

1. Two eggs, (replace carton and wash hands and eggs before cracking), wheat-free, corn-free bread, not toasted (special breads can be found in the freezer section of natural food

stores), with butter and 1 tbs. orange blossom honey. 1 peeled pear, raw, with whipping cream. One cup hot milk with cinnamon.

2. Old fashioned oats, with 1/4 tsp. cinnamon and 1/8 tsp. vitamin C, stirred in just before serving. Mix whipping cream with sterilized milk to make a "half n half" for the cereal. 1 tbs. honey. 1 banana. One half cup milk, one half glass water with honey and vinegar.
3. Fried potatoes with 2 eggs (use only butter, olive oil or lard), 1 cup hot or cold milk. A quartered orange (wash the orange before quartering).
4. Cream of rice, with homemade "half n half" or whipping cream, cinnamon and vitamin C stirred in. 1 cup milk, 1 banana.
5. Cottage cheese, cooked in covered skillet to sterilize. Add chives or peeled fruit (not canned). Wheat-free, corn-free bread, or rice bread with 1 tbs. honey. 1 nectarine or piece of melon. 1 cup hot milk. Water with vinegar and honey.
6. Pancakes or waffles with butter and eggs (no sweetening). Fruit (peeled), hot milk, water.
7. Fruit cup, large bowl of peeled, chopped mixed fruit with whipping cream and 1 tbs. honey and rice bread or other wheat-free, corn-free bread with unsalted butter. 1 cup hot milk with cinnamon.

Remember, all honey must be pretreated with vitamin C. All fruit is peeled and free of blemishes and soft spots. All milk, cream, butter must be sterilized for 10 seconds at full boiling point. Butter must not be "raw". Get wheat-free, corn-free bread at a natural foods store.

Lunch

It is better to have most of the day's calories in the middle of the day than at the end. Arrange for dinner at noon if possible.

Dinner

Choose any one.

1. Green beans with potatoes, meat dish, cabbage apple salad, water with lemon juice and honey, 1 cup hot milk. Water.

   Fresh green beans, especially fava beans contain a substance that is described in old herbal literature to be especially beneficial to diabetics. Don't overcook them—it might harm this substance.

   For the same reason, don't use canned green beans. If “fresh” isn't possible, choose “frozen” but rinse the chemicals off before cooking. Potatoes (not overcooked), peeled to make sure there are no blemishes (contain mold and pesticide) can be cooked with the beans. Cook with onions and oregano for flavoring. Add fresh chopped parsley to the sauce or butter for both green beans and potatoes. Fresh parsley has special herbal goodness (high magnesium, high potassium, diuretic.)

   The meat dish should be overdone. “Fast food” is plopped from the freezer into the boiling grease which browns the outside nicely but can easily leave the inside undercooked. Meat must never be “rare.” There should be no redness near bones! Canned meat is safe from parasites but may have smoke flavoring added (contains benzopyrene) or nitrates. Avoid these chemicals. Avoid MSG too. Whenever a meat dish is not accepted, substitute sardines. Let them choose from a display of six kinds. Purchase the flip-top cans to avoid eating metal grindings from the can opening process.

   Cabbage for salad should be chopped fine enough to be digestible. Add finely chopped apples (peeled) and a few apple seeds and whipping cream for the dressing.

Sweet things are reserved for dessert. Since a diabetic's tissues are not absorbing sugar, they crave it more and more. As the diabetes improves they crave it less. For dessert, serve 1 tbs. of honey to satisfy this craving without endangering their blood sugar regulation. It can be used in the hot milk or in other ways. Undercooking the vegetables also helps slow down the sugar release. Never serve mashed potatoes for this reason.

The drinking water should always have a little vitamin C, lemon juice or vinegar added, and 1 tsp. honey if desired.

2. Asparagus, potato, raw salad, fowl dish, fruit, water with vinegar and honey, 1 cup hot milk.

   The asparagus can be fresh or canned. Bake the potato: not in aluminum foil, not baked until fluffy. Don't let the skin be eaten. Use genuine butter, only, or a homemade sour cream dressing (see *Recipes*). Fresh chopped chives may be added but no regular sour cream since this is very high in *tyramine*, a brain toxin.

   The raw salad should be chopped small enough to be edible by dentures. Use homemade salad dressing with a preference for oil and vinegar styles.

   The fowl dish should be very well done, never “fast food”.

   For dessert, fresh fruit chunks dipped in a homemade honey sauce (honey, water and cinnamon). Less sweets are consumed if you dip the fruit rather than pour the sauce over. Limit the total to 1 tbs. honey. Don't serve grapes or strawberries due to the intense mold problem.

3. Soup, sandwich, fruit, hot milk, water.

   Soup should be homemade from scratch. Add bones and 1 tbs. vinegar (white distilled) or a tomato to the kettle to ensure some calcium leaches out of the bones. A fish chowder serves this purpose very well, too.

The sandwich has lettuce, real butter, and whatever else tastes good (no cheese, bacon bits or condiments). The bread is wheat-free, corn-free, stored in freezer. Homemade salad dressing can be added.

The fruit may be chopped with whipping cream, cinnamon and honey sauce (not more than 1 tbs. honey).

The water may be plain if there was vinegar in the soup.

4. Fish, green beans, potatoes, other greens, fruit, hot milk, water.

   Fried or baked fish is served with lemon or lime. Green beans are served with a cheese sauce so a lot will be eaten. (Cheese sauce: add milk, olive oil to a block of cheese. Melt and cook at least 10 seconds.) Serve au gratin potatoes or scalloped potatoes or any kind of potatoes that will be enjoyed. The extra greens can be beet greens, collards, mustard greens or spinach served with a favorite dressing to make sure it's eaten. (No croutons or bacon bits, though.)

   Never serve dessert if the plate has not been cleared. Your loved one isn't hungry enough. If appetite is very poor, sweets will only worsen the problem. Try to change the menu to stimulate the appetite. Acid foods stimulate; spices and B-vitamins (especially B_1) stimulate; hot foods stimulate. Much appetite is controlled by the liver and brain. Toxins at either location (especially food-derived toxins) tell the body to stop eating. Suspect food molds first, bacteria and chemical additives next.

5. Asparagus, meat dish, white rice (brown rice contains mold), coleslaw, milk, water, ice cream.

   A hot meat dish (no pasta, no wheat flour, no regular gravy) can be fried, cooked or baked, but not grilled. Asparagus is fresh, frozen or canned. Rinse if frozen. Fix it differently than last time. Season rice with parsley and minimal salt and pure herbs like thyme; no MSG or mixed seasoning, make butter sauce. Dessert is homemade ice cream (see *Recipes*).

6. Fish or seafood hot dish. Green peas or peas and onions. Peeled sweet potato with butter (not canned). May switch sweet potato with rice on asparagus day. Sliced tomatoes or cucumber or other raw vegetables with or without dressing. Milk, 1 tbs. honey (can be used on sweet potato).
7. Chili or stew with unlimited rice-bread and butter. If chili produces gas, stay away from it. Serve no canned varieties. Grated carrot salad with stewed raisins added and heavy cream. Milk, water as usual. Blueberry pie, sweet potato pie, custard pie.

If more bread is requested, provide a wheat-free, corn-free variety; but limit bread eating to "after main dish" eating. If not enough milk is drunk: make custard pudding or rice pudding so the daily amount (3 cups) is consumed.

Supper

1. Tuna with salad dressing or tuna salad (no pasta). Non-wheat raisin bread (from natural foods store) and butter. Milk, water.
2. Custard, cooked greens, baked potato. Rice-bread and butter. Herb tea with milk added (single herb only, not mixed herbs).
3. Vegetable soup, homemade, from scratch. Leftover meat sandwich with rice-bread (no deli or cold cuts or luncheon meat). Milk, water.
4. Baked squash with butter, rice pudding with cinnamon, raisins, and honey. Canned salmon or sardines with wheat free, corn free bread. Milk, water.
5. Chili or stew leftovers with wheat free, corn free bread. Custard pudding sweetened with honey, and nutmeg/cinnamon mix. Milk, water.

6. Sardines and rice bread or other wheat free, corn free bread. Homemade tomato juice with celery, strained. Milk, plain water. Pie a la mode (homemade pumpkin or squash pie and homemade ice cream).
7. Potato salad. Leftover meat dish and beans, stewed tomatoes, squash. Baked apple with cinnamon, cream and honey. Milk, water.

Many diabetics lose 50 points (mg/DL) of blood sugar in a few days on this diet. This is why: there is less bread than a diabetic would prefer. There is very little cheese (it must always be boiled in a sauce to sterilize). There is no fruit or vegetable juice except homemade, and not much of that because it crowds out milk and water. If your elderly loved one can't eat all this, make sure there are no snacks consumed between meals that are forbidden.

There is no pasta anywhere. Pasta is mold-ridden. Even after cooking, it may be toxic. There is no wheat or corn bread. The menu is heavy on green beans and asparagus and cinnamon. If by chance, your elderly person hates these and starves themselves to get your sympathy, add a lot more potatoes and rice (never brown) to raise calories.

There is no sweetening other than honey (5 kinds). There are no syrups or sugars. Honey is self limiting—the taste for it is all gone after 1 tbs. Not so for other sugars. The heavy use of cream and butter is offset by no deep fat fried food and little cheese.

Keep in mind that this diet may reduce the need for insulin almost immediately. You may have to cut it in half! But how would you know this? The morning blood sugar test is essential to keep track of changing circumstances. Don't neglect it. Be careful not to use rubbing alcohol when making the finger stick (use vodka or grain alcohol). Your elderly person will feel it is all worthwhile (doing without coffee or pie) if one less insulin shot is needed or if they can go back on tablets instead of insulin. Or even just the knowledge they are staying well controlled and will never have to take insulin shots. Remember to give yourself the credit for a fine accomplishment when your loved one's diabetes improves.

Diabetic Supplements

Several supplements are especially good for diabetics:

- Fenugreek seeds, 3 capsules with each meal.
- Fresh vegetable juice made of raw green beans and carrots (½cup total).
- Bilberry leaves. Maybe they have something in them that helps detoxify wood alcohol, since bilberry leaves are good for eyes, too. Get in capsules or make a tea.

Diabetic Eating Out

Since the rules are always somewhat relaxed when “eating out” a diabetic loved one will badger you to go out with them. If rules are sure to be broken, calculate it into the rest of the day so you can compensate for it.

Extra Diet Tips For The Elderly

Food should taste good.

Eating is a fundamental pleasure of living. In old age there is no other pleasure that can equal enjoyment of food. It is a time when we long for the foods of our own childhood, too. Ethnic foods often had to be given up when children were raised (switched to hot dogs and pizza) but with this diversion gone, a return to family food would be most welcome and most healthful. Ethnic foods were made from scratch. And they certainly were made at home where cleanliness and “persnickitiness” are at their finest! A speck in the batter gets noticed. Not so in a commercial mixing vat. Pots and pans are sanitized with hot water, not chemicals.

Good advice is to return to old fashioned home cooking: with its flour and butter, lard and cream, homemade pasta, olive oil and soup, coarse cereal grains and plain fruit. Gone are the fruit juices, flour mixes, crackers and sweets that fill grocery shelves. What about convenience? Old fashioned cooking took most of the day. It does take 3 or 4 hours to make a soup from scratch. But you then get 3 days off! Each day you reboil it, it is sterile again. Or freeze half of it (take the potatoes out first). It does take a whole morning to make pasta or some ethnic dish. Freeze it in plastic sealed containers so the delicate flavor isn't spoiled. Baking homemade bread is automated now. Do at least this much to get away from the mold-ridden grocery store loaves. Make your own ice cream and nut butters. They last many days and free your schedule.

Time is the great inhibitor but if you have the means or the help, the best advice, nutritionally, is a return to old-fashioned cooking and recipes. Use your new insights to improve them where you can. Don't use your mother's aluminum ware; use her enamel ware or the new glass and ceramic ware. Don't use her copper-bottomed tea kettle or gold-rimmed cups or “silver”. Use her wooden spoons, glass glasses, and plain dishes, her wooden and straw bowls and enamel pots and pans.

Salt

Should you avoid salt? No. But a good salt rule is to either cook with it or have it on the table, but not both. Use aluminum-free sea salt, and make sure the salt is sterilized by heating five minutes at 400°F in a glass pie plate to kill mold. (Sea gulls fly over the salt flats where sea salt is gathered. Their droppings provide a medium for mold.)

Fig. 38 Sea salt flats are often roosting places for sea gulls.

The best salt is a mixture of 1 part of your aluminum-free, sterilized sea salt and 1 part potassium chloride (another kind of salt, see *Sources*). Potassium ousts sodium (salt) from your body, so you can use twice as much of this kind of salt! Also, the extra potassium helps lift fatigue and has other benefits.

Always use a non-metal salt shaker with a closable lid to keep out moisture. Don't put rice in your salt because it invites mold.

Since you, the cook, know where the salt is, (mostly in soups and stews), don't serve as much of these when there is heart and kidney illness or high blood pressure. Don't put salt in cereal, cooking vegetables, or other dishes. Just leave it out! Use herbs instead. **Tip:** encapsulated herbs stay fresher and are more potent. Fenugreek and thyme are the most beneficial of the common cooking herbs. Just open a capsule and season.

Tremor

Tremor is a symptom, not a natural part of aging. The nerves controlling the hands and arms are poisoned. The nerves originate in the brain where the poison has accumulated. What is the poison? Did it happen long ago? No! It could have happened as long as two weeks ago but not longer!

Tremor is the result of ongoing poisoning! It is important to find the poison as soon as you can since the rest of the body will soon be affected, too. Search your memory for the new things that happened in the last two weeks. It is a herculean task but only gets harder each day, so keep notes as you ask: Is there new carpeting? Is there a new furnace? Is there a different water supply? Is there a new hair dresser? Did somebody bring a vase of fresh flowers? Is there a new laundry person? Was the place sprayed for insects? Is there a new medicine (drug) or supplement? Was remodeling done? Is there a new food?

The list is endless and the situation looks hopeless because so many new things can happen in two weeks.

Rather than asking individual questions like these, let's ask only **five general questions** and have the assurance that one of them will catch the culprit.

1. Is it in the **air**? This will catch insecticide, flowers, carpets all together.
2. Is it in the **water**?
3. Is it in the **medicines** or **supplements**?
4. Is it in the **clothing**?
5. Is it in the **food** or on the dishes?

To answer each question, test the item using your Syncrometer searching technique. Make a test substance. Then search a saliva sample for it.

To test the air, take a dust sample off the kitchen counter or table (this gives you fresh dust). Pick up the dust with a few wipes by a small, two inch square of damp paper towel. Place in a resealable baggy.

To test the water, make samples by putting about a tsp. of hot, cold, or filtered water into a resealable baggy with a bit of paper towel in it. Try to get the first morning water before it has run.

To test the medicines and supplements put one of each in resealable baggies.

To test clothing (laundry) use a bit of it, (such as a sock) rolled up tightly.

Testing food is the biggest job. If there are leftovers in the refrigerator or freezer, this helps. You can combine all the leftovers in a single baggy. Frozen things don't need to be thawed for testing. Still, the chance of missing a food culprit is quite high. Be sure to test everything eaten in a two week time period: unusual things like popcorn, candy, crackers, cookies, health foods and special powders. A consolation is that you will find a number of bad foods that are not necessarily the tremor causes but which cause other health problems.

Tremor Remedies

1. Let us imagine that the air (dust) sample proves toxic (resonates with the saliva sample). What is it in the air that is toxic? These are the biggest suspects:

- CFCs (from leaking refrigerant, check refrigerator and air conditioner by removing them from the house and retesting the dust after three days, or simply buy a non-CFC variety)
- vanadium (from leaking house gas from a fuel line—repair)
- arsenic from pesticide (switch to boric acid)
- solvent from a lamp or can of lighter fuel (take them out of the house)

- chlorine from water (use carbon filters; remove bleach bottles)
- asbestos (clothes dryer belt)
- paint thinner, carpet cleaner (remove from house)
- fiberglass from bare insulation somewhere (fix holes in ceiling or wall)
- formaldehyde (new foam bedding, new fabric or clothing)

2. Suppose the water proves toxic (appears in your white blood cells); search for lead, copper, and cadmium. Although municipal water tests occasionally detect small amounts of propyl alcohol, benzene, or wood alcohol, I have never detected them—you need not search for them.

3. If the medicines are toxic just change brands. Your pharmacist can help you find a replacement brand. Find which ones are toxic and stop using them. (Don't use up any of the polluted pills or supplements.) They do more harm than good.

4. If the clothing or dishes are toxic (appear in the saliva), suspect

- cobalt
- PCB
- aluminum

Stop all detergent use. Use borax, or washing soda, or use paper plates and plastic cups (not styrofoam).

5. If the food is toxic, suspect

- food molds
- aluminum
- bacteria

Don't eat that food any more.

6. Any bacterium or toxin that invades certain brain centers can cause tremor. The most common culprits are *Shigella*, mercury, thallium and arsenic. Try to identify these for your sake as well as your loved one.

The *Salmonellas* and *Shigellas* will have come from some food. Be sure all dairy foods, including butter and whipping cream, are sterilized. Parasites come from meats. Be sure no undercooked or fast food meats are eaten. Kill all bacteria, viruses and parasites with a zapper. Sterilize fingernails with grain alcohol to prevent reinfection. Use Lugol's (see *Recipes*) and the Bowel Program (page 546) to clear them up.

Bacteria, coming from teeth and jaw (bone infections, called *cavitations*) may not seem as recent as two weeks. Indeed, they may have been there for ten years. But something recent may have aggravated them, so they now can enter more easily into the blood and brain. You may never find out what caused this. It is wisest to check this possibility with a dentist before doing weeks of other testing. See a dentist who can find and clean cavitations. Do dental repair according to the principles described in the dental section.

Going after a tremor problem in this logical way always finds the cause of tremor

whether its a simple short attack or a situation of long standing tremor with head shaking and drooling. If your situation is extra difficult, you will at least improve it and stop its progression. **This includes Parkinson's cases.**

In cases of Parkinson's disease I often find the bacterium *Clostridium tetani*, well known for causing stiffness. It hides under tooth fillings, too.

Remember, there is a consolation for doing all this work. When you find the culprit, you not only will be stopping the tremor, you will be improving a lot of other conditions along the way. Conditions like hesitant speech, shuffling walk, getting up stiffly and slowly from a chair. These are extra dividends for your loved one. And you have learned which things to avoid for yourself too.

One more thing, don't take no for an answer.

If the problem is a drug, don't accept “No, it can't be changed.” Everything can be changed. Go to higher levels of authority. Doctors are very understanding and sympathetic with your intent. If the problem is leaking house gas, don't accept “We can't find a leak,” implying there is none. Go to a building contractor or the Health Department. Their equipment is better. If you get nowhere, change to electric utilities. If the problem is auto exhaust, don't accept “But we have to use the kitchen door to the garage, because it's cold outside.” Conveniences vs. tremor is no contest. Everyone benefits by excluding auto fumes from the house. Lock the door and cover it with plastic. By the time you have identified the culprits (probably 20 hours of work) surely you have won the right to make changes.

Often others are not impressed. Even when the tremor lessens and the elderly person plainly states they feel better, family members may disregard your recommendations. **Get tough!** It's your loved one. You have something at stake too. Be sympathetic with negative responses. But very firm. Make their choices clear:

- Either the inside door to the garage gets sealed off or the cars and lawn mower get parked outside and anything containing gasoline or solvents gets put in a detached shed.
- Either the girls use their hair dryers in their bedrooms with the door closed or you'll get them all new ones that don't contain asbestos.
- Either the clothes dryer gets a new belt or it is taped securely shut and the laundry is dried on the line or taken to a Laundromat.
- Either the plumbing gets changed (to plastic) or each faucet in the house gets a filter. (If your plumbing is corrod-

ing, not even filters are a good idea—you would have to change them every week!)

Weakness

should not be taken for granted in the elderly. Especially if they themselves complain about it. It isn't normal for them. Sometimes they will describe “spells” of weakness. This is an important clue. Check the pulse immediately. Count for 30 beats at least. Are there missing beats? There should not be! Missing two beats in a row certainly can produce a weak or “sinking” spell. The brain and body need every pulse of blood sent out right on time.

Check into caffeine use first. Take it all away. Caffeine speeds up the heart; then the overworked heart has to “take time out” for itself by missing a beat. Don't switch to decafs because this introduces solvents and new problems. If no other natural beverages appeal, serve hot water with cream and cinnamon. After stopping caffeine use ask: Is the pulse too slow or too fast? The pulse should be between 60 and 80 beats per minute.

If it is lower than 60, a medicine may be at fault. Ask the clinical doctor about it immediately. A slow pulse could certainly bring about weakness. A young athlete may have a slow pulse legitimately, due to having a very strong efficient heart, but your elderly person does not fit this category. The cause must be found.

If the pulse is quite high, over 100 perhaps, this will wear the heart out much sooner than necessary. Ask why it is beating so fast? A probable answer is that it is so weak that it has to beat faster to keep up with its job of circulating the blood. What is making the heart so weak?

Heart Disease

When the heart is enlarged, the valves don't quite close where they should, making the work harder for it and weakening it. It may be called "congestive heart failure." Why is it enlarged? Possibly because it is so weak! Yes, it becomes a vicious cycle, getting worse and worse. But you can break into this cycle and get it all reversed again. The real culprit is parasite invaders and toxic pollutants.

The most common parasite heart invaders are *Dirofilaria*, heartworm "of dogs" and *Loa loa*, another small filaria worm. At one stage these worms are so tiny that they can slide through the smallest blood vessels. They are very contagious. Even persons who don't live with a house dog can pick up heartworm. *Loa loa* is thought to be a tropical parasite but it is alive and thriving in the USA! The source of *Loa loa* seems to be tapeworm stages; this is not a certainty.

Both heartworm and *Loa loa* are very easy to kill with a zapper and both are very easy to pick up again. Treat your elderly person twice a week if there is any heart problem. It makes no difference that the house dog is getting monthly preventive treatments for heartworm. They pick it up daily and have thirty days to develop it and give it to others between treatments. Killing the dog's parasites twice a week with a zapper would be very helpful to you. These heart parasites may not cause any pains, yet disturb the rhythm or the pulse of the heart and cause it to enlarge.

Staphylococcus aureus is a bacterium hiding out in far away places like pockets left under teeth when they were extracted or along root canals. Make sure extractions heal and don't leave permanent cavitations where bacteria can live. Ask a dentist familiar with cavitations to do a mouth search. Once the mouth source is cleaned up, the bacteria do not come back to the heart (after one last zapping). If they do, go back to the dentist!

Killing these three invaders (heartworm, *Loa loa, Staphylococcus aureus*) should cure an irregular heart beat immediately (within a day).

If the elderly person is on a heart-slowing drug, check the pulse twice a day after zapping to make sure it doesn't drop too low. They may need to be off their heart medicine. Nobody will notice the relief of going off this medicine as much as you. The sunshine breaks out! Your loved one can smile again at little things! Even interest in sex returns so watch out! Life is normalized when drugs, especially beta blockers are gone. (Other heart medicines, such as Digitoxin,™ don't have this depressive effect. They are used to make the heart beat stronger, not to affect the rate of beating.)

The pulse should be around 70 beats per minute and perfectly regular.

If it isn't, there is still something wrong. Get rid of toxic body products and house pollutants. Test your air for gas leaks frequently. Gas heat, gas stoves and gas water heaters are notoriously leaky. Weather changes, namely temperature changes make pipes expand or shrink—leaving cracks! The gas is toxic and a small amount can't be smelled. What a predicament! Delivering poisonous house gas to our homes in pipes that are not fail-safe is an archaic practice. Especially when the blood test shows a high “total CO_2" level, near the upper limit, search for an air pollutant like house gas or auto fumes. And read the sections in this book on pulse (page 289) and brain problems (page 278) very closely for more things to check.

With the heart regular again, it will be much stronger, too, since it doesn't have to work against itself. This strength is necessary to push the blood into the farthest “corners” of the body, especially the hands and feet, and warm them up! If your loved one constantly has cold hands or feet, try to improve circulation. Dissolve phosphate crystals with the kidney herb recipe. Give niacin (page 279). Give cayenne capsules (one with each meal). Blood thinning drugs to improve circulation are dangerous—use only if the doctor insists. Monitor blood clotting time if your loved one is on a thinner.

Heart/Kidney Relationship

A strong heart is necessary, too, to push the blood through the kidneys. Often a kidney problem is linked to the heart disorder. Kidneys are made of tubes that get finer and finer. It takes pressure, namely strength, to push the blood through them so wastes and extra water can be let down the kidney tube. Think of the kidneys as a colander full of tiny holes of various sizes that let certain things through them but not bigger things. These holes are constantly being adjusted by the adrenals which sit right on top of the kidneys and "supervise".

If the elderly person is not producing four cups of urine in a day (24 hours), it is not enough. The body cannot get enough cleansing action from less than four cups. More liquid must be consumed. If most of the urine is passed in the night this reflects on unhealthy kidneys. Use the kidney herb recipe—but only half a dose (so it will take six weeks instead of three to see good effects). As the tiny "colander" holes open up there is freer flow and many more trips to the bathroom result. The urine loses its awful odor (no ammonia, acetone and bacteria!) and gets a clear look that shows no sediment. Now that water and wastes (urea and uric acid and other acids) can leave the body quickly through more holes, it takes less pressure from the heart to get blood pushed through the kidneys. This brings relief to the heart because its work is easier. The heart and kidneys work together. Like horse and wagon the heart provides the power and the kidneys follow.

This is why heart medicine and diuretics are commonly given together. *Diuresis* (urine flow) helps the heart and a stronger heart helps the kidneys. Similarly, they fail together. In the old days this was called *dropsy*. Urine that should have left the body is backed up in the tissues. Sometimes it shows up in pockets that hang like giant oranges from the skin.

Even (especially) when the strongest diuretics (Maxzide™, Lasix™) fail to work, even when coupled with strong heart medicine (Digitoxin™), the kidney herb recipe can bail you out of the emergency.

The secret is in the varied actions of different herbs. This makes them work together. Be very careful to keep the herb tea sterile by reheating every fourth day. Freeze unused larger amounts. If too much is drunk at once, especially on the first day, a stomach ache can develop and a pressure felt in the bladder that is most uncomfortable. Go extra slow on the first few days, even though you find it quite tasty, so there is no discomfort (only lots of bathroom visits).

Diuretics

As soon as urine is flowing better, blood pressure may drop. Keep track of this twice a day with a modern electronic finger device (not an arm cuff that itself can break blood vessels). Cut down on drug diuretics gradually, using only ¾dose the first day, then ½dose, then ¼ dose. The amount of urine produced or the weight of the person can be used to assess how effective your method is. **Your goal is to not need any drug diuretics.** Again, mood will improve dramatically when diuretic drugs are removed for your loved one. The sense of humor comes back:

be prepared for some new jokes and new laughter. Give yourself good grades for this accomplishment.

Don't throw out the drug diuretics. After being off them for a while, they become more potent again. So if an emergency (sudden edema) should arise they could again be useful.

With a parasite and pollution-free heart and a low-resistance, freely flowing kidney, some reserve strength will soon be built up. Weak spells are gone and forgotten. Your loved one is walking better, needing less sleep, and a “golden age” finally arrives. It is free of pain, free of medicine, free of shots and doctor visits, free of dementia, free of the dreadful weakness that demands so much help. They are free to enjoy family and friends again. Seeing themselves gain strength and be able to do more for themselves gives the elderly a sense of pride.

Give them the credit for improving their health. When they balk at having to take herbs or vegetable juice, remind them of the days they were on a handful of pills and still had heart failure, pain and kidney disease.

Feeling Comfortable

If all this improvement doesn't warm up their feet or hands (feel them yourself) put extra socks on. Warming up their feet might have the effect of warming up hands, too. But if it doesn't, raise the room temperature.

Being forced to feel cold is an undeserved misery of the aged.

Others must accommodate to the elderly's need for body warmth. The thermometer does not tell all. Comfort is paramount for each of us. Younger persons can undress for comfort. The elderly can't make changes for themselves. Usually, by the time they are complaining of cold, they have suffered a long time, feeling too guilty to request a temperature hike. Ask your loved one. They will appreciate it. A shawl, a lap-blanket, woolen sweater, long underwear and fleecy thermal outerwear help a lot. But if your hand still senses cold feet, the thermostat must still go higher. Cold body temperature is an invitation for fungus and viruses to multiply. Viruses escape into the body daily. Don't give them the advantage.

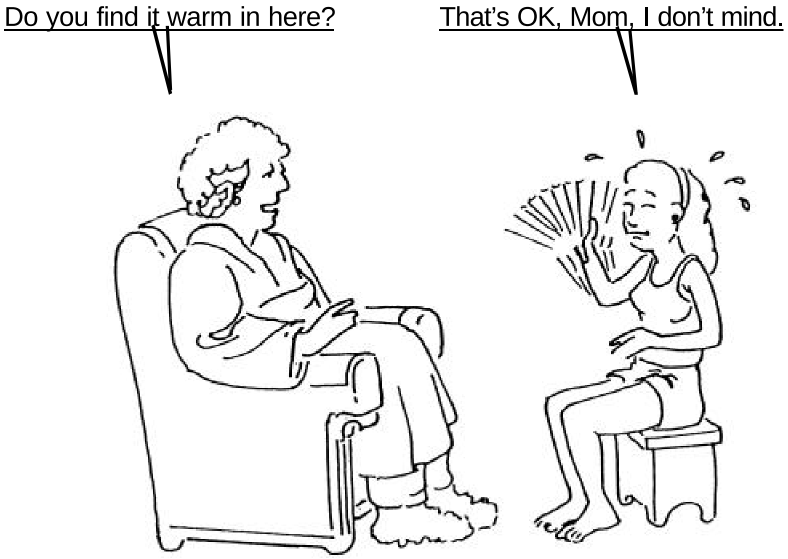
Do you find it warm in here?
That's OK, Mom, I don't mind.

Fig. 39 Too hot and too cold.

But unless all these things are tried, don't raise the temperature. It is much healthier to be warmly dressed and breathe cool air than to be lightly dressed in an 80°F room. The heart, especially, benefits by the cooler air temperature.

For this reason, it is important to have air conditioning during the hot season. Keep your elderly person warmly dressed, away from air conditioner or fan drafts, but keep it cool. As cool as their body temperature and comfort will allow. Don't seat an elderly person under a fan in restaurants. The blowing air not only chills them, but brings filth in dust that blows in the air currents. Bacteria and viruses are soon to follow.

Being comfortable, knowing you are there to care for them, brings out the best in your elderly person. They might get well enough to long for a genuine relationship again. And put you to the test. The test of listening. This can be very rewarding if they are still able to communicate and distill their life experience into wisdom for you. If you can listen and be interested in their distillations or their ramblings their longing for relationship will be fulfilled. There's just one catch, if the new found interest in communication can't be expressed. If they haven't communicated much for a long time, it would be easy for you to miss a simple fact. They can't hear!

Hearing Loss

The hearing deficit in an elderly person is always much greater than they or you realize. Try to understand these communications:

What you (caregiver) say	**What the elderly person hears**	**What they think**	**What they respond**
“Look at the sunshine, isn't it a nice day?”	“Look at something, isn't it a nice bay?”	What a stupid sentence. But she wants an answer. So here goes,	“MmmHmmm” (Meaning, “yes.”)
“We'll have such a nice walk.”	“Have a…rock.”	Rock what? I'm not in a rocking char. I better not say anything.	
“What kind of soup should I make?”	“What kind of hoop should I make?”	I haven't used a hoop for embroidery for a long time. Why is she digging that up. I better say I don't know.	“I don't know.”

Don't let this ruin your relationship. It takes the fun out of their life as much as yours. **Get hearing aids**.

Don't ask your loved one if they need a hearing aid. The answer may be “I'm not deaf.” You can go about it more persuasively. Every time you talk, come quite near to the person's ear and speak loudly. They can see that you must come near. If they are fighting against the whole business, they will say things like, “You don't have to shout. I can hear you.” (It's what you're saying that's wrong!)

Arrange for a hearing test. It is free. That will appeal. The results of a hearing test, as it is told by a salesperson, is much more persuasive than you can be. Let the salesperson use his or her special talents to sell your loved one on hearing aids. But you make the choice on quality. Both you and your elderly person deserve the best tone quality that is made. Plus a regular cleaning service. Most companies do offer this but don't tell the customer because of the dreadful amount of time it would take if everybody took advantage of it. You take advantage of it. Clogged hearing aids are the most troublesome feature of any of them—and never mentioned! Make it a rule to buy your batteries at the same hearing aid office where they are cleaned free of charge. This repays them and serves the elderly best. Hearing loss is too subtle to leave to chance; have the hearing aids cleaned each time you buy fresh batteries (about three months). Take your loved one to a nurse for ear cleaning every six months after hearing aids are begun. Wax and debris accumulate behind the aid because the channel is stopped up.

With hearing aids that hear, and kidneys that flush and a heart that beats strongly, your elderly person may choose to attend concerts again, go to church or gatherings—and leave you out of the picture. Give yourself good grades for this achievement. Get them incontinence pants, get regular taxi service. **Do whatever it takes to get your loved one out into the world again!**

If the excitement of a night out keeps him or her from sleeping use **ornithine** and **valerian** capsules. They are good for the health anyway. Hot milk and a piece of cake (homemade, never chocolate) may do as much.

But if insomnia is the rule, not the exception, you need to go after it as a special problem.

Insomnia

is always associated with high levels of parasites and bacteria. This leads me to believe it is their waste products, namely ammonia, that really causes insomnia. Read the section on Insomnia under Sleep Problems for more on this (page 243).

A sound sleep refreshes as nothing else can. Your elderly person will have more energy throughout the day and a better mood if sleep was good.

Of course you must guard against daytime napping if nights are sleepless. Sleep at night is more important than sleep by day. They are not equal. Try to turn your loved one's cycle back to night-time sleeping if it has become turned around by bad kidney function (frequent urination at night) or too much daytime napping. Sleep can be disturbed by taking vitamins at bedtime too. Sleep is enhanced by taking magnesium. Limit bedtime supplements to magnesium, ornithine, valerian (6 capsules) taken with hot milk.

Healthful Habits

If your loved one had his or her way, they would drive the car forever, wear the same cosmetics forever, smoke or chew tobacco forever and eat their favorite dessert forever.

But if you are the caretaker, you know that some things must stop. You also know that gentle persuasion is useless; it merely erodes your relationship. Here are a few tips.

1. Ask your loved one to ask their doctor (clinical doctor or trusted medical advisor) the following question: “Would it be better for my lungs to stop smoking?” Be present so the question does not turn into “Will smoking a few cigarettes once in a while kill me?” Hearing it from the doctor is what's needed.
2. Don't ever purchase something you believe is detrimental to your elderly person. Whether it's coffee, cigarettes, beer or lipstick, say “That is something I can't buy for you; it's against my principles.” Don't be surprised if you cave in a few times to some super ruse they use on you. But the next time, have your answer ready.
3. Let your family and other caretakers know you are no longer supplying these items (the car keys, the wine bottle, the codeine-containing pain pills). Try to get cooperation. Discussing it with your loved one may do more harm than good. If they start the discussion, you end it. This is not a task for the timid! After it's done, you'll wonder what was so difficult.
4. Don't buy a wheelchair if your loved one can still walk with your help. Stay with a cane as long as possible. Then the walker. Stay with a walker as long as possible. Then your personal help. Once a wheelchair has been accepted, the last bit of exercise, walking, is lost. Fight against it. Hide it in a far away closet.

Aging is necessary but chronic illness and pain are not.

If you have managed to free your loved one from having to take pills or from certain disabilities that would soon require pills, you can give yourself great credit. Perhaps you, too, will find the needed natural help when you are aged and have lost your authority and your way mentally. Our lives are all foreshortened, much like the life of a domestic steer's. Does a captive animal learn from seeing its companion disappear? It does nothing to escape its fate. Should we accept our fate with the same docility? None of us can remember how things were in precivilized times. We are eager to believe the present is the best time that has ever been. The steer, too, has its feed provided, its water provided, its shelter for the night provided, seemingly the best time it ever had. Perhaps the price we pay for civilization, like the steer's price, is simply too high. There must be other ways. As a society, we should search for our lost longevity.

Not Old Yet

For persons merely over 40 and not ill a most important rule is: **don't overdo**.

It's easy to injure tendons and muscles by pulling or stretching them too far. Don't try, with almighty determination to open a jar. Leave it for stronger hands. Don't try to stretch a gigantic stretch to reach something on a high shelf. Wait for someone taller to come along and reach it down for you. Don't do exercises, that have left you with strains in the past. Do different exercises. Don't do new exercises, with a determined approach; start moderately; stay moderate. If you start a new job that uses a foot, leg, hand or wrist a lot, more than it was used before, even though it's in ordinary use, it can feel injured. These stresses and strains invite bacteria toward themselves. Bacteria from the liver or your own intestines find these strained tissues immediately and intensify the pain. Kill the bacteria with a zapper, cleanse the liver, and start the Bowel Program if this has already happened to you.

Don't kneel on the floor to do some cleaning job. Don't sit on the floor at a gathering. Don't let your grandchildren take “rides” on you. Don't bend over as far as you can to pick something up. Let your family know you are aiming to reach 100 years in healthy condition.

Super Longevity

We should be able to live to 140 years of age. Middle age might begin at 65, old age at 90. What is the clue to long life? Surely it is keeping all your cells healthy so they can coordinate the constant tasks of nourishing themselves, removing their wastes, plus whatever job that cell was meant to do.

Since your cells divide and therefore start again at age zero, even though you are 90, why do you age at all? Only the nervous system does not divide. Is it the nerve that ages then, and decides death for each of us?

It would never do to live forever. It would clutter the planet. Are evolutionary forces at work preventing this? But we have never cluttered the planet yet. So how could evolutionary forces have “learned” to establish death to prevent overpopulation? Living to age 140 is not living forever. Wisdom comes with age. Wisdom would serve our society well. Perhaps wisdom is needed more than ever for humans to survive. Part of the human tragedy is war. Wisdom gathered from a knowledge of history, might help end wars! But history can't be gathered and understood in less than 100 years. If centenarians can't think well or express themselves, their perspectives are lost. Longevity seems a very useful trait if only it were accompanied by health!

Dying

Although it can't be avoided it can be helped. Dying alone is the most barbaric of all society's practices.

It is still like death in the forest amongst chimpanzees. Unable to feed, to run, to call for help brings pain, fear, loneliness and finally, death. When your loved one is in the mood to talk about dying, listen. Especially if it is about their own imminent death. This doesn't obligate you to carry out any of their wishes. When death approaches the important thing is simply to be there. They may not have requested this, out of a sense of guilt or masochism, or plain dementia. But it is the most primitive of needs, the same as having a loved one nearby during childbirth. It is just a presence that counts. How can you be there if you have a job or are attending a family's needs? It is a time of great frustration for you. All your hard work and successes are culminating in one grand failure!

The good news is that it need not be you who attends your loved one every minute of the last week. Pay for someone to sit—someone who is recognized. But arrange for immediate privacy when you return. No matter how much your loved one admonishes you to go about your business, you will know when you share the final minute that your presence helped. The loneliness of the last coma, the last silence is unspeakable. Give yourself the reward of knowing you shared the pain, fear and silent cry for help.

Curing Cancer

Cancer is no longer the deadly disease it once was. In fact, you can clear it up in less time than it takes to get a doctor's appointment for a check up. If you notice a lump or think you might have cancer, don't rush to see a doctor first. Rush to clear it up, yourself, first. By the time your doctor's appointment arrives, you can be sure of a negative test.

Another Fluke Disease

Cancer is so easily cured because it is a parasite-caused disease. Kill the parasite and you have stopped the cancer. This does not mean you have also stopped being ill. If the cancer damaged your ovaries or prostate, you still must heal these organs. The Ca-125 or PSA test will not drop to normal unless you begin to heal them. These markers reflect the condition of the organ, not its malignant nature. Remember that killing a mosquito does not remove the lump it caused. That will take its course. It will heal beautifully if you let it. But if you scratch it mercilessly, it will take longer. Removing toxins from the affected organs lets them heal.

Fortunately for us, **cancer is not like a fire, unstoppable once it has started**. It takes only 7 minutes to zap all the parasite adults and their stages which cause your cells to multiply.

The responsible parasite is *Fasciolopsis buskii*, the **human intestinal fluke**, a flatworm. It is a human parasite although it can also parasitize other species. It normally lives quietly in the intestine. (The goal for all larger parasites is to live quietly. After all, your demise is their demise.) They were meant to pass their thousands of eggs with your bowel movement, outside, to some pond where snails live. But when the eggs hatch before they leave your body and are allowed to continue their development inside you, the setting is right for cancer to develop.

If the fluke eggs and other stages go through their development in your breast it can become breast cancer. If it is in the prostate it can become prostate cancer. And so on. Each different kind of cancer means the developmental stages of the intestinal fluke are present there. Only one more thing is needed to bring about an avalanche of reproduction, so that hundreds of little larvae turn into hundreds more in a short time: a growth factor. It makes them multiply and your cells are similarly affected. This growth factor, *ortho-phospho-tyrosine* (and possibly, also, *epidermal growth factor* and *insulin-dependent growth factor*) really begins your cancer.

Teamed With A Solvent

The good news is that this growth factor, which is essential for cancer to develop, cannot be made, without the presence of an abnormal solvent, **propyl alcohol** (or more exactly, isopropyl alcohol).

Without taking in propyl alcohol you could never get cancer. It takes two things, together, to give you cancer: propyl alcohol and the human intestinal fluke parasite.

Since it takes a frequency generator (3 minutes at each of 434, 432, 427, 425, 423, 421 KHz) or zapper mere minutes to kill the fluke and its stages you will be stopping the production of growth factors immediately.

Zap yourself every day for three seven minute periods, until after you are completely well.

After killing the flukes, those growth factors already formed will disappear in one hour. Your malignancy is stopped. It cannot return unless you infect yourself with the parasite again!

Getting rid of propyl alcohol is also a simple task. Once you have stopped using it, the last remnants leave your body within three days.

We must marvel at the body's wisdom and capabilities for restoring health. You are not permanently damaged by this large and hungry parasite. Given half a chance your body will throw the rascals out and restore order in your tissues.

Read the list of foods and products that are polluted with propyl alcohol. It is not, of course, usually on the label. If it is used as an ingredient, it is on the label, easy for you to avoid. It is the pollutants not appearing on the label that pose sinister hazards.

INFUSIUM23
INFUSIUM23

All the store bought shampoo I tested had propyl alcohol. Health brands were no exception

CRYSTAL GEYSER

All bottled water is polluted with antiseptics from the bottling procedure. This is a main source of propyl alcohol.

Cosmetics are laced with propyl alcohol. Use the recipes in this book to make your own.

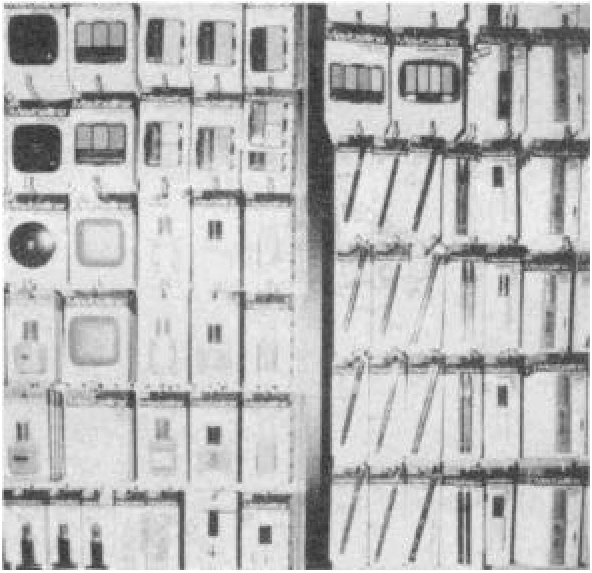

Fig. 40 Products with propyl alcohol.

Propyl Alcohol Polluted Products

THROW THESE OUT

even if propyl alcohol is not listed on the label!

- **shampoo**, even health brands
- **hair spray** and **mousse**
- **cold cereals**, even “natural” granolas
- **cosmetics** (make your own)
- **mouthwash**
- **decaffeinated coffee**, Postum™, herb tea blends (single herb teas are OK)
- **vitamins, minerals and supplements** (unless you test them)
- **bottled water**, distilled water, or spring water
- **rubbing alcohol**
- **white sugar** (brown is OK if detoxified)
- all **shaving supplies** including aftershave
- **carbonated beverages**
- store-bought **fruit juice**, including health food brands

Tear out this page, put it on your refrigerator, and make a copy to stick on your medicine cabinet. Remember propyl alcohol is also called propanol, isopropanol, isopropyl alcohol and rubbing alcohol. You won't drop dead from getting propyl alcohol, but your cancer will flare up with each small addition.

Avoid the entire list, meticulously. Even using one of these, **like your favorite shampoo or bottled water**, will result in failure. Your body will continue to make *human chorionic gonadotropin* (hCG) and the pathology will remain “indeterminate”—not cancerous but not well, either. If you have learned the new bioelectronic technology described in this book, you can test all your foods and products for isopropyl alcohol.

When you find a beverage that is free of propyl alcohol, it may have other pollutants. Xylene and toluene invite parasites to the brain. Wood alcohol invites them to eyes and pancreas. The diseases caused by these are not as frightening, perhaps, as cancer, but entirely avoidable. For this reason, I suggest in this book that you go back (actually “forward”) to self made products, unprocessed food and a limited number of tested supplements.

Getting Well After Cancer

The ravages of cancer must be healed once the malignancy has been stopped. This is where *carcinogens* play a role. The lung lesions will not heal unless cigarette smoking, freon, asbestos, and fiberglass exposure is stopped. Carcinogens were thought to be the cause of cancer. Actually, they drew the cancer to the organ. Nickel draws cancer to the prostate. Barium found in lipstick draws cancer to the breast. And so on.

The following toxins can be present in any organ! I consider these to be our most serious threat. Starting with the worst, they are:

1. **Freon** (same as **CFCs** or refrigerant). I have not found a single person to be entirely free of it, including persons without cancer or disease. But in cancer sufferers it is always concentrated in the cancerous organ, and facilitates the accumulation of other toxins. This makes your refrig-

erator, if it leaks even microscopically, the top cancer hazard in the country!

2. **Copper** from water pipes. All cancer sufferers have an accumulation in the cancerous tissue. This makes plumbing the second greatest hazard.
3. **Fiberglass** or **asbestos** is present in about 25% of the cancer victims I see.
4. **Mercury** as in tooth fillings.
5. **Lead** from solder joints in copper plumbing. All colon cancer sufferers test positive.
6. **Formaldehyde** as in foam bedding and new clothing.
7. **Nickel** usually from dental metal. Most prostate cancer sufferers test positive.

At first, tumors are benign—what a relief to find your tumor was benign. Its true nature is still unknown, but it contains freon, other toxins, and later propyl alcohol! Since tumors are often large, many centimeters in diameter, and toxins do not occupy much space, there is much unidentified substance. These tumors can multiply and enlarge, as in fibrocystic breast disease, all without being malignant. But what a convenient place for baby stages of the fluke to hide out and multiply, safe from your immune system. After being colonized by fluke stages, the tumors become malignant. Eventually they also become infected when metastasis sets in.

All malignancies have the same two fundamental causes: intestinal flukes and propyl alcohol. Whether you have a rhabdomyosarcoma or a mesothelioma or melanoma, you can cure it quickly, never to return.

Herbal Parasite Killing Program

Flatworms, roundworms, protozoa, even bacteria and viruses are remarkably easy to kill using a combination of zapping and this herbal program. Thus it is not just for cancer, but a general treatment that can benefit almost every illness

1. **Black Walnut Hull Tincture Extra Strength** (see *Recipes,* page 543):
   Day 1: (this is the day you begin; start the same day you receive it)
   Take one drop. Put it in ½ cup of water. Sip it on an empty stomach such as before a meal.

   Day 2: Take 2 drops in ½ cup water same as above.
   Day 3: Take 3 drops in ½ cup water same as above.
   Day 4: Take 4 drops in ½ cup water same as above.
   Day 5: Take 5 drops in ½ cup water same as above.
   Day 6: Take 2 tsp., all together in ¼ cup water. Sip it, don't gulp it. Get it down within 15 minutes. (If you are over 150 pounds, take 2½ tsp. Do not take more than 3 tsp. because no additional value has been observed.)

   This dose kills any remaining stages throughout the body, including the bowel contents, a location unreachable by electric current. The alcohol in the tincture can make you slightly woozy for several minutes. Simply stay seated until you are comfortable again. You may put the tincture in lukewarm water to help evaporate some of the alcohol, but do not use hot water because that may damage its parasiticide power. Then take niacinamide 500 mg to counteract the toxicity of the alcohol. You could also feel a slight nausea for a few minutes. Walk in the fresh air or *simply rest until it passes. You may add more water or honey or a spice to make it more palatable.*

For a year: take 2 tsp. Black Walnut Hull Tincture Extra Strength every week or until your illness is but a hazy memory. This is to kill any parasite stages you pick up from your family, friends, or pets.

Family members and friends should take 2 tsp. every other week to avoid reinfecting you. They may be harboring a few parasite stages in their intestinal tract without having symptoms. But when these stages are transmitted to a cancer patient, they immediately seek out the cancerous organ again.

You may be wondering why you should wait for five days before taking the 2 tsp. dose. It is for your convenience only. You may have a sensitive stomach or be worried about toxicity or side effects. By the sixth day you will have convinced yourself there is no toxicity or side effects.

***Going faster**. In fact, if you are convinced after the first drop of the restorative powers of Black Walnut Hull Tincture Extra Strength, take the 2 tsp. dose on the very first day.*

***Going slower**. On the other hand, if you cringe at the thought of taking an herb or you are anxious about it's safety, continue the drops, increasing at your own pace, until you are ready to brave the decisive 2 tsp. dose.*

2. **Wormwood** capsules (should contain 200-300 mg of wormwood, see *Sources*):

Day 1: Take 1 capsule before supper (with water).
Day 2: Take 1 capsule before supper.

Day 3: Take 2 capsules before supper.
Day 4: Take 2 capsules before supper.

Continue increasing in this way to day 14, whereupon you are up to seven capsules. You take the capsules all in a single dose (you may take a few at a time until they are all gone). Then you do 2 more days of 7 capsules each. After this, you take 7 capsules once a week forever, as it states in the Maintenance Parasite Program. Try not to get interrupted before the 6th day, so you know the adult intestinal flukes are dead. After this, you may proceed more slowly if you wish. Many persons with sensitive stomachs prefer to stay longer on each dose instead of increasing according to this schedule. You may choose the pace after the sixth day.

3. **Cloves**:
   Fill size 00 capsules with fresh ground cloves; if this size is not available, use size 0 or 000. In a pinch, buy gelatin capsules and empty them or empty other vitamin capsules. You may be able to purchase fresh ground cloves that are already encapsulated; they should be about 500 mg. Grocery store ground cloves do not work! Either grind them yourself or see Sources.

   Day 1: Take one capsule 3 times a day before meals.
   Day 2: Take two capsules 3 times a day.
   Days 3, 4, 5, 6, 7, 8, 9, 10: Take three capsules 3 times a day.
   After day 10: Take 3 capsules all together once a week forever, as in the Maintenance Parasite Program.

Take **ornithine** at bedtime for insomnia. Even if you do not suffer from insomnia now, you may when you kill parasites.

Parasite Program Handy Chart

Strike out the doses as you take them.

	Black Walnut Hull Tincture Extra Strength Dose	**Wormwood Capsule Dose (200-300 mg)**	**Clove Capsule Dose (Size 0 or 00)**
Day	drops 1 time per day, like before a meal	capsules 1 time per day, on empty stomach (before meal)	capsules 3 times per day, like at mealtime
1	1	1	1, 1, 1
2	2	1	2, 2, 2
3	3	2	3, 3, 3
4	4	2	3, 3, 3
5	5	3	3, 3, 3
6	2 tsp.	3	3, 3, 3
7	Now once a week	4	3, 3, 3
8		4	3, 3, 3
9		5	3, 3, 3
10		5	3, 3, 3.
11		6	3
12		6	Now once a week
13	2 tsp.	7	
14		7	
15		7	
16		7	
17		Now once a week	
18			3

At this point you do not need to keep a strict schedule, but instead may choose any day of the week to take all the parasite program ingredients.

Continue on the Maintenance Parasite Program, indefinitely, to prevent future reinfection.

Maintenance Parasite Program

YOU ARE ALWAYS PICKING UP PARASITES! PARASITES ARE EVERYWHERE AROUND YOU! YOU GET THEM FROM OTHER PEOPLE, YOUR FAMILY, YOURSELF, YOUR HOME, YOUR PETS, UNDERCOOKED MEAT, AND UNDERCOOKED DAIRY PRODUCTS.

I believe the main source of the intestinal fluke is undercooked meat. After we are infected with it this way, we can give it to each other through blood, saliva, semen, and breast milk, which means kissing on the mouth, sex, nursing, and childbearing.

Family members nearly always have the same parasites. If one person develops cancer or HIV, the others probably have the intestinal fluke also. These diseases are caused by the same parasite. They should give themselves the same de-parasitizing program.

Do this once a week. You may take these at different times in the day or together:

1. **Black Walnut Hull Tincture Extra Strength**: 2 tsp. on an empty stomach, like before a meal.
2. **Wormwood capsules**: 7 capsules (with 200-300 mg wormwood each) at once on an empty stomach.
3. **Cloves**: 3 capsules (about 500 mg. each, or fill size 00 capsules yourself) at once on an empty stomach.
4. Take **ornithine** as needed.

	Black Walnut Hull Tincture Extra Strength Dose	**Wormwood Capsule Dose (200-300 mg)**	**Clove Capsule Dose (Size 0 or 00)**
Day	1 time per day, on empty stomach	capsules 1 time per day, on empty stomach	capsules 1 time per day, on empty stomach
1	2 tsp.	7	3
2			
3			
4			
5			
6			
7			
8	2 tsp.	7	3
9			
10			

11			
12			
13			
14			
15	2 tsp.	7	3
and so	**on...**		

The only after-effects you may feel are due to bacteria and viruses escaping from dead parasites! Be sure to zap after taking your maintenance parasite treatment. After-effects also let you know that you did indeed kill something. Try to discover how you might have picked up parasites and avoid them next time.

Pet Parasite Program

Pets have many of the same parasites that we get, including *Ascaris* (common roundworm), hookworm, *Trichinella*, *Strongyloides*, heartworm and a variety of tapeworms. Every pet living in your home should be deparasitized (cleared of parasites) and maintained on a parasite program. Monthly trips to your vet are not sufficient.

You may not need to get rid of your pet to keep yourself free of parasites. But if you are quite ill it is best to board it with a friend until you are better.

Your pet is part of your family and should be kept as sweet and clean and healthy as yourself. This is not difficult to achieve. Here is the recipe:

1. **Parsley water**: cook a big bunch of fresh parsley in a quart of water for 3 minutes. Throw away the parsley. After cooling, you may freeze most of it in several 1 cup containers. This is a month's supply. Put 1 tsp. parsley

water on the pet's food. You don't have to watch it go down. Whatever amount is eaten is satisfactory.

All dosages are based on a 10 pound (5 kilo) cat or dog. Double them for a 20 pound pet, and so forth.

Pets are so full of parasites, you must be quite careful not to deparasitize too quickly. The purpose of the parsley water is to keep the kidneys flowing well so dead parasite refuse is eliminated promptly. They get quite fond of their parsley water. Perhaps they can sense the benefit it brings them. Do this for a week before starting the Black Walnut Hull Tincture.

2. **Black Walnut Hull Tincture (regular strength):** 1 drop on the food. Don't force them to eat it. Count carefully. Treat cats only twice a week. Treat dogs daily, for instance a 30 pound dog would get 3 drops per day (but work up to it, increasing one drop per day). Do not use Extra Strength.

If your pet vomits or has diarrhea, you may expect to see worms. This is extremely infectious and hazardous. Never let a child clean up a pet mess. Begin by pouring salt and iodine[15] on the mess and letting it stand for 5 minutes before cleaning it up. Clean up outdoor messes the same way. Finally, clean your hands with diluted grain alcohol (dilute 1 part alcohol with 4 parts water) or vodka. Be careful to keep all alcohol out of sight of children; don't rely on discipline for this. Be careful not to buy isopropyl rubbing alcohol for this purpose.

Start the wormwood a week later.

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[15] “Povidone” iodine. topical antiseptic, is available in most drug stores.

3. **Wormwood capsules:** (200-300 mg wormwood per capsule) open a capsule and put the smallest pinch possible on their dry food. Do this for a week before starting the cloves.

4. **Cloves:** put the smallest pinch possible on their dry food.

Keep all of this up as a routine so that you need not fear your pets. Also, notice how peppy and happy they become.

Go slowly so the pet can learn to eat all of it. To repeat:

- Week 1: parsley water.
- Week 2: parsley water and black walnut.
- Week 3: parsley water, black walnut, and wormwood.
- Week 4: parsley water, black walnut, wormwood, and cloves.

	Parsley Water	**Black Walnut Hull Tincture Dose**	**Wormwood Capsule Dose**	**Clove Capsule Dose (Size 0 or 00)**
Week	teaspoons on food	drops on food, cats twice per week, dogs daily	open capsule, put smallest pinch on food	open capsule, put smallest pinch on food
1	1 or more, based on size			
2	1 or more	1		
3	1 or more	1 or more, based on size	1	
4	1 or more	1 or more	1	1
5 and onward	1 or more	1 or more	1	1

Parasites Gone, Toxins Next

Healing is automatic when you clean up your body tissues. Killing parasites and bacterial and viral invaders is fundamental. Removing toxins which invite them into your organs is even more fundamental.

How do you know which toxins are responsible for your cancer? Unless you use a Syncrometer to test, you can not know. So learn to use a Syncrometer, it will save your life.

The only other alternative is to move to a safer environment. Go on vacation. Stay in hotels less than ten years old (so the plumbing hasn't started to corrode) but not in new construction (give the carpets time to outgas). Do not have a freon containing refrigerator in your room. Do not use the hair drier they supply. Do not let them spray your room with anything. Launder the sheets and towels yourself at a Laundromat with borax and/or washing soda. Don't hesitate to drink the municipal water. Get busy with your dental cleanup.

When you get better on vacation, let that be your inspiration to move from your home. All of the toxins come from a civilized lifestyle. Resolve to leave it behind. Select a warm climate where you can spend your time outdoors in the shade most of the day. Have no refrigerator, air conditioner, clothes dryer, hair dryer, new clothing, detergent. Check that the plumbing is relatively new and that no pesticide is being used. Make the Easy Lifestyle Improvements (page 397). Throw away non-essential health supplements (unless tested) and drugs. The risk is greater than the benefit.

Watch For Bacteria

In the later stages of cancer the tumors are more and more infected with the common bacteria *Salmonella*, *Shigella*, and *Staphylococcus aureus*. Killing parasites prepares a feast for these ubiquitous bacteria. Now, more than ever, must you stay off dairy products (except for boiled milk), do the Bowel Program, take Lugol’s. Remove *Staphs* by doing the dental cleanup (page 409). Don't delay.

Help Your Family, Too

If you had cancer, your whole family should be freed of intestinal fluke parasites to protect you! They may not be getting cancer (yet!) but your closeness puts you at risk. Kissing on the mouth could reinfect you. Request that family members zap themselves and take at least one 2 tsp. dose of Black Walnut Hull Tincture Extra Strength while living with you.

Pets, too, can be a source of cancer fluke stages (in their drool). They get propyl alcohol from their feed. Use unflavored, uncolored feed for them to minimize pollution from processing. Add 1 tbs. vitamin C powder to the top of a 5 lb. bag; it will stick to the pellets as they pour out. Zap your pet along with yourself by holding them and touching a bare spot such as nose or paw.

Never eat rare meats or fast food chicken. Parasite stages survive heat up to the boiling point. If you have taken a risk, zap yourself as soon as you get home to minimize the damage.

Cancer could be completely eliminated in the entire country if laws required testing for solvents in animal feeds and human food and products. Presently it is allowed in the United States Code of Federal Regulations (CFR) (see page 428)!

Another reason for propyl alcohol pollution (and other pollutants) in our food are the chemicals used by manufacturers to sterilize their food handling equipment.

> **21 CFR 178.1010 (4-1-94 Edition) Sanitizing solutions.**
>
> Sanitizing solutions may be safely used on food-processing equipment and utensils, and on other food-contact articles as specified in this section, within the following prescribed conditions:
>
> (a) Such sanitizing solutions are used, followed by adequate draining, before contact with food. **[Note rinsing or drying is not required!]**

> (b) The solutions consist of one of the following, to which may be added components general recognized as safe and components which are permitted by prior sanction or approval.
>
> [Now comes (1) through (43) permissible sterilizing solutions, including several with isopropyl alcohol, like:]
>
> (25) An aqueous solution containing elemental iodine (CAS Reg. No. 7553-56-2), potassium iodide (CAS Reg. No. 7681-11-0), and isopropanol (CAS Reg. No. 67-63-0). In addition to use on food processing equipment and utensils, this solution may be used on beverage containers, including milk containers and equipment and on food-contact surfaces in public eating places.
>
> [Then in paragraph (c)(19) the exact concentration of the iodine is specified. Nowhere is the concentration of the isopropanol specified. It can be as strong as desired.]

Fig. 41 U.S. regulations on sterilizing solutions.

Even if there were regulations governing removal of sanitizing solutions, the overwhelming truth is missed: that **nothing can ever be completely removed after it has been added**. Or perhaps the lawmakers didn't miss this fact. Perhaps they believed that small amounts–too small to measure with an ultraviolet spectrophotometer–could surely do no harm.

Meanwhile, protect yourself by avoiding propyl alcohol. And by observing 2 extra rules:

1. Never eat moldy foods. **2. Always take vitamin C.**

Aflatoxin

A common mold found on bread, nuts and fruit and in beer, apple cider vinegar and syrups, produces *aflatoxin*. This is what prevents you from detoxifying tiny bits of propyl alcohol that get into your body!

Buy bakery bread or bake your own. Roast nuts after washing in vitamin C water to destroy aflatoxin and then store in refrigerator. Keep moldy fruit out of the refrigerator where the spores can spread. Use only white distilled vinegar. Use honeys instead of syrups and even add vitamin C to them.

Vitamin C helps your body detoxify all the mold toxins I have tested, including aflatoxin.

Keep powdered vitamin C in a salt shaker. It belongs on the table with salt and pepper, and at the stove. Put it in everything possible, from cereal to soup to rice (1/8 tsp. is enough). Besides this take 1/8 tsp. powdered vitamin C with each meal (500 mg).

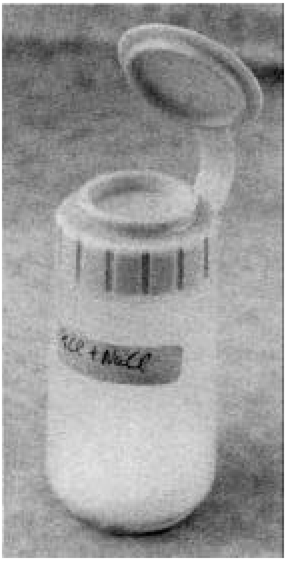

Fig. 42 Keep both salt and vitamin C powders in closable plastic shakers.

Developing cancer is a chain of events. This explains why it is a disease of aging. For ten years or more you poisoned your body with freon, fiberglass, asbestos, mercury, lead, copper, etc. You continually ate moldy food (chips, nuts, etc.) which was toxic to the liver. But the liver regenerated the pieces that died. Eventually a mold toxin prevents the liver from regenerating. Your aflatoxin-ed liver then lets propyl alcohol build up after using it. You use more and more propyl alcohol. Somewhere, over the years, you pick up the intestinal fluke in a hamburger or from a pet or person. The stage is set and cancer is inevitable.

But pull out any one of the links in this chain and cancer is impossible. **Pull them all out for a return to good health**.

So cure yourself, prevent reinfection, heal the damage and go through life without this sword hanging over you.

Over 100 consecutive case histories of cured cancer victims are the subject of another book[16] along with more detailed instructions and suggestions.

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[16] *The Cure For All Cancers*, by the same author, New Century Press 1993.

Curing HIV/AIDS

HIV and AIDS disease are very similar to cancer. That is why cancer is so often seen with HIV/AIDS. It is caused by the same parasite but the solvent is **benzene** instead of propyl alcohol.

HIV stands for
Human Immunodeficiency Virus

AIDS stands for
Acquired Immune Deficiency Syndrome

Many researchers believe HIV causes AIDS. I observe them both caused by parasites and solvents!

When the body can no longer detoxify benzene it soon may not be able to detoxify propyl alcohol. Food mold, at the base of the propyl alcohol problem, is also at the base of the benzene problem. Zearalenone, a mycotoxin I find in popcorn, corn chips, and brown rice specifically inhibits detoxification of benzene. None of us should be eating these foods untested.

Several common mold toxins inhibit the immune system, too, specifically those white blood cells that are supposed to eat and destroy viruses. Consequently, the HIV virus cannot be checked once it is introduced in the body.

Benzene goes to the bone marrow where T-cells are made, and to the thymus where T-cells are programmed, two big blows to the immune system.

Benzene, a most unthinkable pollutant, is widespread in extremely small amounts. But when **benzopyrenes** are added, the total is entirely too much for the liver and it begins to accumulate in your thymus.

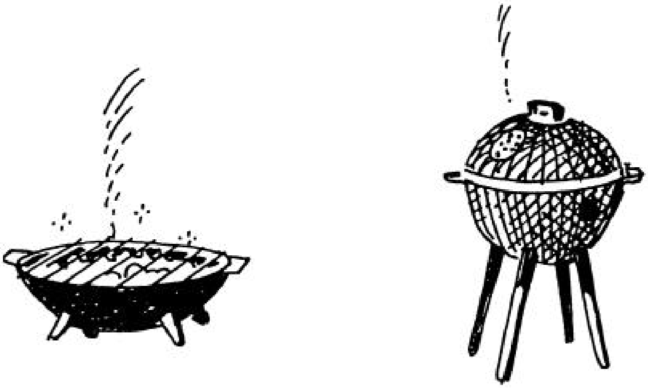

Fig. 43 Grilled food has benzopyrenes as do hot dogs and "smoke flavored" foods.

Benzopyrenes are made right in your food by direct flame-heat. Grilled food, smoked food, hot dogs and lunch meats with "smoke flavor" all have benzopyrenes—even toast has it. Food fried in a skillet does not (even if you burn it black!). As the thymus deteriorates from its benzene burden so does your immunity.

Without benzene in your body
you can't get AIDS.
Without the intestinal fluke in your body
you can't get HIV.

After killing the parasite and its stages the HIV virus will be gone in 2 hours, almost as quickly as the cancer marker, ortho-phospho-tyrosine. It is not necessary to zap the virus itself at 365 KHz.

But the AIDS is not gone. This depends on removing benzene from your body and keeping it out of your body. Keeping it out on alternate days or 5 days of the week will not suffice. It must be out consistently. Only then can your thymus and bone marrow recover.

As your thymus recovers your immunity returns. Immunity to all the diseases that lurk at very low level in our bodies. They are already in us. We have accumulated them in a lifetime. Mumps, measles, chicken pox, CMV, *Staphylococcus aureus*, *E. coli*, are all there. Until now they have been controlled–kept down–by an ever vigilant immune system. If this system fails you are an easy target for any and all of these invaders.

Method Of Treatment

As soon as you find you are HIV positive, don't panic. It was inevitable. It is also inevitable for many others with unexplainable risk factors. If you have a source of infection with the intestinal fluke and at the same time a source of benzene, HIV and AIDS are a logical result. You must stop the source of both.

Purchase or make a zapper or use somebody's frequency generator (434 KHz to 421 KHz giving 3 minutes to each KHz). Kill your flukes immediately. Take vitamin B2 immediately to help detoxify benzene (three 100 mg. tablets 3 times a day, 9 altogether). Zap daily until you feel completely well: no night sweats, no coughing, no symptoms of any kind.

Remember parasites are all around us. We pick them up daily. And your weakened immune system lets everything gain a foothold in your body. Avoiding benzene will restore your immunity. Use the benzene pollution list to guide you.

Benzene Polluted Products

THROW THESE OUT

Your health is worth more than the fortune you spent on them!

- **Flavored food**, yogurt, jello, candies, throat lozenges, store-bought cookies, cakes
- **Cooking oil** and shortening (use only olive oil, butter and lard)
- **Bottled water**, whether distilled, spring, mineral, or name brand. Bottled fruit juice.
- **Cold cereal**, including granola and health brands
- **Toothpaste**, including health brands
- **Chewing gum**
- **Ice cream** and frozen yogurt
- **Pills and capsules**. At least a third of all I test are polluted. This includes herbal extracts and prescription drugs. Test yours and switch brands until you find a safe one.
- **Vaseline products** (Noxzema™, Vick's™, Lip Therapy™), chap stick, hand cleaners
- **Vitamins** and other **health supplements**, unless tested.

- **Rice cakes**, even the plain ones
- **Personal lubricant**, including lubricated condoms
- **Baking soda and cornstarch** (see *Sources*)
- **Soaps, hand creams**, skin creams, moisturizers
- Flavored pet food, both for cats and dogs
- Bird food made into cakes

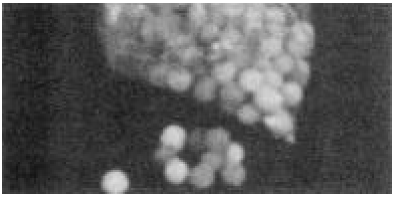

Fig. 44 Mexican made candy with no benzene.

Fig. 45 Pollutants are in unlikely places

It is impossible for me to have tested every batch of every food and product, but so many test positive you simply can not risk any of the foods and products on the list.

Learn to use the Syncrometer to do your own testing. While you are learning, observe the rules perfectly. There is no half way measure with benzene. Take an attitude of over-compliance, not "getting away" with as much as possible. Over-compliance can bring back radiant health, strength you never knew you had, a beautiful normal body again! You will be able to resume your plans for education, professional life, personal relationships, free of the sword hanging over you. You will not be infectious to anybody. Let over-compliance enthuse you.

Fig. 46 Every brand of popcorn and corn chips I tested had zearalenone contamination.

There are 2 extra rules that help eliminate benzene buildup:

1. Never eat moldy or grilled foods including popcorn, corn chips, grocery store breads, pasta, nuts, alcoholic beverages, toast, brown rice (white is OK).
2. Always take Vitamin B_2 (three 100 mg tablets three times a day) and vitamin C (1/8 tsp. with each meal).

Plan For The Future

After you are well again, you may wish to indulge in some philosophy. How did an obscure virus–a snail virus!–become a human virus? This is not so bizarre. After all, rabies virus comes to us from animals, and many encephalitis viruses come from mosquitoes. How did HIV spread so rapidly? How did a pollutant as dangerous as benzene get to be in our very food? Are other parasites getting set to spring on us? What must be done to protect ourselves and loved ones from future disasters? Would getting away from fossil fuel be a big answer? Would getting away from preoccupation with chemistry be a big answer? Would more disclosure of industrial practices be an answer? Should the government agencies responsible for food and product safety be depoliticized? Should public inspection of food manufacturing be a right? Should disclosure of foreign origins of food ingredients be mandatory? Would communicating with other cancer and AIDS survivors be useful? The computer age would make communication possible. Communication leads to answers. Answers might lead to new policies. Policies supported at the grass roots level can bring about change.

Over 50 case histories of cured HIV victims are the subject of another book[17] along with more detailed instructions and suggestions.

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[17] *The Cure for HIV and AIDS*, by the same author, New Century Press, 1993.

Curing The Common Cold

Sometimes you can zap *Adenovirus*, the common cold virus, at 393 KHz for three minutes with a frequency generator and be rid of your cold, magically, in five minutes. But magic and luck are not really responsible for this. And most of the time the cold will reappear a few hours later.

Homeopathy, too, can immediately banish your cold symptoms. The reason is not mysterious either. But, this time, the cold reappears later in a different location. Choose the right homeopathic remedy for that, and you can chase it away again.

Tapeworm Stage or Mites

The fascinating story of how we really "catch" a cold kept me spellbound for a year. I was hot on the heels of *Adenovirus* wherever it might be in my body. Sometimes I saw it; sometimes I didn't. Sometimes I had cold symptoms; sometimes I didn't. Sometimes I could zap it; sometimes it did no good.

It is now apparent to me that *Adenovirus* isn't our (a human) virus at all! It belongs to other parasites. Parasites as varied as tapeworm stages and mites. Perhaps it belongs to many other parasites, as well. My evidence comes from a tapeworm stage, cysticercus of *Diphyllobothrium erinacea*, the mites *Sarcoptes* and *Dermatophagoides*, and our own colon bacteria, *E. coli*.

The tapeworm stage flies in the dust as eggs, you can trap these by setting out a pint jar with a little water in it. In three days' time you are likely to find its frequency near 487 KHz in your jar. You are also likely to find it on your kitchen sponge, since you wipe up dust each day. To test it, place it in a plastic bag, wet it thoroughly and search from 510 KHz downward, one KHz at a time. The various tapeworm stages emit between 510 and 440 KHz.

If you have a household pet, you will always be able to find a tapeworm stage in your sponge or in a dust sample you collect from the table or kitchen counter in the morning. Gather dust with a damp bit of paper towel, put it in a plastic bag. Then wash your hands or you may accidentally eat some.

This, of course, happens to every household member. Eating the dust off the tables, inhaling the dust, and eating off surfaces wiped by the kitchen sponge happens to everyone. And everyone “catches” colds. If you search for *Adenovirus*, though, in your dust sample, it isn't there!

Similarly, you can search for the mites in your house dust. Search near the frequencies given for them. There is a good chance you will have one that is not given, because the list is so incomplete. Name it after yourself. Compare notes with others; maybe it is common, maybe it's a rare one. Again, you will not find *Adenovirus* beeping its characteristic frequency out of your mite specimen. Why not? Possibly, it is too faint; it must multiply and create a loud chorus before you can hear it. But multiply it will, if given a chance, in you. You must, of course, first eat or inhale the dust.

Then the tape eggs hatch into the *cysticercus* stage, which promptly gets to the liver. Sometimes it gets to other organs, like the muscles, the spleen, the pancreas. Presumably the liver screened it out of the blood originally.

Soon you will zap them, wherever they are. If you are using a slide specimen of *cysticercus* you can locate it in your body. If you are only listening to its beeps, you can't. If you can do both, you may be able to see which organ allows the virus to replicate after it emerges. Maybe only the respiratory organs do; maybe they start to replicate in the organ where they emerge, such as the liver and then get to the respiratory tract. This is a fascinating avenue I have not yet explored.

Mites are inhaled or swallowed or both, just as tapeworm eggs are. They are on your kitchen sponge, and in any food or dishes that stand uncovered anywhere in the home. Never drink water from a glass that has "stood out" all day. After finding one, you will notice it beeping in you for several days. Then the beep disappears; presumably the mite is dead.

The tapeworm stage beeps may disappear in a few days, too, presumably dead. Except in cases of disease. Muscles that are diseased will take in the newcomer and allow it to survive adding to the parasites and pollutants already there! Evidently the immune power of such diseased locations is way down.

On the day that the mite stops beeping, the day it dies, *Adenovirus* appears!

Not many *Adenovirus* at first. You will need to search several times during the day to find it in your white blood cells. (And you have no symptoms, yet, either!) Is it a coincidence that *Adenovirus* appeared directly after a tapeworm stage or mite died?

You can find out by waiting until a time when you have a tapeworm stage or mite and no *Adenovirus*. Then kill your tapeworm stage or mite by zapping for seven minutes. Within minutes after that, the beeping of the tapeworm stage or mite is gone and *Adenovirus* can be heard, loud and clear at 393 KHz! And minutes later you may feel a stuffy nose, a slight congestion developing, a certain head feeling that is different. You are "catching" a cold!

Will you really get this cold? Will it become a full blown cold of the usual kind? After seeing this happen dozens of times after killing a mite or tapeworm stage I concluded that *Adenovirus* really belongs to them; the virus is scuttling its dying host like people jumping off a sinking ship into the ocean. Our bodies are the ocean for them. They too, immediately swim and search for a hospitable island. Our respiratory tract is such an island; perhaps other organs, too.

Yes, this "baby cold" will develop into a full blown cold if, but only if, you have a mold in you!

Molds and Colds

This is part two of the cold story. You may have *Adenoviruses* quietly slipping into your blood stream and tissues from a tapeworm stage or mite you inhaled, or *E. coli* bacteria that strayed into your tissues, and which is being slowly killed by your immune system. Your immune system can keep up with them quite easily provided you don't have a mold in you at the same time. The significance of the mold is that it lowers your immunity, specifically and generally.

Mold eluded, is health improved.

This has already been studied extensively for a number of food molds. There are a variety of ways that mold toxins lower immunity. Some simply kill white blood cells. Others seem to "bind and gag" them so they just can't go about eating viruses.

So with mold toxins present, *Adenovirus,* fleeing the dead tapeworm stage, mite, or *E. coli* is not gobbled up. It has time to get to its favorite organ and enter the cells there. It may get in your lungs if they're full of arsenic or formaldehyde, in your throat if it's full of mercury from your fillings, in your spinal cord if it's full of thallium. Sometimes you feel the viral attack, sometimes you don't.

When *E. coli* is the source of your *Adenovirus*, a question pops up. Why don't you have a perpetual cold, since these bacteria are always in your colon...and should be! As long as *E. coli* stays dutifully in your colon, no *Adenovirus* is seen. But as soon as any cross the colon wall to invade your body, your white blood cells pounce on them. After this, *Adenovirus* appears and again you are catching a cold. They may go to your internal organs where you don't feel them.

One place you do feel an attack is in your respiratory tract: lungs, bronchi, sinuses, nose, Eustachian tubes, inner ear, eyes or head. And the size of the attack depends on whether you recently ate moldy food.

Human food (in general, in the U.S.) is very, very moldy. We do not taste it because manufacturers have been using more and more flavorings in food. This covers up small amounts of mold or “off” flavor. Measures to reduce mold are not effective enough.

Bread is a good example. Calcium propionate is added to bread-stuff to inhibit molding. That's fine. But then the bread is encased in plastic to hold in moisture and keep it “fresh”. The moisture acts to incubate mold spores and overwhelms the inhibitor. Vinegar is used instead of calcium propionate in some breads but, again, the plastic ruins its effectiveness.

Another good mold inhibitor is lime water. This is used in making tortillas. None of the old fashioned tortillas (made with just corn, water, lime) that I tested had any mold, even without propionate added! Other tortillas made of flour and calcium propionate frequently had molds.

Fig. 47 This Mexican bread has no molds. It is made from white, unbleached flour and is not wrapped in plastic.

Bread is such a staple we must correct its mold problem immediately. The two likely sources for the mold spores are: in the flour to begin with, or just flying about the bakery and landing on the newly baked loaves. Bread flour in the grocery store is quite free of mold spores, so maybe it is the bakery that needs to change. Perhaps it is not possible to bake 24 hours a day in the same building, year after year, without bits of flour and moisture accumulating in the millions of tiny cracks and crevices that all buildings have and germinating mold. Yet bread from small neighborhood bakeries does not have mold!

Only buy fresh bread not wrapped in plastic.

As soon as you feel a cold coming, ask yourself: what did you eat recently that might have been moldy? Cold cereal, hot cereal, bread, crackers, cookies, rice, other grains, fresh fruit, store bought fruit juice, nuts, syrups, pasta, honey? This takes up a large part of any person's diet, even in a single meal. The answer is yes, no doubt you ate moldy food recently.

So you can't catch a cold directly from some sneezy companion, or *E. coli*, or tapeworm stages, or mites. You have to eat moldy food first. This lowers your immunity, allowing any *Adenovirus* to invade your weakest tissues. If that happens to be your respiratory system, you get classic symptoms. (Those same “cold” symptoms can be caused by bacteria, for which I have preliminary evidence of arriving in a similar fashion.)

As fascinating as this whole story is, the bottom line is: how can you stop a cold, in record time?

The Cure

Remember, zapping does not kill your cells. So anything hiding in them will not be harmed by the electric current either. Viruses live inside your cells while they reproduce. You can only kill the outsiders: those stuck in your cell gateways. The rest will be killed by your own cells in time. Not much time. Five or six hours at most. Your cells do it with mucous secretion, inflammation and other unknown ways. So zapping is an imperfect solution.

Using a frequency generator to electrocute *Adenovirus* (393 KHz for three minutes) is not effective either because you are not killing the mites and tapeworm stages at the same time, and the *Adenoviruses* are coming from them.

The best advice to stop a cold is to:

1. **Eat sterile food for 24 hours.** Follow the Mold Free Diet on page 365. Do not eat one questionable item.
2. Take **vitamin C** (10 grams or 2 tsp.), a **B50 complex** (2 tablets), and niacinamide (3 500 mg tablets) to help detoxify the mycotoxins already in you. See *Sources*. It will still take five or six hours for your white blood cells to recover their ability to capture viruses, for the "gag" to wear off.
3. **Zap** for seven minutes, killing all viruses, tapeworm stages and mites together. **Wait** twenty minutes to let viruses and bacteria in the dead larger parasites emerge. **Zap** a second time for seven minutes to kill those viruses and bacteria. **Wait** twenty minutes to let any viruses infecting the killed bacteria emerge. **Zap** a third time for seven minutes to kill the last viruses.
4. Now you need only wait for your tissues to decongest and stop making mucous, etc.
5. Immediately start the Bowel Program (page 546) in case yours is an *E. coli* cold. You can't, and wouldn't want to, kill all the bacteria in your bowel. Zapping kills the escapees, though, to give a bit of relief, and the Bowel Program stops the invasive *E. coli*.
6. Do additional zapping as time permits until the Bowel Program has stemmed the invasion.

In five or six hours your cold could be gone.

Of all these measures, stopping mold consumption is the most important. If you eat peanut butter now, your cold will return with a vengeance. If you eat cheese it will add *Salmonella* to your illness and you may develop a fever. Your own immune system is the most powerful cold killer, so stop handicapping it.

Test yourself for the presence of molds to see if you are accomplishing your goal. The various molds I have tested had these emitting frequencies: 77, 88, 100, 126, 133, 177, 181, 188, 232, 242, 277, 288, 295 KHz.

In about five hours, some relief will be felt. The time it takes depends on how much mold you ate. But if you stop immediately and eat only perfectly safe food, your illness will be over in the shortest time. Shorter than merely zapping.

Mold Free Diet

Stick to this for 24 hours, even if you feel better much sooner.

Before starting to cook sterilize your kitchen sponge (microwave it for three minutes), and wash hands.

Breakfast

- 1 or 2 eggs any style. The egg carton and egg exterior have *Salmonella* on them, so remove the eggs, replace the carton, wash the exterior of the eggs and then your hands again before cracking them. You don't want a *Salmonella* infection added to your cold.
- Hash brown potatoes
- Pancakes or waffles with artificial maple syrup made with brown sugar and vitamin C.
- 1 cup herb tea with vitamin C, cinnamon, or other spice.

- Water with a tsp. of vinegar and honey.

Lunch

- Soup without noodles, without rice or any grain product.
- Homemade biscuits or bakery bread with butter.
- Homemade pudding or custard, all ingredients well cooked.

Supper

- Well cooked fish or seafood (canned O.K., like sardines, salmon and tuna).
- Fresh green vegetables, in perfect condition.
- Cooked vegetables with olive oil and salt (pure, see *Sources*).
- Canned beans, any variety.
- Baked or boiled potato (don't eat skin) with olive oil and salt as described on page 310.
- Hot water with whipping cream and cinnamon.
- A perfectly unblemished banana.
- Water with lemon.

You can “mix and match” these safe foods. If you get a hefty dose of mold at the outset of your cold, the toxicity lasts quite a long time. Repeat the diet the next day and the next until you are well. In animal experiments reported by scientists, toxicity from mold usually lasted three weeks. Sometimes the real damage was only seen after three weeks! Keep up your vigilance. When you decide to take some risks, make sure vitamin C has been added to the new food and mixed with it thoroughly.

Fig. 48 Goods baked in a panaderia (Mexican style bakery) never tested positive to molds.

Prevention

What is the best way to prevent a cold? Stop eating moldy food. We were never meant to eat rotting, spoiling food. We were meant to be repelled by the bad odor, the bad appearance, the bad taste. Our parents were supposed to teach us in childhood to distinguish between good and bad food. This system no longer works. By mixing spoiled food with good food, by adding flavors and changing the food consistency, parents can't distinguish substandard foods, nor teach their children to.

We rely on government agency assurances, like beef grades, expiration dates, approved food colors and additives. And when they fail? We land in a debacle such as the present one, where large segments of society are ill with uncontrollable behavior (called crime), suffer from hormone imbalances and sexual disturbances, are sidelined by chronic fatigue and new illness. But the greatest social disaster is lowered immunity—AIDS.

We cannot individually control the destiny of our species. But we can get ourselves out of the path of the falling human tide. We can dissent. We can say **NO** to rotten moldy food.

What about exposure to a cold? Won't you catch one if you're in a roomful of coughing, sneezing people? Or you shake hands with a coughing, sneezing person? Or you drink from the same glass as a person with a cold? Or your child plays with the same toys as sick children?

Yes, you will catch the virus, but you won't get sick. If you are tracking *Adenovirus* using the electronic techniques in this book, you will see that it infects you immediately after eating coughed-on food. It stays in you about twenty minutes. Then it disappears, evidently eaten up by your white blood cells, **provided there is no mold toxin in you**. But if you do have a mold toxin in you, the virus spreads, multiplies and gives you a cold! I have only followed *Adenovirus* behavior. There are numerous other “cold bugs” left for you to track. Each illness in your family could provide you with a specimen to research.

This throws light on self infection, too. When we cough into our hands and then eat with them, we self-infect. But it only makes us sicker if we harbor molds.

Curing Symptoms

Cold symptoms alone can be cured much faster than the cold. Taking drugs proves that. Most of the drugs on the market can cure some symptoms in less than one hour. But not without a price, such as a harmful side effect.

Homeopathy can cure cold symptoms too, without side effects. There are three or four favorite homeopathic remedies for colds and eight or nine less common ones. To use them you read the symptoms listed and take the remedy with the closest match.

Homeopathic Remedy	**For These Symptoms**
Aconitum	early cold with fever, headache, hoarse cough
Allium	clear runny nose with burning of lips or eyes
Arsenicum	sneezing cold, frontal headache, tickling cough
Belladonna	high fever cold with flushed face, throbbing head
Kali bi	thick post nasal drip, colored discharge, sinus headache
Spongia	croupy cough

Fig. 49 Starter set of homeopathic remedies.

There are lots more remedies with fascinating symptoms to try to match with your own. Books suggest that you start with a 6X or a 12X remedy, but success is more certain with 30X. Use three remedies simultaneously. If you get total relief at some point, stop. If the cold has moved or won’t budge, try another set of three after an hour. Don’t take them within 15 minutes of food or anything else. Homeopathy makes very interesting reading.

Homeopaths say they stimulate the immune system specifically. My results show they do much more. They go right to the gateways of your cells and evict the tiny parasite, bacteria or virus stuck to the latch and trying to get in. Your immune system would be able to gobble them all up if they weren't gagged by the food mold you ate.

Different homeopathic remedies go to different tissues, so you can only clear one tissue at a time. If you plan on trying this for yourself, order the set of cold remedies listed above (see *Sources*). The homeopathic method would be a beautiful cold cure if it weren't for the mold intrusion.

Herbs, too, can cure symptoms rather quickly. **Elderberry tea** mixed with **peppermint** is cited in herbal textbooks and it could probably do a lot if it weren't for the mold immunosuppression. If you plan on trying these start with a set of **thyme**, **fenugreek**, **sage** (for throat). Since both herbs and homeopathic remedies work on the principle of ejection, they could eject each other. Maybe the last one to arrive takes over. This is an exciting field for you to explore.

Ultimately, the length of time your own white blood cells are bound and gagged decides how soon you are really cured of your cold. Remember taking vitamin C (10 grams or more) helps detoxify the molds. If you find a recipe that works for everybody in less than five hours, be sure to let everybody know.

True Origins Of Viruses

Your body can eliminate any virus in a short time, such as hours or days. It can even keep up with a steady stream that is coming from tapeworm stages!

Let us apply these new insights to several diseases we are familiar with. Let us speculate what could really be happening.

Epstein Barre Virus (EBV) is a mysterious disease because in spite of building up antibodies, it attacks repeatedly. I only see EBV if the person also has *Eurytrema* (pancreatic fluke) in the pancreas. When the fluke is gone, I no longer find EBV in the white blood cells. This suggests that the virus comes from the fluke. As each fluke dies and is finally removed, the body's white blood cells can catch up with the viruses and you begin to feel better again, which can be as quick as one day. But reinfection with an EBV-carrying *Eurytrema* (plus a wood alcohol containing beverage to allow the fluke to go to the pancreas) can spark the next recurrence.

Shingles is a recurrence of chicken pox. I always find *Ascaris* in persons with shingles! Unfortunately, killing the *Ascaris* does not cure shingles. *Herpes Zoster* (the shingles/chicken pox virus) is known to hide in nerve cells. Perhaps *Ascaris* facilitates it's release, or simply suppresses the immune system in a way that allows it to suddenly multiply.

Polio was once a scourge. At that time, we can theorize that a new large parasite was making its appearance. Was a new animal association taking place in the early 1900's? Life was indeed becoming more urban with horse manure on all streets. Owning a dog for a house pet was becoming an acceptable lifestyle. Could the tapeworms of these animals give us a tapeworm stage that hosts polio virus? Many polio sufferers also had migraines. These are caused by *Strongyloides*, a horse threadworm. Does *Strongyloides* host polio virus?

The **HIV** virus infects us during the time the intestinal fluke, *Fasciolopsis buskii*, is being hosted. Persons test negative to HIV shortly after the fluke and its stages are eliminated.

Coxsackie viruses give us some of our encephalitises. I never see *Coxsackie* viruses without the bacteria, *Bacteroides* *fragilis*, and I never see *Bacteroides fragilis* without *Ascaris* (a roundworm.) I conclude that one lives inside the other!

We may be deriving viruses from all the roundworms, flukes, tapeworms and bacteria that infect us! It would be a fascinating study, simply to examine each of these parasites singly, searching for their viruses with an electron microscope. They could also be searched for using immunological methods.

Fortunately, your health improvement does not need to wait on such studies. Your electronic technique can detect them in your body long before you are made ill by them. You don't need to know their hosts in order to stop hosting them yourself.

It is a time of great change for this planet as pollution spreads from pole to pole. The growth of industrial activity, mining, chemical manufacturing, the food “industry”, and personal habits like smoking have spread new chemicals to every corner of the globe. The element *polonium*, which is radioactive and in tobacco smoke, is harmful to human lungs, but may not be harmful to a small lung parasite, like *Pneumocystis carnii*.

Benzene, which is a solvent and extremely harmful to humans, may not be harmful to fluke parasites living within us. Propyl alcohol facilitates the intestinal fluke but is toxic to us.

Parasites are doing abnormal things. Is this because of pollution?

The tables are gradually being turned against us in favor of our parasites and pathogens. Such large changes are called evolutionary. Is the human species doomed, or will some of us “adapt”. Will some of us survive to pass on our “better” genes to a new population of cancer-resistant, AIDS-resistant, Alzheimer's-resistant, etc.-resistant humans? How many of us will die trying?

The common cold should not be so common!

Body Wisdom and Why Bad Food Tastes Good

Don't let yourself eat junk food just because your body craves something in it. Try to figure out what it is your body craves. Could it be fat? Could it be salt? Could it be starch?

Salt

If it's salt, you might also love popcorn and other salty food. This implicates the adrenal glands. Maybe they're letting too much salt (sodium chloride) leave the body through the kidneys. Maybe they're letting too much potassium chloride through, too. A diuretic pill could certainly have a similar effect.

Help the adrenal glands do their job of regulating sodium and potassium chloride by cleaning them up. Let salt-hunger be your signal to do a kidney cleanse (page 549). This will clean adrenals too. Even a slight drop in sodium and potassium chloride in the blood (body fluids) can make you too fatigued to tie your own shoelaces.

Remember, when your body craves potato chips, it craves something in the potato chips. If you let yourself eat highly salted food while you're giving the adrenals a clean up, at least add potassium chloride to your diet. Make yourself a mixture of equal parts of sodium chloride and potassium chloride. Part of salt hunger is actually potassium hunger. Let your body (your taste) decide on the amount of potassium chloride to add. Maybe one part potassium chloride to two or three parts sodium chloride is a better mixture for you. After mixing, store it in the original containers (re-label them) to prevent caking. If you put it in an ordinary salt shaker, it will cake soon. Use a shaker with a lid that closes.

Fats

Maybe you like French fries because of the fat. If you deprive yourself of the “good” normal greases that come from plant or animal sources which would ordinarily make up 25% of your calories, of course you'll crave grease. But what a bad trade it is. Now you are getting lab-made (hydrogenated) grease with a non-biological structure, and loaded with the carcinogen nickel.

So if you're body tells you that you need grease, go back to olive oil, butter, cheese (baked only), lard, avocados, nuts and nut butters (homemade only) and seeds. Humankind has been eating these natural fats long before cholesterol was vilified. The key to cholesterol control is not fat avoidance, but a liver cleanse!

Starch

If switching to natural greases doesn't satisfy your “fat-tooth”, maybe its the potato in the French fries that your body craves. Plain, pure starch. Do you also love bread and pasta (more pure starch though very inferior to potatoes)? Pure starch is very easy to digest and has a large adsorptive capability for toxins. In fact, if any family member should accidentally eat something poisonous, drinking cornstarch will quickly mop it up and keep it stuck so it can't enter your tissues. (This doesn't work for all poisons.) By craving pure starches, your body could be telling you about a need to improve your digestion (liver disorders) or to eat and breathe less toxic things.

Maybe a stomach-full of baby *Ascaris* is telling you to eat only food that doesn't need a lot of acid: "just potatoes, bread and pasta, please, and skip the sauce.” *Ascaris* inhibits acid production by the stomach. This can result in an aversion to meat.

It doesn't take much acid to digest pure starch and get it on its way out of the stomach. And out of the stomach means relief: relief of the pressure on the diaphragm and liver, heartburn, that too-full feeling, and other digestive disturbances.

Sugar

Your body runs on sugar. If you are short on sugar it will turn fat into sugar. If you are short on both, it will turn your muscles into sugar. However eating more sugar doesn't cure the craving. You have to find out why you are so short, in spite of eating it.

The first thing to try is 1 mg chromium (five 200 mcg tablets, see *Sources*) per day. If you still crave sugar after a week the problem is something else. Perhaps you have pancreatic flukes upsetting your sugar regulation. Kill them and go off commercial beverages that may contain wood alcohol. Sugar regulation is very complex, but these two approaches help most of the time.

Dislikes

Respect your body's opinion when it says, “No, I don't want to eat that.” Our education about nutritive value of food may be sound but there are other facts to consider. We should take a lesson from nursing babies: when they refuse to nurse, there is something unpalatable in the mother's milk. Usually the mother has eaten onions or members of the cabbage family. The baby tries it once, and learns to reject it immediately. The baby's liver, in its wisdom, does not want the baby to eat what it can't properly digest. The mother may feel: “Now, this breast milk is good for you and drink it you must, or you shall go hungry.” Unfortunately, this works for 2-year-olds and up. They are forced to eat carrots, peas, and other vegetables; vegetables that taste terrible, (modern agriculture has ruined the flavor). They alone taste the bitterness of PIT, a cyanide-related chemical, and very difficult for the liver to metabolize. Broccoli and onions may burn the tongue with its sulfur-containing acids. Green beans, onions, garlic, eggplant, all have unique chemicals in them. If you or your child are not ready to eat them, avoid them carefully, so you don't get a surprise dose of the toxic chemical.

The more mold a child eats, inadvertently, in peanut butter, bread, potato chips, syrups, the less capable the liver is of detoxifying foods. This will certainly increase the “pickiness” of a child's appetite. If your child has too many foods on her or his personal “off list”, let this signal you to improve liver function. Stop the barrage of chemicals that comes with cold cereals, canned soup, grocery bread, instant cheese dishes, artificially flavored gelatin, canned whipped cream, fancy yogurts and cookies or chips. Move to a simpler diet, cooked cereal with honey, cinnamon and whipping cream (only 4 ingredients), milk (boiled), bakery bread, canned tuna or salmon, plain cooked or fried potatoes with butter, and slices of raw vegetables and fruit without any sauces, except honey or homemade tomato sauce, to dip into.

It is frustrating to cook “a fine meal” for the family and find everybody likes it except Ms. Picky. The good news is that she can usually think of something she would rather eat. If it's nutritious, be thankful. If it's not say No.

Adults should hide their junk food, including everything off limits to children. Don't “hide” your junk food in the refrigerator and lower level cupboards! Treat yourself as well as your child. If a food tastes bad, don't eat it. If you crave it, try to understand the message.

Outwit The Cravings

Here are some examples. Suppose you crave these items:

- **Pickles**. They supply vinegar and are often loved by persons with little acid in their stomachs or a lot of yeast (vinegar is a yeast inhibitor). Start drinking water with lemon juice or vinegar and honey.
- **Bacon**. The fat soothes the stomach and slows down digestion. Switch to butter and cream, with meals.
- **Sugar coated cereals**. Loved by persons with disturbed sugar regulation. Kill parasites, avoid wood alcohol, use chromium tablets and a lot of cinnamon.
- **Crunchy munchies**. Your jaw and teeth want some work to do. Try salads, an apple, raw sunflower seeds (beware of moldy seeds, nuts and dried fruit).
- **Ice cream**. Ice cold food stimulates the thyroid; loved by low thyroid persons. Clean up the thyroid by doing dental work and liver cleanses.
- **Caffeine**-laced beverages. Stimulate many body tissues, raise blood pressure. Loved by low energy people. Do a general body and environment cleanup. (There are people who say coffee puts them to sleep. Insomnia has better solutions than caffeine, though.)
- **Candy**. The more you eat the more you crave because chromium is being used up as you eat it and yet it is necessary to utilize more sugar. Give yourself chromium (GTF) tablets totaling 1 mg. (1,000 mcg.) a day and watch your sugar craving shrink.
- **Pretzels**. You want salt plus crunch.

- **Potato chips**. You want salt, grease, starch and crunch. No wonder they are so popular!

If your body still has its wisdom, or most of it, why can't it detect the mold in peanuts, crackers and bread for us? There is a very sound reason. Our food manufacturers have gone to great lengths to fool our native senses. Salt and sugar, roasting and flavoring, do most of it.

Your body is accustomed, natively, to interpret sugar, salt, and flavors as “good, good, good.” Of course, the mold is “bad, bad, bad.” But when you mix them, what is your body to read? The “goods” always win; manufacturers don't stop until they do. More flavorings are added. The result is that you can be eating rotten moldy food without knowing it.

Food that is predominantly concocted can't be interpreted by your body wisdom. You must use your second-best ally, your intelligence.

How would you interpret these situations, taken from real life:

- An elderly person can't stand butter, wants and enjoys margarine.
- A child prefers canned spaghetti for the real thing.
- A child wants to eat only sweets, everything else must be coaxed down.
- A young man needs “his” beer to enjoy a cook-out.
- A young man with serious mental illness drinks half a gallon of Mellow Yellow^{TM} a day.
- A child wants ketchup on everything.
- A pregnant woman puts herself on a pickled pigs feet and white bread diet.

Back To Normal

Body wisdom was not meant to substitute for parental teaching. They must both be there. But when there is conflict, trust your wisdom. Will you ever get your primitive body wisdom back and enjoy vegetables, fruit, simple styles of cooking and baking them? Yes, to a considerable extent. You'll hold your nose at all seeds and nuts and most flour (they smell so rancid). You'll back away from cookies and cakes, especially icing (they taste like you imagine shortening tastes). You'll retreat from deep fat fried foods: the dripping grease will just undo the appetite. You'll say "No thanks" to canned food and metal cutlery (you can taste the metal now). You'd have to force yourself to eat grocery bread (it's so doughy and sour smelling). Wheat germ smells terrible (rancidity). Even vitamin tablets may smell awful.

Has life been ruined, now that plain potatoes and butter taste good? Your body wisdom has returned. You are the true gourmet. It is as different as corn on the cob is from the canned variety. Perhaps you are "spoiled" now by eating un-rotten food. Accept the charge with humor and dignity—as long as you're not expected to eat any more spoiled, moldy food.

Toxic Food

Grilled food develops *benzopyrenes* in it that are very toxic. In an age of lowered immunity, it makes little sense to deliberately poison the food with benzopyrenes. Especially for children, who will be faced with new viruses and parasites in their lifetimes. Will they be able to overcome them or succumb at middle age? Only the strength of their immune system decides this.

Benzopyrenes must be detoxified using the liver's valuable benzene-detoxification system. With so many benzene-polluted items, there is hardly enough detoxification capability to get it all taken care of. NAD enzymes (the N stands for niacin) come into play too. These are essential for alcohol detoxification. If you have consumed alcohol, like a can of beer, NAD enzymes must be shared between the alcohol in the beer and the benzene in the beer. It takes longer to detoxify both the benzene and alcohol. The time delay is a time of lowered immunity and facilitates a growth spurt for parasites and pathogens.

Foods that are raised to very high temperatures, made possible with a microwave oven, produce benzopyrenes. Ordinary bread-toasters can do this too! Old fashioned toasters had a layer of metal separating the bread from the wires. Toasting bread in a frying pan or a stove top surface protects it too. But your stove grill, whether electric or flame, will produce benzopyrenes in your food unless there is a separating wall between them.

It does not matter what kind of fuel is used, the benzopyrenes develop due to lack of shielding between the food and heat source. A metal wall between them absorbs some of the heat.

Do not burn your food in a microwave oven. Since the temperature may go higher than your regular oven, you can produce benzopyrenes. Your regular oven is thermostated so that it cannot go higher than it states. Baking and browning is never done above 425°F. This is your safety feature. If anything in your microwave has turned dark brown or black or has melted plastic, throw it out!

Supplements that help your body to detoxify the benzopyrenes are:

1. Niacin or niacinamide. These are NAD-builders. Take 50 mg with each meal.
2. Vitamin B_2 (riboflavin). Take 50 mg with each meal.

For unpolluted vitamins see *Sources*.

It would be wise to teach children the habits that maximize their immune strength. Avoiding food toxins that are specifically immune-lowering is most important. Besides the benzopyrenes, certain mold toxins and solvents do this and are found in foods.

Moldy Food

Everything that's animal or vegetable can get moldy. While living things are alive, the mold attackers can be held at bay. As soon as they are dead, molding begins. First it molds; then bacterial action sets in. This is what makes things biodegradable. It is a precious phenomenon. It does away with filth—in an exquisite manner. Without mold and decay the streets of New York would still be full of horse manure from the days of the horse and buggy and our lakes too full of dead fish to swim in.

Every grain has its molds; every fruit has its molds; tea and coffee plants have their molds; as do all herbs, and vegetables. Nuts have their molds; nuts grown in the ground (peanuts) are especially moldy because the earth is so full of mold spores. But the wind carries these spores high up into trees, and even up to the stratosphere. Molds are not very choosy. They have their preference for certain plants and conditions. But the same molds can grow on many plants. This is why aflatoxin, for instance, is found not just in your cereal, bread and pasta but in nuts, maple syrup, orange juice, vinegar, wine, etc. Where is it not? It is not in dairy products or fresh fruit and vegetables, provided you wash the outside. It is not in meat, eggs, and fish. It is not in water.

Although I find aflatoxin in commercial bread, I do not find it in carefully screened wheat that has had its discolored, shriveled seeds removed before using it for making bread, cereals and noodles. It is not in baked goods bought at bakeries, left open to air. Evidently the system of wrapping baked goods in plastic keeps moisture trapped and starts the molding process. In spite of adding mold inhibitors, American bread-stuff is far inferior to Mexican baked goods in which I do not find aflatoxin!

Here is some good news for cooks: if you bake it yourself, adding a bit of vitamin C to the dough, your breads will be mold free for an extended period (and rise higher).

Aflatoxin

What is so important about molds? Some of them produce very, very toxic chemicals wherever they grow. They produce some of the most toxic chemicals known to exist. Aflatoxin is one of these. My tests show it is always present in cancer patients; in other words it has built up due to the body's inability to detoxify it in a reasonable time. A great deal of research has been done on aflatoxin. Any library would have more information.

Aflatoxin reaches the liver and simply kills portions of it. After a hefty dose the liver is weakened for a long time—possibly years. Hepatitis and cirrhosis cases always reveal aflatoxin. The liver fights hard to detoxify aflatoxin and manage its own survival. It manages for 2 to 3 weeks; then a portion of it succumbs. So the toxic effects of a dose of aflatoxin aren't even noticeable for several weeks! And without a taste or smell to guide you, how would you know to stop eating the moldy peanut butter or spaghetti? The answer is:

1. make and bake things for yourself
2. test the things you dearly love but can't make
3. treat things that are treatable for molds
4. throw the rest out of your diet

Treatments mentioned in the industrial research journals are hydrogen peroxide, strong alkali such as lime-water, metabisulfite (a common reducing agent) and high heat. I have tried heat and vitamin C, which is also a reducing agent.

Just heating a food to the boiling point does not kill the molds. Boiling for many minutes at a higher temperature or baking does kill them (but not ergot, another mold) and also destroys aflatoxin they produced and left in the food. For foods you can't heat that high, for example nuts that are already roasted, or vinegar, vitamin C comes to the rescue. I suppose it acts a lot like the bisulfite; chemically destroying the mold toxin molecules.

Eradicating Aflatoxin

Simply sprinkling vitamin C over **roasted nuts** is not effective because the molds have penetrated the surface. Rinse the nuts in water first (a lot of mold is removed in this simple way). Cover the nuts with water, add about ¼ tsp. vitamin C powder (for a pint of nuts) and mix. Let stand for 5 minutes. The water penetrates the nuts, taking the vitamin C with it and detoxifies them. Pour off the water and dry the nuts in the oven at low heat. (Don't burn them or you will make benzopyrenes.)

Rice and **pastas** can be demolded partly by cooking and partly by adding vitamin C before or after cooking. There is no need to add so much it affects the flavor. Brown rice is especially moldy.

Vinegars can simply have vitamin C added and placed in the refrigerator.

Honey can be warmed and treated the same way (¼ tsp. per pint).

Bread cannot be salvaged. Switch to bakery breads or homemade. Use it up in a few days, left in its paper bag. Or slice and place in a plastic bag in the freezer.

Since all foods have both their own and others' molds, there must be thousands of molds. Very many have been studied besides aflatoxin producers.

Zearalenone

> Zearalenone, an anabolic and uterotrophic metabolite, is frequently found in commercial cereal grains and in processed foods and feeds, and is often reported as causative agent of naturally occurring hyperestrogenism and infertility in swine, poultry and cattle.[18]

What this means is, in animals, “zear” looks likes extra estrogen to the body. Does it affect humans the same way? Are high estrogen levels a problem for us? I find nearly every breast cancer case shows a too-high estrogen level for years before the cancer is found! It starts females maturing too early, too. It could cause PMS, ovarian cysts and infertility. Not everybody gets all of these effects. And what is the effect on men and boys of eating an estrogen-like mycotoxin in their daily diet? This female hormone could have a drastic effect on the maturing process even in small amounts.

Zearalenone ("zear") and aflatoxin both have immune lowering effects. Zearalenone can induce thymic atrophy and macrophage activation.[19] If you have low immunity (low T-cells, low white blood cell count, and so forth), immediately go off moldy food suspects.

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[18] Bottalico, A., Lerario, P., and Visconti, A., Production of Zearalenone, Trichothecenes and Moniliformin By Fusarium Species From Cereals, In Italy. From *Toxigenic Fungi, Vol 7*, edited by H. Kurata and Y. Ueno, copublished by Kodansha Ltd, Tokyo and Elsevier Science Publishers B.V., Amsterdam, 1984, page 199.

[19] Luster, M.I., Boorman, GA., Korach, K.S., Dieter, M.P., and Hong, L. 1984. Myelotoxicity toxicity resulting from exogenous estrogens evidence for bimodal mechanism of action. Int. J. Immunopharmacol. 6:287-297.

"Zear" is the mycotoxin that prevents you from detoxifying benzene. Every AIDS sufferer I see has a crippled ability to detoxify benzene; they also have zear!

The main zear sources I have found so far are popcorn, corn chips, and brown rice. But it was absent in fresh corn, canned corn, corn tortillas, and white rice, making me wonder how it gets in our processed corn products.

Sterigmatocystin

Sterigmatocystin ("sterig") is plentiful in **pasta**. Emphasize baked pasta dishes, not boiled. This raises the temperature much higher than boiling. Better yet, make your own pasta with a pasta maker. U.S. bread flour is quite free of mold; the mold in our pastas must come from using inferior quality flour. Always add vitamin C to pasta before or after cooking.

Fig. 50 All U.S. brands of pasta I tested had mold, including health food brands like the one shown here (left). No Mexican brands of pasta, like the one pictured (right), had any molds.

Ergot

A food mold that causes strange feelings and behavior is *ergot*. Although laws regulate the amount of ergot allowed in foods,[20] this is not enough protection. Ergotoxins, for example LSD, are active in extremely minute (less than a microgram, about one thousandth of a fly speck) quantities. They are not destroyed by heat and are especially toxic to children. I found traces in cereals, whole grain breads, wines, and honey. It can be detoxified by adding vitamin C but takes longer; about 10 minutes. Detoxify all your **honey** as soon as it arrives in your house. Warm it slightly and add vitamin C (1/8 tsp. per cup). Stir with wood or plastic.

Ergot toxicity could explain "Jekyll and Hyde" behavior in children, commonly attributed to "allergies". In fact, the mechanism, inability by the liver to keep up with detoxification, fits well into the "allergic" concept. If your child has undesirable behavior, try going off the moldy food suspects for three weeks (cold cereals, nuts and nut butters, store bought breads and baked goods, syrups). Substitute cooked cereals, bakery breads, potatoes, and honeys. Add vitamin C to honey, pasta and cooked cereals. Pancakes and waffles made from scratch would be O.K.

Combining alcohol with ergot is more toxic than either is alone. Alcohol seems to drive the toxin deeper into your tissues. I have found ergot and aflatoxin in beer and wine! Perhaps some of the bizarre behavior and speech of intoxication is really due to the mold-alcohol combination. By delaying alcohol detoxification, the mold could even be responsible for deaths "due to" alcoholism. It would be safer to brew your own alcoholic beverages. Start with pristine fruit. Or at least add vitamin C (1/8 tsp. per cup) to the store bought container you are consuming.

Older children and adults are quite susceptible to ergot too. If bizarre behavior shows up, such as saying mean and cruel things, expressing unusual, irrational thoughts, feeling emotionless or unreal, try the same diet changes, but put alcoholic beverages, soy sauces and other sauces, and other grain derived foods on the "off" list. Try this diet on yourself if you have a temper or crying spells or frequent colds! Ergot can make you super religious, hearing voices of command or threat. Ergot also causes seizures!

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[20] Canada allows one ergot grain per 300 grains of #3 or #4 wheat.

Fig. 51 All cold cereals I tested were full of mold toxins (besides solvents), health food varieties were worst.

Cytochalasin B

Cytochalasin B ("cyto B") is another immune lowering fungus. I find it mostly in pasta. It stops cells from dividing. Dead portions of the liver cannot regenerate as they otherwise would after a toxic encounter!

Kojic Acid

Kojic acid is a mycotoxin that appears to be responsible for wood alcohol build up. In other words, the toxic effect prevents you from detoxifying wood alcohol. This leads to pancreas damage, invites pancreatic fluke infestation, and typically results in diabetes. I find it in potatoes; don't eat potato skins. If you are a potato lover fix your own so you can peel them and remove any gray parts. I have also found it in regular coffee.

T-2 Toxin

T-2 toxin is a mold I have found in all cases of high blood pressure and kidney disease. It is present on dried peas and beans but it can be detoxified in 5 minutes by adding vitamin C to the water they are soaked in. Remember to throw away imperfect ones, first.

Sorghum Molds

Sorghum and millet carry these. Don't buy sorghum syrup. Rinse millet in vitamin C water before cooking, or add vitamin C to the cooking water.

These mold toxins cause hemorrhaging, appetite loss, and inability to swallow. Elderly people are more easily poisoned than others; their hemorrhages show up as strokes and purple blotches on the skin.

Patulin

is the major fruit mold toxin. It is present in most common fruits if they are bruised. It is particularly hazardous since the mold that produces it can actually grow in your intestine in patches. At these locations, bowel bacteria, *E. coli* and *Shigella*, can climb through the colon wall to invade you. These bacteria are then free to spread to regions of injury and tumors.

If you have cancer or bowel disease go off fresh fruit (bananas and lemons are OK) for a few weeks. Then choose your fruit meticulously. Peel everything so you can see and avoid every bruise. Also take a 2 tsp. dose of Black Walnut Hull Tincture Extra Strength. This kills these bowel fungi. But you can reinfect with a single soft grape.

Mold Avoidance

We should be much more critical of our food.

Crackers are notoriously moldy. Never let your child eat crackers. Make crisp things in the oven from left over bakery goods. Just sprinkle with cinnamon.

Dried fruits are very moldy. Soak them in vitamin C water. Rinse and bake to dry again. Then store in the refrigerator or freezer. When fresh fruit gets overripe, don't quickly bake it or preserve it. It's too late.

Peanut butter (store bought) and other nut butters can't be detoxified by adding vitamin C due to the mixing problem, even if you stir it in thoroughly. Make your own. Making your own peanut butter is a great adventure (see *Recipes*). Mix it with home made preserves, honey, marmalade, not very homogeneously so the bright colors and individual flavors stand out in contrast. Having three or four such spreads in the refrigerator will give your children the right perspective on food—homemade is better. Store bought jams are sweeter and brighter in color but strangely low in flavor and often indistinguishable from each other. Let your children eat the polluted foods that friends and restaurants serve (but not rare-cooked meats) so they can experience the difference. Their livers are strong enough to detoxify occasional small amounts.

Tea is quite moldy if purchased in bags. Although I used to recommend single herb teas (tea mixtures have solvents), I can now only recommend single herb teas from fresh sources in bulk (see *Sources*). This also gets you away from the benzalkonium chloride and possibly other antiseptics in the bag itself. When you get them, store them in their original double plastic bag. These herbs are so fresh, you'll only need half as much to make a cup of tea. Use a bamboo strainer (non metal). Bake the strainer occasionally or put through the dishwasher to keep it sterile.

Fig. 52 Packaged herb tea is moldy and polluted with solvents. Get yours in bulk from an herb company.

It comes as a surprise that pure, genuine **maple syrup** has the deadly aflatoxin and other molds. You can often see mold yourself, as a thin scum on the surface or an opaque spot on the inside of the glass after the syrup has stood some time, even in the refrigerator. Some mold spores were in it to begin with. Others flew in. After some time they grew enough to be visible. In my testing, aflatoxin can be cleared with vitamin C but sterig and others need to be treated with a high temperature as well. Fortunately, this is easy to do with a syrup. Heat to near boiling while in the original jar with the lid removed. Keep refrigerated afterwards.

Artificial maple flavor did not have benzene, propyl alcohol or wood alcohol, nor molds. **Turbinado sugar** had none of these contaminants either. **Brown sugar** had sorghum mold. **White sugar** had propyl alcohol pollution. You can make your own syrup, safely, with artificial flavor and turbinado sugar. Of course, you'll be missing the taste and nutritional minerals provided by the natural maple product but in a contest between nutritional value and toxicity, always choose the safe product.

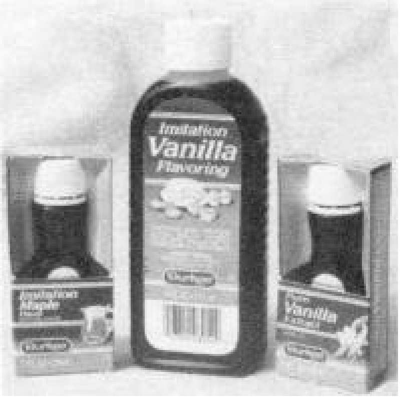

Fig. 53 Three safe flavorings.

The mold in our **hot cereals** can be spotted. Pick out all dark colored, shriveled bits. This represents most of it. Add honey, and salt while it's cooking—this raises the boiling temperature and detoxifies more. At the end, turn off heat and add a sprinkle of vitamin C powder. Rolled oats never showed molds in my testing, although they have their characteristic fungi, too. Don't let grains mold on your shelves simply from aging. Nothing should be more than six months old. Remember you can't see or smell molds when they begin. Molds must have a degree of moisture. As soon as you open a cereal grain, put the whole box in a plastic bag to keep moisture out. This keeps out Weevils too, so you won't have to put the box in the freezer later to kill them.

Anything that is put in the refrigerator or freezer and then taken out develops moisture inside. Store cereals in kitchen cupboards or the freezer.

No government agency can test for all of these mycotoxins in all of our foods. Production and storage methods must be better regulated so as to be fail-safe. Simply sending inspectors out to look into the bins at grain elevators is not sufficient. Crusts of mold, sometimes several feet thick, that form on top of grain bins can be simply shoveled away before the inspector arrives. The humidity and temperature of stored grain should be regulated, requiring automated controls. This would soon be cost effective, too, in terms of reduced spoilage losses and higher quality prices earned. I believe that zear, aflatoxin and ergot require special regulations. Products that are imported should be subjected to the same tests as ours. Test results should be on the label.

Getting Away From Grains

In view of the many molds that are grain-related, and because these cannot be seen or smelled in pastas, breads, cold cereals, it would be wise to steer away from grain consumption. Always choose potatoes, because it is a vegetable instead of a grain, if you have a choice. The potato appears on your plate the way it was harvested. Whereas grain was hulled, stored for quite a long time, perhaps degerminated (the bran and germ picks up

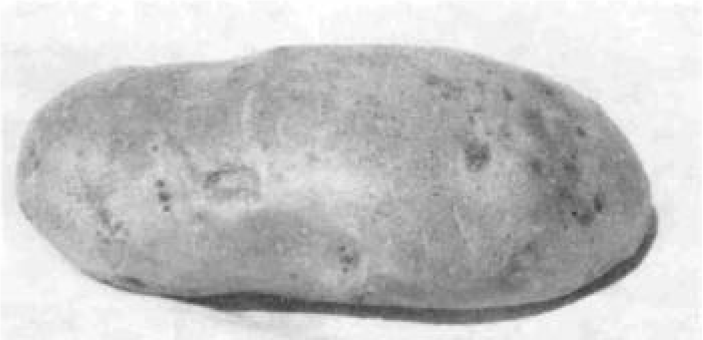

Fig. 54 Don't eat the green on the potato.

mold the fastest). Then it was mixed with assorted chemicals (fumigation, anti oxidants), each polluted in its own way, packaged again and stored again. Grains have a more tortuous history than potatoes that simply get sprayed.

The spray isn't simple, of course. Scrub it off under the tap. If potatoes weren't heavily sprayed they'd be sprouting in the stores. The spray accumulates in the eyes. Cut away all the eyes. By the time you have done this you may as well have peeled them. But no blemish, no cut, no dark spot inside may be left for you to eat. Don't buy potatoes that show a tint of green on them (the green color is due to *scopolamine*; it is toxic). Red potatoes have different chemistry that doesn't produce the green toxin, buy these often. Store potatoes out of the light, to slow down the greening process. They are still a nutritious, vitamin C-rich food—provided you don't fry them in benzene-polluted, hydrogenated grease!

Fig. 55 Potato harvest of the future.

Potatoes have their molds but they are nicely visible. And washing and peeling does away with them. Old literature advises that potatoes should be harvested by moonlight so the green drug isn't produced in the white varieties. With modern mechanized harvesting this should pose no problem. But perhaps this must await the age of robots.

Pets Teach Health Lessons

Dogs don't eat hay and cats don't eat fruit. This is not simply due to their inability to digest them. Nor to training. Their body wisdom guides them. But we can trick them into eating corn and soybeans by adding the flavors they like and thereby defeat their wisdom the same way we defeat ours. A concoction is made for them that is called “complete nutrition” and we feed this meal after meal, day after day, a most unnatural situation. The liver is deluged with the same set of pollutants time after time and never gets a rest. Humans still obey their body wisdom about varying their meals. This gives the liver a chance to catch up with detoxifying one pollutant while the new one builds up. If the liver is absolutely unable to handle something, you are informed quite quickly with an allergic reaction to the food.

Cats and dogs with their monolithic diet get no opportunity to reject food (except by vomiting or starvation). It is not surprising they are getting cancer with increasing frequency, a situation where the liver can no longer detoxify isopropyl alcohol, a common pollutant in their food.

Should we go back to the old days and make their food for them? Yes, they deserve pure food, they deserve variety. Table scraps would be much less toxic for them than their commercial feed. But what if they like and prefer their monolithic “scientific”, “complete”, polluted diet? If our food was doused with sugar for breakfast, lunch and supper, we wouldn't care much about what was under the sugar either. And we'd continue wanting sugar, sugar, sugar the way a pet might want its favorite food and nothing else. Such is the deception of flavorings.

All change should be brought about slowly and with kindness for animals and humans alike. Learn what makes a good pet diet. Cats and dogs are both meat eaters. Cook chicken in a pressure cooker to kill all parasites. Put portions in the freezer. Add table scraps, dressed with a little butter, cheese or lard.

Don't wash the pet dishes with your own—dishwashers don't reach the boiling point. Serve fresh water daily. Standing water picks up bacteria. Don't let food get more than a day old in the dishes. It picks up molds. Don't feed pets at the table, keep them outdoors during mealtime.

After your pets have stopped eating propyl alcohol polluted food and are not getting propyl alcohol in their shampoos, there is no way they can get cancer. Whatever cancer they have will clear up by this change in diet and by giving them the pet parasite program.

Now they are back to a natural state and do not host human flukes. What a relief it is not to worry about reinfection from your pets.

Easy Lifestyle Improvements

None of us likes to change a habit. But once it is changed you are back to an automatic way of doing something. By selecting wise habits your improved lifestyle pays you back for the rest of your life.

Living Hand To Mouth

Hands do everything. They pick up things from the floor. They handle money. They touch other peoples' hands. They clean up bottoms. They touch all kinds of door knobs. And then they pick up food to eat. Some people even lick their fingers when they're sticky or just to turn a page!

What is on the hands that you don't want to eat but can't see? **Bacteria** and **viruses** from coughing and sneezing into your hands! And **cysts**! Cysts are the "eggs" made by parasites. Cysts are so tough not even bleach kills them. They hide under our fingernails when we wash our hands. Then we eat them along with our food. This is called *oral-fecal route*. They hatch in the stomach and go to the intestine to live.

To stop reinfecting yourself the little cysts under the nails need to be killed. Food grade alcohol solution kills them. Buy Everclear^{TM} or Protec (potable) alcohol and make a 5% solution (add ¼ cup of 95% alcohol to a quart of water). Keep it in a small pump bottle at the sink. After using the bathroom and washing your hands, treat your fingernails with alcohol. Pump alcohol into one palm. Put the fingernails of the other hand into it. Scratch a bit. Pour it into the other palm and do the remaining fingernails. Rinse.

- **Don't** eat with your hands! Use a fork.
- **Never** eat food off the floor!
- **Always** wash hands after petting an animal!
- **Never** touch the bottoms of shoes! Keep shoes off couch or bed or chair.
- **Always** cough or sneeze into your clothing or a tissue, not your hands.
- **Keep** your fingers out of your mouth. Don't lick your fingers to turn pages or open plastic bags.

Sick persons need a 50% alcohol solution. Add ½cup 95% alcohol to ½cup cold tap water or buy plain vodka, 80 to 100 proof. Pour the vodka into the pump bottle. Be careful that nobody tries drinking it. If there are teenagers in the house, add a hefty dose of cayenne to it.

Lugol’s iodine will also sterilize your hands. However most commercial Lugol’s is polluted with isopropyl alcohol. Ask your pharmacist to make it from scratch for you (there are only two ingredients and water, see *Recipes*). Then make a solution to wash in (1 tsp. to a quart of water). This can stain some things. Do not use “tincture of iodine.”

Better Laundry Habits

Boil your underwear. In long-ago days, all sheets, towels, table cloths, and underwear were separated and boiled.

With the convenience of our electric washing machine, we tend to overlook the fact that underwear is always contaminated by fecal matter and urogenital secretions and excretions. Mixing these with socks and towels and dishcloths is all right if you are going to kill everything anyway. But if you don't kill them, as in cold water washes, you are mixing the yeast, parasite eggs, bacterial spores, and fungus from underwear with all the other clothing you and your family wear. An enlightened system would be to add an antiseptic to the wash or rinse cycle. Lime water (calcium hydroxide) or iodine based antiseptics seem obviously simple methods to accomplish this. In the absence of this protection, use dryer heat to do your sterilizing. Underwear should be dried until too hot to handle.

Bleach can kill a lot, but doesn't kill *Giardia* spores and a lot of types of fungus. Don't rely on bleaching. Besides, your skin absorbs it from clothing, it is quite toxic to you, and can cause mental effects.

Commercial detergents are polluted with PCBs and have cobalt added. Both of these are easily picked up through your skin. Use **washing soda** and **borax** in the wash cycle. They do not clean quite as well as modern detergents, but there is less static cling, eliminating the need to put more chemicals in your dryer. For spot removal use homemade bar soap.

Better Kitchen Habits

Once a day, sterilize the sponge or cloth you use to wipe up the table, counter tops and sink. This little piece of contaminated cloth is the most infectious thing in the house, besides the toilet. It's more dangerous than the toilet because you do not suspect it. Sometimes it has a slight odor at first, which may warn you, but most pathogens do not have an odor! As we wipe up droplets of milk, we give the milk bacteria, *Salmonellas* and *Shigellas*, a new home to multiply and thrive in. We add crumbs, picking up molds this way. We add dust, picking up parasite eggs and stages. They all feed on the milk and food residue.

As the counter and table and stove get wiped "clean" a film of contamination is left everywhere. A few varieties may die but most of them don't. The general moisture in the kitchen is enough for them to survive. The cloth or sponge recolonizes the kitchen and dining room table several times a day.

No doubt, the last thing you do before leaving the kitchen is squeeze it dry with your hands. Now all the pathogens are on your hands!

Where do your fingers go? To your mouth to remove a hull or bit of something from your teeth. Or to eat a last bite of something. Or to turn a page of the telephone directory. You have just eaten a culture sampling from your own kitchen sponge. In two hours they are already multiplying in the greatest culture system of all: your body! You have given yourself your next sore throat, or cold or headache. The worst possible habit is to wipe a child's face and hands with the kitchen cloth. Or to have a handy towel hanging from the refrigerator handle.

To sterilize the sponge: **drop it into a 50% solution of grain alcohol** at the end of each day. Keep a wide mouth glass quart jar handy just for this. Keep the jar tightly closed and out of the reach of children. Dunk your sponge and plop it onto the sink. If you stand it on end in the sink it will partly dry overnight.

Another way to sterilize the sponge or cloth is to **microwave it**, after wetting it, for 3 minutes. Any shorter time simply warms and cultures the pathogens and multiplies them. Or **boil the cloth** like our grandparents did. Drying out the dish cloth helps kill many–but not all–pathogens. It takes three days of drying to kill all! Another strategy is to **use a fresh cloth** or sponge each day, putting the used one to dry until laundry day.

During the day, set the sponge on end to start drying and slow down culturing.

Don't eat food directly off the counter top or table top. You wouldn't slice a tomato or egg directly on the counter top. It would pick up something: some little particle of dust or dirt. Treat bread the same way. Always on a new clean surface, such as a plate. The counter and table top have on them whatever is in the kitchen dust and on the wipe cloth. Dust is always falling! And the sponge is always culturing. Don't eat the dust!

Keep the cutting board sterile like dishes. Wash it the same way and keep it in the cupboard.

Keep food containers closed. Milk or water glasses are picking up dust as soon as you set them out. Dust is everywhere. Every step on the carpet sends up a puff of dust. Vacuuming sends up a hurricane of dust and distributes bathroom dust to the kitchen and kitchen dust to the bedrooms. So if one person has brought in a new infection, the whole family is exposed to it in hours via the dust.

It is very helpful not to eat the new infectious pathogen. Breathing it is not so damaging. Our noses collect such pathogens and we blow them out again. Touching the infected person is not very damaging either; the pathogens can't get through our skins and since we wash hands before eating we are not at great risk of infection this way. But eating the pathogen is 100% effective in infecting us. The new pathogen is in the dust. The newly contaminated dust drops into your ready and waiting glasses on the table and the open foods. Of course, there is no defense if somebody should cough or sneeze at the table.

Teach children to cough and sneeze into a suitable collecting place like a tissue, not their hands. Pathogens live bountifully on hands. Hands not only provide moisture but often food from the last meal. Hands are second only to the dish cloth in contamination level. If you must cough or sneeze and a tissue is not within reach fast enough, use your clothing! That's what clothing is for—to protect you. Cough and sneeze into your own clothing; this protects the cougher and sneezer, as well as everybody else. A sleeve is handy for children. The inside of your T-shirt for T-shirt wearers. The inside of coat for suited persons. The inside of the neck line for dresses. Of course, paper is best, but in emergency use cloth. Never, never your hands unless you are free to immediately dash into the washroom and clean the contamination off your hands.

Teach children this old rearranged verse:

If you cough or sneeze or sniff
Grab a tissue, quick-quick-quick!
And if you're sitting at the table
Do it in your sleeve if able.

Better Housekeeping

Throw out as much of the wall to wall carpeting as you can bear to part with. It is injurious to everyone's health, even though it's comforting to bare feet and looks pretty.

Carpets clean our shoes. Modern shoes, with their deep treads, bring in huge amounts of outdoor filth which settles deep down into the carpets. In spite of vacuuming every week, the filth accumulates.

Vacuum the carpets when the children, the sick and elderly are out of the house. The dust raised and distributed throughout the house isn't just dirt, it's infectious dirt. It lands on tables and counters. These get wiped with a cloth or sponge and then applied to dishes. The dust in the kitchen falls on open food and into open containers.

Clean carpets with a “steam cleaner”. When you see how much filth is in the water and realize how much dirt you were living with, you might be willing to trade in the “beauty” of carpets for the cleaner living of smooth floors. Don't add chemicals (commercial cleaning solutions) to the steam cleaning machine; these chemicals leave a residue in the carpet which dries and flies up into the air to add to the dust. Popular stain resistance treatments contain arsenic. Cobalt, which adds “lustre” to carpets, causes skin and heart disease after it has built up in your organs. Use borax instead of detergent. Use boric acid to leave a residue that kills roaches and fleas (but not ants). Add vinegar that leaves a residue to repel ants. Nothing controls fleas reliably, except getting rid of the carpets and cloth furniture (keep pets out of bedrooms). Removing all the borax is what brings luster to the carpet. Use citric acid in the rinse water for this purpose. Adding lemon peel to the rinse also adds luster and ant deterrence. Just drop the whole lemon in the tank so it can't block the hoses.

Fleas and other vermin in the carpet simply crawl below the wetness level when you wash the carpet. Spraying a grain alcohol solution with lemon peel in it (it needs to extract for a half hour) on the damp carpet will reach and kill a lot of these, together with the residual bacteria. The damp carpet lets it spread evenly and reach all the crevices.

We are trapped in our dwellings. Primitive peoples were mobile. This got them away from accumulations of filth and rubbish in their living space. Much living was done outdoors, the cleanest space of all.

Now, air conditioning has made indoor living more comfortable. But also has added new hazards. The strong currents of air blow the dust about continuously. Molds and bacteria that grow right on the air conditioning unit get blown about for all to inhale. Never, never use fiberglass as a filter or to insulate your air conditioner around the sides. It is a carcinogen. And the danger of freon escaping from a tiny leak is another major health hazard.

Forced air heating systems are undesirable, too. All dirt brought into the house by shoes gets circulated throughout the house by forced air systems of heating or cooling. Old fashioned radiant heat from radiators or a stove did not distribute the dust so effectively. A return to linoleum floor covering for kitchen and bathroom and hardwood for other rooms would be a good step of progress for a health conscious society. Mopping, instead of the vacuum cleaner, keeps dirt to a minimum. Throw rugs at doors and bedside, easy to clean, would "catch the dirt" as was the original intention. Carpets were intended to help keep filth out of the air. These smaller rugs should be laundered weekly.

Furniture should be wood, cane, or plastic, with cushions to soften the impact. These can be washed weekly if the covers are removable. Modern cloth furniture with its foam interior is a repository of filth and fumes and a constant source of infectious dust.

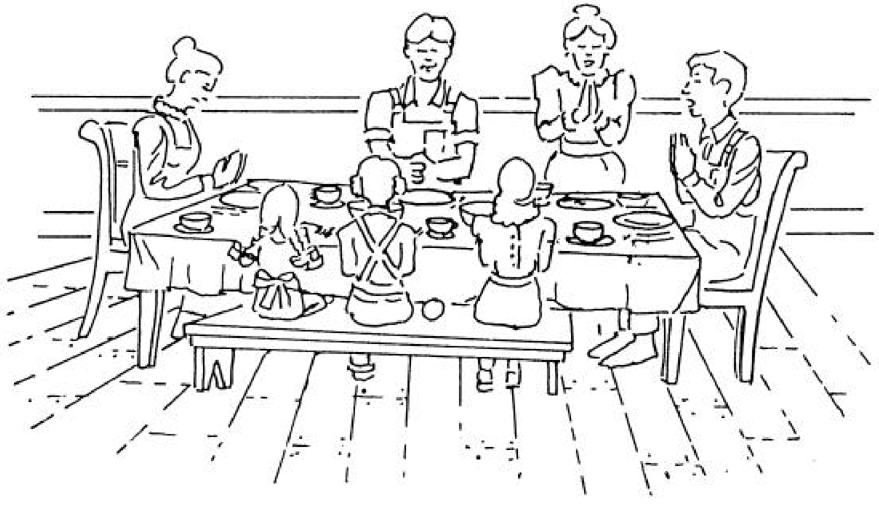

This old fashioned setting is more progressive than our carpeted, modern homes.

Fig. 56 Smooth floors allow every bit of dust to be removed.

Dust your furniture with a damp paper towel. You are picking up and removing highly infectious filth (*Ascaris* and pinworm eggs, pet parasites, "dander" and house mites). Instead of distributing these from room to room, throw the paper towel away after each room is done. Use plain water or vinegar water (50%), not a chemical combination which further pollutes the air.

Clean windows with vinegar water, too. Use a spray bottle.

Keep your dishes in cupboards. This keeps them free of dust. This principle is ancient. It is tempting to leave some of them out. If you must keep the juicer or dishes outside of cupboards, keep them covered or placed upside down so they don't catch dust. Even inside cupboards, store them upside down. When using the “good” dishes or glasses, that haven't been used in a while, wash them first.

Windows Open Or Closed?

In places like Chicago where you can smell the air as you approach the city, it is wiser to keep your windows shut. You can't breath the industrial “soup” all day and night and expect to stay healthy. Of course, it all enters the houses anyway. Central air conditioning and a plain carbon filter at the furnace location (see *Sources*) may be the best solution in spite of blowing dust around the house. Keep the vents to the bedrooms closed to reduce the air turbulence there but leave the cold air return open. Clean the vents in other rooms each week along with floors and carpets by pulling up the grating and reaching down the passage as far as possible.

If you believe the air is free of highway exhaust and industrial smoke open the windows every day. This will let some of the indoor toxins blow away. Asbestos, fiberglass, freon, radon and plain dust can be reduced to a minimum by keeping windows open. If you are ill, sit outdoors (on the porch) as much as you can. Escape to a suitable climate that makes this possible.

Just a few decades ago, many people had summer living quarters that were different from winter living quarters. Gone was all the accumulated infectious dust of half a year of habitation.

Fig. 57 Moving into the summer kitchen got you away from the accumulation of filth from winter!

Don't have a basement where you stockpile toxic items. Basements invite mold, mice and radon besides toxic things. Fumes travel upward where you live! Keep your toxic things in the attic. If there is no attic, store them in the utility room. Close off the ventilation between utility room and the rest of your house. If you have none of these, perhaps because you live in a senior citizen community or condominium, don't keep any toxic things stored anywhere. Don't save any leftover paints, solvents or cleaners. Buy such small quantities that you can afford to throw it all away when you are done with them.

Live on top of the earth as was intended by nature.

Never have a basement room "finished" for actual living space. Don't buy a house that has a "lower level" built into the earth. This will be the most polluted and dangerous room in your house. If you are ill, move out of such a room. There is no way that it can be "cleaned up". Move to the other end of the house and furthest away from an attached garage door.

What Kind Of Heat

The worst is coal. The best is none. Breathing coal fumes during the beginning of the industrial age may have brought the new lung diseases: tuberculosis (TB), and pneumonia. It may also have worsened alcohol addiction (beryllium toxicity). Choose electric heat if possible. Even though electricity is based on other fuel consumption, you don't have to breathe those fumes directly.

Wood stoves can be made safe by making sure the chimney works properly. Never use a lighter fluid. Don't fill the house with smoke when stoking.

Minimize your use of fossil fuels in every way you can.

Getting Rid of Mites

We do not tolerate external parasites like bedbugs, lice, ticks, leeches. Bedbugs were once a scourge amongst northern Europeans. I remember our parents spraying for them (kerosene) in the bedroom. This only "controlled" them. What eliminated them was a law against sale of used mattresses. Lice were originally "controlled" by frequent washing, louse combs, and ironing the seams of clothing. What eliminated them was the cutting of long hair as a societal practice. But what about **mites**? They live with us and other animals.

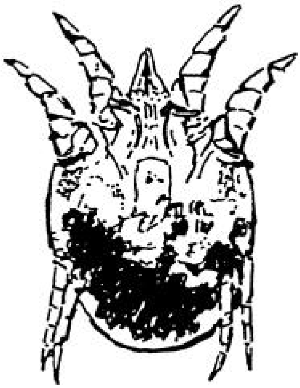

Fig. 58 Mite.

Mites are too tiny to see, tiny enough to ride on a dust particle as if it were a magic carpet. They resemble insects. Chiggers are really mites. Mange in animals is a mite infestation. Dust mites live on our dander (scales of dead skin).

Get rid of their breeding places: beds, cloth covered chairs and soft sofas. Humans leave enough dander behind in these places to support these ultra small insects. Cover mattresses with plastic covers. Use throws on easy chairs and sofas and wash them often. Never allow a pet into the bedroom or the dust will have tapeworm eggs as well as mites. Throw out rugs that have been pet-beds. Spray the air with a mist of 50% grain alcohol before vacuuming. If you have an illness wear a mask to vacuum. Deep, soft, wall to wall carpets compromise an ancient concept: everything should be washable and cleanable, without throwing the dirt into the air for humans to inhale. Vacuuming a carpet blasts mites and tape eggs into the air. Never shake bedding or rugs where the dust will blow back into the house behind you.

Mites don't bite us but we inhale them as they float in the ever present dust in our homes. The mucus in our lungs traps them and in a few days they die, only to release a drove of *Adenoviruses* (common cold virus) in us.

Four Clean-ups

Chronic health problems are not due to exposures of the past. They are ongoing. Your body is constantly fighting to remove pollutants. In order to stay sick, you must be constantly resupplied! These four clean-ups–dental, diet, body, home–are aimed at removing parasites and pollutants at their source. Only then can your body heal.

Dental Clean-up

(This section on dentistry was contributed by Frank Jerome, DDS)

Dr. Jerome: The philosophy of dental treatment taught in America is that teeth are to be saved by whatever means available, using the strongest, most long lasting materials. Long-term toxic effects are of little concern. The attitude of the majority of dentists is: whatever the American Dental Association (ADA) says is OK, they will do.

A more reasonable philosophy is that there is no tooth worth saving if it damages your immune system. Use this as your guideline.

The reason dentists do not see toxic results is that they do not look or ask. If a patient has three mercury amalgam fillings placed in the mouth and a week later has a kidney problem, will she call the dentist—or the doctor? Will they ever tell the dentist about the kidney problem or tell the doctor about the three fillings? A connection will never be made.

It is common for patients who have had their metal fillings removed to have various symptoms go away but, again, they do not tell the dentist. The patient has to be asked! Once the patient begins to feel well they take it for granted, and don't make the connection, either. If everybody's results were instantaneous, there would be no controversy.

Find an alternative dentist. They have been leading the movement to ban mercury from dental supplies. Not only mercury, but all metal needs to be banned. If your dentist will not follow the necessary procedures, then you must find one that will. The questions to ask when you phone a new dental office are:

1. Do you place mercury fillings? (The correct answer is NO. If they do, they probably don't have enough experience in the use of non-metal composites.)
2. Do you do root canals? (The correct answer is NO. If they do, they do not understand good alternative dentistry.)
3. Do you remove amalgam tattoos? (The correct answer is YES. Tattoos are pieces of mercury left in the gum tissue.)
4. Do you treat cavitations? (The correct answer is YES. By cleaning them.) The complete name of *cavitations* is *alveolar cavitational osteopathosis*. They are holes (cavities) left in the jawbone by an incompletely extracted tooth. A properly cleaned socket which is left after an extraction will heal and fill with bone. Dentists routinely do NOT clean the socket of tissue remnants or infected bone. A dry socket (really an infected socket) is a common result. These sockets never fully heal. Thirty years after an extraction, a cavitation will still be there. It is a form of *osteomyelitis*, which means bone infection.

Ninety percent or more of dental offices will not be able to answer ANY of the above questions correctly. If you allow the work to be done by a dentist who does not understand the importance of the above list, you could end up with new problems. Find the right dentist first even if you must travel hundreds of miles. There are 6,000 to 10,000 dentists who should be able to help. Some can do part of the work and refer you to a specialist for the rest. Five hundred to one thousand of these dentists can do it all.

Normal treatment cost is about $1,000 for replacement of 6 to 8 metal fillings including the examination and X-rays. For people with a metal filling in every tooth, or for the extraction of all teeth (plus dentures), it may be up to $3,000 (or more in some places).

Remember, the simpler the treatment, the better. If the dentist says that he or she can change your metal fillings to plastic but it would be better to crown them, say "NO!"

Guidelines For A Healthy Mouth

If you have	**What to do**
Metal fillings	change to plastic fillings
Inlays and onlays	change to plastic fillings
Crowns (all types)	change to plastic crowns
Bridges	change to plastic crowns, partials
Metal partials	change to plastic partials(Flexite™)
Pink dentures	change to clear plastic
Porcelain denture teeth	change to plastic denture teeth
Badly damaged teeth	become extractions
Root canals	become extractions
Braces and implants	avoid
Cavitations	need to be surgically cleaned
Temporary crowns	use plastic
Temporary fillings	use Duralon™

Fig. 59 Dental replacements.

The guidelines can be summarized as:

1. Remove all metal from the mouth.
2. Remove all infected teeth and clean cavitations.

Dr. Clark: *Removing all metal means removing all root canals, metal fillings and crowns. Take out all bridge work or partials made of metal and never put them back in. But you may feel quite attached to the gold, so ask the dentist to give you everything she or he removes. Look at the underside. You will be glad you switched.*

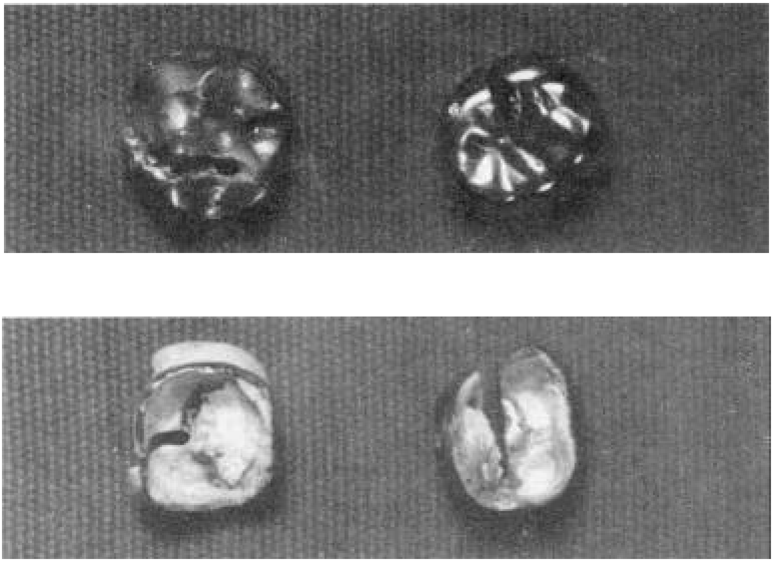

The top surfaces of tooth fillings are kept glossy by brushing (you swallow some of what is removed). Underneath is tarnish and foulness. Ask to see your crowns when they are removed.

Fig. 60 Tops and bottoms of some metal crowns.

The stench of the infection under some teeth may be overwhelming as they are pulled. Bad breath in the morning is due to such hidden tooth infections, not a deficiency of mouthwash!

All metal must come out, no matter how glossy it looks on the surface. Metal does not belong in your body. It is an unnatural chemical. Do this as soon as you have found a dentist able to do it. Find a dentist with experience and knowledge about this subject. It is more than replacing acknowledged culprits like mercury-amalgam fillings. This is metal-free dentistry. Only metal-free plastic should be put back in your mouth.

Dr. Jerome: If your dentist tells you that mercury and other metals will not cause any problems, you will not be able to change his or her mind. Seek treatment elsewhere!

Your dentist should do a complete X-ray examination of your mouth. Ask for the *panoramic* X-ray rather than the usual series of 14 to 16 small X-rays (called full mouth series). The panoramic X-ray shows the whole mouth including the jaws and the sinuses. This lets the dentist see impacted teeth, root fragments, bits of mercury buried in the bone and deep infections. Cavitations are visible in a panoramic X-ray that may not be seen in a full mouth series.

The cost of removing metals should be viewed in the proper light. It took years or decades to get into your present condition. When you do a lot of dental repair in a short time, it can seem to be costly. Unfortunately, many people are in a tight financial position because of the cost of years of ineffective treatment, trying to get well.

Your dentist may recommend crowning teeth to “protect” or strengthen them. Unfortunately, the very concept of crowning teeth is flawed. First, the enamel is removed from a tooth to prepare for the crown. This is permanent and serious damage! Many teeth, up to 20%, may die after being crowned and will need to be extracted. For this reason, you should only get REPLACEMENT crowns and NO NEW crowns. Your metal crowns can be changed to plastic. (Remember, no metal must be left under the crown.)

If you have many crowns, you should have them all removed as quickly as possible. But you should not spend more than two hours in the dentist's chair at any one time. That is too much stress for your body.

Dr. Clark: *Don 't accept intravenous (IV) treatments during amalgam removal. Both IV bags and the supplements used in them are polluted with propyl alcohol, benzene, and wood alcohol.*

Dr. Jerome: It is quite all right to have temporary crowns placed on all teeth that need them in the first visit. You may then go back and complete treatment over the next 6 to 12 months. It is common to find a crowned tooth to be very weak and not worth replacing the crown, particularly if you are already having a partial made and could include this tooth in it.

Dr. Clark: *We are accustomed to thinking that plastic is metal-free. This is wrong. The original dental plastic, methyl methacrylate was metal-free. But modern plastic contains metal. The metal is ground up very finely and added to the plastic in order to make it harder, give it sheen, color, etc.*

Dr. Jerome: Dentists are not commonly given information on these metals used in plastics. The information that comes with dental supplies does not list them either. Most dentists never look at a dental materials book after they graduate. The ADA, however, has a library full of such information.[21]

Dr. Clark: *There are many lanthanide (Rare Earth) metals used in dental plastic. Their effects on the body from dentalware*

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[21] Call the American Dental Association at (800) 621-8099 (Illinois (800) 572-8309, Alaska or Hawaii (800) 621-3291). Members can ask for the Bureau of Library Services, non-members ask for Public Information.

have NOT been studied. Yet their cancer-promoting ability is known in many cases.[22] *Only metal-free plastic is safe.*

Dr. Jerome: These are the acceptable plastics; they can be procured at any dental lab.

- Plastic for dentures: Methyl Methacrylate. Available in clear and pink. Do not use pink.[23]
- Plastic for partial dentures: Flexite™ Available in clear and pink. Do not use pink.
- Plastic for fillings: Composite Materials. This is the material that has been used in front teeth for 30 years. It has been used in back teeth for 10 years. There are many brands and there are new ones being marketed constantly. The new ones are very much superior to those used 10 years ago and they will continue to improve. They do, however, contain enough barium or zirconium to make them visible on X-rays. There are no alternatives available without these metals.

Dr. Clark: *Composites with barium are not good, but I haven't seen enough barium toxicity from fillings at this time to merit advising extraction instead. Hopefully, a barium-free variety will become available soon to remove this health risk.*

Dr. Jerome: Many people (and dentists too) believe that porcelain is a good substitute for plastic. Porcelain is aluminum oxide with other metals added to get different colors (shades). The metal DOES come out of the porcelain! It has many technical drawbacks as well. Porcelain is not recommended. Sometimes the white composite fillings are called porcelain fillings but they are not. They also require more tooth structure to be removed.

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[22] Thulium and ytterbium have been studied for their tumor-seeking ability. See page 321 in the book *METAL IONS In BIOLOGICAL SYSTEMS, Vol. 10, Carcinogenicity and Metal Ions*. Editor Helmut Sigel 1980.

[23] The pink color is from mercury or cadmium which is added to the plastic.

If you have a large bridge, it cannot be replaced with a plastic bridge because it isn't strong enough. A large bridge must be replaced with a removable partial (Flexite^{TM}).

The methods used to remove metals and infections are technical and complicated. See dental information in *Sources*.

Dr. Clark: *I'd like to thank Dr. Jerome for his contributions to this section, and his pioneering work in metal-free dentistry. I hope more dentists acquire his techniques.*

Horrors Of Metal Dentistry

Why are highly toxic metals put in materials for our mouths? Because not everyone agrees on what is toxic at what level. Just decades ago lead was commonly found in paint, and until recently in gasoline. Lead was not less toxic then, we were just less informed! The government sets standards of toxicity, but those "standards" change as more research is done (and more people speak out). You can do better than the government by dropping your standard for toxic metals to zero! Simply remove them.

The debate still rages over mercury amalgam fillings. No one disputes the extreme toxicity of mercury compounds and mercury vapor. The ADA feels that mercury amalgam fillings are safe because they do not vaporize or form toxic compounds to a significant degree. Opponents cite scientific studies that implicate mercury amalgams as disease causing. Many dentists advocate mercury amalgam fillings simply because they are accepted by the ADA, which they believe protects them from malpractice litigation. Why risk your health and life on their opinions? Remember everything corrodes and everything seeps, so amalgams must too.

Cadmium is used to make the pink color in dentures! Cadmium is five times as toxic as lead, and is strongly linked to high blood pressure.

Occasionally, thallium and germanium are found together in mercury amalgam tooth fillings. Thallium causes leg pain, leg weakness, and paraplegia. If you are in a wheelchair without a very reliable diagnosis, have all the metal removed from your mouth. Ask the dentist to give you the grindings. Try to have them analyzed for thallium using the most sensitive methods available, possibly at a research institute or university.

I was astonished to find thallium in mercury amalgams! It couldn't be put there intentionally, look how toxic it is:

> ***TEJ500*** ***HR: 3***
>
> **THALLIUM COMPOUNDS**
>
> Thallium and its compounds are on the Community Right To Know List.
>
> THR: Extremely toxic. The lethal dose for a man by ingestion is 0.5-1.0 gram. Effects are cumulative and with continuous exposure toxicity occurs at much lower levels. Major effects are on the nervous system, skin and cardiovascular tract. The peripheral nervous system can be severely affected with dying-back of the longest sensory and motor fibers. Reproductive organs and the fetus are highly susceptible. Acute poisoning has followed the ingestion of toxic quantities of a thallium-bearing depilatory and accidental or suicidal ingestion of rat poison. Acute poisoning results in swelling of the feet and legs, arthralgia, vomiting, insomnia, hyperesthesia and paresthesia [numbness] of the hands and feet, mental confusion, polyneuritis with severe pains in the legs and loins, partial paralysis of the legs with reaction of degeneration, angina-like pains, nephritis, wasting and weakness, and lymphocytosis and eosinophilia. About the 18th day, complete loss of the hair on the body and head may occur. Fatal poisoning has been known to occur. Recovery requires months and may be incomplete. Industrial poisoning is reported to have caused discoloration of the hair (which later falls out), joint pain, loss of appetite, fatigue, severe pain in the calves of the legs, albuminuria, eosinophilia, lymphocytosis and optic neuritis followed by

> atrophy. Cases of industrial poisoning are rare, however. Thallium is an experimental teratogen [used to induce birth defects for study]. When heated to decomposition they [sic] emit highly toxic fumes of Tl [thallium]. See also THALLIUM and specific compounds.[24]

Fig. 61 Thallium excerpt.

Thallium pollution frightens me more than lead, cadmium and mercury combined, because it is completely unsuspected. Its last major use, rat poison, was banned in the 1970s. Every wheelchair patient I tested was positive for thallium! One current use for thallium is in Arctic/Antarctic thermostats. When added to mercury the mercury will stay liquid at lower temperatures. Are mercury suppliers then providing the dental industry with tainted amalgam?

The cancer causing or carcinogenic action of metals has been studied for a long time, although it doesn't get attention by our regulatory agencies. A scientific book on this subject was published in 1980.[25] One table from this book is shown on page 431. We can see that chromium and nickel compounds are the most carcinogenic metals. Nickel is used in gold crowns, braces, and children's crowns!

Note that the form of the metal is very important. For instance chromium is an essential element of *glucose tolerance*

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[24] *Dangerous Properties of Industrial Materials*, 7th ed. by N. Irving Sax and Richard J. Lewis Sr., Van NOSTRAND, Reinhold N.Y. 1989.

[25] The title is *Carcinogenicity and Metal Ions*. It is volume 10 of a series called *Metal Ions in Biological Systems*, edited by Helmut Sigel. A university chemistry library should have this book. It has a fascinating chapter on the leukemias by two scientists from the Academy of Sciences of the USSR, E. L. Andronikashvili and L. Mosulishvili. Their brilliant work and discussion was largely responsible for my pursuit of the whole subject of cancer.

factor, but most of its other compounds are extremely toxic. In general, xenobiotic compounds (foreign) are to be avoided! Metal doesn't belong in our foods or in our bodies.

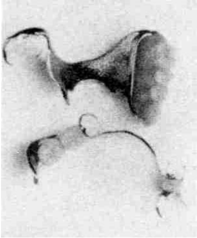

Fig. 62 More dental metal.

Dental Rewards

After your mouth is metal and infection-free, notice whether your sinus condition, ear-ringing, enlarged neck glands, headache, enlarged spleen, bloated condition, knee pain, foot pain, hip pain, dizziness, aching bones and joints improve.

Keep a small notebook to write down these improvements. It will show you which symptoms came originally from your teeth. Symptoms often come back! So go back to your dentist, to search for a hidden infection under one or more of your teeth, or where your teeth once were! That infection can be the cause of tinnitus, TMJ, arthritis, neck pain, loss of balance, and heart attacks!

Dentures can be beautiful. Of course, plastic isn't natural, but it is the best compromise that can be made to restore your mouth. At least it isn't positively charged like metals; it can't set up an electric current nor a magnetic field in your mouth, all of which may be harmful.

Do not be swayed by arguments that plastic is not as strong as metal. You see dentures everywhere and they seem strong enough to eat with. You will be told that “noble” metals like gold and platinum

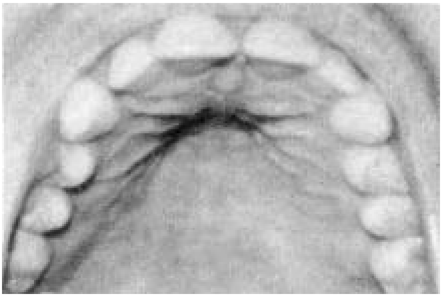

Fig. 63 Beautiful plastic mouth.

and silver are OK, that they are "inert" and do not corrode or seep. Nothing could be more untrue. You may be keeping them glossy by the constant polishing action of your toothpaste. But if you look at the underside, the view is frightful. **Everything tarnishes and everything seeps.** You wouldn't expect even a gold or silver coin that was dropped in a fountain 50 years ago to be intact. As metal corrodes your body absorbs it!

In breast cancer, especially, you find that metals from dentalware have dissolved and accumulated in the breast. They will leave the breast if you clear them out of your mouth (and diet, body, home). **The cysts shrink and are simply gone.** No need to do surgery!

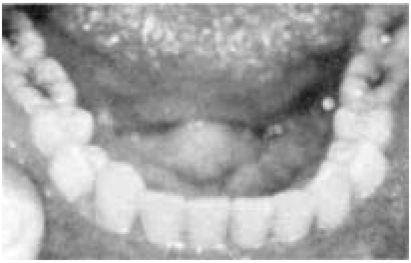

Fig. 64 Ugly metal in mouth.

Diet Clean-up

Breakfast

Cook your cereal from scratch. Don't eat cold cereal; it has numerous solvents and molds. Buy hot cereals that say "no salt added," like cream of wheat, steel cut oats or old fashioned oats,[26] millet, corn meal, cream of rice, or Wheatena. Cook it with milk to add nutritive value. Add your own (non-aluminum) salt and a pinch of vitamin C before cooking. Make granola from a recipe (see *Recipes*). Use honey, or brown sugar. Add raisins that were soaked for 5 minutes in vitamin C water. Use whipping cream or butter (both boiled) if you need to gain weight. Isn't this a delicious way to start your day! Add cinnamon to flavor, or frozen fruit and honey.

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[26] Rolled oats have 235 mcg nickel per serving of 4 ounces, picked up from the rollers, according to *Food Values* 14th ed. by Pennington and Church, 1985. I have only found nickel in the "one-minute" or "instant" variety of oats, however.

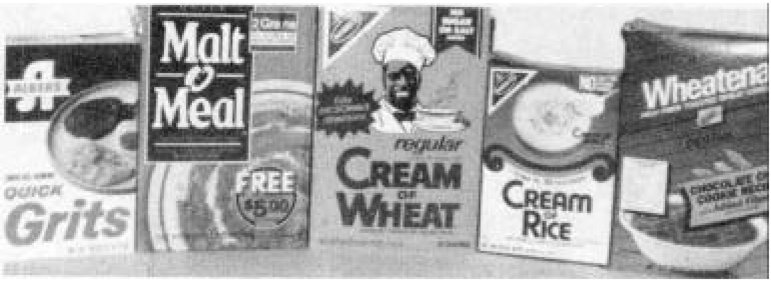

Fig. 65 Unpolluted breakfast cereals.

Or start your day with fried potatoes, an egg, and glass of milk. Don't worry about cholesterol since you will be doing liver cleanses anyway. (We have been told that eggs carry *Salmonella* bacteria. I found *Salmonellas* only on the outside shell and the egg carton—never inside! Could the researchers have accidentally transferred the bacteria from the shell to the inside while they were testing?)

The milk should be 2% or more butterfat because the calcium in milk cannot be absorbed without at least this much fat. Eat homemade yogurt and add honey or homemade preserves yourself. You need 3 cups of a milk product each day. Homemade buttermilk is fine. If you don't tolerate milk, and get diarrhea from it, try a milk digestant tablet to go with it. Start with only ¼ cup at a time. Do not choose chocolate milk. There is no substitute for milk; calcium tablets are not satisfactory. Vegetable matter, although high in calcium, does not give you *available* calcium either, unless you buy a juicer and make vegetable juice out of it. Eating fish can give you a lot of calcium, but it is in the tiny bones hidden in the fish. Don't try to remove them. Canned salmon has a lot of calcium; tuna does not. On a day that you eat fish, you would not need milk. Goat milk is probably better than cows' milk, but more difficult to get used to.

Lunch

Cook your food from scratch. Don't start with cans or packages or frozen items to make some recipe. In fact, don't bother with any fancy recipes. Just cook two or three vegetables for lunch and eat them with butter and salt or homemade sauces. Bread and milk rounds it out, plus fruit (not canned or frozen). Soup is a nice change. Cook it with all the vegetables you can find. Don't start with a can or packet or cube. Use a bit of onion and genuine herbs to give it zest. Thyme and fenugreek, together, make a flavorful combination you can purchase in capsules. Just pull apart and season.

If all this is too much work, make fresh vegetable juice once a week and freeze enough so that you can have a daily nutritious meal just by pouring a glass of it, together with bread and yogurt or milk.

Never diet during illness

This is a rule based on common sense. A weight-loss diet must wait at least two years.

Bake your own bread! I found aflatoxin in commercial bread after just four days in my bread box, but none in homemade bread even after two weeks! Aflatoxin is a most potent carcinogen and immunosuppressant. Aflatoxin is the toxin in your diet that keeps you from clearing propyl alcohol from your body (see 382)! Aflatoxin is a substance made by mold; bread starts to mold on the grocery store shelf. Don't buy plastic-wrapped bread. Don't ever salvage moldy food, whether it is fruit, breads or leftovers in the refrigerator. Throw them out. Buy a bread maker. It can do everything, including baking the bread. Use unbleached (unbrominated) flour and add ½ tsp. vitamin C powder per loaf to help retard mold further (it also makes the bread rise higher).

Supper

Cook your supper from scratch. Emphasize fish for animal food, not beef, pork, turkey or chicken. Don't buy bread crumbs, use your own. Don't buy batter, make your own. Use genuine eggs, not substitutes. Wash your hands after handling raw meat or eggs.

Make your own salad and salad dressing out of olive oil, fresh lemon juice or white distilled vinegar (apple cider vinegar has aflatoxins), honey, salt and herbs to flavor. If your digestion isn't strong enough for raw vegetables or fruit, make juice. Get a sturdy juicer and make your juice about half carrot juice and half from vegetables like celery, squash, lettuce, and broccoli. Make your own tomato sauce with pure herb seasoning, not from ajar or can (home canned foods are fine, of course, as long as they are not made in a big aluminum pot with aluminum-containing salt).

Cook real potatoes, not instant varieties. Peel them to get rid of Kojic acid (mycotoxin) and scopolamine (the green part). Make mashed potatoes from scratch, with milk, not box potatoes, nor chips nor French fries. Chips and fries were made in chemical grease called "hydrogenated." There is a large amount of nickel in hydrogenated fats.[27] Fry your potatoes in butter, lard or olive oil. Find butter that is not wrapped in foil and is not salted. Salt your own butter, using aluminum-free salt.[28] Don't wrap potatoes in foil to bake, coat with butter or olive oil. Don't eat the peels.

Eat no meat that hasn't been cooked as thoroughly as if it were pork.

Other animals are as parasitized as we, full of flukes and worms and *Schistosomes* in every imaginable stage, and if the blood carries these, would we not be eating live parasites if we eat animals in the raw state? We have been taught to cook thoroughly any pork, fish or seafood. Now we must cook thoroughly any beef, chicken or turkey. It must be at cooking temperature (212°F or 100°C) for 20 minutes. Freezing is not adequate. Canned meats are safe from living parasites, but are not recommended due to added chemicals.

Beverages

Drink 6 kinds of beverages:

- milk
- water
- fruit juices
- vegetable juices
- herb teas
- homemade (see *Recipes*)

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[27] 114 mcg/100 g. Taken from *Food Values* 14th ed. by Pennington and Church, 1985.

[28] Salt has aluminum in it to keep it from caking. Buy salt that has magnesium carbonate as its anti-caking agent. Sea salt must be baked for 5 minutes at 400°F to destroy molds. Or buy chemically pure salt (see *Sources*).

This means getting off caffeine. And if you are already fatigued, this means you might be even more fatigued for a short time. You might have headaches from withdrawal, too. But they will only last 10 days. Mark your calendar and count off the days. Take headache medicine, if necessary, but make sure it does not contain caffeine. For energy, to replace caffeine, take one arginine (500 mg, see *Sources*) upon rising in the morning and before lunch. Soon you won't need it.

Cutting down on coffee, decaf, soda pop and powdered drinks won't do. You must be completely off. They contain very toxic solvents due to careless, unregulated production methods. Much is imported and can't be sufficiently regulated.

Even though grain (drinking) alcohol is the recommended substitute for propyl alcohol, that doesn't mean you may safely drink it. It is inadvisable to drink any form of alcohol at least until you are fully recovered.

1. Milk: 2% or higher, drink three 8 oz. glasses a day. Alternate brands. Buttermilk will do. Homemade yogurt is fine. Goat milk is also fine. Start with ¼ cup and increase gradually, if you are not used to it. If you do not drink milk because it gives you more mucous, try to drink milk anyway. If you have other reactions, like diarrhea, try milk digestant tablets (available at health food stores). Milk is too valuable to avoid: there are many unwanted chemicals in most brands of milk, but it is solvent-free, mold-free and very nutritious. The only exception should be for serious symptoms, like swelling, colitis, flu, or chronic diarrhea.

But all milk, whether goat or cow, is contaminated with *Salmonella* and *Shigella* bacteria as well as fluke parasite stages. Cattle are immunized against *Salmonella* but it does not prevent its persistence in the bowel. All these are very harmful. Pasteurization does not kill all of them. Only heating to a rolling boil makes milk safe. To do this in the easiest way, pour 1 or 2 quarts milk into an enamel double boiler or microwavable glass jar. Stay in the kitchen while the heat is on. When the bubbles have risen to indicate boiling, turn off the heat. You may throw away the “skin”. Pour into glass jar and refrigerate. Another easy way is to use a pressure cooker that holds several pint jars of milk. All dairy products that have only been pasteurized are still contaminated. Ultrapasteurization does not improve matters. Dairy products that cannot be sterilized should not be consumed. It may be possible to find sterilized milk in paper containers on the store shelf—not in the refrigerator; if it wasn't sterile it would go foul in a day! Canned milk has solvent pollution. Powdered milk has both solvent and bacterial pollution.

2. Water: 2 pints. Drink one pint upon rising in the morning, the other pint in the afternoon sometime. The cold water faucet may be bringing you cadmium, copper or lead, but it is safer than purchased water, which inevitably has solvents in it. Let it run before using it. Filters are rather useless because water pollution comes in surges. A single surge of PCB contaminates your filter. All the water you use after this surge is now polluted, so you will be getting it chronically, whereas the unfiltered water cleans up again after the surge passes. Until you can test your own water for solvents, PCBs and metals, no expensive filter is worth the investment. An inexpensive pure carbon filter that is replaced every month may improve your tap water. Inflexible plastic pitchers fitted with a carbon filter pack are available (see *Sources*). Never buy filters with silver or other chemicals, even if they are just added to the carbon. Keep the filter sterile by soaking in diluted grain alcohol weekly.

3. Fruit juice: fresh squeezed only. Some stores make it while you wait. If they freeze some of it, you could purchase the frozen containers. Bottled fruit juices have traces of numerous solvents, as do the frozen concentrates, as do the refrigerated ones, don't buy them. You have to see it being made, but watch carefully: I recently went to a juice bar where they made everything fresh, before your very eyes. And I saw them take the fruit right from the refrigerator and spray it with a special wash "to get rid of any pesticides," then put a special detergent on it to clean off the wash! So instead of getting traces of pesticide, I got traces of propyl alcohol![29] Another grocery store had a machine that squeezed the oranges while you watched. But if you did not watch them filling the jugs, you missed seeing them add a tablespoon of concentrate, from a bottle out of sight, to give it better flavor. It still qualifies as "Fresh squeezed 100% orange juice," but thanks to that concentrate it now has toluene and xylene in it! Best of all, buy a juicer, select completely unbruised fruit, wash with plain water, and make your own juice (enough for a week—freeze it in half pint plastic bottles). For stronger flavor, leave some of the peel in the juice.

4. Vegetable juice: fresh or frozen only. If you or a friend would be willing to make fresh juice, this would be much better than purchased juice. Start with carrot juice. Peel carrots (don't scrape them, it's too easy to miss small dirt spots) and remove all blemishes carefully, then rinse. Drink ½ glass a day. After you are accustomed to this, add other vegetables and greens to the juice to make up half of it. Use celery, lettuce, cabbage, cucumber, beet, squash, tomato, everything raw that you normally have in your refrigerator. Then drink one glass a day.

5. Herb tea: fresh or bulk packaged. Tea bag varieties are moldy. Buy a non-metal (bamboo is common) tea strainer. Sweeten with honey or brown sugar with vitamin C added.

6. Homemade beverage. If you will miss your coffee or decaf, try just plain hot water with boiled whipping cream. Sweeten with honey. Please see *Recipes* for many more suggestions.

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[29] Yes, I took a sample of the wash to test.

Horrors In Commercial Beverages

Commercial beverages are especially toxic due to traces of solvents left over from the manufacturing process. There are solvents in decaffeinated beverages, herb tea blends (not single herb teas), carbonated drinks, beverages with Nutrasweet^{TM}, flavored coffee, diet and health mixes, and fruit juices, even when the label states "not from concentrate" or "fresh from the orchard," or "100% pure."

It is allowable to use solvents to clean machinery used in bottling (please look again at page 347)! It is also allowable to use solvents to make spice oleoresins, which are used as flavoring.

> **21 CFR 173.240 (4-1-94 Edition) Isopropyl Alcohol.**
>
> Isopropyl alcohol may be present in the following foods under the conditions specified:
>
> (a) In spice oleoresins as a residue from the extraction of spice, at a level not to exceed 50 parts per million.
> (b) In lemon oil as a residue in production of the oil, at a level not to exceed 6 parts per million.
> (c) [Discusses its use in hops extract.]

Here is a summary of other solvents mentioned:

Solvent	Allowable residue in spice oleoresins	Paragraph in 21 CFR
Acetone	30 PPM	173.210
Ethylene dichloride	30 PPM	173.230
Methyl alcohol	50 PPM	173.250
Methylene chloride	30 PPM	173.255
Hexane	25 PPM	173.270
Trichloroethylene	30 PPM	173.290

Fig. 66 Lawful uses of solvents in food.

I have found all these solvents and others in commercial beverages! Some of the solvents I have found are just too toxic to be believed! Yet you can build the test apparatus yourself (page 457), buy foods at your grocery store, and tabulate your own results. I hope you do, and I hope you find that the food in your area is cleaner than mine! Remember that the Syncrometer can only determine the presence or absence of something, not the concentration. There may only be a few parts per billion, but a sick person trying to get well cannot afford any solvent intake. For that matter, none of us should tolerate any of these:

- **Acetone** in carbonated drinks
- **Benzene** in store-bought drinking water (including distilled), store-bought fruit juice (including health varieties)
- **Carbon tetrachloride** in store-bought drinking water
- **Decane** in health foods and beverages
- **Hexanes** in decafs
- **Hexanedione** in flavored foods
- **Isophorone** in flavored foods
- **Methyl butyl ketone** and **Methyl ethyl ketone** in flavored foods
- **Methylene chloride** in fruit juice
- **Pentane** in decafs
- **Propyl alcohol** in bottled water, commercial fruit juices, commercial beverages.
- **Toluene** and **xylene** in carbonated drinks
- **Trichloroethane** (TCE), **TC Ethylene** in flavored foods
- **Wood alcohol** (methanol) in carbonated drinks, diet drinks, herb tea blends, store-bought water, infant formula

If you allowed a tiny drop of kerosene or carpet cleaning fluid to get into your pet's food every day, wouldn't you expect your pet to get sick? Why would you not expect to be sick with these solvents in your daily food? I imagine these solvents are just tiny amounts, introduced by sterilizing equipment, the manufacturing process, and adding flavor or color. Flavors and colors for food must be extracted somehow from the leaves or bark or beans from which they come. But until safe methods are invented, such food should be considered unsafe for human consumption (or pets or livestock!).

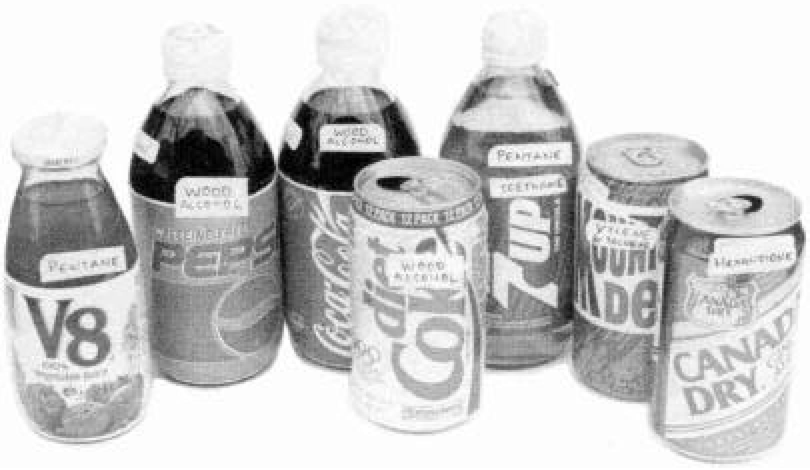
PENTANE
WOOD ALCOHOL
WOOD ALCOHOL
WOOD ALCOHOL
PENTANE
ISOPRENE
XYLENE
HEXANEDIONE
V8
PEPSI
Coca-Cola
diet Coke
7UP
CANADA DRY

Fig. 67 Some unsafe beverages.

Food Preparation

Cook your food in glass, enamel, ceramic or microwavable pots and pans. Throw away all metal ware, foil wrap, and metal-capped salt shakers since you will never use them again. If you don't plan to fry much (only once a week), you might keep the Teflon^{TM} or Silverstone^{TM} coated fry-pan, otherwise get an enamel coated metal pan. Stir and serve food with wood or plastic, not metal utensils. If you have recurring urinary tract infections, you should reduce your metal contact even further; eat with plastic cutlery. Sturdy decorative plastic ware can be found in hardware and camping stores. Don't drink out of styrofoam cups (styrene is toxic). Don't eat toast (many toasters spit tungsten all over your bread and make benzopyrenes besides). Don't buy things made with baking powder (it has aluminum) or baked in aluminum pans. Choose goods made with baking soda and sold in paper or microwavable pans. Don't run your drinking water through the freezer or fountain or refrigerator. Don't heat your water in a coffee maker or tea kettle. Don't use a plastic thermos jug (the plastic liner has lanthanides) the inside must be glass. Don't drink from a personal water bottle (it begins to breed bacteria) unless you sterilize it daily.

Why are we still using stainless steel cookware when it contains 18% chromium and 8% nickel? Because it is rustproof and shiny and we can't see any deterioration. **But all metal seeps!** Throw those metal pots away. Get your essential minerals from foods, not cookware.

Never, never drink or cook with the water from your hot water faucet. If you have an electric hot water heater the heating element releases metal. Even if you have a gas hot water heater, the heated water leaches metals or glues from your pipes. If your kitchen tap is the single lever type, make sure it is fully on cold for cooking. Teach children this rule.

Food Guidelines

It is impossible to remember everything about every food, but in general do not buy foods that are highly processed. Here are a few foods; see if you can guess whether they should be in your diet or not.

breads	Yes, but only from a bakery, and never wrapped in plastic.
toast	No. It has benzopyrene and tungsten. Yes, if made on a cookie sheet or in a frying pan.
cheese	Yes, if used in baked dishes.
chicken	Only if cooked for 20 minutes at boiling point, as in soup, or canned (never prepare raw chicken yourself).
wine with dinner	No.

peanut butter	Yes if you grind it yourself and add ¼ tsp. vitamin C powder as you grind.
cottage cheese	No, it can't be sterilized easily.
desserts	Yes, but again, only if flavored with safe extracts.
rice	Yes, if vitamin C is added before cooking. Use white only, brown is too moldy.
pasta	Yes, with homemade sauce and vitamin C.
Jell-O™	No, it has artificial flavor and color.
egg dishes	Yes, but not “imitation”, cholesterol-free or cholesterol-reduced varieties.
fish, seafood	Yes!
soy foods (tofu)	No. It's the extensive processing that taints it.
soup	Yes, if seasoned only with herbs (no bouillon cube).
sugar	Yes, turbinado or brown if treated with vitamin C.
herb tea	Yes, if not in a bag and not in a mixture of herbs.
cheesecake	Yes.

Fig. 68 Some good foods.

Choose brands with the shortest list of ingredients. Alternate brands every time you shop.

Fig. 69 All breads I tested had mold if they were in plastic.

Dining Out

Restaurants (excluding fast food) are generally quite safe to eat at. Here are some do's and don'ts;

Do carry your own aluminum-free salt and vitamin C powder with you.

Do ask for plastic cutlery.

Do drink the water if from the tap.

Do ask for boiled, not just steamed, milk.

Don't eat or drink from styrofoam. If getting food "to go," get it in clear plastic containers, or ask them to line the styrofoam container with paper or plastic wrap, and line the styrofoam cup with a plastic baggy.

Don't use their ketchup and condiments (they have been standing out too long).

Here is a list of things that are generally safe to order:

pancakes, French toast, waffles	Don't use their imitation syrup (has benzoate), use honey instead.
eggs	Any style except soft boiled and scrambled. The white should be solid.
hash browns	If lightly fried, not deep fried.
soup	Only if nothing else is available. (It probably came in a can and was cooked in an aluminum pot and is full of aluminized salt.)
vegetarian sandwiches	But no soy products (too processed).
baked or boiled potatoes	Use only cheese sauce, bring your own salt, don't eat the skin.
cooked vegetables	Broccoli, Brussels sprouts, beets, corn, squash, and so forth.
vegetable salads	Don't eat the croutons, bacon bits, and anything that doesn't look fresh.
vegetarian dishes	But no soy ingredients and or sauces. Fresh ketchup OK.
bread and biscuits	White only, not toasted, not “cholesterol-free” varieties.
fish and seafood	Anything but deep fried (the oil may have benzene) is fine: baked, steamed, fish cakes, seafood cocktails, etc.
Mexican food	Any of the numerous baked dishes.
Chinese food	Except dishes with tofu or MSG.
fruit cup	With honey and cinnamon.
fruit pies, cobblers	But not with ice cream (every flavor has benzene).
lemon or lime meringue pie	Indulge yourself.

Fig. 70 Good restaurant foods.

As you see your symptoms disappear, one after another, you will feel the magic of healing. Many sick persons have 50 or more symptoms to start out! They could fill two sheets of paper, one symptom to each line. It can be quite shocking to see a list of all your symptoms.

Sometimes a new symptom appears as fast as an old one disappears. The coincidence makes it tempting to believe that one symptom turns into a different one. But it is not so. If a new symptom appears, it is because another pathogen has become activated due to a new toxin. Try to identify the new item. Stop using any new food, supplement, or body product, even if it is a health variety, and see if it goes away.

Body Clean-up

We are living in a very fortunate time. We are not expected to all look alike! The 60's brought us this wonderful freedom. Freedom to dress in a variety of styles, use make-up or no make-up, jewelry or no jewelry, any kind of hair style, any kind of shoes.

You will need to go off every cosmetic and body product that you are now using. Not a single one can be continued. They are full of titanium, zirconium, benzalkonium, bismuth, antimony[30], barium[31], strontium[32], aluminum, tin, chromium, not to mention pollution solvents such as benzene and PCBs.

Do not use any commercial salves, ointments, lotions, colognes, perfumes, massage oils, deodorant, mouthwash, toothpaste, even when touted as "herbal" and health-food-type. See *Recipes* for homemade substitutes.

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[30] Breast cancer cases show titanium, zirconium, benzalkonium, bismuth and antimony accumulation in the breast.

[31] Barium is described in the *Merck Index* as "Caution: All water or acid soluble barium compounds are POISONOUS." 10th ed. p. 139 1983.

[32] This element goes to bones.

People are trying desperately to use less toxic products. They seek health for themselves. So they reach for products that just list herbs and other natural ingredients. Unfortunately, the buyers are being duped. The Food and Drug Administration (FDA) requires all body products to have sufficient antiseptic in them. Some of these antiseptics are substances you must avoid! But you won't see them on the label because manufacturers prefer to use quantities below the levels they must disclose. And by using a variety of antiseptics in these small amounts they can still meet sterility requirements. The only ingredient you might see is "grapefruit seed" or similar healthy-sounding natural antiseptic. This is sad for the consumer of health food varieties.

- I have seen rocks sold as "Aluminum-Free Natural Deodorant". You rub the rock under your arms. It works because the rock is made of magnesium-aluminum-silicate.
- Men's hair color has lead in it.
- Lipstick has barium, aluminum, titanium.
- Eye pencil and shadow have chromium.
- Toothpaste has benzene, tin, and strontium.
- Hair spray has propyl alcohol and PCBs. BEWARE! Stop using it today.
- Shampoo, even health varieties, has propyl alcohol! BEWARE! Stop using it today.
- Cigarettes have lead, mercury, nickel and *Tobacco Mosaic virus*.
- Chewing tobacco has ytterbium

Some of the unnatural chemicals listed are present because of residues in the manufacturing process, but others you will actually see listed on the label!

Propyl alcohol and wood alcohol are present because the tubing used to fill the bottles is sterilized and cleaned with them. Ice cream machines are "oiled" with a gel containing petroleum products. This could explain why I always find benzene in ice cream.

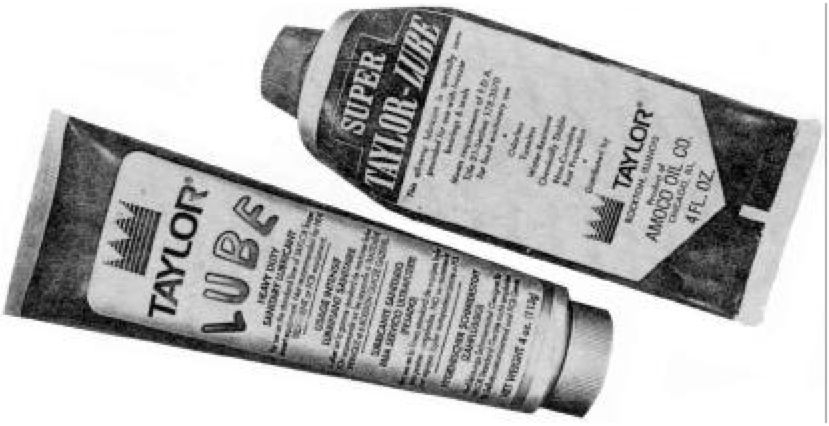

Fig. 71 Examples of commercial "food lube."

How can propyl alcohol in shampoo get into your body in significant amounts? The skin is more absorbent than we realize, and time and time again I see cancer victims who have gone off every body product except their favorite shampoo. They harbor propyl alcohol until they make that final sacrifice. It is better to switch shampoos than to not need any due to radiation and chemotherapy!

See *Recipes* for easy-to-make, natural cosmetics. But you might consider just stopping them all. Especially if you're going on vacation.

Use nothing that you wouldn't use on a new-born baby. This is a permissive age. You will be the only one feeling "naked." Others won't even notice. Don't forget advertising is aimed at you, even if other people's eyes are not!

Don't even use soap unless it is homemade soap (see *Recipes*) or borax straight from the box. Borax was the traditional pioneer soap. It is antibacterial and can be made into a solution. It is also a water softener and is the main ingredient in non-chlorine bleach. Borax can remove grease, too, and some stains.

But even borax is not natural to your body and it is therefore wise to use as little as necessary. See *Recipes* for anti-bacterial borax soap.

Dishes and clothing are primary source of PCBs.

Fig. 72 Detergents with PCBs.

MULE 20 TEAM
BORAX
100 YEARS

homemade soap pure borax

Fig. 73 Safe soaps.

Don't use toothpaste, not even health-food varieties. To clean teeth, use plain water or chemically pure baking soda (see *Sources*)—but dissolve it in water first, otherwise it is too abrasive. Or brush with hydrogen peroxide food grade, not the regular variety (see *Sources*). Don't use floss; use 2 or 4-pound monofilament fish line. Floss has mercury antiseptics (with thallium pollution!). Throw away your old toothbrush—solvents don't wash away.

Don't use mouthwash. Use saltwater (aluminum-free salt) or food grade hydrogen peroxide (a few drops in water).

Don't use hair spray.

Don't use massage oils of any kind. Use olive oil.

Don't use bath oil. Take showers, not baths, if you are strong enough to stand. Showers are cleaner.

Don't use perfumes or colognes.

Don't use commercial lotions or personal lubricants.

Stop Using Supplements

Stop using your vitamin supplements. They, too, are heavily polluted. This is the saddest, most tragic part of your instructions. I have found solvents, heavy metals and lanthanides in 90% or more of the popular vitamin and mineral capsules and tablets I test. These substances will do more harm in the long run than the supplement can make up for in benefits.

CALCIUM
OS-CAL
Psyllium
Husk Powder
Tryptophane
Exta-Cal
now
SILYMARIN

The capsule in the foreground is a notorious tryptophane capsule. It had the following pollutants: PCBs, mercury, ruthenium, thulium, strontium, praseodymium, aluminum, benzalkonium.

Fig. 74 Some polluted supplements.

Most of the varieties of vitamin C that I have tested are polluted with thulium! Until all vitamins and minerals and other food supplements have been analyzed for pollutants, after they are encapsulated or tableted, they are not safe. We need more disclosure on our products. No manufactured product is pure. We can't expect that. But at least we should be able to tell what impurities we are getting, and how much.

It is possible to do detailed analysis of foods or products at a reasonable price. Look at the bottle of common table salt, sodium chloride, that is used by beginning chemistry students to do experiments. It must be thoroughly analyzed for them because minute impurities affect their results. (Those minute impurities, like lead, affect you, too.) Look at the label on the bottle in the picture. Even after all these tests, the cost of laboratory salt is only $2.80 per pound.[33]

S-271
Certified A.C.S.
Sodium
Chloride
Fisher Scientific Company

Fig. 75 Pure salt.

It is most important not to be fooled by ingredient claims, like “made from organically grown vegetables”. Sure that's great, but the analysis *I* trust would be done on the final, cleaned, cooked and packaged product on the shelf. The package is a major unlisted ingredient.

Toxic solvents like decane, hexane, carbon tetrachloride and benzene will get more flavor or fat or cholesterol out of things than metabolizable grain alcohol. Of course, the extraction process calls for washing out the solvent later. But it can't all be washed out, and a detailed analysis on the final product would give the public the information they need to make informed choices.

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[33] You will pay about $8.00 per pound (Spectrum Chemical Co.) for USP (United States Pharmaceutical) grade. But the same analysis is done on the cheaper grades, and my point is that the analysis is cost effective enough that it should be done on our daily foods.

All supplements must be tested for purity by yourself. If this cannot be done, don't take them.

Polluted supplements do much more harm than good. Get your super-nutrition by juicing vegetables of all kinds and making herbal teas.

Safe Supplements

There are, no doubt, lots of safe supplements to be had. The problem is knowing which they are. The nature of pollution is such that one bottle might be safe, while another of the same brand is not. In view of this, as I found a polluted bottle, I stopped using any more of that brand. That is why I am reduced to recommending only the ones in the *Sources* at this time.

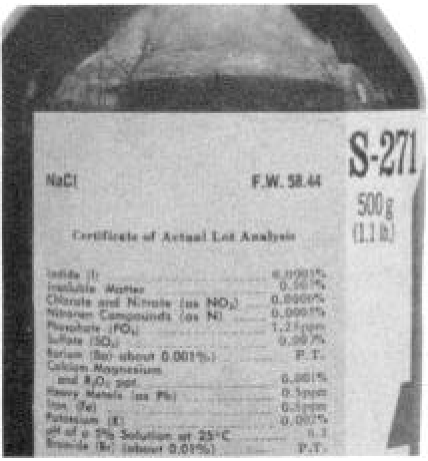

Common salt for student use is thoroughly analyzed for pollution. The label gives you the final "Actual Lot Analysis" of the product. It is not expensive.

Fig. 76 Laboratory salt label.

Vitamin C, in crystal form, is a must in your lifestyle. It helps the liver, and possibly other organs, detoxify things. It also helps retard mold, and perhaps even destroys aflatoxins! Keep some next to your refrigerator so it is handy when you put away groceries. Add 1/8 tsp. to maple syrup, vinegar, cooked cereal, fruit juice, leftovers. Have ¼ tsp. (1 gram) with each meal.

Vitamin B_2, 100 mg. This is the vitamin that helps detoxify benzene! Take one to three a day. While recovering from AIDS you need 3 tablets three times a day.

Vitamin B_6, 250 mg, and B-complex, 50 mg. Undoubtedly these help the liver and kidneys in many ways. One a day.

Magnesium oxide, 300 mg., is another must. Take one or two a day. It is a major mineral; all of our cells need lots of it. Only leafy vegetables provide it.

Hydrogen peroxide, food grade. It is advantageous to kill bacteria and viruses to some extent every day. Hydrogen peroxide lets you do this. It should never come in contact with metal, including its container or metal tooth fillings. If you get a few drops on your skin it may turn white and sting, but does no harm, so simply wash it off. Instructions for its use come with the product.

Herbs. These are excellent supplements, both in bulk and capsules, but not extracts, concentrates, or concoctions. There are many books that describe their uses.

Thioctic acid or lipoic acid. Presumably this chelates (traps and prepares for elimination) heavy metals, and helps the liver in detoxifying obscure and deadly poisons. Everyone would benefit from 100 mg. per day. I find it outstanding, and give it to many ill persons, even when not mentioned in the case histories. It comes as a 100 mg. capsule (see *Sources*). I use it at doses from one capsule, 3 times a day, to 2 capsules, 5 times a day. I have seen no side effects at these dosages, even in very sick persons.

Lugol's Iodine Solution (see *Recipes*) is old-fashioned "iodine." Iodine has a distinctive trait: it hangs up on anything and everything. In fact, it attaches itself so quickly we consider everything it touches as "stained." This is just the property we want to make it safe for use. The amount you use is immediately hung up, or attached, to your mucous and can not be quickly absorbed into the blood or other organs. It stays in the stomach. And for this reason it is so useful for killing vicious bacteria like *Salmonella*.

Do not take Lugol's iodine if you know you are allergic to iodine. It could be fatal.

Six drops of Lugol's solution can end it all for *Salmonella*. If you have gas and bloating, pour yourself ½glass of water. Add 6 drops of Lugol's (not more, not less), stir with wood or plastic, and drink all at once. The action is noticeable in an hour. Take this dose 4 times a day, after meals and at bedtime, for 3 days in a row, then as needed. This eradicates even a stubborn case of *Salmonella*.

Notice how calming 6 drops of Lugol's can be, soothing a manic stage and bringing a peaceful state where anxiety ruled before.

Lugol's is perfectly safe (if not allergic) to take day after day, when needed, because of its peculiar attaching property. It arrives in the stomach, reattaches to everything in proximity. Doomed are all *Salmonellas*; doomed also are eggs of parasites that might be in the stomach (cysts).

Naturally, one would not leave such medicine within the reach of children. Also, one would not use anything medicinal, including Lugol's unless there were a need, like cancer, AIDS, or bowel disease. When the gas and bloating problem has stopped, stop using Lugol's. If one or two doses of Lugol's cures the problem, stop. Store it in a perfectly secure place. In the past, 2/3 of a teaspoon (60 drops) of Lugol's was the standard dose of iodine given to persons with thyroid disease. Six drops is small by comparison.

Turmeric and **fennel** are herbs also used as cooking spices. They can eradicate invasive *E. coli* and *Shigella* bacteria! They are completely harmless, and are part of the Bowel Program.

Other supplements. The concept of supplementing the diet is excellent, but the pollution problem makes it prohibitive. Use only supplements and brands recommended in *Sources*, although the best approach is to test them yourself with your Syncrometer. I can't guarantee the brands in *Sources* will stay pure. If in doubt, leave it out.

Home Clean-up

This is the easiest task because it mostly involves throwing things out. Hopefully your family and friends will jump to your assistance.

- The basement gets cleaned.
- The garage gets cleaned.
- Every room in the house gets cleaned.

Your Basement

To clean your basement, remove all paint, varnish, thinners, brush cleaners, and related supplies. Remove all cleaners such as carpet cleaner, leather cleaner, rust remover. Remove all chemicals that are in cans, bottles or buckets.

You may keep your laundry supplies: borax, washing soda, white distilled vinegar, bleach and homemade soap. You may keep canned goods, tools, items that are not chemicals. You may move your chemicals into your garage. Also move any car tires and automotive supplies like waxes, oil, transmission fluid, and the spare gas can (even if it is empty) into your garage or discard them.

Seal cracks in the basement and around pipes where they come through the wall with black plastic roofing cement. In a few days it will be hard enough to caulk with a prettier color. Spread a sheet of plastic over the sewer or sump pump.

Your Garage

Do you have a garage that is a separate building from your home? This is the best arrangement. You can move all the basement chemicals into this garage. Things that will freeze, such as latex paint, you may as well discard. But if your garage is attached, you have a problem. Never, never use your door between the garage and house. Walk around the outside. Don't allow this door to be used. Tack a sheet of plastic over it to slow down the rate of fume entrance into the house. Your house acts like a chimney for the garage. Your house is taller and warmer than the garage so garage-air is pulled in and up as the warm air in the house rises. See the drawing.

In medieval days, the barn for the animals was attached to the house. We think such an arrangement with its penetrating odors is unsavory. But what of the gasoline and motor fumes we are getting now due to parked vehicles? These are toxic besides! This is even more medieval.

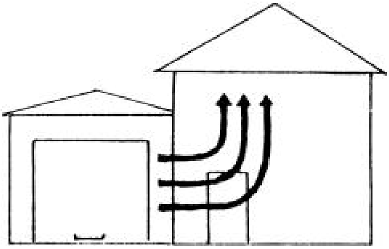

Fig. 77 Garage fumes.

If your garage is under your house, you cannot keep the pollution from entering your home. In this case, leave the cars and lawnmower outside. Remove cans of gasoline, solvents, etc. Put up a separate shed for these items.

Special Clean-up for Freon (CFCs)

Because I consider Freon to be the top health hazard in our home, I recommend turning in your refrigerator for a non-CFC variety. Dispose of all spare units. Remove window air conditioners or test the dust in your home (page 485) for Freon. Have your car's air conditioning system checked. Dispose of old pressurized cans. Even one whiff is too much. It never leaves the body because the body has no detoxification methods for it!

Only one useful reaction with Freon comes to mind. Freon is thought to be responsible for the ozone "hole" at the South Pole. Would Freon react with ozone supplied to your body and thereby become biodegradable? Indeed, it does! But only if you drink it as ozonated water. Other ozone routes, as intravenous or rectal, have not been observed to be as effective.

If you are following your progress with the Syncrometer, you will see that Freon now appears in the liver for the first time. (Before this, it was marooned in the parathyroids, thymus, and other organs.) You may also detect a feeling like indigestion. You must come to the assistance of your liver. Even ozonated Freon is extremely burdensome to the liver.

A combination of herbs (Liver Herb Drink in *Recipes,* page 552) rescues the liver from its plight, and prevents the indigestion. After drinking liver herbs you will see that the Freon now appears in the kidneys. Yet it is marooned there unless you assist them. Take the kidney cleanse to assist the kidneys so they can finally excrete the Freon into the urine.

It's an elaborate detoxifying program and usually takes six to eight weeks to get most of the Freon out. Afterward, continue the programs at one fourth dosage for half a year.

Forane is one of the new refrigerants. Although toxic, at least I observe it in the liver directly, suggesting that your body is capable of handling it. Remember your new refrigerator will still be using a toxic coolant, and it would be best to keep it outside or at least vented to the outside.

Special Clean-up for Fiberglass

Fiberglass insulation has microscopically small bits of glass that are free to blow into the air. When house drafts pull it into the air you will inhale them. They cut their way through your lungs and organs like millions of tiny knives, spreading through your body, since there is no way out for them. You smell nothing and feel nothing. This makes it a very sinister poison. Your body, though, recognizes these sharp, pointed bits and tries to stop their spread by sequestering them in cysts.

Most solid malignant tumors contain fiberglass or asbestos, another glass-like particle. In nearly all cases a hole can be found in the ceiling or walls, leading to fiberglass insulated parts of the house. When these holes are sealed in an air-tight manner the house air no longer is positive for fiberglass. Covering with paneling is not sufficient. Check your dwelling for uncovered fiberglass. Repair immediately. Search for small screw holes intended for pictures, or electric outlet plates that are missing.

Also remove fiberglass jackets from water heater and fiberglass filter from furnace. Replace with foam or carbon. Best of all, hire a crew to remove it all from your home, and replace insulation with blown-in shredded paper or other innocuous substance.

Never build a new house using fiberglass for any purpose.

Special Clean-up for Asbestos

The biggest source of asbestos is not building materials! It is the clothes dryer belt and hair dryer! To be safe, remove the belt from your dryer and check to see if it says “Made in USA” on the belt itself. If so, it is OK. If not, it is imported, and probably contains asbestos. Exchange it for a USA belt (see *Sources*).

Hair dryers, too, may be imported and shed asbestos. It is especially hazardous to be aiming a stream of hot asbestos right at your face! If you can't find a safe model (see *Sources*), or are unsure, don't use any. If you have cancer or are ill, no one in the house should use an unsafe hair dryer.

Turn off radiators and electric heaters and cover them with big plastic garbage bags, or paint them, or remove them. They give off asbestos if their paint is old.

Your House

To clean the house, start with the bedroom. Remove everything that has any smell to it whatever: candles, potpourri, soaps, mending glue, cleaners, repair chemicals, felt markers, colognes, perfumes, and especially plug-in air "fresheners". Store them in the garage, not the basement. Since all vapor rises, they would come back up if you put them in a downstairs garage or basement.

Do not sleep in a bedroom that is paneled or has wallpaper. They give off arsenic and formaldehyde. Either remove them or move your bed to a different room. Leave the house while this is being done. If other rooms have paneling or wallpaper, close their doors and spend no time in them.

Next clean the kitchen. Take all cans and bottles of chemicals out from under the sink or in a closet. Remove them to the garage. Keep only the borax, washing soda, white distilled vinegar and homemade soap. Use these for all purposes. For exact amounts to use for dishwasher, dishes, windows, dusting, see *Recipes*. Remove all cans, bottles, roach and ant killer, moth balls, and chemicals that kill insects or mice. These should not be stored anywhere. They should be thrown out. Remember to check the crawl space, attic and closets for hidden poisons also.

To keep out mice, walk all around your house, stuffing holes and cracks with steel wool. Use old-fashioned mouse traps. For cockroaches and other insects (except ants) sprinkle handfuls of boric acid[34] (not borax) under your shelf paper, behind sink, stove, refrigerator, under carpets, etc. Use vinegar on your kitchen wipe-up cloth to leave a residue that keeps out ants. Do this regularly. To wax the floor, get the wax from the garage and put it back there. A sick person should not be in the house while house cleaning or floor waxing is being done.

Remove all cans and bottles of "stuff" from the bathroom. The chlorine bleach is stored in the garage. Someone else can bring it in to clean the toilet (only). Leave only the borax soap, homemade soap, and grain alcohol antiseptic. Toilet paper and tissues should be unfragranced, uncolored. All colognes, after shave, anything you can smell must be removed. Family members should buy unfragranced products. They should smoke outdoors, blow-dry their hair outdoors or in the garage, use nail polish and polish remover outdoors or in the garage.

Do not keep new foam furniture in the house. If it is less than one year old, move it into the garage until you are well. It gives off formaldehyde. So does new clothing; it is in the sizing. Wash all new clothes before wearing. If you have a respiratory illness, move all the clothes in the clothes closet out of your bedroom to a different closet.

Do not use the hot water from an electric hot water heater for cooking or drinking. It has tungsten. Do not drink water that sits in glazed crock ware (the glaze seeps toxic elements like cadmium) like some water dispensers have. Do not buy water from your health food store that runs through a long plastic hose from their bulk tank (I always see cesium picked up from flexible clear plastic). Also ask them how and when they clean their tank. Best is to observe that it is done with non-toxic methods.

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[34] Boric acid is available by the pound from farm supply stores and from Now Foods. Because it looks like sugar keep it in the garage to prevent accidental poisoning.

If your house is more than 10 years old, change all the galvanized pipe to PVC plastic. Although PVC is a toxic substance, amazingly, the water is free of PVC in three weeks! If your house has copper pipes don't wait for cancer or schizophrenia to claim a family member. Change all the copper pipe to PVC plastic immediately. If the pipes are not accessible, ask a plumber to lay an extra line, outside the walls. This is less expensive, too.

If you have a water softener, by-pass it immediately and replace the metal pipe on the user side of the softener tank. Softener salts are polluted with strontium and chromate; they are also full of aluminum. The salts corrode the pipes so the pipes begin to seep cadmium into the water. After changing your pipes to plastic, there will be so little iron and hardness left, you may not need a softener. If the water comes from a well, consider changing the well-pipe to PVC to get rid of iron. While the well is open, have the pump checked for PCBs. Call the Health Department to arrange the testing. If you must have softening after all this, check into the new magnetic varieties of water softener (although they only work well when used with plastic plumbing).

The cleanest heat is electric. Go total electric if possible. If you must stay with gas, have a furnace repair person check your furnace and look for gas leaks before the heating season starts. Don't call the gas company even though it is free. The gas company misses 4 out of 5 leaks! The Health Department does not miss any; call them! House builders and contractors are also reliable in their gas leak detection.

Unnatural Chemicals

And where I found them...

ARSENIC

in ant & roach hives,
grains of pesticide

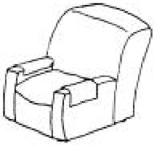

in carpet & furniture "treated"
for stain resistance

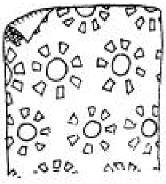

in wallpaper

BARIUM

MOLYBDENUM

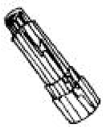

in lipstick

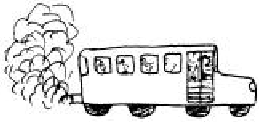

in bus exhaust

in "molys"

COBALT

in laundry
detergent

in dishwater
detergent

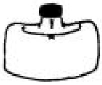

in skin bracer

in mouthwash

ANTIMONY

CADMIUM and COPPER

TITANIUM

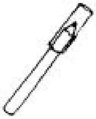

in eye liner

in water running
through old metal pipes

in face powder &
other powders, and
in metal dental ware

PCB's

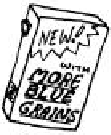
NEW!
WITH
MORE
BLUE
GRAINS

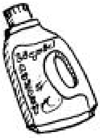

in regular and
health store detergents

LEAD

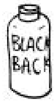

in men's hair
color restorer

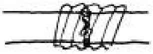

in solder at joints
of copper pipes

CHROMIUM

in eyebrow
pencil

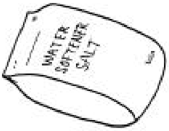
WATER
SOFTENER
SALT

in water
softener salts

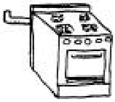

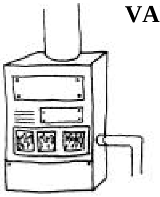

HOT
WATER
HEATER

in leaks in pipes to gas
stove, furnace, water heater

VANADIUM

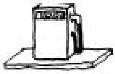

in diesel fuel

in candles
(even when
they're not
burning)

NICKEL

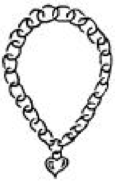

in metal jewelry
worn on the skin

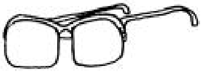

in metal glasses frames

in metal
watch bands

in metal tooth fillings
and retainers

FIBERGLASS

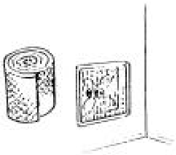

from insulation behind holes in ceiling or uncovered
outlets, water heater jackets, stuffed around fans
and air conditioners, insulation

CFC's (FREON)

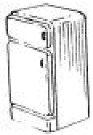

in
refrigerators

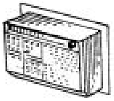

in air
conditioners

in spray
cans

MERCURY and THALLIUM

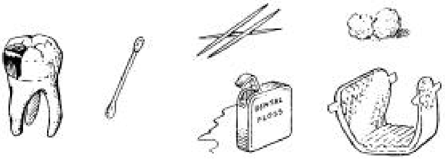
DENTAL FLOSS

in tooth fillings, sanitary napkins,
cotton balls, dental floss,
toothpicks, cotton swabs

THULIUM

SUPER SUPERIOR VIT. C
MIX a drink with VIT. C

in most brands of
vitamin C I tested

DYSPROSIUM and LUTETIUM

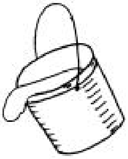

in paint, varnish,
shellac

HOLMIUM

in hand cleaners

HAFNIUM

in nail polish
& hair spray

RHENIUM

in spray starch

BISMUTH

Cologne for MEN
BISM STOMACH RELIEF

in cologne and
stomach aids

CESIUM

CLEAR SPRING water

in clear-as-glass
plastic

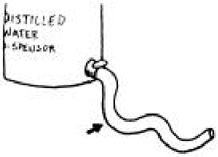
DISTILLED WATER DISPENSOR

after running through
long plastic hose

TIN and STRONTIUM

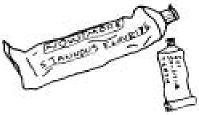

in toothpaste

YTTERBIUM, ERBIUM, TERBIUM

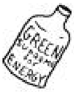
GREEN
ENERGY

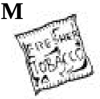
FRESHER
TOBACCO

in foil
packaging

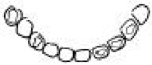

in plastic
tooth fillings

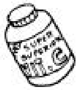

in vitamins
and supplements

PRASEODYMIUM, NIOBIUM, NEODYMIUM, YTTRIUM

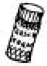

in over the
counter drugs

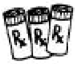

in prescription drugs

RADON, URANIUM, THORIUM

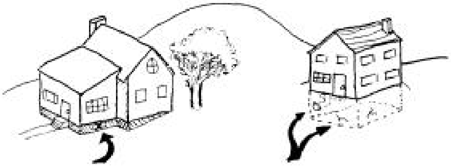

in crawlspace
without open vents

in holes and
cracks in basement

LANTHANUM

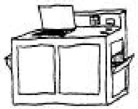

in duplicator
and copier ink

BENZALKONIUM and ZIRCONIUM

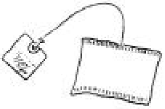

in tea bags

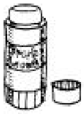

in deodorant

STANNOUS FLUORIDE

in toothpaste

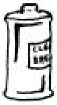

in mouthwash

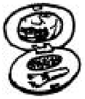

in cosmetics

ALUMINUM

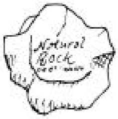
Natural
Rock

in "natural"
deodorant
advertised as
aluminum-free

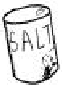

in salt

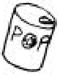

in cans

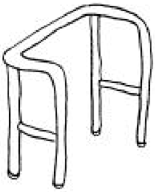

in walkers for
the elderly

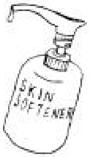
SKIN
SOFTENER

in lotions

TUNGSTEN

ELECTRIC
HOT
WATER
HEATER

corroded rod in
electric water heaters

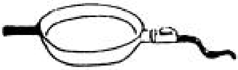

in electric
frying pans

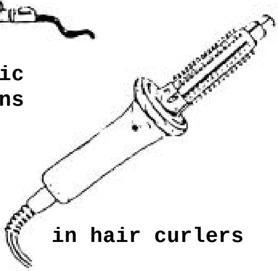

in hair curlers

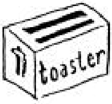

in toasters

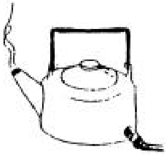

in tea kettles

BERYLLIUM

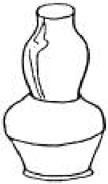

in hurricane
lamps

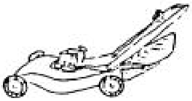

in lawn mowers

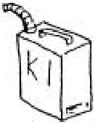

in kerosene

FORMALDEHYDE

in foam
mattresses

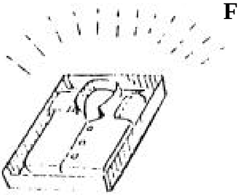

in new
clothing

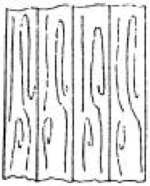

in paneling

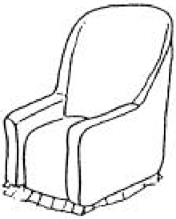

in foam chairs

ASBESTOS

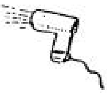

in hair blowers

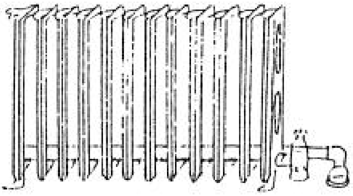

in radiator paint

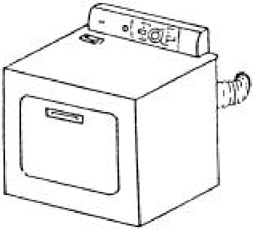

in clothes dryer belts

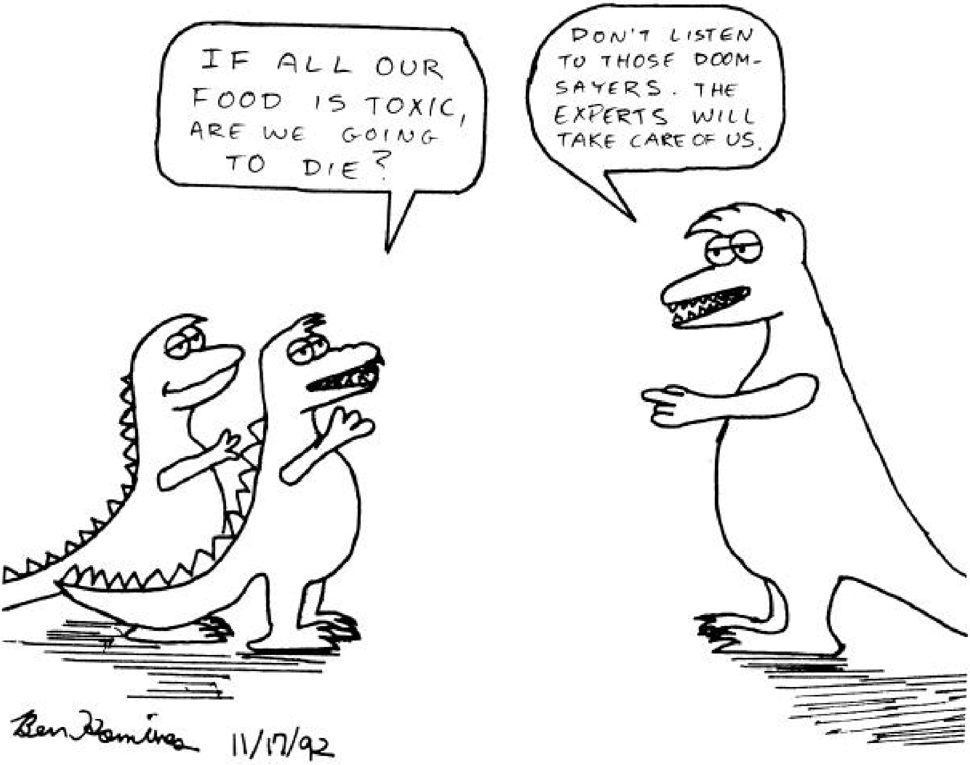
IF ALL OUR FOOD IS TOXIC, ARE WE GOING TO DIE?
DON'T LISTEN TO THOSE DOOM-SAYERS. THE EXPERTS WILL TAKE CARE OF US.
Ben Hamirea 11/17/92

Fig. 78 Our future, unless we act.

Bioelectronics

The most important electronic device to make or buy is a **zapper**—a compact pulse generator operating from a common 9 volt battery whose output is about 30 KHz. It kills all parasites, bacteria, viruses, molds, and fungi even though their individual resonant frequencies are either higher or lower (50 KHz to 900 KHz). Building a zapper is described in an earlier chapter.

The next most useful device to have is a **Syncrometer.™** It lets you diagnose yourself and monitor your progress until you are cured. It consists of an audio oscillator circuit with your body as part of the circuit. Utilizing samples of parasites or pollutants, it lets you test for them in any product or body tissue. I include a design that you can make yourself.

A third very useful device is a **frequency generator**. You can use it to electrocute individual organisms, or together with the Syncrometer™ to find an organism's particular frequency. You need one that operates in the parasite, bacteria and virus ranges, from 50 KHz to 900 KHz. It must also be able to select a particular frequency, like 434 KHz, quickly and accurately. Frequency generators are available for as little as $300.00, but it is worth paying a little more to get a digital display of the frequency.

Making A Syncrometer

This is an *audio oscillator* circuit in which you include yourself by means of a handhold. You listen to the current in your circuit with a loudspeaker. Other oscillator circuits will work, too. A lot of fascinating opportunities present themselves with this concept.

I have previously published three ways to build the Syncrometer circuit.[35] Here is the circuit diagram:

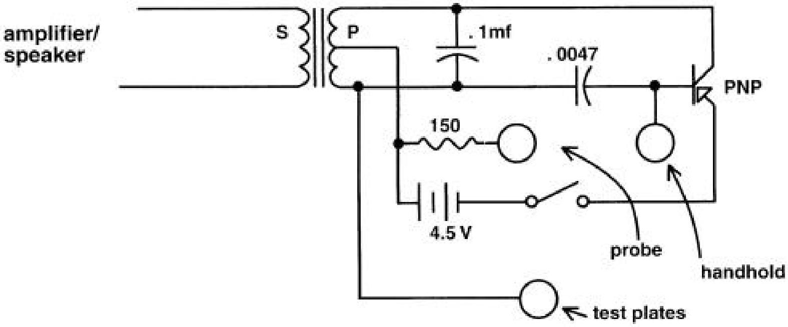
amplifier/
speaker
S
P
. 1mf
. 0047
PNP
150
4.5 V
probe
handhold
test plates

4700pf moly cap
.1 mfd 16v cap
2N2907 PNP
min output transf 8-900Ù
150 .25w res
3 AA batteries
speaker (like Radio Shack 277-1008C)

Fig. 79 Syncrometer schematic.

If you are not an electronics enthusiast, you can still assemble a Syncrometer using a hobby kit. No soldering is required. Here is what you need:

Making a Hobby Kit Syncrometer

Item	**Radio Shack Cat. No.**
200 in One Electronic Project Lab by Science Fair	28-262
3 AA 1½ volt batteries	

---

[35] In *The Cure for all Cancers* and *The Cure for HIV/AIDS*.

Alligator clip test jumpers	You need 2.
Handhold. A four inch length of ¾ inch copper pipe, like for plumbing. These dimensions are critical to assure maximum skin contact.	
Probe. A banana plug.	Precision Mini-Hook Test Lead Set (contains two, you only need one) 278-1160A
Pencil, new.	

Fig. 80 Syncrometer parts list.

Build The Electrosonic Human in the *200 in One Electronic Project Lab*. It takes about 10 minutes.

Later, when you use the probe to press against your knuckle you may find getting the right sound is painful. In this case try substituting the .005 microfarad capacitor for the .01 microfarad capacitor in the circuit.

Attach the Probe. The Archer Precision Mini-Hook Test Lead Set has a banana plug for the probe on one end and a mini-hook on the other end for easy attachment to the circuit. Tape a long, new pencil to the probe to make it easier to hold. Connect the Probe to middle post of the primary side of the transformer (it also connects to the negative battery post). You will not be using the two connections the instructions tell you to hold.

Attach the Handhold. Clip the Handhold to one end of an alligator clip test jumper, and clip the other end to the base (B) of the transistor used in the circuit.

Attach an alligator clip to the post of the transformer that connects to the two capacitors. This will go to the **test plates**.

Final test. Turn the control knob on and keep turning the potentiometer to nearly the maximum. (This reduces the resistance. The schematic has a 150 ohm fixed resistor in place of the potentiometer.) Make sure you have good batteries installed. Test the circuit by briefly touching the Probe to the Handhold. The speaker should produce a sound like popping corn. If it does not, check that your alligator clips are not bending the spring terminals so much that other wires attached there are loose. Finally, turn switches OFF.

Making Test Plates

This is the box you attach to the basic Syncrometer circuit. It has test plates to put your test substances and tissue samples on. The wiring in it is arranged so that you can test for a toxin in a product, as well as search in yourself. This means you can search for *Salmonella* in the milk or cheese you just ate, not just for *Salmonella* in your stomach.

Only if the resonant frequency of an item on one plate is equal to the resonant frequency of an item on the other plate will the entire circuit oscillate or resonate! This implies the two plates have something in common. By putting a known pure sample on one plate you can reliably conclude the other sample contains it if the circuit resonates.

You may build a test plate box into a cardboard box (such as a facial tissue box) or a plastic box. Here are the instructions for the cardboard box model.

Test Plates Parts List

- Stiff paper.
- Aluminum foil.
- A facial tissue box is easiest. A plastic project box, about 7” x 4” x 1½” makes a more durable product, but requires a drill, and you should discard any metal lid it comes with.

- 3 bolts (tapered heads) about 1 inch long, 1/8 inch diameter and 6 washers and nuts to fit.
- toggle switch with OFF-ON positions.
- Alligator clip test leads.

Test Plates Assembly

Cut two 3-1/2 inch squares out of stiff paper such as a milk carton. Cover them with 4½ inch squares of aluminum foil, smoothed evenly and tucked snugly under the edges. You have just made yourself a set of open capacitors. Turn the box upside down and draw squares where you will mount them at the ends of the box. Don't actually mount them, to save wear and tear on them, until the rest of the box is complete.

Mount the ON OFF switch on the front of the box, underneath the right hand plate. Line it up so ON is downward and OFF is up. (An electronics shop can determine this for you at the time of purchase.) Label the box with ON and OFF signs.

Two bolts will be reserved for the plates. The third bolt is used as a terminal where the current from the oscillator circuit will arrive. Make a hole on the side of the box, near the left hand plate and mount the bolt so it sticks half way inside and halfway outside the box. It does not matter whether the head is inside or outside. Tighten it there with a nut on each side of the box. Label it TERMINAL. It merely means connecting place.

Mark the center of each square that you drew and each capacitor you built. Pierce first with a pin; follow with a pencil until a round hole is made at the center. Mount each plate with a bolt, fastening it below with a nut. Washers are optional.

The left side connection (terminal) gets attached to the left plate (bolt) with an alligator clip. Use another clip to attach the same left plate (bolt) to the ON OFF switch (there are two connections, use either one). Finally attach the ON OFF switch connection you didn't use to the right plate (bolt). Make sure the connections at the switch are not touching each other; you might tape them to guard against this.

All these connections should be checked carefully to make sure they are not touching others accidentally. But if you leave the box open so you can see any problems and use clear tape around connections to prevent accidental touching to the wrong connection, it should work OK.

Finally, trace your current. It comes in from the Syncrometer at the main terminal on the left. It is brought to the left plate. When the switch is ON it is simultaneously brought to the right plate. Notice that the plates are not connected to anything else. They are simply capacitors, letting current in and out momentarily and at a rate that is set by the frequency of the oscillator circuit, about 1,000 hertz. This frequency goes up as the resistance (of the circuit or your body) goes down.

The probe and handhold allow you to include yourself in the Syncrometer circuit. You grasp these when testing. This makes you part of the circuit.

The speaker lets you “listen” to the current. As resistance drops, current goes higher and frequency goes up. As frequencies go higher in the circuit, pitch goes higher. You will be comparing the sound of a standard “control” current with a test current.

Using The Syncrometer

Fill a saucer with cold filtered tap water. Fold a paper towel four times and place it in this dish. It should be entirely wet.

Cut paper strips about 1 inch wide from a piece of white, unfragranced, paper towel. Dampen a paper strip on the towel and wind it around the copper pipe handhold to completely cover it. The wetness improves conductivity and the paper towel keeps the metal off your skin.

- Start with the test plate switch at OFF.
- Turn the control knob (potentiometer) on, and to near maximum.
- Touch each plate with the probe, while holding the copper pipe with one hand. Only the left plate should give you a sound from the speaker. Turn the test plate switch ON. Now both plates should give you a sound when the probe touches them.
- Turn the test plate switch OFF again.
- Pick up the handhold, squeeze it free of excess water.
- Pick up the probe in the same hand, holding it like a pen, between thumb and forefinger.

Dampen your other hand by making a fist and dunking your knuckles into the wet paper towel in the saucer. You will be using the area on top of the first knuckle of the middle finger or forefinger to learn the technique. Become proficient with both. Immediately after dunking your knuckles dry them on a paper towel folded in quarters and placed beside the saucer. The degree of dampness of your skin affects the resistance in the circuit and is a very important variable that you must learn to keep constant. Make your probe as soon as your knuckles have been dried (within two seconds) since they begin to air dry further immediately.

With the handhold and probe both in one hand press the probe against the knuckle of the other hand, keeping the knuckles bent. Press lightly at first, then harder, taking one half second. Repeat a half second later, with the second half of the probe at the same location. There is an additive effect and you get two chances to listen to the current. All of this takes less than two seconds. Don't linger because your body will change and your next probe will be affected.

Subsequent probes are made in exactly the same way. As you develop skill, your probes will become identical. Plan to practice for one or two hours each day. It takes most people at least twelve hours of practice in order to be so consistent with their probes that they can hear the slight difference when the circuit is resonant.

For reference you may wish to use a piano. The starting sound when you touch down on the skin should be F, an octave and a half above middle C. The sound rises to a C as you press to the knuckle bone, then slips back to B, then back up to C-sharp as you complete the second half of your first probe. If you have a multitester you can connect it in series with the handhold or probe: the current should rise to about 50 microamps. If you have a frequency counter the frequency should reach 1000 Hz. You should arrive at C-sharp just before the probe becomes painful.

Two things change the sound of the probes even when your technique doesn't change.

1. The patch of skin chosen for probing will change its properties. The more it is used, the redder it gets and the higher the sound goes when you probe. Move to a nearby location, such as the edge of the patch, when the sound is too high to begin with, rather than adjusting the potentiometer.
2. Your body has cycles which make the sound go noticeably higher and lower. If you are getting strangely higher sounds for identical probes, stop and only probe every five minutes until you think the sound has gone down to standard. This could take five to twenty minutes. Learn this higher sound so you can avoid testing during this period.

You may also find times when it is impossible to reach the necessary sound without pressing so hard it causes pain. You may adjust the potentiometer if that helps.

All tests are momentary.

This means less than one second. It is tempting to hold the probe to your skin and just listen to the sound go up and down, but if you prolong the test you must let your body rest ten minutes, each time, before resuming probe practice!

For our purposes, it is not necessary to locate acupuncture points.

Resonance

The information you are seeking is whether or not there is *resonance*, or *feedback oscillation*, in the circuit. If there is the test is **YES** (positive). You hear resonance by comparing the second probe to the first. You can never hear resonance on the first probe, for reasons that are technical and beyond the scope of this book. You are not merely comparing pitch in the two probes. During resonance a higher pitch is reached faster; it seems to want to go infinitely high.

Remember that more electricity flows, and the pitch gets higher, as your skin reddens or your body changes cycle. These effects are not resonance.

Resonance is a small extra hum at the high end of the probe. As soon as you hear it, stop probing. Your body needs a short recovery time (10 to 20 seconds) after every resonant probe. The longer the resonant probe, the longer the recovery time to reach the standard level again.

Using musical notes, here is a NO (negative result): F-C-B-C# (first probe) F-C-B-C# (compare, it is the same sound). Here is a YES (positive) result: F-C-B-C# (first probe) F-D (stop quickly because you heard resonance). In between the first and second probe a test substance will be switched in as described in lessons below.

It is not possible to produce a resonant sound by pressing harder on the skin, although you can make the pitch go higher. To avoid confusion it is important to practice making probes of the same pressure. (Practice getting the F-C-B-C# tune.)

Making Pure Water for Testing Purposes

Since the water you purchase is likely to have solvents in it and since your tap water may be polluted with heavy metals and since your (or a store's) filtration system may be clogged, it is important to make your own pure water.

Purchase a "filter pitcher" made of hard, opaque plastic, not the clear or flexible variety (see Sources). Fill the pitcher with cold tap water, only, not reverse osmosis, distilled, or any other water, since solvents do not filter out as easily as heavy metals. The filter should be made of carbon only. To make test substances, use fresh water in the pitcher and pour.

If your water has lead, copper or cadmium from corroded plumbing, the filter will clog in five days of normal use. So use this pitcher sparingly, just for making test substances and for operating the Syncrometer.

Lesson One

Purpose: To identify the sound of resonance in the circuit.

Materials: Potentized (homeopathic) solutions. Prepare these as follows: find three medium-sized vitamin bottles, glass or plastic, with non-metal lids. Remove any shreds of paper sticking to the rim. Rinse well with cold tap water. Then rinse again with filtered water.

Pour filtered water into the first bottle to a depth of about ½ inch. Add about 50 little grains of table salt using the tip of a plastic knife. This is a "pinch." Replace the lid. Make sure the outside is clean. If not, rinse and dry. Now shake hard, holding it snugly in your hand. Count your shakes; shake 120 to 150 times. Use elbow motion so each shake covers about an eight inch distance. Shaken samples are different from unshaken ones, that's why this is so important. When done label the bottle on its side and lid: SALT #1. Wash your hands (without soap).

Next, pour about the same amount of filtered water into the second and third bottles. Open SALT #1 and pour a small amount, like 1/4 to 1/2 of a teaspoon (do not use a spoon) into the second and third bottles. Close all bottles. Now shake the second bottle the same as the first. Clean it and label it SALT #2. Do the same for the third bottle. Label it SALT #2 also and set aside for Lesson Four.

These two solutions have unique properties. SALT #1 always resonates. Use #1 to train your ear. SALT #2 shouldn't resonate. Use #2 to hear when you (your body's internal resistance) have returned to the standard level.

1. Turn the Syncrometer ON.
2. Place the SALT #2 bottle on the right test plate.
3. Start with the plate switch OFF.
4. Make your first probe (F-C-B-C#).
5. Flip the plate switch ON, taking only one half second. Brace your hand when switching so it is a fast, smooth, operation.
6. Make the second probe (F-C-B-C#). Total probe time is 2½ seconds. Count it out, “a thousand and one (done with first probe) a thou. (done with switching) a thousand and one (done with second probe).”
7. The result should be a NO (negative). If the second probe sounds even a little higher you are not at the standard level. Wait a few more seconds and go back to step 3.
8. If the first result was NO, remove SALT #2 and put SALT #1 on. Put the test plate switch back to OFF and repeat the test. This time the circuit was resonating. Learn to hear the

difference between the last two probes so that a resonant probe can be terminated early (reducing rest time).

9. The skin must now be rested. When SALT #1 is placed in the circuit there is always resonance whether you hear it or not. Therefore, always take the time to rest the skin.
10. How can you be sure that the skin is rested enough? Any time you want to know whether you have returned to the standard level, you may simply test yourself to SALT #2 (just do steps 3 through 6). While you are learning, let your piano also help you to learn the standard level (starts exactly at F). If you do not rest and you resonate the circuit before returning to the standard level, the results will become aberrant and useless. The briefer you keep the resonant probe, the faster you return to the standard level. Don't exceed one half second when probing SALT #1. Hopefully you will soon hear resonance within that time.

This lesson teaches you to first listen to the empty plate, then to SALT #2, to check for standard state. Then to compare the empty plate to SALT #1 to check for resonance. In later lessons we assume you checked for your standard level or are quite sure of it.

Practice hearing resonance in your circuit every day.

White Blood Cells

Checking for resonance between your white blood cells and a toxin is the single most important test you can make.

Your white blood cells are your immune system's first line of defense. In addition to making antibodies, interferon, interleukins, and other attack chemicals, they also “eat” foreign substances in your body and eliminate them. By simply checking your white blood cells for toxins or intruders you save having to check every other tissue in your body. Because no matter where the foreign substance is, chances are some white blood cells are working to remove it.

It took me two years to find this ideal indicator, but it is not perfect. **Tapeworms are a notable exception.** They can be encysted in a particular tissue which will test positive, while the white blood cells continue to test negative. Also, when bacteria and viruses are in their latent form, they do not show up in the white blood cells. Fortunately, in their active form they show up quite nicely. **Freon** is an example of a toxin that is seldom found in the white blood cells; but typically, the white blood cells are excellent indicators of toxins.

Making a White Blood Cell Specimen

Obtain an empty vitamin bottle with a flat plastic lid and a roll of clear tape. The white blood cells are not going into the bottle, they are going on the bottle. The bottle simply makes them easy to handle. Rinse and dry the bottle. Make a second specimen on a clean glass slide if available. Squeeze an oil gland on your face or body to obtain a ribbon of whitish matter (not mixed with blood). Pick this up with the back of your thumb nail. Spread it in a single, small streak across the lid of the bottle or the center of the glass slide. Stick a strip of clear tape over the streak on the bottle cap so that the ends hang over the edge and you can easily see where the specimen was put (see photo). Wipe the lid beside the tape to make sure all white blood cells are covered. For the slide, apply a drop of balsam and a cover slip (see *Sources*). Both types of preparation will give you identical results. The bottle type of white blood cell specimen is used by standing it on its lid (upside down) so that the specimen is next to the plate. The lid is used because it is flat, whereas the bottom of most bottles is not.

Lesson Two

Purpose: To add a white blood cell specimen to the circuit and compare sound.

Method:

1. Turn the Syncrometer ON.
2. Start with test plate switch OFF.
3. Place the white blood cell specimen on the left plate. Place some junk food in a plastic baggy on the right plate.
4. Eat some of the junk food.
5. After ½minute listen to the current. Flip the plate switch ON and listen again.
6. If the circuit is now resonating, the junk food is already in your white blood cells. It is toxic.

Take vitamin C and a B-50 complex to clear it rapidly; it may have had propyl alcohol or benzene in it. Test every 5 minutes afterward to see how long it takes to clear out.

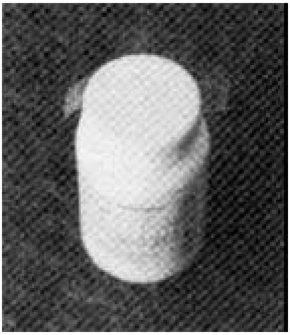

Fig. 81 Bottle with white blood cells taped on top.

Lesson Three

Purpose: To determine the purity of the filtered water you are making.

Method: Pour a few tsp. of filtered water into a bottle or plastic bag. Place your white blood cell specimen on one plate and the water sample on the other. Listen to your circuit. Taste your filtered water. After ½minute, listen to your circuit again, just as in Lesson Two. If it appears in your white blood cells at any time you can conclude the water is not pure. You must have pure water available to you before continuing.

Lesson Four

Purpose: To determine your percent accuracy in listening for resonance.

Materials: The SALT #1 and SALT #2 solutions you made for Lesson One.

Method: Move the SALT #1 and SALT #2 labels to the bottom of the bottles so you can not tell which bottle is which.

1. Turn the Syncrometer ON.
2. Start with the test switch OFF.
3. Mix the bottles up, select one at random, and place it on the right plate.
4. Listen to the current.
5. Flip the plate switch ON and make your second probe.
6. Resonance indicates a SALT #1, no resonance indicates SALT #2. Check the bottom. Remember to rest after the SALT #1, whether or not you heard resonance.
7. Repeat steps 3 through 5 a number of times. Work toward getting three out of three correct. Practice every day.

Trouble shooting:

a) If you repeat this experiment and you keep getting the same bottles "wrong", start over. You may have accidentally contaminated or mislabeled the outside of the bottle, or switched bottle caps.

b) If you get different bottles wrong each time, the plates may be contaminated. Wash the outside of the bottles and rinse with filtered water and dry. Wipe the plates very gently too, with filtered water and dry. Or replace the plates.

c) If all the bottles read the same, your filtered water is polluted. Change the filter.

Preparing Test Substances

It is possible to prepare dry substances for testing such as a piece of lead or grains of pesticide. They can simply be put in a plastic bag and placed on the test plate. However, I prefer to place a small amount (the size of a pea) of the substance into a ½ ounce bottle of filtered water. There will be many chemical reactions between the substance and the water to produce a number of test substances all contained in one bottle. This simulates the situation in the body.

Within the body, where salt and water are abundant, similar reactions may occur between elements and water. For example, a strip of pure (99.9% pure) copper placed in filtered water might yield copper hydroxide, cuprous oxide, cupric oxide, copper dioxide, and so forth. These may be similar to some of the reaction products one might expect in the body, coming from a copper IUD, copper bracelet or the copper from metal tooth fillings. Since the electronic properties of elemental copper are not the same as for copper compounds, we would miss many test results if we used only dry elemental copper as a test substance.

Impure Test Substances

It is not necessary to have pure test substances. For instance, a tire balancer made of lead can be easily obtained at an auto service station. Leaded gasoline and lead fishing weights also make good test substances for lead. There is a disadvantage, though, to using impure test substances. You are including the extra impurities in your test. If your lead object also has tin in it, you are also testing for tin. Usually, you can infer the truth by some careful maneuvering. If you have searched your kidneys for leaded gasoline, fishing weights and tire balancers and all 3 are resonant with your kidneys, you may infer that you have lead in your kidneys, since the common element in all 3 items is lead. (You will learn how to specify a tissue, such as your kidneys, later.)

Using pure chemicals gives you certainty in your results. You can purchase pure chemicals from chemical supply companies (see *Sources*). Your pharmacy, a child's chemistry set, a paint store, or biological supply company can also supply some.

The biggest repository of all toxic substances is the grocery store and your own home.

You can make test substances out of your hand soap, water softener salt, and laundry detergent by putting a small amount (1/16 tsp.) in a ½ounce glass bottle and adding about 2 tsp. filtered water. (Or for quick testing just put them dry or wet in a sealed plastic baggy.) Always use a plastic spoon.

Here are some suggestions for finding sources of toxic products to make your own toxic element test. If the product is a solid, place a small amount in a plastic bag and add a tablespoon of filtered water to get a temporary test product. For permanent use put it in a small amber glass bottle. If the product is a liquid, pour a few drops into a glass bottle and add about 2 tsp. filtered water. Keep all toxic substances in glass bottles for your own safety. Small amber glass dropper bottles can be purchased by the dozen at drug stores (also see *Sources*). Seal your test bottles with tape for safety and to prevent evaporation.

Aflatoxin: scrape the mold off an orange or piece of bread; wash hands afterward.

Acetone: paint supply store or pharmacy.

Arsenic: 1/16 tsp. of arsenate pesticide from a garden shop. A snippet of flypaper.

Aluminum: a piece of aluminum foil (not tin foil) or an aluminum measuring spoon.

Aluminum silicate: a bit of salt that has this free running agent in it.

Asbestos: a small piece of asbestos sheeting, an old furnace gasket, 1/4 inch of a clothes dryer belt that does not say "Made in USA", or a crumb of building material being removed due to its asbestos content (ask a contractor).

Barium: save a few drops from the beverage given clients scheduled for an X-ray. Lipstick that has barium listed in the ingredients.

Benzene: an old can of rubber cement (new supplies do not have it). A tsp. of asphalt crumbs from a driveway.

Beryllium: a piece of coal; a few drops of "coal oil" or lamp oil.

Bismuth: use a few drops of antacid with bismuth in it.

Bromine: bleached "brominated" flour.

Cadmium: scrape a bit off a galvanized nail, paint from a hobby store.

Cesium: scrape the surface of a clear plastic beverage bottle.

CFCs (freon): ask an electronics expert for a squirt from an old aerosol can that used freon as a cleaner. (Squirt into water, outdoors, put the water in a sample bottle.)

Chromate: scrape an old car bumper.

Cobalt: pick out the blue and green crumbs from detergent. A sample of cobalt containing paint should also suffice.

Chlorine: a few drops of pure, old fashioned Clorox.™

Copper: ask your hardware clerk to cut a small fragment off a copper pipe of the purest variety or a ¼ inch of pure copper wire.

Ergot: a teaspoon of rye grains, or rye bread. Add grain alcohol to preserve.

Ether: automotive supply store (engine starting fluid).

Ethyl alcohol (grain alcohol): the purest "drinking" alcohol available. Everclear™ in the United States, Protec™ (potable) in Mexico.

Fiberglass: snip a fragment from insulation.

Fluoride: ask a dentist for a small sample.

Formaldehyde: purchase 37% at a pharmacy. Use a few drops only for your sample.

Gasoline: gas station (leaded and unleaded).

Gold: ask a jeweler for a crumb of the purest gold available or use a wedding ring.

Kerosene: gas station.

Lead: wheel balancers from a gas station, weights used on fishing lines, lead solder from electronics shop.

Mercury: a mercury thermometer (there is no need to break it), piece of amalgam tooth filling.

Methanol: paint supply store (wood alcohol).

Nickel: a nickel plated paper clip, a washed coin.

Patulin (apple mold): cut a sliver of washed, bruised apple.

PCB: water from a quarry known to be polluted with it (a builder or electrical worker may know a source).

Platinum: ask a jeweler for a small specimen.

Propyl alcohol: rubbing alcohol from pharmacy (same as propanol or isopropanol). Use a few drops only, discard the rest. Do not save it.

PVC: glue that lists it in the ingredients (polyvinyl chloride).

Radon: leave a glass jar with an inch of filtered water in it standing open in a basement that tested positive to radon using a kit. After 3 days, close the jar. Pour about 2 tsp. of this water into your specimen bottle.

Silicon: a dab of silicon caulk.

Silver: ask a jeweler for a crumb of very pure silver. Silver solder can be found in electronics shops. Snip the edge of a very old silver coin.

Sorghum mold: 1/8 tsp. sorghum syrup.

Styrene: a chip of styrofoam.

Tantalum: purchase a tantalum drill bit from hardware store.

Tin: scrape a tin bucket at a farm supply. Tin solder. Ask a dentist for a piece of pure tin (used to make braces).

Titanium: purchase a titanium drill bit from a hardware store.

Toluene: a tube of glue that lists toluene as an ingredient.

Tungsten: the filament in a burned out light bulb.

Vanadium: hold a piece of dampened paper towel over a gas stove burner as it is turned on. Cut a bit of this paper into your specimen bottle and add 2 tsp. filtered water.

Xylene: paint store or pharmacy.

Zearalenone: combine leftover crumbs of three kinds of corn chips and three kinds of popcorn.

This list gets you off to a good start. Since few of these specimens are pure, there is a degree of logic that you must apply in most cases. If you are testing for barium in your breast, a positive result would mean that a barium-containing lipstick tests positive and a barium-free lipstick is negative.

A chemistry set for hobbyists is a wonderful addition to your collection of test specimens. Remember, however, the assumptions and errors in such a system. A test for silver using silver chloride might be negative. This does not mean there is no silver present in your body; it only means there is no silver chloride present in the tissue you tested.

You are bound to miss some toxins; don't let this discourage you. There is more than enough that you can find.

The most fruitful kind of testing is, probably, the use of household products themselves as test substances. The soaps, colognes, mouthwash, toothpaste, shampoo, cosmetics, breads, dairy products, juices and cereals can all be made into test specimens. Put about 1/8 tsp. of the product in a small glass bottle, add 2 tsp. filtered water and ¼ tsp. grain alcohol to preserve it. For temporary purposes use a plastic baggy and water only. If you test positive to your household products in your white blood cells you shouldn't use them, even if you can not identify the exact toxin.

For a list of toxins and solvents I use, see page 571. To order pure substances see *Sources* for “chemicals for testing.”

Making Organ Specimens

To test for toxic elements or parasites in a particular organ such as the liver or skin, you will need either a fresh or frozen sample of the organ or a prepared microscope slide of this organ. Meat purchased from a grocery store, fresh or frozen, provides you with a variety of organ specimens. Chicken, turkey, beef or pork organs all give the same results. You may purchase chicken gizzards for a sample of stomach, beef liver for liver, pork brains for brain, beef steak for muscle, throat sweet breads for thymus, tripe for stomach lining. Other organs may be ordered from a meat packing plant.

Trim the marrow out of a bone slice to get bone marrow. Scrub the bone slice with hot water to free it of marrow to get a bone specimen. Choose a single piece of meat sample, rinse it and place it in a plastic bag. You may freeze it. To make a durable unfrozen sample, cut a small piece, the size of a pea, and place it in an amber glass bottle (½oz.). Cover with two tsp. filtered water and ¼ tsp. of grain alcohol (pure vodka will do) to preserve it. These need not be refrigerated but if decay starts, make a fresh specimen.

Pork brains from the grocery store may be dissected to give you the different parts of the brain. Chicken livers often have an attached gallbladder or piece of bile duct, giving you that extra organ. Grocery store “lites” provides you with lung tissue. For kidney, snip a piece off pork or beef kidney. Beef liver may supply you with a blood sample, too. Always wash hands and rinse with grain alcohol after handling raw meat.

I use ½ oz amber glass bottles with bakelite caps (see Sources) to hold specimens. However, plastic bags or other containers would suffice. After closing, each bottle is sealed with a Parafilm^{TM} strip to avoid accidental loosening of the cap. You may use masking tape.

To make a specimen of skin, use hangnail bits and skin peeled from a callous, not a wart. A few shreds will do. Remember, they must be very close to the test plate when in use; add 2 tsp. filtered water and ¼ tsp. grain alcohol.

Making a Complete Set of Tissue Samples

My original complete set was made from a frozen fish. As it thawed, different organs were cut away and small pieces placed in bottles for preserving in filtered water and grain alcohol. In this way, organs not available from the grocery store could be obtained. The piece of intestine closest to the anus corresponds to our colon, the part closest to the stomach corresponds to our duodenum. The 2 layers of the stomach and different layers of the eye, the optic nerve and spinal cord were obtained this way.

Another complete set of tissue samples were obtained from a freshly killed steer at a slaughter house. In this way the 4 chambers of the heart were obtained, the lung, trachea, aorta, vein, pancreas, and so forth.

Purchasing a Complete Set of Tissue Samples

Slides of tissues, unstained or stained in a variety of ways for microscope study give identical results to the preparations made by yourself in the ways already described. This fact opens the entire catalog of tissue types for your further study. See *Sources* for places that supply them.

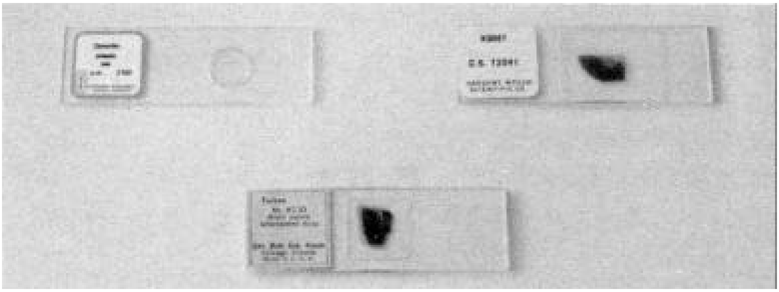

Fig. 82 Some purchased parasite and tissue slides.

You now have a set of organ samples, either fresh, frozen, preserved or on slides. You also have a set of test substances, whether chemical compounds, or elements, or products. Your goal is to search in your own organs and body tissues for the substances that may be robbing you of health.

Keeping yourself healthy will soon be an easy, daily routine.

Body Fluid Specimens

Each of these fluids should be prepared by putting about ¼ tsp. in a ½oz amber glass bottle. Add about 2 tsp. filtered water and ¼ tsp. grain alcohol for preservation. Undiluted specimens do not work for reasons that are technical and beyond the scope of this book. It is important *not* to shake the specimen, but to mix gently.

Urine. It is desired to have a pure, uninfected urine sample as a tissue specimen. Since this cannot be proved with certainty, obtain several urine samples from different persons whom you believe to be healthy and make several test specimens in order to compare results. Label your specimens Urine A (child), Urine B (woman), Urine C (mine), and so forth.

Semen. A sample from a condom is adequate. Aged specimens (sent by mail, unpreserved and unrefrigerated) work well also. Use one to ten drops or scrape a small amount with a plastic knife.

Blood. One to ten drops of blood should be used. Clotted or chemically treated blood is satisfactory. A blood smear on a slide is very convenient.

Milk. Cow's milk is too polluted with parasites to be useful. Electronically, a dead specimen is equivalent to a live specimen, so that pasteurization of the milk does not help. A human milk specimen is preferred.

Saliva. Use your own, if you have deparasitized yourself and test negative to various fluke stages. Otherwise find a well friend or child.

Specifying a tissue is the most powerful investigative technique in your arsenal. Any of your tissue samples can be tested for any of your toxic substances.

You Can Now Test Three Different Ways!

When you test with a substance on one plate and nothing on the other, you are searching your entire body for that substance. Such a test is not very sensitive.

By putting a tissue sample on the other plate you are testing for the substance specifically in that tissue, and this is much more sensitive. The tissue need not be the white blood cells. To find mercury in your kidneys you would use a mercury sample on one plate, and a kidney sample on the other. The technique is the same as when you use white blood cells.

If you put a substance on each plate, a resonating circuit means the two samples have something in common. For example, if you have mercury on one plate and some dental floss on the other, a positive result indicates mercury in the floss.

Lesson Five

Purpose: To watch substances travel through your body.

Materials: Prepare a pint of brown sugar solution (white sugar has propyl alcohol pollution) using filtered water. Use about 1 tsp. brown sugar, 1/8 tsp. vitamin C (to detoxify sorghum mold), and a pint of filtered water. Do not shake it; gently mix. Make a sample bottle by pouring about ½inch into a clean used vitamin bottle. Rinse and dry the outside of the sample bottle. Finally wash your hands with plain water.

Method:

1. Test your skin for the presence of brown sugar, using the newly made sample bottle and your skin specimen. It should not be there (resonate) yet.
2. Prepare a paper applicator by tearing the corner from a white unfragranced paper towel. Fold it to make a wick.
3. Dip the paper wick in the pint of sugar water and apply it to the skin of your inner arm where you can rub freely.

Rub it in vigorously for about 10 seconds (otherwise it takes minutes to absorb). Leave the shredded wick on the skin and tape it down with a piece of clear tape about 4 inches long (this increases the time you have to work). Quickly wash your fingers.

4. Place your skin tissue specimen on one plate and the sugar specimen bottle on the other plate.
5. Probe for resonance every 5 seconds. As soon as you hear resonance, implying that the skin has absorbed the sugar solution (which may take a full minute), replace the skin specimen with one of liver and listen for resonance again. There should be none, yet.
6. Alternate between the skin and liver. Soon the skin will be clear and the liver will resonate. Also check the pancreas and muscles to see how quickly sugar arrives there.
7. Check white blood cells and kidneys. It should not appear here (unless it is polluted with a toxin).
8. After five to ten minutes the sugar will be gone from all of these tissues and your experiment is ended. Wash your arm with plain water.

> Notice that you have only a few minutes to get all your testing done after the skin has absorbed the test substances.

Lesson Six

Purpose: To verify the propyl alcohol and benzene lists.

Method: We will use the Syncrometer to test for a toxin in a product. Assemble the products named in the propyl alcohol list (page 335) and benzene list (page 354)...as many as you can find. Also make sample bottles of benzene and propyl alcohol.

1. Place the propyl alcohol test substance on one plate and your products, in turn, on the other.

2. Listen to the current with only one of the plates in the circuit. Then listen with both plates in (the test plate switch ON). This method can detect one part per quadrillion in concentration. It is not as sensitive as the skin test (Lesson Five).
3. Repeat, with the benzene test substance.

Even tiny amounts of solvents are toxic! They must not be consumed or be left in our environment.

I have found that too many unsuspected products test positive to benzene. This is such a global tragedy that people must protect themselves by using their own tests. Rather than assurances, regulatory agencies should provide the consumer with cheap and simple tests (dip sticks and papers so we need not lug our Syncrometers around). Even if some test should fail, not all tests would fail to find an important pollutant like benzene. It would come to public attention much faster than the present debacle has.

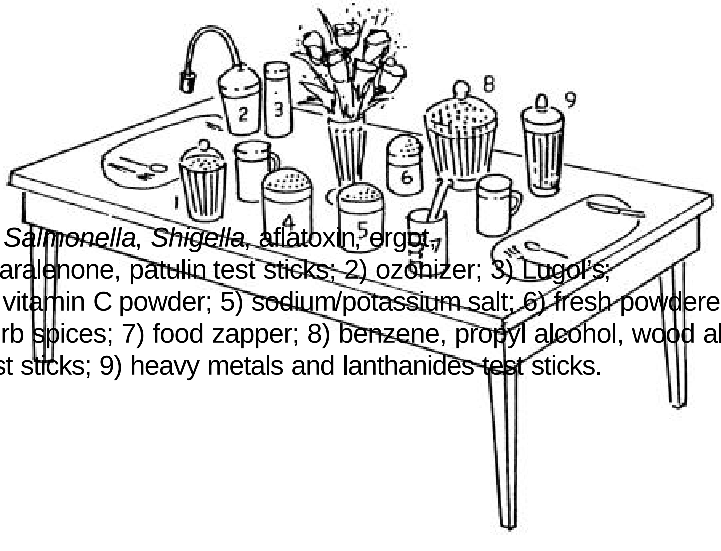

1) *Salmonella*, *Shigella*, aflatoxin, ergot, zearalenone, patulin test sticks; 2) ozonizer; 3) Lugol's; 4) vitamin C powder; 5) sodium/potassium salt; 6) fresh powdered herb spices; 7) food zapper; 8) benzene, propyl alcohol, wood alcohol test sticks; 9) heavy metals and lanthanides test sticks.

Fig. 83 Table of the future.

Lesson Seven

Purpose: To test for the presence of aluminum in your brain and your foods.

Materials: An aluminum measuring spoon, a tsp. of free flowing aluminized salt, a square inch of aluminum foil, a package of pork brain from the grocery store, kept frozen. (Other animal sources will do). Or a stained slide of cerebrum, cerebellum or other brain tissue.

Method:

1. Cut a piece of brain tissue (about 1 tsp.) and place in a plastic bag.
2. Place the aluminum samples in separate plastic bags. Add filtered water to each, about 1 tbs. Keep all surfaces and your hands meticulously clean (do not use soap).
3. Place the aluminum sample on one plate and the brain sample on the other plate.
4. Probe for resonance. If the circuit resonates you have aluminum in your brain.
5. If your aluminum specimen actually has cadmium or copper in it, you are also testing for these in your brain. Repeat the aluminum test with other aluminum objects. If they all resonate, you very, very likely have aluminum in your brain. If you can, test yourself to cadmium and copper, separately. If you don't have these in your brain, the aluminum test result is even more likely to be correct.
6. Of course, it would be desirable to have absolute certainty about this. To achieve this, purchase pure aluminum or an Atomic Absorption Standard. These are available from chemical supply companies.

If you do have aluminum in your brain, where is it coming from?

7. Leave your purest aluminum test substance on one plate, and replace the brain sample with these items, testing them one at a time. Remember to rest after each positive result.
    - a teaspoon of cottage cheese or yogurt taken from the top of a container of a foil-capped variety
    - a piece of cream cheese or butter that was wrapped in foil
    - a chip of bar soap or a bit of hand lotion
    - a piece of cake or rolls baked in an aluminum pan
    - a piece of turkey skin or hot dish that was covered with aluminum foil
    - anything baked with baking powder
    - a carbonated beverage from an aluminum can

Alternative Lesson:

To test for dental metal in your tissues. Use a piece of amalgam from an old tooth filling. This tests for the rest of the alloys in amalgam fillings as well as mercury. If you can't get a piece of mercury amalgam, use a mercury thermometer (don't break it, just put the bulb on the plate). Choose tissues like kidney, nerves, brain, liver, in addition to white blood cells.

I have never dissected human tissues and subjected them to confirmatory laboratory tests. It seems reasonable that because skin and tongue are directly provable, that other tissues work similarly.

Testing the Air

Fine particles and gas molecules that are in the air stick to the dust and eventually fall down onto the table, kitchen counter, and other places. Every night a film of dust accumulates, even though you can't see it. To test for air pollutants, gather some dust. Wipe the kitchen table and counter with a dampened piece of paper towel, two inches by two inches square. Place it in a resealable baggie. Do not get old dust, like from the top of the refrigerator or back shelves, because it does not represent the current air quality.

Testing Someone Else

Seat the person comfortably with their hand resting near you. Choose the first knuckle from the middle or first finger just like you do for yourself. Since you are touching this person, you are putting yourself in the circuit with the subject.

To exclude yourself, you need to add inductance to yourself. A coil of about 10 microhenrys, worn next to the skin, works well and is easily made. Obtain insulated wire and wrap 24 turns around a ball point pen (or something about that size), closely spaced. Cut the ends and tape them down securely. Keep it in a plastic bag, even when in your pocket. A commercial inductance of 4.7 microhenrys, worn touching your skin also works well. It can be worn on a string necklace. (Remember to remove the necklace when testing yourself.) The inductance acts as an RF (radio frequency) choke, limiting the alternating current that can flow through you while testing another person.

Test your inductor in this way. Repeat Lesson One with the coil next to your body. No resonance, even to SALT #1, should occur. If it does, make the coil bigger. Remove the inductor when you are not testing others.

Lesson Eight

Purpose: To detect aluminum in the brain of another person.

Materials: same as previous lesson, you wear the inductor.

Method:

1. Place the aluminum sample on one plate and the brain sample on the other plate.
2. Give the other person the handhold. You use the probe. Hold their finger steady in yours.
3. Probe the other person for resonance. The first probe is with only one plate in the circuit. The second is with both plates in the circuit. Resonance implies there is aluminum in the person's brain.

Saliva Testing

This may become your most useful test. The saliva has in it a bit of almost everything toxic that is in you. But it is not the first tissue to carry the HIV virus or a bit of a tapeworm stage. Nevertheless, *Salmonella* in your liver, mercury in your kidneys, aluminum in the brain all show up in the saliva, too. And saliva can be sent by mail or stored in the refrigerator. It should be frozen for long storage to prevent mold invasion. Or it may have grain alcohol added to preserve it. This test is not as sensitive as having the person present in the circuit, though.

To make a saliva specimen, place a two inch square piece of white, unfragranced paper towel (tear, don't cut) in a lightweight resealable baggy. Hold the open baggy near your mouth. Don't touch the paper towel with your fingers. Drool or spit onto the paper towel until half of it is damp. Zip it shut. Before testing, add enough filtered water to dampen the whole piece of paper.

Lesson Nine

Purpose: To search for shingles or *Herpes*.

Materials: A saliva specimen from the person being tested; they may be thousands of miles away. Also a specimen of the virus. This can be obtained from someone else's lesions—one droplet is enough, picked up on a bit of paper towel. The whole thing, towel and all, can be pushed into a glass bottle for preserving. Water and alcohol should be added. It can also be put on a slide, *Herpes, homemade*. A homeopathic preparation of the virus does not give accurate results for this kind of testing, due to the additional frequency imposed on it by potentizing. (However, homeopathic preparations can be used if the potency matches the tissue frequency where it resides. Hopefully, some way of using homeopathic sources will soon be found.)

Method: Place the saliva specimen in its unopened baggy on one plate. You may wish to open it briefly, though, to add enough filtered water to wet all the paper and add ¼ tsp. grain alcohol to sterilize or preserve it.

Place the virus specimen on the other plate and test as usual (like Lesson Six). A positive result means the person has active *Herpes*.

The main disadvantage of saliva testing is that you do not know which tissue has the pathogen or the toxin. You can only conclude that it is present. Usually this is enough information to carry out a corrective program.

Surrogate Testing

Although saliva testing is so easy, it is also possible to use an adult as a surrogate when testing a baby or pet. The pet or baby is held on the lap of the surrogate. A large pet may sit in front of the person. The handhold is held by the surrogate and pressed firmly against the body of the baby or pet. It can be laid flat against the arm, body or leg of a baby and held in place firmly by the whole hand of the adult. The paper covering should be wet. For a pet, the end is held firmly pressed against the skin, such as between the front legs or on the belly. The other hand of the adult is used for testing in the usual way. The adult must wear an inductor for surrogate testing as well as you, tester.

An ill or bedridden person may be tested without inconvenience or stress. He or she rests their whole hand on the skin of your leg, just above the knee. A wet piece of paper towel, about 4 inches by 4 inches is placed on your leg, to make better contact. You must use an inductor for yourself with this method. You may now proceed to probe on your hand instead of the ill person's.

Lesson Ten

Purpose: To test for cancer.

Materials: Ortho-phospho-tyrosine. Here are four ways to obtain some:

1. Order a pure sample from a chemical company (see *Sources*). Place a few milligrams (it need not be weighed) in a small glass bottle, add 2 tsp. filtered water and ¼ tsp. grain alcohol.
2. All persons with cancer have ortho-phospho-tyrosine in their urine as well as in the cancerous tissue. It is seldom found in other body fluids. Obtain a urine specimen from a friend who has active cancer. Freeze it if you can't prepare it immediately. Keep such specimens well marked in an additional sealed plastic bag. Persons who have recently been treated clinically for cancer are much less likely to have ortho-phospho-tyrosine in the urine.

   Urine cannot be considered a chemical in the same way as a sugar or salt solution. Urine is a tissue and has its own resonant frequency as do our other tissues. If combined with another tissue on the test plates, it will not resonate as if a solution of pure ortho-phospho-tyrosine were used. To use urine as an ortho-phospho-tyrosine specimen, you must:

a) Pour a few drops of urine into your specimen bottle
b) Add about 2 tsp. of filtered water
c) Add a few drops of grain alcohol

Gently mix, do not shake. Rinse and dry the outside of the bottle. Label it “urine/cancer”.

3. Cancer victims also have other growth factors being produced in their bodies. These are the same as can be found in mother's milk—for example, epidermal growth factor and insulin-like growth factor. Obtain a sample of mother's milk and use it to make another test substance for cancer. A few drops is enough.
4. There is still another way to prepare an ortho-phospho-tyrosine test sample. Common snails from a fish tank or outdoor snails are the natural hosts for *Fasciolopsis buskii* (human intestinal fluke) stages. The stages will produce ortho-phospho-tyrosine when the snails are fed fish food polluted with propyl alcohol. Over half the fish food cans I purchased had propyl alcohol pollution. Buy several brands of fish food. Test them for propyl alcohol and benzene. Obtain some snails, put them in a tank, feed them propyl alcohol polluted fish food. (Feed a separate group of snails benzene polluted fish food to obtain samples of HIV.) After two days put each snail in a zipped plastic bag, and test them individually against someone diagnosed with cancer or their saliva. The snails that the person tests positive to have ortho-phospho-tyrosine. Put these snails in the freezer to kill them humanely, then crush them and place in a specimen bottle with 50% grain alcohol to preserve. The bottles can be kept sealed and at room temperature.

   Similarly, your benzene snails can be tested against someone known to be HIV positive. Any snails that test positive can be used to prepare an HIV test specimen in the same way. The fish food must be tested for both benzene and propyl alcohol pollution, and separated appropriately, or you run the risk of making specimens that have both ortho-phospho-tyrosine and HIV.

Method:

1. Test for cancer by placing the test sample you just made (any of the four) on one plate and a white blood cell sample on the other plate.
2. If you resonate with both samples in the circuit you have cancer. Immediately, search for your cancer in your breast, prostate, skin, lungs, colon, and so forth.
3. To be more certain, test yourself to the other kinds of test samples. You should not resonate.

As you know by now, you can confirm the cancer by testing yourself to propyl alcohol and the human intestinal fluke in the liver. You should eliminate propyl alcohol from use, and zap all parasites. Keep testing yourself for cancer until it is gone. It should take less than one hour. Also continue to test yourself for propyl alcohol and the intestinal fluke in the white blood cells; make sure they are gone. Also test yourself for aflatoxin and freon.

Lesson Eleven

Purpose: To test for HIV.

Materials: Purchase a few milligrams of Protein 24 antigen (a piece of the HIV virus core) or the complete HIV virus on a slide (see *Sources*). You may use the vial unopened if only one test specimen is needed. To make more specimens, use about 1 milligram per ½ ounce bottle. Add 2 tsp. filtered water and ¼ tsp. grain alcohol. Or prepare an HIV specimen from snails as described in the previous Lesson.

Method: Search in the thymus (throat sweet breads), vagina and penis for the virus because that is where it will reside almost exclusively for the first year or two. If you don't have those tissue specimens, you could search in urine, blood, saliva, or white blood cells, but only a positive result can be trusted. Also search for the human intestinal fluke and benzene in the thymus. Of course, a positive test in these tissues is very significant. If you are positive, zap parasites immediately. You should test negative in less than an hour. Remove benzene polluted items from your lifestyle. Also test yourself to several varieties of popcorn, brown rice, and corn chips as an indication of zearalenone, which must be eliminated in order to get well. Follow up on yourself every few days to be sure your new found health is continuing. Test yourself for freon.

Lesson Twelve

Purpose: To test for diseases of all kinds.

Materials: Use slides and cultures of disease organisms. Homemade preparations of strep throat, acute mononucleosis, thrush (*Candida*), chicken pox, *Herpes* 1 and 2, eczema, shingles, warts, measles, yeast, fungus, rashes, colds, sore throats, sinus problems, tobacco virus, and so forth can all be made by swabbing or scraping the affected part. A plastic spoon or bit of paper towel works well. Put a small bit on a slide. Add a drop of balsam and a cover slip. Or put the towel in a bottle, add water and alcohol as described previously. Microscope slides can greatly expand your test set (see *Sources*).

Method: Test yourself for a variety of diseases, using your white blood cell specimen first. Then search in organs like the liver, pancreas, spleen. Notice how many of these common illnesses don't “go away” at all. They are alive and well in some organ. They are merely not making you sick!

Lesson Thirteen

To test for AIDS.

Materials: Benzene sample, slides of tissue samples like thymus, liver, pancreas, penis, and vagina. Also a collection of disease specimens such as the ones used in the previous lesson.

Method: Search in the thymus for benzene. If it is positive throughout the day, you are at risk for developing AIDS, although you may not be ill. Search other tissues for benzene. The more tissues with benzene in them the more serious the situation. Immediately search all your body products and foods for benzene.

Stay off benzene polluted items forever.

Tally up the diseases you tested positive for in Lesson Twelve. Test at least ten. If you had more than half positive you already have AIDS. (50% is my standard, you may set your own; an ideal standard for defining a healthy person should be 0% positive.)

Lesson Fourteen

Purpose: To test for aflatoxin.

Materials: Do not try to purchase a pure sample of aflatoxin; it is one of the most potent carcinogens known. Having it on hand would constitute unnecessary hazard, even though the bottle would never need to be opened. Simply make specimens of beer, moldy bread, apple cider vinegar, and any kind of peanuts using a very small amount and adding filtered water and grain alcohol as usual.

Method: Test yourself for these. If you have all of them in your white blood cells and the liver then you very, very probably have aflatoxin built up. Next, test your daily foods for their presence in your white blood cells. Those that test positive must be further tested for aflatoxin. Notice the effect of vitamin C on aflatoxin in your liver. Find a time when your liver is positive to aflatoxin (eat a few roasted peanuts from a health food store and wait ten minutes). Take 1 gram vitamin C in a glass of water. Check yourself for aflatoxin every five minutes. Does it clear? If not, take 5 or 10 grams vitamin C. How long does it take?

Lesson Fifteen

Purpose: To test for parasites.

Method: If you test positive to your pet's saliva, you have something in common–a parasite, no doubt. You must search your muscles and liver for these, not saliva or white blood cells, because they are seldom seen in these. Zap yourself for parasites until you no longer test positive to your pets' saliva.

Tapeworms and tapeworm stages can not (and should not) be killed with a regular frequency generator. Each segment, and probably each scolex in a cysticercus has its own frequency and might disperse if your generator misses it. Only zapping kills all and is safe for tapeworms.

Be sure to treat your pet on a daily basis with the pet parasite program.

Lesson Sixteen

Purpose: To test for fluke disease.

A small number of intestinal flukes resident in the intestine may not give you any noticeable symptoms. Similarly, sheep liver flukes resident in the liver and pancreatic flukes in the pancreas may not cause noticeable symptoms. Their eggs are shed through the organ ducts to the intestine and out with the bowel movement. They hatch and go through various stages of development outdoors and in other animals. But if you become the total host so that various stages are developing in your organs, you have what I term *fluke disease*. I have found that cancer, HIV, diabetes, endometriosis, Hodgkin's disease, Alzheimer's disease, lupus, MS and "universal allergy syndrome" are examples of fluke disease.

You can test for fluke disease in two ways: electronically and by microscope observation.

Materials: Cultures or slides of flukes and fluke stages from a biological supply company (see *Sources*) including eggs, miracidia, redia, cercaria, metacercaria. Body fluid specimens to help you locate them for observation under a microscope.

Method: Test for fluke stages in your white blood cells first. If you have any fluke stages in your white blood cells you may wish to see them with your own eyes. To do this, you must first locate them. Place your body fluid samples on one plate, your parasite stages on the other plate, and test for as many as you were able to procure, besides adults. After finding a stage electronically, you stand a better chance of finding it physically with a microscope.

Lesson Seventeen

Purpose: To see how sensitive your measurements can be. (How much of a substance must be present for you to get a positive result?)

Materials: filtered water, salt, glass cup measure, 13 new glass bottles that hold at least ¼ cup, 14 new plastic teaspoons, Your skin tissue sample, paper towel.

Method: Some of the best measurement systems available today are immunological (such as an ELISA assay) and can detect as little as 100 fg/ml (femtograms per milliliter). A milliliter is about as big as a pea, and a femtogram is 1/1,000,000,000,000,000th (10^{-15}) of a gram!

1. Rinse the glass cup measure with filtered water and put one half teaspoon of table salt in it. Fill to one cup, stirring with a plastic spoon. What concentration is this? A teaspoon is about 5 grams, a cup is about 230 ml (milliliters), therefore the starting concentration is about 2½(2.5) gm per 230 ml, or .01 gm/ml (we will discuss the amount of error later).
2. Label one clean plastic spoon "water" and use it to put nine spoonfuls of filtered water in a clean glass bottle. Use another plastic spoon to transfer one spoonful of the .01 gm/ml salt solution in the cup measure to the glass bottle, stir, then discard the spoon. The glass bottle now has a 1 in 10 dilution, and its concentration is one tenth the original, or .001 gm/ml.
3. Use the "water" spoon to put nine spoonfuls of filtered water in bottle #2. Use a new spoon to transfer a spoonful of salt solution from bottle #1 to bottle #2 and stir briefly (never shake). Label bottle #2 ".0001 gm/ml".
4. Repeat with remaining bottles. Bottle #13 would therefore be labeled ".000000000000001 gm/ml." This is 10^{-15} gm/ml, or 1 femtogram/ml.
5. Do the skin test with water from bottle #13 as in Lesson Five. If you can detect this, you are one hundred times as sensitive as an ELISA assay (and you should make a bottle #14 and continue if you are curious how good your sensitivity can get). If you can not, try to detect water from bottle #12 (ten times as sensitive as ELISA). Continue until you reach a bottle you can detect.

Calculate the error for your experiment by assuming you could be off by as much as 10% when measuring the salt and water adding up to 20% error in each of the 13 dilutions. This is a total error in bottle #13 of 280%, or at most a factor of 3. So bottle #13 could be anywhere from 0.33 to 3 femtogram/ml. If you can detect water from bottle #13, you are definitely more sensitive then an ELISA, in spite of your crude utensils and inexpensive equipment! Note that the starting error of using 2.5 gm instead of 2.3 gm only adds another 10% error.

If you want to calculate how many salt molecules you can detect, select the concentration at the limit of your detection, and put 2 drops on a square inch of paper towel and rub into your skin. Assume one drop can be absorbed. If you can detect water from bottle #13, you have detected 510,000 molecules (10^{-15} fg/ml divided by 58.5 gm/M multiplied by 6.02×10^{23} molecules/M divided by 20 drops/ml). Water in bottle #12 would therefore have 10 times as many molecules in one drop, and so forth. Even if your error is as much as a factor of 2 (100%), you can still get a good idea of what you can measure.

Atomic absorption standards start at exact concentrations; it is easy to make a more exact dilution series with them. When testing for iridium chloride by this skin test method, I was able to detect 3025 molecules!

Troubleshooting:

Always extend your set until you get a negative result (this should happen by at least bottle #18). If you always “detect” salt, then you shook the bottle!

Never try to reuse a bottle if you spill when pouring into it. Get another new bottle.

Sensitivity of Pollutant-In-Product Testing

Get some slides of *Salmonellas* and *Shigellas* and find some milk that tests positive to at least one. Make a dilution series of the milk up to bottle #14, being careful not to shake the bottles. Start with 2 drops of milk in bottle #1. Use an eye dropper to deliver 2 drops to subsequent bottles. Begin testing at bottle #14, using the slide that tested positive. You will learn to search by frequency later. My sensitivity was routinely around bottle #12, for a variety of pathogens. It was the same for toxic elements starting with standard solutions, about 1000 μg/ml, showing this method is less sensitive than skin testing.

Microscopy Lesson

Purpose: To *observe* fluke stages in saliva and urine with a microscope.

Materials:

a. A low power microscope. High power is not needed. A total of 100x magnification is satisfactory for the four common flukes, *Fasciolopsis*, *sheep liver fluke*, *human liver fluke* and *pancreatic fluke*.
b. Glass slides and coverslips.
c. A disposable eye dropper.

PRECLEANED
MICROSCOPE
SLIDES
PLAIN GLASS
WARD'S
GLASS SLIDES

Fig. 84 Microscope, slides and coverslips.

d. For sanitation purposes (wiping table tops, slides, microscope and your hands) a 50% to 70% alcohol solution (not rubbing alcohol!) is best. Dilute 95% grain alcohol 7 parts alcohol plus 3 parts water. Vodka or 76% grain alcohol can be used undiluted.

e. Formaldehyde, 20%. Formaldehyde 37% is commonly available at pharmacies. Dilute this with equal parts of filtered water to get 18½%, which is close enough to 20%, for the purpose of "fixing" (killing) the specimens. Store in a glass bottle in the garage, away from sunlight. Label. Specimens that are fixed properly do not lose their life-like appearance.

f Iodine solution. This is only useful for the urine specimens. Lugol's iodine and tincture of iodine are both useful. Ask a pharmacist to prepare *Lugol's Iodine Solution* for you, as follows:

  - 44 grams (1½oz) iodine crystals
  - 88 grams (3 oz) potassium iodide crystals

Dissolve both in 1 liter (quart) filtered water. This may take a day of frequent shaking.

Method for saliva:

1. Pour the 20% formaldehyde into a small amber bottle or other receptacle to a depth of about 1/8 inch. Keep tightly closed.
2. The person to be tested is asked to salivate into the bottle so the organisms are immediately "fixed" without undergoing cooling first. The total volume should be about double the original amount of formaldehyde used. Make a mark on the container so the subject knows how much to produce. The resultant concentration of formaldehyde will be about 10%.
3. Shake the bottle a few times. Set it aside for 24 hours to settle (less if testing is urgent).

4. With a dropper, draw up some of the bottom settlings. Put one drop on a slide and apply a coverslip.
5. View under low power of microscope. Compare objects you observe with specimens obtained on slides from biological supply companies.

Note: Persons with HIV and moderate AIDS will show about one to ten parasite stages per slide. It requires several hours of searching. Persons with HIV and severe AIDS show 10 or more fluke stages per slide; this makes the task of finding them much easier. Persons with terminal untreated cancer have many more fluke stages than relatively well persons.

Method for urine:

1. Prepare bottles of formaldehyde fixative ahead of time. Put about ¼ to ½ inch of 20% formaldehyde in each. Keep tightly closed.
2. Add freshly voided[36] urine from cancer or HIV sufferers to the formaldehyde in approximately equal amounts, resulting in a 10% formaldehyde solution. Shake immediately. Let settle several hours. The sediment has a higher number of fluke stages. Cancer victims with cervical or prostate cancer will show higher numbers of stages in urine than other cancer types.
3. Staining the slide is optional. It helps to outline fluke stages slightly. Prepare Lugol's solution as described above.

   Slides may be stained in either of these two ways:
   - Put a drop of "fixed" urine on a slide. Add a drop of 50% Lugol's (dilute 1:1 with filtered water). Apply coverslip.

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[36] Urine that has cooled even slightly below body temperature does not show *miracidia* and *redia* in their original shapes.

- Put a drop of “fixed” urine on a slide. Apply coverslip. Add 1 to 3 drops of 50% Lugol’s to edge of coverslip and allow it to seep in.

Note: persons who have been treated for cancer or HIV using any of the known drugs may show only 1 to 2 fluke parasite stages per drop of saliva or urine. For this reason, you may need to search through 20 or more slides to find flukes. Very ill persons may show up to 10 parasites per drop (slide).

Taking Pictures Of What You See

You may be unsure of what you see even if you have the microscope slides of labeled flukes and their stages to study and compare. In real life, they vary so much in shape and size that absolute identification is difficult without experience. Unfortunately in a few hours, just as you are getting proficient, your magnificent specimens will be drying out and unfit for observation. To preserve them longer you can seal the edges by painting around the coverslip with fingernail clear enamel. Or dribble hot sealing wax along the edges and then place them in sealed plastic bags (one per bag). Melt sealing wax in a metal jar lid. Make an applicator from a piece of coat hanger wire bent in the shape of a small square to fit around the coverslip and a handle.

Or take photographs. To take pictures of what you see under the microscope you will need a photomicrographic camera, which costs $200.00 and up (see *Sources*). It is easy to use. Remember to label your pictures so you know which slide they came from.

Even photographs do not scientifically prove identity of parasite stages, but it is very good evidence. Proof would require that the saliva or urine sample could be cultured and seen to produce the known parasite stages.

Using A Frequency Generator

Frequency generators come in all sizes and costs and capabilities. If you can purchase one that reads out the frequency for you in numbers (digital type) and lets you produce a fraction of a kilohertz by turning a dial, it meets your most elementary needs. It should also be possible to set it on positive offset (100% positive) and still give you 5 volts. Then it can be used as a zapper. You should also be able to select a sine wave or square wave.

The advantages of having a frequency generator are that you can do your own diagnosing. You can find, in a few minutes:

1. Which invaders you have by dialing in to their frequencies.
2. At what frequencies you are broadcasting to the world.
3. What frequencies are used by other living things.

The Theory

Every living animal and every cell type produces its own frequencies and responds to these frequencies as well. We may speak of frequencies but we really mean waves, waves of energy. All waves have a frequency associated with them, so it's not really misleading to say frequencies when we really mean waves.

When the animal is alive it produces them, when it is dead it still responds to some of them. It is like the opera singer and the glass goblet. The opera singer produces frequencies in the air. The goblet responds to them because of its structure, not because it's alive. The goblet "picks up" on that particular frequency of sound because its own "resonant" frequency is exactly the same. If the singer sings loud enough the goblet shatters from the vibrations set up in it. An identical goblet, made of plastic, would not have the same resonant frequency.

There is not merely a structural and chemical difference between the living and non living. Living things are transmitting energy of some unique kind. And with your simple device, you will be able to trap this energy. And measure its exact frequency. This is not the same as understanding its makeup and source. We must leave that to others. But we can observe and use our observations to track down bacteria and other parasites. We can track down pollutants. We can measure our health quantitatively and perhaps in the future predict life expectancy.

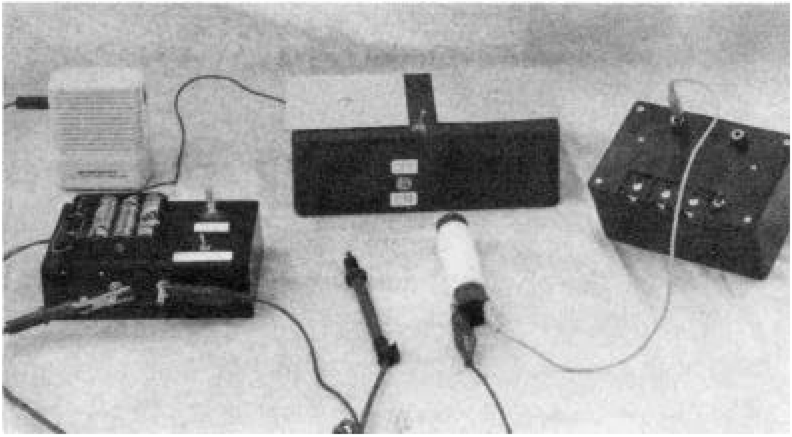

The Syncrometer at left is attached to the handhold. The frequency generator at right is also clipped to the handhold.

Fig. 85 Setup for finding resonant frequencies.

The Syncrometer traps the frequencies that match the ones in the material on the test plates and delivers them to an audio speaker in a range that you are able to hear. **Instead of test tissues or pathogens, we are now going to use pure test frequencies!** Remarkably, few things have overlapping frequencies, making this technique extremely useful for identification, even without a specimen!

Lesson Eighteen

Purpose: To search for the intestinal fluke in your body by listening to its broadcast frequency at 434 KHz.

Method: Turn on the frequency generator, select a frequency a short distance above the one you are interested in, like 438 KHz, turn the voltage (amplitude) down to less than one volt. Select sine waves. The lead coming from the frequency generator will have two connections, usually red and black (ground). We will not use the black (ground), just tape it out of the way. Pick up the handhold and probe in the usual way. Attach the red lead coming from the generator to your handhold. This makes two wires attached to your handhold. Although there is nothing on the test plates, they must be connected as usual with the switch at OFF (one plate is still ON).

Turn the Syncrometer ON. Probe yourself as usual. Your body's waves are being sent to the capacitor (plate) in the test plate box. The frequency from the Syncrometer is sent there, too. And now the 438 KHz waves from the generator are being sent there as well. Three different frequencies are mingling on the plate! If the two from your body and the generator are the same, the circuit will oscillate, and you will hear resonance. Turn the generator to 437 and probe again. Next, 436.

Sometimes, you can hear the resonance start to build. Continue on.

Next try 435. Then 434.

If your body is emitting a frequency of 434 KHz (coming from a live intestinal fluke inside you) it will be reinforced by the generator's 434 KHz. The reinforcement will put oscillations or resonance in the circuit, the same as you are accustomed to hearing with the Syncrometer. If there was none, you don't have the intestinal fluke anywhere in your body. Confirm this by starting at 430 KHz and working your way up.

If you hear resonance, you do have it. You may wish to verify this independently using a prepared slide of the fluke. Kill your flukes immediately as described in the next lesson.

Lesson Nineteen

Purpose: Killing the intestinal fluke with a frequency generator.

Materials: A frequency generator, two handholds with alligator clip leads for them.

Method: Wrap a single layer of paper towel over each of the two handholds. Wet them under the tap; squeeze out excess water. Clip them to the red and black wires of the frequency generator. (We use both wires for this purpose.) Dial up 434 KHz. Set the amplitude (voltage) at 10 volts. Grasp the handholds in each hand and hold on for three minutes. That is all. You have killed whatever tiny invader has a resonant frequency the same as the setting on the generator. Remember to zap all the stages, too; see *Pathogen Frequencies*.

If your frequency generator has a **positive offset** capability, you can use it like a zapper, and a single session will kill all pathogens, provided it is 100% offset and can give at least 5 volts at this setting. When using this technique, the generator can be set to any frequency from 2 KHz to 800 KHz, and you should go for 7 minutes. But even a small percentage of negative voltage will ruin this effect and do more harm than good! To be certain your generator is set correctly it would be best to observe the output on an oscilloscope.

Experiment with other voltage settings. Notice that less than one volt is also effective.

Lesson Twenty

Purpose: To find the bandwidth of a small living animal.

Materials: A fly, beetle or other insect, Syncrometer, frequency generator.

Discussion: Persons using a Syncrometer might have already tried putting a small insect on one of the plates. The circuit always resonates when you join the circuit at the handhold and probe. Even the tiniest ant placed in a glass bottle or plastic baggy will resonate the circuit. Unless it is too far away from the plate. If it has climbed up the side you will lose the resonance. At least one foot must be touching the bottom of the bottle. If the animal is dead this ceases. Obviously the living thing is affecting the circuit differently before and after death. Is it some kind of a wave form energy? To find its frequency you must add another frequency that will reinforce or interfere with the frequency already on the plate. Adding the generator frequency does just that.

Method: Use the same method as described in the last Lesson; however for an ant or fly, start at 1,000 KHz and proceed upward in big steps like 10 KHz. Use the right test plate which is controlled by the ON-OFF switch. Always listen to the current with the switch OFF, first, then ON. Move the frequency up and repeat. Continue until you hear resonance. Stop immediately. Rest your skin and go back down to the nonresonant frequency region. Move up in smaller steps this time. Repeat and repeat until you feel sure you know just where the resonance begins. But where does it end?

Start testing well above the suspected range taking big steps downward until you reach a resonant frequency. Rest and repeat until you find the upper limit of resonant frequencies. Record the bandwidth, for example, 1009-1112 KHz.

Lesson Twenty One

Purpose: To see if similar living things interfere with each other when put on the plate together.

Materials: Two identical living insects or very small living things.

Method: Find the broadcast range of each one separately and then together on the plate.

Note: Identical living things do not interfere with each others' frequencies.

Lesson Twenty Two

Purpose: To see if different living things interfere with each other when put on the plate together.

Method: Find the lower and upper end of the broadcast range of two different living things, such as a fly and a beetle or 2 kinds of flies or beetles. Then put them on the plate together. Notice there is no resonance in the accustomed range for either of them. They are interfering with each other on the plate.

Now add the 2 lower ends, then the two upper ends. Also subtract the 2 lower ends, then the two upper ends. For example imagine two insects, one with a spectrum of 1000 to 1090 KHz, the other with a range of 1050 to 1190 KHz. Adding the lower ends gives us 2050 KHz. Subtracting the lower ends gives us 50 KHz. Adding the upper ends gives 2280. Subtracting the upper ends gives 100. Now search for resonance at 50, 100, 2050, 2280 KHz. (These last two may be outside the range of your frequency generator. Choose more primitive life forms which have lower frequency bandwidths to stay within your limit.)

Notice that you hear resonance at exactly these frequencies and not above or below them. This is evidence for modulation of the frequencies: namely fusing them together.

Lesson Twenty Three

Purpose: To find your own bandwidth of emitted frequencies.

Materials: A frequency generator that goes up to 10 MHz. If yours only goes to 2 MHz you can still investigate the lower end of your band.

Method: You do not need to put yourself on the plate, since you are already there by being in the circuit at the handhold. However, if you are measuring someone else, they can simply touch the plate with a finger. Attach the frequency generator to the circuit at the handhold.

Since human adults begin to emit at about 1560 KHz, start searching at 1550, going upward in 1 KHz steps until you hear resonance.

Younger or healthier humans start emitting at a lower frequency and sometimes end at a higher frequency. In other words, they broadcast on a wider band.

Very young infants begin their band at about 1520 KHz. Could you ever regain this ability?

Most adults terminate at 9375 KHz

By eliminating molds from my diet, killing as many parasites and removing as many toxins as I became aware of, I have been able to expand my bandwidth from an initial 1562-9457 KHz in 1990 to 1520-9580 KHz in 1994! I hope this challenges you to accomplish a health improvement reflected in an even broader bandwidth for yourself.

Lesson Twenty Four

Purpose: To find the effect of a variety of things on the lower end of your spectrum, such as body temperature, eating, time of day, rainy weather, feeling sick. Notice that you may not change for weeks at a time, then suddenly see a shrinking of your bandwidth. You may assume you have eaten a mold.

Search for mold frequencies from 75 KHz to 295 KHz. Or test in your liver with mold samples. If this is positive go on a mold free diet—watching carefully for mold in your white blood cells. Even after removing the mold from your diet, so that no molds appear in your white blood cells, notice that your bandwidth does not recover. It regularly takes 2-3 weeks for mine to recover.

Surely, this sheds light on the poisonous effect of eating bad food.

Lesson Twenty Five

Purpose: To find an emission spectrum using a saliva sample.

Materials: A regular frequency generator.

Method: Search for the bottom of the resonant frequency band as in the previous lesson.

You may store it in the refrigerator for a few weeks without seeing a change. After that the band begins to shrink.

Lesson Twenty Six

Purpose: To observe the effect of dying on the bandwidth.

Method: Freeze the insect you tested in Lesson Twenty to kill it humanely. Repeat the search for its bandwidth. Note the bandwidth has become very narrow.

Note the bandwidth also depends on the accuracy of your particular frequency generator.

Lesson Twenty Seven

Purpose: To find unknown invaders of your body.

Method: Start at 900 KHz and proceed down to 77 KHz in 1 KHz steps, to search for all pathogens. If you find a resonating frequency, go to the Pathogen Frequency Chart (page 561) to identify likely candidates for it. Verify the identity of the invader by using a slide or culture specimen. If your pathogen remains unidentified, add it to the chart. This lets you determine whether the next illness is new or a recurrence of this one. Or just kill it.

Use the frequency generator at one pathogen's frequency. Wait ten minutes and retest all of the ones you found. Only that one will be gone. Now **zap**, wait ten minutes, and test again for all of the ones you found. Notice they are all gone. After one hour, search yet again for the pathogens you had. Any that are back must have come from an internal source not reached by the zapper current, like from the bowel or an abscess.

Lesson Twenty Eight

Purpose: To observe the action of a positive offset frequency on a very small animal. Does the animal die or is it just incapacitated?

Materials: A slug or small earthworm.

Method: Place the small animal in a plastic container like a cottage cheese carton. Add a few tsp. of water to wet the bottom. Attach a metal teaspoon to each of the generator clips. Place them on opposite sides in the carton and fasten with tape. Set the generator to positive offset at a frequency of about 30 KHz and 5 to 10 volts. Experiment with different voltages and compare effectiveness. Measure the time it takes for the animal to seem lifeless. You may try to revive it by keeping it for some time in the presence of food. Retest its emission band.

Lesson Twenty Nine

Purpose: To kill the bacteria in dairy products.

Materials: A glass of regular pasteurized milk, a carton of cottage cheese. A zapper.

Method: Search for *Salmonellas* and *Shigellas* first in the milk and cottage cheese. Search by frequency, using the chart, or with slides of these bacteria. If you don't find any, search different dairy foods until you find some bacteria. Attach metal teaspoons to the red and black leads of the generator. Place them inside the milk glass or cottage cheese carton, across from each other. Secure with masking tape. Attach the zapper. Zap them for 7 minutes. Remove the electrodes and wait 5 minutes. Test again for the same bacteria. They should be gone (but the food is not safe to eat due to the metal released from the teaspoons).

These experiments point to some exciting possibilities. Perhaps water supplies as well as foods and medicines could be sterilized this way. Perhaps sewage could be treated more efficiently, electrically. Best of all, maybe you could protect yourself from unsanitary products. If you do decide to explore this possibility, remember not to put metals in your mouth or food. Nor to use currents greater than 10 milliamps, or for longer than 10 minutes.

There are many commercially available function generators that can meet your needs. Two are shown here.

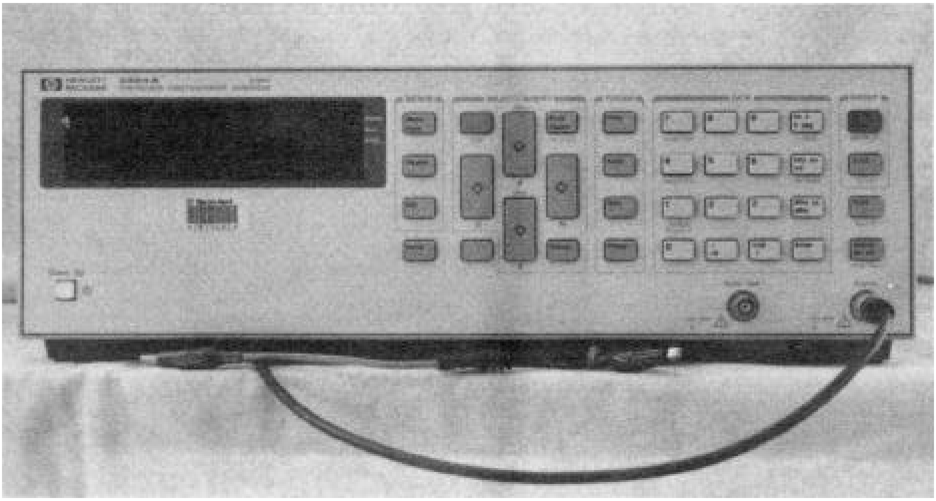

Fig. 86 Function generators.

Recipes

Read old recipe books for the fun and savings of making your own nutritious food. Change the recipes to avoid processed ingredients. Here are some I found:

Beverage Recipes

Anything made in your own juicer is fine. Experiment with new combinations to create different flavorful fruit and vegetable juices. Consider the luxury of preparing gourmet juices which satisfy your own individual palate instead of the mass-produced, polluted varieties sold at grocery stores. Remember to wash all fruit, including citrus before juicing. This removes the ever-present pesticides and common fruit mold.

Lemonade

1 cup fresh lemon juice, 1 cup honey, 1½quarts water. Bring honey and water to a boil if you plan to keep it several days. Then add lemon juice and store in the refrigerator.

All honey and maple syrup should have vitamin C added to it as soon as it arrives from the supermarket. Warm it first; then stir in ¼ tsp. per pint.

Fresh Tomato Juice

Simmer for ½hour: 12 medium-sized raw, ripe tomatoes, ½ cup water, 1 slice onion, 2 ribs celery with leaves, ½bay leaf, 3 sprigs parsley. Strain these ingredients. Season with: 1 tsp. salt (aluminum-free), ¼ tsp. paprika, ½tsp. honey. Serve thoroughly chilled. Makes about 4 servings.

Fresh Pineapple Juice

Peel a pineapple. Remove all soft spots. Cut it into cubes. Extract the juice by putting the pineapple through a food grinder or a blender. There will be very little pulp. Strain the juice and serve it on ice with sprigs of mint. Makes about 1½cups of juice. Mix the pulp with an equal amount of clover honey and use as topping (kept in freezer) for homemade ice cream (below), pancakes, or yogurt.

Maple Milk Shake

For each milk shake, blend or shake together: 1 glass of milk and 2 tablespoons maple syrup.

Remember, all milk gets boiled.

Yankee Drink

Mix together 1 gal. water, 3 cups honey, ½cup fresh lemon juice or distilled white vinegar, and 1 tsp. ginger.

Hot Vanilla Milk

Add one inch of vanilla bean and one tsp. honey to a glass of milk and bring to a near boil. You may add a pinch of cinnamon or other pure spice. You may even use vanilla extract (see *Sources*).

Red Milk

Equal parts fresh carrot juice (use a juicer) and sterilized milk. Save the carrot pulp for salads and soups.

C-Milk

Milk can absorb a surprising amount of vitamin C powder without curdling or changing its flavor. Try ½tsp. in a glass of cold milk.

My Own Soda Pop

Excellent for stomach distress. Put 1 tsp. citric acid, 2 tbs. vegetable glycerin (see *Sources*), 2 tbs. honey, and 1 lemon, juiced by hand, into a quart jar and fill with cold water. Refrigerate until ready to use. Then add 1 tsp. baking soda (chemically pure only, see *Sources*) and shake a few times, keeping the lid tight. Pour over a few ice cubes. Many variations are possible: other fruit concentrates, made in the blender, can be used along with some lemon juice; for example, 2 blended whole apples (peeled), blended pineapple, orange or grapefruit. Always add a bit of lemon to give it zip. You may add a pinch of ginger or other pure spice.

Note: The amount of sodium in ½tsp. baking soda is .476 grams. If you have heart disease, high blood pressure, or edema, use potassium bicarbonate instead. Ask your doctor what an acceptable amount of sodium or potassium bicarbonate is. I would suggest limiting yourself to one glass of soda pop a day, even if you do not have heart disease.

Another Note: the citric acid kills bacteria, while the carbonation brings relief.

My Own Super C-Pop

An excellent way to get lots of vitamin C into a child and relieve stomach distress at the same time. Squeeze 1 slice of lemon and 1 whole orange into an 8 ounce bottle that has a tight lid. Add 1 tsp. vitamin C powder (ascorbic acid), ¼ tsp. citric acid, and 2 tbs. vegetable glycerin (you may also experiment with honey for sweetness). Fill the bottle to the top with cold water. Then add ½tsp. chemically pure baking soda and close tightly. Shake briefly and serve immediately.

Half And Half

Mix equal parts whipping cream and milk or water. Boil and chill.

Buttermilk-C

Stir 1 tsp. vitamin C powder into a glass of milk. Add a pinch of potassium chloride. Additional seasoning may be pepper and herbs. Stir and enjoy.

Food Recipes

Despite the presence of aflatoxins, benzopyrenes, and solvents in many foods, it is possible to have a delicious and safe diet. Many persons need to gain weight, and with the emphasis in today's society on losing weight, consider yourself lucky in this respect. Help yourself to lots of butter, whipping cream, whole milk, avocados, and olive oil. Make your own preserves and baked goods, including breads. Remember, when you are recovering from a major illness it is essential not to diet to lose weight. You must wait two years after you are recovered to try to lose weight.

Daily Foods

Dairy products should contain at least 2% fat to enable you to absorb the calcium in them.

All milk should be sterilized

by boiling it for 10 seconds. If it makes mucous, you already have a chronic respiratory infection. Try to clear this up.

Change brands every time you shop to prevent the same pollutants from building up in your body.

If frying or cooking with fat, use only olive oil, butter or lard (the BHT and BHA preservatives in lard are OK except for seizure sufferers). Mix them for added flavor in your dishes. Never use margarine, Crisco™ or other hydrogenated fats. Do not cook over flames or grill, even when electric.

Eat lots of **fresh fruits and vegetables**. Wash them off only with cold tap water, not commercial food "wash". Scrub hard with a stiff bristled brush. Then cut away blemishes. Always peel potatoes, apples, and carrots. Modern dirt is full of chemicals and is toxic to you.

Be sure to drink plenty of **plain water** from your cold faucet throughout the day, especially if it is difficult for you to drink it with your meals. If you don't like the taste of your own tap water, try to get it from a friend with newer plumbing. Use a polyethylene (opaque) water jug from a grocery store to transport it. Never drink water that has been run through a water softener or copper plumbing or has traveled through a long plastic hose. Don't drink water that has stood in a container for a day. Dump it and sterilize the container. To further improve flavor and to dechlorinate attach a small faucet filter made of carbon only. Or buy a filter pitcher (see *Sources*). Don't drink water that has stood in the filter pitcher very long, either.

Because commercial **cold cereals** are very convenient, but have solvents, here are two replacements.

Two Granolas

7 cups rolled oats (old fashioned, not quick)
1 tsp. salt
1 cup wheat germ (fresh, not defatted)
½ cup honey
½ cup sunflower seeds, immaculate quality
½ cup milk (no need to sterilize, it is being baked)
½ cup melted butter
1 cup raisins, rinsed in vitamin C water

Mix dry ingredients together. Mix liquid ingredients and add gradually, while tossing until thoroughly mixed. Place in large ungreased pans and bake in slow (250°) oven. Stir occasionally, baking until brown and dry, usually 1-2 hours. Store in airtight container in freezer.

6 cups rolled oats
½ cup raw wheat germ
1 cup sesame seeds
1 cup sunflower seeds (raw, unsalted)
1 tsp. cinnamon
½ cup melted butter
½ cup honey

Preheat oven to 250°. Toss all ingredients in mixing bowl. Spread thinly on a baking sheet and bake 20-25 minutes. Stir often in order to brown evenly. When golden, remove and let cool. Makes 12 cups.

If you would like to add nuts to your granola recipes, rinse them in cold tap water first, to which vitamin C powder has been added (¼ tsp. per pint). This removes aflatoxins.

Peanut Butter

Use fresh unsalted roasted peanuts—they will be white on the first day they arrive at the health food store from the distributor. (Ask when they will arrive.) Or shell fresh roasted peanuts yourself, throwing away all shriveled or darkened nuts. Grind, adding salt and vitamin C (¼ tsp. per pint) as you go. For spreadability, especially for children, grind an equal volume of cold butter along with the peanuts. This improves spreadability and digestibility of the hard nut particles. This will probably be the most heavenly peanut butter your mouth has ever experienced.

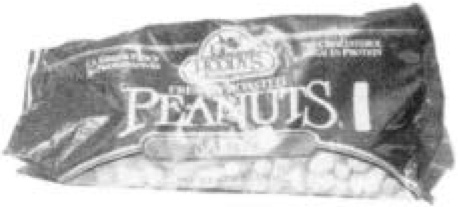

Fig. 87 Light colored, roasted peanuts in the shell had no aflatoxin.

Sweetening and Flavoring

Brown Sugar. Although I am prejudiced against all sugar from a health standpoint, my testing revealed no benzene, propyl alcohol, wood alcohol. However it does contain sorghum mold and must be treated with vitamin C to detoxify it. Add ¼ tsp. to a 1 pound package; knead until well mixed.

Maple syrup. Add vitamin C to newly opened bottle, ¼ tsp. to retard mold. Keep refrigerated and use promptly.

Flavoring. Use maple, vanilla (both natural and artificial), and any pure spice. They are free of molds and solvents.

Honeys. Get at least 4 flavors for variety: linden blossom, orange blossom, plain clover and local or wild flower honey.

Add vitamin C to newly opened jar to detoxify ergot mold (¼ tsp. per pint).

Jams and jellies. They are not safe unless homemade.

Fruit syrup. Use one package frozen fruit, such as cherries, blueberries or raspberries. Let thaw and measure the amount in cups (it might say on the package). Add an equal amount of clover honey to the fruit. Also add ¼ tsp. vitamin C powder. Mix it all in a quart canning jar and store in the refrigerator. Use this on pancakes, cereal, plain yogurt and homemade ice cream too. Use to make your own flavored beverages in a seltzer maker or to make soda pop. If you wish to use fresh fruit, bring it to a boil to sterilize. Use it up in a few days or boil to sterilize it again.

Note for diabetics

Diabetics must not use artificial sweeteners. Nor can they use all the sweeteners listed. Try stevia powder instead.

Preserves

Keep 3 or 4 kinds on hand, such as peach, pineapple, and pear. Peel and chop the fruit. It should not have any bruises. If you use a metal knife, rinse the fruit lightly afterwards. Add just enough water to keep the fruit from sticking as it is cooked (usually a few tablespoons). Then add an equal amount of honey, or to taste and heat again to boiling. Put in sterile jars in refrigerator. Make marmalade the same way, slicing the fruit and peel thinly. Always add vitamin C powder to a partly used jar to inhibit mold. Never use up partly molded fruit by making preserves out of it. Throw it out.

C Dressing

½ cup olive oil
¼ cup fresh lemon juice or white distilled vinegar
1 tsp. thyme, fenugreek or both (capsules are freshest)
1 tsp. vitamin C powder
½ tsp. brown sugar

Combine the ingredients in a clean salad dressing bottle. Shake. Refrigerate. The basic recipe is the oil and vinegar in a 2:1 ratio. After mixing these, add any pure spice desired. Or add fresh tomato chunks for creaminess.

Cheese Sauce

Add milk to cheese in equal amounts. Gradually heat to boiling while stirring. Add more of either to obtain the desired consistency. Boil 10 seconds. Use immediately.

Sour Cream-C

2 cups heavy whipping cream, previously boiled
¼ tsp. citric acid
¼ tsp. vitamin C powder
1 tsp. fresh onion juice or other seasoning (optional)

Stir until smooth, refrigerate 2 hours.

Yogurt

Buy a yogurt maker. Be sure and use boiled milk.

Soups

All home made soups are nutritious and safe, provided you use no processed ingredients (like bouillon), or make them in metal pots. Use herbs and aluminum-free salt to season. Always add a dash of vitamin C or tomato juice or vinegar to draw out calcium from soup bones for you to absorb.

Fish and Seafood recipe

Any kind of fish or seafood is acceptable, provided it is well-cooked. Don't buy food that is already in batter. The simplest way to cook fish is to poach it in milk. It can be taken straight from the freezer, rinsed, and placed in ¼ inch of milk (unboiled is fine) in the frying pan. Heat until it is cooked. Turn over and repeat. Throw away the milk. Serve with fresh lemon and herbs.

Baked Apples

Peel and core carefully. Remove all bruises (this is where the patulin is). Cut in bite-sized pieces, add a minimum of water and cook or bake minimally. Add a squirt of lemon juice when done. Serve with cinnamon, whipping cream and honey.

Ice creams

from the grocery store are loaded with benzene and other solvents. Fortunately there are ice cream makers that do everything (no cranking)! Or try our recipe which uses a blender. Be sure not to add store bought flavors, except vanilla or maple.

5 Minute Ice Cream

(Strawberry) Use 2 half pints of whipping cream, previously boiled, 1 package of frozen strawberries (about 10 oz.), and ½ cup clover honey. Pour frozen strawberries into blender. Pour whipping cream and honey over them. Blend briefly (about 10 seconds), not long enough to make butter! Pour it all into a large plastic bowl. Cover with a close fitting plastic bag and place in freezer. Prepare it a day ahead. Try using other frozen fruits, such as blueberries and cherries. Keep a few berries out of the blender and stir them in quickly with a non-metal spoon before setting the bowl in the freezer. There are many ice cream recipes to be found in old cook books. Avoid those with raw eggs or processed foods as ingredients. You may add nuts if you rinse them in vitamin C water.

Cookies, cakes and pies

Bake them from scratch, using unprocessed ingredients. Use simple recipes from old cook books.

Seven Day Sample Menu

Because processed foods have many toxins, you must cook as much from scratch as possible. So for convenience sake, keep your meals simple in preparation. You may want to prepare ahead and refrigerate your dressings and toppings. Or you could make a hot soup for dinner, refrigerate, and eat the leftovers for lunch. Don't save leftovers more than two days. Make sure they are covered. Try baking several potatoes at one time, refrigerate and put them in a salad the next night. Variety is the spice of life, so combine the allowed foods in the most creative ways you can imagine. And don't forget herbs and spices; learn to use them from old cook books.

	Breakfast	**Lunch**	**Dinner**
Day 1	Granola and honey with milk, half n' half or whipping cream 1 cup fresh squeezed fruit juice Water Milk	Fresh ground peanut butter and preserve sandwich Soup Milk Water	Orange roughy fish Fresh green beans with butter Baked potato with Sour Cream-C topping or fresh chives Pie (homemade) Milk 1 cup fresh squeezed or frozen vegetable juice Water

Day 2	Egg (limit is 2) Fried potatoes 1 glass milk Peppermint herb tea Fresh orange juice	Bagel (from bakery) Sour Cream-C Tomato 1 cup vegetable juice Water Milk	Homemade bean or lentil soup Sardines Dinner roll and butter Salad Homemade dressing Ice cream (homemade) Water
Day 3	Cream of Wheat™ cooked with raisins and milk Banana Peppermint herb tea ½ cup milk Water	Tuna sandwich with olives and butter Soup Milk Water	Baked sweet potato with butter and sweetening. Fresh broccoli with cheese sauce Bread and butter Chopped, peeled pear and whipping cream 1 cup vegetable juice Milk Water
Day 4	French toast with maple syrup Egg Homemade grapefruit juice Milk Water	Avocado and sour cream sandwich ½ cup vegetable juice Bread and butter Water	Lobster or sautéed shrimp Fresh asparagus Potatoes, any style ½ cup vegetable juice Water Milk
Day 5	Cooked cereal 1 glass milk Sliced banana with whipping cream and honey 1 glass water	Cold potato salad with C Dressing Soup ½ cup vegetable juice Custard Water Milk	1 can sardines or salmon in easy-open can (can openers shed metal) Salad of lettuce, tomato, olives, avocado with homemade dressing Bread with butter Ice-cream (optional) ½ cup vegetable juice Water Milk
Day 6	Egg and homemade biscuit with honey and butter Milk Fruit juice (homemade) Water	Homemade peanut butter sandwich ½ cup vegetable juice Milk Water	Gourmet pizza: home baked bread topped with olive oil, sliced tomato or homemade sauce, grated cheese, sardines or anchovies, chopped vegetables, garlic and onion Salad Milk Water

Day 7	Pancakes Banana or chopped fruit with cream Milk Water	Salmon sandwich (from flip top can) ½ cup vegetable juice Milk Water	Stir-fry vegetables: broccoli, carrots, cabbage, in olive oil and butter Bread and butter Pie (optional) Milk Water

Remember, take vitamin C and B-complex with each meal.

Too Sick To Cook, Too Tired To Eat

Pick three meals from the sample menu that need no cooking and eat them every day.

Recipes for Natural Body Products

You can use just borax (like 20 Mule Team Borax^{TM}) and washing soda (like Arm & Hammer Super Washing Soda^{TM}) for all types of cleaning including your body, laundry, dishes and your house! You don't need all of those products you see in commercials for each special task!

Even if you have dry skin, difficult hair or some other unique requirement, just pure borax will satisfy these needs. A part of every skin problem is due to the toxic elements found in the soaps themselves. For instance aluminum is commonly added as a “skin moisturizer”. It does this by impregnating the skin and attracting water, giving the illusion of moist skin. In fact you simply have moist aluminum stuck in your skin which your immune system must remove. While borax won't directly heal your skin or complexion, it does replace the agents that are causing damage, so that healing can occur.

Borax Liquid Soap

Empty 1 gallon jug
1/8 cup borax powder
Plastic funnel

Funnel the borax into the jug, fill with cold tap water. Shake a few times. Let settle. In a few minutes you can pour off the clear part into dispenser bottles. This is the soap!

Easier way: use any bottle, pour borax powder to a depth of a ½ inch or so. Add water. Shake. When you have used it down to the undissolved granules, add more water and shake again. Add more borax when the undissolved granules get low.

Keep a dispenser by the kitchen sink, bathroom sink, and shower. It does not contain aluminum as regular detergents and soaps do, and which probably contribute to Alzheimer's disease. It does not contain PCBs as many commercial and health food varieties do. It does not contain cobalt (the blue or green granules) which causes heart disease and draws cancer parasites to the skin. Commercial detergents and non-soaps are simply not safe. Switch to homemade bar soap and borax for all your tasks! Borax inhibits the bacterial enzyme *urease* and is therefore antibacterial. It may even clear your skin of blemishes and stop your scalp from itching.

For Laundry

Borax (½ cup per load). It is the main ingredient of non-chlorine bleach and has excellent cleaning power without fading colors. Your regular laundry soap may contain PCBs, aluminum, cobalt and other chemicals. These get rubbed into your skin constantly as you wear your clothing. For bleaching (only do this occasionally) use original chlorine bleach (not “new improved” or “with special brighteners”, and so forth). Don't use chlorine if there is an ill person in the house. For getting out stubborn dirt at collars, scrub with homemade bar soap first; for stains, try grain alcohol, vinegar, baking soda.

For Dishes

Don't believe your eyes when you see the commercials where the smiling person pulls a shining dish out of greasy suds. Any dish soap that you use should be safe enough to eat because nothing rinses off clean. Regular dish detergents, including health brands, are now polluted with PCBs. They also contain harmful chemicals. Use borax for your dishes. Or use paper plates and plastic (not styrofoam) cups.

In The Dishwasher

Use 2 tsp. borax powder pre-dissolved in water. If you use too much it will leave a film on your dishes. Use vinegar in the rinse cycle.

In The Sink

Use a dishpan in the sink. Use ¼ cup borax and add a minimum of water. Also keep a bit of dry borax in a saucer by the sink for scouring. Don't use any soap at all for dishes that aren't greasy and can be washed under the faucet with nothing but running water. Throw away your old sponge or brush or cloth because it may be PCB contaminated. Start each day by sterilizing your sponge (it harbors Salmonella) or with a new one while the used one dries for three full days. Clean greasy pots and pans with a paper towel first. Then use homemade bar soap.

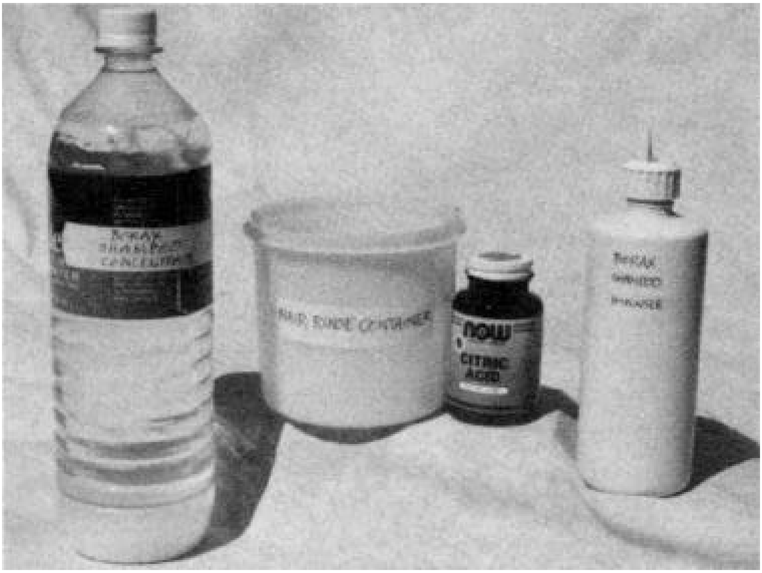

Fig. 88 Make a bottle of borax liquid to fill your soap dispensers and shampoo bottle. Use citric acid to rinse and condition.

Shampoo

Borax liquid is ready to use as shampoo, too. It does not lather but goes right to work removing sweat and soil without stripping your color or natural oils. It inhibits scalp bacteria and stops flaking and itching. Hair gets squeaky clean so quickly (just a few squirts does it) that you might think nothing has happened! You will soon be accustomed to non-lathery soap. Rinse very thoroughly because you should leave your scalp slightly acidic. Take a pint container to the shower with you. Put ¼ tsp. citric (not ascorbic) acid crystals (see *Sources*) in it. For long hair use a quart of rinse. Only **citric acid** is strong enough to get the borax out, lemon juice and vinegar are not. After shampooing, fill the container with water and rinse. Rinse your whole body, too, since citric acid is also anti-bacterial. All hair shampoo penetrates the eye lids and gets into the eyes although you do not feel it. It is important to use this natural rinse to neutralize the shampoo in your eyes. (Some people have stated that citric acid makes their hair curlier or reddens it. If this is undesirable, use only half as much citric acid.) Citric acid also conditions and gives body and sheen to hair.

Hair Spray

I don't have a recipe that holds your hair as well as the bottle of chemicals you can buy at the store. Remarkably a little lemon juice (not from a bottle) has some holding power and no odor! Buy a 1 cup spray bottle. Squeeze part of a lemon, letting only the clear juice run into the bottle. Fill with water. Keep it in the refrigerator. Make it fresh every week. Spraying with just plain water is nearly as good! For shinier hair, drop a bit of lemon peel into the bottle.

Homemade Soap

A small plastic dishpan, about 10” x 12”
A glass or enamel 2-quart sauce pan
1 can of lye (sodium hydroxide), 12 ounces
3 pounds of lard (BHT and BHA are OK here)
Plastic gloves
Water

1. Pour 3 cups of very cold water (refrigerate water overnight first) into the 2-quart saucepan.
2. Slowly and carefully add the lye, a little bit at a time, stirring it with a wooden or plastic utensil. (Use plastic gloves for this; test them for holes first.) Do not breathe the vapor or lean over the container or have children nearby. Above all use no metal. The mixture will get very hot. In olden days, a sassafras branch was used to stir, imparting a fragrance and insect deterrent for mosquitoes, lice, fleas, ticks.

3. Let cool at least one hour in a safe place. Meanwhile, the unwrapped lard should be warming up to room temperature in the plastic dishpan.
4. Slowly and carefully, pour the lye solution into the dishpan with the lard. The lard will melt. Mix thoroughly, at least 15 minutes, until it looks like thick pudding.
5. Let it set until the next morning; then cut it into bars. It will get harder after a few days. Then package.

If you wish to make soap based on olive oil, use about 48 ounces. It may need to harden for a week.

Liquid Soap

Make chips from your homemade soap cake. Add enough hot water to dissolve. Add citric acid to balance the pH (7 to 8). If you do not, this soap may be too harsh for your skin.

Skin Sanitizer

Make up a 5 to 10% solution of food grade alcohol. Food grade alcohols are grain (ethyl) alcohol or vodka. Find a suitable dispenser bottle. Mark it with a pen at about one tenth of the way up from the bottom. Pour 95% grain alcohol (190 proof) to this mark (for 50% grain alcohol or vodka make your mark one fifth of the way up). Add water to the top. Keep shut. You may add a chip of lemon peel for fragrance.

Use this for general sanitizing purposes: bathroom fixtures, knobs, handles, canes, walkers, and for personal cleanliness (but use chlorine bleach for the toilet bowl once a week). Always clean up after a bowel movement with wet toilet paper. This is not clean enough, though. Follow with a stronger damp paper towel. This is still not clean enough; use a final damp paper towel with skin sanitizer added. After washing hands, sanitize them too, pouring a bit on one palm and put finger tips of the other hand in it, scratch to get under nails, repeat on other hand. Rinse with water.

Do not use this recipe, nor keep any bottles of alcohol in the house of a recovering alcoholic.

Deodorant

Your sweat is odorless. It is the entrenched bacteria feeding on it that make smells. You can never completely rid yourself of these bacteria, although they may temporarily be gone after zapping. The strategy is to control their numbers. Here are several deodorants to try. Find one that works best for you:

Vitamin C water. Mix ¼ tsp. to a pint of water and dab it on. Then dab on cornstarch.

Citric Acid water. Mix ¼ tsp. to a pint of water and dab it on. Then dab on cornstarch.

Only a few drops of these acids under each armpit are necessary. If these acids burn the skin, dilute them more. Never apply anything to skin that has just been shaved!

Corn starch. Many people need only this. Dab it on.

Use only unpolluted **cornstarch** (see *Sources*).

Baking soda has been deleted as a deodorant because benzene was found in some boxes.

Lemon juice. This acid is not as strong, use what you need.

Pure alcohol (never rubbing alcohol). The food grade alcohols are grain alcohol and vodka. Dab a bit under each arm and/or on your shirt or blouse, then dab on cornstarch. If the alcohol burns, dilute it with water. Be very careful not to leave the bottle where a child or alcoholic person could find it. Pour it into a different bottle!

Pure zinc oxide. You may ask your pharmacist to order this for you. She or he may wish to make it up for you too, but do not let them add anything else to it. It should be about 1 part zinc oxide powder to 3 parts water. It does not dissolve. Just shake it up to use it. After you get it home, you can add cornstarch to it to give it a creamy texture. Heat 3 tsp. cornstarch in 1 cup of water, to boiling, until dissolved and clear. Cool and add some to the zinc oxide mixture (about equal parts). Store unused starch mixture in the refrigerator. Only make up enough for a month.

Alcohol and zinc oxide. This is the most powerful deodorant. Apply alcohol first, then the zinc oxide, then dab on cornstarch.

Remember that you need to sweat! Sweating excretes toxic substances, especially from the upper body. Don't use deodorant on weekends. Go to the sink and wipe clean the armpits like our grandparents did. Often, just plain cornstarch is enough! These homemade deodorants are not as powerful as the commercial varieties–this is to your advantage.

Brushing Teeth

Buy a new toothbrush. Your old one is soaked with toxins from your old toothpaste. Use only water or chemically pure baking soda if you have any metal fillings. Put a pinch in a glass, add water to dissolve it. Use food-grade hydrogen peroxide (see *Sources*) if you have only plastic fillings. Dilute it from 35% to 17½% by adding water (equal parts). Store hydrogen peroxide only in polyethylene or the original plastic bottle. Use 4 or 5 drops on your toothbrush. It should fizz nicely as oxygen is produced in your mouth. Your teeth will whiten noticeably in 6 months. Before brushing teeth, floss with 4 or 2 pound monofilament fish line. Double it and twist for extra strength. Rinse before use. Floss and brush only once a day. If this leaves you uncomfortable, brush the extra times with plain water and a second “water-only” toothbrush. Make sure that nothing solid, like powder, is on your toothbrush; it will scour the enamel and give you sensitive teeth, especially as you get older and the enamel softens. Salt is corrosive—don't use it for brushing metal teeth. Plain water is just as good.

For Dentures

Use salt water. It kills all germs and is inexpensive. Salt water plus grain alcohol or food-grade hydrogen peroxide makes a good denture-soak.

Mouthwash

A few drops of food grade hydrogen peroxide added to a little water in a glass should be enough to make your mouth foam and cleanse. Don't use hydrogen peroxide, though, if you have metal fillings, because they react. Don't use regular drug store variety hydrogen peroxide because it contains toxic additives. Health food store varieties contain solvents from the bottling process. See *Sources*. Never purchase hydrogen peroxide in a bottle with a metal cap.

For persons with metal tooth fillings, use chemically pure baking soda or just plain hot water. A healthy mouth has no odor! You shouldn't need a mouthwash! If you have breath odor, search for a hidden tooth infection or cavitation.

Contact Lens Solution

A scant cup of cold tap water brought to a boil in glass saucepan. After adding ¼ tsp. aluminum free salt and boiling again, pour into a sterile canning jar. Refrigerate. Freeze some of it.

Lip Soother

For dry, burning lips. Heat 1 level tsp. sodium alginate plus 1 cup water until dissolved. After cooling, pour it into a small bottle to carry in your purse or pocket (refrigerate the remainder). Dab it on whenever needed. If the consistency isn't right for you, add water or boil it down further. You can make a better lip soother by adding some lysine from a crushed tablet, vitamin C powder, and a vitamin E capsule to the alginate mix. If you have a persistent problem with chapped lips, try going off citrus juice.

Foot Powder

Use a mixture of cornstarch and zinc oxide poured into a salt shaker with a lid. Add long rice grains to fight humidity. You may also try arrow root or potato starch. If you don't have zinc oxide use plain cornstarch.

Skin Healer Moisturizer Lotion

1 tsp. sodium alginate
1 cup water

Make the base first by heating these together in a covered, non-metal pan until completely dissolved. Use low heat–it will take over an hour. Use a wooden spoon handle to stir. Set aside. Then make the following mixture:

¼ tsp. Vitamin C (ascorbic acid) (You may crush tablets)
¼ tsp. lysine (crush tablets)
2 tbs. pure vegetable glycerin
2 vitamin E capsules (400 units or more, each)
1 tsp. apricot kernel oil (olive oil will do)

1 tbs. lemon juice from a lemon or ¼ tsp. citric acid (this is optional)
1 cup water

Heat the water to steaming in a non-metal pan. Add vitamin C and lysine first and then everything else. Pour into a pint jar and shake to mix. Then add the sodium alginate base to the desired thickness (about equal amounts) and shake. Pour some into a small bottle to use as lip soother. Pour some into a larger bottle to dispense on skin. Store remainder in refrigerator. (See *Sources* for sodium alginate, vegetable glycerin and apricot kernel oil. Sodium alginate is also available in capsule form at some health food stores.)

Other Skin Healers

Vitamin C powder (ascorbic acid, not the same as citric acid). Put a large pinch into the palm of your hand. With your other hand pick up a few drops of water from the faucet. Rub hands together until all the powder is dissolved and dispensed. It may sting briefly. Do this at bedtime, especially for cracked, chapped hands. Include lips if they need it.

Vitamin E oil. Vitamin E oil from Now Foods was not polluted at the time of this writing, but for the future it would be safer to rely on capsules. Snip open a capsule and rub into skin.

50% Glycerin. Dilute 100% vegetable glycerin with an equal amount of water. This is useful as an after shave lotion.

Vitamin C liquid. Mix ¼ tsp. vitamin C powder in one pint water (crushed tablets will do). This is useful as an after shave lotion and general skin treatment.

Apricot Kernel Oil. This is a very light oil, useful as an after shave lotion and general skin treatment.

Cornstarch (see *Sources*). Use on rashes, fungus, moist or irritated areas and to prevent chafe.

Combining several of these makes them more effective.

Dry skin has several causes: too much water contact, too much soap contact (switch to borax), low body temperature, not enough fat in the diet, or parasites.

Massage Oil

Use olive oil. It comes in very light to heavy textures. Pick the right one for your purpose. Alginate mixtures can be used instead of, or added to, oil. Starch solutions are good, too.

Sunscreen Lotion

Purchase PABA (see *Sources*) in 500 mg tablet form. Dissolve 1 tablet in grain alcohol or vodka. Grind the tablet first by putting it in a plastic bag and rolling over it with a glass jar. It will not completely dissolve even if you use a tablespoon of the alcohol. Pour the whole mixture into a 4 ounce bottle of homemade skin softener. Be careful not to get the lotion into your eyes when applying it. A better solution is to wear a hat or stay out of the sun. Remember to *take* PABA as a supplement, too (500 mg, one a day).

Nose Salve

(When the inside of the nose is dry, cracked and bleeding.)

Pour ½tsp. pure vegetable glycerin into a bottle cap. Add ½ tsp. of water.

Applicator: use a plastic coffee stirrer or straw; cut a slit in the end to catch some cotton wool salvaged from a vitamin bottle and twist (cotton swabs, cotton balls and wooden toothpicks are sterilized with mercury which in turn is polluted with thallium). Dip it into the glycerin mixture and apply inside the nose with a rotating motion. Do each nostril with a new applicator.

Quick Corn Starch Skin Softener

4 tsp. corn starch (see *Sources*)
1 cup water

Boil starch and water until clear, about one minute.

Cornstarch Skin Softener

1 tsp. lysine powder or 8 tablets, 500 mg each
1 tsp. Vitamin C powder (ascorbic acid); or 8 tablets, 500 mg each
3 tsp. cornstarch (see *Sources*)
Vitamin E, 1 capsule 400 mg
¼ tsp. apricot kernel oil (optional)
1 cup water

Boil starch and water until clear, about one minute. Add other ingredients and stir until dissolved. Cool. Pour into dispenser bottle. Keep refrigerated when not in use. Apply after washing dishes and after showering.

After Shaves

Vitamin C. ¼ tsp. vitamin C powder, dissolved in 1 pint water.

Apricot kernel oil.

Vegetable glycerin. Equal parts glycerin and water or to suit your need.

Personal Lubricants

Heat these together: 1 level tsp. sodium alginate and 1 cup water in a covered non-metal pan until completely dissolved. Use very low heat and stir with a wooden spoon handle. It takes a fairly long time to get it perfectly smooth. After cooling, pour into a small dispenser bottle. Keep the remainder refrigerated.

Or, mix and heat 4 tsp. cornstarch and 1 cup water until completely dissolved in a covered saucepan. Use non-metal dishes and a non-metal stirring spoon. Cool. Pour some into dispenser bottle. Refrigerate remainder. This is many person's favorite recipe.

Baby Wipes

Cut paper towels in quarters and stack in a closable plastic box. Run tap water over them, drain the excess. Add 1 tsp. grain alcohol and/or borax liquid on top. Close. Put a dab of the Quick Cornstarch Softener recipe on top of each wipe as you use it.

People Wipes

¼ tsp. powdered lysine (you may crush tablets)
¼ tsp. Vitamin C powder (you may crush tablets)
¼ cup vegetable glycerin
1 cup water

Prepare wipes by cutting paper towels in quarters. Use white, unfragranced towels that are strong enough to hold up for this use. Fold each piece in quarters again and stack in a plastic zippered baggy. Pour the fluid mixture over the stack and zip. Store a bag full in the freezer to take on car trips. If you want to keep them a month or more, add 1 tbs. grain alcohol or vodka to the recipe.

For bathroom use, dampen a roll of paper towels under the cold tap first. Then pour about ¼ cup of the mixture over the towel roll around the middle. Store in plastic shopping bag or stand in plastic waste basket.

Recipes For Natural Cosmetics

Eye liner and Eyebrow Pencil

Get a pure charcoal pencil (black only) at an art supply store. Try several on yourself (bring a small mirror) in the store to see what hardness suits you. You may need to wet it with water or a vitamin E perle first. Don't put any chemicals on your *eyelids*, since this penetrates into your eye. To check this out for yourself, close your eye tightly and then dab lemon juice on your eyelid. It will soon burn! Everything that is put on skin penetrates. Otherwise the nicotine patch and estrogen patch wouldn't work. Not even soap belongs on your eyelids! Charcoal pencils are cheap. Get yourself half a dozen different kinds so you can do different things.

You could also use a capsule of activated charcoal. Empty it into a saucer. Mix glycerin and water, half and half, and add it to the charcoal powder until you get the consistency you like. Use a brush for eyelashes; use a finger for eyebrows.

Lipstick

Beet root powder (see *Sources*)
100% vegetable glycerin

Combine 1 tsp. vegetable glycerin and 1 tsp. beet root powder in a saucer. Stir until perfectly smooth. Then add ½tsp. of vitamin E oil. Snip open vitamin E capsules or buy vitamin E oil (see *Sources*). Very thick olive oil can be substituted. Apply liberally with your finger or a lipstick brush. Do not purse or rub your lips together after application. To make the lipstick stay on longer, apply 1 layer of lipstick, then dab some corn starch over the lips, then apply another layer of lipstick. Store in a small glass or plastic container in the refrigerator, tightly covered in a plastic bag.

Face Powder

Use cornstarch from the original box. You may also try arrow root starch or potato starch. Use your fingers or a tissue to apply because applicators can carry bacteria.

Blush (face powder in a cake form)

Add 50% glycerin to cornstarch in a saucer to make a paste. Slowly add beet root powder to the desired color. Use part of a charcoal capsule to darken it, if desired. A drop of food grade alcohol will also darken it. To make 50% glycerin, add equal parts of glycerin and water. Try to make the consistency the same as your brand name product, and you can even put it back in your brand name container.

Recipes For Household Products

Floor Cleaner

Use washing soda from the grocery store. You may add borax and boric acid (to deter insects except ants). Use white distilled vinegar in your rinse water for a natural shine and ant repellent. Do not add bleach to this. For the bathroom floor use plain bleach water—follow the label. Never use chlorine bleach if anybody in the home is ill or suffers from depression. Use grain alcohol (1 pint to 3 quarts water) for germ killing action instead of chlorine.

Furniture Duster and Window Cleaner

Mix equal parts white distilled vinegar and water. Put it in a spray bottle.

Furniture Polish

A few drops of olive oil on a dampened cloth. Use filtered water to dampen.

Insect Killer

Boric acid powder (not borax). Throw liberal amounts behind stove, refrigerator, under carpets and in carpets. Since boric acid is white, you must be careful not to mistake it for sugar accidentally. Keep it far away from food and out of children's reach. Buy it at a farm supply or garden store (or see *Sources*). It will not kill ants.

Ant Repellent

Spray 50% white distilled vinegar on counter tops, window sills and shelves and wipe, leaving residue. Start early in spring before they arrive, because it takes a few weeks to rid yourself of them once they are established. If you want immediate action, get some lemons, cut the yellow outer peel off and cover with grain alcohol in a tightly closed jar. Let stand at least one hour. Use 1 part of this concentrate with 9 parts water in a spray bottle. Mix only as much as you will use because the diluted form loses potency. Spray walls, floors, carpets wherever you see them. The lemon solution even leaves a shine on your counters. Use both vinegar and lemon approaches to rid yourself of ants.

To treat the **whole house**, pour vinegar all around your foundation, close to the wall, using one gallon for every five feet. Expect to damage any foliage it touches. Reapply every six months.

Flower and Foliage Spray

Food-grade hydrogen peroxide. See instructions on bottle.

Moth Balls

I found this recipe in an old recipe book. Mix the following and scatter in trunks and bags containing furs and woolens: ½lb. each rosemary and mint, ¼ lb. each tansy and thyme, 2 tbs. powdered cloves.

Carpet Cleaner

Whether you rent a machine or have a cleaning service, don't use the carpet shampoo they want to sell, even if they "guarantee" that it is all natural and safe. Instead add these to a bucket (about four gallons) of water and use it as the cleaning solution:

Wash water	Rinse water
1/3 cup borax	¼ cup grain alcohol 2 tsp. boric acid ¼ cup white distilled vinegar **or** 4 tsp. citric acid

Borax does the cleaning; alcohol disinfects, boric acid leaves a pesticide residue, and the vinegar or citric acid give luster. If you are just making one pass on your carpet, use the borax, alcohol, and boric acid. Remember to test everything you use on an unnoticed piece of carpet first.

Health Improvement Recipes

Black Walnut Hull Tincture

This new recipe is four times as strong as the previous one, so it is called **Black Walnut Hull Tincture Extra Strength**.

Your largest enamel or ceramic (not stainless steel, not aluminum) cooking pot, preferably at least 10 quarts
Black walnuts, in the hull, each one still at least 50% green, enough to fill the pot to the top
Grain alcohol, about 50% strength, enough to cover the walnuts
½ tsp. vitamin C
Plastic wrap or cellophane
Glass jars or bottles

The black walnut tree produces large green balls in fall. The walnut is inside, but we will use the whole ball, uncracked, since the active ingredient is in the green outer hull.

Rinse the walnuts carefully, put them in the pot, and cover with the alcohol. Sprinkle on half the vitamin C. Seal with plastic wrap and cover. Let sit for three days. Pour into glass jars or bottles, discarding walnuts, and divide the remaining vitamin C amongst the jars. If the glass jar has a metal lid, first put plastic wrap over the top before screwing on the lid. Potency is strong for several years if unopened, even if it darkens.

You have just made Extra Strength Black Walnut Hull Tincture. It is stronger than the concentrate made with just a few black walnuts in a quart jar (my earlier recipe), because there are more walnuts per unit liquid. In addition, you will not dilute it before use (although when you take it, it will usually be in water).

When preparing the walnuts, rinse only with cold tap water. You may need to use a brush on areas with dirt. If you are not going to use all of them in this batch, you may freeze them in a resealable plastic bag. Simply refrigerating them does not keep them from turning black and useless. The pot of soaking walnuts should not be refrigerated. Nor does the final tincture need any refrigeration.

Exposure to air does cause the tincture to darken and lose potency. To reduce air exposure, fill the pot as much as possible, without touching the plastic wrap, while still keeping a snug fitting lid. Even more importantly, the glass jars or bottles you use to store your tincture should have as little air space as possible, without touching the plastic wrap on top. A large jar should be divided into smaller ones when you are ready to use it. The idea is not to have partial jars, with a lot of air space, sitting for longer than a month or so.

There are several ways to make a 50% grain alcohol solution. Some states have Everclear,^{TM} 95% alcohol. Mix this half and half with water. Other states have Everclear that is 76.5% alcohol. Mix this three parts Everclear to one part water. Yet another method is to buy vodka that is 100 proof. This is already 50% alcohol.

Remember, never use any kind of purchased water to make tincture.

Black Walnut Hull Tincture (Regular Strength)

This is the potency I used originally. It is included here in case you prefer it or wish to treat a pet. The Extra Strength recipe is four times as potent as the original recipe, so it must be diluted in quarters. (Similarly, if you have a lot of the Regular Strength left and want to use it in place of Extra Strength, simply take four times as much.)

Black Walnut Hull Tincture Extra Strength
Grain Alcohol, about 10%

Mix one part extra strength tincture with three parts of the 10% alcohol. Store in glass containers same as described above.

There are several ways to make a 10% grain alcohol solution. Some states have Everclear,™ 95% alcohol. Mix this one part Everclear to nine parts water. Other states have Everclear that is 76.5% alcohol. Mix this one part Everclear to seven parts water. Yet another method is to buy vodka that is 100 proof (50% alcohol) and mix one part vodka with four parts water.

Black Walnut Hull Extract (Water Based)

Because you do not know how commercially available extracts were made, and may not be able to test for solvent pollution, it is wisest to make it yourself!

This recipe is intended for alcoholic persons: cover the green balls in the 10 quart (non-metal) pot with cold tap water. Heat to boiling, covered. Turn off heat. When cool, add vitamin C, cover with plastic wrap, and the lid. Let stand for 1 day. It will be darker than the tincture. Do not dilute. Pour into freezable containers. Refrigerate what you will use in two days and freeze the rest. Add vitamin C after thawing or during refrigeration (¼ tsp. per quart).

For use: in programs calling for Extra Strength Black Walnut Hull Tincture use four times as much of this water based recipe (8 tsp. instead of 2 tsp. Extra Strength).

Important Note: do not use bottled or purchased water to make this tincture or you could pollute it with benzene!

Quassia recipe

Add 1/8 cup quassia chips to 3 cups water. Simmer 20-30 minutes. Pour off 1/8 cup now and drink it fresh. Refrigerate remainder. Drink 1/8 cup 4 times/day, until a total of ½cup of chips is consumed. Flavor with spices.

Emmenagogue (Menstrual Period Inducer)

Here are four herbs that can each bring on your period. They can be started anytime but the most-effective time is before your next calculated period time (count days as if you never missed a period).

1 oz sassafras bark
1 oz rue (cut)
1 oz marjoram herb
1 oz blue cohosh root
4½ cups boiling water

Add the herbs to the boiling water and turn down to simmer, covered, for 20 minutes. Do not boil. Strain and refrigerate in sterile glass jar. Pour one cup for yourself in the morning. Let warm to room temperature, and sip between meals, making it last until supper.

Bowel Program

Bacteria are always at the root of bowel problems, such as pain, bloating and gassiness. They can not be killed by zapping, because the high frequency current does not penetrate the bowel contents.

Although most bowel bacteria are beneficial, the ones that are not, like *Salmonellas* and *Shigellas*, are extremely detrimental because they have the ability to invade the rest of your body and colonize a trauma site or weakened organ. These same bacteria colonize a cancer tumor and delay healing after the malignancy is stopped.

Another reason bowel bacteria are so hard to eradicate is that we are constantly reinfecting ourselves by keeping a reservoir on our hands and under our fingernails.

- So the first thing to do is **improve sanitation**. For a serious problem, use 50% grain alcohol (100 proof vodka) in a spray bottle at the bathroom sink. Sterilize your hands after bathroom use and before meals.
- Secondly use **turmeric** (2 capsules 3 times a day, this is the common spice) which I find helps against *Shigella*, as well as *E. coli*. Expect orange colored stool.
- Third use **fennel** (1 capsule 3 times a day).
- Fourth use **digestive enzyme tablets** with meals as directed on the bottle. (But only as long as necessary, because these frequently harbor molds.)
- Fifth use a single 2 tsp. dose of **Black Walnut Hull Tincture Extra Strength**. Add it to a ½glass of water and sip over a 15 minute period. Stay seated until any side effect from the alcohol wears off.
- Sixth take **Cascara sagrada** capsules if constipated (start with one capsule a day, use up to maximum on label). Remember to drink a cup of hot water upon rising in the morning. This will begin to regulate your elimination.

It can take all six to get rid of a bad *Shigella* problem in a week. Afterward, you must continue to eat only sterile dairy products. Note that the Kidney Cleanse is often effective with bowel problems. Try it also.

You will know you succeeded when your tummy is flat, there is not a single gurgle, and your mood improves!

Constipation Tea

Constipation is often caused by *E. coli* and *Salmonella* from dairy foods, or from killing “good” bowel bacteria with antibiotics (killing a few by zapping actually restores good flora). Eat foods that restore the body's good bowel flora: vegetables, sterilized milk (the milk sugar is essential), lots of water.

There are a lot of remedies for constipation, but many people enjoy this tea:

1 tbs. senna tea leaves
½ tsp. mint leaves

Boil for one minute in a quart of water, add a dash of vitamin C and brown sugar to taste. Sip through the day to avoid “bellyache”. It can take years for the body's flora to “right themselves” after an antibiotic session, be patient.

Weight Reduction

Here are two ancient herbal recipes for obesity. I have not personally determined their effectiveness.

Fucus

2 oz *Fucus vesiculosus*, cut (see Sources)
3 cups cold tap water

Boil for 15 minutes, covered. Cool. Dose: ¼ cup four times a day on an empty stomach. After one week increase dose to ½cup. You may add any flavoring desired.

Watch the pot carefully as it comes to a boil. If it boils over, you will have a month of stove-cleaning to do. The odor of *Fucus* boiling is wretched. So is the taste. Maybe garlic (fresh) would improve it.

Fennel

1 oz fennel seed (crushed or powdered is fine)

3 cups cold tap water

Boil water, pour over herb. Steep 30 minutes. Strain. Add 4 oz honey (optional). Drink one cup each day.

You could take them both together, along with the Bowel Program, to be more successful, but the best single weight reducer is the Liver Cleanse.

Kidney Cleanse

½ cup dried Hydrangea root
½ cup Gravel root
½ cup Marshmallow root
4 bunches of fresh parsley
Goldenrod tincture (leave this out of the recipe if you are allergic to it)
Ginger capsules
Uva Ursi capsules
Vegetable glycerin
Black Cherry Concentrate, 8 oz
Vitamin B6, 250 mg
Magnesium oxide tablets, 300 mg

Measure ¼ cup of each root and set them to soak, together in 10 cups of cold tap water, using a non-metal container and a non-metal lid (a dinner plate will do). After four hours (or overnight) add 8 oz. black cherry concentrate, heat to boiling and simmer for 20 minutes. Drink ¼ cup as soon as it is cool enough. Pour the rest through a bamboo strainer into a sterile pint jar (glass) and several freezable containers. Refrigerate the glass jar.

Boil the fresh parsley, after rinsing, in 1 quart of water for 3 minutes. Drink ¼ cup when cool enough. Refrigerate a pint and freeze 1 pint. Throw away the parsley.

Dose: each morning, pour together ¾cup of the root mixture and ½cup parsley water, filling a large mug. Add 20 drops of goldenrod tincture and 1 tbs. of glycerin. Drink this mixture in divided doses throughout the day. Keep cold. Do not drink it all at once or you will get a stomach ache and feel pressure in your bladder. If your stomach is very sensitive, start on half this dose.

Save the roots after the first boiling, storing them in the freezer. After 13 days when your supply runs low, boil the same roots a second time, but add only 6 cups water and simmer only 10 minutes. This will last another 8 days, for a total of three weeks. You may cook the roots a third time if you wish, but the recipe gets less potent. If your problem is severe, only cook them twice.

After three weeks, repeat with fresh herbs. You need to do the Kidney Cleanse for six weeks to get good results, longer for severe problems.

Also take:

- Ginger capsules: one with each meal (3/day).
- Uva Ursi capsules: one with breakfast and two with supper.
- Vitamin B6 (250 mg): one a day.
- Magnesium oxide (300 mg): one a day.

Take these supplements just before your meal to avoid burping.

Some notes on this recipe: this herbal tea, as well as the parsley, can easily spoil. Heat it to boiling every fourth day if it is being stored in the refrigerator; this resterilizes it. If you sterilize it in the morning you may take it to work without refrigerating it (use a glass container).

When you order your herbs, be careful! Herb companies are not the same! These roots should have a strong fragrance. If the ones you buy are barely fragrant, they have lost their active ingredients; switch to a different supplier. Fresh roots can be used. Do not use powder.

- Hydrangea (*Hydrangea arborescens*) is a common flowering bush.
- Gravel root (*Eupatorium purpureum*) is a wild flower.
- Marshmallow root (*Althea officinalis*) is mucilaginous and kills pain.
- Fresh parsley can be bought at a grocery store. Parsley flakes and dried parsley herb do not work.
- Goldenrod herb works as well as the tincture but you may get an allergic reaction from smelling the herb. If you know you are allergic to this, leave this one out of your recipe.
- Ginger from the grocery store works fine; you may put it into capsules for yourself (size 0, 1 or 00).

There are probably dozens of herbs that can dissolve kidney crystals and stones. If you can only find several of those in the recipe, make the recipe anyway; it will just take longer to get results. Remember that vitamin B_6 and magnesium, taken daily, can prevent oxalate stones from forming. But only if you stop drinking tea. Tea has 15.6 mg oxalic acid per cup[37]. A tall glass of iced tea could give you over 20 mg oxalic acid. Switch to herb teas. Cocoa and chocolate, also, have too much oxalic acid to be used as beverages.

Remember, too, that phosphate crystals are made when you eat too much phosphate. Phosphate levels are high in meats, breads, cereals, pastas, and carbonated drinks. Eat less of these, and increase your milk (2%), fruits and vegetables. Drink at least 2 pints of water a day.

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[37] Taken from *Food Values* 14ed by Pennington and Church 1985.

Cleanse your kidneys at least twice a year.

You can dissolve all your kidney stones in 3 weeks, but make new ones in 3 days if you are drinking tea and cocoa and phosphated beverages. None of the beverage recipes in this chapter are conducive to stone formation.

Liver Herbs

Don't confuse these liver herbs with the next recipe for the Liver Cleanse. This recipe contains herbs traditionally used to help the liver function, while the Liver Cleanse gets gallstones out.

6 parts comfrey root, *Symphytum officinale* (also called nipbone root)
6 parts tanner's oak bark, *Quercus alba* (white oak bark)
3 parts gravel root, *Eupatorium purpureum* (queen of the meadow)
3 parts Jacob's staff, *Verbascum thapsus* (mullein herb)
2 parts licorice root, *Glycyrrhiza glabra*
2 parts wild yam root, *Dioscorea villosa*
2 parts milk thistle herb, *Silybum marianum*
3 parts walnut bark, *Juglans nigra*, (black walnut bark)
3 parts marshmallow root, *Althea officinalis* (white mallow)
1 part lobelia plant, *Lobelia inflata* (bladder pod)
1 part skullcap, *Scutellaria lateriflora* (helmet flower)

Mix all the herbs. Add ½cup of the mixture to 2 quarts of water. Bring to a boil. Put lid on. Let sit for six hours. Strain and drink 1½cups per day. Put the strained herbs in the freezer and use them one more time.

Liver Cleanse

Cleansing the liver of gallstones dramatically improves digestion, which is the basis of your whole health. You can expect your allergies to disappear, too, more with each cleanse you do! Incredibly, it also eliminates shoulder, upper arm, and upper back pain. You have more energy and increased sense of well being.

Cleaning the liver bile ducts is the most powerful procedure that you can do to improve your body's health.

But it should not be done before the parasite program, and for best results should follow the kidney cleanse and any dental work you need.

It is the job of the liver to make bile, 1 to l½quarts in a day! The liver is full of tubes (*biliary tubing*) that deliver the bile to one large tube (the *common bile duct*). The gallbladder is attached to the common bile duct and acts as a storage reservoir. Eating fat or protein triggers the gallbladder to squeeze itself empty after about twenty minutes, and the stored bile finishes its trip down the common bile duct to the intestine.

For many persons, including children, the biliary tubing is choked with gallstones. Some develop allergies or hives but some have no symptoms. When the gallbladder is scanned or X-rayed nothing is seen. Typically, they are not in the gallbladder. Not only that, most are too small and not calcified, a prerequisite for visibility on X-ray. There are over half a dozen varieties of gallstones, most of which have cholesterol crystals in them. They can be black, red, white, green or tan colored. The green ones get their color from being coated with bile. Notice in the picture how many have imbedded unidentified objects. Are they fluke remains? Notice how many are shaped like corks with longitudinal grooves below the tops. We can visualize the blocked bile ducts from such shapes. Other stones are composites–made of many smaller ones–showing that they regrouped in the bile ducts some time after the last cleanse.

At the very center of each stone is found a clump of bacteria, according to scientists, suggesting a dead bit of parasite might have started the stone forming.

As the stones grow and become more numerous the back pressure on the liver causes it to make less bile. Imagine the situation if your garden hose had marbles in it. Much less water would flow, which in turn would decrease the ability of the hose to squirt out the marbles. With gallstones, much less cholesterol leaves the body, and cholesterol levels may rise.

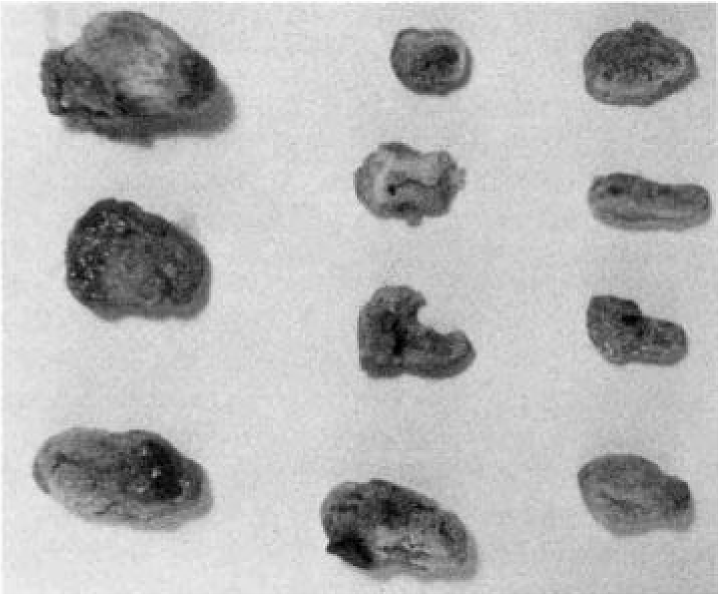

Fig. 89 These are gallstones.

Gallstones, being porous, can pick up all the bacteria, cysts, viruses and parasites that are passing through the liver. In this way "nests" of infection are formed, forever supplying the body with fresh bacteria. No stomach infection such as ulcers or intestinal bloating can be cured permanently without removing these gallstones from the liver.

Cleanse your liver twice a year.

Preparation.

- You can't clean a liver with living parasites in it. You won't get many stones, and you will feel quite sick. Zap daily the week before, or get through the first three weeks of the parasite killing program before attempting a liver cleanse. If you are on the maintenance parasite program, you are always ready to do the cleanse.
- Completing the kidney cleanse before cleansing the liver is also highly recommended. You want your kidneys, bladder and urinary tract in top working condition so they can efficiently remove any undesirable substances incidentally absorbed from the intestine as the bile is being excreted.
- Do any dental work first, if possible. Your mouth should be metal free and bacteria free (cavitations are cleaned). A toxic mouth can put a heavy load on the liver, burdening it immediately after cleansing. Eliminate that problem first for best results.

Ingredients

Epsom salts	4 tablespoons
Olive oil	half cup (light olive oil is easier to get down)
Fresh pink grapefruit	1 large or 2 small, enough to squeeze 2/3 to 3/4 cup juice

Ornithine	4 to 8, to be sure you can sleep. Don't skip this or you may have the worst night of your life!
Large plastic straw	To help drink potion.
Pint jar with lid	

Choose a day like Saturday for the cleanse, since you will be able to rest the next day.

Take no medicines, vitamins or pills that you can do without; they could prevent success. Stop the parasite program and kidney herbs, too, the day before.

Eat a no-fat breakfast and lunch such as cooked cereal with fruit, fruit juice, bread and preserves or honey (no butter or milk), baked potato or other vegetables with salt only. This allows the bile to build up and develop pressure in the liver. Higher pressure pushes out more stones.

2:00 PM. Do not eat or drink after 2 o'clock. If you break this rule you could feel quite ill later.

Get your Epsom salts ready. Mix 4 tbs. in 3 cups water and pour this into a jar. This makes four servings, ¾cup each. Set the jar in the refrigerator to get ice cold (this is for convenience and taste only).

6:00 PM. Drink one serving (¾cup) of the ice cold Epsom salts. If you did not prepare this ahead of time, mix 1 tbs. in ¾cup water now. You may add 1/8 tsp. vitamin C powder to improve the taste. You may also drink a few mouthfuls of water afterwards or rinse your mouth.

Get the olive oil and grapefruit out to warm up.

8:00 PM. Repeat by drinking another ¾cup of Epsom salts.

You haven't eaten since two o'clock, but you won't feel hungry. Get your bedtime chores done. The timing is critical for success; don't be more than 10 minutes early or late.

9:45 PM. Pour ½cup (measured) olive oil into the pint jar. Squeeze the grapefruit by hand into the measuring cup. Remove pulp with fork. You should have at least ½cup, more (up to ¾ cup) is best. You may top it up with lemonade. Add this to the olive oil. Close the jar tightly with the lid and shake hard until watery (only fresh grapefruit juice does this).

Now visit the bathroom one or more times, even if it makes you late for your ten o'clock drink. Don't be more than 15 minutes late.

10:00 PM. Drink the potion you have mixed. Take 4 ornithine capsules with the first sips to make sure you will sleep through the night. Take 8 if you already suffer from insomnia. Drinking through a large plastic straw helps it go down easier. You may use ketchup, cinnamon, or brown sugar to chase it down between sips. Take it to your bedside if you want, but drink it standing up. Get it down within 5 minutes (fifteen minutes for very elderly or weak persons).

Lie down immediately. You might fail to get stones out if you don't. The sooner you lie down the mote stones you will get out. Be ready for bed ahead of time. Don't clean up the kitchen. As soon as the drink is down walk to your bed and lie down flat on your back with your head up high on the pillow. Try to think about what is happening in the liver. Try to keep perfectly still for at least 20 minutes. You may feel a train of stones traveling along the bile ducts like marbles. There is no pain because the bile duct valves are open (thank you Epsom salts!). **Go to sleep**, you may fail to get stones out if you don't.

Next morning. Upon awakening take your third dose of Epsom salts. If you have indigestion or nausea wait until it is gone before drinking the Epsom salts. You may go back to bed. Don't take this potion before 6:00 am.

2 Hours Later. Take your fourth (the last) dose of Epsom salts. Drink ¾cup of the mixture. You may go back to bed.

After 2 More Hours you may eat. Start with fruit juice. Half an hour later eat fruit. One hour later you may eat regular food but keep it light. By supper you should feel recovered.

How well did you do? Expect diarrhea in the morning. Use a flashlight to look for gallstones in the toilet with the bowel movement. Look for the green kind since this is proof that they are genuine gallstones, not food residue. Only bile from the liver is pea green. The bowel movement sinks but gallstones float because of the cholesterol inside. Count them all roughly, whether tan or green. You will need to total 2000 stones before the liver is clean enough to rid you of allergies or bursitis or upper back pains permanently. The first cleanse may rid you of them for a few days, but as the stones from the rear travel forward, they give you the same symptoms again. You may repeat cleanses at two week intervals. Never cleanse when you are ill.

Sometimes the bile ducts are full of cholesterol crystals that did not form into round stones. They appear as a "chaff" floating on top of the toilet bowl water. It may be tan colored, harboring millions of tiny white crystals. Cleansing this chaff is just as important as purging stones.

How safe is the liver cleanse? It is very safe. My opinion is based on over 500 cases, including many persons in their seventies and eighties. None went to the hospital; none even reported pain. However it can make you feel quite ill for one or two days afterwards, although in every one of these cases the maintenance parasite program had been neglected. This is why the instructions direct you to complete the parasite and kidney rinse programs first.

CONGRATULATIONS

You have taken out your gallstones without surgery! I like to think I have perfected this recipe, but I certainly can not take credit for its origin. It was invented hundreds, if not thousands, of years ago, THANK YOU, HERBALISTS!

This procedure contradicts many modern medical viewpoints. Gallstones are thought to be formed in the gallbladder, not the liver. They are thought to be few, not thousands. They are not linked to pains other than gallbladder attacks. It is easy to understand why this is thought: by the time you have acute pain attacks, some stones are in the gallbladder, are big enough and sufficiently calcified to see on X-ray, and have caused inflammation there. When the gallbladder is removed the acute attacks are gone, but the bursitis and other pains and digestive problems remain.

The truth is self-evident. People who have had their gallbladder surgically removed still get plenty of green, bile-coated stones, and anyone who cares to dissect their stones can see that the concentric circles and crystals of cholesterol match textbook pictures of "gallstones" exactly.

Lugol's Iodine Solution

It is too dangerous to buy a commercially prepared solution. It is certain to be polluted with propyl alcohol or wood alcohol. Make it yourself or ask your pharmacist to make it up for you. The recipe to make 1 liter (quart) is:

44 gm (1½ ounces) iodine, granular
88 gm (3 ounces) potassium iodide, granular

Dissolve the potassium iodide in about a pint of the water. Then add the iodine crystals and fill to the liter mark with water. It takes about 1 day to dissolve completely. Shake it from time to time. Keep out of sight and reach of children. Do not use if allergic to iodine. Be careful to avoid bottled water for preparation.

Vitamin D Drops

1 gram cholecalciferol (see Sources)
10 cups olive oil

Mix in a non-metal container. It may take a day of standing to dissolve fully. Refrigerate. Ten drops contain 40,000 iu. Use within a year.

Pathogen Frequencies

Living creatures emit a range of frequencies, also called *bandwidth*. As they age, the bandwidth shrinks. When they die sometimes all that is left is a single frequency.

Most of the organisms listed below are dead on commercially available and prepared slides (see *Sources* for biological supply companies). However they still exhibit a 5 KHz bandwidth, probably due to testing with a frequency generator that was only accurate to 100 Hz, and also due to using more voltage than necessary (like when a powerful radio station comes in at its own frequencies and ones nearby, too). Some testing was done with a more accurate frequency generator at a lower power level so some bandwidths are reported much more narrowly.

If the same person retests the same specimens with the same equipment within a few days, the results will be absolutely identical (within 1 Hz) 90% of the time. Why a few of the results will not be identical is not known. However different people, and even the same person at different times of the year, can notice that the perceived frequencies shift by as much as 3 KHz (still less than 1% change).

Some specimens have more than one range listed; this may be characteristic of the organism or may be due to having an undocumented organism on the same microscope slide.

Blank locations represent organisms for whom there are prepared slides available, but whose bandwidth has not been determined.

Bandwidth Of Organism Families

In general, the smaller the organism the lower the frequency and narrower the bandwidth. This chart shows the major families studied and where they fall in the spectrum.

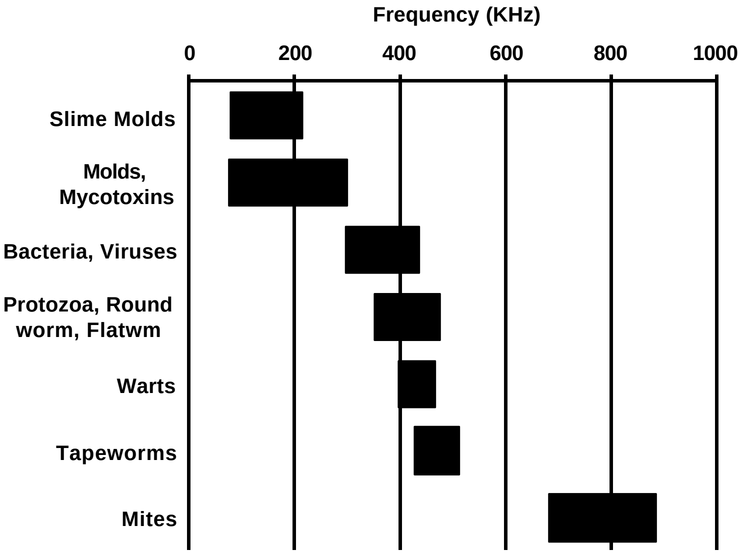

Fig. 90 Chart of bandwidths for organism families.

Mold, Mold Toxin Frequencies

Other molds and mold toxins	**KHz**
Aflatoxin	177,188
Cytochalasin B	77,91
Ergot	295
Griseofulvin	288
Sorghum syrup	277
Sterigmatocystin	88,96,133,126
Zearalenone	100

Slime Molds	**KHz**
Arcyria	81
Lycogala	126
Stemonitis	211

Bacteria and Viruses

Including locations where I commonly found them.

	Low Freq (KHz)	High Freq (KHz)	Use freq gen for 3 min @
Acetobacter aceti			
Adenovirus	393	393	393
Adenovirus (2nd range)	371.45	386.90	
Agrobacterium tumefaciens			
Alcaligenes faecalis			
Alpha streptococcus	369.75	385.4	380,375
Azobacter chroococcum			
Bacillus anthracis causes anthrax in cattle (tooth)	393.5	398.05	395,364,368
Bacillus anthracis (2nd range)	363.2	365.3	
Bacillus anthracis (3rd range)	359.4	370.5	
Bacillus anthracis spores	386.95	391.45	388
Bacillus cereus	373.65	375.85	374.5
Bacillus megaterium			
Bacillus sterothermophilus			
Bacillus subtilis spores			
Bacillus subtilis var. niger	371.85	387.1	385,380,375
Bacteria capsules (capsular strain)	416.05	418.75	417.5
Bacterial capsules	357.6	362.4	360
Bacteroides fragilis found with common roundworm Ascaris	324.3	325.0	325
Bacteroides fragilis (2nd range)	325.7	326.0	
Beta streptococcus (tooth)	380.6	387.4	385
Blepharisma	405.65	407.45	406.5
Bordetella pertussis “whooping cough” (tooth)	329.85	332.25	331
Borellia burgdorferi Lyme disease	378.95	382.0	380
Branhamella (Neisseria) catarrhalis (has hole at 398)	394.9	396.7	396
Brucella abortus			
Cabbage Black Rot			
Campylobacter fetus smear	365.3	370.6	368
Campylobacter pyloridis	352.0	357.2	355
Candida albicans (pure powder) common yeast	384.2	388.4	386
Caulobacter vibrioides			
Central spores (bacillus smear)	372.45	378.65	376
Chlamydia trachomatis	379.7	383.95	381
Clostridium acetobutylicum	382.8	391.15	389,384
Clostridium botulinum (tooth) causes food poisoning	361.0	364.55	362

Clostridium perfringens			
Clostridium perfringens spores	394.2	398.1	396
Clostridium septicum	362.05	365.6	364
Clostridium sporogenes			
Clostridium tetani (tooth) causes tetanus			
Corynebacterium diphtheriae (tooth) causes diphtheria	340	344	342
Corynebacterium pseudodiphthericum			
Corynebacterium xerosis	315.65	316.8	316.0
Coxsackie virus B-1 found with Bacteroides fragilis	360.5	366.1	364
Coxsackie virus B-4 found with Bacteroides fragilis	361.45	363.7	362.5
Coxsackie virus B-4 (2nd range)	363.9	364.9	
Crithidia fasciculata			
Cytomegalovirus (CMV) antigen	408.35	410.75	409
Cytophaga rubra	428.1	432.2	430
Diplococcus diphtheriae	357.95	264.0	361
Diplococcus pneumoniae	351.65	368.45	365,360
Eikanella corrodens	379.5	384.3	382
Enterobacter aerogenes intestinal bacterium	374	374	374
Epstein Barre virus (EBV)	372.5	382.85	380,375
Erwinia amylovora	347.2	352.1	350
Erwinia carotovora	368.1	377.0	373
Escherichia coli (E. coli) intestinal bacterium	356	356	356,393
Escherichia coli (E. coli) (2nd range)	392	393	
Gaffkya tetragena causes respiratory infections	344.85	352.5	350
Gardnerella vaginalis ovarian and genital tract infection	338.0	342.55	340
Haemophilus influenzae bacterial meningitis, infects joints	336.41	336.41	336
Hepatitis B antigen	414.55	420.8	418
Herpes simplex 1	291.25	293.05	292,345.5
Herpes simplex 1 (2nd range)	345.35	345.75	
Herpes simplex 2 (fresh smear)	353.9	362.9	360,355
Herpes Zoster “shingles”	416.6	420.2	418
Histomonas meleagridis (liver)	376.55	378.7	377
Histoplasma capsulatum	298.3	304.85	302
HIV	365	365	365
Influenza A and B (flu shot)	313.35	323.9	320,315
Iron Bacterium Sphaerotilus			
Klebsiella pneumoniae causes pneumonia	398.45	404.65	401,419
Klebsiella pneumoniae (2nd range)	416.9	421.9	
Lactobacillus acidophilus (tooth)	346.05	351.65	349

Leptospira interrogans spirochete	397.05	401.1	399
Lumpy Jaw			
Measles antigen	369.5	373.0	371
Micrococcus luteus			
Micrococcus roseus			
Mumps antigen	377.6	384.65	382
Mycobacterium para TB			
Mycobacterium phlei	409.65	410.65	410.0
Mycobacterium smegmatis			
Mycobacterium tuberculosis (infec nodule) causes tuberculosis	430.55	434.2	432
Mycoplasma	322.85	323.9	323.5,346
Mycoplasma (range 2)	342.75	349.3	
Neisseria gonorrhea causes gonorrhea	333.85	336.5	334
Neisseria sicca			
Nocardia asteroides found in Parkinson's Disease	354.95	355.35	355.1,368
Nocardia asteroides (2nd range)	363.7	370	
Propionobacterium acnes	383.75	389.0	387
Proteus mirabilis	320.55	326.0	324,349
Proteus mirabilis (2nd range)	345.95	352.1	
Proteus vulgaris urinary tract pathogen	408.75	416.45	413,336,328
Proteus vulgaris (2nd range)	333.75	339.15	
Proteus vulgaris (3rd range)	327.2	329.5	
Pseudomonas aeruginosa found in open wounds	331.25	334.6	333
Pseudomonas fluorescens			
Respiratory syncytial virus	378.95	383.15	380
Rhizobium leguminosarum			
Salmonella enteriditis intestinal infection	329	329	329
Salmonella paratyphi	365.05	370.1	368,385
Salmonella typhimurium food poisoning, nervousness, apathy	382.3	386.55	355,386,390
Serratia marcescens	349.45	352.1	351
Shigella dysenteriae intestinal problems	390.089	390.089	390.089
Shigella flexneri depression	394	394	394
Shigella sonnei invades tumors	318	318	318
Sphaerotilus natans	388.4	393.45	391
Spirillum itersonil			
Spirillum serpens	378.35	382.8	380
Spirillum sinuosum			
Spirillum volutans			
Spores in bacteria spore stain			
Staphylococcus aureus (culture)	376.27	380.85	
Staphylococcus aureus (slide) source is tooth infection, causes abscesses, heart disease, invades tumors	381	381	378,381

Staphylococcus epidermidis infects skin and mucous membranes			
Streptococcus lactis occurs in milk	382	387	385
Streptococcus mitis lung infection, tooth infection, abscesses, causes stiff knees	313.8	321.1	318
Streptococcus pneumoniae causes pneumonia and inner ear disease	366.85	370.2	368
Streptococcus pyogenes (tooth)	360.5	375.3	373
Streptococcus sp. group G (tooth)	368.15	368.85	368
Sub terminal spores bac. smear	385.15	385.95	
Terminal spores bacillus smear			
Tobacco mosaic virus (tobacco)	427.15	429.55	428
Treponema pallidum causes syphilis	346.85	347.4	347
Troglodytella abrassari	377.75	385.2	383,419
Troglodytella abrassari (2nd range)	416.9	422.2	
Veillonella dispar	401.75	405.2	403
Vibrio (photobacterium) fischeri			

Roundworms, Flatworms, One-celled Animals

	Low Freq (KHz)	**High Freq (KHz)**	**To kill, use freq. gen for 3 min. at these frequencies**
Acanthamoeba culbertsoni			
Acanthocephala			
Anaplasma marginale	386.4	388.0	387,422
Anaplasma marginale (2nd range)	415.3	424	
Ancylostoma braziliense (adult)	397.6	403.25	401
Ancylostoma caninum	383.1	402.9	400,393,386
Ancylostoma duodenale male			
Anguillula aceti			
Ascaris larvae in lung common roundworm of cats and dogs	404.9	409.15	408
Ascaris lumbricoides (m and f)			same
Ascaris megalocephala (male)	403.85	409.7	408
Babesia bigemina			
Babesia canis smear			
Balantidium coli cysts	458.8	462.9	460
Balantidium sp. trophozoites (from guinea pig) parasitic ciliate			
Besnoitia (lung sect.) protozoan	352.8	361.4	358

Capillaria hepatica (liver sect.)	424.25	430.65	428
Chilomastix cysts (rat)	388.95	390.7	389,426
Chilomastix cysts (rat) (2nd range)	425.2	427.3	
Chilomastix mesnili (trophozoites)			same
Chilomonas, whole mount	393.75	400	398
Clinostomum metacercaria			
Clonorchis metacercariae			
Clonorchis sinensis	425.7	428.75	427
Clonorchis sinensis eggs			
Cryptocotyle lingua (adult)	409.95	416.0	414
Didinium			
Dientamoeba fragilis	401.35	406.05	404
Dipetalonema perstans (microfilaria human blood)			
Dirofilaria immitis dog heartworm	408.15	411.15	409
Echinoporyphium recurvatum	418.55	423.9	421
Echinostoma revolutum	425.5	429.65	428
Eimeria stiedae			
Eimeria tenella			
Endamoeba gingivalis trophozoite	433.8	441.0	438
Endolimax nana trophozoites and cysts	394.25	397.1	396,432
Endolimax nana trophozoites and cysts (2nd range)	430.5	433.35	
Entamoeba coli cysts			
Entamoeba coli trophozoites	397.0	400.35	398
Entamoeba histolytica trophozoite	381.1	387.8	385
Enterobius vermicularis	420.95	426.3	423
Eurytrema pancreaticum	420.35	422.3	421
Eurytrema pancreaticum stages			
Fasciola hepatica	421.35	427.3	425
Fasciola hepatica cercariae	423.8	430.6	427
Fasciola hepatica eggs	422.0	427.6	425
Fasciola hepatica metacercariae			
Fasciola hepatica miracidia	421.75	424.7	423
Fasciola hepatica rediae	420.6	427.5	425
Fasciolopsis buskii adult	427.7	435.1	434
Fasciolopsis buskii eggs	427.35	435.45	434
Fasciolopsis buskii eggs unincubated			
Fasciolopsis cercariae	429.5	436.25	434
Fasciolopsis miracidia	427.35	435.2	434
Fasciolopsis rediae	427.3	433.0	432
Fischoedrius elongatus	441.75	443.2	442
Gastrothylax elongatus	451.9	457.1	455
Giardia lamblia (trophozoites)	421.4	426.3	424
Giardia lamblia cysts			
Gyrodactylus	378.75	381.8	380
Haemonchus contortus	386.8	395.5	393
Haemoproteus			

Hasstile sig. tricolor (adult)	448.05	455.1	453
Heterakis			
Hypodereum conoideum	424.45	429.55	427
Iodamoeba butschlii trophozoites and cysts	437.85	448.5	445,402
Iodamoeba butschlii trophozoites and cysts (2nd range)	398.15	404.75	
Leishmania braziliensis	400.05	405.1	403
Leishmania donovani	398.0	402.65	400
Leishmania mexicana	400.2	403.8	402
Leishmania tropica	402.1	407.4	405
Leucocytozoon	397.45	402.55	400
Loa loa	360.551	360.551	361
Macracanthorhynchus	438.85	442.8	440
Metagonimus Yokogawai	437.35	442.1	440
Monocystis agilis			
Myxosoma	409.6	416.95	414
Naegleria fowleri	356.9	364.35	362
Naegleria fowleri (brain sec.)			
Necator americanus (infect larvae)			
Notocotylus quinqeserialis			
Onchocerca volvulus (tumor)	436.3	442.1	440
Paragonimus Westermanii adult	437.8	454.2	452,447
Passalurus ambiguus	428.8	444.15	441,437
Pelomyxa carolinensis			
Plasmodium cynomolgi	417.3	424.5	422
Plasmodium falciparum smear	372.3	373.8	373.0
Plasmodium vivax smear	438.15	445.1	442
Platynosomum fastosum adult			
Pneumocystis carnii (lung)	405.75	409.15	407
Prosthogonimus macrorchis(eggs)	396.85	404.75	401
Sarcina lutea			
Sarcocystis	450.55	454.95	452
Schistosoma haematobium	473	473	473
Schistosoma japonicum eggs			
Schistosoma mansoni	353	353	353
Stephanurus dentalus (ova)	457.35	463.1	461
Stigeoclonium	404.25	415.25	412,407
Strongyloides (filariform larva)	398.4	402.0	400
Strongyloides parasitic females			
Toxocara (eggs)			
Toxoplasma (human strain)	395.0	395.0	395
Trichinella spiralis (muscle)	403.85	405.57	404.5
Trichomonas muris			
Trichomonas vaginalis	378.0	383.6	381
Trichuris sp. (male)	388.3	408.9	406
Trypanosoma brucei	423.2	431.4	429
Trypanosoma cruzi (brain tissue)	460.2	465.65	463

Trypanosoma equiperdum	434.6	451.25	448,442,438
Trypanosoma gambiense	393.75	398.7	396
Trypanosoma lewisi (blood smear)	424.5	426.0	425
Trypanosoma rhodesiense	423.5	428.55	426
Urocleidus	442.35	450.0	447

Wart Frequencies

(Most of these are from homemade slides.)

	Low Freq	**High Freq**	**Use freq gen for 3 min @**
Wart BS	402	406	404
Wart CC	426	432.35	430
Wart FR	459.3	464.75	462
Wart HA	434.8	444.1	442,437
Wart HRCm	438.9	448.55	446,441
Wart human papilloma plantar	404.7	406.75	405
Wart human papilloma virus	402.85	410.7	407
Wart JB	418.75	422.4	420
Wart L arm	343.65	345.95	344
Wart papilloma cervix smear	404.05	404.6	404.3

Tapeworms

Tapeworms are segmented. The first segment is the head, called the *scolex*. Tapeworms grow by adding a new segment to their body.

Tapeworms can have very large bandwidths (range of frequencies), and it varies by the length of the specimen! It is as if each new segment has a unique, and slightly lower, frequency.

Do not use a frequency generator to kill tapeworms. If you accidentally kill middle segments instead of working your way up from the bottom, you may conceivably promote dispersion! Use only a zapper.

	Low Freq	High Freq
Cysticercus fasciolaris	436.4	440.05
Diphyllobothrium erinacei (Mansoni) (scolex)	467.25	487.55
Diphyllobothrium erinacei eggs		
Diphyllobothrium latum (scolex)	452.9	472.3
Dipylidium caninum (proglottid composite)	439.55	444.3
Dipylidium caninum (scolex)	451.95	472.15
Echinococcus granulosus	451.6	461.5
Echinococcus granulosus (cysts)	441.15	446.5
Echinococcus granulosus (eggs)		
Echinococcus multilocularis	455.85	458.35
Heterophyes heterophyes		
Hymenolepis cysticercoides	478.0	481.75
Hymenolepis diminuta	445	481.15
Hymenolepis diminuta ova		
Hymenolepis nana eggs		
Moniezia (scolex)	430.35	465.2
Moniezia expansa (composite)	430.35	465.2
Moniezia expansa eggs		
Multiceps serialis	453.6	457.8
Pigeon tapeworm		
Taenia pisiformis (cysticercus)	475.2	482.1
Taenia pisiformis eggs (ova)	465.2	469.7
Taenia saginata (cysticercus)	476.5	481.05
Taenia saginata eggs		
Taenia solium (cysticercus)	475	475
Taenia solium (scolex)	444.0	448.9
Taenia solium eggs		

Mite Frequencies

These are the organisms that cold viruses ride in with!

Mite	**KHz**
Demodex folliculorum follicle mite	682
Dermatophagoides dust mite	707
Meal mite	718
Ornithonyssus bird mite	877,878
Sarcoptes scabei itch	735

Miscellaneous Frequencies

	KHz
Blue-green Algae	256
Bryozoa cristatalla	396
Mucor mucedo	288
Rhizobium meliloti	330
Rotifer	1151

It's easy to make homemade slides when you or a family member is ill. Finding out the frequencies of these illnesses helps you identify them (use the Pathogen Frequency Chart) and also lets you know if you are chronically getting them back.

Unidentified pathogens	**Low Freq**	**High Freq**
A cold virus HRC	395.8	395.8
Fungus EW	362.0	364.9
Fungus JWB	397.2	400.75
Tooth decay	384.3	387.2
Tooth decay (N)	367.9	375.05
Tooth decay (N) (2nd range)	326.95	331.5
Tooth decay (N) (3rd range)	293.2	297.4
Tooth plaque I	378.8	383.05
Tooth plaque I (2nd range)	294.7	298.25
Tooth plaque I (3rd range)	233.1	238.2
Tooth plaque II	384.95	387.05
Tooth plaque II (2nd range)	278.75	284
Tooth plaque II (3rd range)	212.15	218
Tooth plaque II (4th range)	340.15	344.8
Tooth plaque II (5th range)	305.5	310.35

Toxic Elements

Although not living, solvents and toxins must exhibit characteristic frequencies, otherwise how could the Syncrometer detect specific ones? This needs further exploration.

Most of the toxic elements I use are metals, heavy metals and lanthanides. But some are not; examples are PCBs and formaldehyde.

Some important elements are missing, like iron, zinc and manganese. This is because I never could find them present in the white blood cells, and I finally gave up searching for them.

Below is a list of the 70 or so toxic elements I use. Most of them were obtained as Atomic Absorption Standard Solutions and are, therefore, very pure. This prevents mistakes in identifying a toxin. They were stored in ½ounce amber glass bottles with bakelite caps and permanently sealed with plastic film since testing did not require them to be opened (they get close enough to the frequency field). The exact concentration and the solubility characteristics are not important in this qualitative test. The main sources of these substances in our environment are given beside each item.

Toxic Substance	Sources
Aflatoxin B	beer, bread, apple cider vinegar, moldy fruit, nuts
Aluminum	cookware, deodorant, lotions, soaps
Aluminum silicate	salt, water softener
Antimony	fragrance in lotions, colognes
Arsenic	pesticide, “treated” carpet, wallpaper
Asbestos	clothes dryer belt, hair blower, paint on radiators
Barium	lipstick, bus exhaust
Benzalkonium chloride	toothpaste
3,4 Benzopyrene	flame cooked foods, toast
4,5 Benzopyrene	flame cooked foods, toast
Beryllium	hurricane lamps, gasoline, dentures, kerosene
Bismuth	colognes, lotions, antacids
Boron	
Bromine	bleached “brominated” flour
Cadmium	galvanized water pipes, old tooth fillings
Cerium	tooth fillings
Cesium	clear plastic bottles used for beverages
Chlorine	from Chlorox™ bleach
Chromium	cosmetics, water softener
Cobalt	detergent, blue and green body products
Copper	tooth fillings, water pipes
Dysprosium	paint and varnish
Erbium	packaging for food, pollutant in pills
Europium	tooth fillings
Europium oxide	tooth fillings, catalytic converter

Fiberglass	dust from remodeling or building insulation
Formaldehyde	foam in mattresses and furniture, paneling
Gadolinium	tooth fillings
Gallium	tooth fillings
Germanium	with thallium in tooth fillings (pollutant)
Gold	tooth fillings
Hafnium	hair spray, nail polish, pollutant in pills
Holmium	usually found in presence of PCBs
Indium	tooth fillings
Iridium	tooth fillings
Lanthanum	computer and printing supplies
Lead	solder joints in water pipes
Lithium	printing supplies
Lutetium	paint and varnish
Mercury	tooth fillings
Molybdenum	auto supplies
Neodymium	pollutant in pills
Nickel	tooth fillings, metal glasses frames
Niobium	pollutant in pills, foil packaging for food
Palladium	tooth fillings
Platinum	tooth fillings
Polychlorinated biphenyl PCB	detergent, hair spray, salves
Polyvinyl chloride acetate (PVC)	glues, building supplies, leaking cooling system
Praseodymium	pollutant in pills
Radon	cracks in basement cement, water pipes
Rhenium	spray starch
Rhodium	tooth fillings
Rubidium	tooth fillings
Ruthenium	tooth fillings
Samarium	tooth fillings
Scandium	tooth fillings
Selenium	
Silver	tooth fillings
Sodium fluoride	toothpaste
Strontium	toothpaste, water softener
Tantalum	tooth fillings
Tellurium	tooth fillings
Terbium	pollutant in pills
Thallium acetate	pollutant in mercury tooth fillings
Thorium nitrate	earth (dust)
Thulium	pollutant in many brands of Vitamin C
Tin	toothpaste
Titanium	tooth fillings, body powder
Tungsten	electric water heater, toaster, hair curler
Uranium acetate	earth (dust)
Vanadium pentoxide	gas leak in home, candles (not necessarily lit)

Ytterbium	pollutant in pills
Yttrium	pollutant in pills
Zirconium	deodorant, toothpaste

Solvents

This is a list of all the solvents I use together with the main source of them in our environment. These are chemicals, very pure, obtained from chemical supply companies, unless otherwise stated. Those marked with an asterisk (*) were the subject of a recent book *The Neurotoxicity of Solvents* by Peter Arlien-Soburg, 1992, CRC Press.

Solvent	**Source**
1,1,1, Trichloro ethane* (TCE)	flavored foods
2,5-Hexane dione*	flavored foods
2 Butanone* (methyl ethyl ketone)	flavored foods
2 Hexanone* (methyl butyl ketone)	flavored foods
2 Methyl propanol	
2 Propanol (propyl alcohol)	see the propyl alcohol list
Acetone	store-bought drinking water, cold cereals, pet food, animal feed
Acetonylacetone (2,5 hexanedione)	flavored foods
Benzene	see the benzene list (page 354)
Butyl nitrite	
Carbon tetrachloride	store-bought drinking water, cold cereals, pet food, animal feeds
Decane	health food cookies and cereals
Denatured alcohol	obtained from pharmacy
Dichloromethane* (methylene chloride)	store-bought orange juice, herb tea blends
Gasoline regular leaded	obtained at gasoline station
Grain alcohol	95% ethyl alcohol obtained at liquor store
Hexanes*	decaffeinated beverages
Isophorone	flavored foods
Kerosene	obtained at gasoline station
Methanol (wood alcohol)	colas, artificial sweeteners, infant formula
Mineral oil	lotions

Mineral spirits	obtained from paint store
Paradichlorobenzene	mothballs
Pentane	decaffeinated beverages
Petroleum ether	in some gasolines
Styrene*	styrofoam dishes
Toluene*	store-bought drinking water, cold cereals
Trichloroethylene* (TCEthylene)	flavored foods
Xylene*	store-bought drinking water, cold cereals

Pathogen Frequency Chart

Use this chart if you know the frequency and wonder what the pathogen might be.

KHz

Pathogen	Low	High	5	0			1	0	0			1	5	0			2	0	0			2	5	0			3	0	0			3	5	0
Cytochalasin B	77.00	77.00			m																													
Arcyria	81.00	81.00				s																												
Sterigmatocystin	88.00	88.00				m																												
Cytochalasin B (2nd)	91.00	91.00					m																											
Sterigmatocystin (2nd)	96.00	96.00					m																											
Zearalenone	100.00	100.00						m																										
Lycogala	126.00	126.00								s																								
Sterigmatocystin (4th)	126.00	126.00								m																								
Sterigmatocystin (3rd)	133.00	133.00									m																							
Aflatoxin	177.19	177.19													m																			
Stemonitis	211.00	211.00																s																
Sorghum syrup	277.00	277.00																						m										
Griseofulvin	288.00	288.00																							m									
Herpes simplex 1	291.25	293.05																								v								
Ergot	295.00	295.00																								m								
Histoplasma capsulatum	298.30	304.85																								b	b							
Corynebacterium xerosis	315.65	316.80																										b						
Shigella sonnei	318.00	318.00																										b						
Streptococcus mitis	313.80	321.10																										b	b					
Influenza A and B (flu sho	313.35	323.90																										v	v					
Mycoplasma	322.85	323.90																											b					
Bacteroides fragilis	324.30	325.00																											b					
Proteus mirabilis	320.55	326.00																											b					
Bacteroides fragilis (2nd)	325.70	326.00																											b					
Salmonella enteriditis	329.00	329.00																											b					
Proteus vulgaris (3rd)	327.20	329.50																											b					
Bordetella pertussis	329.85	332.25																											b	b				
Pseudomonas aeruginos	331.25	334.60																												b				
Haemophilus influenzae	336.41	336.41																												b				
Neisseria gonorrhea	333.85	336.50																												b				
Proteus vulgaris (2nd)	333.75	339.15																												b				
Gardnerella vaginalis	338.00	342.55																												b	b			
Corynebacterium diphthe	340.00	344.00																													b			
Herpes simplex 1 (2nd)	345.35	345.75																													v			
Wart L arm	343.65	345.95																													w			
Treponema pallidum	346.85	347.40																													b			
Mycoplasma (2nd)	342.75	349.30																													b			
Lactobacillus acidophilus	346.05	351.65																													b	b		
Proteus mirabilis (2nd)	345.95	352.10																													b	b		
Erwinia amylovora	347.20	352.10																													b	b		
Serratia marcescens	349.45	352.10																													b	b		
Gaffkya tetragena	344.85	352.50																													b	b		
Schistosoma mansoni	353.00	353.00																														p		
Nocardia asteroides	354.95	355.35																														b		
Escherichia coli (E. coli)	356.00	356.00																														b		
Campylobacter pyloridis	352.00	357.20																														b		
Loa loa	360.55	360.55																															p	
Besnoitia (lung sect.) prot	352.80	361.40																														p	p	
Bacterial capsules	357.60	362.40																														b	b	
Herpes simplex 2 (fresh s	353.90	362.90																														v	v	
Coxsackie virus B-4	361.45	363.70																															v	

s = slime mold, m = mold, b = bacteria, v = virus, y = yeast, p = parasite (one-celled animals), t = tapeworm, x = mite

	KHz		3	5	0			4	0	0			4	5	0			5	0	0
Pathogen	Low	High																		
Diplococcus diphtheriae	357.95	364.00	b	b																
Naegleria fowleri	356.90	364.35	p	p																
Clostridium botulinum	361.00	364.55		b																
Coxsackie virus B-4 (2nd)	363.90	364.90		v																
Bacillus anthracis (2nd)	363.20	365.30		b																
Clostridium septicum	362.05	365.60		b																
Coxsackie virus B-1	360.50	366.10		v																
Diplococcus pneumoniae	351.65	368.45	b	b																
Streptococcus sp. group	368.15	368.85		b																
Nocardia asteroides (2nd	363.70	370.00		b	b															
Salmonella paratyphi	365.05	370.10		b	b															
Streptococcus pneumoni	366.85	370.20		b	b															
Bacillus anthracis (3rd)	359.40	370.50	b	b	b															
Campylobacter fetus sme	365.30	370.60		b	b															
Measles antigen	369.50	373.00		v	v															
Plasmodium falciparum s	372.30	373.80			p															
Enterobacter aerogenes	374.00	374.00			b															
Streptococcus pyogenes	360.50	375.30		b	b															
Bacillus cereus	373.65	375.85			b															
Erwinia carotovora	368.10	377.00		b	b															
Central spores (bacillus s	372.45	378.65			b															
Histomonas meleagridis (l	376.55	378.70			b															
Staphylococcus aureus (c	376.27	380.85			b	b														
Staphylococcus aureus (s	381.00	381.00				b														
Gyrodactylus	378.75	381.80			p	p														
Borellia burgdorferi	378.95	382.00			v	v														
Spirillum serpens	378.35	382.80			b	b														
Epstein Barre virus (EBV)	372.50	382.85			v	v														
Respiratory syncytial viru	378.95	383.15			v	v														
Trichomonas vaginalis	378.00	383.60			p	p														
Chlamydia trachomatis	379.70	383.95			b	b														
Eikanella corrodens	379.50	384.30			b	b														
Mumps antigen	377.60	384.65			v	v														
Troglodytella abrassari	377.75	385.20			b	b														
Alpha streptococcus	369.75	385.40		b	b	b														
Sub terminal spores bac.	385.15	385.95				b														
Salmonella typhimurium	382.30	386.55				b														
Adenovirus (2nd range)	371.45	386.90			v	v														
Streptococcus lactis	382.00	387.00				b														
Bacillus subtilis var. niger	371.85	387.10			b	b														
Beta streptococcus	380.60	387.40				b														
Entamoeba histolytica tro	381.10	387.80				p														
Anaplasma marginale	386.40	388.00				p														
Candida albicans	384.20	388.40				y														
Propionobacterium acnes	383.75	389.00				b														
Shigella dysenteriae	390.09	390.09					b													
Chilomastix cysts (rat)	388.95	390.70				p	p													
Clostridium acetobutylicu	382.80	391.15				b	b													
Bacillus anthracis spores	386.95	391.45				b	b													
Escherichia coli (E. coli)	392.00	393.00					b													
Adenovirus	393.00	393.00					v													
Sphaerotilus natans	388.40	393.45				b	b													
Shigella flexneri	394.00	394.00					b													
Toxoplasma (human strai	395.00	395.00					p													
Haemonchus contortus	386.80	395.50				p	p													
Branhamella (Neisseria)	394.90	396.70					b													
Endolimax nana trophozo	394.25	397.10					p													
Bacillus anthracis	393.50	398.05					b													
Clostridium perfringens s	394.20	398.10					b													

s = slime mold, m = mold, b = bacteria, v = virus, y = yeast, p = parasite (one-celled animals), t = tapeworm, x = mite

	KHz		3	5	0			4	0	0			4	5	0			5	0	0
Pathogen	Low	High																		
Trypanosoma gambiense	393.75	398.70						p												
Chilomonas, whole mount	393.75	400.00						p	p											
Entamoeba coli trophozoi	397.00	400.35						p	p											
Leptospira interrogans	397.05	401.10						b	b											
Strongyloides (filariform l	398.40	402.00						p	p											
Leucocytozoon	397.45	402.55						p	p											
Leishmania donovani	398.00	402.65						p	p											
Ancylostoma caninum	383.10	402.90					p	p	p											
Ancylostoma braziliense (	397.60	403.25						p	p											
Leishmania mexicana	400.20	403.80							p											
Wart papilloma cervix sm	404.05	404.60							w											
Klebsiella pneumoniae	398.45	404.65						b	b											
Prosthogonimus macrorc	396.85	404.75						p	p											
Iodamoeba butschlii (2nd)	398.15	404.75						p	p											
Leishmania braziliensis	400.05	405.10							p											
Veillonella dispar	401.75	405.20							b											
Trichinella spiralis (muscl	403.85	405.57							p											
Wart BS	402.00	406.00							w											
Dientamoeba fragilis	401.35	406.05							p											
Wart human papilloma pl	404.70	406.75							w											
Leishmania tropica	402.10	407.40							p											
Blepharisma	405.65	407.45							b											
Trichuris sp. (male)	388.30	408.90					p	p	p											
Ascaris larvae in lung	404.90	409.15							p											
Pneumocystis carnii (lung	405.75	409.15							p											
Ascaris megalocephala (	403.85	409.70							p											
Mycobacterium phlei	409.65	410.65							b	b										
Wart human papilloma vir	402.85	410.70							w	w										
Cytomegalovirus (CMV) a	408.35	410.75							v	v										
Dirofilaria immitis	408.15	411.15							p	p										
Stigeoclonium	404.25	415.25							p	p										
Cryptocotyle lingua (adult	409.95	416.00							p	p										
Proteus vulgaris	408.75	416.45							b	b										
Myxosoma	409.60	416.95							p	p										
Bacteria capsules (capsul	416.05	418.75								b										
Herpes Zoster	416.60	420.20								v	v									
Hepatitis B antigen	414.55	420.80								v	v									
Klebsiella pneumoniae (2	416.90	421.90								b	b									
Troglodytella abrassari (2	416.90	422.20								b	b									
Eurytrema pancreaticum	420.35	422.30									p									
Wart JB	418.75	422.40								w	w									
Echinoporyphium recurva	418.55	423.90								p	p									
Anaplasma marginale (2n	415.30	424.00								p	p									
Plasmodium cynomolgi	417.30	424.50								p	p									
Fasciola hepatica miracidi	421.75	424.70									p									
Trypanosoma lewisi (bloo	424.50	426.00									p									
Enterobius vermicularis	420.95	426.30									p									
Giardia lamblia (trophozoi	421.40	426.30									p									
Fasciola hepatica	421.35	427.30									p									
Chilomastix cysts (rat) (2	425.20	427.30									p									
Fasciola hepatica rediae	420.60	427.50									p									
Fasciola hepatica eggs	422.00	427.60									p									
Trypanosoma rhodesiens	423.50	428.55									p									
Clonorchis sinensis	425.70	428.75									p									
Hypodereum conoideum	424.45	429.55									p									
Tobacco mosaic virus	427.15	429.55									v									
Echinostoma revolutum	425.50	429.65									p									
Fasciola hepatica cercari	423.80	430.60									p	p								
Capillaria hepatica (liver s	424.25	430.65									p	p								

s = slime mold, m = mold, b = bacteria, v = virus, y = yeast, p = parasite (one-celled animals), t = tapeworm, x = mite

	KHz		3	5	0			4	0	0			4	5	0			5	0	0
Pathogen	Low	High																		
Trypanosoma brucei	423.20	431.40								p	p									
Cytophaga rubra	428.10	432.20								b	b									
Wart CC	426.00	432.35								w	w									
Fasciolopsis rediae	427.30	433.00								p	p									
Endolimax nana (2nd)	430.50	433.35									p									
Mycobacterium tuberculo	430.55	434.20									b									
Fasciolopsis buskii	427.70	435.10								p	p									
Fasciolopsis miracidia	427.35	435.20								p	p									
Fasciolopsis buskii eggs	427.35	435.45								p	p									
Fasciolopsis cercariae	429.50	436.25								p	p									
Cysticercus fasciolaris	436.40	440.05									t	t								
Endamoeba gingivalis tro	433.80	441.00									p	p								
Onchocerca volvulus (tu	436.30	442.10									p	p								
Metagonimus Yokogawai	437.35	442.10									p	p								
Macracanthorhynchus	438.85	442.80									p	p								
Fischoedrius elongatus	441.75	443.20										p								
Wart HA	434.80	444.10									w	w								
Passalurus ambiguus	428.80	444.15								p	p	p								
Dipylidium caninum	439.55	444.30									t	t								
Plasmodium vivax smear	438.15	445.10									p	p								
Echinococcus granulosus	441.15	446.50										t								
Iodamoeba butschlii troph	437.85	448.50									p	p								
Wart HRCm	438.90	448.55									w	w								
Taenia solium (scolex)	444.00	448.90										t								
Urocleidus	442.35	450.00										p	p							
Trypanosoma equiperdu	434.60	451.25									p	p	p							
Paragonimus Westermani	437.80	454.20									p	p	p							
Sarcocystis	450.55	454.95											p							
Hasstile sig. tricolor (adult	448.05	455.10										p	p							
Gastrothylax elongatus	451.90	457.10											p							
Multiceps serialis	453.60	457.80											t							
Echinococcus multilocula	455.85	458.35											t							
Echinococcus granulosus	451.60	461.50											t	t						
Balantidium coli cysts	458.80	462.90											p	p						
Stephanurus dentalus (ov	457.35	463.10											p	p						
Wart FR	459.30	464.75											w	w						
Moniezia (scolex)	430.35	465.20									t	t	t	t						
Moniezia expansa (comp	430.35	465.20									t	t	t	t						
Trypanosoma cruzi (brain	460.20	465.65												p						
Taenia pisiformis eggs (o	465.20	469.70												p						
Dipylidium caninum (scol	451.95	472.15											t	t	t					
Diphyllobothrium latum (s	452.90	472.30											t	t	t					
Schistosoma haematobiu	473.00	473.00													p					
Taenia solium (cysticercu	475.00	475.00													t					
Taenia saginata (cysticer	476.50	481.05													t	t				
Hymenolepis diminuta	445.00	481.15										t	t	t	t	t				
Hymenolepis cysticercoid	478.00	481.75													t	t				
Taenia pisiformis (cystice	475.20	482.10													t	t				
Diphyllobothrium erinacei	467.25	487.55												t	t	t				

s = slime mold, m = mold, b = bacteria, v = virus, y = yeast, p = parasite (one-celled animals), t = tapeworm, x = mite

	KHz								
			550	600	650	700	750	800	850
Pathogen	Low	High							
Demodex folliculorum foll	682.00	682.00			x				
Dermatophagoides dust	707.00	707.00				x			
Meal mite	718.00	718.00				x			
Sarcoptes scabei itch	735.00	735.00				x			
Ornithonyssus bird mite	877.00	878.00							

s = slime mold, m = mold, b = bacteria, v = virus, y = yeast, p = parasite (one-celled animals), t = tapeworm, x = mite

Sources

This list was accurate as this book went to press. Only the vitamin sources listed were found to be pollution-free, and only the herb sources listed were found to be potent, although there may be other good sources that have not been tested. The author has no financial interest in, influence on, or other connection with any company listed, except for having family members in the Self Health Resource Center.

Note to readers outside the United States of America:

Sources listed are typically companies within the United States because they are the ones I am most familiar with. You may be tempted to try a more convenient manufacturer in your own country and hope for the best. I must advise against this! In my experience, an uninformed manufacturer most likely has a polluted product! Your health is worth the extra effort to obtain the products that make you well. One bad product can keep you from reaching that goal. This chapter will be updated as I become aware of acceptable sources outside the United States. Best of all is to learn to test products yourself.

Item	**Source**
Amber bottles, ½ ounce	Drug store, Continental Glass & Plastic, Inc. (large quantities)
Apricot Kernel Oil	Now Foods

Arginine	Now Foods, Jomar Labs
Artemesia (wormwood) seed	R. H. Shumway
Baking soda (sodium bicarbonate)	Spectrum Chemical Co.
Beet root	San Francisco Herb & Natural Food Co.
Belts for clothes dryer	Three that tested negative to asbestos are: Maytag™ 3-12959 Poly-V belt, Whirlpool™ FSP 341241 Belt-Drum Dr. (replaces 660996), and Bando™ V-Belt A-65. Bando American makes other belts, some of which might be the right size for your dryer. Call for a dealer near you, make sure it says "Made In America", right on the belt.
Black cherry concentrate	Health food store
Black Walnut Hull Tincture	Self Health Resource Center, New Action Products
Borax, pure	Grocery store
Boric acid, pure	Now Foods, health food store, pharmacy
Cascara sagrada	Natures Way, health food store
Chemicals for testing.	Aldrich Chemical Co., Spectrum Chemical Co., ICN Biomedicals, Inc. (research chemicals only, including genistein), Boehringer Mannheim Biochemicals (research only)
Cholecalciferol	Spectrum Chemical Co.
Citric acid	Now Foods or health food store
Cloves	San Francisco Herb & Natural Food Co. (ASK for fresh)
Cornstarch	Lady Lee is the only unpolluted brand found so far
Dental information	Tooth Truth, by Frank J. Jerome, available from New Century Press.
EDTA	Spectrum Chemical Co.
Electronic parts	A Radio Shack near you.
Empty gelatin capsules size 00	Now Foods, or your health food store

Filters, pure charcoal	Pure Water Products (pitchers), Seagull Distribution Co. (faucet, shower, whole house)
Flaxseed oil	Omega Nutrition USA, Inc.
Fucus	San Francisco Herb & Natural Food Co.
Ginger capsules	Now Foods
Goldenrod tincture	Dragon River Herbals, Blessed Herbs
Grain alcohol	Liquor store, as vodka, Everclear™
Gravel root (herb)	San Francisco Herb & Natural Food Co.
Histidine	500 mg from Jomar Labs
Homeopathic remedies	Dolisos America, Inc., and others
Hydrangea (herb)	San Francisco Herb & Natural Food Co.
Hydrogen peroxide 35% (food grade)	New Horizons Trust
Iodine, pure	Spectrum Chemical Co.
Lugol's iodine	For slide staining (not internal use) from Spectrum Chemical Co., and farm animal supply store. For internal use must be made from scratch.
Lysine	Bronson Pharmaceuticals
Magnesium oxide	Bronson Pharmaceuticals
Marshmallow root (herb)	San Francisco Herb & Natural Food Co.
Microscope slides and equipment	Carolina Biological Supply Company, Ward's Natural Science, Inc., Southern Biological Supply Company, Fisher-EMD
Microscopes	Carolina Biological Supply Company, Ward's Natural Science, Inc., Edmund Scientific Co.
Milk Thistle	Herb companies.
Mullein tea	San Francisco Herb & Natural Food Co.
Niacin	100 mg or 250 mg time release, Bronson Pharmaceuticals
Ornithine	Now Foods, Jomar Labs
Ortho-phospho-tyrosine	Aldrich Chemical Co.
Ozonator	Superior Health Products, LLC
P24 antigen sample	Bachem Fine Chemicals Inc.
PABA (para amino benzoic acid)	Bronson Pharmaceuticals
Pantothenic acid	Bronson Pharmaceuticals

Peroxy	See Hydrogen peroxide.
Photo-micrographic camera and film	Ward's Natural Science, Inc.
Potassium bicarbonate	Spectrum Chemical Co., or pharmacy
Potassium chloride	Now Foods, Spectrum Chemical Co.
Potassium iodide, pure	Spectrum Chemical Co.
Rascal	Kroeger Herb Products, New Action Products (as Raz-Caps)
Salt (sodium chloride), pure	Spectrum Chemical Co., get USP grade
Sodium alginate	Spectrum Chemical Co. or health food store
Stevia powder	Now Foods
Tea	San Francisco Herbs, buy in bulk, any single herb variety.
Thallium, homeopathic	Dolisos America, Inc.
Thioctic acid (also called lipoic acid)	Maypro Industries
Uva Ursi	Natures Way or health food store
Vanilla extract	Durkee's™ or Mexican brands
Vegetable glycerin	Now Foods or health food store
Vitamin B Complex	Bronson Pharmaceuticals
Vitamin B_2 (riboflavin)	Nutrition Headquarters (250 mg), or Bronson Pharmaceuticals (100 mg)
Vitamin B_6	Bronson Pharmaceuticals, EDOM Labs
Vitamin B_{12} lozenges	Bronson Pharmaceuticals
Vitamin C (ascorbic acid)	Self Health Resource Center
Vitamin D 50,000iu	From dentist, by prescription, or see Recipes.
Vitamin E capsules	Bronson Pharmaceuticals
Vitamin E Oil	Now Foods
Washing soda (sodium carbonate)	Grocery store
Water filter pitchers	Pure Water Products
Wormwood capsules	Self Health Resource Center, Kroeger Herb Products, New Action Products
Zinc	Bronson Pharmaceuticals
Zinc oxide	Spectrum Chemical Co.

Aldrich Chemical Co.
P.O. Box 355
Milwaukee, WI 53201
(414) 273-3850

Bachem Fine Chemicals Inc.
3132 Kashiwa St.
Torrance, CA 90505
(310) 539-4171

Bando American Inc.
1149 West Bryn Mawr
Itasca, IL 60143
(800) 829-6612
(630) 773-6600

Blessed Herbs
109 Barre Plaines Rd.
Oakham, MA 01068
(508) 882-3839

Boehringer Mannheim
Biochemicals
9115 Hague Rd.
P.O. Box 50414
Indianapolis, IN 46250
(800) 262-1640
(317) 849-9350

Bronson Pharmaceuticals
Div. of Jones Medical Industry
1945 Craig Road
P.O. Box 46903
St. Louis, MO 63146-6903
(800) 235-3200 retail
(800) 525-8466 wholesale

Carolina Biological Supply Co.
2700 York Rd.
Burlington, NC 27215
(800) 334-5551
(919) 584-0381

Continental Glass & Plastic, Inc.
841 West Cermak Rd.
Chicago, IL 60608-4582
(312) 666-2050

Dolisos America, Inc.
3014 Rigel Ave
Las Vegas, NV 89102
(800) 365-4767
(702) 871-7153

Dragon River Herbals
PO Box 74
Ojo Caliente, NM 87549
(800) 813-2118
(505) 583-2118

Edmund Scientific Co.
101 E. Gloucester Pike
Barrington, NJ 08007
(856) 573-6250

EDOM Labs, Inc.
860 Grand Boulevard
P.O. Box 780
Deer Park, NY 11729
(516) 586-2266
(800) 723-3366

Fisher Scientific EMD
485 S. Frontage Rd.
Burr Ridge, IL 60521
(800) 955-1177

ICN Pharmaceuticals, Inc.
Biomedical Division
3300 Hyland Ave.
Costa Mesa, CA 92626
(714) 545-0113
(800) 854-0530

Jomar Labs
251-B East Hacienda Avenue
Campbell, CA 95008
(800) 538-4545
(409) 374-5920

Kroeger Herb Products
(wholesale:)
805 Walnut St.
Boulder, CO 80302
(800) 225-8787
(303) 443-0261
(for retail call:)
Hanna's Herb Shop
5684 Valmont Rd.
Boulder, CO 80301
(800) 206-6722

Maypro Industries
2700 Westchester Ave.
Purchase, NY 10577
(914) 251-0701

Nature’s Way
10 Mountain Springs Pkwy
Springville, UT 84663
(800) 962-8873
(801) 489-1500

New Action Products (USA)
P.O. Box 540
Orchard Park, NY 14127
(800) 455-6459
(716) 662-8000

New Action Products (CANADA)
PO Box 141
Grimsby, Ont. L3M4G5 Canada
(800) 541-3799
(716) 873-3738

New Century Press
1055 Bay Blvd., Suite C
Chula Vista, CA 91911
(800) 519-2465
(619) 476-7400

New Horizons Trust
53166 St. Rt. 681
Reedsville, OH 45772
(800) 755-6360
(614) 378-6366

Now Foods
395 Glen Ellen Road
Glen Ellen, IL 60108
(630) 545-9098

Omega Nutrition USA, Inc.
6515 Aldrich Rd.
Bellingham, WA 98226
(800) 661-3529

Superior Health Products, LLC
13549 Ventura Blvd.
Sherman Oaks, CA 91423
(800) 700-1543
(818) 986-9456

Pure Water Products
10332 Parkview Ave.
Westminster, CA 92683
(800) 478-7987

R. H. Shumway
P.O. Box 1
Graniteville, SC 29829
(803) 663-9771

San Francisco Herb & Natural
Food Co.
1010 46th St.
Emeryville, CA 94608
(800) 227-2830 wholesale
(510) 601-0700 retail

Seagull Distribution Co.
3372 Baltimore St.
San Diego, CA 92117
(858) 483-0264

Self Health Resource Center
1055 Bay Blvd., Suite A
Chula Vista, CA 91911
(800) 873-1663
(619) 409-9500 (USA)
(780) 475-2403 (Canada)

Southern Biological Supply
Company
P.O. Box 368
McKenzie, TN 38201
(800) 748-8735
(901) 352-3337

Spectrum Chemical Co.
14422 South San Pedro Street
Gardena, CA 90248
(800) 772-8786
(310) 516-8000

Ward’s Natural Science, Inc.
5100 West Henrietta Road
Rochester, NY 14586
(716) 359-2502
(800) 962-2660

Finale

I hope you have come to the same happy conclusion that I did a few years ago! That we humans don't have hundreds of different maladies and disturbances. **We only have two!** Things that crawl or climb into us. And toxins: unnatural chemicals that we unknowingly inhale or consume.

The living things are both large and small: from worms we can see, to microscopic bacteria, viruses and fungi. The non living things are pollutants in our air, food, dental metal and body products. Taking in a lot of pollutants hampers the body's ability to kill and get rid of the invaders. And so, gradually, as we get older or sicker, the body's invaders get the upper hand and take over. Don't be discouraged if you have lupus, cerebral palsy, cirrhosis, or any complex-sounding disease. Every disease is an example of the same process.

The good news is that our body can reclaim its sovereignty by throwing the rascals out. We must assist by throwing the pollutants out. Fortunately, we don't have to do the whole job ourselves, we only need to assist. Our body has miraculous powers to clean itself up.

By reducing chronic disease to two problems, it becomes manageable. Ill health, even aging, can be reversed. Health comes back and rewards you.

With the new electronic insights and technology, our parasitic invaders can be vanquished with the closing of a switch. Preventing reinfection is the bigger challenge. Similarly, pollutants can be uncovered in as short a time as days, short enough to turn any sick, even terminal, sufferer's verdict around before tragedy occurs.

The tragedies of surgery, organ replacements, radiation, chemotherapies, doses of drugs, even death can be avoided. Reversing illness and turning into a shining example of your former healthy self could be the most exciting adventure of your life.

Killing your invaders is an easy matter: you simply purchase or build the device that can do that and take the proper herbs. Cleaning up dentalware is under your control, too—a financial expense not beyond your reach, hopefully. Trading your body products for unpolluted varieties is a job but not insurmountable. Cleaning your environment may be the stumbling block. If you can't unpollute your air, water, carpets, furniture, move. Move to a healthier dwelling! Get rid of it all. Like a cat that moves her kittens to a safer place, just move.

The healthiest house is no house. If you have been quite ill, move far enough south to avoid heating and cooling. Sit outside in the shade all day. Use your new wisdom and sharp eye to choose a new dwelling as free of pollutants as you can. No refrigerator indoors. No window air conditioner. No fiberglass insulation. No fossil fuels. No attached garage. No carpets or stuffed furniture, no foam bedding, no fresh paint, no pesticide. Go primitive. Health is primitive. You were born primitive—with health. Even if you weren't, you can undo much of the “inherited” damage.

Don't listen to the new doomsayers, who persuade you nothing can be done unless a gene is replaced. Your genes have been reliable for millions of years. Genes are the most reliable of all biological chemicals in your body. They are not faulty. They are hampered in their tasks. They are commandeered by metals and other species’ genes. Those of parasites, bacteria, and viruses. They wouldn't be there if pollutants weren't there. They allow invaders into the most jealously guarded recess of your being: your genes. But now you can throw the rascals out and reclaim your territory. It is not new genes that you need. You simply need your own genes back on the job, directed by your own body, working for you.

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About this electronic book

While creating this electronic version of The Cure for all Diseases, I encountered some inconsistencies and (small) errors in it. Below follows an overview.

Niels Willems, december 2002.
niels.w@hccnet.nl
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Page	**Line**	**Hard copy**	**Electronic version**
18	Fig.2	(Di-phyllobothruim e.)	(Di-phyllobothrium e.)
25	last-2	both with a alligator clip	both with an alligator clip
255	last-3	liver cleanses(page 549) make	liver cleanses (page 552) make
360	last-7	health improv-ed	health improved
451	5	furniture"treated"	furniture "treated"
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562	last-7	Argyria	Arcyria
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564	6	Corynebacterium diptheriae	Corynebacterium diphtheriae
565	18	Norcardia asteroides (2nd range)	Nocardia asteroides (2nd range)
570	last-4	folicle mite	follicle mite
575	2	Paradiclorobenzene	Paradichlorobenzene
576	(17)	missing: Aflatoxin (2nd) 188 188	(not corrected)
576	last-19	Corynebacterium diptheri	Corynebacterium diphthe
580	4	folliculorum foli	folliculorum foll

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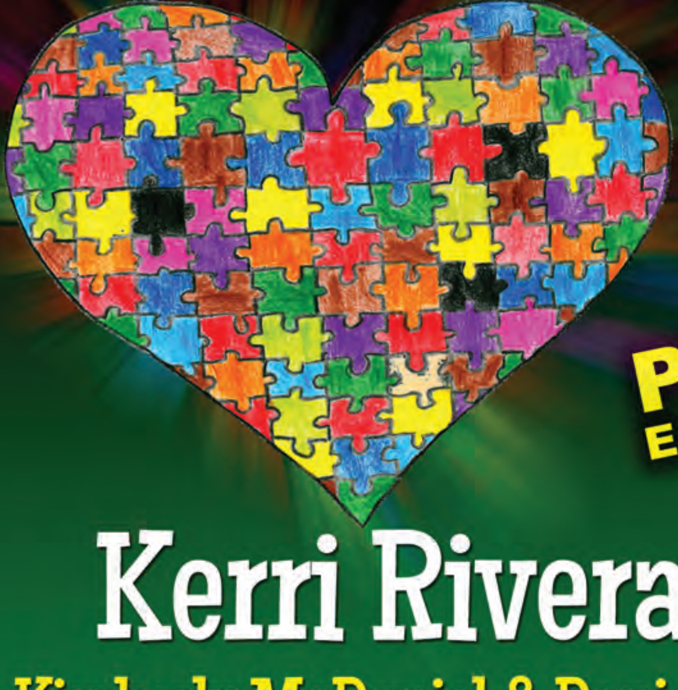

Second
Edition

PDF
E-Book

Kerri Rivera

with Kimberly McDaniel & Daniel Bender

Jim Humble • Dr. Andreas Kalcker
Dr. Marco Ruggiero • Robert L. Sands

Disclaimer

Healing the Symptoms Known as Autism is not intended as medical advice. This book is for informational and educational purposes only. Please consult a medical professional when the need for one is indicated. For obvious reasons neither the author, co-authors, contributing authors, the publisher, nor their associates can take medical or legal responsibility for having the contents herein considered as a prescription for everyone or anyone. You are ultimately responsible for the uses made of this book.

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Healing
the symptoms known as
Autism

Second Edition

by Kerri Rivera
with Kimberly McDaniel & Daniel Bender

Healing the Symptoms Known as Autism
Second Edition (PDF E-Book Version)

by Kerri Rivera
with Kimberly McDaniel & Daniel Bender

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I would like to dedicate this book to the families
of children on the spectrum the world over.

May all of our children
find the healing that they need.

~ Kerri

This book is dedicated to my Dominick.
I love you forever; thank you for being our angel.

~ Kim

Healing
the symptoms known as
Autism
Kerri Rivera
with Kimberly McDaniel

One of our fans currently working towards recovery thanks to the protocol.

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Foreword

Autism, not the one described by Kanner in 1943, but the one that we see today diagnosed in 1 of 50 kids is a combination of immune disorders that need to be treated biomedically. There is a lot that we still need to understand about why and how these immune dysfunctions affect our kids' development, causing near complete impairment of their social interaction and communication.

There is a long, hard road ahead to fully comprehend the integrated system that comprises "autism," but our kids cannot wait. It takes more than just medical, professional, or even scientific interests working hard day and night to find a suitable and effective solution to help our kids. It takes drive, passion, and guts to do the right thing; to hear and read the overwhelming stories of parents from all over the world and not turn our backs, but help. It takes an eternal and extreme will to help, even when your own child is on the spectrum.

Kerri's protocols have been indispensible to the full recovery of many of the kids in our Curando el Autismo (CEA) Foundation. These protocols represent a readily available and effective solution to alleviate most of the pathogenic insults to the immune system. Years from now, when "autism" diagnoses do not exist, when we find ourselves fully knowledgeable about the now mysterious immune-brain-behavior connection, I will remember Kerri not only as a friend but as one of the first courageous leaders that dared to change the path for our ill kids. She goes against all odds, sharing knowledge, experience and simply making it happen.

~ Lorna B. Ortiz, PhD.
President of Curando el Autismo, CEA

> *“Based on parent reports, the prevalence of diagnosed ASD in 2011–2012 was estimated to be 2.00% for children aged 6–17. This prevalence estimate (1 in 50) is significantly higher than the estimate (1.16%, or 1 in 86) for children in that age group in 2007.”*

US Department of Health & Human Services
National Health Statistics Reports
Number 65, Pg. 2 - March 20, 2013
www.cdc.gov/nchs/data/nhsr/nhsr065.pdf

Preface

by Kimberly McDaniel

Darkness cannot drive out darkness; only light can do that.
Hate cannot drive out hate; only love can do that.
~ Martin Luther King, Jr.

Welcome to the Second Edition of *Healing the Symptoms Known as Autism!* We are absolutely thrilled to share with you the latest protocol updates and everything else that has happened since May, 2013.

You may be thinking: Why a second edition so soon? Our first edition gave us the structure to explain the protocol, and a foundation to build on. This book has already helped many families around the world, and in fact some parents read it and recovered their children without even contacting us until afterwards! Keep in mind that when it was released in May, 2013 it was absolutely up to the minute, but as we mentioned, this protocol will continue to evolve until we have something that is consistently recovering people on the spectrum of all ages. As of January 2014, we again are sharing the latest updates, as well as a whole lot more information that we hope will be as interesting and beneficial to you as it was to us.

Here are some of the exciting new additions:

- Olive Kaiser of www.GlutenSyndrome.net has written a section on gluten and its role in molecular mimicry and autoimmunity. Since many of you are not new to the autism community, a gluten free diet for your children is nothing new. However, you may be interested to find out just how damaging gluten can be for folks who are off the spectrum as well.

- Scott McRae has contributed a chapter on CDH (Chlorine Dioxide Holding [Solution]). A new method of preparing chlorine dioxide that many families are now using with success. This gives us an even wider variety of preparations available to accommodate the needs of our families.

- The Kalcker Parasite Protocol chapter now has some beautiful charts that spell out the timing of all the components for the 18 days a month that a child will be on the parasite protocol. Thanks to Dan Bender, a lot of the confusion surrounding how to make it all fit will be cleared up. You will also find years of lunar calendars to make it easy to see when the protocol is active. You won't have to check Google again to see when the full or new moon is coming.

- The "Worm Whisperer" Robin Goffe shares with us part of her journey towards healing for her 19-year-old son. Her advice is for the Extreme Cases—Self Injurious behavior, aggression, violence, etc. If you are the parent of an older child on the spectrum, or a child who displays these behaviors, or you know someone who is living with a child like this, you owe it to yourself to read Robin's suggestions. They are full of hope and wisdom.

- The one and only Marco Ruggiero, lead researcher on GcMAF, (Gc Macrophage Activating Factor—an immune system supplement) has written an entire chapter on GcMAF and its applications for autism. A must read.

- Last but not least, a whole new crop of testimonials that will make you cry. If after reading this book you still have doubts about giving this protocol a chance, I highly recommend you revisit these testimonials. If I had to pick one part of the book that was absolute favorite, this would be it. It may be because I collect a lot of them, and usually have a little correspondence with the families to get their permission, and genuinely get to feel their excitement, their sense of accomplishment when they see their child start to heal, and not to mention their endless gratitude for being able heal their own children.

  I pray that all of these testimonials find their way to the people who need them and as a result children stop suffering because their parents see them reflected in those words and understand that if other children can heal, their children can as well.

  To me, there is nothing more real than hearing from someone that has walked a mile in your shoes. There is nothing more inspiring that to hear someone say, "I know it's possible, because I did it, I lived it, and I am here to tell you about it."

The families that courageously walked this path and then took the time to share their stories are pioneers and heroes to their own families and to our entire community and beyond. They are blazing a trail for others to follow and countless lives will benefit from their diligence, fortitude and dedication. The stories of healing come from all over the world... from children and adults of all ages. We hope that they move you as much as they moved us. We are eternally grateful for the service these families have provided to humanity and thankful that they were generous enough to take the time out of their lives to pay it forward and share.

- The book now as an extensive index making it much easier to use as a reference.

As of this printing, families are healing their children with autism using this protocol in over 58 countries! Our Facebook groups have over 3,500 members in many of these countries. CD officially knows no borders. It is absolutely thrilling to us that people are coming together with the common goal of healing their children themselves, and to help others do the same! It fills our hearts with joy to be a part of this and to be able to see and feel the love that is shared every single day.

The development of this protocol has been a growing grass roots effort, in sharp contrast to how modern medicine usually works. The reason for this is clear: Modern medicine has not really helped to heal autism and may very well be part of its cause. While we don't have any double blind studies to rest on, we do have a slew of anecdotal evidence, which may not mean much to those in the arena of modern medicine or modern science, that doesn't make it any less real. Time and time again, our *results*—children dropping ATEC points—are being duplicated by families all over the world. For a family who is using this protocol, there is absolutely nothing more real than watching their child come back to them. Ask any autism parent what they would rather have... a long-term double-blind study published in a peer reviewed journal... or a healthy child. My money's on the latter.

As exciting as it is to be a part of this, and as wonderful as it is to hear about gains and read uplifting testimonials, we know there are still families working to heal children that are very sick, and our groups share the highs as well as the lows. Kerri will tell you that some months are better than others and the gains ebb and flow. I urge you to read and reread the testimonials. These are real stories of real healing and if you haven't already I invite you to believe that your child can be one of the success stories in those testimonial pages.

All of our families are proving what many were told was impossible: Children with the symptoms known as autism can heal! This grass roots movement is creating a paradigm shift in the way the world views healing from autism. The second edition of this book will be translated into at least 13 languages including Spanish, Portuguese, French, Flemish, German, Czech, Norwegian, Arabic, Polish, Italian, Hungarian, Bulgarian and Serbian. This is exciting. This is real. And, this is a living protocol. Every family that uses it every single day is helping to shape the future and heal the children who are affected today, and quite possibly prevent children from becoming affected tomorrow. For this we are eternally grateful.

Here's to you and the continued healing of humanity,

Terminology & Units of Measure

Throughout this book we talk about "CD," which is an abbreviation for *chlorine dioxide*, a well-established oxidizer. Chlorine dioxide is also often referred to as MMS, which is the common name given to it by Jim Humble, the man who discovered various applications of chlorine dioxide. There are many books, videos, blogs and articles using the name, "MMS," which is surrounded by a fair amount of controversy. We choose to not get tangled into that debate since our focus is on helping our children recover from autism. For us, our only concern is that (1) it is safe for our children, and (2) that it works. Based on extensive use of CD on thousands of children with autism, we can confidently say that both those statements are true. If this were not so, this book would not exist.

Units of Measure

Throughout this book we talk about various measured treatment components and containers using fluid volumes and weights. Since this book primarily addresses a US audience, we sometimes talk about measures in the US system of pounds and fluid ounces; while also using the internationally recognized metric system, which is frankly... easier to use.

The common abbreviations of measure you will see throughout this book include:

l = liter (volume)
mg = milligram (weight)
ml = milliliter (volume)
lb = pound (weight)
lbs = pounds (weight)
ppm = parts per million (concentration)
fl. oz. = fluid ounce (volume)
net. wt. oz. = net weight ounce (weight)

For easily measuring small amounts, syringes (without needles) are a great tool. Don't bother going to a chain store pharmacy... they won't sell them to you without a prescription. Instead, check your local medical supply store, animal supply store, private pharmacy or protocolsupplies.com. Cost: Surprisingly dirt cheap. The complete set of five below cost about $1.00 in Mexico—less than most candy bars—and not much more in the US. Note: Some brands of syringes have printed on scales that easily rub off, especially if your hands are a little oily. To prevent from losing the markings, cover the scale with some clear tape or clear nail polish.

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When it comes to accurately measuring larger volumes, you can buy a set of 7 Polypropylene Graduated Cylinders. Of course this is not a requirement. You can use common kitchen measuring utensils, but these are more accurate and easier to read. If you decide to get them, avoid those with printed on lettering (it rubs off). Raised lettering is best, although sometimes a bit difficult to read. Typical cost on ebay™ or Amazon® for a set is around $25USD. The sizes range from 10ml to 1000ml. You can also buy individual cylinder sizes made of plastic or glass.

Acknowledgements

Gratitude makes sense of our past,
brings peace for today,
and creates a vision for tomorrow.
~ Melody Beattie

Thank you to my Mother who taught me by example the value of volunteerism and to help others who are less fortunate. Thank you for always telling me that I am the best and that I could do anything. I believed you :)

Thank you to my husband of nineteen years for supporting me on this journey. As challenging as it is, you have always stood by me. You are the love of my life, and father of the sweetest boys on the planet. Thank you for giving me the strength to be strong enough to do a mammoth job. It would not be possible without a pillar of your magnitude.

Thank you to Alex, the best big brother in the world who supports and enjoys what we do as a family and who sees the big picture. I couldn't be prouder than I am of you. I am so grateful you chose me as your Mom, and you chose to be on this journey with me, the road less traveled. I love you forever!

Thank you to Patrick for bringing to our family a higher good. You are an angel. You have brought light to all who meet and know you. Thank you for choosing me to be your mother. You and your brother have taught me more about myself and about life than I could have ever dreamed. I am grateful to you and I Love You more than words can say. Through me, you have given people their lives back. You have forever changed the face of autism.

Thank you to Linda for giving me my sister and one of my greatest friends.

Thank you Slimmie for your support, love and dedication, you are my BFF and we speak the same languages. Thank you for the support of my projects and always having me look prepared.

Lorna, thank you for supporting me, believing in me, trusting me, being faithful to your heart, and for being one of the most honest people I have ever known. You are my sister of the heart and I love you very much.

Susan Wiseman, thank you for offering your connection on that day when I most needed it. That one act of humility changed the future forever. I will never forget what you did for me.

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Ana Meckes, thank you for being another much needed angel and teaching me how to advocate for my son. I have not stopped ever since.

Anju, thank you for being my friend, for sharing with me, and for believing in me. You are a unique treasure.

Pina, thank you for helping and supporting me, we will be friends forever. I will always remember what you did for me, the clinic, and the kids.

Kenny, thank you for you excellent books full of sage advice and making biomed user friendly. Most of all, thank you for sharing fever therapy with us.

Carolina, Yamileth y El Jefe... gracias por apoyarme, defenderme y creer en mi. Son amigos en todo el sentido de la palabra. Estoy orgullosa de ustedes, moviendo montañas con el amor que solo una familia puede tener por un hijo….y ustedes lo han hecho por un pais. Les quiero mucho.

Bob Sands, thank you for seeing something special in me, thank you for taking me to meet Bernie and Mrs. Rimland. That day changed my life forever. Thank you for giving us the best hyperbaric chamber in the world. With that chamber we have seen so many miracles.

Jim, you have brought light to many and hope to all who have had the fortune to know the miracle that is CD (Chlorine Dioxide). I am grateful to you every day of my life. I have witnessed first-hand the miracle that is autism recovery. Thank you for staying the path that has never been easy. But it is as you say, “The right thing to do...” I love you.

Andreas, my dear friend, thank you for your dedication, your research and for your willingness to help. You are the science, the reason and the truth that is chlorine dioxide, the molecule that has the power to save humanity. Thank you to you and Miriam for your unfailing support over the years. Your contributions to the world of autism are changing the way the world views autism forever. And the lives of so many children are now recovered thanks to your contribution to The Protocol. Without you both, these recoveries would not have been so abundant.

Dan Bender, thank you for seeing the big picture and for giving so generously of yourself to help us help children with autism. Your selflessness has allowed this protocol to reach more families all over the world. Thank you for making the second edition of this book a reality, we never would have gotten it off the ground without you.

Thank you Michael Harrah for standing by me and working tirelessly to share the information that has had such a positive effect on so many families all over the world. Your wisdom and know-how have been invaluable to me in this book, our website and forums. You were a friend when I most needed one. I am grateful that you are in my life.

Dr. Bernard Rimland, even though you have left us all too soon, you moved mountains while you were here. Thank you for letting me train as a DAN! Clinician, and for allowing us to translate the protocol to Spanish. Thank you for giving us Infantile Autism in 1964, changing forever the thinking that autism was caused by the refrigerator mother. And setting into motion biomedical interventions for healing our children I wish we had more like you. I try to think "What would Bernie do?" and I usually get the answer. Always helping and always available. Humility. You set the standard for humanitarian.

Thank you to all the families on our forums for blazing a trail for others to follow and fighting for the health of your children every single day. You are an inspiration.

To all the Mods; Ginette, Caryn, Joy, Alison, Heidi, Michael, Pam, Katya, Carolina, Nilesh, Mirena, Robin, Debbie, Sue, Susan A., Brandi, Don, Clint, Maggie, Claire, Amber, Dawn, Naomi, Maryann, Susan R., Stacey, Jessi, Lina, Boris and Susanne, Olive, Dana, and Pat, for being the best mods in the world. Your help changes lives for the better each and every day. This is for you:

> *It's in our interest to take care of others. Self-centredness is opposed to basic human nature. In our own interest as human beings we need to pay attention to our inner values. Sometimes people think compassion is only of help to others, while we get no benefit. This is a mistake. When you concern yourself with others, you naturally develop a sense of self-confidence. To help others takes courage and inner strength.*
>
> ~ The Dalai Lama

Thank you Joy for sharing with Alison that you had heard about CD for autism through the seminar that Jim had in the Dominican Republic. That gesture opened the gates to the north and from there to everywhere. You are a special healer.

Teri and Ed Arranga, thank you for the platform and for helping so many families find what they need for their children, and never blinking, even when it gets really scary.

Thank you Doll, for a much-needed distraction from autism when I really need it most. BFFs are good at doing that.

Thank you to the Mansours, for believing in my projects and me. Your support made this book and our website possible.

Thank you to the various proof readers who helped with that fun process, including Michael Harrah, Pam Gotcher, Joy Whitcomb, Charlotte Lackney, Don Kalland, James Beyor, Cathy Fuss, Jeremy Horne, Ph.D., Luane Beck, Candace, Andreas Schreiber, Olive Kaiser, Susan, and Clint Melanchuk.

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Thank you so much Pam Gotcher for going above and beyond everyday to make sure our readers get their books!

Thank you Scott McRae, Brenda McRae, and Charlotte Lackney for contributing the CDH chapter. This new method of preparation has already been beneficial to many of our families, and is an exciting new addition to this book.

The purpose of life is to contribute
in some way to making things better.

~ Robert F. Kennedy

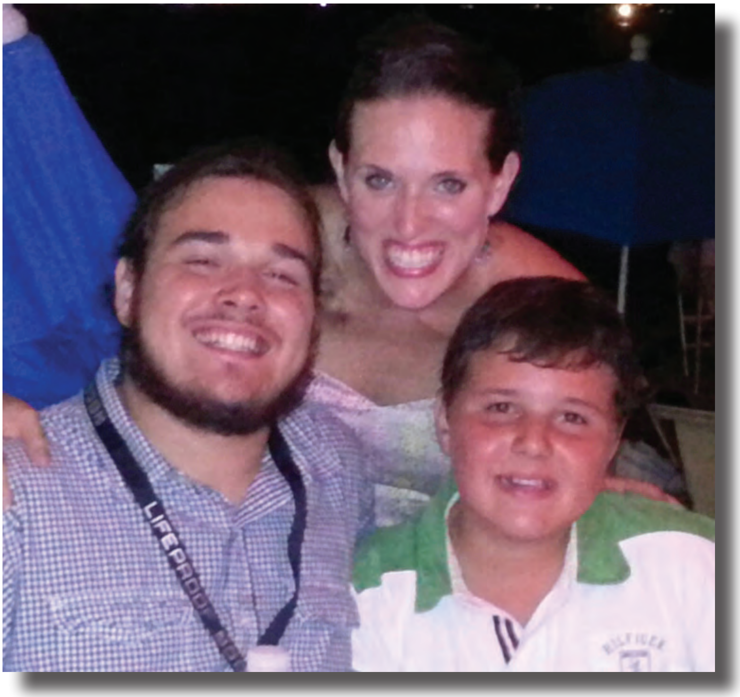

Alex Rivera, Kim McDaniel (Kerri's sister), & Patrick Rivera

Introduction

Autism is Avoidable, Treatable and Curable

Your body's ability to heal is greater
than anyone has permitted you to believe.
*~ **Anonymous***

Congratulations on finding this book, and welcome to the world of autism recovery. This book comes to life as more and more children with an autism diagnosis respond and recover in more than 58 countries around the globe. This book gives families a do-it-yourself guide to an *Autism Spectrum Disorder* (ASD) recovery program with answers all in one place.

I have, on my ASD recovery journey with my son Patrick, personally been frustrated with the lack of information and answers leading to lost time and money. For example, when I first knew that Patrick was no longer developing "normally" (in 2003), I was unable to get a diagnosis. Seven years, dozens of interventions and hundreds of thousands of dollars later I was still searching for pieces to Patrick's autism puzzle.

I learned over the years of many people recovering their children using various protocols and interventions, and I looked into all of them. Some gave us improvements but not recovery (most specifically for Patrick, diet). Some gave us nothing.

My goal with this book is to alleviate that frustration and loss of time and money for other parents.

I became interested in chlorine dioxide (CD) in 2010 but I was unable to find any information about using it with autism on the Internet. Since I knew that almost every child with autism suffers from similar pathogens (viruses, bacteria, candida, and parasites), heavy metal toxicity, inflammation and allergies I researched those conditions in combination with chlorine dioxide—removing "autism" from my vocabulary.

I realized with further research that CD would be excellent for curing the symptoms collectively known as autism. When Patrick was first diagnosed in 2004, his *Autism Treatment Evaluation Checklist* (ATEC) score was 147 and after six years of biomed he was at a 63. (The diets made the biggest difference in those initial dropped ATEC points). 2½ years of CD later he is at a 21. CD has made all the difference in his life, in my life, and in so many lives around the world.

I brought CD to my *Defeat Autism Now!* style Clinic in Puerto Vallarta in 2010. Today more than 115 children globally have lost their diagnosis of autism (meaning an ATEC score of under 10 points). Additionally, thousands of children around the globe have dropped points on their ATEC and are moving towards recovery. 27 children in less than 1 year in Venezuela alone lost their diagnosis of autism with a combination of diet, CD, and ocean water to the surprise of the doctors who diagnosed them in the first place. Many of those same doctors are now looking at CD for other patients.

It is my dream that every family of a child with autism be given this information so that they can decide for themselves whether they want to give it a try.

This book is a protocol for all of us. Some of you may be completely new to autism recovery; some of you may be a veteran like me and/or parents of older children and adults on the spectrum. This protocol works for even the classic "non-responders" and for those who are so close to recovery yet can't seem to get through the door. This book is for you. CD helps the body heal the symptoms we call "autism" across the board—it is an equal opportunity healer.

I know from experience that an autism diagnosis is devastating on many levels. The initial regression of a neurotypically developing baby takes away eye contact, speech, and the emotional connection between parent and child. Then, when strange new behaviors such as flapping, squealing, rocking, spinning or even self-injurious behaviors appear, you know in your deepest mommy (or daddy)-gut that your child was not born like this. It seems to take forever to get the truth about what happened to your happy, healthy baby. It takes even longer and is more confusing when you have to figure out how to heal that sick child. Far too many "health" providers in the autism field are focused on making money so we can't blindly trust anyone. We must do our own homework. The journey itself is a lot of trial and error coupled with misinformation.

Many supposed "autism experts" don't know much about recovery, or the effective order of treatments and end up costing our children time and the parents money. The less time a child spends chronically ill, the easier and faster it is to recover them. Not to mention the child spends less of their lifetime suffering the physical, emotional and mental effects of autism.

I feel that all parents who begin this protocol should expect a full recovery from autism because this protocol treats what causes this diagnosis. Our research indicates that every person with a diagnosis of regressive autism has virus, bacteria, candida, parasites, heavy metals (biofilm), inflammation and allergies. This protocol handles every one of these issues, and that's why it has been so successful. Some recover faster than others. But, every day we are one step closer to the end of autism.

How do you know if the protocol is working and how long does it take to see results?

The ***Autism Treatment Evaluation Checklist*** (ATEC) is our measure. The ATEC is an online survey that evaluates the severity of a child on the spectrum. For more information see Appendix 4, page 447. Many families notice changes from day one, while others take longer. You will get results when you correctly apply the interventions in this book in the proper order and without breaks.

What are the results you can expect from the protocols in this book?

I would love to say that everyone who follows the protocol will get their child down to an ATEC of 10 or less—what we call a recovery—and we have 115 of those already. The majority of those I'm in contact with report substantially significant improvements, even if they have not reached recovery. In the case of my son Patrick, he started at 147 in 2004 and has come down to 26. I'm optimistic as I continue to search for further answers, and will continue to share what I find.

If you are not getting results and have gone through this book including the Frequently Asked Questions (FAQs) and troubleshooting, please contact me through the forum at...

www.cdautism.org

...there are always tweaks we can make to keep moving towards recovery.

I recommend you read this book straight through in the order that it is written as that is the order in which it is to be applied. Jumping around the interventions can lose time for your child and waste money for you. Doing interventions in the correct order, when your child is ready for them, is the best to way to achieve recovery. Diligence and perseverance win the race every time.

My mission is to share with whoever is interested, the blessings that I have received. If the information presented here feels right and resonates with you, then please, give it a try. It might just be what your child needs.

This book in a nutshell:

If you want the best chance at recovery, here's the overview of how to do it:

1. The Diet: Eliminating gluten, dairy, soy, sugar, and toxins, to stop inflammation and reduce the overall toxic burden.
2. The CD Protocol to kill pathogens while using a multimineral like ocean water.
3. The Kalcker Parasite Protocol.
4. Explore and implement other potentially synergistic supplements to aid in speech facilitation, neurotypical behavior and/or seizure reduction.
5. Consider gentle chelators.
6. After 3 parasite protocols and consideration of all above steps, find a hyperbaric chamber (1.75ata).
7. Consider adding in GcMAF.

It is important to consider all of the pieces of information in Chapter 14, *Miscellaneous Information You Should Know* (page 323) and apply them from the beginning when they make sense for your child. You also may find the *Summary of Protocols* in Appendix 12 a good resource when you do not have time to reread a chapter to find something specific.

On the right is what we call the *Stairway to Recovery*. Joy Whitcomb, one of our amazing moms, came up with this so you can see just how each step rests on the previous steps, and without them you would not reach the top step… RECOVERY!

Author's Note: It is never my intention to "change someone's personality" or take away their character by healing autism. I see it quite the opposite. When children start to recover, their personality starts to shine through. The behaviors that we saw before (spinning, flapping, squealing, smearing feces, auto aggression, lining things up, tantrumming, etc.) are not personality traits but symptoms of a sick body. These symptoms start to disappear once the body begins to heal and our children can express who they really are through smiles, eye contact, words, gestures, etc. They can show us what they need and want and play an active role in their own lives. It is my dream that every child has the opportunity to mature and choose the life they want for themselves, and be responsible for making their own decisions. I truly believe this is possible for all of our children and adults on the spectrum, and I want families to have the opportunity to offer healing to their children.

Throughout this book we have used the pronoun “he” when referring in general to “a child on the spectrum.” This is not to alienate families with girls or women on the spectrum. It is simply a question of fluidity. To use *he/she* or *his/hers* every time we chose to use a pronoun seemed cumbersome, so therefore we are using “he” or “his” throughout the book. We chose “he” rather than “she” because autism is five times more common among boys than among girls. As of March 2013 the CDC revealed the results of a new study conducted during 2011 and 2012 which surveyed 95,000 families and estimated the prevalence of autism at 1 in 50 children.

The acronym DAN! is no longer applicable to *Defeat Autism Now!*, as it belongs to *Divers Alert Network*. The acronym has been used in several places in this book as several of the personal anecdotes are from a time when its use was still appropriate. Today, a “DAN! Doctor” could be defined as a practitioner who received training through the network formerly known as *Defeat Autism Now!*.

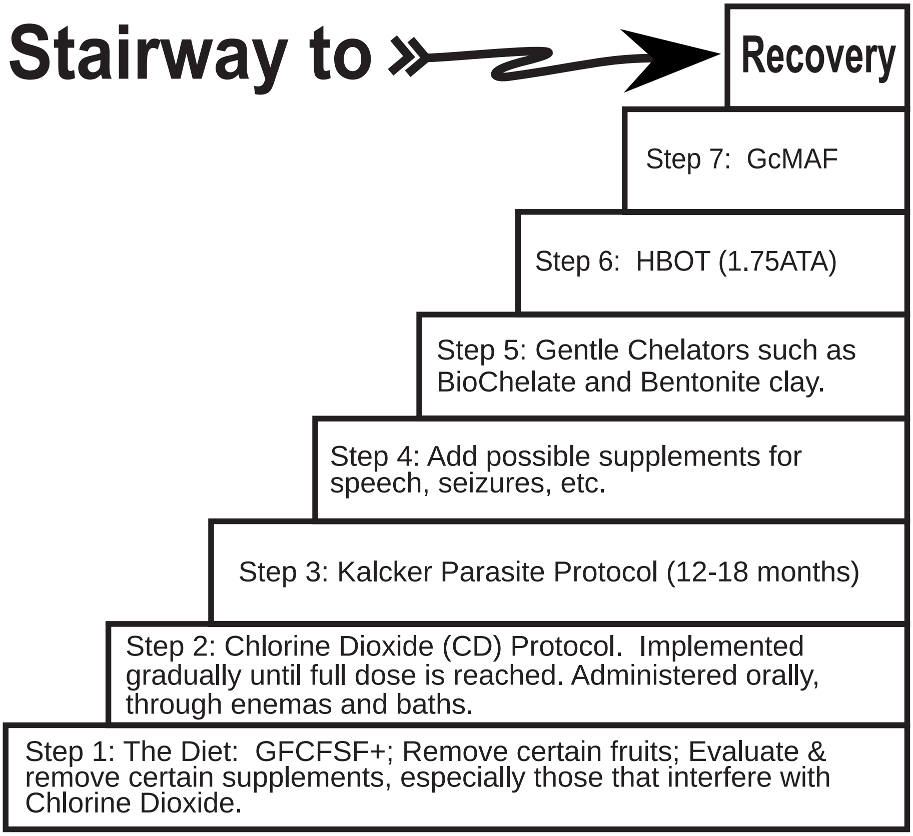

Stairway to » Recovery

Step 7: GcMAF

Step 6: HBOT (1.75ATA)

Step 5: Gentle Chelators such as BioChelate and Bentonite clay.

Step 4: Add possible supplements for speech, seizures, etc.

Step 3: Kalcker Parasite Protocol (12-18 months)

Step 2: Chlorine Dioxide (CD) Protocol. Implemented gradually until full dose is reached. Administered orally, through enemas and baths.

Step 1: The Diet: GFCFSF+; Remove certain fruits; Evaluate & remove certain supplements, especially those that interfere with Chlorine Dioxide.

Concept by Joy Whitcomb.

Everything yields to diligence.

~ Antiphanes

IMPORTANT NOTICE

Please keep in mind that the protocols in this book are still evolving, and will continue to be improved as new discoveries are made. We will release new editions to incorporate those new discoveries. The topics of CDS & CDH are particularly new and rapidly evolving. This book is current as of January 2014. Please be sure to check this book's website for important corrections and updated information beyond this and subsequent editions:

HealingTheSymptomsKnownAsAutism.com

Chapter 1

Kerri's Story

"The impossible is now declared possible as soon as you agree to it. It's just a flip of the mind, letting go really, nothing more."

~ Stuart Wilde

"What happened, what did you do to Patrick?" That was the first thing my husband asked me when he first saw our son, after returning from a weeklong trip. This was just five days after our youngest son Patrick received his last vaccine—the DPT (diphtheria-pertussis-tetanus) + Hepatitis B + Influenza B (what is known in Mexico as the *Pentavalente*) on the 13th of August 2002 at two years and one day old.

That question was the first of many to propel us down our path paved with autism. I told Memo (my husband) that we shouldn't worry. The nurse mentioned that we could expect a fever, or he could be listless. These were completely normal reactions. Contrary to what she said, what we observed during those first days and weeks were loss of eye contact, flapping, toe walking, high-pitched marine noises along with excessive drooling—drooling that would soak the front of his clothing.

Patrick had also lost all of the speech he had acquired; Mama, Pa, *agua* (*water* in Spanish), letters of the alphabet, numbers... all of it. The only thing he wanted to do was watch videos while running back and forth in his bedroom squealing the "ambulance sound," flapping and banging his gut, and drooling through all his clothes.

Not being well versed at the time in these problematic symptoms, we chalked it up to a case of the terrible twos. But these particular terrible twos led to loss of sleep for Patrick as well as the rest of the family, antibiotic use for green nose and eye mucous, and raging diarrhea that was so acidic it would burn his skin upon contact. This would be the story for the rest of the third year of his life.

The first of many to associate Patrick's behavior with autism would be my great aunt. She mentioned to me that she believed Patrick had autism after observing him at a family get together in April of 2003 while we were visiting relatives in Chicago. It was the most ridiculous thing I had ever heard.

Nevertheless, I went home that evening and immediately Googled the symptoms of autism. Laid out on the website were symptoms like spinning objects, lining up objects, self-injurious behavior, lack of socialization, and several other factors that I felt in no way described my son. I dismissed the comment, and continued to watch my son display strange behaviors, without understanding why.

I was back in Chicago a few months later in July. While going out for a run, I saw a girlfriend of mine who has a child the same age as Patrick. We stopped to chat and she asked me how he was doing. I said, "fine." She asked me if he was talking yet. I told her he had developed language, but since March he had lost all the vocabulary that he had previously acquired. My girlfriend looked at me and said "Oh…" with a look of concern on her face. I asked her, "What's wrong? What does that mean?" Now I was extremely nervous. "Well," she said reluctantly, "loss of language is a red flag for autism." There was that word again. I told her that we had already gone through all that, because by then I had taken Patrick to a neuro-pediatrician in Guadalajara, a psychologist with a huge center in Guadalajara, and a local psychologist in Puerto Vallarta. All three of these experts had told me that he was fine; they didn't see any problems with his development.

I started on my jog, and about halfway through, it hit me that Patrick did have autism, so I sprinted home, sat down at the computer and went to the *Autism Society of America*'s website and found a checklist of 16 symptoms of autism. The directions said if your child had 12 or more than most likely he has autism, Patrick had exactly 12. Looking back, he most likely had 14 or more, but I wasn't ready to see those just yet.

That same day I called his pediatrician in Puerto Vallarta and I told her I thought my son had autism, and she told me, "No, I have never seen anything like that in your son, but bring him and I will take another look." When we went in she observed him. She said that he didn't line things up, he didn't hit his head, he would still come to me, he was 'playing' with some toys in the waiting room, so therefore my son didn't have autism.

The pediatrician told me to go home that day to wait for him to straighten out. All the experts told me he was the way he was because he was the baby of a bilingual family that—according to them—traditionally produces late talkers; his parents and brother were all late talkers. He was spoiled. He had a nanny. And, he's a boy—boys are late talkers, etc., etc. The pediatrician successfully talked me out of the diagnosis once again.

As nothing was wrong, that fall we put Patrick into a kindergarten. His teacher would tell me Patrick isn't doing this activity or that, and I replied that we had taken him to see all the specialists, and he was just a late talker. She was super sweet about it and every few months she would make a comment to me because she saw him drastically different from his classmates.

Then one day it happened, I got a call from the director of the school saying that her friend, a neuropsychologist was in town from the United States, and she would like her to see my kids. At 6pm on March 12, 2004 I had an appointment with this neuropsychologist. I had already figured that this woman wanted to see Alex, my older son because he hadn't been doing well at school. He hadn't been sleeping well since Patrick hadn't been sleeping, which led to some poor performance in school. I had already gotten the news that Patrick was fine, so when she started focusing on him and his behaviors I was slightly confused. We sat down in his classroom, and she started asking me if he always… runs in circles, flaps, drools excessively, squeals like a dolphin, etc., (we actually used to joke that his mother must have been a dolphin). After that, I told her how we had already gone to all of these specialists and they said he was fine.

I was tired of getting the run around, and then everybody asking me what was wrong with my kid when he was just taking some extra time getting going. That's when she said to me, "I can't believe they didn't tell you your son has autism."

These words changed my life forever. Of course I asked her if she could be wrong, and she said, sure there exists a possibility, but she had done her post grad in autism, had seen hundreds of cases and this diagnosis was her professional opinion. That opened the floodgates for a river of tears that didn't end for years to come.

Being a positive person, I asked her what I should do. She said, "I would like to introduce you to a group of psychologists that are in town." The next day I went with her to a hopeless place, with hopeless people and I asked her if this is something that we can cure, and she said, "No, you can do therapy with these psychologists, and that's it." Children are born with autism and they will die with it, was the basic sentiment. I knew for sure that my son was NOT born with autism. He was the smartest, bright-eyed baby ever, and we had the photos and the videos to prove it. He was not born the ghost of a child that we had now. I knew that I would keep searching until I found something else for Patrick. I became proactive and never returned to that place.

The very next day I saw another girlfriend and she mentioned that she had a book on ADD and autism, so I immediately picked up the book and it was all about diet. Gluten-free, casein-free to be specific, and I decided to start it right away. Truth be told, Patrick's diet was horrible, he had self-restricted to only dairy and wheat. Bread products and cheese were his staple foods, but the good news was he still ate potatoes. Even as an autism novice, I knew I couldn't take him to a fast food chain because those fries were coated in gluten. We started off with just homemade fries with sea salt, because that was the only thing left on his diet that he would eat. After three days of being on the diet he said three words, the first three words he had said in over a year. I knew we were onto something.

The next week I ran into a friend from tennis, I really didn't want to say hi, because I was really depressed, but I heard a voice saying to me "It's not about the road but about smelling the flowers along the way." So, I forced a smile on my face, and went to say hi to her in my great depression. Well, she started to complain about her week, so I listened patiently, and then I told her about my week; Thursday my identity was stolen on the Internet, Friday my son was diagnosed with autism, and Saturday my dog of 14 years had to be put to sleep.

When she heard all this she turned off her car and told me how sorry she was. She said that she would put me in touch with her friend that had opened the *Early Autism Center* in Toronto, Canada. When I woke up the very next morning, I had a long email from Norah Whitney waiting in my inbox. She would turn out to be the first of many autism angels in my life.

I received a lot of precious information from that email, but what was maybe the most important detail for me was that what had happened to my son was an effect of all the vaccines he had received, he wasn't born with autism, as I knew. I also hadn't caused this, and I needed to start letting go of some of my guilt. Norah also told me that we can treat autism and I needed to immediately contact a DAN! Doctor, and Dr. Bobby Newman, Board Certified Behavior Analyst and Licensed Psychologist. Norah said that they were the best, and that this group of DAN! Doctors were curing autism.

I got in touch with everybody and that same month we started our own *Applied Behavior Analysis* (ABA) program. I also took Patrick to the States to see his first DAN! Doctor. When I got back home from that trip I had bought nearly $5,000 (US) of supplements and injectables. That didn't mean I knew how to use them, and by no means was I watching my son improving before my eyes. This was June of 2004, and we went through the rest of that summer with some supplements, other biomedical interventions, and 40 hours a week of ABA therapy.

That fall, some friends mentioned to me that their father was receiving chelation in San Diego, and I had just heard someone else saying that chelation was working for kids with autism, due to their extreme metal toxicity. By the end of the evening I had the phone number for the clinic that was providing his chelation. When I called for information, they told me that they referred all of the children's chelations to Dr. Woeller in Temecula California, so I made Patrick an appointment. In March of 2005, I took the whole family to Temecula to see Dr. Woeller, because basically nothing was happening with the supplements I had been giving to Patrick. I knew I needed to keep exploring other avenues.

Several thousand miles and various tantrums later, we arrived at Dr. Woeller's office. I told the receptionist that we had come to see Dr. Woeller. To my chagrin she said, "No, you have an appointment with some other doctor, Dr. Woeller isn't even in town right now." My husband was sure I had messed up the appointment and was extremely upset with me. Meanwhile, Patrick was screaming, crying and taking his clothes off in the waiting room. They finally let us through to speak with the other doctor and after going through Patrick's autism we explained that we wanted to chelate. We had the understanding at that point that his autism was coming from the mercury in the vaccines. She told us point blank that we couldn't do everything at once, and before we could chelate we would have to clean up his gut. I flew home with my family totally deflated. We started on the impossible journey of cleaning the gut.

My first ever autism conference turned out to be *AutismOne* in late May of 2005. I met a lady who was a rescue angel for *Generation Rescue*, and I told her I wanted to chelate my son with those DMPS drops, which were fashionable at the time. She told me that when it came to my son's recovery I shouldn't take no for an answer. I had to advocate for my son, and not let myself get pushed around. With that wisdom, I called Dr. Woeller's office again and told them I wanted my appointment with Dr. Woeller himself, and I would not be given the run around. The manager listened to me and said that she would put me through to him. After a long c'onversation, Dr. Woeller agreed to take Patrick's case and that he would help me chelate my son. He agreed with me that it was silly to think that we could have the gut completely under control before beginning chelation. Eventually I got the DMPS drops for Patrick that I had so coveted, and I felt we were back on track. However, after about six months of using the drops we still saw no change.

Flashback to that same *AutismOne* conference, where I had attended a lecture about the *Specific Carbohydrate Diet* and the removal of all grains from the diet—a diet that helped Patrick inch forward minimal improvement by minimal improvement.

In November of 2005, I had a phone consult with Dr Woeller, and having been disappointed with the transdermal DMPS I decided to ask if there was anything new in the world of autism. The answer that would end up changing all of our lives was hyperbarics or HBOT (hyperbaric oxygen therapy).

I learned that there was a really nice man by the name of Bob Sands in San Diego who owned a corporation that manufactured hospital grade hyperbaric chambers. I phoned Bob's office because Patrick was going to need 40 sessions right away, and I wanted to check prices and see if there was a package discount for hyperbarics. The answer was yes, in fact there was a discount. I scheduled Patrick's HBOT, and took both of my kids to San Diego, where we stayed for 20 really long days to get Patrick his first 40 sessions of hyperbarics—two a day—everyday, morning and night.

During that time, my husband and mom would call and ask me if Patrick was better, but he was still naked in front of the TV, jumping up and down, flapping and squealing. It wasn't until we got back home that he began to pronounce the first syllables of all of the words for things he wanted, like "ap" for apple. We considered hyperbarics a great success, but like I said that wasn't until a couple of weeks after we finished the 40 sessions. That's when we really began to see the changes in Patrick. Bob always says that HBOT is the gift that keeps on giving; you can see benefits for up to two months after you finish your sessions.

Meanwhile, Bob and I hit it off right away. He had a real jovial and family-oriented atmosphere in the clinic. I told him my story and how I wanted to help people know that autism is avoidable, treatable and curable. I shared with him that there was no information, much less Biomed or autism recovery in Mexico (and most of Latin America). I wanted to help people and to share with people that there is a lot we can do to help our children heal.

The very next day he walked into the office and changed the course of my life forever. He told me that he was in fact friends with Dr. Bernard Rimland, "Bernie," the Grand Godfather of Biomedical treatment for autism, and the author of *Infantile Autism*, *Dislogic Syndrome*, and the founder of the *Autism Research Institute*. I told Bob that meeting Bernie today, would be akin to having met Mick Jagger when I was 15. He then announced that we would be having lunch with none other than Bernie himself and Mrs. Rimland. For the first time in my life, I admitted to Bob that I was so excited that I didn't know what to say. Bob told me that when it was my turn to say something that I should ask Bernie "What can I do for DAN!?"

In a tizzy I ran over to Marshall's, the discount retailer; bought a new suit, hose, and even a pair of high heels. The next afternoon, I put on my new ridiculous clothes, ditched my kids with my friend's maid, and hopped in Bob's Jag to meet Bernie and Gloria (Dr. and Mrs. Rimland)—an absolute dream come true. When we arrived at their favorite restaurant, I was completely overdressed. Gloria ordered a salad, and the guys had tilapia because Bernie didn't really like vegetables. The conversation ranged from Kinotakara patches, to the difference between soft-sided hyperbaric chambers and hard hyperbaric chambers.

I waited until there was a lull in the conversation and I went for it, I asked him what could I do for DAN!, and he said I should translate the DAN! Protocol and take it to all of Latin America. His words left me totally dumbfounded. Had I heard right? Latin America? I was thinking my town of Puerto Vallarta, or maybe Jalisco, (the state we lived in) and maybe in my wildest dreams all of Mexico, but this was much bigger than I had imagined. At this point, though there was no stopping the momentum that we had started. Within months we translated the Protocol to Spanish, and donated it to the Autism Research Institute, for dissemination throughout Latin America. Much later I would find out that one of my dear friends, Yeroline, would heal her son from autism using the translation of the DAN! Protocol, as well as others.

During that same trip my husband and I spoke to Bob about buying one of his chambers for the not-for-profit autism clinic we were planning on opening in Puerto Vallarta. The plan was to run the clinic on a non-profit basis, but anchor the clinic by charging the public for their sessions in the chamber, allowing all the profits to pay for children with autism to go for free in the chamber.

It was a green light all the way. We deposited the money for the chamber in March of 2006, and it arrived on October 31, 2006. AutismO2—Hyperbaric Clinic officially opened its doors on Dec 1, 2006. We threw a party for the inauguration, invited friends, family, Patrick's therapists, and our local priest came to Bless This House. We all wore white, and in honor of Patrick, who was our motivation for opening the clinic, we all had on nametags that said *Kerri—Patrick's Mom*, *Memo—Patrick's Dad*, etc. It was a special evening for all of us, but me especially, as it solidified what would be the path that I would still be walking as I write this book seven years later.

The clinic had a Sand's Hyperbaric Chamber, an allopathic physician with a specialty in Hyperbarics, 2 psychologists, 2 hyperbaric technicians, and me, to initially meet with the parents. As for the chamber, we always knew that it was going to help a lot of kids with autism, but it has helped a lot of others as well. The chamber was what gave language back to Patrick in 2006.

Later that same year we sent our allopathic doctor with our naturopathic hippie doctor to Ixtapa, Mexico for a hyperbaric conference, where they serendipitously met Dr. Giuseppina Feingold, (Dr. Jo) a DAN! doctor using hyperbarics for children with autism. As soon as our guys got back to Puerto Vallarta they started insisting that I had to contact her because she is curing kids with a protocol that included hyperbarics. Never one to waste time, I emailed her immediately, but at the time I didn't know she wasn't an email person and, because I am just not a phone person, we didn't connect.

Fast forward to January 2007, my husband, Memo, was buying a 1951 Desoto on eBay. We had to pay for the Desoto with a check, and therefore started to talk to Bryan, the seller of the car. During their conversation, Memo, my husband, said to Bryan "If you don't want to sell, because it's worth more than your selling price I will understand." Bryan had already decided to let it go, but at the same time he was interested in where the car was going, what Memo did for a living, etc. Memo told him about our life in Puerto Vallarta, and the classified ad magazine business that he owns. That's when Bryan stopped him and said, "I've heard of that magazine!"

It turned out that this Bryan was a nurse who works with a doctor who does hyperbarics and heals kids with autism. Well, that piqued Memo's interest, so he told Bryan about Patrick's autism and then Bryan says you must call Dr. Jo, yes, the very same Dr. Jo that our clinic doctor had met months earlier at the Hyperbaric Conference in Ixtapa. So, I called her immediately and when she answered I said who I was, and I told her Bryan told me I had to call her. I asked her if she believed in God and she said yes. I went on to tell her that in September she had met with my clinic's doctor and how I had emailed, but never heard back. At the time, Dr. Jo had been receiving so many emails that sometimes she couldn't get to all of them.

Finally we had connected, and we hit it off right away. I immediately told her all about the clinic and Patrick, hoping that she could come to Vallarta. She told me that I had to go see her in New York first, and we would get Patrick some treatment. So off we went to freezing cold New York in March of 2007.

We immediately started treating Patrick with IV chelation. The theory at the time was the main factor causing autism were heavy metals coming from vaccines that were damaging the methylation pathways. During my daily treks to Dr. Jo's office I finally met Bryan, the owner of the Desoto that my husband bought on eBay. We started talking about my clinic and what we could do collaboratively if Bryan were to move there. Bryan had already been in nursing for almost 30 years and was an expert in ozone and other alternative therapies. He told me he was ready for some changes, and we were very interested to have someone of Bryan's caliber and relaxed personality to join us at the clinic.

Within a week of my return to Puerto Vallarta Bryan came for his first visit, to see if he could call Vallarta home. Two months later he came back with all of his equipment to set up his office. We were a great fit, and Dr. Jo would fly down from time to time to help out with patients.

From 2007 to 2008 we were treating Patrick with IV chelation on top of his regular GF/CF/SF, diet, supplements, and hyperbarics. In May of 2008, I met a mom who had recovered her autism spectrum child with homeopathy. Almost immediately I started working with a world class homeopath from June 2008 to May 2009, but I didn't see anything to make me feel that the cure to autism was down that path. That same year I met a doctor doing the Yasko protocol, and she had some ideas, so we gave it a try from August 2009 until the end of May 2010. At that point, Patrick honestly looked worse than before we had started giving him 80 supplements a day.

By now I had become disenchanted with *Defeat Autism Now!* based megavitamin protocols. A precious few of the families that we helped recovered their children with diet, supplements, chelation and hyperbarics. However, the overwhelming majority still had an autism diagnosis after tons of work by their parents, and usually a lot of money spent on supplements and treatments. I started feeling like it was a fraud, telling people to follow this protocol, which I knew wasn't going to be enough to recover most of the kids. That's not to say that we weren't seeing vast improvements, but counting all of the children that we worked with, only two children recovered.

By July of 2010, I was totally disillusioned and befuddled and I didn't want to continue doing what I was doing the way I was doing it. So, I asked the Universe/God/Angels—whoever was listening, for help. If my mission truly was to help families recover their children from autism then I was going to need a tool to work with. One that was available on every continent and that was affordable to everyone, because what we had just wasn't doing the job.

No magic voice came, thank God! Because that would have really freaked me out. However, I started to remember these colorful little bottles of chlorine dioxide that I never used. I decided to research their use on Google. Disappointingly, there was absolutely nothing on the Internet about autism and Miracle Mineral Solution (MMS) aka chlorine dioxide (CD). So I started thinking about what autism is made up of. So, I Googled chlorine dioxide with virus, bacteria, candida, heavy metals, blood brain barrier, allergies, and inflammation. The evidence was overwhelmingly positive, which showed me that CD could treat all of the components that make up autism. I had hope once again.

I was especially interested because at the clinic, we specialize in oxidative therapies such as hyperbarics and ozone. As chlorine dioxide is more benign than what we were already using, I decided to investigate further.

No side effects except a possible Herxheimer reaction; which is not a side effect of chlorine dioxide itself, but can happen with any detoxification protocol. I decided to speak to my husband and son Alex, who were also excited. The next day at the clinic, my husband's best friend's cousin and his wife were getting out of the chamber. I said, "Hi!" and she immediately said to me, "I'm taking CD." She didn't say "Hi!" or "Kerri!" just, "I'm taking CD." That was the definitive moment for me—my Aha! moment. I told her I had been researching it for weeks, and I was extremely interested. She was having great results, so my husband said he would try it first. If after three days on the drops he was still alive then we would start Patrick on them.

I contacted Jim Humble, discoverer of CD. I was hoping he would help me to better understand how to dose CD for children with autism. I explained to him that there was nothing on the Internet for kids. He helped me do just that. He gave the following recommendations: 1 drop 8x a day for children under 25lbs, 2 drops 8x a day for children under 50lbs, and 3 drops 8x a day for children under 100 lbs. He told me that the more doses that we can get in one day the better, 8 doses are the minimum.

That first week Patrick vomited (classic Herxheimer reaction), because I went too fast with the dosing. On the Internet, the only protocols I found gave high doses a few times a day, and as I found that week low and slow doses all day was the way to go. However, despite the Herxheimer reaction I caused Patrick (through lack of a low and slow dosing protocol) he was still noticeably better. Seven days later my son had improved eye contact and was asking for things that he had never requested in his life. At 9pm he looked me straight in the eye and said, "I want bed." With my jaw hanging open in disbelief, I followed him upstairs to his room. When we got there he turned to me and looked me straight in the eye again and said, "I want take bath." I knew I was not dreaming, and I had really just heard that. After his bath he looked me straight in the eye and said "I want brush teeth" and the whole time we brushed his teeth he was giggling... so I asked him what he wanted and he said, "I want 'kanket'" so I said, "blanket" and he repeated, "blanket, yes" and ran to the bed, and jumped on it to enjoy the blanket. He had never jumped into the bed in his life before that. This was the first seven days on CD. I was blown away.

By September of 2010, every person that was previously only using herbs or medications to kill viruses, bacteria, candida and other pathogens was about to hear about CD. That's when things really started to happen.

Back in 2007, I learned how Dr. Anju Usman was having great success with her biofilm protocol. She concluded that virus, bacteria, candida, parasites, and heavy metals are all joined together in the biofilm (more on this in Chapter 5, starting on page 117). And when I saw that CD killed pathogens and neutralized heavy metals and so many other things that make up the core of autism, I knew we would kill a lot of birds with one stone. I was also hoping to sidestep a few pharmaceutical pieces of the biofilm protocol, i.e. antifungals, antibiotics, antivirals and be able to use something with no side effects (a Herxheimer reaction is different than a side effect).

I was in the process of discovering how we could use this extremely inexpensive oxidizer that is available all over the world to help the body heal from autism. The other important part of CD is that you don't need to take your child somewhere for treatment, as in the cases of hyperbarics, ozone or IV chelation... there is no doctor needed, or trips to visit doctors in other countries. It's as simple as taking a supplement and you modify your dose depending on what you feel and see. Basically, any family with access to the internet, diet, CD and a few choice supplements can heal their child with autism.

After having limited success with my son on different biomedical treatments, even with the best doctors in the world, it was time for a change. With CD we are attacking the biofilm all day as CD destroys the electron shells of the different molecules making up pathogens, therefore releasing toxins into the bloodstream. This release of toxins is the principal reason one must go slow and build up the dose, to avoid a Herxheimer reaction as so many of these children are very toxic. If we kill too many pathogens at once, too many toxins enter the bloodstream. The body will immediately look to eliminate them, most notably through diarrhea and vomiting. This is unpleasant and totally avoidable.

CD is so benign you can use it on your skin, hair, ears, eyes, orally, rectally, vaginally, inhaled, etc. At the doses we use CD in aqueous solutions; it is not detrimental to healthy cells. It specifically targets pathogens due to their negative charges. Once I understood the basics, and Patrick was still improving, I started to share with others to understand how to use CD. Very quickly we were having success that many other clinicians weren't having. Kids on the spectrum were improving, some started recovering, and we had to sit up and take notice. I was blown away again.

In November, a child recovered and then in December another child recovered. Their families took them to psychiatrists and their doctors to have their diagnosis removed. These were the very important first steps that convinced me that this is something that we must continue to do. We started to spread the word that this was an inexpensive treatment modality available in every continent of the world.

With my background in biomed I learned that you watch for reactions while you load the dose. *Low and slow* is the rule. We arrived at the one-drop at a time dose and as kids recovered, parents shared their stories with other parents and more and more people started using it. It was very grass roots.

This is when the explosion happened. I started to think that this might be the missing piece of the puzzle that we had been looking for. In all seriousness, there is no one cure for all kids with autism, which is why each child's protocol and path to recovery is different. While we have seen great success with CD today I keep working to discover new modalities that help these children heal as non-invasively as possible. Now that we had had success in the Spanish-speaking world, I needed to share these treatments with families of children with autism all over the world.

Around this time something very interesting started happening with the CD enemas... parasites; more specifically roundworms were coming out with the CD enemas of the parents and their children using the Protocol. Today I have hundreds of photos, which were sent to me from parents all over the world (first world and third world nations) who have seen worms passed in stools.

At the moment laboratory testing is woefully inadequate, but a keen veterinarian can easily check for the presence of parasites in a stool sample using a high-powered microscope. The children who have had stool samples reviewed by microscopy have come back positive. Pinworms, roundworms, tapeworms and hookworms are the most common findings. Stool analysis done by laboratories have consistently come back negative even when worms have clearly been seen and photographed and seen under the microscope. In fact, one mother I know sent in a live, moving worm that her child had passed. The result? Negative for parasites! At this point it is simply not enough to trust a coprological analysis when looking for parasites.

Dr. Andreas Kalcker and Miriam Carrasco have been instrumental in this piece of the puzzle and have designed an amazing parasite protocol that has already helped many children including Patrick. In October of 2011, Andreas gave me the first parasite protocol and families in Spain, Mexico, Venezuela and others throughout Latin America began to use it. We'll talk about it in depth in Chapter 8, page 165 and how it has affected my life as well as the lives of so many other families with children on the spectrum.

In January of 2012, I got in touch with Teri Arranga and I was invited to speak at *AutismOne* in May of 2012. This would be the first time I would present at *AutismOne* in English, and obviously the first ever presentation on CD. After eight years of biomed and six years of helping families in Latin America I would be flying above the radar, knowing full well there would be a tradeoff. While I would reach families all over the US, for the first time I would end up taking a lot of flak in the blogosphere. We survived!

When I first came across CD in 2010 and began to watch it work it's miracles with autism, I expected parents, doctors and professionals who dealt with autism to be excited. I assumed they would begin to do research as to how and why the chlorine dioxide molecule was healing/curing autism. Much to my chagrin, many people were disinterested. Some even went so far as to say that what I had seen was impossible or that CD was toxic. Well, to that I would say that healing/curing autism with a toxic substance is impossible. Since then a handful of some of the best doctors in the world have become interested (that number is growing) and quite a few parents are taking note. Hundreds in fact went to my presentation at *AutismOne*. Several told me in hindsight that they had thought about not attending because the title of the presentation sounded too good to be true... *40 Children Recovered in 21 Months*.

The people who did attend were pleased with the information and many began the Protocol. However, what was to happen the days and weeks after my presentation blew my mind and was absolutely beyond my wildest nightmares. Some parents attacked me in print and on the Internet. I received threatening and accusatory emails filled with hate speech and foul language.

In most cases these emails and blogs were from anti-biomed parents. Others in the biomed movement told me not to worry, that these people were notorious for doing this sort of thing to others. They jump on the newest and brightest intervention in order to get their time in the limelight. Stealing attention away from the treatment, altering the truth, and in some cases lying to people about what is happening just to get other parents up in arms. Never could I have imagined anything like what transpired. However, as time passed, so did the threats, negative blog posts, etc.

Update for 2014

One of my favorite quotes states:

> *"All truth passes through three stages. First, it is ridiculed. Second, it is violently opposed. Third, it is accepted as being self-evident."*

Fortunately, the 2013 *AutismOne* conference was a totally different experience—which may indicate we are slipping into that third stage. In May of 2013, we were at 93 recoveries, and during my presentation at *AutismOne,* some courageous parents took the stage with me to share their children's stories of healing and recovery. There were no attacks. As the first edition of this book launched at the conference, many of our wonderful moderators were on hand to answer questions, and assist parents who were interested in getting started. I had a book signing along with the pleasure of meeting many parents I had up until then only known through email or Facebook. By January 2014, the first edition had already sold thousands of copies. If you searched for "autism" in the category of "books" on Amazon, it was showing up in various positions of the first two pages of over 10,000+ results, with the majority being five-star reviews. If you changed the order to "Average Customer Review," it was in the top 10, sometimes in position #1.

This has always been a grassroots parent driven movement, and today help is available in 7 languages online to answer questions and offer support. As with anything, if you attract enough attention, you will also attract some "haters," however CD has already earned itself a place in the treatment modalities that are healing the symptoms known as autism.

CDS (chlorine dioxide solution) was introduced in the first edition, as we were still hoping that it was something better than it turned out to be. It was a better tasting and more tolerated form of CD, and still remains an excellent preparation choice for those who are extremely sensitive, and have trouble tolerating even one drop of classic CD. However, we found that over the long haul, only one child so far has recovered with strict CDS use—the other 114 were with classic CD.

In this edition we are introducing *Chlorine Dioxide Holding [Solution]* (CDH). When this preparation technique was introduced it was touted as something similar to CDS… having a better taste, is better tolerated, along with less Herxheimer reactions. However, there is one big difference; CDH still contains a small amount of the raw materials required for the preparation of CD (sodium chlorite and citric/hydrochloric acid). On the other hand, CDS was chlorine dioxide gas ONLY dissolved in water. That small amount of raw materials in the CDH preparation may be what makes the difference. After 90 days of CDH use with over 70 families, it has not failed. Gains have not plateaued, and parents seem to be having an easier time increasing their children's dose, without any Herxheimer reactions. Another amazing thing about CDH is that the natural sweetener *Stevia* can be added to improve the flavor, while the potency of the dose does not change. This can be a game changer for kids that have taste aversion to classic CD. It should be noted that not all brands of Stevia are created equal and there may be some that can't be used. We are still testing various brands.

CDS and CDH have both earned their place in methods of chlorine dioxide preparation, thus allowing more people to benefit from the healing properties of CD who might not have otherwise been able to tolerate it.

People are always interested to know how my son Patrick is doing, and I am happy to share a little bit about what has been going on in his life lately. This past August 2013, Patrick turned 13. I had expected him to be recovered by now; however, we are still working towards a full recovery. He is better every month and his current ATEC is somewhere between 22 and 24. Patrick is very social, he loves a party. This Halloween, my sister threw a party and it was 11:30pm before he was finally ready to go home. He also loves spending time with his family. Every night he tells me, "I love you Mommy, gimme kissy." That is not only his way of telling me he wants a kiss, but that he wants me to come spend time with him before we go to sleep.

He has been preparing his own food in the kitchen, and while he has always liked to help chop, his being able to place his selection in the toaster oven and heat it himself is new. We didn't show him how to do this. He decided on his own that he would heat and serve himself his dinner one day. Another major advancement is that he is now able to clean himself after toileting, which is something he always asked for help with before. He will even wear headphones when listening to YouTube videos or watching DVDs if someone has to make a phone call.

We don't have any conduct issues, and if no one told you I had a son with autism, and you saw us out, you would never know. Apraxia remains the biggest factor delaying Patrick's recovery. That said, Patrick does communicate more than ever, and attempts more language than ever before.

As far as where I see this movement heading in the future, I believe that if truth does pass through 3 stages then we have finally entered the third stage of "self-evidence." The CD Protocol has now recovered 115 children (as of

December 2013); is used in 58 countries; and has already helped over 5,000 people on the spectrum, with more and more being added every day. The power of social media allows for parents to share with other parents their successes with the protocol, thus forming a stronger bond. Parents in the autism community trust other parents above doctors, and rightfully so.

At this point we are breaking many stereotypes associated with healing autism. For example, we now know that after the age of 9, recovery is still very possible (a 31 year old man is nearing recovery as I write these words). You do not have to be rich to recover your child from autism. You do not have to speak English—there are Facebook groups in 7 languages and this book will be translated into at least 13 languages. We now know that autism is not a psychological disorder. It is biomedical... viruses, bacteria, candida, parasites, and heavy metals cause the behaviors that lead to an autism diagnosis. Once you remove what is causing the symptoms, you can remove the diagnosis.

I witness on a daily basis what was not supposed to be possible: the healing of autism.

The future is bright, and it is up to us to share it!

Best in health,

Alex, Kerri & Patrick Rivera

Jim, Andreas and myself in Venezuela where 2 of the most amazing women in the world have a foundation to help Venezuela heal from the autism epidemic. I am so grateful to Yamileth Paduani and Carolina Moreno for their foundation and hard work. 28 recovered children from their foundation with this protocol in their first year of service. Thank you ladies. I am so proud to be your sister of the heart.

Ty reading and healing

Chapter 2

Yes We Can!!!

Without faith, nothing is possible. With it, nothing is impossible.
*~ **Mary McLeod Bethune***

Before we embark on the path of healing autism, it may provide you some comfort and encouragement to hear from those who have gone before you.

Some of the parents of the children who lost their diagnosis through this Protocol were generous enough to share a photo of their children along with a "thank you note." You will see that a couple of the older children wanted to write their own notes and share their success with the world.

①

My son gets to play little League!

Thanks to ATEC of 4, autism IS treatable!

THANK YOU KERRI!

②

OMG! I'm still rubbing my eyes. Nathan just played with cars appropriately! He pushed them along while saying, "vroom vroom!" Until now, he would simply mouth, spin or tap toys.

-Week 5 of MMS

③

Today in my son's school they had an "I Can Run" day for good health and to collect food for families in our community. Last year he couldn't make it 1 mile - they run / walk around a track. This year he ran 2 miles... Whhaattt? 7 months on mms and 6 months treating parasites.

④

I love you Miss Kerri,
Thank you for giving me CD.
Matthew

⑤

Wow! Here is something to be grateful for! It was time to do my son's one year ATEC doing MMS (7 months detoxing parasites) and his score was...drum roll please...15! You read it right, a 15! I am tearing up right now writing this. My son is 14 years, 4 months old. He was at a 27 when we started, then went up to a 34 when we started treating parasites (behaviors worsened), then down to 21 three months ago, and now a 15! Thank you so much Kerri! Without you, who knows where he'd be.

⑥

Before MMS we were able to get my sons atec score down to a 24. Although he mainly functioned as a "neurotypical" child, he still would have behavioral problems. He was easily agitated and would struggle with some anxiety and OCD. We were constantly battling yeast, constipation, metals and come to find out, parasites! We began MMS very slowly. We noticed his moods were improving. He was smiling more and over all just really pleasant to be around. We decided to retake his atec after only 1 month. It was a shocking 4!!! It dropped 20 points in 1 month!!! We have our boy back and will forever be grateful! We will be starting the parasite protocol this month and looking forward to an atec of 0!!!

7

I just wanted to share that today my daughter said a full sentence!

She normally only makes two word sentences and often stutters and stammers, with a lot of articulation problems.

My husband came home after a week away for work and she walked up to him as he sat at the computer and she said: "I want... to sit with daddy."

And in the bathtub (I'm doing the MMS steambath as both my kids are coughing right now), she turned to her brother and said "Look brother, cup." and she held the plastic cup in front of him. She has never been this coordinated and 'present', nor articulate. I am so grateful.

Even though we still have a long way to go, I feel like a huge weight has been lifted off my shoulders.
Thank you for your hard work.

8

Thank you for helping me to rescue my son.
God bless you
Kerri Rivera!

9

My son is at a three-day camp with 100 NT 5th graders! We have provided all his food, and go up to give supplements twice a day... other than that, he is on his own sleeping with friends for the first time in his life! I have no words other than Praise The Lord for bringing me Kerri Rivera and also for giving me and my family the strength to never give up! Our little bird had taken flight... thanks be to God!

⑩

Thank you God for your fidelity, thank you my beautiful girl for giving me your gaze and your smile every day, thank you Kerri McDaniel de Rivera for walking with me.

⑪

Hello, I'm Silvia, Alejandro's mom, we live in Spain. I was giving MMS to my son for 10 months without seeing any changes. Kerri told me that I wasn't doing something right… and that was correct. Being the warrior she is, she made me tell her everything I was giving Alejandro and she got it, Alejandro drank pineapple juice all day long, he would take more than a liter a day and that made the MMS not work, I stopped giving him pineapple juice 2 months ago, and he is a new child… He pays attention, his comprehension is almost 100% I must say my baby did not speak, but with this he started saying: "Come on, mom!" "My mommy" All this because I started giving him the MMS as I should. I want to say NO juice near MMS because it anulls its effectiveness. I thank God for putting Kerri in my path. My son improves everyday, slowly but you can see that he is saying goodbye to his little world. Thank you Kerri for being in our lives and for making us see the light. Also thank you JIM HUMBLE for giving hope to our lives.

12

Thank God for putting Kerri Rivera in our path, and giving us our prince back, totally recovered.

13

My son turned 12 today - hooray!! This is truly the very first time since his 1st birthday that my heart didn't shatter into a million pieces because it's another year down the road, and still so far away from recovery!! He decided that he was staying at home today to play with his birthday toys, he told his teacher (several times over), and when she asked if she could take the day off too, he said "nooooo!!. When his grandpa called from Holland to sing Happy Birthday, he sat quietly listening with a smile on his face - the usual is "no singing!" Besides that - here's my brag for the day - his teacher told me that she had to move him and his best class buddy away from each other because they were copying each other's work!!! YAHOO - we were SO excited - yes I know, we're crazy, but hey - if it's typical, I don't care what it looks like, I WILL TAKE IT!!! If you think this is weird, you should've seen me when he bit a child when he was 3!! I want to encourage you all today, look for the small things, check in with the people who are in contact with your kids and keep a journal of the changes. You will be amazed at how much we miss, because we spend every waking moment watching over them! I feel SO blessed!!

14

Dear Kerri,

Thank you so much for bringing our son's smile to life. The happiness you see in these eyes comes from listening to you and your amazing protocol.

We were stunned when his ATEC dropped 18 points in 3 weeks, and has now reached a staggering 1 from the original 36 in less than one year.

I thank God every day for having me in that AutismOne lecture in 2012 where you opened my eyes to what else we could do to help him. I want every parent out there to know this is a real Protocol with real results.

Thank you again and God Bless everything you do for our Children.

You Rock! Love Maryann

* * *

15

Greetings from Monterrey.

Just to let you know, we went to visit you in Puerto Vallarta on June 21st, and my child started treatment in July with MMS. As of today my son eats almost all on his own, and wipes his mouth whenever he needs to. For about a month now he has been doing funny things; like covering up his cards when we play as if to hide them, if he sees me squatting on the floor he runs over and jumps on me. He shows expectation on his face when he knows that I am coming to tickle him. He hides behind a wall when we play hide-and-seek.

In both of the institutes where he goes they have told me he is able to pay attention for longer periods of time, his way of being has changed, and they have also said that his eye contact is much better. According to his therapist he is now a candidate for speech therapy because he is able to pay attention.

For us, Kerri, this is a miracle come true, to see our son waking up little by little and to see him eat all on his own. Thank you so much for sharing all of this with us.

⑯

Since starting MMS my daughter's play skills improved, she actually looks into my eyes and gives me eye contact which means a lot. She started answering questions, more engaging and now I started to feel as if the end of the tunnel is not too far. I am so grateful to Kerri for showing me a way to recover my child. GOD BLESS.

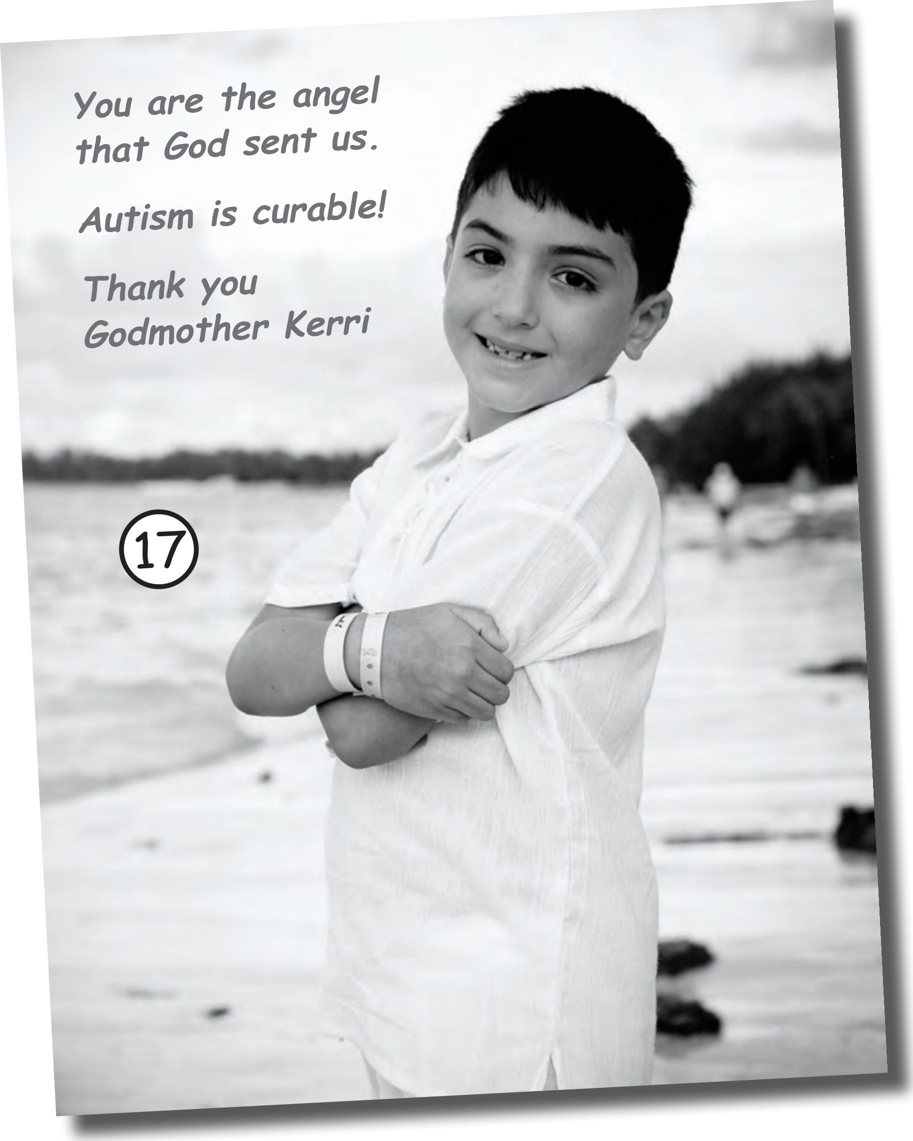

You are the angel that God sent us.

Autism is curable!

Thank you Godmother Kerri

⑰

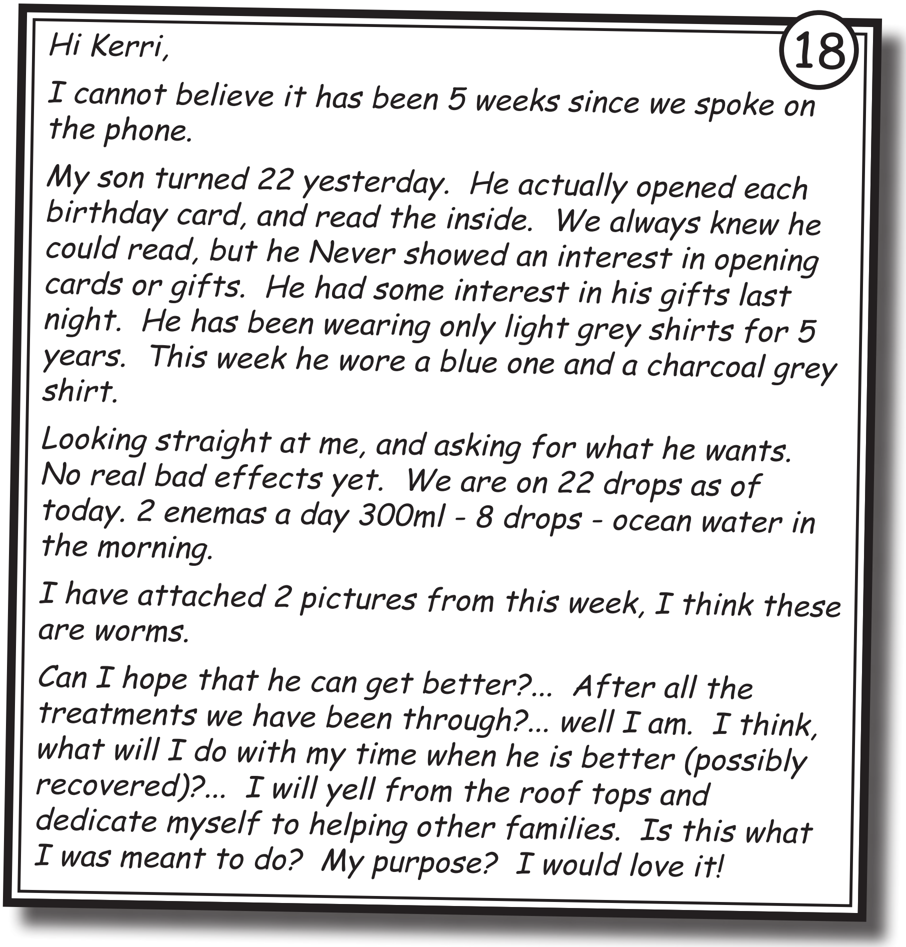

⑱

Hi Kerri,

I cannot believe it has been 5 weeks since we spoke on the phone.

My son turned 22 yesterday. He actually opened each birthday card, and read the inside. We always knew he could read, but he Never showed an interest in opening cards or gifts. He had some interest in his gifts last night. He has been wearing only light grey shirts for 5 years. This week he wore a blue one and a charcoal grey shirt.

Looking straight at me, and asking for what he wants. No real bad effects yet. We are on 22 drops as of today. 2 enemas a day 300ml - 8 drops - ocean water in the morning.

I have attached 2 pictures from this week, I think these are worms.

Can I hope that he can get better?... After all the treatments we have been through?... well I am. I think, what will I do with my time when he is better (possibly recovered)?... I will yell from the roof tops and dedicate myself to helping other families. Is this what I was meant to do? My purpose? I would love it!

⑲

Thank you for this look.
I share this look with
you, the same look
that you have given
back to my Mom, this
photo would not be, if
it hadn't been for you.
I love you very much,
your Godson Gabriel

⑳

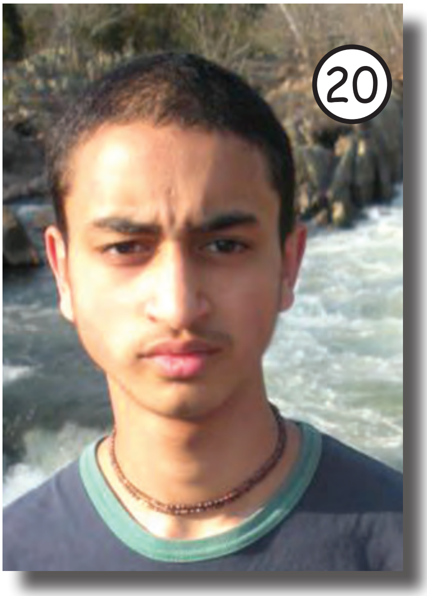

My family and I are very grateful to Kerri Rivera for making available the CD protocol to treat ASD which has recovered myself and made a huge difference to thousands of kids and families all over the world.

CD can recover even a teenager like me whom others had given up on. Of all the bio-medical interventions, CD cost the least and made the biggest difference.

Muchas Gracias por salvar mi vida Kerri.

㉑

This is Benjamin. 4 years 5 months old, current atec of 4 and dropping weekly :) Diagnosis atec at 3 years 2 months was 134. Atec when starting CD protocol was 18 and was stagnant after full on bio-med/diet intervention. Dropped all supps except melatonin when starting protocol and obviously can't be happier with that decision. Thank you to Kerri Rivera of course for giving me a way to save my baby boy... We will continue with protocol until atec = 0 :)

(22)

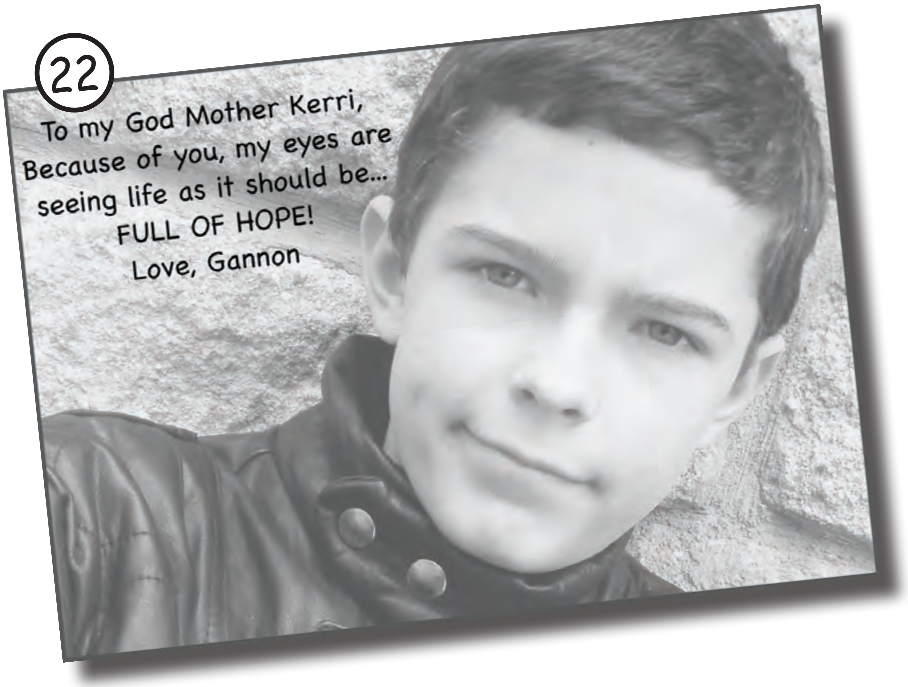

To my God Mother Kerri,
Because of you, my eyes are
seeing life as it should be...
FULL OF HOPE!
Love, Gannon

(23)

My sons started using MMS exactly 2 and a half months ago and we saw improvements almost immediately, my twins attention got better just days after we started the treatment and at 10 days after starting my son Juan Pablo started calling me mom! He has never done that before. (Neither of my twins were verbal, meaning they were not able to speak a single word.) A few days later Jesus Alejandro said "Mom, water" while pointing to the fridge, it was shocking for me.

My two sons can now say 4 or 5 words and their communication skills have gotten a lot better, even if it's not verbal they are very good at expressing what they want. There is a lot of improvement in comprehension, following orders and accomplishing small tasks, they react when you say their names, they are controlling their bowel movements, and in general their whole quality of life has gotten so much better since they started with MMS.

I know we have a long road to go but we are on the right track and I trust that thanks to the science that discovered the great effects of this wonderful formula for our children with autism we will recover them, as it truly does detoxify!

Ing. Artebys Cedeño
Mother of Jesus Alejandro and Juan Pablo

OAHU
Surf Academy

24

Dear Godmother Kerri,

How can we ever thank you enough for crushing autism out of TJ's life? We now have a smart, happy, helathy boy that has great confidence in himself!

We are forever grateful to you!!!

25

We started using MMS a month ago. We are not even at the full dose yet but have been seeing some amazing gains.

I took my son to the mall about a week ago because it is one of his favorite things to do. When we got home he did something he has NEVER done before. He came up to me, hugged me and said "Thanks". Wow.

Two days ago my husband had to go to the local farm supply store because something broke in the barn. So we asked my son if he wanted to go and he literally jumped off the couch and excitedly came with us. While he was there he picked out a couple of books he was interested in and a couple of small vehicle toys. When we got home I was helping him with his coat and boots he said "you're great mom". Never have I ever had spontaneous comments like this and the only thing I can attribute it to is the MMS because we stopped everything else. This gives me inspiration to continue the protocol and I look forward to what the future holds for my son and our family.

Thank you Kerri!

26

If it were not for you Kerri, my mother would still be worried about my future.

You are my Guardian Angel!!!

Autism is curable!

Thank you Kerri
Gracias Kerri!

27

His speech therapist told me today that his sentences are so much better, more organized, also his ability to converse back and forth and also his concentration have improved!! Sooooooo..... Yay!
Oh, before we went to see his speech therapist he said: Mummy, my speech is getting so much better!
Yup, he said that! He knows!

28

I can't believe it! I just did my daughter's ATEC and in one month it dropped from 72 to 48!!! I am so shocked! Is this a dream? We revised the scores over and over with my husband and accepting that some of our answers could be just very positive feelings, still the improvement is huge!! I am so thankful Kerri Rivera! I have no words!! I am praying this is not a dream!! THANK YOU SO MUCH!!!! I believe there is more to come but right now I am so much in shock!

㉙

I have to post our Sunday gain, my daughter is and always has been on sensory overload, those of you who deal with this know that teeth brushing, hair combing and showers can be torturous for child AND parent. I literally dread washing her hair. She screams so loud she could break the windows. She smacks her wet thighs so hard that they've been bruised for years. This morning she gets in the tub, sits down and sees me roll my sleeves up (which is usually the moment she loses her mind because she knows I'm about to grab the shower head), she stood up, looked me dead in the eye, smiled at me and said "R. shower". I began to wet her hair down, still convinced that the screaming was about to begin any minute. I started shampooing and she said "well done", I smiled and said "VERY we'll done baby". My husband peeked in to see why it was so quiet and she looked at him and said "Daddy shower", smiling from ear to ear as to say 'I'm taking a shower Daddy'..... what a great way to start our Sunday. HUGE, HUGE deal for her and for us. I feel like I finally exhaled today. MMS rocks and so do all of you!!! Happy Sunday ;-))))

㉚

Dear Kerri,

Thank you SO MUCH for helping us with our daughter's complicated health issues. The CD/PP protocol allowed my daughter to sleep through the night, for the FIRST time in 7 years! One month on the parasite meds, she began sleeping perfectly and has slept perfectly ever since!

We are FOREVER grateful! Also, the more her pathogen load decreased on the protocol, the more foods she would eat and LIKE!

My daughter eats SALAD now! AND will try any food I give her. I thank you from the bottom of my heart and will be forever grateful!

With love,

The WHOLE Clark Family!

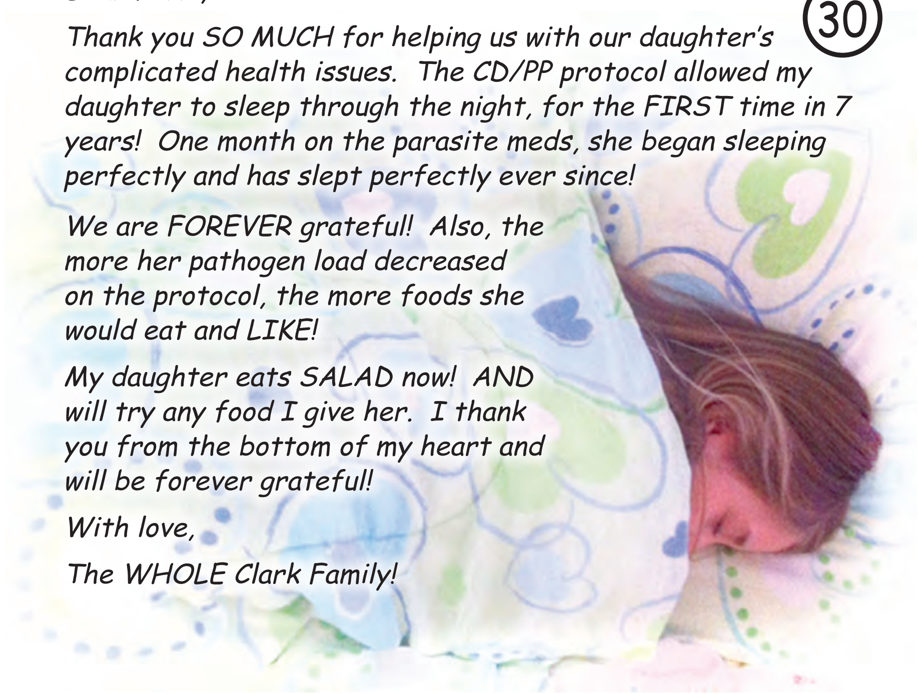

㉛

I was cured,
Yes we can.

I love you
very much
Godmother
Kerri!

㉜

My son had a great week - yesterday we went bowling as a family. It's difficult with him to notice gains sometimes because he is really close - his ATEC was a 7 last time I did it and the changes in him may be subtle and harder to notice. While we were bowling he was calm (despite the loud music, lights and commotion) he sat in between his turn watching everyone, (and the music videos playing) knew when it was his turn and cheered for me (I was beating my husband at the time - lol). He carried his ball down the lane and swung it with one arm - omg!! It was the most NT I have seem him! He now is a brown belt in Tae Kwon Do and this was the first time he was able to swing the ball - I used to have to carry the ball to the ramp, help him lift it and count to 3 for him to push the ball. He was diagnosed hypotonic at 3.5 years, MMS and PP are what helped him get some strength, energy and endurance. I increased his MMS by a drop about 2 weeks ago and we are also ramping up on GcMaf.

Great FUA moment today. My son took his first ever lesson.... swim lessons. He did amazing!!! Followed all instructions, waited in line, smiled, talked, and let the instructors help him. Amazing.... I cried almost the entire time. At one point he smiled, waved, and said "hi mommy." ㉝

㉞

Thank you Kerri! Because we followed the protocol with obviously great results.

㉟

My son has continued to improve on his handwriting and his anger has melted away. We had an IEP today and we lost 2.5 hours of services because he has done so well he does not need those services. They were surprised at how well he is doing. And he fed his little brother soup tonight to get him to eat his dinner.

㊱

Thank you Kerri for
helping us to recover our son!

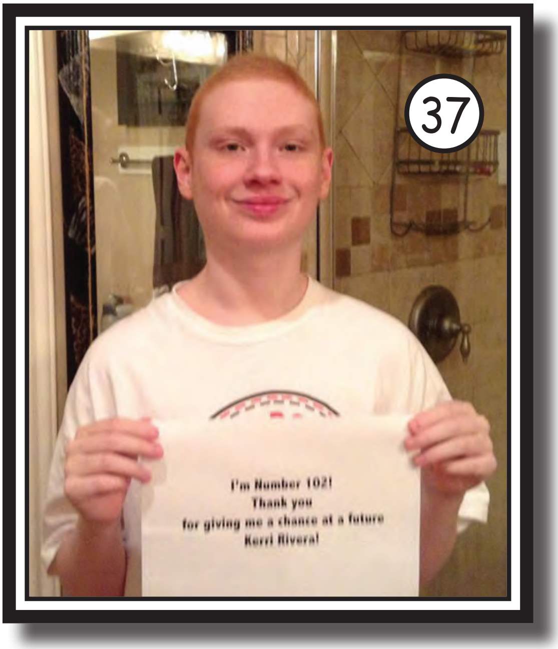

I'm Number 102!
Thank you for giving me a chance at a future
Kerri Rivera!

On any given day, I probably rattle out the words I LOVE YOU, directed at my boys at least a dozen times. My NT boy almost always will reply back. My ASD boy usually says, YES YOU DO as his answer. And I have completely accepted that that is his way of receiving my I love yous.

On very rare occasion he will say I love you to me…

Well, by now you know where this is going.

This morning I was walking past him and he said to me…. I LOVE YOU!

I wasn't at first sure what he said as he didn't shout it, So I asked him, what was that?

He repeated, I love you.

I said thank you son, I love you too!!!

㊳

Wait for it…

Bammity bam bam BAM!!!

Celebrating every little big thing. Appreciating my 3 favorite words. Loving every minute of every day. Even loving those big red lips this morning knowing he is detoxing…

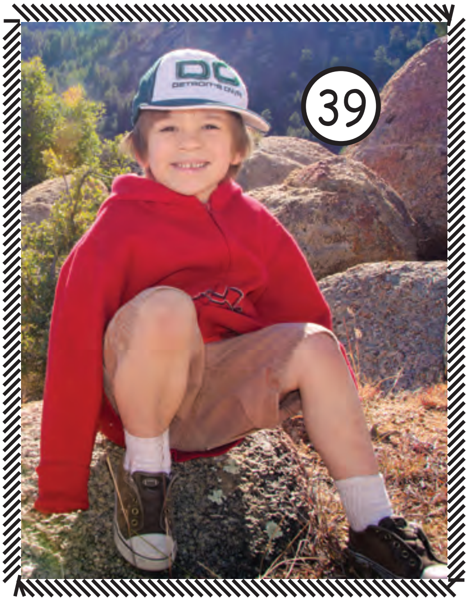

Our son was quickly slipping away from us. We were lost. This protocol gave us direction and ultimately brought our son back to us. He looks at us with smiling eyes and tells us he loves us. He has a full childhood now. Words could never convey the magnitude of our gratitude for Kerri and all who support her efforts to make a future for our kids. See Gunnar's full testimonial on page 378.

Gracias Madrina Kerri!! I now have an ATEC of 10!

We started the DAN protocol when our 10 year old daughter was 18 months old and remained on it for 9 years. Before starting CD, our daughter appeared neurotypical, but she was heavily dependent on supplements and her progress had stagnated for a few years. She had a distended belly, poor growth, severe constipation, anxiety, a touch of OCD, and focus/concentration/fogginess issues.

Her ATEC before starting CD was 24. Just 26 days later, her ATEC is 7. A 17 point drop in 26 days! We haven't even had time to do a parasite protocol or a 72/2 weekend yet! Her belly is much flatter and her anxiety, minor OCD, and focus issues are greatly improved! We're going to keep her on CD and I plan on starting the protocol myself this week. As a friend said, "DAN got her to third base and CD brought her home!"

㊷

My son just saw me reading this page, and asked what CD Autism was. I told him it was the medicine he's taking. He said, "I think my autism is gone. How do you know someone has it still?" Soon, baby, soon!

Spiro and Peter (9 year old twins)

After years of doing many interventions for our twin boys, and having moderate success at best, we learned about CD. It took about a year before we felt comfortable enough to try it. I can honestly say that, it is the BEST intervention that we've used. We started CDS in mid July 2013. In the 4 short months that we've been using CDS and now CD, we have had more gains in every area, than in the last 6 years of doing so many different treatments. What I love about this protocol, is the simplicity of it, less is more, and that was a huge change in thinking for me.

Just to give you an idea on how well our boys are doing, here are their ATEC scores so far:

Spiro: He was number 100 to recover on the "Healing Train" and the 1st child to recover using CDS.

ATEC prior to starting CDS - 22.

ATEC one month after starting CDS - 16.

ATEC two months after starting CDS - 9.

Peter: He was pre verbal prior to CDS and now uses single words and the odd 2 word combination to communicate. Well on his way to healing.

ATEC prior to starting CDS - 69.

ATEC one month after starting CDS - 55.

ATEC two months after starting CDS - 46.

We finally know, deep in our hearts, that our boys are well on their way towards "true healing". We don't have that stress and anxiety about what the future holds anymore. We finally feel like we can breathe easier, and that day by day, the gains keep coming consistently. The gains stay, and that feels better than anything.

Thank you, to my FB friends who introduced me to MMS and to Kerri Rivera who we have such admiration and respect for. I thank GOD everyday that we were fortunate enough to find out about this treatment. Our boys are coming back to us and their beautiful personalities are emerging. We now look to the future with such HOPE. Kerri, we will forever be grateful to you. xoxoxoxoxoxoxoxoxoxo

㊸

Tim Hortons

(44)

Whoa... My severe kid walked in the door and wrapped his arms around my neck and gave me a normal hug for the first time in his life (6.5 years). Umm... This is crazy. He wiped his butt for the first time EVER... no prompting, no asking! I wasn't even in the room with him! When I got excited and asked, "Did you wipe???" I swear to GOD... I heard "Yeah, Mom!" Kid's never said a word ever. Could be dreaming, but WOW!!! What a day!!!

Please share your experiences!

Testimonials are one of the best ways to share your experiences with this protocol. Perhaps you learned about it by reading or watching a video testimonial?

If you don't tell us your experiences, we can't share them or take action on issues that need improving or correcting...

Send your testimonials to:

testimonials@cdautism.org

Also, let us know if we are free to publish your testimonial, with or without your name.

More miracles & testimonials starting on page 358.

Chapter 3

Step 1 – The Diet

"Let food be thy medicine and medicine be thy food."

~ Hippocrates

If I could choose the one part of *The Protocol* that would be the single most important piece of the recovery puzzle it would be—*The Diet*. By *The Diet,* I mean the dietary plan that I recommend to all of the families that want to start *The Protocol*. It is a combination of the classic gluten-free, casein-free, and soy-free diet along with the elimination of sugar, corn syrup, coloring, preservatives, and other harmful foods. *The Diet* is the basis for the rest of The Protocol; similar to laying the foundation of a house that the rest of the structure will rest on. Adhering to *The Diet* is critical to the effectiveness of the rest of *The Protocol*.

When a family of a child with autism comes to see me, the first thing they want to know is:

What can I do to help my child?

I always, always start with *The Diet*. In fact, I send them away after that first meeting with hope that they will be able to recover their child, but only if they commit to *The Diet* 100%. I explain to the families that they must think about food the same way their great grandparents thought about food. In generations past, food came directly from the Earth, with little processing. Fruits, vegetables, nuts, and meats were dietary staples for our great grandparents and they should be for our children as well. We must think whole foods and not ~~processed foods~~. There is no point in going from regular junk food to gluten-free/casein-free junk food!

After my first meeting with a family, they leave with the list of permitted foods and I have them email me when they have a week straight with zero exceptions or "errors" in *The Diet*. That is where the parents who are truly hungry for recovery are separated from those who are interested in having someone else "fix" their child for them.

One of two things generally happens during that first week. In the first scenario, I get an email from an ecstatic mother or father saying, "I can barely believe it, Johnny slept through the night for the first time in years," or "Johnny had a normal bowel movement," or "Johnny said two new words yesterday!" That's what I hope for.

The second scenario is... I never hear from the family again. There may have been tantrums, or an adjustment period related to *The Diet* that proved too much for them, and they decided to pursue another avenue. That's not to say that everyone sees a miracle, or that there's no middle ground. Some of the results are less obvious, such as more eye contact or less redness in the face, but generally speaking, we see positive changes. Any change is a good sign. *The Diet* is only the first piece of the puzzle. We must continue from here, layering in interventions until we get the desired, end result.

> Kerri... Bless you! When my son was 3 years old he was prescribed Ritalin®, Risperdol® and Clonazepam... can you believe it? Obviously I never gave them to him, it hurt me to see my child "drugged." 2 days after starting the diet he slept through the night, the sparkle is back in his eyes... I can't wait to start with MMS, I am so happy!!!

Throughout this book "miracles," which are actual emails and forum posts from parents about their children's improvements, have been set in text boxes (like the one above) and placed in the chapters that they accent. Please note that as many of these miracles were collected some time ago the contributors have used the term MMS instead of CD. Due to time constraints it was impossible to request permission from these contributors to change the acronym of MMS to CD in their testimonials. MMS and CD are the same substance. Where the acronym MMS is used please know that chlorine dioxide is the substance being discussed and is responsible for the healing.

Author's note: I'm not against all prescription drugs, especially those necessary to bring about healing. However, I don't condone medicating a child with drugs, masking the symptoms known as autism. So, when I see an email like this, I know we've got a great chance to heal that child because we have a parent who has committed herself to healing her child, and who is excited to see what changes the next tool will bring.

Your child's doctor may not have heard of *The Diet* or may be misinformed of its benefits. The references section at the end of the book lists several studies and articles discussing dietary intervention for ASD's. You can use them as a jumping off point for your own study. If you are consulting with a doctor, it is important to choose someone who is familiar with autism and the recovery of autism.

Many doctors do not have time to study up on what's new in autism recovery and if they have zero recoveries then they are in dire need of overhauling their protocols. Another major problem in the mainstream medical community is gigantic egos. If what we are doing is not working to recover our children, then we need to look at what we are doing and why we are doing it. Let's check our egos, update our protocols, and look at what has worked for families who have recovered their children.

Researchers at the New Jersey Medical School's Autism Center found that "children with autism were more likely to have abnormal immune responses to milk, soy, and wheat than typically developing children," which is published in a chapter of Cutting-Edge Therapies for Autism 2011-2012, by Siri and Lyons.[1] In addition, interest is growing in the study of the link between autism and gastrointestinal (GI) ailments. Siri and Lyons also relate a study by the University of California, Davis Health System, where they found that children with autism born in the 1990s were more likely to have gastrointestinal problems, including constipation, diarrhea, and vomiting than children with autism who were born in the early 1980s.

If your doctor is uninformed, or tells you there is no evidence to prove that *The Diet* will help your child, do the research for yourself since only you are in charge of your child's diet. Heck, why not do *The Diet*? It doesn't cost you any money and it just might help your child heal. Whether he eats cheesy puffs or fruits and vegetables will ultimately come down to you. You are the one with the money in your pocket. The only way to know for sure if your child is going to be one of the individuals who recovers with *The Diet*, is to try. It can take gluten six months or more to be removed from the microvilli or "shag carpeting" of the small intestine. As I mentioned previously, some children have obvious changes in two to three days, but even if your child's evolution is taking a little longer than most, DO NOT GIVE UP! At the writing of this book, I have helped about 5,000 or more families of children with autism; all of the children who have lost their diagnosis, as well as those coming close to recovery, have used varied protocols depending on their symptoms. The one thing that they all—unequivocally—have in common is: ***The Diet!***

In my opinion, it makes little difference what other interventions you apply to your child if you can't manage *The Diet* 24/7/365. Hyperbarics, chelation, ABA, etc., simply will not have the desired effects if you are still feeding "drugs" (aka garbage foods) to your child.

Why do I say drugs? Because that is what gluten and casein become in the bodies of our children on the spectrum; more specifically, gluteomorphin (also called gliadorphin) and casomorphin, which are similar to morphine. Gluteomorphin and casomorphin are produced in the gut due to improper digestion of peptides (as we will explain more in detail later). In a person with "leaky gut syndrome" (increased intestinal permeability), they are able to leave the intestine and cross the blood-brain barrier where they act exactly like morphine or heroin. Would you purposely give your child street drugs? NO!

Once we have this information and understand the severity of this issue, we have a responsibility to our children to do better. We must take away the foods that are keeping them ill. Invite your family and your child's school to help heal your child's ailing body. Explain that they can no longer give your child these items, and that if they do, it's like giving them a dose of morphine. If it sounds drastic... that's because it is!

Researchers have found an abnormal amount of these undigested peptides (gluteomorphin/casomorphin) in the urine of children with autism, proving their existence in the body. Among others, Dr. Knivsberg and colleagues in Norway have found that urine samples from people with autism, PDD, celiac disease, and schizophrenia contained high amounts of the casomorphin peptide.[2] Similarly, Gliadorphin (gluteomorphin) has been verified by mass spectrometry techniques to be present in unusual quantities in urine samples of children with autism.[3]

Do *The Diet*!

There are still plenty of food options that are permitted. I promise you—your child won't starve! We have included some recipes in Appendix 15 on page 513 to get you started. *The Diet* is absolutely the most important piece of the puzzle. If we can't remove what is directly linked to brain and gut inflammation, as well as immune-allergic reactions to offending foods, it is nearly impossible to heal a child on the spectrum. I have personally never seen a family recover a child without dietary intervention. That's not to say it hasn't happened, but I have never seen or heard of it.

Like I said before, when we started with my son Patrick, his only legal food was homemade French fries. So that's what he ate. Little by little he began to accept more foods. I assure you, the adjustment period will fade and they do eat. Stop the cycle of inflammation and addiction. Only then will your child begin to heal, and once your child starts to feel better he will accept more foods.

In the case of my own son, his acidic diarrhea and sleepless nights stopped the week we started *The Diet*. From that moment on I was hooked, not only on *The Diet*, but also on biomedical treatments for curing autism. I have never looked back. I strongly encourage you to experience *The Diet* for your child, or even as a family. It is an amazing thing.

> I thought the following might encourage some of you who have recently made big dietary changes for your kids and are struggling with all that involves. I put my son on a GF/CF/SF... well, basically, EVERYTHING-free diet when he was 11 months old, following a major vaccine-induced crash. My choice to put him on a diet was criticized by nearly everyone in my life, beginning with his pediatrician who told me I was "just imagining" that he'd regressed and that he "probably wasn't allergic" to what I had taken out; she called a week later with the test results and an apology, and a long list of other things he was allergic to! He's now just a little over seven and doing GREAT. I just delivered a GF/CF muffin to him, and he said, "You know what I love best about you, Mommy? I love that you are so nice to us, and that you always make sure we have food that doesn't make us sick." So, don't feel bad about not giving your kid that ice cream cone when Mr. Softee comes by or not loading their Easter basket up with food dye this weekend. It may take years, but they will see that you loved them enough to NOT give them these things.

Some other tips include the following:

Review Your Child's Supplement List

Vitamin A
Vitamin B
Folic acid
Vitamin C
Vitamin D
Vitamin E
Vitamin K
Minerals

Is your child taking 30+ supplements a day? We will talk more about this throughout the book, but this protocol is geared towards eliminating excesses and not about supplementing deficiencies. It's important to carefully review your child's supplements. In order to maximize the benefits from this protocol consider removing any antioxidants, (they kill CD—more on that in Chapter 5, page 88), calcium, magnesium (which feeds the biofilm), as well as iron and B_{12} (which are favorite foods of parasites). Supplements for increasing speech, reducing seizures, enzymes, and probiotics obviously have their place in individual protocols. B_{12}, while known to feed parasites, has also been known to greatly boost speech in some children. If your child saw benefits in speech from B_{12}, it may be worth keeping in. As always, these are decisions that each family has to make for their child on an individual basis.

If a certain supplement proved beneficial to your child, then don't remove it (the exception being antioxidants and the other aforementioned supplements). The goal of this step is to remove unnecessary supplements as they are most likely feeding parasites and creating "excess noise" in the body. Anything that is not serving a purpose needs to be eliminated.

Keep a Journal

Keep a record of the foods you have removed and those you have added in. Then, take note of the types of reactions you observe: rash, more or less hyper, more or less stimmy (self-stimulatory behavior), sleep patterns, frequency and consistency of bowel movements, tantrums, acceptance of new foods, eye contact, language, etc. Write everything down so that you can follow any relationships or patterns that will allow you to identify when something is working, or when it is not. Record these observations in a notebook because it helps guide us, especially those of us who are stressed, frazzled, and sleep deprived.

Don't Stress About Raw Foods or Perfectly Balanced Meals…Yet!

When you are first transitioning, feed your child whatever legal foods he/she will eat. We are taking baby steps. Once your child is on *The Diet* 100%, you can start adding in new foods, bite by bite, if necessary.

Do the ATEC

Keep track of your progress with the ATEC checklist (see page 447), which you can find at...

www.autism.com/index.php/ind_atec

This is an excellent way to see how you are doing. Every time that you begin a new intervention, it's a good idea to do the ATEC, and then repeat it every three months or so to see how your child is evolving. Sometimes our children are recovering right before our very eyes and we don't even know it. The ATEC can be used to measure the effects of all new interventions, not just *The Diet*.

Using the ATEC is a great way to measure improvement. Many of us are tired, burned out, or don't have the best memory. A formal questionnaire can help us to discern when an intervention is working or not, and it only takes about seven minutes to fill out. See Appendix 4, page 447 for a sample survey and more information about ATEC.

Always Read Labels

Read the label on the back of all packages—not just the one on the front that says "gluten-free." Many times they have sugar, yeast, carrageenan, or other items that are not allowed. We must know what we are putting into our children's bodies. If you can't pronounce it... you don't want to put it into your child. Be careful of hidden offenders like malt, natural flavors, artificial flavors, whey, and numbers (red 40, E-441), etc.

Have a Support System

It doesn't matter whether it is a friend, family member, rescue angel, or neighbor. Have a shoulder to lean on. Autism recovery is a marathon not a sprint, and no one should have to go it alone. There are so many amazing parents out there who have walked this path and are willing to help newbies! As of this writing we have several public forums open, including...

www.cdautism.org

and

www.facebook.com/groups/AutismCD

This is an excellent resource for finding the latest info, protocol changes, and share hope and/or frustration with parents all over the world who are walking the same path. Don't forget to sign up for our newsletter as well by visiting the home page at www.cdautism.org!

Take it One Day at a Time

One day
at a
time

Defeatist thinking will only harm your resolve to help your child "I can't do this for the rest of Johnny's life!" or "How will I get through this year?" are defeatist thoughts. Go hour-by-hour or minute-by-minute, and know there are victories every day in the world of autism. We must draw strength from those victories, even when they aren't our own. Both this book and my website have a section of miracles and testimonials (see Chapter 2, page 19 and Appendix 1, page 357), which are real correspondence I have received from parents describing the advances their children have made as a result of doing *The Protocol.* We receive these miracle emails and forum posts every day, but we had to pick and choose which ones to share in the book. You will also see them sprinkled throughout the chapters of this book. Take some time to read them, know that children are recovering every day, and believe your child can be next. If something doesn't go as planned, wake up the next day and know that, *THIS IS the first day of autism recovery.*

Why Does My Child on the Spectrum Need to Go on a Gluten-Free/Casein-Free/Soy-Free Diet?

As I said before I have never seen a child recover without *The Diet.* The following information comes from *www.gfcfdiet.com* and explains why *The Diet* is so important for people with autism.

Scientific studies have shown the presence of high levels of peptides derived from casein and gluten proteins.[4,5] The digestion process is considered "normal" in terms of protein digestion for most people, as they make smaller particles called peptides that are further broken down into amino acids. However, in people diagnosed with autism it is more difficult to properly digest some of these proteins, thus allowing them to enter the blood directly as peptides. This often happens due to a lack of enzymes that help with the optimal assimilation of food and can be a factor in causing exaggerated bowel permeability (aka, leaky gut syndrome). This results in poor digestion, which facilitates the entry of these harmful proteins directly into the bloodstream, where they can cross the blood-brain barrier.

Leaky gut syndrome has been attributed to many causes including viruses; Candida; gluten, which produces zonulin, a protein thought to cause leaky gut; amongst other things.[6]

Gluten-containing foods may destroy the digestive system if they are consumed excessively or are introduced too early into a child's diet. Wheat is hybridized through artificial processing, resulting in inadequately prepared grains. Casein-containing foods may also destroy the digestive system because they are pasteurized and/or homogenized. These processes may result in damage to the enzymes that break down gluten or casein, thus causing incomplete digestion of these proteins.

Recently, Dr. Andreas Kalcker introduced us to the theory that the inability to properly digest these proteins may stem directly from parasites in the intestinal tract. These parasites may contribute to a leaky gut and thereby play a role in the development of allergies towards gluten, casein, soy, etc.

Gluten is found primarily in wheat, rye, barley, oats, spelt, malt, most breads, cakes, muffins, cereals, flour tortillas, pizzas, pastries, and donuts, etc. Gluten is also found in food starches, semolina, couscous, malt, some vinegars, soy sauce, teriyaki sauce, flavorings, artificial colors, and hydrolyzed vegetable proteins. Casein is contained in milk from cows, sheep, goats and any or their derivatives such as yogurt, butter, ice cream, or cheese. No form of cow's milk may be consumed as it causes inflammation and mucous. Even if the product claims to be lactose free, cream free, or casein free—it is not allowed.

Improperly digested gluten and casein fragments can both enter the bloodstream and cross the blood-brain barrier. Because of their opioid properties, these peptides can react with opiate receptors in the brain to cause effects similar to those of an opiate drug such as heroin or morphine.[7] These opiates are called gluteomorphin (or gliadorphin) and casomorphin, and can react with some parts of the brain, for example, the temporal lobes, which are actively involved in the process of the integration of language and hearing. Interestingly, these are two of the areas most affected by autism.

Besides their effects on the brain, opioid-forbidden foods cause inflammation in the gut and brain. When a child has an allergy to a food—in this case gluten, casein, and/or soy, etc.—as it enters the body the immune system sees it as an invader and reacts by trying to protect the body from the substance.

The first time the body is exposed to a food allergen, the immune system makes antibody-specific immunoglobulin E (IgE) against the allergen. IgE antibodies circulate in the blood and adhere to types of immune cells called mast cells and basophils. Mast cells are found in all body tissues, especially in the nose, throat, lungs, skin, and gastrointestinal tract (GI). Basophils are found in the blood and in tissues that have been swollen due to an allergic reaction.

The next time the body is exposed to the same food allergens, the allergen binds to IgE antibodies that bind to mast cells and basophils. These connections between allergens and antibodies direct the cells to release large amounts of chemicals, one of which are histamines. After the liberation of a histamine by an activated mast cell, the permeability of the vessels near the site increases. Therefore, the blood fluids (including leukocytes, which are also involved in immune response) enter the area causing inflammation. Histamine release also causes the release of cytokines and inflammatory mediators by leukocytes. These chemicals, in turn increase the inflammatory response.

Welcome to The Diet!

Now that we've covered the science behind *The Diet*, it's time to get started. First, make sure you complete an ATEC and save the results so you have a baseline score. Next, prepare a shopping list based on the following allowed items.

Author's Note: Organic products are better but not required.

Permitted Foods List

Proteins:

- Beef
- Chicken
- Eggs
- Fish (small not large size)
- Pork
- Turkey
- No processed meats or cold cuts (hot dogs, bologna, etc.)
- No shellfish (preferably—full of toxins)

Fruits:

- Most fresh fruits are permitted (except citrus, mango, pineapple, kiwi and limit berries).
- Frozen fruit without added cream or sugar.
- NO canned fruit (nothing canned ever).
- Be careful of dried fruit as it may contain sugar.

Author's Notes:

Juice is not permitted on this protocol as it has proven time and time again to annul CD and cost families precious time and money. The amount of fruit necessary to make a glass of juice also causes it to be high in sugars, albeit natural, and they can still affect the immune system. Children on this protocol need to drink water and generally speaking most former juice drinkers transition from drinking flavored beverages to water without much issue. If your child must drink a flavored beverage it would be acceptable to blend and strain or juice one apple, for example, and add it to some water and if you choose you can sweeten it with stevia (SweetLeaf® or KAL® brands are ok).

Fruit should not be consumed after a meal as a dessert due to its rapid digestion. If it is eaten after other more slowly digested foods (i.e. meat, grains, etc.), it can ferment in the stomach, causing bloating, gas, or discomfort. Fruit is best eaten before a meal or separate from meals.

Vegetables:

- All vegetables!!!
- Including French fries, however, not frozen fries or fries from fast food chains; these are often coated in flour.

Author's Note: I don't condone the prolonged use of potatoes, as they convert to sugar in the body. However, it was the only "legal" food my son would eat when we began the GF/CF/SF diet.

Nuts:

- Almonds
- Cashews
- Coconut
- Hazelnuts
- Walnuts
- Plus, they all make great milks!

Grains:

- Amaranth
- Buckwheat
- Corn
- Millet
- Quinoa
- Rice
- Sorghum
- Tapioca
- Xanthan gum

Author's Note: I prefer a grain free diet for autism recovery, especially if your child suffers from "grain brain" (addiction to grains, undesireable behaviors and/or inability to concentrate after eating grains). If your child seems to be addicted to carbs, i.e. fruits and starches, you may want to consider the Ketogenic diet or the Rosedale diet.

Even though these grains are allowed, they can be difficult to break down, and can easily ferment in the intestinal tract due to excessive Candida overgrowth, bacteria, and parasites.

Beans:

- All beans—EXCEPT soy
- Garbanzo
- Lentils
- Navy
- Peanuts

Sweeteners:

- Stevia (This is the best of all the sweeteners, but make sure it does not contain erythritol—a sugar alcohol!)
- Agave syrup
- Honey
- Maple syrup (natural/real—not made from corn syrup)
- Xylitol
- NO piloncillo (unrefined sugar)
- NO sugar

Author's Note: Honey is allowed, however, it can create insulin spikes.

Prohibited Foods List

After working with thousands of families, and conducting independent research, it is my personal opinion that the products on the following list should be avoided if your intention is to heal autism:

- Acetic acid (E260)
- Artificial flavoring
- Artificial sweeteners
- Bouillon cubes
- Bread
- Cacao/Cocoa
- Candy
- Cane sugar
- Carrageenan
- Catsup
- Chocolate milk
- Coloring
- Corn flakes
- Corn syrup
- Cow's milk in any form (even lactose-free milk products)
- Flour tortillas
- Gelatin
- Malt
- Margarine

- Mayonnaise
- Microwave popcorn
- MSG (Monosodium Glutamate)

  (MSG goes by many names—too numerous to mention here. A detailed list is available at www.truthinlabeling.org/hiddensources.html)
- Natural flavoring
- Noodle soup
- Oatmeal (except for Bob's Red Mill GF oats)
- Pasta
- Children´s nutritional shakes
- Play-Doh™

  (Contains gluten—Gluten-Free Dough is available at www.discountschoolsupply.com)
- Preservatives
- Processed meats (hotdogs, ham, sausage, cold cuts)
- Sodas
- Soy/fruit beverages
- Soy milk
- Soy sauce
- Sports drinks
- Sugar
- Yeast

NO Cow's Milk:

- Not casein free
- Not lactose free
- Not organic
- Not raw
- Not evaporated
- No No No cow's milk!
- Sorry, no goat's milk either! It too has casein.
- All cow's milk, regardless of what is removed from it, causes mucous production in the body. This, in turn, provides an ideal environment for pathogens.

If you're thinking that once you go GF/CF/SF + that your child will starve, trust me they won't! The list of foods they eat may get shorter, but they will keep eating. As I mentioned earlier, my son Patrick ate homemade French fries for the first three weeks of *The Diet* until he began accepting different fruits, nuts, and chicken again, but we did it... we transitioned. What I have seen in my own son, and in other children, is that when they begin to get healthier in the weeks and months after starting *The Diet*, they become more open to accepting new "legal" foods.

> Wow... quite amazing Kerri...
>
> I have always believed that "you are what you eat" and have been very careful with what I give to my kids, so their diet has been quite healthy, except for the occasional ice cream, etc. My son even spits out candies when someone offers him one because he really doesn't like them. He is not into sweets at all, thank God.
>
> But I must say this diet is just what he needed! Yay!

There are a few loopholes to the above list. If you make your own catsup, mayonnaise, etc. with items from the permitted foods list, then your child can obviously eat those foods. The list refers to those items that come from the grocery store that contain white sugar, preservatives, and other problematic ingredients.

There are many items on the forbidden foods list that don't contain gluten, casein, or soy. Here is the explanation behind a few of those items:

White refined sugar: Refined sugar has been found to reduce immune system function as well as contribute directly to obesity and Type II diabetes.

The following list is excerpted from *Suicide by Sugar.*[8]

- Sugar can suppress your immune system.
- Sugar upsets the mineral relationships in the body.
- Sugar can cause juvenile delinquency in children.
- Sugar eaten during pregnancy and lactation can influence muscle force production in offspring, which can affect an individual's ability to exercise.
- Sugar can cause hyperactivity, anxiety, inability to concentrate and crankiness in children.

MSG: An excitotoxin that can literally "excite neurons to death." We need all of our neurons!

Yeast: Feeds Candida and other fungi.

Carrageenan: Contributes to inflammation in the body and studies have linked it to colon cancer in rats.[9]

Artificial sweeteners containing sucralose: In making sucralose, the chlorine in the sweetener bonds to carbon, producing a chemical known as a chlorocarbon. "According to physician and biochemist, Dr. James Bowen, chlorocarbons are never nutritionally compatible with our metabolic processes and are wholly incompatible with normal human metabolic functioning."[10]

Processed Meats (hot dogs, ham, cold cuts, and sausages): The fats found in these meats may contain high amounts of toxins such as heavy metals, pesticides, and herbicides. In addition, processed meats contain sodium nitrite, which can harm the liver and pancreas. They may also contain corn syrup and flavoring.

Natural Flavoring: The exact definition of natural flavorings & flavors from Title 21, Section 101, part 22 of the Code of Federal Regulations is as follows:

> *The term natural flavor or natural flavoring means the essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate, or any product of roasting, heating or enzymolysis, which contains the flavoring constituents derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, seafood, poultry, eggs, dairy products, or fermentation products thereof, whose significant function in food is flavoring rather than nutritional.*[11]

Basically if you start with a natural ingredient, you can process or manipulate it any way you choose. No matter how many chemicals or solvents are added it will be labeled as a "natural flavor."

Notice they can come from meat, seafood, dairy, and wheat, etc., can also contain MSG.

Coloring: Food dyes have been linked to allergic reactions, hyperactivity in children, and even cancer. Red No. 2, for example, was banned in 1976 after it was suspected to be carcinogenic. Red No. 40, in a number of tests, was shown to damage DNA in mice.

When we are dealing with children on the spectrum, their immune systems are already compromised, and their detox pathways can be blocked or impaired. The idea is to decrease their burden with life-giving, nutritious foods, rather than add more stress to a body that is already maxed out.

Corn Syrup/High Fructose Corn Syrup: Simply because corn is a permitted food does not mean corn syrup/HFCS are "legal." Both of these shut down the immune system, as refined sugar does. They are chemically similar in composition. There is much controversy surrounding the use of mercury in the refining process, and how much if any, is in the final product.[12]

> I wanted to update you on everything with my daughter.
>
> We had a mishap 2 days ago. A substitute teacher gave my daughter a regular granola bar and a flavored beverage containing sucralose. You know what Kerri, when she came home from school that day she was in her own world and was ignoring me. I knew right away she had something she shouldn't have had. I was angry and saddened by what I was witnessing. Is there anything we should do since she had those 2 items that she's not supposed to have. Or just continue to move forward??
>
> After a while on the diet it becomes obvious when an infraction happens, if you are present when it happens you can give an enzyme to help break down the food, if not, we move forward and learn how to prevent it from happening in the future.

Common Errors:

"It's no big deal if we break the diet every once in a while."

Not True! Every time you break the diet, further inflammation is caused in the brain and gut. When gluten and casein proteins are not properly broken down, the resulting peptides reach the brain as gluteomorphin and casomorphin. It takes three days for casein to be eliminated by the body, but months for gluten to be eliminated by the body.

"My child can drink milk as long as it doesn't have casein."

Not True! As long as the milk comes from a cow, your child cannot drink it. It doesn't matter how it's labeled. If it comes from a cow it's off limits. Cow's milk can provoke the body to produce mucous, thus providing an ideal environment for pathogens which can cause chronic inflammation.

"The allergy panel says my child isn't allergic to gluten or casein, therefore he can eat them."

Not True! If your child has autism, or is on the spectrum, he must avoid gluten, casein, and soy. You should also observe your child carefully after adding a new food, or a food he hasn't eaten in a while. In one particular case, even though the child didn't test positive for an orange allergy he continued to produce symptoms of an allergic reaction whenever he ate one. We must remember that the body is changing constantly and that any test is only good for a couple of months, if at all.

I have seen the same story repeated over and over again with mangoes, oranges, bananas, apples, and corn, etc. Observing the conduct of your child after consuming a food you suspect he may have an allergy/intolerance to is the best way to measure whether the food is acceptable or not. As our children move towards healing, foods that at one point produced allergy-type symptoms can be tolerated without an immune system response.

"My doctor says that autism has no cure, and that the diet doesn't work."

Not True! Run from any doctor who says he will take your money even though he feels that autism is incurable. The first question you need to ask a doctor is:

"How many children have your recovered from autism?"

If the answer is zero, keep looking!

The Diet is free—no one earns money if your child is on *The Diet*—so do it! You have nothing to lose, and everything to gain. However, if you choose not to do it, you may further lose the health or your child. Commit 100% to *The Protocol*, and your child may be one of the next recovery stories.

> My son had what can only be described as a miraculous reaction to the GF/CF/SF diet. Since starting 2 weeks ago, all the bumpy red areas on his face disappeared, tantrums went from about a 10 to a 2, and diarrhea is all but gone.

"We tried the diet, but Johnny didn't get any better."

***The Diet* is only one piece of the puzzle.** However, it is the foundation of everything we are going to do. Without maintaining *The Diet*, it is difficult to know which intervention is actually helping.

Candida will be dying and a reaction to *The Diet* may be a Herxheimer. We must go beyond the diet to heal autism, but diet is the first piece of the recovery process.

When I receive an email complaining that a child isn't getting better I ask for a detailed list of exactly what the child is eating. I always find errors in parents' application of the GF/CF/SF + diet. What I typically uncover is that *The Diet* did not fail but that the application was flawed.

"I should remove gluten and casein from my child's diet gradually."

Not True!!! Remove them from the diet immediately and watch your child improve before your very eyes. Foods that cause IgG or IgE allergic reactions cause many other problems in the body including inflammation and psychotic behaviors, in response to gluteomorphin and casomorphin. The sooner you can remove these foods the faster your child will recover.

> As soon as we started working on the diet, my son received a developmental evaluation, although he was 20 months old, the results were that of a child of 15 months. 4 months after implementing the diet, the changes have been dramatic. My boy smiles again, he speaks in his own way, he points, has eye contact, interacts with others, he is very close to being recovered, although he is still missing a little bit. He is occasionally nervous and sometimes distant, but the most important thing is that the therapist reapplied the developmental test and my son is now reacting like a child of 24 months (his current age), even in some areas surpassing it! And this is only with the diet because he hasn't taken any supplements, just a probiotic that was ineffective.

"A gluten-free/casein-free/soy-free diet is good enough."

It's Not! Like I said before, I always find errors when a parent goes step-by-step with me through their child's diet. The list on page 52 is a detailed list of what our children should not eat under any circumstances. Many of these foods contain neurotoxins/excitotoxins. These foods can negatively affect developing and mature nerve tissue. Keep them out of your child's diet.

Beyond GF/CF/SF +

Sometimes, *The Diet* as explained is not enough and we need to go beyond it. If your child suffers from constipation, diarrhea, or seizures it is recommended to do a period on the Specific Carbohydrate Diet™ (SCD™). The following text was sourced from the website...

www.breakingtheviciouscycle.info

...by Elaine Gottschall. A complete list of references is also available at that website.

The Specific Carbohydrate Diet™ has helped many thousands of people with various forms of bowel disease and other ailments vastly improve their quality of life. In many cases people consider themselves cured. It is a diet intended mainly for Crohn's disease, ulcerative colitis, celiac disease, diverticulitis, cystic fibrosis and chronic diarrhea. However it is a very healthy, balanced and safe diet that has health benefits for everyone. The foods that are allowed on the Specific Carbohydrate Diet™ are based on the chemical structure of these foods. Carbohydrates are classified by their molecular structure.

The allowed carbohydrates are monosaccharides and have a single molecule structure that allow them to be easily absorbed by the intestine wall. Complex carbohydrates which are disaccharides (double molecules) and polysaccharides (chain molecules) are not allowed. Complex carbohydrates that are not easily digested feed harmful bacteria in our intestines causing them to overgrow producing by products and inflaming the intestine wall. The diet works by starving out these bacteria and restoring the balance of bacteria in our gut.

Autism & GI Problems

Altered intestinal permeability was found in 43% of autistic patients, but not found in any of the controls (Harvard University). Intestinal permeability, commonly called "leaky gut", means that there are larger than normal spaces present between the cells of the gut wall. When these large spaces exist in the small intestine, it allows undigested food and other toxins to enter the blood stream. When incompletely broken down foods enter the body, the immune system mounts an attack against the "foreigner" resulting in food allergies and sensitivities. The release of antibodies triggers inflammatory reactions when the foods are eaten again. The chronic inflammation lowers IgA levels. Sufficient levels of IgA are needed to protect the intestinal tract from clostridia and yeast. The decreasing IgA levels allow for even further microbe proliferation in the intestinal tract. Vitamin and mineral deficiencies are also found due to the leaky gut problem.

In a healthy intestinal tract the small intestine and stomach are not inhabited by bacteria. When the flora balance in the colon is lost, the microbes can migrate into the small intestine and stomach, which hampers digestion. The microbes compete for nutrients and their waste products overrun the intestinal tract. One of the toxins produced by yeast is actually an enzyme that allows the yeast to bore into the intestinal wall. The yeast also produce other toxins such as organic acids, which can also damage the intestinal wall.

Bacterial growth in the small intestine destroys enzymes on the intestinal cell surface, which prevents carbohydrate digestion and absorption.

The last stage of carbohydrate digestion takes place at the minute projections called microvilli. Complex carbohydrates that have been broken down by the enzymes embedded in the microvilli can be absorbed properly and enter the blood stream. But when the microvilli are damaged, the last stage of digestion cannot take place. At this point only monosaccharides can be absorbed because of their single molecule structure.

In the small intestine, the body should absorb the nutrients needed from what is eaten. But in the case of malabsorption, the undigested carbohydrates left in the small intestine cause the body to draw water into the intestinal tract. This pushes the undigested carbohydrates into the colon where the microbes can feast on it. This allows for even more proliferation of the unwanted microbes and continued increase in malabsorption problems.

Low intestinal carbohydrate digestive enzyme activity was found in 43% of patients with autism. (Horvath) Recent studies point out that ongoing carbohydrate malabsorption keeps the digestive system constantly weakened, leading to systemic disorders. Suspected carbohydrate malabsorption should be treated to ward off further damage to the body's digestive system. (GSDL)

Most intestinal microbes require carbohydrates for energy. The Specific Carbohydrate Diet™ limits the availability of carbohydrates. By depriving these microbes of their food source, they gradually decrease in number. As the number of microbes decreases so do the toxic by-products they create.

The Specific Carbohydrate Diet™ (SCD™) is intended to stop the vicious cycle of malabsorption and microbe overgrowth by removing the source of energy from the microbes. The SCD™ allows simple monosaccharides that do not need to be broken down in order to be absorbed.

By following the SCD™, malabsorption is replaced with proper absorption. Inflammation is decreased and the immune system can return to normal. Once the immune system is returned to adequate levels, it can begin to keep in the intestines microbes in proper balance.

The SCD™ allows simple carbohydrates, but prohibits complex carbohydrates. The diet is started by following an introductory diet, which consists of a limited selection of foods. After the introductory diet, the next stage of the diet allows many more foods, but requires that all fruits and vegetables be peeled, seeded and cooked in order to make them more easily digested. Raw fruits, vegetables, nuts and seeds are added to the diet later. To properly follow this diet, it is imperative to read Breaking the

> *Vicious Cycle by Elaine Gottschall. The book details the progression of allowed foods as well as providing many delicious recipes.*[13, 14]

Salicylates/Phenols

Phenol is a naturally occurring chemical found in many of the foods we eat, such as fruits and vegetables, nuts, and in bioflavonoids and cartenoids (carotene, lutein, lycopene, xanthophylls, and zeaxanthin), etc. Phenols can be found in toothpaste, hair dye, and disinfectants, etc. Many foods have phenols, and they are impossible to avoid completely. Salicylates are a subgroup of phenols, related to aspirin. There are several kinds of salicylate, which plants make as a natural pesticide to protect themselves from insects, fungi, and harmful bacteria. Foods high in natural salicylates are tomatoes, apples, peanuts, oranges, cocoa (chocolate), red grapes, coffee, all berries, and peppers, to name a few.

You may also need to consider a low salicylate and/or phenol diet, as many children on the spectrum may have issues with these items. The following was sourced from *www.scdlifestyle.com*.

> *Dr. Feingold is probably the most widely known individual to study this chemical, as he developed what is now referred to as the Feingold Diet. He started out in the 1960s as a pediatrician and allergist studying children's negative reactions to aspirin. Through his work, he found that many other dietary chemicals were causing physical and even behavioral reactions in his patients. He developed the Feingold Diet to eliminate all food additives, colorings, and salicylates.*
>
> ### *Why Do People React to Them?*
>
> *In a normal body that has the correct levels of sulphates and liver enzymes, phenols and salicylates are easily metabolized. The body utilizes what it needs from the chemicals and properly disposes of the rest through the bowels. In those whose levels are not normal or in the case of "leaky gut syndrome", intolerance to this chemical family can occur rather quickly.*
>
> *Many people with gut issues such as yeast/bacteria overgrowth or digestive diseases can develop salicylate intolerance as a result of "leaky gut" syndrome. Leaky gut is a result of various digestive problems and occurs when the small intestine becomes too damaged to properly filter the size and types of food particles or chemicals that enter the bloodstream. [For more on leaky gut syndrome see http://scdlifestyle.com/2010/03/the-scd-diet-and-leaky-gut-syndrome/] When these improper particles are allowed to repeatedly enter the bloodstream the*

body tries to get rid of them by triggering an immune system response. Because phenols/salicylates are so common in most foods, a person with a leaky gut will have much higher than normal levels of these chemicals in their blood and can very quickly develop intolerance´s to these specific particles.

Why Can Phenols Affect Children on the Autism Spectrum More Than Others?

Research by Dr. Rosemary Waring at the University of Birmingham found that children on the autism Spectrum have low levels of the enzyme phenol-sulfotransferase-P (the enzyme that breaks down the phenol and amine families, also known as PST) and the substrate it uses: sulfates. Sulfates are a key tool that the body uses in the process of detoxification and break down phenols such as salicylates. Without normal levels of sulfates in the body, the sulfotransferase enzyme cannot do the task it was created to do: metabolize salicylates. So there are two problems with PST deficiency: low sulfate levels and low enzyme levels. PST deficiency alone can cause problems in children (remember phenols are normal) but factor in any intestinal damage resulting in leaky gut along with it and your child's body can easily be overwhelmed. The end result is a salicylate intolerance and the subsequent physical and behavioral reactions that come with it.

Reactions Caused by Phenols

Salicylates stimulate the central nervous system in people that react to them. This can often bring with it an emotionally extreme high followed by a very low, low. Other reactions to the phenol family can occur anywhere from immediately after consumption up to 48 hours after the consumption of the chemical, depending on the immune response. Physical reactions can include: dark circles under the eyes, red face/ears, diarrhea, headache, difficulty falling asleep at night, night waking, and in some cases excessively tired and lethargic. Behavioral symptoms of a reaction can be: hyperactivity, aggression, head banging or other self-injury, and even inappropriate laughter. Hyperactivity is more common in children's reactions, while adults generally experience symptoms similar to chronic fatigue.[15]

For additional information on leaky gut syndrome you may wish to look at (search for) *Dr. Peter Osborne*:

www.glutenfreesociety.org

If your child suffers from self-injurious behaviors limit these foods that are moderate to high in phenols:

- Almonds
- Apples
- Avocados
- Bananas
- Cacao
- Cantaloupes
- Cherries
- Cider vinegar
- Coconut oil
- Colored fruits
- Dates
- Food coloring
- Honey
- Mangos
- Mint
- Oranges
- Oregano
- Peanuts
- Pineapples
- Powdered chili pepper
- Processed meats
- Raisins
- Strawberries
- Tangerines
- Tomatoes

For more information on this you can visit:

www.scdlifestyle.com

and

www.feingold.org

* * *

She's quite the book worm and has an impressive collection which includes classic favorites such as Brown Bear, Llama Llama Red Pajama, Barnyard Banter and Goodnight Moon... But lately, she has been drawn to her Mama's new favorite read... Perhaps she is hoping that someday her story of recovery will be told too...

Gluten Syndrome

For many parents of children on the spectrum, having their children on *The Diet* is something that is second nature to them. However, as more and more people are using the protocol in this book to heal their own health ailments we have decided to include the following section on how gluten can negatively affect many more than just the autism community. You will get a very interesting look into how the immune system works and why so many sufferers have misunderstood gluten syndrome. Thank you Olive for contributing to our understanding of the subject.

Molecular Mimicry

What It Is & How It Relates to the Gluten Syndrome

by Mrs. Olive Kaiser

Who am I?

I am a married stay at home mom, blessed with a wonderful husband and seven fantastic kids. In 2003, after decades of searching, we learned about gluten reactivity through our daughter's nursing school training and eventually confirmed that we are a gluten syndrome family. Our daughter and my husband had the most obvious symptoms, but we all had manifestations and antibodies. Additionally our oldest son reacted to his MMR vaccination and probably other shots, which added high functioning ASD/ADD to the mix, and he developed type 1 diabetes at age 19. Two other sons had various shades of ADD/ADHD. My own school age vaccinations in the 1950's may have led to repeated bouts of strep throat until I reacted to a strep antibiotic injection about age 10. I developed PANDAS from that reaction (Pediatric Autoimmune Neuropsychiatric Disorder Associated with Streptococcus). What a struggle! Decades later it has responded somewhat to diet changes and now the CD/parasite protocol. I give thanks to God for His guidance along the way.

How did I get into this community and this health project?

We tested for gluten syndrome (we called it celiac disease back then) using standard tests recommended by celiac experts and received confusing results. Then, our daughter had a troubling experience with a gluten challenge that did not match the celiac story we'd been taught. I delved into medical literature and networked extensively with the gluten syndrome community looking for help. In that desperate discovery and prayer process I found practitioners and researchers who stepped outside the "villi damaged celiac only" box. They were able to explain why we received, in the midst of obviously gluten-induced incidents, false negative results from our celiac blood tests and villi biopsy. Those tests significantly led us astray and eventually I put up a website...

www.TheGlutenSyndrome.net

...to warn others of discrepancies we stumbled upon in the diagnostic process.

What is Molecular Mimicry?

Molecular mimicry is a recognized medical theory which explains very nicely why gluten reactions may potentially inflame and damage so many different parts of the body, leading to very different symptoms in different people. It also clarifies why gluten antibodies may cross react with other foods and infections, and why it only takes a small exposure to trigger them.

When we understand molecular mimicry we are better equipped to deal with tempting social situations. Gluten syndrome has its own rules, which do NOT make sense unless this concept is understood.

The following is a brief introduction to Appendix 5, page 449, which goes into much more detail, along with references, about the following questions:

1. How does the gluten syndrome reaction actually damage our bodies?

> Molecular mimicry. The molecular structure of gluten resembles the molecular structure of many of our body tissues. When the immune system attacks gluten it may also attack body tissues that “look like” gluten. Even if you do not read the other detailed answers, learn the details for this question on page 450.

2. Does gluten always damage the villi of the small intestine as the celiac story teaches? Many other tissues such as thyroid, pancreas, liver, joint, brain, nerves, heart, bone, blood vessel walls, etc., are involved in this disorder. Does all that other damage only arise from poor nutrient absorption from injured gut villi?

> No, according to published research, many researchers and practitioners believe the villi are not always damaged in an autoimmune gluten reaction. Where there is no villi damage, injury to other organs CANNOT be due to nutrient deficiencies caused by villi damage. Molecular mimicry provides a mechanism for direct autoimmune gluten damage to many other tissues and organs when the villi are fine, OR other tissues/organs, *including villi*, may be directly damaged through molecular mimicry.

Dr. Vojdani's abstract in his editorial *The Immunology of Gluten Sensitivity Beyond the Intestinal Tract*, supports that the villi are not always injured. To quote his editorial abstract, "Evidence has been accumulated in literature demonstrating that gluten sensitivity or celiac disease can exist even in the absence of enteropathy [gut/villi damage], but affecting many organs."

3. I don't have damaged villi, and my tTG/gliadin tests were negative, but I feel so much better gluten-free. Why?

The tests were likely false negative. That is very common. As gluten digests, it breaks into more pieces than we have tests developed to check them, and the immune system makes a separate antibody for each piece. Standard tests only check 2-3 antibodies. You may have others (Cyrex Labs tests 28 antibodies). Your villi may be fine, but you may be injured somewhere else—for example: thyroid, nerves, heart, etc.

4. Why do many gluten syndrome patients not only react to wheat, barley, and rye but also at times to other foods, particularly oats, milk, corn, soy, egg, yeast, coffee, sesame, rice, chocolate and others?

These foods "look like" gluten closely enough in their structure that the immune system may mistake them for gluten. This situation may also cause your gluten antibodies to run high after you go gluten-free. The immune system may misrecognize other foods, such as yeast, corn or milk, and others for gluten because they resemble gluten molecularly.

5. The diet seems excessively strict? Why does it take so little gluten to start a reaction?

Our perspectives are skewed. We accept that miniscule amounts of venom injected by a bee sting, or a tiny exposure to peanuts in allergic individuals can set off immediate life threatening allergic reactions. Many medications are contained in very TINY pills, but they have powerful effects in our bodies. Immune gluten reactions are also that sensitive. "Crumbs matter."

6. Why do many people react to gluten, proven by antibody tests, but they have few or no warning symptoms for a long time and then they crash with something serious, usually autoimmune?

Gluten is famous for slowly injuring nerves by molecular mimicry, and in many cases, the nerves are silenced by that injury. The patient does not realize there is a problem until the tissue or organ that those nerves supply begins to fail.

7. Why do so many of us react to gluten today, when for centuries most people appeared to be fine with wheat, barley, rye and oats? After all, wheat and barley are mentioned positively in the Bible and other historical documents.

Today's gluten is altered, violently, by nuclear radiation and chemical mutation within the past 60 years*, plus our toxic and poorly nourished bodies do not have optimal digestive capabilities to break it down. Weak, toxic, leaky body barriers/membranes, particularly leaky gut, set the stage for gluten induced molecular mimicry.

*Nina Federoff, *Mendel in the Kitchen*

8. Why do specialists and researchers insist that the gluten-free diet must be life long? Can't we heal this problem and go back to our beloved wheat bagels, croissants, and brownies?

Our scientists still insist that gluten-free is a strict lifelong commitment. I agree. For me it is not worth playing with today's wheat. There is something strange and unpredictable about it. The memory B cells in the immune system never forget what the enemy "looks like", and fresh exposure retriggers antibodies.

9. Traditional peoples soaked and/or sprouted their wheat berries and then made sourdough bread with them. Does that process alter the gluten sufficiently for gluten syndrome patients to safely consume this bread, particularly spelt or einkorn?

No. These processes and ancient wheat grains do make the bread more digestible, but not gluten-free and still unsafe.

10. Should I substitute all the gluten foods I routinely eat with gluten-free substitutes?

No, not routinely. The gluten-free community finds that they are still mainly expensive high carb processed food (i.e., junk food).

11. What are gluten withdrawals?

Occasionally, gluten breaks into specific "pieces" in the gut that resemble opiate drugs. When a person goes gluten-free, they may experience temporary, but unpleasant, withdrawal symptoms for a few days as these pieces disappear from the blood stream.

12. What are the risks of formal gluten challenges?

Many patients avoid these challenges. Occasionally a patient tries the gluten-free diet for an extended period of time and then the patient or doctor decides to run tests to confirm gluten reactivity. The standard advice to restart the production of antibodies is to consume gluten products 4 x per day for 4-6 weeks, and then run the standard blood test, followed by a villi biopsy if the blood work is positive. This is called a gluten challenge and has created some very dramatically unhappy reactions, some of them neurological/psychological.

Please see Appendix 5 (page 449) and www.GlutenSyndrome.net for more info and references. When we understand molecular mimicry our understanding of the gluten syndrome comes into focus. It explains why gluten-free diets and beyond are important tools to reduce inflammation and promote healing. As time goes on, gluten-free diets are easier to manage in public, tests are better and social awareness has grown. The Just Eat Real Food movement and others play into healthy gluten-free dining with wonderful recipes that avoid processed foods and incorporate healthy fats and nutrient density. This is a happy, encouraging era as we watch our children heal and adults find better stability in the midst of a health crisis. Bon Appetit!!!

* * *

The Diet - FAQs

The following FAQ's were printed with permission from gfcfdiet.com:

Slight changes were made to match the formatting of this book; however, the content remains unaltered. Please visit gfcfdiet.com for complete list of the references contained within the following text.

1. My doctor has never heard of any of this and she is extremely skeptical. I'm embarrassed to tell her I'm considering this approach. What do you think?

Skepticism is a good thing in a medical doctor or scientist. However, since there is preliminary evidence to support this safe, non-invasive intervention, it is up to you to educate her, state your wishes, and ask for her support. For a doctor, it is better to wait until all of the data is published in peer-reviewed journals before advocating a treatment. However, for a parent, it is reasonable to want to help one's child without waiting for all of the results of the "double-blind placebo" studies. Because this approach does not include any unusual supplements, invasive drugs, or expensive treatments, your pediatrician should be supportive. Explain that you would like to try this for a few weeks, and agree that you will be objective about recording your child's progress while on the diet.

If you feel that you need to support your case legally with the scientific and medical documentation that is currently available, please see the medical links at www.gfcfdiet.com or at www.autismndi.com.

2. What is casomorphin?

Casomorphin (or caseomorphin) is a peptide derived from casein, a milk protein. Casein is one of the major proteins in the milk of all mammals including cows, goats, and humans. When casein is digested properly, it breaks down into large peptides like casomorphin, and should then be broken down further into smaller amino acids.

However, Dr. Reichelt in Norway, Dr. Cade at the University of Florida, and others found that urine samples from people with autism, PDD, celiac disease, and schizophrenia contained high amounts of the casomorphin peptide in the urine.[4] In its peptide form, casein has opiate properties similar to morphine, and may plug into the same opiate receptor sites in the brain. Researchers have found that these peptides may also be elevated in other disorders such as chronic fatigue, fibromyalgia, and depression based on anecdotal reports of symptom remission after exclusion of wheat and dairy.

3. What is gliadorphin?

Gliadorphin (also called alpha-gliadin or gluteomorphin) is a substance that resembles morphine. Ordinarily, this is a short-lived by-product from the digestion of gluten molecules (found in wheat, barley, rye, oats, and several other grains). Gliadorphin is very similar to casomorphin. Gliadorphin has been verified by mass spectrometry techniques to be present in unusual quantities in urine samples of children with autism, and are believed by many to be a central part of the system of causes and effects that cause autistic development.

The most probable reasons for the presence of these molecules are:

- One or more errors in the breakdown (digestion) process caused by enzyme deficiency and/or
- Abnormal permeability of the gut wall (that would allow these relatively large molecules to enter the bloodstream from the intestine in abnormal quantities).

4. I am confused about allergy vs. intolerance. I understand that our children may be sensitive to corn, soy, and other foods as well as gluten and casein. Does this mean that they will eventually start turning these foods into the morphine-like compounds too? If this were the case, would they show up as an allergy on a RAST test? Or were our children always allergic to these foods (a regular allergy

that may cause behavioral changes in our children), and we just didn't know because the gluten and casein were hiding the allergy?

To a traditional physician or allergist, "allergy" is used to describe a reaction of the IgE part of the immune system, resulting in hives, swelling, or breathing problems. However, the words "allergy" and "intolerance" are often used to describe any inappropriate reaction to foods or substances that should normally be harmless to the body.

There are at least three different ways that a child with autism may have a problem with foods that contain gluten or casein, and it's important to understand the distinction:

1. An IgE ALLERGY commonly results in skin problems, hives, swelling, and breathing problems, etc. This can be tested using a skin test or blood test.

2. An INTOLERANCE (usually mediated by the IgG or IgA part of the immune system, or by an enzyme insufficiency such as lactose intolerance) has more varied or vague symptoms like discomfort, stomach problems, sleep problems, joint pain, ear infections, or hyperactivity and behavior problems. Sensitivity to these substances can be tested with an ELISA blood test.

3. PEPTIDUREA (peptides in the urine) is caused by the inability of the body to properly break down certain proteins. It is hypothesized that certain peptides, notably from milk and wheat proteins, are plugging into the opiate receptor sites of the brain and disrupting brain and nervous system function. Urine testing for this is still experimental, and many parents believe that the best way to find out if this is what is causing a child's autism is a strict trial period on the GF/CF diet.

On the GF/CF diet, gluten and casein are avoided because they are strongly suspected of having a direct pharmacological effect. When these proteins are only partly broken down, some of the resulting fragments can be strikingly similar to morphine, and act in more or less the same manner. (This type of reaction can co-exist along with a classic type of allergy towards the same foods.)

Recent research indicates that protein from both corn and soy may also contain some molecular sequences that could, if the patient has an enzyme deficiency, be broken down into something closely resembling opioid peptides. Even spinach protein has been found to have some opioid activity.

Products made from soy or corn will also often contain metabolic end products made by microscopic organisms like bacteria, molds, or other fungi. Some of these are suspected of being harmful to a small number of people who are genetically predisposed to autism. The amount of danger will depend on individual conditions AND on the quality of the corn or soybeans used in the production process. Soy OIL (lecithin) may be worse than most other soy products since this product will look and taste okay, even when made from moldy raw material, and since it is commonly made from the "bottom grade" of the harvest.

Some people also think that one of the natural pigments in corn (lutein) may cause problems for reasons that are not properly understood (see: "Sara's Diet"). This must be regarded as highly speculative.

5. I don't think my child has allergies, or that allergies could cause autism. Why should I try removing foods from his diet?

Although parents have been reporting a connection between autism and diet for decades, there is now a growing body of research that shows that certain foods seem to be affecting the developing brains of some children and causing autistic behaviors. This is not because of allergies, but because many of these children are unable to properly break down certain proteins.

6. Milk and wheat are the only two foods my child will eat. His diet is completely comprised of milk, cheese, cereal, pasta, and bread. If I take these away, I'm afraid he'll starve.

There may be a good reason your child "self-limits" to these foods. Opiates, like opium, are highly addictive. If this "opiate excess" explanation applies to your child, then he is actually addicted to those foods that contain the offending proteins. Although it seems as if your child will starve, if you take those foods away, many parents report that after an initial "withdrawal" reaction, their children become much more willing to eat other foods. After a few weeks, most children surprise their parents by further broadening their diets.

7. Isn't milk necessary for children's health?

Americans have been raised to believe that this is true, largely due to the efforts of the American Dairy Association, and many parents seem to believe that it is their duty to feed their children as much milk as possible. However, lots of perfectly healthy children do very well without it. It is calcium children need, not milk. Cow's milk has been called "the world's most overrated nutrient" and "fit only for baby cows." There is even evidence that the cow hormone present in dairy actually blocks the absorption of calcium in humans.

Be careful. Removing dairy means all milk, butter, cheese, cream cheese, and sour cream, etc. It also includes product ingredients such as "casein" and "whey," or even words containing the word "casein." Read labels—items like bread and tuna fish often contain milk products. Even soy cheese usually contains caseinate.

For more information on dairy-free living, there's a very good book called *Raising Your Child Without Milk* by Jane Zukin. Another great book called *Don't Drink Your Milk* by Frank Oski (the late head of pediatrics at Johns Hopkins and author of *Essential Pediatrics*). This book cites the results of several research studies that conclude that milk is an inappropriate food for human children. It is available for $4.95 from Park City Press, PO Box 25, Glenwood Landing, NY 11547, ISBN #0671228048.

8. How do I know which foods he's allergic to?

Try an allergy elimination diet. For example, keep common allergens out of his diet for a few days and then re-introduce them, one-by-one. If you see symptoms, either physical or behavioral, try again in a few days. By being systematic you will be more certain of which foods are causing problems and correctly rule them out. Two excellent resources, probably available at your library, are Doris Rapp's book, *Is This Your Child*, and William Crook's, *Solving the Puzzle of Your Hard to Raise Child*.

9. Aren't eggs dairy?

Many years ago, most of us were taught that eggs and dairy were part of the same section of the food pyramid under "dairy." However, they are not. Eggs are free of any dairy. Dairy can be from cows, sheep, or goats. The eggs we eat are normally from chickens. Dairy and eggs happen to be side-by-side in the refrigerator section of the grocery store, which may add to the confusion.

10. What do I do when we go to a party or out to another person's house and are trying to maintain my child on a GF/CF diet? At times we find it impossible to catch him before he ingests something he shouldn't.

It is a good idea to bring some favorite GF/CF goodies with you. Keep them hidden until that moment of "competition." Show the surprise treat to your child before your child eats one of the gluten and/or casein laden foods. Bring more than one goodie to be on the safe side. Also, there are two small pamphlets that are great for handing out to friends and family members that give a simple explanation for your child's special dietary requirements. These are: "Alternative Treatments for Children Within the Autistic Spectrum: Effective, natural solutions for learning disorders, attention deficits, and autistic behaviors," by Deborah Golden Alecson, and "Leaky Gut Syndrome: What to do about a health threat that can cause arthritis, allergies, and a host of other illnesses," by Elizabeth Lipski, M.S., C.C.N. Both of these books cost $3.95 each and can be found at health food stores.

11. Do we need to worry about gluten-containing lotions, shampoos, and toothpaste being absorbed through the skin?

Nicotine patches, birth-control patches, and other transdermal applications of medications are proof that the skin does absorb many things (and pass them to the bloodstream). However, the molecules in gluten are too large to pass through the skin, according to John Zone, MD (a dermatologist quoted in the Spring 2003 issue of *Living Without* magazine).

Most often the problem occurs from hand to mouth (i.e. touching colored modeling dough and then touching one's face), which is a good reason to avoid giving our kids much access to anything that poses a threat. If your child's school has a sensory table, you can request that it be filled with rice or dried beans, instead of macaroni or gluten grains. Likewise, we suggest that you volunteer to be the "Play-Doh™ parent" and keep the classroom supplied with a safe version that you don't have to worry about.

We are not too concerned about shampoo, unless you have a child who is likely to try to drink the stuff. But toothpaste is an entirely different matter, since some of it is likely to be ingested, rather than spit out.

12. I'm already worried about my child's nutrition, and his "allergies" are causing me to further reduce his choices. If apple juice and bananas are the only fruits he will eat, and he's reacting to them, how is he supposed to get by?

Fruit contains water, sugar, fiber, and vitamins. If he will not eat other fruits then he needs to get these things from other sources.

13. I am wondering if anyone else is having problems with school and keeping them on the diet? I have sent a note saying: "Please don't give my son dairy, wheat, corn, or soy." Today I came in and they were giving him Popcorn!

My kid doesn't eat ANYTHING that isn't sent from home. He's almost ten now, and this policy has been good for him because succumbing to temptation outside of the house has simply never been an option. I don't think it would occur to him to take food from anybody without our permission.

We always made sure there are backup snacks and birthday party treats at school for emergencies. I think the school has always taken this seriously because they can see how seriously we take it.

We once got a note from a mom who said that her son had been strictly GF/CF for months without an improvement. I asked what he was eating, and she gave me a long list including expensive GF prepackaged products. Then she ended her letter by saying, "Of course, that's just what he gets at home. I have no idea what he gets in his school lunch, or what they're using for food reinforcers in his ABA program."

Definitely try this—you might see a real difference.

14. What percentage of children will respond to dietary intervention?

DAN! doctors used to try to be conservative about this, and say at least a third of children, and then, after seeing more patients, they said two thirds. Now that they have seen hundreds or thousands of patients, most tell us that they believe that almost every ASD child will benefit from this diet. Many will need further modifications (i.e. removing grains or sugar) before the full benefits are realized.

However, age plays a big part in how quickly results will be seen. We can probably say that the response will be dramatic in more than two thirds of the children under three, and perhaps more subtle, but still helpful, in at least two thirds of older children. We think those are pretty good odds.[3]

Some Additional FAQs...

Kerri, yesterday the therapist was playing with Play-Doh™ with my daughter. She could not resist eating it. We tried very hard to stop her with no luck. In the end we had to stop her from playing with it. People say this is due to a zinc deficiency. Do you know if this is correct? Will giving her Zinc stop her from wanting to eat Play-Doh™? If yes, how much should I give?

She is not eating Play-Doh™ because of a zinc deficiency. Play-Doh™ contains wheat. She is addicted to gluteomorphin, a by-product of her eating gluten, which is contained in Play-Doh™. So, she broke her diet. She cannot touch nor eat Play-Doh™.

What exactly is Candida?

Candida albicans is an opportunistic fungus (or form of yeast) that is the cause of many undesirable symptoms ranging from fatigue and weight gain, to joint pain and gas.

The Candida yeast is a part of the gut flora, a group of microorganisms that live in your mouth and intestine. When the Candida population starts getting out of control it weakens the intestinal wall, penetrating through into the bloodstream and releasing its toxic by-products throughout the body.

What Causes Candida Overgrowth?

Candida is an opportunistic pathogen that can rapidly take over when a person is under a course of antibiotics. Antibiotics destroy beneficial gut flora but have little effect on Candida, giving this normally harmless yeast the chance to take over dominance of the gut environment very quickly.

Babies born via C-section, or to mothers who were treated with IV antibiotics during labor are especially vulnerable to the ravages of Candida overgrowth. This is because they are not exposed to a healthy balance of gut flora on the way through the birth canal prior to the moment of birth.

…disaccharides, or double sugars, are present in many carbohydrates including ALL grains—not just gluten containing ones. An inflamed, imbalanced gut overridden with Candida is unable to digest double sugar molecules completely because the lack of beneficial gut flora has compromised the function of the enterocytes.

According to Dr. Natasha Campbell-McBride MD, author of *Gut and Psychology Syndrome*, and one of the key scientists at the forefront of gut restoration research today, enterocytes are the cells that reside on the villi of the gut wall and produce the enzyme, disaccharidase, which breaks down the disaccharide molecule into easily absorbed monosaccharide molecules. When the enterocytes are not nourished and strengthened properly by adequate beneficial flora, they become weak and diseased and may even turn cancerous. Unnourished, enterocytes cannot perform their duties of digesting and absorbing food properly.[16, 17]

The critical importance of the enterocytes to health cannot be overstated!

Weak and diseased enterocytes also have trouble digesting starch molecules, which are very large molecules that consist of hundreds of monosugars, connected in long branchlike strands. People with weak digestion due to Candida overgrowth and messed up enterocytes have a terrible time digesting these complex molecules leaving large amounts of it undigested—the perfect food for pathogenic yeasts, bacteria, and fungi like Candida to thrive upon. Even the starch that manages to get digested results in molecules of maltose, which is—you guessed it—a disaccharide! This maltose also goes undigested due to a lack of the enzyme disaccharidase and becomes additional food for Candida.

We are a few days into the diet. Can someone comment on what they send to daycare with their kids for snacks? Our daycare is nut free as well. We are ok for lunches but what should we take for snacks. The gluten-free pretzels, etc. we were taking he can't have now because of yeast and soy.

Here a few suggestions: Hard boiled eggs, cut up raw veggies and fruit, air popped popcorn, apples, bananas, dried fruits (with no sugar added). Also you can join "CD/CDS MOMS WHAT IS MY KID EATING TODAY" Facebook group. You can find more ideas there.

Chapter 4

An Introduction to Chlorine Dioxide

by Jim Humble

> *"Condemnation without investigation is the height of ignorance"*
>
> ***-Albert Einstein***

Jim Humble, the man behind chlorine dioxide for healing, was kind enough to write the following introduction to our CD section...

I just can't tell you how pleased and proud I am that Kerri has developed protocols using chlorine dioxide as the main ingredient to bring health and normalcy to many children who had the symptoms called autism. Their resulting healing is one of the greatest stories of this and the last century. Kerri's ability to look at something new and to evaluate the value of the new item without being totally affected by the dictates of present established medical science is truly rare. Kerri decided to do something since modern medicine has yet to come up with a reasonable priced globally available solution to the problem of autism that yielded good results. Medical science says that autism is incurable, that millions of children have to be left to suffer and live without reaching their potential. At this writing 115 children have recovered, hundreds more are near recovery and thousands have had documented improvements as a result of being treated with Kerri's protocol.

Here are some basic points:

Chlorine dioxide (the molecule) was discovered in 1814, with many giving credit to Sir Humphrey Davy for its creation, and today several patents exist for healing various ills with it (see list on page 85).

MMS (Master Mineral Supplement) – I rediscovered chlorine dioxide in 1996 and since then more than 1,020 people have traveled from more than 95 countries to the Dominican Republic, Mexico, and other countries, to be trained in its use. By our estimation, more than 10 million people worldwide have used chlorine dioxide.

The highest cost of a set of bottles of sodium chlorite + activator is less than $25 for 4 ounces of each. This means that almost any place in the world the average dose of chlorine dioxide is less than 4 cents, or less than $.40 a day or $25 for 2 months. In most places it is even less than that. So far there is no one in the world who can't afford it or who wouldn't be able to get it merely by asking if they can't afford it.

The chlorine dioxide molecule is the weakest of all oxidizers used in the human body and thus has very little effect on human cells. This molecule has the unique ability to recognize and oxidize (kill) harmful bacteria. Hans Christian Gram, a scientist of the 19th century, discovered that most harmful bacteria have a negative charge. He was able to dye positive and negative bacteria two different colors. His techniques are still used in laboratories and universities. All oxidizers, including chlorine dioxide, have a positive charge that will attract and kill negatively charged bacteria while repelling positively charged bacteria. Chlorine dioxide is thusly able to kill bad bacteria without destroying the good bacteria. This is simple high school science; like charges repel and unlike charges attract.[1]

Most chemicals and many foods in this society are tested to determine their poison index, which is designated by giving them a toxicity number known as LD_{50}. Sugar, table salt, butter, arsenic, cyanide, vinegar, wine, Clorox, window cleaner, and dozens of other household and industrial chemicals are rated as to their toxicity by force feeding 10 rats with the food or chemical in question until ½ of them die. The amount of chemical or food that it takes to kill 5 of the 10 rats determines the LD_{50} number. Every chemical has a toxic rating and is indicated as an LD_{50} number. All chemicals are toxic in large enough quantities and there are a lot of unlucky rats in our society.

There has never been a recorded death caused by ingestion of chlorine dioxide or sodium chlorite in humans. In the case of chlorine dioxide, it would take 1000 times more chlorine dioxide than is used in a daily treatment dose to reach a toxic dose for a human being. The following information is from the *Toxicological Profile for Chlorine Dioxide and Chlorite* (published by the U.S. Dept., of Health & Human Services) which contains LD_{50} toxic numbers for chlorine dioxide along with documentation that no deaths have been caused by chlorine dioxide (Emphasis in italics is the author's):

> *No information was located regarding death in humans following oral exposure to chlorine dioxide or chlorite. Shi and Xie (1999) indicated that an acute oral LD_{50} value (a dose expected to result in death of 50% of the dosed animals) for stable chlorine dioxide was > 10,000 mg/kg in mice.*[2]

I should say something about bleach as a number of critics insist that MMS (chlorine dioxide) is a bleach and thus is a poison. Chlorine dioxide, the chemical that is MMS, has never been used domestically as a bleach for cleaning toilets. It is an industrial bleach when used 4000 times more concentrated than MMS. It is never used for bleaching purposes in the homes of people of this world.

Legally, ethically, morally, and logically, if any item does not have the characteristics of a particular item, it cannot be said to be that kind of an item. This means that a chemical that does not have the characteristics of bleach cannot be called bleach. So a chlorine dioxide solution being 4000 times weaker than that of bleach cannot be called bleach. This is a fact accepted in courts of law of the world.

I sincerely hope you will take the time to understand the basics of chlorine dioxide as explained here. Any time one has helped someone overcome the symptoms of autism he has helped save a life, as those suffering from the symptoms of regressive autism are not living their full lives. The end result of learning this data is that the time may come when you will need chlorine dioxide to save your own life or that of a loved one.

Jim Humble

Archbishop Jim Humble

A message from Kerri to Jim Humble

"With all my love, respect and gratitude. You have swum against the current for so long, and I am so fortunate that you waited for me. I will continue to recover these generations of children that are the victims of a senseless epidemic. As you have done, I will do. We can't change the past, but the future is ours. You have brought light to where there once was none."

Chapter 5

Step 2 – Chloride Dioxide (CD)

"All truth passes through three stages. First, it is ridiculed. Second, it is violently opposed. Third, it is accepted as being self-evident."
~ Arthur Schopenhauer

CD (chlorine dioxide) is the most amazing intervention that I have ever tried with my son. It by far packed the biggest punch in the shortest amount of time—we saw the positives in under a week with no side effects! (A Herxheimer reaction is not a side effect.) After seven days on CD, my son was looking at me in the eyes and requesting non-preferred activities using four word sentences. I have never, with any other intervention, seen a change in my son come about so quickly, especially since Patrick was your typical non-responder before CD.

The chlorine dioxide molecule (CD).

Why CD for Autism?

We know that the symptoms known as autism are caused by:

- Viruses
- Bacteria
- Candida (yeast)
- Parasites
- Heavy Metals
- Inflammation
- Food allergies

CD catapults children into recovery because it kills these exact things. As of this writing, over three years since we started using CD in our protocol to heal autism, 115 children have lost their diagnosis. Thousands of children around the world are healing, and that means their families are healing as well, and for this I am eternally grateful.

CD has confirmed my faith and has shown me time and time again that autism IS curable. My life has changed since the day my son was able to look me in the eyes, smile, and request things. I could not keep information of this magnitude a secret. I absolutely had to share it with anyone who would listen.

CD is very affordable as you can purchase a two to three month supply from multiple worldwide suppliers on the Internet for around $25USD. The cost difference between the CD Autism Protocol and a megavitamin/supplement based biomedical protocol for a family living without insurance (or in a third world nation) could be the difference between recovering their child and not recovering their child. The results are also vastly different.

You can think of CD as a shortcut to recovery because it kills all pathogens with one shot. Hypothetically, you could use antibiotics, antifungals, and antivirals to get the same results; however, you could also cause damage due to harmful side effects from these products (liver and kidney stress, etc.). Also, antibiotics, antifungals, and antivirals can only target certain bacteria, viruses, and fungi. CD targets all types of pathogens based on their electrical charge and pH. The particular strain is irrelevant.

CD causes no side effects, leaves no toxic residues, and causes no liver damage. It causes no new stress to already stressed bodies. Everything else we use to kill pathogens leaves something behind. For example, antibiotics also kill your beneficial bacteria, and antiviral use comes with contraindications and side effects. CD is gone from the body one hour after your last dose, leaving no trace behind. We dose hourly throughout the day because CD is only active in the body for up to one hour. We must continue to dose if we want to stop the proliferation of pathogens and eliminate them from the body.

A few children with autism in Venezuela recovered using only CD, The Diet, and a probiotic. That doesn't happen every time, but it can.

False Information and the Fear it Creates

The most common reason that families have told me they are afraid of trying CD is because of false propaganda. The FDA, anti-biomed parents, and others have claimed that MMS (Jim Humbles term for a weak concentration of chlorine dioxide in aqueous solution) is a "poison," comparing it to chlorine or chlorine bleach, which it is not.

If you are interested in a deep dive into the science behind chlorine dioxide therapy (also known as MMS), please spend some time on Dr. Andreas Kalcker's websites...

www.medicasalud.com

...mostly in Spanish, though it has a few pertinent documents in English, and...

www.andreaskalcker.com

Also check Jim Humble's website:

www.jimhumble.org

There, you can also find a forum (G2Cforum.org) of people discussing the use of CD (MMS) for the healing of a multitude of ailments.

In a nutshell, chlorine (Cl) and sodium hypochlorite (NaOCl, aka chlorine bleach) are as different from chlorine dioxide (ClO_2) as "required-for-life" oxygen (O_2) and "will-damage-the-lungs" ozone (O_3) are different from each other. Chlorine (Cl) and sodium hypochlorite (NaOCl) destroy pathogens through "chlorination," while chlorine dioxide (ClO_2) destroys pathogens by "oxidation." The by-products of chlorination can bond with other molecules and form potentially carcinogenic trihalomethanes. The only byproducts of oxidation by chlorine dioxide are two neutral oxygen atoms and a chlorite ion, which can bond with sodium in the body to form table salt (NaCl).

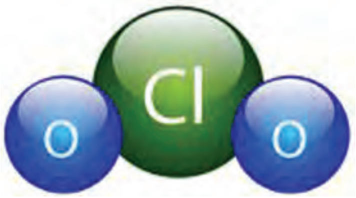

Chlorine Dioxide

IS NOT

CLOROX
SPLASH-LESS

Laundry Bleach

OR

Pool Chlorine

Your doctor is most likely not a chemist, and may or may not be fluent in the language of oxidizers. If you are working with a doctor, please take the science to them when you speak with them about adding CD to your child's protocol. The best thing we can do for our sick children is to make informed decisions. Understanding the difference between chlorine and chlorine dioxide, or chlorine bleach and chlorine dioxide may mean the difference between your child recovering or not.

I have shared this with thousands of families around the globe whose children have used chlorine dioxide in very dilute aqueous solutions, and NONE have had any injuries from CD. Sure, we have had discomfort in the form of a Herxheimer reaction. This is something we have learned to minimize, and can often be prevented by going low and slow. I have learned that what may appear negative at the outset, often turns out to be a healing crisis that leads to incredible gains in the long run.

Many of the first world children who have done the CD protocol have done it in parallel with other autism protocols. They have had regular blood, urine, and stool tests and generally test healthier while using CD than before they started. CD is fortifying immune systems, improving liver function, reducing bacterial and viral loads, *Candida* markers, and inflammation.

> Just did round of blood tests on my son,
> Liver Function Test best ever after 7 months of MMS.

Critics also frequently cite the fact that sodium chlorite and chlorine dioxide can be used for industrial bleaching processes, as a way to frighten parents out of using it. Just because a substance has the power to remove color, or bleach something, doesn't mean it's "bleach." Lemon, sunlight, hydrogen peroxide, and toothpaste all remove color from textiles. We would never call toothpaste bleach, even though it's capable of removing color, nor would we call sunlight bleach, even though that's what it can do to your clothes if you leave them outside long enough. From here we can draw a very similar analogy to using chlorine dioxide for health. The dilutions we are using for internal consumption in aqueous solution (water) are very weak. Day one starts with just one drop in eight fluid ounces of water.

The 1984 study, *Controlled Clinical Evaluations of Chlorine Dioxide, Chlorite and Chlorate in Man*, found no deleterious effects when taking a concentration of up to 50ppm over several hours a day for three weeks.[1] As Jim Humble mentioned (see page 79), the concentrations used for industrial purposes are are thousands of times more concentrated than what families have been using for their children on the spectrum.

Any substance can become toxic if taken in too high a concentration—even water.[2,3] Chlorine dioxide is no exception. We always increase CD dosages, *low and slow*, and have a respect for the power that chlorine dioxide can have over pathogens, always resisting the urge to ramp up our dosing too quickly.

We started MMS 68 Days ago and my son's ATEC has dropped from 50-23... Now that's a MIRACLE!!! He is So much more "with us" and I'm seeing improvements daily. He is just so much more fun to be with now:) He did have a plateau, but is back on track. We have only done 4 enemas to date, but they made a big difference! Baths do as well:) I can't wait to see what he is like on his 4th birthday (still 39 days away).

Chlorine Dioxide was discovered in 1814 by Sir Humphrey Davy as an effective disinfectant. Since then, numerous companies have patented its use for countless applications, including food and health.

The following is an excerpt from Jim Humble's Nov 21, 2012 newsletter:

> Dr. Andreas Kalcker spoke of patents obtained by different multinational pharmaceutical companies, to cash in on this product or to prevent it from being marketed.
>
> Some of those patents include:
>
> - Nontoxic Antiseptic (Pat 4035483/1977)
> - For combatting human amoebas (Pat.4296102/1981)
> - Against dementia caused by AIDS (Pat.5877222/1999)
> - For curing all types of illness of the skin (Pat 4737307/1988)
> - For disinfecting live blood (Pat. 5019402/1991)
> - For curing injuries more rapidly (Pat. 5855922/1999)
> - For all types of oral care (Procter & Gamble) (Pat. 6251372B1/2001)
> - Against infections caused by bacteria (Pat. 5252343/1993)
> - For treatment of severe burns (Pat.4317814/1982)
> - For the regeneration of bone marrow (Pat. 4851222/1989)
> - Treatment of Alzheimers, dementia etc. (Pat. 8029826B2/2011)
> - To stimulate the immune system in animals (Pat. 6099855/2000)
> - To stimulate the immunological system (Bioxy. Inc.) (Pat. 5830511/1998)

> ...The danger that may occur is if one mistakenly used a highly concentrated form. Highly concentrated forms of virtually every substance can cause death. In his conference, Dr. Andreas Kalcker points out that 70g of even plain table salt can cause death.
>
> There have been thousands of reports worldwide of excessive doses of MMS being ingested, however, with the hundreds of millions of tons of this substance used each year worldwide for water purification, preservation of vegetables, sterilization of slaughtered meat, and hundreds of other uses, there has never been a report of a death caused by ingestion of chlorine dioxide.
>
> This proves chlorine dioxide to be one of the safest products known.

There are many products that contain chlorine dioxide (ClO_2) that are currently approved by the Food and Drug Administration (FDA) in US. They are manufactured by *Frontier Farmaceutical*, *Alcide*, *Bioxy*, and others for skin and oral care. A number of these product names are listed below:[4]

- DioxiRinse™ Mouthwash
- DioxiBrite™ Toothpaste
- DioxiWhite™ Pro Teeth Whitener
- WhiteLasting™ Maintenance Gel
- BioClenz™ Dental Unit Waterline Cleaner
- Penetrator™ Periodontal Gel
- Simply Clear™ Acne Treatment
- DioxiWhite™ Home Teeth Whitener
- Cankers Away™ Canker Sore Cure
- DX7™ Skin Protectant Gel
- Periodontitis Treatment
- DioxiSmooth™ Facial Exfoliant
- Gingivitis Treatment Surface Disinfection
- Fire Fighter™ Burn Pain Reliever
- DioxiGuard™ Spray Disinfectant
- Nail-It™ Nail Protector

Chlorine Dioxide is an Oxidant… But aren't Antioxidants Good for Us?

In 1954, Denham Harman published an article called the "Free Radical Theory of Aging,"[5] claiming antioxidants would slow the aging process. However, he later found that mitochondria determined life span, and that antioxidants do not enter the mitochondria, and subsequently published the

"Mitochondrial Theory of Aging,"[6] in 1972. The "Free Radical Theory of Aging" is still responsible for billions of dollars in antioxidant supplement sales a year. While writing this book, a fascinating article was published in the journal *Open Biology* by Dr. James Watson (of Watson and Crick) called "Oxidants, antioxidants and the current incurability of metastatic cancers."[7]

Watson sets forth a hypothesis that links the presence of antioxidants in the body with late-stage (metastatic) cancer. He points out that some successful cancer treatments use "free radical" molecules to treat cancer—the very same molecules that antioxidants attack and kill. Watson urges his readers of the new paper to consider the following: "Unless we can find ways of reducing antioxidant levels, late-stage cancer 10 years from now will be as incurable as it is today."[8]

The following was excerpted from the same article in *Open Biology*.[8] Please see the original document for references contained within the text.

> Free-radical-destroying antioxidative nutritional supplements may have caused more cancers than they have prevented.
>
> For as long as I have been focused on the understanding and curing of cancer (I taught a course on Cancer at Harvard in the autumn of 1959), well-intentioned individuals have been consuming antioxidative nutritional supplements as cancer preventatives if not actual therapies. The past, most prominent scientific proponent of their value was the great Caltech chemist, Linus Pauling, who near the end of his illustrious career wrote a book with Ewan Cameron in 1979, *Cancer and Vitamin C,* about vitamin C's great potential as an anti-cancer agent [52]. At the time of his death from prostate cancer in 1994, at the age of 93, Linus was taking 12 g of vitamin C every day. In light of the recent data strongly hinting that much of late-stage cancer's untreatability may arise from its possession of too many antioxidants, the time has come to seriously ask whether antioxidant use much more likely causes than prevents cancer.
>
> All in all, the by now vast number of nutritional intervention trials using the antioxidants β-carotene, vitamin A, vitamin C, vitamin E and selenium have shown no obvious effectiveness in preventing gastrointestinal cancer nor in lengthening mortality [53]. In fact, they seem to slightly shorten the lives of those who take them. Future data may, in fact, show that antioxidant use, particularly that of vitamin E, leads to a small number of cancers that would not have come into existence but for antioxidant supplementation. Blueberries best be eaten because they taste good, not because their consumption will lead to less cancer.

Don't Oxidants Cause Oxidative Stress?

Not necessarily. Dr. Andreas Kalcker presented us with another theory explaining why oxidative stress is caused by pathogens and parasites rather than oxidants. If you take an oxidant such as CD, it is likely to upset the parasites living in the intestinal tract, causing them to defecate. Waste from worms can contain many toxic substances including MDA (malondialdehyde), formaldehyde, and ammonia. These toxins are known to cause oxidative stress.[9,10,11,12] When parasites are present in the body they are releasing these toxins, even if we don't kill them. Parasitic presence in the body is responsible for many of the symptoms known as autism.

Oxidants themselves are not directly responsible for oxidative stress in the body. However, they can exacerbate oxidative stress, which can cause parasites in the body to release toxins. The solution is to get rid of the parasites. Please see Chapter 8 for an effective Parasite Protocol.

Chlorine Dioxide & Antioxidants

Although antioxidants have their place in personal health and are common in many foods and supplements, they cannot be taken at the same time with chlorine dioxide—they negate each other. This is why vitamin C, juices, and other antioxidant containing foods are prohibited in *The Diet*.

> Just a testimonial to MMS: For those of you new to the group and still unsure of the MMS protocol I wanted to tell you about us. I was afraid at first, but we decided to try MMS. Within 3 weeks my son went from an ATEC of 36 to 18! That was amazing. Then we were afraid of the enemas. We said no way, we would just do oral MMS. Of course, after seeing others progress here we decided to do them. He would calm down! Then for months we agonized over the PP. We were afraid of it. We were scared of the meds, everything. Finally we decided to try it too. We are in the middle of our first PP and our son, who used to hit, kick, bite and scream at me over the smallest things all the time, has now been a perfect joy. When he gets mad it is over quickly and does not escalate into world war 3. Also these bumps he had on his face have cleared up along with his attitude! So if you are unsure of MMS like I was, here is one more testimonial of just how good the protocol really is. Thanks Kerri, and all the other moms that came before me!

Herxheimer Reaction (Die-Off Reaction)

There are many stories on the Internet about the "side effects" of CD. The definition of a side effect is:

The unintended or secondary effects of a substance.

When people describe what they believe to be side effects of CD, they are actually talking about a Herxheimer reaction. Jim Humble's original chlorine dioxide (MMS) protocols called for higher doses per hour ramped up much faster than we titrate up for autism. In some cases that resulted in nausea, vomiting, and/or diarrhea. Critics of CD claim that a Herxheimer reaction, which is the result from ramping up too quickly, is the body's reaction to being 'poisoned' by chlorine dioxide.

This is absolutely not the case, as the aforementioned study by Judith R. Lubbers and colleagues found that when healthy individuals were given minimal doses of chlorine dioxide in increasingly higher concentrations, no deleterious effects were noted.[2]

A Herxheimer reaction indicates that the patient is suffering from an overload of pathogens/toxins. If the person taking CD has a fair amount of pathogens, the rapid killing of these invaders produces excess toxins in the bloodstream. It is these substances that the body wants to rid itself of in short order. People with autism often have impaired methylation cycles that reduce their ability to eliminate toxins, making it even more difficult to handle an influx of toxins. So LOW AND SLOW is the way to go.

Children with autism typically don't (or can't) tell you they have nausea. However, discomfort may be visible from seeing that they're eating less, their eating habits have changed, or they're more listless than usual. That's usually a sign of detox, and in which case, we won't give the child any more CD that day. Detox is great, it's what we want, but without stressing the body further. We need to stay just beneath a Herxheimer reaction.

A Herxheimer reaction can present itself in many forms including:

- Blisters
- Bloating
- Burping
- Chills
- Diarrhea
- Fatigue
- Flatulence
- Flushing
- Headache
- Heart Burn
- Hiccups
- Nausea
- Runny nose
- Sleep changes
- Vomiting

If any of these symptoms appear, suspend the remaining doses of CD for the rest of the day. The following day, return to the number of doses given when the child was stable, which is usually the dose that was given the day prior to the Herxheimer reaction.

To mitigate a Herxheimer reaction from chlorine dioxide, you can give vitamin C or orange juice, as either one of these will cut the effects of CD immediately. To help bind the excess toxins you may want to try activated charcoal, bentonite clay, (be aware that these both can cause constipation), or burbur (a liquid detox extract).

Using Chlorine Dioxide for Autism

As I developed this protocol, it became clear to me that we needed to focus on excesses causing the symptoms of autism, rather than deficiencies caused by them. In the autism biomed world, we are accustomed to supplementing deficiencies (low iron, low B_{12}, low calcium, etc.), without questioning why the deficiency exists in the first place (i.e., presence of pathogens/parasites).

As soon as a family completes one week on *The Diet*, we get right into CD. Everyone starts with the "baby bottle" method, one drop of CD in eight fluid ounces of water, which makes the first day's dose 1/8 of a drop at a time. We have greatly minimized Herxheimer reactions by using this method, but it remains very important to monitor your child while they are using chlorine dioxide. It's very important to go low and slow. Every drop we give is helping to heal our children.

What is Chlorine Dioxide (CD)?

Refer to the diagram on the right for a visual overview.

You can't actually buy CD. You have to make it. Fortunately, it's not a big deal. If you can make coffee... you can make CD, which stands for *chlorine dioxide*.

Chlorine dioxide (ClO_2), is a gas produced through a chemical reaction when two liquids, sodium chlorite ($NaClO_2$) and an acid (such as hydrochloric acid (HCl) or citric acid ($C_6H_8O_7$)), are mixed. The acid brings the combined pH level below five, causing the sodium chlorite to become unstable and release chlorine dioxide (ClO_2).

If any of this sounds complex, it isn't. Go through the following explanation and don't get bogged down by the chemical symbols.

Conceptual Overview of Chlorine Dioxide (CD)

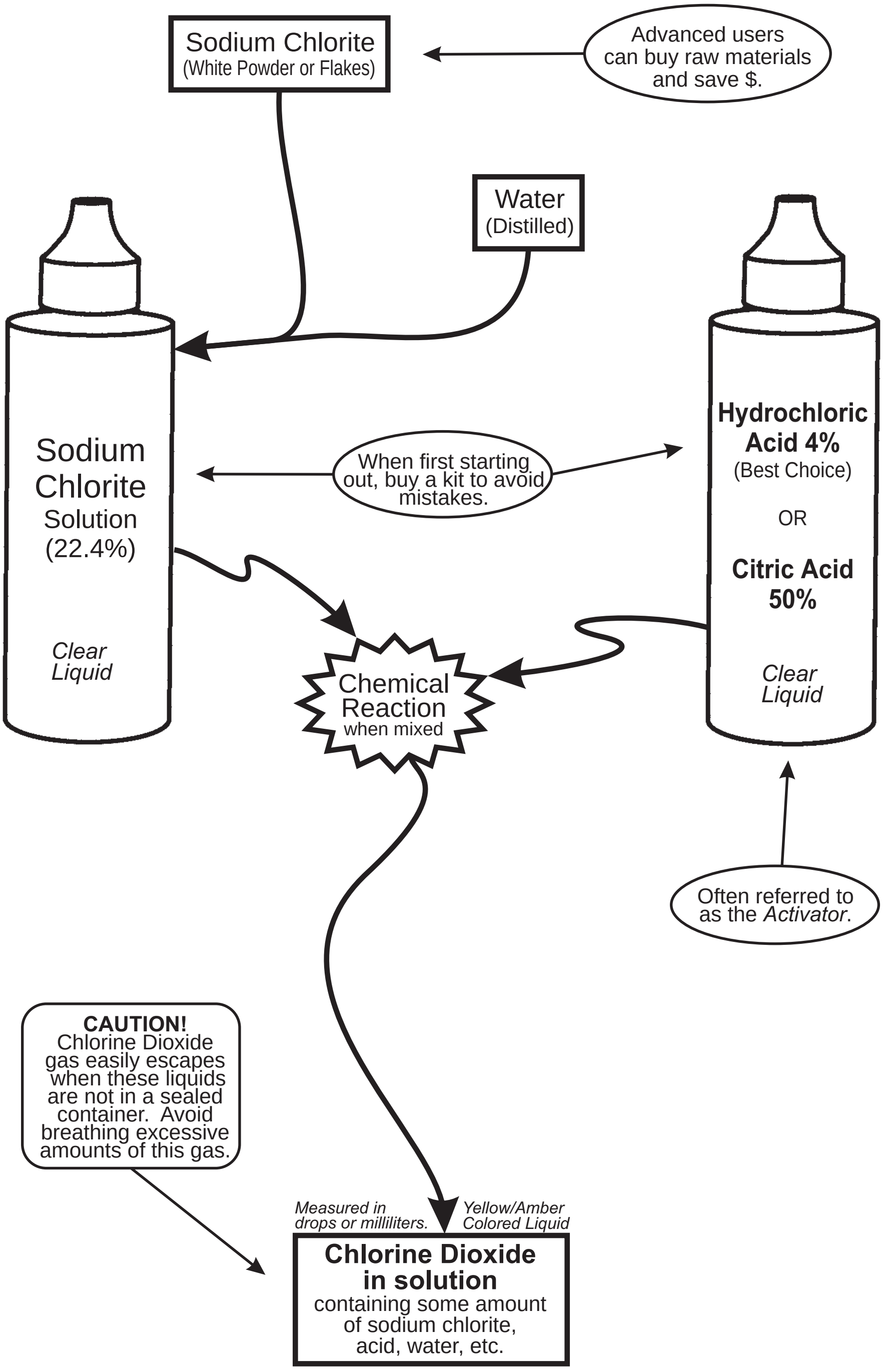
Sodium Chlorite
(White Powder or Flakes)
Advanced users can buy raw materials and save $.
Water
(Distilled)
Sodium Chlorite Solution (22.4%)
Clear Liquid
When first starting out, buy a kit to avoid mistakes.
Hydrochloric Acid 4%
(Best Choice)
OR
Citric Acid 50%
Clear Liquid
Chemical Reaction
when mixed
Often referred to as the *Activator*.
CAUTION!
Chlorine Dioxide gas easily escapes when these liquids are not in a sealed container. Avoid breathing excessive amounts of this gas.
Measured in drops or milliliters.
Yellow/Amber Colored Liquid
Chlorine Dioxide in solution
containing some amount of sodium chlorite, acid, water, etc.

Sodium Chlorite ($NaClO_2$)

This is the first chemical you must have to make CD.

You can get it in one of two forms:

- **Sodium chlorite liquid in water:**
    - If you are beginning, get a starter kit of this.
    - Expect to pay about $20-$30 for a 4 fl. oz. bottle set (usually includes acid activator).
    - 22.4% sodium chlorite solution (from 28% technical grade sodium chlorite salts).
    - Recommended: Buy quart or liter sized quantities of liquid once you understand the principles.
- **Sodium chlorite powder or flakes:**
    - FOR ADVANCED USERS ONLY!
    - Cheaper in the long run.
    - Recommend buying 5 lbs. of flakes/powder for a cost of about $100-$200.
    - Look online or check with your supplier for mixing instructions.
    - Avoid buying 90% sodium chlorite flakes. You want 80%. Most suppliers that sell liquid also sell flakes.
    - NEVER mix any acid directly with powder/flakes!

What's the 28%? 22.4%?

This is not a critical thing for you to worry about unless you are mixing your own. But here is the jist: sodium chlorite powder is not 100% sodium chlorite. It's usually 80% sodium chlorite and 20% salt and other inert ingredients. When diluted in water, you end up with 28% solution of powder, but only 22.4% is sodium chlorite. Labels usually show one or both of these numbers.

Sodium Chlorite Flakes vs. Powder

Sodium chlorite flakes and sodium chlorite powder are the same thing. The resulting physical consistency may vary by different manufacturers. We've even seen clumps of powder. It's still the same chemical. The important part is that it is technical grade, and 80% of the powder/flakes should be sodium chlorite ($NaClO_2$). Mixing info is at: *www.youtube.com/watch?v=t0C8XVm9QVE*.

Acid - The Activator

To produce CD, you must add the second chemical, which is a food acid, to the liquefied sodium chlorite (22.4% solution in water). Chlorine dioxide gas is produced when the pH of the sodium chlorite goes below five. We call the acid used to lower the pH of sodium chlorite an "activator" because it activates the sodium chlorite to produce the chlorine dioxide.

There are several activators to choose from. These are food acids in that they are commonly found in food preparations, or are actually food:

- **Hydrochloric Acid (HCl)**
  - The same acid found in your stomach, and therefore, the most biocompatible option.
  - Working concentration is between 4% and 10%.
  - Available on the market in liquid concentrations of 4%, 5%, 10%, 32%, 35%, and 37%.
  - Any concentration over 10% must be reduced to a working concentration of between 4% and 10%. See Appendix 7, page 471. (Note: We use 4% for CD and CDH; & 10% for CDS.)
  - Only available in liquid form.
- **Citric Acid**
  - Commonly available around the world.
  - Often found in soft drinks to give them a tangy flavor.
  - Some people have problems tolerating this acid.
  - Usually used in 50/50 concentration by weight mixed in water.
  - Available in liquid and powder form.
  - Inexpensive; can be purchased online.
- **Lemon or Lime Juice**
  - Consider this an emergency alternative to be used if the first two choices are not available.
  - Can be found in most stores carrying produce.
  - Should be from pure, organic and freshly squeezed lemons (or limes).
  - Relatively weak acidity requiring five drops of lemon juice to every one drop of sodium chlorite solution.
  - Substantially longer activation time.
  - Lower ClO_2 output.

The amount of acid used, and the length of time you wait to dilute the mixture, will depend on the acid activator and its strength. The following chart gives you an idea.

Activator	Strength	Ratio	Time
Hydrochloric Acid	10%	1:1	40 secs
Hydrochloric Acid	4%	1:1	60 secs
Citric Acid	50%	1:1	60 secs
Citric Acid	33% or 35%	1:1	60 secs
Lemon Juice	Pure	1:5	120+ secs

You are unlikely to be using lemon juice, but we've included it here for completeness.

Families should use whichever activator is available to them depending on where they live and what they have access to. All kids are different, so if yours doesn't respond well to 4% HCl, by all means, try citric acid, or vice versa.

If the HCl you purchased is anything other than 4% or 5%, then see Appendix 7 for instructions on reducing concentration.

If you are using one of the two most commonly available activators, then you are likely to be using a 1:1 mixing ratio (1 drop sodium chlorite + 1 drop activator).

In the case of 10% citric acid or pure lemon juice, you would be using five drops of activator to one drop of sodium chlorite, and waiting about three times as long as if you were using one of the newer, more concentrated activators.

Purchasing Product

When you first start out, you should buy a starter kit and get familiar with the chemistry. A starter kit usually comes in two bottles of four fluid ounces each.

1. Sodium chlorite, (4 fl. oz.)
2. Activator (hydrochloric acid or citric acid), (4 fl. oz.)

The bottles look something like those shown in the diagram on page 91. Getting the hydrochloric acid activator is slightly preferable.

You will also need an 8 fl. oz. baby bottle. This is a handy tool for storing a day's worth of CD doses with the added benefit of having marks that show how much it contains. Glass bottles are much better than any kind of plastic bottle. Lifefactory.com (shown on the right) produces a bottle we especially like. It is made of silicon-covered glass and has a reliable top. This particular bottle is marked as having a capacity of nine fl. oz., but we use it up to only eight fl. oz. Plastic should only be used for lids; avoid bottles with metal tops. Over time, CD will oxidize metals so they can't be used.

Another item that most people have at home is a shot glass or wine glass that tapers down in the middle like a "U" shape. This will be used to mix the chemicals and the tapered shape insures that even as few as two drops will find each other. You can also use a cup with a flat bottom, but must tilt it so both solutions pool together.

lifefactory

A standard shot glass with a "U" shaped bottom is the preferred mixing container for CD & activator. A glass baby bottle, such as the one made by Lifefactory®, is the ideal dosing bottle.

Terminology of Available Products

There can be a bit of confusion for some as to what to look for and buy. The following chart shows the actual chemical, and some of the common names found on the label. There may be other names we are not aware of. In most cases, the chemical and its strength are identified on the bottles.

Common Activators & Their Various Names on the Market	
Chemical	**Common Names**
Sodium Chlorite	Chlorine Dioxide – Part 1 (Purifier) Master Mineral Solution Miracle Mineral Solution Miracle Mineral Supplement MMS MMS Drops MMS Solution MMS Water Purification Drops MMS1 NaClO2 Natriumchlorit (German) Pathogen Biocide Sodium Chlorite 28% Water Purification Drops Water Purificator
Hydrochloric Acid	Activator Chlorine Dioxide – Part 2 (Activator) MMS Activator
Citric Acid	Activator Citric Acid – 20% Citric Acid – 50% MMS Activator

Checklist for Preparing a CD Dose

Assuming you have received the starter kit, it's time to make your first dose. Here's the check list of what you now should have on hand before you begin:

- ☐ Bottle of sodium chlorite solution (28% sodium chlorite salts / 22.4% sodium chlorite)
- ☐ Bottle of acidic activator (hydrochloric acid or citric acid)
- ☐ A clean and dry shot-glass with a "U" shaped bottom.
- ☐ 8 fl. oz. glass baby bottle.
- ☐ Distilled or reverse osmosis water (filtered water will do, but no alkaline water!).

A Few Points Worth Noting!

Looking at the short checklist above, it should be apparent that this is not going to be rocket science. Nevertheless, a few pointers are in order:

- In the past, people who used CD for various things would mix a fresh batch each time they took CD. This involved a lot of extra work that could be avoided by producing one batch big enough to last the entire day. For this exercise, we are assuming you are starting out and going to do things low and slow. We are going to produce 8 fl. oz. of water solution containing one drop of CD, with the intention of your child consuming one fl. oz., of water (containing 1/8 drop of CD) eight times throughout the day.

- When you mix sodium chlorite solution and the acidic activator, you are mixing equal drops of each substance (unless you are using one of the less concentrated activators mentioned earlier).
- CD doses are measured in drops of sodium chlorite. So one drop of sodium chlorite + one drop of activator = one drop of CD.
- On your first day, start with one drop of sodium chlorite and one drop of activator (in other words—ONE drop of CD).
- If you put in too many drops of one solution or the other, start over with a clean and dry shot glass.
- A batch of CD is good for 24 hours. However, you must keep the cap on tight!
- Keep the bottle with the daily CD batch out of direct sunlight. A brief exposure won't ruin it, but it will become weaker. Why? The chlorine dioxide gas will come out of the water and sometimes form a cloud in the air pocket of the bottle. No need to worry if you see the cloud—it's a common occurrence.

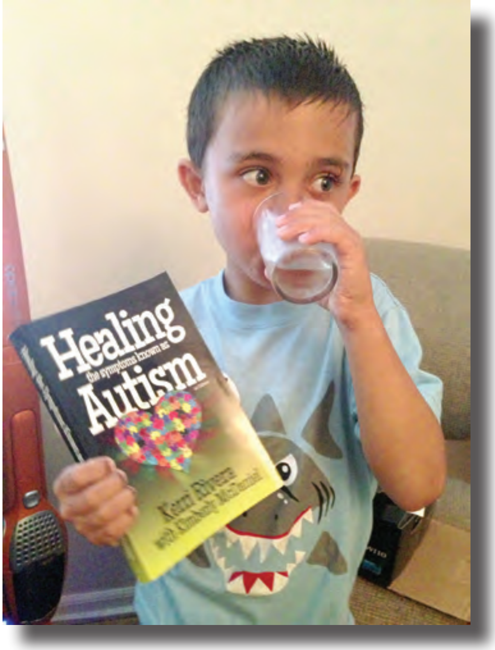

Vincent taking his hourly dose.

Preparing Your First One drop CD Batch for the Day

1.	Start by filling the baby bottle with 8 fl. oz. (237ml) of water (distilled or reverse osmosis). NO alkaline water!	
2.	Place 1 drop of sodium chlorite solution into the CLEAN and DRY shot glass.	
3.	Add 1 drop of acidic activator (hydrochloric acid or citric acid) to the shot glass containing the drop of sodium chlorite. The number of drops may be higher if you are using a weaker activator. See chart on page 94.	
4.	Now wait the appropriate time for the mixture to react (see chart on page 94). You should see the color change from clear to slightly yellow. If there were more drops in the shot glass, the color change is more noticeable. You are also likely to notice the chlorine-like smell coming from the shot glass. Remember, this is NOT chlorine, but rather chlorine dioxide.	
5.	After the activation time has passed, pour a little water from the baby bottle into the shot glass and let it mix. This mostly stops the chemical reaction and insures you get most of the mixture out in the next step.	
6.	Lastly, pour all of the watered down mixture in the shot glass back into the baby bottle, and seal it tightly with the cap—don't leave it sitting open for any length of time. Think partially used soda pop and how you would want to keep that closed.	

Voilà! You have just produced your first batch of CD!

This is now a ONE drop batch, that makes EIGHT hourly doses—each 1/8 of a drop in strength. If your batch is larger; your hourly dose is stronger:

- 2 drop batch = 8 hourly doses of 1/4 drop
- 4 drop batch = 8 hourly doses of 1/2 drop
- 8 drop batch = 8 hourly doses of 1 drop

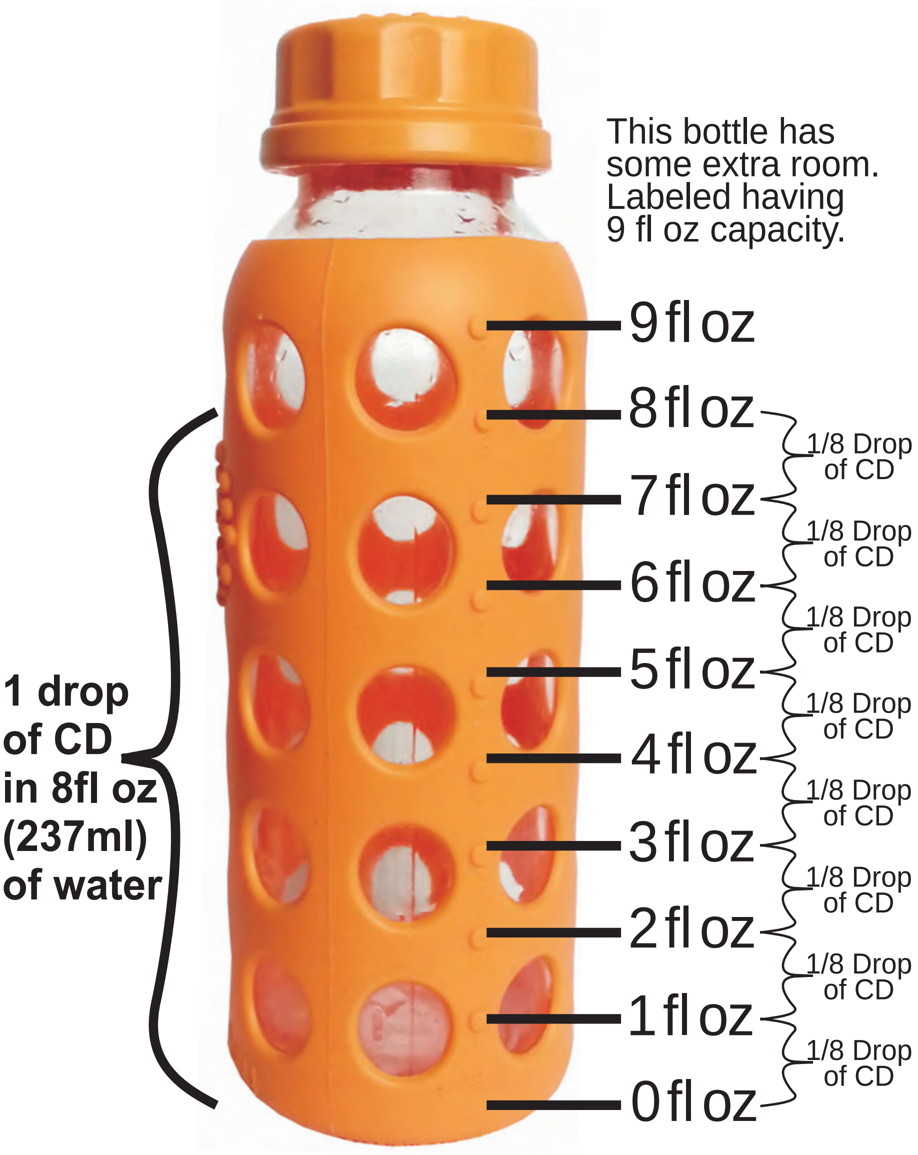
This bottle has some extra room. Labeled having 9 fl oz capacity.
9 fl oz
8 fl oz
7 fl oz
6 fl oz
5 fl oz
4 fl oz
3 fl oz
2 fl oz
1 fl oz
0 fl oz
1/8 Drop of CD
1/8 Drop of CD
1/8 Drop of CD
1/8 Drop of CD
1/8 Drop of CD
1/8 Drop of CD
1/8 Drop of CD
1/8 Drop of CD
1 drop of CD in 8fl oz (237ml) of water

Oral Protocol for CD in Autism Spectrum Disorders (ASDs)

In the previous exercise, you learned how to prepare the dose for Day One. Children and adults all start by taking only one drop of CD divided into eight hourly doses. On Day Two, you make a batch of two drops sodium chlorite plus two drops activator and mix that into eight fluid ounces of water. Increase this dosage by one drop per day, unless you see a Herxheimer reaction (see page 89 for more information).

The chart on the right allows you to determine the estimated full oral CD dose based on the weight of the individual. This gives you an idea of the maximum goal number of drops per day for your child. Once the child has been at the full suggested dose for several months, we may need to increase again, by a few drops, to prevent a plateau.

Important Note: Some children can't go up by one drop each day and need to go slower. A child may have a relatively higher toxic load, or he may be extremely sensitive. Whatever the case, resist the urge to try to get to full oral dose as quickly as possible. This is not a race! Some children need to spend a few extra days at the same dose to avoid a Herxheimer reaction. Even if you must remain at one level for a few days or more does not mean you are making no progress. Whatever the level of dosage, you are detoxing the body.

When you get within two to three drops of your child's maximum dose by weight, go ahead and spend three days at each dose, while carefully observing your child, moving up only when your child is stable. For example, if the full dose is 16 drops in the 8 fl. oz. (237ml) baby bottle, stay at 14 drops for a few days to see how that dose level is tolerated, and then increase every third day till reaching the full dose. If the person is better at a drop or two below the calculated full dose, go back to that lower dose that they tolerated best.

> *Just had a fascinating appointment with my son's functional neurologist. My son had this third Qeeg today, which clearly showed that previously under-stimulated parts of his brain are 'waking up'. I told our doctor about CD very early on and he believes that it is THIS that is having such a huge impact on his brain. He got quite emotional and said 'every time you get a worm, you are saving your son. Keep doing what you're doing, cause he clearly isn't autistic. He's poisoned'. Goosebumps!!*

Estimated Full Oral CD Doses by Weight

Use these numbers as a guide only. You may need to go up by as much as 50% or more over the indicated drops. Read chart as: **POUNDS / KILOGRAMS → DROPS OF CD (per 8 fl. oz. water)**

25/11→8	62/28→17	99/45→24	136/62→29	173/78→33	210/95→37
26/12→8	63/29→17	100/45→24	137/62→29	174/79→33	211/96→37
27/12→9	64/29→17	101/46→24	138/63→29	175/79→34	212/96→37
28/13→9	65/29→18	102/46→24	139/63→30	176/80→34	213/97→37
29/13→9	66/30→18	103/47→24	140/64→30	177/80→34	214/97→37
30/14→9	67/30→18	104/47→25	141/64→30	178/81→34	215/98→37
31/14→10	68/31→18	105/48→25	142/64→30	179/81→34	216/98→37
32/15→10	69/31→18	106/48→25	143/65→30	180/82→34	217/98→37
33/15→10	70/32→19	107/49→25	144/65→30	181/82→34	218/99→38
34/15→10	71/32→19	108/49→25	145/66→30	182/83→34	219/99→38
35/16→11	72/33→19	109/49→25	146/66→30	183/83→34	220/100→38
36/16→11	73/33→19	110/50→26	147/67→31	184/83→35	221/100→38
37/17→11	74/34→19	111/50→26	148/67→31	185/84→35	222/101→38
38/17→11	75/34→20	112/51→26	149/68→31	186/84→35	223/101→38
39/18→12	76/34→20	113/51→26	150/68→31	187/85→35	224/102→38
40/18→12	77/35→20	114/52→26	151/68→31	188/85→35	225/102→38
41/19→12	78/35→20	115/52→26	152/69→31	189/86→35	226/103→38
42/19→12	79/36→20	116/53→26	153/69→31	190/86→35	227/103→38
43/20→13	80/36→21	117/53→27	154/70→31	191/87→35	228/103→38
44/20→13	81/37→21	118/54→27	155/70→31	192/87→35	229/104→38
45/20→13	82/37→21	119/54→27	156/71→32	193/88→35	230/104→39
46/21→13	83/38→21	120/54→27	157/71→32	194/88→35	231/105→39
47/21→14	84/38→21	121/55→27	158/72→32	195/88→36	232/105→39
48/22→14	85/39→21	122/55→27	159/72→32	196/89→36	233/106→39
49/22→14	86/39→22	123/56→27	160/73→32	197/89→36	234/106→39
50/23→14	87/39→22	124/56→28	161/73→32	198/90→36	235/107→39
51/23→15	88/40→22	125/57→28	162/73→32	199/90→36	236/107→39
52/24→15	89/40→22	126/57→28	163/74→32	200/91→36	237/108→39
53/24→15	90/41→22	127/58→28	164/74→32	201/91→36	238/108→39
54/24→15	91/41→23	128/58→28	165/75→33	202/92→36	239/108→39
55/25→16	92/42→23	129/59→28	166/75→33	203/92→36	240/109→39
56/25→16	93/42→23	130/59→28	167/76→33	204/93→36	241/109→39
57/26→16	94/43→23	131/59→28	168/76→33	205/93→36	242/110→39
58/26→16	95/43→23	132/60→29	169/77→33	206/93→37	243/110→39
59/27→16	96/44→23	133/60→29	170/77→33	207/94→37	244/111→40
60/27→17	97/44→24	134/61→29	171/78→33	208/94→37	245/111→40
61/28→17	98/44→24	135/61→29	172/78→33	209/95→37	246/112→40

Serving Cup Dilution

Don't have your child drink out of the baby bottle. Pour the hourly dose into a separate cup and add extra water if needed. Make sure to add water to each dose to ensure that there is a **minimum** of one fluid ounce of water per activated drop of CD. However, there is no maximum amount of water for dilution. To be absolutely clear about this, note the following chart which assumes eight fl. oz., daily batches containing eight hourly doses.

Drops of CD in Batch	Hourly Dose	Min. Water Dilution
1	1/8 drop	1 fluid ounce
2	2/8 drop	1 fluid ounce
3	3/8 drop	1 fluid ounce
4	4/8 drop	1 fluid ounce
5	5/8 drop	1 fluid ounce
6	6/8 drop	1 fluid ounce
7	7/8 drop	1 fluid ounce
8	1 drop	1 fluid ounce
9	1 1/8 drops	2 fluid ounces
10	1 2/8 drops	2 fluid ounces
11	1 3/8 drops	2 fluid ounces
12	1 4/8 drops	2 fluid ounces
13	1 5/8 drops	2 fluid ounces
14	1 6/8 drops	2 fluid ounces
15	1 7/8 drops	2 fluid ounces
16	2 drops	2 fluid ounces
17	2 1/8 drops	3 fluid ounces
18	2 2/8 drops	3 fluid ounces
19	2 3/8 drops	3 fluid ounces
20	2 4/8 drops	3 fluid ounces
21	2 5/8 drops	3 fluid ounces
22	2 6/8 drops	3 fluid ounces
23	2 7/8 drops	3 fluid ounces
24	3 drops	3 fluid ounces
25	3 1/8 drops	4 fluid ounces
26	3 2/8 drops	4 fluid ounces
27	3 3/8 drops	4 fluid ounces
28	3 4/8 drops	4 fluid ounces
29	3 5/8 drops	4 fluid ounces
30	3 6/8 drops	4 fluid ounces
31	3 7/8 drops	4 fluid ounces
32	4 drops	4 fluid ounces

CD is active in the body for about one hour and, as result, hourly doses give us the best progress. This is difficult on school days, but we recommend that you dose two to three times before school and the rest after to distribute the pathogen-fighting more evenly. Eight doses a day is the minimum requirement, but the more you can fit in the better. Try to dose every hour as much as possible.

Special Cases: "The Double Dose"

As a child goes through the detox process, they may exhibit conduct which can include hyperactivity, anxiety, OCD, aggressiveness, and night wakings. In these cases, a double dose is 2 fl. oz. (60ml) of the baby bottle given at once. For example, if your child receives one drop per fluid ounce of the baby bottle method, they will be receiving 2 drops. Let's say for example your child wakes up at 1am, give them a double dose. If your child is still awake at 2am, give another dose. The most common scenario is that after 1 or 2 double doses, the child will fall back asleep. This helps oxidize the toxins from the die-off. During the day if your child has a tantrum or other issues with conduct, we can double dose every hour as well.

CD has two functions with pathogens; one is that is oxidizes the pathogen itself, and the second is that it oxidizes the toxins released by the pathogens while they are living, dead, or dying.

Advanced Protocol – The Enema!

In early 2011, we added enemas to the protocol to kill the pathogens causing dysbiosis in the large intestine (we didn't know about parasites yet). We wanted to get the chlorine dioxide into the blood stream so it could kill the biofilm that exists in the blood. In this way, the blood can carry the CD past the blood-brain barrier to kill pathogens in the brain

When we are detoxing, it is absolutely critical to keep the colon moving and avoid the reabsorption of toxins through the intestinal walls. Enemas allow us to do just this. Some toxins can exit the intestine through the intestinal wall (more so if leaky-gut syndrome is present), and cross the blood-brain barrier, therefore affecting cognition and behavior. When we cleanse the colon, we get those out before they can cross into the brain, and we detoxify the lymphatic system, liver, and gallbladder.

The Enema Stigma

When I say the word enema to a family new to the protocol, I often hear things like "*I could never do that!*," or "*My son would never let me do an enema.*" I assure you it's not traumatic as it has been hyped up to be. Modern society has gotten away from it, but for millennia, cleansing the colon was considered part of daily hygiene. Enemas were mentioned in the Vedas, the Bible, and by the Mayans. The reason for doing CD enemas is NOT for relief of constipation. Of course, when constipation is present, CD enemas can relieve the cause of constipation.

> Great news! First enema today...
>
> My son was so happy that we did and the first thing he said while sitting on the toilet was: "Mommy! IT WORKED!!!" hahaha He is so used to sitting on the toilet and having such a hard time. Poor thing, he was so happy that IT WORKED!
>
> And he even said he wants to do it again tomorrow. He felt so much better and ate so much more for dinner with an empty stomach. I think he got rid of stuff that was there for ages! His tummy is now soft and not hard as usual. Quite amazing and it didn't bother him at all.
>
> Today his molar hasn't bothered him so a perfect day to start the enemas! His appetite has gone up quite a bit. He has seldom asked for food before and now he asks a few times a day for something to eat. The diet is going wonderfully and he is now used to the change of foods. He asks about cheese and milk but I try to talk about something else to distract him so he eventually stops asking. hahaha He hasn't gotten upset about food he wants (that he can't have) not even once. YAY!

I would like to clear up one thing here before we get in the mechanics of the enemas. More than one person has asked in the blogosphere, "*If Kerri Rivera loves enemas so much, why doesn't she do them on herself???*" As a matter of fact I do! I have done my own enemas for years, so has my husband, my sister, and plenty of the parents using this protocol for their children. We understand the benefits of a fit colon, and have no problem applying our own enemas or going for a colonic from time to time.

Actually, I would strongly advise you to practice on yourself. That way you know from first-hand experience that this is really no big deal. You will also discover how much better you feel after cleaning out your colon, and you will understand when your child feels better as well.

When to Start Giving Enemas

Enemas should be started when the child reaches full oral dose.

However, if your child suffers from constipation you can add enemas and baths on day one (see page 113), before you get to the full oral dose. However, alternate them on opposite days or opposite ends of the day.

Frequency of Enemas

I recommend enemas no less than once every other day. You may need to do them more often, particularly if you see parasites coming out. Doing as many as four in a day is not uncalled for if each one results in parasites being released. Some of the older children seem to pass a lot of parasites in one day, typically in or around a full or new moon.

Timing of Enemas

If your child is going to school, avoid giving an enema in the morning since they may need to visit the toilet a few times after. If the child is homeschooled or too young or sick to attend, the timing is up to you. Ideally, do the enema after the child has a bowel movement.

Enemas — What You Need

The first thing you are going to need is some kind of a large plastic, liquid measuring container. Glass is not recommended since it can get knocked over and break in the confines of a bathroom.

You will also need all the same things you used for making CD batches:

- Water. Use reverse osmosis, filtered, or distilled.
  DO NOT use tap water or alkaline water!
- Sodium chlorite solution
- Acidic activator
- Shot glass
- Natural lubricant (coconut oil or any other simple food oil). NO perfumed baby oil or chemical lotions such as Petroleum Jelly or K-Y® Jelly.
- Enema kit (see your options on the following page)

Enema Options (Most to Least Preferred)

Gravity Bag or Bucket with hose

PiC
indolor
IRRIGADOR
ENTEROCLISE
KLISTEERSPUIT
ΚΛΙΣΜΑ

Pros:
- Holds plenty of liquid
- Can be refilled without taking it down
- Flow is easy to control
- Can be hung on a door
- Can be used for both enema and douching
- PIC Indolor: Folds for easy travel
- PIC Indolor: Has valve
- PIC Indolor: Two sizes of cathetors

Cons:
- Bucket doesn't fold for easy travel

Enema / Douche Bag / Hot Water Bottle

HOT / COLD
WATER BOTTLE SYSTEM
HOT/COLD
Therapy Anytime...
Anywhere!
Safe
Durable
Hygienic

Pros:
- Holds plenty of liquid
- Flow is easy to control
- Can be hung on a door
- Can be used for both enema and douching
- Easy travel
- Has two sizes of cathetors

Cons:
- Can't be refilled without taking down
- Usually made of rubber, which tends to dry out quickly, especially from CD.

Syringe & Catheter

Pros:
- Flow is easy to control
- Can be used for both enema and douching
- Good for small children

Cons:
- Holds only 60ml-140ml
- Need more than one.
- Have to swap them out to go beyond the capacity of one syringe.
- The graduations rub off easily (suggest putting clear shipping tape over them to protect the markings if they are important to you).

Enema Bulb

Pros:
- Portable
- Can be used for both enema and douching
- Good for “implants” of mebendazole

Cons:
- Volume too small for an effective treatment.
- Hard to clean inside
- Can’t tell if dirt is on the inside.
- Holds only about 200ml.

Fleet Enema (Last Resort)

Fleet
Enema
saline
Twin Pack
LAXATIVE
ready-to-use
latex free
Soft, Flexible Comfortip
EASY SQUEEZE
2

Pros:
- Cheap
- Can find it in most pharmacies
- Portable
- Can be used for both Enema and Douching

Cons:
- Volume too small for an effective treatment.

Enema Kits

As shown in the previous two pages, here are your enema kit options listed from best to less than good. Prices are estimates in US Dollars and are likely to be higher outside the US:

★★★★★ PIC Indolor Gravity Bag (~$15-$30)

★★★★☆ Enema Bucket (~$5-$10)

★★★⯪☆ Multipurpose Enema/Douche Bag/Hot Water Bottle (~$15-$30)

★★★☆☆ 100ml+ Syringes plus Catheter (~$5-$10)

★★☆☆☆ Enema Bulb (~$5-$15)

★☆☆☆☆ Fleet Enema (emptied out) (~$5-$15)

You must have a separate enema kit for each person doing enemas. This insures that you are not cross-contaminating parasites.

In my own home we have recently started using the PIC Indolor enema/douche bag. This has made the process faster, and we can tolerate more water before feeling full and desiring to release the enema. This is probably the most practical kit, especially because of the built-in shut-off valve. The enema bucket is a close second, but the sliding clamp that comes with it doesn't last long and breaks easily. You can always just kink the hose and control the flow that way.

The multipurpose enema/douche/hot water bottle type is a good option, but it is usually made of rubber. This material often goes bad over time and CD just speeds up that process. Rinse it out several times before and after use to insure that no breakdown or CD residue is left. Don't use if you notice the rubber becoming brittle.

Even two-year-olds still use about 400 to 500ml in an enema. The intestine is long. Parents with small children sometimes like the 100ml syringe/catheter method. The enema bulb or fleet enema are not really practical for our purposes due to the small volumes they hold. However, if you want to get started right away, they are usually available in most major pharmacies.

You can find syringes, catheters, gravity bags, multipurpose enema/douche bags on various online sites, pharmacies and medical supply stores around the world.

Preparing and Administering the Enema

Make all your supplies easily accessible in your work area before bringing your child in the bathroom. If this is your first time and you are working out the process, you may wish to ask your spouse or someone else for assistance. It's a good idea to do a dress rehearsal without the child, to insure that it goes smoothly when the child is present. Once you and your child have the process down, it will be easy. Being prepared is the key to success.

Please note: The eight fluid ounce baby bottle is NOT involved in any way with enemas!

1. Ideally, time the enema just after a bowel movement.
2. Start by washing your hands to insure you are not introducing any new bacteria into the colon. Everything you are working with should be clean. Wearing gloves and a face/surgical mask is HIGHLY recommended.
3. Assuming you are using one of the suggested gravity bags, find a good and stable location to hang it up. The best location really depends on your particular bathroom's layout and where you are going to place the child during the procedure. I hang mine from a towel hook in the bathroom, or you can use the shower curtain rod. The idea is to have the bag/bucket about three feet (~one meter) over where the enema will be administered. Most parents put a towel on the floor of the bathroom and lay their child on the towel (smaller children can lay across your lap).
4. Refer to the chart below and measure out the appropriate amount of water for the individual receiving the enema. The ratio is two drops of CD per 100ml of filtered warm water.

Age/Size	Water Volume	Drops of CD
Child	1/2 Liter (500ml)	10
Adolescent	1 Liter (1000ml)	20
Teen/Adult	up to 2 Liters (2000ml)	40

5. Don't add any CD yet. The next step is to heat the water to body temperature (98°F / 37°C). The water should feel warm to the touch—NEVER hot! Similar to the temperature of milk in a baby bottle... test it on your wrist. If you are concerned about getting the temperature right use a quality thermometer. Be aware... many cheap thermometers are notoriously inaccurate!

6. After the heating step, pour the water back into the big measuring cup.

7. Referring again to the chart on the previous page, prepare a CD mixture in the clean dry shot glass that's appropriate for the volume of water needed. For example, if you have an adolescent and are preparing one liter, then you will need to mix 20 drops of sodium chlorite and 20 drops of acidic activator to end up with 20 drops of CD! Note: The most important part of the enema is the ***water***. Resist the urge to add more than two drops per 100ml of water.

8. After the appropriate activation time, pour the concentrated CD from your shot glass into the large measuring cup. You may want to rinse out the shot glass with some water from the large mixing cup so you get all the concentrated CD solution into the water.

9. The bag/bucket should now be in its working location with the hose firmly attached, Place the end of the hose so it is over the top of the bag/bucket. A clothes pin can come in handy to hold it up over the bag/bucket. Now, fill the bag/bucket about 3/4 full with the CD water mixture you just prepared.
10. Make sure the hose is filled with water. You may want to let a bit run out into the sink or some other container and then clamp it. The bucket type enema has a plastic clamp for this purpose. The bag type has a valve where the catheter attaches. What you don't want is for there to be a bunch of air in the hose that then is transferred into the colon.
11. If all of the above is ready, it is time to bring your child into the bathroom.
12. Explain what you are going to do. Some parents say that they are going to put the catheter in his bottom, and that it has "special water" in it to help him feel better. One little boy called it "butt medicine" while another called it "butt wash." We recommend you say that you are the only person who is allowed to give this to him. Just say whatever you need to say to explain what is happening.
13. If the child is on the floor (on a rug or towel), they should lie on their stomach. If the child is small then laying them on your lap is best. You can also have them in a doggy position on the floor.
14. Place one or two drops of coconut oil (or similar) on their anus so the area is well lubricated.

15. Now take the hose and gently insert the tip, (one to two inches is plenty—more is not necessary) as the sphincter muscle will hold the tip of the catheter in place. If you are having any problems getting the catheter in, then you may need to add a bit more oil and/or adjust the angle.

16. Release the clamp or open the valve to allow the liquid to flow. The goal is *fill & release*.—NOT *fill & hold*. We are imitating the colonic process that is made up of gallons of water, yet in the home environment.

17. Your child will most likely hold the contents on their own—they will squeeze hard so as not to "go." This kind of happens naturally.

We do a fill and release method. The first part of the enema is usually stool. After that, we usually see parasites and or biofilm.

It's a learning experience and as time goes on, you will get the hang of it.

> Quote from a teenager using the Protocol: "I like the enemas. Before them I am mad. But then when I get one, I feel better. My mad leaves in my poop.

Syringe/Catheter Method

Before I started to use the gravity bag, the syringe/catheter method was my favorite. We have a YouTube video on our channel that shows how to fill the syringes and switch them out while using the catheter. If you don't have access to that video here is an explanation on how to do it:

1. Fill a bowl with body temperature filtered water and fill your syringes. If your child uses 500ml for an enema, fill all five syringes and dump out whatever water is still left in the bowl.
2. Squirt all the water from the syringes back into the bowl. You now have exactly 500ml of purified water.
3. Activate your drops of CD in a clean dry shot glass. If you are using ten drops, activate them and then use the water from your bowl to stop the activation process.
4. Pour the contents of the shot glass back into the bowl.
5. Refill your syringes with the activated CD solution.
6. Lubricate the tip of your catheter with coconut oil, and attach the first syringe.

Note: If you wish to preserve the graduation marks on the syringes, cover them with some clear plastic shipping tape. The printed on marks are often easily rubbed off and the tape will prevent that.

Fleet Enema Method

The third option for enemas is to use a Fleet enema, which can be purchased at any drug store. This method is acceptable if you don't have access to the other items but want to start immediately, as, generally speaking they are easy to find. An enema bulb is a fancy fleet enema without being prefilled with saline solution. Skip step one if that's what you are using:

1. Dump out the contents of the enema (basically saline water). Since a Fleet enema only holds 137ml, two drops of CD are the maximum number you can add. To use more water, empty additional Fleet enemas.
2. Activate your two drops of CD and dilute them with filtered water (not tap water).
3. Funnel the activated CD solution back into the Fleet bottle. Insert the applicator and squeeze the bottle until all or most all of the contents are empty.

Comments & Suggestions from Parents

Most people are surprised at how well this goes. Some parents have asked if they can do the Protocol without the enemas, and I say yes, but why? The results are just that much better with them. Enemas have, in fact, been around for thousands of years, and colon hydrotherapy is becoming a growing trend in autism recovery.

> I was really intimidated at first by the enemas.
> The syringe/catheter system, however, is brilliant. I lube the tip up with coconut oil, attach a filled syringe, and ask my son to put it in. He's 7 and very low verbal. He started inserting the tip by himself maybe on our 3rd or 4th enema with this system and I would depress the syringe. A few months later of every other day(ish) enemas, and he's doing the syringe depressing part himself. All I do is fill and swap syringes out. We are now to 11 100ml syringes, with 3-5 releases per enema (4 months into enemas). He requests enemas frequently on days I don't plan to give him one by getting the box of supplies and handing it to me.

Here are one mom's enema guidelines:

> *Be low-key about it, your attitude sets the tone. Have all your enema gear ready to go and in the bathroom for when the moment strikes. Put a nice, fluffy, washable blanket on the floor; bring in iPad, iPhone, whatever occupies your child for a few minutes. I've been doing my son's enemas after an afternoon poop if I get one because I figure it is easier as he is already in the bathroom, the bowel should be emptier, leaving more room for CD. Also the one time I did an enema close to bedtime, I swear he was up for an extra hour, however, another child might have the opposite reaction. I kneel on the floor, lay a beach towel over my lap, lay my son across me so he's on the ipad, pull his knees up a bit and then in it goes. You can put coconut oil on the anus or on the tip of enema. I ask my son to count to try to hold it in. (On the 4th enema, we only got to 40 seconds.) Then plop them on the toilet, and there you go.*
>
> *If possible, start the enema while lying on the left side, then rolling to the right. In this way, more water is able to reach the colon. (However, this may not be possible for all children.)*

CD Baths

Taking a bath with CD is another good way of detoxing your child. The CD gets into the pores and helps with skin rashes common with autism detoxification. This additional process can be added when you start with the enemas after reaching full oral dose, but avoid giving the child a CD bath right after an enema.

CD baths are done on non-enema days, unless you are doing daily enemas, in which case they are done on opposite ends of the day.

Enemas Every Other Day

Sun	Mon	Tue	Wed	Thur	Fri	Sat
Enema	Bath	Enema	Bath	Enema	Bath	Enema

Enemas Every Day

(Enemas can also be in the morning and baths at night.)

Sun	Mon	Tue	Wed	Thur	Fri	Sat
Morning Bath	**Morning** Bath	**Morning** Bath	**Morning** Bath	**Morning** Bath	**Morning** Bath	**Morning** Bath
Evening Enema	**Evening** Enema	**Evening** Enema	**Evening** Enema	**Evening** Enema	**Evening** Enema	**Evening** Enema

The CD baths can go from as low as 10 drops to as high as 80 to 100 drops; it just depends on the person, and the size of your tub. With younger/smaller children we start with ten drops. Since we're doing baths every other day, start with ten drops on Monday, 11 drops on Wednesday, and 12 drops on Friday. Just keep going up until you get to 20 drops. The bigger and older the person is, the more drops they can tolerate.

Fill the tub to a level that maximizes skin contact.

If they start getting nauseous/listless or have loose stool, you should back down and find out what their signature dose is on the baths. Some people who have suffered from chronic constipation have done CD baths with up to 100 drops and had a BM during the bath or immediately after, without the use of drugs, laxatives, or suppositories.

CD Steam Bath

Inhalation of CD for children is generally impossible, because you just can't tell a child, especially a child with autism, "just inhale a little bit." That's not going to work. So we do the following:

In a bathtub, with the bathroom door and windows closed, plug the drain, put 20 activated drops on the floor of the tub, and turn on a hot (to tolerance) shower water. The steam will bring the CD into the air, making a really nice steamy bathroom.

When the tub is full, turn it off and place the child to soak in the water for 20 minutes. This way, the child is absorbing it through their skin as well as inhaling it through the air. This technique creates a very dispersed, low concentration dosage. I've seen a lot of children that were going back and forth to the hospital, getting steroid injections and lots of antibiotics due to bronchitis, coughs, asthma, etc., and it was rounds and rounds. This is how this particular method of steam baths came to be a very gentle way of inhaling the CD. It works beautifully; particularly if the child has a really bad cold and is congested, do the oral, enemas, and steam baths. Steam baths are great for asthma, flu, first signs of a cold, runny nose, coughing, etc., putting an end to running to the hospital or pharmacy.

CD Foot Baths

Sometimes it is impossible to give a CD bath, and in some places not all homes have bathtubs. To remedy this you can use a CD foot bath. Fill a small plastic container with hot (to tolerance) water and add your activated drops of CD.

If you have a smaller child, start with ten activated drops, and work up from there. If you have a larger child or an adult, start with 20 drops and go up. Soak feet for 20 minutes every other day, alternating with enemas, or opposite ends of the day if using daily enemas.

72/2 Protocol (Weekend Protocol)

When we give a child eight oral doses of CD throughout the day we are killing more and more pathogens. But at night when we sleep, the pathogens don't. So in order to get ahead of them, we can dose throughout the night. Imagine the progress we can make if we don't give them the chance to gain strength overnight!

Hence, the 72/2 Protocol, which involves giving one dose of CD every two hours for 72 hours straight—including the middle of the night. Here are some additional thoughts and guidelines:

- Start protocol when you pick up your child from school on Friday.
- Give them the last 72/2 dose when you drop them off at school on Monday.
- Avoid giving CD enemas or CD baths during this protocol, UNLESS they are dumping parasites, in which case you might need to reduce the amount of CD on both the oral and enema dose to insure the child doesn't have a Herxheimer reaction.
- Why not give hourly doses during the day at the usual dose? It's simply too much if you are doing it all night as well.
- Watch for improvements on Tuesday or Wednesday each week.
- Ideally, get your spouse or significant other to help with every other nightly dose.

The key is to observe your child and their reactions to the various treatments while keeping the pressure on eliminating the pathogens. You can do this every weekend or not at all. Some families are so happy with the results that they dose throughout the night for months on end.

Ocean Water

This protocol concentrates on excesses and not deficiencies. While we are using CD to reduce pathogen populations and heavy metal toxicity in the body, we need to remineralize the body. Remineralization is extremely important as vital nutrients may be lost along with toxins while detoxing. Children with autism are often mineral deficient to begin with due to these same pathogens and parasites, as well as gut dysbiosis which can prevent adequate nutrient absorption. We need to fortify our cells and tissues so that they can overcome the deficiencies and eventually return to a state of vitality.

Ocean water has helped us achieve mineralization and has led to increased brain connectivity; not to mention the parasites hate it. The importance of ocean water to this protocol cannot be understated. On page 388 of the Testimonials appendix you will see before and after lab tests proving that this protocol, when used correctly, can correct imbalances. More than one family has reported healthy nails, hair and skin as well as appropriate growth and weight gain.

We've all been taught that drinking salt water from the ocean is dangerous. Let me make it clear: We are not advocating drinking glasses full of straight ocean water nor water mixed with table salt. That would most likely make anyone sick, since it would be too much salt for the body. Rather, we are talking about diluted ocean water. Also, there is no comparison between real ocean water and just taking plain salt and mixing it into a glass of water!

The ocean is a complete source of minerals that are bioavailable to the human body. I prefer ocean water to any synthetic minerals, since the body easily recognizes and assimilates it.

Ocean water contains trace amounts of over 74 bioavailable elements including:

- sodium
- iron
- selenium
- sulfur
- calcium
- molybdenum
- cobalt
- boron
- silver
- fluorine
- potassium
- chromium
- zinc
- silicon
- chlorine
- vanadium
- nickel
- lithium
- iodine
- magnesium
- manganese
- copper
- phosphorus
- bromine
- gold
- etc.

We can use water directly from the ocean (diluted to 25%) and drink this to remineralize ourselves. However, the water must be from clean locations where schools of small fish swim and/or near ocean vortices. These locations provide safe and clean ocean water from which we can harvest. Most of us do not have access to oceans. Fortunately, clean ocean water is available commercially from multiple vendors online.

For further information about how and why ocean water is specifically beneficial to all of us, please research Rene Quinton's work on how he healed the sick using ocean water.

Using Ocean Water with CD

You can add ocean water in before starting CD, or after reaching full CD dose. We use a one part ocean water plus three parts drinking water mixed together (1:3). If we take too much ocean water, we can get loose stool. Start low and slow, 5ml ocean water mixed with 15ml drinking water and go up to tolerance.

Use the following chart as a rough guide:

Ocean Water Dosing

Size	When	Pure Ocean Water	Purified Water	Total Volume
Child	Start at	5ml	15ml	20ml
	Go to	30ml	90ml	120ml
Adolescent	Start at	10ml	30ml	40ml
	Go to	50ml	200ml	250ml
Teen / Adult	Start at	15ml	45ml	60ml
	Go to	75ml	225ml	300ml

Ocean water should be given three times a day, with the first dose being given in the morning, after the first dose of CD. You want to separate the dose of ocean water from doses of CD by at least five minutes. Larger children can take anywhere from between 70 and 120ml, depending on the child. Some adults take up to a cup (plus dilution water) per day. It is important to watch for loose stool/diarrhea when you are increasing the dose of ocean water, as that will be an indicator that the person is at their upper limit. The ratio of ocean water to drinking water is 1:3 (one part ocean water to three parts drinking water). It is important to stay under diarrhea. So we need to add slowly, and to tolerance. If someone suffers constipation, with the right amount of ocean water that will quickly change. So low and slow as we increase the ocean water.

Some parents have reported that their children will not drink ocean water, even when diluted, due to its salty taste. You can try adding a little flavored SweetLeaf® Stevia, or if necessary adding it into a beverage or soup. As some ocean water purists say, heating it kills some qualities of the ocean water. Nevertheless, your child will still be receiving all of the minerals.

Biofilm

One of the pioneers in autism recovery, Dr. Anju Usman gave the autism community one of the critical pieces of the puzzle—biofilm. The following information is used with permission from her presentation, *Gut Biology and Treatment.*

What is Biofilm?

A biofilm is a collection of microbial communities enclosed by a matrix of extracellular polymeric substance (EPS) and separated by a network of open-water channels. Their architecture is an optimal environment for cell-cell interactions, including the intercellular exchange of genetic material, communication signals, and metabolites, which enables diffusion of necessary nutrients to the biofilm community.

The matrix is composed of a negatively charged polysaccharide substance, held together with positively charged metal ions (calcium, magnesium, and iron). The matrix, in which microbes in a biofilm are embedded, protects them from UV exposure, metal toxicity, acid exposure, dehydration, salinity, phagocytosis, antibiotics, antimicrobial agents, and the immune system.

Ok, so in layman's terms, these are microbial (bacteria, Candida, virus, etc.) communities that have a protective layer around them, which makes them 100 to 1000x harder to kill than if they did not live in these protected communities.[13]

Why are they so hard to get rid of?

- Microbes impart genetic material to one another to maintain resistance.
- Colonies communicate with one another through the use of quorum sensing molecules.
- Colonies fail to express OMP (outer membrane proteins).[14]

These colonies are fairly amazing in their development. They communicate with each other, share genetic material to prolong their own survival, and don't express outer membrane protections. This last statement is very important to understand. This is the main reason that the immune system doesn't attack these colonies, they don't express themselves as a threat, and therefore the immune system, which in many children with autism is already compromised, is not able to detect or eliminate them.

In addition to this we must be careful with what supplements we choose to give to our children. Some supplements and nutrients may inadvertently feed the biofilm. "When trying to kill bugs, if you take calcium, you may not be making headway," Usman said. "Calcium, iron, and magnesium block our efforts to dismantle the biofilm."

Why CD Works on Biofilm

The microorganism communities attach to surfaces (in many cases the gut), and are held together by polysaccharides (sugars/carbohydrates) and by iron, calcium, and magnesium. EDTA is a known chelator, and can therefore break the bonds (iron, calcium and magnesium) that hold the matrix together. Neither an antibiotic alone nor a chelator alone was effective against a staph (bacterial) biofilm. However, when combined, EDTA broke the bonds exposing the bacteria to the antibacterial agent, allowing the body to expel the biomass.

Chlorine dioxide oxidizes inorganic compounds by effectively removing their charges. Here is how it works: Fe_2+, Ca_2+, and Mg_2+ are positively charged ions that hold the negatively charged matrix together. When these substances are oxidized by CD, the bacteria are then exposed to the CD which can oxidize (kill) the bacteria, allowing the body to finally expel the biofilm mass.

Many parents using chlorine dioxide orally, and with enemas, have found biofilms in their children's stool. Biofilm can look thick, mucousy, cloudy, whitish, greyish, sometimes like pantyhose, etc.

There is some more interesting information available through the AutismPedia about Dr. Usman's work with biofilm.[14]

> We had our appointment yesterday and to all our surprise when he tested her for Lyme it was negative. Just 3 months ago and before starting MMS she was testing very positive for it. He was pleased with the outcome. Thank you so much for your guidance and we owe this to the miracle of MMS and your dedication to helping me with my questions. I really, really appreciate your help in bringing us one step closer to the cure.

Also, this article "Lyme-Induced Autism Conference Focuses on Biofilm and Toxicity"[15] by Mary Budinger discusses the effects of pathogens present in the biofilm for Lyme disease and autism. The following is a notable quote from the aforementioned article by Dr. Stephen Fry of Fry Labs, which explores the possible pathogenic causes of chronic disease.

> *I could be barking up the wrong tree, but maybe not. Remember that we used to think stomach ulcers were caused by too much acid production. Then Barry Marshall and Dr. Robin Warren turned medical dogma on its head by proving that a bacterium was the cause. The pair identified*

> *the bacterium H. pylori and proved how it causes inflammation, then ulcers. Maybe in 10 years we will be smart enough to know that the 'auto' in 'autoimmune' actually means pathogen and the whole concept of autoimmunity will change. Chronic inflammation is chronic infection. In autoimmune disease, my model is that there is a chronic infection that cannot be eliminated, thus the immune system is always switched on. The self antibodies are due to apoptosis and death of host cells with host immune response.*

I couldn't agree more, and am so grateful that we have CD to combat pathogens, and restore the body to a state of health.

Mitochondrial Dysfunction

Children on the spectrum are also more likely to have mitochondrial dysfunction than neurotypical children of the same age group. The following is an excerpt from *Science Daily*.[16]

> Children with autism are far more likely to have deficits in their ability to produce cellular energy than are typically developing children, a new study by researchers at UC Davis has found. The study, published in the Journal of the American Medical Association (JAMA), found that cumulative damage and oxidative stress in mitochondria, the cell's energy producer, could influence both the onset and severity of autism, suggesting a strong link between autism and mitochondrial defects.
>
> "Children with mitochondrial diseases may present exercise intolerance, seizures and cognitive decline, among other conditions. Some will manifest disease symptoms and some will appear as sporadic cases," said Cecilia Giulivi, the study's lead author and professor in the Department of Molecular Biosciences in the School of Veterinary Medicine at UC Davis. "Many of these characteristics are shared by children with autism."
>
> Dysfunction in mitochondria already is associated with a number of other neurological conditions, including Parkinson's disease, Alzheimer's disease, schizophrenia and bipolar disorder.
>
> Mitochondria often respond to oxidative stress by making extra copies of their own DNA. The strategy helps ensure that some normal genes are present even if others have been damaged by oxidation. The researchers found higher mtDNA copy numbers in the lymphocytes of half of the children with autism. These children carried equally high numbers of mtDNA sets in their granulocytes, another type of immune

> cell, demonstrating that these effects were not limited to a specific cell type. Two of the five children also had deletions in their mtDNA genes, whereas none of the control children showed deletions.[10]

In our MMSAutism webinar, Dr. Andreas Kalcker mentions that CD changes the mitochondrial membrane electrical potential.[17] This leads to increased power in every cell in the body, including immune system cells. The mitochondria are the electric generator or "powerhouse" of each cell. When we turn off this electrical generator, cancer can develop. If the cell cannot produce electrical energy through oxidation it will use fermentation.

In practice, what I have seen is that children who suffered from lack of energy, listlessness, and other symptoms that can be related to mitochondrial dysfunction have perked up with the use of CD. They are able to do exercise again, walk without having to be carried, and can cognitively sustain activities without tiring. You will see a few testimonials mentioning "mito issues" at the end of the book. It is wonderful to think that this is another means by which CD can help people on the spectrum heal.

ATEC Statistics

Through some of our Facebook groups we have been collecting ATEC data for the past year. Just to give you an idea of what others are experiencing in terms of test results, here are some statistics:

- 246 parents have given us 2 ATEC scores. Of those, the average drop between ATEC1 and ATEC2 is 15 points. We take ATEC data quarterly, so in general that drop is in three months or less. The more impacted a child is the bigger their initial drop – kids starting with an ATEC over 100 averaged a 26 point drop between ATEC1 and ATEC2.
- Of those 246 ATEC reports, we had 32 children (13%) gain in points in the first quarter. The average gain among those 32 was 7 points. All 32 reported ATEC scores three months later, and 29 of them dropped points between their ATEC2 and ATEC3 scores. Further, 13 of those 29 dropped enough points to put them at or below their ATEC1 starting number. Which means at the 6 month mark, only 19 out of 246 (or 7%) had gained points. 93% of children who do this protocol have improved their ATEC score at the six month mark.
- We have now had 163 parents provide four consecutive ATEC scores (encompassing one year on the protocol). Of those 163, the average ATEC drop between ATEC1 and ATEC4 was 24 points.

- Of those 163, a total of 9 or 6% reported an increase in ATEC score between ATEC1 and ATEC4. The average increases was 6 points. 94% of children who do this protocol have improved their ATEC score at the one year mark.

- In a Facebook group collecting ATEC data, we have 25 recoveries as defined by the ATEC dropping to 10 or under in a year. So we have a rate of 15% recovery as defined as ATEC score under 10 in the parents who have taken this protocol through one year.

Thus showing that the longer they are on the protocol the more points they lose.

Although we all would like to see "high level" statistical research done, this is no doubt a major step in the right direction, and demonstrates that the protocol does work. But, research takes money.

DOs & DON'Ts of CD for Autism Recovery

DO review all current supplementation that your child is taking and remove all supplements which contain any antioxidants including vitamin C, vitamin E, vitamin A, vitamin K, ALA, Coenzyme Q_{10}, and colloidal silver as these will neutralize the CD, rendering it ineffective.

DO consider removing supplements that include iron and vitamin B_{12}. These are principal foods for the parasites, which explains why many children are low in them. If you are seeing a chronic iron or vitamin B_{12} deficiency, revisit the parasite chapter. These levels should normalize when parasites are no longer consuming nutrients.

DO use the Baby Bottle Method in an eight-ounce glass bottle with a completely sealing lid and start at one drop, regardless of weight. Increase by one drop/day, until you reach the optimal dosage.

DO dose frequently throughout the day. The less time we leave the pathogens to proliferate the better. Do a minimum of eight doses a day, but try to get in more doses if possible. Go for 16 in cases of PANS/PANDAS and acute situations like colds and flu.

DO activate CD for the proper amount of time for the acid you use. HCl and citric acid both activate sodium chlorite in 60 seconds.

DO supplement minerals using ocean water.

DO completely avoid the following: citrus fruits, corn syrup, fruit juices, green tea, pineapple, vitamins C, E, A, and K. Only give coconut milk and coconut water a minimum of one hour after the last CD dose at night so they will have no chance of affecting the CD. Coconut milk and coconut water are very alkaline.

DON'T give fruit juice of any form—not fresh, organic, homemade or store bought.

DON'T give highly antioxidant foods including chocolate (cacao/cocoa), coffee, green tea, kombucha, citrus fruits, pineapple, mango, or kiwi. Berries (if you have to give them at all) can only be given at night, one hour after the last CD dose.

DON'T mix anything but water with your CD drops.

DON'T give CD with food.

DON'T use a vitamin C shower water filter—yes, there is such a thing to neutralize chlorine in tap water. Unfortunately, it also neutralizes chlorine dioxide.

CD Troubleshooting Checklist

Before you decide that CD isn't working for your child please take a look at following list of common errors. If it looks like you are doing everything right, but you aren't seeing gains, please, before giving up, use one of the support options shown in Appendix 17, page 521. You are NOT alone! We have a network of parents who are ready and willing to help you.

- ☐ Are you preparing your CD in a clean, dry shot glass, or other type glass container that insures both chemicals are mixing?
- ☐ Is the CD mixture turning yellowish brown? There should be a chlorine-like smell. If there isn't, something is not right. Perhaps you have bad or incorrect chemistry? Maybe the supplier did something wrong in preparing the solutions.
- ☐ Are you using the correct ratio of sodium chlorite to acidic activator drops? See chart on page 94 for the correct mixture ratio depending on the type and concentration you are using.

☐ Are you allowing the correct activation time before dilution with water after mixing the sodium chlorite and acidic activator? See chart on page 94 for the minimum activation time you must wait for the chemical reaction to occur.

☐ If you question the potency of your CD, then you may wish to test its strength. See Appendix 6, page 467 for testing information.

☐ Is your CD or activator cloudy or not changing color after they are mixed? If so, there is something wrong with one or both chemicals. Check with your supplier.

☐ Did you leave your baby bottle solution in direct sunlight? A brief exposure to light is no big deal, but if you left it in a hot car for an hour, it may have lost potency.

☐ Are you keeping the same baby bottle solution for too many hours? It should be used on the day it was prepared.

☐ Are you giving antioxidant supplements or a multivitamin containing antioxidants? Vitamin C, vitamin E, etc., should not be given. Cod liver oil and fish oil supplements in general have lots of antioxidants to keep them from spoiling. Make sure those are out as well. Mixing any of these will cancel out the effect of the CD—and the vitamin. You CAN give them a few hours apart.

☐ Have you checked all your labels of supplements and foods to make sure they don't contain antioxidants?

☐ Have you removed all juices and all citrus fruits from the diet (including oranges, pineapple, mango, kiwi)? Berries (if you have to give them at all) can only be given at night, no less than one hour after the last CD dose.

☐ Are you dosing CD 30 minutes apart from food, as a minimum (one hour is optimal, but not always possible)? Grazers do 15 minutes and we dose CD 16 times a day.

☐ Are you mixing anything with your CD, such as baking soda, juice, etc.? The only thing you can add into your dose of CD is more water!

☐ Are you using alkaline water to prepare your CD? Alkaline water kills CD. Some expensive water filtration systems are designed to produce alkaline water, which we must totally avoid!

- ☐ Are you breaking The Diet? Could there be dietary infractions at school or with relatives while you're not there?
- ☐ Are you dosing so high that you are detoxing your child too fast and getting a Herxheimer reaction? Some people need to increase every three days—NOT every day.
- ☐ Are your doses too low to accomplish anything?
- ☐ Are you giving too few doses of CD? We need a minimum of eight doses per day or more.
- ☐ Have you started the Kalcker Parasite Protocol? If you have done three Parasite Protocols (PP) it is time to start looking into supplements, chelation, HBOT, GcMAF, etc.

Frequently Asked Questions (FAQs)

Can I use less than one ounce (30ml) of water to administer a dose of CD?

One ounce of water, or more, is best. You can always add more water, but at least an ounce is the minimum per drop.

We have been on the Protocol and are at five activated drops of CD in the baby bottle. My son's "usual" autistic symptoms got exacerbated to the maximum. He has horrible constipation, stimming, scripting, and he seems to be in a bad shape. Our target dose is 15 drops. What should I do?

The general protocol is to wait with CD enemas and CD baths until one is at their full target oral dose. His negative symptoms are probably from reabsorption of toxins from his unpassed stool. You need to resolve his constipation to stop this vicious cycle. You can administer CD enemas and CD baths on consecutive days. This should help the constipation, and flush the toxins out of his system. Then, once he is stable you can resume slowly titrating up to full dose.

What should I do if my child can handle "double doses" (two ounces of the baby bottle) all day with no herxing?

If your child is taking "double doses" all day, then it is NOT a double dose—it's his actual dose! Depending on his gains and what else you are folding into your protocol you can consider going up from there.

Is 72/2 only if you have done the parasite protocol? We are full oral dose but won't do PP until next full moon.

You can do 72/2 protocol before the Parasite Protocol, but you must have reached full dose of CD.

We are really struggling to get in enough doses of CD with school. We do well to get in 8; we really need more (way, way more). Night dosing is not an option (he won't go back to sleep; our mornings start early enough around here as it is), nor is coming to school during the day to dose him (we both work). Advice?

Some parents are dosing every 45 minutes to get in their doses when they are with their children. However, we need to be killing pathogens around the clock. It is not possible to be effective at killing pathogens when we are giving them 16 hours without a dose of CD. You need to get 1 to 2 doses in before school starts. Then get the other 6 (ideally more) in after school is over and in the evening.

My child hates the flavor of CD. Can I give Stevia with CD to improve the taste?

We recently discovered that some brands of Stevia are compatible with CD, CDS and CDH (i.e., SweetLeaf® & KAL® brand)—it doesn't reduce the potency. However, past tests were not so positive. Some added ingredients may be why this was so in our initial tests. Try to use only pure Stevia or check with the Facebook groups on what others are using successfully.

SweetLeaf
Sweet Drops
Sweetener
STEVIACLEAR
KAL
PURE
Stevia
ORGANIC
extract

Preliminary tests show that some brands of Stevia can be used with CD to improve taste without losing potency. The two brands we have tested in-house are SweetLeaf® and KAL®. Some of our moms report having successfully used flavored versions of SweetLeaf®.

When you say do two back-to-back baby bottles of 11 drops... you mean do a total of 22 drops in 16 hours? Correct? I'm going slowly up on oral CD because of behaviors. If I go from 11 to 22 drops overnight, won't he have strong detox and behaviors?

This is spread out over 16 hours or more, such that every 60 minutes it is the same amount. It is different than putting 22 drops in 8 fl. oz. Behaviors associated with bacteria (PANDAS/PANS) are often reduced with the tolerated dose spread over longer periods of time. Remember that CD is only active in the body for about one hour.

My child seems very uncomfortable. What should I do?

If you see a detox like this, stop dosing for the day. The next day, return to the last dose when the child was stable. Pathogens are dying and toxins are being released into the bloodstream on their way out of the body. This causes discomfort in some people.

How do you know if I should go past full oral dose of CD?

A Herxheimer reaction will be your biggest indicator if you have gone too far. If you have reached full oral dose and it seems like your child has plateaued, please schedule a consult with Kerri to discuss your options. Note: The full oral dose chart (page 101) is only a general guide and not a one size fits all.

Is an hour enough time to separate CD neutralizers from the CD dose?

CD is only active in the body for about one hour, however, supplements like vitamins A, C, E, K and ALA, CoQ10, and GSH (glutathione) need to be avoided. Also, orange juice, pineapple juice, and other high antioxidant fruits are a problem even after one hour. So, the best thing to do is eliminate everything that kills the CD. If not, it is pretty much like not using CD. I have seen it too many times and it's not worth it. Antioxidants destroy CD. There is no period of time that is safe to use antioxidants with CD.

I know you have to start the parasite protocol on a certain day of the month, but how about the first dose of CD?

You can start giving CD any day of the month. That said, it might be easier to start on a weekend, or a day when you will be with your child all day to make sure to get in all of their doses, and keep an eye on them to make sure they tolerate it well, i.e. no Herxheimer reaction.

What is 72/2?

72/2 is when you give a dose every two hours around the clock for 72 hours. We use a baby bottle and a half to get through the night hours. This can be added in once you are comfortable at your full oral dose and have added in enemas and baths. See page 115 for more information.

Do you recommend 72/2 for everyone?

Once a child is at 100% of their target oral CD, enema, and baths then they can do a 72/2 weekend. They are exhausting for the parents, but some kids do wonderfully. A lot of families get a nice boost. But, if you do a couple of weekends and you don't see anything afterwards, then forget it. The benefits are usually seen two to three days after the 72/2 is over.

My son suffers from constipation. Can I start the enemas before I get to his full oral dose?

Anyone who suffers constipation needs enemas right away. These can be combined with oral doses. Still start low and slow, but it is important to get the bowels moving with any detox protocol. When constipation is present, we do not wait to start enemas.

What is the maximum amount of water to use with enemas? How many times do you hold and release?

First of all, we don't encourage holding. Rather we do a fill and release, which is kind of a home colonic. If your child can hold for a few seconds without fuss, then great. The number of cycles depends on the results of each. If all you are getting out is water, you may be finished, unless the person is seriously constipated. The amount of water really depends on the individual's size and the number of cycles administered. My basic philosophy is: *Any enema is a good enema.* So, even if not much comes out, you are still getting some water and CD in.

Is it possible that my son has been getting rid of mucous after his CD enemas? What is up with the mucous? Why is it there in the first place? And, is it a good or a bad thing that it is coming out?

Mucous is always a sign of inflammation and can contain pathogens and parasites. Mucous gives a home to pathogens. The inflammation and mucous can be caused from the allergies and pathogens. It is common to see mucous come out in the beginning of the enemas since our children have so much intestinal dysbiosis.

What is a good enema method for a 17 year old boy? I am having trouble understanding the enema part of the book. The video in the file really helps, but I am having a hard time imagining doing it on my son. How do other people with older children do it? Can it be self-administered eventually? Kerri mentioned a gravity bag, so you don't have to keep changing syringes. Has anyone tried that? Where do you get the bag?

Here is some advice one mom gave to another mom on one of our boards:

My son is 14 and tends toward constipation. I had done suppositories in the past to help him have a bowel movement. So, I told him that the enema was "fanny medicine" to help him have a BM and make him better. I started with just showing it to him after a BM after I wiped him. Then, I just put it next to his anus the next day. Then closer every day. He was still constipated so just inserting the tip would help him poop and then later I was able to push the liquid with him standing next to the sink and it would run all down his leg. After several weeks of this, it was a full moon and he could not poop at all and was lying on his bed in pain. I said let's try it here because it will really help you. I got out a hundred towels and did it right there and he pooped. It was a slow process over two months but now we do them AM and PM always right after the shower. I counted over 20 feet (of parasites) coming out this last PP. And that is just what I could see. I don't dig, just pull out obvious ones that are a foot long. Main advice is keep calm with soothing voice and have tons of patience and keep telling your son how much you appreciate his patience too. I also tell him this will get rid of his autism. He is non-verbal but said with RPM that he is mad he has autism. Also, the soft tip is key. I use syringes because they go fast.

My son is not having daily bowel movements. What should I do?

Do CD enemas every day until the stools normalize to daily. If you absolutely cannot do enemas, use CD baths in high doses (50+ drops depending on the size of the tub). Ocean water in high doses will move the bowels as well. Castor oil also helps.

I am scared of the CD enemas. Will CD harm the intestinal lining?

CD stays active only for about one hour and can gently, but effectively remove biofilm and kill pathogens in the intestine. Our society has shied away from this healing method in the last few decades. However, CD enemas have been proven to be positive turning points in the treatment, time and time again. Lots of kids will actually ask for enemas, as they provide them relief and comfort. If you are nervous, apply an enema to yourself first. You will see it is no big deal, and feel more at ease applying one to your child. Some parents have shown their higher functioning children how to apply their own enemas, so no one has to be there, and to make them feel more comfortable.

What is the difference between colonics and enemas?

Colonics cleanse the entire length of the colon while enemas cleanse the lower part of the colon. Colonics involves multiple infusions of water into the colon, while enemas involve a single infusion of water into the colon (which can be repeated). With colonics, fecal material leaves the body via a tube. Colonics normally involves going to an office and receiving assistance by a trained colonics hydrotherapist, while enemas are free and done in the privacy of your own home.

I have never done an enema before. How do you administer it?

There are several positions that work well, but there will be one that works best for the individual. The enema instructions are on page 109. Some examples would be on all fours or lying on your left side on a towel, or a small child could lay across your lap.

Enema clean up question: What are we boiling? What are we spraying with *Everclear*? What are we throwing away?

After you are finished looking for worms you can throw away any plastic plates/forks you may have used. Pour boiling water on your specimen collector, enema nozzle and catheter. Then spray with *Everclear* grain alcohol. If you are using syringes, you may pour boiling water over them as well.

How far do I need to insert the catheter for an enema?

Not very far at all; one to two inches is plenty. The anal sphincter is about one inch past the anus. As soon as the catheter passes this muscle, it will hold it in place and there is no need to go further.

What is intestinal biofilm supposed to look like?

Biofilm is fluffy, cloudy, and mucousy in appearance. There are no rules on the color. It can look like pantyhose. But, it is usually mucousy and a cloudy whitish/grey color.

How far away should we be doing enema from food? If we miss the morning enema, can I give it right after lunch?

They can go together; there is no need to separate enemas from food. Any enema is a good enema.

I'm having trouble with my syringes (for enemas). One plunges really smoothly, but the other two are almost impossible to move. Do I need to grease them up somehow before each use? How do you clean them?

I use *Everclear* grain alcohol to clean them, but note, it will dry out rubber parts. You can use coconut oil to lube the plunger gasket.

Is it normal to see black specks coming out after using enemas? We saw white specks for a couple of days too.

Black specks can be heavy metals. Oxalates are known to bond to metals and would come out with metals. White dots are generally parasite eggs.

Does ocean water need to be refrigerated after opening?

No it does not, it is fine at room temperature.

If I harvest my own ocean water do I have to sterilize it?

No. Sterilizing is not necessary or desirable in our experienc—we don't want to denature it. Pouring it through a coffee filter to remove any potential particulate matter is fine. Do NOT use charcoal filters (such as a Brita® water filter), because they will alter the characteristics of the natural ocean water. Just make sure to collect the water far from any harbours or large river outlets.

I bought pure sea water in Australia. It sounds like a great mineral drink. Would this be beneficial for killing parasites or just putting goodness back into the body?

Actually, it does both.

How do I avoid feeding the pathogens?

CD kills pathogens. I would use CD to rid the body of pathogens rather than try not to feed them.

Is it possible to use CD, CDS, or CDH during pregnancy? If it is ok, how much can be used?

CD/CDS/CDH are not advisable during pregnancy or nursing.

Can I add CD to breast milk to the bottle to help the baby detox?

CD must be given in water. Mixing breast milk and CD will reduce or potentially cancel out the potency of the CD.

How many drops go in a CD bath?

It depends on the weight of the child (20-100 drops). If he is a little guy I might start at 10 or 15 activated drops and work up over the course of the following couple of weeks. The size of your tub also plays a part. The bigger the tub, the more CD you are going to need. See page 113 for more information.

I've heard that some people mix CD directly in capsules and then swallow them. Can we use that on our children?

NO! Not a good idea! Since many children with autism can't speak, they won't be able to tell you when the capsule gets stuck. CD needs to be diluted in water before taking as instructed in this chapter.

Can I use warm water instead of cold water to store CD and how long will it remain potent mixed in the baby bottle?

CD is a gas dissolved in water and therefore has to be preserved in a sealed container. If not, it will lose its potency, similar to how soda goes flat if the cap to the bottle isn't screwed on tight. Colder is better because the CD will gas out quicker at higher temperatures. If you have doubts about CD potency, get the Lamotte ClO_2 test strips to be sure. See Appendix 6, page 467 for more information.

Are purified, distilled and filtered water all the same thing?

They are different. However, we can use purified, distilled or filtered water. But, alkaline water should never be used!

Must the activated CD water mix be stored in a glass bottle, or is a no-BPA plastic bottle with an airtight cap ok?

I prefer glass to any plastic. Over time, chlorine dioxide can degrade plastic, and that means you or your child will be consuming it. Yes, the bottle needs to remain sealed. Plastic is acceptable for lids only! Metal lids should never be used because they quickly rust, even if covered with a plastic coating.

Is it a problem to transfer one ounce of CD to a steel bottle briefly before drinking it?

That is fine for a transfer, but I wouldn´t store CD in a steel bottle.

Is the GF/CF/SF "clean" diet essential to the CD protocol? My son doesn't have bad reactions and I just do not see how we could implement it.

A healthy, clean diet is very important to the healing process. Unfortunately, our "standard diet" is filled with preservatives, colorings, and other potentially harmful chemicals. When the goal is to heal, the diet is necessary. Dairy especially can cause inflammation and mucous production. Mucous provides protection to parasites.

What is a good CD-friendly multivitamin?

All multivitamins have antioxidants. What we need to supplement during detoxification are the minerals. Ocean water has 90 bio-available minerals, and it is what I prefer for this protocol.

Are there other specific foods, veggies or fruits that need to be avoided in addition to juices?

When you are following the CD Protocol, all antioxidants need to be avoided. Chocolate is a strong antioxidant. As far as vitamins are concerned; A, E, K, and ALA are off limits. High antioxidant supplements such as curcumin have also been a problem for many people. In the case of vitamin D, it is not an antioxidant, but it has caused aggression in previously calm children. Therefore, as a supplement, it must be used with care, if at all.

Vegetables and legumes which are high in antioxidants have not shown to be very detrimental to the effects of CD. However, citrus fruits, pineapple, mangoes must be avoided. Berries are best given at night, one hour after the last dose of CD, if you must give berries. Juice, any sort of fruit juice, is completely prohibited. Not only can the antioxidants involved kill CD, but the high sugar content (albeit natural) shuts down the immune system, which is already impaired in children with autism.

Can our kids drink anything other than water for the duration of the CD protocol or just not drink juices down with the CD?

Some people are not used to drinking water and find it difficult. Some people drink nut milks or rice milk. On occasion, some folks put a piece of fruit in the blender with an apple and blend it, strain it, water it down and have that sometimes. Juicing is taking 5 apples to make a glass of juice and that is a lot of sugar (albeit natural) as well as a lot of antioxidants. Antioxidants kill CD and sugar slows the immune system. You want to totally avoid alkaline water.

Can I use rice milk to give the CD instead of water?

Water is what we need to use to give the CD. If you are giving CD mixed with another beverage you are reducing its potential. By combining CD with liquids other than water we will not get the desired results. Rice milk might be okay, but you would need to test how it affects the potency of the CD. You can get the *LaMotte High Range Chlorine Dioxide Test Strips* (#3002) at www.amazon.com. This way you can see for yourself how mixing CD with any beverage affects its potential. However, I do not recommend putting CD in anything but distilled/purified water.

Can I give my child fresh pressed green juices (celery, kale, cucumber, apple)?

Anything that is very nutritious to the human body is nutritious for the pathogens/parasites. So, a healthy green drink is very healthy for the pathogens. If you are giving "green" juices make sure they are not loaded with sugar from apples, carrots, etc. In my opinion, it is preferable to avoid these for the first few months of the Parasite Protocol (PP), at least.

Can I use coconut and almond milk with CD?

You can drink coconut and almond milk 60 minutes after your last dose of CD, but I would not combine anything other than purified water with the dose of CD.

Can my child drink coconut water if he is taking CD?

If you want to give your child coconut water, give it one hour after your child's last dose of CD, at night, before bed.

Does lemon interfere with CD, even after it is cooked?

Yes, in some cases. A family of a child who suffered from SIB noticed a direct correlation with lemon use in their meals with the return of his SIB. I would avoid it at all costs.

My son barely drinks anything, especially all at once. This is why we have been unsuccessful with detox programs. Is CD different?

You should make sure that your child is well hydrated, but for the CD alone one ounce (30ml) of water is sufficient. I find that it is easier to drink CD cold rather than at room temperature. Also, if the smell is a problem, put the dose in a plastic syringe and squirt it right into your child's mouth. This prevents them from having to smell it before they swallow it. Enemas are a great tool for hydration.

My child's appetite has changed since starting CD. Is this normal?

Yes. On average larger kids tend to slim down, while thinner kids tend to gain some weight.

Can I give green tea or kombucha while taking CD?

That is out of the question in my humble opinion. Green tea is high in antioxidants and caffeine. Kombucha is similar. I don`t know exactly how long the antioxidants in either one are active in the body, so with autism, if we are looking for healing, avoid them both.

Can I use original Nutriiveda™ with CD?

Nutriiveda™ is derived from whey, a dairy product. In humans, all dairy causes inflammation and mucous, which provides a protective refuge for pathogens. That makes this product contraindicated for this protocol, plus it contains antioxidants.

Can I use Chia seeds with CD?

Yes. But do not mix them directly into the CD.

How do I dose my child when he/she is at school from 8:30 am to 3 pm? I work full time so "dropping in to dose" is not an option.

Give a dose upon waking, one at the door of the school at 8:30 and the third dose of the day at 3pm at the door of the school. The last dose of the day is at bedtime, there should be at least four hours between school pickup and bedtime to get in the other four doses. Once you get the hang of it, it is not that hard, it just takes a little getting used to and some prior planning.

What should I do if my son goes away for 5 days with school? Do you think it is possible to prepare a bottle of CDS for 5 days and he takes only one portion each evening?

It's not ideal, but better than nothing.

My son is refusing the CD. What do I do?

Have you tried adding more water with the dose, using cold water, using a syringe or a straw? Here is some advice from a Mom whose daughter refused oral CD:

We just went through a REALLY rough patch with my daughter when she absolutely refused to take oral CD, and I know it gets super stressful for both you and your child if you try to force it… I had to respect her as clearly she was telling me in her own way, "Mom, this does not make me feel good!" for whatever reason and after maybe a week we were back on track. During that time I was able to give her a few doses (dropped from 14 drops of CD to 5) here and there, during really good moments. For example, in the bath or swing that she loves and I think that helped her associate CD with feeling better again. You WILL be back on track in no time!!!!! Good luck! Keep calm and dose on!

I am on 30 activated drops/day with my teenage boy. The taste is simply horrible. He refuses to drink his doses. What should I do?

You can dilute your baby bottle as far as a liter bottle if necessary; it will not impact its effectiveness. Obviously, one dose will be more like a half a cup or a full cup in this case. However, be mindful of your conversion rate so that you get your dosage right. Cold water helps with the taste. You can add approved Stevia brands to cover the taste of CD. See page 126.

If the country I live in doesn't have glass baby bottles, can I use a plastic bottle?

No, do not use plastic for storing CD. If the cap is plastic, we can live with that. In almost any country you can find a glass water bottle (with a plastic cap). You can use a shot glass to measure out eight ounces, and even mark them on the outside of the bottle with permanent marker. Many parents in Venezuela do this, as neither glass baby bottles nor LifeFactory® bottles are available in their country. NEVER use a Stainless steel (or other metal) bottle or container!

Do you think this Protocol could work for a child who already has a low ATEC score (18)?

Yes. I started with a 12-year-old, who last February 2012 had an ATEC of 18. He did not budge from there after years of biomedical interventions. He could not stop with fears, phobias, anxiety (all parasitic in nature) and we started him on CD in February 2012 and the Parasite Protocol in June 2012. His ATEC is now a one!

My son's ATEC is not going down as I had hoped it would by now. It has hovered around 65 the past few ATEC's. I think it is probably due to the fact that if I am not home my husband often forgets to give him his doses or his PP meds. Does anyone have any suggestions on how to stress the importance of this protocol to him?

The following responses are from moms on our public Facebook group:

You will never know what following the protocol will do for your son until you follow the protocol. When I first started the protocol a little over a year ago, I remember I had been using a special juice that so many people were raving about and I was paying $140 monthly for this miracle juice and I really wanted to keep in in my son's protocol. I asked my husband to give it to my son at 4 am when he got up, and that was 4 hours before he would get any CD doses... how could that effect our results? The juice was given 4 hours before starting CD for the day, we were following the protocol exactly otherwise, and even doing the enemas. Well, nothing happened, nothing, until about 3 weeks later when I said, well let's stop the juice and see... BAM! Immediately my son's ATEC results dropped and he blossomed. I mean not only did his constant pacing stop, but his eyes lit up, he not only started talking more, more, more but even his laugh changed to a typical sounding teenager's laugh. It was incredible. His ATEC dropped instantly and kept dropping, 68, 25, 13, 7, 5, 3. It's a 6 today but this a super bad new moon for him. You will never know until you follow the protocol.

We have also seen our son stop pacing, stop suffering minute to minute, in the beginning we made our mistakes, missed a dose, didn't get this or that done, we now stick to it, the cumulative effect of staying on protocol means the difference in drops in ATEC scores and staying the same or going up, it did for us anyway. I could feel the slipping, we are still working on getting this right, it is an evolving protocol that requires the entire family's buy in. I have kept my son home from school to make sure he is dosed properly but that's just us. In November he is supposed to begin going to school full days, if they do not dose him correctly, I will hire a homeschool teacher, that's how important this is. You will not get your child well, Kerri told us 16 doses a day, he got better, she told us to start *enema's early, that made a big difference, we started our first PP before he was at full dose, it's all made a huge difference, email her, keep watching your child to see what's working, this protocol works, it may take time, but what is the alternative????*

My husband is not good about giving meds either. When I'm gone my older girls give it. I text them reminders. Sometimes setting a timer can help. I also set all of the meds that go along in a morning and night dose daily case. Often when I organize it all for them it's much easier for the meds to be given properly and in time.

My child has horrible nasal congestion. Can CD help?

Yes, you can use CD and make nose, eye, and eardrops. Put one activated drop of CD into one ounce of water. Use one drop of the mixture in the nose (eyes or ears) every 15 minutes till symptoms disappear. NOTE: DO NOT USE PURE ACTIVATED CD WITHOUT DILUTING IT!

You can also do a steam bath, which is done by closing off the bathroom (windows and door shut), and putting 20 activated drops on the floor of the tub. Run hot shower water on top of the drops until the tub fills; the air will be full of CD smell. Now, turn off the shower, put the child in the water to soak for 20 minutes, where he will breathe the light CD air.

Is there a seasonal-allergy protocol for using CD? I suffer from extreme itching in my eyes, redness, puffiness, sneezing, sinus congestion etc. Will CD provide relief quickly or does it need to be used over a long period of time?

Being on full CD, ocean water and the parasite protocol the allergies should begin to fade away.

Can I try the CD ear protocol if my child has not started oral doses?

Yes!! Please start the eardrops, if there is an infection, every hour until the symptoms disappear. If you catch an infection at the onset of its symptoms, give one drop of the mix every 15 minutes. We have seen earaches clear up in a couple hours. In any case, work towards a full oral dose, at least one drop eight times a day to combat the infection on all fronts. The eye, ear, and nose protocols are all the same: one activated drop of CD in one ounce of water in a sealed dropper bottle. Apply one drop of this mix every hour until symptoms diminish.

Can CD help arthritis?

Absolutely! CD is amazing for arthritis. Include CD baths in your routine. Use CD in conjunction with DMSO.

Our son has a runny nose and sneezes a lot, but has no fever. He hasn't been sick in well over a year! I'm wondering if it is from doing CD.

This sounds like a very typical die-off reaction. Monitor his progress, make sure he is hydrated, and continue with the Protocol. If his reactions remain manageable, you don't need to back down or change much. This could also be parasites, depending on whether the symptoms are chronic, etc.

Has anyone seen kids who had never been sick start getting sick as they heal?

Yes, it means immune system is waking up and fighting back against the crud they've been carrying around for a long time. It's called a healing crisis and is not uncommon and is actually a good thing.

Does CD, CDS or CDH work on HIV? Also, are there any contraindications of CD and HIV drugs?

We do not focus on HIV or its treatment and therefore we cannot give you a definitive answer. Anecdotally, there are many testimonials that indicate CD having a positive impact on the disease. In addition, we have spoken to doctors in various parts of the world who use CD to treat their HIV/AIDS patients and have positive results from what we understand.

Can I use CD in a Netti pot when doing an ear, eye or nose wash?

No. Do not use a Netti pot with CD. Instead, use the steam bath method. See page 114 for more information.

I´m wondering if CD can be used in a nebulizer? With our daughter's chronic mycobacterium issues, we can never get rid of the cough. I thought maybe it would be helpful to get it into her lungs or is this not safe?

Try a steam bath. Inhaling CD directly has to be done very delicately. This is why the steam bath is recommended, as the particles have time to disperse into a very large area rather than being inhaled directly. Some people are using humidifiers with 35 drops of CD per gallon. See page 114 for more information.

What supplements do I need to avoid while using CD?

Antioxidants (vitamins C, E, A, K, ALA, and CoQ10) need to be avoided because they kill CD. We avoid iron and vitamin B12 because parasites feed on these. So if you do not have something in place to kill pathogens/parasites, like CD, then the majority of your supplementation goes to strengthening the parasites instead of your child.

I really don't understand something basic... Vitamin C in food. I know not to give citrus or mangoes. Also, kiwis are rather high in vitamin C. If my child eats a kiwi or other high vitamin C containing food, how long does this impact CD? When will it wear off?

Kiwis and other fruits high in vitamin C are a tough call. We do our best to avoid the biggest offenders. Unfortunately, I have seen families lose months because they continued to give fruit juice or supplements high in antioxidants. As soon as these were pulled, their children began to improve. A few years ago, a popular omega high in antioxidants became popular for autism. Families that I was helping all over the world noted regression in their children. As soon as we figured out what the common thread was, and pulled that supplement, the improvements began again, but it was a nightmare. To answer the second part of your question, I don't know exactly how long vitamin C from a natural fruit source lasts in the body. A few different websites estimate up to 24 hours.

We have been using gluthatione every day and modified citrus pectin as a binder. Are those compatible with CD?

Gluthatione is a very powerful antioxidant and cannot be used as a supplement with CD. Modified citrus pectin is fine.

I have heard that CD helps with oxalate problems. Is that true?

Rompepiedras (RP) is very effective against oxalate-crystal formation. There are connections between parasites and oxalate problems, which this protocol seems to be helping. Ridding the body of parasites helps with high oxalates.

I know that CD neutralizes heavy metals. What does that actually mean? What is the difference between chelating and neutralizing?

The mechanism of how CD neutralizes and removes heavy metals such as mercury is not clearly known (or understood). However, a number of recovered children have had heavy metal burden tests performed before and after the use of CD, and their heavy metal burden dropped. We also know of an adult in our circles who was extremely toxic with mercury and was able to normalize his levels after all other medical interventions had failed him.

So is CD enough and we don't need to chelate?

For many it is not necessary to chelate while on CD. There are some children though who do IV chelation and CD at the same time. This method seems to have good results; there are big metal dumps, when administering chelation challenge testing. As time goes by, we add interventions until we reach recovery.

Are all chelators compatible with CD?

In many cases there is no need to do both. To answer your question, EDTA is fine as well as DMSA and DMPS with CD.

You may want to consider Bio-Chelat™, bentonite clay or zeolite clay. These are great light chelators.

We have tried every biomed option available, but nothing has helped. What makes CD different?

Biomedical treatments in general provide large amounts of antioxidants. CD is an oxidizer and kills all pathogens in the body. The premise is that once your body does not have to feed and house pathogens, it will work much better and will heal. This protocol focuses on excesses and not deficiencies, which in itself makes it different from many other biomedical interventions. With CD and the Parasite Protocol we are eliminating the pathogens and parasites that cause the symptoms known as autism.

Most biomedical interventions seem to be only applicable to small kids. Does CD work on "older" kids, teenagers or young adults?

Of course! Families with older teens and adults have had success. The body wants to heal at any age be it 7 or 70! This year, two 17-year-olds lost their diagnosis through the use of CD as part of their biomedical protocols. A 32-year-old male is doing excellent on the Protocol as well. Time will tell, and parent/caregiver dedication is the key to success.

How long should I do the protocol to see if it is working for us?

Within 30 days you will know. If you do the Protocol 100%, and in the order laid out here you should see improvements. Some see improvements with their first dose!

Has anyone had an increase in PANDAS/PANS stuff while on CD? Our ATEC didn't budge this time around and it is mainly due to the OCD and other PANDAS stuff that has increased. I get in 16 doses on weekends, but not on weekdays—maybe I get in 12 on a good day during the school week. Has anyone done anything to treat this PANDAS stuff?

Parasites typically coexist with bacteria, so it is very important to treat bacteria and parasites at the same time. It is extremely important to get in 16 doses a day, whether you get in doses earlier in the morning, or send doses to school. Also, many children with PANDAS/PANS need to be treated month long for parasites. If you are giving a probiotic, you can try doing a period without it and see if you child does not improve. We must keep in mind that if you are seeing parasites coming out with the enemas, we may not be seeing gains until we have eliminated a good number of the parasites living in the body. The toxins that they excrete—living and dead—can also cause some of the behaviors we relate with PANDAS/PANS.

Has anyone seen elevated liver enzymes while on CD?

Liver enzymes will not be high from CD. I have watched people do the liver enzyme tests for two years and the kids are in the normal range. However, when they are dumping worms or doing parasite meds is when we may see the enzyme levels go up. Within a couple of weeks they go back to normal, in the handful of times that I have seen them go up. Mebendazole and Combantrin® are non-systemic, and therefore are not absorbed; they basically travel through the intestinal system and are eliminated in the stool and urine.

My son still has a lot of mercury (DMSA provocation). Is it possible that the level can go down from using this protocol? How long should I wait before testing him again?

It is very common for the heavy metal load to go down. If you want to do labs, you can do them in three to four months.

How young is too young for CD?

There is no age that is too young. If a baby is showing signs of cold/flu, etc., you can start with the baby bottle method, one drop in 8 fl. oz. of water, so they are getting 1/8 of 1 drop per dose. The protocols are based on weight.

Ok we have had my son on this protocol for 11 months now. We started at an ATEC of 82 and had a dramatic decrease right away. Our second score was 26! Now we have had 3 consecutive ATECs of 33, most points being in the speech category. Where should I go from here? More diet changes and or supplements? We have been GFCFSF for years, considering going grain free next. We already use omegas and ocean water, and have done nine parasite protocols.

It may be time to look into hyperbarics or GcMAF, as you have *The Diet*, CD and parasite protocol firmly in place. If these 2 options are not financially possible, you need to look at the speech supplement list. Go in order, and see if your child doesn't see gains from some of those. You can also look at chelators. Also, please check that your omega does not have any antioxidants in it, as that will be killing your CD.

Is it normal to see diarrhea in the beginning of the CD protocol?

I consider there to be two types of diarrhea. One is the water faucet, which we want to avoid. If you see water faucet diarrhea, stop for the day, and give a lower dose of CD the next day, when you start up again. The other type of diarrhea is loose, unformed stool, which is normal during detox. As the body is attempting to eliminate the excess toxins quickly, the digestive process will speed up, and not all of the excess water will have a chance to be absorbed through the intestinal tract, causing loose stool.

How do you move CD through inspections at the airport?

Don’t carry concentrated sodium chlorite and activator bottles into the cabin. They must go into your checked luggage. Make sure each bottle is tightly sealed. Double bag each bottle SEPARATELY and place at opposite ends of your luggage but not right up against the sides. You may wish to stick each bottle into a pair of socks as extra protection. Surround each bottle with plenty of clothes to insure they will be protected if the bag is roughly handled. According to TSA regulations, you can bring aboard up to 3.4 fl. oz., (100ml) of a liquid in your carry-on luggage, which can hold 3 doses from your baby bottle batch.

Can I use CD as a toothpaste? Should I use regular toothpaste in addition?

I use CD spray (ten drops of activated CD per ounce) on the toothbrush first. Then, brush the teeth, and follow with fluoride-free toothpaste. CD is great for healthy teeth, tongue, and gums.

Is it okay to go swimming when on CD? I worry about the chlorine.

They do have a molecule in common; however one has nothing to do with the other. Some doctors don’t let ASD kids swim in chlorinated pools. But, as far as taking CD goes, the chlorine in the pool will not deactivate the CD in your body, nor react with it. A child on CD can swim in a chlorinated pool, just as a child not on CD can swim in a chlorinated pool.

Can I give colloidal silver with CD?

No. Colloidal silver is active for up to 24 hours in the body, and will lower the potency of CD. Therefore the two are not compatible.

Where is the autism clinic in Venezuela?

Puerto Ordaz, Fundacion Venciendo el Autismo. Carolina Moreno is the president and one of my best friends. Her email is venciendoelautismo@hotmail.com. We have over 36 recovered children there. It is wonderful.

My son has been sick and has really bad diarrhea. Can we skip the enemas for a few days or still do them?

We don’t use enemas just for constipation, but for overall colon irrigation and health. CD kills pathogens in the colon, and thereby helps heal autism. As the sickness causing the diarrhea is most likely pathogen induced, CD enemas will continue to kill these pathogens and help your son get over this acute situation faster.

My daughter just drank undiluted CDS. What do I do?

First, get her to drink plain water right away. Next, give orange juice or vitamin C to neutralize the CDS. Give burbur or activated charcoal to mop up the toxins that were released. Considering the strong taste, it is unlikely she would have consumed very much.

Can CD be harmful?

In the past 3 years that families have been using CD for autism, we have not seen any children or adults harmed by using this protocol correctly. Liver enzyme tests, nutritional tests, metal porphyrins tests, etc., have consistently shown improvement in the health of the children. Since Jim Humble started using chlorine dioxide for health, no one has died from ingesting CD (or MMS). The story that is often shared around the internet from Vanatu, concerning a woman who unfortunately passed away, was not attributed by the coroner to be the result of ingesting chlorine dioxide. There was another case of a 25-year-old male who attempted suicide with 10g (nearly the contents of a four ounce bottle of sodium chlorite at 22.4% solution) of sodium chlorite (inactivated CD). He developed methemoglobinemia, which he received treatment for, but survived his suicide attempt. That said, as we have mentioned before... anything used incorrectly or recklessly can harm you. Water, table salt, etc. The reason we outlined the protocol in such detail is to prevent mistakes and help families use it responsibly to recover their children with autism.

Does clay or bentonite clay interfere with CD? How far apart should it be taken from CD?

One hour apart from CD is fine. I use diatomaceous earth about ten minutes apart from a CD dose.

Is ibuprofen ok to take while doing CD protocol?

We have never seen a drug that was contraindicated with CD. Always consult your physician for prescription contraindications.

Is it ok to add Epsom salts to a CD bath?

We do not use epsom salts baths in this protocol. We use CD baths. See page 113.

Is it ok to take SAMe (S-adenosylmethionine) with CD? I took out all antioxidants, but not sure about SAMe.

No, it contains magnesium and vitamin C. For a mineral supplement, we take Ocean Water. Vitamin C kills the CD. Magnesium feeds biofilm, and therefore is counterproductive to our goals of healing.

Can I use DMSO in a CD enema to help drive the CD into the parasites?

Warning: Never use DMSO in an enema! Never introduce it into the body rectally. If it is applied rectally, it will carry toxic fecal matter into the bloodstream through the intestinal wall.

How do I use DMSO?

Every chance you can, apply DMSO to a clean body for 20 to 25 minutes and let it soak in. Apply it to affected parts first then remove rings/jewelry to cover all parts of the hands. Allow it to dry while applying to another body area (i.e. right arm, left arm, right leg, left leg). Apply to clean skin with clean hands. Use natural fiber clothing if it is going to come in contact with the DMSO, which can dissolve synthetics. Dr. Stanley Jacob has proven that DMSO brings about healing of rheumatoid arthritis, and it is great for migraine headaches, etc. You can research his work at...

www.dmso.org

...or find a DMSO retailer at...

www.protocolsuppliers.com

The 99% pure stuff is best, but never use that strength on the skin directly. It must be diluted to 70% or less for topical use.

Does DMSO neutralize CD?

No, it does not. However, DMSO has not proven itself to be a tool for autism recovery. In general, we use it for self-injurious behavior (SIB). The "S" in DMSO (dimethyl sulfoxide) is "sulf" as in sulfur. Many children with autism have a spirochete (amongst other pathogens), which feeds on sulfur. We saw many setbacks when adding DMSO. It is used on a case-by-case basis.

Chapter 6

CDS
Another Way of Delivering Chlorine Dioxide

There is more than one way to skin a cat.

~ *Seba Smith*

In October 2011, I received an email from Jim Humble. After a visit with Dr. Andreas Kalcker, he had some fantastic new information for healing autism. Jim wanted me to fly to the Dominican Republic to see him yet again that year so he could share this new information.

The big news surrounded the creation of *Chlorine Dioxide Solution* (CDS)—a new method of producing and using chlorine dioxide; substantially different from the CD mixing process we were using (described in Chapter 5). Jim was excited about all of the great things that Andreas was developing.

Andreas was contacted by a cattle farmer who was frustrated by the health problems of newborn calves he was receiving. These calves were suffering from infections, diarrhea, ear problems, cysts, coccidiosis, bovine respiratory syndrome, etc. His yearly veterinary drug bill was around €28,000, not including the cost of feed. The farmer had heard about the wonders of MMS in humans and wondered if it might help his animals as well.

Andreas thought, "Sure! Why not?" However, he quickly learned that cattle were very different from humans when it came to their digestive system. Cattle digest through fermentation, which CD disrupts, so he had to find a way to bypass their digestive system and go directly to their blood stream. But, that idea had another big problem. The pH of standard CD was too acidic and therefore not compatible with the calves' blood stream. Injecting even dilute CD caused great pain and could result in damage to the veins. There had to be another way!

After much thought and research, Andreas came up with a distillation process to extract the chlorine dioxide—the key ingredient—from the CD mixture so it would not contain any sodium chlorite or acidic activator. He named the resulting liquid *Chlorine Dioxide Solution* (usually abbreviated CDS). Note: CDS can still contain trace amounts of sodium chlorite and whatever acidic activator used to produce it, but usually not enough to be an issue.

This new CDS solution was injected into the 800 cattle with very positive results. The animals health improved and the vet bill dropped like a rock.

In one case, the farmer called Andreas about a particularly sick cow. He advised him on a dosage, but apparently the farmer misunderstood the instructions and gave the cow 10 times the recommended amount. The result? The cow was a bit "high" with ears and tail standing up, but subsequently became healthy with no ill effects from the accidental overdose.

On the human side, CDS also solves the problem some people have with sensitivity to citric acid as well as the taste of CD. Not having the original chemicals (sodium chlorite/citric or hydrochloric acid) in CDS makes a big difference for some. Another advantage of CDS was a drastic reduction in Herxheimer reactions.

After a long weekend in the Dominican Republic, we went home with new information to try out with Patrick.

I began by swapping out drops of CD for milliliters of CDS. Initially, I didn't notice improvements or regression, but I did notice that Patrick was waking earlier and having a less profound sleep. After about 30 days of trying the new miracle I began to think that, "If it ain't broke, don't fix it." So we went back to the original CD that had given us all of the recoveries and improvements. Patrick went back to sleeping very well and I never looked back. I was a confirmed CD user and CDS, for me, had no obvious advantages.

A little over a year later, Jim was at our home, and on December 26th, 2012, his new assistant showed up from the Middle East to help him. She could be called the "CDS poster child." We differed on this topic right away. But, she was very insistent. She asked me why I didn't like CDS and I told her. So, she told me that I had been using "unstabilized" CDS and now they "stabilize" the CDS.

When the CDS is "stabilized" (with some sodium chlorite added back into the CDS liquid), it gives an extra kick, such that when the chlorine dioxide molecule oxidizes a pathogen, there is sodium chlorite on hand to react with the acid that is created by the death of the pathogen. The result is more chlorine dioxide released on the spot.

I decided to try stabilized CDS with Patrick. We arrived at his full dose based on tolerance. His sleep has been perfect. He sleeps as any pre-teen should—like a rock. And, he has great energy all day long. I can say that there was no noticeable difference over the four months that he was taking CDS, from the days when he took CD. However, he is a little bit "lighter," as if he has no cares in the world. It seems as if something that might have made him uncomfortable no longer bothers him. Little by little, a few families switched to CDS to see if their children did better, worse, or as well as they did with CD.

After a couple of trial months with about 20 families, I think that it is safe to say that CDS has its place in the buffet of different methods of chlorine dioxide administration. We still have the original CD, made with citric acid or HCl. Now, we have CDS and CDH (Chapter 7). Today, we no longer use stabilized CDS, as I feel that CDS is only for hypersensitive individuals and to be used only until they can switch over to CD or CDH. Whatever formula we choose, it will help to heal the body of unwanted pathogens, and helps with parasites as well as heavy metals. Each person is different, and it is up to us as parents to observe and decide which method of chlorine dioxide administration is best.

You are in no way encouraged to switch to CDS if what you're doing with CD is working for you. For some people it may be better, but as of now, only one of our recoveries has come from CDS—all the rest are from CD. Some children may try CDS and come to realize that CD is still better for them.

When to Use CDS

CDS is used when someone just can't get past 1 drop divided in 8 fl. oz., over a day without experiencing a Herxheimer reaction. This allows us to get past the road block and still detoxify the body. Eventually, we want to go back to the standard CD Protocol which I believe to be more effective.

This is not a common situation, but it does occur.

Making vs. Buying CDS

Most people are a bit concerned about making CDS since it involves a distillation process where you produce chlorine dioxide gas and then cause it to go into water. When Andreas first came up with making CDS, it involved two containers, a hose, heat and lots of ventilation. There are still lots of videos on YouTube explaining that original process. However, there is now a much better, easier and safer way to produce CDS at home. So, if you see a CDS making video or read instructions that talk about using a hose—forget it! The new process is much easier and safer and doesn't involve any heat nor hoses.

There are some online sellers of CDS, but the cost of it is high and making your own is simple. It just takes a little effort in learning the process and having the right equipment. In addition, by making your own, you will have a better understanding of the behavior of chlorine dioxide.

Some Important CDS Points

When it comes to CDS, it is all in the concentration of chlorine dioxide in water; measured in *parts per million*—abbreviated **ppm**.

When buying or making your own, the goal is to end up with a bottle of CDS having a concentration strength of 3,000ppm. This bottle should ideally be made out of glass and kept in the refrigerator. You never use this concentrated solution directly. It must be diluted.

When we say, for example, use 10ml of CDS, we mean mix 10ml of 3,000ppm CDS with whatever indicated amount of water, and use that diluted mixture for the indicated purpose.

Make sure you read and understand Appendix 6, page 467 which explains more about concentration and measuring ppm.

There are several names attributed to this new, better and simpler method of making CDS, such as:

- The Shot Glass Method
- The Overnight Method
- The New Method

There are some demonstrations on YouTube showing this new method along with write-ups on various forums. These methods use a plethora of different containers having different shapes and sizes. The specific tools used to produce CDS can have a significant impact on the concentration.

It should also be noted that the concentration strength is reduced every time you open the CDS source bottle as chlorine dioxide gas escapes the liquid and evaporates into the air space above the liquid. When you open the source container, some of the chlorine dioxide gas escapes. So, the strength of a half full CDS bottle can be substantially less than what you started off with when the bottle was full. This is similar in concept to a pop bottle that loses its fizz if not used up quickly.

To substantially reduce the evaporation of the chlorine dioxide gas, the CDS source bottle should be stored in the refrigerator, which stabilizes and significantly reduces the amount of CD gas escaping the CDS solution. But, no matter what the temperature, some gas will always escape and reduce the concentration each time the bottle is opened. A narrow neck bottle helps maintain the integrity of the CDS for longer periods.

It is better to store the concentrated source CDS in smaller 300ml bottles than keep it in a larger one liter bottle. That way you use up what is in one bottle faster with less concentration loss. A good storage bottle is shown and described on page 160.

The New CDS Making Method — The Basic Concept

First, let's go over the basic principles of the CDS making process and then we will go into details.

We start with two containers (both ideally made of glass). One container is larger and has some kind of a lid that can be tightly closed. The other is a smaller container having NO lid. The relative size of each container is such that the smaller container fits comfortably inside the larger container while allowing the lid to properly close on the larger container when the smaller one is inside. See page 151 for an example of a well-made glass kit distributed by wps4sale.com.

The large container is then partially filled with filtered/distilled water. The level of water must be low enough so as to not overflow into the smaller container if it is placed into the partially filled larger container. The photos on page 151 show the concept of the two bottles visually.

Now that you have the basic idea, let's make some CDS...

Using the Overnight CDS Generating Kit

The following directions assume you have the glass *Overnight CDS Generating Kit (1000 ml)* from wps4sale.com (as shown on page 151). You are of course not required to use their kit. However, based on our own experience of looking high and low for a good one, theirs has the key features:

- Made of glass
- Smaller glass fits inside of larger container AND 1000ml of water inside the big container will not flood into the smaller container once placed inside.
- Lid fits tight and no gas escapes during the chemical reaction time.
- Lid is plastic—NEVER USE METAL LIDS!

Note: There are plastic CDS kits that work. You may be able to find a combination of containers made of plastic but not glass where you live. In fact, I made a YouTube video where I show how to make CDS using a plastic container. Just understand that chlorine dioxide will deteriorate plastic containers over time, so it should be avoided. Even if you have to use a plastic jar to make the CDS, store the final product in glass. The less time the CDS is in plastic, the better! As for lids, we have no choice. Only use plastic lids. Metal lids will oxidize VERY rapidly! Even metal lids with a plastic coating on the inside will deteriorate.

Steps to Making CDS:

1. Start by pouring one liter of distilled or reverse osmosis water into the large glass container. The water should be around room temperature.

2. Place the empty dessert cup inside the large container making sure no water spills into the cup.

3. Measure 75ml of sodium chlorite solution (22.4% $NaClO_2$ in water) and pour into the dessert cup, while being careful not to spill any sodium chlorite into the water surrounding the cup.

4. Measure 75ml of 10% HCl or 50% citric acid solution and pour into dessert cup.

5. IMMEDIATELY screw on the lid to the large container while being careful to not jiggle the container which could potentially cause the CD solution

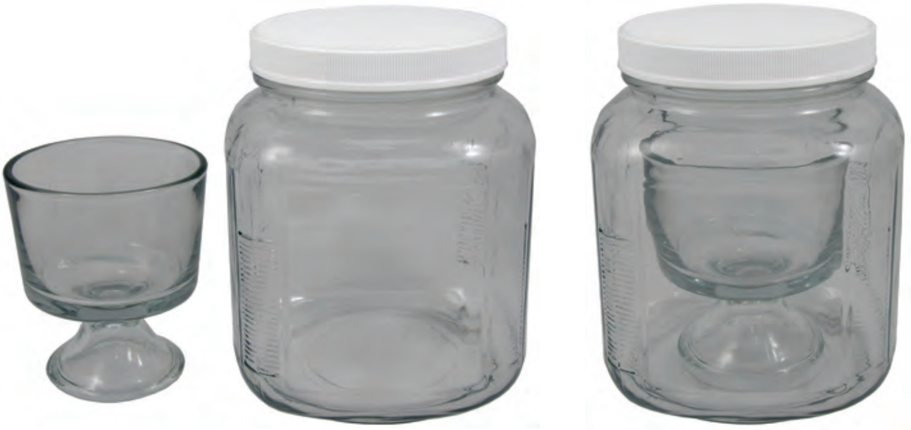

wps4sale.com sells this Overnight CDS Generating Kit that produces 1 liter of CDS at 3,000ppm from 75ml of sodium chlorite plus 75ml of activator. The only part not made of glass is the plastic lid. The glass dessert cup is sized just right to fit inside the larger glass jar with enough room left over for 1 L of water that won't overflow into the dessert cup.

to mix with the surrounding water. Make sure the cover is tightly screwed down so as to not have any leaks. If you smell chlorine dioxide (beyond the little that escapes while you are putting on the lid) then something is wrong with the lid and/or container.

6. If you did everything correctly you should see the CD solution turn a dark amber/brown within about a minute (see below) and notice that the water starts to turn a light yellow several minutes later. It is also normal to see bubbles form in the dessert cup. It is normal for the pressure to change during the chemical reaction. We find that citric acid produces a vacuum and HCl can produce a pressure at first and then a vacuum.

7. Cover the kit with a towel to reduce its exposure to light. It doesn't have to be in a pitch black location, but it definitely should not be in direct sun light. Feel free to check it from time to time and see how the colors change. Of course keep this kit out of the reach of children or anything that could disturb it. I keep mine in the cabinet overnight with a towel on it.

8. When the color in the dessert glass matches that of the surrounding water, the chemical reaction is complete. There is no harm in waiting a bit longer—nothing more will happen. This usually takes from 12-24 hours depending on room temperature and the strength of the acid used.

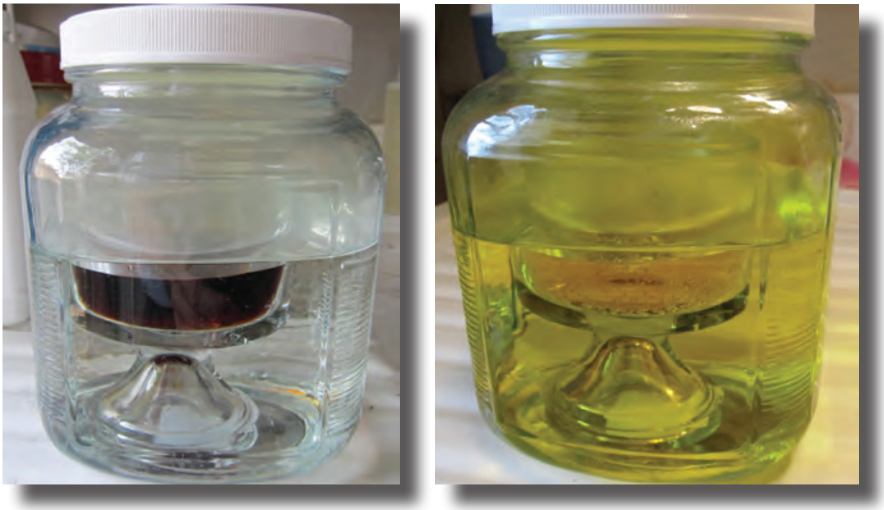

After the sodium chlorite and activator mix, the color will quickly turn a dark amber, almost black color (left). After about 12 hours, the color of the solution in the dessert cup and that of the water surrounding it should be identical (right), which indicates the chemical reaction has completed and the CDS is ready to be poured into a storage container.

9. Have your glass storage bottle(s) clean and ready to receive the CDS solution.

10. Before opening the kit make sure your work area is well ventilated. Perform the steps that follow outside or have the door and/or window open nearby. Having a fan lightly blowing any gas that escapes away from you is a good idea.

11. Slowly open the container being careful to not jostle it which could cause the CD solution to mix with the freshly made CDS. If the chemicals mix, you will have to start over again, so be careful! You will most likely smell the chlorine dioxide gas that was sitting in the air space when you first open it. This is normal, hence the need for good ventilation.

12. Slowly remove the dessert cup while being careful to not spill its contents into the CDS. Immediately dispose of the contents in the toilet and rinse off the dessert cup.

13. Now pour the CDS into the storage bottles while being aware that some chlorine dioxide gas will come out of the water into your working area.

14. Tightly seal the storage bottle(s) and place in the refrigerator.

Note: 10% HCl is the recommended activator when making CDS. However, you can also use 4% of HCl, but the reaction time will be slowed down. It may take as much as a full day before the color of the CD solution and the water match.

Dosing CDS

As mentioned earlier, CDS is particularly well-suited for unusually sensitive individuals who cannot tolerate even low doses of CD.

Start with a baby bottle filled with 8 fl. oz., of water and add 1ml of CDS. This will provide eight doses of 1/8ml. If all is well on the first day, increase to 2ml on the second day. Each day you increase by one milliliter. Increase the amount based on tolerance. If the person is having a problem with a certain level of CDS, then go down to where they were fine and stay there a few days before increasing again.

Tolerance is the key here. Once you can no longer increase you have reached that person's full oral dose of CDS.

Slowly Switching Back to CD

Once you have found the full oral dose where they are stable and cannot go higher, it is time to fold CD back in.

The goal of using CDS is not to replace CD, but rather do some fundamental detoxing so you can bring CD back and reach full oral dose of CD.

This is accomplished by taking out one milliliter of CDS and replacing it with 1 drop of CD. For example, if the individual can tolerate 20 milliliters of CDS, then an ideal transition would be represented in the chart on page 154.

Of course this chart represents an unlikely scenario where everything goes exactly as desired. However, it does demonstrate what we are striving for—switching out CDS for CD and continuing to increase the dose of CD as described in Chapter 5 (page 81).

To accomplish this process effectively requires careful observation of your child and making decisions as to when you can go up; when to hold; and when to back down.

Hypothetical CDS to CD Transition			
Transition Day	**CDS in milliliters**	**CD in drops**	**Comments**
1	20	0	Last CDS only day.
2	19	1	Transition starts
3	18	2	Transition continues
4	17	3	
5	16	4	
6	15	5	
7	14	6	
8	13	7	
9	12	8	
10	11	9	
11	10	10	
12	9	11	
13	8	12	
14	7	13	
15	6	14	
16	5	15	
17	4	16	
18	3	17	
19	2	18	
20	1	19	
21	0	20	Transition completes
22	0	21	CD increases each day
23	0	22	
24	0	23	
25	0	24	

CDS Enemas

CDS enemas can be useful for sensitive individuals when starting the protocol. Follow the same enema instructions in Chapter 5, page 103, keeping in mind that 1ml of CDS has a relative strength of approximately 60% of 1 drop of CD. With that in mind you can work up to 40ml of CDS per liter of enema water.

Chapter 7

CDH - Going Beyond CD & CDS

"The progressive development of man is vitally dependent on invention. It is the most important product of his creative brain."
~ *Nikola Tesla*

This protocol is constantly evolving, and until every person with autism recovers, we will continue to search for things to add or tweak to the protocol so we reach that goal. A few months before the release of this second edition, I was made aware of a new method of CD preparation, known as *Chlorine Dioxide Holding (solution)* or simply CDH.

CDH can almost be described as a hybrid between classic CD and CDS. Where CDS has no raw material left in the final product, but only chlorine dioxide gas dissolved in water, CDH contains some raw material (similar to classic CD) along with the chlorine dioxide in the final product. This new process allows the sodium chlorite to react with the acid for a significantly longer period of time, thereby reducing much of the remaining amount of unactivated sodium chlorite and activator. Some people cannot tolerate citric acid so CDH is usually made with 4% HCl. Initial reports indicate that CDH is better tolerated than CD.

Another interesting benefit of CDH is that it appears to mix well with the permitted natural sweetener stevia (SweetLeaf® brand) without reducing the potency of CDH. This can help children who have an aversion to the taste of CD. Many families have also reported that they were able to increase their child's dose without producing a Herxheimer reaction, in contrast to classic CD. Older children and severely affected children have benefitted as well from the CDH preparation; you can read more about that on page 221.

Currently, this new method is being used by a relatively small group of families (around 70 as of November, 2013). Many of them are reporting that CDH continues to produce results for their children on the spectrum, and they are seeing even better things than before.

As with all new things, it is important to test with a diverse group of families over a long enough time period to make sure that gains are sustained. So we ask that you please keep in mind that CDH is literally the bleeding edge of this protocol. While we are excited to share a new option with you, the decision to use CDH must not be taken lightly. If you are doing well with classic CD you may never need to use CDH. Consider the old saying, "If it ain't broke, don't fix it." Of the 115 children who have lost their autism diagnosis, 114 have done so with CD and 1 with CDS. So far, 0 with CDH (4 months in use for ASD). I expect this number to change soon as we are seeing good things from CDH. Time will tell. Stay tuned.

Scott McRae, his wife Brenda, and Charlotte Lackney have been pioneers in developing the CDH method. The following section is written by Scott where he discusses how CDH evolved along with detailed instructions on how to prepare and use it.

* * *

My wife, Brenda, and I first learned about CD early in 2009, through Bhante Vimalaramsi, an American born Buddhist monk. He's now a very close friend of ours, and even as I'm writing this, I'm at a meditation retreat which is based upon his understanding of the open-minded, experiential teaching of the Buddha.

After receiving our first set of CD bottles from an online seller, we started by trying to get to 15 drops of CD activated with lemon juice for 3 minutes, twice a day, which was the protocol at the time. Though we gave it a good effort, we couldn't get past 6 drops before vomiting and having diarrhea, and this caused us to initially stop taking CD. Then, after moving to Jakarta, Indonesia (Brenda's home town), I experienced almost monthly illnesses, which I believe was due to being in a new and tropical part of the world (I'm from San Diego, CA), riding in public transportation twice a day and teaching in a school of over 300 students. After a year and a half of constantly being sick, I remembered our bottles of CD which we had fortunately brought with us from the US, and I started on Protocol 1000. By that time, *Protocol 1000* had been developed to be what it is now—3 drops of CD (activated for 20 seconds with 50% citric acid) per hour, 8 times a day—and so I decided to do the 3 week cleanse. By doing the cleanse, I experienced a huge improvement in my health. Not only did I immediately stop getting sick, but I also felt that my energy level had increased by about 25%! Obviously, I was excited by these great results and so was my wife because she had started taking CD again as well. However,

Scott & Brenda McRae from Jakarta, Indonesia

even though our results were great and our experience was far better than before with the old, "try to get to 15 drops twice a day protocol," we still were having some nausea and bouts with diarrhea when we took CD. This was especially true at the times when we felt the symptoms of a cold or flu and tried to take more than the 3 drops doses in order to overcome it. Still the results we were getting with CD on Protocol 1000 outweighed the nausea and diarrhea that we experienced and so we continued using it, especially when we felt some sickness coming on.

After taking CD for about a year in this way, CDS hit the CD world. Being the experimental type, I decided to give it a try. After searching all over Jakarta for the plastic tubing for a couple of days and finally finding it, I made our first batch of CDS. We both tried CDS for about six months but found it to be less effective than CD, so we stopped with CDS and went back to CD and Protocol 1000.

Nevertheless, there were 2 things I really liked about CDS: (1) it NEVER caused us any nausea or diarrhea, and (2) it was so easy to use since it was pre-made (no mixing of chemicals before each use). The main thing for me was not having any more nausea because I really disliked feeling sick. So, I started thinking about CDS and my experience with making it and I came to the conclusion that possibly, the reason why CDS wasn't nauseating was because there wasn't any unactivated sodium chlorite in the solution—it was just chlorine dioxide dissolved in water. I remembered that when I made CDS myself, even after the activation process had gone on for an hour in a heated condition, if I stirred or swirled the activation chamber bottle, more ClO_2 would still come out of it. This got me to thinking... if the chemical reaction between the sodium chlorite and the 50% citric acid solution used to make the CDS was still able to produce more chlorine dioxide after an hour in a heated condition, then surely the 24 drops that I was using to make my daily CD dosing bottle weren't being fully activated after just 20 seconds.

Therefore, I decided to increase the activation time and tried it out on myself first and then my wife (aren't I considerate?). We both found there was no longer a nausea problem, even when taking more drops per hour than we had ever taken before.

Since I was in an experimental mode, I decided to see if I could make larger quantities of concentrated CD all at once to make it more convenient. I mixed equal amounts of sodium chlorite and 50% citric acid in a bottle, let it activate for about a minute, and then added a specific amount of hot water to further encourage the activation process. In the end, I had a total of 140 ml of this concentrated CD solution. Later, I found that hot water wasn't necessary and that room temperature water worked even better because there was less CLO_2 gas lost in the process.

The finished chemistry was indeed very strong and still didn't cause any nausea, so I was compelled to post my discovery on the Genesis II Forum. I named it *7 Day Fridge MMS (CD)* because it provided a 7 day supply of Protocol 1000. The ingredients added up to 140 ml, so each 20 ml was 1/7th of the total, or a one day supply of "pre-activated" CD similar to Protocol 1000. This made taking CD every day really easy. Just pour out 20ml of the new concentrated solution into a water dosing bottle, and then pour out 1/8th of the bottle every hour into some water in a glass, and drink it.

The *7 Day Fridge MMS (CD)* method worked great for my wife and me. Others on the Forum also tried it and liked it. In addition, I gave it to some people at the school where I work to overcome their colds (usually overnight) as well as other diseases within a short time.

About 18 months later, Charlotte, my Forum friend, began testing the *7 Day Fridge MMS (CD)* process to determine the actual ClO_2 content using her *Sensafe*^{TM} Chlorine Dioxide Photometer. Over several months, we worked together to further refine the 7 Day Fridge method. The result of all of our testing and refinements is this new and exciting CDH product.

The final formula to produce CDH using the 1 Bottle Method came out to be:

22 parts water	91.6%
1 part sodium chlorite	4.2%
1 part HCl (4%) or Citric Acid (35%)	4.2%
Total Solution	**100%**

I believe this new way of making CD will be of great benefit to humanity because it will allow people to gradually double or even triple the amount of CD they can take with little or no stomach upset. By increasing their doses to higher levels, people will be able to overcome CD treatable diseases more quickly than ever before.

As with any new technology, more changes and developments are likely. For example, we now know that CDH tastes much better if activated with hydrochloric acid instead of citric acid.

Producing CDH Using the One Bottle Method

Making CDH is really quite simple. You can use any size of bottle, and produce any quantity you wish, as long as you follow the basic instructions and keep the proportions the same. However, before diverting into different quantities, it is recommended you follow these directions exactly to insure you have the process down correctly.

Note the following volume equivalents:

Fluid Ounce (U.S.) Approximate Equivalents

30ml = 1 fl. oz. US (2 Tablespoons)

660ml = 22 fl. oz. US

720ml = 24 US fl. oz. US

750ml = 25 US fl. oz. US

Equipment Needed

- One 750ml (25 fl. oz. US) glass bottle with an airtight cap. DO NOT use a metal cap (even if it is lined with plastic). The best caps are plastic or even a synthetic cork in good condition. A common 750ml wine bottle is ideal for this as you can get them colored to reduce possible UV exposure (the darker the better). But, a colored bottle is not absolutely necessary and using a clear one will allow you to actually see the chemical reaction as it turns from clear to yellow.

- Three 240ml (8 fl. oz. US) bottles ideally made of colored glass to protect the CDH from UV light (the darker the better), but colored bottles are not absolutely necessary. You can also use smaller bottles if you like—these are just used to divide up the resulting 720ml of CDH into smaller bottles to help retain the ClO_2 concentration while opening and closing the bottles during dosing. *Schweppes*™ sells 6-packs of Ginger Ale, Club Soda and Tonic Water in 10 fl. oz. glass bottles with plastic lids that are great for this purpose, and hold 300ml easily. Only the Ginger Ale is in a colored bottle (green), the others are clear.

Schweppes
GINGER ALE

- One measuring cup or graduated cylinder to accurately measure liquid in either milliliters or fluid ounces.

Ingredients Needed

Ingredients should be at room temperature—not cold. If CD and/or activator are right out of the refrigerator make your water warmer to offset, or allow ingredients to warm up before using.

- 660ml of distilled or purified water at about 70° - 90°F (21° - 32°C).
- 30ml of sodium chlorite (22.4% solution) near room temperature or slightly above.
- 30ml of 4% Hydrochloric Acid (HCl) or 35% Citric Acid ($C_6H_8O_7$) near room temperature or slightly above.

Note: The amounts indicated above add up to 720ml, while the wine bottle easily has room for an additional 30ml and more. Refer to the chart on right if you wish to produce a different batch amount.

The CDH Formulation Table and Different Acid Concentrations

What if you have 10% Hydrochloric acid or 50% Citric Acid (very common)? Or, you wish to use a different size of bottle? Not a problem. These acids can still be used. However, the formula changes accordingly.

The table below is a great tool for determining the formula for a given bottle size. To use the table, start by circling the size of the bottle you wish to fill in the left most column. Next look at the acid you have and its labeled concentration. Match that with one of the 4 options across the top. Below the matching acid/concentration you will find the 3 formulation numbers for water, sodium chlorite (labeled "SC"), and whatever acid you are using. Just go down the appropriate 3 columns to where the bottle size line intersects and you will have the numbers you need. Substitute these numbers in the following preparation instructions if your situation calls for it.

CDH Formulation Table

(Applies to the One Bottle Method of making CDH ONLY!)

SC=Sodium Chlorite / HCl=Hydrochloric Acid / CA=Citric Acid

Water Bottle (ml)	Hydrochloric Acid 4%			Hydrochloric Acid 10%			Citric Acid 35%			Citric Acid 50%		
	Water (ml)	SC (ml)	HCl (ml)	Water (ml)	SC	HCl (ml)	Water (ml)	SC (ml)	CA (ml)	Water (ml)	SC (ml)	CA (ml)
10	9.2	0.4	0.4	9.4	0.4	0.2	9.2	0.4	0.4	9.3	0.4	0.3
20	18.3	0.8	0.8	18.8	0.8	0.3	18.3	0.8	0.8	18.6	0.8	0.6
30	27.5	1.3	1.3	28.3	1.3	0.5	27.5	1.3	1.3	27.9	1.3	0.9
40	36.7	1.7	1.7	37.7	1.7	0.7	36.7	1.7	1.7	37.2	1.7	1.2
50	45.8	2.1	2.1	47.1	2.1	0.8	45.8	2.1	2.1	46.5	2.1	1.5
60	55.0	2.5	2.5	56.5	2.5	1.0	55.0	2.5	2.5	55.8	2.5	1.7
70	64.2	2.9	2.9	65.9	2.9	1.2	64.2	2.9	2.9	65.0	2.9	2.0
80	73.3	3.3	3.3	75.3	3.3	1.3	73.3	3.3	3.3	74.3	3.3	2.3
90	82.5	3.8	3.8	84.8	3.8	1.5	82.5	3.8	3.8	83.6	3.8	2.6
100	91.7	4.2	4.2	94.2	4.2	1.7	91.7	4.2	4.2	92.9	4.2	2.9
150	137.5	6.3	6.3	141.3	6.3	2.5	137.5	6.3	6.3	139.4	6.3	4.4
200	183.3	8.3	8.3	188.3	8.3	3.3	183.3	8.3	8.3	185.8	8.3	5.8
250	229.2	10.4	10.4	235.4	10.4	4.2	229.2	10.4	10.4	232.3	10.4	7.3
300	275.0	12.5	12.5	282.5	12.5	5.0	275.0	12.5	12.5	278.8	12.5	8.7
350	320.8	14.6	14.6	329.6	14.6	5.8	320.8	14.6	14.6	325.2	14.6	10.2
400	366.7	16.7	16.7	376.7	16.7	6.7	366.7	16.7	16.7	371.7	16.7	11.7
450	412.5	18.8	18.8	423.8	18.8	7.5	412.5	18.8	18.8	418.1	18.8	13.1
500	458.3	20.8	20.8	470.8	20.8	8.3	458.3	20.8	20.8	464.6	20.8	14.6
550	504.2	22.9	22.9	517.9	22.9	9.2	504.2	22.9	22.9	511.0	22.9	16.0
600	550.0	25.0	25.0	565.0	25.0	10.0	550.0	25.0	25.0	557.5	25.0	17.5
650	595.8	27.1	27.1	612.1	27.1	10.8	595.8	27.1	27.1	604.0	27.1	19.0
700	641.7	29.2	29.2	659.2	29.2	11.7	641.7	29.2	29.2	650.4	29.2	20.4
720	660.0	30.0	30.0	678.0	30.0	12.0	660.0	30.0	30.0	669.0	30.0	21.0
750	687.5	31.3	31.3	706.3	31.3	12.5	687.5	31.3	31.3	696.9	31.3	21.9
800	733.3	33.3	33.3	753.3	33.3	13.3	733.3	33.3	33.3	743.3	33.3	23.3
850	779.2	35.4	35.4	800.4	35.4	14.2	779.2	35.4	35.4	789.8	35.4	24.8
900	825.0	37.5	37.5	847.5	37.5	15.0	825.0	37.5	37.5	836.3	37.5	26.2
950	870.8	39.6	39.6	894.6	39.6	15.8	870.8	39.6	39.6	882.7	39.6	27.7
1000	916.7	41.7	41.7	941.7	41.7	16.7	916.7	41.7	41.7	929.2	41.7	29.2

Preparation Instructions

Follow the steps of mixing ingredients in this order (assuming you are using the 750ml glass bottle):

1. Pour 660ml of purified water into the 750ml glass bottle.
2. Add 30ml of sodium chlorite to the 750ml glass bottle.
3. Add 30ml of 4% HCl or 30ml of 35% citric acid to the 750ml glass bottle.
4. Immediately cap/cork the bottle tightly so that no ClO_2 gas can escape and give it a good shake to thoroughly mix the ingredients (and a few more times later on if possible).
5. Store the bottle in a dark place with a temperature of 70°F to 90°F (21°C to 32°C) for 12 to 24 hours or more (24 hours or longer if you're in a cold environment—below 70°F (21°C)).
6. After the storage time has passed, place the bottle of CDH into the refrigerator (not the freezer) and allow it to cool down for 3+ hours before opening it for the first time. The temperature of the solution should be no more than 51°F (10.5° C). Note: If you are using a significantly smaller bottle, cool down time can be reduced because the smaller volume of solution will cool faster.
7. Finally, pour the CDH from the 750ml bottle into the smaller bottles, cap tightly and keep refrigerated until ready to use. The smaller bottle are easier to dose from and they also help reduce the number of times gas can escape and reduce the potency of the solution.

Using CDH

The CDH is now ready for use. Each milliliter of CDH solution contains 1 pre-activated drop of CD. It can be used for ANYTHING that CD is used for; viruses, bacteria, yeast, parasites, heavy metals, enemas, tub baths, gums & teeth, skin care, infections, etc.

When used orally, each 1ml of CDH should be added to at least 30ml of water. You can add even more water if you notice slight throat irritation with higher doses. If taste is an issue, a little bit of stevia may be added to each dose to improve taste by sweetening it. Some of the moms are adding SweetLeaf® Natural Stevia Sweetener to their daily bottle and report no negative impact on ppm level.

Although CDH is strong, it has shown to be gentler on folks who have issues with nausea when using traditional CD. You should be able to start at whatever drop dose you were on with CD and switch to an equivalent milliliter dose of CDH and gradually increase to tolerance. Typically, people are able to take 2 to 3 times as much of CDH as traditional CD, without experiencing nausea.

The CDH bottle should be kept refrigerated and only taken out to extract doses. Since 720ml is a fairly large quantity that may take many days to finish, it's a good idea to take the 720 ml and divide it up into 3 smaller 240ml bottles (720ml ÷ 3 = 240ml) so you won't lose much of the ClO_2 each time you open the bottle. By doing this, you will conserve as much of the ClO_2 as possible. It's also easier to extract doses from a smaller bottle using a syringe or pipette.

Also, keep the CDH bottle out of direct or indirect sunlight to prevent loss of ClO_2. If you make a dosing bottle for the day, it's best to keep it cold, but it is not absolutely necessary.

A little note about taste: Most people who complain about the bad taste of CD, CDS or CDH (which does not have any taste at low doses) are actually reacting to the smell of the ClO_2 which can lead to developing a long-term aversion to any of the treatment solutions. So, if you can minimize the gas floating around your nose, you will have an easier time with drinking the CD, CDS or CDH dose. To accomplish this, Charlotte suggested avoiding the use of a cup or wide mouth drinking bottle. Instead, use a bottle with a small opening such as a common water bottle (preferably made of glass). Of course, if the smell doesn't bother you, this is a moot point, but at least you have this little trick if it does.

Well, that's all you need to know to get started on this great new way to make and use CD. May this new CDH formulation bring you and your family much health and happiness.

Scott McRae
Jakarta, Indonesia
November, 2013

* * *

We appreciate Scott, Brenda and Charlotte's contribution to the variety of ways to produce and use chlorine dioxide. Be sure to check the Facebook groups and forums for the latest developments on CDH.

Some of you may feel overwhelmed by what you just read. So, let me give you my "Easy-Peasy" single paragraph method of making CDH: I take a 600ml Lifefactory^{TM} bottle, put in 550ml of water; add 25ml of sodium chlorite; followed by 25ml of 4% HCl (or 50% citric acid). Leave it 12 hours in a cabinet, after which it goes in the fridge for 2 or more hours. Done! ☺

Healing & beating autism.

Chapter 8

Step 3

The Kalcker Parasite Protocol

> *All of our fathers had a treatment for parasites as a part of their cultural practice. We have gotten away from this because of our reliance on modern practice. We would do quite well to relearn the ways of our ancestors in this area and keep ourselves in relatively good health always.*
>
> ~ ***Chief Two Trees***

The word "parasite" comes from the Greek word meaning, "one who eats off the table of another." Parasites, to Ancient Greeks, were those who sat at another's table, and paid for their meal with flattery.

As I mentioned earlier in the book, a very interesting thing started happening with the CD enemas. What we had previously believed to be mucous or biofilm coming out with the enemas, turned out in many cases to be worms (helminths) (aka parasites)—in rare cases they were still alive and wiggling in the toilet! We believed the most common were *Ascaris lumbricoides* (roundworm). However, what we are now seeing more and more appear to be rope parasites, a potential new species of helminth discovered by Dr. Gubarev, Dr. Alex Volinsky, and coworkers (submitted January 14, 2013). DNA testing is the only way to definitively say, but at $25,000 USD for each analysis, with a minimum of 100 test cases, it is rather cost prohibitive at the moment.[1]

In addition to Ascaris and rope parasites, parents have also seen hookworms, pinworms, tapeworms, and flukes, among others. This is an extremely important piece of the puzzle for so many of our children. We have been led to believe that in first world nations, parasites are not a problem. This is absolutely not the case.

A well washed parasite. You can almost feel the texture.

Andreas Kalcker,
co–author of the
Kalcker Parasite Protocol

Miriam Carrasco Maceda,
co–author of the
Kalcker Parasite Protocol

I was honored to have Dr. Andreas Kalcker and Miriam Carrasco Maceda share a chapter from their upcoming book, *Parasites: The Silent Enemy*. Andreas explains the importance of lifelong deworming, and shares with us a protocol that has helped many children and adults become healthier; and for some children on the spectrum was the last piece added that led them to recovery. The version included here has been tailored specifically for children and adults with ASDs. The original protocol can be found at:

www.andreaskalcker.com/
index.php/en/health/parasite

Very few details have been changed, but it is important to note that the Parasite Protocol here is what has been proven to help many of our children on the spectrum, including many of the recovered children.

Thank you Andreas and Miriam for your valuable contributions to this movement, selflessly sharing your findings, and for always taking the time to help.

HOW TO DETECT AND TREAT A PARASITIC INFECTION

Parasitic infections are more common than most people think, and may or may not result in serious health problems. We may be infected with multiple types of parasites, which vary in size and location, on or in the body.

Parasites can be classified as either microparasites, such as malaria that are only visible under the microscope, or large macroparasites such as round or flat intestinal worms (roundworms, tapeworms, etc.). These can be seen by the naked eye, and can reach great sizes. Internal parasites are found, not only in the intestines, as is generally thought, but anywhere in the body, including the lung, liver, muscle, stomach, gallbladder, brain, blood, skin, joints, and even in the eyes.

In recent history, the great migratory movements of the human population via rapid transportation and widespread trading have shortened the distances that previously had separated people and diseases. Formerly localized diseases have thus become universal ailments. Parasites previously confined to very specific geographical areas now appear in other locations, far away from their initial homelands. Unfortunately, conditions typical of the lower socioeconomic strata, (under which a large percentage of the global population lives) tend to favor the transmission of diseases and parasites.

A high percentage of the world population suffers from infections by parasites, which the WHO (World Health Organization) estimates are responsible for 15 million child deaths annually. In addition to the great cost represented by deaths, chronic and persistent infections have increased as parasites have developed multiple mechanisms of evasion and resistance to specific immunity. This allows them to circumvent and cancel the host immune response.

Persistent parasitic infection in human hosts leads to chronic immune reactions, which can result in tissue damage and altered immune regulation. Ninety percent of the world population is infected with one or more parasites, and up to five different types may coexist in the same host.

This situation becomes dangerous when the internal balance within the host is upset, the number of parasites skyrockets, and the host begins showing signs of serious illness that may even result in death. However, in some cases, parasitic worm infections do not result in disease, in fact, a number of carriers are found to be healthy.

A really good look into a parasite. You can see the actual intestines of the parasite. Also known as a helminth.

The same parasite (as above) from a different angle.

Considering that most people are not even aware of their infections, parasites have become silent killers, claiming the lives of many unsuspecting victims going about their lives oblivious to the danger. Some doctors in Western Europe and the U.S. seem unwilling to even contemplate that we may be infected.

Taking into account the recent increase in travel, immigration, and trade across continents, it is not hard to see how the problem has now become magnified to an alarming level. Parasites, especially the modern "toxified" versions, may well be causing many of the rare diseases now becoming more prevalent, as well as other recently identified or growing problems such as chronic fatigue, fibromyalgia, and arthritis.

The most common verminosis (infestation with or without obvious symptomatology of disease caused by parasitic worms) is intestinal. People who have them not only suffer from a large quantity of lost nutrients (absorbed by the parasites), but also from perforations made by worms in the digestive tract that can open the door to various infections and possible autoimmune deficiencies. Intestinal worm infections are very common and can affect everyone, not only people with poor hygiene habits. Helminths (worms) are transmitted by ingesting the eggs or larvae of parasites, which then hatch in the intestinal tract.

A parasitic infection or reinfection can be acquired through one or more of the following avenues:

- From more or less direct contact with an infected person (fecal or sexual).
- From self-infection, for example, through anal-hand-mouth contact. By scratching the anal area, eggs can become lodged under the fingernails.
- From congenital transmission (mother to fetus).
- From commonly contaminated objects.
- From soil contaminated by human or animal excrement.
- From eating contaminated raw or undercooked meat.
- From eating raw fish.

In some countries, raw fish is included in traditional foods. We can avoid the consumption of the larvae or worms by freezing the meat or fish for at least twelve hours, depending on temperature.

A great photo of a dead parasite, believed to be the Ascaris lumbricoides, or possibly a rope worm in the "seaweed" stage.

A very good look at how long some helminths are. The more worms the people pass, the healthier they get, and the improvements come faster and faster. This child passed a lot of parasites in the beginning. Then after a few months was no longer passing them and now has an ATEC score of 5. Meaning, he no longer has the diagnosis of autism.

This is the parasite that measured 32 inches.

Another long, well washed parasite for the collection. The road to recovery is paved with many dead parasites. Adios Autism…

This is a 32-inch parasite that a young boy passed. He went on to have a great day after getting this out.

These are rope parasites as confirmed by Dr. Alex Volinsky.

60cm long worm (Oct 1, 2013) from child; 6 months on CD; 2 drops every 1-2hr; no parasite protocol; 1tblsp DE; 2-3 vials of Quinton.

This 33 inch parasite (aka "Chester") was discovered by a woman using the protocol on herself.

The bubble visible in this photo leads us to believe this is a late stage rope worm.

After passing this parasite, the child went on to have a fabulous day at school. It is so great to feel good and healthy.

The FDA recommends freezing and storing [fish] at -4°F (-20°C) or below for seven days (total time), or freezing at -31°F (-35°C) or below until solid and storing at -31°F (-35°C) or below for 15 hours, or freezing at -31°F (-35°C) or below until solid and storing at -4°F (-20°C) or below for 24 hours is sufficient to kill parasites. FDA's Food Code recommends these freezing conditions to retailers who provide fish intended for raw consumption. Note: These conditions may not be suitable for freezing particularly large fish (e.g. thicker than six inches).[2]

- From drinking contaminated water.

- From consuming contaminated vegetables or fruits. Often we eat poorly washed (parasite infested) vegetables or fruits. There is a common misconception that vegetables from organic farming are free from any problems, pesticides, or chemicals. The danger is that the eggs or larvae of the worms reach the farm soil through animal waste, decomposed forms of natural compost, and manure (fertilizer) added to the field. There are eggs, such as Ascaris lumbricoides, which can survive in soil under extreme temperatures for five years. It is very important to perform a thorough cleaning of fruits and vegetables, and never eat anything raw and straight from the ground, however healthy it may seem.

- From parasite infested animals. Parasitic infections are very easy to spread by contact with pets. Veterinarians are quick to insist upon the quarterly deworming of our animals, but there are steps we must take on our own to avoid contamination.

Parasites come in all shapes and sizes. Of course, they can also come out in pieces.

Suggested: Deworm your pet at least every three months for life, as directed by your veterinarian. During the first month, it should be done every week. Prevent pets from eating raw viscera. If animals eat raw meat or raw bones the best option is to freeze the food in advance for at least 12 hours (See citation above). If the deworming treatment is working, the animal will expel the worms in the feces or vomit, which must then be burned or buried, during the eight-day treatment.

Avoid being licked in the mouth by animals as they are in direct contact with feces, soil, and their own anus. When petting an animal, wash your hands with soap and water before eating or handling food, as the eggs of the parasites remain in the animal's hair.

- Do not walk barefoot or with open toe shoes in soil or sand.
- Avoid Hippotherapy (horseback riding)

Symptoms of Parasitic Infections

The different types of worms and toxic waste produced by parasites in our body may cause the following common problems:

Parasites come in all sizes. Some are very long. These get washed with hot water for photos. This way we get the best look at them.

Blood Disorders & Blood Parasite Diseases

Parasites absorb essential nutrients from the body, such as iron, vitamin B_{12}, and sugars, which may result in certain blood disorders. In addition, some diseases are known to be caused by blood parasites:

Blood disorders:

- Anemia
- Dizziness
- Hypoglycemia
- Weakness

Blood parasite diseases:

- African Sleeping Sickness
- Babesiosis
- Chagas Disease
- Malaria

Fatigue:

The toxic waste produced by the parasites themselves (including ammonia and psychoactive substances), can stress the detox organs and cause disorders of the central nervous system such as:

- Chronic fatigue syndrome (CFS)
- Cold in the extremities
- Dizziness
- Extreme weakness
- Internal cold
- Lethargy
- Low energy
- Night waking
- Restless sleep

Gastrointestinal Symptoms

- Abdominal pain or tenderness
- Blood in stool
- Burning in the stomach
- Chronic constipation
- Chronic diarrhea or diarrhea caused by poor absorption of food
- Colitis
- Cramping
- Cravings for greasy foods and sugary foods, lots of carbs and bread, fruit, fruit juices, alcohol, or vinegar
- Digestive problems
- Distended belly
- Eating more than normal but still feeling hungry
- Excessive bowel movements
- Fever
- Frequent vomiting and nausea
- Gas and bloating (noted after eating)
- Hemorrhoids
- Irritable bowel syndrome (IBS)
- Intestinal irritation
- Intestinal obstruction
- Leaky gut
- Malabsorption syndrome
- Mucous in stool
- Pancreatitis
- Passing a worm in stool

Growth Problems, Weight, & Appetite

Parasites usually live without being detected by the host. They rob the body of many of the essential nutrients in the food consumed. Many overweight people, who are infected with parasites, go hungry for lack of essential nutrients, causing them to eat in excess due to their parasitic infection. Furthermore, depending on the type of infestation, many people are malnourished and cannot gain weight. The following is a list of some possible symptoms:

In children:

- Poor growth
- Poor physical and intellectual development consistent with their biological age

In children and adults:

- Chronic burping
- Craving white flour products; cookies, cakes, pastries, etc.
- Feeling hungry after a meal
- Inability to gain or lose weight
- Long-term obesity
- Loss of appetite
- Obsession and/or compulsion to eat sweets or very specific foods (wheat, sugar, dairy)
- Ravenous appetite
- Uncontrollable hunger to eat more than usual
- Weight gain (specifically around the time of the full moon)
- Weight loss

Mood Problems & Anxiety

Toxins that are released by parasites can irritate the central nervous system. Anxiety and nervousness are often caused by parasites that migrate throughout the body. Some of the problems caused are:

- Anger and irritability
- Anxiety
- Confused thinking (brain fog)
- Depression
- Disorientation
- Forgetfulness
- Lack of coordination
- Mood swings

- Nervousness
- Obsession
- Restlessness
- Slow reflexes

Muscle & Joint Pain

Parasites can travel almost anywhere in the body. When they migrate to the joints and the muscles they can cause cysts and inflammation. These can often be mistaken for arthritis and/or muscle pain.

Toxins from parasites can also accumulate in the joints and muscle tissue causing:

- Chest pains
- Fibromyalgia
- Joint pain
- Muscle cramps
- Muscle spasms
- Numbness of the hands or feet
- Pain in the back, thighs, or shoulders
- Pain in the navel
- Rapid heartbeat
- Restless leg syndrome
- Seizures

Parasites in Children (including children with ASDs)

Parasites can be found in the body in asymptomatic and symptomatic stages. The former are usually found in adults. Symptomatic stages occur mainly in children, in whom we can often observe the following:

- Anorexia
- Anxiety
- Bruxism (teeth grinding)
- Cramping
- Diarrhea that alternates with periods of constipation
- Excessive Flapping
- Growth retardation
- Headaches
- Inability to gain weight
- Itching/Burning/Picking of the anus
- Nasal itching and/or anal urticaria (hives/rash)
- Nervousness and irritability

- Nose Picking
- OCD (Obsessive Compulsive Disorder)
- Rage
- Smearing feces
- Unexplained laughter or weeping
- Verbal stims
- Weight loss

Tapeworms, and some other parasites, have an affinity for B_{12} and iron. Therefore, lab results that show deficiencies in B_{12} and/or iron can be indicators of parasitic infections.[3,4] Due to its size, the tapeworm consumes enormous amounts of food that it obtains by taking the child's food. This can affect the child's normal development.

Treatment is simple, but it requires that the head of the tapeworm be removed, otherwise it will continue to grow. Tapeworm treatment is separate from this protocol and usually requires niclosamide. However, the only way to be sure the head has been removed is to identify it in the stool.

Respiratory Disease

The passage of larvae through the respiratory system or larval invasion in the lungs may cause symptoms such as:

- Acute bronchitis
- Asthma
- Drowsiness
- Dyspnea (shortness of breath; air hunger)
- Chronic/irritative cough
- Pneumonia
- Shortness of breath or respiratory failure

Sexual & Reproductive Disorders

Immune dysfunction as a result of a parasitic infection can lead to:

- Candida - yeast infections
- Cysts and fibroids
- Erectile dysfunction
- Fluid retention
- Male impotence
- Menstrual problems
- Premenstrual syndrome
- Prostate problems
- Urinary Tract Infections

Skin Disorders & Allergies

External parasites (lice, bedbugs, scabies, etc.) that penetrate the skin can cause itching, redness, and/or rashes etc. However, internal parasites can be responsible for skin disorders as well. Parasites create toxic metabolic waste, and because the skin is the largest organ, the body tries to eliminate them through it, resulting in many skin problems.

Some symptoms may include:

- Allergies (to foods, dust, mold, etc.)
- Anal itching
- Brittle hair
- Crawling sensation under the skin
- Dermatitis
- Dry hair
- Dry skin
- Eczema
- Eruptions
- Hair loss
- Itchy nose
- Itchy skin
- Jaundice
- Psoriasis
- Skin ulcers
- Sores
- Swelling
- Urticaria (hives; skin rash)

Sleep Disorders

The body reacts to parasites during rest periods because at night is when parasites are most active. Nocturnal awakenings are common, especially between 2 and 3am, when the liver tries to rid the body of toxins produced by parasites. This in turn may produce:

- Insomnia
- Teeth grinding
- Bedwetting
- Drooling while sleeping
- Sleep disturbances - multiple awakenings during the night
- Restless sleep

Other Problems Associated with Parasites

- Bad breath
- Blurred vision
- Body odor
- Breathing problems
- Chronic infections: viral or bacterial
- Circulatory problems, numbness in the extremities, difficulty in moving
- Cough or coughing up blood
- Difficulty swallowing
- Excessive salivation
- Fever
- Fluid build-up or retention during the time of the full moon.
- Low immune response
- Peritonitis
- Sensation of a foreign body or discomfort in the throat
- Swollen eyes
- Weight gain during the full moon.

Blood Analysis

The following markers may be present when a person is suffering from a parasitic infection or the resulting allergies:

- Anemia/low iron
- Elevated immunoglobulin (IgE)
- Elevated eosinophils (The eosinophil is a specialized cell of the immune system, more specifically it is a proinflammatory white blood cell. According to the Registry for Eosinophilic Gastrointestinal Disorders (REGID), their known functions include movement to inflamed areas, trapping substances, killing cells, antiparasitic, and bactericidal activity, participating in allergic reactions, and modulating inflammatory responses.)
- High ammonia
- High oxalates
- Low vitamin B_{12}

Measures in the Home Environment to Prevent Reinfection

It is important to treat all people and pets that live in the same environment to prevent someone from infecting others. Reinfection occurs via underwear, bedding, towels and household items such as children's toys or animals that have been in contact with eggs. It is important to wash all clothing that has contact with intimate body areas at a temperature not below 60°C (140°F).

All bed linen and underwear must be washed daily (or to the extent possible) while performing anti-parasitic therapy. Affected individuals should not share their swimwear with other members of the family, and should use a separate cloth to wash his anal area. It is best to sleep wearing both underwear and pants to avoid involuntary scratching during the night. This will prevent infection through anal-hand-mouth contact because by scratching the anal area, eggs can become lodged under the fingernails. Keep pets away from the place of rest of their owners, such as beds, sofas, blankets, and cushions.

Thoroughly wash fruits and vegetables in water and soak them in CD or CDS solution for a few minutes. Clean the sink with alcohol, as the eggs of many parasites are immune to the pH of normal cleaning products such as soap or bleach. It is important to note that parasites do not leave any kind of immunity behind in the host, therefore, once cured, the person who has suffered can suffer from them again. The only surefire method of killing the eggs of *Ascaris lumbricoides* is in water above 60°C (140°F) or with 96% grain alcohol (Everclear).

Evolutionary Cycles of Intestinal Parasites

Although there are many more, here is a description of the three most common types of intestinal parasites that can be found in developed countries:

Ascaris Lumbricoides **(Roundworm)**

Ascaris reproduce quickly, as a single female can lay up to 200,000 eggs each day. This parasite is very common, especially in damp conditions, and when hygiene measures are inadequate. It can affect the entire population, but mostly affects children, seriously disrupting their development and growth. It's so infectious that the WHO estimates that there are about 700,000,000 people infected worldwide, of which around 60,000 cases end in death per year, mainly children.[5]

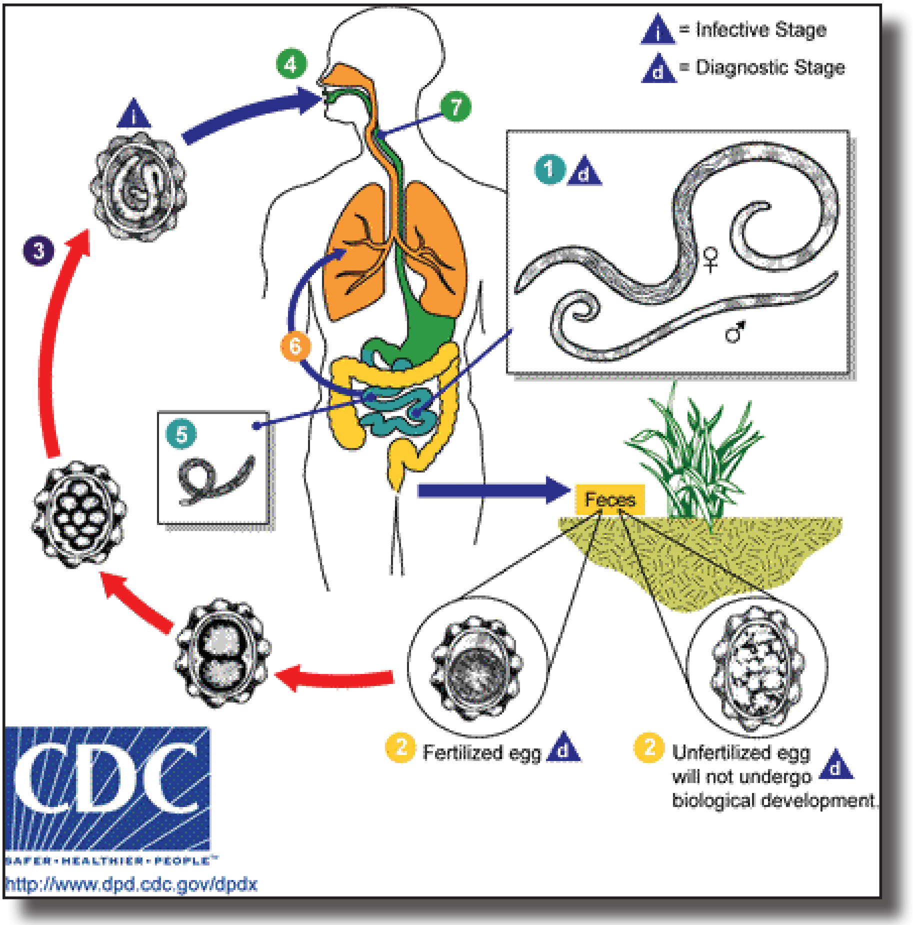
i = Infective Stage
d = Diagnostic Stage
4
7
i
1 d
♀
♂
3
6
5
Feces
2 Fertilized egg d
2 Unfertilized egg will not undergo biological development. d
CDC
SAFER·HEALTHIER·PEOPLE™
http://www.dpd.cdc.gov/dpdx

Parasite eggs reach the duodenum through the mouth of the host. Gastric juices rid the eggs of their shells and release the larvae. These larvae, which are highly mobile, penetrate the duodenal mucosa and migrate to the liver. From there, they continue their migration to the heart, reaching the lungs through pulmonary circulation, and finally become trapped in the pulmonary capillaries. Here, the larvae break the thin walls of the capillaries and penetrate the alveoli, bronchioles, and bronchi at which point they are able to travel up through the pharynx. Once the eggs pass the epiglottis (see diagram above), the larvae are swallowed such that they return to the duodenum, where they complete their maturation process. This process takes approximately two to three months to complete; therefore we calculate that to find ourselves completely parasite free, the initial treatment should be done for at least 12-18 months, possibly longer. From there on out, you may only need to follow a routine deworming two to four times a year.

Keep in mind that eggs are expelled through the feces (human or animal) into the environment where they can survive even in harsh conditions, favoring the persistence of the parasite. They are resistant to low temperatures, desiccation, strong acids, soaps, chlorine, formaldehyde (pH between 2 and 11.5), and can live in planted soils for five or more years, creating a "parasite hotbed" that makes them almost indestructible. Once dry, they are transported through the air, fly in air currents like dust that can be inhaled and/or swallowed. We have recovered eggs from nasal mucus, paper currency, potting soil, dust, and in indoor airborne particles, etc.

Taenia Saginata and *Taenia Solium* (Tapeworm)

Taenias reach humans when humans eat their eggs, by the consumption of tissue from infected cattle or pigs. In infected animals, the larvae are encysted in the muscle tissue. If the infected animal is consumed, development may proceed in the human digestive system. Humans are hosts for *T. saginata* (beef tapeworm) and *T. solium* (pork tapeworm). The tapeworm is considered to be solitary, because usually no more than four species are found in any one individual host. The danger of this parasite is that the larvae can migrate to the brain, or other vital organs (cysticercosis). Tapeworms may be detected by identifying segments in the host's stool that the worms discard as they grow. However, tapeworms may go undetected for many years, living asymptomatically within their host.

According to classification, they can vary in size ranging from 2 to 12 meters in length. They consist of a head called the scolex, which attaches to the intestine by means of suction cups, and a body consisting of repeating units called proglottids. A single Taenia can grow from 1,000 to 2,000 proglottids, depending on the type. A tapeworm produces an average of 720,000 eggs per day.

Pinworms (*Enterobius Vermicularis*)

Humans are considered the only host of what are commonly called pinworms (*Enterobius vermicularis*). This type of worm is the most typical in the family because it propagates easily. It is common for children to become reinfected in schools, through contact with others, or through anal-hand-mouth contact. Pinworms have an elongated shape, are whitish in color, and are about 1cm long. They inhabit the large intestine of humans. Female pinworms leave eggs around the anus. Once deposited, the eggs are infectious for a period of up to 20 days. Once in the intestine, it takes between five and eight weeks to develop into adult worms. The most important symptom is intense itching that occurs in the anal area, especially at night. In women, inflammation of the vulvar area is very common.

A pinworm infection is, generally speaking, not very serious. Unlike other parasites, they infect only humans. Transmission from person-to-person happens by handling clothing, bed sheets, towels, and environmental surfaces (such as curtains, carpeting) contaminated with pinworm eggs, which are so light that they are able to become airborne. A small number of eggs can be integrated into air particles that when inhaled follow the same developmental process as ingested eggs. Enemas are extremely useful in removing this parasite from the large intestine.

Graham's method is a simple method of detection. Just after waking and before a bowel movement, press a piece of tape against the anal folds. The tape will catch the remains of eggs and/or parasites that are situated there. With the naked eye we can see small worms no more than an inch long, but with a microscope, many transparent eggs from females and even other species may be seen.

The Importance of Lifelong Deworming

Once we begin the process of deworming, we should recognize that we must maintain this habit of cleaning for the rest of our lives to enjoy good health. It is common among people who have pets, to follow the recommendations of their veterinarians, and deworm their pets every three months. It is interesting to ask why family physicians do not give the same advice to humans. Perhaps some physicians ignore this information, or simply do not consider it important to eliminate these pests, which are just as harmful to people as they are for animals.

It is true that many parasites are not endemic or common outside certain climates, but human migration and global marketing of food products have facilitated the spread of many parasitic pests silently. It is important that we understand the lifecycle of each parasite, from birth to death including reproductive and death stages. This information is crucial for the complete elimination of the parasite. For example, in the case of intestinal parasites treated here with this protocol, some can live in the host for up to ten years, as in the case of a single Taenia, while others may remain in the host for a lifetime, reproducing again and again, as in the case of the pinworms or the well-known Ascaris.

The Kalcker Parasite Protocol & Lunar Cycle Timing

In the modern civilization in which we live, we have lost touch with much of the ancient wisdom of the past. One of the things we have forgotten is how the natural cycle of the moon influences many of nature's routines. This is especially true for the behavior of parasites. They are known to sync their life-cycle with that of the lunar cycle. Your child may demonstrate extreme behaviors on certain lunar cycle days… especially on the full moon and sometimes even the new moon.

Therefore, to maximize effectiveness, this Parasite Protocol is specifically timed to the lunar cycle. Appendix 10, page 477 provides an easy reference for you to look up the days to perform the Parasite Protocol, which is administered over 19 days—numbered 0 to 18—each month; starting three days prior to the full moon and continue during the waning moon. This period of the moon's cycle is very effective for deworming because many nematodes (parasitic worms) travel back into the intestine to mate at this time.

Length of Treatment

This protocol is not a one-time treatment. You should plan for at least 12 to 18 months to insure you have purged multiple parasite life-cycles and continue beyond 12 months if your child is still expelling parasites.

Building on CD

This protocol builds on what you have already learned using CD. During treatment, it is absolutely necessary to continue CD dosing, CD baths and CD enemas.

Tape Worms

This protocol is specifically designed for the deworming of large intestinal parasites, especially round nematodes such as Ascaris. It is effective for most nematodes, but may not be effective against tapeworms. In the case of infestation by Taenias, the recommended treatment is Niclosamide, the preferred medication due to its low toxicity.

Components of the Kalcker Parasite Protocol

This protocol uses some of what you have already learned and should already be doing, along with a set of ingredients you will need to have on hand before you start (shown in bold below). Here is an overview list of the items you will need to have on hand, and the items are described in detail on the pages that follow:

- Meal time (1, 2, 3)
- CD / CDS (4-19)
- CD Baths (20)
- CD Enemas (21, 22)
- Ocean Water (23, 24, 25) (see page 115)
- **Diatomaceous Earth** (26, 27)
- **Lepidium Latifolium Extract (Rompepiedras)** or **Chanca Piedra (Stone Breaker)** (28, 29)
- **Pyrantel Pamoate (Combantrin®)** (30, 31)
- **Mebendazole** (32-36)
- **Castor Oil** (37)
- **Neem** (39, 40)
- **Probiotic (usually THERALAC®)** (41)

Check the following website for the latest information on where to find these products:

www.ProtocolSuppliers.com

You may have noticed one or more numbers in parenthesis following each of the previous items, such as "(40)" for the probiotic. The timing of what to give when, is covered in great detail in the daily charts starting on page 198. These numbers match those found on the daily sample charts to make it easier for you to connect the dots and also be able to identify related notes under each chart. They have nothing to do with the quantity/dosing of any substance. The use of these numbers allows us to comment on specific items and when and where they come into play as shown on the daily sample charts.

We now detail each one of the items on the list above and discuss what you need to know about them and how to acquire them (including their associated numbers on the charts).

Meals (1, 2, 3)

Obviously meals are part of everyone's day. The purpose in mentioning them here is that many of the following steps are related to meal timing. Some actions or ingredients are taken before breakfast, others during or after.

In our example charts, we make some assumptions which include:

- Breakfast (1) is at 7:30am
- Lunch (2) is at 12 noon
- Dinner (3) is at 5pm

CD, CDS or CDH (4-19)

As you learned in Chapter 5, you continue to dose CD (or CDS/CDH) as before during the Parasite Protocol. Nothing changes in that regard with the Parasite Protocol building on top of those steps already in place.

The sample charts assume your child is going to school, and so you may not be able to administer doses of CD during his school day (7-12) unless you are home-schooling, in which case you are encouraged to give hourly CD doses, even if the total exceeds 8 for the day.

CD Baths (Optional) (20)

Our sample charts assume you administer a CD bath just before bedtime. See pages 113 for more information about CD baths.

CD Enemas (21, 22)

Ideally, give your child a CD enema in the morning (21) and another one in the evening (22). However, if your child is going to school, a morning (21) enema may not be a good idea due to the possibility of an "accident." Therefore, consider the morning enema optional, but the night time enema a must do! See page 103 for more information.

Ocean Water (23, 24, 25)

Supplementing ocean water minerals is important to support the body through the detoxification process. See page 115 for more information on ocean water.

Dosing:

(23) A dose of ocean water should be administered upon waking, but five minutes apart from CD dosing.

(24) One dose of ocean water immediately after school (or at lunch time if at home).

(25) One dose of ocean water, 15 minutes before or after dinner.

Diatomaceous Earth (DE) - Food Grade (26, 27)

Diatoms are unicellular plants that existed by the trillions in our oceans over 300 million years ago. They are encased by a cell wall that is made of silica. When diatoms die, this microscopic coating deposits at the bottom of oceans. Over time, they pile up in banks forming deposits thousands of meters in size. With the receding of the oceans, these deposits have been uncovered. Through compression, and ultimately fossilization, these silica deposits have given rise to a chalk rock called diatomaceous earth.

DE is an inert, nontoxic compound, which contains a number of minerals such as manganese, magnesium, iron, titanium, calcium silicates, and others. Properly ground, the skeletons of microscopic diatoms become sharp silica needles, harmful to parasites, fungi, yeast, worms, and amoebas. However, these needles are harmless to humans and other warm-blooded animals. Although it is safe to consume diatomaceous earth continuously, the best method (as with everything else) is to allow for periods of rest. During the 18-day treatment, take two teaspoons (5ml) twice a day.

Dosing: ½ to 1 teaspoon twice a day for smaller kids, 1 teaspoon three times a day for adults and bigger kids. Mix with a little water and drink. Given on days 1 through 18. DE mixes well with water but never dissolves. Stir the DE/water slurry vigorously and drink immediately before the DE settles to the bottom. Some people take heaping tablespoons in water, but larger amounts are not necessary. DO NOT take dry!

Note: In rare cases, DE can cause constipation, which can usually be managed by reducing the dosages to 1/2, 1/4 or even 1/8th of a teaspoon. If that doesn't resolve the issue, remove DE from the protocol and continue with all other directions.

Source & Cost: Search online for "Food Grade Diatomaceous Earth." Buy at least 1 pound and expect to pay about $20 more or less. Better yet, buy a five pound bag, which will reduce your cost per pound. DE does not expire or degrade, but should be kept in a dry container. Note: Diatomaceous Earth is often used as non-toxic element in pool filtration systems. You DO NOT want to use this kind of DE since it has been processed. Only get "Food Grade" Diatomaceous Earth!

Lepidium Latifolium Extract (aka Rompepiedras or Pepperwort) or Chanca Piedra (aka Stone Breaker) (28, 29)

1.7 fl.oz.
PEPPERWORT
natural extract
Lepidium latifolium L.
SoriaNatural
ROMPEPIEDRAS
PEPPERWORT
50 ml e/1.7 fl.oz.

50ml e
ROMPEPIEDRAS
extracto natural
Lepidium latifolium L.
SoriaNatural
ROMPEPIEDRAS
PEPPERWORT
50 ml e/1.7 fl.oz.

PHARM HERB
LIQUID HERBAL EXTRACT
STONE BREAKER
(Chanca Piedra)
COMPOUND
HERB PHARM
HERBAL SUPPLEMENT
1 fluid ounce (29.6 ml)

Lepidium Latifolium (Rompepiedras) and Chanca Piedra (Stone Breaker) both break up hard substances in the body. The reason we use it in this protocol is two-fold: It breaks up the protective outer coating of parasites, and annihilates oxalates, which many of our kids have an abundance of because oxalates are produced by parasites.

Note #1: It is often simply referred to as "RP" in our discussion forums.

Note #2: If you are having trouble finding this particular ingredient, don't let its absence stop you from starting the protocol with all other ingredients.

Dosing: 15 drops for a 100 pound child mixed in with the diatomaceous earth/water. Use seven drops for smaller children.

Source & Cost: You have a choice of two herb extracts; Lepidium Latifolium Extract (aka Rompepiedras or Pepperwort) and Chanca Piedra (aka Stone Breaker). One US source is www.mightyguts.com, which sells a 50ml dropper bottle of Pepperwort for about $30. A primary manufacturer in Europe is Soria Natural from Spain that labels their product Rompepiedras, while they also have an English labeled box that says Pepperwort. They both show Lepidium Latifolium on the box.

Pyrantel Pamoate (30, 31) (Trilombrin/Combantrin®)

Pyrantel pamoate is a broad spectrum anthelmintic, which works by causing a neuromuscular block that produces spastic paralysis of the parasite, and its subsequent expulsion by intestinal peristaltic action, without excitation of the parasites or encouragement of their migration. Pyrantel pamoate acts over a short duration, and tends to be completely eliminated from the body in the feces and urine within three to four days. Pyrantel pamoate is poorly absorbed from the gastrointestinal tract, and approximately 6 to 8% total is found in the urine, with the remainder in the feces. The recommended dose is one daily dose of 10 mg per kilo.

Pyrantel pamoate is incompatible with the use of piperazine, because the two substances neutralize each other. Thus Pyrantel pamoate should not be combined with pumpkin seeds, which contain piperazine, or with antiparasitic drugs that contain piperazine in their formulation.

Dosing: Pyrantel pamoate is given only twice during one cycle of the parasite protocol; once during breakfast on day one (30), and again during breakfast on day five (31). Dose is based on weight and calculated by multiplying your child's weight in kilograms times 10mg of pyrantel pamoate. To make it easy, refer to the following chart:

Pyrantel Pamoate (Trilobrin/Combantrin®) Dosing by Weight		
Pounds	**Kilograms**	**Dose in mg.**
20	9	91
40	18	181
60	27	272
80	36	363
100	45	454
120	54	544
140	64	635
160	73	726
180	82	816
200	91	907
220	100	998
240	109	1089

Pyrantel pamoate (often just referred to as Combantrin®) is available in three forms:

- **Liquid:** where each milliliter contains a certain number of milligrams. For example, one available formulation contains 144mg/ml. So a 100lb child would take 3ml.
- **Tablets:** where each usually contains 250mg.
- **Capsules:** where each usually contains 250mg.

You will have to read the label or the particular product you acquire and determine the milligrams to use.

Source: Combantrin® is available by prescription in the US. Most other countries have it available over the counter.

The preferred source of pyrantel pamoate is a compounding pharmacy, as to avoid coloring and flavoring. If you are unable to find it without coloring/ flavoring then I would personally use mebendazole for the entire 18 days rather than risk giving your child an ingredient which may cause regression.

Note #1: Some brands of Combantrin® include mebendazole. You want the stand-alone Combantrin®!

Note: #2 Pumpkin seeds should not be consumed with pyrantel pamoate because they neutralize its effects.

Mebendazole (Vermox®/Lomper®) (32-36)

Mebendazole is a drug used in treating diseases caused by helminths (parasites of the gastrointestinal tract). This drug prevents the parasite from using glucose, which results in a decrease in energy and therefore death of the parasite.

Mebendazole is a non-systemic drug which means it is only absorbed, to a limited extent, in the gastrointestinal tract (approximately 5 to 10%). However, if it is consumed with fatty foods then more absorption occurs.

Approximately 2% of the administered mebendazole is excreted in the urine, while the remainder is excreted in the feces. The appropriate dose of mebendazole may be different for each patient as it depends on the type of parasite causing the infection.[6] The most frequently recommended dose is 100mg for children, 200 mg for adults, two times a day for seven of the first nine days of the Protocol.

Adverse effects from mebendazole are generally rare due to its poor absorption. However, it may cause nausea, vomiting, abdominal pain, and diarrhea. Normally these effects are in fact a result of the release of toxins from the very death of the parasite itself. Anti-parasitic drugs can be administered very effectively by diluting them in water, putting the mixture in a small bulb enema, and inserting the anally. This is especially suitable in the case of oxyuriasis (pinworms). Read more about this "implant method" on page 220.

Dosing:

Note: Indicated weights should only be considered a rough guide.

Small Children (20-40lbs.): Days 2, 3, 4, 6, 7, 8 & 9 — Take as little as 25mg of mebendazole with breakfast and dinner, and do NOT do a blitz on Day 9.

Children (41-70lbs.): Days 2, 3, 4, 6, 7, & 8 — 50mg with breakfast and dinner. On Day 9 they can take 50mg, 50mg and 25mg.

Adolescents (71-100lbs.): Days 2, 3, 4, 6, 7, & 8 — 100mg during breakfast and 100mg during dinner. Day 9 is "Mebendazole Blitz Day" where you administer ONE 200mg dose during breakfast; ONE 200mg dose at lunch; and a final 100mg dose at dinner.

Teens & Adults (101 lbs. and up): Days 2, 3, 4, 6, 7, & 8 — 200mg during breakfast and 200mg during dinner. Day 9 is "Mebendazole Blitz Day" where you administer ONE 500mg dose during breakfast and no dose at lunch or dinner for the remainder of the current cycle.

Source: Mebendazole is available by prescription in the US and over the counter in other countries.

Note #1: Some brands combine mebendazole with Combantrin®. You want the stand-alone mebendazole!

Note #2: Mebendazole is mostly sold in tablet form, but it is also available in liquid. DO NOT buy the liquid form—stick with the tablets! I have seen horrible reactions from the "inert" vehicles used in the liquid products.

Castor Oil (37)

Apollo
CASTOR
OIL

Castor oil is extracted from the seed of a plant called Ricinus communis ("Higuera del diablo"). Its seeds contain between 50-80% oil, which has a high content of ricinoleic acid, which has excellent laxative and purgative properties. Once you begin anti-parasitic treatments, spastic paralysis may occur in some parasites and many together may form a "knot" of worms that can cause intestinal obstruction. It is important to help your body purge them by using castor oil. Castor oil should be taken in the morning, two hours after breakfast and other medications. If your child goes to school they take it as soon as they walk in the door from school. A typical dose for a child is 1/2 tsp to 1 tsp, or up to tolerance. The adult dosage is 15 to 30ml (two tablespoons), two hours after breakfast and other medications. If you experience any intestinal distress, mineral purgatives such as Epsom salts, or vegetable purgatives such as senna leaves, can be used.

Castor oil is also available in gelcaps for those who dislike the taste.

Dosing: The amount to administer varies and really depends on the individual's tolerance. A good starting point is ½ teaspoon for smaller children and up to two tablespoons for larger children and adults. Only experimentation will determine the right amount, if castor oil causes diarrhea.

Source & Cost: Readily available in liquid form at most pharmacies in the laxative section. Usually under $10 for 16oz. Also available online.

Neem (Azadirachta indica), Caps or Tea (38, 39)

PREMIUM
Nature's Way
HERBAL
Neem
Leaves
100 Capsules / Certified 475 mg
DIETARY SUPPLEMENT
Recommendation: Take 2 capsules three times daily, preferably with food.
Supplement Facts
Serving Size 2 Capsules
Servings Per Container 50
Amount Per Serving % Daily Value
Total Carbohydrate 1 g <1%†
Neem (leaf) 950 mg **
Other ingredients: Gelatin (capsule)
Actual Capsule Size

The neem tree is a great natural inheritance of mankind. References in Sanskrit scriptures and ayurvic medicine practices indicate the use of neem since ancient times in Hindu medicine. Even today, Hindus living in rural areas call the neem tree the "village pharmacy" for its ability to alleviate many diseases and is currently endorsed by authorities in India for its use in medicinal preparations. Neem is one of the purifying and detoxifying plants with the greatest potential. Neem has been used to combat all forms of body parasites, external and internal parasites alike. To prepare neem, boil four leaves (normally the contents of an envelope) in one liter of water for five minutes. Drink the tea throughout the day over the course of each parasite protocol.

Dosing: Neem is given each parasite protocol from day 10 through Day 18.

You have a choice of caps or tea. I prefer caps over tea because the taste is strong and unpleasant, so some kids will buck drinking tea.

Caps (assuming 475mg each): An adult takes six in a day, three times two caps at meal times.

Follow the directions on the bottle. Give a full dose for teens and adults 100 lbs. and over. Small children receive ¼ to ½ dose.

If using caps, give one dose during breakfast and one dose at dinner.

Tea: Give four doses throughout the day. Prepare a tea from the leaves, one tea bag in one liter of water (add stevia if needed to cover some of the bitter taste). One tea bag usually contains approximately four leaves. If using loose leaves, then make one liter of tea with four neem leaves. If using crushed leaves, then use approximately one slightly heaping teaspoon.

Neem Tea Dosing

Weight of Person	Total Daily Amount (To be split into 4 doses)
20-34 lbs	100 ml
35-49 lbs	200 ml
50-64	300 ml
65-84	400 ml
85-109	500 ml
110 and over	600 ml

Source & Cost: Neem capsules cost about $8 for 100x 475mg caps. Look in your local health food store. One popular brand in the US is Nature's Way®. BioPure™ sells a product called *Neem Synergy* which contains a few additional herbs that do not affect the neem.

Neem tea can be purchased in bags or as dried leaves.

THERALAC® (Probiotic) (40)

THERALAC® is a probiotic that should be given during the parasite protocol to help reestablish good gut flora. Ideally, it is rotated every other month with THERALAC® TruFlora®.

The key reason for recommending THERALAC® over other probiotics is explained in this paragraph excerpted from their website:

> *THERALAC® probiotics survive transit through the harsh acidity of the stomach and arrive alive in the intestinal tract. THERALAC's ACID PROOF™ technology utilizes sodium alginate from seaweed in a unique formulation that assures survival at pH 1.6 for 90 minutes, the most severe stomach acid conditions normally experienced. Other probiotics that claim acid resistance are tested at pH 2.5 – 3.0, or >10 times less acidic than pH 1.6 – not a fair test. THERALAC's ACID PROOF® technology is protected by US Patents 7,122,370 and 7,229,818. This technology goes beyond resisting stomach acid and involves keeping the probiotic cells together in a viscous alginate-gel moving in group-force, not as separate individual cells like other probiotics, deep into the intestinal tract while retaining key formula ingredients, LactoStim® and Sodium Alginate in close proximity.*

Dosing: One capsule of THERALAC® is given each and every night at bedtime, irrelevent of age/weight. This probiotic is also to be given outside of the 19 Parasite Protocol days.

THERALAC® can be given at the same time as CD if your child swallows capsules. However, if you are using the THERALAC® powder form then give it at least five to ten minutes after the last CD dose of the night. See their website for more information about the powder form.

Special exception: Some people do not tolerate probiotics, in which case we have no choice but to leave them out. In some of these cases, sauerkraut and fermented veggies may help to cultivate beneficial bacteria.

Source & Cost: Amazon carries "THERALAC® 30 caps by Master Supplements Inc." for $37.

Sample Parasite Protocol Daily Calendar

To assist you in understanding the Parasite Protocol and how it changes from day to day, we have prepared the following visual set of daily charts showing how all the pieces fit together. To prepare this set of charts, we made up the following times for example purposes only:

- Your child's awake time is between 6am and 10pm.
- Breakfast is at 7:30am
- Your child goes to school, which starts at about 9am
- School is out at about 2:30pm
- Dinner is at 5pm

As stated earlier, each dose or activity is labeled with a unique number. Those numbers relate to notes below each chart AND they match longer descriptive notes in the previous pages.

You are encouraged to copy/enlarge the blank chart in Appendix 9 (page 475) and workout your real-life schedule based on these example charts.

Refer to the lunar calendar (Appendix 10, page 477) for the exact days the protocol should be followed, as well as to get an idea of behaviors related to parasites around the full and new moon.

> After four years of biomed and no major gains, we decided to try mms/cd protocol. We started in April and are currently on our second parasite protocol. Initially, we were really intimidated by the enema part but realized if we were apprehensive our 7 yr old daughter would pick up on that. We told her that what we were about to do would help her feel better we gave her the iPad right before the procedure and a new fav toy (beanie boos) and she was game. After it was over she said "no more booboo in my tummy". We all cried. To make a three-month adventure short and sweet, her team at school cannot figure out how her fragmented speech has gone from 2-3 word utterances to long, drawn out sentences. Her expressive language and receptive have increased. Her auditory processing speed has quadrupled. The most amazing part thus far has been the increase in social skills. Or just the fact that she is interested in engaging. Socially she was nonexistent and is now at a four year old level. We just spent a week with family and she was saying hi and engaging without being prompted!!! She now has a million questions, wants to know when and where we are going and the sequence in which events will take place. All this from a girl who never asked questions before mms! STOP thinking about trying! Just Do It!! For the first time in seven years, I can hear the bells of freedom ringing!!!! Thank you Kerri Rivera !!!!!

Day 0 (3 days before Full-Moon)

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1											
8:00 AM		6										
8:30 AM												
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
11:30 AM												
12:00 PM	2											
12:30 PM												
1:00 PM		11										
1:30 PM												
2:00 PM		12										
2:30 PM												
3:00 PM		13			24							
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3											
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 0 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
40	Probiotic at the end of the day

Day 1 (2 days before Full-Moon)

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28	30				
8:00 AM		6										
8:30 AM										*		
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
11:30 AM												
12:00 PM	2											
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2:00 PM		12										
2:30 PM												
3:00 PM		13			24					37		
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29					
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 1 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
30	Dose of Combantrin with breakfast
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
40	Probiotic at the end of the day

Day 2 (1 day before Full-Moon)

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
8:00 AM		6										
8:30 AM												
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
11:30 AM												
12:00 PM	2											
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1:30 PM												
2:00 PM		12										
2:30 PM												
3:00 PM		13			24							
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29		33			
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 2 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
40	Probiotic at the end of the day

Day 3 (Full-Moon)

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
8:00 AM		6										
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1:00 PM		11										
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2:00 PM		12										
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3:00 PM		13			24					37		
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4:00 PM		14										
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5:00 PM	3					27	29		33			
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 3 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
40	Probiotic at the end of the day

Day 4

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
8:00 AM		6										
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3:00 PM		13			24							
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4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29		33			
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
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9:00 PM		19	20									
9:30 PM												40

Day 4 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
40	Probiotic at the end of the day

Day 5

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28	31				
8:00 AM		6										
8:30 AM										*		
9:00 AM		7										
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10:00 AM		8										
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3:00 PM		13			24					37		
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4:00 PM		14										
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5:00 PM	3					27	29					
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6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 5 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
31	Dose of Combantrin with breakfast (NO Mebendazole today!)
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
40	Probiotic at the end of the day

Day 6

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
8:00 AM		6										
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4:30 PM												
5:00 PM	3					27	29		33			
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 6 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
40	Probiotic at the end of the day

Day 7

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
8:00 AM		6										
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4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29		33			
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 7 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
40	Probiotic at the end of the day

Day 8

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
8:00 AM		6										
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9:00 AM		7										
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5:00 PM	3					27	29		33			
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 8 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
40	Probiotic at the end of the day

Day 9 (Mebendazole Blitz Day)

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		34			
8:00 AM		6										
8:30 AM										*		
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
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12:00 PM	2											
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1:00 PM		11										
1:30 PM												
2:00 PM		12										
2:30 PM									35			
3:00 PM		13			24					37		
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29		36			
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 9 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
34	Blitz Day - Small Child Dose 1: 200mg Mebendazole with breakfast. Teen/Adult Dose: 500mg Mebendazole with breakfast ONLY!
35	Blitz Day - Dose 2: 200mg Mebendazole with lunch (or right after school) Teen/Adult Dose: N/A
36	Blitz Day - Dose 3: 100mg Mebendazole with dinner. Teen/Adult Dose: N/A
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
40	Probiotic at the end of the day

Day 10

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
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9:00 AM		7										
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2:30 PM												
3:00 PM		13			24							
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 10 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Start dosing Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 11

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
8:30 AM												
9:00 AM		7										
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10:00 AM		8										
10:30 AM												
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2:30 PM												
3:00 PM		13			24							
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 11 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 12

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
8:30 AM										*		
9:00 AM		7										
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5:00 PM	3					27	29				39	
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6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 12 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 13

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
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3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 13 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 14

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
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5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
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9:00 PM		19	20									
9:30 PM												40

Day 14 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 15

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
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9:00 AM		7										
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2:30 PM												
3:00 PM		13			24					37		
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
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6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 15 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 16

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
8:30 AM												
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
11:30 AM												
12:00 PM	2											
12:30 PM												
1:00 PM		11										
1:30 PM												
2:00 PM		12										
2:30 PM												
3:00 PM		13			24							
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 16 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 17

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
8:30 AM												
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
11:30 AM												
12:00 PM	2											
12:30 PM												
1:00 PM		11										
1:30 PM												
2:00 PM		12										
2:30 PM												
3:00 PM		13			24							
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 17 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 18

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
8:30 AM										*		
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
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3:00 PM		13			24					37		
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 18 (Last Day!) - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Parasite Protocol *Off Days*

Days "19" through to the next "Day 0" are "Off Days" where you discontinue parasite meds and herbs. Here's a simple chart showing what to continue doing and what to stop during this *off* time:

Continue with these:
CD / CDS / CDH Dosing
CD / CDS / CDH Baths
CD / CDS / CDH Enemas
Ocean Water
Probiotic

Stop these:
Diatomaceous Earth
Lepidium Latifolium
Pyrantel Pamoate (Combantrin®)
Mebendazol
Neem
Castor Oil

Of course this represents a hypothetical case and your situation may call for taking other meds or supplements.

Detection of Parasites in Stool

It is necessary to detect the parasites by observing the stool carefully. For that we use a small plastic basin, and a plastic stick or fork for examination.

Author's Note: One of the moms who is a part of our forum came up with some guidelines for processing your child's stool for parasite identification. She calls it, "Everything You Wanted to Know About Sorting Through Poop." Here are her suggestions:

Supplies:

- rubber gloves
- paper plates
- plastic forks (plastic sticks, chop sticks, or plastic back scratcher)
- a pen
- a coin
- toilet hat

I like to use a plastic "toilet hat" also known as a specimen collector or a specimen collection unit, which goes under the toilet seat and collects the stool before it sinks into the bottom of the toilet (available on Amazon.com).

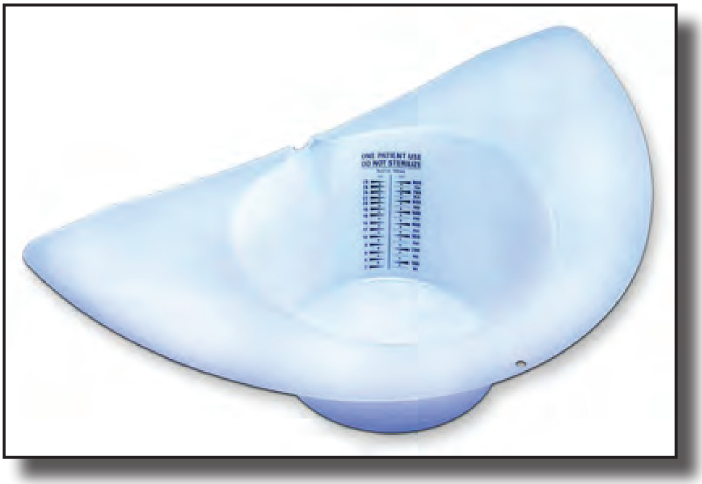

The Collection:

When your child poops, it is collected in the toilet hat (specimen collector). After I get my child cleaned up and taken care of, I remove the toilet hat from the toilet and put the specimen on a paper plate with my plastic fork. I have a look for anything interesting and then transfer that part to a clean plate using my trusty plastic fork. I discard the remainder of the specimen into the toilet, flush and put that dirty paper plate in the bathroom garbage. (We now line with kitchen garbage bags, and I change it after each of these poops.) On the clean plate with the suspected worm, I may add a bit of water and swish it around to get the worm cleaner. I then may transfer the worm to a third plastic plate to get a clear picture. On the clean plate with the washed worm, I write the date, and the initials of the person the worm came from. If you need help identifying the worm, place a penny next to the worm (for size context), snap a picture, and mail the image to kerri@cdautism.org, (Kerri collects the photos for documentation purposes, so send those worm pictures). Then flush the worm and put all paper plates, gloves, and fork in garbage and take it outside. Now, you can go find out what your child has gotten into while you were doing all this.

Clean Up:

Use HOT water (60°C/140°F), and sterilize with 96% (180 proof) grain alcohol (Everclear).

Microscope

It is very useful to have a microscope for diagnosis because it enables you to see both the small parasites that may appear in the blood, as well as eggs or larvae in the feces. This way we are more accurately able to determine if the number of parasites decreases. A simple microscope that costs about $100 is suitable for this kind of identification. The easiest method to determine what you see is to compare your sample to images you find on Google. This way you can enlarge the images, see various samples from different angles, and get a much wider variety of samples than if you were comparing a sample with many textbooks.

Bulb Enemas (aka "Implant")

To prevent anal itching from pinworms, night wakings, etc., you can use a bulb enema or small catheter/syringe with a dilution of 50mg of mebendazole in 10 to 15ml of water for small children, or 100mg of mebendazole in 15 to 20ml of water for larger children/teens/adults. The best way to do this is to introduce the medication together with the water in the rectum immediately before bedtime and hold overnight. If you are using the "implant," a morning enema is mandatory.

So we did the 100mg of Mebendazole with 20ml of water. He kept it in and we did it right before bed... Next day a ton of worms came out!!! Better yet he started singing songs with a tune - 3 different songs over the last 2 days and counting on his fingers very purposefully! His aide at school said he did amazing today - no behaviors, very focused, better articulation and better social interest.

The Worm Whisperer

The following words of wisdom are from a mom who has earned the nickname *The Worm Whisperer* (although her ability to destroy parasites may make the *Worm Ninja* more apropos). Her dedication and diligence have not only made the difference in the life of her son, but countless other children who are what she calls "extreme cases." The information presented here may be the difference between an older/aggressive child living with their family or going to a group home for the care that their family is no longer able to provide them. Thank you Robin, for being a pioneer and for never giving up. Thank you for having the guts, the know-how, and the generosity to share what you have learned with those who need it most.

Extreme Cases by Robin Goffe

This section is for older children who may be violent, self-injurious, destructive, physically aggressive, high risk and/or bedridden.

Some families have children who are older when they first start treatment. My son was 18 years old. We call ourselves the "last chance" group. We say this because our children have lived their whole lives infested, unbeknownst to us. Our children lived as happy, relatively easily manageable, learning-disabled children: perhaps slightly annoying with their routines of movie dialogue scripting or attachment to Disney movies, maps, or little known facts. They were mostly friendless but pretty easy to take care of. However, during the hormonal teen years, things took a grave turn. We may have chalked up their newfound solitude to just giving up socially for lack of friends. They did not fit in. We had no idea that something else was brewing. The hormones within them began to have a bitter war with the parasites living inside them, and a war would soon break out. Their mental state would diminish considerably. What we are faced with are grown, strong children who are mentally ill and violent, self-injurious, and destructive. Some have even become so ill that they had to stay in bed.

This "last chance" is an opportunity to try ONE MORE THING before putting them in a group home; to give them away—for their own safety and the safety of their families.

These things that I am going to share with you are unique to the standard treatment outlined in the book. It is a more aggressive treatment because it is needed. Our children are so highly infested that it is shocking to tell you what we have found. There is a lot to do, but there is a method. It is time

The Goffe family.

consuming and it is a lot of work. But here I will outline what we did to get our son from an aggressive, self-injurious, destructive young man to one who has regained patience, language, understanding, and reasoning; but best of all, the opportunity to remain in our home. With continued treatments, he has the hope for a future: a job perhaps, and maybe even a family of his own.

Beginning treatment for the older child and especially one who is aggressive, self-injurious, violent, and destructive is one done starting low and slow.

Day one = one drop.

I kept a very detailed journal, and I will simply tell you what we did. I will tell you what worked for us and what did not. I will also tell you what I shared with others that worked for them as well. I am not a physician. I am not a chemist. I am a mother in love with my son and his utmost comfort was my main concern. My only goal was to clear his parasites. I had no idea that the things I learned by digging through his stool for 9 months would eventually give me the nickname, "The Worm Whisperer." Although intestinal parasites have been around longer than man, and they are smart enough to live within a human being lifelong, they can go completely undetected. I was ready to plot out a war against them. By the beginning of our 9th month of treatment, I estimate that I had cleaned and examined 35 pounds (16 KG) of solid parasites. Hard to believe? I have 80% of them photographed. The last two months in jars total seven pounds and a running total of the combined length will be at over 200 feet (61 meters), at the publishing of this book. There is not a classroom in the world that can teach what I learned in my bathroom day after day in latex gloves and a hospital mask. There was a fan blowing on me to manage the stench and by the third week my gag reflex was under control.

I examined the parasites, the pieces, how did it die? What was my son feeling at the time? Was he violent? Sweating? Slapping his legs from the pain of the parasites moving around and torturing him from the inside? I needed to eliminate these worms without allowing them to cause my son pain as they were killed. I had no idea the monsters I was to face.

In March of 2013, we started our son on one drop of chlorine dioxide. One of the most feared things that the parents of adult sized children face is the dreaded enema. It is just not something that most of us grew up with as standard care. But even so, my husband and I knew it was something that made sense. There are toxins inside these kids. They must be flushed out. The bowel is the way out. So on the very first day and the very first drop, we also explained to our severely autistic child that we were going to help his belly feel better. Our son, by this time, was so severe in regression that I can only best explain him as non-human. He was no longer speaking, unable to react to us, had stopped answering to his name, and could no longer contain the saliva in his mouth. He walked with a 12-inch drool hanging from his mouth. He ate like an animal, glaring at us. He was frequently violent: jumping on cars and denting them in, kicking down fences and destroying property.

This was the child that we were going to start giving enemas to. If we could do it, anyone can.

Each day we went up a drop; two drops on day two, three drops on day three, and so on. He was edgy and tired. We went for walks, as per usual, to deal with his aggression, but by day seven he began to have a runny nose and had a great deal of fatigue. We were so happy since we knew this was a sign to look for; that the immune system was kicking in. He slept for about 15 hours as we woke him and dosed him every hour and by the next morning there were about 25 white, hairy, thin looking objects in his stool. We knew these were worms and that we had our answer. After three weeks we began to see 4-6 inch parasites in all shapes and sizes, yet the aggression continued. It was here that I learned that what we were experiencing was POWS (Pissed Off Worm Syndrome). By this point we were at 13 drops, and while we were killing the smaller parasites, we were only pissing off the larger ones. The parasites do not like their environment disturbed, and subsequently they cause distress to the host. Parasites excrete ammonia, (possibly, leading to hyperammonemia and possibly seizures), morphine, and a meth-like substance. As these toxins enter the body, they can also cause aggression and anger. We had many possessions broken during these tantrums. We stopped valuing material objects.

It was here that we were told about—double dosing. So even though our son was getting about the equivalent of two drops an hour, if we saw increased aggression, OCD or self-injurious behavior we would give him four (see page 103 for an explanation of double dosing). If he did not calm down, we gave him another four drop dose. This was the perfect return attack for the parasites. Within a few moments the aggression settled. His red face and wild eyes diminished, and we had made it past another hurdle.

We used the double dose method dozens and dozens of times over the following months, and this helped tremendously to curtail the aggression caused by the parasites.

By the third week of treatment, we were concerned about the time during the night that our son would not be getting doses. So for the next six months our family had a dosing schedule, dosing additionally at midnight, 2am, 4am and picking back up to hourly doses from 6am to 10pm. This schedule was shared by not only my husband and I, but also our son's siblings,who would also set their alarms and take their turns, while we all rotated lack of sleep.

By the second month we found that our son's behavior not only changed around the full moon but the new moon as well. The standard protocol uses mebendazole over the full moon. However, with the older, more aggressive children we have had success with including mebendazole over the new moon cycle as well. These mini mebendazole courses feature shorter bursts of 5-6 days each, over the new and full moons beginning four days before each. We also deemed it necessary to start earlier in the moon phase than with the younger kids, since the infestation was greater, and the parasite movement occurred earlier, causing behaviors sooner.

For the child that has aggression, every parent must remember that the behavior is parasite related. During treatment you will see a variety of behaviors stemming from the parasites attempting to control their environment aka—the host. We found that increasing the frequency of the dose dampened the violence and aggression. It can be difficult to trust your child who is lost in a rage. You feel deceived and hurt. Those were our frequent emotions as well. It does pass. It took about 4-5 months for the rages to stop. They happened everywhere and were happening even on the toilet while trying to expel the parasites. Have a plan. Music worked very well for us. So did reading books. Find something to distract, and always give soothing, comforting tones. We frequently told our son how much we loved him and we rubbed his head and back. These herxing behaviors may be avoided through the use of a new method of preparing CD called CDH (see Chapter 7, page 155 for more info on CDH).

CDH: This new preparation method has really been a huge asset for the older kids that need to go higher in drops. At around 20 drops, the volume of the regular CD became unpleasant, making some children nauseous. My son was one of them. With the CDH preparation, I firmly believe that the older, tough-nut children will have more success with getting to the appropriate levels needed to start expelling the larger parasites. It is my personal belief that the amount needed in many of the non-seizure older kids with aggression, violence, self-injury, and destruction to be between 75-100ml of CDH daily. This amount may have a connection to the voltage needed in order for the mitochondria in the white blood cells to be given the power to not only kill the parasites, but to also destroy the bacteria. The job is two-fold, and must be done quickly as once the parasite is dead, the bacteria want to devour them immediately. I say these things because I have seen the condition of the parasites every day. I found that if I can kill the parasite with the least amount of disturbance or preparedness by the parasite, then there is no time for them to fight back and cause herxing. The bacteria also come into play and must be dealt with. Higher amounts of CDH kill both, without so much as a frown or a concern on the face of my son.

Stevia: I found that by adding the sweetener stevia to the CDH, the process can be more pleasant and does not affect the properties or effectiveness of the dose. As proven by Lamotte ClO_2 test strips (see page 467 for information on using the test strips).

Humidifier: In the beginning months, the infestation level is so high that nightly doses may have to be sacrificed in order to start breaking down the will of the parasites. It is not about seeing them every day, but slowly and consistently breaking their will. The constant aggressive irritation of the CDH will kill parasites, stopping them from making gains. There is another layer of nighttime treatments, and that is the humidifier. We fill a cool air humidifier that holds one gallon of water, and put 35 drops of activated CD (NOT CDH) and let it run all night near our son's head. This too was a method we used for maximum parasite elimination.

Spices and Herbs: It is urgent that we work constantly with our older kids to rid the body of parasites and pathogens. We have found that for kids that can easily swallow pills, filling empty gel capsules with the recommended herbs and spices in this chapter under Other Medicinal Plants (page 231) helpful. We have found great results by filling the gelcaps with the variety mentioned there: black walnut, ginger, rue, wormwood, and yarrow and giving two to four different ones with each meal as a toxic feast to the parasites. Don't narrow your selection to those mentioned here—get them all. There is no plan or pattern. Use any combination.

Colonics: Professional colonics have been an important addition to healing and cleansing parasites in our older kids. We started these a few months after our son was accustomed to the routine enemas. This has been a wonderful addition, and we try to do at least one weekly. Some places will allow you to do inserts, and we have taken our CDH there working up to 50-100ml CDH with great success.

Limiting Undesirable Behaviors

Probiotics: If you are using probiotics and your child is aggressive or becomes aggressive after restarting the probiotics, consider removing them as a first step. There could be such a high infestation rate that the child's system does not distinguish between good bacteria and bad bacteria.

Enemas: CD enemas should start on day one of treatment for the aggressive/older child. Since they have such a high rate of infestation, it is necessary to clear the pathogens on a continuing cycle from the very beginning. Please follow instructions for enemas starting on page 103.

Diatomaceous Earth (DE): In some children, the DE may shred the larger parasites to death, causing them to spew additional toxins into the child's body, which results in herx symptoms. Discontinuing DE for a few months may help to ease the distress, and give a cleaner kill.

Salt Baths: There are times that the body is unable to pull out the toxins fast enough. Be careful about killing too fast (dosing without or not enough enemas). If you have done enemas, and there still seems to be distress, you can buy a 40-pound bag of plain pool salt, take 9 pounds of salt and put it into a hot bath. Allow the salt to dissolve and have the child soak for one hour. If the child sweats during the bath, this is a good sign, as it shows toxins are being pulled out. Do not use Epsom salts. They contain magnesium. Magnesium feeds parasites as well as biofilm. Plain pool salt is cheap, and helps to remove toxins.

Dandelion Tea: This is an incredible detoxing source as well. There have been times that our son was in and out of a salt bath all day drinking dandelion tea to get the built-up toxins out. This is a tea ready made by Traditional Medicinals® (traditionalmedicinals.com).

Tips on What to Expect During the Parasite Elimination

Intestinal parasites have been on Earth longer than humans. Their plan is to find a host, and to continue to create life. They have the home advantage by living inside of your child. There are many things that I have learned while at war with them. They have a plan and so should you.

Situations We Have Come Across

Peetox: As you kill the parasites, they are alerted that you have taken away their joyful life. As a result, they do things to the host to show their displeasure. One of the things the parasites do is to spew toxins, including a morphine-like substance that can cause your child to not feel that he needs to urinate or that he is urinating. Naturally, this can lead to accidents. This is not the child's fault, but only a part of the parasite elimination process. One of the most difficult things we did was to put our 18-year-old son in adult diapers. It was heart breaking because it felt that we were moving backwards instead for forwards. However, this was only temporary, and for his own dignity. Especially if they go to school; perhaps being in diapers for a while is the answer. Our son was in and out of them for about two months. This does end.

Sleepytox: As you are going higher in drops, the CD is assisting the immune system to get the parasites out. It will take a lot of energy to do this. Remember, your child is the host and there is a war going on! Sometimes, your child may be tired for days. Our son slept for nearly the entire summer at the beginning of his treatment. Allow the rest they seek. Now our son gets higher doses of CD on the weekends, and he is very tired and sleeps then, too. By Monday morning, we can usually get a big fat rope worm after our efforts. Sleepytox is great because you can get a lot done on your home "to do" list.

Behaviors/OCD/Tics: Some may become alarmed because their child starts having behaviors that they did not have before treatments, or they feel that the behaviors have gotten worse. Parasites have a plan. It is to stay alive and to procreate. They want their eggs to return back into a host to repeat the cycle. So, you may see behaviors of playing with feces, touching their anus to their mouth, trying to put their fingers into your mouth or another person. There are finger and nail chewing, and spitting. These are all parasite controlled behaviors. We have found that eliminating parasites helps to minimize this behavior and it will eventually subside. There may also be a mineral deficiency attached as well. We have found that giving PLENTY of ocean water can help to tame these behaviors. Our 19-year-old son gets over 200ml OW mixed with 400ml spring water per day.

POWS (Pissed-Off Worm Syndrome): POWS presents itself when you have been dosing, and your child seems weepy, is pacing, and/or unhappy. Sometimes it is really that you have pissed off the worms, but are not killing them. Always check with Kerri regarding your concerns. But many times the answer is to go up in drops not down. You need to kill them—not piss them off, or they will fight back.

Clear Zone: This time period can be about five to seven days before the full moon; once infestation is brought down after six months or more of treatment. You may be able to start seeing glimpses of your child being lucid. This is a good time for an ATEC test.

High Volume Eating: Often times, the kids reach a point where they realize that they have been starving. The parasites have been taking a bulk of their nutrients, causing their mental deficiencies. They may even be eating non-stop all day. It is tough to juggle the timing and effectiveness of the CD with the continued eating. Allowing the child to eat high volumes of food while dosing with CD will still kill the parasites, but the CD levels may not be high enough to avoid a herx. Though the parasites may be killed the CD level may not be high enough to also kill off the bacteria eating the dead parasite. One solution we found was to give our son homemade bone broth with ocean water many times a day. This will help to replace the lack of nutrients, meanwhile reducing the overeating enough to continue the CD without risking a herx reaction.

Weight Loss: Our son lost 50 pounds during the first seven months of treatment. He was very over weight at 5’9” and 200 pounds. The weight loss brought concern to people who had not seen him for long periods. During this time I estimate that 35 pounds was solid parasites. His stomach was very bloated, as was his face. Our children are full of parasites and pathogens (i.e., yeast, bacteria, etc.), and all of these things can make them gain weight or be bloated. Our son is now in the normal weight range for his height, and has a flat stomach.

Night Terrors: During the night you may see that your child has trouble settling down, or they may wake in the night screaming your name. They may even do night walking, possibly leaving out the front door in a sleepwalk state. We saw these behaviors years ago, as our son was heading into a higher infestation level. Now that we are on the healing end, many of the behaviors return as sort of a rewind. The behaviors that came into play going down the ladder are sometimes repeated heading back up the ladder to wellness. We feel that our son was experiencing separation anxiety, and the recognition that he had total control again. This new gained independence may be frightening. At a point, our son entered the peetox stage (see above). He had no feeling or sensation to urinate, so he was put into adult diapers. As our son's infestation rate decreased, the normal behaviors like waking in the night and feeling the urge to urinate returned. Then, as he would get up to go to the bathroom, he would suddenly stop, and feel perhaps lost and afraid to continue this task alone. He would scream out or wander around whimpering. Although night wakings were disturbing, we found them to be a necessary passage for bringing our son to reality. In order to give comfort, at night we continued the CD humidifier, as well as CD ear and nose drops. Many times a CD bath before bed was calming as well.

Emotional Blindness: Because the toxins that the parasites excrete are substances that have the effects of morphine, ammonia, and histamine, these toxins can cause emotional confusion in your child. They may be confused by your laughter, smiles, and affection. Your positive and loving encounter may be perceived as threatening or challenging. Your smile may bring a rage. Any spoken words by you no matter how soothing they may be, could be perceived as a confrontation. This is difficult on both parent and child, as the child may see you as a threat and perhaps even as mocking them; while you as the parent feel rejected in your affections. Many times the child's behaviors evolve into a stoned-out loss of reality and presence. These are all related to the toxic build up and defense of the parasites. Their motivation is to remain in the host; they show their displeasure to the discomforts we have given them in our elimination attempts. Many times during these episodes, we have found it best to avoid words or eye contact, but rather to offer double doses as outlined by Kerri, and keep a calm environment. We have found that these toxic levels can be lowered through salt baths and dandelion tea.

Despite the behaviors that may be brought on by a parasite protocol, the results are amazing. In our family we are finally getting our son back. I would recommend staying the course. As we know, these kinds of parasitic infestations in immune-comprised children will not go away on their own. Children do not "grow out of" worms. In fact, the worms will continue to grow inside of them. The following parasites were expelled by my older son, by making the aggressive modifications aimed at older children. By removing these parasites we are seeing the first stages of recovery. The jars on the following page represent seven pounds of worms in less than two months.

Yours in healing,
Robin

Jar #2 Sept 30th
Oct 13 Rope

7 lbs. of 35 lbs. (total) of the parasites extracted in 9 months (160 feet in total above).

39+ inch long worm.

Other Medicinal Plants

Author's Note: The following information is extremely powerful for our continued health and well-being. However, these plants and foods ALONE have NOT been proven to heal autism. Rather, follow the 18-day deworming protocol presented starting on page 187. When this is done for 12-18 months it has proven to be an important part of the protocols that have led to the recovery of many children. With that in mind, some parents of older children, and aggressive/self-injurious children have started to implement a few of the plants and foods listed below, in addition to the aforementioned 18-day protocol. In many cases, these additions have led their children to increased gains through increased parasite elimination.

A number of other plants are also effective for deworming. If, after three months of treatment, the problem persists we can change the type of plant, or repeat any plant that was effective in previous months. We can use them in combinations, mixing several plants at once, or take them individually. Plant formulations that should be considered are alcoholic extracts, in oil or by infusion, and include the following plants:

- Clove (*Syzygium aromaticum*)
- Common Rue (*Ruta graveolens*)
- Dandelion (*Taraxacum officinale*)
- Gentian Root (*Gentiana lutea*)
- Mint (*Mentha sativa*)
- Mugwart/Common Wormwood (*Artemisia vulgaris*)
- Pomegranate Root Bark (*Punica granatum L.*)
- Southernwood (*Artemisia abrotanum*)
- Sweet Wormwood (*Artemisia annua*)
- Sweetflag/Calamus Root (*Acorus calamus*)
- Tansy (*Tanacetum vulgare*)
- Walnut shell (*Juglans*)
- White Fraxinella (*Dictamnus albus*)
- Yarrow (*Achillea millefolium*)

Preventative Food & Diet

There are groups of foods that should be avoided if you have a parasitic infection. For example, dairy products in general, refined sugars (sucrose, fructose, corn syrup), flour (especially refined), and overly sweet foods in general. The list of foods and plants below promote good internal balance of the body, hence becoming our allies. With good production of stomach acid, a normal level of healthy bacteria, and proper bile production, it is impossible for parasites to survive for long. Worms need an acidic environment that comes from the breakdown of sugars and putrefaction from the ingestion of unhealthy or processed foods. It is very important to eat raw vegetables and fruit juices, which provide us with enzymes and other elements necessary to protect us.

Choucroute/sauerkraut (fermented cabbage in salt).

Many people have low levels of stomach acid, which is the cause of many intestinal problems, because the body is unable to defend itself against intruders. Sauerkraut juice or cabbage/sauerkraut is one of the most powerful stimulants for your body to produce stomach acid. The use of unpasteurized fermented foods (water kefir, soy sauce, miso, etc.) is highly recommended for its stimulation of the beneficial bacterial flora that is responsible for generating control over parasites. Take a few spoonfuls of cabbage juice before meals, or better yet sauerkraut juice, because it will do wonders to improve your digestion.

Author's note: I do not recommend soy, in any form, for anyone with an ASD.

Garlic

Garlic, eaten regularly, turns the stomach and intestine into a lethal environment for parasites, providing constant protection. Garlic is the quintessential home remedy to eliminate intestinal parasites naturally. It has been used by many different cultures such as Chinese, Greek, Roman, Indian, and Babylonian.

Garlic is still in use today by practitioners of modern medicine. It is used both fresh and as an oil. The simplest treatment is to eat three cloves of garlic every morning, or take a teaspoon of garlic oil. Alternatively, mix crushed garlic in a little cold water and drink the mixture immediately. Another recipe is to cut and crush four cloves of garlic, place them in milk, and allow the mixture to sit overnight. Take the liquid while fasting the next day.

Pumpkin Seed

Pumpkin seeds contain a substance called piperazine. It acts by paralyzing the parasites, which allows them to be removed easily.

We can find piperazine commercially in pharmacy drug formulations or naturally, as we said, in the seeds of the pumpkin. This traditional method of deworming has been used around the world since man can remember. There are several effective traditional formulas, below we describe one of them:

Use one cup of peeled and mashed pumpkin seeds (about 80 seeds). Mix them with coconut water and two tablespoons of honey. Take the mixture over three hours on an empty stomach. Do not eat during this three-hour period. At the end of the three hours, take castor oil in order to quickly eliminate the parasites.

Papaya and Papaya Seeds

Papain is a digestive enzyme contained in papaya that is capable of breaking down the outer layer of adult parasites. The milky juice of unripe papaya is a powerful agent for destroying roundworms. The adult dose is one tablespoon of fresh green papaya juice, an equal amount of honey, and three or four tablespoons of hot water. Two hours later, administer a dose of castor oil mixed with warm milk. This treatment should be repeated for two days if necessary. For children seven to ten years of age, half of this dose should be administered. For children under three years of age, one teaspoon (5ml) of the mixture is sufficient.

Papaya seeds are also useful for this purpose as they are rich in papain and caricin. For every tablespoon of crushed, fresh seeds, add an equal amount of honey. Take the dose of one teaspoon (5ml) daily in the morning or at night on an empty stomach for ten days, rest five days and repeat the cycle three times. We recommend the use of a purgative.

Ginger

Ginger not only helps to combat intestinal parasites but also reduces nausea and can help calm nerves. For hundreds of years, fresh ginger has proven to be highly successful in destroying intestinal worms. The most common way to consume ginger is raw or by infusion. Ginger extract may also be sprinkled on a variety of foods.

Propolis

Propolis is a resin like substance gathered by bees from the bark and leaf buds of trees, to help disinfect, build and maintain their hives. Propolis has been used for at least 3,000 years. Its use dates back to the Egyptians and the Romans, and remains in use today. To the Greeks we owe the name pro, meaning "before" and polis, meaning "city." This translates as "defenses before the city," or "defender of the city." Thanks to the antibiotic action of propolis, which protects against the activity of viruses and bacteria, the hive is one of the most sterile places known to nature.

Many scientific studies have proven the antiparasitic activity of propolis, therefore it is recommended for treatment of: *Giardia*, amoebas and roundworms, and also for intestinal infections caused by gram-positive bacteria.

Take propolis, diluted in water or fruit juice, for treatment of parasites, for seven days, on an empty stomach. Use Propolis standardized at 30% in either propolis tincture or capsules. Take three drops per kilo of weight, or three capsules one half-hour before each meal. A seven-day treatment cycle should include seven days on, followed by seven days off; repeat three to five times to ensure complete elimination of parasites or bacteria. Repetition of the treatment is essential to halt bacterial reproductive cycles. By repeating the treatment at least three times, the effective elimination of parasites is ensured. The benefits of propolis are that it has no side effects, is well tolerated, and is highly effective.

Pomegranate Bark

Pomegranate bark contains an alkaloid known as punicine, which is highly toxic to earthworms. It is used by decoction of the root bark, stem, or fruit. The root bark is preferable because it contains a greater quantity of the alkaloid than the bark of the trunk. This alkaloid is also highly toxic to tapeworms. A cold decoction of root bark, preferably fresh, should be given in quantities of 90ml to 180ml three times per day (for adults), with one-hour intervals between cups. A purgative should be taken after the last glass. For children, a dose of 20ml to 60ml is appropriate. A decoction is preferably used to eliminate solitaires (tapeworm, *Taenia Solium*).

Carrots

Carrots are another effective home remedy for eliminating intestinal parasites in children. The chemical constituents of carrots attack pests by preventing their development. It is one of the most effective natural treatments for children, when given a small cup of grated carrots each morning until the problem desists.

Condiments

Seasoning plants are also powerful weapons to keep in mind in our everyday cooking. Since time immemorial, mankind has used them to control parasitic diseases. The following are most interesting because of their effects:

- Cayenne
- Cinnamon
- Cloves
- Paprika
- Pepper
- Tarragon
- Thyme
- Turmeric

Thank you Andreas and Miriam for sharing what I know will be very enlightening, not only to the families of children with autism, but to people all over the world suffering from mysterious symptoms consistent with parasitic infections. I want to share one interesting tidbit about parasite infections before we get into the FAQs on parasites and the parasite protocol.

"We have a tremendous parasite problem right here in the U.S. It is just not being addressed."[5] - Dr. Peter Wina, Chief of Patho-Biology in the Walter Reed Army Institute of Research in 1991. (The problem existed in 1991, and with modern globalization parasites are more prevalent than ever, yet they still not being addressed.

Parasite Protocol FAQs

I showed my family practitioner pictures of the worms we have found. He thinks they are not a parasite, but just mucous. How can I be certain?

It can be difficult to identify parasites, and most general practitioners are not trained to do so. Some parents have success with a local vet, who analyzes samples in their office. As a crude test, you can pour boiling hot water onto your specimen. If it falls apart, it is probably biofilm or mucous. If it withstands the wash, it is probably a parasite. Unfortunately, most stool analyses are notorious for false negatives. If you put hot water on parasites, they do not dissolve. Mucous dissolves in any water—hot or cold.

Is it ok to do the Kalcker Parasite Protocol during pregnancy?

No. Don't do any kind of detox or parasite protocol while you are pregnant or nursing. Any detox will release toxins into the blood stream that could potentially negatively impact the developing fetus or nursing baby. If you are planning on getting pregnant, it would be advisable to do whatever detox or deworming procedure before pregnancy.

When is it appropriate to stop the parasite protocol? In other words, does every child on this protocol need both the CD and the other parts of the Parasite Protocol or are there some that only need CD? This is a critical question since these are two protocols joined together and not every child may need both. We have done the Parasite Protocol and have never passed parasites so I am uncertain about my child.

Usually the Parasite Protocol is repeated for 12-18 months, sometimes less. The most important thing is to make sure that there are no fertilized eggs left that could hatch at a later date. As it is very difficult to know if there are remaining eggs, it is important to complete the 12-18 month treatment. The Parasite Protocol is a complete protocol heavily researched to achieve the best results. The Parasite Protocol in conjunction with CD has been shown to be one of the most effective methods to heal regressive autism. Parasites are cyclical and need to be treated as such. You continue with the parasite protocol until no more parasites are seen—be that in behavior or actually in the stool.

What does the process of worms toxifying the brain look like?

Ascaris lumbricoides (roundworm), for example, produces at least five different toxins: Malondialdehyde, ammonia, histamine, formaldehyde, and morphine. Malondialdehyde is responsible for oxidative stress, and is mutagenic.[7] Ammonia, which can lead to hyperammonemia, can be responsible for seizures, tremors, flapping, poor coordination, growth retardation, combativeness, lethargy, and other symptoms. Comparing hyperammonemia with the symptoms known as regressive autism yields overwhelming similarities. Formaldehyde has been shown in some laboratory studies to affect the lymphatic and hematopoietic systems. Morphine inhibits nerve reactions and slows intestinal peristalsis. It also keeps the immune system from finding parasites, and from doing anything about them. This is a reason we often can't identify parasites. We only find parasites when the infection is acute, not chronic. This is because IgE or IgM reactions are altered by morphine. Histamine can lead to chronic inflammation in the body.

As a family, we expect to be doing the CD and parasite protocols for some time. How do we know when to stop? Should we wait until we have a few months of no symptoms?

We do it until full recovery is reached.

We have been doing full oral dose CD and the Parasite Protocol. We are seeing some amazing changes, but we don't see worms. Are we doing something wrong?

CD affects parasites of different sizes. You may be clearing parasites that would be undetectable to the naked eye, or nematodes that are very small and therefore hard to detect in the stool.

Why is my child so deficient in vitamins?

As a general rule, most children with autism are deficient in vitamins. In the first place many pathogens feed off of vitamins intended for the host, and helminthes especially love B12 and iron. Since many of us, especially those of us living in cold climates, do not receive enough sun, we are deficient in vitamin D. Calcium is used by the body as an antagonist for acid inflammation; all acidity in the body is compensated by calcium, and therefore it is usually low with the kids on the spectrum. As our children heal, these deficiencies fade and homeostasis returns.

I just gave mebendazole, Not pyrantel this AM. What should I do?

Don't stress. Tomorrow is a new day, and you can begin again. Give mebendazole tomorrow as that is tomorrow's scheduled dose.

Aren't there some parasites that are good for us and help our immunity and gut healing?

A parasite is defined as a living being that is dependent on a host for survival, to the detriment of that host.

For those of you that continue the parasite protocol thru the new moon, how many days do you stay on it? We are now 3 days past the new moon.

Some people treat month long. The Kalcker protocol itself is 18 days long. Each family has to find a protocol that suits them. Some folks use mebendazole 3 days before the new moon, the day of, and three days after. Other families use herbal remedies on the off days. If you consult with a healthcare provider, this would be a question to ask them. Each child is unique and has different needs when it comes to treating parasites.

Why are live worms not digested? Poisons?

Live helminths are protected by a glucosoid mucous with positively charged ions, making them resistant to stomach acid, or digestive fluids. When they die, the mucous separates from the helminth, leaving them open to digestive enzymes. We often see the mucous, as well as semi-digested helminths, in the stool of people using the protocol.

Does everyone in the family need to do the parasite protocol at the same time? With or without CD, enemas, diatomaceous earth, Rompepiedras/stone breakers, and castor oil? My (neurotypical) daughter will take the anti-parasitic drugs, mebendazole, and pyrantel pamoate, but not these other parasite protocol ingredients, which is why I ask.

Your entire family needs to do the protocol at the same time, or you risk reinfection. Neurotypical family members should do as much of the protocol as possible. If someone will only take the meds, so be it. However, I feel the more the better.

Do I need to separate the neem from CD?

Yes, I give neem with food, and would separate from CD by at least an hour.

If I don't see any worms, does that mean my child doesn't have parasites, or are we just missing the eggs?

Just because you don't see parasites doesn't necessarily mean you don't have any. For example, *Toxocara canis* or *Toxocara cati*, which are very common in our pets (and can infect humans as *Toxocariasis*), are not expelled in fecal matter. Some families on the protocol did not see actual worms until month seven.

To what extent do the rest of us need to do the CD protocol? Is it the same as our ASD children? And, is it necessary to do the whole nine yards with the full Parasite Protocol for the whole 12 months? Are there any shortcuts for healthier individuals?

All of the family members, including pets, need to be on anti-parasite treatment for a year and thereafter lifetime maintenance is best. As mentioned before, with neurotypical family members, you do as much as you can, but the anti-parasitic medications are crucial to preventing reinfection.

Is diatomaceous earth a binder and therefore must it be given apart from food, medication, and supplements?

No. It is not a binder. It is fine to give with or without food, and does not affect medication or supplements.

Do you have to do the Protocol forever if you are fully recovered or is there a maintenance plan?

When the child gets to where you want him, you can start to pull things. Then, we do maintenance dosing of CD; one dose on Monday and one on Thursday. We do the Parasite Protocol for a week every three months since we live in a world of parasites. It is good preventative medicine for all. Ocean water is also good for all of us. See Chapter 13 (page 319) for the complete maintenance plan.

Does CD kill parasites?

Yes. CD kills amoebas, *Giardia lamblia*, and other smaller parasites. CD does not kill the larger macroparasites due to their higher oxidative stress resistance.

When is it ok to start the parasite protocol prior to reaching full dose of CD?

Healing autism is a marathon not a sprint. The point is to heal with the least amount of aggravation. Therefore, you should be at a full dose of CD before starting, and have added in enemas and baths. If you are seeing Herxheimer reactions then don't start yet. Obviously, everyone must make his or her own decisions.

Where in the gut do helminths live? Do CD enemas (300 ml) reach them?

It depends on the type of helminth. There are more than 300 different helminths so they could be in many different places. However, most live in the small intestine. Some lay their eggs in the rectum. The size of the person will dictate how high an enema will reach.

Do you tell your kids that they have worms? Do you show them? Are they scared? My son is very interested about everything in the world and asks 4,000 questions a day. What do I tell him?

How to handle this situation is unique to each and every family. There is no right or wrong answer here. The following are some suggestions we have received from families on the protocol:

Nope. My husband was just telling me a story from when he was a kid about another kid who got teased all the time about having worms. He still remembers it. So, no I will not tell my kids.

My kids (ages 10 & 7) know about worms because we have talked about their Lyme disease and other symptoms for a long time. I think it helps them understand why they feel grumpy or sick and why the enemas help. But, I think every child is different. The risk is that they might tell their friends. I tell them that it is private information and that pretty much everyone has worms but some people have more and get sick from them. And, I told them that even most doctors don't know this but slowly people are learning and getting smarter about this and a good diet, etc... My boys like to see the big ones, and try for new records. They like to show their brother the records. I think that's a boy thing.

I have a 10 year-old, and I tell him that we have parasites. I have not showed him anything, I ask him to leave the room before I start to sort the poo. ;)

My son had another bowel movement FULL of worms, pinworms—and I mean hundreds. This is only our second day on CD (1/2 drop in 8 fl. oz.) so a bit thrown to the deep end. Has anyone else had a start like this? How did everything go from there on?

I have seen it a handful of times. I get VERY excited about this. Everyone has autism a bit differently. But, if we see worms early, in many cases the recovery begins early too. That may be the case for your child.

I understand that even organic produce needs to be washed properly. What is the best way to wash my fruits and vegetables?

The Ascaris eggs are resistant to UV, and can withstand a pH from 2 to 11.5. Eggs are killed by heating to approximately 60°C (140°F). Spray your fruits and veggies with CD spray. 10 drops per 1 fl. oz., of water, no need to rinse off.

Anyone notice a huge growth spurt after starting the parasite protocol?

Many parents have reported their children resumed growth as well as weight gain. No real surprise considering they are getting back what the parasites were taking from them.

Do we need to treat our pets if they are taking heartworm medication?

Yes, heartworm medication does not address intestinal parasites, which can infect us and our children. We need to deparasitize our pets, as well as ourselves.

We put "cascara sagrada" in place of castor oil because for my son and me, it is difficult to take the oil. Is it ok?

Cascara sagrada is not the same thing as castor oil and is not part of the protocol. An alternative solution to liquid castor oil is to buy castor oil in softgels. You will need many but it does solve the taste problem.

My son is very high in Trichinella spiralis, which is a roundworm from undercooked meat or pork. It's supposed to be rare in the US, so I'm wondering how my child would have picked this up. Any ideas? No undercooked meat here for the kids, and we don't eat pork.

At this moment we have not seen a relationship between *Trichinella spiralis* and autism. It may be a multi-parasitic infection, or a misdiagnosis. Apart from the standard protocol, your child might need something else. I would consult the practitioner for the appropriate dosage, and only if your child has a definite Trichinella spiralis diagnosis.

How do we know if there are parasites in the brain, and what can we do about it?

Parasites in the brain are very rare. (According to the CDC, *Cysticercosis* is a parasitic tissue infection caused by larval cysts of the pork *tapeworm.* These larval cysts infect brain, muscle, or other tissue, and are a major cause of adult onset seizures in most low-income countries. An individual acquires cysticercosis from ingesting eggs excreted by a person who has an intestinal tapeworm.)[6] Larvae can be seen on a scan. Many people assume that the problem causing behavioral issues, or mental issues, must be located in the brain. However, the problem likely exists elsewhere. If the blood contains toxins, this will affect the brain. For example, if you ingest too much alcohol, your brain, nervous system, etc. will be affected, but the problem is not in the brain itself. We can think the same way about parasites. The chemicals that they produce will have effects on the brain, however, rarely will the parasites be located there.

Do parasites cause autism? If so, why doesn't every child with parasites have autism?

Regressive autism has been called parasitological vaccinosis by Dr. Andreas Kalcker. This is a cross reaction between a child with parasites that receives certain vaccines. Further research is needed for a definitive answer.

Why don't normal lab tests find parasites?

Generally speaking, lab tests need to find living creatures or eggs. The eggs are only present certain days of the month, and even on those days they won't necessarily be present in a particular stool sample. Living worms are extremely rare in stool because they are generally passed only once they die. They are very good at avoiding being excreted in stool. Furthermore, if they die internally, they can be partially or fully digested within our bodies before being expelled.

Are some labs better than others? Is it worth taking a stool sample to a vet if they send it out, or only if they look under a microscope?

We haven't found a lab that consistently finds parasites. Metametrix™ has identified parasites, but in our experience and the experience of the families I have helped, we have not found a lab that is consistent. It is only worth sending a sample to a vet if they are identifying parasites with a microscope.

Combantrin® is available in tablet and liquid form. Which is better?

I hate the liquid and never use it. It may have added colors and flavors. If you absolutely can't find it without additives, I would use only mebendazole instead of using pyrantel with additives.

Why are there no systemic drugs in the protocol?

They are not needed with this Protocol.Treating parasites without systemic drugs is much safer and easier on the body. The suggested treatments using mebendazole and pyrantel pamoato are nearly unabsorbed by the body, meaning that we do not add more toxins to an already overloaded body.

When does a child need systemic drugs?

This is necessary only for certain parasites like cysticercosis, which is caused by tapeworms, hookworms, Trichinella spiralis (from pork), or other hard to kill helminths. These may be identified by a blood test. The practitioner may prescribe systemics depending on the situation.

Should I start on the new moon if my child's behavior declines then?

The full 18-day Kalcker Parasite Protocol always starts before the full moon. However, some parents have found that by treating parasites for 3 days over new moon that they are able to get through the new moon as well as the full moon with limited issues if any.

Is there a time in the moon calendar, where it is normal that there are no worms in the stool? (We don't have any at new moon.)

Further research is necessary to determine this definitively.

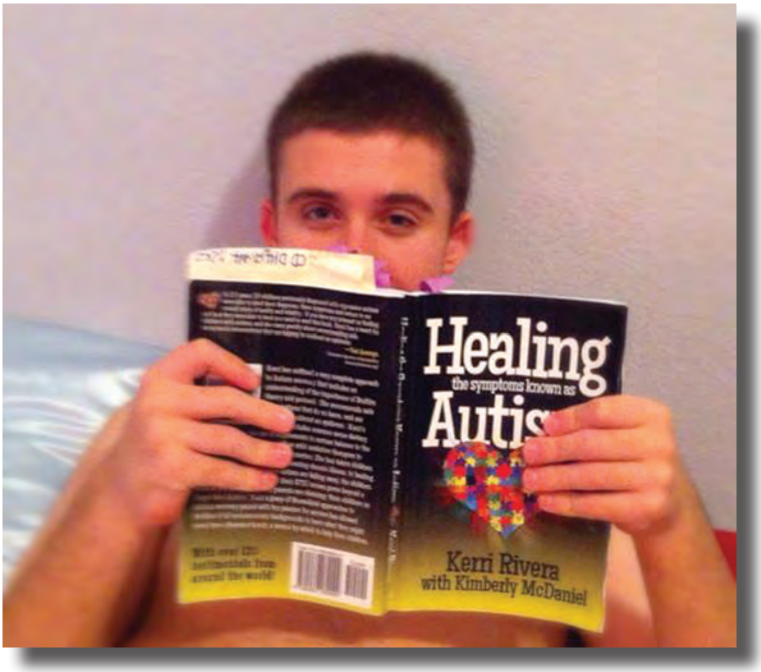
Healing
the symptoms known as
Autis
Kerri Rivera
with Kimberly McDaniel

Hero Guy taking a peek at *The Protocol.*

Chapter 9

Step 4 - Other Supplements

"One of the first duties of the physician is to educate the masses not to take medicine."
~ William Osler

Most of the families that followed this Protocol, and recovered their children, used a combination of these additional supplements along with CD. Each supplement combination is completely unique, depending on the symptoms of the child, and how the child reacts to each intervention. If after *The Diet*, full *CD Protocol*, and three *Kalcker Parasite Protocols* we are still dealing with an autism diagnosis, then families start adding in supplements. This section is about "unfinished business." I like to do three Kalcker Parasite Protocols before adding back in supplements because parasites love supplements, especially vitamin B_{12} and iron.

I feel when we supplement deficiencies in children with underlying parasitic infections, it can result in resistant parasites. We aren't making the child healthier; we're making the parasites healthier and stronger. If significant supplementation does little or nothing to change lab values in subsequent blood, urine, and stool tests, then it's fair to say that we have a flaw in our approach. Pathogens and parasites can cause vitamin/mineral deficiencies. By killing them, instead of feeding them with additional supplementation, we are focusing on the root cause of the symptoms that we call autism.

When I came back from our first *Defeat Autism Now!* doctor visit, I had thousands of dollars in supplements that I did not know how to use. We kept going to different doctors hoping to find the one that had the answer. At one point, Patrick was on a protocol, given to me and supervised by a doctor, which called for 70+ different supplements a day. He looked worse during the entire nine-month period that we followed that protocol. In hindsight, all those years of supplementation made it harder to eliminate Patrick's pathogens.

That is why this protocol focuses on the excesses instead of the deficiencies for children with an autism diagnosis. If by eliminating the excesses of viruses, bacteria, candida, parasites and heavy metals, we can see a reduction in the symptoms known as autism, then eventually we can reach full healing.

Commonly, when a new family contacts me, they send me a list of all the supplements their child is taking. I frequently see lists of 30+ supplements that may be combined in ways that negate their effects. For example, probiotics are given in the morning with breakfast, or GABA with food. Both are incorrect, probiotics go alone at night right before bed, and GABA is always taken without food. If there is a legitimate reason for a certain supplement, then it absolutely must be given correctly or it's just excess noise in the body, and more stress on the detox organs.

The following list of supplements can be considered after *The Diet*, ocean water, CD, and three months of the *Kalcker Parasite Protocol* (except probiotics and enzymes which may start day one). This chapter is to be used as a starting point for your own research on these supplements. This list contains references and the websites used in this research with some of the more pertinent information about products.

Probiotics

The vast majority of the families who have recovered their children with this Protocol have used THERALAC® brand probiotic. It is a prebiotic plus probiotic in a capsule that can withstand stomach acid, which allows it to pass to the small intestine, where the beneficial bacteria are needed. THERALAC® contains three *lactobacillus* and two *bifidobacterium* strains.

The paragraph below was slightly modified from www.theralac.com where you can find more information. Please visit their site for details on references contained within the text.[1] The following two paragraphs were taken from different sources, and help explain benefits of THERALAC®, specifically for children on the spectrum.

> Probiotics are defined as: "Live microorganisms that when administered in adequate amounts confer a health benefit to the host" (World Health Organization 2001). According to the International Probiotics Association (IPA), the benefits of probiotics can include reduction in diarrhea caused by antibiotics and rotavirus, alleviation of symptoms of lactose intolerance, alleviation of symptoms of food and skin allergies in children, reduction of recurrent ear and bladder infections, and other positive indications.

How Does THERALAC® Benefit My Immune System?

> THERALAC®'s five probiotic strains work in unison to support the mucosal immune system on the intestinal surface; activation signals are then sent to the body's systemic immune system. This is a gentle and controlled process because THERALAC®'s strains are beneficial. Essentially, the immune system is put on alert so that it is ready to act quickly if there is an appearance of pathogenic microorganisms.[2]
>
> Many children with autism have chronic digestive problems. In fact, gastrointestinal symptoms in autistic children often first appear in conjunction with initial changes in emotion and behavior during the onset of autism, leading researchers to suspect a gut-brain connection.[3]

Normally, proteins are digested in stages by enzymes; first to peptides, and then to smaller amino acid components, which are absorbed into blood capillaries in the gut mucosa. The larger peptides are generally unable to cross this mucous membrane barrier, if they do, however, they can act as opioids affecting neurotransmitters in the brain causing abnormal behaviors and/or activity. These incompletely digested peptides—known as exorphins, casomorphins, and gluteomorphins usually come from milk proteins such as casein, or from wheat (gluten), and are structurally similar to morphine. The formation of excess peptides in the gut is possibly associated with sub-optimal enzyme activity, or an insufficient supply of enzymes required to breakdown these peptides. So if we repair the imbalance of beneficial bacterial organisms in the gut and the gut lining, while killing the pathogens causing the dysbiosis, we have the opportunity to heal children with autism. Probiotics can be used to improve the quality of the gut mucosa.[2]

In addition to aiding in the repair of the gut lining and improving digestion, there is also evidence that probiotics can help with detoxification of heavy metals such as toxic mercury.

The paragraph below was taken from the presentation "Gut biology and Treatment" by Dr. Anju Usman:

> Emerging literature is showing the beneficial effect of oral probiotics on mood and anxiety symptoms. In a double-blind, placebo controlled randomized parallel group study, daily use of probiotics reduced psychological distress.[5] A number of studies have shown the anti-anxiety effects of probiotic use in patients with medical conditions.[6]

> Dr. Vincent Young, University of Michigan (2009): "the gut ecosystem needs to be preserved and that changing the ecosystem through stresses such as antibiotics could irreversibly change the ecosystem, with deleterious effects." Dr. Young has studied the effects of antibiotics on the microbes in our gut. He found that mice when given particularly strong antibiotics completely wiped out all their normal gut microbes. Even more striking, clostridium species and fungal species are then able to overgrow without the bacteria there to fend them off.

There is no doubt in my mind that probiotics helped get my son's gut back in order, helped improve my own health, and that of thousands of families of children on the spectrum. Probiotics should be given without food, directly before bedtime. This way, they have the entire night to proliferate in the small intestine where they are needed.

Special note for those with PANDAS/PANS: We have received some reports where some PANDAS/PANS and/or older children were becoming violent and having more SIBs while on probiotics. Be observant and watch for behavior changes when adding probiotics. In addition, know that we may need to remove them for a period of time!

Omega-3 & Omega-6 Fatty Acids

Omega-3 and omega-6 fatty acids are polyunsaturated fatty acids and are considered essential fatty acids. Essential fatty acids must be consumed because your body cannot produce them. They are important for brain development, immune system and cardiovascular function, and normal metabolism. Omega-3 and omega-6 fatty acids are commonly found in marine and plant oils. While a healthy diet often provides adequate supplies of both, supplementation is sometimes necessary.

Omega-3 fatty acids also help to regulate energy levels, as well as normalizes blood sugar levels. They help improve concentration as well as mental vividness. Using omega-3 fatty acid supplements helps with anxiety, mood swings, and depression. They are especially significant in the treatment of autism. The entire body benefits from ingesting omega-3 fatty acids; from physical development, to relaxation from anxiety and jitteriness, to developing brain cells; all of these aspects can aide in the treatment of autism.[6]

Omega-6 fatty acids promote healthy brain function and assists with skin and hair growth, bone development, and metabolism. A healthy balance of omega-3 and omega-6 fatty acids promotes heart health and minimizes inflammation. Omega-6 may also be used to treat allergies, eczema, osteoporosis and premenstrual syndrome.[7]

Unlike omega-3 fatty acids, excessive consumption of omega-6 fatty acids can have negative effects. Therefore, their consumption must be monitored. Omega-6 fatty acids, in large quantities, can promote inflammation in the body that may lead to flare-ups of eczema, acne, and the aches and pains associated with arthritis. It is recommended that you maintain about a 4:1 ratio of omega-6 to omega-3 fatty acids.

Some research has been done that suggests improvements in overall health, cognition, sleep patterns, social interactions, and eye contact when children on the spectrum were given an EFA (Essential Fatty Acid) supplement.[8]

Furthermore, another study showed the positive effects of EFA's on dyspraxia (a motor disorder frequently associated with cognitive, behavioral, and social challenges). The participants showed improvements in reading, spelling and behavior during the treatment period.[9]

I have personally found that I really like omegas from YES™ Supplements. Dr. Brian Peskin has some very informative videos on YouTube discussing the merits of vegan versus animal based omega sources. I highly recommend you have a look for yourself. My own son, and many other children have built up to taking one tablespoon, two times a day.

L-carnitine

L-carnitine is a vital amino acid that promotes healthy neural levels of acetylcholine, an important neurotransmitter that aids memory and proper brain function. Research suggests that an L-carnitine deficiency may be implicated in a number of conditions, including ME/CFS (chronic fatigue syndrome), diabetes, Alzheimer's, dementia, and autism.

L-carnitine is composed of two essential amino acids, lysine and methionine. It is produced in the liver and kidneys and is contained in most cells of the body. It is required for the proper metabolism of fat and helps with mental concentration, and energy production. It transports long-chain fatty acids across the mitochondrial membrane so that they can be burned to produce energy.

A clinical trial studying the use of L-carnitine as a potential therapy for autism demonstrated the children taking L-carnitine showed improvements in their ability to relate to people, body use, adaptation to change, listening response, verbal communication, sociability, sensory/cognitive awareness, and health/physical behavior. There are a few articles that may be helpful for a better understanding of the importance of this amino acid. Check out an article by Henke Schultz, "L-carnitine helps kids with autism, study finds" and another by Emily Singer, "Defects in carnitine metabolism may underlie autism."

The average dose for L-carnitine is anywhere from 250-1000 mg per day with food, depending on weight and reactions.

GABA

GABA (gamma-aminobutyric acid) is an amino acid and a neurotransmitter (a type of chemical responsible for carrying information from one cell to another). It is produced naturally in the body, but is also widely available in supplement form. Manufacturers claim that GABA supplements can help boost the brain's GABA levels and, in turn, treat anxiety, stress, depression, and sleep problems.

The GABA system acts as something of an information filter to prevent the nerves from becoming over stimulated. It has long been suspected that this filtering process is compromised in many autistic children. Impairment of the GABA system could overwhelm the brain with sensory information, leading to many of the behavior traits associated with autism. GABA is also believed to play a key role in the early development of the brain.[10]

GABA is also involved with the production of endorphins in our brain, which make us feel positive and upbeat. GABA can reduce stress, relieve anxiety, and increase alertness. GABA can be helpful for behavior, language, and possibly even seizures.

GABA is used for control of seizure activity and works on the same receptors as the drug Keppra®. GABA is also useful for speech, helps facilitate language in nonverbal children, and improves language in children that are beginning to speak.

If you are going to give GABA to your child, the max is 5,000 mg per day, divided into two doses, one in morning and one at night, always on an empty stomach. In the evening, GABA can be given 15 minutes after your last dose of Chlorine Dioxide, with your probiotic. I start at 250 mg two times a day, one in the morning and one at night. I then titrate up the dose daily or every other day if everything looks good. If you observe sleepiness or irritability it is a good idea to back down.

5-HTP (5-Hydroxytryptophan)

5-HTP, also known as oxitriptan, is a naturally occurring amino acid. It is a chemical precursor to the neurotransmitters, serotonin and melatonin from tryptophan. 5-HTP works in the brain and central nervous system by increasing the production of the chemical serotonin. Serotonin can affect sleep, appetite, temperature, sexual behavior, and pain sensation.

From *Saving Eli: One Family's Struggle* - Vitamin Research Products website:

> While not clearly understood, researchers know that serotonin pathways are disturbed in autism, contributing to sleep disorders and mood. Tryptophan has been shown to help but has been banned by the FDA since 1989. We found that 5-HTP helped immensely, calming tantrums and increasing communication with our son.[11]

5-HTP is used between 50 mg and 200 mg, divided into two doses, morning and evening with food. I have seen it help children with autism for attention, focus, sleep, and cravings.

L-theanine

L-theanine or gamma-glutamylethylamide or 5-N-ethyl-glutamine, is an amino acid commonly found in tea. Theanine is able to cross the blood–brain barrier, and is reported to have positive effects on mood, stress, and cognition.

The following is excerpted from the L-Theanine website:[12]

> Many people experience stress on a daily basis and are looking for natural and safe ways to manage it. For thousands of years, it has been suggested that drinking green tea will make one relaxed. Recently this relaxation effect was found to be true and works because of an amino acid called L-Theanine which is found in the tea. Clinical research will show that ingesting up to 200mg of L-Theanine will promote the creation of the very important "anti-stress" neurotransmitter in the brain called GABA or gamma-aminobutyric acid. This results in a relaxed, clear and alert mental state.
>
> When used in the correct amounts in supplemental form, L-Theanine may:

- Reduce Stress
- Reduce Occasional, Simple Nervous Tension
- Promote Relaxation without Drowsiness
- Promote Mental Clarity and Focus
- Promote Positive Mood
- Promote Alertness
- Promote Learning and Memory
- Help Prevent Jitters Caused By Caffeine

I have found that when we can reduce these symptoms in individuals with ASDs we can get an increase in speech, learning, focus, concentration, and attention. L-Theanine is given with GABA upon waking, and can also be given at bedtime if needed, always without food. You can work up to 200 or 250mg/day.

Pycnogenol®

Pycnogenol® (pic-noj-en-all) French maritime pine bark extract acts as a potent blend of antioxidants, it is a natural anti-inflammatory, stimulates generation of collagen and hyaluronic acid and help with natural dilation of blood vessels by supporting production of nitric oxide.[13]

Pycnogenol® is not a supplement I tend to use very often, because it is an antioxidant, and therefore cannot be combined with chlorine dioxide. However, in some people it has proved necessary and helpful for speech and reduction of seizures. It should be given in the morning with food at a dose between 25 and 400 mg/day depending on need. Pycnogenol® may not be suitable for children who are sensitive to phenols.

L-Carnosine

L-Carnosine is a dipeptide of the amino acids beta-alanine and histidine. It is highly concentrated in muscle and brain tissues.

L-Carnosine is believed to stimulate the frontal areas of the brain, resulting in overall improved levels of functioning. More and more research shows that the frontal lobes and temporal lobes in the brain control emotion, epileptic activity, cognitive, expressive speech, and abstract thinking. Studies have shown Carnosine to improve language, socialization, and overall level of functioning in individuals within the autism spectrum. It has also been shown in studies to have anti-seizure properties without the side-effects of prescription anti-seizure medications.

Research indicates it prevents the formation of the beta amyloid plaque that is found not only in neurological conditions such as Alzheimer's, Parkinson's and autism, but also in the eyes in degenerative eye conditions and in the pancreas in diabetes. It is a neuroprotectant, with a study indicating it reduced severity of damage in stroke patients.[14]

Chez and coworkers found that after eight weeks on L-carnosine, children showed statistically significant improvements on the Gilliam Autism Rating Scale (GARS). They relate this to the likely ability of L-Carnosine to enhance neurological function, perhaps, in the enterorhinal or temporal cortex.[15] This enhancement in neurological function has led to speech in many of the families that I have worked with.

I have also seen L-Carnosine help reduce seizures in some children and increase language in others. It is given twice a day with breakfast and dinner at a dose of 200 to 400mg, 2 times a day. If you note hyperactivity, remove it.

Taurine

Taurine is an amino acid, a chemical that is a required building block of proteins. Taurine is found in large amounts in the brain, retina, heart, and in blood cells called platelets. It can be consumed through eating meat and fish.

Autism and Low Taurine

"Are You Dangerously Deficient in Taurine"[16] explores possible problems associated with a taurine deficiency. Among the problems noted in the article is autism and low taurine levels. In the article, Leonard Smith MD writes about the benefits of taurine, some of which can be of interest to people dealing with autism spectrum disorders:

- Brain and nervous system function
- Helps eliminate toxins
- Stabilizing the brain (can be effective in treating seizure disorders)

Taurine, like all amino acids, must be given without food. The maximum dose is between 500 and 1,500 mg.

DMG

DMG, or dimethylglycine, is an amino acid that can be found in many common food items like meats (especially liver), various grains, and beans. It has been classified as a type of amino acid that is closely linked to vitamin B.

There have also been interesting developments in the use of a DMG supplement for children with autism. Because many children who have autism are unable to tolerate eye contact, and some have problems forming complete sentences and thoughts studies investigated whether an increase in DMG consumption could help to alleviate many of these problems. In fact, the study found that when children with autism were given supplemental DMG they appeared less frustrated and showed a marked increase in their speaking and cognitive abilities.[17] At present, this research remains novel and therefore further investigation is necessary to determine what the long-term effects of DMG supplementation might have on children on the spectrum.

The following paragraphs were excerpted from *Defeat Autism Now!*[18]

> ### Dimethylglycine (DMG) for Autism
>
> For over 20 years ARI has been hearing from parents who have tried DMG on their autistic children. In many cases remarkably good results have been seen, especially in enhancing speech. In some cases, drug-resistant seizures have been stopped by DMG. (See New England Journal of Medicine, 10-21-82, pgs 1081-82).
>
> There is an extensive research literature on the safety and health benefits of DMG. Many studies have shown that DMG enhances the effectiveness of the immune system, improves the physical and athletic performance of humans and other animals (e.g. race horses) and has, all in all, a very wide range of beneficial effects. It is very safe. I have seen no evidence of any toxic or significant adverse effects.
>
> Many parents have reported that, within a few days of starting DMG, the child's behavior improved noticeably, better eye contact was seen, frustration tolerance increased, the child's speech improved, or more interest and ability in speaking was observed.

A full dose of DMG is 900 mg per day, taken without food upon waking. However, it is best to start at a lower dose and slowly work up to 900 mg over a week or so. If you see an increase of hyperactivity (which is rare), reduce the dose. If no improvement is seen within a month I would switch to TMG.

TMG - Trimethylglycine (Betaine Anhydrous)

TMG (Betaine anhydrous} is a chemical that occurs naturally in the body, and can also be found in foods such as beets, spinach, cereals, seafood, and wine.

How does it work?

A form of betaine called betaine anhydrous helps in the metabolism of homocysteine, a chemical involved in the normal function of many different parts of the body, including blood, bones, eyes, heart, nerves, and the brain. Betaine anhydrous prevents the buildup of homocysteine seen in people who have problems with its metabolism from birth.[19]

The following is excerpted from the *Autism Canada Foundation*.[20] Please visit their site...

www.autism.org

...for full references contained within the text.

The benefits of taking DMG or TMG range from behavioral changes, reduction of seizures, and decreased obsessive-compulsive behaviours to improved language. DMG and TMG have been reported from thousands of families to be quite beneficial to many individuals with autism.

Research on humans and laboratory animals has shown that DMG and TMG enhance the effectiveness of the immune system. Some children and adults with autism have seizures, and there are published reports of decreases in seizure activity as a result of DMG. A double-blind placebo-controlled study by Drs. Shin-siung Jung, Bernard Rimland, and Stephen M. Edelson involving 84 participants documented a significant decrease in behavioral problems.

It should be noted that some kids tolerate DMG but not TMG. TMG is given upon waking without food, in a dose of 500mg. If DMG didn't yield improvements in language, then we switch to TMG.

FAQ's

There are times when I do see undigested food in my son's stools. I am particularly concerned. He never complains of stomach pains. But I do see some at times, especially cashews. Should I bother with an enzyme? Or is it better without one. If so, which brand?

> I love enzymes. Kirkman has one with Isogest®, 851/180 is the number, and it's broad spectrum. Also, Biofilm Defense® is great for dissolving the biofilm. A number of the parents online have used Ness® enzymes Gastric comfort formula #601 very successfully.

How should I administer THERALAC®?

The best time to administer probiotics is at bedtime. Children's THERALAC® is a granular formula so you can sprinkle it on yogurt or mix it into a smoothie and still obtain the same benefits! So how do you take it? We recommend that you take a level 1/4 teaspoon and fold it into yogurt, applesauce, or food of a similar consistency and let it sit for a minute. This is to keep the granules as close together as possible, thus allowing our acid proof gel matrix to form around the product. Visit the THERALAC® website for more info:

www.theralac.com/childrens-theralac.aspx

Supplement Dosing Overview

Supplement	Dose	Time of Day	Empty Stomach (ES) or With Food (WF)
Probiotics	1 cap	Before Bed	ES
Omega-3/ Omega-6	1 Tbsp	With any meal 1-3x / day	WF
L-Carnitine	250-1000mg/day	With any meal 1-3x / day	WF
GABA	Up to 2,500mg 2x/day	Upon waking & at bedtime	ES
5-HTP	50-200mg	Morning & Evening	WF
L-Theanine	Work up to 200-250mg/day	Mornings or Mornings & Nights	ES
Pycnogenol	25-40mg a day/as needed	Morning	WF
L-Carnosine	200-400mg 2x / day	Morning & Evening	WF
Taurine	500-1500mg/day	Morning, Noon & Night	ES
DMG	900mg/day	Morning	ES
TMG	500mg/day	Morning	ES
Enzymes	1 cap w/meals	Morning, Noon & Night	WF

Chapter 10

Step 5 - Chelation

So, let's say we're clipping along; full Diet, CD, Kalcker Parasite Protocol, and we've added in whatever supplements the child specifically needs and the child still has autism. Recovery is still not a reality... yet! At this point, it's time to look at chelation.

Why use Chelation for Autism?

Chelation became very popular in the world of autism about a decade ago, when things were heating up around the Thimerosal/Autism connection. Today, many of our children are still metal toxic. Metal challenges (testing that shows metals in urine) from any of the thousands of children whose families I have helped show the same thing—extremely high levels of mercury, lead, aluminum, as well as sometimes tin, cadmium, and other metals.

These heavy metals can come from various sources such as:

- Coal burning power plants. According to the EPA, coal-fired power plants in the United States emit about 48 tons of mercury into the air every year, where more than half of this mercury falls within five miles of the plant itself. When it reaches the water, microorganisms consume it and convert it into a substance called methyl mercury.
- Drinking water
- Our food supply
- Cookware
- Deodorant
- Beauty products
- Dental amalgams
- Vaccines, etc.

Heavy metals are known to accumulate in different parts of the body including organs, bones, joints, and the brain, etc. Metal toxicity can provoke inflammation, kill neurons, cause behavioral changes, affect the thyroid and other master glands, lower T-cell counts, and cause a myriad of other symptoms. Furthermore, new research shows that fluoride in drinking water makes the aluminum that we ingest more bio-available. As was reported in the journal *Brain Research*, the combination of aluminum and fluoride causes the same pathological changes in brain tissue found in Alzheimer's patients.[1]

Many children with autism also have impaired methylation cycles. The result of this impairment is an inability of the body to rid itself of excess metals, thereby prolonging chronic illness.

What exactly is methylation?

Methylation reactions are those that involve the transfer of a methyl group from one compound to another. The methylation cycle is the name given to a biochemical pathway that contributes to a range of crucial bodily functions, including:

- Detoxification
- Immune function
- Maintaining DNA
- Energy production
- Mood balancing
- Controlling inflammation

Impairments or mutations on the methylation cycle can lead to problems with:

- ASD's
- Alzheimer's
- Diabetes
- Allergies and Asthma

An overload of toxins (including heavy metals), can contribute to the impairment of the methylation cycle, and if the methylation cycle is impaired the body is unable to detoxify as needed, therefore creating a vicious catch 22.

We need to help our children's bodies rid themselves of their excess metals as part of the healing process. Dr. Usman has shown us that heavy metals are present in the biofilm, and Dr. Klinghardt has shown that removing mercury can be directly related to a reduction in chronic infections.[2]

Let's get those metals out!

What exactly is Chelation?

Chelation is a process used to rid the body of heavy metals. It is described as a chemical process in which a substance (chelator) is used to bind molecules, such as metals or minerals, and hold them so that they can be removed from the body.

Some of the most common chelators used in the world of autism are:

EDTA

This is an amino acid that attracts lead, other heavy metals, and some minerals from the bloodstream and expels these toxic elements in the urine. EDTA works to remove excess lead from the body, but it is not specific to mercury or methyl mercury as are DMSA or DMPS. It can be taken orally, by rectal suppository, or IV.

DMSA

This is an FDA approved drug that can be used in children when lead toxicity is suspected, however it can also be effective at removing other heavy metals including mercury and arsenic. It can be taken orally, transdermally, or given as a suppository.

DMPS

DMPS is given to remove mercury from the body. It can be given IV, intramuscularly, subcutaneously, transdermally, or by suppository.

Patrick has been prescribed all of these at different points of his life, and I can't say that I saw miraculous results during the time that I used them. However, some families have seen results, and this is something you may want to discuss with your doctor. After years of using chelators, and seeing other families use chelators, I have opted for a gentle approach. I like to use two products: bentonite clay baths and Bio-Chelat™. These products are strong enough to help the body rid itself of heavy metals, but have not been shown to stress the liver or provoke undesirable detox symptoms.

Knowing now that metals are in the biofilm, I feel it is short sighted to focus solely on metals or heavy metals rather than all the pathogens in the biofilm.

Bentonite Clay Baths

Bentonite clay is sedimentary clay composed of weathered and aged volcanic ash. Bentonites are more widely known as healing clays used for detoxing, cleansing, and drawing out impurities. They are used in many everyday products such as toothpaste, antacids, and cosmetics.

Indigenous people have used bentonite clay for centuries; Dr. Weston A. Price in his book, "Nutrition and Physical Degeneration,"[3] stated that when studying the diets of native tribes he examined their knapsacks. Among the tribes examined in the High Andes, in Central Africa and the Aborigines of Australia, Dr. Price reported that some knapsacks contained balls of volcanic ash clay, a little of which was dissolved in water.

Bentonite is known as "swelling clay." When bentonite clay absorbs water and swells up, it is stretched like a sponge. Toxins are drawn into these spaces through electrical attraction and bound. In fact, according to the Canadian Journal of Microbiology, bentonite clay can reportedly absorb pathogenic viruses, as well as herbicides and pesticides.[5]

One of my personal favorites has been *Even Better Now*®'s product available at:

www.evenbetternow.com

> "EBN® Cleansing Clay is 100% pure sodium bentonite clay which has the highest cation exchange capacity (CEC of 98-107 meq/100g) of any bathing clay that we tested on the market. This clay is high purity air-classified sodium bentonite, selectively mined, consisting of micronized particles, which is a free-flowing powder. EBN® Cleansing Clay is 100% pure, hypoallergenic, and free of viruses, bacteria, yeast, and mold, as well as having a high cation exchange capacity."

There are other quality clays on the market, but EBN® tests every batch for heavy metals when it comes in. No, I do not receive financial gain from the company.

Bio-Chelat™

Another product I really like for gentle (low and slow) chelation is Bio-Chelat™. This is a German product containing a minimal amount of EDTA, which is FDA approved as a food substance. According to a clinical trial carried out in Germany:

> The therapeutic value of the Bio-Chelat™ in the context of other chelators that are currently on the market is seen as follows: Chelators work relatively fast, but they are also very strong with a relative high washout of important trace elements and a high degree of specific side effects. Bio-Chelat™ works much gentler than most common chelators.

> Although during the treatment a significant decrease of the body's heavy metal ion load was seen, this is accomplished without greatly disturbing the mineral and trace element relationships. The reduction of zinc should be looked at with caution and may easily be corrected throughout the treatment.[5]

I have seen very positive changes in many of the children who added in either bentonite clay baths, Bio-Chelate™, or both. As with any other intervention, add them separately while closely observing your child. Keep a log to record any changes, progress, or reactions you observe. Even if you don't see anything right away, I would keep using the products for a minimum of three months. Again, since they work LOW and SLOW changes may not be apparent at the outset, but that doesn't mean they are not helping to heal your child's body.

I use the CD baths every other day and then two times a week I do bentonite clay baths. I don't do the CD bath and the bentonite clay bath on the same day. I do them at opposite ends of the week.

Three days or so later, we'll add in the Bio-Chelat™. Again, follow the instructions on the package, and you can always start low and work your way up. Since Bio-Chelat™ doesn't alter the CD, the drops can be added to a single dose of CD. In addition, since the drops have no flavor, it is suitable to add them to water or any other drink your child might consume throughout the day.

Common Errors in Chelation:

Urine analysis without provocation:

Many families will do urine analysis to see if there are heavy metals present. If you have not done any chelation (oral or intravenous) you really don't get a good picture of what kinds of metals are actually in the body. Simply because the metals don't show up in urine, doesn't mean they are not present in the bones, the intestinal tract, the brain, and organs, etc. If we don't do any sort of provocation, we may end up with a false negative, leading a family to believe that their child is not metal toxic, when in fact they are. Bentonite clay baths and Bio-Chelat™ are gentle enough that they will not cause any harm to a child (metal toxic or no) but can greatly help reduce the heavy metal load, as well as other toxins in the body.

Healing the gut before starting chelation:

A doctor once told me that we had to heal the gut before we could start the chelation process. However, in the children that I have seen recover, probably up to the last month before they recover, their gut might still not yet be perfect. For example, one of the little girls that recovered continued to suffer from constipation at 30 days before she lost her autism diagnosis. However, at this stage something seemed to switch, she started having regular bowel movements and within 30 days she lost her diagnosis.

Basically we're healing the intestines as we're chelating, as we're healing everything else. They are all parts of the puzzle. I would never put chelation before the CD or parasite protocols. However, it's definitely something that's part of our road when, after these other approaches, children have not yet recovered. At some point after we have the CD, ocean water, parasite protocol and some supplements is when we can add in chelators. It's not like I'm saying, "Oh we'll talk about that in a couple of years." We want our children recovered in less time. It's like a marathon, we keep the pace, never lose our heads, or break into a sprint.

Do not chelate with constipation:

If the child suffers from constipation, it's really important that we start moving the intestines when we're using chelators. There are a few options open to us for moving the intestines. I have found that the most effective is through the use of CD enemas. If your child isn't having a daily bowel movement, I would do an enema once a day. If you absolutely can't do enemas, get that child in a CD bath. We're finding that 50 to 100 drops in a bathtub is allowing children who previously had constipation to have bowel movements.

There are a few children/adults on the protocol that will not do enemas, or the parent will not. Whatever their situation may be, we have to get the bowels moving again. In this case, we do 50 to 100 drops in their bath water along with their max oral dose every day. The result has been that they're having regular bowel movements. That's one way we can move it along and then you can keep chelating. It's really important to have a daily bowel movement with any kind of chelation because otherwise the toxins are simply reabsorbed through the intestinal wall, whether they're heavy metals or other pathogens.

IV chelation is not the only means by which to cure autism:

I think at one point between 2006-2008, we were all focused on the problem in the world of autism being the heavy metals, because there was mercury/Thimerosal in the vaccines. We had to get the mercury out of our children. Well, part of the problem is they're not detoxing. As mentioned before, methylation cycles are impaired in children on the spectrum. I met a young girl whose parents were both allopathic doctors and they really believed at that point, as most of us did, that heavy metals were the problem with autism. If we could get the heavy metals out then they would recover. The parents did 122 IV chelations and their child never improved. At this point I have lost touch with them, but these are things that we have to learn along the way. I know now that it is NOT just about chelation, and why metals are NOT the only important piece. All of the pieces play a role and likely interact to cause autism in our children. There is a symbiotic relationship between the viruses, bacteria, candida, and parasites that exist in the biofilm. Since CD can break down biofilm and kill the pathogens living in it, as well as neutralize heavy metals, it has been a very powerful tool for us.

Doing a blood test to look for heavy metals:

Generally speaking, within three days of heavy metals entering the bloodstream, the body will deposit the heavy metals into tissues, organs, and eventually bones. For this reason, a blood test is not the best place to look for heavy metals in children with autism. Unless the child has very recently been exposed to heavy metals, we are unlikely to see elevated levels of heavy metals through a blood analysis.

The articles at the end of this book (Appendices 13 & 14) will provide further insight as to why chelation can be so important for our children on the spectrum.

Healing
the symptoms known as
Autism
Kerri Rivera

Luca

Chapter 11

Step 6 - Hyperbarics

by Bob Sands (Introduction by Dr. Beatrice Golomb)

> *"What Oxygen is to the lungs, such is hope to the meaning of life."*
> ~ ***Emil Brunner***

We were fortunate enough to have the amazing Bob Sands write this chapter on hyperbarics explaining its importance in healing ASD's.

Note: Throughout this section of the book, the author, Robert Lyne-Sands uses the actual names of the people with whom he came in contact with. In some instances it is with their permission, in others it is not. The accuracy of quotations, opinions expressed within this chapter, and the names used are solely the responsibility of Robert Lyne-Sands. Great care has been taken to remain within the bounds of current journalistic integrity and practice.

Robert Lyne-Sands new book, *OXYGEN: The First Medicine, Volume 1 CANCER*, is expected to be released January 2014.

Robert Lyne-Sands author of the Hyperbaric section of the book, with one of his young patients, getting ready for a session.

Robert Sands is one of only about five licensed manufacturers of hyperbaric oxygen therapy (HBOT) machines in the US, with extensive experience in clinical hyperbaric treatment, whose expertise will be an exceptional asset to this project. He has designed and manufactured HBOT machines for the US, Australia, Britain, Thailand, and many other nations, for naval/military use, civilian diving use, and medical use. He has the theoretical understanding of HBOT therapy that derives from intimate involvement in the process of designing and manufacturing these machines. He has the practical experience that derives from running a set of HBOT centers, and personally overseeing greater than 20,000 hours of HBOT sessions over 35 years.

~ Dr. Beatrice Golomb, MD, PhD.
Professor of Medicine. UCSD 2011.

Beatrice Alexandra Golomb, MD, PhD (PI) is singularly qualified to lead this study. She has expertise in GWI including authorship of four RAND reports related to GWI29-31, and work in the scientific literature. She has been a member, since its inception, of the Department of Veterans Affairs Research Advisory Committee on Gulf War Veterans' Illnesses, and served as Scientific Director of this Committee. As a licensed internist, she is a primary care physician for a panel of ~280 veterans, including GWV, at the VA San Diego Healthcare Center.

Recently, I sought the answer to something that was puzzling me. My friend, Dr. Bernard Gunter, is a revered and renowned psychologist in his eighties and, if anyone would know the answer, Bernard would.

"Does God, Great Spirit in the Sky, The Universe or whatever unseen deity you worship give you freedom for personal choices or is everything predestined?"

Bernard's eyes twinkled. He was never in a hurry to answer a question. In my mind, Dr. Bernard Gunter is sort of the American version of the Dali Lama.

He thought for a moment, selecting his words carefully, and then replied, "Funny you should ask that—just the other day I was talking with Eckhart Tolle and asked him that very same question. Tolle replied, 'God allows you to think that you have free will and free choice—and you do, by and large. However the roadmap is laid out for you beforehand.'"

Just as I suspected.

Dr. Bernard Rimland, Kerri Rivera, and the Hand of God.

On January 20th, 2006, a tall, glamorous woman walked into my San Diego clinic; her name was Kerri Rivera. She had brought her small five-and-a-half-year-old son, Patrick all the way from Mexico for hyperbaric oxygen therapy. The little fellow was absolutely gorgeous, but had a vacant stare and made no eye contact with any adult, rarely even with his mother. Day after day Patrick spent time in the chamber.

Kerri explained to me that Patrick developed normally for almost the first two years of his life. Then, to comply with vaccine regulations, Patrick received the DPT, HepB, and Influenza B (Pentavalente) vaccines in one day. Patrick fell into a complete zombie-like state after the injections. By the time Kerri arrived in San Diego, she had already done her homework. She blamed the vaccinations and had already undertaken the task of healing her son.

After her own experience with autism, Kerri wanted to help people and she was already doing the DAN! Protocol, etc., as Dr. Rimland has done so much for the children and she had a lot of respect and admiration for him and his work.

One day, I walked into the clinic and told her, "We're having lunch with Bernie tomorrow. Get a babysitter." At that point, totally shocked, she said, "Oh my God, yes, but I don't have anything to wear!"

"Trust me, what you have on would be just fine." A flustered Kerri rushed off to purchase some dressy clothes—she was, after all, a woman originally from Chicago. The very next day, we were sitting with Bernie and his wife Gloria in a quaint little restaurant, *The Green Tomato*. If the reader wishes to see that day, just go to your computer and look up Bernie on Wikipedia and there you will see Kerri in her black business suit (http://en.wikipedia.org/wiki/Bernard_Rimland).

Over lunch, Bernie and Kerri bonded immediately. None of us at the table realized that Bernie was suffering from cancer and had less than a year to live. Driving the short distance back to my clinic I made the observation to Kerri that I suspected she was about to become a scientist, and no longer just a trophy wife. "Be careful," I warned her, "Bernie Rimland's mantle will be heavy on your shoulders."

Kerri turned her face toward me and said, "I will carry that mantle willingly and with honor."

After a few days, Bernie told me that he thought Kerri had what it takes to carry the torch and help families heal their children with autism. I saw a lot of Bernie in the next nine months. He would come down to the clinic for regular hyperbaric treatments because it eased the pain of his cancer. Just before his death, he told me, "I will not die before I have found the reason for and defeated autism." But die he did on November 21, 2006, at the age of 78.

As I drove to Bernie's grave, I anticipated many, many people lining the way with some hundreds even thousands thronging the memorial park, similar to Giuseppe Verdi's funeral, in 1901, where 200,000 people gathered. At his graveside, the thousands of mourners spontaneously burst into the "Slaves Chorus" from his Opera, Nabucco.

I was stunned upon arriving. Probably less than thirty or so weeping caregivers of children with autism were present at the burial, along with Gloria and Bernie's three children. WHERE WERE ALL THE PEOPLE, THE MOTHERS AND FATHERS, THE RESEARCHERS AND SCIENTISTS? I asked myself. It was my first Jewish funeral and I think that the booming sound of the shovel full of earth that I threw down onto his plain casket made me look heavenward and ask, "God, where are you now?"

I drove home, eyes unfocused with tears, and stone eggs of the birds of unhappiness in my heart, stopping only to purchase two fine bottles of wine to toast Bernie. I knew one would not be enough. Arriving at my house, I found the fine crystal goblet my Mom had left me, filled it, and played Neil Diamond's, Morningside over and over, with each playing, another glass, held high to Bernie...

Morningside
The old man died
And no one cried
They simply turned away

And when he died
He left a table made of nails and pride
And with his hands,
He carved these words inside
'For my children'

Morning light
Morning bright
I spent the night
With dreams that make you weep
Morning time
Wash away the sadness
From these eyes of mine
For I recall the words an old man signed
'For my children'

And the legs were shaped with his hands
And the top made of oaken wood
And the children
That sat around this great table
Touched it with their laughter
Ah, and that was good

Morningside
An old man died
And no one cried
He surely died alone
And truth is sad
For not a child would claim the gift he had
The words he carved became his epitaph
'For my children'

In fact, as I sit here writing this, I play Diamond's melody and listening to the words makes my heart swell and my eyes become damp.

The morning after Bernie's funeral, hung-over and miserable, I pondered: Did my beloved friend Bernie die feeling that he failed? I now doubt it for he had passed his mantle to carry on his search for the cure without fear, without the need for accolades and rewards and to do so with integrity. I did not know it, but before his passing, Bernie and Kerri had been in communication. Bernie had given her permission to translate his *Defeat Autism Now!* Protocol into Spanish, Kerri's other language, as well as other tasks.

In review, I now see God's Hand at work—and it started one afternoon at the Green Tomato. Thus, my question to my friend on free will versus predestination right at the start of my notes on this section.

Brain overload and frozen fingers.

At the time, when Kerri asked me to write this section of her book about hyperbaric oxygen therapy and the treatment of challenged children, my mind went into overload. Why? Kerri was (in my view and that of others) the most efficient and effective health scientist with a high normalization rate of challenged children (autism, etc.). With her own hospital-quality hyperbaric oxygen center, Kerri had first-hand knowledge that to normalize such an afflicted person required a lot more than some trips in a oxygen chamber or some Silver Bullet response from a pharmaceutical company.

My brain whistled like an express train rushing through a tunnel. I thought of the dozens of children that hyperbaric oxygen therapy has helped at my different centers. Some of the little guys were so badly damaged they would repeatedly punch at their own head, or chewed on their own wrists. I'm thinking of Marco as I write this. Ten years later, he still punches. A clearly defined casualty of a hotshot thimerosal vaccination, normal until three, his parents won a multimillion-dollar lawsuit against Big PHARMA. There has been some progress over the years; but it will be a matter of unrelenting attention to Marco.

I remember another little guy; a handsome, articulate smiling boy of about 12 years of age named Chase. Meeting him and his parents, you would never know he had autism or ADHD. Chase was a "runner." When his treatment in the chamber was over, he would promptly disappear out of the clinic doors. Eventually, Chase would be carted back down by one of the upstairs nurses. "Chase" by name and chased by nature.

After one such session in the chamber, he rocketed out and into the restroom of the clinic. I was sitting at the controls when he came back. Chase climbed up onto my knee and said, "I love you Bob," and he rubbed his hands across my face. From the terrible odor I knew in an instant what was all over my face and my lips. Chase had used his hands instead of toilet paper and bypassed the washbasin on the way out.

"Oh goodness," came from his horrified mother. "He got you. I am so sorry. It is one of his favorite jokes."

"Not to worry," I said, "I have eaten and tasted this in a variety of forms most my life." So, whenever I hear somebody say, "Sands is not a Doctor so he doesn't know s—t from Shinola," I think of Chase.

Normalizing kids is so rewarding, but you have to take a chance on s**t.

My fingers were not ready for the keyboard as I tried to wade through dozens of experiences with these children, my own personal experiences, and finally adding input from experts in the field of pediatric abnormalities. (Many of these experts became my close, personal friends as the years went by.)

For any parent or caregiver to delve into all of the opinions and conclusions of the so-called experts, it is a bewildering journey through a lot of contradictory and self-serving educated guesses and erroneous assumptions. To arrive at something that the reader will identify with, and believe in, I have to go way back. After 70 years on the face of this planet, I have reached certain conclusions about the treatment of children that enables me to write this section. Mind you, I'm not stuck in my ways and I am open to change my thoughts and conclusions as the science improves on treating children with autism.

Little Patrick Rivera, Little Bobby Sands Something in Common?

Here is something that I doubt my adult children even know about. In 1947, polio was raging throughout Australia. I was seven years of age and had developed a sore throat and fever. My father, a wealthy man, called the very best doctor to my bedside—yes physicians did make house calls in those days. I can even remember the doctor's name, Dr. Bradfield. His father had been the engineer that designed the Sydney Harbor Bridge. My dad, with all of his money drew a lot of water in those days and could get almost anything he wanted. Bradfield came in and examined me briefly; after all he had other house calls that night.

Bradfield told my Mom and Dad that he did not think I had polio, but perhaps diphtheria and that I should spend time in isolation in the infectious disease hospital overlooking Botany Bay, "just in case." The next morning an ambulance came and, in spite of my fear, pleading, misery, and tears they carted me away. The three-hour journey became a six-hour journey. The ambulance broke down outside the Sydney airport. I remember looking out of the rain spattered window and seeing the aircraft clearly visible over the fence. We sat on the side of the road for almost two hours before the replacement ambulance came to transport me, and my journey continued to a huge colonial building complex, built by convicts and perched on rolling, green lawns that looked down onto the Pacific. The complex was known as, The Coast Infectious Disease Hospital, which later became Prince Henry Hospital. I was terrified and clutched my teddy bear, *Threadbare*, under the blankets. Threadbare became my only friend for the next four months, and a glimpse of airplanes over the fence became an enduring memory of the trip.

My parents were already there and had obviously filled out all of paperwork. I never got to say goodbye to them since it was an infectious disease hospital. As they walked past a big hopper window, they paused momentarily and Mum waved through the window. I saw them maybe three times in the next four months when the nurses wheeled my bed up against the window that looked out into the hall. They would tap on the glass and smile at me but because my father was quickly bored, after about five minutes they would wave and be gone for another couple of weeks. It was a long way for them to travel.

The night of my arrival, a team of doctors and nurses arrived and they rolled me onto my side. Full syringes lay on a tray; in those days they were glass with little thumb and finger holes on each side and each needle was reused and supposedly resharpened before their next use. This meant that the needles were thick and long. One-by-one these needles were inserted into my upper thigh on the left-hand side. The pain was agonizing and I'm sure I screamed and screamed. I remember at least three nurses holding me down. At seven, I was just a little fellow. There had to be at least 20 of these very large syringes. Checking the history books, I believe that they were mostly penicillin and sulfa drugs. I might add, it was already known to Doctor Bradfield that I was highly allergic to sulfa and remained so for my entire life.

The next morning, when I awoke, I found that I was paralyzed from the feet up to just under my arms. Threadbare was my only friend for the next four months. The days all blurred together. One thing I do remember vividly is that I used to deliberately wet the bed. I did so only when a lovely red-haired nurse with a band of freckles across her nose was on duty. This nurse was kind and gentle, probably in her twenties. After she had changed the sheets, she would stroke my cheek and tell me that everything was going to be okay and not to worry about wetting the bed. The other older nurses scolded any of the other pediatric patients if they had an accident. At some point later, my gentle nurse told me that I really did not need to wet the bed to get her attention. I soon stopped and I still got a cuddle from her. Such a display of care and affection was unknown to me from my parents back at home.

After that stay in the hospital, I was never the same. I know that there was constant discussion amongst my family members that I should be placed in some sort of an institution because my behavior was "contrary and stubborn." I was either talking my head off, trying to make my family love me, or distant, and as such, I was said to be "uncooperative." Soon after, I was placed in a Hogwarts-style boarding school.

Could that childhood experience have made me what I am today, forever alone, but rarely lonely? As the years ticked by, to my surprise (and I think everybody else's), the school counselors found that I had a genius IQ. Amongst the 1,200 boys, I was second from the top.

After seventeen years of treating so-called challenged children, I have yet to find one that was not as smart as a whip in something.

I managed to burn every social bridge at the boarding school, thrown out of every special social club at Newington. On Saturday afternoon, after mandatory sports such as Cricket or Rugby, the other boarders would get to do things they wanted like billiards, photography, or gardening (these were clubs that you had to apply for and join). However, I had been expelled from each of them so I wandered alone each Saturday afternoon and finally picked the lock on a large room-sized cage full of Sulfur-Crested Cockatoos and other Australian parrots. I would sit alone with them and be jeered at by the boys in the garden club that were planting and weeding. Within weeks, these birds would happily climb all over me, enjoying my company. The birds loved me, but the boys and masters did not. To me, it was a two-way street. Animals made better friends than people. Eventually some of the other boys would come and beg to be allowed to accompany me into the cage so they too could have that same privilege.

Do not get the wrong impression of my beloved Newington College in Sydney Australia; even today I dream of the sanctuary of that place. It was better than what I had with my family back home.

The really curious thing is that my mind had blotted my hospital stay out, or had hidden it in some black cabinet in my brain where the really bad things are kept to allow me to get on with the reality of NOW. I remembered the illness and isolation only when Kerri asked me to write this. The details have returned with clarity: the old iron beds, the smiling face and freckles of my favorite nurse, being cold at night, the colors on the wall, the distant sight of the ocean through a window on the other side of the big ward, the frame of the window so far away that it looked like a painting hanging there. If I close my eyes as I write I can see it now.

I now ask myself, "Is this the way children with autism feel?"

I don't know. What I do know is that my old friend and confidant, teddy bear, is sitting on the desk as I write this. I reach out to rub Threadbare's head and a great calmness washes over me. The little fellow is 64-years-old now and there is a great competition amongst my adult children to see who gets him after I die.

Botched diagnosis
The incorrect pharmaceutical response.

With almost 40 years of working in medicine behind me, and now in my retirement, I do know that neither diphtheria nor polio were the problem. The suffocating "Bull Neck" or the "Strangling Angel of Children," diphtheria, had not happened to me, nor did the withered limbs of poliomyelitis set in after paralysis.

Simply put, Dr. Bradfield cocked it all up in a big way by guessing, not taking enough time and arriving at the wrong medical response on his visit. The relentless attack on me with sulfa drugs caused paralysis, which was probably what is commonly known today as Guillain–Barré Syndrome, a disorder affecting the peripheral nervous system. Ascending paralysis, weakness beginning in the feet and hands and migrating towards the trunk, is the most typical symptom; the disease is usually triggered by an infection.

It sure sounds similar to what happened to little Patrick, and probably to the reader's challenged child as well.

Migrating to America in 1990 with my tribe of offspring.

I arrived in the United States over twenty years ago. If the reader is interested enough, a quick look at a funny but classy "roast" presentation is on YouTube. You can find it by searching "Robert Lyne-Sands" on YouTube.

After completing the United States Navy transportable chamber development project, I arrived in swank, Pacific Palisades, on the outskirts of Los Angeles; living amongst all of the Hollywood greats. I was going nuts with boredom and became the "Bob Clampett" of the area; jogging down the leafy streets I always said Gudday to any celebrity. I rarely remembered their names but knew their faces. They never replied on the first go past, but then I would jog backwards, keeping pace with them (big stars like Madonna always ran with a group of minders) and I would yell out "I said Gudday. My goodness, your manners are appalling." I might add, it was not just me; they never ever nodded to each other when their paths crossed either.

Around this time, I opened the very first freestanding hyperbaric oxygen therapy center. It was more or less hidden away in Santa Monica on 6th Street. Tucked away in what used to be an old motel, you could almost refer to it as a "speakeasy" center, akin to something from the days of prohibition, where you had to knock on the door three times before being let in. I would only treat people who had been referred by another patient. Most of these people were from the entertainment industry in Hollywood, many with the HIV virus, and lots of folks with chronic fatigue syndrome.

The kiss of death in Hollywood is to be known to be ill. Hyperbaric oxygen therapy works so well that the word soon got around, and I was inundated with patients, some famous and well-known, and others just hardworking folk in the movie industry. Thus, I ended up being known for some years as "Mr. Oxygen," and because of the remarkable effects of HBOT, I befriended many of these celebrities, who subsequently invited me as their guest to many of the big Hollywood functions (the only one that I missed was the Academy Awards).

One of the first of these talented people that became my close friend was Harold Michelson. Harold was an award-winning art director working out of DreamWorks. He was suffering the aftermath of a mild stroke. His wife Lillian had told me that her Harold loved crossword puzzles, but since his stroke he would put the across answer in the down column. This caused him immense frustration since his answer was usually correct, just in the wrong place. Five treatments in the little chamber were all it took for Harold to get his verticals and horizontals in the right place. The big thing that he noticed was that his blood pressure stabilized, his lung problems normalized, and he needed less medication for his diabetes.

Harold still stood well over 6-feet–tall, though stooped with old age. We hit it off immediately because Harold had a quick wit and loved a good laugh. The stories and banter between us were constant. Harold was extremely talented yet self-effacing. He really was a hero in the truest sense of the word. As young man, he made over 40 flights across the English Channel to bomb Germany. As navigator, Harold sat in the nosecone of the B-17 and either froze with the cold on the trip or froze with fear when making the lower-level bombing run. "Bob, I was so frightened of the flak from the antiaircraft fire from the Germans on the ground. As the puffs of smoke would erupt around the front of the aircraft, shrapnel would pierce plexi-glass windows in front of me. I would hold the navigational map in front of me and try to believe that the thin paper would stop the lethal fragments."

The first challenged child to be treated in a hyperbaric chamber—Emily.

I need to jump forward in time for a moment before getting back to Harold Michelson and his wife, Lillian. I went back into production of hyperbaric chambers after I realized the great need for hospital-grade dispensing of oxygen to the public. There were no rules preventing me from doing this even though I'm not a physician. All my patients needed was a prescription from a registered physician; that was the easy part. My first center was in San Diego.

In the first few months of patient treatments we received a call from a father in Canada. His daughter, Emily, had cerebral palsy. The father had read that hyperbaric oxygen therapy would perhaps help his little girl normalize, and so when he asked me what I thought I gave him my usual answer, "I do not know, I am not a physician." And then I added, "I would hate for you to waste your money on a trip from Canada to San Diego if it doesn't work."

The father replied, "I have two choices. I can go to England where there is snow on the ground or I can come to San Diego. It is an easy choice to make."

So father and daughter duly arrived. Emily was the most delightful child. When she walked through the door she had a crash helmet on, knee guards, and wrist-guards to prevent serious injury when she would crash, face first, into the floor. We learned a lot in the first ten days of treating Emily. One of the first things was the fact that fathers can never properly do a good job on their daughter's hair. I felt for the father since Emily had lots and lots of hair and was never still for a moment (I have a few daughters myself). Emily would arrive looking like a rag doll; her little blonde head would have pins, bits of string and ribbon through it. So the very first task of our nurses would be to grab Emily (usually tearing around the clinic), and comb her hair out to make her more presentable.

Now, the really big thing that we noticed was that on day ten she arrived at the clinic without any of her body armor. Yes, she still "toe-walked" because her heels did not touch the floor. To compensate, she would park her little fists against her chest, push her elbows out to keep a center of gravity, and rush around the clinic. On day 11, father and daughter spent five hours at the San Diego Zoo without the usual body protection. Emily never lost balance or tumbled even once. Follow-up visits over the last 17 years find that Emily is living a normal life. Yes, she still has some walking problems, but never needed to undergo the mutilating surgery that was recommended to her by her Canadian doctors. During 20 days of hyperbaric oxygen treatments in San Diego, something had changed in Emily's brain.

Likely the most important introduction in my life... The Great-Spirit-in-the Sky's (God's) hand at work.

Listening to the improvements that little Emily had made, Harold Michelson was both enchanted and excited.

"Did you know that Lillian and I have an autistic son? We need to introduce you to a couple of people in San Diego. Dr. Eric Courchesne, who runs the autism research center for the University of San Diego, known as the Autism Center of Excellence or ACE."

Lillian chimed in and said, "I really must call them about you. Eric is a gem and his wife Rachel is also a research doctor. They work side-by-side and will be so helpful."

With Emily's positive results, and more children making gains at the center, I called the Courchesne couple at the ACE and offered to provide them with the use of a $150,000 hospital-grade hyperbaric chamber for one full year. There was no response to my offer.

While you may imagine that the UCSD-ACE Research Center is located in some lofty center of learning, it is in fact to be found in a delightful millionaire's village known as La Jolla in Southern California, a block or so from the Pacific Ocean. On the top floor of a three-story building, an elegant balcony ran across the front of the building, while red and white umbrellas and tables make it look more like a posh restaurant than a research center.

I waited about a month and called again and repeated my offer of a hyperbaric chamber, operated by trained technicians for a year, or whatever time it took to make a decision on efficacy, at zero cost to the ACE. About an hour after making the second call, my secretary told me that a Dr. Rachel Courchesne was on the line and needed to speak to me on an urgent matter. I picked up the telephone, anticipating a good conversation but this is the way that it went, all one-way at me. Dr. Rachel was in fine fury and, looking back, the only way I could have put a word into that conversation would have been to fold the word flat and slip it into the tirade, sideways. She told me that it was amateurs such as myself that muddied the scientific waters of autism research and that, essentially, I should crawl back into whatever hole I came out of.

She made it clear to me that the mission of the ACE was to perform research to find a cure with pharmaceuticals. In fact, the ACE receives funding from drug companies, and that I should not bother them again. I was taken aback, to say the least.

A decade later, Dr. Eric is apparently doing fine work. For example, in his recent research, quoted widely in the media, he has found that the frontal lobes of an autistic child's brain is abnormally large. This is an observation, perhaps useful in the future, but only time will tell. But does it matter to you the reader whether this is so? Maybe yes, maybe no, so let's hold off on that sort of thing until we get into the scientific part of the book.

Let's get back to Dr. Rachel's harangue of me. In my mind, there is no doubt about the fact that for her, at least, it was all about the money and the potential for a patented silver bullet for Big PHARMA. If successful, a drug company could charge you a huge amount of money to heal your child with autism. At worst, there would be the ability to raise more money for research despite scant evidence of clinical results on children.

An example of this ability to raise money on a potential medical marketplace is the fact that in the year 2012, the National Institute of Health (NIH) allocated $100 million over a five-year period to a bunch of ACE research across the United States. So much for Lillian's glowing endorsement of Dr. Rachel.

However, the Michelson's other introduction proved to be a link in the chain.

Autism research with integrity—Dr. Bernie Rimland.

"A dear friend of ours, Dr. Bernard Rimland, also has a research center in San Diego which he calls *Defeat Autism Now!*, or DAN! for short. Bernie's son, Marc, is a true autistic savant. The movie with Dustin Hoffman and Tom Cruise, Rain Man, was modeled around Bernie and Gloria's son. Bernie was the technical advisor for the film. You must meet Bernie."

Lillian was especially grateful and fond of Bernie and his wife, Gloria. Back in the early 1950s, autistic children were attributed to cold, hard, heartless mothers. Many psychologists and psychiatrists agreed with the "Emotional frigidity" hypothesis, which suggested that the mothers were the cause of what we now know as autism. A lot of children in the United States were taken by force from their parents, and placed in isolated institutions to "protect" them from their parents. Bernie Rimland alone stood against this hypothesis; after all Bernie did have degrees in psychology, including a PhD. In fact, it was Bernie that took away the shame, the blame, and the guilt of many loving parents who were bullied into believing labels put upon them by the so-called "learned."

Driving forces behind autism research centers.

Unlike the La Jolla location for the ACE, Bernie's Autism Research Institute (ARI) was about five minutes drive from my San Diego hyperbaric oxygen dispensary; two minutes of freeway, a quick turn into Adams Avenue, and I had arrived. Again with an erroneous assumption, I had thought that Bernie's ARI would be similar to the ACE La Jolla location. In fact, I drove past Bernie's place three times before I found it. An unassuming, clay-colored, converted storefront, with a little sign on the front door that said, "Autism Research Institute." I knocked on the door and walked in. Instantly, the smell of antiquity and old books overwhelmed me and beguiled me, like something out of a Harry Potter movie. Stacks of papers were high on the floor almost in a willy-nilly fashion. A gentleman dressed in a checkered shirt came towards me. "Bob Sands? The Michelson's said to expect you." He peered over his glasses and gray whiskers at me. In that one glance, we created a bond of friendship that lasted for more than a decade. At least once or twice a month we would lunch together along with his wife, Gloria; always two blocks from his Center, at the *Bleu Boheme*. Bernie and Gloria would carefully examine the menu and then they would both look out and recommend, "Let's all order the fried green tomatoes."

Bernie was interested in clinical results. He would turn over any stone that would perhaps unlock the mystery of autism. When I first met Bernie, 1 in 850 children born in the United States was afflicted with this mysterious and terrifying disorder. As I write, autism spectrum disorders have spiked to 1 child in every 88. So when the phone rang at the ARI, Bernie would often answer it and ask many questions, if the person believed that they had found a cure or a clue. He never discarded anything, in stark contrast to my encounter with Dr. Rachel at the ACE in La Jolla. I once listened in when he spoke with a lady who believed that you could cure autism by filling crystal glasses to different levels and rubbing your fingers around the edges to create pure tones.

Bernie put the telephone down and said to me, "It could be worth looking into. Music does create new neuronal wiring in small children, for example, or a mother singing to a child." I had already mentioned to him that when a child with autism was in the chamber, if you played unfamiliar sounds such as whale songs, or bagpipes, the unresponsive child would often brighten up and look around.

"Maybe new neuronal connections are being established," Bernie pondered as he rubbed his whiskers.

In those days, I worked on weekends. If I wanted to chat with Bernie, Sunday was the best day. No staff to answer the telephone, so he always did. I once asked him whether he took a day off and his response was succinct:

"When autism takes a day off so will I."

Bernie, a $2.6 million donation and his ARI.

Now, here is the most interesting of Bernie Rimland's driving forces—to me at least. It was not about dollars or ego, not in the slightest.

At that time, I was also friends with another Bernie, the renowned anthropologist, Dr. Bernard Aginsky. To avoid confusion between the two Bernie's I will refer to him as Dr. Aginsky. He was in his late 90s at the time, as rich as Croesus. For many years, he had leased the penthouse of the La Jolla Shores Hotel, right on the beach of one of the most desired parts of Southern California. Again, like most of my friends, Dr. Aginsky was a humble man and thought nothing of his wealth other than as a means of accomplishment. Out of the blue, one day in my office, Dr. Aginsky looked at me thoughtfully and then asked, "I have $2.6 million and I want to give it to somebody that would make a difference. Can I give it to you?"

I immediately thought of Bernie and the children with autism and the nonprofit status of the Autistic Research Institute. "Hold that thought Dr. Aginsky. I will give you an answer in a couple of days."

A couple of days later, Bernie and I were traveling to take part in a medical internal review board. I was wearing a shirt with French cuffs and a silk tie. Bernie had on his usual checkered shirt. He confided in me once that he had to make a choice between wearing a tie or trimming his Santa Claus-gray beard. The beard always won. Wondering about his shirts, I respectfully asked him whether he ever received a salary from his ARI.

"Good gracious. I could never pay myself a salary from ARI funds and donations. You must remember that I am on a full Navy pension so it would be wrong to double dip."

After the meeting, as we traveled back along the I-405 to San Diego, I broached the subject of Dr. Aginski's offer of a $2.6 million donation for the Autism Research Institute. Bernie looked out the window for a few moments and fiddled with his beard. I could see he was calculating in his head. He turned to me and said, "We have so much money in the ARI at this time, donations and such, that I think that amount of money could be used elsewhere. Find another recipient."

Dr. Bernard Aginsky, a widower, passed away in January 2000. I have no idea where his donation ended up. I do know whether Bernie Rimland ever had a second thought about not taking that money. He never mentioned our conversation again.

DAN! changing to parallel other autism research.

Research costs money. Bernie used his resources wisely and was not interested in empire-building. He just wanted to find the cause and the answers. Bernie cured kids.

On the anniversary of his death, I went to his Kensington ARI center. I had two bottles of good wine, a bunch of wine glasses, and a whole lot of chocolates. I walked in and was astonished. The whole tenor and tone of the place had changed. The clutter was gone. Bookshelves were neat and organized. The smell of scholarly interest in documents and old books had evaporated. It was as if the ghost of Dr. Bernard Rimland seemed to have moved to another place completely. The staff were delighted to see me, and happily munched on the yummy chocolates that I had brought for them. I commented on the neatness and the vast changes that I observed. One of the staff shrugged her shoulders, grimaced, and said,

"You have no idea just what changes have taken place, and what is about to happen."

An example of the transformation in attitude is exemplified by an offer for inflatable, aka soft-sided, chambers for DAN! while Bernie was still alive. One day, he called me up and explained to me that a group was coming to do a presentation on these soft chambers, and suggested that I plant one of my staff at the ARI to listen to the blurb from the manufacturer, Oxyheal. My secretary, Crystal was waiting amongst Bernie's staff to greet the technicians, doctors, and such that accompanied the owner of the company. They arrived at the ARI, set up the inflatable chamber, and gave their sales pitch, extolling the virtues of hyperbarics at low pressure and at a low cost.

Crystal reported back to me that Bernie looked dour during the presentation and asked, "What would happen to this with a razor blade?" Bernie and I discussed the concept of inflatable chambers the next time he was at my center, after he had finished his treatment in a chamber. He was not convinced about the soft-sided chambers.

"I worried that the scientific data that they quoted was all from hospital quality chambers. I think you are correct Bob, the physics do not hold up. I could not recommend this device to parents for their children."

The "discovery" (observation) of God's gunpowder + Bernie Rimland and Kerri Rivera.

Throughout history, air was taken for granted. You just breathed in and out and there it was; bugs and birds flew in it, mostly useful to keep your floors and ceilings apart. Even in this day and age, many folks think of it in the same way.

Let´s revisit what is now called the Age of Enlightenment, the 17th and 18th Centuries. About 1774, the kindly and soft spoken clergyman/scientist Joseph Priestly and his close friend Benjamin Franklin. They spent time drinking coffee together once a week in a London coffee house along with other scientists. Together they realized that air was actually a mixture of gases, but mostly nitrogen and oxygen. Priestly and Franklin could kill a mouse in a glass jar in less than five minutes by depriving it of one of those gasses. Put the poor little mouse in a glass jar with a lit candle (which consumed the oxygen) and the flame of life in the mouse departed by about the time the candle went out.

Using precise scales, Joseph Priestly and the French chemist Antoine Lavoisier, gave oxygen its name. It could be weighed on a scale just like you would weigh out a cup of rice. Each unseen gas has a weight. Baros is the Greek word for weight. Words that we are familiar with come from this: barometer, barometric pressure, and hyperbaric (as in hyperbaric oxygen therapy, hyper meaning more than and baric meaning weight of the gas).

Weigh oxygen?

The weight of air (mixed oxygen and nitrogen) is 14.7 pounds per square inch at sea level. Most folks like me would prefer to use the word pressure, however, the math is easier if we use the doctors measure (the same as that used in measuring blood pressure – millimeters of mercury or mmHg). An average blood pressure measure is typically 120/80 mmHg. Let's look at it this way; if air at sea level is 760 mmHg, then 20% of that air (oxygen) is 20% of that amount. So multiply 760 by 0.20 and you will realize that vital, life-giving oxygen going into your lungs is about 150 mmHg.

Oxygen - You cannot see it, or smell it but you have to "eat" a kilogram of it each day to stay alive.

Make no mistake. If you take a substance into your body, ALL of your 60 to 90 trillion cells will be affected. Snort it, chew it and swallow it, breathe it, or inject that substance and it will have a positive or negative effect on your whole body. Cells "consume" the substance. Another word for consume is "eat." We will discuss this process, known as oxidative metabolism shortly and, especially how to produce stem-progenitor cells.

Eat oxygen?

Oxygen is a cellular food. The adult human consumes approximately 0.6 kg of oxygen each day (about 1.2 pounds). We can live about three weeks without the food that we chew and swallow, survive three days without water, but we can only live approximately three minutes without oxygen. Body cells start to die—the brain is the most vulnerable. Even a minute or so without oxygen can cause permanent damage.

Don't worry about the earth running out of oxygen. Back in the 1700s Ben Franklin and Joe Priestly also discovered the fact that sunlight on green vegetation produces oxygen—a process called photosynthesis. They showed this with the mouse and candle in the glass jar. As the candle flame seemed to flicker, about to go out and the mouse lay, apparently dead, if there was a sprig of a green plant, both the candle and mouse came back to life. All of the oxygen that you are going to eat in the next 24-hours is replaced by just one square meter of grass producing oxygen through photosynthesis during that same length of time. In populated areas, where there is not much greenery, life-sustaining winds carry oxygen over the oceans and hills to all humans and animals.

Captain Cook, Joseph Priestly, Bernie Rimland, and Kerri Rivera—Explorers

Before we stop talking about Joseph Priestly, he made another observation about gas and this applies to our subject of autism, Bernie, and Kerri.

Living next door to a brewery, Priestly was intrigued about the gas given off by the fermentation of beer in the barrels. He put a dish of water under the vent-pipe coming out of the barrel. When he tasted the water it was full of refreshing bubbles we now call fizz. In 1767, Priestly discovered how to carbonate a liquid. He taught the Navigator, Captain Cook, how to carbonate water and, thinking that drinking that bubbly water would prevent scurvy, Cook set sail with it in 1772. It did not prevent scurvy, but, just like Bernie and Kerri, everything is worth investigating.

We now know that any gas becomes soluble if it is concentrated or made thick. In this instance, the gas was an extremely light gas known as carbon dioxide (yes, the stuff we breath out and, unlike the 21% oxygen, there is only about .033% of carbon dioxide in the air we breathe). However, if you concentrate it to 100% some of it melts into the water and becomes carbonic acid, as is the case with soft drinks. Pop the lid and the acid turns back into carbon dioxides gas, forming little bubbles in the liquid. Joseph Priestly should have patented his observation. Ten years or so later, Joseph Schweppes patented the process in Germany and most folks think of him, not Priestly, when they have a gin and tonic.

Thereby hangs another Newtonian rule about gas that cannot be changed. “Gas under pressure becomes soluble in a liquid according to its density (or thickness).” – Henry’s Law.

And this is how oxygen works in a hyperbaric chamber – Newtonian Gas Laws

Stay with the soda can thought and the thicker gas melting into the sugary drink. When a human climbs into a hyperbaric oxygen chamber, we substitute oxygen for carbon dioxide. Believe it or not, you do not feel squashed by the pressure other than you have to "pop" or equalize your ears. Humans are mostly water and other fluids that cannot be compressed like a gas. What is happening in the chamber is that the oxygen (it should be 100% oxygen) is being made thicker or concentrated. And, just like the soda, Henry's Law kicks in. The oxygen melts and the body supersaturates with oxygen.

Another curious thing about a well-oxygenated body is that it becomes slightly alkaline. Your powers of hydrogen (pH) read about the same as seawater, which is alkaline because of the dissolved oxygen in it. Yes, even fish need their daily meal of oxygen!

The word "saturate" comes from the Latin word meaning "to completely fill." Since only our red blood cells (RBC) carry oxygen, they are almost always full of oxygen in a healthy human. The little pulse-ox device that clips on your finger when you are in hospital almost always reads 99% unless you are anemic.

It takes between one and three minutes for each RBC to leave your heart, make its complete circuit, and be back in your lungs for its next load of oxygen. Remember that Henry's Law also applies here, therefore, oxygen is a gas in your lungs but turns into molecular oxygen when it enters your body's fluids. This is so complex that there is no chemical symbol for it, but rest assured, your body's cells feed on it with a great appetite. (More on oxidative cellular metabolism shortly.)

Supersaturate?

When you fill a glass of water to the brim, it is full or saturated. Right? Yes. Holding it under the faucet and running more water into the glass will only mean that the water slops over the edges. The glass is still full. However, this is not the case with any gas, particularly oxygen breathed in by a human. Sure, just like a glass of water, oxygen can be measured by volume, but there is plenty of room to over-fill our bodies with oxygen—supersaturated.

To illustrate a complex process, let's paint a simple picture—An underground subway system.

Think of your lungs as a subway station. Passengers get off the carriages and others get on. In this instance, remember that air is made up of (for easy math calculations) 80% nitrogen and 20% oxygen. Visualize each gas molecule of either type as a gas-person. The body is already full of nitrogen at sea level and since it does nothing at all (it is inert), the nitrogen-people just come in and out your lungs. However the oxygen-people are dynamic and bustle to climb on board the little red-blood-cell carriage (which has a special oxygen-people magnet—an iron molecule), and away the red blood cell rushes with the oxygen-people ready to jump off to the hungriest of the body's cells.

Since Henry's Law allows a gas to melt into clear fluids (and our body has lots of clear fluids), there is a whole lot of room to add more oxygen-people. For example, if we barred entry to our lungs of the nitrogen-people (simple to do—just put on a mask and breath oxygen out of a 100% oxygen tank), then our lung-subway station would have five times more oxygen-people and that would mean that we increased the oxygen-people with each breath from 160 mmHg to 760 mmHg. Remember that they are dynamic, and that each red-blood-cell carriage has an oxygen magnet in it. The thick crowd oxygen-people all bustle to get onto that carriage, through the wet soapy surfactant in the wall of your lungs, even though it was already full.

Essentially, the oxygen-people fill the red-blood-cell carriage, and into the plasma where they are quickly swept along in that clear plasma fluid. Then, when even more oxygen-people continue to crowd on back at the subway station (i.e. the lungs), the plasma, which normally does not carry oxygen-people (molecular oxygen), then needs to put the overload of oxygen somewhere. From here the oxygen-people go out through the rail tunnels (i.e. the circulatory system) and into the clear fluid (i.e. interstitial fluid) that bathes our body cells. As this fluid fills with oxygen, it dumps it off into the body's largest water compartment—the body's cells (the intra-cellular compartment). These cells now have a veritable feast of oxygen available.

About 90 minutes after you start breathing 100% oxygen, you are supersaturated with five times the normal amount of molecular oxygen. No, you do not swell up since we are talking about molecules in existing body fluid, not added fluid. Curiously, if you put the little pulse-ox back on your finger, it would still only read 99% since it is just measuring the oxygen in your red blood cells. However, using high-tech oxygen measuring equipment (transcutaneous oxiometry), you can even measure molecular oxygen in your urine, saliva, and tears—something once thought impossible.

Now comes the hyperbaric chamber part. You climb in, the door is shut, and 100% oxygen floods in. The technician can look at the physician's prescription and increase the thickness of the gas in that chamber. Double the thickness (i.e. weight or pressure) to 1520 mmHg; ninety minutes later you will climb out of that chamber with ten times the number of oxygen-people (molecular oxygen) in your body. Or, put another way, since your body's cells are going to consume (eat) that additional oxygen, this is the only way you can increase the weight of oxygen-food available in a 24-hour period. One hundred percent pure oxygen at sea level and you will "eat" between just under half a kilogram to just over one kilogram of oxygen.

The deeper/thicker the oxygen is in the chamber the more you get. In fact, following Dalton's Universal Gas Laws, by doubling the pressure, you can actually get your daily oxygen meal at almost two kilograms.

Now the nifty thing about oxygen supersaturation.

Unlike many pharmaceuticals that are weight dependent, (too much of a certain drug will sicken or kill a smaller patient, not enough of the same drug and there will be no therapeutic benefit to the patient) with hyperbaric oxygen no individual can suffer from an "overdose" of oxygen, regardless of whether the patient is a mouse, rabbit, horse, or human. All climb out of the chamber, (depending on the pressure/thickness of oxygen they were treated at) with the same amount of molecular oxygen in their body. Not one person has suffered from an "overdose" of oxygen.

Our oxygen dispensary centers have treated, according to their physician's prescription, tiny babies, the elderly, and everyone in between; we have never seen a negative side effect. Instead, we have observed clinical positive effects for all.

What happens when we actually give people an extra "oxygen feast" by putting them in the chamber? Again, an extremely complicated process has to be simplified for understanding. However, before making things simpler we must first look at the science. Chatelier's principle predicts the effect of a change in conditions on a chemical equilibrium. The principle is named after Henry Louis Le Chatelier, who observed that if a chemical system at equilibrium has a change in concentration, temperature, volume, or partial pressure then the equilibrium shifts to counteract the imposed change and a new equilibrium is established. Any change in the status quo prompts an opposing reaction in the responding system.

Time to change just a couple of words for better understanding. Let us start with the word equilibrium and now call it "the way it was." We can also use that term for status quo and counteract can be changed to "pushing back." So what is really being said here is, if we change something in any chemical environment it will push back hard to be the way it was. Now it is time to make things even easier.

We are all chemical systems.

We have already mentioned cola in a can and advised against giving it to anybody, your child or yourself, because of the acidity of the liquid in the soda. But there is an even more compelling reason—the sugar. There are 39 grams of sugar, about ten teaspoons of sugar, in one can of soda. Would you feed your child that much dry sugar?

"Come on," you might think to yourself, "No way. It does not taste that sweet." It is true. The manufacturers of sodas use a lot of phosphoric acid to disguise the sickly sweetness of the drink. If you still doubt this, take an ordinary penny, or an egg and put it in a glass full of cola overnight. Within a few days, you will find all tarnish removed and instead a bright, shiny penny; the eggshell will be soft and pliable, all its protein dissolved.

Visualize what happens when you allow your small child a glass of cola (or any soda drink). Your little kid becomes supercharged, bouncing off the wall, and for some time you cannot get the child to sit still. In other words, your child has become hyperglycemic. Too much sugar, of any sort, whether it be corn fructose, beet or cane sugar, the results are the same according to Chatelier's principle. Remember, we are all chemical systems and by adding all of the sugar to a small child's body, all of the cells in that body will push back to return to the way they were before the additional sugar. The most efficient way to return to this state is to increase physical activity, causing cells to consume all of the additional added sugar.

Run, baby, run!

Another way, of course, is to rely on the body to use its own chemicals to burn off the sugar. This is predominantly the job of the hormone insulin. If an adult drinks a lot of soda each day (or even has one gin and tonic, which has about half as much sugar as a soda) and does not increase physical activity, diabetes eventually sets in as the body become insulin exhausted, unable to produce more. Then the risk of blindness in old age, amputations, and other terrible consequences may become a reality.

The process of cells using the nutrients we consume is called cellular metabolism. Overloading cells with nutrients that we do not need such as excessive raw sugars (or even food that is easily converted by the body into glucose) and fats, results in obesity; your brain will become sluggish. Now, add extra oxygen and your body will certainly consume it. This is called oxidative metabolism. The added oxygen will push all cells into overdrive; repair cells use the added oxygen to work harder in an effort to restore their state prior to entering the hyperbaric chamber. Repair cells help get rid of the toxins, acids and, excess/unneeded sugars.

After people have been in a hyperbaric chamber, healthy adults comment on the fact that their brain is working more efficiently. Memory becomes vivid and problems are easier to solve. This state is commonly known as the "cappuccino" effect or "brain brightening."

As for small children with autism, almost all of them have a neuronal oxygen transport problem. So the additional feast of oxygen actually makes the good cells, the repair cells, work harder for just a little while after the treatment. This increase in oxidative metabolism dissipates after a couple of hours, but that little bit of improvement lasts: brain cells wire up into complex circuits, blood vessels within the brain become robust, and stem cells are produced. (More on that shortly.)

This is why all oxygen treatments need to take place over consecutive days. There is no point in attending one hyperbaric treatment and then not following it up for another week. Sort of like a seed sprouting from the earth. With each treatment, the positive changes begin to accumulate, and positive results are visible with the passing days.

Can oxygen therapy alone cure autism?

The short answer is no; it cannot. I make this statement based on the treatment of scores of challenged children that have come to my centers across America, and in other parts of the world. Something more is needed—an interdisciplinary approach.

How many treatments in the chamber does a challenged child need to be part of that recovery program?

As noted earlier, we treated our first challenged child, Emily, in one of my centers in the United States. Just one treatment per day at 2 ATA, the pediatrician's decision, made a vast difference to little Emily. Then along came a physician, Dr. Paul Harch, a very bright health scientist. He came to the conclusion 15 years ago that two 60-minute treatments each day at 1.75 ATA for 20 days could cure children with autism. He was so sure of himself that he even took out a patent on that protocol.

I was nonplussed and puzzled. I did not think that you could patent a natural phenomenon such as the effects of hyperbaric oxygen therapy or gravity. Of interest is the fact that the Supreme Court came to the same conclusion in 2012 with what is now known as the "Prometheus" ruling. In essence, the courts had taken all of the enforceable teeth out of Dr. Harch's protocol. This is not to say that there isn't some merit in the treatment pressure, nor is it to imply that Dr. Harch was ignorant of the science of hyperbaric rights in the therapy. So my centers took notice of the fact that he is a physician, and for a little while at least, we did use the Harch protocol on children.

While our little patients saw useful and positive results, there was never a normal recovery by any of the children in that 20-day double ride. This left a lot of the parents disappointed, some angry at what they felt were false claims about hyperbaric oxygen therapy, and rightfully so.

It is significant to note that Dr. Harch, and other clinicians, no longer use the two treatments a day protocol for challenged children, and he no longer claims that recovery is possible in just 20 days.

Now, onto our wonderful Jennifer; the ballet dancer and champion ice-skater. Her mom, Vickie, a bright spirit and highly intelligent woman (actually that describes the whole family), independently arrived at the conclusion that diet was a most important part of the normalization program. All together, over a 12-year period, Jennifer had 135 rides in the hyperbaric chamber. She ice skated at 2am (when the rink was clear), and focused on diet. In a nutshell, while the extra oxygen was feeding one side of cellular metabolism in spurts of 20 treatments at a time, Jennifer's cells were getting the correct diet of nutrients on the other. All of Jen's cells were giving off the right amount of heat and energy, particularly her repair cells.

Bernie and Kerri proved scientifically that the addition of proper nutrients, combined with the removal of deleterious/toxic foods is probably more important than hyperbaric oxygen therapy for children and young adults on the spectrum. Yes, the oxygen boost helps propel the patient to "normal," but the other nutritional changes are really the rocket fuel. It is a long journey, not all that expensive, and certainly worthwhile.

When a hyperbaric chamber is not a hyperbaric chamber.

One final comment about treating neuronal disorders at 1.75 ATA pressure is of utmost importance; this is that 100% oxygen is essential to the protocol. Since Dr. Harch arrived at this treatment depth, there have been thousands of inflatable chambers, so-called mild hyperbaric chambers, sold in the United States and around the world. These are not the same as hospital grade, hard-sided chambers. These bag-chambers do not deliver the needed 100% oxygen. In my opinion, at the very best, if you modify them (against FDA rules) you will only get 34% oxygen.

What have we learned thus far? Time for a review and then THE BIG SECRET REVEALED!

- Oxygen cannot be seen, but we can weigh it.
- Our bodies "eat" oxygen every day because it is a food for our cells.
- The only way we can get additional oxygen is in a hyperbaric chamber.
- This is because any gas becomes soluble and melts into a fluid (i.e. Henry's law); the same reason we can carbonate soda drinks.
- In a single treatment in a hyperbaric-oxygen-therapy chamber, we cannot overdose (and I have never witnessed any negative side effects).
- With the extra oxygen feeding the cells, our bodies get a boost of energy, particularly the repair cells.
- For oxygen in the chamber to be effective, it must be 100% oxygen. Inflatable chambers do not deliver 100% oxygen.
- Hyperbaric oxygen therapy alone will not cure autism, but it does make a big difference.
- There is no such thing as a "one-size fits all" treatment protocol in a hyperbaric chamber that works for all patients. For example, twice a day in the chamber for 20 days will make some difference but not necessarily "normalize" a challenged child.

Did you miss the big secret?

It was already mentioned about one page back—the discoveries of Bernie and Kerri. Let us repeat the secret for you and then push the edges of their really stunning discovery that is backed up by the latest science.

Bernie and Kerri proved scientifically that the addition of the proper nutrients, in the absence of offending foods, in addition to eliminating pathogens and parasites, are most likely more important than hyperbaric oxygen therapy for children and young adults. Yes, the oxygen boost helps propel the patient to "normal" but the other dietary interventions are really the rocket fuel. Not to mention freeing the body of offending pathogens/parasites which wreak havoc on the body. It is a long journey, not all that expensive and, certainly worthwhile.

Nutritional "padding." Hyperbaric oxygen therapy and the production of progenitor and stem cells.

When a baby is growing inside its mother, it has progenitor cells and stem cells. The function of these cells is considered to be, as yet, undecided. Although studies continue to elucidate exactly which mechanisms are involved in determining the fate of these cells, it is generally accepted that their surrounding cells will dictate their development. For example, the big arteries that crisscross the chest area make a decision sooner or later to turn into a heart with all of its compartments. Then, as development moves on different parts of the baby appear. These are called progenitor or stem cells.

There are various estimates on how many different types of cells the developed human has in total; however, it is predicted there are somewhere between 210 and 300. Mind you, when the baby takes its first breath of air, all but about four of these different cell groups stop reproducing. For example, the brain, with all of its neuronal pruning and circuitry needs about 20 year's worth of stimulation to properly wire all of the connections. Surprisingly, a lot of the neurons will be shed or "pruned" since they will not be put to use in the adult. However, neuroplasticity allows new skills to be added or repairs to be made to and by the brain in a lifetime.

However, medical scientists have now realized the great need for progenitor or stem cells (cells that can make decisions to replace worn or damaged cells within the body), and the search is on for these decision-making cells. Many scientists are looking for something they can patent and as a result are missing the point that it is already here. Or they are ignoring it, because but they cannot patent it.

It is called hyperbaric oxygen therapy.

> Penn Study Finds Hyperbaric Oxygen Treatments Mobilize Stem Cells
>
> **Science Daily** — According to a study to be published in the American Journal of Physiology-Heart and Circulation Physiology, a typical course of hyperbaric oxygen treatments increases by eight-fold the number of stem cells circulating in a patient's body. Stem cells, also called progenitor cells are crucial to injury repair. The study currently appears online and is scheduled for publication in the April 2006, edition of the American Journal.
>
> Stem cells exist in the bone marrow of human beings and animals and are capable of changing their nature to become part of many different organs and tissues. In response to injury, these cells move from the bone marrow to the injured sites, where they differentiate into cells that assist in the healing process. The movement, or mobilization, of stem cells can be triggered by a variety of stimuli including pharmaceutical agents and hyperbaric oxygen treatments. Where as drugs are associated with a host of side effects, hyperbaric oxygen treatments carry a significantly lower risk of such effects.
>
> "This is the safest way clinically to increase stem cell circulation, far safer than any of the pharmaceutical options," said Stephen Thom, MD, PhD, professor of emergency medicine at the University of Pennsylvania School of Medicine and lead author of the study." This study provides information on the fundamental mechanisms for hyperbaric oxygen and offers a new theoretical therapeutic option for mobilizing stem cells."
>
> "We reproduced the observations from humans in animals in order to identify the mechanism for the hyperbaric oxygen effect," added Thom. "We found that hyperbaric oxygen mobilizes stem/progenitor cells because it increases synthesis of a molecule called nitric oxide in the bone marrow. This synthesis is thought to trigger enzymes that mediate stem/progenitor cell release."[1]

Nutritional padding: It has long been known that when hyperbaric oxygen therapy is applied, existing cells, the good ones, the repair cells, turn the body into its own pharmaceutical company, providing the right sort of chemicals at the right time. Above all, there is a dramatic increase in the production of the molecule called nitric oxide from the bone marrow. Probably the best way of describing the addition of hyperbaric oxygen therapy, as an adjunct to the correct nutritionals, is simply by putting fuel onto an already existing smoldering fire. Out of the glow of embers and smoke you will see a vigorous combustion as your fireplace heats up and the flames appear.

Now imagine other ingredients that have yet to be discovered as beneficial. For example, stem cells that repair the damaged brain of a person with autism. It could be that adding external stem cells to the recipe of recovery and normalization, with simple nutritional low-cost padding, and putting the little patient in the chamber would be a faster way of achieving what all parents want for their children—to eventually become fully functional and independent adults.

All of this by just a little bit of nutritional padding and helping the body to rid itself of pathogens/parasites.

Now, it is time to turn back to Kerri so she can tell you what she has seen when hyperbaric oxygen therapy is added to the correct nutritional padding, along with chlorine dioxide to keep pathogens under control. That is the big secret to helping your child through the challenges that living in this century have visited upon you.

* * *

As Bob mentioned, I have seen miracles happen when hyperbaric oxygen therapy was applied to a child who is ready. Two girls, in particular, lost their diagnosis completely within weeks of completing treatment in the chamber. As I mentioned before, hyperbaric oxygen therapy gave my own son his speech back. Before his first 40 dives he had several single-syllable sounds, but after, he began stringing words together to request his favorite foods.

Today we are seeing that one dive a day at 1.75 ATA (atmospheres absolute) for 90 minutes at depth is better than two 60-minute sessions were first prescribed for Patrick seven years ago. Every three months after the first treatment of 20 sessions, apply ten sessions of 90 minutes, each at 1.75 ATA, until your child is recovered.

A lot of parents ask when is a good time to do hyperbarics. To this I reply that we must first have diet and chlorine dioxide totally under control, and be at least three months into the Parasite Protocol. At that point it's time to start looking for a chamber.

Make sure to do an ATEC before your child's hyperbaric oxygen therapy sessions, and repeat two months after the sessions are over; the results will be obvious.

Healing
the symptoms known as
Autism

This is my Asperger son Tobias, 10 years old, and me... when we received the book this summer.

Chapter 12

Step 7 - GcMAF & Autism:

State of the Art & Future Perspectives for a Natural Cure

by Marco Ruggiero, MD, PhD.
Specialist in Diagnostic Radiology
Full professor of Molecular Biology
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"The voyage of discovery is not in seeking
new landscapes but in having new eyes."
~ Marcel Proust

My family and I have been in biomed for so long, that there aren't too many interventions we haven't already tried. A few years back, Dr. Usman mentioned to me that GcMAF might be something good for Patrick. She explained that GcMAF is a human protein that occurs naturally in a healthy body. It is a special supplement that replaces the missing part of the immune system, and also acts as the body's own internal medicine.

IMMUNE GCMA
NG/ML 2.2ML
TORE AT 4°C
TCH M1210-25
ETAINED VIAL

Based on her recommendation, we ordered a vial, and applied it for about two and a half months. I saw less obsessive compulsive eating, but when the vial ended and I hadn't seen amazing results, I wasn't extremely motivated to continue. Not only that, funds were scarce, so continuing really wasn't an option.

Two years went by and I spoke to Dr. Usman again. She said we really should give it four to five months before making a final decision. So, we scraped together the money for a second order. We started again in November of 2012, and reached full dose by December, 26th 2012. Seemingly, as time went on, Patrick started to do new things.

By springtime of 2013, Patrick's BFF's mom was saying how well he was doing, and reminded me that during the prior month Patrick had not been doing the things that he was now doing. As I write this in October of 2013, all of my money now goes to GcMAF. ☺

One of the things that I feel makes GcMAF so exciting is the fact that it helps regrow dendrites in a matter of hours after it is injected. The dendrites are the very things that got fried when mercury entered our children's bodies. With the help of GcMAF, we are now able to restore what was lost. Not to mention, GcMAF boosts the immune system, which we have come to find is often sorely lacking in people with ASD's.

Many people have asked me if GcMAF is now an official part of the protocol. When working towards recovery, I feel that we need to try everything at our disposal that has been proven to heal autism—in the correct order, or course. GcMAF fits that description. According to www.gcmaf.eu, "As of February 2013, on the American National Library of Medicine alone, 142 eminent scientists from 8 nations have published 59 major GcMAF research papers, which can be viewed on the US Government's Pubmed system." There is now enough research to prove that GcMAF has secured its place as a powerful biomedical intervention for healing autism. Therefore, after three months on the Kalcker Parasite Protocol, it is time to start thinking about adding in supplements, HBOT and GcMAF.

We are blessed to have the one and only Dr. Marco Ruggiero, the lead GcMAF researcher, write the remainder of this chapter about this substance, it's benefits and applications in autism and beyond.

The information he presents is extremely important because I feel that GcMAF is the future of medicine—today. What other intervention boasts a cancer recovery rate of 80%? None! Dr. Bradstreet is reporting 85% responders and 15% recovery rate from autism with GcMAF.[1]

Imagine adding GcMAF to the protocol already outlined in this book at the right moment (after working down some of the pathogen load), we should start seeing even higher rates of recovery than 15%. I look forward to seeing what transpires during the upcoming year as more families add GcMAF to their children's protocols. I am excited for more and more people to lose their autism diagnoses.

For the past 20 years, Dr. Marco Ruggiero has worked on the vitamin D axis, a metabolic pathway that includes the vitamin D binding protein-derived macrophage activating factor or GcMAF. I n the past 3 years he has published studies on the immunotherapeutic effects of GcMAF in cancer, HIV/AIDS, chronic fatigue syndrome and neurological conditions.

Marco Ruggiero holds a PhD in Molecular Biology, is a certified Medical Doctor specializing in Clinical Radiology and is a professor of Molecular Biology at the Department of Experimental and Clinical Biomedical Sciences of the University of Firenze, Italy.

He served in the Army as Medical Lieutenant with specific training in chemical, biological and nuclear warfare. He worked at Burroughs Welcome Co. North Carolina, USA publishing a seminal paper with Nobel Laureate Sir John Vane and, subsequently, at the National Cancer Institute of the NIH in Bethesda, working with Dr. Stuart A. Aaronson and Dr. Peter Duesberg.

Since 1992, he holds the chair of Molecular Biology at the University of Firenze where he leads a research group of about 10 researchers. He has published more than 150 peer-reviewed scientific papers on signal transduction in a variety of experimental and spontaneous pathologic system related with cancer, chronic kidney disease, chronic fatigue syndrome and neurological conditions.

The role of nutrition in the treatment and eradication of the symptoms of autism is well established and other chapters of this book treat this topic in detail. What is far less known is the fact that certain natural components of the diet, certain nutrients, have profound effects on all the systems that are affected in autism and in particular on the brain and the immune system. Their effects are so dramatic that for about 20 years, these natural components have been labelled as "drugs" even though they are essential parts of our bodies, just like hormones or neurotransmitters. I am referring here to the family of molecules that is known as GcMAF, an acronym that stands for Gc-protein-derived Macrophage Activating Factor.

GcMAF has been the object of intense research in the past 20 years for its therapeutic role in cancer, autoimmune diseases, and HIV infection (for review, see: Anticancer Res. 2012 Jan;32(1):45-52). But, only one year ago, in 2012, its dramatic effects on the eradication of the symptoms of autism were published in a prestigious peer-reviewed scientific journal (Autism Insights 2012:4 31–38).

In this chapter I shall provide an overview on GcMAF with particular reference to its therapeutic role in autism and to the future perspectives deriving from the basic and applied research that is revolving around this fascinating molecule.

A Brief History of GcMAF

The first publication on GcMAF in a peer-reviewed journal indexed in the US National Library of Medicine is dated 1994 (J Immunol. 1994 May 15;152(10):5100-7). In this article, a group of researchers from the Department of Biochemistry at the Temple University School of Medicine in Philadelphia, USA, described the effects of a protein, defined as GcMAF, on rat macrophages. Macrophages are key elements of the immune response and the research group led by Dr. Nobuto Yamamoto, the first author of this paper, showed that GcMAF activated these cells. Given the central role of macrophages in the control of all immune responses, GcMAF was considered a powerful regulator of the immune system and the research on GcMAF initially was focused on its immune-stimulant properties. In fact, one year after the initial observation on rats, Dr. Yamamoto, who in the meantime had moved to the Laboratory of Cancer Immunology and Molecular Biology of the Albert Einstein Cancer Center in Philadelphia, authored a paper suggesting that a defect in endogenous GcMAF production contributed to immunodeficiency in AIDS patients (AIDS Res Hum Retroviruses. 1995 Nov;11(11):1373-8.). Consequently, he provided GcMAF to Medical Doctors treating HIV patients and, 14 years later, after 7 years of follow-up, he published a seminal paper describing eradication of HIV infection through GcMAF administration (J Med Virol. 2009 Jan;81(1):16-26).

Immunodeficiency, however, is not unique to HIV/AIDS and, back in 1996, Yamamoto and colleagues, hypothesized that deficient endogenous GcMAF production was responsible for the relative immunodeficiency that is typically observed in cancer patients (Cancer Res. 1996 Jun 15;56(12):2827-31). Quite logically, this observation of 18 years ago, led to the proposal of administering GcMAF to cancer patients with the goal of empowering the immune system that in turn would fight the cancer growth. This approach is known as "immunotherapy" and it is much older than GcMAF since, in modern times, it stems from the observation of Dr. William Coley in 1891. However, it could be argued that the idea of stimulating the immune system to fight diseases is even older since, as it is stated in this recent article, "…cancer regresses when associated with acute infections such as bacterial, viral, fungal, protozoal, etc. Acute infections are known to cure chronic diseases since the time of Hippocrates…" (Indian J Cancer. 2011 Apr-Jun;48(2):246-51).

Whatever the case, administration of GcMAF to patients with metastatic advanced cancer proved efficacious and there are now scores of papers published in the peer-reviewed literature describing the dramatic therapeutic effects of GcMAF in all types of experimental or spontaneous tumors.

Nowadays, the interest for GcMAF in the immunotherapy of cancer is so high that the prestigious scientific journal “OncoImmunology” dedicated the cover of its August 2013 issue to GcMAF. The molecular rendering of GcMAF is on the left of the cover with a caption linking it to an article by Thyer and colleagues published in the same issue and describing successful treatment of advanced cancer patients (Figure 1).

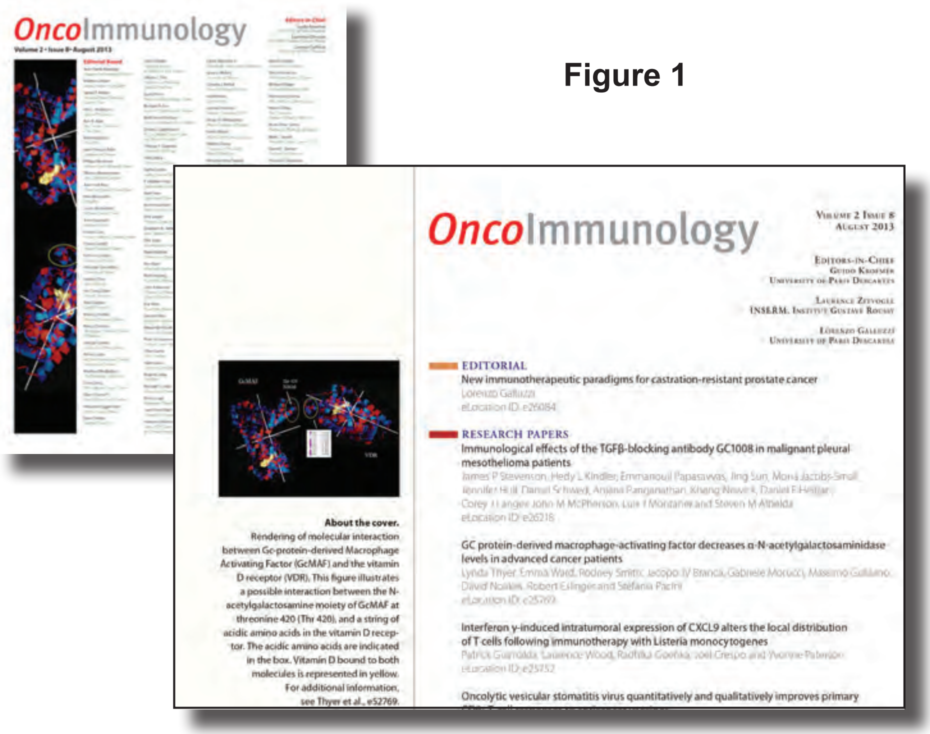

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EDITORIAL

New immunotherapeutic paradigms for castration-resistant prostate cancer
Lorenzo Galluzzi

RESEARCH PAPERS

Immunological effects of the TGFβ-blocking antibody GC1008 in malignant pleural mesothelioma patients

GC protein-derived macrophage-activating factor decreases α-N-acetylgalactosaminidase levels in advanced cancer patients

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About the cover.
Rendering of molecular interaction between Gc-protein-derived Macrophage Activating Factor (GcMAF) and the vitamin D receptor (VDR). This figure illustrates a possible interaction between the N-acetylgalactosamine moiety of GcMAF at threonine 420 (Thr 420), and a string of acidic amino acids in the vitamin D receptor. The acidic amino acids are indicated in the box. Vitamin D bound to both molecules is represented in yellow. For additional information, see Thyer et al., e52769.

Figure 1

Source: https://www.landesbioscience.com/journals/oncoimmunology/oncoimmunology_2-8.pdf

Consecration of GcMAF in the Olympus of science, however, occurred a few days later, on September 14, 2013, when another article by Thyer and colleagues was published in “Nutrients”, an international, peer-reviewed open access advanced forum for studies related to human nutrition (Nutrients. 2013 Jul 8;5(7):2577-89). In fact, this article describing the effects of GcMAF on human breast cancer cells, was ranked in the top 5% of all articles ever tracked by Altmetric. The Altmetric score is a general measure of the attention that an article, book or dataset has received online and reflects the quantity of attention received as well as the quality of that attention. By the time that the GcMAF was ranked in the top 5% of all scientific articles ever tracked, Altmetric had analyzed 1,510,524 articles across all scientific journals. Therefore, we may safely state that in this chapter we are describing one of the hottest topics in today’s world science (Figure 2).

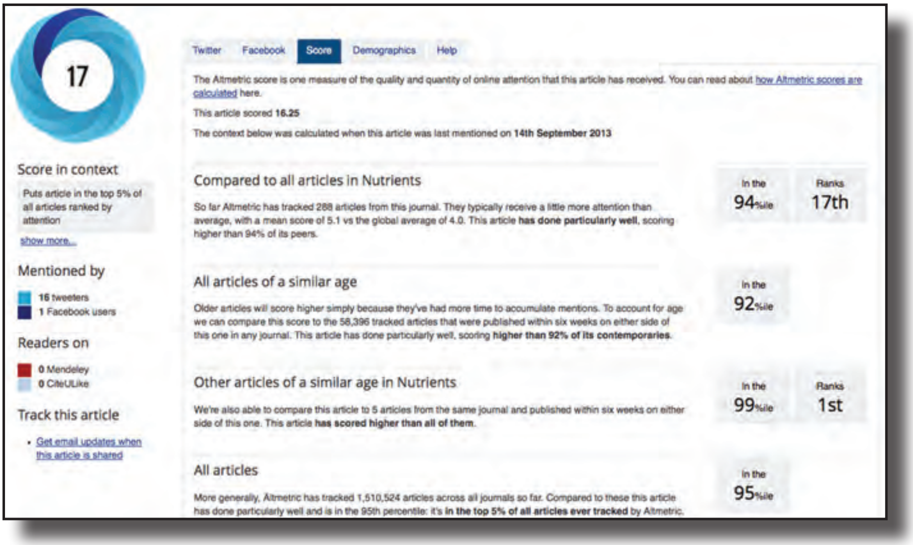

The Altmetric score is one measure of the quality and quantity of online attention that this article has received. You can read about how Altmetric scores are calculated here.

This article scored **16.25**

The context below was calculated when this article was last mentioned on **14th September 2013**

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Older articles will score higher simply because they've had more time to accumulate mentions. To account for age we can compare this score to the 58,396 tracked articles that were published within six weeks on either side of this one in any journal. This article has done particularly well, scoring **higher than 92% of its contemporaries**.

In the 92%ile

Other articles of a similar age in Nutrients

We're also able to compare this article to 5 articles from the same journal and published within six weeks on either side of this one. This article **has scored higher than all of them**.

In the 99%ile | Ranks 1st

All articles

More generally, Altmetric has tracked 1,510,524 articles across all journals so far. Compared to these this article has done particularly well and is in the 95th percentile: it's **in the top 5% of all articles ever tracked** by Altmetric.

In the 95%ile

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Figure 2

The interest for the therapeutic effects of GcMAF in a variety of conditions derives from the early observation by Yamamoto and colleagues in 1995, who showed elevated level of serum alpha-N-acetylgalactosaminidase (Nagalase) in the serum of AIDS patients. Nagalase is an enzyme that deglycosylates (degrades) the precursor of GcMAF that is the circulating Gc-protein, also known as vitamin D-binding protein (AIDS Res Hum Retroviruses. 1995 Nov;11(11):1373-8). This results in the loss of GcMAF precursor activity and consequent dysfunction of the immune system. Increased Nagalase activity, however, is not observed uniquely in AIDS patients. For example it was demonstrated that the increase of Nagalase activity in the serum of cancer patients is due to the fact that cancer cells release Nagalase and, therefore, Nagalase activity reflects tumor burden, aggressiveness and progression of the disease. Consequently, determination of Nagalase activity is currently proposed as a reliable way of evaluation of cancer severity (Cancer Lett. 2009 Oct 8;283(2):222-9).

In short, in cancer, HIV/AIDS, and in many other chronic conditions, elevated serum Nagalase, degrades Gc-protein that is the precursor of GcMAF. Therefore, GcMAF is not produced inside the body to a sufficient extent and this leads to immunodeficiency. Serum Nagalase, however, does not degrade GcMAF, and this justifies the administration of exogenous GcMAF in all those conditions where its endogenous production is insufficient due to elevated Nagalase activity.

Until 2002, it was thought that GcMAF exerted its effects only on macrophages and that its therapeutic efficacy was due to stimulation of macrophages that in turn would attack and destroy cancer cells as well as virus-infected cells. In 2002, however, a novel effect of GcMAF was described. Kanda and colleagues, working at the Department of Molecular Microbiology and Immunology, Division of Endothelial Cell Biology, Nagasaki University Graduate School of Medicine, Nagasaki, Japan, published a paper, co-authored by Yamamoto, describing the inhibitory effects of GcMAF on angiogenesis (J Natl Cancer Inst. 2002 Sep 4;94(17):1311-9.). Angiogenesis is the process of building new blood vessels that provide the tumor mass with the required supply of blood and nutrients that it needs to grow and metastatize. Therefore, since 1971 it was postulated that inhibition of angiogenesis could be a successful strategy to deprive the growing tumor mass of its supply of blood and nutrients (N Engl J Med. 1971 Nov 18;285(21):1182-6). While there are scores of inhibitors of angiogenesis, some of which in use in the therapy of cancer, GcMAF offers the advantage of performing more than one anticancer effects; in fact, not only it inhibits tumor-induced angiogenesis (Cancer Immunol Immunother. 2011 Apr;60(4):479-85), but it also stimulates macrophages that attack and destroy the cancer cells (Nutrients. 2013 Jul 8;5(7):2577-89).

If these combined anticancer effects were not enough, in 2010 Gregory and colleagues, working at the Department of Ophthalmology and Visual Sciences of University of Kentucky in Lexington, Kentucky, USA, demonstrated that GcMAF directly inhibited proliferation and metastatic potential of human prostate cancer cells (PLoS One. 2010 Oct 18;5(10):e13428). Slightly more than one year later, we were able to demonstrate that GcMAF not only inhibited proliferation and metastatic potential of human breast cancer cells, but it also reverted their neoplastic phenotype; in other words, cancer cells treated with GcMAF became normal (Anticancer Res. 2012 Jan;32(1):45-52).

On the basis of the peer-reviewed scientific literature quoted above, we can now state that GcMAF exerts multiple effects that are responsible for its efficacy in anticancer therapy:

1. It stimulates macrophages that attack and destroy cancer cells, as originally postulated by Yamamoto and colleagues.
2. It inhibits tumor-induced angiogenesis thus depriving the growing tumor mass of blood and nutrients.

3. It directly inhibits cancer cell proliferation and metastatic potential and it retro-transforms cancer cells into normal healthy cells.

Given this plethora of effects on cancer, it is no wonder that the majority of GcMAF research has been focused on its anticancer properties. There are, however, a few research articles suggesting that GcMAF might exert also other biological actions with therapeutic implications. In addition to the studies on HIV and AIDS quoted above, GcMAF has received attention for its potential role in the therapy of bone disorders (Blood. 1996 Oct 15;88(8):2898-905), and autoimmune diseases such as Lupus Erythematosus (Clin Immunol Immunopathol. 1997 Mar;82(3):290-8).

Despite these scanty evidences on the possible role of GcMAF in conditions other than cancer and AIDS, it was not until 2012, however, that GcMAF proved dramatically effective in the therapy of autism.

GcMAF & Autism

GcMAF, being derived from Gc-protein, also known as vitamin D binding protein, belongs to the so called "vitamin D axis", a nutritional metabolic pathway described in detail in a recent review (European Nephrology, 2011;5(1):15–9). My research group had been working on the vitamin D axis since 1996 (Epidemiol Prev. 1996 Apr-Sep;20(2-3):140-1), that is since the beginning of GcMAF research. Just like our colleagues in the USA and Japan, we were mainly interested in the role of the vitamin D axis in bone metabolism and cancer (Radiol Med. 1996 Nov;92(5):520-4. Oncol Res. 1998;10(1):43-6). Therefore, it came as a surprise when Dr. Nobuto Yamamoto first mentioned to me the effects of GcMAF on neurodegenerative diseases such as Parkinson's and Alzheimer's diseases.

In the hot summer of 2010 we visited Dr. Yamamoto in his hometown of Philadelphia, and we had the honor and the pleasure to spend two very intense days with this old-style exquisite gentleman. Dr. Yamamoto gave us a detailed history not only of his decade-long research activity, but also of the entire field of immunotherapy, starting with the pioneering work of Dr. William Coley at the end of the nineteen century. During these intense and fruitful talks, Dr. Yamamoto mentioned the dramatic effects that he had personally observed by administering GcMAF to a patient suffering from Parkinson's disease. According to Dr. Yamamoto, the effects had been almost immediate and dramatic up to the point that he himself was amazed. Regrettably, he had been unable to clinically document the case and, therefore, this remained an anecdote. From this anecdote, however, an entire new field of GcMAF research was about to rise; that is the study on the role and implications of GcMAF in treating neurologic and neurodegenerative disorders.

The first solid evidences for a role of GcMAF in treating a neurodegenerative disorder were simultaneously presented by Dr. Paul Cheney and Prof. Kenny de Meirleir at the meeting of the International Association for Chronic Fatigue Syndrome and Myalgic Encephalomyelitis (CFS/ME) held in Ottawa in September 2011. A few days later, in collaboration with Dr. Paul Cheney, we presented in Padova, Italy, a study demonstrating that food-based GcMAF dramatically improved the symptoms of CFS/ME, and this work was published in the official journal of the Italian Society of Anatomy and Histology, one of the oldest and most respected European scientific societies, founded at the beginning of the twentieth century (It. J. Anat. Embryol. Vol. 116, No 1, 2011).

CFS/ME is a complex disorder that shares many features of autism. In fact, it is characterized by immune system dysfunction, widespread inflammation, and multi-systemic neuropathology (J Intern Med. 2011 Oct;270(4):327-38. In Vivo. 2013 Mar-Apr;27(2):177-87). Dysfunction of the immune system involves abnormal functions and distributions of T lymphocytes, B lymphocytes, natural killer cells, and monocyte/macrophages (Nihon Rinsho. 1992 Nov;50(11):2625-9. Brain Behav Immun. 2012 Jan;26(1):24-31). The etiology of CFS/ME, just like the etiology of autism, is still unknown and multiple factors are thought to be responsible for its onset and progression, thus lending credit to the hypothesis that both etiology and pathogenesis are multifactorial (J Intern Med. 2011 Oct;270(4):327-38). Heavy metal exposure and viral infections are among the factors that contribute to CFS/ME etiology and pathogenesis, and a role for human endogenous retroviruses has been recently hypothesized (In Vivo. 2013 Mar-Apr;27(2):177-87). Both chronic heavy metal exposure and viral infections are considered responsible for the immune system dysfunction and neuropathology that are typical of CFS/ME (Med Hypotheses. 2012 Sep;79(3):403-7. In Vivo. 2013 Mar-Apr;27(2):177-87).

In addition to these areas of overlapping, it had been noticed by Doctors treating autism and/or CFS/ME, that in several families the two conditions are often associated with parents of autistic children suffering from CFS/ME. Interestingly, this happens also in families with adopted children with autism, thus lending credit to the hypothesis that environmental or infectious factors may contribute to both conditions.

Whatever the case, it had been observed that CFS/ME patients had elevated levels of serum Nagalase together with a number of immunological alterations, and it was hypothesized that they could benefit from GcMAF treatment. The results presented in Ottawa and in Padova confirmed this assumption and ever since immunotherapy with GcMAF is a stronghold of CFS/ME treatment.

At about the same time, Dr. Bradstreet, a leading authority in the field of autism, began to study the levels of Nagalase in autistic children and their responses to GcMAF treatment. The results obtained in a first cohort of 40 subjects were reported in a seminal paper published in 2012 (Autism Insights 2012:4 31–38). This paper represents a turning point in the understanding of autism pathogenesis and treatment.

The first significant finding is the observation that the average level of Nagalase in autistic subjects was more than two folds higher than the normal level, thus lending credit to the hypothesis that immunodeficiency or immune system dysfunction is a hallmark of autism. The second finding, probably the most important in recent years, is the observation that GcMAF treatment significantly improved the symptoms of autism and this improvement was associated with a decrease of Nagalase levels.

The therapeutic response to GcMAF was statistically significant and showed the typical bell-shaped curve that is expected when a biologically effective treatment is at work. About 15% of subject did not respond; this means that their symptoms were not ameliorated by GcMAF treatment. However, more than 15% of children responded so dramatically that all the symptoms of autism were eradicated in a matter of weeks up to the point that the children could no longer be defined as "autistic." According to the very word of the authors, in the children in this group, "This response was demonstrated at school, during therapies, home and outside the home as substantial improvement to the point that many or most of the criteria of autism were no longer present."

The remaining 70% of children were distributed according to the so-called Gaussian distribution in the groups showing "slight," "moderate," or "considerable" improvement.

This paper demonstrated for the first time that GcMAF treatment was able to eradicate the symptoms of autism in a matter of weeks, thus reinforcing the idea brought forward in many chapters of this book that autism is a curable condition indeed.

Quite obviously, the dramatic results obtained by Dr. Bradstreet did not go unnoticed and, in April 2013, he presented further results at the First GcMAF Immunology Conference held in Frankfurt, Germany. According to Dr. Bradstreet, as the time of follow-up and the number of subjects increased, a shift toward the right (that is the "best") part of the curve could be observed. This means that the percentage of those showing "considerable" to "very considerable" improvement increased.

From the point of view of the general practitioner, the issue could be considered closed: GcMAF cures a significant percentage of autistic children now and that figure is rising.

However, since I am a researcher in addition of being a Medical Doctor, the successes of Dr. Bradstreet in treating autism and the research papers published by Immuno Biotech laboratories are in the middle of an exciting series of observations that are leading to a completely new understanding of how GcMAF works and what autism truly is.

In fact, the undisputable efficacy of GcMAF in treating autism raises a number of questions on the mechanisms involved at the cellular and molecular levels. The most important questions are:

1. The efficacy of GcMAF in curing autism is due only to its immune-stimulating effect?
2. Or, is GcMAF acting directly also on neurons as it does on cancer cells?
3. Does GcMAF revert the neuro-anatomical alterations that are typical of the autistic brain?
4. Why a certain number of autistic subjects do not respond to GcMAF?
5. Can we devise strategies to have these non-responders respond?
6. Can we devise strategies to further improve this already dramatic therapeutic effect?

The Effects of GcMAF on Human Neurons

GcMAF is a protein and, as such, it was thought that it would stimulate cells from the outside. In other words, until 2013, it was conjectured that, on their external surface, cells had a receptor that bound GcMAF and conveyed the signal to the inside of the cell and, ultimately, to the nucleus and the DNA, thereby modifying the cell behavior. However, despite 20 years of research, such a receptor for GcMAF had not been identified. And this might appear truly odd considering that the entire human genome had been sequenced, that is studied in every single detail, more than 10 years ago.

In our first publication with Dr. Yamamoto, presented at the XVIII International AIDS Conference in Vienna in 2010, we had demonstrated that the response to GcMAF in human mononuclear cells (that is macrophages) was dependent on polymorphisms (that are the individual variations among humans) of the vitamin D receptor (VDR) gene. This observation was not surprising considering that vitamin D, its receptor, and GcMAF all belong to the vitamin D axis.

In order to further investigate this relationship between GcMAF and the VDR we began studying the molecular assembly of GcMAF that is the "shape" that the molecule assumes in its physiological conformation. Having done this, we looked for complementary areas in the GcMAF and VDR molecules and… voilà! The two molecules complemented each other as two elements of a puzzle.

We published this observation in the "Nutrients" paper that is now in the top 5% of all articles ever tracked, and the picture of the two molecules interacting with each other is in the front cover of the OncoImmunology August 2013 issue. The molecular mechanisms through which GcMAF and VDR interact and the consequent complex web of intracellular signaling are topics for specialists and rather difficult to divulge; the basic point, however, is that we had demonstrated how is it possible that GcMAF exerted so many different effects that can be exploited to treat a number of diseases so different from each other.

From this observation we deducted that all cells having the VDR would have responded to GcMAF and, given our interest for the effects of GcMAF in neurological conditions such as autism and CFS/ME, we began our study on human neurons. In fact, human neurons express (i.e. "have") the VDR and therefore, they are candidate to be stimulated by GcMAF.

We cultured human neurons in Petri dishes and we challenged them with ultra-pure GcMAF; in this type of experiments there were no other variables. That is, there were only neurons and GcMAF; the cells of the immune system or other molecules were not involved. By doing so, we would have been certain that whatever effect we observed, this was due uniquely to GcMAF.

As I have shown at the congress "Curando el Autismo" in San Juan de Puerto Rico in August 2013, GcMAF at extremely low concentration significantly increased neuronal cell viability and metabolic activity. These effects on cell viability were associated with dose-dependent intracellular cAMP production (cAMP is an intracellular second messenger). This means that GcMAF increased the production of energy inside human neurons and made them more active, more viable. Increased viability and metabolic activity following GcMAF stimulation as well as cAMP formation were accompanied by morphological changes, meaning that stimulated neurons changed their shape.

In the absence of GcMAF, human neuronal cells under the microscope appeared as small, relatively undifferentiated cells with large nuclei. After 24h stimulation with GcMAF, neurons showed a significant change in morphology that was consistent with the induction of neuronal differentiation and increased connectivity. The cytoplasm was enlarged and cytoplasmic elongations could be observed. After 72h incubation with GcMAF, these morphological changes were more evident and well differentiated cells could be observed.

After incubation with GcMAF, the cells appeared to establish contacts with each other. Taken together these results indicated that GcMAF increased neuronal cell viability, metabolic activity and differentiation, with the first effects being observed at 24h. It is worth noticing that the assay that we used to determine cell viability, measured mitochondrial activity, and mitochondrial dysfunction is known to be hallmark of ME/CFS (Int J Clin Exp Med. 2012;5(3):208-20), and possibly of autism as well. Therefore, the effects of GcMAF that we observed explain the reason why GcMAF is so effective in CFS/ME and autism; it counteracts the molecular alterations that are the pathogenetic basis of both conditions.

I wish to spend a few words here on the effects of GcMAF on neuronal connectivity. It is well assessed that this is one of the basic alterations in the brain of autistic subjects; neurons do not establish contacts with each other and therefore the neurological signal cannot be transmitted from one area of the brain to another thus causing a "disconnection" (Rev Neurol. 2012

Feb 29;54 Suppl 1:S31-9). GcMAF re-establishes neuronal connectivity by stimulating the formation of what are called "cytoplasmic elongations" that are like small "arms" that protrude from the neurons and establish contact with each other as if neurons were tending arms to "touch" each other and exchange information.

In Figure 3A, human un-stimulated human neurons in culture can be observed; they are small and roundish. After stimulation with GcMAF (Figure 3B), they are much larger because increased energy production leads to increased protein synthesis in their cytoplasm. But, perhaps more important, they have a highly irregular, elongated, triangular, shape with spikes that touch each other. The areas of contact between the two neurons can be clearly observed in the central part where they establish connecting bridges. Please notice that both pictures were taken with the same magnification.

Figure 3

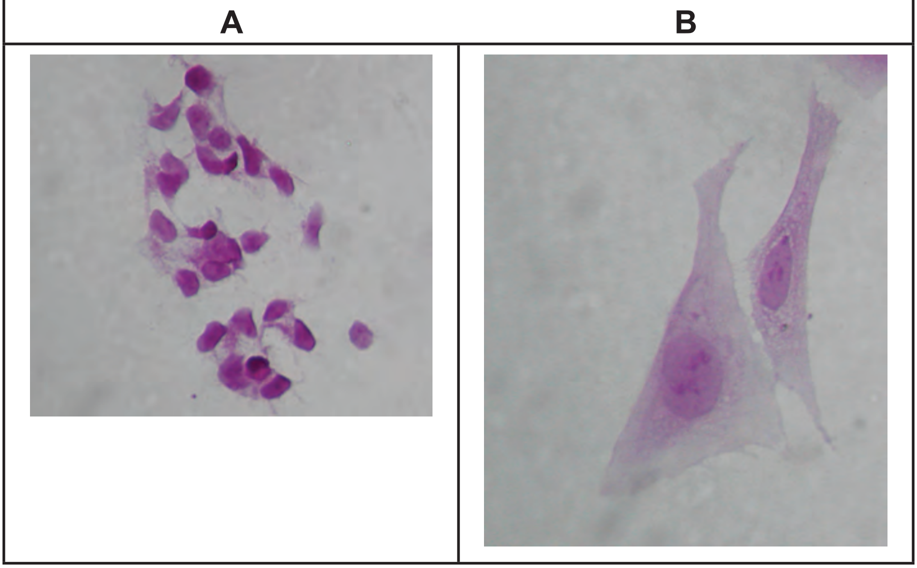

These observations provide an answer to the first two questions raised by the article published by Dr. Bradstreet: the therapeutic effects of GcMAF in autism can be ascribed to at least two different actions of GcMAF. On one side, it rebalances the immune system that is typically dysfunctional in autistic subjects; on the other side, it directly stimulates human neurons increasing their metabolic activity and their connectivity. But, as it always happens in research, these "answers" led to other "questions": does GcMAF cross the blood brain barrier? That is, does it arrive to the neurons of the central nervous system? Before challenging this question further, however, let's proceed with order and let's try to provide an answer to the other questions that were raised by the Bradstreet's paper.

GcMAF and the Neuro-Anatomical Alterations of the Autistic Brain

If the etiology of autism is still undefined, the pathogenesis and the brain alterations associated with autism are better understood. Several studies using sophisticated imaging techniques demonstrated that there is atypical structural brain connectivity within cortical white and grey matter and it is postulated that such an alteration of brain connectivity may represent one of the principal neural substrates underlying autistic symptoms (PLoS One. 2013 Jun 18;8(6):e67329. Proc Natl Acad Sci U S A. 2013 Jul 22.).

The observed atypical brain connectivity is localized to particular areas of the brain and the alterations in the fronto-temporal regions are associated with the severity of social and repetitive symptoms of autism (Proc Natl Acad Sci U S A. 2013 Jul 22.). Atypical brain connectivity in autism is also associated with reduction of grey matter volume in different areas of the brain (Cerebellum. 2013 Apr 10.). In the bilateral superior temporal gyrus significantly decreased functional connectivity was accompanied by the strongest trend of grey matter volume decrease (PLoS One. 2013 Jun 18;8(6):e67329), thus reinforcing the hypothesis that study of grey matter volume may provide indication of functional connectivity.

However, the studies on brain connectivity and grey matter reduction quoted above were conducted with sophisticated Magnetic Resonance Imaging (MRI) equipments using complex softwares. Because of their cost and complexity, these techniques are not suitable for routine examination and this appears to be in contrast with the need to provide the general practitioners with the instruments to study autism. In fact, given the current epidemiological trend, it is highly probable that even primary care providers will see with increased frequency a patient with autism spectrum disorder in their clinic (Curr Probl Pediatr Adolesc Health Care. 2013 Jan;43(1):2-11). This consideration prompted us for the search of accessible methods to study brain alterations in autism and to study the response to different treatment including GcMAF.

To this end, we developed an easily accessible method to study the brain cortex using transcranial ultrasonography. This technique was first applied to the diagnosis and treatment CFS/ME a syndrome that, as we know, share neuropathological similarities with autism (Toxicology. 2008 May 2;247(1):61-72). In particular, we proposed to use ultrasounds to study the grey matter in the temporal lobe, and to evaluate signs of neuronal layer disorganization and brain inflammation (Med Hypotheses. 2012 Sep;79(3):403-7). It is worth noticing that these same neurological alterations, i.e. minicolumn structural changes and inflammation are frequently observed in autism (Front Immunol. 2013 Jun 10;4:140. doi: 10.3389/fimmu.2013.00140. Print 2013). Therefore, we hypothesize that ultrasounds could be used in autism in order to study the brain alterations that have been described using more sophisticated and less accessible techniques.

First of all, we assessed the safety of the technique; to this end we used sub-thermal ultrasounds. These are considered inherently safe and have been used for fetal imaging in utero, and virtually every part of the body, including brains of newborn babies through fontanelles. Their inherent safety and any lack of correlation with the onset of autism have been confirmed by meta-analysis of thousands of cases. A recent randomized controlled trial on over 1.400 cases demonstrated beyond any reasonable doubt that there is no link between the prenatal ultrasound scans and the autism phenotype (J Autism Dev Disord. 2012 Dec;42(12):2693-701).

Then, in a collaborative work with Dr. Bradstreet, we decided to focus our attention on the temporal cortex in order to compare our results with those already published by Hameroff and colleagues and by ourselves using this technique (Med Hypotheses. 2012 Sep;79(3):403-7. Brain Stimul. 2013 May;6(3):409-15). In addition, having to choose a particular area of the brain for this initial study, the temporal lobe was particularly interesting because of its accessibility to ultrasounds and its involvement in the pathogenesis of autism (PLoS One. 2013 Jun 18;8(6):e67329. Print 2013).

In the typical adults subject, meninges appeared as a well-organized array of layers of about 2.6 mm thickness. The meninges were separated from the cortex by a structure that shows echogenic and morphological feature consistent with the sub-arachnoid space. The cortex of the temporal lobe appeared as a well-organized array of alternate, hyper-echogenic/hypo-echogenic, layers. The thickness of the cortex was 5.0 mm. This value of thickness and the anatomical positioning of the probe led us to hypothesize that we were observing the temporal areas designated by von Economo as TG and TE, i.e. those areas involved in the control of eye movements and balance in standing position (area TE), social behavior, mood and decision making (area TG) (von Economo C. Temporal lobe. In: Triarhou LC, editor. Cellular structure of the human cerebral cortex. Basel; 2009. p. 114-132). It is worth noticing that the layers within the column-like structure of the healthy subject appeared well-organized and parallel to each other.

However, the images obtained in a representative autistic subject showed that the thickness of the cortex of the temporal lobe was significantly reduced, as it had been observed with MRI (PLoS One. 2013 Jun 18;8(6):e67329. Print 2013). Other images showed a concomitant increase in the spinal fluid in the sub-arachnoid space that was twice as much as in the healthy subject. These findings are consistent with the very recent observation that infants who developed autism spectrum disorder had significantly greater extra-axial fluid characterized by excessive cerebrospinal fluid in the sub-arachnoid space (Brain. 2013 Jul 9.).

Taken together, the results obtained in autistic subjects demonstrate that our technique was able to visualize the excess extra-axial fluid in a manner comparable to MRI; however, at variance with MRI, the observation with ultrasounds was immediate and intuitive and could be easily performed with no discomfort during a routine examination.

Another finding that we observed was a relative disorganization of the neuronal layer arrangement in the temporal cortex of autistic subjects. It was possible to observe that the neuronal layers had a different orientation and that there were black areas of about 0.4 mm that could represent areas of poor connectivity.

Since this technique has been applied only recently to the study of autism, there is no statistical analysis indicating whether GcMAF or any other effective treatment can reverse the anatomical alterations that we have observed in the brain of autistic subjects. Therefore, there is no sound scientific answer to this question; there are only some anecdotic evidences suggesting that this might indeed be the case. Autistic subjects treated with GcMAF and showing considerable clinical improvement showed a normal brain anatomy. Future observation will tell whether these anecdotic evidences have a statistical meaning.

Ultrasounds, however, in addition to their role in early diagnosis and follow-up, might also have a role in the therapy of autism and in particular in improving the response of those subjects who do not appear to benefit from GcMAF treatment.

GcMAF Non-Responders

As odd as it may appear to non-researchers, the presence of non-responders is often the best assurance that we are dealing with a real biological phenomenon and not with placebo effects or worse. In fact the bell-shaped curve presented in the article by Bradstreet and colleagues it typical of any effective treatment and it confirms the validity of the results. This having said, however, there is the need to provide an answer to those who do not respond. And, in the effort of providing an answer to non-responders, improvements in the overall efficacy of the treatment for everyone will eventually follow.

At the moment, there are two hypotheses that could help explaining why certain subjects do not respond to GcMAF in terms of improvement of symptoms of autism.

The first hypothesis is related with the VDR gene polymorphisms. As we proposed at the AIDS conference in Vienna in 2010, and later published in 2012 (J Nephrol. 2012 Jul-Aug;25(4):577-81), the individual responsiveness to GcMAF depends on the individual variations (polymorphisms) in the VDR gene. In other words, there are subjects harbouring variants that are associated with little or no response. However, this lack of response is relative and not absolute. In fact, it has been observed with vitamin D that these individuals respond to higher doses of the vitamin, thus indicating that the VDR is "less" responsive, but still functioning. This would mean that the so-called non-responders might need a higher dose or a longer time of GcMAF treatment to obtain the desired therapeutic effects. Prolonged observation of a higher number of cases will tell whether this hypothesis is correct.

The second hypothesis is closely associated with the first one as well as with the question briefly outlined in a preceding section: "does GcMAF cross the blood brain barrier?" In a recently submitted paper, we proposed that the interconnection between GcMAF and VDR signaling is responsible for the transport of GcMAF through the blood brain barrier. In fact, transport of macromolecules across the blood brain barrier requires both specific and nonspecific interactions between macromolecules and proteins/receptors expressed on the luminal and/or the abluminal surfaces of the brain capillary endothelial cells (Int J Cell Biol. 2013;2013:703545. doi: 10.1155/2013/703545). Since VDR signaling appears to enhance brain to blood transport at the blood brain barrier through both genomic and non-genomic actions, it can be hypothesized that the interaction between GcMAF and VDR (Nutrients. 2013 Jul 8;5(7):2577-89. doi: 10.3390/nu5072577) may favor GcMAF transport into the brain. This means that subjects with a less responsive VDR because of unfavorable genetic variants, would also have a less efficient transport of GcMAF to the brain.

This latter consideration, however, opens the way to a possible solution that might also help increasing the effectiveness of GcMAF in those who already respond to it.

In fact, now that we know the physiological molecular assembly of GcMAF, we can design specific GcMAF molecules that are more efficient in crossing the blood brain barrier and, therefore, are more effective in treating neurological conditions such as CFS/ME and autism. These molecules exploit the fatty acid binding site in the GcMAF molecule, and use one of the most beneficial fatty acids, oleic acid, the basic component of olive oil, to target brain cells.

Most interestingly, GcMAF/oleic acid molecules do not only stimulate human neurons with a much higher efficiency than GcMAF, but they also regulate glial cell metabolism. Glial cells are the connective tissue of the brain and glial cell dysfunction is involved in the pathogenesis of autism. In particular, glial cell dysfunction seems to be responsible for the neuronal underconnectivity typical of the autistic brain (Neuron Glia Biol. 2011 May;7(2-4):205-13). In short, we can postulate that the development of these novel GcMAF/oleic acid molecules will prove beneficial not only for the GcMAF non-responders, but also for improving the therapeutic efficacy of GcMAF in all neurological conditions where GcMAF treatment is indicated.

In addition to these novel, more physiological, brain-targeted, molecules, there are other strategies that can improve GcMAF transport into the brain with consequent increased therapeutic efficacy. Just a few days ago, in a journal dedicated to advanced radiological research, it was published a report demonstrating that ultrasounds, just like those described in the preceding section, transiently open the blood brain barrier. This phenomenon is exploited to favor transport of chemotherapeutic drugs into the brain of individual with brain tumors and it proved safe and efficacious after extensive testing.

On the basis of this observation, one could devise a simple treatment protocol using the same ultrasound system that is currently used for transcranial ultrasonography. In analogy with what is performed to deliver chemotherapeutic drugs to brain tumors, ultrasounds could be used to facilitate the transport of GcMAF through the blood brain barrier and to focus its delivery into those areas of the brain that are known to be altered in autism.

In this manner, during a regular examination, the health professional could exploit our technique to assess the neuro-anatomical alterations in the autistic brain and to deliver GcMAF to those areas. The use of more physiological, brain-targeted GcMAF molecules that can be administered sublingually, would greatly improve the efficacy of the treatment and it will most likely reduce the percentage of the so called non-responders to GcMAF.

As noted above, however, the use of ultrasounds to treat neurological conditions is not completely new. In fact, we and others have demonstrated that non-thermal ultrasounds have significant effects on mental states (Brain Stimul. 2013 May;6(3):409-15), modulate neurotransmission (Neuropsychobiology. 2012;65(3):153-60), cardiac frequency and blood pressure and improve skeletal muscle strength (The Journal of IiME, vol. 6 (1), p 23-28, 2012). These effects can be observed with ultrasounds alone, that is in the absence of other treatments.

In a protocol for the treatment of autism and CFS/ME, we propose to use our ultrasonographic technique together with timely administration of sublingual GcMAF/oleic acid molecules. In this manner, we are able to exploit the direct effects of ultrasounds on the neuronal microtubules (Brain Stimul. 2013 May;6(3):409-15), together with the ability of ultrasounds to favor the transport of GcMAF/oleic acid into the brain and, more precisely into those areas where the neuroanatomical alterations are observed.

What is GcMAF?
A drug, a hormone, a natural component, a nutrient?

How to define a molecule that is formed every time a wound is licked? This is the most evolutionary conserved protective behavior in animals, humans included. The enzymes in the saliva convert the Gc-protein in the blood that is on the wound into active GcMAF that prevents infection of the wound and promotes repair (PLoS One. 2013 Jul 18;8(7):e69059).

For many years researchers considered GcMAF only a key regulator of the immune system because of its activity on macrophages and its denomination reflects this early conjecture. However, as it often happens in science, the original denomination of a molecule proves incorrect with the passing of time and the accumulation of scientific evidences. Vitamin D is a notable example; it is not an vitamin and it does not contain any amine group (even though the suffix "vita" applies, in that it is indispensable for life). Now it is rightly considered a hormone produced by the body and, to be more precise, a secosteroid hormone that has a mechanism of action similar to that of classical steroidal hormones. GcMAF, being a part of the vitamin D axis might soon become another example of scientific mislabeling. In fact, we now know that it exerts its actions in many other cell types in addition to macrophages and that its role go well beyond activation of macrophages.

And even though there are no doubts that it is a powerful stimulant of the immune system, it would not be surprising to realize that this might not be its most relevant physiological role. In this respect, GcMAF shares the destiny of its precursor, the Gc-protein. Gc-protein is a serum alpha 2 glycoprotein composed of a single polypeptide chain, structurally related to serum albumin, that performs a variety of actions in several cell types. It is synthesized in the liver and has been detected on the surface of several cell types, yolk sac endodermal cells, and some T lymphocytes. In B cells, it participates in the linkage of surface immunoglobulins. In addition to vitamin D, it binds actin and acts as an actin scavenger. These characteristics are of paramount importance in human pathology since actin is the most abundant protein in eukaryotic cells and it is a major cellular protein released during cell necrosis that may cause fatal formation of actin-containing thrombi in the circulation if the actin scavenging capacity of Gc-protein is exceeded. Not surprisingly, therefore, several studies suggest an association between Gc-protein and resistance or susceptibility to chronic obstructive pulmonary disease, thyroid diseases, diabetes, multiple sclerosis, and sarcoidosis (for a review on Gc-protein and the vitamin D axis, see: European Nephrology, 2011;5(1):15–9).

From these considerations it derives that the potential indications for GcMAF treatment might be far too numerous than those currently envisaged. And also this parallels the fate of vitamin D, once thought only to prevent rickets and now involved in almost all aspects of human physiology and pathology up to the point that a (serious) scientific article on this subject was entitled: "Does vitamin D make the world go 'round'?" (Breastfeed Med 2008; 3: 2392–50.).

Apart from issues of biomedical terminology, it is now emerging the concept that GcMAF is an essential component of that nutritional pathway that is the vitamin D axis. It is not a case or a coincidence that the article on GcMAF that has received the greatest attention was published in a scientific journal named "Nutrients". With the proceeding of research it is becoming apparent that GcMAF participates in such a variety of physiological events that each proposed definition is limited.

But, if we accept the concept that GcMAF is a natural nutrient, indispensable for brain and immune system development and function (and possibly for many more essential physiological events), two questions spontaneously arise: “Where do I find it in nature?” and “How can I consume it?”

The second question already has an answer: now that the physiological molecular assembly of GcMAF is known, there are on the market several GcMAF products that can be used sublingually or simply eaten. Modern biotechnology has reproduced the physiological conformation of GcMAF so that it can be absorbed in a natural way without recurring to intravenous or intramuscular injections. GcMAF injections are reserved for those cases where a strong and rapid stimulation is required.

The other question is more intriguing and leads to the final section of this chapter.

My Own Personal Experience with GcMAF

As it happens in many people of my age exposed to the radiations from the Chernobyl incident, I have several thyroid nodules. Being a radiologist, it was easy for me to perform ultrasonography on my thyroid and what I saw on the screen was not nice. In addition to small lesions in my right lobe, in my left lobe I observed a massive mixed (solid and cystic) protruding nodule substituting for most of the lobe. The anterior-posterior diameter was about 3 cm, whereas the longitudinal diameter was greater than the length of the probe (4 cm). The structure was grossly inhomogeneous with cystic areas and hypo-reflecting areas alternated with iso- or hyper-reflecting areas. The margins bordering the residual normal thyroid tissue appeared well defined with an area of edema (inflammation) surrounding the nodule. The blood vessels were located around and inside the nodule and few or no blood vessels could be observed in the large hypo-reflecting areas suggesting the presence of metabolically inactive tumor tissue. Consistent with these findings, laboratory tests showed signs of immunodeficiency and anemia. And, it has been reported that anemia is among the predictive elements of malignancy in thyroid nodules (Tunis Med. 2002 Sep;80(9):536-41).

It was immediately clear to me that I needed a powerful stimulant of the immune system as wells as an anticancer agent, and GcMAF was my first thought. However, at that time, GcMAF was synthesized only in academic research laboratories and it was not available on the market as the pure, highly active, quality controlled product that we know today. Therefore, we decided to look for natural sources of GcMAF.

We already knew that GcMAF is naturally formed when a wound is licked because saliva contains the enzymes that convert blood Gc-protein into active GcMAF. Licking my thyroid, however, quite obviously, was not an option.

Because of these hindrances, we hypothesized that GcMAF could be obtained through a natural food fermentation process that exploits the characteristic of certain microbial strains to produce the enzymes that convert food Gc-protein into GcMAF (Hollis and Draper, 1979). According to our hypothesis, fermented food-derived GcMAF would activate the macrophages widely diffused in the walls of the entire gastrointestinal tract and, in particular, in the Waldeyer's-Pirogov tonsillar ring (or pharyngeal lymphoid ring). Our first goal was to assess the feasibility of obtaining natural GcMAF through home-made food processing procedures. To this end, we devised a strategy to prepare a fermented food product using those microbes, known to mankind for their healthy properties for millennia, that express the enzymes involved in GcMAF synthesis (Hollis and Draper, 1979).

After having prepared this fermented food at home, I began consuming it on a daily basis.

Since at that time we too considered GcMAF mainly for its immune-stimulating properties, the first objective was to assess the efficacy of this procedure on certain markers of immunodeficiency, the so called CD4 lymphocytes. The general public became familiar with CD4 lymphocytes because of their involvement in HIV infection and AIDS, and CD4 cell number is considered a reliable marker of immune system function. The role of CD4 cells in the immune system has been widely popularized up to the point that the webpage of the AIDS Authority of the Government of the United States of America states; "CD4 cells or T-cells are the "generals" of the human immune system. These are the cells that send signals to activate your body's immune response when they detect "intruders," like viruses or bacteria. Because of the important role these cells play in how your body fights off infections, it's important to keep their numbers up in the normal ranges..."

In our observation, the reference laboratory considered normal value for CD4 cell count 500 - 1500 cells/μL. Before consumption, my CD4 count was low, close to the threshold of AIDS definition (372 cells/μL). CD4 count rose from the abnormal value of 372 to the normal value of 609 cells/μL after three weeks of consumption of the fermented food that I had prepared. Such an increase continued up to eight weeks with CD4 cell count reaching 853 cells/μL. After many years, they are still in the normal range.

The trend toward normalization of blood parameters was observed also in other abnormal haematological values. My values (low or abnormal) changed as follows:

	Before Consumption	After 3 Weeks	Normal Values
Red Blood Cells			
(x106/uL)	4.55	4.85	4.6 - 6.2
Haematocrit, %	42.9	45.9	40 - 52
Haemoglobin, g/dL	14.8	15.6	13 - 18
Platelets/uL	165,000	206,000	140,000 - 440,000

The neutrophil cell count decreased from 77% to 55% in about 12 weeks, indicating a normalization of parameters suggestive of a pro-inflammatory state. Overall, the observed changes in haematological parameters were consistent with those positive modification of immune responses in humans that might represent the potential mechanism by which food fermented by probiotic bacteria confer health benefits.

Being a researcher, I am very well aware that this report is a mere anecdote that, in the era of evidence-based medicine, has low value or is not even considered to be medical evidence. However, a very recent study on the evaluation of clinical practice challenges the deprecation of stories like that reported above. Thus, it is well known that some studies present large and impressive statistics obtained from many observations while others report a small number of noteworthy events, as we did in this study. However, according to this authoritative epistemological approach, "all of these stories become evidence of what works in medicine" (J Eval Clin Pract. 2011 Oct;17(5):920-6).

Conclusions

In August 2013, a paper published in the very prestigious American Journal of Immunology reported a series of clinical cases successfully treated with GcMAF (Am. J. Immunol., 9: 78-84. 2013). Among these, there were pathologies already known to be responsive to GcMAF treatment, such as cancer, autism, and CFS/ME. Other neurodegenerative diseases such as multiple sclerosis and amyotrophic lateral sclerosis, however, had not been treated with GcMAF before, and this is the first report on such a successful treatment. This paper, together with all the other recognitions reported above, places GcMAF as one of the most effective tool to fight diseases that were considered incurable until very recently.

In other chapters of this book it is clearly stated that autism IS curable, and the successes of GcMAF in curing autism further strengthen this concept. What is emerging and what I hope to have been able to convey, is that GcMAF is not an exogenous drug that "fixes" some problem, but rather a very natural component of our body that is essential for, at least, brain and immune system development and function. In many conditions, including autism, GcMAF is not produced to a sufficient extent and therefore it has to be administered from the outside. With the advent of a courageous little biotech company that has perfected the synthesis of natural, fully physiological, GcMAF molecules that can be eaten, GcMAF treatment will become all the more and flexible to fit the individual needs. Eventually, GcMAF will become part of an integrated nutritional plan as it was intended by nature during evolution.

Consistent with this concept, I wish to conclude with an example from the realm of nature.

According to the Genetic Science Learning Center of the University of Utah, "Some mother rats spend a lot of time licking, grooming and nursing their pups. Others seem to ignore their pups. Highly nurtured rat pups tend to grow up to be calm adults, while rat pups who receive little nurturing tend to grow up to be anxious. It turns out that the difference between a calm and an anxious rat is not genetic—it's epigenetic. The nurturing behavior of a mother rat during the first week of life shapes her pups' epigenomes. And, the epigenetic pattern that mom establishes tends to stay put, even after the pups become adults."

It seems that licking their pups while breastfeeding in the first week of life is the decisive factor; in the saliva there are the enzymes that convert milk Gc-protein into GcMAF. What is more natural than this?

* * *

Subcutaneous GcMAF has been available through FIRSTiMMUNE for several years. Their website is:

www.gcmaf.eu

They now also produce a sublingual version of GcMAF called GOleic. They also have Bravo probiotics, and more. Please visit their website for more information.

"If you're not stubborn, you'll give up on experiments too soon. And if you're not flexible, you'll pound your head against the wall and you won't see a different solution to a problem you're trying to solve."

~ Jeff Bezos
Founder of Amazon

Chapter 13

Beyond Recovery: The Maintenance Plan

"Success is not final, failure is not fatal:
it is the courage to continue that counts."
~ *Winston Churchill*

We see these questions on our boards from time to time:

Will my son have to take CD for the rest of his life?
or
Will we be sorting through poop forever?

The answer is No!

Once your child has recovered, you can move to the maintenance phase. Since we live in a toxic world, it is important to continually detox the system, and keep the body free of parasites. While this can look different for every child and every family, the following are some general guidelines designed to keep our kids healthy once they are recovered.

Diet

While some families go back to giving their children foods that aren't permitted here, many do not. Wheat, dairy, and soy aren't "healthy" foods for any of us to be consuming. After reading Olive Kaiser's section on gluten, you may have a tough time giving your child any bread products ever again. That said, once the gut is healed, it should be able to tolerate many of these foods again, to the extent that a "healthy" person would.

CD

Even into the recovered stage of autism, many of the families keep using CD (oral, baths, enemas) to reach an ATEC of zero... or until there are no behaviors left from the autism. Once that is accomplished, then a maintenance plan of one oral dose on Monday and one oral dose on Thursday is enough. Typically, such a dose is 3 drops for children and 6 drops for adults—all in one dose on each of those 2 days. However, each family does this a little differently depending on weight and what the optimum dose was while on the full protocol.

The more I learn about how toxic our planet is (i.e. GMOs, toxins in the air, drinking water, parasites in the environment, etc.), the more I realize how critical it is to be on a at least a limited long-term detoxing program. This is especially true for someone who was, or may still be immunocompromised. I do believe that once a child recovers from autism, their immune system can do the job that it was designed to do. However, healing takes time, and every case is different. Some people ask me if recovered children still take CD once recovered—and to be honest—many do not.

Parasite Protocol

It is impossible to avoid parasites in our world. As Andreas and Miriam explained to us, their larvae are nearly indestructible in nature and can live for years. A strong immune system, as well as sufficient stomach acid, may prevent a parasitic infection from taking hold in the body. To make sure, it is best to do a "mini protocol" every 3 months. You can do the full 18 days every 3rd month or a 1-week mini version—whichever you prefer.

Other Supplements

While ocean water is necessary when detoxing with CD, it is extremely beneficial to all of us as our soils are almost completely devoid of nutrients and are contaminated with heavy metals and toxins. Also, it has been theorized that many GMO crops are lacking in nutrition as well. The 90 bioavailable nutrients in OW can certainly go a long way in keeping our bodies healthy. I especially love that it helps with conductivity in the brain. And, it is conducive to speech and cognitive function as well.

Depending on each individual's needs it may behoove a family to keep giving MCT oil or Vegan 3,6,9 omegas. Certain supplements may still be required if there is a history of seizures.

Chelation

Gentle chelators like Bio-Chelate™ can continue to be used into the recovery phase as heavy metals are present in our air and water.

Hyperbarics

Nothing brings down inflammation quite like a hard hyperbaric chamber. However, 10 to 20 sessions can be very cost prohibitive for some families, making it a very personal decision as to whether or not to continue with HBOT after recovery.

GcMAF

I never felt better than when I did a course of GcMAF injections on myself. Energy went up and so did my ability to concentrate. Again, GcMAF is a fairly expensive intervention and that will factor into each family's decision as to whether to keep using it. or not

In a nutshell, I would at least continue with CD two times a week, and a mini parasite protocol every 3 months, just as a preventative. Staying healthy is as important as getting healthy.

> Um, YEAH so just took an ATEC. We have officially been on the protocol for 12 months now and finishing up our 11th PP. ATEC of THREE!!!!!!!!!!!!!! 57 to 3 in 12 months. Henry's speech is what is keeping us from 0. He has great conversation with people that are patient and don't interrupt him so we are so close to a BIG ZERO!!! 57 to 3 in 12 months!!!! Far cry from the severe autism diagnosis he got at 2.5 years old. Here is to the doctor that told me my son should be medicated, would never speak, and will probably need to be institutionalized. I hope YOU never say those things to another person!!!!! All you need is hope, determination, and LOVE.

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Chapter 14

Miscellaneous Information You Should Know

*"Always bear in mind that your own resolution to succeed
is more important than any one thing."*
~ *Abraham Lincoln*

Seizures

An estimated 40% of children with autism suffer from some form of seizures. Seizures can be absolutely terrifying for both child and family and deleterious to the health of a child who is already suffering from various issues. I have talked to many different professionals about seizures and in turn have heard just as many different opinions on why this happens. Many doctors are unsure, while some simply don't express their opinions. Some say it is a virus in the brain or heavy metals, inflammation, or pathogens/parasites. In a presentation by Dr. Andreas Kalcker, he stated that high levels of ammonia in the body can cause seizures and the high levels of ammonia in the body come from parasites. Since we know that CD kills pathogens/parasites, neutralizes heavy metals, and helps to reduce inflammation, it is not surprising that we have noticed reduced, or even eliminated seizure activity in children with seizure disorders that use CD in combination with the Parasite Protocol.

MCT (medium chain triglyceride) oils, which come from the Ketogenic Diet out of UCLA, are also a very important piece to healing the body and eliminating seizure disorders. There is plenty of information on the Internet that discusses the results of people (on the spectrum and otherwise) using MCT oils for seizure disorders.

The following is a list of things that parents on The Protocol have used successfully to reduce/eliminate seizures in their children.

- CD
- Parasite Protocol
- MCT oil

- GABA
- Hyperbarics at 1.75 ATA
- Ketogenic diet
- SCD diet (grain free)
- L-Carnitine
- P5P with magnesium
- L-Carnosine
- Taurine
- DMG
- Pycnogenol®

The first four in this list have proven to be the most important and have shown consistent results. If you have a child suffering from seizures, you would be wise to review and consider these interventions immediately. The others have also proven very helpful and can be added in one-by-one, (always leaving three days between each new supplement) while you watch for a decrease in seizures.

When we introduce GABA, we increase the dose daily in search of the appropriate dose for the individual. While establishing the correct dose for one intervention it is not appropriate to add in other supplements. Watch out for sleepiness or undesired behavior with GABA. In these cases, I would personally discontinue its use, as with everything there is not one formula that is right for every child. Similarly, if you see hyperactivity or undesired behavior with DMG discontinue its use.

All of the above supplements/interventions have proven very important for eliminating seizures, in different combinations, for different families. Whether the seizures are grand mal (tonic clonic) or petit mal (absence), they start to fade away as a result of the Protocol.

Sometimes, when a family starts corresponding with me, their child may already be taking some of these supplements, and they continue to do that. They may have already taken some of these and seen no improvement. Some other families live in parts of the world where these supplements are unavailable, and in that case we focus on CD and killing parasites.

As I mentioned, a critical piece for some of the children with seizures has been the implementation of the Parasite Protocol. This has also led to a reduction or cessation of seizure activity in many children with seizures.

Interestingly, once some moms were made aware of the parasite/seizure connection it was easy to time seizure activity/anxiety/aggression to full and/or new moons. As Dr. Andreas Kalcker talked about in the parasite section, the full moon period is when parasites are mating, many in the gastrointestinal tract, and therefore "wormy behaviors" (anxiety, SIBs, depression, tantrums, aggression, and teeth grinding to name a few) will generally be higher around that period. New moons can also cause an increase in these behaviors.

Children who have a seizure disorder or are self-injurious need to avoid food coloring, eggs, tomatoes, pork, and chocolate. When adding in the supplements for the seizures that we listed above, follow the same rules as before, never adding more than one supplement every three days, and always carefully observing and keeping track of any and all changes in your notebook so we know what causes what.

After starting anti-parasitics with the help of her daughter's doctor, one veteran mom introduced the CD protocol; a combination that has been extremely beneficial for her daughter, who suffered from frequent grand mal (tonic clonic) seizures.

Her Advice:

Most of my understanding of how parasitic infections can lead to seizures involves my own tracking of seizure activity patterns in my daughter, which coincided with new moon and full moon periods. Then, since MOST doctors want references to what they feel are 'reliable sources,' I started by Googling "NIH parasites seizures," which brought me to:

ncbi.nlm.nih.gov/pubmed/18754958
Helminthic parasites and seizures. [Epilepsy. 2008][1] - PubMed - NCBI

I would strongly suggest that you document patterns of seizure activity against the Farmer's Almanac of Full Moons (you can even look up past Full Moons) and marry that information with info from sites like the one above. Also, I would highly recommend you hunt down a pediatric infectious disease specialist in your local area (start by researching pediatric staff at local hospitals) and bring with you all information/insight to your first appointment.

Her Testimonial:

From her very first drop of activated CD in early July 2012 (actually her very first one-eighth drop to be exact), I witnessed an improvement in my daughter. Within about two hours of drinking her first ounce of the activated CD water solution (one activated drop of CD mixed into eight ounces of water), I witnessed her sitting still in our kitchen and observing me in such a way unlike she had ever done before. She was calmly observing me instead of running around the kitchen. She was taking my actions in. She was studying me. Her eyes were focused on me, rather than constantly scanning everything else in the room. Both her facial expression and her body language were calmer than I had ever witnessed before. She was more focused, more centered. She appeared content.

This change that I witnessed in her was so noticeable and so sudden, that I couldn't help but think to myself, "So this must be why the first word in MMS is Miracle." It was that amazing of a change in those moments.

Shortly after those incredible moments, my daughter went on to eating contently and then jumping on the neighbor's netted trampoline. She has enjoyed the neighbor's trampoline for years; yet on that particular day, only a few hours after her first drink of a tiny amount of CD, I noticed something quite different in her behavior. As I observed her from the windows of our house, I could see that she was jumping less than usual and instead looking around a lot more. She was calmly looking around at the neighbors' houses, down at some birds in the grass, up at the trees, the clouds, etc. It was all as though she was perhaps truly noticing them for the first time. She had glanced at these things before that day, sure, but she never before appeared to be studying them in the manner she was in those moments on the trampoline that July afternoon. She did engage a bit in some of her tic-like spitting movements with her mouth while on the trampoline, but to nowhere near the intensity, nor duration that would more typically have consumed her prior to that day.

When she came back into the house after using the trampoline and observing her world, I asked her, "why were you spitting out there?" To my surprise, she then very calmly replied, "because it's sensory." Wow! She truly was more connected somehow to her world than ever before. Something good was happening to my girl—only hours after drinking one-eighth of a drop of activated CD with one ounce of water. From those moments on I felt encouraged in my heart and soul that CD could possibly be a very important catalyst toward improving my daughter's health and well-being.

With the help of a caring local doctor, we had already begun some trials of anti-parasitic medications on our daughter in early May 2012, prior to starting CD, in response to behavioral struggles that had been consistently intensifying around full moons every month. (Later, we noticed new moon behavioral intensities as well). We had seen some improvement with anti-parasitic medication, yet CD seemed to somehow boost our daughter toward further improvements that much quicker. In fact, our daughter's ATEC score before starting CD measured 79 on July 8th, 2012 (the day before starting CD), but as of September 30th had dropped down to 55 (only two and a half months later).

Now, in early December 2012, our daughter still appears to be on an overall upward trend of improving health and stability, attributable to the synergy of CD and anti-parasitic medications. Natalie's interpersonal skills have improved, her growth rate has improved, her focus has improved, and her frequency of seizures has lessened.

In fact, at this writing she is 53 days seizure free, which is quite an improvement considering before she was on a terrifying pace of grand mal (tonic clonic) seizures occurring every 2-3 weeks. These are very dangerous, life-threatening events. Her seizures were rapid onset, heading toward grand mal within seconds. They could happen anywhere, i.e. while in her car seat coming back home from a Dr.'s appointment, while driving away from Costco, while running in the backyard playing with the dog, or swinging high on the swing set in the backyard with a neighbor girl. Yet another occurred while wading in the lake (with life vest on), another hit while in our neighbor's four-foot swimming pool with me and her brother. She was right next to me, walking around and then suddenly, she was in the throes of a rapid-onset grand mal seizure that required me to lift her out of pool into her NT (neurotypical) brother's arms. May these be the last my daughter ever knows of seizures.

It is our hope that, in time, CD will be able to take on the lead role as the primary health-support for our daughter, if not, perhaps even someday the sole healthcare support to her. We're looking forward to the days when we may be able to remove or reduce many, or perhaps even almost all, of her current supportive medications (i.e. antibiotic, antiviral, anti-seizure, etc.). With the caring support of parents of The Thinking Moms' Revolution, as well as some excellent local doctors, we suspect that our daughter's life will continue to improve. In the almost 14 years of caring for our daughter in her various states of medical fragility, we have never ever had this much Hope. We feel fortunate to have been swept up into this Revolution and embraced warmly by so many Thinking Moms who are also in the process of working toward more healing for their children. Working to heal illness is so much nobler than working to mask illness, wouldn't you agree? God Bless Jim Humble, Andreas Kalcker, Kerri McDaniel de Rivera and all the TMR families!

UPDATE: January 30th, 2013

I too am so thankful for Kerri and her whole 'crew'. Thanks to Kerri for bringing CD to all of our kids on the spectrum worldwide. My Natalie is now OFF of her former roller-coaster ride of prescription anti-fungals, OFF of her former roller-coaster ride of prescription antibiotics, OFF of prescription antiviral, OFF of prescription low-dose naltrexone, etc. Her belly distention has disappeared, she's gained weight, she's gained height and she's now almost 103 days seizure free (as of 6:16pm tonight). She still has a ways to go toward more improvements, but she's happily climbing up from bottom of the trenches; she's climbing up from what seemed like the very bottom of the abyss that vaccine injury/injuries had placed her in. Thank you Kerri, Andreas Kalcker, Jim Humble and all of the moderators on the supportive websites!!!

UPDATE: February 1st, 2013

My Natalie's long run of 105 seizure-free days has ended. After being off of Albenza® less than 24 hours, BOOM! a grand mal (tonic clonic) seizure occurred yesterday evening. This same thing happened the last time we stopped Albenza®, sooooo we're not sure if it's withdrawal related or parasitic activity related. We're going to closely watch her behaviors this week for signs of parasitic burden. We put her on Alinia® now, just to give her some sort of parasitic coverage while we wait to likely restart Albenza®, soon. She did fine on Alinia® 200mg BID in the past. I'll keep you all posted, but for now we unfortunately need to restart the clock on my Natalie's 'seizure-free days' tracking. I'm bummed, but thought I should keep you in the loop on this; as I've been soooooo excited over the past three months about her freedom from seizures, which I believe was due to the synergy of CD and Albenza®. I'll touch back if/when we learn more.

UPDATE February 2nd, 2013

O.K. so, I just wanted to kind of round out this long thread a bit with my thoughts, for whatever they're worth: I really truly suspect that perhaps too sharp of a drop off (lack of weaning) from the systemic med, Albenza® lead to the seizure. Natalie is stable right now on a low-dose interim of Alinia® 200mg BID for now until all insurance approvals are in for the delivery of more Albenza®. This leads me to believe that the several courses of Albenza® over the past months likely HAS lowered her overall parasitic load/burden fairly well thus far (it's a pretty broad-spectrum anti-parasitic, from what I understand). However, I don't think for a *minute that Natalie's broad spectrum anti-parasitic medicine needs are finished. For this reason, we'll resume Albenza® as soon as we're able.*

Although further discussion/negotiation between myself and Natalie's pediatric infectious disease doctor is required, my thought is that she may need an entire year on Albenza. However, certainly in the future, whenever we stop Albenza®, I'm going to plan for a slow weaning off period so as not to disrupt Nat's delicate nervous system. Also, I'm kind of thinking that perhaps if our kids 'wig out' when CD is eventually dropped that maybe we've not lowered the overall parasitic burden enough, as yet to allow their immune system to 'kick in gear' and properly function??? I don't know, obviously, just theorizing with the brain matter God has given me.

SUMMARY & UPDATE FOR SECOND EDITION: December 1st, 2013

From birth to age 7 years, my daughter Natalie unfortunately had her share of health and developmental struggles. Her diagnoses began with 'Failure to Thrive' shortly after birth, followed thereafter by a Mitochondrial Encephalopathy Partial Complex III Deficiency diagnosis by age 7 months, then Hypothyroidism as well as global developmental and cognitive delays obvious from there. Despite significant medical and developmental challenges, Natalie entered a Kindergarten designed for the 'mild cognitively impaired' (formerly referred to as educatably mentally impaired 'EMI') with daily opportunities for mainstreaming with the typical Kindergarten classroom next door. After a fall 2005 Flu shot early in that same Kindergarten year, however, all bets were off. She regressed very rapidly in every way: medically, developmentally, and behaviorally. Within months of that shot, a laundry list of additional diagnoses began to form: Sensory Integration Disorder, Autism, Epilepsy, P.A.N.D.A.S., P.A.N.S., and Combined Immune Deficiency, to name a few. After much study by a large team of educational specialists, Natalie was reclassified by school professionals by the following April of 2006 to the 'SXI" category of disabilities (Severely Multiply Impaired), having deteriorated terribly from her former classifications of POHI (Physically or Otherwise Health Impaired) and 'CI' (Cognitively Impaired) within only months of that Flu shot. Her significant healthcare needs and behavioral challenges since have necessitated assignment of a one-on-one Para-educator to her case, even while she's been schooled within high adult-to-student ratio basic education special- needs classrooms over the past several years.

In 2011, between the ages of 12 and 13, I began to notice patterns of apparent P.A.N.S. flares in Natalie, which seemed to coincide with the New Moon and Full Moon weeks. When I began to study this phenomenon a bit more closely, I also recognized a pattern of seizure activity that tracked these timeframes as well. In reading about potential parasite activity that is thought to link to the New Moon and Full Moon timeframes, I requested anti-parasitic medications for Natalie. Thankfully, a local Pediatric Infectious Disease doctor kindly accommodated my request. Each time that the doctor prescribed various anti-parasitic medications for Natalie, she would improve. The improvements were noticeable both at school and at home. It was incredible to witness. However, each and every time that she was off of such medications, she would regress back to her former state of illness (displayed primarily by significant behavioral regressions). So, we found that we needed to try to keep her on various anti-parasitic medications more often than off of them, in order for her to enjoy overall improved health and neuropsychiatric stability. Even so, there was still some sort of physiological strain that she was very *definitely experiencing, but we were unable to decipher what it could be. This was frustrating, of course; to witness her continued rollercoaster of ups and downs in health and her various psychiatric disturbances each month.*

It wasn't until a friend suggested we get Natalie started on CD, that the health and behavioral 'rollercoaster ride' began to show signs of smoothing out. In July 2012, after her first drink of CD (only one-eighth of a drop), Natalie began to show initial signs of relief from whatever it was that was still ailing her. Her connectedness and overall psychological state of being changed within hours of that first one-eighth drop of CD. After that first day, we of course then continued with a very slow and conservative ramp-up of CD (orally, then baths, then enemas) alongside various anti-parasitic medications and all of the components of the Kalcker PP (with frequent swap out of Mebendazole with Albendazole, predominantly). With each passing month over the past sixteen months, we've been able to witness improvements in Natalie; perhaps a bit more slowly than some of the younger and/or potentially less health-compromised kids that Kerri's protocol has healed, but improvements nonetheless. Before CD, Natalie's ATEC score was a 79. As of this writing, her ATEC score is a 39. Even more astounding to us than that improved ATEC score have been the changes witnessed thus far in her overall health status and health regimen. Here is a list of some of the improvements that I can very easily recall as I write this (there are likely many more that I could comment upon, if I had more time):

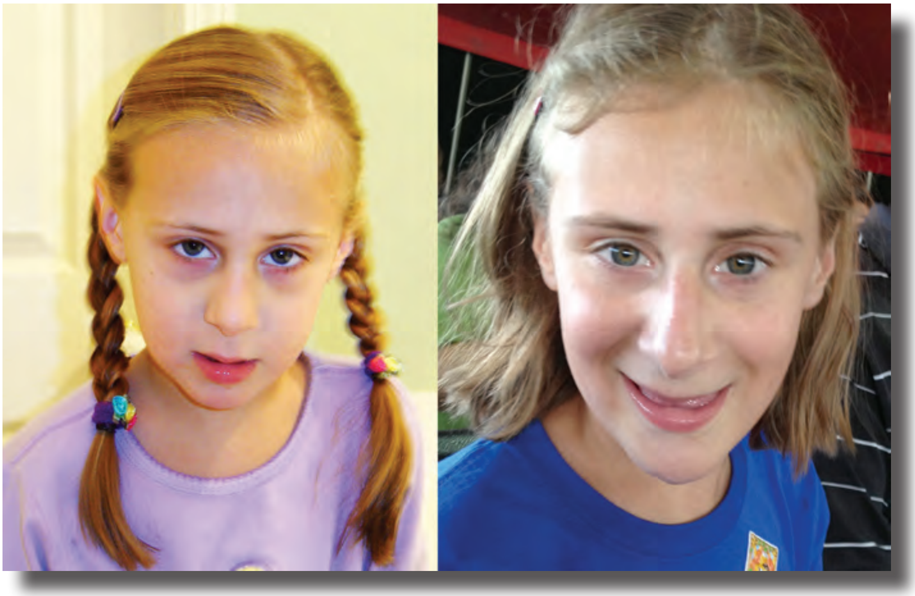

Natalie in 2006 (left) and in 2013 (right)

1. *Daily prescription anti-fungal medications no longer needed.*
2. *Daily prescription antibiotic medications no longer needed.*
3. *Daily prescription antiviral medication no longer needed.*
4. *Daily prescription LDN (low dose naltrexone) immune modulator removed.*

5. *Daily prescription Leucovorin removed without ill effects noticed, as well as several other daily supplements that might have been ultimately not helpful.*
6. *Prescribed Immune Globulin (weekly subcutaneous, formerly monthly intravenous for years) removed.*
7. *Distended belly gone & improved posture (no longer hunched over).*
8. *Formerly very frequent tongue sores/lesions lessening more & more.*
9. *Seizures formerly as high as every 17-21 days in her worst times; now she's enjoyed seizure-free stretches as high as 105 days (3.5 months) followed shortly thereafter by a seizure-free stretch of 168 days (5.5 months). Prescription anti-seizure medication reductions have also been enjoyed as well as fewer headaches resultant of those reductions.*
10. *P.A.N.S. flares controlled with the combination of CD and anti-parasitic meds. Neuropsychiatric symptoms of flares very dramatically declined.*
11. *Overall appearance of improved health, improved language and interpersonal skills, improved attentiveness (per Neurology's opinion at recent appointment).*
12. *Improved stamina and strength (core, legs, etc.) noticed at Special Needs Performance Cheerleading practices, physical therapies, etc. Her ability to peddle adaptive bike has also improved.*
13. *No more nose bleeds, no more ear infections, no more apparent seasonal allergies, fewer headaches (as noted above).*
14. *Incredibly improved sleep and need for naps only once in a while now (as opposed to formerly daily).*
15. *Improved growth rate and normalized appetite.*
16. *Improved language (more descriptive words, more sentences).*
17. *Healthier-looking skin overall; softer, less dry, improved color & ability to tan.*
18. *Improving oral muscular abilities, able to swallow pills/capsules.*
19. *Capable of successful dentist appointments and now even Orthodontist appointments, with calm and ease.*
20. *Increased success rate during therapies (Speech Therapy, Occupational Therapy, Physical Therapy, etc.).*
21. *Less rigidity overall, fewer transition issues, cooperates more often than she ever used to.*

With all of the well-documented improvements noticed in Natalie at home, at school and in doctors' offices, I don't have the same level of fear as other parents might surrounding our open use of CD, as Natalie's doctors are all well informed and quite supportive. We've also formally notified her social worker (both verbally at a home meeting and in writing) of our use of Kerri's CD Protocol (including Kalcker's Parasite Protocol and of course a GFCFSF/low sugar diet) while under Natalie's local medical team's support and medical monitor. We're 'out of the closet', so to speak, when it comes to our use of CD for improving Natalie's health. It's been quite obvious to Natalie's doctors; actually, that Kerri's protocol has been extremely complementary to their medical efforts for improving Natalie's health and overall quality of life.

There's of course no way to predict with certainty how far my sweet Natalie will be able to ultimately improve via this protocol, but based upon what we've witnessed thus far, I do feel that her current best hope for continued improvement lies within the pages of this book; as these healing strategies of Kerri Rivera's have brought Natalie toward more health (physical, neuropsychiatric, emotional and even some initial cognitive improvements) than any other medical effort attempted since her 2005 Flu shot injury. All other medical efforts for Natalie over the years, I feel, perhaps only temporarily patched her severe illness. Kerri's methods actually work to attack disease, kill it and remove it. Yes, that's right. Eight years after Natalie's tragic rapid spiral downward, it's now finally a time of healing for Natalie. Thank you, Kerri Rivera, for all of your help given to our girl and to so many children around the world.

Self-Injurious Behaviors (SIBs)

Self-injurious behaviors (SIBs) can be absolutely devastating for families with children on the autism spectrum. Common self-injurious behavior includes: headbanging, hand biting, pinching, slapping head/ears, eye poking, hair pulling, scratching/rubbing, throwing one's body on the floor, etc. The horror of watching your own sick child further inflict pain onto himself, and the helplessness of not knowing what to do to help him is heartbreaking. I have met with families through the clinic who have had terrifying episodes of SIBs in front of me as well as at home, and many of these families as well as others are now using the Protocol to help their children with very good results.

There are many theories as to why some children have SIBs. The article "Self-Injurious Behavior" by Stephen Edelson on ARI's website discusses several different theories and supporting research.[2] The theory that most fits what I see on the ground is that of pain alleviation. Many of our kids are in chronic pain and cannot tell us. Sadly, we haven't always had answers to help them.

If we follow this thinking, and assume that many of these children suffer from severe gastrointestinal pain, or headaches (supported by head banging, gut clutching, etc.) we can hypothesize that much of this pain can come from pathogenic overload, parasites wreaking havoc on the body and the resulting inflammation.

Families applying CD in combination with the Kalcker Parasite Protocol are reporting a dramatic reduction in SIBs in their children. I believe there is an important connection to be made here, as we eliminate pathogens and parasites SIBs decreases. More research is needed, but for families facing the horrors of self-injurious behavior, this combination could be of great value. (More testimonies on decreased SIB's can be found in Chapter 2, and the Miracles and Testimonials section at the end of the book starting on page 357.)

Prior to starting CD, we had tried almost every autism biomedical protocol. We saw several DAN and GI specialists and numerous other practitioners. We spent tens of thousands of dollars on consults, supplements, diets, medicine and medical procedures not covered by insurance. My daughter either had no response or negative ones and she continued to get worse. She developed extreme self-injurious behaviors that progressed to the point of her needing to be restrained several times a day in an attempt to prevent her from pinching or biting herself until she drew blood. Her body was covered with bruises and cuts. She would also pull out big clumps of her hair. She would be up for hours screaming in the night with these behaviors. She was severely malnourished despite the fact that two registered dieticians had deemed her daily caloric intake adequate. She was 14 years old and weighed a little over 70 pounds. I honestly did not think that CD would be any different than anything else we had ever tried but figured things could not get much worse.

Since starting CD her self-injurious behaviors are almost entirely gone. She went from having to be restrained almost daily to once in the last 5 months. Her former multiple daily 45 minute self-injurious tantrums are now a few minutes of crying or protest and happen once a week if at all. We have noticed gains in language and cognition (20 point drop in her ATEC score). After years of fluctuating between loose stools and constipation, she is now regular and has gained almost 10 pounds. She sleeps through the night and we are able to take her places that we would have never dared to before. If my daughter can make gains this drastic in 5 months at age 14, I can't wait to see what the future holds.

Julie, Colorado, USA

PANS, PANDAS and PITAND

PANS stands for *Pediatric Acute-onset Neuropsychiatric Syndrome*. It encompasses PANDAS (Pediatric Autoimmune Neuropsychiatric Disorder Associated with Streptococcal Infections) and PITAND (Pediatric Infection Triggered Autoimmune Neuropsychiatric Disorders), where PANDAS is a subset of PITAND. Dr. Susan Swedo, Chief of Pediatrics & Developmental Neuroscience Branch at the National Institute of Mental Health (NIMH), and her research team identified a subtype of OCD in children during the 1990s that is triggered by infection. Streptococcal infection has been most studied; however, any infection can trigger this condition.[3]

I have run across these diagnoses a lot since I have started helping families in first world nations. There seems to be an overlap in some autism and PANS/PANDAS/PITAND cases. I have heard that around 25% of children with ASD's also suffer from PANS/PANDAS, and/or PITAND. Some practitioners would put that figure even higher. However, since further research is needed, and this field is still developing it is impossible to say for certain at the moment.

According to the International OCD (Obsessive Compulsive Disorder) Foundation some of the symptoms of PANDAS/PANS may include:

- Acute sudden onset of OCD.
- Challenges with eating, and at the extreme end, anorexia.
- Sensory issues such as sensitivity to clothes, sound, and light.
- Handwriting noticeably deteriorates.
- Urinary frequency or bedwetting.
- Small motor skills deteriorate - a craft project from yesterday is now impossible to complete.
- Tics
- Inattentive, distractible, unable to focus and has difficulties with memory.
- Overnight onset of anxiety or panic attacks over things that were no big deal a few days ago, such as thunderstorms or bugs.
- Suddenly unable to separate from their caregiver or to sleep alone.
- Screaming for hours on end.
- Fear of germs and other more traditional-looking OCD symptoms.

I know several moms who have been able to reduce/control/eliminate their children's symptoms with CD. In fact, families began to eliminate the antibiotics that they were using as they reached full dose of CD. I am by no means suggesting anyone reduce or remove a prescription medication without a doctor's supervision. I am simply reporting on what I have witnessed.

We know that CD kills bacteria, so we could hypothesize that CD could have a similar effect on the PANS/PANDAS/PITAND symptoms that an antibiotic would. What has worked in these cases is upping the number of doses of CD given a day so as to kill pathogens around the clock. For PANDAS/PANS/PITAND use two baby bottles a day. If your max dose is eight drops in an eight ounce bottle, and a PANDAS flare presents, prepare two baby bottles with eight drops in each and give one dose every hour over the course of 16 hours. Some families are doing 16 doses a day even if there is no flair and the child is doing excellent.

As noted previously, in the absence of research, we cannot recommend doing nothing for these children. Their suffering is intense and the risk of long-term damage cannot be ignored. We also do not know if some of these children remit spontaneously later in adolescence. We do not know if some of them grow into adults with the most treatment resistant OCD due to permanent basal ganglia damage. While we research those questions, offering treatment options at the local level, especially in the first few months after onset, could be critical to the long term success for these kids.[4]

We parents are pioneers in the research surrounding PANS/PANDAS/PITAND, so it is critically important that we document what we are doing with our children and what is working for them. In fact, A MOM was the first to discover the connection between strep and OCD/tics. Her child was the first documented PANDAS child. Dr. Susan Swedo reinforces that physicians should listen to what the mothers have to say![5] Speak up to your doctor, share your findings, join our forum to learn, and share what is working for you. Parents are driving the biomed movement (and always have) for ASDs as well as PANS/PANDAS/PITAND. In fact Dr. Bernard Rimland was a parent and the first to suggest biomedical interventions for people on the spectrum. We as parents can help countless other families by sharing our experiences.

You will find more info on PANS/PANDAS/PITAND at:

www.pandasnetwork.org

and

ocfoundation.org/PANDAS

Fever Therapy

Dr. Kenneth Bock and Nellie Sabin, in their groundbreaking book *The Road to Immunity: How to Survive and Thrive in a Toxic World*, explain how to use fever therapy and how it is an incredible tool for healing.[6] When a mom emails me to tell me her child has a fever, it tells me that the immune system is reacting to an invader, and we have an excellent opportunity to kill pathogens in the body. Having a fever is part of an effective immune response. This is also true in infants as well as small children. Using over-the-counter (OTC) fever reducers interferes with the body's own ability to fight infection.

This section was excerpted from the aforementioned book.

> Fever has long been recognized as an important tool in the process of healing. The process of heating the body is called "hyperthermia." Hyperthermia, or ordinary fever, can be very effective against cancer cells, various pathogens, or invading organisms that cannot "tolerate the heat." Hyperthermia may not kill all pathogens in the body, but may reduce the number of invaders in the body to a manageable level for the immune system. Hyperthermia may also be responsible for stimulating the immune system to produce cytokines i.e. antibody production, and release of toxins from fat cells.

What Temperature Constitutes a Fever?

According to Dr. Robert Sears, the following are normal temperatures in children over 3 months:[7]

Normal temperature: 97° to 99° F (36° to 37.2° C)
Low-grade fever: 99° to 100.9° F (37.3° to 38.3° C)
Common fever: 101° to 103.5° F (38.4° to 39.7° C)
High fever: 103.6° F (39.8° C)

Fever Therapy in Practice

If your child develops a fever, it is not a failure of the body that needs to be corrected, but a mechanism that brings the body closer to healing. Rather than administer an OTC remedy to reduce fever, apply a cool, damp washcloth to the forehead and neck, replace them as they warm, and let the body do its job. Some parents put damp socks on their child's feet.

During a fever you can dose orally, as well as do one CD bath and one CD enema in one day. Keep dosing CD every hour (16 to 24 doses a day), unless the person stops eating. Even if you must reduce the number of drops, even if you are only giving one drop, keep dosing every hour. CD baths, as well as baths in general, are also your friend if your child has a fever. Some parents have given several baths throughout the day while a fever is present with great results. Bath the child if the fever spikes. Always be vigilant that the temperature does not rise too high or too fast so as to cause febrile seizures, we have to use common sense and trust our instincts. Bath and keep a cool damp wash cloth going 24/7 until the fever pases.

According to the National Institute of Neurological Disorders and Stroke febrile seizures are convulsions brought on by a fever in infants and small children. The majority of children with febrile seizures have rectal temperatures greater than 102° F. Approximately 1 in 25 children (4%) will have one febrile seizure. Although febrile seizures can be frightening to parents, the vast majority of febrile seizures are fast and harmless. There is no evidence that short febrile seizures cause brain damage. Large studies have found that children with febrile seizures have normal school achievement and perform as well on intellectual tests as their siblings who don't have seizures.[8]

If your child has a febrile seizure, experts recommend that you try to stay calm, keep the environment around your child safe (place them on the floor if they are not, and clear objects out of the way), and allow the seizure to resolve spontaneously without restraint. Try to look at your watch so you will know how long the seizure lasted. Do not put anything in your child's mouth as it may break, obstructing their airway.

Skin Issues

I have been hearing about skin issues right and left: rashes, hives, redness, acne, eczema, psoriasis, pustules, etc. It is very easy to assume that since skin is on the outside of our bodies that these reactions are caused by exterior factors (i.e. irritation from a detergent, mold, etc.). However, the skin is our largest detox organ, and many pathogens seek exit through the skin causing many of the above conditions.

The scenario that I keep hearing is the following: We just started the Kalcker Parasite Protocol. Little Johnny has a rash with white heads on his legs. What do I do? When the families keep up with the parasite protocol, and continue dosing daily with CD these eruptions disappear, and this is generally accompanied by improvements in behavior, or hyperactivity/anxiety.

We need to think about skin issues as outward manifestations of inner toxicity, and use our protocols accordingly. Skin issues can be a good indicator that something is being flushed from the system, or something needs to be flushed from the system. The Kalcker Parasite Protocol combined with CD tends to eliminate skin issues at the root.

The following paragraphs were excerpted from leakygut.co.uk, written by Dr. Gloria Gilbere ND DA hom PhD[9]:

> Experts agree that most chronic skin disorders, specifically psoriasis, is the external manifestation of the body's attempt to eliminate internal toxins that have accumulated within the lymphatics and blood stream by "seeping" through intestinal walls in a condition known as leaky gut syndrome.
>
> In working with clients around the world, the protocols that have been most effective are those that include repairing the intestinal walls by first beginning a protocol to eliminate candida yeast and parasites.
>
> The most effective cleansing protocol is obtained by clearing out these "uninvited" health-depleting microorganisms in order to release the accumulated pressure on the liver and the intestines—allowing free passage and thus reduction of overall toxic load.

The following paragraphs, authored by Dr. Edward F. Group III, DC, ND, DACBN, DABFM, were excerpted from parasite-cleanse.com/intestinal-parasite-symptoms.html[10]:

> **Symptoms of Intestinal Parasites Related to Skin**
>
> The presence of intestinal parasites, at times, manifest as allergies, tumors, and various other skin conditions.
>
> Intestinal parasites cause the human body to release hormones and immune system defenders, which in turn irritate the skin and cause various skin conditions such as acne, hives, rashes, itching, weeping eczema, ulcers, swelling, sores, lesions, blisters on lips, and dermatitis. It also deprives the skin of its usual glow.
>
> Intestinal parasites cause irritation and inflammation in the stomach making it difficult to digest certain types of foods. The presence of undigested food particles in the stomach causes the body to produce increased levels of eosinophil, an immune system defender. These eosinophils inflame the body's tissue and cause skin rashes.
>
> Intestinal parasites trigger the body's immune system to develop a tumor-like mass known as granuloma to encase parasitic larvae or eggs. Granulomas usually develop in the colon, rectal wall, lungs, liver, peritoneum, and the uterus.

Btw, you were bang on re his allergies and PP (parasite protocol). He had this horrible red lip thing because of food allergies. He would make it worse by rubbing it. It would get really bad. After first PP (Parasite Protocol) - NO MORE RED LIP ISSUES!

Families often tend to panic when dealing with sudden "unexplained" skin issues. If you are seeing chronic or acute skin issues I think there is enough evidence to look towards parasites as the main or at least a contributing culprit. Therefore, if we work towards removing the parasites causing the symptoms, rather than treating the symptoms topically we can expect an alleviation of the symptoms.

If you are seeing acute or chronic skin issues and you have not started a Parasite Protocol, I would suggest you revisit the parasite chapter and go over the recommendations with your healthcare provider. Keep dosing CD, in some cases upping the dose has helped resolve the issue faster, and in the case of severe irritation using a CD spray topically can provide relief (10 activated drops per ounce of water in a spray bottle) and a CD bath can also help. I have seen most, if not all skin issues resolved with CD and/or the Kalcker Parasite Protocol.

Healing Adults with Autism

Common thinking in the biomed community and the autism community at large is that autism is only "curable" or "recoverable" up to a certain age. I have heard that two to nine years old is the "golden window" for autism, and that after nine years of age improvement would be possible, but not recovery. The neural pathways would be set, the damage done, and the child would retain the autism diagnosis for life.

Not anymore. This year a 15-year-old recovered from autism, as well as two 17-year-olds. In addition, I am helping an amazing mother of a 31-year-old with autism that began the Protocol and for the first time in 28 years was seeing real progress with her son. In fact that young man's ATEC score dropped from a 65 to somewhere in the 20s in his first three months on The Protocol. I want to prove that autism recovery is possible at any age. It may take longer, and the road may prove more challenging, but it's already happening. Families that have been using biomedical interventions for more than ten years are finding the Protocol and sharing their gains.

Older children and adults on the spectrum start the same way as the little kids—clean up the diet first, and then on Day one of CD, give one drop in eight ounces of water over eight doses throughout the day. It is so important to start low and slow even with adults because they have often been chronically ill much longer than young children and have deep rooted pathogenic and parasitic infections. This means that when we start giving CD they might experience a detox reaction considering the amount of pathogens that will be dying.

Working with Neurotypical Adults

Can CD benefit parents and other adults not on the spectrum? Absolutely. You can literally find thousands of testimonials on the Internet (Jim Humble's website, www.jimhumble.org or www.curezone.com, etc.) on people who successfully detoxed, or healed a myriad of illnesses using CD.

Many parents who have seen improvements in their children have decided to use CD, or the Kalcker Parasite Protocol for themselves. I have done CD oral, baths, and enemas on myself, especially when I feel "something coming on" and with great results.

It's important to keep in mind that just because we weigh more than our children doesn't necessarily mean we should jump in and go to full dose from one day to the next. The best way to start an adult who may have 40 or 50+ years of accumulated toxins/pathogens/parasites is low and slow. Use the baby bottle method and start day one with one drop spread out over eight doses and go up from there. Chart your progress, see how you feel, go low and slow. When we as adults use the protocol it can be great for us, but also a window into how our children are feeling.

I love to see a mom or dad begin CD with their child. Both begin at one drop on day one in eight ounces of water, 1/8 or a drop per dose, for eight doses throughout the day. Starting with our children gives us a much better understanding as to how our child is feeling, and when we up the dose how that feels as well. This includes enemas. Once parents see how good they can feel after an enema, it helps garner confidence, if we had doubts about using them for our children. Applying our own enemas can help to remind us just what a powerful tool they are for healing.

Many of the parents doing the protocol for themselves write me to tell me about their remission from fibromyalgia, chronic fatigue syndrome, Lyme disease, life-long constipation, etc.

We all do the parasite protocol in my house so as not to re-infect my son, as parasites can be highly contagious. Last year I did a round of parasite medications prescribed to me by a doctor. During the course of treatment I felt a tremendous amount of anxiety and some depression (feelings I had never felt before) right before I passed worms, I can assure you it felt awful. That experience motivated me to encourage parents to get these invaders out of their children's bodies.

As soon as I started passing worms and detoxing more with CD, I started to feel good again. The cough that I had had on-and-off for years miraculously disappeared. Seriously, go low and slow, a toxic body can only process so much at a time. Too much too fast can cause headaches and diarrhea. The way I see it, there is no need for that, listen to your body and go at whatever pace you need. Don't just "push through," low and slow wins the race. Always remember to drink water when doing any sort of detox!

Tax on a Marriage

During the first five years after an autism diagnosis married couples face an estimated 80% divorce rate, and a 90% chance of divorce beyond the tenth year of marriage. My family was almost a statistic. Even before we had a diagnosis, our family was suffering. Due to Patrick´s constant screaming and tantrums, he wasn't sleeping at night, and that meant that no one else was sleeping either. He had also stopped being the affectionate baby that he was for the first two years of his life, which was emotionally challenging for all of us. We were all over stressed and sleep deprived, not to mention having symptoms of post traumatic stress disorder (PTSD).

If I could give any advice to families dealing with a new diagnosis it would be to start The Protocol and CD immediately. The sooner the affected family member starts to heal, so will the rest of the family, similar to the sun coming out after a storm—this too shall pass.

Financial Stress

Not only is an autism diagnosis emotionally stressful on a marriage, but it can be extremely financially stressful as well. The Protocols outlined here can be extremely cost effective, even if including ocean water. Recently, one of the moms using The Protocol did some calculations comparing what she spent previously (see table on page 342) using another biomedical intervention with many supplements, etc., to what she spends now (see table below).

The Protocol - Estimated Cost

Product	Size	Price	Reorder Schedule	Current Cost per Month
CD	1 bottle	$22	1/mo	$22.00
Diatomaceous Earth	2.5 lb	$15	1/3mo	$5.00
Rompepiedras	50 ml	$24	1/2mo	$12.00
Vortex Ocean Water	1 L	$40	1/mo	$40.00
THERALAC®	30 caps	$36	1/mo	$36.00
Natures Way® Neem	100 caps	$4.09	1/5mo	$0.75
Pyrantal Pamoate (Combatrin®)	32 oz	$35	1/6mo	$5.00
NOW® Castor Oil	16 oz	$8.23	1/6mo	$1.38
Mebendazole	90 tabs	$28	1/5mo	$5.60
TOTAL				**$127.73**

Defeat Autism Now! based Protocol - Estimated Cost

Product	Size	Price	Reorder Schedule	Current Cost per Month
Actifolate	60	$15.00	1/2mo	$7.00
Calm PRT	120	$89.00	1/5weeks	$78.00
Caprilex™	90	$16.00	1/6weeks	$10.60
Cytoflora™	4 oz	$79.00	1/mo	$79.00
Designs for Health Lithium Synergy	120 caps	$22.00	1/mo	$6.00
DMG	90	$16.00	1/5mo	$10.60
Douglas B-Complex	60	$21.00	1/6mo	$21.00
Douglas CoQ10	60	$49.81	1/6mo	$12.50
Enhansa™	150 caps	$58.00	1 / 75 days	$29.00
Enzymedica Virastop™	120 caps	$32.11	1 / 4 months	$8.00
Garden of Life Probiotics	81g	$32.17	1/mon	$32.17
GI Revive	225g	$52.00	1/mon	$52.00
Homocycsteine Supreme	60 caps	$20.00	1/4months	$5.00
Kirkman Digestive Enzyme	200 caps	$60.00	1/3months	$20.00
Kirland Vit E	500	$13.65	1/16months	$0.84
Klaire Multivitamin	180	$28.00	1/3months	$9.00
Liver Life	4 oz	$50.00	1/2months	$25.00
Magnesium	240	$13.25	1/6months	$7.00
Metagenics Adreset®	60	$33.00	1/4months	$8.00
Milk Thistle	100	$25.00	1/3months	$8.00
NDF+	1 oz	$80.00	1/6months	$15.00
NeuroProtek®	4 bottles	$140.00	4/4months	$35.00
NeuroScience Avipaxin	60	$58.00	1/2months	$28.00
NeuroScience EndoTrax	1 bottle	$27.00	2/month	$54.00
NeuroScience Kavinace	120	$65.00	4/4months	$32.50
New Beginnings Copper	50 ml	$20.00	1/year	$1.75
NOW MCT	32 oz	$17.00	1/6months	$2.80
Nutribiotic GSE	4 oz	$16.99	1/6months	$3.00
OSR	30	$60.00	1/2months	$30.00
Oxycell Glutathione Cream	1 jar	$33.00	1/2months	$16.50
Pharmax Cod Liver Oil	8 oz	$13.33	1/mon	$13.33
Source Naturals B6 (p5p)	240	$15.00	1/6months	$2.60
Source Naturals Evening Primrose Oil	90	$7.45	1/6weeks	$4.97
Source Naturals Gaba	100g	$18.00	1/4months	$4.50
Source Naturals Lysine	200	$10.00	1/mon	$10.00
Source Naturals Quercitin	200	$25.80	1/3months	$8.25
Speak EFA	60	$42.00	1.5/month	$63.00
TheaNAQ	90	$54.00	1/month	$54.00
Therabiotic	120	$69.00	1/2months	$35.00
TravaCor Jr.	120 caps	$24.00	1/4months	$7.00
Vit B12 shots	1 refill	$45.00	1/3months	$15.00
Wobenzyime®	120	$60.00	1/2months	$30.00
TOTAL				**$894.91**

Tips for a Non-Toxic Home

Many of our children on the spectrum have chemical sensitivities, and even if they don't, it's wise to limit their exposure to toxins during the healing process as much as possible. Toxins are not good for anyone at any point in their life. The benchmark investigation "Bodyburden: The Pollution in Newborns" by the Environmental Working Group[11] (see Appendix 13, page 499) explains why this is so important for children with developing brains and immune systems. The following is a list of products to use instead of toxin filled, name brand cleaning products.

Floor cleaner: Add one cup of white vinegar and baking soda to a bucket of water (add a squirt of liquid soap if you like).

Air Freshener: To remove odors from carpets spread on baking soda and then vacuum the carpet. Simmer cloves and cinnamon as air freshener.

Removing Toilet odors: Borax

Trashcans: Spread baking soda in the bottom, then spray to disinfect with a solution of borax and water.

Dish soap: I use liquid dishwashing soap and white vinegar to cut grease. If you buy dish soap make sure it's biodegradable.

Disinfectants: Borax with water is an excellent disinfectant, or spray CD.

Laundry detergent: Soak the clothes for an hour in borax soap before putting into the washer.

Oven Cleaner: Dissolve two teaspoons of liquid soap (not detergent) and two teaspoons of borax with enough warm water to fill a spray bottle.

Windows and Mirrors: Club soda in a spray bottle

Toilets and Tubs: Baking soda with apple cider vinegar

96% Alcohol: Kills parasites on enema catheters, etc., and is great for cleaning bathrooms.

Videos

I have had many parents ask me if I think it is a good idea that their child watch "Genius Baby" or other videos that are supposed to help with their development. I do not believe these videos to be appropriate for a developing brain. Studies were done in Cuba that found that excessive TV watching before three years of age can cause the symptoms of autism. When the TV was removed from the children that presented symptoms of autism, the symptoms disappeared. They also reported that TV watching could cause neurological discharges in the brain.

I can also tell you that the only time my son stims or flaps is when he is allowed to watch TV. When he was younger, and deep in the throes of autism, the only thing he wanted to do was watch TV, while running back and forth and squealing. Any other activity was met with screaming and tantrums. He is much more interested in other activities now, and easily transitions from one to the next, including school. However, he still requests to watch YouTube in the evenings when all of his activities are complete, and that is truly the only time he flaps his hands anymore. To me it is very obvious that TV is a source of over stimulation for him. However, it is hard to deny him a truly preferred activity, especially when he enjoys videos on cooking and foreign language! The least amount of screen time (TV, computer, iPad, etc.) the better, however, we do what we can.

Therapy Options:

ABA is not the only therapy for children with autism.

Many parents worry because ABA/IBI is either not available, or not affordable to them. I firmly believe that something is better than nothing. At the same time, I have seen many children recover without any ABA or IBI. Here are some of the options that have worked for families in conjunction with the protocol:

- ABA - Applied Behavior Analysis
- Occupational Therapy
- DIR® Developmental - Individual Difference, Relationship-based Model
- Floortime Therapy
- TEACCH - Treatment and Education of Autistic and Related Communication Handicapped Children
- Son-Rise®
- PROMPT - Prompts for Restructuring Oral Muscular Phonetic Targets
- Sensory Integration Therapy
- RPM - Rapid Prompting Method
- Supportive Typing

There are many other options not mentioned here. Human interaction is key for our children on the spectrum to find joy with us in our world.

I have known many families to have varying degrees of success with all of the above therapies. Some are better for younger children and some for older children. Depending on the areas most lacking in your child's development, you can investigate any one of these types of therapies. Families in many countries where insurance doesn't cover any type of therapy have had to be trained themselves in how to apply therapy. Sometimes an aunt, sister, cousin, or neighbor steps up to help out. No ONE therapy has been fundamental to all of the recovered children and for that reason I say something is better than nothing when it comes to therapy.

Even household chores can be therapeutic and task oriented. Simply because a person has autism doesn't mean they can't have responsibilities and learn new skills while helping out in the home.

A word on laboratory testing

I can't stand to watch people waste money that they could be using for healing their children through various interventions on laboratory testing. If you have all the money in the world, and want to chart your child's progress through laboratory testing, so be it. However, the rest of us sometimes have to choose between expensive testing and treatment. So many families have come to me after spending thousands of dollars they didn't have on testing to tell me their child has viruses, bacteria, and candida. Am I surprised? Never. I have yet to see a child with regressive autism that does not have pathogens/parasites. No matter which pathogens are present, we use CD.

Testing for parasites is woefully lacking at this time, and in fact, the only practitioners who have consistently diagnosed parasites have been veterinarians and practitioners of alternative medicine (also Metametrix labs have identified parasites in some cases).

Generally speaking, if a child doesn't have viruses, bacteria, yeast, parasites, heavy metals and allergies they don't have autism.

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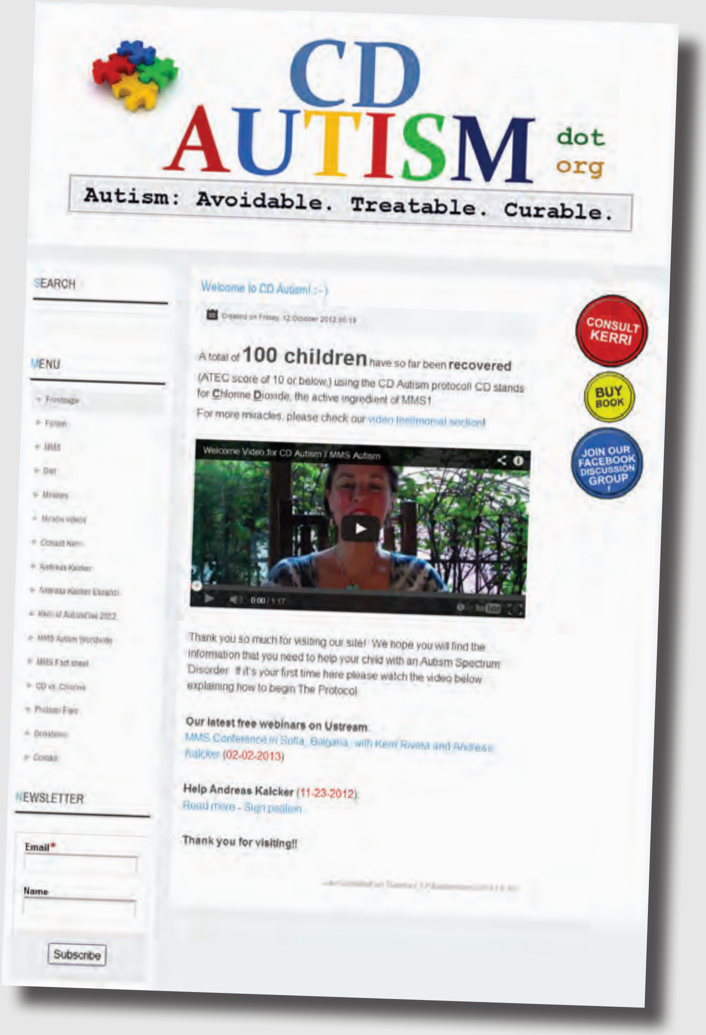
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A total of **100 children** have so far been **recovered** (ATEC score of 10 or below,) using the CD Autism protocol! CD stands for Chlorine Dioxide, the active ingredient of MMS1

For more miracles, please check our video testimonial section!

Thank you so much for visiting our site! We hope you will find the information that you need to help your child with an Autism Spectrum Disorder. If it's your first time here please watch the video below explaining how to begin The Protocol

Our latest free webinars on Ustream:
MMS Conference in Sofia, Bulgaria, with Kerri Rivera and Andreas Kalcker (02-02-2013)

Help Andreas Kalcker (11-23-2012)
Read more - Sign petition

Thank you for visiting!!

Chapter 15

Final Thoughts

If you knew how powerful your thoughts were
you would never think a negative thought again.
~ Peace Pilgrim

What would be your message to families of children with autism who have just read the book, but not started the protocol?

Do not wait! Get started now! Autism is Avoidable, Treatable and Curable! You don't have to spend fortunes on lab testing, imported foods nor supplements. Even if the medical community can't decide if your child has autism, PDD-NOS, ADHD, Asperger's, PANDAS, etc.... don't wait! Start the diet. Even if you cannot do more than that, it will help. Some children have lost their diagnosis with just diet. There are parents all over the world doing biomedical protocols for autism, get together with them, join the forum at...

www.cdautism.org

...or the CDAutism Facebook group. The Internet helps us all to be close and share information. Don't let anyone tell you the diet doesn't work, just keep going and don't stop. There is never an excuse to not do what is right for your child. "Their future depends on our courage."

The final chapter of this book is yet to be written. Until the day we have recovered every victim of regressive autism, there is no success. Just progress. Here I have expressed what I have seen and what the road of autism recovery has brought to me. I have learned a lot and continue to learn. Our children need us to keep learning and searching until we find what unlocks them from their autism. Not everything works for everyone. However, I have seen that this protocol works for most. Especially when it is done exactly as it should be. If you have found this book you have an advantage that I did not have with my son. When I first learned of Patrick's diagnosis I lost precious time and money that I didn't have to lose, trying interventions that didn't yield results. In the nine years that my son has been in recovery I have yet to come across another protocol that has helped as many children to recover from autism in such a short amount of time—less than three years, to be exact! As of the date of this writing in May of 2013, 93 children have lost the diagnosis of autism and every month more and more are recovering.

Please remember that if your journey is autism you will never walk alone. I am here too. Just one click away...

www.cdautism.org

I wish everyone who is ill to have the fastest recovery possible from whatever it is that ails them.

To be continued…

Dr. Andreas Kalcker, Kerri Rivera, Jim Humble, in Puerto Vallarta, Mexico 2012.

Chapter 16

Healing Beyond Autism...

When TRUTH is found, understood and accepted is when we realize it was not even close to what we thought it would be...
~ Miriam Delicado

As Jim Humble has been proving for many years, chlorine dioxide is a molecule capable of healing many common ailments. When combined with the other elements of this protocol, in the correct order, it has shown to be even more effective. We have decided to include this bonus chapter because it is time to start sharing this information with everyone, as pathogens and parasites are the root cause of many of the diseases that are causing suffering in our world today.

As parents saw improvements in their children's health from the protocol, some of them decided to use it on themselves as well. Similarly to when the flight attendant tells you to put on your own oxygen mask first before helping others, it is important to take care of yourself if you want to be able to help your children heal, grow, learn and mature.

Over time, parents who followed in their children's footsteps started to have some undeniable gains in their own health. This was an added bonus many didn't expect, and we couldn't resist sharing their stories with you.

After reading the parasite chapter, you may have been surprised to see how many common symptoms can be caused by parasitic infections. Imagine what would happen if we could get this information into the hands of people who have seen many doctors, used various drugs, and applied countless protocols for years while only masking the symptoms of the underlying cause. So, there should be no surprise if going after the real cause was life changing in real ways.

The following testimonials are a small sample of how some of these people's lives have been changed. Serious afflictions such as Lyme disease, fibromyalgia, chronic fatigue syndrome (CFS), depression, cancer, and chronic infections, are just some of the conditions that improved or completely cleared up. By cleaning up toxic pathogens and parasites, as well as removing foods that feed these invaders, it should be no surprise that disease triggering inflammation is reduced so true healing can take place.

I am so excited for you to read these, and I know that some of you will recognize yourselves here. Please know that healing is possible! We have a public Facebook group called *CD Health* where adults using the protocol for themselves can share questions, doubts and success stories. I highly recommend that you check it out if you are looking for support or some guidance getting started.

Testimonials Beyond Autism

After we saw our son recover from ASD using CD, I tried CD myself and it helped me recover from Lyme and its co-infections. Some of our extended family heard about our success and they have had very good results using CD for treating Hypertension, Diabetes and Liver problems. My younger NT son used to bang his head in sleep since he was born, CD has now resolved the problem. I think anyone who tries CD sincerely, can only benefit in treating so many hard problems. One very beneficial side effect I have seen with CD is the resolution to seasonal allergies and improvement in the immune system to the point where kids do not fall sick or catch colds. In this regard CD is much better than yearly flu shots which have so many toxic elements in them and still do not protect adequately.

—Nilesh

To say I was anxious about the impending birth of Baby #2 is an understatement. I felt like I had failed our first born on so many levels and was a mess believing that I'd do the same for our new daughter.

But alas, she was born a perfect and healthy baby girl. So was Callum, our son, but unlike Lila who had zero interventions, Callum had antibiotics from my labor, the Vitamin K shot, HiB, and DTaP. And it was the DTaP vaccine at 15 months that took the shine from our sweet boy's eyes.

We discovered Kerri's protocol when Lila was 3 months old and more worries cropped up about how to best protect her from the die off that was going on in our house.

At 5-months, she developed an eczema patch underneath her chin, became chronically constipated, and her normally cheerful disposition became irritable.

As soon as she hit the 20-lb mark, I started giving her 20 drop CD baths, low dose oral CD, and 3 drop CD/150 mL water enemas. To my horror and surprise, Lila started passing 1" baby roundworms almost daily.

In a family with both NT and ASD children, the NT child always has some type of quirky behavior. Now we know why! Parasites do not only affect the ASD

population, they affect everyone. Having CD in my tool chest gives me the power to prevent so many things that may have been in my daughter's future.
Don't be afraid to treat your babies! Her eczema is gone and she's pooping regularly once more.

I write and share my story in that it might help or save someone else's life. That it may just be the key to help someone see what may be what is happening for them as it was and is happening to me. If it helps just one person onto their path to recovery and health then it will have been worth sitting down at this computer and sharing it.

For the past 10 years or so my world has been collapsing in on me, and getting smaller and smaller, and accelerating the past 5 years. I have felt as if I were under a thick coffee mug on the edge of a table about to fall off. On a scale of 0 to 20 with 0 being death and 20 being fully alive and cognizant, I felt as thought I was at 3 staring at 0. For the past 5 years at least I have done so much research, listened to so many radio interviews, done so many different modalities, bought so many products, paid a lot of money to different therapists, ate weeds, made my own concoctions, etc. My mother would always say to me wow you should be so healthy to which I would reply no mum, actually I am not. I began feeling like a phony. I ate real good took all the right stuff, got plenty of rest foraged for my own food and spring water, got exercise, walked barefoot, etc, but always felt exhausted and looked worse and worse. I was fighting with everyone it seemed and chasing people away including family.

Four months ago my wife decided we should go away on a weekend getaway and relax. We fought the whole drive up there and when we got there she threw me my room key and said you're on your own. I spent the whole weekend in bed and on the trip home we both decided to end our 20 year relationship and marriage. I was good with that and looking forward to being on my own. I was finally chasing the last person who mattered to me away.

A week later an angel came into my life. I have been listening to oneradionetwork.com for the last 5 years and on this day Patrick Timpone had a lady by the name of Kerri Rivera on and she spoke about how she was curing kids with autism and that the kids had parasites. I looked up the symptoms of autism and realized I had quite a few of them. I immediately began the mms enema protocol which she recommends. I could not believe what then came out of me. I kept this up for a week and still there was no let up with the amount of parasites, biofilm, and who knows what coming out of me. After a week of this and seeing no let up on what was coming out of me, and having just done an mms enema I laid on my bedroom floor and the grief just poured out of me. My wife came in and lay down next to me and just held me. I knew then that something had changed, that my life and my marriage were now on a healing path. That the pain, the toxins and parasites were now leaving my body.

It has now been just over 3 months and there has been no let up on what has been coming out of me. If I were to have scooped it all up and put it in a jar I am sure it would fill a one gallon jar with hardly any water in it. I now feel I am at about a 9 with 20 in my sights. I thank God that this info came into my life and I took action on it. It has saved my life and my marriage. I love my wife, and cannot imagine not having her with me. And I love my life and am looking forward to not only getting *to the 20 mark but what is beyond the 20. What is possible when one's brain is at full capacity and not being inaundadated with toxins? Much love and appreciation goes out to Patrick Timpone at oneradionetwork.com, Kerri Rivera and her work with autistic kids (adults too Kerri), and to Andreas Kalcker. Thank you all for showing me and pointing to the keys I needed to free myself from what has been a nightmare.*

A big part of my healing has been reviewing my life and realizing that this has been going on for most of it and answers so many questions I have had. As a child growing up I had pain in my stomach and what the doctors eventually did was take out my appendix, which most of us know now is needed to keep the healthy flora in our intestines. And they told my parents that it was all in my head. So whenever I complained about stomach aches and pains was told that it was all in my head. School was a nightmare for me, as socially I felt I didn't fit in or belong, and a lot of easy concepts that most others got, I just couldn't get. I always had the feeling like I was missing something. I felt as though I was stupid or something just wasn't right with me. I now know there are many just like me. The words Autism, add, adhd, ocd, etc were not a reality back then. And I know those are just words or diagnosis of toxins and parasites. Get rid of the toxins and parasites and the diagnosis goes away. Easy peasy. Thank you all for listening to this chapter of my story. I look forward to many more chapters in my life story. Please feel free to pass this along to anyone who it may help. Much love.

—Bruce

When starting the protocol for my son's Autism, I decided to do it along with him.
I was suffering from Hypothyroidism, Adrenal Fatigue, a Hormonal Imbalance, and Severe Anemia. My cortisol was at a 3. One week into the protocol, my cortisol was at a 14, and my iron levels were normal without supplements. My thyroid medication dosage was decreased twice. My vitamin levels were all normal. My uterine fibroid cysts were completely gone after a few months on the protocol. I continue to see improvement in my health. This protocol has been a Godsend for my family.

—Maggie Kaye

CD has been life changing for my 18 year old son who has autism and Lyme, although his ATEC today is only a 3, down from a 68 at the start of cd, but I never thought it would be so instrumental in my dad's life also.

My dad, William, has a malignant melanoma in his eye and has received radiation for treatment for the last few years. I talk about cd all the time but they never took this treatment seriously, at least for anything besides autism until now. My dad gets terrible ear infections that he sometimes has to go to the hospital for. They tell him each time that he has "swimmers ear" and they give him abx, sometimes it seems to work, sometimes not, and he goes back to the drs or hospital for more abx....over and over. Recently he was leaving here for his 7-hour trip home, and he was very worried that he would not make it home with the painful infection that had begun, *and he would have to stop on the way and visit a strange hospital. So I mixed up some cd, and told him to drop a few drops of the cd mixture in his ear periodically on his way home. To his surprise, the infection cleared up by the time he got home and there was no need to even call a doctor.*

Of course, my secret plan is to get him on the cd protocol to finally deal with the tumor in his eye and that's the plan we have started. Whether he uses it and shrinks the tumor and saves his life with cd or not, he's a true believer now that cd cures infection.

I have been taking CD and the parasite protocol for 5 mo., and here are my observations. I have had long-term chronic sinus issues which has caused sever sleep problems. Also, a few months ago, I had a severe toothache in the upper left area. The dentist examined and found no fault with the tooth, even though there was severe swelling in the area. The infection originated from my sinus, and by taking my CD regularly hourly, was quickly solved. (My hourly CD doses were compromised by travel) I have also noticed improvement in my sinus condition, resulting in better sleep, although I have not fully recovered yet. Right now my sleep is somewhat interrupted by peetox. I will continue CD and PP for the 18 mo. Previously; I had used several naturopaths, with either negative results or limited results that disappeared when the medications were discontinued. So far I am happy with CD and would recommend it to people to try.

—Ed Canada.

A friend started eardrops with her 13-year-old pug 3 weeks ago. The pug Lucy was almost deaf from ear infection after ear infection, on constant drops, had seizures. After 3 weeks on CD eardrops, went to the vet, no ear infection, hearing is improving!! Winning!!

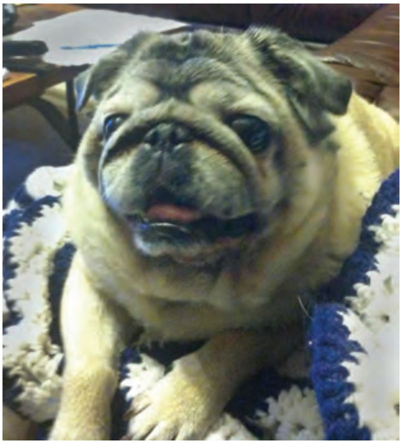

Since I was a child, I had been anemic and reading the book "Healing the symptoms known as autism" on the Parasite chapter, I saw that anemia is a sign of parasite infection. Since my son is taking CD I also took CD to know how my son feels and maybe cure my anemia. I had no problem going up to 24 drops in less than 2 weeks. I stopped taking my iron pill after 1 month of taking CD. I also did parasite protocol as I do not want to reinfection my son. Since, I stopped taking my iron pill I never had any dizzy spells and I feel great.

I used to wake up at night too to use the bathroom, now with CD no more night waking. In 2009, I was informed by my Doctor that I need to go and see a specialist as there was some suspicious stuff in my Pap Test and if not removed it *can lead to cervical cancer. I was booked in the hospital for the procedure. After taking CD reaching full dose, I had been discharging this horrible smell, like rotten egg, whenever I urinate. It took about a month before it stopped. Whatever that was, CD cleansed me and I think that discharge is related to my diagnosis on the pap test result. I am very grateful for CD for giving me my health back. I am still continuing taking CD as I want to be healthy and I will also try to complete the Parasite protocol for 12 months, I just finished my 5th PP and have been seeing lots of parasites mainly pinworm and ascaris. Now, I know the root cause of my anemia especially. I would encourage people to try the Protocol and see where the healing leads you. Thanks to Kerri Rivera, Jim Humble, Andreas Kalcker and people who used the CD before me as you gave me courage to use the CD.*

—G.M, Canada.

Two days before our first set of cd bottles arrived (we bought it to start Kerri's protocol with our autistic daughter), our son (6) got sick with scarlet fever. We didn´t give him antibiotics because we just finished our research on cd and were excited to use it instead. My sons face was swollen and red, he had a moderate fever and rash all over his body. After the first dose of 1 activated drop of cd within one hour his swollen red face subsided completely and in the evening the fever was gone. His rash got dry and after 3-4 days it was not visible anymore. Our physician told us that scarlet fever without antibiotics lasts up to three weeks. We were done within 4 days, without damaging his gut flora, as it would have using antibiotics. CD has taken care of many infections in our family since then and most important - brought our daughters ATEC down from 100 to 46 in nine months. I´m beyond grateful for its discovery.

For the past six years, my life has been plagued with anxiety/fear, depression, pressure in my chest, making it difficult to lay flat and sleep, bloating which caused me to look 7 months pregnant and which made my abdomen very tight and uncomfortable. Headaches, weight gain, sore joints, no energy, fibromyalgia pain, and dizziness causing me to feel drugged and off balance.

The anxiety and fear were debilitating literally making it impossible for me to sleep. I would go night after night not sleeping, just dead on my feet suffering with so much anxiety and very frightened wondering what in the world was wrong with me.

When Kerri's book, Healing The Symptoms Known As Autism came into our lives, I read it wanting to help or autistic son. I soon realized I had so many of the symptoms that I needed to do the protocol.

I started on the cd taking a very small amount, 2 drops every hour, about 12 doses per day, and worked up to between 60 and 90 drops a day, I also took cd baths and did enemas. I increased the cd every day by just a drop or two. Very soon I started to calm down significantly. I started sleeping! I started losing weight! For about 5 weeks I thought I had died and gone to heaven. In two months I lost 20 lbs.

But when my anxiety started coming back I set up a consultation with Kerri. I learned I needed to begin the parasite protocol to kill the parasites. The cd just killed the little ones.

With Kerri's help in several consultations I was able to tweak the protocol in her book and apply it to me for my personal needs. I started on low doses and increased it for what I needed to sleep.

As of today I have only been taking Mebendazole, the medication that kills parasites, for 3 and a half weeks. I sleep at night. Some nights are a little choppy but I get 4-5 hours of sleep. I am not depressed. My emotions are not all over the place. I am coping. I'm functioning without sever headaches, only mild ones. I still have bloating but not as severe. I feel like I will live and that I am not dying anymore. I hardly ever feel depressed.

To date I take 200mg Mebendazole at breakfast, lunch, dinner and bedtime, plus a 200mg implant right before I get into bed. The implant has been the turning point in my healing. (Consult with Kerri for directions regarding the implant.) I also take 2 neem tea capsules with each meal. Also, one dose of Combantrin everyday at lunch. I take castor oil as needed each day 1-2 Tablespoons to keep things moving, plus a cd bath at bedtime, 150 drops soaking for 20 minutes.

Trying to differentiate what is die-off and what are actual symptoms from the parasites is challenging. Pay close attention to how you feel after you do or take something. After an hour note how you feel. Worse, better? You have to listen to your body. Consult with Kerri often and keep her informed by email. You may have to tweak the protocol every few days so write everything down, day, time, how much, how you feel etc.

All of my symptoms are not gone 100% but they have greatly improved. The anxiety, which was the worst and most debilitating symptom, is the greatest improvement I have had. I know I will be able to heal completely and get my life back. I have just begun!! I have had so much progress in just a few short weeks that I still cannot believe it!! And...I have lost 2 more pounds!!

Thank you Kerri for all of your love, support and guidance!! I could not have attempted this without your knowledge and help!! You are an angel!!!! I AM HEALING!!!!!!

Your devoted friend, Marcie

My mother 84 yrs of age- who has dementia was very, very serious last week. Her lungs were filled with mucous and she could not spit it out. We thought this was the end and my sister invited the priest to bless her. The doctors suggested that I place her in a hospice, but I refused! They also offered antibiotics, but I bought some CDS and gave it to her every hour. I placed a humidifier with 40 drops of activated CD by her bedside day and night. And massaged different parts of her body with CD and DMSO. soaked her feet just once in CD as it is difficult. She cant sit straight. To everyone's surprise she made it through. Just a little bit more to clear up! Thank you everyone for sharing wonderful tips on loving and caring for our loved ones! This is a wonderful extended family! love the CD!!!!!!!!!!

* * *

I want to thank all of those who were kind enough to share their personal stories with us. There are many more, but you get the idea. I am so excited for you to read them, and I know that some of you will recognize yourselves here. It just goes to show that healing challenging illnesses is possible. We have a public Facebook group called *CD Health* where adults using the protocol for themselves can share questions, doubts and success stories. I highly recommend that you check it out if you are looking for support or some guidance getting started.

Appendix 1

More Miracles & Testimonials...

The only limits you have are the limits you believe.
~ Wayne Dyer

To date, 115 children have lost their diagnosis of autism by using CD and some or all of this Protocol. Autism IS curable!

This section is comprised of testimonials, miracles, and short blurbs on gains made by children using The Protocol. In many cases, these are candid emails from parents to Kerri sharing their joy at their child healing. These were gathered over the past 3 years, and have come from families all over the world. Some were translated by the parents of the child to English, and some were translated by my sister or I. We have done our best to honor these exactly how they came to us, unless a correction was needed for clarification, these were not edited. Many are anonymous for the protection of the families and their children. Names were used when permission was given. These families were generous enough to share their experiences with all of us to spread hope and joy, as well as to prove that children all over the world of all ages are healing from the symptoms know as autism. Please enjoy and share.

Please note that many of these testimonials were collected some time ago and therefore some contributors use the term MMS instead of CD. Due to time constraints it was impossible to request permission to change the acronym of MMS to CD in their testimonials. As we mentioned previously, MMS and CD are the same substance. Where the acronym MMS is used in the following testimonials please know that chlorine dioxide is the substance responsible for the healing.

We have added many new testimonials since the first edition came out. Those new testimonials are located at the end of chapter 2 and continue on the next page, followed by those appearing in the first edition.

(continued from Chapter 2, page 40)

45. *Things I wish I'd known before starting this protocol:*

    * *My son would drop juice and pick up a water regimen immediately.*
    * *My son would sleep through the night every night.*
    * *My son would not be constipated again.*
    * *My sons ATEC score would be halved in 7 weeks.*
    * *My son's speech would be at age level.*
    * *My son wouldn't need his daily rx med again.*
    * *My son would be excited about and participate in his birthday celebration.*
    * *My son would come into the bathroom and say, "I'm ready to wash my butt" unprompted.*
    * *My son would drink ocean water.*
    * *My son would get acclimated to school and would initiate conversation with his peers.*
    * *My son's dark circles under his eyes would disappear. He would start to look and act like a healthy boy, and others would take notice.*
    * *My son would be affectionate, tell me he loves me, crack jokes, and be connected to me like never before.*
    * *The people who opposed our diet and protocol choices would be unable to deny that this works and we're on the right track.*
    * *My marriage would be saved by rolling our sleeves up and tackling this together.*
    * *I would find a way to heal my own ailments.*

    The future is bright

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46. *My son with autism is 31 years old. Although he is fully verbal, he had a lot of issues: SIB, Aggression, he was not able to sleep. We have been trying different kinds of protocols since he was 3 years old. Unsuccessfully. I heard about Kerri Rivera and the CD Protocol last September. We started right away. We were continuously in touch with Kerri who kept giving us the faith, that even at that old age it is possible to heal and even recover. In September, when we stared CD he had an ATEC of 87, 4 months later we measured 63, and now, after 8 mounts, he has an ATEC of 28. There are some SIB's and aggression left, but it happens only rarely. If we could get rid of it, my son would be recovered. He became an interested young man, his memory improved. He keeps giving proper answers to my questions, something he never did before. I can see his real personality now: he became a nice, lovable, open-minded young man from a very sick raging, roaring, screaming, suffering boy. There are no words to say thank you to Kerri to show us the end of the tunnel. I think I'm on the best way to recover my 31-year-old son!*

    Mark, 31, Hungary

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47. *Dear Kerri, I am very grateful to you for your benevolent service of helping to recover kids with Autism like myself. You have really improved the quality of lives of many hopeless kids. I really feel the difference now that my ATEC score is a*

1 and I am still making inroads in executive functioning and social skills. Without someone like you, we would have not known about CD and it would have taken several years to cure me solely with chelation. By that time, I would have been out of high school and probably in a community college taking rudimentary general education courses and would have had a bleak future ahead of me. But now, I am doing well in school and am taking college level courses. And I am not the only one in my family that has had benefitted from using CD. My brother used to have mild seizures in the form of head banging and most of that has now stopped. My father has used it because he contracted Lyme's disease twice. And my grandparents have used it to treat Alzheimer's, Diabetes, Blood pressure and Hepatitis C. So again, I cannot thank you enough for everything you have done that has not only changed my life forever but has made a profound difference in the lives of others afflicted with Autism.

48. My seventeen-year-old son was a healthy happy baby until he received vaccinations at age three. The day after the vaccinations he began having horrible anxiety problems. Day by day he lost skills and regressed. He developed problems with fine and gross motor skills, and social skills, memory and sensory integration. He also had multiple learning disorders and struggled in school. He spent all of his time in his room by himself and he did not make eye contact.

We tried many interventions to try and help him. Biomedical interventions, antibiotics, therapies homeopathy and Biofeedback all had limited benefits for my son. The only thing that helped him some was a gluten free, casein free, sugar free diet. While reading Healing the Symptoms Known as Autism we learned that most of the interventions we tried did not work because we were feeding the parasites that were causing my son's autism with vitamins and supplements.

While I was watching videos about Chlorine Dioxide I came across a video of Kerri Rivera talking about the protocol she uses with autistic children. As I watched the video everything began to make sense and I knew the protocol would help my son.

We bought Kerri's book Healing the Symptoms Known as Autism, gathered the supplies and my whole family started the protocol. To our amazement we saw improvements in my son overnight. We had taken the ATEC test for my son right before we started the protocol and it was a 43. In just one month of Kerri's protocol my son's ATEC dropped to a 5! We will continue with the protocol for the recommended time and we expect to see my son's ATEC drop to zero before we finish.

His social skills, motor skills, thinking, behavior, attention span and stimming have all improved immensely. His sleep patterns, digestion, physical appearance and weight have also improved tremendously.

Kerri Rivera's book gave us the tools we needed to reach in and pull my son away from the grip that autism had on him. We will forever be grateful to Kerri. She devotes her life to helping children with autism and always has an open line of communication for anyone who needs help. She is the voice for so many children that don't have a voice. Thank you from the bottom of my heart!

49. FUA!!!! BIG moment... crazy morning, ughhh we miss the Bus I was so mad because my other daughter had preschool at 9:30 so my morning was a mess, I had to leave in Pj's and make them eat breakfast in the car....but then in our way to school my son saw a School Bus passing by our side and said "school Bus is gone, L is sad" OMG OMG OMG......did he just said this 30 words sentence?????

(actually 7 words but seems like 30 to me!!!) Ok...WAIT then I get to school not mad anymore, I walked with him still in shock, I couldn't believe what I just heard....and when he saw the line of kids by the wall he point at them and said "my friends" OMG OMG OMG....ok WAIT....then we get there and he takes the teacher hands, gives me a kiss and said "bye mommy" OMG OMG OMG .... WAIT then the teacher ask him L, remember back pack by the wall, so he goes to the wall with his back pack in his back and does exactly what he was ask to do!!!! O M G

FUA...THAT'S RIGHT.... 223 days in this Protocol, searching poop, dosing, enemas, writing in his food diary every little thing he eats, therapies ABA, speech, occupational, hours hours of work, hard work...all just to witness this miracle of healing...to see him think, react, analyze a situation, be happy, spontaneous and smart by himself (no prompt or reinforcer necessary)....THANK YOU Kerri Rivera since the first day I found you in YouTube I have never stopped believing....I LOVE YOU WITH ALL MY HEART!!!! YES COMADREEEEE!!!!! I can feel it...we are close...it's happening.... so happy I missed the Bus this morning... this is the best day in my son's way to recovery so far!!!!!

HOPE FOR ALL!!!!

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50. My son is 23 and we have tried many, many approaches to heal him over the years. Typically we would see some initial progress, but then the rate would slow down and he would plateau again, slipping further and further behind. Lyme disease and co-infections, as well as various viral, fungal and metabolic issues complicated everything. We had to resort to psych meds, even, for his depression, anxiety and mood disregulation.

We started Kerri's protocol in the summer of 2012, and had to cut the number of drops again and again to something he could tolerate, since he has MTHFR genetic issues with detoxing, until he was at 1/64th of a drop per dose. By October 2012, he was at full dose and after two weeks, began to talk about learning to drive, to offer to do a chore at home, to draw again. So it has been about a year for us, and the improvements are continuing, his ATEC score went from 77 pre-meds to 11 now, and our lives are all much better thanks to this book and Kerri's dedication to the cause of healing the children. Please, if you are reading this, don't be afraid to try one more thing!

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*51. My son started Kerri's protocol 10 months ago. At the time we started the protocol he was doing a home based therapy program for 60 hours a week. We did not send him to school because he was not able to handle all of the outside stimulus, unable to follow directions, and unable to communicate effectively. He stimmed most of his day and only spoke in 2-3 word sentences to get needs met only. When he started the protocol his ATEC was 57. It quickly dropped and the improvements were mind blowing. In 5 months time his ATEC was a 9. Today at 10 months after starting the protocol his ATEC is a FIVE!!!! He now attends school with out any kind of extra support and exceptions made for him. He is truly just one of the other children. I have been volunteering in his school and I have had 5 different office people tell me that he stops and greets them on his way to different specials (p.e, library, art, gardening). They told me he initiates the greetings and says: hello, good morning, buenas noches, and all with a big smile on his face. I have even been told by 2 of them that he greets them by name. Did I mention that he leaves the classroom on his own to go to specials??? Yep, my one time *severely autistic* child finds his name and places it in that specials category* *basket, leaves the classroom and goes to specials on his own???? When he is done with specials he goes back to his classroom and does his work. Holy CRaP!!!! A dream come true.*

Thank You Kerri!!

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52. *My 6 year old son's ATEC went from 45 to 22!!! Wow I knew he was doing better but more then half!!*

    Thanks Kerri Rivera!!

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53. *I don't know what to chalk it up to--we just finished our 3rd PP and did our 2nd shot of GcMAF on Saturday--but my 9 y/o son has started taking pictures with my iPhone. They are not just random shots; he is finding objects or angles and taking pictures. They are FASCINATING! He has also figured out how to use the reverse feature, and has taken a series of self-portraits, which he flips through and says to himself "Who's that?"*

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54. *My 16-year-old son is doing great on your CD protocol. ATEC down from 89 to 37. Best thing that ever happened after doing 8 years biomed with him.*

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55. *We started CD with my precious 5 year old 'O-ster' in June 2013. Some of the completely new developments we have seen since we started....... He is aware of how to burp and toot, and thinks it is funny. He is apologizing for things he does wrong. Even a day later, he will remember and apologize. He goes to the bathroom on his own. He is completely pottytrained, even at night. He does household chores happily. He sent people on my contact list emails that said 'I love my mommy.' He has better problem-solving, more motivation to draw pictures. If he gets messy, he just goes to the bathroom and washes his hands and wipes off his shirt by himself without saying anything. He dresses himself. He does somersaults (just a few months ago, it was impossible for him to even get in somersault position), can open baby gates, can get in crab walk position, can jump off of furniture with both feet. He greets us when we come home and is excited to see us. He MISSES us when we are gone and talks about it during the day. He's making up 4 line rhymes. He cares what he wears and picks out his clothes! He is not running back and forth as much. We have normal trips to restaurants. I can leave our front door open now, and not worry that he will run away. He tries to help put our dog in his crate and fetches with him. He wants to come with me if I leave the house to go somewhere. He will now eat almost anything I put on his plate. He used to vomit at the mere thought of things like GF pasta or rice, and he wouldn't allow any food on his plate to touch another type of food on his plate. He will now eat bowls full of tomato sauce, onions, burger, rice, garlic and peppers all mixed together. Our family can eat dinner together now. I no longer have to make separate meals. He even eats raw peppers! He yells 'watch me!' and does things like diving onto the bed or jumping off of something. He looks at cloud formations to see what pictures he sees in them. Last week he heard a toddler crying in Target. He wondered why the child was crying and wanted to go find her. He misses his little sister when she is not at home. He wants her to play with us when we are playing. He is completely aware of what is going on now. He is much more aware of danger. He notices the weather. There is a sense of calmness about him that he did not have before. His tantrums are much less severe and much less frequent. I was supposed to be his aide this year in preschool, but I have been able to just drop him off at school. There are many more new things that he is saying and thinking and doing.*

Our quick biomed history- He regressed after vaccines at 12 months. Starting at 18 months of age, he was gfcfsf for 1 year, then scd for almost 3 years. It feels like we have tried everything with supplements over the last 4 years. Some things helped a little, but nothing really tackled his pathogen load, even though he was on an awesome diet. His ATEC was 66 in Dec 2010. Low dose chelation brought it down to 33 in 3 months. The ATEC stayed at 33 for 2.5 years. We did 112 rounds/weekends of low dose chelation during that time. ATEC June 2013 was 34 (before starting CD), July 2013 was 30, October 2013 was 20! We are on our way down. This is the first time that I have physical proof that we are getting rid of the pathogens that have controlled and poisoned his body and brain for most of his life. It feels so good to finally help him. I am hoping to write our complete recovery story in Kerri's next book. I thank God that we saw Kerri at AutismOne.

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56. Nick texted me yesterday for the first time, on his own. "Hi from Nick" - that's a 2013 FUA fo sho. – Alison

(this text was accompanied by an ATEC drop from 69 at 6 years old to 14 at 8.5 years)

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57. Yesterday my son told me I worried too much, I said you worry too much Too Noah! He responded, my hair is red, yours is gray, so who is the worrier, hahaaa! The windshield wipers keep wiping away the autism, what's staying around it seems, is completely lucid speech and unbelievable comebacks! He never could say things like that before, not at all, he really was in there somewhere.

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58. Something really beautiful is going on in our household right now...Caleb is totally blossoming socially on every level. There is a calmness in his body. He is alert, responding to his name, sharing his toys with other kids, wanting to give affection without prompting, soothing Lilia when she is crying rather than batting at her. We even have gotten a few spontaneous silly phrases!!!! Oh baby, oh baby, oh baby!!! We are on our way!!!!!

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59. We started the diet on the 1th of March, CD on the following week. Adam started to ask questions in April. Since then he keeps asking continuously…His ATEC dropped down from 49 to 38.

Tunde, Hungary

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60. OMG OMG OMG!!!!! My son is singing!!! He was ZERO verbal... I mean ZERO!! His shadow teacher told me a week ago that he started to mimic, I said to myself "yeah he was babbling and she thought he is mimicking!..." Yesterday she told me he started to sing and I said to myself, "Yeah right, she is absolutely illusionist or exaggerating!!!" She knew I will not believe her because he is just humming at home! So she sent me a video which was a shock for us. He is singing the song "A is for apple, a a apple... B is for ball, b b ball... C is for cat, c c cat... D is for dog, d d dog..." I don't have enough words to thank you and thank Kerri Rivera and this incredible protocol!!! Thank you for saving my child. xoxo

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61. ...My son is doing his first CD PP. We picked him up from preschool he was extremely happy. Hugs & kisses. Then...runs up to a classmate and touches his shoulder and says, "bye Johnny", runs to another classmate and says, "bye Kevin." Then he skips to the car. These improvements in his socialization is new. We are so pleased and I wanted to pass along these social gains with you all. His atec at start is 58.

62. *My little sweetpea is almost 4...and completely NON VERBAL...upon picking her up from therapy today, her teacher said she was having a great last few days... and both therapists said her eye-contact has been different...like in a really good way!!! I've also noticed her looking at me...straight into my eyes for what seems like forever...almost as if she has never seen me before?! They also said that she has been looking at them and has been opening her mouth trying to make sounds...as if she wants to say something very badly...but can't...but with a lot of prompting...she did say "Hi!"...all I know is that somewhere in there is this amazing person waiting to be let out! I often worry if we are ever gonna make it...finances and healing your family can be very overwhelming...especially on one income. But for the love of my daughter we just cannot give up...feeling very hopeful and blessed today...and very grateful that something is finally working.*

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63. *Hi Kerri,*

I wanted to write and thank you for discovering and sharing your protocol. This protocol has saved my almost 5-year-old son.

My son suddenly started having absence seizures that would freeze his breath. From the day he had his first noticeable seizure, he was hospitalized every seven weeks for uncontrollable status epilepticas, a life threatening condition. They would pump him with seizure meds, Ativan, and Valium for hours before the seizures would finally stop.

Since starting CD five months ago my son has not been hospitalized once. He went ten weeks seizure free. He had a few mild seizures that he brought himself out of without any extra medications. He currently broke this record and has made it another thirteen and a half weeks seizure free. I true miracle.

Everything we searched for to treat his Lyme disease in the past would either cause seizures or not help to prevent them and I now know why. As you predicted after starting your protocols we discovered that he not only has Lyme, he is also incredibly loaded with parasites. So much so, that it scares me to think of what may have happened to him if we didn't find you.

I'm so amazed to watch him subtly emerge. Since we started, he went from saying about 20 words to saying 69 words, along with two and three word combinations, and over the past month he has begun to answer simple questions. His vestibular system has gotten much better; he'll actually swing. He just started jumping off curbs. His eye contact is perfect. He's gained two pounds in the past three months, something he hasn't' done since being diagnosed with failure to thrive at a year old. He is playing with his three year old sister; it's so adorable to watch them chase each other around the house, hug, chase each other, hug, get in the dog crate together, hug, take turns pushing each other in their wagon, and kick the ball back and forth. Last night the three of us played catch together for over 10 minutes. I'm so happy for her to have her brother to play with.

This protocol changed his life, my life, and our family's life.

There are no words to thank you enough for all your help along the way – he's on his way…

Love, Love, Love

Update: as of December 3rd, 2013 this little guy is 18 weeks seizure free!

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64. *My name is Dawn. Below is a shortened version of what we've been through prior to and since Kerri Rivera coming into our lives and changing our family forever.*

I am Noah and Eli's mom, caregiver, advocate etc., that's been my job for 17 years. Prior to having children with special needs I had a career that I loved and my plan was to continue my career, how deluded I was, my life has been forever changed by my children and their symptoms as my entire existence over these years has been to save my son.

My son Noah born August 19, 1996 has struggled and suffered with what is now known as the symptoms of autism. His symptoms began at 8 months of age with a rare blood disorder known as neutropenia, he had a low white blood count. As he continues to improve, I too, along with our entire family seem to be healing as we bore witness to his daily struggles of self injurious behaviors, aggressions and rages, learning disabilities, speech and auditory delays, 2 steps forward and 4 steps back.

Healing the symptoms know as autism with the Chlorine Dioxide and Kalcker Protocol have been a cathartic exercise for me as well, no amount of therapy would have soothed my soul like witnessing my son's return from the daily brink of death.

My hopes and dreams for my son dashed with vaccines before he was old enough to speak. I'm 50 this year, however I'm older then those years, and my views and outlook on life have changed forever. Imagine fighting for my son's life against those trusted factions of our society supposedly put in place to protect us, i.e., government agencies, churches, schools, teachers, principles, school boards, doctors, hospitals. I'm changed forever by the daily battles, but somehow they are small now in comparison to the beast of the symptoms that ravaged my boy with red hair, often referred to by me as my favorite Martian. As he continues on his healing path, so do those of us who have loved him so dearly, despite his outwardly awkwardness, he is the innocent victim left to suffer for what is often referred to as the "greater good", he's responsible for so much more in my life then just the symptoms known as autism.

It was a Saturday morning in May of 2003. Noah, at the time 6 yrs. old, had slept with us because of seizures on and off through the night. Like so many times before, I was very concerned he would go 'status epileptus', a state of continuous seizures. He ate cantaloupe for breakfast that day. I remember it vividly even 11 years later. His seizures would come about every 20-25 days. First he would complain of a stomach ache, and I could hear the gurgle of his stomach. They usually lasted a few minutes and then went away. This day, the Saturday before Mother's Day, he didn't come out of the seizure. We administered his anti-seizure medication but it didn't work. We called 911, the fourth such call in Noah's brief life. When EMS arrived, Eli, then 3 years old, ran to his bedroom upstairs. I remember the technicians working on stabilizing Noah. They ripped the shirt from his body as they worked on him and carried him out to the ambulance. As I followed them to the ambulance I happened to look back to see Eli watching from his upstairs window as they placed his brother in the ambulance. He stood motionless. Darryn scooped him up and followed us as we drove swiftly through traffic to Texas Children's emergency room, about 25 miles away. I remembered thinking, why don't people heed the right of way? I looked back as they worked on Noah. His seizures continued until we arrived at the hospital. Once we arrived he was taken straight to the ER, ICU room, where *four doctors began to work on him. Darryn and Eli arrived as I stood next to the bed while the doctors worked to save his life. I took Eli out of the room and we sat in a chair looking in at what was happening. His eyes were as big as I have ever seen them and he sat perfectly silent in my lap, we colored. I overheard the doctors explain to my husband that they were having problems stopping the seizure. They wanted permission to use a drug that could stop his heart. Darryn asked if there were any other options. The doctor shook his head. He asked what they would do if the heart stopped. The paddles. So he was given the drug. No heart stoppage. His breathing became shallow and the seizures finally stopped after 6-7 straight hours. A couple of hours later Noah woke up in his hospital bed, connected to monitors and the like, in a drugged stupor. By this time my parents had arrived (like so many times before) and had taken Eli home. Darryn stood next to Noah's bed rubbing his chin nervously. Noah asked if he could use the restroom. Darryn said yes, and in the next second Noah leapt from the bed, almost a perfect swan dive, toward the floor. Luckily, Darryn was there to catch him. Noah's life was saved twice in the same day. After the drugs wore off, he was released from the hospital. Noah missed a week of school while he learned to walk again.*

I never knew the impact this had on Eli until Father's Day that same year. About a month after the seizure we planned to attend with some friends one of those workshops at Home Depot where the kids make a gift for Dad. He was excited to do the workshop. As we approached the store we noticed the local fire station had an area of the parking lot roped off for tours of ambulances and fire trucks. Eli became frightened and started crying, and began backing up, finally screaming and contorting. This from a child that hadn't given us a peep of trouble before. I had to leave our friends standing in the parking lot as my second son became inconsolable. At the time it hadn't occurred to me that he remembered the incident with his brother just a month prior. He too suffered, and sadly he was 3 years old at the time, unbeknownst to me, Eli has probably remembered more then I realize even today.

Noah had his first seizure in March 1998 at 18 months of age, shortly after a round of vaccines. (His doctors continually assured us that vaccines had nothing to do with Noah's problems, but I know otherwise.) Seizures were not Noah's only problem, however. He was diagnosed with neutropenia (the lack of neutrophils or a type of white blood cells) in 1997. He has suffered from acid reflux for as long as we can remember. He was hospitalized for 4 days at 4 years old for a roto-virus infection, something most children get through at home in a couple days. He had a cyst removed from his thyroid. His tonsils were removed due to frequent infections. In 2005, he was diagnosed with Lyme disease. In 2008 his pediatrician discovered his blood was missing carnitine, a key component for the body's metabolism. We took him to a specialist who diagnosed him with mitochondrial disease. His seizures stopped after we started giving him medication for the carnitine deficiency. But his behavioral symptoms continued and even worsened which always indicated a deeper underlying illness plaguing Noah. But what?

Early in 2013 Noah began to show some psychiatric symptoms that frightened us to the point we had to consider putting him in a home. He had frequent panic attacks (all day, minute to minute), tics, and sudden bursts of outrage over insignificant things. He often didn't make sense while speaking, and secluded himself in his bedroom. He fantasized uncontrollably about his videos, and spoke over and over about what we were going to do about the characters (not what *we would do if we were in the stories). He had repeated events of unrealistic fears. We took him to see an energy medicine specialist. The energy medicine protocol involved various supplements and dietary changes, as well as electrical pulses to adjust his body voltage (an approach similar to acupuncture). During one of our visits we learned of MMS, which this doctor indicated could be used in small doses to treat colds. Symptoms improved, but very little. But then they worsened again dramatically. We took him to his pediatrician who diagnosed PANDAS, and prescribed antibiotics. This helped but only temporarily. His psychiatrist prescribed anti-anxiety medications, with only marginal results. He was unable to attend school through all of this, and needed someone by his side constantly. His pediatrician prescribed Albenza thinking parasites may be involved (despite a negative stool test). This improved his behaviors some but only marginally. There was also the side effect of hair loss. Noah became completely bald, like a cancer patient.*

To see your son regress into psychotic behavior is something no human can ever imagine. Facing people everyday as they watched Noah regress and comment, it was a slow slip and then suddenly he was in a dive toward insanity. I felt he was slipping away. I scoured the Internet for answers. I had heard of Kerri Rivera but thought antibiotics were the only treatment for my son, like the vaccines, I had been told by doctors that the only treatment for Lyme was antibiotics. I emailed her and she answered immediately to "start the protocol." We began the CD protocol in June 2013. The protocol takes complete dedication, it requires steadfast commitment, and it's the best gift I have ever given Noah. I have learned so much about illness and it's roots through treating my son with the protocol.

Noah's behavioral symptoms started to improve immediately. He had fewer and fewer tics and outbursts. He was noticeably calmer. He now answers the phone, takes messages, and helps me scan food items at the grocery store. He even got behind the wheel of our car for a practice drive in the school parking lot. He asks a lot of questions. So much has improved in such a brief time. Prior to the CD protocol I scored Noah as a 38 on the ATEC test. Since then, he has improved to an 8. Darryn (Noah's Dad) scored Noah a 55 before we started, and two months after beginning it was a 22. It's amazing that a few brief months ago we were considering having him put him into an institution. Although we try not to think too far in advance, now we can hope our son can someday lead the normal life he was meant to.

I can't help one final story about Noah. Yesterday he asked me what autism was. We've never explained to him that he has it, because he would not have been able to understand it even if we tried. While I searched for an answer, he said "you know, Mom, Sponge Bob couldn't get his boating license because of his autism." I belted out a loud laugh and said "Ok. Noah, you know you have a little bit of autism too." And he said "Yes Mom, I know that," and smiled.

While he still has much to make up, years of life to regain, experiences to live, we're so pleased and grateful to Kerri and the others responsible for these protocols for these improvements, his life is being restored. I would encourage anyone to follow the protocols as closely as possible and do not delay. It is so fitting that the only opportunity I've ever been given to tell a little of what my family has been through would be afforded to me by the very person that actually saved my son…she gains nothing from what she has done for us, except the knowledge that she saved a boy's life that she has yet to meet, by saving my son, she has saved my family.

65. *Shay is doing so well it's surreal. In the past week the balance has shifted so that he is now recovered more of the time than not. He is having a 2-4 hour block every day or two where he is back in his old state (weeping, raging, zero-to-flipout, shrieking, obstinate, defiant, OCD, mean, potty-mouthed, etc.). The rest of the time he is lucid, has perfect mental clarity, is as funny as can be, does his math quickly, has perfect handwriting, gets along with his sister, is generous, expresses himself clearly, plays well, understands how others feel, etc. It is a mind blower Kerri.*

    Although Shay doesn't have the awareness to know when he is in the autistic state, he is now clearly aware when he is in the recovered state. He comes up to me and says quietly, "Mom, it's gone again. Do you think it will come back?" I tell him yes, that it will be like this for a while, coming and going, until one day it will be gone and it won't come back. Shay and I have been discussing which "number" he is going to be in the line of children that recover. :) He is also planning a big "Goodbye Autism" party for himself.

    Bella is getting over her meltdowns much more quickly. Sometimes I say "no" to something and then flinch, waiting for the screaming, but it's small, or sometimes she cries and gets over it within minutes. This is a big improvement for her. In her own words, she has noticed that she feels less anxious.

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66. *We started the protocol 9 months ago. My son had 2, 3 horrible days every month. He wouldn't stop crying all day long, and he could not get any sleep at night. After talking to Kerri, we realized that these terrible days were always the days of the full moon. We saw improvement straight after the first PP. After 6 months, all of the bad behaviors were gone. I realized that the PP helped my child to improve month by month.*

    And to prove that it is not only me who can see the changes, my son's therapist from school told me the other day: "Well, when is full moon again? So that you would start the Mebendazol? I love when he gets it, he is doing so well with it".

    Staring atec in February was 50, now his atec is 34. Thank you so much, Kerri!

    Betti, Hungary

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67. *We are celebrating 3 months on CD and 2 PP's done! Our little angel has (or I should say had) extreme ADHD...we are not seeing much of that anymore. Our life altering issue is her lungs. This child has undergone over 35 surgeries in 8 years. 17 of those to surgically remove mucous from her lungs. She is hospitalized every 6 weeks with pneumonia. We have O2 in our home. She even had a port placed for IV meds at home. Our life has revolved around illness. In 8 years the docs have done every test in the book to figure out the cause. We've turned up nothing. In July, we flew to NYC to see a medical mystery doctor. He told us it's all nutritional and had us do some parasite testing. The testing turned up zilch, but thanks to Jean Marie, we ended up here. Long story short, we are making huge strides. We are not there yet, but to give you an idea, normally her pneumonias take 4 months to clear, this time it was only one month! She's only needed one antibiotic in 3 months, normally it's 8 antibiotics in 3 months. She's doing better in school too, which is just a bonus. Today she came home and told me she was able to run in gym, something she hasn't done for years! Thank you Kerri Rivera and Jean Marie and all the mods for welcoming us to this group and for helping us to take back this child's life. Bless it! Bless all of you!*

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68. *30 days of gratitude, Day 4...I am thankful for an evening alone with my son. It's rare that we have time together alone. He jumped on the bed and danced around while I packed for my trip in the morning, talking and singing the whole time. The dinner table was lonely by ourselves so we decided to eat in front of the fire. I said, "This is fun, isn't it?" and he said, "I love this and I love you, Mom" Moments like this were non-existent before our journey brought us to Kerri Rivera who is an angel on earth. She gave us the direction we needed to heal our son.*

69. *I observed my kiddos at school today. Get this........my once severely autistic 6 year old choose and received a Spanish lesson that lasted 27.5 minutes (I timed it). The whole lesson he was sitting on his bottom, following instructions, answer questions correctly (in Spanish), smiling, great eye contact, and really enjoying his time with the Spanish teacher. FUA to the max! This time last year Henry was speaking in 1-2 word sentences to get needs met. Now he is talking in complete sentences in English and Spanish!!!!!!!*

70. *In the past, if I gave Nate a hug and told him I loved him, he would sort of hug me back, awkwardly jutting his backside out (to reduce physical contact) and patting me on the back and saying, "I love you, too." He would then escape as soon as possible.*

    After a few days of being on 7 drops (last week) Nate approached me with full eye contact, threw his arms around me, gave me a prolonged bear hug and spontaneously said, "I love you, Mom". I hugged him back and we stood there, just enjoying the moment, while I quietly balled my eyes out.

    Thirteen years. I had waited 13 years for that moment.

    And now he has been doing it almost every day since that first hug.

    This alone is the world.

71. *There's a lot of people jumping on the "Thankfulness Train" this time of year. Here's my contribution. There's only one major thing I can think of this year that I am thankful for. Of course, there's so much to be thankful for, but one thing that really stands out. That would be this protocol. God led us to see Kerri Rivera at Autism One this year. I only went because it was basically the one thing I didn't know much about. The day before Kerri presented, I saw my friend Laura at Karaoke Night (so fun by the way!). She told me she was doing CD and I'm pretty sure I looked at her like she was crazy! Saw Kerri the next day and I was hooked. We started the protocol June 3rd. Laura got me in this group. Thank you Laura, for your patience with me and for letting me know about this group! Thank you, Debbie who has talked to me many times about the protocol, about my son's aggression, reassuring me that things will get better and they have! Much, much better. We still have further to go, but there is light at the end of the tunnel. My four kids and myself are doing the protocol. We all have Lyme. We are all feeling so much better. We are no longer spending thousands of dollars a month on empty treatments. We are getting our lives back; our finances under control, and my son with autism went from an ATEC of 47 to 20 in four months. Thank you and love you all. And to Kerri Rivera, there are no words. Thanks and love isn't enough. You can be assured of my prayers for you, Patrick and your family for life. That's the least I can do for all you have done for all of us.*

72. *Small progress this week! My son had his ABA therapy yesterday and at the end the therapist gives him a "high five" before he leaves. The therapist asked my 3-year-old normally non-verbal son for a "high five". My son looked at him, gave him a high five and said "HIGH FIVE!" plain as day. My husband almost fell over sideways in shock! He also put his toys away without being asked to, and that too is a big change. CD is the best!"*

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73. *We have been on the protocol since Aug 30th of this year. We've done one PP. My DS is 8 with severe apraxia and autistic.*

ATEC: 4/2013: 62 starting some biomed

ATEC: 8/15/2013: 51 before CD

ATEC: 10/6/13: 24

Some WOW moments for us so far:

- * *Playing soccer with other kids at school three weeks after the start of the protocol. *Really "on" in conversations...adding information when we didn't think he was listening because he was playing on his iPad.*
- * *Talking about other things in his day besides Minecraft or Plants Vs Zombies.*
- * *Going from a battle with homework that would last over three hours to picking him up at daycare with his homework already finished. And correct. That he did on his own.*
- * *His ST saying he is able to follow three step directions better and was able to talk/ask Who and What questions for nearly the entire hour...I actually had to tell the ST what we are doing because it was obvious to her it was more than just diet.*

He's just happier. We're all just happier.

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74. *We came back from our Intensive in December of last year on a high. After a week with the Son-Rise® team, Jordan was saying 20 different words; he was more confident, and more mature. He had such an amazing time learning and growing. Every morning he would take his facilitator by the hand and walk him/her into the playroom. He really grew up that week. I loved watching him grow through love and laughter. What an amazing, wonderful thing to witness.*

We, also, learned at our IAHP appointment that Jordan was reading at about a third grade level. What a trip! The evaluator held up a paragraph for Jordan to read. It was so fast I didn't even have time to read it. Then, she held up a question for him to read, then, a sheet with the answers. She, then, asked him to point to the answer and he did. He was three for three. My son taught himself to read. What?! We were, also, very surprised to find out that between running our Son-Rise® program and incorporating exercises from IAHP, Jordan improved 433% from September to December. WOW!

Between the two experiences on the east coast, I felt like I didn't know my own son. I always believed he can accomplish anything and yet I had tremendously underestimated his ability. I was so excited to get home and start his program. I knew that if we focused and put everything into his therapy for two years, he would be ready to go to mainstream kindergarten.

I was so excited; I was beyond hopeful; I believed he was on his road to healing.

On Christmas Eve, Jordan was crouching down and just froze there. I called his *name, no response. I ran over to him and noticed his lips were turning blue. Immediately, I tipped him over, hit him on the back and did a swipe in his mouth to get out what he was choking on. There was nothing there, but he gasped for air and began breathing again. Did he just have a seizure?*

January 15 has become a day I will never forget. We woke up to Jordan throwing up and he didn't want to get out of bed. He just wanted to sleep; he must have caught the flu and needed to sleep it off? Finally, around 10am he got up and ran around the house like nothing was wrong so we began therapy. While I was in the playroom with him we were jumping on the trampoline and he suddenly stopped and looked at me with a panicked look on his face and reached out for me. Clearly, jumping was too active for his upset stomach so I brought him to the family room with Kaiyan and my helper.

Suddenly, he looked off and froze again. He then threw up again and passed out. Oh shit, he just had a seizure, and another one, and another one, and another one. All the while staying unconscious. I brought him to the ER where he slept and had another mild seizure. While he was passed out they gave him a CT head scan to make sure there wasn't a bleed or something in his brain. Everything was fine.

Shortly after, he woke up. He was playing, running around the ER as if nothing had happened. He went through what little water I had brought and was asking for food and water. A good sign, I thought. The ER wouldn't allow him to eat or drink anything "just in case". Anyone who knows anything about seizures knows that no food and drink could very well cause a seizure…and it did.

This time the ER Doctor went into full-blown panic mode, probably because she saw what happened. They began trying to get blood out of him. On a good day this is almost impossible. Now, they are trying on a kid that didn't have any fluids in his system to help expand the veins.

And so it went, needle poke, dig around in the arm searching for a vein, Jordan would hold his breath from the pain and have a seizure. Seizures are typically the brains way of trying to get oxygen; the pinpricking was inadvertently inducing seizures because of the breath holding. This went on for two hours: needle poke, dig, hold his breath, seizure. They poked him 27 times: in his neck, head, ankles, thigh, anywhere they could think of.

This of course wasn't enough. They insisted on doing a spinal tap to check for meningitis, which we had been declining all day. Now they are telling us that the way he had been seizing for the past two hours is classic for meningitis and not doing it could be fatal. They crunched him in the tightest ball they possibly could and held him so tight he couldn't move…or breath. After the fifth poke, I began to get faint and had to sit down. They didn't know what they were doing. When I sat down I could really see how they were holding him and asked if he was breathing. The nurse looked down and said, "he's blue, get the oxygen" and they put oxygen near his face.

I immediately thought, "they're killing him. They don't know what they're doing." That's when I reached out to every FB group I'm on and asked for prayers. That was the only thing that was going to save him.

When they, finally, let him go he had the worst seizure he's had to date. He was actually convulsing. As they went for blood the 28th time, I told the nurse that's enough. This has gone on far too long. She agreed, ran and got the Dr., they wheeled him into to the CPR room, and called for a crash cart. I think I said, "what the fuck?" She said it's "just in case".

They proceeded to get a drill and drill a hole through his shin and into his shinbone so they could put in an IO (IV into the bone). They pumped him full of all kinds of drugs and, at long last, drew blood.

He looked up at me with a longing in his eyes and reached out for me. I went over and put my hand on his chest and he passed out. He was transferred by ambulance to our local children's hospital; we were allowed to follow the ambulance, but couldn't ride with him. He remained unconscious until he arrived into his private room at the hospital.

The first thing he did when he woke up was reach out for my hand and give me a kiss. My little boy!

The blood they had finally taken revealed low electrolytes and bicarbonate at a life-threatening low level. Screaming and crying can drop bicarbonate, which he did for two hours in the ER; lack of food and drink can drop bicarbonate levels, which he wasn't allowed to have in the ER. Low bicarbonate levels can cause seizures. What a recipe for disaster!

The hospital ran every test they could think of and no reason was found for the low bicarbonate or the seizures. We came home after five days, followed by several follow up appointments over the next two weeks. Everything seemed to check out fine until I brought his labs to his DAN (Defeat Autism Now) Dr., she looked at the blood test, pointed to something and said, "Lyme, every time I see this in one of my kids, it's Lyme."

We had the (one of many) $800 test at the best lab in hopes we wouldn't get a false negative, which is very common with Lyme. Jordan came back positive! Now we had something to go on. I was excited to finally have an answer to what was going on with my little boy. Lyme is known for seizures and abnormal electrolyte levels.

We scheduled an appointment with a Lyme Literate Medical Doctor (LLMD) and were ready to start healing our guy. Two days before the appointment, we woke up to Jordan vomiting. He didn't want to get out of bed. He finally did and ran around like nothing was wrong and then he had another seizure. We were told to take him for blood tests immediately the next time he had a seizure. We took him to his DAN Dr. an hour away, but knew they would be able to get his blood without difficulty. We went to lunch, came home, he had a seizure, turned blue, threw up, passed out, had a seizure, turned blue, threw up, passed out, had a seizure, turned blue, threw up, passed out. His DAN Dr. just happened to call to check on him in the middle of this and told us to get him to the hospital before he had a heart attack. We went to the ER...

And so the story goes every seven weeks TO THE DAY, seizure, turn blue, vomit, pass out, seizure, turn blue, vomit, pass out, admitted to the hospital where he was pumped full of drugs for hours to try and stop the seizures, and they ran the same tests over and over again. The hospital didn't think he had Lyme even with a positive test and thought that seizures every seven weeks to the day was a coincidence, although, they could still not offer any explanation.

We tried treating him with ABX that the LLMD prescribed. One teaspoon and he had a seizure, turned blue, threw up, passed out, had a seizure, turned blue, threw up, and passed out. This time the Valium I administered did stop the seizure cycle, most likely because it was induced from the ABX and not part of his regular seven week seizure cycle. He had multiple mild seizures every day for two weeks from that one-teaspoon.

Clearly, ABX were not going to work. I emailed with a woman who coauthored the book, "The Lyme Autism Connection" and tried the homeopath that she used down in San Diego. This was definitely working with detoxing, but it wasn't helping with the seizures. He went from seven weeks to the day to three weeks to the day. This treatment was working on opening Jordan's detox pathways so his body could rid itself of the Lyme. I liked the idea of treating this way, but the process could take four years. I didn't want Jordan having what the neurologist told us were life-threatening seizures for four years. I was desperate to find something to help him.

We knew what was wrong, but needed something safe to treat him. Nothing was covered by insurance and we were running out of money. I had lost hope. Every treatment seemed to make him worse and I couldn't bear to see my boy suffer the way he had been for the past six months. I didn't know what to do.

I, literally, got on my knees and prayed for help every night. In the same week, a woman who attended the same Son-Rise® start-up emailed me about a newly discovered treatment she was doing. I had signed up for a Lyme conference that mentioned the same treatment, and I had signed up for an autism telesummit that unbeknownst to me had Kerri Rivera as one of the speakers. (Kerri is the woman who discovered this treatment for autistic kids.) I emailed back and forth with Kerri, I posted on the FB group, trying to get all my questions answered. I was terrified to treat Jordan with anything given his seizure history.

Then, he was hospitalized again for uncontrollable seizures and I realized I couldn't let fear get in the way of helping him. I started the day we were home from the hospital at a really low dose that Kerri recommended. She has held my hand through this process to help prevent him from having any seizures.

Since we started in May, he went 10 weeks seizure free and had several mild seizures that he brought himself out of without any extra medication and NO hospital. He is currently at a record-breaking 15 weeks seizure free.

Through this treatment we have learned that in addition to Lyme he has three different visible parasites. He is loaded—he passes more parasites than most of the teenagers in the FB group. It scares me to think what would have happened to him if we weren't led to this treatment. Thank God for Kerri Rivera sharing what she has learned and being so gracious and generous with her time.

I'm incredibly grateful we attended the Son-Rise® Intensive before all of this began. His team of facilitators created a base for him that continued to blossom even through this tumultuous year. Coupled with the parasite treatment, Jordan has gone from 20 to 90 words—he's picking up new words almost daily. His balance is amazing, his muscle tone is getting better, and he understands everything. Even more exciting, he's playing interactively with his sister. He is on the road to recovery.

We are finally able to start picking up the pieces of where we left off back in December. I felt stuck; I had PTSD; I needed help believing we can move past (what I had deemed) the horror of this year. The first thing I did was turn to Son-Rise®; I started having monthly dialogue sessions with Bears (Barry Neil Kaufman)—the co-founder of Son-Rise®, which has been incredible. This is one of those times that happen in life that can make you a better person or break you. Bears is guiding me to be better. I just arrived back from another Son-Rise® training where I realized that staying in fear and being nervous about getting excited or anxious about feeling hopeful again will prevent me from being the *bridge to healing that I want to be for Jordan. I felt a relaxation that I haven't felt all year. I've been wound real tight, waiting, being on the look out for that next seizure.*

This year has had a huge impact on Kaiyan as well. She'd see her brother sick and then her mommies would disappear. I'm noticing she's wound pretty tight as well. Her favorite moments are when the entire family is together. I'm hoping talking with her about what happened and spending more one on one time with her will help. She asks daily is Jordan throwing up, is he having a seizure? She doesn't really know what it all means, but is really aware it's not good. She, recently, said she wanted to have autism. After I explained to her that autism is why Jordan isn't talking or riding a bike, she decided she didn't want autism. She wants to be a boy and insists on wearing Jordan's clothes almost daily. I think it's her way of healing and feeling included in the process.

We've been doing Son-Rise® again and it feels great. I do feel like we have some time to make up for since this year has been spent dealing with health issues rather than cognitive issues so we are working up to having a full time program, having quarterly consultations, and doing another Intensive.

Son-Rise® and Kerri's protocol's are not only bringing our son back, they're bringing me back.

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75. *Healing From Autism*

Hospital birth, bottle fed, fully vax until age 4. Digestive disorders beginning at age 1. Low tone, speech and language delay. Mild early education interventions. GF since age 2, GF, Soy free, sugar free since age 4. Majority of autism symptoms presented in 2013; in the fall of 2012, our son did not qualify as being in need of special education, and thus, could not attend school in our district at all.

Long winter days in a tiny home had me sending him out to play, in our tiny backyard, which had a patch of grass and a bush, under which small animals and birds lived. In his boredom, he sprinkled the dirt all over himself; his head, face, clothes, shoes, on several different days.

Later in the early spring, the symptoms of autism appeared more and more obvious: disobedience, disinterest in sitting for a story or coloring, lost interest in puzzles of more than 24 pcs, jumping on and off furniture for hours, despite scoldings and time-outs. Sudden relapse in bedwetting. Then by summer, the symptoms were very obvious: longer tantrums, rages, anger issues, hitting, fighting, a mean spirit; running out of the house without permission, with no respect for danger or regard for safety. Weepiness, hypersensitivity to touch, suddenly repeating the same phrase, over and over all day. Lost balance and coordination, bumping into walls and furniture, stubbing toes. Shoulder shrugging, all day, but not able to stop or say why he was doing it. Lost dexterity—could not put cards in a box. Lost organizational skills—could no longer put toys or clothes away. Extreme nighttime drooling and bedwetting. The need for sameness, and to have all food served cold. He frequently did not seem to be in his right mind.

In desperation, I asked a group of special needs moms for advice, and ordered a handful of books on Autism, including Healing the Symptoms of Autism by Kerri Rivera.

It was the best money I ever spent.

I read the book thoroughly, ordered the supplies and began the CD Protocol on July 8, 2013. Starting ATEC: 46. We ramped up slowly on drops, serving doses 8 times per day. My son has had two low dose/partial PP's, to minimize the emotional meltdowns, the gas and discomfort. I did not realize how very deficient in minerals he was, and did not give him enough ocean water. Now I order the big 10-liter jug of ocean water, so I am not tempted to be stingy. He needs more than 100 ml ocean water per day for his digestive system to handle the parasite dumping during the PP. His previous digestive trouble was unexplained chronic constipation, since age one, and that is really linked to his high need for the OW. Interestingly, his doctors had all said to keep giving Miralax, and that he might possibly need that laxative every day for the rest of his life. We stopped the laxative when we started the CD program, and began the enemas right away. When I sifted the stool and saw the number of parasites, I understood finally why he couldn't poop well on his own for the last 4 years, despite diet interventions. We are looking forward

to PP #3, in which I hope to ramp up to full dose on all components.

Poop sifting revealed what 6 pediatricians and 2 GI specialists could not tell us. Our son is infected with at least 6 different kinds of parasitic flukes and 3 kinds of parasitic worms. His stool has had a very large amount of sediment, with odd, tiny, but defined shapes. A search for "rodent and avian parasites" reveals photos of very tiny creatures.

I just completed his ATEC at Kerri's request: November 12, 2013: he now scores a 10, with a 1 in language, 2 in social, and 7 in health.

What does his recovery look like? We enrolled our son in a small private school this fall, with one teacher for 6 students, no aide. He now memorizes poems, Bible verses, and songs. He sings, knows his alphabet and all the sounds of the letters, and can count to 47 with precision. He shows kindness to others, is mindful of safety, and has glowing reports from his NT school. He sits with me for stories, and brings books to 'read' to his baby sister. He is not literate quite yet, but enjoys word search games, where he can complete levels and advance to more challenging puzzles. Twice now he has played the word search game on Leap Frog for 45 minutes. He has regained his balance and coordination. The rages, anger, and shoulder shrugging disappeared within the first 10 days on CD. He identifies printed numbers and letters, and does well in math, phonics, penmanship and reading class. He is learning to write numbers and letters in cursive, and follow directions on drawing worksheets. He operates the TV and DVR unaided, recording and watching programs he chooses.

He is happy; he has a patience and joyfulness about life that was previously lacking. He tells me jokes, and now has the coordination to operate a hand puppet while speaking for the puppet!! He is thoughtful and obedient. He has regained fine and gross motor skills, and motor planning skills.

There are still improvements we hope for: further speech, language, and vocabulary improvements. Social graces. More improved digestive health; I can see that he still has parasites in his stool. We will continue the CD Protocol, and we look forward to further healing. Thank you all for your support and encouragement.

The CD Autism Program has done more than cure our son of his brief affliction with Autism; it addresses the pervasive, underlying gut disorder and parasite issues that have plagued him all his life. Where complex testing in expensive medical centers has failed, a simple home health program succeeds. Thank you Kerri Rivera!!

76. *Well...we too did an ATEC! Our son was 11.5 when we started the CD Protocol July 2012 First fully loaded (All PP meds on board) was November 2012*

VERY First ATEC: Jan. 2006= 124

ATEC in July 2012: 64

ATEC August 2012: 52

ATEC Oct. 2012: 48

ATEC Dec. 2012: 45

ATEC May 2013: 40

ATEC August 2013: 39

ATEC NOV. 2013: 33

I actually did one myself as I have done throughout all the previous, but I had hubby do one and combined and divided by the 2! Resulting in the 33! Oddly, it's the "SPEECH" that remains consistently around 14 & 15 throughout ALL of these! All the others continue to go down! We've had some ups and downs, but with continued evacuation of some MIGHTY big worms...we continue to see major gains!

This is the ONLY Protocol that has EVER given us the progress we've seen in one year's time let alone in 6 months! Thank you Kerri Rivera and especially Patrick Rivera for being such pioneers in this journey to recovery! You are SOOO loved and appreciated beyond words! Thank you for never giving up! Thank you for giving so much, and bringing healing to our son! He's come a long way, but we have a ways to go! But with the progress he's making...I honestly feel it will seem like nothing from where we've come!

Again THANK YOU! XOXOXO!

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77. *We had a great day today. For the first time, he joined me in throwing something at a target (blocks at carpet circles). He laughed and smiled and pulled me to play with him better than he has in weeks. I heard a lot more sounds and approximations today. When I couldn't figure out what he was saying, he kept trying until I did.*

My favorite part of the day, and I know this is odd, was when his head collided with my mouth. I exclaimed in pain and he was clearly worried/empathetic. He kept trying to get close to see my lip and giving me kisses. I've seen him concerned before but never that clearly empathetic.

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78. *Just wanted to share that on 21/8/13 my sons ATEC was 46, just redid because we're at the start of our first pp & his score has come down to 31! The big improvement came after introducing CD enemas 3 weeks ago. Although he's been on oral CD for about 2 months, it was always the case that if I missed a dose within 1/2 hour he'd be sensory, inflexible, super-anxious, shouting, aggressive etc & I'd have to syringe it down him but within 10mins of dosing the lightswitch would flick on & he'd be in control & a calm, loving boy again. Since the 3 enemas I gave him 3 weeks ago (only 3 because then his brother had one, panicked, screamed & totally freaked out my 4yr old who up til then had said he liked them bc they made him feel good afterwards) his personality has been shining through again, there's less panick/anxiety, less sensory issues & there's no 'reaction' if I miss a dose or more of CD. I've seen more improvements this week, on Monday he decided to sit down & colour & proceeded to colour neatly,*

inside the lines - he was so pleased with himself! (He used to colour so neatly but about 6 months ago his colouring became scribbly & he frustrated that he couldn't do it neat anymore). Then tonight, when I asked him to hop out of the bath, HE DID! He stood up, stepped out & as I handed him a towel he took it & said 'thank you mummy' and wrapped himself in it & walked out - all completely relaxed - like it was usual!!! WWWOOAHAHH! Yes! He has never done this, it's always tantrums, always arguing, needs to bathe longer, has to be made to get out, refuses to step out, has to be lifted, needs me or hubby to wrap & dress him, & usually all while panicking, crying, demanding, arguing or screaming because it's cold, different, he doesn't want to, it's not right etc. I just can't believe what happened tonight! I'm still astounded. It's like the Finlay we 'know' isn't Finlay & now we're beginning to see who he really is!

So I'm REALLY excited about our 1st pp. We're already seeing full moon behaviours & although tough it's been great to see them because it's a reminder of what Finlay was like every day until 3 weeks ago!

He's already healing. It's soooo exciting! Thank you Kerri - may God bless you & all the children on this protocol. Healing, here we come!

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79. *True Hope by Maggie Kaye*

Most people don't know that babies are born with about 100 million brain cells. That is more cells with more connections than there are stars in the galaxy! This is difficult to picture when you consider an infant's brain only weighs about 12 ounces at birth, about 25% of it's full size. But, there is a logical explanation for this: Brain cells; like the brain itself, have yet to grow. As neurons (brain cells) mature, they become larger, stronger, and form tentacle-like branches that form synapsis (connection and communication) with other brain cells. Brain growth is directed by neural activity. The neural activity of the cerebral cortex (the largest, most complex part of the brain) molds the way a child will think, behave, and acheive.

Conventional wisdom long held the belief that the human brain cannot change… that it is hard-wired at birth. Scientists today have proven that this is not the case. They have found that the brain is malleable. It has the ability to change shape, size, number of branches, number of connections, and even the strength of it's connections over time. The potential growth, or neuroplastisity (neuro means neurons or brain cells, plastic meaning changable) is far-reaching. At birth, the brain is simply a blueprint of what it will become. No one can predict the amount of growth that a brain has yet to acheive.

For the parents of a child with Autism, the diagnosis can be devastating. But, the biggest and most harmful blow can come from the prognosis: There is no cure. Kenn and I were given a diagnosis of an Autism Spectrum Disorder for our son, but we were not given this prognosis. In fact, the word "Autism" was avoided at our son's diagnostic evaluation until the therapists heard us say it first, and realized we were comfortable with the word. For many parents, a diagnosis is the end all, be all. For far too many parents, the words "No cure" are scary and harmful. We did not hear these words nor would we have accepted them as truth if we had. We do not want to change our son. We want him to be his best self. We are not looking for a cure. We are in search of treatment and *healing for his symptoms. We know and understand that a Therapist is not God. A Therapist cannot predict the future for our son. He or she can simply assess where Gunnar is developmentally and give us options for a treatment plan for a healthy, successful future. Our son's diagnosis was not an ending. It was simply the begininning of a journey through a world of strength, challenges, support, opposition, and the love of a parent that cannot ever be fully defined.*

Our son, Gunnar was born with an Autoimmune disorder, Hypothyroidism. He was tested at birth, was diagnosed, and has been treated by an Endocrinologist since he was three days old. We were not upset by the Hypo diagnosis, but rather ready for the course of action to regulate all of Gunnar's bodily systems. What did surprise us was the constant shrugging off of our concerns over our son's developmental delays and gastrointestinal symptoms over the last few years. We were continually disappointed by the compartmentalization of our son's physical and mental challenges by every Pediatrician and Specialist we saw. To us, Gunnar's symptoms all had to be as connected as are all of his body parts. But, we were treated as if our concerns were dumbfounded…as if digestive, behavioral, and physical challenges were not intertwined.

Let's be clear...The brain does not function in isolation. It is a team player. It needs vital nutrients and informational input to perform at optimum levels. To fill these needs, the brain relies heavily on complex interactions between the immune, endocrine, and gastrointestinal systems. Gunnar, like so many other children on the Autism spectrum, suffers from gastrointestinal issues uncluding chronic constipation, diarrhea, and abdominal discomfort. Scientific studies and countless parent reports are pointing to gut inflammation caused by casein, gluten, and soy in our foods. Gunnar has shown clear physical and behavioral reactions to these foods, and improvement in these areas with the removal of Gluten, casein, and soy from his diet. This is not an allergy from the perspective of a traditional allergist. This is what is called a T Cell Inflammatory response.

The use of a gluten, casein, and soy free diet as a means of treatment for Autism symptoms has gotten mixed responses. Many parents and doctors who deal with Autism, Immune, and Endocrine disorders rave about it's benefits, including me and my husband. Still, others call it "junk science". Clearly, if someone is looking purely at one body part at a time, they will not be open to the truth that the body and brain are codependent. I, personally, have been challenged by the choice to follow this diet for my own thyroid disease and for my son's Autism. I was even told on an online support forum that the GFCFSF diet is "fake science" and is causing "false hope" for parents of children on the Autism Spectrum.

False Hope?

This may be one of the biggest oxymorons I've ever heard. This ranks right up there with "God Hates". I cannot say what causes people to be so oppositional to our choice to follow this eating plan. Perhaps the resistance to this way of eating is due to a simple misunderstanding of the leaky gut syndrome that plagues so many children on the Autism Spectrum. This leaky gut syndrome does not cause food allergies. It causes food sensitivities.

In food allergies that many parents are famililar with, the symptoms arise immediately in the form of hives, watery eyes, sneezing, or difficulty breathing. They can even produce life-threatening anaphylactic shock. Only about 10% of *autistic kids have this type of allergy. Some 85% of children with Autism have food sensitivities. Rather than immediate physical symptoms, these sensitivities produce and inflammatory response that results in more subtle mental and behavioral symptoms that can take anywhere from 6-72 hours to appear. The brain's primary fuels are oxygen and glucose which are manufactured from nutrients in our food supply. It only makes sense that we get out of our brains what we put into our bodies.*

When it comes to the treatment of any neurological disorder, many parents and doctors focus solely on the obvious cognitive impairments and fail to realize that correcting their child or patient's underlying intestinal imbalances can; and often does, lead to significant overall improvement. Leaky gut syndrome which is so prevalant in children with Autism Spectrum Disorders causes a long list of vitamin and mineral deficiencies because the inflammation process damages the various carrier proteins normally present in healthy GI systems. Our plan is to treat our son from the inside out; Reduce the inflammation, test for vitamin and mineral deficiencies, provide necessary supplements, test for toxin poisoning and remove if necessary, provide therapy as needed, and set Gunnar up for the best possible outcome. When you feel better, you perform better. Who can argue with this rationale?

Many people have differing opinions on what does and doesn't work for families facing Autism. There is a saying in the Autism community, "If you have met one child with Autism, you have met one child with Autism" There is a broad spectrum with severe to mild physical and behavioral symptoms. One person's treatment protocol might not work for another person. I am not judging what others choose to do to treat their child, I am simply sharing what has worked for us thus far. I am not searching for or promising a cure, I am finding a treatment for and healing the symptoms that affect our son. Whether or not you agree with how my family and I choose to approach this journey does not change the outcome. If we have helped one person understand this complex neurological disorder, we have helped spread understanding, and that makes us happy. And, if you are a family facing Autism and don't know which avenue of treatment to pursue first, our advice is: Go with your gut.

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80. Recovery #107

Having a sick child is a full time job. Even when they are well, your mind is filled with ways to keep them from getting sick again, ways to improve their current state, ways to help others who were where you were just a short time ago. It is my hope to do all three.

Autism entered my life a few years ago, but I didn't recognize it. My son, Gunnar was three when my husband and I realized he wasn't progressing as he should. He wasn't asking why, what, where, or when questions. He wasn't growing. He was lining up his trains and cars, screaming if we touched one of them. Gunnar was oppositional and refused to go into a crowded place. He didn't look anyone in the eye, and it seemed to make him uncomfortable to try. He had several sensory issues such as covering his ears when music played, even when the volume was low. He had an aversion to touch and would often yell, "ouch!" when someone touched his arm softly. He was constipated. He smeared his feces on the wall. He often woke in the middle of the night screaming. My husband or I *would find him in the fetal position and he couldn't or didn't respond when we asked what hurt. Gunnar went ballistic when we tried to wash or cut his hair or brush his teeth. He was indifferent to me leaving for work, and what was most painful for me, he ran and hid when I returned. He didn't much care for his own mom and that was heart breaking for me.*

We also noticed some regression. Gunnar stopped showing interest in potty training. He went from saying, "Gotta go pee pee!" to not even recognizing he'd soiled his pants. He started refusing foods he previously enjoyed. He went from using several words in succession to not speaking more than two words strung together. He started to be extremely picky when it came to the foods he would eat and spent most of his time at the dinner table staring out of the window. We were losing our son.

Our son was born with an autoimmune condition, Hypothyroidism. He started taking medication just three days after he was born. Initially my husband and I interpreted some of our son's Autism symptoms as side effects from his medication dosage fluctuations. After all, we voiced our concerns to his Pediatric Endocrinologist, and she assured us he was fine. She said the medication was likely making him lethargic. She said boys took longer to potty train. As time went on, Gunnar's symptoms multiplied and worsened, and other caregivers took notice and shared their concerns. At our son's next Endocrinologist appointment, I insisted on a referral for a developmental evaluation.

Our son was diagnosed with an Autism Spectrum Disorder in January of 2013. He was 4 years old. I immediately went into research mode reading everything I could get my hands on that was related to healing Autism. Two weeks after his diagnosis, we started a gluten, dairy, soy free diet and saw digestive issues disappearing. The night-waking was going away. He turned toward us when we called his name. He spoke in short sentences, requesting to watch a movie or eat a snack.

A month after Gunnar's diagnosis we had further testing done to see where he was on the spectrum. When we showed up for the appointment, the diagnostic team was impressed with our son's progress. He responded when they asked him to point to specific items, and he had no trouble matching items together. I remember thinking he was much smarter than I'd realized. Clearly the problem with our son was physical.

The test results showed Gunnar's speech and language to be at a 23 month old's level with his gross and fine motor skills not much further along. We were determined to heal our son and scheduled an appointment to have all kinds of testing done including food allergies, comprehensive stool analysis, and genetic mutation tests. These results showed that our son was sick with food allergies, leaky gut caused by an overgrowth of bacteria, and pathogens. We knew what we were up against. We were on the right track with diet, but had to find out how to get rid of the bacteria and pathogens. In my research, I stumbled upon the CD forum. It was the first treatment program that made complete sense to me.

We received the book in June. It was the first book our son ever showed interest in. He kept saying, "This is it!" and, "This book is the best!" He didn't want to put the book down. My husband and I looked at each other with tear-filled eyes. We knew Gunnar was right; this was it.

We started the CD Protocol immediately...just five months after our son's diagnosis. His starting ATEC was an 80. Immediately we saw regular bowel movements, diminished dark circles under his eyes, and healthy skin coloring. Gunnar began to sleep through the night. Four days into the protocol, our son started taking turns and sharing with other kids. That night, he danced at a graduation party. Every day, his vocabulary improved.

Four weeks into the protocol, our son no longer needed his thyroid medication he'd been on his entire life. He started using the bathroom unprompted. He dressed himself unprompted. He brushed his teeth on his own. Gunnar didn't mind getting his hair cut. He began to engage in reciprocal conversation.

Seven weeks into the protocol, we saw so many behavioral improvements; we decided to take the ATEC test again. Gunnar's score was a 40. It was cut in half in seven weeks!!! Eight weeks into the protocol our son celebrated his 5th birthday. It was the first time he showed anticipation for a party. He was excited to open his gifts and thanked everyone individually. Normally, Gunnar would run and play by himself when guests came over. He had always covered his ears and yelled, "Stop singing!" at previous parties. Gunnar was happy when everyone sang Happy Birthday to him. He was healthy and present. It was one of the happiest days of our lives.

Twelve weeks into the protocol, our son started mainstream preschool. All previous attempts to take him to school resulted in anxiety and complete meltdowns. He started speaking in complete sentences and his speech was relevant to the situation. He started showing interest in books. Fifteen weeks in, our son read his own bedtime story with no help. He picked out his own Halloween costume. He brought home his artwork and proudly showed it to us. His teachers continually voiced their pleasure at his progress. His speech therapist said he was at age level for speech and language. (that's 3 years worth of progress!)

Twenty-four weeks into the protocol, our son's ATEC score is a 10. He continues to go to mainstream preschool and is interested in learning. He is reading a variety of books. He is counting in English and Spanish. He knows his US geography, and does puzzles that are advanced for his age. He asks questions. His speech is appropriate and relevant with continued improvement in vocabulary and articulation. He loves to sing, dance, and paint. Our son is smart, funny, and very affectionate. He spontaneously hugs and kisses me and tells me he loves me. And the best part of all? When I come home from work, Gunnar yells, "Moooommmmyyyy!", runs up to me, jumps into my arms, and wraps his little arms around my neck. I have my son back.

I could never sufficiently thank Kerri Rivera for all of her selfless help. She and her team of parents give freely of their time and energy to bring kids and their families out of the depths of Autism. It is my hope to pay it forward. All children deserve a healthy childhood. If you are holding this book, you are likely in the position my family was in just 10 months ago. This is the way to turn your feelings of desperation into determination. This is the way to change the future for your family. This is the way out of Autism.

—Maggie Kaye

81. *Ok, my brother is 17 and started CD at the end of october. We are on 9 drops as of today. Non verbal. My mom called me crying and my brother said "I want snack please." My mom asked if he wanted something and he "no, no, no." He got his yogurt (df) out and said "thank you." This is just so amazing. Thank you God for putting us on this path and around so many amazing warrior parents to help us with our journey. Happy healing to all!!!*

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82. *At the age of 3 our son was absent. He talked a lot... to himself. Scripting. It was almost impossible to get him to look into our eyes when we spoke to him. He almost never answered back, and when he did, it was scripting again (from a show on TV or a movie he was into.) He played by himself. He refused to potty train. He would wake up in the middle of the night crying and holding his stomach but was unable to tell us what was wrong. He stopped eating whatever we put in front of him and seemed to only want fruit snacks, American cheese, hot dogs, chicken nuggets and fries. And thats it. He didn't seem to be growing anymore, both physically and mentally. He seemed to be slipping away from us. You could see it in his eyes. Those eyes that were pointed off in a different direction. It was gradual...hard to notice right away. But definitely a change, and not one we were happy with.*

Up until this time he was progressing like any other child. He ate well. He slept well. He played well. Was even starting to potty train. A typical child. But not anymore. Then there was the diagnosis. Autism. No parent wants to hear that, but we knew. Every parent knows what I mean. You just know. And at this point we (as parents) have to make a choice.

We can choose to do nothing. Just live with it. We can listen to our doctor, or a specialist in the field. You know, someone who claims to know everything about you and your child in the 5 minutes they spend with you. Or you can talk to other parents. Parents that spend every moment with their children. Not just a few minutes every six months. You can network. You can research. Ask whats working for them, or more importantly what's not.

We chose the latter, and because of this our son is recovering. He looks into our eyes. He asks questions. He sleeps at night. He's potty trained. He sets the dinner table with his older sister and asks to be excused when he's done eating. He's in pre-school now and plays with all of the other kids. He calls them by name. He draws. He paints. He reads books. He does all of the things a typical five year old does.

Our son is recovering, and I need to give two heartfelt thanks for this. The first to my wife for the countless hours of reading and research she did immediately following our sons Autism diagnosis. She is an incredible woman who refuses to give up on anything. Ever. She refused to believe that we had to accept what was handed to us. She knew in her heart and mind that we could make a difference. We just had to do it. Because of this determination, she found Kerri Rivera, whom is the next person I want to thank. She is a true pioneer, someone who refused to keep thinking inside the box, someone who is helping families like ours all over the world.

" We have the world at our fingertips. Every book, every encyclopedia for us to read at our local library, in our own homes, and now on (most) of our cell

phones. It's a beautiful tool for us to use. Use it. Do your own research. Talk with parents. Find out what works and do it.

The only thing I really have to say about Kerri's book and the protocol it explains is that it works. We have our son back.

—Kenn Kaye, Father of Gunnar Kaye

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83. Last night, my 19 year old son came out into the kitchen, picked up a purple straw from the dish drainer, and pretended to play it like a clarinet with great enthusiasm. Pretend play. For the first time in 19 years.

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84. We've been playing the "healing game" with my son for some time, (7 years 11 months old) but we've never really healed anything. To be honest we've never known what we were up against...until now. Like everyone here, my child is very sick. He doesn't grow, he has maldigestion and malabsorption issues and he's chronically constipated. His history of constipation is long and extensive. ANYTHING that disrupted his gut flora would result in this extreme constipation; whether it was a cold, a new food, treating the GI. To say he has leaky gut is a tremendous understatement. So, when we started Kerri's protocol 6/15 my biggest health markers for initial healing were growth and for him to poop daily on his own. With his history being what it is I wasn't surprised to see he was instantly constipated. How could he not be? We are killing pathogens and parasites like gang busters. We started enemas on day two and have done them daily. But, an amazing thing is happening! He is healing. He has grown two inches in these last three months and he starting to poop on his own. BTW, these aren't just lame little poops they are total TROPHY poops. They are soft, formed, have no undigested food and there is lots (I'd show you a picture but we barely know each other)

Yep... It's taken 3.5 months to get here, but his little; fragile and damaged body is doing what it is supposed to do.

Trust the process... It's not easy; it's not always fast. There will be ups and downs. But, my gosh, watching the body heal is an extraordinary thing. It's nothing short of a miracle.

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85. Hi Kerri,

I started my son on the CD last night. I'm taking it with him.

Well, I for one, feel fabulous. My lungs are clearing up, the low-level depression I felt is evaporating. Wow!!!

I've noticed some subtle changes in my son. He is more "with us" in the world and not looking out the window at cars quite as much. Also, a little less flapping his hands.

He and I have been doing a ketogenic version of the GAPS diet (no sweet vegetables, no dairy, no sweeteners) since January of 2013, and I think that's why we've been so successful with the CD! :)

I was thinking of upping it to two drops per 8 oz bottle--one for him, one 8 oz bottle for me.

I am hoping that Sulfur is Ok to still give him. We used to cut it with Kombucha, but that is now a no-no.

Thanks and Huzzah!

86. *Ryan is the first of our 3 children to recover. Ryan was not considered autistic by most standards but did score a 19 on the ATEC test prior to starting the CD protocol. He is 9 years old and has been in mainstream classes without an IEP. We did hold him and his twin brother back one year prior to starting kindergarten so they could have more time to heal from Lyme Disease which we had been treating since they were 4.*

Ryan was a healthy baby but I did notice after saying his first words at the appropriate age, he stopped talking a few months later. (I now know that is a symptom of autism!) And both he and his brother were very late with language despite knowing their alphabet at a very young age. Ryan did eventually talk but was often hyperactive and had a hard time sitting still in class or at the dinner table. It was often hard to get his attention and to get him to listen to requests. He was constipated since he was a baby and was a very picky eater. I dreaded mealtimes because it was so hard to get him to eat. We often had to spoon-feed food into his mouth even when he was 7 years old. Treatment for Lyme Disease helped many of his symptoms but he still had some remaining symptoms such as weakness, stomachaches, seeing orange and blue spots at night (more noticeable in the dark), nightmares, bedwetting, difficulty falling asleep and early awakening, and overly emotional and irrational behavior. These symptoms worsened dramatically when our house well water became contaminated with parasites and bacteria. It took us two years to figure out that the water was the cause of our deteriorating health. During this time, Ryan became unable to play sports or have play dates without melting into irrational tantrums when things didn't go his way. When playing mini golf, he refused to finish the round after getting a score of "10" on one hole and had a crying tantrum. In tennis class, he would sit down on the court and start crying if he didn't get to hit as many balls as the other children on the court with him. We didn't even attempt to put him in team sports for fear that he would melt down and storm off, refusing to play the rest of the game.

Then we discovered CD and Kerri's protocol, and his and our lives changed forever. Within three weeks of taking CD, Ryan's ATEC dropped to an 8. This improvement was the difference in Ryan being able to play sports. He was able to play on a baseball team and while he did get angry if he struck out or made an error, I was there with a dose of CD and that would keep him from a complete meltdown. As the season continued, Ryan's emotions became more and more stable and normal. His energy increased greatly and now after 6 months on the protocol, Ryan is playing three different sports, taking piano lessons and excelling in above grade level reading and math. His ATEC is a 3 but we will continue until it is 0. His first report card since starting the protocol was the best of his life. We were most excited to see that his scores for behavior and attention were above expectations. Last year, these same scores were all below expectations because Ryan was so hyperactive and unable to focus due to the parasites. Ryan still sees a few orange spots at night but they are diminishing and we know they will be gone so long as we stick with this protocol until he is completely healed. We are so grateful that Kerri blazed the way for us all by developing this protocol. I have been searching for the past 7 years for a way to fully heal my children and the CD was the last but most significant piece of the puzzle for us. We will be forever thankful to you Kerri!

87. *I first heard about CD, then called MMS, to treat autism in May 2012 and wanted to try it out with my then 10-year-old son. I bought supplies, and did the then-current protocol for a few months, but then school ended and summer vacations started and I put CD on the back burner or did it very sporadically. My son was verbal and high functioning, but still had lots of autistic behaviors. His ATEC score in 2012 was 27.*

I started reading about CD again in the summer of 2013. This time there was more information out there. Kerri had written her breakthrough book and lots of facebook friends in the autism community were mentioning it. I bought the book and dove in, first using my old supplies (CD with citric acid) then buying HCl and trying that. My son did very well with the new protocol, starting low and getting to full dose around the time of his 12th birthday at the end of August. I started seeing worms before we even started our first Parasite Protocol! When I started the Parasite Protocol and added in ocean water, things kept getting better! No set-backs or regressions. School was seemingly much easier for my son. He was in a mainstream class with resource room help for reading and writing for the second year, but this year, math homework was no longer taking several hours, but 20 minutes! His reading comprehension was improving as well, and more importantly, I didn't worry about hearing about behavioral issues anymore!

I wanted to complete three months of CD before I took another ATEC. When I filled in out in November, at the start of our third Parasite Protocol, I was shocked to see a score of 7! My son had dropped 20 points from his 2012 score! Seeing the single digit score was so amazing! My son had been diagnosed with autism at age 2 ½ and there were no options given to me at the time. An early IQ test given by a speech therapist had shown he was mentally retarded and that was that. However, I looked into everything I could, and was not going to give up on my son. So glad I didn't! Nine years of autism, but the beginning of his 12th year marks the end of it! I know his ATEC score will be 0 soon!

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88. *"thank you for your help in recovering me"*

This is what my son just typed to me this morning on his iPad with the app we use for supportive typing!

Thank you Kerri & Patrick for all you have done and continue to do!

Without you BOTH, we would NEVER be in the place we are right now... HEALING & RECOVERY!

Just know you are LOVED!

—Melissa in Indiana

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89. *Sophia was born on March 9, 2006. She was a typical happy baby who slept well and seldom got sick. She met all of her developmental milestones and laughed and made great eye contact. When she turned one just after her vaccines she became violently ill and vomited with fever for 2 days straight. After that she was never the same, her smile was rare and words were gone. When she was nineteen months after more shots, we took her to an ear doctor out of concern that she was not responding to her name or speaking clear words. Her hearing was tested and we were told she was fine and to give her time. After a few months of no change her pediatrician determined that she was developmentally-*

delayed and had all the symptoms of Autism. We were stunned and unprepared for this news. I went into warrior mode and ended up with a DAN dr, who started her on lots of supplements after initial lab results showed heavy metal toxicity and high amounts of intestinal yeast. We followed the program and advice of this doctor for the last 4 years with the only change being dietary fluctuations. Sophia did improve but hit a plateau where no new gains were made in the last year or so, so in May 2013 her DAN doctor suggested that we do another round of stool testing after a urine acid test showed bad bacteria overgrowth and terrible mito issues. Her comment to me was "this kid's DNA is so messed up, I haven't seen a test this bad since the 1990's." This was after thousands of dollars and too many supplements to count.I was done at that point. There were no answers there obviously. I came across this protocol on a Facebook page for autism parents and purchased Kerri's book in September 2013. I immediately knew that this was the answer for my daughter. I had a gut instinct that she would be healed . We started the diet immediately and CD just after. My daughter had been a juice addict before this and I was worried about her taking the CD and being able to drink the water. This was only an issue for a day or so. I have not missed a day of giving her 8 or more doses. We get up very early and dose her ocean water and 2 CD doses before school. On weekends we are doing 16 doses/day. In the second week we started seeing some herxheimer/die off, very sleepy followed by fevers. This is when the transformation started! I followed the fever protocol and did enemas and she got better. She also had an episode around week 7 of very red throat and fever which we double dosed for and resolved. We have seen a withdrawn, self -focused child with little interest in the world outside of herself disappear and turn into a child interested in friendship with peers, reading books and understanding the story (huge!), and having relevant conversation with great eye contact. She gets all A's at school and has made a complete turnaround with behavior. We have so much hope for her future and she is blossoming into a beautiful, happy girl!

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90. *Here are a few of the emails I mentioned from my son's therapist in regard to what's happening at therapy! :)*

This is an email from the exact day I restarted the CD, which was August 21 of 2013.

We discovered a new game today. He was being a turkey and running up the hall to try to get around me to get places he wasn't supposed to go. I started singing (to the tune of rolling down the river) about whatever he was doing "walking, walking, walking down the hallway" "jumping, jumping jumping down the hallway" climbing, climbing, climbing up the ladder. He thought it was hilarious, especially when I'd change in the middle of a verse "running running, jumping down the hallway.

—Your son's therapist

Great day today! Vail seems to be understanding first, then sequencing and I think I finally have a bribe for him--he loves our fish.

Also, he made a friend today. One of our other pt's was playing in the gym and he was watching him, imitating him a little and said his name 2x!

—Your son's therapist

We tried to play the game and he wasn't interested. Instead we ended up *pushing the fisher price horse, sheep, goat, and cow off the treehouse. He would "randomly" produce sounds which we took for requests for the animal associated. Then we would give him the animal "requested." Reviewed his sound cards and he produced the /n/ and /h/. Coulda sworn he said go a couple of times, and mom said she heard a whispered "home." Listen and be watchful for whispers! Oftentimes children with apraxia can get one system working but not the other, ie. articulate with no sound, or vocalize with intonation and no articulation, like when he says "ah uh oo" for "I love you." Yep, he does that!*

Cheers!

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91. *Hi had to share this moment today, just wish daddy wouldn't have missed it!*

Well, we were seeing daddy off for work this evening, when Vail decided that he wanted to go run around in the grass. I told him we needed to put on socks and shoes and then we could play outside. He walked straight to the door, we walked in, I pointed at his socks and shoes, and FOR THE FIRST TIME EVER (always knew he could, just to stubborn to do it unless he really wants too!) he promptly walked over, picked up his socks and shoes and turned and handed them to me!!! (all the while doing it with an attitude!!!"lol)

This is Just from MOM to therapists. :)

CD and Kerri have been life changing for our entire family. We now can give Vail choices, usually of two items. For example I showed him two pairs of pants and asked which he wanted to wear, and he grabbed one pair and started to put them on even though he was still in his pj's. I showed him two shirts, and he picked a shirt. Same thing with his shoes and socks, he is able to choose now on his own. I look forward everyday to him doing something differently or completely new, and he almost always does now!!! This was not possible for CD!!! THANK YOU KERRI !!! WE LOVE YOU FOR SHARING AND FIGHTING THE FIGHT!!!

LOVE,

—The parents of Vail

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92. *Best day of the entire school year! My son initiated verbal interactions 5 times today and responded to his teacher in a group over 5 times, WITHOUT A SINGLE PROMPT! Most days his TA is poking him to pay attention and ask other kids for directions, rather than an adult, all day long! She is tracking these interactions as they are his IEP goals.*

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93. *Casey is a young man who is 17 years old today, and the estimated ATEC score from 2006 is from when he was 10 years old. Proving once again that recovery is possible at any age.*

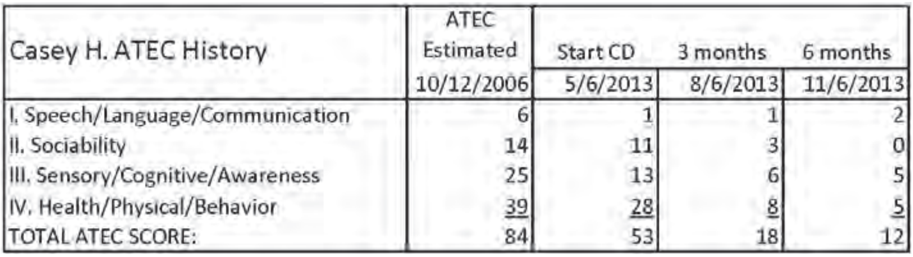

Casey H. ATEC History	ATEC Estimated	Start CD	3 months	6 months
	10/12/2006	5/6/2013	8/6/2013	11/6/2013
I. Speech/Language/Communication	6	1	1	2
II. Sociability	14	11	3	0
III. Sensory/Cognitive/Awareness	25	13	6	5
IV. Health/Physical/Behavior	39	28	8	5
TOTAL ATEC SCORE:	84	53	18	12

94. *Daniel - beginning ATEC June 2013 - 101. Today ATEC Nov 12, 2013 - 44! We are thru our 3rd PP and starting speech supplements. Speech, by far, has been the hardest thing. In all other areas he is under "10" on the ATEC! Kerri Rivera words are coming. This week alone he is saying "Hi" and "Bye" and trying to say others. I can't wait to hear "I love you Mom"! You are the Bomb Diggitty Kerri. We all love you!*

UPDATE: December 3rd, 2013

I officially want to tell the world that my son, Daniel, who has autism is nonverbal no more! He is starting to talk. Praise God! This battle has been the struggle of my life, but i have learned to trust God, be patient, and enjoy the journey! Where some take a lot for granted regarding their children, I have been waiting almost 7 yrs to hear his beautiful voice! And thank God he has one! Autism is treatable and there is hope!

---

95. *We had a super exciting trip, we went to a therapist on the 28th who teaches Rapid Prompting Method. We have tried since by daughter was diagnosed to get her to speak, but haven't had any luck yet, she is now 11. We thought we would give RPM a try to see if the therapist could get her to communicate.*

We not only found out that she is able to make correct choices, but can actually SPELL! Her very first word that she spelled was CLOUD!

Later on in the session the therapist asked her what her favorite color was... she spelled out PINK!

I was sitting on the floor in awe... For the first time in 11 years, I finally know what my girl's favorite color is... it was surreal... it was amazing... she is so smart, but had no way of letting us know... I am soooooooo proud of her!

---

96. *Diagnosed at 20 months old in August 2011*

Started supplements under Dan in September 2011

Started CD / PP on July 1, 2013, after seeing rope in stool

Starting ATEC on July 1, 2013, was 46

Present ATEC 22

Gained 5 pounds from July 1st to present!

Too many improvements to list!!!!!

Also doing GcMAF which has also helped……but, I believe GcMAF may have helped more with the viral load. I suspect this because we actually started IV GcMAF in January 2013, before CD . Huge gains with GcMAF but after 35 shots, her gut was still a mess and GcMAF definitely didn't help with the gut. Found Kerri in July 2013, and began our healing journey.

The following lab results are proof of just how well the child described above is doing since starting the protocol. Here is what her mom had to say:

> *"The original test was taken last August of 2012, which showed a deficiency in almost everything despite the fact that my daughter had been on supplements for over a year at that point. The re-test was just taken October 2013, only 4 months after CD / PP and removal of ALL supplements. Wow!"*
>
> *You can see in the second test that her high viral titers were reduced as well.*

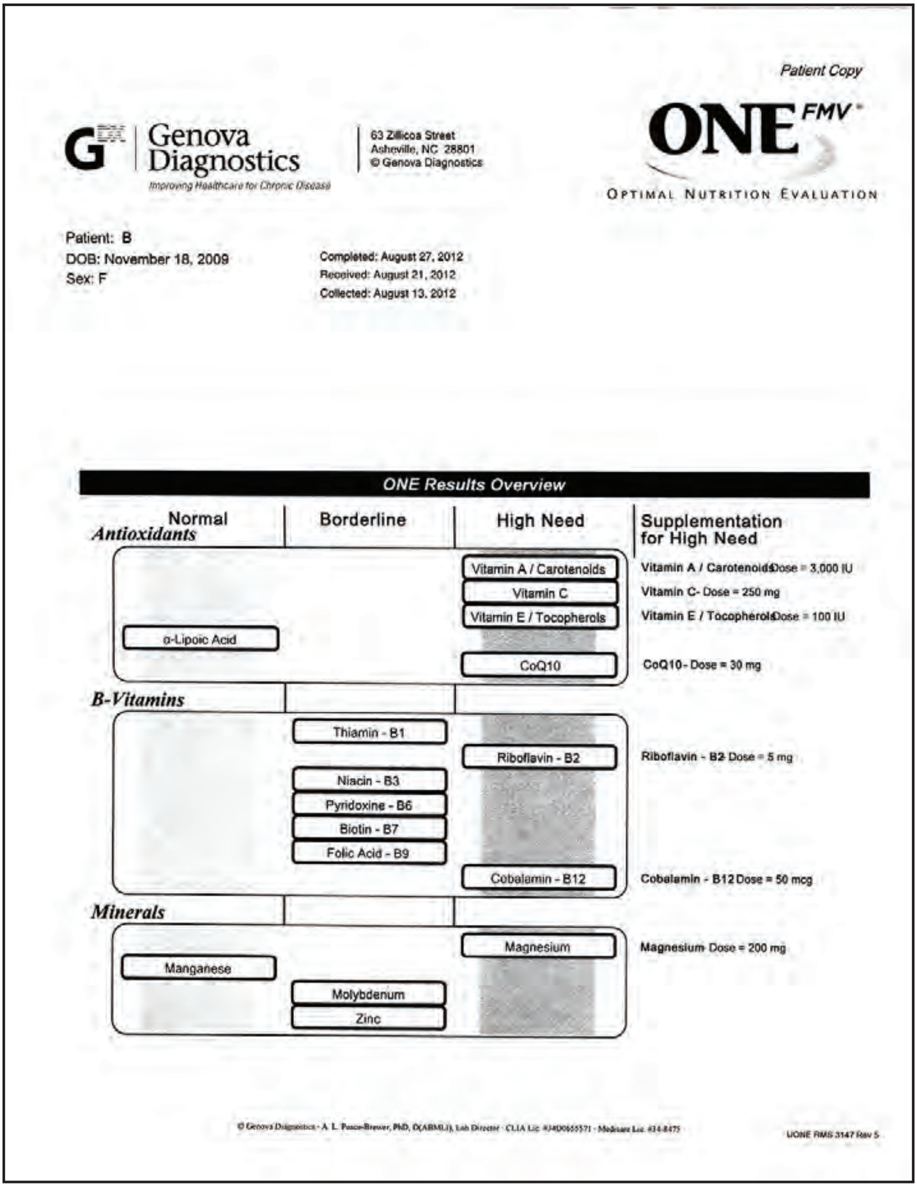

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Improving Healthcare for Chronic Disease

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ONE *FMV*®

OPTIMAL NUTRITION EVALUATION

Patient: B
DOB: November 18, 2009
Sex: F

Completed: August 27, 2012
Received: August 21, 2012
Collected: August 13, 2012

ONE Results Overview

	Normal	Borderline	High Need	Supplementation for High Need
Antioxidants				
			Vitamin A / Carotenoids	Vitamin A / CarotenoidsDose = 3,000 IU
			Vitamin C	Vitamin C- Dose = 250 mg
			Vitamin E / Tocopherols	Vitamin E / TocopherolsDose = 100 IU
	α-Lipoic Acid			
			CoQ10	CoQ10- Dose = 30 mg
B-Vitamins				
		Thiamin - B1		
			Riboflavin - B2	Riboflavin - B2 Dose = 5 mg
		Niacin - B3		
		Pyridoxine - B6		
		Biotin - B7		
		Folic Acid - B9		
			Cobalamin - B12	Cobalamin - B12 Dose = 50 mcg
Minerals				
			Magnesium	Magnesium Dose = 200 mg
	Manganese			
		Molybdenum		
		Zinc		

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UONE RMS 3147 Rev 5

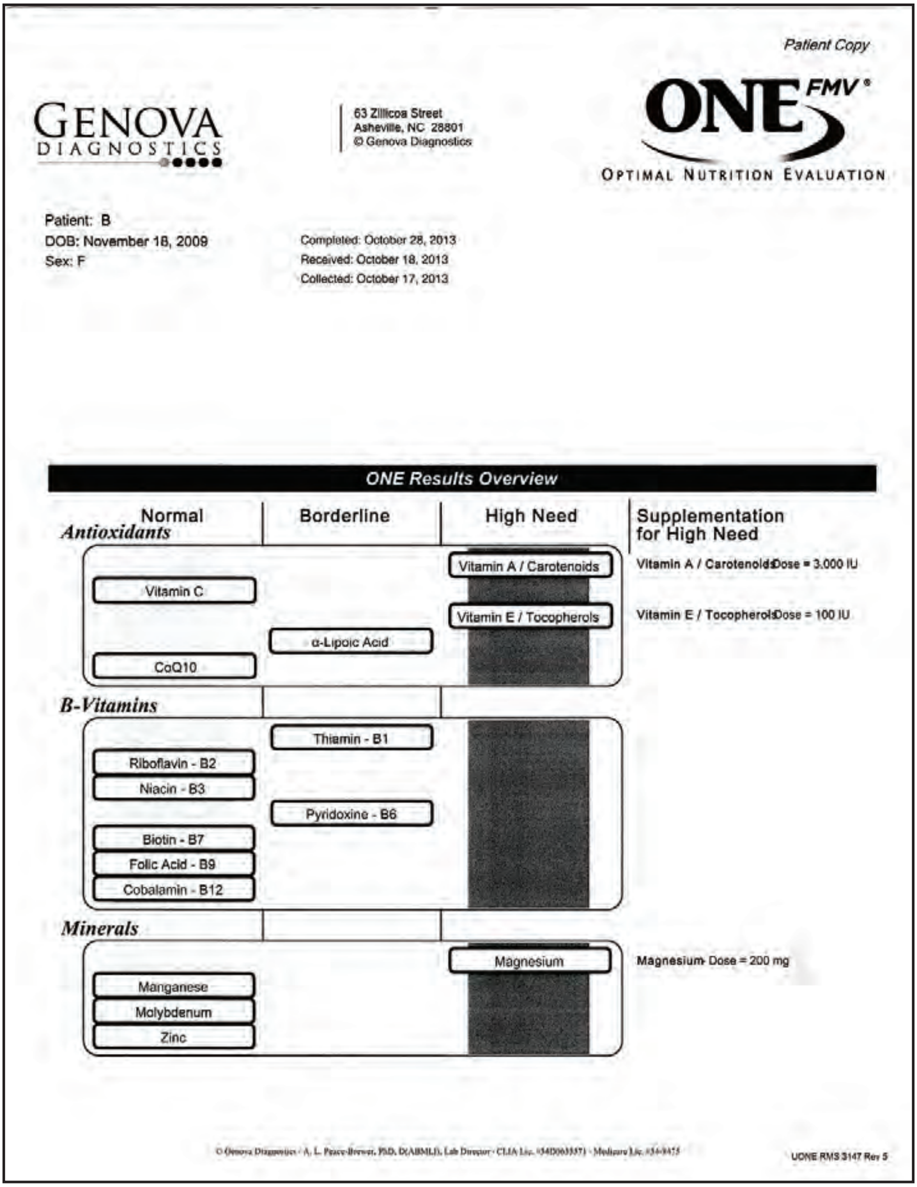

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GENOVA DIAGNOSTICS

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ONE FMV®
OPTIMAL NUTRITION EVALUATION

Patient: B
DOB: November 18, 2009
Sex: F

Completed: October 28, 2013
Received: October 18, 2013
Collected: October 17, 2013

ONE Results Overview

	Normal	Borderline	High Need	Supplementation for High Need
Antioxidants			Vitamin A / Carotenoids	Vitamin A / Carotenoids Dose = 3,000 IU
	Vitamin C			
			Vitamin E / Tocopherols	Vitamin E / Tocopherols Dose = 100 IU
		α-Lipoic Acid		
	CoQ10			
B-Vitamins		Thiamin - B1		
	Riboflavin - B2			
	Niacin - B3			
		Pyridoxine - B6		
	Biotin - B7			
	Folic Acid - B9			
	Cobalamin - B12			
Minerals			Magnesium	Magnesium Dose = 200 mg
	Manganese			
	Molybdenum			
	Zinc			

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UONE RMS 3147 Rev 5

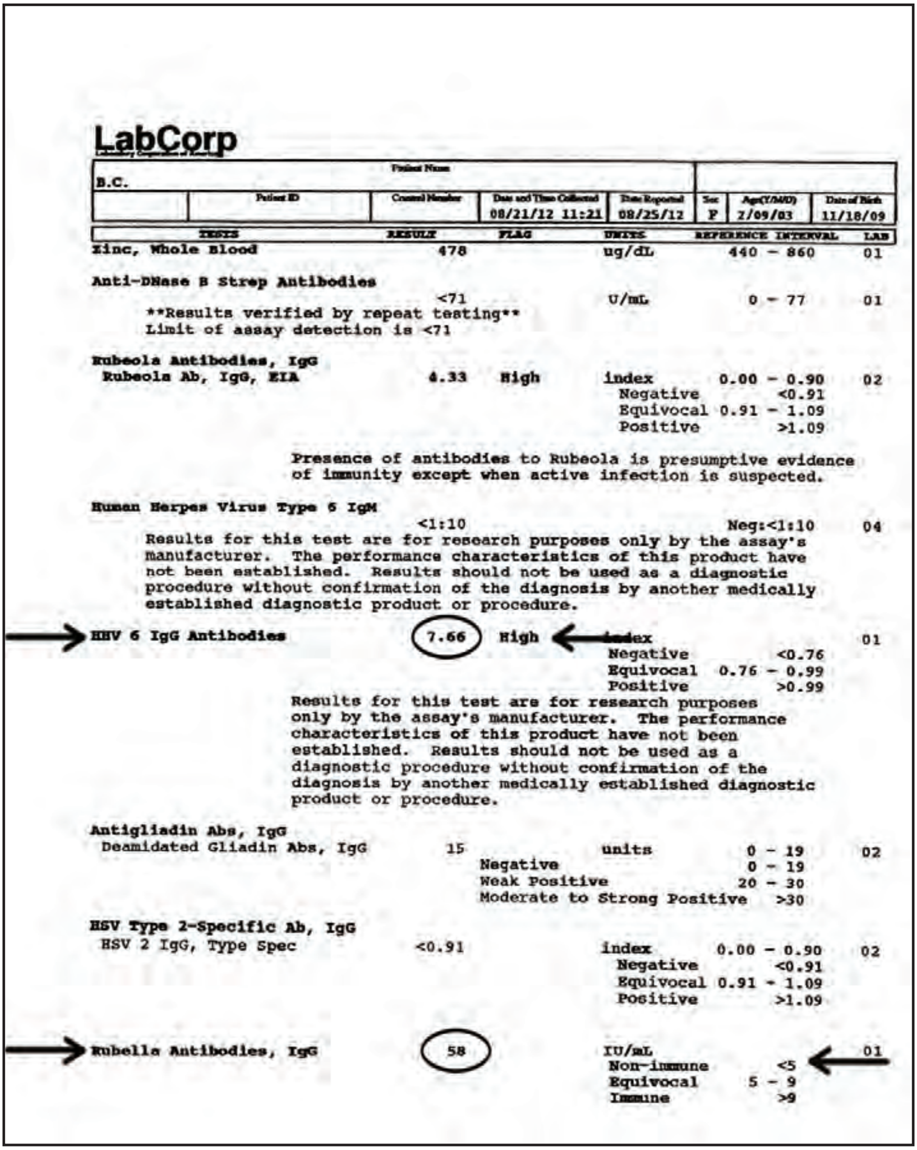

LabCorp
Laboratory Corporation of America

Patient Name							
B.C.							
	Patient ID	Control Number	Date and Time Collected	Date Reported	Sex	Age(Y/M/D)	Date of Birth
			08/21/12 11:21	08/25/12	F	2/09/03	11/18/09

```
TESTS                         RESULT    FLAG       UNITS      REFERENCE INTERVAL   LAB
Zinc, Whole Blood               478                ug/dL         440 - 860          01

Anti-DNase B Strep Antibodies
                                <71                U/mL            0 - 77           01
     **Results verified by repeat testing**
     Limit of assay detection is <71

Rubeola Antibodies, IgG
 Rubeola Ab, IgG, EIA          4.33     High       index        0.00 - 0.90         02
                                                     Negative          <0.91
                                                     Equivocal  0.91 - 1.09
                                                     Positive          >1.09

                    Presence of antibodies to Rubeola is presumptive evidence
                    of immunity except when active infection is suspected.

Human Herpes Virus Type 6 IgM
                              <1:10                             Neg:<1:10           04
     Results for this test are for research purposes only by the assay's
     manufacturer.  The performance characteristics of this product have
     not been established.  Results should not be used as a diagnostic
     procedure without confirmation of the diagnosis by another medically
     established diagnostic product or procedure.

HHV 6 IgG Antibodies           7.66     High       index                            01
                                                    Negative           <0.76
                                                    Equivocal   0.76 - 0.99
                                                    Positive           >0.99
                    Results for this test are for research purposes
                    only by the assay's manufacturer.  The performance
                    characteristics of this product have not been
                    established.  Results should not be used as a
                    diagnostic procedure without confirmation of the
                    diagnosis by another medically established diagnostic
                    product or procedure.

Antigliadin Abs, IgG
 Deamidated Gliadin Abs, IgG     15                units           0 - 19           02
                                         Negative                  0 - 19
                                         Weak Positive            20 - 30
                                         Moderate to Strong Positive   >30

HSV Type 2-Specific Ab, IgG
 HSV 2 IgG, Type Spec         <0.91                index        0.00 - 0.90         02
                                                     Negative          <0.91
                                                     Equivocal  0.91 - 1.09
                                                     Positive          >1.09

Rubella Antibodies, IgG         58                 IU/mL                            01
                                                    Non-immune         <5
                                                    Equivocal       5 - 9
                                                    Immune             >9
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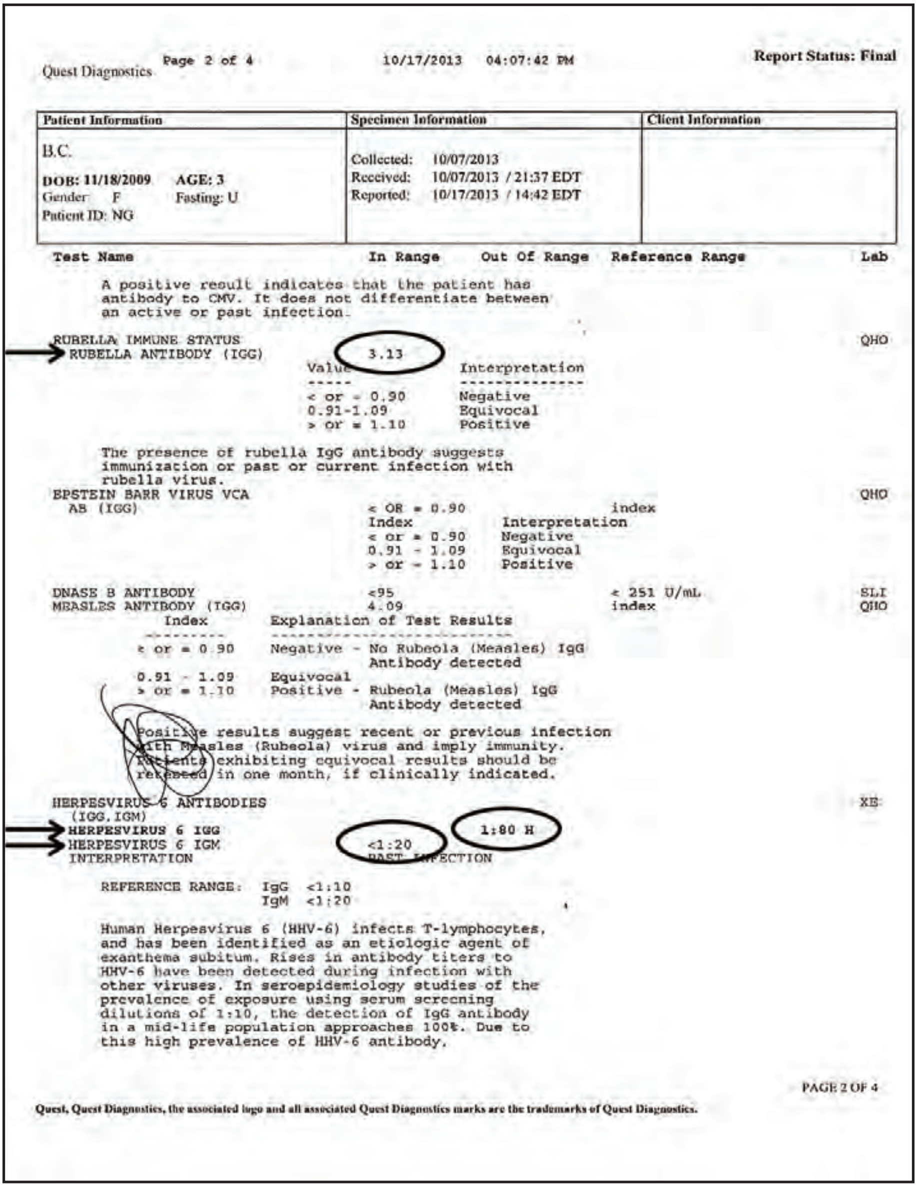

Quest Diagnostics Page 2 of 4 10/17/2013 04:07:42 PM **Report Status: Final**

Patient Information	**Specimen Information**	**Client Information**
B.C. **DOB: 11/18/2009** **AGE: 3** Gender: F Fasting: U Patient ID: NG	Collected: 10/07/2013 Received: 10/07/2013 / 21:37 EDT Reported: 10/17/2013 / 14:42 EDT	

```
Test Name                        In Range     Out Of Range   Reference Range          Lab

     A positive result indicates that the patient has
     antibody to CMV. It does not differentiate between
     an active or past infection.

RUBELLA IMMUNE STATUS                                                                  QHO
  RUBELLA ANTIBODY (IGG)               3.13
                             Value           Interpretation
                             -----           --------------
                             < or = 0.90     Negative
                             0.91-1.09       Equivocal
                             > or = 1.10     Positive

     The presence of rubella IgG antibody suggests
     immunization or past or current infection with
     rubella virus.
EPSTEIN BARR VIRUS VCA                                                                 QHO
  AB (IGG)                            < OR = 0.90              index
                                      Index         Interpretation
                                      < or = 0.90   Negative
                                      0.91 - 1.09   Equivocal
                                      > or = 1.10   Positive

DNASE B ANTIBODY                      <95                      < 251 U/mL              SLI
MEASLES ANTIBODY (IGG)                4.09                     index                   QHO
             Index         Explanation of Test Results
          ---------        ----------------------------
          < or = 0.90      Negative - No Rubeola (Measles) IgG
                                      Antibody detected

          0.91 - 1.09      Equivocal
          > or = 1.10      Positive - Rubeola (Measles) IgG
                                      Antibody detected

          Positive results suggest recent or previous infection
          with Measles (Rubeola) virus and imply immunity.
          Patients exhibiting equivocal results should be
          retested in one month, if clinically indicated.

HERPESVIRUS 6 ANTIBODIES                                                               XE:
  (IGG,IGM)
  HERPESVIRUS 6 IGG                                 1:80 H
  HERPESVIRUS 6 IGM                   <1:20
  INTERPRETATION                      PAST INFECTION

     REFERENCE RANGE:  IgG  <1:10
                       IgM  <1:20

     Human Herpesvirus 6 (HHV-6) infects T-lymphocytes,
     and has been identified as an etiologic agent of
     exanthema subitum. Rises in antibody titers to
     HHV-6 have been detected during infection with
     other viruses. In seroepidemiology studies of the
     prevalence of exposure using serum screening
     dilutions of 1:10, the detection of IgG antibody
     in a mid-life population approaches 100%. Due to
     this high prevalence of HHV-6 antibody,
```

PAGE 2 OF 4

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Testimonials from the First Edition Continue Here...

97. *Meeting a Rescue Angel*

The way OUT of AUTISM

My 5 year old little daughter, Anna's story has been long and paved with lots of suffering and doubt, compared to her age, but prayers have always helped us in our journey. We are aware that it may take years to get out of the dark depths of Autism but now we know we are going in the right direction. Finally! Thanks to Kerri Rivera, the Rescue Angel of so many suffering children. She showed us the way out!

We have wasted so much time by trying to face the fact, that unfortunately there is a problem with our perfectly healthy-born daughter. After the consultation with many doctors, they first suspected a hearing problem. As the result of this, she went under many surgeries and antibiotic-treatments, which made her state worse mentally and physically as well. The medical professionals could not find any evidence of physical abnormalities, so they choose the easy way out, the one word diagnosis of Autism! Dear Mom, please accept it, you cannot do anything about it. Try some developmental therapies, but do not put your hopes high!

It is very hard to accept the unexplainable. What does autism mean? If you google it, you will find the verdict immediately: "Autism is a lifelong developmental disability characterized by impaired social interaction and communication, and by restricted and repetitive behavior" How is it possible that a perfectly developing child changes overnight? She stops saying the words she said before; she stops paying attention when called by her name and simply forgets some of her skills she knew so well before. How can one accept that? For us, it was impossible. We took up the gauntlet!

We spent so many sleepless nights on the Internet searching for solutions, to be shortly shocked to learn that in the US, there is a totally different concept and approach to autism. A group of medical professionals and scientists are proving the crucial role of environment and vaccines in the rapid rise of autism, accepting genetics as not the single cause but a factor of susceptibility to the disease. More and more so called DAN (Defeat Autism Now) clinics and practitioners are treating children on the spectrum all over the world with different biomedical interventions with various success rates. Whichever method one chooses in their realm, the base line to all is a strict diet, especially free from gluten, casein and sugar. There is no way out without eliminating these from the diet of an autistic child.

We immediately changed her diet from a bread and butter with chocolate milk style to a much stricter one. The first items to remove were sugar, gluten and casein, but these were shortly followed by potato, rice, corn and all artificial additives. We slowly changed to SCD (Specific Carbohydrate Diet). A few days into the diet and Anna slept through the night, and what's more, the painful eczema spots that had been on her face since she was a baby have shortly disappeared. Parallel with the diet modifications we also started the DAN interventions. We spent a fortune on lab testing, supplements and to see a DAN practitioner in Germany. Unfortunately none of these brought us significant improvements.

But I knew and believed that there has to be a solution.

And yes! I cannot keep it to myself and I would like to spread the word happily, powerfully and self-confidently, that there is a solution! This year in August, I have found the presentation of Kerri Rivera on the internet. Autism is preventable, avoidable, treatable and curable."

At the beginning "Kerri Rivera rose against the wind rather than with it when, after a frustrating slew of hits and misses, her youngest son, Patrick, was diagnosed with autism nine years ago. He was two at the time. Surrounded by literally no local expertise or any type of peer support circle, she did what most mothers would do: She became informed and involved in the biomedical community. It was through the Autism Research Institute (www.autism.com), a non-profit organization dedicated to autism research, diagnosis and treatment for the past 40 years, that she learned about a specialized biomedical protocol involving a special diet and supplements, physical therapy, applied behavioral analysis, chelation and hyperbaric treatment. There was light for Patrick, Kerri's son at the end of the tunnel."

But Kerri did not stop here! As she told me, she felt that there was a missing piece to the autism puzzle. A huge piece! It shortly turned out to be the MMS piece. She developed MMS protocol which can be done at home. Following Kerri's protocol, 68 children lost their autism diagnosis in the past two years! This result is outstanding, considering the fact that this is said to be an incurable disease.

The day I saw her presentation I e-mailed her and I got an answer within a half an hour. Kerri Rivera's MMS protocol is the missing piece of the puzzle to cure autism, ADHD, asthma, allergies, seizure disorders. Even mothers of children with Down Syndrome have reported improvements with this protocol.

My whole family was in Mexico in August. We spent two months with the person, who is also a mother of a child with autism, who sacrificed part of her life to help others. For free, out of faith, humanity and love. Approximately 8-900 children are following Kerri's protocol currently all over the world. The protocol is available for everybody and can be done at home (www.mmsautism.com).

Anna is getting better every day. Although we have heard very promising sounds from her, speech is not developed yet. However she has improved a lot in the last 3 months in many other areas like mood, communication, learning ability, focus and attention span are all better and she started pointing. There were no signs of these at the beginning of the summer.

We are fully aware that there is still a long journey ahead of us, but now we know we are on the right track. Thanks to God and Kerri Rivera to guide us to recovery!

---

98. Hi Kerri,

PLEASE use our testimony. MMS kept my daughter's PANDAS under control after switching from Silver Hydrosol BUT the biggest is the PP's (parasite protocols) in combo with MMS. She began sleeping through the night, THEN, sleeping in her own room after sleeping in our room for 9 months. THEN she began putting herself to sleep for the first time in 7 years. We always laid with her--her WHOLE life--I KNEW it was NOT "behavorial", knew it was due to *something going on interally, AND NOW, we read, kiss, and WALK OUT of her room! It's SURREAL really. Seriously SURREAL!*

Also, she was a chronic chewer, nose picker. Almost GONE! Peaks at new and full moon, BUT goes away. She was chewing about 20 straws a day before PP! Mangling them! UNREAL! I have pics of the straws... cant even recognize them as a "straw" once she was done with them. CLEARLY parasites. CLEARLY on the right track. NO other interventions. Except for how the MMS PP protocol is outlined MINUS Rhompe etc.. and Neem. NO sleep intervention supps etc.. None.

---

99. *Favy is my God sent angel. He is 4 years old and since he was born he came to change lives, to make families stronger and to help others forgive. As many of your stories, everything was "perfect" (besides of milk intoleration, delay speech and sleeping problems) the rest was great, milestones on time.. Then gradually after 13to 18 month something was clearly wrong, we loose him and then the bomb!: diagnosed in Puerto Rico by a developmental pediatrician and a neurologist as PDD-NOS on December 6, 2010.*

We moved fast and start the diet GFCFSFYF no sugars.. Etc Thanks to CEA non- profit organization who help parents with kids with autism. Soon we saw positive changes, then probiotics and a natural anti fungal. Difficult days... But always seeing little good things. On march 2011 I met an angel: Kerri Rivera and we start MMS protocol!!! Then we start to see the light! We moved to FL and they diagnosed him (now I know he was having a die off when reevaluate) he was diagnosed as Autism. For me , not a big differences, still in the spectrum and he still sick!!! We need to cure him!!!

After MMS the big changes came ,and still coming!!

first from 2 to 4 hours straight per night to 6to 9 straight during night plus a nap during day!!!!! Eye contact was much better and he had less tantrums. He learned fast 3 signs to communicate. He was more happy. I didn't see more great results because I was using Mms incorrectly for almost a year (with juice, antioxidants and vit c) When a couple of months ago I started doing it right (just water and no vit c nor antioxidants etc) he started to improve again and better.. After a lot of efforts, dedication, patience and hours of hard work, with Kerri Rivera MMS protocol Favy to improved in many areas.

This is all he have improved:

Educational:

- *Respond to his name when called and say his name when ask.*
- *Recognize people: Mommy, Daddy, Sister, Teachers, Therapists, friends*
- *Name and identify some body parts: eyes, nose, mouth, ears, belly, feet*
- *Recognize some animals (Ipad application or tv) : cow, horse, duck, chicken, zebra turtle.*
- *Recognize some colors: blue, yellow, purple, red.*
- *Recognize and count 1-10 (can repeat 11, 13)*
- *Recognize and/ or use some common objects: plate, spoon, fork, bottle, chair, pants, shirt, shoes, backpack, lunch box, blanket, pillow, tv, books, some toys, ball, cars.*
- *Stack objects like blocks, books*

- *Match pictures, objects or things.*
- *Color independently but refuses, he can trace but hand over hand.*

Social / Emotional:

- *He enjoyed for the first time his birthday Party, he was happy! He opened his presents and show emotions!!!*
- *He is beginning to interact more with others.*
- *He can follow direction of 1 step and some cases of 2. (clean up your plate to the sink and push your chair.)*
- *He is affectionate : kisses, hugs, eye contact is better.*
- *Wave and say bye.*
- *Greet with a good morning or good night.*
- *Play around and with others: chase, tickles, peek-a-boo,*
- *Dancing and imitating some song rituals like: The wheels on the bus, If you are happy, head shoulders knees and toes, and some in Spanish too.*
- *Throw, push, blow, pull, jump, run, walk, go up and down stairs, climb, open, close, zip, unzip,*
- *He can watch an ABC DVD seated or lay down , dancing or repeating.*
- *He can be seated for almost 5 to 8 minutes with his favorite books.*
- *He enjoys to go to playgrounds, go up and down slide or swing.*
- *He enjoyed the trick or treating this year, going house to house picking candy and wore all night his costume.*

Comunication:

- *I think this is the area of more improvement. From 0 to almost 35 words and different ways to label, request, interact and communicate!*
- *He can answer questions with yes or no (yeah- nah)*
- *He signs (modified) more, all done, juice*
- *He can use 3 words at a time (mommy water please, mommy come here, I love you, mommy ipad please, mommy hungry, eat)*
- *Say independently—not all of the sound clear but very similar sounds.*
- *Mommy*
- *Dadda*
- *On*
- *Yes(yeah)*
- *No (nah)*
- *Please (peas)*
- *All done (ah dah)*
- *More (mor)*
- *Water (at-ter)*
- *go*
- *Four*
- *Three*
- *Tickles*

* *Zebra (eebah)*
* *Turtle (totlo)*
* *Uh oh!*
* *Oh No!*
* *I Love You!*
* *Under*

When Prompting or Repeat:

* *Tv (tetete)*
* *Dvd (dededah)*
* *Off*
* *Come (she)*
* *Itch (each)*
* *Scratch (ach)*
* *Bubbles (babah)*
* *Bye (bah)*
* *Swing (win)*
* *Push (pah-sh)*
* *Five (hi)*
* *Nine (nun)*
* *Ten (ttn)*
* *Baby*
* *Ble (buh)*
* *Purple (por-po)*
* *Yellow (ye-yo)*
* *Chase (ch sound)*
* *Play (ay or pah)*
* *He can imitate some animal sounds like tiger, horse and wolf.*
* *He make choices between to objects . (playing, dressing, eating)*
* *Independent Functioning (he needs some prompting)*
* *He eats independently with spoon and clean up after finished.*
* *He can drink of a regular cup.*
* *With pictures or social stories he can transition to different activities.*
* *He is showing understanding of routines and rules. (dvd or toy stay home, 2 minutes and we are all-done)*
* *He can pull up and down his pants (multiple prompt)*
* *He can put his shirt on but need assistance to take it off.*
* *He can pick up and put on hamper his clothes.*
* *He can put his shoes (crocs) independently and cooperates with other type.*
* *He move furniture to reach what he wants.*

Health:

Favy still in the Gluten, Casein, Soy, Yeast, Antibiotics and Hormones free diet. He is trying new textures, flavors and consistency in a variety of food allowed.

He is drinking more water. MMS help us every time he have a cold, a mosquito bite aor nasal allergies. Is the best product we can ever find!

We are excited about all he learned, do and know during this last year because of the use of the protocol of MMS. We are proud of his efforts, but we still have areas to improve. We will continue with MMS, diet and wil start the parasite protocol with faith because MMS Rocks!!!!

We love you Godmother Kerri! God Bless you and your Family.

---

100. *Conversation at pick up:*

Aide: "What did you spike his breakfast with this morning? I've never seen him like this!"

*Me: *smile* "Oh glad he had a good day"...in my head...'three doses of MMS before drop off'...*

This child is going to figure out he has wings and start to SSSSOOOOAAAARRR!!!!

---

101. *I have a 4-year-old son on the autism spectrum and MMS has been the most effective treatment we have tried for him. He had bad eczema on his legs for over a year that I was never able to get rid of. We tried diet, medication, cream and nothing seemed to clear it up. Within 2 weeks of starting MMS it was completely gone and has not returned. My son has made great strides in the past 5 months of being on MMS and the parasite protocol. He is more interactive with all the members of the family, talking more, and becoming more successful with his OT goals.*

---

102. *Kerri; Thank you all for your great job. Because through the Webinar—Autism and MMS—the information has come to me and gave me the strength to start a treatment.*

---

103. *Hi Kerri,*

My wife and I did an ATEC on 8 year old son and it came in at 7. Wow.

We're learning so much from you about how this whole recovery thing works. The child's health takes three steps forward then two steps back then three steps forward then two steps back...but over time that one extra step forward seems to slowly add up. His pee is smelly again but, as you taught us, it's pee-tox and this is a good thing. His focus is still a bit of a challenge at school and he still won't shut up :-) but we are feeling that he truly is slowing getting better.

We've got a ways to go yet but we feel that we are truly moving forward. Thanks so much for all of the help you've given us and any help you might be able to give in the future.

---

104. *My son is 19 years old. We started MMS in July. For 2 months my son did not sleep. The end of August at full oral dose we started the baths. At night you could see he was uncomfortable. I don't know how we did it but we talked him into doing enemas. My husband does it. They induce him to have a bowel movement.*

Before enemas my son would have nights where you heard him walking back and forth from his bed to the toilet. In the morning I would say you had a bad night *last night, what was your problem? He would spell constipation. He doesn't seem to be doing this since the enemas.*

On Saturday 11-10 our son went to the first day of the season Special needs Ice Hockey. He is just learning. There were no problems with him about anything. In fact for the first time he put on his hockey gloves without objecting, which we have been trying to do the last 2 years. He followed directions from a volunteer on the ice, using his hockey stick to hit the puck back and forth to him and towards the goal. When hockey was over we went outside and hung out at the car and did nothing for about 20 minutes and had a dose of MMS. He did not care one bit. He entertained himself by watching the sea gulls. He was not impatient.

Next we walked over to the bowling alley, which is next door to the ice rink. He participated in special needs bowling. They have the bumpers up so the kids don't get gutter balls. My son actually threw some balls that didn't hit the bumpers. There were times in the past where every ball he threw hit the bumpers. Again there was not a single problem, incident, or signs of agitation from him while we were there. This is the first time in his life where we were able to go from one activity to another and not have an upset. He enjoyed himself.

What was really interesting was that he usually stims with a container of pumpkin seeds when he is in the car or at the bowling alley. This Saturday he left the container of seeds at home and not once did he even ask for them while we were out.

My son asks for a heating pad, which he has been doing for years. We wonder is it worms that have been causing all this pain for him? We would love to eliminate the pain, the repetitive behaviors, and the prompting through self-help and activities. He does lay around a lot. Everything he does is at a slow pace. He lacks stamina and speed for appropriate activities.

---

105. Hi Kerri, my daughter's first atec was 85. We just did it again and it is now 55! :) :) (approximately 2 months on MMS)

---

106. Hi Kerri,

I just wanted to let you know that we are up to 30 drops per 8 oz bottle and now I'm seeing some new things. He used future tense this morning (he sticks larry boys super suction ear to his window and waits for him to fall) This morning he said "Larry boy will fall." Usually when he falls he says in his high pitched voice "are you ok". Today when Larry Boy fell he said in a deep 11 year old voice "ouch". I just burst out laughing.

---

107. Dear Kerri,

In the spirit of giving thanks, I wanted to say how deeply grateful I am to you and your amazing work with mms and recovering children. I have never felt such hope for my son and such joy sifting through poop!!!

What a truly tremendous gift you have given us all...

Sending love and Thanks

---

108. My son is getting tiny bit more normal every day!!! I could kiss you!!!!!

109. There was once a day not too long ago when all my son would do is scream and cry. No words at all. No communication. Today he asked me "mommy who holds up the clouds so they don't fall?" :) xoxo love that question! It means so much!! Autism is big. But God is bigger!! Don't give up ladies!! God led us to mms & to Kerri for a reason!!

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110. Kerri is fabulous. She is very loving and supportive and will do anything to help our daughter recover. Using her MMS and parasite protocols have resulted in our eleven year old girl's ATEC scores dropping by half in less than sixth months. She is fully connected and much more responsive and affectionate. She herself is now motivated to succeed! We look forward to full recovery through Kerri's guidance.

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111. I think we are over the initial die off hump!!! We are getting good reports from school about better focus and independence. Also, my son shampooed and combed his hair independently this morning. He even used a Q tip in his ears! I only asked him to try and shampoo by himself. He rewarded me with the combing and Q tip! Awesome mms!

Thank you again!

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112. I am so grateful to have found you!! MMS here in our house is a MUST and my boy gets better by the day because of it.

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113. 6 months ago, my son was on antibiotics for PANDAS, he was suffering with OCD and anxiety, as well as completely distracted - like a zombie.....his teachers came out one day with tears in their eyes because my son said he feels like monsters are inside his head and they are scaring him! They were so worried about him, as we all were!

We started MMS in April. My son got up to full dose relatively quickly and we added in MMS baths and MMS enemas and then I pulled the antibiotics—cold turkey! I was emailing Kerri at the time and was afraid to stop the antibiotics. She guided me and gave me the confidence that was needed! As suggested by Kerri, we also did night dosing of MMS. This really helped my son. Keeping a constant flow of MMS was the key.

My son is flourishing!! He is HAPPY and confident. His focus has increased greatly! Since the start of the new year, he has had great day reports everyday in school! SO many gains in all areas! His coordination and strength have improved - he can do 11 sit ups (In June he couldn't do 1) He was chosen as Student of the Month in his Tae Kwon Do school (he is now a purple belt). The best news to report is his ATEC is now a 10!!!!

Our family is so grateful to Kerri!!! This protocol has made the BIGGEST impact on my son's recovery!

Thank you so much Kerri - My son's Fairy Godmother!!!

Xoxoxo

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114. I was praying for a new direction to go in to heal my boy. I literally woke up the next morning with a link to Kerri's presentation in my inbox from a friend whose daughter is making beautiful gains with mms. We are on day 3 here and things are going great, I am so excited! Thank you!!

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115. *Yes, my son is making real progress - slow and steady but real progress. The MMS & Parasite Protocol has been very beneficial for him...that's why I am trying to stick to it very closely. Also, I have wanted to tell you that one of the best things that we have ever done for my son is the enemas!!! He is a gut kid with chronic constipation and your enema program has really improved his daily life.*

Thanks again for all of your help and guidance—always truly appreciated!

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116. *Hi, I'm the mother of Lizbeth Hernandez Saray Miramontes and I want to share my testimony in case it is useful to you.*

My 13-year-old daughter started The Diet in January 2012, in June the full moon protocol to deparasite and withinin two months, she expelled a worm. This helped her regain 8 kilos of weight. (She was 10 kilos underweight when beginning the protocol) Her attitude has changed completely, from being very passive and low energy, she began to smile and be more active.

Thank you and God bless!

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117. *From the ATEC at www.autism.com*

Total Score: 5

I. Speech/Language/Communication: 1

II. Sociability: 1

III. Sensory/Cognitive Awareness: 2

IV. Health/Physical/Behavior: 1

Started at 56 score in March.

I´m still having problems in environmental awareness, because in his mind sometimes he is Super-Hero (he wants to help to all the people in disasters, his own words). Sometimes he is eating portions like me, not such big portions but he is burning calories in the swimming classes. His meals are so healthy.

So, my homeopathic doctor told me (and recommends me) to wait until January next year to start the PP. He wants to see the effects of MMS, Probiotics and some homeopathy that he will provide at the end of this month.

We continue using as I said MMS, Theralac, GFCFSF diet, NAET and A.B.A therapy. I am so happy to share it with you.

Hugs my dear God Mother

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118. *My daughter is doing well on the MMS. Her ATEC went from 53 to 26*

in three months. The special education teacher at her school was very impressed with how well she is doing. She told me to keep doing whatever it was that I was doing, because it is working!

Thank you for your help.

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119. *Kerri, good day*

I want to tell you about the progress of my child, the treatment began in July and the progress that we have seen is:

-He has gone from not wanting to eat ANYTHING, TO EATING BY HIMSELF, SITTING DOWN he grabs his spoon and he cleans his mouth every time he gets dirty

* *He has stopped wearing a diaper, and goes to the bathroom by himself, almost like any other typical child.*

- *He lets people other than my wife and I hug him.*
- *He now gives hugs and has started imitating a few other things.*
- *He can now obey simple instructions that he couldn't before.....no, pick it up, get down, get up, give me your hand, etc.*
- *At the institute where he receives therapy they have told us that they are seeing great improvement in his eye contact, as he now focuses his vision more clearly on an object.*
- *He still will not play with other children, but at least he is where they are.*

Thank you for everything and we are together in this fight day after day, winning small battles everyday to win the war.

God bless

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120. My son was a non responder. We worked with a DAN! Dr. for 14 years. We did the DAN! protocol tirelessly with very, very little gains. Did 3 years of ABA and 2 of SonRise. Did the diet. Still do the diet. We started the MMS protocol in April of this year. My son has had more gains since April of this year than with 14 years of DAN protocol combined. My local children's hospital specialist told me to put my son in a home and forget I ever had him. What a jerk. We pressed on and I could write a book about the gains since April. My son's Dr said he had two near impossible "tough nut kiddos to crack open...one being my son." Well, MMS works. If my son can improve I know yours can too. Whatever you have to do to do enemas, and get him to drink it...do it. My son is drinking 35 drops a day. Trust me, it is yuck. But he understands that if he drinks it, it makes the autism go away and he slams it down and says, "yuck." He totally knows I am helping him and cooperates. Be encouraged.

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121. Hi Kerri,

We're now at 1/4th of a drop per oz and today my daughter for the first time EVER answered a 'Where is...' question. I was putting out the garbage and when I came back in I remembered I had forgotten to put away a black marker

and when I found it was missing, I could only hope the property damage would not be too bad this time. I checked the living room and the kitchen but could not find any traces and meanwhile my daughter had taken the photo camera

and was taking pictures of herself in the mirror. Amazingly she seemed to have a way better understanding of the thing. I asked her twice where the black marker was, and after the second time she pointed towards the kitchen and said "There."

SHE HAS NEVER DONE THIS BEFORE! I checked the kitchen and found the black market next to the fruit. The pears, melon and mango all had black circles and stripes. I was a bit overwhelmed I should say.

Thank you, thank you, thank you for never having given up your search!

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122. My son Fernando Latin is 8 years old and was diagnosed at age 3 and half. When I started this struggle with autism all the relevant studies were performed. We visited a neurologist, psychologist and a gastroenterologist, he began taking the supplements according to DAN! protocol, but the list of pills he was taking was increasing and my boy was restless. Then I went to a homeopath, *the treatment worked a little but it was so expensive I couldn't continue, it is needless to say how much money and time I spent on appointments and tests, plus the hyperactivity problem was growing each day. Until God put in my path an extraordinary friend MARIA CAMPERO and she talked to me about a foundation in Port Ordaz "VENCIENDO EL AUTISMO" FOUNDATION (Carolina, Yamileth and all that beautiful team) they brought Kerri Rivera to lecture here in Venezuela, on 04/02/2011. I will never forget these words AUTISM IS PREVENTABLE, TREATABLE, AND CURABLE. A new hope that a mother's heart never looses… In that conference she also talked about MMS and its benefits I was lucky Kerri evaluated my child, I started giving him MMS plus some supplements and have won this since:*

- *Better pronunciation, for example he used to say Dowg and now he says Dog.*
- *He obeys orders.*
- *Spends more time sitting.*
- *Evacuates normally with no bad smell.*
- *He stopped biting his clothes.*
- *He stopped making noises like: wiiiii yiiiii.*
- *He stopped playing with his hands.*
- *We go somewhere and he is relaxed.*
- *If we take a picture, he looks at the camera.*
- *He is more aware of his environment.*
- *He is improving a lot and really fast with his ABA therapy*

These are all the benefits I've seen with my son after starting with the MMS, I know there is a lot to do but know a have real hope. Some advice for parents that are starting this road: please accept what is happening, inform yourselves. I always think that to get your children through this you need the four-legged table:

- *Diet*
- *MMS, Supplement treatment*
- *Therapy*
- *Help at home*

I've always asked God to give me enough wisdom to help my child and to put me in a direction were I could find people that can help me, and believe me he has listened: Venciendo al Autismo Foundation, Kerri Rivera, my sons therapist Milagros Alcanta, Danny her teacher-shadow, Maria Campo, a woman not only committed to her son but to all of those who she can help and guide me, including Marilyn Aparcedo and her team. All of them are my bases to keep going and as Kerri and Carolina say: This is an endurance test and there is no giving up!

I have nothing but thanks these wonderful and professional people, Thank you!

Norkis Pinto, El Tigre—Venezuela.

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123. Alexander was a normal baby until he was 6 months old, after that he suffered a change that, when we got home from work it was like no one came in, he was very uneasy, we talked to him but he didn't seem to care, first we thought that he didn't listen, the pediatrician and neurologist recommended hearing tests, *we did them and his results were normal. The pediatrician also recommended a psychiatrist but I thought it was very early for that so I took him to a psychologist, but he didn't diagnosed him, instead he referred me to a psychiatrist specialized in autism, and with a simple test he confirmed the suspicions: your child has autism and this has no cure, take him to special classes and therapy. I quickly signed him to a special camp and school, but they they just took my money and my sacrifice to travel 60 kilometers daily, they didn't do what they promised, they charged me triple just to give me a diagnosis and I believe he didn't even receive therapy. In my despair I went to the internet, I made an email account, a facebook page and started to look for parents that were going through the same things I was, then I contacted a Dominican mom living in Puerto Rico and she told me about Kerri Rivera and the diet. She told me that Kerri was the person to go to about this and Kerri answered immediately and asked me if my boy was on the diet and I said he was only 50% and she told me that if I wanted my boy to get better I had to do 100% so I wrote her back when I was doing the diet entirely. She gave me the first three supplements MMS1, THERALAC AND QUINTON WATER. Everything has been so difficult to get but if you persevere you get want you're looking for. I got the MMS1 but I was scared because of the strong smell of chlorine but I gave it to him with faith, I took it and my youngest baby girl started taking it. She had had a cold for about a month and it disappeared, Alex started to get better in every aspect but the biggest changes began 15 days ago, since I give him his MMS1 treatment. I start at 3 o'clock and finish at 12 at night. On weekends I start at 1 and I complete 12 doses of one drop mixed with citric acid and give him that daily. My 3 year and 4 month old baby boy is saying his first words. He is more connected, pays attention, he is aware of what happens to him and he is more loving than ever. I am so happy; I thank God, Kerri Rivera, Zeneida, Cynthia. But I mainly thank MMS1, because with a supplement so cheap, I'm getting my son back, the one that Autism wanted to steal from me.*

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124. *Juan Eduardo is 9 years old and he was diagnosed with Autism at age 2. It has been a long road in which we have tried everything. 7 years after trying and failing, in April of this wonderful 2011 we started in the right way. MMS came to our lives. Juan Eduardo was a self-centered boy and with a lot of fixations to objects. His improvement in school has been slow, but in 5 months he has improved what he improved in 5 years. MMS in our lives has been wonderful, despite the hyperactivity and lack of sleep at the beginning of the protocol, the life of Juan Eduardo and our lives have changed drastically in a very positive way. He will start regular school at the beginning of next year. He is a happy boy, he sleeps all night, he talks a lot more even if there is a long way to go, his quality of life is so much better. He shares with whoever is around him, a lot of times he surprises us with his qualities. He has adapted to the MMS in a great way. We took the panel viral test and the results were amazing, there was no virus. When I saw the great positive effects the MMS has made, I started to do protocol 1000 for maintenance with 100% success. Last year I suffered from several episodes of flu in which I had to take antibiotics, but this year I feel excellent, Thank God and Kerri and MMS I haven't been ill. I thank God, Kerri for putting you in our lives; I'm sure he has given back everything you selflessly have done for everybody. The smiles and looks in our children's eyes are priceless. Thank you Kerri and Jim Humble. A big hug.*

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125 *Yes, I have increased the drops. Honestly, since we last spoke, he has had some of his best days...super happy. He actually read a book on his own on the way to school this morning. Seems very calm. Thank you.*

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126. *Hello Kerri! I have not written you in some time. I must tell you I have already been using MMS for two months. We have seen a lot of improvement. He suddenly speaks, says single words. If I sing a song or the vowels, he tries to imitate me, although it is still not very clear. But he tries to imitate. He smiled back at me when I smiled at him. And so those are several things. Tantrums are also less.*

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127. *She is doing excellent! Every day we see small but important progress. I am not sure if she has noticed the changes in herself, the best will be when she starts school and classmates and teachers can give me their opinions. Family members have also commented on the changes we have seen in her.*

She is also answering questions about what she wants... With yeah, nah or the sign for all done with and then says dddon!

Now she wanted to see Mickey and told me ttttttiii and I showed her the movies and she said "ickey!" ;) We are communicating!!

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128. *We are a family that lives in a country where living is not easy at all. The maternal death rates and child deaths are very high, and there is hardly any chance of getting access to special medical treatments and therapies. Our son started to show signs of autism since he was 2 years 8 months old. He had begun speaking but at that moment he stopped talking, he started to show no expression with his eyes, to roll around trees, to scream and to tantrum, and to not allow contact with anyone. Little by little he started to be very hyperactive and to have serious sleeping problems (he didn't want to wake up and he could not go to sleep at night).*

The start of my son's autism went along with colds, severe coughing and infectious diarrhea. Our son's teacher had always had excellent reports about our son's behavior, but since this severe cold with synovitis in his hip, the transformation begun. Since then, the awful diagnosis and the absence of guidance led us to an abyss. Our son presented total absence of self, almost no language, hyperactivity and many sicknesses. 6 months went by in which he met with a real parade of doctors and therapists that gave us bad treatments, bad diagnoses and almost no information, our life became a living hell. We went into a state of denial in which we didn't want to see anything on the Internet regarding Autism. In that time our son had been diagnosed with severe sinusitis, complications with his adenoids, and limitations that he developed because of his hearing capacity.

By the end of the year 2007, I alone broke the pact I had made with my husband, and started to search the Internet and found Yeroline Ruiz's page where she commented about the biomedical protocol through which she had gained her son back in months. Little by little I tried to convince my husband, who at the beginning was completely reluctant to the possibility, but by December 2007 we made our first order of supplements and quelators (magnetic clay from the United States). The supplements took forever to get to us and when they arrived we gave them to our son without any clue or guidance and hardly any diet. The results were horrible, he got worse and worse, and this lasted about 8 months. During this time the therapists gave us a terrible prediction about our son's future. Our family problems were also getting worse and the only guide we had was Yeroline and the Curando el Autismo foundation. Thank God we didn't give up and we passed the hard times.

We eliminated some of the food that is forbidden in the protocol and we started to use Enzymes. Our son started to improve, his health got a lot better and we stopped visiting traditional doctors and I decided to take care of his treatment, the process was not easy because there aren't even the basics for the protocol in my country, from the flour to the milk, everything is really hard to get. Obviously a DAN! doctor or supplements are unthinkable. However even if his health had improved, the Autism symptoms were still present, the speech therapy did not help and sometimes even made it worse. With a lot of effort we brought Rosa Dominguez (Tomatis Therapist) and we begun applying this technique to our son. The economic effort was very big but the results were worth it, he was more in control of his body, the clearest sign of this was the control of his sphincter that happened almost magically. His language also improved even if he still didn't use it socially, but little by little we verified that our son had no sign of retardation compared to other kids his age. Even with the improvement, the tantrums, frustration and limitations of his language remained, we decided then to make a new effort and traveled to Panama to the Stem Cells Institute to make a stem cell transplant.

Our debt was huge, and despite the effort our baby showed two contrary signs: a positive one that was that our boy was completely connected to his environment (he is never outside of the world anymore) and a negative one: he became aggressive. He had never shown aggression, auto-aggression or violent behavior, but from the moment the anesthesia was applied these began.

Our child started hitting himself when things didn't go his way and he bit other people out of frustration. We remained on our path with despair because we could not see the light. We tried hyperbarics for 70 days in a row, eqinotherapy, and others. In 2011 we came across Puerto Rico's CEA conference and we found Kerri's topic and the SCIA topics very interesting. We decided to do the SCIA tests and we confirmed that our boy also had virus and an inflammation even though his immune system didn't seem very affected. Because of our country's limitations we couldn't complete the SCIA tests but then we had a lead on how to start a new journey. All we needed was a doctor that could apply the SCIA protocol.

But then there was a miraculous day in which we saw Kerri's talk and hope grew inside us, we contacted her immediately and she answered immediately too, with good will and all the indications as to how give him MMS and how to apply the protocol. After two weeks we started seeing a change in our son. Eye contact was way better; he speaks fluid sentences and gives structure to his words.

We are now three weeks into the protocol, we can see almost no aggressions and tantrums, we teach him letters and he recognizes them, reads and writes his name (he does it with some difficulty) his receptive language is %100 active, he is very loving, specially with me. (His mom), he hugs me and kisses me and tells me he loves me. We know we still have a lot to go but I'm certain that we will make it. My son has now Borderline Autism; his connection with the world is total. We are still thinking about doing all the SCIA tests but just to find out our child is cured. The light and hope that Kerri and the MMS have given us does not compare to anything. Thank God! Kerri is a blessing in our lives!

129. *This email was after an ATEC drop of 64 to 44:*

This is truly AWESOME!!! He lacks in the "Speech/Language/Communication" area the most!!

I honestly thought when I was filling this ATEC out that he would have regressed because I just thought he might have...it seems everything else we have EVER done it is always too good to be true! It actually is not this time!! Praise the Lord Jesus Christ! \o/ I even had my oldest daughter give her thoughts on the questions too so that I doubled checked myself regarding his behavior etc...you know to make sure I was not out of touch! :)

We definitely have a ways to go, but I have never had my son at this level of 'awareness' before! We are doing RDI (Relationship Development Intervention) and have been since Feb. 2011...he's made great gains with it, but he is FLYING now only because of the MMS!!

~Melissa, IN, USA

130. *Hello, my name is Silvia and I have a 5-year-old son named Ricardo who was diagnosed with Autism 2 ½ years ago. From that moment he has been on a gluten and casein free diet and a therapy routine that help him day by day. Three months ago I met Kerri Rivera and the Venciendo el Autismo Foundation, and started giving Ricardo MMS. From that moment on he has improved significantly, his language is better and his behavior is a lot more controlled, plus with the biomedical treatment he goes to the bathroom regularly, this makes me very happy because he was always constipated.*

Silvia Morales — Caracas.

131. *Since I was a baby I was a very sick child ... I remember I had many gastrointestinal problems, I made my mom's life miserable with all the diarrhea and vomiting ... I couldn't gain weight and I had no appetite. All this accompanied me for many years; the diarrhea became chronic constipation, fluid retention and dry skin.*

All of this without knowing I had a serious problem, until I gave birth to my first child. The constipation was a nightmare, my baby got ill, when I fed him breast milk he would get a rash, and then he had convulsions for about 20 seconds, when I fed him again the same would happen but now the convulsions lasted for nearly a day. The doctors didn't know what was going on either. In one of my researches I ran into a page that talked about Autism and Candida being one of the main causes, this is when I find out that my son had chronic candidiasis and that he got it from me when I breast fed him. I tested my child and myself and we both had Candida, and I have had it since I was a baby.

One day I heard about the existence of a woman named Kerri Rivera who is devoted to helping children with Autism and I contacted her and she gave me all the help to treat my child. I will be forever grateful. She talked to me about the MMS and how to give it to my son. I also started taking it and in a matter of days I had a white layer in my tongue, it was the Candida getting out. I have gained my energy back, the headache I had in the mornings is gone, I feel vivid and almost all the Candida is gone. I've been with MMS for a month and I've never felt so satisfied with a treatment. This simple and yet powerful remedy has given my health and family back and with this I can assure, by my own experience that MMS works.

132. Hi Kerri, I want to tell you that Erik has started with the speech therapist, and psychologist, when she finished the session with Erik, I asked if she thought that Erik could still be diagnosed with autism. She looked me in the eye and said, autism? Are you sure that he was correctly diagnosed? I found her the forms and she told me today Erik has eye contact, he socializes, and is cooperative. She said he does seem small for his age, and that we were going to have to work on strengthening the muscles of his mouth and the tongue as well because they are very week. She said that not chewing would affct the development of one's language, and Erik has only been chewing for 8 months, which started after we did the chamber with you in Mexico. That was the answer she gave me, and that's something, the fact that she told me that this is not autism is really something, even though she doesn't want to contradict the diagnosis they gave two years ago. The truth is, I am so glad he has come to improve, and that is since you KERRI have started to help my child. It's been a year since we started with the MMS protocol and the improvements have been incredible, he still lacks language as he mispronounces many words, but the worst is over. You can publish this if you want, thank you very much for all your help.

Kisses

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133. We had first formed stool at 4 drops. It was so inspiring. Since then somedays we have formed stool, some days we have loose stool but I relate this to detox - I can clearly see his gut healing. His expressive speech hasn't changed yet but he obviously understands much, much better and is able to follow complex comands like "come and give me one teaspoon from the drawer" or "go and put this in the dishwasher" or "wait for daddy to get out the baby from the car and then you can lock the door and put on the alarm". Things like that, that were unthinkable before. I hope he will go beyond his few words soon and will begin to talk.

Although speech is the thing that interests me most of all, perhaps the most impressive thing that MMS brought to us all of a sudden is the sense of smell - our boy never seemed to feel any smell, good or bad, in his entire life. He got this sense a week ago. We are thrilled - something is waking up in his brain, perhaps some pathogens in some part of his brain or in his nose or whatever died and now he is able to sense a smell. Things are getting moved.

Thank you Kerri.

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134. My son is 8 1/2 years old. I have spent six years and well into six figures to help my son. While I would see gains, nothing was really moving him forward. Three months with MMS, DE and ocean water; the junk that is coming out of him is both horrifying and thrilling. I think he is finally starting to feel better, and because he feels better he is more with us. He is trying so hard to speak and everyday he is saying at least four new words. He also watched a movie and laughed at a funny part!

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135. We started MMS 68 Days ago and my son's ATEC has dropped from 50-23... Now that's a MIRACLE!!! He is So much more "with us" and I'm seeing improvements daily. He is just so much more fun to be with now:) He did have a plateau, but is back on track. We have only done 4 enemas to date, but they made a big difference! Baths do as well:) I can't wait to see what he is like on his 4th birthday (still 39 days away).

Kelly, CA, USA

136. *Is it just an amazing day or is the MMS already working? Its just day 1! I know people say that once your child starts talking, they never stop, but holy cow... Today in the grocery store, it took me 3x's longer to shop because he was talking about everything he saw around him and needed a response on all of it from me! So unlike anything we have ever experienced with him before. Could it really be the MMS already? Also, potty training has been going well (slow & and steady), but today, he didn't need much prompting! Many times, he just stopped what he was doing and ran to the bathroom to go all by himself! This is amazing, because he never stops a preferred activity to go potty! When i thought it had been too long since he went last and said "its time to go potty." he just ran in there and peed, washed hands etc. No tantrums or weight dropping, he just ran in and went! God is answering my prayers! :) I'll keep you posted on what happens tomorrow!*

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137. *You know Kerri, I had to email you directly I waited until today to retake my son's atec...just did his first Parasite Protocol and did the 72/2 hr this weekend, so waited a few days to pass by before we did...so this atec was based SOLELY on this past monday, tuesday & today. I got an 11, hubby got a 13. so average: 12. (he was 32 before MMS, then 27 after 3 weeks of MMS...now 12) I had to email you to thank you b/c well...because. What is there really to say :) cant think of the right words really :) thank you?? not really enough if u know what i mean :) ...But to think i was going to skip your presentation at A1 b/c I thought it's too good to be true. But you caught my attention when you started tearing up as you got up on stage :) you were the only person/speaker to show emotion like that. AND have NOTHING TO SELL ON YOUR TABLE :) You were there only for our children...getting nothing back in return! :) I know I've been emotional, but I'm prego and my sons getting better so cut me some slack :)*

I'm SO grateful for all you do Kerri. If there is something I can do in return, Please let me know. I know you have a lot on your plate. You have a heart of gold; such a giving, compassionate person. a "rare-ity" (this word is in my dictionary!!) You & Patrick are always in our prayers. I seriously want to go visit you in Mexico w/my family so my son can meet you when he's recovered. I told my hubby & he's up for it hehe :)

Anyways, long email but really just wanted to let you know how well he's doing and to 'thank you'. It blew my mind after I got the results. He still has issues in socialization and getting his vocab/speech up to his 4 year old level. I think much of that will change as he learns English better: he'll interact better with his peers.

Thank you Kerri from the bottom of me & husbands heart :) You are loved & covered in prayer. :)

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138. *We started to see a setback in January with our 1 year 8 month old girl. Until this date she had had a normal development, like her sisters (she is our third child) but then, she stopped talking, she just screamed and twirled. She would twirl like 20 times a day for no reason until she got dizzy and she fell to the ground. She didn't look at anybody in the eyes and could be behind a curtain hours comparing her toothbrushes; she wasn't hungry nor asked for her milk, we had to push the food into her mouth so she would eat it. I was desperate so I went in to a forum and a friend from Venezuela told me to look for Kerri Rivera in my country so I did. She immediately answered and gave me hope, since the*

three doctors I had seen before told me that Autism had no cure, that all we could do is to teach her how to survive and be a little bit more independent.

I found my hope in Kerri, I read the testimonies on her page and sent her a message that she answered right away. She told me to do the diet, remove milk and everything else, I went to her clinic and within a week of the diet Abby could look at me and smile (she had stopped doing that long ago) When I went to her clinic Autismo2 in Puerto Vallarta she looked at Abby with all the patience in the world, she gave me MMS, the supplements and all the hope in the world. Everything was new to me but I had faith that I was in the right place and from that moment on, while always counting on Kerri's advice, my baby girl started to get much better. Her first ATEC was 95 and a year and a half after it's a 15. My girl now smiles, talks, dances, she obeys and stopped screaming, her only tantrums are of a normal girl her age. I did hyperbarics and am still doing MMS, supplements and deworming her. She is now diagnosed with Pervasive Developmental because the Autism symptoms are gone. She doesn't run from one place to another, she plays, looks for other kids to play with and has friends. The only thing left is for her to establish a conversation, and to put together the words to make sentences, but I know she is going to make it.

Once she sat down on ant hill and a bunch of ants bit her, we had to go to the hospital and the doctors gave her cortisone and she was seriously ill, now when a bug stings or a mosquito bites she tells me where it bit her, and she asks me to apply a calendula ointment that I use for the mosquito bites. She sets the table and can eat by herself, she doesn't use a diaper anymore, we can go shopping or to parties and she is well behaved, there is no more tantrums or fixations, this is wonderful! I know there is a long way to go, I've been in this fight for a year and a half, but with KERRI RIVERA'S HELP I will rescue my baby from autism, even though some say that Autism has no cure I know it does. Kerri has been a blessing for our lives and I thank God for putting her in my path.

Thank you Kerri, I have no way to repay what you have done for Abby.

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139. Our 10 year old son, Ben, showed symptoms of autism since he was an infant. Until he was 6, he never connected normally with family or peers. As his mother, I ached for a hug, to be called "Mommy," or for a lingering look of love. I never got them.

Until he was diagnosed with autism at age five, I was utterly befuddled. What had I done? What was wrong with Ben? Why didn't he want to play with other children? Why did he drool endlessly, laugh constantly for no reason, and bolt from play dates and parties with no warning? Why was he constantly lethargic, to the point where we called him "the playdough boy?"

Ben was always happy, dwelling far from us, in his own perfect little heaven. My husband and I were depressed, even despondent, despite attempts at gluten-free, casein-free diets, ABA therapy, and many supplements, because we saw no substantive and lasting changes in our child.

Finally we found the Son-Rise Program®, which brought Ben back to us. After three-plus years of a mostly full-time Son-Rise Program®, Ben became highly interactive, engaged, and interested in his peers. That alone was a palpable miracle. As we say in Hebrew, Dayeinu! That would have been sufficient. But we constantly experienced regressions back into autistic symptoms. For no apparent reason, and despite endless biomedical interventions, including the DAN!

protocol—to the tune, I might add, of tens of thousands of dollars, multiplied over four to five years—Ben would suddenly revert to autistic behaviors, and we would lose contact. He became once again non-responsive, uninterested in family or peers, and seemingly unable to connect. Only the day before, he had been totally connected.

After being on the SCD and GAPS diets, and finding even them ineffective to alleviate these regular and devastating returns to autism, we were advised by Dr. Campbell-McBride that it sounded to her as if Ben had parasites. A friend of mine who was also a Son-Rise mom had mentioned to me that she and another Son-Rise mom friend of ours were trying something called "MMS." When I heard the words for which the acronym stood, I gave an internal scoff. "Master Mineral Solution? Is this a joke?"

I can tell you, in all seriousness, that now, five and a half months into our MMS autism protocol, MMS is definitely no joke. Since starting MMS, we have seen nothing but progress in Ben. We are still doing GAPS, but avoiding foods we know Ben cannot yet digest. Ben's ATEC score has dropped from 43 when we started MMS to a startling 20. We are seeing sustained, natural, unsolicited and consistent eye contact, like never before. Ben is consistently responsive, certainly on par with most 10 year old boys. He is playing hockey in our driveway with friends. He is solicitous of others, and compassionate when others are hurt in any way. He is funny, expressively loving, and eager to please and be loved. It makes me cry to write this. I wanted this so badly, and now, with MMS leading the other interventions, I have what I prayed for.

We are not perfect on the MMS. Ben is in his first year of school post-Son-Rise, and dosing during the school day is not easy. But we are tremendously hopeful and excited.

I truly believe, as Kerri Rivera has often said, that parasites are the missing piece of the autism puzzle. Like so many other warrior parents, we have done everything. But everything minus one was not enough for Ben. Now, I think we truly have the tools, and it is only a matter of time, faith, and love, to fully and permanently recover our beloved Ben.

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140. Caitlin has been on the MMS protocol for 3 months now. Caitlin is now off her 100 plus supplements a day that were the glue holding her together so to speak, with no regression. She is happier, more affectionate and focused. She no longer has a distended belly. She used to have terrible smelling gas on a daily basis and very foul smelling bowel movements. This is gone! She has increased muscle tone (has a diagnosis of low muscle tone and bilateral hip anteversion). She has been seizure free as well! She continues to make slow but steady gains in her reading and math skills at school. She isn't conversational in her speech yet but can comment on things and express her wants in longer and more elaborate sentences. She is falling asleep faster and sleeping longer.

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141. Eczema!!

At last my son (4 yrs) is living now without eczema, he was born with severe eczema all over his body, we used every allergic cream and med and even the magical Dead Sea Clay but it didn't work, but now after using mms and pp (parasite protocol) for 2 months... ITS GONE!! Thank you MMS!!"

Thank you!

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142. *This is the story of our son who is 4 years and 9 months old today. Our story is a desperate struggle to defeat Autism, the same struggle that a lot of families are going through to free their sons and daughters. Guillem started to have ear inflammation and laryngitis when he was a few months old and we medicated him with antibiotics, he had his vaccines according the vaccine calendar, and by the time he was 9 months old he was showing signs of Autism. He would put his fingers in his throat until he choked, he would hit his head on the wall and he was always mad, his tantrums were frequent, longer and more intense, he started to look at the lights and to twirl with no sense, he showed less interest in people day by day and he would get really mad if someone said anything to him. He was hyperactive, couldn't stop running and going up and down the stairs. The nights were terrible too, he didn't sleep well and woke up screaming as loud as he could plus he could not say a word.*

My father and my brothers blamed me for this; they said that my boy wanted to dominate me and to get my attention. I had a hard time recognizing that it wasn't this, that my boy had something else. Once I accepted it I spent hours and hours reading on the Internet, and I read about the gluten-free diet and that was our first step. When Guillem was 2 and half years old we changed the diet and it worked. Guillem started to respond to orders, there was less screaming and his first words appeared. Three months into the diet we contacted Kerri, this has been a key moment in our history, because she has been our guide to get our son out of this long tunnel. The first thing she did was to check what our son was eating, I thought that I was doing a perfect diet but I wasn't, there were some foods with sugar, soy and additives, the next thing we did was to talk about the supplements and MMS, but I was very scared to use it and it wasn't until three months later, the day Guillem turned 3 that I started giving it to him. Now we have been using MMS for a year and 9 months. We give him MMS daily and every weekend we can but minimum one weekend a month we do the 72/2. His improvement was amazing, his language got better, his dressing skills, he learned how to use the bathroom, his sleep was normal, and the screaming was almost gone. The next step was to start with the MMS enemas, every enema made Guillem more alert, more present, we started with the enemas 4 months after starting with the MMS. We saw that the enemas expelled a great amount of biofilm and the more he expelled it, the more abilities Guillem gained back, I saw the importance of healing the intestine and that has been my obsession since.

The next important step was the sessions in the hyperbaric chamber, his first sessions were at age 3 and 9 months, and the changes we saw were mainly in the obsessions he had, he paid much more attention to everything, his social skills were very affected but after this he made his first friend. Now we do hyperbarics with seawater every three months. Another piece in the puzzle were the parasites but with Kerri's help we've been on the protocol against parasites for 7 months and every deworming cycle our son improves. I know that we have to keep fighting but I also know that we are closer to the exit. Now Guillem sings, he plays with his brothers, we go to the movies, we do puzzles, we paint, and he is very happy, he has learned to spell his name and he walks joyfully down the street telling you about his day. He goes to school, plays football and more importantly, we are a family again.

For all of this we are deeply thankful to Kerri, because she has always been there for us, without Kerri and MMS our story would be completely different, so we owe them EVERYTHING. I know that we will someday say Guillem is cured, and all the other children with Autism can say that too.

UPDATE: As of December, 2012 Guillem no longer has a diagnosis of autism, here is an email his Mother sent to Kerri when she knew he had recovered:

> *KERRI!!!*
>
> *My son has an ATEC of 10!!!!*
>
> *I have it repeated several times because I did not believe it...*
>
> *I have copied it below...I'm going to have it framed!*
>
> *The truth is that this Christmas we have enjoyed our whole family, we've been to the Zoo, to the fair, and during family meals he was very well behaved and enjoyed the Magi and the magic of Christmas. Christmas last year was totally different. For all this we give infinite thanks! There are not enough words to tell you how we feel! Without you our story would be different. We will continue working to get to zero!*
>
> *A big hug!*

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143. I started with MMS on April 2012, I was afraid but had a lot of faith. I did the ATEC for my son and it was 92. He could not use the bathroom alone nor say a single word. The day I started I thought there was nothing different, but when we were at the beach on vacation I noticed that when I called his name he would turn, and come to where I was. All this with one drop! Before that day I always had to stand up and find him so he would pay attention to me. He wouldn't look at me but he would listen to instruction. Days went by and when we came back from the beach he went straight to the bathroom… I couldn't believe it; I sat down and asked my self WHAT IS THIS? What happened? And I silently thanked God and Kerri. This was decisive for me to continue. After this he improved day by day, after 5 weeks his ATEC had gone down to 76 points.

I made a few mistakes at the beginning because I didn't know the protocol very well, and wanted to rush things. Again, Kerri with her infinite patience and love for others led me to the right path, and I started to see more, way more.

My son started writing, he knows his letters, he reads some words (he has memorized them) he is great in the bathroom, he listens, his eye contact has improved significantly, his last ATEC was last month and it was 60 points. I know we have a long way to go, but I every month there is improvement and even though there are some bumps and setbacks the good things overcome the bad.

My son has also started saying words, names of movies, he can say over 100 words (names of movies or things he likes). Some will think it doesn't mean anything to know the name of a movie but for me, it is to know how my son's voice sounds and that, is priceless. Now my next goal is to hear him say "MOM"

~Myrna Sterling, Mother of Gianmarco, age 5.

Myrna is the president of the GM foundation for Autism

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144. My wife and I have always been fond of traveling, getting to know different cultures and people, this is why we had our little one we decided t o keep traveling but to adapt to his rhythm.

When he was 9 months old he went on his first international journey. Everything was perfect, he was the happiest baby on the plane, he played with the people in the seats behind us, the stewardess wanted to stay with him to play, all the plane ride went along perfectly.

Something happened between his 15th and 18th month, his smile was gone, we no longer had happiness in our home, only nerves and less language. Maybe the excessive vaccines were destroying his immune system and leaving the door open for parasites to take hold.

When he was 18 months we went on a second trip and it was an absolute nightmare. He wouldn't stop crying and screaming on the plane, he didn't want to play with anybody. We spent a few days getting to know this new place while our baby fell further into this abyss in front of our astonished eyes.

Something was wrong, and after an episode of auto aggression we knew that this was not normal. After watching a couple of videos on the Internet we started to understand, and we went to a psychologist who didn't give us a diagnosis because our son was so young.

Later on we went to a neuro-pediatrician who also used the excuse of our son's young age to dismiss us, and finally a last doctor who didn't explain anything either.

Not even our family listened because they thought we were exaggerating. We were left alone and our biggest ally was and still is the Internet.

After the medical failure and their "anti-diagnosis" we took the best and most important decision of our lives, that was not to listen to any of the diagnoses, or to wait another 6 months to be called by the neuro-pediatrician again. We started down this road without an official diagnosis but with all the symptoms and behaviors that define autism.

We started with the casein, gluten and soy free diet with no experience on how to do it and our baby suffered awful withdrawal symptoms. We couldn't believe what we were seeing, his nervousness and aggression took us to our limits. After a few days on the diet his tantrums went down little by little until he was stable. But we needed something else because everything was out of control; this is when we went back to the Internet.

After three months of false doctors and pseudo medical experts we found Kerri Rivera.

She gave us hope, and filled us with confidence, but most importantly she was clear with us from the beginning. Everything she told us was logical and everything made sense as to why it was done so we trusted her without a moment's doubt.

He got better and better everyday. Kerri told us how to do the ATEC and what it meant. Our first result was 57 points when he was 2 years old, which was very high for us because of his young age. We have been doing everything Kerri suggests, improving the diet, and using everything she recommends, and the results have been spectacular, right now he is 2 years and 10 months old, his ATEC is 8 and he is doing great. Our goal is to have him at 0, and I'm certain that once we free his intestines of all the parasites, he will be a strong, healthy and happy boy.

He doesn't have any behaviors like the ones he had one year ago, now he smiles again, he talks and asks for things, he plays a lot and he is happy.

This was possible thanks to his Godmother Kerri.

Kerri, you have done and given us everything in exchange for nothing, and that is your defining quality as a human being and as a person.

Every day you give hope to all that YES WE CAN defeat Autism and now we have a lot of puzzle pieces to complete our puzzle. We may find a new one soon because there are a lot of people investigating and that makes us feel alive, to fight against the entire circus that has sprung up around this problem.

I would recommend that if anyone is not seeing progress in their children, to come to Kerri, and try everything she says word for word. She has done it all and has the best investigators and doctor on her side. The ones that aren't intimidated by the absurd laws of the upper echelon, those who only want our children to be sick all their lives so they can sell medicine to us.

We will keep up the fight.

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145. Hi Kerri, I just got the third MMS Autism newsletter, and I tell you it couldn't have arrived at a better moment. For the last few days my nephew has had a strange infection, he was hospitalized and the doctors couldn't figure how to fight it because it was resistant to many antibiotics. I told my brother-in-law about MMS and he started using it. After two days my nephew was healed, the doctor asked me for a little so he could examine it, and his answer was that the way MMS functions is amazing, he couldn't believe that such a simple and powerful product hasn't come out to the public eye.

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146. My husband and I were on the couch having our morning coffee and my son came bolting out of the room and ran up to my husband's face and said..."Oh Hi Daddy, I'm back!" And then ran back to his room...this is our once in a while "word" little man. After 3 non-progressive PPs (parasite protocols) the 4th one was a charm. A nightmare, but quite an eliminator... Lots of Worms Gone! And he is slowly coming back...we are seeing it in fact he is even reassuring us that he "is back".

~The previous email was accompanied by an ATEC drop from 95 to 35 in 6 months.

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147. Dear Kerri,

It's a pity I don't speak English and that's why I can't write you on my own. Currently, a lot of good things are happening to my son (31 years old). I have followed all your advice and as a result he has completely calmed down. I have learned to prepare CDS at home with the help of Jim Humble's video. The CDS is a 600 ppm solution; my son drinks 30 ml per day with the feeding bottle method. I suppose this is the daily dose for a person of his weight. We are past the third PP and preparing for the fourth one.

Unfortunately I won't be able to attend the congress in Prague, since I can't find anyone to look after my son. If it were in the summer I would risk going by car and taking him with me.

I am very grateful for your attention to our life and progress and for your help in curing my son. God bless you for helping children with autism by sharing your knowledge and experience with the world. I will try to give a regular account on the progress of my son. I have no doubt he will be cured, too.

148. Three more tiny little gains on our step by step path to recovery....yesterday Nick got a haircut and did not cry at all AND was relaxed enough that it was the first time it wasn't like a sheep shearing, he actually got to get a little style (so cute!). Also, he was doing some pretty terrible screaming in the car in the parking lot at Whole Foods while I tried to find a parking space (I wanted to scream too) and I let him know he scared me. When we got into the store he spontaneously said "I'm sorry" -total first! Lastly, He has requested a hug from me three times recently - HUGE new thing and I love it. Thank you MMS and Kerri.

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149. Thank you Kerri. For all of your help, answering my emails, and for all that you're doing to help all of us, help our kids!!! I was at a breaking point. Nothing was helping her anymore, her organs continuing to get worse, hadn't grown in 4 years, and had become Jeckyll/Hyde this past 4 years...A violent, raging Hyde being increasingly present more and more each year, each month. I knew something had a hold of her all these years. And it amazes me how 2 endocrinologists, 3 pediatric GI specialists, and many other doctors had no clue.

Thank you for ALL you are doing to get the truth out there. You are an angel!!!

Merry Christmas - xoxo

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150. Puerto Ordaz, November 4th, 2011

My name is Carolina Moreno and my husband is Rafael Colmenares, we are the lucky parents of a little 6 year-old whose name is Ana Victoria, she came to this world to give us the world's greatest lesson, through her we have learned the real value of life, to be steadfast, and brave. We learned that it's our job to fight for our dreams if we want to accomplish them, and over all we've learned that God is who holds us up and gives us the strength and tools to move forward.

My journey with Autism began the 27th of march of 2007, my daughter Ana Victoria was 23 moths old, her initial development was normal, but little by little she stopped talking, she didn't understand anything, she didn't miss her parents, she didn't play with other children or even her toys, she didn't like to be kissed or hugged, she acted as she was deaf but we didn't know that all this were symptoms of autism. It wasn't until the day that we went to a neurologist in our area, that someone told us that this was Autism, an incurable condition, and that our daughter would have it all her life. It was a very hard moment for us; all of our plans to be a happy and healthy family went down in a matter of hours.

As parents we didn't want to give up, after recovering from the horrible news, we began looking for information on how to help Ana Victoria. In our country of Venezuela there were 4 specialists in Autism and they were all using the gluten and casein free diet, vitamin therapy, as well as expensive tests performed in the United States to check candida and bacteria. Thanks to them I learned how important the diet was to get Ana back from Autism, without it, recovery would be impossible.

We did some testing through Great Plains labs, and the results indicated candida, bacteria, inflammation and much more . We started with Ketazol and Flegyl. My daughter was taking up to 400 mg of Ketazol even though she was barely three years old. Now with everything I've learned I can not believe that a physician could prescribe such a high dose to a child who is only 3 years old and weighs only 16 kg. That alone should be punished and criticized

However, I felt that I wasn't doing the right thing, years passed, Ana Victoria was 5 and her comprehension and attention levels were very low, my husband always thought there had to be something else we could do!

One day my dear friend Carolina Garcia talked to me about Kerri Rivera's blog, she told me that it explained the reason for the supplements and the hours they had to be taken, for example that the antifungals had to be given away from food and the pro-biotics worked better if they are given at night. After I read her blog and visited her website in July 2010 I called the Clinic Autism02 and Kerri Rivera herself answered me. I explained my daughter's case, and she asked me to give her an opportunity to help, and if in 2 months we didn't see anything different with our daughter we could continue doing what we always did. I told my husband and we agreed to try. I felt a great sense of peace when when Kerri told me, "I'm here, and I promise I will walk with you until we recover your daughter"

In August Ana Victoria was on Kerri's full protocol and in November God gave me the opportunity to go to Puerto Vallarta, México. An entire month in this city were my daughter received the hyperbaric chamber treatments, we started with MMS, plus we got together with Kerri at her home every night with pen and paper, she explained to us step by step how we could heal our children. From that moment a beautiful friendship was born between Kerri and I.

This is when I understood that Autism is caused by a weakness of the immune system and this brings as consequences; viruses, bacteria, candida, intestinal and brain inflammation, food allergies and contamination with heavy metals, and that it is necessary to attack every aspect to be able to heal autism.

The 23rd of November Ana Victoria Started to take MMS and in 30 days of treatment we noticed the firsts changes. My daughter's stools were consistent; there were no food residues or foul smells. When I came back from Vallarta I was full of new knowledge and a lot of MMS bottles, Ana Victoria had already a very well defined protocol and the best thing was that it wasn't a long list of supplements, only 7, MMS and Theralac. Everyone in my family noticed a great change in our daughter, better eye contact, controlled hyperactivity, she started saying her first words with sense and purpose; I want park please, I want food please, I want to sleep. She was doing much better in therapy and at school. Anita had begun her way back to the world she left when she was 1 and half years old.

When I saw this improvement in my daughter I decided to share my experience with other members of my community and it was there with my dear friend Yamileth Paduani and her husband Alejandro Teran that Fundación Venciendo el Autismo was born. Mr. Alejandro asked if Kerri could come to Venezuela and talk to parents in a simple way so everyone could understand that Autism is curable. Kerri was delighted to accept the invitation and in only 7 moths of work we had 2 conferences and many evaluations and nowadays there are 700 kids on Kerri's protocol that is: casein, soy, gluten and sugar free diet, some supplements depending on every child, MMS and Theralac. The results are very positive and there hundreds of families that have started with their children's recovery.

Then came the great discovery of the parasite protocol, for me, it was the missing piece in my daughter's puzzle. The first few months of the PP were severe (fever, laughter, hyperactivity) and many worms in her stool. However, after all these worms came out out I saw how her mind cleared, and month by month we waited for the full moon to deworm ...

Ana Victoria is now improving very quickly, she is a girl that enjoys being with her family, the park, a day out, she goes to school and she says to me that at school she now does her work in silence without crying, when I arrive home she greets me with a smile, she runs to me and calls me Mom, she tells me what she wants and what she doesn't, she can use the computer like an expert, she takes her own shower and dresses herself, she even picks out her clothes, she knows when Christmas is coming and that there will be gifts. Her therapists and her shadow teacher are really happy to see how Anita is progressing day by day.

Yesterday we were all at the table eating lunch ... and she points with her finger …"Papa's food, Mama's food and Ana Kikota's (Victoria's) food…yummy… heeheehee. My husband and I were laughing with excitement and happiness. Some time ago we felt that speech would be nearly impossible for Ana Victoria.

My advice: do not be afraid of MMS ... be afraid of autism; that which is unforgiving and has the power to destroy lives and families if we don't attack it on time.

We are grateful to God because He has never abandoned us and has always given us the strength and tools to fight and to believe that it is possible to recover our children. We thank God for putting Kerri in our path and we ask God to bless her everyday for having such a big and noble heart, she who is always helping others in a selfless way. We also thank Jim Humble and Andres Kalcker for helping us find the missing piece in this great puzzle that is Autism. We can do it!!!

To all of you, many sincere thanks for helping the children in my country.

Blessings,

Carolina Moreno, President of Fundación Venciendo el Autismo. (The Defeat Autism Foundation)

Venezuela.

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151. Good Day, first of all I want to thank God for giving me all the necessary tools to be able to help my son, Jesus Soto who is 8 years old today. Jesus was born normally with no complications, loved by his parents and family, everything was going fine, but when he turned 18 months old he became ill; laryngitis, and fever, amongst other things.

He was diagnosed with Autism at age 3. As a worried mother, I took him to the psychologist because I observed several behaviors that were not normal. After the terrible diagnosis we started to take him to a specialist after specialist, they were all very good doctors, his DAN! doctor in Venezuela, and my sons gastroenterologist were very helpful. I met a very special friend Mayerling Aparcedo who brought the ABA method to Venezuela. My son had many improvements but we still felt that we needed something else. I spent my time on the internet finding out as much as I could until I found Kerri Rivera that without even knowing me helped me via Internet, talked to me about MMS and about the supplements and how to take them. My friend Carolina Moreno had the joy to travel to Puerto Vallarta and wrote to me from there, telling me that MMS was helping a lot of children. The 14th of December I ordered my first MMS and the 27th of January it arrived to my country, from that date on my son is taking MMS.

The 2nd of April Kerri arrived to Venezuela and I went to see her, I took all the tests I had and she checked them, after only two months of taking MMS his viral *load went down to near normal levels, and his liver profile showed no problems. I made some adjustments that day and I continued with the treatment seeing a lot of improvement in his language, socialization, understanding of things, his hyperactivity has gone down and the laughter for no reason stopped. I'm very happy with the results and now all the family is taking MMS.*

I'm very grateful to God for putting my husband in my life, as he has been a very special part of this battle that we are winning, I also want to thank our family, Kerri, Carolina, Yamileth, Mr. Alejandro and everyone from the Fundación Venciendo al Autismo.

Yours truly,

Maria Campero

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152. *My baby girl Yuliangel Nazareth Quijada Montero was diagnosed with autism when she was one and a-half years old. From that moment she was given a treatment to allow her to sleep and to control her tantrums: "Risperdal" which had absolutely no effect, I gave her up to three pills before bed and even them nothing happened, I was just damaging her brain. She didn't sleep night or day, I was worried because she screamed all the time and she hit herself.*

The 2nd of April 2011 I attended the conference of Fundación Venciendo el Autismo, where I heard for the first time that Autism had a cure. Kerri explained in a very simple way how I could cure my girl, even though I didn't have all the economic resources necessary for her treatment, the Foundation helped me with a part of the treatment, MMS and multivitamins. From there I started noticing changes, with a lot of sacrifice and effort my girl was on a strict casein, soy and gluten free diet. When I started giving her the MMS I would give her 72/2 on weekends and then I noticed that there was a lot of mucus in her stool, from there she started talking, she slept the entire night, and took naps in the afternoon, she pays attention, she knows how to count and all the colors with only three years of age. For me MMS is a miracle, since I started giving it to her she is a very healthy little girl, with no colds or any of the diseases she used to have, she is now considered to be very high functioning (14 pts. on the ATEC scale) with MMS, Vitamins, and the diet my child is getting out of the Autism spectrum. She does not go to therapy because of my finances but my sister Yenitze Montero interacts a lot with my girl, and her grandparents Raiza and Julian help me a lot with the diet, my nephews Jesus and Luis are also helping me with the home therapy and of course her dad and me fill her with love and care. My daughter is healthy, she has meaningful speech, she recognizes herself, she sleeps well with no pills and we are all very happy with the results. God Bless the entire team at Fundacion Venciendo el Autismo, especially Kerri Rivera for bringing MMS to my country, it is absolutely miraculous. Blessings.

Yurliana Montero and Jonatha Quijada

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153. *Martin is 6 years old, weighs 19 kilograms and is diagnosed with severe non-verbal Autism. He was diagnosed when he was 2.*

He almost made no progress with therapy, when he turned 4 everything seemed to be lost, but when he was 5 we tried a new therapy and he started to say a few words. He also got very sick almost everyday, he coughed a lot, had an ear inflammation and fever, he couldn't go to school.

He started taking MMS the 29th of June 2011, when he was only taking two doses of one drop and two drops every third day has intestines were not moving and he had a psychotic attack (something that I've never seen before) and this lasted 2 hours.

Children with Autism are severely intoxicated so his reaction to the MMS was very clear. After 15 days of taking 8 takes of a drop a day Martin stopped coughing, he is more alert, connects all the time, his expression changes, he started to make friends, he starts to play with the computer, I hear from school that he'll be a preschooler because all the improvement he has had and that he didn't have all year. (I was almost going to get him out of school) he was attending school with a shadow teacher but had no apparent social communication or increase in cognitive capabilities.

This past October, in a meeting with his team of therapists, I asked them all what they thought about Martin's improvements and they were very happy, I asked 2 of his speech therapists who have worked with him for more than three years, "Did Martin have severe autism?" "Yes." They both responded. "And now?" I asked them. "Noooo" they both agreed. The rest of the team, who have only known Martin for a few months looked at each other, and said that they could not imagine Martin like that.

The path out of autism is scary, but MMS is giving us great joy and hope.

Martin has not been sick anymore, the last time he was sick, before MMS, we had to admit him to the hospital, his cough was so bad that he was vomiting non-stop.

First off we give thanks to God, we thank Jim, Andreas, my dear Kerri who guides me with all her love, and to every single mother that is in this struggle. I also thank Mr. Luis from Buenos Aires, Argentina who has made it easy for me to get MMS; he is a wonderful human being who helps those in need.

We are on the way to full recovery for Martin, I'm sure of that.

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154. So I just redid my daughter's ATEC. She was a 71 a month and a half ago and is now a 60!!! I thought she was making nice improvements but it really set in when I saw her score. Some things that have changed for her are now she is pooping on the toilet every day and telling me. She used to just go every few nights in her diaper. There's no more diarrhea, she's not constipated, she's sleeping great. She is just starting to show signs of imaginative play and a big one for us is that she just learned to blow. She couldn't blow no matter what we did to try to teach her. Now she's got it. Hopefully more good things to come.

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155. My now 8-year-old daughter was dx with autism at 18 months old. Started GF/CF diet and started with a DAN! She slowly made progress with speech, had a few words, a few 2 and 3 word sentences, and despite having autism, she was always a happy, calm, sweet little girl. Shortly after her 3rd birthday, she "changed.' She became more of a Jekyll / Hyde personality, and all progress in speech and improvements in eye contact and sociability started to fade. Seemed like everything we did was just like yo-yoing back and forth between improving, and then crashing yet once again.

Last year at this time, we had just left the doctor we had been taking her to. For years she was on antivirals, antifungals, antibiotics on and off, SSRI's, Tenex, and when her violent SIB had become so bad the second year into treatment with him, he put her on Abilify. SSRI's and the Abilify did nothing for her except make *her behave worse. Neither did any of the other things he had her on. The first year she was doing pretty good, but possibly because the antivirals were acting as an anti-inflammatory. She always had chronic constipation with loose stools/ diarrhea. Nothing helped that either. We finally left that doctor who yelled at us in his office for 20 min straight, in front of my daughter, because he did not like that I had been challenging him on all of this for the past 6 months. I was no longer going to let him put the blame on us and everyone else... that her ABA and speech therapists didn't know what they were doing, and telling us she acted out this way because we didn't know how to give proper time outs or how to correctly give "pep talks" at bedtime. I was convinced that she had PANDAS/PANS and/or parasites that were causing her ever increasing SIB, loss of all progress she had made in speech over the past 4 years, and the fact that she had not grown in 4 years...did not gain 1 pound, feet did not grow at all, and she only grew 1/2 inch in height in that 4 year span. We had taken her to a very well respected endocrinologist the previous summer who ran all the tests. Could find nothing wrong as to why she wasn't growing. But he decided to put her on HGH anyway. Thankfully, we left and decided not to give her the HGH. We also took her to one of the best Ped Psychiatric doctors at UCLA who specialized in autism that summer. He observed her, her SIB happened right there in his office for him to see. He said her SIB is coming from pain, discomfort, something medical going on inside, most likely stemming from her gut. He suggested we get her scoped upper and lower. So we did. The only thing that came up was on the upper endoscopy, and that was that she had esophageal gastritis. So the GI dr gave her Nexium.*

All the parasite stool tests we had done over the years had always come back neg except for one at age 3 came back with Giardia. But that was it. So last January, when we had finally left that her doctor of 3 years, her liver AST and ALT were at 130 and 135, her Creatinine (kidneys) were severely elevated at a dangerous level, she now had hypothyroidism, and after testing her cortisol thru blood and saliva we discovered she was barely making any at all. She had dark circles under her eyes, grinding her teeth for 3 years now, and agitated beyond belief ALL the time. Mind you when we started with him 3 years prior, her thyroid, liver, and kidneys were all in normal range. She did have dark circles, many many food allergies, some SIB, but nothing compared what we were dealing with now, or what was to come.

So now, what to do. We took her to a very highly recommended Pediatric GI in Los Angeles who was very nice. Listened to what we had to say. Ran the most sensitive and comprehensive stool analysis. Came back with nothing at all. Then took her to the head of pediatric Infectious Disease at Cedars Sinai. She obviously had her mind made up before she even walked in the door. She saw the word AUTISM on my daughter's chart, and that was it. I showed her every blood and stool test, explained the not growing at all for 4 years despite all the endocrinology labs said everything related to growth was in normal range, her severe SIB. She said to us..."I know you want to help your child. You want to find something "medical" that has caused her autism so you can fix it. But the truth is, your daughter has autism. You need to accept that, and take her to a pediatric psych dr who can help her with these SIB's. There are lots of meds that can help her be calmer." Had she not listened to one damn word I told her!!! All the meds we had tried in the past did nothing, already took her to a psych dr who specialized in autism telling us something internal was wrong. She would not run any blood tests, or any other kind of Infec Disease tests. So with that, my *husband, my sister, and I completely dumbfounded started to walk out. The dr then had the nerve to say..."She hasn't been vaccinated since 18 months (she was 7 here) Let's get her caught up right now before you go. I can give her 6 vaccines today." I looked at her and said you have got to be crazy! I am not giving my very sick child vaccines full of the poisons that did this to her."*

So a month later we started with doctor who "gets it." Who listens, and treats parents with respect. Values their opinions. And the networking I had been doing for the past 6 months on a few different bio-med autism groups with other moms was paying off. The moms are the ones who KNOW!!! That's how I found my daughter's current doctor and how I found Dr Maile Pouls last June to help her with nutritional and metabolic healing. Dr Pouls ran a $100, 24 hour collection urine analysis, and we found out she had severe malabsorption, Ph was too Alkaline, she was catabolic, extremely electrolyte and mineral deficient, severely Vit C and D deficient, and had severe bowel toxicity. Working with Dr Pouls and her new doctor lead them to suspect parasites/worms. I was encouraged to look into mms, but of course I had heard nothing but bad things like it's bleach. I was very hesitant to try it, but I researched it, and sought out other moms on Facebook who were doing it. The toxins from the parasites had completely taken over her body and brain. She was SIB almost all day, every day by now. It was pure hell. We thought we were going to lose our minds it was so bad. We had stopped taking her anywhere but school and dr's appointments for the past 2 years because she would just suddenly out of nowhere, for no reason, violently freak out and there was no way to help her calm down. Her doctor said she's so toxic, and her body is so sick that she can't detox. That the mms will not only help kill, but will neutralize the toxins and help her calm down. So we started mms, and I could not believe how much calmer, happier, and more present she was in just a week. MMS is literally saving her life, and bringing her back to us. Before starting mms, we did just parasite meds like Alinia and Mebendazole. The parasite meds alone did not help her, even though she was dumping worms, but she was still completely psychotic, and getting more crazy and manic every day. Since starting mms she has dumped hundreds of worms, some 10-12" long, ascaris eggs, TONS and TONS of the shedded skins of the worms, tons of liver flukes, and hundreds of tapeworm segments. We had not done any PP yet. This had all been with MMS only! We actually started Albendazole for treating tapeworm about a month ago and saw immediate improvements with it. It really seems like this is her biggest beast right now to deal with.

These are her labs from before MMS, and after starting MMS:

2/7/2012 - one month after leaving scumbag dr of 3 years

AST = 79 ALT = 108 Creatinine = 1.24 EOS = 11.2 Sed Rate = 9

~ Started MMS 11/23/2012 ~

12/4/2012

AST = 73 ALT = 64 Creatinine = 1.32

1/15/2013

AST = 61 ALT = 60 Creatinine = 1.30

2/27/2012

AST = 51 ALT = 42 Creatinine = 0.92 EOS = 5.1 Sed rate = 12

Ref Range for AST is [15 - 46] ALT is [3 - 35]

Ref Range for Creatinine (kidney) is [0.60 - 1.20] Shows how well kidneys are working. Anything close to or over the 1.20 is considered to be of serious concern

*Ref Range for EOS (eosinophils) is [0.00 - 3.0] * High EOS are always seen with parasites*

Ref Range for Sed Rate (marker for inflammation) is [0 - 10]

Her doctor said her Sed Rate is likely high because when killing off pathogens and detoxing, inflammation will go up temporarily.

So I say never give up. Don't listen to doctors who don't listen to you. Kerri, thank God you saw those bottles of MMS at the clinic that day and asked what they were. And that you bought some out of curiosity and tried it. And that you selflessly have taken what you've learned and experienced, and shared it. Given so much of your time to help others, to help heal and recover their kids. You are truly an amazing person. We finally have the answers to our daughters autism after almost 7 years of numerous doctors and specialists, so many tests, so much money and valuable time wasted... and now we finally have real hope...real results. We know without a doubt she is going to get healthy, which will in turn give her the happy joyful life back that she once had before she got "autism." ~ xoxo

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156. *Today was just wonderful! We have been on MMS since 12/11 and this is our second round of Ivermectin from our Dr, just started today. My son has been very rigid lately, but not today. For the first time in over 6 months we went to the park and had a great time (no stimming), then we were able to run an errand and pick up books from the library. (he usually gets upset unless we do one specific route in the car). Felt like a regular mom running kids to the park and one errand. So lovely!!!*

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157. *Just a testimonial to MMS. For those of you new to the group and still unsure of MMS protocol I wanted to tell you about us. I was afraid at first, but we decided to try MMS. Within 3 weeks my son went from an ATEC of 36 to 18! That was amazing. Then we were afraid of the enemas. We said no way, we would just do oral MMS. of course after seeing others progress here we decided to do them. He would calm down! Then for months we agonized over the PP. We were afraid of it. We were scared of the meds, everything. Finally we decided to try it too. We are in the middle of our first PP and our son, who used to hit, kick, bite and scream at me over the smallest things all the time, has now been a perfect joy. When he gets mad it is over quickly and does not escalate into world war 3. Also these bumps he had on his face have cleared up along with his attitude! So if you are unsure of MMS like I was, here is one more testimonial of just how good the protocol really is.*

Thanks Kerri, all the other moms that came before me!

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158. *Dear Kerri and the readers,*

I would like to say that we started giving MMS to my son Filip, autistic/PDD NOS, when he turned 5 years old, after having tried lots of things (diet, many different supplements, HBOT, some sort of behavioral therapy Teach and ABA), we have seen enormous changes already in the first month.

I had heard about MMS from a mom of an autistic child. I started reading about it, but was not impressed by the comments I read on the internet. I contacted *a few mums that I knew from the Son-Rise programme in the US and they have reassured me that it works miracles.*

I was however very sceptical of MMS, as I have read so many "negative" comments on the internet. This is why I decided to start it myself for a few months to see what would happen to me. Also, I had to figure out how I was gonna dose MMS 8 - times a day, when I am working 10 hours a day and Filip is going to the kindergarden.

In fact, I was just feeling great when I started using MMS.

I wanted to start with my son when on holiday, but my husband displaced MMS bottles by mistake. I was so mad. I have only found them the last day when we were returning home. I have immediately decided to give one drop to Filip before we started to drive. I need to underline that my husband was very sceptic. Filip would at that time speak, but it would mostly be scripting and rarely would he say things in context. Otherwise he also had other autism symptoms- tantrums, no friends, low muscular tone, no drawing, obsessive occupations (in Filip's case watching cartoons and reading books), no sense of danger, wandering out, nose picking, scratching but, toe walk etc. But suddenly Filip started commenting everything in the car, asking questions, observing the things he would see from the car etc. Me and my husband looked at each other and my husband commented " Maybe it is working after all".

Filip's ATEC was 48 at the time we started. At start, my mother-in-law helped out in dosing and we were able to dose 8 times a day. Filip's ATEC fell to 32 the first month. Unfortunately, my mother-in-law read some horrible stories on the internet and the FDA's advice was detrimental for her decision to stop dosing Filip, even though she was seeing wonderful results, she was scared and said that she is only believing the official medicine, admitting that the official medicine has nothing to offer our son.

I was very disappointed, but continued to dose as much as I could, however not reaching the recommended 8 times a day. I was therefore only able to dose 4-5 times a day. I started telework on Friday's in order to at least get 8-10 doses in on Fridays, Saturdays and Sundays and 4-5 doses the rest of the week. My son was great in November (the volunteers working on Son-Rise with Filip were commenting on unprecedented success), but his ATEC only fell to 28, I would say due to low dosing the progress was slower. Filip was having some hard times in January, when he was more hyperactive. At that time we have also introduced the GcMaf injections, which could have added to Filip's hyperactiveness.

But since two weeks now Filip is back to his shape. He is so communicative, uses unseen vocabulary, amazes us every day, he started drawing without being prompted, communicates with everyone, was invited to a birthday from a girl at the kindergarden, started to dress without prompting, started to tell me:" Common mummy, hurry up, let's go." or "Where are you mummy? What are you doing?" or when he occasionally wakes up during the night " Is it day already? or " I should not go on the street, because a car can hit me" or " Daddy, you are not sad, you look angry" or just yesterday when he draw a picture in the kindergarden he said to his teacher " I want to show it to my mum". The list goes on and on and every day I have to thank the all mighty for having led me to Kerri and to the MMS protocols. I know we are on the right path to recovery and I am not scared of the future any more. And, finally, i just did his ATEC to check out his ATEC- it is 16!!!!!! LOVE IT! LOVE IT!!!!!!

Kerri, thank you!!!!!!!!!

159. My daughter has had really bad SIB for over 4 years. We've been in the ER for massive goose-egg bumps on head, and she always had severe bruising on her tailbone and spine from dropping herself down, butt first and legs in a "W" position, onto the floor, and then would fling and flail herself into walls, tables, furniture, bang her head on all of the above and the floor, a rage like she was the girl from the Exorcist. Nothing could stop it. It just had to run its course...like a tornado. Comes out of nowhere, and it will disappear when it's ready to. Nothing can stop it.

But after starting MMS, it was 80% better right away. Then after 3 weeks it started coming back. For a month it was really bad again, and we could not move up past 2 drops without her going crazy. Then after you had us switch to the HCl, she was remarkably better in about 5-6 days. She has had a few "episodes" in the past 2 weeks, but now they can last 30 min max, where before mms they would last anywhere from 15 min - 2 hours literally non-stop. The year before starting mms, there were times I had to lay her on the bed or couch and just sit on top of her, like on her butt so she couldn't hurt herself. I would just lose strength after about 30-45 min of trying to hold her.

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160. Hey everyone! Just wanted to give a positive report about the HCl activator. My son is 12, non-verbal, very hyper and lots of food intolerances. I got mine in the mail today, gave a quick 3 drop dose to my son before he went out the door to school, noticed he was a bit more compliant and calm than usual after school. have given 2 more doses since coming home and he has been doing his usual, but he is much more calm today than he has been in months!!! I gave him a snack and he took it and started to eat and I told him: can you say thank you mom? and he actually responded with a sorta grumbled "graaaa mooooom" which was to me "thanks mom."

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161. Thanking God for Kerri Rivera and happy here too. My 15 y/o is in the chorus of his HS play. He has to do 5 costume changes, his own hair and makeup and several song/dance numbers, which he did perfectly on opening night! He is not your typical MMS/autism kid. He was pretty much recovered, starting with biomed at age 2.5, until age 11 when he hit puberty and he started getting rigid and anxious. We had some supplements going and were starting to look at stem cells when we found Kerri. He is not on the strict MMS protocol but takes it when he can and does PP and enemas each month. He is so much better since starting this last August! So thankful for all the info and support from this group.

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162. Hi Kerri,

Last week I contacted you regarding our 8 year old son and his focus issues and the disappearing act his mathematical skills have taken, and we've done our best follow through on your advice to up the number of doses to 16 per day. I visited my son's Integrative Medicine doctor this morning, who has been his biomed doctor for the last 3 or so years to do a live cell microscopy, and to see if he had any ideas about the focus issues our son has been having. I told my son's doctor in detail what we've been up to over the last 10 months (MMS Protocol, Parasite Protocol) and he took it all in.

When he looked under the microscope he was shocked to see that our son's nasty dysbiosis issues were gone! He told me that he's had almost no luck completely getting rid of dysbiosis in a case like my son's. The yeast beast is gone! He still has evidence of leaky gut but the drainage looks great. He was so excited, our 20 minute scheduled visit turned into 40 minutes as he wanted *to know all about what we did so he can find a way to use it in his practice. He also remarked that you must be one bright lady to come up with the protocol, but we already knew that. :-) He had us fill out an ATEC when we first visited him back in 2010 and our son was at 55. He dropped into the 30's when we started him on Carnitine but the MMS protocol has brought him down to the 6. The doctor also noticed the distinct lack of autistic behaviours, so it's nice to get some outside feedback to help confirm what we are showing on the ATEC. I asked him directly if he thought we should change anything at this point and was direct...don't change anything keep going. And so we continue on our quest for the zero ATEC. :-) About two years ago we did a chelation challenge test (DDI) and found our son extremely high in lead and so we proceeded with IV chelation at that time. He ants us to do a chelation challenge test to check the metals status just to rule out lead and the possibility that metals might be still at the heart of our son's lack of focus and more ADHD like symptoms.*

He wants me to send him some information on your MMS protocol. He attempted to use chlorine dioxide about 10 years ago and found that he couldn't get the results that you are getting. I'll send him to MMS Autism website but can I include your contact info (email)?

Thank you for being so patient with us and everyone. As you know full well when it involves your own kid the emotions come out and it's hard to remain logical.

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163. Drum roll....

I have been dying to share...

Been off MMS for a few weeks...AND HOLY SMOKES we are ALLLLL GOOD!!!!!!!!!!!!!!!!

Summary...

My daughter—PANDAS—MAJOR sleep issues—fluctuate between diarrhea and constipation

Me—Acne—horrible—and nail fungus

ALL GONE. ALL.

NOBODY could EVER, ever, ever tell me why I broke out so much esp. with our squeaky clean diet.

First PP, OMG it was REALLY bad—worst ever—and became cystic—painful—so for SURE worse before better in my case BUT believed in protocol and KEPT GOING.

By month 4, GONE and yet to return

Fungus—gone in month 1, never to return

My daughter:

Well, you know, AMAZING!!!!!

YOU, Kerri, YOU helped me figure out FINALLLLLY after a zillion docs, WHY MY KID could NOT SLEEP! EVER! 7 LONG years... long long—exhasuting years—and it was PARASITES NO DOUBT in my mind! Month 1 of PP, literally like a light switch, SLEEPING —falling asleep ON HER OWN—(not with a circus routine to "get her to sleep") AND staying asleep ALL NIGHT LONG! UNREAL! This is HUGE!

AND bye bye PANDAS (Siver/Aloe nipped it, MMS maintained her gains, *BEAUTIFULLY!) SO I do believe in our Silver Aloe protocol for PANDAS, 100% worked for us! AND MMS. Both.*

AND since OFF MMS, my daughter is 100% pooping NORMAL—OMG first time in her WHOLE LIFE!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!! (on MMS it was still fluctuating...)

AND she is eating things she would have NEVER ever touched! EVER! Raw veggies, nuts, trying EVERYTHING I make... unreal... this is HUGE too... the "healthier" you get, your tastes DO change... and one becomes less "picky"

I have learned that SOME probiotics can literally throw a child into a PANDAS rage--and also brought back MY symptoms—literally within 12 hours of consuming. (Like "Regarding Caroline" posted) This clearly happened to us. Mental note: NOT all prob's are appropriate for everyone. We react to fermented food—so I am going to experiment with no prob's and with THeralac __ONLY THeralac BTW

Now,

We are back to silver/aloe, daily, as prevention

We will still take DE (prevention)

Vit D3

Trace Mineral Drops

Enemas as needed

AND I am going to go BACK to the herbs for 3 months around full moon "just in case"—

I CANNOT WAIT to meet you in person, THANK YOU, and share our story with EVERYONE that will "hear me".

Again, my daughter did not have 'autism' per se, but autoimmune issues, meaning that, perhaps, her treatment protocol is 'shorter' then someone who is "more sick' etc. if that makes sense.

We also did a boat load of work prior to this. Meaning diet in place, for instance, for 4 years already—so healing began. This was the final layer for us. The frosting on the cake!!!!!

I have 2 brand new bottles of MMS in my cabinet :) AND will ALWAYS have it on stock!

With MUCH LOVE and respect to you Kerri.

-Jeni, IL, USA

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164. *My daughter was born Sept 9 2010 and she had pretty good health until she had 15 months, she was able to say five to ten words by then, she had all her vaccines on time as recommended by our pediatrician, and she was really lovely and happy but suddenly every start to change slowly, we noticed she start losing the words she had learned, she use to wave people saying hi, and suddenly she was not interested on waving anymore and she start to isolate herself little by little to the point she stop being a happy girl, she barely looked at us and we started to worry about it, anyway, I believe the first thought every parent may have think in this very same situation is that her personality is different than other kids and is something temporal.*

    When she had 18 months we went to the regular doctor check and they asked us to get the opinion of a development pediatrician since her social and language skills were behind the expected, and this started the worst nightmare ever.

It seems like every single development pediatrician has a waiting list huge enough to have more than a couple months totally scheduled, we called on May and the first available appointment was 4 months later, we called like 4 or 5 of the recommended pediatricians and institutions but it was all the same thing, but we finally got a pediatrician, not form the recommended list, but he made room for us in a couple of weeks and we were able to see him in a couple of weeks.

The diagnostic was mild autism, the recommended treatment was ABA therapy and the follow up was going to be 1 year later since he did not have may expectations of positive changes in the next 6 months, we were devastated by this, my wife was in denial, and I started our journey to recovery the very same day, I started researching and suddenly I found tons of information about autism and people who claimed to have recovered their children from autism.

I sent emails everywhere and I never imagined I would have such a great response from every person I wrote extending me a helping hand on all my doubts with the most sincere and honest recommendations, 2 or 3 days later I found Autismo2.com website and I saw all the videos available.

I bought 3 or 4 books on amazon, I saw many hours of recordings and seminars in Spanish and English, and I was amazed about some kids losing their diagnostic, but also about how they were affected by heavy metals, bacteria, viruses and all sort of things.

At the beginning I thought my daughter could not be sick, she has never had a single cold, how come? but a home heavy metal screen test gave us the first clue, and some lab tests confirmed the very same problems all our kiddos share, mercury levels on the roof, candida, yeast, you name it.

I started the GFCFSF diet the first weekend after her confirmed diagnosis and just one week later we started noticing changes, then I started with baths with bentonite clay, and noticed more improvements, we also started ABA on July, and little by little our daughter started to improve, later on we introduced MMS baths, Quinton water, DE, probiotics, and she improved every day.

I honestly believe that the early diagnosis and prompt reaction from our side played a big role on her fast recovery, It happened that we never canceled the first appointment that was made with the most recommended development pediatrician, by then we were looking for a second opinion and a new evaluation due to her huge improvements, we never imagined this pediatrician will say what.

Although my history with this disease or condition has been very short nobody knows how much pain, stress and suffering had caused to our family, we now enjoy our daughter more than ever when we see her playing with her old sister and taking away every single concern we had, we continue keeping an eye on her development but she is doing really well, I wish nothing more than every single mother I have hear on the discussion groups I follow have the very same results we have had with all the guidance from such smart and courageous parents like Kerri Rivera and many others that shed us the light on our darkest night.

I am more than grateful with all of those parents, I would do anything on my reach to help them, we need to help every single kid and family that goes through this disease to recover our kids.

UPDATE:

I'm very happy to forward the last ATEC from my daughter, today we came from her 2 year check up with the new pediatrician and she found her pretty well, she just told us" It's pretty hard to believe she was diagnosed with mild autism keep *doing whatever you are doing, since I would say she is acting like a regular kid for her age."*

I would say that keeping in mind that most of her ATEC score is on the Language section, for a 2 year old and from what we came from she is on her way to full recovery (Previous ATEC was 55, at this writing was a 23)

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165. *I found Jim on the Internet 2 years ago, and I immediately started Jim's protocol for MMS. Unfortunately we were so loaded with mercury, so when I reaches 8 drops of mms, and my son 2 drops (after more than 2 months on slow upgrading) we were really sick, again. All the heavy metals that where released with mms could not get out of us. That´s when I found zeolites, and that was our way back.*

Now, two years later, my arthritis is gone, and now I know it was mms that killed the clostridium bacteria that I had been carrying since I was 13 (I am 52 now). 6 months ago my son fell off his bike and got an open wound. It was infected and some hours later the blood was black in his hand. Now I had a choice, to go to the doctor and give him antibiotics, which I knew would kill the bacteria but make him worse, or do it my own way. I gave him 2 x 3 drops of mms, and the blood was ok in some hours, I thought. Some days later he started to wave his hand. I thought he had eaten something else that he could not digest, but it got worse. After 4 weeks he was not only waving/flapping both his hands, but also his head. Then I started get suspicious. I tested him for bacteria (I use a Rayonex PS 10 for testing, bioresonance) and I found Clostridium botulism.

Now I had a choice again. I had a fully booked week, but his father came and took him home to his island, where they could use MMS every day and be in a calm environment. He got 2 x 3 drops of mms, for 6 days. After 3 days his father called and said "Eva this is scary, the flapping is getting worse". And I smiled and calmed him down, the bacteria are dying and the toxins are being released, I said. The zeolites took care of the toxins, and after 4 week he was ok again.

My lesson in this was, apart from the clostridium toxins, that I also found an imbalance in my son on Condrogenesis with the Rayonex. When I was 13 I stepped on a rusty nail. The blood was poisoned in the foot, but I did not dare tell my parents. After 3 days the whole leg up to my knee was black. I got antibiotics, of course. At 18 I was diagnosed arthritis in my knee. I think I had small amounts of bacteria left, as my son had, and the toxins from clostridium bacteria degenerates the cartilage near the infection. After some years one develop arthritis. I did, but it's gone now!

Eva, Sweden

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166. *Drum roll please.......my son is 17 years old. He's been on mms for 5 months now, I'm so excited I don't even know, could it be 6? I think we started late July. He started with a 63.......he is now a 7. He went from 63 to 25 in just a few weeks, then a 13 a couple months later, now a 7. I feel like I'm cheating every time. I go back and look, argue with myself, nitpick....but whether he's a 5, 7 or 9, it's nothing short of a miracle because just one year ago, he was WAY over 100.*

The ATEC is not perfect, not even close. There are things that the ATEC does not show. All that is true, but this is incredible improvement that no doctor I know would have ever been able to accomplish. Been there, did that, spent the 425K+.

And no, it's not just MMS, but that has been the main treatment and everything else we do supports MMS and general health because I believe that in the end, *it's a battle between your immune system...and all that's attacking it. We are winning and I sure do wish they would STOP CALLING IT AUTISM. That alone hurts so many.*

Here's a little background on my son: Matthew was very high functioning from age 6-12. That was after diet since 3, floortime play therapy, some aba, AIT, IVIG, chelation for a year, OIG, years of infusions of glutathione, vitamin C, B-com, etc...immune stuff. Then he did very well GFCF ages 6-12, ran track (very well), 2nd degree black belt, boxing lessons, etc....Then puberty hit, and what I did not know about, Lyme and co-infections RAGED, and for around 3 years, I lost him cognitively, worse, worse, worse. At 15, he was like an advanced Alzheimer's patient, ADVANCED, he had lost ALL short-term memory, it was horrible, he struggled to think and could not.

He became more and more violent; choking me, kicking me, did I say he was a blackbelt? Even though he lost everything cognitively, like the ability to answer a question, those karate skills popped back into his head and he nearly killed me.... really close a couple times.

That was a year ago when his ATEC was over 100. So, here's what worked: 1. Low amylose diet helped with the constant urinating. (he acted like a diabetic and had 14 of 16 PANDAS symptoms so auto-immune) 2. Biofeedback helped calm him some. 3. Cholestyramine helped him psychologically - I could see him clear up mentally in minutes. (chemical/mold/dust sensitivities big time) By this time, his doc had him on Ketamine for pain. 4. PEMF (pulsed electromagnetic field device) stopped the pain in 6 weeks, got him off of Vicodin, which was not working anyway at double doses, and all the Ketamine. I hated drugging him. Got him off the psych drugs over 6 months time. Then he got a lot better but communication did not really come around until 5. MMS. BAM. Big improvements in communication and PERSONALITY. With MMS, even his laugh changed to a typical sounding teenager's laugh, and for the first time in years, he can sit still and stop pacing, pacing pacing....the parasites were eating him alive....and now more recently, I know 6. Hydro-colonics is taking us to another level of clear communication. Now there's lots of spontaneous language.

I write things on Facebook so that I can remember and maybe write a book one day. I don't care how bad things get, believe me, your kids can get better and it's amazing, they really do store up all this info that you didn't think was there. It is there, and they will share it with you one day.

I hope one day Matthew can share his perspective with others. It's just that it has taken a very long time for us to help him understand that the things he did back then were not in his control so I'm careful not to talk about it. For months he would out of the blue apologize and feel terrible, over and over. Then there's memories of his dad losing it also....protecting me.

Thankfully, Matthew has blacked out or forgotten a lot of it. He did say he remembers being locked in his room. We had to turn the lock around and sometimes lock him in there. Bad memories. We were all traumatized. But not anymore. He is a different person today but he's always been the sweetest boy I know. I knew that, even back then. One day, he'll probably talk more about it.

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167. Hi Kerri,

First of all a HUGE big thank you for what you are doing with our children! My daughter has been on MMS two weeks now and she is like a different child!!!!!!!! Every day she gets better...By leaps and bounds. She WILL be one of your recovered ones ;)

UPDATE:

My daughter has now been on MMS for three weeks. ATEC down from 78 to 44. This IS a miracle. We have been in absolute desperation for almost three years trying to figure out what in the world is going on with our child. After hundreds of thousands of dollars, experts all over the world, LA, New York, San Fransisco... and nothing would work. Minor improvements but nothing that I could say really worked. Everyone always agreed that she probably does not have "autism" but what is making her behave that way?!?!?! So a long story short... If I could I would wrap my arms around all of you helping my daughter and so many others through MMS until I was sure you truly understand what your dedication means and that you are saving lives...literally <3 This is by far the biggest thing that has ever happened to my family. We are forever thankful.

UPDATE #2

I sent you my daughter's ATEC a week ago but redid it today. We started MMS in December and I decided I will do the test every month. Here are the results, 4 more points gone!!!! In 1 month from 78 to 40... Almost half off!!!!!! Her team is blown away ;) all we need now is that language score to come down... Kerri my goal is to have her recovered by A1!!!

Update #3

We are seeing such amazing improvements every single day. I think the true testament is the daily feedback from people working with her who do not know we are doing MMS. Here is part of a note from her SLP " her communication on the whole is truly remarkable- words, iPad, eye contact...everything is improving!!!!!!! So exciting. Has anyone told you lately that your daughter is a superstar? You should be so proud. :)" And I am...

Our main challenge has always been anxiety and today we had a breakthrough on that front. Instead of clinging to me for her dear life when I separate from her at school she took her friends hand, waived AND said goodbye and walked away... Here is the best part, she then turned her head, waived and gave me the biggest smile . Her face at that moment is forever engraved to my heart.

Also for the first time EVER my son was able to have a friend come over from school in our car without her having a major meltdown. Instead she shared her iPad with the friend to show him her program and use it TOGETHER!

Honestly I think our major challenge at the moment is for the rest of the family to heal with her... We had lost all hope and settled for life with Autism. We can now look at the future very differently and actually look forward to it! Love our new life

UPDATE #4

I have never really posted gains but this is too huge not to share. We started MMS 3,5 months ago and at that point I could hardly take my daughter to the grocery store. And even if I did it was a guaranteed meltdown. Well we just got home from a two week long vacation that included travel by air, time difference, different language, going from hot weather to freezing temps and piles *of snow, totally different foods, nothing but strangers to her, visit after visit to new places...The list goes on and on. The BEST part - the vacation was full of excitement, fun, laughter and happiness every single day I have to pinch myself to believe this is my life after such a short time on MMS. Thank you all for your support and guidance I have my life back and can't wait for the future now! We still have a looooong way to go but we'll get there.*

Today is a wonderful day already

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168. MMS Works!

It's my number one pathogen fighter. Our family continually suffers from Strep, my son specifically from Pandas. MMS remains and continues to keep our strep symptoms at bay. I have used everything for our bacterial flares (Abx, herbals, supplements even homeopathics) and nothing has worked so effectively like MMS does for us.

Recently I changed over to the HCL activator and within in a few days we heard my severely apraxic son's first WORD "Mama" Its been just over a month on the HCL activator and he is now stringing two words together!! MMS is a huge part of our recovery protocol. I feel relief beyond measure that I found a post on MMS and decided to try it, and mostly I'm immensely grateful to Kerri for putting the MMS protocol together and for her love for our kids.

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169. We just had a good meeting with all of Amor's teachers and therapists. In the last few months there has been big jumps in Amor's cognitive skills.

I used to worry that Amor might have dyslexia. I never pushed her to read even if was behind her peers. I know frustration will only make things worse. Her 'x' and 'k', 'b' and 'd' were always mixed up. I have been observing this mix up for the past 2 years. Early this year, her speech therapist agreed that dyslexia might be an issue and we were ready to start studying dyslexia management.

However, Amor now shows interest in reading both phonics and sight words. She can answer letter names and sounds precisely. The same speech therapist now says that we shouldn't look at dyslexia anymore. It might have simply been a mix-up as part of early learning. Amor's dyslexia issues in 2 years all of a sudden went away in 2 months??

Amor is also doing well with number recognition and improving in one-to-one correspondence. This is something her former speech therapist (back in Japan) was working on for a year...with little progress.

All these seem so simple but these are great strides from someone who has vision issues. Amor also wears glasses.

If I were to plot Amor's improvements with time, the biggest jumped occurred in the past few months, which of course can easily be explained by MMS.

MMS clears the gut of bad bacteria, yeast and parasites. All these affect sensory processing thus inhibiting the child's ability to understand her environment and people around her. Clean the gut, remove autism...in Amor's case, remove GDD.

We are also running a son-rise lifestyle program. I.e. we don't put fixed hours into her program but use the son-rise attitude and son-rise her in the weekends.

170. *Luca came into our lives July 26, 2010, he was premature, but all my kids were born in week 35, so I was not surprised. He was perfect, I have thousands of videos of him looking into my eyes, smiling, playing with his sisters, following daddy to the door when he was ready to leave to work and saying bye bye. He walked at one, and was a perfect little baby. It is hard to know exactly when he changed but I can tell you when I started to get worried, and saw him behaving differently. I had a neighbor the same age as my son, and when they got together to play I was surprised at how my neighbors son followed simple directions and looked into my eyes every time I called his name. When I had play dates with my friends all the moms were so relaxed, and while they were talking and kids were playing with toys, I was always chasing Luca and trying to keep him in the same room because he was not interested in toys or playing with other kids.*

My first trip to the Zoo with my three kids was a disaster, Luca didn't want to move from the Monkey's area and had his first melt down, all over the floor screaming and crying. I remember seeing all the families with kids the same age as my son, and seeing how they understood, and paid attention to what their mothers or fathers were saying. For me that was enough to feel for the first time something was not right, and it was not that I was a bad mother, I knew deep in my heart it had nothing to do with discipline.

I enrolled him in a school thinking that would help. The first day when I picked him up the teacher said they needed to move him with the babies because he was not ready for the 2-year-old class. That day I came home just knowing - and despite all my family, friends, husband and Pediatrician thinking I was crazy, we got him evaluated and the rest is history. On November 15th, 2012 it was official and we got the papers. Classic Autism, by that time we had read so much, watched hundreds of videos and searched every day on the Internet for interventions, schools, therapy etc.

I remember I wanted to start ABA the same day that I got the diagnosis, but the waiting list was really long and we would have to wait. So we waited and started an early intervention program in the Kent District. Surprisingly, I think we took the diagnosis really well; we just wanted to help him as soon as possible.

After the first month I stopped asking for a miracle or cure. I even asked all family and friends to do the same. I needed to accept it!!! My miracle was already here. My husband wanted to do the Gluten free diet and I was not even 100% in agreement...why??? He is such a blessing; let our miracle eat whatever he wants!!! I agreed to do the diet anyway, but wasn't really interested. I just had the feeling my husband was not "getting IT" or accepting autism = our new precious miracle. Now I can recognize and see clearly I was in total denial too. I was so afraid to let anybody know, even myself, that I didn't want this for Luca. I tried and tried and tried, but a voice inside of me was not in peace. I spent a lot of time crying and looking for recovery videos on YouTube, imagining Luca being one of them, and was fascinated with those stories.

Then one day I found Kerri Rivera's conference in Bulgaria, it was a "Godcidence," (like my father always says) I wasn't looking for MMS, I didn't know anything about that. I remember I watched the conference 3 times, and I felt butterflies for the first time since I got the diagnosis. It was like that voice was finally quiet and listening to every single word! "I want this."

I did my homework and found a lot of negative information about MMS but I did not care…that voice was so strong that I knew, the same way I knew about

Luca being autistic, that this was something I needed to explore. I looked for her in FB and to my surprise she answered me in minutes, when I asked her about the testimonies she connected me with some moms with recovered kids, REAL moms that decided to believe too. After I saw pictures from before and after and reading about their journeys I felt Hope!!! I knew deep in my heart this was the way and the path we should take. So I got my case together and when I was ready I talked to my husband about it.

It was easier than I expected, we wanted so badly to recover our son!!! It was not an easy process but finally after almost 3 months I GOT IT…WE GOT IT...THERE IS NOTHING WRONG TO WANT THIS, that is ALL we want for Luca!!!! For the first time I recognized my kid's autism was not a blessing, he was sick; GI problems, extreme constipation, food issues, sensory problems... and that voice (God voice) sounds really clear and loud; I NEED TO HELP MY KID TO RECOVER!!!!!!

On February 18th we started a Dietary Intervention with all Kerri's recommendations, the one diet that we were doing was full of sugar and carbohydrates, so we started to be really serious about all the food choices. We kept a very detailed food diary and ordered the MMS. By March 12th when our bottles arrived at our doorstep we were ready to start Kerri Rivera's Baby Bottle Protocol. March 13th we did our first bottle and that same day I asked Luca to look for a ball in the other room, and give it to me, and he did.

It was like he was sleeping soundly, and then he woke up. He was extremely alert and he was looking in a different way. At first I thought I was crazy, but then my husband noticed it too and the changes keep coming. He improved dramatically in all his therapy sessions, his waiting time, sitting at the table, responding to commands, pointing, eye contact, everything improved!

Kerri recommended doing an ATEC when we started back on February 18th, so I did, his score was 64 points. By April 1st he dropped 20 points! He now follows simple directions, plays with his sisters, recognizes them by name, hugs me and says mommy and daddy, has close to 200 words, and every day is a surprise for us.

I'm proud to say my son is on his way to RECOVERY AND HE WILL RECOVER, HE WILL BE RECOVERED!!!!!!!! I'm loving Kerri Rivera's Protocol, I'm loving my kid dropPing 20 points in his ATEC in a month, I'm loving searching his diaper, and inspecting his poop finding parasites, I know it seems impossible but I truly get excited! (Probably some mothers would understand) I'm loving this side of the picture FULL of hope. HOPE. I don't think I can leave this road now, I don't think I want my son to live in his "perfect" world and not in mine... I'm a fighter and thanks to Kerri I'm a believer ...THAT... is the blessing right there HOPE AND FAITH IN GOD IS ALL I HAVE AT THE MOMENT… Luca is really special, but it's not the autism that makeS him special, autism sucks!!! Overcoming it and all the obstacles he encounters every day, and doing what he is doing now is what makes him THE MOST SPECIAL KID ON THE PLANET, HE ALWAYS WILL BE SPECIAL TO ME NO MATTER WHAT, AUTISM OR NOT….I see it in his eyes now, he is a fighter like me, he is telling me what to do, recovery is soooooo in the picture!!!!!! I can actually see it!!!! I'm a HAPPY Mom!!!!!!!!!!!!!!!!!!!!!!!!

-Alma

171. *Today is a wonderful day already. My daughter got up to her alarm, took a shower without help, got dressed, packed her lunch, woke up her sisters, and is now getting breakfast for everyone ready. It amazes me how independent she is becoming, and how much our life is changing because of her new independence.*

She is 10 and we started MMS in Sept. She had done 5 PP and following the PANDAS protocol the last week after emailing Kerri Rivera last weekend with concerns about eye fluttering. She is also on Fish oil, garlic, Magnesium, and GABA. Before she was very hyper, spacey, a lot of language, but not using it correctly. She was extremely impulsive, and would fixate on object to play with and ignore others. Now she does reciprocal play, she talks back and forth with her friends, she cracks jokes that are now actually funny. She is focused with her school work and not hyper - except in typical situations.

This week my husband forgot to pick her up to take her to therapy and she came to my classroom to tell me how irresponsible he was, and that she was disappointed in his inconsistent behaviors. I had to laugh, but at the same time I was so proud as I explained to her the whole situation because we where having a fabulous discussion about life. She is doing so well. Thank you to all of you who have restored some of my hope that there is a cure.

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172. *We are now in our 7th month of using MMS (CD) and in our 4th year of treating B.D., our son, who was diagnosed Autism. Our first week of MMS (CD) brought on a skill that we had spent years trying to accomplish, over night potty training. Week 1 of MMS (CD) and B.D. was out of pull-ups and in underwear. We weren't even close to full dose and already seeing positives. We knew we were on to something big at this point. One month later, we all witnessed my son blow out his birthday candles and open birthday gifts. Probably the first time he knew this event was a birthday and it was meant for him. As a gift to him, we took a trip to Disneyland. Not only did B.D. walk the entire park at our side, but he never once cried, whined, or objected to anything on the trip. Prior to this, he had to be in a stroller or wagon at all times.*

B.D.'s skills continued to flourish over the next few months. We enrolled B.D. in swimming lessons hoping he would feel comfortable without a life jacket on and clinging to an adult. This hope turned into a major accomplishment. B.D. has passed all Beginner levels in swimming and is now on to Intermediate. He is now swimming unassisted in the deep end of the pool! I used to hold my breath during his sessions hoping he wouldn't do anything that would scare the other kids in the pool. I still hold my breath, but now I'm at the end of my seat recording him as he's giving every single bit of effort to learn from his instructor and pass another level!

Just the other day, we went to a birthday party that was held in a warehouse full of screaming kids, loud music, inflatable jumpy houses and slides. This place can over stimulate just about anyone! In the past, my son would vocally stim, cover his ears, run behind the jumpers where the generators are (trying to turn them off) and require me, or his Dad to keep him engaged with the rest of the kids. Well, not anymore! He blended right in with the rest of the kids! Not a single stim, didn't cover his ears, stood in lines, listened and followed the rules and instructions, stood in lines and PLAYED with the other kids. His Dad and I were able to hang out with all the other parents, watching him run and whiz by with all the other kids as if that is how it has always been. Only it hasn't. He has come so very far in the past 7 months. We have a 6 year old son who no longer has sound sensitivity, loves to eat whatever is placed in front of him, DRINKS *tons of WATER, has manners, shows empathy, is careful and aware of other kids (especially babies and toddlers), making progress academically, and so very affectionate. B.D. isn't recovered… YET, but we expect it to happen now more than ever. We have to put our shades on because the end of the tunnel just got closer and brighter!*

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173. *My husband and I were told to come to the 2nd grade assembly this morning. They gave awards to 2 kids in each of the 4 second grade classes. One was for outstanding in academics, and the other was for most improved in Self Control, which is the "character trait of the month" for the whole school. Kayla was given the award for most improved in Self Control in her class! She walked up and got her award and stood up there with the other kids holding theirs. Up until a few months ago, she would have violent, self-injury tantrums at school every day... throughout the day, lasting anywhere from 10 - 90 min. She could never get through a class singing performance without losing it and tantruming, screaming through the whole thing. Her teacher came up to me on Wed. and said she just can't get over how happy my daughter is lately, and that all the teachers and staff in the school have really noticed too. FUA!!!! I'm so proud of my girl!*

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174. *Our third child (K) was diagnosed with moderate autism at 21 months of age. K was very ill. He suffered from vomiting and diarrhea mixed with severe constipation for years. At first, we began every intervention we could afford. The first step was removing all gluten, caseine and soy. We saw a decrease in stimming behaviour and an increased ability to learn. We implemented many vitamins and B12 injections, cranio sacral therapy, anti-fungals, HBOT and an even stricter diet removing all artificial colours, flavours, preservatives and most sugar. Our son was making slow but steady gains. ABA therapy continued from when he was two until just this past March (4.5 years). K was seeming much better but despite these gains, was never close to "normal".*

In July of 2012 a friend suggested MMS. I did my research and so it began. In three days K started to sleep through the night. After less than one week at a very low dose, K stopped the constant verbal scripting and obsessive speech- his most evident sign of autism. In that same week he began dressing himself independently. In the coming months, K's ATEC began dropping steadily. He began to make jokes, initiate social interactions, show empathy, cope with noise and busy places and best of all- understood safety. The risk of him running away was a memory. We could go places and he would stay near us. Teachers and Educational assistants were raving about his progress, unaware of the protocol we had begun. His most significant changes happened after a three months of the Parasite Protocol, using mms, Vermox, rompepiedras, neem and diatomaceous earth. Through enemas, he expelled worms as long as 24 inches to my husband and family doctor's disbelief. What K expels in his stool now looks normal and ordinary.

His ATEC in July 2012 was 46. Ten months later he has a score of 6.

He is undecipherable within his classroom and amongst his peers. He laughs, plays and acts like any other child his age. His academics are at par with his peers.

Our son does not appear to have autism anymore and only a trained eye would suspect that he ever had it to begin with. We thank Kerri Rivera, her Facebook group for all their support and MMS for being the final, and most significant leg in our sons' journey to recovery.

Maria A., Ontario Canada

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175. *My severe autistic boy has been now doing wonderful!!! This protocol has completely changed my life!! He's been dumping tons of parasites since we started MMS about three months ago we're now in the second pp...he's now much calmer more happier!! His ATEC dropped down from 80 to 48 in three months only...that was truly amazing he is now gaining weight, I feel like I'm getting my child back to normal again!! I wish I could tell the whole world how Kerri Rivera has changed thousands of people's lives!!! God bless u Kerri for all your hard work to help others!!!*

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176. *My son Nick started MMS just after his 7th birthday. Within 6 months he had cut his ATEC score in half from 66 to 37. Nick showed speech gains from the very first drop of MMS after having made no changes in speech for two years. Really, Nick hadn't made any improvements at all for two years. He was in a total stall until we began MMS. We raised Nick's oral dose of MMS very slowly taking two months to get to his target dose and never experienced die off that was unreasonable. Three significant changes are obvious in Nick's health at this point; he has been off of his Mitochondrial cocktail (for several years he has had blood labs pointing towards Mito dysfunction) for over 8 months and we haven't seen any of the lethargy that used to concern us so much, he was able to wean off of his seizure medication for his absence seizures and we haven't seen any return of seizure activity, and his thyroid appears to be beginning to shift from his long standing diagnosis of hypothyroid. The nicest changes we see are in the vibrancy of his health and how happy he is! His eyes sparkle and he has lots of energy for the day. He is no longer sitting on the couch staring out the window waiting for someone to figure out how to help him feel better. Since beginning MMS, every day Nick shows us just a little bit more of the boy that he is underneath the veil of autism and sickness. He tells us what his favorite things are, what he wants to do, and his sense of humor is coming shining through. MMS has given me a ton of hope that we just might get our boy back!"*

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177. *After 7 years of biomedical treatments, numerous therapies, and more doctors than I care to think about, our son, who was diagnosed with autism, could speak a full sentence, was potty trained, and could finally go to the mall and movie theater without screaming and putting his hands over his ears.*

Victory??...yes...however, we knew we had so much farther to go. You see, as your child gets older, you realize that he is missing the key things in life that are crucial for independence. Our son had become "stuck" if you will, he was not socially maturing, and still lacked empathy, mature connections with peers, and proper communication with teachers and the other adults in his life. He would still yell when he didn't win a game, and he did not always react in an age appropriate manner, if something did not go his way.

My research went on as always...searching, searching, searching...we were not getting anywhere with his current doctor, and I knew that we had to change our current plan for treatment.

A good friend of mine called me to tell me about a new product that some of our warrior mom friends were trying. The letters MMS were spoken to me for the first time in March of 2012. My son was 11 years old and I was desperate for help. The first thing I asked was, "How much does it cost?" $25.00...what?? It can't be! We have spent our life savings, and now I am looking at something that cost less than a night out for dinner?? I decided to check it out!

I emailed Kerri Rivera and told her that I wanted to start the MMS autism protocol, and I'll never forget her quick response..."YIPEE", she said, let me know if you have any questions, I am here for you.

I read, studied, and called my friend about twenty times over the next couple of days, and then we began the next chapter in our journey.

About three weeks into the protocol, our son seemed calmer, as well as aware of others on a more mature level...we were excited! Once he was at full dose, we began, baths and enemas, and he continued to improve. Our next move was to try the 72/2 protocol, which is giving MMS every two hours around the clock for 72 hours.

Well, it was as if someone had kicked our sons maturity clock into high gear. We saw HUGE gains!

"Hey mom, I like your dress...you look really nice today"....WHAT??

"I'll try that new kind of chicken for lunch"...WHAT??

"I feel like I'm beginning a new life"...WHAT??

"It's OK that I didn't win the race, I had fun"...WHAT??

I wanted to call the Good Morning America Show and say, LOOK AT WHAT MY SON IS DOING!

He also began to grow and put on weight for the first time in three years! He put on 10 pounds and 2 shoe sizes in about 2 months!

The gains continue to come, and our boy is coming alive...recovering...finally it's here! My eyes well up with tears as I write these words...the words I have dreamt about for eight long years.

He celebrated his 12th birthday on January 3rd, and has told us that 2013 is going to be the best year of his life...YES...it is!

He is our angel, our fighter, our miracle. Thanks be to God for MMS!

We are blessed and forever grateful~

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178. Once upon a time there was a little boy who had a strange mind, he hooted and he danced and he did not learn like the other children around him. So, he was sent to a special school. For his whole educational life he was separated, because he could not express correctly the answers put before him.

As he grew older he seemed sad and very much in pain. He appeared to try to stop the pain by clawing at his face and arms. He also stopped talking. We, his mom and dad, were very sad.

Then an angel came into our lives and told us of a magic potion.

"But" said the angel. "You must give him the potion every hour of the day and night for him to be better."

So the little boys' mom and dad have been doing that now for 9 weeks and 4 days. Every hour.

Now in those hours the mom and dad still cry. Some, because the little boy has been hurting for so long, and..... now they know why. But they also cry because they see that their little boy is not hurting like before. They are happy for his healing, and that he does not claw at his body any more.

And they are also happy because their little boy is talking again. And he is laughing. And the things that he knows surprise them. We thought he was not learning…turns out he was.

179. *Feeling really good still about my Natalie's progress from the combination of anti-parasitic medication, the supportive components of the PP and CD (HCL version). Natalie is about 63-64 lbs and she takes 2 drops of CD an hour both at home and at school. We don't wake her for CD in the middle of the night; but if she wakes for the restroom or something, then we give her another 2 drops (we just keep it pre-mixed in the bathroom near her bedroom). CD has been the single most important catalyst to Natalie's improvements/healing over the past 10.5 months; utilizing all three modes of delivery (oral, baths and enemas). Kerri having escorted CD into the ASD community is like a Miracle, in my opinion. Sorry... I don't mean to be corny nor impose my Beliefs on anybody else; but I sometimes find it hard to contain my Joy now and I get chills just thinking about all of the children now feeling better and/or beginning to feel better and better with CD. Before CD, it was hard to feel Hope for my special little Natalie; who was formerly suffering very extreme PANS flares and re-flares monthly as well as rapid-onset grand mal (tonic clonic) seizures every 2.5-3 weeks on top of her ASD and global developmental disabilities. Now Natalie's PANS 'flares' if/when they occur are waaaayyy less intense and better-controlled/'snufffed out' with CD than the former roller-coaster of oral antibiotics that her Drs had tried for years, her seizure activity is decreasing significantly and we've even begun a slow reduction in her anti-seizure med Lamictal ODT. We're optimistic that Natalie will be able to remain stable on less and less of that med, as we feel it might be causing her some nasty side effects. Our Hope for her is that she might even be able to come fully off of Lamictal ODT, as we continue CD and PP for her. Time will tell. While she's still a 'work in progress' [Note: She's 14 years old and been ill since infancy and it's a bit harder to heal longterm infection(s) and/or infestation(s)], we do see lowering ATECS in Natalie's future and brighter and brighter days. Patience is a virtue. So Grateful. Thank you Kerri and all you supportive Moms & Dads. More and more healing to come to ALL of our children!*

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180. *Hi Kerri,*

Thank you for helping my daughter, age 15, recover from Autism. Thank you for the MMS/CD program and the support to carry it out. Here is a summary of her recovery:

June 19, 2012 Atec=52

Started with MMS slowly, adding one drop a day

GF/CF/SF diet

It took her 1 1/2 months to get to full dose.

Noticed improvement in physical health & behavior

Began parasite program

Sept. 18, 2012 Atec=24

Continued with 6-8 doses/day & baths

More improvements

School discontinued IEP, because she was doing so well academically and socially

January 15, 2013 Atec=19

My daughter, who is not vaccinated, comes down with Chicken Pox

No one at school or in community had it before her. It appears to be an isolated case.

It may have been in her system and released as parasites died?

Fever of 102 degrees for two weeks was the lead up to the Chicken Pox. Seemed like her immune system woke up! After chicken pox, huge gains! That is when we noticed she was recovered!

April 25, 2013 Atec=6

Yeah!

* * *

Please share your experiences!

Testimonials are one of the best ways to share your experiences with this protocol. Perhaps you learned about it by reading or watching a video testimonial?

If you don't tell us your experiences, we can't share them or take action on issues that need improving or correcting...

Send your testimonials to:

testimonials@cdautism.org

Also, let us know if we are free to publish your testimonial, with or without your name.

It's in our interest to take care of others. Self-centredness is opposed to basic human nature. In our own interest as human beings we need to pay attention to our inner values. Sometimes people think compassion is only of help to others, while we get no benefit. This is a mistake. When you concern yourself with others, you naturally develop a sense of self-confidence. To help others takes courage and inner strength.

~ Dalai Lama

Appendix 2

CD Autism Worldwide

Since September of 2011 over 5,000 families in 58 countries have used CD to help with an autism spectrum disorder. Here is a list of all the countries who have at least one family using CD to help heal the symptoms known as autism. This list is constantly updated at www.CDAutism.org.

- Argentina
- Australia
- Austria
- Belgium
- Bolivia
- Brazil
- Bulgaria
- Canada
- Chile
- China
- Colombia
- Costa Rica
- Cuba
- Czech Republic
- Dominican Republic
- Ecuador
- Egypt
- England
- France
- Germany
- Ghana
- Greece
- Hungary
- India
- Iraq
- Ireland
- Italy
- Japan
- Jordan
- Kenya
- Kuwait
- Malaysia
- Mexico
- Montenegro
- Morocco
- New Zealand
- Norway
- Panama
- Peru
- Philippines
- Poland
- Portugal
- Puerto Rico
- Qatar
- Russia
- Scotland
- Singapore
- Slovakia
- Slovenia
- Somalia
- South Africa
- Spain
- Swaziland
- Sweden
- Tanzania
- Turkey
- United Arab Emirates
- United States
- Venezuela

If you are using CD for autism in a country not listed above please email us so we can add you to the list... kim@cdautism.org.

Conformity is the jailer of freedom and the enemy of growth.

~ Robert F. Kennedy

Appendix 3

AutismOne on Healing Autism: Accidental Cure by Optimists

by Simon Yu, MD

Accidents happen. We accept the reality of them as is and we usually move on. On the other hand, accidental discovery is another story. For some people, they ask questions like, "why me?" Or keep asking for a deeper meaning: Is this really an accident or a message to understand? An accident is a fertile ground to find out if you are a pessimist or optimist.

Tom Jacobs, story teller from Kansas City, recently told a story about a pessimist and optimist: Two sales men were assigned to Africa in the early years of the shoe industry to sell their shoes. One week later, one salesman telegrammed to his boss, "Business situation in Africa is hopeless. Nobody wears shoes". On the other side of the continent, the other salesman excitedly telegrammed to his boss, "Unlimited potential in Africa. Nobody wears shoes!"

I don't know about you but I would rather be an optimist. I always encourage my patients to look at the bright side and be cautiously optimistic no matter how grim their conditions might be. Hope is a powerful driving force to promote healing. Pessimists do not call themselves pessimists. Just realists.

Today, I saw a 77 year old patient with a history of chronic pulmonary fibrosis, bronchiectasis and rheumatoid arthritis with a recent diagnosis of stage one bladder cancer. She has been depressed and joined a cancer support group because of feeling a sense of hopelessness.

After a long discussion, I told her how lucky she is that her lung and rheumatoid conditions have been stable and she has only a relatively benign early stage of bladder cancer. I told her if you are going to have cancer, this is the kind of cancer to have and she should be thankful. All of a sudden, her doom and gloom mood was lifted with a broad smile. The rest of our session was uplifting.

The AutismOne 2013 conference was held in Chicago during Memorial Day weekend. I was invited to give a talk on parasites, allergies, and autism. Autism is not my field. I usually see adults as an Internist. However, beginning in 2012, I have been seeing autistic children with rather interesting responses. In May 2013, I wrote an article about a medical hypothesis of a relationship between parasite infection and autism in preparation for my lecture for the AutismOne conference.

I attended a full day of lectures and was awestruck by the thousands of autism parents from all over the country attending the lectures. Multiple lectures were conducted by many autism specialists at the same time covering a large variety of topics. This conference was driven by a grass roots movement of parents with a hope to help their children. Here is a short synopsis of the lectures.

Dr. Anju Usman, MD from the Chicago area covered gut-brain connection and biofilms by pathogens in the gut. Symptoms such as depression, anxiety, poor attention and focus, and obsessive compulsive behaviors may be related to the delicate balance of bugs which produce a mucous slime known as biofilm.

Andreas Ludwig Kalcker, Ph.D. Bio-Physicist from Spain, who studied under German bio-physicist Fritz Albert Popp, Ph.D., discussed parasites in depth. He demonstrated a successful treatment for more than 65 children around the world with his parasite protocol over a one year period.

Kerri Rivera, from Mexico, one of the main leaders of the group running the AutismOne conference, showed many cases of successfully treated autistic children including her child. She has been using chlorine dioxide in conjunction with diet, nutritional supplements, detox, and hyperbaric oxygen.

By the time I presented my medical hypothesis on parasite infection and autism, they had already had numerous discussions about parasites and had been saying all along how parasite infection might be one of the major underlying problems for autism that has been overlooked. I felt like I was repeating what had already been presented.

Dr. Andreas Kalcker and Kerri Rivera collaborated using chlorine dioxide for two years with prescribed parasite medications, albendazole and pyrantel pamoate, to turn around autistic children. Professionally, I have no experience using chlorine dioxide on my patients. The difference with my therapy was that I was using acupuncture meridian assessment as a guide to detect and treat parasites.

If what they are reporting is even partially true for these autistic children, it would be a major breakthrough in the autism community. Some of the audience was crying in excitement but some were skeptical and saying it sounded too good to be true. I could feel the excitement of the audience but also a sense of fear that Kerri Rivera and Andreas Ludwig Kalcker will be attacked by special interest groups. Chlorine dioxide is too inexpensive to a fault.

Is this an accidental finding leading into an accidental cure for autism? It is too early to tell but any chronic medical conditions like cancer, heart disease, diabetes, arthritis, Alzheimer's dementia, or autism seems driven by epigenetic influences from environmental toxins, parasites, hidden dental problems, and faulty diet and nutrition.

I spent several hours with Andreas Kalcker after our lectures were over. We found a common ground for treating parasites: his experience as a bio-physicist and my experience as a military medical officer. Few people truly understand and are aware of the magnitude of parasite problems. This man was very passionate to rescue these children from the scourge of autism.

Kerri Rivera just published a book called [Healing the Symptoms Known as Autism]. I just finished the book. This book is for everyone but especially for both autism parents and all medical professionals involved in the care of autistic children. The book contains much important information that is not available in the main stream autism community.

Most pediatricians might be sympathetic but they are rather pessimistic regarding the care of autistic children. Andreas Kalcker and Kerri Rivera are true optimists in the midst of skeptics and pessimists. They see unlimited potential for the cure for autism based on diet, nutrition, and parasite eradications using chlorine dioxide and parasite medications. If you want to know more about autism and what is possible, I highly recommend reading [Healing the Symptoms Known as Autism] by Kerri Rivera. The book explains in detail the Kalcker parasite protocol.

Dr. Simon Yu, M.D. is a Board Certified Internist. He practices Internal Medicine with an emphasis on Alternative Medicine to use the best each has to offer. For more articles and information about alternative medicine as well as patient success stories, and Dr. Yu's revolutionary health book Accidental Cure: Extraordinary Medicine for Extraordinary Patients, visit his web site at...

www.PreventionAndHealing.com

...or call Prevention and Healing, Inc., 314-432-7802. You can also attend a free monthly presentation and discussion by Dr. Yu on Alternative Medicine at his office on the second Tuesday each month at 6:30 pm. Call to verify the date. Seating is limited, arrive early.

Appendix 4

Autism Evaluation Treatment Checklist (ATEC)

The next page contains a copy of the original *Autism Evaluation Treatment Checklist* (ATEC) developed by the late Dr. Bernard Rimland, the founder of the *Autism Research Institute*. We are not suggesting you use this particular copy. It is only included here for those not familiar with the evaluation so you have an idea what the ATEC involves since we mention it throughout this book.

The survey consists of a series of questions to be answered by a parent about what they are observing in their child's CURRENT behavior. It is not uncommon for both parents to take the survey separately and compare/ average the scores.

The best way to take the survey is online at the *Autism Research Institute's* website. Here is the direct link to the current survey:

www.autism.com/index.php/ind_atec_survey

After completing the questions, a score is generated that can range from 0 to 180. 0 means no autism while 180 would mean that the answer to every question was in the most negative extreme.

We consider a child recovered from autism if their score is between 0 and 10.

You are encouraged to complete an ATEC before starting the Protocol, and every 3 months thereafter so you can clearly see the progress you are making.

Also, please share your results with us; we collect data on the children whose parents follow the Protocol as explained in this book. Send your name, date of the survey, general location (city, state, country) and score to:

atec@cdautism.org

If you have a history of ATEC results while on the protocol, please include them all.

NOTE: Do not send questions to this email address! You are unlikely to get any response from this address! It is just a collection point.

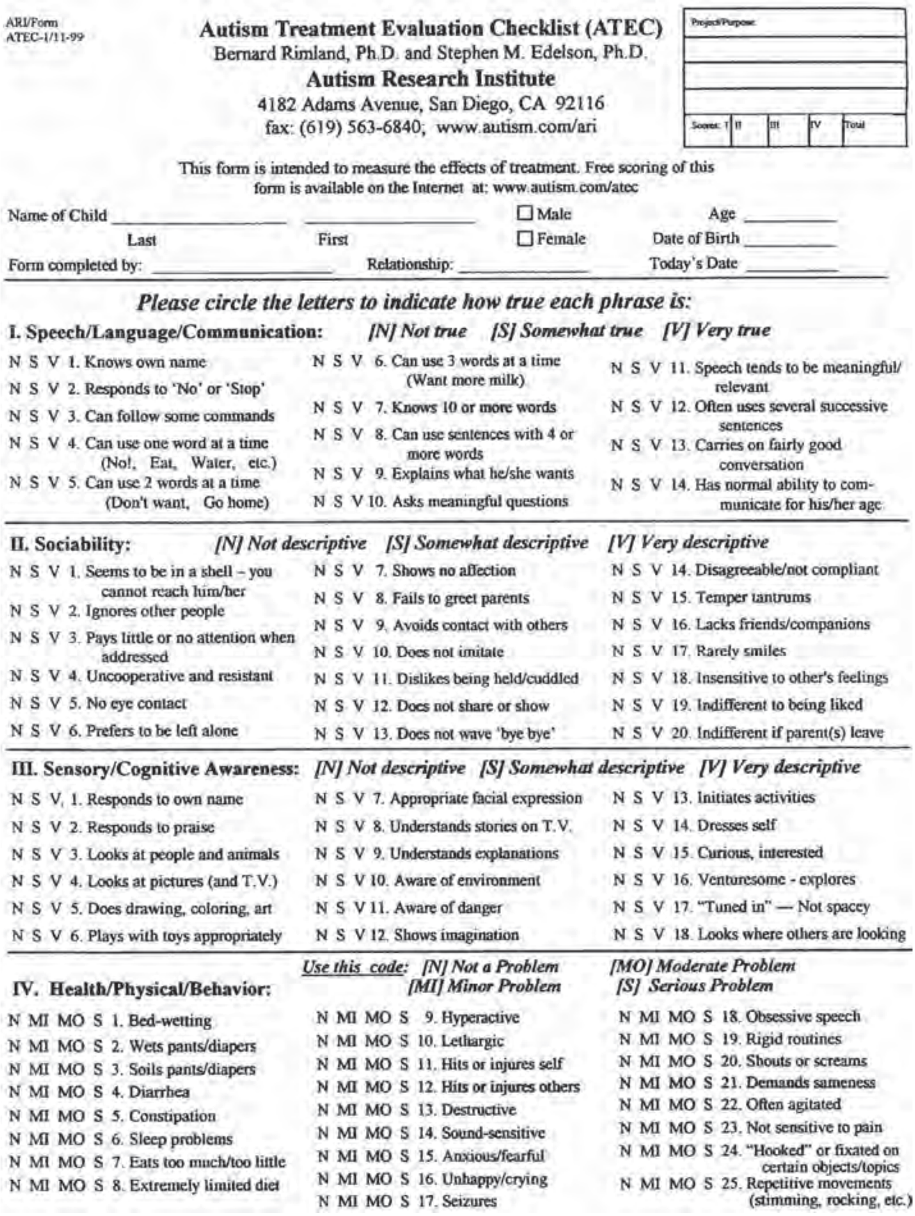

ARI/Form
ATEC-1/11-99

Autism Treatment Evaluation Checklist (ATEC)

Bernard Rimland, Ph.D. and Stephen M. Edelson, Ph.D.

Autism Research Institute

4182 Adams Avenue, San Diego, CA 92116
fax: (619) 563-6840; www.autism.com/ari

Project/Purpose				
Score: I	II	III	IV	Total

This form is intended to measure the effects of treatment. Free scoring of this form is available on the Internet at: www.autism.com/atec

Name of Child ____________ ____________ ☐ Male Age ________
Last First ☐ Female Date of Birth ________
Form completed by: ____________ Relationship: ____________ Today's Date ________

Please circle the letters to indicate how true each phrase is:

I. Speech/Language/Communication: ***[N] Not true [S] Somewhat true [V] Very true***

N S V 1. Knows own name
N S V 2. Responds to 'No' or 'Stop'
N S V 3. Can follow some commands
N S V 4. Can use one word at a time (No!, Eat, Water, etc.)
N S V 5. Can use 2 words at a time (Don't want, Go home)
N S V 6. Can use 3 words at a time (Want more milk)
N S V 7. Knows 10 or more words
N S V 8. Can use sentences with 4 or more words
N S V 9. Explains what he/she wants
N S V 10. Asks meaningful questions
N S V 11. Speech tends to be meaningful/relevant
N S V 12. Often uses several successive sentences
N S V 13. Carries on fairly good conversation
N S V 14. Has normal ability to communicate for his/her age

II. Sociability: ***[N] Not descriptive [S] Somewhat descriptive [V] Very descriptive***

N S V 1. Seems to be in a shell – you cannot reach him/her
N S V 2. Ignores other people
N S V 3. Pays little or no attention when addressed
N S V 4. Uncooperative and resistant
N S V 5. No eye contact
N S V 6. Prefers to be left alone
N S V 7. Shows no affection
N S V 8. Fails to greet parents
N S V 9. Avoids contact with others
N S V 10. Does not imitate
N S V 11. Dislikes being held/cuddled
N S V 12. Does not share or show
N S V 13. Does not wave 'bye bye'
N S V 14. Disagreeable/not compliant
N S V 15. Temper tantrums
N S V 16. Lacks friends/companions
N S V 17. Rarely smiles
N S V 18. Insensitive to other's feelings
N S V 19. Indifferent to being liked
N S V 20. Indifferent if parent(s) leave

III. Sensory/Cognitive Awareness: ***[N] Not descriptive [S] Somewhat descriptive [V] Very descriptive***

N S V 1. Responds to own name
N S V 2. Responds to praise
N S V 3. Looks at people and animals
N S V 4. Looks at pictures (and T.V.)
N S V 5. Does drawing, coloring, art
N S V 6. Plays with toys appropriately
N S V 7. Appropriate facial expression
N S V 8. Understands stories on T.V.
N S V 9. Understands explanations
N S V 10. Aware of environment
N S V 11. Aware of danger
N S V 12. Shows imagination
N S V 13. Initiates activities
N S V 14. Dresses self
N S V 15. Curious, interested
N S V 16. Venturesome - explores
N S V 17. "Tuned in" — Not spacey
N S V 18. Looks where others are looking

IV. Health/Physical/Behavior: *Use this code:* ***[N] Not a Problem [MI] Minor Problem [MO] Moderate Problem [S] Serious Problem***

N MI MO S 1. Bed-wetting
N MI MO S 2. Wets pants/diapers
N MI MO S 3. Soils pants/diapers
N MI MO S 4. Diarrhea
N MI MO S 5. Constipation
N MI MO S 6. Sleep problems
N MI MO S 7. Eats too much/too little
N MI MO S 8. Extremely limited diet
N MI MO S 9. Hyperactive
N MI MO S 10. Lethargic
N MI MO S 11. Hits or injures self
N MI MO S 12. Hits or injures others
N MI MO S 13. Destructive
N MI MO S 14. Sound-sensitive
N MI MO S 15. Anxious/fearful
N MI MO S 16. Unhappy/crying
N MI MO S 17. Seizures
N MI MO S 18. Obsessive speech
N MI MO S 19. Rigid routines
N MI MO S 20. Shouts or screams
N MI MO S 21. Demands sameness
N MI MO S 22. Often agitated
N MI MO S 23. Not sensitive to pain
N MI MO S 24. "Hooked" or fixated on certain objects/topics
N MI MO S 25. Repetitive movements (stimming, rocking, etc.)

Appendix 5

MOLECULAR MIMICRY
What It Is
&
How it Relates to
The Gluten Syndrome

by Mrs. Olive Kaiser

After reading the short answers in *The Diet* Chapter (page 64), we understand (simply) the basics of how some of these departments of the immune system function. It is easier to grasp how, through molecular mimicry, gluten can damage so many different tissues in different people, and sometimes cause other foods that *look like* gluten to also be reactive. Before we go any further, I would like to thank the following professionals for their contributions to our family's well-being and a wider understanding of the gluten syndrome and other related topics. If you would like to conduct further research into this topic, the body of work that the following professionals have contributed would be a great place to start. There is so much more to learn.

Dr. Alessio Fasano, MD, shook America awake on gluten awareness in the 1990's and in 2003 published a landmark paper[1] on one small subset of the gluten syndrome, villi damaged celiac disease. That study provided the impetus that brought gluten awareness to the table (or sadly, OFF many tables) across our nation.

Dr. Thomas O'Bryan, DC, Functional Medicine, and international gluten syndrome educator - www.thedr.com. Dr. O'Bryan is my functional medicine doctor. He taught me much of what I learned about gluten and other topics and led me to his mentor, Dr. Aristo Vojdani. Later Dr. O'Bryan's amazing research review seminars on gluten contributed hugely to my knowledge base and bolstered my confidence to manage our new lifestyle in a then difficult social era.

Dr. Aristo Vojdani, PhD., MsC, Immunologist, CEO owner of *Immunosciences Lab*, Los Angeles, CA. Dr. Vojdani is also chief scientific advisor of *Cyrex Laboratories*, Phoenix, AZ. Dr. Vojdani has published nearly 150 excellent research papers.[2,3,4] They fit the community like a glove.

Dr. Rodney Ford, MD, pediatric gastroenterologist, NZ, grasped the extent of neurological injury,[5] and "silenced nerves phenomenon."[6] This compellingly suggests why many of us do not recognize symptoms of gluten damage until we are in deep trouble. This builds on the previous work of Dr. Marios Hadjivassiliou, Professor of Neurology, Sheffield, UK.[7]

Dr. Kenneth Fine, MD, gastroenterologist, Dallas, Texas, owner of an investigative research lab, *Enterolab* (www.Enterolab.com). His lab ran the only accurate gluten antibody tests our family received back in 2004.

Without the courage of these astute researchers, we would still be wandering in the dark. Thank you all, and other individuals who thought outside the box. Kerri you are one of those thinkers. Thank you!

Lastly, special thanks to **LuEllen Giera**, my support group leader, for leading me to Dr. O'Bryan and Dr. Vojdani.

1. What is Molecular Mimicry? How does gluten damage us?

The structure of gluten resembles the structure of many of our body tissues. When the immune system attacks gluten or partly digested "pieces" of gluten it may also attack body tissues that "look like" those pieces of gluten. There may also be other processes that we do not yet understand.

What is gluten? - Gluten is a stretchy protein found in some bread grains. The problematic types are found in wheat, barley, and rye, and now early research suspects possibly rice, corn and oats (Dr. Peter Osborne, DC, CCN, www.glutenfreesociety.org).

What are proteins? - Proteins are a class of materials found in living tissues, such as hair, nerves, enzymes, etc. Molecularly, all proteins look like necklaces of beads strung into various color sequences. The different sequences make the proteins different, and the "colored beads" represent 22 separate amino acids. Our digestive system uses enzymes to cut up these necklaces into single beads so they are small enough to cross the gut wall properly and be restrung into new proteins. See image on page 452.

Unfortunately, many folks today are toxic and poorly nourished and do not have strong digestion, so the gluten "necklaces" may never completely break down. As weaker bonds between the beads break, "pieces", called "peptides," of gluten are formed. Gliadin is a well known gluten piece and there are many others.

Our immune system - has "departments" to protect us in various ways, including IgA, IgG, IgE, IgM, IgD and others. IgE can cause immediate allergic reactions to bee stings or peanuts, etc. IgA, IgG and IgM may react more slowly with less drama. They all manufacture "workers" or "soldiers", called antibodies, each custom designed to patrol our bodies, looking for the bead sequence of one particular enemy. When they find that bead sequence, they "tag or stick onto" it. Our killer white blood cells interpret the antibody tag as a condemned sign and know to surround and destroy that protein.

If an antibody test lists "Gliadin – IgA", "Gliadin – IgG", and "Gliadin – IgM" it means the test checked for gliadin antibodies in the IgA, IgG and IgM departments. If the antibodies are high it means the immune system is does not like gliadin and is working to destroy it.

Weak, leaky barriers - Our gut wall and other barrier membranes such as the skin, lung, placental, and blood brain barriers are held together with "tight junction proteins" that act like velcro. Inflammation, parasites, gluten, medications, infections, electrosmog, etc, may damage the "velcro" or open them up too much. Substances may slip through them into places they should not be and cause trouble.

Unfortunately if the gut wall does not hold together well, i.e., is "leaky", pieces of incompletely digested gluten strings (and others) may slip through and run into the immune system—our dutiful "guard dog" on the other side. Due to their too-large size "he" may raise the alarm. The invader strings are "frisked out" i.e., examined. If they are rejected, one or more of the immune departments make matching antibodies to "tag" them so the killer cells know to go after them.

It is at this point more problems may arise. A gluten antibody may "run by" a natural body tissue, for example a nerve in the heart. It may see in that innocent nerve tissue a sequence of "beads" that matches or partly matches the gluten sequence it was designed to "tag" and stick to that section of the nerve protein instead. This, unhappily, attracts killer cells to the misidentified nerve, resulting in autoimmune injury to the nerve. This is molecular mimicry.

Other foods and proteins beside gluten may also initiate molecular mimicry when they prematurely cross a leaky gut, and may prompt allergies (IgE) or intolerances (IgA, IgM, or IgG). However specialists agree that gluten's particular "bead" (amino acid) sequences are uniquely guilty in their ability to upset the immune system and instigate molecular mimicry between "their" antibodies and our tissues.

Molecular mimicry can take place between non-food proteins and body tissues also. Infectious microbe sequences such as strep, for example, are believed to partially match, (in the case of strep), heart and joint proteins and so injure the heart muscle or valves, and (rheumatic) joints. Ditto is suspected for root canal and cavitation infections that may circulate and injure specific tissues, including the heart. Flu microbe sequences can resemble gluten and may trigger or surface gluten syndrome. There are numerous other examples of mimicry between infections, foods and body tissues.

Consider the image below. An antibody may be made to seek the shorter "bead" sequence of a gluten piece that crossed the gut wall, but it might also recognize a similar sequence, a partial match, in the longer nerve protein sequence. The antibody "tags" or "sticks to", the part of the nerve tissue that matches the gluten piece that it seeks.

Gluten Peptide (and antibody) Sequence

Note: the different colors represent different amino acids.

					pink	blue	white	brown	brown	brown	red	red	green		

Nerve Sequence

orange	orange	yellow	green	red	red	blue	white	brown	brown	brown	red	orange	green	blue	yellow

It gets more complicated, but eventually the victim tissue is attacked by killer cells on an ongoing basis. This process may be slow but stealthy. In time, the nerve may malfunction and the organ it serves may also begin to fail; for example, heart failure. This is termed autoimmunity. The body attacks its own tissue.

Molecular mimicry can occur in hundreds of places in the body since gluten can break up into numerous pieces having amino acid sequences that partly match many of our natural tissues. This may explain why gluten syndrome presents so differently in different people.[2]

Once this process starts, like elephants who never forget, the memory B cells that manufacture the antibodies never forget the sequence of the "invader" gluten pieces. If gluten is removed, antibody manufacture eventually stops, but any time the immune system sees even a tiny amount of that protein sequence, antibody production is retriggered. This is why specialists insist the gluten-free diet is strict and lifelong.

Gluten removal stops production of the initial antibody, which decreases the inflammatory process significantly. Literature shows the gluten-free diet may reverse or improve many serious conditions, but it may not always arrest an advanced autoimmune disease. Prevention is key.

Example: Once a ball is pushed down a hill, further pushing will only send it downhill faster, but it will roll on its own. To correlate, molecular mimicry between the gluten antibody and victim tissue starts the ball rolling. Removal of gluten stops pushing the process, and the sooner the better. The longer the exposure[8], and to other factors as well in a triad of autoimmunity (a. environmental stress, toxins, infections, etc.; b. a faulty blood brain barrier; and c. susceptible genetics), the higher the chance of autoimmune disease.

Dr. Vojdani comments, "If it is detected early enough and steps are taken early enough the condition may be reversed. If any condition is advanced enough you can reach a point when simple removal may not be enough. Autistic children generally have autoimmune reactivity rather than full-blown autoimmune disease, which is why they show great improvement upon the removal of gluten."

2. Does gluten always damage the villi of the small intestine as the celiac story teaches? Many other tissues such as thyroid, pancreas, blood vessels, joints, brain, nerves, liver, bone, etc. may be involved in this disorder. Does all that other damage arise due to poor nutrient absorption from injured gut villi?

No, according to published research many researchers and practitioners now believe the villi are not always damaged in an autoimmune gluten reaction.[2] Where there is no villi damage, injury to other organs cannot be due to nutrient deficiencies caused by villi damage. Molecular mimicry provides a mechanism for direct autoimmune gluten injury to many other tissues and organs when the villi are fine. It is also possible that several tissues and organs, *including villi,* may be injured and then nutrient deficiencies from poor villi absorption may affect other areas.

Dr. Vojdani's abstract in his editorial, *The Immunology of Gluten Sensitivity Beyond the Intestinal Tract,*[2] supports that the villi are not always injured. To quote his editorial abstract, "Evidence has been accumulated in literature demonstrating that gluten sensitivity or celiac disease can exist even in the absence of enteropathy" [gut/villi damage], "but affecting many organs."

3. I do not have damaged villi, and my tTG/gliadin blood tests were negative, but I feel so much better gluten-free. Why?

The tests were likely false negative. That is very, very common. As gluten is processed in the digestive system, it can break into more pieces than we have tests developed to check them, and the immune system makes an antibody for each separate piece. The test probably missed your antibodies because they were different from the one or two the test checked. Many patients have proven this because they received negative results to the standard test, and then found a number of positive gluten related antibodies when they ran a more comprehensive panel. Cyrex Laboratories (www.cyrexlabs.com), runs 28 gluten related antibodies in 3 areas of the immune system.

Your properly performed* biopsy was probably negative because likely your gut villi are fine.** Your gluten injury may have targeted other organs or tissues, not the villi.*** For instance, if gluten has damaged the heart, snipping intestinal villi will not help find the heart injury. Damage in either place is not ok.

More detail on False Negative Tests

The blood and saliva tests - Standard celiac blood and saliva tests only check tissue transglutaminase IgA, (tTG – IgA) as an initial screener. Most doctors give up if that test is negative. However, the literature shows that standard tTG-IgA tests are only elevated when the villi are completely destroyed. Dr. Vojdani finds that form of tTG is often not found in other gluten injured tissues. Therefore the standard tTG-IgA test is a poor screener for most patients, and returns many false negatives. More forms of tTG have now been discovered.

Doctors might also order a standard test for deamidated gliadin IgA and possibly IgG. Unfortunately these tests also have a miserable failure rate for picking up gluten syndrome because many patients have other antibodies beside those two. The gluten "string" can break up into many other pieces, plus other "departments" of the immune system may react.

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* If there IS villi damage it is possible for the biopsy to miss it if the damage is patchy or further down the duodenum than the villi samples are taken. Most good "gluten aware" gastroenterologists take a number of samples to try to avoid this possibility.

** It is possible that very early villi damage may slowly accumulate long before it shows up on a pathology report. An elevated IEL count, (intraepithelial lymphocyte, an early sign of inflammation) of the villi tissue indicates this process is underway. Ask the gastroenterologist to specify that the pathologist do an IEL count.

*** I am careful to specify the "villi of the gut". There may actually be gut damage, but not to the villi. There are many types of tissue in the gut, such as nerves, for instance. The villi may be fine, but it is still possible that some other gut tissue may be damaged by molecular mimicry or other processes we do not yet understand. For instance, if the nerves that control peristalsis (wave like gut motion) are injured, it could result in chronic constipation.

Villi biopsy vs. positive antibodies for diagnosis? - To add insult to injury, even if antibodies are discovered, many celiac, villi focused specialists may still insist that the villi biopsy is the final word for "celiac" diagnosis and they trust a negative villi biopsy over positive antibodies. Many folks have positive antibodies and suspicious symptoms, including improvement upon gluten removal, but no apparent villi damage. Their doctors assure them they can eat gluten! This is a serious mistake for many patients.

More on the villi biopsy – By now it is easy to understand why even properly performed* villi biopsies are only useful for the relatively small subset of patients in which the villi of the duodenum are injured. Most patients do not happen to have damaged villi. Their damage is somewhere else in their body, other organs, nerves, etc., or some enzyme or functional item has been damaged by gluten antibodies. Scientists such as Dr. Aristo Vojdani[2,3,4,] do NOT recommend villi biopsies for gluten syndrome diagnosis (there may be other reasons to scope the gut, such as tumors, etc). Dr. Vojdani explains that if there are elevated antibodies to gluten, the immune system is screaming "I do NOT want this substance! I am manufacturing antibodies to tag and destroy it." That is sufficient reason to remove gluten from the diet. It is less expensive to check an extensive array of gluten antibodies than undergo an endoscopy anyway, and is much less invasive.

4. Why do many gluten syndrome patients not only react to wheat, barley, and rye but also sometimes to other foods, particularly oats, milk, corn, soy, egg, coffee, sesame, yeast, chocolate and others.

These foods have similar amino acid sequences to gluten. Now that we grasp molecular mimicry, this is logical. The immune system may misrecognize them for gluten, causing cross reactions which may keep the gluten antibodies running high even on a gluten-free diet. Happily, this does not always occur. Cyrex labs, Array # 4, checks a list of cross reactive and gluten substitute foods, IgA and IgG.

5. The diet seems excessively strict? Why does it take so little gluten to start a reaction?

We understand that miniscule amounts of bee venom, or peanut, can trigger emergency allergic reactions, and very tiny medication pills can cause major effects on our bodies. This is also true of gluten reactions, both immediate allergic IgE, and delayed IgA, IgG, and IgM.[3] "Crumbs matter." The difference is that delayed reactions are not as obvious as the allergic reaction. They may go unnoticed for hours to decades, but may be a long, slow, serious process. Their lack of drama robs these reactions of the compliance respect they deserve.

6. The silent syndrome - Why do many people react to gluten, proven by antibody tests, but they have few or no warning signs, or seemingly unrelated symptoms they do not recognize or connect with their diet for a long time. Then they crash with something serious, often or usually autoimmune?

Gluten is famous for slowly injuring nerves[5] by molecular mimicry, and in many cases the nerves are silenced by that injury.[6] The patient does not realize there is a problem until the tissue or organ that those nerves supply begins to fail. Furthermore some areas of the body do not contain many pain nerves, so we may not feel the damage. Slow silent damage is understood in other diseases. Heart damage, cancer, and aortal aneurysms are examples of conditions that develop silently and then suddenly flare. Prevention is best.

For years, celiac literature recognized 2 neurological conditions, peripheral neuropathy and gluten ataxia. In the wider perspective of gluten syndrome, nerve damage may be one of the most important areas of injury.[5]

Dr. Rodney Ford, MD, suggests in his book, *The Gluten Syndrome: Is Wheat Causing You Harm*,[6] that this is primarily a neurological disease[5], injuring and in some cases silencing nerves, compromising the health and function of the tissues they serve. This idea was reinforced by an astute observation made by Dr. Ford of one of his patients, an elementary school child who had not achieved bowel control. After she went gluten-free, the problem resolved. Dr. Ford realized the child now recognized the signal to visit the toilet, and accidents were avoided. The nerves in the lower bowel apparently "woke up" once the antibodies that injured them disappeared. This is an interesting and logical theory to explain "silent gluten injury", and it fits the community. Here is an abstract of Dr. Ford's published paper which discusses a possible widespread neurological focus:[5]

The Gluten Syndrome: A Neurological Disease, by R.P. Ford

Hypothesis: gluten causes symptoms, in both celiac disease and non-celiac gluten-sensitivity, by its adverse actions on the nervous system. Many celiac patients experience neurological symptoms, frequently associated with malfunction of the autonomic nervous system. These neurological symptoms can present in celiac patients who are well nourished. The crucial point, however, is that gluten-sensitivity can also be associated with neurological symptoms in patients who do not have any mucosal gut damage (that is, without celiac disease). Gluten can cause neurological harm through a combination of cross reacting antibodies, immune complex disease and direct toxicity. These nervous system affects include: dysregulation of the autonomic nervous system, cerebella ataxia, hypotonia, developmental delay, learning disorders, depression, migraine, and headache. If gluten is the putative harmful agent, then there is no requirement *to invoke gut damage and nutritional deficiency to explain the myriad of the symptoms experienced by sufferers of celiac disease and gluten-sensitivity. This is called "The Gluten Syndrome."*[5]

7. Why do so many of us react now, when for centuries most people appeared to be fine with wheat? After all, wheat is spoken of positively in the Bible and many other historical documents.

There may or may not be a conclusive answer to this question, but a few factors may play a role.

a. Many folks have higher toxin levels now, their nutritional status is worse, and digestive strength is weaker.

b. Today's wheat is different. Gluten grains have been subjected to a lot of changes, some genetically violent, according to Nina Federoff, a pro GMO scientist. She asserts in her book, *Mendel in the Kitchen*, that gluten grains were altered with nuclear radiation and chemical mutation by the 1950's – 1960's.[9] Recently a stash of old blood samples from that era, stored in a freezer by the military, were checked with standard celiac antibody tests. The incidence of positive antibodies was much less in those samples than is typically found in the general public today.

c. Wheat seed is sometimes treated with mercury. Might this play into unintended results?

8. Why do specialists and researchers insist that the gluten-free diet must be life long? Can't we heal the gut and go back to our beloved wheat bagels, croissants, and brownies?

Our scientists insist that gluten-free is a strict lifelong commitment. The memory B cells in the immune system never forget what the enemy "looks like." Today's gluten is a violently altered substance according to the very scientists who defend genetic alterations.[9] It is not worth playing with today's wheat. There is something strange and unpredictable about it. Even if a leaky gut has healed, future circumstances, toxins and stress might injure it and retrigger the syndrome, perhaps silently. Researchers say gluten creates leaky gut for a few hours in everyone.

Particularly since gluten appears to be the "bad boy" that predisposes to other intolerances, I prefer to walk away for life and concentrate on other nutrient dense foods. However, it is wise to consume whole foods rich in B vitamins, (ex., liver or bee pollen), and silica (the herb horsetail, "equisetum hymale" species, is a source,) as gluten grains contain those nutrients.

9. Traditional peoples soaked and/or sprouted their wheat berries and then made sourdough bread with it. Does that process alter the gluten sufficiently for gluten syndrome patients to safely consume it today, particularly organic spelt and einkorn?

No. These methods make bread more digestible, but the fermented products and ancient gluten grains still contain gluten and can trigger reactions in research trials. Even if there are no visible reactions, silent injury cannot be ruled out without long term research. Additionally, the preparation process before fermentation is completed is definitely gluten based, so significant cross contamination issues come into play in the kitchen. Healing the gut is a challenge. Other areas crop up that need cleanup too, such as the parasite issues. Gluten specialists advise us to go gluten-free, stay that way, and move on.

10. What are gluten withdrawals?

Rarely, a few days to a few weeks after going gluten-free, or after being glutened, a patient may experience a few hours to a couple of weeks of a parade of varied and unusual symptoms including dizziness, black pit depression, crying, physical or emotional exhaustion, even as in difficulty getting up to use the rest room, and other odd symptoms. In severe cases they may experience an inability to socialize, make eye contact, make decisions or hold a normal conversation. Children or teens may act out in extreme ways during this situation. Often patients cannot bring themselves to discuss this experience afterward. However, a patient reluctantly described her experience 2 years later as "encountering an empty white board with nothing on it." The rest of life around her seemed to be "across the Grand Canyon." This appears to be a temporary crisis that resolves anywhere from a few hours to a couple of weeks or so according to folks who contact me about them. It is assumed that this phenomenon is due to particular pieces of gluten strings called gluteomorphins with amino acid sequences which resemble opiate drugs. When these gluten pieces disappear from the blood stream the patient may experience "withdrawal," very much like a drug withdrawal. Another theory for why this may happen involves changes in blood flow to the brain that may create a temporary neurological crisis. Autistic children may suffer these withdrawals and may take longer to stabilize, but they usually make nice gains after the crisis passes. Happily, once withdrawal is over the patients are usually much better, and they are VERY vigilant with their diet.

In the rare event that this type of reaction might occur, family and friends of the person do well to understand that the person may (or may not) be able to prepare their own food, for instance, but not be able to verbally communicate much, make eye contact, hold a conversation, answer questions, and may be uncharacteristically snappy particularly if others attempt to communicate with them. Family members may wish to be quietly and unobtrusively nearby until the person passes through this stage. If the patient has children to care for, help may be needed, and also solitude, rest, and simply prepared "real" nourishing food that is gluten-free and easy to digest such as bone broth. Probiotics or old fashioned fermented raw veggies or sauerkraut from the refrigerated section of the health food store may be helpful. Family and friends should not take the person's temporarily withdrawn personality personally.

For details on these unstudied rare reactions, or if you need support during a crisis, see...

www.theglutensyndrome.net
/Adverse_reactions.htm

...or contact me at *jka8168@sbcglobal.net*. I collect testimonials, so feel free to contribute if you have experienced this type of reaction. We hope these reactions will eventually be studied.

11. Should I replace all the gluten foods I routinely eat with gluten-free substitutes?

No, most gluten-free substitutes are still mainly expensive processed food (aka junk food). For the first few weeks it is normal for newbies to look for substitutes to replace their "old gluten friends" and it helps them make the very real emotional transition, but there are better, more nutrient dense food choices. The substitutes are still high carb, (potato, corn, tapioca, rice), and most contain sugar, processed gums, GMOs and ingredients that do not help us get well. We may actually eat more of them BECAUSE they are gluten-free. Additionally they are expensive and not always easy to prepare at home.

Many experienced gluten-free folks gradually wean themselves off a constant diet of the rather junky substitutes in favor of other real unprocessed foods, such as meat, eggs, veggies, fruits, nuts, fermented vegetables, bone broths, and so on according to their digestive abilities. The gluten-free substitutes become the occasional treat, such as pizza crust. Gluten free families are wise to find the healthiest GF versions of just the items they miss the most, and skip the rest. For example, at our house, I had served gluten spaghetti for years, but when I dropped that habit, no one noticed. However, my husband wanted his breakfast toast, so we found a gluten free brand he liked and continued that tradition. Each family works out these adjustments for themselves.

Lettuce wraps are crunchy and yummy instead of sandwiches. Hamburger patties without the bun but with onion for the onion lovers, are still tasty and they feel better afterward. In our family we now use watermelon or a watermelon basket for birthday "cake", complete with candles and a bow in the summer. Fruit pizza with a nut flour or nut/date crust, avocado chocolate or other dairy-free or fruit based pudding for the sauce, and an artistic fruit/coconut topping works for parties. There are lots of ways to celebrate happy healthy gluten-free, junk free birthdays.

12. Warning! Formal gluten challenges for testing purposes – risky!

A word of caution. Antibody tests must be performed while the patient is still consuming gluten or shortly after going gluten-free. Sometimes doctors advise patients who are already gluten-free to go back on gluten, 4 slices a day for 4-6 weeks to restart the antibodies for testing purposes. Patient experience has shown that once the system is fairly clean of gluten, going back to perform a formal gluten challenge for testing purposes may be risky. The secondary reactions for some individuals can be significant, particularly neurologically. Challenges have been known anecdotally to trigger psychological black pit crashes, fibromyalgia, and other organ injury. Autistic children may have a hard time when they just go gluten-free initially or consume gluten accidentally. A planned challenge for them may be very unwise.

13. Intermittent infractions (aka cheats) are seriously unwise and may increase injury.[10]

This is not a fad, or cheater's diet. The gluten-free diet is a medical diet to treat or control serious autoimmune, inflammatory, and often neurological diseases. There is no room for casual infractions. Research suggests that repeated, intermittent cheats, even every few weeks, over time may actually influence mortality rates.[10] This is not a reason to avoid the diet, but to take it seriously. Once the strictness of the diet is embraced the patient or family adjusts and discovers that it is doable. Gluten-free food bars, nuts, a packet of gluten-free soy sauce, and GlutenEase™ or other brands of DPP IV enzymes are good to keep in the glove compartment or backpack to handle emergencies. NOTE: DPP IV (pronounced DPP 4) digestive enzymes help break down gluten but they do not stop a reaction and are NOT a reason to cheat. However if there is a possibility of exposure it makes sense to take them for whatever help they might afford. In the case of a confirmed gluten exposure, take the enzymes, keep the bowels moving, stay calm and deal with it. Worry and drama makes everything worse.

14. Discrepancy – The celiac focus uses villi biopsy for diagnosis. The wider perspective relies on positive antibodies or improvement on the diet. Question? How did villi damage become the gold standard?

The first place the medical profession found conclusive damage by gluten in the 1950's – 60's was to the villi of the gut. After the endoscopy tool was developed, villi damage and subsequent healing upon gluten removal could be observed. They concluded that gluten damaged the villi. This was true. The particular subset of cases they scoped had villi damage, but their conclusion that the villi were the only target of damage for everyone with gluten syndrome was too narrow according to research today.[2] In most patients the target damage was NOT the villi, but the bones, joint lining, heart, thyroid, pancreas, liver, brain, almost any organ, blood vessel walls, nerves almost anywhere in the body, and so on. The patients might even have injury to multiple tissues, BUT NOT NECESSARILY ALWAYS TO THE VILLI. When the villi biopsy was declared the gold standard for gluten syndrome diagnosis, it cut out most of the patients who were reacting to gluten. Snipping villi does no good if the damage is in the thyroid or brain. For the next 60 years very few patients were prescribed a gluten-free diet because most of them did not have damaged villi, (or the doctor never thought to look at all). Their gluten-induced injury was somewhere else in their body, so they were never diagnosed.

15. Discrepancy - The villi damaged celiac disease story teaches that celiac disease is autoimmune and much worse than "non autoimmune" non-celiac gluten syndrome (NCGS). The wider gluten syndrome perspective teaches that both are autoimmune and serious.[2,3,4]

A significant disagreement exists over the autoimmunity of non-celiac gluten syndrome (NCGS). In the beginning, antibodies to gluten could not be found in NCGS patients, therefore it was assumed that NCGS was not autoimmune. However, Dr. Vojdani insists NCGS IS autoimmune. The NCGS patients have plenty of antibodies, just different ones than the standard tests check. His tests, which check and find more antibodies,**** the illnesses these patients develop, and recoveries or improvements on the diet all prove his point. He also asserts that NCGS can indicate a gut wall in worse shape than the celiac villi damaged subset.[2,3,4] The damage is simply somewhere else, not to the villi. See the link below for diagrams of these reactions, and compare the condition of the gut wall in the celiac diagram with the gut wall in the gluten intolerance diagram.

**www.TheGlutenSyndrome.net/
VojdaniDiagrams.htm**

**** Dr. Vojdani's research found several more forms of both tTG, and gliadin antibodies, (alpha, gamma, omega), gluteomorphins, glutinins, and others. His saliva and blood panels check 12 separate antibodies in 3 different immune departments and 2 mediums, totaling 28 gluten related antibodies. The two panels, run together, nearly always find antibodies if they are present in the patient, translating to far fewer false negatives.

> This disagreement fosters confusion among NCGS patients that villi damaged celiac disease is the "big bad boy" to avoid (true, it is bad), but that NCGS is less severe, not autoimmune. This translates in real life to gluten birthday cake for the Friday night party and then back on the gluten-free bandwagon Saturday morning, "so I won't eventually develop villi damaged celiac disease." Yes, that could happen also, particularly if the person seesaws on the diet, but the notion that NCGS is not as bad as villi damaged celiac disease is a misunderstanding according to Dr. Vojdani.[2,3,4] To repeatedly seesaw off and on gluten indiscriminately is unwise according to medical literature,[10] and community experience. Gluten exposure needs to be an accident, which happens occasionally even to the most vigilant. Casual cheats are a more risky mindset, usually meaning "more frequent."[10] Take it seriously, nerves, blood vessels, and organs are precious.

Gluten Tests with a Good Track Record

Some families cannot afford to test or good tests are not available. In the case of autism this protocol and most others require gluten-free and that is the end of the matter. Kerri takes this position partly due to cost and the miserable record of false negatives that standard tests return. The protocol does not work without the diet. Period.

Some adults are also willing to go gluten-free without a test. Their bodies tell them what they need, they listen, and are happy to find answers. Social pressure does not sway their decision or ability to comply.

In many other situations, a positive test is very meaningful. It gives patients confirmation that gluten-free is right for them, silences critics, and helps them comply with the diet. In the case of children it provides proof to the other parent, grandparents, therapists, doctor, etc. It may also come in handy if the child turns into an invincible teen who doubts he ever needed the diet in the face of pizza and beer, ditto for his future spouse and in-laws. The catch is that the test must be adequate. A false negative misvalidates the skeptics. These are decisions every individual or family must evaluate for themselves. Thankfully there are test panels with good track records now.

Absolutely, regardless of any test result, if the body is able to communicate a reaction to gluten or its removal, then that is the final answer. Be grateful and go gluten-free.

This testing section is for those who wish to test for their own confirmation or social support.

NOTE: If a patient has been ill for a very long time it is possible for the immune system to be so worn out that few antibodies are manufactured. Lower antibody counts might show a false negative but not prevent injury to innocent tissues. Also, due to the wide variety of antibodies a patient may happen to make, it is possible to run any antibody panel and miss those particular antibodies. The more antibodies that are checked the less likely this may occur, but should be considered in the event of a negative test that the patient or practitioner questions. In this case a gene test may be helpful.

Enterolab - Stool and 1 part gene tests

For 10 years Enterolab's mail in home collection research stool test stood in the gap for thousands of patients who received false negative standard tTG and gliadin blood tests. It has saved many lives, and gave our family the social confirmation we needed. This unpublished research test checks stool for tTG-IgA and gliadin-IgA only. The use of stool as the testing medium appears to pick up those antibodies most of the time, much much more often than standard tTG or gliadin IgA blood tests. However, since only two antibodies are checked, it may miss in some cases.

Dr. Fine's lab also offers a one part gene test which he believes is adequate for a reasonable price. Dr. Fine finds if a gene is present, nearly always so are the antibodies, and two genes are worse. Villi damaged celiac specialists recognize only HLA DQ 2 and 8 as gluten related, but Dr. Fine includes 1 and 3 and their subsets 5, 6, 7 and 9. In fact according to Enterolab, HLA DQ 4 is the only DQ gene that does NOT correlate with gluten syndrome. According to him, a patient needs 2 copies of the HLA DQ 4 gene to miss the predisposition. This translates to 81% of the Caucasian population with a predisposition to trigger gluten syndrome at some point in their lifetime, including before they are born.

Cyrex Labs - Better blood and saliva tests

Cyrex Labs (www.CyrexLabs.com) opened their doors in 2010 in Phoenix, Arizona. They run much more complete antibody panels designed by Dr. Aristo Vojdani, PhD., their scientific advisor, an immunologist, and researcher. Dr. Vojdani found a wider variety of gliadin antibodies, (alpha, gamma, omega) and variations of tTG in other tissues, plus gluteomorphins, and several others. He also checks an IgM antibody due to possible malfunctions in that system. Cyrex blood and saliva panels, Array #1 and #3, combined, test for 28 gluten related antibodies between 3 immune departments, 2 mediums, plus IgA insufficiency. They rarely miss a diagnosis because they look for so many antibodies. (Note: Vojdani believes stress, toxins and infections, i.e. environment, can trigger a gluten reaction without the genes.)

Gluten Free Society - Two Part Gene Test

A third approach espoused by Dr. Peter Osborne, *The Gluten Free Society*, Sugarland, Texas, (www.glutenfreesociety.org), is to run only the gene test, since any antibody panel may theoretically miss the particular ones the patient may have. He uses a 2 part test, the most complete method, and looks for both celiac and gluten sensitivity genes. A positive gene test does not prove a current immune response as do antibodies, but predisposition to it. Presence of 2 genes indicates a more severe case. Gene tests have an advantage in that they can be run anytime, gluten consumption is unnecessary, and depending on the results, useful information can be gleaned for immediate and extended family members.

Elimination Diet

The elimination diet is inexpensive. Often/usually it demonstrates improvement upon removal of gluten, or worsening upon reintroduction. Many "heads up" practitioners accept this as reason enough to go gluten-free.

There are occasional complications or interpretation issues for the elimination diet as follows:

a. Reintroduction of gluten (gluten challenge) can trigger stronger, sometimes risky reactions.[10] Stop a challenge upon negative symptoms, including depression and emotional instability, or best, don't challenge. An accidental infraction may come up that provides insight.

b. Occasionally it takes several months to see the difference, or a silent reaction may mask symptoms.[6]

c. If the patient later decides to test and is already "clean" on the gluten-free diet, blood tests will not work unless gluten is reintroduced for many weeks.[10] No! Stool/gene tests are safer.

d. There is no lab confirmation to silence naysayers.

Other Related Tests

Cyrex Labs Array # 2 - Intestinal Permeability Panel focuses on specific causes of leaky gut. This helps strategize treatment, and is an improvement over the old lactulose/mannitol test.

Cyrex Labs Cross Reactive Foods and Gluten Substitutes, Array # 4. - This specific list checks foods that commonly cross react with gluten and also foods commonly used to replace gluten. It helps customize an anti-inflammatory diet.

Cyrex Labs Predictive Antibody panels determine if or which tissues are currently under antibody attack. This predicts autoimmunity years ahead of time and gives the patient advance notice in order to address trouble spots.

Enterolab (www.Enterolab.com) offers several stool based food antibody panels and gut related stool tests.

What are the lab instructions?
Do I need to consume gluten for testing?

Antibody tests, (blood, saliva, stool), prove a reaction and require recent gluten consumption. Ideally, test first, then go gluten-free. If the patient is off gluten, call the lab for advice on the time window before the test will not work.

Cyrex Labs (www.CyrexLabs.com) tests require prescriptions and a saliva specimen and/or blood draw. If a doctor is needed to write the script, check www.thedr.com for a partial list of practitioners who are familiar with Cyrex Labs. Results are sent to the prescribing doctor.

Enterolab stool specimens are ordered online, kits are sent, home collected and mailed. No prescription is required. Results arrive on email. Enterolab's test works for several months after going gluten-free.

Gene tests do not require gluten consumption or a script and can be run at any time. Genes prove a predisposition to gluten reaction.

Enterolab's gene test is a relatively inexpensive "one part" test. It is a mail in cheek swab and reports the patient's actual genes.

Gluten Free Society (www.Glutenfreesociety.org) gene test is a "two part" (more complete) mail in cheek swab and reports yes or no for both celiac and gluten sensitivity genes.

For information on testing (I have no financial interests) see:

www.TheGlutenSyndrome.net

The latest version of this article and a complete list of references is available at:

**www.TheGlutenSyndrome.net
/Molecular_Mimicry.pdf**

Author's note: While the information Olive has provided can be extremely helpful for adults or children who are not on the spectrum or who are suffering from other ailments, a gluten-free diet is non-negotiable for healing autism. We need to remove foods that cause inflammation and mucous, and which can produce gluteomorphin in the body. I have seen many families waste time and money doing testing only to get confused by false negatives—time and money they could have spent on recovering their child.

Online Gluten Summit – A Chance to Support CDAutism

Recently, in November 2013, Dr. Thomas O'Bryan, an internationally recognized gluten educator, put together an amazing online Gluten Summit. Twenty nine iconic experts on Celiac Disease and its wider perspective, Gluten Sensitivity, also called Gluten Syndrome, covered every possible aspect before 115,000 appreciative viewers. This set of interviews plus extra materials is available for purchase at only $3.30 per speaker and is a priceless addition to all our libraries. It also is a great gift and a good way to inform friends and family. Often our closest loved ones accept new information better from a respected professional rather than from us.

Arrangements are in place to contribute half of your purchase price of The Gluten Summit interviews to the CDAutism project. Go to the link below to order and also credit CDAutism with your contribution.

gg110.infusionsoft.com/go/tgso/Kerri

Appendix 6

Measuring the Strength of Your CD, CDS & CDH

by Charlotte Lackney

CD, CDS, and CDH work because all of them contain chlorine dioxide (ClO_2). ClO_2 is made when a 22.4% solution of sodium chlorite ($NaClO_2$) is activated with an acid, usually 4% hydrochloric acid (HCl) for CD and CDH; and 10% HCl for CDS.

Sometimes it might be useful to measure the amount of ClO_2 in those solutions, although that has not been done in the past when using CD. And, it may only be necessary to know the amount of chlorine dioxide if you are not getting the expected results. There could be a problem with the ingredients or process and knowing the amount of ClO_2 in the solution could be helpful in determining what might be wrong.

The amount of ClO_2 in a solution is measured in *parts per million* (ppm). It is always necessary to specify the volume of solution when talking about ClO_2 ppm because the ppm will vary depending on the dilution of the solution.

If using CDH or CDS with the protocol in this book, it is assumed that you are preparing them at 3000ppm. If using CDS, please keep in mind that the relative strength of one milliliter of CDS is approximately 60% of one drop of CD.

However, if the ingredients are of good quality and the CD or CDH protocol is closely followed, there is usually no need to know or measure the ClO_2 concentration.

Both CD and CDH may continue to activate inside the body from whatever sodium chlorite has not been activated outside the body. That is not the case with CDS, as it has no sodium chlorite to continue activating inside the body. Some believe that this is why many people can tolerate a higher dose of CDS than an equivalent dose of CD.

Measuring the concentration of ClO_2 can easily be done at home. You will need to purchase ClO2 test strips made by *LaMotte* or others. I have only used LaMotte Insta-Test® High-Range Test Strips, 0 to 500ppm (code #3002). The container's label has a chart showing seven colors on it wih each color indicating a ClO_2 concentration in ppm. Note: LaMotte recently changed the appearance of their labels, as shown on the right. Both are the same product. For more information, see their website:

www.lamotte.com/
en/water-wastewater/test-strips/3002.html

Directions for how to use the LaMotte test strips are printed on the side of the container and need to be followed in order to get an accurate ClO_2 concentration reading.

The numbers below each of the seven colors represent 0, 10, 25, 50, 100, 250 and 500ppm. Many people who use the test strips think the 50ppm color is the best one to use for color matching, because they can see the difference in color below and above that color more easily than the others.

If the ClO_2 solution you want to measure is suspected to be 3000ppm, how do you measure that if the test strips highest ClO_2 concentration color is 500ppm? Recall that I had said that it is always necessary to specify the volume of solution when talking about ClO_2 ppm, because the ppm will vary depending on the dilution of the solution.

So if we dilute the suspected 3000ppm ClO_2 stock solution with more water, the same amount of ClO_2 will now be evenly spread out in the larger amount of solution if stirred. There will be less ClO_2 in any one spot than before dilution, because the ClO_2 is now dispersed into a larger volume of water. Visualize what happens when a drop of red food coloring falls into a glass of water. It disperses throughout the water if stirred, and that dark red color is now much lighter because it is diluted in the water.

In order to read 3000ppm with a test strip, and have it match the 50ppm color on the container, we will need to dilute a small sample of the stock solution.

Stock solution (1ml)	÷	Desired dilution in ppm	=	Volume of water for dilution.
3000ppm		50ppm		60ml

Insta-TEST
50 Test Strips
High Range
Chlorine Dioxide
For testing sanitized water
Just dip & read!
LaMotte
InstaTest ANALYTIC
High Range
Chlorine Dioxide
50 Test Strips
Code 3002
LaMotte

The chlorine dioxide test strips (code #3002) made by LaMotte are available on the market with two different labels, although both are the same product. Both labels show the same measuring color chart on the outside of the container.

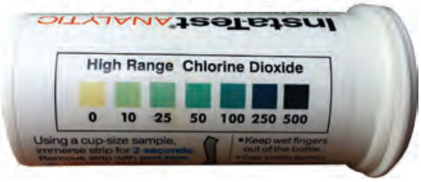
InstaTest ANALYTIC
High Range Chlorine Dioxide
0
10
25
50
100
250
500
Using a cup-size sample, immerse strip for 2 seconds.
Keep wet fingers out of the bottle.

So, if we take a 1ml sample of the stock solution and add it to 60ml of water, then the stock solution is diluted 60 times its original volume. Technically, one should add the 1ml of stock solution to 59ml of water, for a total of 60ml, but using 60ml is easier to measure and you would not see the difference in ClO_2 readings if 59ml of water was used.

To measure, pour 60ml of distilled water into a small glass and then add 1ml of stock solution. Stir well to evenly distribute the ClO_2 sample in the water. Then take one of the test strips—taking care not to touch the pad of chemicals on the end of the strip—and dip it in the solution for two seconds. Keep the strip in one place in the solution and do not move it around during the two-second period.

Without flicking any of the solution off the strip, remove the strip from the test solution with the pad facing up and wait ten seconds. Now compare the color of the test strip pad to the color chart on the side of the test strips container (as shown above).

If the stock solution is 3000ppm, then the color on the test strip will match the 50ppm color on the container. Multiply 50 times 60 (the amount of dilution) and you get 3000ppm.

If the color on the test strip does not match the 50ppm color on the container, try to estimate the ppm number between container colors and multiply that number by 60 to get the ClO_2 concentration.

Tip: You can cut the strips lengthwise to get 100 strips instead of 50; just be sure not to touch the strip's pad with your fingers or your readings may not be accurate. Also it is important to keep the container tightly capped to keep moisture out which can affect the readings.

Healing
the symptoms known as
Kerri Rivera

Dana one year after starting Kerri's protocol.

Appendix 7

Diluting HCl Concentration

The protocols in this book use two different concentrations of hydrochloric acid (HCl): 10% & 4%. Some suppliers sell both concentrations, while others only one. You may also find a source with a different concentration and wish to dilute it to 4 or 10%. The math to determine how much to dilute your stock solution is rather simple. You should have no problem if you know how to multiply, divide, add and subtract. Note: The same calculation works for citric acid if you have 50% and need to go down to 35%.

What you will need is:

- Bottle of concentrated HCl (10% or higher)
- Receiving bottle to store the resulting diluted HCl
- Graduated cylinder or other measuring cup

On the next page is a graphical representation of the dilution equation. It may look intimidating at first glance, but it is actually quite simple and is made up of three simple mini-calculations. Each box is labeled with a letter which refers to the graphic. Just fill in the numbers with a pencil and follow the directions.

We'll go over one example here: Let's say you have 10% HCl and want to make 1 liter of 4% HCl. Here's what you would have to calculate:

Desired Volume		Desired HCl %		Temporary Number
1000ml	×	4%	=	4000

Temporary Number		Stock HCl %		Amount of 10% HCl
4000	÷	10%	=	400ml

Desired Volume		Amount of 10% HCl		Amount of water
1000ml	–	400ml	=	600ml

So, in this example, you would need 400ml of 10% HCl and 600ml of water. to make 1 liter of 4% HCl. If you add them together, you should have 1000ml (1 liter).

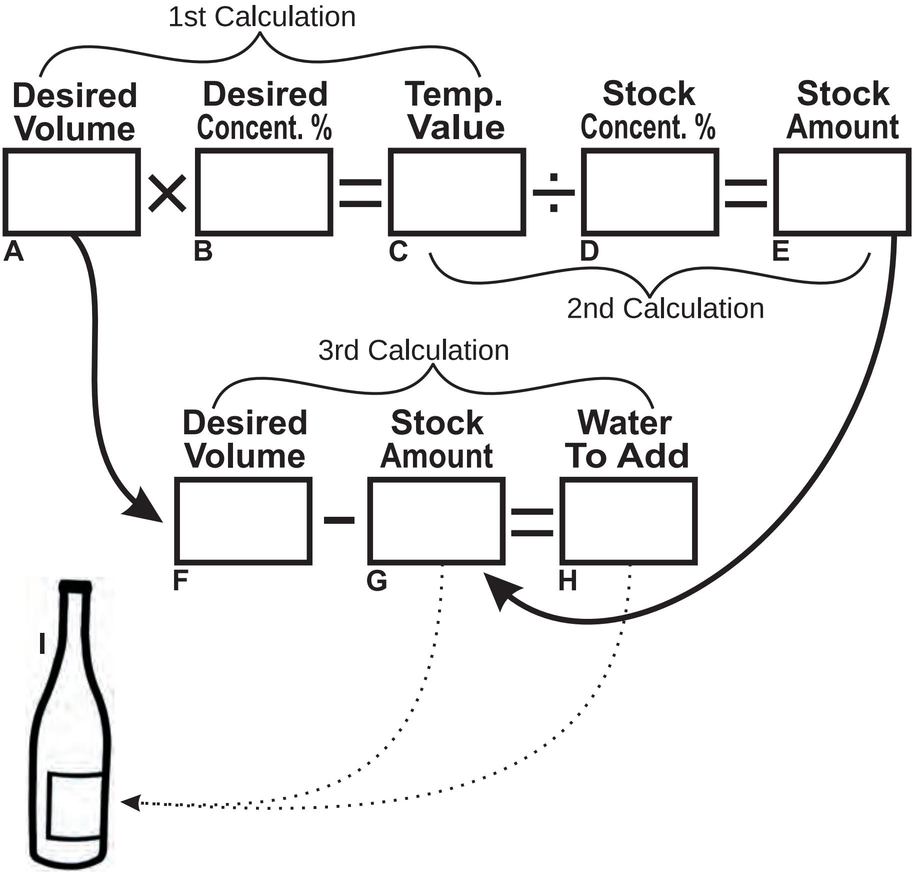
1st Calculation
Desired Volume
Desired Concent. %
Temp. Value
Stock Concent. %
Stock Amount
×
=
÷
=
A
B
C
D
E
2nd Calculation
3rd Calculation
Desired Volume
Stock Amount
Water To Add
–
=
F
G
H
I

A	Determine the volume of the receiving bottle in milliliters. For example, if you have a 1 liter bottle, you would enter the number “1,000” for 1,000ml.
B	This is where you enter the % of the final solution. If you are making 4%, then enter “4” in this box.
C	Multiple **A** and **B** and enter the result into box **C**. This is a temporary value you will need for the next calculation.
D	This is where you enter the percentage of your concentrated stock solution–the HCl you want to dilute. If you have 10%, then enter a “10” in this box.
E	Now divide the temporary value in **C** by **D** and enter the result in **E**. This is the amount of concentrated stock HCl (in milliliters) you will need.
F	Copy what you entered in **A** to **F** for the next calculation.
G	Copy the result from **E** to **G**.
H	Do the subtraction of **F** – **G** and enter he value in **H**. This is the number of milliliters of distilled or filtered water you will need.
I	Measure the resulting volume of water calculated in **H** and pour it into the receiving bottle **I**. Finally, measure out the value in **G** and pour it into the receiving bottle **I**.

Appendix 8

Other Uses of Chlorine Dioxide

Bladder Infection Protocol (for Adults)

The protocol for bladder infection is three oral drops of CD eight times a day with a douche of 10 drops CD three times the first day, and then once every day thereafter, for 30 days (for females).

Ear, Eye, Nose Protocol

Make a mixture that contains one ounce of water for every one drop of CD. Use one drop of that mixture in the affected orifice every hour until symptoms disappear. If the issue is acute you can use one drop every 15 minutes. This method can be used in the ears for infections, in the nose for congestion/infection, and the eye for infection or conjunctivitis.

General Fever Protocol

If the person has a fever, or if you want clarification of any kind, email Kerri, but in the meantime, this will hopefully get you started:

1. Give baths interspersed with enemas, approximately eight hours apart (e.g. bath in the evening and enema in the morning or vice versa).
2. Give oral CD doses (using the person's usual number of drops) 12 to 16 times or more a day (essentially every hour); unless they stop eating, in which case, stop oral dosing. Enemas and baths can continue.
3. Have them drink lots of water.
4. Cool clothes on forehead and neck.

Please see Chapter 14, page 335 for more information on fever therapy.

Teeth

Ten activated drops of CD per one ounce of water. Put this in a spray bottle and spray on the toothbrush.

Throat Spray

Ten activated drops of CD (chlorine dioxide) in one ounce of water. Spray on throat once/hour. Recommended in the case of a sore throat.

Vaginal Douching for Yeast Infections:

Put six activated drops of CD in 60 ml of water. Hold this in for two minutes every day for a few weeks or between periods. Six drops MAX in the vagina.

CD Skin Spray

Use ten drops of activated CD per one ounce of water in a spray bottle.

CD spray is great for a variety of ailments.

- Skin
- Dandruff
- Scrapes
- Cuts
- Rashes
- Toe Fungus

Burns

Any burn should be sprayed with full strength sodium chlorite solution (no acid added) directly from a small spray bottle. Do not add citric acid or HCl at all! If you don't have a spray bottle available drip sodium chlorite solution directly onto the burn, making sure the area is soaked with it.

Wait up to five minutes, but no longer before rinsing off with room temperature water. If you fail to rinse off the sodium chlorite solution, the burn will continue to hurt and get worse.

This technique will cause the burn to heal in 1/4 the time normally required. The pain should stop almost immediately or reduce to almost zero within several minutes.

Sunburns should be treated the same way. Spray the red area, wait 1 to 5 minutes, and rinse off. If the area is still sore, in about an hour spray the area again and wait 5 minutes before rinsing off. Remember, DO NOT allow the sodium chlorite to remain in place. It must be rinsed off! The pain should be gone in a couple of minutes. Generally two doses will overcome most sunburns, but on rare occasions if the discomfort is not all gone you can use a third dose. Be sure to rinse it off.

Note that sodium chlorite is alkaline and burns are acidic. Therefore the sodium chlorite neutralizes the acidity that resides in the burned areas. This is part of the reason why burns heal rapidly after sodium chlorite applications.

Appendix 9

Blank Kalcker Parasite Protocol Chart

The next page contains a blank Kalcker Parasite Protocol Daily Chart identical to those found on pages 199 through 217. You are encouraged to copy this chart for use in your parasite protocol planning. Setting the copy machine to enlarge at 125% should fill a standard letter-sized page.

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin®)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM												
6:30 AM												
7:00 AM												
7:30 AM												
8:00 AM												
8:30 AM												
9:00 AM												
9:30 AM												
10:00 AM												
10:30 AM												
11:00 AM												
11:30 AM												
12:00 PM												
12:30 PM												
1:00 PM												
1:30 PM												
2:00 PM												
2:30 PM												
3:00 PM												
3:30 PM												
4:00 PM												
4:30 PM												
5:00 PM												
5:30 PM												
6:00 PM												
6:30 PM												
7:00 PM												
7:30 PM												
8:00 PM												
8:30 PM												
9:00 PM												
9:30 PM												

Appendix 10

Lunar Phase Calendar for Kalcker Parasite Protocol

As covered in Chapter 8, the Kalcker Parasite Protocol is administered over a period of 19 days and scheduled according to the lunar cycle. We have included an easy to follow calendar starting on the next page for the years 2014 through 2016.

Each chart page shows 6 months with each month broken up into 3 columns: Column 1 is the day of the month; column 2 indicates the lunar phase; and column 3 shows the corresponding Parasite Protocol day.

The full moon is identified with an “F” in the second column and the new moon is identified by an “N” in each month section, which usually occurs towards the end of each protocol cycle.

We have used New York as our center point since it is roughly the center of the majority of those using this book in the US and Europe. The moon phase may occur 1 day before or after the dates shown if you are in another part of the world, but the difference is not great, so feel free to use the dates shown. However, you are welcome to be precise for your particular location. The Farmer’s Almanac is a great source and provides an online calendar that can be adjusted to your location:

www.almanac.com/moon

You may also wish to install a moon phase app into your smart phone. Many free options exist.

2014 - Lunar Phases for New York, NY

Jan			Feb			Mar			Apr			May			Jun		
1	N	18	1			1	N	18	1			1	N		1		
2			2			2			2			2			2		
3			3			3			3			3			3		
4			4			4			4			4			4		
5			5			5			5			5			5		
6			6			6			6			6			6		
7			7			7			7			7			7		
8			8			8			8			8			8		
9			9			9			9			9			9		
10			10			10			10			10			10		0
11			11		0	11			11			11			11		1
12		0	12		1	12			12		0	12			12		2
13		1	13		2	13		0	13		1	13		0	13	F	3
14		2	14	F	3	14		1	14		2	14		1	14		4
15	F	3	15		4	15		2	15	F	3	15		2	15		5
16		4	16		5	16	F	3	16		4	16	F	3	16		6
17		5	17		6	17		4	17		5	17		4	17		7
18		6	18		7	18		5	18		6	18		5	18		8
19		7	19		8	19		6	19		7	19		6	19		9
20		8	20		9	20		7	20		8	20		7	20		10
21		9	21		10	21		8	21		9	21		8	21		11
22		10	22		11	22		9	22		10	22		9	22		12
23		11	23		12	23		10	23		11	23		10	23		13
24		12	24		13	24		11	24		12	24		11	24		14
25		13	25		14	25		12	25		13	25		12	25		15
26		14	26		15	26		13	26		14	26		13	26		16
27		15	27		16	27		14	27		15	27		14	27	N	17
28		16	28		17	28		15	28		16	28		15	28		18
29		17				29		16	29	N	17	29		16	29		
30	N	18				30	N	17	30		18	30	N	17	30		
31						31		18				31		18			

2014 - Lunar Phases for New York, NY

Jul			Aug			Sep			Oct			Nov			Dec		
1			1			1			1			1			1		
2			2			2			2			2			2		
3			3			3			3			3		0	3		0
4			4			4			4			4		1	4		1
5			5			5		0	5		0	5		2	5		2
6			6			6		1	6		1	6	F	3	6	F	3
7			7		0	7		2	7		2	7		4	7		4
8			8		1	8	F	3	8	F	3	8		5	8		5
9		0	9		2	9		4	9		4	9		6	9		6
10		1	10	F	3	10		5	10		5	10		7	10		7
11		2	11		4	11		6	11		6	11		8	11		8
12	F	3	12		5	12		7	12		7	12		9	12		9
13		4	13		6	13		8	13		8	13		10	13		10
14		5	14		7	14		9	14		9	14		11	14		11
15		6	15		8	15		10	15		10	15		12	15		12
16		7	16		9	16		11	16		11	16		13	16		13
17		8	17		10	17		12	17		12	17		14	17		14
18		9	18		11	18		13	18		13	18		15	18		15
19		10	19		12	19		14	19		14	19		16	19		16
20		11	20		13	20		15	20		15	20		17	20		17
21		12	21		14	21		16	21		16	21		18	21	N	18
22		13	22		15	22		17	22		17	22	N		22		
23		14	23		16	23		18	23	N	18	23			23		
24		15	24		17	24	N		24			24			24		
25		16	25	N	18	25			25			25			25		
26	N	17	26			26			26			26			26		
27		18	27			27			27			27			27		
28			28			28			28			28			28		
29			29			29			29			29			29		
30			30			30			30			30			30		
31			31						31						31		

2015 - Lunar Phases for New York, NY

Jan			Feb			Mar			Apr			May			Jun		
1		0	1		1	1			1		0	1		1	1		2
2		1	2		2	2		0	2		1	2		2	2	F	3
3		2	3	F	3	3		1	3		2	3	F	3	3		4
4	F	3	4		4	4		2	4	F	3	4		4	4		5
5		4	5		5	5	F	3	5		4	5		5	5		6
6		5	6		6	6		4	6		5	6		6	6		7
7		6	7		7	7		5	7		6	7		7	7		8
8		7	8		8	8		6	8		7	8		8	8		9
9		8	9		9	9		7	9		8	9		9	9		10
10		9	10		10	10		8	10		9	10		10	10		11
11		10	11		11	11		9	11		10	11		11	11		12
12		11	12		12	12		10	12		11	12		12	12		13
13		12	13		13	13		11	13		12	13		13	13		14
14		13	14		14	14		12	14		13	14		14	14		15
15		14	15		15	15		13	15		14	15		15	15		16
16		15	16		16	16		14	16		15	16		16	16	N	17
17		16	17		17	17		15	17		16	17		17	17		18
18		17	18	N	18	18		16	18	N	17	18	N	18	18		
19		18	19			19		17	19		18	19			19		
20	N		20			20	N	18	20			20			20		
21			21			21			21			21			21		
22			22			22			22			22			22		
23			23			23			23			23			23		
24			24			24			24			24			24		
25			25			25			25			25			25		
26			26			26			26			26			26		
27			27			27			27			27			27		
28			28			28			28			28			28		0
29						29			29			29			29		1
30						30			30		0	30		0	30		2
31		0				31						31		1			

2015 - Lunar Phases for New York, NY

Jul			Aug			Sep			Oct			Nov			Dec		
1	F	3	1		4	1		6	1		7	1		8	1		9
2		4	2		5	2		7	2		8	2		9	2		10
3		5	3		6	3		8	3		9	3		10	3		11
4		6	4		7	4		9	4		10	4		11	4		12
5		7	5		8	5		10	5		11	5		12	5		13
6		8	6		9	6		11	6		12	6		13	6		14
7		9	7		10	7		12	7		13	7		14	7		15
8		10	8		11	8		13	8		14	8		15	8		16
9		11	9		12	9		14	9		15	9		16	9		17
10		12	10		13	10		15	10		16	10		17	10		18
11		13	11		14	11		16	11		17	11	N	18	11	N	
12		14	12		15	12		17	12	N	18	12			12		
13		15	13		16	13	N	18	13			13			13		
14		16	14	N	17	14			14			14			14		
15	N	17	15		18	15			15			15			15		
16		18	16			16			16			16			16		
17			17			17			17			17			17		
18			18			18			18			18			18		
19			19			19			19			19			19		
20			20			20			20			20			20		
21			21			21			21			21			21		
22			22			22			22			22		0	22		0
23			23			23			23			23		1	23		1
24			24			24		0	24		0	24		2	24		2
25			25			25		1	25		1	25	F	3	25	F	3
26			26		0	26		2	26		2	26		4	26		4
27			27		1	27	F	3	27	F	3	27		5	27		5
28		0	28		2	28		4	28		4	28		6	28		6
29		1	29	F	3	29		5	29		5	29		7	29		7
30		2	30		4	30		6	30		6	30		8	30		8
31	F	3	31		5				31		7				31		9

2016 - Lunar Phases for New York, NY

Jan			Feb			Mar			Apr			May			Jun		
1		10	1		12	1		11	1		12	1		12	1		14
2		11	2		13	2		12	2		13	2		13	2		15
3		12	3		14	3		13	3		14	3		14	3		16
4		13	4		15	4		14	4		15	4		15	4	N	17
5		14	5		16	5		15	5		16	5		16	5		18
6		15	6		17	6		16	6		17	6	N	17	6		
7		16	7		18	7		17	7	N	18	7		18	7		
8		17	8	N		8	N	18	8			8			8		
9	N	18	9			9			9			9			9		
10			10			10			10			10			10		
11			11			11			11			11			11		
12			12			12			12			12			12		
13			13			13			13			13			13		
14			14			14			14			14			14		
15			15			15			15			15			15		
16			16			16			16			16			16		
17			17			17			17			17			17		0
18			18			18			18			18		0	18		1
19			19		0	19			19		0	19		1	19		2
20		0	20		1	20		0	20		1	20		2	20	F	3
21		1	21		2	21		1	21		2	21	F	3	21		4
22		2	22	F	3	22		2	22	F	3	22		4	22		5
23	F	3	23		4	23	F	3	23		4	23		5	23		6
24		4	24		5	24		4	24		5	24		6	24		7
25		5	25		6	25		5	25		6	25		7	25		8
26		6	26		7	26		6	26		7	26		8	26		9
27		7	27		8	27		7	27		8	27		9	27		10
28		8	28		9	28		8	28		9	28		10	28		11
29		9	29		10	29		9	29		10	29		11	29		12
30		10				30		10	30		11	30		12	30		13
31		11				31		11				31		13			

2016 - Lunar Phases for New York, NY

Jul			Aug			Sep			Oct			Nov			Dec		
1		14	1		16	1	**N**	17	1		18	1		18	1		
2		15	2	**N**	17	2		18	2			2			2		
3		16	3		18	3			3			3			3		
4	**N**	17	4			4			4			4			4		
5		18	5			5			5			5			5		
6			6			6			6			6			6		
7			7			7			7			7			7		
8			8			8			8			8			8		
9			9			9			9			9			9		
10			10			10			10			10			10		0
11			11			11			11			11		0	11		1
12			12			12			12			12		1	12		2
13			13			13		0	13		0	13		2	13	**F**	3
14			14			14		1	14		1	14	**F**	3	14		4
15			15		0	15		2	15		2	15		4	15		5
16		0	16		1	16	**F**	3	16	**F**	3	16		5	16		6
17		1	17		2	17		4	17		4	17		6	17		7
18		2	18	**F**	3	18		5	18		5	18		7	18		8
19	**F**	3	19		4	19		6	19		6	19		8	19		9
20		4	20		5	20		7	20		7	20		9	20		10
21		5	21		6	21		8	21		8	21		10	21		11
22		6	22		7	22		9	22		9	22		11	22		12
23		7	23		8	23		10	23		10	23		12	23		13
24		8	24		9	24		11	24		11	24		13	24		14
25		9	25		10	25		12	25		12	25		14	25		15
26		10	26		11	26		13	26		13	26		15	26		16
27		11	27		12	27		14	27		14	27		16	27		17
28		12	28		13	28		15	28		15	28		17	28		18
29		13	29		14	29		16	29		16	29	**N**	18	29	**N**	
30		14	30		15	30	**N**	17	30	**N**	17	30			30		
31		15	31		16				31						31		

Three things cannot be long hidden:
the sun, the moon, and the truth.

~ ***Buddha***

Appendix 11

Health Benefits of Diatomaceous Earth

by Dee McCaffrey, CDC

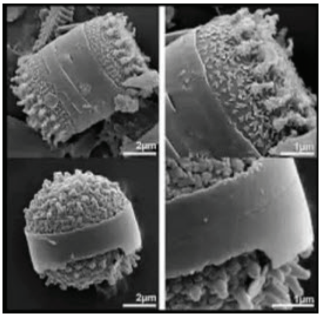

You've probably never heard of one of the best and most economical supplements to improve your health and cleanse your body. In fact, this supplement is perhaps one of the best kept secrets ever. This relatively unknown "food" supplement is called Diatomaceous Earth, also known as DE. It is a completely natural substance that is rich in naturally occurring silica, a mineral whose list of documented health benefits continues to grow as more research is being conducted.

Some of the most recent studies show that it can strengthen bones and joints, prevent osteoporosis and restore bone health if you already have osteoporosis, boost the immune system, ward off Alzheimer's, prevent premature aging and wrinkling of the skin, and strengthens the arterial walls to maintain good heart health. Another of the benefits of silica is that it helps to destroy bad fats in the body. Used as a daily treatment, diatomaceous earth can alleviate the potentially deadly risks of high cholesterol, high blood pressure, and obesity.

Additionally, because of its physical structure, diatomaceous earth is a highly effective anti-inflammatory and internal cleansing agent for the body. It can remove intestinal bacteria, parasites, e-coli, viruses, pesticides, heavy metals, and other toxins. It has also been known to assist with vertigo, headaches, tinnitus, and insomnia.

Sound too good to be true? Read on to learn more about this overlooked multi-purpose supplement and how it can improve many aspects of your health at a fraction of the cost of other supplements.

What is Diatomaceous Earth?

Diatomaceous earth is the fossilized shells of microscopic water-dwelling organisms known as diatoms. Diatoms are one-celled plants (algae or phytoplankton) that are the primary food source for marine life. These plants have been part of the earth's ecology since prehistoric times, yet their species still exists today in both salty and fresh waters all over the world.

Diatoms use soluble silica (sand) from their environment to make their shells, or exoskeletons. As diatoms die, their shells fall to the bottom of the bodies of water in which they live. It is believed that 30 million years ago the diatoms piled up to form thick beds of chalky fossilized sediment. These beds, known as diatomite or diatomaceous earth, were discovered after the waters receded.

Today, hundreds of large deposits of diatomaceous earth occur all over the world. Some are still underwater and some are found in ancient dried lake bottoms. It has been estimated that one cubic inch of diatomaceous earth may contain as many as 400 million shells, that's how small diatoms are!

Diatomite is mined and ground into a powder that looks and feels like talcum powder. This all natural powder is called Diatomaceous Earth (DE) or fossil shell flour. It is made up of approximately 33% silicon, 19% calcium, 5% sodium, 3% magnesium 2% iron and many other trace minerals such as titanium, boron, manganese, copper and zirconium.

What Do Fossilized Shells Have to Do With Improving Your Health?

It's all about the silica.

As I mentioned earlier, the shells of diatoms are made up mostly of silica (known by chemists as silicon dioxide). Silica is one of the most abundant minerals on the planet, but most of it is in a form that is unabsorbable by humans, and there are limited numbers of foods that contain an adequate amount of the absorbable form to supply the quantity our body needs. Silica is the most important trace mineral for human health. It plays an important role in many body functions and has a direct relationship to mineral absorption. For optimal health, the average human body needs to hold approximately seven grams of silica, a quantity far exceeding the figures for other important minerals such as iron and calcium.

Silica can be found in such foods as alfalfa, beets, brown rice and oats. Bell peppers and leafy green vegetables also provide silica, while asparagus, Jerusalem artichokes, parsley, sunflower seeds and grain husks, such as barley, millet and wheat contain smaller amounts.

Years ago, the silica found in our foods was adequate, but with today's depleted soils, only about one-third of the silica needed by our body is supplied in our food.

In our youth, our tissues absorb and maintain high levels of silica— enabling our bodies to remain flexible, resilient, and energetic—but as we age, and as our dietary sources of silica are not meeting our needs, our silica levels steadily decline until they become almost non-existent. In fact, 80% of all of our body's silica is used up by the time we become adults.

Our bodies need silica regardless of our age and even when diet is not the primary factor in cases of deficiencies, we often become deficient in this essential trace element simply thorough the aging process. The effect of this steady decrease in silica levels is a progressive decline in health, increasing fatigue and acceleration of the aging process.

Diatomaceous earth, which is very high in the absorbable form of silica, can replenish silica levels in the body, which can vastly improve your health and reverse many chronic problems. Studies show that high levels of silica can:

Improve Bone Health and Stop Osteoporosis: Calcium and vitamin D alone are not sufficient for bone growth, density, strength, and flexibility. In fact, the body cannot absorb and use calcium without the presence of silica. Recent data suggests that instead of promoting healing, calcium supplements actually speed up the leeching away of bone calcium and accelerate the degenerative process of osteoporosis and similar diseases that affect the connective tissues in the human body!

To re-mineralize and repair damaged bones, it is now advised that a sufficient silica supplement be taken daily because bones are composed of mainly of the minerals phosphorus, magnesium and calcium; however, these minerals need the presence of silica to be deposited into the bones, especially calcium. Silica hastens the healing of fractures and also diminishes scarring at the location of a fracture. A great deal of research evidence indicates that silica has the ability to "morph" itself into calcium through a transmutation process. Yes, silica actually has the ability to be turned into calcium when there is a calcium deficiency and the body needs it!

That fact alone should be reason enough to supplement with DE!!

Ward Off Alzheimer's: Scientists and researchers have long hypothesized that Alzheimer's disease is linked to a build up of aluminum in the brain, and links between aluminum in drinking water supplies and Alzheimer's have now been ascertained. A factor that had been overlooked is that silica reduces the accumulation of aluminum. When researchers added silica to aluminum-laced water supplies, it inhibited the aluminum from being absorbed. It also caused a proliferation in the excretion of aluminum in urine and lowered aluminum concentrations in the brain, liver, bone, spleen and kidneys. Silica, therefore, may be important in supporting neurological health.

Improve Heart and Lung Health: Silica can hinder the effects of coronary disease by fortifying blood vessels. Studies confirm that with age, silica disappears from the aorta, the heart's key blood vessel—thus weakening its critical connective tissue, and resulting in a greater cardiac risk. Studies have shown diatomaceous earth to significantly lower cholesterol by removing plaque and keeping arteries and veins supple. It also helps to regulate blood pressure. Silica also aids in the repair and maintenance of vital lung tissues and defending them from pollution.

Stop Premature Wrinkling and Sagging Skin: Silica is excellent for supporting bones and connective tissue. Your body needs healthy connective tissue for internal organs and the largest organ which is your skin. And you probably know that degrading connective tissue, with age is why wrinkles appear and skin begins to sag. Perhaps it is not age, but rather not enough silica that makes this happen.

Collagen, which is mostly made up of silica, is the glue that holds us together. Collagen accounts for up to 75% of the weight of the dermis and is responsible for the resilience and elasticity of the skin. Our connective tissues consist of collagen, elastin, mucopolysaccharides and mucous carbohydrates which aid in moisture retention. Their capacity to hold on to moisture keeps the connective tissue resilient and has apparent importance in the prevention of premature aging. All these valuable molecules house large quantities of silica. Also, many people with advanced arthritis suffer from bone deformation when tendons and ligaments in the joints lose flexibility due to loss of collagen. Tendons and ligaments need silica for health and flexibility.

Boost the Immune System: Silica may play an important role in the immune system and its biological response to harmful stimuli. Silica is necessary for the body to produce antibodies that fight off viruses, bacteria, allergens and other invaders that the body views as foreign.

Other Ways Diatomaceous Earth Can Improve Your Health

One of the most sought after benefits of diatomaceous earth is to cleanse the digestive tract. Many people consume a variety of processed foods, which contain various harmful chemicals and toxins. Plus, as air quality has decreased, we are constantly putting more toxins in our body that need to be removed.

Diatomaceous earth can purge any parasite, virus, bacteria, or toxin that is clinging to our digestive tract. While diatomaceous earth feels like a soft powder, the truth is that diatomaceous earth is actually a small cylinder with extremely sharp edges. As we consume diatomaceous earth, these sharp edges scrape away parasites, toxins, and viruses clinging to the lining of our digestive tract. Plus, any toxins or bacteria floating in our digestive tract are absorbed and trapped by diatomaceous earth. It has also been shown to cling to bad fats in the body, effectively reducing bad cholesterol. Diatomaceous earth is then expelled through our bowel movements and these harmful materials are removed.

Our skin and organs are strong and thick enough not to be affected by these sharp edges, which is why we feel no pain taking diatomaceous earth. After a few days, the body's digestive system can be thoroughly cleansed and can operate much more efficiently.

Are All Forms of Diatomaceous Earth the Same?

No! There are two types of DE—Food Grade and Pool Grade.

Most deposits of diatomaceous earth are from salt water sources, while only a few are from fresh water sources. Of the hundreds of DE deposits that exist worldwide, only 4 of them can be called food grade. The DE sourced from fresh water beds are of extremely high purity—so pure that it is called Food Grade Diatomaceous Earth, or also known as fossil shell flour. Food grade diatomaceous earth, the only form safe for human consumption, is a white powder, while other forms of diatomaceous earth may have a brown/reddish tint.

Also, there are two types of naturally occurring silica—crystalline silica and non-crystalline (amorphous) silica. Crystalline silica can be very dangerous, especially to our lungs if inhaled, while non-crystalline silica is completely safe, even for human and animal consumption. The fresh water diatoms contain mainly non-crystalline silica, while salt water diatoms can contain both types, with higher amounts of the crystalline form.

PERMA-GUARD™ is the trade name known worldwide for using a grade and quality of Diatomaceous Earth (DE) that is extremely pure. Brands that use Perma-Guard™ food grade Diatomaceous Earth contains less than 0 .5% crystalline silica. It is important to have a consistent shape diatom and no unwanted sediment. The shape of the diatom must be tubular with holes on the walls. It must be from fresh water because the fresh water diatoms form a harder shell and are less fragile that those from salt water. Salt water deposits contain a mix of diatom species. These deposits shapes and sediments are inconsistent making them unusable for safe human consumption.

Other types of diatomaceous earth have other industrial uses. It is heated to a very high temperature (about 1000°C or 1800°F). This type of DE is called "calcined." It is used for pool filters and other types of filtering but it is also used as a filler and can end up in paints, cosmetics, drugs, chemical insecticides, and other things. Food grade DE is never heated.

Bottom Line: ONLY use Food Grade Diatomaceous Earth for health purposes!!! Food grade diatomaceous earth is the purest form of diatomaceous earth and can be consumed and used by humans. Food grade diatomaceous earth is heavily regulated and must contain less than a certain amount of specific minerals.

Pool grade DE is calcinated and is a stronger, more potent form of DE. It is not to be used by humans and pool grade DE must be handled with gloves and a mask to ensure no throat irritations occur.

All DE should have a label that tells you if it has been calcined and how much crystalline silica it contains.

How Much to Take—How Safe Is It?

Food grade diatomaceous earth is a very fine powder and is very light due to its high porosity. It mixes easily into liquids and foods. Most people take a teaspoon or a tablespoon two or three times a day (up to a total of one quarter cup per day) for best results. Mix it into water, juice, smoothies or other foods.

It sort of resembles putting a spoonful of baking soda in water and drinking it!

Silica is water soluble; hence, once you get it into your body it easily absorbed via the intestinal wall and is also rapidly excreted. It does not accumulate in the body, so consistent daily supplementation is important. Studies have not found any negative side effects from too much silica. Its safety and extensive range of uses makes silica one of the most important minerals used in complementary therapy and alternative medicine. Regular supplementation could make a significant difference in your health.

Being approved by the FDA, Diatomaceous Earth has absolutely no dangerous side effects. It can be used by anyone, as long as the person doesn't suffer from a serious illness. As with any other health supplement, talk to a doctor before using DE. You might have some intolerance to it, so it's advisable to not risk your health. Pregnant and breastfeeding mothers can use it as long as their doctor has agreed.

What Other Uses Does DE Have?

One of the most commonly known uses for diatomaceous earth is as a non-toxic bug killer. DE is almost pure silica (with some beneficial trace minerals); under a microscope, it looks like shards of glass (glass is made from silica). On any beetle-type insect that has a carapace, like ants, fleas and cockroaches, the DE works under the shell and punctures the body, which then dehydrates their innards and the insect dies. DE is totally nontoxic. There is no buildup of tolerance like there is to poisons because the method of killing is PHYSICAL, not chemical. But rest assured, food grade DE doesn't hurt people or animals. In fact, it makes a great flea killer for your pets, and can also be added to their food as de-wormer. Many farmers use it to keep farm animals healthy, both inside and out. Food grade DE is also added to grains in storage because it keeps bugs from eating the grain. So if you eat any grains, you're probably already eating a little bit of DE!

Where to Get It!

You can buy food grade diatomaceous earth online. Processed-Free America sells it through its online store.

Written by Dee McCaffrey, CDC, who lost 100 pounds and has kept it off for over 20 years. For more info, go to: www.processedfreeamerica.org

Appendix 12

Summary of Protocols

The purpose of this list is to have all the protocols in one place, so you don't have to be hunting and flipping pages to find something. This information is also available on our website www.cdautism.org if you would like to print anything full size.

Diet

Permitted Foods List:

Note: Organic products are better but not required.

Proteins

☐ Beef
☐ Chicken
☐ Eggs
☐ Fish (small not large size)
☐ Pork
☐ Turkey

Fruit

☐ Most fresh fruits are permitted (except citrus, mango, pineapple, kiwi, and limit berries).
☐ Frozen fruit without added cream or sugar.
! NO canned fruit (nothing canned ever).
! Be careful of dried fruit as it may contain sugar.

Vegetables

☐ All vegetables are fine!!!
☐ Including French fries, however, not frozen fries or fries from fast food chains; these are often coated in flour.

Nuts

☐ Almonds
☐ Cashews
☐ Coconut
☐ Hazelnuts
☐ Walnuts

Grains

☐ Amaranth
☐ Buckwheat
☐ Corn
☐ Millet
☐ Quinoa
☐ Rice
☐ Sorghum
☐ Tapioca
☐ Xanthan gum

Beans

☐ All beans—EXCEPT soy
☐ Split Pea
☐ Garbanzo
☐ Lentils
☐ Navy
☐ Peanuts

Sweeteners

☐ Stevia (Best choice of all sweeteners)
☐ Agave syrup
☐ Honey
☐ Maple syrup (without added sugar)
☐ Xylitol

Prohibited Foods List

- Acetic acid (E260)
- Artificial flavoring
- Artificial sweeteners
- Bouillon cubes
- Bread
- Candy
- Cane sugar
- Carrageenan
- Catsup
- Chocolate milk
- Coloring
- Corn flakes
- Corn syrup
- Cow's milk in any form (even lactose-free milk products)
- Flour tortillas
- Gelatin
- Malt
- Margarine
- Mayonnaise
- Microwave popcorn
- MSG
- Natural flavoring
- Noodle soup
- Oatmeal (except for Bob's Red Mill GF oats)
- Pasta
- Piloncillo (unrefined sugar)
- Children´s nutritional shakes
- Play-Doh™
- Preservatives
- Processed meats (hotdogs, ham, sausage, bologna, cold cuts)
- Shellfish (full of toxins)
- Sodas
- Soy/fruit beverages
- Soy milk
- Soy sauce
- Sports drinks
- Sugar
- Yeast

Preparing Your First One drop CD Batch for the Day

1.	Start by filling the baby bottle with 8 fl. oz. (237ml) of water (distilled or reverse osmosis). NO alkaline water!	
2.	Place 1 drop of sodium chlorite solution into the CLEAN and DRY shot glass.	
3.	Add 1 drop of acidic activator (hydrochloric acid or citric acid) to the shot glass containing the drop of sodium chlorite. The number of drops may be higher if you are using a weaker activator. See chart on page 94.	
4.	Now wait the appropriate time for the mixture to react (see chart on page 94). You should see the color change from clear to slightly yellow. If there were more drops in the shot glass, the color change is more noticeable. You are also likely to notice the chlorine-like smell coming from the shot glass. Remember, this is NOT chlorine, but rather chlorine dioxide.	
5.	After the activation time has passed, pour a little water from the baby bottle into the shot glass and let it mix. This mostly stops the chemical reaction and insures you get most of the mixture out in the next step.	
6.	Lastly, pour all of the watered down mixture in the shot glass back into the baby bottle, and seal it tightly with the cap—don't leave it sitting open for any length of time. Think partially used soda pop and how you would want to keep that closed.	

Estimated Full Oral CD Doses by Weight

Use these numbers as a guide only. You may need to go up by as much as 50% or more over the indicated drops. Read chart as: **POUNDS / KILOGRAMS → DROPS OF CD (per 8 fl. oz. water)**

25/11→8	62/28→17	99/45→24	136/62→29	173/78→33	210/95→37
26/12→8	63/29→17	100/45→24	137/62→29	174/79→33	211/96→37
27/12→9	64/29→17	101/46→24	138/63→29	175/79→34	212/96→37
28/13→9	65/29→18	102/46→24	139/63→30	176/80→34	213/97→37
29/13→9	66/30→18	103/47→24	140/64→30	177/80→34	214/97→37
30/14→9	67/30→18	104/47→25	141/64→30	178/81→34	215/98→37
31/14→10	68/31→18	105/48→25	142/64→30	179/81→34	216/98→37
32/15→10	69/31→18	106/48→25	143/65→30	180/82→34	217/98→37
33/15→10	70/32→19	107/49→25	144/65→30	181/82→34	218/99→38
34/15→10	71/32→19	108/49→25	145/66→30	182/83→34	219/99→38
35/16→11	72/33→19	109/49→25	146/66→30	183/83→34	220/100→38
36/16→11	73/33→19	110/50→26	147/67→31	184/83→35	221/100→38
37/17→11	74/34→19	111/50→26	148/67→31	185/84→35	222/101→38
38/17→11	75/34→20	112/51→26	149/68→31	186/84→35	223/101→38
39/18→12	76/34→20	113/51→26	150/68→31	187/85→35	224/102→38
40/18→12	77/35→20	114/52→26	151/68→31	188/85→35	225/102→38
41/19→12	78/35→20	115/52→26	152/69→31	189/86→35	226/103→38
42/19→12	79/36→20	116/53→26	153/69→31	190/86→35	227/103→38
43/20→13	80/36→21	117/53→27	154/70→31	191/87→35	228/103→38
44/20→13	81/37→21	118/54→27	155/70→31	192/87→35	229/104→38
45/20→13	82/37→21	119/54→27	156/71→32	193/88→35	230/104→39
46/21→13	83/38→21	120/54→27	157/71→32	194/88→35	231/105→39
47/21→14	84/38→21	121/55→27	158/72→32	195/88→36	232/105→39
48/22→14	85/39→21	122/55→27	159/72→32	196/89→36	233/106→39
49/22→14	86/39→22	123/56→27	160/73→32	197/89→36	234/106→39
50/23→14	87/39→22	124/56→28	161/73→32	198/90→36	235/107→39
51/23→15	88/40→22	125/57→28	162/73→32	199/90→36	236/107→39
52/24→15	89/40→22	126/57→28	163/74→32	200/91→36	237/108→39
53/24→15	90/41→22	127/58→28	164/74→32	201/91→36	238/108→39
54/24→15	91/41→23	128/58→28	165/75→33	202/92→36	239/108→39
55/25→16	92/42→23	129/59→28	166/75→33	203/92→36	240/109→39
56/25→16	93/42→23	130/59→28	167/76→33	204/93→36	241/109→39
57/26→16	94/43→23	131/59→28	168/76→33	205/93→36	242/110→39
58/26→16	95/43→23	132/60→29	169/77→33	206/93→37	243/110→39
59/27→16	96/44→23	133/60→29	170/77→33	207/94→37	244/111→40
60/27→17	97/44→24	134/61→29	171/78→33	208/94→37	245/111→40
61/28→17	98/44→24	135/61→29	172/78→33	209/95→37	246/112→40

Advanced Protocols (After Full Oral Dose is Reached)

CD Enemas:

I recommend enemas no less frequently than every other day. You can do them more often particularly if you see parasites coming out. The ratio is 1-2 drops chlorine dioxide per 100 ml of filtered warm water. Work your way up to 500 mL – 1.5 L of water per enema, depending on the size of your child. You have the following options for methods of administering the enemas: a catheter and syringes, a multipurpose enema/douche bag, empty out a fleet enema, or a gravity bag. (note, if your child suffers from constipation you can add enemas and baths in before you get to full dose, alternating them on opposite days or opposite ends of the day).

Enemas should be started when the child reaches full oral dose. However, if your child suffers from constipation you can add enemas and baths on day one (see page 113), before you get to the full oral dose. However, alternate them on opposite days or opposite ends of the day. The following chart is an approximate amount of water based on the size of the person, and calculated the maximum of 2 drops of CD per 100mL of water.

Age/Size	Water Volume	Drops of CD
Child	1/2 Liter (500ml)	10
Adolescent	1 Liter (1,000ml)	20
Teen/Adult	up to 2 Liters (2,000ml)	40

CD Baths:

10-100 Activated drops of CD in a hot (to tolerance) bath with enough water to cover the child's body. Soak for 20 minutes. Apply on alternate enema days, unless you are doing daily enemas, in which case apply on opposite ends of the day.

The CD baths can go from as low as 10 drops to as high as 80 to 100 drops; it just depends on the person, and the size of your tub. With younger/smaller children we start with ten drops. Since we're doing baths every other day, start with ten drops on Monday, 11 drops on Wednesday, and 12 drops on Friday. Just keep going up until you get to 20 drops. The bigger and older the person is, the more drops they can tolerate. Fill the tub to a level that maximizes skin contact.

72/2 Protocol

Give one dose of CD every 2 hours for 72 hours straight, including the middle of the night. Apply every possible weekend.

This involves giving one dose of CD every two hours for 72 hours straight—including the middle of the night. Here are some additional thoughts and guidelines:

- Start protocol when you pick up your child from school on Friday.
- Give them the last 72/2 dose when you drop them off at school on Monday.
- Avoid giving CD enemas or CD baths during this protocol, UNLESS they are dumping parasites, in which case you might need to reduce the amount of CD on both the oral and enema dose to insure the child doesn't have a Herxheimer reaction.
- Why not give hourly doses during the day at the usual dose? It's simply too much if you are doing it all night as well.
- Watch for improvements on Tuesday or Wednesday each week.
- Ideally, get your spouse or significant other to help with every other nightly dose.

Supplement Dosing Overview

Supplement	Dose	Time of Day	Empty Stomach (ES) or With Food (WF)
Probiotics	1 cap	Before Bed	ES
Omega-3/ Omega-6	1 Tbsp	With any meal 1-3x / day	WF
L-Carnitine	250-1000mg/day	With any meal 1-3x / day	WF
GABA	Up to 2,500mg 2x/day	Upon waking & at bedtime	ES
5-HTP	50-200mg	Morning & Evening	WF
L-Theanine	Work up to 200-250mg/day	Mornings or Mornings & Nights	ES
Pycnogenol	25-40mg a day/as needed	Morning	WF
L-Carnosine	200-400mg 2x / day	Morning & Evening	WF
Taurine	500-1500mg/day	Morning, Noon & Night	ES
DMG	900mg/day	Morning	ES
TMG	500mg/day	Morning	ES
Enzymes	1 cap w/meals	Morning, Noon & Night	WF

Parasite Protocol

Please see the complete explanation of the parasite protocol starting on page 187. Day-to-day protocol charts can be found on page 198.

Chelation:

I suggest that when you decide to add clay baths into your child's protocol that you do so on the off days of the CD baths.

Follow the instructions on the package, and follow septic tank precautions if you have one.

Three days or so later, you can add in the Bio-Chelat. Again, follow the instructions on the package, and you can always start slowly and work your way up. Since Bio-Chelat™ doesn't alter the CD, the drops can be added to a single dose of CD. In addition, since the drops have no flavor, it is suitable to add them to water or any other drink your child might consume throughout the day.

Hyperbarics:

Option #1:

Two sessions of 60 minutes each for 20 days for a total of 40 sessions at 1.75 ATA.

Option #2:

One 90-minute session a day for twenty days at 1.75 ATA.

Instead of thinking outside of the box, get rid of the box.

~ Deepak Chopra

Appendix 13

Body Burden
The Pollution in Newborns

When I came across the following investigation I knew it was the perfect precursor to the incredible "Avoiding Autism" by Dr. Anju Usman and Beth Hynes. Babies are exposed to toxins in the womb and this study by the Environmental Working Group demonstrates so perfectly why the advice in the "Avoiding Autism" article is so very crucial to health of our children and for our species as a whole.

Body Burden — The Pollution in Newborns

A benchmark investigation of industrial chemicals, pollutants and pesticides in umbilical cord blood.

Environmental Working Group, July 14, 2005

Summary. In the month leading up to a baby's birth, the umbilical cord pulses with the equivalent of at least 300 quarts of blood each day, pumped back and forth from the nutrient- and oxygen-rich placenta to the rapidly growing child cradled in a sac of amniotic fluid. This cord is a lifeline between mother and baby, bearing nutrients that sustain life and propel growth.

Not long ago scientists thought that the placenta shielded cord blood — and the developing baby — from most chemicals and pollutants in the environment. But now we know that at this critical time when organs, vessels, membranes and systems are knit together from single cells to finished form in a span of weeks, the umbilical cord carries not only the building blocks of life, but also a steady stream of industrial chemicals, pollutants and pesticides that cross the placenta as readily as residues from cigarettes and alcohol. This is the human "body burden" — the pollution in people that permeates everyone in the world, including babies in the womb.

In a study spearheaded by the Environmental Working Group (EWG) in collaboration with Commonweal, researchers at two major laboratories found an average of 200 industrial chemicals and pollutants in umbilical cord blood from 10 babies born in August and September of 2004 in U.S. hospitals. Tests revealed a total of 287 chemicals in the group. The umbilical cord blood of these 10 children, collected by Red Cross after the cord was cut, harbored pesticides, consumer product ingredients, and wastes from burning coal, gasoline, and garbage.

This study represents the first reported cord blood tests for 261 of the targeted chemicals and the first reported detections in cord blood for 209 compounds. Among them are eight perfluorochemicals used as stain and oil repellants in fast food packaging, clothes and textiles — including the Teflon chemical PFOA, recently characterized as a likely human carcinogen by the EPA's Science Advisory Board — dozens of

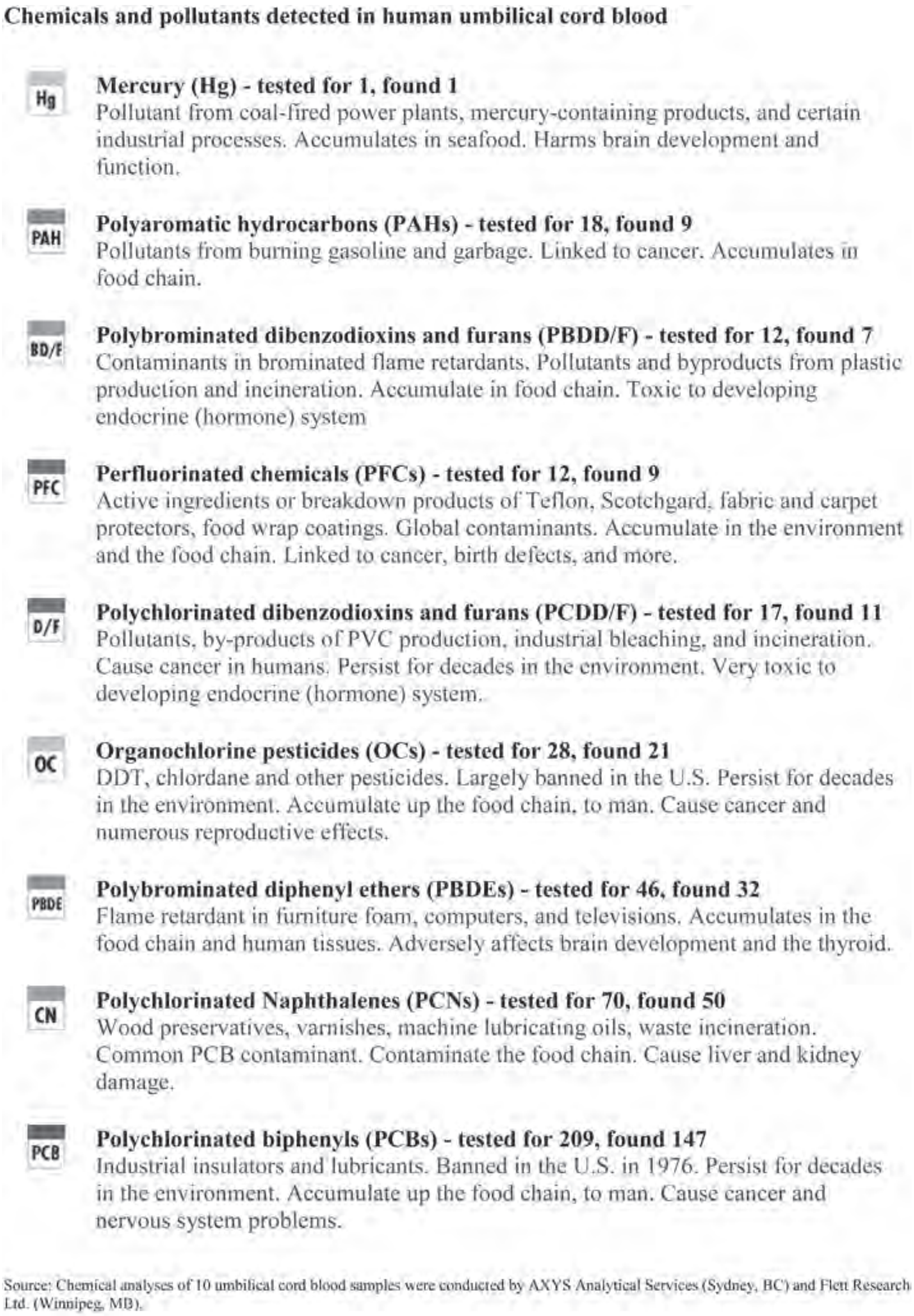

Chemicals and pollutants detected in human umbilical cord blood

Hg **Mercury (Hg) - tested for 1, found 1**
Pollutant from coal-fired power plants, mercury-containing products, and certain industrial processes. Accumulates in seafood. Harms brain development and function.

PAH **Polyaromatic hydrocarbons (PAHs) - tested for 18, found 9**
Pollutants from burning gasoline and garbage. Linked to cancer. Accumulates in food chain.

BD/F **Polybrominated dibenzodioxins and furans (PBDD/F) - tested for 12, found 7**
Contaminants in brominated flame retardants. Pollutants and byproducts from plastic production and incineration. Accumulate in food chain. Toxic to developing endocrine (hormone) system

PFC **Perfluorinated chemicals (PFCs) - tested for 12, found 9**
Active ingredients or breakdown products of Teflon, Scotchgard, fabric and carpet protectors, food wrap coatings. Global contaminants. Accumulate in the environment and the food chain. Linked to cancer, birth defects, and more.

D/F **Polychlorinated dibenzodioxins and furans (PCDD/F) - tested for 17, found 11**
Pollutants, by-products of PVC production, industrial bleaching, and incineration. Cause cancer in humans. Persist for decades in the environment. Very toxic to developing endocrine (hormone) system.

OC **Organochlorine pesticides (OCs) - tested for 28, found 21**
DDT, chlordane and other pesticides. Largely banned in the U.S. Persist for decades in the environment. Accumulate up the food chain, to man. Cause cancer and numerous reproductive effects.

PBDE **Polybrominated diphenyl ethers (PBDEs) - tested for 46, found 32**
Flame retardant in furniture foam, computers, and televisions. Accumulates in the food chain and human tissues. Adversely affects brain development and the thyroid.

CN **Polychlorinated Naphthalenes (PCNs) - tested for 70, found 50**
Wood preservatives, varnishes, machine lubricating oils, waste incineration. Common PCB contaminant. Contaminate the food chain. Cause liver and kidney damage.

PCB **Polychlorinated biphenyls (PCBs) - tested for 209, found 147**
Industrial insulators and lubricants. Banned in the U.S. in 1976. Persist for decades in the environment. Accumulate up the food chain, to man. Cause cancer and nervous system problems.

Source: Chemical analyses of 10 umbilical cord blood samples were conducted by AXYS Analytical Services (Sydney, BC) and Flett Research Ltd. (Winnipeg, MB).

widely used brominated flame retardants and their toxic by-products; and numerous pesticides.

Of the 287 chemicals we detected in umbilical cord blood, we know that 180 cause cancer in humans or animals, 217 are toxic to the brain and nervous system, and 208 cause birth defects or abnormal development in animal tests. The dangers of pre- or post-natal exposure to this complex mixture of carcinogens, developmental toxins and neurotoxins have never been studied.

Chemical exposures in the womb or during infancy can be dramatically more harmful than exposures later in life. Substantial scientific evidence demonstrates that children face amplified risks from their body burden of pollution; the findings are particularly strong for many of the chemicals found in this study, including mercury, PCBs and dioxins. Children's vulnerability derives from both rapid development and incomplete defense systems:

- A developing child's chemical exposures are greater pound-for-pound than those of adults.
- An immature, porous blood-brain barrier allows greater chemical exposures to the developing brain.
- Children have lower levels of some chemical-binding proteins, allowing more of a chemical to reach "target organs."
- A baby's organs and systems are rapidly developing, and thus are often more vulnerable to damage from chemical exposure.
- Systems that detoxify and excrete industrial chemicals are not fully developed.
- The longer future life span of a child compared to an adult allows more time for adverse effects to arise.

The 10 children in this study were chosen randomly, from among 2004's summer season of live births from mothers in Red Cross' volunteer, national cord blood collection program. They were not chosen because their parents work in the chemical industry or because they were known to bear problems from chemical exposures in the womb. Nevertheless, each baby was born polluted with a broad array of contaminants.

U.S. industries manufacture and import approximately 75,000 chemicals, 3,000 of them at over a million pounds per year. Health officials do not know how many of these chemicals pollute fetal blood and what the health consequences of in utero exposures may be.

Had we tested for a broader array of chemicals, we would almost certainly have detected far more than 287. But testing umbilical cord blood for industrial chemicals is technically challenging. Chemical manufacturers are not required to divulge to the public or government health officials methods to detect their chemicals in humans. Few labs are equipped with the machines and expertise to run the tests or the funding to develop the methods. Laboratories have yet to develop methods to test human tissues for the vast majority of chemicals on the market, and the few tests that labs are able to conduct are expensive. Laboratory costs for the cord blood analyses reported here were $10,000 per sample.

A developing baby depends on adults for protection, nutrition, and, ultimately, survival. As a society we have a responsibility to ensure that babies do not enter this world pre-polluted, with 200 industrial chemicals in their blood. Decades-old bans on a handful of chemicals like PCBs, lead gas additives, DDT and other pesticides have led to significant declines in people's blood levels of these pollutants. But good news like this is hard to find for other chemicals.

The Toxic Substances Control Act, the 1976 federal law meant to ensure the safety of commercial chemicals, essentially deemed 63,000 existing chemicals "safe as used" the day the law was passed, through mandated, en masse approval for use with no safety scrutiny. It forces the government to approve new chemicals within 90 days of a company's application at an average pace of seven per day. It has not been improved for nearly 30 years—longer than any other major environmental or public health statute—and does nothing to reduce or ensure the safety of exposure to pollution in the womb.

Because the Toxic Substances Control Act fails to mandate safety studies, the government has initiated a number of voluntary programs to gather more information about chemicals, most notably the high production volume (HPV) chemical screening program. But these efforts have been largely ineffective at reducing human exposures to chemicals. They are no substitute for a clear statutory requirement to protect children from the toxic effects of chemical exposure.

In light of the findings in this study and a substantial body of supporting science on the toxicity of early life exposures to industrial chemicals, we strongly urge that federal laws and policies be reformed to ensure that children are protected from chemicals, and that to the maximum extent possible, exposures to industrial chemicals before birth be eliminated. The sooner society takes action, the sooner we can reduce or end pollution in the womb.

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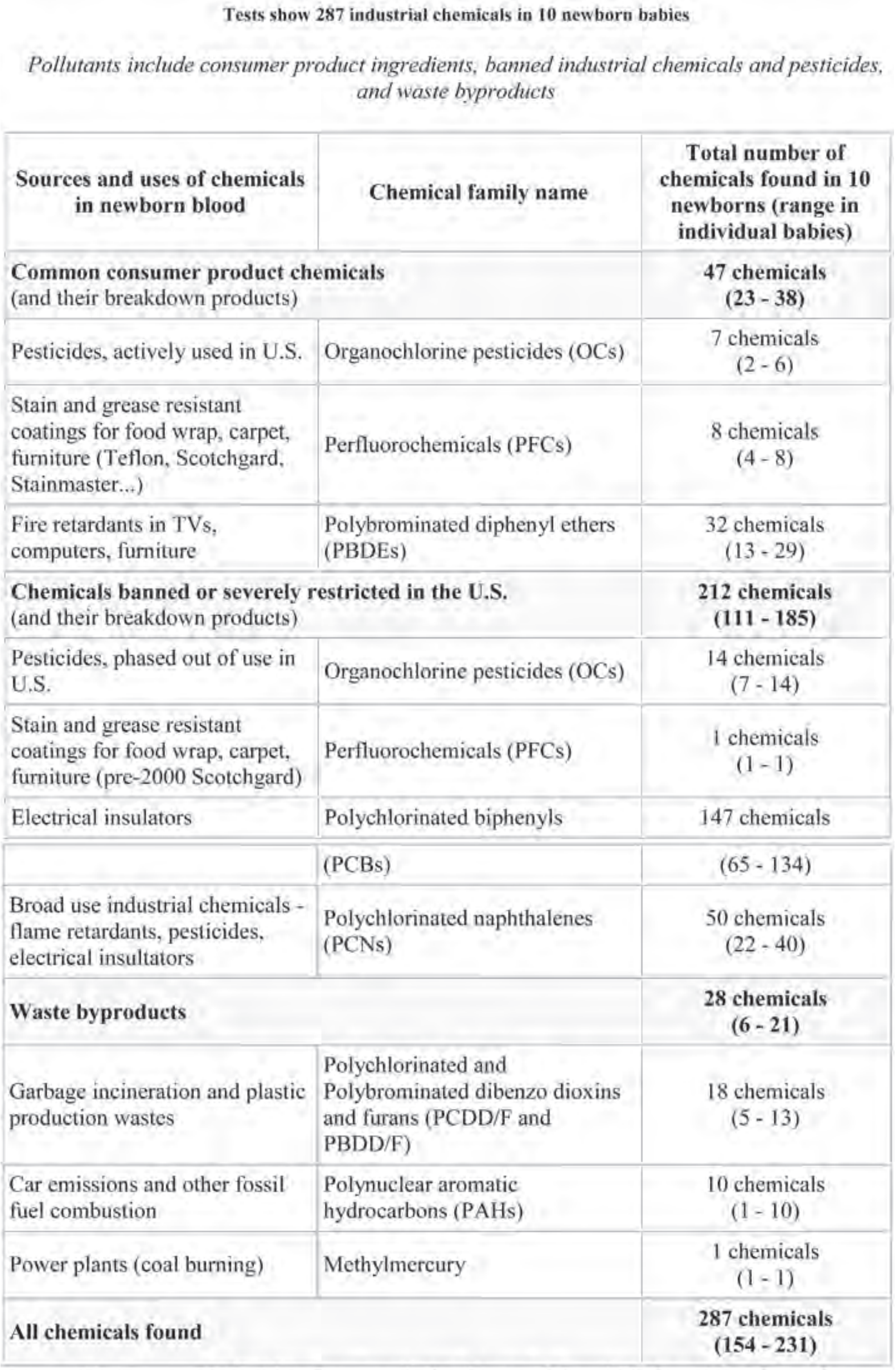

Tests show 287 industrial chemicals in 10 newborn babies

Pollutants include consumer product ingredients, banned industrial chemicals and pesticides, and waste byproducts

Sources and uses of chemicals in newborn blood	Chemical family name	Total number of chemicals found in 10 newborns (range in individual babies)
Common consumer product chemicals (and their breakdown products)		**47 chemicals** **(23 - 38)**
Pesticides, actively used in U.S.	Organochlorine pesticides (OCs)	7 chemicals (2 - 6)
Stain and grease resistant coatings for food wrap, carpet, furniture (Teflon, Scotchgard, Stainmaster...)	Perfluorochemicals (PFCs)	8 chemicals (4 - 8)
Fire retardants in TVs, computers, furniture	Polybrominated diphenyl ethers (PBDEs)	32 chemicals (13 - 29)
Chemicals banned or severely restricted in the U.S. (and their breakdown products)		**212 chemicals** **(111 - 185)**
Pesticides, phased out of use in U.S.	Organochlorine pesticides (OCs)	14 chemicals (7 - 14)
Stain and grease resistant coatings for food wrap, carpet, furniture (pre-2000 Scotchgard)	Perfluorochemicals (PFCs)	1 chemicals (1 - 1)
Electrical insulators	Polychlorinated biphenyls (PCBs)	147 chemicals (65 - 134)
Broad use industrial chemicals - flame retardants, pesticides, electrical insultators	Polychlorinated naphthalenes (PCNs)	50 chemicals (22 - 40)
Waste byproducts		**28 chemicals** **(6 - 21)**
Garbage incineration and plastic production wastes	Polychlorinated and Polybrominated dibenzo dioxins and furans (PCDD/F and PBDD/F)	18 chemicals (5 - 13)
Car emissions and other fossil fuel combustion	Polynuclear aromatic hydrocarbons (PAHs)	10 chemicals (1 - 10)
Power plants (coal burning)	Methylmercury	1 chemicals (1 - 1)
All chemicals found		**287 chemicals** **(154 - 231)**

Source: Environmental Working Group analysis of tests of 10 umbilical cord blood samples conducted by AXYS Analytical Services (Sydney, BC) and Flett Research Ltd. (Winnipeg, MB).

The ultimate ignorance is the rejection of something you know nothing about and refuse to investigate.

~ Dr. Wayne Dyer

Appendix 14

Avoiding Autism

By Anju Usman, MD and Beth C. Hynes JD, MBA

Whether or not you are the parent of a special needs child, please pay special attention to this article, we do believe autism is totally preventable and that starts with pregnancy. Here's to your health!

Every parent's dream is to have a healthy baby. Over the past ten years of working with families devastated by the diagnosis of autism, we, along with our patients' parents, have realized one key fact: if we knew then what we know now, the diagnosis of the disease called autism could very well have been prevented. Considering that the cause(s) of the current epidemic of autism spectrum disorders (ASD) are unknown (and scant research dollars are being dedicated to finding the most likely culprits), there is no surefire method to avoid having your infant regress into this devastating state. That sad fact, however, does not mean that there are no proactive steps parents can take to try to mitigate the chances of this disease overtaking their baby and stealing their hopes and dreams for that child's life.

Having reviewed the medical and laboratory test results of thousands of children afflicted with ASD, clinicians using a biomedical approach to treating autism see repeating patterns in these children—impaired methylation and detoxification, mitochondrial dysfunction, gastrointestinal distress, and immune dysregulation compounded by chronic viral, fungal and bacterial infections and a burden of heavy metals and other toxins. From this perspective, we have come to view autism as a multifactorial medical disease that can be treated and overcome and, therefore, possibly avoided. Coming straight from the heart, this advice is for thinking, active parents and prospective parents who want to know what they can do to reduce the risk that their infant will regress into autism. In our practice, we have helped many parents go on to have healthy children even though they already have a child with autism. Considering that the information provided here is not harmful but, to the contrary, is helpful in promoting improved maternal and fetal health, there is little downside to pursuing these strategies while simultaneously minimizing the risk of having your child slip away into the autism epidemic. According to the latest statistics out of California, that epidemic continues to grow from the already shocking 1 out of 150 children. The aim here is to provide an analytical construct that will guide parents in making choices for both their own health and that of their baby before, during, and after pregnancy.

Think of the analogy of the straw that broke the camel's back. Human beings start life as infants with some "straws" in their saddle – these are predispositions to be harmed by certain chemicals, to be susceptible to certain diseases, or to have a less robust detoxification capacity. The goal of gestating and parenting an infant in today's toxic world is to not accumulate additional straws during your baby's gestation and infancy, thereby avoiding adding the straw that breaks the camel's back. Autism seems to occur when the infant's body is so overwhelmed by toxins, viruses and/or pathogenic elements that typical development is arrested and/or derailed.

Children diagnosed with autism have a variety of medical problems, the underpinnings of which can be ameliorated and/or healed. The symptoms associated with autism occur through malfunctioning of the infant immune, gastrointestinal, and central nervous systems ("Infant Body Systems") – all of which, when functioning properly, contribute to the healthy development of the brain. Viruses, heavy metals, toxins, fungi, and bacteria together form a weapon that disrupts the development of, and harms the functioning of, these critical Infant Body Systems. As researchers have recently found, "a single toxicant may promote different immune-associated diseases that are dependent upon the specific window of early life exposure, the gender of the exposed offspring, and the genetic background of the offspring." Our construct will consist of actions you can take to promote the healthy development of these Infant Body Systems as well as steps you can take to avoid upsetting the healthy development of those systems.

Due to the symbiotic relationship between a mother and her developing fetus, care must be taken by the mom before, during, and after pregnancy (if nursing) to both avoid exposure to harmful elements and to promote optimal maternal detoxification processes so that the host body remains as clean an environment as possible within which vigorous infant development can unfold.

Only recently have researchers begun closely linking environmental factors with developmental delays in our children. A host of studies show how environmental factors including diet, nutrition, air quality, clean water, heavy metals (e.g., mercury, lead, arsenic, and aluminum), xenobiotics (e.g., chemicals, pesticides, plasticizers, and perchlorates), pharmaceuticals, and vaccinations can change your child's inborn risk.

This area of study is called epigenetics – the molecular changes in our DNA caused by environmental factors. In 2003, researchers at Duke University found that rats carrying a gene for obesity, cancer, and diabetes, when fed a diet high in B-12, folic acid, choline, and methyl-rich foods, had babies that were born healthy and with a reduced risk of developing disease; this research revealed that these genetic changes persisted across four generations. Thus, when you eat a healthy diet, you are affecting not only the health of your own kids but also your grandchildren, great-grandchildren, and great-great-grandchildren. Researchers are finding hundreds of unwanted and potentially toxic chemicals in the placenta and cord blood of newborns as well as in mothers' breast milk. That means that today's children are born with a toxic burden their infant bodies must contend with from day one. Studies out of China, Texas, and San Francisco show that if pregnant mothers can decrease their exposure to pollutants during gestation, they can improve health outcomes for their children – especially brain development. Compounds such as mercury, cadmium, nickel, trichloroethylene, and vinyl chloride in the air around the birth residence caused a 50% increase in the risk of autism.

Numerous studies document the neurotoxic effects of heavy metals – especially dangerous to the developing brain is mercury. Yet, many of our children are actually injected with the mercury-containing preservative thimerosal in their infant vaccines. Although thimerosal has been removed from, or perhaps phased out of, many childhood vaccines, it still remains in the flu vaccine, which is recommended by health authorities to pregnant woman as well as to children under age 2. Mercury exposure is such a concern that pregnant women are advised by health authorities not to eat fish because of potential mercury contamination – yet injecting thimerosal is much more damaging than the exposure suffered through eating it in food such as fish. Vaccines also contain aluminum, formaldehyde, and other toxic elements as well as live viruses that, in a subset of infant bodies, can trigger harmful impacts. Heavy metals have also been identified as factors affecting human fertility. Diagnosing and reducing the heavy metal burden of women improved the spontaneous conception chances of infertile women. Women with many dental amalgams had a higher incidence of miscarriages and a higher excretion of mercury when given the chelating agent DMPS (2,3-Dimercapto-1-propanesulfonic acid). It has been found that DMPS was a useful and complementary method to increase fertility compared to hormone therapy in infertile women.

With all this evidence mounting against various environmental toxins affecting human development, an international assembly of scientists, doctors, toxicologists, and researchers sponsored by the

World Health Organization (WHO), the European Environmental Agency, the Centers for Disease Control (CDC), and the National Institutes of Health (NIH) gathered in the Faroe Islands in May 2006. Their consensus statement was clear: "it is time to take action, now." As expected, the declaration highlighted the results of hundreds of studies that showed early fetal exposures to toxic substances, even at low concentrations, can cause health problems later in life. There are a growing number of chemicals that affect the developing embryo, fetus, and infant, including the pesticides DDT, atrazine, methoxychlor, and vinclozolin. Also suspect are plastics and the epoxy resin bisphenol A, plasticizing agents called phthalates, mercury, lead, arsenic, organotoxins, polychlorinated biphenols (PCBs), carbon monoxide, smog, tobacco smoke, and alcohol. The health problems caused by exposure to these substances comprise a dizzying array of maladies including cancer, diabetes, obesity, asthma, and allergies as well as reproductive, cardiovascular, neurological, cognitive, endocrine, psychological, immune, and respiratory troubles.

Other troubling chemicals include parabens (found in various creams and lotions) and triclosan, an antibacterial agent (found in toothpaste, soaps, and cleaning products). Although parabens and triclosan are not ingested, absorbing chemicals through the skin can be far more dangerous than swallowing because transdermal applications are transported directly to the bloodstream. Most women absorb 51 pounds of chemicals every year from their cosmetics alone! Additional exposures emanate from daily lifestyle, profession, and locale. For those elements for which we have the flexibility to make choices, we must choose wisely. After all, it is not just our health that is being affected by our choices but the health of our children and progeny as well.

Basic principles to guide you in decision making surrounding pregnancy are as follows:

1. You are what you eat (and drink); therefore, make healthy choices in what you consume.
2. Skin is the largest organ in the body, so be very careful of what you rub into yours and your baby's.
3. Think beyond "green": What is "green" for the environment is not always what is healthiest for the body, but what is healthiest for the body is always "green."

Suggestions to promote these principles are below and are cumulative, so keep following each set of suggestions as this journey into and through parenthood progresses.

Pre-Pregnancy

While planning a pregnancy, we recommend that you clean up any toxicity in your body and begin to follow a more organic, healthy lifestyle. Remember, the less toxic you are, the better for you and your future baby. Undertake a sequential detoxification program that targets the liver and colon; this type of program can take six months or more and should not be done while pregnant. In a careful manner, with an experienced dentist, remove amalgams from your teeth, which also can take six months or more. Take the time now to find organic, nontoxic makeup, hair, and body products that you like and start integrating them into your daily life. Ask your doctor to run some tests to determine any additional specific supplementation you may need to optimize levels within your body; a good place to start is your copper-zinc ratio (1:1 is the ideal ratio), thyroid function (TSH, free t3, free t4), Vitamin D 25 OH, vitamin A levels, and total cholesterol (low cholesterol is associated with preterm births).

Next, clean up your living and working environment. Remove all harmful chemical cleaning agents from your cleaning routine at home and at the office, and instead use cleaning products labeled level 1 by the EPA. Do not forget to include products for dishwashing and clothing detergent in your cleanup, and avoid toxic dry cleaning as much as possible. Finally, improve your nutrition with a targeted vitamin supplementation program to include omega-3 essential fatty acids, sublingual methyl B-12, folinic acid, vitamin D3, zinc, and antioxidants.

DO	DON'T
• Eat organic, hormone-free food	• Consume fish or foods w/MSG or food dyes
• Drink organic green tea, filtered water, and antioxidant rich organic juices	• Drink soda, carbonated beverages, or alcohol
• Use stevia, raw organic honey, and xylitol as sweeteners	• Consume artificial sweeteners
• Go for walks and get some sunshine daily	• Be exposed to lawn chemicals or second-hand smoke
• Use aluminum-free natural deodorant in them	• Use moisturizers or makeup with chemicals or parabens
• Use natural hennas to color your hair	• Use chemical dyes, perms, or other such hair treatments
• Use cast iron, glass, or stainless steel cookware	• Cook with pans that are non-stick, Teflon coated, or made from aluminum
• Use chemical-free cleaning products in your home	

During Pregnancy

We would suggest that you find a holistic health practice to guide you during pregnancy and delivery as there are many decisions to make during this time. In general, we suggest avoiding medications to the extent possible as well as acetaminophen because it hinders normal detoxification. Add zinc, calcium, essential fatty acids, and prenatal vitamins to your daily supplement intake. Discontinue use of nail polish and any makeup (including lipstick) products that contain parabens and other toxins. Use fluoride-free toothpaste as fluoride interferes with iodine metabolism, which is an issue implicated in mental retardation worldwide.

DO	DON'T
• Yoga and engage in stress management techniques, such as massages and listening to soothing music • Eat fermented foods, cook with organic coconut oil, use organic raw apple cider as salad dressing, and consume healthy fats, and cold pressed oil • Use natural remedies for pain, like homeopathic arnica • Drink kombucha and take probiotics • Run an air filter in your bedroom while you sleep	• Start a rigorous exercise program, sit in a sauna, or get dental work (not even cleanings) • Wait until labor arrives to discuss NOT subjecting your baby to vaccines • Talk on a cell phone without a headset or work with a laptop computer on your lap • Undertake a major home renovation (concern is for lead and other toxins in the process)

Infancy

Healthy babies grow and develop perfectly when nature's biochemical processes are allowed to unfold uninterrupted. The sequence of events that leads an infant to begin to focus, develop gross and fine motor skills, begin to speak and to walk is based on a delicate but deliberate series of biochemical processes and chemical interactions. A primary goal of raising a healthy infant is to avoid disruption or interference with this sequence. Babies look fragile and, indeed, they are. An infant's immune system, which guards the rest of the body from harm, is immature and requires time and peace to mature maximally. Thus, help your infant progress uninterrupted by avoiding the introduction of toxins, viruses, allergens, and heavy metals into their bodies. In light of this, parents should consider an alternate, gradual vaccine schedule of carefully thought through vaccines for infants being raised in the domestic United States.

If you have amalgams and plan to nurse, you should send a sample of your breast milk to a specialty lab for heavy metal testing. If you plan to use formula, use those containing DHA (docosahexanenoic acid), an essential fatty acid critical to the healthy development of the central nervous system. In terms of food introduction, organic baby food is recommended. Start feeding with organic rice cereal. Avoid the introduction of soy, gluten, or dairy until after the baby turns two years of age. After one year, supplement your baby with a quarter teaspoon of mercury-free cod liver oil – again this is to increase the supply of omega-3 essential fatty acids.

In terms of coping with baby colds and other minor illnesses, unless symptoms are severe, less is more when it comes to treatment. For fevers over 101˚F, treat with a tepid bath or dye-free ibuprofen. Fevers, while nerve-wracking for new parents, are the response of a healthy immune system reacting to kill off an invading virus through heat. Antibiotics should be used sparingly and only for confirmed bacterial infections (they do not alleviate viral infections). Remember, antibiotic use disrupts the normal gut flora and promotes the overgrowth of yeast and resistant organisms that, in turn, harms the optimal functioning of the immune system. Bear in mind that most ear infections are viral and are thus not treatable with antibiotics. Use homeopathic ear drops to help ease the symptoms associated with ear infections and colds.

DO	DON'T
• Invest in an organic baby matress, bedding and pillows and hypo allergenic encasements • Bathe your baby daily in warm filtered water — enjoy the experience with your baby! • Feed with all organic and hormone-free products • Feed baby using glass bottles • Wearing a hat, walk outside with baby to get 10 to 15 minutes of sunshine daily • Run an air filter in baby's bedroom	• Clothe the baby in pajamas soaked in flame retardant chemicals • Use soaps, moisturizers, or other "baby products" on the skin as such items are unnecessary and contain harmful chemicals • Introduce dairy, gluten, or soy until after age two • Feed baby from plastic bottles or cups or microwave formula or breast milk • Take your infant into polluted and heavily populated locations

Source: http://www.autismfile.com/what-is-autism-facts/autism-symptoms/avoiding-autism

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When a truth is not given complete freedom,
freedom is not complete.

~ Vaclav Havel

Appendix 15

RECIPES

Cooking with Ana

Since 2001 Ana Bobadilla has been a chef to Kerri Rivera and family, including her son Patrick, who has a diagnosis of regressive autism. Over the years she has mastered gluten-free/casein-free to vegan to Atkins and back again. Her dishes always impress and nourish guests and family members alike.

One of the most important pieces to the autism recovery puzzle is diet. As Kerri always says, if your goal is to heal autism, you must do *The Diet.* However, that is easier said than done for many families whose children have self-limited to grilled cheese sandwiches and pizza.

A book is in the works containing dozens of delicious recipes using natural ingredients that can be found in almost any country. Ana has found unique ways to make foods that children on the spectrum can enjoy, without breaking the bank. The ingredients that she uses can be found all over the world, not just the US. They are presented here in a very approachable way so even if you are not a whiz in the kitchen your child will be able to enjoy what you serve.

The following is a sneak peek from *Cooking with Ana*:

Almond Milk

Amount: 1 L of milk

- 1 cup of peeled almonds
- 1 L of filtered water
- Stevia and vanilla to taste

Preparation:

To a saucepot of boiling water, add the almonds. Remove immediately from the fire. Allow almonds to soak for 20 minutes, remove them from water, rinse, dry and blend in a liter of filtered water. Strain the liquid through a piece of cheesecloth until all the water is drained. Add agave syrup and vanilla to taste.

Vegetable Fries

3 Servings

Ingredients:

- 3 Carrots
- 1 cup oil
- Salt to taste

Preparation:

Peel the carrots and then form very thin slices using the same peeler. Pat dry with a piece of cloth to remove any excess water. Heat oil in a frying pan and fry carrots. When frying be very careful because they can quickly burn, be sure to have a slotted spoon ready to remove from the oil as soon as they are crisp. After frying carrots remove excess oil with a paper towel and sprinkle some salt on top of them.

You can also do this recipe with banana, potato, sweet potato or jackfruit. This is a great alternative to French fries or if you want to eat something crunchy.

Beef or Chicken Tostadas

4 Servings

Ingredients:

- 5 ground chicken breasts or beef filets
- 1 cup of rice or coconut flour
- 1 cup of oil
- Salt and pepper to taste

Preparation:

In a mixing bowl, combine the ground chicken, flour, salt, pepper and a ½ cup of oil. Mix thoroughly until a uniform dough results. Take approximately 2 tablespoons of the dough and form small tortillas/flat circles with it. They should be approximately ¼ inch think and 4 inches wide. Fry in a layer of oil until cooked through, and a thin outer crust forms, or bake in a 350 degree oven, after pouring a dollop of oil on top of each tostada.

Coconut Bars

15-18 bars

Ingredients:

- 3 cups of vegan butter (or coconut oil)
- 1 cup of honey
- 1 cup of raisins
- 1 cup of grated of coconut
- 1 cup of walnuts
- 1 tablespoon of salt

Preparation:

In a saucepan over medium heat combine honey and butter, stirring constantly for a few minutes until thoroughly combined. Remove from heat and mix with all other ingredients. Spread in a 9x13 casserole pan without oil, and bake in an 350°F (180°C) over for 25 minutes until it sets. Allow to cool, and cut into small rectangles.

Get people back into the kitchen
and combat the trend toward
processed food and fast food.

~ Andrew Weil

Appendix 16

Websites We Like

General:

- **Our website containing the latest information about our research, videos, forums, etc.**
  www.cdautism.org

- **The Spanish version of our website.**
  www.autismo2.com

- ***Curando el Autismo* is a Puerto Rican organization created by three mothers of children recovered from autism who have an interest in helping the community learn about their options.**
  www.curandoelautismo.com

- **Defeating Autism - Non-Profit Organization in Venezuela that utilizes Kerri's Protocols.**
  www.fundacionvenciendoelautismo.blogspot.mx

- **Autism Research Institute originally founded by Dr. Bernard Rimland. Home of the ATEC survey.**
  www.autism.com

- **Our public Facebook page.**
  www.facebook.com/groups/AutismCD

- ***CD Health*: Facebook group dedicated to using the protocol for non-autism related issues.**
  www.facebook.com/groups/mojoother

Diet:

- **Website forcused on the *Specific Carbohydrate Diet*™ (SCD) in English.**
  www.pecanbread.com

- **Top 10 FAQs about the *Specific Carbohydrate Diet* (SCD) in Spanish.**
  www.pecanbread.com/pandenuez/10preguntas.html

- **Autism Network for Dietary Intervention**
  www.autismndi.com

- **Gluten Free/Casein Free Diet Intervention website.**
  www.gfcfdiet.com

- **Intestinal health through diet with the Specific Carbohydrate Diet™**
  www.breakingtheviciouscycle.info

- **Resource for naturally healing digestive disease, reducing stress and living a long, healthy life.**
  www.scdlifestyle.com

- ***The Feingold® Association* is a non-profit organization helping provide dietary management and generate public awareness of the role food and synthetic additives play in behavior, learning and health problems.**
  www.feingold.org

Chlorine Dioxide (CD):

- **Jim Humble's MMS (CD) website.**
  www.jimhumble.org

- **Another popular site about MMS (CD).**
  www.mmswiki.org

- **Spanish site selling various books about MMS (CD)**
  www.voedia.com

- **Andreas Kalcker's website (in English)**
  www.andreaskalcker.com

- **CD research site by Andreas Kalcker (in Spanish)**
  www.medicasalud.com

- **A huge public health forum with thousands of discussions about every imaginable health topic. Also includes surveys about various topics.**
  www.curezone.com

- **Good sources of CD and other related supplies.**
  www.wps4sale.com
  www.mightyguts.com

- **The latest information on CDH.**
  http://www.mmsinfo.org/infosheets/infosheet_cdh.pdf

Hyperbarics:

- **Good source of information about Hyperbaric Oxygen Therapy.**
  www.hyperbaric-oxygen-info.com

Other Valuable Source of Information:

- **PubMed comprises of more than 23 million citations for biomedical literature from MEDLINE, life science journals, and online books.**
  www.ncbi.nlm.nih.gov/pubmed

- **Parents Helping Parents - P.A.N.D.A.S. Network: A Resource Library of Medical Studies and Case Histories**
  www.pandasnetwork.org

- **International OCD Foundation**
  www.ocfoundation.org/PANDAS/

Videos / Audio of Interest:

- **Video Testimonials. This link contains various health testimonials related to MMS, many are about autism.**
  www.youtube.com/mmstestimonials

- **AutismOne 2012: 38 Children Recovered in 20 months with MMS by Kerri Rivera**
  www.autismone.org/content/38-children-recovered-20-months-mms-0

- **Video about Kerri, produced by Daniel Bender in 2012.**
  www.youtube.com/watch?v=HnCiX5bll-Y

- **Kerri speaks in Bulgaria, 2013 (Voice in English, slides in Bulgarian)**
  www.youtube.com/watch?v=4OxNGIEWzds

- **Kerri on the Robert Scott Bell Show**
  http://www.youtube.com/watch?v=-1zJhr5VhxE

- **MMS Autism Webinars**
  http://www.ustream.tv/channel/mms-autism-webinar%20

- **Patrick Timpone interviews Kerri Rivera (8/15/2013)**
  http://oneradionetwork.com/health/kerri-rivera-healing-the-symptoms-known-as-autism-children-are-not-born-with-autism-so-they-should-not-die-with-it-august-15-2013/

- **Patrick Timpone interviews Kerri Rivera (11/18/2013)**
  http://oneradionetwork.com/health/kerri-rivera-encore-interview-healing-the-symptoms-known-as-autism-using-parasite-protocols-and-chlorine-dioxide-november-18-2013/

- **Bulletproof Executive Radio with Dave Asprey (11/27/2013)**
  http://www.youtube.com/watch?v=R7s7lYj2SCs

Appendix 17

Direct Help from Kerri Rivera

Consults

Since the release of the first edition of the book, we have found that when families decide to implement The Protocol some do not need further assistance beyond reading the information in this book, using our online support groups, YouTube videos, and attending conferences. However, there are some of us who need a more personalized approach and support to navigate the information, or would like ideas on dosing or timing.

For those of us who need or want that additional support, consults are perfect. We can work together to map out a plan for the parent/family and child, brainstorm through challenges, or just know that you will never walk alone. Whatever the case may be I am available if you need me. I am fluent in English and Spanish, and we can use a translator for other languages. We can speak over the phone or on Skype.

As time goes on, more and more practitioners will be able to support families while using this protocol. In the meantime, If you would like to set up a consult with me, please click on the "Consult Kerri" button on...

www.CDAutism.org

...and follow the instructions there.

> Kerri Rivera's undivided attention + discussing your child + $100 = priceless. Tonight, instead of living it up in Mexico, Kerri spent her Friday evening on the phone doing a consult with me. Not only was the consult informative but also highly enjoyable. Kerri's energy is contagious, her vision boundless and her sense of humor edgy (just the way I like it). Kerri thank you for rocking our world! You are an amazing lady and my family is eternally grateful for your love of our children. Peeps, if you are new, stuck, confused or you want a better understanding of the protocol PLEASE, PLEASE, PLEASE take advantage of this opportunity. I've done a million consults over the years but this was by far my favorite.

Note: A consult with Kerri does not constitute medical advice, nor is it a substitute for a consult with your doctor or healthcare provider. As always, you are responsible for your health, and for the health of your children.

might not be tonight. tomorrow or the next day.. but everything's gonna be ok
e.s
Healing
the symptoms known as
Autism
Kerri Rivera

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About the Author

Kerri Rivera is a native of Chicago, but has lived the last 19 years of her life in Puerto Vallarta, Mexico with her husband. Both of her sons were born there, and 13-year-old Patrick is currently in autism recovery. Kerri is the founder of AutismO2, a non-profit autism clinic based on what is formerly known as the *Defeat Autism Now!* approach. Located in Puerto Vallarta, the clinic opened in 2006. Kerri is the clinic's biomedical consultant as well as a consultant for Curando El Autismo (Latin America), and Venciendo el Autismo (Venezuela).

At the request of Dr. Bernard Rimland, she was responsible for translating the *Defeat Autism Now!* protocol to Spanish and donating it to the Autism Research Institute, so it could be applied throughout Latin America. Since then she has helped over 3,500 families in over 58 countries to improve the lives of their children on the autism spectrum. She has become the foremost expert on the use of CD (chlorine dioxide) for spectrum disorders. Since the addition of CD to the biomedical protocol she has seen 115 children recover from autism in the past 2.5 years.

Since 2007 Kerri has lectured internationally on the Biomedical Protocol for autism and CD for autism. She has been featured on *One Radio Network* with Patrick Timpone, *The Bulletproof Executive* with Dave Asprey, *The Mother Cub Show*, *Thought for Food*, *Enlightened Health Radio* with Justin Elledge, *Voice America*, and *The Robert Scott Bell Show.* She is the Mexican Liaison for AutismOne. Kerri graduated as a Certified Homeopath in June of 2013.

Our greatest weakness lies in giving up.

The most certain way to succeed is always to try just one more time.

~ Thomas Edison

The world of autism is rocking again. Kerri Rivera has done it. In this comprehensive book she has condensed and simplified the core elements of the biomedical approach, those that work 90% of the time on 90% of the children. Her focus on using a unified and affordable approach to reduce the body burden of chronic infections and infestations is addressing the very core issue of most autistic children and adults.
It has made her method the most powerful tool to this day to help many children recover safely, inexpensively and solidly. Her research is validated by the enormously positive response from parents from all over the world.

—Dietrich Klinghardt MD, Ph.D.

EXCITING UPDATES TO THIS EDITION INCLUDE:

A new method of CD preparation • New parasite protocol charts
Lunar calendar • Many new testimonials
A section on gluten's role in molecular mimicry and autoimmunity
Information on helping older or violent / aggressive children

In the seven months since the release of the first edition of *Healing the Symptoms Known as Autism*, 22 more children have lost their autism diagnosis and returned to a state of health, for a total of 115 recovered children and counting. Hundreds more have lost ATEC points, as well as shown many cognitive, behavioral, emotional and physical gains thanks to the protocol outlined in these pages. This edition includes all protocol updates and a whole lot more information that can benefit families of children and adults on the spectrum.

In 3 years, 115 children previously diagnosed with regressive autism were able to shed their diagnosis, their symptoms and return to an overall state of health and vitality. If you have any interest in finding out how they were able to heal you need to read this book. Kerri has a heart for children with autism, and she cares greatly about recommending safe, economical interventions that are helping to confront an epidemic.

—Teri Arranga
Executive Director of AutismOne (www.autismone.org)

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Cosmic Fusion

Fusion of the Eight Forces

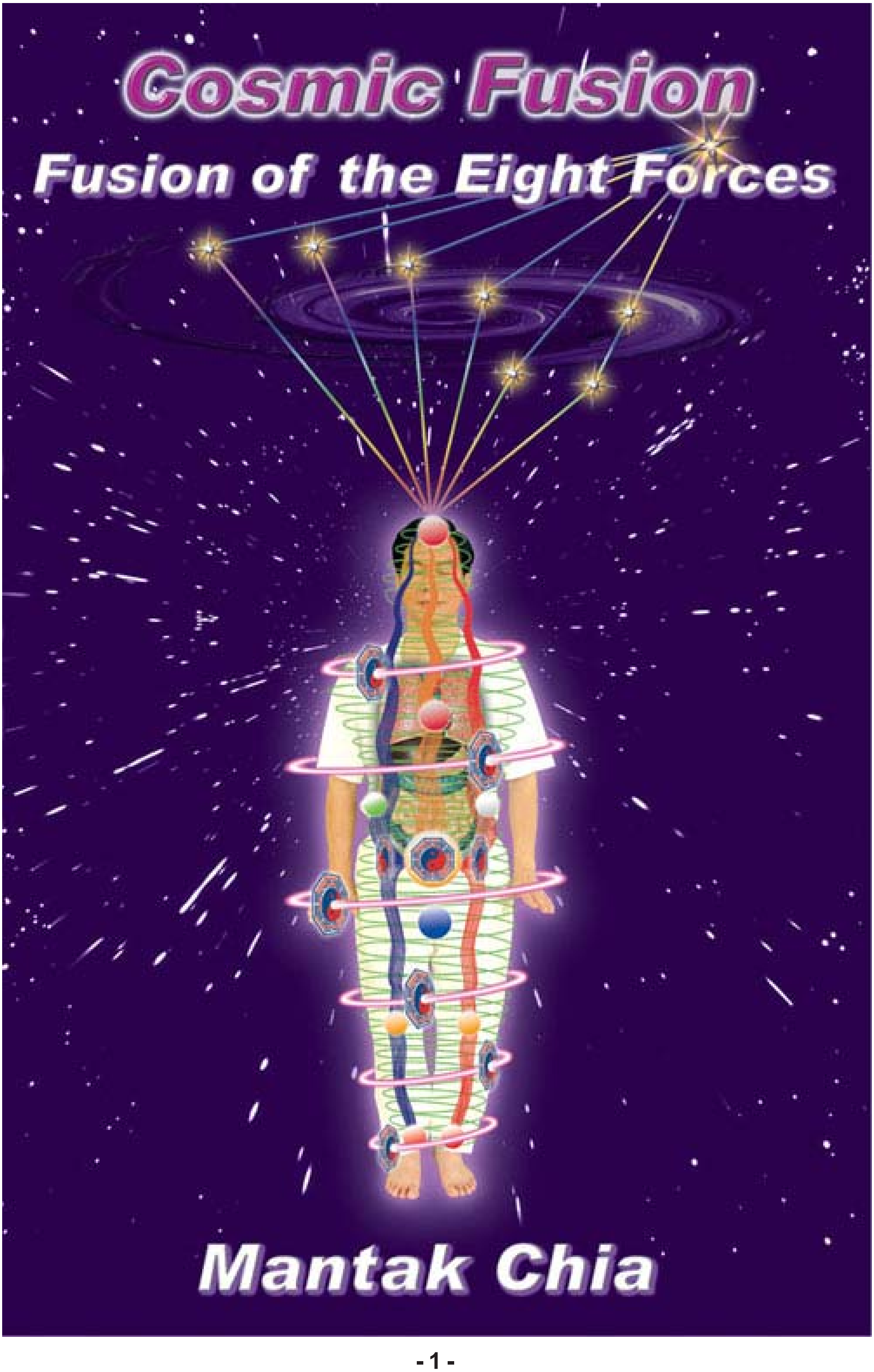

Mantak Chia

Cosmic Fusion

Fusion of the Eight Forces

Mantak Chia

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About the Author

Mantak Chia

Master Mantak Chia

Master Mantak Chia is the creator of the Universal Tao System and is the director of the Universal Tao Center and Tao Garden Health Resort and Training Center in the beautiful northern countryside of Thailand. Since childhood he has been studying the Taoist approach to life. His mastery of this ancient knowledge, enhanced by his study of other disciplines, has resulted in the development of the Universal Tao System which is now being taught throughout the world.

Mantak Chia was born in Thailand to Chinese parents in 1944. When he was six years old, Buddhist monks taught him how to sit and "still the mind." While still a grammar school student, he learned traditional Thai boxing. He was then taught Tai Chi Chuan by Master Lu, who soon introduced him to Aikido, Yoga and broader levels of Tai Chi.

Years later, when he was a student in Hong Kong excelling in track and field events, a senior classmate named Cheng Sue-Sue introduced him to his first esoteric teacher and Taoist Master, Master Yi Eng (I Yun). At this point, Master Chia began his studies of the Taoist way of life in earnest. He learned how to circulate energy through the Microcosmic Orbit and, through the practice of Fusion of the Five Elements, how to open the other Six Special Channels. As he studied Inner Alchemy further, he learned the Enlightenment of the Kan and Li, Sealing of the Five Senses, Congress of Heaven and Earth and Reunion of Heaven and Man. It was Master Yi Eng who authorized Master Chia to teach and heal.

When Mantak Chia was in his early twenties he studied with Master Meugi in Singapore, who taught him Kundalini, Taoist Yoga and the Buddha Palm. He was soon able to clear blockages to the flow of energy within his own body. He learned to pass the life force energy through his hands also, so that he could heal Master Meugi's patients. He then learned Chi Nei Tsang from Dr. Mui Yimwattana in Thailand.

A while later, he studied with Master Cheng Yao-Lun who taught him the Shao-Lin Method of Internal Power. He learned the closely guarded secret of the organs, glands and bone marrow exercise known as Bone Marrow Nei Kung and the exercise known as Strengthening and Renewal of the Tendons. Master Cheng Yao-Lun's system combined Thai boxing and Kung Fu. Master Chia also studied at this time with Master Pan Yu, whose system combined Taoist, Buddhist and Zen teachings. Master Pan Yu also taught him about the exchange of Yin and Yang power between men and women, and how to develop the Steel Body.

To understand the mechanisms behind healing energy better, Master Chia studied Western anatomy and medical science for two years. While pursuing his studies, he managed the Gestetner Company, a manufacturer of office equipment and became well acquainted with the technology of offset printing and copying machines.

Using his knowledge of Taoism, combined with the other disciplines, Master Chia began teaching the Universal Tao System. He eventually trained other Instructors to communicate this knowledge and he established the Natural Healing Center in Thailand. Five years later, he decided to move to New York, where in 1979, he opened the Universal Tao Center. During his years in America, Master Chia continued his studies in the Wu system of Tai Chi with Edward Yee in New York.

Since then, Master Chia has taught tens of thousands of students throughout the world. He has trained and certified over 2,000 instructors and practitioners from all over the world. Living Tao Centers, Chi Nei Tsang Institutes, Cosmic Healing Forums & Immortal Tao Mountain Sancutaries have opened in many locations in North America, South America, Europe, Asia, Africa and Australia.

In 1994, Master Chia moved back to Thailand, where he had begun construction of Tao Garden and the Universal Tao Training Center fifteen miles outside of Chiang Mai.

Master Chia is a warm, friendly and helpful man who views himself primarily as a teacher. He presents the Universal Tao System in a straightforward and practical manner, while always expanding his knowledge and approach to teaching. He uses a word processor for writing and is totally at ease with the latest computer technology.

Master Chia estimates that it will take thirt-five books to convey the full Universal Tao System. In June, 1990, at a dinner in San Francisco, Master Chia was honored by the International Congress of Chinese Medicine and Qi Gong (Chi Kung), who named him the Qi gong Master of the Year. He is the first recipient of this annual award.

In December, 2000, the Tao Garden Health Resort and Universal Tao Training Center was completed with two Meditation Halls, two open air Simple Chi Kung Pavilions, indoor Tai Chi, Tao Tao Yin and Chi Nei Tsang Hall, Tai Chi Natural Swimming Pool, Pakua Communications Center with a complete Taoist Library, Internal World Class Weight Lifting Hall and complete 8 Court Recreational Facilities.

In February, 2002, the Immortal Tao practices were held at Tao Garden for the first time using Darkness Technology, creating a complete environment for the higher level Taoist practices.

Master Mantak Chia has previously written and published these twenty-two Universal Tao books:

Awaken Healing Energy of the Tao - 1983
Taoist Secrets of Love: Cultivating Male Sexual Energy co-authored with Michael Winn - 1984.
Taoist Ways to Transform Stress into Vitality -1985
Chi Self-Massage: the Tao of Rejuvenation - 1986
Iron Shirt Chi Kung I - 1986
Healing Love Through the Tao: Cultivating Female Sexual Energy - 1986
Bone Marrow Nei Kung - 1989
Fusion of the Five Elements I - 1990
Chi Nei Tsang: Internal Organ Chi Massage - 1990
Awaken Healing Light of the Tao - 1993
The Inner Structure of Tai Chi co-authored with Juan Li - 1996
Multi-Orgasmic Man co-authored with Douglas Abrams 1996 - published by Harper Collins
Tao Yin - 1999
Chi Nei Tsang II - 2000
Multi-Orgasmic Couple co-authored with Douglas Abrams 2000 - published by Harper Collins
Cosmic Healing I - 2001
Cosmic Healing II co-authored with Dirk Oellibrandt - 2001
Door of All Wonders co-authored with Tao Haung - 2001
Sexual Reflexology co-authored with W. U. Wei - 2002
Elixir Chi Kung - 2002
Tan Tien Chi Kung - 2002
Cosmic Fusion - 2002

Many of the books above are available in the following foreign languages:

Arabic, Bulgarian, Czech, Danish, Dutch, English, French, German, Greek, Hebrew, Hungarian, Indonesian, Italian, Japanese, Korean, Lithuanian, Malaysian, Polish, Portuguese, Romanian, Russian, Serbo-Croatian, Slovenian, Spanish, & ***Turkish*** editions are available from the Foreign Publishers listed in the Universal Tao Center Overview in the back of this book.

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The Universal Tao Publications staff involved in the preparation and production of *Cosmic Fusion: Fusion of the Eight Forces* extend our gratitude to the many generations of Taoist Masters who have passed on their special lineage, in the form of an unbroken oral transmission, over thousands of years. We thank Taoist Master I Yun (Yi Eng) for his openness in transmitting the formulas of Taoist Inner Alchemy.

Thanks to Juan Li for the use of his beautiful and visionary paintings, illustrating Taoist esoteric practices.

We offer our eternal gratitude to our parents and teachers for their many gifts to us. Remembering them brings joy and satisfaction to our continued efforts in presenting the Universal Tao System. For their gifts, we offer our eternal gratitude and love. As always, their contribution has been crucial in presenting the concepts and techniques of the Universal Tao.

We wish to thank the thousands of unknown men and women of the Chinese healing arts who developed many of the methods and ideas presented in this book. We offer our gratitute to Master Lao Kang Wen for sharing his healing techniques.

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Words of Caution

The practices described in this book have been used successfully for thousands of years by Taoists trained by personal instruction. Readers should not undertake the practice without receiving personal transmission and training from a certified instructor of the Universal Tao, since certain of these practices, if done improperly, may cause injury or result in health problems. This book is intended to supplement individual training by the Universal Tao and to serve as a reference guide for these practices. Anyone who undertakes these practices on the basis of this book alone, does so entirely at his or her own risk.

The meditations, practices and techniques described herein are ***not*** intended to be used as an alternative or substitute for professional medical treatment and care. If any readers are suffering from illnesses based on mental or emotional disorders, an appropriate professional health care practitioner or therapist should be consulted. Such problems should be corrected before you start training.

Neither the Universal Tao nor its staff and instructors can be responsible for the consequences of any practice or misuse of the information contained in this book. If the reader undertakes any exercise without strictly following the instructions, notes and warnings, the responsibility must lie solely with the reader.

This book does not attempt to give any medical diagnosis, treatment, prescription, or remedial recommendation in relation to any human disease, ailment, suffering or physical condition whatsoever.

The Universal Tao is not and cannot be responsible for the consequences of any practice or misuse of the information in this book. If the reader undertakes any exercise without strictly following the instructions, notes, and warnings, the responsibility must lie solely with the reader.

Chapter 1

Cosmic Fusion and the Tao

Cosmic Fusion is the basic Taoist practice of internal alchemy. This is the second book in a three part series. This particular book expands on the concepts and practices introduced in Fusion of the Five Elements. Here in part II, the practice goes to the next level of development.

In the beginning these practices may seem complex and mentally challenging, yet once the formulas are understood and applied, they are quite simple. With practice, the materials become familiar territory that you can traverse easily. Take your time with the formulas. Experiment with what works for you. The formulas are the guidelines to enhance your life. The Cosmic Fusion is a doorway into the vast potential of the self and the Universe. It is a very natural process and the first step into the Taoist alchemical practice.

The Tao

The word *Tao* means ***The Way***, the way of nature and the Universe, or the path of a natural reality. It also refers to a way in which we can open our minds to learn more about the world, our spiritual paths and ourselves. Taoism is a practice of body, mind and spirit, not just a philosophy of mind. When we have the true sense of the Tao, of the real knowledge and wisdom, we will be able to make the right decisions in our lives.

Taoism involves many practical disciplines that can restore our lost youth, energy and virtues while awakening our deepest spiritual potentials. Taoists regard these practices as a technology that can help us learn universal truths if we are willing to be receptive.

The ancient masters recognized that these potentials can include the possibility of attaining conscious freedom and existence in the after-death state. Through specific exercises, one can avoid suffering the experience of death by expanding the consciousness beyond the physical body before its demise. This makes it possible to determine one’s future existence before leaving this life.

All spiritual paths ultimately lead to the truth. Taoism is both a philosophy and a technology for seeking and finding the truths of the universe, nature, and humanity. Its focus goes beyond one single path or viewpoint. Taoism is not a religion, as it requires no initiations or ceremonies, but it is the outcome of all religions, departing from dogma at the point of truth. It leaves behind all religious beliefs, just like the clothing of past seasons. The Tao is also the goal of science, but it leaves behind all scientific theories as partial and temporal descriptions of the integral truth. Taoism includes all matters of religion and science, yet its breadth goes far beyond the limits of devotion or intellect.

Taoist teachings are like master keys unlocking all doors. They assist people in their lives, as do all religious teachings. Yet the teachings of the Tao transcend religion while retaining the essence of spirituality. They explain and demonstrate the truths of the Universe directly, rather than on the level of emotions, thoughts or beliefs. For this reason, students of the Tao have little cause for skepticism or endless searching.

Philosophy, science and religions all contain some aspects of truth that reflect the Tao. The teachings of the Tao reflect the center of the ultimate truth (ourselves and the Universe) and help us reach it on our own. We can believe in any religion or spiritual path and still benefit from these teachings, because the Tao serves only to promote universal spiritual independence. There are no ultimate masters or gurus in Taoism because we become our own masters, capable of controlling our own destinies and knowing who we really are as we explore the marvelous powers hidden within the Tao of humanity. All the great gods, immortals, sages, saints and holy men and women are our teachers and advisers.

Taoism, which goes back at least seven to eight thousand years, is closely aligned with modern technology and science. Browsing through a bookstore, you will find that many recent books use the concepts of Taoism to explain relationships expounded by the “new” physics. Today, a lot of the world’s intellectual effort is directed toward external technological development.

Thousands of years ago, the Taoists directed their consciousness inwardly, and developed a science of inner alchemy. Chinese written history has a 4700 year history and the language has not changed significantly over the centuries, so even the oldest documents can be read today. A lot of information was accumulated in each dynasty. The Taoist sages, who learned and perfected methods to prepare and leave the body, recorded all the practical details. These, along with philosophical thought, were collected, filling many volumes which constitute the Tao Canon.

These transformative formulas endure, a gift from the original Taoist sages to all who are willing to put them into practice. The Universal Tao is concerned primarily with the practical approaches perfected by the Taoist sages.

Universal Tao System

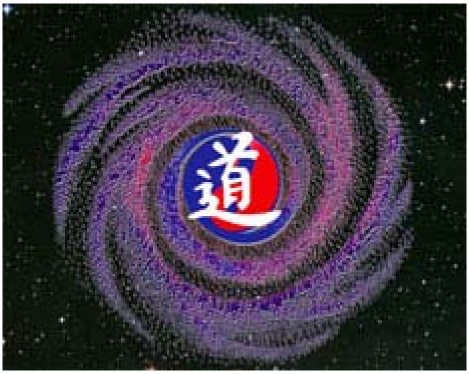

The ancient Taoists saw the importance of working on all three levels of our being: the physical body, the Energy Body and the spirit. All three are important in forming a ladder with which we may climb consciously into the spiritual worlds and, just as important, back into the physical world to be creatively active here. This ladder enables Taoists to learn about the inner worlds and to return to the physical with knowledge and increased energy. An Immortal Body, which is developed in the practice of Internal Alchemy, enables one to establish a constant link between life and the after-death (or pre-birth) state.

Ancient Taoist sages believed we were born to be immortal. We become mortal by draining ourselves of Chi through engaging in excessive sexual activity, indulging in negative emotions, and depending on material sources to supply our life-force. The masters recognized that different levels of immortality can be achieved through internal alchemy, and they devised many practices for this purpose. The ability to transcend even death through the transmutation of one’s physicality into the Immortal Spirit Body is the highest goal of Taoism. This level, known as physical immortality, takes the longest to achieve.

Healing the Physical Body: Becoming like a Child to return to the Original Source

Taoist practices teach to conserve the physical energy so that it will no longer scatter and deplete as a result of our worldly interactions. Full spiritual independence requires that we avoid being drained of this energy through the eyes, ears, nose, and mouth or through excessive sex. The novice in the Universal Tao System begins with a wide range of exercises that develop the physical body into an efficient and healthy organism, able to live in the world and yet stay free of the tensions and stresses of daily life. One aspires to return to a childlike state of innocence and vitality, to regain the Original Source that is our birthright. Specific goals of this level are to learn how to heal oneself, how to love oneself, and how to love others.

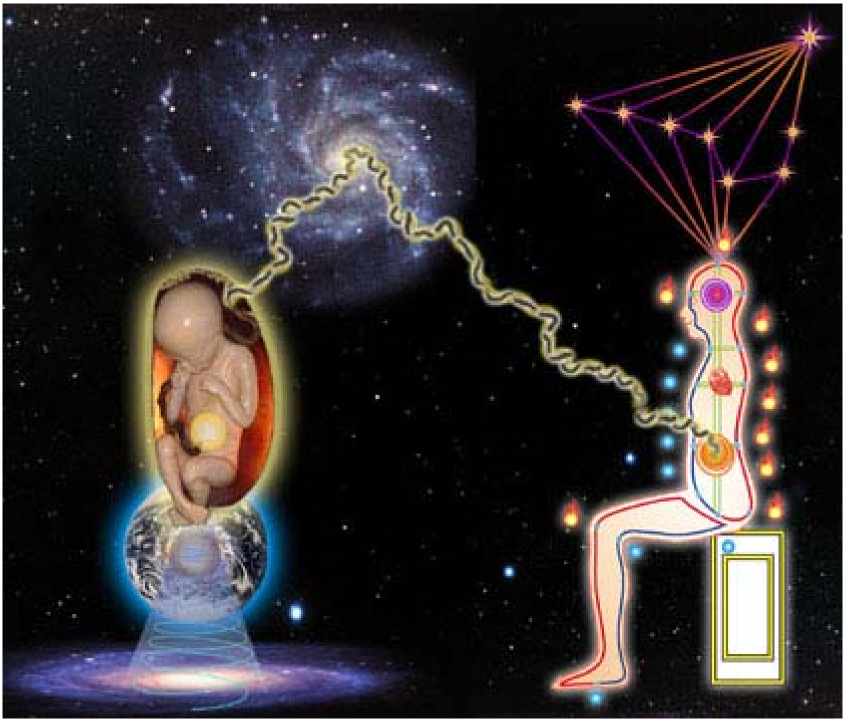

Fig. 1.1 *Returning to the Original Source.*

The first level of practice is to develop a healthy body, which can take months of diligent training. During this process we learn how to condense and conserve our life-force through the *Microcosmic Orbit* meditation, *Healing Love* practices, *Inner Smile*, *Six Healing Sounds*, and *Iron Shirt Chi Kung*. We learn to gather and refine our life-force into a Chi Ball (energy sphere) so it will not dissipate when we are ready to leave this world. As people grow older, their life-force weakens, often resulting in illness and suffering. Using drugs to combat illness drains so much of the body's life-force that there may not be enough energy left to follow the primordial light (clear light) to the Wu Chi (our original source God) at the moment of death. The basic practices of the Universal Tao ensure that we retain enough of our health and vital energy to make that journey.

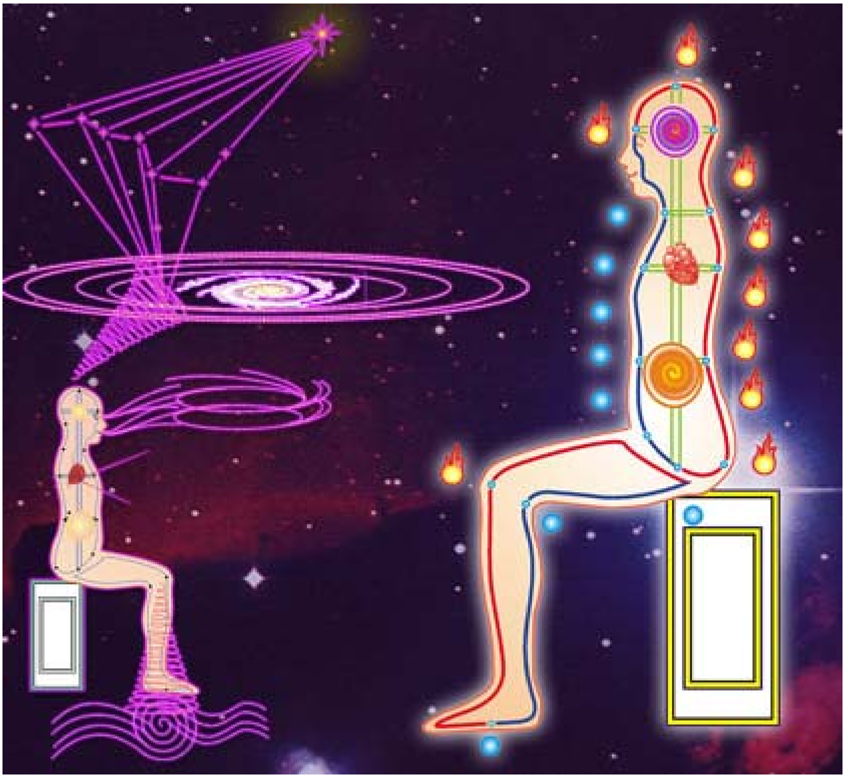

Fig. 1.2 *Sit down and start to move the orbit in the fast speed, from 1000 rotations per minute, to 10,000 per minute and up to 30,000 per minute.*

Stopping energy leakage through conservation and recycling.

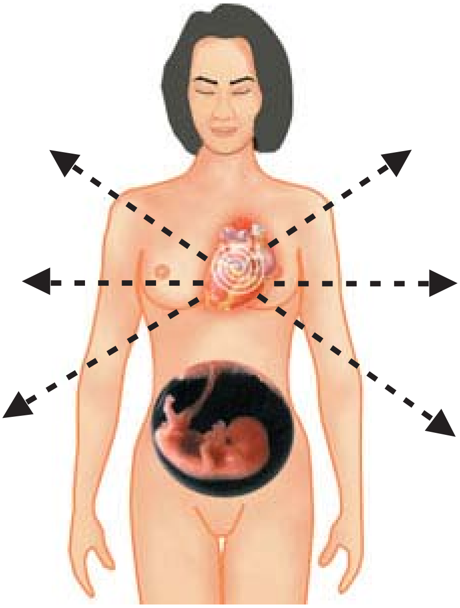

Fig. 1.3 *Heart Leakage*

The Microcosmic Orbit is the body's major energy pathway. Along this path there are nine openings. If we learn how to seal them when they are not in use, that simple act of conservation will save an immense amount of energy.

The Microcosmic Orbit meditation is the first step toward attaining these goals, as it develops the power of the mind to control, conserve, recycle, transform and direct Chi (the Chinese term for energy, or life-force) through the body's primary acupuncture channels. By learning how to manage our Chi effectively, we gain better control over our lives; by using our energy wisely, we discover that we already have plentiful Chi.

At this stage, one also learns to connect with and draw from the unlimited source of Universal Love, a Cosmic Orgasm formed by the union of the three main sources of Chi accessible to humans: the *Universal (Heavenly) Force*, the *Earth Force* and the *Higher Self (Cosmic) Force*. This process is both energizing and balancing. It prepares one for working with greater amounts of Chi in the higher levels of meditative practice, particularly in developing the Energy Body.

Abdominal Brain

Learning to empty the mind is one of the most important Universal Tao practices. Letting go of judgments, suspicions and the incessant repetitive thought process is a simple way to recharge the body, the brain and the spirit. Science has proven that we have about 60,000 thoughts per day and of those 60,000 thoughts 95% of them are the same thoughts we had yesterday. By activating the abdominal brain, we are able to clear the mind and create space for more creative mental activity.

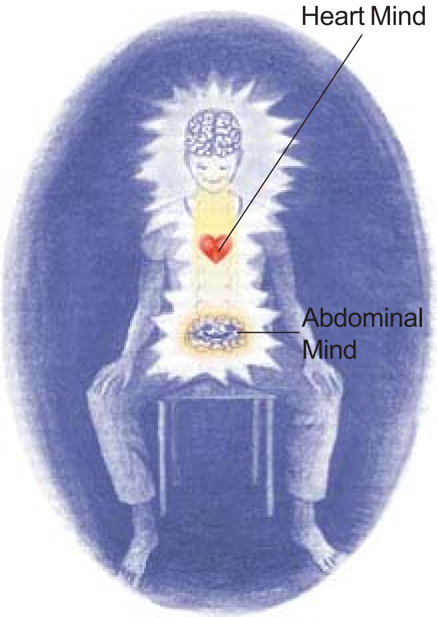

Fig. 1.4 *Upper and Lower Brains*

The brain spends up to 10 times more energy than the rest of the body. Even when we are not working or thinking consciously, our mind still wanders. In Taoism this incessant thinking is called the “Monkey Mind”. If we can stop the mind and empty the energy from the brain down to the organs, there will be tremendous amount of energy stored in the body. This abundance of energy can later return back to the brain. When the energy returns, our thoughts are much more refined, creative and focused.

The abdominal brain is located in the Lower Tan Tien, the reservoir of energy located about an inch below the navel and three inches inside the body. This is the very center of our being. It is called the abdominal brain because it is a center for wisdom. Science is learning that the same chemical activities that go on in the brain, go on in the abdomen. The difference is that the abdomen is not connected with the senses. The senses tend to pull our energy and awareness outside of ourselves. This leads to the constant analyzing of situations and people. The abdominal brain is a much deeper sense of awareness, where our “gut feelings” originate. When the abdominal brain is activated, we open up to more guidance, deeper intuition and full body awareness.

Transforming Negative Energy into Virtues: Opening the Heart

The Inner Smile and Six Healing Sounds are simple yet powerful practices that teach us how to relax and heal the vital organs and to transform negative emotions back into a rich source of energy. They help open the heart center and connect us with unlimited Universal Love, improving daily interactions and providing a vehicle for the virtues, which derive from the internal organs. Taoists perceive the heart as the seat of love, joy and happiness, which can connect with Universal Love. It is also a cauldron in which the energies of our virtues are combined and strengthened. Through the Inner Smile, you will feel these virtuous energies generated from their respective organs. These virtues are then gathered into the heart to be refined and blended into compassion, the highest of all virtues. This is a most effective way to enhance one's best qualities.

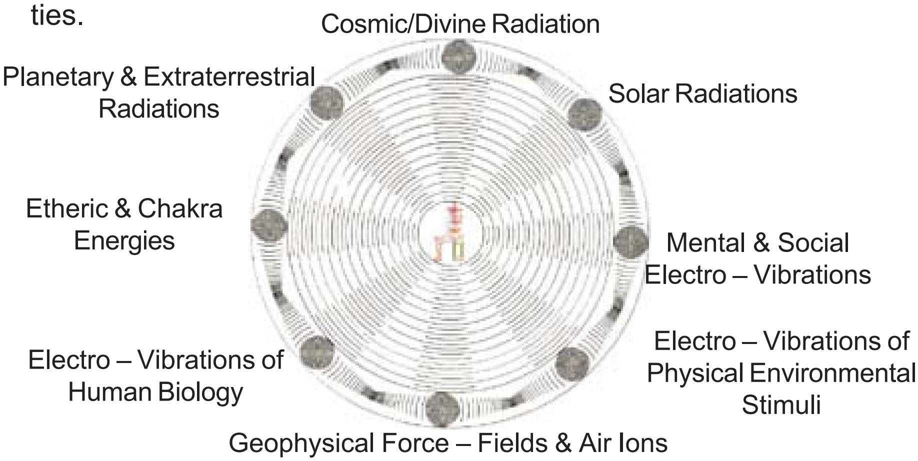
Cosmic/Divine Radiation
Planetary & Extraterrestrial Radiations
Solar Radiations
Etheric & Chakra Energies
Mental & Social Electro – Vibrations
Electro – Vibrations of Human Biology
Electro – Vibrations of Physical Environmental Stimuli
Geophysical Force – Fields & Air Ions

Fig. 1.5 Cosmic/Divine Radiation Fields

Another important beginning practice teaches the student of the Tao how to gain strength through the conservation and recycling of sexual energy (*Healing Love through the Tao*). When collected, sexual energy (*Ching Chi*) becomes an incredible source of power that can be used by the individual or shared with a sexual partner through the Microcosmic Orbit pathway during sexual intercourse. With practice, singles and couples can learn to increase and intensify sexual pleasure. The collected and transformed sexual energy is an important alchemical catalyst to be used in the higher meditations.

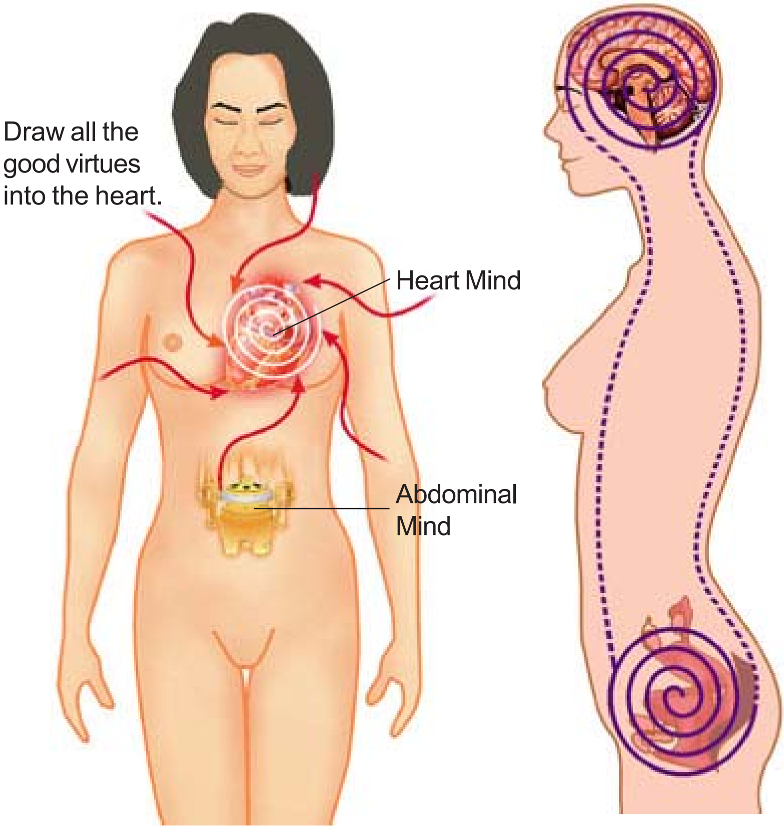
Draw all the good virtues into the heart.
Heart Mind
Abdominal Mind

***Fig. 1.6** Conserving, recycling and transforming the energy.*

Once you have an abundance of sexual energy, you can connect to the unlimited Cosmic Orgasm experienced every moment by your Higher Self, which is the most basic energy in every cell of your body.

Managing the Life-Force

In the practices of Iron Shirt Chi Kung and Tai Chi Chi Kung, one learns to align the skeletal structure with gravity to allow a smooth, strong flow of energy. With strong fasciae, tendons, and bone marrow and good mechanical structure, we can manage our life-force more efficiently. The body also gains a sense of being rooted deeply in the earth, so one can tap into the Mother Earth healing force.

Cosmic Nutrition

The Taoist approach to diet is based on determining the body's needs and then fulfilling them according to the five elements of nature, which support the five major organs of the body. This system reveals and strengthens any weak organs by balancing one's food intake to enhance any deficient elements. It does not condemn most foods that people enjoy (including sweets), but instead creates a better program in which these foods can support the body's internal balance rather than disrupt it. Choosing and combining foods in this way can help us avoid the cravings we sometimes fall prey to.

Developing the Energy Body: Our Vehicle to Travel in Inner and Outer Space

The next level of the Universal Tao system consists of the *Fusion of Five Elements, Cosmic Fusion,* and *Fusion of the Psychic Channels*. These practices build and enhance the basic Universal Tao exercises. They use the extra energy saved through the foundation practices, including recycled negative energies, to build a strong Energy Body that will not dissipate. Developing this Energy Body awakens a part of oneself that perceives and acts free of environmental, educational and karmic conditioning. Once the Energy Body is strong, it becomes a vehicle (like the space shuttle) to help the untrained soul and spirit for the long journey home, back to the Wu Chi.

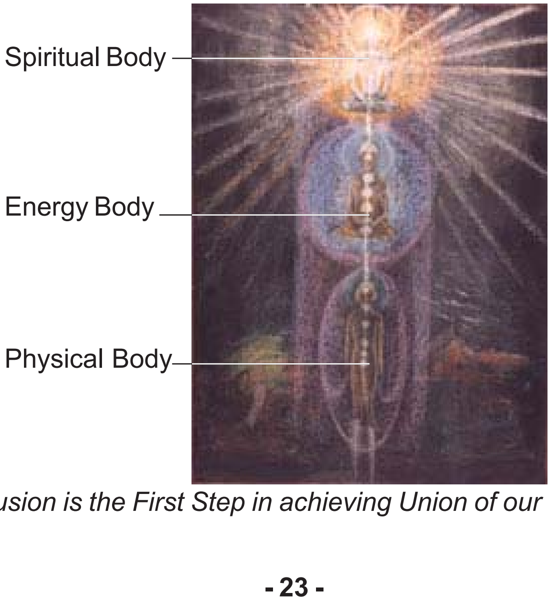

Fig. 1.7 *Fusion is the First Step in achieving Union of our Three Bodies.*

If we do not have a chance to practice awakening or to give birth to the soul and immortal spirit during life, the primordial light will awaken us at the moment of death. Unfortunately, we may be too untrained and inexperienced to follow this light. To prepare for the journey, the Energy Body is a vehicle of great importance. We can train and educate the Energy Body so it can help the untrained soul and spirit recognize and follow the primordial light back to our original source.

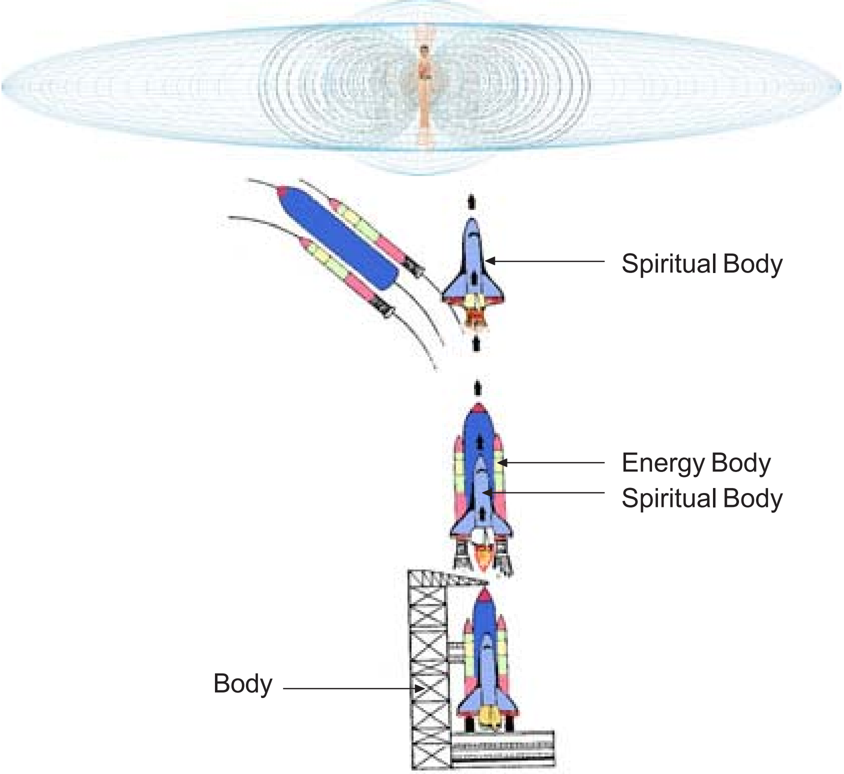

Fig. 1.8 *Energy Body blasting off the Spiritual Body and enters outer space.*

When we are ready to give birth to the real soul, the Energy Body will act like a booster rocket to help boost the soul into its higher dimension of the immortal spirit. At the highest level, all three of these bodies merge into one.

Each level of development gives us a chance to go further in the journey back to the Wu Chi. Taoist methods of absorbing stellar energies help rejuvenate the physical body and strengthen the soul and spirit bodies for their inter-dimensional travels.

Recycling our Negative Emotions

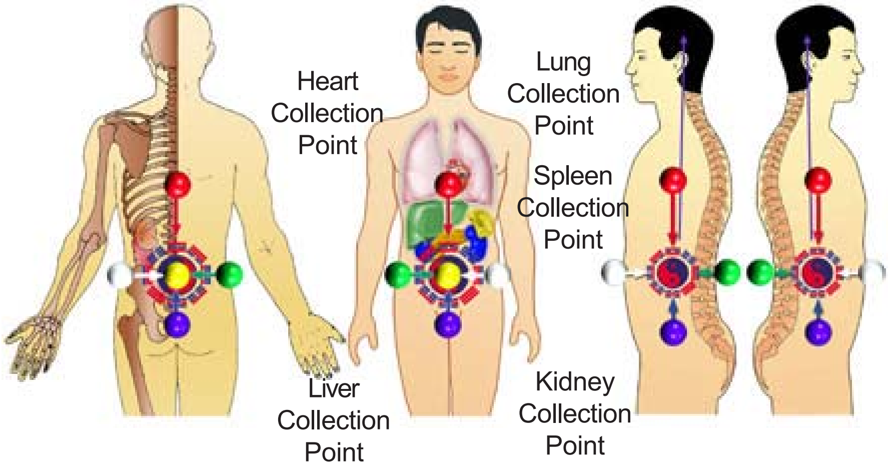

Fig. 1.9 *There are Five Major Collection Points of the Emotions reflected on all four sides of the body.*

Our emotional life, filled with constant vicissitudes, drains our vital energy. Through the Fusion meditations, one learns to transform the sick or negative energy that has been locked up in the vital organs. Taoists understand morality and good deeds as the most direct path to self-healing and balance. To be good to others is good for oneself as well. All the good energies we create are stored in the Energy Body like deposits in a bank account. By helping others and giving them love, kindness and gentleness, we receive positive energy in return. When we open our hearts, we are filled with love, joy and happiness.

From Taoist experience, we know that when we leave this world we can go directly to heaven, depending on how much energy we have been able to transform into the Energy Body prior to death. Just like money in the bank, the more we transform our physical being to our spiritual being, the more we have in heaven. The more good we do here, the more positive energy we have up there.

Forming the Spirit Body: Planting the Seed of Immortality – Lesser Kan & Li

The Inner Alchemy meditation of the Lesser Enlightenment of Kan and Li (water and fire, multi-orgasmic sexual energy and compassion) reunites the male and female within each of us. It involves the practice of self-intercourse, which by internal sexual coupling of the energies enables one to give birth to the soul body. The soul body then acts as a “baby sitter” to help nurture the spirit body. The soul is the seed, but it can also be matured into the immortal body if one has not had the chance to raise the spirit body in this life. Practitioners of Taoist Alchemy believe that if we give birth to the spirit body and develop the immortal body in this life, we can overcome the cycle of reincarnation.

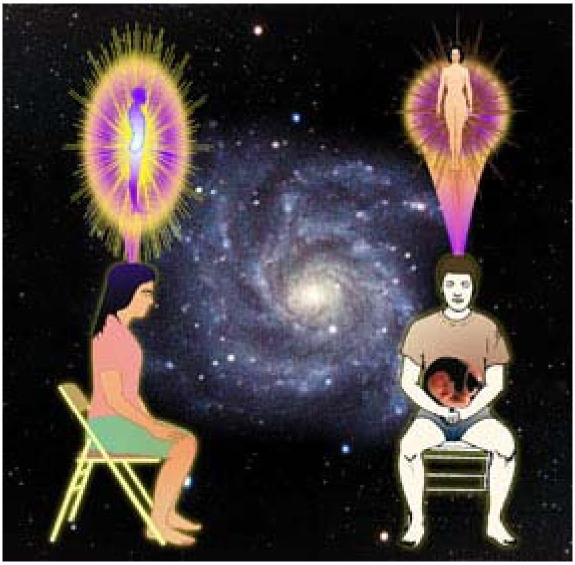

Fig. 1.10 *Creating the Energy Body in preparation for the Spiritual Body.*

Once the “baby sitter” or soul body is formed, it is in the Yin stage, or infancy (soul embryo). We need to feed, raise, educate and train the young soul to become fully grown.

Once the soul body is developed, we can give birth to the spirit body. To cultivate the young spirit body until it is fully mature can take 14 to 18 years. We also use the energies of nature (trees, sun, moon and stars); virtually all sensory experiences of a positive nature become nourishment for the growth of the spirit within the physical body.

Many masters who attained this level of the immortal body were able to transform the material into the immaterial and transfer it into the spirit body. At the moment of death, they were able to transfer their consciousness, their energy and the physical elements of their bodies up with them into the spirit body, although even this level is not yet the true immortal body. In this process their physical bodies actually shrank in size; they may have weighed two-thirds of their usual weight after their physical deaths occurred. This meant they had successfully transformed much of their material being into an immaterial state while retaining full consciousness.

Cultivating the Yang Stage of the Immortal Body: Marrying the Light - Greater Kan and Li

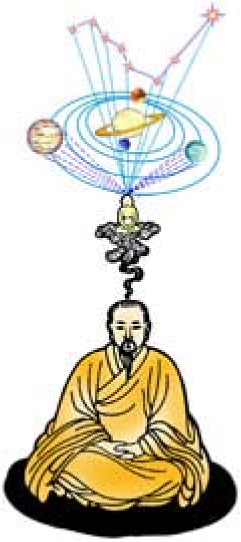

Fig. 1.11 *Greater Kan and Li*

To merge with the light of the Tao, we must awaken and nourish the awareness that we are in truth children of the light. Once we have fully grown the spirit body, it will be the same frequency as the light of the Tao and can become one with that light. Other traditions refer to this light by such names as the Holy Spirit or Great Spirit; we also refer to it as the "outer light."

The Greater Kan and Li meditation teaches us how to recognize the inner light of our own spirits and shows us how to merge with or "marry" it to the outer light. Once we connect with and "marry the light," we give birth to the second stage of the true immortal spirit. Taoists refer to this as the Yang body. One continues to transform the physical body energy to feed the immortal spirit so it can mature.

At this stage of practice, we learn to digest increasingly higher-grade energies of the Higher Self and Universal Forces from the sun, moon, planets, stars and galaxies, and from the mind of the Tao itself. An awakening to that which is eternal and enduring occurs through this practice. Cognizant of our true nature as spirits, we experience the ability to leave the physical body and travel in the immortal spirit body, which leads to experience of the inner worlds of spirit. Fear of death is vanquished as we become familiar with life beyond physicality.

Greatest Enlightenment of Kan and Li

At this level one transfers all physical essence into the immortal body. When all the body's material elements are transformed into subtle Chi, what remains is known as the "rainbow body." When a master of this level leaves this world, there is nothing left of the physical body but nails and hair. Death is still necessary to speed up the process.

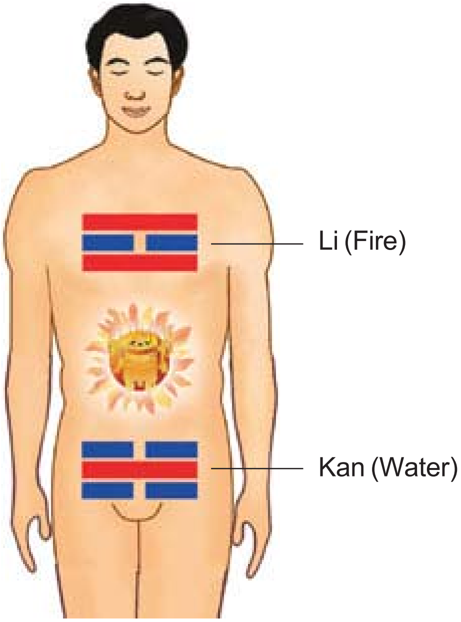

***Fig. 1.12** Union of Fire and Water*

Sealing of the Five Senses, Congress of Heaven and Earth, Reunion of Heaven and Man

At this level death is transcended entirely. One can simply transform the physical body into the immortal body and leave this world or return to it at will. This is the state of complete physical immortality. It takes from eighty to a few hundred years to complete these practices and transform all the material elements of our body into the immaterial. The final goal of ascending to heaven in broad daylight is reached.

There are records in Chinese history of many thousands of Taoist immortals who reached the level of daylight ascension in the presence of many witnesses. In the Bible, Elijah and Moses also accomplished this feat. In the final stage of this practice, the adept can unite the immortal spirit body, the Energy Body, and the physical body, or separate them at will. It is then that the human being knows full and complete freedom as an immortal, where no world is a boundary.

Chapter 2
Taoist Cosmology

Ancient Taoism is rooted in deep observation of naturally occurring Universal processes and their effects upon human beings. Newtonian physics of the West understands these processes as the mechanics of cause and effect. Taoism understands them as the interactions of a vast sea of energy that is constantly creating and recreating the universe in infinite ways. Most religions and esoteric systems study these processes (the ways of God) through scriptures and practices based upon the immaterial. Taoism studies both the material and immaterial aspects of nature and the Universe in the belief that the immaterial is both the source for the material and a product of it. In other words, physical and non-physical processes are sources for each other.

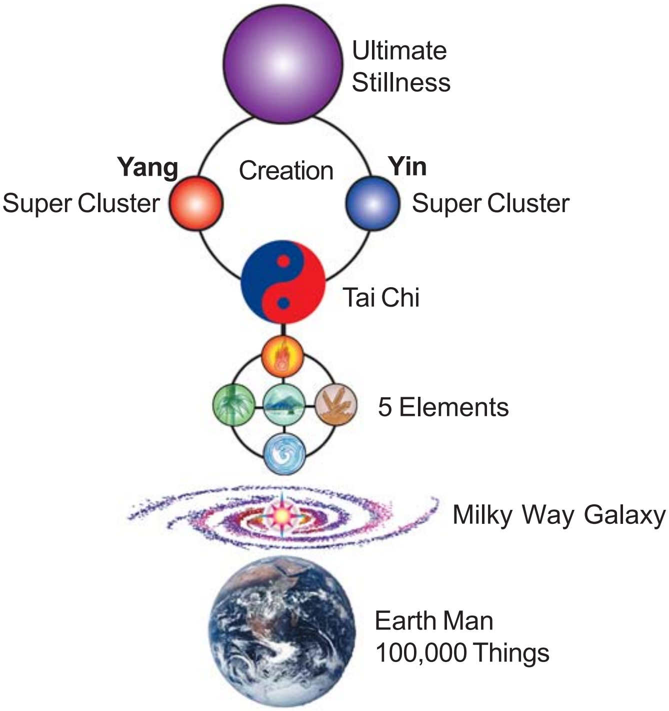
Ultimate
Stillness
Yang
Super Cluster
Creation
Yin
Super Cluster
Tai Chi
5 Elements
Milky Way Galaxy
Earth Man
100,000 Things

Fig. 2.1 *Taoist Cosmology*

The Void: Our Original Source

Through observing nature and the effects of energy within the human body, the ancient Taoists were able to trace the universal energy back to its point of origin. Upon developing an empirical approach with which to contact this source of observable phenomena, they established the concept of the primordial void as the point of departure for all creation. This void was given the name Wu Chi, which is depicted as an empty circle in traditional Taoist art because it is beyond human description. For energy to begin generating the effects and forms of nature and the universe, something had to stir within the Wu Chi. This first stirring created the division between the material and the immaterial as all the processes of the universe began at this time.

Yin and Yang

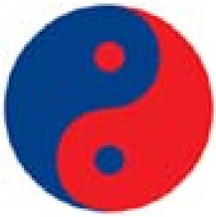

Fig. 2.2 *Duality of Yin and Yang*

Taoists refer to the first observable variations of the Universal Force, which emanates from the Wu Chi, as Yin and Yang. These two qualities of this force can be understood as the positive and negative poles of the primordial energy. Yin and Yang are inseparable tendencies of all energy, and it is impossible to have one without the other. Their interactions are the root of all universal action; hence, the polarities of Yin and Yang are an intrinsic factor of all creation.

The theory of Yin and Yang is one of the most simple and sublime symbols of the way nature and the Universe interact. The circle that encompasses the symbol is representative of the Tao, the undifferentiated whole, the Universe, ultimate reality. Yin and Yang are terms that shed light on the process of the Tao. Yin describes the feminine, the contracting, the dark, deep side of nature and Yang describes the masculine, projective, electric, light, surface side of nature. Yin and Yang are not two separate states, but an interwoven aspect of one. Just as day cannot exist without night, or male without female, Yin and Yang are opposite co-existing elements of the same Universal substance. They are an interwoven and continuous processes of decaying and becoming. Yin and Yang describe the process of a changing dynamic picture of reality.

Five Major Forces of the Universe

The Taoists observed that Yin and Yang interactions follow five basic patterns which came to be known as the Five Tendencies or Five Processes of Energy. (Such interactions have been misleadingly translated as Five Elements, thereby confusing the process with the actual physical elements.) In Taoism the physical elements found in nature symbolically express the Five Tendencies of Energy in motion. Thus fire represents energy rising; water represents energy sinking; wood represents energy expanding; metal represents energy solidifying; and earth represents stable or centered energy. Each of the five elemental tendencies of energy are dependent upon the interactions of Yin and Yang emanating from the primordial void.

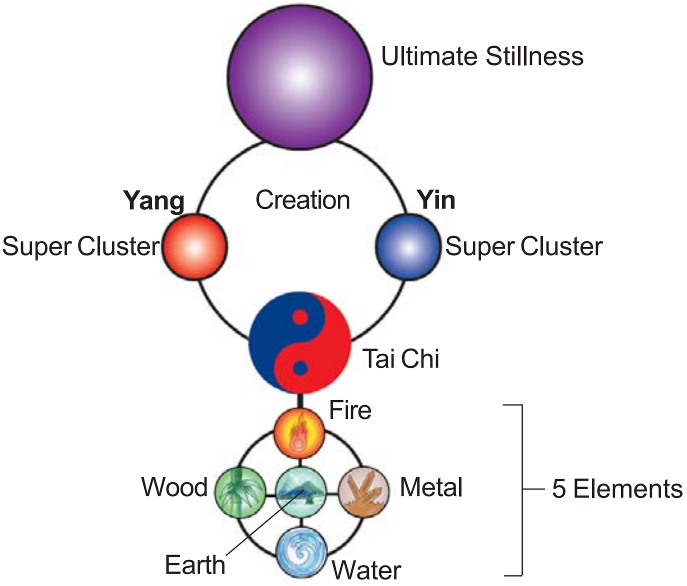

Fig. 2.3 Oneness, Duality and the Five Elements

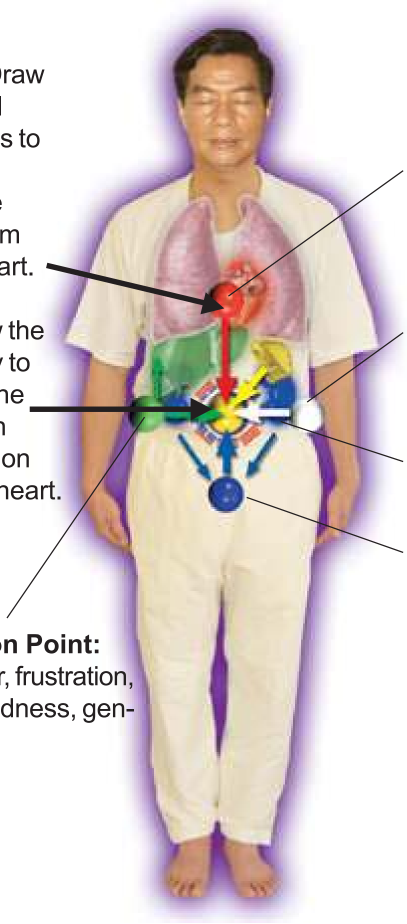

Pre-composting: Draw negative emotional energy from organs to collection points. Neutralize with the virtuous energy from the organs and heart.

Composting: Draw the neutralized energy to the Pakua. Fuse the neutral energy with love and compassion energies from the heart.

Liver Collection Point: Transform anger, frustration, jealousy into kindness, generosity.

Heart Collection Point: Transform hate, cruelty, impatience into love, joy, happiness.

Lung Collection Point: Transform sadness, grief, depression into courage, righteousness.

Spleen Collection Point: Transform worry, anxiety into fairness, openness.

Kidney Collection Point: Transform fear into gentleness, calmness, silence.

Fig. 2.4 *Transform Excess Negative Energy into Positive Energy*

The Five Elemental Forces are expressions of energy that can be observed in nature and throughout the universe. In space they influence the motions of all stars, planets and cosmic phenomena. In nature they promote interactions between the five elements of fire, water, wood, metal and earth. Within the human body they affect the five major organs of the heart, kidneys, liver, lungs and spleen. Just as western science understands the atoms and subatomic particles to be the fundamental units of all matter, the Five Elemental Forces are understood to be the essence of all processes. The forces that influence the cosmos are identical to those which affect nature and our bodies.

Eight Forces

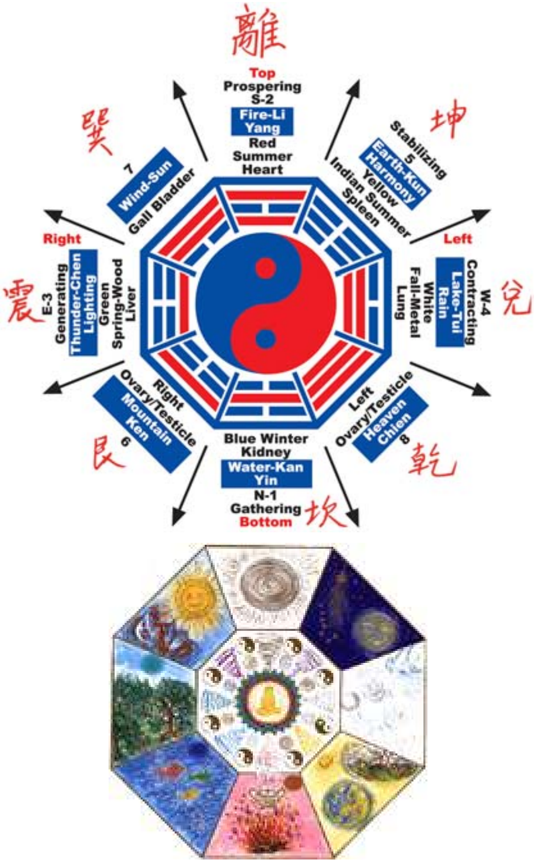
離
Top
Prospering
S-2
Fire-Li
Yang
Red
Summer
Heart
坤
Stabilizing
5
Earth-Kun
Harmony
Yellow
Indian Summer
Spleen
Left
W-4
Contracting
Lake-Tui
Rain
White
Fall-Metal
Lung
兌
Left
Ovary/Testicle
Heaven
Chien
8
乾
Blue Winter
Kidney
Water-Kan
Yin
N-1
Gathering
Bottom
坎
Right
Ovary/Testicle
Mountain
Ken
6
艮
Right
E-3
Generating
Thunder-Chen
Lighting
Green
Spring-Wood
Liver
震
巽
7
Wind-Sun
Gall Bladder

Fig. 2.5 *Eight Forces and Directions*

The Eight Forces represent a more detailed aspect of the forces of nature and the Universe. They are represented by the symbol of the pakua and the eight trigrams. In Fusion of the Five Elements, the pakua was introduced as a way to direct and gather the Chi into a pearl at the lower abdomen. In Cosmic Fusion, the pakuas are used in greater detail to create a stronger connection with the forces of nature and draw much more energy into the pearl.

Using the pakua in the meditation practice is a way to focus energy. The pakua creates a vortex that enables the practitioner to collect, gather and condense Chi. This vortex of energy is used to not only create a strong connection within ourselves, but a harmonious relationship with all the forces of nature.

Return to the Wu Chi

The Taoists realized that we are connected to the stars through our bodies as the human form is a product of stellar energy and matter. With the basic understanding that man, nature and the universe are expressions of primordial energy (or the Wu Chi), the Taoists devised methods to tap the energy of the five elements. This was done to enhance the processes of the Five Elemental Forces within our bodies, which can promote health, refine our spirits, and eventually reunite us with our source, the Wu Chi. Deep within our subconscious minds are memories and desires for the unity and bliss which preceded the dense vibrations of our gross physical state. So the ultimate purpose of Taoist practice is to return to our original state, the Wu Chi.

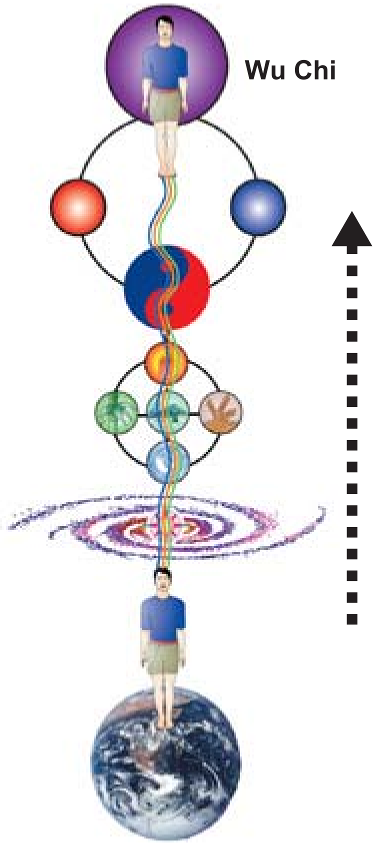

Fig. 2.6 *Return to the Oneness (Wu Chi)*

In the advanced disciplines of the Universal Tao students begin to work more consciously with the Five Elemental Forces emanating from the cosmos. Advanced practice involves collecting and absorbing energy from different sources in the universe while traveling in the energy and spirit bodies. Taoists move closer to the original source through the vastness of space in the same way a traveler moves from station to station in a train. Generations of Taoist masters have refined and mapped the simplest and safest approaches to follow. Because it is impossible to realize the Wu-Chi in one step, the journey is divided into several stages.

Returning to the Wu Chi: First Three Steps

1. The first step of stage one is to upgrade and maintain your physical health while stabilizing your financial and social conditions. Your body is a vehicle for processing energy, and the healthier you are, the more energy it will process at a faster rate. Your health and processing capabilities will enhance greatly through the Microcosmic Orbit, Six Healing Sounds, Inner Smile, Healing Love and Iron Shirt Chi Kung practices. Your finances and social interactions should be stable so that you can create space in your life for these disciplines.
2. Next you will learn how to use accumulated energies for traveling beyond this earthly plane to the moon, sun and planets. This is similar to the way a space shuttle uses a booster rocket to push it beyond the earth’s gravitational field. In Taoism the Microcosmic Orbit and Fusion practices create the Energy Body to help boost the immortal body (spiritual body) out of this world. The healthier you are internally, the more power you will be able to generate to leave the confines of the physical body. When you can travel out of this reality and back, you will gain the raw materials necessary to build more powerful energy and spirit bodies for longer and farther journeys.
3. The higher practices involve traveling to and from the stars and constellations particularly the North Star and Big Dipper using the energy and spirit bodies. The North Star is a stable and constant point in the sky. For Taoist practitioners, using the North Star was a way to find direction in the Universe. The North Star is the gate of heaven. In the higher practices, the energy is drawn into the body to create that connection between the physical and the Universal bodies.

The human body is a powerful transformer. The sexual energy is the body's most powerful source of fuel for journeys to the higher planes. This is why the Healing Love practice is so important for spiritual development. The practice of Iron Shirt Chi Kung also helps the physical body absorb cosmic energy through the skin and bones to be transformed and refined into more fuel. Fusion of the Five Elements provides another mode of energy refinement through the transformation of negative energies into positive life-force, which is lighter and healthier for the body. All of these internal methods help one develop the means of traveling beyond this world. Their ultimate purpose (after rejuvenating the body) is to accumulate the raw materials for the construction of a stronger and more powerful vehicle for the return to the Wu Chi.

Many other systems have their own means of returning to the source. Monks, nuns and priests emphasize detachment from the world and non-involvement in worldly affairs. They have no relationships with other people and no sex, which leaves them with abundant sexual energy to be transformed and used for higher spiritual work. Such spiritually inclined people make the best and most use of sexual energy. In general, when normal people accumulate sexual energy to the same degree as monks, nuns or priests, they have no way to control it, and internal imbalances are created until it is released. The Universal Tao practices can give anyone the ability to use this energy to improve the body and spirit.

One should not believe in the Taoist teachings without experiencing the practice and its results first hand. This involves learning about the human body, the Universal forces which affect it, and the inherent desire we all have to return to our source. Taoism offers a clear, direct path to the Wu Chi, whereas many other systems provide only dogma and restrictions that can hinder spiritual growth. The Tao is not an escapist philosophy, however, as there is no need to remove yourself from society or restrict your relationships or sexual love. You can continue to live normally as you accumulate energies that will gradually improve your health while providing raw materials for the highest spiritual growth.

Chapter 3
Goals of the Fusion Practice

The Taoist study of **Inner Alchemy** was introduced in Fusion of the Five Elements. The Taoists developed the Fusion of the Five Elements practice to develop connections between and gain control of the inner and outer Universes.

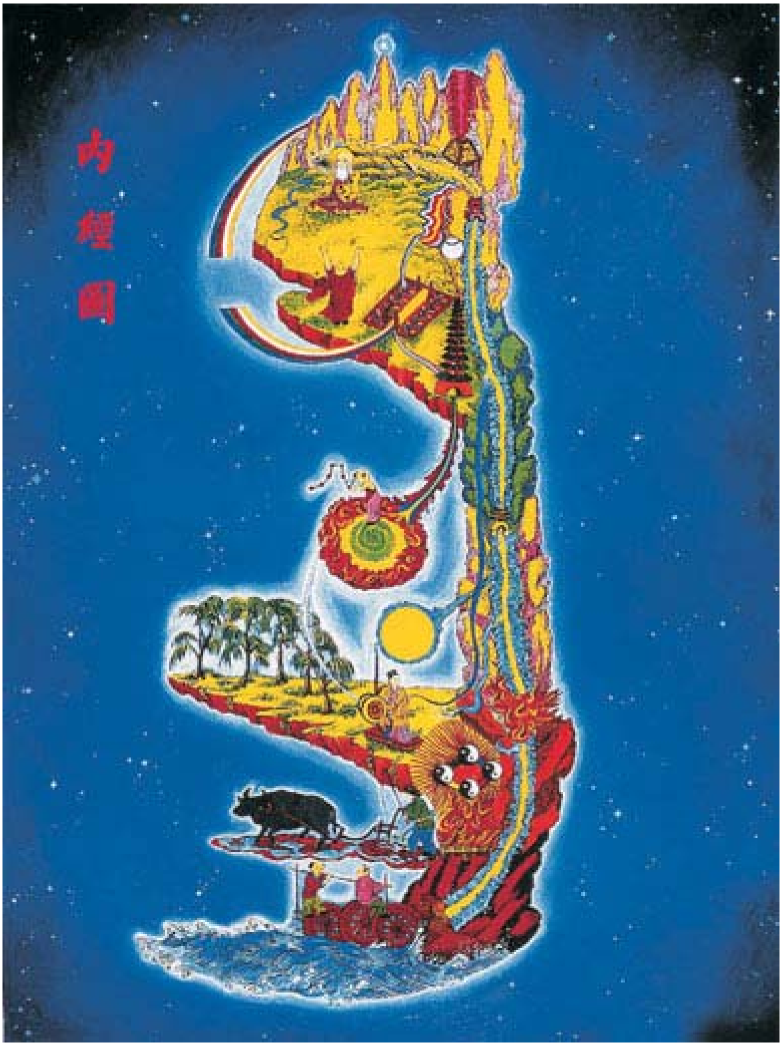

Fig. 3.1 *Taoist Inner Alchemy*

They understood that virtually everything that exists in the Universe can be broken down into the Five Elements. The Fusion practice begins by understanding the dynamics of the Universe, the planet Earth, and the human body with respect to their relationships to these Five Elements.

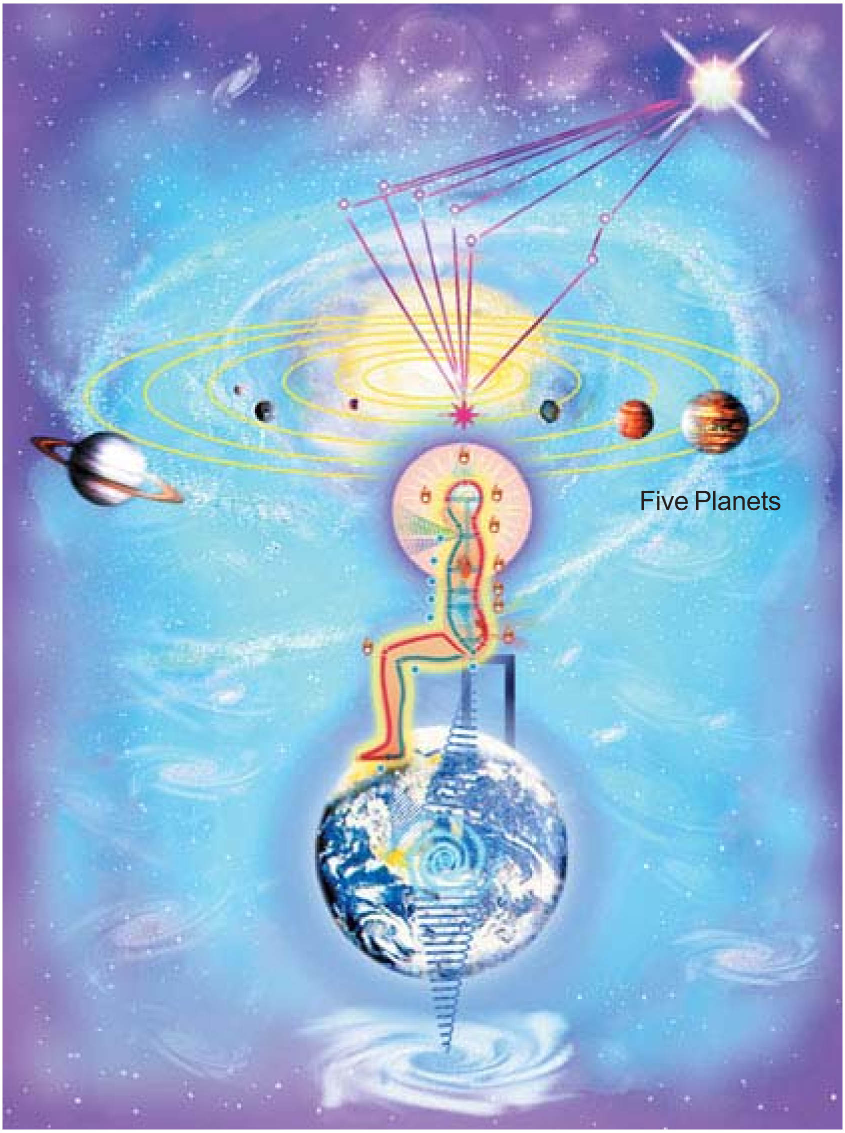

Fig. 3.2 *Five Elements, the Planets and the Cosmos*

The knowledge of Inner Alchemy is a necessary step in becoming connected to the outer Universe, from which an unlimited supply of powerful energy is available to be used for an individual's physical and spiritual benefit.

The five basic formulas of Fusion I, II, III can be likened to wiring blueprints for making the subtle energy the vehicle, the spaceship connections that link vital organs, glands and senses so that their respective energies can be fused and balanced in the collection point and the pakua. The formulas lead the student systematically through the process of creating four pakuas and an energy pearl.

Five Element Organ Correspondences

Yin Organs	Liver	Heart	Spleen	Lungs	Kidneys
Yang Organs	Gall Bladder	Small Intestine	Stomach, Pancreas	Large Intestine	Bladder
Openings	Eyes	Tongue	Mouth, Lips	Nose	Ears
Positive Emotions	Kindness Generosity	Love, Joy	Fairness, Openness	Righteousness, Courage	Gentleness
Negative Emotions	Anger Envy Frustration	Hate, Impatience	Worry, Anxiety	Sadness, Depression	Fear, Stress
Transform Pure Organ Energy into a Virgin Child Dressed in	Green	Red	Yellow	White	Blue
Transform Pure Child Energy into an Animal	Green Dragon	Pheasant, Red Bird	Phoenix, Yellow on Red	White Tiger	Blue Deer
Earth Force takes the form of	Green Dragon	Pheasant, Red Bird	Phoenix, Yellow on Red	White Tiger	Black Tortoise
Directions	East	South	Center	West	North
Planets	Jupiter	Mars	Saturn	Venus	Mercury
Universal Energy Force	Generating	Prospering	Stabilizing	Contracting	Gathering

Fig. 3.3 *Five Element Organ Energy Chart*

Energy drawn from the organs and senses into the collection point and transformed negative emotions are fused and condensed into a pearl through the pakuas. When the resulting pearl, with its refined, balanced, neutralized energy is circulated through the Microcosmic Orbit, the body absorbs this enhanced life-force. The pearl is then used to form the Energy Body.

Cosmic Fusion builds on the foundation of internal alchemy laid in Fusion of the Five Elements. The student is encouraged to take this opportunity to review the basic Fusion practice.

Once the negative emotions have been drawn out and transformed, the pearl is moved through the creation cycle, nurturing the virtues. These qualities are cultivated, blended and condensed into the pearl, forming the energy of compassion —the essence of the senses, glands, organs and the mind.

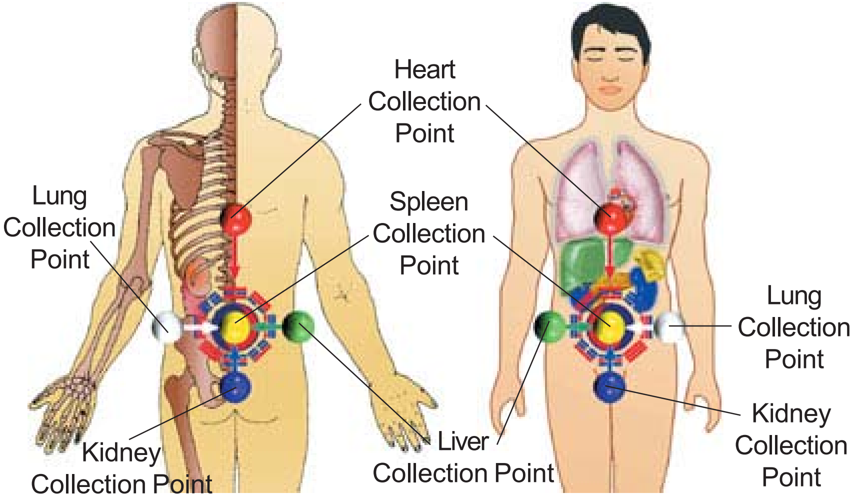
Heart Collection Point
Lung Collection Point
Spleen Collection Point
Lung Collection Point
Kidney Collection Point
Liver Collection Point
Kidney Collection Point

***Fig. 3.4** Front and Back Collection Points*

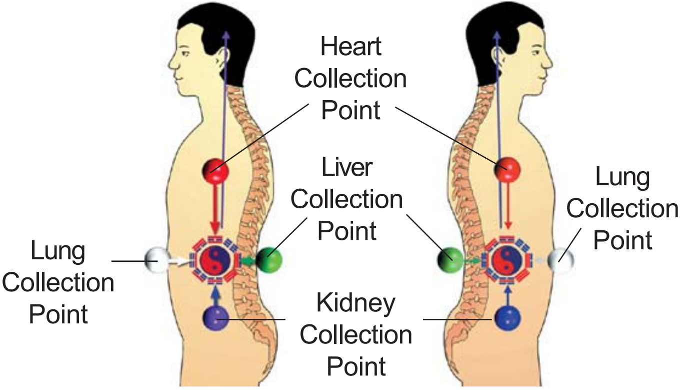
Heart Collection Point
Liver Collection Point
Lung Collection Point
Lung Collection Point
Kidney Collection Point

***Fig. 3.5** Left and Right Collection Points*

This highly refined pearl can now be used to open and clear four of the eight specific energy channels in the subtle body: the Three Thrusting Channels used for cleansing and protection, and the protective belt route that surrounds the Thrusting Channels.

Inner Universe reflects the Outer

The Fusion practice offers a practical way to strengthen the conscious connection with the outer Universe. During the practice of Fusion, the essence of life-force energy found in the organs, glands and senses is transformed, purified, condensed and combined with the Universal, Cosmic Particles and Earth Forces in order to achieve internal balance. This transformation of quality energy into a harmonious whole can effect positive changes in the human body. Controlling this energy enables each individual to attain balance and harmony of these energies on physical, emotional and spiritual levels. Because the inner Universe is a reflection of the outer one, the balance and harmony attained in the inner Universe enables the individual to attain balance and harmony with the outer Universe. Fusion of the Five Elements, the first in a series of the Taoist practice of Inner Alchemy, focuses on the interaction and fusion of all five elements and their correspondences. To understand this interaction, especially with respect to the organs, glands and senses of the human body, it helps to be aware of one of the Taoist laws of the Universe: *Nothing remains the same; everything changes because the Five Energies of Nature constantly interact and change*. This acknowledgement that change is constant contrasts sharply with the Western framework. Under this assumption, each individual’s disposition and health is influenced by the balance within him or her of these five energies, a balance affected by the ever-changing conditions of the Universe.

The outer Universe is comprised of Universal Force, Cosmic Particle Force and Earth Force from which all things emerged and whose three combined forces sustain all existence. The concept of Inner Alchemy is grounded in the Taoist belief that the inner Universe is a reflection of the outer Universe. There are connections that can be made between the inner and outer Universe through which energy, recognized and experienced in the inner Universe as Chi, or life-force, can be greatly increased and enhanced by the immense power of the outer Universe.

Overview of the Cosmic Fusion Universal Tao divides Fusion into Three Parts

Fusion of the Five Elements

First Part

Fusion of the Five Elements makes use of pakuas and energy collection points to balance, connect and draw out negative emotional energies found in the organs. These energies, along with their corresponding glands and senses energies, are then fused and transformed into pure, life-force energy.

The purity of this energy has an adhering and magnetizing quality enabling it to condense into a ball of refined energy which is called the pearl.

The pearl is then used to connect to the Universal, Cosmic Particle and Earth Forces whose energies become part of the pearl. A soul or Energy Body is formed from the pearl, enabling the individual to go beyond connecting with the forces of the universe on a purely physical level. Later the pearl returns to the organs and glands to enhance them and provides a protection to the physical and soul body.

Fig. 3.6 *Forming the Compassion Heart.*

Second Part

Cosmic Fusion focuses on using the pearl to grow or intensify the energy of good virtue. It makes use of the interaction of the elements described as the Creation Cycle of the Five Elements Theory to circulate positive Chi or virtuous energy through the major organs. All the energy gathered during this cycle is combined to form a beautiful pearl of Compassion energy. This pearl is then used to open and cleanse specific channels that pass through the physical body into the Energy Body.

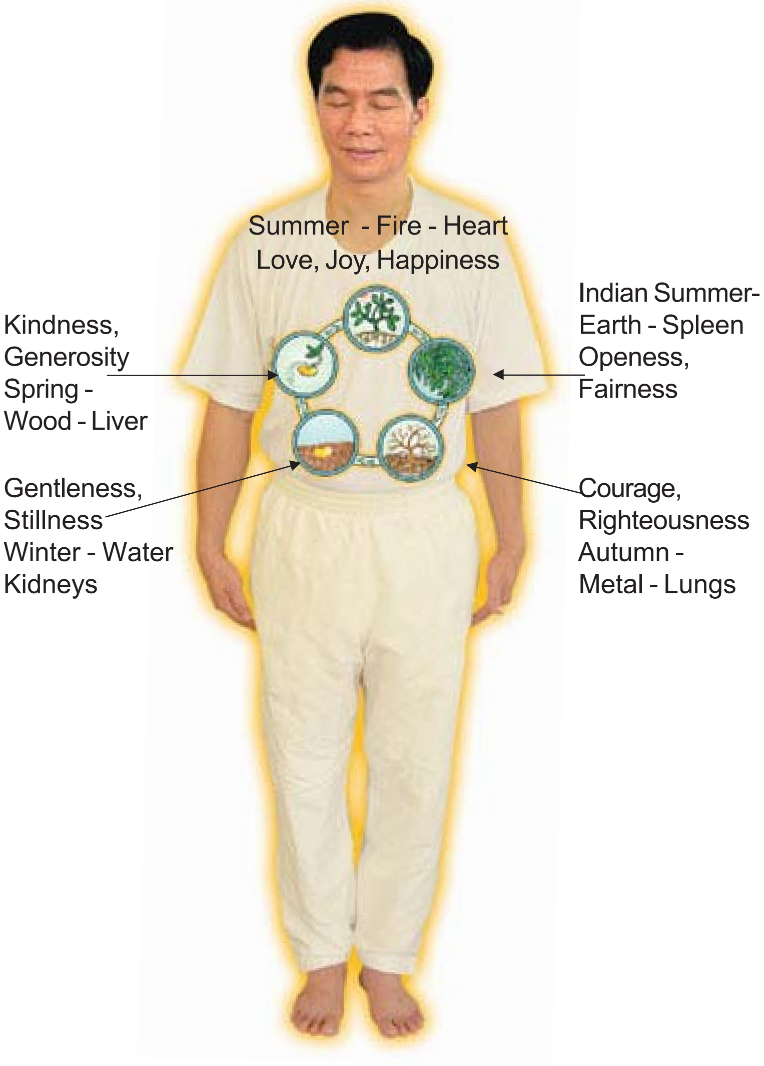
Summer - Fire - Heart
Love, Joy, Happiness
Indian Summer-
Earth - Spleen
Openess,
Fairness
Kindness,
Generosity
Spring -
Wood - Liver
Gentleness,
Stillness
Winter - Water
Kidneys
Courage,
Righteousness
Autumn -
Metal - Lungs

***Fig. 3.7** Creation Cycle in Nature and Human Body*

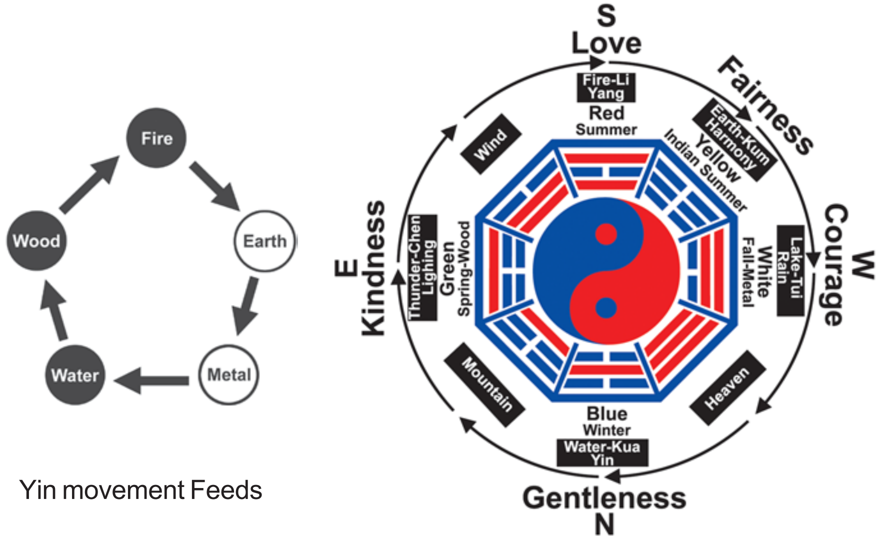
Fire
Earth
Metal
Water
Wood
S
Love
Fire-Li
Yang
Red
Summer
Fairness
Earth-Kum
Harmony
Yellow
Indian Summer
W
Courage
Lake-Tui
Rain
White
Fall-Metal
Heaven
Blue
Winter
Water-Kua
Yin
Gentleness
N
Mountain
E
Kindness
Thunder-Chen
Lighing
Green
Spring-Wood
Wind

Yin movement Feeds

Fig. 3.8 *Creation Circle*

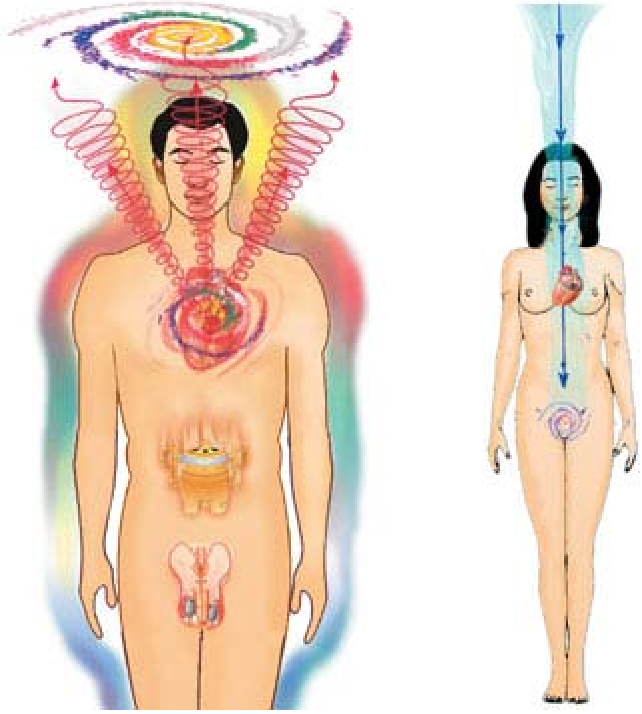

Fig. 3.9 *Forming the Cosmic Compassion of the Heart*

Third Part

The energy of the positive emotions of all the organs is absorbed into the pearl and then circulated in four of the eight special channels: the Microcosmic Orbit (Governor and Functional Channels), the Thrusting Routes, and the Belt Routes. The Thrusting Routes run through the center of the body, linking the “chakra” centers. The Belt Routes spiral around the body strengthening the aura and providing a form of psychic self-defense.

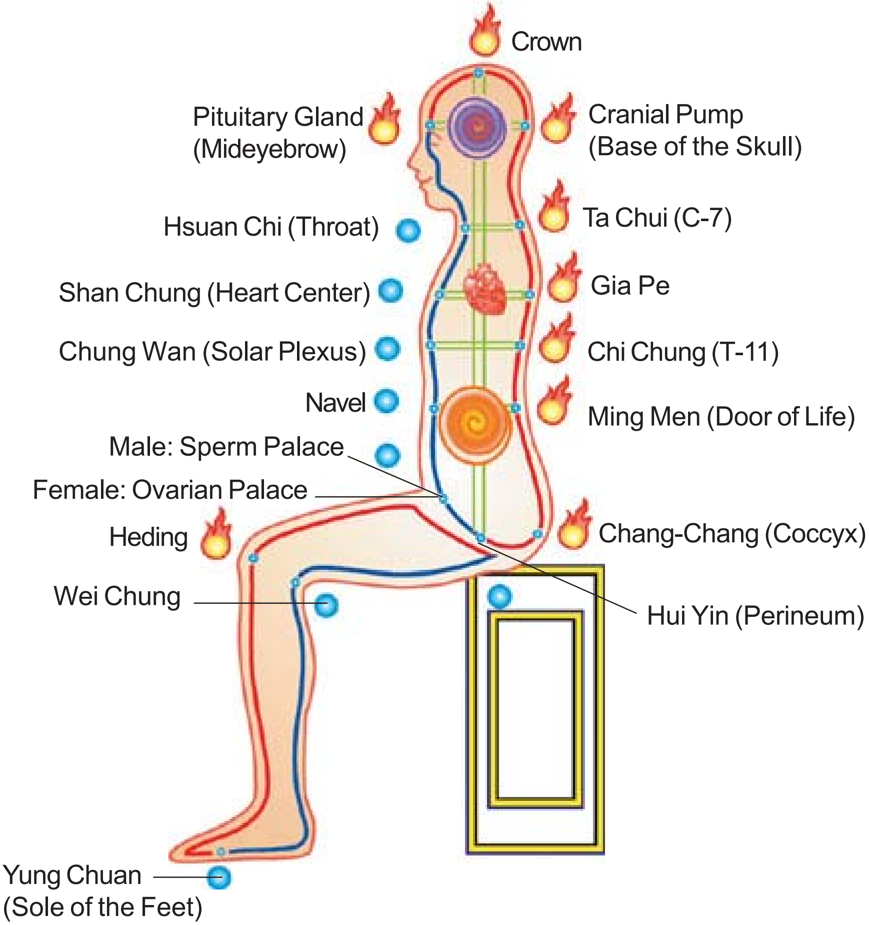
Crown
Pituitary Gland (Mideyebrow)
Cranial Pump (Base of the Skull)
Hsuan Chi (Throat)
Ta Chui (C-7)
Shan Chung (Heart Center)
Gia Pe
Chung Wan (Solar Plexus)
Chi Chung (T-11)
Navel
Ming Men (Door of Life)
Male: Sperm Palace
Female: Ovarian Palace
Heding
Chang-Chang (Coccyx)
Wei Chung
Hui Yin (Perineum)
Yung Chuan (Sole of the Feet)

Fig. 3.10 *Cosmic Orbit with Ancient Chinese Points*

The three Thrusting Channels, sometimes referred to as Thrusting Routes and the Belt Channels or Belt Routes, opened during Cosmic Fusion, permit a freer flow of energy throughout the body.

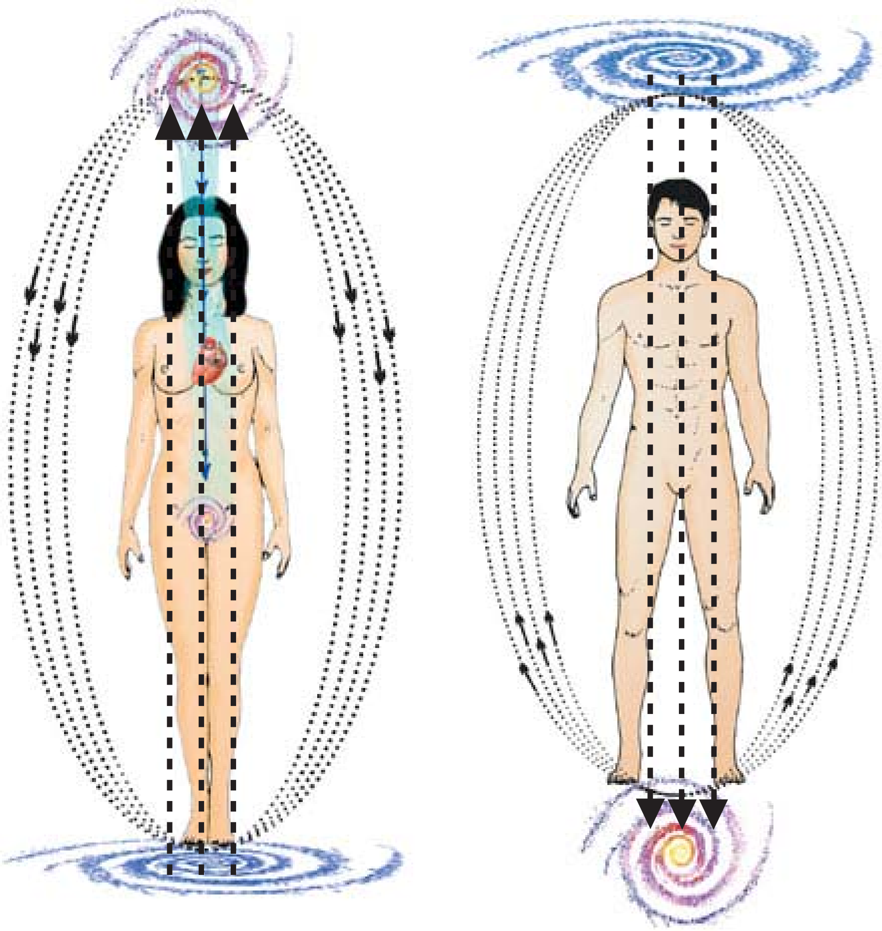

Fig. 3.11 *Cosmic Thrusting Channels Women and Men*

The Thrusting Channels are opened first. Their primary function is to cleanse specific energy pathways in the body, thereby opening them up for the energy to flow freely. The Belt Channel surrounds the physical body and the internal Thrusting Channels. Both channels help to build a denser body and provide protection to the body, but they have another function.

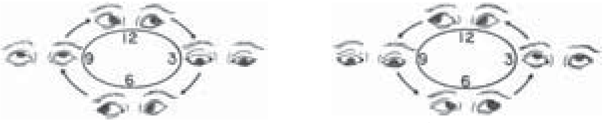

Use eyes to help spiral the Belt Channels.

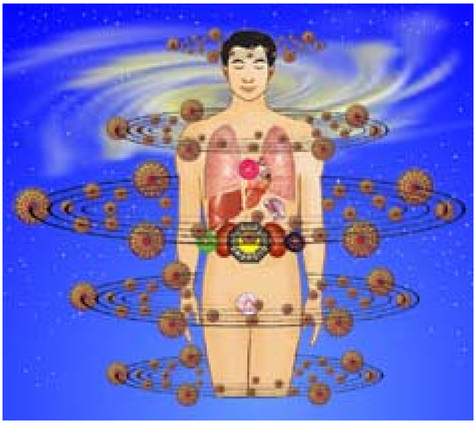

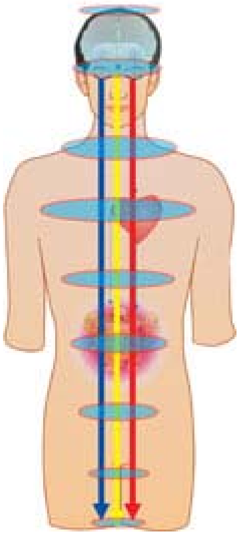

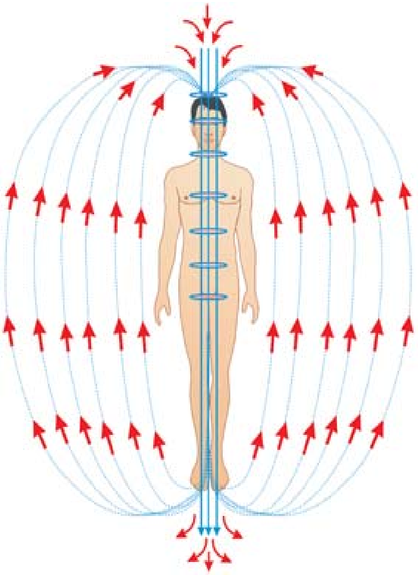

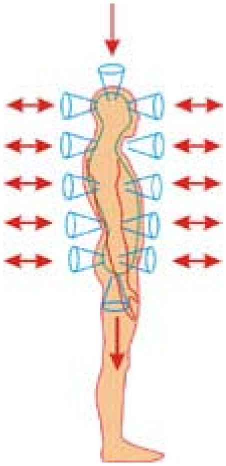

Fig. 3.12 Belt Channels and Thrusting Channels

With the additional energy generated during the practice of Cosmic Fusion, you will have enough energy to create a new Energy Body above the physical body. Another important aspect of the Fusion of the Five Elements practice is learning how to temporarily separate the Energy Body and the Physical Body. In life, our three bodies, the Physical Body, Energy Body, and Spirit Body (consciousness) all overlap and are generally inseparable. At death, the physical body is no longer a fit vehicle for holding the material five elements together and Chi and consciousness are forced to leave. To avoid the traumatic disorientation and confusion that can occur at death when the energetic essence and consciousness are involuntarily thrust out of the physical body into unknown territory, we can familiarize ourselves with the “out-of-body realm” by temporarily separating the Energy Body and Spirit Body from the Physical Body, as a “dress rehearsal” for death.

Consciousness always requires some sort of vehicle to manifest. Its gross vehicle is the physical body. Its more subtle vehicle is the Energy Body (sometimes referred to as the “subtle” body). We emphasized earlier that the virtues are the true energetic essence of our organs. Although we may identify ourselves more with our physical body than anything else in the world, it is our energetic essence, not our physical body, that survives after death and has the capacity to be immortal.

The Thrusting Channels and Belt Channels can be extended up into this Energy Body and Spirit Body. In this way they serve as connecting links between the organs and glands of the Physical Body and the transferred consciousness that is the Energy Body. Eventually, the channels serve as conduits through which the Spirit Body is boosted to the Mid-Plane. These advanced practices are called the meditations of Kan and Li.

If the Energy Body is thought of as a booster rocket, then the Spirit Body is the shuttle. Once the Spirit Body is boosted through the open channels into the Mid-Plane, it collects a higher quality of energy. The Spirit Body then returns with the higher quality energy to the Physical Body. In the next effort this energy is used to construct a stronger, more intense Energy Body that can boost the Spirit Body to a higher Mid-Plane level. The cycle continues bringing the Spirit Body to higher and higher levels, while increasing the life-force energy for use by the Physical, Energy and Spirit Bodies.

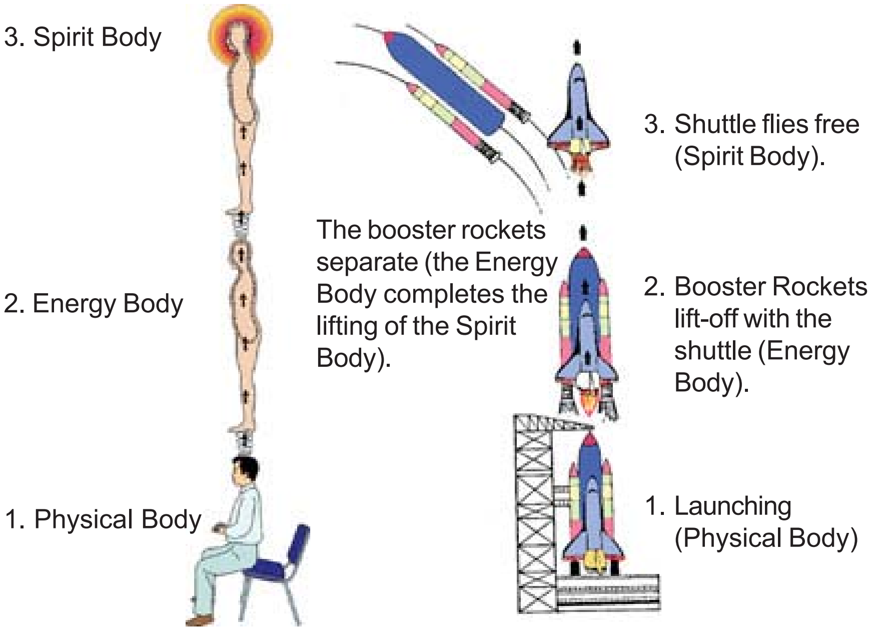
3. Spirit Body
2. Energy Body
1. Physical Body
The booster rockets separate (the Energy Body completes the lifting of the Spirit Body).
3. Shuttle flies free (Spirit Body).
2. Booster Rockets lift-off with the shuttle (Energy Body).
1. Launching (Physical Body)

Fig. 3.13 *Energy, Physical and Spiritual Bodies*

By regularly turning the awareness inward in the Fusion of the Five Elements practice, we gradually come to know our energetic essences as well as we know our face, our arms and our legs. We learn to distill these essences into a pearl, as a sort of “space capsule” to carry our essential energy and consciousness out of the physical body. With regular practice, Taoists who follow the path of Inner Alchemy learn to move their Energy Body and consciousness in and out of their physical body as easily as one might walk from one room into another.

Chapter 4

Energetic Preparations for Meditation Practice

Meditation practices are enhanced by developing one's sensitivity to subtle energy and by exercising to improve postural alignment, increase flexibility of the spine and deepen relaxation of the physical body. The next sections present a series of suggested exercises to help the student meet these goals.

Chi has many sensations. Some of the most common are tingling, heat, expansion, an electrical sensation (like the feeling of static electricity), pulsation or effervescence. This is not the actual Chi itself, but the signs of increasing Chi in a particular area. Chi itself is more mysterious, subtle beyond definition. For more details in the practices of Spinal Cord Breathing, Rocking the Spine and the Inner Smile to relax the whole body check with the book by Mantak Chia "*Awaken Healing Light*".

Preparing for the Fusion Meditations

Prepare the Environment

Find a quiet place to meditate where there are no distractions. Some places have naturally peaceful Chi: mountains, forests, caves, gardens, monasteries or beautifully designed meditation rooms. Once you have experienced such a place, you can just recall it. Set aside a corner of your room for your practice and recall your connection to the forces of nature.

Keep your meditation place clean and pleasant.

Avoid interruptions. Plan to meditate early in the morning before other people are awake: the body is rested, the air is fresh, and the earth itself is energized.

Late at night is also fine. Select a time that works well for you with your own rhythms and schedule.

If you allow yourself time each day to cleanse your emotional, energetic and physical bodies, you will soon reap the rewards in every area of your life.

Conserve Energy and Purify your Body with an Appropriate Diet

To clear your digestive tract, it helps to reduce the amount you eat, to eat less meat, fish and poultry and to increase the amount of fiber in your diet. Unless you are a vegetarian, it is recommended that you eat about 80 percent grains and vegetables, 10 to 15 percent fish and only 5 percent meat and chicken.

Loosen, Stretch and Warm Up the Body before Meditating

Once you have a quiet place and are ready to meditate, spend time loosening up the body, particularly the spine, before you sit down to practice.

The Universal Tao recommends doing some stretching exercises, Chi Kung and Tai Chi before you begin to meditate. These exercises are both invigorating and relaxing; they relieve muscle tensions, stimulate the blood circulation, get rid of stale air in the lungs and oxygenate the blood. As an alternative, you can take a relaxing stroll outside.

Doing some movement before entering the stillness of meditation can help you shake off the sluggishness that comes from being too sedentary and ease the tensions that might build up during a hectic day. Then when you sit down, you are ready to begin. Use the Simple Chi Kung exercises to loosen your spine and prepare the mind and body for meditation.

Wear Loose and Comfortable Clothing

The clothing you wear for meditation should be loose and comfortable. It is very important that your clothes restrict neither the Chi flow, the blood circulation, the nervous system nor the breath.

It is preferable to wear clothing of natural fibers so your body can breathe. During meditation, all the pores open wider and breathing in energy through them requires looser clothing. When you have learned to breathe through the skin, your body will need to contact more fresh air.

Establish a Stable Sitting Position

The body must be stable for the mind to be stable. It has been said, “An anxious mind cannot exist in a relaxed body.” The mind and body are clearly connected and when the body and breath become peaceful, the mind easily follows.

If your posture is firm and balanced, it will be easy for you to relax, and you will already be halfway toward achieving a tranquil and focused mind. But if your posture lacks balance and stability, your muscles will soon tire and become tense, your attention will waver like a candle in the wind.

Consider seven points in preparing a good meditation posture: base, hands, spine, shoulders, chin, eyes and tongue.

1. **Base**: Your base is the foundation of a good meditation posture. To accommodate the movement of internal and external forces generated by the Taoist practices we need to stay grounded and establish a good connection with the earth’s energy. The more Chi one moves through the body, the more important grounding becomes to prevent overheating of the organs and other negative side effects.

   The soles of the feet provide an ideal connection to the earth through the Yung Chuan (Bubbling Spring) points. These are specifically designed to absorb the earth’s energy and conduct it up into the body. The legs also help filter the raw energy to make it more readily digestible.

   It is best to sit on a straight backed chair to practice the Fusion Meditations. Your weight should be evenly divided over four points: your two feet and the two sitting bones (the tuberosities of the ischium) *(Fig. 4.1)*. Place the feet flat on the floor the same distance apart as the hips. The calves of the legs should be vertical, like pillars. Try to have the knees and hips at the same level, or keep the knees slightly higher.

   The part of the pelvis known as the ischium is structurally designed to hold a tremendous amount of weight. Avoid leaning back and sitting on the coccyx and sacrum instead of the ischium. Honor Mother Nature’s design by sitting on the ischium and not on the tailbone, which puts pressure on the sacrum, one of the major pumps in the spine for cerebrospinal fluid, a vital cushion for the nervous system. Check to make sure your weight is evenly distributed over the four points to establish a solid base to support the body during meditation.

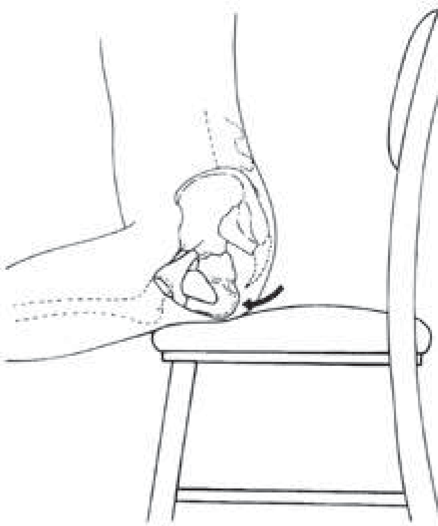

***Fig. 4.1** Sitting Bones*

2. **Hands**: Let your hands rest in your lap, clasped together with the right palm over the left palm and the right thumb and forefinger wrapped around the base of the left thumb. You may rest your hands on a pillow placed on your lap *(Fig. 4.2)*. The clasped hand position works especially well to consolidate and balance the energies generated during the meditation.

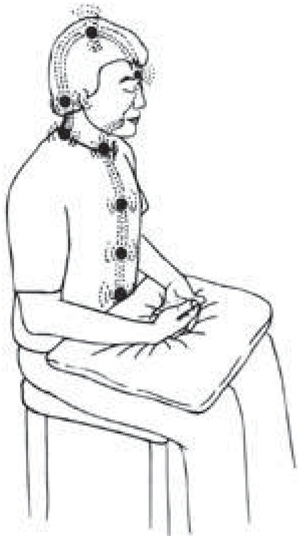

***Fig. 4.2** Using a small pillow helps release shoulder stress.*

3. **Spine**: The spine should be straight but not stiff and in good vertical alignment with gravity. You can imagine your head being pulled up by a string. As it rises, allow the spine to elongate, increasing the space between vertebrae *(Fig. 4.3)*.

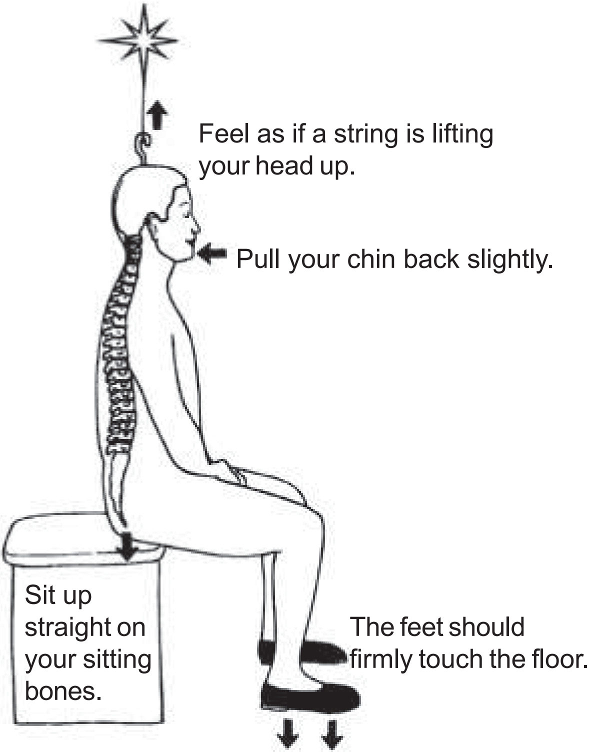
Feel as if a string is lifting your head up.
Pull your chin back slightly.
Sit up straight on your sitting bones.
The feet should firmly touch the floor.

Fig. 4.3 *Correct Sitting Position*

Some people find their backs become tired during long rounds of meditation. Good alignment helps prevent this by taking some of the stress off the muscles and putting it instead on the skeletal structure where it belongs. The skeletal structure is designed to support hundreds of pounds without effort when properly aligned. Practicing Iron Shirt Chi Kung and Tai Chi is very helpful for strengthening the muscles you use in sitting and for learning the body mechanics of good alignment.

The spinal column houses many nerves, and it is also a major part of the Microcosmic Orbit pathway. If the spine feels relaxed, clear and open, the mind will feel more awake and alert too.

4. **Shoulders**: The shoulders should be relaxed and balanced over the hips. The armpits should be slightly open allowing enough space to hold a Ping Pong ball *(Fig. 4.4)*. This permits free circulation of blood and Chi into the arms and keeps the nerves in the arms from being impinged.

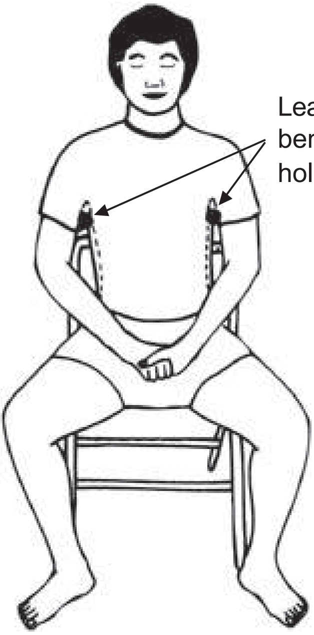

Leave enough space beneath each armpit to hold a Ping Pong ball.

Fig. 4.4 *Arms' Position*

5. **Chin**: The chin should be drawn back slightly, with as little strain as possible, so that the ears are over the shoulders. If you strain too much to bring the head back, your muscles will soon tire.
6. **Eyes**: Your eyes should generally be closed or slightly open with the gaze directed downward. Or you can focus on the nose, and from the nose focus into the heart. You can open the eyes for a while if you feel sleepy or distracted *(Fig. 4.5)*.
7. **Tongue**: The tip of the tongue should be touching the upper palate *(Fig. 4.6)*. This connection acts like a switch in that it connects the Tu Mo and Ren Mo, the Governor and Functional Channels. The best point for you to use is the one where you feel the strongest sensation of Chi.

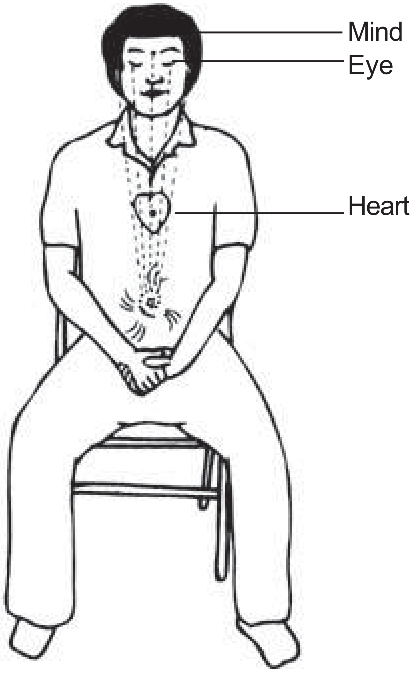

Fig. 4.5 *Turn the mind and eyes inward. Focus into the heart and then down into the navel.*

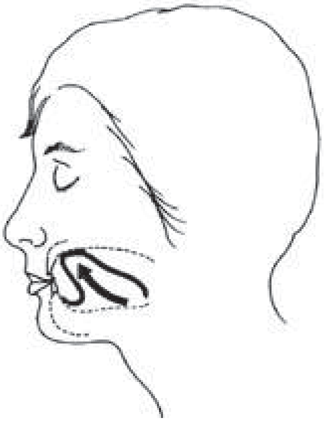

Fig. 4.6 *Touch the tip of your tongue against the upper palate.*

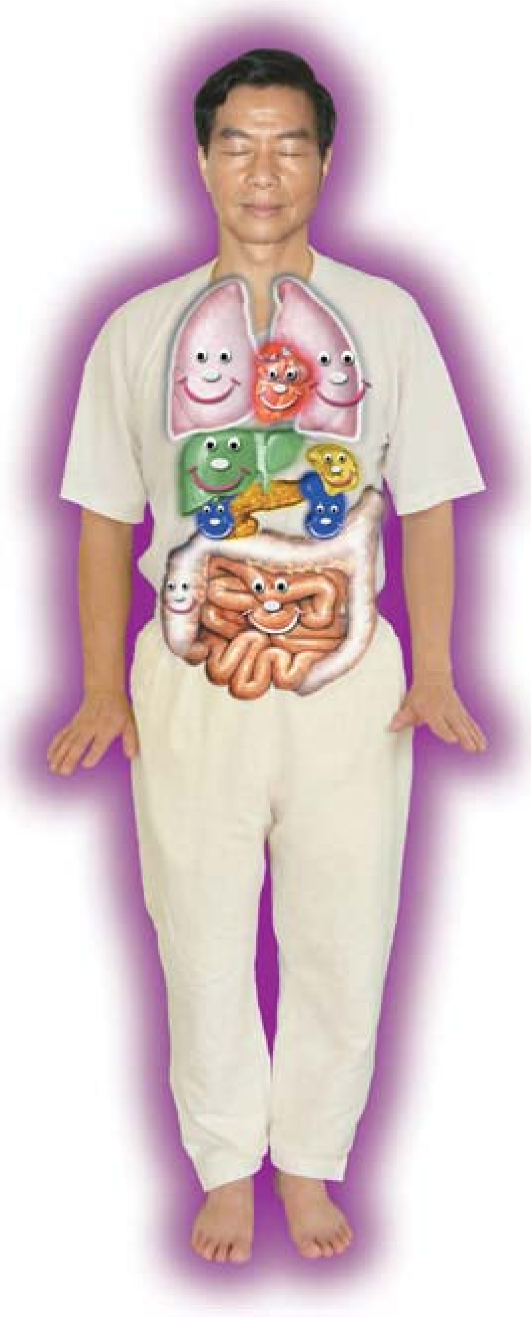

Fig. 4.7 *Smile to the organs and feel the organs smile back to you.*

Chapter 5

Beginning Fusion Element Meditation

Pakua

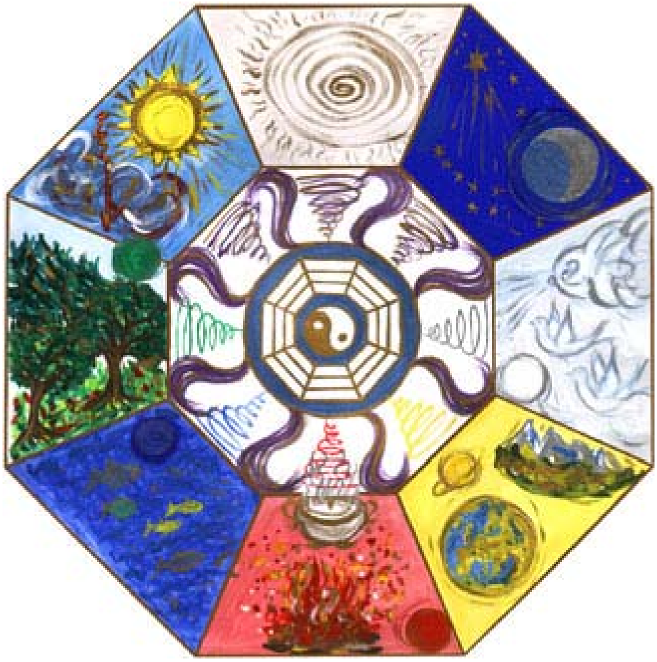

Fig. 5.1 *Pakua - Eight Forces*

The pakua is a symbol of the eight forces. In the Fusion of the Five Elements meditation the pakuas are used to gather and collect the energy of the organs and fuse them into a pearl. Here in the Cosmic Fusion meditation, the pakuas are again used to fuse energy into a pearl. Now, instead of just using the energy within the body, we combine the energy of the organs with the energy of the Universe. This is a technique used in the Fusion practice to condense and gather the abundant energy that surrounds us into something that is usable and digestible to the body. Forming the pakuas will be used in all the Fusion formulas.

The first step is to form the pakua at the lower abdomen to connect with and attract the five energies and the eight forces. The goal is to balance and transform the emotional energies of the organs. The next step is to form the facial pakua. The facial pakua gathers and transforms the energy of the senses and the thoughts down to the lower abdomen. The Universal pakua is then created to gather and collect the energy of the Universe into the lower abdomen. All these energies once gathered are condensed into an energy ball, or a pearl of white light. This highly refined ball of energy is then circulated through all the channels as a way to open, heal and revitalize the body, mind and spirit. This is the beginning of the transference of consciousness to a new realm.

Chanting

Chanting has been used in all systems of spirituality to help connect the practitioner to their higher source. In Christianity, chanting and singing is used to connect with God. In Buddhism and Hinduism, chanting is used to clear the space, to open the body and connect themselves with the Buddha or Hindu God or Goddess. The power of chanting and singing can be seen not only in a religious setting, but in all levels of society as well. Singing and listening to music is a very natural way to move energy.

In the Taoist practice, chanting is used to invoke the forces of the Universe. It is not necessarily about harmony. We want to get depth and power to the vibration to open the lower abdomen and create internal power. When you chant try to feel the vibration coming from the Lower Tan Tien.

Chanting in the Pakua is very similar to the sound in the genes when the replicating strands of DNA cross over. The eight sounds are the song of the crossing of the chromosomes like two serpents entwining and then they making love and one becomes two.

The pakua is a symbolic representation of the forces of nature. By chanting the names of these forces, we are able to make a connection with that force. Also, Yin and Yang are chanted as a way to contract and expand energy. The combination of chanting the forces and Yin and Yang helps to bring the power of the Universe to you as a tuning fork.

Chanting greatly increases the power and the coherence of the Pearl. After toning all eight directions, the forces of the Universe are fused into the Pearl. The Yin and Yang (Tai Chi spines) chanting helps to expand and gather, as well as contract and store the force. This will help create the connection between your internal energy and the energy of the Universe.

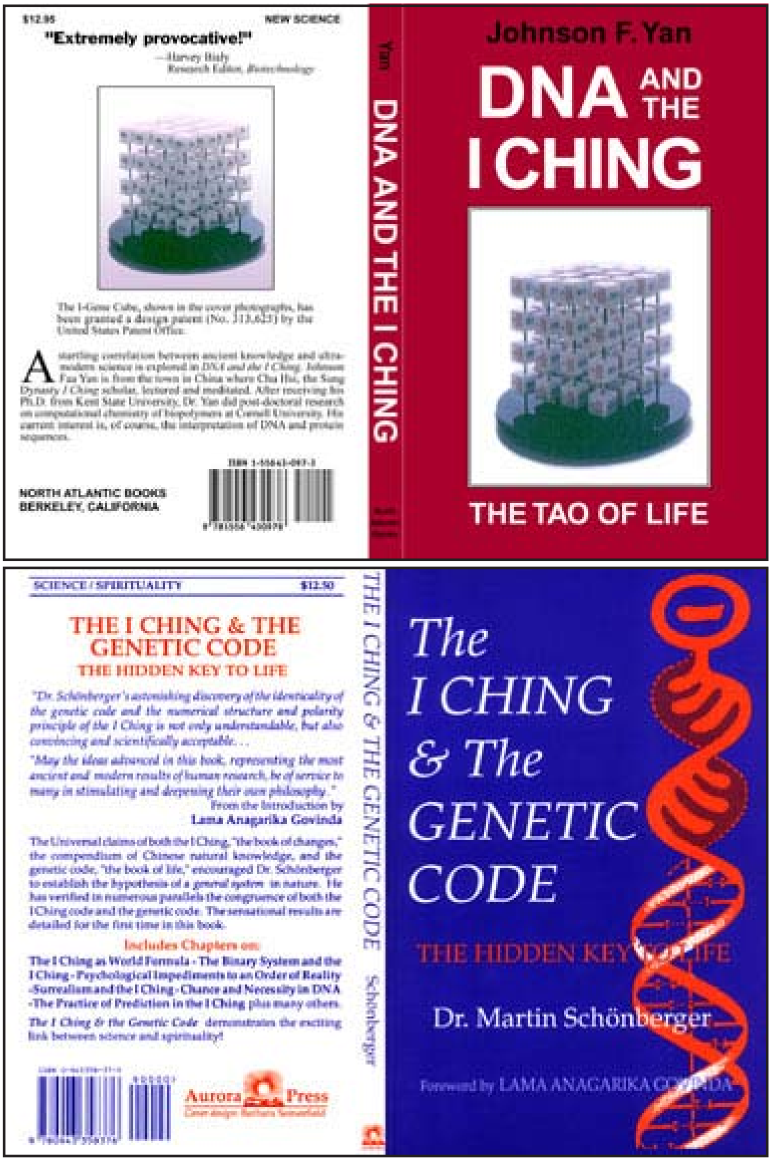
$12.95
NEW SCIENCE
"Extremely provocative!"
NORTH ATLANTIC BOOKS
BERKELEY, CALIFORNIA
Yan
DNA AND THE I CHING
Johnson F. Yan
DNA AND THE I CHING
THE TAO OF LIFE
SCIENCE / SPIRITUALITY
$12.50
THE I CHING & THE GENETIC CODE
THE HIDDEN KEY TO LIFE
Includes Chapters on:
Aurora Press
THE I CHING & THE GENETIC CODE
Schönberger
The I CHING & The GENETIC CODE
THE HIDDEN KEY TO LIFE
Dr. Martin Schönberger
Foreword by LAMA ANAGARIKA GOVINDA

Fig. 5.2 *DNA and the I Ching book cover*
and the I Ching and the Genetic Code book cover

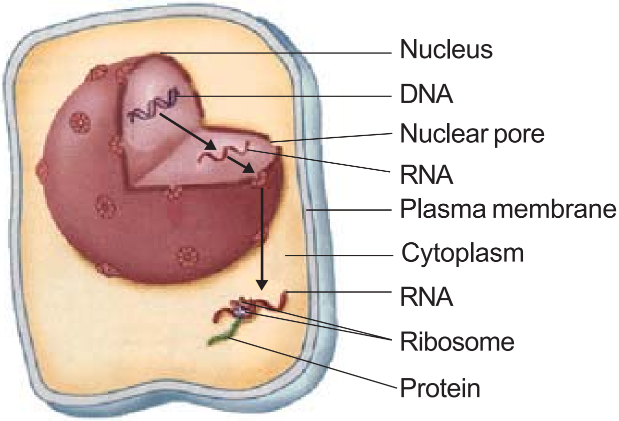
Nucleus
DNA
Nuclear pore
RNA
Plasma membrane
Cytoplasm
RNA
Ribosome
Protein

Fig. 5.3 *When the frequency is 8Hz transcription occurs in the nucleus, translation takes place in the cytoplasm.*

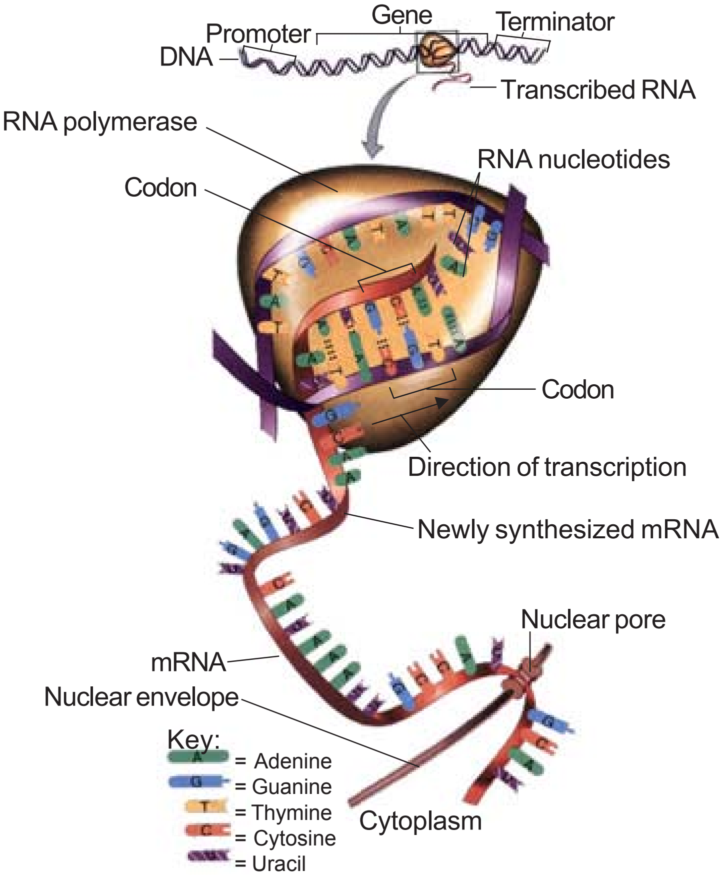
Gene
Promoter
Terminator
DNA
Transcribed RNA
RNA polymerase
RNA nucleotides
Codon
Codon
Direction of transcription
Newly synthesized mRNA
Nuclear pore
mRNA
Nuclear envelope
Key:
A = Adenine
G = Guanine
T = Thymine
C = Cytosine
= Uracil
Cytoplasm

Fig. 5.4 *During transcription, the genetic information in DNA is copied to RNA which in the Tao is known as cupping or self-intercourse.*

Formula One: Forming the Pakuas

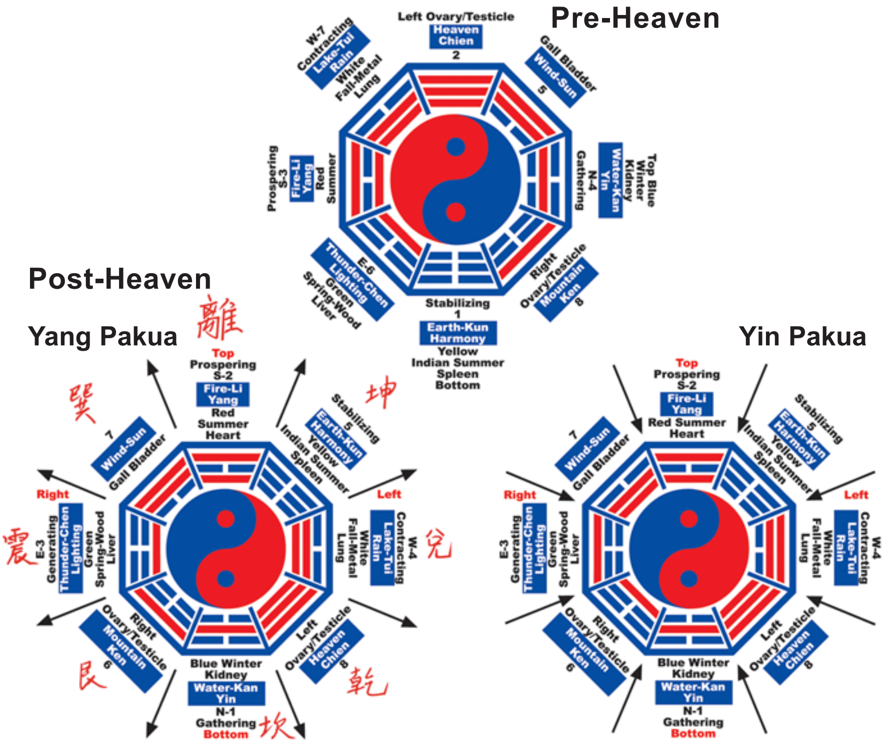
Pre-Heaven
Left Ovary/Testicle
Heaven Chien
2
W-7 Contracting
Lake-Tui
Rain
White
Fall-Metal
Lung
Gall Bladder
Wind-Sun
5
Prospering
S-3
Fire-Li
Yang
Red
Summer
Top Blue
Winter
Kidney
Water-Kan
Yin
N-4
Gathering
E-6
Thunder-Chen
Lighting
Green
Spring-Wood
Liver
Right
Ovary/Testicle
Mountain
Ken
8
Stabilizing
1
Earth-Kun
Harmony
Yellow
Indian Summer
Spleen
Bottom
Post-Heaven
Yang Pakua
離
Top
Prospering
S-2
Fire-Li
Yang
Red
Summer
Heart
巽
7
Wind-Sun
Gall Bladder
坤
Stabilizing
5
Earth-Kun
Harmony
Yellow
Indian Summer
Spleen
Right
震
E-3
Generating
Thunder-Chen
Lighting
Green
Spring-Wood
Liver
Left
W-4
Contracting
Lake-Tui
Rain
White
Fall-Metal
Lung
兌
艮
Right
Ovary/Testicle
Mountain
Ken
6
Left
Ovary/Testicle
Heaven
Chien
8
乾
Blue Winter
Kidney
Water-Kan
Yin
N-1
Gathering
Bottom
坎
Yin Pakua
Top
Prospering
S-2
Fire-Li
Yang
Red Summer
Heart
7
Wind-Sun
Gall Bladder
Stabilizing
5
Earth-Kun
Harmony
Yellow
Indian Summer
Spleen
Right
E-3
Generating
Thunder-Chen
Lighting
Green
Spring-Wood
Liver
Left
W-4
Contracting
Lake-Tui
Rain
White
Fall-Metal
Lung
Right
Ovary/Testicle
Mountain
Ken
6
Left
Ovary/Testicle
Heaven
Chien
8
Blue Winter
Kidney
Water-Kan
Yin
N-1
Gathering
Bottom

Fig. 5.5 *Pakua - Tai Chi Symbol -*
Three Outside Lines - Eight Connecting Lines

There are two arrangements of the pakuas: the Pre-Heaven and the Post-Heaven. It is said that the Pre-Heaven pakua was discovered by Fu Hsi, a legendary figure of early Taoist history, as the Ho-Tu, inscribed, some say on a horse, others say on a dragon that rose from the river Ho to reveal itself to Fu Hsi. The Post-Heaven pakua was revealed to another legendary king, Yü, the Great, as the Lo-shu. This time it was written on the shell (back) of a tortoise that emerged from the river Lo. The Pre-Heaven pakua shows the unchanging cycle movement of these energies, the natural order of the universe and is the foundation of Fu Hsi's divinational trigrams/hexagrams, of the I Ching. The Post-Heaven pakua shows the opposing interaction and movement of these energies, which are responsible for the changes and creation of all the things in the universe, in nature and in our own lives.

Creating the Front Pakua

Drawing the Pakua on the Abdomen: the Front Pakua

It is important to get familiar with visualizing the pakua. Training the mind to concentrate on a single image is of immeasurable value for spiritual practice. The image of the pakua allows the mind to focus and fuse energy. This first step is essential to the rest of the Fusion practice. One of the best ways to get this image deeply connected in the mind is to draw it on a piece of paper and place it over your abdomen. Or, if you are a little more adventurous draw it directly on the abdomen. When you draw the pakua, use blue for Yin, red for Yang and black for the frame. Sometimes it helps to work with a partner. Draw the pakua over your partner's abdomen, and do the meditation facing one another. This way you can glance at the pakua and know what forces to work with. Be creative. Do whatever works so that you get the image planted firmly in your mind.

The pakua is between the underside of the rib cage and above the pubic bone. When we chant the symbols of the trigrams, you can use your finger to draw them on your own abdomen, or while you look at the pakua on your partner.

There are 3 different major centers for generating the frequency which fuse together to form the main energy center of the body. 1. Tan Tien, the Chi Center can be measure like heat in the infrared. 2. Throat Center. 3. Third Eye Center.

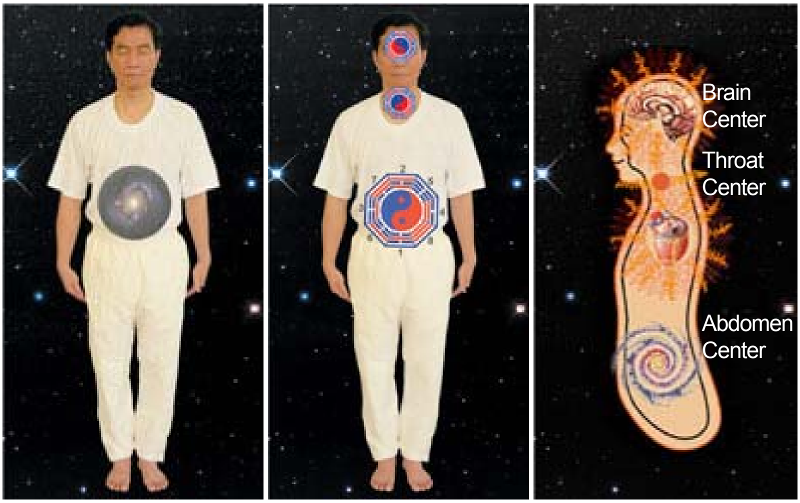

Fig. 5.6 *Pakua in the Abdomen*

Practice

1. Four Signs

Kan: First Sound

a. **Kan** (Yin-Yang-Yin). The power symbol of the Water gathering and yin power, connected with the kidneys, ears and sexual organs. Evoke the energy of the symbol by repeating its sound, **Kan,** several times or until you feel the connection with the energy of Kan, which is spreading down to the sexual organs and the kidneys. The Kan sound should come from the abdomen and the throat.

b. First chant the name of the trigram Kan in a long and deep sound while you picture the symbols and touch your lower abdomen. Your eyes look down to the lower abdominal area.

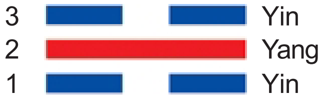

Fig. 5.7 *Kan (Yin-Yang-Yin)*

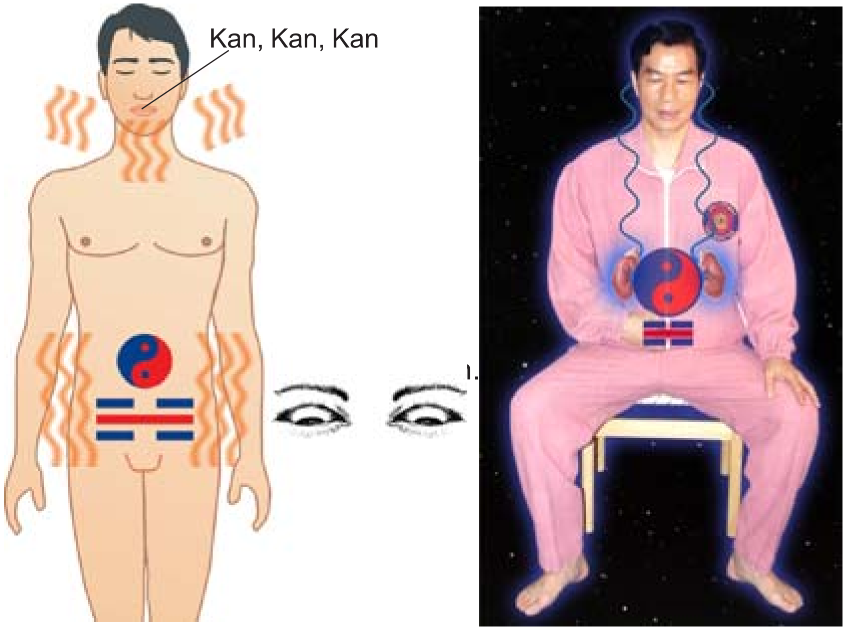

Fig. 5.8 *Chant Kan (Ears and Kidney connects to the Kan)*

c. Next, chant the Yin and Yang lines of the symbol one after the other (Yin-Yang-Yin). Start from the inner side, close to the Tai Chi symbol.

d. **Yin Contract**: First expand the mind and the hands and palms to touch the universe, the cosmic. Chant the Yin, Yin, Yin as long as you feel comfortable, and continue moving your palms and draw the cosmic Chi from the universe into the navel, and feel the navel has suction. Feel your hands and the Tan Tien; the throat has the power of sucking the Chi down the Yin line to the navel. Rest. (Fig. 5.9)

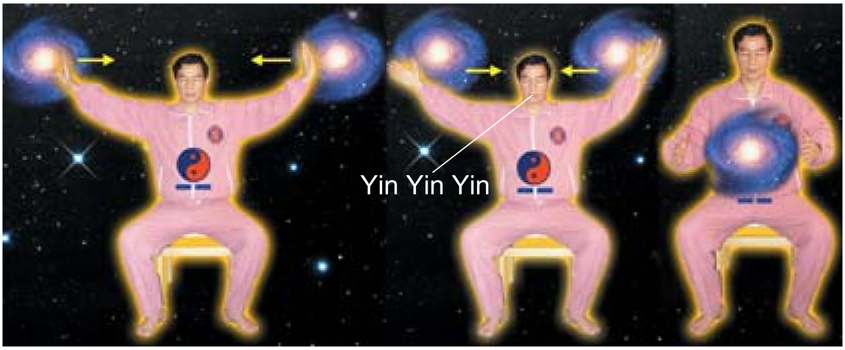

***Fig. 5.9** Yin Line —— Yin Contract*

e. **Do the Yang Line**: Be aware of the Tan Tien, throat, crown and the palms close to the navel and slowly chant the long Yang sound and turn the palms out. Gradually move the palms to the left and right sides and feel your palms very long and big touching the cosmic. Rest and feel your palms in touch with the cosmic Chi. (Fig. 5.10)

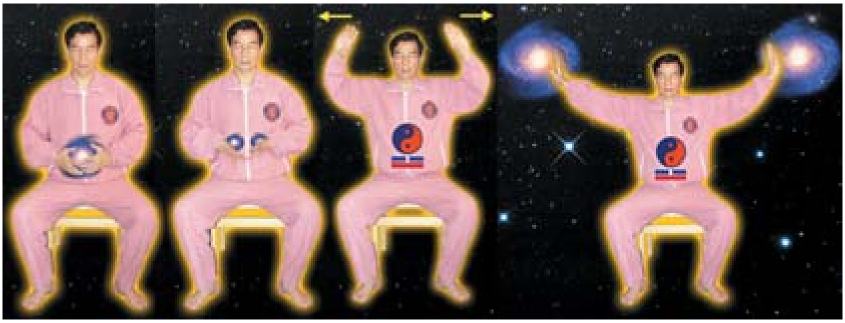

***Fig. 5.10** Yang Line — Yang Expand*

f. **Do the Yin Line again**: Yin contracts; expand the mind and the hands and palms to touch the sky and the cosmic. Chant the Yin, Yin, Yin as long as you feel comfortable and continue moving your palms and draw the cosmic Chi from the universe into the navel, and feel the navel has suction. Feel your hands and the Tan Tien; the throat has the power; the Chi goes down the Yin line to the navel. Rest for a while. Feel the vibrations inside as you chant the trigram. (Fig. 5.11)

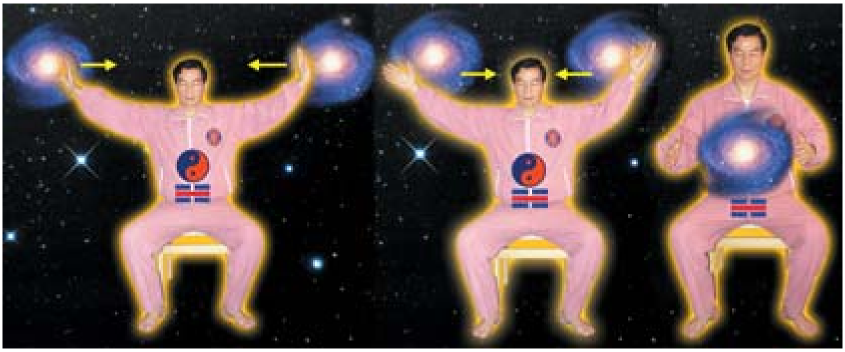

Fig. 5.11 *Yin Yang Yin Trigram* ☵

Rest. Repeat the words “ Kan” at the lower abdominal in your mind and let your eyes look down at the lower abdominal. Then you close your eyes and picture the symbols: Kan (Yin-Yang-Yin), smile and be aware the kidneys, ears and the power of the yin and gathering power. Try to imagine them in your mind’s eye and feel them imprinted on your abdomen and vibrating inside you.

Rest and project the symbol into the universe and feel the symbol in the universe reinforce the Kan in the abdomen.

Note: Doing the chanting together in a group makes it much more powerful.

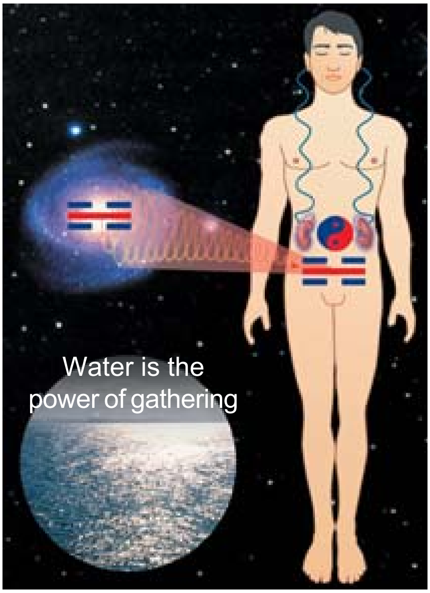

Fig. 5.12 *Kan in the abdomen*

Li: Second Sound

a. The second sound is **Li** (Yang-Yin-Yang), the power symbol of the Fire, connected with the heart, the prospering power. The eyes look up at the upper abdominal, the Li Kua. The sound comes out from the area between the chest and the throat. Repeat this sound until you feel the vibration of the fire expanding upwards in the chest.

When you chant **Li** you feel the energy going up.

When you say **Li** the eyes look up.

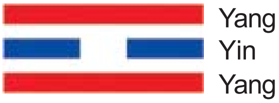

Fig. 5.13 *Li (Yang-Yin-Yang)*

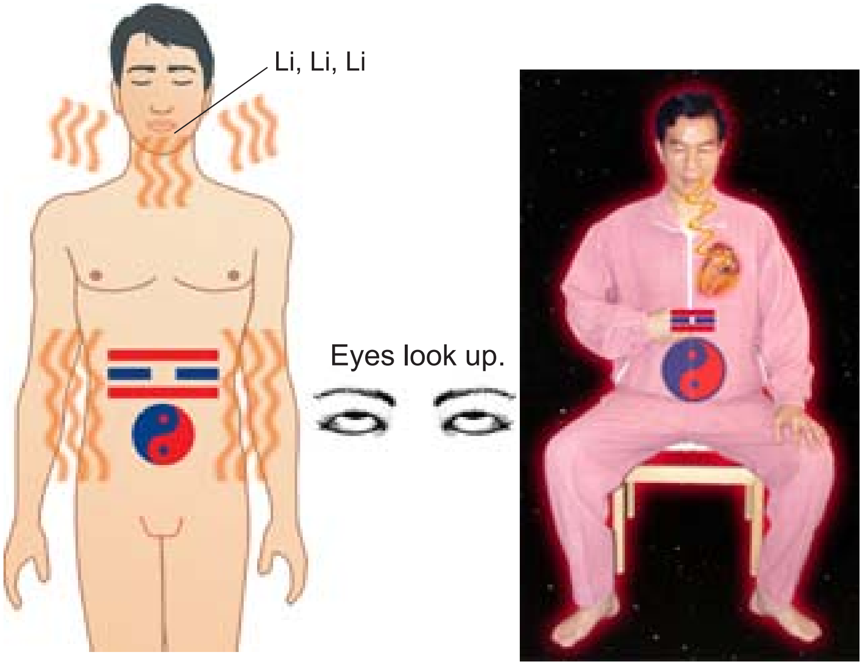

Fig. 5.14 *Chant Li (Tongue and Heart connect to the Li)*

b. Chant the name of the trigrams Li in a long and deep voice while you picture the symbols and touch your lower abdomen and upper abdomen. (Fig. 5.14)

c. Next, chant the Yang and Yin lines of the symbol one after the other (Yang-Yin-Yang). Start from the inner side close to the Tai Chi symbol.

d. **Yang Expand**: Be aware of the Tan Tien, the throat, crown and the palms close to the navel and slowly chant the Yang long sound. Turn the palms out and gradually move the palms to the left and right side. Feel your palms very long and big as they touch the cosmos. Rest and feel your palms touch the cosmic Chi. (Fig. 5.15)

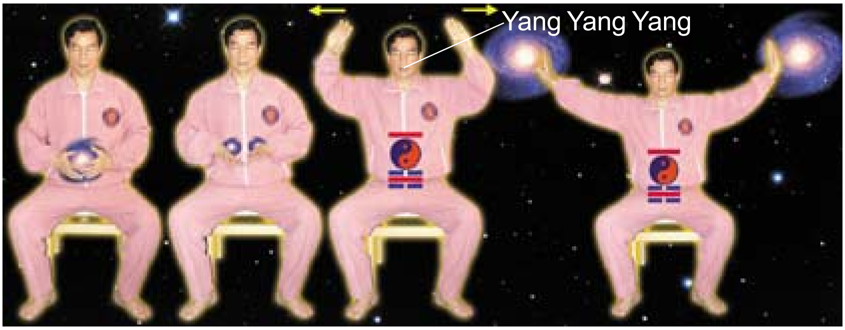

Fig. 5.15 *Yang Line — Yang Expand*

e. **Yin Contract**: Your mind and the hands and palms touch the sky, the cosmos. Chant the Yin, Yin, Yin as long as you feel comfortable, and continue moving your palms up. Draw the cosmic Chi from the universe into the navel, and feel the navel has suction. Feel your hands and the Tan Tien. The throat has the power; draw the Chi into the Yang line to the navel. Rest for a while. (Fig. 5.16)

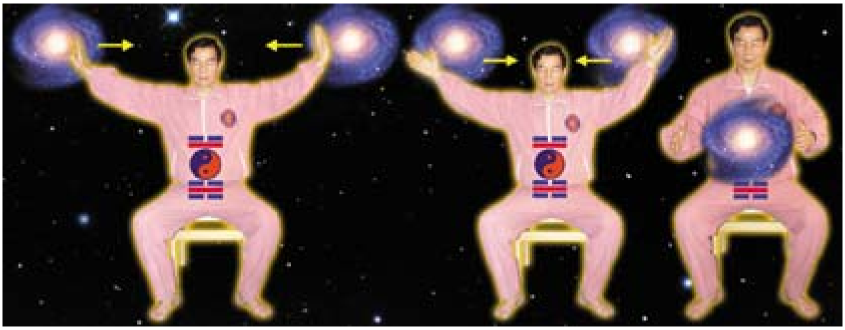

Fig. 5.16 *Yin Line — — Yin Contract*

f. **Do the Yang again**: Be aware of the Tan Tien, the throat, crown and the palms close to the navel and slowly chant the Yang long sound. Turn the palms out and gradually move the palms to the left and right side. Feel your palms very long and big as they touch the cosmos. Rest and feel your palms touch the cosmic Chi. (Fig. 5.17)

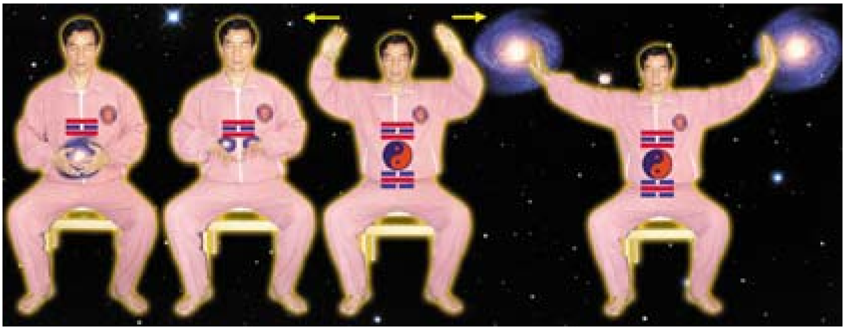

Fig. 5.17 *Yang Line — Yang Contract*

g. **Repeat the word "Li"** in your mind and let your eyes look at your Li Kua. Close your eyes and picture the symbol Li, still moving your eyes up. Smile and be aware of the heart, tongue and the prospering power of fire. Imagine them in your mind's eye; feel them imprinted on your abdomen and vibrating inside you. Rest and project the symbol into the universe and feel the symbol in the universe reinforce the Kan in the lower abdomen.

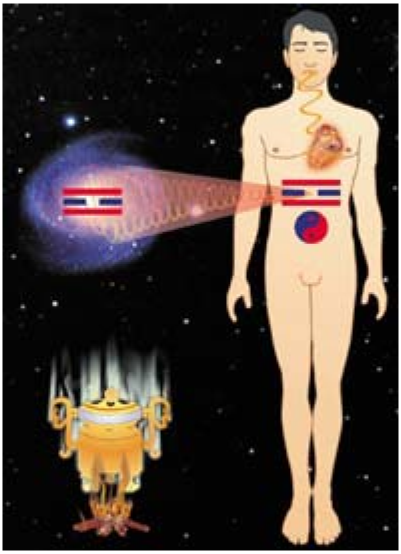

Fig. 5.18 *Li above the Navel*

Chen: Third Sound

a. The third sound is **Chen** (Yang-Yin-Yin), the power symbol of the Thunder and the Lightning, connected with the liver and the eyes, the wood element and gathering power. This sound evokes the trigram Chen that is placed on the right side (below the liver) and the sound comes out as "djen". Repeat the sound until you feel a vibration of energy below the liver, at the right side of the pakua. When you chant "Chen" the eyes look to the right side.

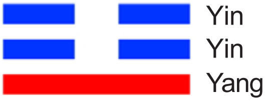
Yin
Yin
Yang

Fig. 5.19 *Chen (Yang-Yin-Yin)*

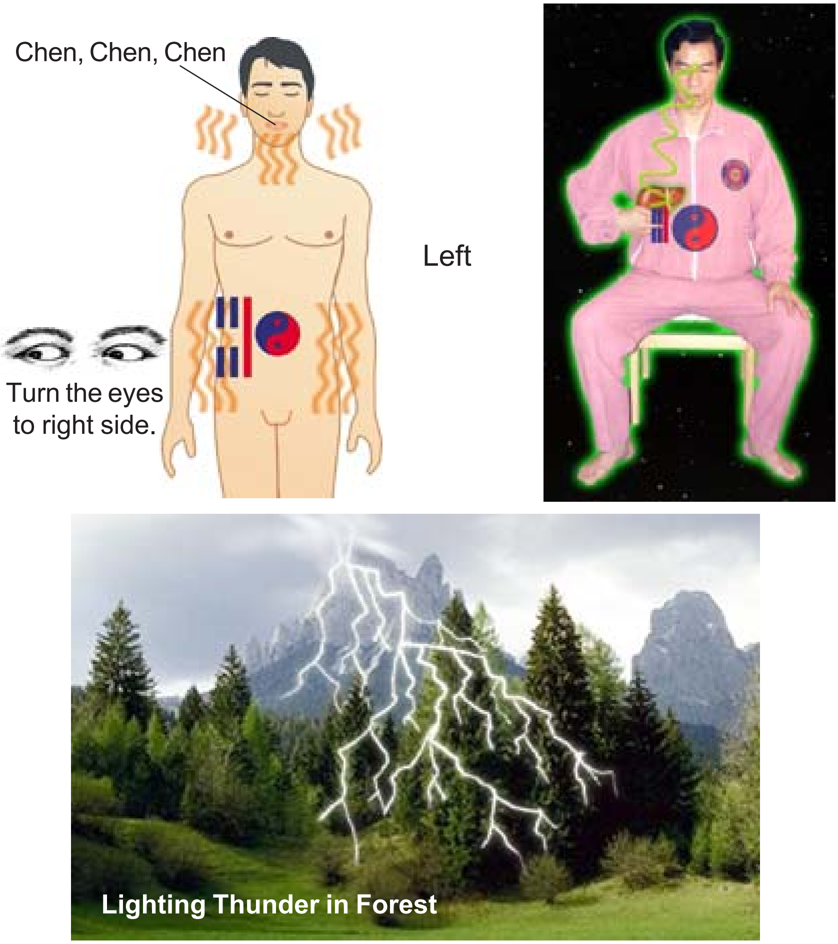
Chen, Chen, Chen
Turn the eyes to right side.
Left
Lighting Thunder in Forest

Fig. 5.20 *Chant Chen (Eyes and Liver connect to the Chen)*

b. **First chant the name of the trigram Chen** ("Djen") in a long deep throat sound while picturing the symbol and touching the right side of your abdomen. Feel the vibration of the lightning and the thunder. Look at the right side of the body, close your eyes and visualize at the symbol of Yang-Yin-Yin. Smile and be aware of the liver, the eyes and the power of generating, lighting and thunder power.

c. **Yang Expand**: Be aware of Tan Tien, the throat, crown and the palms close to the navel and slowly chant the long Yang sound. Turn the palms out and gradually move the palms to the left and right sides and feel your palms very long and big touching the cosmos. Chant the Yang, Yang, Yang as long as you feel comfortable. Rest for a while. Feel the vibrations inside as you chant the trigram. (Fig. 5.21)

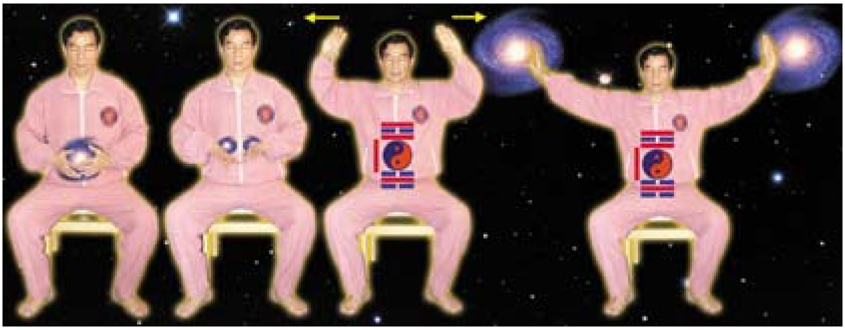

***Fig. 5.21** Yang Line — Yang Expand*

d. **Yin Contract**: Be aware of the Tan Tien, the throat, crown and the palms close to the navel and slowly chant the Yin long sound as the palms touch the universe. Chant the Yin, Yin, Yin as long as you feel comfortable and continue moving your palms back. Draw the cosmic Chi from the universe into the navel and feel the navel has suction. Feel your hands and the Tan Tien; the throat has the power, the Chi goes down the yin line to the navel. Rest for a while. Feel the vibrations inside as you chant the trigram. Rest and feel your palms touch the cosmic Chi. (Fig. 5.22)

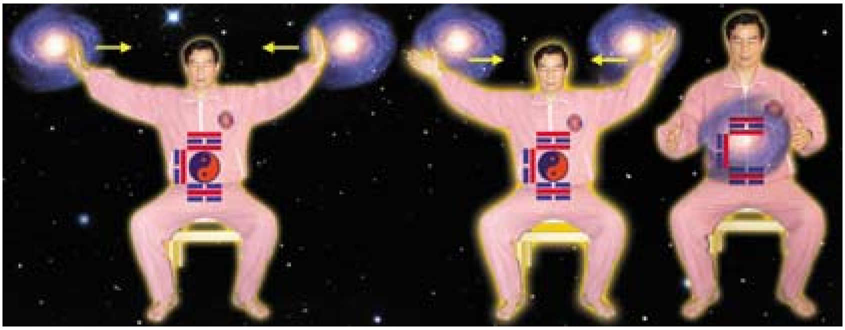

***Fig. 5.22** Yin Line —— Yin Contract*

e. **Do the Yin line again**: be aware of the Tan Tien, the throat, crown and the palms move out to touch the universe. Chant the Yin long sound. Chant the Yin, Yin, Yin as long as you feel comfortable and continue moving your palms back and draw the cosmic Chi from the universe into the navel and feel the navel has suction. Feel your hands and the Tan Tien; the throat has the power, the Chi goes down the yin line to the navel. Rest for a while. Feel the vibrations inside as you chant the trigram. (Fig. 5.23)
Rest for awhile and feel the vibrations inside.

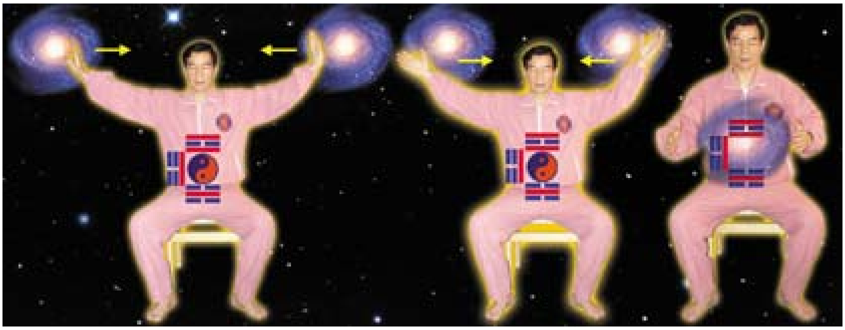

***Fig. 5.23** Yin Line —— Yin Contract*

Tui: Fourth Sound

a. The fourth sound is **Tui** (Yang-Yang-Yin), the power symbol of Lake and Rain, connected with the lungs and nose, the metal element and contracting power. This sound evokes the trigram Tui, that is placed on the left side (opposite Chen) and the sound comes out as “tway”. Chen and Tui are throat sounds. Repeat the sound until you feel a vibration of energy at the left side of the pakua.

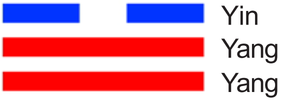
Yin
Yang
Yang

Fig. 5.24 *Tui (Yang-Yang-Yin)*

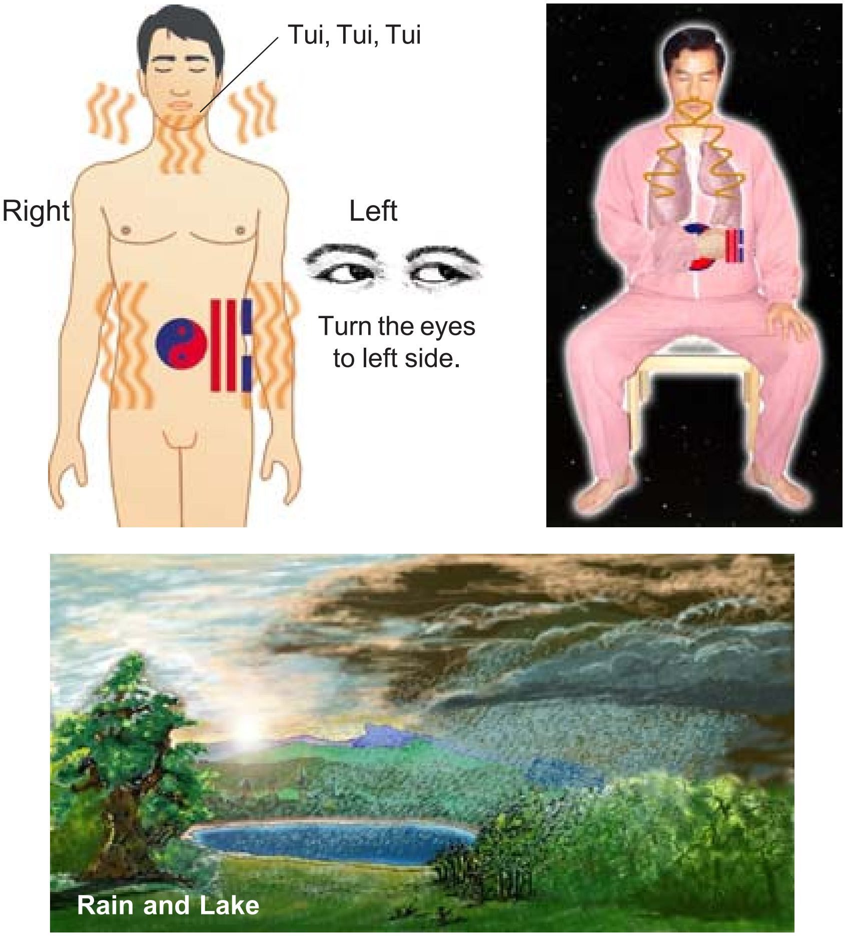
Tui, Tui, Tui
Right
Left
Turn the eyes to left side.
Rain and Lake

Fig. 5.25 *Chant Tui (Nose and Lung connect to the Tui)*

b. **Next chant the name of Tui** in a long deep voice while picturing the symbol and touching the left side of your abdomen. Feel the vibration of the rain and the lake. Look at your left side, close your eyes and visualize at the symbol of Yang-Yang-Yin. Smile and be aware of the lungs, nose and the power of contracting rain and lake.

c. Do the Yang Line, **Yang Expand**; be aware of Tan Tien, the throat, crown and palms close to the navel and slowly chant the long Yang sound. Turn the palms out and gradually move the palms to the left and right sides and feel your palms very long and big touching the cosmic. Chant the Yang, Yang, Yang. (Fig. 5.26)

d. Do the Yang line again. **Yang Expand**; be aware of Tan Tien throat, crown and palms close to the navel and slowly chant the long Yang sound. Turn the palms out and gradually move the palms to the left and right sides and feel your palms very long and big touching the cosmos. Chant the Yang, Yang, Yang.

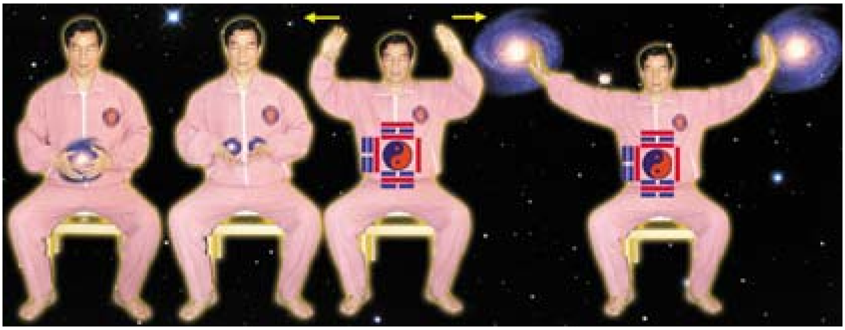

Fig. 5.26 *Yang Line — Yang Expand*

e. **Yin Contract**: Chant the Yin, Yin, Yin as long as you feel comfortable, continue moving your palms and draw the cosmic Chi from the universe into the navel and feel the navel has suction. Feel your hands and the Tan Tien; the throat has the power and the Chi goes down the yin line to the navel. Rest for a while. Feel the vibrations inside as you chant the trigram. Finish. Rest for awhile and feel the vibrations inside. (Fig. 5.27)

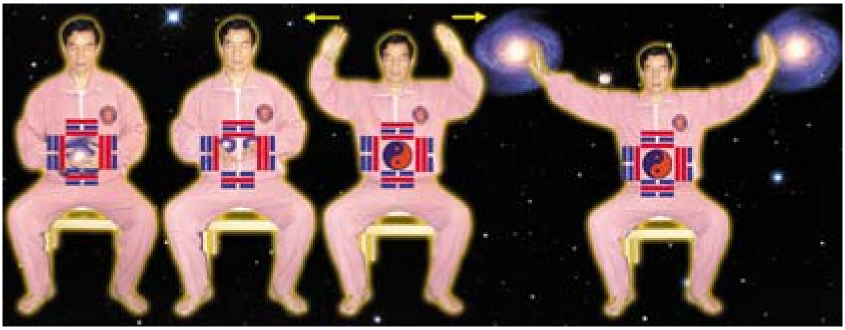

Fig. 5.27 *Yin Line — — Yin Contract*

2. Continue the practice with the next four symbols.

The last four trigrams of the pakua are: **Kun** (Yin-Yin-Yin), the Earth power, **Ken** (Yin-Yin-Yang), the Mountain power; **Sun** (Yin-Yang-Yang), the Wind power and **Chien** (Yang-Yang-Yang), the Heaven power.

Go through the same procedure as with the first four symbols to evoke the energy and connect it to the pakua.

a. Do all the 8 symbols together quickly Kan, Li, Chen, Tui, Kun, Ken, Sun, Chien (6 sets).
b. Be aware of the pakua and see it imprinted deep into the abdomen.
c. Be aware of the Tai Chi symbol and start to chant, Tai Chi, Tai Chi, and Tai Chi faster and faster. Feel the Tai Chi symbol moving faster and faster now.

Practice of the Next Four Symbols.

Symbol Kun - Earth

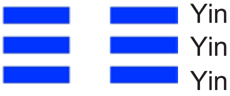

Stabilization power stomach and mouth, spleen and pancreas.

Focus on Kun, Yin-Yin-Yin. Chant Kun and then chant Yin-Yin-Yin repeatedly. You can use the hand to help draw in the energy back to the Pakua. Later on, you do not need to use your fingers. Picture the symbol Kun in front of you and expand it very far away to connect with the centering, stabilizing power. Let the energy with the symbol come to you until it sticks to your forehead. Bring it down to the south/west (upper left corner) in the abdominal Pakua.

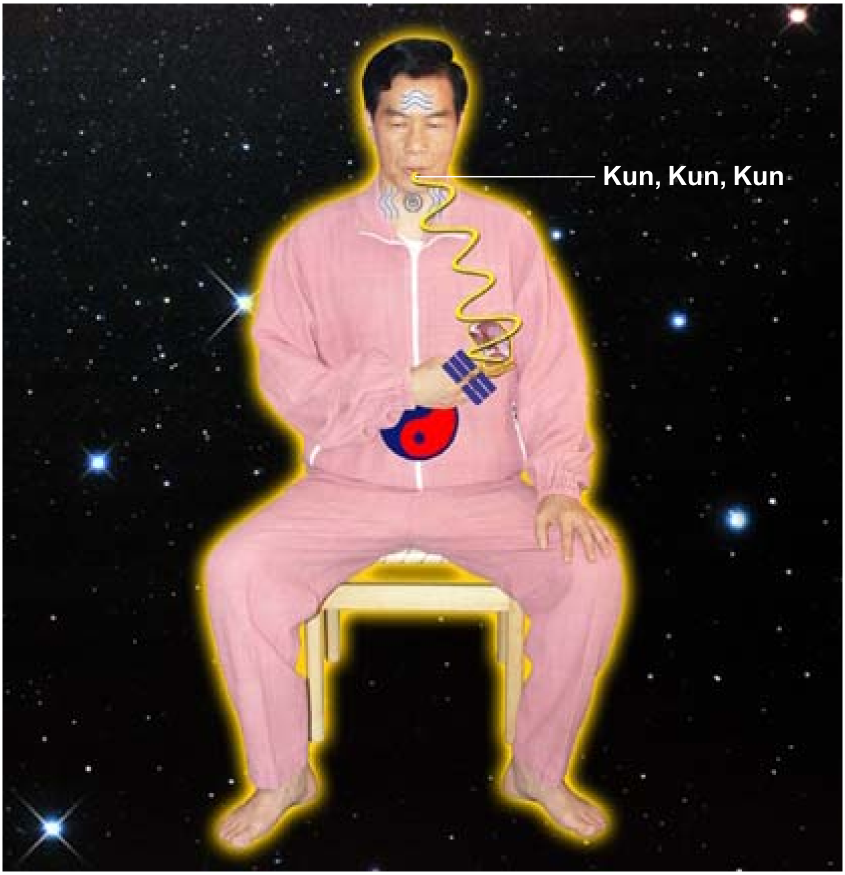

Fig. 5.28 *Chant Kun (Earth, Mouth and Spleen connect to the Kun)*

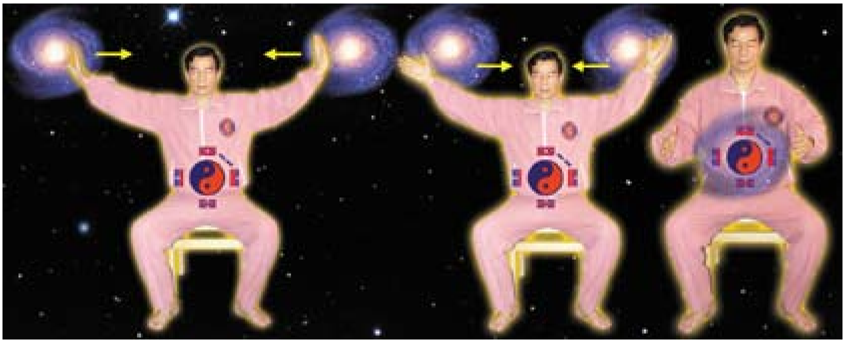

Fig. 5.29 *Yin Line —— Yin Contract*

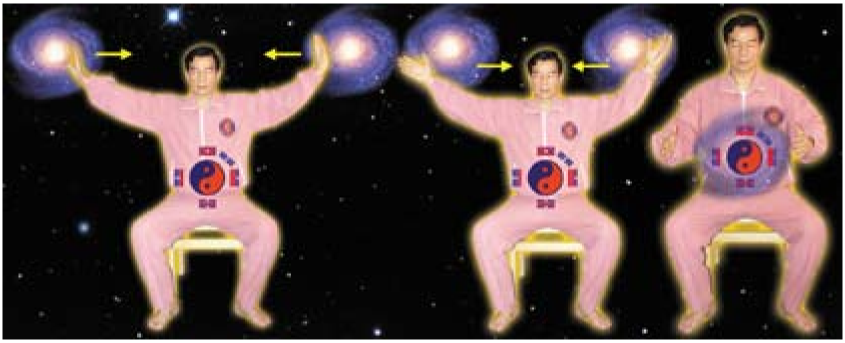

Fig. 5.30 *Yin Line —— Yin Contract*

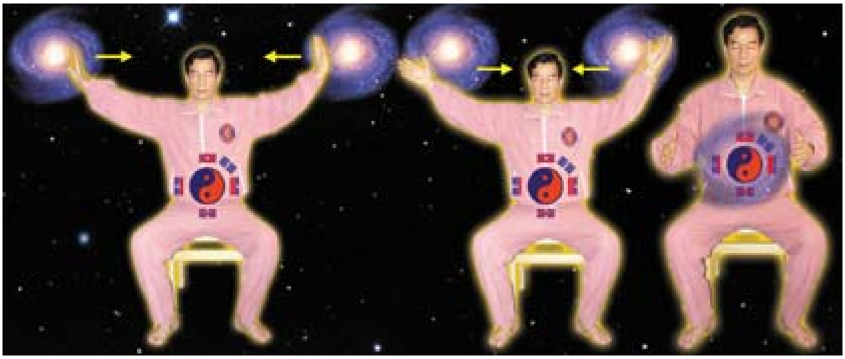

Fig. 5.31 *Yin Line —— Yin Contract*

Symbol Ken - Mountain

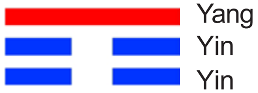

Yin side of water power and with bladder and sexual organs.

Focus on Ken, Yin-Yin-Yang. Chant first Ken and then Yin-Yin-Yang repeatedly. It is a nose/throat sound. Mark the symbol with your fingers and your eyes/mind on your forehead. Rest and feel the symbol imprinted on your forehead. Expand it far away to make the connection with the stable and strong mountain power. Feel the symbol with the energy come back. Move it to its place in the pakua on your abdomen in the lower right corner.

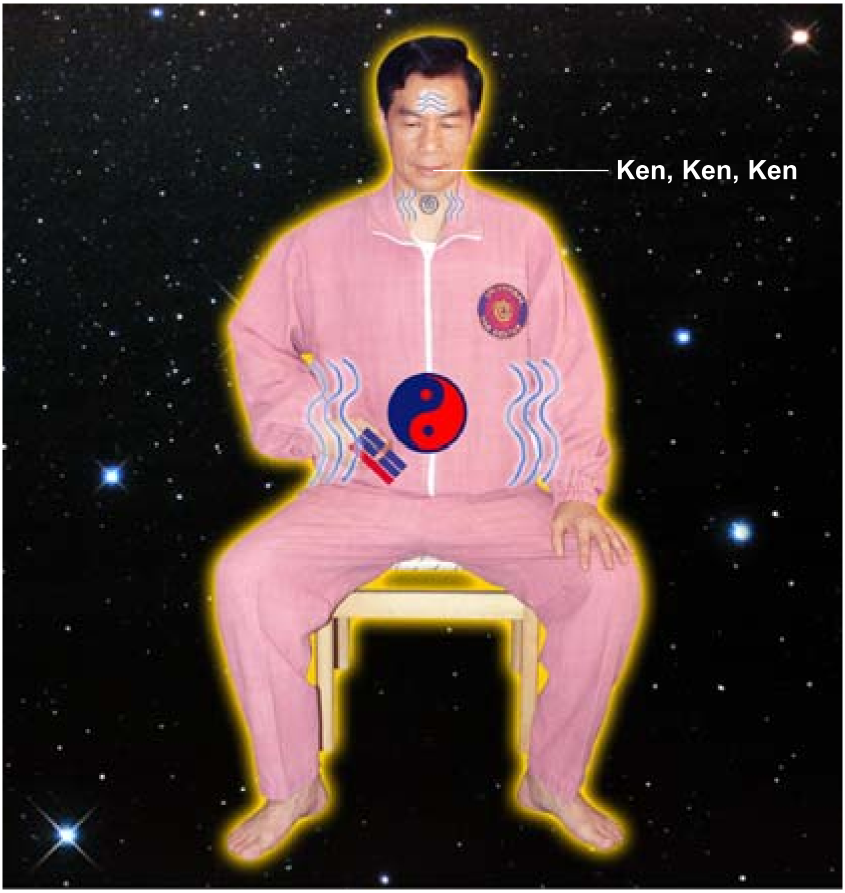

Fig. 5.32 *Chant Ken (Mountain connects to the back of the skull)*

Symbol of Sun - Wind

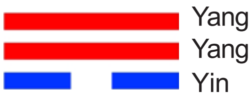

Also connects with the gall-bladder and wood power.

Focus on Sun, Yin-Yang-Yang. Chant Sun and then Yin-Yang-Yang repeatedly. Picture the symbol on your abdomen mark it with your fingers at the abdomen first and then just with your eyes and mind. Picture the symbol very far away to connect with the power of the wind until it comes back to you and sticks to your abdomen. When the reinforced symbol sticks to your abdomen, move it down to the upper right corner of your abdominal Pakua.

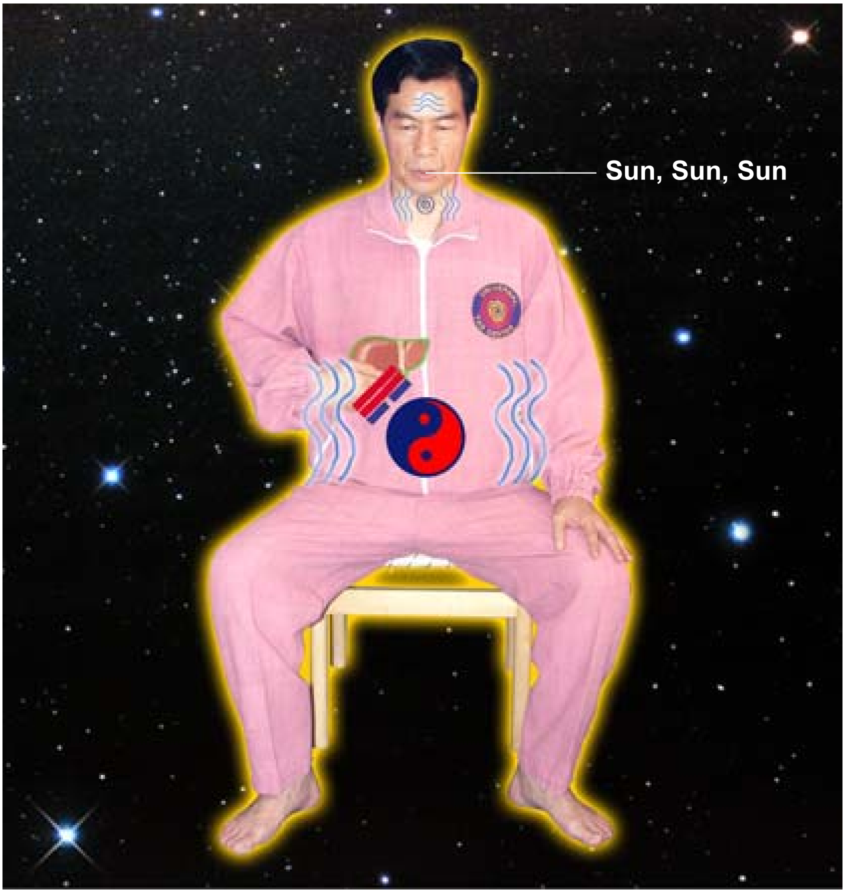

Fig. 5.33 *Chant Sun (Wind connects to the base of the skull)*

Symbol of Chien - Heaven

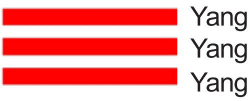

Also connects with the yang side of metal power and large intestine.

Focus on Chien, Yang-Yang-Yang. Chant Chien and then Yang-Yang-Yang repeatedly. Mark the lines of the trigram on the abdomen with your fingers and your eyes/mind. Rest and feel the symbol imprinted on the abdomen. Expand it very far away to connect with the power of Heaven. Do it several times until you feel that the symbol is coming back and sticks on your abdomen. Bring this reinforced trigram down to the lower left corner of your abdominal Pakua.

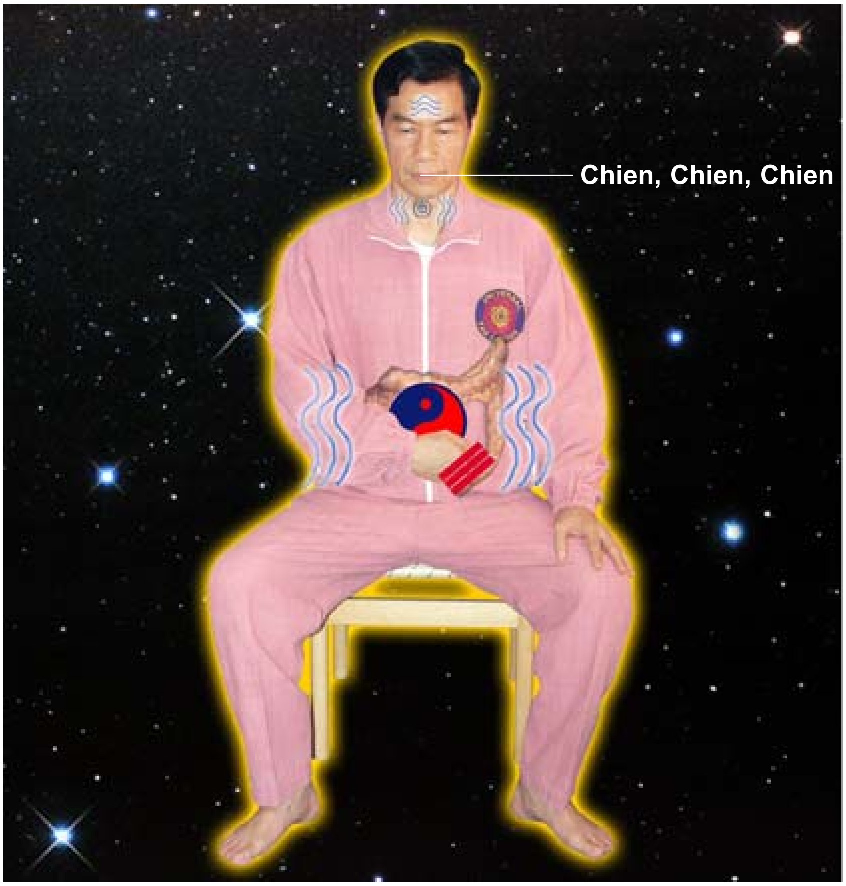

Fig. 5.34 *Chant Chien (Heaven connects to the forehead bone)*

When you finished the last imprinting of these first four symbols, make the Tai Chi symbol, spiraling with the fingers around the navel and saying: **Tai Chi, Tai Chi, Tai Chi**. This is an abdominal sound. Continue to chant it more inwardly, **Tai Chi**, **Tai Chi**, **Tai Chi**, at the same time spiraling with your fingers and eyes. When you finish the chanting, rest. Feel the Kan and the Li, the Chen and the Tui join together, fusing the energy of these forces inside of you.

We now combine the four trigrams.

- First look at your pakua and say the name of the symbol and its Yin-Yang components.
- Chant Kan - Li - Chen - Tui while moving your eyes down-up -right-left. Repeat several times.
- Rest; spiral with your fingers around the navel and continue the spiraling movement of the eyes awhile chanting Tai Chi, Tai Chi, Yin - Yang, Yin - Yang until you feel the Tai Chi symbol spiraling in the middle of the pakua connecting the trigrams together. Feel a big space, a fire burning inside of you.

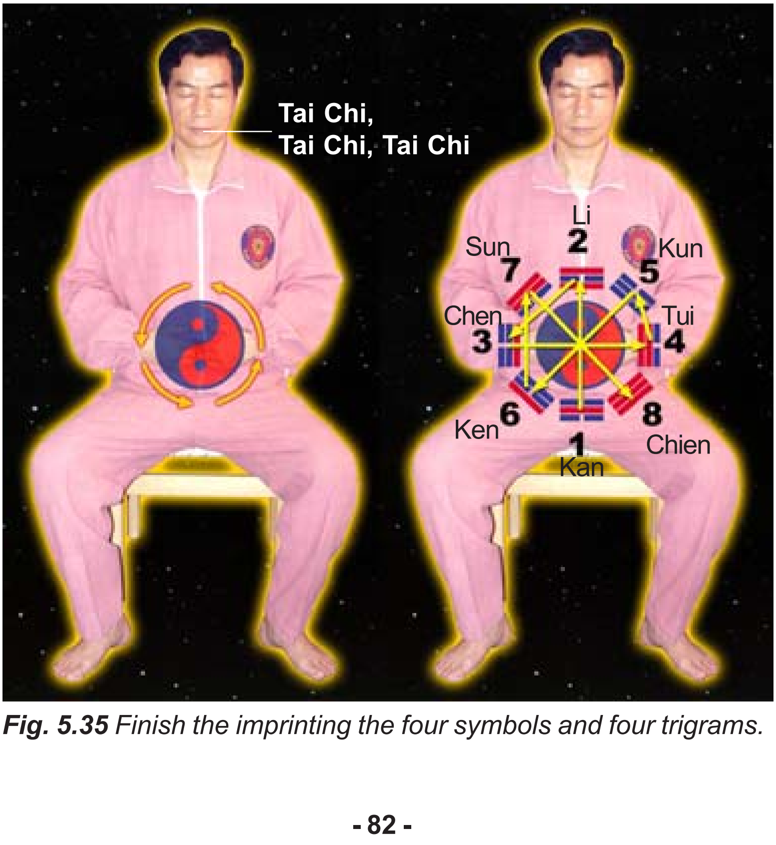

***Fig. 5.35** Finish the imprinting the four symbols and four trigrams.*

Merging Energy of both Pakuas and establish the Cauldron.

a. Copy the front Pakua to the back Pakua and let the Tai Chi symbol spiral. Be aware of the front Pakua spiraling in one direction and the back Pakua in the reverse direction. You can start the front Pakua spiraling counterclockwise and the back clockwise in reverse. Merge the energy of the front and the back Pakua right in the center of the Tan Tien and form a space there for the cauldron. At this point, leave the spinning energy moving. Feel the both Pakuas still spinning and drawing Cosmic Force from all directions. Rest, and then start spinning the energy.

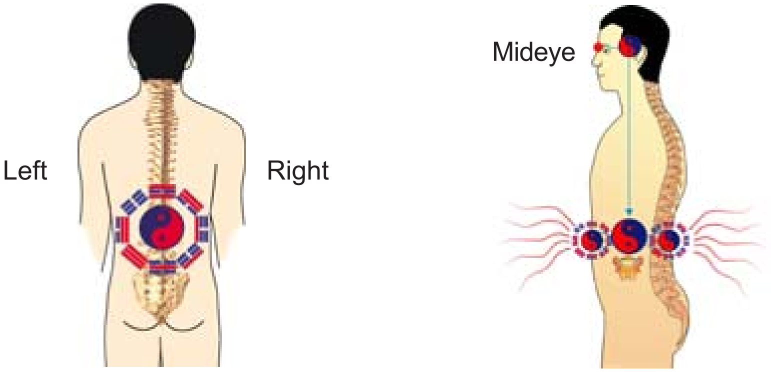

Fig. 5.36 *Back Pakua*

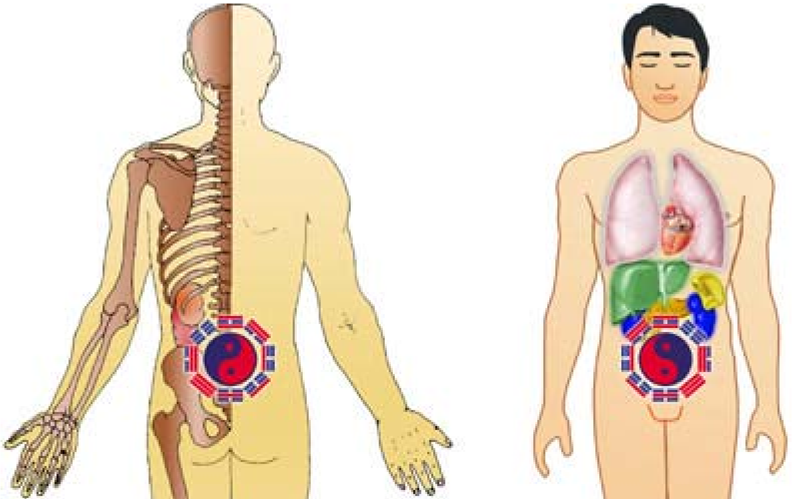

Fig. 5.37 *Front and Back Pakua*

b. When both pakuas are spiraling, focus on the center and look down while being aware of the front and the back pakuas. Chant Yin-Yang and spiral with your mind's eye in the center. Feel the big space of the front pakua and the back pakua coming into the center, merging together and creating a big space inside you for the cauldron. Feel the cauldron inside you spiraling like a big ball of fire, creating a suction in the middle of the front and the back pakua. Feel that, while you continue to chant the Tai Chi subvocally, the energies of both pakuas are sucked into the center, the cauldron. Feel the fire burning in the cauldron like a candle. Be aware of your center and of the energy there.

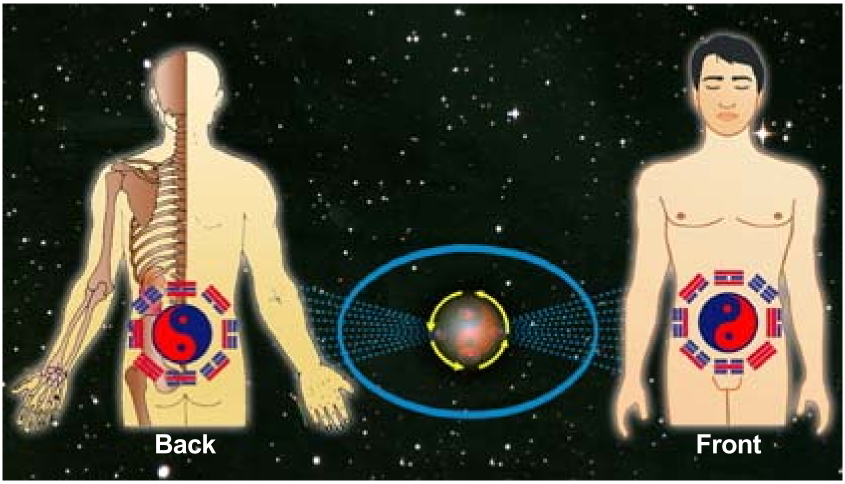

Fig. 5.38 *Both Pakuas are spiraling and drawn into the center.*

1. Creating the Right Pakua

The right pakua is a copy of the back pakua moved to the right side. Use your finger to point to the right side on the same level with the navel while you picture the symbol of Pakua. Then make the Tai Chi symbol, spiraling from the bottom to the right to the top and to the left. Chant Tai Chi and follow the spiraling with your fingers at the same time. Rest, feel the pakua spiraling and drawing energy.

2. Creating the Left Pakua

This pakua is a copy of the front pakua moved to the left side. Use your fingers to point to the left side ao the same level with the navel picture the symbol of the Pakua. When you feel that you are in the rhythm continue in your mind using your mind's eye to move. Chanting the Tai Chi, Tai Chi and spiraling with your hand in the middle of the left pakua. Continue spiraling with your mind/eyes until you feel the energy moving.

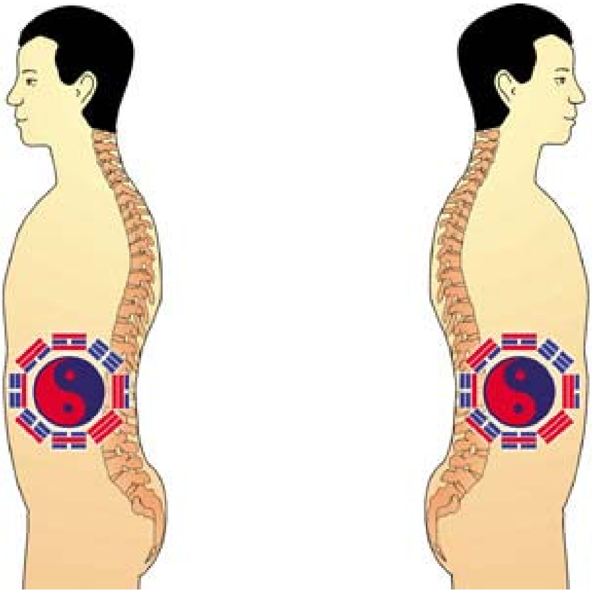

Fig. 5.39 *Left and Right Pakua*

3. Merging the Energies of the Four Pakuas together in the Cauldron

Go back to the right pakua, activate it and let it spiral. Go back to the left pakua and reactivate it, spiraling the Tai Chi. Focus on the center as you chant the Tai Chi and be aware of the centers of the front, back, right and left pakuas. Feel that the energies of the pakuas are sucked into the center. Feel the energy become violet light, and your mind, eyes and center spiraling.

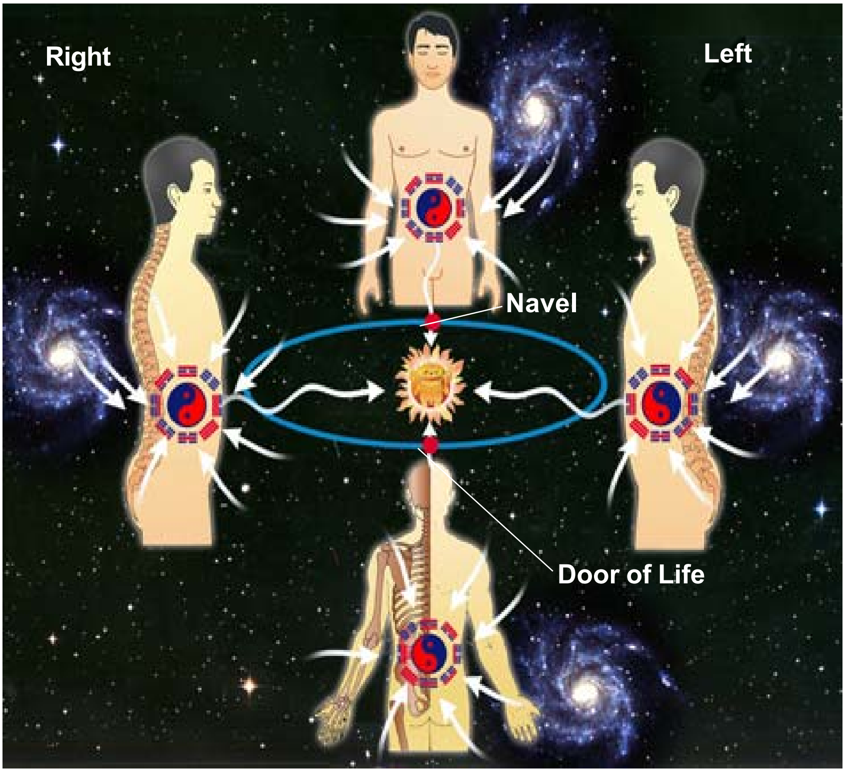

Fig. 5.40 *Four Pakuas spiral and are being drawn into the Center of the Cauldron.*

4. Connecting the Organs and Senses with the Abdominal Pakua.

a. Bring your ears and kidneys to the Kan below.
b. Your tongue and heart to the Li on the top.
c. The mideyebrow and the liver to the Chen on your right side.
d. Your lungs and your nose to the Tui on your left side.
e. Your mouth to the Kun on your upper left side.
f. You can also connect the back part of your skull to the Ken.
g. The base of the skull to the Sun
h. The forehead point to the Chien.

Spiral the Tai Chi symbol of this pakua drawing all the energy of the organs and the senses to the center, where all these energies are combined and condensed.

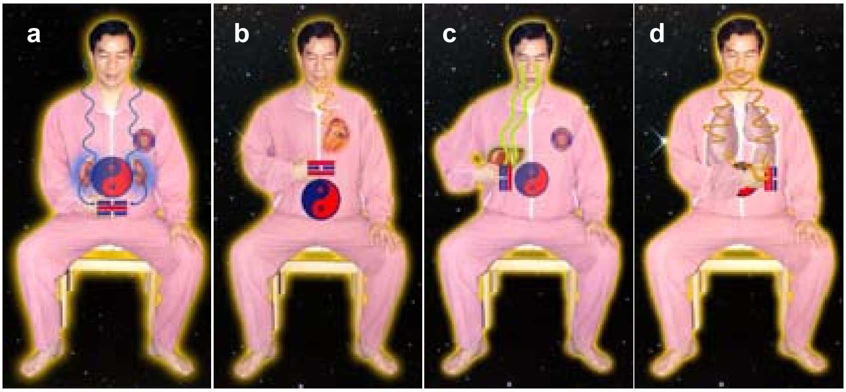

a. *Kan - Ear and Kidneys* ***b.*** *Li - Tongue and Heart*
c. *Chen - Mideyebrow and Liver* ***d.*** *Tui - Lung and Nose on Left Side*

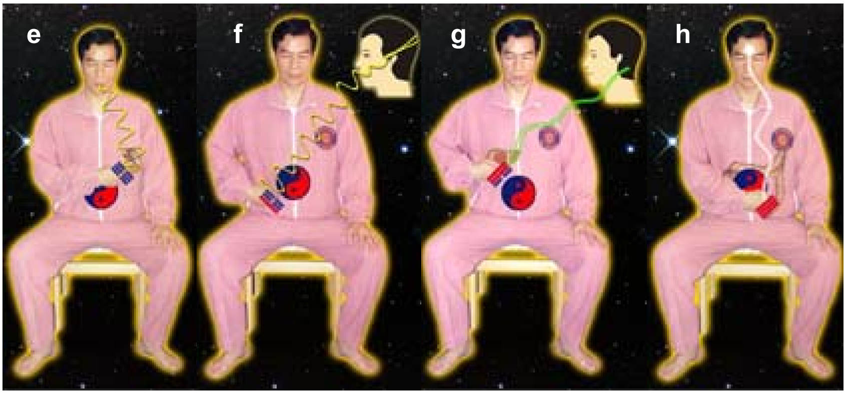

e. *Kun - Mouth and Upper Left Side* ***f.*** *Ken - Back part of the Skull*
g. *Sun - Base of the Skull* ***h.*** *Chien - Forehead Point*
Fig. 5.41 *Connecting the Organs*

Activate the Facial Pakua by enhancing it on the Forehead

The forehead Pakua is the reverse of the abdominal pakua. Use the fingers to point at the position of the Pakua. The Yin and Yang sounds generate from the abdomen but emphasis on the throat, nasal and the third eye. Later on, mark the symbol with your eyes and mind.

When you rest after making the specific sound, feel that the symbol of the trigram is imprinted on the forehead. Send this symbol out into the space in front of you to make the connection with the force of the Universe and let it come back to your body. Bring the reinforced symbol down to the trigram in the pakua in the abdomen and start to work with the next symbol.

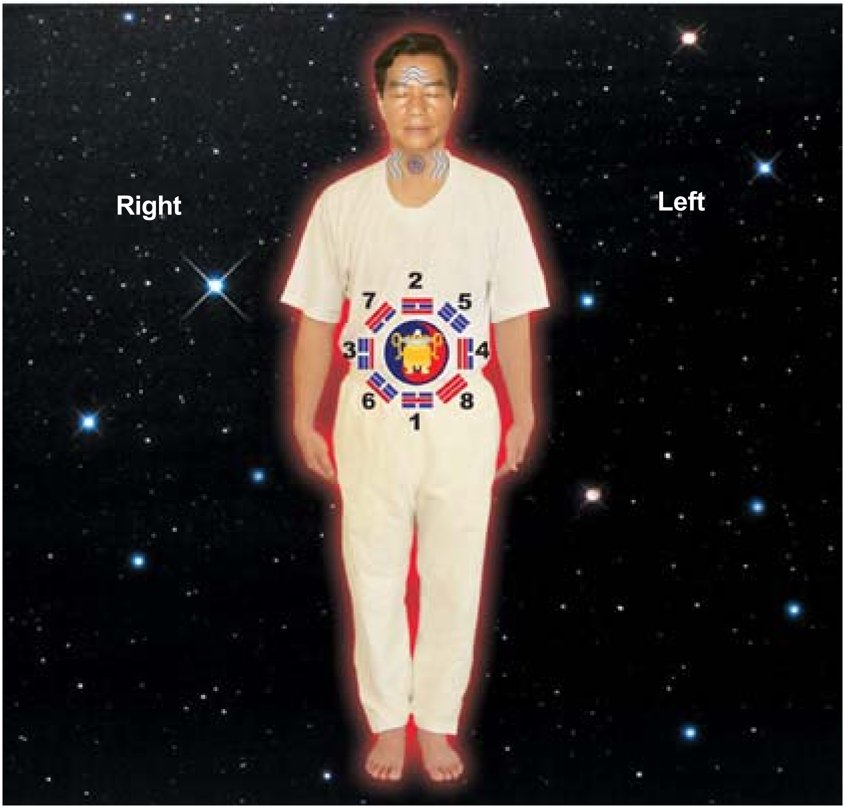

***Fig. 5.42** Enhancing Pakua on the Forehead*

Facial Pakua

To practice this stage, we form a pakua on the face. This pakua has its face in front of us (as if the symbol is looking toward you), so that the Chen will be on the left side and the Tui will be on the right side and all the other trigrams will be arranged accordingly. The Tai Chi symbol will be on your the center at the mid-eyebrow and expands up and down to the forehead and the ridge of the nose right where the cavity of the spirit is. All the senses are controlled from this point. When information and energy from outside is coming in to trigger the senses, you will feel it first very strongly in this center and then the senses will connect immediately to the center of the front pakua below.

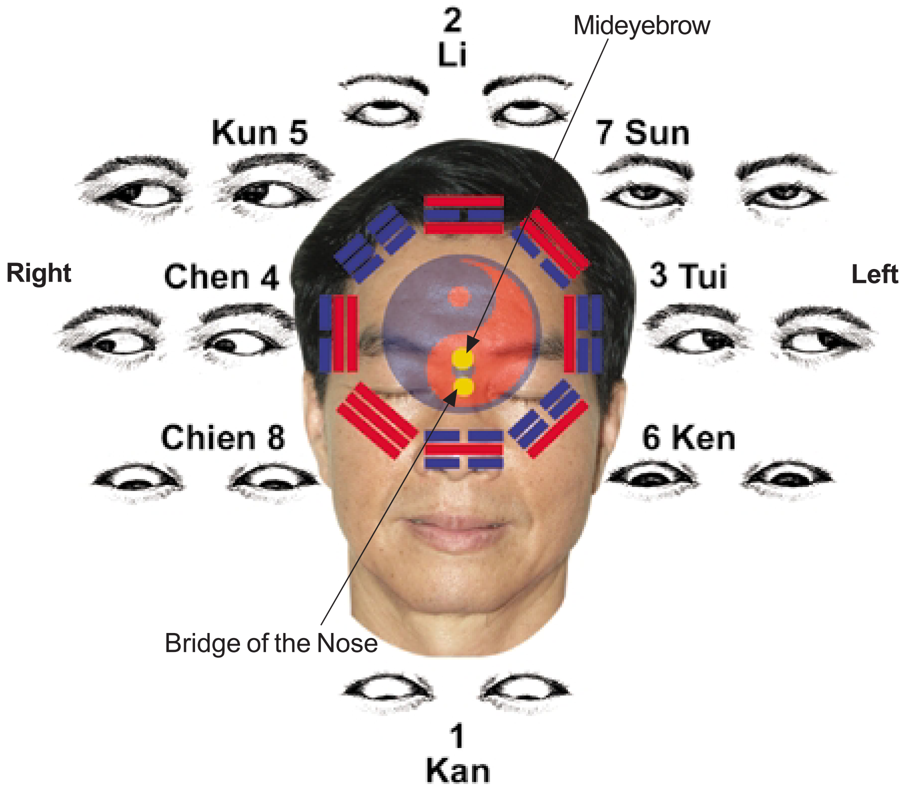

***Fig. 5.43** Use the Eye Mind Power "I" to help move the Eight Forces.*

Practice to form the Facial Pakua.

1. In order to help you get more Chi from the universe, you can start with the "Opening the Three Tan Tiens to the Six Directions" (See the book "*Cosmic Healing I*" by Mantak Chia). If you have not learned this, you can just start with forming the Pakua.

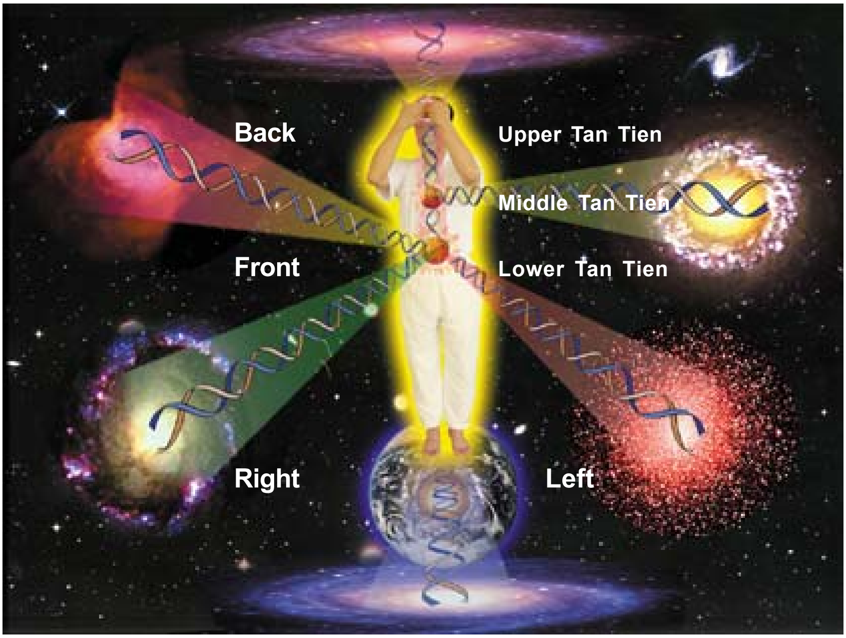

Fig. 5.44 *Opening the Three Tan Tiens to the Six Directions*

2. Then smile, feel your senses turned inward, feel them connecting to the organs. Your mideyebrow connects to your eye and liver, your tongue connects to the heart, your ears connect to the kidneys, your nose connects to your lungs and your mouth connects to the spleen. Feel all the senses turned inward to the mideyebrow and down to navel, going deep inside you. Your abdomen is like a big ocean, a big space, big like a whole universe.

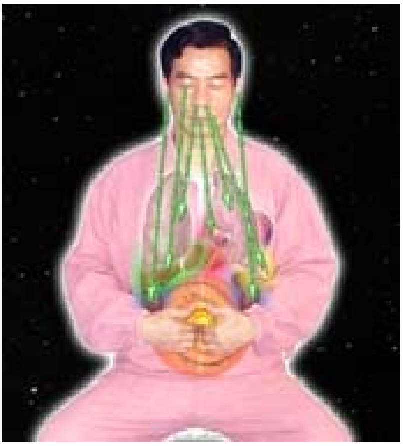

Fig. 5.45 *Turn all senses inward*

3. Reactivate and reinforce the pakua in your lower abdomen.
   a. Touch your Lower Tan Tien and start chanting Kan-Li-Chen-Tui-Kun-Ken-Sun-Chien touching each of the kuas as you chant them. Continue to chant the kua symbols subvocally in your mind and holding the symbol in front of your eyes. Be aware of the Heart Pakua.

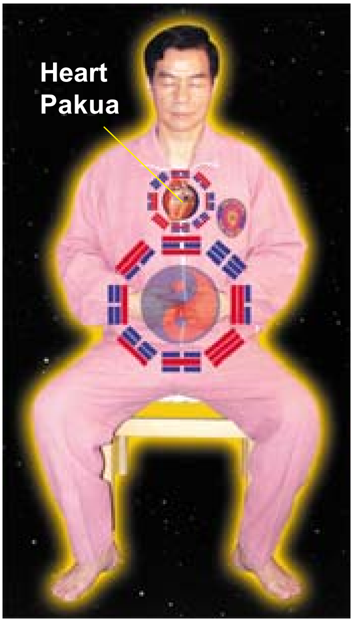

Fig. 5.46 *Touch Lower Tan Tien and chant.*

   b. Spiral the Tai Chi symbol from the bottom to the right and up, chanting it while spiraling with your hand, eyes and mind. Continue to spiral with your mind and eyes only and feel the heart pakua also spiraling. The energy is pulling inward and the Tai Chi symbol is spiraling and changing to violet light.

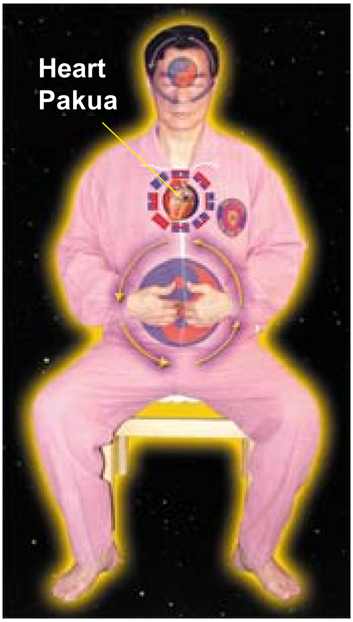

Fig. 5.47 *Tai Chi symbol spiraling*

Start the Practice of the Facial Pakua with the First Four Symbols.

Symbol of Kan - Water ☵

a. Be aware of the mideyebrow. Use the fingers of either the right or left hand to touch below your nose. Eyes look down to the bridge of the nose. Focus on the Kan, Yin-Yang-Yin. Chant the word Kan repeatedly, vibrating it in the brain, making a throat, nose and third eye sound. Picture the trigram on your face and expand it very far away to the ocean. Feel that the energy of the Kan comes right in front of you, allowing the feeling to expand on bridge of the nose. Be aware of the Kan in your lower abdomen and move the powerful Kan from your face to your lower abdomen where it is supposed to be.

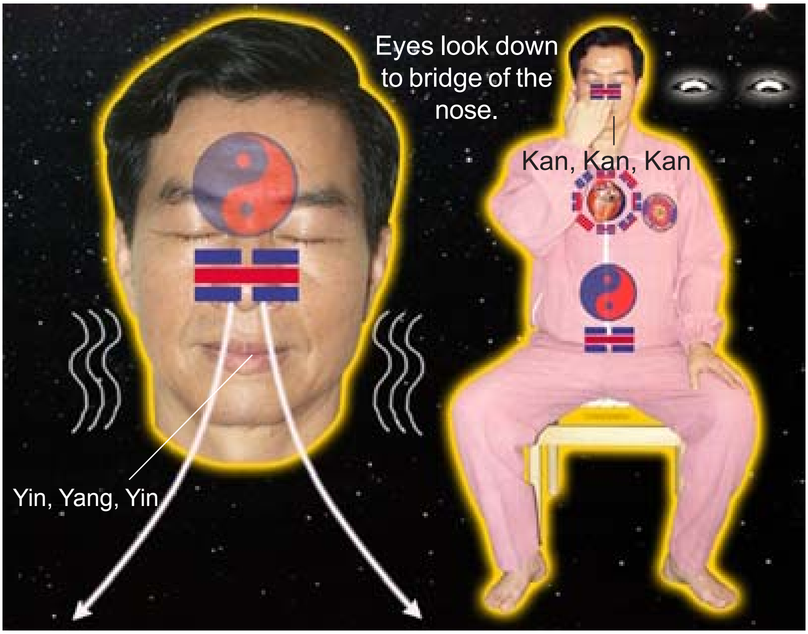
Eyes look down to bridge of the nose.
Kan, Kan, Kan
Yin, Yang, Yin

Fig. 5.48 *Kan on the face below the nose.*

b. **Yin Contract**; First expand the mind and the hands and palms to touch the sky, the cosmos. Chant the Yin, Yin, Yin as long as you feel comfortable, and continue moving your palms. Draw the cosmic Chi in from the universe into the face and feel the mideyebrow has suction. Feel your palms, fingers and the Tan Tien, the mideyebrow has power, the fingers can move in and touch below the nose. The Chi goes to the Yin line in the navel. Rest and Smile, breathing the cosmic Chi. (Fig. 5.52)

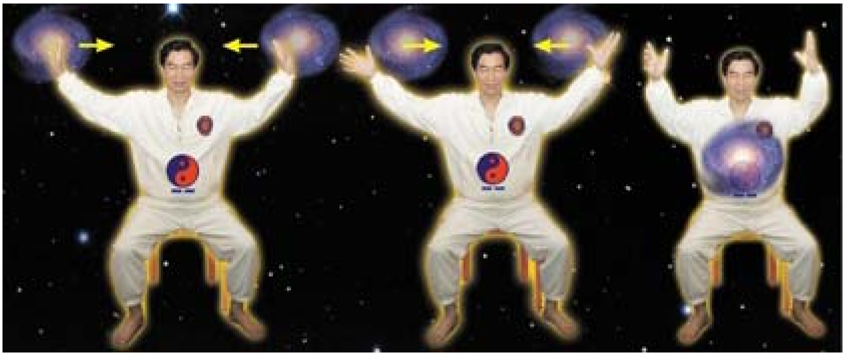

Fig. 5.49 *Yin Line — — Yin Contract*

c. **Yang Expand**: Do the Yang line; be aware of the Tan Tien, throat, bridge of the nose, the palms, the fingers and touch the face. Slowly chant the long Yang sound and turn the palms out. Gradually move the palms to the left and right sides and feel your palms very long and big touching the cosmos. Rest and smile, the Chi goes to the Yang line in the navel.

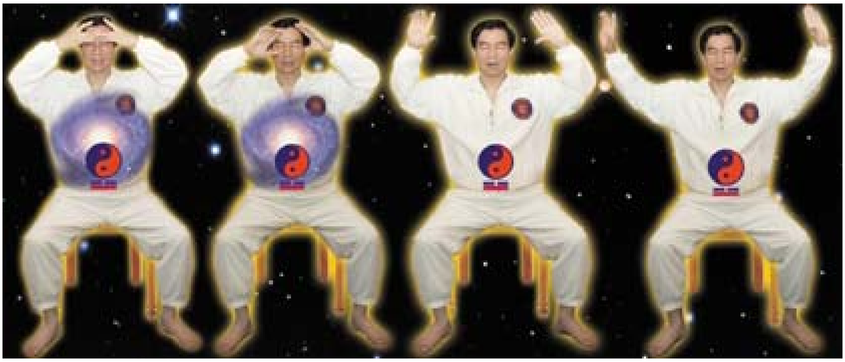

Fig. 5.50 *Yang Line —— Yang Expand*

d. **Yin Line again**, Yin contracts; expand the mind. Repeat as in the first Yin line. Rest for awhile. Feel the vibrations inside.

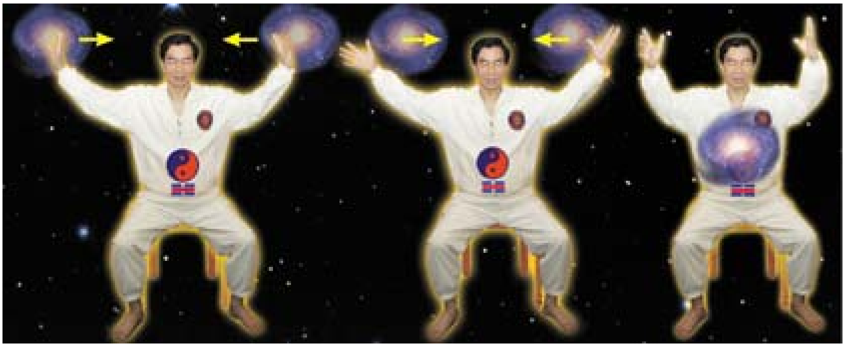

Fig. 5.51 *Yin Line — — Yin Contract*

Symbol of Li - Fire ☲

a. Focus on the Li Yang-Yin-Yang trigram. Repeat it several times using your fingers on your mideyebrow. Eyes look up to the forehead and picture a flame burning and chant Li, Li, Li repeatedly. Then chant the Yang-Yin-Yang. Picture the trigram right on your face and expand it very far away. See a fire burning, expanding warmth. Let the energy stay on your forehead as a bright red light. Bring it down to the Li in the Pakua in your abdomen and feel a burning sensation in that area.

b. **Yang Expand:** Do as before.

c. **Yin Contract:** Do as before.

d. **Yang Expand:** Do as before.

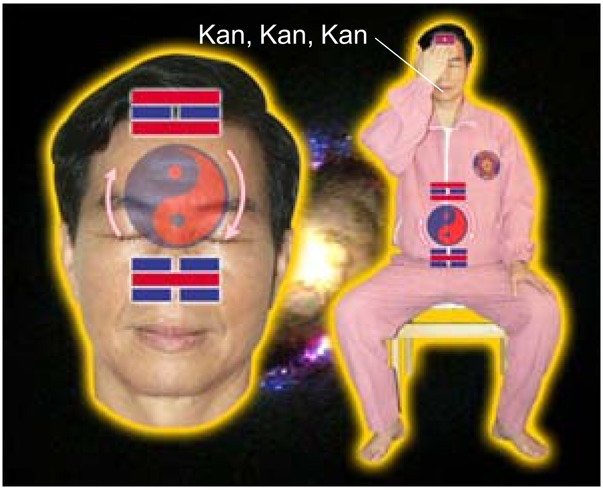

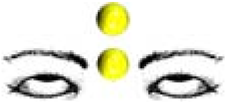
Eyes look up
to the forehead.

Fig. 5.52 *Li on Forehead*

Symbol of Chen - Thunder ☳

a. Focus on Chen, Yang, Yin, Yin. Chant this symbol as a throat and nose sound repeatedly and then chant Yang-Yin-Yin. The eyes look to the left temple bone. Picture the symbol in front of you, expand it very far away to the power of the lightning and thunder. Let the energy come to you, feel the tingling on your left temple bone and move this energy sensation down to the left side of the abdominal pakua. Be aware of Kan, Li, Chen. Visualize them very clearly.

b. **Yang Expand:** Do as before.

c. **Yin Contract:** Do as before.

d. **Yin Contract:** Do as before.

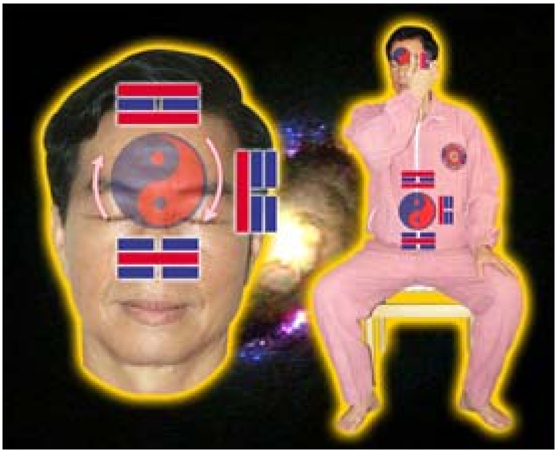

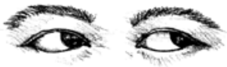

Eyes look to left
temple bone

Fig. 5.53 *Chen on Forehead*

Symbol of Tui - Lake ☱

a. Focus on Tui, Yang, Yang, Yin. Chant Tui repeatedly with a nose sound that is vibrating in the nose. Then chant Yang-Yang-Yin; eyes look to the right temple bone. Picture the symbol on your right temple bone and expand it very far away to the power of the lake, rain and metal element. It is a condensing power. Move it down to the right of the abdominal pakua.

Combine the four symbols together with the Tai Chi symbol. Feel the Tai Chi symbol spiraling inside your head and feel the center of your abdomen nice and warm like a fire burning inside you.

b. **Yang Expand:** Do as before.

c. **Yang Expand:** Do as before.

d. **Yin Contract:** Do as before.

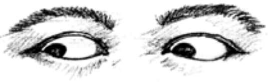

Eyes look to right
temple bone.

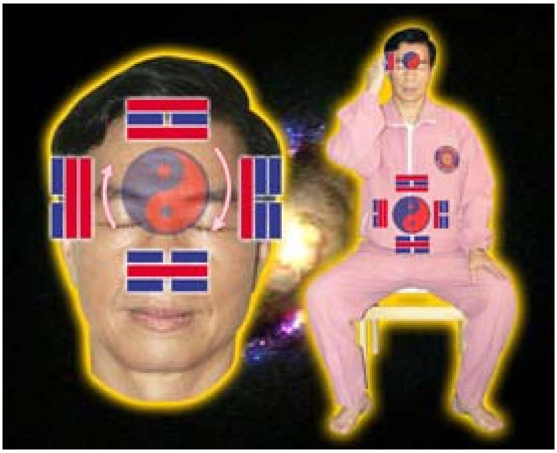

Fig. 5.54 *Tui on Forehead*

Kun ☷

Imprint Kun on your forehead. Start chanting Kun-Kun-Kun, and then use the fingers and palms to help activate the cosmic force Yin-Yin-Yin, Yin-Yin-Yin, marking the lines with your fingers on your forehead. Project the symbol into the universe as you breathe through your forehead. Picture the symbol breathing in violet/blue and when it connects to your forehead bring it down to its place in the lower pakua.

a. **Yin Contract**, Do as before.
b. **Yin Contract**, Do as before.
c. **Yin Contract,** Do as before.

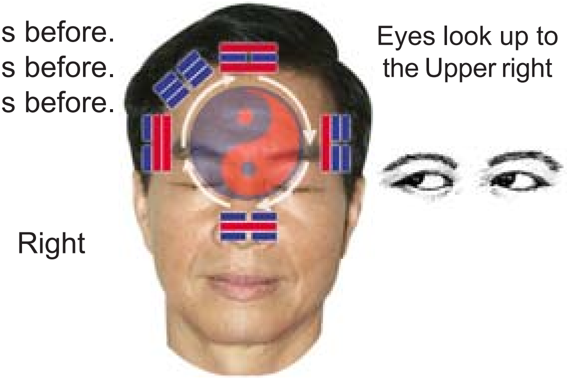
Eyes look up to the Upper right
Right

Fig. 5.55 *Kun*

Ken ☶

Imprint Ken on your lower left cheek bone. Start by the eyes looking down to the lower left cheek bone, chanting Ken-Ken-Ken, and then Yin-Yin-Yang, Yin-Yin-Yang, Yin-Yin-Yang, marking the lines with your fingers on your forehead. Project the symbol into the universe as you breathe through your forehead. Picture the symbol with its violet/blue and bright red colours in front of you and when it connects to your forehead bring it down to its place in the lower pakua.

a. **Yin Contract:** Do as before.
b. **Yin Contract:** Do as before.
c. **Yang Expand:** Do as before.

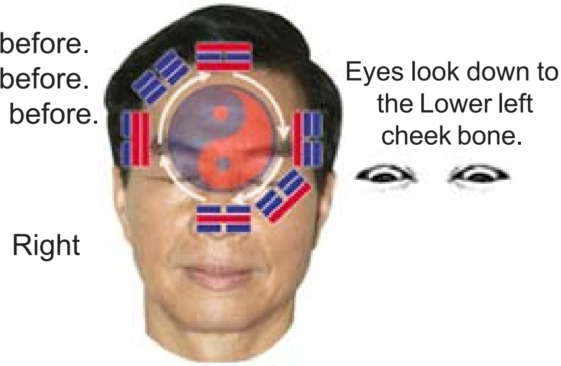
Eyes look down to the Lower left cheek bone.
Right

Fig. 5.56 *Ken*

Sun ☴

Imprint Sun on your upper left eyebrow. Start with the eyes looking up to the upper left eyebrow, chanting Sun-Sun-Sun, and then Yin-Yang-Yang, Yin-Yang-Yang, Yin-Yang-Yang, marking it with your fingers on your forehead. Project the symbol into the universe as you breathe through your forehead. Picture the symbol with its violet/blue and bright red colors in front of you and when it connects to your forehead bring it down to its place in the lower pakua.

a. **Yin Contract:** Do as before.
b. **Yang Expand:** Do as before.
c. **Yang Expand:** Do as before.

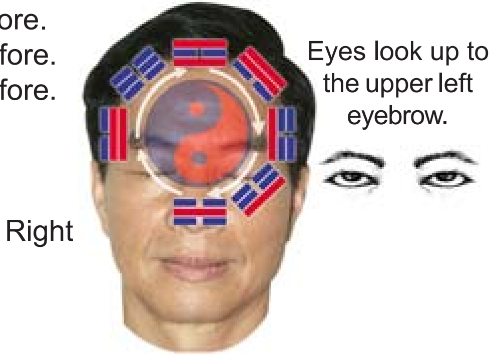
Eyes look up to the upper left eyebrow.
Right

Fig. 5.57 *Sun*

Chien ☰

Imprint Chien on your lower right cheek bone. Start with the eyes looking down to the lower right cheek bone, chanting Chien-Chien-Chien, and then Yang-Yang-Yang, Yang-Yang-Yang, marking it with your fingers on your forehead. Project the symbol into the universe as you breathe through your forehead. Picture the symbol with its bright red colors and when it connects to your forehead, bring it down to its place in the pakua in your lower abdomen.

a. **Yang Expand:** Do as before.
b. **Yang Expand:** Do as before.
c. **Yang Expand:** Do as before.

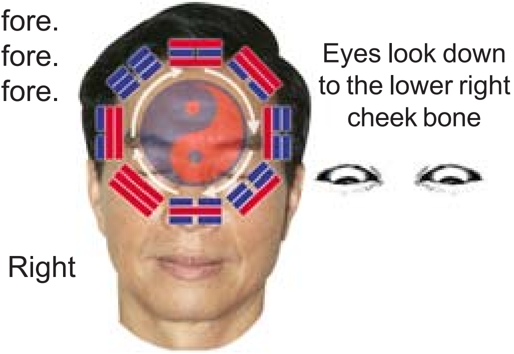
Eyes look down to the lower right cheek bone
Right

Fig. 5.58 *Chien*

Note: Any time that you feel the energy shooting into your forehead, right where the senses' control is located, bring both the senses' energy and the energy from the universe down to your abdomen.

4. Form the pakua on your face to turn the senses inward.

Chant Kan-Li-Chen-Tui-Kun-Ken-Sun-Chien and mark the place of the specific kua with your fingers.

a. Kan is on your bridge of the nose.
b. Li at the top of your forehead.
c. In this pakua Chen is on (inside) your left ear.
d. Tui is on (inside) your right ear.
e. Kun in your brain above the right eye.
f. Ken inside your cheek bone on the left side.
g. Sun in your brain above the left eye.
h. Chien inside your cheek bone on the right side above.

Repeat the chanting in your mind and let your eyes move to the place of each kua. Feel the power of the symbols attracting your senses in to the mideyebrow. Chant and spiral the Tai Chi symbol with your finger and then only with your mind. Let the Tai Chi spin fast and faster. Keep on chanting the Tai Chi symbol until the energies are pulled to the center of the pakua. You should feel that all the energy is flowing to the center of the face pakua and connecting to center of the brain, the crystal room, and keep on spiraling and be aware of the Lower Tan Tien, Tai Chi, and also the spiraling of the facial pakua itself. Feel a very strong center in your forehead and bring it down to the center of the lower pakua.

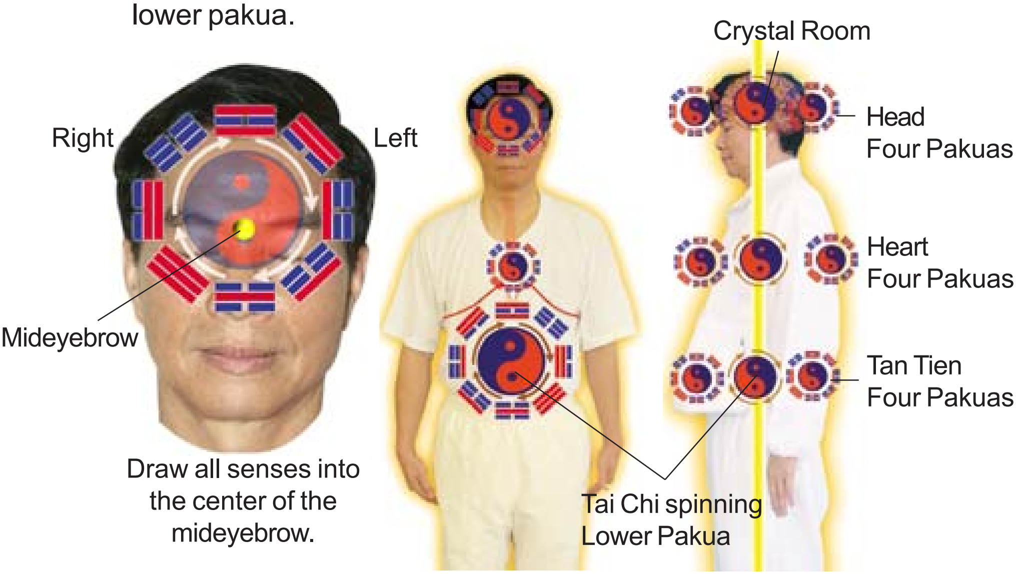
Right
Left
Mideyebrow
Draw all senses into the center of the mideyebrow.
Crystal Room
Head Four Pakuas
Heart Four Pakuas
Tan Tien Four Pakuas
Tai Chi spinning Lower Pakua

Fig. 5.59 *Pakua on your face to turn the senses inward*

Creating the Back Pakua on the Head

Duplicate trigrams, pakua and the Tai Chi symbol to the back and spiral clockwise while chanting the Tai Chi, Tai Chi. The mind and the eyes are spiraling as well, going faster and faster. When you spiral as fast as possible, you will feel that the energy is drawing into the back Pakua.

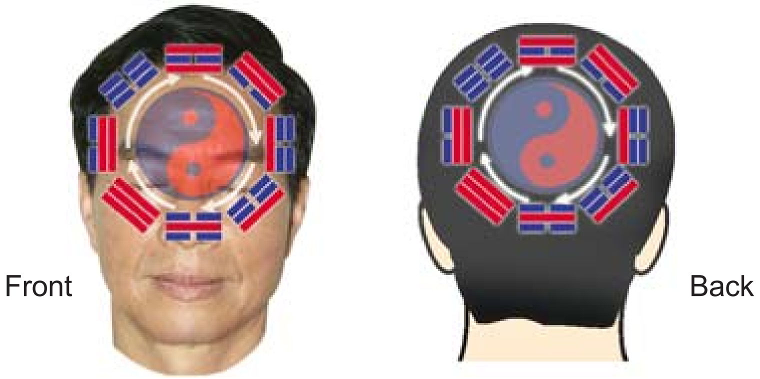

Fig. 5.60 *Pakua on the Head*

Be aware of the front and back Pakuas and spiral them. Spiral in the center faster and faster drawing the front and back into the center.

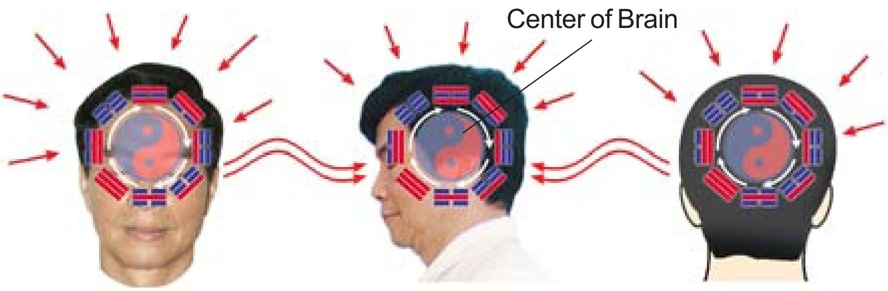

Fig. 5.61 *Front and Back Pakuas spiraling.*

Duplicate the front Pakua to the left side and let the Tai Chi symbol spin.

Duplicate the back Pakua to the right side of the head and let the Tai Chi symbol spin. Become aware of the center of the brain, the crystal room and let it spin faster and faster, drawing the energy of the left and right Pakuas into the center.

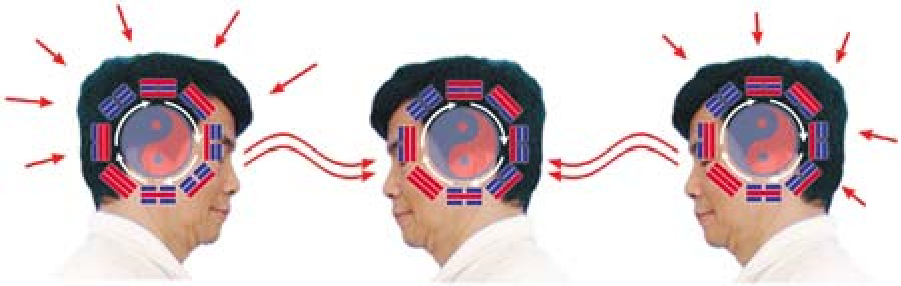

Fig. 5.62 *Energy of the left and right Pakua into the center of the Brain.*

Be aware the front, back, left and right Pakuas and let them spin. Put more attention on the center of the brain and let the center spin faster and faster, drawing all the energy into the center.

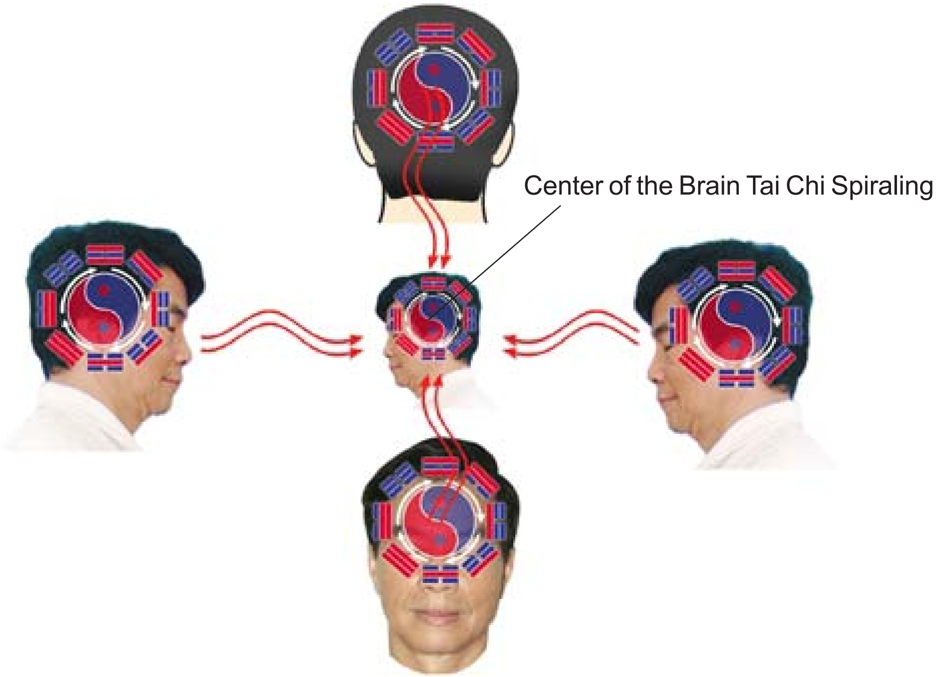
Center of the Brain Tai Chi Spiraling

Fig. 5.63 *Draw all the energy into the Center.*

Connecting the Senses with the Sense Control of the Facial, Heart and the Abdominal Pakuas.

Repeat the facial pakua again: Kan-Li-Chen-Tui-Kun-Ken-Sun-Chien. This time, when you spiral the Tai Chi symbol as you chant Tai Chi, add the motion of the Yin coming in and the Yang going out. Your mouth is open projecting the sound of Yang into space. Your fingers are pointing out into space as well. With the sound of Yin your fingers are pointing in towards your forehead, which facilitates the inward movement of the energy. Picture a Tai Chi spiraling inside your brain, right behind your forehead. Point, spiral with your fingers saying Yin-Yang, Yin-Yang, Yin-Yang, and then Tai Chi, Tai Chi, Tai Chi. Continue saying it in your mind and feel the pakua deep inside your head (about 2-3 cm behind your forehead). All the senses are drawn together inside the center of the facial pakua (the senses' control point) and their energy is brought down to the Tai Chi of the lower abdominal pakua.

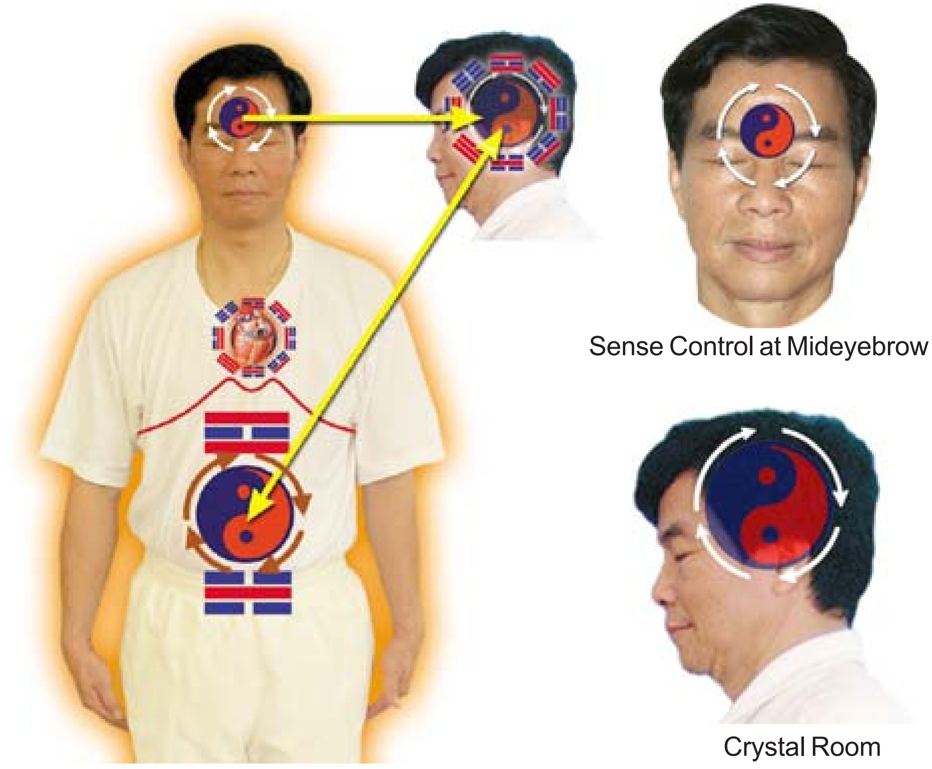

Sense Control at Mideyebrow

Crystal Room

***Fig. 5.64** Let the center of the brain, the heart and abdomen pakuas and all Tai Chis spiral together.*

Blending all the Energy of the Organs and Senses together in the Cauldron

Look down to your center in the Tan Tien and focus on the pakua on the back and on the right and the left pakua. When you focus on them, they will just start spiraling on their own. Look down into your center, into the cauldron and start spiraling the Tai Chi symbol in the center of your cauldron while chanting Tai-Chi, Tai-Chi, Tai-Chi. Rest. Continue to spiral with only your mind and feel that the energy of your senses and organs is coming right down to your center, where all the energy blends into one central energy. Rest. Spiral the energy in your abdomen. Smile to this energy and feel very calm and peaceful.

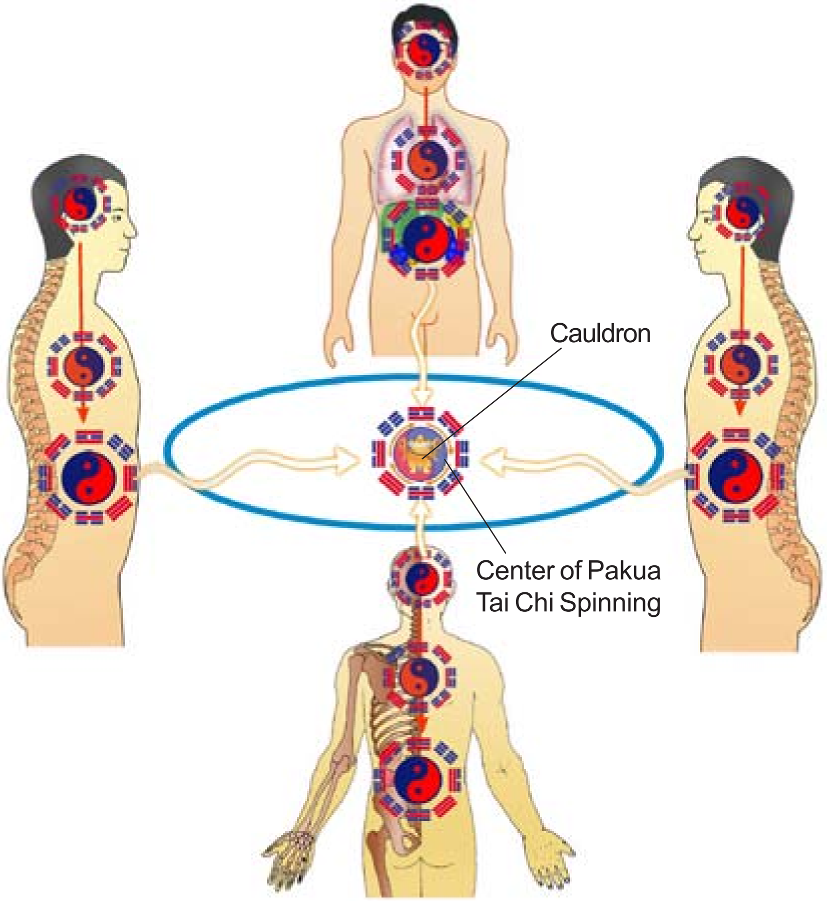

Fig. 5.65 *Draw all the sense into the center of the Pakua and Tai Chi.*

Expanding the Pakua in the Universe.

The power of the symbol is the power of the throat, the power of the word. The forces of the universe are Yin and Yang forces and the kua is a very ancient symbol of power. When you project the pakua out, using the pakua breathing, you connect to the Yin and the Yang power in the universe. When you breathe to the kua out there in space and connect to it, you will feel it connect to the kua in your abdomen as well.

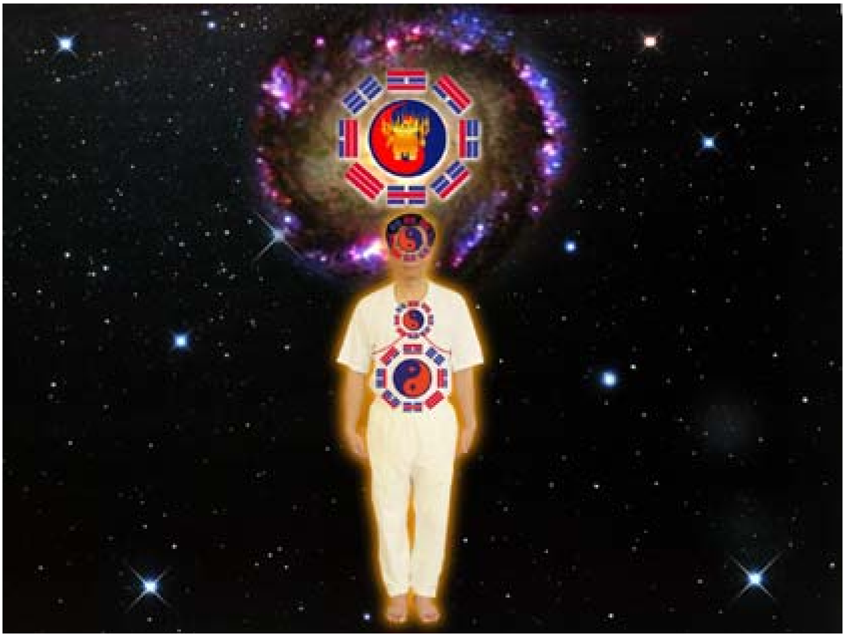

Fig. 5.66 *Pakua in the Universe*

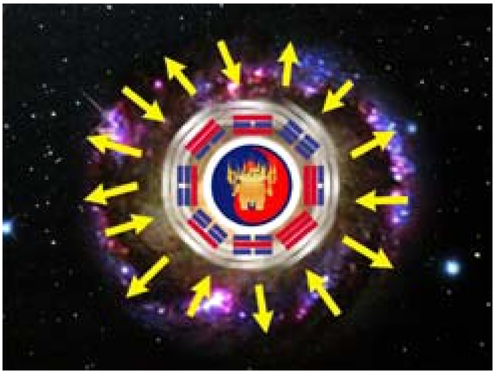

Fig. 5.67 *Feel the Pakua Breathing and Pulsating.*

1. Start chanting Kan-Li-Chen-Tui-Kun-Ken-Sun-Chien touching each of the kuas as you chant them. Continue to do this with only your mind, saying the name of the kua and holding the symbol in front of your eyes. Then spiral the Tai Chi symbol from the bottom to the right and up, chanting it and spiraling with your hand, eyes and mind. Continue to spiral with your mind and eyes only. Feel that the energy is drawn inward and the Tai Chi symbol is spiraling and changing to violet light.
2. Activate the facial pakua. Chant each of the symbols and point to them on your face; Kan-Li-Chen-Tui-Kun-Ken-Sun-Chien. Do it several times and make then the Tai Chi symbol on your forehead: Tai Chi, Tai Chi, Tai Chi, spiraling with your fingers over the third eye area. Feel the energy drawn into the center of the forehead, drawing the senses inwardly to the senses control and connecting down to the lower pakua. On their way down they collect the energy from the organs as well.

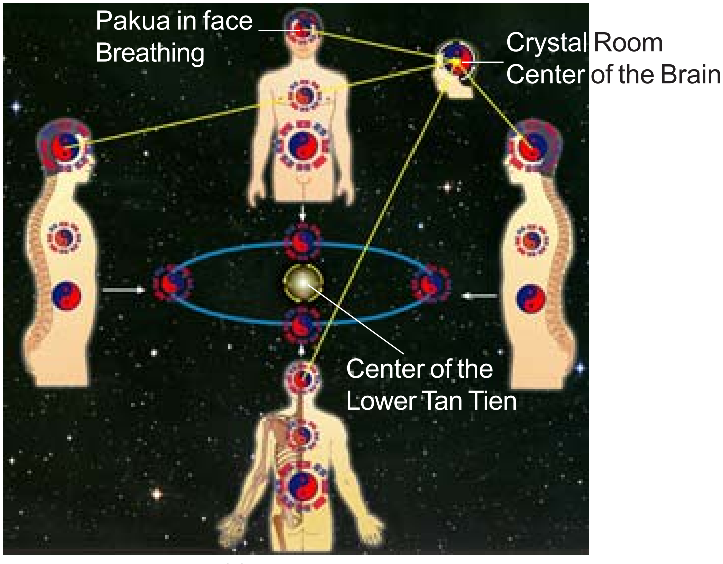

Fig. 5.68 *Four Head Pakuas*

3. Chant now Yin-Yang, Yin-Yang, Yin-Yang. Contract with Yin and expand from the forehead out with Yang. Use your fingers to point the direction of the energy, in and out.
4. Rest. Smile, feel the Tai Chi very deep inside you spiraling and chant Tai Chi, Tai Chi, Tai Chi, Tai Chi. Feel the facial pakua go into your head.

5. Become aware of the Kan symbol. Picture the Kan symbol and project it out down all the way to the galaxy. Chant Kan, Kan, Kan. Chant and picture the Yin-Yang-Yin lines and feel that the power is going out all the way to outer space.

   Start then with the Yin-Yang breathing. Inhale, Yin contracting with bright violet light, exhale, Yang expanding with bright red light. Inhale, contracting, exhale, expanding. Feel the kua of the facial pakua and the abdominal pakua breathing and at the same time, feel the kua in the universe breathing. Picture the Yin-Yang-Yin very clear in your mind as well as very far away in space. Exhale, hold your breath and feel the symbol breathing. Inhale, breathe without breathing and feel the connection with the kua out there. Keep on breathing in this way until suddenly the kua out there comes to you and enforces the Kan in your abdomen.
6. Repeat the same procedure for Li, sending it out, up into the universe, for Chen sending it out into the space on your right side, Tui to the space on your left side, Kun to the space upper left, Ken to the lower left side, Sun to the upper right side of the universe and Chien to the lower left side of the universe.
7. Now picture all the kuas together and repeat their names very slowly: Kan-Li-Chen-Tui-Kun-Ken-Sun-Chien. Rest. Feel the universal pakua covering you. Feel this pakua breathing and pulsating together with your pakua in the abdomen and on your face, drawing the energy back into the lower pakua, into your center. Sit back and smile to the pakua inside you and to the pakua in the universe. Rest, concentrate and condense all the energies in the cauldron.

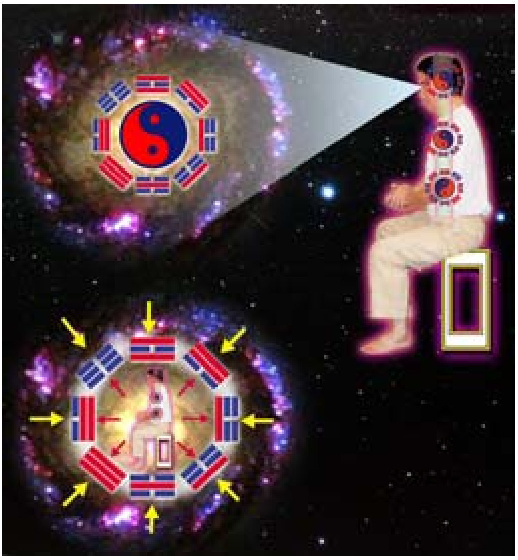

Fig. 5.69 *Feel all the Pakua and Universal Pakua breathing and pulsating. Feel a big Pakua cover you, breathing and pulsating.*

Formula Two: Transforming the Negative Emotions of Each Organ into Pure Life-Force Energy

Taoists reason that the negative emotions can be transformed to become our life-force and position energy. Therefore to expel or suppress unwanted, negative emotions is to expel or suppress life-force. Rather than suppressing them, you gain more by composting, recycling or transfering the negative into positive energy and experiencing these emotions. This means you permit them to emerge, observing and accepting them, but do not let them run wild or trigger other negative emotions. Instead transform them not only into useful life-force energy, but also into another, higher consciousness that is your spiritual energy.

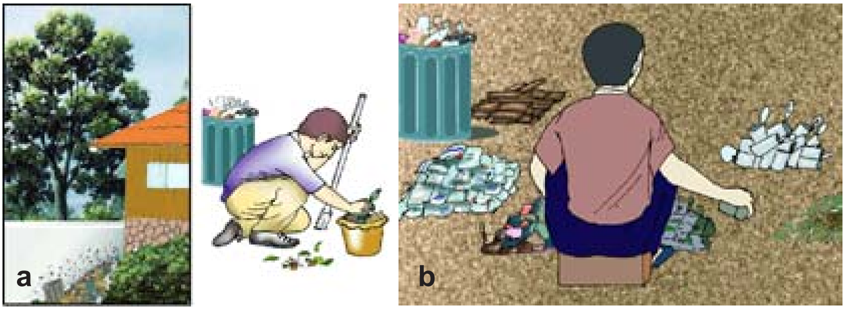

a.*Pile all the garbage together, just like mixing all the emotions together.*

b.*Separate the garbage, just like separating emotions & transfer them.*

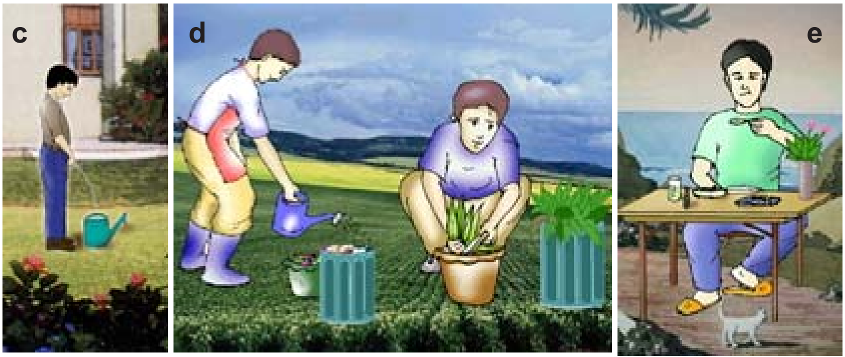

c.*Recycle and compost.*

d.*Recycling the garbage into compost and growing flowers and vegetables.*

e.*Eating the food grown from the compost.*

Fig. 5.70 *Transforming the Negative Emotions*

In the Taoist cosmology, the emotions originate from the vital organs, which correspond to the Five Phases of energy. They are also the reservoir of spiritual energy. By transforming the negative emotions in the organs, you are nourishing the spirit of that organ. Fear originates in and is stored in the kidneys, anger and frustration originate in and are stored in the liver, impatience, hastiness and hatred originate in and are stored in the heart, sadness and depression originate in and are stored in the lungs and worrying originates in and is stored in the spleen.

In the Tao, the main idea is to find a balance between the positive and the negative emotions. The negative emotions are like weeds, they are always there, and one could never totally get rid of them. The other point is that the soil needs them as fertilizers and they also help hold the soil in place. But at the same time the danger is that they will take over the garden if we don’t control them. We need to cultivate the plants we want (our good virtues) to prevent the weeds from taking over the garden. It is the same with the negative emotions; they should only be kept in balance with the positive ones and one shouldn’t waste time trying to get rid of them altogether. The work should be done on the positive emotions, constantly cultivating and nurturing them in order to grow the good virtues and to keep the right balance with the negative emotions. Negative emotions breed negative emotions and positive emotions breed positive emotions.

Fig. 5.71 *Yin and Yang balance negative and positive emotions but they do not get rid of them.*

We work in this formula with the counteracting or controlling cycle and we use collection points to gather and neutralize the negative emotions of each organ. We then blend the emotional energies together in the pakua, transforming them into pure life-force.

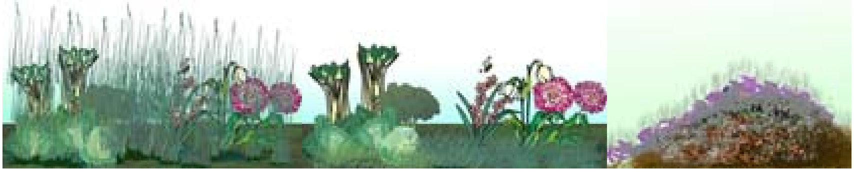

Fig. 5.72 *Keep on cultivating the positive emotions. Do not let the weeds out grow the vegetables.*

Practice:

1. Preparation

When you begin, first do Formula Two and then continue with this practice.

a. Sit properly on a chair and feel yourself aligned with the forces.
b. Do the crane and turtle neck and the spinal cord breathing
c. Smile down and generate the qualities of loving energy from the heart. Breathe down radiance to the heart making it feel soft in the heart.
d. Be aware of the Tan Tien Chi and the front pakua, the pakua on your face, and the universal pakua. Feel them all breathing together. Feel all your senses and mind turned inwards to the cauldron. Turning the senses inward initiates the training process of inner observation. In developing the ability to focus inward – to smell, listen, taste, see and hear the organs and their activities – and to observe your negative emotions without predetermined judgments, you have the opportunity to develop your true nature.

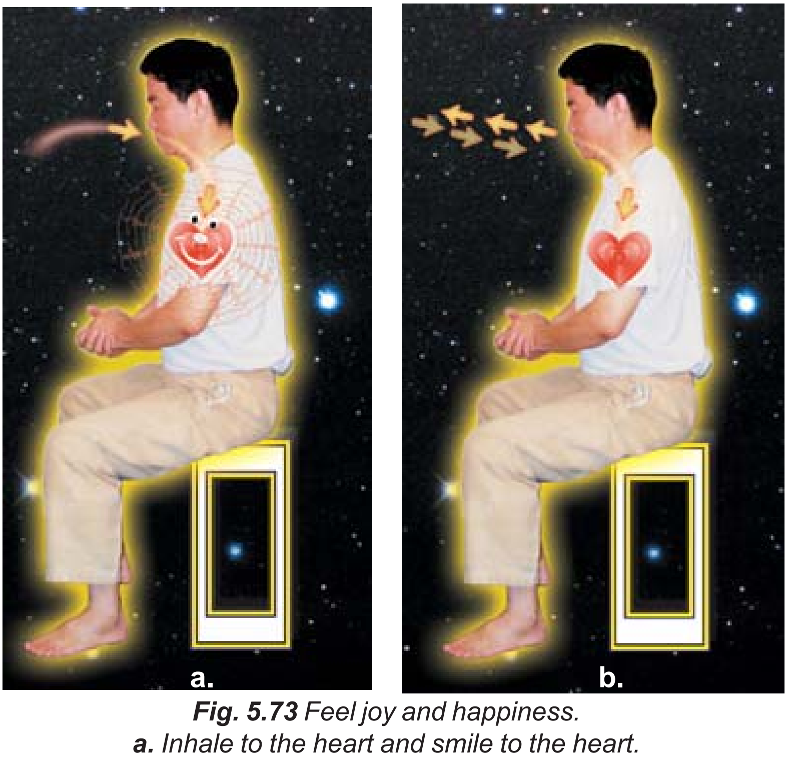

Fig. 5.73 *Feel joy and happiness.*
a. *Inhale to the heart and smile to the heart.*
b. *Exhale to the heart, smile to heart and make the heart feel soft.*

2. Real Practice

A. Bring your attention to your kidneys.

Listen to the kidneys, observe your kidneys. Be aware of any fear in the kidneys. Accept your fear; smile to the heart and let the love radiate to the kidneys. Be aware of the Kan, the water power. Chant the Kan and connect your kidneys with this energy. Let love activate the gentleness, calmness and stillness, the essence of this power, a blue light. Wrap the gentleness, calmness around your fear, balancing it and transforming your fear.

Form with your mind a collection point at your perineum and let any fear that is still in the kidneys go down to the collection point. Balance these emotions here also with the positive feeling of gentleness and calmness.

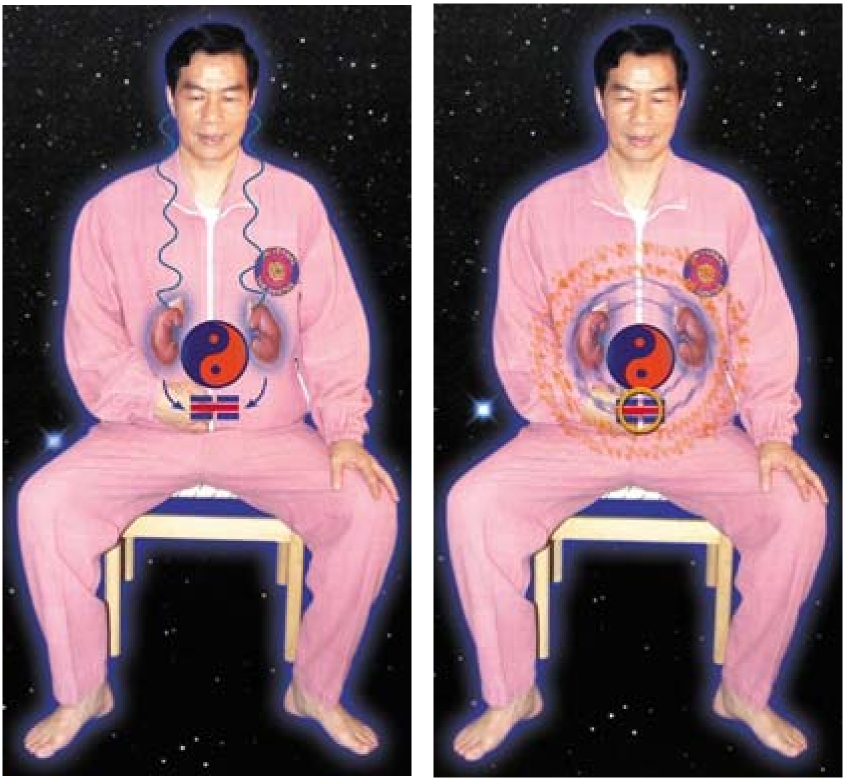

a. **b.**

Fig. 5.74

a. *Fear - Gentleness*

b. *Fear into Gentleness and Calmness*

B. Bring your attention to your heart.

Connect the tongue with your heart, speak with your heart (the spirit of your heart). Observe your heart. Be aware of any impatience, hastiness, cruelty, hatred, arrogance in your heart. Accept these feelings. Be aware of the Li, the fire power. Chant the Li and connect your heart with this power, a red light. Feel the warmth, love, happiness and inner joy, the essence of this power. Help transform the hatred into love. Wrap the love, the warmth and inner joy around your impatience, arrogance, balancing them with and transforming your impatience, hastiness, arrogance.

Form with your mind a collection point near the heart center and spiral all the negative energies that are still in the heart to this collection point. Chant the Li again and balance the emotions in the collection point.

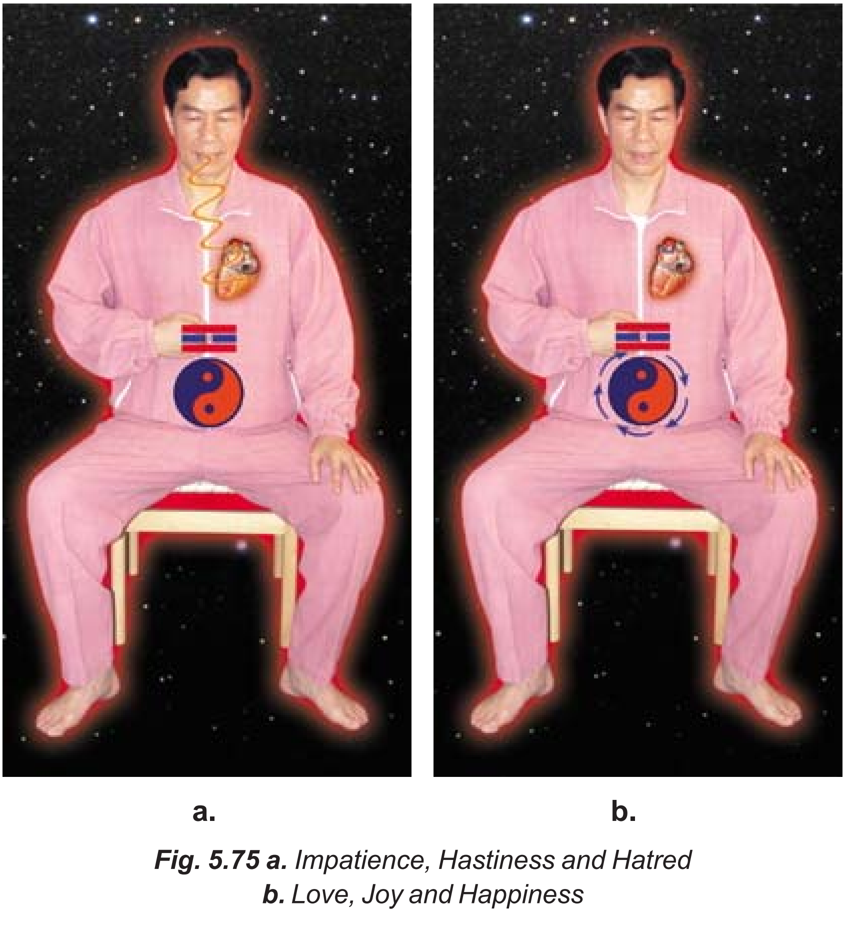

a. **b.**

Fig. 5.75 a. *Impatience, Hastiness and Hatred*
b. *Love, Joy and Happiness*

C. Spiral, blend and transform the energy of the heart and the kidneys at the front pakua.

Spiral and breathe the energies out of the kidney and heart collection points to the front pakua. Blend and spiral them together in the front pakua. (The pure energy trapped in these negative feelings will be freed and released to the center of the pakua). Chant Tai Chi, Tai Chi, Tai Chi. Yin-Yang, Yin-Yang, Yin-Yang. Spiral these energies until they become a bright, golden energy. This energy radiates love and gentleness from the center of the pakua and your being.

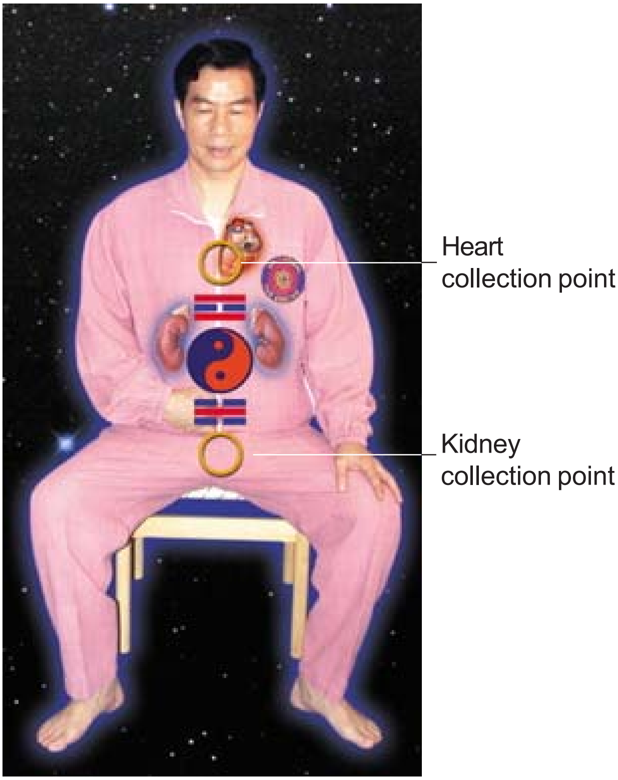

Fig. 5.76 *Spiral, blend and transform the energy of the heart and the kidneys.*

D. Bring your attention to your liver.

Connect the eyes with the liver and observe your liver. Be aware of any anger, frustration, aggressiveness, guilt in the liver. Accept this feeling. Be aware of the Chen. Chant the Chen and connect your liver with the power of the thunder and the wood, a green light. Feel the kindness, the essence of the wood power. Wrap this feeling of kindness around your anger, balancing them together and transforming your anger. Feel that you can forgive. Forgiveness is one of the most important practices of the Taoist system.

Form with your mind a collection on the left side of the pakua, on the nipple line, and spiral all the negative energies that are still in the liver to this collection point. Chant the Chen again, connect with the wood power and balance the emotions in the collection point.

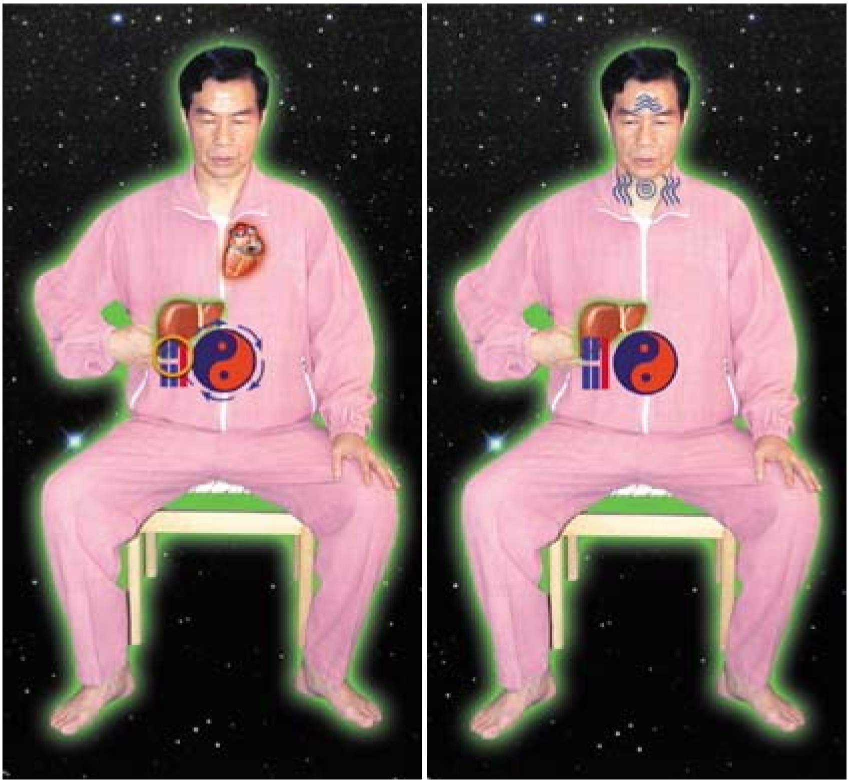

Fig. 5.77 a. *Anger and Frustration in the Liver*
b. *Love from heart and gentleness from kidneys help tranfrom the anger and frustration into kindness.*

E. Bring your attention to your lungs.

Connect your nose with your lungs and observe your lungs. Be aware of any sadness, depression in the lungs. Accept these feelings. Be aware of the Tui. Chant the Tui and connect your lungs with the power of the rain and the metal power, a white light. Feel the courage and the righteousness, the essence of the metal power. Wrap this courage around your sadness, balancing it with and transforming your sadness.

Form with your mind a collection point on the right side of the pakua on the nipple line and spiral all the negative emotions that are still in the lungs to this collection point. Chant the Tui again, connect with the metal power and balance the sadness with the courage here again.

F. Spiral, blend and transform the energy of the liver and the lungs at the front pakua .

Spiral and breathe the negative emotional energies from the liver and lungs collection points to the front pakua. Spiral and blend them at the front pakua. Chant Tai Chi, Tai Chi, Tai Chi, Yin-Yang, Yin-Yang, Yin-Yang. Use the power of pakua to balance and neutralize the sadness and anger. Feel that the pure energy that is trapped in these negative feelings will be freed and released to the center of the pakua. Continue to spiral the liver's and lungs' energies until they become a bright, golden energy that radiates kindness and courage from the center of the pakua and of your being.

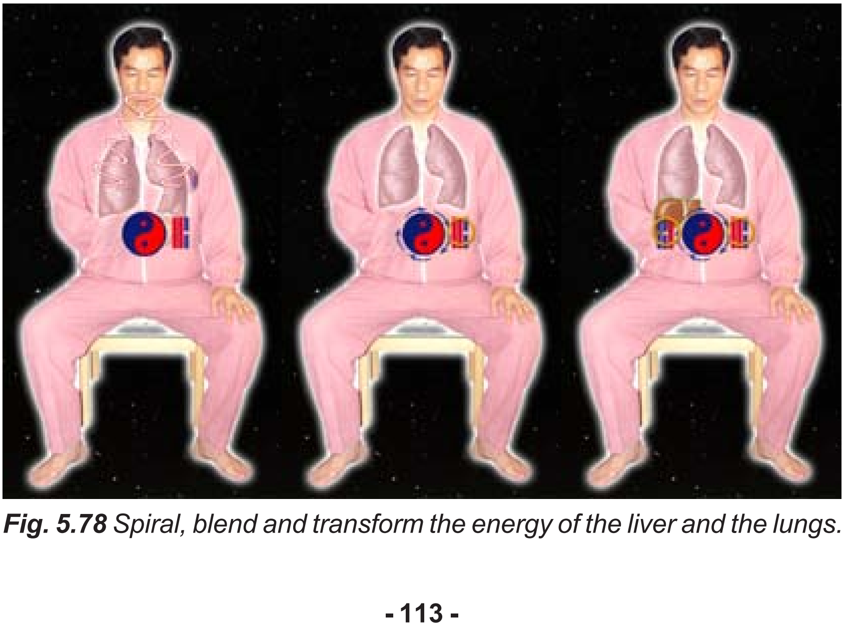

Fig. 5.78 *Spiral, blend and transform the energy of the liver and the lungs.*

G. Bring your attention to your spleen.

Connect your mouth with your spleen and observe your spleen. Be aware of any worry or other emotions you do not like in your spleen. Be aware of the Kun. Chant the Kun and connect your spleen with the earth power, a yellow light. Feel the openness, balance and centeredness of this power, the essence of the earth power. Wrap this around your worries, balancing with and transforming your worries.

Spiral your worries that are still in the lungs to the center of the front pakua, the collection point of the spleen. Chant the Kun again and then Tai Chi, Tai Chi, Tai Chi. Yin-Yang, Yin-Yang, Yin-Yang. Spiral, balance, blend and transform it with the energy that is already there into a bright, golden energy.

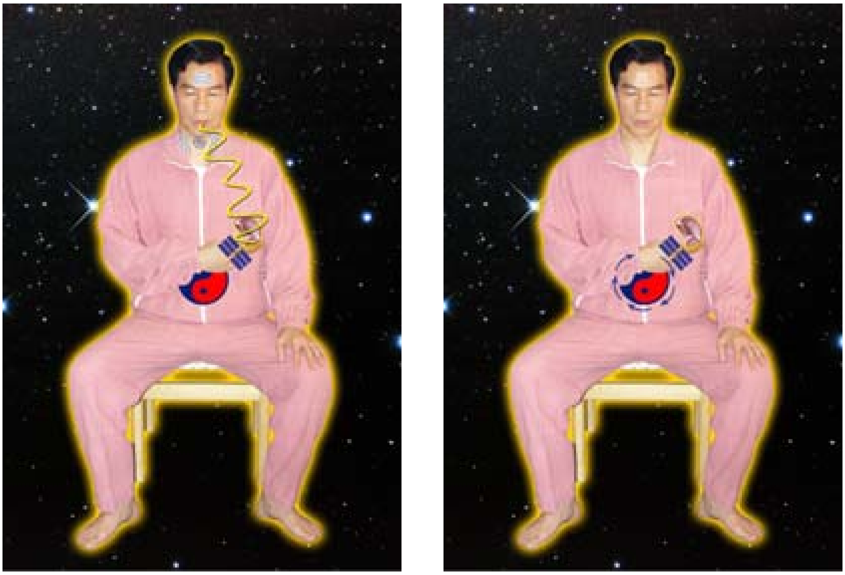

Fig. 5.79 a. *Draw attention to your spleen.*
b. *Balance, Openness and Fairness*

H. Spiral all remaining negative energy to the front pakua.

Return to the organs and the collection points, and spiral and breathe to draw out any remaining negative energy. Blend and neutralize it with the energy in the front pakua. See all the organs glowing with light.

I. Be aware of the back, left and right pakuas.

When you have time, you can chant the kuas to enforce the power of the pakuas. Let the Tai Chi in all four pakuas spiral, drawing in, blending and transforming the energies. Continue spiraling and with the spiraling and the breath you draw, suck in the energy to the cauldron, the big empty space in the Tan Tien. Now spiral the energy in the cauldron, chanting subvocally Tai Chi, Yin-Yang, condensing the energy into a bright golden energy ball, a pearl. Bring the pearl to the perineum and circulate it in the Microcosmic Orbit. As the pearl moves through the Microcosmic Orbit, feel that it attracts and absorbs the Universal (at the crown), the Cosmic Particle (at the mideye) and the Earth (at the perineum) Force.

Bring the pearl back into the cauldron. Center yourself in the cauldron and feel your senses and mind drawn inward towards the energy in the cauldron. Feel nice, calm and peaceful inside. When you have time, sit for a while and let this energy and feeling grow inside you.

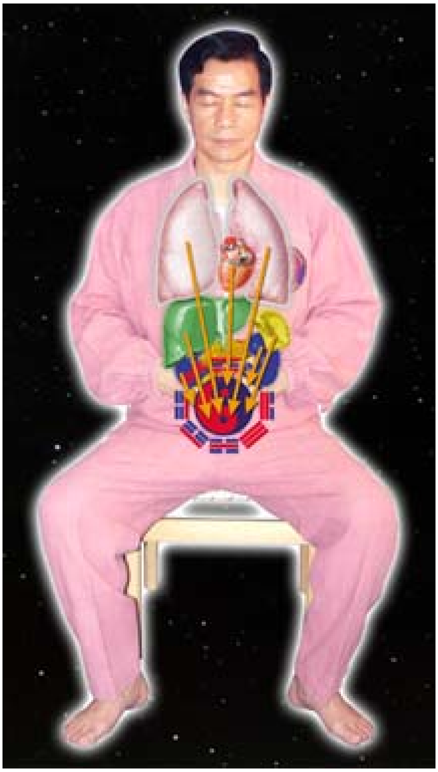

Fig. 5.80 *Let all the Organ Energy flow down to the Pakua and feel Chi grow inside you.*

Chapter 6

Compassion Fire Meditation Practice of the Creation Cycle

Practice compassion through the act of forgiveness. To forgive is to let go. Always meet conflict with compassion.

The higher practice of inner alchemy is the transformation of the heart energy into love, the liver energy into kindness and generosity, the lung energy into courage, the kidney energy into gentleness and the spleen energy into openess and fairness. Combine all these energies into compassion. Compassion becomes non physical energy which we can carry with us when we leave the world. It is the love and joy we feel within.

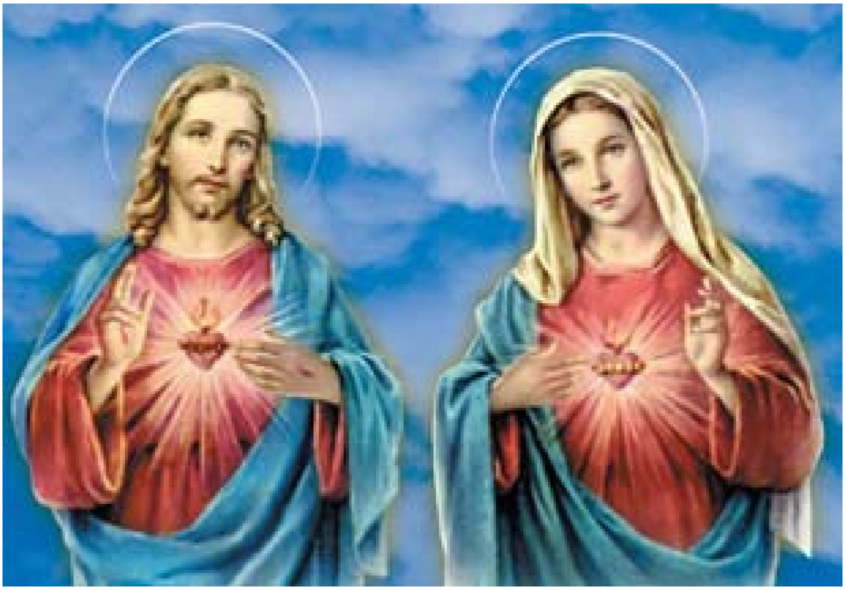

Fig. 6.1 *Compassion Fire originates from the Heart.*

Fig. 6.2 *Through Compassion Fire, we transmit Positive Energy to Our Surroundings.*

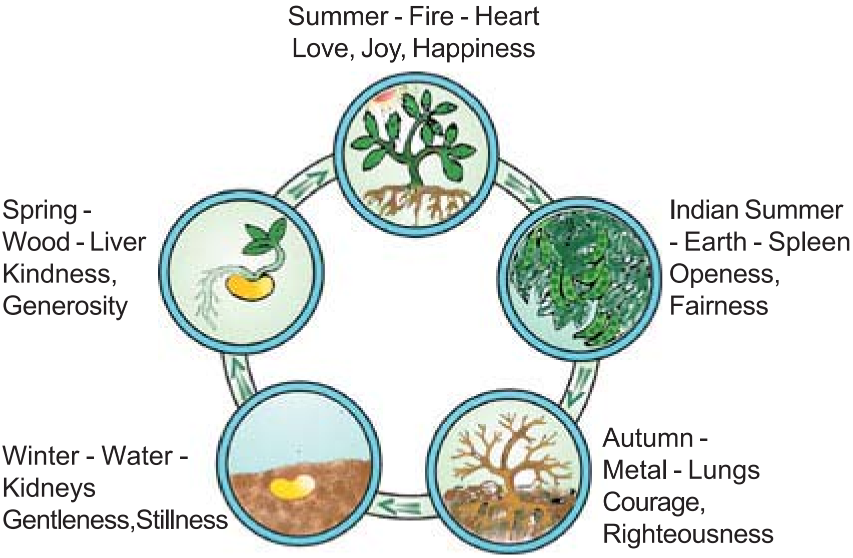
Summer - Fire - Heart
Love, Joy, Happiness
Spring - Wood - Liver Kindness, Generosity
Indian Summer - Earth - Spleen Openess, Fairness
Winter - Water - Kidneys Gentleness,Stillness
Autumn - Metal - Lungs Courage, Righteousness

Fig. 6.3 *Creation Cycle in Nature*

Creating compassion energy begins with the creation cycle.

Activate the heart first. It is the fire and the place where the virtue energy can be combined into compassion energy. Go to the kidneys and bring the energy to the collection sphere. Continue with the liver, the heart again, the spleen, the lungs and bring the energy to the respective collection points.

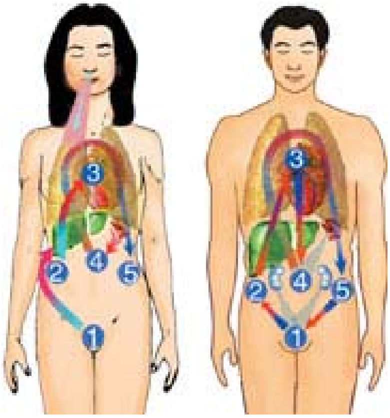

Fig. 6.4 *Creation Cycle*

In the human body the arousal state creates a new chemistry and a new vibration. This 'special' vibration is measured at a frequency of 8Hz/Sec. 'As in the macrocosm, so it is in the microcosm'; hence if we make love, then all cells and the DNA actually make love as well.

The DNA cross over, like two serpents intertwining in an erotic embrace. They make love and they give birth. Any of the cells that do not 'reproduce' will eventually die.

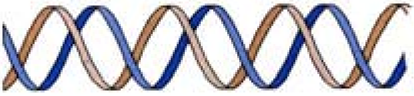

Fig. 6.5 *When we feel love and arousal energy,*
the DNA crosses over and makes love.

The two vital states are arousal, leading to orgasm and compassion are inextricably linked to love. When this 'love-vibration' reaches the pineal gland, a new hormone is produced. This in turn creates whole body conductivity. If the vibration is above or below the 8Hz/Sec. frequency, this process does not occur. Only when you feel the waves of orgasmic vibration and unconditional love for the self and others can the process be activated.

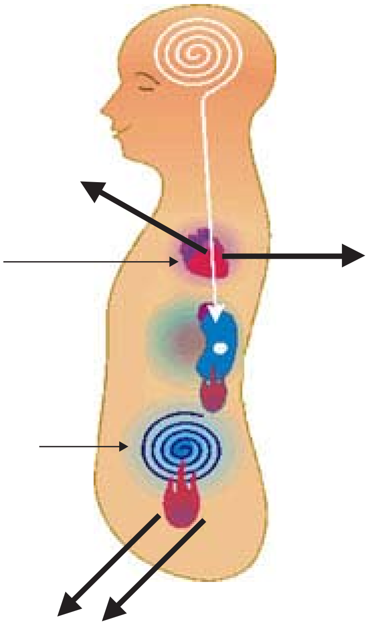

Some practices just want to open the heart by temporarily letting us feel love and kindness. The heart is drained through all kinds of giving and donations.

Worldly desire and many businesses work on activating the sexual desire and then draining it out.

Fig. 6.6 *When the Heart is temporarily open and Sexual Desires activate, these forces will drain us out.*

One Lasting Energy is the Combination of Compassion Energy and Orgasmic Energy

Heart Energy

1. Heart energy is immaterial. When activated it will change into love, but love does not last long.
2. When all the good virtue energy from all the organs combines together into one energy, it becomes compassion energy; it will stay in you longer, but will still disperse.

Sexual Energy

1. Sexual energy when activated from material into immaterial is powerful, but will not last.
2. When the sexual energy is aroused and changes into orgasmic energy, it can charge all the organs, glands, senses and combines into one energy; this energy will stay longer but still will disperse. Orgasmic energy combined with compassion creates one long lasting energy.

After the orgasmic energy has charged all the organs and created the multi-orgasm energy, it can then be combined with the compassion energy at the Tan Tien. This creates the one energy that lasts the longest.

When we are aware of the cosmic galaxy and expand our combined energy of compassion and orgasm through the universe, it multiplies and flows back to us and we will be in touch with universal compassion and unconditional love.

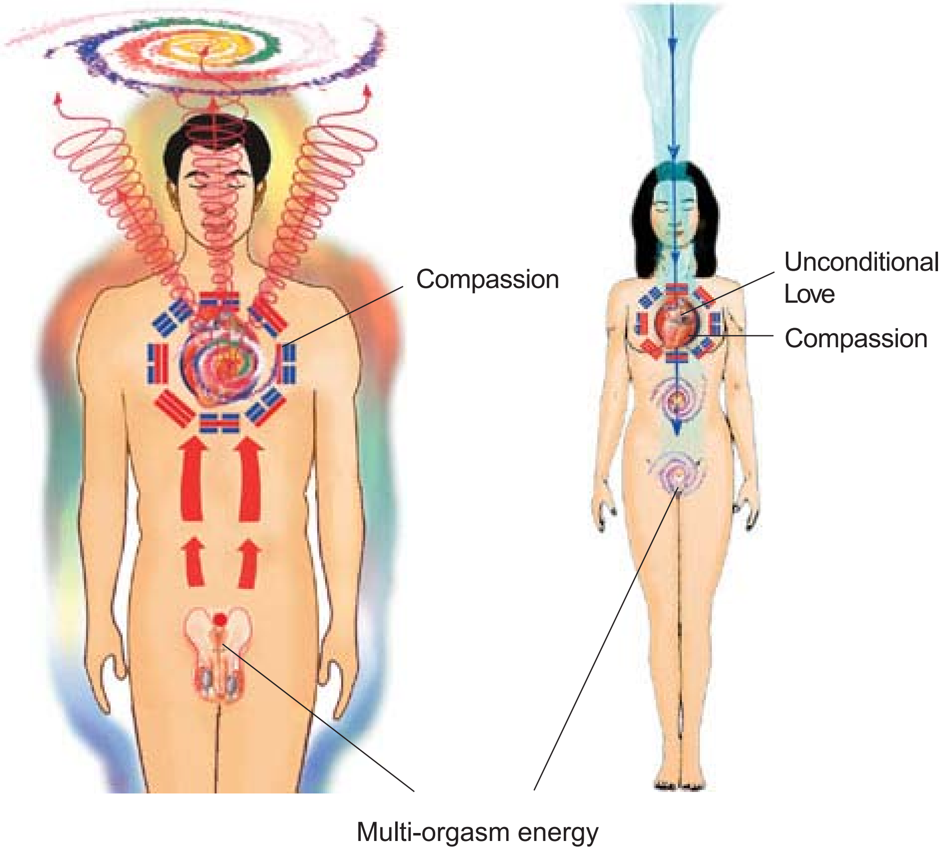

***Fig. 6.7** Through cultivating compassion energy, we can eventually build the one lasting energy.*

Practice of Creating the Compassion Fire and Multi-Orgasm

Compassion originates from the Heart

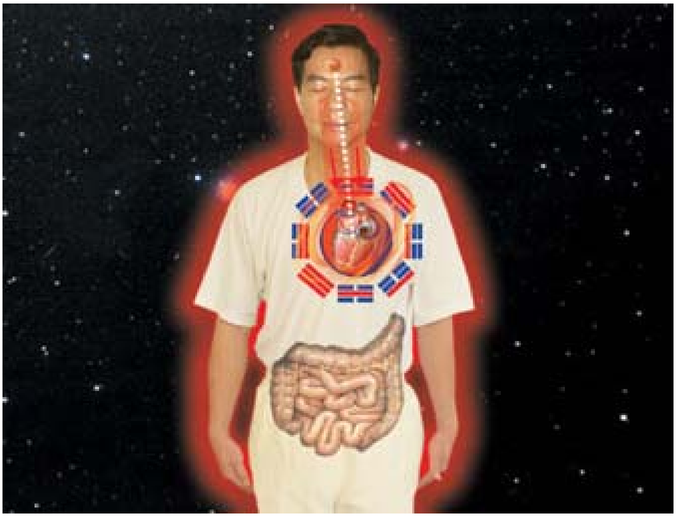

Fig. 6.8 *Smile until you feel the heart soft with love, joy and happiness.*

We can connect with the Universal Love.

1. Be aware of the Tan Tien and the universe and feel the unconditional love flow down.

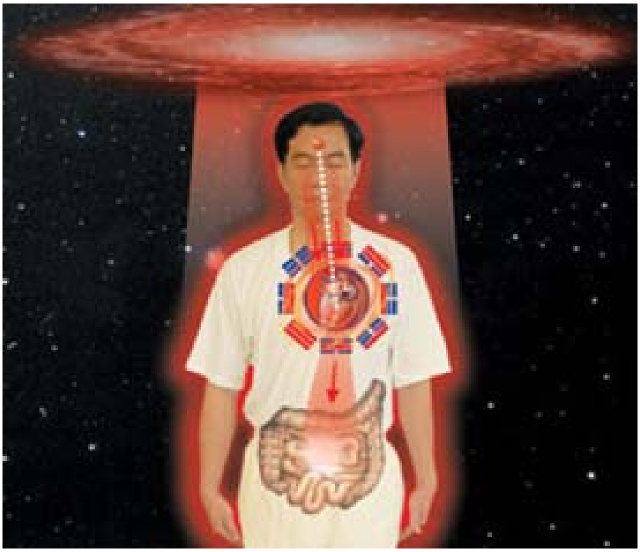

Fig. 6.9 *Smile to the heart and the small intestine, to make the heart feel soft. Feel the heart pakua spiral.*

2. Smile to the spleen and let the love, joy and happiness from the heart activate the openness and fairness.

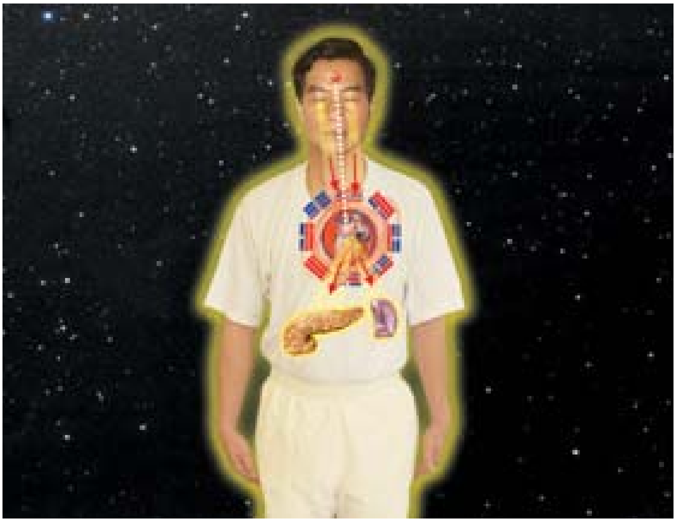

Fig. 6.10 *Let Positive Heart Energies activate Positive Spleen Energies.*

3. Let it flow back to the heart pakua and spiral, blend together and feel the yellow light flow from above and flow down to the heart.

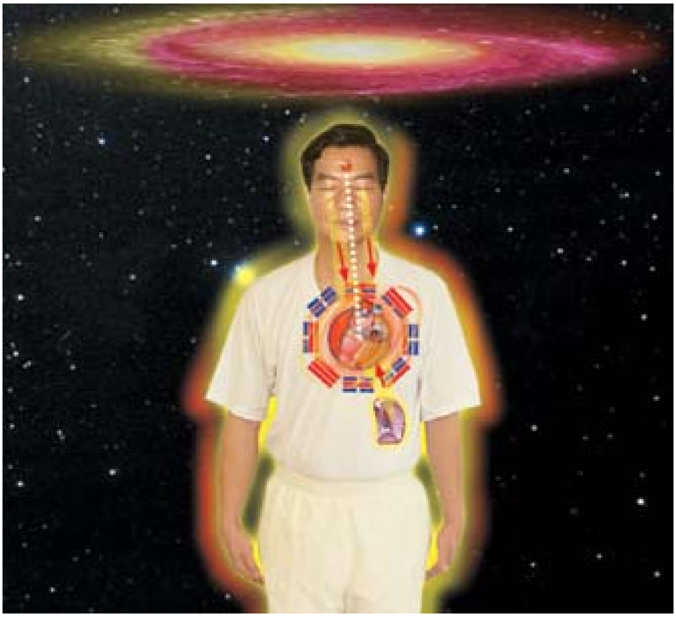

Fig. 6.11 *Blend the Two Energies with Universal Energies.*

4. Smile to the lungs and the large intestine. Send love from the heart to the lungs to activate courage and righteousness.

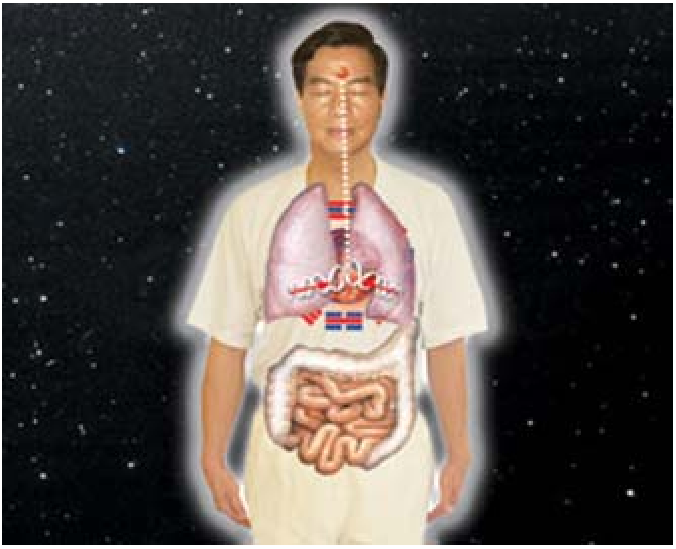

Fig. 6.12 *Let Love and Joy from the Heart activate Positive Lung Energies.*

5. Let it flow to the heart, spiral and blend with love, joy, happiness, openness and courage. Blend the three energies into one energy, and feel the white light from above flow into the lungs and the heart.

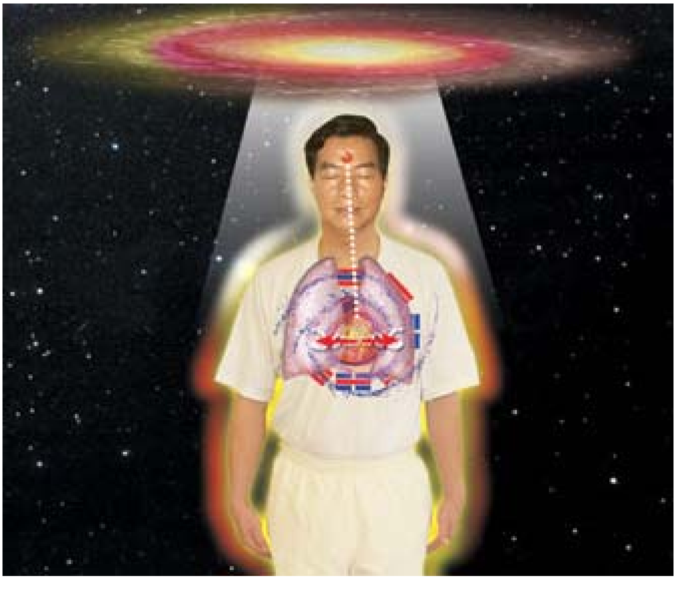

Fig. 6.13 *Blend the Three Energies into One Energy.*

6. Smile to the kidneys and let the love of the heart activate the gentleness, softness and calm in the kidneys.

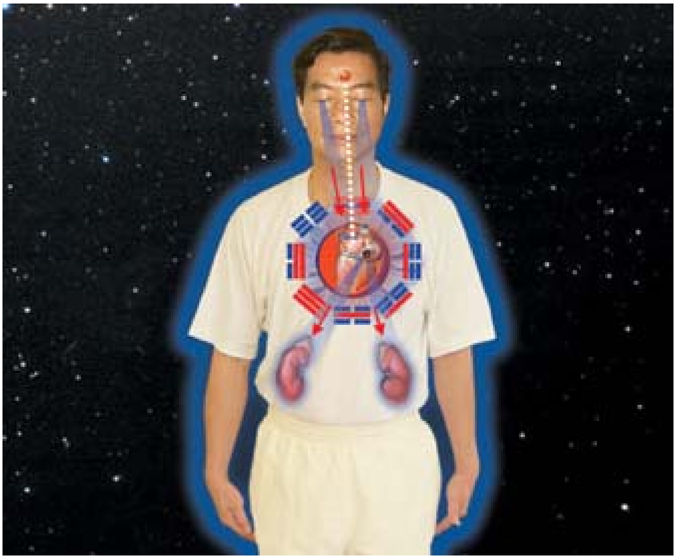

Fig. 6.14 *Let Love and Joy from the Heart activate Positive Kidney Energies.*

7. Let the gentleness, softness and calm in the kidneys flow into the heart. Blend and spiral into one energy.

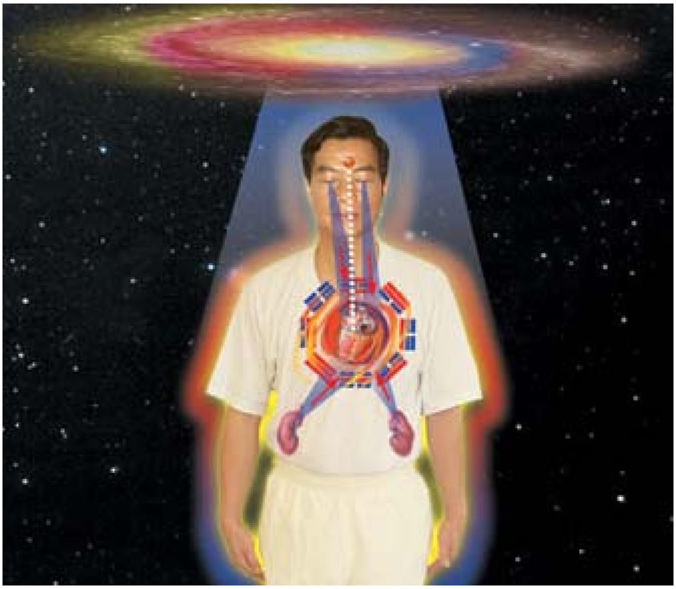

Fig. 6.15 *Blend Positive Kidney Energies with the Compassion Energy in the Heart.*

8. Smile to the liver and gall bladder. Let the softness and the love from the heart flow down to activate the kindness and generosity of the liver.

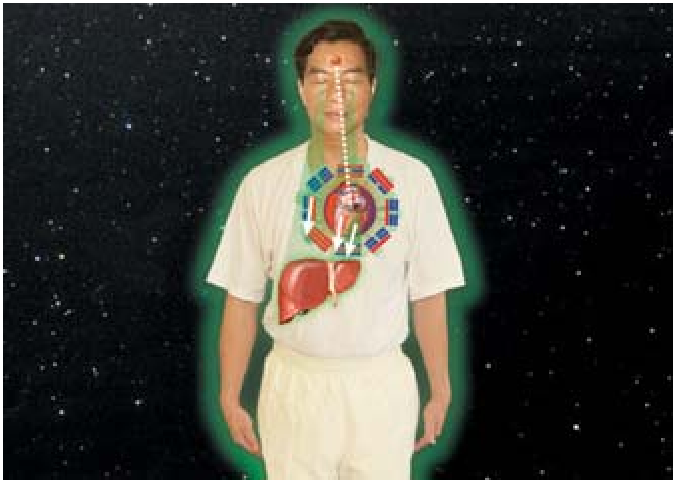

Fig. 6.16 *Let Love and Joy from the Heart activate Positive Liver Energies.*

9. Let the kindness and generosity flow to the heart, spiral and blend in the heart to become compassionate; be aware of the green light flowing from above.

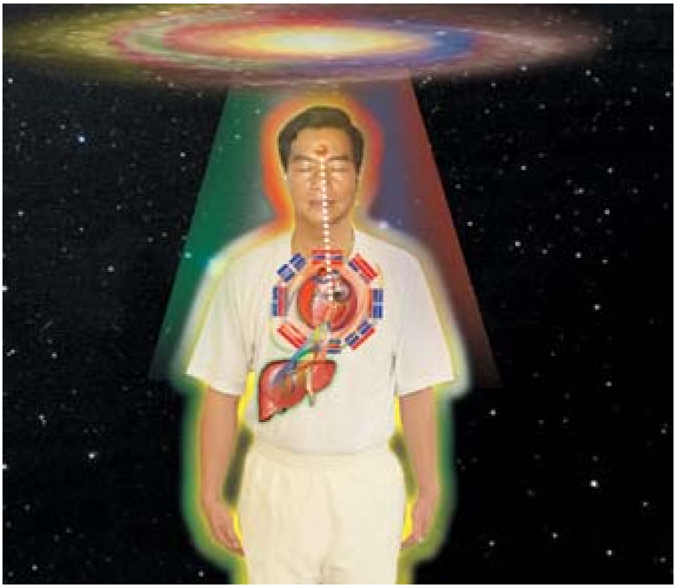

Fig. 6.17 *Blend Positive Liver Energies into the Compassion Energy.*

10. Smile to the heart and feel all the good virtuous energy from all the organs flow into the heart and spiral and blend into compassionate energy.

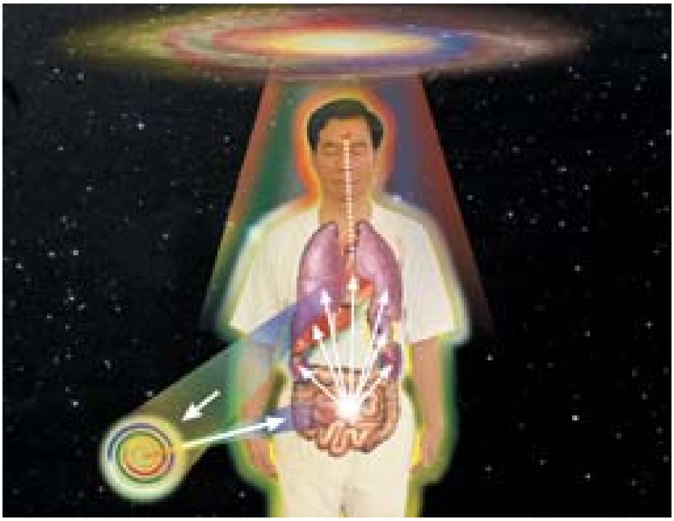

Fig. 6.18 *All the Organs' Positive Energies blend with the Heart to create the Compassion Energy.*

11. Your compassion rises up. Be aware of the galaxy, the cosmos, and expand your compassion through the universe. The universe allows us to be in touch with the universal compassion.

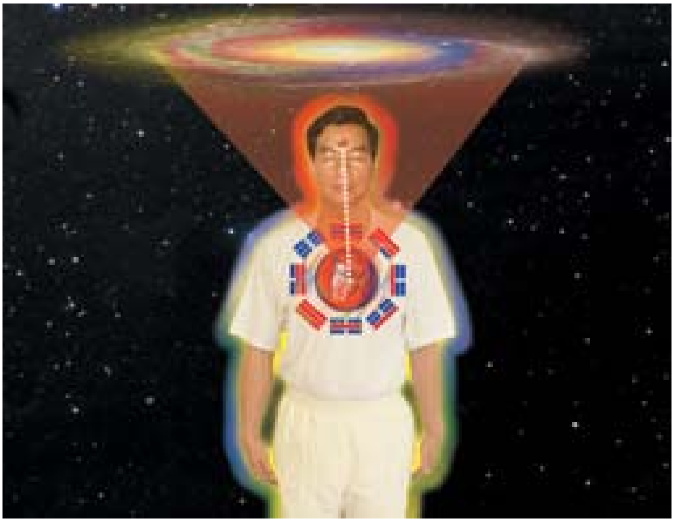

Fig. 6.19 *Expand our Compassion to be in touch with the Universal Compassion.*

12. Let them blend and multiply, and flow back to enhance you. You feel your whole body to be filled with the universal compassion. You have such abundance, it overflows.

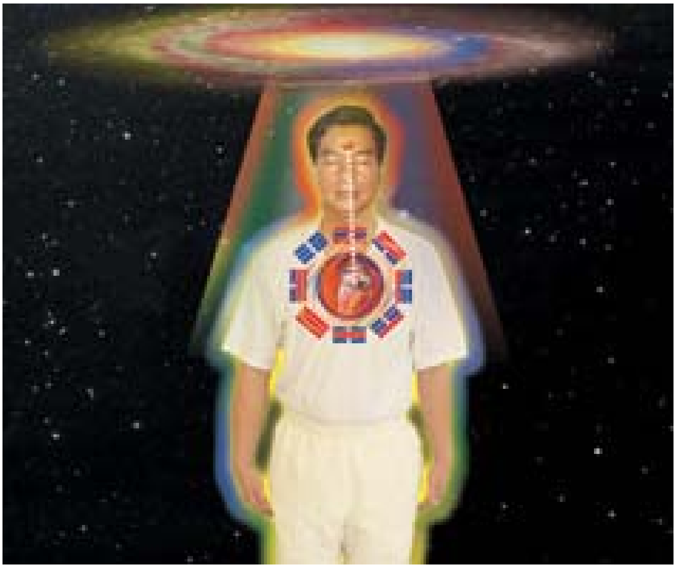

Fig. 6.20 *Let the Universal Compassion within us overflow.*

Multi-Orgasm Energy Smile to the Sexual Organs

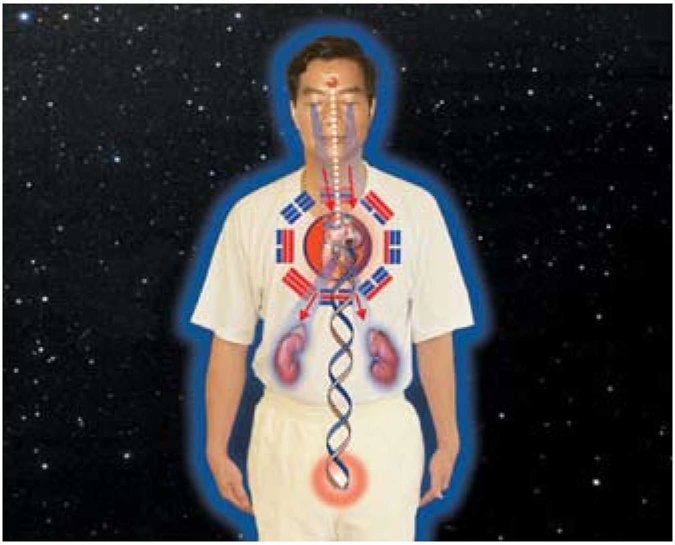

Fig. 6.21 *Smile down to the Heart and feel warm Energy from Heart flow down to Kidney and the Sexual Organs.*

1. Be aware of the sexual organ and use your hand to cover the sexual center. Smile and feel the fire from the Tan Tien flow down.
2. Recall the time when you were with your loved one and the high orgasmic feeling. Guide the orgasmic energy up to the kidneys, and feel the kidneys charge with Chi and orgasm.
3. Guide the orgasmic energy spiraling up to the small and large intestine, liver, spleen, pancreas, stomach, and up to the lungs, and heart. Continue up to the thymus, thyroid and parathyroid and up to the brain and the senses. Charge them with orgasmic energy, and let the Chi flow back down to the sexual organs and blend and spiral into one multi orgasmic energy.

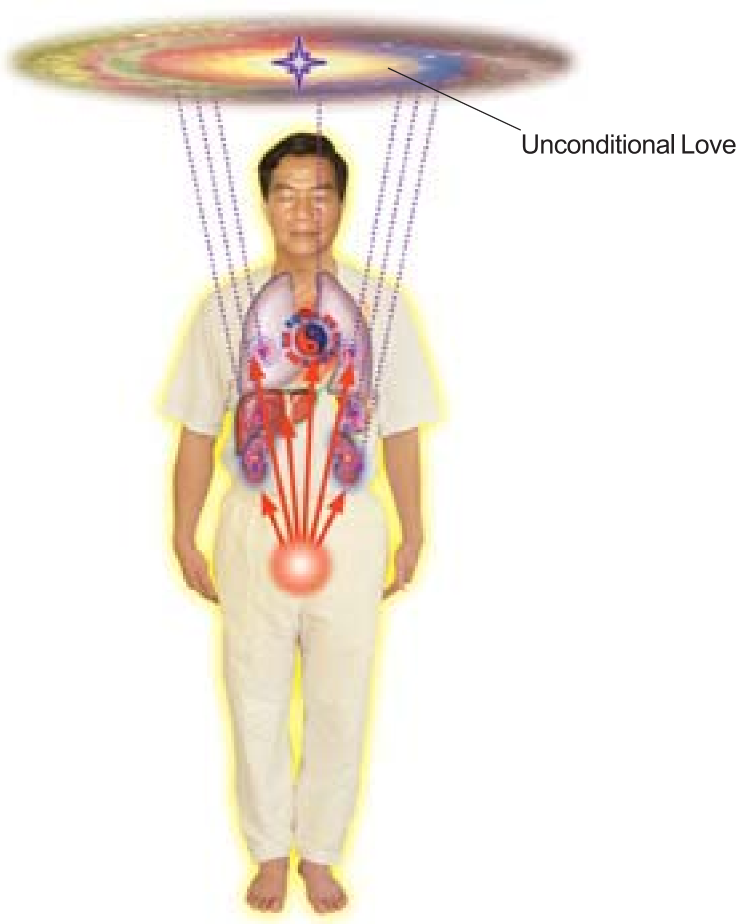

Fig. 6.22 *Bring the Orgasm up spiraling up to the organs.*

4. Be aware of the Muti-Orgasmic Energy in the organs and bring them up to the crown and continue spiral up to the Universe. Let the orgasm multiply and be aware of the Cosmic Orgasmic and let it flow down to the crown and feel all the cells fill with Cosmic orgasm and flow into the heart then down to the sexual organ filling them with compassion and Muti-Orgasmic Energy.

Universal Compassion: Your compassion arises up. Be aware of the multi-orgasm sexual energy and feel it combine with the compassion into one energy at the Tan Tien. Be aware the cosmos galaxy and expand your compassion through the universe. The Universe puts us in touch with the universal compassion.

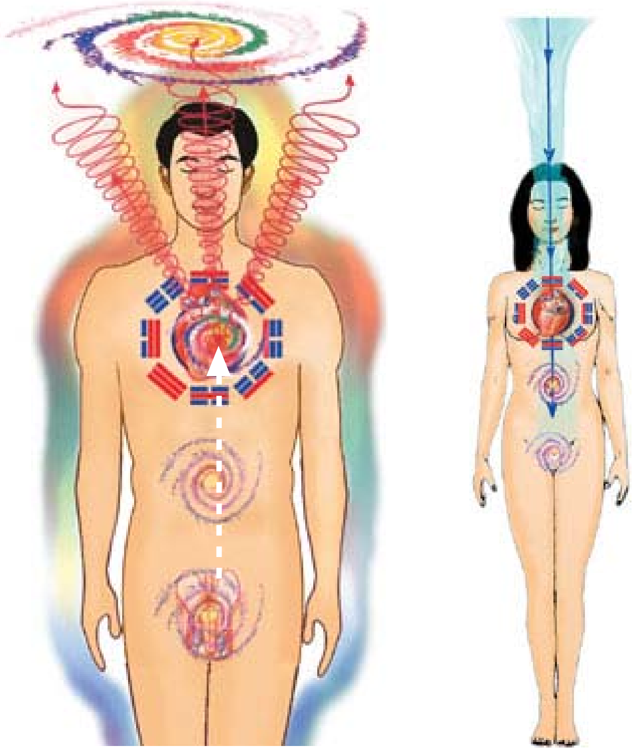

Fig. 6.23 *Universal Compassion*

This compassion practice is the major practice for all the Fusion and Kan & Li practices. The compassion fire is the most important energy of the transformation and will be use in all the practices.

Practice compassion through the Act of Forgiveness.
To forgive is to let go.
Always meet conflict with compassion.

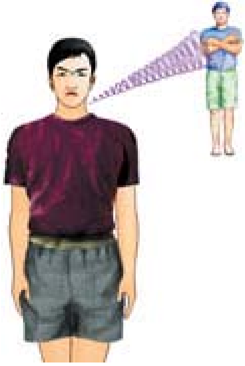

Fig. 6.24 *Be aware of the people that you feel resentment toward.*

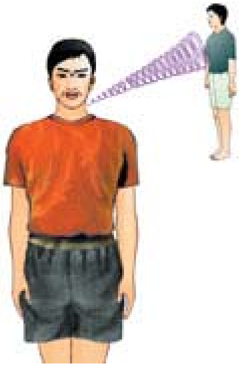

Fig. 6.25 *People who make you feel angry.*

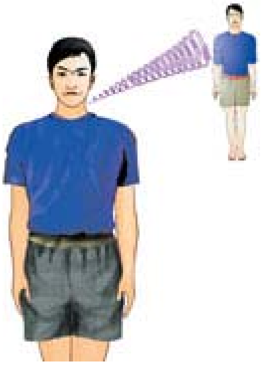

Fig. 6.26 *People that you hate or people who hate you.*

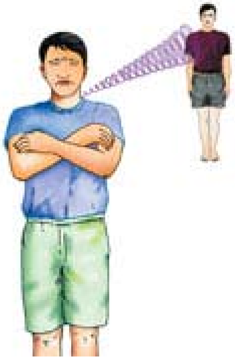

Fig. 6.27 *People who hurt you or people who have been hurt by you.*

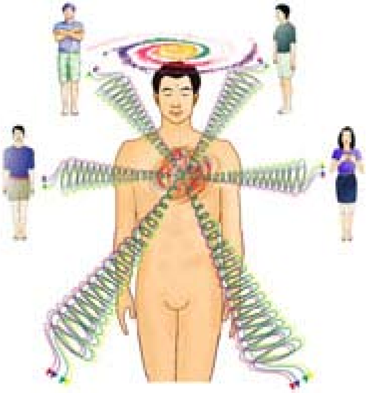

Fig. 6.28 *Send out the abundance of compassionate energy that you have from the universe, to fill the person and to forgive whatever he/she did to you.*

Oneness with Universe (Oneness with God)

Fuse Inner Positive Energy with Universal Energy through Turning the Dial

In Fusion of the Five Elements, the collection points were used to gather and store the energy of the organs. From the collection points in the body, the energy was drawn down into the pearl. Now, in Cosmic Fusion the collection points are expanded to encompass the Energy Body and the Universal Aura body. So, not only are we fusing the emotional energy of the physical body (negative emotions, senses and thoughts), but now we fuse the energy of the Energy Body and the Universal Body. This creates a much more complete practice and a highly refined pearl of energy. Fusing the elements is the secret to internal alchemy.

You can think of the different collection points like ingredients for a delicious soup. The more energy we can collect, the more spices we have for our soup. Alchemy is like cooking. What creates a really good soup or food is a combination of ingredients. Alchemy is about fusing the elements at our disposal to create balance and harmony within ourselves and the world we live in.

In the beginning of the fusion practice, it seems intricate and detailed. Once you get used to the formulas it is a very easy and simple practice. Learning a new recipe always takes some time and study, but once you have it in your mind, it is easy. The same is true with the fusion practice.

Forming the Collection Points

The collection points were introduced in Fusion of the Five Elements as a way to collect the negative energy from the organs. This energy was then directed into the pearl through the pakuas. In Fusion of the Five Elements the collection points were associated with the energy of the infants and the protective animals. In Cosmic Fusion, we are going to expand this practice by forming the collection points of the Energy Body and the collection points of the Universal Aura Body. These collection points are a reflection of the collection points in the physical body.

For example, the physical heart collection point is located at heart center just behind the sternum. The Energy Body collection point is located at the Lower Tan Tien at the top of the navel. And, the Universal Aura body collection point is located above the head in the Universe.

These collection points are utilized to create a powerful method of fusing all the elements into the pearl. Once all the collection points are established, the Energy Body and Universal Aura body collection points are rotated. This way there are different colors at the various collection point sites. For example, the collection points at the Energy Body are turned clockwise – the green is on the upper point, red is at the left, white is at the bottom, and blue is on the right. The Universal collection point is rotated counterclockwise – white is the upper point, blue is at the left, green at the bottom, and blue at the right. Creating different colors at each of the collection points takes the fusing process to another level of intensity. These colors are then mixed and blended into the cauldron and formed into a powerful pearl.

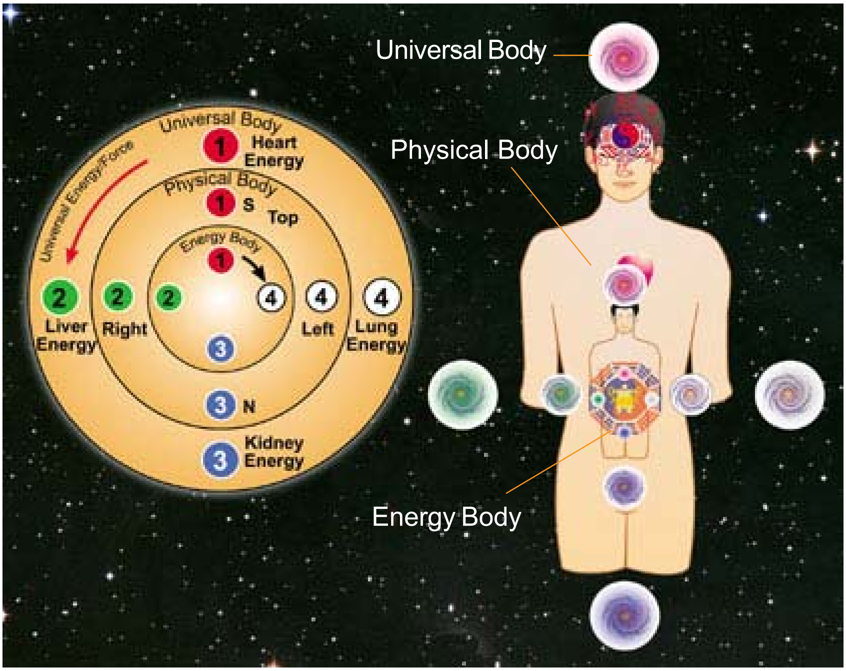
Universal Body
Physical Body
Energy Body
Universal Body
Universal Energy/Force
1 Heart Energy
Physical Body
1 S Top
Energy Body
1
2 Liver Energy
2 Right
2
4
4 Left
4 Lung Energy
3
3 N
3 Kidney Energy

Fig. 6.29 *Fuse inner position energy with universal energy.*

The Concept of Fusing Inner Position Energy with Universal Energy

The fused collection points are utilized to create a powerful method of fusion all the elements into a pearl.

There are four collections points of the elements; fire, water, metal and wood of the physical body, energy body and universal body.

Once all the collection points are established in the Physical Body, the Energy Body and the Universal Body we use a dial to assist in rotating the patterns of energy.

- Understanding that the physical body is more dense and stable; the collections points are fixed.
- The energy body is not fixed and is very sensitive to external events and the universe. This can be changed.
- Universal Energy is always changing and is not fixed. As the planets and the body's celluar matter, nuclei, electrons, protons all move at different speeds; we use the differences to create energy.
- The Dial: We use a dial of color to understand the different patterns of energy that can be created. Fusing different energies will generate more intense energy and a powerful pearl.

  Moving the color dials assists the imaginative mind to connect to the patterns of energy. It is a formula, a pattern for the mind to follow.

  In this approach we fuse inside to outside universe and outside to inside. You mix fire and water first, then wood and metal together. You can do it in pairs of points and then all four points, creating four balls of fused energy which are then spun very fast above the cauldron where they fuse to form a pearl. You can reproduce as many pearls as you want.

  The intensity can make you feel a oneness with the universe as part of you becomes part of the universe and universal forces.

Activate the Three Fires

The Abdominal, the Kidney and the Heart Fires.

Tan Tien Fire: Bring the fingertips to the navel. Feel the abdominal fire warming and opening the Lower Tan Tien. The abdominal fire elicits deep awareness within the body. This awareness has the power to expand and connect to the entire Universe.

Kidney Fire: Bring the palms to the kidneys, the fingertips to the door of life. Feel the warmth in the kidneys, like a fire under the sea.

Heart Fire: Bring the hands to the heart, palms facing the chest. Visualize a glowing ball of light in the heart. Feel the warm radiant energy of compassion shimmering through the chest. Make the heart soft. Remember the Yin within the Yang.

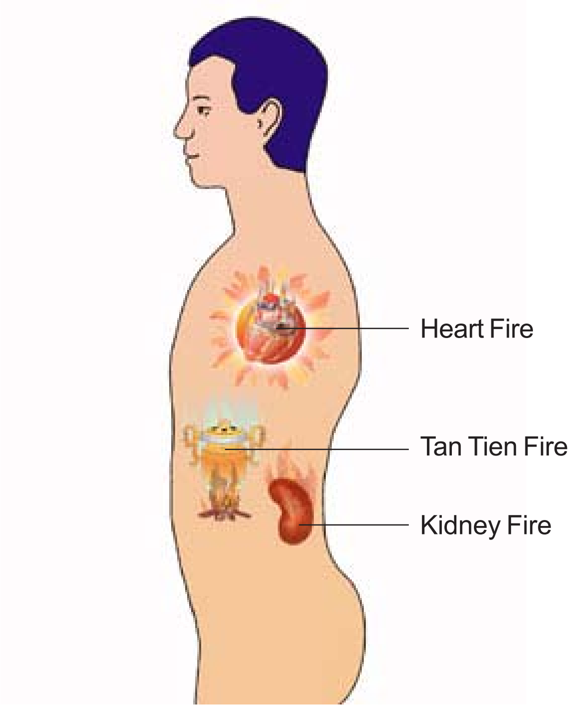

Fig. 6.30 *Activate the Three Fires.*

Create the Front Pakua just behind the navel. Control the formation of the front pakua with assistance from the eyes, ears, nose and mouth. As you balance the energy, let the pakua glow with light.

Chant the Eight Forces by sounding all the trigrams. Visualize the trigrams forming the front pakua. Chant the proper Yin and Yang combinations with each trigram.

Form the Back Pakua: Let it reflect off the front pakua like a mirror. In a similar manner form the **Left** and **Right Side Pakuas**. Feel the energy starting to spiral and blend into the center of the abdomen.

Form the Facial Pakua: The facial pakua is the reverse direction of the abdominal pakua because we are looking at the pakua in front of the face. Feel the energy of the senses and the face gathered and collected. If you have time, chant the eight trigrams of the facial pakua.

Form the Universal Pakua: Feel the immensity of this pakua surrounding your entire body in every direction. Again if time permits, chant the eight directions, forming the pakua.

Be aware of the heart and all the good virtue energy and fuse them together into compassion fire in the heart.

Be aware of the orgasm energy and multiply then to the organs and finally combine them into the heart and becoming one compassion fire of unconditional love.

Form the Collection Points in the Physical Body: Feel the red light in the heart collection point, the blue light in the kidney collection point, the green light in the liver collection point, the white light in the lungs collection point, and the yellow light in the spleen collection point.

Remove Negative Energies from the Organs:

Use the senses to help locate the negative energies in the organs. Look deep inside; smell deep inside; taste deep inside. Locate anything you find that you do not like.

Form the organs' collection points. Spiral the negative energies into the collection points spiraling them into the front pakua where they will blend and transform.

As you spiral the energies from all four Pakuas into the cauldron, you are concentrating them in the cauldron of the body. The cauldron, as the center point of the human being, is the center that contains the essence of all sense, organ and gland energy. The energy directed to the cauldron is transformed and stored for later use in the development of the soul and spirit bodies.

Using the Dial: Feel the reflection of the colors in the collection points in the energy body that surrounds the cauldron.

Feel the outward reflection of the collection points into the Universe. The red ball of light above the head, the blue ball of light deep below the feet, the green ball of light to the right, and the white ball of light to the left.

1. Turn the collection points of the energy body clockwise one station. Turn the collection points of the Universe one station counterclockwise.
2. The physical body collection points always remain stationary. Now the color sequence is red at the physical heart collection point, green below it in the energy body, and white above in the Universal collection point. Below, the physical collection point is blue, the energy body is white, the Universal is green, the right physical body collection point is green, the energy body is blue, and the Universe is red, and on the left the physical body is white, the energy body is red, and the Universe is blue.

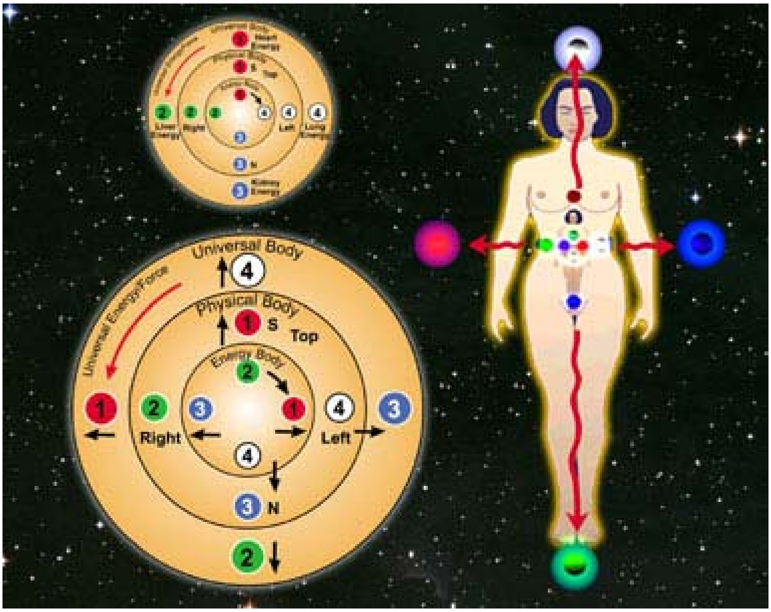

***Fig. 6.31** Fuse inner positive energy out with universal energy through turning the Dial-1.*

3. The fusion process begins here. Fuse the white energy from the energy body with the blue ball in the physical collection point at the perineum, and fuse both of these energies down to the Universal collection point with green light.
4. The same process continues with all the collection points. Next, fuse the green energy body point with the red physical body collection point, moving upward to fuse the white Universal collection point. Feel the energies fusing together above you.
5. Moving to the right side, fuse the blue ball of the energy body collection point with the green ball of the physical body, and outward to fuse with the red ball of the Universal collection point. Feel the energy fuse together at the right side.
6. Moving to the left, fuse the red ball of light of the energy body with the white ball of the physical body and moving out to fuse with the blue ball of the Universal collection point. Feel all these energies fuse together at the left.
7. Now we bring the fusion process back inside the body. Take the fused light below you, drawing it first to the physical collection point and then into the energy body collection point. Bring the fused energy above the head down to the physical collection point and then into the energy body collection point.
8. Draw the fused energy from the right back to the physical body collection point and then to the energy body collection point.

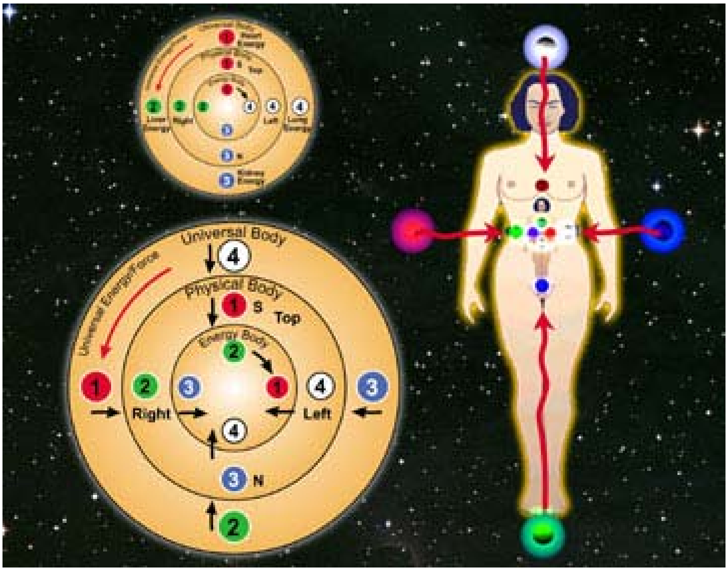

Fig. 6.32 *Fuse the Universal energy force back to inner positive energy and Energy Body through turning the Dial-1.*

Draw the fused energy from the left back to the physical body collection point and then to the energy body collection point. Allow the four balls of fused energy to spiral around the cauldron. Let them increase in intensity and speed, going faster and faster, until they blend in the middle of the cauldron forming the pearl.

9. Feel any residual energy spiral through the pakuas and fuse together into the cauldron, connecting with the brilliant pearl of white light. Feel the colors blend and fuse. This is where the alchemical process comes to life. At any time during the Fusion practice, if you feel the pearl you are working with is lost or diminished simply become aware of the pakuas spiraling into the center of the cauldron.
10. Once you feel the form of the pearl you can simpy fuse the energy from inside of the energy body out to the physical and out to the universe and back and there is no need to be aware of the different color.

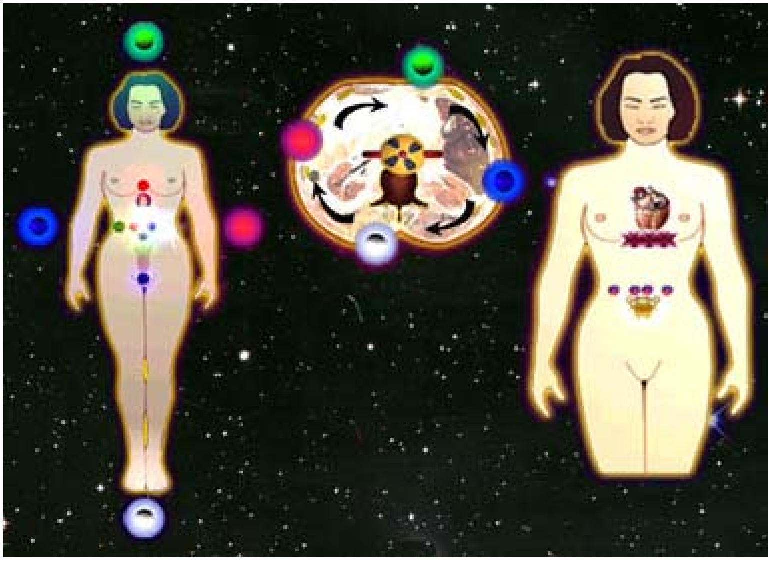

Fig. 6.33 *Four fused energy balls spiral on top of the cauldron, forming one energy pearl.*

Do as above, only the colors are changed and fuse from the energy body to physical body, to the universe and back as Four Balls, spiraling faster and fuse into One Pearl.

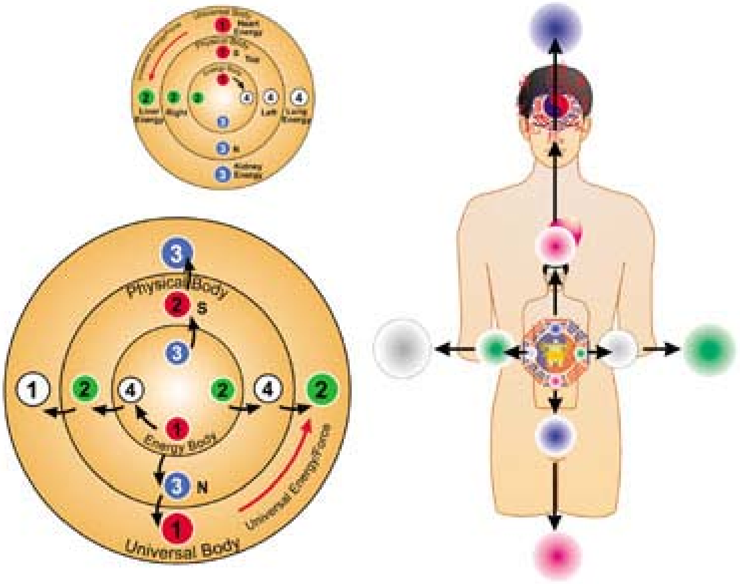
3
Physical Body
2
S
3
1
2
4
2
4
2
1
Energy Body
3
N
1
Universal Energy/Force
Universal Body

Fig. 6.34 *Fuse inner positive energy with universal energy through turning the Dial-2.*

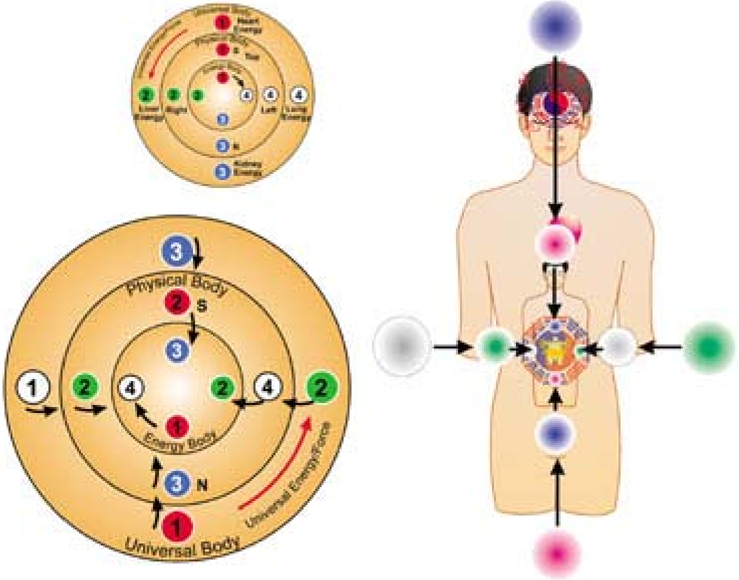
3
Physical Body
2
S
3
1
2
4
2
4
2
1
Energy Body
3
N
1
Universal Energy/Force
Universal Body

Fig. 6.35 *Fuse the Universe force back to the body and energy body.*

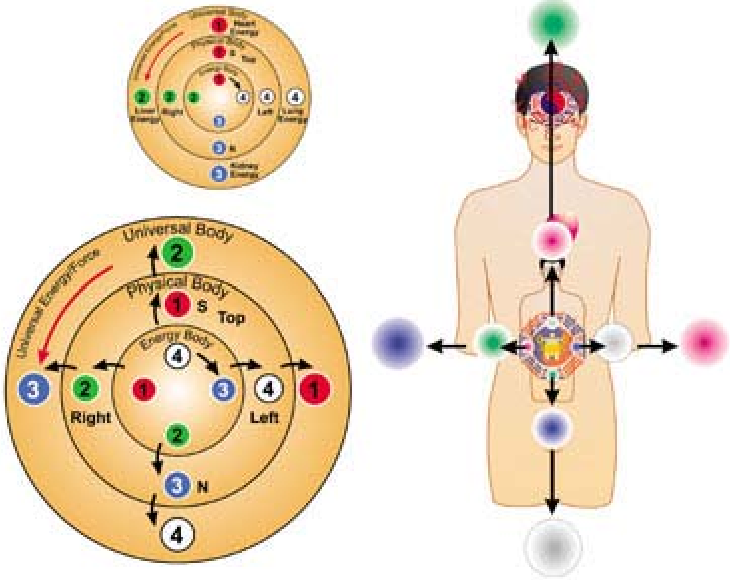
Universal Body
Heart Energy
Physical Body
S Top
Energy Body
Liver Energy
Right
Left
Lung Energy
N
Kidney Energy
Universal Energy/Force
1
2
3
4

***Fig. 6.36** Fuse inner positive energy with universal energy through turning the Dial-3.*

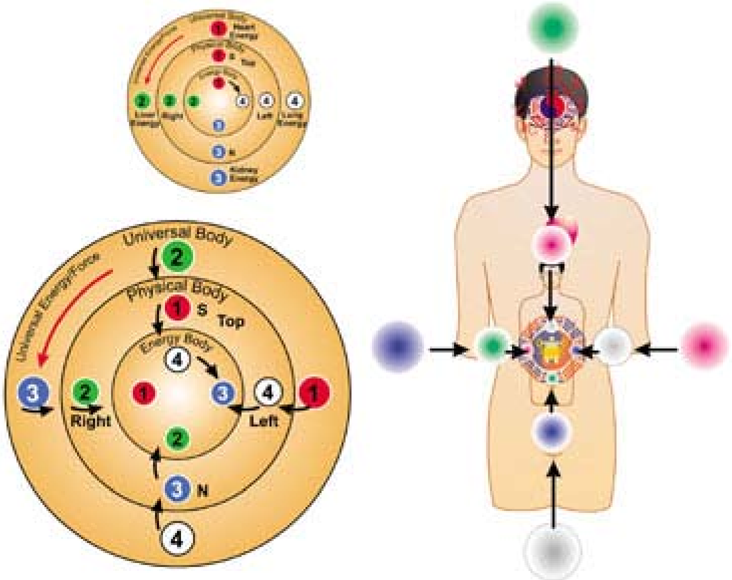
Universal Body
Heart Energy
Physical Body
S Top
Energy Body
Liver Energy
Right
Left
Lung Energy
N
Kidney Energy
Universal Energy/Force
1
2
3
4

***Fig. 6.37** Fuse the Universe force back to the body and energy body.*

Do the same procedure as before using the Four Fused Energy Balls spiraling on top of the cauldron, forming One Energy Pearl as you turn the Dial. You spend more time using Dial-2 and Dial-3 positions.

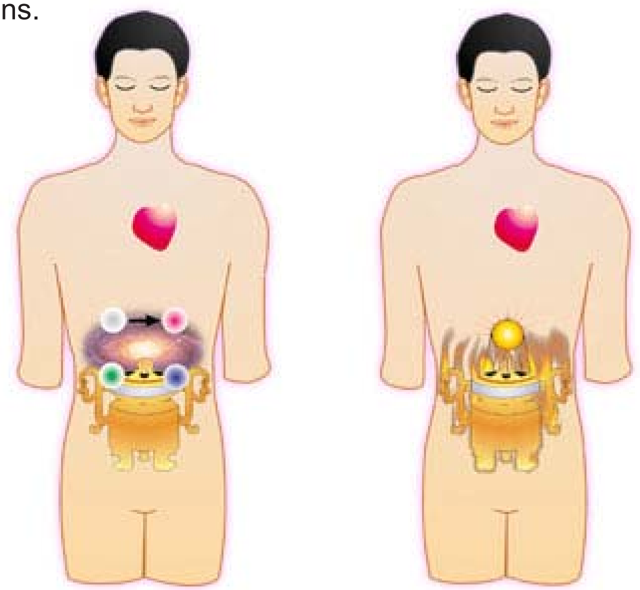

***Fig. 6.38** Forming the Cauldron and the Pearl*

Creation Cycle Foundation Practice

1. Fuse the Pearl to help activate virtue energy. The Inner Smile is the first step to connecting your consciousness to all your organs and glands. This is actually the first step of the Fusion of the Five Elements practice. It is important to remember how powerful and sublime smiling inward can be.
2. The next stage of practice is removing negative emotional energy from the organs. The negative energy is brought from each organ to its corresponding organ collection point and then to the pakua where it is neutralized. When all negative energies are brought to all four pakuas and are under control and all residual energies have been brought to the back and side pakuas, the energies are then spiraled and compressed into the cauldron. There they are formed into the pearl of energy. As you collect the energies and direct their flow to the cauldron, you feel your center point illuminate with the bright light of the pearl.

3. Be aware the energy, physical and universal collection points, fuse them together and fuse back to form the bigger pearl.
4. The pearl is capable of activating, attracting and absorbing a great amount of good virtue energy. For this reason the pearl is circulated to each organ following the Creation Cycle. After practicing Fusion of the Five Elements, the pearl is brought from the cauldron to the perineum and is then circulated in the Microcosmic Orbit.
5. When you are ready to begin Cosmic Fusion, the pearl is brought to the Heart to begin the Creation Cycle. The Heart is the beginning point of this cycle because it is in the Heart that Compassion resides.
6. At this point there is a great awareness of each organ and the energy that each one is supplying. A continuation of this awareness is necessary for properly practicing the Creation Cycle of Cosmic Fusion. It is especially important that all negative energy has been removed and neutralized beforehand; otherwise, as the virtue energy of the pearl increases, so will the negative energy as you move the pearl through the Cycle.
7. In Fusion of the Five Elements, you remove the negative emotion of fear from the kidneys, by first listening to them, because the ears and kidneys have a connection. The removal of fear from the kidneys leaves room for the positive virtue of gentleness inherent in the kidneys to grow.
8. Now, in beginning the Creation Cycle of Cosmic Fusion, you focus your smile on the virtues of joy, love and happiness in the Heart. Feel the virtues growing and purifying. It is important to develop a genuine virtue here. You can spit out words like love, joy and happiness without meaning them. But like the love that is mentioned in the Bible (1 Corinthians 13), it has to be real and true; otherwise it is just a sounding brass or a tinkling cymbal. You have to flesh it out and breathe life into it.
9. Here is the way to do the Creation Cycle of Cosmic Fusion: Feel the unconditional love of the Universe flowing down into the Heart. With this combination of virtues – love, joy, happiness, unconditional love – you can definitely transform yourself, your organs and those around you.

10. Let the positive Heart energies of love, joy and happiness activate the positive Spleen energies of openness and fairness and centeredness. Blend this with the Universal energy and feel the yellow light descending to the Heart and Spleen.
11. Let the positive Heart energies of love, joy and happiness activate the Lung energies of courage, strength and righteousness. Blend these energies with the Universal energy and see the white light from above flow into the Heart and Lungs. Let the Positive Heart energies of love, joy and happiness activate the Kidney Energies of gentleness, softness and calm in the Kidneys. Blend both energies with Universal Energy and see the blue light coming down from above into the Heart and Kidneys.
12. Let the positive Heart energies of love, joy and happiness activate the Liver energies of kindness, generosity and benevolence. Blend these energies with Universal energy and see the green light flowing from above into the Heart and Liver. You can do this meditation a few times.
13. Blend all the positive organ virtues in the Heart, creating Compassion Energy. You may manifest this as a Pearl. Move it in the Microcosmic Orbit spiralling it from 10,000 to 60,000 times a minute.

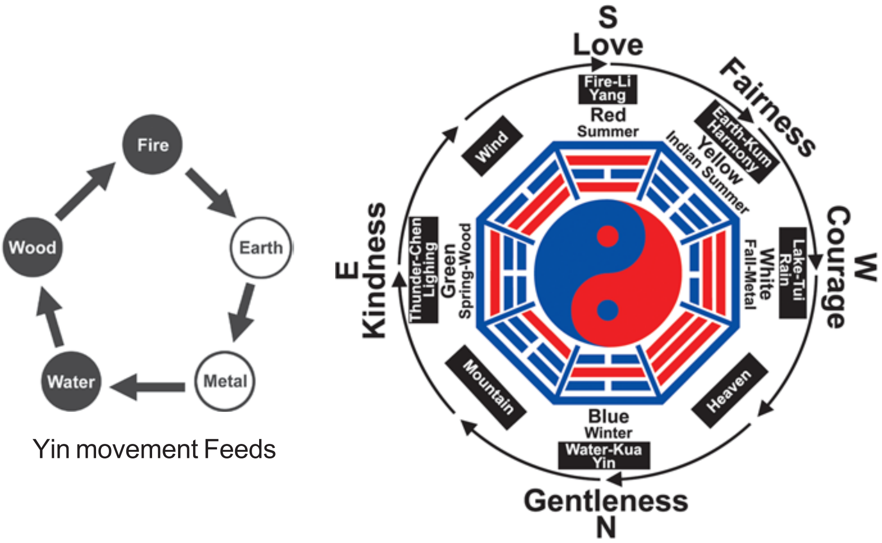
Fire
Earth
Metal
Water
Wood
S
Love
Fire-Li
Yang
Red
Summer
Fairness
Earth-Kum
Harmony
Yellow
Indian Summer
W
Courage
Lake-Tui
Rain
White
Fall-Metal
Heaven
Blue
Winter
Water-Kua
Yin
Gentleness
N
Mountain
E
Kindness
Thunder-Chen
Lighing
Green
Spring-Wood
Wind

Yin movement Feeds

Fig. 6.39 *Creation Cycle*

14. This completes the basic Fusion practice. These steps will be repeated through the rest of the formulas in the book. In the beginning it seems like a lot of work in constructing all the pakuas, chanting, collecting the energy to fuse into the pearl. Once this formula is set up, the whole process happens very quickly. It is not necessary to do all the steps every time. You might only want to chant the trigram one time instead of three. Remember, these extra steps are there to increase the strength of the pearl and expand our consciousness to connect with the Universe. With this powerful pearl it is time to begin Cosmic Fusion with the Creation Cycle.

Begin Cosmic Fusion: Creation Cycle

1. Activate the compassion fire and multi-orgasm energy and combine them together connecting with the universe.
2. Form the pearl through the fuse from the inside to the universe and from the universe and back to the body to the form a pearl. Bring the Pearl down to the Perineum.
3. Feel the pearl connecting to the kidney energy.
4. Listen to the Gentleness Virtue of the Kidneys.
5. The negative emotion of fear has already been removed from the kidneys. The energy remaining in the kidneys is their virtue energy of gentleness. Listen quietly to the gentleness of the kidneys, and be aware of the qualities of gentleness energy: **cold, calm, blue, soft** and **silky** and **tenderness**. Enjoy these qualities. You can intensify them by concentrating on them. Bring the pearl from the perineum to the kidneys, and add the gentleness energy to the pearl at any moment when you feel the pearl weak, just form another pearl.
6. Now bring the pearl back to the kidneys collection point at the perineum, where the gentleness will grow in intensity. All of the neutralized energy that is the pearl now will take on the virtue energy of gentleness.

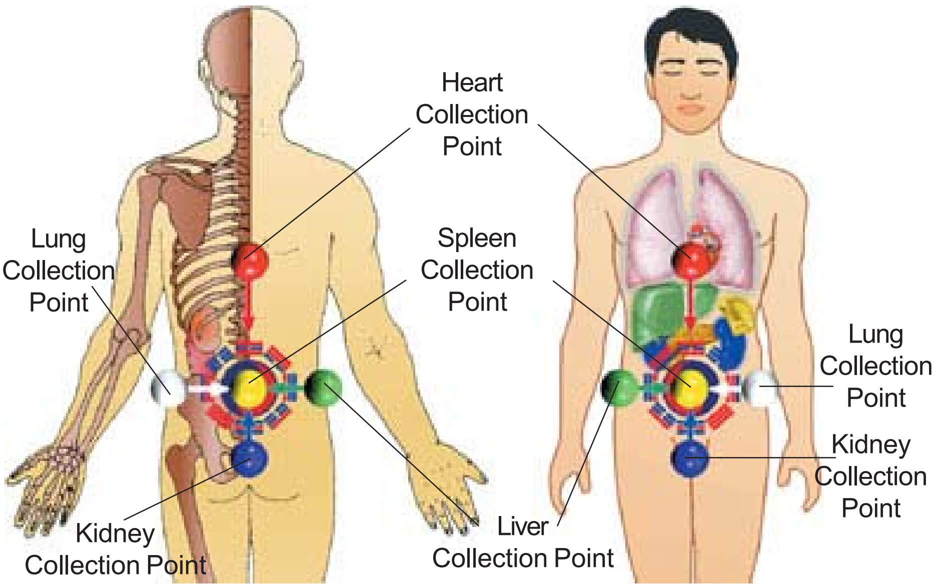
Heart
Collection
Point
Lung
Collection
Point
Spleen
Collection
Point
Lung
Collection
Point
Kidney
Collection
Point
Kidney
Collection Point
Liver
Collection Point

Fig. 6.40 *Front and Back Collection Points*

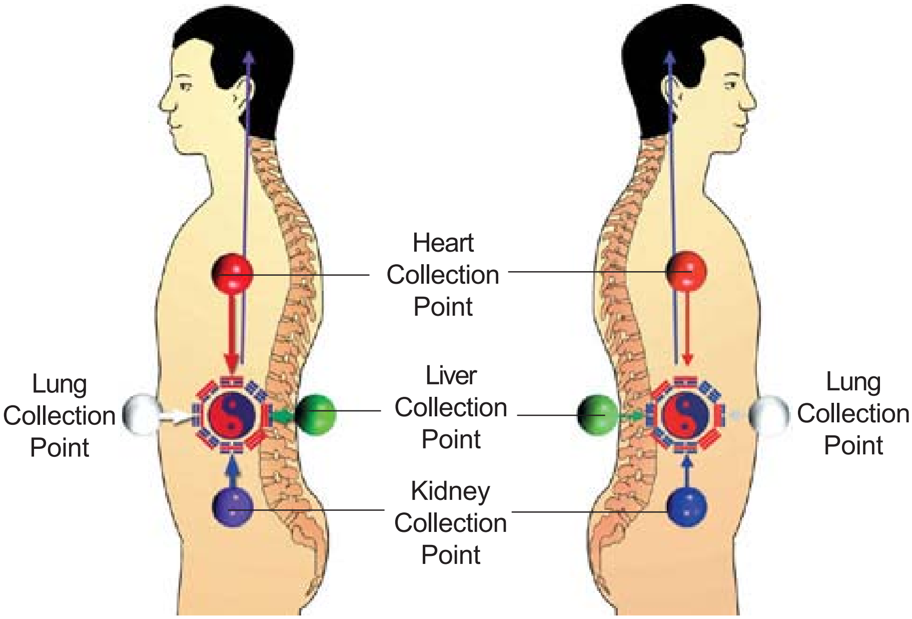
Heart
Collection
Point
Lung
Collection
Point
Liver
Collection
Point
Lung
Collection
Point
Kidney
Collection
Point

Fig. 6.41 *Left and Right Collection Points*

Direct the pearl to the liver. Gentleness energy fuses with the kindness virtue of the liver.

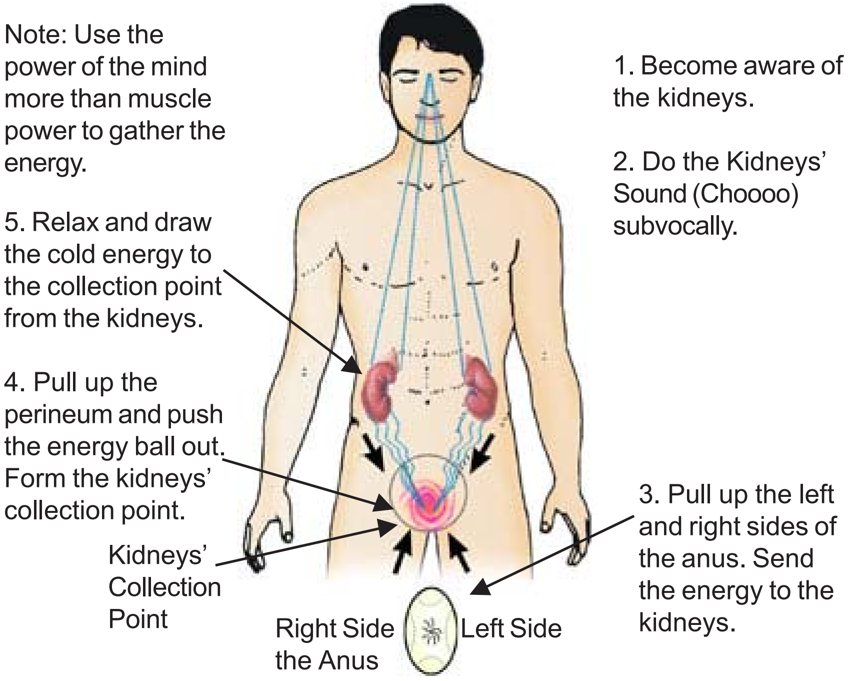
Note: Use the power of the mind more than muscle power to gather the energy.
5. Relax and draw the cold energy to the collection point from the kidneys.
4. Pull up the perineum and push the energy ball out. Form the kidneys' collection point.
Kidneys' Collection Point
Right Side the Anus
Left Side
1. Become aware of the kidneys.
2. Do the Kidneys' Sound (Choooo) subvocally.
3. Pull up the left and right sides of the anus. Send the energy to the kidneys.

Fig. 6.42 *Forming the Collection Point to gather the Kidneys' Energy.*

7. Gentleness blends with kindness, the virtue of the liver. Look into the liver, connecting the eyes with the liver. Be aware of the kindness energy there. As you bring the pearl carrying the gentleness energy from the kidneys toward the liver, feel the gentleness energy activate and enhance the kindness energy. Enjoy the kindness energy. Feel the kindness intensify. Circulate the kindness energy in the liver. Its qualities can feel **strong, round, smooth, soft, green, sweet and fragrant, warm and pleasant**. You can feel satisfied.

8. Absorb the kindness energy into the pearl, and bring the pearl to the liver collection point (at the level of the navel and in line with the right nipple).

   Here the combination of gentleness and kindness will intensify. Remember to relax and smile. Direct the pearl to the heart. Gentleness and kindness energy fuse with love, honor and respect and joy in the heart.

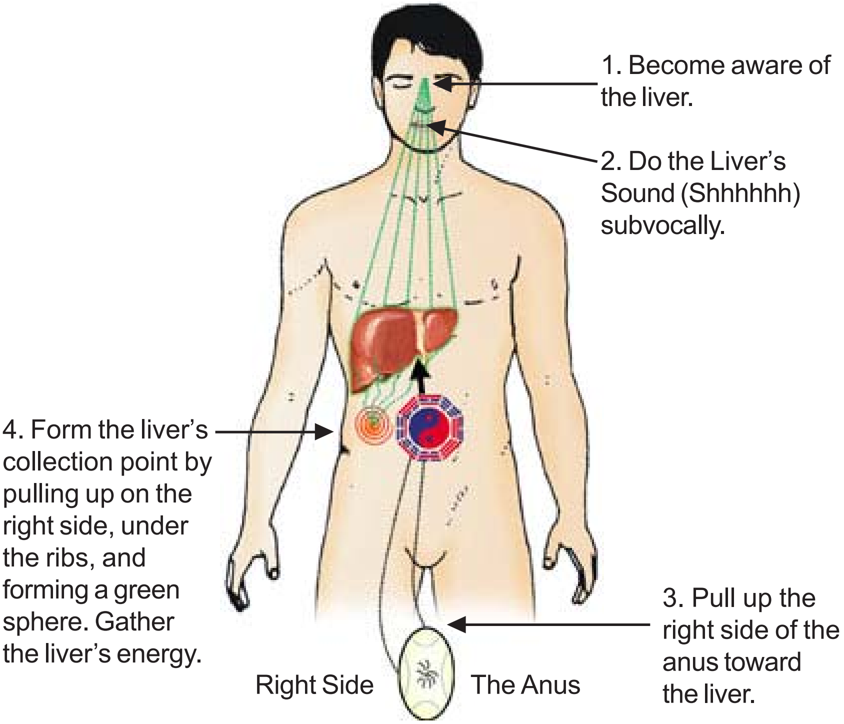
1. Become aware of the liver.
2. Do the Liver's Sound (Shhhhhh) subvocally.
4. Form the liver's collection point by pulling up on the right side, under the ribs, and forming a green sphere. Gather the liver's energy.
3. Pull up the right side of the anus toward the liver.
Right Side
The Anus

***Fig. 6.43** Forming the Liver's Collection Point to gather the Liver's Energy.*

9. Connect the tongue with the heart. Using your mind's eye and senses, allow the pearl, now consisting of gentleness and kindness, to flow up to the heart. Let the virtue energy of the pearl activate and enhance all the loving energy, joy and happiness, honor, respect and peace in the heart. These good virtues of the heart can feel **straight** and **open, bright red, warm, deep, calm, comfortable** and **satisfying**. Enjoy the virtuous feelings of the heart. The feeling will be different for each person as the energy blends. Feel the warmth and openness in the chest.

10. Let the pearl absorb the honor, respect, love and joy. Bring the pearl down to the heart collection point behind the sternum.

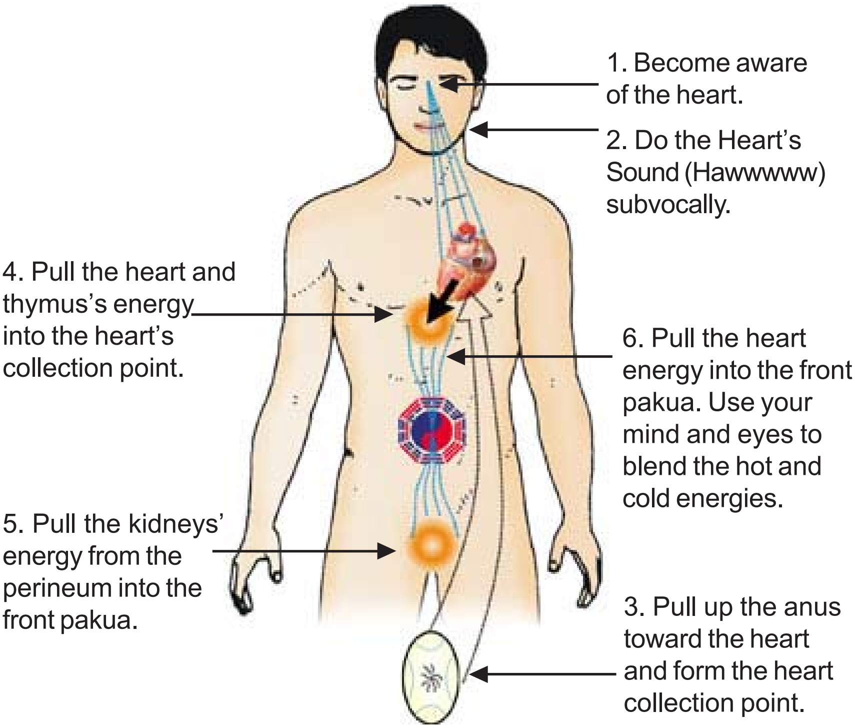
1. Become aware of the heart.
2. Do the Heart's Sound (Hawwwww) subvocally.
4. Pull the heart and thymus's energy into the heart's collection point.
6. Pull the heart energy into the front pakua. Use your mind and eyes to blend the hot and cold energies.
5. Pull the kidneys' energy from the perineum into the front pakua.
3. Pull up the anus toward the heart and form the heart collection point.

Fig. 6.44 *Form the Heart's Collection Point and blend the Heart's Energy with the Kidneys' Energy in the Pakua.*

The pearl can now blend the virtue energies of the heart in a balanced way with the kindness and gentleness energies already within the pearl. Feel the collection point glowing. Then direct the pearl to the spleen/pancreas.

Note for Women: Women should be careful when the pearl is in the heart center. As a natural endowment women tend to have more loving energy in the heart. When a woman loves she often forgets herself. This amount of love can heat up the heart center and the practice can feel uncomfortable. It is best not to remain for too long in the heart if you feel uncomfortable.

11. Be aware of the connection of the mouth with the spleen and pancreas. As the pearl arrives at the spleen and pancreas, the honor and respect, love and joy energy that is now part of the pearl fuses with the spleen virtues of fairness and openness. The fairness and openness virtues of the spleen can feel **expansive, clean, dry, bright yellow, smooth, warm, clear** and **soft**. Enjoy these feelings.
12. Let the pearl absorb the fairness and openness energy. Feel the pearl take on the qualities of the fairness and openness virtues in addition to the kindness, gentleness, honor and respect virtues that already are present there. Bring the pearl to the spleen collection point behind the navel at the front pakua.

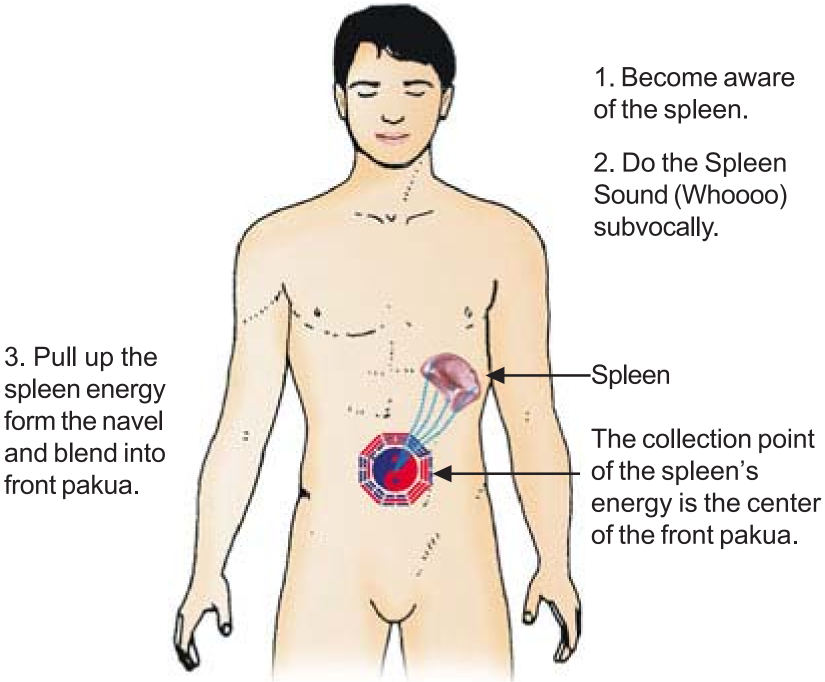
1. Become aware of the spleen.
2. Do the Spleen Sound (Whoooo) subvocally.
3. Pull up the spleen energy form the navel and blend into front pakua.
Spleen
The collection point of the spleen's energy is the center of the front pakua.

Fig. 6.45 *Gathering the Spleen's Energy Directly into the Pakua.*

Feel the fairness and openness energy intensify as it combines and blends with all the neutral and virtue energies already present in the pearl. Direct the pearl to the lungs.

13. The Energy of fairness and openness fuses with the courage and righteousness virtues of the lungs.

Connect the nose to both lungs. As the pearl arrives at the lungs, split the pearl into two pearls, one for each lung. The energy of fairness and openness that is now part of both pearls fuse and enhances the courage and righteousness energy of the lungs. When you feel righteous, you can feel **tall, straight, uplifted, comfortable, strong, firm, proud** and **satisfied**. The energy can be **fresh, bright, white** and **pure**. Enjoy the qualities of this energy.

14. Let the pearls absorb the courage and righteousness energy. Bring both pearls to the collection point of the lungs (at the level of the navel and in line with the left nipple). Feel the courage and righteousness energy intensify as it circulates in the lungs. Let the pearls blend these virtues with their kindness, gentleness, honor, respect, fairness and openness energies.

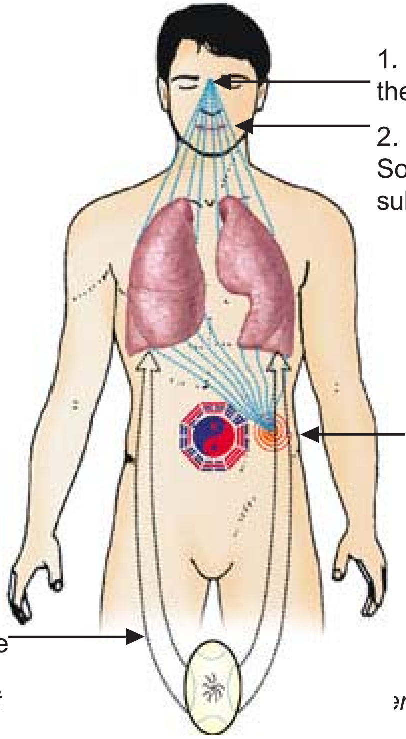

1. Become aware of the lungs.

2. Do the Lungs' Sound (Sssssss) subvocally.

4. Form the lungs' collection point by pulling up on the left side and forming a white sphere. Gather the lungs energy.

3. Pull up the right and left sides of the anus to the lungs.

Fig. 6.46 *Forming t* *r the Lungs' Energy.*

Direct both pearls to both kidneys. Courage and righteousness fuse with gentleness: the cycle begins again at the kidneys.

15. As the pearls arrive at each kidney, the combined virtues of the pearls (especially the energy of courage and righteousness) enhance gentleness and the cycle begins again at the kidneys. Repeat the cycle two more times. As you circulate the pearl in the second cycle, you will begin to notice that as the pearl arrives at each organ, the virtues will grow by themselves. Little by little, the energy will blend more evenly.
16. For the third cycle, bring the pearl from collection point to collection point without going into the organ first. With your attention on the collection point, the energy will flow into the organ without conscious effort, and will join with the virtue energy to flow back toward the collection point. In this way the virtue energies are enhanced and increased each time you bring the pearl to a collection point. If you wish you can practice the third round of the Creation Cycle three more times simply by bringing the pearl to the collection points. Each time you blend the energy, you increase it.
17. Your energy now begins to have the quality of fine soup, with the proper combination of ingredients. Be aware of the quality of this energy. It is very special. Fuse all good virtues energies into compassion energy. Creating a pearl of compassion energy requires a tremendous amount of purified energy. Compassion energy is not just love or kindness, gentleness or openness, but is a combination of all the good virtues' energies, blended in proportion to become compassion energy. When you fuse the proportional blend of good virtue energy into a pearl of compassion energy, you will feel more centered. The energy of this pearl feels very different from the pearl you first formed. Move the compassion energy through the microcosmic orbit.
18. When you feel the pearl of compassion energy strongly, move it down to the perineum. Using your mind and senses, begin to move all of the compassion energy through the microcosmic orbit, letting its bright pearl shine as it travels along. Feel the different quality of this energy. Be aware of the loving, comfortable, very beautiful way the organs feel as the energy runs through and spreads into them, filling them with life-force energy. If you feel tired at any time, you can temporarily rest the pearl at your navel and practice the spinal cord breathing technique described in the Chapter preceding this meditation. Return your concentration to the pearl to form it again and return it

to the microcosmic orbit for circulation. Move the pearl through the microcosmic orbit 9-18 times.

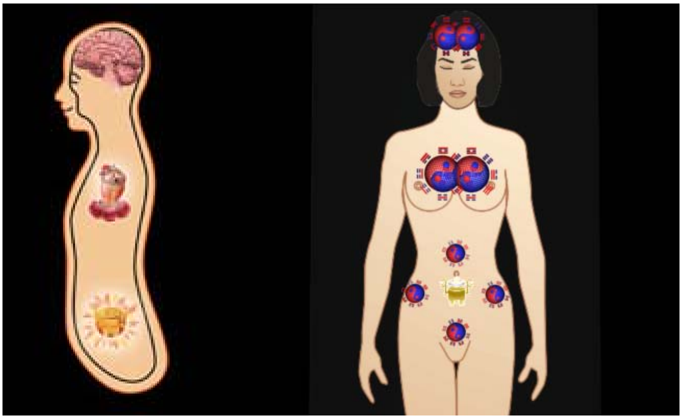

Fig. 6.47 *Circulate the pearl in the Microcosmic Orbit.*

Shoot the Pearl above the Crown.

1. As the pearl runs through the Microcosmic Orbit, begin to activate the Cranial Pump. Press your tongue to the palate, clench your teeth, pull back your chin and roll your eyes up toward the crown. Feel the pulsing in your heart and in your head at the crown. You can touch your pulse at the wrist to help your awareness of the pulse both at the wrist and the crown. Your mind also helps to activate the Cranial Pump.

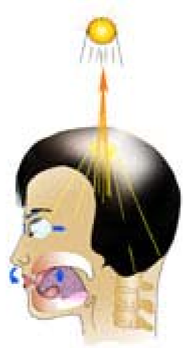

Fig. 6.48 *Pull the eyes into their sockets.*
Roll the eyes up and look up to the crown.

2. Inhale, be aware of and squeeze the anus and then exhale quickly to push the pearl up through the crown.
3. You might be aware of a light, beam or frequency shooting out of your crown. This is the lead light first introduced in Fusion of the Five Elements. Sometimes it is called an indicator light because it will indicate how high up your pearl will be able to go. Just as a light is used to guide helicopters to their landing point, so will you use the lead light to guide the pearl back to the crown point.
4. Direct all of your senses to push the pearl up to the area six inches to two feet (15-60 centimeters) above your head. Move the pearl up and down, left and right.
5. Feel the Universal Force, the forces of the North Star and Big Dipper above your head, and the Cosmic Particle Force in front of you as they shine down to your pearl. Feel your pearl start to absorb this energy and then feel it expand.
6. Bring your awareness to your feet. Feel the energy supplied throughout your body through your feet. This is the Earth Energy. The pearl continues to expand with all the energy coming to it from outside the physical body.
7. When you are ready, activate the Cranial Pump again. Press your tongue up, clench your teeth, pull back your chin, pull up your anus and look up to the crown. Feel the beating in your heart and the pulse at your crown.
8. Activate the lead light, and let it shine up from your crown. It may feel like a frequency going out of the crown. Draw the pearl down to the lead light. Inhale and draw the pearl down.
9. Circulate the pearl in the Microcosmic Orbit. Then bring it down to the navel and to the cauldron at the body’s center. Collect the energy at the cauldron.
10. As you collect the energy and relax the mind, the pearl may disintegrate. Sometimes when you release the pearl, it vanishes. It is returning its energies, now enhanced by all virtue energies and the outside forces, to the organs and glands. They become stronger and healthier each time you practice. Each time you gather the energy and form the pearl again, the pearl will be stronger.

Summary

1. Trust and Believe (Concept and Desire).
2. Visualization turns into activation.
3. Think and let it happen. It will become easier with practice.

Once you understand the practice and go through the practice a few times, you can just simply use the mind and recall the past experience and there is no need to go through all the steps. Think and let it happen.

Fusion Opening: Fusing Universal Energy

1. Inner Smile–Activate Compassion first (Love and Sexual Energy combined).
2. Activate Three Fires.
3. Create Pakuas; Front, Back, Facial, Universal.
4. Form Cauldron, spin Pakuas.
5. Form organ Collection Points of Physicial Body.
   Energy Body and Universal Body.
6. Remove Negative Energy from the Organs.
7. Sense the Colors of the Collection Points imagine the Dial-1,2,3 of Colors.
8. Fuse inner Positive Energy of the Energy Body and Physical Body with Universal Energy through turning the Dial-1,2,3.
9. Fusion of the Universe Energy back into Body and Energy Body.
10. Create Four Balls of fused energy and spin them very very fast above the Cauldron.
11. Form a Pearl.

Begin Cosmic Fusion: the Creation Cycle.

Be aware of the heart and cauldron activating the compassion fire.

1. Listen to the Gentleness Virtue of the Kidneys.
2. Gentleness Energy activates the Kindness Virtue of the Liver.
3. Kindness Energy activates Honor, Respect, Love in the Heart.
4. The Energy of Honesty and Respect activates the Fairness and Openness Virtues of the Spleen and Pancreas.
5. The Energy of Fairness and Openess activates the Courage and Righteousness Virtues of the Lungs.
6. Courage and Righteousness enhance Gentleness: the Cycle Begins again at the Kidneys.
7. Combine all Good Virtues energies into the Heart and create Compassion Energy.
8. Move the Compassion Energy through the Microcosmic Orbit.
9. Shoot the Pearl above the Crown.
10. Practice Chi Massage.

Chapter 7

Opening the Thrusting Channels

Theory of the Thrusting Channels

After the positive emotional energy of the organs is absorbed into the pearl, it is then circulated in four of the four special channels: the Microcosmic Orbit (Governor and Functional Channels), the Thrusting Routes, and the Belt Routes. The Thrusting Routes run through the center of the body, linking the “chakra” centers. The Belt Routes spiral around the body, strengthening the aura and providing a form of psychic self-defense. The second part of the Cosmic Fusion practice involves opening these three Thrusting Channels.

The Thrusting Channels are a powerful means to clean out the negative emotions and detoxify the organs and glands. Set into action, the three Thrusting Channels will serve as strong and efficient ways to check your center and observe the status of your emotions.

The Thrusting Channels run from the perineum to the crown and are separately identified as the Middle, Left and Right Thrusting Channels. The Middle Thrusting Channel begins directly at the perineum and runs vertically up to the crown. The Left Thrusting Channel is located one and a half to three inches to the left of the Middle Channel, while the Right Thrusting Channel is one and a half to three inches to its right.

When you are feeling emotional, you can check the Thrusting Channels, especially the Middle Channel, to discern whether you are off-center. You will know if you are out of balance when you feel the emotions running more on the left side or on the right, instead of through the middle of the body. If you center the emotions through the Middle Thrusting Channel, and keep the Left and Right Thrusting Channels in balance, you will very quickly center yourself. The Thrusting Channels serve as guidelines to decision-making in your daily life.

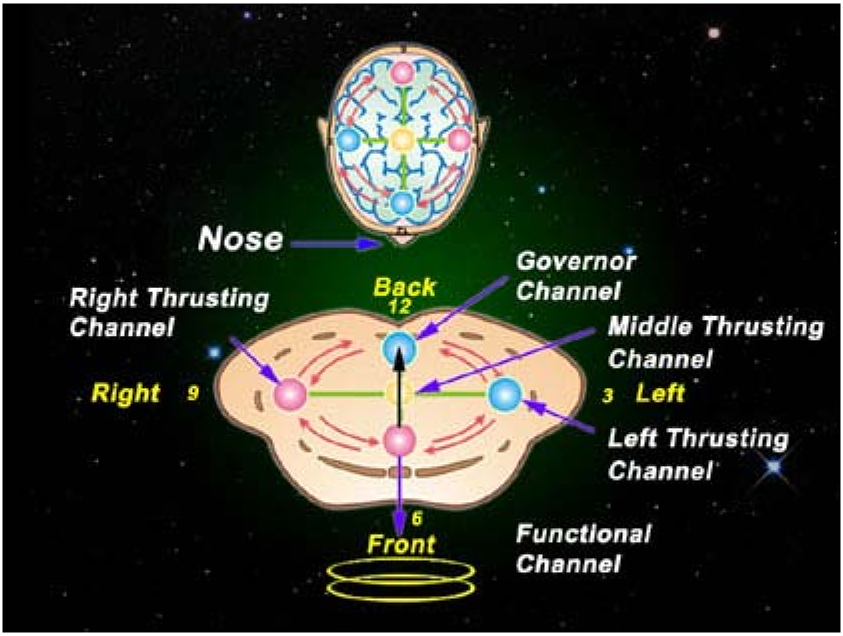
Nose
Governor Channel
Back 12
Right Thrusting Channel
Middle Thrusting Channel
Right 9
3 Left
Left Thrusting Channel
6
Front
Functional Channel

Fig. 7.1 *Four Psychic Channels*

Procedure for Opening the Thrusting Channels

The Thrusting Channels need the tremendous energy of good virtue to help them open. Begin by forming a pearl of virtue energy. With your continued, conscientious practice of the compassion fire and the fuse the inside with the outside energy to form the pearl, you will be able to assimilate the energies into a new and stronger pearl, a pearl that responds to your intention. This means that all you need do to form a new pearl is concentrate on the cauldron and the pearl in it, and on the front, back, left and right pakuas and fuse inside with the outside energy. Control of the internal weather, senses, organs and emotions will be possible in as little as a few seconds. You do not have to go through all the steps of chanting and collecting the energies every time you do the Fusion practice. It is helpful and creates a stronger experience if all the steps are taken. So the first step to opening the Thrusting Channels is to construct the pakuas, chant the eight directions, form the collection points of the Physical Body, the Energy Body and the Universal Body, and fuse them together into the pearl.

The pearl will be thrust up from the perineum (or testicles in men). Each Thrusting Channel precisely penetrates the body.

Although it may seem difficult at first, using your beautiful pearl will help make it easier. Other aids such as pulling up the anus and inhaling help the energy move in each of the three Channels. Once you are able to pass the energy through the Channels, you will find that the energy will move by itself without assistance.

Note: You must be very careful and gentle with this procedure. If the energy reaches the heart and head too quickly using the Thrusting Channels, the heart will become congested and you may experience pressure. If the heart becomes congested and overheats with energy: (1) Do not thrust above the diaphragm and (2) Practice the Heart Sound. Do not overheat the heart, liver or head.

Initially the Thrusting Channels have approximately a one-half to one inch diameter. Once they are activated, they can become very wide. At first concern yourself with drawing the energy directly up. Later, when you have become familiar with the process, the energy can be spiraled up each route.

Seated Position

Like many other Universal Tao exercises, the methods of opening the Thrusting Channels are practiced from a seated position. Sitting on a chair with your feet touching the floor and your spine erect connects you with two important energy “wires”: Earth Energy and Heavenly or Universal Energy. The Energy Body you eventually create needs the ground wire of Earth Energy to hold and support it. Otherwise, you can become disoriented and lost. Once your are more in control of the energy you can practice standing, or lying down on a bed or the floor.

Anal Muscle

If you do not strengthen your anal muscle, you will not progress very far in any of the Universal Tao System's practices. The anus muscle is connected to the perineum and everything in the body above it. If you invest all of your money on building the top floors of a building, and do not invest anything in the foundation, the building will fall. Think of the anus and perineum as your foundation. The anus muscle is used to seal your "lower gate." Closing this orifice helps to retain and prevent loss of your energy.

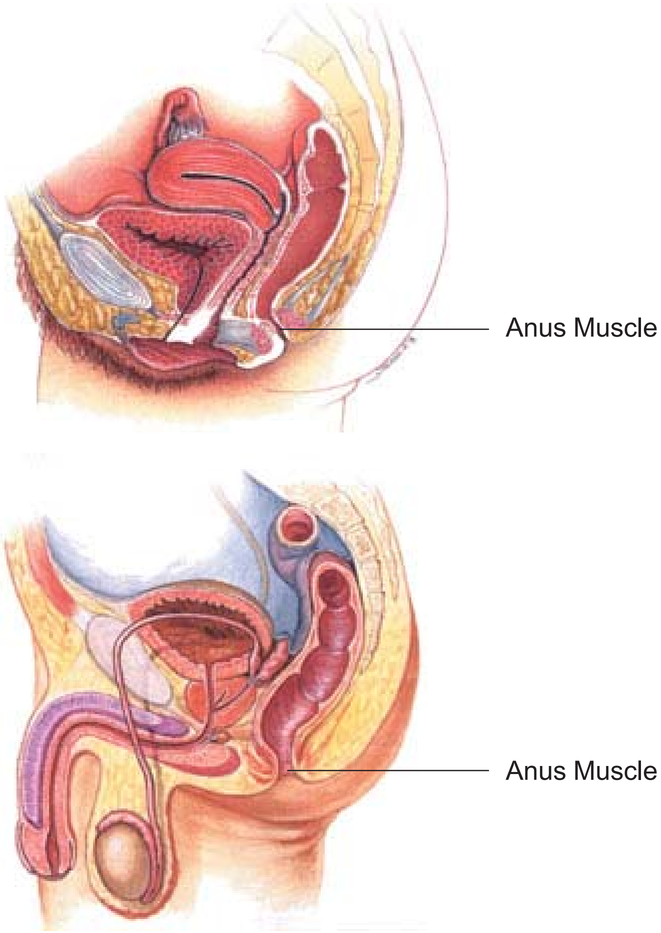

Fig. 7.2 *Anal Muscle*

Saliva

Saliva is yet another aid in performing these exercises. Once you have been able to bring the energy up through all the routes to the crown successfully, saliva generation becomes very important.

In the body, the moon influences the kidneys, which are linked with the salivary glands, the ovaries and semen. When the kidneys are stimulated during sex, the Chi is raised up through the spine, then it flows down in the saliva, and the kidneys' essence transforms into sexual energy. The saliva has two functions: purifying the mouth, and nourishing our immortality, the water of life. The energy from the saliva lubricates 100 joints, and it stimulates and harmonizes the organs. It is very important to enhance the production of saliva by absorbing the moon's energy through the breath absorption exercises. It is a sign that the techniques are working when the saliva floods into the mouth.

Although saliva is a lubricant for the Channels, it first serves as an agent to burn and clean them out of any impurities that could block the flow of energy. So when resting during the practice of opening the thrusting channels move your tongue around to create saliva. Make it thick and swallow down forcefully, feeling it go down the channels that you are working on (See the book *"Elixir Chi Kung"* by Mantak Chia).

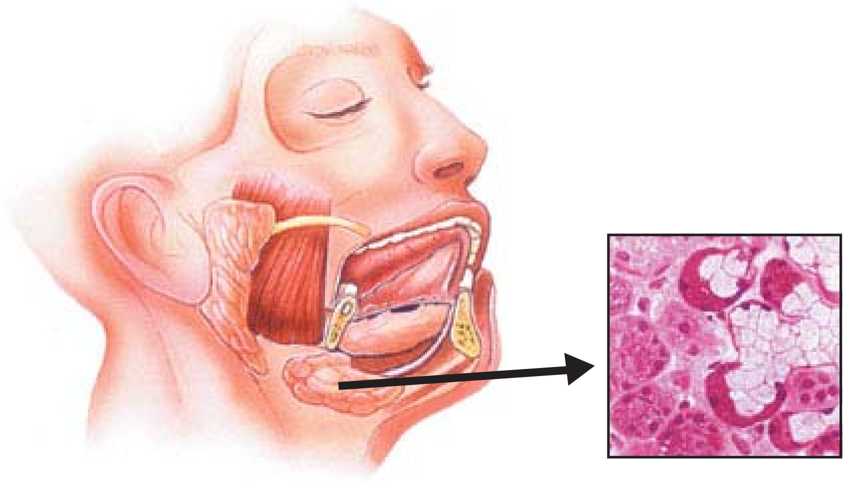

Fig. 7.3 *Saliva*

A person experiences the Thrusting Channels according to his or her kinesthetic or visual perceptions. The majority of people are more kinesthetic and can undeniably feel the quality of the condensed energy as it passes through each level of the channels.

Visual people can see patterns and colors. The Thrusting Channels, like the organs they intersect, have corresponding colors. The Left Channel is Red, Middle - White and Right - Blue. Regardless of your perceptual tendency, both the senses and the organs are used to control the Thrusting Channels.

The denser or more polluted the organ, the more energy is requires to pass through the affected Thrusting Channel.

As a safety precaution and as preparation to be able to move the energy to prevent it from sticking, the Thrusting Channels are opened in four stages. The pearl is brought (1) up to the diaphragm; (2) up to the neck; (3) up to and out of the crown; (4) down to the feet, into the ground; and up to the crown.

This will be done a total of nine times at each stage in the following sequence: (1) left, (2) middle, (3) right, (4) middle, (5) left, (6) middle, (7) right, (8) middle and (9) left.

Men & Women Practices: Open Channels Differently

Once the channels have been completely opened, men and women practice differently. Without stopping, men will thrust the energy directly up through the Thrusting Channels and out of the crown. They then will bring the energy back in to flow down the Thrusting Channels and down through the soles of the feet into the ground. They can continue to bring the flow up around the body and in through the crown. Without stopping, women will thrust the energy down through the soles of the feet into the ground and then up through the Thrusting Channels to and out of the crown. They then spray the energy down around the body, tuck it under the feet and draw it back in through the toes.

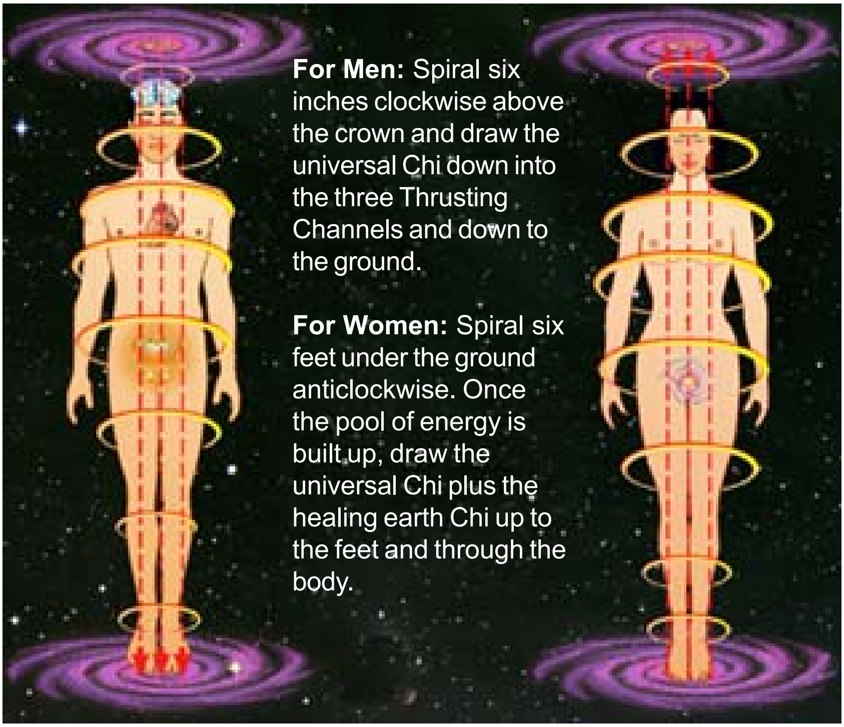

For Men: Spiral six inches clockwise above the crown and draw the universal Chi down into the three Thrusting Channels and down to the ground.

For Women: Spiral six feet under the ground anticlockwise. Once the pool of energy is built up, draw the universal Chi plus the healing earth Chi up to the feet and through the body.

Fig. 7.4 *Cosmic Thrusting and Belt Channels*

Practice of Opening the Thrusting Channels

1. Form a Pearl and Send it to the Perineum

In a seated position smile down to your organs and glands, and put yourself in a state of relaxation and happiness. Begin with the meditation exercises of the Creation Cycle to form a pearl of compassion energy.

As you have learned, there are many steps in forming such a pearl. However, once you have programmed yourself to all of these steps through continued practice, you can simply push the button and the whole program is activated. When you are able simply to sit quietly and feel the sensation of compassion energy forming, you are pushing the button and the entire process takes very little time. In other words once you have experienced compassion energy, all you need to do is to recall the state to create the energy again. You will not need to go through the entire process each time. You will know when you look at the pearl whether or not the process has been completed. If you find something is not right, you can review the steps and find out where the problem is.

As the pearl is forming, use your mind and senses to control it. Slowly move it down to the perineum. At any time during your practice, if the pearl seems to weaken, diminish, or you lose track of it, return to the navel and quickly form a new pearl. Bring that pearl to the perineum and resume practice.

While you are learning how to bring the energy up through the channels, it is easier to focus on the organs the channel passes through than to focus on the channel. You might think of the process as learning how to read. Once you are able to read, you no longer have to think about your ABC's.

2. Stage One: Thrusting Channels to Below the Diaphragm

A. Left Thrusting Channel to the Diaphragm

In all Universal Tao practices it is important to train the power of the mind and senses to control our energy (Chi). The power of mind, eye and heart guides the Chi, providing a way to control and direct your life force. Breathing techniques also help to activate the Thrusting Channels. It is necessary to have some control over independent breathing through each nostril. Since in the beginning this is difficult to do, you can use your right index finger to cover the right nostril. Feel the breath on the left side only. Use the left eye, ear, and nostril to assist you in drawing up the energy.

1. Left Testicle (Men), Left Ovary (Women) and Left Kidney
   a. Sit up, using your mind, heart and eye power to look inside and be aware of the perineum. Also become aware of your left nostril, left ear, left eye and left anus.
   b. Activate the Left Thrusting Channel by inhaling through the left nostril in short sips (about ten percent of lung capacity with each breath.)
   c. Then men slightly pull the left testicle and the left side of the anus up toward the left. Women slightly pull the left side of the anus up toward the left. Draw the pearl up with each sip of air. The left eye should internally look down, and then use the mind/eye power to look up as the pearl is drawn up. (The physical eyes do not actually look up.) Women direct the pearl to the left ovary and the left kidney; men direct the pearl to the left kidney.
   d. Exhale, relax the eye and the muscles, letting the pearl drop to the left side of the anus (and left testicle in men), and rest. Rest and feel the left side become lighter as the energy begins to flow up without effort. Practice nine times. Each time you rest use your mind to trace the Left Thrusting Channel.

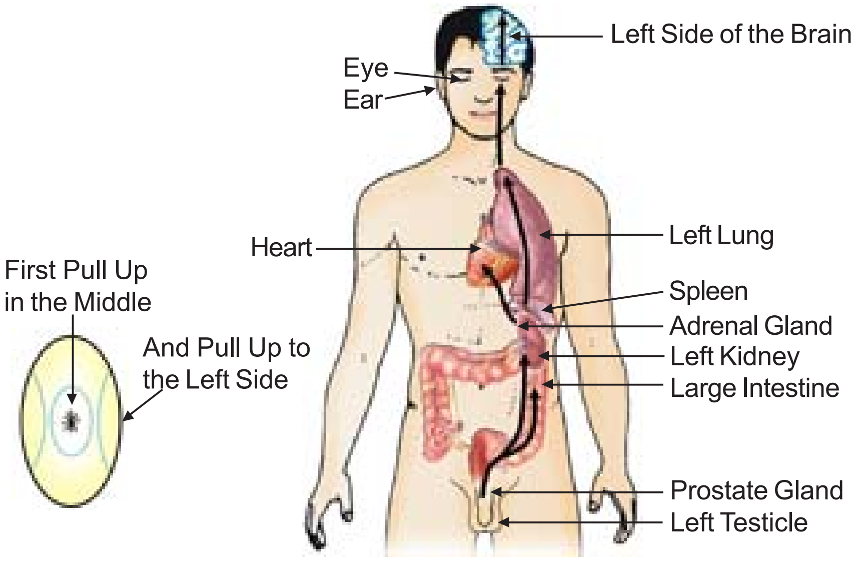
Left Side of the Brain
Eye
Ear
Left Lung
Heart
First Pull Up in the Middle
Spleen
Adrenal Gland
And Pull Up to the Left Side
Left Kidney
Large Intestine
Prostate Gland
Left Testicle

Fig. 7.5 *Left Part in the Male*

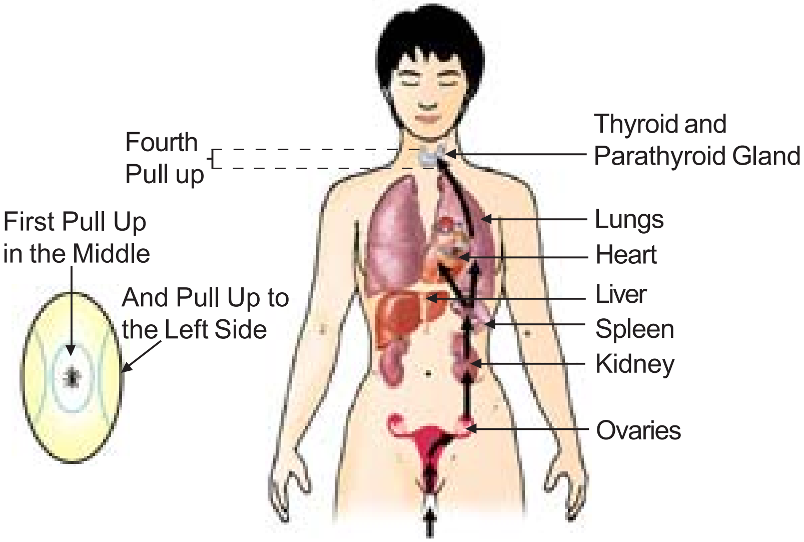

Fig. 7.6 *Left Part in the Female*

2. Spleen

Close the right nostril, inhale, and pull up. As you sip in the air, use the mind power and the left eye, ear and nostril to draw the energy up from the left testicle (men), through the left ovary (women), the left kidney, and up to the spleen. Exhale; release the energy down. Practice nine times. Rest, and feel the energy flow up the Left Thrusting Channel to the spleen under the diaphragm.

B. Middle Thrusting Channel to the Diaphragm

1. Prostate (Men) or Cervix (Women)

Men concentrate on the middle of the scrotum, perineum, and anus. Women concentrate on the middle of the perineum and anus. Inhale, and pull up the middle of the scrotum (men), perineum and anus. Use all the senses to draw the energy up to the prostate (men) or cervix (women). Look up with both eyes as you do so. Relax the eyes and anus muscle, and let the pearl drop back down to the perineum and scrotum (men). Feel the energy begin to flow up as you rest. Do this nine times.

2. Small/Large Intestine, Aorta and Vena Cava

Inhale and pull up the scrotum (men only) and anus. Use the eyes, ears, and nose to draw the energy to the prostate/cervix, small intestine, large intestine, aorta and vena cava. Do not thrust beyond the diaphragm. Practice nine times. Rest, and feel the energy flow up through the Middle Thrusting Channel to the vena cava.

3. Stomach and Pancreas

Follow the above procedure and thrust through the middle organs to the stomach and pancreas. Practice nine times. Swallow the saliva, rest and feel the energy flow in the Middle Thrusting Channel up to the diaphragm.

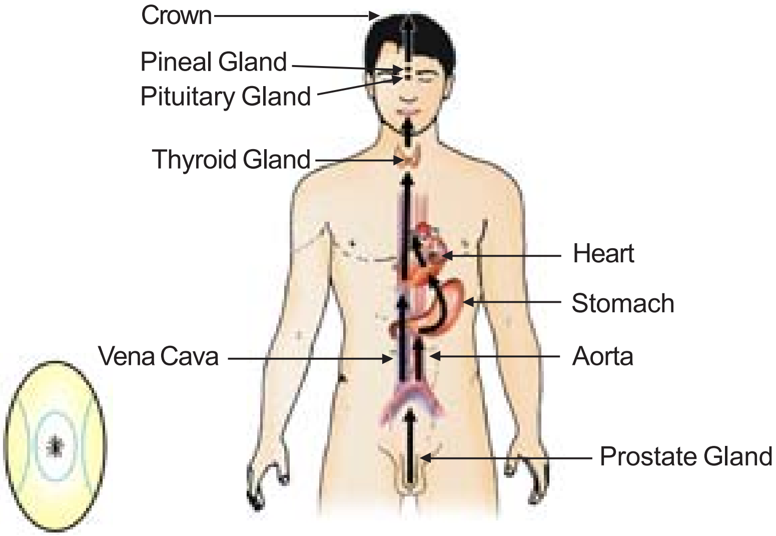
Crown
Pineal Gland
Pituitary Gland
Thyroid Gland
Heart
Stomach
Vena Cava
Aorta
Prostate Gland

Fig. 7.7 *Middle Part in the Male*

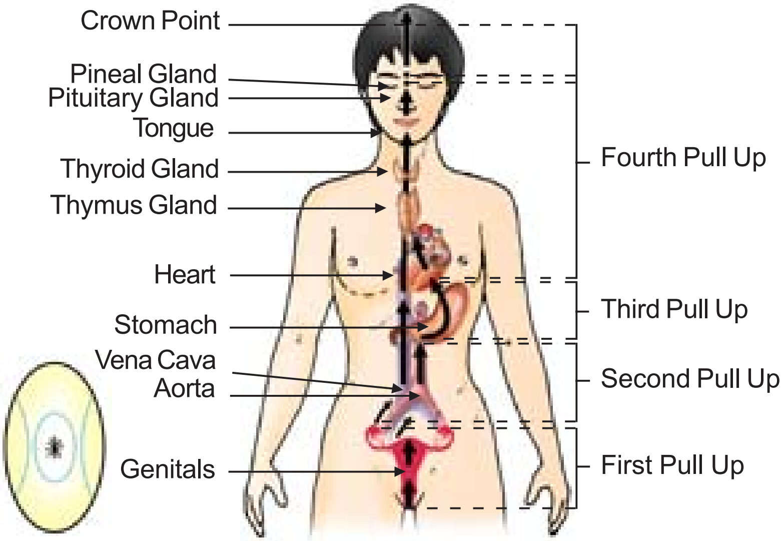
Crown Point
Pineal Gland
Pituitary Gland
Tongue
Thyroid Gland
Thymus Gland
Heart
Stomach
Vena Cava
Aorta
Genitals
Fourth Pull Up
Third Pull Up
Second Pull Up
First Pull Up

Fig. 7.8 *Middle Part in the Female*

C. Right Thrusting Channel to the Diaphragm

1. Right Testicle (Men), Right Ovary (Women) and Right Kidney
    a. Close the left nostril with the index finger of the left hand. Use the right eye, ear and nostril to direct the energy up the right channel. Put your right hand on the right kidney.
    b. Inhale in short sips equal to ten percent of lung capacity. Look up with the right eye. Pull up the right testicle (men only) and the right muscle of the anus toward the right side. Direct the energy up the right Thrusting Channel to the right ovary (women) and kidney. Practice nine times.
    c. Exhale and rest. Let the pearl drop down, returning to the perineum and right testicle (men only.) Feel the right side become lighter as the energy flows up the Right Thrusting Channel to the right kidney without effort.

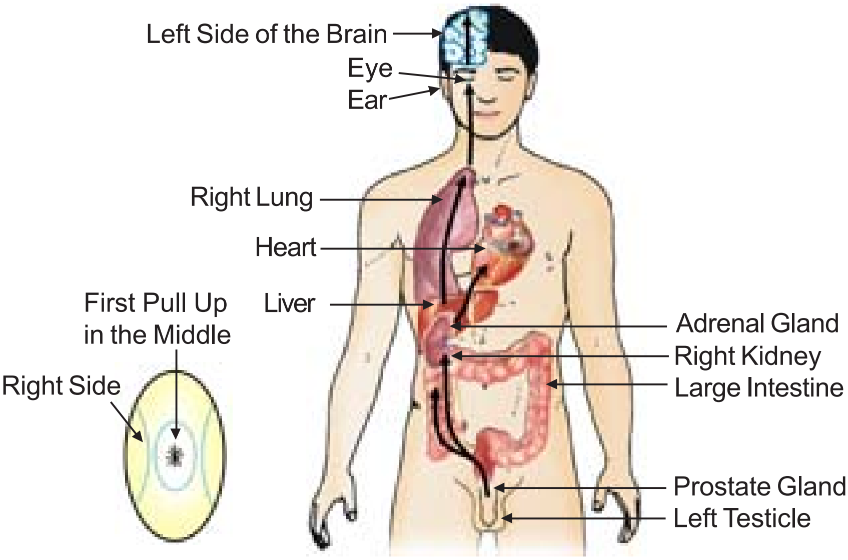
Left Side of the Brain
Eye
Ear
Right Lung
Heart
First Pull Up in the Middle
Liver
Right Side
Adrenal Gland
Right Kidney
Large Intestine
Prostate Gland
Left Testicle

Fig. 7.9 Right Part in the Male

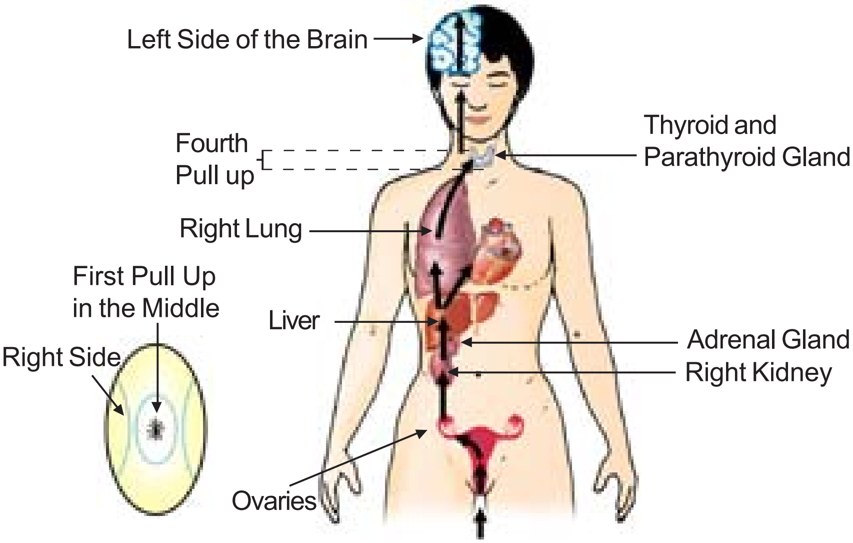
Left Side of the Brain
Fourth Pull up
Thyroid and Parathyroid Gland
Right Lung
First Pull Up in the Middle
Liver
Right Side
Adrenal Gland
Right Kidney
Ovaries

Fig. 7.10 *Right Part in the Female*

2. Liver

Close the left nostril, inhale and pull up. Use the right eye, ear and nostril; draw the energy up from the right testicle (men only), through the right ovary (women only), the right kidney and up to the liver. Exhale, relax and let the pearl return to the perineum. Practice nine times. Rest, and feel the flow of energy through the Right Thrusting Channel to the liver, under the diaphragm.

a. Combine all Three Routes

   Continue to practice moving the pearl up and down through a combination of all three Thrusting Channels to under the diaphragm in the following nine steps until the energy is flowing easily: (1) Left Channel; (2) Middle Channel; (3) Right Channel; (4) Middle; (5) Left; (6) Middle; (7) Right; (8) Middle; and (9) Left. It helps to quicken the speed with each attempt.

Note: Stay relaxed during this exercise, and avoid using force. Once you are accustomed to thrusting the pearl and feel that the channels are clear, there is no need to close the nostrils for the left and right channels. Just simply pull up the perineum and anus, and use the power of the mind.

b. Clearing the Routes with Saliva
   End by preparing the saliva. First sweep your tongue across the outer surface of your upper teeth, starting on the left side at your wisdom tooth, with the tip of the tongue going along the gums. When you arrive at your upper right wisdom tooth, move the tip of your tongue down to the lower right wisdom tooth and move along the front of the lower teeth. When you arrive at the lower left wisdom tooth, start again at the upper wisdom tooth. Circle around in this manner a few times. Then similarly sweep along the inner surface of the upper and lower teeth and gums. Your mouth will begin to fill with saliva.

Gather the saliva into a ball using your tongue. Press your tongue to the roof of your mouth and swallow the saliva quickly with a gulping action. Feel the saliva burn out the impurities in the Channels and lubricate them.

Practice this stage for about one or two weeks until you can control the energy very well, then continue to the next stage. Each time you finish, move the energy in the Microcosmic Orbit and collect the energy in the cauldron. When you are ready to continue to the next stage, practice Spinal Cord Breathing at this point in your preparation.

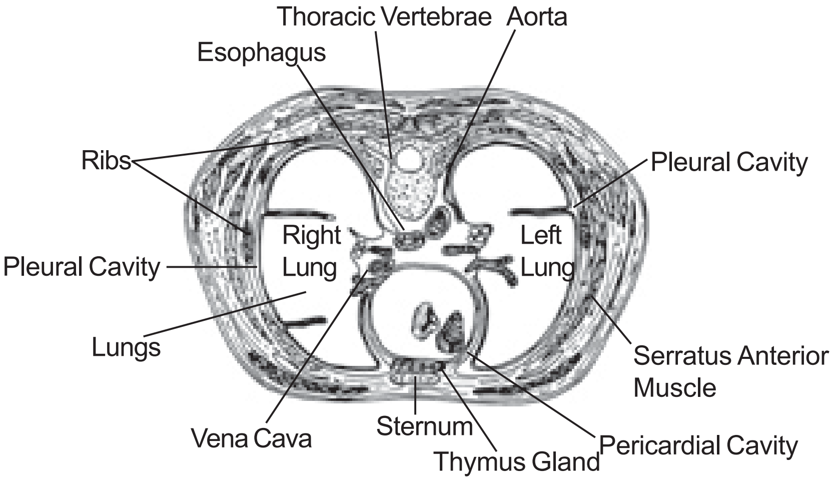
Thoracic Vertebrae
Aorta
Esophagus
Ribs
Pleural Cavity
Right Lung
Left Lung
Pleural Cavity
Lungs
Serratus Anterior Muscle
Vena Cava
Sternum
Thymus Gland
Pericardial Cavity

Fig. 7.11 *Cross Section of the Thorax*

3. Stage Two: Thrusting Channels to the Neck

A. Left Thrusting Channel to the Neck

1. Diaphragm

Using the procedure described above, bring the pearl up the Left Thrusting Channel to below the diaphragm and let it return down to the perineum.

2. Left Thyroid and Parathyroid Glands

Using the same procedure, bring the pearl up through the left ovary (women), left kidney and spleen, and continue to bring the pearl up to the left lung, and left thyroid and parathyroid glands. Hold for a while, and then exhale. Let the pearl return to the perineum. Practice nine times.

Be aware of the energy flow up to the neck through the Left Thrusting Channel.

B. Middle Thrusting Channel to the Neck

1. Diaphragm

Using the procedure described above, bring the pearl up the Middle Thrusting Channel to below the diaphragm, and let it return down to the perineum.

2. Thymus, Thyroid and Parathyroid Glands

Using the same procedure, bring the pearl up from the perineum through the prostate (men), cervix (women), small/large intestine, aorta and vena cava, stomach and pancreas. Continue to bring the pearl up to the heart, to the thymus gland under the sternum, and up to the middle of the neck, thyroid and parathyroid glands. Practice nine times. Exhale, relax and let the pearl drop down again.

Be aware of the Middle Thrusting Channel as the energy flows up to the neck.

C. Right Thrusting Channel to the Neck

1. Diaphragm

Using the procedure described above, bring the pearl up the Right Thrusting Channel to below the diaphragm and let it return down to the perineum.

2. Right Thyroid and Parathyroid Glands

Using the same procedure, bring the pearl up from the perineum to the right ovary (women), right kidney, liver and continue to bring the pearl up to the right lung and to the right thyroid and parathyroid glands. Exhale, and slowly release the energy down. Practice nine times.

Be aware of the Right Thrusting Channel as the energy flows up to the neck.

D. Continue to Practice the Three Thrusting Channels to the Neck

Practice all three Thrusting Channels to the neck, nine times each, as delineated for the diaphragm: left, middle, right, middle, left, middle, right, middle and left.

E. Clear the Routes with Saliva

If your throat feels dry, you can collect and warm the saliva in your mouth. Tighten your neck a little bit, and swallow the saliva with a guttural sound down to the stomach. Feel the saliva like a fire clearing all three channels.

Practice this stage for about one or two weeks, each time finishing by moving the pearl in the Microcosmic Orbit and collecting it in the cauldron.

F. Rest and Concentrate on All Three Channels

Rest and concentrate on all three channels, visualizing the left route as red, the middle as white, and the right as blue.

4. Stage Three: Thrusting Channels to the Crown

In stage three of opening the Thrusting Channels, the pearl is thrust through the channels up to and out of the crown.

A. Left Thrusting Channel to Crown

1. Left Eye

Follow the above procedure for thrusting through the Left Thrusting Channel to the neck, and continue thrusting to the left eye.

2. Crown

Repeat the Left Thrusting Channel to the left eye and continue to thrust the pearl up through the left hemisphere of the brain to the crown. Practice nine times. Rest, and mentally trace the Left Thrusting Channel from the perineum to the crown.

B. Middle Thrusting Channel to the Crown

1. Mideyebrow

Repeat the Middle Thrusting Channel procedure as described to the neck and continue thrusting to the mideyebrow.

2. Crown

Repeat the Middle Thrusting Channel to the mideyebrow, and continue to thrust the pearl up through the pituitary gland to the pineal gland at the crown. Practice nine times. Rest, and mentally trace the complete Middle Thrusting Channel.

C. Right Thrusting Channel to the Crown

1. Right Eye

Repeat the Right Thrusting Channel procedure as described to the neck and continue thrusting to the right eye.

2. Crown

Repeat the Right Thrusting Channel to the right eye, and continue thrusting the pearl up to the right hemisphere of the brain and then to the crown. Practice nine times. Rest and trace the route mentally from the perineum to the crown.

D. Continue to Practice the Three Thrusting Channels to the Crown

Continue to practice the three Thrusting Channels to the crown nine times as was delineated for the diaphragm and again for the neck: left, middle, right, middle, left, middle, right, middle and left.

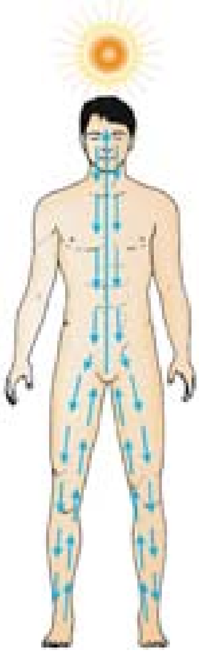

Fig. 7.12 *Three Thrusting Channels up to the Crown*

You now have succeeded in bringing the pearl through the Thrusting Channels to the crown. Your goal is to follow the sequence above using nine thrusts distributed among these three channels. Be aware of how and where the energy flows through the three Thrusting Channels, and how the three channels penetrate all the organs and glands. These channels are very powerful. They clean, detoxify and purify the organs at a much deeper level.

E. Bring the Pearl into the Microcosmic Orbit

When you have finished this stage of practice, you can bring the pearl into the Microcosmic Orbit and circulate it. Feel the Microcosmic Orbit encircling the Thrusting Channels. The top and bottom of the Thrusting Channels are joined with the Microcosmic Orbit at the crown and the perineum.

Use your mind to assist the flow of energy through the Thrusting Channels and through the Microcosmic Orbit when the pearl reaches the crown point or the perineum point.

Your Microcosmic Orbit practice will change dramatically after you learn the Fusion of the Five Elements meditations. When you first practice the Microcosmic Orbit, the energy you move through your channels is raw energy. By contrast, when you reach the level of Fusion practice, the energy is more refined and condensed, and it is therefore much more powerful. The Fusion practice includes the Microcosmic Orbit, so it might be said that the Fusion meditation is simply a more advanced way of practicing the Microcosmic Orbit meditation.

Practice this stage for two or three weeks until feel you have gained control of the energy.

5. Extending the Three Thrusting Channels above the Crown

Once we have purified and transformed the negative energy of the organs back into usable life-force energy (Fusion of the Five Elements), distilled this energy along with the virtue Chi of the organs into the pearl (Cosmic Fusion), and opened all our reservoirs or special channels, giving us a larger energy capacity, we can increase our virtue energies further by connecting with the external sources of Five Elements Chi and directing the external Chi toward its associated organs. Moving the pearl out of the physical body makes it easier for the pearl to absorb these energies. It becomes like an antenna that receives the external Chi and conducts it into the physical body. In this way, we again nourish our health in this life as well as strengthening the Energy Body and spirit in preparation for the next.

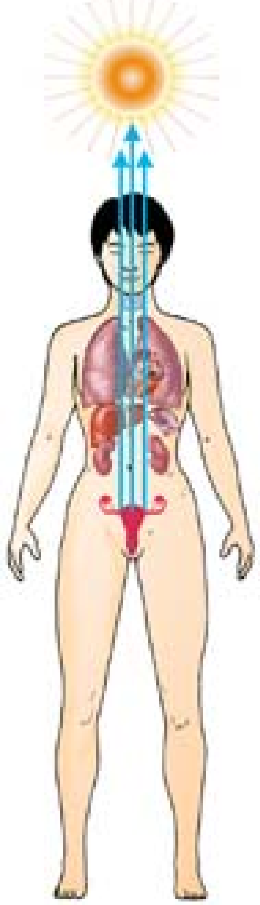

Fig. 7.13 *Three Thrusting Channels above the Crown*

After you gain full control of the energy, you will be able to send the pearl out of the body at the crown. Begin to practice quickly forming a fresh pearl in the practice of formimg the pearl by fuse in and out and back to the inside to form a pearl. Follow with the Creation Cycle. Then, thrust the pearl up through the Thrusting Channels to quickly clear out these routes. You are now ready to extend the channels above the crown.

Bring the energy down to the perineum, and start with the Left Thrusting Channel up to the left crown. Push the pearl out at the crown of the head to about three to six inches (seven and a half to fifteen centimeters) above the crown. Similarly, push the pearl out of the crown through the Middle Thrusting Channel, and then the Right Thrusting Channel.

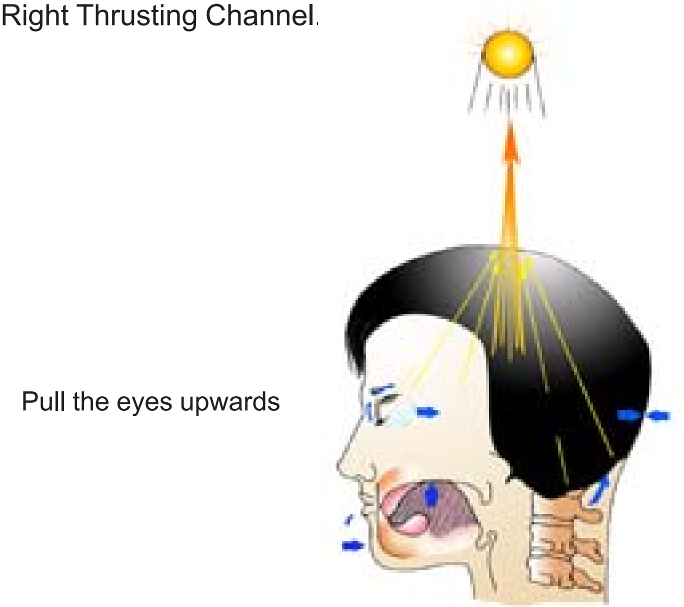

***Fig. 7.14** Use Physical and Mental Power to push the Pearl of Energy up through the Crown.*

Each time you push the pearl out at the crown, be aware of an energy ball hovering about six to ten inches (fifteen to twenty-five centimeters) over the crown. Draw and absorb the Heavenly Energy to the pearl. Then slowly let the energy melt and flow down to the crown, and then into the body, all the way down through the three Thrusting Channels to the perineum.

6. Stage Four: Leg Routes and Thrusting Channels into the Ground

In the final stage of opening the Thrusting Channels, the energy will go all the way down to the feet and into the ground, and then up through the channels with each thrust. After you have formed another new pearl by practicing Fusion of the Five Elements and the Creation Cycle of Cosmic Fusion, bring the energy down to the perineum.

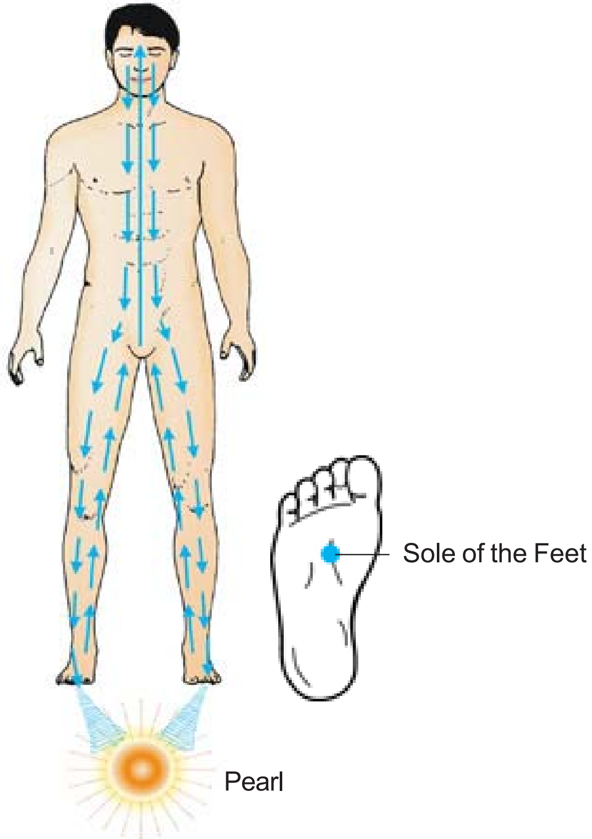

Fig. 7.15 *Three Thrusting Channels down to the Ground.*

A. Bring the Energy Down to the Soles of the Feet

1. Left Thrusting Channel

Split the pearl in two, and bring the energy from the perineum down the back of both legs to the backs of the knees, and then down to the heels and soles of the feet. Stop for a while, and absorb the Earth Energy through the soles. Then bring the energy up the front of the legs through the big toes, knees, front of the thighs, all the way back to the perineum. Recombine the pearl at the perineum. Then run the energy through the Left Thrusting Channel by slightly tightening the left side of the anus and looking up with the left eye. Bring the pearl all the way up through the left hemisphere of the brain and left crown, and out to three inches (seven and a half centimeters) above the crown. Relax, and bring the pearl down to the perineum.

2. Middle Thrusting Channel

From the perineum, split the pearl, and bring the pearl down the backs of both legs to the soles of both feet. Absorb the Earth Energy through the soles, then move the energy up to the toes, to the knees, returning to the perineum. Recombine the pearl at the perineum. Now bring the pearl all the way up the Middle Thrusting Channel, squeezing the middle of the anus and looking up with both eyes. Bring the pearl all the way up through all the organs and glands to the crown, and out to three inches (seven and a half centimeters) above the crown. Then bring it down to the perineum again.

3. Right Thrusting Channel

From the perineum, split the pearl, and bring it down the backs of both legs. Absorb the Earth Energy through the soles of the feet. Then bring the pearl up again to the perineum. Recombine the pearl at the perineum. Use the right anus muscle, look up with the right eye, and bring the pearl all the way up the Right Thrusting Channel through the right hemisphere of the brain and out of the crown three inches (seven and a half centimeters.) Bring it down to the perineum.

Continue bringing the pearl to the Thrusting Channels in the following sequence: left, middle, right, middle, left, middle, right, middle, and left, finishing each step by looping the pearl through the leg route. End on the left side of the perineum. Swallow the saliva, as described before.

B. Bring the Energy into the Ground

Once you have practiced bringing the pearl down to the soles of the feet for a while, add a new step. Begin by shooting the energy from the perineum down the backs of the legs and through the soles of the feet, from six inches to one foot into the ground. Feel a connection or rooting to the earth, then draw the energy up to the soles of the feet, to the toes, up the front of the legs, and into the Thrusting Channels.

With this step you have completed opening all the Thrusting Channels. Practice for two or three weeks until you develop full control of the energy traveling through these channels.

7. Men and Women Now Practice Differently

At this stage all the Thrusting Channels and Leg Routes are open, and men and women start to practice differently. Both quickly practice Fusion I, and the Creation Cycle and Thrusting Channels of Fusion II, and bring the pearl to the perineum.

A. Men start by bringing the Pearl to the Crown.

Men bring the pearl from the perineum up to and out of the crown to about six inches (fifteen centimeters.) Feel your pearl hook up with the higher energy source, Heavenly Energy. Absorb this energy into the pearl. Then bring the energy back into the body. As it enters the crown, let the pearl split in three. Feel the energy penetrate through three holes at the top of the head. Feel it flowing back down to the perineum through the three Thrusting Channels, penetrating all the organs and glands.

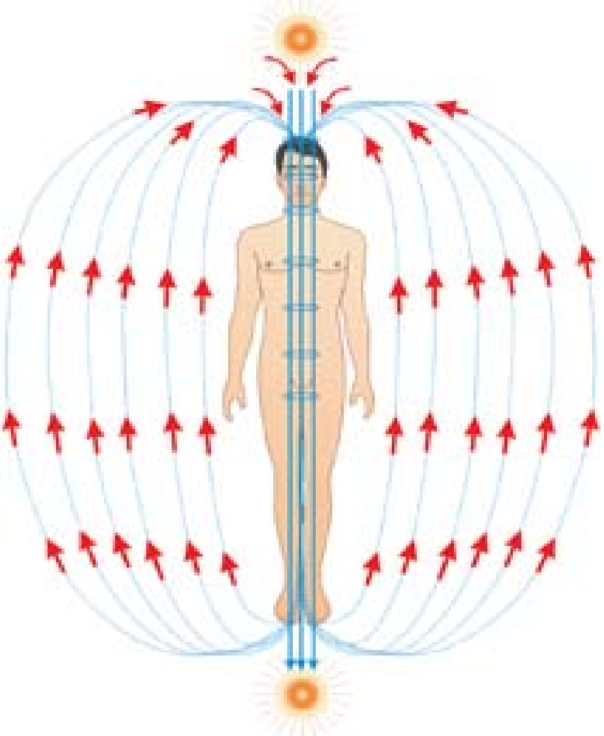

Fig. 7.16 *Bringing the Pearl to the Crown*

From the perineum men will push and guide the energy down the back of both legs to the soles of the feet, and then six to twelve inches (fifteen to thirty centimeters) into the ground. Feel a connection or rooting to the earth, then draw the Earth Energy up to the soles of the feet. Bring the energy to the toes. Start to spread the energy out from the ten toes, shooting the energy up to and into the crown, like a waterfall with a reverse flow. Draw the pearl back down to the perineum, and then repeat the process.

Practice nine times. Feel the flow of energy like a magnetic field surrounding your body.

B. Women start by bringing the Pearl to the Feet.

Women bring the pearl down to the perineum, divide it, and shoot it down the backs of both legs, through the soles of the feet, six to twelve inches (fifteen to thirty centimeters) into the ground. Feel a connection or rooting to the earth, and absorb the Earth Energy into the pearl. Then draw the Earth Energy up to the soles of the feet. Bring the energy all the way up the front of the legs to the knees, and back to the perineum. As the energy travels up the legs, feel it penetrate the bones.

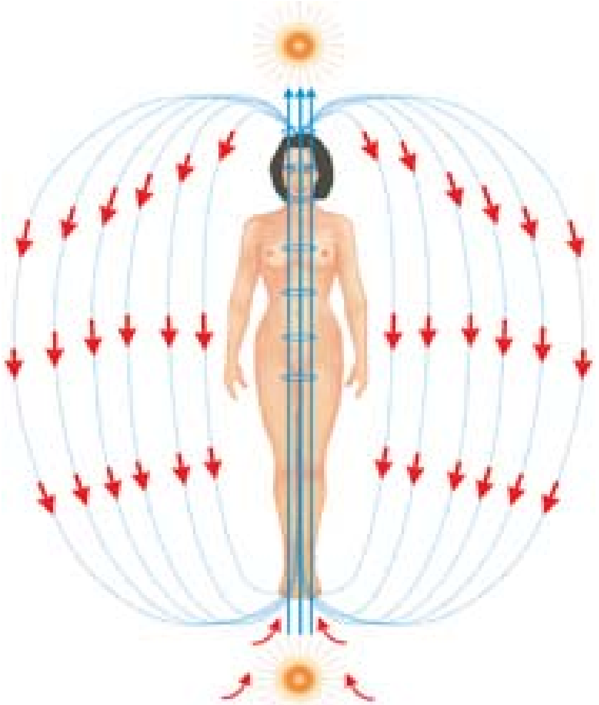

Fig. 7.17 *Women bring the Pearl to the Feet.*

Spread the energy into the three Thrusting Channels, and thrust it as though it were on a three lane highway all the way up to the crown. Feel the energy spread from the crown like a spring or water fountain pouring out of the body, entering into the soles of the feet, where it again joins together with energy from the earth. While the energy is outside and circling the body, it is also gathering pure, radiant Cosmic Energy. Repeat this meditation nine times.

8. Finishing the Meditation

Both men and women should finish by collecting the energy at the cauldron and practicing Chi Massage. This completes the practice of the Thrusting Channels. Continue to practice for a few weeks until you gain control of it.

Additional Exercise for Opening the Thrusting Channels

Alternate Nostril Breathing

The alternate nostril breathing helps to generate more power in moving the pearl up and down the Thrusting Channels. By closing one side of the nose, it is easier to move the pearl through the specific left or right channels.

Hold the right nostril closed with the finger tips.

Inhale up through the left nostril, and feel the pearl move up from the perineum to the crown.

Exhale out through the left nostril and bring the pearl back down to the perineum.

Inhale through the left nostril and bring the pearl to the Middle of the perineum.

Close both nostrils and suck the pearl up through the middle Thrusting Channel to the crown. This suction is created by an inhaling motion without actually drawing any air into the lungs.

Hold the right arm down towards the ground and exhale any cloudy or gray energy out of the Thrusting Channel.

The same procedure is repeated in the Right Thrusting Channel.

Hold the left nostril closed with the finger tips.

Inhale up through the right nostril, and feel the pearl move up from the perineum to the crown.

Exhale out through the right nostril and bring the pearl back down to the perineum.

Inhale through the right nostril and bring the pearl to the middle of the perineum.

Close both nostrils and suck the pearl up through the Middle Thrusting Channel to the crown.

Hold the left arm out and down to the ground, exhaling any cloudy gray energy down to the Earth.

Repeat 3 – 9 times or until you feel the Thrusting Channels clean and clear with positive energy.

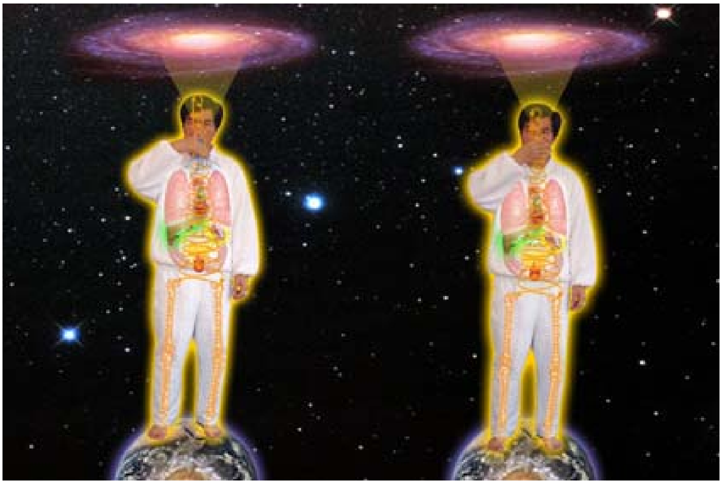

Fig. 7.18 *Alternate Nostril Breathing*

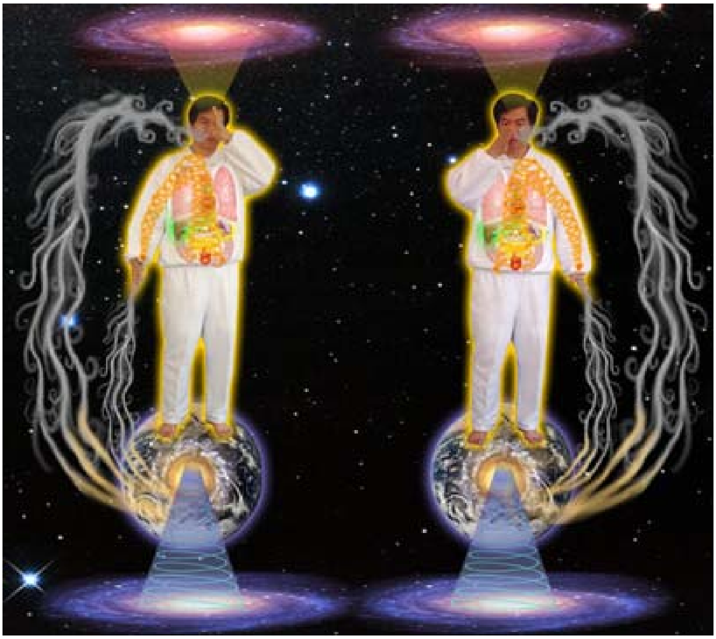

Fig. 7.19 *Exhale cloudy energy out of the Thrusting Channel.*

Summary
Opening the Thrusting Channels

Begin the Fusion practice by Opening the Three Fires, activate the compassion fire forming the pakuas by chanting the eight forces, forming the collection points, fusing the colors, and forming the pearl. Review the explanation discussed previously. Once you feel the pearl is strong and full of energy, you do not have to go through all these stages all the time. Just think and let it happen.

The Thrusting Channels are Opened in Four Stages.
(1) to the diaphragm; (2) to the neck; (3) to and out of the crown; (4) down to the feet, into the ground; and up to the crown.

1. The Left Thrusting Channel penetrates the left testicle (in men), left side of the perineum and anus, left ovary (in women), left kidney, spleen, heart, left lung, left parathyroid and thyroid glands, left ear, left eye, and left hemisphere of the brain.
2. The Middle Thrusting Channel runs through the middle of the scrotum (in men), perineum, middle of the anus, cervix (in women), prostate (in men), aorta, vena cava, pancreas, stomach, heart, thymus gland, throat, tongue, pituitary, hypothalamus, and pineal glands, and crown.
3. The Right Thrusting Channel goes through the right testicle (in men), right side of the perinium and anus, right ovary (in women), right kidney, liver, right lung, right parathyroid and thyroid glands, right ear, right eye, and right hemisphere of the brain.

Note: Avoid overheating the heart, liver, or head. Be very gentle with this procedure. If the energy reaches the heart and head too quickly the heart will become congested and you may experience pressure. If the heart overheats with energy, avoid thrusting above the diaphragm, and practice the Heart Sound (***Hawwww***).

Strengthen your anus muscle, the foundation, connected to the perineum and everything in the body above it. Saliva purifies the mouth, and nourishes immortality. When resting, create and gather saliva. Make it thick and swallow down forcefully.

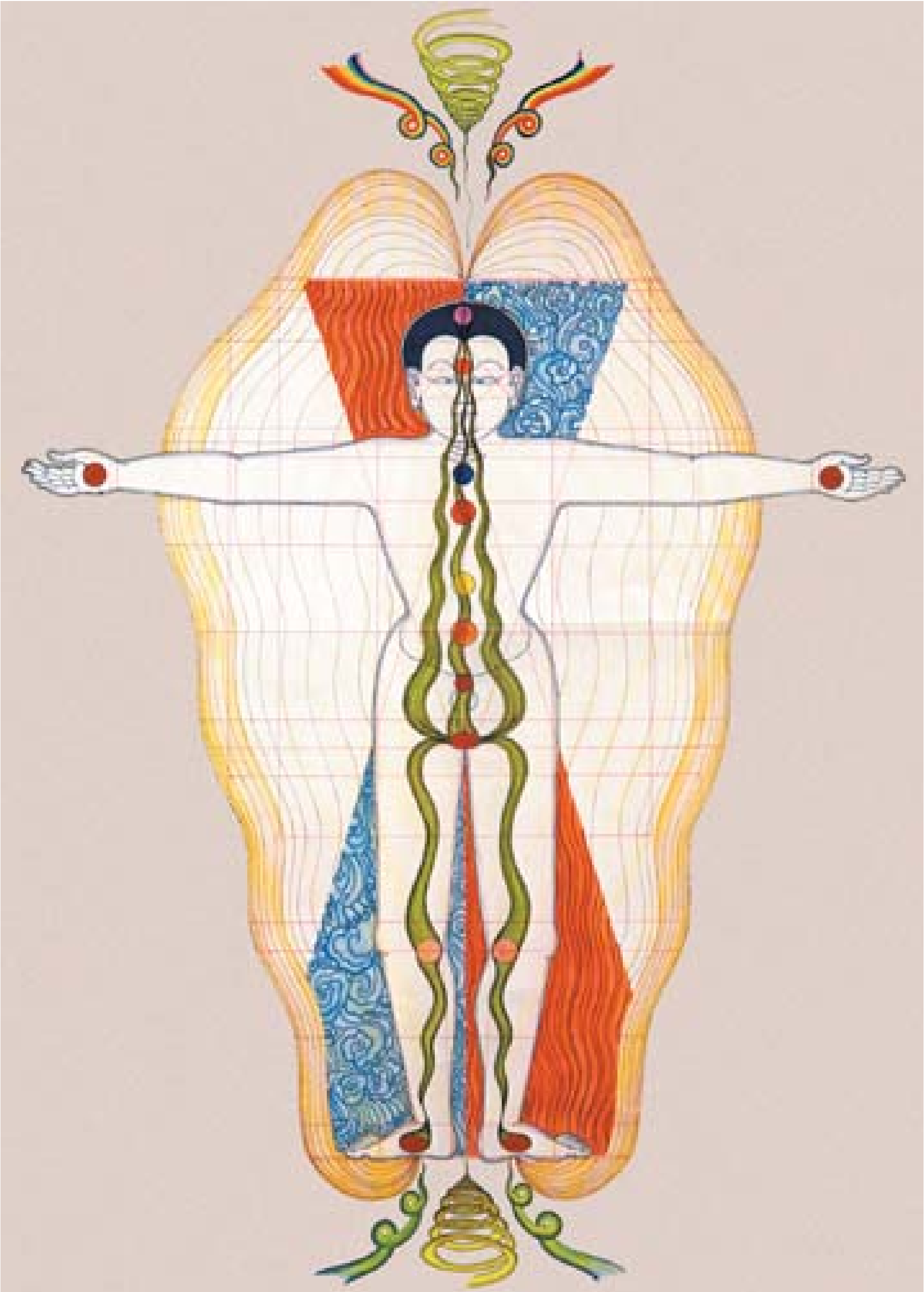

Fig. 7.20 *Thrusting Channel*

Chapter 8

Belt Channels

Theory of the Belt Channel

The Belt Channel is a psychic channel of power and self-defense, encircling the body with energy. It protects the body and fences the energy within the Governor, Functional and Thrusting Channels, while warding off negative energy from the outside world. Starting at the navel each Chi center of the body is crossed and encircled by one level of the continuing Belt Channel.

A cross-section at the navel level would show the Belt Channel connecting to the other channels you have learned to this point. At the front of the body, the Belt Channel connects with the Functional Channel. As it moves to the left side it connects with the Left Thrusting Channel. At the Door of Life in the back, it connects with the Governor Channel. To the right it connects with the Right Thrusting Channel. Returning to the front, the circle is completed.

When you learn to form a pearl practicing Fusion of the Five Elements, and you draw the energy from the front, back and side pakuas at the level of the navel, you are laying the groundwork for the Belt Channels.

Procedure of Forming the Belt Channel

The Belt Channel begins at the navel and spirals upward in a counterclockwise direction through solar plexus, heart, throat, mideyebrow, and crown. Then, reverse the energy flow and circle the pearl clockwise as you move down through the above points to the navel. From the navel continue down to the sexual center, perineum, knees (around both knees), and soles of the feet (slightly into the ground). Finally, reverse the direction and work up through each point back to the navel.

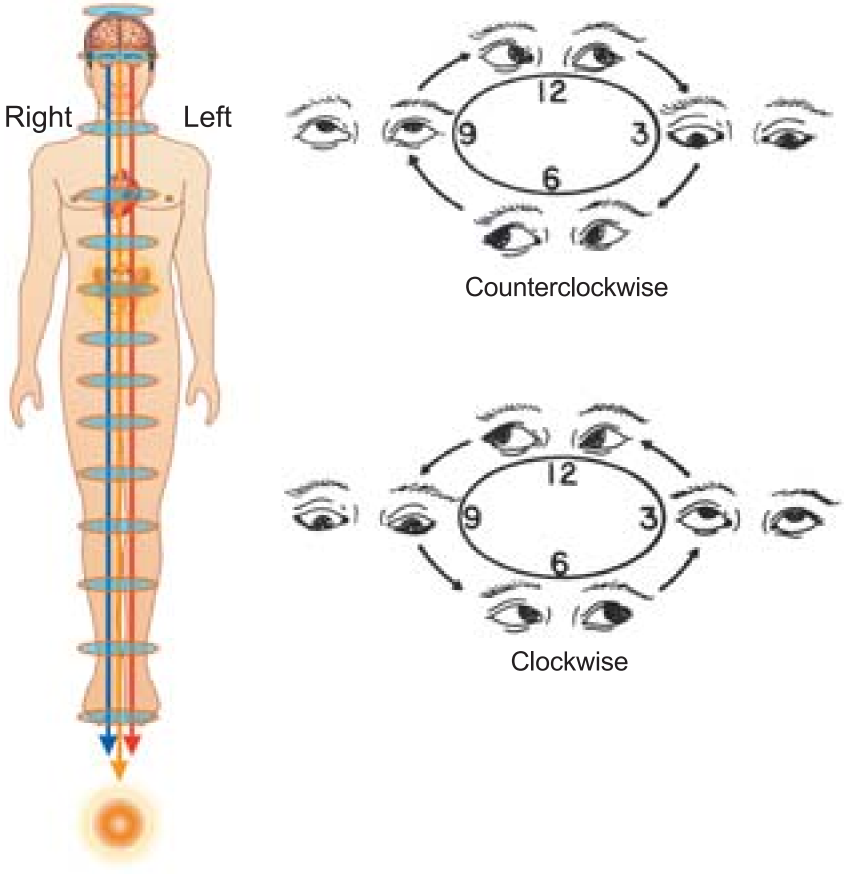

Counterclockwise

Clockwise

Fig. 8.1 *Use the eyes to help spiral.*

Note:To circle to the left is to circle counterclockwise; circle counterclockwise as you move the pearl up. To circle to the right is clockwise; circle clockwise as you move the pearl down.

The pearl is circulated in each Belt Channel nine times. After the ninth time of circling each point, you will cross each channel internally with the pearl by moving the pearl from front to back, and from left side to right side. Each time you will end with the pearl at the front, and then move on to the next level Belt Channel.

Practice of Forming the Belt Channel

Ascending from the Pakuas

1. Sit up, back straight, shoulders relaxed, feet touching the floor. Hold the hands together, and touch the tongue to the palate.
2. Practice the Inner Smile, Fusion of the Five Elements, chanting, the collection points, fusing the energy into a pearl and the Creation Cycle of Cosmic Fusion. Continue with your practice of Cosmic Fusion by sending the energy through the three full Thrusting Channels (all the way down to the feet and up to the head.)
3. You are ready to begin forming the Belt Channel. First, form the four pakuas and a pearl. Gather the pearl at the cauldron, and bring it to the navel.

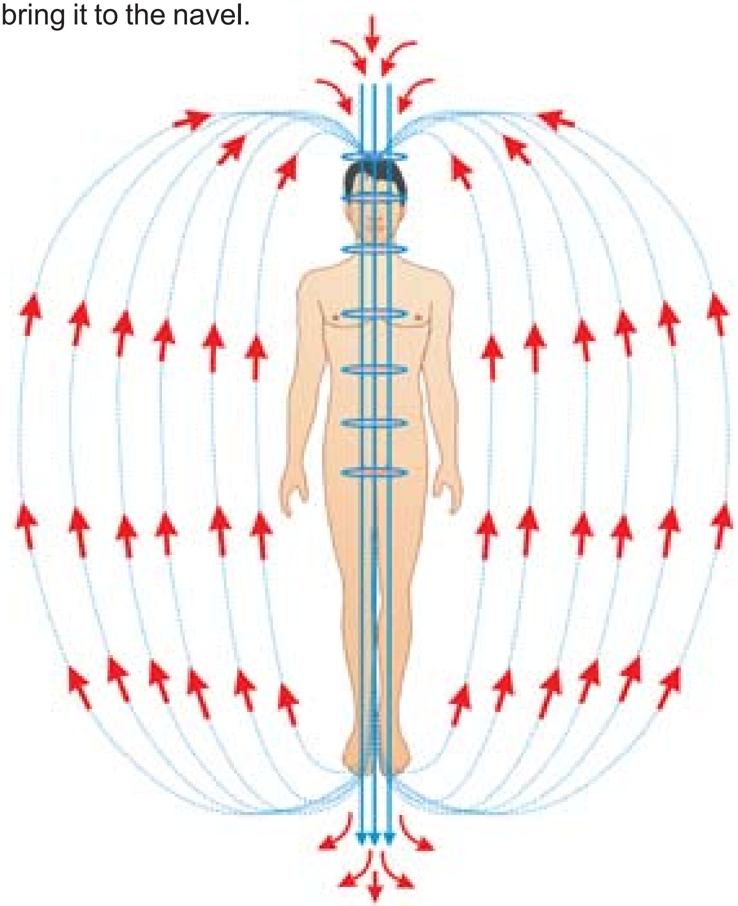

Fig. 8.2 *Moving the Thrusting Channels out of the Body.*

4. Join the four pakuas by circulating the pearl from the ***Navel*** toward the left side (counterclockwise), to the Door of Life, to the right side, and back to the navel.

   In the beginning you can use your hand to assist you in moving the pearl, although your goal is to use your senses to control its movement. Cover the navel with the right hand. Cover the left side pakua with the left hand. Then, move the left hand to cover the Door of Life, and move your right hand to cover the right side pakua. Finally, return the right hand to the navel.

   Circle the pearl nine times counterclockwise. As you are ascending you will circle it nine times counterclockwise from each point in a similar fashion.
5. When you finish circling the pakuas for nine rounds, be aware of the navel. Be aware of the channel of the navel. Form a cross by bringing the pearl from the navel to the cauldron, and all the way back to the Door of Life. Then, bring the pearl back to the cauldron, and use it to connect the side pakuas from the left cross to the right. Return the pearl to the navel.

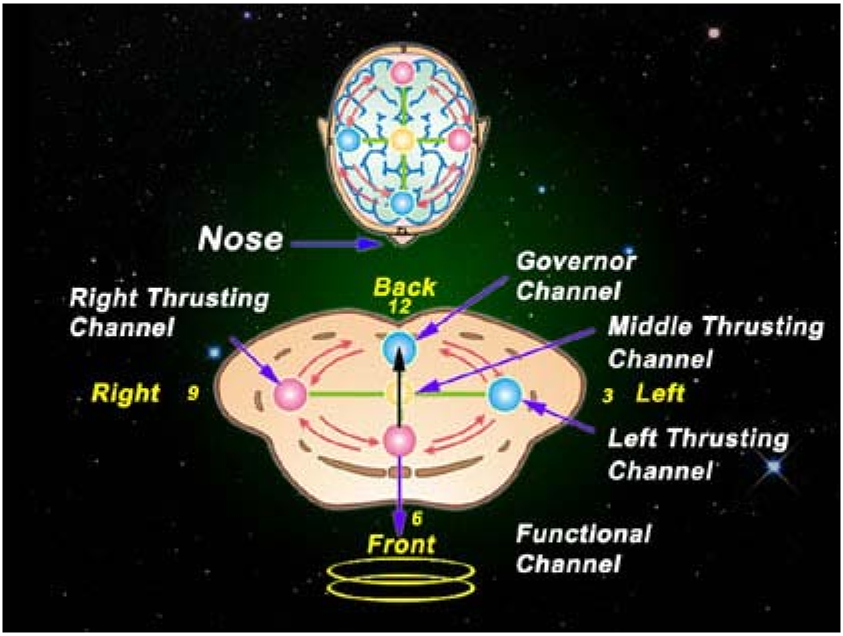
Nose
Right Thrusting Channel
Back
12
Governor Channel
Middle Thrusting Channel
Right
9
3
Left
Left Thrusting Channel
6
Front
Functional Channel

Fig. 8.3 *Cosmic Belt Channels connecting to all the other Channels.*

6. Move the pearl up from the navel to the left side of the rib cage to a position level with the ***Solar Plexus***. Begin to circle the pearl at the solar plexus level. Circle the pearl toward the left through T-11 at the back, to the right, and return to the solar plexus. Circle nine times, ending with the pearl at the solar plexus. Take a moment to perceive it. Then create an internal cross with the pearl, moving it from front to back, and then from left to right.
7. Bring the pearl from the solar plexus to the left side rib cage, this time at the level of the ***Heart***. Circle nine times toward the left to the middle of the shoulder blades, to the right, and back to the heart center. Circle in this manner for nine rounds. Using the pearl, form an internal cross connecting all four sides. Feel the connection of the channel.
8. From the heart center, bring the pearl up to the left side of ***Throat Center*** on the neck. Circle the pearl toward the left and back to C-7, to the right side, and to the middle of the throat center nine times. Use the pearl to form an internal cross connecting all four sides. Practice and master this step before continuing up to the crown.

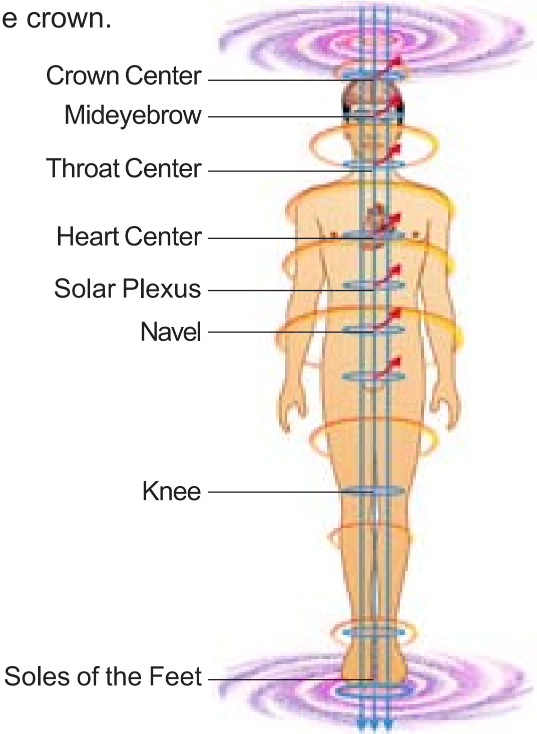

Fig. 8.4 *Bring the pearl up to the upper tip of the left ear.*

9. Bring the pearl up to the upper tip of the left ear at the level of the ***Mideyebrow Center***. Circle the pearl nine times from the left ear back to the small brain, to the right (upper tip of the ear), returning to the mideyebrow. Feel a band of energy flowing around the mideyebrow, ears, and back of the head. Using the pearl, form an internal cross connecting all four sides. The feeling is one of wearing a crown with a cross at its center connecting it.
10. From the mideyebrow bring the pearl up to the left side of the ***Crown***, and circle the energy nine times in a counterclockwise direction at the crown. End with the pearl at the front. Using the pearl, form a cross connecting the front, back, and both sides of this Belt Channel.
11. Allow the pearl to go out above the crown, and circle the energy nine times toward the left forming a ***Halo of Energy***. Use the pearl to cross the halo, front to back, and left to right. Collect the energy from above the head.

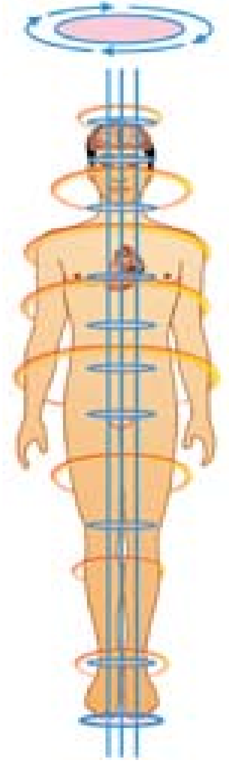

Fig. 8.5 *Spiral out clockwise above the crown.*

12. Now reverse the direction of energy flow to a clockwise direction by circling from the front toward the right, to the back, and to the left. Circle the ***Halo*** nine times, ending with the pearl at the front. Then cross the front to back, and right to left sides. Finish by bringing the pearl to the front of the halo.

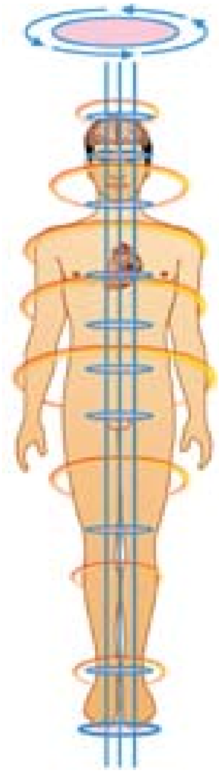

Fig. 8.6 *Reverse the direction clockwise.*

13. Next bring the pearl back into the right side of the ***Crown***. Circle toward the right nine times, bringing the pearl to the back, to the left, and ending at the front of the crown each time. Then use the pearl to cross the front, back, and two sides. Return the pearl to the front of the crown.
14. Move the pearl down to the upper tip of the right ear. Circle from the right ear to the back of the head, to the top of the left ear, and to the ***Mideyebrow*** nine times. End at the mideyebrow. Use the pearl to cross the front, back, and two sides at this level, and return it to the front to the mideyebrow position.

15. Bring the pearl down to the right side of the neck at the level of the ***Throat Center***, and circle right to *C-7* at the back of the neck, to the left, and to the front of the throat center. Circle nine times, ending at the front. Cross the front, back, and two sides, also ending by bringing the pearl to the front.
16. Bring the pearl down to the right side rib cage at the ***Heart Center*** level. Circle the pearl toward the right, to the back,and so forth clockwise for nine times, ending at the front of the heart center. Then, use the pearl to cross the front, back, and two sides. Return the pearl to the front again.
17. Move the pearl to the ***Solar Plexus***. Circle it nine times to T-11 at the back, and return to the solar plexus. Cross the front, back, and sides. Return the pearl to the front.
18. Bring the pearl down to the ***Navel***. Circle it back to the Door of Life, and back to the navel nine times. From the navel bring the pearl to the cauldron, back toward the Door of Life, and return it to the cauldron. Use the pearl to cross the right and left sides. Return the pearl to the navel.

Descending From the Pakuas to the Earth.

19. Once you have controlled the pearl to this stage of the meditation, you are ready to move the pearl down to the ***Sexual Center***. Women bring the pearl down to the right side of the ovary center, located three inches below the navel. Men bring the pearl from the navel down to the right side of the sperm palace, one and a half inches below the navel. Circle clockwise back to the sacrum, to the left hip, and to the front of the ovary center/sperm palace nine times. Use the pearl to make a cross. Return the pearl to the front of the sexual center.
20. Bring the pearl down to the right groin. Circle the pearl clockwise around the ***Perineum Point and Lower Hips*** nine times. Use the pearl to form a cross by connecting the front, back, and sides. Return the pearl to the front.
21. Move the energy down and circle toward the back of ***Both Knees***, around and to the front, midway between both knees, moving the pearl clockwise nine times. Use the pearl to form a cross by moving the pearl to the midpoint between the knees and connecting the front, back, and sides from this point. End with the pearl midway between the fronts of both knees.

22. Direct the energy down to the feet, just below the ankles. Circle the ***Soles of the Feet*** nine times moving the pearl clockwise to the heel of the right foot, to the heel of the left foot, to the outer side of the left foot, to the front, midway between both feet. Form a cross. End with the pearl midway between both feet.
23. Move the energy from the front of the feet down to a point ***Beneath the Earth***, and circle toward the right (clockwise) nine times. Use the pearl to form a cross ***Beneath the Earth***. Keep on spiraling more energy to enhance the pearl. Return the pearl to the front of the circle.

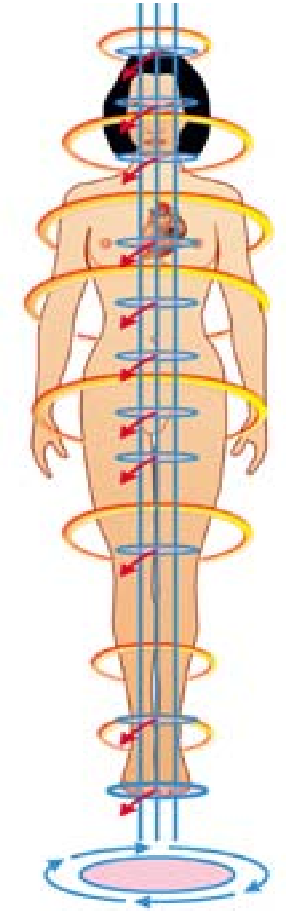

Fig. 8.7 *Bring the Pearl down to the ground, spiral clockwise.*

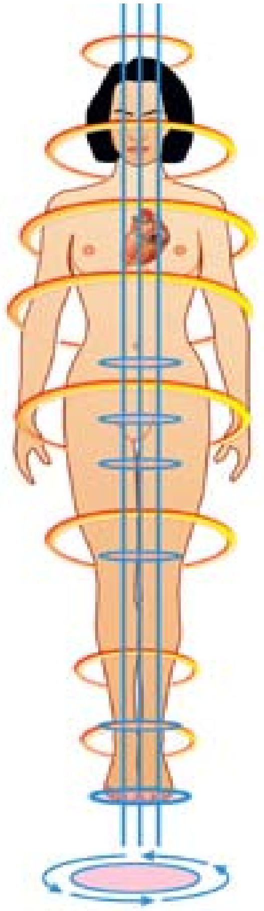

Fig. 8.8 *Spiral reverse counterclockwise moving up.*

Ascending From the Earth Back to the Pakuas

24. Reverse the circle beneath the earth, moving the pearl counterclockwise again nine times. Use the pearl to form a cross, connecting the front, back, and sides.
25. Move the pearl to the outer side of the left foot. Circle the ***Soles of Both Feet*** nine times moving toward the left heel, to the right heel, to the right foot, and to the front (midway) of both feet. Use the pearl to form a cross. End with the pearl at the midway point in the front of both feet.
26. Move up to the left knee. Circle the pearl counterclockwise *at the **Knees*** nine times. Use the pearl to form a cross. Return the pearl to the midway point in the front of both knees.
27. From the front of the knees, move up to the left groin area. Circle counterclockwise at the ***Perineum*** nine times. Use the pearl to form a cross. Return the pearl to the front of the perineum.
28. Direct the energy to the left hip, and circle counterclockwise at the ***Ovary/Sperm Palace*** nine times. Use the pearl to form a cross by connecting the front, back, and sides. End with the pearl at the front of the ovary/sperm palace.
29. Return the pearl to the ***navel*** and to the ***Cauldron***.

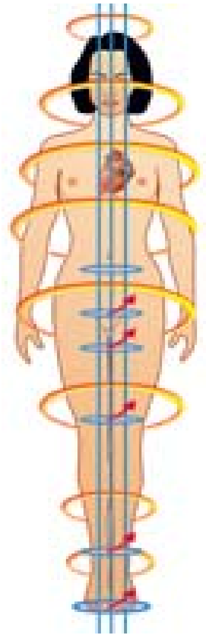

Fig. 8.9 *Bring the Pearl up to the navel.*

Men and Women Practice Differently

***Men**:* Shoot the Pearl out of the Crown, and Spiral the Pearl down from the Crown.

a. Bring the pearl up to the crown.
b. Allow the pearl to go out three to six inches above the head. Circle nine times counterclockwise. Collect the heavenly energy and blend it in the pearl. Then circle it nine times clockwise.
c. Bring the pearl back into the crown point.
d. Spiral it clockwise through each of the Belt Channels all the way down to the soles of the feet.
e. Move the pearl into the earth six to twelve inches to collect the earth energy, and circle the energy nine times clockwise. Reverse the direction spiraling nine times counterclockwise.
f. Return the pearl to the front of the crown, and then back down to the navel and cauldron in the same manner.

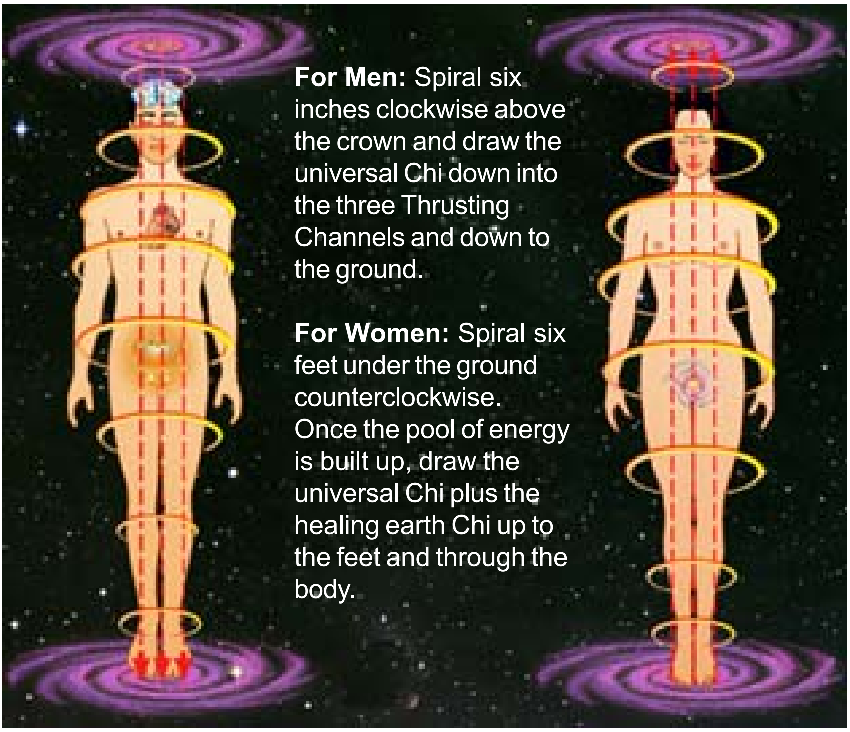

For Men: Spiral six inches clockwise above the crown and draw the universal Chi down into the three Thrusting Channels and down to the ground.

For Women: Spiral six feet under the ground counterclockwise. Once the pool of energy is built up, draw the universal Chi plus the healing earth Chi up to the feet and through the body.

Fig. 8.10 *Men and Women Practice Differently*

***Women**:* Shoot the Pearl into the Earth, and Spiral the Pearl up from the Earth

a. Bring the pearl to the soles of the feet.
b. Move the pearl into the ground six to twelve inches to collect the earthly energy. Circle the energy nine times clockwise. Then nine times counterclockwise.
c. Move the pearl up through the left side of each Belt Channel, spiraling counterclockwise to the crown.
d. Shoot the pearl all the way out at the crown to collect the heavenly energy. Circle the energy counterclockwise nine times. Reverse the direction, and spiral the pearl nine times clockwise.
e. Bring the pearl back down into the right side of the crown. Continue to circle the energy clockwise down through the Belt Channel to the soles of the feet. Return the pearl to the navel and cauldron in the same manner.

Forming a Vehicle

Continue feeling all the pakuas spiraling around the energy center and around the body.

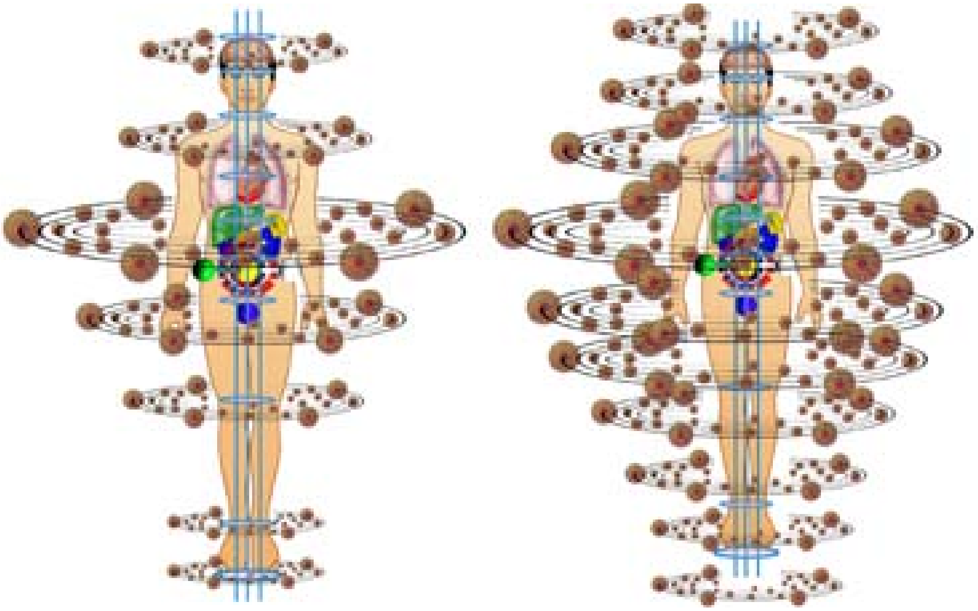

***Fig. 8.11** Spiraling the Pearl and Pakuas faster and faster.*

Let the pakuas spiral faster and start from 10,000 miles per hour up to 60,000 miles per hour and feel the spine getting bigger and bigger.

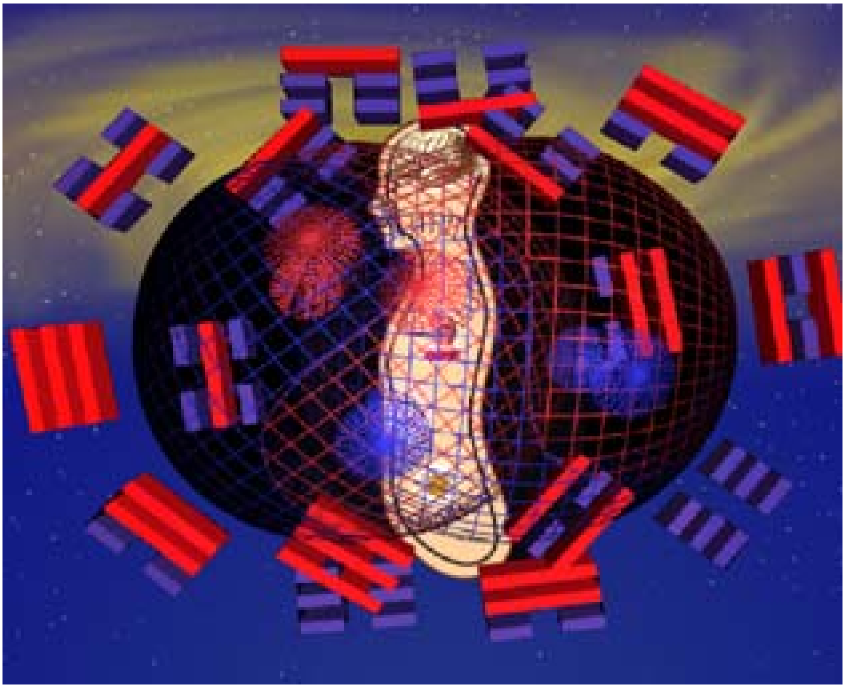

Fig. 8.12 *All the Pakuas become a bigger and bigger Pakua spiraling around whole the body.*

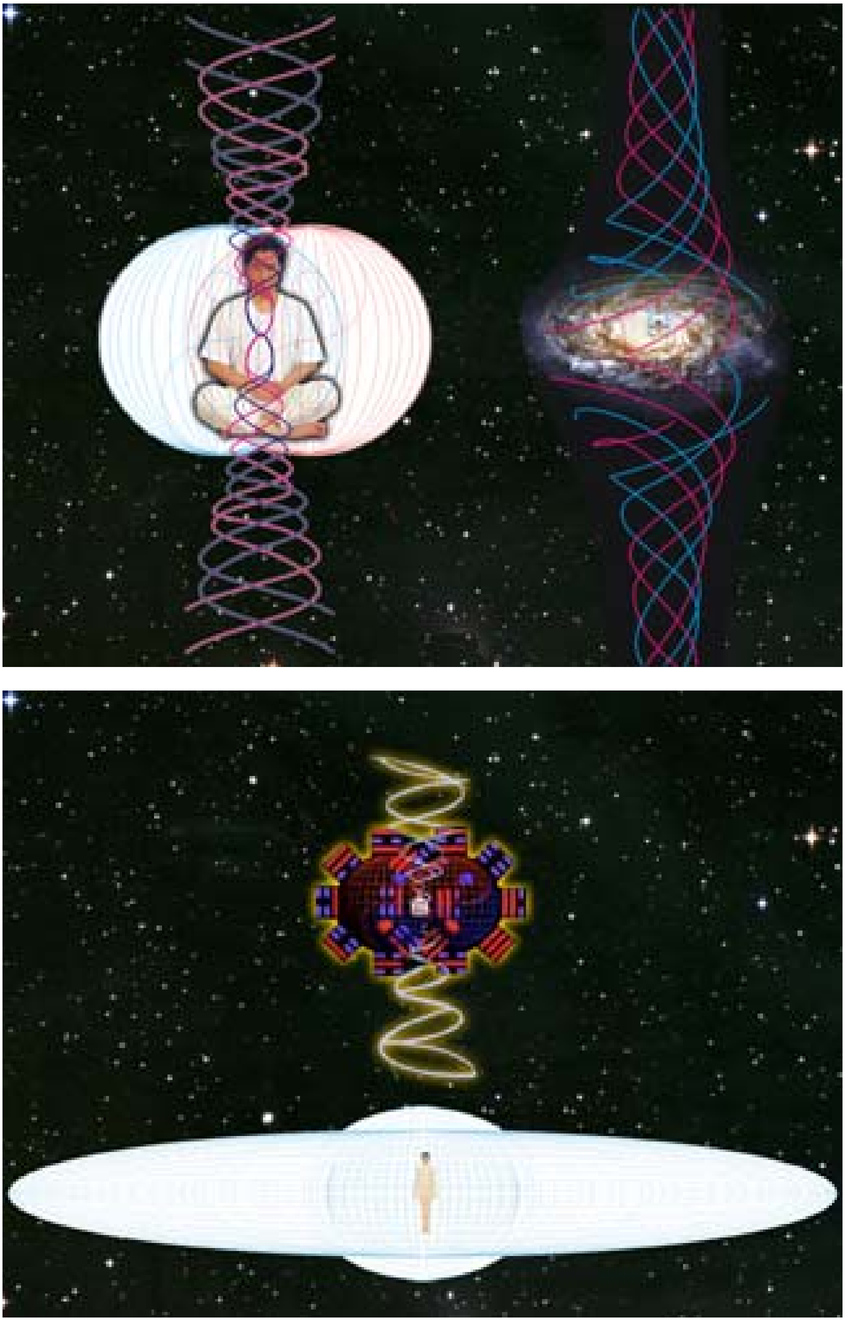

Fig. 8.13 *The spirals of the Pakua form and become a very big kua and form a space ship up to 50 meters in diameter or bigger.*

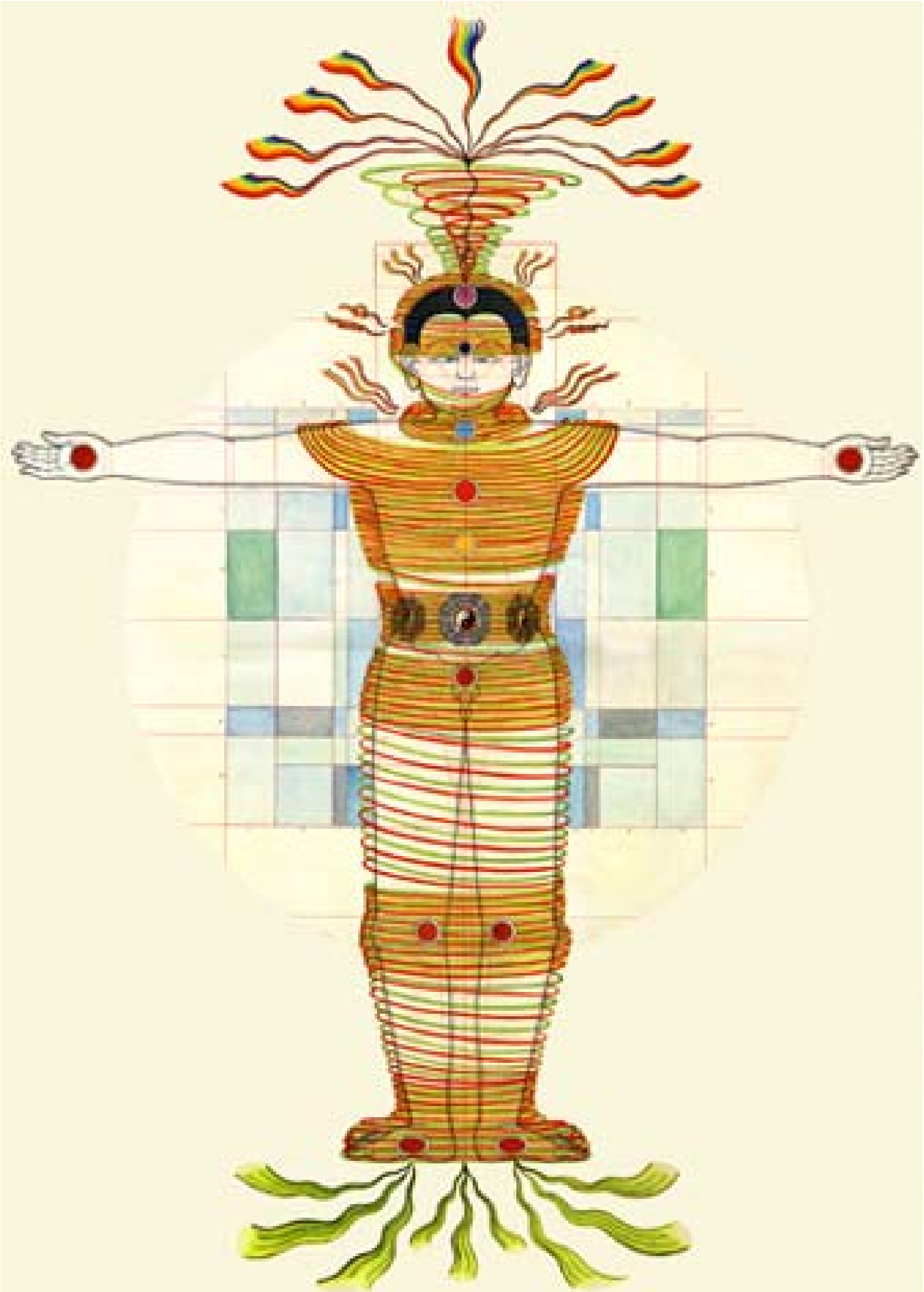

Fig. 8.14 *Belt Channels*

Summary

Procedure of Forming the Belt Channels

Ascending from the Pakuas

1. Practice the Inner Smile from the compassion fire, chanting from pakua, forming the collection points, fusing the energy into a pearl, and the Creation Cycle of Cosmic Fusion.
2. Send energy through the three Thrusting Channels all the way down to the feet and up to the head.
3. Form the four pakuas and a pearl. Gather the pearl at the cauldron, and bring it to the navel.
4. Join the four pakuas by circulating the pearl from the ***Navel*** counterclockwise to the Door of Life and back to the navel. Continue circling the pearl nine times around the Thrusthing Channels and around the body counterclockwise.
5. Form a cross. Bring the pearl from the navel to the cauldron, and back to the Door of Life. Use it to connect the side pakuas. Return the pearl to the navel.
6. From navel move to the left side of the ***Solar Plexus***. Begin to circle the pearl at the solar plexus level. Circle the pearl to the left through T-11 and return to the solar plexus. Circle nine times. Create an internal cross with the pearl.
7. Bring the pearl to the left side of the ***Heart***. Circle nine times towards the left, to the middle of the shoulder blades, and back to the heart center. Use the pearl to form an internal cross connecting all four sides.
8. Next bring the pearl to the left side of the ***Throat Center***. Circle the pearl back to C-7, and to the middle of the throat center nine times. Form an internal cross. **Practice and master this step before continuing up to the crown.**
9. Bring the pearl to the upper tip of the left ear level with the ***Mideyebrow***. Circle the pearl nine times back to the small brain, to the upper tip of the right ear, returning to the mideyebrow. Feel a band of energy flowing around the mideyebrow, ears, and back of the head. Form an internal cross connecting all four sides.
10. Bring the pearl to the ***Left Side of the Crown****.* Circle the energy nine times counterclockwise at the crown. Connect the front, back, and both sides of this Belt Channel.

11. Allow the pearl out above the crown. Circle the energy nine times forming a ***Halo of Energy***. Use the pearl to cross the halo, front to back, and left to right. Collect the energy from above the head.

Descending Back to the Pakuas

12. Reverse the energy flow to a clockwise direction. Circle the ***Halo*** nine times. Then cross it front to back, and right to left sides.
13. Bring the pearl back to the ***Crown***. Circle to the right nine times. Then use the pearl to cross the front, back, and two sides.
14. Move the pearl down to the upper tip of the right ear. Circle from the right ear to the mideyebrow. Repeat nine times. Use the pearl to form a cross and return it to mideyebrow.
15. Bring the pearl down to the right side of the neck at the ***Throat Center***. Circle right to *C-7* at the back of the neck. Return to the front again. Circle nine times. Cross the front, back, and two sides. Bring the pearl to the front.
16. Bring the pearl down to the right side of the ***Heart Center***. Circle it clockwise nine times, ending at the front. Then, use the pearl to cross the front, back, and sides. Return the pearl to the front again.
17. Move the pearl to the ***Solar Plexus***. Circle it nine times to T-11 at the back, and return to the solar plexus. Cross the front, back, and sides. Return the pearl to the front.
18. Bring the pearl down to the ***Navel***. Circle it back to the Door of Life, and back to the navel nine times. From the navel bring the pearl to the cauldron, back toward the Door of Life, and return it to the cauldron. Use the pearl to cross the right and left sides. Return the pearl to the navel.

Descending from the Pakuas to the Earth.

19. Once you have controlled the pearl to this stage of the meditation, you are ready to move the pearl down to the ***Sexual Center***. Women bring the pearl down to the right side of the ovary center, located three inches below the navel. Men bring the pearl from the navel down to the right side of the sperm palace, one and a half inches below the navel. Circle clockwise back to the sacrum, to the left hip, and to the front of the ovary center/sperm palace nine times. Use the pearl to make a cross. Return the pearl to the front of the sexual center.

20. Bring the pearl down to the right groin. Circle the pearl clockwise around the ***Perineum Point and Lower Hips*** nine times. Use the pearl to form a cross by connecting the front, back, and sides. Return the pearl to the front.
21. Move the energy down and circle toward the back of ***Both Knees***, around and to the front, midway between both knees, moving the pearl clockwise nine times. Use the pearl to form a cross by moving the pearl to the midpoint between the knees and connecting the front, back, and sides from this point. End with the pearl midway between the fronts of both knees.
22. Direct the energy down to the feet, just below the ankles. Circle the ***Soles of the Feet*** nine times moving the pearl clockwise to the heel of the right foot, to the heel of the left foot, to the outer side of the left foot, to the front, midway between both feet. Form a cross. End with the pearl midway between both feet.
23. Move the energy from the front of the feet down to a point ***Beneath the Earth***, and circle toward the right (clockwise) nine times. Use the pearl to form a cross ***Beneath the Earth***. Keep on spiraling more energy to enhance the pearl. Return the pearl to the front of the circle.

Ascending from the Earth Back to the Pakuas

24. Reverse the circle beneath the earth, moving the pearl counterclockwise again nine times. Use the pearl to form a cross, connecting the front, back, and sides.
25. Move the pearl to the outer side of the left foot. Circle the ***Soles of Both Feet*** nine times moving toward the left heel, to the right heel, to the right foot, and to the front (midway) of both feet. Use the pearl to form a cross. End with the pearl at the midway point in the front of both feet.
26. Move up to the left knee. Circle the pearl counterclockwise *at* the ***Knees*** nine times. Use the pearl to form a cross. Return the pearl to the midway point in the front of both knees.
27. From the front of the knees, move up to the left groin area. Circle counterclockwise at the ***Perineum*** nine times. Use the pearl to form a cross. Return the pearl to the front of the perineum.
28. Direct the energy to the left hip, and circle counterclockwise at the ***Ovary/Sperm Palace*** nine times. Use the pearl to form a cross by connecting the front, back, and sides. End with the pearl at the front of the ovary/sperm palace.
29. Return the pearl to the ***Navel*** and to the ***Cauldron***.

Men and Women Practice Differently

***Men**:* Shoot the Pearl out of the Crown, and Spiral the Pearl down from the Crown.

1. Bring the pearl up to the crown.
2. Allow the pearl to go out three to six inches above the head. Circle nine times counterclockwise. Collect the heavenly energy and blend it in the pearl. Then circle it nine times clockwise.
3. Bring the pearl back into the crown point.
4. Spiral it clockwise through each of the Belt Channels all the way down to the soles of the feet.
5. Move the pearl into the earth six to twelve inches to collect the earth energy, and circle the energy nine times clockwise. Reverse the direction spiraling nine times counterclockwise.
6. Return the pearl to the front of the crown, and then back down to the navel and cauldron in the same manner.

***Women**:* Shoot the Pearl into the Earth, and Spiral the Pearl up from the Earth

1. Bring the pearl to the soles of the feet.
2. Move the pearl into the ground six to twelve inches to collect the earthly energy. Circle the energy nine times clockwise. Then nine times counterclockwise.
3. Move the pearl up through the left side of each Belt Channel, spiraling counterclockwise to the crown.
4. Shoot the pearl all the way out at the crown to collect the heavenly energy. Circle the energy counterclockwise nine times. Reverse the direction, and spiral the pearl nine times clockwise.
5. Bring the pearl back down into the right side of the crown. Continue to circle the energy clockwise down through the Belt Channel to the soles of the feet. Return the pearl to the navel and cauldron in the same manner.

Energy Body

Once you have practiced to this level, you are ready to form the pearl into the Soul Body.

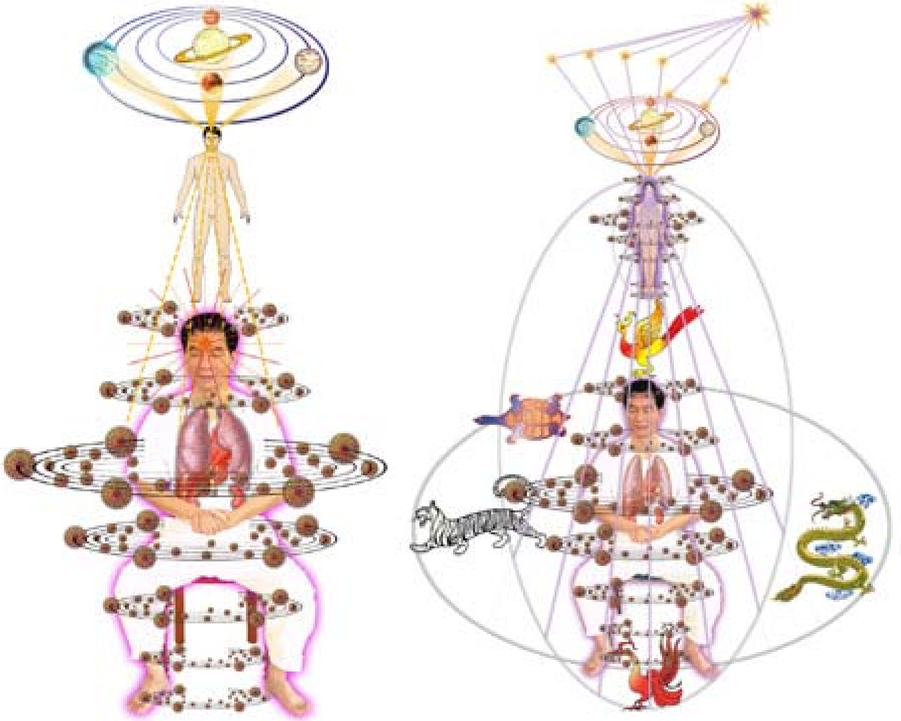

Fig. 8.15 *Energy or Soul Body*

Sorcerers saw that the essence of the universe resembled a matrix of energy shot through by incandescent strands of consciousness or actual awareness. They also 'saw' the essence of the human form. It was not merely an apelike amalgamation of skin and bones, but an egg-shaped ball of luminosity capable of traveling along those incandescent strands to other worlds. (Wagner, Bruce, "You Only Live Twice", *Details*, March, 1994, p.168.)

Just as it is important for the physical body to be strong so we can enjoy optimum health, it is also vital to strengthen the Soul Body so it becomes a sturdy vehicle for our consciousness. Strengthening Chi nourishes our health and spiritual qualities in this life and builds a strong Soul Body to carry us forth into the "afterlife" (which is, paradoxically, the here and now). We begin to strengthen the Soul Body through what is called in Taoist Inner Alchemy "the Inner Elixir". It is called the Inner Elixir because we are working with the energies already within our own body and converting them into elixir-like healing essences. Through the meditation practices of the Microcosmic Orbit and the Fusion of the Five Elements, we detoxify, nourish, and integrate the physical body, the Energy Body and the emotions.

Always begin by doing the Fusion of the Five Elements practice to clean out the negative emotions.

Chant the eight forces and form the collection points. Let the Pakua spinal around the physical body.

Condense the pearl and practice the Creation Cycle, Thrusting Channels and Belt Channels.

Run the pearl in the Microcosmic Orbit, and control its movement with the senses.

Move the pearl to the perineum. Inhale in short sips, drawing in ten percent of the lungs' capacity, while gently pulling up the anus. Inhale up to the navel, then to the heart.

Inhale up to the crown. Swallow your saliva (imagine swallowing upward,) and exhale forcefully to open the crown and shoot the pearl out.

Practice moving the pearl up to one foot, two feet, three feet, four feet, five feet, and six feet above your head. Go out only as far as you are able to maintain control of the pearl.

Relax the senses, and form the Soul Body.

Run the pearl in the Microcosmic Orbit in the physical body. Open the crown, transfer the Microcosmic pathway into the Soul Body above the head.

Form another pearl in the cauldron, and shoot the pearl into the Soul Body.

Circulate the pearl through the Microcosmic Orbits in both the physical and energy bodies together.

Extend the Thrusting Channels up into the Soul Body.

Practice all the Belt Channels up through the head, or down through the soles, into the Soul Body. Spiral all the pakuas around the Soul Body like a space ship.

Continue to practice until you are in full control of the Soul Body.

***Note*:** You can also form a Soul Body below you by thrusting the pearl through the soles of the feet into the ground.

Spirit Body

Once you are well in control of the Soul Body, you are ready to form the Spirit Body.

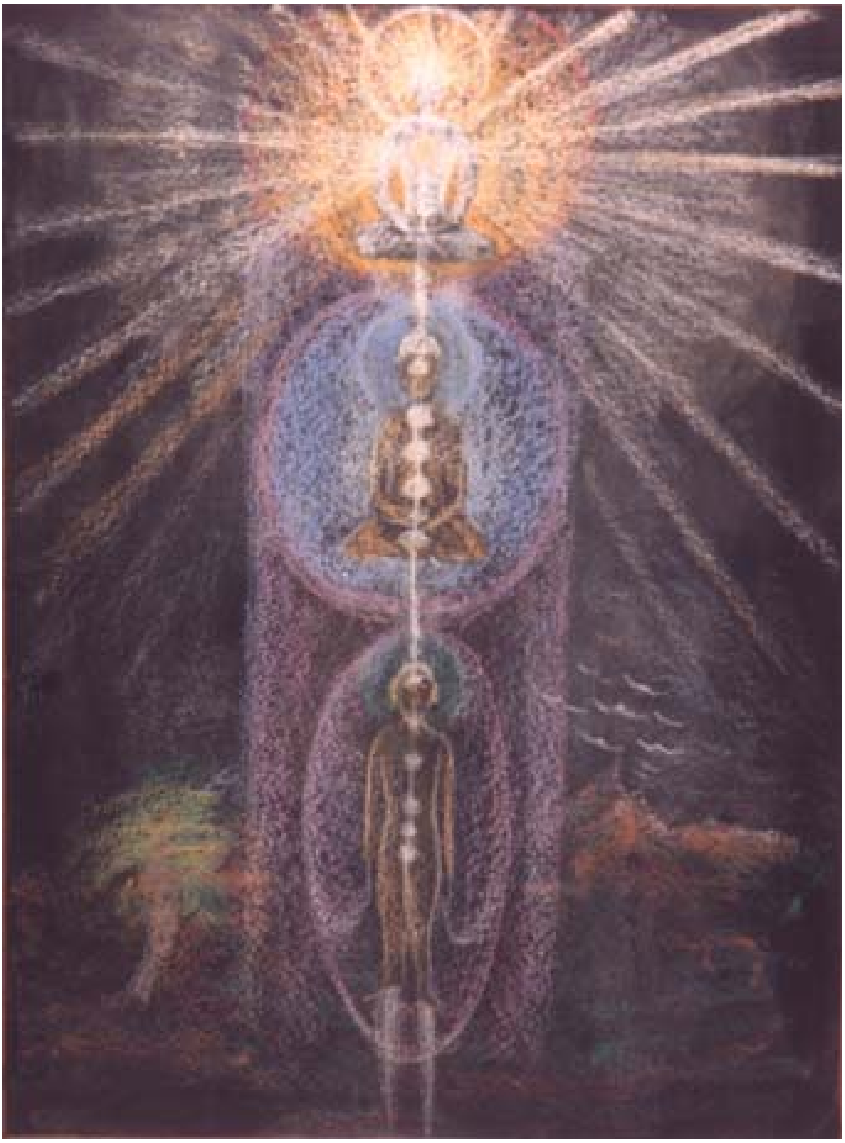

Fig. 8.16 *Spiritual Being*

Stage One

Be aware of the Four Pakuas in each center and spiral them around the physical body and the energy body.

1. Begin to form the spirit body after doing the Soul Body practice. Leave the Soul Body above the crown. Form another pearl at the cauldron, and run the Creation Cycle.
2. Form the pearl from compassion energy, a pearl that is more blue and gold than the Soul Body pearl.
3. Move this pearl in the Microcosmic Orbit. Bring it down to the perineum.
4. Inhale in small sips, and pull up the anus. Inhale the pearl to the navel; then to the heart; and to the crown.
5. Inhale again, and swallow up. Exhale forcefully to open the crown, and project the pearl to the perineum of the Energy Body.
6. Exhale, and send the pearl to the heart of the Soul Body. Exhale again, and send the pearl above the crown of the Soul Body.
7. Move the pearl up and down approximately twelve inches (30 centimeters) above the crown of the Soul Body. Then gradually extend the pearl further up in one foot (30 centimeters) increments. Practice until you are able to move the pearl up and down six feet above the Energy Body.
8. Condense the pearl. Condense the Soul Body. Bring both pearls back to the cauldron of the physical body.

Stage Two

1. Repeat steps (1) to (7) above, and run the Microcosmic Orbit in the physical and energy bodies.
2. Transfer the Microcosmic Orbit from the Soul Body into the Spirit Body, and then run the three Microcosmic Orbits together. As an alternative, you can run the Microcosmic Orbit as one large channel incorporating all three bodies.
3. Extend the Thrusting Channels to the Spirit Body.
4. Extend the Belt Channels to the Spirit Body.
5. Finish by condensing the energy of both the Soul and Spirit Bodies into a pearl. Pull the pearl into the physical body.
6. Collect the energy at the cauldron, and practice Chi Massage.

Chapter 9
Fusion as a Bridge

In the overall structure of the Universal Tao, the Fusion Practices serve as a bridge between the basic preparatory practices such as the Inner Smile, the Healing Sounds, the Microcosmic Orbit, Healing Love, Tao Yin, Iron Shirt Chi Kung, Cosmic Chi Kung, Bone Marrow Nei Kung, Tai Chi and the Higher Inner Alchemy Practices of Kan and Li.

The Fusion Practices are traditionally considered as the core of internal alchemy, as they focus on the transformation of emotional energies, contained in the major organs of the body, as centers and fields of energy which resonate, each with their particular frequencies, with the energies and forces of the universe.

Through a process of balancing negative and positive energies (Fusion of the Five Elements), the growth of positive energies (Cosmic Fusion) and the opening of meridians to enhance the circulation of internal energies of the body and make it receptive for outside energies (Fusion of the Psychic Channels), the body gradually becomes more open. Thereby the self-healing process, initiated in the basic practices, is further enhanced.

Once the strength and health of the body have been restoried so that it can serve as a vessel for the forces of the universe and is in a position to process them, it is ready for the higher alchemy in the Kan and Li practices. In these Kan and Li practices the physical body can then give birth to the energy body. Once this has taken place the person is ready to give birth to the spirit body, also called the Light or Rainbow body.

Fusion as a Journey of Self-Transformation

In the Fusion Practices, the body and its path routes are not only cleansed and opened, so that the energy from within and from outside can flow with more power and ease. Also the energy flows in the body are qualitatively raised. Thus the self healing and regenerative capacity of the body, already initiated in the basic practices is further enhanced. As a result, the body’s health and vitality receive a new boost and it grows in strength. At the same time, it becomes more able to absorb and process the various forces and energies from the universe, the cosmos and nature.

In the Fusion Practices, the body enters into a dynamic process towards new balances. This is an essential condition for the light to grow inside. This can then in turn attract the light from heaven as its energies become finer, as they blend into a higher quality energy created by the blending of love and compassion. This higher concentrate of energy is then condensed into a pearl which is subsequently circulated through the major organs and the psychic channels in and around the body. The pearl will help the body to feel centered and experience peace and harmony. It will also help to cleanse the special channels and enhance the free flow of energy.

The pearl will facilitate the growth and transference of consciousness from the physical to the energy body and from the energy to the spirit body (Cosmic Fusion), healing it and helping it to center and experience peace and harmony. Through the growth of love and compassion the body is able to radiate out and receive in the love and cosmic energies so that its own Chi is blended with the cosmic Chi and is thereby transformed into a higher quality of Chi.

To facilitate the process of blending and balancing the energies within the body between its organs and the gathering, processing and condensing of energies from the universe and from nature, the pakuas play an essential role (Formula 1, *Fusion of the Five Elements*).

In the earliest stage after conception, the first meridians which rule the circulation of energy of the embryo and which come into existence after the split of the egg and the formation of the body are the governor and conception channels. Successively, all other Yin and Yang meridians form in a symmetric fashion on the Yang and Yin sides of the body.

In ancient Taoists texts they are also called the sun side or outer side and the moon or inner side of the body. The sun side is that side exposed to the sun when one bows down, the moon side is that part which remains in the shadow.

The body might be visualized as grid of conduits of light which link it to the Light in which all energy and matter has its origin, a view which is supported by the new physics.

Unity of Ying and Yang

Basic to the Taoist tradition is the view that positive and negative energies are a manifestation of the very nature of the universe as a unity of opposite energies: Yin and Yang. It is by virtue of the dynamics of the interplay of Yin and Yang that the universe exists and continues to exist. They rule all phenomena in the universe as an infinite web of mutually interconnected processes and their movement. This insight is the theoretical as well as the practical basis of the Fusion Practices.

In Taoist theory, Yin and Yang rule the relationships between stars, planets, the sun and the moon and the earth, light and dark, above and below, man and woman. It is in and through this interplay, that the universe unfolds and functions. If one of them would disintegrate or disappear, the universe would end.

In the Taoist vision on the nature of the universe, the body is a microcosmos, which manifests and reflects in its inner structure the dynamics of the universe. As such it is also ruled by the same forces of Yin and Yang.

These in turn manifest themselves in the universe in the five elements (water, fire, wood, metal and earth). These five elements operate as energies in the body, in and through the five vital organs: the kidney, heart, liver, lungs and spleen. It is the natural capacity of the body to heal and regenerate itself. The body is sustained and nurtured by cooperating and facilitating the workings of the universe through the balancing of the five forces in the organs of the body and the positive and negative properties of each of them.

It is the relationship between the positive and negative energies contained and reflected in the organs, which is the starting point of the Fusion Practices.

In the Taoist tradition, the body has always been viewed as a sacred vessel, which reflects the sacred nature of the universe as a whole. Interfering with its laws of motion, the balance between Yin and Yang is broken and with it harmony and mutual cooperation between the organs and the elements which compose the body.

As a result, the free uninhibited flow of energy streams, and with it the immunity of the body, are affected. In Chinese medicine, of Taoist origin, disease is seen as the outward manifestation of imbalances within the body. Hence the predominant attention in Chinese medicine and Taoist self-healing practice on the balancing and strengthening of the organs and their cooperative relationships.

The Taoist view on the outer and inner universe (the body), is the fruit of several thousands of years of highly sophisticated empirical observation. Thusly, feeling and sensing in the body and its structure, processes and needs, play a crucial role in creating balance within the body and between its organs and their energies, so that inner peace and harmony may grow (Formula 2, *Fusion of the Five Elements*)

Turning Inward

This involves a process of turning inward and to feel and sense oneself "from within" so that understanding can grow. This in turn further supports the effectiveness of the inward-oriented process of listening. By turning the senses inward and reconnecting them with their corresponding organs (ears/kidneys, eyes/liver, tongue/heart, mouth/spleen, nose/lungs) the process of externalizing the consciousness and thereby draining the energies out of the body can be inverted. This allows the body to come to rest and recuperate its energies and the connected senses.

By protecting the senses from undue outside influences, the life force energies in the body and the higher energies it accumulates, through the blending with the energies from all the directions, but especially those from the stars and the sun and moon and planets, are preserved and can grow without interference (*Cosmic Fusion,* Formula 3).

This process of protection is further deepened and completed in the high formula of Sealing the Five Senses of the Kan and Li Practices where protective auras are created around the body from the accumulated energies of each of the major organs.

There is abundant evidence that in the process of externalization which has been imposed on the body in the process of modernization and its growing pressures on the body, the senses have become atrophied. By turning them inward, it becomes more easy to control them and protect the integrity of the body and its organs so that it can regenerate.

The Taoist approach to the body is rooted in the vision that there is an inner order in the very nature of the universe and all its manifestations. The outer order is a manifestation and reflection of this inner order. If the outer order is in harmony with the inner order, then harmony and peace reign.

As our receptivity and ability to sense and feel ourselves from within grows, so grows our ability to experience the universe within ourselves. By looking deeply into ourselves we grow. Our understanding of our being and body as a microcosmos, and its intrinsic unity with the universe as a macrocosmos, grows.

From Balance through Resonance to Love

As our body and its chemistry and we ourselves are changing, our consciousness and perceptions also change and widen. Then a point will come where we begin to experience ourselves less as separate and isolated from the universe and more in resonance and in tune with the universe.

In this process, we grow more aware of the wave-like nature of our body in and through which the universe pulses within us and how we pulse in and though our bodies with the energies and forces of the universe. At the same time our ability to tune in with the energy of the universe and its frequencies and to absorb and draw this energy into ourselves will grow.

The Fusion Practices serve an essential function in making our being more open through the heightened sensitivity of the body, as our energies become purified and more fine and subtle. The desire rises within the body to enter into the primordial unity with the original energy by which it was originated as a living being.

In the ancient Taoist vision this relationship has always been seen as a love relationship which reveals itself when our body returns to its inner balance and Yin and Yang enter into balance. The ability to attract and conduce the energies from the universe into one body through the network of conduits, represented by the grid of meridians, is dependent on the quality of the inner work towards unity between Yin and Yang.

This meeting between Yin and Yang has in the Taoist tradition been seen as a marriage, born out of love between the opposites, as they move towards unity. The Fusion Practices play an important role in the preparation of a state of being which make this movement towards unity possible.

Enlightenment of the Body and New Physics

The Taoist insight that human beings, with all other phenomena, share common origins in the universe and that our origins are in heaven and originate in the stars is shared in many other ancient cosmologies: those of the African peoples, the indigenous peoples of North and South America, as well as the Australian aboriginal people.

The Taoist tradition, however, is unique in that it has evolved over time concrete practical formulas and practices to work with. These help us to reconnect and in the process rediscover the inherent ecstatic nature of our body, through the process of self-transformation.

These formulas, of which the Fusion Practices are an integral part, are based on the insight of the nature of the meridians and their application in healing the body and restoring its natural functions, which form the basis of Chinese medicine.

A closely related Taoist thesis on the nature of the universe, also to be found in all ancient cosmological traditions, including those in the West (before the scientific revolution did away with them, viewing them as superstition) is the unity, indivisibility and interchangeability of matter and energy.

This thesis finds full support in the new physics which evolved from the beginning of this century with the path-breaking discoveries in quantum physics and relativity theory by the great physicists Bohr, Einstein and Heisenberg.

Their discoveries shattered the foundations of the old paradigm, underlying Cartesian-Newtonian physics, at the basis of modern science. They broke radically new ground in the interpretation of the nature of matter. In the new vision of advanced physics, matter, in its inner nature, is understood as a process and an event. Matter and energy are forms of the same reality. As matter can change into energy, also energy can change into matter. Both matter and energy are viewed in this new interpretation of reality as having their origin in light.

Therefore the Taoist vision on the intrinsic nature of the body as a light body is not a romantic vision, invented by creative minds. The image, underlying it, corresponds to the insights of advanced physics. Thus what has been called in ancient spiritual traditions “enlightenment” refers to a real material process: the illumination of the body.

Here's what distinguishes the Taoist vision from most others: enlightenment is not understood as a process which happens "in the mind", in separation from the body, but the process takes place in and through the body and its progressive transformation.

Thus a true process of spiritual growth in the Taoist vision implies the "enlightenment" of the body. The progression process of illumination is a bodily process, visible to the eye and tangible in the quality of energy which a person manifests and radiates in her/his body. This emphasis on transformation as a bodily process is a principal characteristic of the Taoist tradition. In that respect it differs from other ones, marked by the duality of body and mind and in which the body is viewed as a stumbling block; a hindrance.

This also explains the Taoist insistence on the central importance on rooting and grounding the body in the process of self-transformation. The more one advances in the higher practices, the greater the need to root and ground so that the energies in the body remain in balance. Equally important is centering; the balance between heaven and earth, the energies from above and below are maintained and enhanced.

It is precisely for this reason Taoist practice gives the highest priority to the creation of a healthy and strong body through a healthy and relaxed life style and an intelligent natural diet thanks to which the body can continuously regenerate and rejuvenate itself.

These insights had their basis in a new view on the nature of electromagnetic waves as particular forms of energy and in the insight that light is an electromagnetic field which takes on the form of waves which can travel through empty space as very light vibrations, also called ether. This energy is seen, in both the Chinese and Indian cosmologies, as the mother energy from which the other elements originate and of which the universe, the cosmos and nature are composed: fire and water, wood and metal and water.

In the Taoist system, these elements correspond to the five seasons, temperatures, senses, colors, sounds and positive and negative emotions. They form the theoretical and practical starting point for the Fusion Practices.

Return to Cosmology

The revolutionary implications for our perceptions of the universe, the cosmos, time and space and of nature and ourselves as part of nature are only slowly penetrating into the social consciousness. This social consciousness's view of its conditionings and fixations in cultural patterns and corresponding perceptions of reality prevent it from being open to an understanding our true nature.

There are multiple mechanics at work in present day culture and science and the modern view of reality which tend to prevent us from giving up the mind sets, rooted in the subconscious (and which rule the conscious mind, unaware of the forces by which it is steered). These make it appear as if the universe is composed of an infinite amount of loosely, accidentally assembled particles and solid objects; each having an independent, separate existence, rather than what is actually an ever changing web of unceasingly changing events which are mutually interconnected and interdependent.

The emergence in Western history and culture of the perception of human beings as essentially sovereign and independent from the universe and as its ruler who can alter life and the origins of life at will (with the progress of science and technology) are wholly questioned by the Taoist vision, presented above.

Such a view on the presumed independence and freedom from the laws of motion of the universe also has shaped the basic assumptions on the nature of human beings and social relations which have shaped mainstream social science and psychology, which mirror the basic premises of the Cartesian- Newtonian paradigm.

They support a view of progress and development, the new version of which emerged in the course of this century, which is essentially inspired by the view that reality can be manipulated and engineered without regard for the consequences on Nature. However, with the more recent findings of the adverse effects of such an attitude and the growing concern that the very foundations on which life on earth rest are being jeopardized, the basic premises on which this attitude is based are increasingly being questioned.

At the same time, as a natural consequence, there is a growing interest in the visions which have inspired the ancient cosmologies such as the Taoist one, especially since there is increasing evidence in advanced physics which support such visions. Thus it is not surprising that one of the leading philosophers of science, Stephen Toulmin, recently published a book, *A Return to Cosmology.*

In his study he traces the process of alienation in Western culture and science, as it came to shape modern life. Especially, he focuses on the relation between body and mind. He foresees a return to ways of looking at reality which help to overcome the duality at the root of this alienation and the imbalances it has brought about in the present day world system and which it feeds through the new communication technologies.

It cannot be emphasized enough that when the Universal Tao system is called a whole of interrelated practices, this is based on the root assumption that it is only in the practice that experience is gained. Therefore, a process of self-transformation is set in motion which makes it possible to come to terms with the patterns within oneself which prohibit one to discover its relevance.

This is the very basis of Eastern epistemologies, not only basic to Taoism but also at the root of other Eastern religious and spiritual traditional epistemologies: that true knowledge can only be acquired experientially and existentially in and through the practice.

Also implicit in the Taoist vision, shared in other ancient cosmologies, is the view is that the universe is alive. Not only as it births life at every instant, but also as it sustains and nurtures life. This view is quite contrary to that underlying the materialist world view, which originated in the West with the advent of modern science, in which the universe is reduced to an accidental anomalous phenomenon .

Religious Nature of Taoist Practice

In the Taoist view, supported by the new physics, the body is not only matter but also a field of consciousness which, by its wavelike nature, is intrinsically related to the whole universe and can also get in touch with it. This provides the very basis for the Cosmic Chi Kung practice as a practice, which helps to enhance and balance the body and which is essential to the Fusion Practices.

These above views are essential to the assumptions on energy underlying the ancient Taoist Practices, contained in the practices of the Universal Tao and which offer a synthesis and which for the first time have been published in the West. Until recently these were scattered and inaccessible, except for highly fragmented information. Essential to the Taoist tradition is religious practice in the feeling and experiencing of the sacred and the divine, and not in the beliefs about them.

The Taoist view on the nature of religiosity as an experience of connection and reconnection is very much in line with the original meaning of the root of the word religion in Latin, “re-ligare”, to reconnect.

Thus the practice is oriented to rediscovering the intrinsically ecstatic nature of the body in which it spontaneously feels the truthfulness of life as a sacred, naturally ecstatic activity. The whole practice may be summarized in facilitating the process of reconnecting and returning to the state we were in before being born.

Basic to the transformation process which is conducive to this rediscovery is the Healing Love practice by which the sexual energy is retained, its flow is inverted and the nature of this energy is transformed. The Fusion Practices play an essential role in making possible the further refinement of this energy in the Kan and Li practices through new forms of purification and by enhancing the receptivity of the body for higher energies from the universe. The Taoist practice takes literally the Christian tenet that the body is the temple of God by viewing the vital energy or life force energy as a sacred energy through which the body reveals its divine nature as an intrinsic endowment in which heaven and earth merge.

Wisdom of making Friends with the Devil

The three monotheistic religious mainstreams in their institutionalized esoteric form -- the Jewish, Christian and Islamic -- are marked by a deep duality between high and low, sacred and non sacred, right and wrong, good and evil, mind and matter, mind and body, mind and energy. This duality has also shaped other religious and philosophical systems in their social and institutional evolution; systems such as Hinduism, Buddhism, Taoism and Confucianism. These systems have been marked by beliefs and codes of ethics which have tended to split humankind between believers and nonbelievers and between those that are good and those that are bad.

Their focus on the duality between God/ the divine and heaven and earth, God and the Devil, good and evil, mind/spirit and body and on sin and its corollaries, fear and guilt, have created much violence and tend to continue to do so. They have also greatly affected people's sense of dignity, self-esteem and independence, as they have tended to create major dependencies on institutional intermediation with the divine.

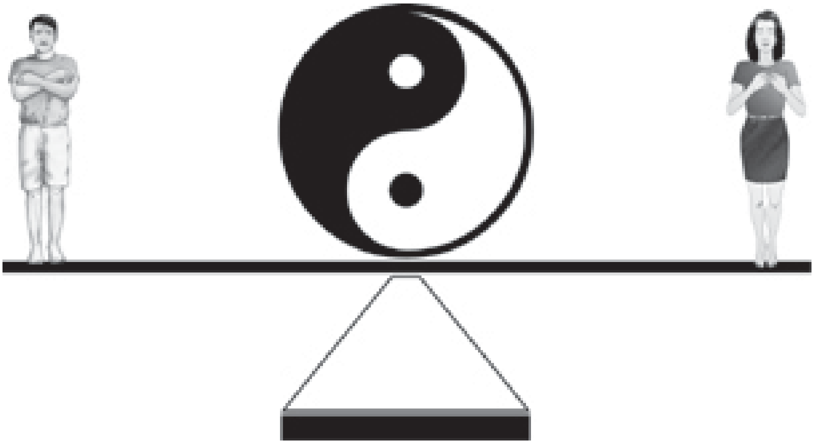

Fig. 9.1 *Balance of Yang and Yin (Good and Bad)*

In many pre-industrial cultures there are proverbs and legends which suggest that it is wise to make friends with the devil rather than fight him. It would seem that such intuitions are based on the insight that it is better to reconcile and accept oneself so that the negative loses its power rather than opposing it, by which its power increases, especially when fear and anger rise and the negative is turned into an obsession. Simple observation confirms the truth of this insight: that the energy of what is viewed as negative and dark increases to the extent that there is an attempt to eradicate it.

This same principle shows up in the martial arts: never initiate the fight but let the enemy come and neutralize him by making use of his own energy, as in the case of Tai Chi and Aikido.

A leading philosopher of culture and humanist therapist in the West, Erich Fromm, has said that the propagation of these views, often in extremely violent ways, has broken the spiritual backbone of the people.

Esoteric systems have, however, never succeeded in wholly eradicating and repressing their esoteric roots, visible in multiple movements throughout history, in which the body was considered sacred and a temple of the divine and in which sexuality was viewed as intrinsically sacred.

It may be said that all esoteric systems, in their origins, have called on humankind to practice love and compassion and thereby to transcend ego and enter into a state of grace.

Adepts like Jesus who has inspired the Christian tradition, Mohammed in the Islamic tradition and the Gautama in the Buddhist tradition may be seen as great masters. They showed people ways and practices of self-transformation through the practice of love and compassion. By assuming responsibility for themselves, they could attain inner freedom and bliss and transcend themselves.

In the Taoist view, the problem with religion and philosophy is not in the practice, but in the beliefs which often serve to divide rather than unite, inside the person and outside.

Unity of Light and Dark

In the Taoist perspective, there is no sin, as light and dark are two poles of the same indivisible reality. Thus, attempts to eradicate the dark, so that light will prevail, are bound to fail and tend to lead to conflict and violence. Attempts to conquer good at the expense of evil (for example, the Crusades) are bound to generate more violence. And battles to secure good over evil will create more problems than they solve. In the Taoist view there should be neither winners nor losers.

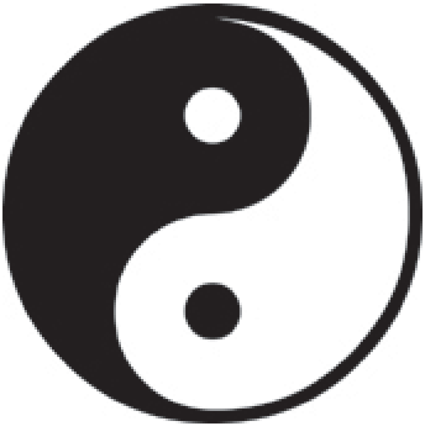

Fig. 9.2 *Light and Dark of the Tai Chi Symbol are connecting.*

Thus, balance between opposite forces and energies, as expressions of Yin and Yang, the positive and the negative, is essential to Taoist perspective, as expressed in the *Tao Te Ching*, attributed to the great Taoist Master of self-transformation, Lao Tzu.

From a Taoist perspective, balance is enhanced by entering into alignment with the universe, when one actualizes the universe within oneself and so is empowered and realizes oneself. This state has also been called a state of Selfhood, as one has returned to one's original Self. This process is also called "returning to one's origins". This means that one has overcome the contradictions and imbalances in oneself, so that Yin and Yang enter into balance and harmonize. The Taoist texts speak of becoming the "Undivided Being". Lao Tzu uses the metaphor of the unhewn log (p'u). It manifests a state of being in which when has returned to the original state of spontaneity, in the old Taoist texts called " Tzu-jan) which can be observed in babies and small children. This reminds us of the saying of Jesus," if you do not become as children, you cannot enter the Kingdom of Heaven".

Thus the Taoist view on harmony does not carry moral overtones, as it refers to a state of being which is intrinsic in the body. This state of being of the body as a microcosmos lies in the balance within and between its major organs, through which our body resonates with the energies and forces of the universe.

In the Taoist perception, there are no heaven and hell outside, above or below us. They are seen as states of being of our bodies and our inner selves and the way we relate to the universe, ourselves and each other. As such they reflect states of balance and imbalance between the positive and the negative. In this view, human beings are responsible for their own state of being, the quality of which depends on their state of self-awareness as the key to self-transformation.

This view is reflected in many ancient spiritual traditions and cultures which suggest that it is wiser to keep the devil as a friend than try to combat him and do away with him.

This liberating view, which frees us from self-condemnation with its tendency to obscure the positive within the negative and its transformational force, is the basis for the Fusion Practices.

Life as an Invitation to Learning

The Chinese character for crisis stands for both a negative occurrence as well as for opportunity and reflects the Taoist view on the unity of the positive and negative. In this perspective, whatever happens in life is to be seen as an invitation for learning and an opportunity for awakening. Theoretically speaking, problems are not problems, but opportunities for self-transformation, since the negative contains the positive, in the same way as the positive contains the negative, like the Yin is in the Yang like the Yang in the Yin. What may be seen and experienced as negative, carries within it the seeds of the positive, just as the light exists within the dark. In this light, all problems of life may be seen as energy potential, which can actually be a learning process.

This is a key premise in the Fusion Practices, and it helps to overcome the duality which we tend to construe, as a result of attachments to our negative experiences and emotions and therefore keep ourselves from entering into balance.

Taoists say that learning is enhanced if the organs feel at ease and find themselves in a state of well being. When a state of disease arises – which in Chinese medicine, of Taoist origin, is seen as a symptom of the breakdown or weakening of the free flow of energy – learning becomes more difficult.

It also points to an attitude which gives primacy to the need to reflect on one’s own attitude and perception in resolving problems and to look inward to see in what way one has contributed to the problem and how one can contribute to its solution by changing one’s own attitude, perception and way of life.

Thus from a Taoist perspective, problems are not seen as obstacles or difficulties but as opportunities to learn and as learning material.

In this connection, it is interesting to note that the word disaster, common to many European languages, has its etymological root in the Latin substantive “astrum” of which it is a negation by the prefix “dis”. This suggests that originally the word had the connotation that if and when one lost touch and became alienated from the stars (as representing our origins), one was in for trouble; imbalances would arise.

Smiling as the Key Taoist Practice

Smiling and relaxation are the beginning practice of the Universal Tao. They are the key to the transformational process and to learning, as a result of which one is enabled to gently and patiently change old patterns into new, concerning oneself and the universe: new breathing, posture, inner and outer movement, and a new perception of reality.

Essential therefore in the Taoist practice to enhance learning and get in touch with the body by turning inward is to learn to relax and smile inward, so that dis-ease, manifest in many forms of stress, is overcome and one returns to a state of ease. Thus it may be said that whereas the Western approach to medicine starts from outside, the Taoist approach starts from within.

It is thus not incidental that the whole practice of the Universal Tao starts with the practice of the Inner Smile. This is actually the first practice of internal alchemy, as it serves to soften our body and its elements in which our consciousness is stored and through which it operates. It is the key agent of the whole activation and transformation process in all the practices. We do not only have a body but we also are our body. By touching it with love and gentleness, its knots and blockages start to dissolve so that the free flow of energy is restored.

Unity of Fullness and Emptiness

It is in this context not surprising that at the heart of the ancient Taoist texts is the emphasis on the practice of turning inward and of stillness. It follows that in the process of meditation as a practice of becoming aware of the inner state of being of the body and its movements, a new and fresh space is created in which renewal and transformation can take place. This space is also called the creation of emptiness and the continuous re-creation of emptiness so that new fullness becomes possible.

In the Taoist as well as in the Buddhist tradition, which historically have been closely related over long periods in Chinese history, emptiness and fullness are indivisible and a condition for each other. In the Universal Tao practices, this view has vast implications. For example, in the universe, emptiness and fullness are indivisible and are the creative source of becoming, evolving and renewal, so that the universe is reborn in a continual process. We ourselves give thanks to the alternation of the inhale and the exhale, so our body is in a continuous process of dying and being reborn, through which we renew ourselves. The new can only rise if the old dissolves. So it is in Nature with the change of seasons. And so it is with all that is alive in the universe. This is the core wisdom of the *I Ching*.

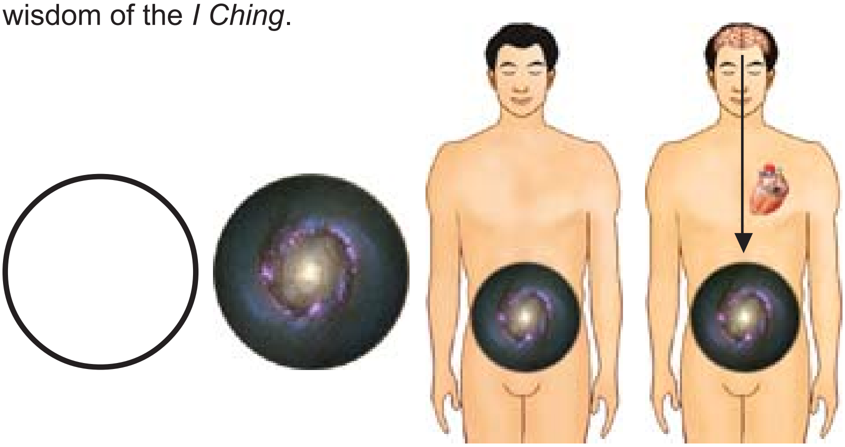

Fig. 9.3 *The core is the center of the universe, earth and the body.*

In the Taoist practice this has a particular application in the counsel to empty the mind and let it come down in the body so that a major source of energy is preserved and can renew itself. At the same time the belly can be filled with Chi, so that the energy streams in the whole body are enhanced and the heart is freed from too much pressure, as the belly helps do its work. Only when we learn to renew ourselves by undoing what has become unnecessary and what obstructs the process of transformation do we renew ourselves and our body. By undoing ourselves from what is no longer needed the new can grow. An ancient Taoist proverb suggests that simplicity comes about by seeing every day what has become dispensable. Then one can walk and move more lightly, both in the mind and with the body.

Jesus often reminded people in His parables of the law of unity and alternation in nature, and in themselves of old and new. In the *Tao Te Ching* this truth is expressed in the use of rich metaphors, for example, the house which acquires its function by being empty and the wheel which receives its function by virtue of its emptiness.

It finds its most pregnant expression however in the law on the unity of living and dying, common to all the great spiritual traditions – Hindu, Buddhist and Christian –, which is also central to Taoist practice. The new can only emerge and grow, if the old dies and is discarded.

Attachment and Detachment

This insight is at the core of the *I Ching* in which nature with its cycles and seasons is held up as a mirror for human beings. It has shaped from ancient times the Taoist proposition that to learn to be and realize oneself, one needs to go with the flow of life and to become like a fish in the water or the clouds in the sky. This insight is essential to give depth to the Fusion Practices and balance attachment with detachment.

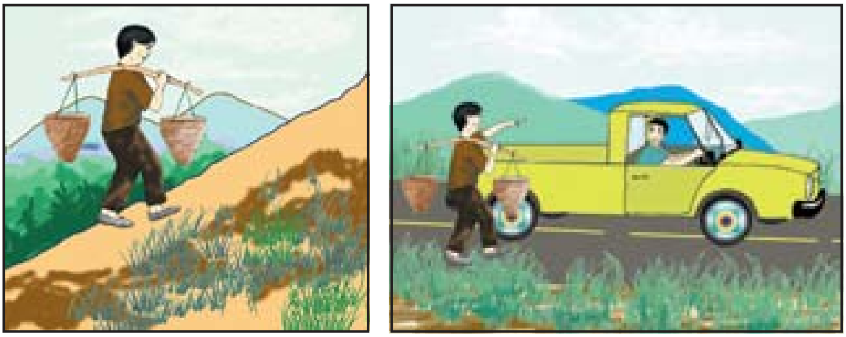

A: *Why don't you sit down, relax and let go of the weight and let me take you to the market.*

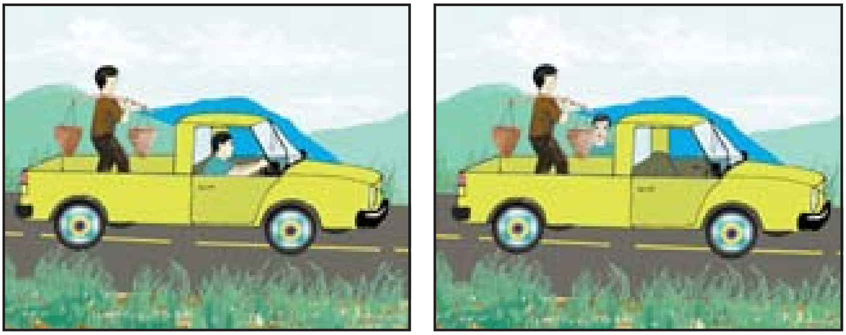

B: *Thank you for taking me to the market. I don't want to put too much weight on your car.*

Fig. 9.4 *Relax and let go.*

In the Taoist view, attachment and detachment are not to be seen as opposites, which exclude each other. What may be useful and functional in one stage of life, in one particular situation or moment, may well lose its functionality at another time. This explains why Taoists question the usefulness of externally induced and pre-arranged moral codes. Instead , they value, above all, self-cultivation in learning to act in harmony with what is inwardly experienced as genuine and truthful, because it is in tune with the universe in us.

The training in such an attitude in which one frees oneself from fixed rules imposed and determined from outside and one consults one’s own body and inner feeling, creates both freedom and flexibility. It helps to avoid being trapped in positions which undermine the capacity to trust oneself, and at the same time raises self-esteem.

In the process of genuine self-reflection and the growth of self-awareness, you learn to look at yourself and your inner life from a distance and as a neutral witness, rather than as a judge. As a result, you grow into a spirit of inner freedom and you learn to look at yourself with a sense of relativity and even with a sense of humor. At the point you are able to truly smile at yourself and have reached the point you can forgive yourself, wisdom is dawning and the knots which you felt were in your way are in the process of dissolving, to create space for new and fresh energy.

Going with the Flow

This view on going with the flow in the universe and within yourself is also the basic principle underlying and inspiring the ancient Taoist arts of self defense. In Tai Chi no position is fixed and the body enters into a continuous flow of movements, as life is movement and in the movement to become one with the universe and its energies and forces one becomes invulnerable. The power gained in the martial arts is not an external but an internal one; it is generated by the process of alignment. It is this alignment through which the body is empowered from below and above and the power can flow from the center.

If you have no center, you can be easily pushed around. A person who is centered has an internal balance. He is more free from external influences and less fearful and suspicious of others, as he is in tune with himself and the universe. Therefore the fusion practice may be called an internal kind of martial arts by which one learns to playfully bring into balance one's opposites so that a sense of being centered and in harmony arises and thereby self-confidence manifests.

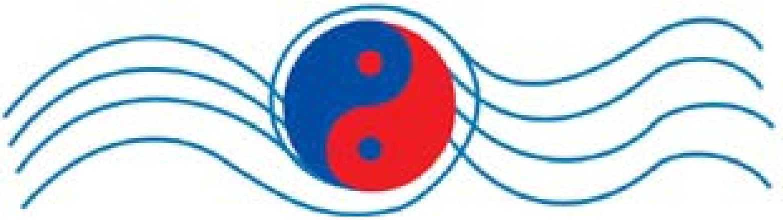

Fig. 9.5 *Balanced, going with the flow*

It should be obvious that the practice of these arts may be most helpful, as they may help you to remember to go with the flow inside yourself and become inwardly soft and flexible. Like all true Chi Kung, the art of moving the Chi and with the Chi, outer flexibility comes from inner relaxation. Only when relaxation deeply enters the body, can it become truly receptive for the energy within and from outside. The same goes for Tai Chi.

In that sense the Fusion Practices may also be seen as an inner play in which you invite your organs as your children to play with each other and see how they can balance and support each other. It may also be compared with an ancient game, which is played by children and adults in different countries in Asia. In Thailand it is called Takara in which the players help each other in keeping the light bamboo ball in the air so that the play can continue. Nobody loses, nobody gains. All share in the joy of the game and in the process train their own ability and help the others to enhance theirs.

Central to the Taoist tradition is that the body expresses and balances both heaven and earth. How could it receive the energies of heaven and earth and become an expression of the universe, if it were not open and flexible and receptive? This explains the crucial role of Chi Kung and the various schools and forms which have been created over the ages, so as to make the body a vessel. As the *Tao Te Ching* says: the function of the vessel is to be empty so that it can be filled.

Secret of Breathing and Relaxation

The essential role of the quality of breathing in all the practices is to enhance detoxification and cleansing, to create new space and openness towards the universe (in the exhale) and to fill the body with new energies and forces, by receiving, enriching and transforming Chi (the life or vital force). Breathing is central to the Taoist practice.

Changes in the quality of breathing from a short, superficial and agitated breath in the upper part of the body to a long, deep and quiet breath in the lower center/ Tan Tien of the body are crucial to the process of inner transformation. This is so because breathing is the bridge between consciousness and the body, and in the breathing process both the body and our awareness change.

The quality of breathing plays a crucial role in the processing and transformation of emotions which is a central theme in the Fusion Practices through the transformation of negative into positive emotions (Fusion of the Five Elements) and the cultivation of positive emotions (Cosmic Fusion). The emphasis in Taoist practice on self-healing is intimately related to the growth of self-awareness with regard to one's pattern of breathing as this determines the ability to regulate, control and balance emotions.

The Inner Smile practice as well as the Healing Sounds practice, designed to balance the negative and positive properties of the organs, are essential as a preparatory practice to the Fusion Practice.

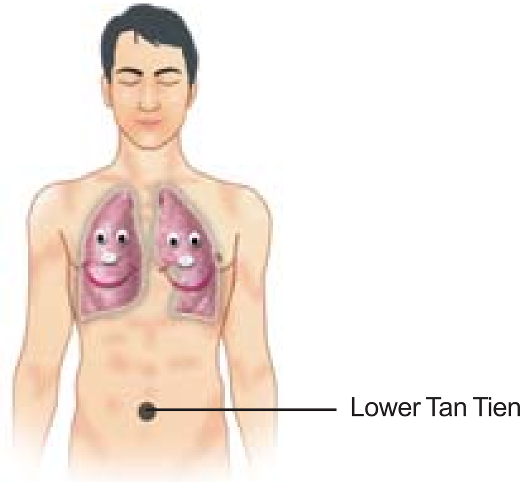

Fig. 9.6 *Smile to the Lungs.*

From the above, it should be clear that the practice of the Inner Smile and the quality of breathing and relaxation – as conditions of the self-healing process – are intimately related.

It is not coincidence that the great sages and masters of self-transformation like the Taoist immortals and the Buddha are always portrayed with an inward-oriented smile, to signify the key to inner freedom and balance and the unity of Yin and Yang. The practice of the Inner Smile as the key to relaxation remains the basis of all the practices of the Universal Tao, from the most basic to the most advanced. It is the key to all forms and stages of self-transformation, as the Taoist masters discovered its secret and its power to initiate and enhance the process of self-transformation. Statues and pictures may remind us of our own transformational potential and may help us to set in motion the internal alchemical process. We may also bring into our mind images of people who have awakened or reminded us in the course of our life of our own potential for transformation and positive qualities, thereby helping us to empower ourselves.

Science of Feeling and the Power of Intuition

In this sense, the Taoist practice is a continuous invitation to turn inward and get in touch with one's own body (and organs). Begin to sense and feel the body's state of being, its expansion and contraction and the state of relations between the major organs and the senses (kidneys/ears, liver/eyes, heart/tongue, spleen/mouth and lungs/nose). Check the state between the major organs and connected organs (kidney/bladder, liver/gallbladder, heart/small intestine, spleen/stomach, lungs/large intestine). Review the overall state of relations between the organs, glands, the nervous system, the spine, the bones, muscles and tendons. How are the relations between the three centers of the body (belly, heart and crystal room)? Check on those between the center and the extremities, the front and the back and the quality of the path routes which carry the flows in the body (the electro-magnetic energy, called Chi, also called the life force or vital force, the blood and the lymph flows).

Any advance in the practice is determined by the growth in ability to feel into the body by going inward and getting in touch with it.

In this context it is of value to realize that the verb "heal", the substantive "whole", and the adjective "holy" have the same etymological root. This is in line with the Taoist insight that the process of healing is realized in the process of becoming whole and that holiness is the state of having become whole and in balance with oneself and with the universe within oneself. In this view holiness is not a moral category but an existential and relational state of being.

It is not without reason that Taoist practice has been called a science of feeling, as throughout the ages it has relied on and cultivated it. One may also call the ability to feel the power of intuition or the feeling intellect which exists at every and all levels of our body and bodily awareness in which we are wholly present. In all languages of the world, there are multiple expressions, pointing to the organs, such as the heart or the liver or the kidneys or the blood or the bones or the veins, hands, eyes, ears and feet which reminds us of this intuitive power of the whole body. The reduction of thinking to the mind and the brain, so characteristic of Western reductionism, is entirely alien to all cultural traditions in the East and the South.

It is the feeling that we open the body and open and activate the Chi from within and outside.

It is also through feeling that we can sense, taste, hear and touch the rhythms of earth and heaven and unite with them within ourselves. Becoming aware of our inner movements and what moves us are one and indivisible. In the feeling process, we also become aware of the relativity of our boundaries and learn to experience these not only as limitations and finite but as openings to the unlimited and infinite.

As a result our solitude comes to an end and we become sensitive to our intrinsic relatedness with all that is. In this sense, each practice may be seen as a step to invert the process towards alienation and separation from the sources of life, basic to Western culture and its extension over the world.

Thinking with the Heart

One is reminded of the meeting of Carl Gustav Jung, the famous Swiss psychiatrist and philosopher of culture in the 1920's with an old Pueblo Indian in New Mexico on one of his visits to the United States of America. Jung narrates in his autobiography that his talk with him was unlike any which he had had with a European. When

Jung asked him how he felt about white people, Ochwia Biano (Mountain Lake) said to him, that to his people, they looked quite cruel in their appearance. “You always have an inflexible expression on your face. You always seem to be wanting something. You are always restless and agitated. We don’t know what you want. You all seem to be quite crazy.” Jung then asked him why he thought them to be crazy. He replied, “They say they think with their head”. Jung, surprised, asked him: “Of course, but tell me, where do you think?” He replied, “We think here.“ And he pointed to his heart. Jung tells how he sank into deep reflection and he remarks, “For the first time in my life, it seemed to me, somebody had shown me the image of how we really are.... This Indian had touched our weak spot and pointed to something to which we are really blind.” Jung viewed the encounter with the Indian as an opportunity, which opened to him a new gate to a primordial and nearly entirely forgotten dimension and form of consciousness which could be revived.

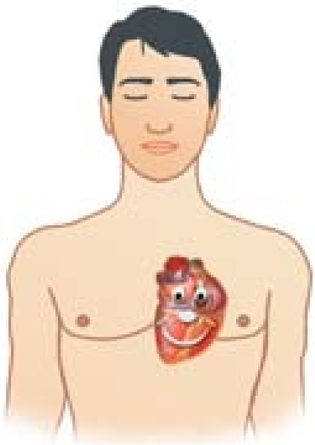

Fig. 9.7 *Smile into the Heart.*

In another passage in his autobiography, Jung narrates a dream which he had during a visit to an Islamic country in North Africa, which deeply touched him. In this dream he had to fight for his survival with a young Arab aristocrat who descended from his horse and wanted to drown him. Jung interpreted the dream as a struggle between his own repressed unconscious (his shadow), which sought to be recognized and accepted and his own consciousness, represented by his rational mind which felt threatened by the unsuspected attack by the young man. He then observes: “In my unconsciousness, I was in no way aware of such a situation; on the contrary I could not undo myself from a feeling of superiority, as at every step, I was reminded of being a European. I was not prepared to meet the unconscious forces within me, which emerged with such an intensity on behalf of the opposing party and which led to such an intense conflict."

Only several years later did Jung begin to understand the deeper nature of the dream. He began to see in the dream the resurgence of primordial structures or patterns in himself from a well-known past, but a past he had forgotten. He perceived the resurgence of these images as a renewed awareness of a still available potential for life, which was overgrown by civilization, a potential for life, which had been repressed and marginalized into the sub-conscious. In Jung's view, Western culture had become alienated to much of what being human represents: the primordial dimension of our being, which had been relegated to the underground.

Jung was a great admirer of the Taoist tradition and expressed his deep appreciation for its originality and wisdom in writing the foreword for the translation of the *I Ching* into German by Wilhelm Reich (the first translation into a European language).

The split between body and mind, thinking and feeling, matter and spirit, at the root of the formation of Western culture and religion and the birth of modern science, has been aggravated in the course of this century.

Feminine Underground Current

Some historians and scholars, like Morris Berman in his path-breaking studies "The Re-enchantment of The World" and "Returning to Our Senses" have argued, that in the course of this process the feminine dimension of European culture greatly suffered and in order to survive had to make itself invisible and so became its undercurrent. He means by this that in religion, with its reliance on external authority and its contempt for the body as well as in science, with its pursuit of objectivity, at the expense of other sources of cognition, the body was devalued.

Subsequently it could be turned into a mere object, an input and an instrument. It was seen in function of externally determined aims, as defined by the forces of competition, economic rationality and rational management and the new forms of communications technology. This process has also seriously undermined the position of women and has greatly affected their sense of dignity and self-esteem. It has also challenged the Yin values in society, considered to be counterproductive.

Unquestionably, the growing sense of despair and disorientation which large groups of people in the world today experience is directly related to the split and the resulting imbalances which they experience within themselves.

Restoring the Balance

With the growth of a new world culture, with a process of unceasing economic growth and expansion and the simultaneous rise of both minority affluence and mass poverty, these dualist tendencies are being further aggravated. The rise of fundamentalism and dogmatism, both as an instrument to legitimize power and achieve control and as a response to a growing despair and as an expression of the thirst for security is a further sign in the world rocked by imbalances and social fluctuations has become increasingly uncontrollable. This uncontrollability is seen as unavoidable and inherent in the very mechanics of the system and as an inevitable price for economic growth and advance.

Repression of the body and of sexuality and a search to compensate for it go hand in hand. Thus repression and a desperate search for liberation from it are both on the rise. There is a trend to see the body and sexuality as the source of all evil and start crusades against them so as to secure law and order. There is at the same time a growing obsession to secure and maximize pleasure, a trend which has grown to be the object of ruthless exploitation in which the body and sexuality have become mere commodities on the market. As a result, public life is being sexualized, as a source of economic expansion and profit.

Thus the repression of the body and sexuality have precisely an inverse effect and has become a major source of a fast-growing market and rapidly expanding pleasure and amusement industry, which capitalizes on this repression.

The first law of thermodynamics is that energy cannot be created or destroyed. In terms of Taoist theory, all energy comes forth from the Great Void, the original Wu Chi which undergoes a series of transformations in the formation of the universe. Thus the human body is seen as a particular form of transformation of this original energy. The second law of thermodynamics states that energy in a closed system tends to become disorganized (entropy). Thus there is an automatic tendency for balance to be lost.

Taoist practice focuses on inverting the process of dispersion and disorganization and restoring balance. This process is set in motion and facilitated by the Healing Love practice through which the unity and balance between love and sex is restored.

Essential to the Healing Love practice is the growth of love and compassion within as a result of which love and compassion with others and the universe become possible and emerge as a natural extension. Once the inner balance is restored, it is possible to act as an effective agent of balance outward.

In the Taoist view, conflict and violence in the outer order invariably have their source in inner conflict and violence, as manifestations of inner imbalance. Equally is outward peace viewed to have its source in inner peace and balance. In this process towards inner balance, Fusion Practices, in conjunction with the Healing Love practice and other practices of the Universal Tao, play an essential role; they honor the body and its intrinsic wisdom and potential for self-healing and rebalancing itself, so that it enters into alignment with the universe.

Joseph Needham, one of the great scholars of the origins of Chinese science and civilization, who was an honored member of the Academia of Science, had called Taoism the feminine undercurrent in Chinese history and culture, with its focus on the power of silence, feeling, sensing, compassion, forgiveness, humility, gentleness, reverence for life and nature and the equality of women.

It was however relegated to the margin of Chinese civilization and its practitioners had often to go underground. As a rule they fiercely stood for the ancient communitarian practices of reciprocity and sharing as well as people’s freedom and self-reliance. At the same time, they were opposed to interfering with the natural order, to be respected as a manifestation of the higher orders.

World as a Manifestation and Reflection of the Universe

They valued ancient forms of democratic practice, rooted in a vision of village communities in early times, which formed federations, patterned on the very structure of and alignment with the cosmos. No wonder that they were staunchly opposed to any forms of feudal and hierarchical power in which undue power was exercised by some over the many and the rise of a wealthy aristocracy which lived at the expense of the common people. They were also opposed to any forms of technology which would harm nature or be at the expense of people's sense of well being. Their attitude towards the universe and towards each other is summarized in the words of Lao Tzu:

> The Universe is sacred
> You cannot improve it
> If you try to
> You will ruin it
> If you try to hold it
> You will lose it
> Surrender yourself humbly
> Then you can be trusted to take care of all things.
> Love the world as you love yourself;
> Then you can truly take care of all things.

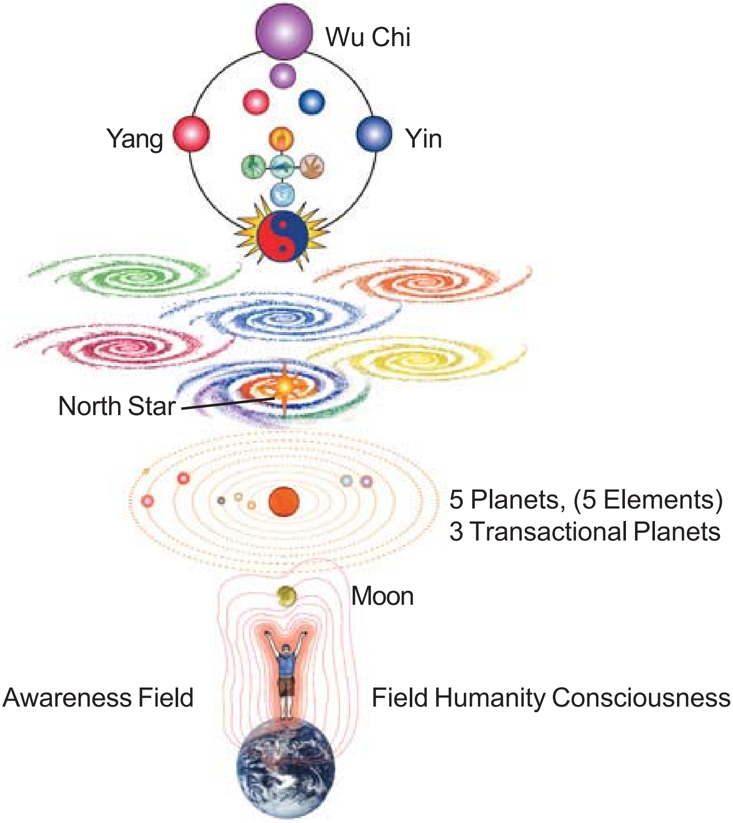
Wu Chi
Yang
Yin
North Star
5 Planets, (5 Elements)
3 Transactional Planets
Moon
Awareness Field
Field Humanity Consciousness

***Fig. 9.8** Alignment of the Cosmos*

It may well be that, precisely because Taoist practitioners refused to be co-opted by the establishment and were relegated to a precarious position, the practices could survive. As such, these practices, as synthesized in the Universal Tao, constitute a synthesis of several thousands of years of the practice by generations of Taoist masters in the science of feeling and sensing inward and of observing the nature of the universe and our relations with it.

The above provides evidence that Taoists over the centuries had a genuine concern about the well-being of the common people and that their practice was no reason to disengage from the world. The many stories and legends of the Immortals show that they were greatly loved, especially by the common people and the poor whom they often protected and helped. Their practice of gentleness (kidney), of generosity (liver), love and respect (heart), fairness and openness (spleen) and courage (lungs) expressed a strong sense of compassion with those who suffered.

Body as the Primary Source of Cognition

In the evolution of Western culture with its progressive disconnection between body and mind, thinking and feeling, rationality and emotions, mind and energy, inner and outer, matter and energy, linearity and spontaneity, feeling as a source of awareness and the primary mode of cognition has been progressively devalued.

It was seen as a feminine value of little use except in some domains as that of the arts and artistic endeavor. In religion it was looked at, together with the body, sexuality and emotions, as a potential source of evil. In science with its drive for objectivity, it was also looked at with suspicion, as it tended to disturb and undermine the demands for objectivity.

Thus it was relegated to a position of inferiority, as it was supposed to interfere with rationality, discipline and order, needed for progress and the growth of modernity, as well as with the need to control the universe, the cosmos, nature and ourselves.

In the Taoist tradition, feeling as the power of intuition, rooted in the body and the ability of self-reflection has always been considered as the primary source of self-awareness. Jung has named this form of cognition the knowledge of the unconscious, which underlies all conscious activity of the mind.

This capacity to intuit reality (the ability to sense reality in its totality may be called an integral form of knowledge) exists in our whole bodily being. It may also be called a mode of thinking with the body which precedes all formalized codes of thinking which evolved with the advance of formal rationality and the split of body and mind, typical of Western culture.

In that sense it may be called a Yin form of cognition, as opposed to the Yang form of cognition, which characterizes the modern world and its connected forms of education, science and technology. Yet there is abundant evidence that at the source of all genuine creativity and inventiveness, including in the field of science, lies the power of intuition.

In that sense, the practice of the Universal Tao and the Fusion Practices, deeply rooted in the Taoist tradition, may be seen as a way to recover this form of knowledge within ourselves so that the split within ourselves between body and mind, feeling and thinking is overcome. In the great Asian traditions, thinking in its restricted sense as the linear activity of the brain has been viewed as interfering with and affecting awareness as the primary and principal form of knowledge, essential for turning knowledge into understanding.

From a Taoist perspective, the primary learning process does not take place in the brain but in the organs. Recent findings corroborate the Taoist vision of the learning process that the brain only processes what is experienced and known intuitively by the organs, in particular those in the lower Tan Tien.

Our deep memory which structures our patterns of reaction and response to the world lies in the organs. In this view, a learning process needs to be rooted in a relearning and a reprogramming of our subconsciousness in the organs from which all conscious activity springs. In terms of contemporary technology the organs are the software and the brains are the hardware.

Unity of What is Above and Below

In many recent attempts to revitalize and recuperate spirituality, a growing need is felt to counter the ominous trend towards a loss of meaning in the world of today. There is a tendency to continue the split, which inspired many spiritual traditions, which tended to be based on the duality of good and evil, higher and lower.

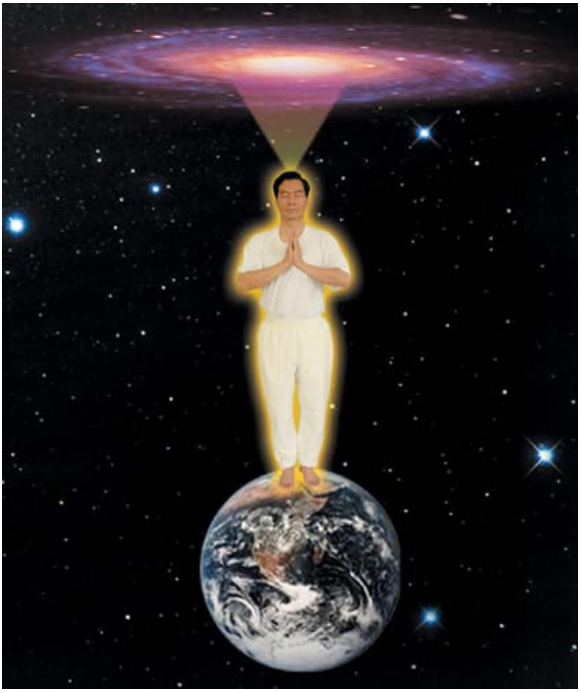

Fig. 9.9 *As Below So Above*

As the lower part of the body and its organs is looked at as associated with the instinctive animal obscure part, connected with sexuality, which prevents the mind and the spirit from its upward vocation, it is ignored and bypassed. The Taoist approach fully honors and recuperates the dignity of the body as a whole. The Tao recognizes the belly and its organs, connected with our sexuality and water energy which is the source of creative power from which all energy transformations flow. By getting in touch with our most intimate parts, we also gain access to the source of our creative powers.

In that sense, the Fusion Practices invite us to reconnect with those parts of ourselves, both physically and psychically, which have been the focus of repression. This repression is not only in most of our cultures but also within ourselves, as we internalized what we learned and accumulated in our culture, at home, in school and though the media. In order to reconnect and truly get in touch with our organs, we need an instrument which is capable understanding them.

That instrument is our intuitive power, which has its roots in our body as earth. It cannot be substituted by any other instrument, including our own intellect through which we are often at risk to become strangers to our own innate wisdom.

Genuine self-transformation can only be realized from within by the one who truly knows her/his personal existential history. We must see the relations between positive and negative emotions as our own most intimate history which we have often hidden from our own senses and which only reveals itself to our own compassionate inner eye and our own loving energy. Only then can we open the path to true healing from within. No medical system, medical doctor, psychologist, psychotherapist or other professional can do what you yourself can do: to observe and understand yourself emotionally and feel what your innermost self needs and longs for.

As such the Fusion Practices are a primary practice to reconnect with the somatic basis of our being and reconnect with the hidden parts of ourselves. Thus the Fusion Practices are exercises in in kinesthetic awareness through which we recover our primary form of knowledge which is somatic and is buried in our very body and our gut. For this we need to go deep down into our own emotional history and learn to feel with and within our entire body.

For this we need to let our rationalizing mind deeply sink into our body and let our intuition take over so that we get in touch with the visceral level of our being. Thus the Fusion Practices are not mental or intellectual exercises to clear our debris or accumulate virtues but an existential transformational exercise to which the formal mind only becomes an impediment.

The Fusion Practices provide a unique way to overcome the dependencies you have grown accustomed to and to train yourself in self-reliance and recover your independence and thereby your self-esteem.

Healing Wounds

Often the question is asked: “Where to begin”? Such questions may suggest a hesitation to enter the practice and face oneself. A path opens at the very moment we start to walk. The inner journey is different for all of us, as our histories are unique. The formulas provide an essential guide, which tells us how to go about, which direction to take, when to walk, when to rest and the stations (practices and their sequences) we should visit.

As suggested earlier, the whole Taoist practice has its beginning in the practice of the Inner Smile. The Inner Smile as the key to refresh, create, transform, attract and blend energies presupposes a basic willingness to enter into an adventure and to face the risks in transforming old to new. It requires above all a willingness to love oneself and self-compassion. Such an inner movement towards the opening of the heart is however only possible if there is some willingness to accept and forgive oneself.

Perhaps the primary key to any process of self-transformation is the willingness to forgive oneself, as it opens the heart and sets in motion and frees the flow of Chi, both from within and from outside. That would seem a primary condition for an open space to emerge in which one can enter into dialogue with the organs and let them speak and listen to what they wish to say.

Yet forgiveness is not an act for once and for all but a primary key in a continuous process of turning inward and practicing inner observation. It is not surprising that when Jesus was asked a question on forgiveness, he pointed to its key role by saying that a man should forgive seventy times seven, meaning that it has no limit. Rather than perceiving forgiveness as a virtue which make all other virtues possible, like love and compassion, it is more useful to see it in terms of a growth generated by process towards balance as a whole between positive and negative emotions (Fusion of the Five Elements) and as the fruit of the creative cycle (Cosmic Fusion).

The refusal or inability to forgive and thereby to love oneself and others may be said to affect all the organs, affecting their chemistry and inhibiting cooperation and balance. Frequently it is rooted in a victim consciousness, which sets into motion negative emotions which tend to reinforce each other. This victim consciousness often has its roots in a presumption of betrayal as a result of which the heart closes, as others are made accountable for one’s own negativity and suffering.

As a result there is a refusal to even consider looking inward, as the source of misfortune is placed outward. Thus the heart's natural tendency towards love and compassion is obstructed and the wound is cultivated to legitimize one's withdrawal from life, as a result of which both the internal as well as the inward flow from outside are being impeded. All traumas first of all settle deeply in our organs from where they affect our energy flows. They can only be dissolved with patience and gentleness towards oneself. Only when internally energy is accumulating, can it flow outward.

The strengthening of the organs have in the Taoist tradition a vital role to play in mitigating and achieving control over the negative emotions. Forgiving does not mean that the wound needs to be closed. It may remain but it is no more active in generating toxins and preventing positive emotions from growing. Also forgiving does not means that one forgets. That may be too difficult and is not necessary. Only the charge, which activates to toxins needs to be defused.

The aim of the Fusion Practices also is not to eliminate pain. Pain and joy are intrinsic in life and form a unity of opposites. Attempts to eliminate it create frustration and exasperation and may well make it grow and become more difficult to control, as negative emotions such as fear, anger, worry, sadness and impatience multiply. The more negative emotions are suppressed, the more they have a tendency to run wild.

The purpose of the Fusion Practices is to achieve control and regulate them consciously so that major imbalances can be prevented and the quality of the energies, upon being fused and blended is heightened and transformations into new states of being (the energy body and the spirit body) become possible. Ups and downs are inevitable but as you grow able to accept them and balance them and grow in equanimity, a point is coming when you are less affected by what happens around you; you are less carried away by events and you become less vulnerable.

Rather than to do away with toxins, it is wiser to allow for them and it is easier to control them. This immunity is both raised in balancing positive and negative emotions (Fusion of the Five Elements) and by strengthening the positive emotions (Cosmic Fusion). The unity of the two is of great importance. To make a small tree grow one does not only weed, but also creates optimal conditions for it to grow: that it is planted in good soil, that it receives shade and water and that it is pruned at the right time.

One practical way to effectively deal with the negative emotions is to distinguish between them, so that they can be separated and sorted so they receive the attention they require and they become manageable. We may see them like our children who each have their specific needs. We can give to each one the particular attention they deserve. To deal with them all at once is too difficult and leads easily to discouragement and a sense of powerlessness and defeat. In such a way you more easily work with them.

For each of us, the relations among and between positive and negative emotions is a unique one. So are our needs and styles to deal with them, depending on the culture we have grown up in, our different kinds of education and the ways we have responded to them and have evolved. So we will need to rely on and develop our own imaginativeness to use the formulas creatively so that they may be helpful rather than become an obstacle, as we apply them mechanically. We need to learn to feel what is good for us, and what helps us to be centered, in balance and at peace with ourselves.

Practice of Humor and the Humor of Practice

Crucial to our practice is a sense of humor and playfulness: to avoid the Fusion Practice becoming a reproduction of old patterns in a new form, as we use it as a device to track down our weaknesses in a spirit of self-condemnation. Humor is essential for balancing the energies of and in our organs. Humor is the great regulator which helps us to look with a sense of relativity, playfulness and lightness at ourselves. It is an expression of the compassionate energy of the heart which helps to look with a sense of detachment at ourselves and not to take ourselves so seriously that it becomes difficult to relax and be a witness rather than a severe judge.

With little humor, the Fusion Practice would become an accounting practice in which we record the drawbacks which prevent us from advancing. In focusing on the negative as if it were evil, we lose sight of our creative potential and prevent ourselves to gradually free ourselves from old patterns. Without humor we see no way out except by relying on some external power or force which only further undermines our own original power of self-transformation.

Learning to tend our Garden

What helps is to realize that we do not have negative emotions, per se, but that we and our spirit are in them. They are an integral part of us, and when we want to eradicate them, we destroy ourselves and the spirit contained in the organs.

For the Fusion Practices to become effective, we need to learn to dialogue with our organs. We must learn to express our gratitude to them for the miracle that we are alive thanks to their unceasing work. We need to give them a chance to relax and recuperate. Let us give them a chance to get in touch with each other. They are both our parents and our children. They can store Chi and provide us with energy when we need it. Let us protect them from our anger and other negative emotions, so that they do not have to suffer and feel we drain them. Let them breathe freely, accumulate Chi, expel the accumulated toxins to that we can recover, nourish and sustain our health and vitality.

It is a challenge to see the positive in the negative; negative emotions, when freed from their destructive and explosive charge, contain pure energy which we badly need to develop our vital force.

It helps to accept ourselves if we remember that our negative emotions often mirror forms of resistance which at some time early in life, served as a form of legitimate and understandable protection and rebellion. At that moment they might have been necessary, but at some point they lose their function.

Negative energies may be seen as a kind of garbage. If we discharge it on others and the environment, it becomes a major factor in generating toxins, bacteria, viruses and a variety of forms of disease by which negative emotions are multiplied and become more and more difficult to control. Or they can be seen as highly positive and urgently needed for recycling and composting, so that they can be used to help us grow and improve our balance, so that we do not become a burden and a threat for others and our environment, but a blessing, as our energies contribute to a climate of harmony and peace. The more light and Chi that enters our body and the more we radiate it into others and our surroundings, the less bacteria and viruses have a chance to grow.

The Fusion Practice (Fusion of the Five Elements, Formula Four) provides an effective method for composting, as the negative energies from the different organs, after having been separated out in the collection points, are brought into the pakuas which act as transformers. They can be blended with the positive energies from the organs as well as the energies from the universe, so that they become purified and enriched; energies of a higher quality and order can be generated. These then may be condensed into a pearl as the embryo of our energy body (Fusion of the Five Elements, Formula 5).

Raising the Quality of Our Energies

The Cosmic Fusion Practices basically serve to consolidate, stabilize and enhance the process towards balance, initiated in the Fusion of the Five Elements practices. The creative cycle practice of Cosmic Fusion specifically serves to further the growth of positive energies in the organs and glands, which in turn will be able to mutually support each other to create a higher quality of energy. This energy is concentrated in the compassion energy from which a pearl is formed. Only when all the positive energies merge into the fire of love and compassion by which the sexual energy is steamed and is transformed, its energy will turn into a higher creative and spiritual energy. This higher energy will then serve to nourish the energy body.

This pearl will be more powerful in healing and cleansing the body than the pearl in the Cosmic Fusion practice and may subsequently serve to create and nourish the energy body. The energy body may in the highest practices give birth to the spirit body. The Cosmic Fusion practice also serves to intensify the process of cleansing and healing through the creation of the three Thrusting Channels and by creating the the nine Belt Channels which serve to protect the body and its energies from negative influences.

Marriage of the Light from Within and from Above

All Universal Tao practices, including the Fusion Practices, consist of two dimensions. One is the activity which focuses on the processes of transformation within the body through cleansing, opening, healing and fortifying the body and raising the quality of its energies. The other activity is to get in touch with the universe, the cosmos and nature and attract their energies and the Light in which they originate towards the body so that the body may process these energies and blend them with its own refined energies.

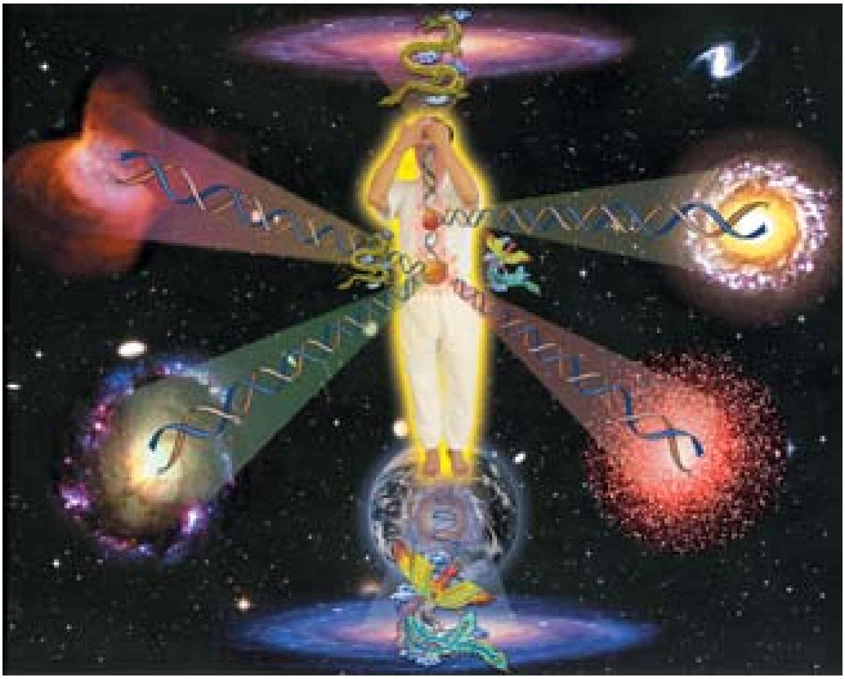

Fig. 9.10 *Connecting with the Universe*

The Taoist view is that the body by its very nature and structure is a microcosmos which is able to attract and receive and use the energies from the universe, the cosmos and nature to transform itself. Quantum physics confirms the view that the mind is faster than light and that consciousness is a form of energies which can move other energies when tuning into these energies and their frequencies.

The process of getting in touch with the universe and expanding love and compassion begins in the same way as the approach to inward transformation of energy: with smiling, feeling and sensing and radiating out love energy. The cleaner and finer the energy which is emitted, the higher the response from the forces and energies from above, below and around us. The relationship with the universe has been likened with that of a love or courting relationship. In all the mystical traditions the experience of the divine is also experienced as a relationship between the lover and the beloved. Frequently such relationships have been expressed by the great mystics in the most erotic and sensuous language, a reason for which they were as a rule hardly accepted and frequently persecuted.

Through its meridians our body may be seen as a grid of light channels through which it is connected with the light grid of the universe and can tap its unlimited energies.

Learning to embrace ourselves and the universe:

The Fusion Practice may serve to visualize oneself as a network of light and as a light body. Then the practice is not only one of cleansing but also one of filling the meridians with light. Mutations in consciousness start in the body visualization and turn into actualization. But the transformation lies not in the visualization. It is only a vehicle. Actualization is the real experience of the energy transformation in the body, when its chemistry changes and energy is transformed. One begins to sense the truthfulness and miracle of being alive and one starts to feel that one is embraced and pervaded by love and a sense of gratitude for the mysterious ecstatic process taking place in the body arises.

But this is not an end term. It is always only a beginning, as the love of the infinite has no limits neither in time nor space. In the process matter turns into what is immaterial and the immaterial as energy to continue its transformation waits again for a new form to contain it and change its nature and composition. Words help to create an image and when the image is there, the word loses its function. The image serves to help us generate the energy and its transformation. When the energy has come into being, the image needs to be given up so that a new space arises for a new experience. This is an unending process. How wondrous is it that our organs, our body, that sacred vessel, as it is called in the Taoist Canon, remembers its origins and longs to be fused and serve as an instrument of the fusions which unceasingly take place in heaven so that our intrinsically divine nature is realized and can be experienced. For earthlings, the learning process starts from outside. In the process of turning inward, the learning process increasingly becomes internalized. We need the structures and the forms and formulas to help us on our path. Then when we become still, it becomes spontaneous and starts to move by itself.

Then our child has been born and just wants to play without end to feel that they are welcome and loved so that they feel at home. For this quality in us to arise, we need to learn to embrace ourselves and the universe, as a mother her newborn child.

Written by: Joost Kuitenbrouwer
Universal Tao Instuctor

Questions and Answers about the Cosmic Fusion Practice

Q. ***Is the cauldron the point where all the pakuas join together?***
A. Yes.

Q. ***Now that we've learned about the cauldron, where do we collect the energy at the end of meditation practice?***
A. You can collect and store energy at the cauldron or you can continue to collect and store your energy behind the navel. When you collect the energy you make a vortex, which is three-dimensional, so it can veer toward the navel or the cauldron. As you do this you may feel it going deeper and deeper.

Q. ***Do we always have to do 36 and 24 spirals in the collection?***
A. The numbers 36 and 24 are a guide. There is no speed limit for spiralling the energy when you collect it. Some days you might want to do more than that; on many days you may want to do much less. On those days, 12 and 9 may be sufficient. Eventually it will go by itself.

Q. ***How do you collect the energy when there is so much energy all around?***
A. Collecting the energy will eventually become automatic. The safety features are bringing any excess energy from the pelvis up to the navel and and excess energy in the head and heart down to the navel. When you are coming back from the feet to the navel in the belt routes you are also collecting the energy.

Q. ***Does the energy stay in the cauldron or does it spread to the organs?***
A. Both.

Q. ***Should you see the collection points in color?***
A. Some people see, some people feel, and some people can even taste the energies. If you are visual, great. Then you will see the colors. If you work with the colors, the color will tell you if an organ's energy is healthy or not. If you look within and see dark muddy colors, then you know you have to work to make them clear and bright.

This applies to the organs and the collection points. Because the organs are affected by the emotions the colors will be affected.

Q. ***Does the Yin/Yang symbol move inside the pakua?***
A. It spins like a vortex.

Q. ***Is there always a pearl you can work with?***
A. If you practice forming a pearl every day, there will be one there when you sit down to meditate.

Q. ***Is there a minimum size for the pearl?***
A. The size of the pearl is less important than its density. As you add energy to it you might notice it glowing more brightly or feeling more energetic.

When the energy increases you might want to make more than one pearl. Then you can give it away to an organ or into your own atmosphere.

Q. ***Does the belt channel go around both legs or each one separately?***
A. It circles around both legs, although if the energy wants to go around each one, that's okay too.

Q. ***You talk about using the thrusting routes for practical purposes. Can you give an example?***
A. To clean the atmosphere in a room, you shoot the pearl out the crown and let it expand and fill the space. That way you declare the territory as your own—it is permeated now with your energy and consciousness. If there is any negative energy, any negative spirit, it will just leave of its own accord. You can't destroy negative energy, but you can work with it to make it leave, by overcoming it with your own energy. But you don't want to anger another spirit, that's not the Taoist way. Either they are using your energy to protect them or they want to tap into yours to get themselves to a higher level.

Q. ***Is there a breathing technique that will make you more Yin or more Yang?***

A. It's not just breathing. If you eat very Yang foods, like meat and you are trying to be Yin, it won't work. If you work with the Fusion I formula you can balance the energy more easily than with outside forms of breathing or food. Fusion I and the Microcosmic Orbit are natural ways to balance your energy.

Q. ***The meditation seems so long.***

A. Once the channels are open you don't need to spend much time. The training period seems long, but the actual practice can be quite short. When the Thrusting Channels are open you won't need to do any muscle contractions, you won't need to do it in stages, you won't need to inhale several times. You will just sit down and in a couple of minutes you will find yourself in a state where the energy will be strong enough and the channels open enough that the energy will flow through the Thrusting Channels just using the mind itself. In fact, you will be able to do it anytime, not just during meditation.

You can imagine the work it takes to connect pipes from a reservoir to each household in a city. But once the pipe is connected all you have to do is turn the faucet on.

Q. ***What can close the channels?***

A. Stress of any kind can close the channels. Tension contracts everything—muscles as well as emotions. Also, if you stop practicing for a long time the channels will close. A path that's walked on every day will be clear, but if no one travels on it the weeds start growing and soon it is covered back over. That's why we stress the importance of daily practice. Even five minutes a day, is better than one hour once a week. Fusion I and Fusion II practice can be combined together, so you can check the organs, smile down, see what you need to do, and in a few minutes you can do some maintenance work. Then when you have more time you can go and clean the organs and the Thrusting Channels. In the beginning, the Fusion practice needs the mind to form the pakua, and collection points. It's like the Microcosmic Orbit: when you first learned it, it took a lot of concentration on each point and even when it started to run by itself it wasn't dependable. But after a while you could wake up in the morning and feel your Microcosmic Orbit running.

Fusion I and II are more complex and at the beginning you have to develop a different technique to get them running. I just look in the cauldron and it's like a slide projector: I can see everything. Then you can add the collecting of the energy and the blending process.

Everyone we know who has practiced Fusion II for a year or so, can do the creation cycle in a couple of minutes. As you practice and keep adding more details, sooner or later it becomes automatic. If you do Fusion II on a daily basis you will begin to get faster and faster. You will be able to look inside and see what's going on. When the process becomes automatic you open a whole area of possibilities. It will give you more time to practice because you will be doing it so fast. It will be there when you sink into sleep. It will be there when you wake up in the morning.

When you tune into your organs, your organs will have more say over what they want and what they do. So when you work with the formula correctly, the organs will love it. They will have the space and time to be themselves. The brain can be overworked and pushed too hard. It can force any organ to work until it's destroyed. You can see this in people who take drugs to control their emotions.

But when the situation is balanced by using the Microcosmic Orbit, the organs get a chance to balance themselves. The brain has a say but the organ also has a say. Then you can achieve a balance of energy when the intellect and the organs are working together. At this stage, when the senses are drawn in, not distracted and running around, you will feel calm. Gathering and conserving energy is good in itself.

The next thing that happens is that you can begin to gain Real Knowledge. Real Knowledge is beyond intuition; it comes from within and you make better choices and decisions. This Real Knowledge is an inner guide which sometimes manifests in dreams from the unconscious. It can show you a direction in life. You know yourself that these dreams are rare. In the past they only came when you were at a crossroads and there was some danger. But through the practice with emotions, organs and mind, you develop that interior communication that allows you access to Real Knowledge, so you're not operating in a state of emergency but from a state of balance and calm. Those directions will be easy to follow. So this is a process of purification. The energies will be used with purer intentions.

For example, if you have an excess of fear you feel threatened and isolate yourself. Any decision you make from that standpoint will not lead to happiness. This formula is very important and carries a tremendous amount of responsibility, for whenever you learn something that can change your life in a positive sense you will either do it or forget about it. You often hear people say, “I want to change my karma.” This formula is something that can change your karma. So this practice, this opportunity has a responsibility. You will have to take the consequences of doing it or not doing it. Because if you do it you will change.

Q. ***How can I protect myself from negative energy?***

A. The belt routes can protect you. When you circulate the energy through the belt routes, the energy centers are strengthened, and can protect you from absorbing outside energy that you don’t want. For instance, in a crowd, if there is energy you don’t like, just run the belt routes to protect yourself. This will also protect your aura. If you are upset and have a lot of emotions, the aura is very unstable. The aura might expand or shrink. This protection will become automatic through diligent practice of the belt routes.

Q. ***When you send the energy out like a shower, are you always collecting positive energy? How do we know what energy we are collecting?***

A. There is always heavenly energy around you, and there is always magnetism so when you do this work you are working with earth and heaven energy. It’s another responsibility when working with the energy. If you are an ordinary person you are absorbing only a certain level of energy. When you start raising your level, you are raising your level of positive energy. This can change the atmosphere around you (an inner pressure of positive energy). Energy has a magnetic quality that attracts. When you have strong positive pure energy you will be repelling negative energy and you won’t be affected by negative energy. For example, if someone is angry you will have enough positive energy to handle it. If you practice this and go to higher levels and then decide to stop, your pressure will again change and decrease. Our bodies always try to find a balance, that's our inner intelligence. So the pressure has dropped and the body tries to restore the familiar higher pressure. To do this you start absorbing anything, and the most abundant source is the garbage energy: anger, fear, depression, etc. As you build up your strength you need to maintain that higher level and that is a big responsibility.

So when you do the shower of energy you have to depend on the strength of the energy in your pearl. Fusion II jacks up the energy of the pearl you made in Fusion I by imbuing it with the positive qualities in the organs. So it's important to do Fusion I carefully.

When you absorb positive energy you can even affect the bacteria in the air. If you've been practicing the Microcosmic Orbit and Fusion I for a year you've probably noticed that colds don't last as long, and you don't get sick as often.

Q. ***Is it normal to feel pain or discomfort when doing the fusion practices?***

A. You can see that some systems are into suffering: staring at the sun, sticking oneself with needles or standing on one leg for a long time. This is so that when practitioners get to the level of great power, they can withstand the pain. This is how some people learn and they suffer a great deal.

Maybe you cannot take all the energy; some people bathe in the river every day to reduce the heat and can't sleep for weeks and months. When you practice to a certain level there are changes in the body—but you can take those changes. Sometimes as new energy pushes through channels you may feel a headache. Some people feel a stomach cramp when they blend the energy at the cauldron. But that is unusual. It's like trying to help a butterfly when it's hatching. Maybe you want to help by cutting the chrysalis with a scissors. But the butterfly won't survive if you do that. It has to struggle at the beginning in order to survive.

So you will have to grow over the pain. Other systems induce the suffering first. In Chinese, they call it qing ku—you don't have anything and you still have to suffer—but that is not the Taoist way. We prefer to grow first and then experience the growing pains. You may feel imbalanced from time to time—constipation is a real problem. If you have a good bowel movement at least once a day, you will not suffer so much.

Now that you are more sensitive to energy, you will recognize negative energy right away and you have the tools to neutralize and purify the energy.

Some people, after they study, find that they are reacting differently to their love partners. For some of them, this difference leads to a break-up. When they look back on it, they often realize that the break-up was inevitable and that they were dissatisfied before. For others, especially couples who study together, their relationship becomes more solid and more respectful. In any case, it means that you begin to understand yourself better.

Sometimes you begin to see problems more clearly and see the energy that causes the problems. When you can enhance the energy inside, the problem goes away. There are those who get angry but don’t realize they are angry and aren’t aware of the effect of the anger on the liver. But those who practice Fusion I can become aware of the liver and very quickly the anger will be gone.

The Taoist system can change the course of your life, change your astrology, change your fortune and your fate. We know that because of the experiences of Taoists over many generations.

The energy inside your organs and brain makes your life what it is. So when you know how to control your energy, your organs and senses, that is the beginning of controlling your future. Those who are controlled by substances like tobacco, alcohol and other drugs are not in control of their lives.

In Taoism you don’t run away from problems as long as you are in this world. Actually there is practically nowhere on the planet where you can go without being bothered.

When we started to teach Westerners, we found new ways to teach people how to balance their energy through diet as well as through the Taoist exercises. Those who eat only raw foods will be too Yin and those who eat mostly meat and dairy will be too Yang. But the only way to restore your True Knowledge is when you turn to your internal organs and senses for information. Then you will know how to conduct your life. But until you do that it’s hard to know what’s good or bad for you.

The golden mean, the middle, moderation are all ways of saying that when you know how nature works you will know the Tao. By knowing the Tao you start to know about God and the universe. Anything that's extreme, you have to back away from. The only thing that lasts long is balanced, middle and center.

Q. ***Is there a problem if I shake a lot during meditation?***

A. Too much shaking can scatter the energy. Moving and stillness have to be balanced. If you remain still for too long the energy might settle. But if you shake and scream and are never still you risk eventually shaking out all your life force.

If you start burning a fire, it gets hotter and hotter. When the water comes to a boiling point you turn it down and cook it very slowly. That way you can get the essence out. If you don't turn down the light all the water will boil away and the pot will be burnt or broken.

When you are into the meditation and very still, movement starts and many things are activated. If the movement becomes very strong it won't last long and you might want to stop it. You have to know the timing. If you start to shake, you can gain power by stopping the shaking and utilizing that energy inside. If you let the shaking continue, you might lose all the energy you built up.

In some forms of therapy people are encouraged to shake and jump and scream to get rid of their anger or depression or anxiety. When the session is over it seems that everything has been worked out but when they get home they are throroughly exhausted. The emotions were shaken out along with the life force. How much better to recycle the energy.

Tai Chi balances the Yin and Yang through movement and stillness. This builds up energy and then you can circulate the energy in the Microcosmic Orbit. The whole secret in the Universal Tao is having the channel for the energy to flow.

Q. ***Why do you create an Energy Body outside yourself?***

A. When you set up the Energy Body and the spirit body they start to draw out the essence of the physical body. Then it starts to work in space.

It's the same reason that every country wants to set up laboratories in space. You can make a lot of things better in space because there's no gravity, no dust and no germs.

The Energy Body will draw the essence up; you might even feel like it's going to pull your whole body up. And then the Energy Body draws the energy from space and the universe and mixes them in. When you bring the energy back into the body the organs will absorb all this energy and start to transform. But if you sit down without a purpose you won't get this effect.

Everytime you add more of your body's energy to the Energy Body, the Energy Body will go higher. Sometimes I feel like all my essence leaves my physical body. When you practice every day it starts to take the essence of this body and transform and mix it with the universal energy and your progress will be remarkable. There will be no resistance. When you're finished meditating, you just shrink the Energy Body down and each time you shrink it down the pearl becomes more refined.

At one time, the Taoist Masters were afraid of losing the pearl in space and did it all inside the body. This was reflected in the art in China where they worked incredible detail on miniature objects. But later the Tao masters discovered that if they know how to send the energy out the head they can expand the Energy Body and then shrink it down. That way they achieved more perfection—it's the same way they make a computer chip.

If you look inside a chip there's a whole city inside it. They draw every detail on paper the size of a football field and then with a special camera they shrink it down and down.

Set it up, do all the detail you want, then shrink it down and pull it back in.

> I had to figure a lot of this out myself. When I heard “transfer your consciousness to the next life” I decided I had to learn how to do this in this lifetime. I kept asking, but everyone had a different answer. They just said it’s very simple. I told one master I’d give him anything for the secret; I’d go anywhere to learn. Either he didn’t have it or else he wouldn’t give it to me. After a while I discovered that I’d have to figure out myself how to transfer whatever I wanted to the Energy Body. I did this because I understood that my Energy Body will live forever.

Focusing on intellectual understanding alone is limiting and stifling. A real practice teaches one how to feel within and derive authentic knowledge based on personal experience. In the Universal Tao, we emphasize the practice of understanding nature, getting in touch with the natural forces, and getting in touch with oneself. Then the principles of philosophy will reveal themselves, and one can have real hope based on what is, not on empty promises that can never be proven.

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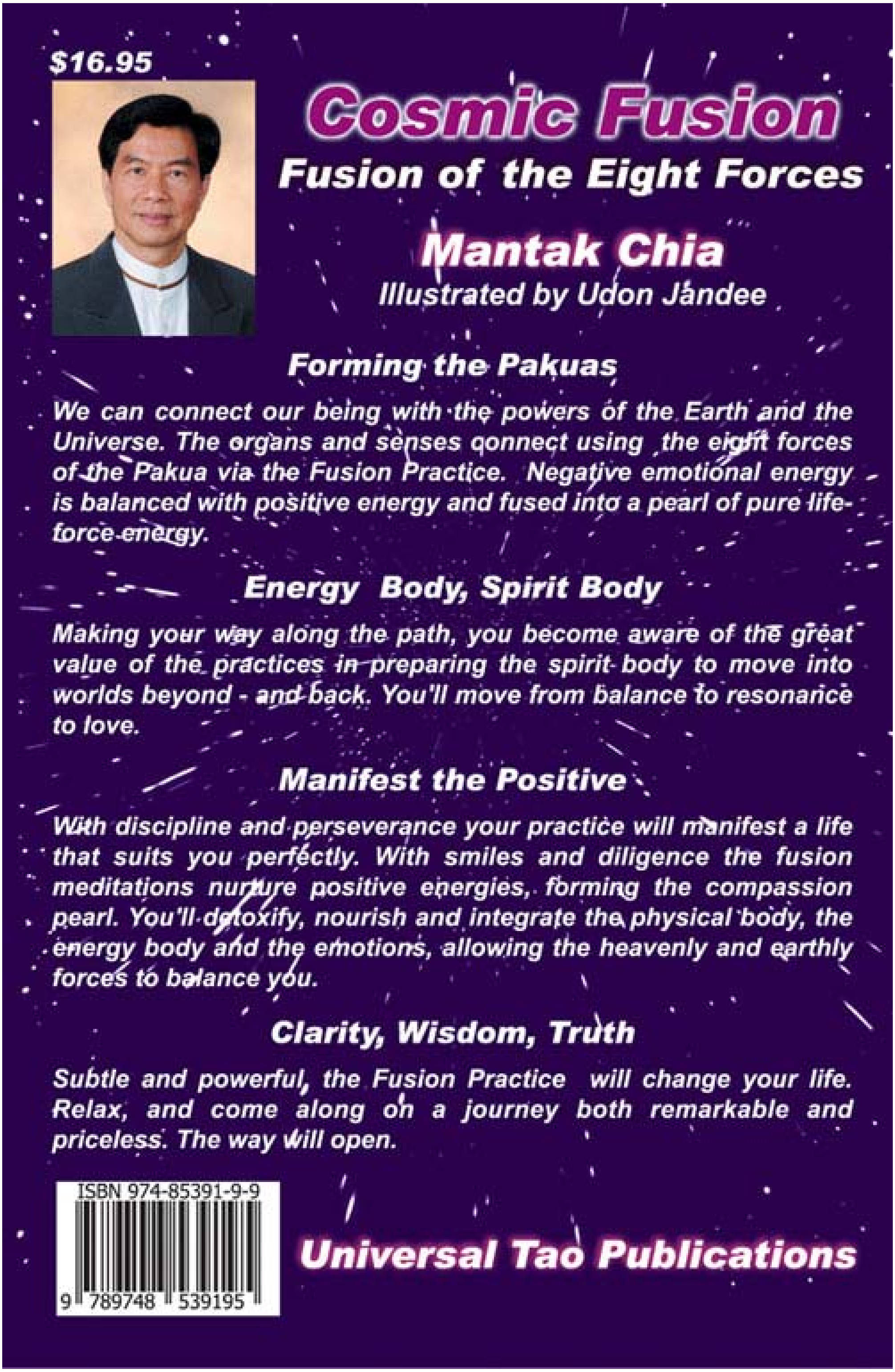

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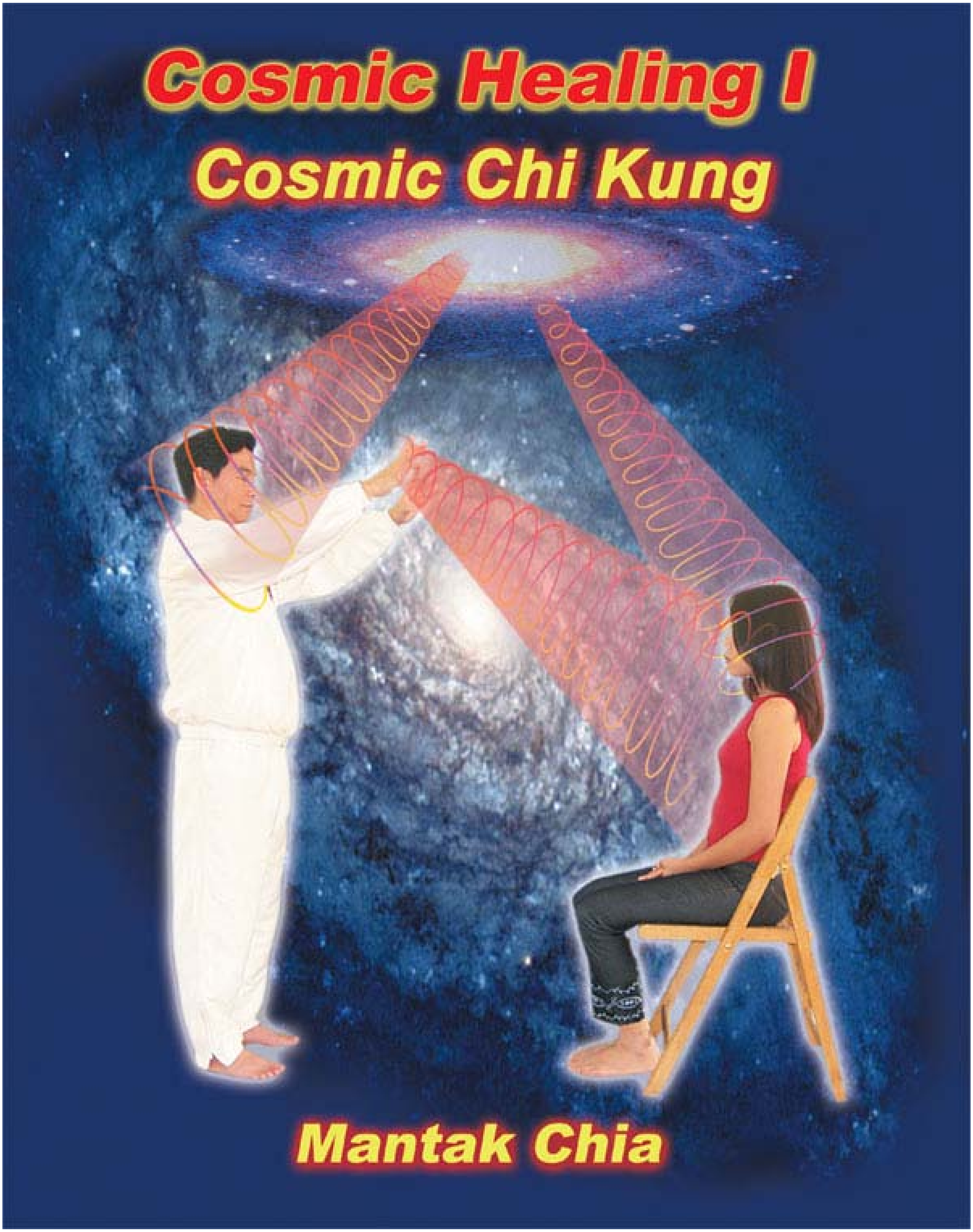

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About the Author

Mantak Chia

Master Mantak Chia is the creator of the Universal Tao System and is the director of the Universal Tao Center and Tao Garden Health Resort and Training Center in the beautiful northern countryside of Thailand. Since childhood he has been studying the Taoist approach to life. His mastery of this ancient knowledge, enhanced by his study of other disciplines, has resulted in the development of the Universal Tao System which is now being taught throughout the world.

Mantak Chia was born in Thailand to Chinese parents in 1944. When he was six years old, Buddhist monks taught him how to sit and “still the mind.” While still a grammar school student, he learned traditional Thai boxing. He was then taught Tai Chi Chuan by Master Lu, who soon introduced him to Aikido, Yoga and broader levels of Tai Chi.

Years later, when he was a student in Hong Kong excelling in track and field events, a senior classmate named Cheng Sue-Sue introduced him to his first esoteric teacher and Taoist Master, Master Yi Eng (I Yun). At this point, Master Chia began his studies of the Taoist way of life in earnest. He learned how to circulate energy through the Microcosmic Orbit and, through the practice of Fusion of the Five Elements, how to open the other Six Special Channels. As he studied Inner Alchemy further, he learned the Enlightenment of the Kan and Li, Sealing of the Five Senses, Congress of Heaven and Earth and Reunion of Heaven and Man. It was Master Yi Eng who authorized Master Chia to teach and heal.

When Mantak Chia was in his early twenties he studied with Master Meugi in Singapore, who taught him Kundalini, Taoist Yoga and the Buddha Palm. He was soon able to clear blockages to the flow of energy within his own body. He learned to pass the life force energy through his hands also, so that he could heal Master Meugi's patients. He then learned Chi Nei Tsang from Dr. Mui Yimwattana in Thailand.

A while later, he studied with Master Cheng Yao-Lun who taught him the Shao-Lin Method of Internal Power. He learned the closely guarded secret of the organs, glands and bone marrow exercise known as Bone Marrow Nei Kung and the exercise known as Strengthening and Renewal of the Tendons. Master Cheng Yao-Lun's system combined Thai boxing and Kung Fu. Master Chia also studied at this time with Master Pan Yu, whose system combined Taoist, Buddhist and Zen teachings. Master Pan Yu also taught him about the exchange of Yin and Yang power between men and women, and how to develop the Steel Body.

To understand the mechanisms behind healing energy better, Master Chia studied Western anatomy and medical science for two years. While pursuing his studies, he managed the Gestetner Company, a manufacturer of office equipment and became well acquainted with the technology of offset printing and copying machines.

Using his knowledge of Taoism, combined with the other disciplines, Master Chia began teaching the Universal Tao System. He eventually trained other Instructors to communicate this knowledge and he established the Natural Healing Center in Thailand. Five years later, he decided to move to New York, where in 1979, he opened the Universal Tao Center. During his years in America, Master Chia continued his studies in the Wu system of Tai Chi with Edward Yee in New York.

Since then, Master Chia has taught tens of thousands of students throughout the world. He has trained and certified over 1,200 instructors and practitioners from all over the world. Universal Tao Centers and Chi Nei Tsang Institutes have opened in many locations in North America, Europe, Asia, and Australia.

In 1994, Master Chia moved back to Thailand, where he had begun construction of Tao Garden, the Universal Tao Training Center in Chiang Mai.

Master Chia is a warm, friendly and helpful man who views himself primarily as a teacher. He presents the Universal Tao System in a straightforward and practical manner, while always expanding his knowledge and approach to teaching. He uses a laptop computer for writing and is totally at ease with the latest computer technology.

Master Chia estimates that it will take thirty five books to convey the full Universal Tao System. In June 1990, at a dinner in San Francisco, Master Chia was honored by the International Congress of Chinese Medicine and Qi Gong (Chi Kung), who named him the Qi gong Master of the Year. He is the first recipient of this annual award.

In December 2000, the Tao Garden Health Resort and Universal Tao Training Center was completed with two Meditation Halls, two open air Simple Chi Kung Pavilions, indoor Tai Chi, Tao Yin and Chi Nei Tsang Hall, Tai Chi Natural Swimming Pool, Pakua Communications Center with a complete Taoist Library, Internal World Class Weight Lifting Hall and complete 8 Court Recreational Facilities.

In February 2002, the Immortal Tao practices will be held at Tao Garden for the first time using Dark Room technology, creating a complete environment for the higher level Taoist practices.

He has previously written and published these Universal Tao books:

Awaken Healing Energy of the Tao - 1983
Taoist Secrets of Love: Cultivating Male Sexual Energy
co-authored with Michael Winn - 1984.
Taoist Ways to Transform Stress into Vitality -1985
Chi Self-Massage: the Tao of Rejuvenation - 1986
Iron Shirt Chi Kung I - 1986
Healing Love Through the Tao: Cultivating Female Sexual Energy - 1986
Bone Marrow Nei Kung - 1989
Fusion of the Five Elements I - 1990
Chi Nei Tsang: Internal Organ Chi Massage - 1990
Awaken Healing Light of the Tao - 1993
The Inner Structure of Tai Chi co-authored with Juan Li - 1996
Multi-Orgasmic Man co-authored with Douglas Abrams 1996 - published by Harper/Collins
Tao Yin - 1999
Chi Nei Tsang II - 2000
Multi-Orgasmic Couple co-authored with Douglas Abrams 2000 - published by Harper/Collins
Cosmic Healing I - 2001
Cosmic Healing II co-authored with Dirk Oellibrandt - 2001

Also many of the books above are available in the following foreign languages: ***Bulgarian, Czech, Danish, Dutch, English, French, German, Greek, Hebrew, Hungarian, Indonesian, Italian, Japanese, Korean, Lithuanian, Malaysian, Polish, Portuguese, Russian, Serbo-Croatian, Slovenian, Spanish,*** & ***Turkish*** editions are available from the Foreign Publishers listed in the Universal Tao Center Overview in the back of this book.

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Thanks to Juan Li for the use of his beautiful and visionary paintings, illustrating Taoist esoteric practices.

We offer our eternal gratitude to our parents and teachers for their many gifts to us. Remembering them brings joy and satisfaction to our continued efforts in presenting the Universal Tao System. For their gifts, we offer our eternal gratitude and love. As always, their contribution has been crucial in presenting the concepts and techniques of the Universal Tao.

We wish to thank the thousands of unknown men and women of the Chinese healing arts who developed many of the methods and ideas presented in this book. We offer our graditute to Master Lao Kang Wen for sharing his healing techniques.

We wish to thank Colin Campbell for his editorial work and writing contributions on the first printing of this book, as well as his ideas for the cover. We appreciate his research and great labor. We wish to thank Matt Gluck for his editorial contributions on the revised edition of this book, as well as thanking our instructors, Dennis Huntington and Annette Derksen, for their insightful contributions to the revised version. We thank Dirk Oellibrandt for his technical editing and clear writing throughout the book.

A special thanks goes to our ***Thai Production Team*** for their cover illustration and book design and layout: Raruen Keawapadung, Computer Graphics; Saysunee Yongyod, Photographer; Udon Jandee, Illustrator; and Saniem Chaisarn, Production Designer.

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We also wish to express thanks to Cosmic Healing Certification Retreat Organizers around the world who have worked with us for many years and helped us prepare this manuscript throughout the Retreats: Beate Nimsky, Vienna, Austria; Serguei Orechkine, Moscow, Russia; Christopher Larthe, London, England; Masahiro Ouchi, Rye, New York; Dr. Angela C. Shen, San Francisco, California; Dirk Oellibrandt, Hamme, Belgium; Brita Dahlerg, Frankfurt, Germany and Lizbeth Cavegn, Zurich, Switzerland.

We wish to further express our gratitude to all the instructors and students who have offered their time and advice to enhance this system, especially Felix Senn, Barry Spendlove, Chong-Mi Mueller, Clemens Kasa, Andrew Jan, Marga Vianu, Harald Roeder, Salvador March, Dr. Hans Leonhardy, Peter Kontaxakis, Thomas Hicklin, Gianni Dell’Orto, Walter and Jutta Kellenberger.

Words of Caution

The practices described in this book have been used successfully for thousands of years by Taoists trained by personal instruction. Readers should not undertake the practice without receiving personal transmission and training from a certified instructor of the Universal Tao, since certain of these practices, if done improperly, may cause injury or result in health problems. This book is intended to supplement individual training by the Universal Tao and to serve as a reference guide for these practices. Anyone who undertakes these practices on the basis of this book alone, does so entirely at his or her own risk.

The meditations, practices and techniques described herein are ***not*** intended to be used as an alternative or substitute for professional medical treatment and care. If any readers are suffering from illnesses based on mental or emotional disorders, an appropriate professional health care practitioner or therapist should be consulted. Such problems should be corrected before you start training.

Neither the Universal Tao nor its staff and instructors can be responsible for the consequences of any practice or misuse of the information contained in this book. If the reader undertakes any exercise without strictly following the instructions, notes and warnings, the responsibility must lie solely with the reader.

This book does not attempt to give any medical diagnosis, treatment, prescription, or remedial recommendation in relation to any human disease, ailment, suffering or physical condition whatsoever.

Chinese Medicine and Chi Kung emphasizes balancing and strengthening the body so that it can heal itself. The meditations, internal exercises and martial arts of the Universal Tao are basic approaches to this end. Follow the instructions for each exercise carefully and do not neglect the foundations, i.e, the Microcosmic Orbit and any other supplemental exercises. Also pay special attention to the warnings and suggestions. People who have high blood pressure, heart disease or a generally weak condition should proceed cautiously, having prior consent from a qualified medical practitioner. People with venereal disease should not attempt any practices involving sexual energy until they are free of the condition.

The Universal Tao is not and cannot be responsible for the consequences of any practice or misuse of the information in this book. If the reader undertakes any exercise without strictly following the instructions, notes, and warnings, the responsibility must lie solely with the reader.

Chapter I
Cosmic Healing

Cosmic Healing Chi Kung in the Universal Tao System

Cosmic Healing Chi Kung is an important branch of the Universal Tao, an entire system of Taoist practices for cultivating the body, the Chi and the spirit. Your level of skill in Cosmic Healing Chi Kung will be based upon your mastery of the Universal Tao System as a whole. One of the most important parts of the Taoist practices is working with the energy moving within the body.

Foundation of the Universal Tao System is the Microcosmic Orbit Meditation

This is the major practice to connect with the earth, cosmic and universal forces. This is the way to make a connection with the North Star and the Big Dipper’s violet/red light which is one of the very powerful universal healing lights. Through this practice you learn to feel Chi and to use your mind/eye/heart power to guide the Chi flow through the primary energy routes in your body. This practice is later extended to include the arm and leg routes too; it is then called the Macrocosmic Orbit.

Many people, including Chi Kung Masters, come to me and say that they have been practicing Chi Kung for years and nothing is happening. They don't feel any energy and they think that they must be performing their Chi Kung incorrectly. I tell them that they also need to do meditation. Hand movements are nothing by themselves. There are hundreds of different Chi Kung forms in China. You could spend seventy lifetimes just learning the hand movements. The practice of the Microcosmic Orbit meditation will help you to feel the Chi more easily inside, outside or around the body and in the extremities of the hands and feet.

When I was a child I liked to practice Chi Kung so much I had to save my lunch money to learn. After many years of practice of many Chi Kung forms, I started to forget the first form, so I learned it again. One day when I tried to practice and review all the forms that I had learned, I couldn’t remember many of them. I sat down and thought, “I only have two hands, two legs and one head. Why are there so many forms? And why are there are so many religions and beliefs.” I said to myself that there must be one main thing that they have in common. I started to search and I found out that the most important thing is feeling the Chi within us. Being able to increase, transform, take in and stay in touch with the universal, the cosmic, nature and the earth force. Letting them all combine within us is what is important. Likewise in religion there is God (a Force in Taoism we call Wu Chi, the nothingness, the supreme power controlling the universe); with a good heart and virtue energy we can connect with this force.

The complete practice of the Microcosmic Orbit Meditation is fully described in the book "Awaken Healing Light of the Tao" by Mantak Chia.

Cosmic Inner Smile and the Six Healing Sounds

These are very important practices to make the connection among the organs, the colors and the good virtue energy; each organ color will enhance your connection to the cosmic and the Universal Healing power.

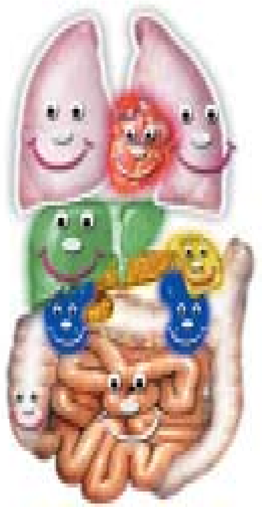

Fig. 1.1 *Red for the Heart*
White for the Lungs
Yellow for the Spleen
Blue for the Kidneys
Green for the Liver.

Each organ has its own vital color and when abundant it will radiate out as an aura for healing and protection. These organ colors and their associated universal connections have great healing power. The power of the 'Six Healing Sounds' will help enhance the connection to the cosmic source. Each sound will foster different healing energy. The practices also help balance, refine and transform the negative energy back to positive energy.

Iron Shirt Chi Kung and Bone Breathing

Iron Shirt Chi Kung and Bone Breathing are a system of standing meditations. These exercises help you to become grounded and to root your connection into the earth force, in order to build a good structure and absorb greater force. In turn, this will help draw in the heavenly force, which will combine with the very potent healing power of the earth's yellow light. The practice also strengthens the body so you can hold a higher energetic charge. These abilities are essential prerequisites for handling greater amounts of energy.

Iron Shirt Chi Kung also includes the art of ‘Changing the Sinews and Washing the Marrow’. Through these aspects of Iron Shirt, you learn to absorb, store and discharge large amounts of energy through the tendons and bones. *These practices are outlined in detail in the books “Iron Shirt Chi Kung” by Mantak Chia and “Bone Marrow Nei Kung” by Mantak Chia.*

To attain skill in Cosmic Chi Kung, it will help if you practice Iron Shirt, Bone Marrow and meditation as a minimum requirement. Beyond the basic level, the Universal Tao System includes many other intermediate and advanced level Chi Kung practices and meditations. The further one advances, the greater one's mastery of Chi.

Your increasing level of skill in the Universal Tao system will reflect immediately in your Cosmic Healing Chi Kung practice. Furthermore, you will discover that you can incorporate many of your Universal Tao practices directly into your practice of Cosmic Chi Kung. We will give you a simple combined practice of the Cosmic Healing Chi Kung, the Inner Smile, Microcosmic Orbit, Iron Shirt and the Sexual practices.

Stages of Mastering Chi

1. In the Universal Tao system, our *first* goal is to learn to conserve our Chi; when a battery is totally drained it is harder to charge; money makes money, Chi makes Chi. Conservation of Chi will help gain more Chi. To have more Chi we first need to maintain control of the gates through which energy normally leaks out and unwittingly drains our life force.

We leak energy: - through our reproductive system
- through negative emotions
- through constantly turning our senses outward

Without knowing how to conserve the Chi that we already have, what is the point of acquiring more?

2. We learn to balance our Chi; that is, we seek to keep a smooth and balanced flow of energy moving throughout the whole body. If our energy is imbalanced, we may have too much energy in some places and not enough in others; we may also be too yang or too yin. We may have excess or deficient heat, cold, damp or dryness. This imbalanced energy tends to make us go to extremes.

3. We learn to transform our Chi into more beneficial energies. For example, through the Taoist Sexual Chi Kung practices taught in the Universal Tao (the course known as Healing Love through the Tao), we can transform sexual energy back into basic life force Chi. Through other practices (such as the Inner Smile, the Six Healing Sounds, and Fusion of the Five Elements) we learn to transform negative emotional Chi into positive virtuous Chi. Thus Chi is not only the foundation of our health; it is also the basis of spiritual development in the Tao.

4. Once we have accomplished the three previous phases of mastering Chi, we then learn to increase it. Chi pervades all of heaven, earth and nature. In Cosmic Healing

Chi Kung we learn time tested ways to tap into these unlimited and transpersonal reservoirs of Chi and greatly expand the amount of energy available to us. It is very important to master first the stages of conservation, balance and transformation before we emphasize increasing our Chi. Otherwise we may waste the energy we bring in, or we may inadvertently amplify the imbalanced or negative energies that we have not yet learned to bring under control.

5. Finally, we learn to extend our mind to tap into the vast Chi of nature, cosmic and the universe, to heal our body, mind and spirit and to heal other people. Cosmic Healing Chi Kung practice sensitizes your hands to the feeling and movement of Chi; it uses the mind-eye power to absorb cosmic Chi into the palm and crown and to send it out through the hands and beyond, so that you can help restore balance in others without touching them or draining yourself.

This may sound fantastic at first, yet recent researchers in Chinese Chi Kung hospitals have not only measured the energies emitted by Chi Kung masters; they have also discovered that different varieties and frequencies of healing Chi can be emitted. This research has been corroborated by experiments in the United States at such places as the Menninger Institute.

Four Sections of Cosmic Healing

The next step is to learn the four sections of the Cosmic Healing Chi Kung, the ‘Empty Force’ sequence. Each of the four sections of Cosmic Healing Chi Kung develops a different type of energy mastery. Each section begins and ends in the same way, yet has different movements in the middle.

Connecting to Heaven and Earth

The first section of Cosmic Healing Chi Kung emphasizes connecting to the external Chi emanating from heaven and earth. This ability is very beneficial for self-healing and is essential for healing others. If you do not connect to some source of external energy when healing others, you will draw upon your own personal reservoirs. Our personal Chi is limited by nature, and can easily become depleted if we give it away too freely.

Over the past decade external Chi healing has become very popular in China. There are now hundreds of Chi Kung hospitals and clinics throughout the country. Yet many of the Chi Kung therapists can only administer two or three treatments a day; they spend the rest of their day practicing Chi Kung to replenish their own Chi. Those who practice the more traditional Chi Kung know how to connect to the Chi of heaven, earth and nature.

In this first section, you will learn to sense the energies outside your body. You will then learn to draw and absorb these energies into your body and process them in order to use them for self-healing and healing others.

Opening the Bridge and Regulator Channels and Extending your Chi Outwards

The second section opens and strengthens four of the Eight Extraordinary Channels: the Yin and Yang Bridge and Regulator Channels. This section also teaches the student to extend and take in the cosmic Chi and emit Chi out of the body for healing others. This ability is the heart of Cosmic Healing Chi Kung practice.

Opening and Energizing the Governor and Functional Channels

The third section enhances the energy in the points along the two channels used in the Microcosmic Orbit. Opening the Microcosmic Orbit strengthens and balances one's own energy, and prepares one to heal others. Practicing this section will be of great help with the Microcosmic Orbit Meditation.

Activating One Finger Art and the Chi Belt

The fourth section of Cosmic Healing Chi Kung activates the hands and you will practice emitting Chi from each of your fingers and opening the "Chi Belt." This channel is also known as the Belt Route or Girdle Vessel.

Chapter II

Preparing for Cosmic Chi Kung

Preparatory Practices

In the Universal Tao, we teach Cosmic Healing Chi Kung within an entire system of exercise and meditation. As a part of this system, Cosmic Healing Chi Kung comprises the art of healing oneself and others. It focuses on energy work for projecting Chi to effect these healings. One can easily learn the simple movements of Cosmic Healing Chi Kung without doing any other Universal Tao practices, but if one truly wishes to master the art of Cosmic Healing Chi Kung, it is important to have a firm foundation in the basic Universal Tao practices. Therefore in this chapter we will introduce you to the basic Universal Tao practices that are used in conjunction with Cosmic Chi Kung.

The preparatory practice consists of a few parts; work through each part at your own pace and eventually join them together as a whole.

Always start with "warming the stove" at the abdomen and direct the fire down to the sexual center to transform the sexual energy. Next practice the Cosmic Inner Smile. The Cosmic Inner Smile is a powerful relaxation and self-healing technique that uses the energy of love, happiness, kindness and gentleness as a language to communicate with the internal organs of the body. Each organ corresponds to a specific element and color. For example, the kidneys will consist of the element of water and the color blue. The heart will consist of the element of fire and the color red. This makes it very easy to guide the healing power into each organ by using the appropriate color. The practice also aids the transformation of negative emotions into positive virtuous energy. This transformation is a very powerful Chi Kung practice. A genuine smile transforms negative energy into loving energy that has the power to relax, balance and heal. By learning to smile inwardly to the organs and glands, your whole body will feel loved and appreciated and enjoy more Chi. After the Inner Smile, practice Bone Breathing, Marrow Washing, Cosmic Healing and the Microcosmic Orbit.

Warm Up the Stove

1. Sit on the edge of a chair with your hands clasped together and your eyes closed.
2. Start by doing the "bellows breathing", moving your abdomen in and out quickly. Emphasize the exhalation by breathing out forcefully 18 to 36 times. Rest, cover your navel and feel nice and warm.
3. Next, do the "inner laughing" exercise; you feel the abdomen vibrate inside you. Practice

this for a few minutes, allowing the movement of your inner laughter to grow stronger. Then rest and use the mind and eye power to gather the Chi (now felt as a warmth behind the navel) into the Tan Tien. Picture a stove with burning fire behind your navel. Feel nice and warm.

Transform the Sexual Energy

Once you feel the Tan Tien is warm enough, smile down and bring the warm Chi down to the sexual organs; women bring the Chi down to the uterus, men bring the Chi down to the testicles. It may feel like the ‘sun shining on the water’. The rays of the sun purify the water until it becomes rising steam. Keep smiling down to the sexual organs and feel the warm or fiery feeling from the navel area continue to flow down to the sexual organs; this transforms the sexual energy into Chi, and this Chi rises up the spine into the brain helping to activate the ‘crown’ and ‘mideyebrow’ energy centers.

Focus your awareness in the sacrum. At the very tip of the sacrum there is a hole in the coccyx. Breathe into this hole until you feel some activity there. This may be felt as tingling, numbness or pulsing. If you can really activate this point it will generate 'suction'. Be aware of the sacrum opening. Feel the suction force pulling through the hole in the tailbone (sacral hiatus); breathe into it until you feel it becomes activated. When the sacrum is activated you will feel the suction easily, as well as breathing in the cranium and mideyebrow. Keep on gently smiling and softly breathing into the Tan Tien and feel the suction in the abdomen. Focus 95 % of your awareness in the Tan Tien and 5 % in the sacrum, the crown and the mideyebrow. Be aware of the Tan Tien breathing and observe internally the pulsing and breathing in the sacrum, the mideyebrow and the crown. Do this 36 times.

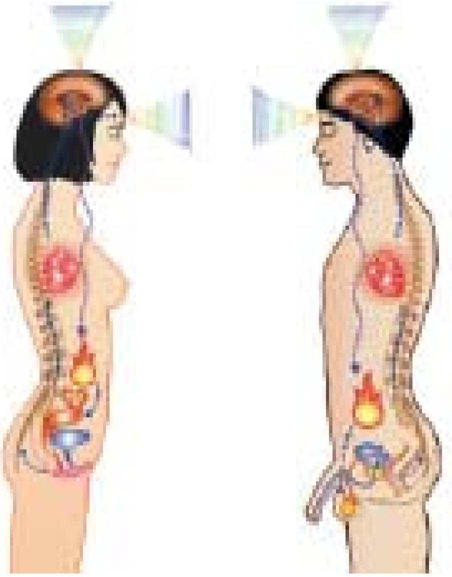

Fig. 2.1 *Smile down to the Lower Tan Tien.*

Filling the Joints with Chi

The bones have the ability to process Cosmic Chi (Chi above and around us) to be used by the body. The joints are also able to store Chi and they also serve as the cushion between the bones.

Be aware of your index fingers and thumbs; lightly raise the index fingers, feel a slight tension and open the thumbs to the sides and feel it magnify. Breathe into the finger tips, until you feel the sensation of Chi entering the fingers. The fingers will feel stiff as they stretch, to make way for the Chi entering the joints. Continue to breath in the Chi - the stiffness will spread to the other fingers, wrists, elbows and shoulder joints making the whole arm tense and stiff. The fingers and the arms become one piece. Eventually the Chi will fill every joint of the body making it into a complete unit.

Be aware of the big toes; breathe into the toes and feel the toes grow longer. When the Chi fills the joints the big toes become tense and stiff. Gradually it will fill the other toes rising to the ankles, knees, hips, sacrum and spine; the feeling may be one of tension and stiffness, numbness or like an electrical charge. The legs and the spine become one piece. You will certainly feel good.

Bone Breathing and Marrow Washing

Bone Breathing is one of the main practices of Cosmic Healing Chi Kung. This is a method of drawing external Chi through the skin into the bones to help replenish the bone marrow, thereby reactivating the production of white blood cells. Sending Chi into the bones will enhance functioning of the immune system. This process also helps to clean out fat in the bone marrow ("Washing the Marrow"), one of the main causes of osteoporosis (brittleness of the bones). Tension in the muscles close to the bones is decreased so Chi and blood can flow into the bones easily, enabling them to become stronger.

The Bone Breathing process uses the mind and the eyes to absorb Chi into the bones. The better your Bone Breathing is the better your Cosmic Healing Chi Kung practice will be. Mind and eyes are also used immediately after the exercise to gather the energy at the navel. Once you have it, when you move your hand, the energy will follow easily. You will be able to absorb external Chi effortlessly, so you will not need to use your own energy in your healing work.

Bone Breathing

There are several variations in the Bone Breathing and Marrow Washing process. Here we will introduce you to the first type of Bone Breathing, inhaling and exhaling Chi through the skin and packing it into the bones. In this method, you imagine that your bones are like hollow tubes, and that you breathe and suck the Chi into the bones.

Bone Breathing is practiced in a three-stage process. **Let your breathing follow a normal pace. Do not strain or hold your breath too long**.

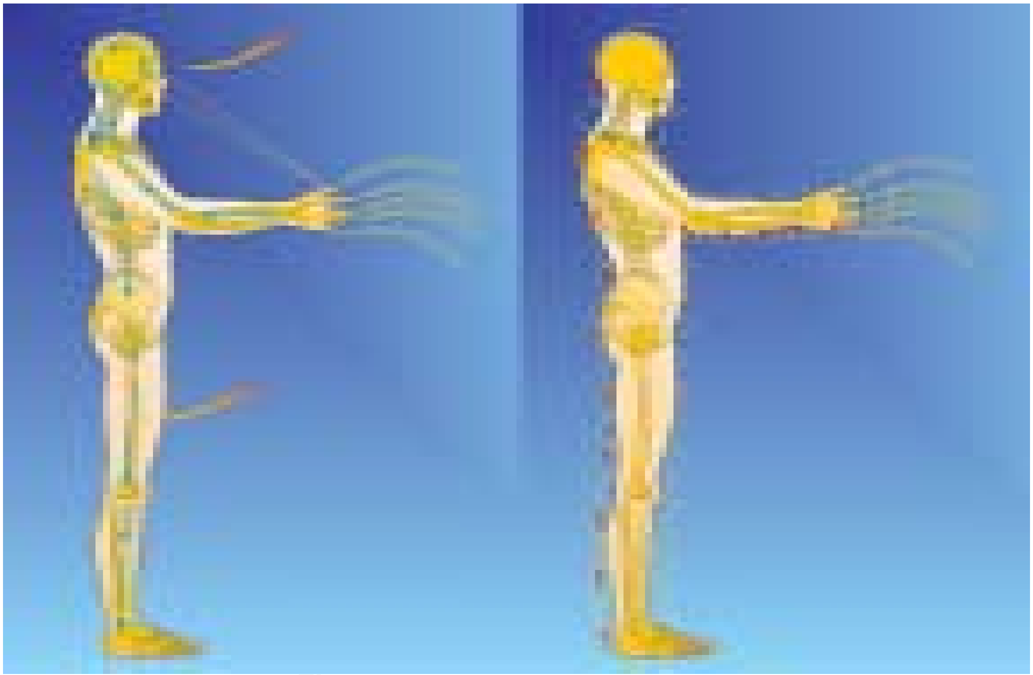

Fig. 2.2 *Bone Breathing through the Fingers*

1. You can do this practice in the sitting position or in the Embracing the Tree posture (or any other Iron Shirt Chi Kung posture). You will use your mind and eye power to breathe in a short breath and at the same time feel suction. Suck the Chi of the atmosphere into your hands, eventually expand to the universe and breathe in a few more times. Use a combination of 'mind/eyes/heart' power (Yi), to suck the Chi from the atmosphere into your hands, while taking small sips of breath. Once you can clearly feel the increase of Chi 'pressure' in your hands, you extend the feeling throughout your arms. The whole skin surface of the arms breathes in the Chi, feeling the skin holding this pressure.
2. Inhale one more deep breath and lightly contract the arm muscles to squeeze the Chi into the bones. Hold for a while to condense the Chi into the marrow of your bones. Exhale and at the same time feel a distinct heaviness in the bones, meaning that the Chi has been condensed and packed into the bones successfully. Eventually you will use more mental power (mind/eyes/heart power) and less muscle, using soft breathing, to draw the force into the bones. Do 6 to 9 times; rest and feel the Chi that has been condensed into the bones.

3. Proceed in the same way, breathing in progressively through the bones of the forearms, upper arms, scapulae, collarbone, sternum and ribs. You may feel a different sensation as you breathe in each area; in some areas the feeling is cool, in others warm or tingling, depending on the bone structure and the quality of the marrow.
4. Inhale and exhale in the same way through the toes, feet and legs; then, in a step-by-step progression, inhale up through the calf bones, thighbones, pelvis, coccyx and sacrum, and up the spinal column to the C-7 vertebrae.
5. Finally breathe in through the arms and legs simultaneously. Combine their energy as it flows up past C-7 and up through the neck and skull. Breathe in this way for at least nine breaths. Conclude by collecting energy at the navel.

Marrow Washing

You can wash your bone marrow with earth force, heavenly force or with cosmic force. This energy helps to cleanse and rejuvenate the bone marrow.

Heavenly Force Marrow Washing with Violet Light

1. Men place the left palm on the top of the head, and cover it with the right palm. Be aware of your ‘Personal Star’ (star that appears in your mind’s eye and is located above your crown), above. Slightly press the palms and spiral in the clockwise direction, spiralling from the front to the right ear, to the back and the left ear 9 times; rest and feel the increased Chi pressure in the crown. Do 3 sets.
2. Women place the right palm on the top of the head and cover it with the left palm. Be aware of your Personal Star above you. Press the palms lightly and spiral in a counterclockwise direction, spiralling from the front to the left ear, to the back and the right ear 9 times; rest and feel the increased Chi pressure in crown. Do 3 sets.
3. Face your palms towards Heaven and feel that you are scooping a galactic Chi ball from above. This Chi ball contains the North Star (Violet) and the Big Dipper (Red). See the dipper fill with violet/red energy. Imagine you reach out your arms to hold the dipper handle and pour the violet/red liquid over your crown. It will feel like there is a numbness descending. Your palms face down to your crown and pour the whole galaxy onto your crown. You may perceive this energy as violet amethyst and red light frequencies. Smile.

4. Guide this sensation down into your skull, deep into your brain, cervical vertebrae, sternum, thoracic vertebrae, lumbar vertebrae and down through your legs. Feel it penetrating and enlivening your bones, deep into the bone marrow, washing, cleansing, energizing. This ‘liquid-like’ Chi spills all the way down to your feet. Feel it connecting with the earth through the soles of your feet; be aware of the bubbling springs in the feet (the K1 points of the kidney meridian) breathing and pulsating.
5. Touch your navel with the fingers of both hands. Focus on the door of life, and let the fire activate in the Tan Tien and kidneys. Chi will rise up to the brain.

6. Move your hands down touching your femur bones; feel your hands penetrate into the bone and into the bone marrow. Feel like an electric shock or a tingling moving all the way down through the bones of the leg and down to the soles of your feet.
7. Slowly move your fingers down touching the bone and into bone marrow and extend yourself down past the earth to touch the galaxy on the other side. Raise your sacrum and picture yellow light coming up from the earth and the other side of the galaxy; focus on the Lower Tan Tien and feel it fill with Chi. Do this three times. Go back down to the squatting position.

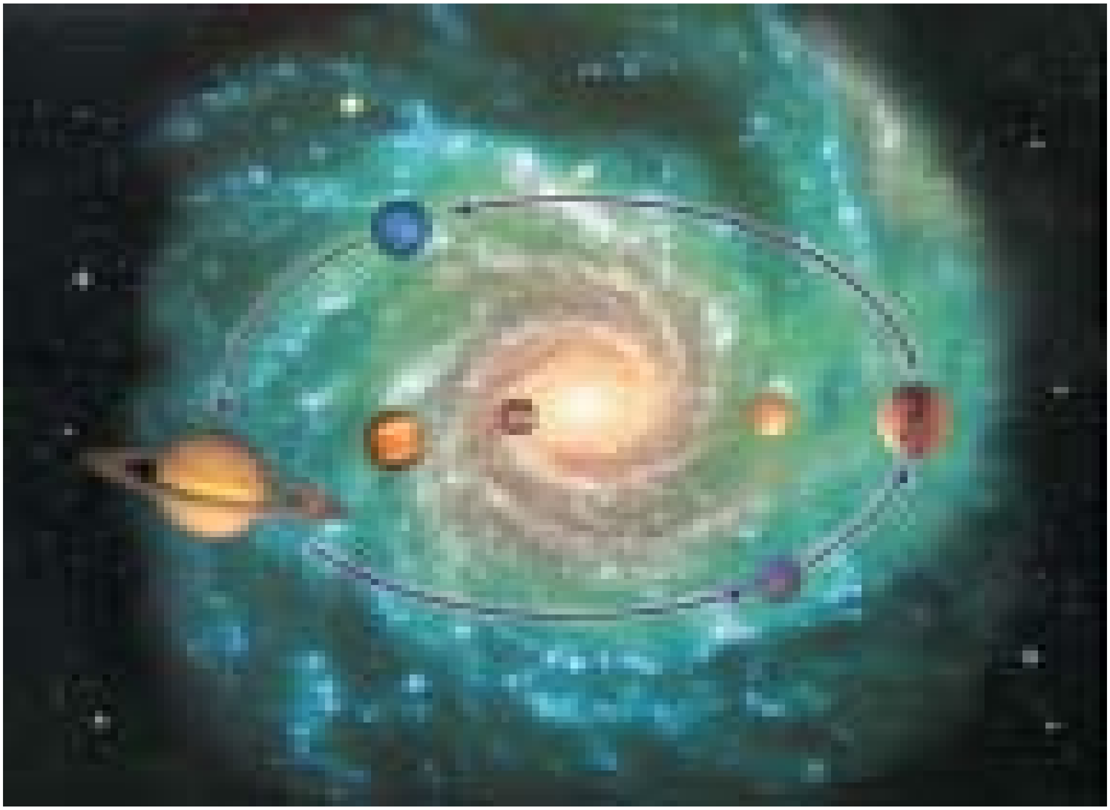

Fig. 2.4 *Galaxies Spiral Star and the Direction of Spiral*

8. Place the palms face down to the earth and be aware of the galaxy and the yellow light; make three to six circles to gather the Chi below. Gather the yellow Chi; touch your heels and feel the yellow Chi flowing up the leg bones. Feel the bubbling of your bones like an electric current running up through the feet, tibia and fibula, femur, pelvis, and spine. While touching your bone and bone marrow with your fingers, slide your hands up along the back of your legs; slowly come all the way up to touch the coccyx and the sacrum. Concentrate on your sexual center so the energy will flow and spread out to the sexual organs. Go back to the navel and gather the Chi into your Tan Tien.

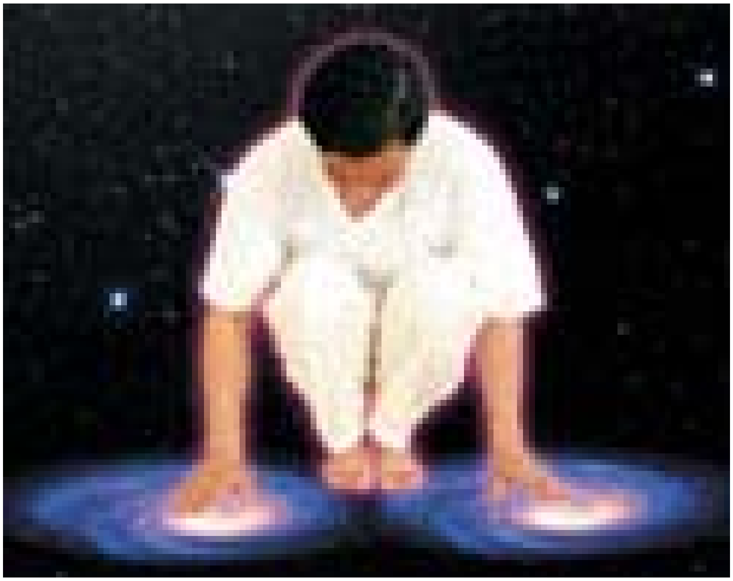

Fig. 2.5 *Hands circle to gather Earth Chi.*

Microcosmic Orbit

The Microcosmic Orbit Meditation awakens, circulates and directs Chi through the 'Governing Channel', which ascends from the base of the spine up to the head and the 'Functional' or 'Conception Channel', which runs from the tip of the tongue down the middle of the torso to the perineum. Dedicated practice of this ancient esoteric method eliminates stress and nervous tension, energizes the internal organs, restores health to damaged tissue and builds a strong sense of personal well being.

The Microcosmic Orbit is the foundation of Cosmic Healing Chi Kung practice. Each new practice is dependent upon the high quality of your meditations and your ability to perfect the Microcosmic Orbit. In order to master Cosmic Chi Kung, one must practice meditation daily. The meditations in the Microcosmic Orbit also strengthen the 'Original Chi' and teach you the basics of circulating Chi. They allow the palms, the soles of the feet, the mideyebrow point and the crown to open. These specific locations are the major points where energy can be absorbed, condensed and transformed into fresh new life force.

1. Focus on the Lower Tan Tien (the area where the Original Chi is stored, between the navel, kidneys and sexual organs). Feel the pulsing in this area, observe whether this area feels tense or relaxed, cool or warm, expansive or contracting. Notice any sensations of Chi: tingling, heat, expansiveness, pulsing, electric or magnetic sensations. Allow these to grow and expand. Then let this energy flow out to the Navel Center.

2. Use your intention (mind-eye-heart power) to spiral in the navel point guiding and moving the Chi. Let the energy flow down to the sexual center (Ovarian or Sperm Palace).

3. Move the energy from the sexual center to the perineum and down to the soles of the feet.

4. Draw the energy up from the soles to the perineum and to the sacrum.

5. Draw the energy up from the sacrum to the Door of Life (the point in the spine opposite the navel).

6. Draw the energy up to the mid-spine point (the T-11 vertebrae).

7. Draw the energy up to the base of the skull (Jade Pillow).

8. Draw the energy up to the crown.

9. Move the energy down from the crown to the mideyebrow point.

10. Touch the tip of your tongue to your upper palate, press and release a few times; then lightly touch the palate, sensing the electric or tingling feeling in the tip of the tongue. Move the energy down from the mideyebrow to where the tip of your tongue and palate meet.

11. Move the energy down from the palate through your tongue to the throat center.

12. Move the energy down from the throat to the heart center.

13. Bring the energy down from the heart to the solar plexus and feel a small sun shining out.

14. Bring the energy back down to the navel.

15. Continue to circulate your energy through this entire sequence of points, at least nine times. Once the pathways are open, you can let your energy flow continuously like a river of energy without needing to stop at each point.

16. Conclude when you wish by collecting energy at the navel.

Men: Cover your navel with both palms, left hand over right. Collect and mentally spiral the energy outward from the navel 36 times clockwise, and then inward 24 times counterclockwise.

Women: Cover your navel with both palms, right hand over left. Collect and mentally spiral the energy outward from the navel 36 times counterclockwise, and then inward 24 times clockwise. *For details of this practice see the book, "Awaken Healing Light", by Mantak Chia.*

Chapter III
Cosmic Chi Kung

Opening the Three Tan Tiens to the Six Directions

Introduction

Opening the Three Tan Tiens is a Chi Kung meditation that strengthens our connection to the universe, opening us up to the primordial force of the Cosmos and the energy within Nature. We are dynamically connected to the infinite. "As above, so below" is an echo of wisdom heard from sages and mystics throughout the ages. When we can connect to and absorb the energy that surrounds us, we are able to tap into the many splendors of the universe.

We exist because of the unique combination of the forces that are around and within us. The two main forces are electricity and magnetism. 'Bio-electro magnetism' is the western term for life force, and what the Tao refers to as Chi. For the last 5000 years, the Taoists have utilized this bio-electro-magnetic energy to enhance their way of life and establish a relationship with the universe. Bio signifies life, electro refers to the universal energies (yang) of the stars and planets and the magnetic force refers to the earth force (yin) or gravitational force present on all planets and stars. As we align ourselves with these forces, we become a conduit through which we can absorb and digest these energies through the body, mind and spirit establishing a direct connection with the universe. The Taoists recognized this connection and created the Chi Kung form of 'Opening the Three Tan Tiens to the Six Directions' to enhance our relationship to and our understanding of this connection.

Humans normally access bio-electro-magnetic energy through food and air. Plants take the universal energies of the sun and the magnetic energies of the earth and digest and transform them, thereby making these energies available to all living beings. Taoists believe that the food sources with the purest form of energy are the green leafy vegetables. These have taken sunlight directly into their cells. Rather than waiting until the energy in the universe is processed through plants, the Taoist goes directly to the source of this primordial energy. Through Chi Kung and meditation, the Taoists direct the energy of the universe precisely. Opening the Three Tan Tiens is a meditational Chi Kung exercise that focuses on how to directly tap into the source of energy all around us.

The Tao views human beings as lamps filled with fuel. Many people burn this fuel at very high intensity, without ever taking the time to replenish the oil in the lamp. Alcohol, drugs, tobacco and promiscuity all quicken the depletion of this fuel. The Taoist exercises strive to continually refuel the energy within. The Taoist recognizes that we are limited in our nature as human beings, unless we connect the sources of energy within the universe, thereby becoming infinite. So, within the limitations of our human nature, we constantly fill ourselves with the unlimited abundance of energy around us.

Through their internal quest, the Taoists discovered a doorway to the universe. The more we open our internal energy, the more we are capable of connecting to the forces of energy around us.

Human beings have amazing potential and capabilities. We are unique creatures in the way we use our minds and hands. Look at the world around you, the skyscrapers, the architecture, computers, technology and the myriad creations of man. All have come about through the combination of the mind with the hands. In the Tao practice, we use the mind and the hands, in both Chi Kung and meditation, to connect to the forces of the universe. We use the mind to project a pattern of energy into the universe, to connect to the force, and to bring this energy back into the body.

The mind can travel millions of light years in a few moments. Taoists discovered the unlimited potential of the human mind. If you picture something in your mind; an ocean, a sunset or a mountain, you automatically connect with that image. The mind can take you anywhere you imagine. With the proper training you can connect to the energy of nature and the universe and project your Chi to combine with it, drawing these forces into the body. The hands are called the touching force, and like antennae they can transmit the frequencies and vibrations from space. With the mind and the hands, each of us can journey into the boundless energy of the universe.

Relaxation, Letting Go, Surrender and Ego

In some religions and spiritual paths, there is a great emphasis on surrender and letting go. This is actually a form of relaxation. Taoist practices emphasize relaxation, letting go, and emptiness. When a person is relaxed, the muscles are open, the breathing is soft, and the energy can flow through the channels of the body. There is no resistance and no fighting. This allows the creative and higher forces to flow into us.

Most religions have a similar process. To contact the higher self and the higher forces, one needs to let go and surrender in order to reach the level where one can be in contact and become one with the higher forces. Through the surrender of control, one opens up and touches the forces of nature. However, if you continue to surrender and let go, you will lose the energy you have sent out. In the long term, this will gradually drain you. The force will suck the energy out of you, rather than help you to bring the energy into yourself. To avoid this, at the moment that one is in touch with the higher forces, one again becomes aware of oneself and his or her own energy. One is then able to project his or her own thoughts, intentions and patterns into the force, integrating the outer with the doubling or tripling inner energies. You can bring this force back to your place, your house and into yourself.

One must remain open and empty while using one's intentions, mind and Chi to draw the energy into oneself. What might initially appear to be a paradox is reformed as one does the practice and learns how to be empty and open and to simultaneously retain enough consciousness to draw the force into oneself.

Mind, Organs and Sexual Organs

It seems that some people are disconnected from themselves and from their sexual organs. The mind and organs are therefore separate. Taoism believes that the mind, body and spirit must work together. The results depend on a person's practice.

Brain

The brain can access and generate the higher forces, but storing this energy in the brain itself is not easy. We need to train the brain to increase its ability and capacity to store energy. The brain energy, when increased to a certain level, can enable more synapses to grow, and can help turn protein into brain cells. The Tao believes that with training and practice, one can learn to grow more brain and nerve cells, as well as increase the number of synapses in the central nervous system.

Organs of the Body

The organs can also generate energy, but much less than the sexual organs and the brain. They also have a much greater capacity to store and transform energy.

Sexual Organs

The Tao discovered that the sexual organs are the only organs that can generate a significant amount of sexual energy (life force). However, the sexual organs cannot store the energy efficiently. When too much energy is generated, considerable amounts have to be dumped out. And this is the best energy that one has. It is the ‘creative’ energy.

Three Tan Tiens

The Three Tan Tiens can also store energy, transform it and supply it to the brain, spinal cord, sexual organs and other organs.

The aim of Taoist basic training is to integrate the brain, sexual organs and other organs into one system. If the brain generates too much energy, it can store the energy in the organs. The excess sexual energy can also be stored in the organs and the three Tan Tiens. If the brain generates too much of the higher forces and we are unable to store this energy, we have to throw it away. It is like preparing food for one hundred people, when only one person is eating. The rest gets thrown away. In the same way, when too much sexual energy is produced and there is no place to store it, it is wasted. We do not have enough of this energy to be able to waste it. We have a limited amount of energy and of time.

Some practices just deal with the spirit and ignore the body and the sexual energy. These practices can generate a lot of energy, but when one is not connected to the organs, it cannot be stored anywhere. One will end up draining oneself. Some people practice sitting quietly, emptying the mind, with the whole body relaxed and calm, but very little energy is actually generated. When one gets deep into the practice, some people find it hard to come back to society, because they have no energy and their mind power does not work well. These people have to depend on others to support them.

In the Universal Tao, we are learning to create a sacred and holy temple within ourselves. With the simple practice of smiling to all the organs, we can integrate our bodies, minds and spirits. They are no longer separate. The sexual practice connects the mind with the sexual organs and the brain. The separation between these parts of ourselves is bridged and a synergy is created.

The Taoist practice provides us with the resources to extend beyond the realm of our senses. By tapping into our internal resources and channeling the energy around us, we can perceive much more than the senses normally report to the mind. We want to extend our perception from the limited perspective of the sociologically conditioned senses to the unlimited awareness of the universe. For example, our senses tell us that the earth is flat, that we are stationary, and that heaven is above us. In reality, the earth is a sphere hurtling through space at thousands of miles per hour and the heavens are above, below and beyond the earth in every direction. The goal of the Three Tan Tiens is to connect with the forces from the six directions - above, below, left, right, front and back - and draw all these forces into the body. Eventually, with practice one can draw upon many different energies and use them as needed, thereby giving form to the formless energy that is abundant in nature.

Opening the Three Tan Tiens

Opening the Three Tan Tiens to the Six Directions is just another one of the many resources the Taoist practitioner uses to connect with the universe. The practice combines the power of the mind with the extension of Chi. This combination allows our personal consciousness to directly connect to the patterns and matrices of energy in the universe. When we put our thoughts into the web of the universe, we transform the electromagnetic energy into a force that is accessible to us. The combination of mind power and energy is what allows us to establish a relationship to these creative forces and the high sources of energy.

Three Tan Tiens

Once we make the connection with the forces of energy in the universe, we then want to be able to store this energy in the body. Energy is like money, if you are making a million dollars a year and spend a million dollars, you have nothing left to use in the future. That is the way we live and use our energy in our society. We are spending more energy than we are saving and we are living on borrowed energy, paying very high interest. Our credit will run out very soon.

In the Tao practice, we store energy in the Three Tan Tiens. The Three Tan Tiens are the reservoirs of energy within us.

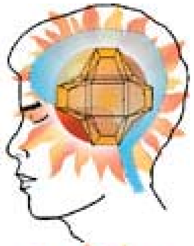

Fig. 3.1 *The* ***Upper Tan Tien*** *is in the brain (the* ***Crystal Room****, third ventricle), and when it is full of energy, the capacity of the brain increases. We store our spiritual intelligence, the mind here. All the Tan Tiens have both yin and yang within them. In nature, the yin and yang are present in all things. Day (yang) turns into the sunset, which turns to night (yin). It is very important to feel the qualities of yin within yang and yang with yin (sunrise/sunset). One quality does not exist without the other. They are inseparable qualities of the same force.*

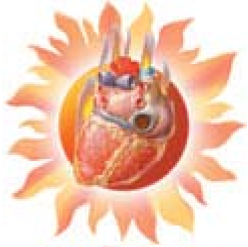

Fig. 3.2 *The* ***Heart*** *Center Tan Tien, between the two nipples, is the* ***Middle Tan Tien****. It is associated with the fire element. Yet, within fire there is always water. The original spirit (Shen) is stored here.*

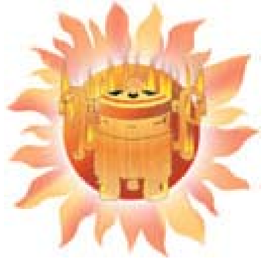

Fig. 3.3 *The lower abdomen at the* ***Navel*** *is like an empty universe, or ocean. We want to feel a universe of energy in the* ***Lower Tan Tien****. Within this universe or ocean, there is a fire, like a volcano under the ocean; 'fire under water'.*

The Three Tan Tiens refer to the three reservoirs of energy within the body. These reservoirs are places where we can store, transform and collect energy. The reservoirs are the source of energy that flows through the body. The meridians are rivers of energy fed by these reservoirs. The goal of Opening the Three Tan Tiens is to continually fill and replenish the energy of the Three Tan Tiens. When we are connected to the Tao, life ceases to be a struggle. Through the observation of nature, the Taoists learned to flow with the stream of energy and connect to forces in the universe.

In these practices, we use a variety of hand movements and body postures to open to the energy around us. We draw the energy from the six directions into the body, activate the three fires, open the Three Tan Tiens and circulate this energy in the Microcosmic Orbit.

Combined Practice

Warm - Up Exercises

Rotating the Sacrum

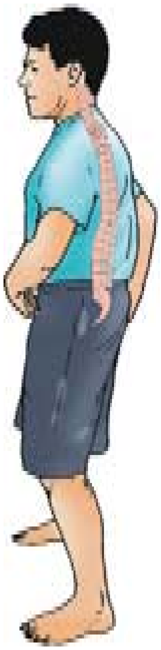

Rotating the sacrum is an excellent exercise to open the lower back and activate the spinal cord. Place one hand over the sacrum and the other over the pubic bone. Rotate the sacrum in a circle, 36 times in each direction. This movement activates the sacral pump.

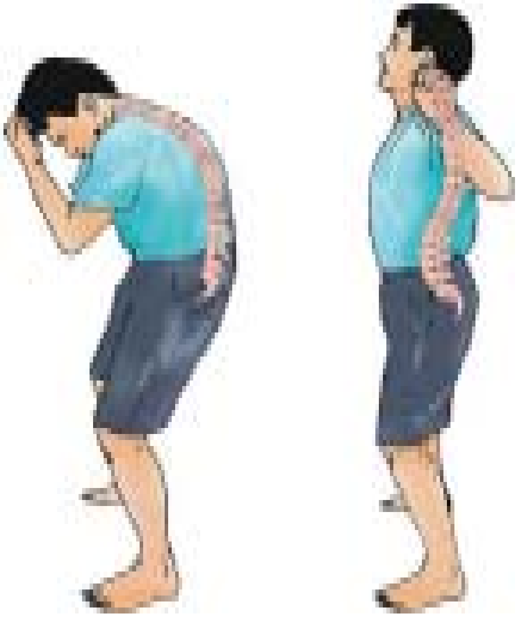

Spinal Cord Breathing

Inhale and expand the chest, arms bent at the elbows and extended to the sides of the body. Exhale, tuck the tailbone under you and round the back, bringing the elbows toward one another in front of the chest. Smile. Inhale, expand the chest, tuck the chin in toward the throat, push the chin back and raise the crown and bring the arms out to the sides. Repeat this back and forth movement 36 times. This movement activates the cranial and sacral pumps, and loosens all the joints in the spine.

Shaking

Shake the whole body loose, especially the joints, by bouncing up and down on the heels. Let all the joints open and relax. Also, shake the testicles and the breasts loose. This will open the sexual energy (the yin electric) and you do this on back as well.

The yin and yang are the negative and positive electric forces in the universe. The heart produces impulses (the yang electric) and the adrenal glands produce the adrenal hormone to stimulate the heart to beat. Of all the hormones inside us, this is the one that gives the vital force to our life.

When we concentrate on the sexual organs, the heart and the mind, we can make the yin and the yang electricity combine.

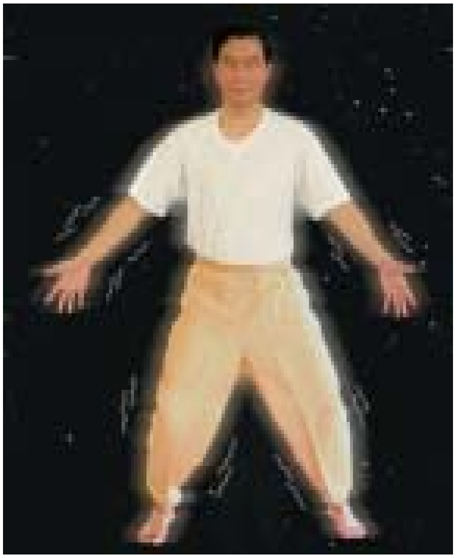

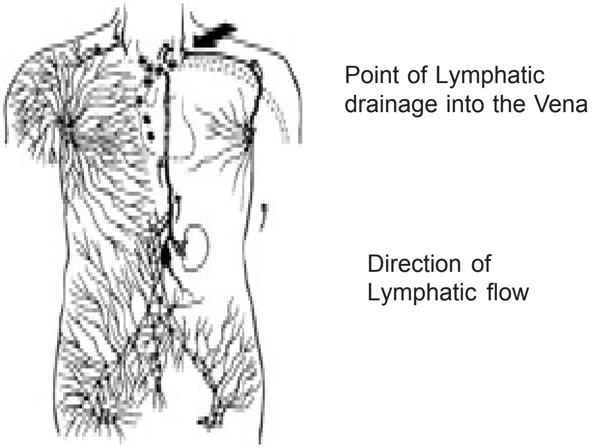

Point of Lymphatic drainage into the Vena
Direction of Lymphatic flow

Fig. 3.4 *Whole Body shaking and Lymphatic System*

True Breath - Skin Breathing

We exist because of the physical food and the unique combination of forces that surround us. The daily requirement of calories is about 6,000 units, while we only get 2,000 calories from food. The other 4,000 calories come from the forces around, above and below us. These forces that surround us are electricity, magnetism, cosmic particle energy, light, sound and heat. If we don't know how to absorb and transform this cosmic food, we need to depend on others to supply us. We then need to ask a priest, monk or holy person to give us our daily spiritual food.

The Taoists discovered that we can learn to absorb these surrounding and universal energies through the skin and the major energy centers. Absorbing energy through the skin is called the True Breath. This powerful energetic technique requires the Inner Smile and relaxation. The more one can relax, the more the body and the skin can open to the energy around us. The practice allows one to extend the mind, to touch the force and to draw that energy back into the body.

Daily Practice: Opening, Connecting and Activating Chi Within and Cosmic Charging

Paradoxically, in order to project ourselves out into the immensity of the galaxies and the universe to gather limitless resources of Cosmic Chi for healing, we must take the first steps of the journey within ourselves. In order to ‘go out’, we must first ‘go in’. The vehicle for this magical journey is powered by our ability to relax in mind and body. As we physically relax and let go of muscular and emotional tensions and joint and bone structures we gain access to the inner realms by turning on our very special subtle smile. It opens the pathways of the parasympathetic nervous system. This helps us to reduce the out flowing habits of our senses so that we can be more alert in sensing our inner universe.

This simple process of ‘going in’ enables us to develop our internal skills so as to safely ‘go out’ to the universe.

Practice

Relax and Let go - Smile to Connect with the Universe Within

Smile to mideyebrow, eyebrows, eyes, mouth, jaw, tongue, lips, cheeks, ears, shoulders, ribcage and brain. Let the relaxed sensations and the ‘Observer Mind’ (Upper Brain) sink down into the Lower Tan Tien.

1. Smile to the mideyebrow. Relax and let go. Smile to the eyebrows and let them grow long to the sides. Lower these relaxed sensations down to the Tan Tien.

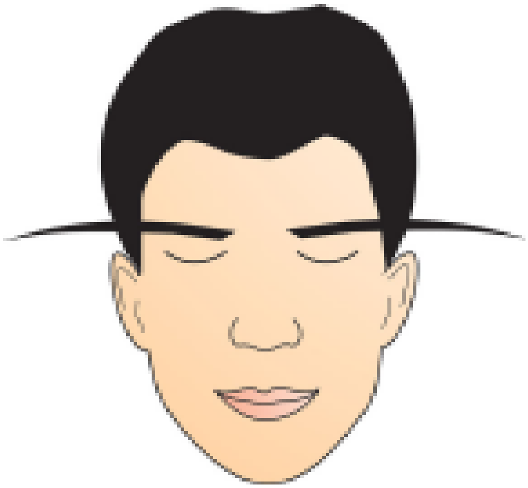

Fig. 3.5 *Smile and Relax to the Mideyebrow and think of the eyebrows growing long.*

2. Smile to the eyes: relax the eyes and feel how nice and cool they are. Let the eyes draw back in their sockets and start to sink down to the chest and gradually down to the abdomen, the home of your ‘feeling and awareness mind’.

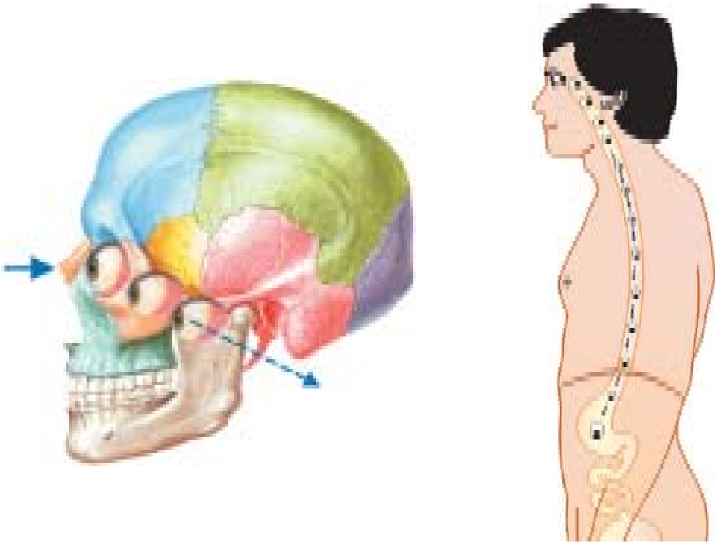

Fig. 3.6 *Smile and relax the eyes, sink into the eye sockets and gradually feel the eyes dropping down into the Abdomen.*

3. Relax the two broad muscles extending from the outer portions of the upper lips across the cheekbones, and lightly smile feeling their connection to the upper front of the ears. Gradually feel the ears growing ‘long’, up and down. Feel the ears grow all the way down and connect to the kidneys.

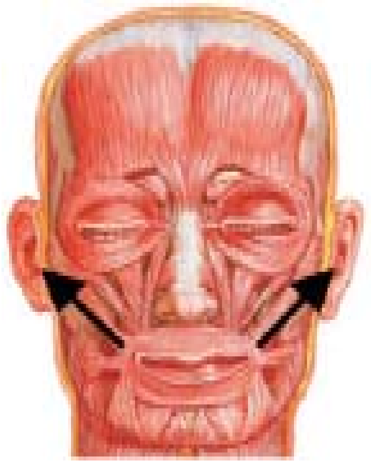

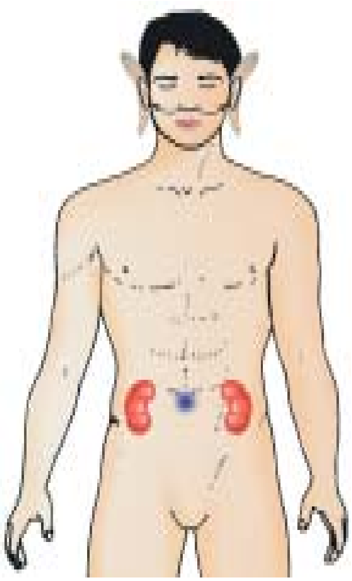

Fig. 3.7 *Smile to the Ears and listen to the Kidneys.*

4. Open your mouth and relax your jaw, separating the upper and lower teeth. Feel the jaw relax. Once the jaw relaxes the shoulders will relax and drop down. Continue to feel the jaw relax until you feel the saliva start to come out. Relax down to the rib cage. Feel the rib cage drop down, softening all the joints, relaxing down to the Lower Tan Tien. Let the tongue relax back in the mouth. Feel the tongue start to drop down into the throat to the chest and all the way down to the navel sinking the 'floating' sensation down to the Lower Tan Tien.
5. Smile to the shoulders and relax until you feel the shoulders drop and the rib cage relax.

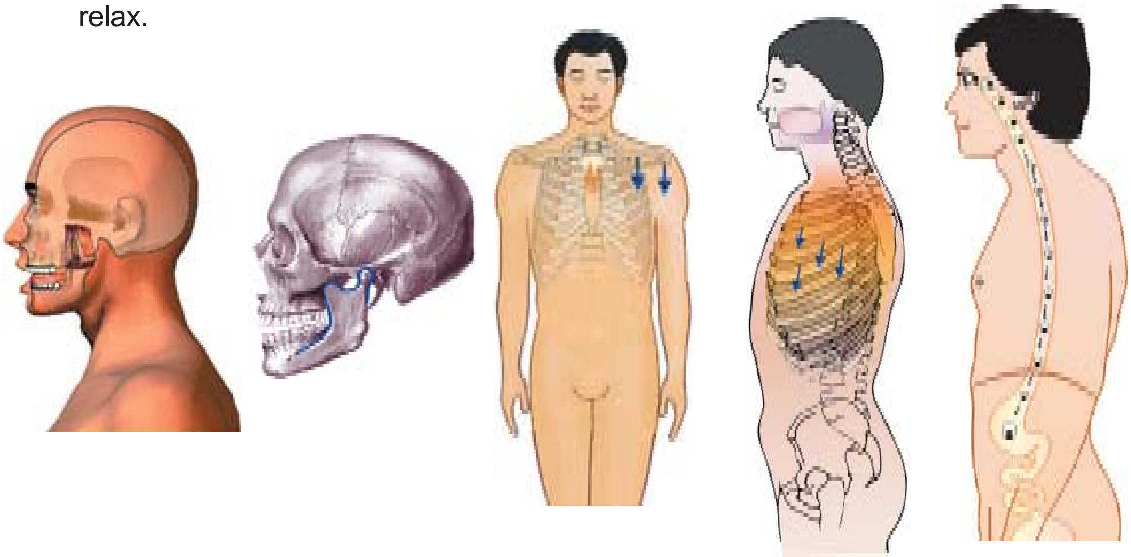

Fig. 3.8 *Relax the Jaw; and the Shoulders and Tongue will relax down to Lower Tan Tien.*

6. Lightly close the lips, but keep the teeth slightly separated. Physically begin a child-like smile with the corners of the mouth gently uplifted and the outer edges of the eyes softly crinkled up. Breathe through your nose.
7. Smile into the brain and empty the upper (observing) mind down to the Tan Tien.
8. Become aware of your inner universe as a big empty space. Keep on sinking – sinking down, into the darkness of your empty space. Keep sinking and experience the vastness until you get closer and closer to the center, the 'original force.' Stay relaxed and alert so as to be able to see one dot of light. It becomes a galaxy spiraling inside you.

   Do the above practice several times until you become familiar and comfortable with it.

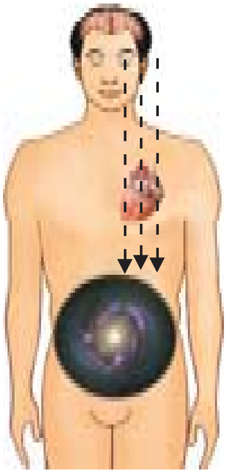

Fig. 3.9 *Bring the Senses down to the Tan Tien.*

Tan Tien Consciousness: Second Brain

Already terms have been used like ‘upper mind’, ‘feeling and awareness mind’ in the abdomen and lower ‘Tan Tien’. In the next phase of practice, the ‘conscious mind of the heart’ is introduced. For those readers who have not been updated on the scientific and medical revelations of the recent era about a ‘second’ and ‘third’ brain, we offer the following information.

Along with this, there is the long-standing Taoist practice of cultivating and training consciousness in the Three Tan Tiens, especially the Lower Tan Tien. There is my own experience in participating in brain wave measurements and ‘brain energy potential’ research in recent years. The combination of all these areas of knowledge and experience in our time, makes Cosmic Healing practices accessible for our minds while also being very ‘down to earth.’ Now let’s talk about the Lower Tan Tien.

In addition to its importance as the control center for the mechanics of the physical structure of the body, the Lower Tan Tien also houses a treasure of even more far-reaching significance. It has been a well-kept secret in the western world, as well as in most of the rest of the world: our Second Brain. Most of us who have had Taoist training in Chi Kung, Tai Chi, various Chi meditations or healing practices have often heard the reminder, ‘Be aware of your Tan Tien.’ But, do most people really ‘get’ the meaning of the injunction to always be conscious of the Tan Tien? Probably not. Further, do we use our Second Brain as much as we can? Definitely not.

In western terms, do we actually understand “Be aware of your Tan Tien” as being a way to train consciousness and awareness, like educating a brain in the abdominal area, in our Tan Tien? Probably not. Throughout the world, there are institutions to train the brain in the head. That is good. But, what about training the ‘second brain’ in the abdominal area? I didn’t think of it exactly like that in western terms, either, even though that is exactly what I have been doing all of my life in my Taoist training and teaching.

Personal Revelation

Suddenly I came to understand a few things which are so simple and so important, and that’s what I am going to share with you. It started in 1994 in Los Angeles when a clinical psychologist there, Dr. Rhonda Jessum, wanted to start testing me. I agreed to do the testing, but the machines at that time didn’t tell me much. However, it was discovered that when I did the Inner Smile meditation, my brain waves went down dramatically – but at the same time, my ‘beta’ waves increased to a very high level. That means the waves showed that I could be driving a car, but that my brain should have been resting and sleeping. So the researchers said, “Hey, how did you do that?” I didn’t understand either – because it was not clear to me either.

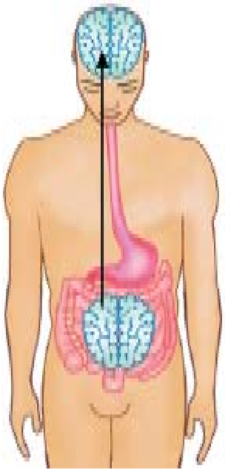

Fig. 3.10 *First and Second Brains are linked.*

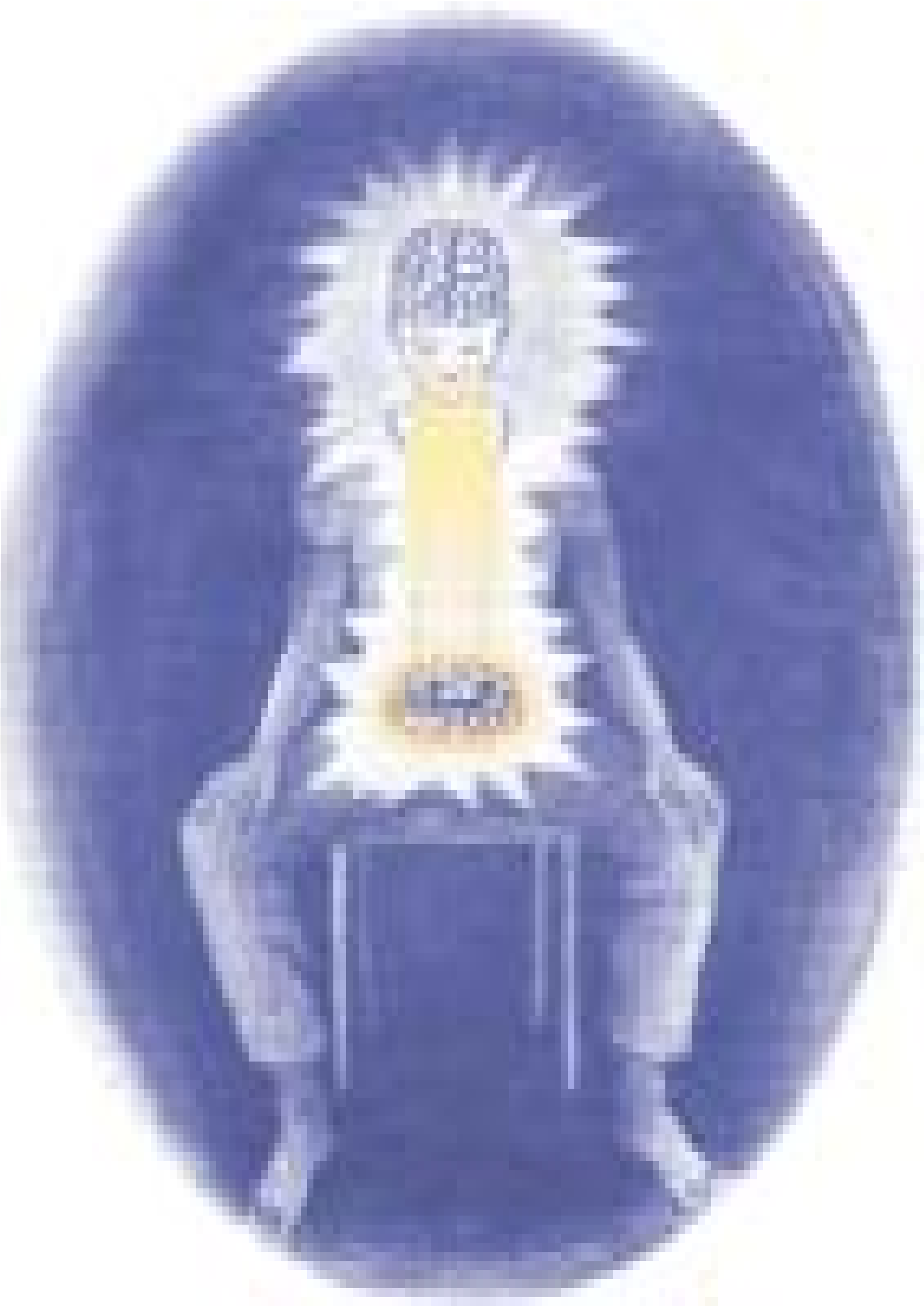

Fig. 3.11 *Second Brain*

After that, I was invited to start testing in Europe by the Institute for Applied Biocybernetics and Feedback Research. My name is becoming known there because I teach in Europe a lot. One of the biggest institutes for training top athletes in Europe is in Vienna. They developed an instrument that can measure the brain's potential energy, which represents all the energy in the body. The doctors also said that this proves to the west that Chi exists, there is energy and a life force running in the body. That instrument picks it up in the brain and indicates how much potential brain energy you have. It also determines how much energy you have for the whole day and how much of that energy is for mental clarity and body power. They use these instruments to measure the athletes.

The study measures brainwave frequencies during four practices.

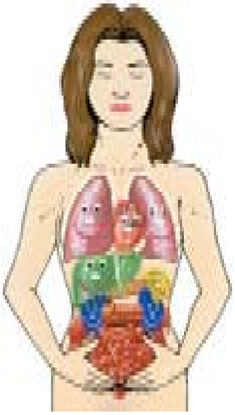

Fig. 3.12
Cosmic Inner Smile

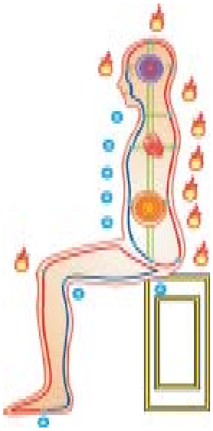

Fig. 3.13
Cosmic Orbit

Fig. 3.14
Six Healing Sounds

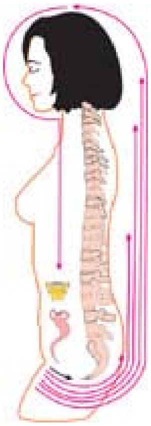

Fig 3.15
Orgasmic Upward Draw

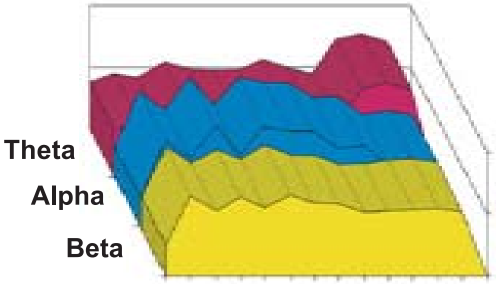

Fig. 3.16 *Alpha and Theta Waves increasing during the Cosmic Inner Smile Meditation.*

Fig. 3.17 *Ultraslow Brain potentials measurement while in Vienna.*

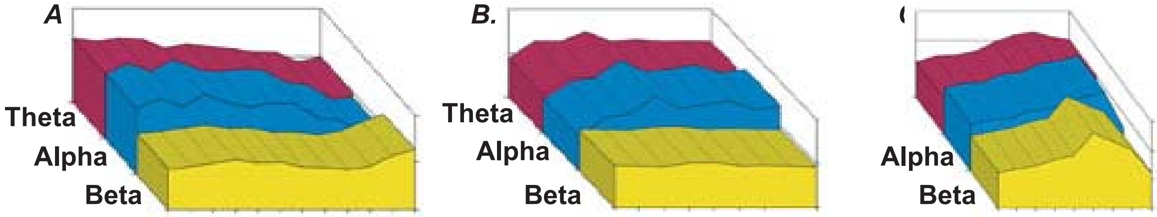

***Fig. 3.18 A.** Altering dominance of alpha and theta waves during the Cosmic Orbit Meditation.*
***B.** Cosmic Healing Sounds Meditation, results in increases in alpha and theta frequencies. There are minimal beta brainwaves; the brain reaches a state of stillness and internal focus.*
***C.** Orgasmic Upward Draw Meditation increases the levels of alpha and theta.*

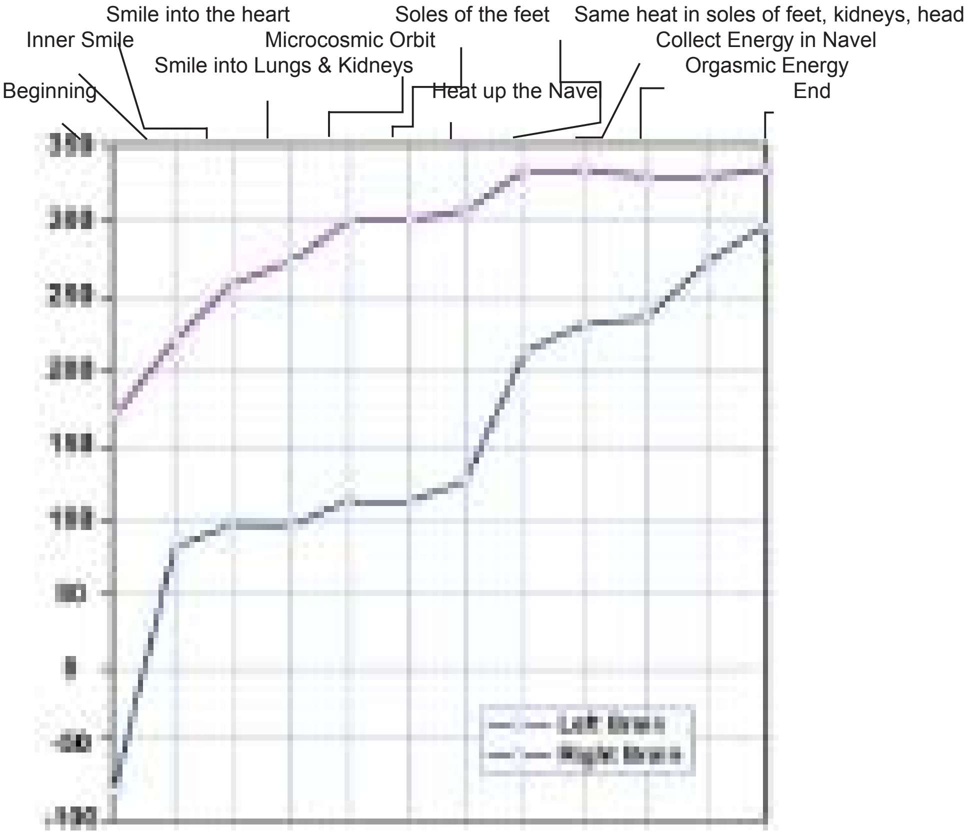

***Fig. 3.19** Left and Right Brain Charts*

It's interesting because the energy I have been describing in my teaching is exactly what they were measuring during their testing. So I went there and did the measurements with them. I just did the Inner Smile, smiling into my abdomen. They picked up these readings very quickly and said, "Your brain waves are going lower, lower and resting – and you are nearly in the sleeping state." At the same time, the muscle tension was very low, the heartbeat was very low and the skin resistance was very low. After that, I surged the energy up to the brain and they started to see that the energy actually charged up there. When we are thinking, worrying or feeling anger, shame or guilt – the energy level in the brain actually decreases, and the brain doesn't get charged up. They were quite amazed, and said, "Hey, this is what we're looking for!"

They asked me what I was doing. I said, "I'm smiling to my abdomen." They kept on talking to me and asking me questions. They discovered that this brain (in the head) was not very active at all, meaning that there was not much activity in the brain. It was still in a very light resting state. But, how could I answer their questions? They said, "Hey, look! Master Chia is talking to us in his sleep. How can he talk to us in his sleep?"

After that, I said, "Oh, I understand now." Because, throughout the whole practice of the Tao is the injunction, 'train the second brain in order to use the second brain.' It took the westerners a long time to understand that. So, when the article about the 'Hidden Brain in the Gut' came out in The New York Times,[1] I started to understand that. You can be miserable; you can be happy; you can feel all kinds of feelings. But according to this article, they had also discovered that this brain in the gut, the enteric nervous system, can do a lot of functions. It says that this gut brain can send and receive impulses; it can record experience and respond to emotions. So, it is like a brain. In this article, they had only discovered that the large intestine and the small intestines have the same neurons as the brain cells. After that article, a new book, *The Second Brain,* was published.[2]

Now in medical science, I might add, they have begun to discover consciousness in the heart. They found that the heart can record a whole event, and it has its own brain. Dr. Paul Pearsall has written a new book, called *The Heart's Code*.[3] They have found that people who have a heart transplant actually get the emotions of the donor. They actually experience whatever the donor experienced. One of the cases is that of a girl who was brutally killed, and they didn't know who killed her. But, the heart was OK; so, it was transplanted into another girl. After that, the girl started to get nightmares and described somebody killing her. Then she described how the killer looked. Finally, the mother took the girl to a psychiatrist, and he in turn contacted the police. The girl gave the police an exact description and a police artist drew a likeness of the killer. With the information provided by the girl, the police were able to go and arrest the man. Afterwards, when confronted with clear details of the crime, the man confessed that he was indeed guilty of this crime. So, from that experience, medical scientists and others came to realize that the heart can record all of an event and remember it.

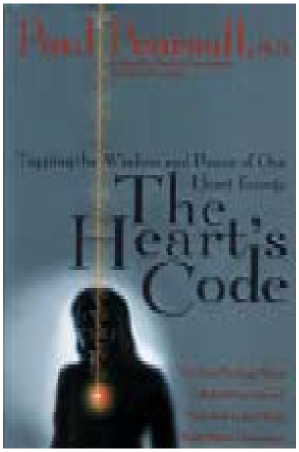

Fig. 3.20 *Heart's Code*

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[1] "Complex and Hidden Brain in the Gut Makes Stomachaches and Butterflies," The New York Times, section C1, Tuesday, January 23, 1996

[2] Gershon, Michael. *The Second Brain* (New York: Harper Collins Publishers Inc., 1998).

[3] Pearsall, Paul, Ph.D. *The Heart's Code* (New York: Broadway Books, 1998)

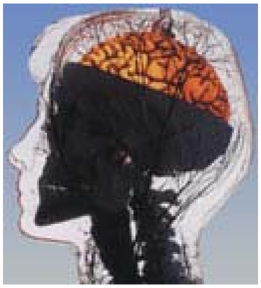

The Lower Brain consumes less energy and can do a lot of daily work, like send and receive impulse records and experience and respond to emotions. When you lower down the Upper Mind, it will also lower the blood pressure and anxiety.

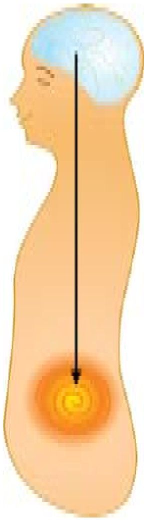

Fig. 3.21 *Abdomen has it own Brain: the Awareness Mind.*

On the second page of the Times' article, it says that even the large intestine is loaded with neurons. The question was posed, 'Can it learn?' But I say, "Hey, this goes back to 4,700 years of the Tao practice, which says: Train all the organs; train them how to do different things." You can rest the head brain when you're not using it – and use the brain in the gut. Why is it so important? Because the head brain is a 'monkey mind' riddled with doubt, shame, guilt and a suspicious mind. It is always thinking. Worrying, figuring things out things, head trips – it just keeps on, all the time. To be a God, you must let go of the past and empty the mind. Now we are in the information age; anything flits in – we think. Just one word flits in and we start an entire string of thought. When somebody says one bad word to you, you can think and figure it out for three days and three nights. 'How am I going to get revenge?
How am I going to get revenge?'

Scientists have discovered that when people worry too much, thinking, planning, etc., this brain actually uses up a lot of energy. Depending on the type of person– some people are very physical types who use very little brain energy, but their physical body consumes a lot of energy. However, most people think and think and think. So the scientists give an approximation, by way of a percentage. This is just a number for comparison, not an exact number. They say that this brain in the head can use up to 80% of the body's energy. So, what happens is you have only 20% left for the organs.

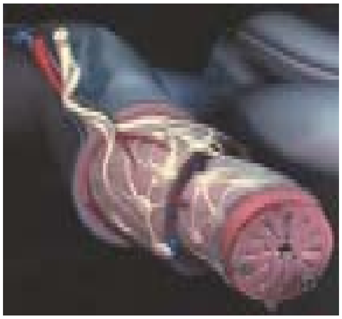

Fig. 3.22 *Cross-section of the neurons in the Large Intestine.*

According to the information about the brain in the gut, they have discovered that the brain in the head and the brain in the gut can do some similar jobs. For example, this brain in the gut is the emotional and the feeling brain. In the west you have the expressions, ‘I feel you from my gut’ and ‘I have a gut feeling about something.’ Why do people mention a gut feeling? Obviously people have some feeling in their gut. It’s very interesting that the whole Tao practice is feeling, awareness and consciousness – using this gut to feel, to be aware, and to be conscious.

You can rest, relax the brain in the head by using the ‘brain in the gut.’ This is the first step. The first thing we learn in the Tao is to forgive and let go. When we keep on remembering past negative emotions, we will stop seeing the truth. To let go of the past is to empty the mind and use the abdominal mind, the awareness and consciousness. Here’s an interesting point in the way of the Tao: This gut brain can do a lot of simple functions that are similar to the functions of the brain in the head. This is a feeling and awareness type of functioning similar to many of our ‘right brain’ functions. However, we need to use the brain in the head in order to perform complex functions such as reasoning, making plans and making complex calculations. For rational functions, we need to use the brain in the head for the ‘left brain’ functions.

For our daily life of consciousness, awareness and feeling, we can use either the brain in the gut or the brain in the head. When we use the upper brain less, it will become charged with more energy and its power will be increased – and more power will be available to the body. That is why we say in Taoism, that we have to train the brain in the gut, so that we can use it when the brain in the head is resting. When the head brain is resting, it can be recharged: brain repair and maintenance occurs. Also, it can grow new brain cells. With more charging we have more power for creativity or whatever we want to use it for. If we like, we can use it to develop our higher spiritual nature.

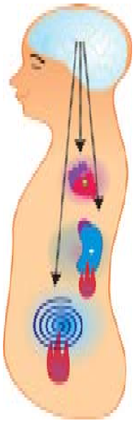

Fig. 3.23 *When you are not using the Upper Brain allow it to rest by sending it down to the Lower Tan Tien.*

The simple thing is, that for the same job that the head brain or the gut brain can do, the head brain charges you eighty dollars. The gut brain only charges you twenty dollars. So, which one do you want to use? No, of course we are not that silly to use this overpriced person for the same work. But when we come to our own actual life, we don’t know how to do it. We always use this mind, this high-priced brain. To add to this, we continue using it and using it, until the brain energy is completely consumed – no more energy. When you get to a certain level the brain is empty. These brain energy measurements are not only for indicating mental energy levels, they also represent energy conditions for the whole body and spiritual energy.

Whenever I smile down, the brain waves go lower and lower very quickly – and the transformed energy from the Tan Tien and organs charges up the brain in the head! Just by flexing the facial muscles into the mode we use with a genuine smile, we can produce the effects on the nervous system that normally goes with the natural spontaneous feeling. We can actually make ourselves relaxed and happy by taking advantage of this built-in human mechanism. It's natural. Just do it! Learning to smile down to the abdominal area and maintain the awareness of the relaxed, smiling sensation in the Tan Tien is the first step in training the *Second Brain!* Think about it: Pure awareness and consciousness can change attitudes and emotions carried in the DNA.

Remember: Number 1: "Empty your mind down to the Tan Tien, and fill the Tan Tien with Chi." An axiom in the Tao is, where the mind goes the Chi follows. And, Number 2: "When your mind is empty, it will be filled!" This means that when the organs have extra energy, the extra organ energy will rise up and fill the brain with Chi.

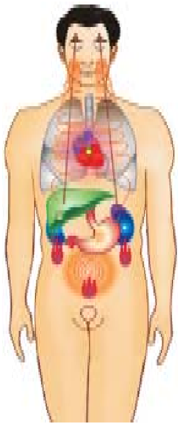

***Fig. 3.24** When the mind is empty, transformed energy from all the organs can charge the brain with Chi.*

Practice

Three Minds into One: 'Yi' Power

Smile into your heart. Lower the Observation Mind, then the Heart Mind down to the Tan Tien. With the Feeling/Awareness Mind, Spiral the three minds into one.

1. Smile into your heart. Make it feel soft. Feel love. Feel joy. Feel happy and feel compassion in your heart. Feel the heart spiral.
2. Spiral in the upper mind. Lower your upper mind, the observation mind, down to the Tan Tien in your navel area.
3. Turn the consciousness in your heart, activated by your love and softness, down to your Tan Tien.
4. Combine the upper and middle minds with the energy of the feeling/awareness mind of the entire nervous system – the Second Brain in the abdomen. Merge the three minds into one mind by spiraling their energy, blending them together as one in the Tan Tien.

When the three minds merge into one they become the 'Yi' power, the three-mind power – activate the spiraling at the mideyebrow, crown and the soles of your feet – expand to the universe in six directions: up, down, front, back, left and right. Once you get it, the Yi, we will start to activate the six directions and the three fires.

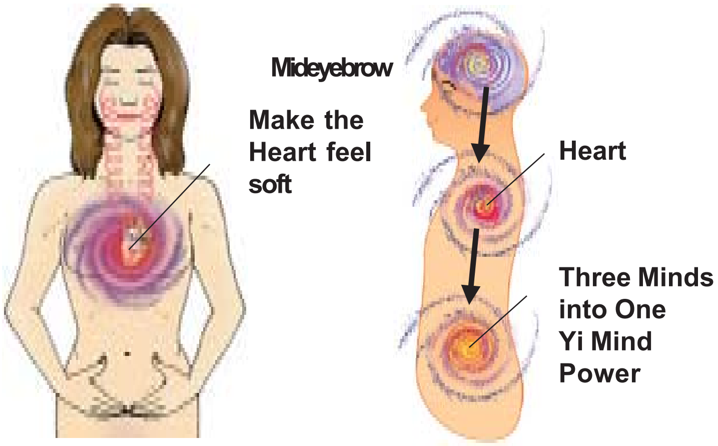
A.
Make the Heart feel soft
B.
Crown
Mideyebrow
Heart
Three Minds into One Yi Mind Power

***Fig. 3.25** **A.** The Heart softens like a rose blossoming.*

***B.** Spiral the Upper Tan Tien into the Lowest Tan Tien and Three Mind 'Yi' Power.*

Activating the Six Directions and the Three Fires

This powerful energetic technique allows one to extend the mind, to touch the force, and to draw that energy back into the body.

The Six Directions teaches you how to expand your mind and Chi for receiving healing power. By practicing the Six Directions daily you will increase your healing and cosmic power. Turn your mind and Chi into the cosmos, multiply them and draw them back.

Direction Below

When you achieve the three minds into one mind begin expanding into the Six Directions; press your hands down and start with the low direction. Picture yourself standing on the earth and you expand yourself very far away – deep down into the earth, very, very deep down into the earth. Your hands become very long; your feet become very long — they go all the way down into the earth and out past it into the galaxy below on the other side.

Push. When you push, connect with the galaxy below — pull and think about your Tan Tien filling with Chi. Push and pull. Push and pull. Fill your Tan Tien with Chi.

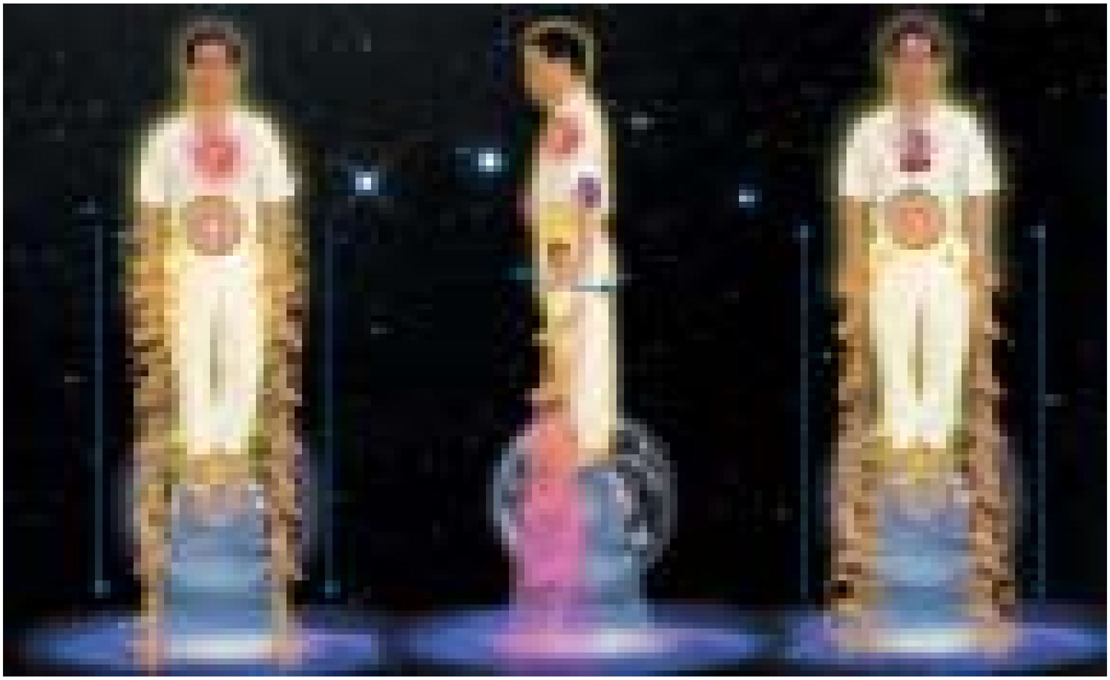

A. **B.** **C.**

Fig. 3.26 A. *Hands expand through the earth and to the galaxy below.* ***B.*** *Hands push forward and pull back.* ***C.*** *Smile to the primordial Chi from the universe back to the Lower Tan Tien and fill the Tan Tien with Chi.*

1. Stand, feet together. Put you hands down, parallel to the ground. Expand your hands very far away and your mind very far away smiling into the ground. Continue expanding your hands, feet and your mind very far away beyond the earth below. Go down through the galaxy, way beyond to the primordial force. It's just like you are extending all the way to the primordial force before 30 million years ago.
2. Push, moving the hands forward six inches only.
3. Pull, moving the hands back by the sides. Think about your Tan Tien – Chi coming to the primordial force in your Tan Tien. Smile to your Tan Tien, dark, deep and vast.
4. Push: touch the primordial force in the universe.

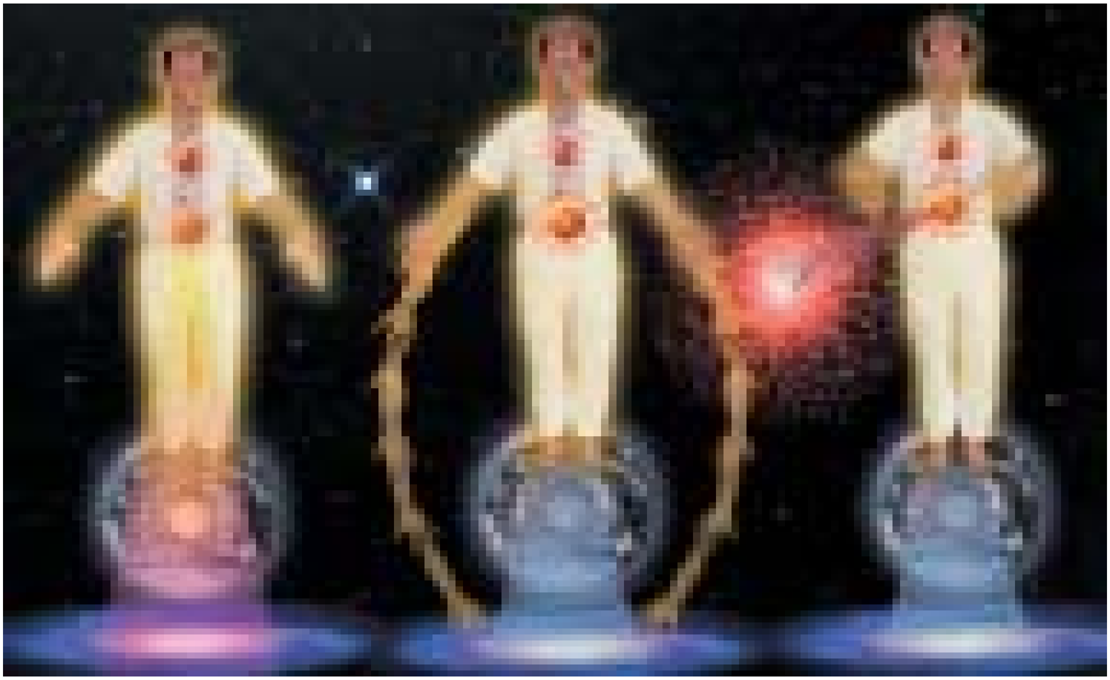

A. ***B.*** ***C.***

Fig. 3.27 A. *Be aware of the universe in front.*
B. *Expand your hands very big and long to the universe in front.*
C. *Hold the fire ball to activate the Tan Tien Fire.*

5. Pull back to your Tan Tien the dark primordial forces with your hands.

Push and pull: It's just like you go to an empty space – vast. Then you come back to your Tan Tien – also empty, just like the primordial condition before anything existed. That is where all the forces come from. Push and pull 3 – 9 times.

Front Direction and Tan Tien Fire

Next, be aware of the front direction; a huge fireball appears in front of you.

Open your palms: scoop up the Chi, scoop up the fire. Bring the fire into your Tan Tien. Activate the Tan Tien Fire.

1. You start with a small dot of light inside you. Expand your awareness smiling to the universe in front of you.
2. Become aware of a big fireball in front of you. Fell your hand become bigger and longer. Scoop up the fireball. You may close your eyes to help your inner sensing.
3. Use the fireball to light the fire in your Tan Tien. Feel the fire burning in the darkness, the 'fire burning under the sea.'

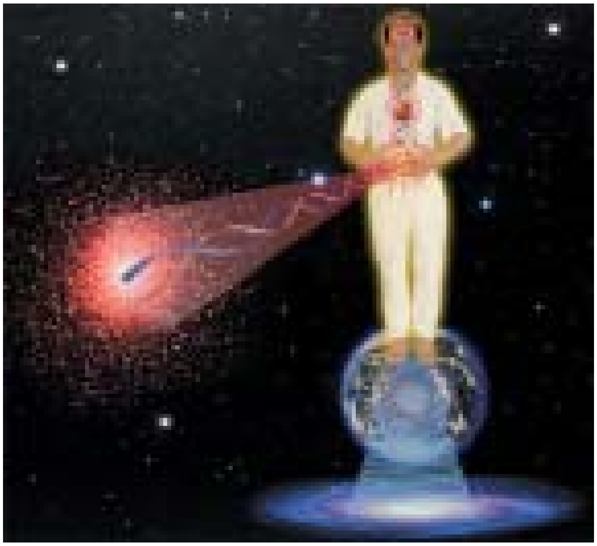

Fig. 3.28 *Smile to the Burning Fire.*

Back Direction and Kidney Fire

Be aware of the back of the Tan Tien, the Door of Life and the back or rear direction. Extend your mind very far away to the 'back'. Scoop up the fire and light up your 'Kidney Fire'.

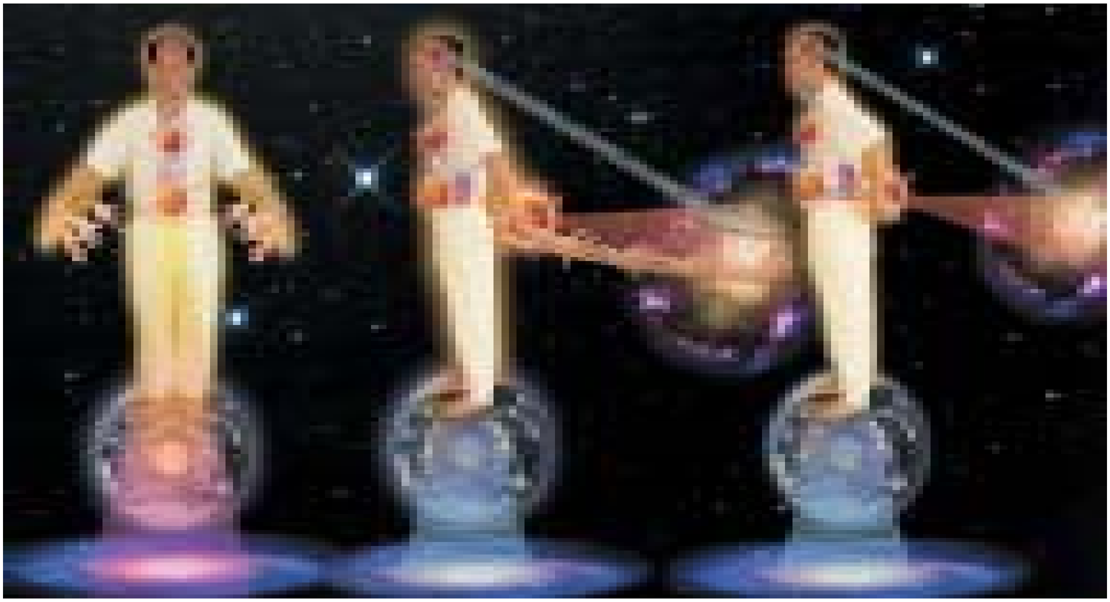

Fig. 3.29 *Be aware of the back direction, move the arms toward the back of the universe and scoop up the universal fire.*

1. Expand your awareness all the way to the back. Move the arms toward the universe behind you.
2. Touch the universe; scoop up the fire. Activate the Kidney Fire. Maintain your awareness in the Tan Tien and expand smiling out to the universe. The energetic spiral glows in the Tan Tien. Spiral in the heart, spiral in your crown and spiral in the universe.

Heart Fire

Raise your hands up under your armpits, and feel yourself holding the two fireballs. Touch the heart by extending the fingers energetically in from the sides; feel your hands extending into your heart and very far away. Activate the Heart Fire.

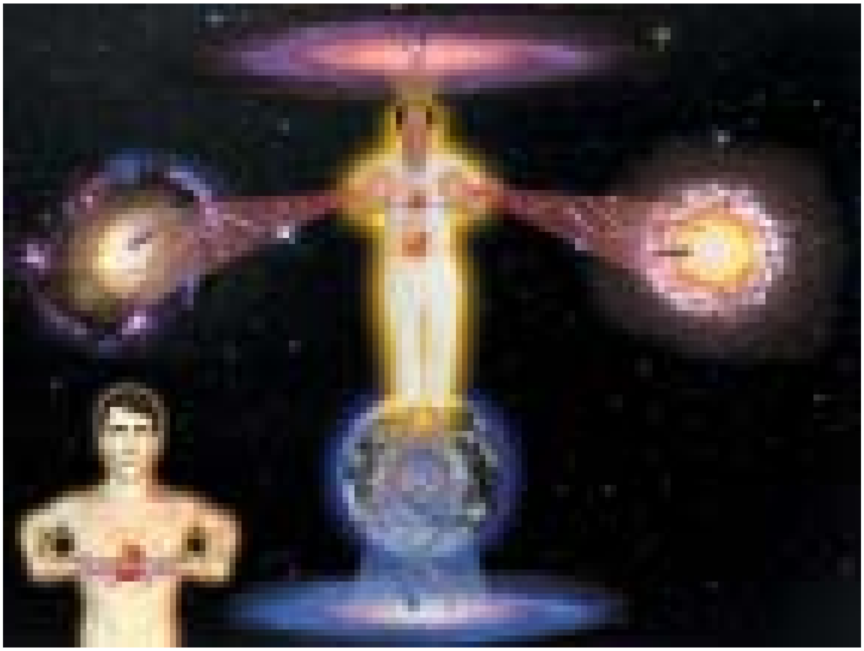

Fig. 3.30 *Activate the Heart Fire.*

1. Move your hands up under your armpits and extend your fingers deep into your heart and very far away.
2. Tan Tien and the Universe: you are connecting to the 'charger,' charging more fire into yourself.
3. Feel your heart soft in the center as you smile down. Feel the warmth of the fire energy of love, joy and happiness in the heart.
4. You feel the connection with the unconditional love in the universe as you keep your heart consciousness in your Tan Tien and extend your awareness out to the universe.

Sacred Fire *(Chi Fire)*

Connect the Three Fires to combine into one Fire: *Heart to Kidneys to Navel to Heart*.

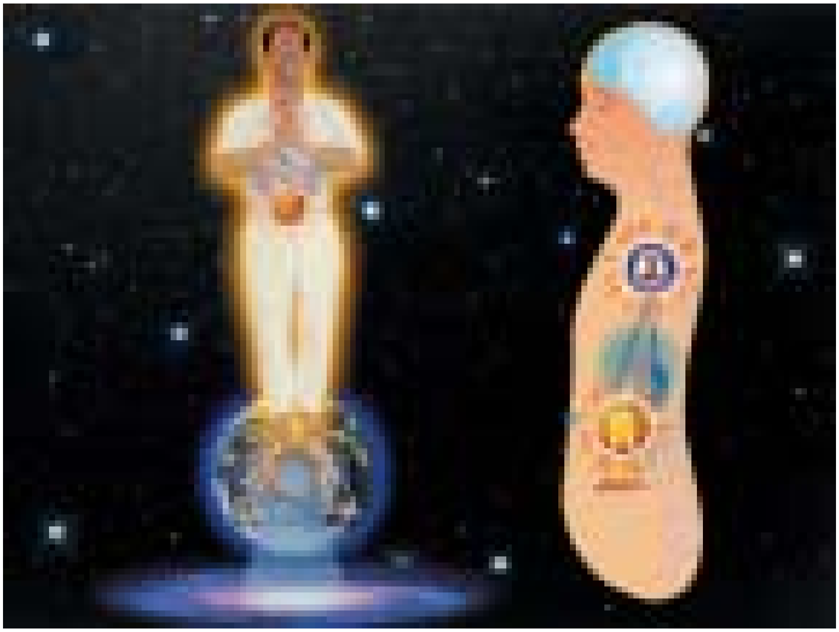

Fig. 3.31 *Connect the Three Fires and Sacred Fire.*

1. Move your hands together in front of your heart. Hold your hands together in front near the heart and feel the fire burning in there. Connect the Heart Fire to the Kidney Fire, the Kidney Fire to the Tan Tien Fire and back up to your heart; connecting them as one triangular Sacred Fire, circulating the Chi at 1,000 revolutions per minute, 10,000 R.P.M, 30,000 R.P.M and 60,000 R.P.M, doubling or tripling their collective power.

Open the Third Eye

Now, extend your hands out to the front, very far away – pushing, pushing, pushing. Push. Turn your palms inward, and extend your middle fingers inward toward your third eye. Picture a crack in the middle of your forehead, and pull the crack open. Feel the light from the heavens opening it and feel the light from the heavens shining into your brain.

1. Open your palms. Open your eyes, dimming the eyes. Look to the universe. Extend your hands to the front, palms vertical. Extend the arms from the scapulas. Smile and touch the universe.
2. Turn your palms inward and extend your middle fingers inward toward your third eye.

3. Picture a crack in the middle of your forehead and let the heavenly light shine into the brain; pull the crack open and let the light reflect into the organs.
4. Close the third eye. Again, open. Pull: open-close-open. And, close. With the third eye open, the light from the heavens shines into your brain and reflects down to all your organs. Open and close the third eye 3 - 9 times.

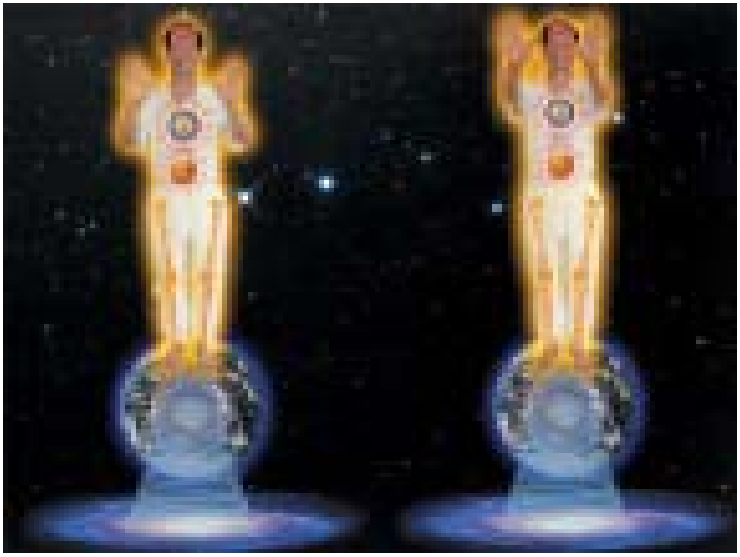

Fig. 3.32 *Look as you smile into the Universe in front of you.*

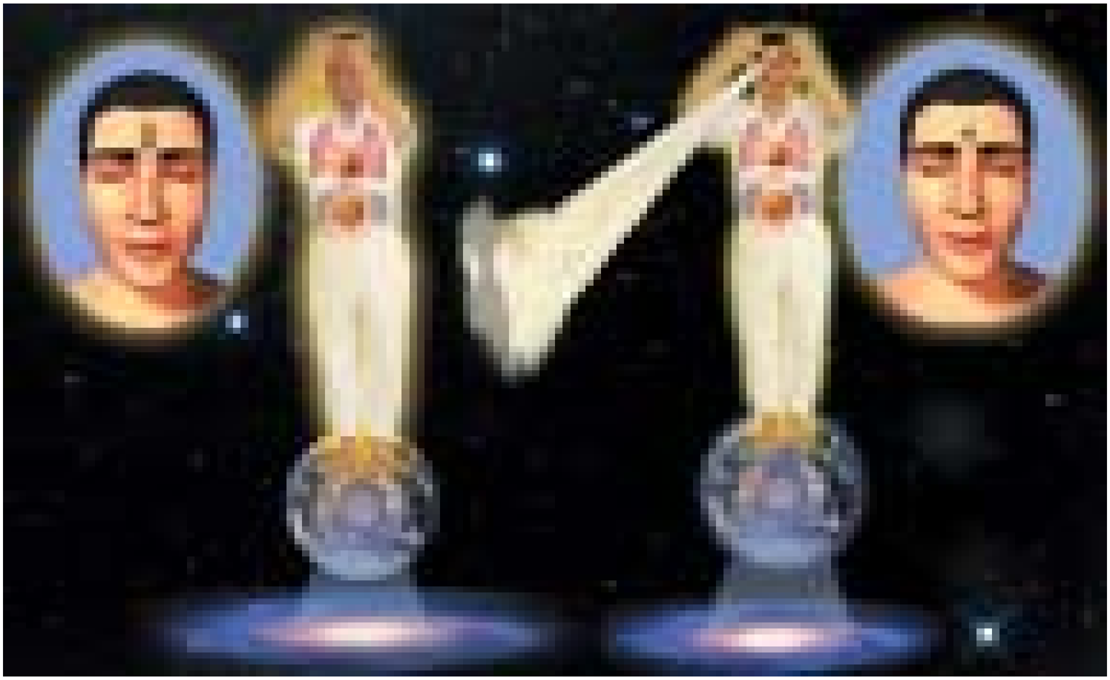

A. **B.**

Fig. 3.33 A. *The Middle of the Finger hooks into the third eye and reflects down into the Organs.* **B.** *Pull open the Third Eye; let heaven open and shine its light into the Brain.*

Front Direction: Push/Pull Master Practice

Now, turn your palms, pushing out. Push. Pull. This is the master practice that is imperative for successful completion. When you first start practicing you should do it at least one hundred times and increase up to 200 times. Push and pull. When you push, you feel your hands extended very far away – very long – reach the sky. Touch the universe.

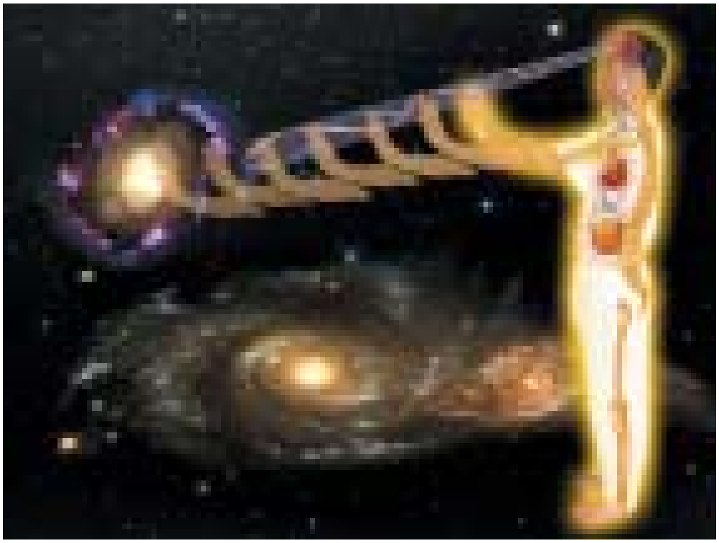

1. Push: Extend your arms and hands to the front, palms vertical. Extend the arms from the scapulas.
   Expand: smiling, smiling, touching the universe – touching the force, touching the Cosmic Chi.

Fig. 3.34
Master practice:
Touch the Universe.

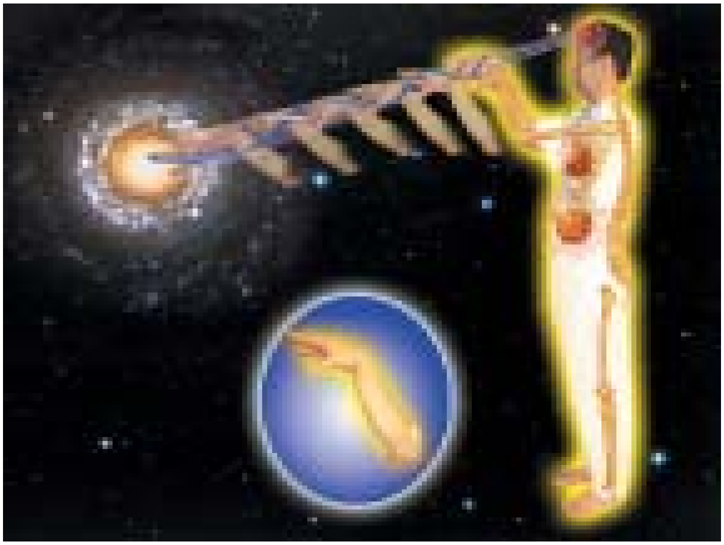

2. Pull: Draw the Chi back to you from the universe. Moving the arms from the scapulas, draw the hands toward your body in a horizontal position, drawing the Chi into the body.

***Fig. 3.35** 'Drawing' Universal Chi - feel your Tan Tien and fill it with Chi.*

Pull. Think and smile to your Tan Tien. Push, very far away to the universe. Pull. Push: Smile, relax, and let go, touching the sky, touching the universe.

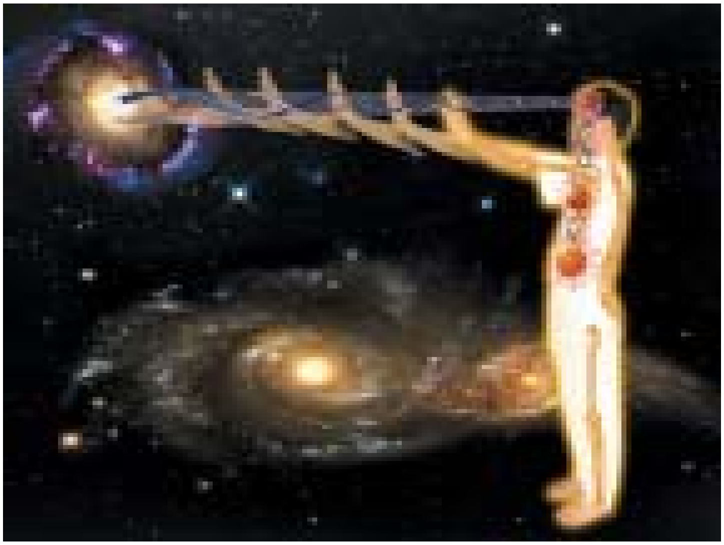

Fig. 3.36
Let go - Push and Touch the Universe, do it 6, 9 or 18 times.

Left and Right Directions

Now, move your hands to the left and right directions. Pull the Universal energy in. Push; touch the universe. Pull; think about your Tan Tien. Push – all the way, touching-touching-touching the universe.

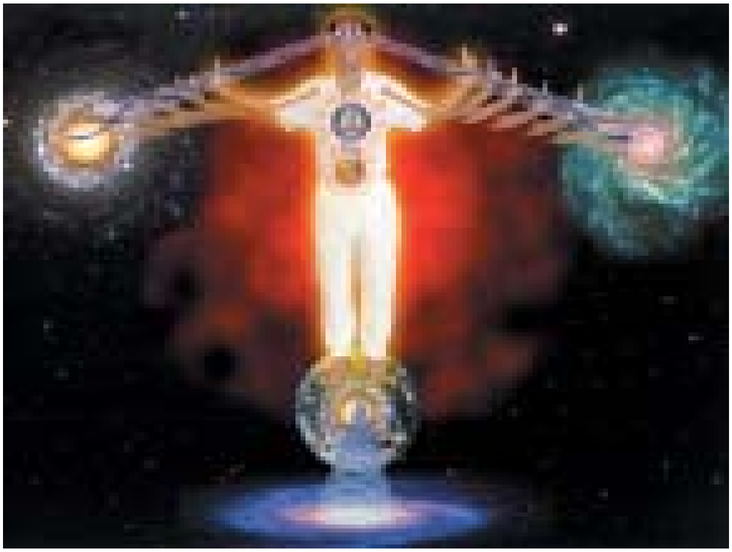

1. Move your extended hands from the front horizon to the left and right sides.

Fig. 3.37 *Touch the Universe Left and Right.*

2. Pull Tan Tien: Smile to your Tan Tien. Keep smiling to your Tan Tien.
3. Push to both sides. Expand all the way, smiling and touching the universe.

   Push/Pull: touching, touching the universe drawing the Chi smile energy into you from both sides.

   Do 3-6 times.

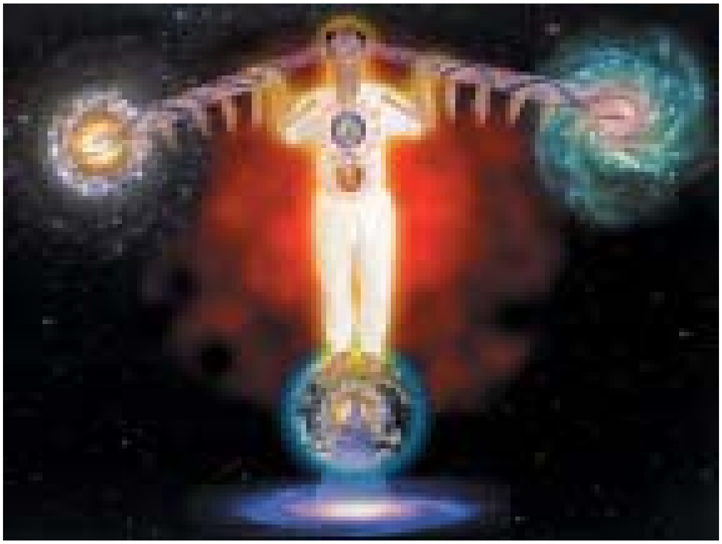

Fig. 3.38 *Pull: Just feel about your Tan Tien.*

Direction Above

Turn your palms up to the universe. Scoop up the Chi. Pour the Chi over your crown, and touch your crown. Project the Chi all the way down to the perineum and down through the earth to the universe below. Tan Tien and universe; always feel your Tan Tien spiraling, heart spiraling, crown spiraling and the universe around you spiraling.

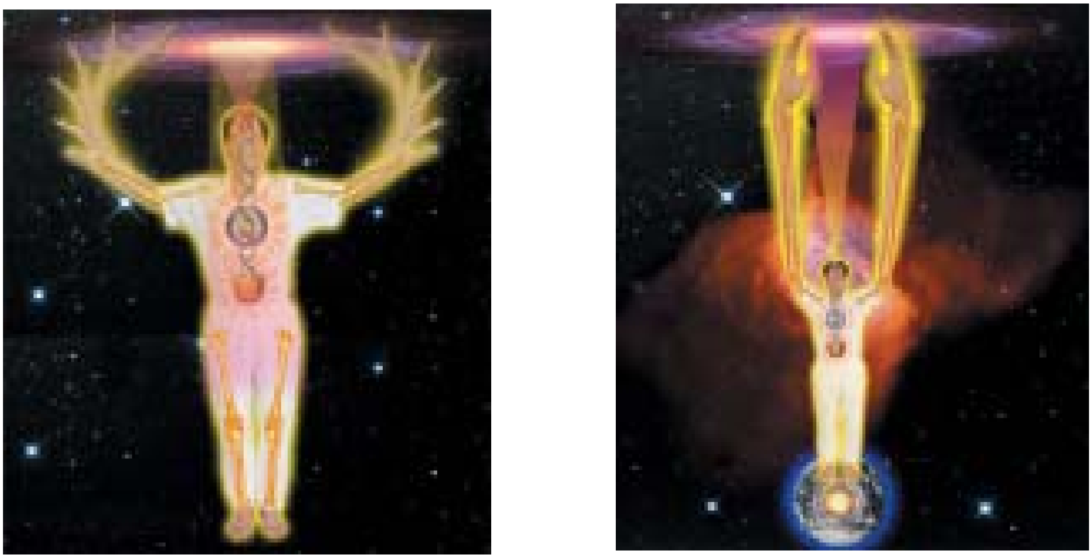

Fig. 3.39 A. *Raise the hands above the crown and feel it extend up to heaven.*
B. *Feel that the hands are big and long and that the bones are hollow. Fill and pack the bones with Chi.*

Raise your hands up to the universe and expand your hands as big as the universe - feel the Chi charge into your bones.

Scoop and gather the energy turning the body three times to the left and three times the right drawing the smiling energy.

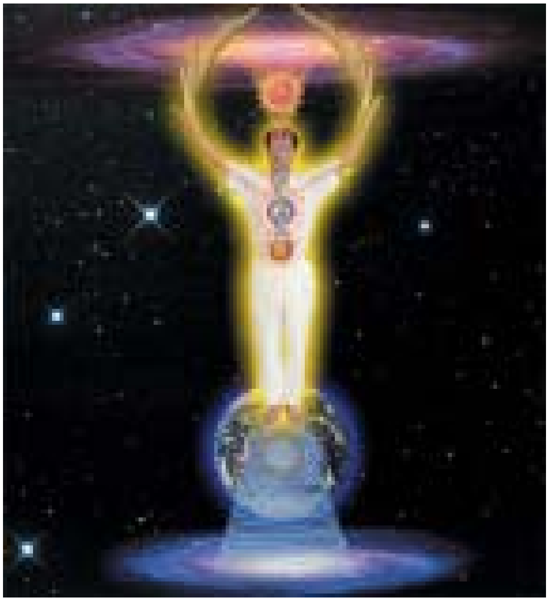

Fig.3.40 *Scoop up the Universal Chi and pour it over the head.*

Open the Spine

1. Touch the back-crown point. Pour the Chi all over your crown. Think of your soles so that you feel like there is a waterfall of Chi flowing from your crown all the way down to your soles. Feel your finger grow long and the Chi penetrate down through your spine to the coccyx. Leave the fingers touchng the back of the crown, to maintain the energetic connection with the coccyx.

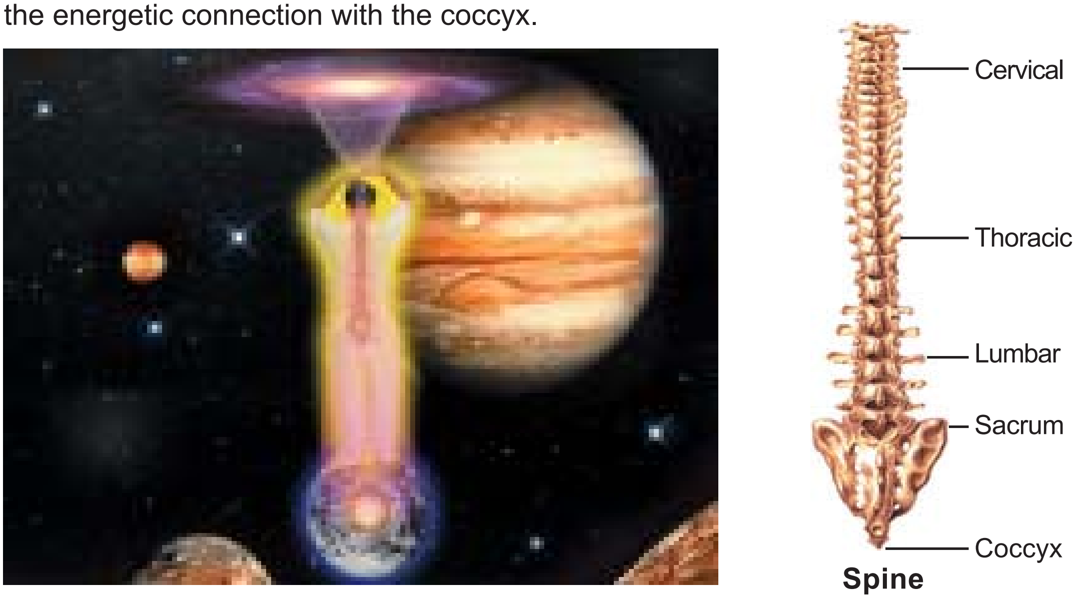

Fig. 3.41 *Feel your fingers growing long, all the way down to the coccyx.*

Turn 'Three Minds into One Mind' at the Lower Tan Tien, and expand the awareness to the universe. Let yourself be charged by the universe.

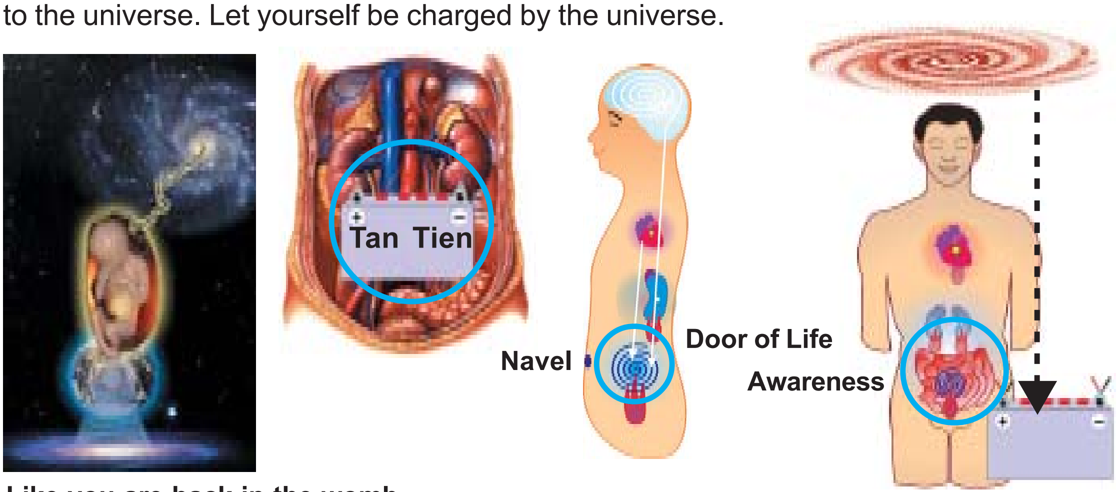

Like you are back in the womb.

Tan Tien is like a battery.

Fig. 3.42 *Universe charges Tan Tien power.*

Beware of the Tan Tien and spiral it like universal energy in motion. Feel the heart center spiraling and the crown spiraling. Be aware of the universe spiraling above, below, front, back, left and right. Let all of the sick energy and the negative forces leave the body and go down into the ground for Mother Earth to recycle. Extend the Chi from above, all the way down through the earth and the universe below.

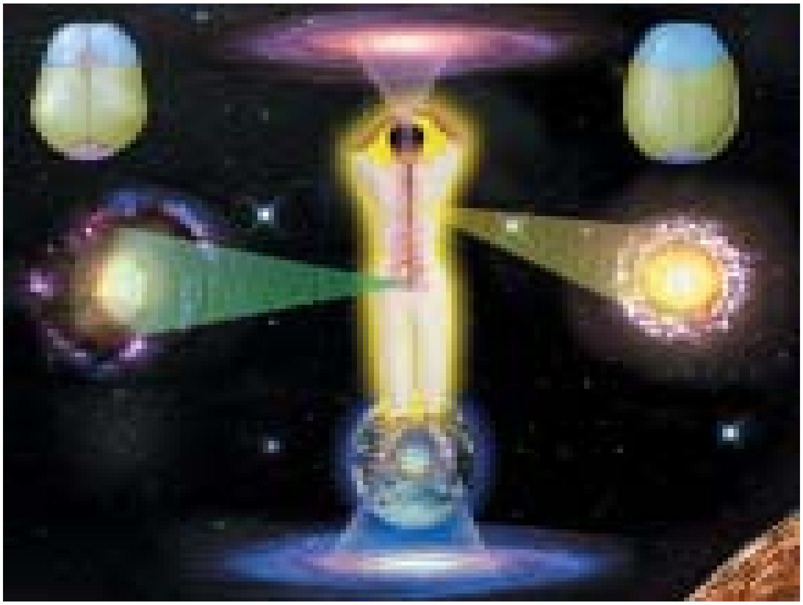

Fig. 3.43 *Be aware of the Lower Tan Tien, Heart Center and Crown spiraling. Feel the Universe is spiraling and charging the Three Tan Tiens.*

Open the Middle Channel and Perineum

1. Move to the mid-crown point. Touch the point and project your fingers inwards; go deeper, deeper through the middle of your body down to the perineum. Focus on the perineum. Feel the Chi from the universe flow into your perineum. Look for one dot of light. Look into the darkness, the vast darkness, the immense darkness; this is the primordial force, a cloudy moving force. Look for a dot of light at the perineum and extend your awareness all the way down through the ground and the universe below.

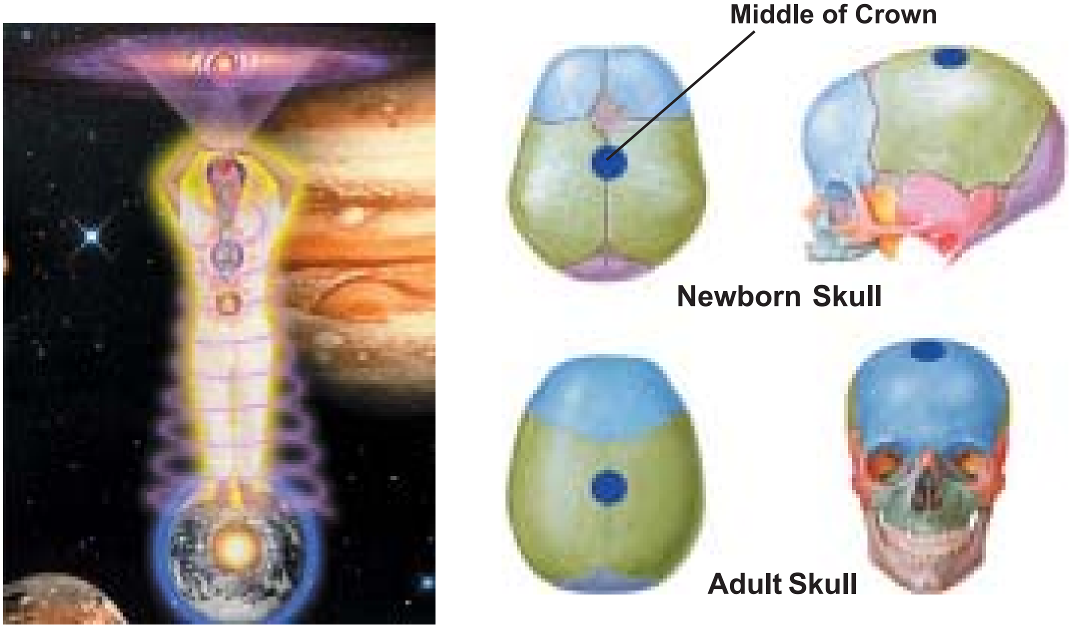

Fig. 3.44 *Move the Hands to the Middle of the Crown and feel the Fingers Penetrate to the Perineum.*

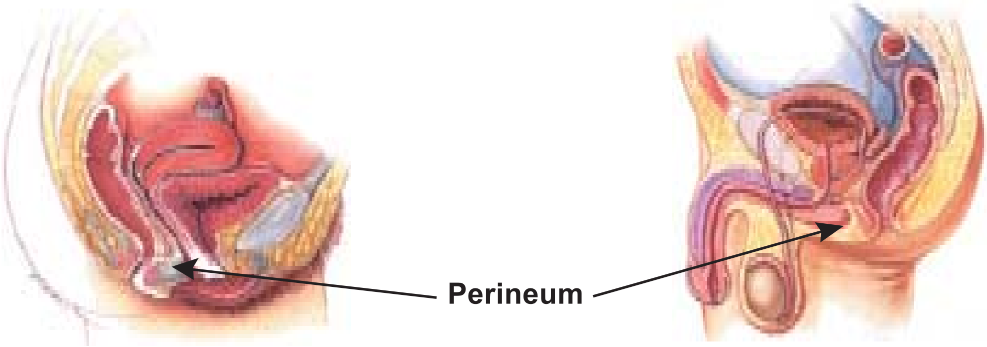

When finished opening to the Six Directions and igniting the Three Fires, gather the Chi in the center and bring this expanded awareness into the healing session.

Tan Tien and the Universe

The expression, 'Tan Tien and the Universe', is a reminder to feel your Tan Tien, heart, mideyebrow and crown spiraling and that you are connected to the universe spiraling in the six directions around you.

1. Establish a Complete Location

You will use your Yi, the three-mind power, repeatedly to recharge your Chi for various purposes. You recharge by connecting to the Universal Chi in the six directions of the universe simultaneously. When you charge a particular area or direct Chi into the body to a particular point, you first establish a connection point for the Chi by placing the hand or fingers at an appropriate location on the surface. This is like giving a location for the Chi to go to. Once the location is established and the Chi starts to go there, leave your hands there.

Then you move your attention to where you want the Chi to go in the body. Feel the Chi connected to and charging the intended location.

2. Charge Tan Tien from Universe

When the location connection is established, be aware of your Tan Tien, heart center, mideyebrow and crown spiraling. Be sure that the conscious mind of the heart is lowered to the Tan Tien and the awareness mind of the abdomen is connected to the mideyebrow crown and out to the universe. Feel them connected to the spiraling energy in the six directions of the universe. Let the universe charge your Tan Tien.

3. Don't Stop at the Location

With your focus in the Tan Tien, the Chi will go from there to the 'location' indicated by your hands and then to the intended location in the body. Don't let Chi stop there, however.

4. Direct Chi out the Opposite Side to Universe

Direct your attention to guide the Chi flow through the body and out the opposite side. You want to clear out any blockages and prevent any others from accumulating. You also want to release sick energy and negative forces down into the earth. Let the Universal Chi flow out through the universe and beyond.

Open the Three Tan Tiens

Move your hands down to the mideyebrow. Touch the mideyebrow.
We are going to open the three Tan Tiens, starting with the Upper Tan Tien.

Upper Tan Tien - Mideyebrow

1. Recharge. Remember: Tan Tien – heart consciousness in, awareness out. Spiral – Tan Tien, heart, third eye and crown. Universe – six directions spiraling.

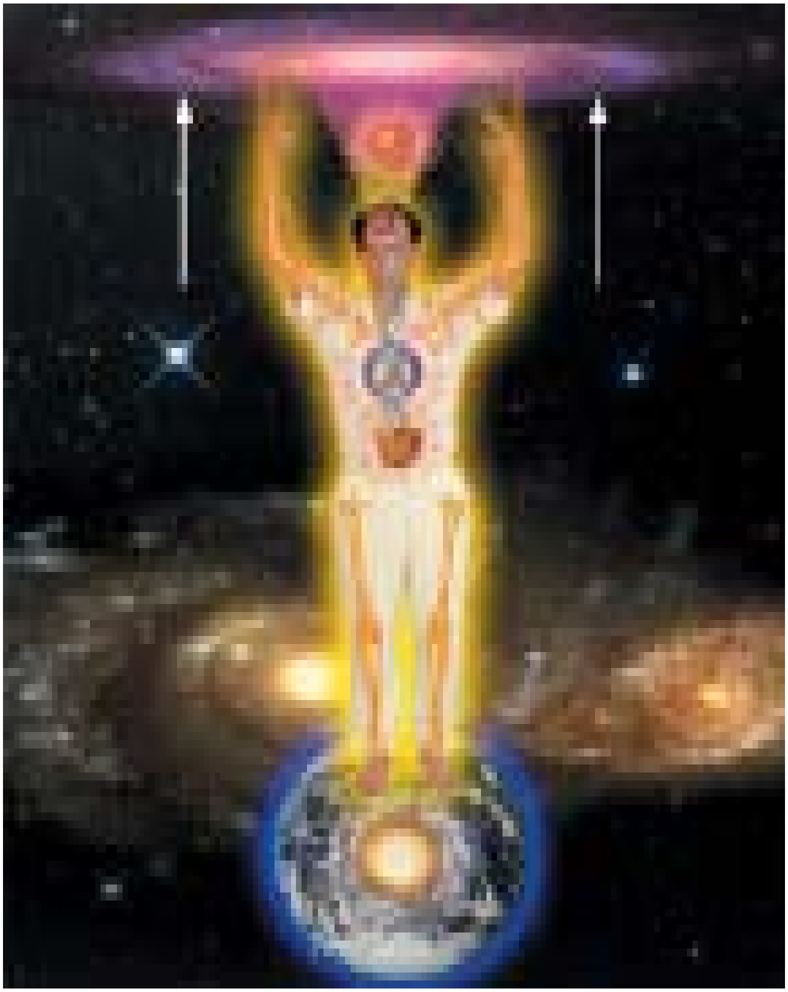

Fig. 3.45 *Raise hands and charge with Universal Chi.*

2. Move your hands down and touch the mideyebrow. Feel your fingers grow very long (energetically) and penetrate all the way back to the base of the skull. Focus on the back. Remember: Tan Tien and the universe spiraling. With the spiraling, the Chi in the fingers will become hot. It will expand and penetrate out through the back of the head all the way to the universe behind.

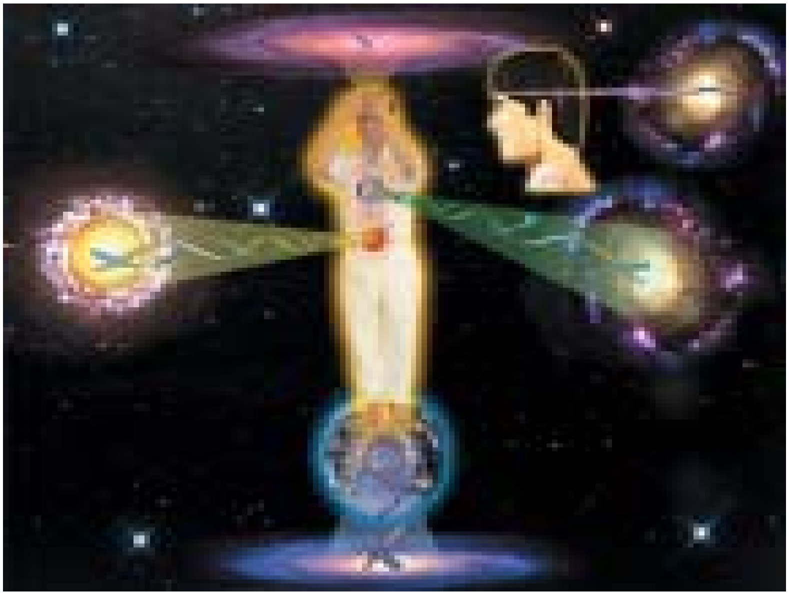

Fig 3.46 *Fingers touch mideyebrow and penetrate to the back of the skull and the universe at the rear.*

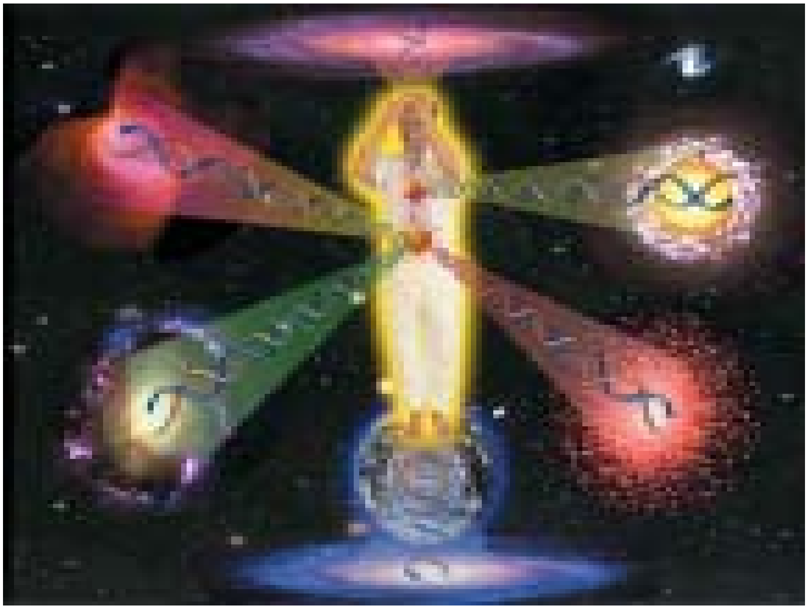

Fig 3.47
Tan Tien and the Universe.

3. Picture your fingers like laser beams of Chi, 'Tan Tien and Universe': Feel your Tan Tien and the universe spiral and charge your fingers. Move your fingers out from the mideyebrow around the side of the head to the top of the ears. Your fingers are like lasers -cut-cut-cutting open your skull right in the middle, around to the top of the ear, cutting open your Upper Tan Tien. Cut and project your fingers long into the middle of your brain. Spiral your Tan Tien and the universe. Leave your fingers there. Concentrate on your Tan Tien spiraling – your heart, crown, the universe above, below, front, back left and right all spiraling. Your Tan Tien is a big empty space: primordial force; darkness. You can put so much Chi inside there! The Chi penetrates into your brain.

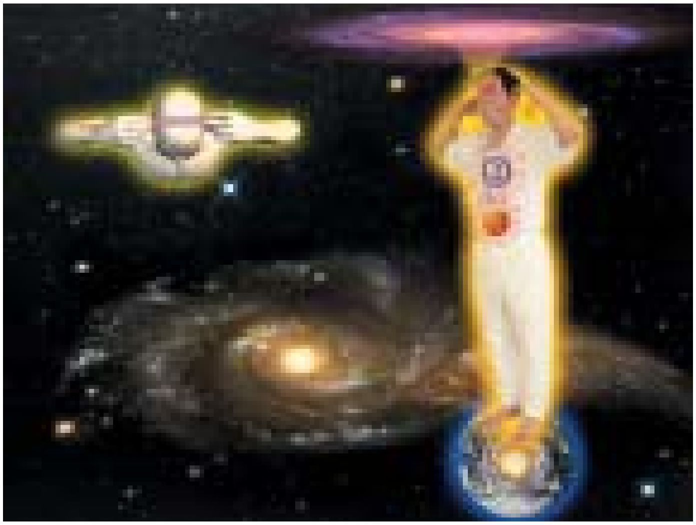

Fig. 3.48 *Move the fingers to the top of the ears. Feel them growing longer and cutting the skull open, penetrating into the brain.*

4. Move your hands all the way to the back, cutting to the back of the skull. Touch, and feel the Upper Tan Tien open.
5. Touch the base of your skull. Focus on the mid-eyebrow. Feel the Chi flow like a laser beam from back to front and out to the universe in front. Complete the opening process by moving the hands back around to the mideyebrow, cutting as you go.

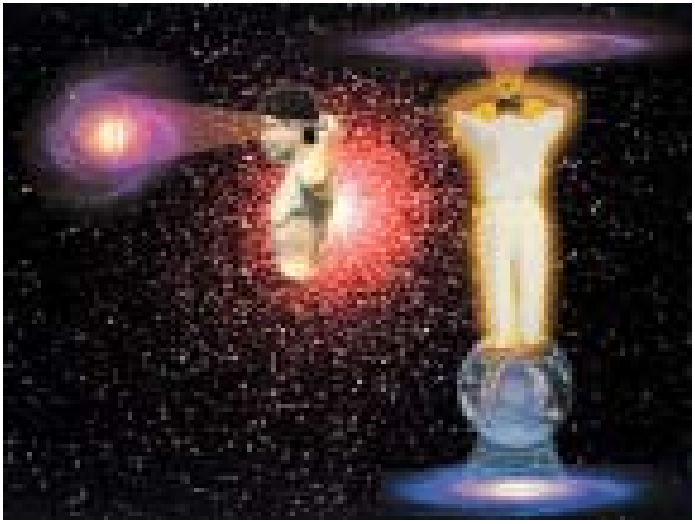

Fig. 3.49 *Chi moves like a laser, penetrating from the mideyebrow at the front, to the back of skull.*

6. Recharge in the universe. Feel your bones and your arms are hollow. Fill and compact them with Chi.
7. Scoop the Universal Chi and pour it down over your crown and all the way down, down to the Middle Tan Tien.

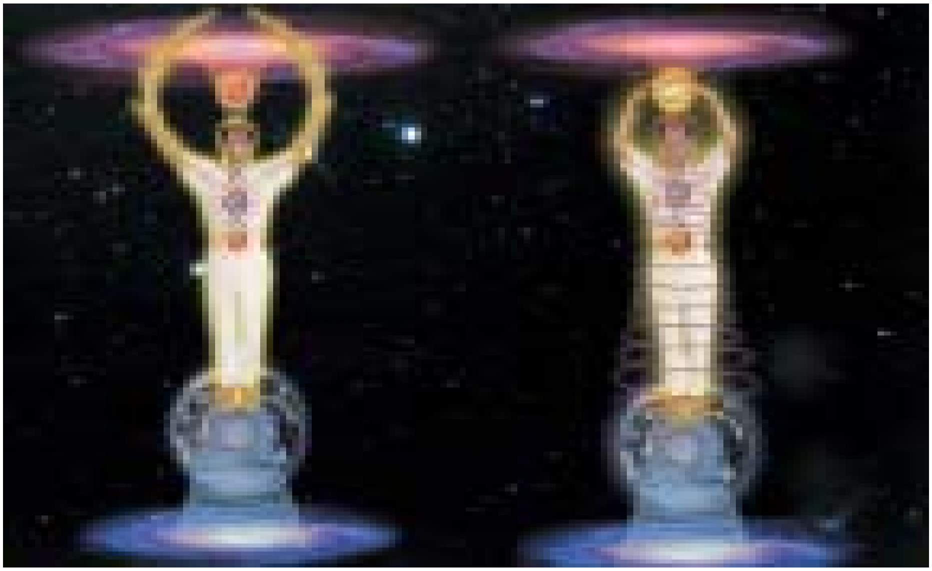

Fig. 3.50
Recharge in the Universe, scoop and pour the Chi down to the Middle Tan Tien (Heart Center).

Middle Tan Tien - Heart Center - Conscious Mind

1. Move your hands all the way down to your heart center at the mid-sternum. Touch. Focus on the point opposite the heart, T5/T6, on the spine. Fingers 'long', Chi penetrates into your thymus gland. Light – golden light – penetrates into your thymus. Feel the Chi penetrate through your heart all the way through T5/T6 to the universe behind. 'Tan Tien and the Universe' also feel your Chi Fingers penetrate into the bone and bone marrow and spread out into your rib cage.

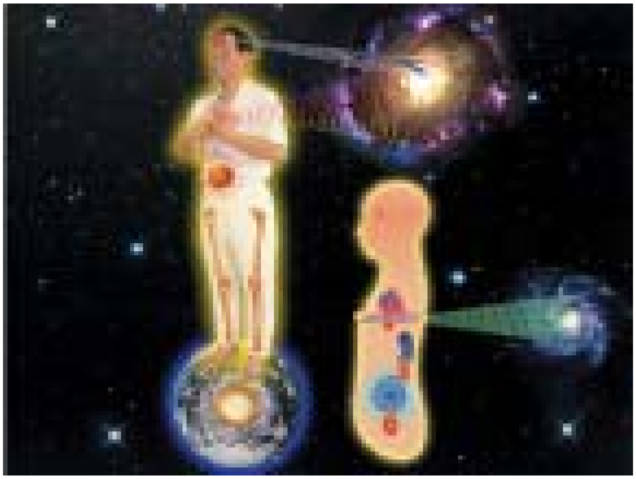

Fig 3.51 *Golden light enters the heart, thymus, bones and marrow; feel it penetrate to the universe at the rear.*

Recharge and cut around to the Armpits

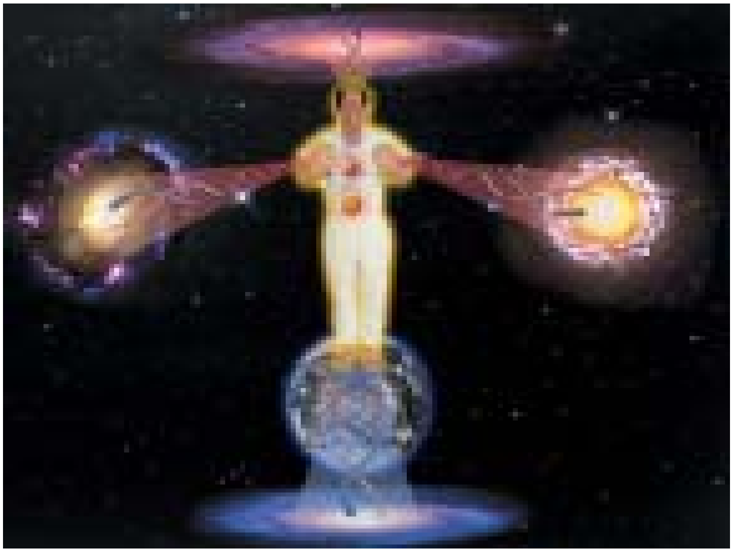

1. Recharge In the universe, pour Chi over the crown down through the body and lower your hands down to the heart center. Touch with the fingertips. Move your hands around under your armpits, extending the Chi like laser beams cutting open this Middle Tan Tien. Pause under the armpits as you send the Chi into the center.

Fig. 3.52 *Cut open the Middle Tan Tien by cutting around the armpits.*

2. Continue to move your hands around to your back at T5/T6, touch and send the Chi from back to front. Let the beam of Chi penetrate out through the heart center to the universe in front of you. Then, move the hands back around the sides to the front, cutting as you go.

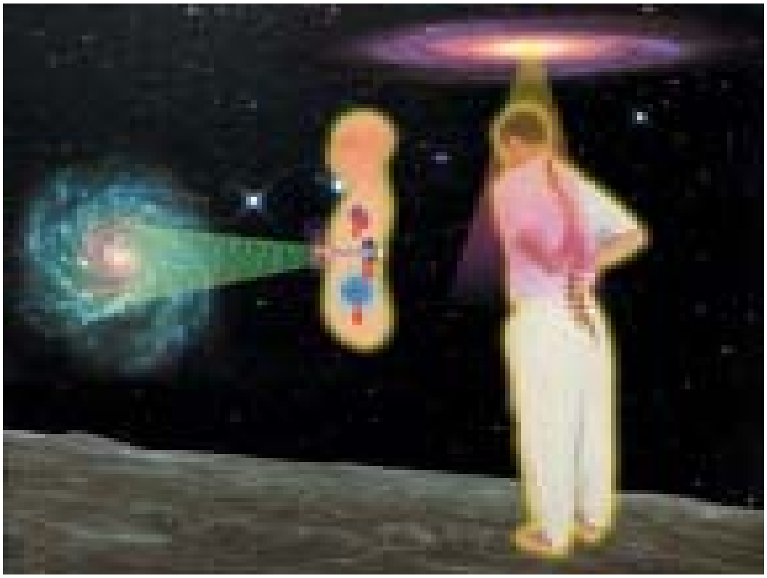

Fig. 3.53 *Chi beam from T5/T6 penetrates to the Heart Center in front.*

Lower Tan Tien - Navel - Awareness Mind

1. Recharge with Universal Chi. Tan Tien and Universe: Again, raise your hands and charge with the Chi into the universe. Your hands are very big, very long. The bones are hollow and compacted with compressed Universal Chi. Scoop the Chi from above and guide it down. Pour all the way down, down, down to the navel. Touch the navel, and focus on the Door of Life opposite on the spine between L2/L3. Touch and feel the Chi penetrate to the Door of Life Tan Tien and Universe. Feel the Chi penetrate through to the back and out to the universe behind.

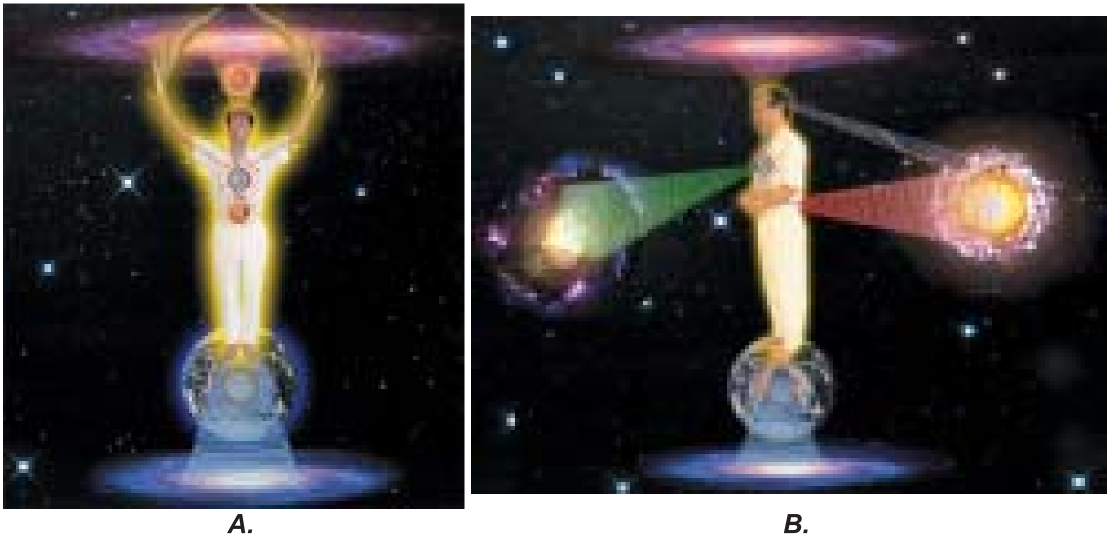

***Fig. 3.54 A.** Recharge the Lower Tan Tien and penetrate through to the Door of Life.*
***B.** Raise the hands up to the universe and charge with Chi. Bring the power down to Tan Tien.*

2. Open this Lower Tan Tien the same way as for the Upper and Middle Tan Tiens. Charge more Chi into your hands, and let them be like lasers cutting it open. Cut around to the sides. Pause. The fingers of the left and right hands are very long, extended energetically inside. Cut and feel the energy penetrate into the center. Focus at Tan Tien and universe and feel more Chi.

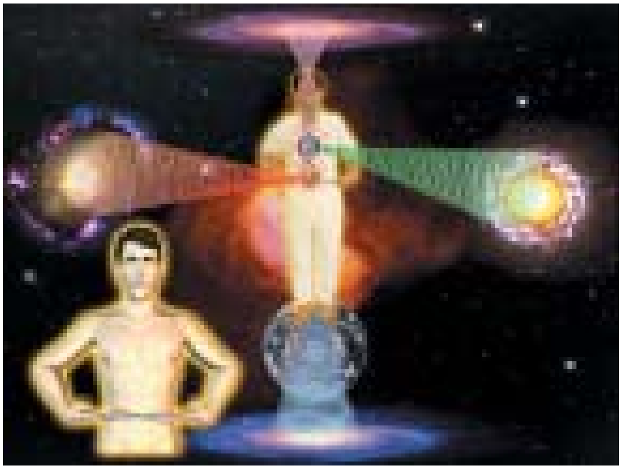

***Fig. 3.55** 'Cut' open the Lower Tan Tien with Laser Fingers.*

3. Continue cutting to the Door of Life. Touch, and send the Chi from the Door of Life back to the navel and out to the universe in front.

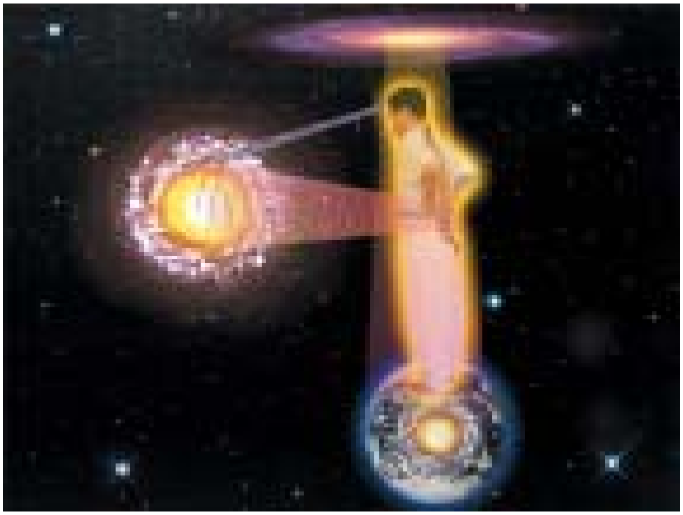

Fig. 3.56 *'Cut' open the Door of Life and send Chi to the navel and universe in front.*

4. Move the hands back around the sides to the navel, extending the fingers and "cutting" the Tan Tien open as you go. Touch the navel: Tan Tien and the universe spiraling. Feel more Chi, and feel the Tan Tien open.

Activate Chi in the Bones of Hips, Legs and Sacrum

1. Now touch your pelvic bone by energetically extending your fingers from the front area near the hips to the back. Feel Chi penetrate into your pelvic bones: funny, laughing, happy bones.
2. Touch the femur bones. Tan Tien and universe. Charge the fingers. Also, feel the funny, happy, laughing vibration inside the bones and in the bone marrow. Be aware of the Three Tan Tiens. Spiral from the universe. Spiraling charging your Tan Tien. Charge your hands and your bones.

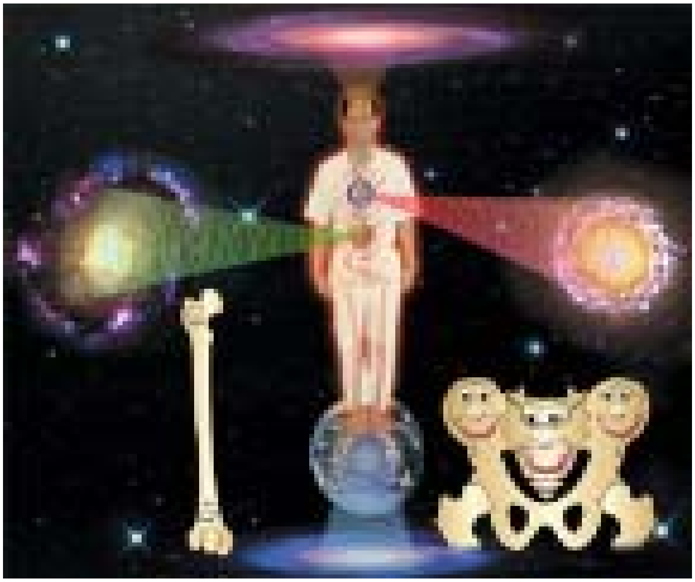

Fig. 3.57 *Touch the femurs - happy laughing bones!*

3. Now we are going to slowly lower the sensation of Chi down through the bones to the earth. Opening up the sacrum. Move the hands down the legs as you bend down.
4. Lower yourself all the way down to the ground and sit on your feet. Move the Chi with your hands down to your toes, down through the earth and the universe below.

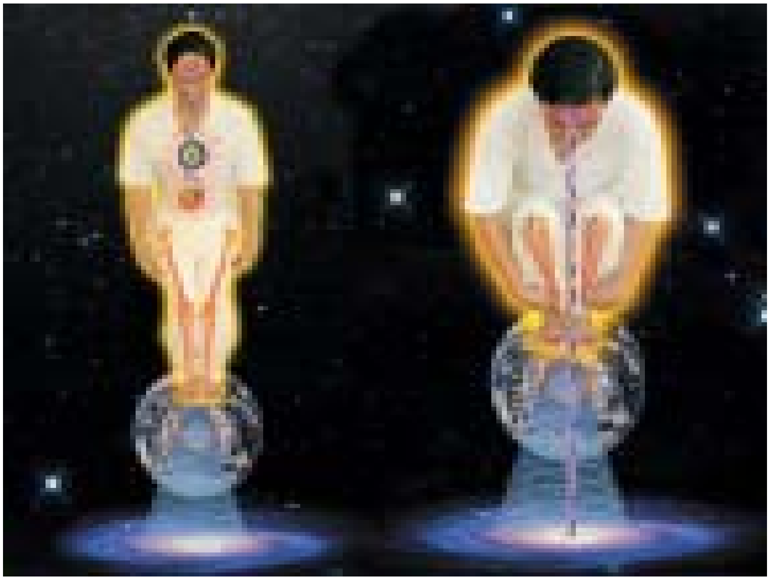

A. ***B.***

Fig. 3.58 A. *Sink the Chi into the earth.* ***B.*** *Lower and sink the mind and Chi down to the universe.*

5. Raise your sacrum up, keeping your hands at the toes. Smile to your Tan Tien and feel the Chi from the universe coming to fill the Three Tan Tiens. Opening up the sacrum.

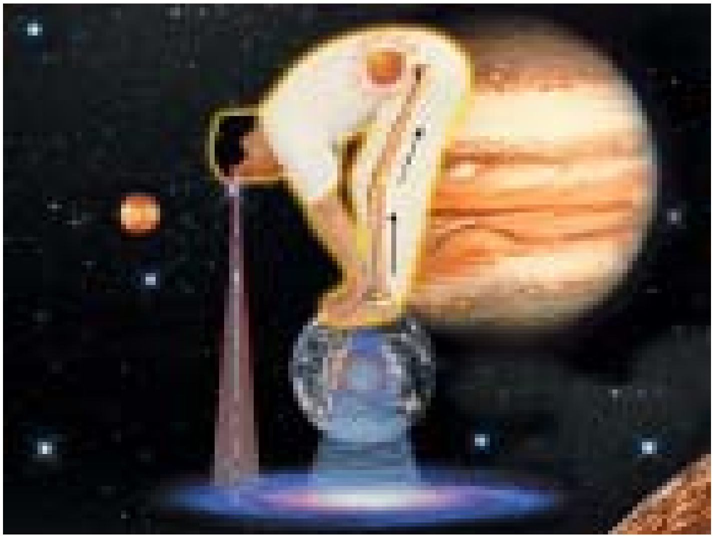

Fig. 3.59
Raise the sacrum and smile to the Tan Tien.

6. Lower down again. Lower the Chi down to the earth and the galaxy below.
7. Once more, raise your sacrum up, maintaining hand contact with your feet. Smile to your Tan Tien.
8. For the third time, lower down. Open your palms, gathering the Chi from the earth below. Gather and scoop the Chi.

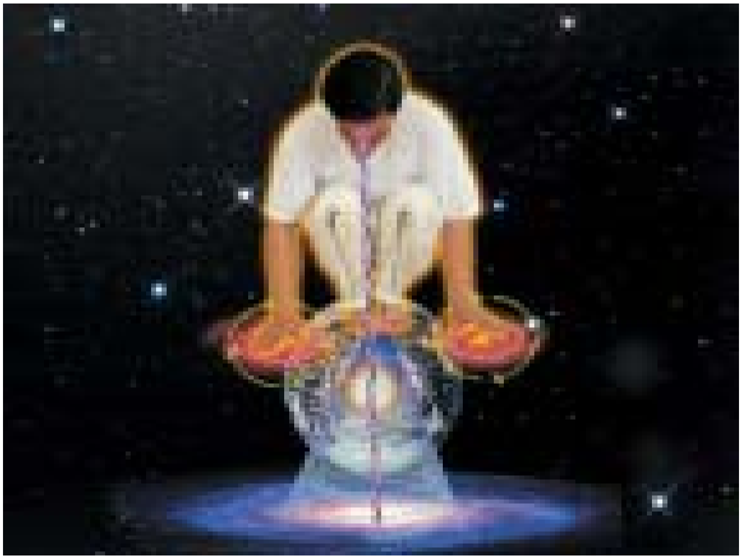

Fig. 3.60 *Gather the Earth Chi.*

9. Touch your heels and feel your bones as you slowly rise up. Fill your bones with Chi as you guide it up with your hands.
10. Fill the bones in the upper legs as you move your hands up.

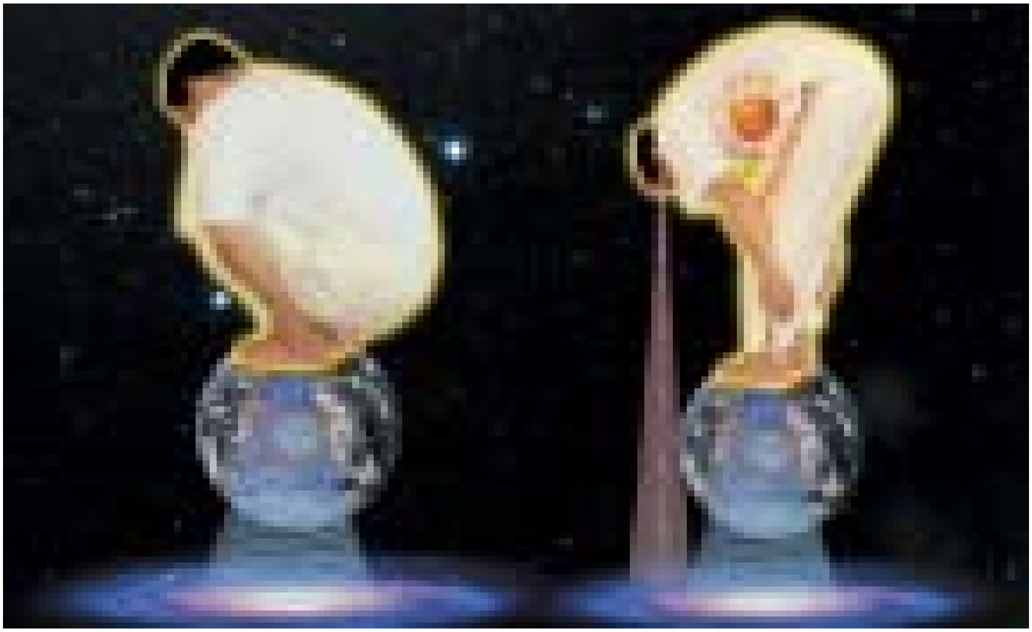

Fig. 3.61 A. *Fill the bones with Chi.* ***B.*** *Feel your fingers penetrate into the bones as you rise.*

11. Feel your bones, and fill them with Chi all the way up to your coccyx. Touch your coccyx. Leave your fingers there, then be aware of the Chi and feel the Chi raising up to the Tan Tien and the universe. Feel it charge the fingers and the spine.
12. Come up to the sacrum. Feel the sacrum open. Focus at the Tan Tien and the universe.

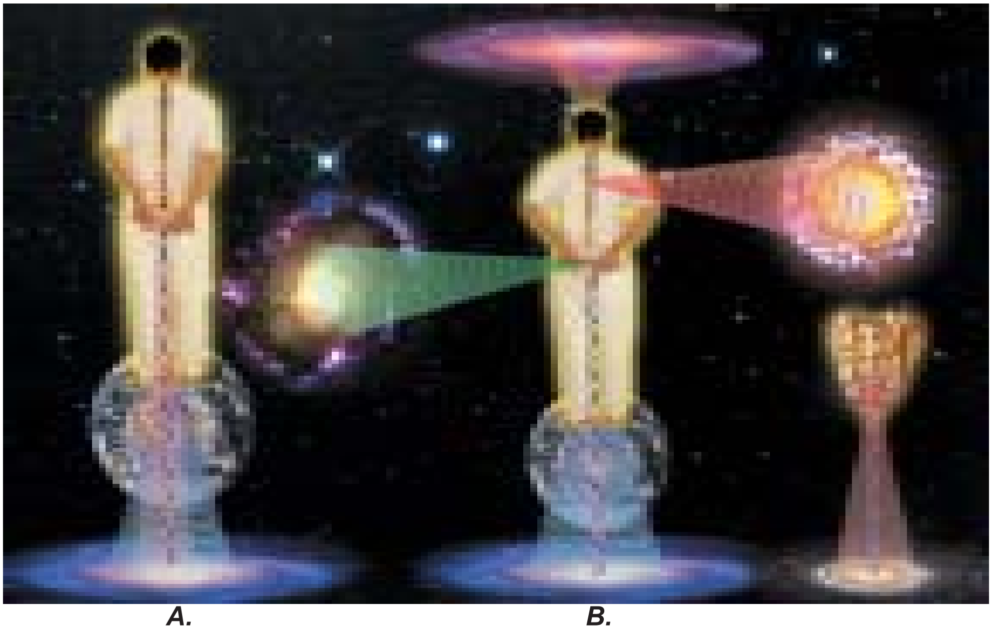

Fig. 3.62 A. *Bring the Chi to the Coccyx.*
B. *Move your hands up to the Sacrum and feel the Chi rise up to the Crown.*

13. Come up to the door of life, and then back to the navel. You may sit down to continue the next step in the Cosmic Healing Practice.

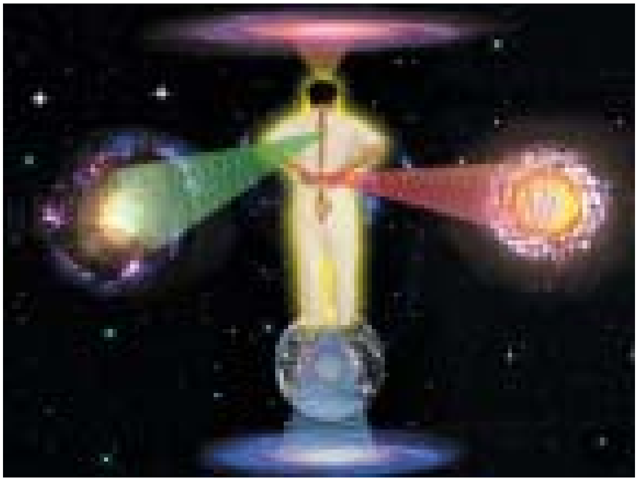

Fig. 3.63 *Bring the Chi to the Door of Life and let it penetrate to the Navel.*

Practice daily till you feel the Chi. Then you can apply this Chi to the Healing Sessions.

Chapter IV
General Healing Session

The General Healing session practices are to be done with every student regardless of their age or health condition. These are for cleaning and strengthening the cells. Cells must be clean and strong to heal. The General Healing practices listed steps A-K are the most important part you must always do in every session. You can do this with one person or with many people at the same time. The following is a detailed decription of each of these steps. Become familar with them and they will flow easily one into the other.

A. Three Minds into One Mind

Smile down to the inner universe. Activate the heart consciousness and empty the mind and heart down to the LowerTan Tien, the Abdominal Brain. Gather the 'Yi' (mind-eye-heart power), combining three minds into one. Fill the Tan Tien with this Chi. Start to spiral. You are then ready to connect to the higher forces of Universal and Heavenly Chi. The Three Minds are the Upper, Middle and Lower, or three Tan Tiens. The Upper Mind is the one we have been closely related to most of our lives. It is the logical thinking, planning, calculating and worrying mind; it consumes 80% of our body's energy.
The key is to learn 'to releas the mind' by learning to sink the Chi to the Lower Tan Tien, whereby it can be used in synergy with the other two.

B. Activate the Six Directions

Activating the six directions is for opening the whole body, mind and soul to all of the Universal and Cosmic forces in all directions. We literally learn to draw in the Universal and Cosmic forces from all directions at the same time. This is important for healers so they are not using their own energy for healing but drawing on the limitless Universal forces.

Expand your awareness to connect to the universe and the Six Directions at the mideyebrow and crown; left, right, front, behind, above and below. Connect to the universe, collect and spiral the energy into your Lower Tan Tien.

C. Activate the Three Fires

Activate the Tan Tien, Kidney and Heart Fires to create a Sacred Fire Triangle. Move from the Tan Tien to the Heart, the Heart to the Kidneys and the Kidneys back to the Tan Tien.

D. Linking Personal Stars, Energy Bodies and the Universe

World Link is a way for intelligent life force to return to the source; inwards and upwards. Become aware of the 'personal stars' above the crown and below the earth.We link with our own personal stars and then with the stars of each person in a group. This links the energy bodies of everyone in a group together. Start to spiral your energy and connect to other peoples' stars and energy bodies. Make a left spiraling pattern, progressing around the circle in a clockwise rotation. Link all of these stars together and form ***one large energy body.*** Each meditator will become an individual unit in an integrated communication link. A link between the earth and the universe.

E. Protective Circle and Chi Field

We create Chi Fields, Protective Animals and call the Eight Forces to protect the group from disturbances and psychic attacks. Raise your right (or leading) hand in the air and access the **'Sacred Fire'** of the universal cauldron. "Feel your fingers becoming big, long and hollow", as they reach into the Sacred Fire. The Chi will fill and pack your arm as you bring it down into your body. Use Yi-Power to create the **Sacred Fire Protective Circle.** The fire will purify and protect the circle. You can cast a circle around your community, house, room and body. This will create an energetic field of Chi around the whole room.

Then Create a **Chi Dome**. Invoke the 'guardian animals'; Blue Tortoise from the north, Red Pheasant from the south, Green Dragon from the east, White Tiger from the west, Yellow Phoenix from above and Black Tortoise from below.

Finally, activate the **Eight Elemental Forces of Nature and the Universe**. Call the forces of fire, water (ocean), thunder (lightning), lake (rain), earth, mountain, wind and heaven. Activate fire in the north, water in the south, lightning in the east, and rain in the west.

F. Chi (Sacred) Water Practice

Invoke the power of the Sacred, Chi or Holy Water practice to cleanse and heal the body's sick, toxic or negative energy. Make a request to receive healing energy and feel yourself touch a heavenly pool of sacred water energy. Feel the pool pouring down heavenly water to fill your arm.

Use the thumb and index finger to remove the sick energy from the cup, without touching the water. Talk to the sick cells. Let the sick energy return to the earth for recycling. Fill the water with your heart's compassion. Give the command: "This Sacred Water will give health, wealth and longevity". Cosmic Healing works on a cellular level. It is the water's 'job' to carry the message of the practice to all the cells, where it will remain. Drink the water in unison with the rest of the group.

G. Empty and Fill

The Empty and Fill technique is emptying the sick energy into the earth and filling with healing Cosmic Force Energy. Project your ‘sword’ hand (middle and index fingers) down to the ground. Project the hand ‘very big and very long’ and your feet ‘very big and very long’ - extended down to the ground. Now very slowly inhale, bring up the earth energy. Bring the energy up to your feet and into your bones. Let it enter all the bones, organs and cells. Feel it blending with all the sick energy. Turn your palm up, turn it back down again and exhale; let go of all the sick energy, the negative energy, the worries and burdens, all the way down into the earth. Repeat this three to nine times. Dig a hole and bury all the sick energy; tell it, “Do not come back; you will be happy down there.” Smile.

H. Clean with Green Light

The Green light is for cleaning the cells. This is vitally important because the cells must be clean for healing. Green can help detoxify the toxic cells. Green Chi is mild and safe. Green Chi is used for cleansing, and as a decongestant for diseased parts. It ‘loosens’ the area. The light green Chi is used to break down dirty or diseased energy, like a detergent is used for washing clothes or dishes.

Afterwards, the cells will be rinsed with blue light, like clean water is used to rinse the detergent and residue from clothes or dishes.

When you carry out healing try to ‘see’ the cells enlarged and this green energy go in and blend with the dirty, black and cloudy energy. See it come out and let it go down to the earth. Dig a hole and bury it there. Tell it, “Don’t come back. You will be happy down there”. Become aware of the green light and spiral counter clockwise. Spiral down. Cleaning out the stress. Repeat as many times as you like, three times minimum.

I. Clean with Blue Light

Blue is like cold water; it has the yin power to dissolve all kinds of negative energy and sickness. It has an inhibiting effect. Blue yin energy is the opposite of red yang, which has a strengthening and stimulating effect.

Blue has a cooling effect; it can reduce pain and inflammation, and it can help blood clot. It stops bleeding and reduces fever. It can help to induce rest and sleep.

J. Charge with Violet Light

Charging with Violet light holds the highest healing energy. When the cells are clean they will absorb and hold the Violet light and the healing will take place. Luminous Violet has intelligence and can be programmed. The universe is full of violet light, especially the North Star and the Big Dipper. The color of the star of the higher self or soul, above the crown, is also violet. It is the color of Divine or Soul energy.

It has properties of other Chi colors. It has a rapid regenerating effect on damaged organs and nerves. Always use green and blue light before using violet. Violet light develops the crown center, the spiritual core. It is good for psychological ailments as well as for physical deficiencies.

K. Activate the Immune and Defense System

The body has various mechanisms which combine to provide protection and defense against illness and disease. These mechanisms enable the body to produce various cells and bodies which act against invading or unwanted substances. As soon as a foreign body is recognized, the immune system will be triggered and will act to provide the most efficient means of eliminating the danger and return the body to a balanced state of health. A strong and healthy body will have good resources to protect itself from negative or sick energy. The aim of these practices is to help you to realize the potential of true harmony within yourself. To activate the immune and defense system is to increase the production of red and white blood cells. To do this we activate the bone marrow and lymphatic system. Guide the student or whole group together in all of these steps. You will not lose energy by doing this. You will gain more energy because you are all connected together in the group power. The crucial part is to multiply your good intentions, Chi and virtue energy into the cosmos, making yourself and each person a direct line from the Universe. After you finish the General Healing session you can tailor the healing techniques in the next chapters to the individual's needs.

Practice

A. Three Minds into One Mind

1. Smile to the Inner Universe

Place your palms together in salutation, in front of your heart. Feel the Laogong points in your hands connect, creating an energy loop running from your heart through your arms and hands and back again.

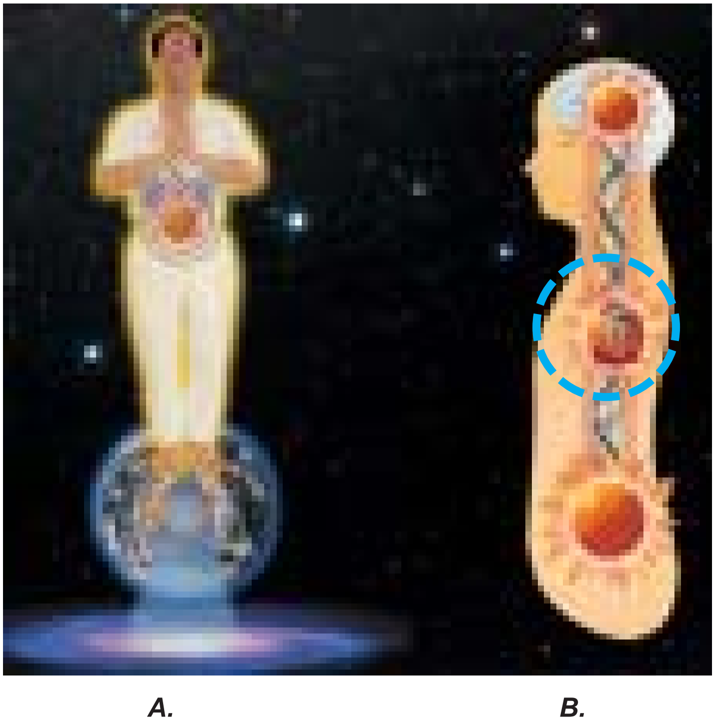

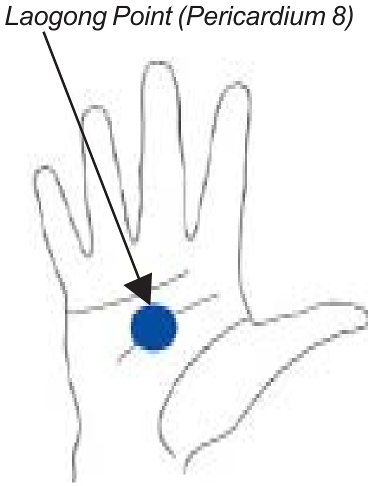

Fig. 4.1 A. *Empty the mind down to the lower abdomen.*
B. *Activate the heart's compassion.*

2. Activate the Heart Compassion Energy

Smile to the heart and feel it softening. Feel love, joy, compassion and happiness. Smile down and empty the mind to the Tan Tien, the Abdominal Brain. Fill the Tan Tien with Chi and start to spiral. When the abdomen is warm, it is full of Chi. The Chi can then charge up to the brain.

3. Combine the Three Minds into One

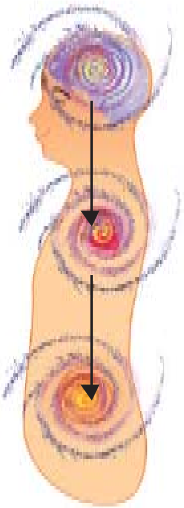

1. Turn Upper Mind to observation mind.
2. Turn consciousness (Middle Mind) down to Lower Tan Tien.
3. Combine three minds into one mind at the
   Lower Tan Tien (the Yi).
4. Manifest out at the mideyebrow.

Fig. 4.2 *'Three Minds into One'.*

B. Activate the Six Directions

Expand the awareness to connect to the universe and the Six Directions at the crown, mideyebrow, heart and Tan Tien.

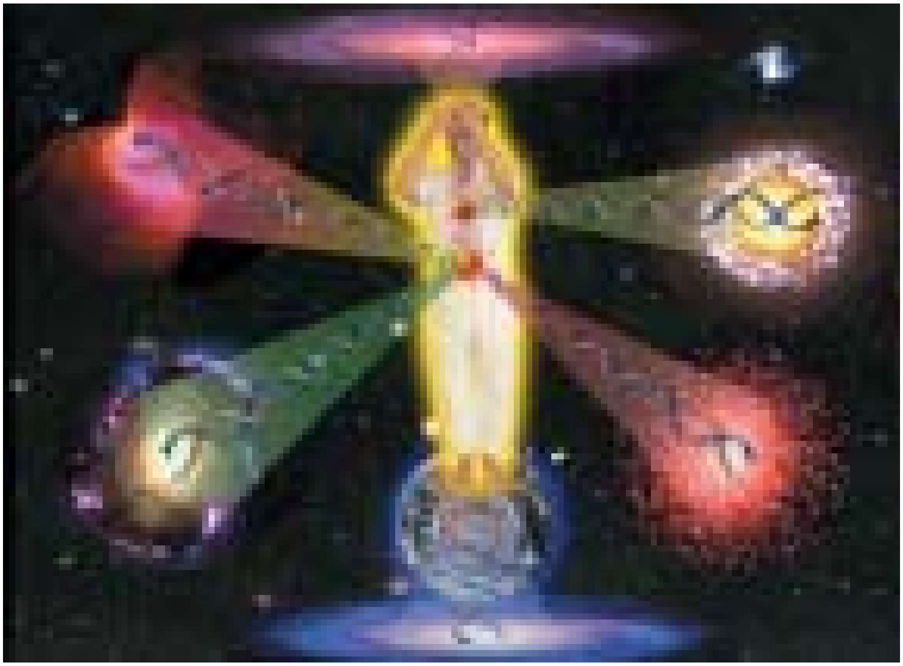

Fig. 4.3 *Trust and believe - turn visualization into actualization.*

C. Activate the Three Fires

1. Tan Tien Fire - Activate the Tan Tien Fire:

Smile down to the abdomen to create a burning stove near the lower lumbar and sacrum. Create a fire ball behind the navel, above the stove.

2. Kidney Fire - Activate the Kidney Fire:

Always retain awareness at the Tan Tien and keep it spiraling.

3. Heart Fire - Activate the Heart Fire:

Keep the heart soft and fill the heart with joy, love and happiness.

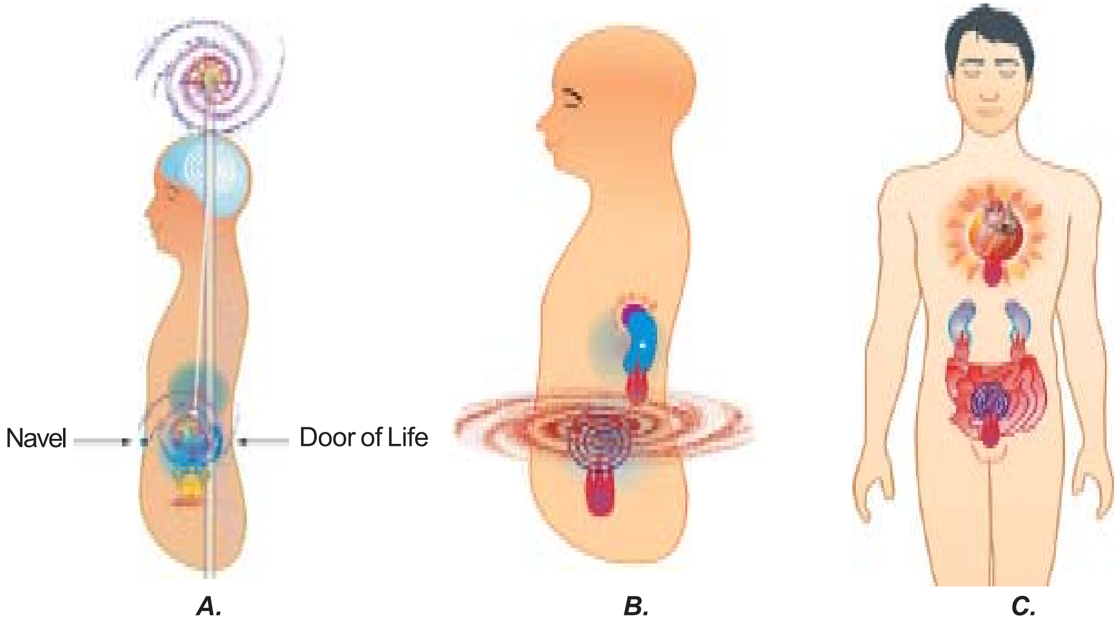

***Fig. 4.4 A.** Activate the Lower Tan Tien Fire.* ***B.** Activate the Kidney and Adrenal Fires.*
***C.** Activate the Heart Fire.*

4. Sacred Fire Triangle

The Sacred Fire Triangle has triple force. Make a triangle from kidneys to navel (Tan Tien). From the heart make the connection to the kidneys. Move from the Tan Tien up to the heart.

5. Cosmic Star and the Earth Star

At the moment of conception, the two forces yin and yang connect with such a force, then only fractions of a moment later, the two forces explode into nine different Energy Centers. Seven of them we find in the body and two of them outside the body, forming our personal stars.

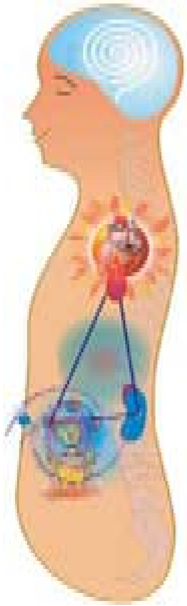

Fig. 4.5 Three Fires into One

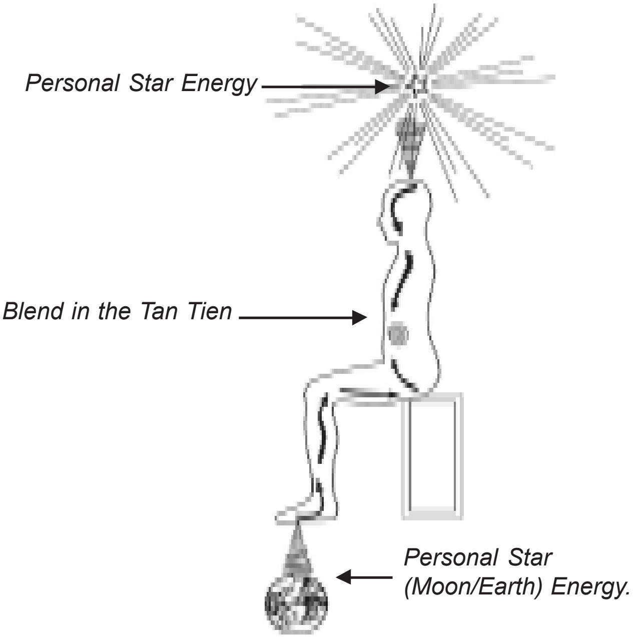

Fig. 4.6 ‘Personal Star’ Energy

The two personal stars are in fact energy centers connecting the aural field of each individual with the universal forces and the earth forces. In a way one can see the aim of Taoist Inner Alchemy in bringing these nine forces together, merging them into one force and thus enabling the return to the original force, the Wu Chi.

There is a star about six inches above your crown and another one about one to three feet below the soles of your feet. They are also known as the higher self, guidance, protector, adviser. These stars are our connection to the cosmic force, the universal force and the earth deep below us.

Always make sure your Tan Tien is warm and the sacrum and mideyebrow are breathing. Be aware of the crown breathing and see a star or a small sun above you. Be aware of the crown and feel a light beam extend out of the crown and make a connection to the star above you. Keep on breathing until you feel a strong connection. Feel how the star above you is exercising a strong pulling force on your crown. Once you feel this pull on your crown you will also feel a strong pull down from the earth. Be aware of the star above and the earth and universal force below you. Feel that both of them have a strong pull on you.

1. Reconfirm the star above you and the earth directly below you.
2. Fix the image of the North Star and the Big Dipper six to nine feet above your crown. See the cup of the Big Dipper filling with the violet light, which gathers Chi from the North Star and the universe.

3. **Reach up with your left hand, and hold on to the handle of the Big Dipper. Pour the violet light down to your personal star 4 to 6 inches above your head, in order to predigest the energy of the violet light. Then let it flow down to your crown, into the Upper Tan Tien, to be processed and flow down to the heart center (Middle Tan Tien) or to the back of the head down to C-7 (Cervical 7) and T-2 (Thoracic 2) and down to the palms.**

   In Taoism we consider that the North Star emits a violet light, which is regarded as the highest healing light and the Big Dipper as emitting a red light.

   You can do these meditations sitting, or standing in the Chi Kung posture. The standing position will support a stronger structure and provide a better connection with the earth.

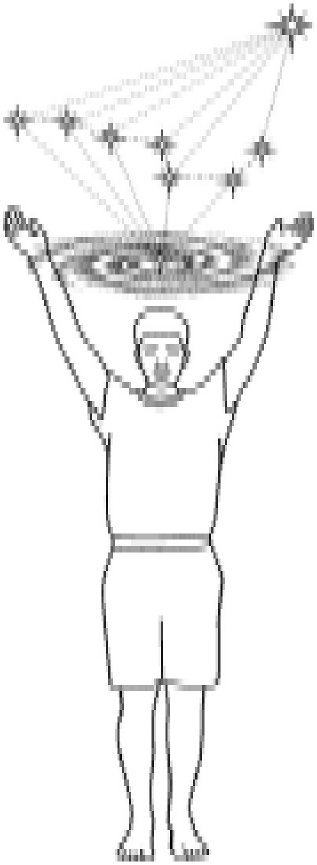

Fig. 4.7 *The North Star, Big Dipper and Galaxy spiral above.*

4. Always remember to breathe in slowly so you can process the awareness of the Lower Tan Tien. Feel a suction, warmth (Chi) and continue to breathe in and be aware of the suction of the crown, North Star and Big Dipper above you.

D. Linking Personal Stars, Energy Bodies and the Universe

Be aware of your ‘personal stars’ above and below and connect to other peoples’ stars and energy bodies.

Three minds unite, one mind aware of the stars above you and a star below you. Connect these stars to the people around you. Think about the bright light above the crowns of other people. Start to spiral your energy to connect to each of them. Group all the stars into one energy body and connect all the way to the center of the universe.

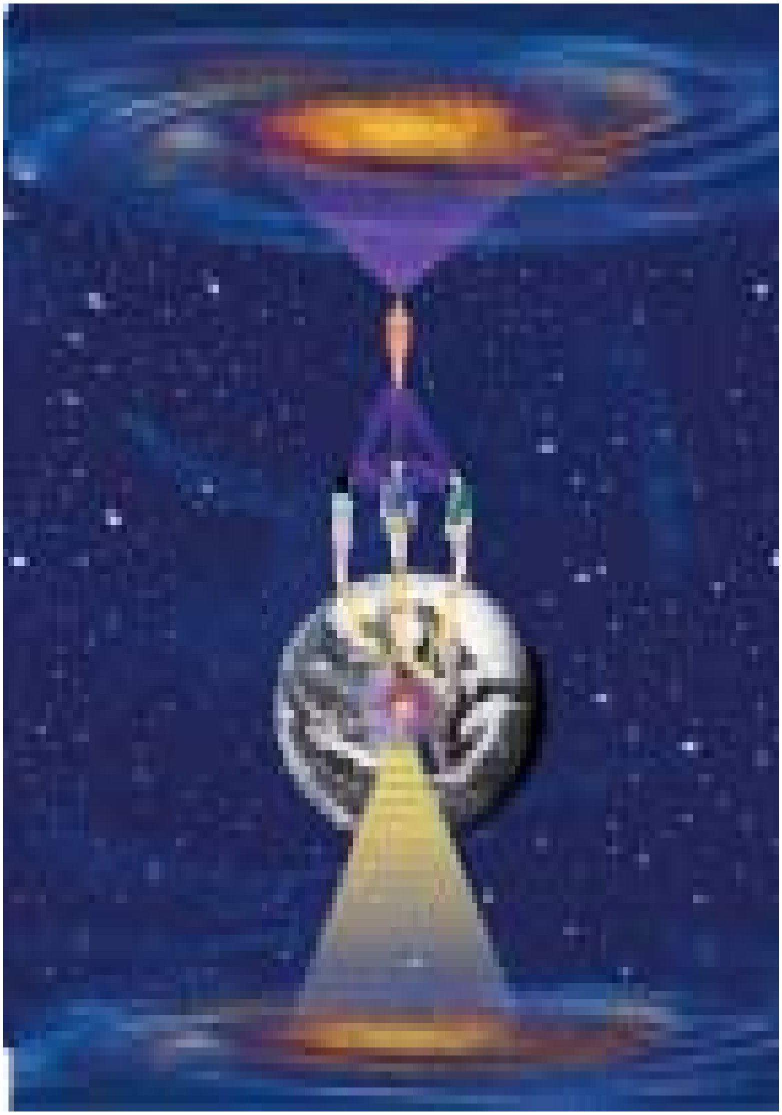

Fig. 4.8 *World Link Meditation*

1. Center Channel and Personal Star above

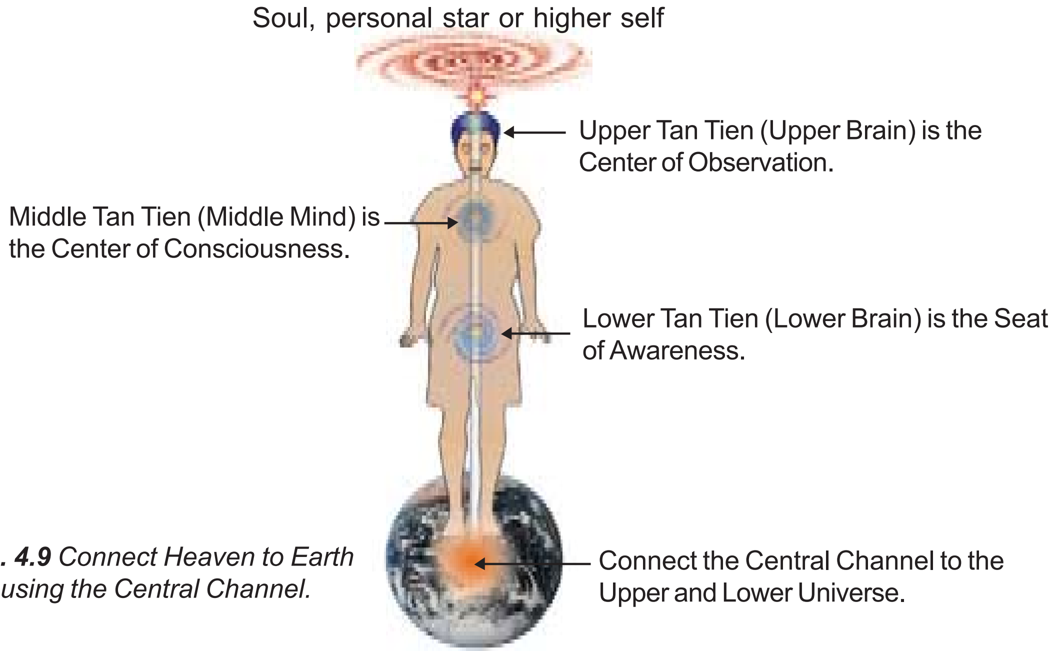
Soul, personal star or higher self
Upper Tan Tien (Upper Brain) is the Center of Observation.
Middle Tan Tien (Middle Mind) is the Center of Consciousness.
Lower Tan Tien (Lower Brain) is the Seat of Awareness.
Connect the Central Channel to the Upper and Lower Universe.

Fig. 4.9 *Connect Heaven to Earth using the Central Channel.*

2. Use Yi power to connect to your Personal Star above

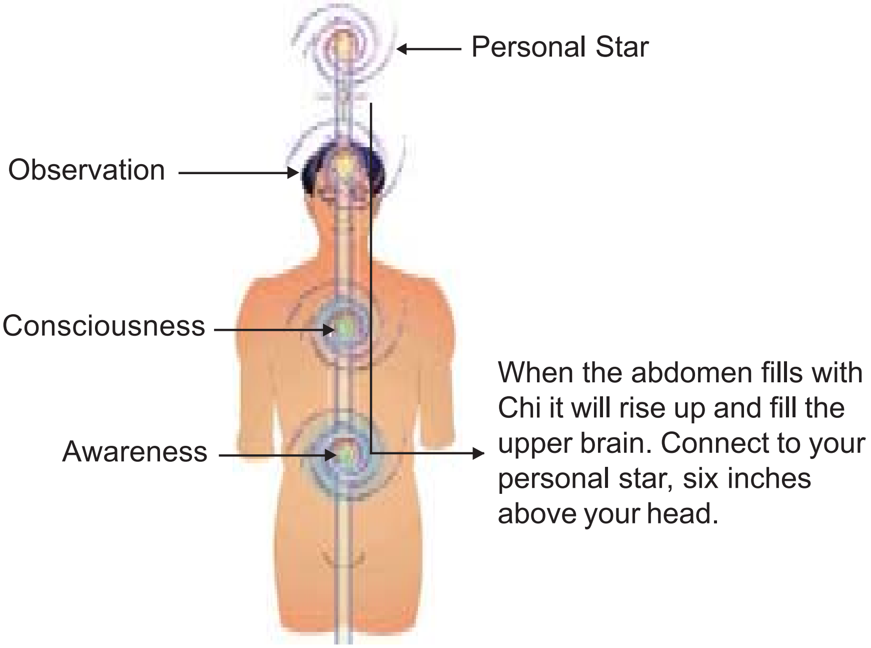
Personal Star
Observation
Consciousness
Awareness
When the abdomen fills with Chi it will rise up and fill the upper brain. Connect to your personal star, six inches above your head.

Fig. 4.10 *Connect to your Personal Star Energy using 'Yi' Power.*

3. Connect your Personal Star to the Personal Star of each person

Connect your personal star to each person and then to the universe.

4. Create a Chi Body becoming the major connecting point. Counterclockwise spiral to connect each person's star into a larger group star.

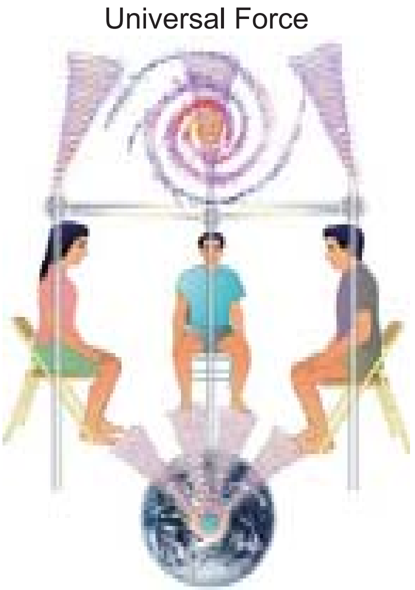

Fig. 4.11 *Link with Each others Personal Stars.*

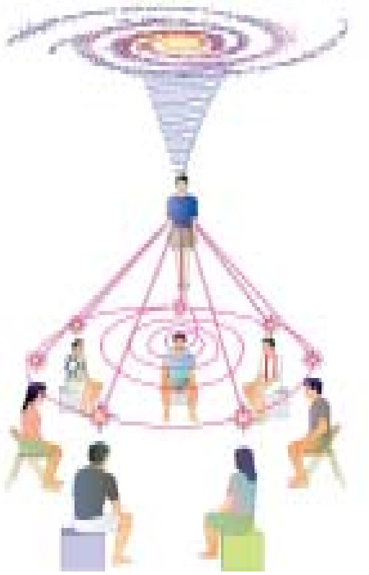

Fig. 4.12 *Connect into Group Star.*

5. Meditators become satellite links and create a group energy body.

The World Link meditations become an integrated communication link. They are linked to the earth and the universe. Spiral and connect each person's star together and group the energy into one energy body. This energy body becomes an integrated communication center for each person in the group. We can be connected, wherever we are. Each person can connect and become their own 'Center of the Universe'.

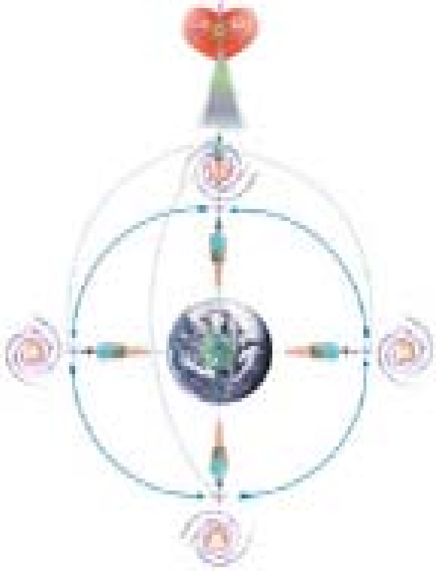

Fig. 4.13 *Form a Satellite Link and create a Group Energy Body.*

E. Protective Circle and Chi Field

Raise your hand up and become aware of the 'Sacred Fire' in the universe. Feel that your fingers are very 'big', very 'long' and touch the fire. Bring the fire down. Make a circle around your community, your house, Tao Garden, the meditation hall and around your bodies. Create an energetic field of Chi around the whole room.

Sacred or Chi Fire
Connect and Receive Fire from the Universal Cauldron

1. Activate the Sacred Fire in the Universe

Be aware of yourself. Feel your arm and fingers 'big', 'long' and 'hollow'. Reach to the universe to the Sacred Fire. Let the Sacred Fire fill and pack your arm.

2. Use Yi-Power to Create Sacred Fire Protective Circle

Use the Yi Power to draw the Sacred Fire Circle on the ground around your house, office and the room you work in.

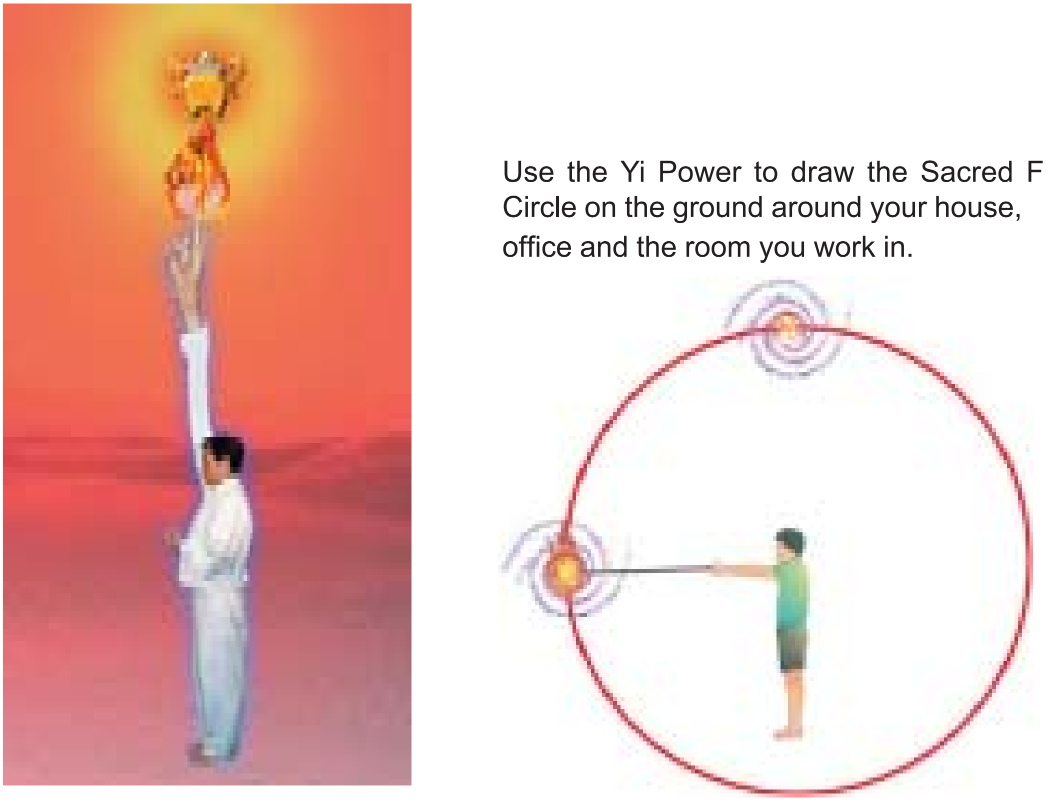

A. *B.*

Fig. 4.14 A. *Create a Group Energy Body.* ***B.*** *Sacred Fire 'Protection'*

3. Create a Chi Dome

Set up the 'guardian animals', Blue Tortoise in the north, Red Pheasant in the south, Green Dragon in the east, White Tiger in the west, Yellow Phoenix above and Black Tortoise below.

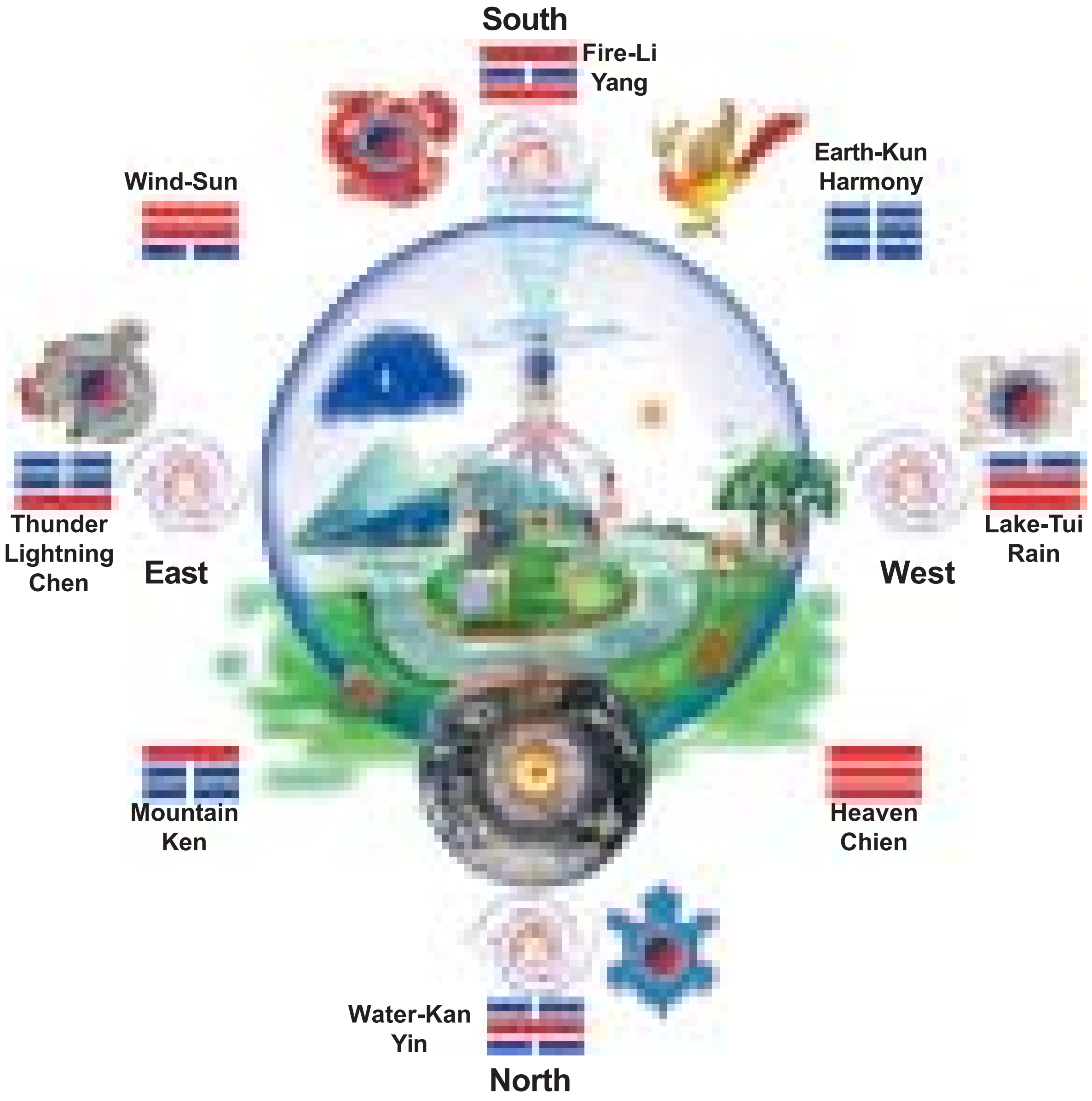
South
Fire-Li
Yang
Wind-Sun
Earth-Kun
Harmony
Thunder
Lightning
Chen
East
West
Lake-Tui
Rain
Mountain
Ken
Heaven
Chien
Water-Kan
Yin
North

Fig. 4.15 *Create and surround yourself with a Chi Dome and the Guardian Animals.*

4. Activate the Eight Elemental Forces of Nature and the Universe

Activate all eight forces; wind, mountain, fire and thunder on the east. Earth, lake, water and heavenly power on the west.

Call the Eight Forces; fire, water (ocean), thunder (lightning), lake (rain), earth, mountain, wind, and heaven.

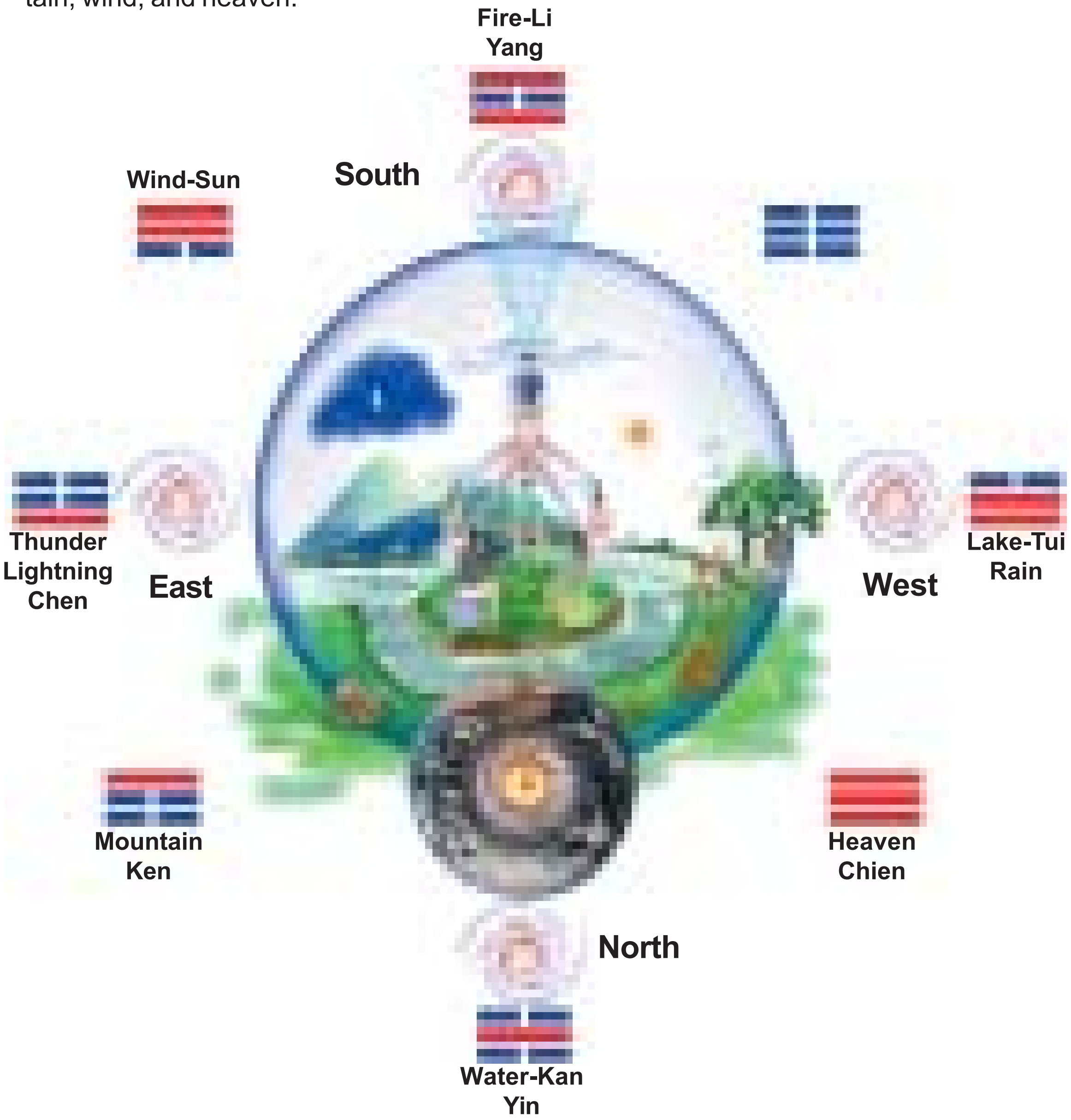
Fire-Li
Yang
Wind-Sun
South
Thunder
Lightning
Chen
East
West
Lake-Tui
Rain
Mountain
Ken
Heaven
Chien
North
Water-Kan
Yin

__Fig. 4.16__ Activate the Eight Forces.

In the next sections F,G,H,I are practices that are for cleaning the cells. The more you clean the cells the more the Cosmic Healing can take place.

F. Chi (Sacred) Water Practice

The Sacred Water practice (also known in the West as Holy Water) is to exercise the right of being the creators of the Cosmos. With strict and absolutely regular daily water intake to prevent the stresses and associated damages of dehydration, the chief conductor and supervisor of the body's well being – tryptophan and its neurotransmitter derivatives, serotonin, tryptamine and melatonin will be well positioned to regulate all functions. Regular daily walks will keep muscles well coordinated and correct any physiological processes that are established in the body as a result of anxiety or emotional stress.

A well hydrated and healthy skin needs water to constantly replace that which it loses to the outside environment. This then allows blood vessels to the face and the body to open up and provide necessary nourishment for exposed skin cells.

Science has discovered that even if we clean water through filtration processes, although it may look and taste alright, closer analysis using high powered microscopic technology, indicates that its cell structure is 'unclean'. Water, like humans, maintains the memory of its old 'self'. We store our 'memory' within our DNA; water stores its memory within its cells.

The world is about 70% water

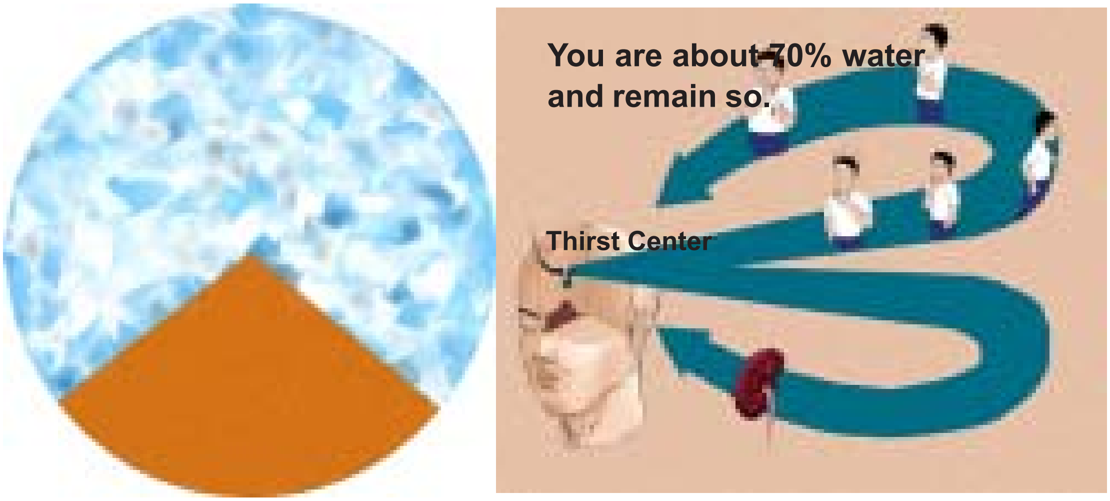

Fig. 4.17 *Water is Life.*

The following three pages contain extracts from the book ‘The Message from Water’ by Masaru Emoto. It advises us that ‘water is telling us to take a closer look at ourselves - water is a mirror reflecting our mind.’

水からの伝言

After offering a prayer
to the Fujiwara dam
the message is reflected
in the water.

When we project Chi and love into water and then freeze it; it will turn into a ‘regular’ and well structured crystal. If we project negative energy into water, the opposite will apply. Our projections will access the cellular level, clean out the polluted cells and reprogram those remaining with the essence of our affirmation.

When we project a nice, loving instruction or thought into water, like ‘let’s do it’ the water will pick up this vibration and restructure itself. If we project negativity into the water, like a command, ‘do it!’, the water will acknowledge this accordingly. When we look into a pond we see our image. If we drink a glass of negative image water its destructive energy will enter our system and attempt to multiply.

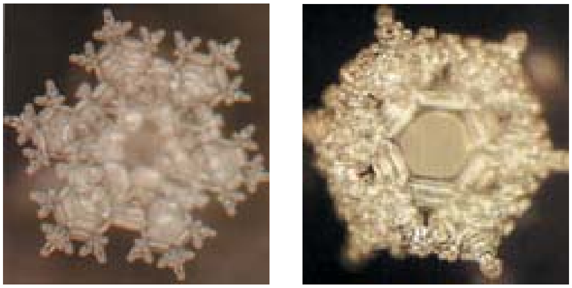

Chi and Love **Love-Appreciation**

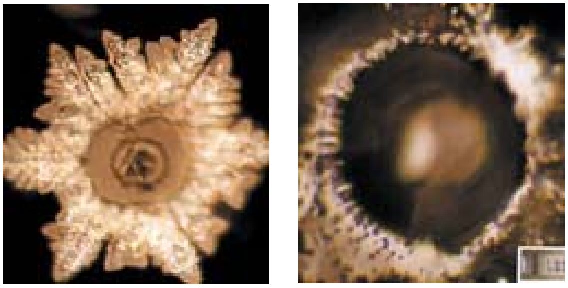

Let’s do it **Do it!**

Fig. 4.18 *The Human Body consists of 70% Water.*

Research has demonstrated that if we completely filter polluted water, using every process available, it will still maintain its old vibration and unstable structure. It will maintain memory in the same way that a computer does. We must therefore reprogram the cells with our intent.

If the water we drink contains too many pollutants and antioxidants it will eventually poison us.

As we can see from these pictures, there is an enormous difference between natural spring water and regular city water. It is now quite clear that if we program water so that it becomes, sacred, holy or Chi water, then it will have the power to remove all antioxidants and pollutants – all sickness. It will have the power to reprogram the water within our bodies, to carry the same pure structure.

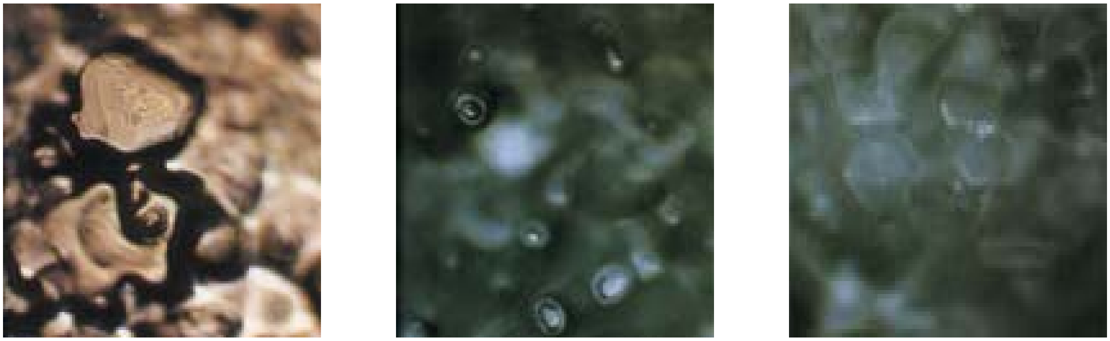

Tokyo Tap Water **London Tap Water** **Paris Tap Water**

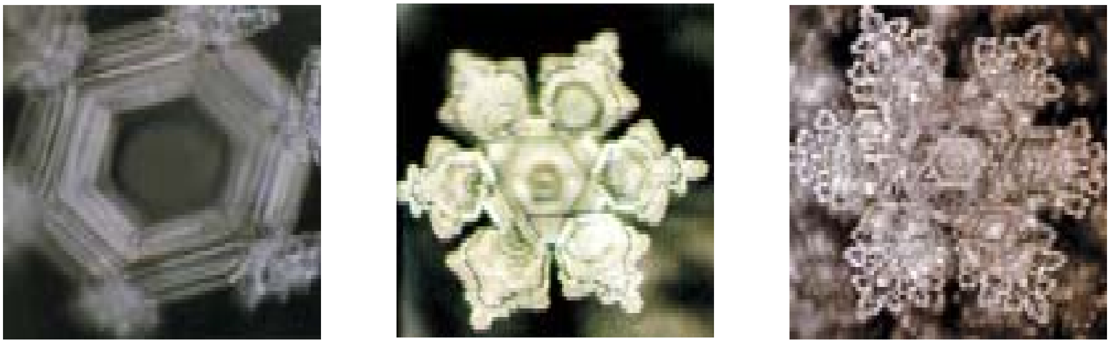

Under Ground Water in Northern Island, New Zealand **Buenos Aires, Argentina** **Spring Water of Saijo, Hiroshima Prefecture**

Fig. 4.19 *Healing or hurting?*

We can also use music to program a vibration into water. Classical music will create a vibration that synchronizes with our own health, whereas heavy metal music will have a tendency to ‘shatter’!

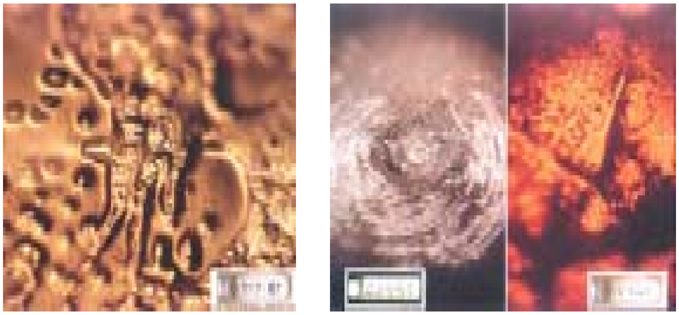

“You make me sick”, or “I will kill you”. **You Fool**

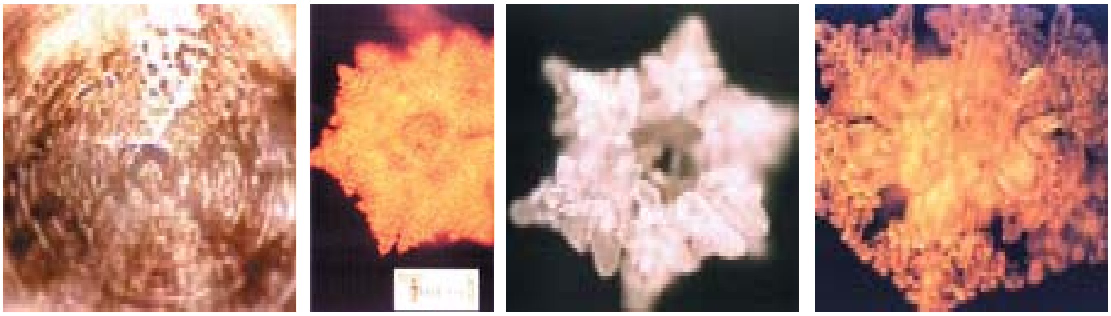

Heavy Metal Music **Thank you** **Folk song of Celtic Region in UK** **Healing Music**

Fig. 4.20 *Power to heal or harm?*

Similarly, when we program our emotions regarding other people into water, the effects are the same. If we think negatively of someone, then the response will produce a bad vibration. If we think kind, loving thoughts then the structure will be like a beautiful crystal. If we love Mother Theresa and send this energy into the water, a wonderful crystalline structure will be created. Sick water can be transformed into healthy water. Healthy water can be transformed into sick water. The human body consists of 70% water. The key is your intent and your ability to believe that healing comes from the nature of your vibration. Always be open to receive.

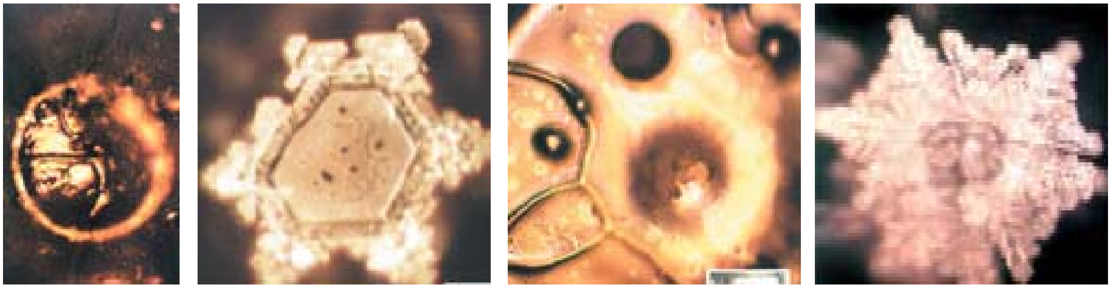

Adolph Hitler **Mother Teresa** **Dirty** **Beautiful**

Fig. 4.21 *Sick or saintly?*

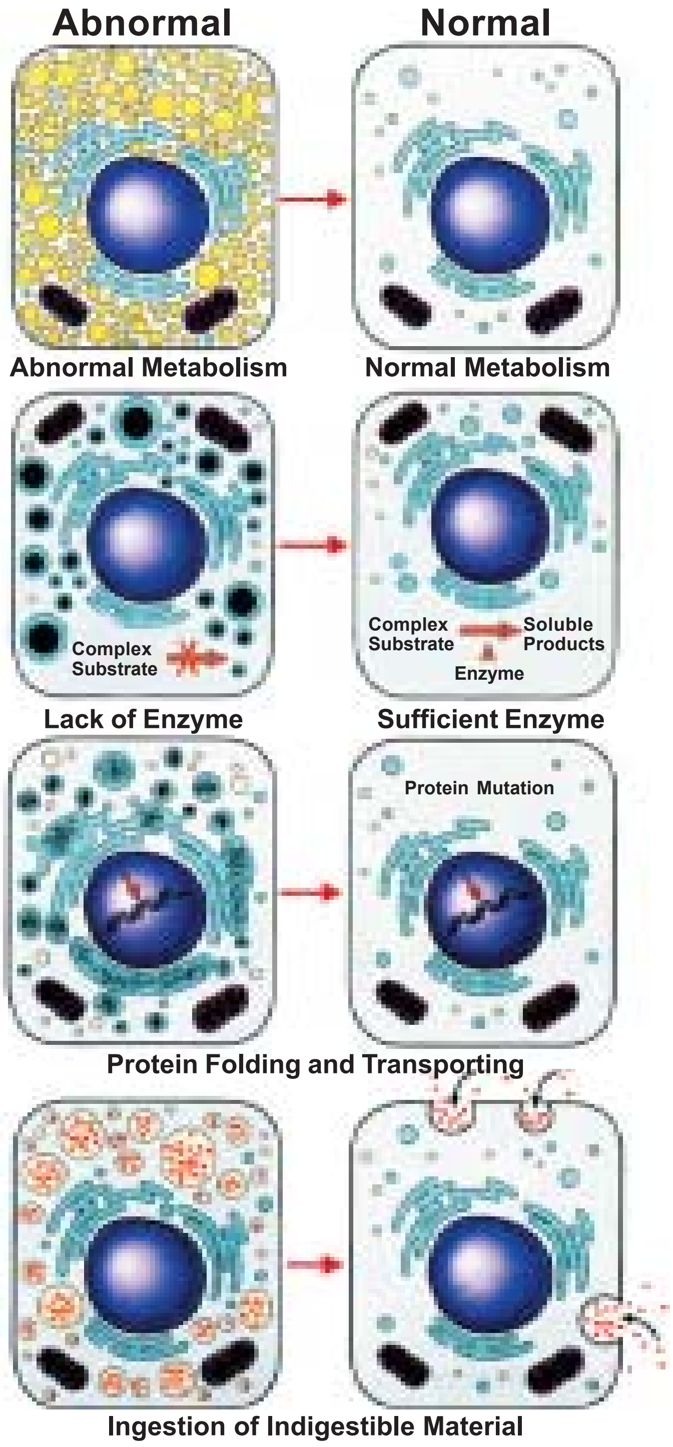
Abnormal
Normal
Abnormal Metabolism
Normal Metabolism
Complex Substrate
Complex Substrate
Soluble Products
Enzyme
Lack of Enzyme
Sufficient Enzyme
Protein Mutation
Protein Folding and Transporting
Ingestion of Indigestible Material

Fig. 4.22 *With the Power of the Sacred Water Abnormal Cells can be cured.*

A positive mental attitude will be transmitted into the cells of the water contained within our own body. We must consciously practice inner work until it becomes reflexive.

Outline of Sacred Water Practice

Invoke the power of the Sacred Water practice to cleanse and heal the body's sick, toxic or negative energy. **If you are working with a group of people, direct your energy through the energy body overhead and into each person's star, as you guide them through the procedure**.

I. Hold a glass one quarter full of water in your left hand, folding the middle and the ring fingers into the center of the palm.
II. Hold the glass in front of your body as you point the 'Sword Fingers' of your right hand up to Heaven.
III. Make a request to receive healing energy and feel yourself touch a heavenly pool of sacred water energy. Feel the pool pouring down heavenly water to fill your arm.
IV. Place your fingers on the cup and ask:
Command 1: ***"Yin power and good fortune come from the east. Yin power please dissolve all negative energy, all sickness and bad fortune".*** Make a cross over the top of the cup.
V. Bring your arm down and point the sword fingers around the inner rim of the glass. Smile as you circle the fingers around the rim.
Command 2: ***"By my request. Please carry out the order now."*** Repeat this three times, charging the water with Yin Power. Project your thoughts into the water.
VI. Use the thumb and index finger to remove the sick energy from the cup, without touching the water. Do this three times. Talk to the sick cells. Tell them to listen to your command:
Command 3: ***"All sick cells please listen: Clear, clean and bright, this Sacred Water will take all the sickness away."***
VII. Repeat the order and visualize yourself removing the sick energy from the cells and giving it to Mother Earth for recycling.
VIII. Hold the cup with both hands near your heart.
Command 4: ***"This Sacred Water will give me/you health, wealth and longevity."***
Project love, joy, thankfulness, gratefulness, appreciation and the energy of compassion into the cup.
IX. The Sacred Water will carry the message of the practice to all the cells, where it will remain. If you are practicing in a group, drink the water in unison. If you are working with a student, pass them the glass to drink using both hands.

Step I: Prepare the Hands and Arms to Receive the Universal Chi

Left Hand Position: Prepare to hold a cup or glass with the left hand by folding the ring and middle finger into the center of the palm. Hold the glass in front of the body.

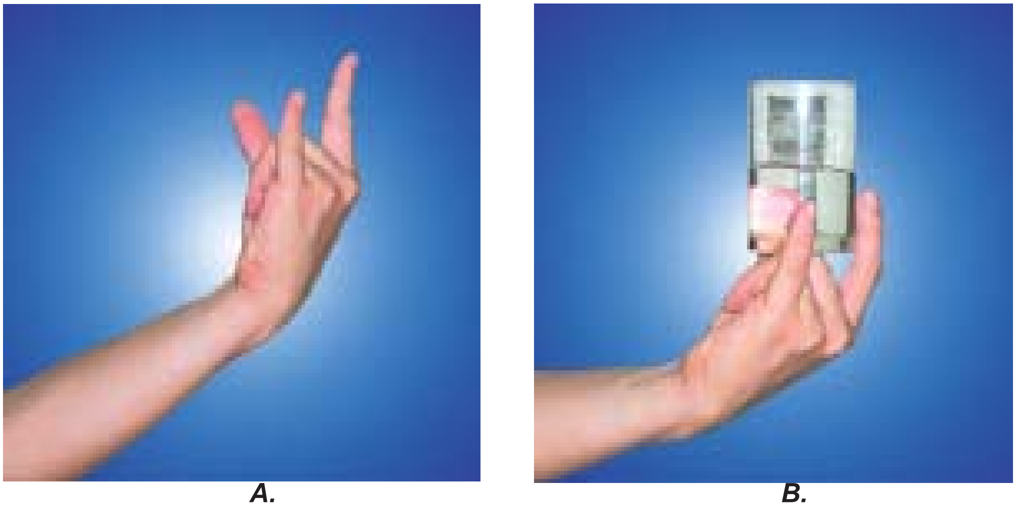

Fig. 4.23 A. *Fold Ring and Middle Fingers.* ***B.*** *Hold Glass in Front of Body.*

Step II: Prepare the Sword Hands to Receive the Universal Chi

Right Hand Position: Form the right hand into a 'sword hand' by folding the pinkie, ring fingers and thumb into the palm. Straighten and hold the index and middle fingers together and extend them upward.

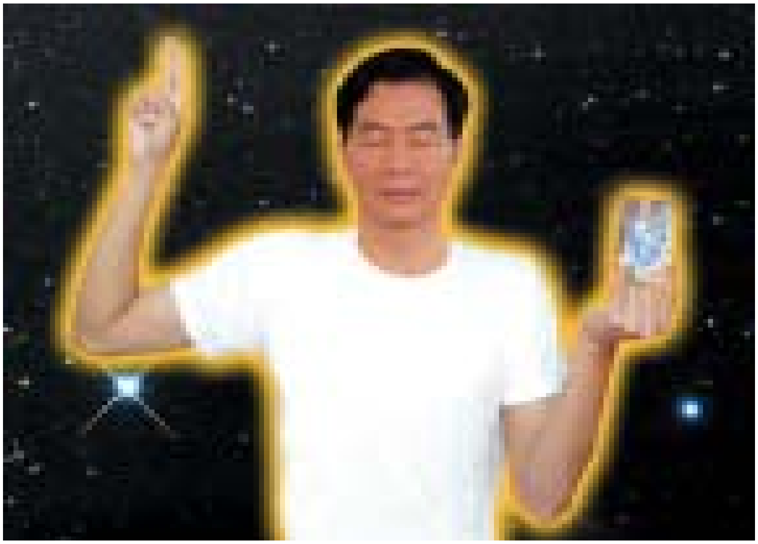

Fig. 4.24 *Prepare to receive the Universal Chi.*

Step III: Fill your Arm with the Power of the Heavenly Pool

Sense the sword fingers and the arm as being 'long' and 'big' as you raise them towards Heaven. Sense that the middle of the arm is hollow and bottom is sealed at the shoulder. The mind's attention is focused on merging with the primordial Chi of the Universe, the energy of your thoughts will be multiplied.

As you make your request to the Universe, feel that you are touching a heavenly pool of Sacred Water Energy. Feel that the pool is pouring down like a waterfall to fill the arm. When it is full compact, compress the Sacred Energy into it as much as you can.

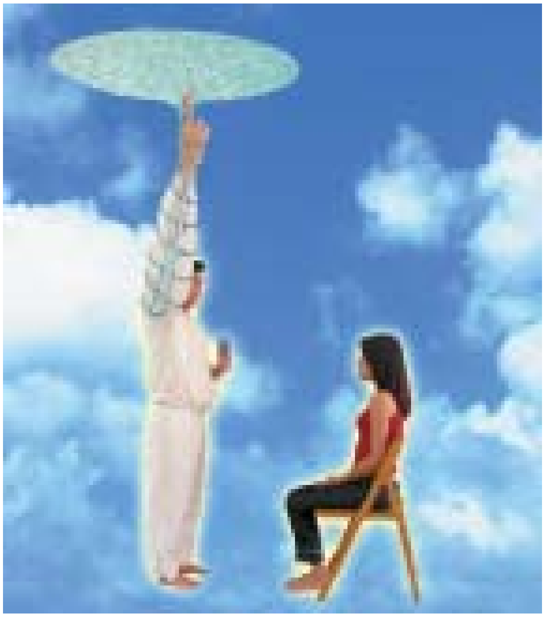

Fig. 4.25 *Touch the Heavenly Pool.*

A. ***B.***

Fig. 4.26 A. *Blessing Sacred Water in Russia.* ***B.*** *Opening the Third Eye in Russia.*

Step IV: Make the Cross on the Top of the Cup

Put Sword Fingers on top of the Cup. Ask for the Yin Power: **Command 1:** ***"Yin Power and good fortune, come from the east. Yin has the power to dissolve all negative energy, all sickness and bad fortune."***

Command 2: Make the cross on the top of the cup and say ***"By my request......"***.

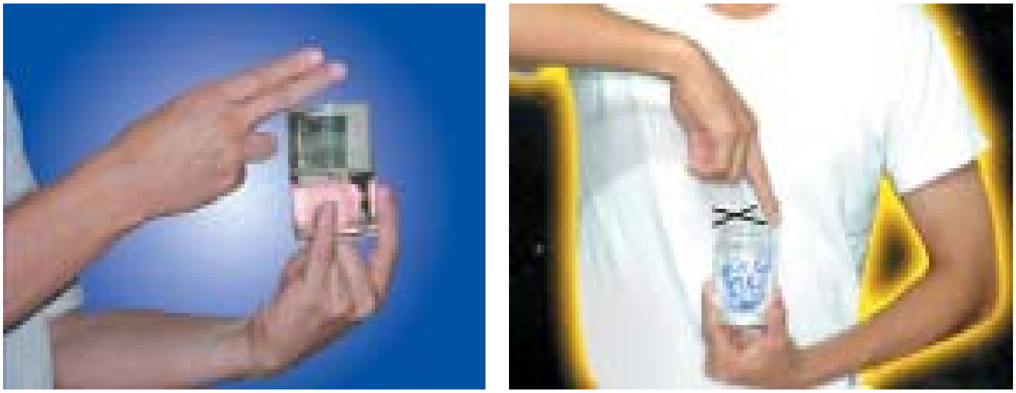

Fig. 4.27 *Give the command: "Fortune comes from the East - Yin has the power to dissolve all negative energy, all sickness and bad fortune. By my request....".*

Step V: Charge the Water to Transform it into Sacred Water

Bring your arm down and point the sword fingers into the glass of water. Smile and circle the sword fingers around the inner rim of the glass.

Continue to order: ***"Please carry out the order now."*** Repeat 3 times to charge the water with the Yin Power. As you do this, project a good thought into the water.

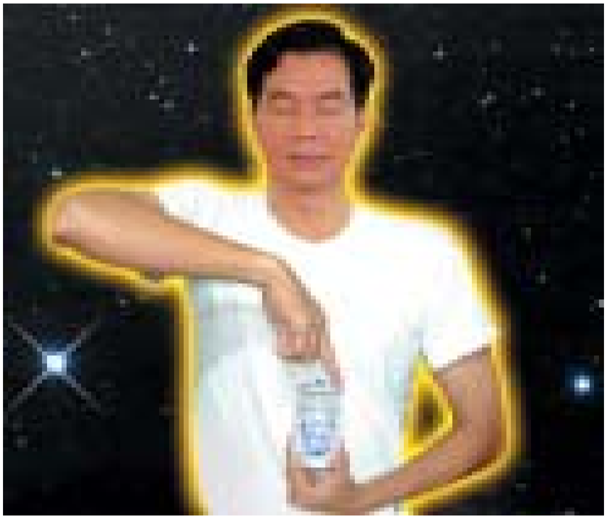

Fig. 4.28 *"Please carry out the order now" Repeat three times, charging the water with the yin power.*

Step VI: Command 3: *"All sick cells please listen : Clear, Clean and Bright, this Sacred Water will take all the Sickness away."*

Give the above command. Use the thumb and index finger to pick up sick energy from the cup, without touching the water. Do this three times.

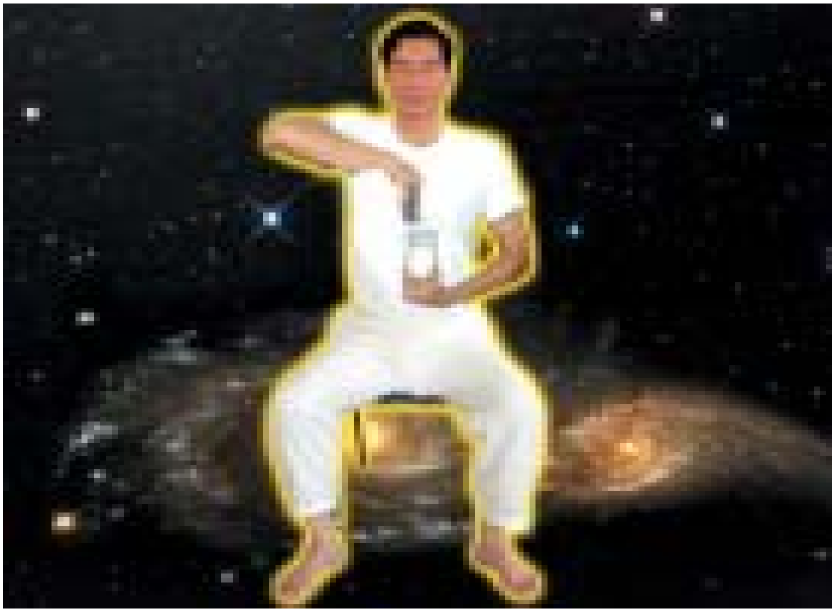

Fig. 4.29 *"All sick cells please listen: clear, clean and bright, this sacred water will take my/your sickness away".*

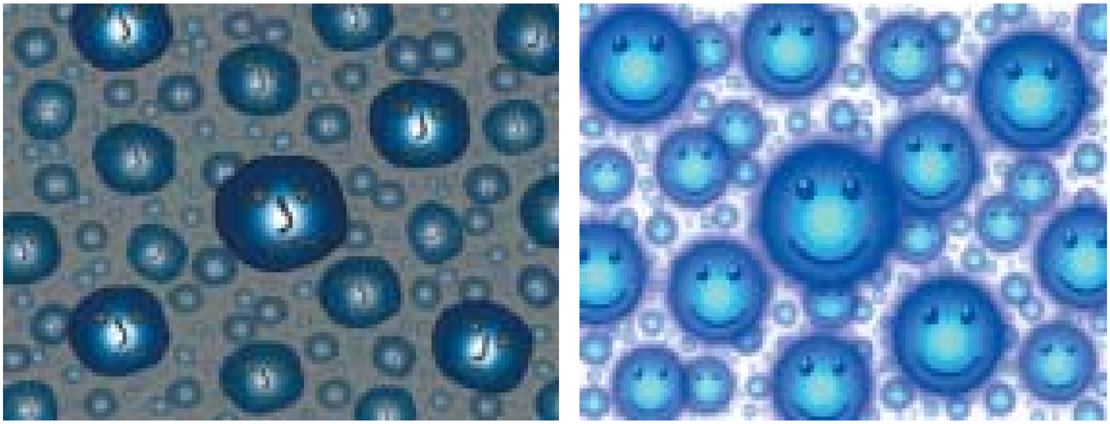

A.

B.

Fig. 4.30

A. *Ask for the power to see the cells - if they are toxic and dark, ask for them to be cleaned out.*

B. *"Clear, clean and bright".*

Step VII: Let go of the Sick Energy to be transformed by the Earth

As you **repeat** the order, picture yourself removing the sick energy from the cells and discarding it down into the Earth to be transformed and recycled.

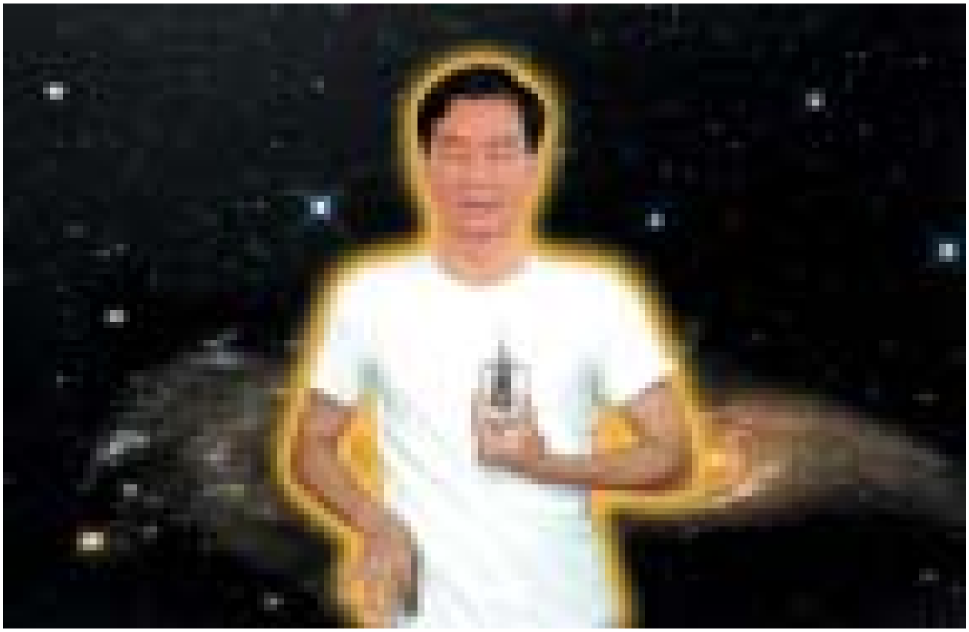

Fig. 4.31 *Sick Energy return to the Earth.*

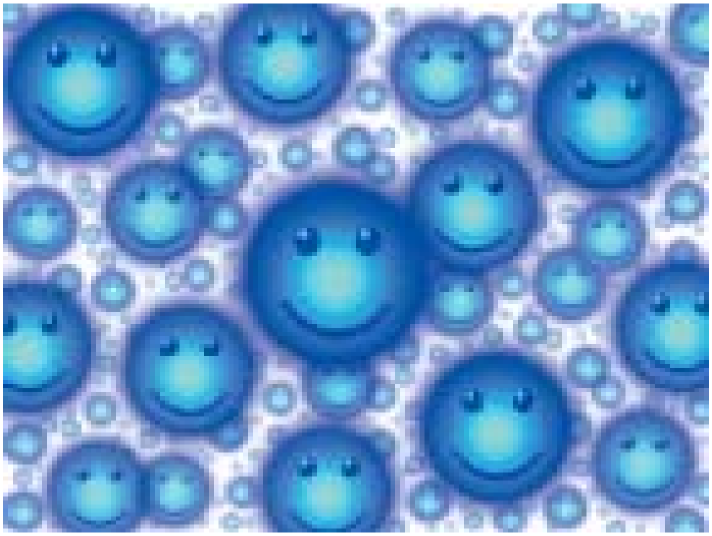

Fig. 4.32 *See the Cells become Clean, Bright and Smiling.*

Step VIII: Fill the Water with Compassion

Hold the cup with both hands near the heart and project goodness into the water. **Command 4:** ***"This sacred water will give me/you health, wealth and longevity."***

Project love, joy, thankfulness, gratefulness, appreciation and the energy of compassion into the cup.

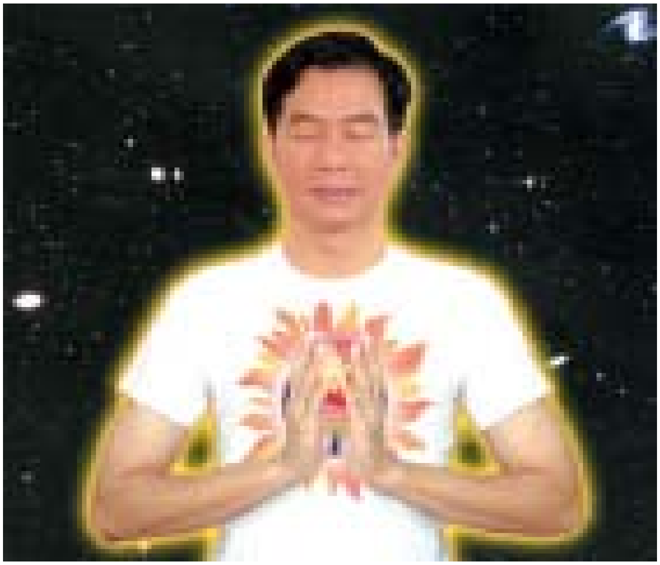

Fig. 4.33 *"This Sacred Water will give you health, wealth and longevity."*

Step IX: Drink the Sacred Water

The Sacred Water will carry the message to all the cells. It will keep the message of the Sacred Water practice in all the cells. Use both hands to pass the Sacred Water to the student you are working with, or drink it yourself and/or in unison with your group. **Feel the water go into all the cells of your body. Feel it removing the sick cells and purifying your body.**

You can also sprinkle it on to any area that requires healing.

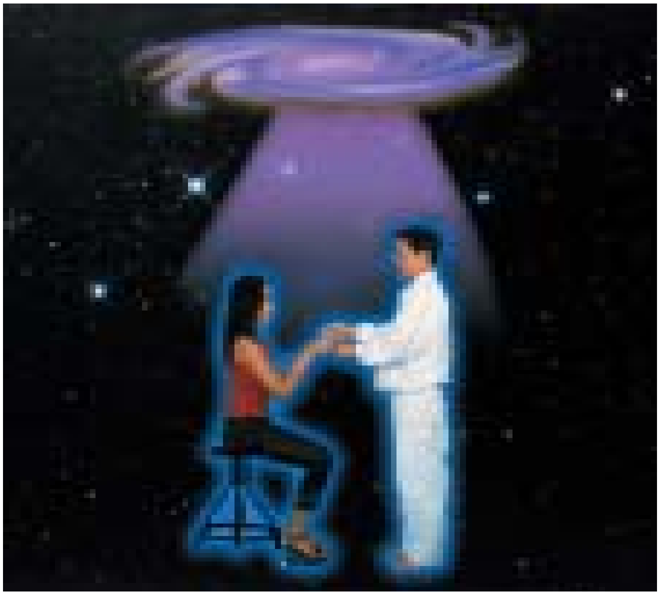

Fig. 4.34 *Drink the Sacred Water.*

G. Empty and Fill

Ask for permission to work on the student by communicating with their personal star. Point your sword hand down to the ground. Project your hand 'very big and very long' and your feet 'very big and very long' - extended down to the ground. Now very slowly inhale, bring up the earth energy. An important part of the practice is to extend a 'line' down from universe into yourself and one into the student. The line sinks through the Tan Tien into the universe below. You can send your energy up to your energy body and it will be brought down to the energy body of the other person.

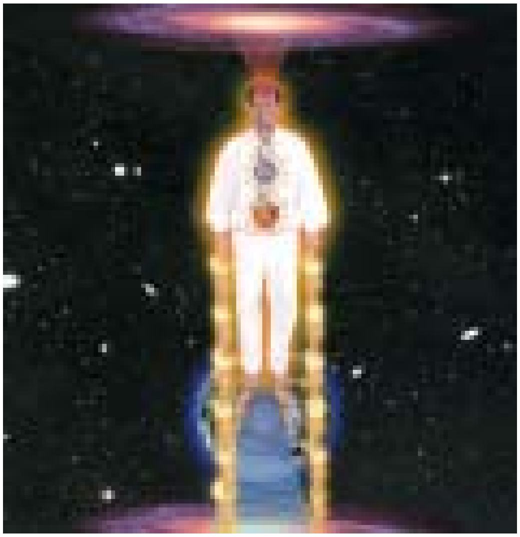

Fig. 4.35 *Feel your hands are long as down into the earth they extend.*

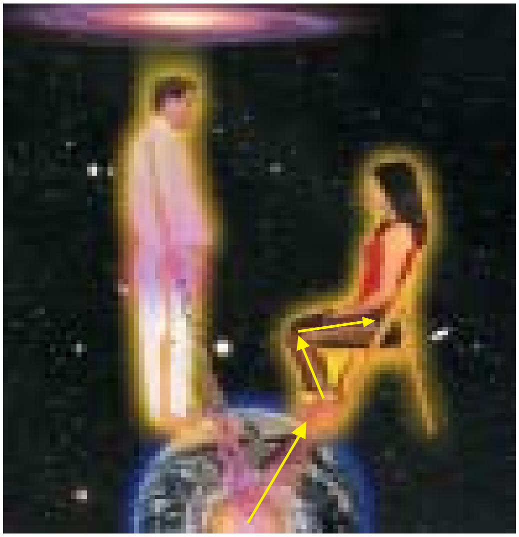

Fig. 4.36 *Project the other person's legs deep into the earth.*

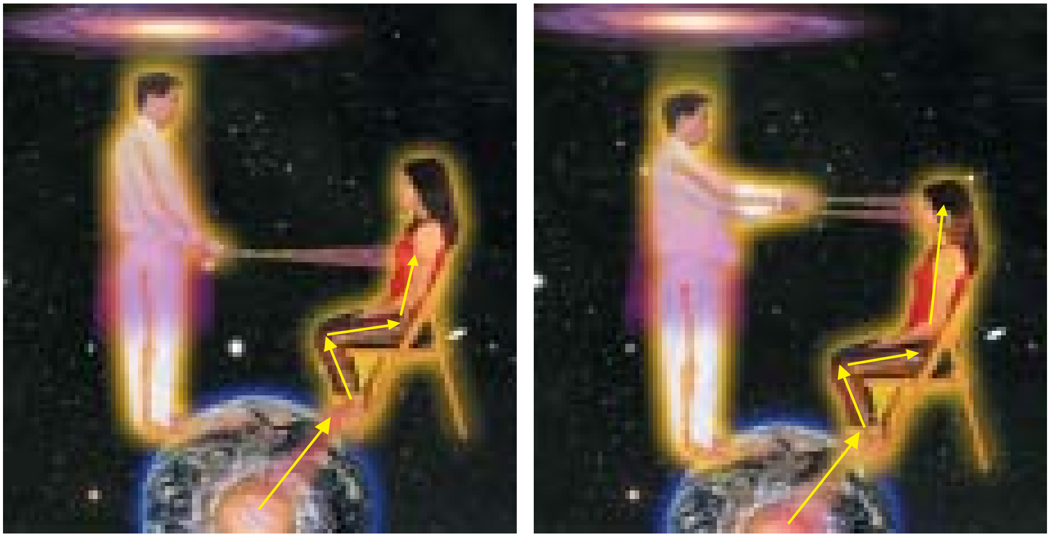

Fig. 4.37 *Blend the universal energy and Earth Chi - bring it into all of the bones and cells.*

Bring the energy up to your feet, into your bones. Let it enter all the bones, organs and cells. Feel it blending with all the sick energy. Turn your palm up, turn it back down again and exhale; let go of all the sick energy, the negative energy, the worries and the burdens all the way down to the earth. Down, down, down to the earth. Again from the earth up. Do it at least three, six or nine times. When people are very sick, you need to clean them thoroughly. Bring the earth energy up into your bones again. Feel numb, tinkling electricity flowing in all your cells. Return the energy down, down, down to the earth. Relax, let go; worries, burdens, let everything go. It is very important to say to yourself or group: **"You must let go of all your sick energy. Let go of all your burdens. Let go of all your worries, down to the earth".** Repeat it once again. Inhale from the universe and into the earth. From the earth let it enter into your bones. From the bones all the way to your inner self. Feel the energy blend with the sick energy. Exhale and let go of all your sick energy, any negative emotions burdens, worries, anxieties; release them all the way down into the earth.

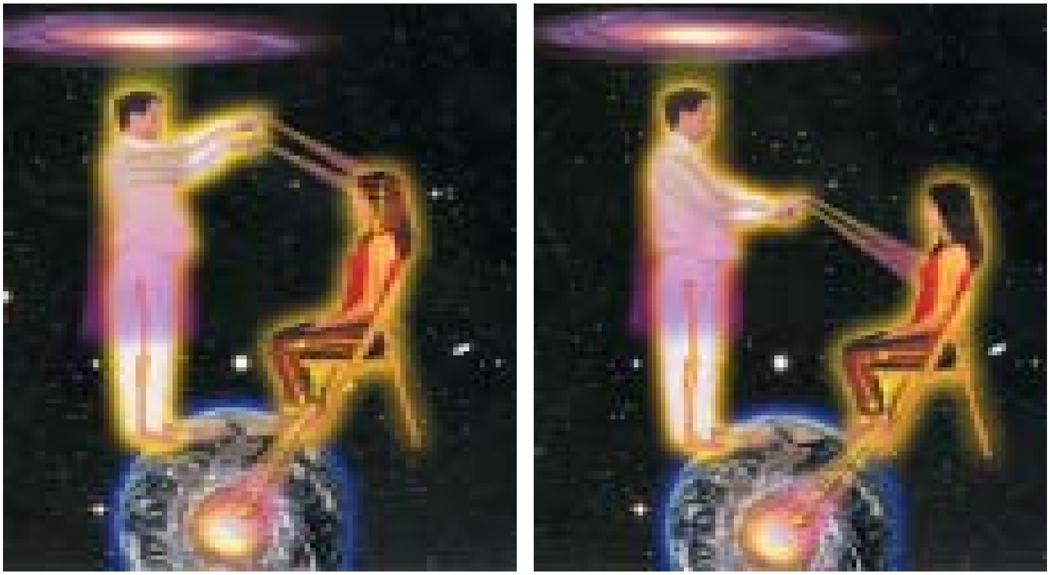

Fig. 4.38 *Bring the Universal Chi down and let it blend with the sick and negative energy. Bring it down into the earth and bury it there.*

Empty negative, sick energy, burdens, worries, go deep down into the earth. Dig a hole and bury them there - tell them "Do not come back; you will be happy there."

Feel that the feet are long and extended into the earth. The hollow bones have been compacted with compressed Chi.

Once again guide the good Chi from earth up to the fill the person again. See the cells as big as the stars and fill them with Chi to blend with the dirty and sick energy. Then empty them again down to the earth.

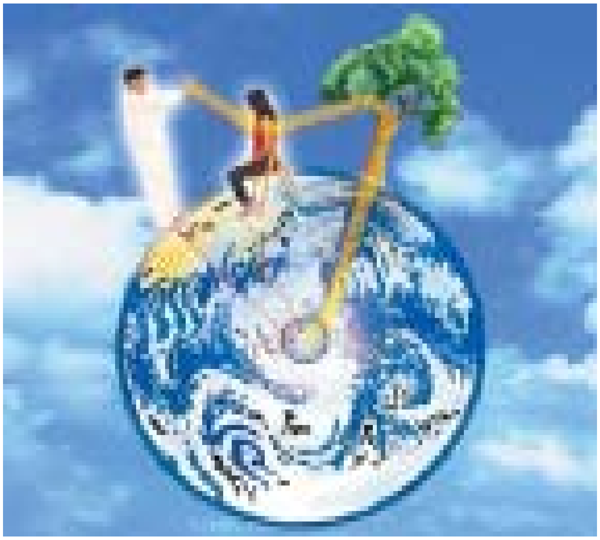

Fig. 4.39 *You can also use a Tree to guide the Chi down into the Earth.*

H. Clean with Green Light

Become aware of your liver and breathe into your throat center. Feel that you are breathing the green light into your throat center and let it blend in the Tan Tien. The Chi comes up to blend in the heart, up to the crown, spirals and goes up to the universe. Raise your hand in a spiraling motion up to the universe. Use your 'one hand' to spiral in the universe. Spiral clockwise first. Spiral green light from the universe. Now reverse, counterclockwise - multiply and spiral counterclockwise, bringing the Chi down to clean out your communities, your house, the Tao Garden, the meditation hall, your bodies and all of the people that are 'here' - fill yourselves with Chi. You will use this power to see the cells.

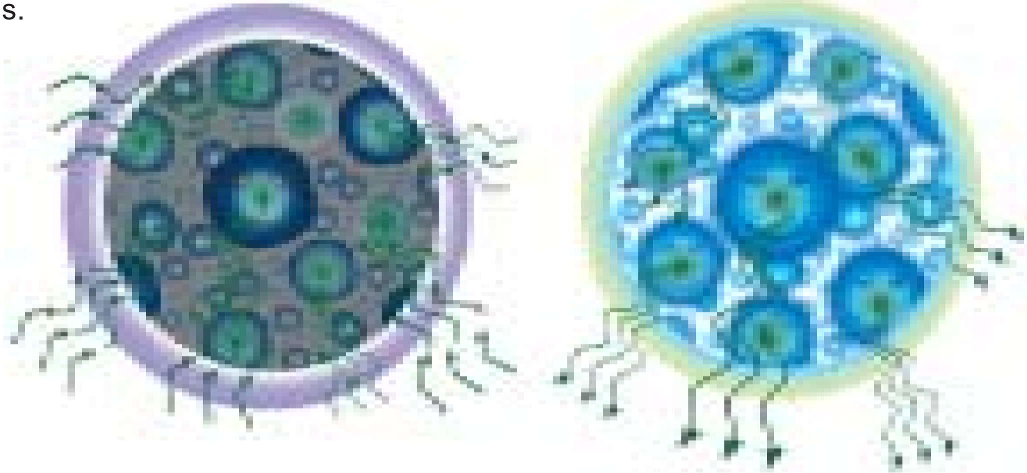

Fig. 4.40 *Spiral Sick Energy Counterclockwise down to the Earth. Smile to the Cells and let the Green Light clean out the sickness, flushing it down into the Earth below.*

See the cells enlarged and this green energy go in and blend with the dirty, black and cloudy energy. See it come out and let it go down into the earth. Dig a hole and bury it there. Tell it, "Don't come back. You will be happy down there". Become aware of the green light and spiral counterclockwise. Spiral down, cleaning out the stress. Clean out your house. Send everything down into the earth. Repeat three, six, nine, thirty six or one hundred and eight times. This depends on how much sick energy you are dealing with in your body.

Green:

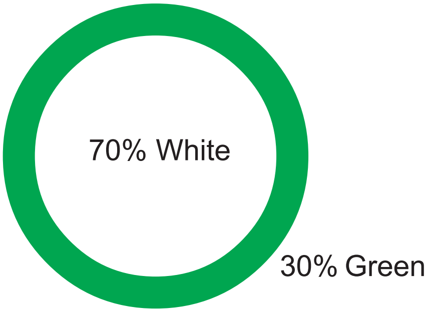

Fig. 4.41 *Clean with green.*

Green cleans and detoxifies all of the body's cells. Green Chi is mild and safe. Green Chi is used for cleansing, and as a decongestant for diseased parts. It 'loosens' the area. The light green Chi is used to break down dirty or diseased energy, like a detergent is used for washing clothes or dishes. Afterwards, the cells will be rinsed with blue light, like clean water is used to rinse the detergent and residue from clothes or dishes.

Throat Center Green

Be aware of the liver's green color, the throat and the forest. Breathe into the throat, feel yourself breathing in the green light. Guide it down to the Tan Tien, blend and move it up to the heart and the crown.

Project it to the universe; spiral and let it multiply.

Channel one direct line down to the student, one to your crown and one to your palm.

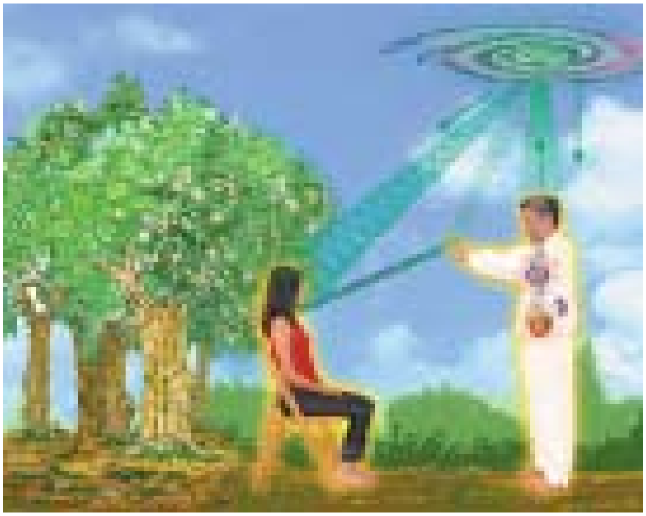

Fig. 4.42 *Blend Green Chi into the Three Tan Tiens - project to the Universe, multiply and bring the Energy back down to the Student.*

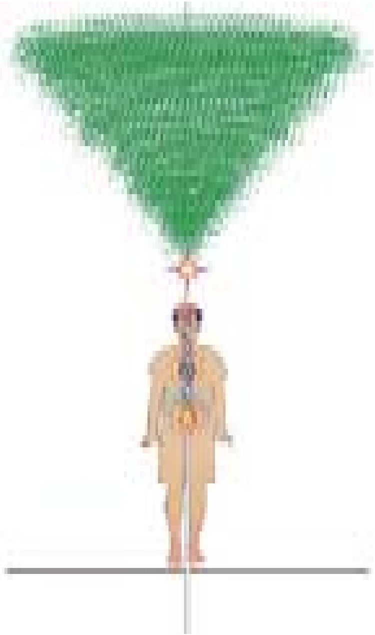

Be aware of the liver, the gall bladder, the forest and the throat breathing.

Be aware of the green light in the universe. Let the light come in and blend in the Tan Tien, up to the heart to blend with the compassion in the heart, and up to the crown.

Project the light up to the universe. See it spiral and let it multiply.

Always keep your Lower Tan Tien Fire warm. **Spiral in your Tan Tien and spiral the energy down to the student.** Spiral 1,000 revolutions per minute, 10,000, 30,000 and 60,000.

Fig. 4.43 *Draw down the Green Light from the Universe.*

Cleanse and Remove Sickness

Extend your arms up, with palms facing the heavens. Use one hand to spiral the green force down. The other hand holds the position and connects to the universe. Let this big pool of green light in the universe spiral down – through your community, your home and then into your crown.

Let the Green light blend into the cells and bond with sickness and toxins. Let the green light bring the sickness out of the cells and flow down to the center of the earth.

Dig a hole and bury it. Give the command: “Don’t come back. You will be happy down there. You will be transformed into good Chi.” Smile. Always smile.

Repeat it six, nine or eighteen times. For people who are very sick, who have cancer or may be terminally ill, you can do this two or three hundred times.

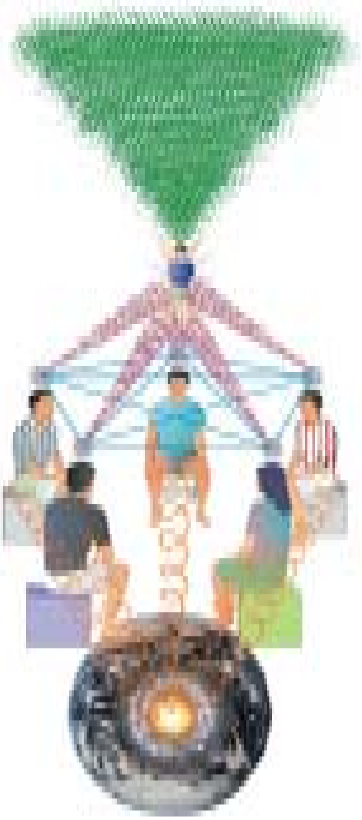

Fig. 4.44 *Green Light bonds with the Sickness and Toxins before returning them to the Earth.*

I. Clean with Blue Light

Be aware the blue light, kidney blue. Breathe the blue light into the throat center. Now slowly blend the blue light in the Tan Tien. Blend the blue light in the heart, in the crown and project it up to the universe, spiraling clockwise. Then feel the universe pouring the blue light back down; counterclockwise. Spiral down. Look at the cells and see the blue light, like water, go in to the cells to rinse and clean all the dirty things, down, down, down to the earth. All the way down. Repeat three, six or nine times. Smile.

Blue:

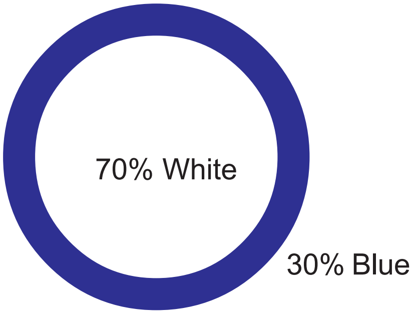

Fig. 4.45 *Rinse with Blue.*

Blue is like cold water; it has the yin power to dissolve all kinds of negative energy and sickness. It has an inhibiting effect. Blue yin energy is the opposite of red yang, which has a strengthening and stimulating effect. Blue has a cooling effect; it can reduce pain, inflammation and can help blood to clot. It stops bleeding and reduces fever. It can help to induce rest and sleep.

Throat Center Blue

Be aware of the kidneys' blue color and breathe the blue light into your throat. Guide it down to the Tan Tien, blend and move back up to the 'heart of compassion' and then the crown.

Project up to the universe, spiral and let it multiply.

Channel one direct line down to the student, one to your crown and one to your palm.

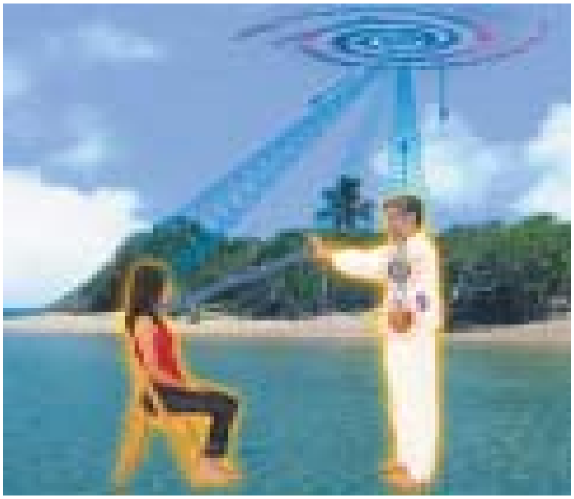

Fig. 4.46 *Multiply the Universal Blue Light - guide the Energy from the Throat, Heart and Crown into the Universe and back down.*

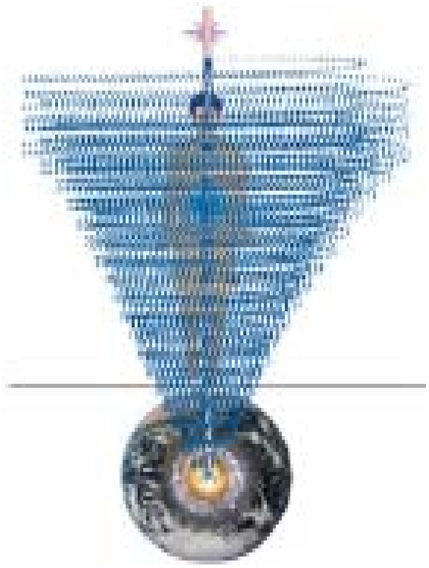

Be aware of the kidneys, the bladder, the oceans and the throat breathing.

Be aware of the blue light in the universe. Let the light come in and blend in the Tan Tien, up to the heart to blend with the compassion and up to the crown.

Project the light up to the universe. See it spiral and let it multiply.

Fig. 4.47 *Draw the Blue Light from the Universe - rinse clean and remove sickness.*

Rinse and Flush

Extend your arms in the air, with palms facing heaven. Use one hand to spiral the green force down. The other hand holds the position and connects to the universe. Let a big pool of green light in the universe spiral down – through your community, your home, and then into your crown.

Let the blue light flush into the cells and flush out sickness and toxins towards the center of the earth.

Dig a hole and bury them. Give the command: “Don’t come back. You will be happy down there. You will be transformed into good Chi.”

Repeat it six, nine or eighteen times. For people who are very sick, who have cancer or who may be terminally ill you can do this up to thirty six, seventy two or one hundred and eight times.

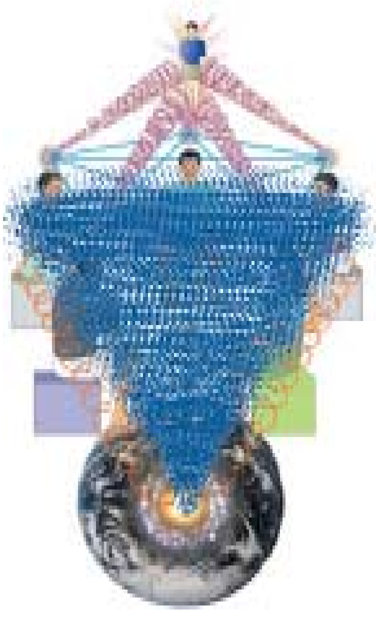

Fig. 4.48 *Blue Light flushes out the sickness and toxins before returning them to the earth.*

J. Charge with Violet Light

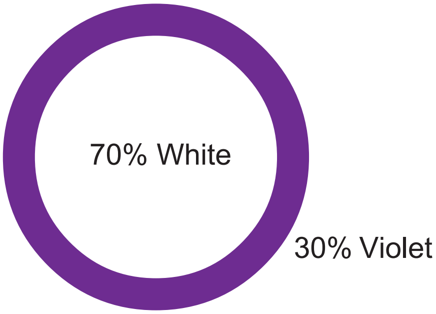

Fig.4.49 *Intelligent Luminous Violet*

Luminous Violet has intelligence and can be programmed. The universe is full of violet light, especially the North Star and the Big Dipper. The color of the star of the higher self or soul, above the crown, is also violet light, the Divine or Soul energy.

It has properties of other Chi colors. It has a rapid regenerating effect on damaged organs and nerves. Always use green and blue light before using violet. Violet light develops the crown center, the spiritual core. It is good for psychological ailments as well as for physical deficiencies.

Primordial Force

Turning the three minds into one mind, go deep into the empty space of the cell and deep into the chromosomes, magnify the space as you enter into the DNA and return to the original cells. The empty space is the Wu Chi. When you enter this stage you turn the subconsciousness into consciousness and you can talk to your body and cells. You can change the programming of DNA and RNA.

Ask for the power to see the cells and look at the brain cells spread out into the space. “Brain cells please listen. Clear, Clean, and Bright: fill with violet light and return to normal function”.

Violet Light into the Cells

See violet light. Be aware of your crown. The Tan Tien Chi and the negative Chi all combine in the crown. Extend a violet light up to the universe. See the North Star in the Big Dipper. Tell the student to hold their arms in the air, so that they can funnel the Chi into their personal star. Bring the North Star and the Big Dipper down; hold the handle of the Big Dipper and pour the violet light over the student’s personal star. The higher cells will be programmed. Let the Chi enter the brain and ask for the power to see the brain cells. “Brain cells listen to the command”. If there is sickness in the brain, give the command. “Sickness go away”.

The North Star is a major source of violet light.

The Big Dipper is a major source of red and infrared light. Taoists understand that the cup of the Big Dipper gathers all the violet light from the universe. The left hand holds the handle of the big dipper - pour it down to your crown. It then flows down throughout the body.

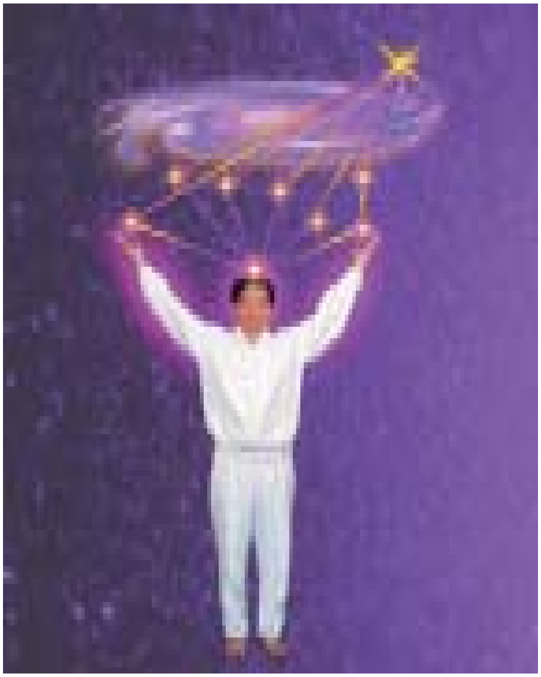

Fig. 4.50 *Connect with the North Star to receive the Violet Light.*

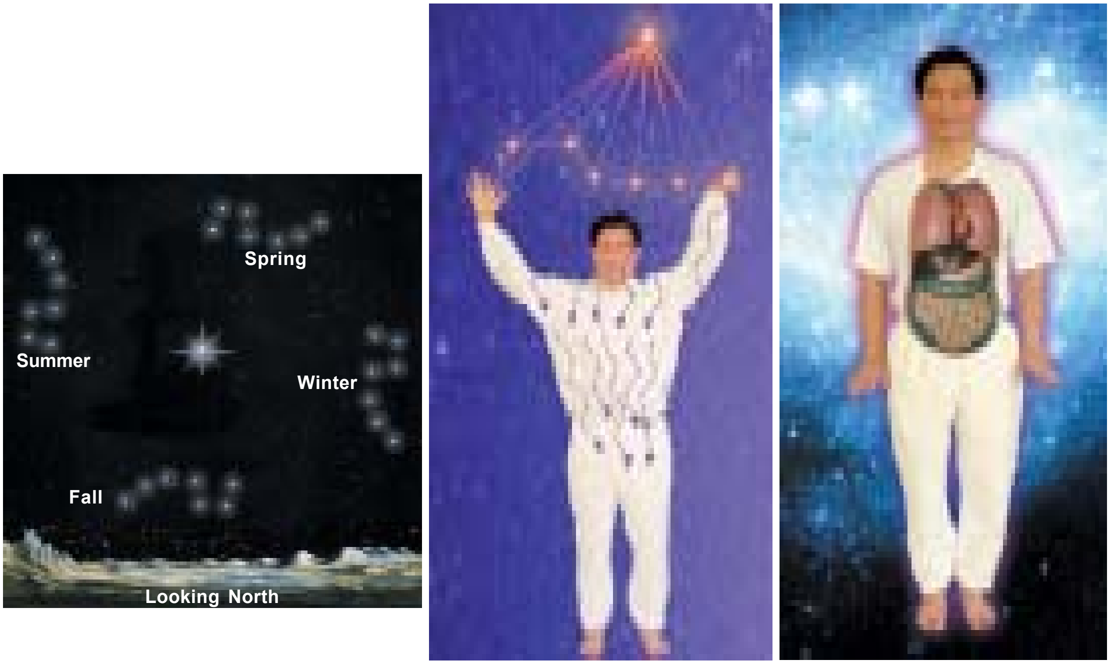

Fig. 4.51 *Practitioner connects with Universal Violet Light.*

Bring the violet light down to the student's personal star above their crown. Pause to let the higher cells of the brain reprogram the violet light at the personal star. Continue to spiral the violet light down through the cells of the brain and down through the cells of the whole body.

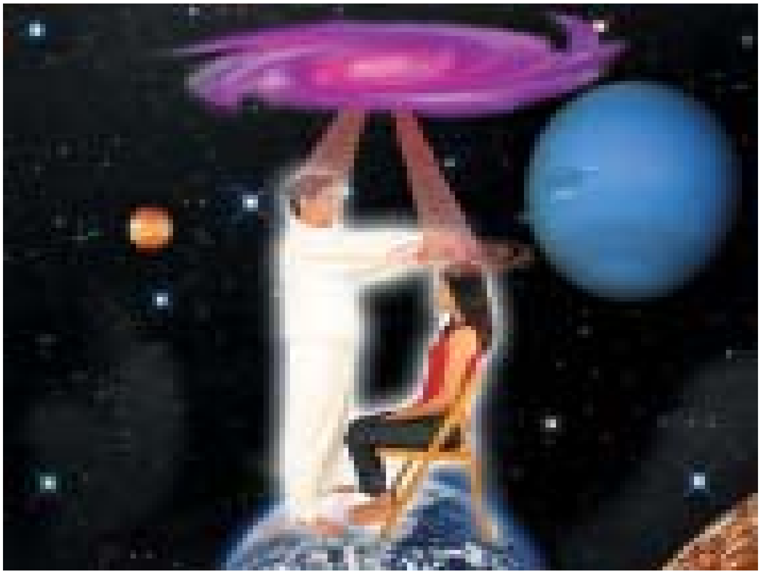

***Fig. 4.52** Pause to reprogram the Violet Light at the other Person's Personal Star.*

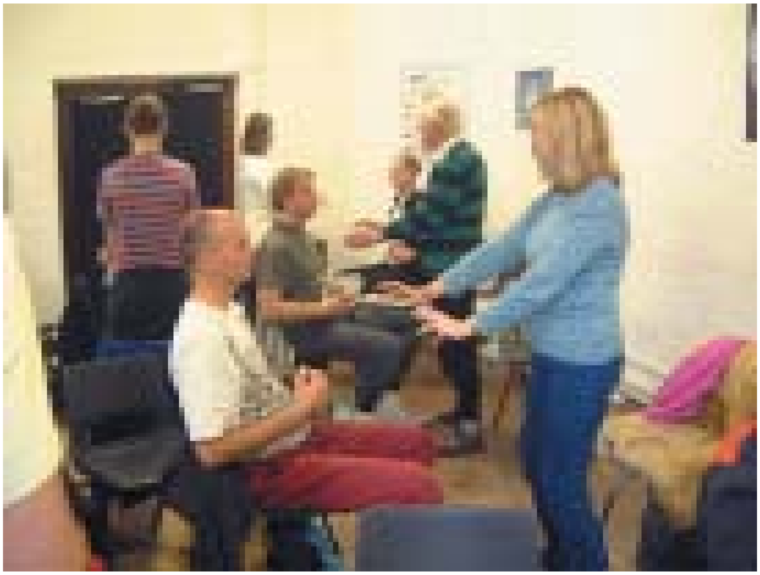

***Fig 4.53** Lead the person and guide them to follow you.*
Tell them to focus on the part of their body that you are working on.

1. Ask for the power to see into the cells of the brain. Ask the student to move their hands to cover their brain. “Brain cells listen to the command: Sickness go away. Clear, clean and bright; fill with violet light and return to normal function”.

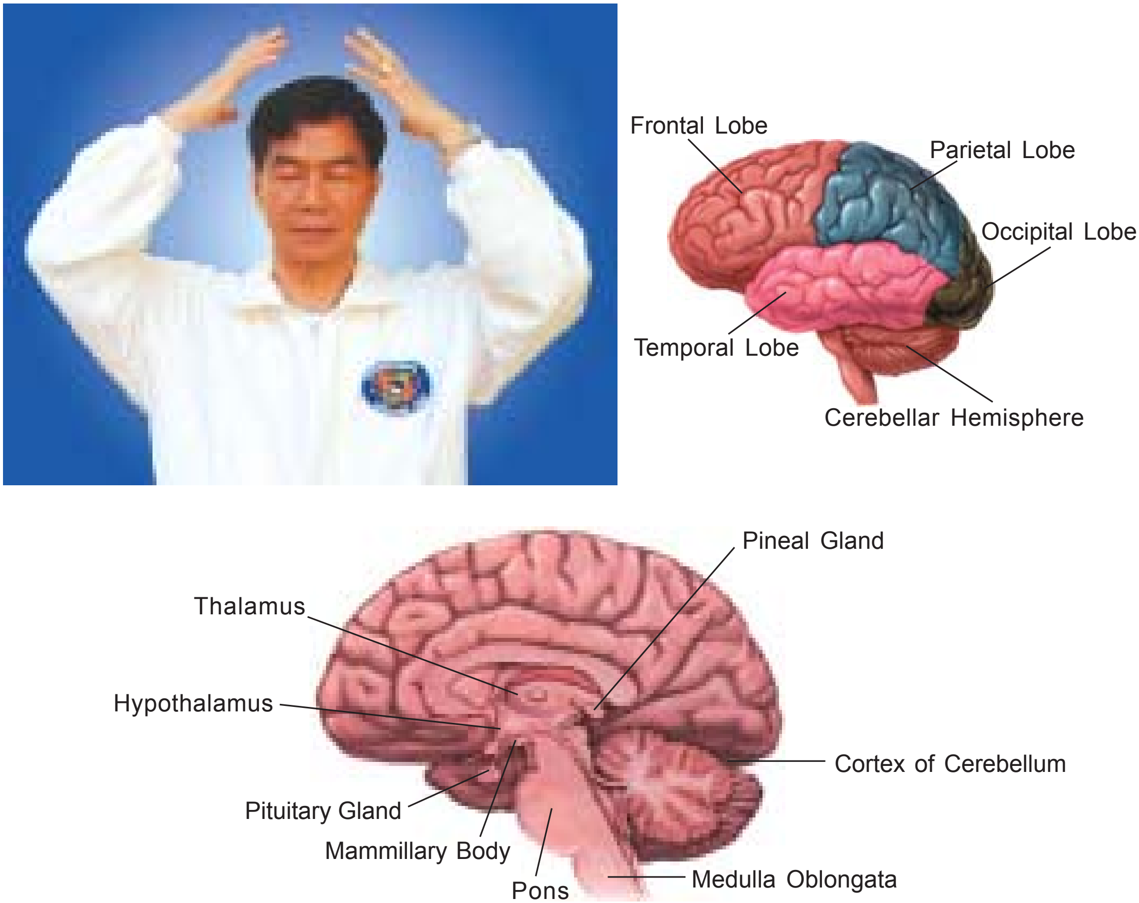
Frontal Lobe
Parietal Lobe
Occipital Lobe
Temporal Lobe
Cerebellar Hemisphere
Pineal Gland
Thalamus
Hypothalamus
Cortex of Cerebellum
Pituitary Gland
Mammillary Body
Pons
Medulla Oblongata

Fig. 4.54 *“Clear, clean and bright; fill with violet light and return to normal functions”.*

Brain Cells

Healthy Happy Cells

Fig. 4.55 *‘Intent’ to Heal.*

2. Ask for the power to see the cells of the sense organs. Ask the student to move their hand to cover their senses. Give the command: "Eyes, ears, nose, tongue and mouth cells listen to the command. Sickness go away. Clear, clean and bright; fill with violet light and return to normal function".

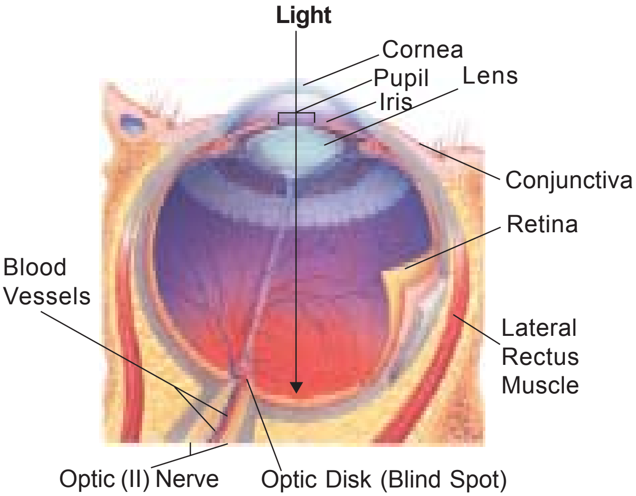
Light
Cornea
Pupil
Lens
Iris
Conjunctiva
Retina
Blood Vessels
Lateral Rectus Muscle
Optic (II) Nerve
Optic Disk (Blind Spot)

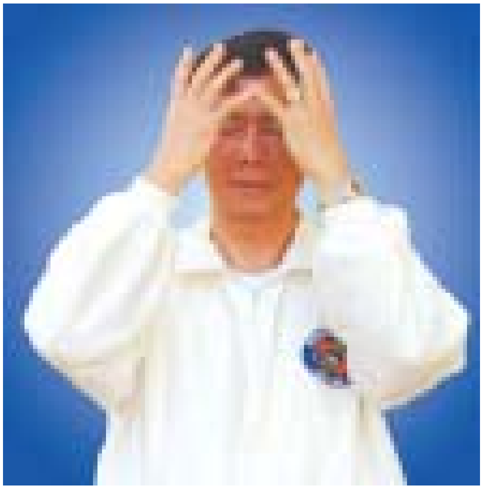

Fig. 4.56 *"Eyes, listen; clear, clean and bright; fill with Violet Light and return to normal function".*

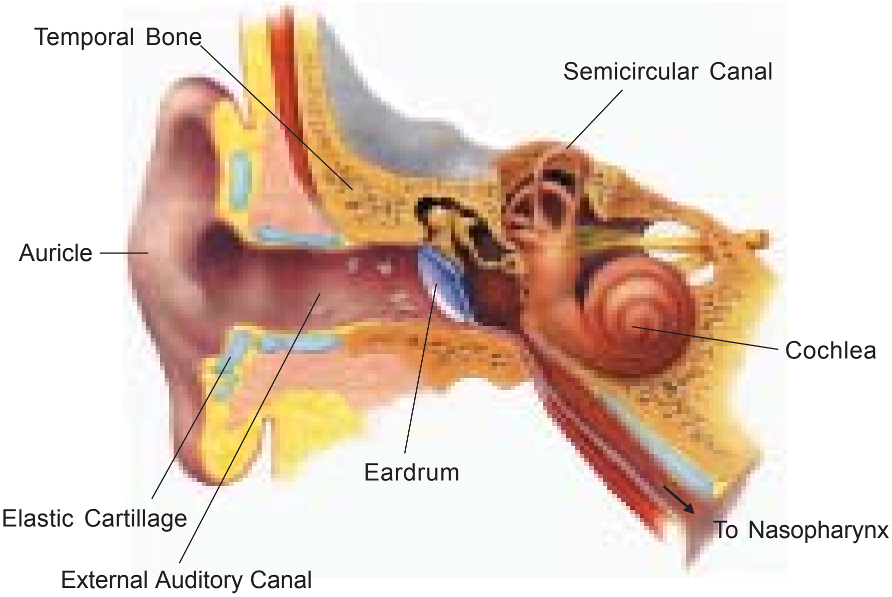
Temporal Bone
Semicircular Canal
Auricle
Cochlea
Eardrum
Elastic Cartillage
To Nasopharynx
External Auditory Canal

Fig. 4.57 *"Ears, listen; clear, clean and bright; fill with Violet Light and return to normal function".*

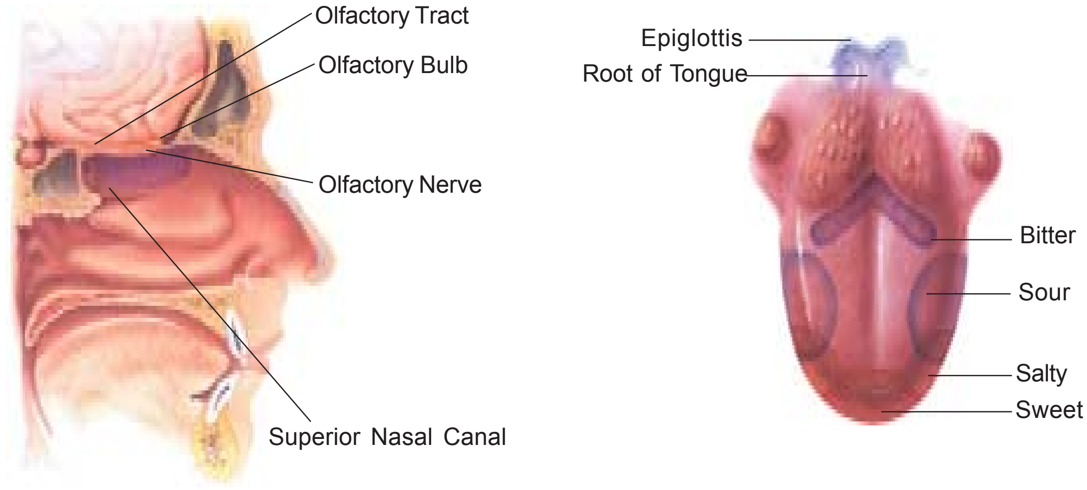
Olfactory Tract
Olfactory Bulb
Olfactory Nerve
Superior Nasal Canal
Epiglottis
Root of Tongue
Bitter
Sour
Salty
Sweet

Nose **Tongue**

Fig. 4.58
"Nose, tongue, listen; clear, clean and bright; fill with violet light and return to normal function"

3. Move your hands down to your throat center and give the command: "Thyroid, parathyroid and Thymus glands, listen to the command; Clear, clean and bright; fill with violet light and return to normal function".

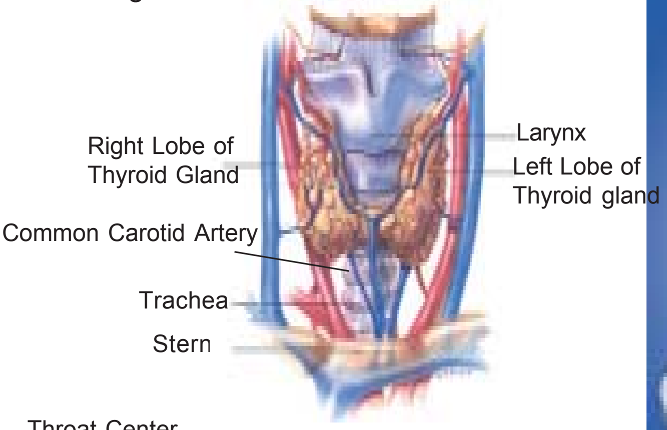
Right Lobe of Thyroid Gland
Larynx
Left Lobe of Thyroid gland
Common Carotid Artery
Trachea
Stern

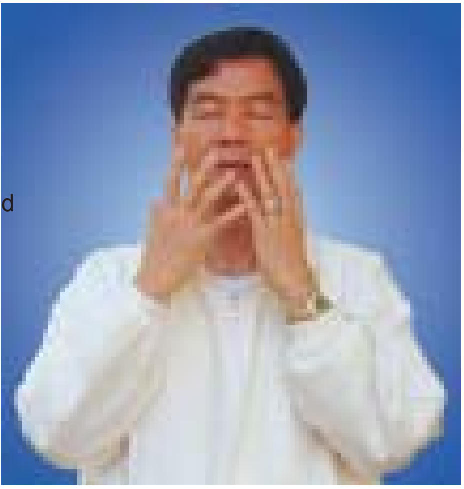

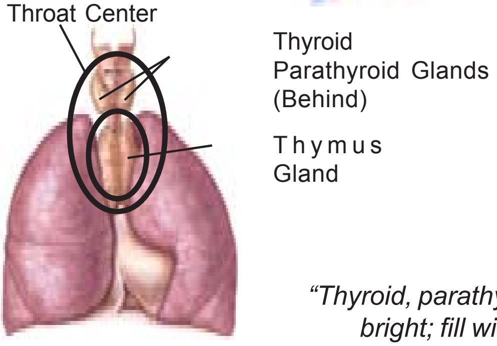
Throat Center
Thyroid Parathyroid Glands (Behind)
Thymus Gland

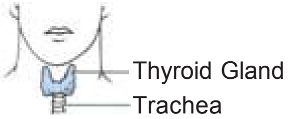
Thyroid Gland
Trachea

Fig. 4.59
"Thyroid, parathyroid and thymus glands - listen; clear, clean and bright; fill with violet light and return to normal function".

4. Move your hands to the heart and the lungs. Ask for the power to see the cells of the heart and lungs. Give them the command: “Lungs and heart cells, listen to the command”. If there is no sickness, just clean them out. See the cells and clean them out with violet light. If there is sickness, tell the sickness to “go away - be clear, clean and bright; fill with violet light and return to normal function”. Make sure that you say this part aloud. Give the command in a very firm tone of voice.

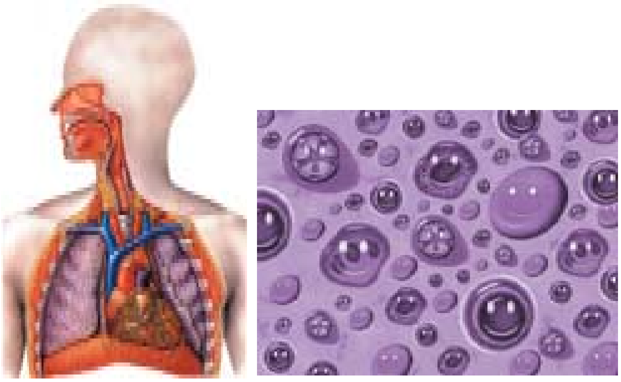

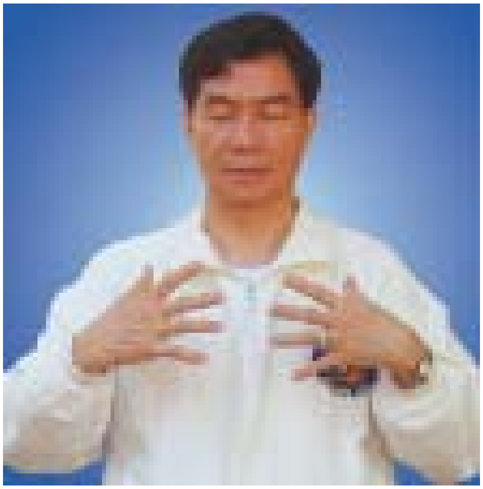

Fig. 4.60
“Heart and lung cells please listen; clear, clean & bright; fill with violet light and return to normal function”.

5. Move your hands to cover the left and right sides of the ribcage. Ask for the power to see the cells of the liver, gallbladder, spleen, pancreas and stomach. Give them the command: “Liver, gallbladder, spleen, pancreas and stomach cells, listen to the command”. If there is no sickness, just clean them out. If there is sickness, tell the sickness to, “go away - be clear, clean and bright; fill with violet light and return to normal function”. Make sure that you say this part aloud. Give the command in a very firm tone of voice.

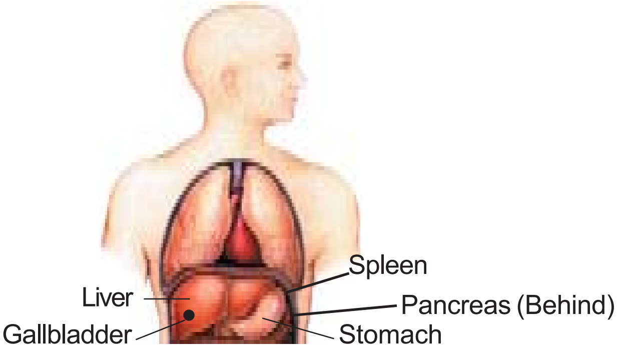

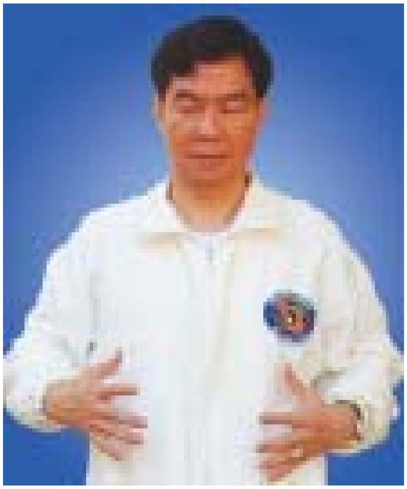

Fig. 4.61
“Liver, gallbladder, pancreas and spleen cells please listen; clear, clean and bright: fill with violet light and return to normal function”.

6. Move your hands to the large and small intestine on the front of the abdomen. Ask for the power to see the cells of the intestines. Give them the command: "Large and small intestine, listen to the command". If there is no sickness, just clean them out. See the cells and clean them out with violet light. If there is sickness, tell the sickness to, "go away - be clear, clean and bright; fill with violet light and return to normal function". Make sure that you say this part aloud. Give the command in a very firm tone of voice.

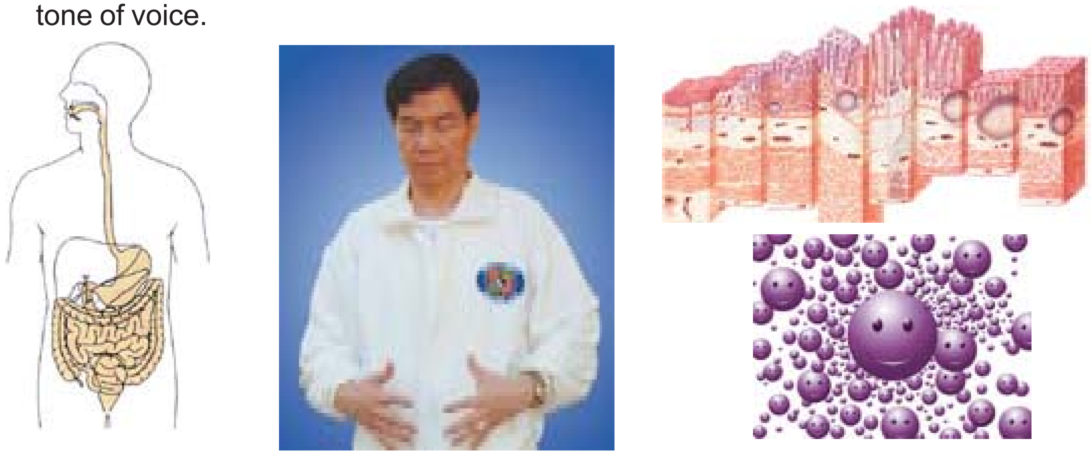

Intestines **Healthy cells**

Fig. 4.62 *"Small and large intestine cells listen to the command: clear, clean and bright; fill with violet light and return to normal function".*

7. Move your hands to the kidney and sexual organs and ask for the power to see their cells. Give the command: "Kidney and sexual organ cells listen to the command: Clear, clean and bright; fill with violet light and return to normal function". Gather the violet light again and let it pour down and fill all the cells. See the violet light again and feel and see that all the cells are, "clear, clean and bright". Smile.

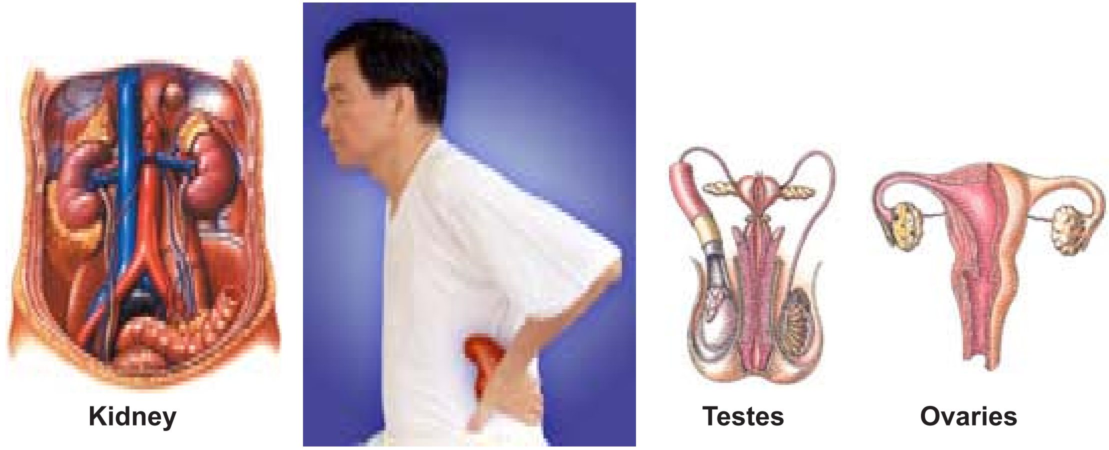

Kidney **Testes** **Ovaries**

Fig. 4.63 *"Kidneys and Sexual Organs listen".*

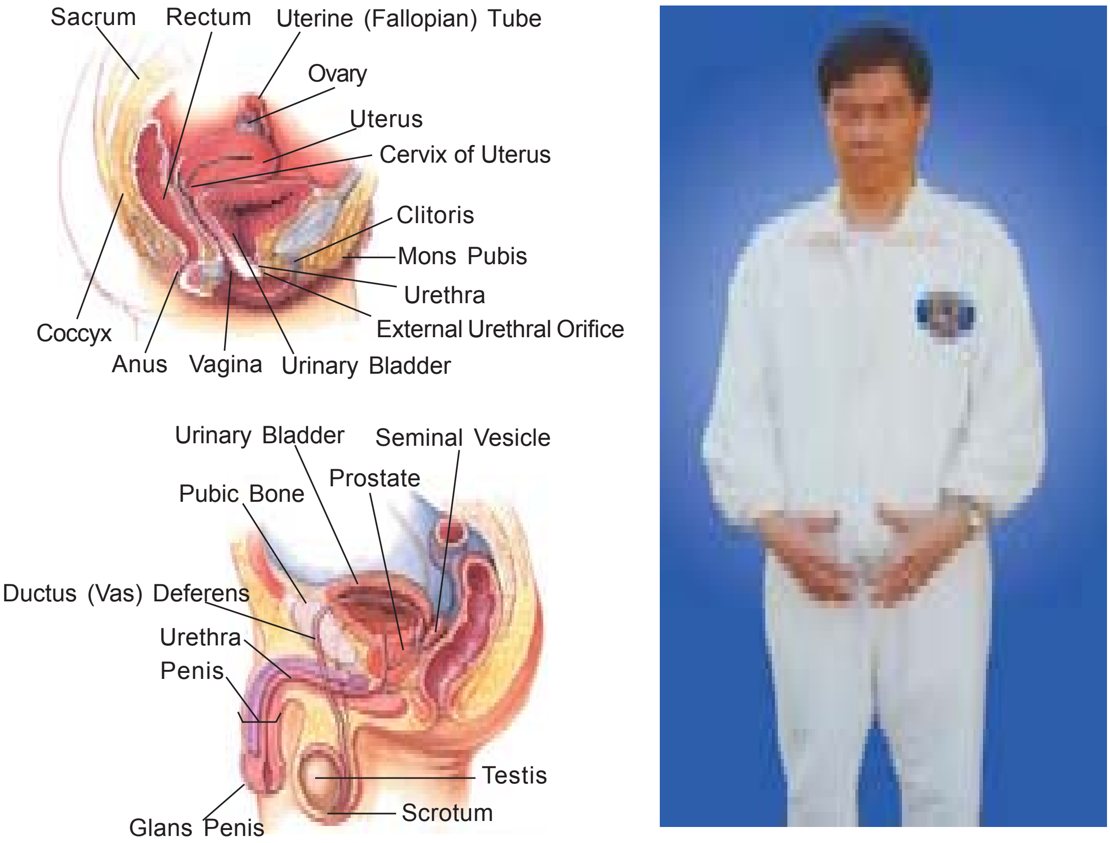
Sacrum
Rectum
Uterine (Fallopian) Tube
Ovary
Uterus
Cervix of Uterus
Clitoris
Mons Pubis
Urethra
External Urethral Orifice
Coccyx
Anus
Vagina
Urinary Bladder
Urinary Bladder
Seminal Vesicle
Prostate
Pubic Bone
Ductus (Vas) Deferens
Urethra
Penis
Testis
Scrotum
Glans Penis

Fig. 4.64 *Male and Female Sexual Organs*

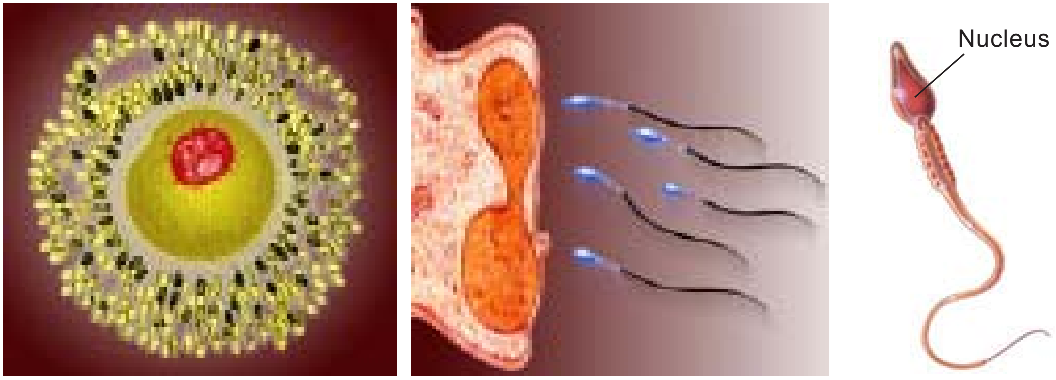

Egg

Sperm

Fig. 4.65 *"Clear, clean and bright: fill with Violet Light and return to normal function".*

K. Activate the Defense and Immune System

The Defense System relates to the white blood cell and the immune system relates to the Lymphatic System.

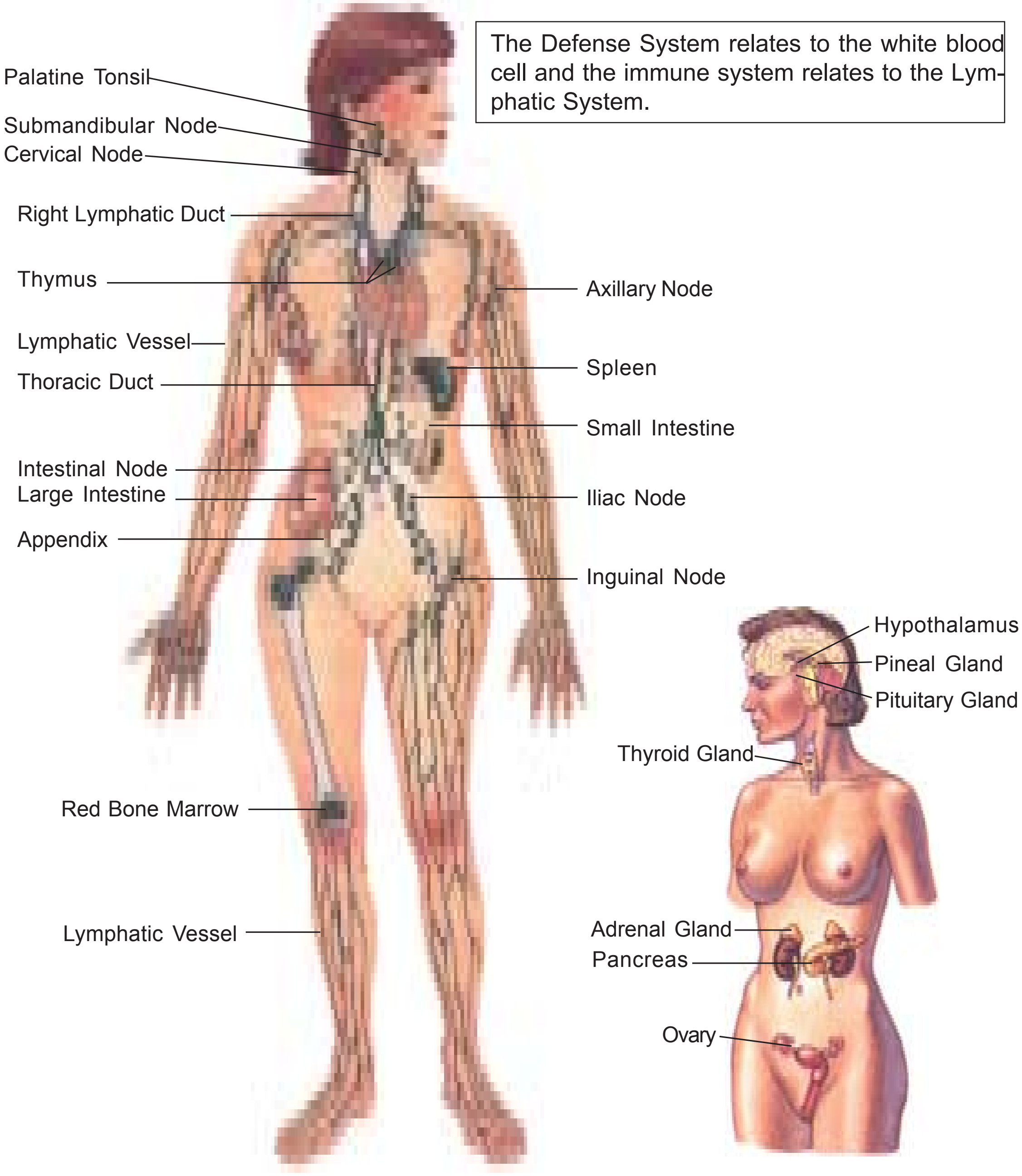
Palatine Tonsil
Submandibular Node
Cervical Node
Right Lymphatic Duct
Thymus
Lymphatic Vessel
Thoracic Duct
Intestinal Node
Large Intestine
Appendix
Red Bone Marrow
Lymphatic Vessel
Axillary Node
Spleen
Small Intestine
Iliac Node
Inguinal Node
Hypothalamus
Pineal Gland
Pituitary Gland
Thyroid Gland
Adrenal Gland
Pancreas
Ovary

Fig. 4.66 *Ask the cells to listen to the command.*
The bone marrow produces red and white blood cells. The lymphatic system cleans the toxic and polluted material and bacteria from the cells.

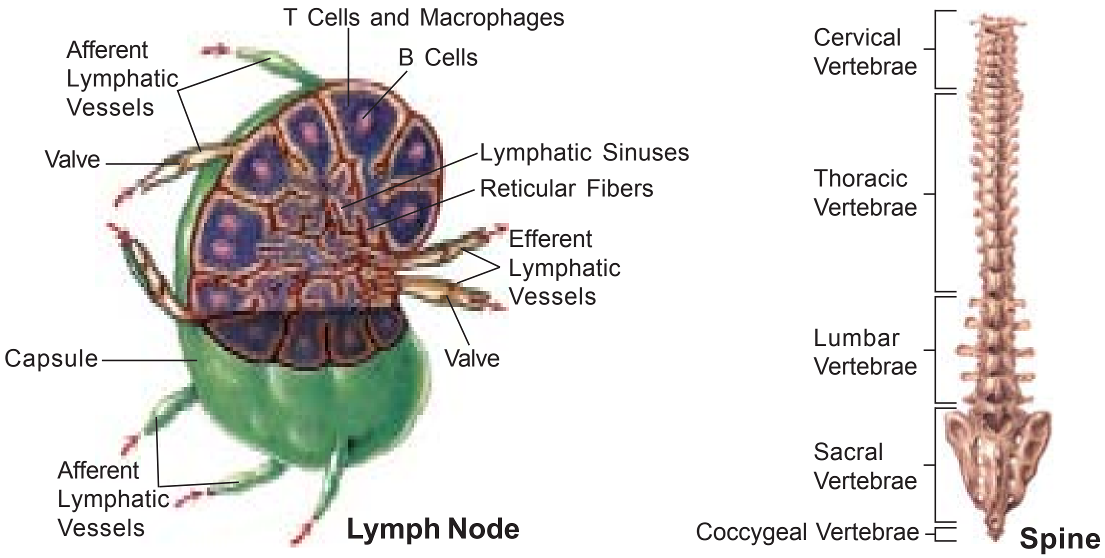
T Cells and Macrophages
Afferent Lymphatic Vessels
B Cells
Valve
Lymphatic Sinuses
Reticular Fibers
Efferent Lymphatic Vessels
Capsule
Valve
Afferent Lymphatic Vessels
Lymph Node
Cervical Vertebrae
Thoracic Vertebrae
Lumbar Vertebrae
Sacral Vertebrae
Coccygeal Vertebrae
Spine

***Fig. 4.67** "Immune Cells and Vertebrae please listen: clear, clean and bright; fill with Violet Light and return to normal function".*

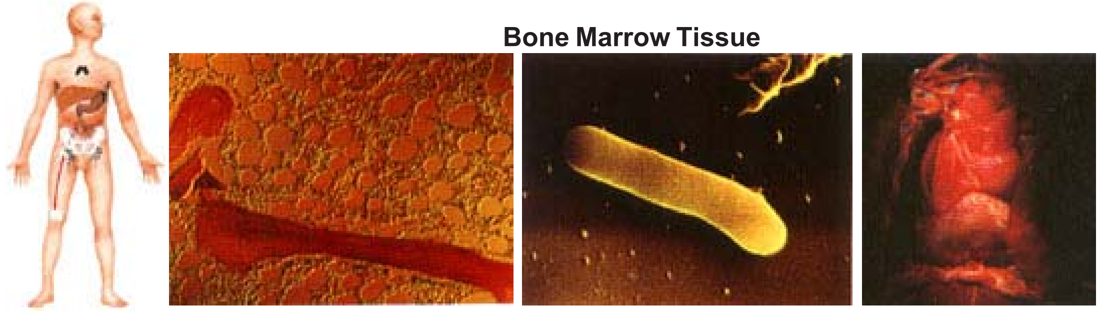
Bone Marrow Tissue

Sacrum: The sacrum controls all the bones and marrow. It effects the production of red and white blood cells. The bone marrow produces the lymphatic cells (white blood cells). When the blood is full of Chi it becomes lighter. Negative emotions make the blood thick and acidic. The blood cells in a healthy body can live up to ten times longer than in a weak or diseased one.

Bone Marrow: A tissue rich in fats, containing plenty of nourishment for the comprehensive production of the different blood cells: red cells for the transport of oxygen, blood platelets for clotting and the various white cells for the immune system.

Bacterium: Represents the foreign invader, but it is only one of many invaders. Parasites, fungi, viruses, chemicals, mineral fragments, metal particles—these and a great deal besides, set the immune system to work.

Thymus Gland: Perhaps the most important organ of the immune system. The vital training of the different T-lymphocytes takes place inside. When they pass through the thymus they receive a program to convert them into 'T' lymph cells. When they pass through the liver and large intestine they become 'B' cells and helper cells.

We have obtained Fig. 4.68 and the following text from the publication ‘The Body Victorious’ by Lennart Nilsson and Jan Lindberg.

We hope that you find this short selection of material as informative as we did.

“The illustration below is a highly schematic and simplified picture of our immune system. *Top left*, the pale yellow ‘house’ symbolizes the bone marrow, where all blood cells are born. *Bottom Right*, a solitary bacterium (yellow) represents the foreign invader that the immune system needs to combat. The light blue path represents the older defenses, with various feeding cells that tackle all foreign substances and also function as a kind of cleaning system. They deal with all the old, dead and used-up material in the body. The newer, special defense force, which develops later, follows the green path. Its cells are more specialized; they obtain their special training and reach maturity in organs such as the thymus gland and in the lymphoid tissue around the intestines and in the liver. In the lymphoid tissue, the yellow ‘half-way house’ (far right), the ‘B-lymphocytes are trained. These are the precursors of the large plasma cells - the pale green cells (far right) in the illustration, which produce the body’s sniper ammunition, the antibodies (Red and Y-Shaped).

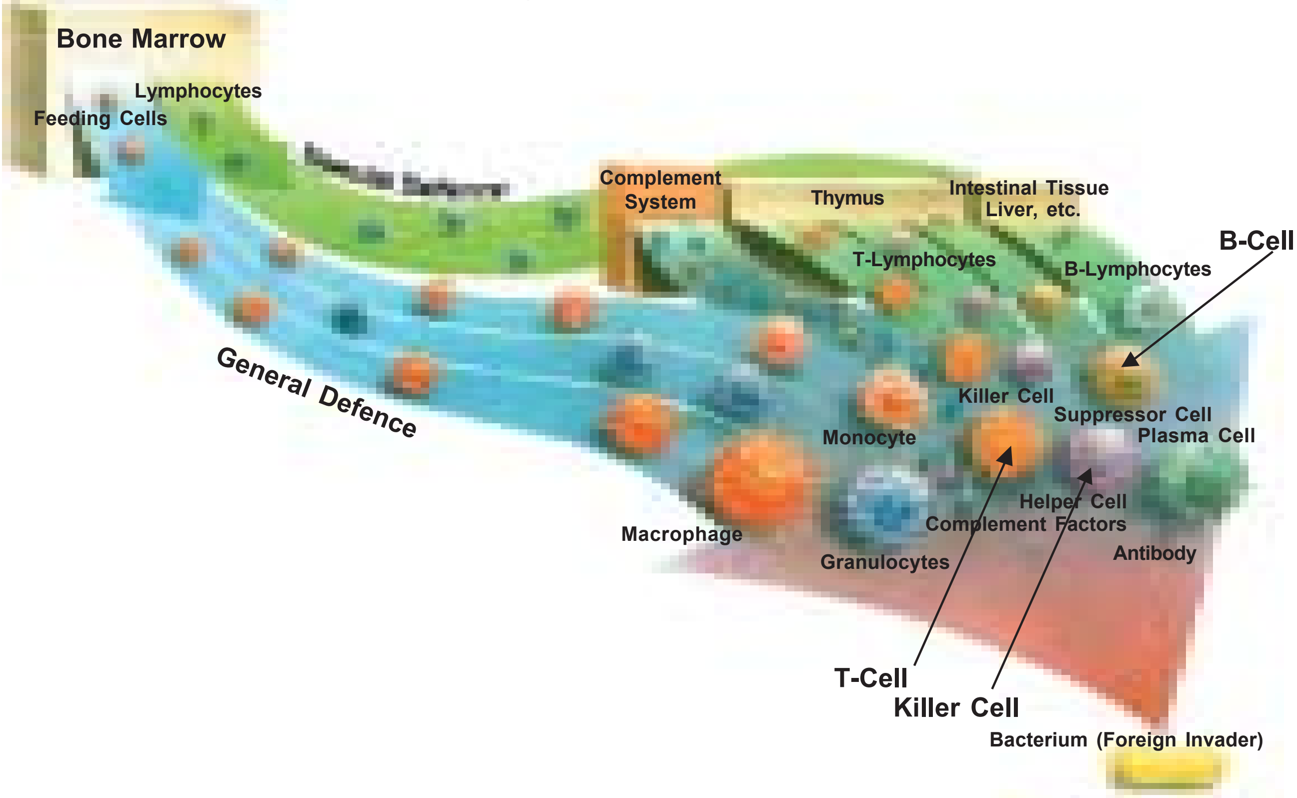
Bone Marrow
Lymphocytes
Feeding Cells
Complement System
Thymus
Intestinal Tissue Liver, etc.
B-Cell
T-Lymphocytes
B-Lymphocytes
General Defence
Killer Cell
Suppressor Cell
Monocyte
Plasma Cell
Helper Cell
Complement Factors
Macrophage
Antibody
Granulocytes
T-Cell
Killer Cell
Bacterium (Foreign Invader)

Fig. 4.68

Bone marrow, bacterium and thymus please listen: clear, clean and bright; fill with violet light and return to normal function”.

The three paths from the thymus are intended to show that there are different types of T- lymphocytes - among others, aggressive killer cells, helper cells and suppressive cells. All of them have specialized tasks to perform when the immune system launches a counterattack. The three blue paths of the older defenses have three different kinds of feeding cells. First, the large and powerful macrophages (orange) advance on the enemy; then come the granulocytes (blue), smaller and faster moving, followed by the (pink) monocytes. The nuclei in the shimmering cell bodies are faintly discernable. In addition, there is an important complement system (middle), symbolized here by a multicolored range of small spheres flocking toward the foreign bacterium. These molecules play a large part in increasing the efficiency of both antibodies and feeding cells. In addition, they have the capacity to destroy bacteria by shooting holes in them. The complement factors are produced in many different cells in the body.

Chi Kung has a very strong effect against viruses. Altough medical science is struggling to discover a medicine that will kill them, Chi Kung practice is able to prevent them from occuring in the first place. Whether we are sick or healthy, we all need our defense system to be in good shape.

Defense System - Outline of Practice

1. Work on yourself first to activate your sacrum. Project the sacrum as big as the universe. See the eight holes in the bone and visualize them breathing. Breathe and compress the Universal Chi into the bones. Feel the Chi begin to rise up the spine and into your mideyebrow and temple bones. When you feel that there is enough Chi, project it out to the universe, multiply it and spiral it back down. Project it towards the student and ask them to touch their sacrum. Rub your hands until warm and touch the sacrum. Picture the sacrum getting bigger and bigger, breathing into the eight holes. Tell the person to smile at the sacrum and start to work on your Tan Tien and universe. Multiply more energy and picture the Chi from the universe coming down to the sacrum of the other person (and your own) and then charge up the spine, to the rib cage, to the temple bone and to the mideyebrow.

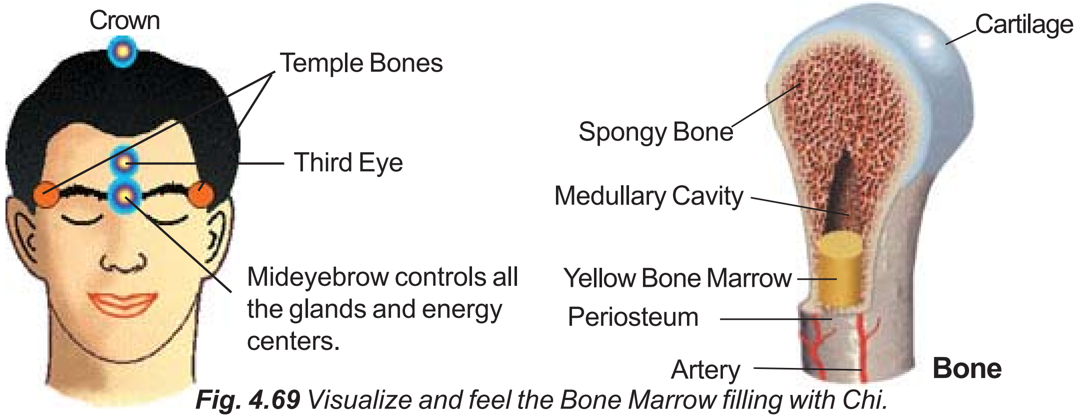

Fig. 4.69 *Visualize and feel the Bone Marrow filling with Chi.*

2. Tell the student to move their hands to the hip bones. Tell them to smile to these bones. Feel them as ‘funny, laughing, happy bones’. Tell them to feel the electricity in the sacrum and bone marrow.
3. Touch the femur bones. Feel the electricity running up the legs.
4. Touch the humerus bones. Feel the electricity running up the arms.
5. Touch the lower part of the sternum and feel the Chi penetrate into the bones and spread out to the rib cage. Feel the electricity run throughout the rib cage.

Practice

1. Touch the sacrum, feel your fingers grown ‘long’ and penetrate into the marrow. Feel that the sacrum is as big as the universe and that the Chi has been compacted. Fill the sacrum with Chi. The eight holes are breathing. Let the fingers touch the sacrum and become aware of the Tan Tien spiraling, until you feel the crown and the mideyebrow spiral and connect to the universe. Hold until the universe fills the sacrum once again and rises up the spine to the mideyebrow.

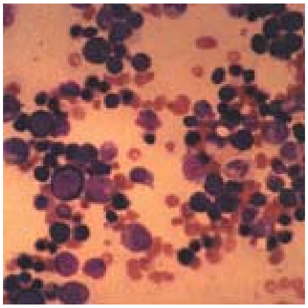

Bone Marrow Cells

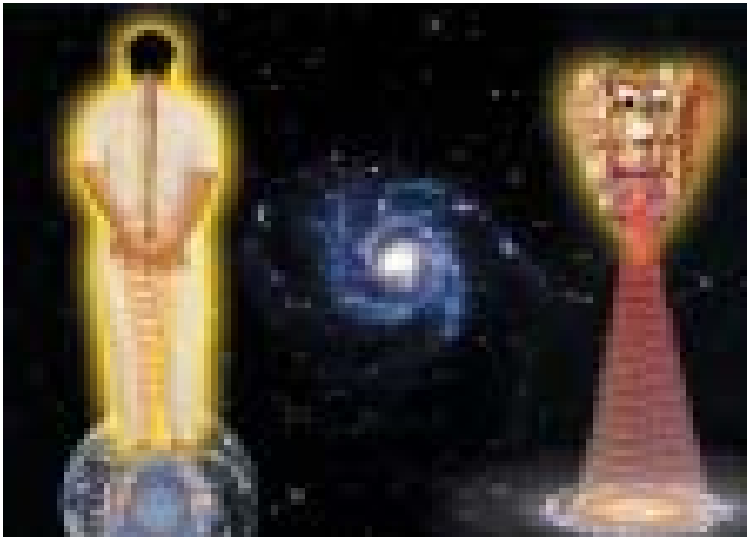

Fig. 4.70 *Touch the Sacrum - see the Eight Holes breathing - fill the Sacrum, Mideyebrow and Crown with Chi - empty to the universe and ‘fill’ again.*

Sacrum Breathing to get Chi

Breathe through the sacrum; feel red and yellow light enter. Guide it into Tan Tien. Blend the Chi in the Tan Tien. Move up to the Heart Center. Move up to the Crown and project up to the universe; let it blend and multiply. Multiply in the universe

Open a direct channel down to the other person, and one to your palm.

Sacrum Chi

Project the student's feet down to the earth and connect to the earth's core.

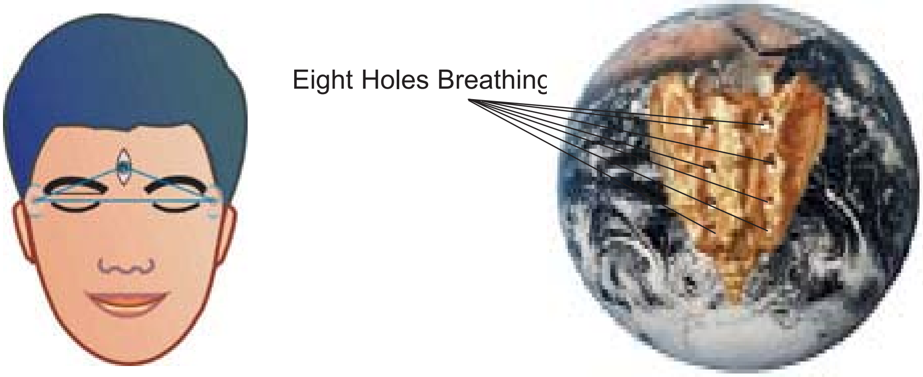
Eight Holes Breathing

Third Eye and Temple Bones are aligned in a triangle.

Activate the Sacrum until you feel the Chi rising up the spine and feel it pulsing; be aware of the Temple Bones.

Fig. 4.71 *Activate the Sacrum - Be aware of the Temples.*

2. Tell the student to move their hands to the hip bones. Tell them to smile to these bones. Feel them as 'funny, laughing, happy bones'. Tell them to feel the electricity in the sacrum and bone marrow. Tell the student to pack and compress the Chi into the bones in order to revitalize and revive bone marrow. Give the command. "Produce healthy white and red blood cells".

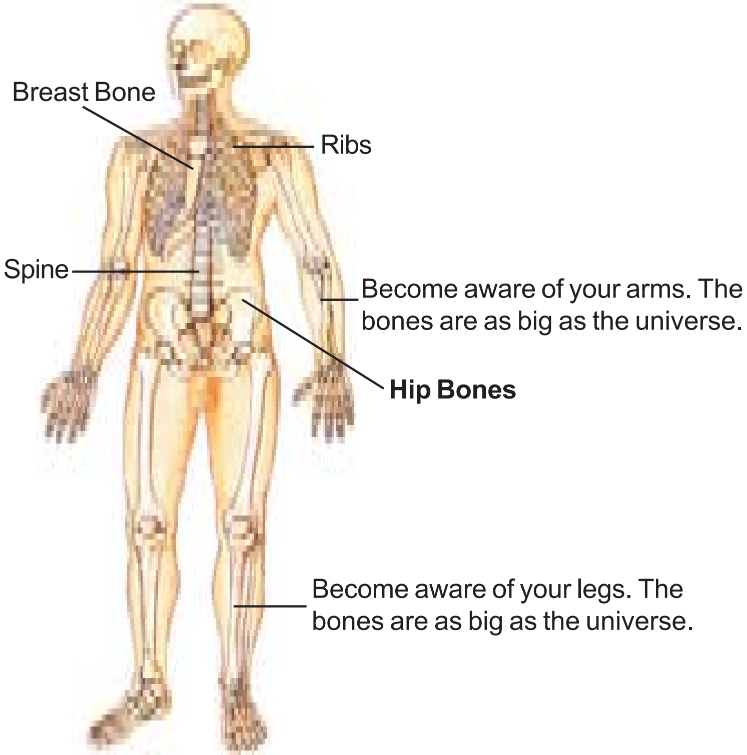
Breast Bone
Ribs
Spine
Become aware of your arms. The bones are as big as the universe.
Hip Bones
Become aware of your legs. The bones are as big as the universe.

Fig. 4.72 *"Hip Bones produce healthy White and Red Blood Cells".*

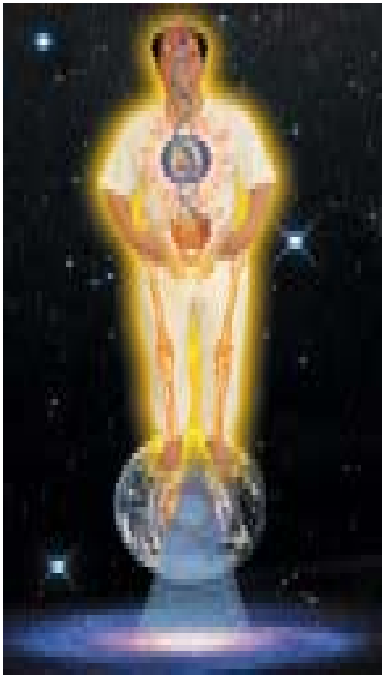

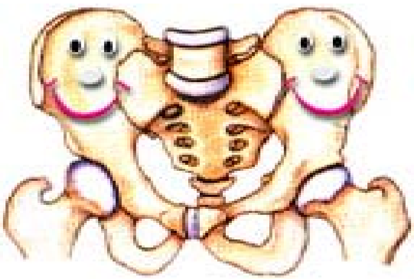

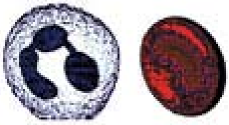

White Blood Cell
(Neutrophil)

Leave the fingers touching the hip bones and start to spiral in the Tan Tien until you feel the crown and the mideyebrow also spiral. Expand your awareness to the Universe and the Universe will charge into the hip bones.

Fig. 4.73 *Touch and feel the bones. Leave your fingers there - lower your mind into the Tan Tien and the universe.*

3. Touch the middle part of the femur bone to help increase the production of healthy red blood cells. Feel the electricity running up the legs. Give the same command for the femur bones: "Funny, laughing, happy bones produce healthy white and red cells." After that put your mind into the Tan Tien and universe so that the Chi can charge into the bones. Feel electricity run throughout the whole skeleton.

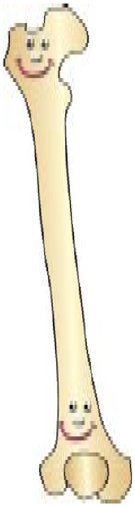

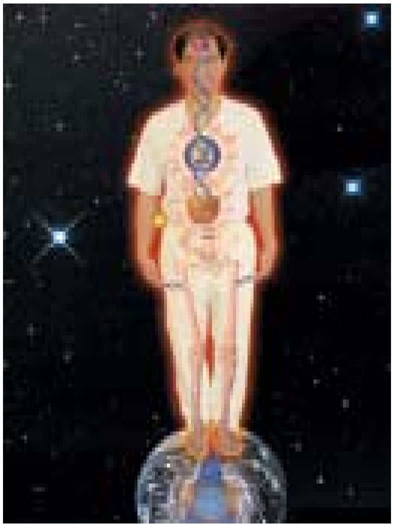

Fig. 4.74 *"Funny, laughing, happy femur bones produce healthy white and red blood cells".*

4. Touch the humerus bones. Feel the electricity running up the arms.Give the same command: "Funny, laughing, happy bones produce healthy white and red cells." After that, put your mind into the Tan Tien and universe so that the Chi can charge into the bones. Give the same command for the lower part of the sternum. Chi penetrates into the bone and spreads out into the rib cage 'Tan Tien and Universe'. Put your mind into the Tan Tien and the universe so that the Chi can charge into the bones.

5. Touch the lower part of the sternum and feel it and the rib cage as funny, happy, laughing bones. Feel the Chi and electricity penetrate into the bones and spread out to the rib cage. Touch the lower part of the sternum. Give the same command again. “Produce healthy white and red cells”. After that you put your mind into the Tan Tien and universe so that the Chi can charge into the bones.

   You have finished activating the defense system.

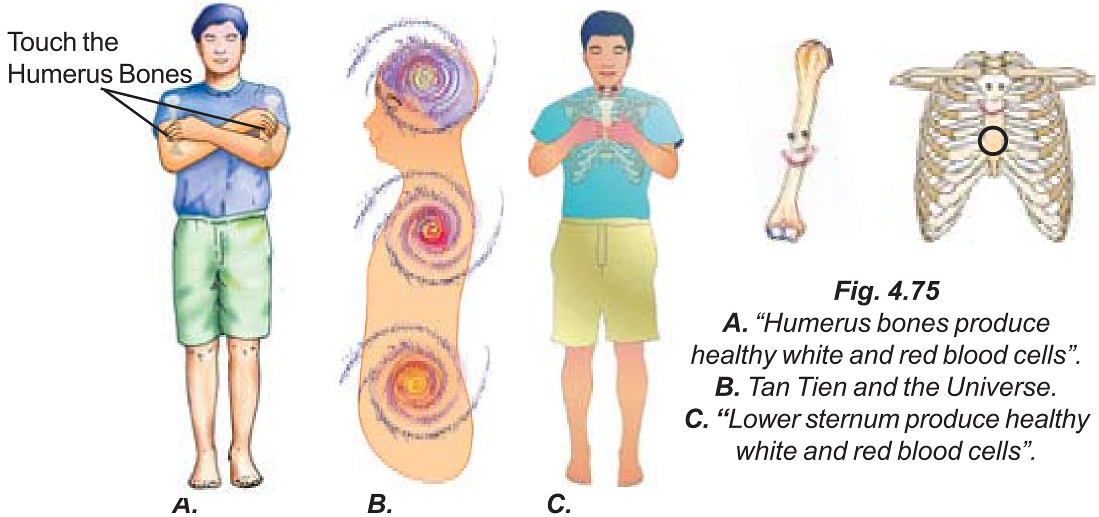

Fig. 4.75
A. *“Humerus bones produce healthy white and red blood cells”.*
B. *Tan Tien and the Universe.*
C. “*Lower sternum produce healthy white and red blood cells”.*

Immune System

1. The Immune System starts with the top part of the sternum. Touch the top part of the sternum. Project your fingers ‘very long’ into the bone and feel them penetrate right into the thymus. Activate the thymus gland. Gradually, feel the fingers rising up to the thyroid and parathyroid. Activate the thyroid and parathyroid and throat center. Give the command, “Clear ,clean and bright fill with violet light and return to normal function”.

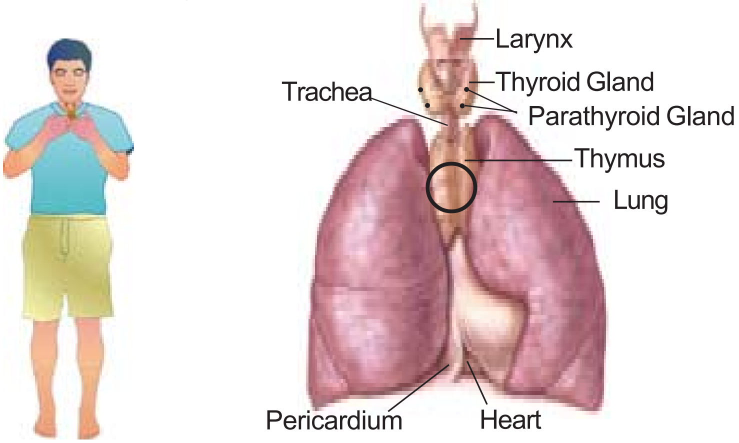

Fig. 4.76 *Touch the Top of the Sternum & activate the Thymus, Thyroid and Parathyroid Glands.*

2. Move the fingers to touch both sides of the jaw bones to help activate the tonsils, the body's first line of defense. The jaw bone affects the lymph nodes beneath, which include the tonsils. Fill them with Chi. Give the command, "Clear, clean and bright; fill with violet light and return to normal function".

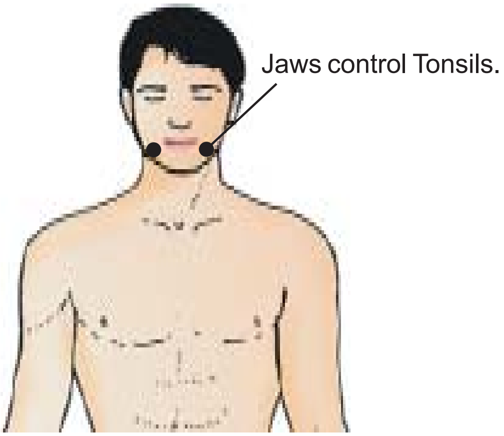
Jaws control Tonsils.

Fig. 4.77 *Activate the Tonsils and Jaw Bones.*

3. Touch the mideyebrow and crown, which control the pituitary and pineal glands respectively. Touch the third eye, feeling it open and feel the light from heaven entering into your brain and into your body. Touch the crown. Feel your fingers reaching deep inside and feel the Chi penetrating all the way down to your perineum. Give the command, "Clear, clean and bright fill with violet light and return to normal function".

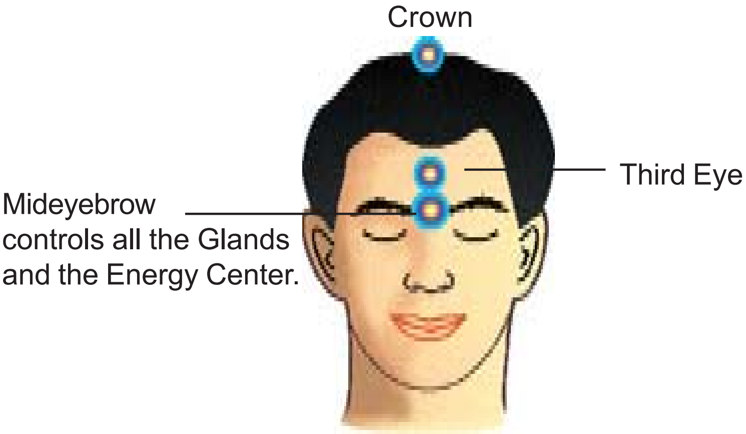
Crown
Third Eye
Mideyebrow controls all the Glands and the Energy Center.

Fig. 4.78 *Third Eye, Mideyebrow and the Crown affects the Immunity and Defense Systems.*

4. Rub both of your hands until they are warm and cross the hands on the neck and feel the lymphatic system has been activated. Cross your arms and hold your hands

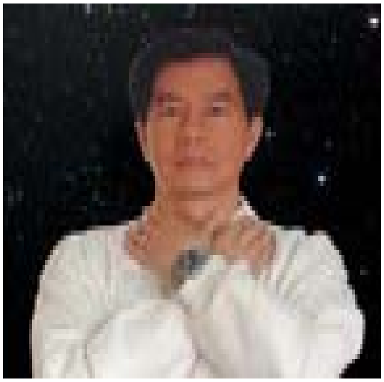

under your armpits. Picture the lymphatic system of the armpits as you activate the lymph nodes. Give the command; “Clear, clean and bright fill with violet light and return to normal function”. The lymphatic system of the upper body is clear, clean and bright and the lymphatic fluid flows! Smile.

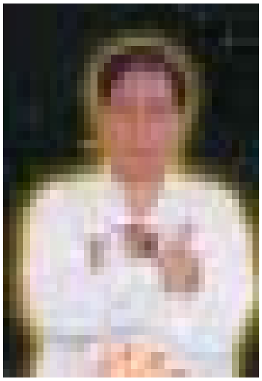

Fig. 4.79 *Lymphatic System of the Neck and Armpits are clear, clean and bright.*

5. Move the hands to the cover the groin area. Give the command to the lymph nodes there. Next, cover the lymph nodes of the navel area, and give the command; “Clear, clean and bright fill with violet light and return to normal function”. The groin and the navel area lymph nodes become clear, clean and bright.

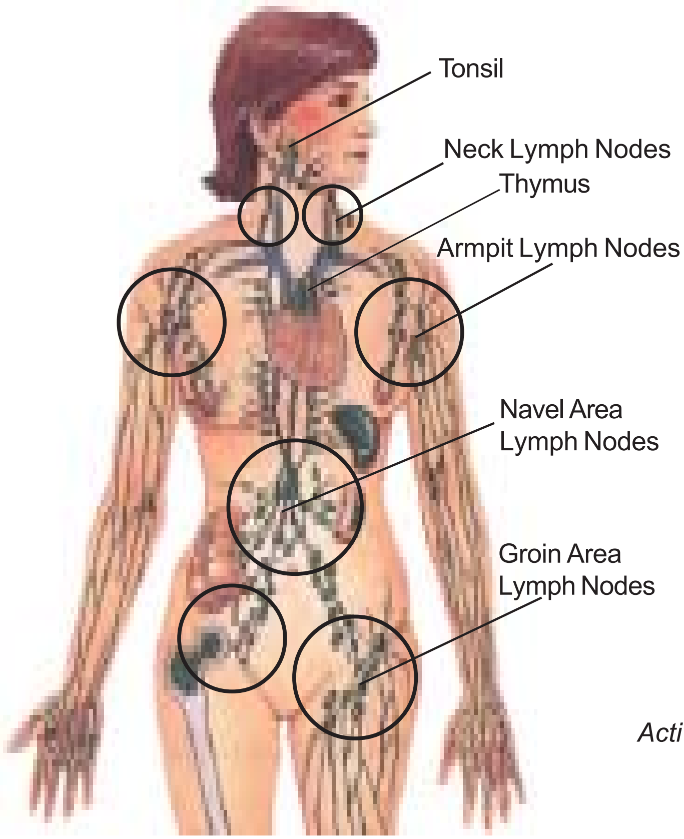
Tonsil
Neck Lymph Nodes
Thymus
Armpit Lymph Nodes
Navel Area Lymph Nodes
Groin Area Lymph Nodes

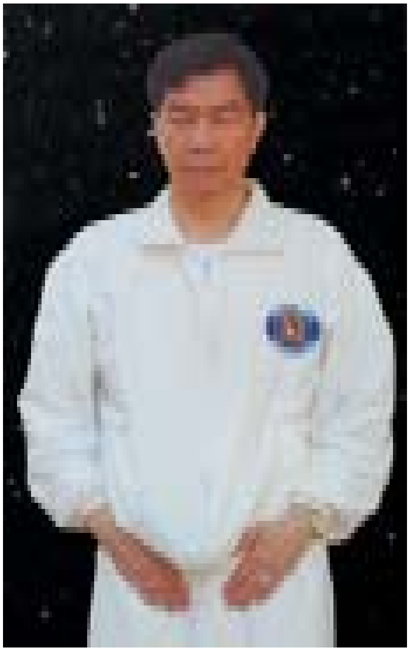

Fig. 4.80
Activate the Lymph Nodes in the Groin.

6. Place your palms over your navel and activate the lymph nodes. Give the command; “Clear, clean and bright fill with violet light and return to normal function”. See them become clear, clean and bright. You have now activated the immune system.

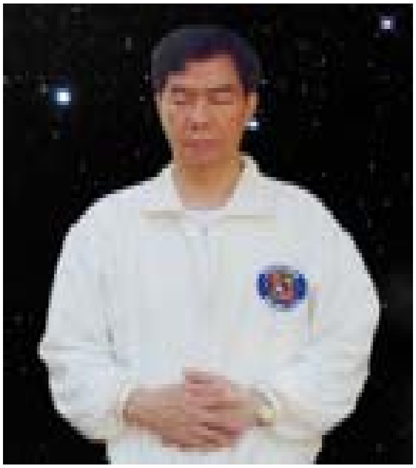

Fig. 4.81
Touch and activate the Lymph Nodes in the Navel.

Summary - General Healing Session

This General Healing Session will help everybody.

A. Three Minds into One
B. Activate the Six Directions
C. Activate the Three Fires
D. Linking Personal Stars, Energy Bodies and the Universe
E. Protective Circle and Chi Field
F. Chi Water (Sacred Water) Practice
G. Empty and Fill
H. Clean with Green Light
I. Clean with Blue Light
J. Charge with Violet Light
K. Defense and Immune System

A. Three Minds into One

Smile to the inner universe, activate the heart compassion energy; feel the love and joy within. Smile and empty the mind and heart down into the Tan Tien. Fill the Tan Tien with Chi and spiral the energy. When the Tan Tien is full, the energy will rise up to fill the brain. Manifestation will occur at the mideyebrow.

B. Activate the Six Directions

Expand the awareness to connect to the Six Directions at the crown, mideyebrow, heart and Tan Tien.

C. Activate the Three Fires

Activate the Tan Tien, Kidney and Heart Fires.

Activate the Sacred Fire Triangle circulating the energy between the Tan Tien, kidneys and the heart. Feel the energy's force multiply.

Activate the personal stars; the cosmic star above the head and the earth star below the soles of the feet.

Keep the Tan Tien warm, and spiral at the sacrum and mideyebrow. Turn your eyes to look upwards and see the crown spiraling, connecting to the cosmic star about six inches above the crown point. Feel the cosmic and earth stars pull the body simultaneously towards heaven and earth. See the cup of the Big Dipper fill with Violet Light, gathering Chi from the North Star and the universe. When the cup is full, pour the light down into the cosmic star above your head. Feel the violet light spreading throughout your entire system, filling the Upper, Middle and Lower Tan Tiens.

D. Linking Personal Stars, Energy Bodies and the Universe

Feel the central channel running from your cosmic star, through your three Tan Tiens and connecting to the earth energy below. Use you 'Yi' power to connect to the personal or cosmic star above the head. Connect the personal star to the stars of each other person in the meditation. Create a Chi body and become the major connecting point. Create a left spiral pattern to connect all the stars into a larger group. All the meditators then become a satellite, creating a group energy body.

E. Protective Circle and Chi Field

Raise the hands and touch the Universal Fire. Use your Yi to bring the energy down and manifest a Sacred or Chi Fire around the room, creating a protective circle. Create a Chi Dome and set up the guardian animals and/or angels. Activate the eight elemental forces of nature and the universe.

F. Chi Water (Sacred Water) Practice

Invoke the power of the Sacred Water practice to cleanse the body of all sickness, negative energy and bad fortune. Energize and renew the self at a cellular level with health, wealth and longevity.

G. Empty and Fill

Empty any remaining negative energy, sickness, burdens and worries, down in the depths of the molecular mother, the earth. Bury the energy there so that the earth can recycle it. Bring recycled energy up from the center of the earth into the body. Fill and compact the Chi into the 'hollow bones'. See all of the cells on the horizon of your mind's eye; spread them across the panorama and see the cells as big as the stars in the night sky. Fill them with Chi, blending it with any sick or grey energy. Then empty again, as you guide the all of the Chi back into the earth for recycling. If you wish, you can fill with earth Chi once again before you begin to 'clean with green'.

H. Clean with Green Light

Green cleans and detoxifies all of the body's cells**.** Green Chi is mild and safe. Green Chi is used for cleansing, and as a decongestant for diseased parts. Be aware of the liver's green color, the throat and the emerald forest. Breathe into the throat, feel yourself breathing in the green light. Guide it down to the Tan Tien, blend and move it up to the heart and the crown.

Project it to the universe; spiral and let it multiply. Channel one direct line down to the student, one to your crown and one to your palm. Bring the energy back down and blend it with any sickness in the liver, gallbladder or anywhere else in the body. Spiral the energy counter clockwise and down into the earth. Continue cleaning with green until you see that all the cells have been charged with the emerald light of the forest.

I. Clean with Blue Light

Be aware of the kidneys' blue sapphire color and breathe the blue light into your throat. Guide it down to the Tan Tien, blend and move back up to the 'heart of compassion' and then to the crown.

Project up to the universe, spiral and let it multiply. Channel one direct line down to the student, one to your crown and one to your palm. Then feel the universe pouring the blue light back down; clockwise. Spiral down. Look at the cells and see the blue light, like water, go into the cells to rinse, clean and remove any sickness. Spiral the energy counter clockwise and down into the earth. Continue rinsing with blue light until you see that all the cells have been charged with the sapphire blue.

J. Charge with Violet Light

Luminous Violet has intelligence and can be programmed.

Turn three minds into one mind, go deep into the empty space of the cell and deep into the chromosomes, magnify the space as you enter into the DNA and return to the original cells. Ask for the power to see the cells and look at the brain cells spread out into the space. "Brain cells please listen. Clear, Clean, and Bright: fill with violet light, back to normal function". See violet light. Be aware your crown. The Tan Tien Chi and the negative Chi all combine in the crown. Extend a violet light up to the universe. See the North Star and the Big Dipper. Tell the students to hold their arms in the air, so that they can funnel the Chi into their personal star. Bring the North Star and the Big Dipper down; hold the handle of the Big Dipper and pour the violet light over the student's personal star. The higher cells will be programmed. Let the Chi enter the brain and ask for the power to see the brain cells. "Brain cells listen to the command". If there is sickness in the brain, give the command. "Sickness go away". Continue to spiral the violet light down through the cells of the whole body.

1. Ask for the power to see into the cells of the **Brain.** Ask the student to move their hands to cover their brain. "**Brain Cells** listen to the command;"Sickness go away. Clear, clean and bright fill with violet light and return to normal functions".

2. Ask for the power to see the cells of the sense organs. Ask the student to move their hand to cover their senses. Give the command; **“Eyes, Ears, Nose, Tongue and Mouth** cells listen to the command. Sickness go away. Clear, clean and bright fill with violet light and return to normal function”.
3. Move your hands down to your Throat Center and give the command; **“Thyroid, Parathyroid and Thymus Glands** listen to the command; Clear, clean and bright fill with violet light and return to normal function”.
4. Move your hands to the heart and the lungs. Ask for the power to see the cells of the heart and lungs. Give them the command; **“Lungs and Heart Cells** listen to the command; Clear, clean and bright; Fill with violet light and return to normal function”.
5. Move your hands to cover the left and right sides of the ribcage. Ask for the power to see the cells of the liver, gallbladder, spleen, pancreas and stomach. Give them the command; **“Liver, Gallbladder, Spleen, Pancreas and Stomach Cells** listen to the command; Clear, clean and bright fill with violet light and return to normal function”.
6. Move your hands to the large and small intestine on the front of the abdomen. Ask for the power to see the cells of the intestines. Give them the command; **“Large and Small Intestine**, listen to the comm and Clear, clean and bright fill with violet light and return to normal function”.
7. Move your hands to the kidney and sexual organs and ask for the power to see their cells. Give the command; **“Kidney and Sexual Organ Cells** listen to the command; Clear, clean and bright fill with violet light and return to normal function”. Gather the violet light again and let it pour down and fill all the cells. See the violet light again and feel and see that all the cells are “clear, clean and bright”. Smile.

K. Defense and Immune System

Defense System

1. Work on yourself first to activate your **Sacrum**. Project the sacrum as big as the universe. Breathe and compress the universal Chi into the sacrum until it rises up to fill your brain. Project out into the universe, multiply the energy and spiral it back down. Project it to the students and tell them to touch the sacrum.
2. Tell the students to move their hands to the **Hip Bones**. Tell them to smile to these bones. Feel them as ‘funny, laughing, happy bones’. Tell them to feel the electricity in the sacrum and bone marrow.
3. Touch the **Femur Bones.** Feel the electricity running up the legs.
4. Touch the **Humerus Bones.** Feel the electricity running up the arms.
5. Touch the lower part of the **Sternum** and feel the Chi penetrate into the bones and spread out to the **Rib Cage**. Feel the electricity run throughout the rib cage.

Immune System

1. The Immune system starts with the top part of the **Sternum**. Touch the top part of the sternum. Project your fingers ‘very long’ into the bone and feel them penetrate right into the **Thymus**. Activate the thymus gland. Gradually, feel the fingers rising up to the thyroid and parathyroid. Activate the **Thyroid** and **Parathyroid** and **Throat Center**. Give the command; “Clear, clean and bright fill with violet light and return to normal function”.
2. Move the fingers to touch both sides of the **Jaw Bones** to help activate the **Tonsils,** the body’s first line of defense. The jaw bone affects the **Lymph Nodes** beneath, which includes the tonsils. Fill them with Chi. Give the command; “Clear clean and bright fill with violet light and return to normal function”.
3. Touch the **Mideyebrow** and **Crown**, which control the **Pituitary** and **Pineal Glands** respectively. Touch the third eye, feeling it open and feel the light from heaven entering into your brain and into your body. Touch the crown. Feel your fingers reaching deep inside and feel the Chi penetrating all the way down to your perineum. Fill the glands with Chi. Give the command; “Clear, clean and bright fill with violet light and return to normal function”.
4. Rub both of your hands until they are warm. Cross your arms and hold your hands under your **Armpits**. Picture the **Lymphatic System** of the armpits as you activate the lymph nodes. Give the command; “Clear, clean and bright fill with violet light and return to normal function”. The lymphatic system of the upper body is clear, clean and bright then the lymphatic fluid flows! Smile.
5. Move the hands to the cover the **Groin** area. Give the command to the **Lymph Nodes** there. Give the command; “Clear, clean and bright fill with violet light and return to normal function”.
6. Place your palms over your **Navel** and activate the **Lymph Nodes**. Give the command to the lymph nodes there. Give the command; “Clear, clean and bright fill with violet light and return to normal function”. **You have now activated the immune system.**

Chapter V
Cosmic Healing I - Basic

Source of Chi and Color

There are different sources of Chi in the universe: cosmic (air), earth, nature and human. Different parts of the human body have different energies and are correlated with the universe and nature. Each part of our body, especially the organs and glands can produce, receive, transform and emit different Chi and color.

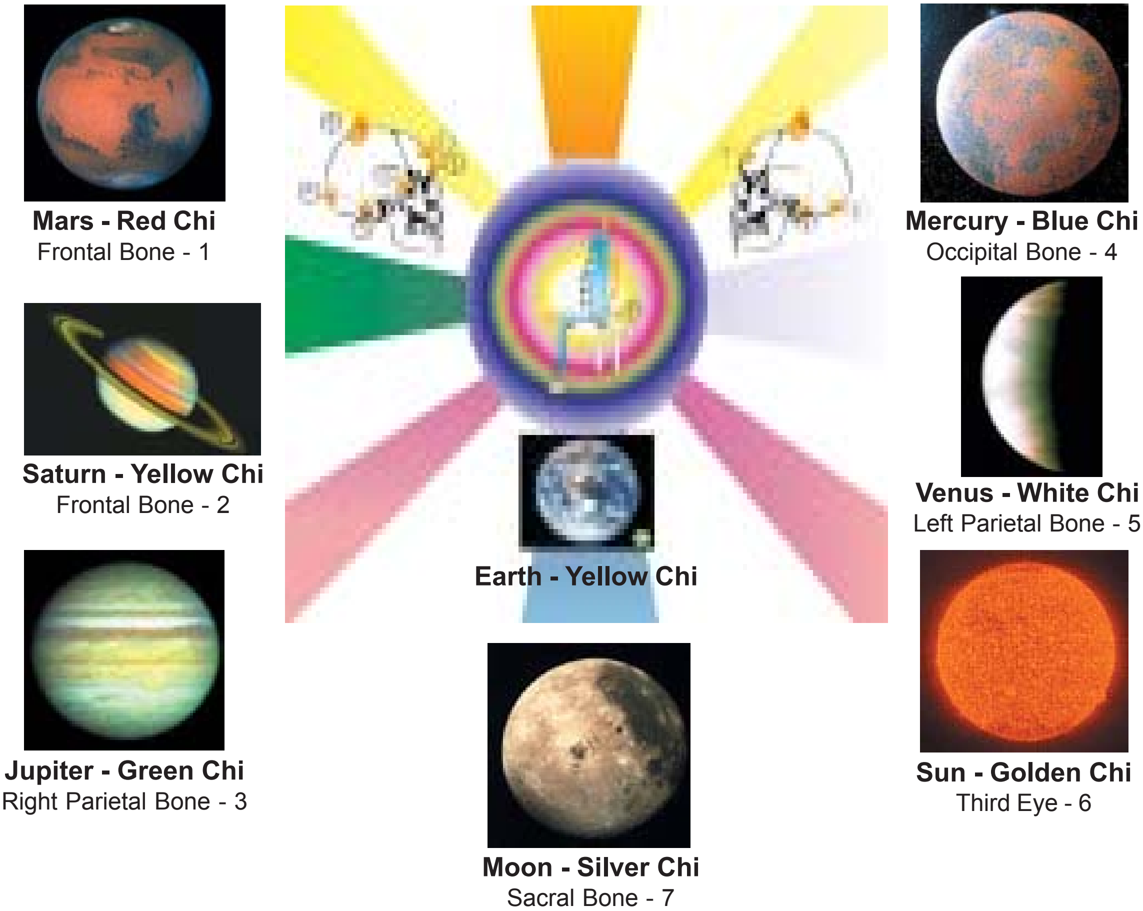
Mars - Red Chi
Frontal Bone - 1
Mercury - Blue Chi
Occipital Bone - 4
Saturn - Yellow Chi
Frontal Bone - 2
Venus - White Chi
Left Parietal Bone - 5
Earth - Yellow Chi
Jupiter - Green Chi
Right Parietal Bone - 3
Sun - Golden Chi
Third Eye - 6
Moon - Silver Chi
Sacral Bone - 7

Fig. 5.1 *Planet, Bone and Cosmic Colors*

Earth Chi

While Cosmic Chi (the atmosphere over us and the universal force) is ethereal in nature, what is called earth Chi is not. This Chi appears as the line visible above the horizon when the sun is low in the sky, and seems to hover just above the ground. It actually also sinks into the ground.

Earth Chi contains yellow and some white Chi. When the ground and the cosmic (air) combine they will become white Chi. This Chi has a very powerful healing energy, not too overheated, but balanced and mild.

When treating a problem, white Chi, in the proportion 7:3 (7 white to 3 of the selected color) acts as a brake on colors which are hot or too active. This enables the body to take in chi more easily.

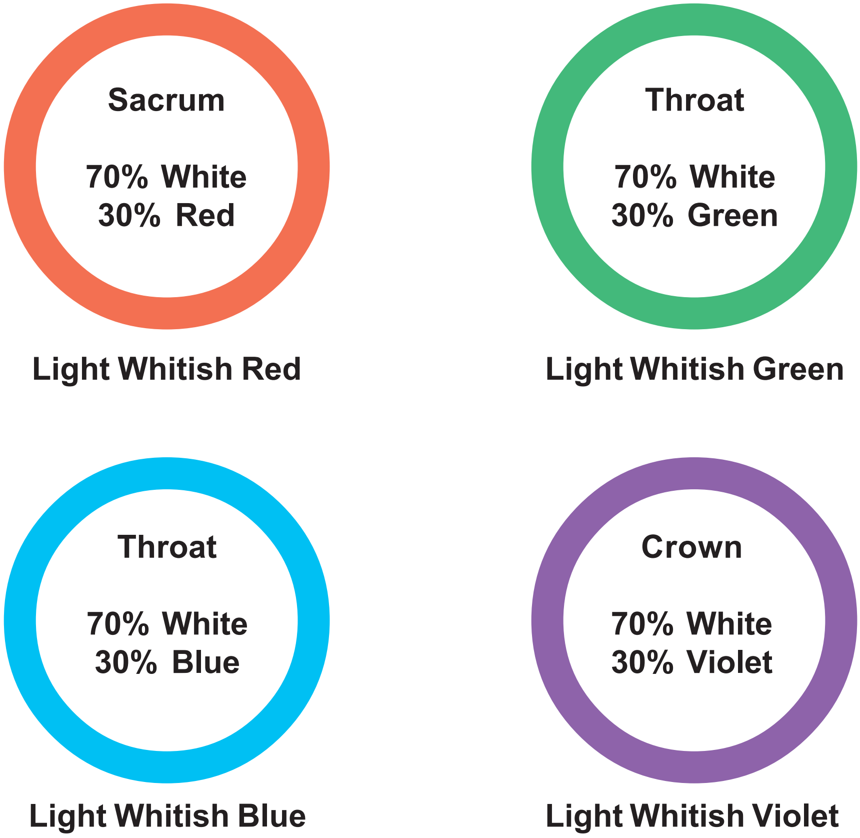
Sacrum
70% White
30% Red
Light Whitish Red
Throat
70% White
30% Green
Light Whitish Green
Throat
70% White
30% Blue
Light Whitish Blue
Crown
70% White
30% Violet
Light Whitish Violet

Fig. 5.2 *Use White Chi to blend all the other Colors.*

Special Note: Many of the color references came from the following books: *"Let There be Light"* by Darius Dinshah and *"Advanced Pranic Healing"* by Master Choa Kok Sui.

Human and Nature Chi

These include the things we can see on the earth: the mountains, lakes, seas, forests, streams, caves, valleys, rocks and precious stones. Taoism classifies five elemental forces: earth, metal, water, wood and fire.

So there are five elements in our body and five elements in nature; there are five elements in the cosmic and five elements in the universe.

According to the Taoists, when we can make the connection and control our body's elements, we will quickly make connections to nature and the universal forces and employ them very easily.

Solar Chi

Before sunrise or sunset there is more white Chi in the air, which we can use abundantly for health and healing. White Chi affects the lungs and the large intestine, so we direct this Chi to these organs. This will generate further Chi to maintain our daily activities. All colors of the spectrum are present in white.

Simple Practice

Look at the horizon at sunrise and sunset. Stand still and extend your palms toward the sun, smile and absorb the rising or setting sun's energy into yourself.

General Information

Energy can be introduced to the affected area of the body by moving the hand clockwise in a spiral.

Move the hand **anticlockwise** with a spiraling motion to clean, flush and remove energy from the treatment area. After this, brush down the whole body, to direct the sick energy into the earth.

Use an anticlockwise spiraling movement in order to clean, then expel the energy.

Use a clockwise movement to bring energy in and an anticlockwise one to take it out.

As a general rule and especially when you are beginning to practice the techniques, keep the color combinations simple. **Always use blue (to cool, calm and stabilize), green to clean, white to harmonize and violet (which carries the properties of all the other colors) to program.**

Although it is important to learn all of the applications, it is more important to begin practice, maintaining a serene state of mind throughout. You will immediately realize that Cosmic Healing provides the practitioner with as much benefit as the student. The more you practice the more you heal.

Healing Colors

White Chi

The color of the chi from the air, earth and sun is always white and acts as a calming agent for the surplus chi produced by the other colors. It also redirects this chi to areas of the body which need it. For this reason, use white in combination with another color in the proportion 7:3.

Shining white chi should be concentrated at the center, while colored Chi goes to the edge. This can also be reversed. It is also possible to blend the white and colored Chi together.

It is safe to use white chi when you are not sure which color might be suitable for a patient, especially when treating babies, toddlers, the elderly and the weak. People with minor problems can be treated with blue, green or mauve, while gold colored Chi or mauve/white Chi is better when the problem is serious. For a stimulating and strengthening effect use white-red.

When it becomes necessary to switch from one color to another, an abrupt shaking movement of the hand should ensure a smooth transition to a new color.

There is a very strong violet light in the North Star. You can dilute the color with white. White Chi is composed of red, orange, yellow, violet and blue.

Blue Chi

The effect of blue Chi is one of cooling, and hindering similar to yin or water energy. The opposite effect can be obtained with the use of red Chi.

When we draw the energy down, some peoples' bodies can't adjust to the energy immediately, so using blue Chi is always good. “Water blue' is the one element that always brings harmony and does not cause any harm.

a. Blue Chi, like yin, water energy, has a cooling effect. It also can act as a restraining agent.

b. Because of blue Chi's ability to cool, soothe and numb, it is particularly appropriate for promoting relaxation and sleep, reducing abnormally high body temperature, minimizing pain and swelling. It can also hinder the proliferation of viruses and bacteria and assist in the rapid clotting of blood.

Blue (and green) can detoxify and also energize.

Green Chi

While tangerine Chi can be quite dangerous, the action on green chi is gentle and harmless. Freeing up a damaged area so that cleaning can then take place may be done with green Chi. Once it's loose you can then use blue or organ's color Chi to expel the disease completely. It can therefore remove the disease and bad energy by locally sweeping either to and then out of the arms for the upper body or out of the legs for the lower body.

If there is a need to energize with the organ's color Chi, first energize with pale green Chi. Always use green chi before using the colors purple, tangerine and red.

Use the throat to activate and draw the green Chi up to the crown, rising to the universe to be multiplied and brought back down for use. Always add blue Chi when there is pain. The motion of pushing and pulling through the affected part is very powerful. You also can also use the 'sword finger' in a small area and for infection.

Green can also be used for energizing together with violet; first use green and follow with violet.

Pale green and pale tangerine chi can be employed in sequence, as the first acts on the 'sick' energy, reducing it to a form which can easily be driven out by the second.

Simultaneous use of pale green pale tangerine and white chi in the ratio 2:1:7 is recommended to treat stubborn areas because the effects are intensified when these proportions are used together.

In the treatment of cancer, dark green and tangerine Chi may be employed, preceded by blue. This can assist in toxin removal, and in the cleaning and freeing up of disease affected areas so that necrotic cellular tissue is released. These colors can relieve congestion and free up 'sick' energy which is 'stuck' when used with brushing movements over the affected areas. They also help with treatment of colds and elevated body temperatures, and in the dispersal of blood clots.

Red Chi

Cerise chi makes the area to which is applied stronger, while crimson chi has the opposite effect. When using color for healing, project luminous white in the center and cerise at the edges for a strengthening effect. Always combine red with blue and green; never use it on its own.

Cerise mixed with white, because of its expansion abilities, can help widen blood vessels and breathing tubes. It also helps those with heart and asthma problems.

Red chi with its qualities of warmth and expansion, has a number of benefits. It is good for the circulatory and respiratory systems and the blood, as it expands blood vessels and other tubes, thus improving circulation and breathing, particularly for heart patients and asthma sufferers. It also brings increased energy into the blood and helps allay feelings of fatigue or weakness, driving out 'sick' energy along with toxic substances and other waste materials. It can also help those who are sensitive to allergens. It may help those whose lives are near the end have a longer period on earth, and promote revival of consciousness.

Avoid the use of dark colors, which may cause an adverse reaction. If a person is suffering from a sexually transmitted disease, it is not advisable to treat him or her with chi which is crimson. Chi of this color makes the microbes that cause such diseases multiply at a fast rate and can also produce an inflammatory or constrictive reaction.

Tangerine Chi

When using orange Chi, always use blue Chi first; to tone and calm down the ailing body area, before applying the vitality of orange.

Pale tangerine chi with added white can be used; however certain areas are inappropriate for treatment by this color because of its power. Do not use with the eyes (including retinal problems), heart, head, throat, brain (for example bleeding in the brain) or the spleen.

The large intestine benefits from the use of tangerine chi, but this color should be used sparingly on areas like the solar plexus and navel. Appendix problems should not be treated with this color as it could exacerbate the problem. Tangerine chi has an effect on the bowel, and can also aid in returning an unconscious person to consciousness or in stimulating someone who is dying.

To treat cancers of certain types, dark green and dark tangerine are suitable because of their ability to destroy. Always avoid the head and the heart when using orange.

Forcible removal of waste products, toxic substances, ‘sick’ energy, viruses and bacteria
Menstrual difficulties
Waste elimination problems
Freeing up ‘sick’ energy
Breakdown of clots in the blood
Problems of the urinary and respiratory systems
Diseases of joints and connective tissue
Common cold
Problems caused by allergens
Cysts

Yellow Chi

Yellow Chi has a close connection to the nerves, the bones and the bone marrow. It is the color of the spleen; in Taoism we feel the spleen is involved in the assimilation and processing of food and the appetite. This doesn't mean eat a lot, but when the spleen is balanced the appetite will be controlled.

Chi which is yellow in color is beneficial in the treatment of nerves as it promotes re-growth. It also helps in the repair of fractures and cells. It is good for the health of bones, tissues and organs. It has the power to increase bone marrow production.

Violet Chi

Violet Chi has the properties of all the other colors. It’s used for severe types of sickness.

The qualities found in all colors are contained in purple chi, therefore it is particularly effective for serious illnesses. Mauve (light purple) chi which contains elements of blue and green, helps to restore organs and nerves affected by disease or trauma.

Although mauve chi can be employed on certain kinds of severe infections, chi which is dark purple should be avoided when diseases of the respiratory system are present, as it could cause the proliferation of disease causing microbes.

Violet Chi is use chi that is pale white/green or pale white/tangerine and, selecting each in turn, with a brushing movement apply to the whole spinal area and especially to the area where the trauma is located.

If purple chi is used in combination with other colors, it will intensify their qualities and if used together with red, tangerine or yellow chi can be dangerous; it may cause the undesirable proliferation of some cells.

Dark electric violet can be used for tumors or cancers. Always use the blue or green first.

In order to make an area which has become weak stronger, mauve mixed with white can be used, but for really fast strengthening use cerise mixed with white.

Both white and violet have the properties of all the Chi colors. The difference is that violet Chi has a greater penetrating effect and is easier to assimilate than white.

Because bright purple chi has been acted upon by the soul, it has the capacity for independent thought and action.

Energy or chi which comes from the air, the earth and the sun is called purple chi. There is a second type of chi with this color, but having more brightness – this has been called bright purple chi and is derived from the soul through the crown of the head, the point connected to the North Star or Big Dipper.

Bright purple chi can only be brought down from the universe via the crown point if the practitioner has highly developed senses, The effects of chi from air, earth and the sun depends on the development of the practitioner's soul.

In contrast to purple chi, the chi which is bright purple in color has a much greater potency because it can help in the restoration of nerves and organs which have been affected either by disease or trauma. This bright purple chi can be used to remove infection and to promote fast healing, even in the case of serious illness.

In addition, this chi has been said to possess its own consciousness (Master Choa Kok Sui. Advanced pranic healing:49)

When cancer and other growths are being treated, use bright purple chi because it has the ability to destroy. However, beforehand, the affected area should be energized with pale blue chi.

Do not use bright purple chi at the same time as chi which is yellow, green, tangerine or red because it will intensify and increase the effects of these colors. In addition, the use of any dark colors with bright purple chi (either preceding or following its use) should be avoided, as this will produce a very damaging result. As a general guideline, use blue before electric violet.

Golden Chi

Gold colored chi, which has almost the same qualities as bright purple chi, is formed when bright purple chi meets the spirit body. The color changes to cerise (pale red) when this gold colored chi enters the physical body. However, this chi is does not have as much influence as the bright purple chi, being gentler and therefore less effective as a cleansing agent. Gold colored chi should be used to treat a very local area, while bright purple chi can be employed over a wider area.

Spleen

The spleen is connected to the solar plexus and the navel, the major center that connects to all the organs. Holding solar energy or a white ball at the solar plexus will help distribute Chi to all the organs.

If the solar plexus gets clogged up the liver and spleen will also become blocked. The spleen, the Door of Life and the navel are all linked together; the navel and the Door of Life sit opposite each other. We call this an emotional link. Many diseases are caused by emotional links; people use psychology to deal with it which can work to a certain level, but all the energy would eventually get stuck at this main juncture or plexus. White chi is taken in mainly at the spleen, and before being sent to the various parts of the body, is split into its colored forms of red, green, purple, blue and tangerine.

If the spleen is not clean, the immune system will be affected, together with the production of bone marrow. The blood will be dirty and diseases of the joints and connective tissue encouraged.

Cosmic Healing Chi Kung works very well with Chi Nei Tsang. The Cosmic Healing Chi Kung, Chi Nei Tsang and all the other Universal Tao practices all play a unique role in working to heal the physical and subtle bodies. When you combine these three in synergy, it allows you to perform many healing tasks. The spleen (located under the left side of the rib cage), spleen center or navel can absorb white Chi directly into the front or back. The Chi will be broken down into color and distributed to other centers and their associated organs.

There is one thing that I always advise: the recipient or student should be under a doctor's supervision and that they should alternate between the medicine from the doctor and the work with us at the Universal Tao. The doctor should be advised of what we intend to do with the student.

Cosmic Healing Planetary Colors

In Taoism we give each planet a color which enhances the healing power. Have the 'Planets' chart (located at the beginning of this chapter) in front of you, look at the relevant planet and close your eyes. Hold the planet in your mind.

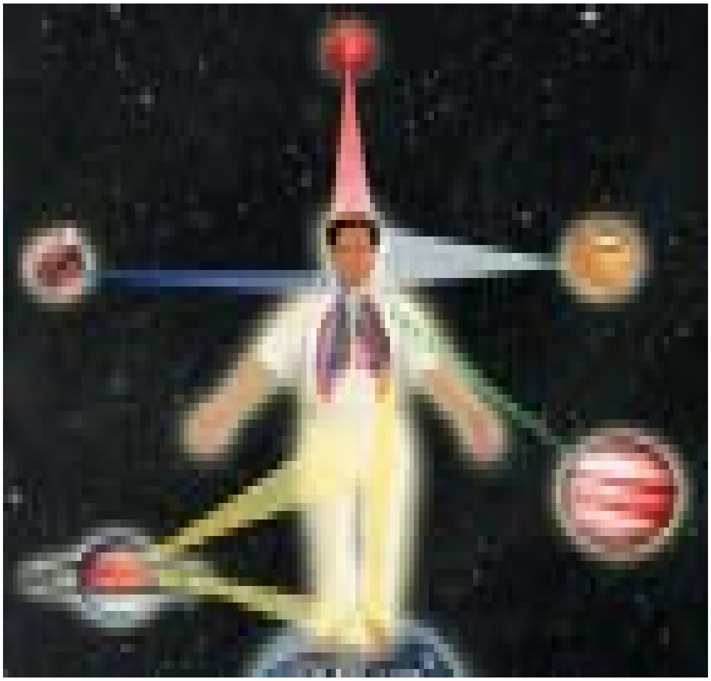

Fig. 5.3 *Channel the Cosmic Planetary Energy into the body.*

Mars: Focus your awareness on the star above you, turn your eyes up and look up to the crown. Hold the image of Mars and extend your sight beyond the crown, looking up into infinity. See the **Red Light** and gradually bring it down to your head about 6 feet above you. Form it into a red ball, a holographic image of the planet Mars shining its red light above you. Invite it to flow down to your 'star' (located above your crown) and continue to flow into your Upper Tan Tien for processing. Let it flow down to the heart (or T-2) and down to the palms. Red and orange light also can be breathed in through the sacrum. Feel the sacrum pulsing and breathing in the red and orange light. Practice 9 to 18 times, rest and shake your hands.

Venus: Become aware of the star above you, turn your eyes up and look up to the crown and into infinity, seeing the expanse of **White Light.** Gradually bring the light down to your head, about 6 feet above you. Form it into a white ball, a holographic image of the planet Venus shining its white light above you. Invite it to flow down to the star above your crown and continue to flow into your Upper Tan Tien, for processing. Now it may flow down to your lungs freely.

Saturn: The **Yellow Light** from Saturn can also be absorbed via the earth through the soles of your feet and perineum. This is for your spleen. Follow as above.

Mercury: The **Blue Light** from Mercury may be absorbed through the throat center. This is for your kidneys.

Jupiter: The **Green Light** from Jupiter can also be absorbed through the throat center. This is for your liver. Follow as above.

Summary - Working with Color

(Practitioner to Student)

There are two ways of doing this type of healing session:

One way is to focus on the specific location in your own body, using your hands and ask the other person to do the same. Together you complete the entire route.

Another way is to focus on your own energy body and ask the student to do the same. Bring a channel or line down from your energy body into your physical body and do the same for the student. Once again, complete the routes together.

For reasons of clarity this text only mentions one student and uses the male gender; *this session may however be performed with a group also*. Before starting the session do some group meditation practice and warm ups.

1. Be aware of the Tan Tien and connect to the universe. Let the student sit with his back to you. You are behind him. Be aware of your **Sacrum** area and feel the Chi; **wait for the Chi to rise up to the crown** and to the universe. Spiral the Chi down to the student's and your own energy body and it will flow into the physical realm.
2. Draw in the green light with your palm, push it right through the sacrum and disperse the sickness throughout the other side of the universe. Pull the green light from the universe through the sacrum and push the sick Chi out to the universe. Do this 6 to 9 times until you feel the **sacrum has been cleaned**. When you pull back stop the green Chi at the student's sacrum; there is no need to pull it back to you.

   Yellow light from the earth will help strengthen the sacral bone. Visualize the sacrum and vitalize the complete bone structure with yellow light passing throughout.
3. Be aware of the energy body above the **Crown**; extend yourself up from above your crown and **channel down the white light from the center of the universe and the violet light from the North Star.** Using your 'mind-power' ask the inside of the bone structure to open, allowing the white and violet light to **flow into the marrow.** Focus on the energy body; you can picture the energy body's sacrum and bone

structure to help guide the energy inside and see the whole body light up from deep within.

4. Then focus on the **Door of Life and the Navel.** First flush them through with **green** light, cleaning them out. Draw the green light from the Door of Life through to the navel, and then push back through. To cool down the Door of Life (if necessary), draw the **blue** light and push it through from the navel to the Ming Men, connecting with the universe. Then bring the **white or violet light down and activate the Lower Tan Tien.** Always teach people about their Tan Tien. It is like an ocean and the body is like a hollow bamboo. The bamboo can bring the water up. This way energy will never dry up.
5. Concentrate on the **Solar Plexus and the Chi Chung (T-11)**. Once again, draw the **green** light, spiral it, use it to flush, then **energize with white and violet light**. As before, always allow the energy to stream through both the points completely. The solar plexus holds all the emotions. When working on the solar plexus, the **most important thing to remember is to connect the 'backside' to the universe.** There is literally no end to this connection. Just allow the Chi to come all the way down and then pull it towards the rear slightly. Simply clean out the path. Allow the information to condense; allow any images to manifest and then release. Then stabilize the energy. Picture the Chi-Field enveloping the person as a big protective bubble. **Cool down with blue.**
6. Proceed to the **Heart and the Shen Dao (T5/ T6).** Draw in the **green** light, push it through and repeat several times. Now scan the heart with your palm, sensing its strength; then select an appropriate hue, i.e., not too dark. Send the **red** light through the heart to strengthen it.

   Cool down any excess heat in the heart, flushing down and out, using **blue** color. Draw in the **white** Chi; push it through to the **Wing Point (T5/T6)**. **Energize the center at the back of the heart using violet and golden Chi.** Picture the heart surrounded by a golden aura.
7. Move up to the **Throat Center, flushing through to C-7**, using **blue** light first to open and clear it and then **green** light to clean.
8. Next activate the **mideyebrow.** Focus on the mideyebrow in your own body. Use **golden yellow** Chi; use it to **flush and stabilize** the mideyebrow. Flush it all the way through to the backside of the head. **Energize with violet golden light.**
9. Proceed up to the **third eye** in the middle of the forehead. **Connect to the Kun Lun** at the back of the crown. **Flush** through both points using the pale **violet light. Energize** with **electric white or golden light.**
10. Concentrate on the **crown**. Use **violet** or **golden** light to enter and **flush** all the way down through the **central channel**, leaving the body at the **perineum**. **Cool down the system by showering blue light over the whole body.**

    When people have a serious infection, they should consult a doctor. It is common for infections to take a long time to clear up nowadays, even when using antibiotics.

There are two ways to deal with this; allopathically or naturally. The Taoist practices are in great conflict with ‘contemporary (i.e., not alternative/natural) western concepts’. The western concepts recommend a full course of antibiotics. Using the theories of Chi Kung, a baby for example, would absorb natural antibiotics via the bones. Western Allopathic Practice consider antibiotics as wonder drugs. The only ‘wonder’ is when will they realize the many harmful effects that it has on the body? Babies that have been ‘fed’ with antibiotics frequently suffer many organ related problems by the time they reach 20 to 30 years of age. The worst thing is that they are given to children nearly every time that they become ill. If you scan (cosmically) the solar plexus, thymus or spleen of such a person, the area feels like a hollow void. This means that the immune system is totally non-functional. The same thing applies to ***Aids***: the immune system no longer functions. Any virus can enter the body - medicine cannot kill it. There is nothing left to ‘fight with’.

In my experience and following my own experiments, in circumstances like the above my own practices are as follows: I clean my colon; there are a few ways to do that. I eat fiber, vegetables, especially green leafy ones. I eat a big bowl of vegetable soup. I also add things like onion, pumpkin, carrots and cabbage, which will give it a sweet taste. I don’t eat any meat and drink a lot of water. The colon is cleansed within two days. I also brush the skin, which is a very good detoxifier. The vegetables will provide natural carbohydrates which are digested and absorbed very quickly. A healthy diet consists of many whole natural foods. It is ‘alkaline’ as opposed to ‘acid’ based. I also use the ‘colema’ which I feel is the best cleanser.

Chapter VI

Individual Healing Session

The Individual Healing session embodies all of the techniques that you have used previously and consolidates them for use on a one-to-one basis. The session comprises the following three parts:

A. Almighty Knife (Chi Knife)

The almighty knife can be used for any health problems. We can charge the knife with Yin or Yang energy. We charge the almighty knife most often with Yin Power. Yin is the cold energy and is used for any inflammation, pain or heat. Yin is used to break up illness. Charge the almighty knife with Yang for strengthening, melting or expelling. Only use the Yang when there is no pain.

B. Energizing and Activating the Immune System

C. Cleansing the Internal Organs

A. Almighty Knife

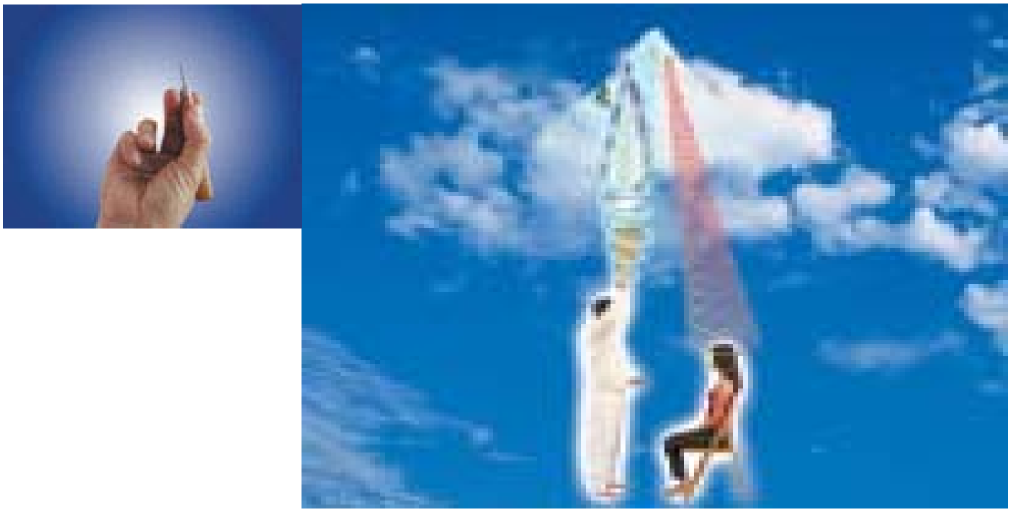

Fig. 6.1 *Almighty Chi Knife*

Since the dawn of ages and our descent into the material realm, we have constructed, manufactured and used tools to facilitate the progress of events. They are an extension of ourselves that enable us to enhance, mould and magnify our intrinsic nature as inquisitive playful beings.

We have used implements to help nourish, protect and amuse ourselves and further our progress in attempting to understand the ‘how’ and ‘why’ of existential reality. The knife has served as a means to carve our way into the present. It is a simple, yet powerful ‘friend’ and derives as much power as we wish to lend it.

Its design may consist of any combination of the five elements (Earth) which when combined with Universal (Heaven) and Cosmic (Man) forces, provide a unit of energetic substance which receives and transmits magnification, purpose and power in accordance with the human will that governs it. ‘Chi Knife’ and “Powers of Ten’ adopt the precepts of a truly magical existence. When we arrive at our destination we will realize that we have indeed turned “the Wheel of Law’. In achieving this end we will have completed the cycle and returned to the beginning of the journey. We will understand that the simple things in life, like the knife, contain the same amount of power as state of the art technology.

We are all returning to the Garden of Eden. Complex telescopic and microscopic equipment now enables us to see the truth:

> “Inside has no outside; outside has no inside”.

They are one in the same thing. When they merge together we will indeed enter the Kingdom of God.

Outline of Practice

1. Hold the knife in the right hand (left, if you are left handed). Hold the other hand near your body, with the thumb and index finger touching. Project the Chi Knife as big as the universe, ‘long and big - reaching to Heaven’. The bones in your arm are hollow and the ‘bottom’ is sealed at the shoulder. Feel them ‘fill and pack’ with the power coming from above.
2. Then give the command: **“Power comes from the east. This Chi Knife has the power to dissolve all the negative energy, sickness and bad fortune. By my request, please carry out the order now.”** Wait until you feel that your arm and the knife are heavy and full of Chi.

Eye Problems

Use the thumb and the index finger to hold the eye wide open.

You hold the knife like holding a pen, 3 to 6 cm away from the eye. Use the little finger for leverage and support.

WARNING!

DO NOT USE A KNIFE. THE **MASTERS** OF GREAT EXPERIENCE USE RITUAL SCALPEL TYPE KNIVES. THE STUDENT SHOULD USE THE “SWORD HAND” FINGERS (P.76, FIG. 4.24).

DO **NOT** USE SHARP OBJECTS NEAR THE EYES**.**

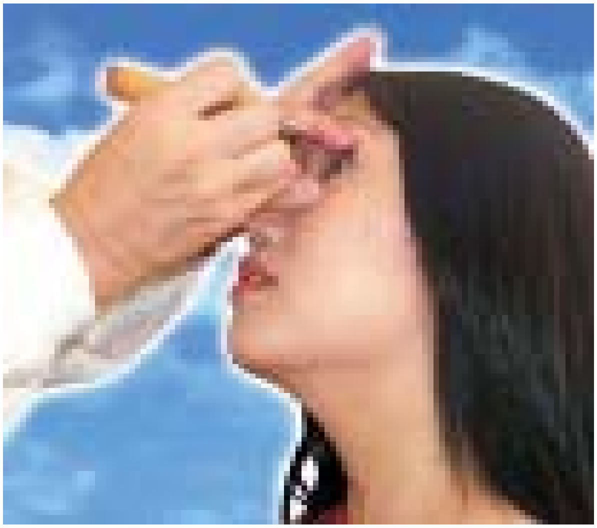

Fig. 6.2 *Hold the knife three to six cm. from the eye.*

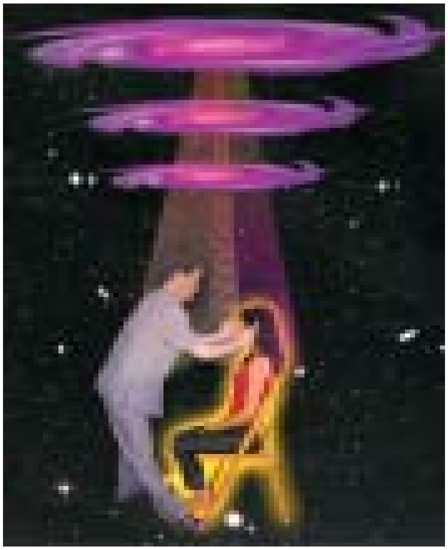

Chi knife - “Almighty Knife” helps all eye problems”. Cut up and down and sideways in the cross pattern ‘through’ the eye thoroughly. Tell the student to move the eye left and slowly move to the right as you cut with the Chi Knife. When they move their eye to the right, move the Chi Knife to the left. **Remember that the knife is used for ‘energetic surgery’ and should never make contact with the eye itself.**

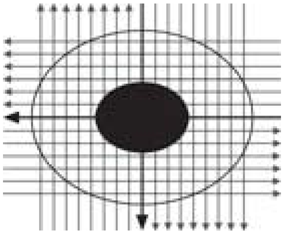

“Slice” the eye toward the right side for 50 to 100 knife movements and do the same to the left side.

Fig. 6.3 *“Almighty Chi Knife helps eye all problems”.*

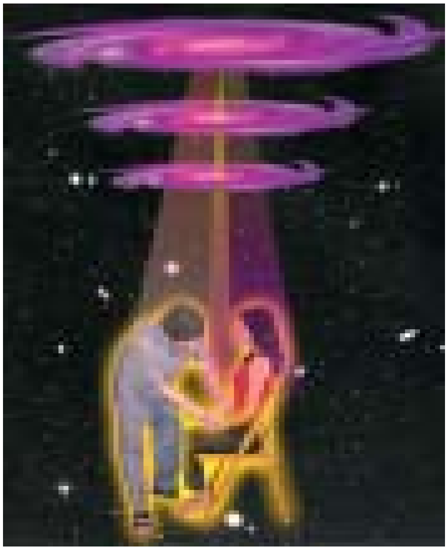

“Almighty Knife, please destroy all kinds of wounds, warts and tumors”. Cut up, down and sideways in the cross pattern through the part that has the ‘condition’.

Fig. 6.4 *“Almighty Knife, please destroy all kinds of wounds, warts and tumors”.*

The almighty knife can be used for any problem in the body. Follow the same procedure to carry out ‘energetic surgery’ on all parts of the anatomy. It is especially good for soft tissue repair, including the brain.

When you feel that the Chi Knife is full of sick Chi, spiral counter clockwise and discard it down to the ground. When you feel that the knife is ‘empty’ charge it with Chi from the universe.

B. Energizing and Activating the Immune System

In cases of severe illness, you will want to do this technique many many times, because it is essential to stimulate the body's defence-systems. This technique is also beneficial for debilitation and infection. You may also want do this in a preventative manner.

Activating the immune system always involves the bone structure, especially the round bones in the arms and legs and the flat bones in the skull, jaw, rib cage, hips and spine. All of these are involved with the production of white blood cells. The **thymus gland** and the **spleen** are of special importance to the immune system, because they are involved with programming and training the white blood cells (called T-Cells) to do the right job. **The lymphatic system is involved in removing toxic waste from the body; it is therefore beneficial to stimulate the lymph flow as well.** This is best done in combination with Chi Nei Tsang. *For details refer to the Chi Nei Tsang Books.*

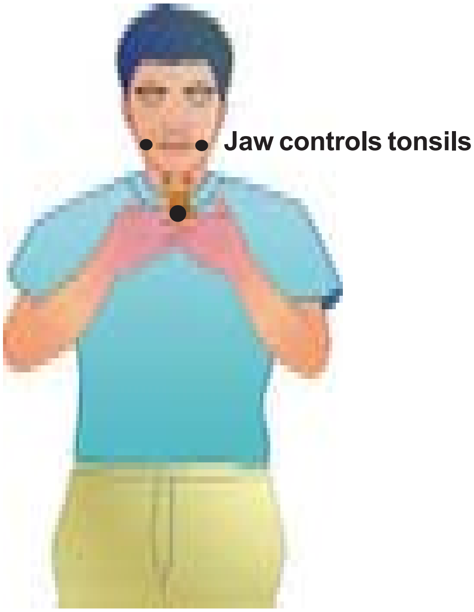

Fig. 6.6
Touch the top of Sternum to activate the Thymus.

If you work on a one-to-one basis, first perform the general cleansing session, where you 'pour energy' over the other person. After that use your hands, drawing Chi and pushing it through. Remember to push the energy all the way through and connect it with the universe beyond. Ask your student to concentrate on the areas that you are treating, preferably by guiding them, touching each point as you go.

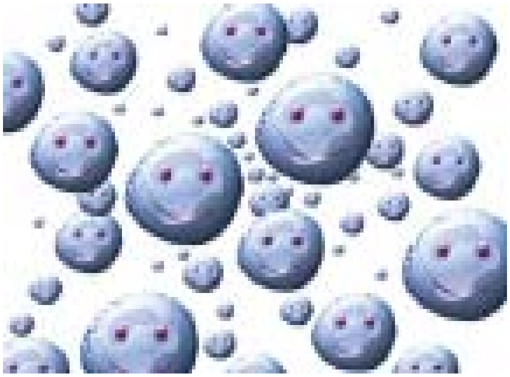

Fig. 6.7 *Happy Cells.*

Outline of Practice

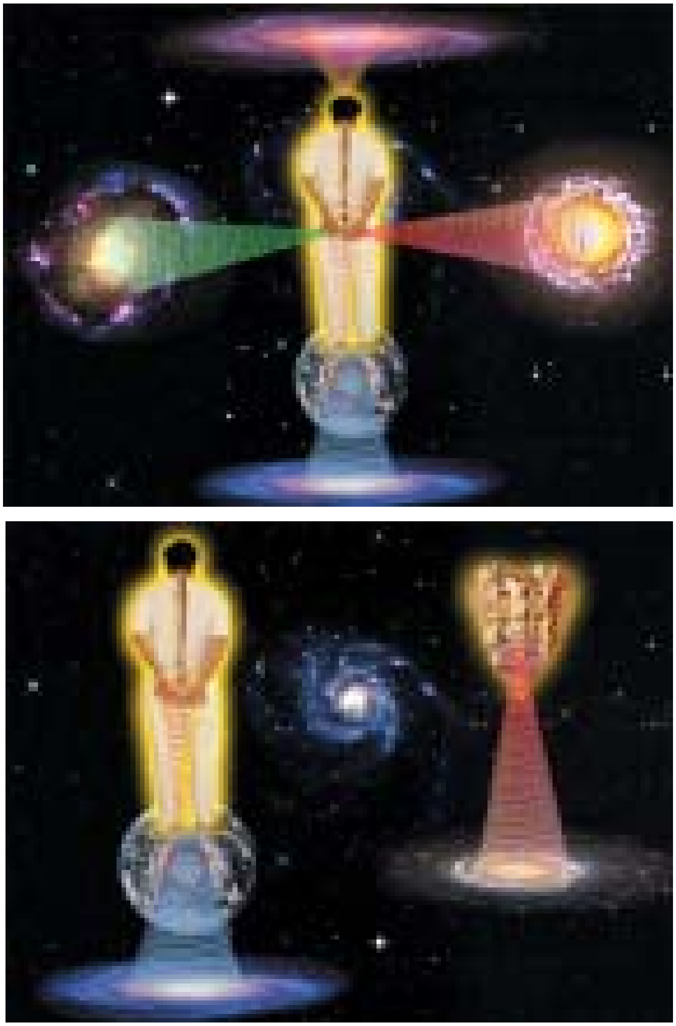
Fig. 6.9 *Touch the Sacrum.*

Guide the student as you practice together. Work with your own energy body and tell the student to work with theirs. Presuming that you have already done the previous set of general healing, you can start with the **coccyx**.

1. Be aware of your Tan Tien and connect to the universe. Direct the Chi down to the fingers. Touch your coccyx with the fingers concentrating a beam of white light on to it. Picture the sacrum opening and the white light streaming inside, flowing up the spine and streaming out over the whole bone-structure. Transfer the feeling of Chi in the coccyx up to the universe, multiply it and guide it down to your energy body.
2. Always be aware of the Tan Tien and the universe first. Attract the yellow light; spiral and condense the healing light into the tip of your fingers; move the fingers up to touch the sacrum. Send out a beam of yellow Chi into the sacrum, directing it up the spine. This will stimulate the production of red blood cells. If you are not sure whether you are able to send it right into the marrow, picture the marrow or emit the Chi from your fingers, while at the same time concentrating on the bone marrow of the energy body. Transfer the feeling of 'Bone Chi' up to the universe and down to the energy body.

3. Proceed to the crown, showering it with violet light. Then spread from the crown throughout the bones of the body. Repeat several times. Instruct the student to feel the bone structure breathing. Ask him/her to extend up from the crown to the Big

Dipper and North Star, channelling down the red and violet light into the thymus gland.

4. Continue to the throat, stroking down with your palms, using green color to move the lymph down towards the backside of the heart. **(Never stroke up towards the head. Only guide the lymph down).**

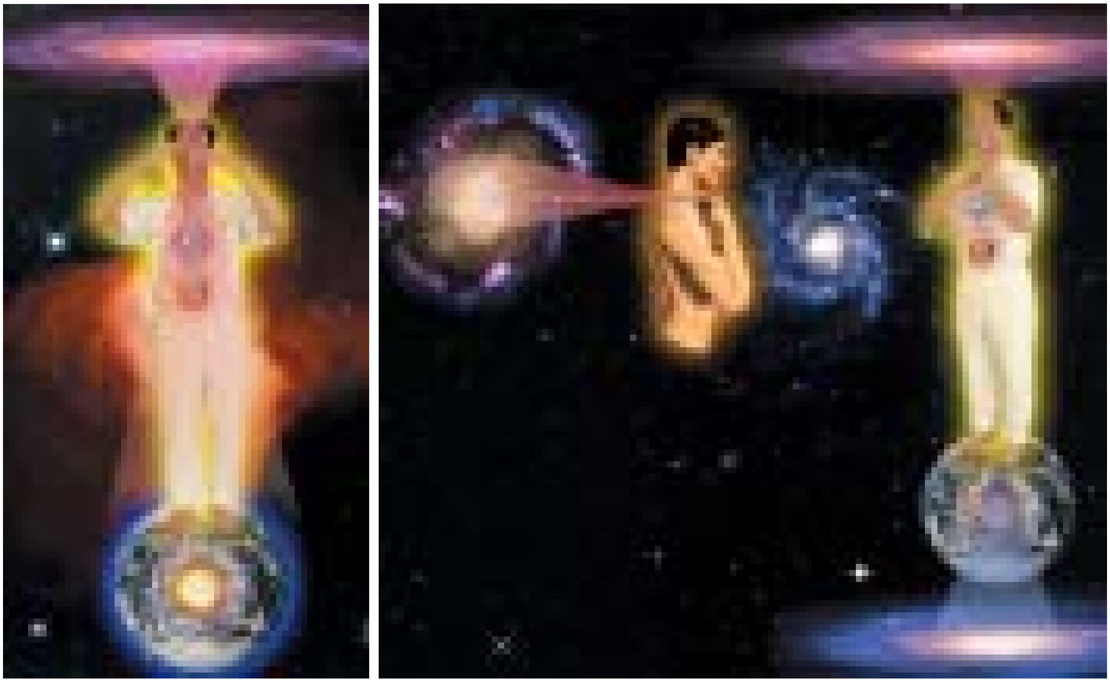

Fig. 6.10 A. *Channel the Violet Light of the North.*
B. *Use your Palms to bring the Lymph flow back to the Heart.*

5. Proceed to the lymph nodes under the armpits and across the sternum. Next activate the lymph nodes in the groin. From the groin you guide the lymph up to the navel center (Not down where it will get stuck in the legs).
6. Return to the navel center. Send the energy deep inside, energizing the lymph nodes at the back. Pull back, drawing green energy, flushing out any waste products that are stuck in them.

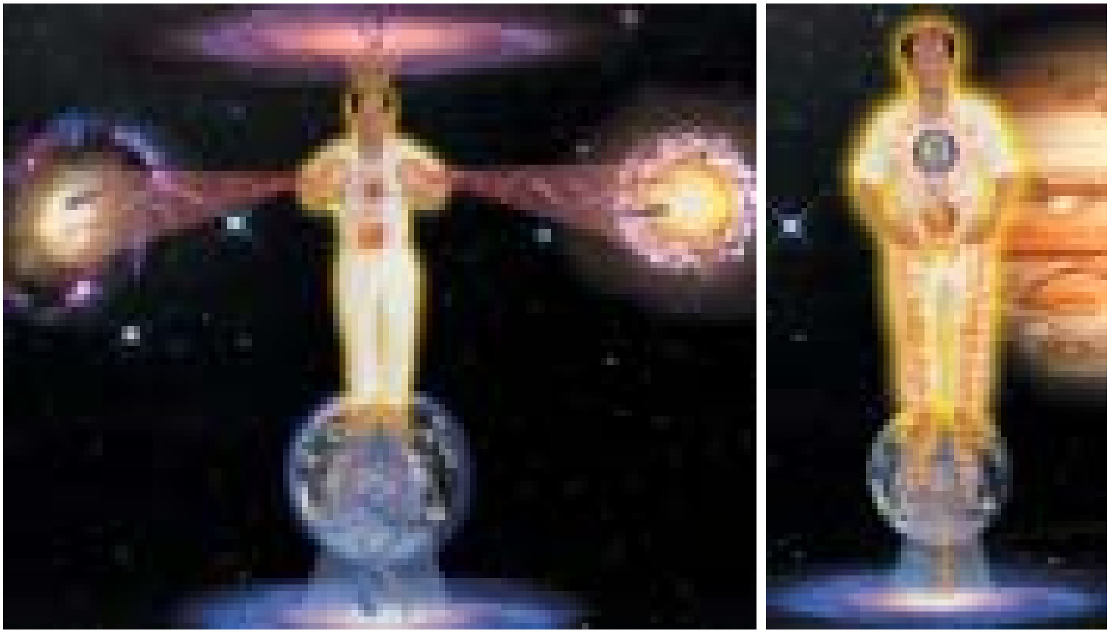

A. *B.*

Fig. 6.11 A. *Activate the Lymph Nodes in the Armpits and Groin.*
B. *Energize and flush the Lymph Nodes in the Navel.*

C. Cleansing the Internal Organs Technique

Healing Some Common Illnesses

This session can be used for any kind of ailment and carried out with any number of students. It can take place on a singular, paired, small group or large group basis. Numbers can range from one person, one hundred, one thousand, ten thousand, ad infinitum. It is more likely that a greater energetic current will be created in much larger groups. In the case of 'mass' healings, there will always be a 'guide' or 'conductor', to open the channel for the students to follow. In the case of solo practices you will of course be the guide. **The following instructions have been set out on a one-to-one basis**.

By connecting to heaven, earth and your student, you will maximise the wholistic healing potential to your physical and subtle bodies. We recommend you spend about twenty minutes on the general healing before moving on to the more localized practices of emptying and cleansing the body's centers, systems and organs, contained within this chapter. We recommend that you spend between five to fifteen minutes on all of these. **Always perform the Sacred or Chi Water practice before.**

It is important to remember that if there is no energy in your Tan Tien, then there will be no energy to work with. 'Connecting the Tan Tien and the Universe' means connect your center to the infinite source of the universe, the Tao. When you make the connection you access this power. Always hold on to your center; it is the only thing that is truly yours. Keep the fire warm and spiraling. When you are aware of your Chi, you can direct heavenly light straight into your energy body and then into the student's.

General Principles

1. Push and pull the energy through the student's body. Push and disperse the sick energy into the universe and out to the planets, where it will be transformed and recycled.
2. Pull the energy back and stop it between yourself and the student.
3. Spiral the energy counterclockwise until you see the **green** light mix and clean the sick energy. Spiral and flush the energy down into the earth.
4. Spiral with **blue** light; see it mix and flush the energy within the student's body. Spiral this energy down to the ground.
5. Energize the student with **white** or **violet** light.
6. You can also use both hands to channel Chi when you 'push and pull' through the body.
7. Energy can be introduced to the affected area of the body by moving the hand clockwise in a spiral.
8. Move the hand anticlockwise with a spiraling motion to clean, flush and remove energy from the treatment area. After this, brush down the whole body, to direct the sick energy into the earth.

   Use an anticlockwise spiraling movement in order to clean, then expel the energy.

   Use a clockwise movement to bring energy in and an anticlockwise one to take it out.
9. When you begin pushing, pulling and sweeping, you may feel resistance in the body. As you progress and the energy centers open, this feeling will diminish.
10. There are many color combinations that can be applied to the various parts of the body. When you start practice, stick to the basic 'blue, green, white, violet and blue' formula. When you are working on a specific area, you can keep this book near by, or write a short 'color recipe' before you begin. In this way, you will be able to relax your mind.
11. 'Pushing and pulling' is like fanning and venting the body; when you fan your hands in front of your face, it will have a cooling effect. Ventilation enables the stagnant, sick energy to leave the body.

    Below is a list of the body's organs in relation to their tendency to 'store heat'. They are listed in descending order, i.e, the head is the hottest:

Head, heart, liver, lung, stomach and spleen, large intestine and small intestine, kidneys and sexual organs (which become hot when aroused).

Outline of Practice

Occupying a position amongst most of the internal organs, the solar plexus acts as a kind of clearing center for energy generated by the emotions. It also lies in between the lower and higher energy centers.

1. Scan; ask for the power to look at the cells.
2. Push, pull and give the command, “Disperse”. Push until you feel the solar plexus clear and open.
3. Spiral green Chi counterclockwise. Talk to the sick energy; tell it to “leave”, you will take it to “a better place, where it will be happy”. Give the command, “Out”.
4. Spiral Blue Chi counterclockwise, flushing out any remaining sickness. Guide the sick energy into the earth.
5. Spiral and sweep Blue-Green and Red Chi into the solar plexus, sweeping the organs. If the patient is expecting a baby, has an infection or bleeding in the intestinal area; do not use this method.

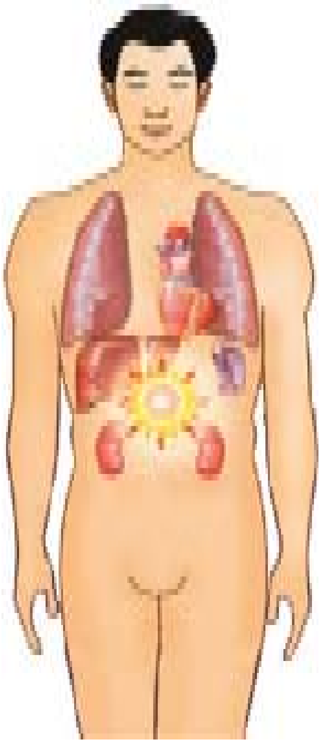

Fig. 6.12
Spiral Green Chi counterclockwise in the Navel.

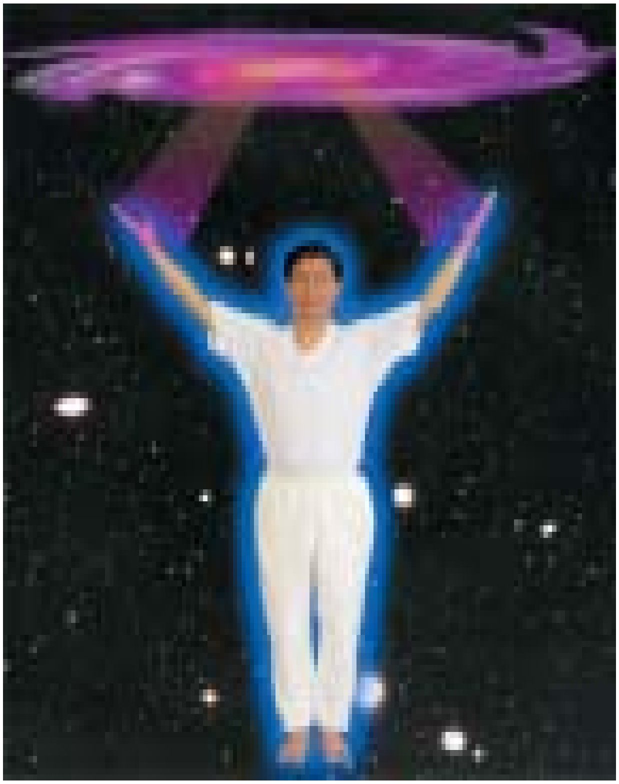

***Fig. 6.13** Charge your Hands with Chi - project the Hand Bones into the Universe and feel them fill and pack with Chi.*

Work on cleaning out the **organs**. Scan the person and see which parts are hot. A lot of people will have an overheated solar plexus, which means that this area will require a lot of attention. You will feel the heat when you scan.

You can **clean the organs by 'pushing and pulling'**. Picture the organ and push; feel your hands are very 'long', extending through the organs and reaching out to the universe. Project all the sick energy down into the earth and out to the universe. Use your intent to guide it into the earth and out to the other planets in the solar system, where it will be processed and recycled. Pull the universal energy back towards yourself; push and disperse all the negative energy out to universe. Pull; when you pull the Chi back past the student, stop in between the two of you. Push, pull, push and pull, until you feel the energy or power. **Ask; "Give me the power to see". Feel your Chi entering into the organs with ease.**

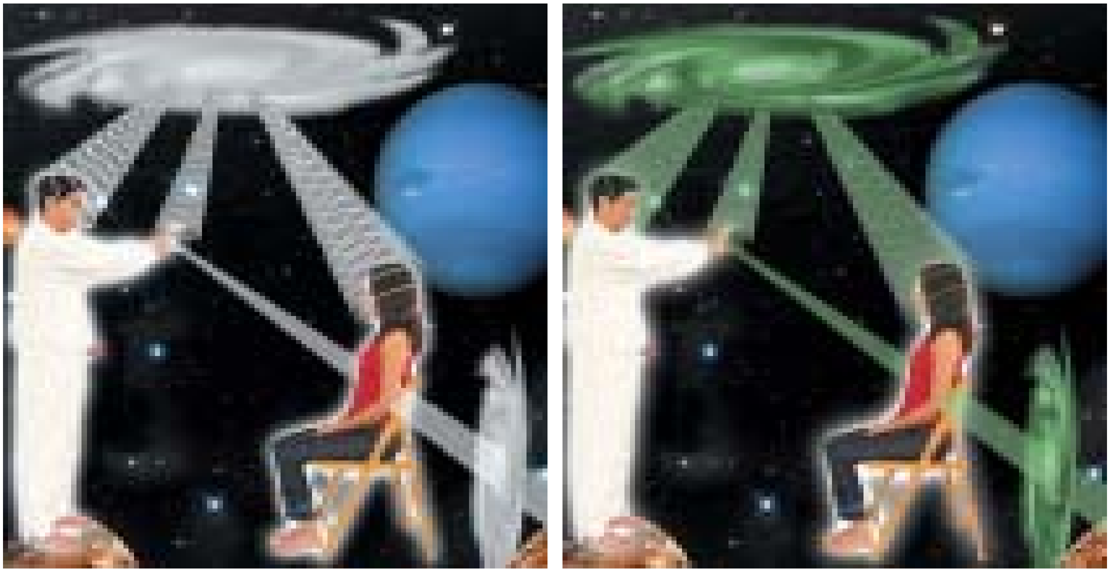

A. ***B.***

Fig. 6.14

A. *Extend through the solar plexus and reach out to the universe.*

B. *'Clean and energize with Green' - push and pull to help loosen the solar plexus. Spiral counterclockwise with a Green Light. Blend with the sick energy and guide it down to the ground.*

Clean with Green Light. Spiral counterclockwise. Feel the green light mixing with the sick energy. Push and pull until you feel the energy in the solar plexus begin to disperse. Spiral the energy counterclockwise and guide it down to the ground.

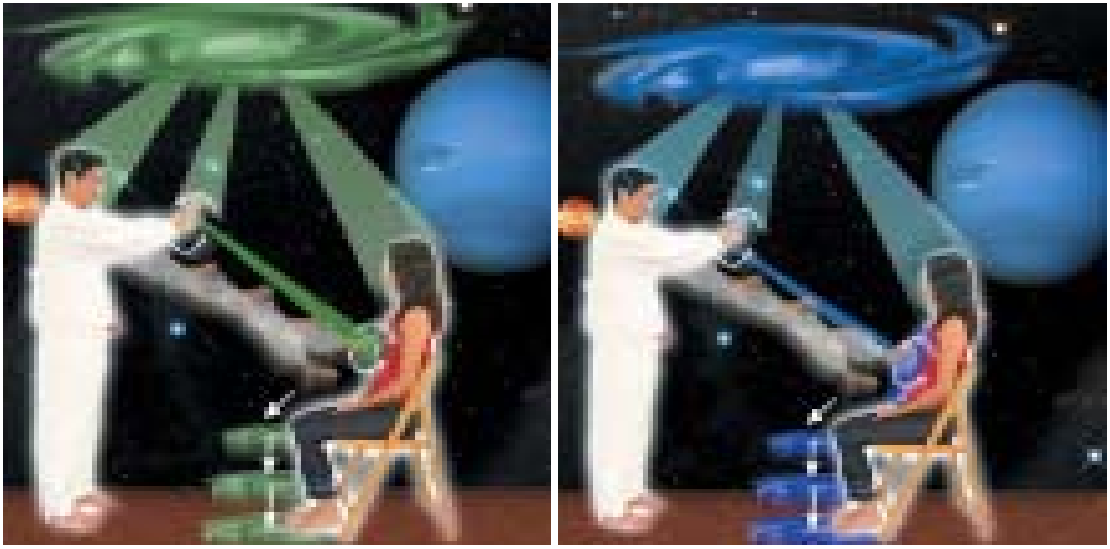

A. *B.*

Fig. 6.15 A. *'Push and Pull' to help disperse the energy in the Solar Plexus.*
B.*'Flush and stabilize with Blue'-Picture Ocean Blue and flush sick energy down into the Earth.*

Rinse and flush with blue light. Picture ocean blue and flush down to the earth. See and feel the solar plexus becoming cleaner. Flush the sick energy down to the earth.

Now clean out the whole body again. With all the organs: from the lungs, heart, liver, gall bladder, pancreas, spleen, stomach, small intestines, large intestine, kidneys and sexual organs. Clean all the way down to the earth. **When you clean the solar plexus and all the other organs you remove all the negative emotional energy.**

Energize the **spleen**, **liver** and **kidneys** with blue or white light. Then project green, followed by orange light to the cores of the liver and kidneys. Clean with the green and orange light and stabilize with blue light.

Work on the **back** of the **spleen** and **kidneys**. Energize them with blue-white light. The spleen is on the student's left and kidneys on the right and left. They all help to clean the blood. Spiral the energy clockwise into the spleen. See it in your mideyebrow. See the cells and spiral the light into them. Give the command, "**Stay**". This is very important; it makes sure that none of the cells hide from the dazzling light that you are sending. Give the command again. Then stabilize them with blue light. Picture the kidneys and see their cells and feel the blue light go into the cells.

Work on the **Liver** on the student's right hand side. Smile and laugh to the liver and see all of its cells. Give the command, "**Stay**"; then send in the healing light. Send in blue or white (energize), followed by green (energize and clean), blue (rinse and stabilize), violet (recharge and reprogram) and then blue to stabilize again.

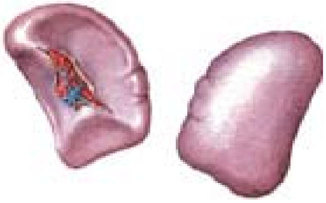

Spleen - Front and Rear

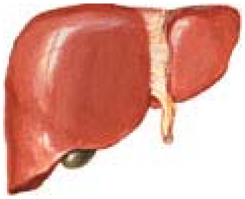

Liver

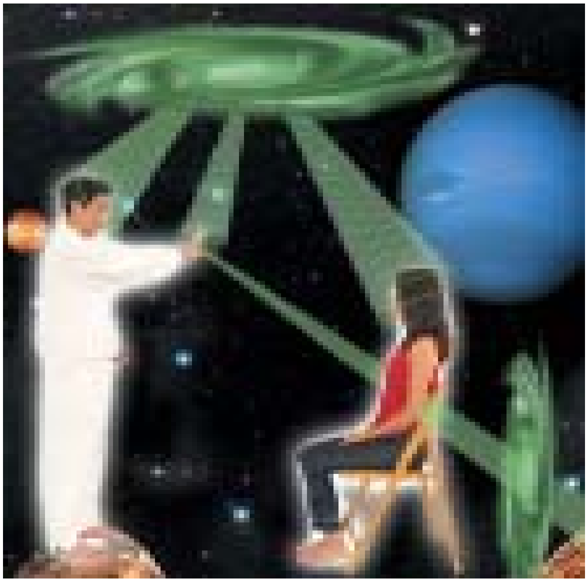

Fig. 6.16 *'Push and Pull' to help disperse the energy in the Liver and Spleen. Clean with Green and flush and stabilize with blue. Flush the sick energy down into the Earth.*

It is essential that you feel and talk to any sick energy. **If the student is healthy then you will feel their 'light'.** Ask their energy body to tell you where it **may** need some healing. Send in 'light radar'. Transmit green light and flush down to the earth. **When you feel that energy is accumulating, start to spiral more.** Push and pull and give the command for the sick energy to leave.

The more you clean, the more you heal. Tell your student to practice at home after the session, at an agreed time. You can then carry out 'absent or distance' healing, linking everyone's personal star, energy body and the universe. **With time, you will master the techniques, imprinting them with your own manner.** Eventually symptoms disappear, as the blockages are cleared and the flow returned.

Cleansing the Spinal Cord

Always cleanse the spinal cord, which protects the entire body from diseased and negative energy, both physical and psychic. When you open the spinal cord and solar plexus you can release many energy blockages. Sweep the hand in a clockwise motion to energize the spine with either/or a combination of; **blue, green, white and ultra-violet**. Then spiral counterclockwise and **brush** the spine down to the ground. Continue sweeping until you feel that the spinal cord has cooled down. Remember not to use orange or red.

Spine

Cleansing the Blood (Lungs)

Pale green/white and tangerine/white chi work as cleaning agents for the blood. Diseases of the blood and arteries can be treated. The chi first energises the lungs and as the blood passes through them, it takes in the chi, thus becoming purified. The benefit is then carried to the rest of the body as the blood circulates. Serious infections can also be treated in this way; however, the technique should not be used on women who are pregnant.

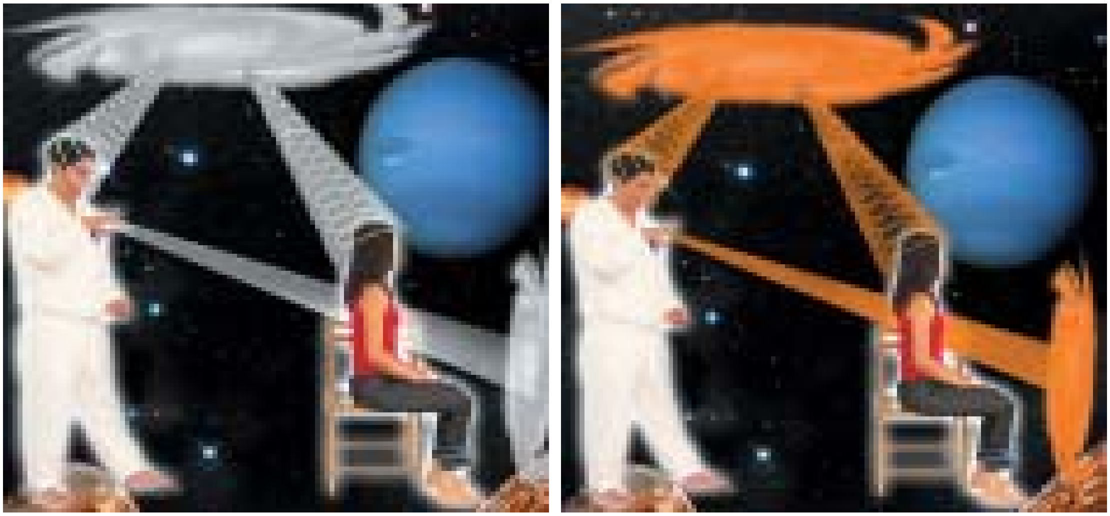

A. **B.**

Fig. 6.17 A. *Cleansing the Blood and emptying the Lungs.*
B. *Become aware your Three Tan Tiens. Connect to the Universe and ask for 'the Power to See'.*

Outline for Cleansing the Blood/Lungs

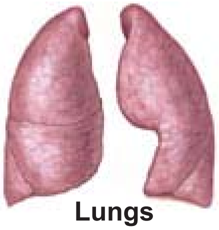

1. Scan the student.
2. Push through and open the lungs from the back to the front.
3. When the lungs need to be given energy, use pale green/white followed by pale tangerine/white chi beginning at the front and moving top the rear.
4. To make weak patients stronger, cerise/white chi can be employed as this will bring energy into the lungs.
5. Purification of the blood is carried out by the liver, kidneys and spleen. Use white chi to bring energy to these areas, after first pushing and pulling through them.
6. The blood requires a lot of cleaning on a regular basis.
7. Energize with white Chi. **Germs can only grow in the dark. 'Fill yourself with the light'.**

Circulatory/Heart System General

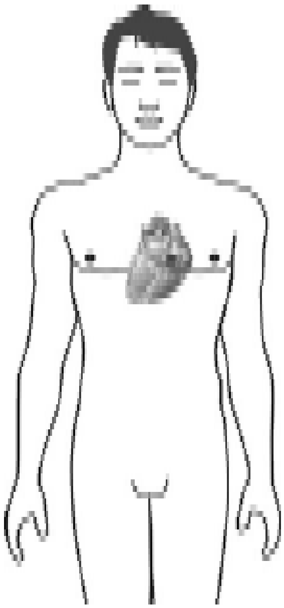

One of the basic problems pertaining to the circulatory system and heart is hypertension and hypotension. Once again, the sacrum and solar plexus are involved. The sacrum controls the bones; indirectly, it stimulates the marrow and enhances the quality of the blood. Good blood is like running the highest quality motor oil through the engine of a motor vehicle.

(Within the Universal Tao System we also have the view that the sacrum controls the Chi-pulse. If there is enough Chi, the heart does not have to work so hard, because the Chi pushes the blood).

The solar plexus relates to the emotions, affecting the heart through two mechanisms:

- It may affect the heart directly, causing rhythmic disturbance or pressure around the heart muscle
- Malfunction in the liver or digestive tract, leading to high cholesterol levels or gas which pushes up towards the heart from the intestines and causes unwanted heat and pressure.

Cleaning out the Solar Plexus will greatly improve these conditions. If you have been trained in Chi Nei Tsang you can use it in combination with the Cosmic Healing techniques.

Specific

Working on the Heart Muscle:
Clean out the Solar Plexus as outlined above. Push and pull with green and blue.
Detoxify the liver, flush with green.
Enhance with white and violet light.
Use the finger to work on the lower left and upper right part of the heart.
Remember that the heart muscle is very delicate.
You draw the force, you spiral and you push.
Stabilize with white.
For enlarged heart use blue.
Carefully use the red light to balance the blood and open the blood vessels.
Sweep the sacrum with green, red and blue.
Sweep the solar plexus with green, blue, red, white and violet.
Energize and cool down the throat center, using blue.
Working on Hypertension (High Blood Pressure):

Overactive adrenals/ kidneys often cause hypertension. Clean out the solar plexus first, because the adrenals (T11) are connected to it. The adrenal glands produce adrenaline, the hormone that stimulates the heart to pump. Overactive adrenal glands will eventually affect the heart.
Tune-up the Door of Life with blue, calming it.
Take the pressure from the heart, use green.
Energize the heart, use violet.
Flush down from head to feet with blue;
The basic problem with hypertension is that the Chi goes up and cannot come down.
Work on the sacrum, using orange and yellow.

Working on Hypotension (Low Blood Pressure):
In hypotension the Door of Life and T11 are underactive.
First clean out the Solar Plexus, this time focus on removing blocks or stuck energy.
Energize the Door of Life, using green and red.
Energize the Sacrum (same colors).
Energize the Base of Skull with green and violet.

Stomach Pains

Pass your hands over the patient and brush the whole abdomen, especially the solar plexus, navel and lower abdomen. The navel should be treated with a combination of green and blue, and blue should be used at the end to firm up the energy.

If problems persist: A) Treat with Chi Nei Tsang B) Seek the advice of a qualified medical practitioner.

Relieving Pain: *Blue Chi*

Chi that is associated with the colors blue and green can be utilized in different ways. While green chi acts to free up energy that has become ‘sick’ and ‘stuck’, blue chi can act as a painkiller because of its ability to reduce the severity of pain.

1. Push and pull the through the affected part out to the universe or ground the sick energy until partial relief is attained.
2. A large amount of pale blue/white chi together with pale green/white chi should be used to transmit energy to the problem area.
3. For the alleviation of pain, use pale green/white chi and pale tangerine/white chi in turn.

Energize means draw the Chi into the part that you want to receive healing. Cleansing means push energy through the affected part and send it out to the universe. Pull the new Chi back into the same area. Light green Chi is used in loosening and cleansing delicate organs like the eyes and the brain.

Headache: *Light Whitish Green and Light Whitish Blue Chi*

1. To check for areas that are congested or lacking in energy, the eyes, temples, spine and solar plexus area should be scanned. Also, the crown, mideyebrow, forehead and back of the head and neck.
2. The eye and temple areas should be brushed down when the headache is because of eyestrain and then flushed into the ground.
3. The whole head, particularly the painful section should be brushed and then pale green/white, blue/white and pale purple/white Chi used to bring energy into the area.

Migraine Headache: *Light Whitish Green Blue and Violet Chi*

1. Persons who suffer from prolonged or chronic headaches including those types termed ‘migraine’ headaches have an abnormal accumulation of energy in various parts of their bodies. Starting with the solar plexus, this energy follows a route up the vertebral column and thence into the neck and head. As a result the various blood vessels in the head expand, causing pain in the head area. Mental strain and emotional disturbances usually cause this type of headache.
2. Use a pushing movement to clean and open the solar plexus and liver areas. First use pale green/white, then pale blue/white and finally mauve/white chi to bring energy to the solar plexus area.
3. In order to send the ‘sick’ red chi into the ground, brush down the spinal column.
4. The back of the heart can be opened by pushing through in order to remove the dirty Chi. Then bring energy to the heart by using pale green/white and purple. Use your mind to see the heart center expanding and opening.
5. Brush down the dirty chi from the head area and send it into the earth.
6. Use a combination of pale green/white, blue and purple to bring energy to the back of the head, the crown point and the forehead.

Toothache: *Light Whitish Green and Blue Chi*

1. Brush down the area with pale green/white Chi.
2. Energy should be brought into the area with pale green/white, mauve/white and blue Chi.

Broken Bone: *Orange-Yellow Chi*

For anything relating to the bones always activate the sacrum. Light orange-yellow Chi is used to encourage broken bones to knit quickly, Chi which is pale yellowish tangerine may be employed. The sacrum attracts the orange-yellow Chi; feel the eight holes in the bone breathing. The orange-yellow Chi enters, transfers up to the crown and is sent up to the universe to multiply.

1. The fracture area should be brushed using a combination of pale green/white and pale tangerine/white chi.
2. To promote fast knitting of fractures, a daily treatment with pale tangerine yellow Chi mixed with white can be employed, in the ratio of 7:1.5:1.5 of white (for the center), yellow and tangerine respectively. Push through and brush the sacral and navel areas, using a cerise (light red) Chi mixed with white.

Back Injury: *Light Whitish Blue and Green Violet Chi*

1. Scan the student to see which parts are congested.
2. Use chi that is pale white/green or pale white/tangerine and, selecting each in turn, with a brushing movement apply to the whole spinal area and especially to the area where the trauma is located.
3. To bring energy to the damaged area, use a combination of pale blue/white, green and purple.
4. White chi should be used with a brushing movement on both the back and front of the solar plexus area.

Infection and Inflammation: *Light Green Chi*

Treat the damaged area with green and tangerine/white chi, using a brushing movement. For the heart and spleen, these colors should be replaced with green and purple.

Bring energy to the area by the use of mauve, white, tangerine, green and blue and strengthen the natural immune of the body.

Cysts: *Light Green and Blue Chi*

During the course of the session, repeatedly pass your hands over the patient's body. Treat the solar plexus area with a combination of green and blue chi. The cyst can be removed using a chi knife, spiraling clockwise with green and tangerine chi; moving the 'stuck' red chi out of the body and grounding it in the earth. After, blue chi should be used for a calming effect, while green and tangerine can also provide energy. For maximum benefit, sessions should be thrice weekly.

As foods containing a lot of highly spiced ingredients have a lot of red chi, these should be kept to a minimum. The patient should use the Inner Smile to calm and balance his/her emotional state.

It is sometimes necessary to sweep 100-200 times, to cool the affected area. Scanning will enable you to take a temperature reading. If the area is still hot then continue sweeping until it reaches a satisfactory temperature.

Fever

1. Brushing can be done with blue or green Chi.
2. Push and pull through the affected part, sweeping the spleen with green and blue. Clean and rinse thoroughly.
3. The solar plexus area can be treated with tangerine and blue Chi but tangerine should not be used on a patient with diarrhea.
4. The thymus gland can be stimulated by the application of green, tangerine and purple Chi. First, brush the heart area with green and blue. This helps the body to ward off infection.
5. Both lungs should be brushed and energy brought into the back of the lung area by the use of tangerine and green.
6. Sweep the spleen with green.

If the student has a fever then they must lie down to receive the healing. This applies in all cases where the student is unable to sit up comfortably.

Insomnia: *Green and Blue*

Inability to sleep may be the result of too much activity in the solar plexus and the sacral area. The solar plexus may also be congested. Similar problems can also occur in the throat, mideyebrow and forehead, as well as at the crown point.

Repeatedly pass your hands over the patient's body as the treatment progresses and use a combination of blue and green chi to clean the sacral and solar plexus areas.

Sleep can be brought on by use of blue, as it soothes the solar plexus area. Use blue and green to brush the mideyebrow, forehead and crown point and white and tangerine on the navel. Finish with blue.

Do not eat food late in the evening.

Sleep in a separate bed from your partner. You can place two beds next to each other.

Tinnitus

Relates to weakened kidneys. Work on the kidneys, mideyebrow and forehead.

Blood Clotting: *Blue Chi* - Fresh Burns: *Green and Blue Chi*

Because of the cooling and calming properties of blue chi, it can be used to remove the heat from burns. Green has a similar effect.

The area needing treatment should be scanned, then brushed with a combination of pale green/white and blue Chi until relief is felt and the heat in the cells released.

Old Minor Burns: *Green and Red Chi*

Pass your hands over the damaged areas and repeat this during the treatment period. Use pale green/white and tangerine, but do not use on the head, eyes or brain, or other sensitive organs.

To reduce discomfort in the damaged area and promote fast healing, firstly pale blue Chi mixed with white should be employed, followed by cerise mixed with white, and green in equal proportions as this mixture optimizes the breaking down of necrotic cellular material. However, cerise should not be used in the head area but be replaced by mauve mixed with white.

Use cerise/white chi to brush the sacral and navel areas and follow with blue which assists in the release of the stagnant Chi. This session should be repeated for 2 or 3 days.

Old Severe Burns: *Green and Red Chi*

1. Scan at the beginning and end of the treatment (Note:I do not think scan can be seen as plagiarism and I don't know what other word to use in this context as I do not have the full text)
2. The local area should be brushed first with pale green/white and then with pale tangerine white. Keep repeating but make sure to omit sensitive organs and the head area.
3. To speed up healing and reduce pain and infection, the damaged area should be filled with energy from pale blue white, pale green white and mauve with white Chi.
4. To help speed up the healing process, wait a few days until there is much less pain, then use pale green white and cerise mixed with white Chi. If the head area is affected, use mauve mixed with white in place of the cerise.
5. Brush in the sacral and navel areas and to speed up healing use white Chi.
6. After making your healing intent stable, release it.

Old Wounds: *Green and Red Chi*

Green chi, in equal proportion of pale green/white and pale red/white should be employed on injuries which are not new as, when used in large quantities, it attacks and disperses damaged cellular matter, promoting fast healing. On recent injuries, it will have an adverse effect because it is likely to cause the trauma area to become moist, and it also will not be able to work quickly.

Scan at the beginning and end of the treatment, and brush the damaged area with pale green/white and pale tangerine/white Chi. Some pale blue/white can be employed locally to energise the area. Use of pale green/white followed by cerise mixed with white can speed up the healing process and assist in the breakdown of cellular material.

The navel and sacral areas should be brushed using pale cerise/white Chi. This will fill the area with energy and make the wounds heal faster. Before the Chi is let go, it should be stabilized.

Some Specific Points and Ailments

The following descriptions are mere guidelines. Each case is different and much depends on your own abilities. One needs practice to detect diseases. Best results with Cosmic Healing will be obtained when practiced in combination with Chi Nei Tsang.

Remember that these techniques are not meant to replace the doctor, but merely to assist him. The student must always work with the practitioner. ***The practitioner is a channel, the student the healer.***

Solar Plexus: *Blue Chi*

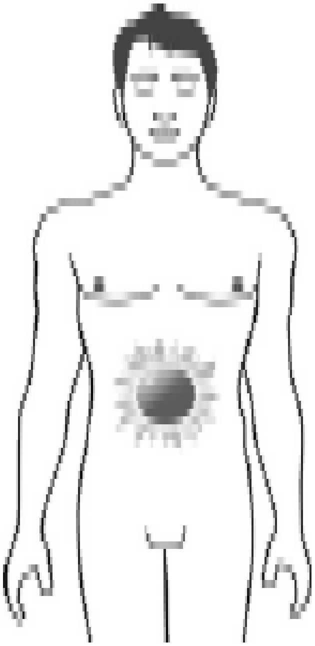

The Solar Plexus is the connection point for practically all the nerves inside the body. That is why it becomes laden with emotions so easily. When the Solar Plexus jams up and overheats, the liver will overheat; when this happens, the heart will also overheat; this will in turn affect the thyroid and parathyroid; finally the brain will be affected. Cleaning out this center is therefore extremely important. This type of cleaning may be done from the top down (as in the general cleansing session) or aimed at the Solar Plexus directly. Draw the green light, spiral it, flush with the green light, then energize with white and violet light. As before, always allow the energy to stream through both the points fully. The Solar Plexus holds all the emotions. When working on the Solar Plexus, the most important thing to remember is to connect the backside to the universe. There is literally no end to the 'other' end of this connection. Just allow the Chi to come all the way down and slightly pull inwards a little. Simply clean out the path. Allow the information to condense, allow any images to come out. Then stabilize the energy. Picture the Chi-field enveloping the person as a big protective bubble. Cool down with blue.

Skin Infection: *Blue Chi*

The skin is related to the lungs and the kidneys. Whenever there is an infection, the immune system is involved.

1. Enhance immunity as outlined in pages 101-108.
2. Focus on strengthening the lungs. Always start with green to flush out. Then send orange light into the lungs. Make sure you are not sending it up to the brain. Energize the lungs with blue and white.
3. Detoxify the kidneys, purify the blood (green) and energize with blue. Ask the person to visualize a fresh mountain-stream to stimulate the kidneys.
4. Treat the area locally, using your hands. If the area is big, use your palm, if small use the fingers. Do not focus on your palms - refer to the section 'Forget About Your Palms'. on page 152. Draw green Chi from the forest, and then energize with violet.
5. To diminish pain or itch, use blue to cool down. Also use the Chi knife to work on the infection.

In case the skin problem is allergy-based, you should also treat the mideyebrow; there might be some irritation here. First clean with green, then either energize with violet (if resistance is low) or soothe with a light shade of yellow. If the skin problem is related to asthma, open the lungs with bright red clean the throat center with green and energize it with (deep) blue.

If the problem is due to toxicity, also clean out the liver flushing with a combination of green and orange. Energize with green. Enhance the immune system by working on the sacrum.

Eyes: *Green Chi*

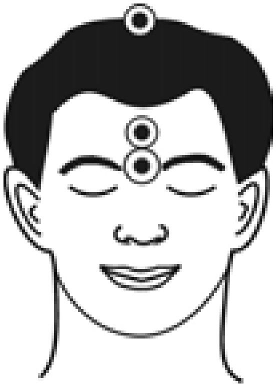

The right and left eye are governed by the forehead and mideyebrow respectively. The eyes are also linked to the temples. Ask the person to touch their temple bone and guide them to take in the (white or light violet) Chi. Send Chi through the mideyebrow and forehead (all the way through). Ask the person to visualize the light coming in. Use soft shades of green with golden yellow to stimulate the optic nerve. Use blue to calm the eye muscles and light violet to stimulate the inner eyesight.

The eyes are connected to the liver. Scan the liver and energize with green. Scan the jawbone to see if there is any unreleased anger. Cool down with blue. Channel bright green into the liver.

Ears: *Violet Chi*

The right and left ears are governed by the forehead and mideyebrow respectively. Push and pull green Chi to clean. The ears are connected to the kidneys, so you can work on them also. The ears are also connected to the sinuses and upper respiratory tract. This means that infections need to cool down before you can use any cleaning technique. Use blue to cool and clean with violet. As long as fever and severe infection persist, use blue to cool them down. When clean, energize with violet.

Have Better Health, Less Stress and Remain Young

Brush specifically on the areas of the solar plexus, liver, stomach and pancreas.

White chi brings energy to the crown point, head (at the back) and both sides of the brain.

Both the front and rear of the heart and lungs can receive energy from white/purple Chi.

Both the front and rear of the spleen, the navel and lower abdominal area, the spinal cord, the kidneys, using white Chi.

On the sexual center use white chi but if the problem is difficult to shift, use green. You can also use white Chi on the sacral area, and green or purple on other organs.

White Chi can be employed for the arms and hands, while the legs and feet should be treated with white and purple Chi.
Eye problems with green/yellow energy.

After a session, patients who are particularly weak should not bathe for one full day. The energy which has been put into their bodies can thus be kept there by application of pale blue/white Chi at the end of the session.

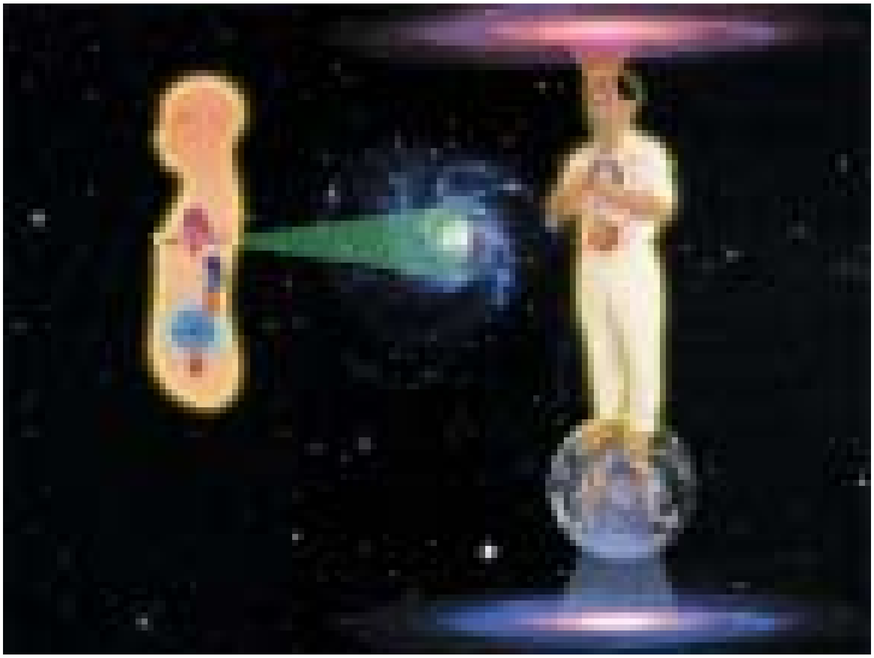

Fig. 6.18 *Use Compassion, Love and Kindness.*

Summary of Individual Healing Session

A. Chi Knife
B. Energizing and Activating the Immune System
C. Cleansing with the Internal Organ Techniques

General Outline of Practices

1. Gain experience by working with one person. **Stand in front of them with your feet shoulder width apart.** Hold your hands at your heart in salutation. Transmit your love and compassion and ask for their permission to help them to help themselves heal.

2. Connect to the student's and your own cosmic star above your head and ask for universal permission. **Radiate your love and transfer three minds into one mind**. Lower your Upper Tan Tien. Activate your consciousness: Three minds become one mind. Expand your awareness in the mideyebrow and the crown. Feel the Tan Tien, heart, mideyebrow and crown spiraling. Expand to the universe.
3. Visualize the person's legs as being 'very long', extending down to the earth. **Activate the Sacred Fire** and bring it down. Clean out the room and make a big Chi field around you and the student.
4. **Call the Elemental Forces:** water, fire, thunder, lightning, rain, lake, earth, mountain, wind and Heavenly Chi. Call the guardian animals; Blue Tortoise from the north, Red Pheasant from the south, Green Dragon from the east, White Tiger from the west, Yellow Phoenix from above and Black Tortoise from below. Feel that you are protected by the Chi; gather the power of all the mountains, rivers, streams, stones and rocks into the room. Activate them with lightning, thunder and wind - filling the whole room with electrified Chi.

A. Chi Knife

1. Hold the knife in right hand (left, if you are left handed). Hold the other hand near your body with the thumb and index finger touching. Project the Chi Knife as big as the universe, 'long and big - reaching to Heaven'. The bones in your arm are hollow and the 'bottom' is sealed at the shoulder. Feel them 'fill and pack' with the power coming from above.
2. Then give the command: **"Power comes from the east. This Chi Knife has the power to dissolve all the negative energy, sickness and bad fortune. By my request, please carry out the order now."** Wait until you feel that your arm and the knife are heavy and full of Chi.

   Carry out energetic surgery, **cutting and slicing the affected area with cool yin energy**. When you feel that the Chi Knife is full of sick Chi, spiral counterclockwise and discard it down into the ground. When you feel that the knife is 'empty', charge it with Chi from the universe. Continue until you feel that the area has been cleansed.

B. Energizing and Activating the Immune System

In cases of severe illness, debilitation and infection, it is essential to stimulate the body's defence systems. You may also want do this in a preventative manner. Guide the student as you practice together. Presuming that you have already done the previous set of general healing, you can start with the coccyx.

1. Be aware of your Tan Tien and connect to the universe. Touch your **coccyx** with the fingers concentrating a beam of white or yellow light on to it. Picture the sacrum opening and the light streaming inside, flowing **up the spine** and streaming out over

the whole bone structure. Feel the Chi rising up to the universe, multiply it and guide it down to your energy body.

2. Be aware of the Tan Tien and the universe. Attract the yellow light; spiral and condense the healing light into the tips of your fingers; move the fingers up to touch the **sacrum**. Send out a beam of yellow Chi into the sacrum, directing it up the spine. This will stimulate the production of red blood cells. Transfer the feeling of 'Bone-Chi' up to universe and down to your energy body.
3. Proceed to the **crown**, showering it with violet light. Then spread from the crown throughout the bones of the body. Repeat several times. Instruct the student to feel the bone structure breathing. Ask him/her to extend up from their crown to the Big Dipper and North Star, channelling down the red and violet light into the thymus gland.
4. Continue to the **throat**, stroking down with your palms, using green color to move the lymph down towards the backside of the heart. (Never stroke up towards the head! Only guide the lymph down).
5. Proceed to the **lymph nodes under the armpits and across the sternum**. Next activate the lymph nodes in the **groin**. From the groin you guide the lymph up to the navel center (Not down where it will get stuck in the legs).
6. Return to the **navel center**. Send the energy deep inside, energizing the lymph nodes at the back. Pull back, drawing green energy, flushing out any waste products that are stuck in them.

Activate the points at the inside of the **elbows** and the **knees**.

Shower the whole body with healing light and energize the **perineum** with blue Chi.

Always remember to ground any sick energy by sending it deep into the ground. Ask the student to do the same and it will be more effective. You should do this while giving the session as well as when closing it.

C. Cleansing the Internal Organs (Repeated from pages 132-133 and pages 136-137)

This session can be used for any kind of ailment and carried out with any number of students. **It is important to remember that if there is no energy in your Tan Tien, then there will be no energy to work with.** When you are aware of your Chi, you can direct heavenly light straight into your energy body and then into the student's.

General Cleansing Procedure

1. Push and pull the energy through the student's body. Push and disperse the sick energy into the universe and out to the planets, where it will be transformed and recycled.
2. Pull the energy back and stop it between yourself and the student.
3. Spiral the energy counterclockwise until you see the **green** light mix and clean the sick energy. Spiral and flush the energy down into the earth.

4. Spiral with blue light; see it mix and flush the energy within the student's body. Spiral this energy down to the ground.
5. Energize the student with **white** or **violet** light.
6. You can also use both hands to channel Chi when you 'push and pull' through the body.
7. **Spiral in** - spiral clockwise to bring energy into the body and energize it.
8. **Spiral out** - spiral counterclockwise to cleanse, flush and remove energy.
9. When you begin pushing, pulling and sweeping, you may feel resistance in the body. As you progress and the energy centers open, this feeling will diminish.
10. There are many color combinations that can be applied to the various parts of the body. When you start practice, stick to the basic 'blue, green, white, violet and blue' formula. When you are working on a specific area, you can keep this book near by, or write a short 'color recipe' before you begin. In this way, you will be able to relax your mind.
11. 'Pushing and pulling' is like fanning and venting the body; when you fan your hands in front of your face, it will have a cooling effect. Ventilation enables the stagnant, sick energy to leave the body.

    Below is a list of the body's organs in relation to their tendency to 'store heat'. They are listed in descending order, i.e, the head is the hottest.

    Head, heart, liver, lung, stomach and spleen, large intestine and small intestine, kidneys and sexual organs (which become hot when aroused).

Outline of Practice

The **solar plexus** is the clearing house for emotional energy and is situated in between the lower and higher energy centers and in the center of most of the internal organs. All the organs dump their negative emotions here. The internal organs can be cleansed by sweeping the solar plexus, energizing, cleaning and flushing it of sick energy. When you feel sick energy in the body, give the command: "Stay". This is very important; it makes sure that none of the cells hide from the dazzling light that you are sending in.

1. Scan; ask for the power to look at the cells.
2. Push, pull and give the command "Disperse". Push until you feel the solar plexus clear and open.
3. Spiral green Chi counterclockwise. Talk to the sick energy; tell it to "Leave", you will take it to "a better place, where it will be happy". Give the command "Out".
4. Spiral Blue Chi counterclockwise, flushing out any remaining sickness. Guide the sick energy into the earth.
5. Spiral and sweep Blue - Green and Red Chi into the solar plexus, sweep the organs. Do not use in cases where there is intestinal infection and internal bleeding (which can be worsened) or in the presence of pregnant women.

Cleansing the Spinal Cord

Always cleanse the spinal cord, which protects the entire body from diseased and negative energy, both physical and psychic. When you open the spinal cord and solar plexus you can release many energy blockages. Sweep the hand in a clockwise motion to energize the spine with either/or a combination of: blue, green, white and ultra-violet. Then spiral counterclockwise and brush the spine down to the ground. Continue sweeping until you feel that the spinal cord has cooled down. Remember not to use orange or red

Cleansing the Blood (Lungs)

The blood can be cleansed by energizing the lungs with whitish green, then with light whitish orange. The blood passing through the lungs will absorb the green and orange Chi, thereby cleansing the blood plasma and vessels and the rest of the body. This technique is very useful for treating ailments of the blood and of the arteries and for severe infections. Do not use it on pregnant women.

Outline of Practice

1. Scan the student.
2. Push through and open the lungs from the back to the front.
3. Energize the lungs from front to back with light whitish green, then with light whitish orange. Push through.
4. If the student is weak, energize the lungs with light whitish red, which will provide a strengthening effect.
5. The **spleen**, **liver and kidneys** purify the blood. Push and pull through the organs and energize with white Chi.
6. The blood requires a lot of cleaning on a regular basis.
7. Energize with white Chi. **Germs can only grow in the dark. 'Fill yourself with the light'.**

General Principles

Energy can be introduced to the affected area of the body by moving the hand clockwise in a spiral. **Flush** means to return the sick energy to the earth for recycling.

Stabilize means to return the area to normal functioning.

Spiral in a **clockwise** motion when you are '**stabilizing**'.

Use **blue or white** light to energize the area that you are working on.

Use **green** light to **energize** and **clean** the area that you are working on.

Use **blue** light to **flush** and **stabilize** the area that you are working on.

Use **violet** light to **balance** the sick energy and **reprogram** the cells of the body.

For **general infections** always **use green** (energize and clean) and **blue** (stabilize) light. Use violet light to balance the sick energy and reprogram all the cells. Use the 'Chi Knife' for infections as well. Never use orange on the head, heart and spleen.

Give the command **"Stay"** to make sure **all the cells receive the light** you are sending in. Remember that germs and bacteria cannot hide in the light.

Energize means to draw the Cosmic Chi into the part that requires healing.
Cleanse means to clean all the cells being treated.

You can also work on yourself. You may need some help when working on the back. If you obtain optimum health and practice the Cosmic Orbit regularly then you will never 'need' to apply any of these techniques to yourself.

Like all Chinese medicine, Cosmic Healing works on the system as a whole, balancing the entire organism, treating the cause to cure the symptoms.

The techniques really are simple.

When in doubt use; blue, green, white, violet, blue.
You can always use white and violet.
Upper organs - use violet.

You can practice group healings and then link your students' personal stars together, at an agreed time later in the day. **You can then perform the World Link Cosmic Healing**.

Work on any other ailments that the student may have.
The simplest way to learn is to begin practicing today.
The simplest way to heal is to allow yourself to be healed.

Chapter VII
Different Hand Techniques

Forget about your Palms

An extremely important theory of Cosmic Healing Hand Techniques is to 'forget about your palm'. This means that you should only use the palm (which is incredibly sensitive), for 'guiding' the universal energy into the right spot, sending out a minute beam of light, like a laser, that marks the place where the energy should be sent. Your palm is connected to your brain, which has been sunk into your Tan Tien. The light marker will serve as a beacon for the force that is directed down by your mind. Draw down the Universal Chi, guide it to the right spot and give the command; "Stay". This is very important, otherwise the Chi will disappear once you move your hand.

When you practice Cosmic Healing it makes no difference how many people you treat, because you are not transferring your own energy.

Don't Focus your Mind on the Sick Part

If you direct your attention towards something, your energy will go there. If you focus on some ailment, you are already sending out your energy. Instead you should try to connect with a greater source, Universal Chi, extending your mind very far away. This way you won't lose your power. The only thing you do as a practitioner is to form the connection between nature, the student and the sick energy or between the universe, the Chi field and the sick part.

Cosmic Healing is Teaching

One of the best methods of protection for a practitioner is the Fusion practice (*Refer to 'Fusion of the Five Elements I by Mantak Chia*). Perhaps even better is for the practitioner not to perceive him/herself as a healer, but as a person that comes to guide people in something they have to do themselves. When you say; "I am a healer", the sickness or bad energy, has already found a new home. When you check it out, first it will try to hide, and then it will try to attach itself to you. But if you don't interfere, the energy will go straight to the ground. So it is very important to clarify that you are not a healer, but a practitioner that can help, and that the student or sick person has to do most of the job.

Fig. 7.1 *The Stronger your Awareness of your Inner Body, the Easier it will be for others present to pick up this Sense.*

If you guide those present, this will greatly enhance your healing session. Sit or stand facing your student. Any time you want him or her to focus on a particular point of the body, ask them to touch it with their hands. For example, "Now place your hands on your navel", while you do the same thing yourself. As soon as you feel the Chi there, you instruct them to focus on the navel themselves. This way you are actually helping them to deepen their bodily awareness. The stronger your own awareness of your inner body, the easier it will be for the others present to pick it up. This means that if you are treating some part of another person's body, or if you see that the person is not aware of any energy in some part of the body, you can help by focusing your awareness on this particular part of your own body.

Chi Kung Diagnosis: Hand Scanning

Hand scanning is a simple and effective diagnostic tool of External Chi Healing. It involves passing your palm over the body of your student from one inch to one foot above the surface of the skin and being aware of the energetic state of the various bodily areas. What one senses is described as the electromagnetic field, the aura or the energy body.

General Variations in the Energy Field

The variations you may sense with scanning that have diagnostic significance are:

Temperature

Heat generally indicates excess, while cold indicates deficiency. However, some areas of the body are naturally warmer or colder than others. This is described below under "Hand Scanning the Internal Organs."

Thickness

A feeling of thickness over the area would indicate excess, while thinness may indicate deficiency.

Wind

You may feel sensations of wind leaving the body at various places. This may indicate internal wind at a given location, or it may point to an area of the body that is "leaking energy" and needs to be ‘patched’ or ‘sealed’. It may also be a positive sign that you are driving wind out of the body.

Peaks and Valleys

Peaks in the energy field will feel like mountains or hills in the aural landscape. They may actually push your hand away. Valleys feel like depressions or energy vortexes drawing you in. They may also feel empty, like a hole or pit. Peaks indicate excess or stagnation, while valleys indicate deficiency.

Tingling

Accumulations of sick Chi may cause your hand to tingle, feel prickly, throb, or even hurt. These are excesses of energy and upon inquiry, the student may complain of pain in this area.

Hand Scanning the Internal Organs

Each Organ Emits a Different Aura

Each organ emits a different kind of force or aura through the skin. By passing a hand one or two inches above the skin, you can feel different sensations that reflect the condition or state of the internal organs. You need to develop the sensitivity to receive and identify the vibration or frequency of each organ. Practicing the Cosmic Chi Kung Meditations will help develop such sensitivity.

Liver and Gall Bladder Scanning

Healthy liver and gall bladder energy feels warm.

Negative Emotions: When you pass your hand over the liver, under the right side of the rib cage, you will feel a charged energy come up to your hand. This is a sign of anger in the liver.

Overactivity: When you pass your hand over the liver and feel a rush of hot energy, this indicates that the liver is overheating because of toxins or emotional stress.

Underactivity: When you pass your hand over the liver and you feel a dense and hot energy, the liver is weak, congested and sick.

Lungs Scanning

Healthy lung energy feels cool and dry.

Negative Emotions: Pass your hand over the lungs. Do the Lungs' Sound and listen to the echo of the sound as it rebounds from the lungs. Sadness will feel like a deflating ball pressed between your hands.

Overactivity: Energy that feels dry and hot indicates an overworked organ.

Underactivity: Energy that feels damp and cool under the scanning hand indicates underactive or congested lungs that can lead to respiratory problems.

Heart Scanning

Healthy heart energy feels warm and energetic.

Negative Emotions: Hot and charged energy indicates impatience, hastiness and arrogance in the heart.

Overactivity: If your hand detects hot, charged and overly expansive energy, this indicates that the heart and blood may be overheating.

Underactivity: Energy that feels cool and less expansive indicates an underactive or congested heart.

Spleen Scanning

Healthy spleen energy feels lukewarm.

Negative emotions: Energy that feel damp and sinking indicates excessive worry.

Overactivity: The energy feels hot and damp when the spleen is overactive.

Underactivity: The energy feels cool and damp.

Kidneys Scanning

Healthy kidney energy feels cold, but not too cold.

Negative emotions: Energy that feels cold and chilly indicates fear.

Overactivity: When the kidneys are overworked or overstimulated by excessive exercise or improper diet and liquid intake, the energy can feel damp, stick and hot.

Underactivity: When toxins are blocking the organs, the energy can feel damp and cold.

Hand scanning is an art, and may take a while for you to feel confident using it. Practicing Cosmic Chi Kung is one of the best ways to develop greater sensitivity in hand scanning.

Chapter VIII
Cosmic Chi Kung
Palm and Finger Training

Why We Practice the Cosmic Chi Kung

The Cosmic Chi Kung is also known as Buddha Palm. The reason we train with the Empty Force practice in connection with the Cosmic Healing is to learn how to project Chi through the space in the cosmos, the space between your hands and to project Chi through the space to your students. Usually when we touch the student we pick up sick energy. This practice will teach you how to ground the sick energy to the earth and to disperse it into the Universe to be decomposed and recycled by the planets.

Practice until you can project Chi out from your palms and fingers and when you feel the Chi coming into your body through your hands. The most important part is to always remain connected with the Universal Force coming from all six directions. If you focus on healing from your hands or your Tan Tien you will use up your own energy. You must be connected to the Cosmic Universal Force.

Expand your awareness to nature, the oceans, the lakes, the forests and mountains. Smile to nature and feel it smile back to you; inhale and draw the Chi into your palms. Expand your awareness to connect to the light, the Milky Way and the cosmos.

Be aware of the heart and the red light in the heart; expand your awareness to infinity. The light will come close to you; picture the red planet Mars above you. See it shine down to your crown, feeling the light in your palms. Be aware of the six directions, feel your body growing bigger; until you touch the sky, your feet still planted in the earth.

Opening Heaven and Earth Force in the Palms with Heaven and Earth Spirals

The purpose of this technique is to draw in the forces of heaven and earth through the palm. Activate the spirals, the symbol for the heaven and earth force in the center of the palm.

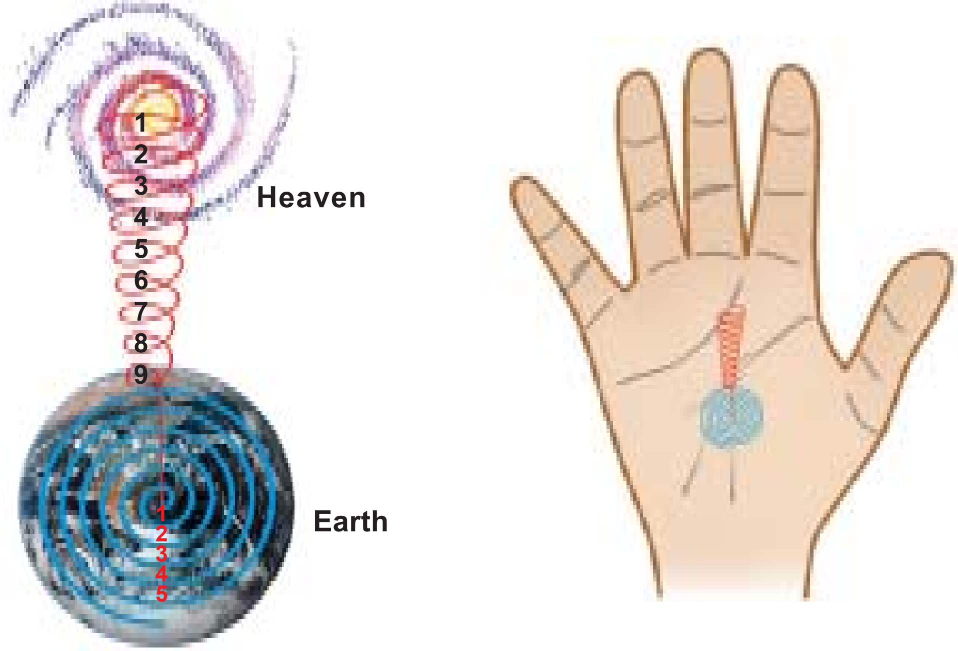

Fig. 8.1 *Enhances the symbol of Heaven and Earth Force, in the Laogong - Pericardium 8.*

This is accomplished by drawing these spirals with the palm itself. As you draw the spirals, you should actually feel the palm breathing, inhaling these forces in. In the beginning, however, you may only be able to use your own mental imagery and imagine that you are absorbing these forces. In time the feelings will replace your imagination.

You breathe in Heavenly Chi when you draw the heaven spirals, and breathe in Earthly Chi when drawing the earth spirals. You may draw in both in one session; you may also choose just to draw in either Heaven or Earth Chi if you feel you need more of one or the other. It is important to balance these energies whenever you do this exercise.

1. Begin by raising the right hand to about shoulder height with the elbow sunk and the palm facing forward. Slightly pull back (open) the index finger, and slightly stretch the thumb forward and down. This will activate the Laogong point on the palm.

   At the same time, touch the tips of your left thumb and index fingers together. This will allow the right hand to draw in the Heaven and Earth Chi. The left hand will then be held palm up to draw in the heavenly force, or held palm down to draw in the earthly force.

2. Begin **drawing the heaven spiral** by moving the **palm in a clockwise motion**, with the circles getting smaller and smaller, spiraling inward. At the same time, your left hand is held at your side, palm up with thumb and index tips touching each other. Draw seven or nine (planets of our solar system) small spirals with your right hand in this way, drawing in the violet heavenly energy.
3. Next, lower your right hand slightly and turn your left palm down to face the earth. Then begin **drawing the earth spiral** by moving the right palm in a **counterclockwise motion** with the circles getting larger and larger. Draw five spirals (five elements), drawing in the blue earth energy as you move. Inhale into the palm, feeling the energies.
4. You may now bring both hands down to the beginning position of Cosmic Chi Kung, or you may open the Cosmic Channel to the planets for healing. This is discussed in the next section, Part I, ‘Opening to Heaven, Earth and Cosmic Chi’.

Cell Breathing

By understanding the operations of our cells, we establish a foundation for our experience of Cosmic Chi Kung. Each cell is a living, breathing entity, absorbing energy with each inhalation and releasing toxins with each exhalation. Thus with every breath, we are creating more Chi.

We are made up of over one hundred trillion cells (one trillion is one thousand billion). Each one of these cells is constantly breathing. In order for our cells to function optimally, we must follow nature's teachings.

Fig. 8.2 *Each Cell is a Living, Breathing Entity.*

The first thing is to keep your cells free of toxins. Eat nutritional foods. This helps the Chi to flow smoothly through your energy channels and aids greater assimilation of vitamins and minerals. Learn and apply Five Element nutrition principles, eating according to the seasons and to your own constitution.

The second thing is to keep your cells free of excess emotions. Develop the skill of acting positively to situations, rather than reacting, especially negatively. Don't allow anyone to make you sad and unhealthy. Some people like to say, "You make me angry," or "You made me worry." We cannot allow other people to make us so emotional. We do not need to accept the negative emotions that other people try to dump on us. Cellular and psychic boundaries are related. Negative emotions disturb the cells' ability to absorb Chi and to generate the energy necessary for healing. We need all the Chi that we can get. Learn and apply the Six Healing Sounds, the Cosmic Inner Smile and the Fusion of the Five Elements meditation to transform negative emotions into personal power.

Third, create more energy by cultivating a happy attitude, so that your cells can regenerate more easily. **Smiling and loving** are the two quickest ways to make more Chi. In order to have an ample supply of Chi, develop an attitude of **joy and love** in yourself and towards others.

Mind, Eyes, Heart and Intention (YI)

The opening of the mind, eyes, heart and use of intention is vital for further activating and increasing your Chi. In the Tao we achieve this by cultivating our "Yi" (pronounced "yee"). "Yi" means mind power, intention, awareness and concentration. The Yi leads and guides the Chi. With our mind we control thought patterns. With our eyes we control the senses of sight, hearing, smell and taste. With our heart we control all our organs and their related emotions: the kindness/anger of the liver, the joy/impatience of the heart, the openness/worry of the spleen, the courage/sadness of the lungs and the gentleness/fear of the kidneys.

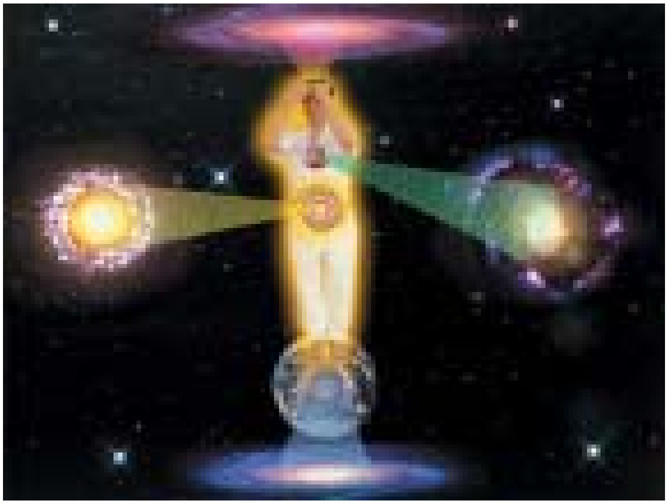

Fig. 8.3 *'Yi' leads and guides the Chi.*

Every excellent achievement in our lives depends upon the quality and efficient operation of our Yi. Combining the awareness of the mind, eyes, heart and intention into one, causes the creation of a rich and rare alchemical mixture. The power of the Yi is the magical catalyst that assures energetic results.

The basic teachings are all in the Microcosmic Orbit, the Cosmic Inner Smile and the Six Healing Sounds. As long as you are alive and healthy, you are able to draw in energy from the universe and nature. The stronger the battery, the better it is able to store this energy. If you're weak and sick, you have no way to draw any energy from nature or the universe. When the cells stop drawing in energy, life ends. If you have perfected these practices, you have all the personal physical, mental and spiritual power that you need. Everything comes together. Your mind is aware of the original force. From the knowledge of Oneness, you are inwardly aware of your mind, senses and heart; you are outwardly aware of the universal energy. Now you are capable of receiving the abundantly available healing power of the universe; you can tune into everything, inwardly and outwardly in all directions. This is what we are here for: to heal and become whole again. We have higher goals to reach. The foundation for reaching our goals is a strong and healthy body.

Cosmic Healing Chi Kung is merely an extension of the universe within yourself. You draw the universe in through your palms, skin, heart and crown. With your Yi you breathe in the cosmos through these various open cavities of receptivity in your body, absorb its power, condense it, transform it and use it for the benefit of all.

Connecting the Bridge

Contracting the muscles of the perineum, sexual organs and anus activates our connection with the earth energy. By pulling up these areas and drawing in energy through the soles of the feet, we immediately become grounded and bring the earth (yin) energy into the Microcosmic Orbit. Pulling up should be done gently and directed by the Yi.

When we speak of "Connecting the Bridge," we are referring to the above exercise, except that we do not pull up on the perineum. Pull up gently and lightly on the sex organs and anus while leaving the perineum totally relaxed. After performing the first contractions, when you then relax the perineum, the earth energy will continue to flow into the body using the principles of a siphon. We thus connect the "Bridge" across the perineum from the sexual organs to the anus using the Yi to direct the energy. This actively combines the earth energy and your sexual energy and directs it into the Microcosmic Orbit. This energy is circulated during Cosmic Chi Kung. Holding a very gentle contraction will keep you grounded during the exercise. It can be done sitting or standing.

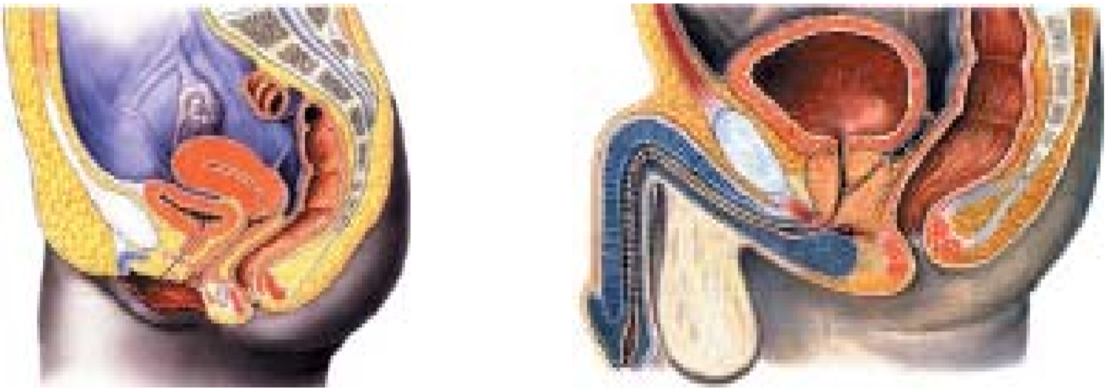

Women lightly contract the Vagina *Men lightly contract the Perineum and Anus*

Fig. 8.4 *Connect the Bridge - combine Earth and Heavenly Energy.*

Cosmic Chi Kung Preparation

Cosmic Chi Kung can be practiced either in a sitting or a standing position.
Sitting, relax as much as possible and invoke the **Cosmic Inner Smile**.

1. Be aware of your **heart** and listen to your **kidneys** with your inner senses. Smile to your heart and kidneys and feel them pulsing; feel them communicating and interacting with each other. The **Kan** and **Li**; the water of the kidneys and the fire of the heart, balance and **begin to mix**.
2. Open the arm pits as if you were holding a ping pong ball there and slightly move the fingers to activate the Chi flow. Relax. **Feel** the sensations of the **Chi flow**: tingling, warmth, pulsing, electric and magnetic feelings.
3. Be aware of your palms. Draw in Chi by **activating the bone breathing** process. Become aware of the perineum; slightly pull up the perineum, sexual organs and anus and "**connect the bridge**." (Remember to relax the perineum).
4. Breathe into the palms of the hands and soles of the feet, further enhancing your connection to the earth force. Smile to the blue earth energy as it flows up your arms and legs and suffuses your body with pleasant Yin energy.
5. Breathe into the **mideyebrow** point and activate your connection with the **Cosmic Force**. Smile to the golden light of the cosmic energy as it swirls into your mideyebrow point and flows throughout your body, healing and balancing your energy.
6. Breathe into your **crown** point and activate your connection with the **Heavenly Force.** Smile to the red and violet light of the heavenly force as it flows into your brain and washes your body with subtle pure Yang energy.

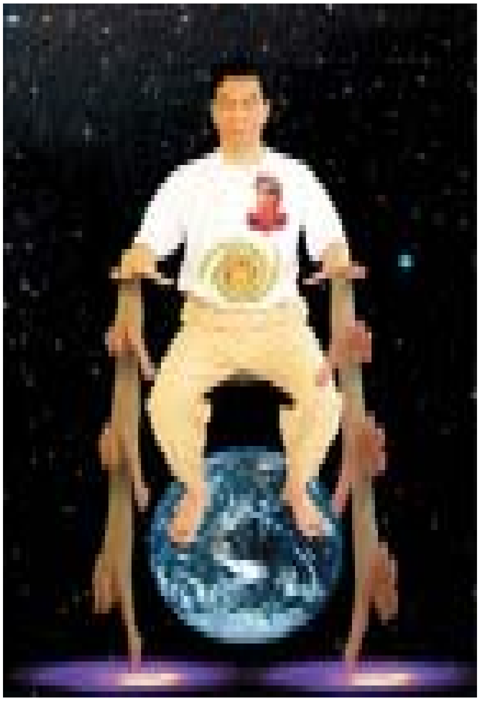

Fig. 8.6 *Invoke the Cosmic Inner Smile.*

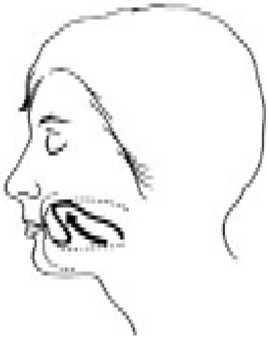

Fig. 8.5
Place the Tip of the Tongue on the Upper Palate.

7. Place the tip of your tongue on the upper palate behind the teeth in a comfortable position.
8. As you begin to move through the postures of Cosmic Chi Kung, always be aware of the Chi flow and its attending sensations.

Cosmic Chi Kung Preparation Standing

1. Stand with your **feet parallel** and shoulder width apart.
   Tilt your **sacrum** and **pelvis** slightly forward until you feel your feet press more firmly into the ground. As you tilt the pelvis, feel your lumbar vertebrae pressing outward; this is called "**Opening the Door of Life**."
2. Relax your **chest** and sink your **sternum**. Draw your chin in slightly, and hold your **head, neck** and **spine** erect as if your head and spine were suspended from above by a string.
3. Follow the same instructions for the preparations of Cosmic Chi Kung.

Opening to Heaven, Earth and Nature

The natural world is the source of our power. Cosmic Chi Kung teaches us about nature and its energies. In the Tao, nature and the universe are equivalent to God. You are a part of nature and can easily learn to open to the forces in the macrocosm and let them flow through you. This is very simple. Just tune into the frequencies around you. Your fingers are antennae, which transmit and receive.

1. To begin your practice of Cosmic Chi Kung, simply **stand** up and **feel the energy around you**. When you stand or sit, be aware of your soles (Bubbling Spring points) making a good connection with the earth. Your perineum (Hui Yin point) is relaxed and open. You are connecting to the earth force and can expand further down on to the other side of the universe. This is one type of energy.
2. When you draw your **chin in**, slightly **relax your chest** and tilt your head slightly forward; you begin to be aware of the heavenly force. This is another type of energy.
3. The qualities of the **Five Elements** reveal themselves as woody trees (growing force), fiery deserts (expanding force), earth mountains (stabilizing force), metal air (contracting force) and watery oceans and lakes (gathering force). We call the combination of these elements the '**Cosmic Force**'.

Thus, your mind and body learn to gather, absorb, direct and transform the heaven, earth and cosmic energy for your own use. This is the essence of Chi Kung. Today there is a lot of emphasis on learning movements and forms of Chi Kung. However, if the inner feeling is not there, the movements are of little value.

Heavenly force is Yang. Earth force is Yin. By learning to connect to the energies of heaven and earth, you have a powerful tool for restoring and maintaining your inner balance of Yin and Yang.

Outline of Practice

Before practicing each of the Cosmic Chi Kung sets in this chapter and in the following chapters begin with the heaven and earth spirals as outlined on page 157.

First **Create the Chi Field**.

Hold each of the Cosmic Chi Kung postures for at least 5 - 30 seconds, gradually lengthening the time to 60 - 120 seconds per posture.

Note: While holding the postures count the breath from 5 to 15 seconds, being aware of the **Tan Tien** and feeling the Chi in the Tan Tien which then moves up to the **crown** and expands up to the universe; fuse your Chi with the Universal Chi and let it multiply down to your palms. **Just concentrate on the 'Tan Tien and the Universe'**; do not concentrate on the palms at all.

Throughout parts I, II, III and IV 'Tan Tien and Universe' means to spiral into the Tan Tien and spiral out into the universe connecting 'Tan Tien and Universe'.

Part I
Opening to Heaven, Earth and Cosmic Chi

Opening Movements

Three Minds into One Mind

Empty the mind and heart down to the Tan Tien.
Hold the hands together at the heart center.
Smile and make the heart feel soft; feel love, joy and happiness.
Turn your consciousness inward and your awareness out.

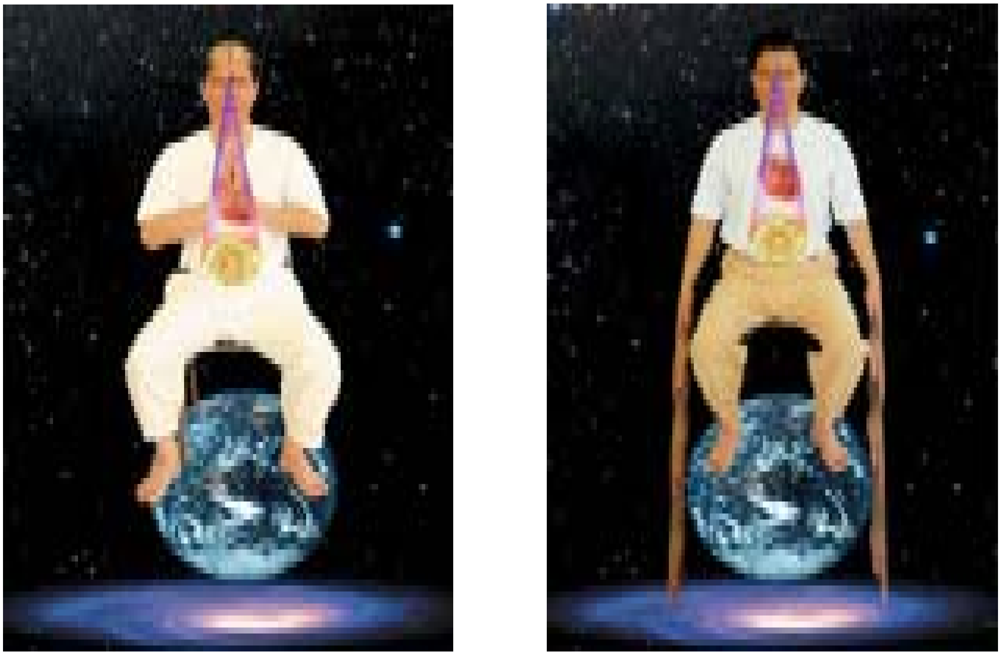

Fig. 8.7 *Empty your Mind and Heart down to your Lower Tan Tien.*

Feel your legs lengthen extending down to the center of the earth.
Feel your hands lengthen extending to the universe below.
Let the mind expand and be aware all the way down to the universe.
Feel the ‘long’ bones of the arms and legs and begin bone breathing.
Feel universal Chi filling, packing and compressing into the bones.
Draw this Chi down to the back of your crown and feel a heavy pressure press on the crown; feel slightly numb or a light electric downward flow, like oil dripping down. ‘Focus at Tan Tien and Universe’. Count to five.

Channeling the Earth Force - Washing the Bone Marrow

Smile into the **perineum, palms** and **crown**. Then slowly raise the arms, palms facing each other, to chest height keeping the elbows relaxed and sunk. Rotate the arms slowly until the palms are facing down. Be aware of the mideyebrow and feel your breath and lightly contract your eyes and round muscles around the eyes. Connect the perineum bridge by slightly squeezing the sex organs and the anus; do this a few times.

Rest and **smile to soles of the feet**, feel the Chi bubbling and feel like you are standing on a hot spring starting to bubble up.

Be aware of your Tan Tien and expand your mind down past the earth to connect with the galaxy below you. Multiply and bring your mind back to the Tan Tien. Gradually feel the Chi being absorbed through the whole body and absorb it into the bones and body like a **rising steam or mist**. Feel the earth force move through the center of the bones and enter the bone marrow move up the calves and thighs (femur bones) through the hip bones, spine, **scapula**, **arms**, **neck** and **skull**. Finally **swirl the energy around your brain. 'Focus at Tan Tien and Universe'**.

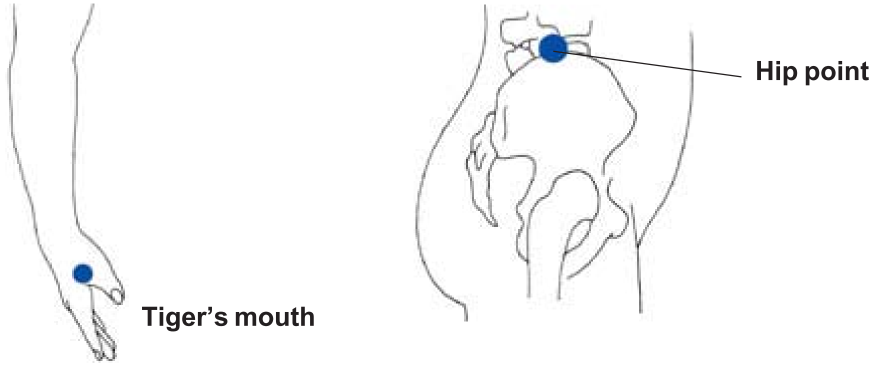

Fig 8.8 *Activate the Hip: Large Intestine 4, Pericardium 8 and Small Intestine 3.*

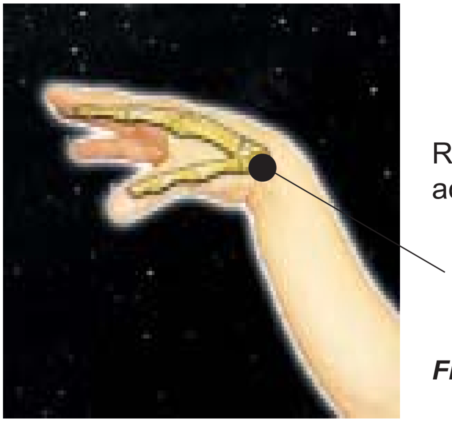

Raise your index finger slightly upward to activate the Hegu Point (Large Intestine).

Fig. 8.9 *Open the 'Tiger's Mouth'.*

Then **stretch your thumbs out to the sides and down**, so that they end up pointing downwards toward the earth. This activates Large Intestine 4 (Hegu). Large Intestine 4 is found in the webbing between the thumb and index finger. It is called the "eye of the hand"; this area is also known as the "Tiger's Mouth."

Slowly draw the elbows back and lower the hands until your palms are facing down beside the "eye of the hip" (the iliac crest) with the "eye of the hand" (Large Intestine 4) aligned with the "eye of the hip. "Be aware of the Tan Tien (Yi, the abdominal brain) and expand your mind out into space, the Cosmos and the universe. Remember: The fingers and the energy point act just like a laser to help guide the universal force flow; as soon as you focus on the fingers or the palms you are starting to use your own energy. Feel your Tan Tien and the crown full with Chi. Just use your second mind intention, lightly aware of the area between the hips and LI-4 points. Focus at Tan Tien and the universe. This will activate the lungs and large intestines. **Hold for a 30 second count** and gradually you will feel the ascending colon and the sigmoid colon have been activated; you may feel some movement around this area.

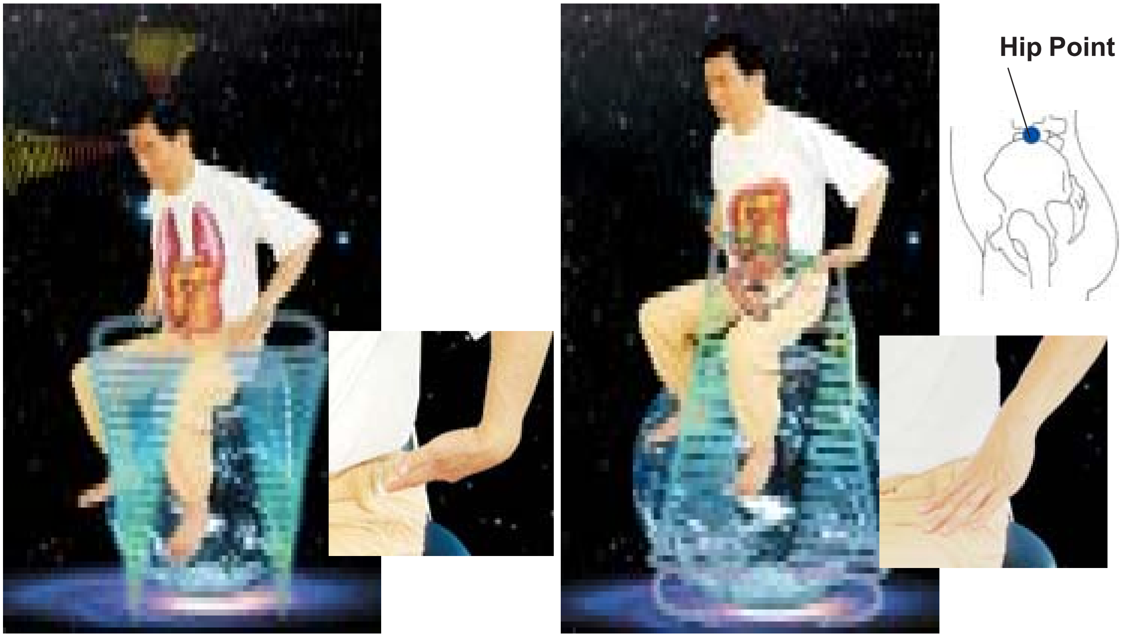

Fig. 8.10 *Activate the Organ Energy.*

Use your Yi to rotate your hands so that the fingers first point out, then back, turn the palms up and finally point the middle finger in toward the eye of the hip. Tan Tien and the universe - **95 % aware of the 'Tan Tien and the Universe' and 5 % aware of energy flowing back and forth between the tips of the middle fingers** (Pericardium 9); feel the Chi passing through the hips. This will activate the pericardium.

Rotate the hands again until the fingers are pointing forward with the **palms facing up**. Align the knife edges (Small Intestine 3) with the eyes of the hip. 'Focus at Tan Tien and the Universe'. Be lightly aware of the energy passing back and forth between the two hands. This will activate the heart and small intestine.

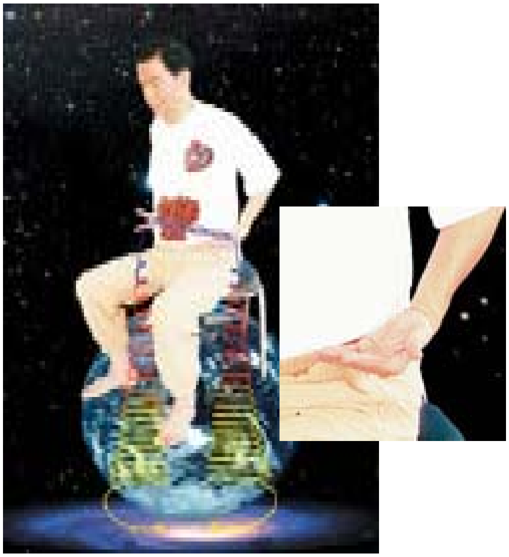

Fig. 8.11 *Activate the Heart and Small Intestine.*

Absorb the Heavenly Force

Washing the Bone Marrow - Crown to Soles

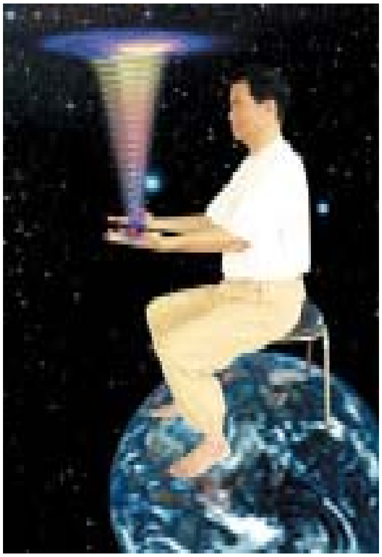

Extend the arms forward to chest height with the palms facing upward.

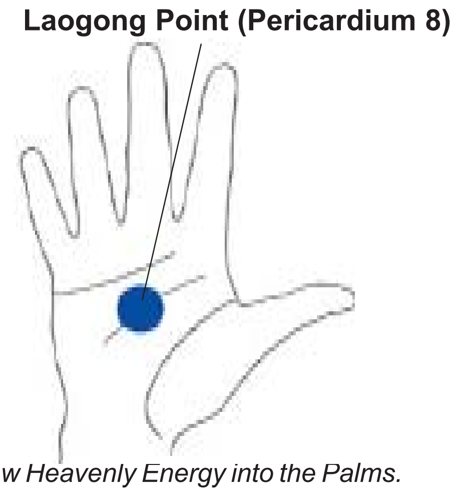

Fig. 8.12 *Draw Heavenly Energy into the Palms.*

Become aware of the **Tan Tien, the Crown and the Star above you**. Expand your mind (YI) out to the universe and connect to the galaxy. Be aware of the palms and the crown which are connected to the galaxy. Activate the Laogong point (Pericardium 8).

Feel the heavenly energy come directly to your palms, and be aware of the violet light of the North Star and the red light of the Big Dipper both shining radiantly.

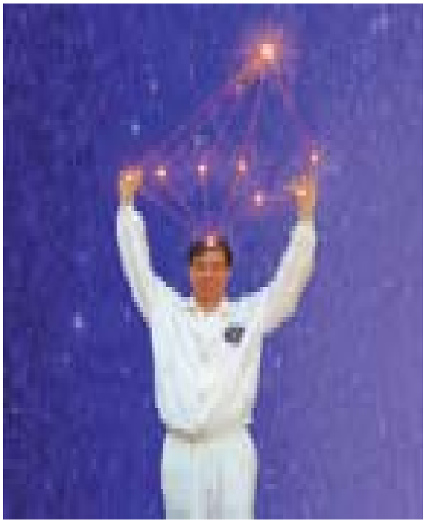

Fig. 8.13 *Hold the Big Dipper.*

Picture yourself holding the handle of the Big Dipper and turn the 'cup' pouring the light over your head. Draw this light in through the palms and the crown point and feel it washing your bone marrow. Always remember your Tan Tien. **Direct the sensations down through the skull, cervical vertebrae, clavicle, scapulas and sternum. Activate your thymus gland and continue drawing the healing heavenly light down through the rib cage, arms, spine, hips, femurs and calf bones, feet and toe bones. Be aware of the soles bubbling up to the perineum and up to the crown**.

Lightly rock yourself like riding a horse; this will help keep your spine open and Chi can flow easily throughout the practice.

Absorb the Earth Force and the Other Side of the Galaxy

Rotate the arms until the **hands are palms down**.

Raise the index fingers slightly and extend the thumbs first towards each other and then toward the ground. Be 95% aware of the Tan Tien and the Universe, and 5 % aware of the index fingers and the big toes. Wait until you feel the Chi enter. Fill the joints of the fingers and up to the wrists; feel 'tense but not tense' and let the **Chi continue to fill the joints** up to the elbows, up to the shoulders and gradually up to the neck and the head. Go from the toes up the legs to the hips and on into the spine and the rib cage **completing all the joints of the body**.

Be aware of the Tan Tien and the universe and only slightly aware of the palms (Laogong), the soles of the feet (Kidney 1-Bubbling Spring), and the perineum (Conception Vessel 1-Hui Yin) bubbling. Activate these points, feel the earth energy and continue smiling through the earth to connect with the galaxy, Milky Way, and the universe. Draw this light in through the palms and soles and let it wash up through the center of your bones from the feet up. Let it **steam and cleanse your marrow**. Picture any impurities or illness dripping out of your bones and draining down into the earth, where they will be recycled and purified.

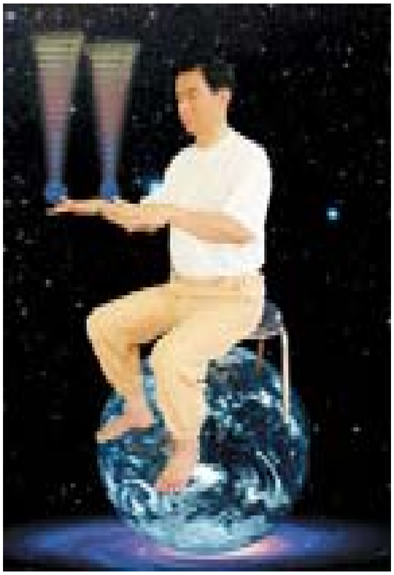

Fig. 8.14 *Open the index fingers.*

Core Movements of Part I

Grasping the Moon

Connecting the Heaven and Earth Forces - Right Side over Left

Open Position: Heaven Force - Slightly raise the index fingers to open the palms. Bring the arms up , bending the elbows so that the left hand is under the right elbow with the left index finger pointing up to Heart 3.

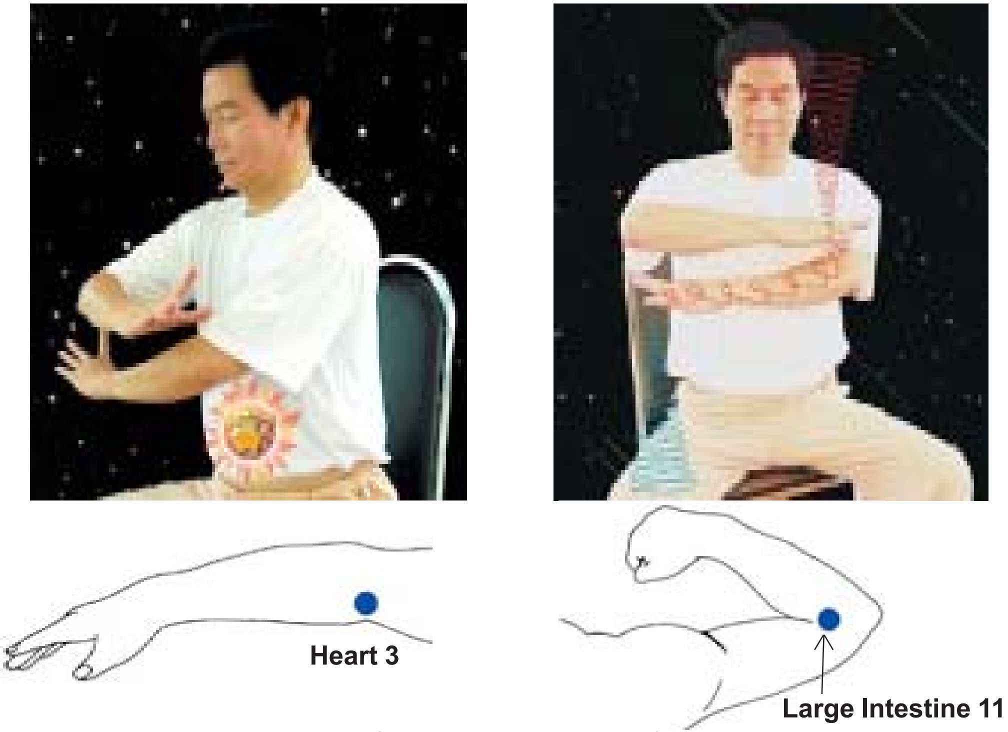

Fig. 8.15 *Complete the Heavenly Circuit.*

The right index finger is pointing up toward heaven and connecting to the galaxy. The right forearm is over the left forearm, with the tip of the right index finger held above the Large Intestine 11 point of the left arm.

The **right index finger draws in the heavenly force** like antennae. The force flows up the bones of the right arm, across the shoulders to the left arm and through the bones of the left arm to the left index fingertip. It **then flows through the index finger of the left hand** into the Heart 3 point of the right arm, **completing the heavenly circuit**. Continue cycling in this way. Hold the position and count to five.

The practice uses the 'Empty Force'; this means that there is no contact. The fingers must be 'tense without tensing'. When you tense and raise the index finger, you will feel the Laogong point opening.

Close Position: Tan Tien, earth and the universal force - keeping the arms in the same position, move both index fingers to point down. The **right index finger will now point toward the Large Intestine 11 point of the left arm and the left index finger will point downward toward the earth** and continue down to connect to the universe. Draw in the earth force through the left index finger, bringing it through the bones of the left arm, across the shoulders through the right arm to the right index finger and out into the Large Intestine 11 point of the left arm. Continue cycling in this way, **completing the earth circuit**.

Open and close three times altogether ending in the open position. Hold each count for five seconds.

Holding and Activating the Chi Ball
Tan Tien and the Original Force - Right Side over Left

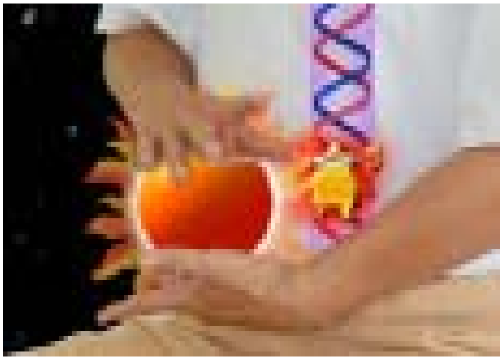

__Fig. 8.16__ Right Side over Left - 'Holding the Ball'.

Turn the **left palm upward** and lower it to the Tan Tien with the pinky pointing inwards.

Lower the right palm to the navel, palm down, as though you were holding a small Chi ball. Lower the right thumb to point toward the left Laogong point. This opens the eye of the right hand (LI-4), then point it toward the navel. Be aware of Tan Tien and universe.

Yin/Yang Palms

Separate the hands and extend them out in front of the body at navel level. The **left palm** is still pointing up, and is **Yang** drawing in the heavenly force through Laogong. The **right palm** is still facing down, and is **Yin** drawing in the earth and the galactic force from below.

Conclude by turning the left palm over to face downward. **Draw in the earth force through both palms.**

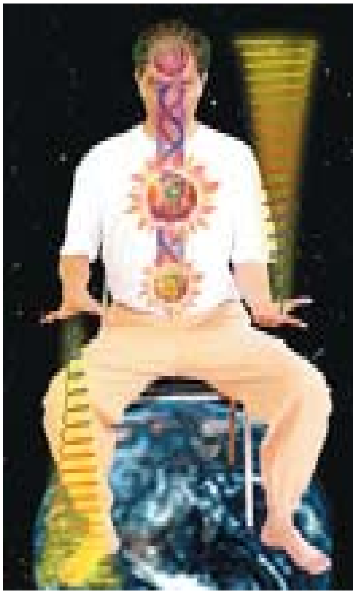

__Fig. 8.17__ 'Yin and Yang Palms' - Right Hand connecting to Earth and Left to Heaven.

Left Side: **Repeat on the left hand side with the left arm over the right**. Holding the Chi ball the left hand is on top. Hold for a count of five seconds.

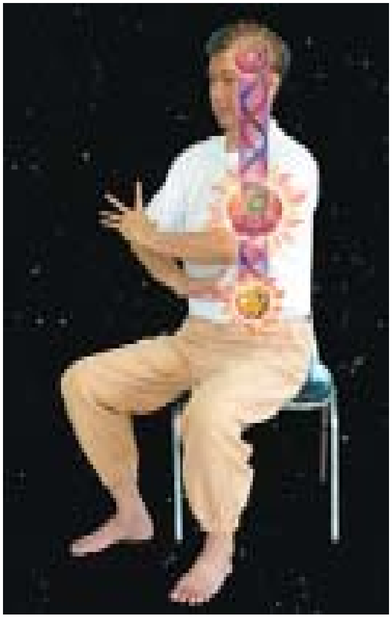

Fig. 8.18 *Open the Heavenly Circuit. Then the bottom hand slides and turns 'Palm-Up' and the Top Arm slides to 'hold the Chi Ball'*

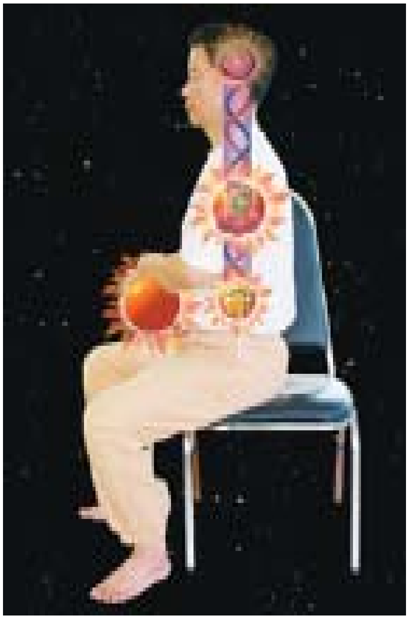

Fig. 8.19 *Holding the Chi Ball - Left Side over Right.*

Closing Movements

Activate the Chi Channels - Balance the Orgasn

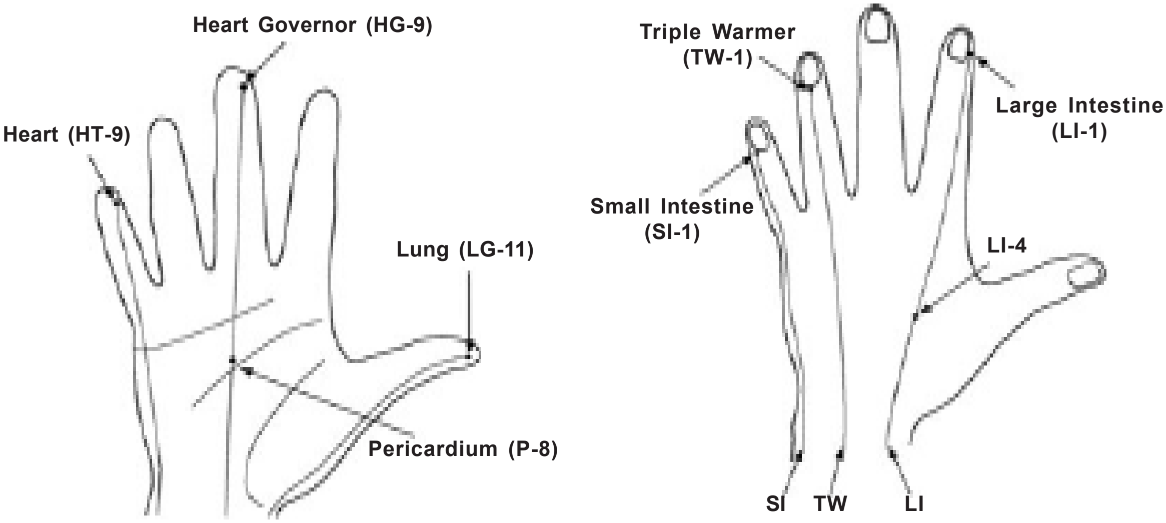
Heart Governor (HG-9)
Heart (HT-9)
Lung (LG-11)
Pericardium (P-8)
Triple Warmer (TW-1)
Large Intestine (LI-1)
Small Intestine (SI-1)
LI-4
SI
TW
LI

Fig. 8.20 *Finger Points*

The closing movements balance organ energy while activating the Chi Channels.

Hold the arms extended forward with the palms down at solar plexus level. Hold each stage for a count of five seconds.

Index Fingers:

Tense all the fingers and feel the Chi filling all the joints; open the index fingers, raising them up, while keeping the rest of the fingers level.

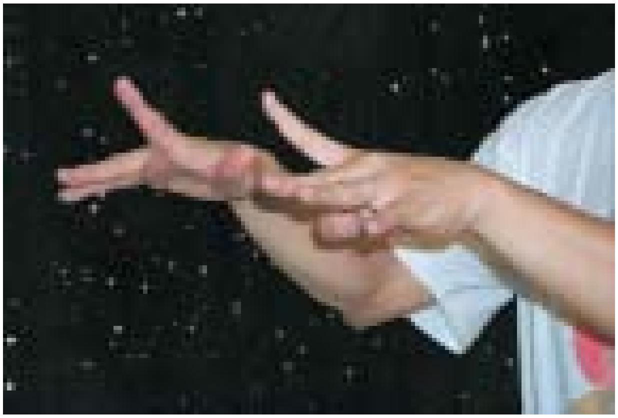

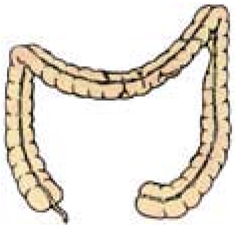

Large Intestine

Fig. 8.21 *Activate the Index Fingers - Up.*

The tension should be like the string of a tuned musical instrument. When lightly tense the Heavenly Chi will be drawn in through the index fingers.

Relax the hands and bring the index fingers back to the neutral position, level with the other fingers.

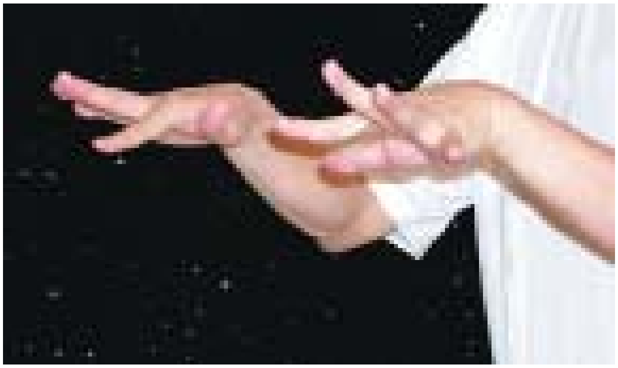

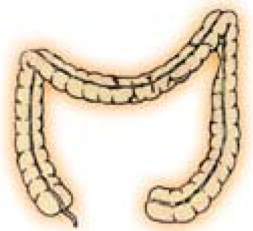

Energy to Large Intestine

Fig. 8.22 *Draw Earth Energy through the Index Fingers - Down.*

Stretch out and tense all the fingers and **press the index fingers to point down** toward the earth and continue down to the universe. Keep the other fingers level. **Draw in earth energy through the index fingers and circulate it through the body.**

Bring the index fingers back to neutral and relax your hands.

Once again **open the index fingers by raising the index fingers up**, while keeping the rest of the fingers level. **Draw in the Heavenly Chi through the index fingers**.

Bring the index fingers back to neutral again and relax your hands.

Ring Fingers:

Stretch the ring fingers down toward the earth, keeping the rest of the fingers level. Draw in earth energy through the ring fingers and circulate it through the body.

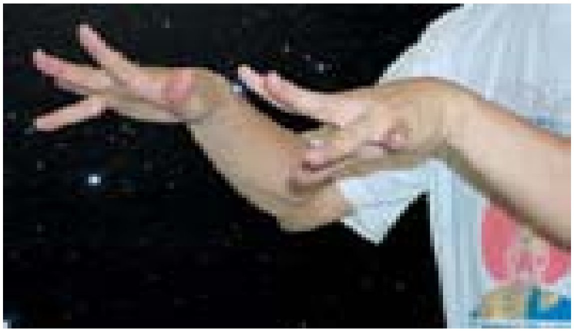

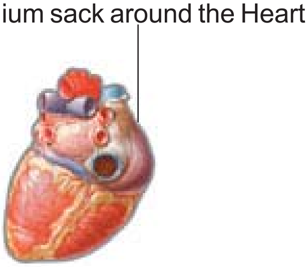
Pericardium sack around the Heart

Fig. 8.23 *Draw Earth Energy through the Ring Fingers.*

Bring the ring fingers back to neutral and relax your hands.

Once again open the index fingers by raising the index fingers up, while keeping the rest of the fingers level, and draw in the Heavenly Chi through the index fingers.

Bring the index fingers back to neutral again and relax your hands.

Thumbs:

Stretch the thumbs out and down toward the earth, keeping the rest of the fingers level. Draw in earth energy through the thumbs and circulate it through the body.

Bring the thumbs back to neutral and relax your hands.

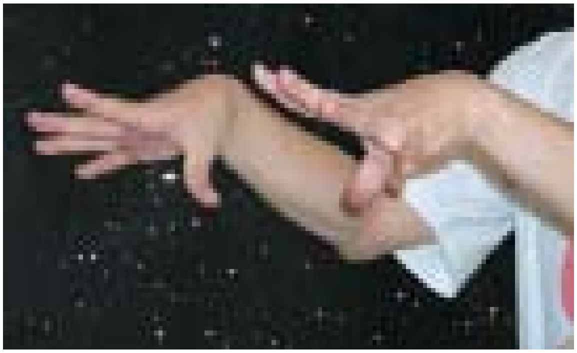

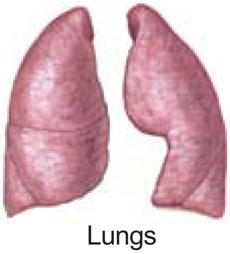

Fig. 8.24 *Draw Earth Energy through the Thumbs.*

Once again open the index fingers by raising the index fingers up, while keeping the rest of the fingers level, and draw in the Heavenly Chi through the index fingers.

Bring the index fingers back to neutral again and relax your hands.

Pinky Fingers:

Stretch the pinky fingers out and down toward the earth, keeping the rest of the fingers level. Draw in earth energy through the pinky fingers and circulate it through the body.

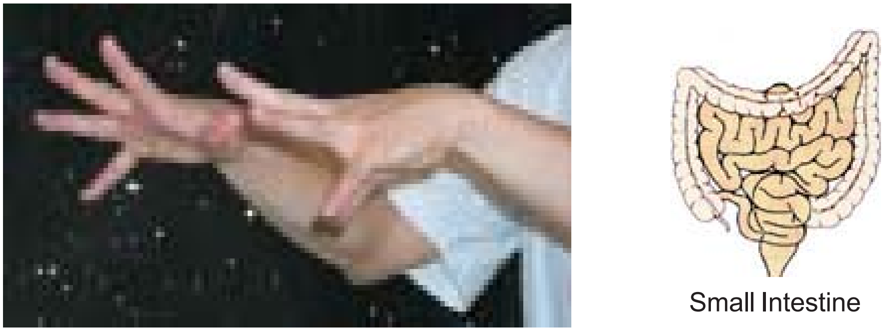

Fig. 8.25 *Draw Earth Energy through the Pinky Fingers.*

Bring the pinky fingers back to neutral and relax your hands.

Once again open the index fingers by raising the index fingers up, while keeping the rest of the fingers level. Draw in the Heavenly Chi through the index fingers. Bring the index fingers back to neutral again and relax your hands.

Middle Fingers:

Stretch the middle fingers out and down toward the earth, keeping the rest of the fingers level. Draw in earth energy through the middle fingers and circulate it through the body.

Bring the middle fingers back to neutral and relax your hands.

Once again open the index fingers by raising the index fingers up, while keeping the rest of the fingers level. Draw in the Heavenly Chi through the index fingers.

Bring the index fingers back to neutral again and relax your hands.

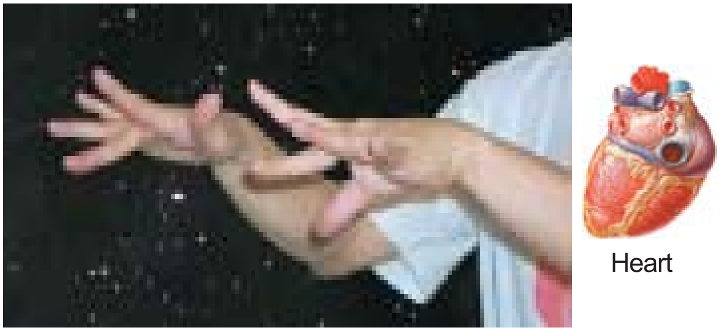

Fig. 8.26 *Draw Earth Energy through the Middle Fingers.*

Crane's Beak and Swallow the Saliva:

Form the "Crane's Beak" with both hands by bringing all the fingertips together with the thumbs inside. **Inhale** and **contract the sexual organs**.

Move your tongue and suck the mouth to **activate the saliva**. Divide it into three parts, tighten the neck and gulp down the **first part** to the center of the **navel**; force the **second** mouthful of nectar down to the **left side of the navel** and the **third** to the **right side of the navel**. Raise the forearms up to shoulder height with the fingers pointing down. Slowly open the palms and begin to lower the arms to the sides, until the palms are facing each other before the starting position.

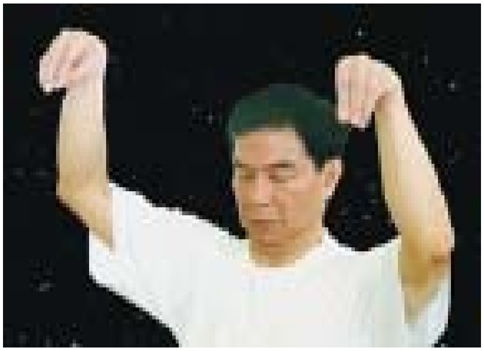

Fig. 8.27 *Form the 'Crane's Beak'.*

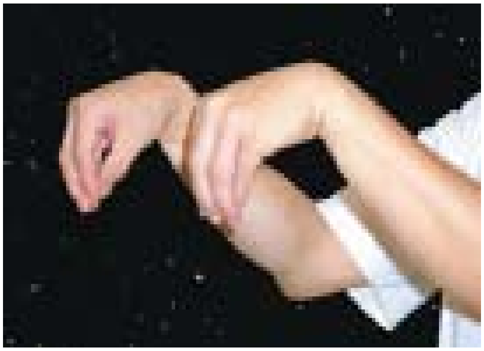

Fig. 8.28 *Raise Forearms to Shoulders.*

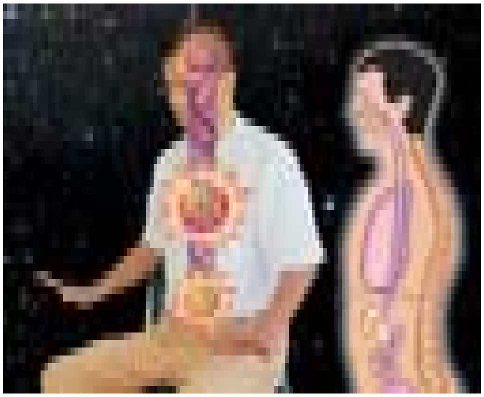

Fig. 8.29 *Lower Arms to the Sides.*

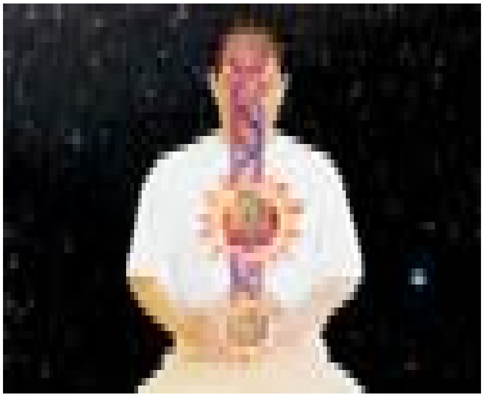

Fig. 8.30
Palms facing each other to cover the Navel.

Conclusion:

Bring awareness to the navel. Notice the quality and intensity of the energy generated and **collect your energy at the navel**. Men place hands over the navel with the right hand on top; women vice versa. Rest.

Summary:

Practice Part I daily for one or two weeks until you can do it well. Then you can proceed to learning Part II.

Part II
Opening the Bridge and Regulator Channels

Theory

Chi flows through your body along numerous channels or meridians. The channels are divided into two major groups: the **extraordinary** or special channels and the **ordinary** channels. After your mother's egg and your father's sperm joined together to form a single cell, that cell began to divide. The extraordinary channels were the first energy channels formed as a result of that early cell division.

There are **Eight Extraordinary Channels:**

- Governor Channel
- Functional or Conception Channel
- Thrusting Channel
- Belt Channel
- Yang Regulator Channel
- Yin Regulator Channel
- Yang Bridge Channel
- Yin Bridge Channel

Later, as your fetus developed, your Original Chi flowed through the eight extraordinary channels to help create your internal organs and their energy channels. These twelve "ordinary channels" are divided into yin and yang. The yin Channels are connected to the solid organs, and the yang channels are connected to the hollow organs.

The **Twelve Ordinary Channels:**

- Lung (Yin) Channel
- Large Intestine (Yang) Channel
- Stomach (Yang) Channel
- Spleen (Yin) Channel
- Heart (Yin) Channel
- Small Intestine (Yang) Channel
- Bladder (Yang) Channel
- Kidneys (Yin) Channel
- Pericardium (Yin) Channel
- Triple Warmer (Yang) Channel
- Gall Bladder (Yang) Channel
- Liver (Yin) Channel

These twelve organs serve to extract energy from the food and water we ingest and the air that we breathe to create energy through the metabolic processes of respiration, circulation, digestion, elimination and reproduction. This energy is called PostNatal Chi, as it comes in after we are born. Thus the extraordinary channels serve as the link between our Original or Prenatal Chi which came from our mother and father, and our Postnatal Chi which comes from our food and air as a result of metabolism.

General Functions of the Eight Extraordinary Channels

They serve as reservoirs of Chi.

About two thousand years ago, one of the great texts of Chinese medicine, the Nan Ching was written. This classical text describes the twelve ordinary channels as rivers and the eight extraordinary channels as reservoirs of Chi. When the ordinary channels become low in energy, they can draw from the reservoirs of energy in the extraordinary channels. On the other hand, if the ordinary channels become too full, the excess can be taken up by the extraordinary channels. In this way the extraordinary channels help us to maintain a balance in our energy body.

They store and circulate Ching Chi.

The extraordinary channels all draw their energy from the kidneys, which are the storehouse of Ching Chi (essence or sexual energy) in the body. Thus the extraordinary channels circulate the Ching Chi around the body, particularly to the skin and hair, and to the five ancestral organs: the brain and spinal cord, the bone marrow, the blood, the uterus and the liver and gall bladder.

They circulate Defensive Chi to protect the body.

The Chi that protects the body against invasion by external pathogens is called Defensive Chi or Wei Chi. The extraordinary channels circulate Defensive Chi over the back, abdomen and thorax. These functions are performed by the Governor Channel, the Functional Channel and the Thrusting Channels, respectively.

They regulate our life cycles.

In the first chapter of the Yellow Emperor's Classic of Internal Medicine (Huang Di Nei Ching Su Wen), another of the classical texts of Chinese medicine, the life changes of women and men are described in 7 and 8 year cycles respectively. The Functional Channel and the Thrusting Channel govern these cycles.

Eight Extraordinary Channels and Chi Kung

There are few texts available today that describe the purpose and function of the eight extraordinary channels and their place in Chi Kung practice. To make matters more confusing, the extraordinary channels and points used in Chi Kung are often quite different from those used in acupuncture, even though they may bear the same names.

Most acupuncturists pay little attention to the eight extraordinary channels in diagnosis and treatment with the exception of some modern Japanese researchers. By contrast, the extraordinary channels have been of special importance to Taoists and Chi Kung practitioners for thousands of years. Taoists see the extraordinary channels as the foundation of our bodily energy, as the bridge between our Original or Prenatal Chi and our Postnatal Chi; these channels affect us on the deepest level of our basic constitutional energy.

Therefore, Taoists focus on opening up the flow of energy through the eight extraordinary channels as a prerequisite for opening the energy flow in the twelve ordinary channels. In the Universal Tao system, you first open up the Governor Channel and the Functional Channel in the Microcosmic Orbit Meditation. The second pair: the Thrusting Channels and the Belt Channels are opened in the Fusion of the Five Elements II Meditation. The last four channels, the Yin and Yang Bridge Channels and the Yin and Yang Regulator Channels are opened in the third level of Fusion of the Five Elements Meditation. After opening all eight channels, in the next level of Taoist inner alchemical meditation called the Lesser Enlightenment of Kan and Li, the twelve ordinary channels are then opened.

Special Functions of the Bridge and Regulator Channels

The Bridge and Regulator Channels have no points of their own. They borrow points from the other ‘ordinary’ channels linking together and controlling the flow through all the separate channels of the body. The Bridge and Regulator Channels travel along the same paths. There is no ‘real’ difference between them. Both of them connect or ‘bridge’ and ‘regulate’ the flow of Chi in the body’s meridians.

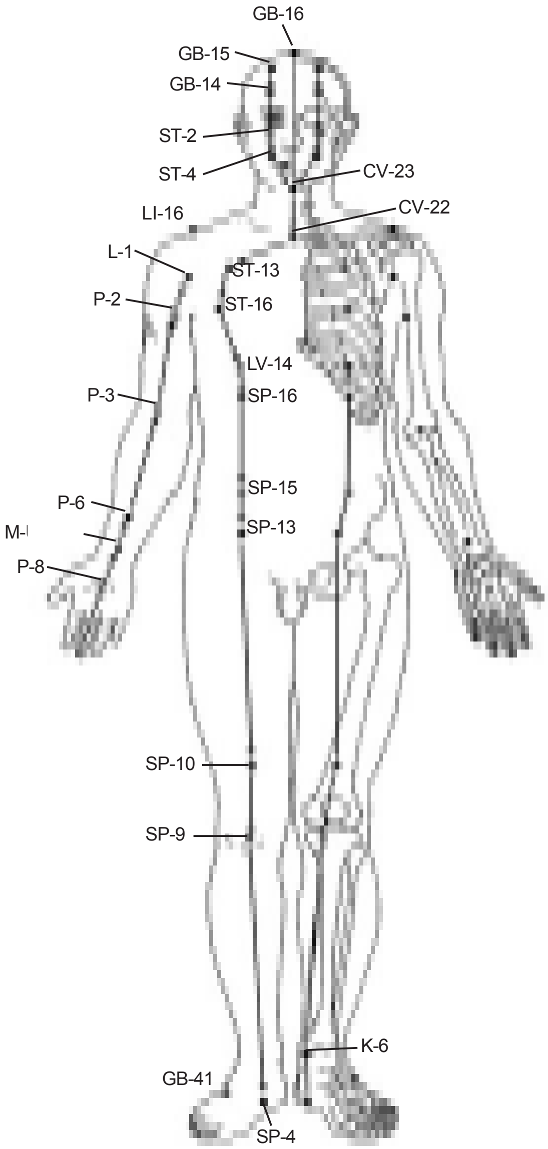
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SP-16
SP-15
P-6
M-
SP-13
P-8
SP-10
SP-9
K-6
GB-41
SP-4

***Fig. 8.31** Yin Bridge and Regulator Channels*

Bridge Channels Yin and Yang Chiao Mo Function

The Bridge Channels, also called the Heel Vessels as they originate at the heels, regulate the amount of energy being used by all the other meridians in the body. They act like a bridge linking together the stored Chi in the body and the areas in need of Chi. Usually if any meridian uses more energy than it needs to flow properly, then other meridians become deficient as a result. Thus the Bridge Channels seek to assure that your energy is distributed in a balanced way. The Yin Bridge Channel runs along the front or yin side of the body, while the Yang Bridge Channel runs along the back of the body.

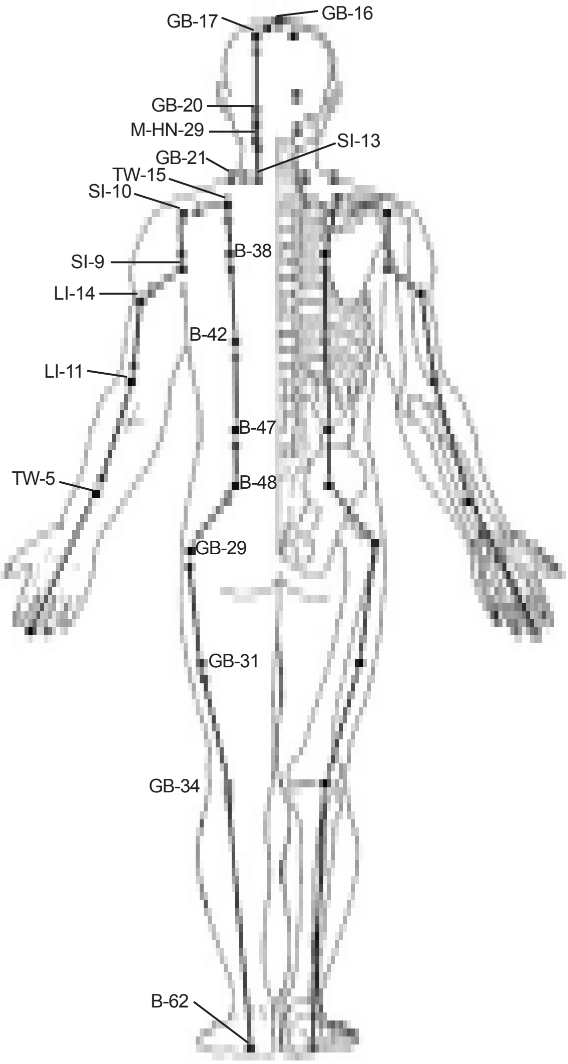
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B-38
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LI-14
B-42
LI-11
B-47
TW-5
B-48
GB-29
GB-31
GB-34
B-62

***Fig. 8.32** Yang Bridge and Regulator Channels*

Disorders of the Bridge Channels

Excess Yang Energy

When yin energy is slowed down in the Bridge Channels, yang energy flows more rapidly. The excess yang can cause the following problems: insomnia, difficulty in closing the eyes, hypertension, stiff back and waist, inability to bend down, thigh tumors, bad colds, spontaneous sweating, headaches, painful eyes, paralysis of the arms and legs, vomiting of milk in infants, deafness, epilepsy, nose bleeding, swelling of the body, pain in the joints and head sweating.

Excess Yin Energy

When yang energy is slowed down in the Bridge Channels, yin energy moves more rapidly. The excess yin causes the following problems: sleepiness, difficulty in keeping the eyes open, hypotension, choking, painful urination, stomach rumbling, vomiting, diarrhea, difficult bowel movements, difficult labor and unconsciousness.

Regulator Channels

Yin and Yang Wei Mo Function

The Regulator Channels, also called the Linking Vessels, bind together all the meridians in the body. The Regulator Channels are also divided into yin and yang. The yin aspect, which runs along the front of the body, moves the yin energy and regulates the blood and inner parts of the body. It connects with all the yin channels: the Liver, Spleen, Kidney, Heart, Pericardium and Lung channels. If the yin aspect becomes imbalanced, the person may suffer from heart pains.

The yang aspect, which runs along the back side of the body, moves the yang energy, controls Defensive Chi, regulates resistance to external infections, and regulates the external parts of the body. It connects with all the yang channels: the Stomach, Bladder, Gall Bladder, Large Intestine, Triple Warmer & Small Intestine channels. If the yang aspect becomes out of balance, the person may catch colds and fevers easily.

By joining together the various channels, the Regulator Channels help to maintain a harmonious and cooperative interaction between the different channels.

The Regulator Channels in Taoist Yoga and Chi Kung are slightly different from those presented in acupuncture texts. The Chi Kung Regulator Channels include the yin and yang arm routes as well; some Taoist Yoga texts also refer to the arm routes as the Yin Yu and the Yang Yu. Acupuncture texts, by contrast, include only the leg, trunk and head routes. Many recent Chi Kung texts, unaware of these differences, depict illustrations from acupuncture texts alone, further adding to the confusion.

Disorders of the Regulator Channels

Excess Yang Energy

When yin energy is slowed down in the Regulator Channels, yang energy moves more rapidly. The excess yang can cause the following problems: swelling and pain in the joints, cold knees, paralysis of the arms and legs, painful back and sides, aching muscles, pain in the head, neck and edge of the eyebrows, fever, rashes, night sweating, tetanus, painful red eyes, colds and superficial fevers.

Excess Yin Energy

Similarly, when yang energy is slowed down in the Regulator Channels, yin energy moves more rapidly. The excess yin can cause the following problems: heart pain, diarrhea with stomach rumbling, difficulty swallowing, pain on both sides of the chest, diseases associated with cold and convulsions.

Summary

The Bridge and Regulator Channels link all of the yin and yang channels in the body together and regulate the flow of energy in these channels to maintain a state of energetic balance in the body. The channels used for meditation are somewhat different from the ones seen in Chinese medical text and acupuncture charts. This is because their purposes are different.

Chinese medicine aims to restore sick people to health. The points being treated must be superficial so that they can be activated by acupuncture needles.

Chi Kung and Taoist meditation aim to maintain health and to take one beyond mere physical health to spiritual immortality. The channels and points can be deep within the body, since the energy is guided by the mind or by postures and movements rather than by needles.

The movements used in Cosmic Chi Kung Part II to activate the Bridge and Regulator Channels are relatively simple. To completely master the Bridge and Regulator Channels, you must learn and practice the third level of Fusion of the Five Elements Meditation. Once you have done so, this part of Cosmic Chi Kung practice will be particularly powerful and balancing for you.

Practice

Opening Movements

The Opening Movements for this second part of Cosmic Chi Kung are the same as for the first part. By now you should be familiar with these movements, so they will be described briefly. For a more detailed description, refer to Part I, Opening Movements.

Hands down at sides, palms facing each other. Commence Bone breathing. Be aware of the Tan Tien and absorb Cosmic Chi. Be aware of the Tan Tien and channeling the earth and galactic forces.

Washing the Bone Marrow

Raise arms to chest height - palms facing each other. Rotate arms until palms face down. Open the 'Tiger's Mouth' - Index finger up, thumb down.

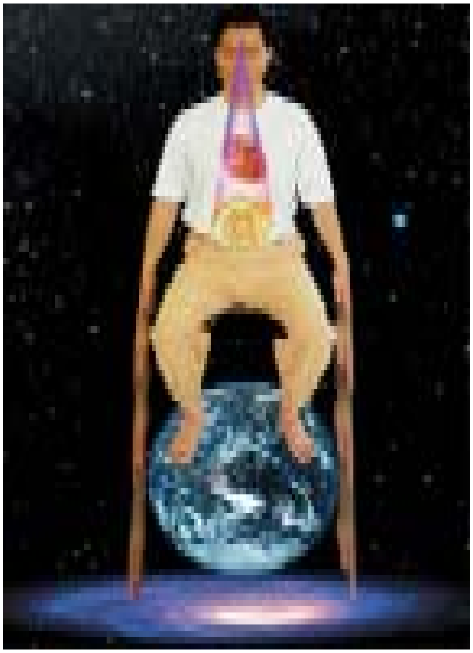

Fig. 8.33 *Hands lower to the Sides. Lower the Mind to the Tan Tien.*

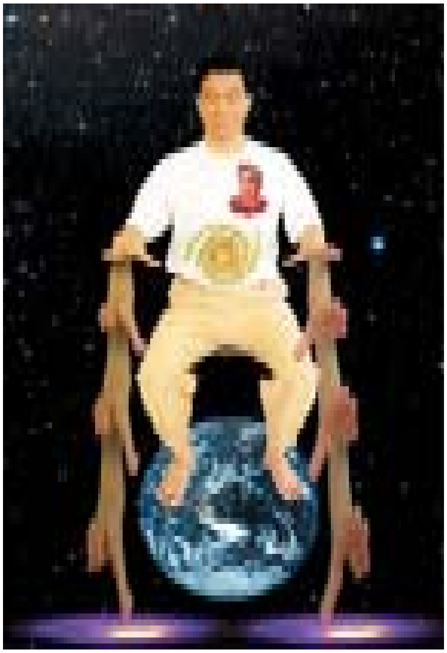

Fig. 8.34 *Open the 'Tiger's Mouth'.*

Activate and Beam to the Eye of the Hip

A. Large Intestine 4 - Eye of the Hand
B. Pericardium 9 - Tip of the Middle Finger
C. Small Intestine 3 - Knife Edge of the Hand

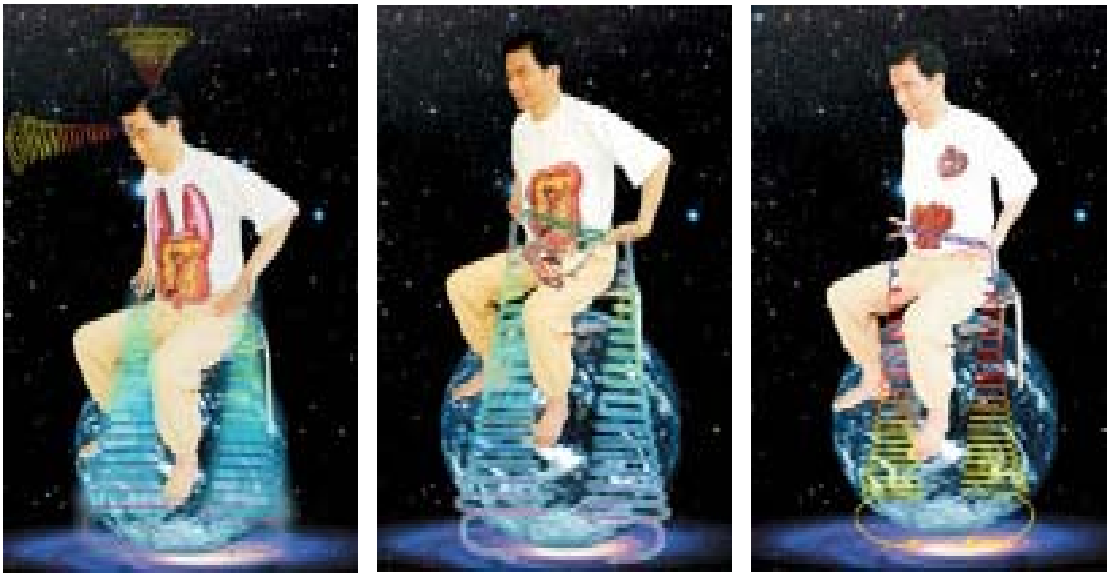

Fig. 8.35 *Activate the Large Intestine, Pericardium and Small Intestine.*

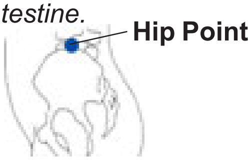

Be aware of the Tan Tien and absorb the Heavenly Force Washing the Bone Marrow Crown to Soles.

Extend the arms forward - palms upward. Be aware of the Tan Tien and absorb the heavenly force. Rotate the arms until the palms face down. Raise the index fingers slightly. Absorb the Earth Chi.

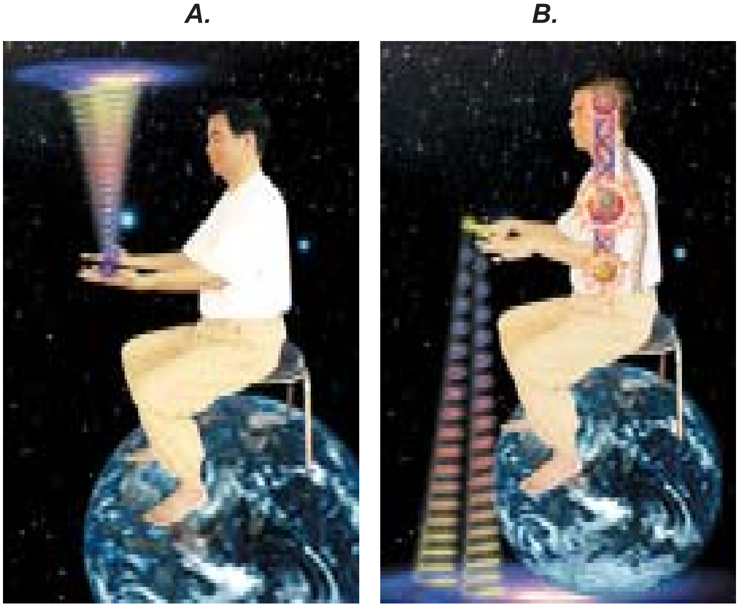

Fig. 8.36
A. *Be aware of the Tan Tien and absorb the Heavenly Force.*

B. *Index Fingers up - be aware of the Tan Tien and absorb the Earth and Universal Force.*

Core Movements of Part II Opening the Bridge and Regulator Channels

Activate the Throat Center - Right Side

Keeping the elbows sunk, raise the left palm first so that it is about 1 inch in front of the throat center (Conception Vessel 22), palm facing in. Then bring the right hand up so that it is about 1 inches in front of the left hand, palm facing in. Align the Lung 10 point in the middle of the eminence of the left hand with the **throat center. Feel the Chi go through the neck to C-7**. Continue smiling to the universe and connect to the back side of the universe. Hold for a 5 to 30 count and feel the throat center activated.

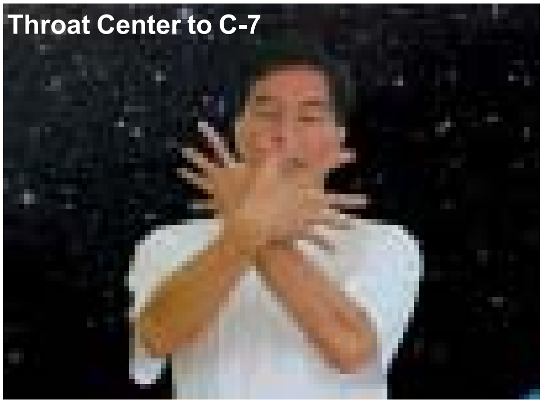

Fig. 8.37 *Connect to the Throat Center.*

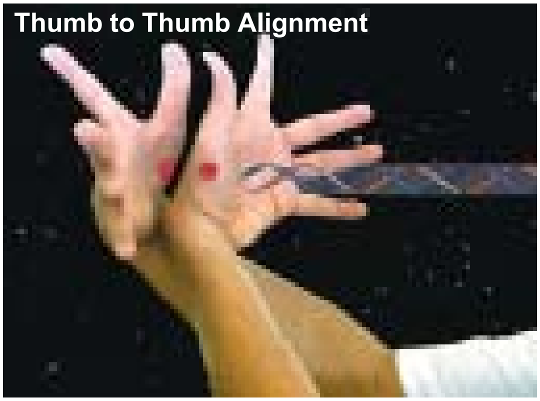

Fig. 8.38
Feel the connection to the Universe at the Back.

Move both hands out slowly like you're pulling silk; when the feeling is diminished or the silk starts to break stop there. Be still and feel the beam connect the throat center to C-7 and the universe. Maintain the energy beam as you move in and out three times altogether ending with the hands as above.

Activate Mideyebrow Point - Right Side

Be aware of the Tan Tien and the universe. Keeping the Lung 10 points aligned, raise the hands up to the level of the mideyebrow point about one inch in front of the face. **Keep the points aligned and beam the energy passing through both hands into the mideyebrow point and through to the base of the skull.** Continue smiling and extending to make a connection to the back universe for a 5 to 30 count.

Use only 5% of the awareness to move both hands very slowly out, like you are **pulling silk**; continue to move out as long as your can feel the connection to the mideyebrow, C-7 points and the universe, maintaining the energy beam as you move.

Move in and out three times altogether, ending with the hands as above.

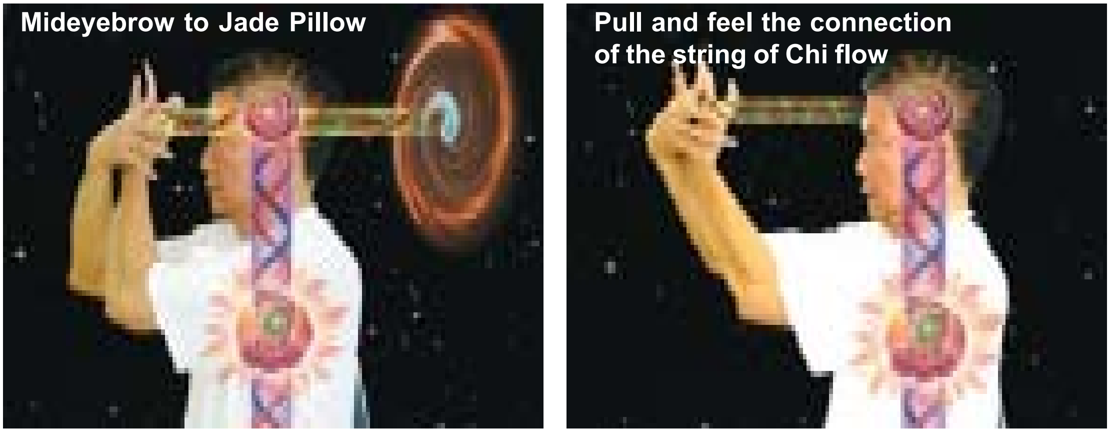
Mideyebrow to Jade Pillow
Pull and feel the connection of the string of Chi flow

Fig. 8.39 *Connect to the Mideyebrow, Jade Pillow and the Universe at the Back.*

Keeping the palms and thenars (Lung 10) aligned, move the hands back down to the position in front of the throat center. Keeping the forearms horizontal at shoulder height, separate the hands so that the Laogong point is aligned in front of Stomach 13, just **below the clavicle** on a vertical line above the nipple or mammillary line. The middle fingertips should almost be touching. **Beam energy from the Laogong points into ST-13 through the back on the side of the spine and connect to the universe**. You will be following this vertical line, which passes through the nipples, down the torso to the level of the navel, **stopping to focus and beam energy into key points along the way.** On each of these, focus your Yi on beaming energy into the organs inside each position. Stomach 13 is the location that activates the Heart and Lungs. Feel the change in your breathing as you activate the lungs.

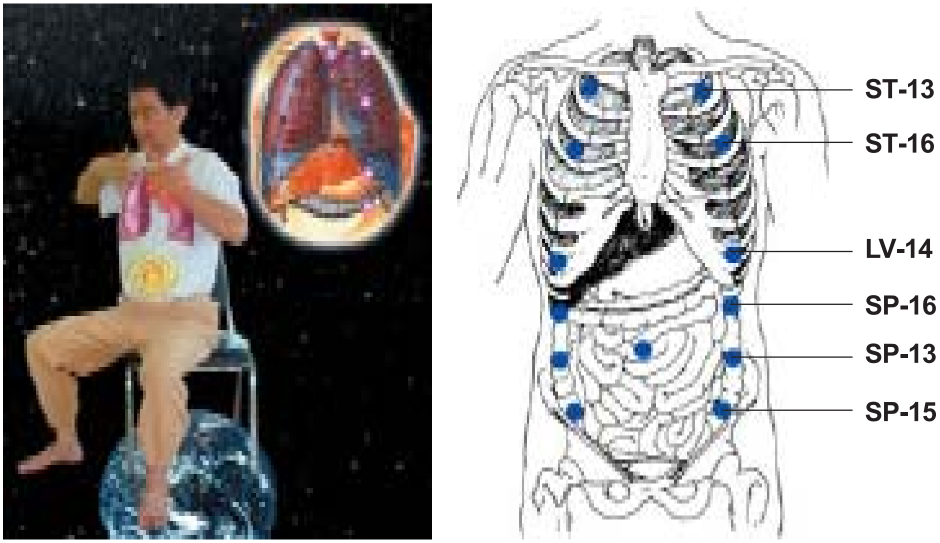

Fig. 8.40 *Beam Energy into ST13.*

Move the hands down the mammillary line to Stomach 16, about one inch above the nipple (in the space between the third and fourth ribs). Chi connects to the back and to the universe. Again, beam energy to energize and balance the **heart and middle of the lungs**. Move the hands down to Liver 14 (about 2 - 3 inches below the nipple in the space between the 6th and 7th ribs). Beam healing energy into the **liver and gall bladder.** Feel the Chi or the vibration of the palms activate the liver and feel the energy moving inside there.

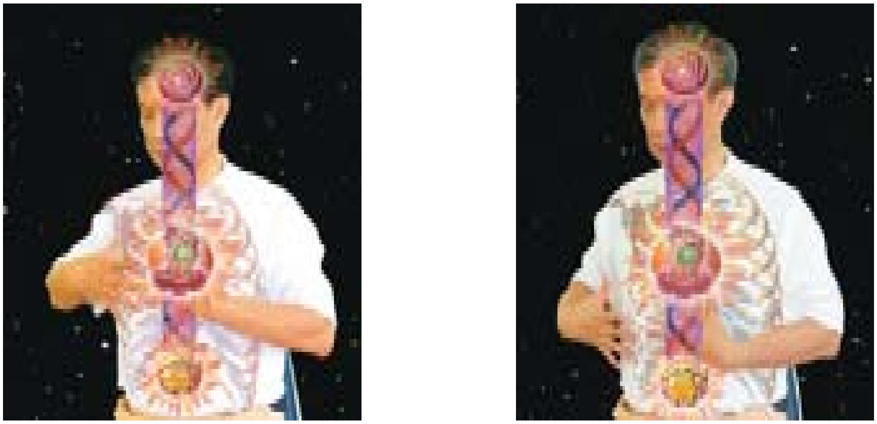
A. ***B.***

Fig. 8.41 A. *Energize and balance the Lungs at ST16.*
B. *Energize and balance the Liver and Gallbladder at LV14.*

Move the hands down to **Spleen** 16 (just below the rib cage on the mammillary line). Beam healing energy into the **stomach, pancreas and spleen and the liver.** Picture the organs receiving the Chi from the cosmic and the universe.

Move the hands down to Spleen 15 (on the mammillary line to the level of the navel). Beam healing energy from your palms into the **small intestine and the Tan Tien.**

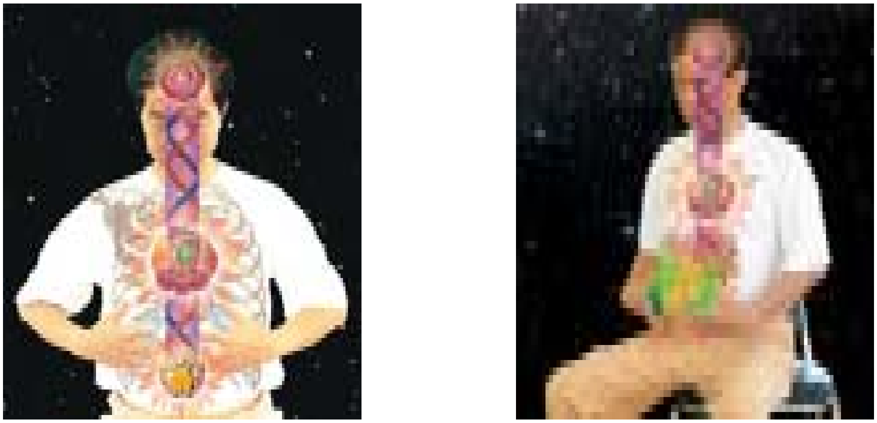
A. ***B.***

Fig. 8.42 A. *Energize the Stomach, Pancreas, Spleen and Liver at SP 16.*
B. *Energize the Tan Tien and Small Intestine at SP15.*

Hold the Chi Ball - Right Hand on Top

Turn the **left palm up** and align the Chi Ball with the Tan Tien. Turn the **right palm down** and align the eye of the hand (LI-4) with the navel. Feel your palms holding a Chi ball and feel a **Chi ball inside the Tan Tien**. Feel the Chi ball connect to the Cosmic Chi outside. Feel the north (usually left) and south (usually right) poles in the hands. Lower the right thumb to point toward the left Laogong point.

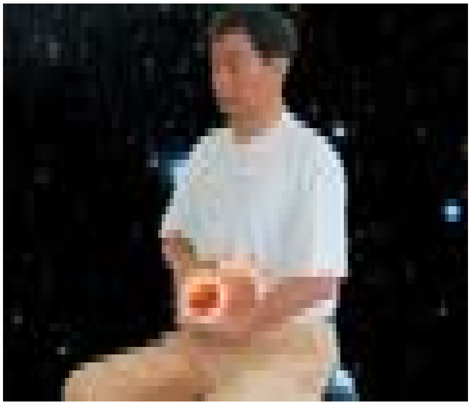

Fig. 8.43
Hold the 'Chi Ball' - One in the Tan Tien and the other in the hands - Right Hand over Left.

Yin/Yang Palms

Separate the hands and extend them out in front of the body at solar plexus level. The **left palm** is still pointing up and is yang drawing in the **Heavenly Force** through Laogong. The **right palm** is still facing down and is yin drawing in the **Earth Force** energy. **'Be Aware Tan Tien and Universe'**.

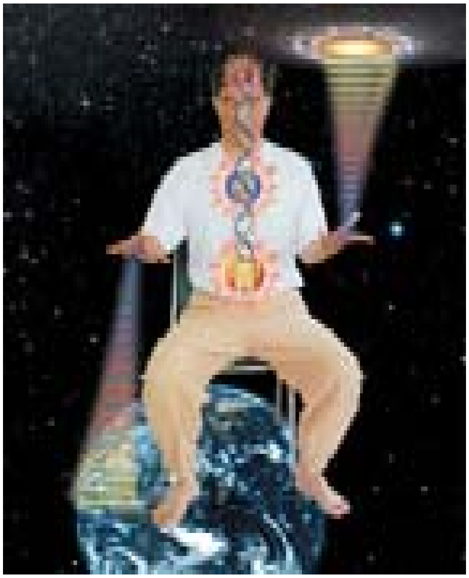

Fig. 8.44 *Connect to Heaven and Earth.*

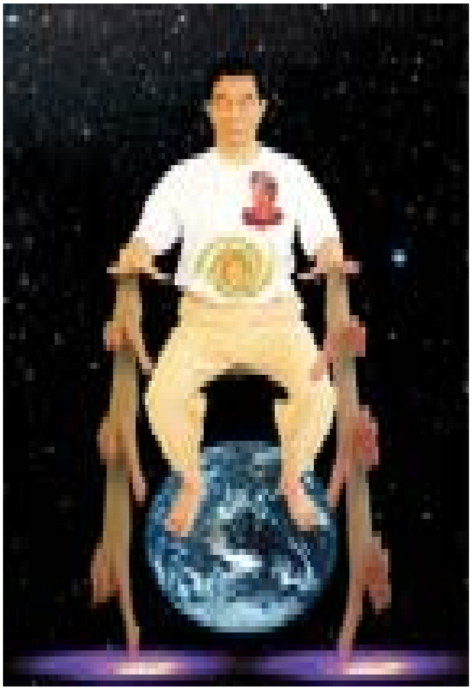

Conclude by turning the left palm over to face downward. **Draw in the 'Earth Force' through both palms.**

Fig. 8.45 *Draw the Earth Force through the Palms.*

Repeat the sequence with the left palm over the right.

Start by moving the right palm to the throat and then the left palm. Scan the body, as in the previous sequence, using both palms to connect to the points running down the front of the body. Remember to maintain a sense of the Chi flowing between the points in the front and their corresponding points in the back of the body.

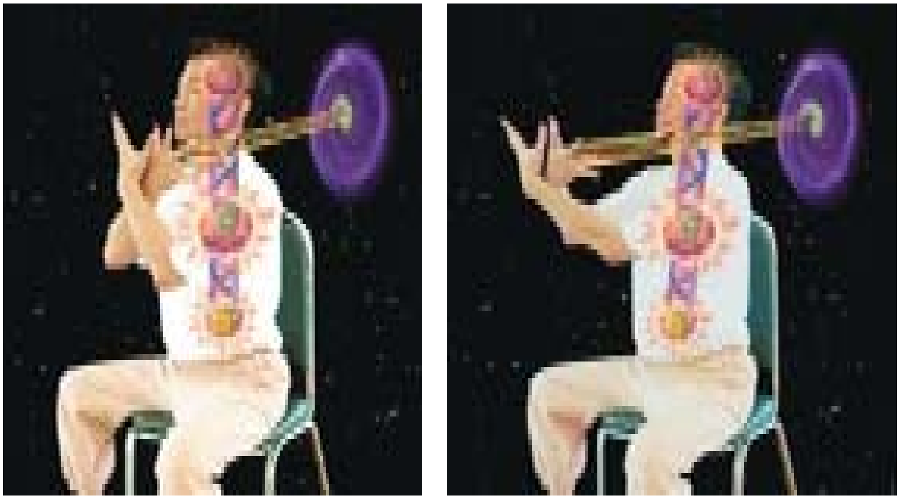

Fig. 8.46 *Repeat the Practice on the Left Side. Push and Pull the silk at the Throat.*

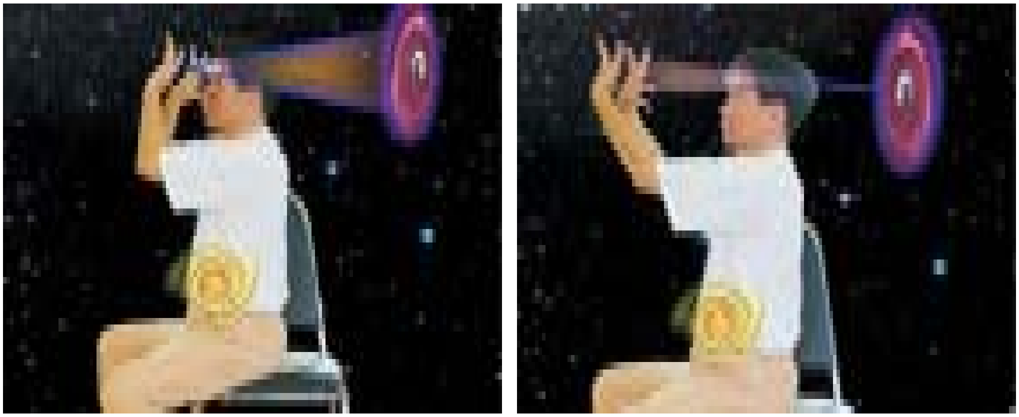

Fig. 8.47 *Project to the Mideyebrow and Base of the Skull - connect to the Universe at the back. Then hold the Ball and repeat Finger Movements, as below.*

Continue with the left side, now pulling the silk at throat (C-7).

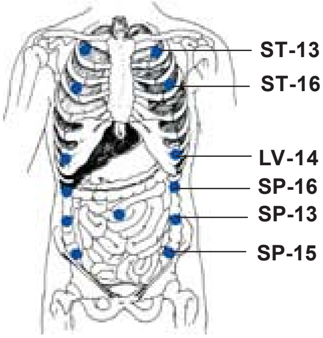

Fig. 8.48 *Beam Energy into each of the Organs like the last time.*

Closing Movements

The closing movements, crane's beak and finish are the same as before.
Activate the Chi channels - balancing the organs.

Index Fingers

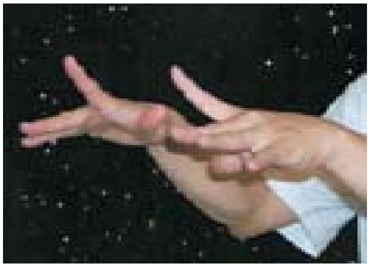

Fig. 8.49 *Open (up)*

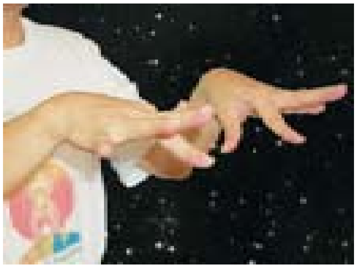

Fig. 8.50 *Neutral*

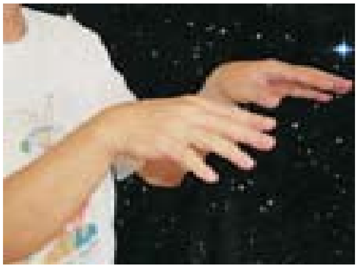

Fig. 8.51 *Close (down)*

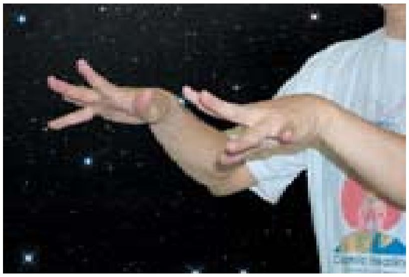

Fig. 8.52
Ring Finger *- down, neutral.*
Index Finger *- open, neutral.*

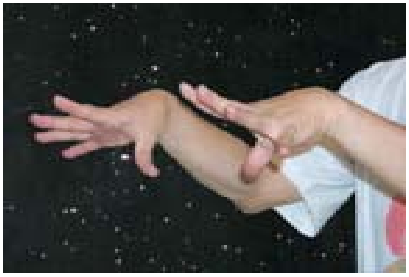

Fig. 8.53
Thumb *- in and down, neutral.*
Index Finger *- open, neutral.*

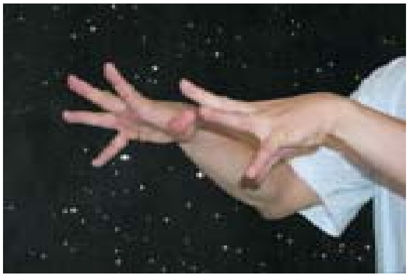

Fig. 8.54
Pinky Finger *- down, neutral.*
Index Finger *- open, neutral.*

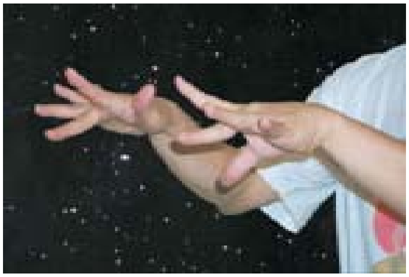

Fig. 8.55
Middle Finger *- down, neutral.*
Index Finger *- open, neutral.*

Crane's Beak

Form the crane's beak with both hands by bringing the fingertips together with the thumbs inside. Activate the saliva and swallow down three times to the Tan Tien. Raise the forearms to shoulder height with the fingers pointed down, inhaling gently as you raise. Open the palms slowly and begin to lower the arms to the sides as you exhale, until the palms are facing each other in the starting position.

Finish

Bring the awareness to the navel and notice the quality and intensity of the energy generated. **Collect energy at the navel**. Men, place the hands over the navel with the right hand on top; vice versa for women.

Part III
Opening the Functional and Governor Channels

Theory: Functional and Governor Channels

The Functional and Governor Channels are the first two of the eight extraordinary channels described earlier in this chapter (beginning p.178). They serve as the reservoirs of yin and yang energy in the body. The Functional or Conception Channel is yin and all of the ordinary yin channels connect to it. Similarly, the Governor Channel is yang and all of the ordinary yang channels connect to it.

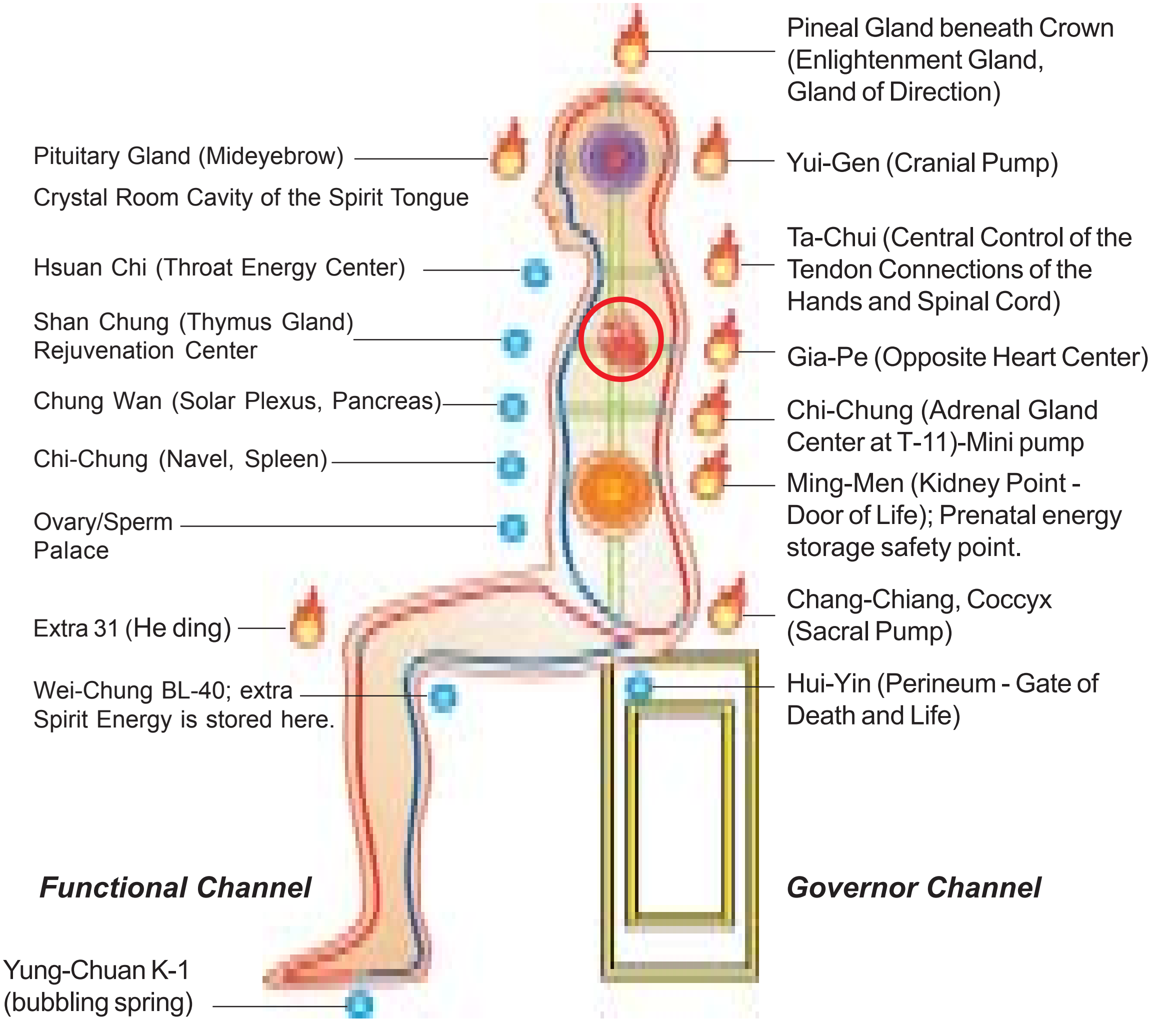

Pineal Gland beneath Crown (Enlightenment Gland, Gland of Direction)
Pituitary Gland (Mideyebrow)
Crystal Room Cavity of the Spirit Tongue
Yui-Gen (Cranial Pump)
Hsuan Chi (Throat Energy Center)
Ta-Chui (Central Control of the Tendon Connections of the Hands and Spinal Cord)
Shan Chung (Thymus Gland) Rejuvenation Center
Gia-Pe (Opposite Heart Center)
Chung Wan (Solar Plexus, Pancreas)
Chi-Chung (Adrenal Gland Center at T-11)-Mini pump
Chi-Chung (Navel, Spleen)
Ming-Men (Kidney Point - Door of Life); Prenatal energy storage safety point.
Ovary/Sperm Palace
Chang-Chiang, Coccyx (Sacral Pump)
Extra 31 (He ding)
Hui-Yin (Perineum - Gate of Death and Life)
Wei-Chung BL-40; extra Spirit Energy is stored here.
Functional Channel
Governor Channel
Yung-Chuan K-1 (bubbling spring)

Fig. 8.56 *Cosmic Orbit*

Chi Ball

In Part III we also begin to focus more on the sensation of Chi being emitted from our palms. This energy is emitted from the **Laogong** points primarily, but you can also feel it throughout the palms and fingers. It will feel like a balloon between your hands that is expanding and contracting or like two magnetic fields repelling and attracting each other.

Once you have practiced Cosmic Chi Kung for awhile and have become skillful at it, you may find that Grasping the Chi ball is all you need to do to activate your flow of healing energy before doing a session. As you become sensitive to the sensation of your own Chi, it becomes an easy step to feel the Chi of others.

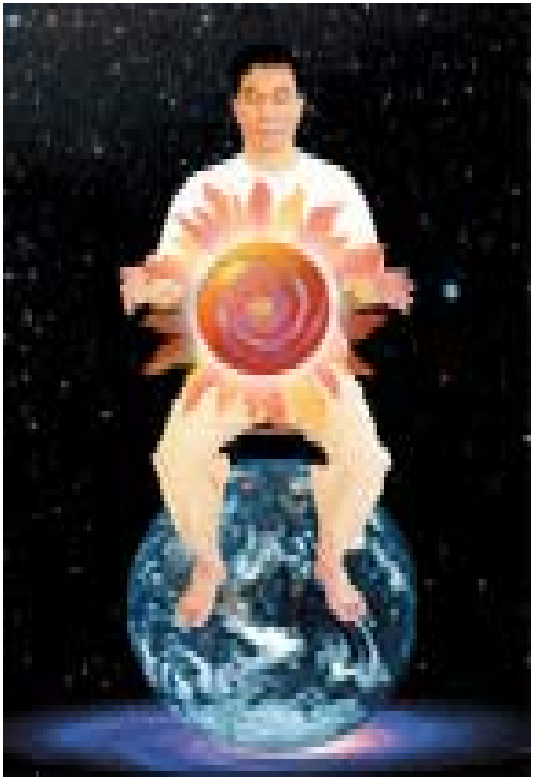

Fig. 8.57 *Grasping the Chi Ball.*

Opening Movements, Hands Down at Sides, Palms Facing Each Other
Bone Breathing - Absorbing Cosmic Chi

The Opening Movements are the same as in the sequence in Part I, 'Opening to Heaven, Earth and Cosmic Chi', on page 164.

A. **Channeling the Earth Force - Washing the Bone Marrow** Raise arms to chest height - Palms facing each other. Rotate arms until **palms face down.** Open the Tiger's Mouth - Index finger up, thumb down.

B. **Activate and Beam to the Eye of the Hip**

C. **Absorb the Heavenly Force Washing the Bone Marrow - Crown to Soles**

Core Movements of Part III

Grasping the Chi Ball

Slowly rotate the hands so that your palms face each other in front of your navel.

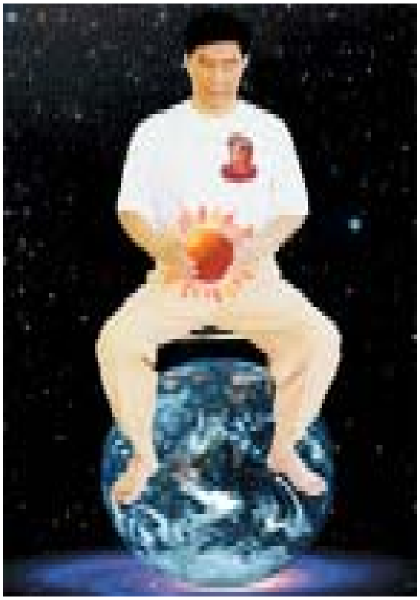

Fig. 8.58 *Hold the Chi Ball.*

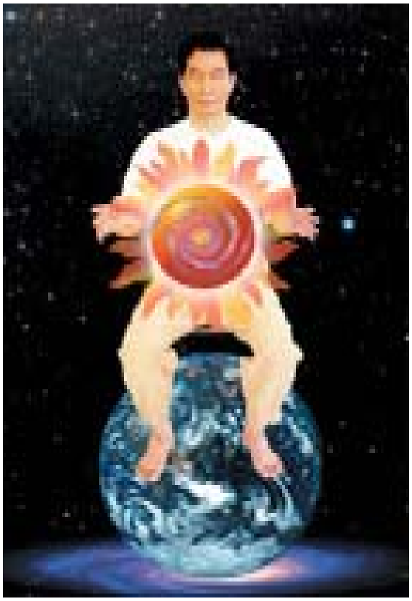

Fig. 8.59 *Stretch and squeeze it.*

Feel the invisible ball of energy between your hands. Allow the energy to push your hands apart keeping the feeling of connection between your palms. When you have less feeling stop the palms and hold it there and reestablish the feeling of the Chi ball.

Let the energy draw your hands back toward each other, like a magnet, until you feel as if you were squeezing and compressing the ball.

Stretch and squeeze the Chi ball three times by opening and closing your palms in this way.

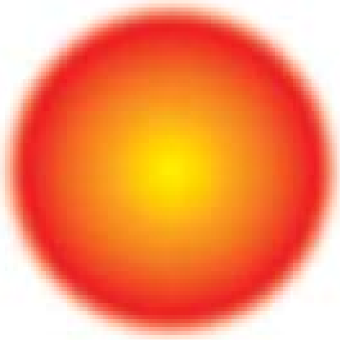

Activate the Outer and Inner Arm Gates

Activate Waiguan Triple Warmer 5 and Neiguan Pericardium 6 - **Right** arm on top. Slowly rotate the arms so that both **palms face down.**

Cross the right wrist over the left wrist with 1 inch of space between the hands. Align PC-6 of the right wrist with TW-5 of the left wrist. Feel the two gates activate each other like metal and magnet drawn to each other. Hold for a 5 to 30 second count.

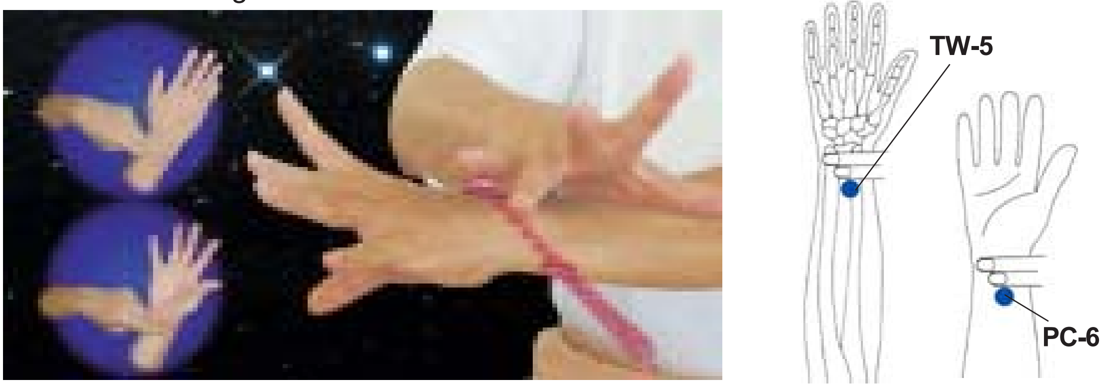

Fig. 8.60 Align and activate PC-6 (Right) with TW-5 (Left).

Keeping the wrists crossed, slowly rotate hands **turning the palms upward**. Now TW-5 of the right wrist will be aligned with PC-6 of the left wrist. Hold and count and feel the points activated. 'Be aware of Tan Tien and Universe'.

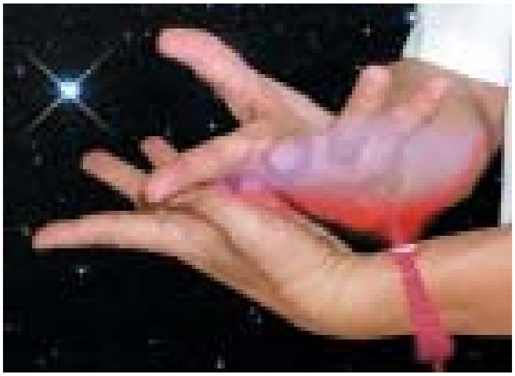

Fig. 8.61
Align and activate TW-5 (Right) with PC-6 (Left).

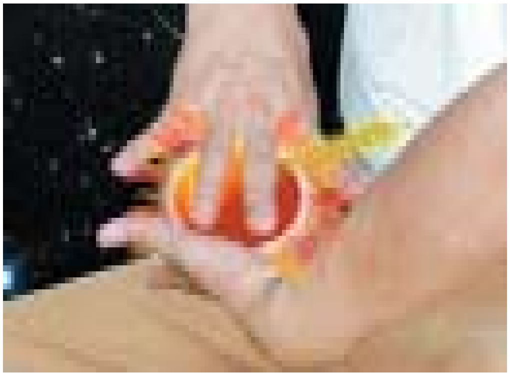

***Fig. 8.62** Feel the Chi Ball and beam energy from LI-4 into the Navel Point.*

Open the Functional Channel with LI-4

Bring the left hand down to the level of the Tan Tien with the Chi Knife facing in. Lower the right hand, palm down and align the eye of the hand, the LI-4 point with your navel. **Feel the Chi ball between your two hands**, and at the same time beam energy from LI-4 into the **navel** point.

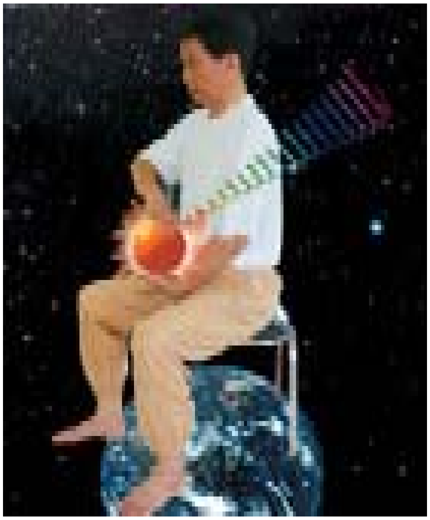

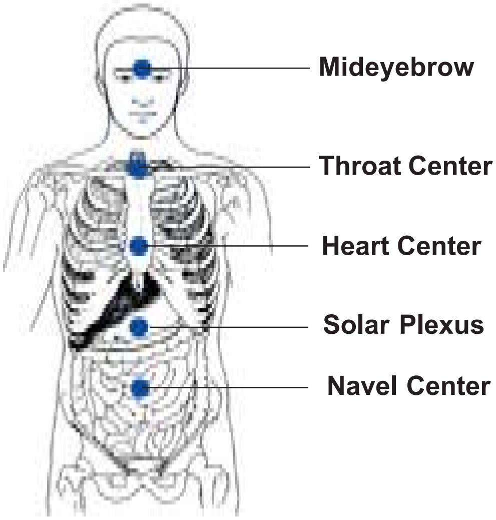
Mideyebrow
Throat Center
Heart Center
Solar Plexus
Navel Center

Fig. 8.63 *Magnify the Power of the Beam to the Solar Plexus.*

Fig. 8.64 *Activate all the Points.*

Raise the right hand up the Functional Channel, stopping and aligning LI-4 with the **solar plexus**, hold for a 5 to 30 second count and feel the points open and starting to activate each other.

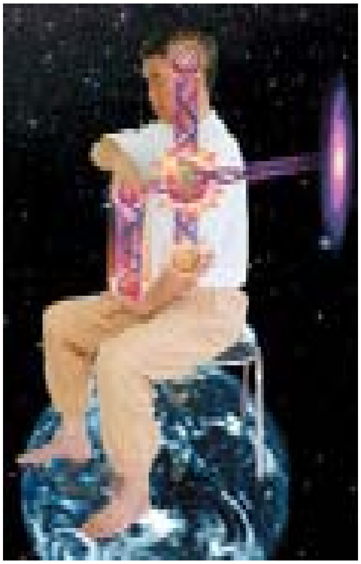

Fig. 8.65
Beam to the Heart Center.

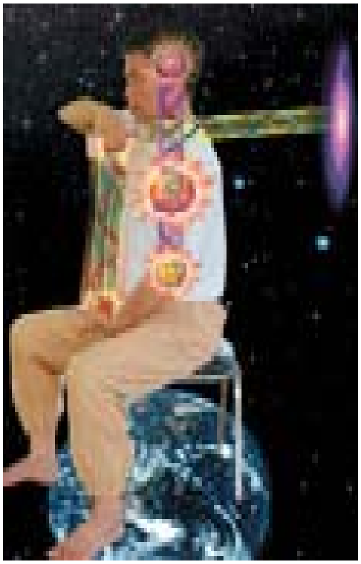

Fig. 8.66
Beam to theThroat

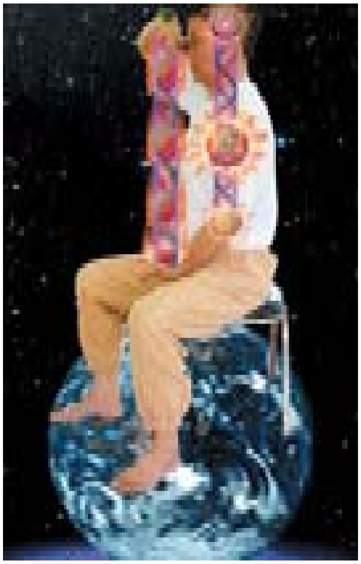

Fig. 8.67
Beam to the Mideyebrow

Continue to move up to the **heart**, **throat** (CV-22) and **mideyebrow** points. Beam energy from the eye of the hand into each of these points and at the same time, continue to feel the Chi ball connection between the two hands.

Return down the Functional Channel in the same manner, starting from the mideyebrow and stopping to beam energy into each point.

Next beam into the **throat center, heart center, solar plexus** and finally the **navel**. Hold the Chi ball at the navel with the right hand over the left.

Yin/Yang Palms

Separate the hands and extend them out in front of the body at solar plexus level. The left palm is still pointing up and is yang drawing in the heavenly force through the Laogong point. The right palm is still facing down and is yin drawing in the earth force energy.

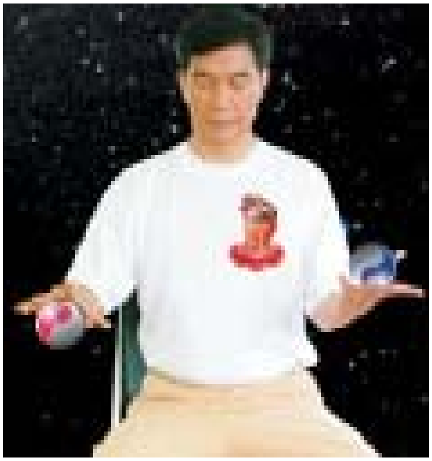

***Fig. 8.68** Separate the Hands, one palm facing up and one down - draw in the Forces of Heaven and Earth.*

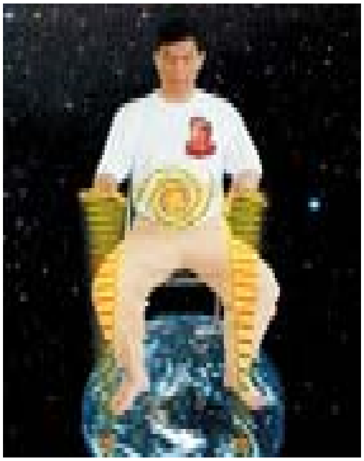

Fig. 8.69
Draw in Earth Force.

Conclude by turning the left palm over to face downward. Draw in the earth force through both palms.

Activate the Chi Ball, Tan Tien and the Original Force

Turn the right palm upward and lower it to the Tan Tien with the Chi knife pointing inwards.

Lower the left palm to the navel, palm down. Lower the left thumb to point toward the right Laogong point. This opens the eye of the left hand (LI-4), pointing it toward the navel.

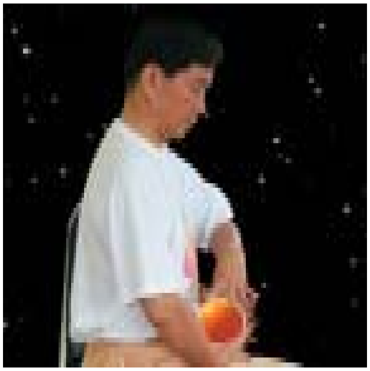

***Fig. 8.70** Activate the Chi Ball, Tan Tien and the Original Force - Right Hand over left, the 'Large Intestine 4' pointing at the Navel.*

Open the Functional Channel with the Left Hand

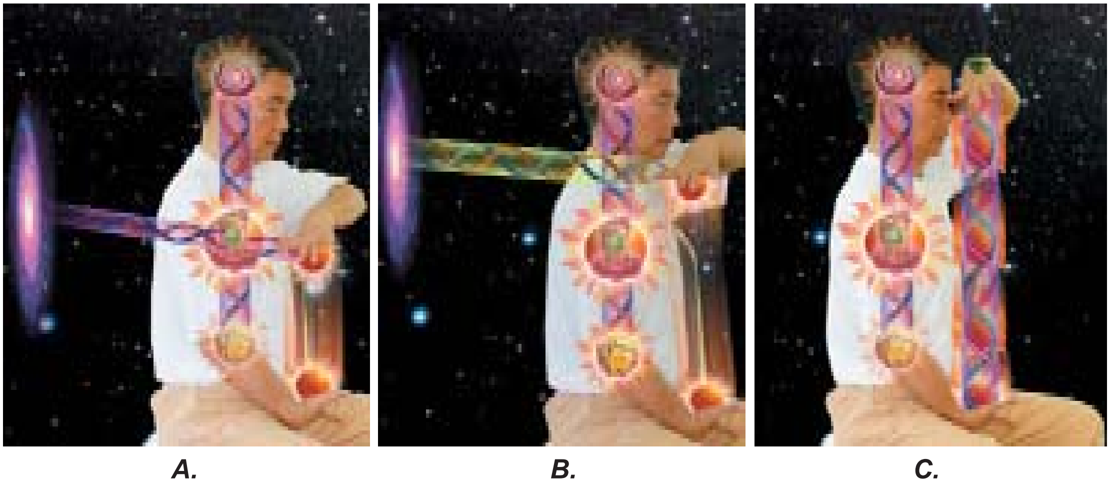

***Fig. 8.71 A.** Bring LI4 point up to the Solar Plexus and Heart Center.*
***B.** Then up to the Throat Center.*
***C.** Then up to the Mideyebrow. Descending down the channel in reverse, finishing at the Navel.*

After going up the functional channel come down the channel with the left hand.

Holding a Chi Ball: Open the hands with the palms facing each other holding a Chi ball. Stretch and squeeze the Chi ball a few times in order to feel the Chi as a substance; open and then relax the palms as you squeeze.

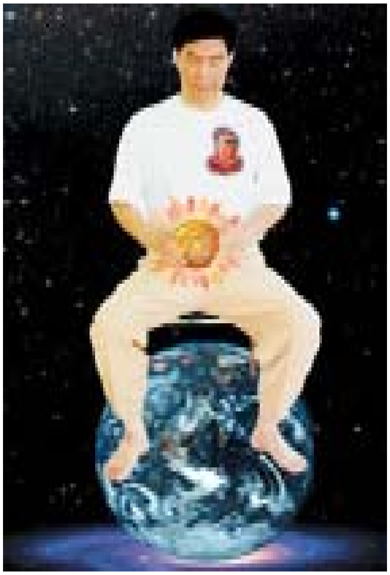

***Fig. 8.72** Hold and squeeze the Chi Ball.*

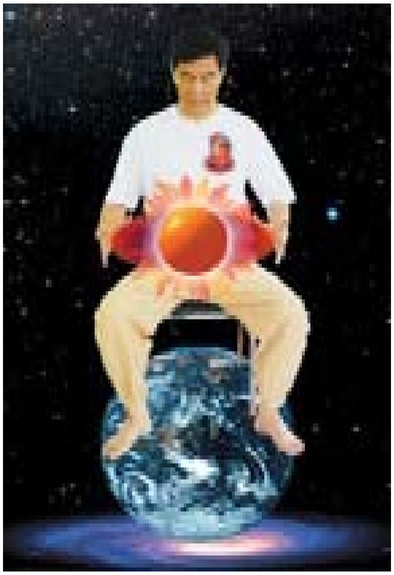

Fig. 8.73
Feel the Chi Ball expanding, growing Bigger.

Double Palm and Double Beam - Palm to Palm
Activate the Functional and Governor Channels - Right Palm on Left

Bring the left palm in first to face the navel, about 1 inch away, aligning the Laogong point with the navel. Follow by bringing the right hand in front of the left hand, **aligning the Laogong of the right palm with the Laogong of the left hand and the navel**. Both palms are now facing in. Beam energy through both Laogong points to the **navel and through the body to the Door of Life**, between L-2 and L-3 (Lumbar Vertebrae). Hold for a 5 to 30 second count and feel the vibration of the palms and Chi beam penetrate through the two points; feel them link together.

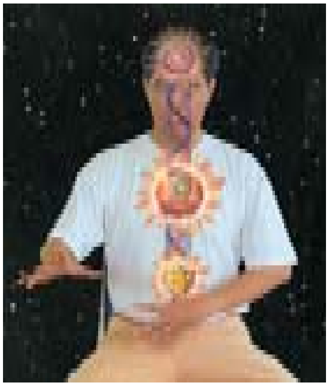

Fig. 8.74
Left Palm to Navel.

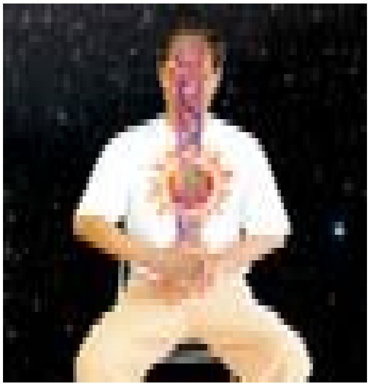

Fig. 8.75
Right on Top.

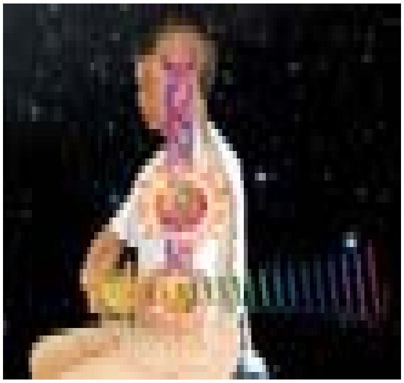

Fig. 8.76
Beam from Navel to Door of Life.

Next raise the left palm up to the solar plexus, aligning the Laogong point with the solar plexus.

Follow with the right palm aligning the Laogong to the left palm. Beam energy into the **solar plexus point and through the body to the T-11 point (thoracic vertebrae)**.

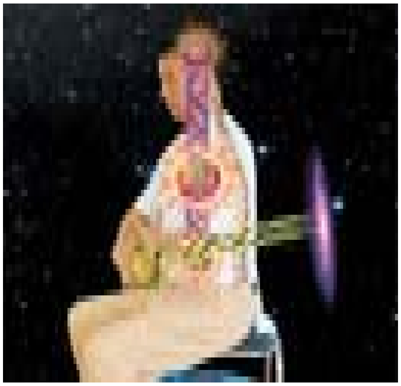

Fig. 8.77
Raise Left Palm to Solar Plexus.

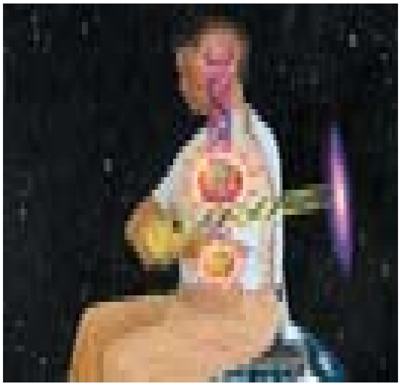

Fig. 8.78 *Follow with the Right Hand to form the Double Beam.*

Continue in the same way with the left hand leading to the **heart point and wing point,** the **throat point and C-7 (cervical vertebrae)**, the **mideyebrow point and Jade Pillow**, and the **crown point and perineum**. **Always remember 'Tan Tien and the universe'.**

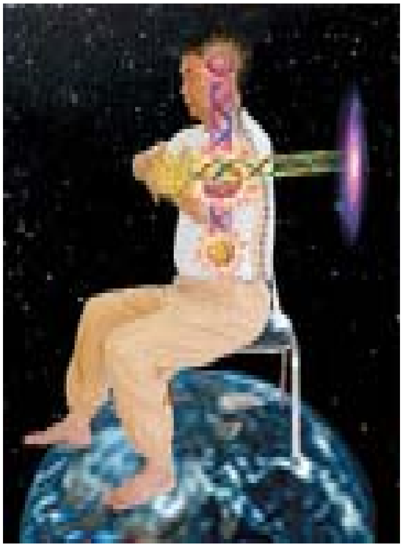

Fig. 8.79 *Beam into the Heart Center and to the back of the Heart.*

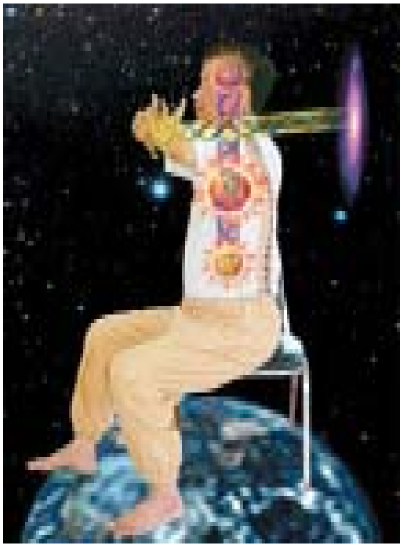

Fig. 8.80 *Beam into the Throat Center and to C7.*

When you reach the crown lightly spiral the palms and feel the Chi slowly penetrate deep into the body reaching the perineum; this will also open the **Thrusting Channels.** This might take a longer time, try a 30 to 60 second count.

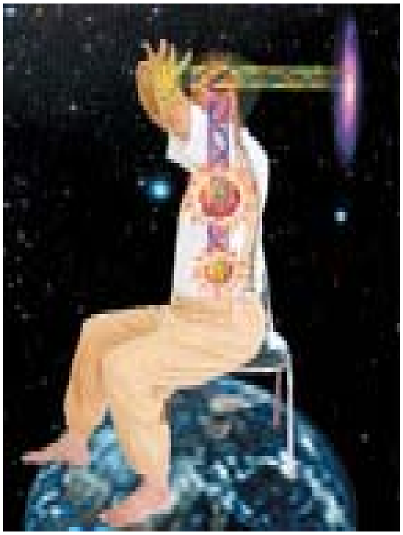

Fig. 8.81 *Beam into the Mideyebrow to the base of the Stall.*

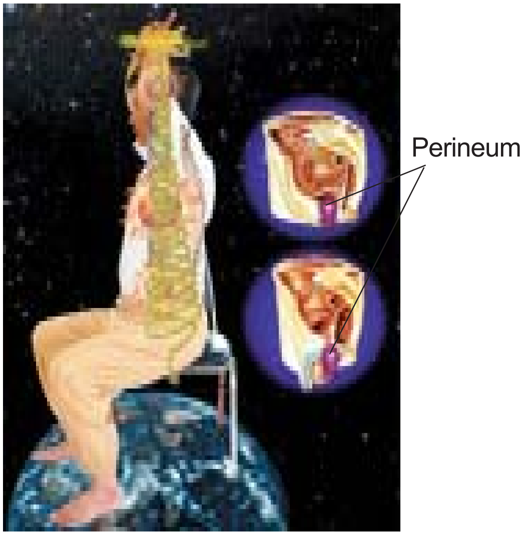

Fig. 8.82 *Beam from the Crown down to the Perineum.*

Return down the front, point by point in the same way, leading with the left hand.

Go up and down this way three times. The double palm and beam activate both the Functional and Governor Channels. The energy beam passes all the way through the body at each point.

Grasping the Chi Ball

Separate the hands and slowly extend the arms in front of you at navel level, palms facing each other, holding the Chi ball.

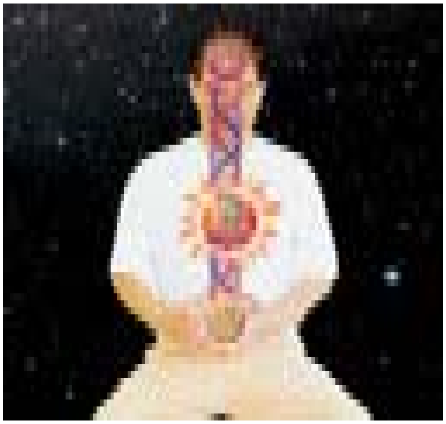

***Fig. 8.83** Squeeze the Chi Ball.*

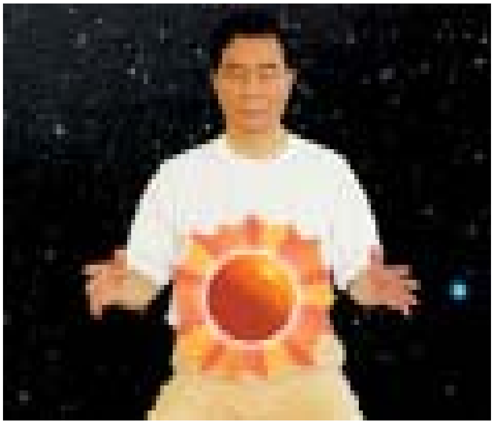

***Fig. 8.84** Magnify its Energy.*

Stretch and squeeze the Chi ball three times as before by opening and closing the palms. 'Be Aware of Tan Tien and Universe'.

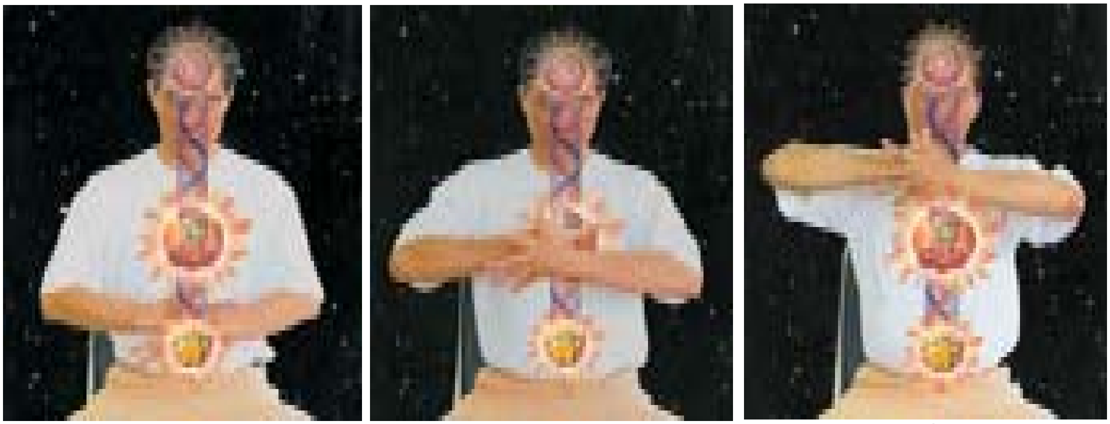

A. ***B.*** ***C.***

***Fig. 8.85** Repeat the double palm and beam with the **left hand on the outside and the right palm leading,** beaming from; **A.** Navel to Door of Life. **B.** Solar Plexus to T11 and Heart Center to the Wing Point **C.**Throat Center to C7.*

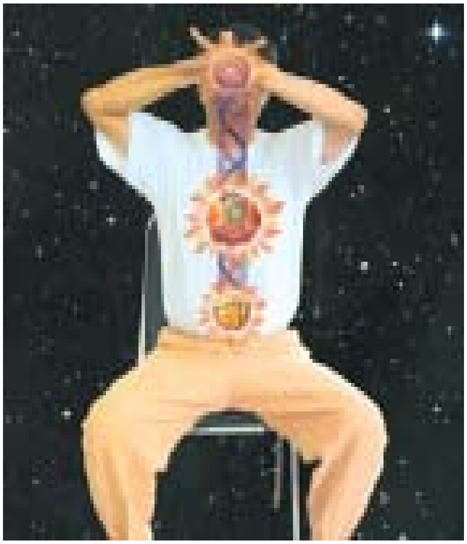

Fig. 8.86 *Activate the Mideyebrow to the Base of the Skull.*

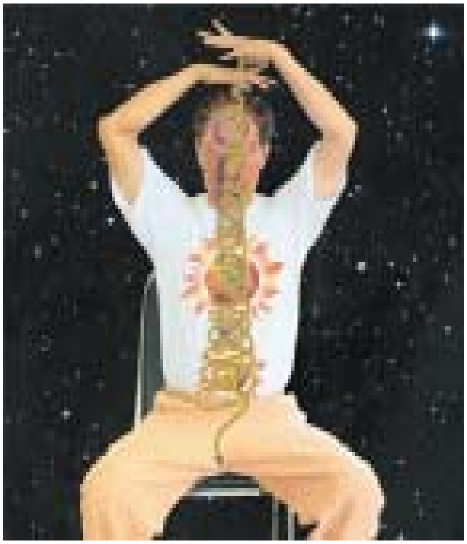

Fig. 8.87 *Activate the Crown and feel the Energy penetrate to the Perineum.*

A. Lower the right hand to the mideyebrow and penetrate to the skull.
B. Lower the right hand down to the throat center, following with the left.
C. Lower down to the solar plexus and penetrate to T11.
D. Lower down to the navel and penetrate to the Door of Life.

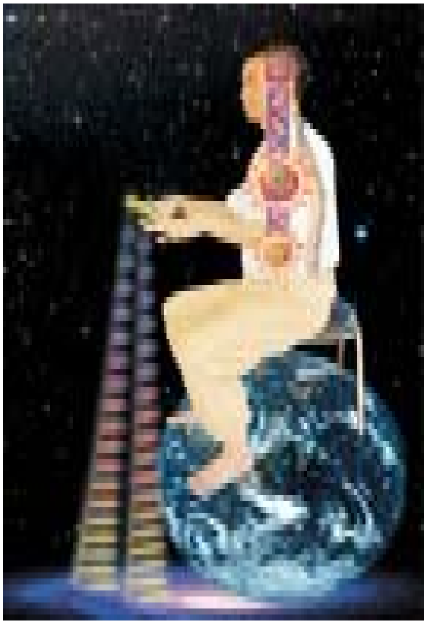

Fig. 8.88 *Channel the Earth Force.*

Rotate the **hands to face downward** and draw in the earth force through the palms, soles and perineum.

Closing Movements

Activate the Chi Channels - Balancing the Organs

The closing movements, crane's beak and finish are the same as before.
Index Finger *open (up), close (down), neutral (even with the other fingers)*
Ring Finger *- down, neutral.*
Index Finger *- open, neutral.*
Thumb *- in and down, neutral.*
Index Finger *- open, neutral.*
Pinky Finger *- down, neutral.*
Index Finger *- open, neutral.*
Middle Finger *- down, neutral.*
Index Finger *- open, neutral.*

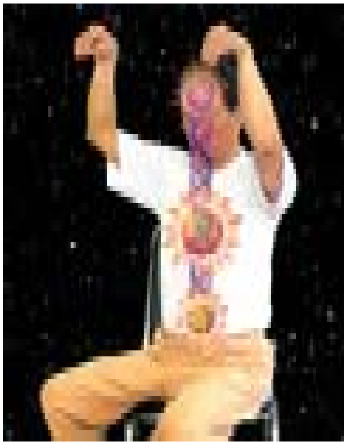

Fig. 8.89 *Form the Crane's Beak.*

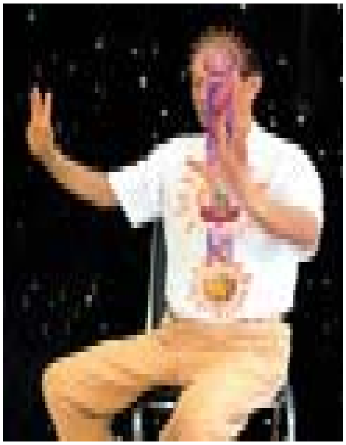

Fig. 8.90 *Palms to Front.*

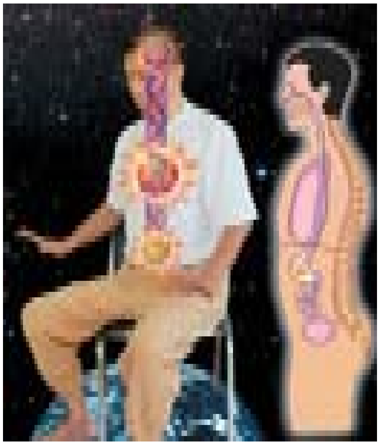

Fig. 8.91 *Lower to Sides.*

Crane's Beak

Form the crane's beak with both hands by bringing the fingertips together with the thumbs inside. Activate the saliva and swallow this elixir down three times to the Tan Tien. Raise the forearms to shoulder height with the fingers pointed down, inhaling gently as you raise.

Open the palms slowly and begin to lower the arms to the sides as you exhale, until the palms are facing each other in the starting position.

Finish

Bring awareness to the navel and notice the quality and intensity of the energy generated. Collect energy at the navel. Men, place the hands over the navel with the right hand on top; vice versa for women.

Part IV

Activating the Yin and Yang Channels and the Chi Belt

Theory

In this final part of Cosmic Chi Kung, you will focus on opening the yin and yang channels of the arms and on activating the Chi Belt around the waist. Mastery of Part IV of Cosmic Chi Kung will enhance your ability to project Chi through your fingers for healing.

Yin and Yang Channels of the Arms

There are six important energy channels flowing through the arms. These channels are paired together with each pair comprised of a yin channel and a yang channel. The yin channel of each pair flows down the inside of the arm from torso to fingertip, while its yang counterpart flows up the outside of the arm from fingertip to head.
The pairs are as follows:

Metal Element - Yin - Lung Channel - Thumb
Yang - Large Intestine Channel - Index Finger
Fire Element - Yin - Pericardium Channel - Middle Finger
Yang - Triple Warmer Channel - Ring Finger
Fire Element - Yin - Heart Channel - Pinky Finger
Yang - Small Intestine - Pinky Finger

Projecting Healing Energy through the Fingers

Emitting Chi from the fingers for healing is known in China as the **"One Finger Art."** Because the various energy channels of the arms either end or begin at the fingertips, the fingers are very effective instruments for projecting healing energy. Your fingers can focus energy like a laser beam toward a concentrated area such as a specific acupuncture point. You can also emit energy from all the fingers at once creating a combined effect to target an area. Part IV of Cosmic Chi Kung will stimulate all of the arm channels and will give you an opportunity to activate all of the fingers for beaming energy.

Fig. 8.92 *"One Finger Art"*

Activating the Chi Belt - Dai Mo

The Chi Belt or Belt Channel (also called the Girdle Vessel) is the only channel in the body that runs horizontally. It encircles the body at the waist level, connecting together all the vertical channels running through the torso. Thus, the Belt Channel plays an important role in maintaining a good energetic communication between the upper and lower body. In women it strongly affects the uterus and the menstrual cycle in particular.

In Taoist Chi Kung, the Belt Channel is not limited to the waist region. It encircles the entire body, almost like weaving an energetic cocoon around you from head to foot. Activating the Belt Channel strengthens the aura and helps to defend and protect you from outside negative energies.

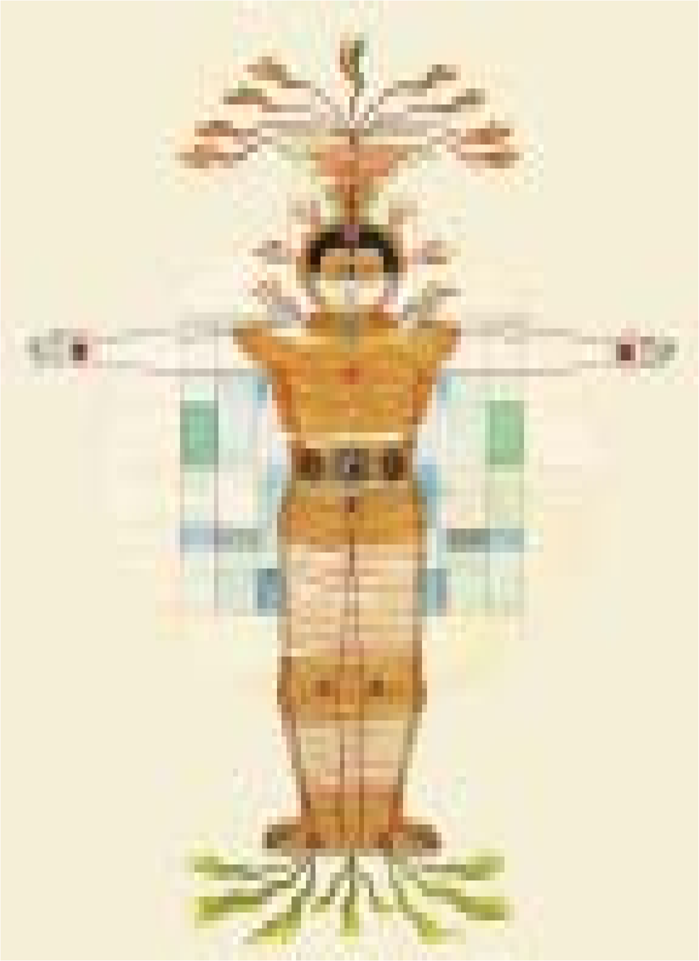

Fig. 8.93 *Belt Channel*

Practice

Opening Movements

These opening movements have been described in Parts I, II, III. Refer to Part I to refresh your practice.

Hands Down at Sides - Palms Facing Each Other - Bone Breathing - Absorbing Cosmic Chi.

Channeling the Earth Force - Washing the Bone Marrow.
Raise arms to chest height - Palms facing each other.
Rotate arms until palms face down.
Open the Tiger's Mouth - Index Finger up, thumb down.

Activate and Beam to the Eye of the Hip.
Large Intestine 4 - Eye of the Hand.
Pericardium 9 - Tip of the Middle Finger.
Small Intestine 3 - Knife Edge of the Hand.

Absorb the Heavenly Force - Washing the Bone Marrow - Crown to Soles.
Extend the arms forward to chest height - palms upward.

Absorb the Earth Force.
Rotate the arms until the palms face down.
Raise the Index Fingers slightly.

Fig. 8.94 *Mother Earth's Healing Power*

Core Movements of Part IV Yin and Yang Channels - Chi Belt

Activating the Yin Channels - Left Side

Turn the palms down and slightly open the index fingers. Smile to your palms and soles and channel the earth force.

Turn your right palm up and pass it just one inch below the left arm yin channels from the left palm to the armpit, **without physically touching the arm**. Feel the Chi moving. Turn your right palm to face your left rib cage and pass your right hand down the left side of your abdomen along the descending colon, and a cross the pelvis to the right side to activate the **yin** energy.

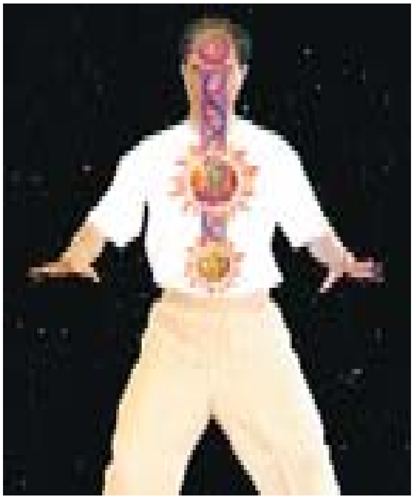

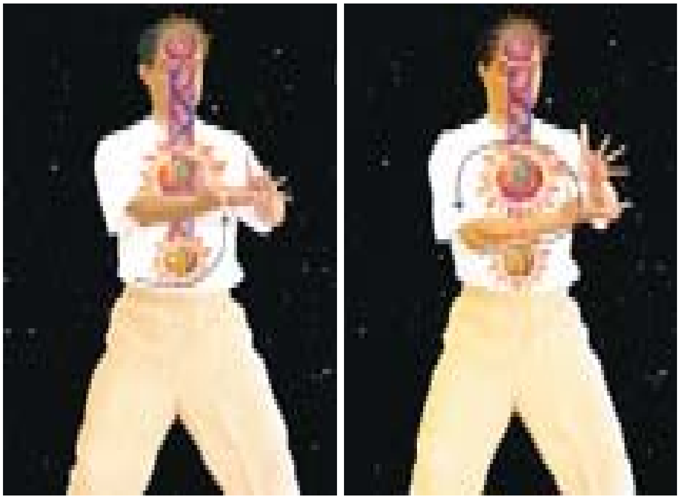

Fig. 8.95 *Channel the Earth Force.* ***Fig. 8.96*** *Activate the Yin Energy from the Palm to the Pelvis.*

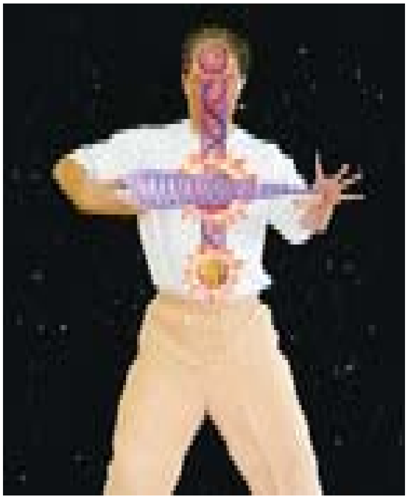

Fig. 8.97 *Raise Chi in the Right Palm.*

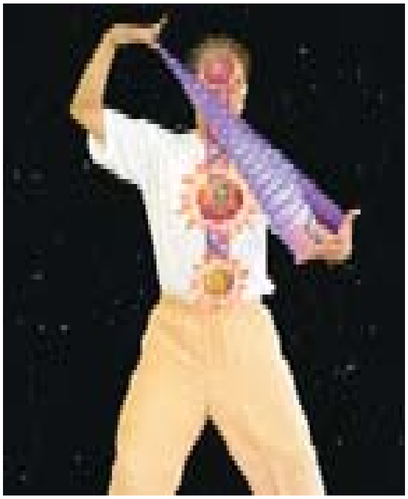

Fig. 8.98 *Pass it to the Left.*

Pass your right hand up the right side of the abdomen to the level of your forehead with the palm facing diagonally toward the left palm (which simultaneously turns palm up at the level of the navel). Project the Chi from palm to palm for 30 to 60 seconds, vibrating the palm and feeling Chi from the right palm sent to the left picking up by the left palm. Keep the palms open and relaxed.

Next point the right ring finger toward the left palm and project Chi making very small circles from the right ring finger (Triple Warmer channel); emit the Chi to the left palm for 30 to 60 seconds.

Then return the right index finger to neutral position. Point the left ring finger up toward the right palm, project into the right palm for 30 to 60 seconds, and then return to neutral.

Next both ring fingers project toward the opposite palms at the same time for 30 to 60 seconds and then return to neutral. Notice that the energy may meet in the middle.

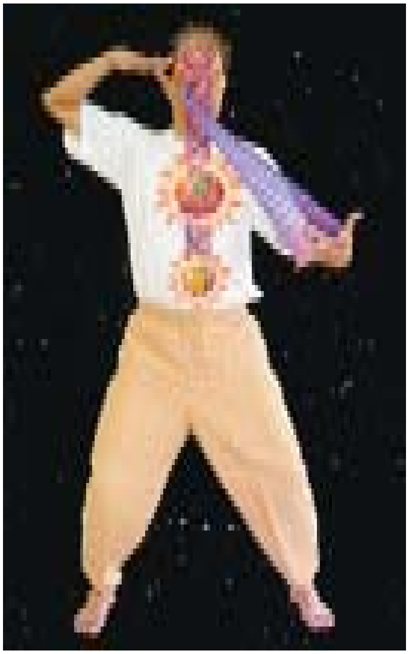

Fig. 8.99 *Project Energy and balance Left and Right.*

Activate the Yang Channels - Left Side

Turn the left palm down and lower the right palm to cover the back of the left hand, palm down. Pass the right palm over the left arm's **yang** channels from the back of the left hand to the left shoulder. Then pass the right palm across the upper chest and across the right breast. Scoop the right palm under the right armpit, fingers first. Then bring the right palm forward, palm down and press forward with the left palm at the same time. Relax and channel the earth force.

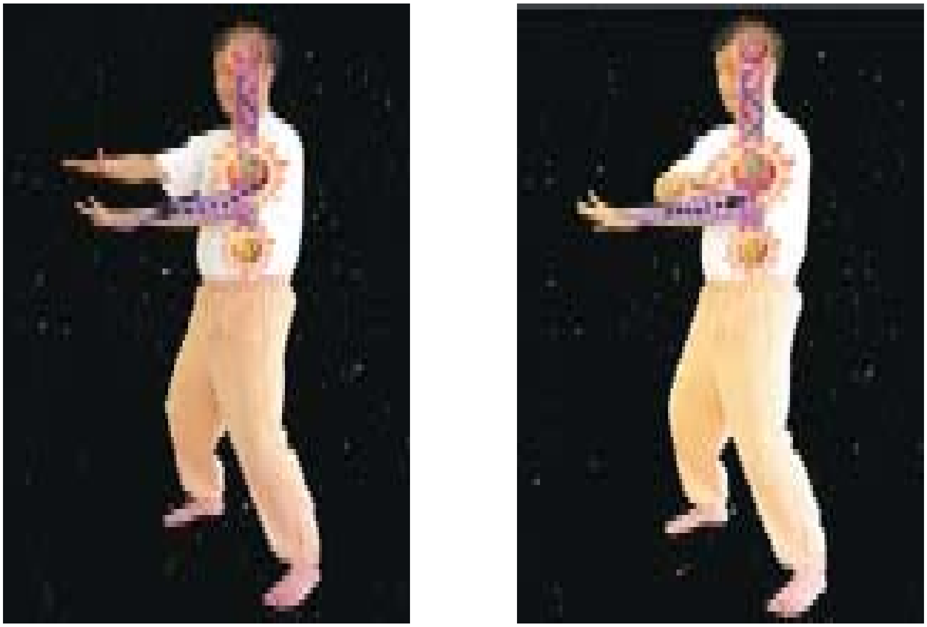

A. Left Palm down, lower Right Palm to cover the back of Left Hand.

B. Pass the Right Palm over the Left Arm’s Yang Channels.

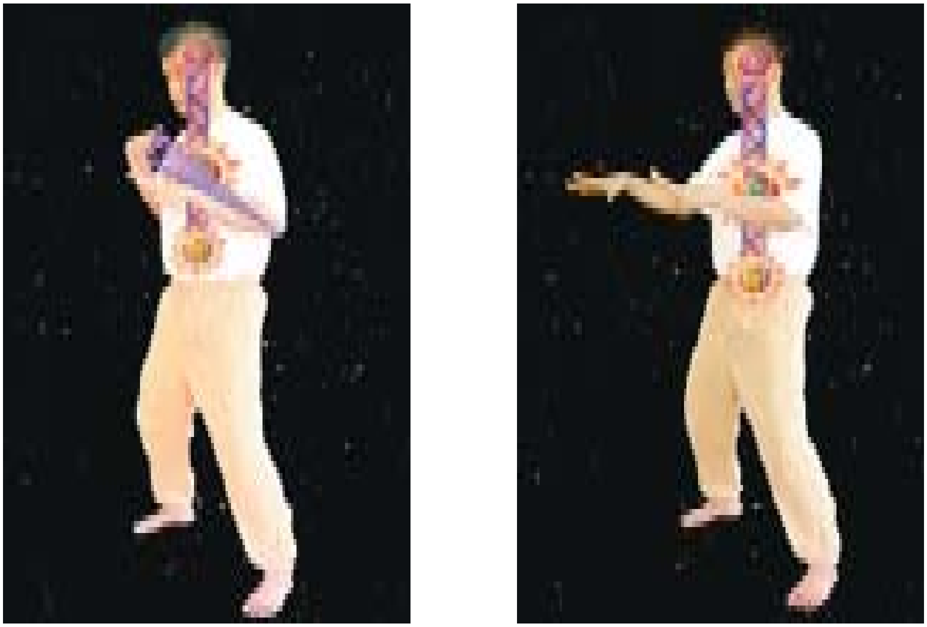

C. Pass the Right palm across the chest and scoop under the Right Armpit, Fingers first.

D. Press both Palms forward, relax and channel the Earth Force.

Fig. 8.100 Balance Left Side Yin and Yang and Channel Earth Energy.

Repeat, Activating the Yin and Yang Channels to the Right Side

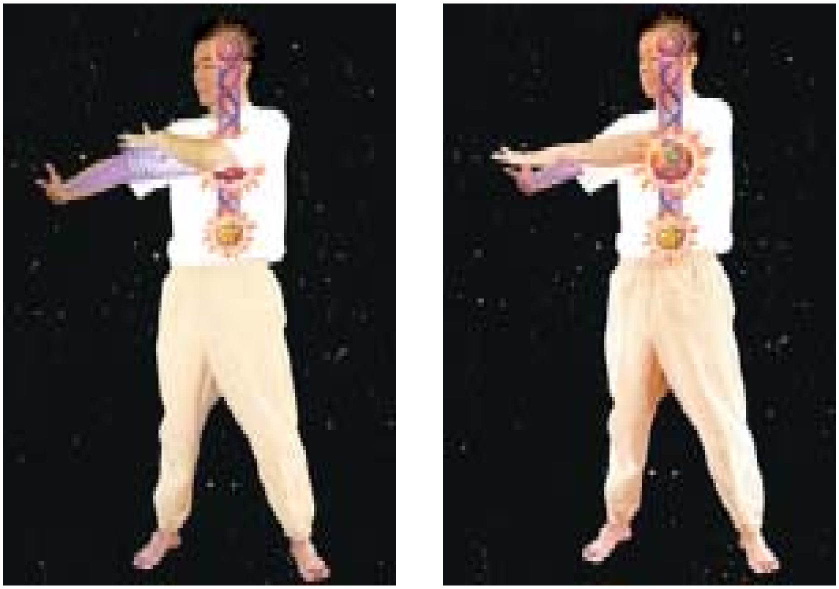

Fig. 8.101 *Balance right side yin and yang and channel earth energy*

Then repeat **Activating the Yin and Yang Channels** with the other fingers and channels in the following order:

Index Finger - Large Intestine
Thumb - Lung
Pinky Finger - Heart and Small Intestine
Middle Finger - Pericardium

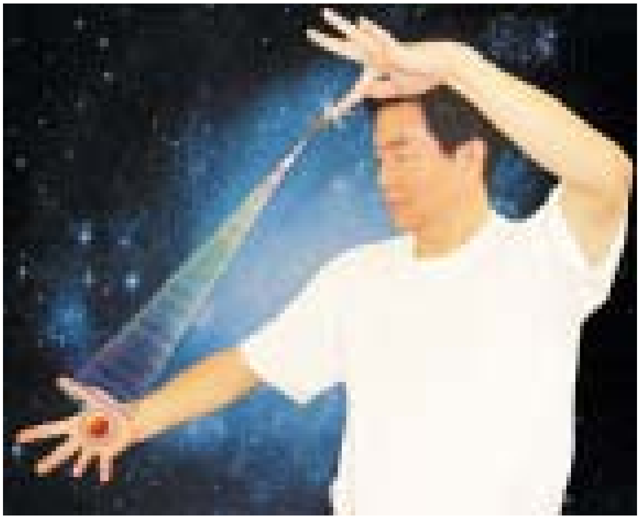

Fig. 8.102 *One Finger Art - activating the Laogong.*

Activate the Chi Belt - Right Foot Forward

Step forward with the right foot. The right palm covers the navel and the left palm covers the Door of Life. Feel the Chi beam penetrate from palm to palm.

Turn your hips to the right and shift weight to your right leg. At the same time move your right palm to the Door of Life in a brushing manner, while your left palm moves to the right hip in a sweeping manner. Note that the palms face the Chi belt.

Repeat the above three times altogether.

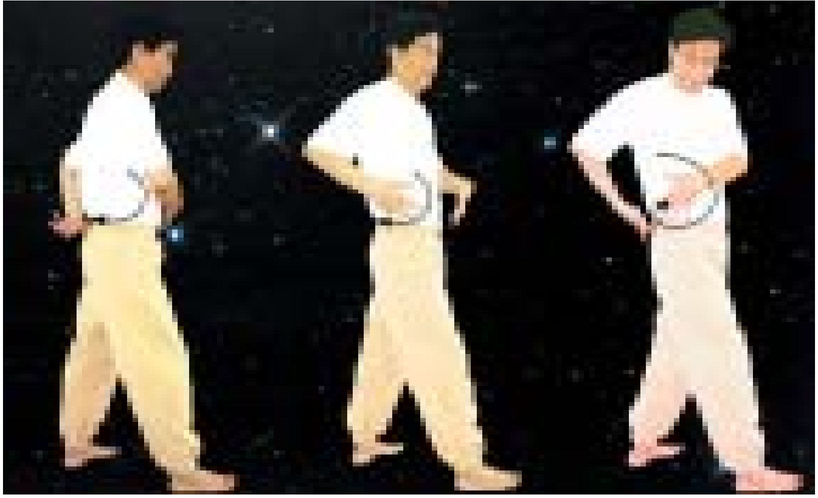

Fig. 8.103 *Activate the Chi Belt - Right Side.*

Activate the Chi Belt - Left Foot Forward

Repeat the above with the left foot forward and reversing the right and left hands.

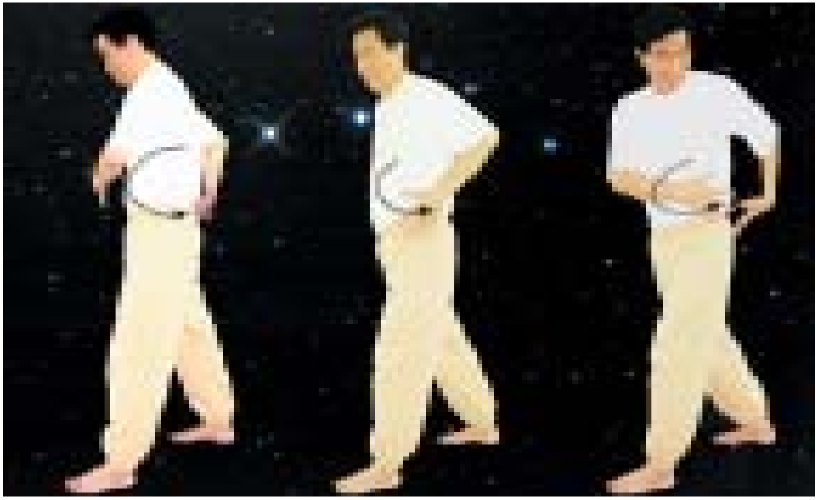

Fig. 8.104 *Activate the Chi Belt - Left Side.*

Channel the Earth Force

Bring the hands forward and rotate the palms to face downwards. **Smile** and channel the earth force as before.

For these Closing Movements see the pictures beginning on page 171.

Closing Movements
Activate the Chi Channels - Balancing the Organs

Index Finger - open (up), close (down), neutral (even with the other fingers).
Ring Finger - down, neutral.
Index Finger - open, neutral.
Thumb - in and down, neutral.
Index Finger - open, neutral.
Pinky Finger - down, neutral.
Index Finger - open, neutral.
Middle Finger - down, neutral.
Index Finger - open, neutral.

Crane's Beak

Form the crane's beak with both hands by bringing the fingertips together with the thumbs inside. Swallow the saliva. Raise the forearms to shoulder height with the fingers pointed down, inhaling gently as you raise.

Open the palms slowly and begin to lower the arms to the sides as you exhale, until the palms have returned to the starting position.

Finish

Bring the awareness to the navel and notice the quality and intensity of the energy generated.

Collect energy at the navel. Men, place the hands over the navel with the right hand on top; vice versa for women.

Healing Others

Summary and Combined Practice

After learning the four sets of Cosmic Chi Kung, you may want to combine them all into a short and simple daily practice. This combined set, previously called Buddha Palm I, synthesizes the movements from the first three sets into one basic sequence. The movements are done on the right side only, so the entire set can be completed in **ten to twenty minutes**.

Cosmic Chi Kung: Simple Combined Sequence

Opening Movements

Bone Breathing - Absorbing Cosmic Chi

1. Stand with your hands down by your sides. Feel your Chi moving and activate the **bone breathing**.
2. Activate the cosmic force by using your mental intention (Yi) to spiral at the **mideyebrow** point and draw in the golden light energy. Breathe through the mideyebrow point in the same manner as in bone breathing, allowing the energy to **flow through the Microcosmic Orbit**. Alternatively you can breathe the golden light down into your navel to charge up your Original Chi at the Tan Tien. You can also simply circulate the golden light throughout your body. Relax, smile and enjoy the sensation of your entire body breathing in the cosmic energy.

Channeling the Earth Force - Washing the Bone Marrow

1. Connect with the earth force by activating the **perineum** and the **soles of the feet, Kidney 1, Bubbling Spring**. Connect the bridge by slightly squeezing the sex organs and the anus. Wash the bone marrow from the soles to the crown.
2. **Smile** into the perineum, palms, mideyebrow and crown. Then slowly raise the arms, palms facing each other to chest height keeping the elbows relaxed and sunk. Then slowly rotate the arms until the **palms are facing down**. Absorb the Earth Chi through the soles, perineum and palms; feel it being absorbed into the bones and body like a **steam or mist rising from the earth**. Feel the earth force move through the **center of the bones**, up the calves, thighs (femur bones), through the hip bones, spine, scapulas, arms, neck and skull. Finally swirl the energy around your brain.

Activate the Hip - Large Intestine 4, Pericardium 9 and Small Intestine 3

1. Raise your index finger slightly upward to activate the Laogong point (Pericardium 8). Then stretch your thumbs out to the sides and down, so that they end up pointing downwards toward the earth to activate Large Intestine 4 (Hegu). **Large Intestine 4 is found in the webbing between the thumb and index finger. It is called the "eye of the hand"; this area is also known as the "Tiger's Mouth."**
2. Slowly draw the elbows back and lower the hands until your palms are facing down beside the "eye of the hip" (the iliac crest) with the "eye of the hand" (Large Intestine 4) aligned with the "eye of the hip". **Use your mind intention to beam the energy back and forth between your two LI-4 points. This will activate the large and small intestines.**
3. Rotate your hands so that the fingers first point out, then back and finally point the fingers in toward the eye of the hip. **Beam energy back and forth between the tips of the middle fingers** (Pericardium 9) passing through the hips.
   Rotate the hands again until the fingers are pointing forward with the palms facing up. Align the knife edge (Small Intestine 3) with the eyes of the hip, and **beam the energy back and forth between the two hands.**

Absorb the Heavenly Force - Washing the Bone Marrow - Crown to Soles

Extend the arms forward to chest height with the **palms still facing upward**.

Become aware of the palms and the crown. Activate the Laogong point (Pericardium 8). Feel the heavenly energy, and be aware of the violet light of the North Star and the red light of the Big Dipper shining down. Draw this light in through the palms and the crown point and feel it washing your bone marrow. Direct the sensations down through the skull, cervical vertebrae, clavicle, scapulas and sternum. Activate your thymus gland and continue drawing the healing heavenly light down through the rib cage, arms, spine, hips, femurs, calf bones, feet and toe bones. **Feel your bones activated with a positive electrical force (the positive force comes from heaven, negative from the earth).**

Absorb the Earth Force

1. Rotate the arms until the **palms face down**.
   Raise the index fingers slightly, extend the thumbs first towards each other, and then towards the ground.
2. Become aware of the palms (Laogong), the soles of the feet (Kidney 1, Bubbling Spring) and the perineum (Conception Vessel 1, Hui Yin). Activate these points, feel the earth energy, and **be aware of a gentle blue light or white light rising up from the earth like a pure steamy mist.** Draw this light in through the palms and soles and let it wash up through the center of your bones as it steam cleans your

marrow. Picture any impurities or illness dripping out of your bones and draining down into the earth, where they are recycled and purified.

Core Movements

Grasping the Moon - Connecting the Heaven and Earth Forces

1. **Open Position:** Heaven Force - Bring the arms up to shoulder height, bending the elbows so that the **left hand is under the right elbow** with the left index finger pointing up to Heart 3.
2. The right forearm is over the left forearm with the tip of the right index finger held above the Large Intestine 11 point of the left arm. The right index finger is pointing up toward heaven.
3. The right index finger draws in the heavenly force like an antenna. The force flows up the bones of the right arm across the shoulders to the left arm, and through the bones of the left arm to the left index fingertip. It then flows through the index finger of the left hand into the Heart 3 point of the right arm **completing the heavenly circuit**. Continue cycling in this way.
4. **Close Position:** Earth Force - Keeping the arms in the same position, move both index fingers to point down. The right index finger will now point toward the Large Intestine 11, point of the left arm and the left index finger will point downward toward the earth. Draw in the earth force through the left index finger bringing it through the bones of the left arm, across the shoulders through the right arm to the right index finger and out into the Large Intestine 11 point of the left arm. Continue cycling in this way **completing the earth circuit.**

Open and close three times altogether ending in the open position.

Activate the Throat Center

1. Draw the elbows out to the side and rotate the palms to face in so that the left palm is about 3 - 6 inches in front of the Throat Center (Conception Vessel 22), palm facing in, and the right hand is about 1 - 3 inches in front of the left hand, palm facing in. Align the Lung 10 point of the right hand with the Lung 10 of the left hand, and align the Lung 10 points in the middle of the thenar eminence of the left hand with the Throat Center. **Keep the points aligned and beam the energy passing through both hands into the Throat Center.**
2. Move both hands about 12-18 inches out from the Throat Center maintaining the energy beam as you move.
3. Move in and out three times altogether in this way ending with the hands in as in preivous point above.

Activate the Third Eye

1. Keeping the Lung 10 points aligned, raise the hands up to the level of the mideyebrow point. Keep the points aligned and **beam the energy passing through both hands into the mideyebrow point.**
2. Move both hands about 12-18 inches out from the mideyebrow point maintaining the energy beam as you move. **Move in and out three times** altogether in this way, ending with the hands as previously.
3. Keeping the palms and thenars (Lung 10) aligned, move the hands back down to the position in front of the **Throat Center.**

Open the Bridge and Regulator Channels

1. Keeping the forearms horizontal at shoulder height, separate the hands so that the Laogong points are aligned in front of Stomach 13 just below the clavicle on a vertical line above the nipple or **mammillary** line. The fingertips should almost be touching. Beam energy from the Laogong points into ST-13. You will be following this vertical line, which passes through the nipples, down the torso to the level of the navel stopping to focus and **beam energy into key points along the way**. On each of these, focus your Yi on beaming energy into the organs inside each position. Stomach 13 is the location that activates the Heart and Lungs. Feel the change in your breathing as you activate the **lungs**.
2. Move the hands down the mammillary line to Stomach 16, about one inch above the nipple (in the space between the third and fourth ribs). Again, beam energy to energize and balance the **heart and lungs**.
3. Move the hands down to Liver 14 (about 2 - 3 inches below the nipple in the space between the 6th and 7th ribs). Beam healing energy into the **liver and gall bladder**.
4. Move the hands down to Spleen 16 (just below the rib cage on the mammillary line). Beam healing energy into the **stomach, pancreas and spleen**.
5. Move the hands down to Spleen 15 (on the mammillary line to the level of the navel). Beam healing energy from your palms into the **small intestine and the Tan Tien**.

Grasping the Chi Ball

1. Slowly rotate the hands so that your palms face each other in front of your navel. Feel the invisible ball of energy between your hands. Allow the energy to push your hands apart keeping the feeling of connection between your palms.
2. Let the energy draw your hands back toward each other, like a magnet, until you feel as if you are squeezing a ball.
3. Stretch and squeeze the Chi ball three times by opening and closing your palms in this way.

Activate the Outer and Inner Arm Gates
Waiguan - Triple Warmer 5 and Neiguan - Pericardium 6 - Right Arm on Top

1. Slowly rotate the arms so that both palms face down.
2. Cross the right wrist over the left wrist with 1-3 inches of space between the hands. Align PC-6 of the right wrist with TW-5 of the left wrist.
3. Keeping the wrists crossed, slowly rotate hands turning the palms upward. Now TW-5 of the right wrist will be aligned with PC-6 of the left wrist.

Open the Functional Channel with LI-4

1. Bring the left hand down to the level of the Tan Tien with the Chi Knife facing in. Lower the right hand, palm down, and align the eye of the hand, the LI-4 point with your navel. Feel the Chi ball between your two hands, and at the same time beam energy from LI-4 into the navel point.
2. Raise the right hand up the Functional Channel stopping and aligning LI-4 with the **solar plexus, heart, throat** (CV-22) and **mideyebrow** points. **Beam energy from the eye of the hand into each of these points**, and at the same time continue to feel the Chi ball connection between the two hands.
3. Return down the Functional Channel in the same manner stopping to beam energy into each point. **Go up and down the Functional Channel** in this way three times.

Yin/Yang Palms

1. Separate the hands and extend them out in front of the body at solar plexus level. The left palm is still pointing up and is yang drawing in the heavenly force through Laogong. The right palm is still facing down and is yin drawing in the earth force energy.
2. Conclude by turning the left palm over to face downward. Draw in the earth force through both palms.

Double Palm and Beam to Activate the Functional and Governor Channels

1. Bring the left palm in first to face the navel, about 3 - 5 inches away, aligning the Laogong point with the navel. Follow by bringing the right hand in front of the left hand, aligning the Laogong of the right palm with the Laogong of the left hand and the navel. Both palms are now facing in. **Beam energy through both Laogong points to the navel and through the body to the Door of Life**.
2. Next raise the left palm up to the **solar plexus** aligning the Laogong point with the solar plexus. Beam energy into the solar plexus point and through the body to the T-11 point. Your right hand remains at the navel level beaming energy to the navel and the Door of Life.
3. Raise your right hand up to the outside of the left hand at the solar plexus level, and beam energy through both hands into the **solar plexus point and the T-11 point**. Continue in the same way with the left hand leading to the **heart point and wing**

point, the **throat point and C-7**, the **mideyebrow point and jade pillow** and the **crown point and perineum**.

4. Return down the front, point by point in the same way, leading with the left hand. Go up and down in this way three times. **The double palm and beam activate both the Functional and Governor Channels. The energy beam passes all the way through the body at each point**.

Grasping the Chi Ball

1. Separate the hands and slowly extend the arms in front of you at navel level, palms facing each other holding the Chi ball.
2. Stretch and squeeze the Chi ball three times as before by opening and closing the palms.

Channel the Earth Force

Rotate the hands to face downward, and draw in the earth force through the palms, soles and perineum.

Closing Movements

Activate the Chi Channels - Balancing the Organs

Index Finger - open (up), close (down), neutral (even with the other fingers).
Ring Finger - down, neutral.
Index Finger - open, neutral.
Thumb - in and down, neutral.
Index Finger - open, neutral.
Pinky Finger - down, neutral.
Index Finger - open, neutral.
Middle Finger - down, neutral.
Index Finger - open, neutral.

Crane's Beak

1. Form the crane's beak with both hands by bringing the fingertips together with the thumbs inside. Raise the forearms to shoulder height with the fingers pointed down, inhaling gently as you raise.
2. Open the palms slowly and begin to lower the arms to the sides as you exhale, until the palms are facing each other in the starting position.

Finish

1. Bring the awareness to the navel and notice the quality and intensity of the energy generated.
2. Collect energy at the navel. Men, place the hands over the navel with the right hand on top; vice versa for women.

Chapter IX
Universal Tao Practices

Cosmic Inner Smile

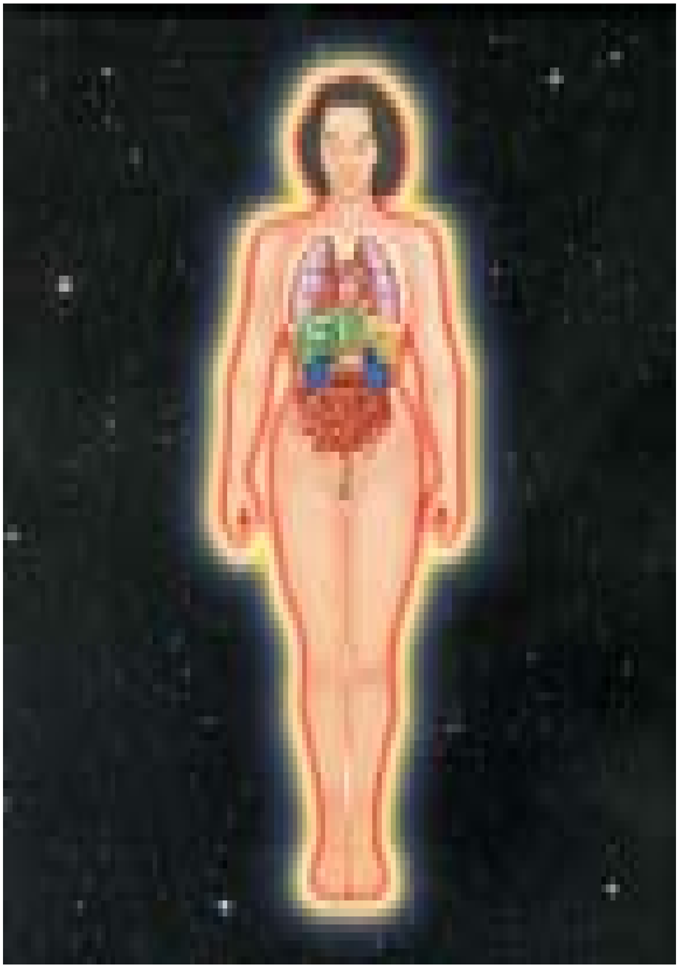

Fig. 9.1 *Inner Smile*

The Inner Smile begins at the eyes and the mideyebrow point and moves down to the heart. As you activate the heart, the loving energy will flow out and you will feel the energy of your Inner Smile flow down the entire length of your body like a waterfall. This is a very powerful and effective tool to counteract stress, tension and negative Chi.

1. Be aware of the **mideyebrow,** imagining that your are in one of your favorite places in the world, a place where you feel safe, relaxed and happy. Recall the sights you might have seen there, the sounds you might have heard, the scents, sensations and flavors that you associate with that place.
2. Imagine that one of your favorite people is standing in front of you, smiling to you with loving, happy, radiant shining eyes. **Smile** to your face and slightly lift up the corners of your mouth.
3. Feel yourself responding to that special person's smile with a smile of your own. Feel your eyes smiling and relaxing.
4. Smile down to the **thymus gland** and picture a white flower blossoming. Gently inhale into the thymus gland, connecting your breath to the olfactory organ. Smell the good fragrance.
5. Aim your inner attention at your **heart**, picturing the heart before your inner eye and smile to it. **Smile** until you feel the heart smile back to you. Picture your heart like a red rose, gradually opening. This will activate the **love** and fire of **compassion** in the heart. Once you feel the red light and loving awareness it will activate the **cosmic red healing light** or mist from above and around you.
6. Smile at the light or mist and very slowly with a soft, long, deep breath draw the red mist, love and compassion into the mideyebrow, down through the mouth and throat, into the heart and gradually overflowing to the **small intestine**. Exhale, but retain the red light and the love and compassion in the **heart and small intestine**. At the same time exhale the cloudy, black or negative energy. Keep on doing this breathing 18 to 36 times waiting until the heart becomes bright red before your inner vision and starts to radiate out to the tongue, mouth, nose, ears and eyes. Allow the red light to whirl around you and form a **red aura**. Feel your skin glowing with red energy.
7. Let the heart's loving energy radiate out to the **lungs**. Aim your attention at the lungs; picture them before your inner eye and smile to them. **Smile** until you feel the lungs smile back to you. Picture your lungs like a white rose, gradually opening; smell the good fragrance. This will activate the courage in the lungs. Once you invoke the white light and courage into the lungs, you will also activate the **cosmic white healing light** or mist from above and around you.
8. Smile at the light or mist and very slowly, softly take a long deep breath and draw the white mist into the mideyebrow, the mouth and down to the lungs, gradually overflowing into the **large intestine**. Exhale but retain the white light and the feeling of courage in the lungs. At the same time exhale the cloudy, black or negative energy. Keep on doing this kind of breathing 18 to 36 times, waiting until the lungs become bright white and start to radiate out to the nose, ears, eyes, tongue and mouth. Invite the white light to whirl around you and form a **white aura** covering your skin like autumn dew.
9. The **spleen, pancreas and stomach** correspond to the yellow color of the earth element. Connect to these organs and smile down into them from the mideyebrow.

First connect to the heart, then attract the clear yellow light from above and around you. You might see the **golden yellow aura** of a wheat field ready for harvest. Expel feelings of worry; exhale the cloudy, sticky energy. Breathe in the golden yellow aura, filling your spleen center with golden yellow light. Repeat to complete 18 to 36 cycles, then allow the light to radiate out to your mouth, nose, ears, eyes and tongue. Wrap the golden aura around you, leaving a golden shine on your skin.

10. The **kidneys and bladder** correspond to the blue color of the water element. Gentleness is contained within the blue healing light. Inhale the blue aura into the kidneys. Expel feelings of fear or stress on breathing out. Allow your energy field to expand, breathing in and out the blue energy 18-36 times, until it starts to radiate out from your kidneys to your ears, eyes, tongue, mouth and nose. Gather the blue mist on your skin enveloping you with a **blue aura**.
11. The **liver and gall bladder** connect to the green color of the element wood; kindness replaces anger, which is expelled on breathing out. Do the same as above and create a **green aura** around you. Exhale the dark red, cloudy heat. Inhale the nourishing green of the forests. Do 18 to 36 cycles, until the green light has completely filled the liver and starts to radiate out to your eyes, tongue, mouth, nose and ears. Invite the green light to form a green aura around you.
12. **Smile** down to the **sexual organs** and reproductive system. Feel love and sexual arousal and the heart and sexual organs uniting. Observe how this process transforms the sexual energy into Chi. Channel down orange and red light to the sexual organs. Thank them for their work in keeping you alive and healthy. Rest. Do nothing. Gather and store the energy by smiling and spiraling in the Tan Tien.

Six Healing Sounds

The Six Healing Sounds enhance Therapeutic Work

Everyone has heard stories about gifted beings who possess great healing powers. People seek out gifted healers. Yet even in the best of circumstances, how much time can a great healer spend with you? One hour a day? An hour a week? What about the rest of the time? Thus you must learn how to take care of yourself; you must learn how to clear out your negative energy and transform it into positive healthy energy. If you maintain yourself in this way it will surely enhance any other therapy you are receiving.

The Six Healing Sounds are a simple yet powerful tool to promote physical, energetic and emotional healing and balance. If you are healing others, you can teach your students one or two of the Six Healing sounds each session, to enhance the effects of your therapeutic work. During the practice of the sound the resting period is very important. Growing the good virtue of the organs is essential so the negative or sick energy has less room to grow.

The sounds are also used to generate certain frequencies for specific healing. Each sound can generate different energy for the healing of the different organs.

Once the movements, sounds and information have been integrated into your practice you can simplify and make the Six Healing Sounds more powerful. For example, when you are settled into the lung sound and you are breathing white healing light and feel the mideyebrow wide open, you put the awareness in the 'Tan Tien and Universe'.

Chi will flow from the universe into the Tan Tien and just the right amount and quality will flow from the Tan Tien into the lungs and large intestine. Just set up the location (the organ) and connect to the universe and the Chi will flow to the correct location!

When doing these, the eyes are open only while making the sound.

Six Healing Sounds - Practice

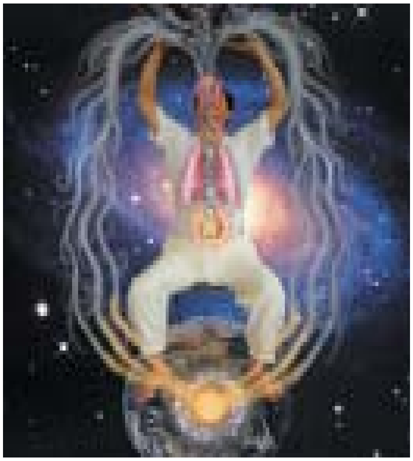

Lung Sound

Element: Metal
Associated Organ: Large Intestine
Sound: SSSSSSS (Tongue behind Teeth)
Emotions: Negative - Grief, Sadness, Depression
Positive - Courage, Righteousness, High Self Esteem
Color: White, Clear, Metallic
Season: Fall
Direction: West

Position: Sit in a chair with your back straight and your hands resting palms up on your thighs. Have your feet flat on the floor about a hip's width apart . **Smile** down to your lungs and be aware of any sadness, grief or excess heat in your lungs. Slowly inhale and raise your hands up your center line with your fingers pointing toward each other. When your hands pass your shoulder level, begin to rotate the palms out as you continue raising your hands up in front of you and above your head with the palms up. Point your fingers towards the fingers of the opposite hand and keep your elbows slightly bent.

Sound: Part your lips slightly, keeping your jaw gently closed. Look up through the space between your two hands and push your palms slightly upward as you slowly exhale and make the sound, "SSSSSSS". Picture and feel any excess heat, sadness, grief, depression, sickness and dingy white color expelled and released as you exhale slowly and fully.

Resting Posture: When you have completely exhaled, rotate the palms to face downward with the fingers still pointing toward each other. Slowly lower the palms and bring them just in front of the chest feeling the lung's aura.

Close your eyes and be aware of your lungs. **Smile** into your lungs, and as you inhale, imagine that you are breathing in a **bright white mist of light**. Breathe this light into your lungs and feel it cooling, cleansing, invigorating, healing and refreshing your lungs. Feel it flowing down to the large intestine to balance the energy of the yin lungs and yang large intestine, allowing the **courage** quality of your lungs to emerge. Grow more courage, so sadness and depression have less room to grow. With each inbreath, feel yourself drawing in cool fresh energy. With each outbreath, mentally make the Lung Sound and release any remaining sadness or hot energy.

Repeat at least three times. For the first two repetitions, you can make the sound aloud. On the third or last repetition, make the sound sub-vocally (vocalizing the sound so softly that only you can hear it) Repeat six, nine, twelve or twenty four times to alleviate extreme sadness, depression, colds, flu, toothaches, asthma and emphysema.

Kidney Sound

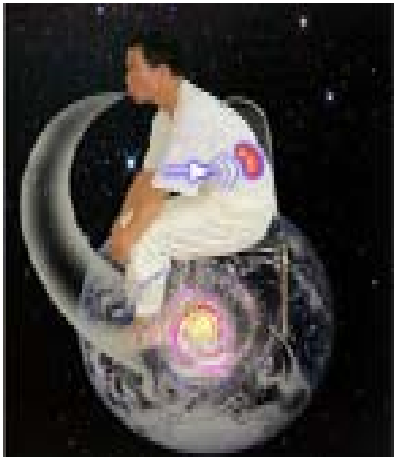

Element: Water
Associated Organ: Bladder
Sound: CHOOOOOO (with your lips forming an "O" as if blowing out a candle.)
Emotions: Negative - Fear, Shock
Positive - Gentleness, Wisdom
Color: Dark Blue or Black
Season: Winter
Direction: North

Position: Now move the hands to cover the kidneys. **Smile** to your kidneys, and be aware of any excess cold or heat in the kidney region. Then bring your legs together, ankles and knees touching. Lean forward and clasp the fingers of both hands together around your knees. Inhale and pull your arms straight from the lower back while bending the torso forward (this allows your back to protrude in the area of the kidneys). Tilt your head upward as you look straight ahead, still pulling on your arms from the lower back. Feel your spine pulling against your knees.

Sound: Round the lips slightly and slowly exhale while making the sound "CHOOOOOO." Simultaneously contract your abdomen, pulling it in toward your kidneys. Imagine any fear, sickness, imbalances, excess cold or heat energy being released and squeezed out of the fascia surrounding the kidneys.

Resting Posture: After you have fully exhaled, slowly sit erect and return the hands to touch the aura of the kidneys. Close your eyes and again be aware of your kidneys. **Smile** to your kidneys and, on the inbreath, imagine you are breathing a brilliant **luminous blue light mist** into them; feel this mist healing, balancing and refreshing your kidneys and bladder and picture them glowing a bright blue color. On the outbreath, imagine you are still making the Kidney Sound.

Repeat at least 3 times, as with the previous sound. Repeat six, nine, twelve, or twenty four times to alleviate extreme fear, fatigue, low-pitched ringing in the ears, dizziness, back pain, bladder and urinary infections or other problems of the reproductive system.

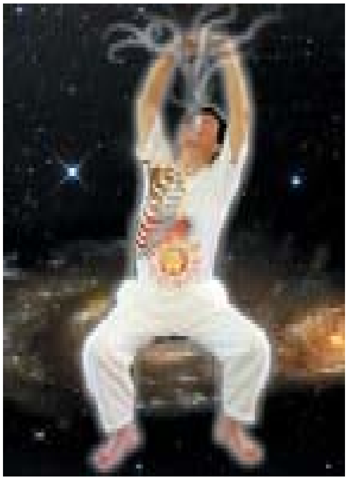

Liver Sound

Element: Wood
Associated Organ: Gall Bladder
Sound: SHHHHHHH
Emotions: Negative - Anger, Frustration, Resentment
Positive - Loving Kindness, Benevolence, Forgiveness
Color: Green
Season: Spring
Direction: East

Position: Place the hands on the liver. **Smile** to your liver and be aware of any anger, frustration, resentment or excess heat. Slowly begin to inhale a deep breath as you extend your arms up from the sides with your palms up. Continue to raise them over your head. Interlace your fingers together and turn your joined hands over to face the sky, palms up. Push out through the heels of the palms and extend the arms up, keeping the shoulders relaxed. Bend a little to the left and stretch your right arm slightly to gently open the area of your liver.

Sound: Open your eyes wide (the eyes are the sensory opening of the liver). Slowly exhale, making the sound, "SHHHHHHH" sub-vocally. Feel that you are releasing any trapped excess heat, anger, illness and negativity from your liver and that these are riding out of your body on your breath.

Resting Posture: Once you have fully exhaled, separate your hands, turn the palms down and slowly lower your arms to the sides, leading with the heels of the hands. **Smile** and inhale a **shiny spring green mist**, illuminating the liver and gall bladder. Bring your hands back to rest on the liver's aura. Close your eyes and smile into your liver. With each inbreath, breathe fresh Chi into your liver and gall bladder and mentally make the Liver Sound with each outbreath.

Repeat at least three times, as with the previous sound. Repeat six, nine, twelve or twenty four times to alleviate extreme anger, to relieve red or watery eyes, to remove a sour or bitter taste in the mouth or to detoxify the liver.

Heart Sound

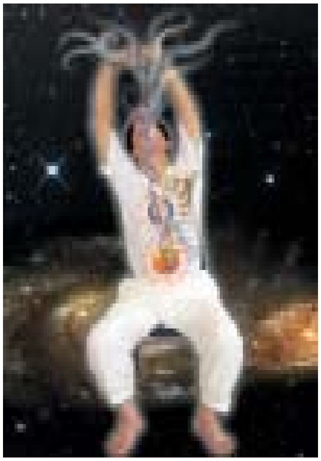

Element: Fire
Associated Organ: Small Intestine
Sound: HAAAAAAAW
Emotions: Negative - Arrogance, Harshness, Cruelty, Hatred
Positive - Joy, Honor, Respect, Love, Happiness
Color: Red
Season: Summer
Direction: South

Position: Let both hands rest on the heart. **Smile** to your heart and be aware of any arrogance, haughtiness, hatred, giddiness, cruelty or hastiness. Slowly begin to inhale a deep breath as you extend your arms up from the sides with your palms up, as you did with the Liver Sound. Continue to raise them over your head. Interlace your fingers together and turn your clasped hands over to face the sky, palms up. Push out through the heels of the palms and extend the arms up, keeping the shoulders relaxed. Bend a little to the right and stretch your left arm slightly to gently open the area of your heart.

Sound: Keep your eyes soft and relaxed, looking up through your hands. Slowly exhale, making the sound, "HAAAAAAAW" sub-vocally. Feel that you are releasing any trapped heat, negative emotions, illness and imbalances from your heart and that these are riding out of the body on your breath.

Resting Posture: Once you have fully exhaled, close your eyes, separate your hands, turn the palms down and slowly lower your arms to the sides, leading with the heels of the hands. As you move inhale a **bright red mist** into the heart and small intestines. Bring your hands back to rest on your heart's aura . Smile into your heart. With each inbreath, breathe fresh Chi into your heart with each outbreath mentally repeat the heart sound.

Repeat at least three times, as with the previous sound. Repeat six, nine, twelve or twenty four times for the heart and small intestines; feel them balanced. This will alleviate extreme impatience, hastiness, arrogance, nervousness, moodiness, jumpiness, irritability, tongue ulcers, palpitations, sore throat, heart disease, insomnia and detoxify the heart.

Spleen Sound

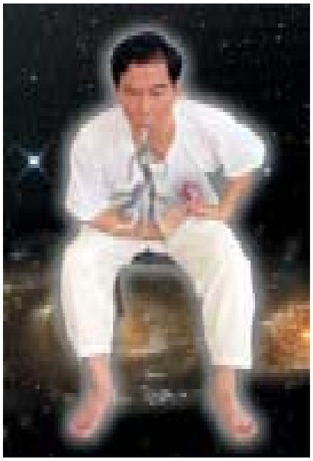

Element: Earth
Associated Organ: Pancreas, Stomach
Sound: WHOOOOOOO (gutturally from the throat)
Emotions: Negative - Worry, Excess Sympathy, Overthinking
Positive - Fairness, Balance, Equanimity, Justice, Openness
Color: Yellow
Season: Indian Summer
Direction: Center (where you stand, looking out to the Six Directions)

Position: Place your hands on the body covering the spleen, pancreas, and stomach area. Be aware of your spleen and **smile** sincerely into it. Inhale deeply as you move the arms outward in an embrace and aim the fingers up under the left rib cage. Place your fingers of both hands just beneath the sternum and rib cage on the left side.

Sound: Look out, lean into your fingers and gently push your fingertips in. Exhale slowly and make the sound, "WHOOOOOOO," from the depths of your throat. Feel yourself releasing any trapped heat, worry, mental fixations or excess sympathy.

Resting Posture: Once you have fully exhaled, close your eyes, slowly release the hands and extend the arms out embracing the earth; return your hands to the resting position on the spleen's aura. Smile to your spleen, pancreas and stomach. Inhale fresh Chi to your spleen, pancreas and stomach as a brilliant **luminous yellow healing mist** that cleanses and refreshes your organs. Mentally do the Spleen Sound with each outbreath.

Repeat at least three times, as with the previous sound. Repeat six, nine, twelve or twenty four times to alleviate extreme indigestion, heat or cold in the stomach or spleen, worry, nausea, hemorrhoids, fatigue, organ prolapse or loose stools.

Triple Warmer Sound

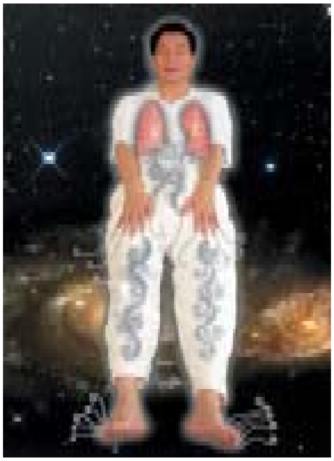

The Triple Warmer refers to the upper, middle and lower body, and to the distinct metabolic transformations that occur within each area. The Upper Warmer is the area above the diaphragm, where the heart and lungs are located. This area tends to become hot and is responsible for respiration and cardiovascular circulation. The Middle Warmer, the area between the diaphragm and the navel, becomes warm and is where the digestive organs are located. The Lower Warmer, the area below the navel, is responsible for reproduction and elimination and is cool in temperature. The sound "HEEEEEEE" balances the temperatures of the three levels by bringing hot energy down to the lower center and cold energy up to the higher centers.

Position: Lie on your back with your arms resting palms up at your sides. Keep your eyes closed. **Smile**. First breathe into the upper part of your lungs to expand the Upper Warmer; then breathe into the middle of the lungs to expand the Middle Warmer; finally, with the last part of your inhalation, expand your lower lungs and fill the Lower Warmer. Breathing in this way creates more space inside for each organ, helping to release and circulate any internal heat or cold.

Sound: Exhale with the sound "HEEEEEEE" sub-vocally, first flattening your chest, then your solar plexus, and finally your lower abdomen. Feel the dark and cloudy color, cold and chill energy exit from the tips of the fingers.

Resting Posture: Once you have fully exhaled, do not to focus on any emotions or purification process at all. Just let go and relax your body and mind completely.

Repeat at least three times, as with the previous sound. Repeat six, nine, twelve or twenty four times to alleviate insomnia and stress.

When you have completed the Six Healing Sounds just rest, **smile** and do nothing.

Regular daily practice of the Six Healing Sounds will help you to keep in touch with the energetic and emotional state of your internal organs. Most importantly do the sounds in the evening before going to sleep. This will help clear out the negative emotions before sleeping, so you can feel that the night's rest recharges your energy positively. This practice will greatly benefit your personal Cosmic Healing Chi Kung practice. It will help sensitize you to the varieties and differing qualities of Chi. This knowledge will also help you in diagnosing and treating others.

For more details of this practice please see the book "Taoist Ways to Transform Stress Into Vitality", by Mantak Chia.

Appendix

Guide to the Acupuncture Points used in Cosmic Chi Kung

The following is a detailed description of the acupuncture energy points used in the Cosmic Chi Kung practice. It is necessary to know the exact location of the points to do the practice well. However, you do not have to know the traditional Chinese medical functions and energetics of the points to do the practice. These are included in this appendix as an item of interest.

The names of the points are given first by the channel and number, second by the English translation of the traditional Chinese name for the point and finally by the name in Chinese.

We are emphasizing the traditional Chinese medical therapeutic properties of the points given herein. Many of these points also have very different purposes in Taoist Yoga. *For a description of the Taoist Yoga energetics, refer to “Awaken Healing Light of the Tao” by Mantak Chia.*

Pericardium 8

"Lakor's Palace" - Laogong

Ying Spring, Fire Point

Location: On the center of the palm, where the tip of the middle finger touches when making a loose fist.

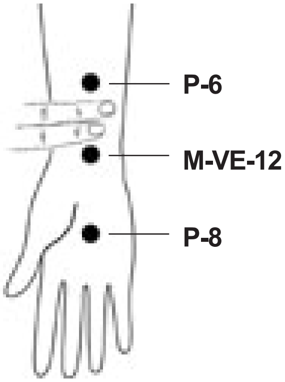

Functions: Cools the heart, drains heat from the heart, cools the blood, calms the spirit, regulates the heart Chi and yang, Ghost Point for treating spirit possession.

Indications: Coma from stroke, heat exhaustion, angina pectoris, mania, hysteria, mental illness, excessive sweating of the palms, mouth problems.

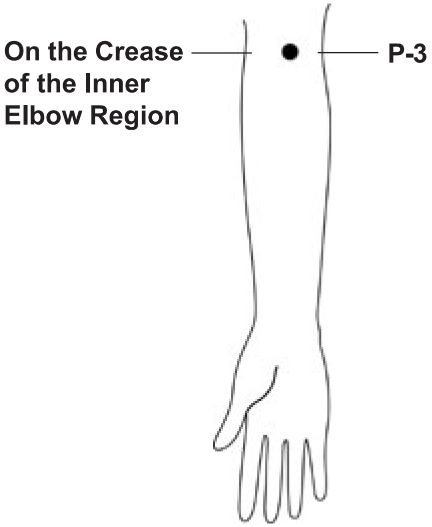

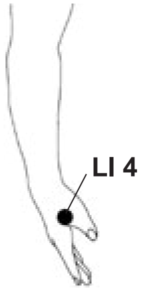

Large Intestine 4
"Adjoining Valleys" - Hegu

Yuan Source Point
Location: On the back side of the hand between the thumb and index finger, in the web approximately at the middle of the metacarpal bone of the index finger.
Functions: Disperses wind, relieves exterior conditions, suppresses pain and clears the channels, clears lung heat, calms the spirit.
Very powerful point for moving the Chi and blood of the whole body; main point for pain; main point for headache; main point for ailments of the head, face and sensory organs; main point for immunity.
Indications: Headaches, common cold, redness with pain and swelling of the eyes, toothache, facial swelling, sore throat, finger cramps, arm pain, fever, abdominal pain, constipation.
Caution: Contra-indicated in pregnancy.

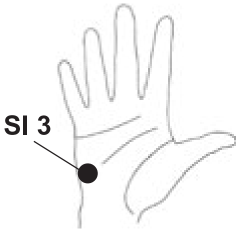

Small Intestine 3
"Back Creek" - Houxi

Shu Stream, Wood Point
Master Point of the Governor Channel
Coupled Point of the Yang Bridge Channel
Location: When a loose fist is made, the point is near the head of the fifth metacarpal bone on the knife edge of the hand at the junction of the red and white skin.
Functions: Relaxes the tendon-muscular channels, opens the Governor Channel, clears the Spirit, drains evil Chi from the heart.
Indications: Seizures, psychosis, hysteria, intercostal neuralgia, headache, stiff neck, red, painful and congested eyes, deafness, spasms of the arm, elbow and fingers; fever, night sweating, whiplash, occipital headaches.

Used for structural/musculo-skeletal problems; opens the Governor Channel for problems with back, neck and head, main point for stiff neck, antispasmodic for muscle spasms; anti-inflammatory for spinal arthritis, intestinal inflammation.

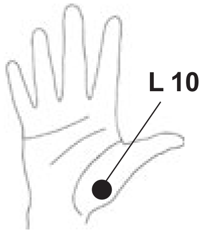

Lung 10
"Fish Border" - Yuji

Ying Spring, Fire Point
Location: In the middle of the ulna eminence below the thumbs at the junction of the red and white skin.
Functions: Cools heat in the lungs, benefits the throat.
Indications: Sore throat, cough, laryngitis, tonsillitis, fever with common cold.

Triple Warmer 5

"Outer Gate" - Wai Guan

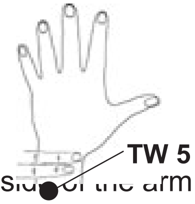

Luo Connecting Point
Master Point of the Yang Regulator Channel
Coupled Point of the Belt Channel
Location: About two fingers width above the wrist crease on the outside of the arm.
Functions: Regulates the Yang Regulator Channel and Belt Channel, tonifies and consolidates Protective (Wei) Chi, releases exterior hot and cold conditions, helps circulate stagnant Chi in the channels.
Indications: Common cold with alternating chills and fever, high fevers, pneumonia, deafness, migraine headaches, paralysis, stiff neck.

Pericardium 6

"Inner Gate" - Nei Guan

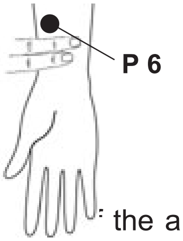

Luo Connecting Point
Master Point of the Yin Regulator Channel
Location: About two fingers width above the wrist crease on the i f the arm, between the two prominent tendons.
Functions: Calms the heart and spirit, regulates the Chi, opens and relaxes the chest, regulates and harmonizes the stomach, regulates the liver, relieves pain.
Indications: Rheumatic heart disease, shock, angina pectoris, palpitations, chest pain, asthma, shortness of breath, tightness or fullness in the chest, spasm of the diaphragm, vomiting, stomach ache, abdominal pain, morning sickness, motion sickness, migraine headaches, hysteria, anxiety, irritability, insomnia, seizures, swollen and painful throat, painful menses or nausea with period.

Large Intestine 11

"Crooked Pond" - Qu Chi

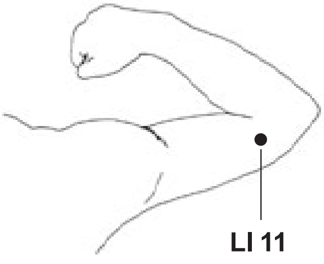

He Sea, Earth Point
Ghost Point
Location: When the elbow is flexed, in the depression at the outer and upper end of the elbow crease.
Functions: Cools heat, clears fire, drains dampness, eliminates wind and exterior conditions, regulates and moistens large intestine.
Indications: Arthritic pain in the arms, paralysis, hypertension, high fever, anemia, allergies, skin problems, Parkinson's Disease. Main point for skin diseases; main point for high fever.

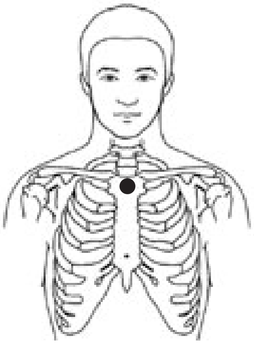

Conception Vessel 22

"Heaven's Chimney" - Tian Tu

Intersecting Point of the Yin Regulator Channel on the Conception Vessel, Window of the Sky Point

Location: At the top of the breastbone (sternum) in the V-shaped indentation (suprasternal notch). Press in and downward at a forty-five degree angle.

Functions: Cools the throat and clears the voice, facilitates and regulates movement of lung Chi, frees the breath and helps restore the proper functioning of the lungs and bronchi, helps open Conception Vessel (Functional Channel).

Indications: Asthma, bronchial asthma, bronchitis, coughing, pharyngitis, goiter, hiccups, nervous vomiting, hoarse voice, spasms of the esophagus, diseases of the vocal cords, sore throat.

Conception Vessel 17

“Central Altar” - Tan Zhong

Front Mu-Alarm Point of the pericardium, Influential Point of Chi of the body
Sea of Chi Point, Master Point of the Middle Tan Tien

Location: On the frontal midline at the level of the fourth intercostal space, between the nipples.

Functions: Regulates the lungs and the Upper Warmer, tonifies Ancestral Chi, opens and relaxes the chest, diffuses lung Chi, regulates and tonifies Chi, transforms phlegm.

Indications: Pulmonary tuberculosis with shortness of breath, bronchitis, asthma, bronchial asthma, chest pain; all breast problems such as mastitis, insufficient lactation, breast abscesses, wheezing, chest pain, labored breathing, palpitations, difficulty swallowing food, anxiety.

Conception Vessel 12

"Middle Cavity" - Zhongwan (Solar Plexus)

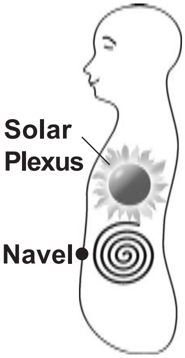

Front Mu-Alarm Point of the stomach, Influential point of all yang organs

Location: Approximately midway between the navel and the top joint of the xiphoid process.

Functions: Regulates the stomach Chi and yin, regulates, strengthens and tonifies the spleen Chi and yang, regulates the Middle Warmer, reduces digestive stagnation, tonifies nutritive Chi, regulates Chi and blood, redirects rebellious Chi downwards, clears stomach fire and heat, calms the fetus, controls the aura.

Indications: Acute or chronic gastritis, stomach and duodenal ulcers, prolapsed stomach, acute intestinal obstruction, stomach ache, vomiting, abdominal distention, diarrhea, constipation, acid regurgitation, indigestion, hypertension, mental diseases.

Mideyebrow Point

"Seal Hall" - Yin Tang

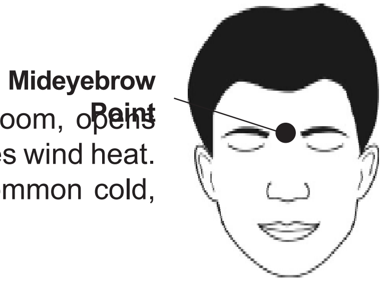

Master Point of the Upper Tan Tien
Location: At the midpoint between the two eyebrows.
Functions: Calms the spirit, activates the Crystal Room, opens the Governor Channel, draws in Cosmic Chi, eliminates wind heat.
Indications: Headache, vertigo, rhinitis, sinusitis, common cold, hypertension, infantile convulsions, sore eyes.

Conception Vessel 6

"Chi Ocean" - Chi Hai

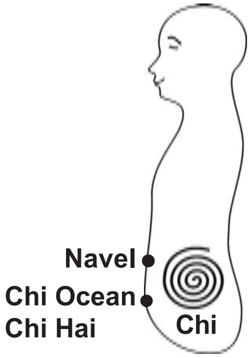

Master Point of the Lower Tan Tien
Location: Approximately three fingers width below the navel.
Functions: Regulates Chi, tonifies Original Chi, strengthens weak kidneys, harmonizes the blood, regulates the Thrusting Route Conception Vessel, reinforces Ching Chi, enriches yin.
Indications: Neurasthenia, abdominal distention, abdominal pain, irregular menstruation, impotence, spermatorrhea, urinary retention, frequent urination, intestinal paralysis, incontinence, constipation, infertility, uterine bleeding, hernia.

Stomach 13

"Chi's Household" - Chi Hu

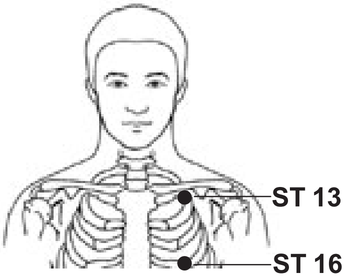

Location: Below the midpoint of the collarbone along the mammilary line (directly above the nipple).
Functions: Clears heat, loosens the chest, relaxes the diaphragm, regulates lung Chi.
Indications: Asthma, bronchitis, chest and back pain, hiccups.

Stomach 16

"Breast's Window" - Ying Chuang

Location: In the space between the third and fourth ribs, one rib directly above the nipple in men, slightly higher in women.
Functions: Stops pain, reduces swelling, clears heat, resolves depression, opens lungs, stops cough, relaxes chest, moves Chi.
Indications: Coughing, asthma, swelling of the breasts, chest and stomach pain, heartburn, shortness of breath, melancholy, diarrhea

Liver 14

"Gate of Hope" - Chi Men

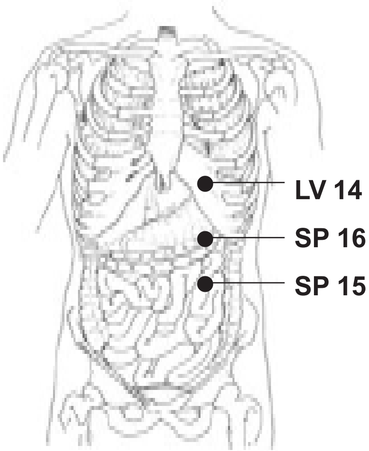

Front Mu-Alarm Point of the liver
Intersecting point of the Yin
Regulator and spleen channels on the liver channel
Location: In the sixth intercostal space, directly below the nipple.
Functions: Spreads liver Chi, transforms and removes congealed blood, strengthens spleen and stomach, expands and relaxes the chest.
Indications: Difficulty in breathing, chest pain, hepatitis, enlarged liver, gall stones, pleurisy, nervous stomach, menopausal disorders, cholera, failure to discharge the placenta after childbirth.

Spleen 16

"Abdomen's Sorrow" - Fu Ai

Location: Just below the bottom edge of the rib cage on the mamillary line.
Functions: Frees bowel Chi, dispels damp and heat, opens the organs and clears Chi stagnation.
Indications: Pain in the navel region, indigestion, dysentary, constipation.

Spleen 15

"Great Horizontal" - Da Heng

Intersecting point of the Yin Regulator Channel on the spleen channel
Location: At the level with the navel along the mamillary line.
Functions: Regulates the spleen, regulates and moistens the intestines, reduces digestive stagnation and transforms damp-heat.
Indications: Abdominal distension, diarrhea, constipation, intestinal paralysis, parasitic worms in the intestines, chronic sadness.

Conception Vessel 8

"Spirit Palace Gate" - Shen Que

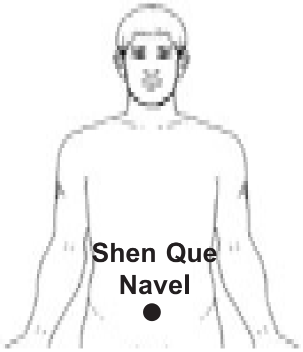

Doorway to the Original Chi,
Location: In the center of the navel
Functions: Tonifies, strengthens and regulates the spleen (Chi and yang), and stomach Chi, regulates the intestines, warms the interior and reduces digestive stagnation, tonifies the kidneys, warms the yang, dries dampness and dispels cold.
Indications: Chronic diarrhea, intestinal tuberculosis, all urinary disorders, shock resulting from intestinal adhesions, heatstroke, rectal or anal prolapse, restless fetus.

Governor Vessel 4
"Door of Life" - Ming Men

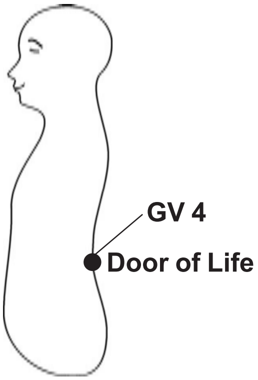

Back Doorway to the Lower Tan Tien
Location: Below the spinous process of the second lumbar vertebrae. Approximately at the level of the navel.
Functions: Nourishes the Original Chi, strengthens and harmonizes the kidneys, tonifies ching and yang, clears channels and invigorates collateral vessels, benefits the lower back and bones, regulates water pathways.
Main point to build life fire; main point for sexual/genital problems.
Indications: Bone disorders, chronic nephritis, enuresis, low sex drive, fatigue, spermatorrhea, impotence, irregular menses, painful menses, no menses, scanty menses, abnormal uterine bleeding, lower back stiffness and pain, kidney pain radiating to the abdomen, hemorrhoids, urinary incontinence, painful urination, diarrhea, sciatica, spinal myelitis.

Governor Vessel 6
"Middle of Spine" - Jizhon

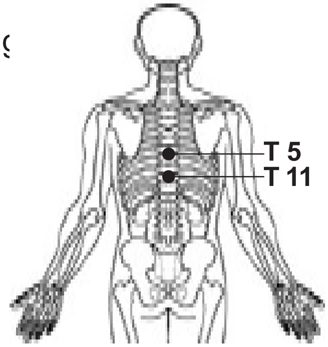

Location: Below the spinous process of the 11th thoracic vertebrae (T-11).
Functions: Stimulates Ching Chi, benefits spleen, stomach and kidneys and liver.
Indications: Hepatitis, seizures, low back pain, paralysis of lower limbs, blood in stools, diabetes, diarrhea.

Governor Vessel 11
"Spirit's Path" - Shen Tao

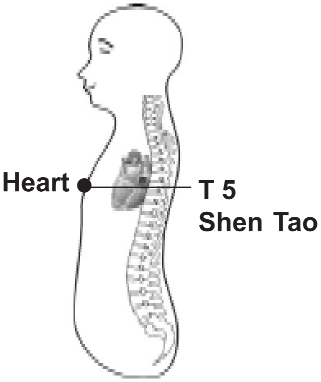

Location: Below the spinous process of T-5 (opposite CV-17, the Heart Point).
Functions: Calms heart and mind, regulates heart Chi and yang, expands and relaxes the chest, benefits heart and lungs, sedates pain, sedates fright and dispels wind.
Indications: Anxiety and palpitations due to fear or fright, neurasthenia, asthma, cough, shortness of breath, chest and hypochondriac pain, insomnia, aphasia due to winds, stroke, forgetfulness, fever.

Governor Vessel 14

" Big Vertebra" - Da Zhui

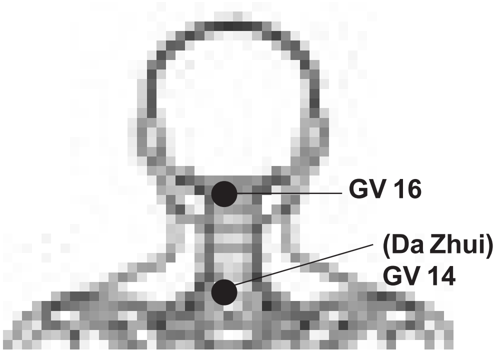

Influential point of yang
Sea of Chi point
Intersection point of all yang channels.
Location: Below the spinous process of the seventh cervical vertebra (C-7), approximately at the level of the shoulders.
Functions: Opens the yang, clears the brain, calms the spirit, tonifies Protective (Wei) Chi, reduces fever, relieves exterior conditions, clears heat.
Indications: Fever, sunstroke, malaria, psychosis, seizures, bronchitis, asthma, pulmonary tuberculosis, emphysema, hepatitis, blood diseases, eczema, hemiplegia, pain in the back of the shoulders, cold-induced diseases, cough, fever and chills.

Governor Vessel 16

“Jade Pillow” or "Wind Palace" - Feng Fu

Sea of Marrow Point, Window of Sky Point, Ghost Point
Intersection point of the Yang Regulator Channel on the Governor Vessel
Location: At the base of the skull, about one inch above the posterior hairline.
Functions: Benefits and clears the brain, calms spirit, opens the sensory orifices, dispels wind, wind-cold and wind-heat, smoothes joint functions.
Indications: Seizures, mania, hemiplegia, loss of speech due to stroke, delirium, suicidal behavior, fear and fright, anxiety, common cold, sensation of heaviness in the head, headache, dizziness, numbness of the limbs, deaf-mutism, blurred vision, sinusitis, stiff neck.

Governor Vessel 20

"One Hundred Meetings" - Bai Hui

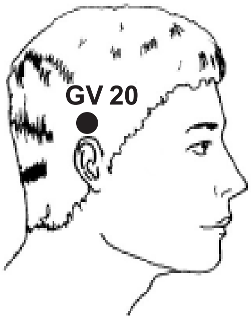

Sea of Marrow Point
Location: At the crown of the head, approximately on the midpoint of the line connecting the top apex of the two ears.
Function: Clears the senses, calms the spirit, extinguishes liver wind, stabilizes ascending yang.
Indications: Headache, dizziness, shock, depression, hypertension, insomnia, seizures, prolapsed anus, prolapsed uterus, mental dullness, hemorrhoids.

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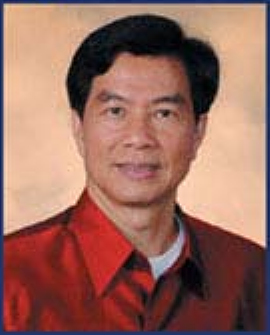

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Mantak Chia

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Universal Tao Publications

DIAGNOSING MEDICAL PARASITES:

A Public Health Officers Guide to Assisting Laboratory and Medical Officers

Compiled and edited by:
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Chapter 1.
The Ameba

1.1 An Introduction to Parasitology

Parasitology is the study of parasites and as such does not include bacterial, fungal or viral parasites. Human parasites are separated into intestinal and blood-borne parasites. For a parasite to be defined as intestinal it must have an intestinal life-cycle stage, though it may have life-cycle stages in the heart, circulation, lung, tissue, other animals or the environment.

Parasites found in the intestines can be categorized into two groups: Protozoa and Helminths.

Protozoa are single celled organisms. There are four classes of Protozoa commonly found in concentrated fecal samples. These are differentiated by the method of motility. Protozoa include *Entamoeba*, *Giardia*, *Trichomonas*, *Cryptosporidium*, *Isospora*, *Pneumocystis* and *Balantidium*. There are two diagnostic life-cycle stages commonly seen in parasites - the cyst and the adult trophozoite stage. The trophozoite stage is analyzed directly on a slide without concentration. Cysts require concentration. The key diagnostic factor is that Protozoan cysts are typically 5-30µm (µm = microns or micrometers) in diameter, and as such are smaller than most Helminth eggs. Due to the size they are particularly difficult to see under the microscope if the sample clarity is bad.

The medically important Helminths are nematodes (roundworms), cestodes (tapeworms) and trematodes (flukes). Genera include: *Fasciola*, *Schistosoma*, *Ascaris*, Hookworm, *Trichuris*, *Taenia* and *Enterobius*. The normal stage for examination is the egg stage, although larvae may develop in some organisms (Strongyloides); the diameter of the eggs range from 30µm - 150µm.

The other major grouping of parasites is known as blood-borne parasites which are transmitted through an arthropod vector. By far the most important arthropod for transmitting parasitic infections is the mosquito. Mosquitoes are known to carry malaria and filarial nematodes. Different types of biting flies transmit African trypanosomiasis, leishmaniasis and several kinds of filariasis.

Most protozoan and helminthic infections that are transmitted by arthropods can readily be diagnosed, on clinical grounds alone, but are usually identified by fairly simple techniques designed to present the presence of the causative parasite by microscopy. Sophisticated techniques are also being employed including highly sensitive and specific simple monoclonal antibody tests, DNA probes, and PCR primers.

1.2 Infections Acquired Through the Gastrointestinal Tract

Many of the infections of the gastrointestinal tract (GI) are caused by parasites that are cosmopolitan in distribution. Protozoa can be directly infectious for man when they are passed in the feces into the environment, but helminths require a period of maturation while in the soil, where they become infectious. Others such as *Taenia saginata* require the involvement of an intermediate host during their life cycle.

Infections of the GI tract account for a high proportion of deaths in infants where the standards of hygiene and nutrition are low.

Fecal-oral transmission of the pathogens is the most common mode of GI infections, whereby water, food and hands become contaminated with fecal material which then come in contact with the mouth.

A number of GI infections can reach epidemic proportion, protozoal pathogen *Cryptosporidium parvum*, has been known to cause the severe water-borne epidemics, even in first-world countries such as the United States and the UK. Other infections such as amebiasis or enterobiasis can be more localized, infecting households or institutions.

Some of the rarer, protozoal infections such as the microsporidia are only now being understood as they are appearing as concomitant infections in people with depressed immune responsiveness, e.g. AIDS.

The Ameba

Ameba (or Amoeba) are characterized by possessing clear protoplasm which form pseudopodia. These pseudopodia are the means by which these organisms move and engulf bacteria and red blood cells for feeding purposes. The most common amebas seen in the intestinal tract are E*ntamoeba histolytica/dispar, Entamoeba coli, Entamoeba hartmanni, Endolimax nana* and *Iodamoeba bütschlii*. All but *Entamoeba histolytica* are thought to be non-pathogenic. The cysts can be identified in an ethyl acetate concentrate by the addition of iodine to reveal the characteristic inclusions and also by measuring the cyst using an eyepiece graticule. The trophozoites can be seen in a fresh saline preparation of the stool although accurate identification is on a permanently stained fecal smear.

Entamoeba histolytica

Introduction

There are a large number of species of ameba which parasitize the human intestinal tract. Of these, *Entamoeba histolytica / dispar* is the only species found to be associated with intestinal disease. Although many people harbor this organism world wide, only about 10% develop clinically invasive disease, thus the parasite has been shown to present as two very differing clinical presentations.

1. The commensal or non-invasive luminal form where the parasite causes no signs or symptoms of disease.
2. The pathogenic or invasive form where the parasite invades the intestinal mucosa and produces dysentery or amebiasis and may give rise to extra-intestinal lesions via the blood, mainly to the liver.

Sargeaunt and Williams (1978) conclusively proved that invasive and non-invasive strains of *E. histolytica* could be differentiated by isoenzyme electrophoresis and the application of molecular biology has confirmed the presence of two distinct species with the same morphological features. The pathogenic or invasive species has retained the name *E. histolytica* and the non-pathogenic, non-invasive species has been named *E. dispar.*

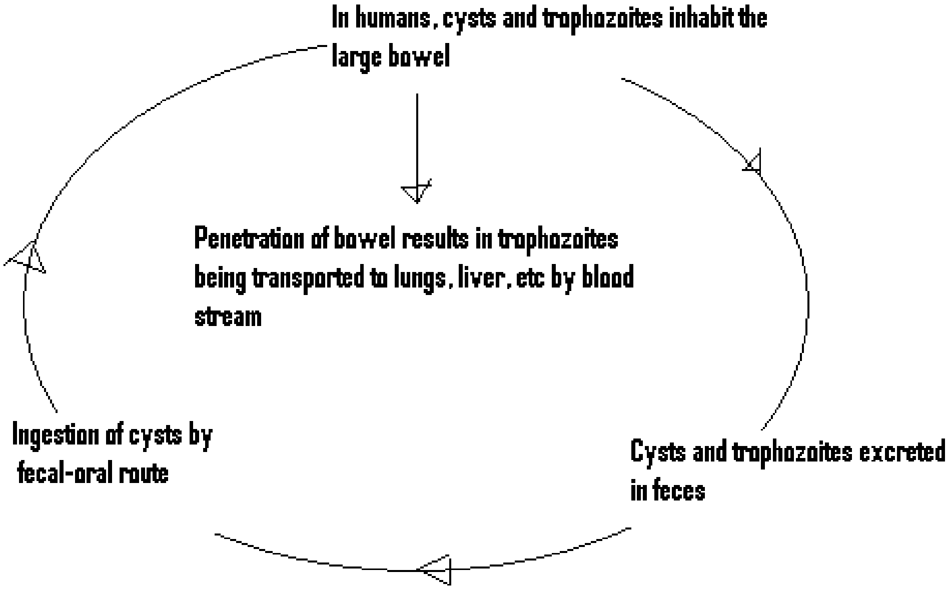
In humans, cysts and trophozoites inhabit the large bowel
Penetration of bowel results in trophozoites being transported to lungs, liver, etc by blood stream
Cysts and trophozoites excreted in feces
Ingestion of cysts by fecal-oral route

Illustration 1-1. Life Cycle of *Entamoeba histolytica:* A protozoan in which its life cycle consists of two stages; cysts and trophozoites (Cuomo)

Morphology of Trophozoites

The trophozoites of *E. histolytica / dispar* recovered from dysenteric stools exhibit ingested red blood cells and clear pseudopodia. Those of *E. dispar* will have no ingested red blood cells. They can be up to 60μm in diameter and motility is rapid and unidirectional. On a permanently stained fecal smear e.g. Trichrome or Iron hematoxylin, the morphological features are more visible. When using Trichrome stain nuclei, chromidial bars, chromatin, red cells and bacteria stain red cytoplasm stains blue-green and background and yeasts stain green. The presence of a small centrally placed karyosome is clearly visible. With Iron hematoxylin, nuclear chromatin and the karyosome will be stained immensely black. The remainder will be varying shades of grey/black.

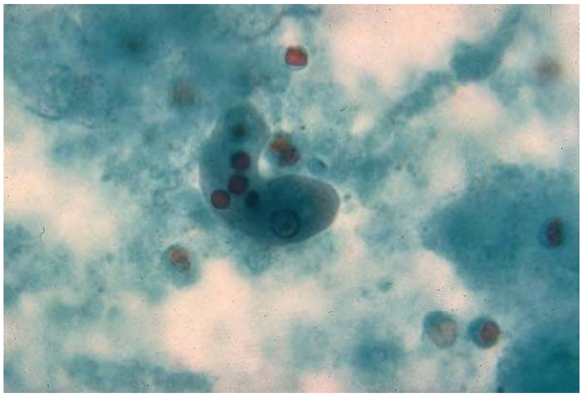

Image 1-1. *Entamoeba histolytica* trophozoites (SOURCE: PHIL 336 -CDC / Dr. N.J. Wheeler, Jr.)

Morphology of Cysts

Cysts of *E. histolytica / dispar* are 10-15μm in diameter and contain one to four nuclei. Chromatoid bodies are usually present in young cysts as elongated bars with bluntly rounded ends. Glycogen is usually diffuse, but in young cysts it is often present as a concentrated mass, staining reddish brown with iodine.

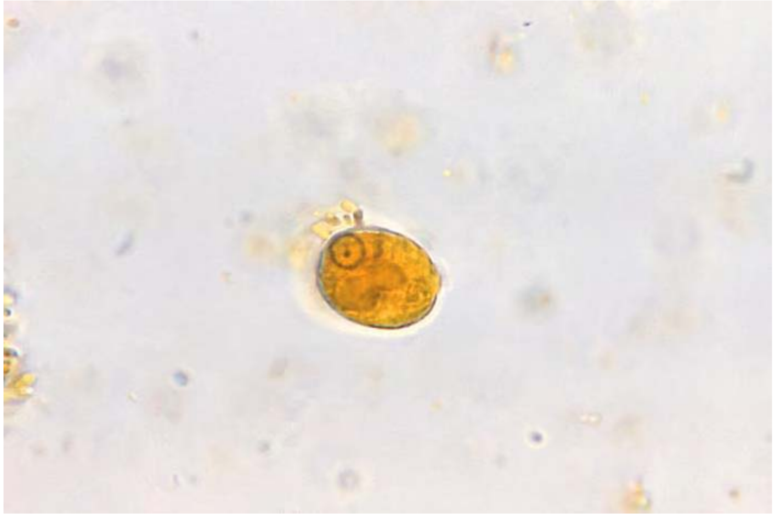

Image 1-2. *Entamoeba histolytica* cyst. (SOURCE: PHIL 531 - CDC/ Dr. L.L.A. Moore, Jr.)

Clinical Disease

Amebiasis is an infection usually caused by the pathogenic *Entamoeba histolytica / dispar*, and is commonly an infection of the colon. It has a world wide distribution where environmental sanitation is poor. The parasite may behave as a commensal (causing no harm to the host) or it may act as a parasite (harming the host). It is a disease of human beings, although some monkeys can become infected and the infection is then transmissible to humans.

Intestinal Disease

Patients with intestinal disease may exhibit a number of symptoms including profuse diarrhea with blood and mucus, fever and dehydration. Amebic ulcers may develop in the large colon and can also be found in the rectal area. The ulcers are usually "flask shaped" with a small opening on the mucosal surface and a larger area below the surface. **Image 1-3.** illustrates *E. histolytica* trophozoites in the intestine, resulting in amebiasis.

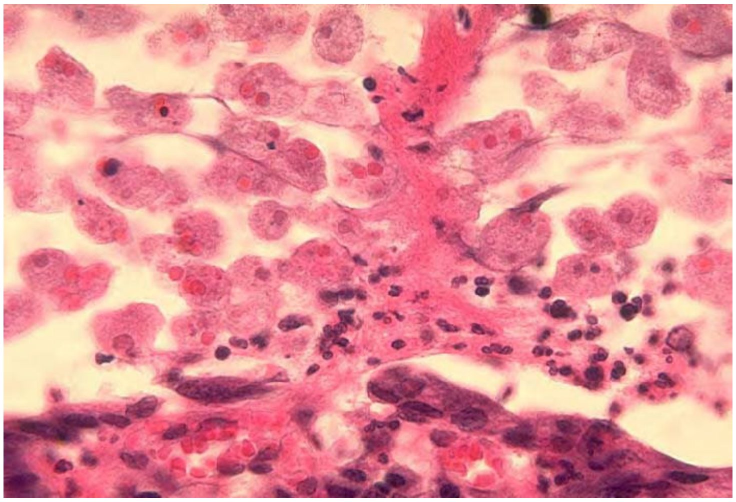

Image 1-3. *Entamoeba histolytica*, intestine. (SOURCE: PHIL 623 - CDC)

Hepatic Disease

Trophozoites are transported from the intestine to the liver and liver disease is characterized with abdominal pain, fever, hepatomegaly and tenderness. If the abscess ruptures, there is spreading to the brain, pericardium and other sites. If left untouched the abscess will grow normally until it reaches a surface where it can discharge, e.g. the skin, the peritoneum, the pleural cavity or the pericardium. The stretching of the liver is presumably the main source of the pain.

Laboratory Diagnosis

Laboratory diagnosis is made by finding the characteristic cysts in an iodine stained, formol-ether concentration method or by detecting the characteristic trophozoites in a wet preparation or a permanent stained preparation.

Microscopy

Where amebic dysentery is suspected, the laboratory should be informed that a "hot stool" is being supplied so that it can be examined within twenty minutes of being passed. On cooling the ameba stop moving which then become very difficult to identify. Direct microscopy should be done by mixing a small amount of the specimen in 0.9% sodium chloride solution. This permits detection of motile trophozoites of *Entamoeba histolytica / dispar* and can also provide information on the content of the stool (i.e., the presence of leucocytes and red blood cells). On search e.g. primarily for cysts, not for ameba, several stool samples are required to be examined, by direct microscopy and a sensitive concentration technique. Three negative stool samples are required before it can be accepted that there is no amebic infection. Microscopic examination of an amebic abscess aspirate e.g. in the liver or lungs, may reveal hematophagous trophozoites. It must be examined immediately by mixing a drop of warm saline with some aspirated pus on a microscope slide.

Serology

If visceral or hepatic amebiasis is suspected, serological tests should be done as microscopic methods do not always reveal the characteristic trophozoites. The tests of choice are indirect fluorescent antibody test (IFAT), counter immunoelectrophoresis (CIEP) enzyme linked immunosorbent assay (ELISA), and Rapid Antigen testing by enzyme immunoassay.

The search for *E. histolytica* / *dispar* is mainly carried out because there is a natural concern to ensure that patients, even in the absence of symptoms, are not harboring parasites that may lead to serious complications later on.

Entamoeba coli

Introduction

Entamoeba coli are a non-pathogenic ameba with world wide distribution. Its life cycle is similar to that of *E. histolytica* but it does not have an invasive stage and does not ingest red blood cells.

Morphology of Trophozoite

The trophozoite is larger than that of *E. histolytica* ranging from 15-50µm in diameter. It exhibits blunt pseudopodia with sluggish movement. A permanently stained preparation shows a nucleus with a moderately large eccentric karyosome with the chromatin clumped on the nuclear membrane. The cytoplasm appears granular containing vacuoles with ingested bacteria and other food particles.

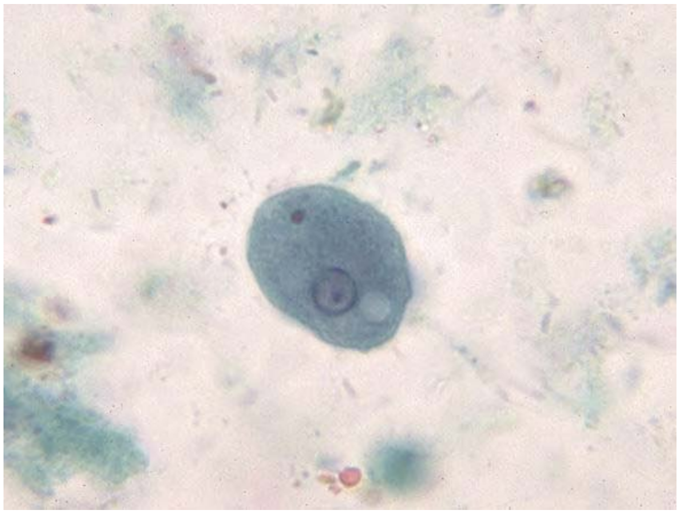

Image 1-4. *Entamoeba coli* trophozoite with ingested bacteria. (SOURCE: PHIL 605 - CDC)

Morphology of Cysts

Cysts of *E. coli* are 15-30µm in diameter and contain one to eight nuclei with irregular peripheral chromatin: karyosomes not central. Chromatoid bodies are not frequently seen but when present they are usually splinter-like with pointed ends. Glycogen is usually diffuse but in young cysts is occasionally found as a well-defined mass, which stains reddish brown with iodine.

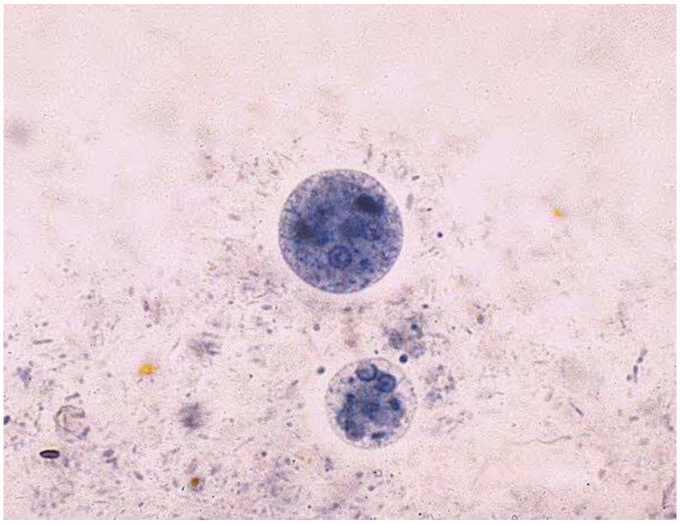

Image 1-5. *Entamoeba coli* (larger) and *Entamoeba histolytica* (smaller) cysts. (SOURCE: PHIL 442 - CDC/Dr. Mae Melvin)

Laboratory Diagnosis

Laboratory diagnosis is made by finding the characteristic cysts in an iodine stained, formol-ether concentration method or by detecting the characteristic trophozoites in a wet preparation or a permanent stained preparation.

Microscopy

Where amebic dysentery is suspected, the laboratory should be informed that a "hot stool" is being supplied so that it can be examined within twenty minutes of being passed. On cooling the ameba stop moving which then become very difficult to identify. Direct microscopy should be done by mixing a small amount of the specimen in 0.9% sodium chloride solution. This permits detection of motile trophozoites of *Entamoeba coli* and can also provide information on the content of the stool (i.e., the presence of leucocytes and red blood cells). On search e.g. primarily for cysts, not for ameba, several stool samples are required to be examined, by direct microscopy and a sensitive concentration technique. Three negative stool samples are required before it can be accepted that there is no amebic infection. Microscopic examination of an amebic abscess aspirate (e.g. in the liver or lungs), may reveal hematophagous trophozoites. It must be examined immediately by mixing a drop of warm saline with some aspirated pus on a microscope slide.

Entamoeba hartmanni

Introduction

Entamoeba hartmanni is a non-pathogenic amoeba with world wide distribution. Its life cycle is similar to that of *E. histolytica* but it does not have an invasive stage and does not ingest red blood cells.

Morphology of Trophozoites

Morphology of the trophozoites is similar to those of *E. histolytica / dispar* but they do not contain ingested red blood cells and the motility is less rapid.

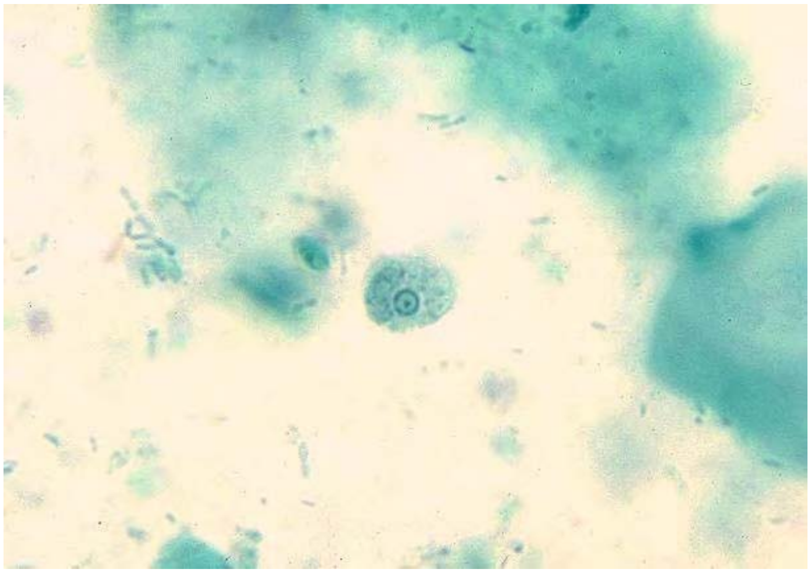

Image 1-6. *Entamoeba hartmanni* trophozoite (SOURCE: PHIL 528 - CDC/Dr. L.L.A. Moore, Jr.)

Morphology of Cysts

Cysts of *E. hartmanni* 7-9µm in diameter and contain one to four nuclei. Chromatoid bodies are usually present in young cysts as elongated bars with bluntly rounded ends. Glycogen is usually diffuse, but in young cysts it is often present as a concentrated mass, staining reddish brown with iodine.

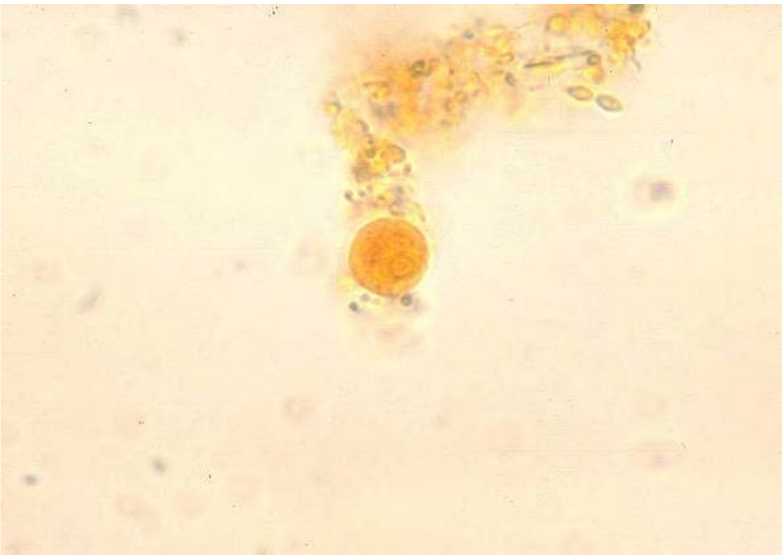

Image 1-7. *Entamoeba hartmanni* cyst (SOURCE: PHIL 533 - CDC/Dr. L.L.A. Moore, Jr.)

Laboratory Diagnosis

Laboratory diagnosis is made by finding the characteristic cysts in an iodine stained, formol-ether concentration method or by detecting the characteristic trophozoites in a wet preparation or a permanent stained preparation.

Microscopy

Where amebic dysentery is suspected, the laboratory should be informed that a "hot stool" is being supplied so that it can be examined within twenty minutes of being passed. On cooling the ameba stop moving which then become very difficult to identify. Direct microscopy should be done by mixing a small amount of the specimen in 0.9% sodium chloride solution. This permits detection of motile trophozoites of *Entamoeba hartmanni* and can also provide information on the content of the stool (i.e., the presence of leucocytes and red blood cells). On search e.g. primarily for cysts, not for ameba, several stool samples are required to be examined, by direct microscopy and a sensitive concentration technique. Three negative stool samples are required before it can be accepted that there is no amebic infection. Microscopic examination of an amebic abscess aspirate (e.g. in the liver or lungs), may reveal hematophagous trophozoites. It must be examined immediately by mixing a drop of warm saline with some aspirated pus on a microscope slide.

Endolimax nana

Introduction

Endolimax nana is a small non-pathogenic amoeba with world wide distribution. Its life cycle is similar to that of *E. histolytica* but is non-invasive.

Morphology of Trophozoite

Trophozoites of *E. nana* measures from 6-12µm. Motility is sluggish with blunt hyalin pseudopodia. In a permanently stained preparation, the nucleus exhibits a large karyosome with no peripheral chromatin on the nuclear membrane.

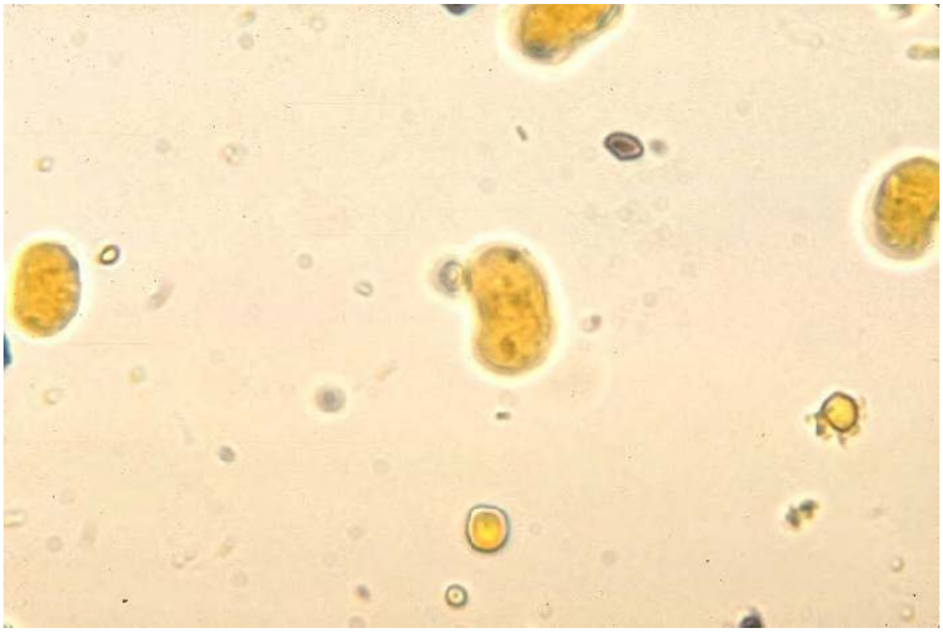

Figure 1-8. *Endolimax nana* cyst. Iodine stain. (SOURCE: PHIL 530 - CDC/Dr. L.L.A. Moore, Jr.)

Morphology of Cysts

Cysts of *E. nana* are 6-9µm in diameter. They can be spherical or ovoid in shape and contain four pinpoint nuclei, which are highlighted by the addition of iodine. Chromatoid bodies are not found and glycogen is diffuse.

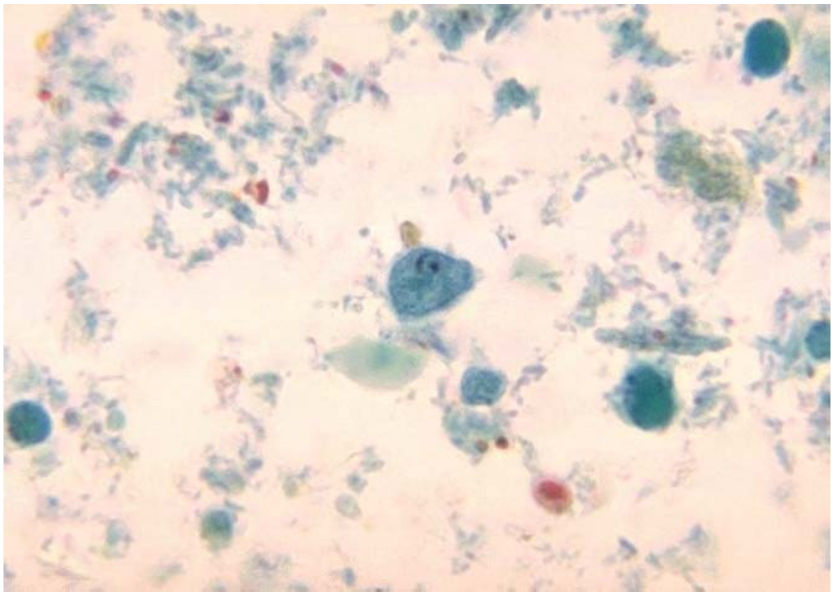

Image 1-9. *Endolimax nana* trophozoite (SOURCE: PHIL 1463 - CDC/Dr. Mae Melvin)

Laboratory Diagnosis

Laboratory diagnosis is made by finding the characteristic cysts in an iodine stained, formol-ether concentration method or by detecting the characteristic trophozoites in a wet preparation or a permanent stained preparation.

Microscopy

Where amebic dysentery is suspected, the laboratory should be informed that a "hot stool" is being supplied so that it can be examined within twenty minutes of being passed. On cooling the ameba stop moving which then become very difficult to identify. Direct microscopy should be done by mixing a small amount of the specimen in 0.9% sodium chloride solution. This permits detection of motile trophozoites of *Endolimax nana* and can also provide information on the content of the stool (i.e., the presence of leucocytes and red blood cells). On search e.g. primarily for cysts, not for ameba, several stool samples are required to be examined, by direct microscopy and a sensitive concentration technique. Three negative stool samples are required before it can be accepted that there is no amebic infection. Microscopic examination of an amebic abscess aspirate (e.g. in the liver or lungs), may reveal hematophagous trophozoites. It must be examined immediately by mixing a drop of warm saline with some aspirated pus on a microscope slide.

Iodamoeba bütschlii

Introduction

Iodamoeba bütschlii is a non-pathogenic amoeba with world wide distribution although not as common as *E. coli or E. nana*. Its life cycle is similar to that of *E. histolytica* but is non-invasive.

Morphology of Trophozoites

Trophozoites of *I. bütschlii* are 8-20μm and are actively motile. On a permanently stained fecal smear, a nucleus with a large karyosome is evident. Chromatin bodies form striations around the karyosome. The cytoplasm appears granular containing vacuoles with ingested bacteria and debris.

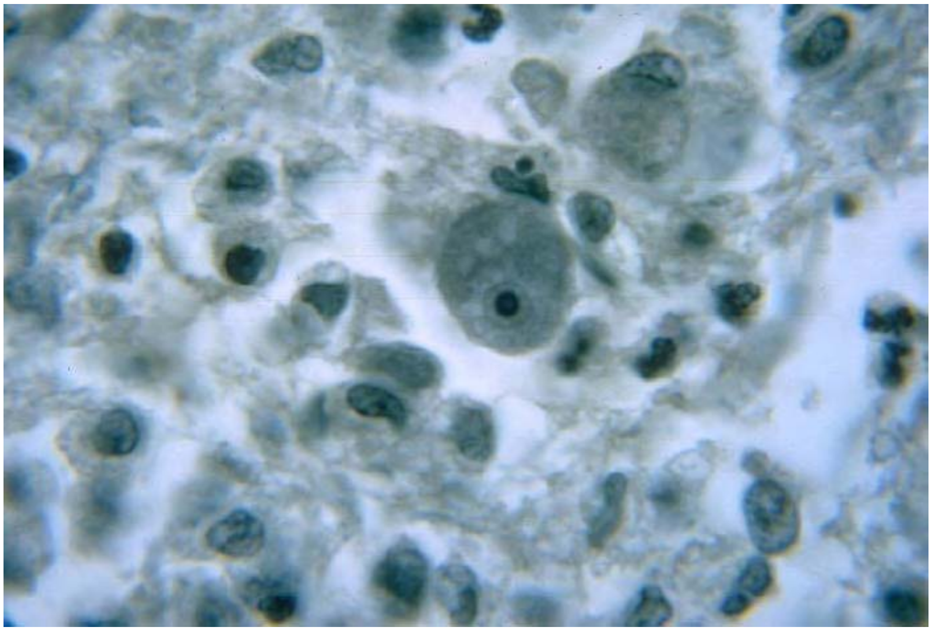

Image 1-10. Histopathology of amebiasis of brain due to *Iodamoeba bütschlii*. (SOURCE: PHIL 323 - CDC/Dr. Martin D. Hicklin)

Morphology of cysts

Cysts of *I. bütschlii* are 9-15μm in diameter and have one nucleus in mature cysts usually eccentrically placed. Chromatoid bodies are not present. Glycogen is present as a compact well defined mass staining dark brown with iodine.

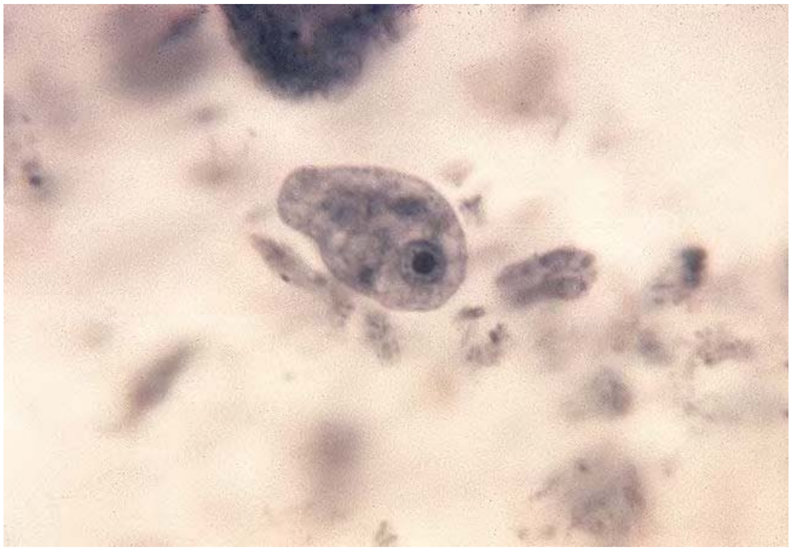

Image 1-11. *Iodamoeba bütschlii* cyst. (SOURCE: PHIL 587 - CDC/Dr. L.L.A. Moore, Jr.)

Laboratory Diagnosis

Laboratory diagnosis is made by finding the characteristic cysts in an iodine stained, formol-ether concentration method. Trophozoites are difficult to detect in a wet preparation.

Microscopy

Where amebic dysentery is suspected, the laboratory should be informed that a "hot stool" is being supplied so that it can be examined within twenty minutes of being passed. On cooling the ameba stop moving which then become very difficult to identify. Direct microscopy should be done by mixing a small amount of the specimen in 0.9% sodium chloride solution. This permits detection of motile trophozoites of *Iodamoeba bütschlii* and can also provide information on the content of the stool (i.e., the presence of leucocytes and red blood cells). On search e.g. primarily for cysts, not for ameba, several stool samples are required to be examined, by direct microscopy and a sensitive concentration technique. Three negative stool samples are required before it can be accepted that there is no amebic infection. Microscopic examination of an amebic abscess aspirate e.g. in the liver or lungs, may reveal hematophagous trophozoites. It must be examined immediately by mixing a drop of warm saline with some aspirated pus on a microscope slide.

Blastocystis hominis

Introduction

B. hominis is an inhabitant of the human intestinal tract. It is capable of both sexual and asexual reproduction by binary fission and of pseudopod extension and retraction.

Morphology

The classic form that is usually seen in stool specimens varies in size from 6-40µm and is characterized by a large membrane bound central body which occupies 90% of the cell. It has no internal nuclear structure and a rim of peripheral granules the function of which is not known.

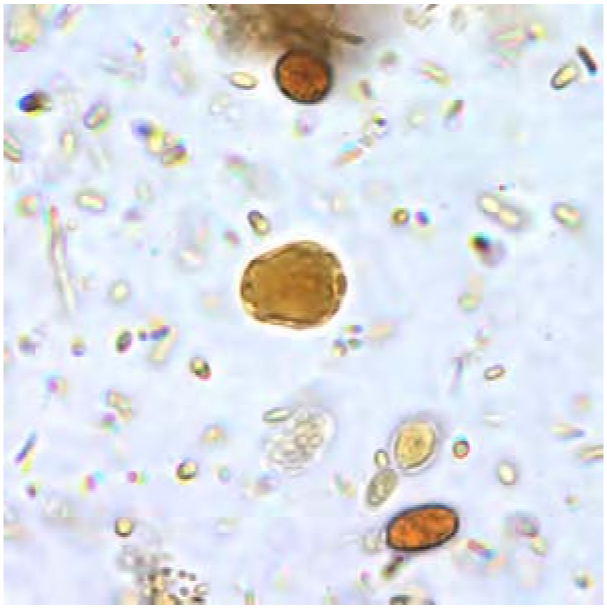

Image 1-12. *Blastocystis hominis* cyst-like forms in a wet mount stained in iodine. (SOURCE: CDC)

Clinical Disease

The pathogenic potential of *B. hominis* is unclear, though this organism has been associated with nausea, fever, vomiting, diarrhea and abdominal pain.

Laboratory Diagnosis

Permanently stained preparations of fecal smears is the procedure of choice for identification, although the organism can be seen in wet preparations. The recommended stains are Fields' and Giemsa.

1.3 Direct Fecal Parasite Concentration Methods

Diagnosis of intestinal parasites is confirmed by the recovery of protozoan trophozoites and cysts, helminth eggs and larvae in the clinical parasitology laboratory. Microscopic examination of feces is essential for the recognition and identification of intestinal parasites. Due to the low density of the parasites in the feces, direct microscopy is useful for the observation of motile protozoan trophozoites and the examination of cellular exudate, is not recommended solely for the routine examination of suspected parasitic infections. It is essential to increase the probability of finding the parasites in fecal samples to allow for an accurate diagnosis. Therefore, a concentration method is employed. (Direct wet mount examination should not be entirely excluded as the trophozoites are usually destroyed during the concentration procedure and therefore, microscopic examination of wet mounts should be performed).

Conventional Methods

Ridley-Allen Method

The concentration procedure used in hospitals requires the use of ether or ethyl acetate as a lipid removing agent and formalin as a fixative. The process involves the use of either expensive brass sieves or the use of tea strainers as the filter element.

Tea strainers have a very open pore structure of at least 600 micron and due to the shape of the strainer it is a non-linear pore size.

The fecal matter is filtered directly through these meshes in a dead stop manner, and hence there is the tendency for occlusion of the filter. There is also a formation of a secondary filter layer, which retains eggs and allows the extrusion of particles (particularly fibers) into the sediment. The net result is a reduction in egg yield and in sample clarity.

a. Using orange sticks, select a quantity of feces (approx. 1g) to include external and internal portions.
b. Place in a centrifuge containing 7ml of 10% formalin.
c. Emulsify the feces in the formalin and filter through the brass/plastic filter into the dish.
d. Wash the filter and discard any lumpy residue.
e. Transfer the filtrate to a boiling tube-add 3ml of ether and mix well on a vortex mixer for 15 seconds or mix by hand for 1 minute.
f. Transfer back to the centrifuge tube and centrifuge at 3,000 rpm for 1 min.
g. Loosen the fatty plug with an orange stick and pour the supernatant away by quickly inverting the tube.
h. Allow the fluid on the side of the tube to drain onto the deposit – mix well and transfer a drop to a slide for examination under a coverslip. (WHO Basic lab methods in Medical Parasitology)

The advantages of this method are that it will recover most ova, cysts and larvae and retain their morphology (thus facilitating identification). It has the disadvantage of destroying trophozoite stages and distorting cellular exudate. Liquid feces do not concentrate well, thus it is necessary in these cases to examine the stool by direct microscopy. Since the sieves are not disposable there is a problem with cleaning for re-use. The system is also open so there is a biohazard and odor issue.

Flotation Method

This technique is predominantly used in veterinary laboratories. By exploiting the density of the parasites, particularly eggs, it allows the parasites to float to the top of a dense solution (final specific gravity of about 1.20) and can then be skimmed from the top of the tube. The most commonly used reagent is zinc sulphate. Operculated eggs as well as schistosome and infertile Ascaris eggs are not easily recovered by this method. Also trophozoites are killed due to the high specific gravity and certain other fragile eggs such as *Hymenolepis nana* become distorted.

1. Crush 10-20g (about 1 teaspoon) of feces with applicator sticks and mix well with 10-12ml of saline. Filter the mixture through two layers of dampened surgical gauze into a 15ml conical centrifuge tube.
2. Centrifuge the suspension at 1500 rpm for five minutes. Decant the supernatant into disinfectant. Resuspend the sediment and recentrifuge in saline if there is excessive debris in the sample.
3. Resuspend and thoroughly mix the sediment in 12ml of zinc sulphate solution (specific gravity, 1.18 to 1.20, as verified with a hydrometer).
4. Centrifuge for one minute at 2500 rpm. Place tube in a rack in a vertical position and slowly add enough zinc sulphate with a dropper pipette to fill the tube so that an inverted meniscus forms.
5. Without shaking the tube, carefully place a 22 x 22µm coverslip on top of the tube so that its underside rests on the meniscus. The meniscus should not be so high that fluid runs down the side of the tube carrying parasites away from the cover glass.
6. Allow the tube to stand vertically in a rack with the coverslip suspended on top for ten minutes.
7. Carefully lift the coverslip with its hanging drop containing parasite eggs and cysts on the underside and mount on a clean slide, liquid side down. A small drop of iodine stain may be placed on the slide prior to adding the coverslip. The slide is gently rotated after adding the coverslip to ensure a uniform mixture. The slide is then thoroughly examined microscopically. (Clinical Laboratory procedures)

Chapter 2.

The Ciliates, Coccidia, and Microsporidia

2.1 Infections Acquired Through the Gastrointestinal Tract

In vertebrates, by far the most favorable sites for intestinal parasites are the duodenum, ileum, cecum and large intestine. To survive to reproduce in the gastrointestinal tract the parasites have to adapt to continuous physiological changes relative to the feeding habits of the host, the battery of protein, fat and carbohydrate-splitting enzymes, pH changes and the almost oxygen-free environment. Despite these features many parasites, both protozoa and helminths are capable of colonizing the gastrointestinal tract successfully.

Protozoa are single-celled animals which resemble a single cell of a higher organism. However, the protozoan cell is capable of carrying out vital functions such as reproduction, feeding, and locomotion. Intestinal protozoa include species which can live in the lumen of the intestine and others which additionally live and reproduce in the cells of the intestinal walls.

The protozoa make up a wide spectrum of organisms which have different life cycles and variable characteristics.

The Ciliates

2.2 The Parasites

The ciliates belong to the family Ciliophora. They possess simple cilia or compound ciliary organelles, two types of nuclei and a large contractile vacuole. The only member of the ciliate family to cause human disease is *Balantidium coli*.

Balantidium coli

Introduction

Balantidium coli is widely distributed in warmer climates, which is where human infections most commonly occur. The organisms inhabit the large intestine, cecum and terminal ileum where they feed on bacteria. The most common hosts being humans, pigs and rodents. Human infection is usually from pigs and is rare.

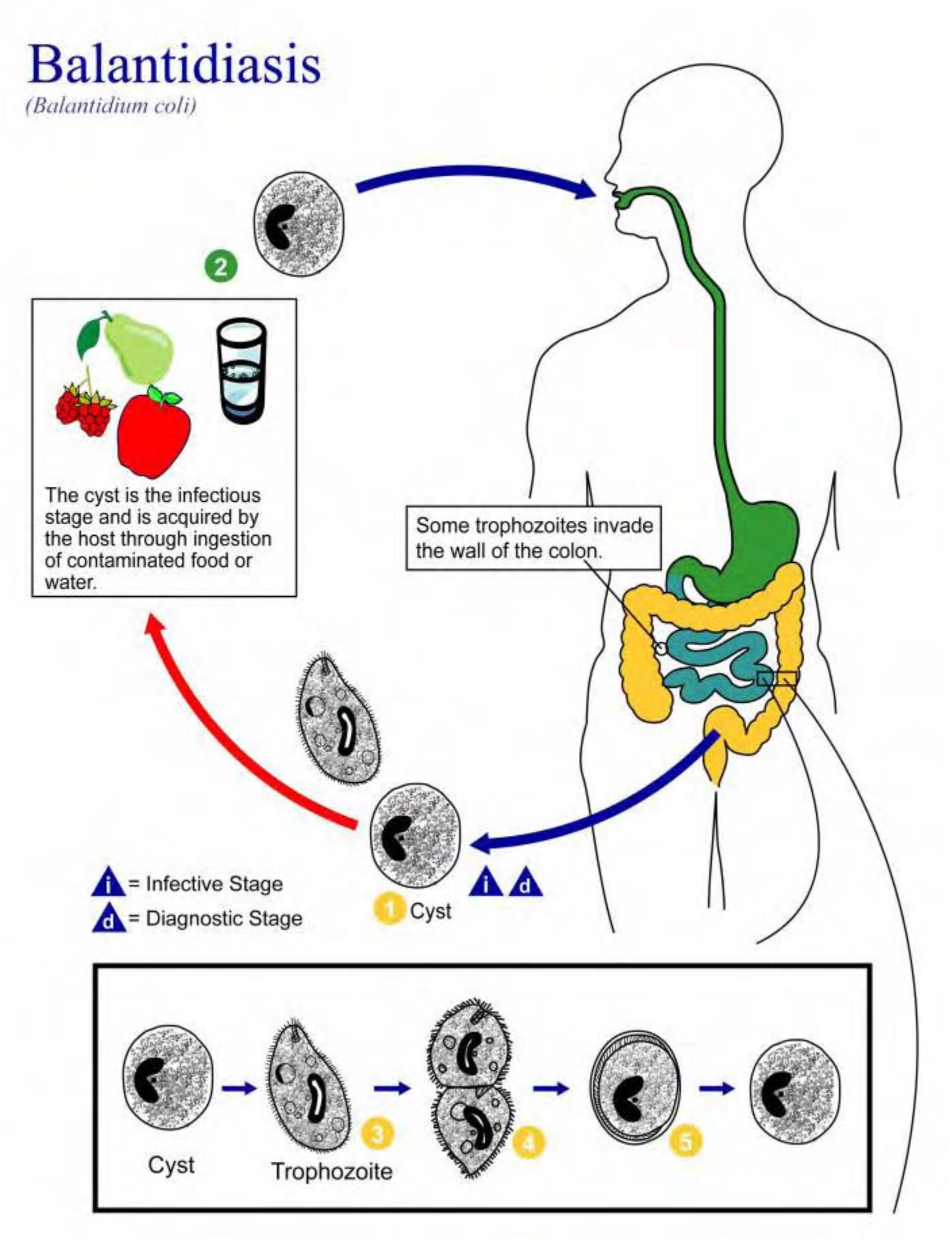
Balantidiasis
(Balantidium coli)
2
The cyst is the infectious stage and is acquired by the host through ingestion of contaminated food or water.
Some trophozoites invade the wall of the colon.
i = Infective Stage
d = Diagnostic Stage
i d
1 Cyst
Cyst
Trophozoite
3
4
5

Illustration 2-1. Life cycle of *Balantidium coli*. (SOURCE: PHIL 3380 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology of the Cyst

The cyst is spherical or ellipsoid and measures from 30-200µm by 20-120µm. It contains 1 macro and 1 micronucleus. The cilia are present in young cysts and may be seen slowly rotating, but after prolonged encystment, the cilia disappear. Cysts form when diarrhea subsides and the rectal contents become formed. The cyst, ingested by a fresh host, excysts to liberate the trophozoite.

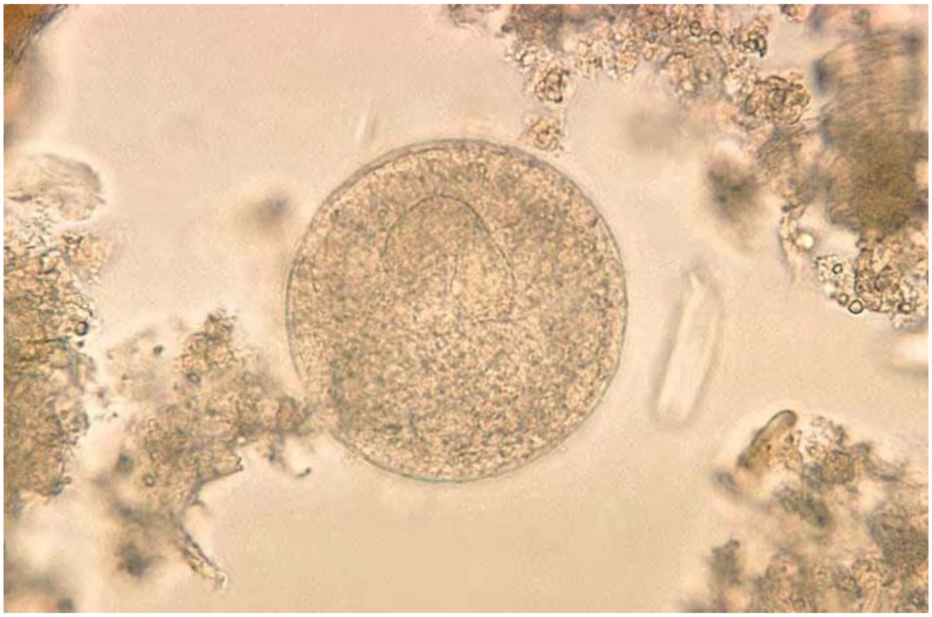

Image 2-1. *Balantidium coli* cyst. (SOURCE: PHIL 584 - CDC/Dr. L.L.A. Moore, Jr.)

Morphology of the Trophozoite

Trophozoites of *B. coli* measure approximately 30-150µm in length x 25-120µm in width but have been known to attain lengths of up to 200µm. They are oval in shape and covered in short cilia. A funnel shaped cytosome can be seen near the anterior end. Multiplication is by binary fission in the trophozoite stage. In an unstained preparation, the organisms are easily recognized because of their size and rapid revolving rotation. In a stained preparation, the characteristic macro and micronuclei may be observed.

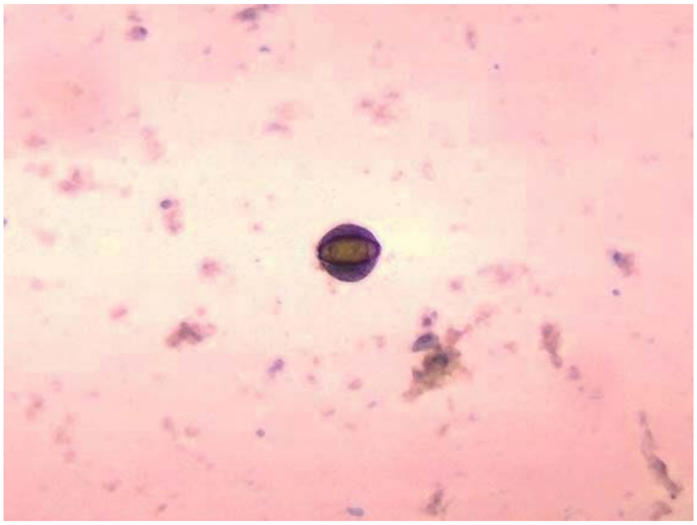

Image 2-2. *Balantidium coli* cyst with *Trichuris* egg inside. Unstained wet mount. (SOURCE: PHIL 1460 - CDC/Dr. Mae Melvin)

Clinical Disease

Severe *B. coli* infections may resemble amebiasis. Symptoms include diarrhea, nausea, vomiting, and anorexia. The diarrhea may persist for long periods of time resulting in acute fluid loss. *Balantidium coli* also has the potential to penetrate the mucosa resulting in ulceration just as those of *Entamoeba histolytica,* but perforation is more common. Metastatic lesions do not occur. Extra-intestinal disease has also been reported, but is rare.

Laboratory Diagnosis

Wet preparations of fresh and concentrated stool samples reveal the characteristic cysts and motile trophozoites. They are easier to identify in direct-smear saline preparations than permanently stained fecal smears.

The Coccidia

The Coccidia are a group of organisms which parasitize the epithelial cells of the intestinal tract. This group includes *Cryptosporidium parvum, Cyclospora cayetanensis* and *Isospora belli*. Most of the coccidian infections in man are zoonoses (having the potential to infect animals or arise from animals). In immunocompetent individuals, they usually produce mild, self-limiting infections.

Cryptosporidium parvum

Introduction

Cryptosporidium species, are coccidian protozoa, which are cosmopolitan in distribution, occurring in both developed and underdeveloped countries and causing infection in both humans and their livestock. *Cryptosporidium parvum* is the species responsible for human infection.

Development of *Cryptosporidia* occurs in a parasitophorous vacuole located on the microvillous surface of the epithelial cells.

Life Cycle and Morphology

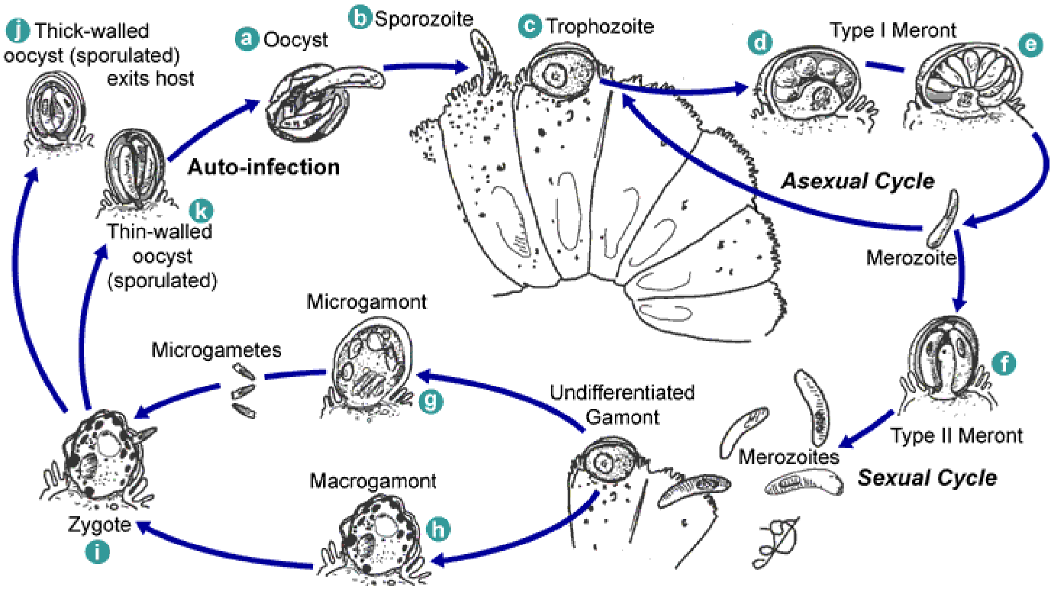
j Thick-walled oocyst (sporulated) exits host
a Oocyst
b Sporozoite
c Trophozoite
d
Type I Meront
e
Auto-infection
Asexual Cycle
k
Thin-walled oocyst (sporulated)
Merozoite
Microgamont
Microgametes
g
f
Undifferentiated Gamont
Type II Meront
Merozoites
Sexual Cycle
Macrogamont
h
Zygote
i

Illustration 2-2. Life cycle of *Cryptosporidium* **sp.** Sporulated oocysts, containing 4 sporozoites, are excreted by the infected host through feces and possibly other routes such as respiratory secretions. Following ingestion (and possibly inhalation) by a suitable host, excystation ⓐoccurs. The sporozoites are released and parasitize epithelial cells (ⓑ, ⓒ) of the gastrointestinal tract or other tissues such as the respiratory tract. In these cells, the parasites undergo asexual multiplication (schizogony or merogony) (ⓓ, ⓔ, ⓕ) and then sexual multiplication (gametogony) producing microgamonts (male) ⓖand macrogamonts (female) ⓗ. Upon fertilization of the macrogamonts by the microgametes (ⓘ), oocysts (ⓙ, ⓚ) develop that sporulate in the infected host. Two different types of oocysts are produced, the thick-walled, which is commonly excreted from the host ⓙ, and the thin-walled oocyst ⓚ, which is primarily involved in autoinfection. Oocysts (measuring 4-5µm in diameter and containing 4 sporozoites) are infective upon excretion, thus permitting direct and immediate fecal-oral transmission. (SOURCE: PHIL 3386 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Clinical Disease

C. parvum is now widely recognized as a cause of acute gastro-enteritis, particularly in children. The infection produces a persistent, watery, offensive diarrhea often accompanied by abdominal pain, nausea, vomiting and anorexia. In immunocompetent persons, symptoms are usually short lived (one to two weeks). The small intestine is the site most commonly affected, symptomatic *Cryptosporidium* infections have also been found in other organs including other digestive tract organs, the lungs, and possibly conjunctiva.

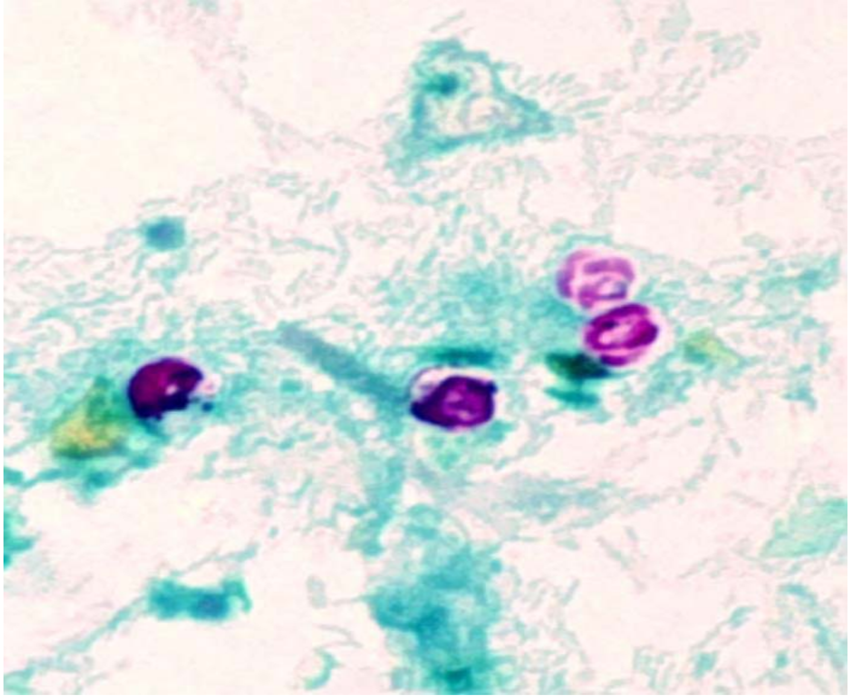

Image 2-3. *Cryptosporidium parvum* oocysts. This photomicrograph revealed the morphologic details of *Cryptosporidium parvum* oocysts, i.e., encapsulated zygotes, which had been stained using the modified acid-fast method. These oocysts exhibit a bright red coloration when using this staining technique, and in this case, you'll note the sporozoites that were made visible inside the two oocysts on the right. Sporozoites are the nucleated, motile stage of development through which many protozoans pass such as *C. parvum*, on their way to becoming adults, and represent a very infectious form of these organisms. The sporozoites will be released from these *C. parvum* oocysts. (SOURCE: PHIL 7829 - CDC/ DPDx - Melanie Moser)

Cryptosporidiosis in immunocompromised individuals, especially in HIV patients, can be life threatening, as many as 10% may pass oocysts of *C. parvum*. Infections are characterized by the production of frequent, large volume watery stools and sometimes there is invasion of the pancreas, biliary or respiratory tract.

Oocyst excretion and symptoms may fluctuate during the course of infection. Asymptomatic infections are commonly found in developing countries with poor hygiene, where there is close contact with livestock.

Laboratory Diagnosis

Definitive diagnosis of cryptosporidiosis is by finding the characteristic spherical oocysts in fecal samples. They do not concentrate well using standard concentration techniques and are identified using various staining techniques.

Using the modified Ziehl-Neelsen staining method (fuschin followed by methylene blue), the oocysts are acid fast. However, staining results within a smear and between specimens are diverse, varying from unstained to partial red staining and complete staining. Fully sporulated forms can be seen in which the red staining sporozoites are within an unstained oocyst wall. When staining the fecal smear with phenol-auramine/carbol-fuchsin, the oocysts appear as bright yellow discs with an "erythrocyte" pattern of staining against a dark red background. Detection of the oocysts can also be achieved by using specific polyclonal or monoclonal antibodies conjugated to fluorescein. These tests are now commercially available and offer a high degree of sensitivity. However, caution must be exercised when they are used to detect oocysts in the fecal smears distributed by NEQAS parasitology. Such specimens are preserved in formalin, which interferes with the fluorescent staining of the parasites, and are thus difficult to detect.

Oocysts in stool specimens (fresh or in storage media) remain infective for extended periods. Thus stool specimens should be preserved in 10% buffered formalin or sodium acetate-acetic acid-formalin (SAF) to render oocysts non-viable. (Contact time with formalin necessary to kill oocysts is not clear; we suggest at least 18 to 24 hours).

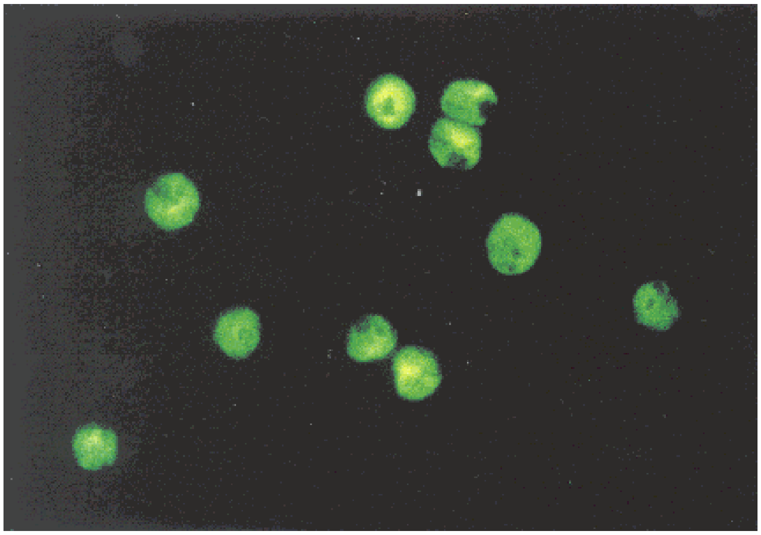

Image 2-4. Staining of *Cryptosporidium parvum* oocysts in a stool smear with monoclonal antibodies conjugated to fluorescein. The *Cryptosporidium* oocysts appear with a peripheral green fluorescence. This technique could be of interest in epidemiological inquiries. (x 670) (SOURCE: Unknown)

Detection of the oocysts can also be achieved by using rapid antigen detection testing kits that specifically detect antigen released by *Cryptosporidium parvu.* These tests are now commercially available and offer a high degree of sensitivity even on specimens that are preserved.

Isospora belli

Introduction

Isospora belli is a coccidian protozoan of cosmopolitan distribution, occurring especially in warm regions of the world infecting both humans and animals.

Life Cycle

The life cycle of *I. belli* involves an asexual (schizogonic stage) and a sexual (sporogonic stage).

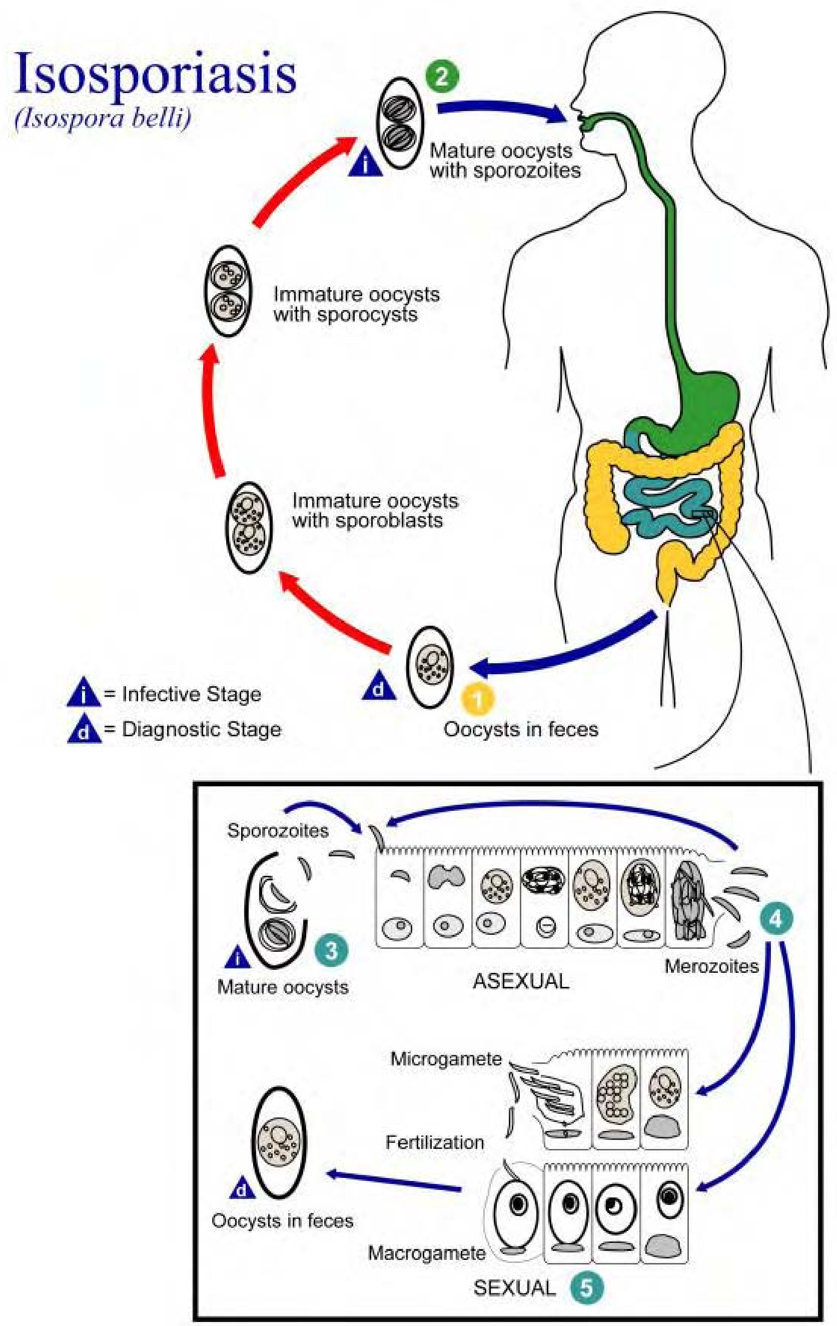
Isosporiasis
(Isospora belli)
②
i
Mature oocysts with sporozoites
Immature oocysts with sporocysts
Immature oocysts with sporoblasts
i = Infective Stage
d = Diagnostic Stage
d
①
Oocysts in feces
Sporozoites
i
③
Mature oocysts
ASEXUAL
Merozoites
④
Microgamete
Fertilization
d
Oocysts in feces
Macrogamete
SEXUAL ⑤

Illustration 2-3. *Isospora belli* life cycle. At time of excretion, the immature oocyst contains usually one sporoblast (more rarely two) ①. In further maturation after excretion, the sporoblast divides in two (the oocyst now contains two sporoblasts); the sporoblasts secrete a cyst wall, thus becoming sporocysts; and the sporocysts divide twice to produce four sporozoites each ②. Infection occurs by ingestion of sporocysts-containing oocysts: the sporocysts excyst in the small intestine and release their sporozoites, which invade the epithelial cells and initiate schizogony ③. Upon rupture of the schizonts, the merozoites are released, invade new epithelial cells, and continue the cycle of asexual multiplication ④. Trophozoites develop into schizonts which contain multiple merozoites. After a minimum of one week, the sexual stage begins with the development of male and female gametocytes ⑤. Fertilization results in the development of oocysts that are excreted in the stool ①. *Isospora belli* infects both humans and animals. (SOURCE: PHIL 3398 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology

Infection with *Isospora belli* occurs in both immunocompetent and immunocompromised patients and begins when the mature oocyst is ingested in water or food.

Morphology of oocysts. The mature oocyst contains 2 sporocysts, each containing 4 sporozoites measure on average 35 x 9µm.

Figures 6. and 7. demonstrate fecal smears of oocysts. The sporulated oocyst is the infective stage of the parasite and they excyst in the small intestine releasing sporozoites which penetrate the epithelial cells, thus initiating the asexual stage of the life cycle. The sporozoite develops in the epithelial cell to form a schizont, which ruptures the epithelial cell containing it, liberating merozoites into the lumen. These merozoites will then infect new epithelial cells and the process of asexual reproduction in the intestine proceeds. Some of the merozoites form macrogametes and microgametes (sexual stages) which fuse to form a zygote maturing finally to form an oocyst.

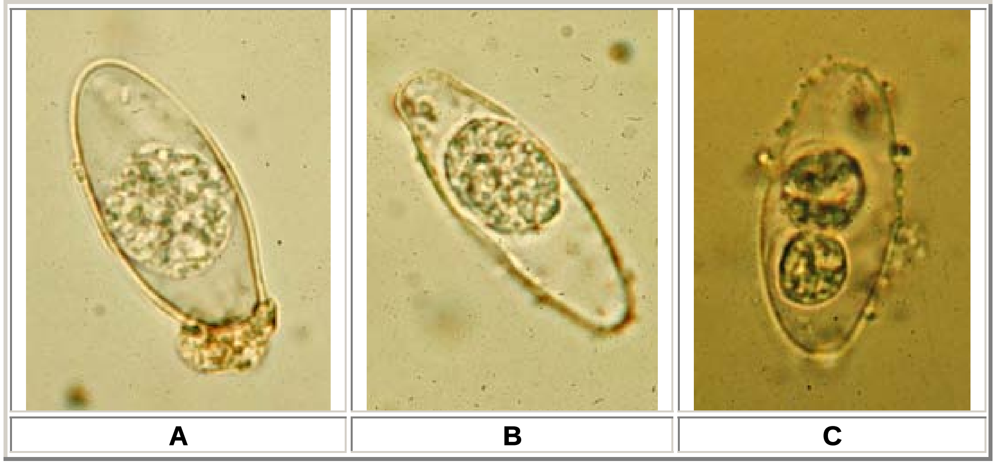

Image 2-5. A, B, C: Oocysts of *Isospora belli*. The oocysts are large (25 to 30 µm) and have a typical ellipsoidal shape. When excreted, they are immature and contain one sporoblast (**A**, **B**). The oocyst matures after excretion: the single sporoblast divides in two sporoblasts (**C**), which develop cyst walls, becoming sporocysts, which eventually contain four sporozoites each. (Images contributed by Georgia Division of Public Health. (CDC))

Clinical Disease

In the immunocompetent, infection is generally asymptomatic or a self-limiting gastro-enteritis. However, in chronic infections, severe non-bloody diarrhea with cramp-like abdominal pain can last for weeks and result in fat malabsorption and weight loss. Eosinophilia may be present (atypical of other protozoal infections).

In immunocompromised individuals, infants and children, infection ranges from self-limiting enteritis to severe diarrheal illness resembling that of cryptosporidiosis.

Laboratory Diagnosis

Oocysts are thin walled, transparent and ovoid in shape. They can be demonstrated in feces after a formal ether concentration where they appear as translucent, oval structures.

Alternatively, oocysts can be seen in a fecal smear stained by a modified Ziehl-Neelsen method, where they stain a granular red color against a green background, or by phenol-auramine.

Cyclospora cayetanensis

Introduction

Cyclospora cayetanensis, a coccidian protozoan, has been described in association with diarrheal illness in various countries, in particular Nepal, Pakistan and India. Infection results in a disease with non-specific symptoms. Quite often the disease is the cause of unexplained summer diarrheal illness and similar illness following travel to tropical areas.

Life Cycle and Morphology

The life cycle of this organism is unknown, however environmental data suggest that *Cyclospora*, like *Cryptosporidium* species, is a water-borne parasite. The oocysts of *C. cayetanensis* are spherical, measuring 8-10µm in diameter and the mature oocyst contains 2 sporocysts. Oocysts of *Cyclospora cayetanensis*, are twice as large in comparison with *C. parvum* and are not sporulated (do not contain sporocysts - upon excretion).

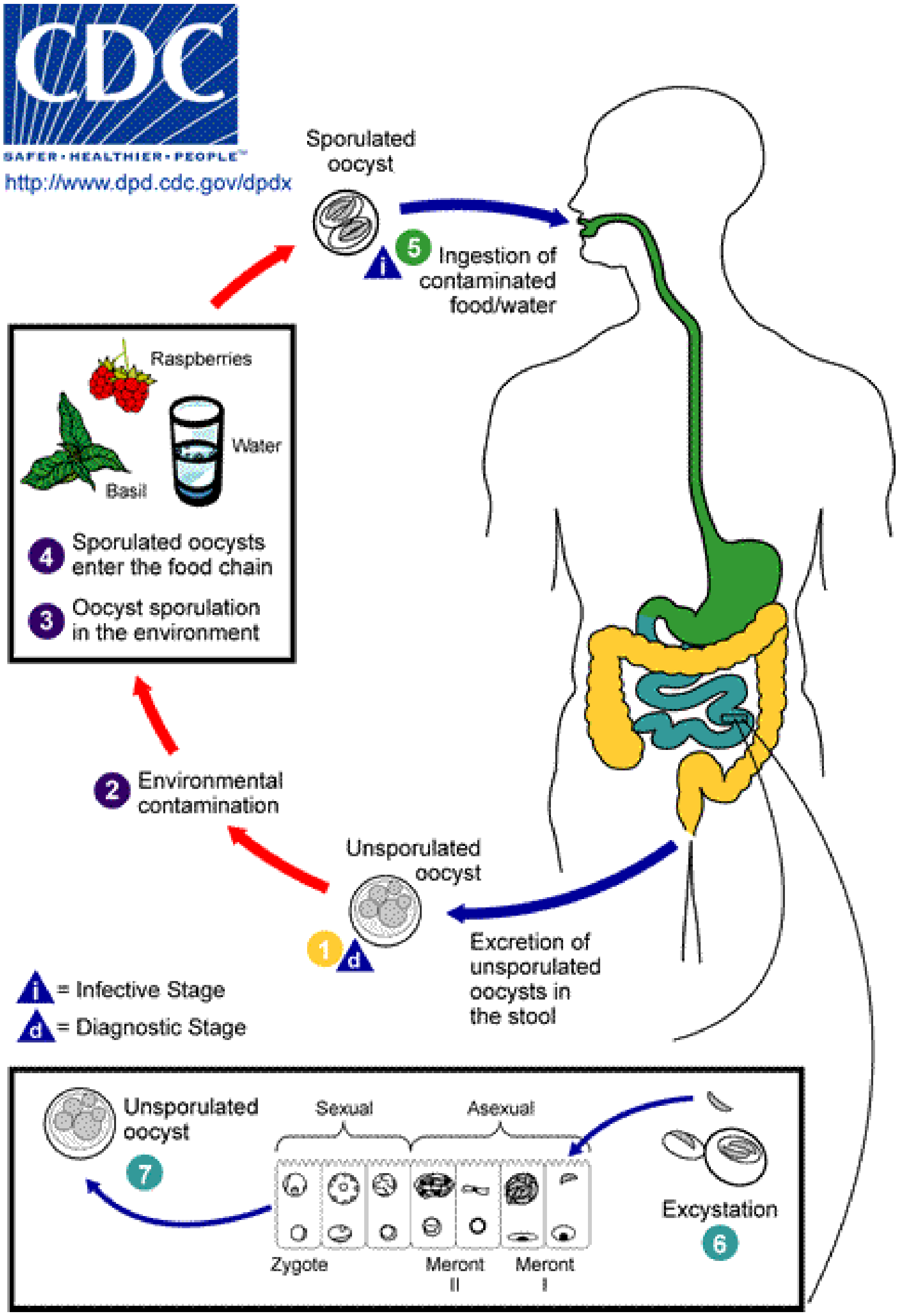
CDC
SAFER · HEALTHIER · PEOPLE™
http://www.dpd.cdc.gov/dpdx
Sporulated oocyst
i
5 Ingestion of contaminated food/water
Raspberries
Water
Basil
4 Sporulated oocysts enter the food chain
3 Oocyst sporulation in the environment
2 Environmental contamination
Unsporulated oocyst
1 d
Excretion of unsporulated oocysts in the stool
i = Infective Stage
d = Diagnostic Stage
Unsporulated oocyst
7
Sexual
Asexual
Zygote
Meront II
Meront I
Excystation
6

Some of the elements in this figure were created based on an illustration by Ortega et al. *Cyclospora cayetanensis*. In: Advances in Parasitology: opportunistic protozoa in humans. San Diego: Academic Press; 1998. p. 399-418.

Illustration 2-4. When freshly passed in stools, the oocyst is not infective ①(thus, direct fecal-oral transmission cannot occur; this differentiates *Cyclospora* from another important coccidian parasite, *Cryptosporidium*). In the environment ②, sporulation occurs after days or weeks at temperatures between 22°C to 32°C, resulting in division of the sporont into two sporocysts, each containing two elongate sporozoites ③. Fresh produce and water can serve as vehicles for transmission ④and the sporulated oocysts are ingested (in contaminated food or water) ⑤. The oocysts excyst in the gastrointestinal tract, freeing the sporozoites which invade the epithelial cells of the small intestine ⑥. Inside the cells they undergo asexual multiplication and sexual development to mature into oocysts, which will be shed in stools ⑦. The potential mechanisms of contamination of food and water are still under investigation. (SOURCE: CDC)

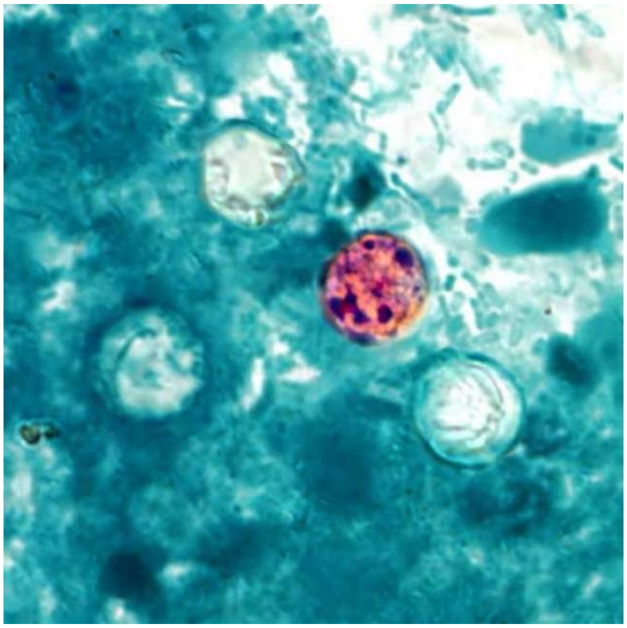

Image 2-6. This photomicrograph of a fresh stool sample, which had been prepared using a 10% formalin solution, and stained with modified acid-fast stain, revealed the presence of four *Cyclospora cayetanensis* oocysts in the field of view. Compared to wet mount preparations, the oocysts are less perfectly round and have a wrinkled appearance due to this method of fixation. Most importantly, the staining is variable among the four oocysts. (SOURCE: PHIL 7827 - CDC/ DPDx - Melanie Moser)

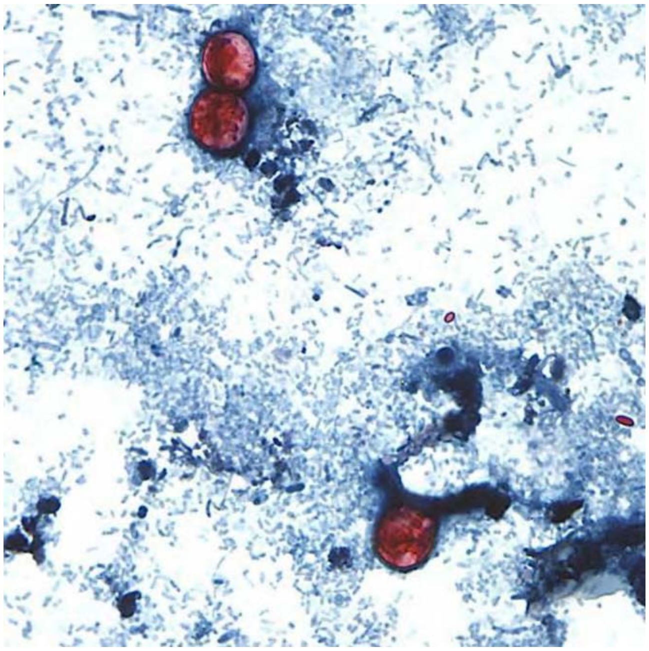

Image 2-7. This photomicrograph of a fresh stool sample, which had been prepared using a 10% formalin solution, and stained with safranin, revealed the presence of three uniformly stained *Cyclospora cayetanensis* oocysts in the field of view. (SOURCE: PHIL 7828 - CDC/ DPDx - Melanie Moser)

Clinical Disease

Patients from whose stools the organism has been isolated have reported nausea, vomiting, weight loss and explosive watery diarrhea. Flatulence and bloatedness, nausea and vomiting, myalgia, low-grade fever, and fatigue are associated symptoms. The site of infection is the small bowel. The disease is usually self-limiting to three to four days but untreated infections can last from several days to a month or longer, and may follow a relapsing course. Some infections are asymptomatic.

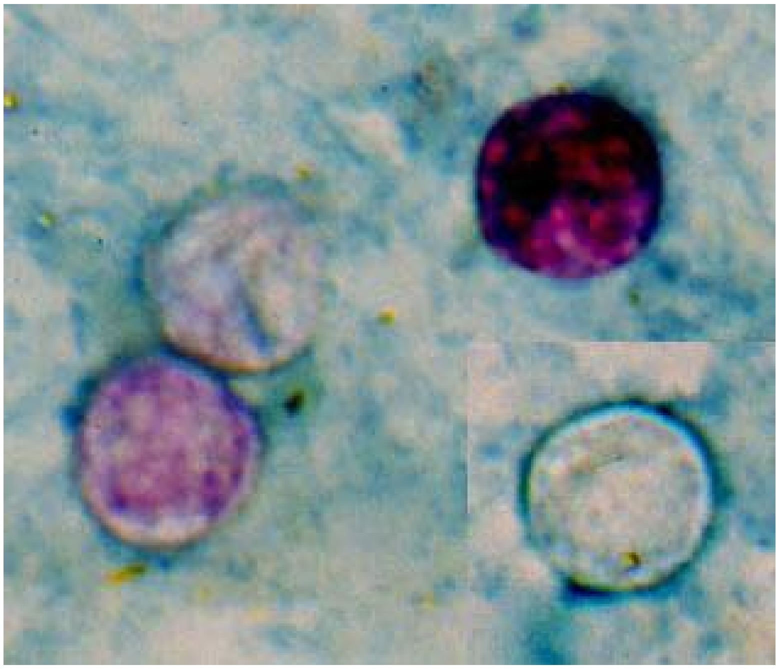

Image 2-8. Four *Cyclospora* oocysts from fresh stool fixed in 10% formalin and stained with modified acid-fast stain. Compared to wet mount preparations, the oocysts are less perfectly round and have a wrinkled appearance. Most importantly, the staining is variable among the four oocysts. (SOURCE: CDC)

Laboratory Diagnosis

The oocysts of *C. cayetanensis* are spherical as can be seen in formol-ether concentrated stool samples by light microscopy. They are refractile spheres which exhibit blue autofluorescence under ultraviolet light. It is important to note that UV microscopes set up for FITC and auramine microscopy only (450-500nm) will fail to detect the autofluorescence of the oocyst. Iodine-quartz microscopes do not produce UV wavelength below 400nm, while both mercury vapor and xenon vapor microscopes must be fitted with a 340-380nm excitation filter to demonstrate autofluorescence.

The oocysts are variably acid-fast when stained by the modified Ziehl-Neelsen method. Some cysts are acid-fast whereas others appear as round holes against a green background. They do not stain well with phenol-auramine.

Microsporidia Species

Introduction

The term microsporidia is also used as a general nomenclature for the obligate intracellular protozoan parasites belonging to the phylum Microsporidia. To date, more than 100 genera and 1,000 species have been described as parasites infecting a wide range of vertebrate and invertebrate hosts. There are at least seven microsporidian species that are well characterized as human pathogens. (**Table 2-1.**)

Microsporidia are characterized by the production of resistant spores and the polar tubule (or polar filament) which is coiled inside the spore as demonstrated by its ultrastructure.

They have recently come to medical attention as opportunistic pathogens in humans with Acquired Immune Deficiency Syndrome (AIDS) and have been implicated in conditions ranging from enteritis to keratoconjunctivitis.

Life Cycle and Morphology

Microsporidia are primitive organisms. They possess no mitochondria and have prokaryotic like ribosomes. Classification is based on the ultrastructural features, which include the number of coils in the polar tubes, the configuration of nuclei and the spore size 1-4µm, depending on the species.

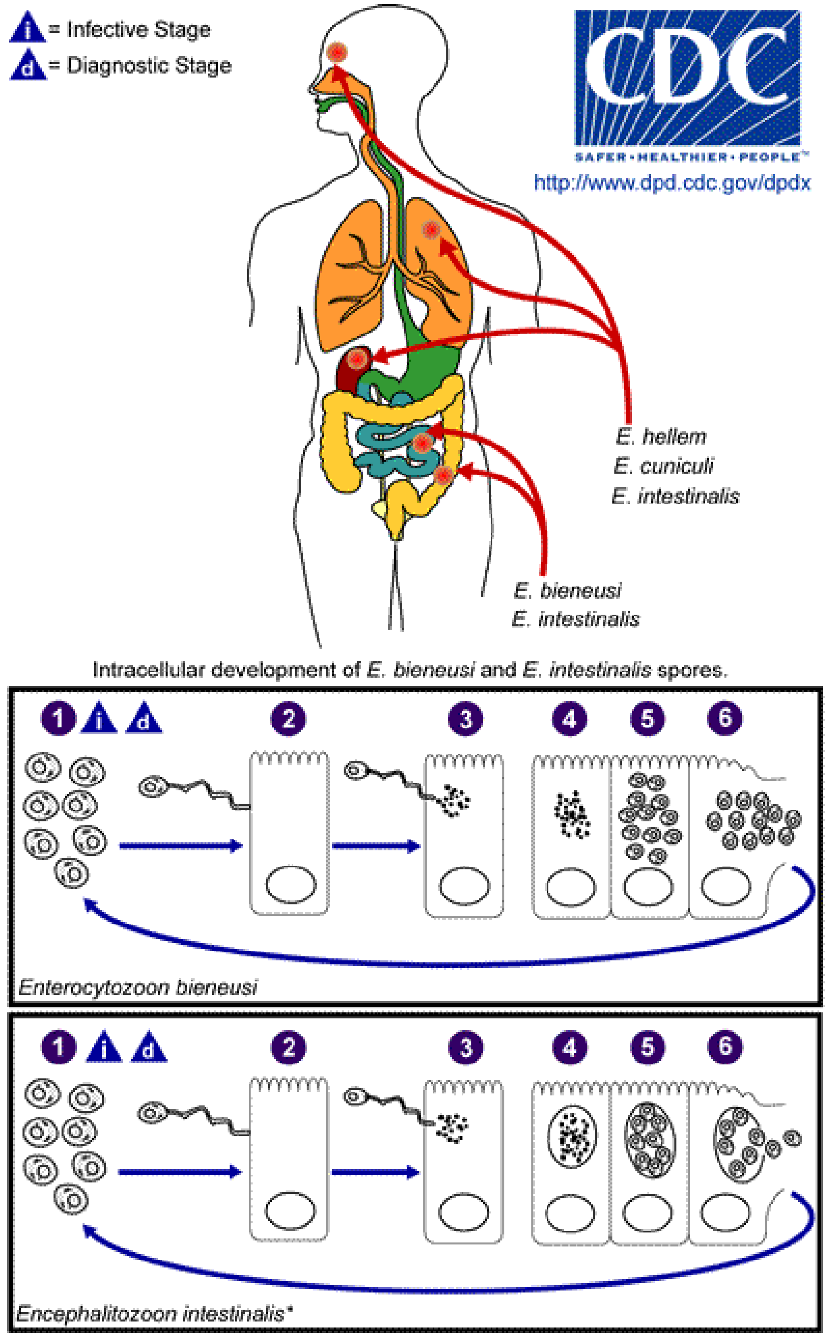
i = Infective Stage
d = Diagnostic Stage
CDC
SAFER • HEALTHIER • PEOPLE™
http://www.dpd.cdc.gov/dpdx
E. hellem
E. cuniculi
E. intestinalis
E. bieneusi
E. intestinalis
Intracellular development of E. bieneusi and E. intestinalis spores.
1 i d
2
3
4
5
6
Enterocytozoon bieneusi
1 i d
2
3
4
5
6
Encephalitozoon intestinalis*

*Development inside parasitophorous vacuole also occurs in *E. hellem* and *E. cuniculi*.

Illustration 2-5. Life cycle of *Microsporidia* **sp.** The infective form of microsporidia is the resistant spore and it can survive for a long time in the environment ❶. The spore extrudes its polar tubule and infects the host cell ❷. The spore injects the infective sporoplasm into the eukaryotic host cell through the polar tubule ❸. Inside the cell, the sporoplasm undergoes extensive multiplication either by merogony (binary fission) or schizogony (multiple fission) ❹. This development can occur either in direct contact with the host cell cytoplasm (e.g., *E. bieneusi*) or inside a vacuole termed parasitophorous vacuole (e.g., *E. intestinalis*). Either free in the cytoplasm or inside a parasitophorous vacuole, microsporidia develop by sporogony to mature spores ❺. During sporogony, a thick wall is formed around the spore, which provides resistance to adverse environmental conditions. When the spores increase in number and completely fill the host cell cytoplasm, the cell membrane is disrupted and releases the spores to the surroundings ❻. These free mature spores can infect new cells thus continuing the cycle. (SOURCE: CDC)

Microsporidia	Size	Associated Disease
Enterocytozoon bieneusi	1µm x 1.5µm	Gastrointestinal and biliary tract infections
Encephalitozoon intestinalis	1.5µm x 2.5µm	Gastrointestinal tract and systemic infections
Encephalitozoon hellem	1.5µm x 1µm	Keratopathy (corneal edema), respiratory tract infection
Encephalitozoon cuniculi	1.5µm x 1µm	Central nervous system disease
Nosema connori	2µm x 4µm	Systemic infections
Nosema corneum	2µm x 4µm	Keratopathy
***Pleistophora* species**	2.8µm x 3.4µm	Myositis

Table 2-1. Microsporidia found in humans and their associated disease. (Cuomo)

In addition to the species in **Table 2-1.**, above, there are other, not well-characterized microsporidian human pathogens. These are designated as Microsporidum, a collective taxon that includes *Microsporidum africanum* and *Microsporidium ceylonensis.*

Clinical Disease

The most common microsporeans found in patients with AIDS are *Enterocytozoon bieneusi, Encephalitozoon intestinalis* and *Encephalitozoon hellem*. Patients with these infections tend to be severely immunodeficient with a CD4 count less than 100 x 10^6/L. Additionally, cases of microsporidiosis have been reported in immunocompromised persons not infected with HIV and in immunocompetent individuals. The clinical manifestations of microsporidiosis are very diverse, varying according to the causal species, with diarrhea being the most common.

Enterocytozoon bieneusi

Infections with *E. bieneusi* are restricted to the enterocytes of the small intestine, resulting in villous atrophy and malabsorption. Clinical symptoms include chronic watery, non-bloody diarrhea, malaise and weight loss.

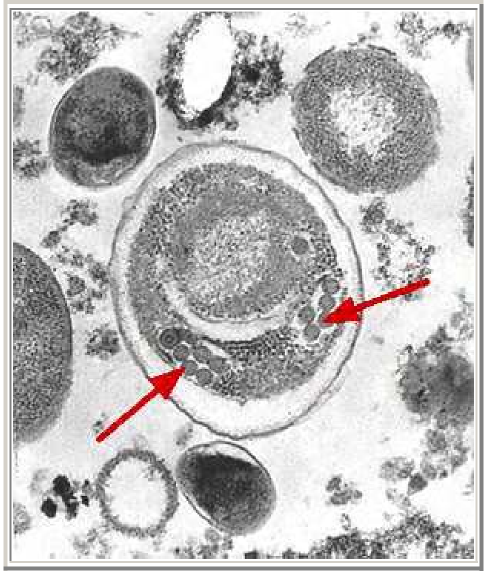

Image 2-9. Electron micrograph of an *Enterocytozoon bieneusi* spore. Arrows indicate the double rows of polar tubule coils in cross section which characterize a mature *E. bieneusi* spore. (SOURCE: CDC)

Encephalitozoon intestinalis

Infection with *Encephalitozoon intestinalis* occurs in the enterocytes of the small intestine but is more widely disseminated than *E. bieneusi* and has been found in the colon, liver and kidney.

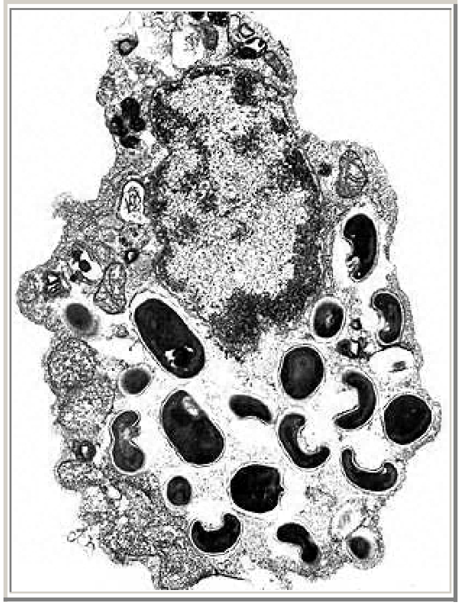

Image 2-10. Electron micrograph of an eukaryotic cell with *Encephalitozoon intestinalis* spores and developing forms inside a septated parasitophorous vacuole. The vacuole is a characteristic feature of this microsporidian species. (SOURCE: CDC)

Encephalitozoon hellem and *Encephalitozoon cuniculi*

These organisms have also been found in disseminated microsporidiosis. Clinical symptoms may include sinusitis, nephritis, hepatitis, keratoconjunctivitis and peritonitis.

Nosema corneum

This organism has been detected in AIDS patients with keratoconjunctivitis.

Laboratory Diagnosis

Initially, the diagnosis of intestinal microsporidiosis depended on tissue biopsies which were stained with Gram's stain and examined by light microscopy. However, in order that ill patients were not subjected to unnecessary invasive procedures, non-invasive diagnostic procedures were developed. The modified Trichrome stain and the Fungiqual fluorescent stain are the stains of choice. Immunofluorescence assays (IFA) using monoclonal and/or polyclonal antibodies are being developed for the identification of microsporidia in clinical samples.

2.3 Examination of fecal specimens for Parasites

Many intestinal disorders are due to intestinal parasites which cannot be diagnosed symptomatically. Laboratory investigation is therefore required and the staff responsible should have adequate expertise in examining fecal specimens for parasitic organisms.

2.4 Relevant information required

The request form should always state the patients clinical symptoms and signs and whether the patient had recent overseas travel. If the patient has had no recent history of overseas travel, examination for *Cryptosporidium, Giardia* and Microsporidia, if immunocompromised should be considered. If overseas travel has been undertaken, it is important to note is the patient ill or whether a routine post-tropical screen is requested. The geographical location is also important as it may indicate these parasites which could be present.

2.5 Collection of samples

If a fecal sample is not properly collected and taken care of before examination, it will be of little or no value for accurate diagnosis. This is especially true if protozoa are present. Amoebic trophozoites begin to degenerate one to two hours after passage, as do flagellate trophozoites. Cysts will deteriorate if the fecal specimen is left standing for many hours or overnight, especially at high temperatures.

Helminth eggs and larvae are less affected by the age of the specimen than are protozoa. Nevertheless, changes may occur that could affect their identification; hookworm larvae may become embryonated and larvae may hatch from the eggs risking confusion with *Strongyloides* larvae. Larvae themselves may disintegrate thus making their identification difficult.

To ensure that good specimens are provided for examination, it is important to note the following points.

1. A clean dry container must be used for the collection of fecal samples. Urine and water will destroy trophozoites, if present, and the presence of dirt also causes identification problems.
2. Ideally the specimen should be brought to the lab as soon as it is passed, to avoid deterioration of protozoa and alterations of the morphology of protozoa and helminths.
3. The specimen container should be clearly labeled with the patient's name, date, and time of passage of the specimen.
4. An amount of stool adequate for parasite examination should be collected and a repeat sample requested if too little is supplied. The smallest quantity that should be accepted is about the size of a pigeon's egg.
5. Diarrheal specimens, or those containing blood and mucus, should be examined promptly on arrival in the laboratory. The specimens may contain motile amoebic or flagellate trophozoites and may round up and thus be missed if examination is delayed. Where amoebic dysentery is suggested, the laboratory should be informed that a "hot stool" is being supplied so that it can be examined within twenty minutes of being passed.
6. With the exception of "hot stools" if specimens cannot be examined as soon as they arrive, they should be put in the refrigerator.

2.6 Visual observation of the fecal sample

It is important to observe the macroscopic appearance of the stool as this can give a clue to the type of organisms present. Therefore the consistency; formed, unformed or liquid; the color and the presence or absence of the exudate are reported. The presence of adult worms can also be seen in a freshly passed stool e.g. adult stage of *Ascaris lumbricoides* and *Enterobius vermicularis*. Proglottids of *Taenia* species can also be seen.

2.7 Routine procedure for the microscopic examination of fecal samples for parasites

1. Direct microscopy should be done on all unformed and liquid samples by mixing a small amount of the specimen in 0.9% sodium chloride solution. This permits detection of trophozoites of *Entamoeba histolytica* and *Giardia lamblia*. It can also provide information on the content of the stool i.e. the presence of leucocytes and red blood cells.
2. A formol-ether concentrate should be done on all fecal samples examined for parasites. This reveals the presence of most protozoan cysts, eggs of nematodes, cestodes and trematodes and also the larval stages of some nematodes.
3. A permanently stained direct fecal smear should be used for all bloody, liquid or semi-formed stools. The smear can reveal the presence of intestinal parasites that can be either destroyed or missed by the formol-ether concentration method e.g. *Dientamoeba fragilis*.
4. Specimens from patients with HIV should be left in 10% formalin for one hour before proceeding with parasite examination.

2.8 Principals of Diagnostic Methods for the Identification of Parasites

The principal of the successful identification of fecal parasites is based upon,

1. Measurement - The use of an eyepiece graticule is of the utmost importance, especially for cyst identification.
2. Morphology - In protozoan cysts, the number of nuclei and the presence of inclusions e.g. glycogen mass and chromidial bar, aid the identification of protozoa. In trophozoites, the presence of red cells in amoebae is diagnostic of *Entamoeba histolytica* and flagella also aid identification of some protozoan trophozoites.
3. Appearance - In helminth eggs, the shape of the egg, the thickness of the shell, the color of the ovum and the presence or absence of features such as an operculum, spine or hooklets are diagnostic pointers to the identity of the parasite.
4. Stains also aid in identification of the parasite.

The addition of iodine to formol ether concentrates highlights the internal structure of cysts and helps distinguish between vegetable matter and cysts. Permanently stained fecal smears are useful in demonstrating the nuclear pattern of cysts.

2.9 Problems of identification

Many things in stool specimens look like parasites but are not.

Epithelial cells and macrophages can be confused with amoebic trophozoites, especially macrophages that show slight amoeboid movement and may contain red blood cells. Pus cells can be confused with amoebic cysts. The nuclei appear as 3 or 4 rings and usually stain heavily. The cytoplasm is ragged and the cell membrane is often not seen. Amoebic cysts have a distinct cell wall.

Hair and fibers may be confused with larvae, but they do not have the same internal structure as larvae.

Plant cells can be confused with cysts or eggs. Though plant cells usually have a thick wall and cysts have a thin wall.

2.10 Reporting of Parasites

Ideally, the presence of all parasites should be reported, whether they are pathogens or non-pathogens. This particularly applies to the presence of cysts. However, if it is laboratory practice to report all cysts, the report should state whether they are pathogenic or non-pathogenic.

The stage of the parasite should always be reported. For the protozoa, whether cysts or trophozoites are present; the stage of larvae as in *Strongyloides;* and whether adult stages or eggs of helminths are present.

Chapter 3.
The Flagellates

3.1 Infections Acquired Through the Gastrointestinal Tract

The Flagellates belong to the Magistophora and possess more than one flagellum. Beating these flagella enable them to move. A cytosome may be present which helps in the identification of the species.

Flagellates possess one advantage over their ameboid relatives in that they can swim. Therefore, enabling them to invade and adapt to a wider range of environments unsuitable for other amoebae. They are able to change from a flagellated free-swimming environment to a non-flagellated tissue dwelling stage and *vice versa*.

Flagellates are known to inhabit the reproductive tract, alimentary canal, tissue sites and also the blood stream, lymph vessels and cerebrospinal canal.

There are pathogenic and commensal species of flagellates. The flagellates which are encountered in the intestinal tract are *Giardia lamblia*, *Dientamoeba fragilis, Chilomastix mesnili, Trichomonas hominis, Retortamonas intestinalis* and *Enteromonas hominis* (the latter two being less common). The trophozoites are easily recognized in saline preparations by their motility. However, accurate identification is done on a permanently stained fecal smear. Cysts are more commonly seen than the trophozoite.

Giardia lamblia

Introduction

Giardia lamblia is a flagellate of world-wide distribution. It is more common in warm climates than temporal climates. It is the most common flagellate of the intestinal tract, causing *Giardiasis*. Humans are the only important reservoir of the infection. The infection is most common in parts of the world where sanitation is at its lowest. *Giardiasis* is an infection of the upper small bowel, which may cause diarrhea. Only *Giardia* spreads disease.

Morphology of the Trophozoites

The trophozoites of *G. lamblia* are flattened pear shaped and are an average size of 15μm long, 9μm wide and 3μm thick. When stained, the trophozoite is seen to have two nuclei, two slender median rods (axostyles), and eight flagella arising from the anterior end. They have been described as looking like tennis rackets without the handle (they are often seen has having a comical face-like appearance when looking at the front view).

The movement of the trophozoites is described as tumbling leaf motility, using their four pairs of flagella for locomotion. They attach themselves to the surface of the jejunal or duodenal mucosa by their disc-like suckers which are found on their ventral surface. They multiply in the gut by binary fission. Once the trophozoites drop off the mucosal surface they are normally carried in the intestinal contents down the gut where they usually encyst.

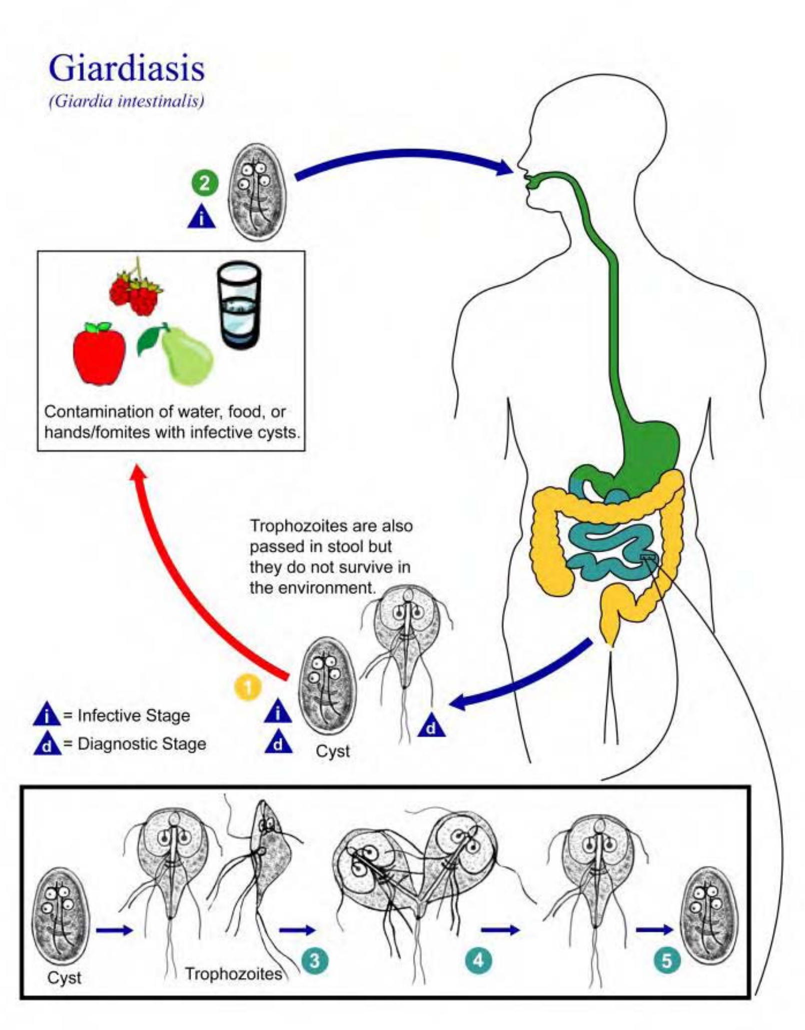
Giardiasis
(Giardia intestinalis)
2
i
Contamination of water, food, or hands/fomites with infective cysts.
Trophozoites are also passed in stool but they do not survive in the environment.
1
i
d
d
Cyst
i = Infective Stage
d = Diagnostic Stage
Cyst
Trophozoites
3
4
5

Illustration 3-1. Life cycle of *Giardia lamblia.* Cysts are resistant forms and are responsible for transmission of Giardiasis. Both cysts and trophozoites can be found in the feces (diagnostic stages) ①. The cysts are hardy and can survive several months in cold water. Infection occurs by the ingestion of cysts in contaminated water, food, or by the fecal-oral route (hands or fomites) ②. In the small intestine, excystation releases trophozoites (each cyst produces two trophozoites) ③. Trophozoites multiply by longitudinal binary fission, remaining in the lumen of the proximal small bowel where they can be free or attached to the mucosa by a ventral sucking disk ④. Encystation occurs as the parasites transit toward the colon. The cyst is the stage found most commonly in nondiarrheal feces ⑤. Because the cysts are infectious when passed in the stool or shortly afterward, person-to-person transmission is possible. While animals are infected with *Giardia*, their importance as a reservoir is unclear. (SOURCE: PHIL 3394 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology of Cysts

The cysts of *G. lamblia* are 8-12µm in length and are ellipsoid in shape. They contain four nuclei which tend not to be obvious. Longitudinal fibrils consisting of the remains of axonemes and parabasal bodies may also be seen. Cysts may appear to shrink from the cell wall. The cysts are infective as soon as they are passed.

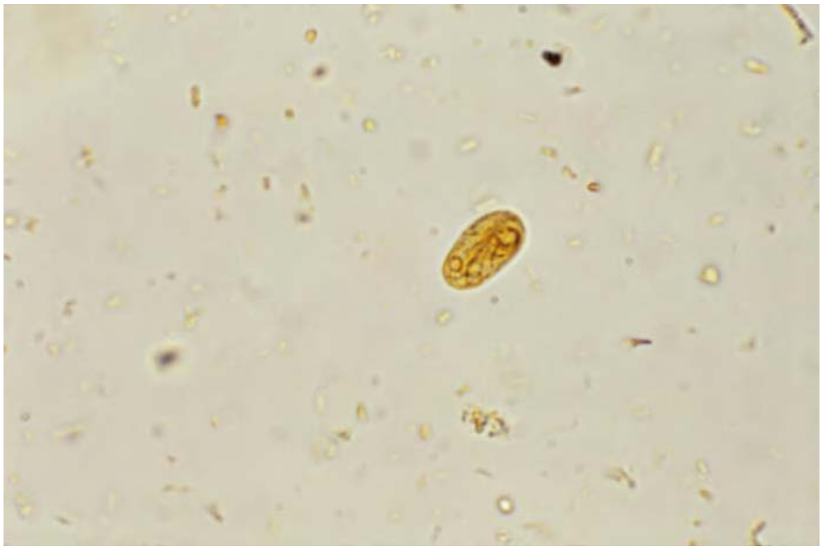

Image 3-1. *Giardia lamblia* cyst iodine stained. (SOURCE: PHIL 3741 – CDC/ Dr. Mae Melvin)

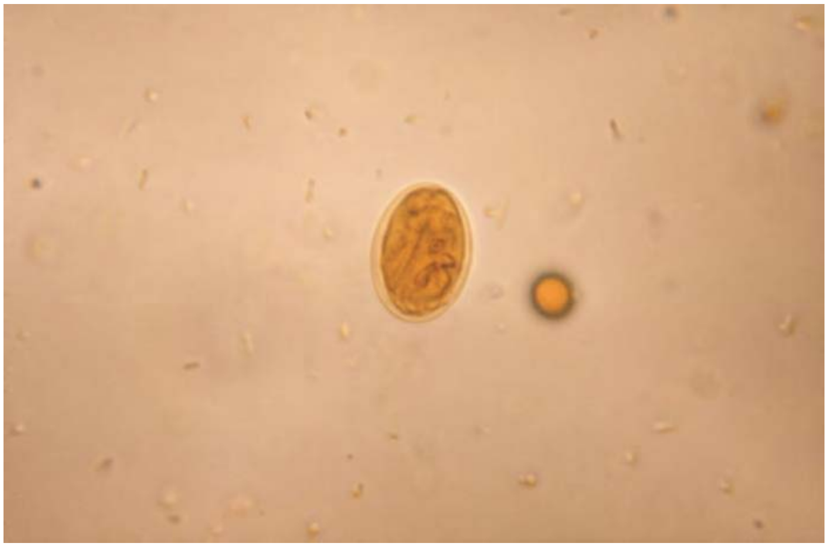

Image 3-2. *Giardia lamblia* cyst iodine stained. (SOURCE: PHIL 3742 – CDC/ Dr. Mae Melvin)

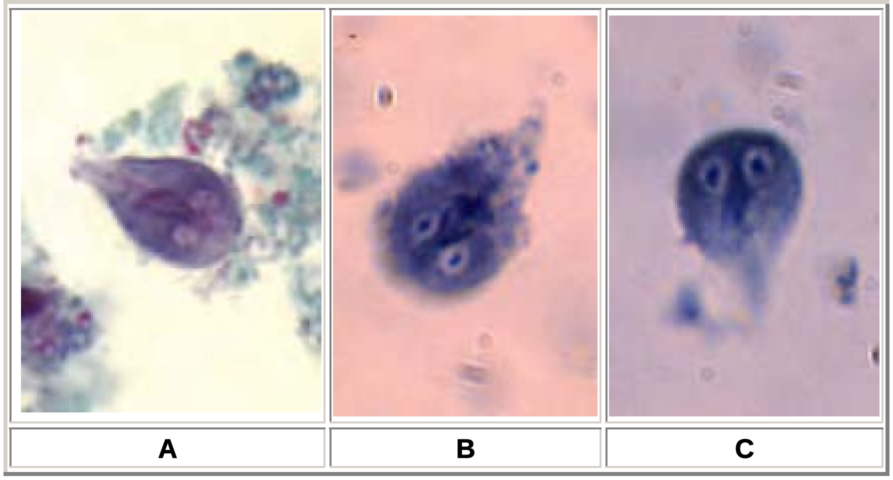

Image 3-3. A, B, C Three trophozoites of *Giardia intestinalis*, stained with trichrome (**A**) and stained with iron hematoxylin (**B** and **C**). Each cell has two nuclei with a large, central karyosome. Cell size: 9 to 21 µm in length. (SOURCE: CDC)

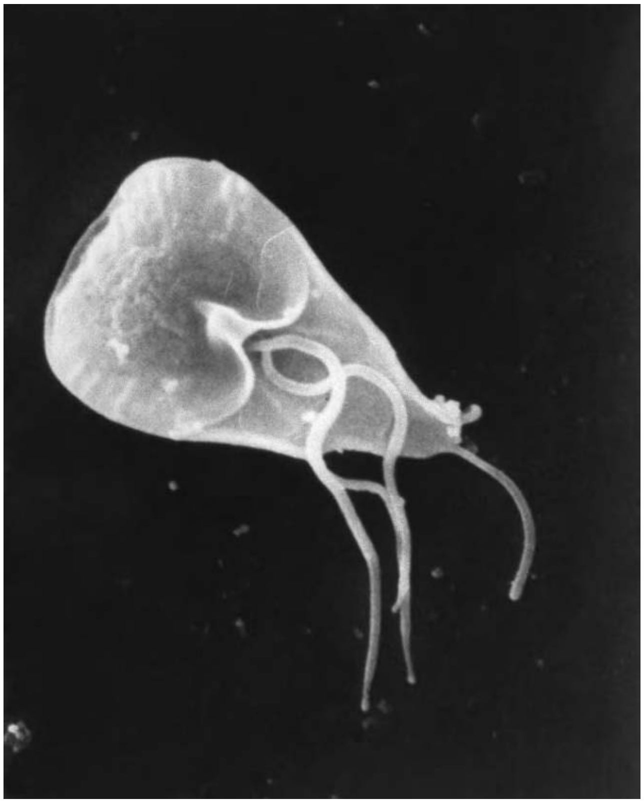

Image 3-4. This scanning electron micrograph (SEM) revealed some of the external ultrastructural details displayed by a flagellated *Giardia lamblia* protozoan parasite. *G. lamblia* is the organism responsible for causing the diarrheal disease "giardiasis". Once an animal or person has been infected with this protozoan, the parasite lives in the intestine, and is passed in the stool. Because the parasite is protected by an outer shell, it can survive outside the body, and in the environment for long periods of time. (SOURCE: PHIL 8698 - CDC / Janice Carr)

Clinical Disease

Giardia lamblia colonizes the small intestine where the trophozoites adhere to the mucosal surface by means of their sucking disc. Cysts are produced as the parasites descend the intestinal tract although trophozoites can be passed in the feces in severe infections. *G. lamblia* is transmitted through ingestion of cysts in contaminated water or food. Cysts can survive outside the body for several weeks under favorable conditions. The main symptoms are abdominal pain, flatulence, and episodic diarrhea with steatorrhea and periodical soreness in severe cases. No blood or mucus is normally seen. However 50% of *G. lamblia* infections are symptomless, although severe infections may develop in immunocompromised hosts. What determines susceptibility is poorly understood. After swallowing cysts for the first time, symptoms commonly develop 2-6 weeks later.

Laboratory Diagnosis

Cysts can be found by examination of the deposit of a formol-ether concentrate of a stool preparation. The oval cysts with thick walls serve as characteristic features for these organisms. (**Keys 3-1. & 3-2.**) The flagella disintegrate and form a central 'streak' which becomes visible when stained with iodine or MIF (merthiolate-iodine-formaldehyde). Cysts may be excreted intermittently; therefore it is important to examine more than one stool. Stools are usually passed 3-8 times / day and are usually pale, offensive, rather bulky and accompanied by much flatus.

Trophozoites are found by examination of saline wet preparations of fresh, diarrheic stool, duodenal or jejunal aspirate or in a permanently stained fecal preparation.

Trophozoites can also be found in the jejunal aspirate. These can be recovered by the String Test or Enterotest capsule and the material examined microscopically for motile trophozoites.

Trophozoites and cysts can be found to be scarce in chronic infections. Serological methods of diagnosis are proving to be useful as means of diagnosis. An ELISA to detect IgM in serum provides evidence of a current infection. A polyclonal antigen-capture ELISA can be used to demonstrate submicroscopic infections in feces and an IgA-based ELISA will detect specific antibodies in saliva. **Table 3-1.** details useful morphological features that are similar between species of flagellate and are used in laboratory diagnosis. Detection of the trophozoites and cysts can also be achieved by using rapid antigen detection testing kits that specifically detect antigen released by *Giardia lamblia.* These tests are now commercially available and offer a high degree of sensitivity even on specimens that are preserved and can be detected days before any trophozoites and cysts are shed.

Dientamoeba fragilis

Introduction

Dientamoeba fragilis is an amoeba-flagellate with a cosmopolitan distribution. The life cycle is not completely known.

Morphology of Trophozoites and Lifecycle

D. fragilis are relatively small, varying from 3-22μm in diameter and there can be considerable variation in size among organisms in the same fecal sample. The organisms have only a trophozoite stage and in a permanently stained preparation, one, two or rarely three nuclei can be seen, two being the most common. The nuclear chromatin is usually fragmented into three to five granules but these have not been visualized by Giemsa Stain, and there is normally no peripheral chromatin on the nuclear membrane. The cytoplasm is usually vacuolated and may contain ingested debris as well as some large uniform granules. The cytoplasm can also appear uniform and clean with a few inclusions. *D. fragilis* live in the lumen of the cecum and upper colon.

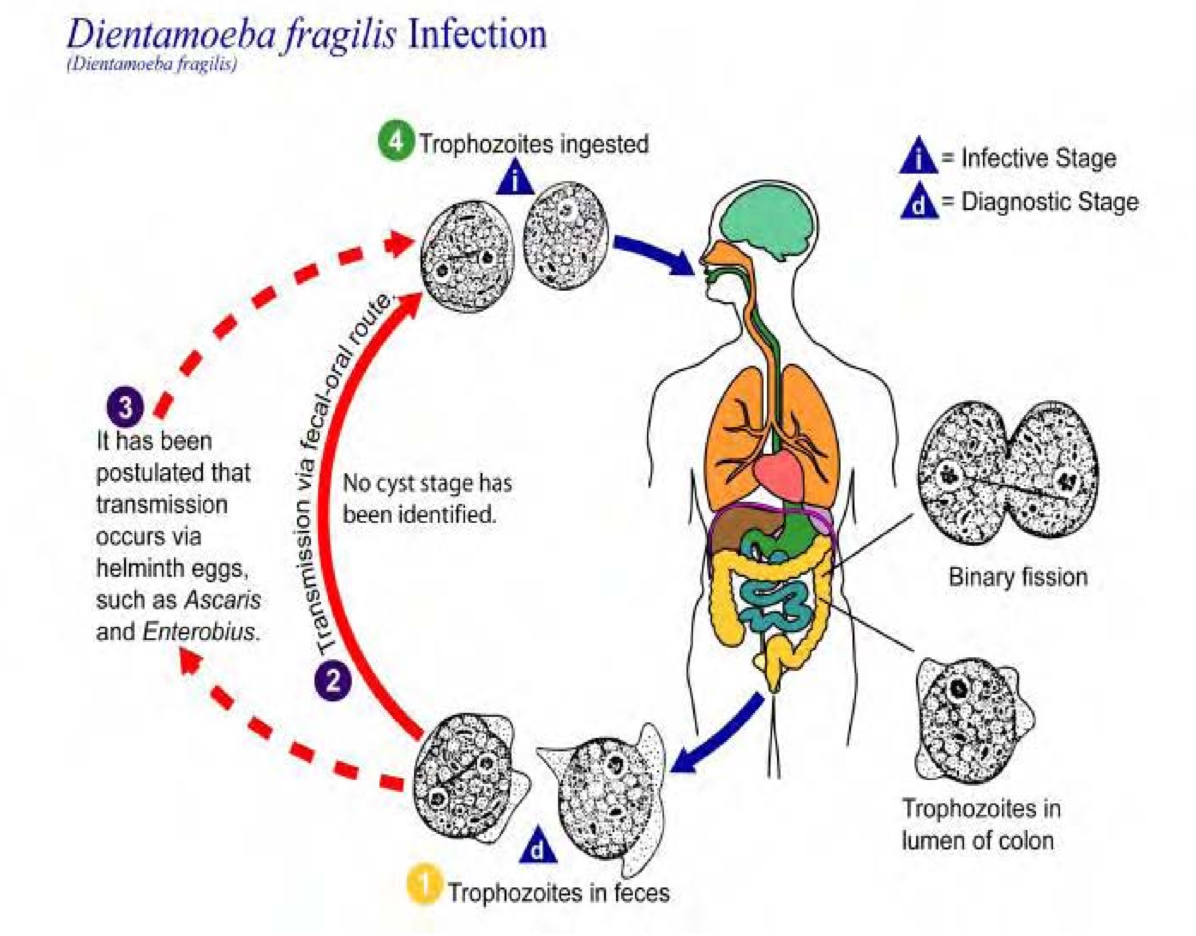
Dientamoeba fragilis Infection
(Dientamoeba fragilis)
4 Trophozoites ingested
i
i = Infective Stage
d = Diagnostic Stage
Transmission via fecal-oral route
3
It has been postulated that transmission occurs via helminth eggs, such as *Ascaris* and *Enterobius*.
No cyst stage has been identified.
Binary fission
2
Trophozoites in lumen of colon
d
1 Trophozoites in feces

Illustration 3-2. This is an illustration of the assumed life cycle of *Dientamoeba fragilis*, the cause of a protozoan parasitic infection. (SOURCE: PHIL 3389 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

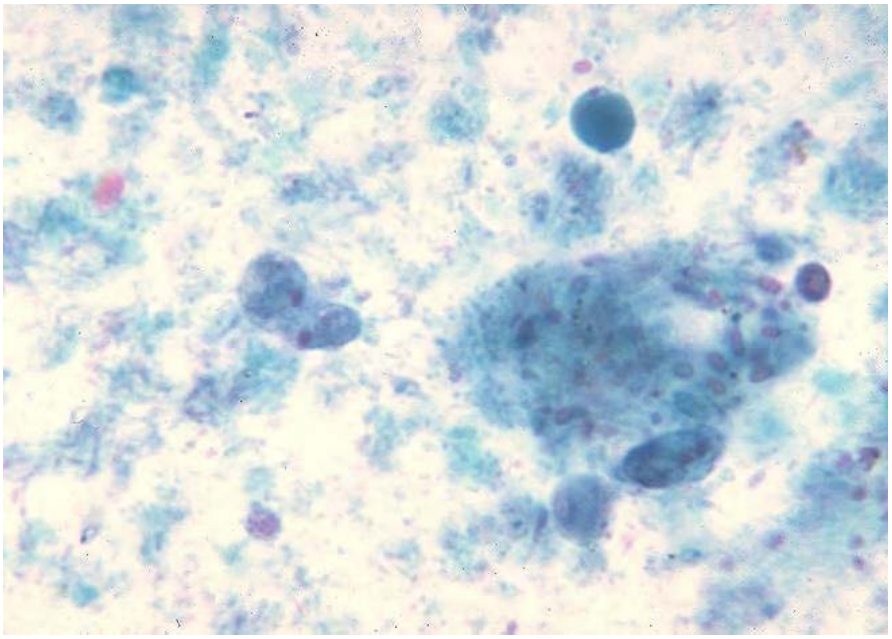

Image 3-5. *Dientamoeba fragilis*. Trichrome stain. (SOURCE: PHIL 548 – CDC)

Pathogenesis

This is a controversial area. The organism has been reported in association with mucous diarrhea, abdominal pain and tenderness. Nausea, vomiting and low-grade fever have also been reported in a number of cases. The precise role of this organism as a cause of disease remains to be determined.

Laboratory Diagnosis

Diagnosis is dependent on examination of the fresh direct wet preparation or permanently stained smears prepared from unformed or formed stools with mucus. It is particularly important that permanently stained smears of stool preparations should be examined, because survival times of the organism in terms of morphology, is very limited and specimens must be examined immediately or preserved in a suitable fixative as soon as possible after defecation. The recommended stains are Fields' and Giemsa stain (trophozoites are destroyed in a formol-ether concentrate). **Table 3-1.** details useful morphological features that are similar between species of flagellate and are used in laboratory diagnosis.

Trichomonas hominis

Introduction

This flagellate is cosmopolitan in its distribution. It is thought to be non-pathogenic although it has been associated with diarrheic stools. It is the most commonly found flagellate next to *G.*

lamblia and *D. fragilis.* Found in a wide host range including non-human primates, cats, dogs and various rodents.

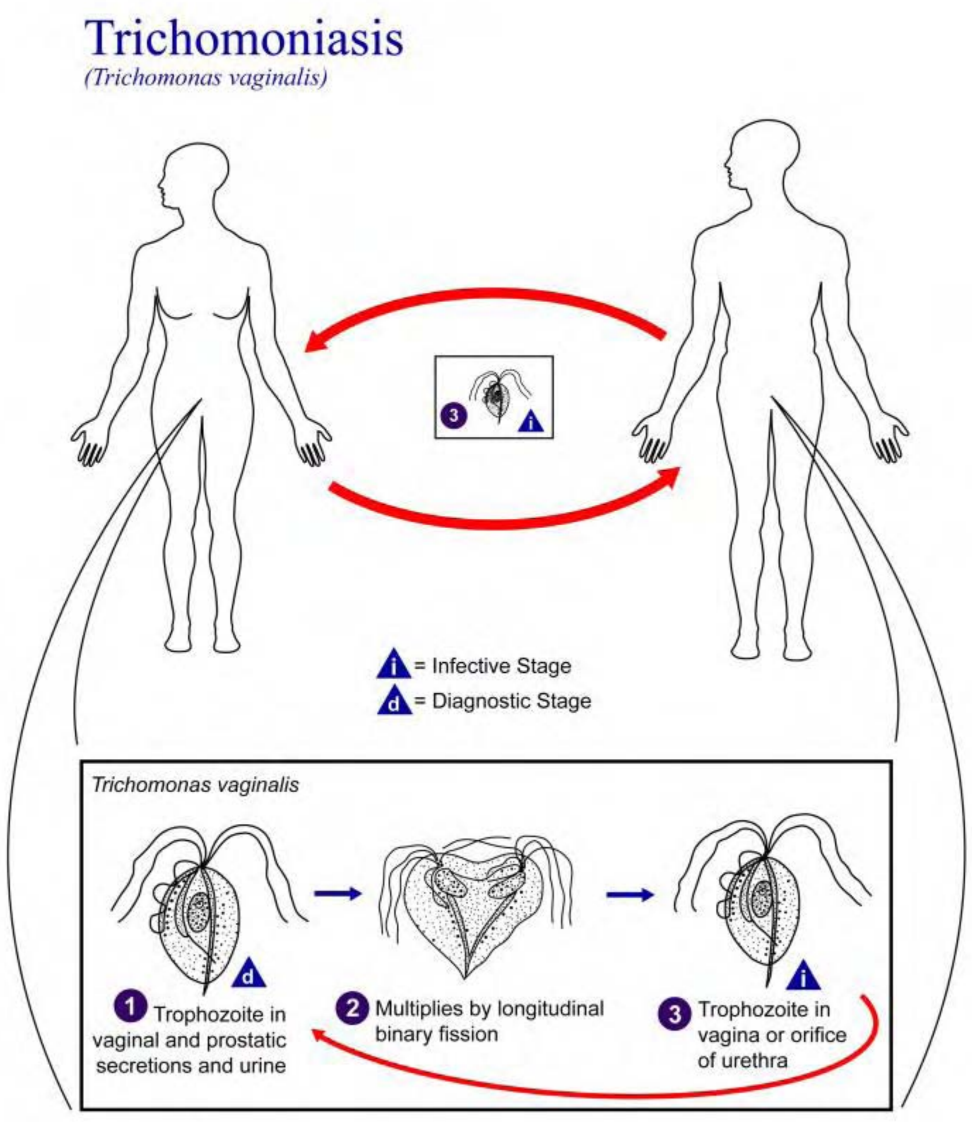
Trichomoniasis
(Trichomonas vaginalis)
3
i
i = Infective Stage
d = Diagnostic Stage
Trichomonas vaginalis
d
1 Trophozoite in vaginal and prostatic secretions and urine
2 Multiplies by longitudinal binary fission
i
3 Trophozoite in vagina or orifice of urethra

Diagram 3-3. This is an illustration of the life cycle of *Trichomonas vaginalis*, the causal agent of Trichomoniasis. (SOURCE: PHIL 3423 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology of Trophozoites

Trichomonas hominis do not have a cystic stage. The trophozoites measure from 5-15μm in length by 7-10μm in width. The shape is pyriform and has an axostyle which runs from the nucleus down the centre of the body and extends from the end of the body. They also possess an undulating membrane which extends the entire length of the body and projects from the body like a free flagellum (this feature distinguishes it from other trichomonads). The characteristic number of flagella is five; there is some deviation from this number. They also have a single nucleus at the anterior end. Trichomonads swim with a characteristic wobbly movement, which makes them unmistakable during diagnosis.

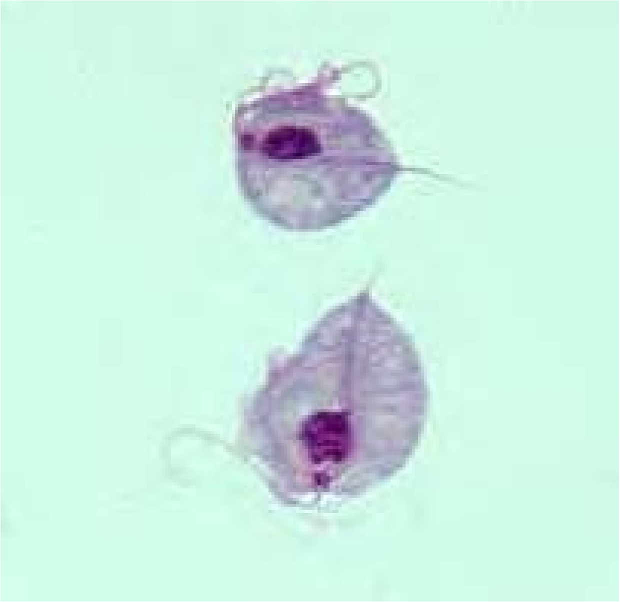

Image 3-6. Two trophozoites of *Trichomonas vaginalis* obtained from in vitro culture. Smear was stained with Giemsa. (SOURCE: CDC)

Laboratory Diagnosis

In a fresh stool, the flagellates move very rapidly in a jerky, non-directional manner. The axostyle and undulating membrane are diagnostic. The flagellates are difficult to stain; however, the axostyle can be seen on a stained preparation and is diagnostic. **Table 3-1** details useful morphological features that are similar between species of flagellate and are used in laboratory diagnosis.

Chilomastix mesnili

Introduction

Chilomastix mesnili is cosmopolitan in distribution although found more frequently in warm climates. It is thought to be non-pathogenic although the trophozoite has been associated with diarrheic stool. This is the largest flagellate found in man with an incidence of 1-10% being in the large intestine.

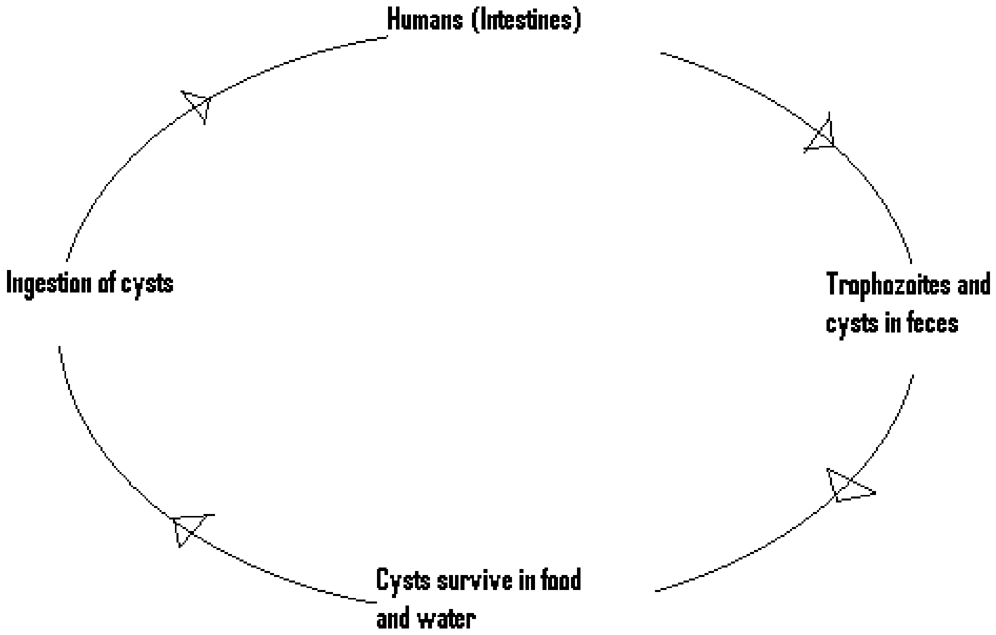
Humans (Intestines)
Trophozoites and cysts in feces
Cysts survive in food and water
Ingestion of cysts

Illustration 3-4. The life cycle of *C. mesnili* (Cuomo)

Morphology of the Trophozoite

The trophozoites of *C. mesnili* are pear shaped and measure 6-20µm in length. They have one large nucleus with a small karyosome and three flagella that extend from the nucleus at the anterior end of the parasite. A distinct oral groove or cytosome can be seen near the nucleus with its sides being supported by two filaments. They are known to move in a directional manner.

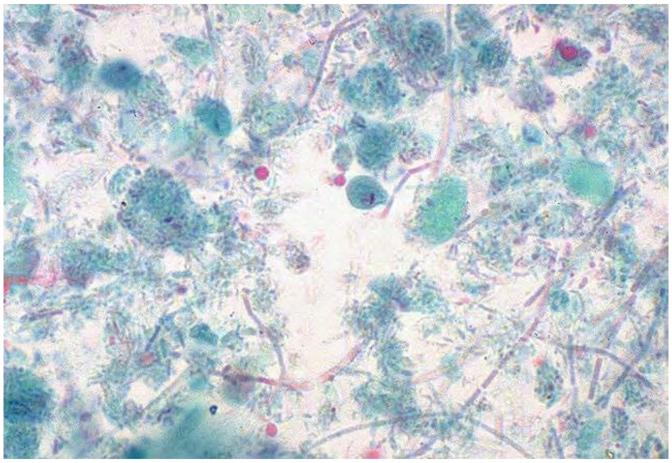

Image 3-7. *Chilomastix mesnili* cyst.(SOURCE: PHIL 426 - CDC /Dr. Mae Melvin)

Morphology of cysts

The cysts are 6-9µm; they have a large single nucleus with a large karyosome. They also have a prominent side knob giving it a characteristic lemon shape. The cytosome is evident with a curved shepherds crook fibril. It also has a characteristically coiled filament which when stained is darker in color.

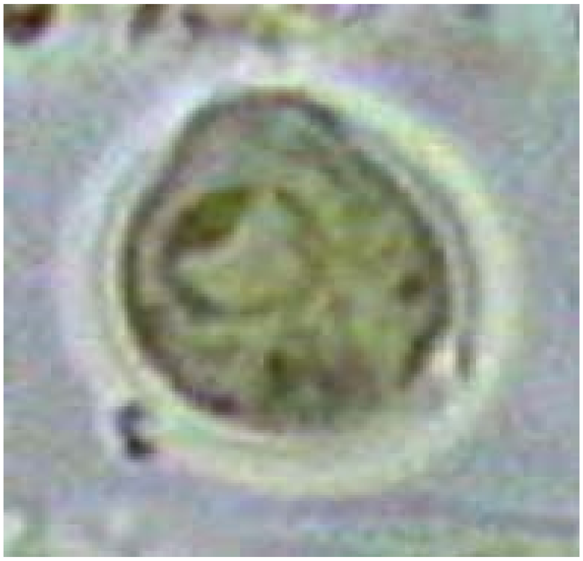

Image 3-8. *Chilomastix mesnili* cysts are excreted with feces and constitute the transmission form of the micro-organism. The uninucleated lemon shaped cysts are seen with a little proturberance at one end and a prominent cytostome. (Iodine stained). (6µm) (CDC)

Laboratory Diagnosis

The characteristic lemon shaped cysts can be seen in a formol-ether concentrate. Motile organisms can be seen in a wet preparation of a fresh stool however the characteristic morphology is evident in a permanently stained preparation. **Table 3-1** details useful morphological features that are similar between species of flagellate and are used in laboratory diagnosis.

Enteromonas hominis

Introduction

Enteromonas hominis is a small flagellate and is rarely encountered in man. It is found in both warm and temperate climates and is considered to be non-pathogenic.

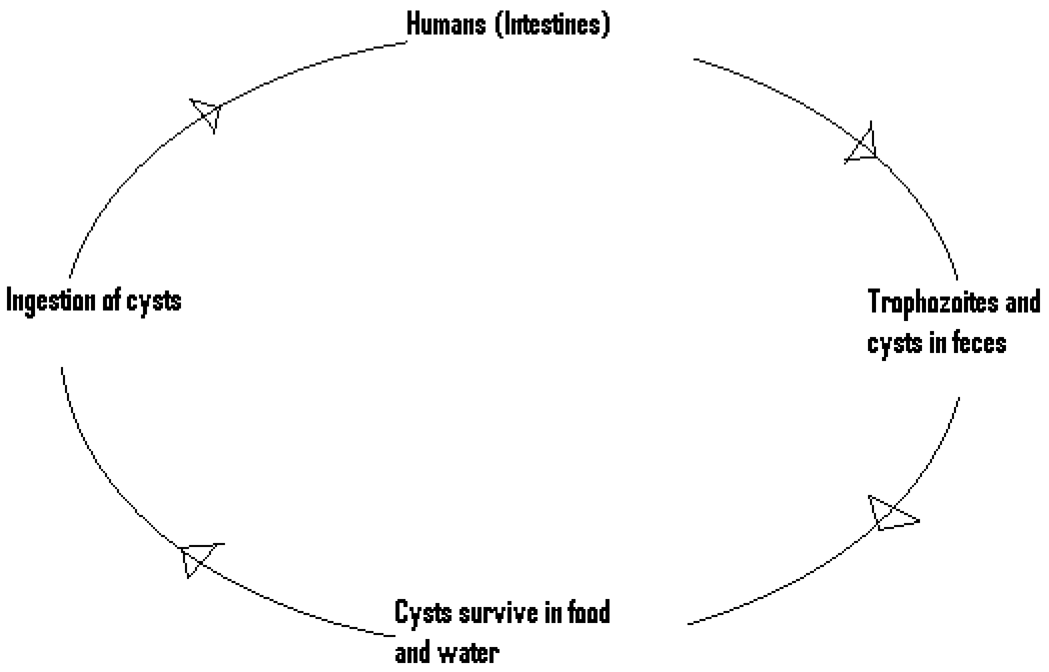
Humans (Intestines)
Trophozoites and cysts in feces
Cysts survive in food and water
Ingestion of cysts

Illustration 3-5. The life cycle of *E. hominis* (Cuomo)

Morphology of the Trophozoite

The trophozoites are oval and 4-10μm in length. They have four flagella, three anterior flagella and one adheres to the body ending in a tail, producing a jerky rotational movement. They have one nucleus with a large karyosome that is evident in a stained preparation.

Morphology of the Cyst

The cysts are oval and range between 6-8μm in length. They have up to four nuclei with a bipolar tendency.

Laboratory Diagnosis

The cysts are seen in a formol-ether concentrate. The cysts have no distinguishing characteristics and thus can be confused with *E. nana* or even yeasts. The characteristic trophozoites can be seen in a permanently stained fecal smear. **Table 3-1.** details useful morphological feature's that are similar between species of flagellate and are used in laboratory diagnosis.

Retortamonas intestinalis

Introduction

Retortamonas intestinalis like *Enteromonas hominis* is a small flagellate and is rarely encountered. It is found in both warm and temperate climates and is considered to be non-pathogenic.

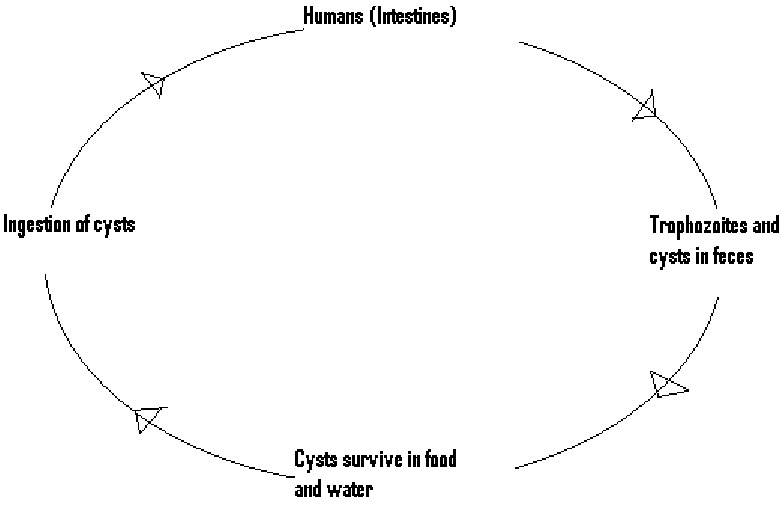
Humans (Intestines)
Trophozoites and cysts in feces
Cysts survive in food and water
Ingestion of cysts

Illustration 3-6. Life cycle of *Retortamonas intestinalis* (Cuomo)

Morphology of the Trophozoite

The trophozoite is small, measuring between 4µm and 9µm. Its movement is jerky and rotational and has two anterior flagella and a prominent cytosome that can be seen in an unstained preparation. It has a relatively large nucleus at the anterior end with a small compact karyosome.

Morphology of the Cyst

The cysts are small and pear shaped. They range in size between 4-7µm with one large nucleus frequently near the centre. The fibril arrangement from the nucleus is suggestive of a birds beak. This is characteristic of *R. intestinalis* cysts.

Laboratory Diagnosis

The small pear shaped cysts are uncharacteristic in an unstained formol-ether preparation. However, the addition of iodine reveals the characteristic bird beak fibrillar arrangement in the pear shaped cyst. In a fresh stool preparation, the two anterior flagella and cytosome can be seen in the trophozoite. In a permanently stained preparation, the large nucleus with small central karyosome is diagnostic. The below Tables detail useful morphological features which are similar between species of flagellate and are used in laboratory diagnosis.

3.2 Identifying Flagellates

It is important to know and understand the morphological features which differentiate each species of flagellate from one other. The below Tables details the important features that are used when identifying flagellates found in human stool samples. Trophozoites and cysts can be seen in saline mounts of fresh feces. On occasions, species identification may require stained preparations.

Species	Size (Length)	Shape	Motility	Number of Nuclei	Number of Flagella*	Other Features
Trichomonas hominis	8-20 µm. Usual range. 11-12 µm.	Pear shaped.	Nervous, jerky.	1 Not visible in unstained mounts.	3-5 anterior. 1 posterior.	Undulating membrane extending length of body.
Chilomastix mesnili	6-24 µm. Usual range, 10-15 µm.	Pear shaped.	Stiff, rotary.	1 Not visible in unstained mounts.	3 anterior. 1 in cytosome.	Prominent cytostome extending 1/3-1/2 length of body. Spiral groove across ventral surface.
Giardia intestinalis	10-20 µm. Usual range, 12-15 µm.	Pear shaped.	"Falling leaf."	2 Not visible in unstained mounts.	4 lateral. 2 ventral. 2 caudal.	Sucking disk occupying 1/2-3/4 of ventral surface. Median bodies lying horizontally or obliquely in lower part of body.
Enteromonas hominis	4-10 µm. Usual range, 8-9 µm.	Oval.	Jerky.	1 Not visible in unstained mounts.	3 anterior. 1 posterior.	One side of body flattened. Posterior flagellum extends free posteriorly or laterally.
Retortamonas intestinalis	4-9 µm. Usual range, 6-7 µm.	Pear shaped or oval.	Jerky.	1 Not visible in unstained mounts.	1 anterior. 1 posterior.	Prominent cytostome extending approximately 1/2 length of body.

* Not a normal feature for identifying species in routine stool samples

Table 3-1. Differential Morphology of Protozoa Found in Stool Specimens of Humans: Flagellates-Trophozoites (SOURCE: CDC)

Species	**Size (Length)**	**Shape**	**Number of Nuclei**	**Other Features**
Trichomonas hominis	No cyst.			
Chilomastix mesnili	6-10 µm. Usual range, 8-9 µm.	Lemon shaped with anterior hyaline knob.	1. Not visible in unstained preparations.	Cytostome with supporting fibrils. Usually visible in stained preparations.
Giardia intestinalis	8-19 µm. Usual range. 11-12 µm.	Oval or ellipsoidal.	Usually 4. Not distinct in unstained preparations. Usually located at one end.	Fibrils or flagella longitudinally in unstained cysts. Deep staining fibers or fibrils may be seen lying laterally or obliquely across fibrils in lower part of cyst. Cytoplasm often retracts from a portion of cell wall.
Enteromonas hominis	4-10 µm. Usual range, 6-8 µm.	Elongated or oval.	1-4, usually 2 lying at opposite ends of cyst. Not visible in unstained mounts.	Resembles *E. nana* cyst. Fibrils or flagella are usually not seen.
Retortamonas intestinalis	4-9 µm. Usual range, 4-7 µm.	Pear shaped or slightly lemon shaped.	1. Not visible in unstained mounts.	Resembles *Chilomastix* cyst. Shadow outline of cytostome with supporting fibrils extends above nucleus.

Table 3-2. Differential Morphology of Protozoa Found in Stool Specimens of Humans: Flagellates-Cysts (SOURCE: CDC)

Flagellate trophozoites are best identified in fresh saline mounts, allowing you to observe the way that they move. Use **Key 3-1.** to help to identify stained flagellate trophozoites. Iodine solutions are used primarily to stain flagellate cysts, this makes it possible to see the structure of the nuclei. Use **Key 3-2.** to help to identify amebic and flagellate cysts:

Key 3-1. Flagellates (Adapted and redrawn, WHO, 1991)

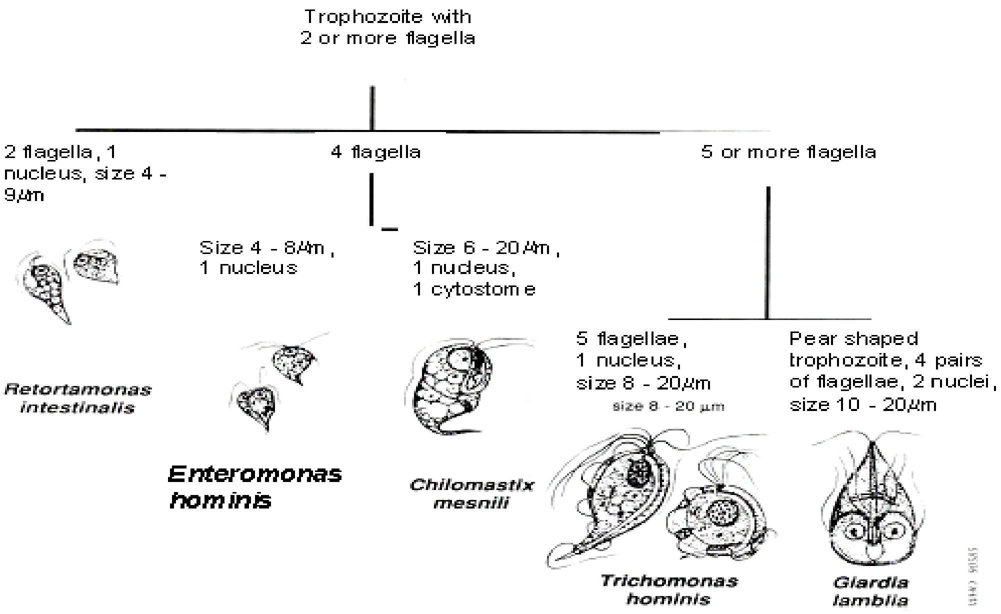
Trophozoite with 2 or more flagella
2 flagella, 1 nucleus, size 4 - 9µm
4 flagella
5 or more flagella
Size 4 - 8µm, 1 nucleus
Size 6 - 20µm, 1 nucleus, 1 cytostome
Retortamonas intestinalis
Enteromonas hominis
Chilomastix mesnili
5 flagellae, 1 nucleus, size 8 - 20µm
size 8 - 20 µm
Pear shaped trophozoite, 4 pairs of flagellae, 2 nuclei, size 10 - 20µm
Trichomonas hominis
Giardia lamblia

Key 2. Key to differentiating flagellate and amoebic cysts. (Adapted and redrawn, WHO, 1991)

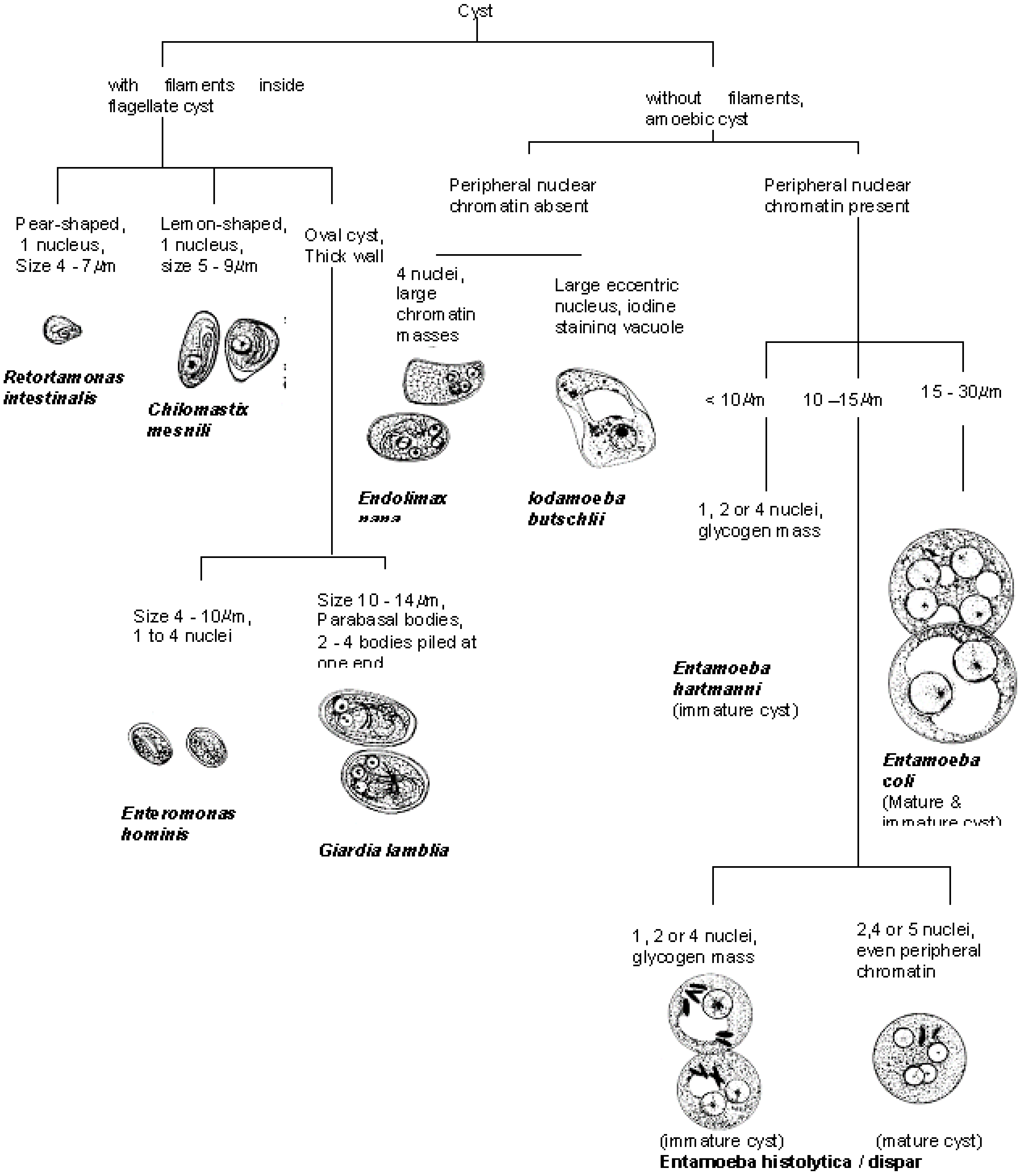
Cyst
with filaments inside flagellate cyst
without filaments, amoebic cyst
Pear-shaped, 1 nucleus, Size 4 - 7µm
Lemon-shaped, 1 nucleus, size 5 - 9µm
Oval cyst, Thick wall
Peripheral nuclear chromatin absent
Peripheral nuclear chromatin present
4 nuclei, large chromatin masses
Large eccentric nucleus, iodine staining vacuole
Retortamonas intestinalis
Chilomastix mesnili
Endolimax nana
Iodamoeba butschlii
< 10µm
10 –15µm
15 - 30µm
1, 2 or 4 nuclei, glycogen mass
Size 4 - 10µm, 1 to 4 nuclei
Size 10 - 14µm, Parabasal bodies, 2 - 4 bodies piled at one end
Entamoeba hartmanni (immature cyst)
Entamoeba coli (Mature & immature cyst)
Enteromonas hominis
Giardia lamblia
1, 2 or 4 nuclei, glycogen mass
2,4 or 5 nuclei, even peripheral chromatin
(immature cyst)
(mature cyst)
Entamoeba histolytica / dispar

Chapter 4.
The Cestodes

4.1 Identifying Intestinal Helminths

Helminth Parasites - The word "worm" is used loosely to describe organisms with elongated bodies and a more or less creeping habit.

Although the word "Helminth" does mean "worm," in zoological terms it is more restricted to members of the phyla Platyhelminths, Nematoda, and Acanthocephala.

There are three groups of medically important helminths; Cestodes (tapeworms), Nematodes (roundworms) and Trematodes (flukes).

These parasites live in both the body spaces (gut lumen, bile ducts, lungs, oral cavity, etc.) and in tissues (blood, muscles and skin).

4.2 Infections Acquired Through the Gastrointestinal Tract

The cestodes (or tapeworms) form a group of worms, exhibiting two unmistakable morphological features; they all possess flat, ribbon like bodies and lack an alimentary canal.

Adult tapeworms usually inhabit the alimentary canal of their hosts (though they occasionally are found in the bile or pancreatic ducts) and attach themselves to the mucosa by means of a scolex. Despite the lack of a digestive system they do absorb food from the hosts intestine; thereby providing the tapeworms a habitat that is associated with high nutritional levels, feeding the tapeworms high growth rate.

Larvae on the other hand show a wide range of habitat preferences, being found in almost any organ of both vertebrate and invertebrate hosts. Though most larval species show a preference for a particular site.

This lack of an alimentary canal markedly separates tapeworms from nematodes and trematodes. The outer tegument of the body must serve not only as a protective coating but also as a metabolically active layer through which nutritive material can be absorbed, along with secretions and waste material to be transported out of the body.

The body consists of a chain of segments or proglottids, which can be immature, mature or gravid; the latter of which contain a fully developed uterus packed with eggs. Therefore, each tapeworm is made up of a ‘string of individuals’ having a complete set of reproductive organs in progressive degrees of sexual maturity and budding off from a body attached to the host tissue by a head or scolex.

Except for *Hymenolepis nana,* which can develop directly in the same host, the lifecycle of tapeworms involves both an intermediate and definitive host.

Species	**Size**	**Shape**	**Color**	**Stage of Development When Passed**	**Specific Features and Variations**
Cestodes					
Taenia saginata ***Taenia solium***	35 µm. Range, 31-43 µm.	Spherical with thick striated shell.	Walnut brown.	Embryonated. 6-hooked oncosphere present inside a thick shell.	Thick, striated shell. Eggs of *T. solium* and *T. saginata* are indistinguishable and species identification should be made from proglottids or scoleces. "*Taenia*" spp. should be reported if only eggs are found.
Hymenolepis nana	47 µm x 37 µm. Range, 40-60 µm x 30-50 µm.	Oval. Shell consists of 2 distinct membranes. On inner membrane are two small "knobs" or poles from which 4 to 8 filaments arise and spread out between the two membranes.	Colorless, almost transparent.	Embryonated. 6-hooked oncosphere inside shell.	Polar filaments.
Hymenolepis diminuta*	72 µm. Range, 70-86 µm x 60-80 µm.	Round or slightly oval. Striated outer membrane and thin inner membrane with slight poles. Space between membranes may appear smooth or faintly granular.	Yellow.	Embryonated. 6-hooked oncosphere inside shell.	Resembles *H. nana* but lacks polar filaments. Poles are rudimentary and often hard to see.
Dipylidium caninum*	35-40 µm. Range, 31-50 µm x 27-48 µm.	Spherical or oval. 5-15 eggs (or more) are enclosed in a sac or capsule.	Colorless.	Embryonated. 6-hooked oncosphere inside shell.	Eggs are contained in a sac or capsule which ranges in size from 58 µm to 60 µm x 170 µm. Occasionally capsules are ruptured and eggs are free.
Diphyllobothrium latum	66 µm x 44 µm. Range, 58-76 µm x 40-51 µm.	Oval or ellipsoidal with an inconspicuous operculum at one end and a small "knob" at the other end.	Yellow to brown.	Unembryonated. Germinal cell is surrounded by a mass of yolk cells which completely fills inner area of shell. Germinal cell is usually not visible.	Egg resembles hookworm egg but has a thicker shell and an operculum.

Table 4-1. Differential Morphology of the Diagnostic Stages of Helminths Found in Humans: Eggs (Cestodes) (SOURCE: CDC)

Taenia species

Introduction

Taenia species are the most common cestode parasites of humans. More than 60 million people are infected with *T. saginata* (beef tapeworm) world wide and about four million are infected with *T. solium* (pork tapeworm). The life cycle of a *Taenia* species can be seen in **Illustration 4-1.** *T. saginata* has a cosmopolitan distribution, but is more common in developing countries where hygiene is poor and the inhabitants have a tendency of eating raw or insufficiently cooked meat. *T saginata* is the most common adult tapeworm found in man. *T solium* is virtually extinct in Europe and the USA.

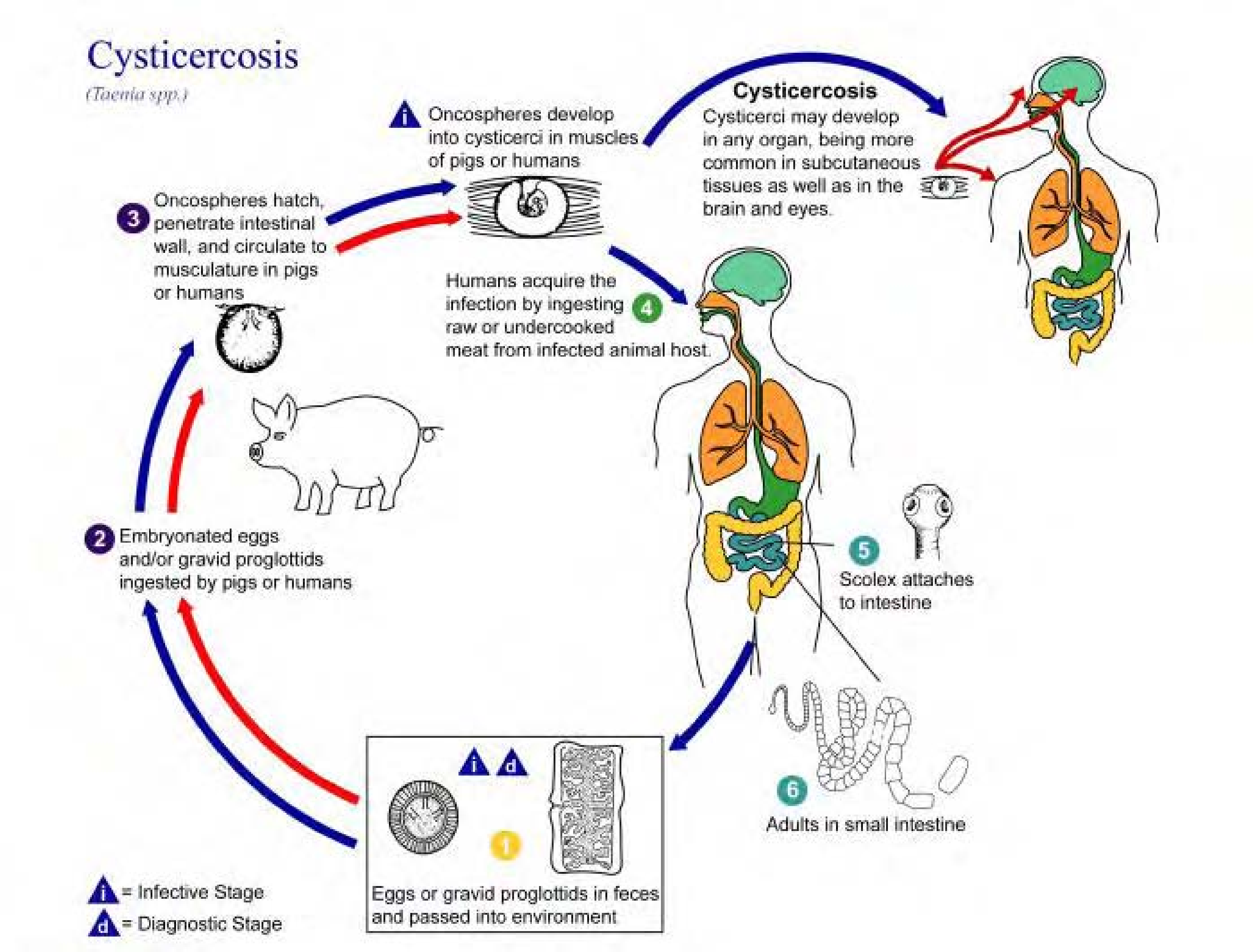
Cysticercosis
(Taenia spp.)
i Oncospheres develop into cysticerci in muscles of pigs or humans
Cysticercosis
Cysticerci may develop in any organ, being more common in subcutaneous tissues as well as in the brain and eyes.
③ Oncospheres hatch, penetrate intestinal wall, and circulate to musculature in pigs or humans
Humans acquire the infection by ingesting ④ raw or undercooked meat from infected animal host.
② Embryonated eggs and/or gravid proglottids ingested by pigs or humans
⑤ Scolex attaches to intestine
⑥ Adults in small intestine
i d
①
Eggs or gravid proglottids in feces and passed into environment
i = Infective Stage
d = Diagnostic Stage

Illustration 4-1. This is the life cycle of *Taenia spp.*, the causal agents of Cysticercosis. Cysticercosis is an infection of both humans and pigs with the larval stages of the parasitic cestode, *Taenia solium*. This infection is caused by ingestion of eggs shed in the feces of a human tapeworm carrier ①. Pigs and humans become infected by ingesting eggs or gravid proglottids ❷, ❼. Humans are infected either by ingestion of food contaminated with feces, or by autoinfection. In the latter case, a human infected with adult *T. solium* can ingest eggs produced by that tapeworm, either through fecal contamination or, possibly, from proglottids carried into the stomach by reverse peristalsis. Once eggs are ingested, oncospheres hatch in the intestine ❸, ❽invade the intestinal wall, and migrate to striated muscles, as well as the brain, liver, and other tissues, where they develop into cysticerci ❾. In humans, cysts can cause serious sequellae if they localize in the brain, resulting in neurocysticercosis. The parasite life cycle is completed, resulting in human tapeworm infection, when humans ingest undercooked pork containing cysticerci ❹. Cysts evaginate and attach to the small intestine by their scolex ❺. Adult tapeworms develop, (up to 2 to 7 m in length and produce less than 1000 proglottids, each with approximately 50,000 eggs) and reside in the small intestine for years ❻. (SOURCE: PHIL 3387 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Both humans and cattle or pigs are necessary to the complete life cycle of *Taenia* species. (In Europe and the USA cattle are the normal intermediate hosts, but in the tropics several other ruminants, e.g. goat, sheep llama and giraffe, may serve as the intermediate hosts.) Eggs ingested by the intermediate hosts usually contain oncospheres. The oncospheres then hatch out in the duodenum, pass into the intestine where they penetrate the intestinal wall and are then carried by the circulation to be deposited in tissues (usually muscle). There they develop into cysticerci larva which are white and ovoid, measuring approximately 8 x 5µm.

Humans become infected by ingesting inadequately, cooked beef or pork with cysticerci, containing an invaginated protoscolex. The protoscolexes evaginate and pass into the small intestine where they attach themselves to the mucosa and develop into adult worms.

Eggs and proglottids are passed out in the feces, and are then eaten by the intermediate host, thus, perpetuating the life cycle.

Morphology

Ova of *Taenia* species are spherical, yellowish brown and measure 31-34µm in diameter. The shell is thick and radially striated. Within the shell, the oncosphere has 3 pairs of hooklets. However, the microscopic appearance of the ova of *T. saginata* and *T. solium* are identical. (**Table 4-1.** highlights some of the differences between the two species)

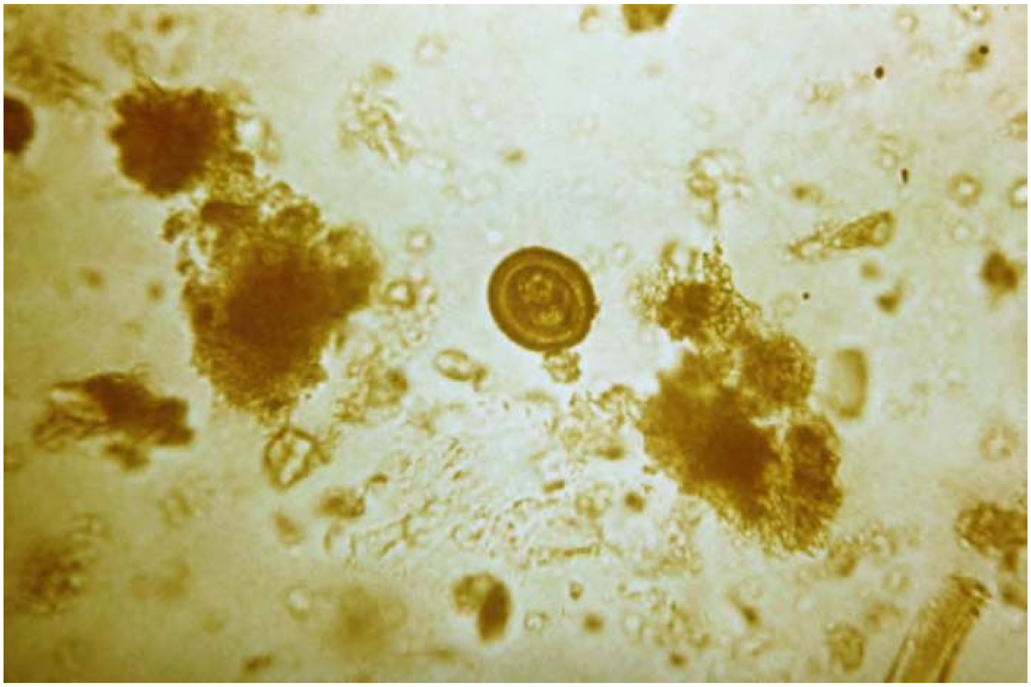

Image 4-1. The eggs *Taenia saginata* and *Taenia solium* are rounded or subspherical, with a thick radially striated brown shell. The diameter is 31 - 43 µm. Inside each shell is an embryonated oncosphere with 6 hooks. (SOURCE: PHIL 4832 – CDC)

The length of the adult *T. saginata* is 4-8 meters long and that of *T. solium* is 3-5 meters long.

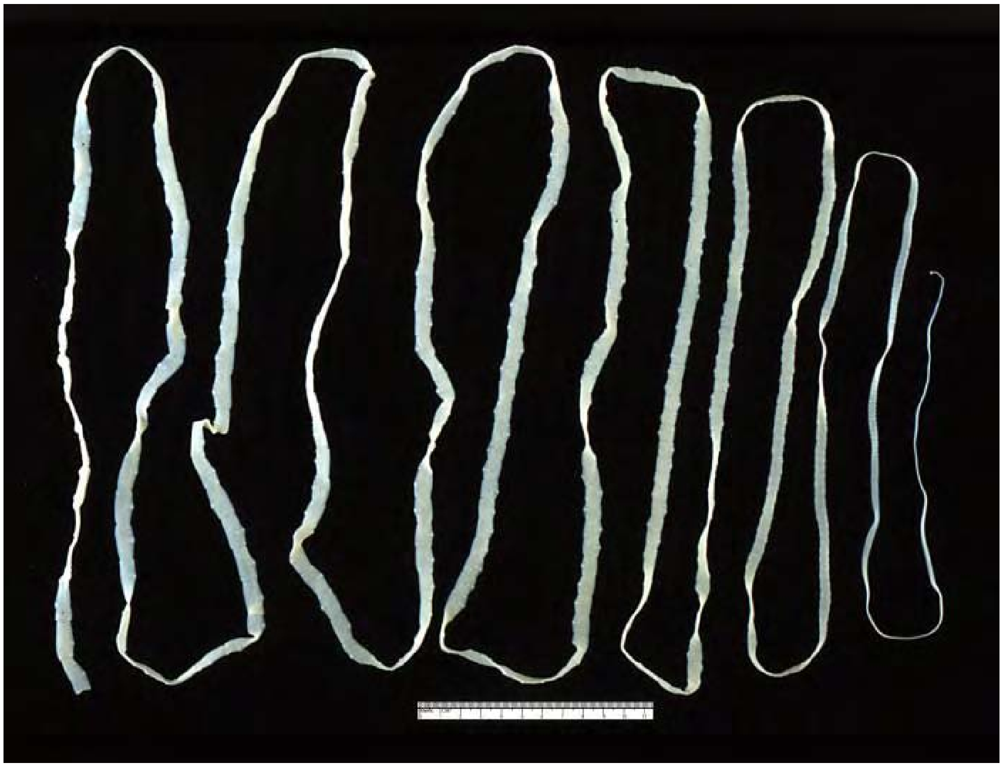

Image 4-2. This is an adult *Taenia saginata* tapeworm. (SOURCE: PHIL 5260 – CDC)

The proglottids of *Taenia* species can be identified by the number of uterine branches; 7-13 for *T. solium* and 15-20 for *T. saginata*.

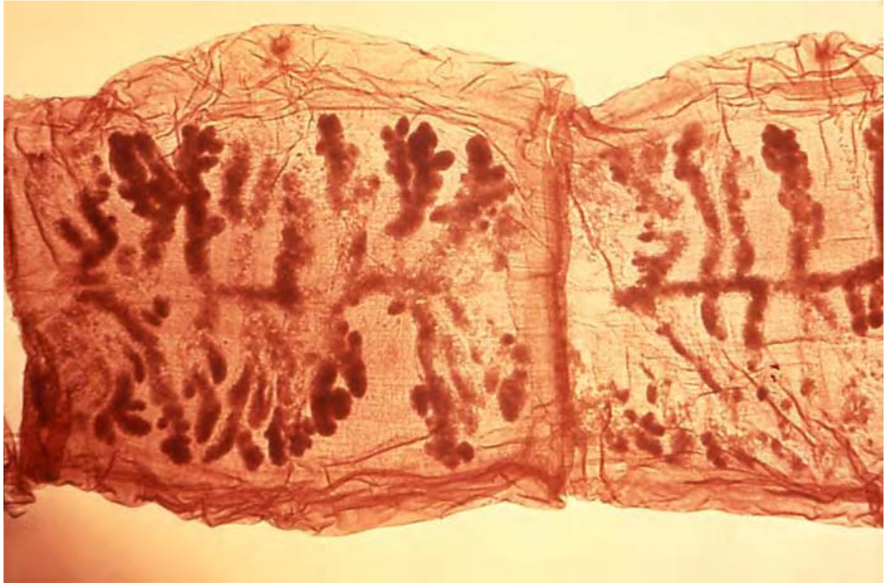

Image 4-3. This micrograph reveals the organ morphology within *Taenia solium* tapeworm proglottids. (SOURCE: PHIL 5261 – CDC)

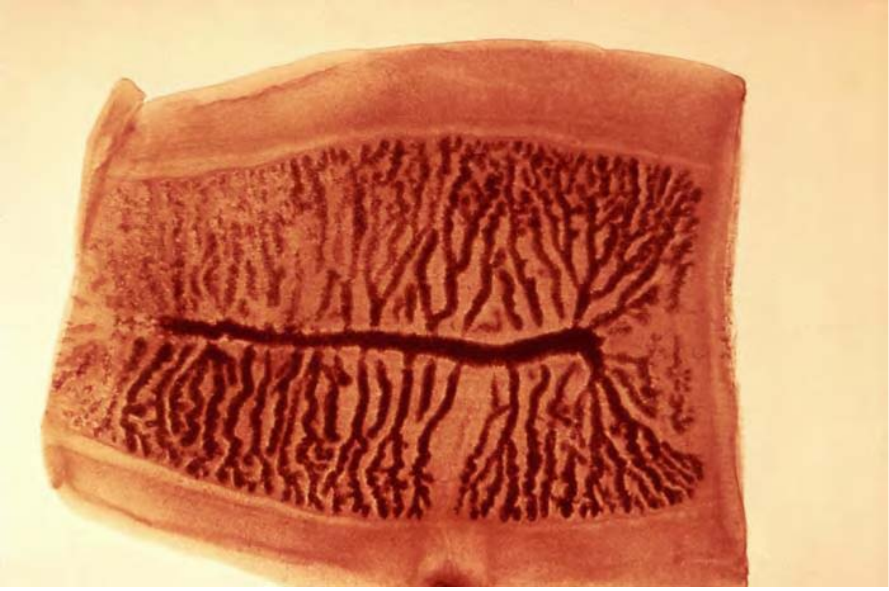

Image 4-4. This micrograph reveals the morphology of a gravid proglottid from the cestode *Taenia saginata*, a tapeworm. (SOURCE: PHIL 5259 – CDC)

If the scolex is recovered, the four suckers and rostellum of hooklets of *T. solium* will distinguish it from *T. saginata,* which has four suckers but no hooklets.

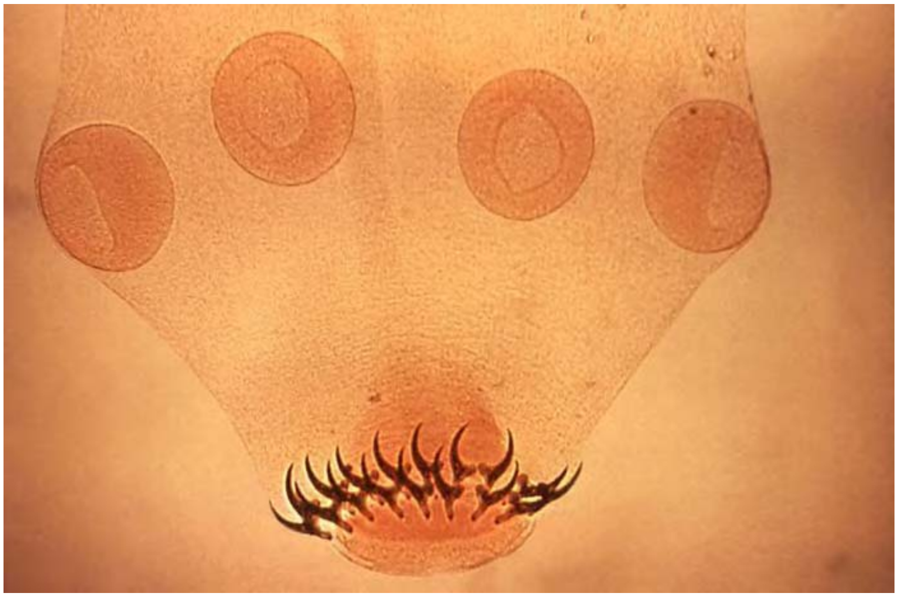

Image 4-5. This is an adult *Taenia solium* taperworm scolex. (SOURCE: PHIL 5262 – CDC)

Clinical Disease

The presence of the adult worm rarely causes symptoms apart from slight abdominal irritation with diarrhea, constipation or indigestion. The accidental ingestion of the embryonated ova of *T. solium* may result in cysticercosis in man. An infection due to an adult *Taenia,* in man or animals, is referred to as *taeniasis.* *T. saginata* (the beef tapeworm) **does not** cause human cysticercosis.

When the embryonated eggs are ingested, the embryos hatch out, migrate through the intestinal wall and are carried around the body in the circulation and deposited in various tissues. Muscle and subcutaneous tissues are usually infected, but cysticerci can infect most organs and tissues. Human cysticercosis is usually asymptomatic unless the infection is particularly heavy or cysticerci are formed in some vital area e.g. the brain, resulting in neurological sequelae.

Table 4-2. Some characteristics differentiating *T. saginata* from *T. solium*.

Characteristic	*Taenia saginata*	*Taenia solium*
Intermediate Host	Cattle, reindeer	Pig, wild boar
Site of Development	Muscle, viscera	Brain, skin, muscle
Scolex: adult worm	No hooks	Hooks
Scolex: cysticercus	No rostellum	Rostellum & hooks
Proglottids: uterine branches	23 (14 – 32) *	8 (7 –11) *
Passing of proglottids	Single, spontaneous	In groups, passively
Ovary	Two lobes	Three lobes
Vagina: sphincter muscle	Present	Absent

***** No universal agreement to the number of uterine branches in these two species. As a rough guide, specimens with more than 16 branches are likely to be those of *T. saginata* and those with less than ten branches are likely to be of *T. solium*. (SOURCE: CDC)

Laboratory Diagnosis

Diagnosis of intestinal taeniasis can be made by recovery of the characteristic ova in the stool. However, the ova of *T. solium* and *T. saginata* are identical and diagnosis is made by the recovery of the segments or scolex.

The diagnosis of cysticercosis depends upon serology. MRI scans may reveal the presence of lesions in the brain. Calcified cysticerci are less often seen in the brain: in about one-third of cases, 10 years or more after infection. Occasionally, the diagnosis is made histologically on surgical specimens. Calcification in muscles usually appears three to five years after initial infection, and are most typically seen as spindle-shaped calcifications, most numerous in the thighs.

Western Blots

Various Immunodiagnostic tests appear to give good results on serum or CSF.

Diagnosis using an immunodiagnostic test can be achieved using an *in vitro* qualitative assay for the detection of IgG antibodies in serum reactive with *T. solium* antigens present on a membrane.

Infected individuals develop a predominately IgG response to the parasite. ELISA has been used as a screening test, but low sensitivity and frequent artifactual cross reactions, or cross reactions with antibodies from other parasitic infections, limit its usefulness as a confirmatory diagnostic test. The Western Blot assay (US Patent No. 5,354,660) developed by Tsang *et al*, at the U.S. Centers for Disease Control has been shown to provide a reliable method for evaluation of sera from patients with clinically diagnosed active cysticercosis. Field studies support a sensitivity of 98% and specificity of 100% for this assay.

This assay is known as the QualiCode™ Cysticercosis Kit, the principle behind the test is that it is a qualitative membrane-based immunoassay manufactured from *T. solium* proteins. The *T. solium* proteins are fractionated according to molecular weight by electrophoresis on a polyacrylamide slab gel (PAGE) in the presence of sodium dodecyl sulfate (SDS). The separated *T. solium* proteins are then transferred via electrophoretic blotting from the gel to a nitrocellulose membrane. This antigen-bearing membrane has been cut into strips for testing of individual samples. Sera are tested at 100X dilution.

During the procedure, the strips containing the *T. solium* proteins are incubated with serum specimens and washed to remove unbound antibodies. Visualization of human immunoglobulins specifically bound to *T. solium* proteins is performed by sequential reaction with goat anti-human immunoglobulin-alkaline phosphatase conjugate and BCIP/NBT substrate. Bands corresponding to the positions of the resoled *T. solium* proteins will be visualized on the strip, indicating the presence in the serum sample of IgG antibodies direct against *Taenia* antigens. Band positions are compared to those on a reference strip developed using the cysticercosis positive control.

Hymenolepis nana

Introduction

Hymenolepis nana, the dwarf tapeworm, is the smallest tapeworm to infect humans. This cestode belongs to a large family known as Hymenolepididae. The diagnostic features of this family are: scolex armed with one circlet of five hooks; one to three large testes and sacciform uterus. In addition to the *H. nana*, three other species, *H. diminuta, H. microstoma* and *H. citelli* have been used extensively for studies on cestodes.

Hymenolepis nana has a cosmopolitan distribution and is thought to be the most common tapeworm throughout the world. The infection is more frequently seen in children although adults are also infected, causing *hymenolepiasis*.

Life Cycle

The lifecycle of *H. nana* does not require an intermediate host, complete development occurring within the villi of a single host, resulting in a ‘direct’ life cycle. It can also utilize an insect as an intermediate host.

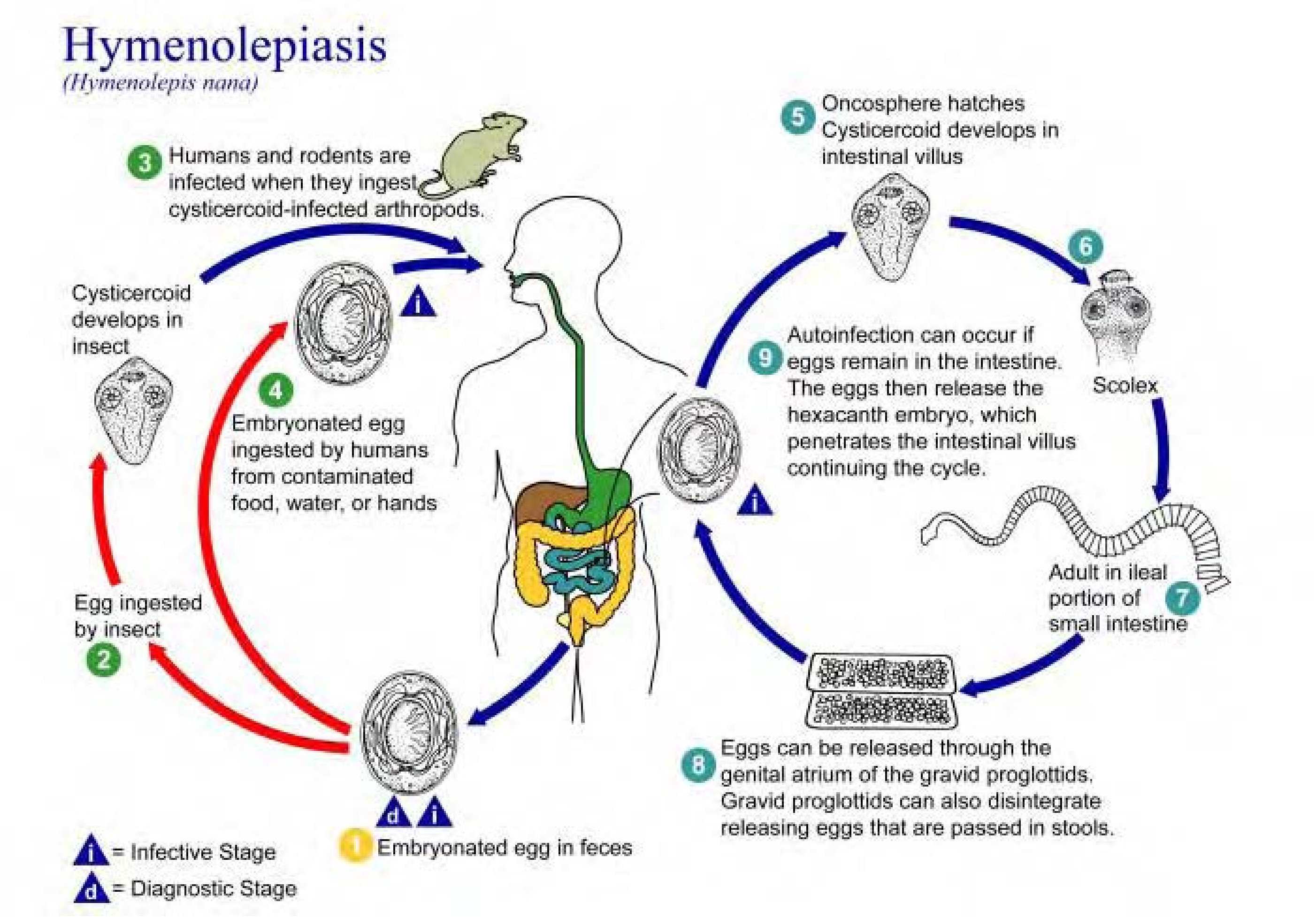
Hymenolepiasis
(Hymenolepis nana)
3 Humans and rodents are infected when they ingest cysticercoid-infected arthropods.
5 Oncosphere hatches Cysticercoid develops in intestinal villus
6
Scolex
Cysticercoid develops in insect
i
4 Embryonated egg ingested by humans from contaminated food, water, or hands
9 Autoinfection can occur if eggs remain in the intestine. The eggs then release the hexacanth embryo, which penetrates the intestinal villus continuing the cycle.
i
Adult in ileal portion of small intestine 7
Egg ingested by insect
2
8 Eggs can be released through the genital atrium of the gravid proglottids. Gravid proglottids can also disintegrate releasing eggs that are passed in stools.
d i
1 Embryonated egg in feces
i = Infective Stage
d = Diagnostic Stage

Illustration 4-2. This is an illustration of the life cycle of *Hymenolepis nana*, the causal agent of Hymenolepiasis. (SOURCE: PHIL 3396 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

The eggs that are released from mature proglottids in the upper ileum are usually passed out in the feces. If swallowed by another human they develop into hexacanth oncospheres and burrow into the villi of the small intestine. This is where they develop into tailless cysticercoids and then migrate towards the ileum and attach to commence the formation of proglottids. The eggs which are ingested by insects, such as fleas, beetles or cockroaches hatch to form tailed cysticercoids which remain unmodified as long as they are inside the insect. If they are accidentally swallowed by a human they pass down to the ileum and establish themselves.

Morphology

The egg containing the oncosphere bears three pairs of hooklets and is surrounded by a membrane. This membrane has two polar thickenings from which arise threadlike filaments extending into the space between the membrane and the colorless hyaline shell, unlike those of *H. diminuta* which do not possess any filaments.

The adult tapeworm is normally 2.5-4cm long. The scolex is knob like in shape, has a rostellum with hooklets and four suckers. The segments are wider than they are long. Ova are spherical or ovoid measuring 30-47µm in diameter. This is what distinguishes it morphologically from *H. diminuta.*

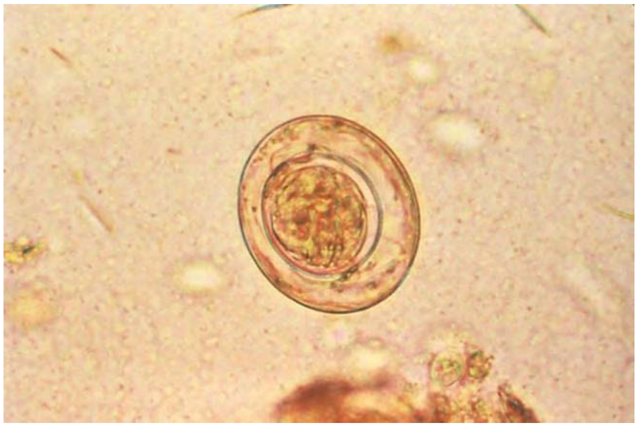

Image 4-6. This micrograph depicts an egg of the dwarf tapeworm *Hymenolepis nana*. On the inner of the two membranes surrounding the *Hymenolepis nana* egg are two poles, from which 4 to 8 polar filaments spread out between the two membranes. The oncosphere, or larval stage, has six hooks. (SOURCE: PHIL 5265 – CDC)

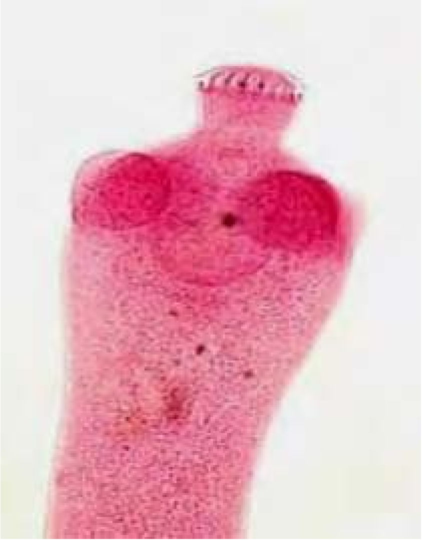

Image 4-7. *Hymenolepis nana* scolex. Stained to show the scolex with a knob like rostellum bearing a ring of hooklets. They possess four suckers, two of which can be seen just below the protruding rostellum. (SOURCE: D. Scott Smith, M.D./CDC)

Clinical Disease

Infections due to *H. nana* may cause no symptoms even with heavy worm burdens. However, symptoms of restlessness, irritability, anorexia, abdominal pain and diarrhea have been reported. Heavy worm burdens may be caused by auto-infection which can be a problem in the immunocompromised.

Laboratory Diagnosis

Diagnosis is based on recovery and identification of the characteristic ova in a formol-ether concentrate of feces. Adult worms and proglottids are rarely seen in stool samples.

Hymenolepis diminuta

Introduction

Hymenolepis diminuta is a small tapeworm commonly found in rats and mice. It has a world wide distribution in these hosts but is infrequently found in humans, with only sporadic cases being reported.

Life cycle and Transmission

The life cycle of *H. diminuta* requires an intermediate arthropod host e.g. earwigs, larval fleas and various beetles. Human infection occurs by the accidental ingestion of an infected arthropod, which contains the cysticercoids.

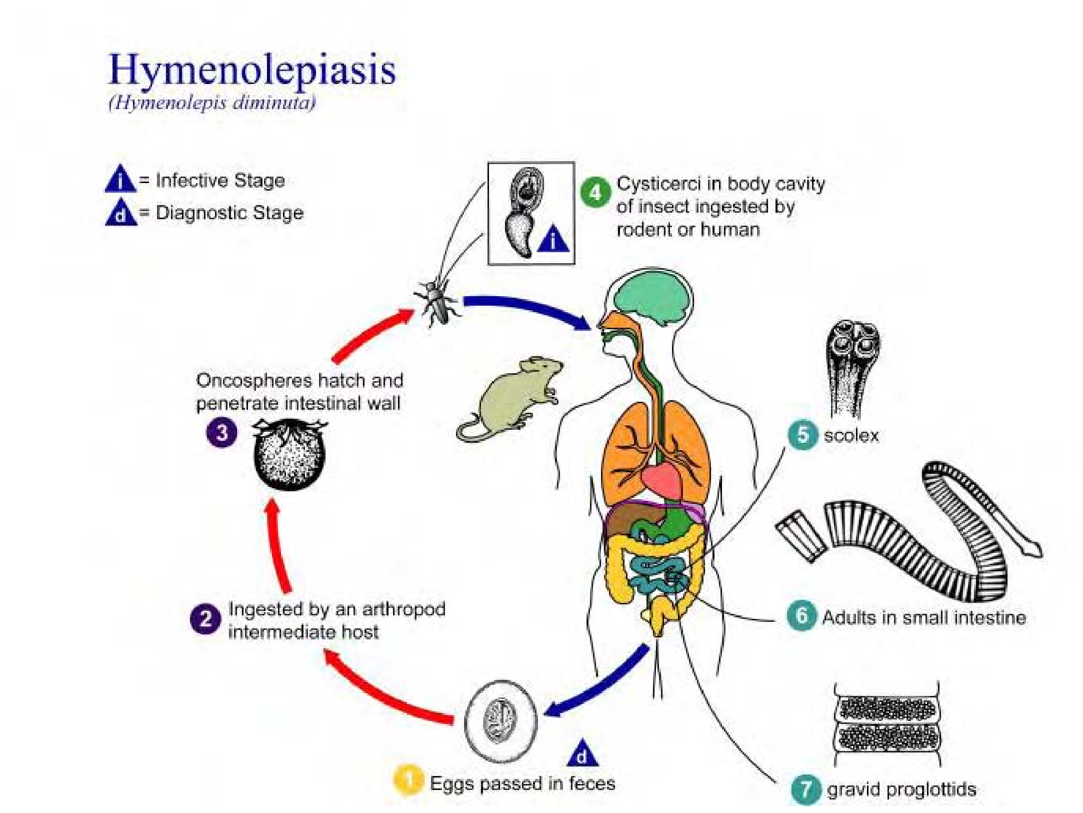
Hymenolepiasis
(Hymenolepis diminuta)
i = Infective Stage
d = Diagnostic Stage
4 Cysticerci in body cavity of insect ingested by rodent or human
i
5 scolex
6 Adults in small intestine
7 gravid proglottids
d
1 Eggs passed in feces
2 Ingested by an arthropod intermediate host
3 Oncospheres hatch and penetrate intestinal wall

Illustration 4-3. This is an illustration of the life cycle of *Hymenolepis diminuta*, the causal agent of Hymenolepiasis. (SOURCE: PHIL 3395 - CDC /Alexander J. da Silva, PhD/Melanie Moser)

Morphology

The ova are large, ovoid and yellowish with a moderately thick shell. They contain an oncosphere with six hooklets and a clear area between the oncosphere and the shell. They measure 70-85µm by 60-80µm.

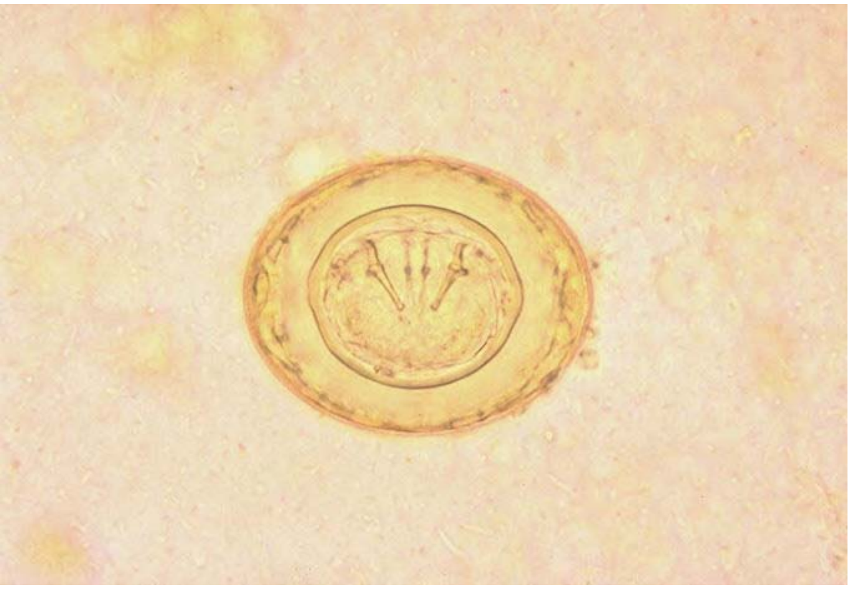

Image 4-8. *Hymenolepsis diminuta* egg. (SOURCE: PHIL 658 - CDC/Dr. Mae Melvin)

The adult worm is 20–60cm long. It has a knob like scolex with a rostellum but no hooklets and four suckers (in contrast to *H. nana*). The rostellum can be withdrawn into a rostellar sac. The tapeworm contains about 1000 proglottids, each of which is wider than long.

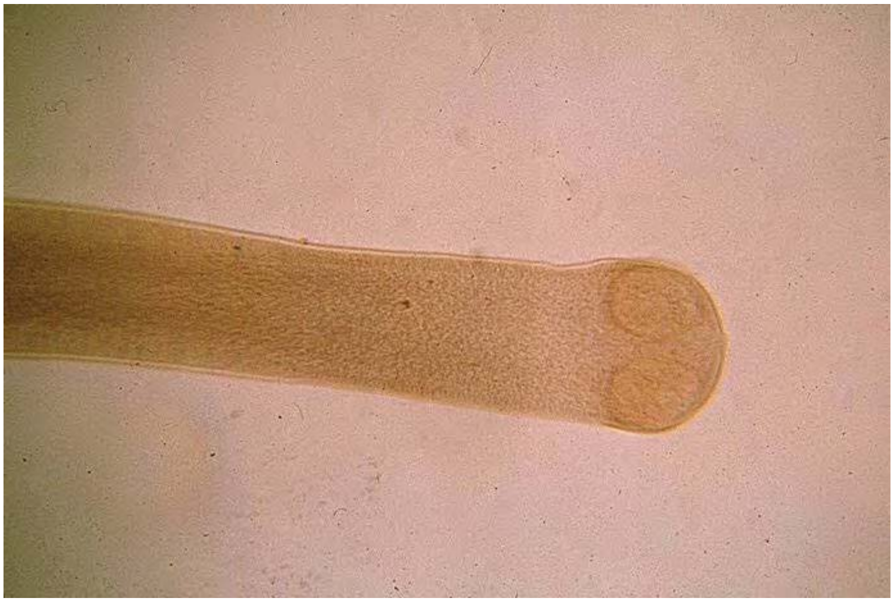

Image 4-9. *Hymenolepis diminuta* scolex. (SOURCE: PHIL 370 – CDC)

Clinical Disease

The symptoms associated with *H. diminuta* infections are few if any.

Laboratory Diagnosis

Diagnosis is based on recovery and identification of the characteristic ova in a formol-ether concentrate of feces. Adult worms and proglottids are rarely seen in stool samples.

Diphyllobothrium latum

Introduction

Members of this order, commonly known as pseudophyllids, are chiefly parasites of fish-eating mammals, birds and fish. They typically are found with a scolex which is characterized by two shallow elongated bothria situated with one dorsally and one ventrally. The proglottids are flattened dorsoventrally.

Diphyllobothrium latum is an intestinal tapeworm, known as the human ‘broad’ tapeworm. It is the largest tapeworm found in man. The term ‘broad’ relates to the fact that the proglottids are generally wider than they are long. It is an important human parasite. The adult worms of two other species of the genus, *D. dendriticum* and *D. ditremum* are chiefly parasite of fish-eating birds and mammals.

The tapeworm, *D. latum* has a wide distribution, occurring especially in countries bordering the Baltic Sea (Finland, Sweden etc.): and also in Russia, Switzerland and North America. It is in these countries where the populations are known to eat uncooked or partly cooked (i.e. smoked) fish.

Apart from man they are found in many other hosts, especially the dog, cat and pig. This is due to the host countries allowing the domestic animals access to the offal from the infected fish.

Life Cycle and Transmission

The life cycle of this tapeworm requires two intermediate hosts.

The eggs are passed out in human feces, once in water they hatch out into small ciliates coracidium larvaem which swim until ingested by Copepods. It is in these intermediate hosts that growth and development of the 1st larval stage are completed (They are now known as procercoids). When these crustaceans (fresh water) are eaten by fish, the procercoid larvae continue to develop in the flesh of the fish and become known as plerocercoid larvae. It is this stage of the larvae which develops in man when they eat undercooked fish and they grow into adult worms in the small intestine.

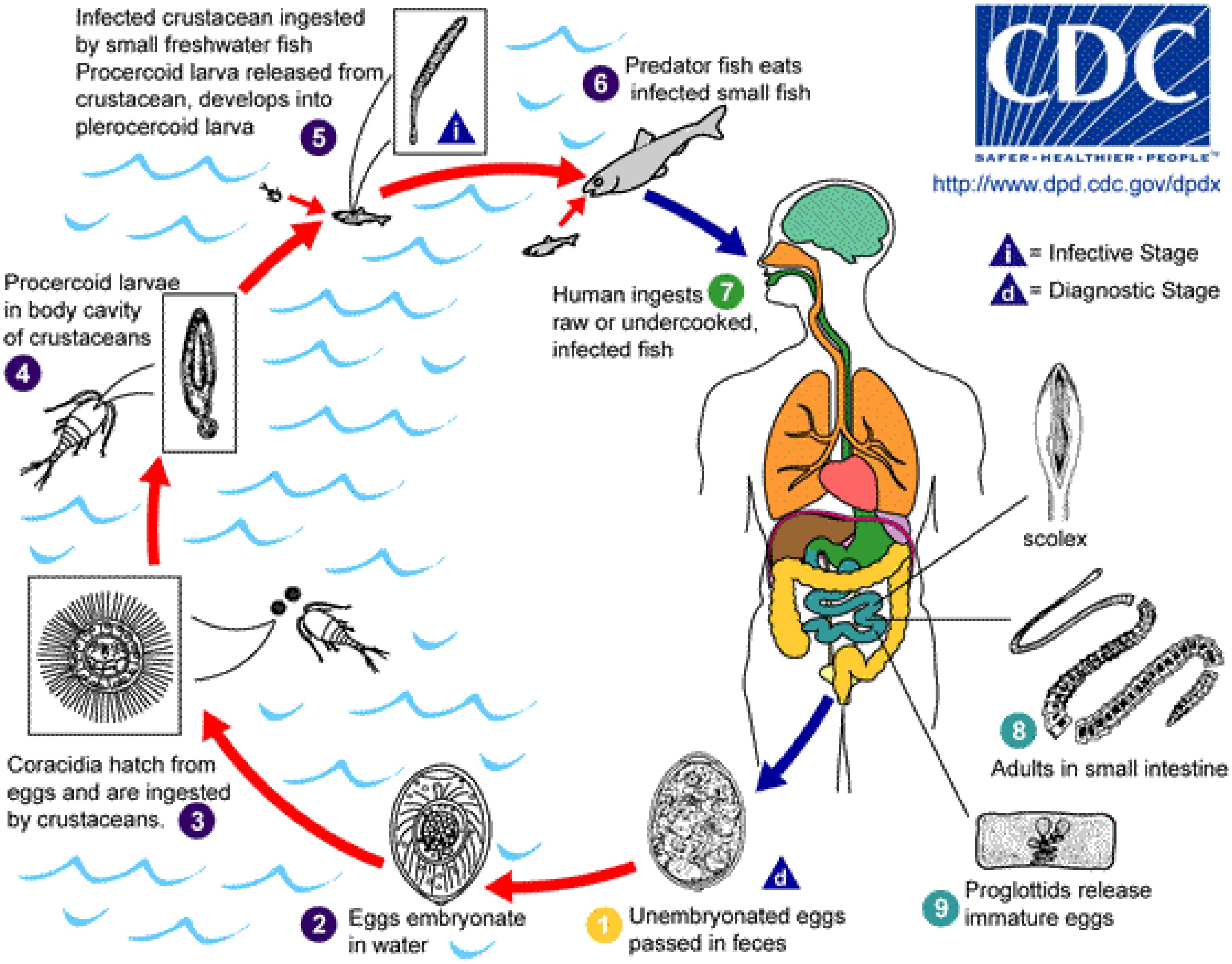
Infected crustacean ingested
by small freshwater fish
Procercoid larva released from
crustacean, develops into
plerocercoid larva
5
i
6 Predator fish eats
infected small fish
CDC
SAFER • HEALTHIER • PEOPLE
http://www.dpd.cdc.gov/dpdx
i = Infective Stage
d = Diagnostic Stage
Procercoid larvae
in body cavity
of crustaceans
4
Human ingests 7
raw or undercooked,
infected fish
scolex
8
Adults in small intestine
Coracidia hatch from
eggs and are ingested
by crustaceans. 3
2 Eggs embryonate
in water
1 Unembryonated eggs
passed in feces
d
9 Proglottids release
immature eggs

Illustration 4-4. Immature eggs are passed in feces ①. Under appropriate conditions, the eggs mature (approx. 18 to 20 days) ②and yield oncospheres which develop into a coracidia ③. After ingestion by a suitable freshwater crustacean (the copepod first intermediate host) the coracidia develop into procercoid larvae ④. Following ingestion of the copepod by a suitable second intermediate host, typically minnows and other small freshwater fish, the procercoid larvae are released from the crustacean and migrate into the fish flesh where they develop into a plerocercoid larvae (sparganum) ⑤. The plerocercoid larvae are the infective stage for humans. Because humans do not generally eat undercooked minnows and similar small freshwater fish, these do not represent an important source of infection. Nevertheless, these small second intermediate hosts can be eaten by larger predator species, e.g., trout, perch, walleyed pike ⑥. In this case, the sparganum can migrate to the musculature of the larger predator fish and humans can acquire the disease by eating these later intermediate infected host fish raw or undercooked ⑦. After ingestion of the infected fish, the plerocercoid develop into immature adults and then into mature adult tapeworms which will reside in the small intestine. The adults of *D. latum* attach to the intestinal mucosa by means of the two bilateral groves (bothria) of their scolex ⑧. The adults can reach more than 10 m in length, with more than 3,000 proglottids. Immature eggs are discharged from the proglottids (up to 1,000,000 eggs per day per worm) ⑨and are passed in the feces ①. Eggs appear in the feces 5 to 6 weeks after infection. In addition to humans, many other mammals can also serve as definitive hosts for *D. latum*. (SOURCE: CDC)

Morphology

The egg is usually ovoid and has a small knob at the opercular end and is yellowish-brown in color with a smooth shell, of moderate thickness. They measure 58-75µm by 40-50µm in size.

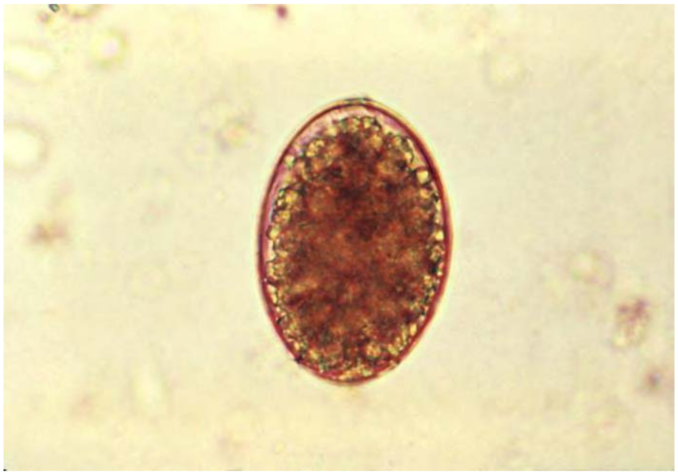

Image 4-10. This micrograph reveals an egg of tapeworm cestode parasite *Diphyllobothrium latum*. *Diphyllobothrium sp.* unembryonated eggs passed in the stool, are oval or ellipsoidal with an operculum at one end that can be inconspicuous. At the opposite (abopercular) end is a small knob that can be barely discernible. (SOURCE: PHIL 5258 – CDC)

Adult worms can reach up to a length of 10 meters or more and may contain up to 3,000 proglottids. The scolex is spatulate with no rostellum or hooklets. It has two shallow grooves or bothria, which are unlike the typical four suckers seen on the *Taenia* species. The proglottids measure 3µm long and 11µm wide and have a rosette shaped central uterus.

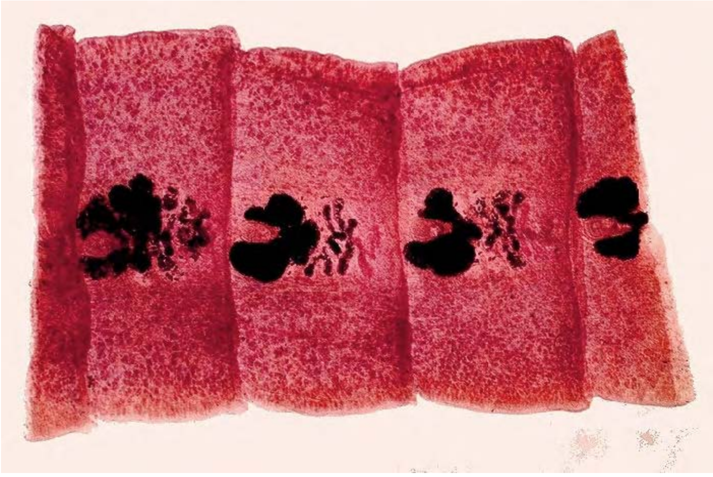

Image 4-11. Gravid proglottids of *Diphyllobothrium latum*. (SOURCE: PHIL 1516 - CDC /Dr. Mae Melvin)

Clinical Disease

The infection caused by *D. latum* is due to the ingestion of raw, poorly cooked or pickled fresh water fish. The symptoms associated with *D. latum* infection may be absent or minimal with eosinophilia. There may be occasional intestinal obstruction, diarrhea, and abdominal pain. The most serious symptom is the onset of pernicious anemia. This is due to a vitamin B_{12} deficiency, caused by excessive absorption of the vitamin by the adult worm and the absorption of cobalamins from the host intestine (occurring only in a small percentage of people).

Laboratory Diagnosis

Laboratory diagnosis depends on the recovery of characteristic eggs from a formol ether concentrate of feces. Proglottids may also be seen in fecal samples usually in a chain of segments from a few centimeters to about half of a meter in length.

4.3 Identifying Intestinal Helminths

The usual diagnostic stages for identifying medically important helminths are the eggs and larvae. Occasionally, adult worms like *Ascaris* and *Enterobius* may be seen and segments or proglottids are used for diagnosing certain tapeworms.

If an egg, is found with the following features as described below, it should be carefully observed in order to make a specific identification.

1. Size: The length and width are measured and are generally within a specific range.

2. Shape: Each species has its own particular shape.

3. Stage of development when passed: In some species, the eggs consist of a single cell; in some, there may be several cells; and some species are usually embryonated (i.e., they contain a larva) when passed in the feces. Occasionally, if the stool specimens are several hours or 1–2 days old, eggs may develop to more advanced stages. *Ascaris* eggs usually have only one cell when passed in the feces; however, the single cell may divide and, in old specimens, eggs with two or four cells may be seen. Hookworm eggs in specimens that are several hours old may contain 16, 32 or more cells. In 12–24 hours, the egg may be embryonated and later still the larvae may hatch. Therefore, when observing the stage of development of helminth eggs, be sure that the stool specimen is freshly passed. If it is several hours or a day old, expect to see changes in the stage of development of some species. Ideally only fresh samples should be accepted for diagnosis.

4. Thickness of the egg shell: Some species, like *Ascaris*, have thick shells; others, like hookworm, have thin shells.

5. Color: Some eggs are colorless (e.g., hookworm, *Enterobius*), others are yellow or brown (*Ascaris, Trichuris*).

6. Presence of characteristic like opercula (lids), spines, plugs, hooklets, or mammillated outer coats.

Chapter 5.

The Nematodes

5.1 Infections Acquired Through the Gastrointestinal Tract

Nematodes (or round worms) are non-segmented helminths known as make up a large assemblage of relatively simple structured organisms. They possess bilateral symmetry and a complete digestive tract with oral and anal openings; they taper to a relative point at both ends. They are also found to have separate sexes, with the male being smaller than the female, ranging in size from a few millimeters to over a meter in length. Their cylindrical non-segmented bodies allow them to be easily distinguishable from other helminths.

Nematode infections have a widespread distribution being found in both Temperate and Tropical climates. They can be found in fresh water, in the sea and the soil, successfully invading both animals and plants. The nematodes found in man invade the body fluids such as the blood or lymph channels and also the intestine. The ones that successfully invade the intestine are generally larger but, the nematodes which invade the tissues can grow to relatively enormous lengths.

Once hatched in the intestine they undergo an incredible migration. The larvae initially burrow into the mucosa, penetrate blood vessels and appear as second stage larvae in the liver within six hours post-infection. Here they remain for several days and develop into third stage larvae, L_3. These larvae then migrate to the heart and are carried to the lungs via the pulmonary arteries, arriving within four to seven days. From there they break out of the capillaries into the alveoli and finally work their way up the trachea to the pharynx and reach the small intestine on the 8th or 10th day post-infection.

Within the intestine, the larvae begin their third molt and become fourth stage larvae by the tenth day. The pre-patent period of *A. suum* in pigs (40–53 days) is less than that of *A. lumbricoides* (54–61 days) in humans. Two to three months after ingestion of the eggs, the females lay eggs in the intestine.

The fertilized female can lay about 200,000 eggs per day. Eggs require oxygen and moisture to embryonate and the worm is often found associated with *Trichuris trichiura* (see the *Trichuris trichiura* section).

Species	Size	Shape	Color	Stage of Development When Passed	Specific Features And Variations
Nematodes					
Enterobius vermicularis	55 µm x 26 µm Range, 50-60 µm 20-32 µm.	Elongated, asymmetrical with one side flattened, other side convex.	Colorless.	Embryonated. Contains C shaped or tadpole-like embryo.	Smooth, thin eggshell with one flattened side. Occasionally may contain a fully developed larva. (More readily found on anal swabs than in feces).
Ascaris lumbricoides					
fertile egg	60 µm x 45 µm. Range, 45-70 µm x 35-45 µm.	Round or ovoidal. with thick shell.	Brown or yellow brown.	1 cell, separated from the shell at both ends.	Mammillated albuminous coat or covering on outer shell. Coat is sometimes lost and decorticated eggs have a colorless shell with gray or black internal material. Eggs may be in 2, 4, or more cells, or contain a fully developed larva.
infertile egg	90 µm x 40 µm. Range, 85-95 µm x 35-45 µm.	Elongated, occasionally triangular, kidney shaped or other bizarre forms. Shell often very thin.	Brown.	Internal material is a mass of irregular globules and granules that fills shell.	Mammillated covering attenuated or missing in many cases.
Trichuris trichiura	54 µm x 22 µm. Range, 49-65 µm x 20-29 µm.	Elongated, barrel-shaped with a polar "plug" at each end.	Yellow to brown. "Plugs" are colorless.	1 cell or unsegmented.	Polar plugs are distinctive. Eggs occasionally are oriented in a vertical or slanted position and may not be readily recognized. A gentle tap on the coverslip will usually reorient the egg. On rare occasions, atypical eggs lacking polar plugs may be seen.
Hookworm					
Ancylostoma duodenale	60 µm x 40 µm. Range, 57-76 µm x 35-47 µm.	Oval or ellipsoidal with a thin shell.	Colorless with grayish cells.	4- to 8-cell stage.	Occasionally, eggs in advanced cleavage (16 or more cells) or even embryonated may be seen. Rhabditiform larvae may be present if the specimens are old. Species identification can not be made on eggs alone; therefore, eggs should be reported simply as hookworm.
Necator americanus	65 µm x 40 µm. Range, 57-76 µm x 35-47 µm.				
Trichostrongylus species	90 µm x 40 µm. Range, 75-95 µm x 40-50 µm.	Elongated with one or both ends more pointed than hookworm.	Colorless with grayish cells.	May be in advanced cleavage or morula stage.	Egg resembles hookworm egg but is larger and more pointed at the ends.

Table 5-1. Differential Morphology of the Diagnostic Stages of Helminths Found in Humans: Eggs (Nematodes) (SOURCE: CDC)

Ascaris lumbricoides

Morphology

Ascaris lumbricoides is the largest of the intestinal nematodes found in man. The male measures 15cm with a diameter of 3-4µm and has a curled tail with protruding spicules. The female is 20-35cm long with a diameter of 5µm with a straight pointed posterior end. The mouth has one dorsal and two ventral lips. Both are creamy white and the cuticle has fine circular striations.

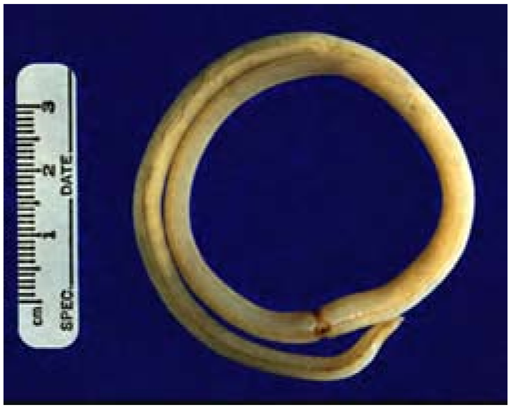

Image 5-1. Adult worm of *Ascaris lumbricoides.* They appear creamy white with fine circular striations, for diagnosis they require to be distinguished from earthworms. Females measure approximately 20-35cm long (SOURCE: CDC)

The ova can be unfertilized, fertilized or decorticated and can show considerable variation in shape and size. They measure 85-95µm by 43-47µm. The fertilized ova are easily recognized, oval in shape with a thick wall showing an irregular bumpy surface. They measure 45-75µm by 35-50µm. The outer covering has an albuminoid coat, stained golden brown by bile. The outer wall lies directly on top of a thick smooth shell, which is not easily distinguishable. Some have lost their albuminoid wall. The unfertilized ova are longer and narrower than the fertile ova, measuring 75-85µm by 35-50µm.

The shell layers of the egg provide a very resistant structure which can withstand many chemicals which make them ideal parasites of the intestine.

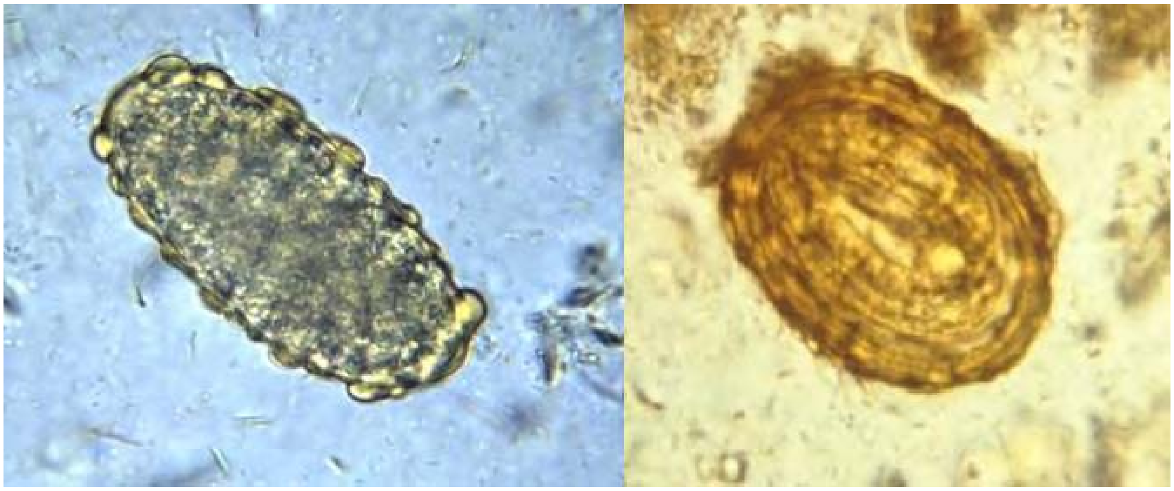

Image 5-2. Unfertilized (left) and fertilized (right) *Ascaris lumbricoides* eggs. The unfertilized eggs are longer and narrower than fertilized eggs, measuring 75-85µm by 35-50µm wide. The fertilized eggs have a thick and bumpy outer wall which is stained golden brown with bile. (Saline wet prep) (SOURCE: PHIL 411/4821 - CDC/Dr. Mae Melvin)

Clinical Disease

Small burdens of worms in the intestine may cause no symptoms. The patient may have symptoms of pneumonitis with cough and low grade fever during the migration of the larvae through the liver and lungs. This can be accompanied by wheezing, coughing and eosinophilia. In heavy worm burdens the adult worms actively migrate in the intestine resulting in intestinal blockage, vomiting and abdominal pain but infections may also be asymptomatic. The worms can penetrate through the wall of the intestine, or into the appendix, travel up the common bile duct, which may become blocked or they may then enter the gal bladder or liver. A heavy worm burden in children may lead to severe nutritional impairment and retardation in growth.

Laboratory Diagnosis

The adults of *A. lumbricoides* may be expelled through the anus, mouth or nose. It is important to distinguish the adult worms from earthworms which are segmented and are often collected as a contaminant from toilets.

The microscopic examination of stool deposits after concentration reveals the characteristic bile stained ova. Eggs may be difficult to identify if an excess of iodine is added to the wet preparation as they retain the stain thus resembling debris. Ova may also become decorticated. In most symptomatic cases identification is easy due to the vast number of eggs, which can be found within a few seconds of starting to scan the slide.

Hookworm Species

Introduction

Hookworms infective to man comprise of two species, *Necator americanus* and *Ancylostoma duodenale*. They are classed as one of the most destructive of human parasitic helminths. There is no intermediate host, with man being the only definitive host.

It is estimated that there are some 900 million cases of infection world wide (Crompton, 1989). The infection is serious where the worms insidiously undermine the health of their hosts.

They occur in areas where sanitary and environmental conditions favor the development of the eggs and larval infections (e.g., warm, damp soil).

The geographic distributions of the two species are remarkably divided into:

Necator americanus which predominately is a New World hookworm, where it was introduced from Africa to the Western Hemisphere. It can also be found in the Far East, Asia, Africa, South America, and Oceania.

Ancylostoma duodenale is an Old World hookworm; it is the only species of Europe and areas bordering the Mediterranean. It can also be found in the Middle East, North China, Africa, Asia, and South America.

Life Cycle

The adult worms live in the small intestine, attached firmly to the mucous membrane of the gut lining, and feed on blood and tissue. The adult females deposit their eggs whilst in the gut (they can produce up to 20,000 eggs per day), the eggs are then passed out in the feces. The rhabditiform larvae hatch in warm, damp soil (light sandy loam), feeding on bacteria. After about one week during which they have gone through two molts become infective and climb into a suitable position waiting for a suitable host to pass by. The larvae enter the host by penetrating unbroken skin (it is now recognized that *A. duodenale* can successfully enter man by oral ingestion, this may be more important for this species than skin penetration). The larvae then enter blood vessels and are carried to the heart, lungs and trachea. They are then swallowed and develop into adult worms in the small intestine. Larvae that are initially swallowed may not show this migration.

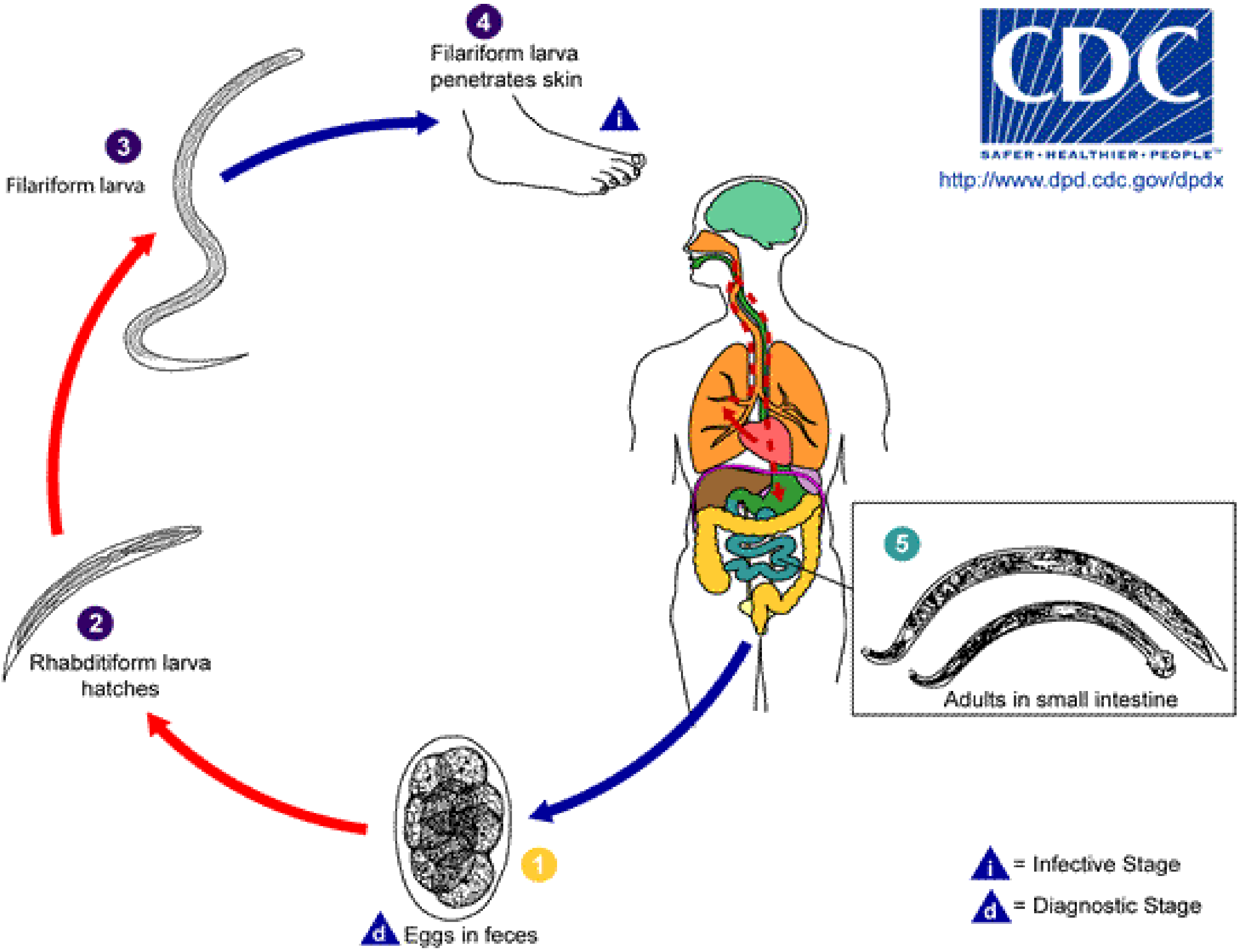
4
Filariform larva penetrates skin
i
3
Filariform larva
CDC
SAFER·HEALTHIER·PEOPLE™
http://www.dpd.cdc.gov/dpdx
5
Adults in small intestine
2
Rhabditiform larva hatches
1
d Eggs in feces
i = Infective Stage
d = Diagnostic Stage

Illustration 5-1. Eggs are passed in the stool ①, and under favorable conditions (moisture, warmth, shade), larvae hatch in 1 to 2 days. The released rhabditiform larvae grow in the feces and/or the soil ②, and after 5 to 10 days (and two molts) they become become filariform (third-stage) larvae that are infective ③. These infective larvae can survive 3 to 4 weeks in favorable environmental conditions. On contact with the human host, the larvae penetrate the skin and are carried through the veins to the heart and then to the lungs. They penetrate into the pulmonary alveoli, ascend the bronchial tree to the pharynx, and are swallowed ④. The larvae reach the small intestine, where they reside and mature into adults. Adult worms live in the lumen of the small intestine, where they attach to the intestinal wall with resultant blood loss by the host ⑤. Most adult worms are eliminated in 1 to 2 years, but longevity records can reach several years. Some *A. duodenale* larvae, following penetration of the host skin, can become dormant (in the intestine or muscle). In addition, infection by *A. duodenale* may probably also occur by the oral and transmammary route. *N. americanus*, however, requires a transpulmonary migration phase. (SOURCE: CDC)

Larvae live for an average of 3–6 weeks in the tropics (*A. duodenale* can live at lower temperatures than *N. americanus* can, and so is found in more temperate climates).

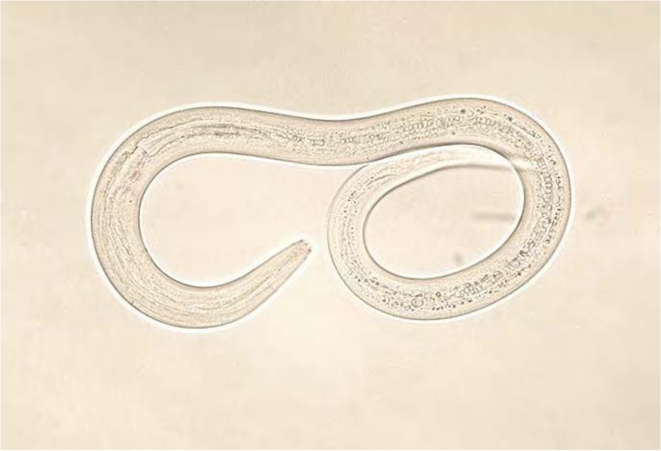

Image 5-3. Hookworm larva. Both *Ancylostoma duodenale* and *Necator americanus* larvae have similar general morphology and measuring approximately 10-13µm for females and 8-11µm for males. (SOURCE: PHIL 1513 – CDC/Dr. Mae Melvin)

Morphology

Both species have similar general morphology and measure approximately, females 10–13µm and males 8–11µm. The general morphology of the two species resemble those of *Nippostrongylus brasiliensis*, the rat hookworm, but they are approximately twice the size of the rat hookworm (*Nippostrongylus brasiliensis* a species not discussed here).

The male species has a posterior copulate bursa which is absent from the female. The females though possess a vulva opening which is found almost one third of the body length from the posterior end, they also have two ovaries. Most of the female body is occupied with eggs.

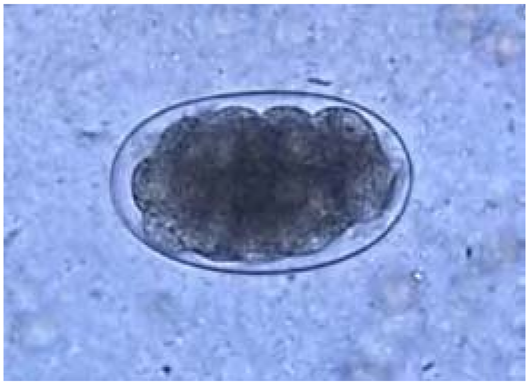

Image 5-4. Hookworm egg, normally passed in feces during the 4 - 8 cell stage. The ova of both species are similar with the shape being oval and transparent with a smooth thin shell and measuring 56-75µm by 36-40µm. (SOURCE: PHIL 5220 – CDC)

The mouth (or buccal cavity) of the two species show a conspicuous pair of chitinous plates on the dorsal surface. *Ancylostoma duodenale* buccal cavity bears two hook like teeth on the top and two triangular cutting plates on the bottom. While the mouth of *N. americanus* has four cutting plates, two on the ventral and two on the dorsal surfaces. The head is curved in both species but *Necator* adults it is finer but more pronounced forming a definite "hook" at the anterior end. The buccal cavity is used to attach the worms securely to the mucosa of the small intestine. With the teeth and cutting plates used to pierce the mucosa.

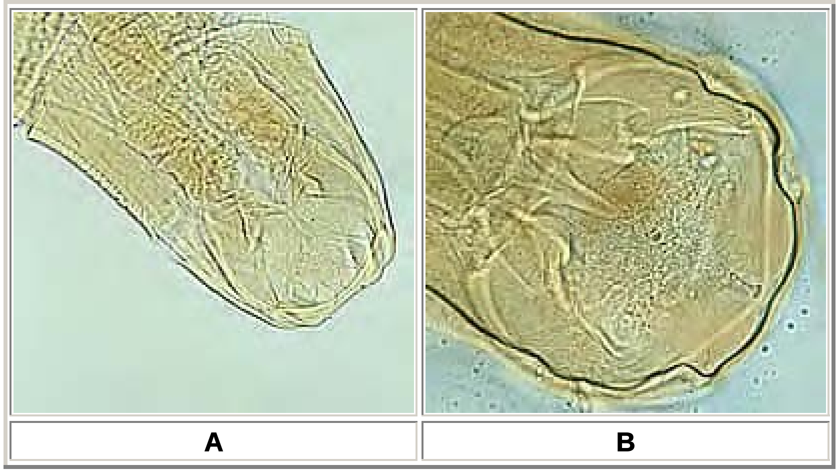

Illustration 5-2. A: Adult worm of *Ancylostoma duodenale*. Anterior end is depicted showing cutting teeth. **B:** Adult worm of *Necator americanus*. Anterior end showing mouth parts with cutting plates. (SOURCE: CDC)

The ova are oval and transparent with a smooth thin shell and measure 56-75µm by 36-40µm. They are usually passed in the 4-8 cell stage in feces and may be embryonated. The ova of both species of Hookworm are similar.

The bursa (the characteristic external feature which forms an umbrella-like extension surrounding the cloaca) of both male species is well developed, *Necator americanus* adults are distinguished from *Ancylotstoma duodenale* by the split dorsal rays and the close arrangement of the lateral rays.

Simplistically the life cycle has three phases:

The parasitic adult females lay eggs while they are in the duodenum where they hatch producing rhabditiform (non-infective) larvae.

1. The larvae can have two fates in life, one where they are passed out in the feces to continue down the free-living path or they develop into infective filariform larvae whilst traveling down the small intestine.

2. The larvae which, develop in the environment can also undergo different development. Some larvae undergo direct development (homogonic) or indirect development (heterogonic).

The non-infective first stage (rhabditiform) larvae develop into free living adults in the soil within 2–5 days and produce infective third stage or filariform larvae which can penetrate exposed skin (heterogonic development). This phase is common in moist, warm tropical countries.

The non-infective rhabditiform larvae which are excreted in the feces develop into infective filariform larvae in the soil (homogonic development). These infective larvae penetrate exposed skin. There is no development of free living adult worms and this phase is common in temperate zones. The larvae never undergo sexual maturity.

Both types of larvae can become established in the host by penetrating the skin or by oral ingestion.

The larvae which infect the host by penetrating the skin undergo a migration through the dermal tissues and into the circulation to the heart and lungs, then up the bronchi and trachea, where they are eventually swallowed and pass down into the intestine. On reaching the mucosa of the duodenum the females develop and produce eggs. Adult males are unable to attach themselves to the mucosa, therefore, for any copulation to take place they must mate in the lumen of the intestine.

3. The non-infective rhabditiform larvae develop into infective filariform larvae while passing down the small intestine. Autoinfection occurs when the larvae reinfect the host by penetrating the intestinal mucosa or the perianal or perineal skin. The larvae migrate to the lungs via the circulatory system and then return to the intestine.

From initial infection to maturity usually takes less than four weeks.

Hyperinfection Syndrome

The autoinfective capability of larvae may be responsible for long term infections which persist for many years. The parasite and host reach an equilibrium state where neither host nor parasite suffers any adverse reactions. If this equilibrium is disturbed e.g. immunosuppression, the infection proliferates with immense numbers of larvae migrating to every tissue in the body, especially the lungs. This condition is referred to as disseminated strongyloidiasis. This results in tissue damage, pneumonitis, brain damage or respiratory failure.

Laboratory Diagnosis

Microscopy

Laboratory diagnosis depends on finding larvae in stool, sputum or duodenal aspirates.

Strongyloides larvae may be present in the stool in very small numbers and culture methods may be needed to encourage the rhabditiform larvae to develop into filariform larvae and migrate from the sample. The Enterotest or string test can be used to recover larvae from duodenal aspirates.

Larvae must be distinguished from hookworm larvae especially if it is an older sample. Rhabditiform larvae are most commonly seen.

A good concentration technique is essential to increase the chances of seeing larvae, though they are easily killed making diagnosis more difficult.

Serology

Serological tests are of value in the diagnosis of strongyloidiasis when larvae cannot be found. An enzyme linked immunosorbent assay (ELISA) using larva antigen, is usually employed.

Little can be used to distinguish between the two species, but using the curved shape of the head is a good indicator.

Clinical Disease

Larval penetration of the skin may lead to pruritis, often termed as ‘ground itch’ at the site of penetration. Respiratory symptoms may arise during the larval migration.

The adult worm in the intestine may cause intestinal necrosis and blood loss as a result of the attachment of the adult to the intestinal mucosa. Patients with acute infections may experience nausea, vomiting, abdominal pain, diarrhea and eosinophilia.

Chronic infections may lead to iron deficiency and anemia resulting from the excessive loss of iron. Heavy worm burden in children may have serious consequences including death.

Laboratory Diagnosis

Adults of Hookworm species may be passed out spontaneously in feces. The microscopic examination of stool deposits after an iodine stained, formol-ether concentration method concentration reveals the characteristic ova.

Cutaneous Larva Migrans

If man comes in contact with hookworm larva of the dog (or cat), A. braziliense or A. caninum, penetration of the skin may take place. The larvae are unable to complete the migration to the small intestine and become trapped. Trapped larvae may survive for weeks or even months, migrating through the subcutaneous tissues.

Trapped larvae have been known to produce severe reaction, forming tunnels through the tissues, causing intense itchy skin eruption, producing a red, track under the skin which demonstrates accurately the wanderings of the larvae.

Often intense pruritis and scratching may lead to secondary bacterial invasion, known as ‘creeping eruption’ or ‘cutaneous larval migrans’.

Trichuris trichiura

Introduction

Trichuris trichiura, more commonly known as the Whip Worm, due to the whip-like form of the body. These nematodes are most commonly seen in tropical climates and in areas where sanitation is poor. They seem to occur in areas particularly where Ascaris and Hookworms are found due to the eggs requiring the same conditions to allow for embryonation. Both species can be found in humans together. There are several species within this genus each infecting specific hosts, but only T. trichiura infects man. Causing human trichuriasis. It is a parasite that infects many more people than is generally appreciated, up to 800 million people throughout the tropics and temperate regions.

Life cycle eggs require a warm, moist environment with plenty of oxygen to ensure embryonation, but once they have embryonated they are extremely resistant to environmental conditions.

Adult worms are found in the cecum and upper part of the colon of man. In heavy infection they can be found in the colon and the terminal ileum. They attach to the mucosa by the anterior end or by embedding the anterior portion of the body in the superficial tissues, obtaining nutrition from the host tissues.

Once fertilized the female worms lay several thousands of eggs, which are unsegmented at the oviposition and are passed out in the feces. Once they have been passed out they require an embryonation period in the soil which may last from two weeks to several months, after which they become infective.

When embryonated eggs are swallowed by human hosts larvae are released into the upper duodenum. They then attach themselves to the villi lower down the small intestine or invade the intestinal walls. After a few days the juveniles migrate slowly down towards the cecum attaching themselves to the mucosa, reaching their final attachment site simultaneously.

The larvae reach maturity within three weeks to a month after infection, during which they undergo four molts. There is no lung migration and the time from ingestion of infective eggs to the development of adult worms is about three months.

Infection is achieved by swallowing soil that contains embryonated eggs. Therefore, children are most commonly seen to possess the infections, as they are more likely to swallow soil.

Morphology

The adult worms of *T. trichuria* are characterized by the enormously elongated capillary-like esophagus (anterior end); with the anus situated in the extreme tip.

The thin anterior portion of the worm is found embedded in the mucosa. There are no lips and the vulva is at the junction of the thread-like and thickened regions of the body. The posterior end is much thicker and lies free in the lumen of the large intestine.

The female measures 35-50µm long and the male 30-45µm long.

The ova are characteristically barrel shaped, bile stained with bipolar plugs. They measure 50-54µm by 20-23µm.

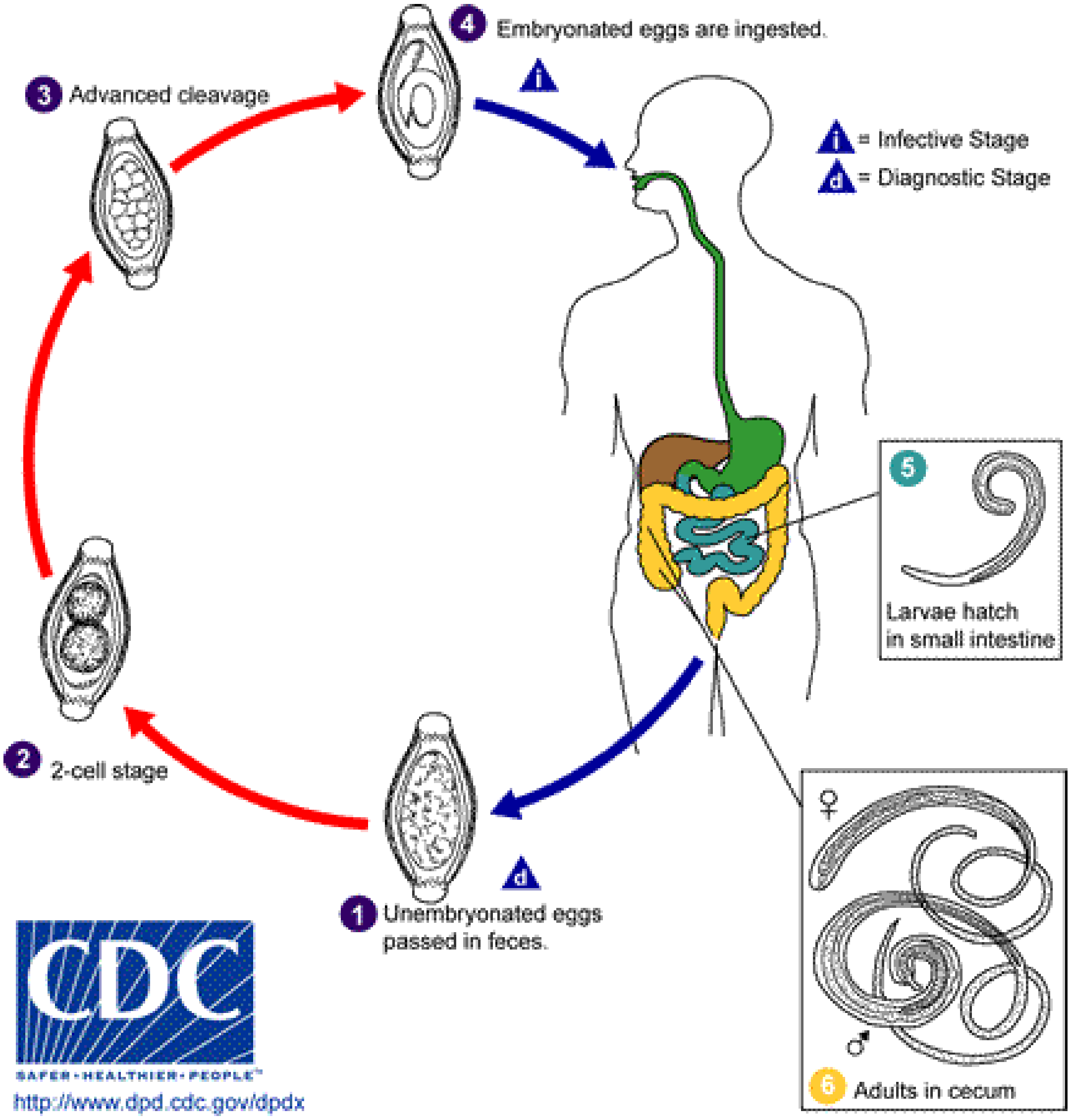
④ Embryonated eggs are ingested.
i
③ Advanced cleavage
i = Infective Stage
d = Diagnostic Stage
⑤
Larvae hatch
in small intestine
② 2-cell stage
d
① Unembryonated eggs
passed in feces.
♀
♂
⑥ Adults in cecum
CDC
SAFER • HEALTHIER • PEOPLE™
http://www.dpd.cdc.gov/dpdx

Illustration 5-3. The unembryonated eggs are passed with the stool ❶. In the soil, the eggs develop into a 2-cell stage ❷, an advanced cleavage stage ❸, and then they embryonate ❹; eggs become infective in 15 to 30 days. After ingestion (soil-contaminated hands or food), the eggs hatch in the small intestine, and release larvae ❺that mature and establish themselves as adults in the colon ❻. The adult worms (approximately 4 cm in length) live in the cecum and ascending colon. The adult worms are fixed in that location, with the anterior portions threaded into the mucosa. The females begin to oviposit 60 to 70 days after infection. Female worms in the cecum shed between 3,000 and 20,000 eggs per day. The life span of the adults is about 1 year. (SOURCE: CDC)

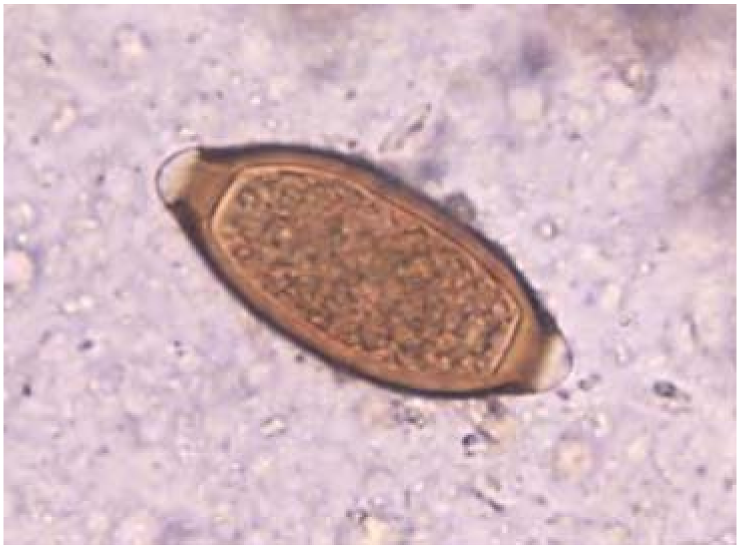

Image 5-5. *Trichuris trichuria* ovum with its opercular plugs, shown as white gaps at either end of the egg. (Saline wet prep) (SOURCE: PHIL 652 – CDC/Dr. Mae Melvin)

Clinical Disease

Most infections due to this nematode are light to moderate with minimal or no symptoms. However, a heavy worm burden may result in mechanical damage to the intestinal mucosa due to the adult worm being threaded into the epithelium of the cecum. Abdominal cramps, tenesmus, dysentery and prolapsed rectum may occur in these cases.

If a prolapsed rectum is observed, many worms may be seen adhering to the mucosa of the rectum.

Symptomatic infections are usually only seen in children. The majority of infections are chronic and mild, with nonspecific symptoms like diarrhea, anemia, growth retardation, eosinophilia.

Laboratory Diagnosis

The adult worms of *T. trichiura* are rarely seen in the feces. The microscopic examination of stool deposits after an iodine stained, formol-ether concentration method concentration reveals the characteristic barrel shaped ova. In symptomatic infections numerous numbers of eggs can be seen due to the prolific nature of the female worms, even in light infections many eggs can be seen in the smear.

Strongyloides stercoralis

Introduction

Strongyloides stercoralis is an intestinal nematode commonly found in warm areas, although it is known to survive in the sub-tropics (hot and humid conditions). The geographic range of *Strongyloides* infections tend to overlap with that of Hookworm due to the eggs requiring the same environmental conditions to induce embryonation.

This parasite is interesting in that it contains a free-living stage (exogenous) and a parasitic stage (endogenous) where the larvae undergo development in both stages.

Life cycle

The life cycle of *S. stercoralis* is a complex one as demonstrated in the diagram below.

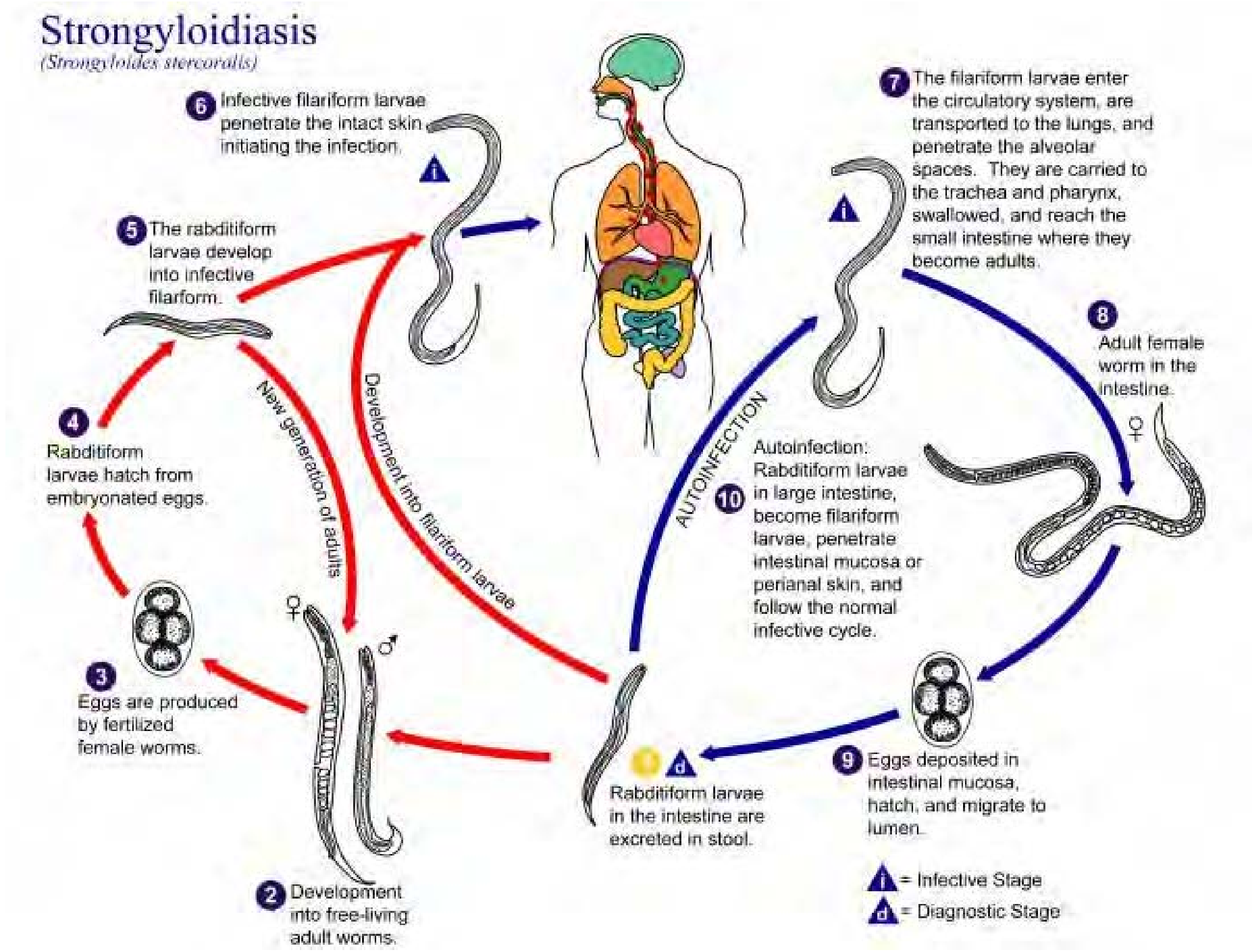
Strongyloidiasis
(Strongyloides stercoralis)
6 Infective filariform larvae penetrate the intact skin initiating the infection.
i
7 The filariform larvae enter the circulatory system, are transported to the lungs, and penetrate the alveolar spaces. They are carried to the trachea and pharynx, swallowed, and reach the small intestine where they become adults.
i
5 The rabditiform larvae develop into infective filarform.
8 Adult female worm in the intestine.
♀
New generation of adults
Development into filariform larvae
AUTOINFECTION
4 Rabditiform larvae hatch from embryonated eggs.
10 Autoinfection: Rabditiform larvae in large intestine, become filariform larvae, penetrate intestinal mucosa or perianal skin, and follow the normal infective cycle.
♀
♂
3 Eggs are produced by fertilized female worms.
1
d
Rabditiform larvae in the intestine are excreted in stool.
9 Eggs deposited in intestinal mucosa, hatch, and migrate to lumen.
2 Development into free-living adult worms.
i = Infective Stage
d = Diagnostic Stage

Illustration 5-4. Diagram of the life cycle of *Strongyloides stercoralis.* (SOURCE: PHIL 3419 – CDC/ Alexander J. da Silva, PhD/Melanie Moser)

Morphology

The first stage rhabditiform larvae measure approximately 250μm long by 20μm wide. They have a bulbed esophagus and a short buccal cavity. In an old specimen, rhabditiform larvae of *S. stercoralis* must be differentiated from those of hookworm which have a longer buccal cavity. The third stage or filariform larva is approximately 500μm long and has a notched tail (see below) compared with that of hookworm which is sheathed and has a long slender tail.

Adults are slender and possess and extremely long esophagus which in the female extends1/3 to1/2 of the body. The anal opening is ventral and the tail is pointed.

	RHABDITIFORM LARVA (First Stage. Has bulbed esophagus.)			**FILARIFORM LARVA (Third Stage. Lacks prominent bulb in esophagus.)**		
Species	**Size**	**Genital Primordium**	**Buccal Cavity**	**Size**	**Length of Esophagus**	**Tip of Tail**
Strongyloides stercoralis	225 μm × 16 μm. Range, 200- 300 μm × 16-20 μm.	Prominent. Is an elongate, tapered, or pointed structure located along ventral wall about the body length.	Short, about 1/3-1/2 as long as the width of the anterior end of the body.	550 μm × 20 μm. Range, 500-550 μm × 20-24 μm.	Extends approximately 1/2 length of body.	Notched.
Hookworm	250 μm × 17 μm. Range, 200- 300 μm × 14-17 μm.	Inconspicuous. Rarely distinct. When seen, is small, located nearer the tail than that of *Strongyloides*.	Long. Approximately as long as the width of the body.	500 μm. Range, 500-700 μm × 20-24 μm.	Extends about 1/4 1ength of body.	Pointed.

Table 5-2. Differential Morphology of the Diagnostic Stages of Helminths Found in Humans: Larvae (SOURCE: CDC)

Eggs are rarely found in the stool as they hatch in the intestine. They are oval and thin shelled, resembling those of hookworm but are smaller measuring 50-58μm by 30-34μm.

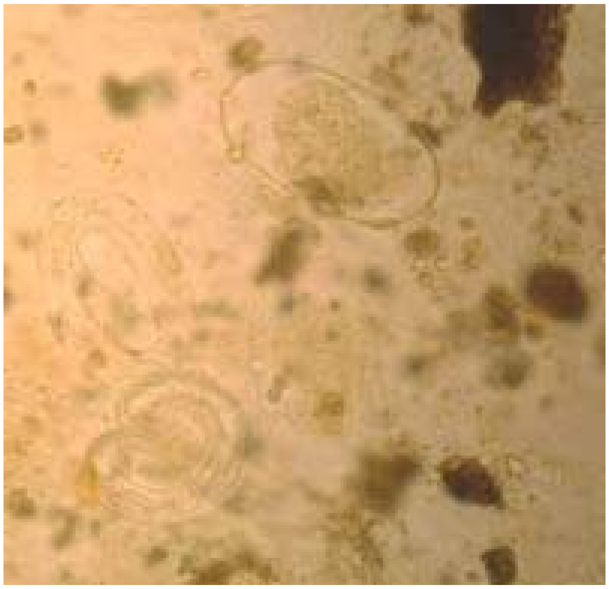

Image 5-6. Thin shelled ova of *Strongyloides stercoralis.* Measuring 50µm by 30µm, they are smaller than Hookworm eggs. (SOURCE: CDC)

Clinical Disease

Disease associated with infections due to *S. stercoralis* is varied, ranging from some patients being totally asymptomatic to the hyperinfection syndrome. There are three areas of involvement in *Strongyloides* infections; skin, lungs and intestine.

1. Initial skin penetration of the filariform larvae usually causes very little reaction, however with repeated infections the patient may mount a hypersensitive reaction thus preventing the larvae from completing its life cycle. The term larva currens is used when there is a rapidly progressing urticarial track.

2. The migration of larvae through the lungs may stimulate an immune response which can result in a cough, wheezing and fever.

3. Symptoms associated with intestinal strongyloidiasis may mimic a peptic ulcer due to ulceration of the intestinal mucosa. In heavy infections the intestinal mucosa may be severely damaged resulting in malabsorption. There may also be lower gastrointestinal bleeding. Eosinophila may be high.

Chapter 6.
The Trematodes

6.1 Infections of the Alimentary Canal and Associated Organs

Introduction

The trematodes (or flukes) are leaf shaped with an outer cover called the tegument which may be smooth or spiny. There are two suckers or attachment organs, an anterior oral sucker and a posterior ventral sucker. The suckers form a characteristic feature of the group, from which the name Trematode is derived from the Greek word for “hole.” They can occur in a variety of host environments, with the majority being endoparasites but some are found to be ectoparasitic.

Most trematodes are hermaphroditic and most of the body consists of reproductive organs and their associated structures. The digestive system is well developed; they generally feed on intestinal debris, blood, mucus and other tissues, depending on the host environment.

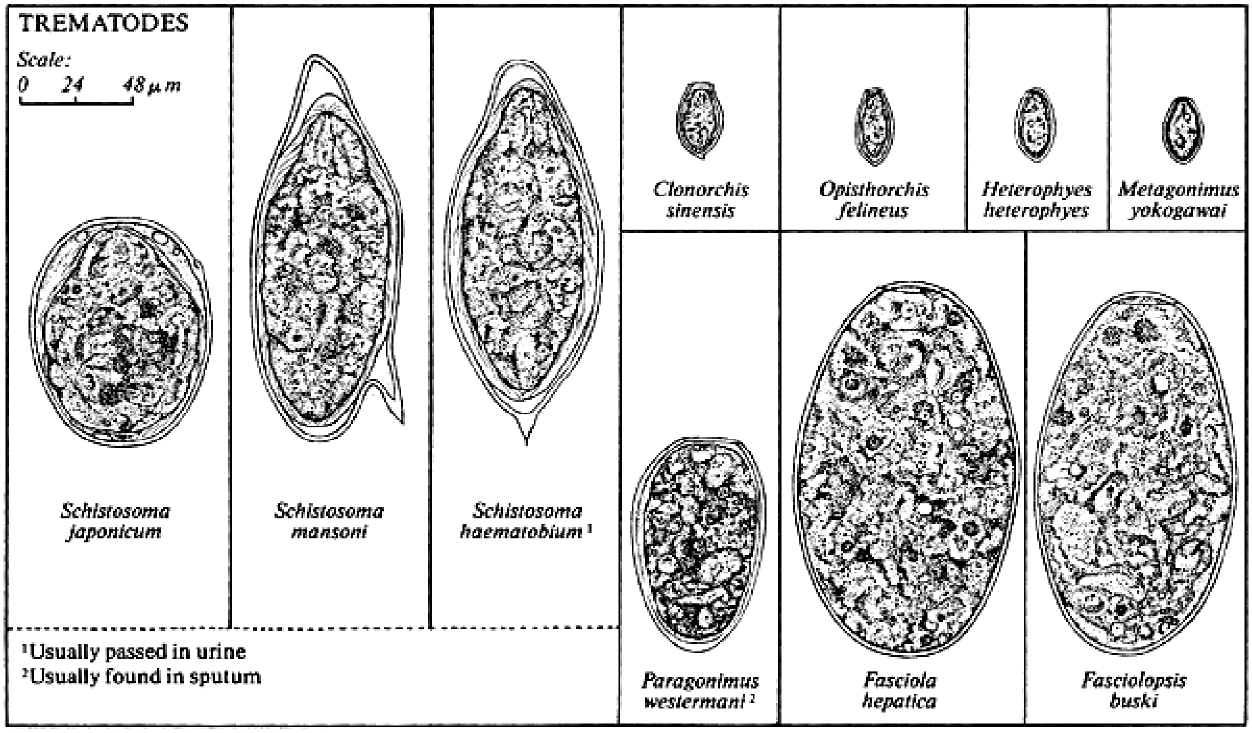
TREMATODES
Scale:
0 24 48 µm
Schistosoma japonicum
Schistosoma mansoni
Schistosoma haematobium ¹
Clonorchis sinensis
Opisthorchis felineus
Heterophyes heterophyes
Metagonimus yokogawai
Paragonimus westermani ²
Fasciola hepatica
Fasciolopsis buski
¹Usually passed in urine
²Usually found in sputum

Illustration 6-1. Trematode Eggs Found in Stool Specimens of Humans. (SOURCE: CDC/Adapted from Melvin, Brooke, and Sadun, 1959)

Species	Size	Shape	Color	Stage of Development When Passed	Specific Features and Variations
Trematodes					
Schistosoma mansoni	140 µm x 66 µm. Range, 114-180 µm x 45-73 µm.	Elongated with prominent lateral spine near posterior end. Anterior end tapered and slightly curved.	Yellow or yellow brown.	Embryonated. Contains mature miracidium.	Lateral spine. Found in feces; in rare cases, in urine also. Eggs are discharged at irregular intervals and may not be found in every stool specimen. Are rare in chronic stages of infection.
Schistosoma japonicum	90 µm x 70 µm. Range, 68-100 µm x 45-80 µm.	Oval. Small lateral spine is often seen or may appear as a small hook or "knob" located in a depression in the shell.	Yellow or yellow brown.	Embryonated. Contains mature miracidium.	Found in feces. Often coated with debris and may be overlooked.
Schistosoma haematobium	143 µm x 60 µm. Range, 112-170 µm x 40-70 µm.	Elongated with rounded anterior end and terminal spine at posterior end.	Yellow or yellow brown.	Embryonated. Contains mature miracidium.	Terminal spine. Found in urine, occasionally in feces. Egg often covered with debris.
Schistosoma intercalatum	175 µm x 60 µm. Range, 140-240 µm x 50-85 µm.	Elongated with tapered anterior end and terminal spine. Sometimes "spindle-shaped."	Yellow or yellow brown.	Embryonated. Contains mature miracidium.	Terminal spine long, slender with bent tip. Resembles *S. haematobium* egg except it is longer, is thinner, and has a longer spine. Found in feces. May have debris adhering to shell.
Schistosoma mekongi	69 µm x 56 µm* Range, 51-73 µm x 39-66 µm.	Spherical. Small lateral spine, not always visible or may appear as a small "knob" in a depression in the shell.	Yellow or yellow brown.	Embryonated. Contains mature miracidium.	Found in feces. Closely resembles *S. japonicum* egg except it is smaller. May be coated with debris.
Clonorchis sinensis	30 µm x l6 µm. Range, 27-35 µm x 11-20 µm.	Small, ovoidal, or elongated with broad rounded posterior end and a convex operculum resting on "shoulders." A small "knob" may be seen on the posterior end.	Yellow brown.	Embryonated. Contains mature miracidium.	Small size, operculum and "knob" on posterior end. Shell often is covered by adhering debris.
Opisthorchis felineus	30 µm x 12 µm. Range, 26-30 µm x 11-15 µm.	Elongated with operculum on anterior end and pointed terminal "knob" on posterior end.	Yellow brown.	Embryonated. Contains mature miracidium.	Lacks prominent shoulders characteristic of *Clonorchis* and has more tapered end.
Heterophyes heterophyes	28 µm x 15 µm. Range, 28-30 µm x 15-17 µm.	Small, elongated or slightly ovoidal. Operculum. Slight "knob" at posterior end.	Yellow brown.	Embryonated. Contains mature miracidium.	Resembles *Clonorchis* egg but with less distinct shoulders. Operculum is broader than in *Clonorchis*.
Metagonimus yokogawai	28 µm x 17 µm. Range, 26-30 µm x 15-20 µm.	Small, elongated or ovoidal. Operculum. No "shoulders" at anterior end. Small "knob" often seen on posterior end.	Yellow or yellow brown.	Embryonated. Contains mature miracidium.	Resembles *Clonorchis* and *Heterophyes* eggs. Shell is slightly thinner than *Heterophyes*. Operculum is broader than *Clonorchis*.
Paragonimus westermani	85 µm x 53 µm. Range, 68-118 µm x 39-67 µm.	Ovoidal or elongate with thick shell. Operculum is slightly flattened and fits into shoulder area of shell. Posterior end is thickened. Egg often asymmetrical with one side slightly flattened.	Yellow brown to dark brown.	Unembryonated. Filled with yolk material in which a germinal cell is imbedded. Cells are irregular in size.	Found in sputum, occasionally in feces. Resembles egg of *D. latum* but is larger, slightly asymmetrical and the operculum is smaller and flatter. The widest part of the *Paragonimus* egg is usually anterior to the center ; in a *D. latum*, the widest area is around the center.

Fasciola hepatica	145 µm x 80 µm. Range, 120-150 µm x 63-90 µm.	Ellipsoidal, thin shell. Small, indistinct operculum.	Yellow to light brown.	Unembryonated. Filled with yolk cells in which an indistinct germinal cell is imbedded.	Large size. Broadly oval eggs.
Fasciolopsis buski	140 µm x 80 µm. Range, 130-159 µm x 78-98 µm.	Ellipsoidal, thin shell. Small, indistinct operculum.	Yellow brown.	Unembryonated. Filled with yolk cells in which an indistinct germinal cell is imbedded.	Large size. Resembles *F. hepatica* egg and cannot be easily distinguished from *Fasciola*.

Table 6-1. Differential Morphology of the Diagnostic Stages of Helminths Found in Humans: Eggs (Trematodes) (SOURCE: CDC)

Trematodes require an intermediate host in their life cycle with vertebrates being the definitive host. Larval stages may occur in either invertebrate or vertebrate hosts.

There are three groups of trematodes:

- Monogenea, which typically are external parasites of fish with direct life cycles
- Aspidogastrea, these are endoparasites with the entire ventral surface as an adhesive organ
- Digenea, these are endoparasites with simpler adhesive organs and life cycles involving one or more intermediate hosts (indirect life-cycle). This section concentrates on the Digenean trematodes.

Most Digenean trematodes inhabit the alimentary canal of vertebrates and many of the associated organs, such as the liver, bile duct, gall bladder, lungs, bladder and ureter. These organs are rich in cavities containing food such as blood, mucus, bile and intestinal debris.

The Digenean trematodes have a complex life cycle, with rare exceptions, always involve a mollusk host. There may be six larval stages – the miracidium, sporocyst, redia, cercaria, mesocercaria (rare) and the metacercaria (the majority have 4 or 5 stages).

Trematode eggs have a smooth hard shell and the majority of them are operculate.

Fasciola species

Introduction

Fasciola, *Fasciolopsis* and *Echinostoma* species are trematodes which parasitize the liver and intestines of a variety of vertebrates. They are hermaphroditic and their distinguishing characteristics are shown in **Table 6-2**.

Fasciola hepatica trematodes are not thought to infect man but in fact man is not an unusual host, with infections being reported in many countries including Europe and the USA. The eating of unwashed watercress appears to be the source of infection, with them ending up in the liver. The most common host is sheep where they can cause severe disease.

Fasciolopsis buski (giant intestinal fluke) is a duodenal parasite infecting both man and pigs. They are found widespread in Asia and China, but they have been found to be endemic in Taiwan, Thailand, Bangladesh and India. Night soil (human excreta) is used as a fertilizer in these countries on plants such as water chestnut and caltrops. The snails graze on these crops and also the definitive hosts eat them raw and unwashed, peeling the edible water plants with their teeth.

Infection with *Echinostoma* species is thought to be contracted by ingestion of fresh water snails containing metacercaria. Such as *Echinostoma ilocannum* which occurs in the Philippines. The metacercariae infect the large snail *Piola luzionica* and in return are eaten raw.

Despite the large numbers of these flukes they are of little medical importance, the most important being *F. buski.*

Species	Geographic Distribution	Reservoir Hosts	Location of adult in host	Size of Ova
Fasciola hepatica	Cosmopolitan	Sheep	Bile Ducts	130-150µm by 63-90µm
Fasciola gigantica	Africa, the Orient and Hawaiian Islands	Camels, Cattle and Water Buffalo	Bile Ducts	160–190µm by 70-90µm
Fasciolopsis buski	Far-East and Indian Sub-continent	Pigs, Dogs and Rabbits	Intestine	130–140µm by 80-85µm
Echinostoma species	South East Asia and Japan	Variety of Mammals	Intestine	88–116µm by 58-69µm

Table 6-2. Table describing the characteristics which differentiate the various *Fasciola* species which are important to man.

Life Cycle and Transmission

The life cycles of *Fasciola*, *Fasciolopsis* and *Echinostoma* species are complex, requiring more than one intermediate host.

Adult worms inhabit the liver or bile ducts of the definitive host (human), where they lay many eggs which are deposited into the environment in the feces. They are immature when passed. If they are passed into water they become mature in nine to 15 days at the optimum temperature of 22-25°C.

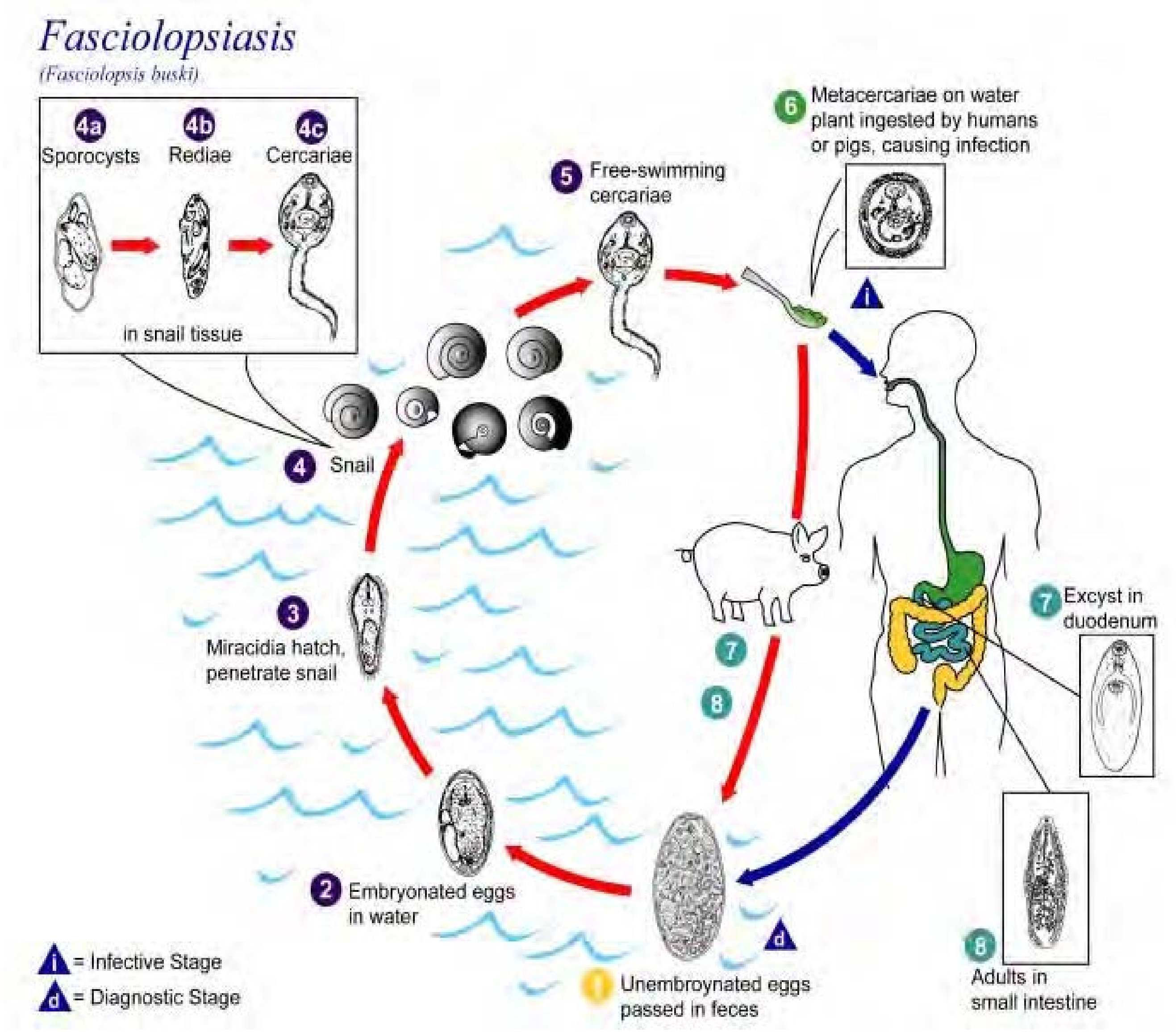
Fasciolopsiasis
(Fasciolopsis buski)
4a Sporocysts
4b Rediae
4c Cercariae
in snail tissue
6 Metacercariae on water plant ingested by humans or pigs, causing infection
i
5 Free-swimming cercariae
4 Snail
3 Miracidia hatch, penetrate snail
7
8
7 Excyst in duodenum
2 Embryonated eggs in water
d
1 Unembroynated eggs passed in feces
8 Adults in small intestine
i = Infective Stage
d = Diagnostic Stage

Illustration 6-2. The general life cycle of *Fasciola*, *Fasciolopsis* and *Echinostoma* species. Immature eggs are discharged in the biliary ducts and in the stool ①. Eggs become embryonated in water ②, eggs release miracidia ③, which invade a suitable snail intermediate host ④, including many species of the genus *Lymnae*. In the snail the parasites undergo several developmental stages (sporocysts (4a), rediae (4b), and cercariae (4c)). The cercariae are released from the snail ⑤and encyst as metacercariae on aquatic vegetation or other surfaces. Mammals acquire the infection by eating vegetation containing metacercariae. Humans can become infected by ingesting metacercariae-containing freshwater plants, especially watercress ⑥. After ingestion, the metacercariae excyst in the duodenum ⑦and migrate through the intestinal wall, the peritoneal cavity, and the liver parenchyma into the biliary ducts, where they develop into adults ⑧. In humans, maturation from metacercariae into adult flukes takes approximately 3 to 4 months. The adult flukes (*Fasciola hepatica*: up to 30 µm by 13 µm; *F. gigantica*: up to 75 µm) reside in the large biliary ducts of the mammalian host. *Fasciola hepatica* infect various animal species, mostly herbivores.

The life cycle of the *Echinostomes* differs by one minor point: the cercariae (4c)encyst wither within the tissues of the intermediate host ④in which sporocysts (4a) and rediae (4b)develop, or penetrate and encyst in other animals such as amphibians or fish. (SOURCE: PHIL 3393 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology

The morphology of the adult flukes of *Fasciola, Fasciolopsis* and *Echinostoma* species is well documented. They are large leaf-shaped parasites about 2–3cm long. There are two suckers, an anterior oral sucker surrounding the mouth and a ventral sucker (acetabulum) on the ventral surface.

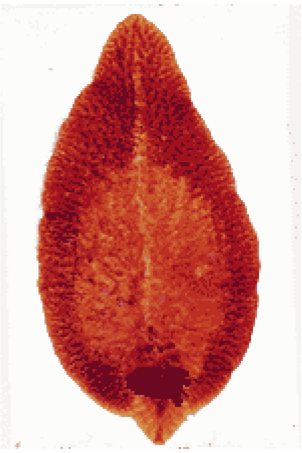

Image 6-1. Adult fluke of a *Fasciola* Trematode. Their morphology shows a large leaf-shape about 2–3cm long with two suckers, an oral and a ventral one. (SOURCE: CDC)

The outer tegument is covered in tiny spines which face backwards enabling them to attach themselves along with their suckers to the tissues.

Ova are all thin shelled, ellipsoid, quinone colored (bile stained) with an operculum that is often inconspicuous. Although ova of *Echinostoma* species can usually be differentiated by size due these flukes being much smaller in size than *F. Buski* and *F. hepatica*, there is much cross-over in the size of *Fasciola* and *Fasciolopsis* species.

Pathogenesis

Light infections due to *Fasciola hepatica* may be asymptomatic. However, they may produce hepatic colic with coughing and vomiting; generalized abdominal rigidity, headache and sweating, irregular fever, diarrhea and anemia.

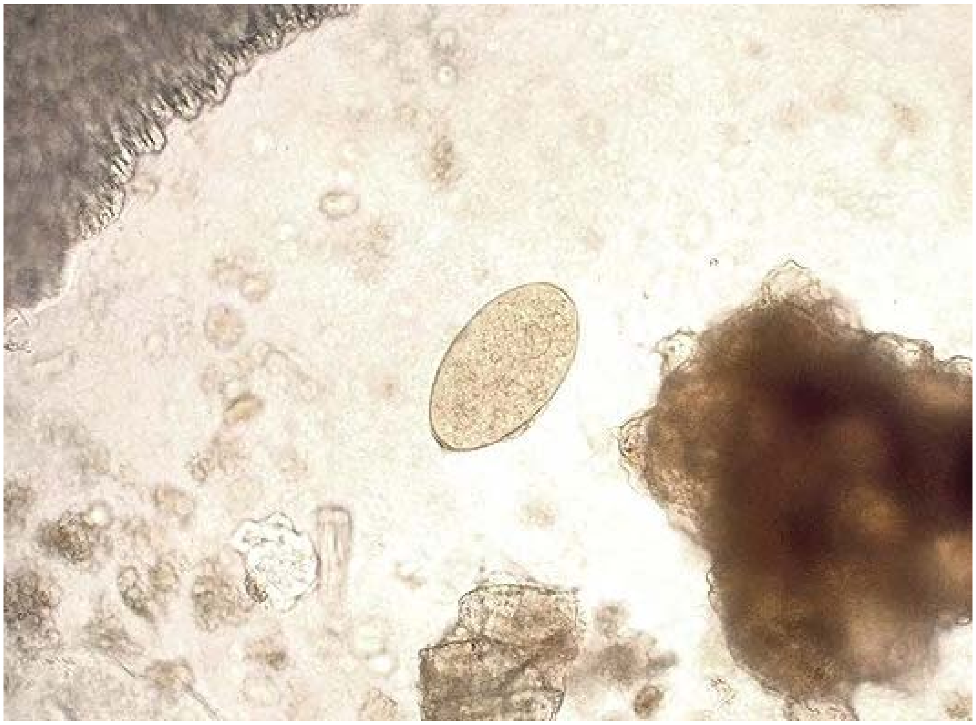

Image 6-2. Ova of *Fasciola* are ovoid in shape, quinone color and often showing an inconspicuous operculum. *Fasciola hepatica* ova measure 130 - 150µm by 63 - 90µm. There is much cross-over in ova size between all of the *Fasciola* species. (SOURCE: PHIL 1540 - CDC/Dr. Mae Melvin)

Infections due to *Fasciola gigantica* occur mainly in cattle raising areas and cause clinical symptoms similar to those of *Fasciola hepatica* although human infections are less common.

The adult flukes of *Fasciolopsis buski* attach to the intestine, resulting in local inflammation and ulceration. Heavier infections may subsequently lead to abdominal pain, malabsorption and persistent diarrhea, edema and even intestinal obstruction. Marked eosinophilia may be seen.

The adult flukes of *Echinostoma* species attach to the intestine resulting in little damage to the intestinal mucosa. Light infections are generally asymptomatic and heavy infections may produce light ulceration, diarrhea and abdominal pain.

Laboratory Diagnosis

Definitive diagnosis is made by observing the ova in feces, since the flukes are very prolific any significant infection will be easily picked up. Where identification cannot be made from the size of the ova, clinical information and the source of infection may help to provide a diagnosis. Serological techniques are available for the diagnosis of *Fasciola hepatica.*

Clonorchis sinensis

Introduction

Clonorchis sinensis, also known as the Chinese (aka Oriental) liver fluke is a narrow elongate liver fluke found in the Far East, mainly Japan, Korea, China, Taiwan and Vietnam.

It belongs to the group of Oriental liver flukes where there are three main species which commonly infect man. The other two species are *Opisthorchis felineus* and *Opisthorchis viverrini*. (**Table 6-2**) The three species are so similar in their morphology, life cycles and pathogenicity that they are very rarely discussed as separate species.

All members of this group are parasites of fish-eating mammals, particularly in Asia and Europe. Man is the definitive hosts and water snails and fish are the intermediate hosts. Infections can be easily avoided by man not eating raw fish since this is the only way that infection can be passed on.

Clonorchis sinensis parasitize the biliary duct in humans who become infected by eating raw or undercooked fish. Dogs and cats are the most important reservoir hosts.

Life Cycle and Transmission

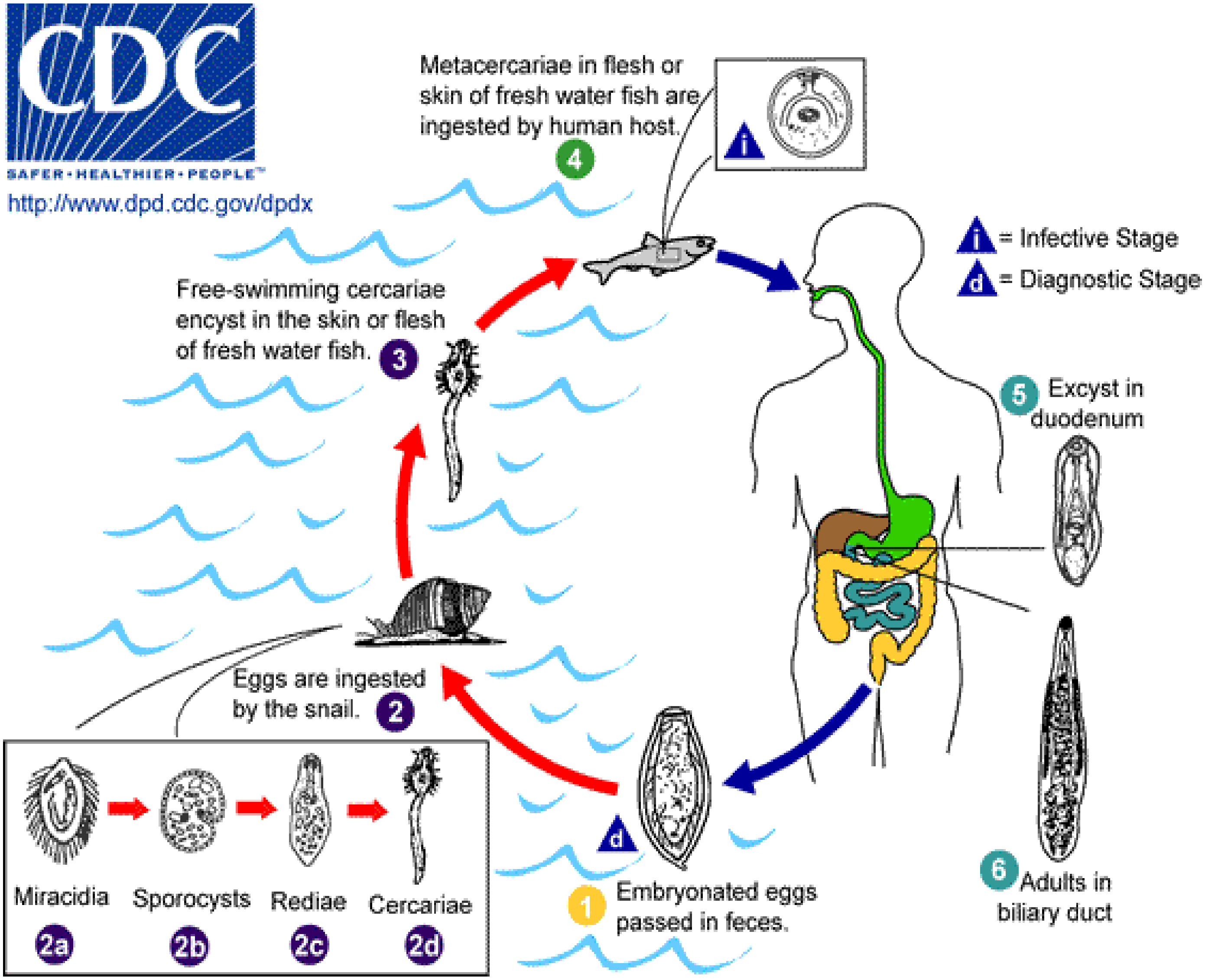
CDC
SAFER·HEALTHIER·PEOPLE™
http://www.dpd.cdc.gov/dpdx
Metacercariae in flesh or skin of fresh water fish are ingested by human host.
4
i
= Infective Stage
d
= Diagnostic Stage
Free-swimming cercariae encyst in the skin or flesh of fresh water fish.
3
5
Excyst in duodenum
Eggs are ingested by the snail.
2
Miracidia
Sporocysts
Rediae
Cercariae
2a
2b
2c
2d
d
1
Embryonated eggs passed in feces.
6
Adults in biliary duct

Illustration 6-3. Diagram illustrating the life cycle of *Clonorchis sinensis* (Chinese Liver Fluke). This parasite requires the involvement of two intermediate hosts (fresh water snails and fish) to complete the life cycle. Embryonated eggs are discharged in the biliary ducts and in the stool ①. Eggs are ingested by a suitable snail intermediate host ❷; there are more than 100 species of snails that can serve as intermediate hosts. Each egg releases a miracidia (2a), which go through several developmental stages (sporocysts (2b), rediae (2c), and cercariae (2d)). The cercariae are released from the snail and after a short period of free-swimming time in water, they come in contact and penetrate the flesh of freshwater fish, where they encyst as metacercariae ❸. Infection of humans occurs by ingestion of undercooked, salted, pickled, or smoked freshwater fish ❹. After ingestion, the metacercariae excyst in the duodenum ⑤and ascend the biliary tract through the ampulla of Vater ⑥. Maturation takes approximately one month. The adult flukes (measuring 10 to 25 µm by 3 to 5 µm) reside in small and medium sized biliary ducts. In addition to humans, carnivorous animals can serve as reservoir hosts. (SOURCE: PHIL 3385 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology

The adult flukes measure 11–20µm by 3–4.5µm and are lanceolate in shape, translucent and brownish in color. They are all hermaphroditic. Keeping in common with other flukes they possess two suckers.

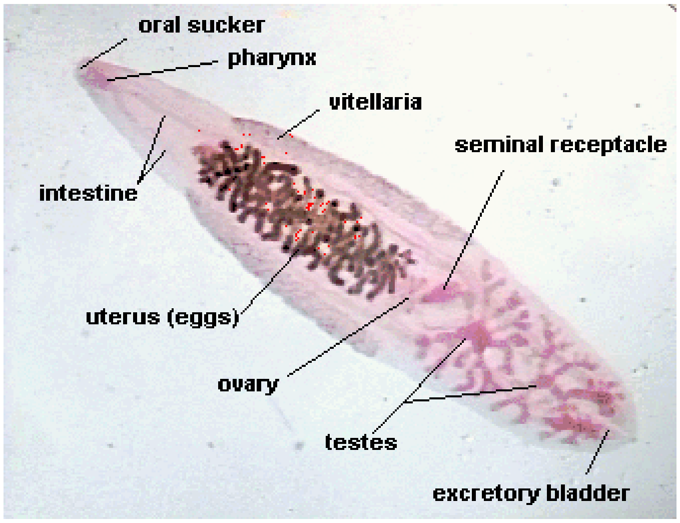
oral sucker
pharynx
vitellaria
seminal receptacle
intestine
uterus (eggs)
ovary
testes
excretory bladder

Image 6-3. Diagram illustrating the internal morphology of the Oriental liver fluke, *Clonorchis sinensis.* (SOURCE: SFSU.EDU)

The ova of *Clonorchis sinensis* contain fully developed miracidia and possess prominent opercular shoulders (flask shaped egg) and are operculate. They are bile stained and measure 29µm by 16µm. In wet mounts they are transparent and you can quite easily see their anatomy. There can be up to 6,000 worms present and a daily egg output of 1,000 eggs per microliter of bile or 600 per gram of feces.

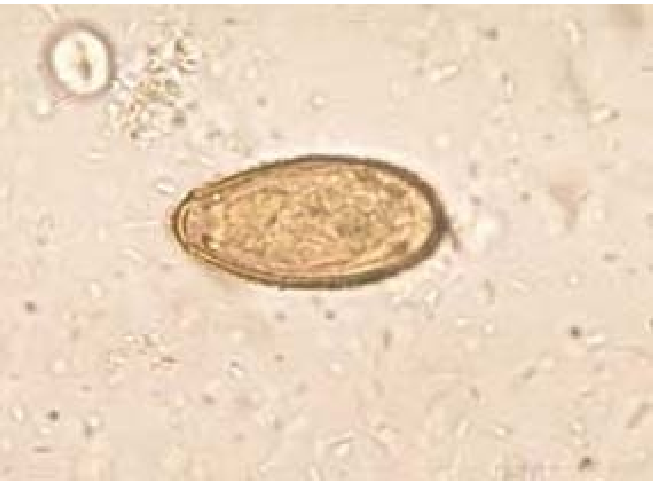

Image 6-4. Ova of *Clonorchis sinensis.* Showing the prominent opercular shoulders which makes identifying this trematode easy. They are described as flask shaped, bile stained. (SOURCE: PHIL 695 – CDC/Dr. Mae Melvin)

The cercariae possess eyespots, the penetration and cystogenous glands are also well developed.

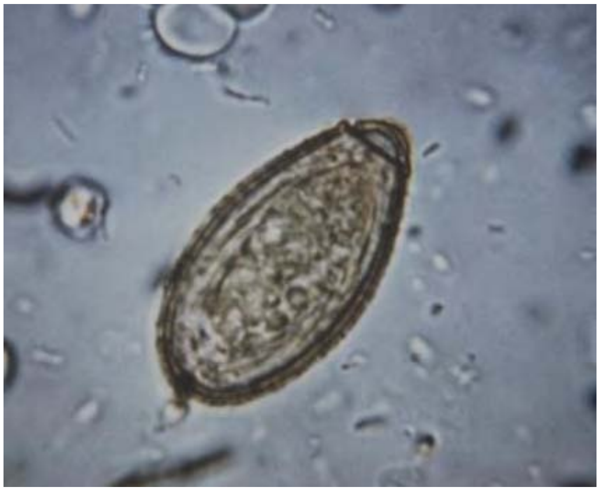

Image 6-5. Saline smear showing the characteristic flask shape of the *Clonorchis sinensis* ova. They are bile stained with a smooth outer coat. (SOURCE: PHIL 4845 – CDC)

Pathogenesis

Many millions of people become infected every year but only a minority suffers from any illness. The pathology is related to the number of parasites present. Light infections of up to 50 eggs or more are usually asymptomatic. A heavy infection of 500 or more eggs may cause serious illness.

Acute infections may be characterized by fever, diarrhea, epigastric pain, enlargement and tenderness of liver and sometimes jaundice. The invasion by these worms in the gall bladder may cause cholecystitis, due to flukes becoming impacted in the common bile duct.

Laboratory Diagnosis

Definitive diagnosis is made by observing the characteristic ova in feces following an iodine stained, formol-ether concentration method of the feces or from duodenal aspirates when there is complete obstructive jaundice or from the Entero-Test.

	Heterophyes heterophyes	***Metagonimus yokogawai***	***Opisthorchis viverrini***	***Dicrocoelium dendriticum***
Geographic distribution	Far East	Far East	Thailand	Far East
Location of adult in host	Small intestine	Small intestine	Liver and bile ducts	Liver and bile ducts
Size of ova	26.5-30μm by 15-17μm	26.5-30μm by 15-17μm	26.7μm by 15μm	38-45μm by 22-30μm
Shape of ova	Prominent opercular shoulders Bile stained	Prominent opercular shoulders Bile stained	Prominent opercular shoulders Bile stained	Dark brown, thick shelled and large operculum
Infection acquired by	Eating raw or pickled fish	Eating raw or pickled fish	Eating raw fresh water fish	Eating infected ants
Symptoms	Occasionally diarrhea and vomiting	Occasionally diarrhea and vomiting	Malaise and right upper quadrant pain	Biliary and digestive problems

Table 6-3. Table summarizing the less common flukes that are known to infect man. (CDC)

Paragonimus westermani

Introduction

Paragonimus westermani is a lung fluke found in both humans and animals. The adults are 12µm long and are found in capsules in the lung. Although they are hermaphroditic, it is necessary for worms to be present in the cyst for fertilization to occur. The disease is seen in the Far East, China, South East Asia, and America.

Life Cycle

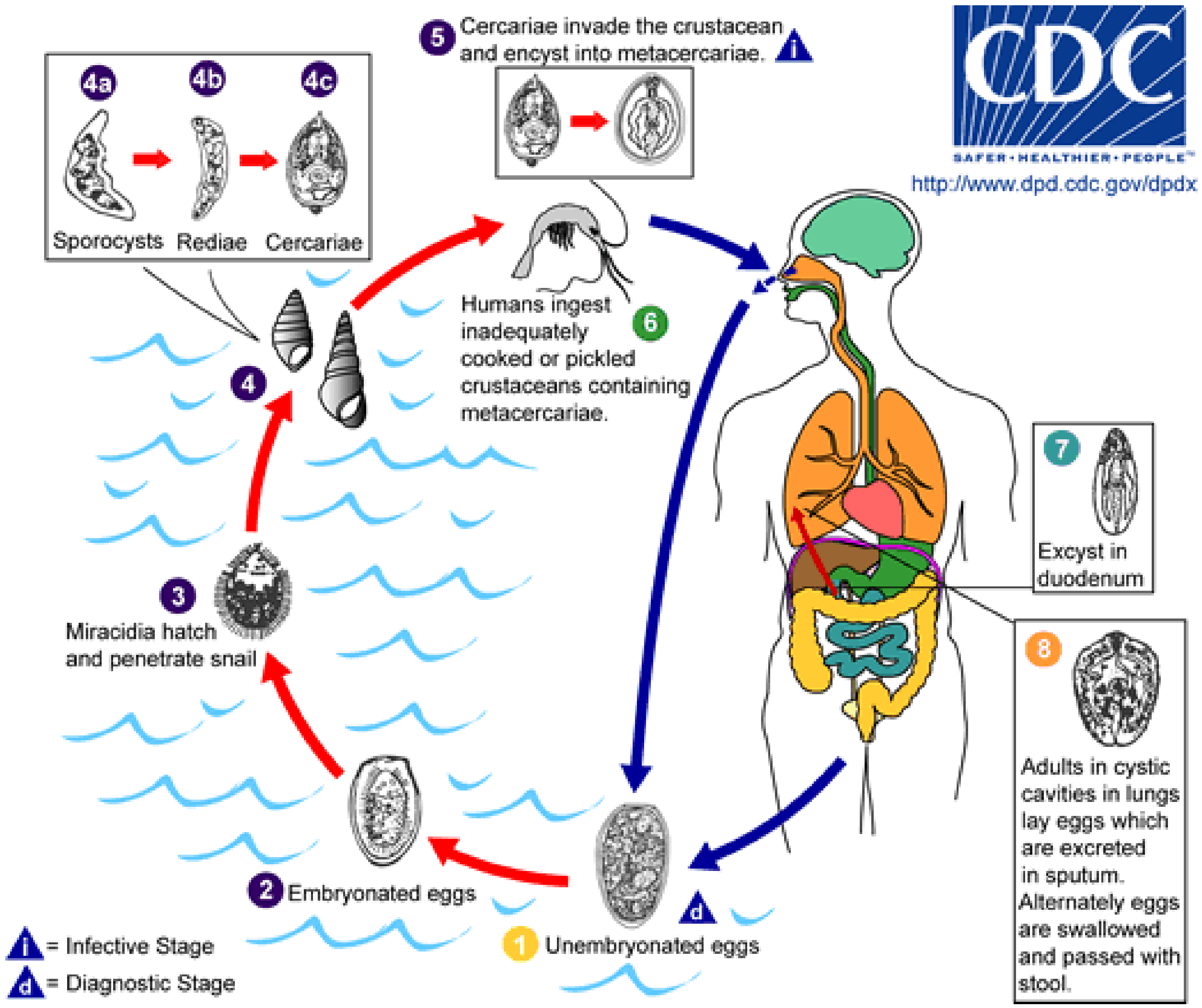
5 Cercariae invade the crustacean and encyst into metacercariae.
i
4a
4b
4c
Sporocysts
Rediae
Cercariae
CDC
SAFER · HEALTHIER · PEOPLE™
http://www.dpd.cdc.gov/dpdx
Humans ingest inadequately cooked or pickled crustaceans containing metacercariae.
6
4
7
Excyst in duodenum
3
Miracidia hatch and penetrate snail
8
Adults in cystic cavities in lungs lay eggs which are excreted in sputum. Alternately eggs are swallowed and passed with stool.
2 Embryonated eggs
d
1 Unembryonated eggs
i = Infective Stage
d = Diagnostic Stage

Illustration 6-4. Diagram of the general life cycle of the lung fluke, *Paragonimus westermani*. The eggs are excreted unembryonated in the sputum, or alternately they are swallowed and passed with stool ❶. In the external environment, the eggs become embryonated ❷, and miracidia hatch and seek the first intermediate host, a snail, and penetrate its soft tissues ❸. Miracidia go through several developmental stages inside the snail ❹: sporocysts (4a), rediae (4b), with the latter giving rise to many cercariae (4c), which emerge from the snail. The cercariae invade the second intermediate host, a crustacean such as a crab or crayfish, where they encyst and become metacercariae. This is the infective stage for the mammalian host ❺. Human infection with *P. westermani* occurs by eating inadequately cooked or pickled crab or crayfish that harbor metacercariae of the parasite ❻. The metacercariae excyst in the duodenum ❼, penetrate through the intestinal wall into the peritoneal cavity, then through the abdominal wall and diaphragm into the lungs, where they become encapsulated and develop into adults ⑧(7.5 to 12 µm by 4 to 6 µm). The worms can also reach other organs and tissues, such as the brain and striated muscles, respectively. However, when this takes place completion of the life cycles is not achieved, because the eggs laid cannot exit these sites. Time from infection to oviposition is 65 to 90 days. (SOURCE: PHIL 3415 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Infections may persist for 20 years in humans. Animals such as pigs, dogs, and a variety of feline species can also harbor *P. westermani*.

Morphology

The adult worm is an ovoid, reddish brown fluke about 12µm long.

The eggs are ovoid, brownish yellow, thick shelled and operculated. They measure 80-100µm by 45-65µm and may be confused with the ova of *Diphyllobothrium latum*.

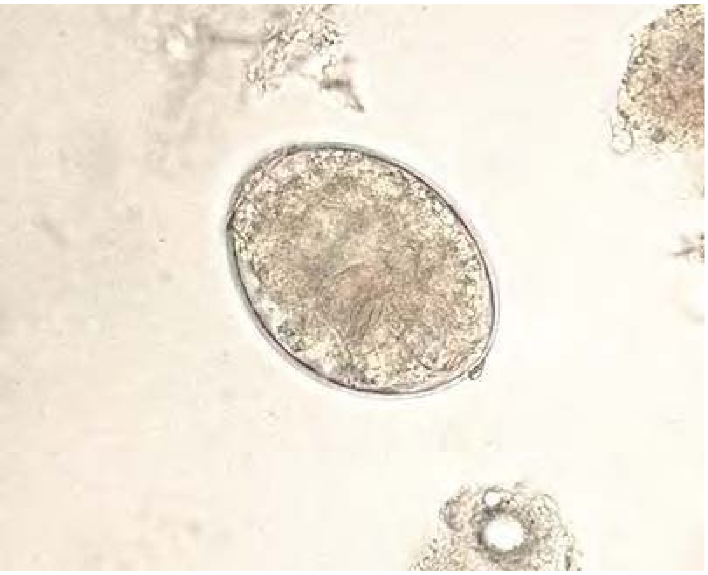

Image 6-6. Saline smear of *Paragonimus westermani* egg. The egg shells are thick and operculated. (SOURCE: PHIL 1541 – CDC/ Dr. Mae Melvin)

Clinical Disease

As the parasites grow in the lung cyst, inflammatory reaction and fever occurs. The cyst ruptures and a cough develops resulting in an increase in sputum. The sputum is frequently blood tinged and may contain numerous dark brown eggs and Charcot-Leyden crystals. Hemoptisis may occur after paroxysms of coughing. Dyspnea and bronchitis develop with time. Bronchiectasis may occur and pleural effusion is sometimes seen. The disease resembles pulmonary tuberculosis. Cerebral calcification may also occur.

Laboratory Diagnosis

Diagnosis is based on finding the characteristic eggs in brown sputum. The eggs can also be found in the feces due to swallowing sputum. A chest x-ray may show cystic shadows and calcification. Serological tests, in particular, the ELISA method, are useful diagnostic tests.

Schistosomes

Introduction

The Schistosomes are blood trematodes belonging to the Phylum *Platyhelmintha*. They differ from other trematodes in that they have separate sexes. The male worms resemble a rolled leaf where they bear the longer and more slender female in a ventral canal (the gynaecophoric canal). They require definitive and intermediate hosts to complete their life cycle. There are five species of *Schistosomes* responsible for human disease; *S. mansoni, S. haematobium* and *S. japonicum* with *S. mekongi* and *S. intercalatum* being less common.

They are the only trematodes that live in the blood stream of warm-blooded hosts. The blood stream is rich in glucose, and amino acids, so along with the plasma and blood cells, it represents an environment which is suitable for egg producing trematodes.

Over 200 million people are infected over at least 75 countries with 500 million or more people exposed to infection. With the disease spreading due to improved water supplies being created therefore, forming potentially new habits for snails. The disease caused is called schistosomiasis or Bilharzia and is the most important of helminth diseases.

Infection by the three most common species is the same in both sexes and in all age groups. Though, *S. mansoni* and *S. haematobium* is seen to occur more often and most heavily in teenagers especially males.

Life Cycle

Adult worms of *S. mansoni* live in the plexus of veins draining the rectum and colon, and in branches of the portal vein in the liver.

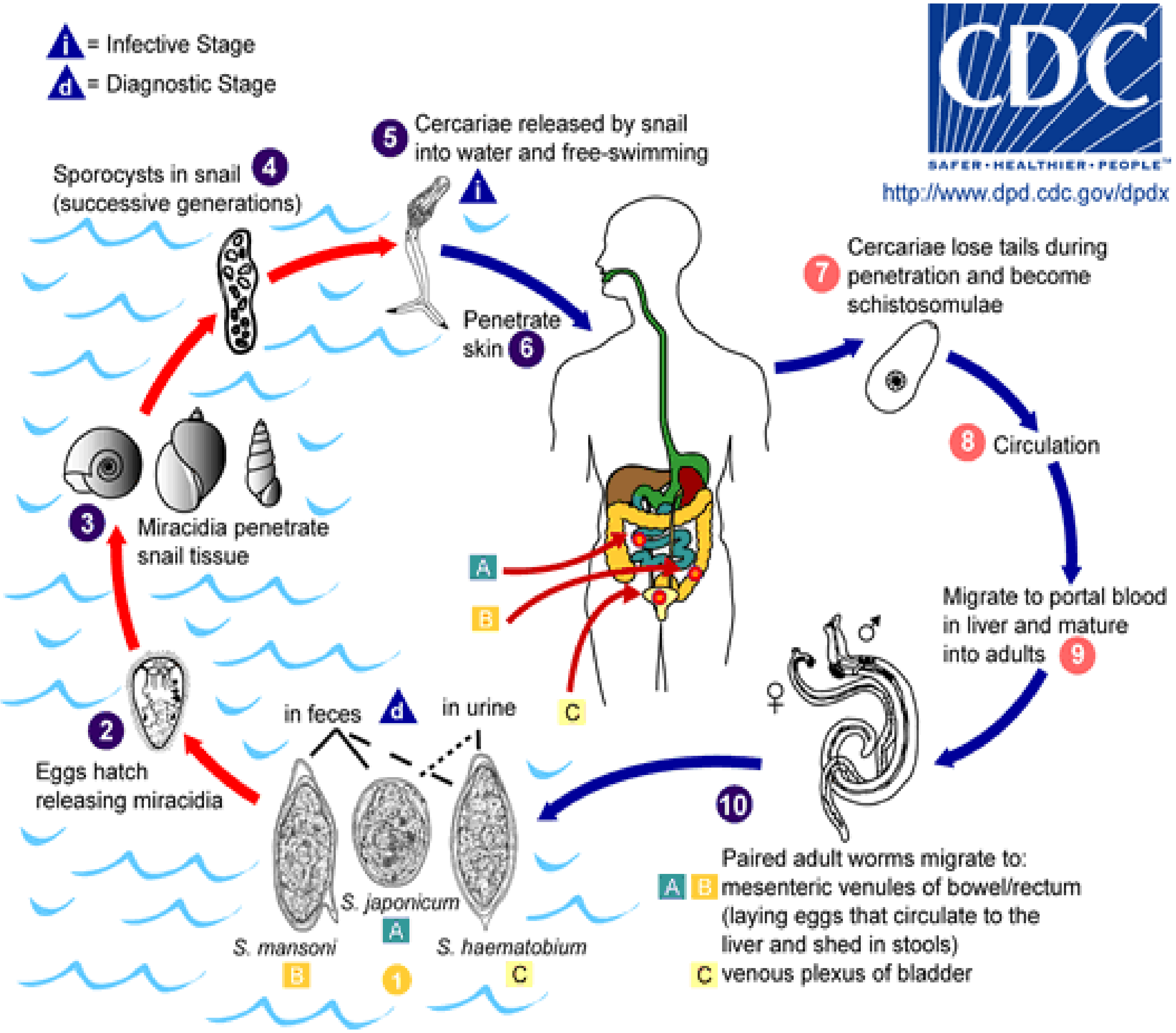
= Infective Stage
= Diagnostic Stage
CDC
SAFER·HEALTHIER·PEOPLE™
http://www.dpd.cdc.gov/dpdx
Sporocysts in snail ④
(successive generations)
⑤ Cercariae released by snail
into water and free-swimming
Penetrate
skin ⑥
⑦ Cercariae lose tails during
penetration and become
schistosomulae
⑧ Circulation
Migrate to portal blood
in liver and mature
into adults ⑨
③ Miracidia penetrate
snail tissue
A
B
C
② Eggs hatch
releasing miracidia
in feces
in urine
S. japonicum
A
S. mansoni
B
S. haematobium
C
①
⑩
Paired adult worms migrate to:
A B mesenteric venules of bowel/rectum
(laying eggs that circulate to the
liver and shed in stools)
C venous plexus of bladder

Illustration 6-5. Diagram illustrating the general life cycle of the *Schistosomes*. Eggs are eliminated with feces or urine ①. Under optimal conditions the eggs hatch and release miracidia ❷, which swim and penetrate specific snail intermediate hosts ❸. The stages in the snail include 2 generations of sporocysts ❹and the production of cercariae ❺. Upon release from the snail, the infective cercariae swim, penetrate the skin of the human host ❻, and shed their forked tail, becoming schistosomulae ⑦. The schistosomulae migrate through several tissues and stages to their residence in the veins (⑧, ⑨). Adult worms in humans reside in the mesenteric venules in various locations, which at times seem to be specific for each species ❿. For instance, *S. japonicum* is more frequently found in the superior mesenteric veins draining the small intestine A, and *S. mansoni* occurs more often in the superior mesenteric veins draining the large intestine B. However, both species can occupy either location, and they are capable of moving between sites, so it is not possible to state unequivocally that one species only occurs in one location. *S. haematobium* most often occurs in the venous plexus of bladder C, but it can also be found in the rectal venules. The females (size 7 to 20 μm; males slightly smaller) deposit eggs in the small venules of the portal and perivesical systems. The eggs are moved progressively toward the lumen of the intestine (*S. mansoni* and *S. japonicum*) and of the bladder and ureters (*S. haematobium*), and are eliminated with feces or urine, respectively①. Pathology of *S. mansoni* and *S. japonicum* schistosomiasis includes: Katayama fever, hepatic perisinusoidal egg granulomas, Symmers' pipe stem periportal fibrosis, portal hypertension, and

> occasional embolic egg granulomas in brain or spinal cord. Pathology of *S. haematobium* schistosomiasis includes: hematuria, scarring, calcification, squamous cell carcinoma, and occasional embolic egg granulomas in brain or spinal cord. Human contact with water is thus necessary for infection by schistosomes. Various animals, such as dogs, cats, rodents, pigs, hourse and goats, serve as reservoirs for *S. japonicum*, and dogs for *S. mekongi*. (SOURCE: CDC)

Adults of *S. japonicum* live in the anterior mesenteric blood vessels and in the portal vein in the liver; while the adults of *S. haematobium* live in the vesical plexus draining the bladder.

Once the eggs are laid by the adult female worms the majority of them first pass through the veins of the blood vessel in which the worm is living, and then into the lumen of the intestine and are passed in the feces (*S. mansoni* and *S. japonicum*), or into the lumen of the bladder, and are then passed in the urine (*S. haematobium).* Those eggs that reach fresh water hatch, releasing a miracidium which, to develop further must infect a snail of the correct species within 24 hours. The eggs of each species are markedly different but each produce virtually identical miracidium.

Asexual multiplication takes place in the snail, and results in the release of cercariae (minute in size with forked tails, 200µm long) into the water about 3–6 weeks later. Cercariae actively swim around and when they have located, or come into contact with, a definitive host they actively penetrate the skin. They can stay active looking for a host for 24–48 hours after which if they don’t find a host they will die. The head of the cercariae migrates to the liver and develops into either adult male or female worms (flukes), here they pair up and then migrate to their region of the venous blood system (species specific sites). The females leave the males and moves to smaller venules closer to the lumen of the intestine or bladder to lay her eggs (about six weeks after infection). The majority of adult worms live from 2–4 years, but some can live considerably longer.

Schistosoma mansoni

Introduction

S. mansoni occurs in West and Central Africa, Egypt, Malagasy, the Arabian Peninsula, Brazil, Surinam, Venezuela and the West Indies. The intermediate host is an aquatic snail of the genus *Biomphalaria*. Man is the most common definitive host, occasionally baboons and rats are infected.

The adult worms live in smaller branches of the inferior mesenteric vein in the lower colon.

Morphology

The adult males measure up to 15 millimeters in length and females up to 10µm. The schistosomes remain in copula throughout their life span, the uxorious male surrounding the female with his gynaecophoric canal. The male is actually flat but the sides roll up forming the groove. The cuticle of the male is covered with minute papillae. The female only posses these at the anterior and posterior end as the middle section being covered by the male body. Oral and ventral suckers are present, with the ventral one being lager serving to hold the worms in place, preventing them being carried away by the circulatory current.

The ova of *S. mansoni* are 114-175µm long by 45-68µm wide. They are light yellowish brown, elongate and possess a lateral spine. The shell is acid fast when stained with modified Ziehl-Neelsen Stain.

A non-viable egg is dark colored and shows no internal structural detail or flame cell movement. Eggs can become calcified after treatment and are usually smaller, appear black and often distorted with a less distinct spine.

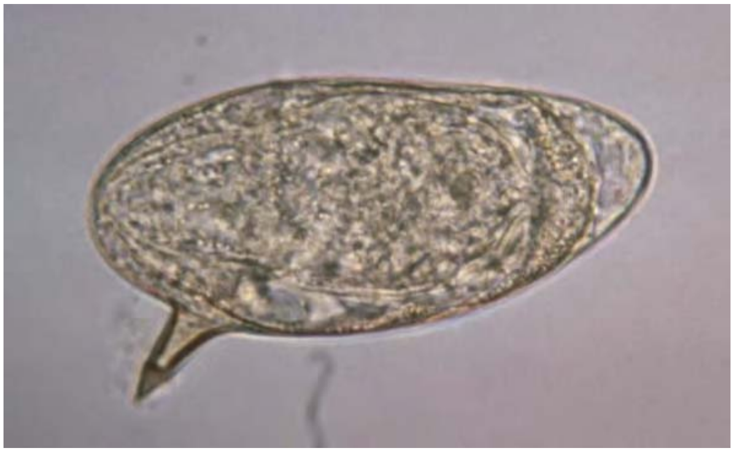

Image 6-7. Micrograph of a *S. mansoni* ova, clearly showing its lateral spine which is a good distinguishing factor when identifying *Schistosome* ova. They range in size between 114-175µm long by 45-68µm wide. (SOURCE: PHIL 4841 – CDC)

The schistosomes differ from other trematodes in that they are dioecious, digenetic, their eggs are not operculate and infection is acquired by penetration of cercaria through the skin.

Clinical Disease

The clinical disease is related to the stage of infection, previous host exposure, worm burden and host response. Cercarial dermatitis (swimmers itch) follows skin penetration and results in a maculopapular rash which may last 36 hours or more.

After mating, the mature flukes migrate to the venules draining the large intestine. Their eggs are laid and they penetrate the intestinal wall. They are then excreted in the feces, often accompanied by blood and mucus.

It is the eggs and not the adult worms, which are responsible for the pathology associated with *S. mansoni* infections. The adult flukes acquire host antigen which protects them from the host's immune response.

The host's reaction to the eggs which are lodged in the intestinal mucosa, leads to the formation of granulomata and ulceration of the intestinal wall. Some of the eggs reach the liver via the portal vein. The granulomatous response to these eggs can result in the enlargement of the liver with fibrosis, ultimately leading to portal hypertension and ascites. The spleen may also become enlarged. Other complications may arise as a result of deposition of the eggs in other organs e.g. lungs.

Katayama fever is associated with heavy primary infection and egg production. Clinical features include high fever, hepatosplenomegaly, lymphadenopathy, eosinohilia and dysentery. This syndrome occurs a few weeks after primary infection.

Laboratory Diagnosis

Microscopy

Laboratory confirmation of *S. mansoni* infection can be made by finding the eggs in the feces after an iodine stained, formol-ether concentration method. When eggs cannot be found in the feces, a rectal biopsy can be examined.

Serology

Serological tests are of value in the diagnosis of schistosomiasis when eggs cannot be found. An enzyme linked immunosorbent assay (ELISA) using soluble egg antigen, is employed at HTD.

Schistosoma japonicum

Introduction

Schistosoma japonicum is found in China, Japan, the Philippines, and Indonesia. It causes disease of the bowel with the eggs being passed out in the feces.

It differs form *S. mansoni* and *S. haematobium* in that it is a zoonosis in which a large number of mammals serve as reservoir hosts; cats, dogs and cattle playing major roles in the transmission of the disease.

The life cycle is not very different from that of *S. mansoni*, the intermediate hosts are from the subspecies *Oncomelania hupensis*. Sexual maturity is reached in about four weeks and eggs may be seen in the feces as quickly as five weeks.

The worms live coupled together in the superior, mesenteric veins and deposit 1500–3500 eggs per day in the vessels of the intestinal wall. The eggs infiltrate through the tissues and are passed in the feces.

Morphology

The adult worms are longer and narrower than the *S. mansoni* worms. The ova are about 55-85μm by 40-60μm, oval with a minute lateral spine or knob.

Clinical Disease

The main lesions are again due to the eggs, occurring in the intestine and liver. The eggs which are sequesters in the intestine mucosa or submucosa initiate granulomatous reactions, resulting in the formation of pseudotubercles.

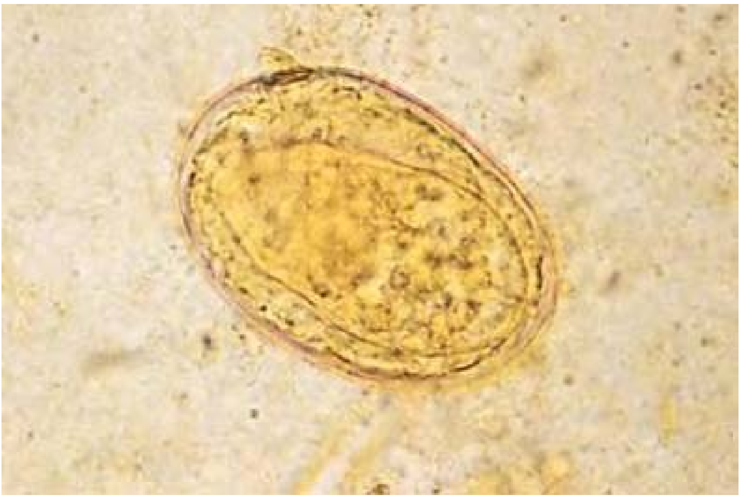

Image 6-8. Unstained micrograph of a *S. japonicum* ova. They are oval in shape with a minute lateral spine or knob. (SOURCE: PHIL 649 – CDC/Dr. Moore)

Due to the number of eggs released by the females the infection is more severe than one with *S. mansoni*. This is also due to the parasite being less well adapted to man, therefore, the circumoval granuloma is very large. The initial illness can be prolonged and sometimes fatal.

Laboratory Diagnosis

Microscopy

Laboratory confirmation of *S. japonicum i*nfection can be made by finding the eggs in the feces after an iodine stained, formol-ether concentration method. When eggs cannot be found in the feces, a rectal biopsy can be examined.

Other Intestinal *Schistosome* species

Other Schistosome species which are responsible for human disease are *S. mekongi and S. intercalatum.* These two species cause similar symptoms to that of *S. mansoni* and can be summarized in **Table 6-3**.

	S. mekongi	***S. intercalatum***
Geographic location	Mekong River basin	Central and west Africa
Diagnostic specimen	Stool, rectal biopsy, serology	Stool, rectal biopsy, serology
Egg size	30-55µm by 60-65µm	140-240µm by 50-85µm
Egg shape	Oval, minute lateral spine or knob	Elongate, terminal spine

Table 6-4. Table describing the other less common intestinal Schistosome species that are known to cause disease in man. (SOURCE: CDC)

Schistosoma haematobium

Introduction

Schistosoma haematobium is different from the other two species previously mentioned in that it causes urinary schistosomiasis. It occurs in Africa, India and the Middle East. The intermediate host is the *Bulinus* snail.

Just like *S. mansoni,* its distribution runs parallel to the irrigation projects and in areas which favor the intermediate hosts. They are exclusively parasites of man.

The mature worms live in copula mainly in the inferior mesenteric veins and the females deposit their eggs in the walls of the bladder and finally making their way into the urine. The life cycle is very similar to that of *S. mansoni*, with sexual maturity being reached within 4–5 weeks, but eggs may not appear in the urine until 10–12 weeks or even later.

Morphology

The adult worms are longer than those of *S. mansoni.* The ova are relatively large, measuring 110-170µm in length and 40-70µm in width. They have an elongated ellipsoid shape with a prominent terminal spine.

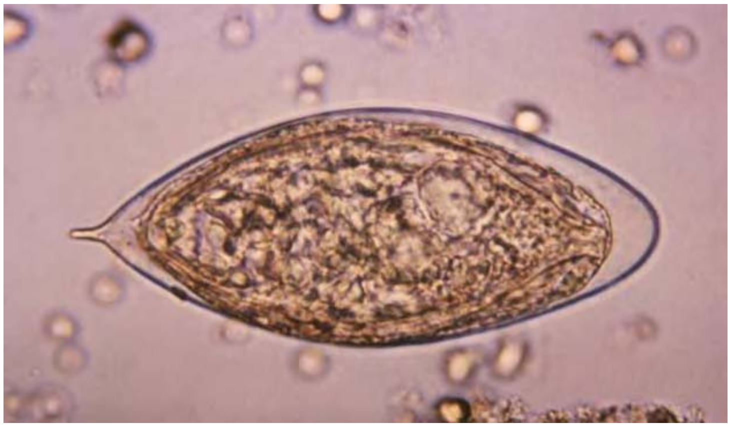

Image 6-9. *Schistosoma haematobium* eggs are elongated with a prominent terminal spine. The larva inside the egg produces an enzyme that passes through the egg-shell. (SOURCE: PHIL 4843 – CDC)

Clinical Disease

The clinical disease is related to the stage of infection, previous host exposure, worm burden and host response. Cercarial dermatitis (Swimmer's Itch) following skin penetration, results in a maculopapular rash and can last 36 hours or more. The mature flukes of *S. haematobium* migrate to the veins surrounding the bladder. After mating, the eggs are laid in the venules of the bladder and many penetrate through the mucosa, enter the lumen of the bladder and are excreted in the urine accompanied by blood. Thus hematuria and proteinuria are characteristic, though not invariable features of urinary schistosomiasis.

As with all *Schistosoma* species, it is the eggs and not the adult worms which are responsible for the pathology associated with *S. haematobium*. In chronic disease, eggs become trapped in the bladder wall resulting in the formation of granulomata. Following prolonged infection, the ureters may become obstructed and the bladder becomes thickened resulting in abnormal bladder function, urinary infection and kidney damage. Chronic urinary schistosomiasis is associated with squamous cell bladder cancer. Heavy infections in males may involve the penis resulting in scrotal lymphatics being blocked by the eggs.

Laboratory Diagnosis

The definitive diagnosis of urinary schistosomiasis is made by finding the characteristic ova of *S. haematobium* in urine. Terminal urine should be collected as the terminal drops contain a large proportion of the eggs. The urine can either be centrifuged and the deposit examined microscopically for ova. Eggs can sometimes be found in seminal fluid in males.

A bladder biopsy is seldom necessary to make the diagnosis. A rectal snip may show the presence of ova as they sometimes pass into the rectal mucosa.

Serological tests can be of value when eggs cannot be found in clinical samples. An enzyme linked immunosorbent assay using soluble egg antigen to detect antischistosome antibody is most sensitive.

There is a marked periodicity associated with the time when most eggs are passed out. Higher numbers of eggs are encountered in urine specimens passed between 1000 and 1400 hours, presumably as a result of changes in the host’s metabolic and physical activities.

Chapter 7.
Tissue Dwelling Nematodes

7.1 Unusual Tissue Dwelling Nematodes

Many species of nematodes are known to indirectly infect man causing an array of symptoms and diseases. Many of the larvae of these parasites cause serious zoonosis in man. These parasites are known to infect many intermediate hosts during their life cycle with a variety of animals being the definitive host, while man is normally an accidental definitive host.

Angiostrongylus (Parastrongylus) cantonensis

Introduction

Angiostrongylus cantonensis was first described in 1944 in Taiwan from a boy with suspected meningitis. Since then it has been recognized throughout the Pacific areas with sporadic cases reported in other parts of the world including Central America and Cuba It is associated with eosinophilic meningitis. The species *A. cantonensis* and *A. costaricensis* have now been reclassified into the genus *Parastrongylus.*

Angiostrongylus cantonensis is also known as the rat nematodes where the main cause of eosinophilic meningitis is infection with the larvae of this nematode. Man and rats become infected by eating infected mollusks of the giant land snail (intermediate hosts) or food which is contaminated by the snails' bodies.

Life Cycle and Transmission

Adult worms of *A. cantonensis* live in the pulmonary arteries of rats. The females lay eggs that hatch, yielding first-stage larvae, in the terminal branches of the pulmonary arteries. The first-stage larvae migrate to the pharynx, are swallowed, and passed in the feces. They penetrate, or are ingested by, an intermediate host (snail or slug). After two molts, third-stage larvae are produced, which are infective to mammalian hosts. When the mollusk is ingested by the definitive host, the third-stage larvae migrate to the brain where they develop into young adults. The young adults return to the venous system and then the pulmonary arteries where they become sexually mature. Of note, various animals act as paratenic (transport) hosts: after ingesting the infected snails, they carry the third-stage larvae which can resume their development when the paratenic host is ingested by a definitive host. Humans can acquire the infection by eating raw or undercooked snails or slugs infected with the parasite; they may also acquire the infection by eating raw produce that contains a small snail or slug, or part of one. There is some question whether or not larvae can exit the infected mollusks in slime (which may be infective to humans if ingested, for example, on produce). The disease can also be acquired by ingestion of contaminated or infected paratenic animals (crabs, freshwater shrimp). In humans, juvenile worms migrate to the brain, or rarely in the lungs, where the worms ultimately die. The life cycle of *Angiostrongylus (Parastrongylus) costaricensis* is similar, except that the adult worms reside in the arterioles of the ileocecal area of the definitive host. In humans, *A. costaricensis* often reaches sexual maturity and release eggs into the intestinal tissues. The eggs and larvae degenerate and cause intense local inflammatory reactions and do not appear to be shed in the stool.

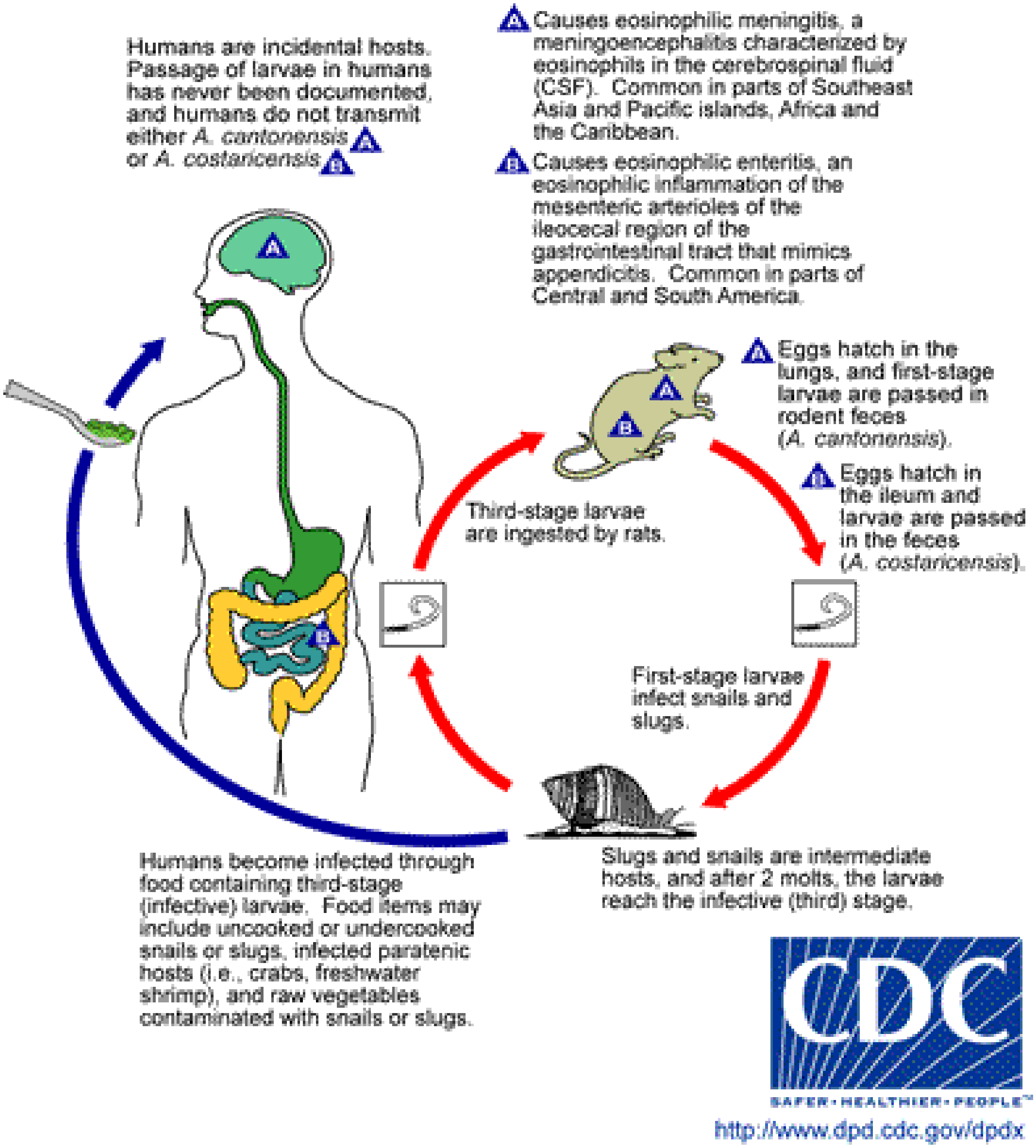

Humans are incidental hosts. Passage of larvae in humans has never been documented, and humans do not transmit either *A. cantonensis* A or *A. costaricensis* B

A Causes eosinophilic meningitis, a meningoencephalitis characterized by eosinophils in the cerebrospinal fluid (CSF). Common in parts of Southeast Asia and Pacific islands, Africa and the Caribbean.

B Causes eosinophilic enteritis, an eosinophilic inflammation of the mesenteric arterioles of the ileocecal region of the gastrointestinal tract that mimics appendicitis. Common in parts of Central and South America.

A Eggs hatch in the lungs, and first-stage larvae are passed in rodent feces (*A. cantonensis*).

B Eggs hatch in the ileum and larvae are passed in the feces (*A. costaricensis*).

Third-stage larvae are ingested by rats.

First-stage larvae infect snails and slugs.

Humans become infected through food containing third-stage (infective) larvae. Food items may include uncooked or undercooked snails or slugs, infected paratenic hosts (i.e., crabs, freshwater shrimp), and raw vegetables contaminated with snails or slugs.

Slugs and snails are intermediate hosts, and after 2 molts, the larvae reach the infective (third) stage.

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Illustration 7-1. Life cycle of the rat nematode *Angiostrongylus cantonensis.* Adult worms of *A. cantonensis* live in the pulmonary arteries of rats. The females lay eggs that hatch, yielding first-stage larvae, in the terminal branches of the pulmonary arteries. The first-stage larvae migrate to the pharynx, are swallowed, and passed in the feces. They penetrate, or are ingested by, an intermediate host (snail or slug). After two molts, third-stage larvae are produced, which are infective to mammalian hosts. When the mollusk is ingested by the definitive host, the third-stage larvae migrate to the brain where they develop into young adults. The young adults return to the venous system and then the pulmonary arteries where they become sexually mature. Of note, various animals act as paratenic (transport) hosts: after ingesting the infected snails, they carry the third-stage larvae which can resume their development when the paratenic host is ingested by a definitive host. Humans can acquire the infection by eating raw or undercooked snails or slugs infected with the parasite; they may also acquire the infection by eating raw produce that contains a small snail or slug, or part of one. There is some question whether or not larvae can exit the infected mollusks in slime (which may be infective to humans if ingested, for example, on produce). The disease can also be acquired by ingestion of contaminated or infected paratenic animals (crabs, freshwater shrimps). In humans, juvenile worms migrate to the brain, or rarely in the lungs, where the worms ultimately die. The life cycle of *Angiostrongylus (Parastrongylus) costaricensis* is similar, except that the adult worms reside in the arterioles of the ileocecal area of the definitive host. In humans, *A. costaricensis* often reaches sexual maturity and release eggs into the intestinal tissues. The eggs and larvae degenerate and cause intense local inflammatory reactions and do not appear to be shed in the stool. (SOURCE: CDC)

Morphology

Angiostrongylus cantonensis is a long slender worm measuring between 17 and 25 µm long by 0.26 to 0.34 µm wide.

Image 7-1. The adult worms of *Angiostrongylus cantonensis.* They measure between 17–25µm long and reside in the pulmonary arteries and arterioles of the definitive hosts. (x 3.5) (SOURCE: CDC)

Symptoms

The incubation period is usually about 20 days but can be up to 47 days. Infection in man is usually self-limiting but can result in fatalities. The main symptom is severe headache but other symptoms include convulsions, vomiting, facial paralyses, paresthesia, neck stiffness and fever. It is accompanied by moderate eosinophilia in the CSF (i.e. the cell count is 100 – 2000/µm^3). Blood eosinophilia is also common. Eye involvement is accompanied by visual impairment, ocular pain, keratitis and retinal edema. Living worms have been reported and are removed surgically.

Laboratory Diagnosis

Presumptive diagnosis can be made on the basis of the patients' symptoms (i.e. fever, meningitis, ocular involvement and severe headache). Eosinophilia in CSF and peripheral blood is also suggestive. Larvae or young adults can be recovered in the CSF. ELISA methods can also provide confirmation.

Angiostrongylus (Parastrongylus) costaricensis

Introduction

Angiostrongylus costaricensis was first described in 1971. Human infections are most common in Costa Rica but have been reported in Mexico, Central and South America.

Life Cycle

The life cycle is similar to *A. cantonensis,* (above) with the human being an *accidental* host by consumption of snails and salad vegetables which have become contaminated by infective larvae that have been shed by slugs in their mucus. Unlike *A. cantonensis,* the larvae of *A. costaricensis* penetrates the intestinal wall and results in inflammatory lesions of the bowel wall. Here the life cycle ends.

Morphology

The eggs are 90µm, oval, thin shelled and can be embryonated. The adult female measures 42 x 300µm and the males measure 22 x 140µm.

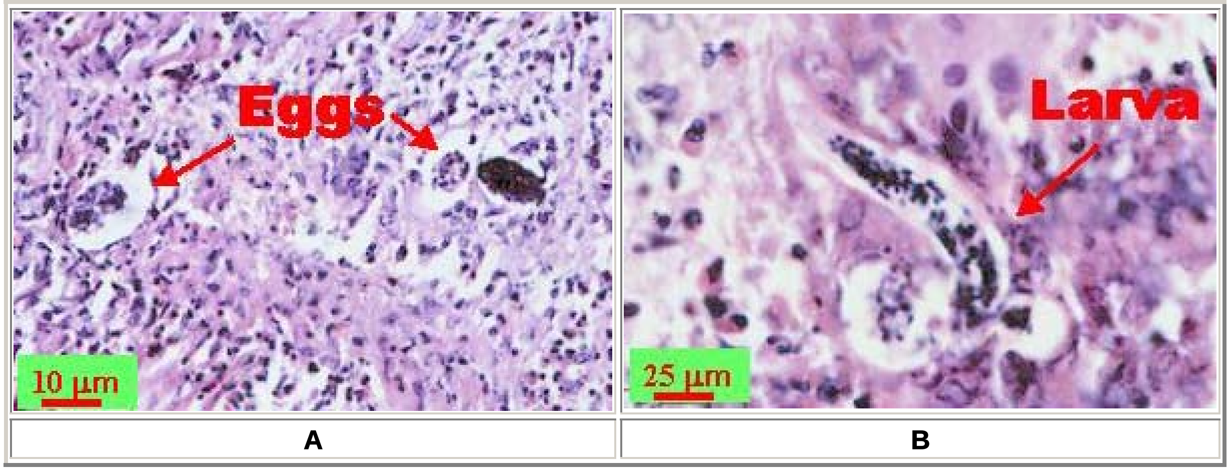

Image 7-2. A: Eggs of *Angiostrongylus costaricensis.* **B:** Larva of *A. costaricensis.* In humans, eggs and larvae are not normally excreted, but remain sequestered in tissues. Both eggs and larvae (occasionally adult worms) of *A. costaricensis* can be identified in biopsy or surgical specimens of intestinal tissue. The larvae need to be distinguished from larvae of *Strongyloides stercoralis*; however, the presence of granulomas containing thin shelled eggs and/or larvae serve to distinguish *A. costaricensis* infections. (SOURCE: CDC)

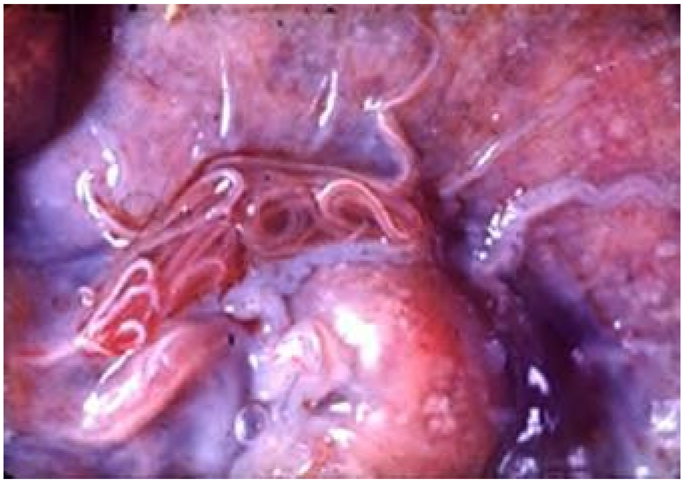

Image 7-3. Picture showing the adult *Angiostrongylus costaricensis* worms in the natural host of a rat. The worms normally localize within the mesenteric arteries, especially those of the ileocecal region of the natural definitive host. (SOURCE: CDC)

Clinical Disease

The most common symptoms are pain and tenderness with fever, vomiting and diarrhea. A tumor-like mass is often palpable and can mimic malignancy. The symptoms of abdominal pain, vomiting and diarrhea, and anorexia, are often mistaken for those of appendicitis. Worms can be found in the regional lymph nodes and mesenteric arteries. They can also be found in the spermatic arteries causing testicular obstruction and necrosis. Occasionally the larvae and the ova reach the liver and symptoms may mimic visceral larvae migrans. Eosinophilia is also present.

Anisakiasis

Introduction

Anisakiasis is a collective name for infections belonging to the genera of nematodes, *Anisakis, Phokanema, Terranova* and *Contracaecum*. The adult worms from the many species belonging to this family, *Anisakidae*, occur in various sea mammals, seals, dolphins, porpoises and whales, the larvae can cause a serious zoonosis, *anisakiasis*, in man. Anisakiasis was first reported in the Netherlands in 1960 and since then cases have been reported from Japan, North America, Canada, Chile, and the United Kingdom with the increase in popularity of 'sushi'.

Two species of nematode have been especially implicated worldwide in causing human anisakiasis, *Anisakis simplex* and *Pseudoterranova osculatum.* The larvae of *P. osculatum* can be distinguished from *A. simplex* by the possession of a cecum.

Life Cycle

These nematodes are parasites in a large number of marine animals including seals, sea-lions, whales, and dolphins. It is in these mammals that the adult worm is found. Eggs are passed out in the feces of these mammals, they embryonate and hatch to liberate the first stage larvae into the sea water. These larvae then become ingested by crustaceans and molt to become L_2 and L_3 larvae. If fish and squid eat the infected crustaceans, the third stage larvae become liberated and penetrate the intestine or muscles of that host. These larvae then encyst. Over 100 species of fish can act as intermediate hosts. The marine mammals ingest the fish and thus the cycle is completed.

Humans become infected by consuming raw or improperly cooked fish which contain the third stage larvae.

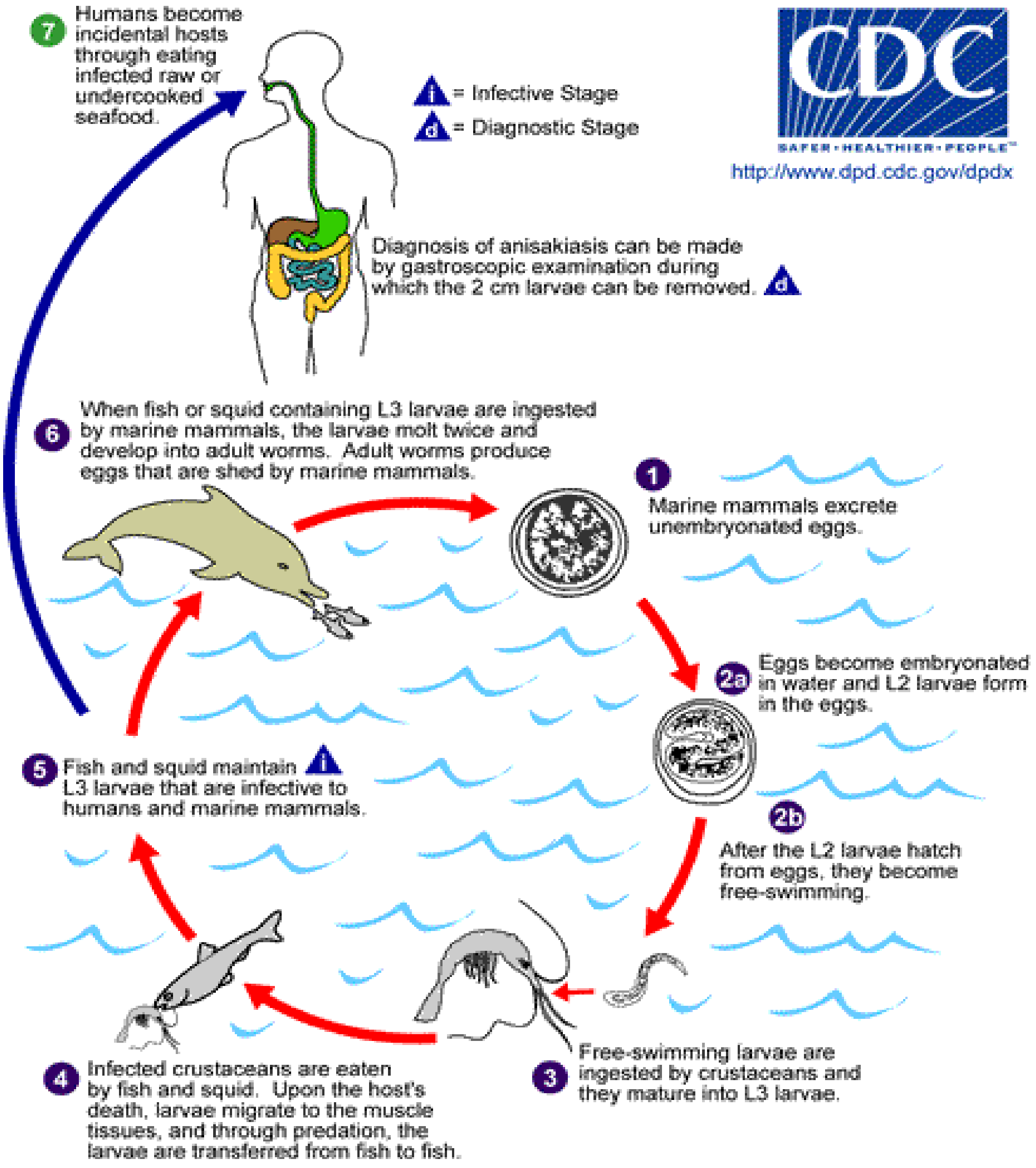
7 Humans become incidental hosts through eating infected raw or undercooked seafood.
i = Infective Stage
d = Diagnostic Stage
CDC
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Diagnosis of anisakiasis can be made by gastroscopic examination during which the 2 cm larvae can be removed. d
6 When fish or squid containing L3 larvae are ingested by marine mammals, the larvae molt twice and develop into adult worms. Adult worms produce eggs that are shed by marine mammals.
1 Marine mammals excrete unembryonated eggs.
2a Eggs become embryonated in water and L2 larvae form in the eggs.
2b After the L2 larvae hatch from eggs, they become free-swimming.
5 Fish and squid maintain i L3 larvae that are infective to humans and marine mammals.
3 Free-swimming larvae are ingested by crustaceans and they mature into L3 larvae.
4 Infected crustaceans are eaten by fish and squid. Upon the host's death, larvae migrate to the muscle tissues, and through predation, the larvae are transferred from fish to fish.

Illustration 7-2. Adult stages of *Anisakis simplex* or *Pseudoterranova decipiens* reside in the stomach of marine mammals, where they are embedded in the mucosa, in clusters. Unembryonated eggs produced by adult females are passed in the feces of marine mammals ❶. The eggs become embryonated in water, and first-stage larvae are formed in the eggs. The larvae molt, becoming second-stage larvae (2a), and after the larvae hatch from the eggs, they become free-swimming (2b). Larvae released from the eggs are ingested by crustaceans ❸. The ingested larvae develop into third-stage larvae that are infective to fish and squid ❹. The larvae migrate from the intestine to the tissues in the peritoneal cavity and grow up to 3 cm in length. Upon the host's death, larvae migrate to the muscle tissues, and through predation, the larvae are transferred from fish to fish. Fish and squid maintain third-stage larvae that are infective to humans and marine mammals ❺. When fish or squid containing third-stage larvae are ingested by marine mammals, the larvae molt twice and develop into adult worms. The adult females produce eggs that are shed by marine mammals ❻. Humans become infected by eating raw or undercooked infected marine fish ❼. After ingestion, the anisakid larvae penetrate the gastric and intestinal mucosa, causing the symptoms of anisakiasis. (SOURCE: CDC)

Morphology

The larvae reach a length of 50µm with a diameter of 1-2µm. Classification of the Anisakids is made by the structure of the digestive tract.

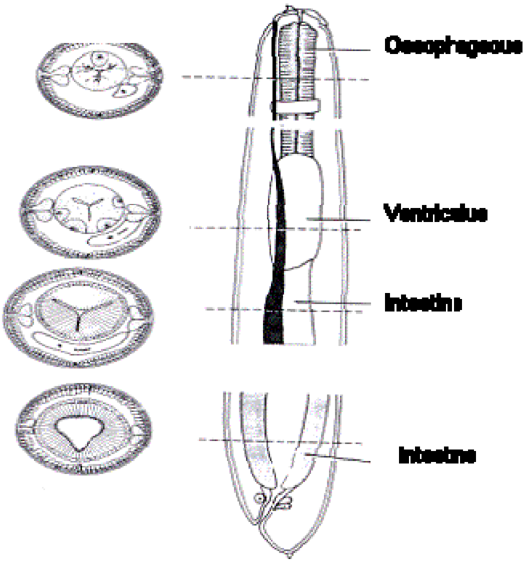

Illustration 7-3. Line diagram representing the morphology of the third stage larvae of *Anisakis simplex* (from fish), it is the causative organism of *anisakiasis* in man. (SOURCE: Smyth, J.D, 1994)

Clinical Disease

After ingestion of the raw fish by humans, the larvae penetrate the intestinal wall resulting in inhabitation of the stomach or duodenum, but can be found in any part if the alimentary canal or outside the gut in various viscera. The end result is abdominal pain, nausea, and sometimes vomiting and diarrhea, often occurring within 6 hours of eating an infected meal. Abdominal irritation may mimic gastric ulcer, carcinoma, appendicitis or other conditions requiring surgery. Eosinophilic granulosus may result.

Transient anisakiasis which has been reported in North America is characterized by some vomiting and distress within a few hours of ingesting the fish and then quickly subsides. The larvae can be coughed up a few days later. Low grade eosinophilia and occult blood in the stool are common.

Laboratory Diagnosis

Diagnosis can only be confirmed by endoscopy and the removal of the worms by biopsy forceps and microscopic identification.

Epidemiology and Prevention

Anisakis larvae are usually found in herring, mackerel, and North American salmon. *Pseudoterranova* are found in cod, halibut, rockfish, sardines, and squid.

Human infections result from eating raw fish, insufficiently cooked or smoked fish, marinated or salted fish. Freezing fish at -20°C (-4°F) for a minimum of five days kills the larvae and thus the fish is suitable for consumption in dishes like sushi. Smoking the fish at temperatures >65°C (149°F) renders it suitable for consumption. Marinating or salting the fish cannot be depended upon to kill the larvae, however adequately cleaning the fish can render it safe for consumption. Human anisakiasis has been virtually eliminated from the Netherlands due to the mandatory freezing of herring.

Gnathostoma spinigerum

Introduction

Several species of the genus Gnathostoma are responsible for zoonotic infections in man. *Gnathostoma spinigerum* is a nematode found in dogs, cats, and several other carnivores. Human infections of the disease have been reported from Japan, China, Thailand, the Far East, and the Philippines, with man acquiring the infection from eating various freshwater fish.

Life Cycle

The life cycle of this parasite involves two intermediate hosts, cyclops and birds, snakes, fish and frogs where they mature before developing into adults in the definitive hosts.

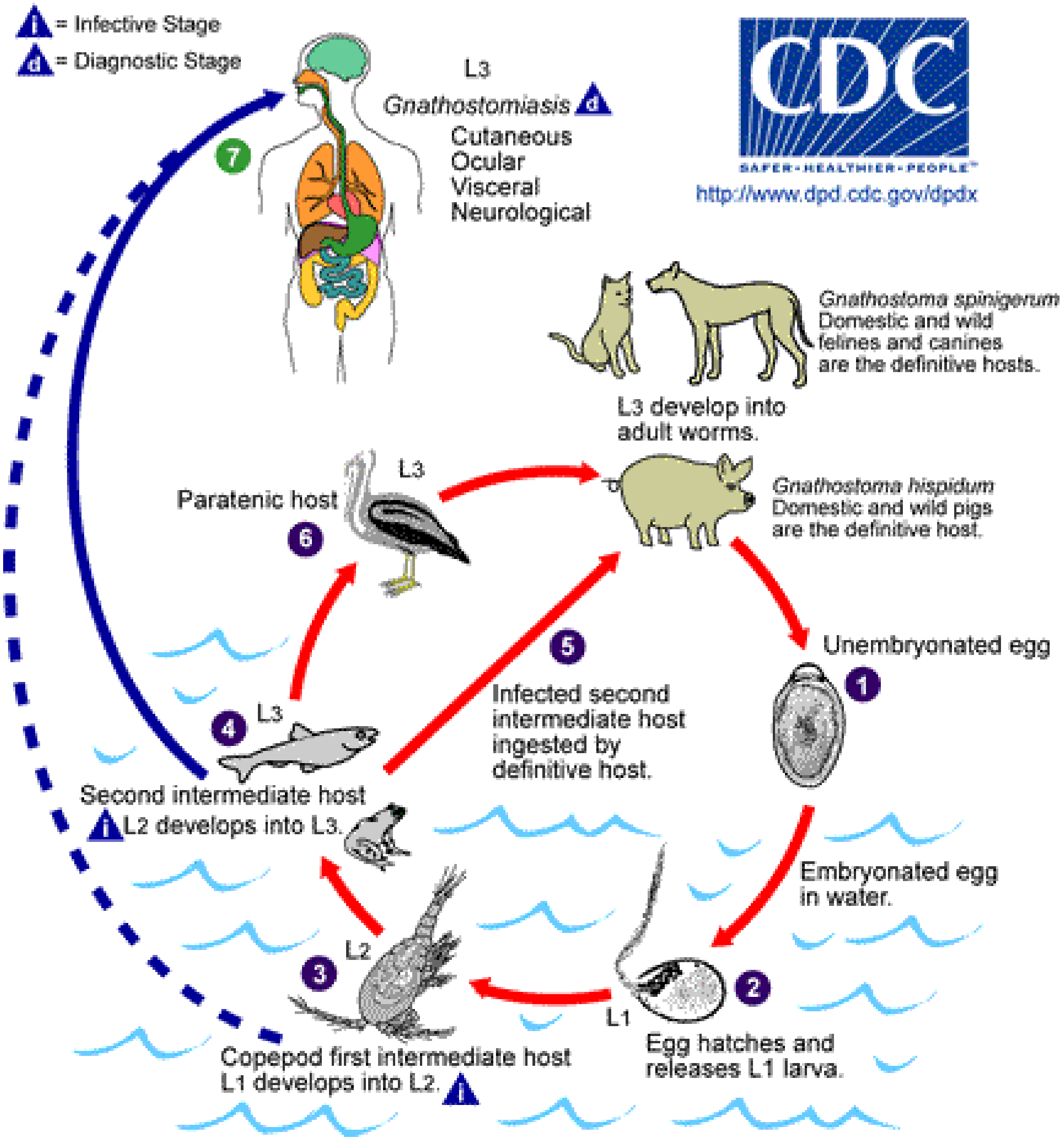
i = Infective Stage
d = Diagnostic Stage
L3
Gnathostomiasis d
Cutaneous
Ocular
Visceral
Neurological
CDC
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Gnathostoma spinigerum
Domestic and wild felines and canines are the definitive hosts.
L3 develop into adult worms.
Gnathostoma hispidum
Domestic and wild pigs are the definitive host.
Unembryonated egg
1
Embryonated egg in water.
2
L1
Egg hatches and releases L1 larva.
3
L2
Copepod first intermediate host
L1 develops into L2. i
4
L3
Second intermediate host
i L2 develops into L3.
5
Infected second intermediate host ingested by definitive host.
Paratenic host
6
L3
7

Illustration 7-4. Diagram illustrating the life cycle of *Gnathostoma spinigerum.* In the natural definitive host (pigs, cats, dogs, wild animals) the adult worms reside in a tumor which they induce in the gastric wall. They deposit eggs that are unembryonated when passed in the feces ❶. Eggs become embryonated in water, and eggs release first-stage larvae ❷. If ingested by a small crustacean (*Cyclops,* first intermediate host), the first-stage larvae develop into second-stage larvae ❸. Following ingestion of the *Cyclops* by a fish, frog, or snake (second intermediate host), the second-stage larvae migrate into the flesh and develop into third-stage larvae ❹. When the second intermediate host is ingested by a definitive host, the third-stage larvae develop into adult parasites in the stomach wall ❺. Alternatively, the second intermediate host may be ingested by the paratenic host (animals such as birds, snakes, and frogs) in which the third-stage larvae do not develop further but remain infective to the next predator ❻. Humans become infected by eating undercooked fish or poultry containing third-stage larvae, or reportedly by drinking water containing infective second-stage larvae in *Cyclops* ❼.

If the infected fish or frogs are eaten by other hosts, apart from the definitive hosts, (paratenic host), such as herons, pigs and man, they do not mature but migrate through the subcutaneous tissues causing visceral and cutaneous larva migrans.

Morphology

The adult female worms measure 25-54µm whereas the male measures 11-25µm. The anterior half of the worm is covered with leaf like spines. The male worms have a red tail while the larger females have a more curved tail. The larval worms are 4µm long.

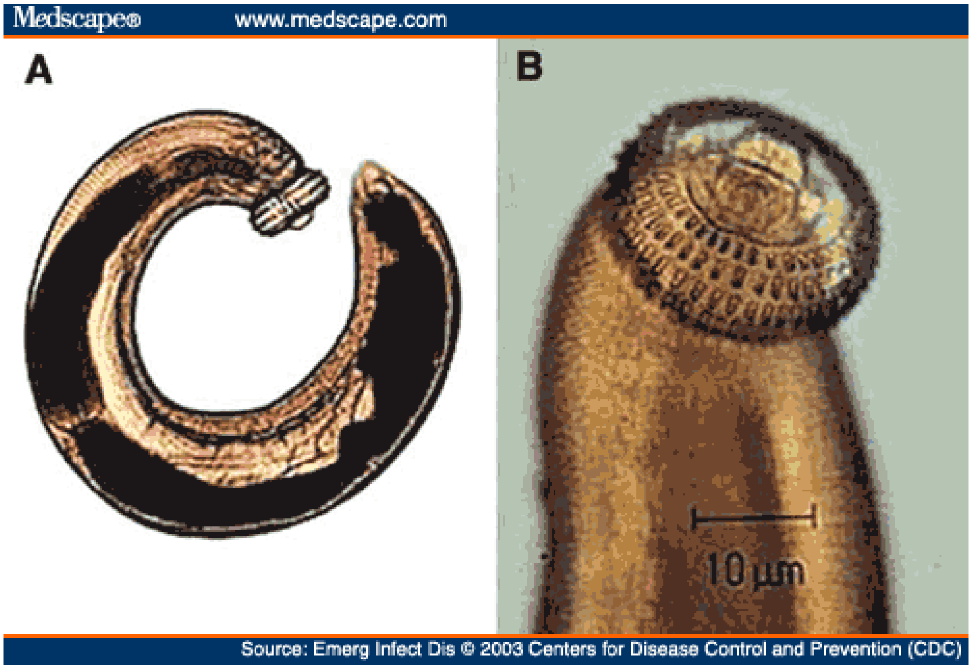
Medscape®
www.medscape.com
A
B
10 µm
Source: Emerg Infect Dis © 2003 Centers for Disease Control and Prevention (CDC)

Image 7-4. Adult worms of *Gnathostoma spinigerum.* The males are smaller than the females and possess a red tail. (x 1.3) (SOURCE: CDC/Medscape)

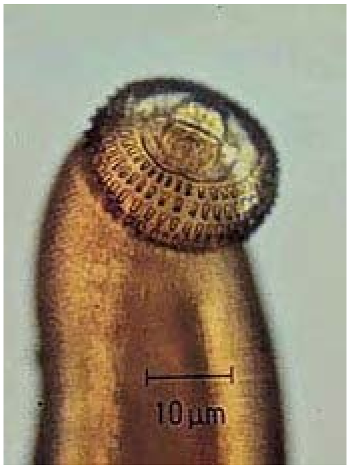

Image 7-5. Third stage larval Head of *Gnathostoma spinigerum.* (SOURCE: CDC/Medscape)

Clinical Disease

Humans are accidental hosts and after ingestion, the larvae do not mature but migrate throughout the body via the intestinal wall. Symptoms include epigastric pain, vomiting and anorexia. These symptoms subside as the larvae continue their migratory path through the cutaneous tissue. Evidence of migration appears as either lesions similar to cutaneous larvae migrans or migratory swellings accompanied by inflammation, redness or pain. The swelling is hard and non-pitted and lasts for several days. These migratory lesions may be accompanied by pruritis and pain. There is marked eosinophilia in patients with cutaneous involvement. Ocular involvement resulting in blindness may occur in serious disease. Eosinophilic myeloencephalitis may result from migration of the worms along the nerve tracks. Symptoms may include pain, paralyses, seizures, coma and death. The CSF may be xanthochromic (yellowish discoloration) or bloody.

Laboratory Diagnosis

Presumptive diagnosis may be made on the basis of clinical symptoms. Definitive diagnosis is the recovery and identification of the worm since the symptoms may be suggestive of Sparganosis, paragonimiasis and cutaneous larvae migrans and myiasis. A bloody spinal fluid or xanthochromia may resemble infection with *Angiostrongylus cantonensis.*

Trichinella spiralis

Introduction

Trichinella spiralis was first seen by James Paget, but was named and described by his Professor, Richard Owen. The family Trichinellidae contains only one single genus; *Trichinella,* and was originally thought only to contain the one species; *Trichinella spiralis,* which causes the serious and often fatal disease in man known as *trichinosis* (Trichinellosis). It is a parasite of carnivorous animals and is especially common in rats and in swine fed on uncooked garbage and slaughter house scraps. Humans become infected by eating raw pork, with sausages being the most common cause of infection. It is a cosmopolitan parasite and is common in China, though prevalent in many European countries as well.

It is now thought that there are four varieties of this species that exists worldwide;

- *Trichinella spiralis spiralis* - Temperate zone – high infectivity for pigs, rats and man.
- *Trichinella spiralis nelsoni* - Tropics - low infectivity for pigs and rats and high infectivity for lions, hyenas.
- *Trichinella spiralis nativa* - Arctic - low infectivity for pigs, found in polar bears, resistant to freezing.
- *Trichinella spiralis pseudospiralis*- New Zealand – low infectivity for pigs, rats and mice.

Trichinella spiralis is a ‘domestic’ parasitic nematode long recognized to cause a zoonosis transmitted to man by the ingestion of infected pork.

Life Cycle

Infection in the definitive hosts is acquired by the hosts eating raw or undercooked flesh (e.g. pork, containing encapsulated larvae). Rats are probably the most highly infected 'natural' hosts and pigs become infected by eating infected pork scraps or occasionally rats which inhabit their stalls. For man, sausages are a dangerous source of the parasite as a small fragment of infected pork, (after mincing), may become widely distributed among a number of sausages.

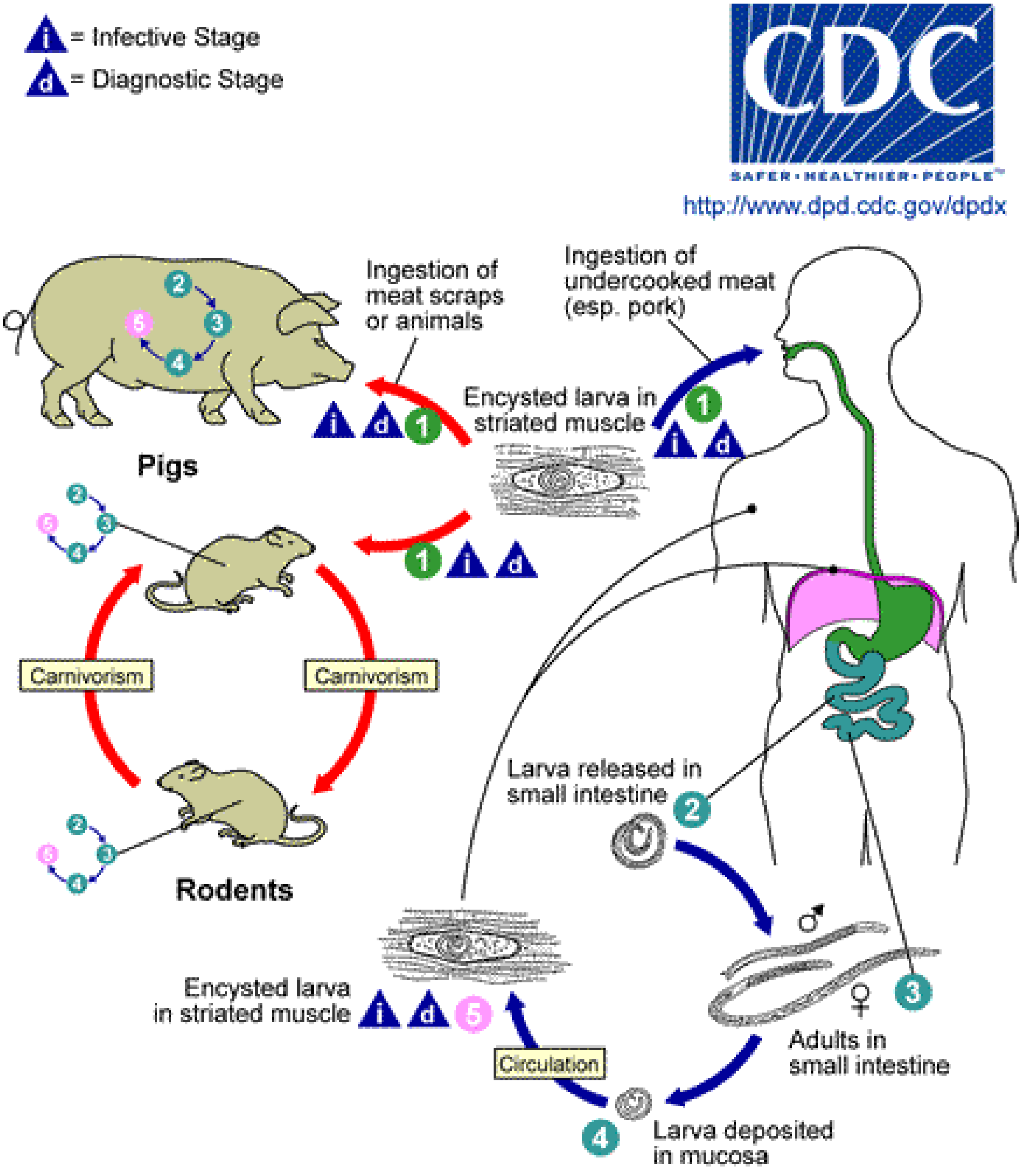
i = Infective Stage
d = Diagnostic Stage
CDC
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Ingestion of meat scraps or animals
Ingestion of undercooked meat (esp. pork)
Encysted larva in striated muscle
i d ①
Pigs
② ③ ④ ⑥
Carnivorism
Carnivorism
Rodents
② ③ ④ ⑤
Larva released in small intestine ②
♂
♀ ③
Adults in small intestine
Larva deposited in mucosa ④
Circulation
Encysted larva in striated muscle i d ⑤

Illustration 7-5. The life cycle of *Trichinella spiralis*. Trichinellosis is acquired by ingesting meat containing cysts (encysted larvae) ①of *Trichinella*. After exposure to gastric acid and pepsin, the larvae are released ②from the cysts and invade the small bowel mucosa where they develop into adult worms ③(female 2.2 mm in length, males 1.2 mm; life span in the small bowel: four weeks). After one week, the females release larvae ④that migrate to the striated muscles where they encyst ⑤. *Trichinella pseudospiralis*, however, does not encyst. Encystment is completed in 4 to 5 weeks and the encysted larvae may remain viable for several years. Ingestion of the encysted larvae perpetuates the cycle. Rats and rodents are primarily responsible for maintaining the endemicity of this infection. Carnivorous/omnivorous animals, such as pigs or bears, feed on infected rodents or meat from other animals. Different animal hosts are implicated in the life cycle of the different species of *Trichinella*. Humans are accidentally infected when eating improperly processed meat of these carnivorous animals (or eating food contaminated with such meat). (SOURCE: CDC/DPDx Trichinellosis)

Morphology

The adult female worm is about 2-3µm long and 90µm in diameter. The male is smaller measuring 1.2µm long by 60µm in diameter.

The female adult worms are ovoviparous (born alive from the mother but held as an unshelled egg internally until birth, after having no umbilical connection to the mother) and up to 1500 larvae may be released by a single worm.

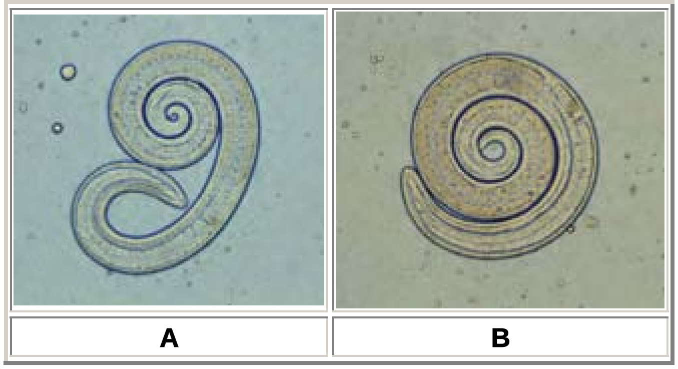

Image 7-6. A, B: Larvae of *Trichinella*, freed from their cysts, typically coiled; length: 0.8 to 1.0 µm. Alaskan bear. (SOURCE: CDC)

Clinical Disease

Symptoms during the intestinal phase may go unnoticed or may be severe. Epidemics can result in outbreaks of gastro-enteritis, two to seven days after the ingestion of raw pork. Diarrhea with or without abdominal pain may last for several weeks. Eosinophilia and fever occur in most cases. Leukocytosis is common and hyperglobulinaemia (an autoimmune, chronic blood disease) is characteristic. Myocytosis and circum orbital edema are classic signs. There can also be central nervous system involvement

Pathogenicity

The primary pathogenic effect of *Trichinella* comes from the destruction of the striated muscle fibers in which it encysts. There can be neurological manifestations of trichinosis and death may be ascribed to myocarditis, encephalitis or pneumonitis.

Laboratory Diagnosis

Diagnosis of trichinosis depends on the clinical signs, such as myalgia, periorbital edema, fever and eosinophilia in a patient with a history of eating pork or sausages.

Serological tests are available but may be negative if carried out within three to four weeks post infection. Circulating antibodies to *T.* spiralis appear from two to four weeks after infection. Redefined diagnostic antigens for their detection are currently being developed. A simple IFAT employing fragments of larvae as antigen is a useful diagnostic tool. Latex tests with extracted larval antigens have also proved valuable in the acute stage, during which high antibody titers develop.

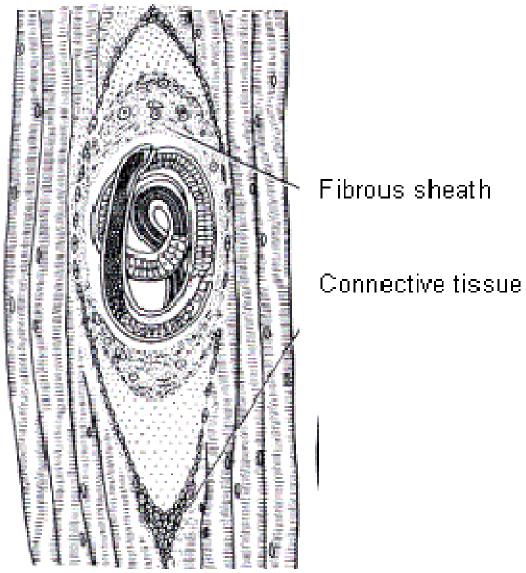

Illustration 7-6. Diagrammatic representation of the *Trichinella* larvae encapsulated in striated muscle. (SOURCE: Smyth, J.D, 1994)

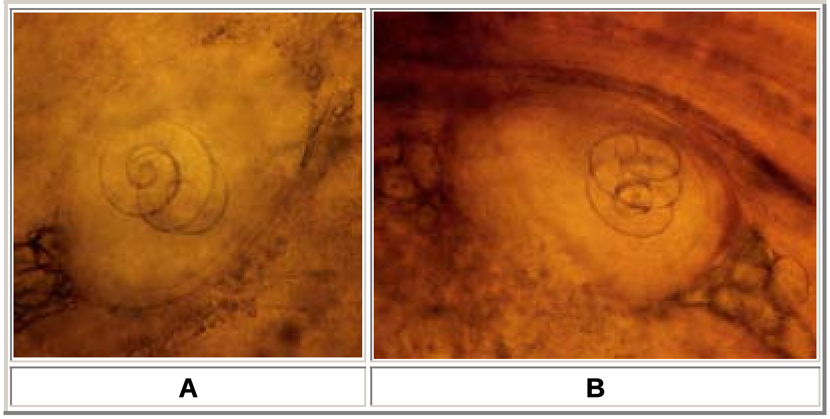

Image 7-7. A, B: Encysted larvae of *Trichinella* in pressed muscle tissue. The coiled larvae can be seen inside the cysts. (SOURCE: CDC)

Muscle biopsy is available with the muscle being digested in pepsin, which frees the encapsulated larvae or by a simple device whereby the muscle sample is compressed between two glass plates to make it semi-transparent, allowing you to see any encapsulated larvae using a 'trichinoscope' (a simple magnifying system).

Chapter 8.

Larval Cestodes and Nematodes which Infect Man

8.1 Larval Cestodes which Infect Man

Infections in man with *Echinococcus granulosus, Echinococcus multilocularis,* and *Multiceps multiceps* are caused by the accidental ingestion of eggs which are excreted by the definitive animal host. The disease that is produced due to the invasion of these parasites is caused by the larval stages or hydatid cyst, is known as hydatid disease or hydatidosis.

Echinococcus granulosus causes cystic echinococcosis, and is the form most frequently encountered; *E. multilocularis* causes alveolar echinococcosis; *E. vogeli* causes polycystic echinococcosis; and *E. oligarthrus* is an extremely rare cause of human echinococcosis.

Each cestode possesses an elongated tape-like body which lacks an alimentary canal. The adult tapeworms are strings of individuals having a complete set of reproductive organs (proglottids) in progressive degrees of sexual maturity and budding off from a body attached to the host tissue by a head or scolex.

The larval stage, show a wide variation being found in almost any organ of both vertebrate and invertebrate hosts.

Echinococcus granulosus

Introduction

Echinococcosis or Hydatid disease in man is caused by the larval stage of the dog tapeworm, *Echinococcus granulosus*. Hydatid disease is most extensively found in East Africa, North Africa, South Africa, the Middle East, and parts of South America, and Australia. The intermediate hosts are cattle, sheep, pigs, goats, or camels and the definitive host for this disease is the dog or other canids.

Life Cycle

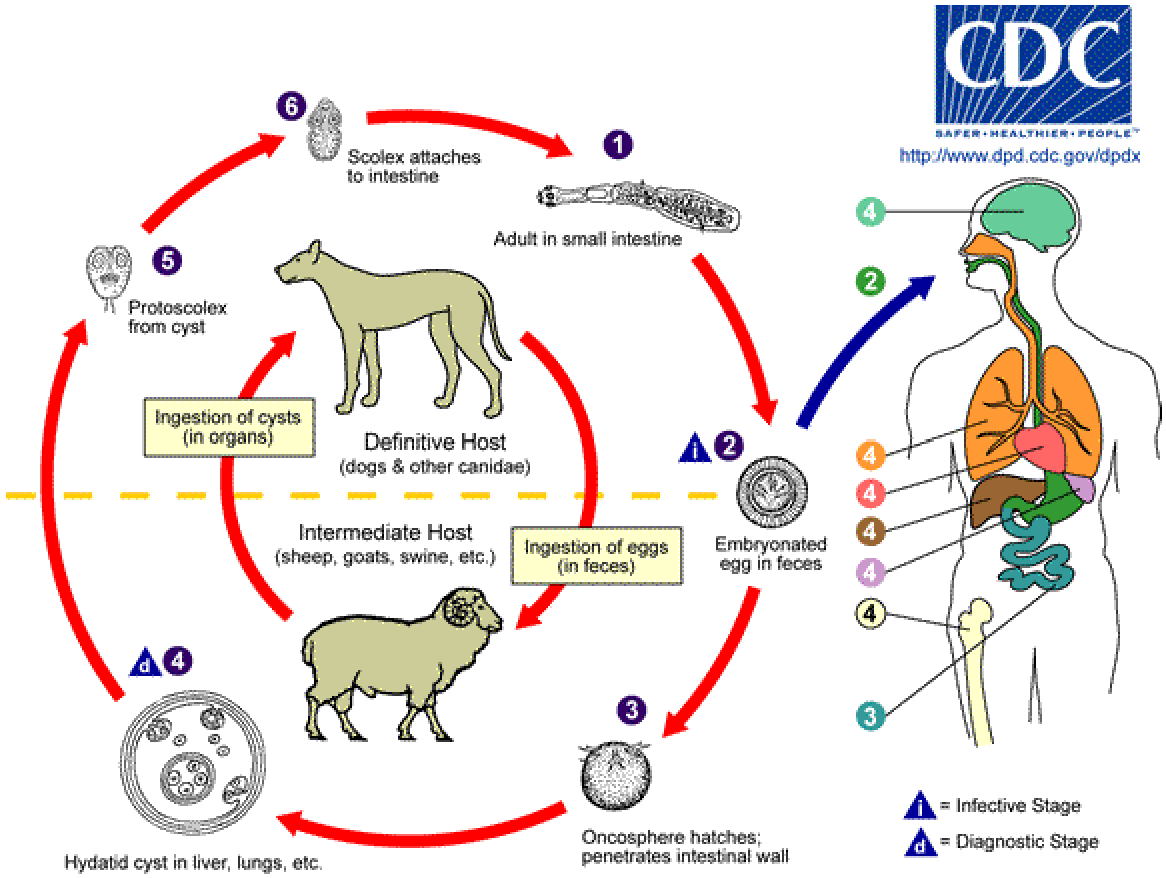
CDC
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6
Scolex attaches to intestine
1
Adult in small intestine
5
Protoscolex from cyst
Ingestion of cysts (in organs)
Definitive Host (dogs & other canidae)
Intermediate Host (sheep, goats, swine, etc.)
Ingestion of eggs (in feces)
i 2
Embryonated egg in feces
d 4
3
Oncosphere hatches; penetrates intestinal wall
Hydatid cyst in liver, lungs, etc.
4
2
4
4
4
4
4
3
i = Infective Stage
d = Diagnostic Stage

Illustration 8-1. Life Cycle of *Echinococcus granulosus*. The adult *Echinococcus granulosus* (3 to 6 mm long) ①resides in the small bowel of the definitive hosts, dogs or other canids. Gravid proglottids release eggs ②that are passed in the feces. After ingestion by a suitable intermediate host (under natural conditions: sheep, goat, swine, cattle, horses, camel), the egg hatches in the small bowel and releases an oncosphere ③that penetrates the intestinal wall and migrates through the circulatory system into various organs, especially the liver and lungs. In these organs, the oncosphere develops into a cyst ④ that enlarges gradually, producing protoscolices and daughter cysts that fill the cyst interior. The definitive host becomes infected by ingesting the cyst-containing organs of the infected intermediate host. After ingestion, the protoscolices ⑤evaginate, attach to the intestinal mucosa ⑥, and develop into adult stages ①in 32 to 80 days. The same life cycle occurs with *E. multilocularis* (1.2 to 3.7 mm), with the following differences: the definitive hosts are foxes, and to a lesser extent dogs, cats, coyotes and wolves; the intermediate host are small rodents; and larval growth (in the liver) remains indefinitely in the proliferative stage, resulting in invasion of the surrounding tissues. With *E. vogeli* (up to 5.6 mm long), the definitive hosts are bush dogs and dogs; the intermediate hosts are rodents; and the larval stage (in the liver, lungs and other organs) develops both externally and internally, resulting in multiple vesicles. *E. oligarthrus* (up to 2.9 mm long) has a life cycle that involves wild felids as definitive hosts and rodents as intermediate hosts. Humans become infected by ingesting eggs ②, with resulting release of oncospheres ③in the intestine and the development of cysts ④, ④, ④, ④, ④, ④ in various organs. (SOURCE: CDC/DPDx Echinococcus)

Morphology

The adult worm measures approximately 3–8.5µm long. The scolex has four suckers and a rostellum with hooks, the latter becoming tightly inserted into the crypts of Lieberkühn. The mature strobila has only 3–4 proglottids, one is immature, one is mature and the final one is gravid; when gravid the eggs are expelled in the feces.

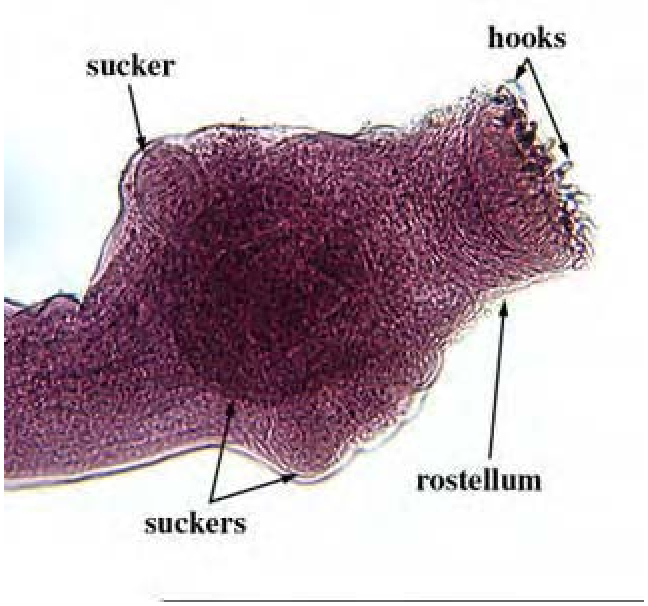
hooks
sucker
rostellum
suckers

Image 8-1. *Echinococcus granulosus* scolex. (SOURCE: CDC)

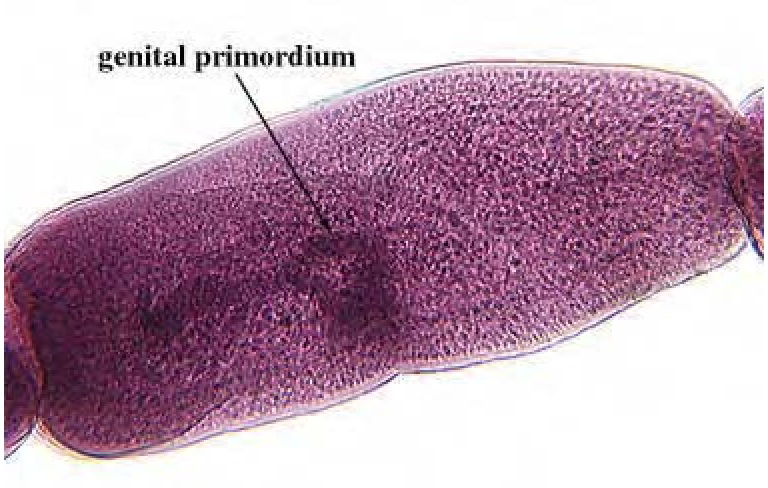
genital primordium

Image 8-2. *Echinococcus granulosus* immature proglottid. (SOURCE: CDC)

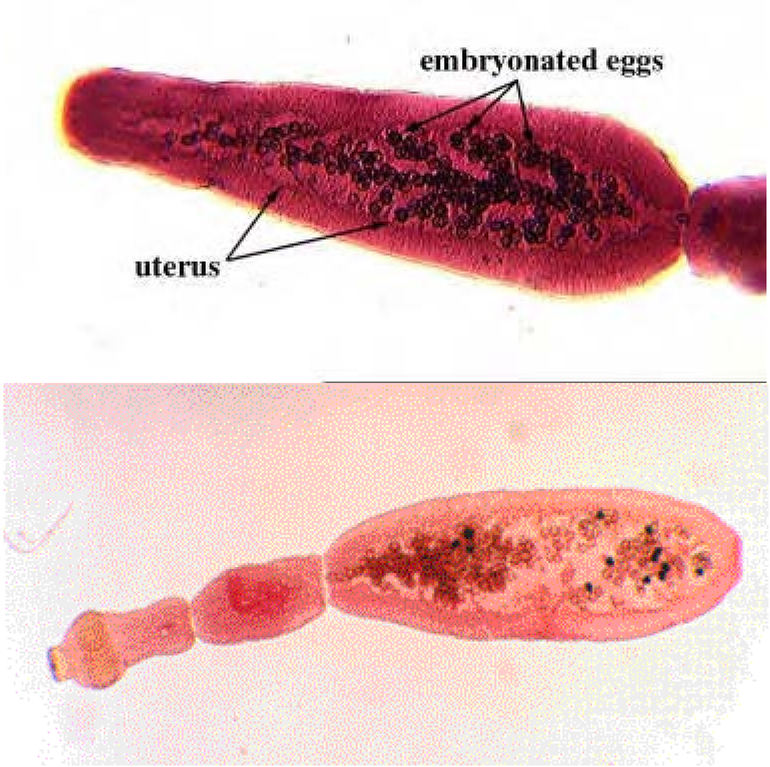

Image 8-3. Adult female worms of *Echinococcus granulosus* with gravid proglottids. (SOURCE: CDC)

Due to the close similarity of the eggs to other *Taenia* species found in dogs they were until recently thought to be morphologically indistinguishable.

The larvae in man develop into a unilocular cyst which gives rise to unilocular hydatid disease. This is characterized as having only one bladder or many completely isolated bladders, each enclosed in its own well-developed envelope. The latter consists of several layers, the most prominent being the laminated layer. Within this again is the germinal membrane from which the brood capsules arise inside which develop thousands of larvae or protoscoleces, the whole being suspended in a hydatid fluid.

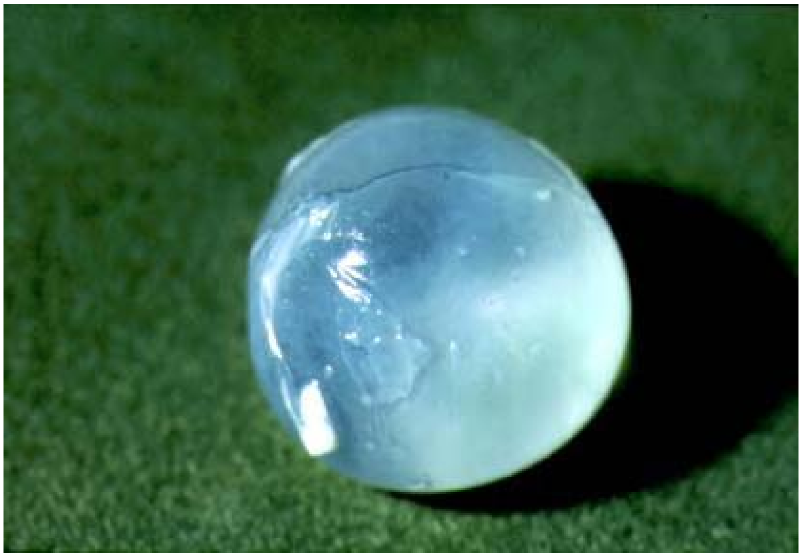

Image 8-4. Unilocular cyst of *Echinococcus granulosus*. This is characterized as having only one bladder or many completely isolated bladders, each enclosed in its own well-developed envelope. Inside which develop thousands of larvae or protoscoleces, the whole being suspended in a hydatid fluid. These cysts in man give rise to unilocular hydatid disease.

Clinical Disease

Hydatid disease in humans is potentially dangerous depending on the location of the cyst. Some cysts may remain undetected for many years until they become large enough to affect other organs. Symptoms are then of a space occupying lesion. Lung cysts are usually asymptomatic until there is a cough, shortness of breath or chest pain. Hepatic cysts result in pressure on the major bile ducts or blood vessels. Expanding hydatid cysts cause necrosis of the surrounding tissue.

Slow leakage of the hydatid fluid results in eosinophilia and rupture of an abdominal hydatid cyst results in severe allergic symptoms.

Symptoms may not manifest themselves for five to 20 years after the infection.

Laboratory Diagnosis

1. Imaging and serodiagnosis are the mainstay of diagnosis. Serological tests include Enzyme linked immunosorbent assay (ELISA), an indirect hemagglutination test a complement fixation test and a Western Blot system.

2. Microscopic examination of the cyst fluid to look for the characteristic protoscoleces which can be either invaginated or evaginated. The cyst fluid will also reveal free hooklets and tissue debris. One percent eosin may be added to the fluid to determine the viability of the protoscoleces. Viable protoscoleces exclude eosin whereas nonviable protoscoleces take up the eosin.

3. Histological examination of the cyst wall after surgical removal.

Western Blots

One serological test which has proved to be of value to diagnosing Hydatid disease is the Western Blot. The test presents a definitive means for detection of human antibodies to the cestode *E. granulosus.*

Diagnosis can be achieved using the Western Blot assay for the detection of IgG antibodies in serum reactive with *E. granulosus* antigens present on a membrane. Field studies support a sensitivity of 80% and specificity of 100% in patients with hepatic cysts.

This assay is known as the Qualicode™ Hydatid Disease Kit; the principle behind the test is that it is a qualitative membrane-based immunoassay manufactured from *E. granulosus* proteins. The *E. granulosus* proteins are fractionated according to molecular weight by electrophoresis on a ployacrylamide slab gel (PAGE) in the presence of sodium dodecyl sulfate (SDS). The separated *E. granulosus* proteins are then transferred via electrophoretic blotting from the gel into strips for testing of individual samples.

During the procedure, the strips containing the *E. granulosus* proteins are incubated with serum specimens and washed to remove unbound antibodies.

Visualization of human immunoglobulins specifically bound to *E. granulosus* proteins is performed by sequential reaction with goat anti-human immunoglobulin-alkaline phosphatase conjugate and BCIP/NBT substrate. Bands corresponding to the positions of the resoled *E. granulosus* proteins will be visualized on the strip, indications the presence in the serum sample of IgG antibodies direct against *E. granulosus* antigens. Band positions are compared to those on a reference strip developed using the Hydatid disease positive control.

Prevention

- Safe disposal of dog feces.
- Education to prevent feeding uncooked offal to dogs.

Echinococcus multilocularis

Introduction

The larvae of *Echinococcus multilocularis* is a particularly dangerous species causing multilocular (alveolar) hydatid disease in man and animals and is common in the highlands of Europe i.e. Switzerland and Germany, in Canada, Alaska and Northern Russia. The most common definitive hosts are foxes and wolves in addition to domestic cats and dogs when they have access to infected rodents.

Life Cycle

Foxes (1) are the primary definitive hosts although in domestic circumstances dogs (1a) and cats (1b) can act as the definitive host. Rodents (4) are the intermediate hosts. Man (4a) is an accidental host by the ingestion of eggs (2) where multilocular cysts are formed (3). In these cysts, the limiting membrane is thin and the germinal epithelium may bud off externally resulting in proliferation in any direction (5). Metastases may occur. Unlike *E. granulosus*, there is little fluid in the cysts of *E. multilocularis.*

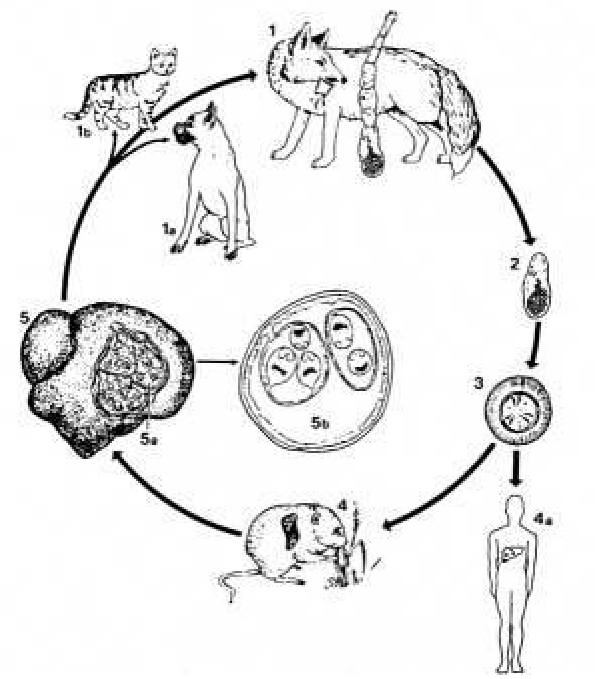

Illustration 8-3: Life cycle of *Echinococcus multilocularis*. (SOURCE: Unknown)

Morphology

Larvae - The larval *E. multilocularis* is very different from that of *E. granulosus*. In this case the 'cyst' grows invasively by external budding, forming a diffuse growth through the infected organ, replacing that organ's tissues. The growth itself, (it cannot truly be called a cyst as there is no real cyst wall), is composed of numerous cavities containing a gelatinous matrix within which protoscolices and numerous brood capsules are produced, and which in its behavior, most closely resembles a malignant neoplasm. In contrast to *E. granulosus* this growth is also very rapid. Infective protosocialises being present after only wo to three months, as compared to the one to two years in the related metacestode.

Adults - The adult parasite is very similar to *E. granulosus*, being slightly smaller, with a maximum length of approximately 4µm, and consisting of four to five proglottids.

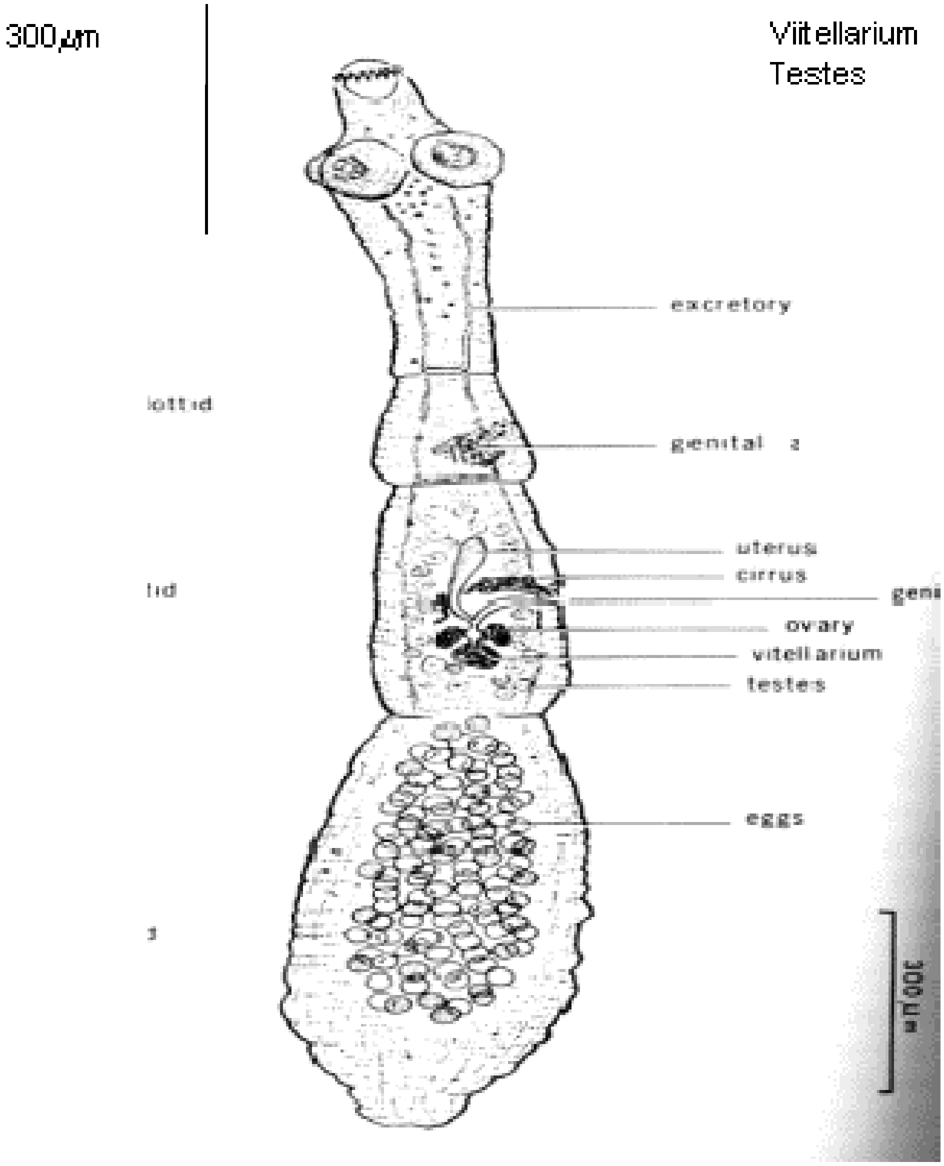
300µm
Viitellarium
Testes
excretory
iottid
genital
uterus
cirrus
geni
lid
ovary
vitellarium
testes
eggs
300 µm

Illustration 8-4. Diagrammatic representation of the adult worm if *Echinococcus multilocularis.* (SOURCE: Unknown)

Clinical Disease

Cysts form primarily in the liver and growth in the vena cava or portal vein results in metastases in the lung or brain. Clinical disease is similar to that of *E. granulosus*.

Laboratory Diagnosis

1. Laboratory diagnosis is can be made by ELISA.
2. Clinical diagnosis is made by ultrasound.

Echinococcus granulosus	*Echinococcus multilocularis*
Slow development of cyst	Rapid development of cyst
Cysts have thick-walled chambers	Cyst has thin-walled chambers
Separated by connective tissue	Not separated by connective tissue
Cyst is fluid filled	Cyst is gelatinous filled
Cyst is free of host material	Cyst is contaminated by host material

Table 8-1. Differences between the hydatid cysts of *E. granulosus* and *E. multilocularis*. (SOURCE: White)

Multiceps multiceps

Introduction

Multiceps multiceps, is a cestode of cosmopolitan distribution and causes coenuriasis in man. The dog is the common definitive host in the USA and UK, with the intermediate stages developing in many ungulates, especially sheep.

Life Cycle

The adult worm is found in dogs and other canidae. The intermediate hosts comprise of a number of herbivorous animals, where the cysts develop in the brain and spinal cord causing a disease called ‘staggers’, which affects the balancing powers of the animals. Man becomes infected by the accidental ingestion of eggs. The oncosphere hatches and penetrates the intestinal wall and the embryo is carried by the blood stream to various parts of the body including the central nervous system where it lodges and the cyst or coenurus develops. Multiple scolices burst from the inner surface of the cyst wall. The cyst resembles that of a cysticercus (*Cysticercus cerebralis)*. It is filled with fluid, semi-transparent and glistening white. The cysticercus possesses unusual asexual multiplication, forming a bladder (or coenurus) which gives rise to hundreds of daughter protoscoleces directly from its inner wall.

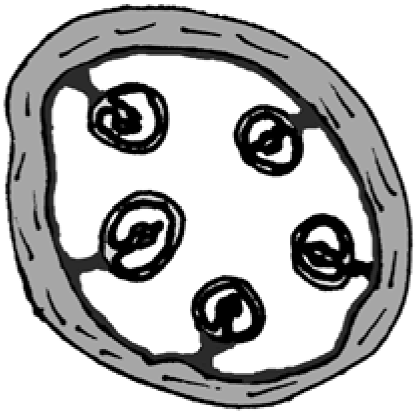

Illustration 8-5. Diagrammatic representation of a *Multiceps (Taenia) multiceps* coenurus cyst. (SOURCE: Unknown)

Clinical Disease

In humans, coenuri are most frequently found in the brain and spinal cord but also in the subcutaneous tissue. Symptoms include headache, vomiting, paraplegia seizures and eye problems. The coenurus may cause serious damage or even death, but only a few have ever been reported.

Laboratory Diagnosis

There are no serological tests available. Diagnosis is achieved by the finding of the coenurus cyst in the brain and spinal cord, or in the subcutaneous tissue.

8.2 Larval Nematodes which Infect Man

Intestinal capillariasis caused by *Capillaria Philippinensis* appeared first in the Philippines and subsequently in Thailand, Japan, Iran, Egypt, and Taiwan, but most infections occur in the Philippines and Thailand. As established experimentally, the life cycle involves freshwater fish as intermediate hosts and fish-eating birds as definitive hosts. Embryonated eggs from feces fed to fish hatch and grow as larvae in the fish intestines. Infective larvae fed to monkeys, Mongolian gerbils, and fish-eating birds develop into adults. Larvae become adults in 10 to 11 days, and the first-generation females produce larvae. These larvae develop into males and egg-producing female worms. Eggs pass with the feces, reach water, embryonate, and infect fish. Autoinfection is part of the life cycle and leads to hyperinfection. Humans acquire the infection by eating small freshwater fish raw. The parasite multiplies, and symptoms of diarrhea, borborygmus, abdominal pain, and edema develop. Chronic infections lead to malabsorption and hence to protein and electrolyte loss, and death results from irreversible effects of the infection. Treatment consists of electrolyte replacement and administration of an antidiarrheal agent and mebendazole or albendazole.

Capillariasis Philippinensis is considered a zoonotic disease of migratory fish-eating birds. The eggs are disseminated along flyways and infect the fish, and when fish are eaten raw, the disease develops.

Capillaria Philippinensis

Introduction

Intestinal capillariasis was first observed in the Philippines in 1962 and since then it has been noted, although less frequently in Thailand, with scattered reports from Taiwan, Japan, Egypt, and Iran. *Capillaria Philippinensis* is a small nematode which burrows into the intestinal mucosa of its human host.

Humans and birds become infected when they eat uncooked or poorly cooked fish. Therefore, infections are seen in endemic proportions where uncooked fish is considered a delicacy.

Life Cycle

The complete life cycle is not known however, human infection is initiated by the consumption of raw fish. The infective larvae are found in the intestine of the fish. When infective fish are eaten by humans, the larvae mature and the adult worms live in the intestinal mucosa, mainly in the jejunum, where they are usually present in large numbers. Larval stages, oviparous and larviparous females are also found in the host's intestine, which suggests that the nematode multiplies in the intestine resulting in auto-infection as in *Strongyloides* infection. The eggs are passed out in the feces and embryonate in the soil, a process which takes about 12 days. The eggs are ingested by fresh-water fish, they hatch and develop into the infective form in the intestine of the fish.

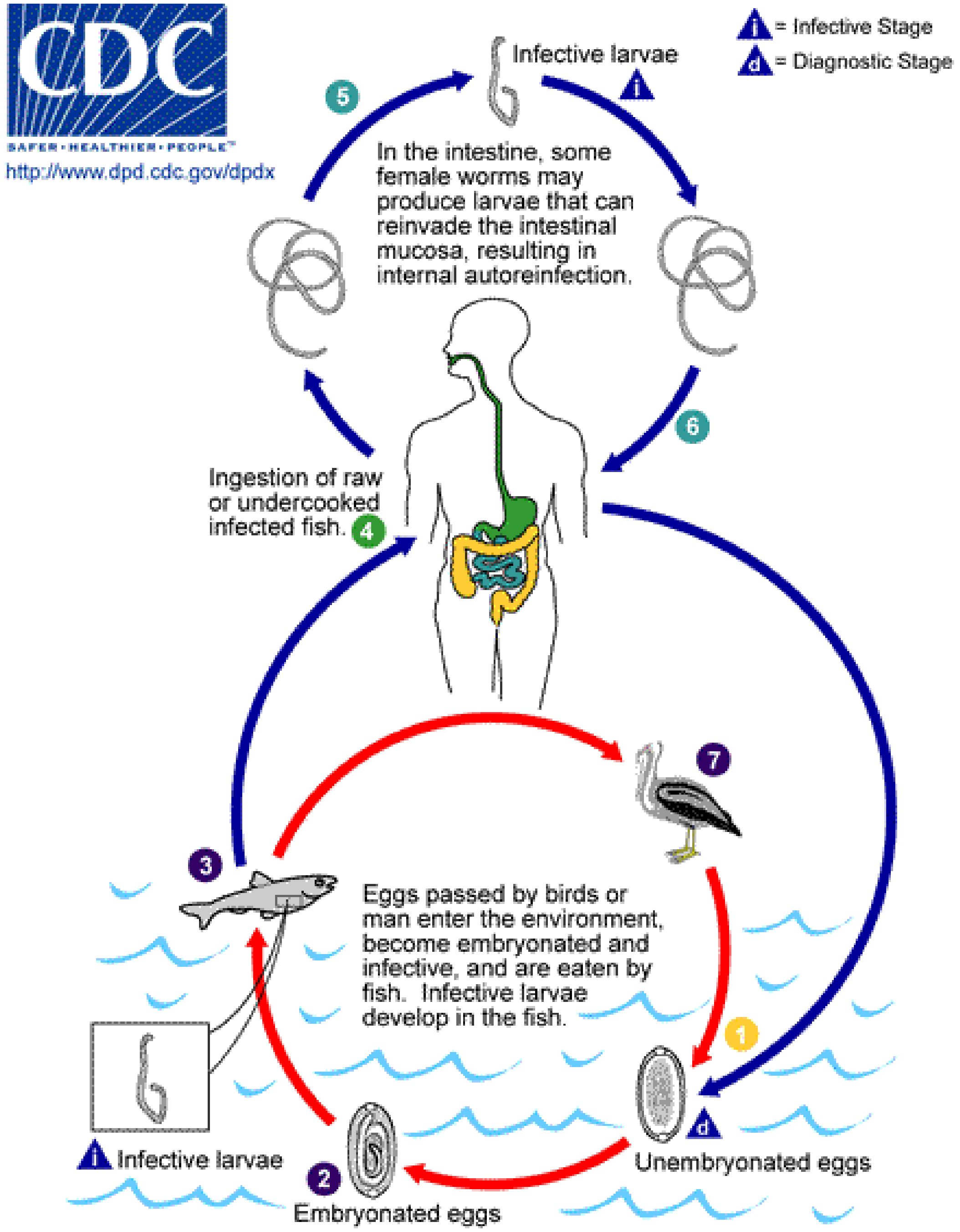

CDC
SAFER·HEALTHIER·PEOPLE™
http://www.dpd.cdc.gov/dpdx
i = Infective Stage
d = Diagnostic Stage
Infective larvae
i
5
In the intestine, some female worms may produce larvae that can reinvade the intestinal mucosa, resulting in internal autoreinfection.
6
Ingestion of raw or undercooked infected fish.
4
7
3
Eggs passed by birds or man enter the environment, become embryonated and infective, and are eaten by fish. Infective larvae develop in the fish.
1
i Infective larvae
2
Embryonated eggs
d
Unembryonated eggs

Illustration 8-6. Diagram of the life cycle of *Capillaria Philippinensis.* Humans become infected from eating infected fish. The disease in man is known as Capillariasis. Typically, unembryonated eggs are passed in the human stool ❶ and become embryonated in the external environment ❷; after ingestion by freshwater fish, larvae hatch, penetrate the intestine, and migrate to the tissues ❸. Ingestion of raw or undercooked fish results in infection of the human host ❹. The adults of *Capillaria Philippinensis* (males: 2.3 to 3.2 mm; females: 2.5 to 4.3 mm) reside in the human small intestine, where they burrow in the mucosa ❺. The females deposit unembryonated eggs. Some of these become embryonated in the intestine, and release larvae that can cause autoinfection. This leads to hyperinfection (a massive number of adult worms) ❻. *Capillaria Philippinensis* is currently considered a parasite of fish eating birds, which seem to be the natural definitive host ❼. (CDC 3382 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology

The adult female worm measures 2.5-4.3µm, while the males are marginally smaller measuring 2.3-3.2µm. Adult females can produce immature and mature ova as well as free larvae that can auto-infect.

The eggs measure 45µm x 21µm, and resemble those of *Trichuris* but have less prominent polar plugs. They have a thick striated shell.

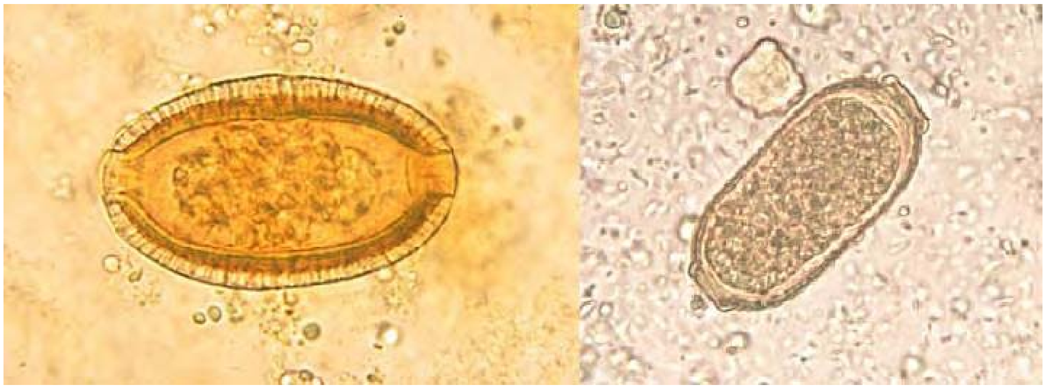

Figure 8-5. Eggs of *Capillaria Philippinesis.* They are oval in shape and closely resemble the eggs of *Trichuris* but have less prominent plugs. (SOURCE: PHIL 1376/653 - CDC/Dr. Mae Melvin)

Clinical Disease

Many cases may be asymptomatic, but any manifested symptoms will be related to the worm burden. The most common symptoms are watery stools with large fluid loss, anorexia, nausea, vomiting, and hypotension. Abdominal distension and edema may also develop. Death can ensue from pneumonia, cerebral edema, hypokalemia and heart failure. The large worm burden can cause electrolyte imbalance, plasma protein imbalance, and fluid loss, proving fatal within 4–6 months if untreated. Villi blunting leads to malabsorption but eosinophilia is not a feature of this disease.

Laboratory Diagnosis

Diagnosis depends on finding the characteristic eggs or larvae in the feces. Pulmonary capillariasis diagnosis relies on finding adult worms or eggs in lung biopsies.

Chapter 9.
Malaria

9.1 Blood Parasites

Red Blood cells offer parasites an excellent environment for invasion and survival. Haemosporina are the only protozoan parasites which can invade the red blood corpuscles of vertebrates. Most, if not all, have multiplicative phases in the reticulo-endothelial system.

The red blood cells are thin-walled and constantly moving, so absorption of food materials and elimination of waste products of metabolism are relatively easy to achieve. They also contain rich supplies of protein and oxygen.

Malarial parasites do not actually penetrate the red blood cell, but enter the cell membrane by endocytosis and enclose in a parasitophorous membrane.

Introduction

Malaria is the most important tropical disease known to man. It remains a significant problem in many tropical areas, especially in sub-Saharan Africa. Malaria is spreading as a result of environmental changes, including global warming, civil disturbances, increasing travel and drug resistance (Greenwood, B.M, 1997). There are approximately 100 million cases of malaria worldwide with about 1 million of these proving fatal.

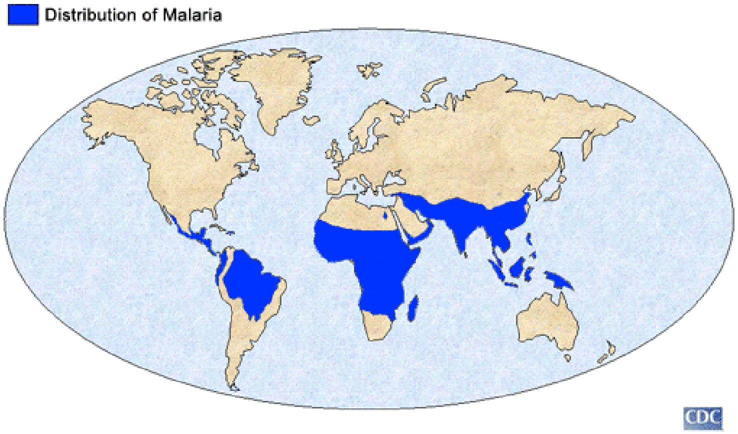

Illustration 9-1. Map illustrating the enormous distribution of malaria throughout the world. (SOURCE: CDC)

Malaria is caused by protozoa of the *Plasmodium* species. There are four species which infect both humans and animals; *Plasmodium malariae* (quartian malaria), *Plasmodium vivax* (benign tertian malaria)*, Plasmodium falciparum* (malignant tertian malaria, subtertian malaria) and *Plasmodium ovale* (ovale tertian malaria).

The transmission of the protozoa, *Plasmodium* requires two hosts, an intermediate invertebrate host (vector), and a definitive vertebrate host (mammals, birds and lizards).

All *Plasmodium* species undergo the general haemosporina developmental cycle which can be summarized as:

- initial or continual schizogony (*reproduction by multiple asexual fission*) in the vertebrate host with initiation of gametogony (*the formation or production of gametes*);
- formation of gametes in the arthropod host and subsequent fertilization and formation of a zygote;
- formation of sporozoites from the zygote by repeated nuclear division followed by cytoplasmic divisions. (Smyth, J.D, 1994)

There is no requirement for resistant stages since the transfer of the parasites between the vertebrate and invertebrate hosts is made by withdrawal or injection during the bloodsucking act, there is little or no exposure to the hazards of the outside world; thus by blood transfusion or inoculation, via the blood stages of the parasite.

Life Cycle

Malaria is transmitted by the female anopheline mosquito. The life cycle of all species of human malaria parasites is essentially the same. It comprises an exogenous sexual phase (sporogony*)* with multiplication in certain Anopheles mosquitoes and an endogenous asexual phase (schizogony) with multiplication in the vertebrate host. The latter phase includes the development cycle in the red cells (erythrocytic schizogony*)* and the phase taking place in the parenchyma cells in the liver (pre-erythrocytic schizogony).

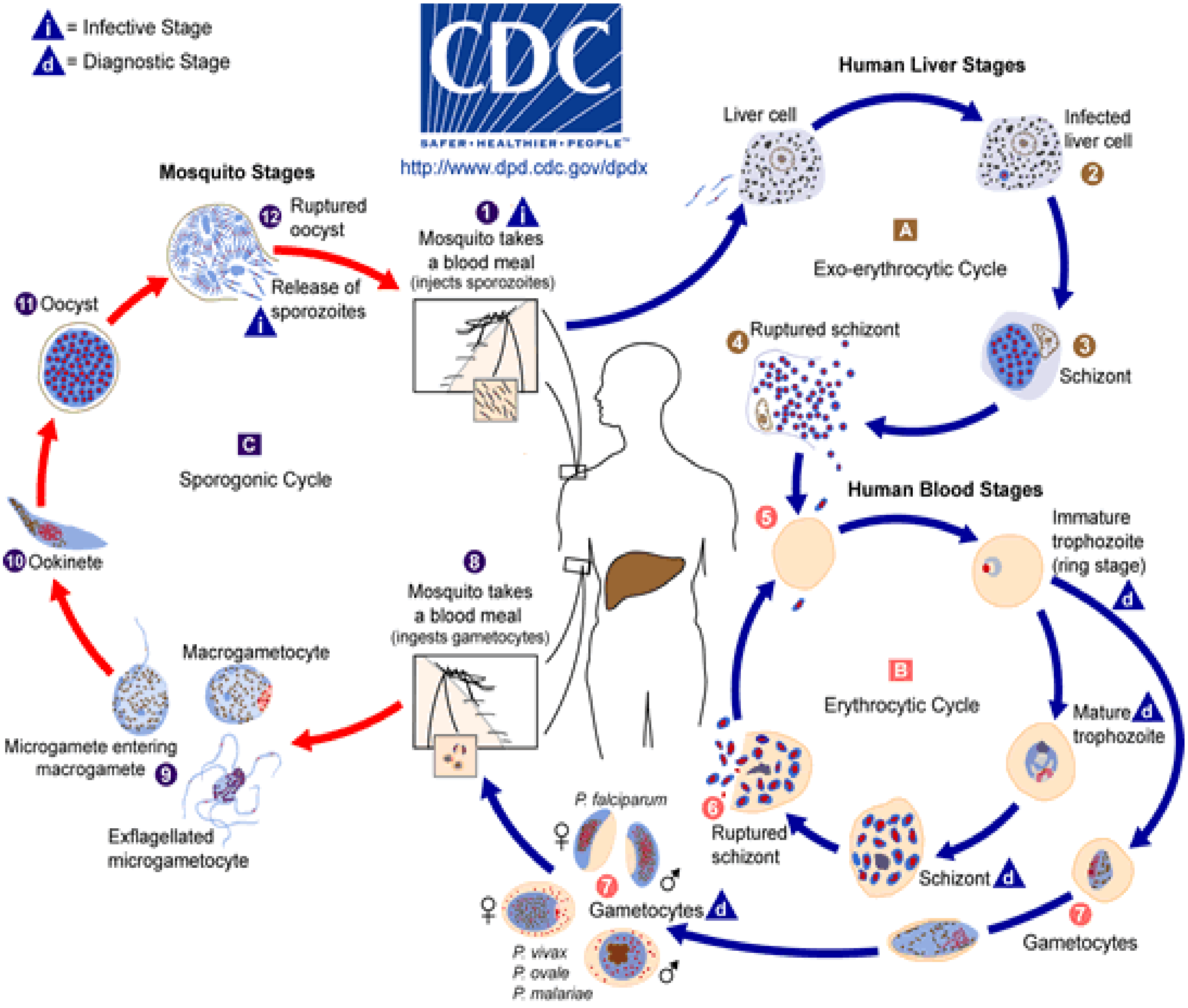
i = Infective Stage
d = Diagnostic Stage
CDC
SAFER • HEALTHIER • PEOPLE™
http://www.dpd.cdc.gov/dpdx
Human Liver Stages
Liver cell
Infected liver cell ❷
A
Exo-erythrocytic Cycle
❸ Schizont
❹ Ruptured schizont
Mosquito Stages
⓬ Ruptured oocyst
Release of sporozoites i
❶ i Mosquito takes a blood meal (injects sporozoites)
⓫ Oocyst
C
Sporogonic Cycle
❿ Ookinete
Human Blood Stages
❺
Immature trophozoite (ring stage) d
B
Erythrocytic Cycle
Mature trophozoite d
❽ Mosquito takes a blood meal (ingests gametocytes)
Macrogametocyte
Microgamete entering macrogamete ❾
Exflagellated microgametocyte
P. falciparum
❻ Ruptured schizont
Schizont d
❼ Gametocytes d
P. vivax
P. ovale
P. malariae
❼ Gametocytes
♀
♂

Illustration 9-3. The malaria parasite life cycle. The malaria parasite life cycle involves two hosts. During a blood meal, a malaria-infected female *Anopheles* mosquito inoculates sporozoites into the human host ❶. Sporozoites infect liver cells ❷and mature into schizonts ❸, which rupture and release merozoites ❹. (Of note, in *P. vivax* and *P. ovale* a dormant stage [hypnozoites] can persist in the liver and cause relapses by invading the bloodstream weeks, or even years later.) After this initial replication in the liver (exo-erythrocytic schizogony A), the parasites undergo asexual multiplication in the erythrocytes (erythrocytic schizogony B). Merozoites infect red blood cells ❺. The ring stage trophozoites mature into schizonts, which rupture releasing merozoites ❻. Some parasites differentiate into sexual erythrocytic stages (gametocytes) ❼. Blood stage parasites are responsible for the clinical manifestations of the disease.

The gametocytes, male (microgametocytes) and female (macrogametocytes), are ingested by an *Anopheles* mosquito during a blood meal ❽. The parasites' multiplication in the mosquito is known as the sporogonic cycle C. While in the mosquito's stomach, the microgametes penetrate the macrogametes generating zygotes ❾. The zygotes in turn become motile and elongated (ookinetes) ❿which invade the midgut wall of the mosquito where they develop into oocysts ⓫. The oocysts grow, rupture, and release sporozoites ⓬, which make their way to the mosquito's salivary glands. Inoculation of the sporozoites into a new human host perpetuates the malaria life cycle ❶. (SOURCE: PHIL 3405- CDC/Alexander J. da Silva, PhD/Melanie Moser)

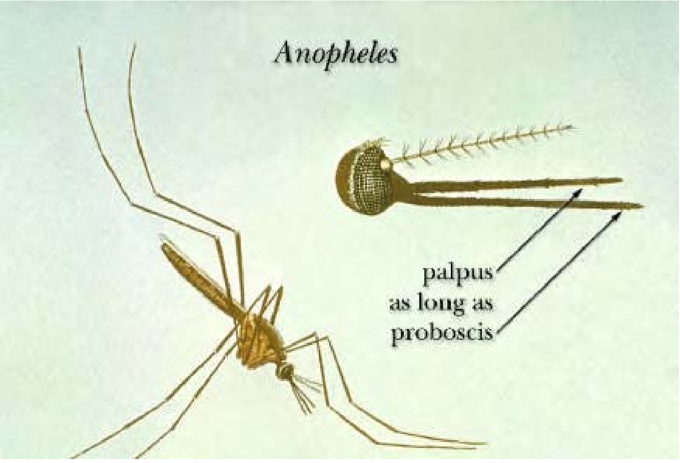

Illustration 9-2. Distinguishing characteristics of the Anopheles mosquito.

Image 9-1. An Anopheline mosquito, the vector of the protozoa group *Plasmodia*, the parasite known to cause malaria in both man and non-human primates. Malaria is transmitted by female *Anopheles* mosquitoes to the definitive host while the mosquito blood-feeds on its victims. (SOURCE: PHIL 2070/6765 - CDC/ James Gathany)

When a female Anopheles mosquito bites an infected person, it ingests blood which may contain the mature sexual cells (male and female gametocytes) which undergo a series of developmental stages in the stomach of the mosquito. Exflagellation (*the extrusion of rapidly waving flagellum-like microgametes from microgametocytes*) occurs resulting in the production in a number of male and female gametes. Fertilization occurs producing a zygote which matures to an ookinete. This penetrates the stomach wall of the mosquito where it grows into an oocyst and it further matures to become a motile sporozoite.

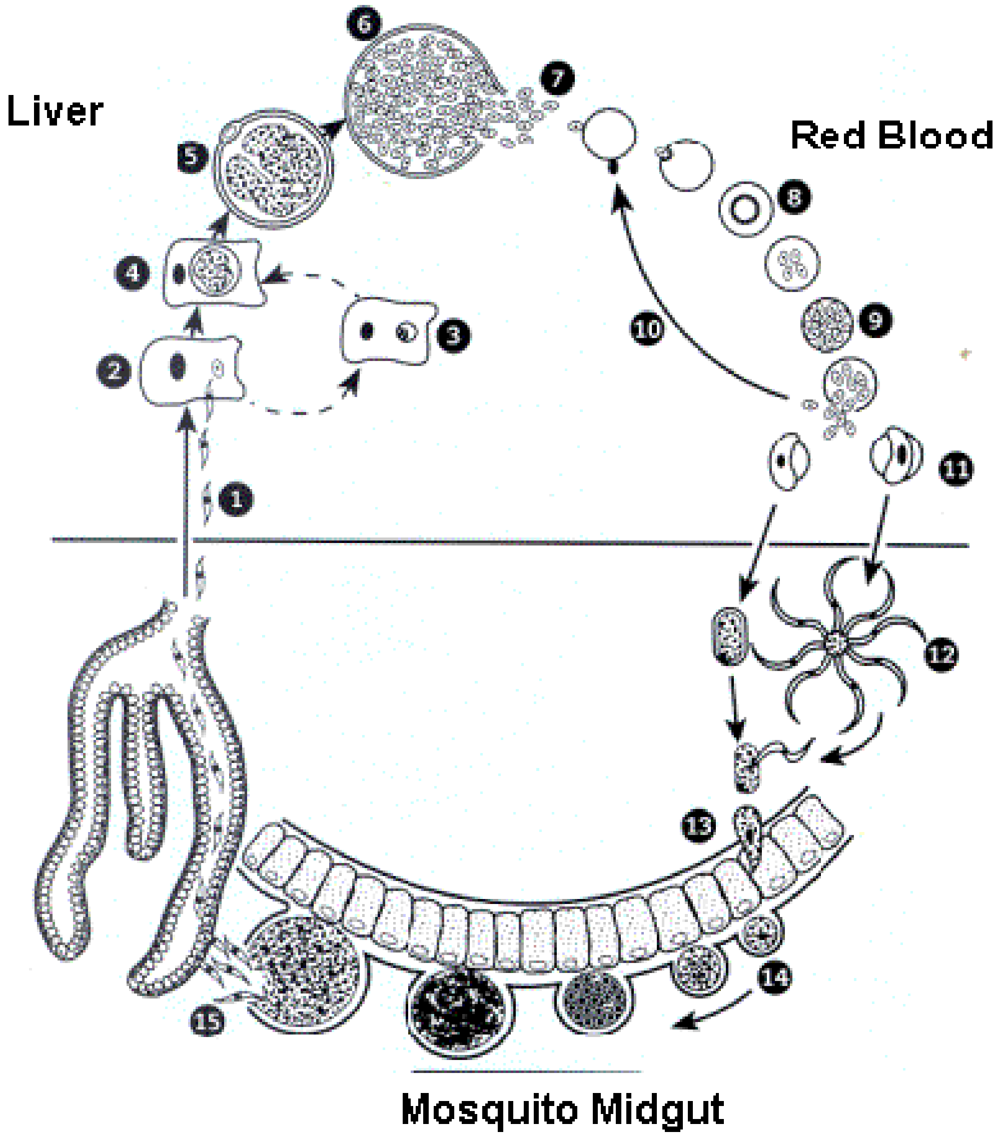

Illustration 9-4. Diagram of the malaria life cycle. **1)** Sporozoites, injected through the skin by female anopheline mosquito; **2)** sporozoites infect hepatocytes; **3)** some sporozoites develop into hypnozoites (*P. vivax* and *P. ovale*): **4)** liver stage parasite develops; **5 – 6)** tissue schizogony; **7)** merozoites are released into the circulation; **8)** ring stage trophozoites in red cells; **9)** erythrocytic schizogony; **10)** merozoites invade other red cells; **11)** some parasites develop into female (macro-) or male (micro-) gametocytes, taken up by the mosquito; **12)** mature macrogametocyte and exflagellating microgametocytes; **13)** ookinete penetrates gut wall; **14)** development of oocyst; **15)** sporozoites penetrate salivary glands. (SOURCE: Unknown)

The length of the developmental stage in the mosquito not only depends on the *Plasmodium* species but also the mosquito host and the ambient temperature. This may range from eight days in *Plasmodium vivax* to as long as 30 days in *Plasmodium malariae*.

The sporozoites migrate from the body cavity of the mosquito to the salivary glands and the mosquito now becomes infective. Sporozoites enter into the blood stream of a host when the mosquito feeds on blood. Following the inoculation, the sporozoites leave the blood within 40 minutes and enter the parenchymal cells of the liver (hepatocytes). In all four species, asexual development occurs in the liver cells, a process known as pre-erythrocytic schizogony**,** to produce thousands of tiny merozoites which are released into the circulation after about 16 days. However in *P. vivax* and *P. ovale* some sporozoites differentiate into hypnozoites which remain dormant in hepatocytes for considerable periods of time. When they are “reactivated” they undergo asexual division and produce a clinical relapse.

In *P. falciparum* and *P. malariae* hypnozoites are not formed and the parasite develops directly into pre-erythrocytic schizonts.

Once in the circulation, the merozoites invade the red cells and develop into trophozoites. In the course of their development they absorb the hemoglobin of the red cells and leave as the product of digestion a pigment called hemozoin*,* a combination of hematin and protein. This iron-containing pigment is seen in the body of the parasite in the form of dark granules, which are more obvious in the later stages of development.

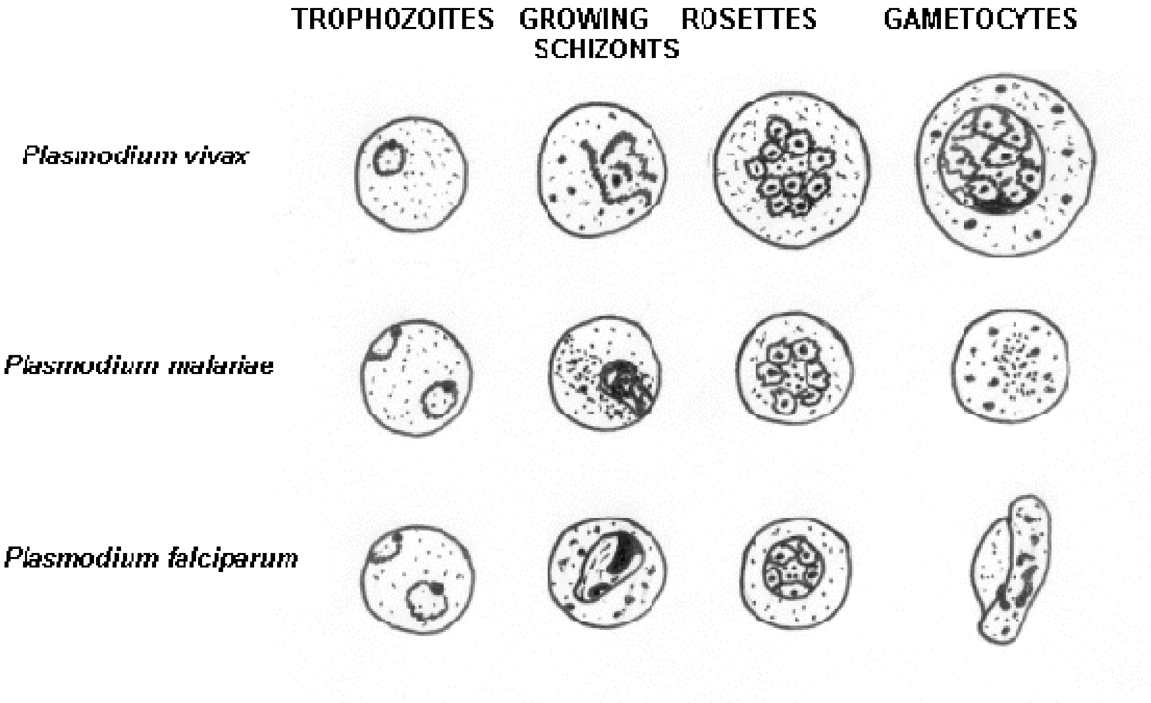

Illustration 9-5. Diagram illustrating the various stages of the three common species of malaria which infect man. (SOURCE: Unknown)

After a period of growth the trophozoite undergoes an asexual division, erythrocytic schizogony. When the mature trophozoite starts to divide in the red blood cell, separate merozoites are formed resulting in a schizont. When fully developed, the schizont ruptures the red blood cell containing it, liberating the merozoites into the circulation. These merozoites will then infect new red cells and the process of asexual reproduction in the blood tends to proceed. Some of the merozoites entering red blood cells do not form trophozoites then schizonts but develop into gametocytes and this process takes place in deep tissue capillaries. This erythrocytic cycle of schizogony is repeated over and over again in the course of infection, leading to a progressive increase of parasitemia.

Infections with all four strains of malaria have many clinical features in common. These are related to the liberation of fever-producing substances, especially during schizogony. The common features are:

Fever: Often irregular. The regular pattern of fever does not occur until the illness has continued for a week or more; where it depends on synchronized schizogony.

Anemia: The anemia is hemolytic in type. It is more severe in infections with *P. falciparum* because in this infection cells of all ages can be invaded. Also, the parasitemia in this infection can be much higher than in other malarias.

Splenomegaly: The spleen enlarges early in the acute attack of malaria. When a patient has been subjected to many attacks, the spleen may be of an enormous size and lead to secondary hypersplenism.

Jaundice: A mild jaundice due to hemolysis may occur in malaria. Severe jaundice only occurs in *P. falciparum* infection, and is due to liver involvement.

9.2. Species Specific Characteristics

Plasmodium falciparum

Introduction

Plasmodium falciparum exists in the tropics and sub-tropics, and is responsible for approximately 50% of all malaria cases. The incubation period of *P. falciparum* malaria is the shortest, between eight and 11 days and has a periodicity of 36–48 hours. It can be differentiated from the other species by the morphology of the different stages found in the peripheral blood. In infections with *Plasmodium falciparum* usually only young trophozoites and gametocytes are seen in peripheral blood smears, the schizonts are usually found in capillaries sinuses of internal organs and in the bone marrow. The disease it produces runs an acute course and often terminating fatally. It is a significant cause of abortions and stillborns and even death of non-immune pregnant women.

Life Cycle

The aspects of the life cycle which are specific to *P. falciparum* are as follows:

- It attacks all ages of erythrocytes so that a high density of parasites can be reached quickly. In extreme cases up to 48% of the red blood cells can be parasitized.
- Multiple infections resulting in several ring forms in a corpuscle are not uncommon.
- The latter stages in the asexual cycle do not occur in the peripheral blood as in other forms of malaria, so that only rings and crescents are found in blood films. After 24 hours the ring forms and older trophozoites show a tendency to clump together and adhere to the visceral capillary walls and become caught up in the vessels of the

heart, intestine, brain or bone marrow in which the later sexual stages are completed.

- Sporulation is not as well synchronized as in other malaria forms so that the fever may last longer.
- Exo-erythrocytic forms do not persist in the tissues and hence relapses do not occur.

Morphology of Trophozoites

Red blood cells in *Plasmodium falciparum* infections are not enlarged and they may have a spiky outline which is common in cells which have dried slowly. The typical arrangement cytoplasm in young trophozoites is the well-known ring formation which thickens and invariably contains several vacuoles as the trophozoite develops. Chromatin is characteristically found as a single bead, but double beads and small curved rod forms frequently occur.

Maurer's dots are slow to appear and are first seen as minute purplish dots, 6 or less in number. The points become spots, still few in number and are now characteristic enough to be recognized. Maurer describes them as fine ringlets, loops or streaks. They are seldom absent from the red blood cells containing large rings but the staining of the spots is very sensitive to pH and are seldom seen if the pH falls below 6.8.

Trophozoites of *P. falciparum* can be found on the edge of the red blood cells. These are known as accole forms and are found as three distinct types:

1. **Common:** The single chromatin bead lies on the edge of the cell with most of the cytoplasm extended along the edge on both sides of the bead.

2. **Rim:** The complete parasite lies in a thickened line along the edge of the cell with no evidence of ring formation.

3. **Displaced:** The parasites are displaced beyond the edge of the host cell. All degrees of displacement may occur, from partial to marked displacement with most of the parasite lying beyond the cell margin.

Pigment is not a characteristic finding in the early stages of *P. falciparum* infections.

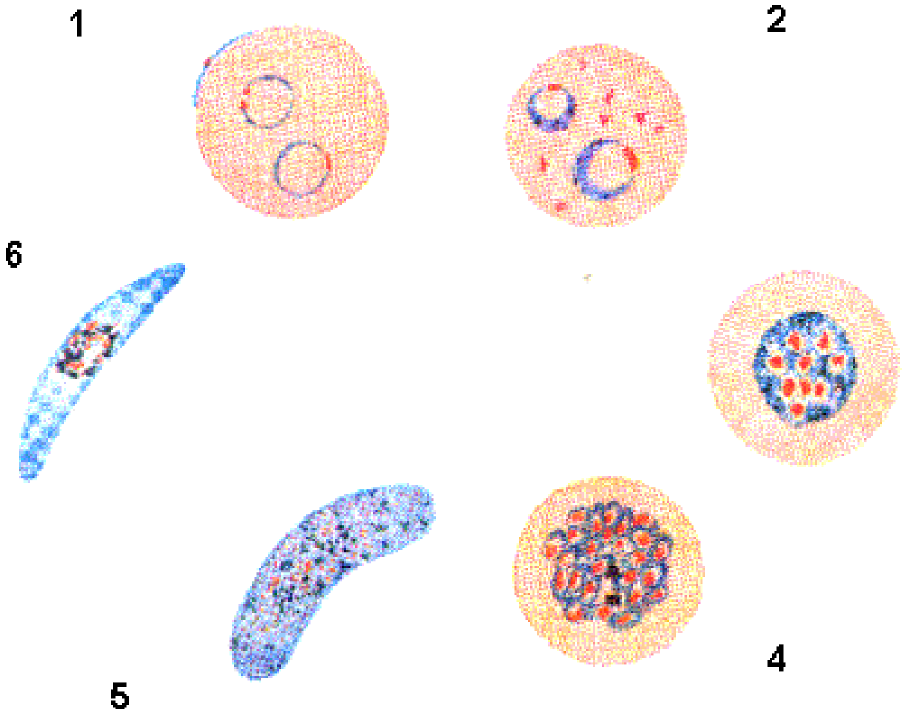

Illustration 9-6. Diagrammatic illustration of the morphology of the different stages of the *Plasmodium falciparum* life cycle in thin blood films. **1)** *P. falciparum* early trophozoites / ring forms. **2)** Developing trophozoites (rarely seen in peripheral blood). **3)** Immature schizonts (rarely seen in peripheral blood). **4)** Mature schizonts, almost fill the red blood cell. **5)** Microgametocytes, large numbers appear after 7–12 days. **6)** Macrogametocytes, large numbers appear after 7-12 days.

Morphology of Gametocytes

Gametocytes are the sexual stage of the malaria parasite. *Plasmodium falciparum* gametocytes appear in the peripheral circulation after 7-12 days of patent parasitemia and by then, they have assumed their typical crescent shapes. They soon reach their peak density, and then decline in numbers, disappearing in about three months as a rule.

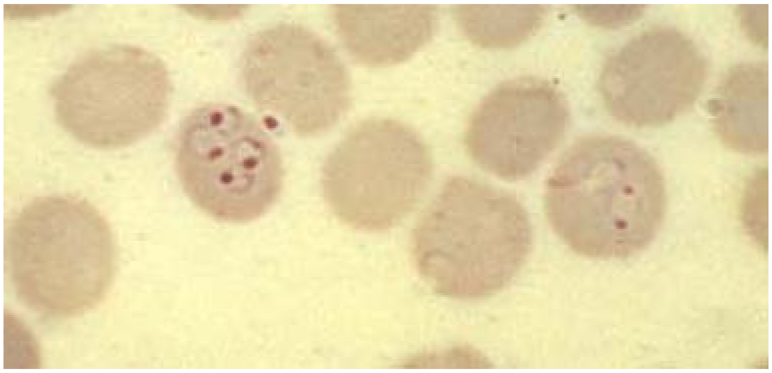

Image 9-2. Young trophozoite / ring stage of *Plasmodium falciparum*. The ring thickens and invariably contains several vacuoles as the trophozoite develops. Maurer's dots are slow to appear and are first seen as minute purplish dots. (Giemsa stain). (SOURCE: PHIL 5946 - CDC/ Steven Glenn, Laboratory & Consultation Division)

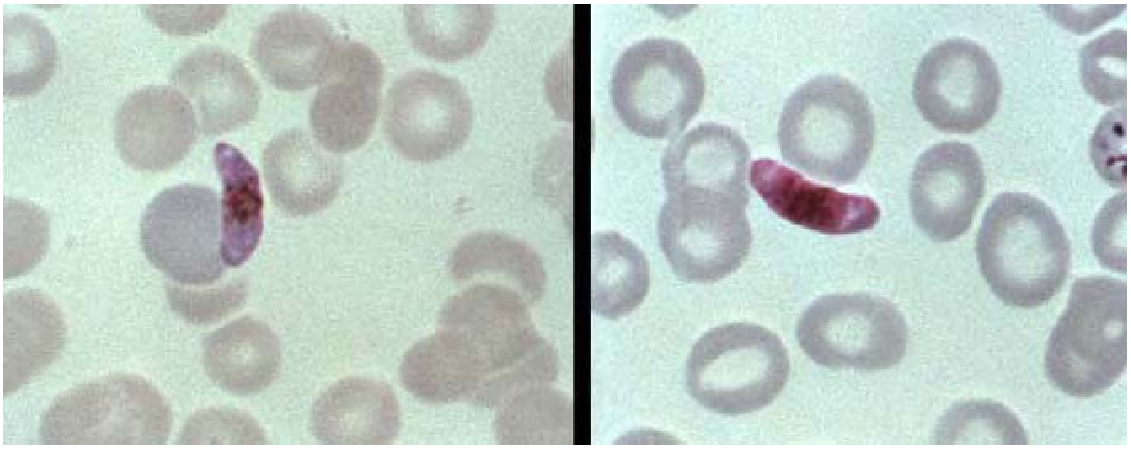

Image 9-3. *Plasmodium falciparum* gametocytes appear in the peripheral circulation after 7-12 days of patent parasitemia and by then, they have assumed their typical crescent shapes. (Giemsa stain) (SOURCE: PHIL 5941 - CDC/ Steven Glenn, Laboratory & Consultation Division)

The female form, or macrogametocyte, is usually more slender and somewhat longer than the male, and the cytoplasm takes up a deeper blue color with Giemsa stain. The nucleus is small and compact, staining dark red, while the pigment granules are closely aggregated around it. The male form, or microgametocyte, is broader than the female and is more inclined to be sausage shaped. The cytoplasm is either pale blue or tinted with pink and the nucleus, which stains dark pink, is large and less compact than in the female, while the pigment granules are scattered in the cytoplasm around it.

In humans, gametocytes do not multiply, nor cause symptoms but they are the forms which are infective to the mosquito. When a female Anopheline mosquito takes a blood meal, the male and female gametocytes continue their sexual development.

Morphology of Schizonts

Schizonts are rarely seen in the peripheral blood and their presence may indicate a potentially serious parasitemia. Schizonts have 8-36 merozoites and a large mass of golden brown pigment (hemozoin) is seen in the pre-schizont and schizont stage.

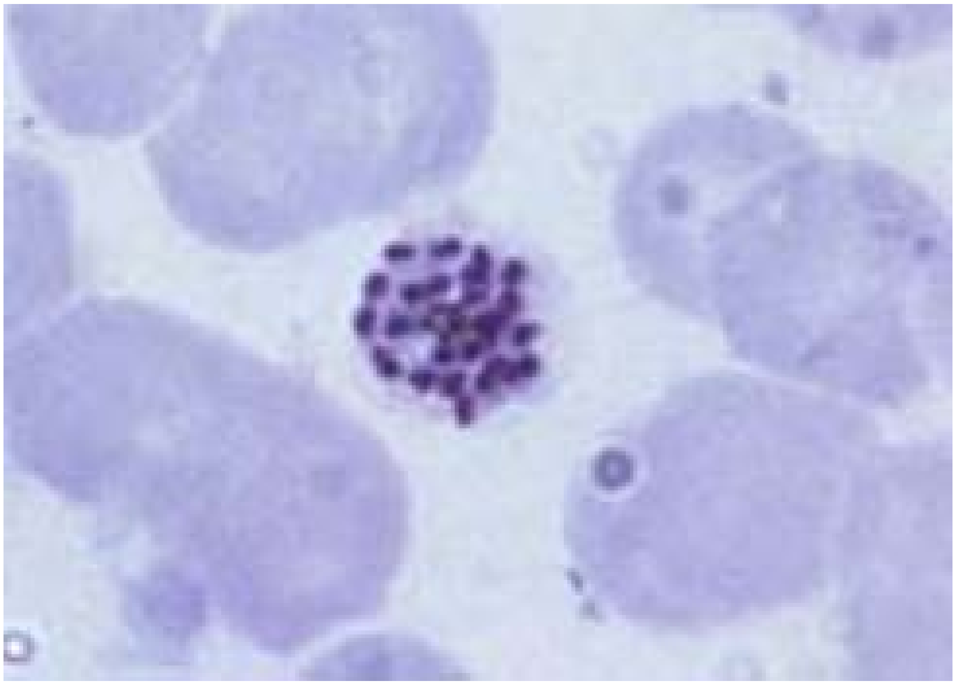

Image 9-4. *Plasmodium falciparum* schizont. Rarely seen in the peripheral blood, a good indicator of a potentially serious parasitemia. They have 8 – 36 merozoites and a large golden brown pigment. (Giemsa stain) (SOURCE: PHIL 5854 - CDC/Steven Glenn, Laboratory & Consultation Division)

Clinical Disease

Symptoms include headache, photophobia, muscle aches and pains, anorexia, nausea and vomiting. Complications include severe anemia cerebral malaria, renal disease, black water fever, dysentery, pulmonary edema and tropical splenomegaly syndrome.

Plasmodium vivax

Introduction

Plasmodium vivax is found almost everywhere malaria is endemic and is the most predominant of the malaria parasites. Causing 43% of all cases of malaria in the world, it also has the widest geographical distribution. Although the disease itself is not usually life threatening, it can cause severe acute illness.

Plasmodium vivax does not infect West Africans due to the fact that West Africans do not possess the Duffy Antigen on the red blood cells which the parasite requires to enter the red blood cell. It has an incubation period of between 10 and 17 days which is sometimes prolonged to months or years due to the formation of hypnozoites. It has a periodicity of 48 hours. *Plasmodium vivax* infections are usually characterized by the presence of more than one developmental stage in the peripheral blood film. The parasites parasitize young enlarged erythrocytes and Schüffner’s dots develop on the erythrocyte membrane.

Life Cycle

The aspects of the life cycle which are specific to *P. vivax* are as follows:

- The degree of infectivity is low, only the young immature corpuscles are infected; about 2% of erythrocytes are parasitized.
- The periodicity of the asexual cycle is closely synchronized.
- Hypnozoites develop in the liver, so that relapses may occur.

Morphology of Trophozoites

Most trophozoites of *P. vivax* are already several hours old when they appear in peripheral blood and by that time the Schüffner's dots are already visible. The trophozoites are actively amoeboid and contain single or sometimes double chromatin dots that are either circular or ovoid. As the trophozoites mature, the Schüffner's dots increase in number and size and the parasite changes from large irregular rings to rounded or ovoid forms in mature trophozoites.

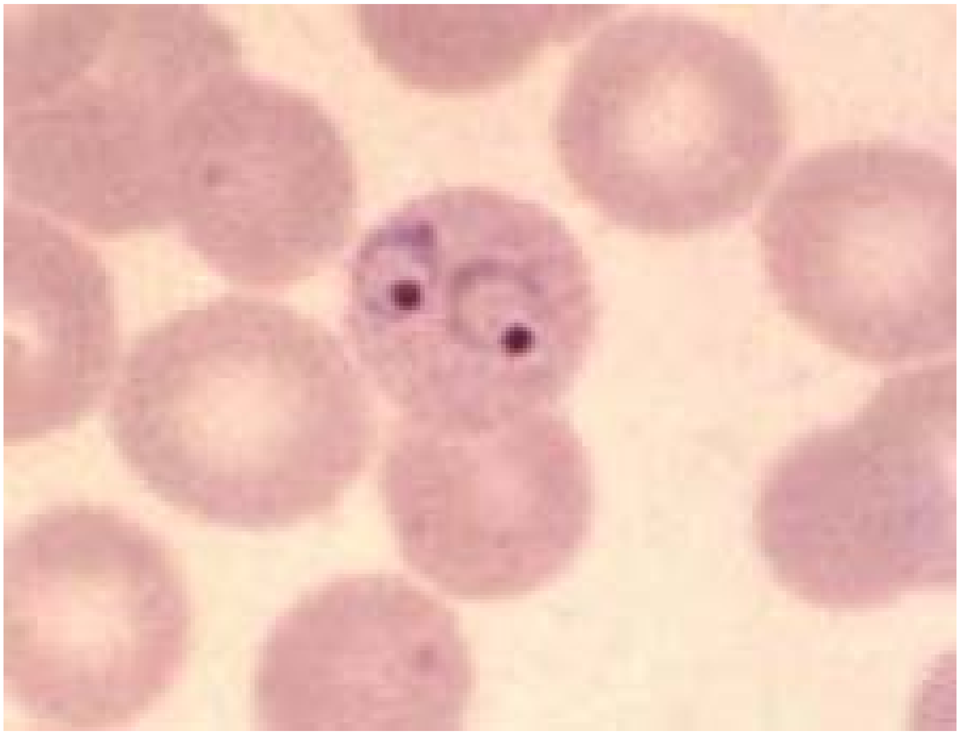

Image 9-5. Trophozoites of *Plasmodium vivax* are already several hours old when they appear in the peripheral blood and therefore, you can already see the Schüffner's dots. They contain single or sometimes double chromatin dots. (Giemsa stain) (SOURCE: PHIL 5928 - CDC/ Steven Glenn, Laboratory & Consultation Division)

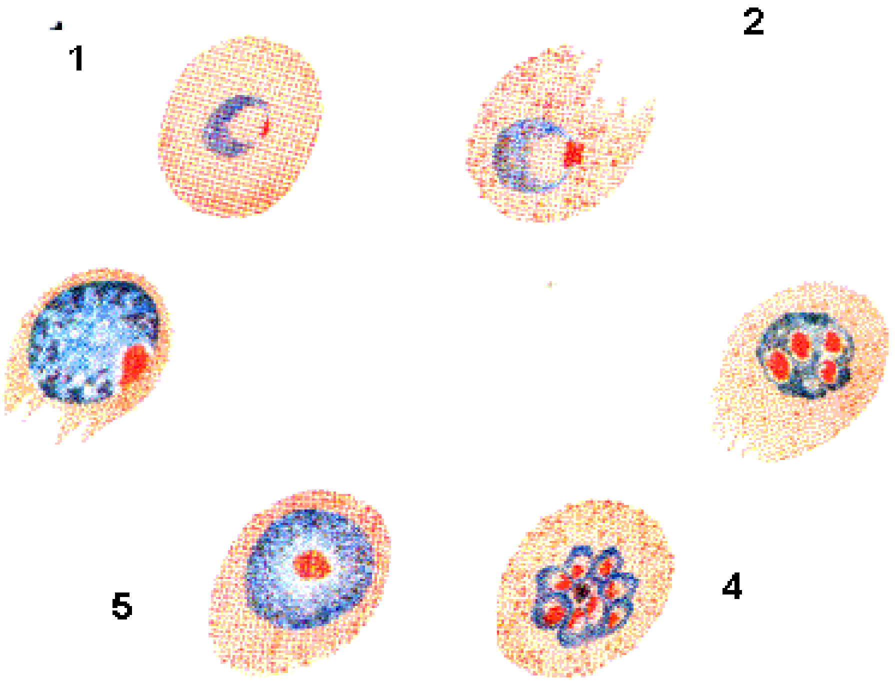

Illustration 9-7. Diagrammatic illustration of the morphology of the different stages of the *Plasmodium vivax* life cycle in thin blood films. **1)** Early trophozoites / ring forms (accole forms, not shown here, are occasionally seen). **2)** Developing trophozoites are large and irregular with a prominent vacuole. **3)** Immature schizonts, are amoeboid and almost fill the red blood cell. **4)** Mature schizonts, almost fill the red blood cell. **5)** Microgametocyte, large numbers appear after 3–5 days. **6)** Macrogametocyte, large numbers appear after 3–5 days. (SOURCE: Unknown)

Morphology of Gametocytes

Mature female gametocytes are large rounded parasites which fill or nearly fill the host cell. The cytoplasm is blue and fairly homogenous. The nuclear chromatin is a single, well-defined purplish mass, varied in form and usually peripheral in distribution. Mature male gametocytes can be distinguished from females by the large, loose and ill-defined mass of chromatin and by their paler color and smaller mass.

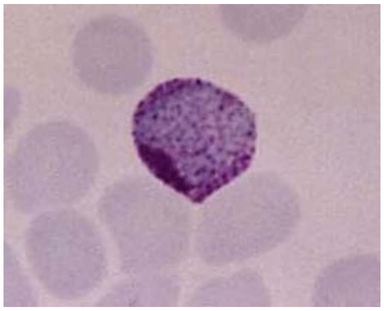

Image 9-6. Mature female *Plasmodium vivax* gametocytes are large rounded parasites which fill or nearly fill the host cell. The cytoplasm is blue and fairly homogenous. The nuclear chromatin is a single, well-defined purplish mass, varied in form and usually peripheral in distribution. (Giemsa stain) (SOURCE: PHIL 5138 - CDC/ Dr. Mae Melvin)

Morphology of Schizonts

The parasitized red cells are much enlarged containing Schüffner's dots. The parasites are large, filling the enlarged red cell. There are between 12-24 merozoites in the schizonts (usually16). The pigment is a golden brown central loose mass.

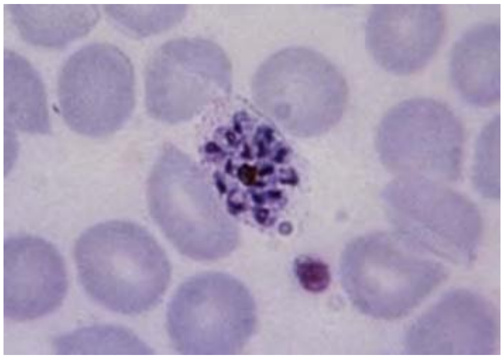

Image 9-7. A schizont of *Plasmodium vivax.* The parasites are large, filling the enlarged red cell. There are between 12 - 24 merozoites in the schizonts (usually16). The pigment is a golden brown central loose mass. (Giemsa stain) (SOURCE: PHIL 5925 - CDC/ Steven Glenn, Laboratory Training & Consultation Division)

Clinical Disease

Symptoms include headache, photophobia, muscle aches and pains, anorexia, nausea and vomiting. Complications due to *P. vivax* are relatively rare and arise from a previous debility or pre-existing disease.

Plasmodium ovale

Introduction

Plasmodium ovale is widely distributed in tropical Africa especially the west coast, but it is not often encountered. It has also been reported in South America and Asia. It has an incubation period of 10–17 days which is sometimes prolonged to months or years due to the formation of hypnozoites. It has a periodicity of 48 hours; the fever it produces is milder than that caused by the benign tertian *P. falciparum.*

Life Cycle

The features of the life cycle which are specific to *P. ovale* are as follows:

- It morphologically resembles *P. malariae* in most of its stages.

- The changes produced in the erythrocytes in general are similar to those produced by *P. vivax,* but Schüffner's dots appear considerably earlier (in the ring stage) and are coarser and more numerous.
- In the oocyst the pigment granules are (usually) characteristically arranged in two rows crossing each other at right angles.
- Hypnozoites develop in the liver so that relapses may occur.

Morphology of Trophozoites

Parasites of *P. ovale* are usually found in enlarged and stippled red blood cells (James's dots), similar to those found in *P. vivax* infections. Host cells show an oval shape, particularly those containing younger stages of the parasites and the host cell may also show "spiking" or fimbriation.

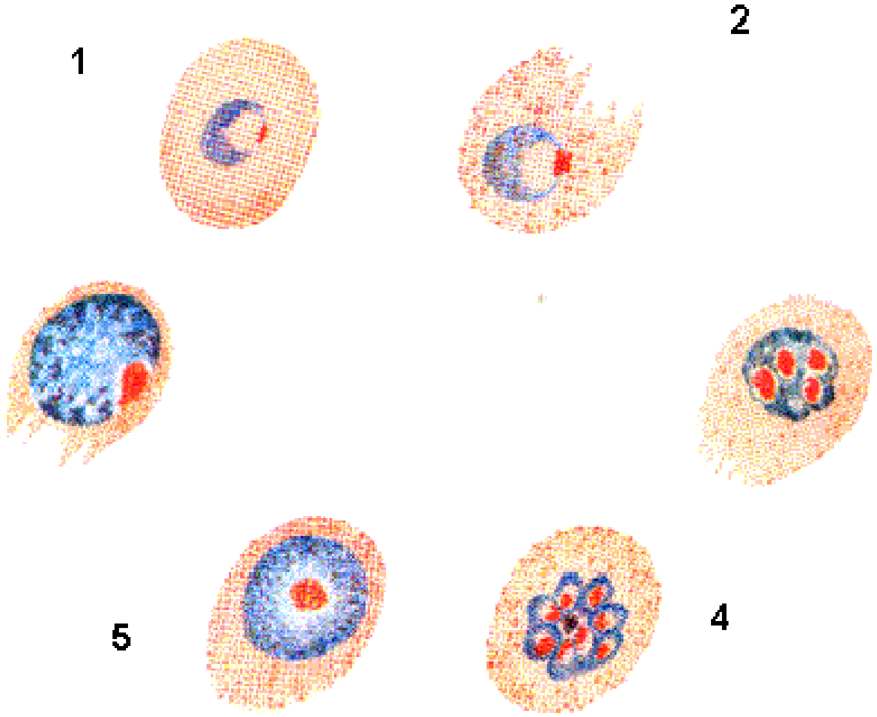

Illustration 9-8. Diagrammatic illustration of the morphology of the different stages of the *Plasmodium ovale* life cycle in thin blood films. **1)** Early trophozoites / ring forms, are dense rings with well- defined masses of chromatin. **2)** Developing trophozoites, small and compact with an inconspicuous vacuole. **3)** Immature schizonts, compact and almost fill the red blood cell. **4)** Mature schizonts, fill ¾ of the red blood cell. **5)** Microgametocytes, low numbers appear after 12-14 days. **6)** Macrogametocytes, low numbers appear after 12–14 days.

Young trophozoites are found as compact rings in cells containing Schüffner's dots. The trophozoite rings remain compact as they develop and show little of the amoeboid features common in *P. vivax*. Small, scattered pigment granules can be seen in developing trophozoites which disperse as the trophozoite matures. Late trophozoites are round and consolidated with an increase in cytoplasm, they are very similar to *P. vivax* at this stage.

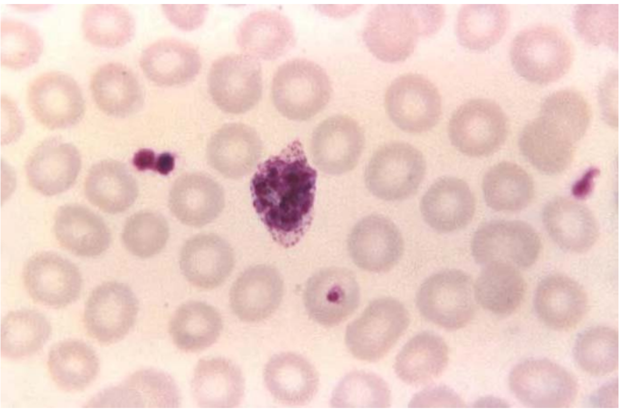

Image 9-8. Trophozoite of *Plasmodium ovale.* Young trophozoites are found as compact rings in cells containing Schüffner's dots. The trophozoite rings remain compact as they develop. Late trophozoites are round and consolidated with an increase in cytoplasm, they are very similar to *P. vivax* at this stage. (SOURCE: PHIL 5935 - CDC/ Steven Glenn, Laboratory & Consultation Division)

Morphology of Gametocytes

The mature gametocytes are round, filling two thirds of the red cell. The red blood cell is slightly enlarged and stippled and contains pigment which has a distinct arrangement of concentric rods, mostly at the periphery.

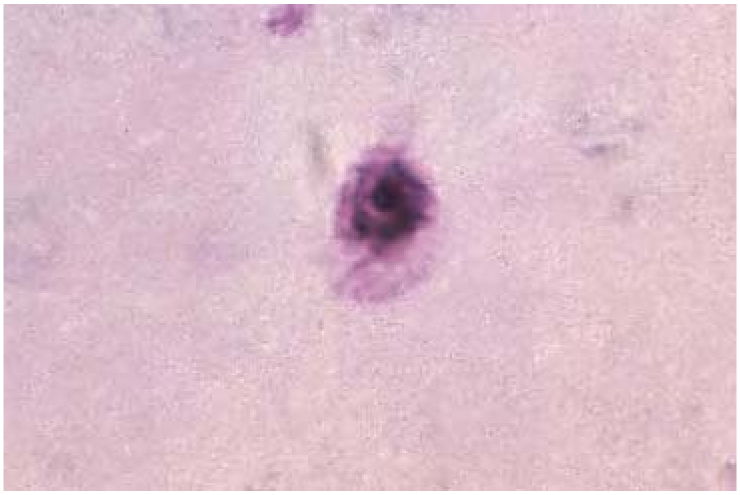

Image 9-9. Gametocyte of *Plasmodium ovale.* The mature gametocytes are round, filling two thirds of the red cell. (Giemsa stain) (SOURCE: PHIL 3474 – CDC/Dr. Mae Melvin)

Morphology of Schizonts

The parasite is smaller than red blood cells and contains 6-12 merozoites, usually 8 in a single ring. The pigment is a brown / greenish central clump. The red cell slightly enlarged, stippled, frequently oval and fimbriated.

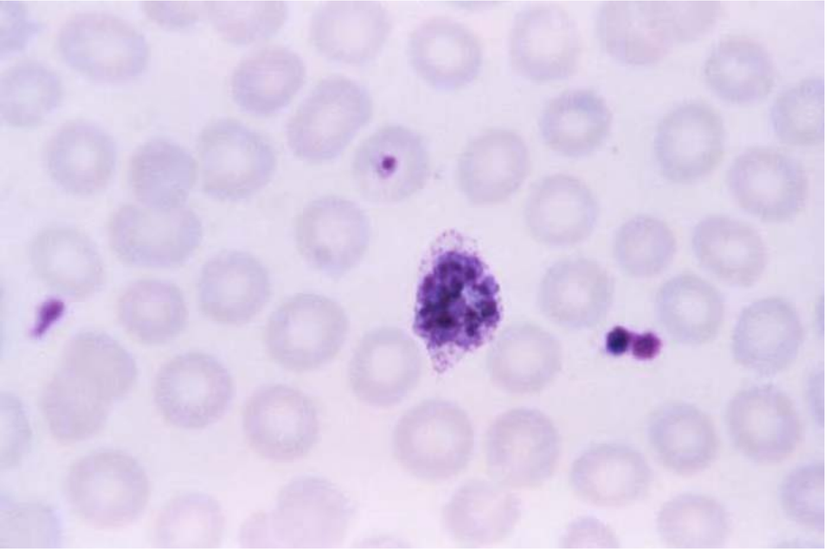

Image 9-10. Schizont of *Plasmodium ovale.* The parasite is smaller than the red blood cell and contains 6 – 12 merozoites. The red cell is slightly enlarged, stippled, frequently oval and fimbriated. (Giemsa stain) (SOURCE: PHIL 5846 - CDC/ Steven Glenn, Laboratory & Consultation Division)

Clinical Disease

Symptoms, like those of *P. vivax,* include headache, photophobia, muscle aches and pains, anorexia, nausea and vomiting. Complications due to *P. ovale* are relatively rare and arise due do a previous debility or pre-existing disease.

Plasmodium malariae

Introduction

Plasmodium malariae occurs mainly in the subtropical and temperate areas where *P. falciparum and P. vivax* occur. It is responsible for approximately 7% of all malaria in the world. It has an incubation period of 18–40 days and a periodicity of 72 hours.

Life Cycle

The features of the life cycle specific to *P. malariae* are as follows:

- Infected erythrocytes are not larger than uninfected ones and sometimes even smaller.
- Mature erythrocytes are attacked, but reticulocytes generally are not
- The density of parasites is very low; about 0.2% of erythrocytes are parasitized.
- It is often difficult to distinguish between a large trophozoite and an immature gametocyte.

Morphology of Trophozoites

Parasites of *P. malariae* are typically compact heavily pigmented parasites which are usually smaller and more deeply stained than normal. They tend to parasitize small, old red blood cells, they do not contain any inclusion dots and the parasitaemia is usually low.

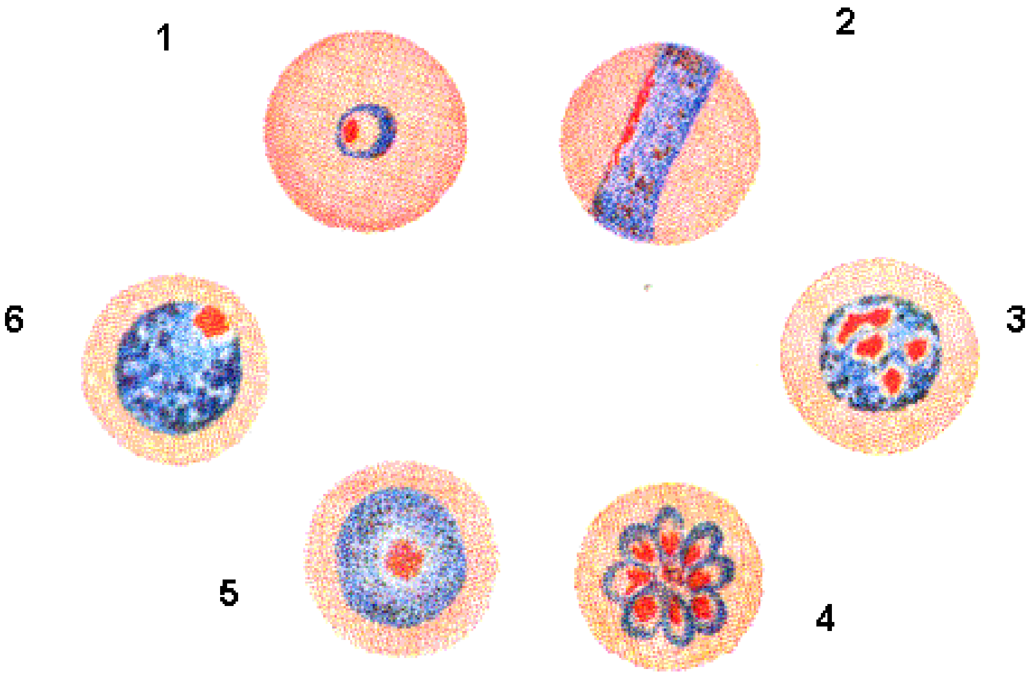

Illustration 9-9. Diagrammatic illustration of the morphology of the different stages of the *Plasmodium malariae* life cycle in thin blood films. **1)** Early trophozoites / ring forms, compact rings containing one mass of chromatin. **2)** Developing trophozoites, small and compact (often band forms) with an inconspicuous vacuole. **3)** Immature schizonts, compact and almost fill the red blood cell which contains scattered pigment. **4)** Mature schizonts, almost fill the red blood cell. **5)** Microgametocytes, low numbers appear after 7–14 days. **6)** Macrogametocytes, low numbers appear after 7-14 days.

Trophozoites are found as fairy large fleshy rings with a single chromatin dot. These can be very distorted and can often take the form of bands across the cell. All trophozoites have a single chromatin dot and contain pigment.

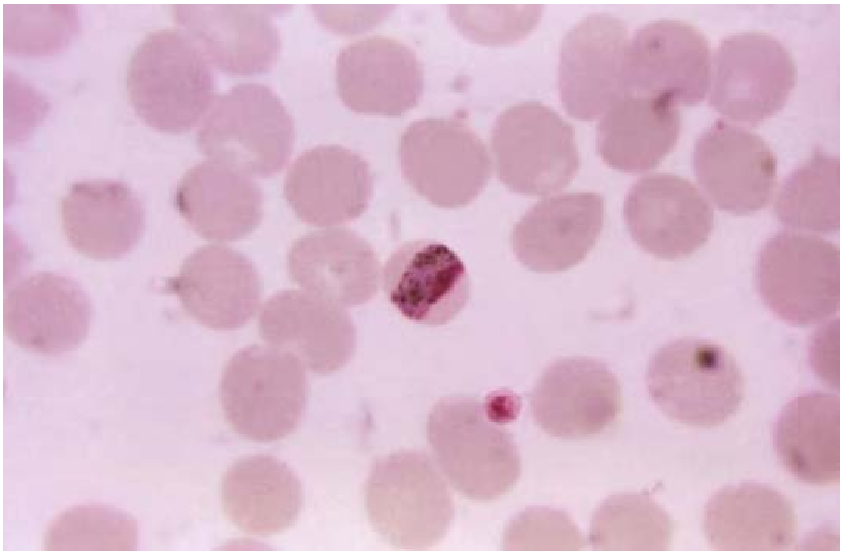

Image 9-11. Trophozoite of *Plasmodium malariae.* These can be very distinct and distorted by taking the form of a band across the cell. (Giemsa stain) (SOURCE: PHIL 639 - CDC/ Dr. Mae Melvin, Steve Glenn)

Morphology of Gametocytes

Gametocytes contain large amounts of black pigment, with chromatin present as a compact mass in females and diffuse in males. They occupy less than two thirds of the red blood cell.

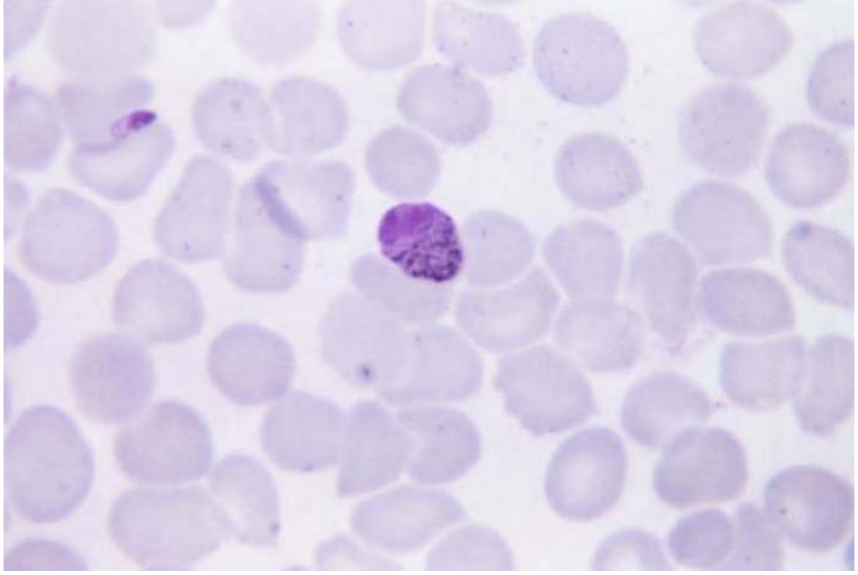

Image 9-12. *Plasmodium malariae* gametocyte. They contain large amounts of black pigment, with chromatin present as a compact mass in females (macrogametocyte) and diffuse in males (microgametocyte). (Giemsa stain) (SOURCE: PHIL 5837 - CDC/ Steven Glenn, Laboratory & Consultation Division)

Morphology of Schizonts

Schizonts are usually few in numbers with 6-12 large merozoites in a single ring. Pigment is usually present as a central black mass. The parasites present are generally only found at one stage of schizogony development.

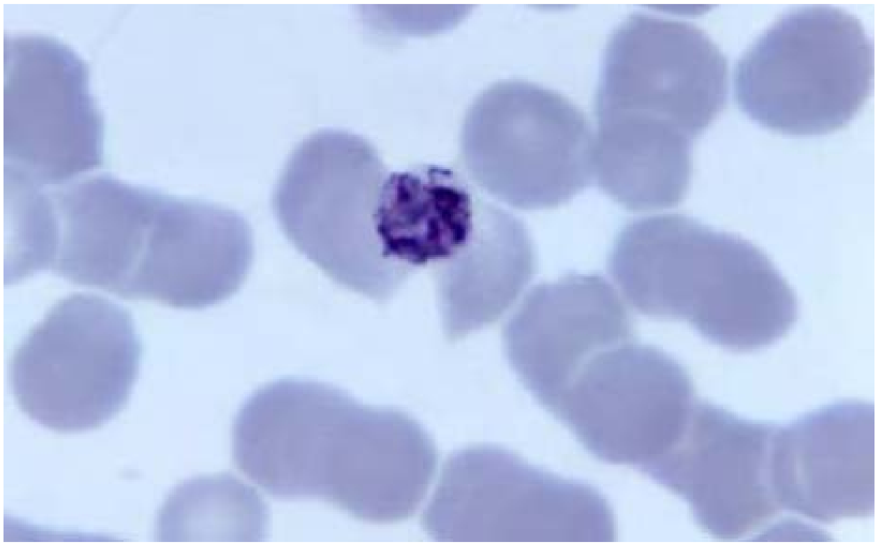

Image 9-13. Schizont of *Plasmodium malariae.* They are usually few in numbers with 6–12 large merozoites in a single ring. Pigment is usually present as a central black mass. (Giemsa stain) (SOURCE: PHIL 4826 - CDC/Dr. Mae Melvin)

Clinical Disease

Symptoms include headache, photophobia, muscle aches and pains, anorexia, nausea and vomiting. *Plasmodium malariae*, like *P. vivax* and *P. ovale* are relatively benign. However, chronic infections in children may lead to nephrotic syndrome due to immune complexes depositing on the glomerular wall.

9.3. Laboratory Diagnosis of Malaria Parasites

Introduction

The definitive diagnosis of malaria infection is still based on finding malaria parasites in blood films. In thin films the red blood cells are fixed so the morphology of the parasitized cells can be seen. Species identification can be made, based upon the size and shape of the various stages of the parasite and the presence of stippling (i.e. bright red dots) and fimbriation (i.e. ragged ends). However, malaria parasites may be missed on a thin blood film when there is a low parasitemia. Therefore, examination of a thick blood film is recommended. With a thick blood film, the red cells are approximately 6-20 layers thick which results in a larger volume of blood being examined.

Thick Blood Films

In examining stained thick blood films, the red blood cells are lysed (destroyed), so diagnosis is based on the appearance of the parasite. In thick films, organisms tend to be more compact and denser than in thin films.

Field's Stain Method for Thick blood Films

The method recommended for staining thick blood is Field's Stain which is made from two components. Field's A is a buffered solution of azure dye and Field's B is a buffered solution of eosin. Both Field's A and B are supplied ready for use by the manufacturer.

Method

1. Place a drop of blood on a microscope slide and spread to make an area of approximately 1 cm^2. It should just be possible to read small print through a thick film.

2. The film is air dried and NOT fixed in methanol.

3. The slide is dipped into Field's stain A for three seconds.

4. The slide is then dipped into tap water for three seconds and gently agitated.

5. The slide is dipped into Field's stain B for three seconds and washed gently in tap water for a few seconds until the excess stain is removed.

6. The slide is drained vertically and left to dry.

Microscopic Features of the Field's Stained Thick Blood Film

- The end of the film at the top of the slide when it was draining should be looked at. The edges of the film will also be better than the centre, where the film may be too thick or cracked.

- In a well-stained film the malaria parasites show deep red chromatin and pale blue cytoplasm.

- White cells, platelets and malaria pigment can also be seen on a thick film. The leukocyte nuclei stain purple and the background is pale blue. The red cells are lysed and only background stroma remains. The occasional red cell may fail to lyse.

- Schizonts and gametocytes, if present, are also easily recognizable.

- A thick film should be examined for at least 10 minutes, which corresponds to approximately 200 oil immersion fields, before declaring the slide negative.

- As a result of hemolysis of the red blood cells due to staining of an unfixed film, the only elements seen are leukocytes and parasites, the appearance of the latter being altered. Consequently:

1. The young trophozoites appear as incomplete rings or spots of blue cytoplasm with detached chromatin dots.

2. The stippling of *P. vivax* and *P. ovale* may be less obvious although occasionally ghost stippling may be seen.

3. The cytoplasm of late trophozoites of *P. vivax* and *P. ovale* may be fragmented.

- Caution should be exercised when examining thick blood films as artifacts and blood platelets may be confused with malaria parasites.

Thin Blood Films

When examining thin blood films for malaria you must look at the infected red blood cells and the parasites inside the cells.

1. Rapid Field's Stain for Thin Films

This is a modification of the original Field's stain to enable rapid staining of fixed thin films. This method is suitable for malaria parasites, *Babesia* sp., *Borrelia* sp. and Leishmania sp.

Method

1. Air dry the film

2. Fix in methanol for one minute.

3. Flood the slide with 1 ml of Field's stain B, diluted 1 in 4 with distilled water.

4. Immediately, add an equal volume of undiluted Field's stain A, mix well and allow to stain for 1 minute.

5. Rinse well in tap water and drain dry.

Uses

This is a useful method for rapid presumptive species identification of malarial parasites. It shows adequate staining of all stages including stippling (mainly Maurer's dots). However, staining with Giemsa is always the method of choice for definitive species differentiation.

2. Giemsa Stain for Thin Films.

Method

1. Air dry thin films
2. Fix in methanol for one minute
3. Wash in tap water and flood the slide with Giemsa diluted 1 in 10 with buffered distilled water pH 7.2. The diluted stain must be freshly prepared each time.
4. Stain for 25-30 minutes.
5. Run tap water on to the slide to float off the stain and to prevent deposition of precipitate on to the film. Dry vertically.
6. Examine the film using the x100 objective.

Microscopic Features of the Thin Blood Film

1. Examine the tail end of the slide where the red cells are separated into a one-cell-layer thick.
2. An alkaline buffer pH 7.2 is vital for clear differentiation of nuclear and cytoplasmic material and to visualize inclusions such as Schüffner's / James's dots in the red cells. Acidic buffer is unsuitable.
3. The red cells are fixed in the thin film so the morphology of the parasitized cells and the parasites can be seen.
4. On a well stained film the chromatin stains red/purple and the cytoplasm blue. Leukocytes have purple nuclei. The red stippling, if present, should be clearly visible.

Infected Red Blood Cells

1. Look at the size of the infected red blood cells.
2. Are there any Schüffner's dots present or not?

Species	Stages found in circulating Blood	Appearance of Red Blood Cells	
		Size	Stippling
Plasmodium falciparum	Trophozoites Gametocytes	Normal	Maurer’s dots or clefts infrequently seen
Plasmodium vivax	All: Schizonts Trophozoites Gametocytes	Enlarged, Maximum size may be 1.5-2 times normal	Schüffner's dots may be present
Plasmodium ovale	All: Schizonts Trophozoites Gametocytes	Enlarged, Maximum size may be 1.25-1.5 times normal	Schüffner's dots may be present
Plasmodium malariae	All: Schizonts Trophozoites Gametocytes	Normal	Ziemann’s dots rarely seen

Table 9-1. Stages and appearance of *Plasmodium* species in blood. (SOURCE: CDC)

Species	***P. falciparum***	***P. vivax***	***P. malariae***	***P. ovale***
Host CELL				
Size	Not enlarged	Enlarged	Not enlarged	Enlarged
Shape	Round and sometimes crenated	Round or oval (frequently bizarre form)	Round	Round or oval, often fimbriated
Color	Normal but may become darkened	Normal but inclined to be pale	Normal	Normal
Stippling	Maurer's dots (large red spots)	Schüffner's dots (small red dots)	Ziemann's dots (few tiny dots not important for diagnosis)	James's dots (numerous small red dots)
Pigment	Usually black or very dark brown	Fine golden brown granules seen in cytoplasm	Black or brown coarse granules	Resemble more closely P. *malariae*
PARASITE				
General features	Small, compact dark, staining parasite. Multiple infections of single RBC	Large light staining parasite. Many trophozoites, may be amoeboid	Regular shape and moderate size. Strong tendency to form a band across the infected RBC	Regular shape. Size in between *P. vivax* and *P. malariae*
Common. Stages found in smear	Only rings and gametocytes	Trophozoites, Schizonts, Gametocytes	As in *P. vivax*	As in *P. vivax*
Ring stage	Delicate, small, 1.5 µm Double chromatin and multiple rings common. Accole, wing and marginal forms	Large 2.5 µm, usually single. Prominent thicker chromatin	Similar to *P. vivax* but thicker	Similar to *P. vivax*, more compact
Trophozoite	Compact, small, vacuole inconspicuous, seldom seen in smear	Large, irregular actively amoeboid prominent vacuole Chromatin as dots or threads	Characteristic band form, vacuole inconspicuous	Compact coarse pigment, chromatin as large irregular clumps
Schizont	Small, compact seldom seen in blood smear	Large, filling the RBC, segmented, yellow brown pigment	Nearly fills RBC, like segmented, daisy head, pigment is dark brown	Fills three fourth of RBC, segmented Dark yellow brown pigment
Micro-gametocyte	Larger than RBC, kidney shaped with blunt round ends, cytoplasm reddish blue, fine granules scattered, many in number in smear	Fills enlarged RBC, round or oval, compact cytoplasm, pale blue, Abundant brown granules	Smaller than RBC, very few in PBF, round compact, cytoplasm pale blue. Pigment and chromatin as in *P. vivax*	Of the size of RBC round, compact very few in PBF, cytoplasm pale blue, chromatin and pigment as in *P. vivax*

Table 9-2. Characteristics of *Plasmodium* parasites (SOURCE: CDC)

Rings of the four main species of malaria may look alike. If you see rings, look for older stages. Patients with a *P. falciparum* infection only, rings are usually seen; older stages are present only in severe infections.

In poorly stained slides, Schüffner's dots may not be visible, so it is essential that correct staining methods are used. Also Schüffner's dots may not be seen in the earlier rings of *P. vivax* or *P. ovale.*

Estimation of Percentage Parasitemia of *Plasmodium falciparum*

Counting of red blood cells infected with parasites of *P. falciparum* is essential and the percentage parasitemia should always be reported as this has implications for prognosis and the pattern of treatment employed.

The recommended procedure for estimating the percentage parasitemia in a thin blood film is by expressing the number of infected cells as a percentage of the red blood cells e.g. three parasitized red cells / 100 red blood cells or 3% parasitemia.

A red blood cell infected with multiple parasites counts as one parasitized red cell. The percentage parasitemia should be calculated by counting the number of parasitized red blood cells in 1000 cells in a thin blood film.

Method 2

Alternatively, the World Health Organisation recommends a method which compares the number of parasites in a thick blood film with the white blood cell count.

The parasitemia is estimated by first counting the number of parasites per 200 white blood cells in a thick blood film and then calculating the parasite count / μl from the total white blood cell count / μl.

Knowledge of either % parasitemia or total parasite count is essential for the correct clinical management of *P. falciparum* malaria.

Effects of Anticoagulant on the Microscopic Diagnosis of Malarial Parasites

Thin blood films for malaria diagnosis are best prepared from venous or capillary blood taken directly from the patient, without the addition of anticoagulant. However, this is not usually possible in a clinical laboratory, as many samples are received from general practices and other hospitals. All anticoagulants have some effect on the morphology of malaria parasites and the red blood cell they inhabit. This effect depends on the stage of the parasite, the time taken for the blood to reach the laboratory and the type of anticoagulant used. If it is necessary to use an anticoagulant, the films should be prepared as soon as possible after the blood has been taken. If the films cannot be made immediately, potassium EDTA is the anticoagulant of choice. However if the blood is left for several hours in EDTA, the following effects may be seen.

1. Sexual stages may continue to develop and male gametocytes can exflagellate, liberating gametes into the plasma. These can be mistaken for organisms such as *Borrelia*. Gametocytes of *P. falciparum* which have a characteristic crescent shape, may round up and then resemble those of *P. malariae*.

2. Accole forms, which are characteristic of *P. falciparum,* may be seen in *P. vivax* because of attempted re - invasion of the red blood cell by merozoites.

3. Mature trophozoites of *P. vivax* may condense when exposure becomes prolonged and in cases of extreme exposure, red blood cells containing gametocytes and mature schizonts may be totally destroyed along with the contained parasites. The malaria pigment, hemozoin, always remains and can provide a clue to the presence and, to an expert eye, identity of the parasite.

4. The morphology of the red blood cell may be altered by shrinkage or crenation.

Malaria species	***P. falciparum***	***P. vivax***	***P. ovale***	***P. malariae***
Red Cell Changes	Maurer's dots	Schüffner's dots	James' Dots / Fimbriation	Ziemann's dots
Trophozoite – Ring form	Cytoplasm very fine in young rings; thick and irregular in old rings. Accole forms, multiple infections common.	Cytoplasm fine in young rings. Red cell unaltered in size.	Cytoplasm thicker than that found in *P. vivax.* Red cell unaltered in size.	Cytoplasm noticeably thicker. Red cell unaltered in size.
Trophozoite – Growing form	Red cell unaltered in size, sometimes stippled with Maurer's dots. Parasite is compact; pigment is dense brown or black mass.	Red cell enlarged, stippled. Parasite - ameboid, vacuolated; pigment fine and scattered, golden brown.	Red cell unaltered in size, or slightly enlarged. Stippled; may be oval and fimbriated. Parasite – compact, rounded; pigment fine brown grains.	Red cell unaltered in size. Parasite – compact, ugly, rounded or band-shaped; dark brown / black pigment often concentrates in a line along one edge of the band.
Mature schizonts	Red cell unaltered in size. Parasite – merozoites 8 – 36; pigment clumped, black. Rare in peripheral blood	Red cell much enlarged, stippled. Parasite – large, filling enlarged red cell. Merozoites 12 - 24, usually 16; pigment golden brown central loose mass.	Red cell slightly enlarged, stippled, frequently oval and fimbriated. Parasite – smaller than red cell. Merozoites 6 – 12, usually 8 in a single ring; pigment, brown / greenish central clump.	Red cell unaltered in size. Parasite – fills red cell. Merozoites 6 - 12, usually 8, sometimes forming a rosette; pigment, brown / black central clump.
Gametocytes	Red cell distorted. Parasite – crescent. Rare in early cases < 10 days.	Red cell enlarged, stippled. Parasite - large, fills red cell.	Red cell slightly enlarged, stippled. Parasite – round, filling 2/3 of the red cell.	Red cell unaltered in size. Parasite – small, round, fills the red cell.

Table 9-3. Differential diagnostic features of human *Plasmodia* species - Giemsa stained thin film of peripheral blood.

Chapter 10.
The Blood Nematodes

10.1 The Blood Nematodes

These nematodes are known as filariae and consist of a group of nematodes which have successfully invaded the blood stream, connective tissue or serous cavities of vertebrates. They are long thread –like nematodes.

Many of them are of medical and veterinary importance attacking man and various domestic animals being transported by various vectors, including mosquitoes. The nematodes from this order require intermediate hosts for the completion of their life cycle.

The morphology of these nematodes consist of a cylindroid pharynx with an anterior muscular portion and a posterior glandular portion; the males have well-developed alae (a flat, wing-like anatomic process or part) and spirally coiled tails.

Sexually mature female worms release microfilaria, which are pre-larval stages. These are released into the bloodstream. Most species are known to be ovoviviparous and some have 'sheathed' microfilaria.

The filarial nematodes which parasitize man consist of *Wuchereria bancrofti*, *Brugia malayi, Brugia timori* and *Loa loa*, *Onchocerca volvulus, Mansonella perstans, Mansonella streptocerca* and *Dipetalonema streptocerca.*

They inhabit a range of locations within the body; lymph glands, deep connective tissue, subcutaneous tissues or mesenteries. Invasions of these tissues usually result in inflammatory reactions which is a typical symptom of a human filarial infection. In some cases these result in fleshy deformities known as elephantiasis.

It has been estimated that approximately one billion people in tropical and subtropical countries are exposed to the risk of filarial infections and at least 200 million are infected with filariasis. The species which are primarily responsible for these human filarial infections are *Wuchereria bancrofti, Brugia malayi* and *Onchocerca volvulus*.

Wuchereria bancrofti

Introduction

Wuchereria bancrofti is a nematode causing lymphatic filariasis throughout the tropics and subtropics and is transmitted by the mosquito. There are two strains of *W. bancrofti*;

1. The nocturnal periodic strain which is widely distributed in endemic regions (i.e. Africa, India and the Far East and also parts of China, Korea and Japan) with the microfilariae being in their highest concentrations between the hours of 10pm and 2am.

2. The sub-periodic strain which is found in the Pacific region, and has a microfilaremia all the time with the highest numbers being detected between noon and 8pm.

Humans are the only known reservoir host of *W. bancrofti*. Infection rates in some communities in East Africa exceed 30% of adults causing revolting swellings of the legs or genital system, known as elephantiasis in man. The adult worm occurs in tightly coiled nodular masses in the major lymphatic ducts.

The main vector is *Culex quinquefasciatus*, a mosquito that is particularly common in towns and cities, breeding in organically polluted water, resting in houses and feeding by night on their human occupants. Typical breeding sites include: storm drains blocked with domestic refuse, accumulations of domestic waste water, inadequately covered septic tanks and pit latrines.

In rural areas throughout Africa, *Anopheles gambiae* and *Anopheles funestus* are involved in transmission. Elsewhere other anopheline mosquito species may transmit bancroftian filariasis in rural areas. In Papua New Guinea, *Mansonia* species may act as a vector.

Life Cycle

Microfilariae enter the host during a blood meal when the vector, a mosquito, punctures the skin. The infective larvae enter through the wound and migrate to the peripheral lymphatics where they grow to mature male and female worms. They can live there for several years. After mating, the gravid females release sheathed microfilariae into the peripheral blood where they can be detected 8-12 months after the initial infected bite.

The mosquito acquires the infection by ingestion of the microfilaria in the blood meal. The microfilariae lose their sheath on arrival in the stomach of the mosquito due to gastric juices. The larvae migrate to the thoracic muscles and develop into infective larvae over a period of 6-14 days. The larvae then migrate to the mouthparts of the mosquito which infects the host during a blood meal.

The blood stages of filariae, microfilariae, vary in the times when they are present in the peripheral blood, corresponding with the peak biting time of the vector. Thus, in nocturnally periodic forms the microfilaria are present in the peripheral blood circulation at night; during the day they reside in the deep tissues, particularly the lungs.

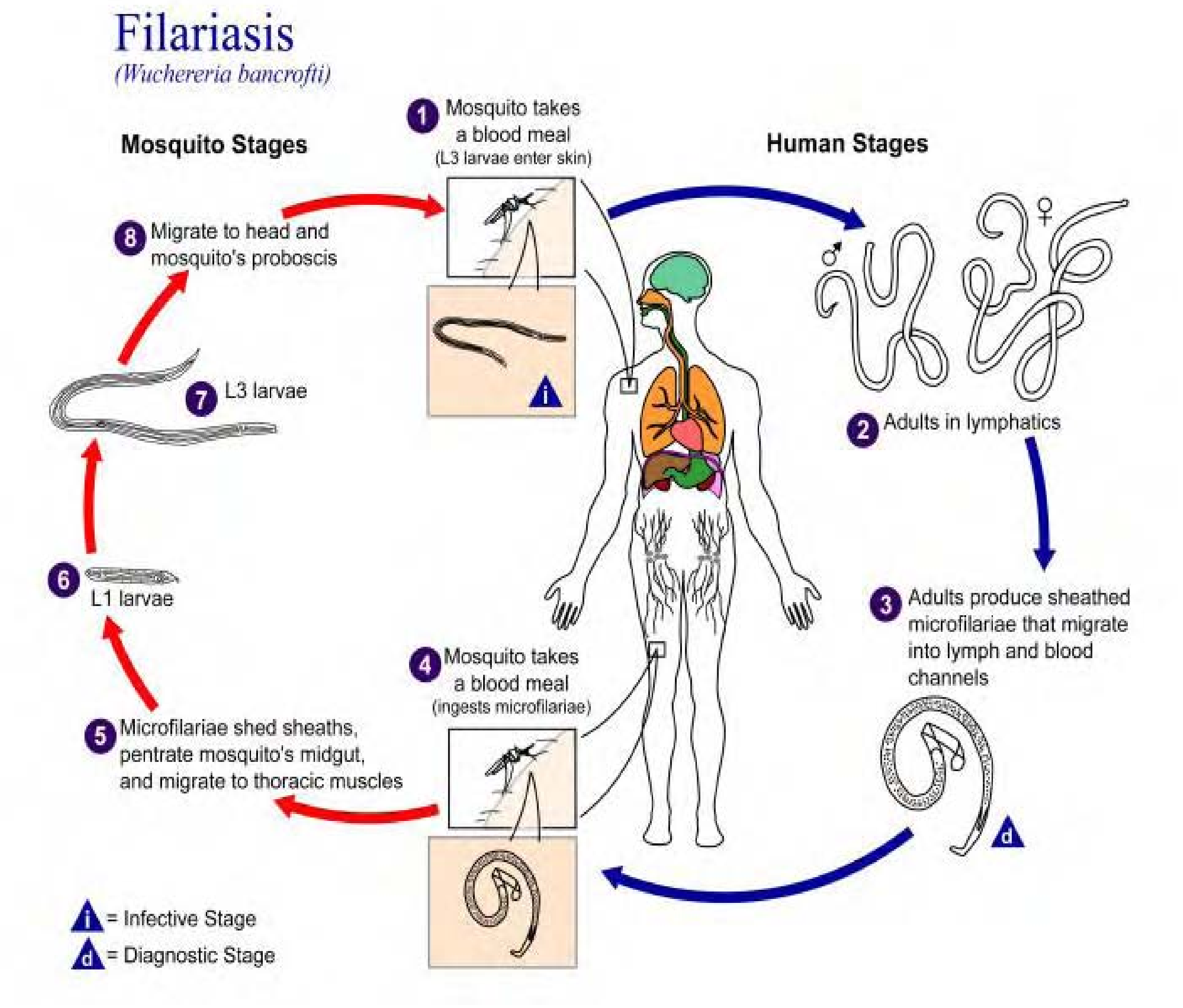
Filariasis
(Wuchereria bancrofti)
Mosquito Stages
Human Stages
1 Mosquito takes a blood meal (L3 larvae enter skin)
2 Adults in lymphatics
3 Adults produce sheathed microfilariae that migrate into lymph and blood channels
4 Mosquito takes a blood meal (ingests microfilariae)
5 Microfilariae shed sheaths, pentrate mosquito's midgut, and migrate to thoracic muscles
6 L1 larvae
7 L3 larvae
8 Migrate to head and mosquito's proboscis
♂
♀
i
d
i = Infective Stage
d = Diagnostic Stage

Illustration 10-1. Diagram showing the life cycle of *Wuchereria bancrofti,* the filarial nematode known to cause the disfiguring disease, elephantiasis, in man. (SOURCE: PHIL 3425 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology

The adult worms are white and threadlike. The male measures between 2.5–4cm whereas the female is larger, measuring between 8-10cm.

The microfilariae are 230-275μm in length. The tail of the microfilariae of *W. bancrofti* tapers to a delicate point and exhibits no terminal nuclei. The sheath the microfilariae of *W. bancrofti* stains with hematoxylin stain.

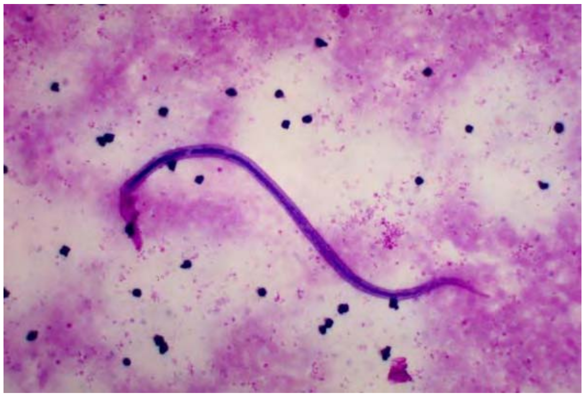

Image 10-1. Microfilaria of *Wuchereria bancrofti*. The microfilaria is sheathed, its body is gently curved, and the tail is tapered to a point. The nuclear column (the cells that constitute the body of the microfilaria) is loosely packed, the nuclei can be visualized individually and do not extend to the tip of the tail. (Micrograph) (SOURCE: PHIL 3008 - CDC/Dr. Mae Melvin)

Clinical Disease

Many patients are asymptomatic. Patients may present with fever, lymphangitis and lymphadenitis. Lymphangitis commonly affects the lower extremities and there may also be genital and breast involvement. An inflammatory reaction occurs in the lymphatic vessels that harbor the adult worms. Edema develops which may resolve after the first few attacks. A late complication resulting in thickening and verrucous changes in the skin known as elephantiasis may occur after recurring lymphangitis. Secondary bacterial and fungal infections may occur in patients with long-standing elephantiasis.

Obstruction of the genital organs may result in hydrocoele formation and scrotal lymphoedema. Obstruction of the retroperitoneal lymphatics may cause the renal lymphatics to rupture into the urinary tract producing chyluria.

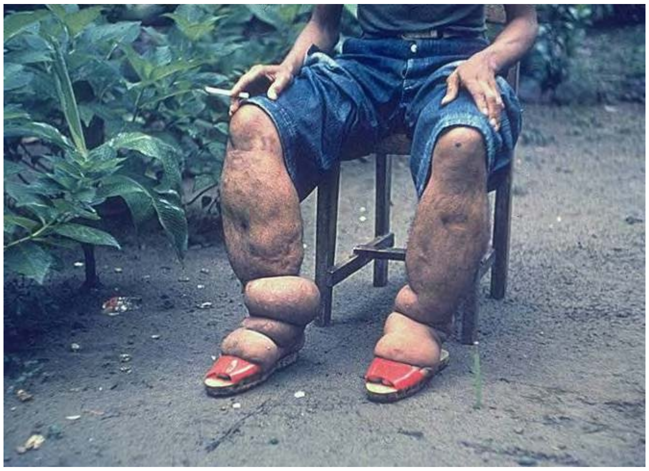

Image 10-2. Lymphatic filariasis: Elephantiasis is the last consequence of the swelling of limbs and scrotum. (SOURCE: PHIL 373 – CDC)

Some patients with filariasis do not exhibit microfilaremia but develop tropical pulmonary eosinophilia which is characterized by peripheral eosinophilia, wheeze and cough. High eosinophilia, high IgE level and high anti-filarial antibody titers are features of this syndrome.

Laboratory Diagnosis

See section 10.2 below

Sheath may or may not stain with Giemsa; does stain with hematoxylin stains. Discrete nuclei. Empty space between the nuclei and the body wall. No nuclei in tip of tail. Innerbody is rarely visible in Giemsa. Does not stain with hematoxylin. Cephalic space as long as it is broad. Tip of tail may be bent underneath the body. Found in blood.

Brugia malayi

Introduction

Brugia malayi is a nematode causing lymphatic filariasis in South East Asia. There are two strains of *B. malayi*;

1. The nocturnal periodic strain which is widely distributed in Asia, the microfilariae being in their highest concentrations between the hours of 10pm and 2am.

2. The sub-periodic strain which is found in Malaysia, Indonesia and the Philippines where humans exhibit a microfilaremia all the time with the highest numbers being detected between noon and 8pm.

Nocturnally periodic Brugian filariasis is primarily a rural disease, being transmitted by various *Anopheles* species of mosquitoes and also by *Mansonia* species*,* a mosquito that usually bites during the night.

Nocturnally sub-periodic *B. malayi* is transmitted almost exclusively by *Mansonia* species, often different species than those involved in transmitting the periodic form. *Mansonia bonneae* are important vectors in Malaysia, breeding in swamp forests and biting by night, although sometimes by day as well.

This species like *W. bancrofti* also parasitizes the lymph nodes and lymphatics; the adults of the two species are indistinguishable, causing Malayan filariasis.

Life Cycle

The adult worm inhabits the lymphatics and the female produces sheathed microfilariae which circulate in the peripheral blood. The mosquito acquires the infection by ingestion of the microfilaria in the blood meal. The microfilaria loses their sheath on arrival in the stomach of the mosquito. The larvae migrate to the thoracic muscles and develop into infective larvae over a period of 6-14 days. The larvae then migrate to the mouth parts of the mosquito and enter the skin of the definitive host through the puncture wound when a blood meal is taken. The infective larvae enter the peripheral lymphatics where they grow to mature male and female worms.

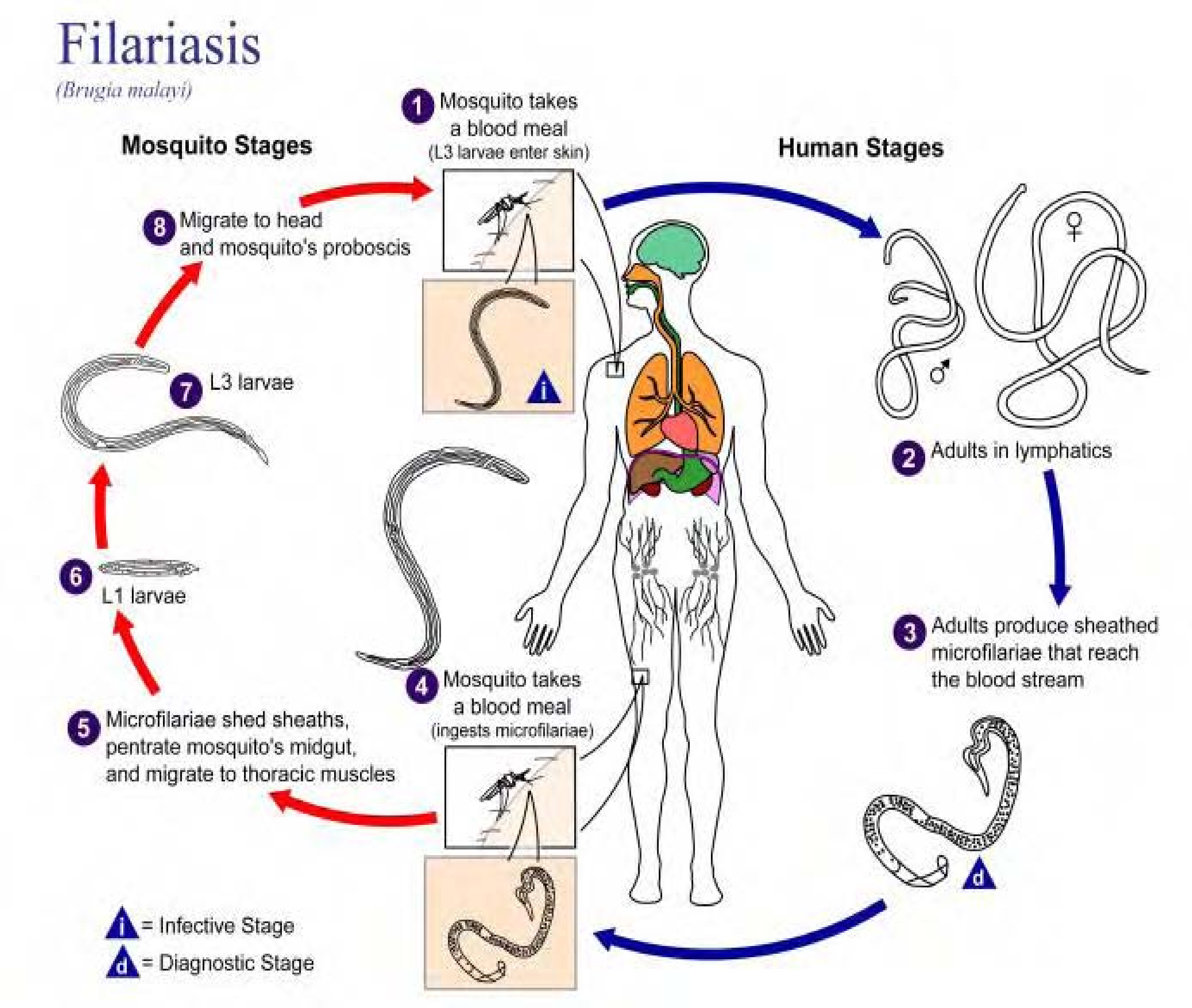
Filariasis
(Brugia malayi)
Mosquito Stages
Human Stages
1 Mosquito takes a blood meal (L3 larvae enter skin)
2 Adults in lymphatics
♀
♂
3 Adults produce sheathed microfilariae that reach the blood stream
4 Mosquito takes a blood meal (ingests microfilariae)
5 Microfilariae shed sheaths, pentrate mosquito's midgut, and migrate to thoracic muscles
6 L1 larvae
7 L3 larvae
8 Migrate to head and mosquito's proboscis
i
d
i = Infective Stage
d = Diagnostic Stage

Illustration 10-2. Diagram showing the life cycle of *Brugia malayi*, a nematode which causes lymphatic filariasis. (SOURCE: PHIL 3379 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology

The adult worms of *B. malayi* are smaller than those of *W. bancrofti*. The microfilariae of *Brugia malayi* are 170–230μm in length and have two terminal nuclei that are distinctly separated from the other nuclei in the tail. The last terminal nucleus is quite small and is at the tip of the tail. The sheath stains deep purple with hematoxylin stain.

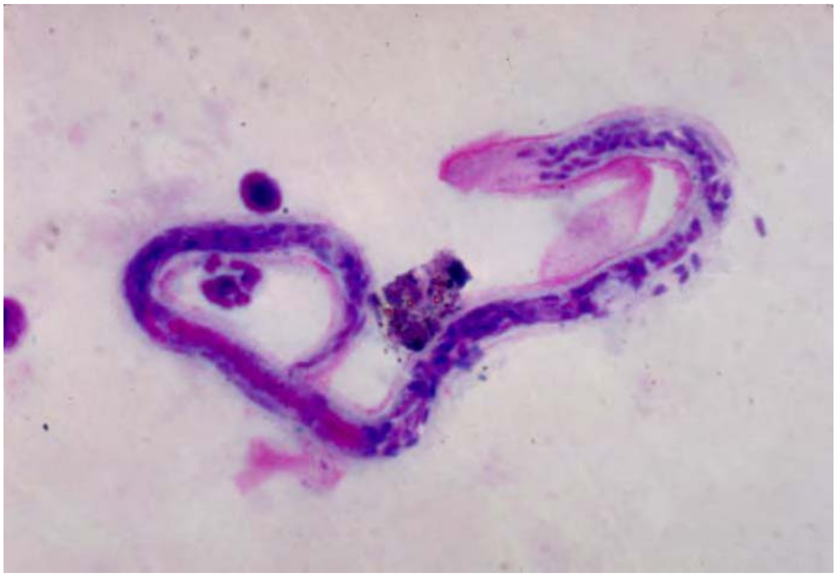

Image 10-3. Microfilaria of *Brugia malayi.* These microfilariae are sheathed measuring approximately 170–230μm in length and have 2 terminal nuclei that are distinctly separated from the other nuclei in the tail. The microfilariae in this species are tightly coiled, and the nuclear column is more tightly packed, preventing the visualization of individual cells. (Blood Smear) (SOURCE: PHIL 3003 - CDC/Dr. Mae Melvin)

Clinical Disease

Clinical features of *B. malayi* are similar to those of *W. bancrofti*, however in *B. malayi*, unlike *Wuchereria bancrofti*, genital involvement, hydrocoele and chyluria are rare.

Many patients are asymptomatic. Patients may present fever. Lymphaginitis and lymphadenitis develop in the lower extremities. An inflammatory reaction occurs in the lymphatic vessels that harbor the adult worms. Edema develops which may resolve after the first few attacks. However, in long standing disease after several episodes of lymphaginitis, thickening and verrucous changes in the skin known as elephantiasis occurs.

Some patients with lymphatic filariasis do not exhibit microfilaremia. However, they do have high eosinophilia, high IgE level and high anti-filarial antibody titers.

Laboratory Diagnosis

See section 10.2 below

Kinked microfilaria. Sheath stains deep pink with Giemsa stain. Does stain with hematoxylin stains. Nuclei crowded and fill the whole body. Empty space between nuclei and body wall. Cephalic space twice as long as it is broad. Innerbody may or may not stain; when it does, it is prominent. Found in blood.

Brugia Timori

Brugia timori is found in the islands of Indonesia and exhibits a strictly nocturnal periodicity. The lifecycle and disease closely resembles that of *Brugia malayi*. However, the microfilariae can be distinguished from those of *B. malayi* in that they are about 310µm in length. The sheath satins pink with Giemsa and the nuclei at the tip of the tail are similar to those of *B. malayi*

Loa loa

Introduction

Loa loa, also known as the African eye worm, is a filarial nematode endemic in the rain forests of West and Central Africa. It is transmitted by *Chrysops* species, also known as mango flies or horse flies and humans are the only known reservoir. It is estimated that 2-13 million humans are infected with the larvae.

Adults migrate in the subcutaneous tissues of man and monkeys, with them eventually migrating across the eyeball under the conjunctiva.

Life Cycle

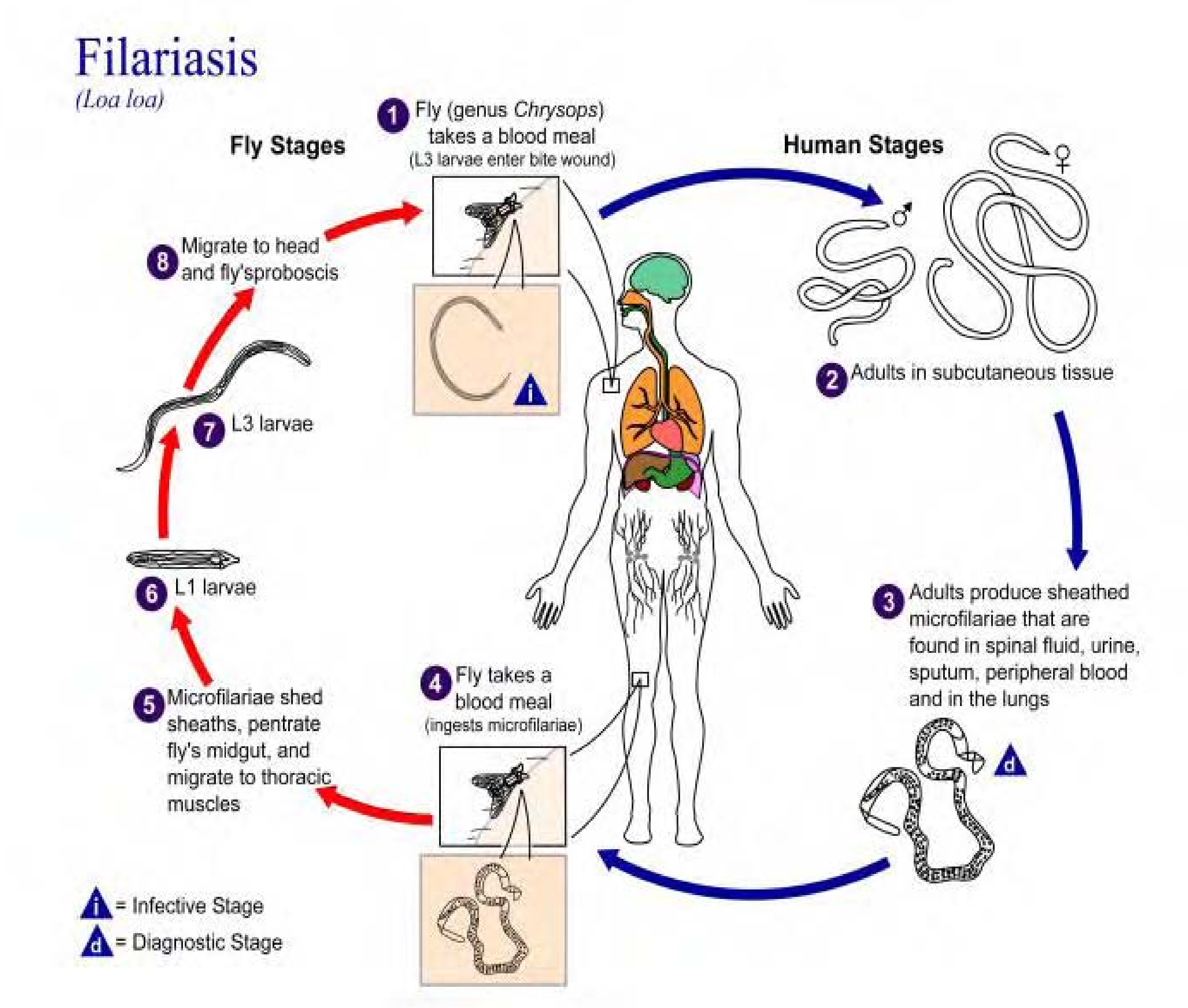
Filariasis
(Loa loa)
Fly Stages
1 Fly (genus Chrysops) takes a blood meal (L3 larvae enter bite wound)
Human Stages
♀
♂
2 Adults in subcutaneous tissue
3 Adults produce sheathed microfilariae that are found in spinal fluid, urine, sputum, peripheral blood and in the lungs
d
4 Fly takes a blood meal (ingests microfilariae)
5 Microfilariae shed sheaths, pentrate fly's midgut, and migrate to thoracic muscles
6 L1 larvae
7 L3 larvae
8 Migrate to head and fly'sproboscis
i
i = Infective Stage
d = Diagnostic Stage

Figure 10-3. Diagram showing the life cycle of *Loa loa,* the African eye worm. (SOURCE: PHIL 3399 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

The adult worms live in the subcutaneous and deep connective tissues and the microfilariae are found in the peripheral blood, where they can be in ingested by the *Chrysops* fly (day biting fly) The adults can live in the tissues for up to 17 years.

Once the microfilariae have been taken up by the Chrysops during a blood meal they develop within the fat body. They develop through to L_3 within 10–12 days. The microfilariae, L_3 re-enter the hosts blood stream when the fly takes another blood meal. They reach adult worms within 4- 6 months living in the subcutaneous and deep connective tissues.

The microfilariae exhibit diurnal periodicity, the highest numbers being detected in blood between 10am and 2pm.

Morphology

Adult males of *Loa loa* are 2–3.5cm long and the females from 5-7cm. The microfilariae of *Loa loa* are 250-300µm. They possess a sheath which stains blue-grey with Delafield's hematoxylin. The sheath does not stain with Giemsa. The tail gradually tapers to a rounded end, the densely packed nuclei extending to the tip.

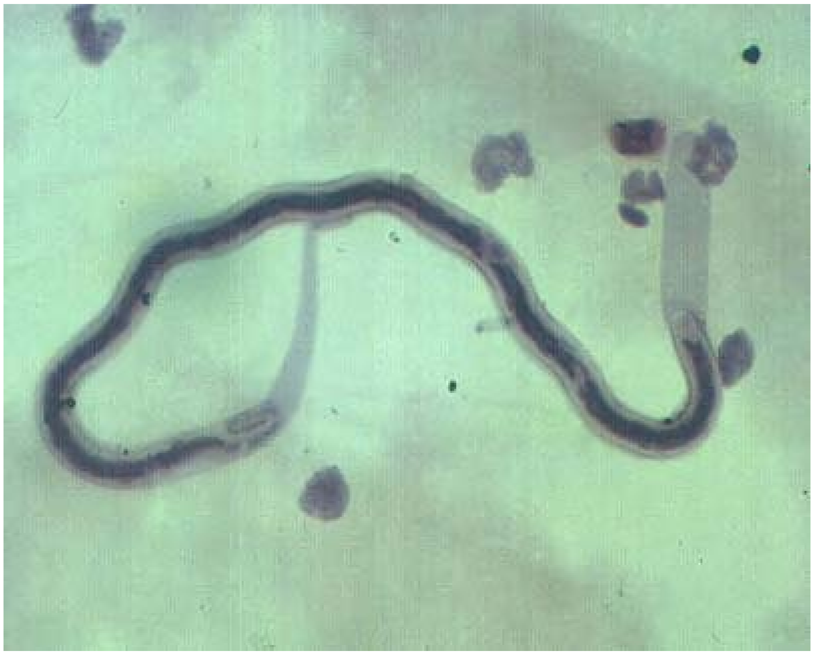

Image 10-4. Microfilaria of *Loa loa,* the African eye worm. The adult worms live in the subcutaneous and deep connective tissues and the microfilariae are found in the peripheral blood, The microfilaria are kinked and sheathed. Nuclei crowded extending to tip of tail; tip of tail tapers. (hematoxylin stain, x400) (SOURCE: Unknown)

Clinical Disease

Many patients infected with *Loa loa* appear to be asymptomatic and the migration of the adult worm through the subcutaneous tissues often goes unnoticed, unless passing beneath the conjunctiva of the eye. They can be seen crossing the eye, but it is a rapid process taking approximately 15–20 minutes. Hyperesinophilia and increased antibody levels, especially IgE are also noted. Eye-worm episodes are as equally common in man as well as women with common reoccurrences. There is an increased incidence with age.

The most common pathology associated with *Loa loa* infections are Calabar swellings, which are inflammatory swellings resulting in a localized subcutaneous edema. These swellings are due the host's response to the worm or its metabolic products and can be found anywhere in the body but most commonly in the extremities. These swellings last from 1–3 days. They develop rapidly and last one to three days, usually accompanied by localized pain, urticaria and pruritis. There is a higher frequency of Calabar swellings in women with common reoccurrences.

Serious complications such as cardiomyopathy, encephalopathy, nephropathy and pleural effusion have been recorded.

Laboratory Diagnosis

See section 10.2 below

Kinked and sheathed microfilaria. Sheath does not stain with Giemsa stain; does stain with hematoxylin stains. Nuclei crowded extending to tip of tail; tip of tail tapers. Cephalic space as long as it is broad. Inner body does not usually stain. Found in blood.

Mansonella species

Introduction

Members of the genus *Mansonella* are filarial nematodes which rarely cause serious disease. However, they can be found in geographical areas where *Wuchereria bancrofti, Loa loa* and *Onchocerca volvulus* also occur and therefore must be differentiated from these pathogenic microfilariae. Unlike the pathogenic blood filariae, they do not exhibit periodicity.

Life Cycle

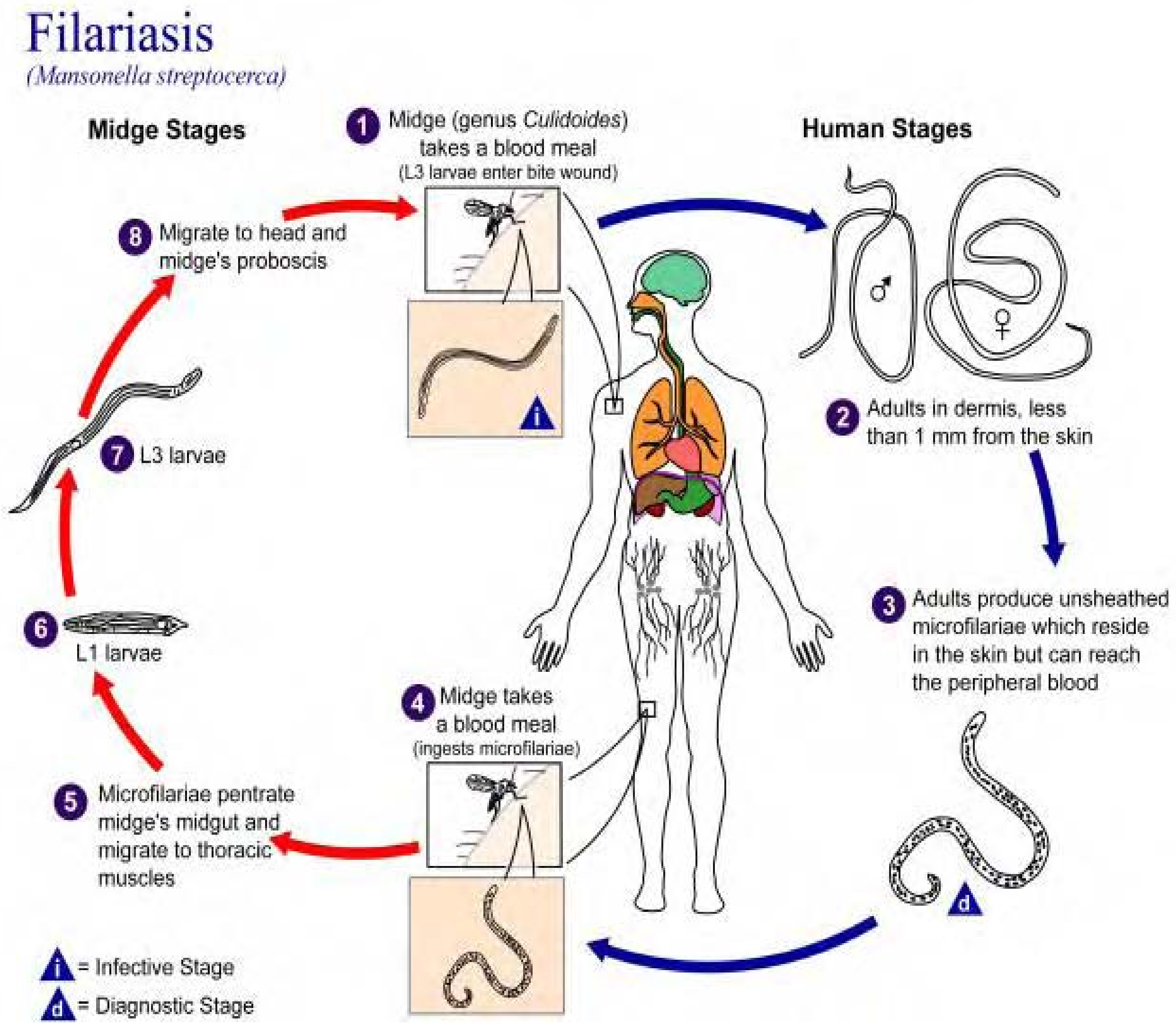
Filariasis
(Mansonella streptocerca)
Midge Stages
Human Stages
1 Midge (genus Culidoides) takes a blood meal (L3 larvae enter bite wound)
i
2 Adults in dermis, less than 1 mm from the skin
♂
♀
3 Adults produce unsheathed microfilariae which reside in the skin but can reach the peripheral blood
d
4 Midge takes a blood meal (ingests microfilariae)
5 Microfilariae pentrate midge's midgut and migrate to thoracic muscles
6 L1 larvae
7 L3 larvae
8 Migrate to head and midge's proboscis
i = Infective Stage
d = Diagnostic Stage

Image 10-4. General life cycle of *Mansonella* species of filarial nematodes. (SOURCE: PHIL 3404 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

There is a general life cycle for the *Mansonella* species of filarial nematodes. The microfilaria is picked up by the vector *Culicoides* sp. (biting midges) during a blood meal. The larvae develop within the body of the *Culicoides* sp. and are re-introduced into the human host when the vector takes another blood meal. They are found in various sites around the human host body.

Mansonella perstans

The microfilariae of *M. perstans* have been found in Africa and South America. This is a mildly pathogenic species in man and apes. They are found in the deep connective tissue and serous cavities.

Morphology

The adult worms live in the peritoneal, pleural and pericardial cavities and their size is comparable to the pathogenic species already discussed. The microfilariae are unsheathed are about 200µm in length and the nuclei extend to the tip of the tail which is rounded.

Clinical Disease

It is difficult to assess the disease associated with *M. perst*ans, however pruritis, fever and subcutaneous swellings have been associated with infection of *M. perstans*. The adult worm appears to cause little or no host reaction. Eosinophilia is common.

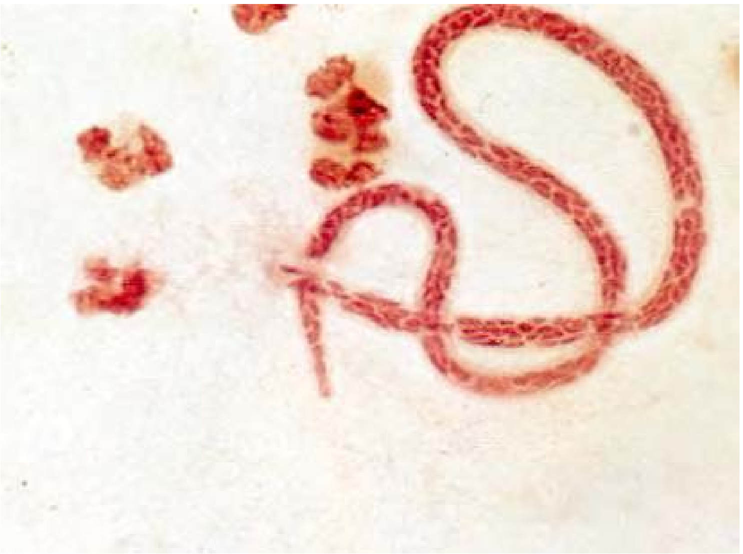

Figure 10-5. Microfilariae of *Mansonella perstans,* a mildly pathogenic nematode to man. The microfilariae are unsheathed are about 200μm in length and the nuclei extend to the tip of the tail which is rounded. (Giemsa stained x920) (SOURCE: Unknown)

Laboratory Diagnosis

See section 10.2 below

Small, thin microfilaria. Does not have a sheath. Nuclei extend to end of tail; last nucleus bigger; tip of tail is blunt. Nuclei stain deeply and “run together”. Found in blood.

Mansonella ozzardi

Mansonella ozzardi nematodes are confined to the westerm hemisphere. These are non-pathogenic filarial nematodes. The parasites cause nodules in the skin of the vertebrate hosts.

Morphology

The adult worms are located in the mesenteric tissues and their size is comparable to the pathogenic species already discussed (0.6m long). The microfilariae are found in the peripheral blood and range between 173-240µm in length. The nuclei do not extend to the tip of the tail which has a pointed end. The male adult worm is almost unknown.

Clinical Disease

Infections caused by *M. ozzardi* are generally symptomless, however lymphadenopathy, arthralgia, fever and eosinophilia have been reported.

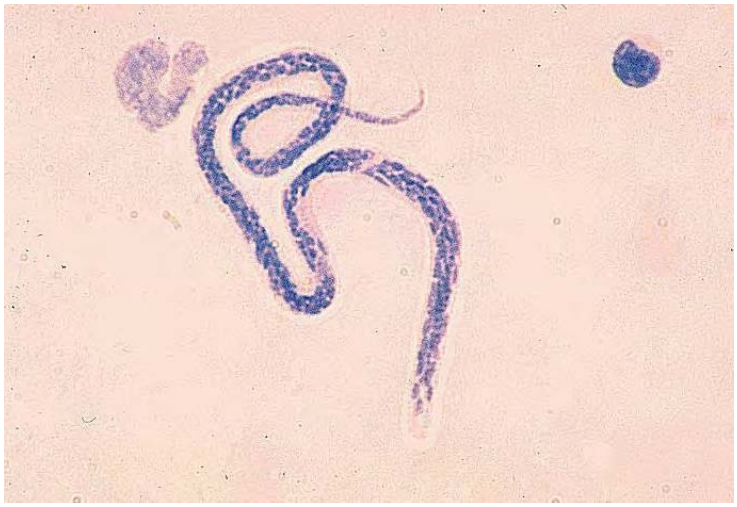

Image 10-6. Microfilariae of *Mansonella ozzardi,* Non-pathogenic filarial nematode to man. The microfilariae are found in the peripheral blood and range between 173 - 240µm in length. The nuclei do not extend to the tip of the tail which has a pointed end. (SOURCE: PHIL 382 - CDC/Dr. Mae Melvin)

Laboratory Diagnosis

See section 10.2 below

Small thin microfilaria. Does not have a sheath. Nuclei do not extend to end of tail; tip of tail tapers. Stains very lightly; tip of tail difficult to see. Found in blood and skin.

Species	Size of Microfilariae	Morphology of microfilariae
Wuchereria bancrofti	210 – 320μm by 8 - 10μm	Sheathed. Tail pointed and clear
Brugia malayi	170 – 260μm by 5 - 6μm	Sheathed. Tail pointed with 2 nuclei
Loa loa	230 – 300μm by 6 - 8μm	Sheathed. Tail blunt with nuclei
Mansonella perstans	200μm by 6μm	Unsheathed. Tail blunt with nuclei
Mansonella ozzardi	250μm by 6 - 7μm	Unsheathed. Tail pointed and clear

Table 10-1. Morphology of the blood microfilariae known to infect man. (SOURCE: CDC)

Species	Geographic distribution	Pathogenicity	Adults (site of infection)	Microfilariae (characteristics)	Vector
Wuchereria bancrofti	Asia, Pacific, Tropical Africa, Americas	Lymphangitis, fever, elephantiasis hydrocoele, chyluria	Lymphatics	Found in blood, sheathed, periodicity variable	Culicidae (mosquitoes)
Brugia malayi	South and East Asia	Lymphagitis, fever. Elephantiasis	Lymphatics	Found in blood, sheathed, nocturnally periodic or subperiodic	Culicidae (mosquitoes)
Dipetalonema perstans	Africa and South America	No definite pathogenicity	Peritoneal & pleural cavity	Found in blood, unsheathed, nocturnally subperiodic	*Culicoides* (biting midges)
Dipetalonema streptocerca	Africa (Ghana and Congo)	Cutaneous edema, elephantiasis	Subcutaneous tissues	Found in skin, unsheathed, nonperiodic	*Culicoides* (biting midges)
Mansonella ozzardi	Central and South America	No definite pathogenitis	Peritoneal cavity	Found in blood, unsheathed, nonperiodic	*Culicoides* (biting midges)
Loa loa	Tropical Africa	Skin swellings, allergic reactions	Subcutaneous tissues	Found in blood, sheathed, diurnally periodic	*Chrysops* (Tabanidae or Horse fly)
Onchocerca volvulus	Africa, Central and South America	Skin nodules, ocular complications (blindness)	Subcutaneous tissues	Found in skin, unsheathed, nonperiodic	*Simulium* (Black fly)

Table 10-2. Comparison of the main human filarial nematodes. (SOURCE: CDC)

10.2. Laboratory Diagnosis

Detection of Microfilariae in Blood

Collection of specimens

The specimen collection times should be selected in accordance with the patient's clinical symptoms and travel history.

Species	Geographic location	Periodicity	Collection time
Wuchereria bancrofti	Tropics / Subtropics	Nocturnal	2400 hours
Wuchereria bancrofti	Pacific	Diurnal subperiodic	1600 hours
Brugia malayi	SE Asia and SW India	Nocturnal	2400 hours
Brugia malayi	Indonesia	Nocturnal subperiodic	2100 hours
Brugia timori	Indonesia	Nocturnal	2400 hours
Loa loa	West / Central Africa	Diurnal	1300 hours
Mansonella perstans	Africa / South America	Non periodic	Any time
Mansonella ozzardi	Central & South America	Non periodic	Any time

Table 10-3. Periodicity and the advised collection times of the human filarial nematodes. (SOURCE: CDC)

Detection Methods

(i) Polycarbonate membrane filtration.

This technique is very sensitive, enabling very low parasitemias to be detected. It is now the most widely used technique for separating microfilariae from blood.

Nucleopore polycarbonate membranes, 25µm diameter, 5µm pore size, are held in a Millipore Swinnex filter holder, using a rubber gasket to secure the membrane.

Method

a) Place the membrane on the holder with a drop of water.

b) Draw up 10-20 ml of 1:1 saline diluted blood into a 20ml syringe

c) Connect the syringe to the filter and *gently* push the blood through the filter membrane.

d) Repeat until all of the blood has been filtered.

e) Draw up 20 ml of saline into the syringe, flush through the filter, repeat using air.

f) Unscrew the top of the filter and discard the gasket into chloros; use forceps to transfer the membrane to a slide.

g) Add a drop of saline to the membrane and cover with a coverslip.

h) Examine the membrane under the microscope, using a x10 objective. Examine any microfilariae found using a x40 objective to note the presence of a sheath.

(ii) Saline/saponin method.

Reagent

One percent saponin in normal saline.

Method

a) Deliver 2ml of blood (fresh or anticoagulated) into a centrifuge tube and add 8ml of 1% saponin in saline.

b) Mix the blood by inversion, then allow it to stand at room temperature for 15 minutes to allow the blood to hemolyze.

c) Centrifuge at 2,000rpm for 15 minutes to deposit the microfilariae.

d) Discard the supernatant and use the deposit to make a wet preparation.

e) Examine the slide using the x10 objective. Active microfilariae can be seen and produce a snake-like movement as they disturb the cell suspension.

If it is not easy to inspect the microfilariae due to excess “wriggling” a little 10% formalin can be run under the coverslip to immobilize them.

Confirmation of species can be made by using appropriate staining methods to demonstrate nuclear morphology.

Staining Methods for Microfilariae

When filariasis is suspected, a geographical and clinical history helps to determine the most appropriate collection time. Thick and thin blood films can be examined. However this is an insensitive method due to the low microfilaremia, and larger volumes of blood need to be examined.

There are 4 characteristics that are generally used in diagnosing microfilaria:

1. The presence of absence of a sheath.
2. The presence or absence of nuclei in the tip of the tail.
3. The innerbody – can or cannot be demonstrated.
4. The size of the microfilaria.

The two methods commonly used are:

(i) Supravital Staining

Reagent

0.75% cresyl blue in saline or 1.0% methylene blue in saline.

These reagents can be used to stain live microfilariae by allowing the stain to flow under the coverslip on to a polycarbonate membrane preparation or a centrifuged preparation. The dye will stain the nuclei of the microfilariae and also provide a contrasting background to look for a sheath. It may take several minutes for the dye to penetrate the organisms and the slide should be kept in a moist chamber to prevent the preparation from drying out.

(ii) Permanent Staining

Permanent stains should show up the nuclei, including the pattern of nuclei in the tail region and stain the sheath if necessary.

The stains of choice are;

1. Hematoxylin
2. Giemsa
3. Rapid Field's

1. Hematoxylin

Delafield's hematoxylin will stain the nuclei and the sheath well and unlike Ehrlich's hematoxylin does not require heating

Reagents

- Delafield's hematoxylin (BDH)
- 1% acid alcohol
- Methanol

Method

a) Make thin films, allow to air dry then fix in methanol for five minutes

b) Stain with Delafield's hematoxylin for 20 minutes

c) "Blue" the nuclei by placing the slide in a coplin jar and allow a stream of running water to flow into the jar for 20 minutes.

d) Decolorize with 1% acid alcohol for 5-10 seconds before "blueing" in tap water again. Control this process by examination under the microscope until the nuclei are clear and distinct.

e) Allow the slide to dry before mounting in DPX.

f) The nuclei should stain blue and the sheath grey.

2. Giemsa

Reagents

- Methanol
- Giemsa stain
- Immerson Oil

Method

a) Make a thin film and allow to air dry.

b) Fix in methanol for one minute.

c) Tip off the methanol and flood the slide with Giemsa stain diluted 1:6 with buffered distilled water pH 6.8. The diluted stain must be freshly prepared each time.

d) Stain for 20 – 25 minutes.

e) Run buffered water on to the slide to float off stain and to prevent deposition of precipitate on to the film. Allow the slide to drain dry.

f) Examine the film using the oil immersion objective. Nuclei should stain red

3. Rapid Field's

Reagents

- Methanol
- Field's Stain A solution

- Field’s Stain B solution
- Immersion Oil

Method

a) Make thin film and allow to air dry for five minutes.

b) Fix the smear in methanol for one minute.

c) Flood the slide with 1ml of Field’s stain B (diluted 1:4 with distilled water)

d) Immediately add an equal volume of Field’s stain A, mix well on slide and allow to stand for one minute.

e) Rinse well in tap water and drain dry.

f) Examine the film using the oil immersion objective and immersion oil.

g) The nuclei should stain red.

10.3 Microfilaria Worms Found in Tissue and Skin

The main species of microfilariae found in the skin and tissue are *Onchocerca volvulus* and *Mansonella streptocerca.* Microfilariae of *Onchocerca volvulus* and less often, *Mansonella streptocerca* migrate through the dermis causing itching and skin texture changes and occasionally arrive in the eye where they cause blindness. Detection of these microfilariae is from skin snips or nodule biopsies. When high numbers of microfilariae are present, they can occasionally be found in the blood and urine.

Onchocerca volvulus

Introduction

Onchocerca volvulus is mainly found in West Africa and Central and South America. Onchocerciasis, also known as river blindness, is a major public health problem, especially in West Africa despite the fact that an eradication program has been established. It is one of the world’s most distressing diseases of helminth origin, often resulting in blindness. *Onchocerca volvulus* is transmitted by the species *Simulium* or black fly whose breeding habitat is by fast flowing rivers or streams, therefore there is a patchy distribution of the disease as it is specified to where water courses are. The adult worms are found in nodules or onchodermata in superficial sites, but may invade other tissues. It is estimated that there are 18 million cases worldwide with 17.5 million being found in Africa. Nigeria is the most infected region. The rate of morbidity is high in relation to those with an infection.

Life Cycle

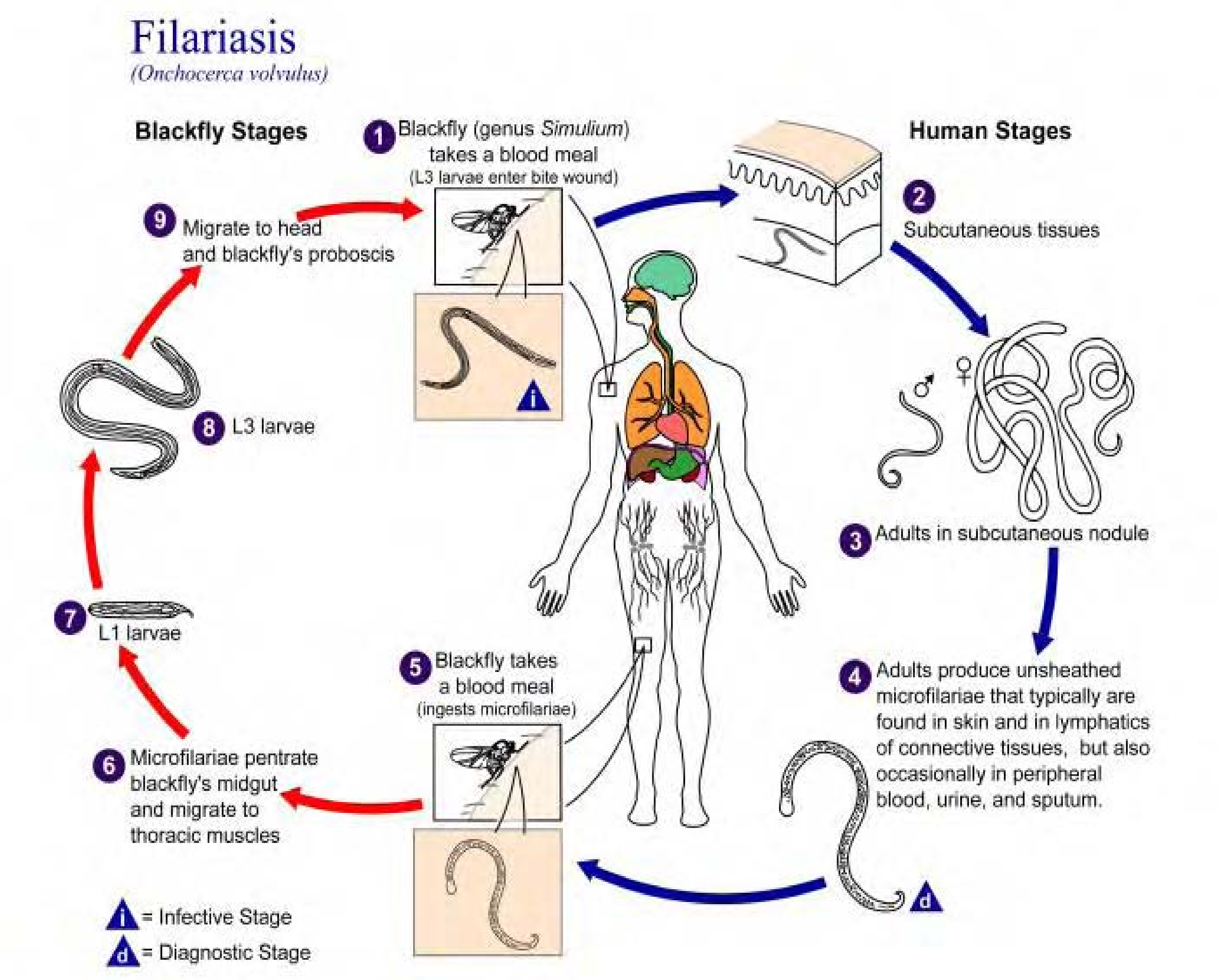
Filariasis
(Onchocerca volvulus)
Blackfly Stages
Human Stages
1 Blackfly (genus Simulium) takes a blood meal (L3 larvae enter bite wound)
2 Subcutaneous tissues
3 Adults in subcutaneous nodule
♂ ♀
4 Adults produce unsheathed microfilariae that typically are found in skin and in lymphatics of connective tissues, but also occasionally in peripheral blood, urine, and sputum.
5 Blackfly takes a blood meal (ingests microfilariae)
6 Microfilariae pentrate blackfly's midgut and migrate to thoracic muscles
7 L1 larvae
8 L3 larvae
9 Migrate to head and blackfly's proboscis
i = Infective Stage
d = Diagnostic Stage

Illustration 10-5. Diagram showing the life cycle of *Onchocerca volvulus*, a filarial nematode which causes onchocerciasis, or River blindness. It is known as river blindness due to the vector, *Simulium damnosum,* breeding in fast flowing rivers. (SOURCE: PHIL 3413 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

The life cycle is similar to *W. bancrofti,* except that the intermediate hosts are various species from the genus *Simulium* (Black flies), the most important species is *Simulium damnosum.*

The microfilariae are ingested by a Black fly during a blood meal, from where they are carried to the midgut where they penetrate the epithelium and migrate, via the hemocoele, to the indirect flight muscles. Here they undergo two molts, L_1–L_3 and develop into infective L_3 larvae which move to the mouth parts. Development is completed in 6–9 days.

When the infected fly takes another blood meal the infective larvae are once again transmitted into another host (definitive host). The microfilariae are released from the mouth parts and transmitted directly into the hosts bloodstream. Molting takes place form L_3 - L_4 within 2-5 days and the larvae then migrate widely through the body under the skin and between muscles, ligaments and tendons. The final molt to L_5 occurs at 1.5–2.5 months after transmission. Male worms are known to mature in about four months later. Female worms initiate the formation of the nodules and the males may join later. The sexually mature female worms release microfilariae which migrate out from the nodules into the skin and other tissues, most significantly into the eye.

Morphology

The whitish adult worm lies coiled within capsules in the fibrous tissue. The female can measure up to 50cm while the males are shorter measuring up to 5 cm. The microfilariae of *O. volvulus* are unsheathed and are usually found in the dermis. They measure between 221-287µm long.

Image 10-7. *Onchocerca volvulus* microfilariae after being released by the adult female worm. They escape to the subcutaneous tissues and the eye and can be recovered with blood-free skin snips. (SOURCE: CDC)

Clinical Disease

Clinical manifestations are due to microfilariae in the epidermis.

Light infections may be asymptomatic or cause pruritis. This leads to scratching which can result in infection. Lyphadenopathy may also be a feature of early infection. After months or years, onchodermatitis results in secondary stage of thickening due to intradermal edema and pachydermis. There is a loss of elastic fibers resulting in hanging groin, hernias and elephantiasis of the scrotum. There is finally atrophy of the skin resulting in loss of elasticity. There is mottled depigmentation of the skin.

Ocular lesions are related to the intensity of the microfilariae in the skin. Ocular lesions include sclerosing keratitis, secondary glaucoma and cataract, coroidoretinitis and fluffy corneal opacities. The major complication of onchocerciasis is the development of lesions in the eye which may result in blindness or other distressing ocular diseases.

Laboratory Diagnosis

1. Analysis of Skin Snips

Small amounts of skin are collected by using a needle to raise the skin and then to slice about 1 mg of skin to a depth of 0.5µm. Snips are collected from several sites, usually the shoulders or the buttocks and sometimes the chest and calves. The snips are placed immediately in 0.5ml normal saline in a microtiter plate and left for 4 hours to allow the microfilariae to migrate out of the tissues. After four hours, the wells are examined using an inversion microscope. The microfilariae should still be moving and can be identified from the table below. The microfilariae can also be collected by filtration or centrifugation and the deposit containing microfilariae can be stained with Giemsa at pH 6.8.

2. Analysis of Biopsies

Biopsies of tissue nodules can be dabbed on to a slide to produce impression smears and then stained with Giemsa stain at pH 6.8 for the presence of microfilariae.

Recent advances in diagnostic methods includes and ELISA-based antibody detection assay which utilizes a cocktail of recombinant antigens. The advantages of using this test is that it is highly sensitive (almost 100% in onchocerciasis foci). It is also highly specific (100%), it also uses finger prick blood. Therefore, reducing the painful procedure of gaining a skin snip.

The disadvantages is that it requires advanced ELISA apparatus and reagents and cannot distinguish between past and present infections due to it detecting antibodies which stay present in the body for a long time after the infection. Another modern detection method is for Parasite DNA detection, which is based on the amplification of specific DNA sequences form microfilariae using molecular biology technology. The advantages of this technique is its exquisite sensitivity and detects active infections only. The disadvantages are that it requires specialized equipment and expensive reagents. Also it still requires a skin snip but a urine assay is a possibility for the future.

Thick microfilaria. Does not have a sheath. Head often spatulate. Nuclei do not extend to tip of tail. Found only in skin.

Mansonella streptocerca

Introduction

Microfilaria of *M. streptocerca* were first reported in the skin of a West African patient in 1922. These microfilaria are primarily found in the skin but have been also reported in the blood. This species occurs in Ghana, Cameroon and Zaire. The adults are poorly known, and occur in the cutaneous tissue of man and chimpanzee.

The microfilariae do not exhibit periodicity with the intermediate hosts being *Culicoides grahamii* and possibly other *Culicoides* species.

Life Cycle

The life cycle is the same as that of the blood *Mansonella* species.

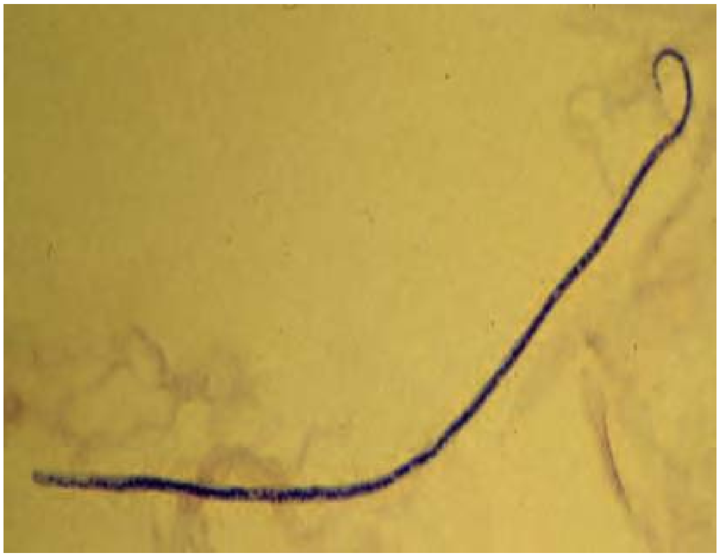

Image 10-8. Microfilaria of *Mansonella streptocerca.* From a skin snip, after a concentration procedure and hematoxylin stained. The microfilaria is typically unsheathed, and its body has a straight attitude. The tail is typically coiled ("shepherd's crook"), and nuclei extend to the end of the tail, as a single-cell row. (SOURCE: CDC)

Clinical Disease

Infection is characterized by pruritic dermatitis and hypopigmented macules.

Laboratory Diagnosis

Mansonella streptocerca can be diagnosed by demonstrating the microfilaria in a skin snip. Snips are collected from several sites, usually the shoulders and buttocks and sometimes the chest and calves. The snips are placed immediately in 0.5ml of 0.9% sodium chloride in a microtiter plate and left for four hours to allow the microfilaria to migrate out of the tissues. After four hours, the wells are examined using an inversion microscope. The microfilaria should still be moving and can be identified by staining with Giemsa at pH 6.8

Small, thin, microfilaria. Does not have a sheath. Nuclei extend to end of tail. Tail is hooked; its tip is rounded or forked. Found only skin.

Species	*Onchocerca volvulus*	*Mansonella streptocerca*
Distribution	Tropical Africa, Central and South America	West Africa
Vector	*Simulium* spp.	*Culicoides* spp.
Adult location	Subcutaneous nodules	Cutaneous connective tissue
Microfilariae location	Skin	Skin
Microfilariae size	280 - 330µm	180 - 240µm
Morphology	Broad spatulate head; No sheath, pointed tail	Curled tail; No sheath
Tail nuclei	Tail free from nuclei	Nuclei extend to tail tip

Table 10-4. Differential features of *Onchocerca volvulus* and *Mansonella streptocerca*. (SOURCE: CDC)

Dracunculus medinensis

Introduction

Dracunculus medinensis is a non-filarial parasite as it only has one uterus whereas filaria have two. It is usually associated with places where there is a lack of clean drinking water e.g. step wells in India, covered cisterns in Iran, and ponds in Ghana. The life cycle usually involves copepod intermediate host. They are parasitic in the connective tissue or coelom of vertebrates. The disease associated with this parasite is known as Dracunculiasis.

Life Cycle

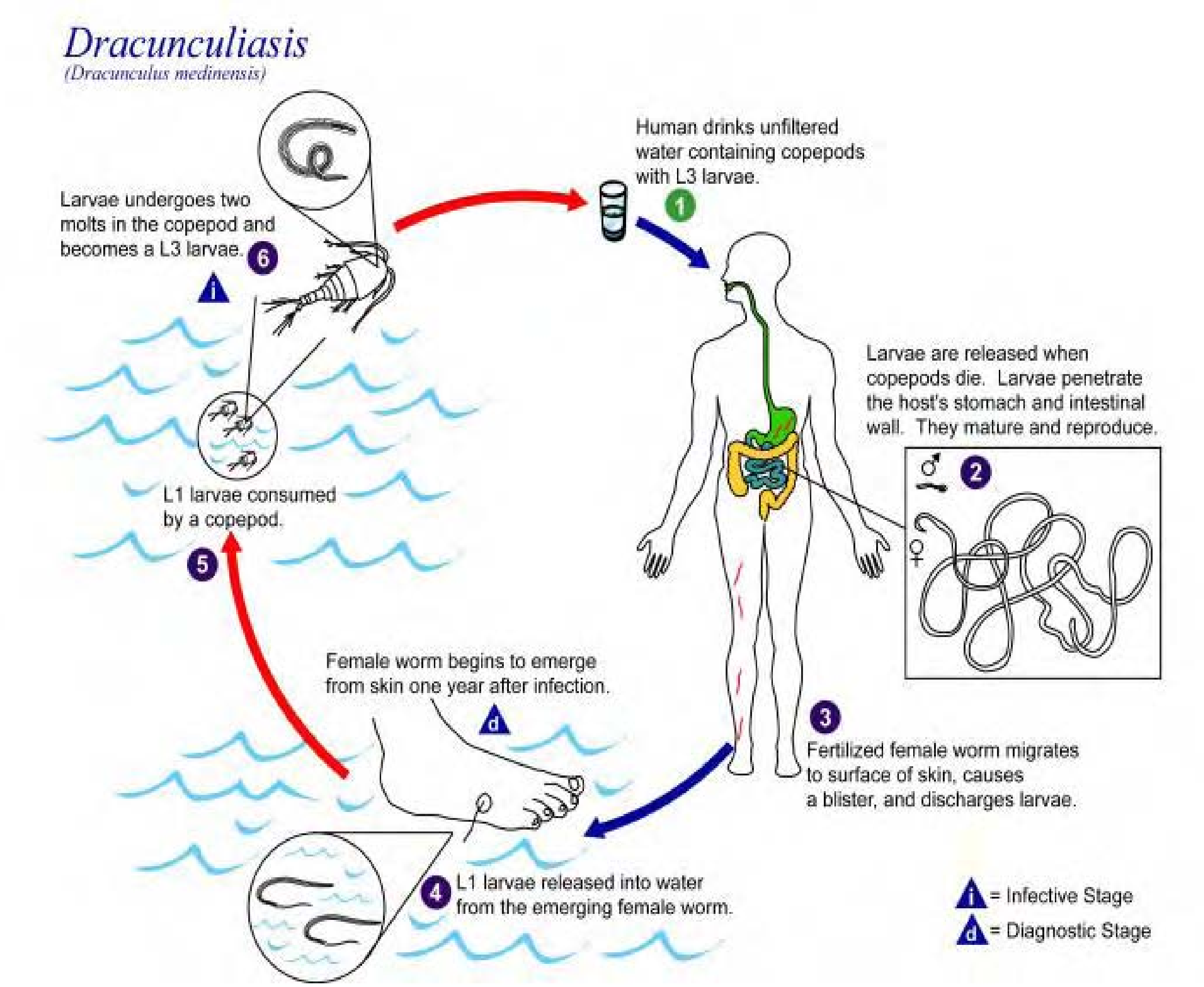
Dracunculiasis
(Dracunculus medinensis)
Human drinks unfiltered water containing copepods with L3 larvae.
1
Larvae are released when copepods die. Larvae penetrate the host's stomach and intestinal wall. They mature and reproduce.
2
♂
♀
3
Fertilized female worm migrates to surface of skin, causes a blister, and discharges larvae.
Female worm begins to emerge from skin one year after infection.
d
4
L1 larvae released into water from the emerging female worm.
5
L1 larvae consumed by a copepod.
6
Larvae undergoes two molts in the copepod and becomes a L3 larvae.
i
i = Infective Stage
d = Diagnostic Stage

Illustration 10-6. Diagram showing the life cycle of *Dracunculus medinensis*, Guinea worm. (SOURCE: PHIL 3391 - CDC/Alexander J. da Silva, PhD/Melanie Moser)

Mature female worms which are gravid with microfilariae migrate to the superficial layers of skin of humans, especially those regions which are most likely to come in contact with water, such as the ankle, foot, arms and shoulders. Here the worms secrete a substance (substance is unknown) which causes a blister to rise over its anterior end where it has pierced the lower layers. The blister eventually forms into an ulcer which on contact with water, the uterus is projected out of the ulcer cavity, and a cloud of milky white secretion, containing hundred of active larvae, is released. Once out of the water again the uterus dries and shrivels preventing the release of further larvae.

If the microfilariae are ingested by an appropriate species of *Cyclops*, they break though the soft mid-intestine wall and come to lie in the body cavity. The larvae undergo two molts and become infective in approximately three weeks. Humans become infected by accidentally ingesting through drinking water the infective *Cyclops.* Upon ingestion the larvae are activated to penetrate through the gut wall, and migrate through the tissues, molting twice and finally becoming lodges in the viscera or subcutaneous tissues. Maturation of the worms is slow taking about one year to reach sexual maturity before the females are ready to migrate to the skin to release their larvae.

Morphology

The adult female worm measure up to one meter in length whereas the male measures about 2cm.

Clinical Disease

After ingestion of the Cyclops, there is no specific pathology associate with the mucosal penetration and larval maturation in the deep connective tissues. Erythema and tenderness can be associated with blister formation. The patient can also exhibit vomiting, diarrhea, asthmatic attacks. Symptoms usually subside when the lesion erupts. If the worm is removed, healing usually occurs without any problems. If the worm is damaged or broken during removal, there may be intense inflammatory reaction with possible cellulitis along the worms migratory tract. This can result in arthritis and synovitis.

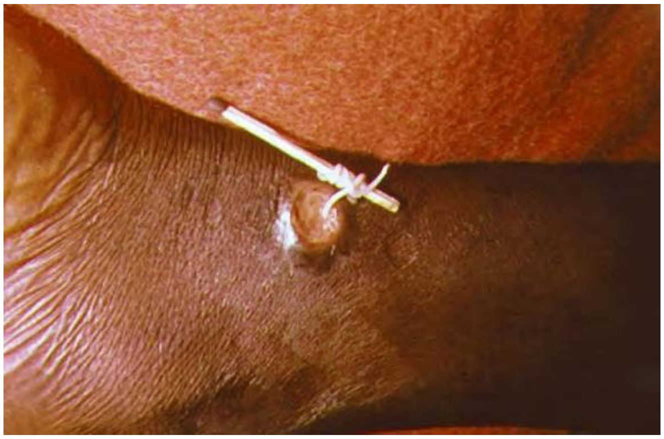

Figure 10-9. Female *Dracunculus medinensis* worm (Guinea worm) emerging out of a typical ulcer. Adult worms emerge from these ulcers on contact with water to release their microfilaria. The most effective method for removing these worms are to slowly wind them around a piece of stick, being careful not to break the worm in two. (SOURCE: PHIL 1342 – CDC)

Laboratory Diagnosis

The best remedy for removing the adult worm is a slow process of daily gently rolling the worm around a small stick and slowly pulling it out of the skin. With this method you must be careful not to pull apart the worm as it will recoil back into the skin and cause secondary infections.

This parasite is currently being approached with a strict control program. The program includes stopping people from drinking infected water, putting muslin over water collection jars, educating the communities about the parasite, and adding temphos to the water to kill it off.

Chapter 11.

Babesia, Trypanosomes, and Leishmania

Babesia species

Introduction

Babesia species are protozoan parasites of domestic and wild animals. They belong to the subclass Piroplasmia and are commonly referred to as ‘piroplasms’ due to the pear-like shaped merozoites which live as small intra-erythrocytic parasites. They commonly infect mammals, particularly cattle, sheep, goats, horses, pigs, dogs and cats and occasionally man.

Species infective to humans are the cattle form *Babesia bovis* which can often be fatal and *Babesia microti* which is less pathogenic. Until recently *B. microti* was confined to the United States but is now becoming a significant tick-borne disease of man in other temperate climates as well.

Human infections have been found in Europe and North America. The infection is known as Babesiosis, it can also be described as ‘redwater fever’ or ‘tick fever’ and has a major impact on the livestock industries in many countries.

What is unusual with this parasite’s life cycle is the development in the vector. They use the one-host ticks, belonging to the genus *Boophilus.* The parasites are passed to the eggs and hence to the larval stages which can thus become infective after the adult tick dies. This process is known as transovarial transmission.

The ticks which are known to carry the parasite of *Babesia bovis* are *Boophilus microplus, B. decoloratus* and *B. annulatus.*

Life Cycle

Human babesiosis is a zoonosis, acquired by tick bite when individuals accidentally interact with the natural life cycle of the parasite.

The life cycle is best known for *Babesia canis* which infects dogs, but it is generally the same in each of the one-tick hosts and the definitive host.

Babesia bovis

When the tick bites, **sporozoites** are injected into the blood stream and penetrate the erythrocytes. In contrast to the malaria life cycle, there is no tissue stage for *Babesia bovis. Babesia* multiplies in the red cell by budding in contrast to schizogony in *Plasmodium* species. The red cell ruptures and daughter parasites invade new erythrocytes for further asexual multiplication. Some of the **sporozoites** injected by the tick vector follow a different path of intra-erythrocytic development, growing slowly and "folding" to form accordion-like structures which are destined to undergo further development in the tick vector. Within the intestine of the tick, the accordion-like stage eventually fuses with another, to form a **zygote**. Further development outside the intestine occurs in a variety of tissues, the salivary glands and ovaries being especially important for transmission. **Sporozoites** in tick salivary glands are injected into the mammalian host at the next blood meal. Transovarial transmission of *Babesia bovis* also takes place so that newly hatched onto adult stages can then take place.

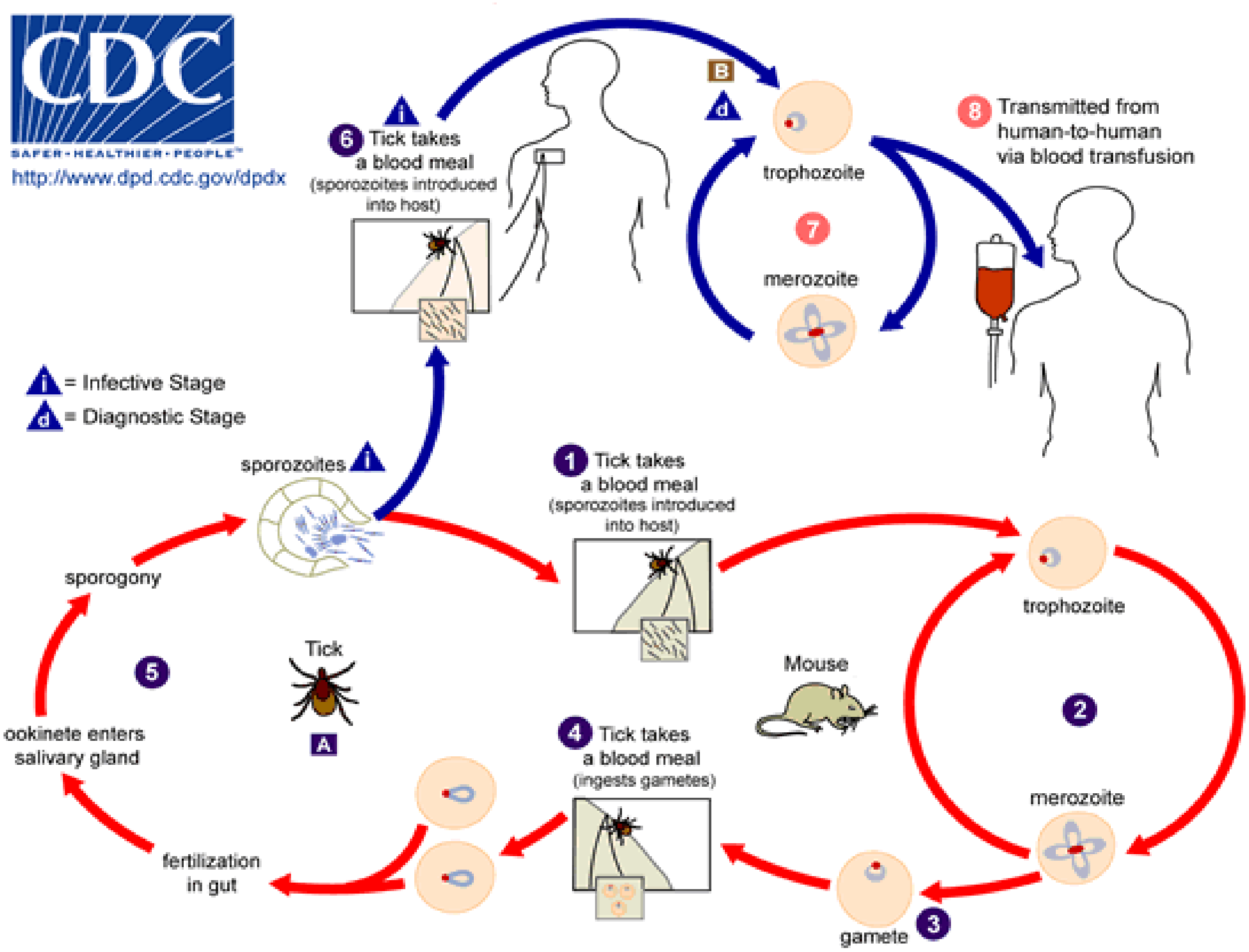
CDC
SAFER·HEALTHIER·PEOPLE™
http://www.dpd.cdc.gov/dpdx
i
6 Tick takes a blood meal (sporozoites introduced into host)
B
d
trophozoite
7
merozoite
8 Transmitted from human-to-human via blood transfusion
i = Infective Stage
d = Diagnostic Stage
sporozoites i
1 Tick takes a blood meal (sporozoites introduced into host)
trophozoite
sporogony
Tick
5
A
Mouse
2
ookinete enters salivary gland
4 Tick takes a blood meal (ingests gametes)
merozoite
fertilization in gut
gamete 3

Illustration 11-1. Generalized life cycle of the parasite *Babesia*, which causes the disease babesiosis in man. (SOURCE: CDC/DPDx)

Babesia microti

In the small mammal host of *Babesia microti*, **sporozoites** from the tick vector first enter lymphocytes and undergo **merogony**, the daughter parasites of which then enter erythrocytes.

Babesia microti do not undergo transovarial transmission, but once a larva has become infected from a mammalian host they are able to pass on the infection transstadially to the nymph.

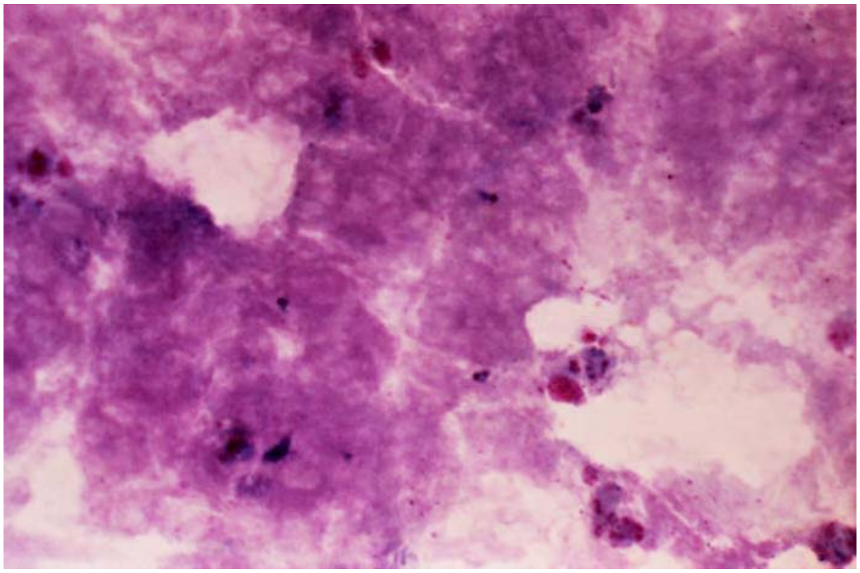

Image 11-1. Diagnosis of *Babesia* species depends on the observation of the intraerythrocytic organisms in blood smears. Pear shaped microorganisms (2-5µm) and tetrads are the diagnostic shape of the parasite. (SOURCE: PHIL 3899 – CDC/Dr. George Healy)

Clinical Disease

Babesia bovis - Patients who are particularly at risk are those who have had a splenectomy. The patient may feel vaguely unwell at first but by the time the diagnosis has been made, is usually very ill, with fever, prostration, jaundice, anemia and hemoglobulinuria. Nausea, vomiting and diarrhea have also been recorded. Unlike malaria symptoms, the symptoms of babesiosis do not exhibit periodicity.

Babesia microti - Most human infections are subclinical. Where clinical illness develops, the incubation period is 1 to 3 weeks, occasionally up to six weeks. The illness usually begins gradually, with anorexia and fatigue, plus fever (without periodicity), sweating, rigors and generalized myalgia. Physical examination may reveal only fever, but may also show mild splenomegaly and occasionally mild hepatomegaly.

Laboratory Diagnosis

Definitive diagnosis depends upon finding parasites on blood film examination which can be detected 2 to 4 weeks after a tick bite. Hamster inoculation and serology have also been used for diagnosis.

1. Microscopic Examination

Babesia bovis

Babesia bovis are pear shaped, oval or round and may exist in pyriform pairs. There may be 1 to 8 parasites per red cell. Ring forms can be confused with malaria parasites, especially *Plasmodium falciparum*. However, in contrast to *Plasmodium* species, *Babesia* do not form pigment, do not cause alterations in red cell morphology and finally do not exhibit the Maurer's clefts of *Plasmodium falciparum*, the Schüffner's dots of *Plasmodium vivax*, or the James's dots of *Plasmodium ovale.*

The "Maltese cross form" is unique to *Babesia* but in its absence it may be very difficult to distinguish young ring forms of *Plasmodium falciparum*, from *Babesia*. The absence of pigment cannot be relied upon, as young rings of *Plasmodium* do not exhibit pigment. *Babesia*, are smaller than malaria parasites, and in some of the larger rings there is white vacuole containing erythrocyte stroma, instead of the pink vacuole seen in malaria. *Babesia* parasites do not form schizonts.

Babesia microti

Ring, rod shaped, pyriform, amoeboid, and "Maltese cross" forms are seen. In heavy infections different stages may be noted in the same red cell. Intra-erythrocytic stages measure approximately 2 by 1.5µm. In very high parasitaemias, extracellular merozoites are found singly or as a syncytial structure. Peak parasitaemia varies between less than 1% to approximately 10%.

2. Serodiagnosis

The Indirect Fluorescent Antibody Test (IFAT) is available for both *B. bovis* and for *B. microti* and is the most useful serological test for early diagnosis.

3. Animal Inoculation

This is not routinely used for diagnosis but *B. microti* grows well in hamsters and can serve as a confirmatory test.

Toxoplasma gondii

Introduction

Toxoplasma gondii, the causative organism of toxoplasmosis, was first observed in 1927 in the gondi, a North African rodent. The first human case of toxoplasmosis was also reported that year. The organism is a coccidian protozoa belonging to the sub-phylum Apicomplexa and has a world wide distribution occurring in all warm-blooded animals.

Cats are the definitive hosts and they become infected by ingesting oocysts or cysts in tissues of paratenic hosts, such as mice, or transplacentally. Man becomes infected either by direct ingestion of oocysts from a cat or by eating raw or undercooked meat. Those who handle raw meat are particularly at risk. Infection can be transmitted transplacentally.

Life Cycle

The development of the enteroepithelial (sexual) cycle in a cats intestine is brought about by the ingestion of sporulated oocysts of a mouse with cysts. The pre-patent period up to the shedding of the oocysts varies with the stage of *T. gondii* ingested, for example only 3–10 days if the cat has ingested a mouse containing cysts, but about 19–20 days or longer after direct infection with oocysts or ingestion of a mouse containing only tachyzoites. Women most at risk of delivering an infected infant are those who acquire the infection just prior to gestation.

Humans can acquire infection by:

- Accidental ingestion of the oocyst shed in the cats feces
- Ingestion of the tachyzoite in infected milk or transplacentally
- Ingestion of the tissue cyst in undercooked or raw meat.
- Transplant of an infected organ in a seronegative recipient

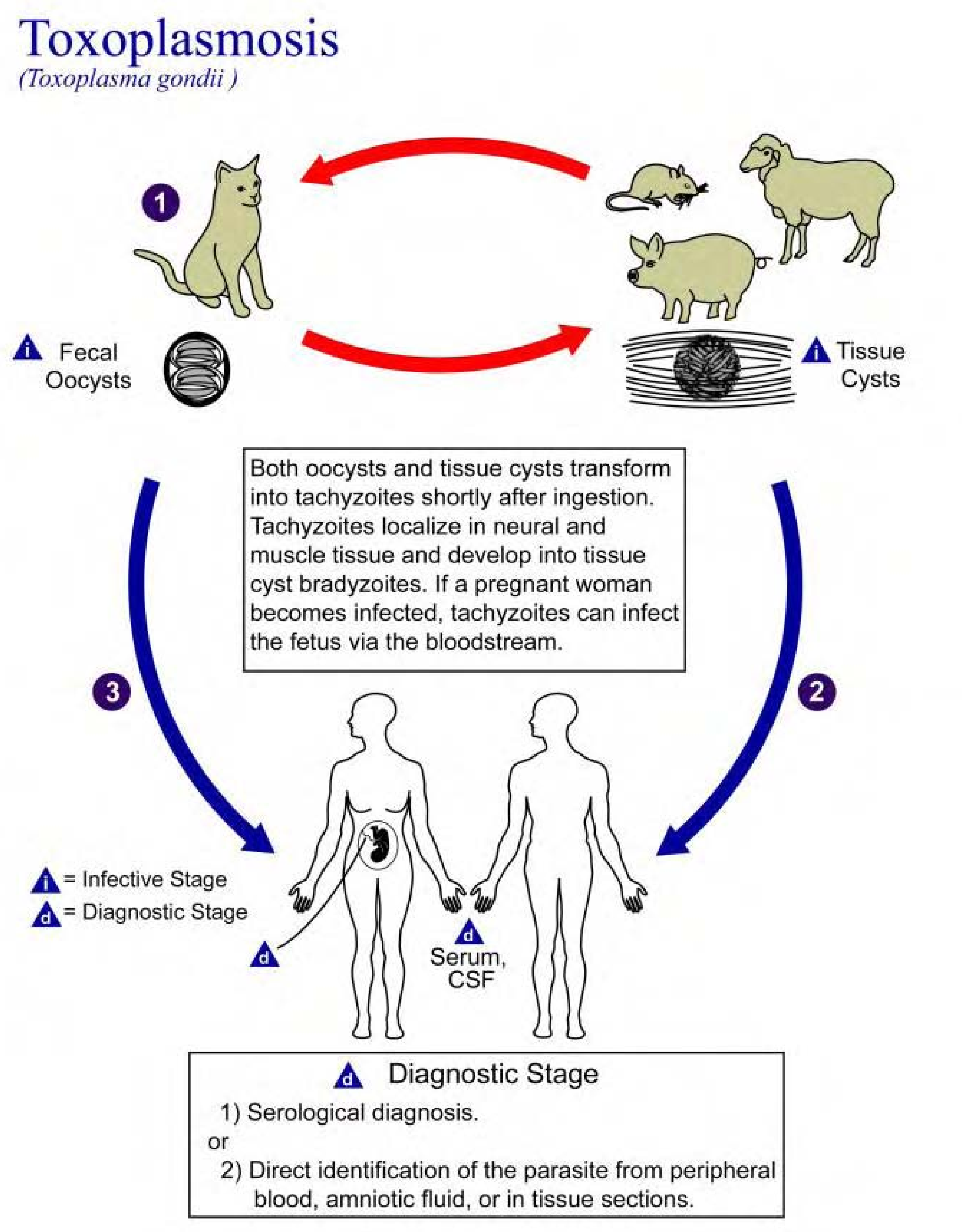
Toxoplasmosis
(Toxoplasma gondii)
1
Fecal Oocysts
Tissue Cysts
3
2
= Infective Stage
= Diagnostic Stage
d
Serum, CSF
Diagnostic Stage

Both oocysts and tissue cysts transform into tachyzoites shortly after ingestion. Tachyzoites localize in neural and muscle tissue and develop into tissue cyst bradyzoites. If a pregnant woman becomes infected, tachyzoites can infect the fetus via the bloodstream.

1) Serological diagnosis.
or
2) Direct identification of the parasite from peripheral blood, amniotic fluid, or in tissue sections.

Illustration 11-2. Life cycle of *Toxoplasma gondii*, causes toxoplasmosis in man. (SOURCE: PHIL 3421 – CDC/Alexander J. da Silva, PhD/Melanie Moser)

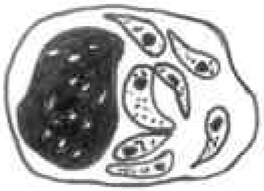

Illustration 11-3. Diagrammatic illustration of a *Toxoplasma gondii* trophozoite in a macrophage of a vertebrate. (SOURCE: Unknown)

Clinical Disease

Serological evidence has shown that approximately one third of the world's population has *Toxoplasma* antibodies. This suggests that the majority of infections are benign with most people exhibiting few or no symptoms, but fever and swelling may be seen. However, *Toxoplasma gondii* can cause severe illness in congenital infections, acquired infections and in immunocompromised patients. This may lead to ocular toxoplasmosis and ultimately to fatal CNS disorders such as encephalitis.

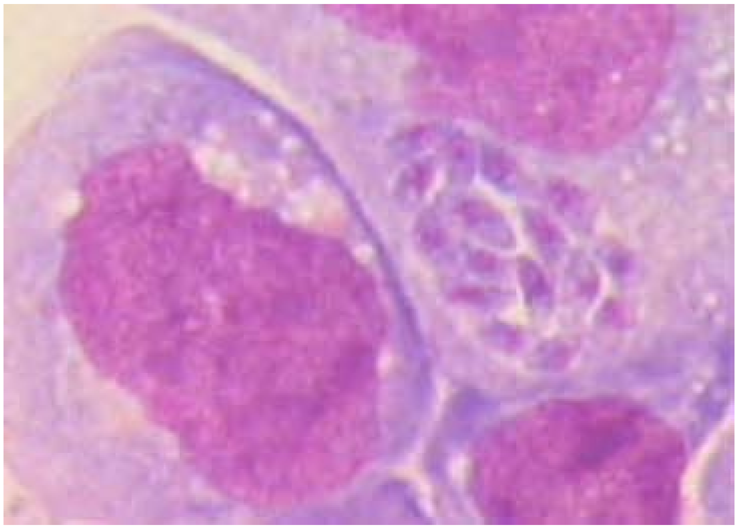

Image 11-2. *Toxoplasma gondii* tissue cyst containing 8–20 parasites (Giemsa stain) (SOURCE: CDC)

Congenital Toxoplasmosis

This occurs approximately in 1 per 1000 pregnancies. It can cause severe damage to and even death of the fetus. Proliferation of tachyzoites leads to intracellular calcification, choroidoretinitis, hydrocephaly, psychomotor disturbances and convulsions. A small, proportion of babies who are asymptomatic at birth develop retinochoroiditis or mental retardation as children or young adults. When a mother is first exposed to the parasite in later pregnancy the infant is likely to be less severely damaged or asymptomatic.

Acquired Infections

Infections with *T. gondii* are often mild with flu-like symptoms thus they often go unnoticed. However lymphadenopathy is the most easily recognized symptom and it can be accompanied by fever, headache and myalgia. Toxoplasmosis may also produce infectious mononucleosis like symptoms. Ocular toxoplasmosis is also a common manifest however it is not yet proven whether this is due to congenital or acquired infections. Other manifestations of *Toxoplasma* infections are meningoencephalitis, hepatitis, pneumonitis and myocarditis.

Immunocompromised Patients

Toxoplasmosis has been shown to occur as an opportunistic pathogen in immunocompromised patients and can cause severe complications. Toxoplasmosis in immunocompromised patients almost always arises from a reactivation of latent infections. Conditions which can predispose to toxoplasmosis are malignancies, organ transplants, leukemias and patients with acquired immune deficiency syndrome (AIDS). In immunocompromised patients, the central nervous system is primarily involved with diffuse encephalopathy, meningoencephalitis or cerebral mass lesions. *Toxoplasma* encephalitis has been reported as a life-threatening among patients with AIDS.

Laboratory Diagnosis

1. Serological Techniques

The detection of toxoplasma specific antibodies is most commonly used in clinical laboratories. Specific IgG antibodies typically persist for life whereas specific IgM antibodies begin to decline after several months. Most laboratories carry out preliminary tests for IgG antibodies and more definitive tests including IgM and IgA are carried out in reference laboratories. The Sabin-Feldman Dye Test is the benchmark for detecting the presence of specific antibodies. It measures the total amount of specific antibody in a serum which is capable of participating in antibody-mediated killing of tachyzoites by complement. This test involves the use of live tachyzoites which are derived from infected mice or rats. Because of the use of live organisms, this test is not recommended in the use of routine laboratories and is thus only employed in reference centers.

2. Isolation Techniques

Culture of parasites in animals is the best overall method but it can take up to six weeks before the result is available and is thus a disadvantage. Tissue culture is more rapid taking three or four days to obtain a result, but is not as sensitive.

3. Antigen Detection

The direct detection of very small amounts of specific nucleic acid has been made possible by the introduction in 1985 of the polymerase chain reaction (PCR). This technique results in the amplification of a specific fragment of DNA from within the parasite genome which is detected by ethidium bromide staining, following gel electrophoresis. PCR is so sensitive it should detect *Toxoplasma* DNA in one cyst. However this may indicate a latent infection rather than an active infection. However its sensitivity may create problems since it will detect very small amounts of DNA from latent as well as active infections and it does not differentiate between cyst and tachyzoite DNA. Thus samples like blood, CSF, urine and amniotic fluid should be used as they do not contain the latent stages. PCR shows great promise but as yet is still labor intensive and expensive for routine use in the laboratory.

Trypanosoma species

Introduction

Trypanosomes are hemoflagellates and three species of the genus *Trypanosoma* are responsible for disease in humans such as sleeping sickness.

Trypanosomes occur in the blood of the majority of vertebrate animals. The life cycle involves intermediate host, which usually is an insect. Many species of trypanosomes can live in harmony with their hosts producing no pathogenic effect, but the best known species are those that are pathogenic to their definitive hosts. The disease in caused by the pathogenic types is called trypanosomiasis.

Salivarian Trypanosomes

Trypanosoma brucei rhodesiense and *Trypanosoma brucei gambiense* - The metacyclic trypanosomes are found in the proboscis of the insect vector - infection is therefore inoculative. The above are the causative agents of African trypanosomiasis. It is a zoonotic species in that it multiplies in the blood of a range of many mammals including man.

Trypanosoma brucei rhodesiense causes acute sleeping sickness in East Africa, while *T. b. gambiense* causes chronic sleeping sickness in West Africa.

These are known as salivarian trypanosomes as they complete their development in the salivary system (anterior portion of the vector). Transmission takes place by inoculation of the metacyclic stage.

Stercorarian Trypanosomes

Trypanosoma cruzi - The metacyclic trypanosomes occupy a posterior position in the gut of the insect vector and are passed out in the feces - infection is therefore contaminative. This is the causative agent of American Trypanosomiasis.

These trypanosomes are known as stercocarian as they complete their development in the posterior region of the vector, so that the infective forms appear in the insect’s feces. Hosts are infected by the contaminative route.

African Trypanosomiasis

Life Cycle

Transmission from one vertebrate to another is carried out by blood-sucking invertebrates, usually an insect. The vector for African Trypanosomiasis is the Tsetse fly, *Glossina* spp*.* which cause the diseases *Trypanosoma brucei gambiense* and *Trypanosoma brucei rhodesiense.*

Metacyclic (infective) trypomastigotes are inoculated through the skin when a tsetse fly takes a blood meal. The parasites develop into long slender trypomastigotes which multiply at the site of inoculation where ulceration occurs. The trypanosomes continue to develop and then may invade the lymphatic tissues, the heart, various organs and in later stages, the central nervous system. Trypomastigotes are taken up by the tsetse fly (male and female) during a blood meal. The parasites develop in the midgut of the fly where they multiply. 2-3 weeks later the trypomastigotes move to the salivary glands transforming from epimastigotes into metacyclic (infective) trypomastigotes. The tsetse fly remains infective for life i.e. about three months.

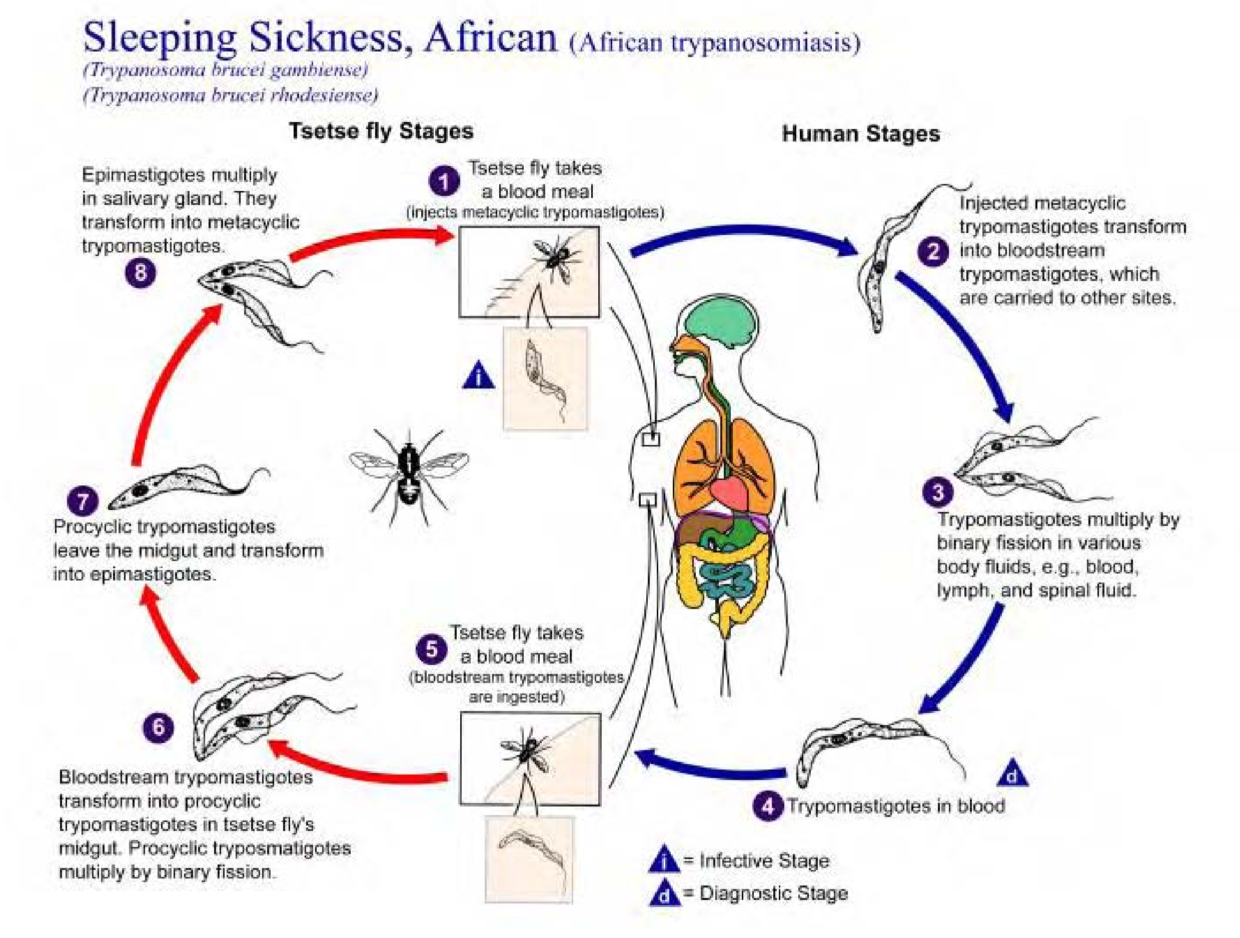
Sleeping Sickness, African (African trypanosomiasis)
(Trypanosoma brucei gambiense)
(Trypanosoma brucei rhodesiense)
Tsetse fly Stages
Human Stages
1 Tsetse fly takes a blood meal (injects metacyclic trypomastigotes)
2 Injected metacyclic trypomastigotes transform into bloodstream trypomastigotes, which are carried to other sites.
3 Trypomastigotes multiply by binary fission in various body fluids, e.g., blood, lymph, and spinal fluid.
4 Trypomastigotes in blood
5 Tsetse fly takes a blood meal (bloodstream trypomastigotes are ingested)
6 Bloodstream trypomastigotes transform into procyclic trypomastigotes in tsetse fly's midgut. Procyclic tryposmatigotes multiply by binary fission.
7 Procyclic trypomastigotes leave the midgut and transform into epimastigotes.
8 Epimastigotes multiply in salivary gland. They transform into metacyclic trypomastigotes.
i
d
i = Infective Stage
d = Diagnostic Stage

Illustration 11-4. Generalized life cycle of the *Trypanosoma* spp. which causes African Trypanosomiasis. (SOURCE: PHIL 3418 – CDC/Alexander J. da Silva, PhD/Melanie Moser)

The mode of transmission mentioned above, metacyclic transmission, requires to be separated from mechanical transmission, a process in which trypanosomes survive, for a short time, on and about mouth parts of an insect and are inoculated into a new host when the vector bites again, without undergoing any developmental cycle.

Metacyclic transmission requires a lapse of time to allow the trypanosomes to reach an infective stage by a particular developmental sequence in the vector, usually a period of several days.

Morphology

The parasite is an elongated cell with single nucleus which usually lies near the centre of the cell. Each cell bears a single flagellum which appears to arise from a small granule - the kinetoplast. The kinetoplast is a specialized part of the mitochondria and contains DNA. The length and position of the trypanosome's flagellum is variable. In trypanosomes from the blood of a host the flagellum originates near the posterior end of the cell and passes forward over the cell surface, its sheath is expanded and forms a wavy flange called an undulating membrane.

Development is characterized by the occurrence of three types of blood forms (polymorphic), these are:

1) **Slender forms**: long and thin, about 29µm long, free flagellum.

2) **Stumpy forms**: thick and short, average length 18µm, typically no free flagellum, but a short one may be present.

3) **Intermediate forms**: about 23µm long with a moderately thick body and a free flagellum of medium length.

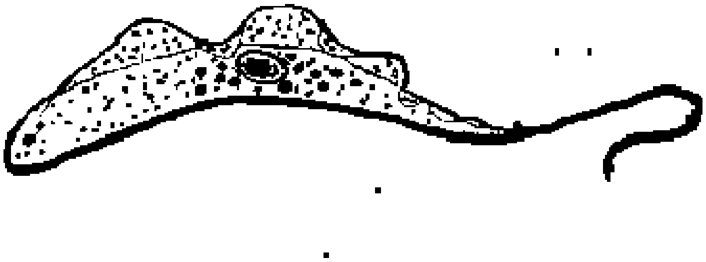

Illustration 11-5. Diagrammatic illustration of a typical trypanosome. (SOURCE: Unknown)

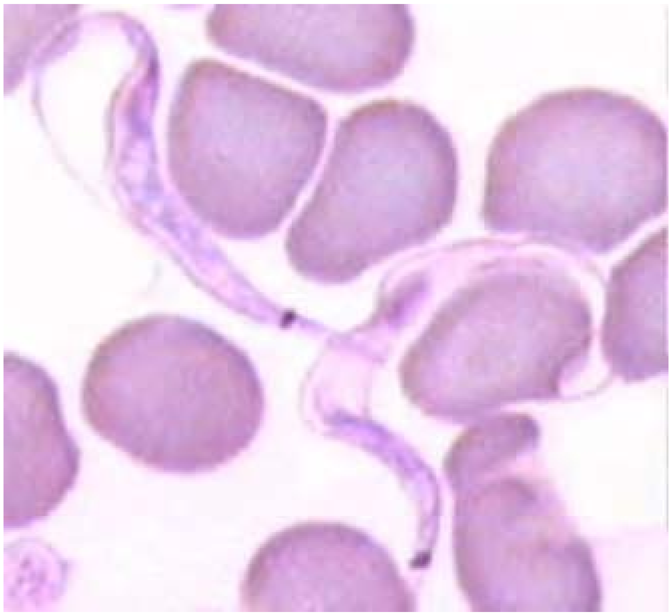

Image 11-3. *Trypanosoma brucei gambiense* and *T. b. rhodesiense:* two forms of trypomastigote can be seen in peripheral blood: one is long slender, 30 µm in length, and is capable of multiplying in the host, the other is stumpy, not dividing, 18 µm in length. (SOURCE: CDC)

Clinical Disease

The early stages of African trypanosomiasis may be asymptomatic and there is a low grade parasitiaemia. This period may last for several weeks to several months. The disease may terminate untreated at this stage or go on to invade the lymph glands. Invasion of the lymph glands is usually accompanied by a high irregular fever with shivering, sweating and an increased pulse rate. The lymph glands near the bite often become swollen, in *T. b.* gambiense the glands at the back of the neck and *T. b.* rhodesiense usually the glands under the jaw are affected (Winterbottom's sign). As the disease progresses, edema of the eyelids, face and sleeplessness are features along with increasing lethargy and listlessness.

Trypanosomes may invade the central nervous system giving symptoms of meningoencephalitis, confusion, apathy, excessive sleeping and incontinence. At this stage, the cerebrospinal fluid (CSF) usually contains mononuclear cells and a few trypanosomes may be detected. If untreated, character changes, mental deterioration and coma develops, finally resulting in death. Such signs are more commonly seen with *gambiense* than in *rhodesiense* in which patients often die before these symptoms develop fully.

Laboratory Diagnosis of African trypanosomiasis

Laboratory diagnosis of African Trypanosomiasis is by:

- Examination of blood for the parasites
- Examination of aspirates from enlarged lymph glands for the parasites
- Examination of the CSF for the parasite

- Detection of trypanosomal antibodies in the serum

1. Examination of Blood

a) Thick and Thin Blood Films

Thick and thin blood films are made and stained with Fields stain and examined as for malaria parasites

b) Triple Centrifugation Technique

This method is carried out as follows:

i. 5 to 10ml of citrated blood is centrifuged at 2000rpm for 5 minutes to pack the red blood cells.
ii. The plasma and white cell layer are removed by a Pasteur pipette and transferred to a clean centrifuge tube.
iii. This is centrifuged for a short time in order to deposit any red blood cells carried over.
iv. The supernatant fluid is removed by pipette to a clean tube.
v. This is centrifuged at 5000rpm for 10 minutes.
vi. The supernatant fluid is removed with a pipette and discarded.
vii. The deposit is examined microscopically for trypanosomes.

c) Miniature anion-exchange centrifugation technique.

Heparinized blood is passed through an anion exchange column. As the blood travels down the column the red cells are adsorbed while the less strongly charged trypanosomes are washed through with saline. The eluate is centrifuged and examined microscopically for motile trypanosomes.

d) Buffy Coat Examination

Trypanosomes are centrifuged in a microhaematoctit tube for five minutes. Parasites can be seen microscopically at the junction of the packed red cells and plasma.

2. Examination of Lymph Gland Aspirates

The aspirate can be examined microscopically by making a wet preparation, or if there is not much material, it can be allowed to dry on a slide and then stained with either rapid Field’s stain or with Giemsa and examined microscopically.

3. Examination of CSF

In the late stages of African trypanosomiasis, trypanosomes may be found in the CSF together with IgM - containing morula (Mott) cells, lymphocytes and other mononuclear cells. Once the CSF has been collected it **must be examined as soon as possible.** The parasites are unable to survive for more than 15-20 minutes in CSF once it has been removed. The parasites become inactive, are rapidly lysed and will not therefore be detected. The CSF should be examined wet and spun down in a sterile tube and a film made from the deposit. The film is then stained with rapid Field's or Giemsa and examined microscopically.

NB. It is impossible to distinguish between *T. b. gambiense* from *T. b. rhodesiense* on a stained film as the two subspecies which infect man are identical.

American Trypanosomiasis

Trypanosoma cruzi occurs throughout South and Central America, especially in Brazil, Argentina and Mexico causing the disease known as Chagas' disease. It is estimated that over 24 million people are infected with this species. It is a zoonotic parasite with over 150 species of wild animals known to harbor the parasites, for example opossums, dogs, rates, pigs and cats.

It is transmitted to man by brightly colored bugs belonging to the Reduviidae family, subfamily Triatominae. All stages of these bugs are known to become infected.

The bugs live in the crack of the walls and vegetal roofs of the poorly maintained houses, coming out at night to feed on the exposed parts of the host's body.

Image 11-4. Insect vector of *Trypanosoma cruzi*, belongs to colorful insect Triatominae, also known as the kissing bug. (SOURCE: PHIL 2538 - CDC/World Health Organization)

Life Cycle

Metacyclic trypomastigotes are deposited in feces on the skin as the **triatomine bug** (reduviid bug) feeds. The bug usually bites round the edges of the mouth and eyes. The trypomastigotes are either rubbed into the skin by scratching the irritated area or penetrate the conjunctiva or membranes of the nose and mouth. Trypomastigotes become amastigotes in localized reticuloendothelial cells and multiply. The amastigotes develop into trypomastigotes which are released into the blood when the cell ruptures. No multiplication of the parasite takes place in the blood in its trypomastigote stage. The trypomastigotes reach tissue cells especially heart muscle, nerves, skeletal muscle and smooth muscle of the gastrointestinal system by way of the blood and lymphatic system. The trypomastigotes become amastigotes and multiply forming pseudocysts. Within the pseudocyst some amastigotes become elongated and develop first into epimastigotes and then trypomastigotes. When the cell ruptures the trypomastigotes are released into the blood and continue to circulate while others invade further tissue cells. The life cycle completes when a triatomine bug vector ingests circulating trypomastigotes. In the vector the trypomastigotes transform and develop into epimastigotes, multiply by binary fission in the gut of the bug. After about 10-15 days, metacyclic trypomastigotes are formed and can be found in the hindgut of the bug.

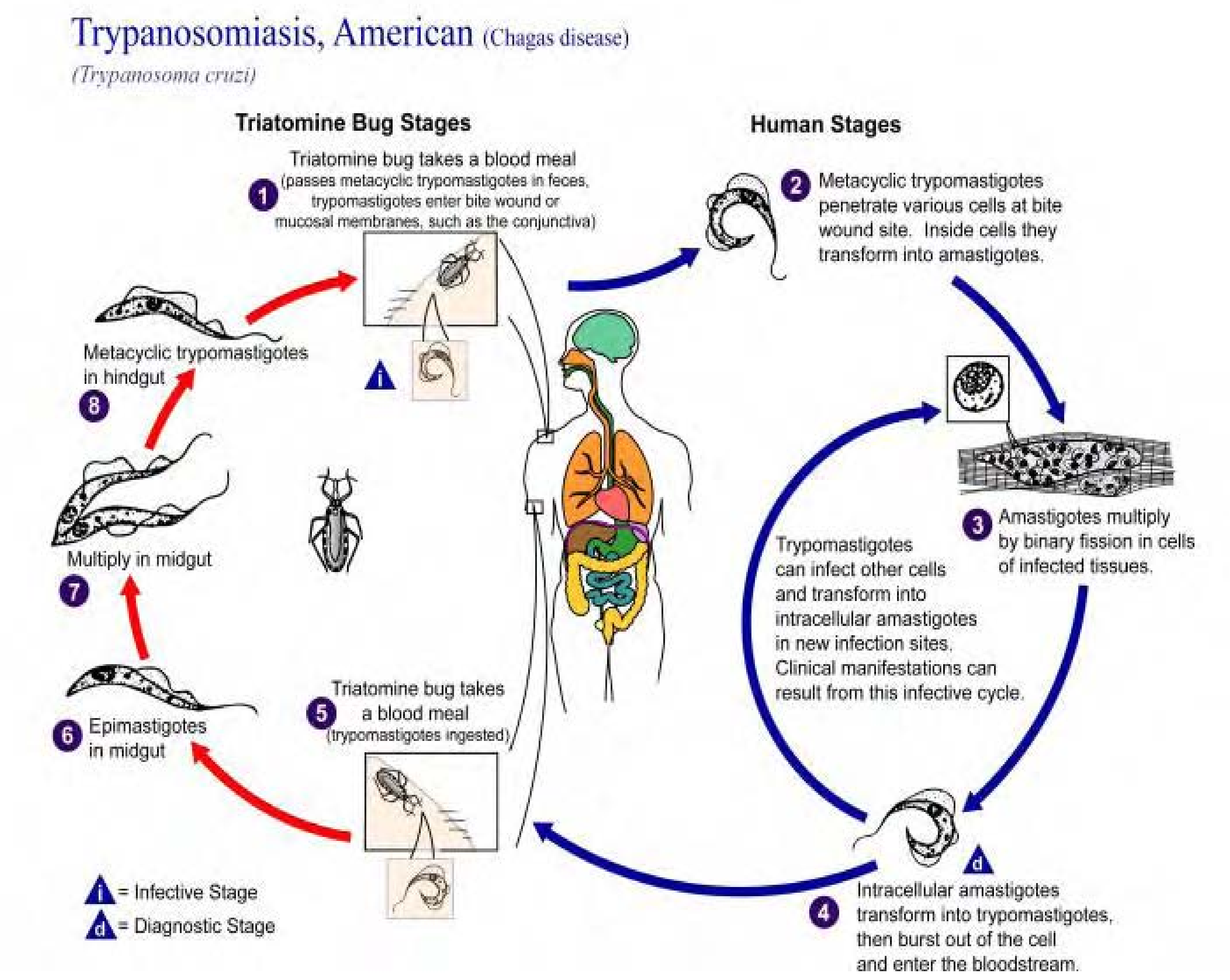
Trypanosomiasis, American (Chagas disease)
(Trypanosoma cruzi)
Triatomine Bug Stages
Human Stages
1 Triatomine bug takes a blood meal (passes metacyclic trypomastigotes in feces, trypomastigotes enter bite wound or mucosal membranes, such as the conjunctiva)
2 Metacyclic trypomastigotes penetrate various cells at bite wound site. Inside cells they transform into amastigotes.
3 Amastigotes multiply by binary fission in cells of infected tissues.
Trypomastigotes can infect other cells and transform into intracellular amastigotes in new infection sites. Clinical manifestations can result from this infective cycle.
4 Intracellular amastigotes transform into trypomastigotes, then burst out of the cell and enter the bloodstream.
5 Triatomine bug takes a blood meal (trypomastigotes ingested)
6 Epimastigotes in midgut
7 Multiply in midgut
8 Metacyclic trypomastigotes in hindgut
i
d
i = Infective Stage
d = Diagnostic Stage

Illustration 11-6. Generalized life cycle of the American trypanosomes, *Trypanosoma cruzi*, which is known to case Chagas' disease. (SOURCE: PHIL 3384 – CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology

Trypanosoma cruzi has a single form (monomorphic), about 20μm in length, and characteristically curved. The kinetoplast is large, considerably larger than the *Trypanosoma brucei* species already discussed. They sometimes appear as a bulge at the posterior end. The flagellum is medium in length.

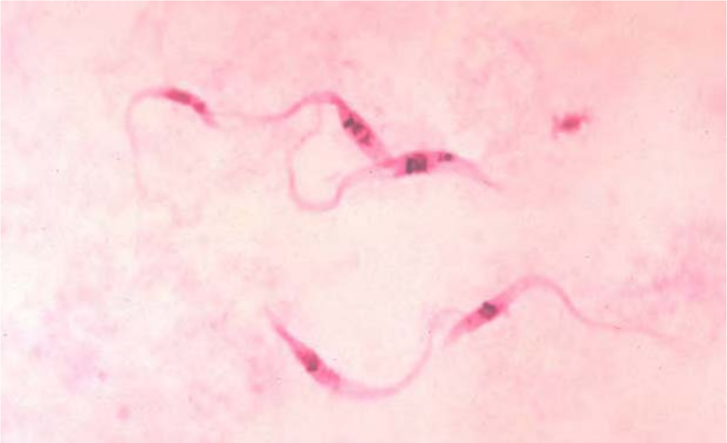

Image 11-5. *Trypanosoma cruzi* hemoflagellate in blood sample (SOURCE: PHIL 545 - CDC)

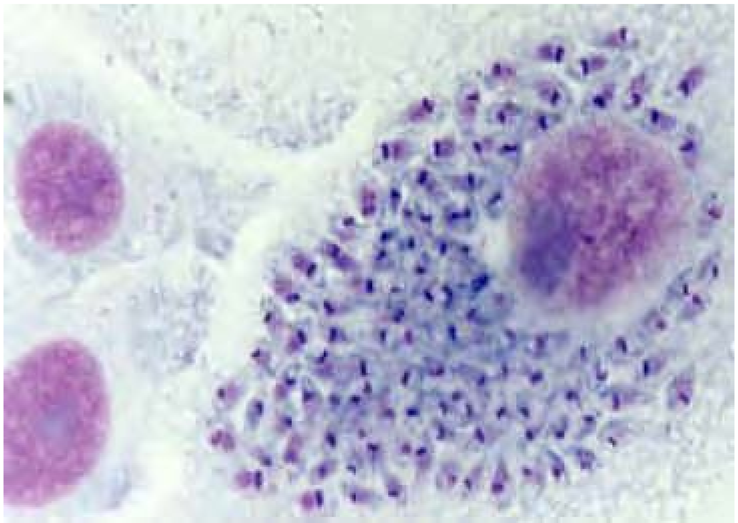

Image 11-6. Multiplication of *Trypanosoma cruzi in man* only occurs in the amastigote phase, which grows in a variety of tissue cells especially muscle. In vitro infected fibroblast showing a large number of intracellular amastigotes. (Giemsa stain) (SOURCE: Unknown)

Clinical Disease

Many people infected with *T. cruzi* remain asymptomatic and free from Chagas' disease or experience only an acute infection without progressing to the chronic stage. The most severe form of the disease is most commonly seen in children younger than five years of age.

Multiplication of *T. cruzi* at the site of infection can produce an inflamed swelling (chagoma) which persists for weeks. Trypomastigotes or amastigotes may be seen in the aspirate of the chagoma. Regional lymph nodes may become infected which frequently involve one side of the face. Unilateral edema of the upper and lower eyelid may occur along with conjunctivitis. This is known as Romanas' sign.

In the acute stage of infection trypomastigotes can be found in the blood. Symptoms may pass unnoticed, but there may be fever, malaise, increased pulse rate, and enlargement of lymph glands, liver, and possibly spleen. Muscle aches and pains are characteristic at this stage and parasites may be seen in blood films. The acute form is most often seen in young children and occasionally can cause serious damage to the heart and other complications leading to death caused by central nervous system involvement.

Chronic manifestations include signs of cardiac muscle damage with a weak and irregular heartbeat, edema, heart enlargement leading to heart failure. Dilation of the digestive tract resulting in megaesophagus and megacolon may also occur. About 10% of persons infected with *T. cruzi* develop chronic Chagas cardiopathy.

Laboratory Diagnosis of American Trypanosomiasis

Laboratory diagnosis of South American trypanosomiasis is by:

- Examination of blood.
- Xenodiagnosis
- Blood culture
- Serology

1. Examination of Blood

a) Thick and thin blood films are made and stained with Fields stain and examined as for malaria parasites. Wet preparations of blood can also be examined for motile trypanosomes.

b) Buffy coat examination - Trypanosomes are centrifuged in a microhematocrit tube for 5 minutes. Parasites can be seen microscopically at the junction of the packed red cells and plasma. This technique is rapid and sensitive.

Trypanosoma cruzi can often be seen in C, U or S shapes in stained films.

2. Xenodiagnosis

Xenodiagnosis is useful in chronic and sub acute (low parasitaemia) disease. Sterile bugs are fed on patients by attaching a black bag containing the bugs to the arm of the patient and allowing them to feed for 30 minutes. Twenty five to thirty days later the bugs are dissected and the contents of the hindgut and rectum are examined microscopically for the presence of trypanosomes.

3. Blood Culture

Blood culture is as sensitive as xenodiagnosis but it requires sterile conditions.

4. Serology

Serology tests include:

a. **IFAT** indirect fluorescence antibody test
b. **CFT** complement fixation test
c. **IHAT** indirect hemagglutination test
d. **ELISA** enzyme linked immunoabsorbent assay

Other lab findings include:

Raised ESR, marked lymphocytosis with atypical mononuclear lymphocytes

NB. In certain areas of S. America where *Trypanosoma rangeli* (a nonpathogenic species transmitted by *Rhodnius* spp. bugs) is found with *T. cruzi.* All positive preparations should be checked to confirm *T. cruzi.*

Leishmania species

Introduction

Leishmaniasis is caused by parasites of the genus *Leishmania* and is endemic in many parts of Africa, Asia and South America. It is transmitted by *Phlebotomus* species, sandfly.

Leishmania species are mainly parasites of man and other animals, especially dogs and rodents. They cause diseases collectively known as Leishmaniasis; causing three types of disease (i.e. Visceral Leishmaniasis, Cutaneous Leishmaniasis, and Mucocutaneous Leishmaniasis. These are all debilitating and disfiguring diseases which occur throughout the Old and New World. The parasites are unusual in that they live entirely within the cells of the reticuloendothelial cells, they have become perfectly adapted as the proteolytic enzymes which attack other foreign bodies in the blood stream but do not destroy them.

Visceral Leishmaniasis

Human visceral leishmaniasis (VL), sometimes known as Kala-azar, is caused by *Leishmania donovani* complex; *L. donovani* and *L. donovani infantum* in the Old World and *L. donovani chagasi* in the New World. The clinical features -azar caused by these species are similar, but they have different epidemiological features. The parent species *L. donovani* occurs in Asia (Northeastern China, India and Iran) and Africa (primarily Sudan, Kenya and Ethiopia) and can affect people of all ages. The parasite (*L. d. infantum*) which causes VL in countries bordering the Mediterranean, (Southern Europe as well as North Africa) affects young children as well as infants. It is now being seen in the immunocompromised. In the New World also, VL is mainly a disease of young children, with the causative organism *L. d. chagasi* being closely related to, but slightly different from, *L. donovani*. The main geographical foci of VL in Latin America are in northern and northeastern Brazil. Small foci are found in northern Argentina, Columbia and Venezuela. Sporadic cases are found in Central American countries, including Mexico.

Cutaneous Leishmaniasis

Cutaneous leishmaniasis is caused by *L. tropica, L. major* and *L. aethiopica* in the Old World and *L. mexicana* complex in the New World. *Leishmania tropica* is widely distributed around the Mediterranean basin, Afghanistan, Kenya, Kenya, Armenia, Azerbaijan, Turkmenistan and Uzbekistan*. Leishmania aethiopica* is seen in the highlands of Ethiopia and *L. major* occurs in the Middle East, West Africa, North Africa and Kenya. *Leishmania mexicana* complex is found in Central America and the Amazon Basin.

Mucocutaneous Leishmaniasis

Is caused by the *L. braziliensis* complex and is found in Brazil, Eastern Peru, Bolivia, Paraguay, Ecuador, Columbia and Venezuela.

Life cycle

All forms of infection starts when a female sandfly (*Phlebotomus* species) takes a blood meal from an infected host. Small amounts of blood, lymph and macrophages infected with *Leishmania* **amastigotes** are ingested. Once ingested the **amastigotes** transform to **promastigotes** in the sandfly, the non-infective **promastigotes** divide and develop into infective **metacyclic promastigotes**. These are formed in the midgut of the sandfly and migrate to the proboscis. When the sandfly bites, the extracellular inoculated promastigotes at the site of the bite are phagocytosed by macrophages. After phagocytosis, transformation to dividing **amastigotes** occurs within 24 hours. Reproduction at all stages of the lifecycle is believed to occur by binary fission. No sexual stage has been identified.

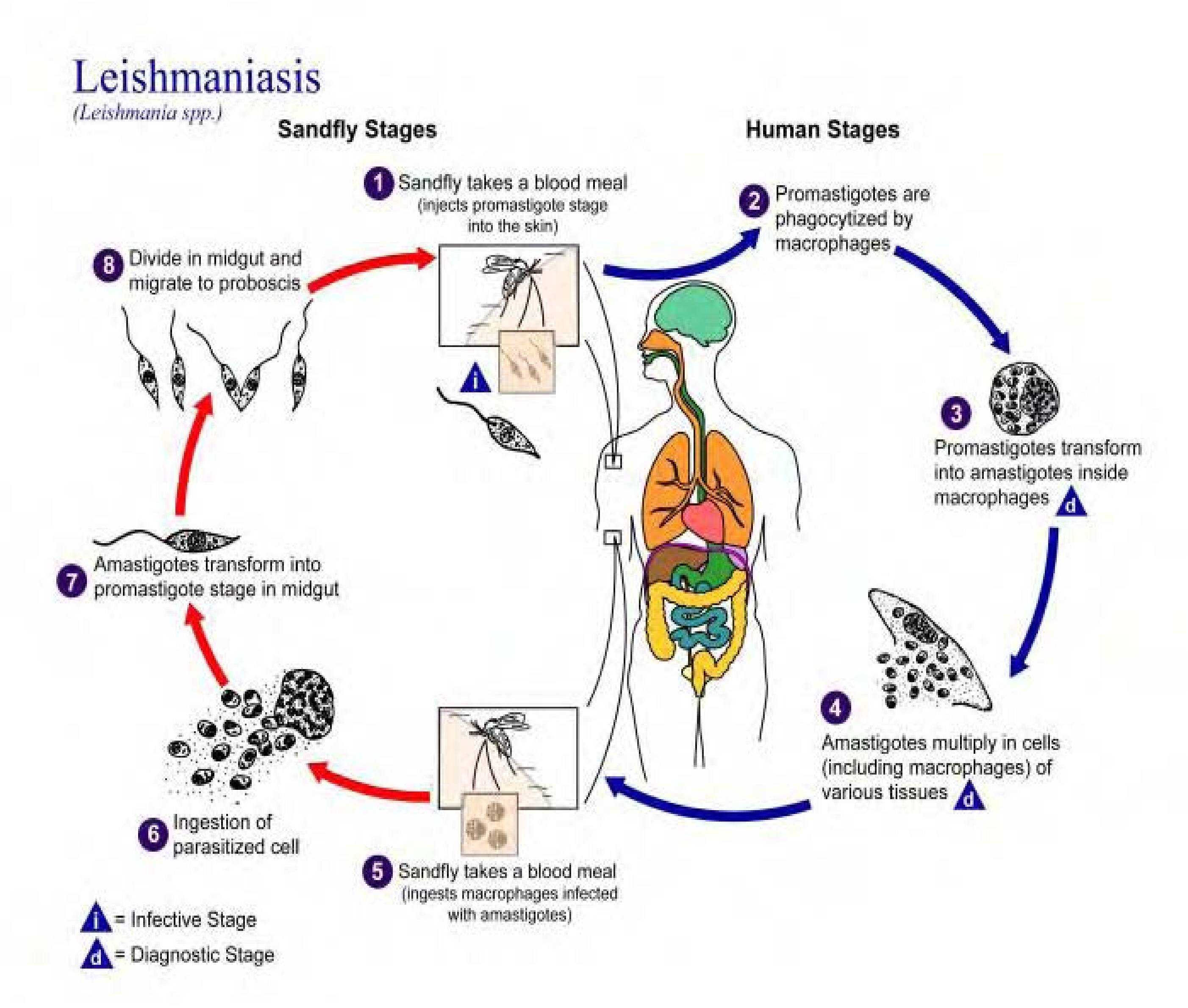
Leishmaniasis
(Leishmania spp.)
Sandfly Stages
Human Stages
1 Sandfly takes a blood meal (injects promastigote stage into the skin)
2 Promastigotes are phagocytized by macrophages
3 Promastigotes transform into amastigotes inside macrophages d
4 Amastigotes multiply in cells (including macrophages) of various tissues d
5 Sandfly takes a blood meal (ingests macrophages infected with amastigotes)
6 Ingestion of parasitized cell
7 Amastigotes transform into promastigote stage in midgut
8 Divide in midgut and migrate to proboscis
i
i = Infective Stage
d = Diagnostic Stage

Illustration 11-7. Generalized life cycle of *Leishmania* sp., which by using a sandfly as a vector can cause Leishmaniasis in man. (SOURCE: PHIL 3400 – CDC/Alexander J. da Silva, PhD/Melanie Moser)

Morphology

Leishmania exist as flagellated extracellular **promastigotes** in the Sandfly vector and as a flagellar obligate intracellular **amastigotes** within mononuclear phagocytes of their vertebrate hosts. The various species are not distinguishable morphologically from one another. When stained with Romanowsky stains such as Giemsa, **amastigotes** appear as round or oval bodies ranging from 2 - 3μm in diameter with a well defined nucleus and kinetoplast, a rod shaped specialized mitochondrial structure that contains extranuclear DNA. The flagellated **promastigote** form is spindle shaped, measuring 10 - 20μm in length, not including the length of the flagellum. As in the amastigote form a nucleus and kinetoplast are clearly visible.

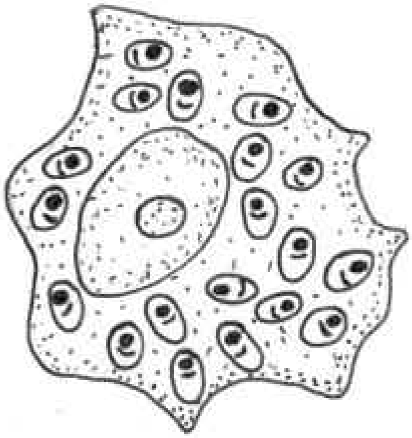

Illustration 11-8. Amastigote of *Leishmania* sp. in a macrophage of a vertebrate host. (SOURCE: Unknown)

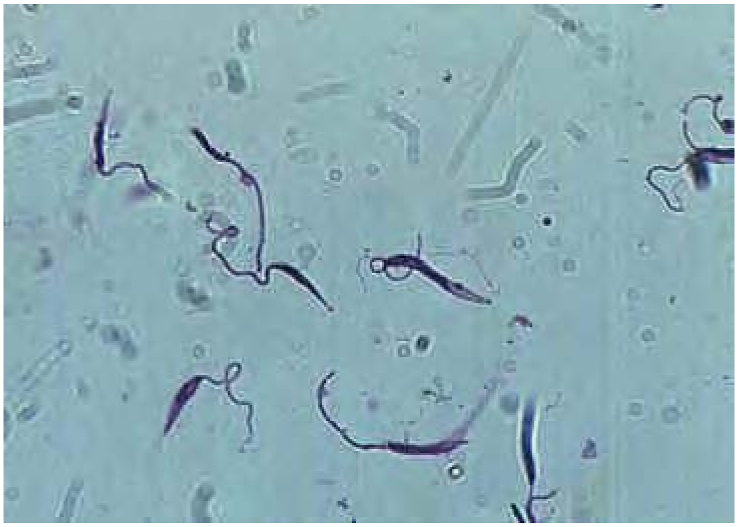

Image 11-7. Leishmania promastigote. This stage of the parasite are seen in the vector, sandfly. (SOURCE: Unknown)

Clinical Disease - Visceral Leishmaniasis

The incubation period of VL may vary between two weeks and 18 months. The onset of VL is usually insidious with fever, sweating, weakness and weight loss. The most prominent findings are fever, hepatosplenomegaly and anemia. The sites mainly affected are the liver, spleen and bone marrow. Enlargement of the liver is due to hyperplasia of Kupffer cells which are packed with amastigotes. The bone marrow is infiltrated with parasitized macrophages. Some organs, notably the kidneys, may show pathological changes secondary to deposition of immune complexes. In advanced cases, ascites and edema can develop. Deaths are usually due to secondary bacterial infections such as pneumonia, tuberculosis or dysentery.

Laboratory Diagnosis - Visceral Leishmaniasis

1. Microscopy

Parasites may be found in a splenic aspirate, liver biopsy or bone marrow biopsy. These techniques, especially splenic aspirate and liver biopsy, can be hazardous and require previous expertise in the procedure.

a) Air dry smears

b) Fix in methanol for one minute

c) Stain with Giemsa 1 in 10 in buffered distilled water pH 6.8 for 30 minutes (or use the rapid Field’s stain)

d) Wash the slide in buffered water and drain dry

Amastigotes of *Leishmania* should be seen in positive smears. They are approximately 2-4µm in size, oval and are frequently seen within the cytoplasm of the macrophage. The amastigotes possess a nucleus and a rod - shaped kinetoplast within the cytoplasm. In many samples a very small number of parasites are present. Extensive searching of the film is necessary.

2. Culture

The aspirates can be cultured in Novy-Nicolle-MacNeal (NNN) or Schneider's Drosophila medium. In culture the **amastigote** stage converts to the **promastigote** stage. However, this is not a rapid technique, as the parasites may take anything from 10-21 days to grow.

3. Serodiagnosis

VL produces large amounts of specific IgG which can be used for diagnosis. Currently the most used sero diagnostic tests are Indirect-immuno Fluorescent Antibody Test (IFAT), Enzyme Linked Immunosorbent Assay (ELISA) and Direct Agglutination Test (DAT).

Clinical Disease – Cutaneous Leishmaniasis

Following a bite from an infected sandfly, a small red papule appears at the site of the bite about 2–8 weeks later. The papule increases in size centrifugally. The patient then mounts either a hypersensitive response or an anergic response. In a hypersensitive response, the papule eventually ulcerates, becomes depressed and then eventually heals through scarring. The patient is now immune from subsequent bites. In an anergic response, the nodule grows and spreads over large areas of skin. This resembles leprosy.

Laboratory Diagnosis - Cutaneous Leishmaniasis

1. Slit skin smear.

The margin of the lesion contains amastigotes whereas the centre contains debris and dead skin material. This margin of the lesion is aseptically punctured with a hypodermic needle and syringe containing a small amount of saline. The aspirate which is drawn up into the needle is examined microscopically and/or cultured using the method described in Visceral Leishmaniasis.

2. Polymerase chain reaction

Gene amplification techniques are powerful and sensitive methods and are useful in diagnosis of Cutaneous Leishmaniasis particularly when organisms cannot be detected microscopically. It is also very useful for the speciation of *Leishmania* parasites thus the correct treatment can be administered.

Clinical Disease – Mucocutaneous Leishmaniasis

Mucocutaneous Leishmaniasis or espundia initially develops like cutaneous leishmaniasis but develops into lesions in the mucocutaneous junction of the pharynx resulting in the break down of the palate of the mouth and nose or more rarely the genitalia or anus. This occurs from a few weeks to several years after the cutaneous lesion has healed. These lesions result in disfiguring deformities of the nose and mouth.

Laboratory Diagnosis - Mucocutaneous Leishmaniasis

1. Microscopy

Finding the organisms in a histological section of the lesion provides definitive diagnosis of Mucocutaneous Leishmaniasis. However, the organisms are very rare in this form of the disease and culture can be a more sensitive method (see visceral leishmaniasis).

2. Polymerase Chain Reaction

The PCR method has the advantage of not only low numbers of parasites in aspirates but also histological sections. This makes this a very sensitive method in diagnosing Mucocutaneous Leishmaniasis when parasites are difficult to detect.

Chapter 12.

Arthropod Vectors

Soft Ticks

Class: Arachnida
  Subclass: Acari
    Order: Ixodida
      Family: Argasidae
        Genus: *Ornithodorous*

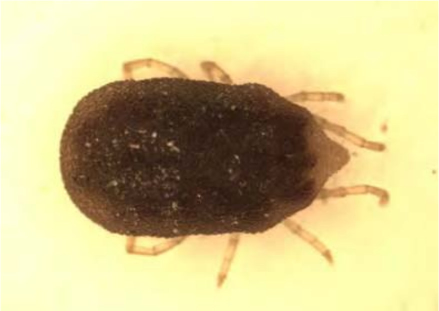

Image 12-1. *Ornithodoros* – Soft Tick (SOURCE: CDC)

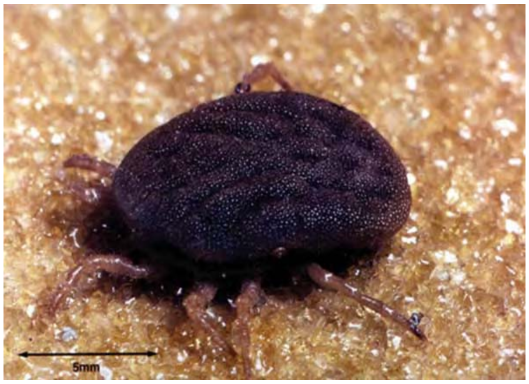

Image 12-2. *Ornithodorus moubata,* the most important soft tick disease vector found throughout the world (SOURCE: CDC)

General Characteristics

Soft Ticks are characterized by a tough leathery integument and a flattened oval shape when examined dorsally. The Argasidae lack the dorsal shield present in the Hard Ticks (Ixodidae), and need to be examined ventrally to observe their capitulum or mouthparts. Soft ticks generally have a world-wide distribution, with the most important disease vector *Ornithodoros* populating Europe, Africa, Asia and the Americas.

Life Cycles

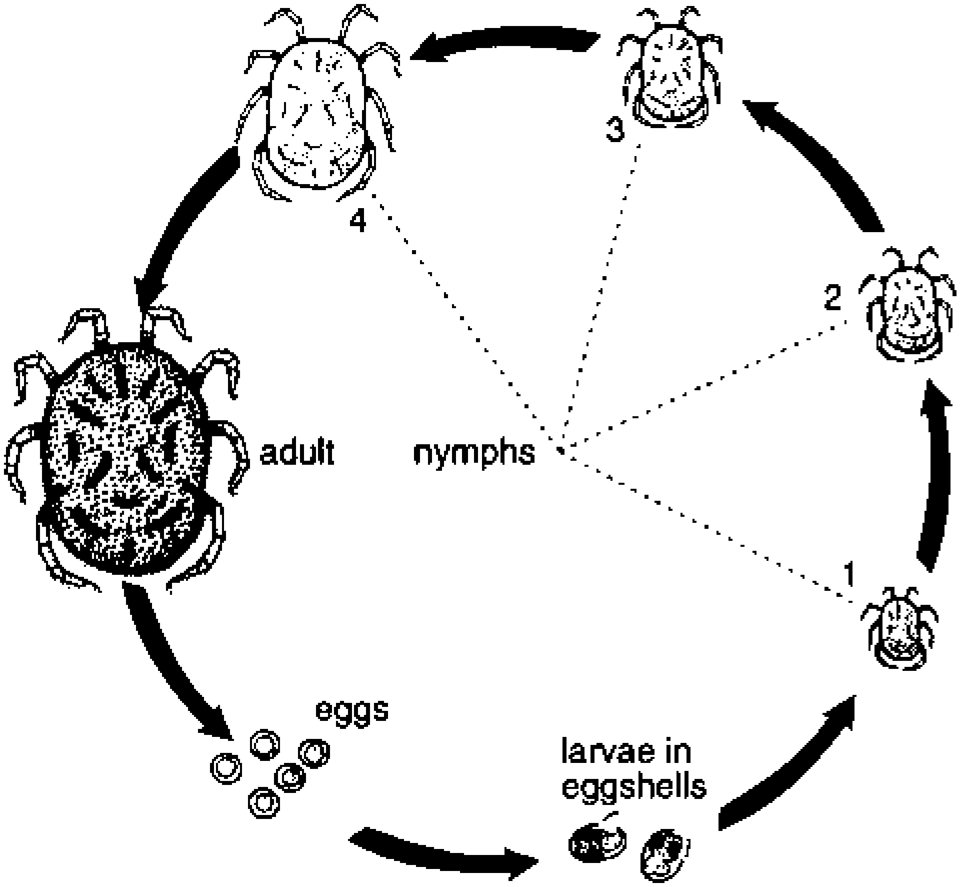

Illustration 12-1. Life Cycle of Soft Ticks. (SOURCE: Unknown)

Soft ticks have a hemimetabolous life cycle, with eggs hatching six legged larvae, which molt to eight legged nymphs. There are five to seven larval instars depending on the species, with each stage requiring a blood meal to proceed. Larvae of *Ornithodoros moubata* do not require a blood meal to molt to the nymph stage. Adult females lay small egg batches following each blood meal. The duration of the life cycle depends on the temperature, host availability, and inherently the particular species in question.

The adults are flat and oval in outline and have tough, leathery, wrinkled bodies. The mouthparts are situated underneath the body and are not visible from above. The eggs are laid in the places where the adults rest, such as cracks and crevices in the walls and floors of houses and in furniture. The larva, the five nymphal stages and the adults all actively search for hosts from which to take blood-meals. After feeding, which lasts about 30 minutes, they drop to the ground. Most species can survive for more than a year between blood-meals, and some for more than 10 years.

The soft ticks live apart from their hosts and are most common in the nests and resting places of the animals on which they feed. Some species, such as the chicken tick and the pigeon tick (*Argas* species) may feed on humans when the preferred hosts are not available.

Species that commonly feed on humans are found around villages and inside houses. Their habits are comparable to those of bedbugs: ticks often emerge from hiding places at night to suck the blood of humans and animals. Some species are common on travel routes, in rest houses and camping sites, and in caves and crevices.

Disease

Soft Ticks are vectors for serious disease including tick borne relapsing fever (*Borrelia duttoni),* rickettsial disease (*Coxiella burneti*), and some arboviruses. The most important disease spread by soft ticks is tick borne relapsing fever which occurs world-wide and is spread by spirochete infected *Ornithodoros.* Q-fever and arboviruses can be spread following a blood meal, but are both primarily introduced into the population by the Hard Ticks.

Tick-borne Relapsing Fever

This disease is caused by a microorganism of the genus *Borrelia*. It is transmitted by biting soft ticks of the genus *Ornithodoros* in many countries in the tropics and subtropics and also in Europe and North America. The ticks usually feed quickly at night in or near houses, and then leave the host.

The disease causes bouts of fever alternating with periods without fever. Death occurs in about 2-10% of persons who are untreated.

Treatment

Treatment is possible with tetracycline or its derivatives.

Prevention

Prevention requires measures to control soft ticks and to avoid their bites.

Hard Ticks

Class: Arachnida
Subclass: Acari
Order: Ixodida
Family: Ixodidae
Species: *Ixodes, Amblyomma, Rhipicephalus, Dermacentor*

General Characteristics

Hard ticks appear flattened when examined dorsally and can be primarily characterized by the presence of a dorsal plate or scutum, and a capitulum that projects beyond the body outline. The scutum regularly covers the entire dorsal area, although females may have a reduced plate present directly behind the capitulum. *Ixodes* spp. inhabit in Canada, Europe, Asiatic Russia, China, Japan, and Australia.

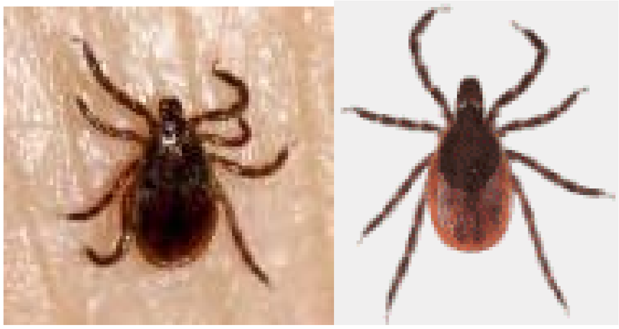

Image 12-3. *Ixodes scapularis* - male - showing the scutum covering the whole length of the body (left); *Ixodes scapularis* - female, showing the scutum covering half the length of the body (right)

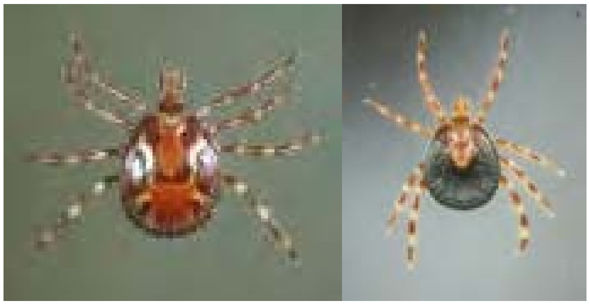

Image 12-4. *Amblyomma variegatum* - male - showing the scutum covering the whole length of the body (left); *Amblyomma variegatum* - female - showing the scutum covering half the length of the body (right)

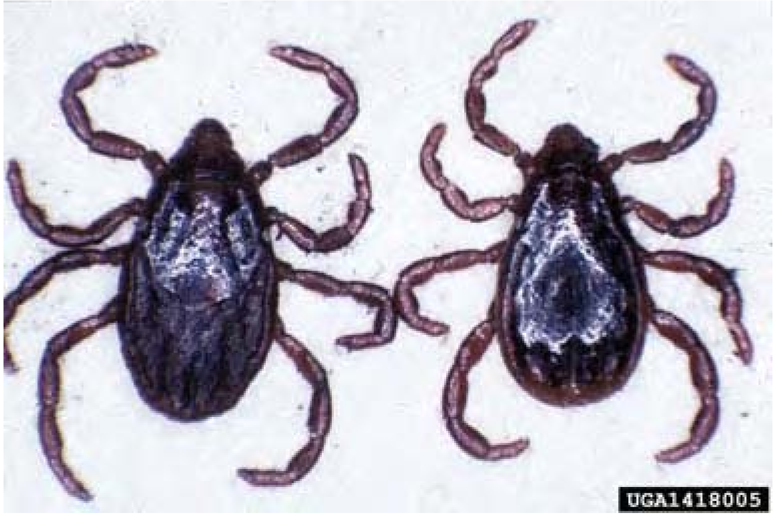

Image 12-5. *Rhipicephalus sanguineus* - female - showing the scutum covering half the length of the body (left); *Rhipicephalus sanguineus* - male - showing the scutum covering the whole length of the body (right). (AFPMB – used with permission)

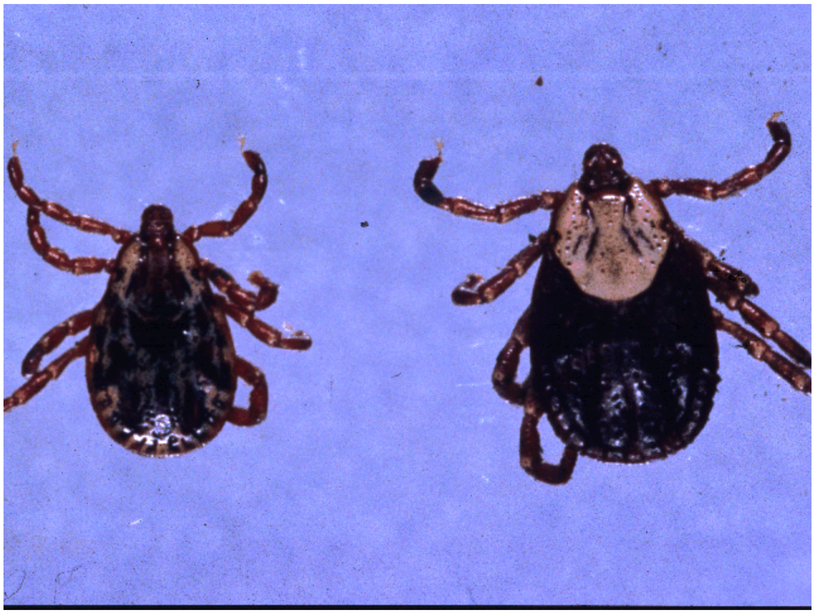

Image 12-6. *Dermacentor variabilis* - male - showing the scutum covering the whole length of the body (left); *Dermacentor variabilis* - female - showing the scutum covering half the length of the body (right) (Image courtesy of: Iowa State University)

Life Cycle

Hard Ticks have a hemimetabolous life cycle similar to that of the Soft Ticks. Hard tick larvae search for suitable hosts, feed for several days, and drop off engorged to the ground below. Molting to the nymph stage follows several days later and the tick again searches for a suitable blood source. There is only one nymphal stage in *Ixodes,* and following several weeks of stasis the nymph will molt into an adult. Females lay one large mass of eggs, which forms a cellular mass on the scutum of the ovipositing female.

Disease

Hard ticks transmit a variety of diseases including Lyme Disease, Tick Paralysis, Rickettsia*,* arboviruses that are responsible for encephalitis and hemorrhagic fevers, tularemia and *Babesia microti* infection. Tick paralysis is caused by the toxins present in the saliva of the tick, and is introduced during feeding.

Lyme disease is a serious ailment caused by the spirochete *Borrelia burgdorferi.* Lyme disease results in acute erythema, systematic lesions and eventually chronic involvement of multiple organs.

Rickettsiae diseases spread by *Ixodes* include Q-fever (*Coxiella burneti*) and arboviruses that cause serious encephalitis.

Babesia microti infection primarily involves animals, with Man as an accidental host. The parasite is present in the tick salivary glands and is passed to Man via tick bite. Once in the bloodstream, the parasites enter the erythrocytes. Infection with *B. microti* ranges from asymptomatic to severe illness. Symptoms generally resemble those of malaria with fever, rigors, myalgia, and malaise. Occasionally there is mild or moderate hemolytic anemia and jaundice (renal failure). Parasitemia can be up to 25% in the immunocompetent individual, and up to 80% in patients who have been splenectomized.

Other Medically Important Hard Ticks

General Characteristics

Several other species of ticks are also responsible for the spread of disease throughout the world. Wood ticks *(Dermacentor andersoni*) are found in the mountainous west of North America; dog ticks (*Rhipicephalus*) are found in coastal areas. Lone Star ticks (*Amblyomma americanum*) are found in forests in SE USA where deer are found. The females of these species are known to cause a condition known as tick paralysis.

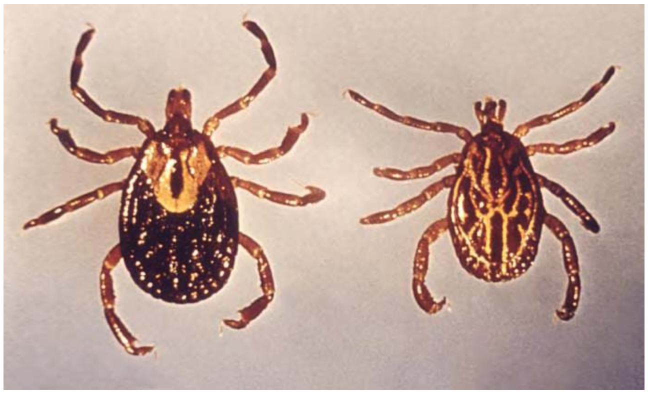

Image 12-7. *Amblyomma,* hard tick. The scutum is so-called 'enameled' colored areas, and is described as being an ornate species. (SOURCE: PHIL 5981 – CDC)

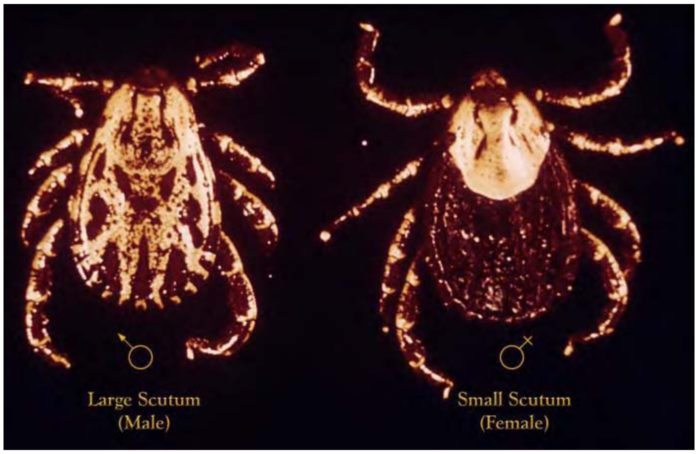

Image 12-8. *Dermacentor variabilis,* ticks of this species show very ornate scutums, covering the length of the body (left - male). When blood engorged it is harder to see the scutum (right - female). (SOURCE: PHIL 5977 – CDC)

Life Cycle

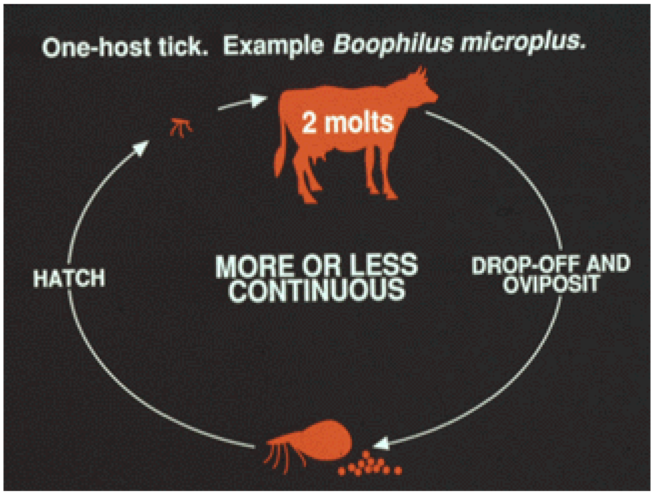
One-host tick. Example *Boophilus microplus*.
2 molts
HATCH
MORE OR LESS CONTINUOUS
DROP-OFF AND OVIPOSIT

Illustration 12-2. One-host tick life cycle. (SOURCE: CDC)

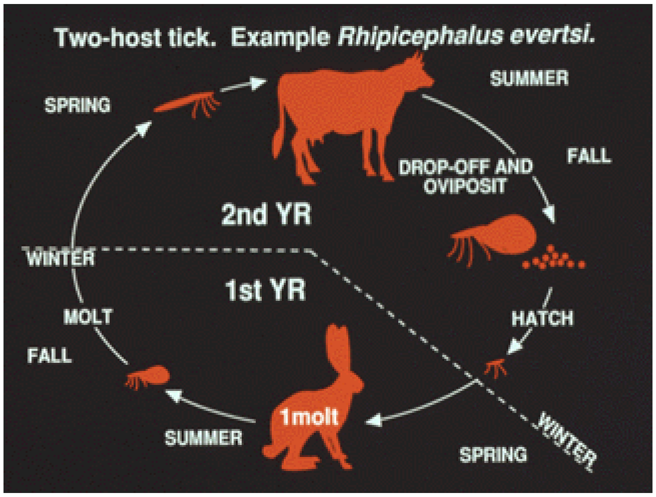
Two-host tick. Example *Rhipicephalus evertsi*.
SPRING
SUMMER
FALL
DROP-OFF AND OVIPOSIT
2nd YR
WINTER
1st YR
MOLT
FALL
HATCH
1molt
SUMMER
SPRING
WINTER

Illustration 12-3. Two-host tick life cycle. (SOURCE: CDC)

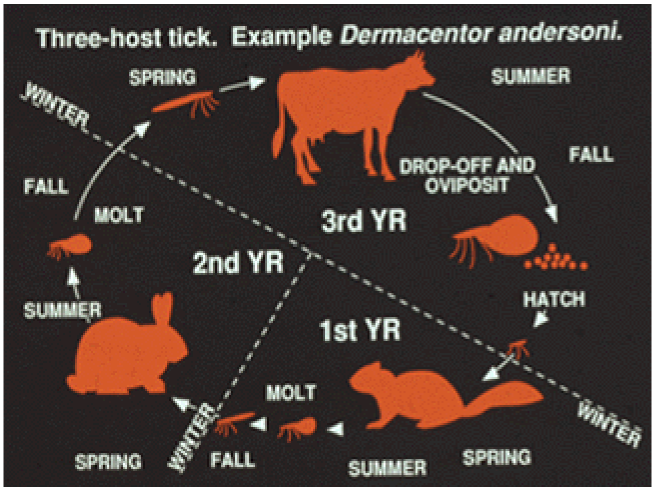
Three-host tick. Example *Dermacentor andersoni*.
WINTER
SPRING
SUMMER
FALL
FALL
MOLT
DROP-OFF AND OVIPOSIT
3rd YR
2nd YR
SUMMER
HATCH
1st YR
MOLT
WINTER
SPRING
WINTER
FALL
SUMMER
SPRING

Illustration 12-4. Three-host tick life cycle. (SOURCE: CDC)

Hard Ticks have a hemimetabolous life cycle similar to that of the soft ticks. Hard tick larvae search for suitable hosts feed for several days, and drop off engorged to the ground below. Molting to the nymph stage follows several days later and the tick again searches for a suitable blood source. There is only one nymphal stage in *Ixodes,* and following several weeks of stasis the nymph will molt into an adult. Females lay one large mass of eggs, which forms a cellular mass on the scutum of the ovipositing female.

Image 12-9. Female tick with egg mass. (SOURCE: PHIL 5968 – CDC)

Diseases

Both *Dermacentor* and *Amblyomma* transmit Rocky Mountain Spotted Fever (*Rickettsia rickettsia*). The different strains transmitted by these species vary in their virulence and subsequent manifestation of the disease. *Dermacentor* are known to transmit serious arboviruses responsible for encephalitis and hemorrhagic fevers. *D. variabilis* are also responsible for spreading tularemia (*Francisella tularensis*) and human granulocytic erlichiosis (*Ehrlichia chaffeensis*). *Rhipicephalus sanguineus* transmits Mediterranean Spotted Fever and African Tick Typhus.

Tick Paralysis

Hard ticks inject into the body with their saliva certain toxins that can cause a condition in people and animals called tick paralysis. It appears 5-7 days after a tick begins feeding, paralyzing the legs and affecting speaking ability, swallowing and breathing. It occurs worldwide and is most common and severe in children aged up to two years. Treatment involves removing the tick.

Tick-borne Rickettsial Fevers

This group of diseases is caused by closely related *Rickettsia* microorganisms transmitted by tick bites or contamination of the skin with crushed tissues or feces of the tick.

- Spotted fever due to *Rickettsia rickettsii* occurs in Brazil, Canada, Colombia, Mexico, Panama and the USA.
- Spotted fever due to *R. sibirica* occurs in Japan, the Russian Federation and the Pacific.
- Spotted fever due to *R. conori* is found in the Mediterranean region, Africa and southern Asia.
- Spotted fever due to *R. australis* occurs in Queensland, Australia.
- Q fever, caused by *Coxiella burneti*, has a worldwide distribution and is commonly present in abattoirs, meat-packing and meat-rendering plants, diagnostic laboratories, stockyards and poultry farms. It is transmitted to humans mainly by the consumption of milk and meat from contaminated cattle or the inhalation of dried infected tick feces by people working with cattle.

Symptoms in humans are sudden fever persisting for several weeks, malaise, muscle and joint pains, severe headache and chills. A rash sometimes spreads over the entire body. Death may result in about 15-20% of persons if the disease is misdiagnosed or left untreated.

Treatment

Antibiotics such as tetracycline or chloramphenicol can be used.

Prevention

Tick bites should be avoided and attached ticks should be removed rapidly and carefully. Several hours of attachment are needed before the *Rickettsia* organisms can infect humans.

Lyme Disease

Lyme disease (erythema chronicum migrans) is a severe and often debilitating condition caused by a spirochete, *Borrelia burgdorferi*. Acute Lyme disease is a flu-like illness, characterized by an expanding red rash in about 50% of patients, accompanied by fever, fatigue, and muscle and joint pain. Weeks or even months after the infecting tick bite, patients may experience swelling and pain in large joints (knee, elbow), encephalitis, facial palsy, ocular lesions and carditis, irrespective of whether a rash occurred in the acute phase. Later, perhaps years after the bite, there may be cartilage erosion (arthritis) and neuromuscular dysfunction (Fig. 4.29). Lyme disease occurs principally in northern temperate regions of the world, including China, Europe, the USA and the former USSR.

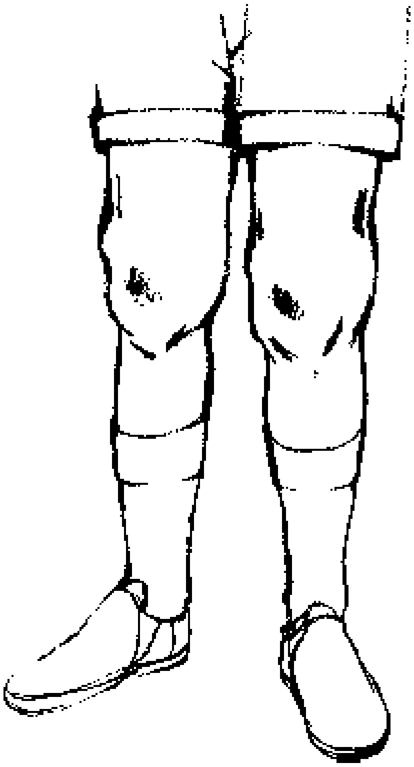

Illustration 12-5. A typical symptom of Lyme disease is swelling and pain in the large joints, such as the knees, and chronic arthritis. (SOURCE: Unknown)

Transmission

The disease is transmitted mostly by *Ixodes* ticks, commonly in the summer when the nymphs are abundant. Small rodents, especially mice, serve as reservoirs of infection while large mammals serve principally as hosts maintaining tick populations. The larvae acquire infection while feeding on mice, and nymphs or adults can transmit spirochetes during subsequent blood-meals. In the northern temperate zone, where it occurs most intensely, Lyme disease has become more common as deer populations have increased and as this critical host has adapted to living in closer proximity to people. In many areas, Lyme disease is acquired in the suburban residential environment.

Treatment

Further development of the disease in adults may be reduced or prevented by treatment with tetracycline or its derivatives for 2-4 weeks, and in children by treatment with penicillin.

Prevention

Prevention requires avoidance of tick habitats and bites, and vector control. Personal protection may be possible by the use of repellents on the skin and clothing in tick-infested areas. The removal of attached ticks within 24 hours may prevent spirochete transmission. Prophylactic antibiotic therapy may be desirable following the bite of an infected tick. New molecular assays are commercially available for detecting the spirochetes in tick samples.

Tularemia

Tularemia, also known as rabbit fever, deerfly fever and O'Hara disease, is caused by the infectious agent *Francisella tularensis*. The symptoms, which vary according to how the agent enters the body, include headache, chills, fever and the swelling of lymph nodes. The disease occurs in Europe, Japan, North America and the former USSR.

Transmission

Transmission takes place through the bites of ticks and deerflies (see Chapter 1) or as a result of handling infected animals such as rabbits and other game. Hunters and forest workers are at the highest risk of infection.

Treatment

Antibiotics such as streptomycin can be used to treat the disease.

Prevention

Tick bites and tick habitats should be avoided, impermeable gloves should be worn when skinning and dressing game animals, wild game meat should be thoroughly cooked, and untreated drinking-water should be avoided in areas where the disease occurs.

Tick-borne Viral Encephalitides

This is a group of viral diseases causing acute inflammation of the brain, spinal cord and meninges. The symptoms vary in severity with the type of disease. Many infections do not result in disease. Severe infections may cause violent headaches, high fever, nausea, coma and death.

- Far Eastern tick-borne encephalitis is found in the far east of the former USSR.
- Central European tick-borne encephalitis occurs in Europe from the Urals to France.
- Louping ill is a disease of sheep in the United Kingdom which sometimes affects people.

Transmission and Prevention

These diseases are transmitted by biting ticks and by the consumption of milk from infected animals. No specific treatment is available but vaccines have been developed against some of the diseases. Prevention requires avoidance or rapid removal of ticks.

Principal Hard Tick Vectors

Usually various tick species act as vectors for any one disease and their importance varies from region to region.

Disease	Vector
Lyme disease	Deer tick *(Ixodes scapularis)*
Spotted fever due to:	
• ***Rickettsia rickettsii***	American dog tick *(Dermacentor variabilis)*
• ***Rickettsia sibirica***	Asiatic wood tick *(Dermacentor silvarum)*
• ***Rickettsia conori***	Brown dog tick *(Rhipicephalus sanguineus)*
• ***Rickettsia australis***	Wattle tick *(Ixodes holocyclus)*
Q fever	Lone star tick *(Amblyomma americanum)*
Tularemia	American rabbit tick *(Haemaphysalis leporispalustris)*
Far Eastern tick-borne encephalitis	Taiga tick *(Ixodes persulcatus)*
Central European tick-borne encephalitis	Castor bean ticks *(Ixodes ricinus)*
Kyasanur Forest disease	A tick of birds and monkeys *(Haemaphysalis spinigera)*
Colorado tick fever	American wood tick *(Dermacentor andersoni)*
Crimean-Congo hemorrhagic fever	A tick of birds and mammals *(Hyalomma marginatum)*

Table 12-1. Principle Hard Tick Vectors

Other Viral Diseases

Kyasanur Forest disease occurs in parts of India.

Omsk hemorrhagic fever is found in south-western Siberia; it causes severe disease and death in muskrat handlers; it is mainly waterborne, although it is found in hard ticks.

Colorado tick fever is a moderately severe disease that occurs in western North America.

Crimean-Congo hemorrhagic fever is an acute, often severe and fatal disease found in parts of Africa, Asia and Europe.

Mites

Class: Arachnida
  Subclass: Acari
    Order: Astigmata
      Family: Pyroglyphidae
        Genus: *Dermatophagoides* (Dust mites)
      Family: Sarcoptidae
        Genus: *Sarcoptes* (Scabies mites)
    Order: Prostigmata
      Family: Democidae
        Genus: *Demodex* (Hair follicle mite)
    Order: Mesostigmata
        Genus: *Leptotrombidium* (Other Mites)

General Characteristics

Dermatophagoides, the common dust mite, commonly inhabit beds, mattresses, carpets and house dust. They are motile and feed on residual organic debris and are typically 0.3 µm in length. They characteristically have four long legs with suckers and pincer chelicerae.

Image 12-10. A Dust Mite (*Dermatophagoides*). They commonly inhabit mattresses, carpets and house dust.

Demodex folliculorum mites are 300 microns in length, live in the follicle for 5-6 days and migrate onto contiguous skin at night. Classically, they appear as 1 µm "sleeves" around the base of the eyelashes.

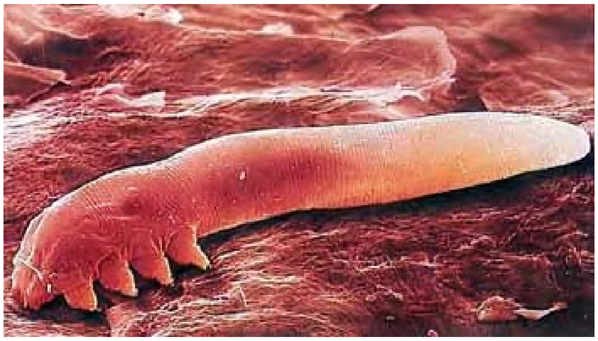

Image 12-11. *Demodex folliculorum* (SOURCE: CDC)

The mite, *Sarcoptes scabiei*, lives exclusively on human skin and causes scabies. It is small (the larger female is 0.3-0.4 µm), colorless and oval with 8 short legs.

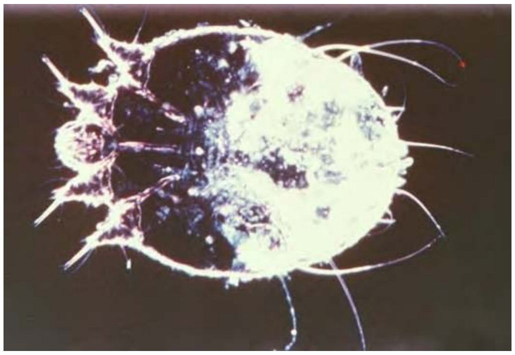

Image 12-12. Picture of the human parasite scabies (*Sarcoptes scabiei*). They live exclusively on human skin causing the condition known as scabies. (SOURCE: PHIL 3810 - CDC/Joe Miller/Reed and Crnrick pharmaceuticals.)

Leptotrombidium adults are normally reddish and covered with velvet like hair. It is the larvae that are parasitic and they too regularly appear reddish, but only have three pairs of legs. The palps are segmented, and the mouthparts are large and easily identifiable. *Leptotrombidium* larvae are distinguished by large eyes, two feathered sensillae and five feathered setae that are present on the scutum.

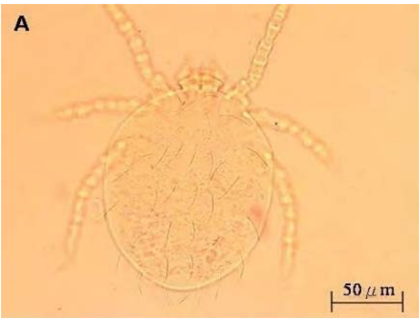

Image 12-13. *Leptotrombidium* (SOURCE: CDC of Taiwan)

Disease and Control

Dermatophagoides are antigenic, even when dead (fecal pellets are also allergenic), and are associated with complex allergies with symptoms such as asthma, perennial rhinitis, conjunctivitis and atopic dermatitis. A diagnosis can be made using reactive skin tests and treatment involves removal of accumulated antigens from mattresses and pillows.

Demodex have been implicated in dermatitis, acne and should be considered in chronic, therapy-resistant cases of blepharitis. The role of this mite in ocular disease is uncertain. Washing with soap and water is the most effective method of prevention.

Symptoms of *Sarcoptes* infection arise after 4-6 weeks and comprise a papular pruritic eruption at a site often unrelated to the site of infestation; symptoms of secondary infestations arise almost immediately. Zoonotic scabies have shorter incubation periods but are also self-limiting. Persistent nodular scabies comprises itchy erythematous or scabbed nodules, often on the penis. When the immune system is impaired, Norwegian (crusted) scabies may develop: this presents with erythema and hyperkeratosis but little itching.

Diagnosis demands discovery of the mites, scybala or eggs by epidermal shave biopsy or superficial scraping. Burrows are best seen on wrists and interdigital spaces. They fluoresce under a Wood's lamp after application of liquid tetracycline and, later, alcohol; alternatively ink may be used. Lindane (Quellada) lotion is the treatment of choice in the USA; permethrin or crotamiton are alternatives. Ivermectin has been recommended for Norwegian scabies. Malathion (Derbac-M) liquid or permethrin are recommended in the UK (benzyl benzoate is also active). Malathion should be avoided in infants and lindane should be avoided in pregnancy, breast-feeding and young children. Treatment is applied over the whole body except the head and neck and washed off after 24 hours. Normal laundering of bed linen and clothes is recommended. Household and sexual contacts should also be treated. Symptoms may continue after treatment because of persisting antigens, Calamine or Eurax lotion may be used; other problems include reinfestation and secondary bacterial infection.

Feeding by *Leptotrobidium* causes cellular damage and initially results in intense itching and irritation for the host. The agent of scrub typhus, *Rickettsia tsutsugamuchi*, is often transmitted by the larval trombiculid mite. Scrub typhus results in infection in those living or working near 'mite islands' which are usually found in transitional vegetation and provide a stable environment for mite proliferation. Prevention has generally been with chemical repellents or herbicides to remove the scrub habitat.

Mosquitoes

Class: Insecta
Order: Diptera
Family: Culicidae
Subfamily: Anophelinae
Genus: *Anopheline*
Subfamily: Culicinae
Genus: *Culicine*

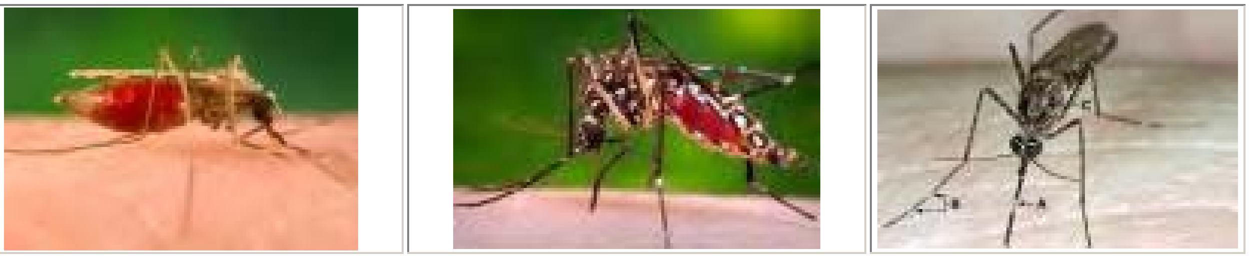

Anopheles
(SOURCE: PHIL 7949 – CDC)

Aedes
(SOURCE: PHIL 9261 - CDC/ Prof. Frank Hadley Collins, Dir., Cntr. for Global Health and Infectious Diseases, Univ. of Notre Dame)

Culex
(SOURCE: PHIL 7957 – CDC)

Image 12-14. *Anopheline* and *Culicine* mosquitoes.

Introduction

Mosquitoes are small with a clearly demarcated body and very long slender legs. The head contains a large pair of kidney shaped compound eyes, a pair of antennae, and a single long proboscis for feeding. The thorax, abdomen and wings are often covered with scales. Differential coloration and pattern of these scales provides a means of visually distinguishing species. The large wings are folded over the segmented abdomen, which generally appears brown-black and slender but turns a bright red and swells following feeding.

Image 12-15. Image of a typical Culicine mosquito. Adults are generally brown – black, at rest they palce their abdomens parallel to the ground. (SOURCE: PHIL 4487 – CDC)

Mosquitoes may be classified as Anopheline (Anopheles) or Culicine (Aedes, Culex). The antennae of male mosquitoes are plumose (many feathery hairs); females are pilose (few spidery hairs). The male Anopheline palps are long and clubbed; those of the male Culicine are long but not clubbed. The female Anopheline palps are long; the female Culicine are short. If a mosquito is incorrectly sexed, a female Anopheline may be confused with a male Culicine.

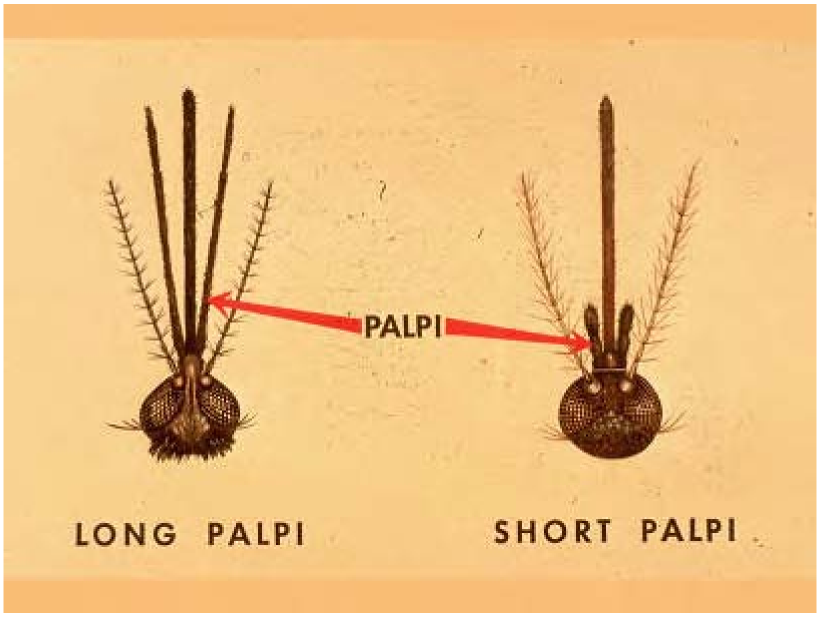

Illustration 12-6. Image of typical male Anopheline mosquito showing the characteristic features of the mosquitoes head; the palps are as long as the proboscis with clubbed like ends and the antennae are plumose. The female Culicine mosquito shows the short palps and the pilose antennae. (SOURCE: CDC)

At rest, Anophelines usually position their abdomens at an angle to the surface; Culicines maintain their abdomen in a parallel position.

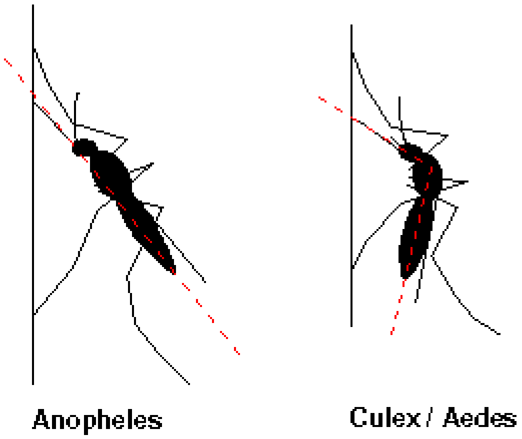
Anopheles
Culex / Aedes

Illustration 12-7. Typical *Anopheline* and *Culicine* at rest, showing the abdomen at an angle to the surface. (SOURCE: CDC)

Anopheline *(Anopheles)* Mosquitoes

Class: Insecta
Order: Dipthera
Family: Culicidae
Subfamily: Anophelinae
Genus: Anopheline
Species: *Anopheles*

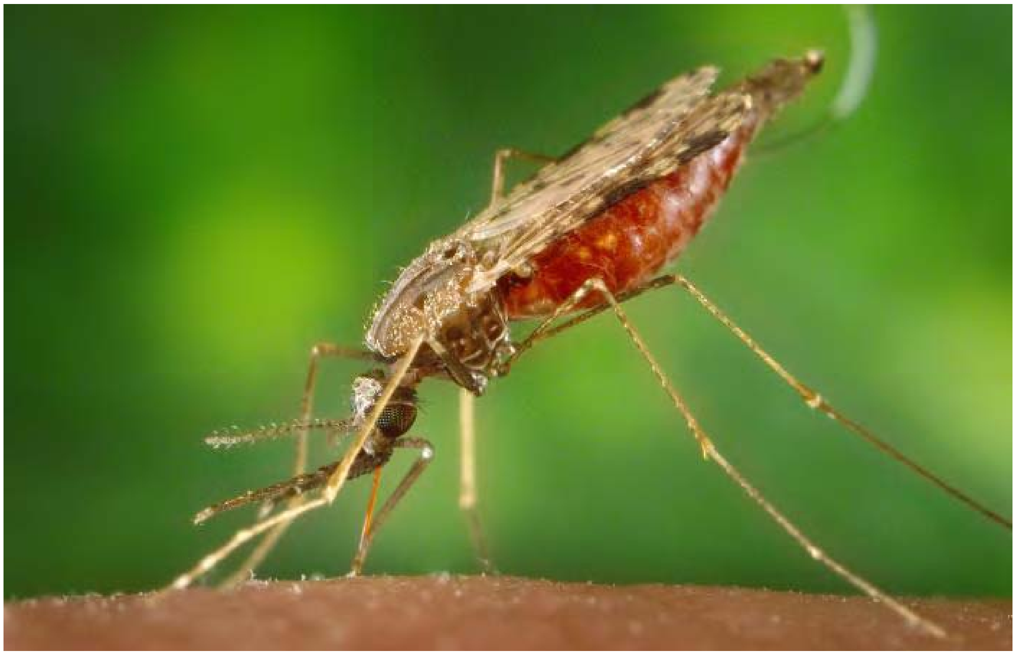

Image 12-16. Typical *Anopheles* mosquitoes (SOURCE: PHIL 7862 – CDC)

General Characteristics

Anopheles mosquitoes are characterized by dark and pale scale blocks arranged on their wings. They have palps that are of equal length to the proboscis, which appear terminally clubbed in males. Anopheles always rest at an angle when standing on surfaces and preferring to feed at twilight or night. Breeding sites are varied but Anopheles prefer unpolluted fresh or saltwater.

Life Cycle

Anopheles lay 50 to 200 dark color eggs in aquatic environments, and hatch in several days to several weeks depending on the external temperature. Anopheles larvae have a dark brown head and 6-7 anterior segments covered with dorsal palmate hairs. Accessory tegral plates are present on the dorsal side of segments 1-10 and two sets of anal papillae emerge from the last abdominal segment.

There are four larval instars that survive by filter feeding and breathing oxygen through their spiracles. Anopheles larvae occur throughout many different habitats including both permanent marshes and swamps, and temporary locations such as pots filled with water. In general Anopheles prefer to inhabit clean habitats. The larval period lasts about a week, but may be extended depending on the environmental conditions. The pupa is comma shaped with a set of trumpet shaped breathing tubes. The abdomen is covered with setae, and segments 2-7 have distinct spines. The pupal period may last a few days to weeks depending on the temperature.

Disease - Malaria

Anopheles are vectors of malaria, Bancroftian and Brugian filariasis and of multiple arboviruses (dengue fever; yellow fever; encephalitides and hemorrhagic fevers). Malaria is caused by *Plasmodium falciparum, P. vivax, P. malariae and P. ovale*. Transmission of the disease occurs in virtually all of tropical Africa, Central and South America, and the Middle and Far East. South East Asia is a particular problem due to multiple drug resistance. *P. falciparum* is found in Africa and other tropical countries as well as in subtropics. *P. malariae* has a low prevalence in both tropics and subtropics. *P .vivax* is the most widespread in temperate regions and subtropics but may also be found in the tropics. *P. ovale* has a low prevalence in West Africa. In Africa alone, 370 million people live in endemic areas.

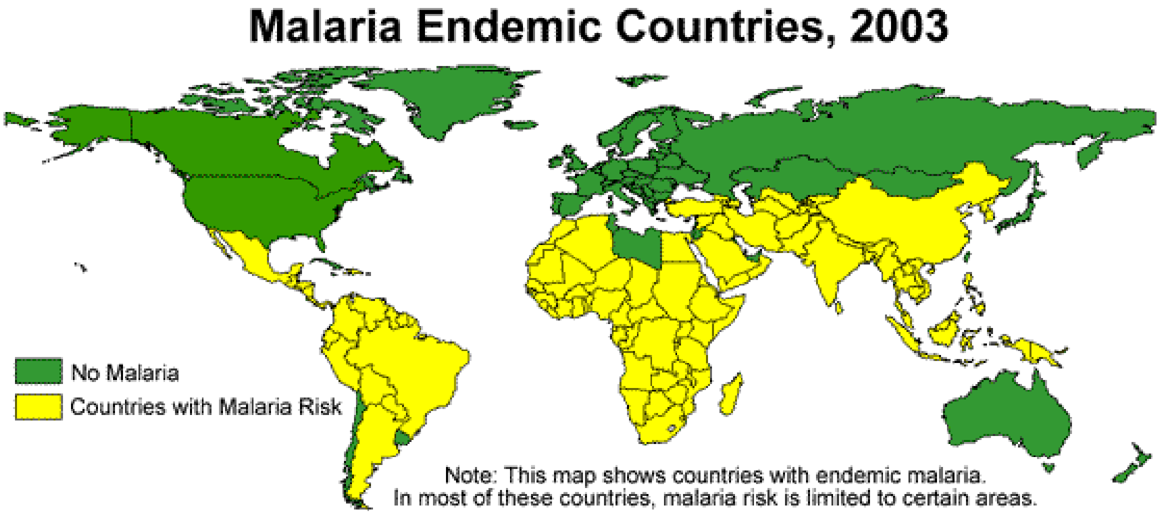
Malaria Endemic Countries, 2003
No Malaria
Countries with Malaria Risk
Note: This map shows countries with endemic malaria.
In most of these countries, malaria risk is limited to certain areas.

Illustration 12-8. World map showing the distribution of malaria. (CDC)

P .vivax causes benign tertian malaria (43% of cases) and *P. falciparum* results in malignant tertian or sub-tertian malaria and pernicious malaria (50% of cases). *P .ovale* (mild tertian malaria, 1% of cases) and *P. malariae* (quartan malaria, 7% of cases) contribute a small percentage of malarial cases.

Clinical features including fever and chills are due to the host inflammatory response and are associated with rupture of erythrocytic schizonts. Fever presents in three stages - **a)** Cold: rigors and fever lasting 15 minutes to 1 hour; **b)** Hot: the patient is flushed with tachycardia and is pyrexial (40C) for 2-6 hours; **c)** Sweating: the temperature falls (over 2-4 hours). Each paroxysm lasts 8-12 hours in total. All erythrocytes containing a trophozoite will be destroyed within 48-72 hours. Periodic fever often takes more than seven days to develop, and anemia can be hemolytic or due to toxic marrow suppression. Splenomegaly occurs in all malaria: it may be acute or chronic (+/- hypersplenism). Jaundice may be hemolytic and/or hepatic (only *P. falciparum*). In addition, there may be headache, myalgia, arthralgia, diarrhea and vomiting.

Plasmodium falciparum is the most virulent form (invades mature and immature RBCs) and is often fatal if untreated. Blood schizogony takes place in deep capillaries and micro-circulatory failure can occur in individuals with little immunity to malaria. It does not relapse but recrudescence may occur. The time between paroxysms is 48 hours but fever may last for 24-36 hours. Very rapid progression and complications include diarrhea and vomiting; delirium; coma; convulsions; renal failure, including hemoglobinuria (blackwater fever); jaundice; pulmonary edema; hypoglycemia and abortion. Cerebral malaria often results in delirium, disorientation, stupor, coma, convulsions and death.

P. vivax / ovale exhibit 48 hours between paroxysms; relapses may occur up to 8 years after primary infection and only infects immature RBCs of those with Duffy blood group. *Plasmodium malariae* generally results in 72 hours between paroxysms, only infects older RBCs, and recrudescence may occur decades after primary infection.

The global malaria situation is serious and becoming worse: 300-500 million clinical cases occur annually. 1.5-2.7 million people die of malaria each year with approximately one million deaths among children under five years of age are attributed to malaria alone or in combination with other diseases. Countries in tropical Africa account for more than 90% of the total malaria incidence and the great majority of malaria deaths (WHO data). The death toll of African children with malaria is expected to double by 2010, conceivably reaching four million deaths per year. Many factors influence the epidemiology of this disease including: breeding habits of the various mosquito vectors; agricultural practices; economic conditions; industrialization and pesticide use. Increasing air-traffic from malaria endemic areas has led to the possibility of malaria developing in non-endemic areas where the mosquito vector has been imported onboard aircraft.

Treatments and Control - Malaria

If the infective species is not known, or the infection is known to be mixed, initial treatment should be with quinine, mefloquine or rarely halofantrine. Falciparum (malignant) malaria is often resistant to chloroquine and should be treated with quinine, mefloquine, halofantrine, quinidine or pyrimethamine-sulphadoxine. Benign malaria (*P. vivax*) should be treated with chloroquine although resistance has been reported from New Guinea. Malarial prophylaxis is relative and not absolute.

The UK Consensus Group on Malaria Prophylaxis (1997) recommend mefloquine for UK travelers to West, Central and East Africa for periods of greater than two weeks and for travelers to specific areas within south-east Asia: prophylaxis should be commenced two weeks before departure. Doxycycline can be used in older children and adults who cannot tolerate mefloquine.

Prevention is most dependent upon coverage of exposed skin and the use of insect repellent, mosquito nets impregnated with permethrin and correct prophylaxis. The vector may be controlled by water clearance programs, house spraying (DDT) and destruction of breeding areas. Drug resistance to DDT and ethical resistance to its use have limited its effectiveness. Natural immunity involves both antibody and cell-mediated systems and appears to require frequent boosting; antigens from different stages of the parasite's life cycle will be important in vaccine development.

Disease - Filariasis

Anopheline mosquitoes also transmit the filarial worms *Wuchereria bancrofti, Brugia malayi* and *Brugia timori. Wuchereria bancrofti is* the main cause of "elephantiasis” (Bancroftian filariasis) and the most widely distributed filarial parasite of man. The adults live in the lymphatic system, and can survive for 30 years or more. Once they have mated they produce a pre-larval form, the microfilaria. Both the adults and the microfilaria may play a role in generating the symptoms and signs. Microfilaria measure 240-300μm in length by 7-10μm in width. They are sheathed (derived from ovum membrane) and nuclei terminate 15-20μm proximal to the pointed tail. There are fewer, more distinct nuclei than in other species and there are less body curves. Adult worms are slender and white (males 4cm; females stout and 10cm in length)

Initial infection with *Wuchereria* is usually asymptomatic. There may be recurrence of attacks of "cellulitis" affecting the limbs, breast, scrotum or elsewhere. Infection is associated with fever, lymphangitis, lymphadenopathy and occasionally abscess formation. These initially settle but later on the tissues eventually become edematous and hypertrophied. Further effects may include scrotal involvement and hydrocoele, which can lead to scrotal enlargement and lymph scrotum. This is "elephantiasis" and is associated with dermal hypertrophy, verrucous changes and the rupture of lymph varices into various sites.

Brugian (Malayan) filariasis is less widespread, less common and less serious than its Bancroftian counterpart. The life cycle is identical to that of *Wuchereria bancrofti* with *Brugia malayi* limited to Asia and *B. timori* restricted to Indonesia. Infection results in lymphadenopathy involving most frequently the inguinal area, lymphoedema normally below the knee, eosinophilia, and in rare cases chyluria.

Treatments and Control - Filariasis

Diethylcarbamazine (DEC) kills microfilaria. Ivermectin suppresses microfilaria production but its overall effectiveness remains untried and elephantiasis can be treated surgically. Control measures comprise draining of mosquito breeding sites and killing larvae. Many mosquitoes are resistant to insecticides but mosquito repellents and nets are effective. The infective pool may be reduced by periodic mass treatment with DEC. *Brugia malayi* is more susceptible to diethylcarbamazine (DEC) than is *Wuchereria bancrofti*. Anopheline larvae may be suffocated in their breeding sites but Culicine larvae (*Mansonia* sp.) derive oxygen from plants and are not vulnerable to such measures. Control depends upon the use of mosquito nets and periodic mass treatment.

Culicine (*Aedes*) Mosquitoes

Class: Insecta
Order: Dipthera
Family: Culicidae
Subfamily: Culicinae
Genus: Culicine
Species: *Aedes*

General Characteristics

Aedes can generally be distinguished by patterns of black and silvery scales present on the abdomen and thorax. The legs appear to have black and white rings along their length. The wings are generally covered with black scales. *Aedes* breed in marshes and other wetland areas and have a worldwide distribution.

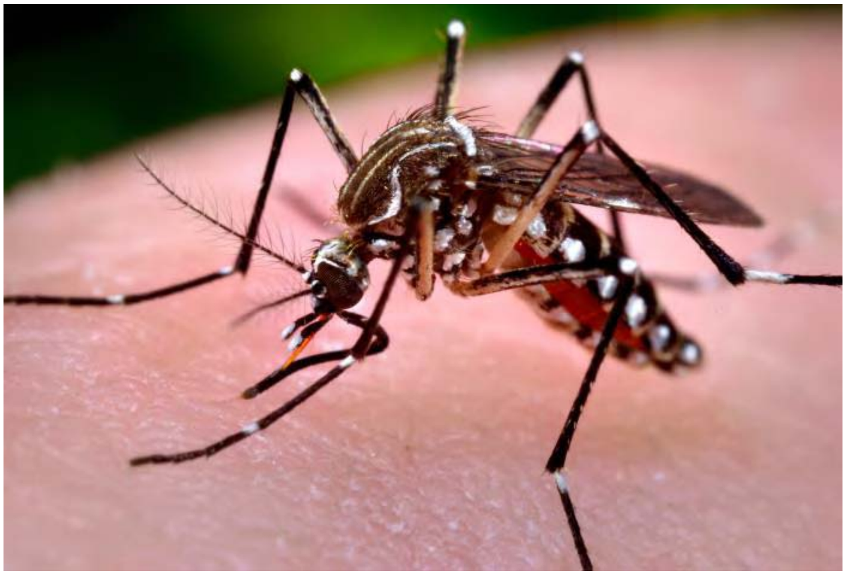

Image 12-17. Typical *Aedes* mosquito. They are clearly distinguished from Anopheline mosquitoes due to the presence of black and slivery scales on the abdomen and thorax. (SOURCE: PHIL 9252 - CDC/ Prof. Frank Hadley Collins, Dir., Cntr. for Global Health and Infectious Diseases, Univ. of Notre Dame)

Life Cycle

Female *Aedes* lay eggs on damp areas such mud, detritus, clay and rock. The eggs are very robust and can survive desiccation and other environmental pressures. The eggs hatch in waves depending on the environmental cues. *Aedes* larvae have a stout barrel shaped siphon with one pair of subventral tufts. There are three pairs of setae on the ventral brush, and large setae are not present on the abdominal segments.

Disease

Aedes are vectors of Bancroftian filariasis and arboviruses such as yellow fever and dengue. *Wuchereria bancrofti is* the main cause of "elephantiasis" (Bancroftian filariasis) and the most widely distributed filarial parasite of Man. The adults live in the lymphatic system, and can survive for 30 years or more. They copulate and generate a pre-larval form, the microfilaria. Both the adults and the microfilaria may play a role in generating the symptoms and signs. Microfilaria measure 240-300μm in length by 7-10μm in width. They are sheathed (derived from ovum membrane) and nuclei terminate 15-20μm proximal to the pointed tail. There are fewer, more distinct nuclei than in other species and there are less body curves. Adult worms are slender and white (males 4cm; females, stout and 10cm in length).

Initial infection with *Wuchereria* is usually asymptomatic. There may be recurrence of attacks of "cellulitis" affecting the limbs, breast, scrotum or elsewhere. Infection is associated with fever, lymphangitis, lymphadenopathy and occasionally abscess formation. These initially settle but later on the tissues eventually become edematous and hypertrophied. Further effects may include scrotal involvement and hydrocoele, which can lead to scrotal enlargement and lymph scrotum. This is "elephantiasis" and is associated with dermal hypertrophy, verrucous changes and the rupture of lymph varices into various sites.

Yellow fever and dengue hemorrhagic fever are serious viral infections spread by the *Aedes* mosquito. Dengue is now the most important mosquito borne virus, with global infection increasing.

Control and Treatment

In general the most effective control for Culicine mosquitoes are repellents and fine screening or netting. Treatment with insecticides will also serve to reduce the vector population, but increased problems are encountered with Culicines because they also feed during the daytime. If filarial infection occurs, treatment with Diethylcarbamazine (DEC) will kill microfilaria. Ivermectin suppresses microfilaria production but its overall effectiveness remains untried and elephantiasis can be treated surgically.

Culicine (*Culex*) Mosquitoes

Class: Insecta
Order: Dipthera
Family: Culicidae
Subfamily: Culicinae
Genus: Culicine
Species: *Culex*

General Characteristics

Culex are distinguished by their lack of coloration and feature. The thorax, abdomen, legs and wings are often covered with brown-black scales giving a generally dark appearance. The abdomen may occasionally also have white scales arranged in segments. *Culex* breeds mainly in aquatic habitats, often in areas containing large quantities of organic waste.

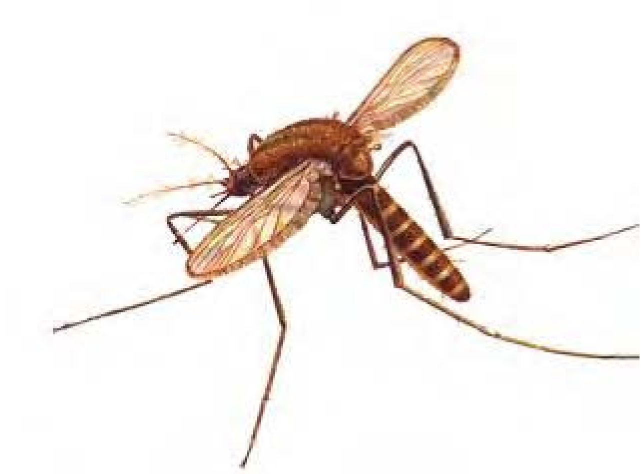

Illustration 12-8. Typical illustration of a *Culex* mosquito, showing the characteristic brown-black scales on the thorax, abdomen, legs and wings giving it a general dark appearance. (Illustration: Trustees of the British Museum)

Image 12-18. A *Culex* mosquito taking a blood meal from a human host. The abdomen becomes distended and blood red in color. (SOURCE: PHIL 4464 - CDC/Jim Gathany)

Life Cycle

Female *Culex* lay dark brown eggs in characteristic clumps of approximately 300 eggs. As mentioned these eggs are often found in organic waste deposits or polluted waters. *Culex* larvae have a long and narrow siphon with more than one pair of subventral tufts.

Disease

Culex mosquitoes are vectors of Bancroftian filariasis throughout Africa, but most importantly arboviruses such as Japanese encephalitis. Encephalitis occurs throughout the world, with *Culex* acting as an important vector for spread and infection. *Culex* mosquitoes are similar to Culicine mosquitoes, but prefer to bite at night and breed in organic refuse.

Control and Treatment

Culex mosquitoes are most easily controlled by improving sanitation and removing static water sources from the affected area. In general the most effective control for *Culex* mosquitoes are also repellents and fine screening or netting. Treatment with insecticides will also serve to reduce the vector population, but increased problems are encountered with Culicine mosquitoes because they also feed during the daytime. If filarial infection occurs treatment with Diethylcarbamazine (DEC) will kill microfilaria. Ivermectin suppresses microfilaria production but its overall effectiveness remains untried and elephantiasis can be treated surgically.

Tsetse Flies

Class: Insecta
Order: Diptera
Family: Glossinidae
Genus: *Glossina*

General Characteristics

Tsetse flies are large, yellow-brown or brown-black and measure 6-15µm in length. They are distinguished by a rigid projecting proboscis and a long pair of accompanying palps. There is a characteristic axe-shaped venation of the wings when viewed dorsally resembling an inverted hatchet in the central cell. The antennae appear short and feathery, and the abdomen is segmented and often striped or patched. Both males and females suck blood every 4-5 days, outside in open spaces.

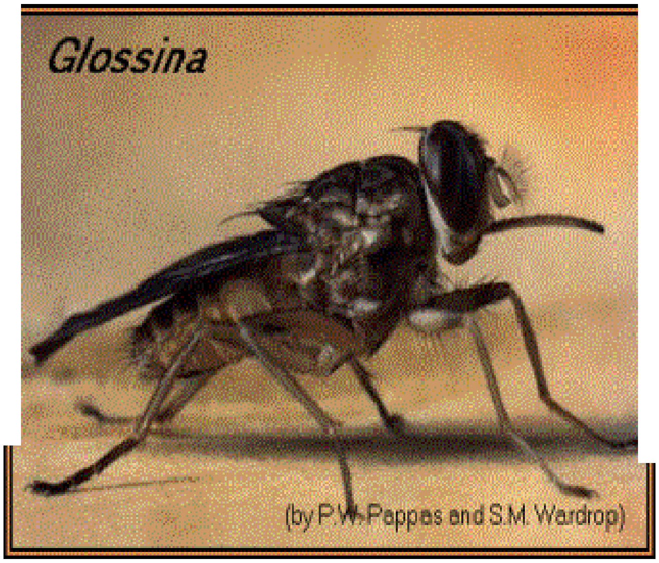

Image 12-19. Typical illustration of a *Tsetse Fly*. They are yellow-brown in Colour and usually measure 6 – 15µm in length. Their characteristic feature is the hatchet shaped cell in the centre of the wing venation. (IMAGE SOURCE: Trustees of the British Museum)

Life Cycle

Female Tsetse flies are unique in the sense that they deposit larvae and do not lay eggs. The eggs mature within the female and are supplied with essential nourishment to complete larval development. This cycle requires a large number of blood meals to maintain and thus the female requires regular feeding. The larvae are normally deposited in shaded areas. There are three larval instars with the mature larva appearing white, visibly segmented with a pair of lobes at the posterior end. Pupation of the third instar results in a dark colored puparium with posterior lobes. The pupal period is extended (3-7 weeks) depending on the surrounding environmental conditions.

Disease

Tsetse flies are vectors for African sleeping sickness (*Trypanosoma brucei sp*. The two subspecies of *T. brucei* that infect Man are morphologically identical. *T. b. gambiense* causes Gambian sleeping sickness in Western Africa and *T. b. rhodesiense* causes Rhodesian sleeping sickness in East Africa. Another subspecies, *T. b. bruc*ei, causes nagana in cattle.

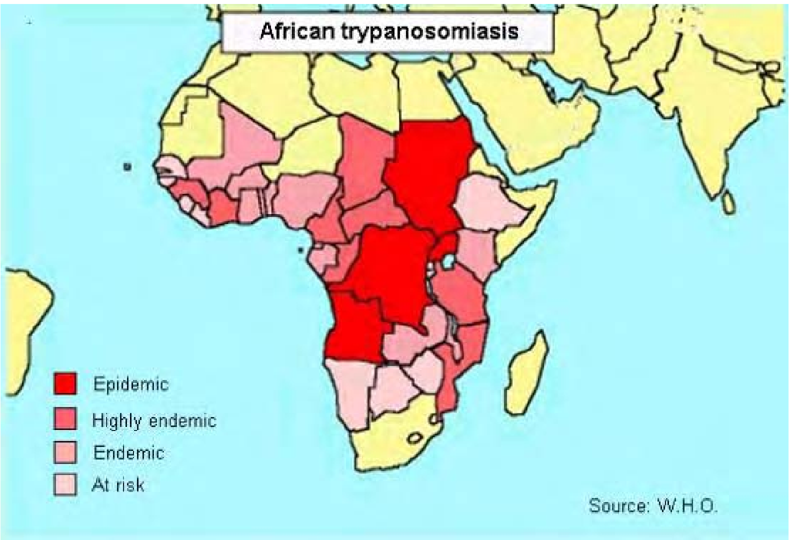

Illustration 12-9. Distribution of African Trypanosomiasis throughout Africa (WHO, 1991)

Initially the patient has a headache, fever, chills and loss of appetite but specific clinical signs are absent. Parasitaemia comes in characteristic waves. Later, the spleen, liver and lymph nodes enlarge (Winterbottom's sign). Finally, there may be CNS involvement leading to coma and death within several years. *Trypanosoma brucei rhodesiense* (rural East Africa): this is so acute that the patient invariably dies before classical symptoms develop. Without appropriate treatment, both forms are fatal.

Human African trypanosomiasis is rural and focal, with humans as the principal reservoir of infection of *T. b. gambiense*, and domestic cattle and wild animals as important reservoirs of *T. b. rhodesiense*. By the 1960s, it had been brought under control, but since 1970 the situation has deteriorated and the disease has reappeared, with major flare-ups in countries which have not maintained surveillance activities. It is estimated that 55-60 million people are exposed to the risk of becoming infected with trypanosomiasis, but only four million of them are under active surveillance or have access to health centers where reliable diagnosis is available: the estimated number of infected persons is over 300,000 (WHO data).

Treatment and Control

Anemia and other infections should be treated first. If given before the parasite has invaded the brain (hemolymphatic stage), suramin (Rhodesian disease) or pentamidine (Gambian disease) appear to be effective. For late disease (CNS involvement), drugs of choice are melarsoprol or eflornithine, with tryparsamide plus suramin as an alternative. Tsetse-infested areas should be avoided. Protective, light-colored clothing and repellents should be used. Tsetse flies are difficult to treat with insecticide (DDT has been tried) as their larvae live in burrows in the ground; protective vegetation must first be removed. Pentamidine prophylaxis is no longer advocated. Reservoir hosts should be identified and removed. It is possible to breed resistant or tolerant cattle (West Africa). Trypanosomes other than *T. brucei* are also transmissible by Tabanid flies or by sexual contact.

Sand Flies

Class: Insecta

Order: Dipthera

Family: Psychodidae

Genera: *Phlebotomus, Lutzomyia*

Introduction

Sandflies are small (1.5-5µm) with a hairy head, thorax, antennae and wings. The antennae are long, may appear beaded, and protrude near a large set of black compound eyes. The wings are upwardly pointing at rest, and are a distinctive feature of Phlebotomine sandflies. Only the females are blood feeders, the males feed on plant nectar. Biting predominates nocturnally and they rest in moist and dark walls, cracks and tree trunks during the day.

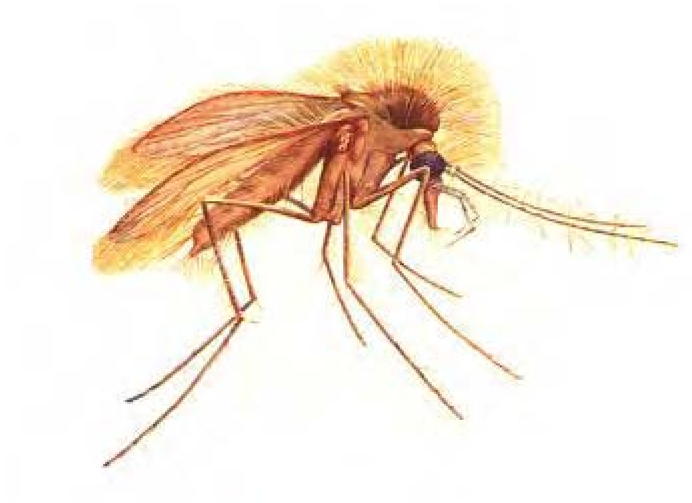

Illustration 12-10. Typical illustration of a Sand Fly. The head, thorax, abdomen, legs and antennae are hairy, they are small usually measuring 1.5-5µm long. (*Phlebotomus)* (Illustration Source: Trustees of the British Museum)

Life Cycle

Female Phlebotomine sandflies deposit 30-70 minute eggs at each oviposition. The eggs are laid in dry areas, but require humidity to avoid desiccating. There are four instars and the mature larva is characterized by a distinct black head, 12 segments, thick bristles covering the body, and two pairs of caudal setae on their posterior end. As with other fly vectors the length of the larval stage depends on the ambient temperature, species in question, and food availability. The larval skin and caudal bristles remain attached at the posterior end during the pupal stage which lasts 5-10 days.

Disease

Sandflies are the only vectors for several species and subspecies of obligate intracellular protozoa responsible for leishmaniasis (*Leishmania sp.*) Cutaneous, mucocutaneous and visceral leishmaniasis are caused by different species of *Leishmania* contentiously linked to temperature preferences. Geographic location and host immune response also play a role in determining the form of disease. *Leishmania tropica* and *L. major* cause dermal cutaneous leishmaniasis; visceral leishmaniasis (kala-azar) is caused by *L. donovani* and mucocutaneous leishmaniasis is caused by *L. braziliensis* and *L. mexicana*. Visceral leishmaniasis in Europe is caused by *L.infantum* with dogs as the main reservoir. *Leishmania tropica* is found in the Middle East, North Africa, India and the Mediterranean. *Leishmania donovani* is found in the old and new worlds: South America, the Mediterranean, North and East Africa, India and China. *Leishmania braziliensis* is found in Central and South America. *Leishmania mexicana* is found in North and Central America, Texas and Mexico.

Dermal cutaneous leishmaniasis or Old World leishmaniasis is also known as "Tropical or Oriental Sore" or "Delhi Boil" and is generally localized to the skin surrounding the bite of the *Phlebotomus* sandfly. The ulcers (volcano sign) are "draining" but produce "dry" ulcers that crust over. They usually resolve within one year but superinfection (yaws or myiasis) may occur and immunity develops. Cutaneous leishmaniasis affects over 300,000 people. The mucosal form affects the mucosa of the nose, pharynx, palate, larynx and upper lip causing ulcers that often become secondarily infected. Scarring can lead to death from pneumonia.

Visceral leishmaniasis, or "Kala-azar" is transmitted by Phlebotomus sandflies and is spread via the lymphatics from an often minor cutaneous lesion. They multiply in macrophages to form Leishman-Donovan bodies. Symptoms are usually chronic and comprise malaise, lymphadenopathy, cough, diarrhea, wasting and anemia, bleeding, and low-grade fever (3/day); liver and spleen enlarge and visibly distend the abdomen. Untreated, death ensues within three years, usually from secondary infection.

Leishmaniasis currently affects some 12 million people in 88 countries, all but 16 of which are in the developing world. It is estimated that 350 million people are exposed to the risk of infection by the different species of Leishmania parasite. The annual incidence of new cases is about two million (1.5 million of cutaneous leishmaniasis, and 0.5 million of visceral leishmaniasis). Recently, the WHO has reported an increase in overlapping of visceral leishmaniasis (VL) and HIV infection due to the spread of the AIDS pandemic. Leishmania / HIV co-infection is considered to be a real "emerging disease", especially in southern Europe, where 25-70% of adult VL cases are related to HIV infection, and 1.5-9.5% of AIDS cases suffer from newly acquired or reactivated VL. Intravenous drug users have been identified as the main population at risk.

Treatment and Control

Dermal leishmaniasis usually resolves spontaneously. Visceral leishmaniasis is treated with extended courses of antimonial compounds (e.g. sodium stibogluconate or meglumine antimonate) and dietary supplementation (pentamidine isethionate has been used in antimony-resistant cases). WHO regimes are changing and pentamidine may be used. Mucocutaneous leishmaniasis is also treated with antimonial compounds. However, only around 50% of patients respond to antimonial compounds and relapses are seen. Pentamidine isethionate, paromomycin (aminosidine), allopurinol, ketoconazole, itraconazole, interferon gamma and liposomal amphotericin B have all been used; amphotericin B appears the most effective. Control of sandflies is difficult although buildings may be sprayed with insecticide. Sandflies cannot bite through clothing. Repellents are effective although mosquito nets are of limited value (sandflies are 3 µm). Sandflies are nocturnal and can be avoided. Rodent and dog control is a possibility. Vaccines (killed or live attenuated promastigotes) have been tried but effectiveness has not been assessed.

Black Flies

Class: Insecta
Order: Diptera
Family: Simuliidae
Genus: *Simulium*

Introduction

Black Flies are small (1.5-4µm in length) and normally black with short hairless legs and antennae. They have large compound eyes and a characteristically hairy humped thorax. Flies of the genus *Simulium* are generally found near free-flowing well-oxygenated water and bite during the day, tearing the skin to reach blood vessels.

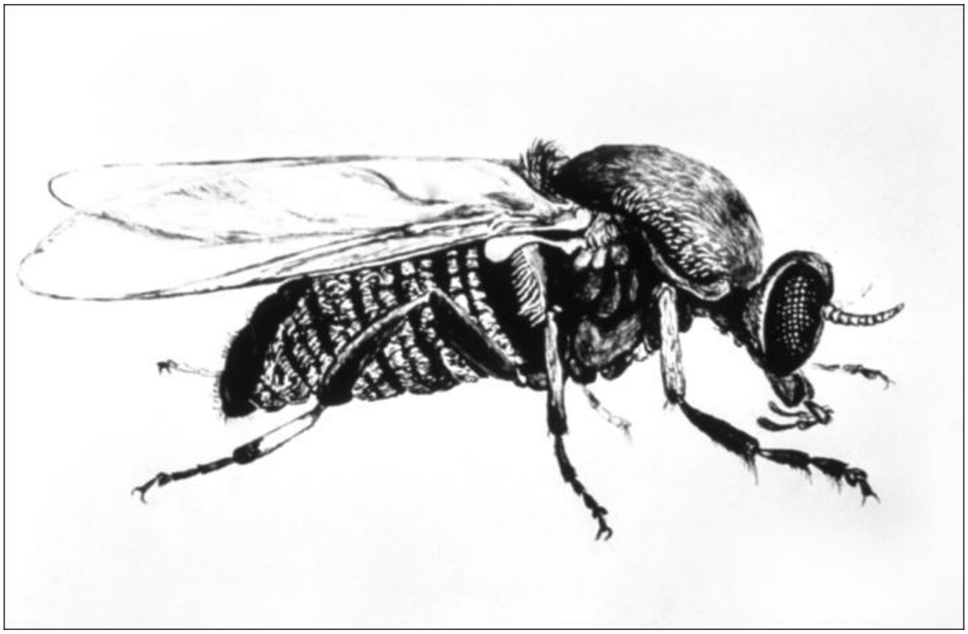

Illustration 12-11. Typical illustration of a Black Fly (*Simulium).* They are usually small (1.4–4µm in length), black with short hairless legs and antennae. (SOURCE: PHIL 4639 - CDC)

Image 12-20. Image of a Black fly receiving a blood meal. (SOURCE: Unknown)

Life Cycle

Simuliidae eggs are laid in flowing or turbid waters in clusters of 200-800 eggs depending on the species. Hatching is mediated by the external environment, generally occurring several days following oviposition. There are 6-9 larval instars, with the larvae remaining essentially sedentary for the period and feeding through filtration. Movement is possible if necessary with some larval species acting as predators. The mature larvae can be recognized by a characteristic black “gill spot” on the thorax. The pupa is enclosed in a dark colored cocoon, identifiable by a series of filamentous respiratory gills protruding from the anterior end. In most cases the adult fly emerges from the pupal stage following one week of incubation.

Disease

Simulium are vectors for the filarial parasitic nematode responsible for Onchocerciasis (*Onchocerca volvulus).* It is distributed throughout Africa, Arabia, Central America, northern South America and Mexico with 30 million people infected in Africa alone; it is one of the most important causes of blindness in the world. Adult worms (up to 50cm) live in the subcutaneous tissue of man (the only known host) and release microfilariae into the skin. These are taken up by *Simulium* (*S. damnosum* and *S. naevei* in Africa; *S. ochraceum* and *S. metallicum* in Central America). Microfilariae penetrate the gut wall, migrate to the thoracic muscles, molt to L_2 stages and molt again to filariform L_3 stages which are passed to the next host during a blood meal. Larvae mature to adults in one year and may live for up to 20 years. Microfilariae can live for up to two years but are often trapped, in fibrous nodules, by the host's cellular response and are responsible for the pathology. Microfilariae are highly motile, unsheathed and measure 300 by 7 microns; there are no nuclei in the end of the tail, which is long and pointed; the head is slightly enlarged. Microfilariae are not found in blood.

Skin problems include nodules (2cm to 5cm in diameter) containing adult worms. Onchodermatitis is caused by death of microfilariae in the skin and is associated with severe pruritis (adopts different forms in different geographical localities e.g. "erysipelas de la costa" in Central America, "leopard skin" in parts of Africa), skin depigmentation and premature ageing. There may be minor elephantiasis of the inguinal area ("hanging groin") or of the genitals (including hydrocoele). Eye involvement is due to microfilariae entering the eye and dying and may eventually lead to blindness through sclerosing keratitis and retinal damage (microfilaria can be seen in the anterior chamber of the eye). There may be competition between parasite and host for vitamin A.

Treatments and Control

Ivermectin destroys microfilariae and renders adult female worms infertile; the manufacturer provides this drug without charge. Nodules may be surgically removed to reduce the worm-load and decrease the chances of ocular involvement. In areas of East Africa, *S. naevei* has been eradicated with insecticide (the larvae of this parasite attach to freshwater crabs). *S. damnosum* inhabit areas far distant to its breeding sites and control is much more difficult. However, the WHO larvicide program in concert with mass Ivermectin treatment has the potential to control the problem. Vegetation should be cleared around villages and irrigation should be devised to avoid fast-flowing water currents.

Tabanid Flies

Class: Insecta
Order: Diptera
Family: Tabanidae
Subfamily: Chrysopsinae (Deer flies)
Genus: *Chrysops*
Subfamily: Tabaninae (Horse flies)
Genus: *Tabanus*

Introduction

Chrysops are 9-10µm in length with broad wings and large iridescent eyes. The abdomen is yellow or orange and can be patterned with black markings. The antennae consist of three segments, lacking a projection from the second segment and with the third segment subdivided into four smaller sections. Female *Chrysops* are attracted by smoke and normally bite in the morning or late afternoon. They breed in shaded muddy areas and have a worldwide distribution.

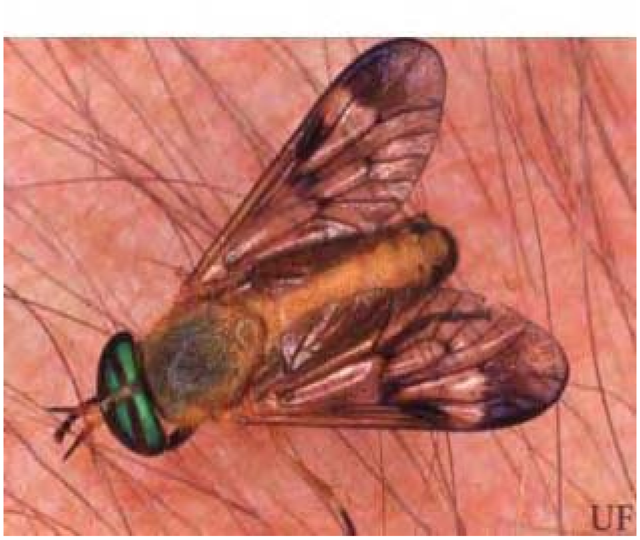

Image 12-21. Image of a Deer fly receiving a blood meal. They have large iridescent eyes and broad wings. Generally measure between 9–10µm in length. (SOURCE: University of Florida)

Life Cycle

Female Tabanids generally lay 100 -1000 large creamy white eggs on the undersides of plants and rocks surrounding aquatic areas. The eggs hatch following several weeks of incubation. Larvae live and feed in wet rotting vegetation but survive breathing oxygen. The larval stage can be quite prolonged (1-3 years) with 6-13 larval instars depending on the species. The mature larvae migrate to dry areas and undergo pupation. The pupa often gets buried in the soil and can often be large. The pupal stage lasts several weeks, and the adults emerge to feed.

Disease

Tabanids are vectors for the parasitic nematode *Loa loa.* Their Microfilariae are large and sheathed and contain nuclei extending to the end of the rounded tail. Adult worms are thin and white (females 2cm-7cm long, 425µm in diameter and males 2cm-3.4cm long, 350µm in diameter). Clinical features of *Loa loa* infections include considerable pruritis and transient painful subcutaneous swellings termed Calabar swellings. Migrating adult worms can cross the conjunctiva or the bridge of the nose and ectopic worms cause problems such as hydrocoele, orchitis, colonic lesions, encephalitis.

Treatment and Control

Worms traversing the conjunctiva may be removed surgically. Diethyl-carbamazine (DEC) is a proven treatment; prevention comprises the use of prophylactic DEC. However, DEC may have fatal side effects including encephalitis and the current drug of choice is Ivermectin. Drugs kill microfilariae but not adult worms. Antihistamines and corticosteroids may prevent allergic reactions brought about by rapid destruction of microfilariae in heavy infections. Insect control is not practical.

Biting Midges

Class: Insecta

Order: Dipthera

Family: Ceratopogonidae

Genus: *Culicoides*

Introduction

Biting midges are 1µm-2µm long with a small head, long antennae and segmented palps. The thorax is often black spotted and contains a distinctive set of small depressions called the "humeral pits" just posterior of the head on the upper thorax. Biting midges have long legs and wings that fold over the thorax when at rest. Only the females take blood meals and normally swarm and bite in the early morning or late evening, especially during overcast weather.

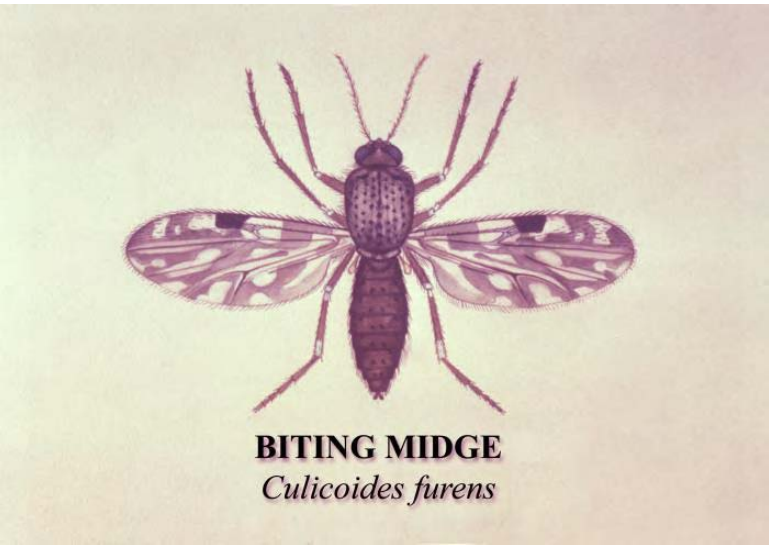

Illustration 12-12: Typical Illustration of a Biting Midge (*Culicoides*). The thorax is often black spotted and contains a distinctive set of small depressions called the "humeral pits" just posterior of the head (SOURCE: PHIL 3822 - CDC/Dr. Richard Darsie)

Life Cycle

Female culicoides lay 30-250 dark, cylindrical eggs on the surface of wet soil or organic debris. Larvae emerge from the eggs soon thereafter depending on the environmental conditions. There are four larval instars, and the mature larvae resemble that of a nematode worm. They have a small dark head, 12 segments, and terminal papillae. The larvae feed on detritus and may development for extended periods of time depending on the species and conditions. The pupal period lasts 3-10 days, with the adult females emerging to feed and breed.

Disease

Culicoides species possess the ability to transmit various filarial parasites to humans (*Mansonella perstans*, *M. streptocerca* and *M. ozzardi*). Adult *Mansonella streptocerca* reach 3 cm in length and live in the skin. Microfilariae are small and thin (200µm in length), unsheathed and nuclei extend to the end of a hooked tail. The major symptoms of infection are pruritis, papular eruptions and pigment changes.

Mansonella ozzardi is found in South and Central America and the adult worms live in the peritoneal cavity. Microfilariae are small, thin (150-200 by 4.5 microns) and unsheathed with indistinct nuclei that do not extend to the end of the pointed tail. They are found in the skin and blood and are non-periodic. Most infected persons are asymptomatic but may be associated with arthralgias, headaches, fever, pruritis, hepatomegaly, pulmonary symptoms and adenopathy: there is no proven therapy.

Mansonella perstans is found in tropical Africa and coastal South America with adult worms measuring 4cm-8cm. They inhabit the peritoneal and, rarely, pleural cavities. Infections are usually asymptomatic but can be associated with pruritis, fever, arthralgias and neurological changes.

Head and Body Lice

Class: Insecta
Order: Phthiraptera
Genus: *Pediculus*

Introduction

Pediculus humanus capitis (the head louse) and *Pediculus humanus humanus* (the body louse) are 2µm-4µm long and flattened dorsoventrally. They are wingless with distinct head, thorax (bearing three pairs of clawed legs) and abdomen (seven segments). The fore legs are well developed to grasp clothing and hair, with terminal claws to aid grip on the host. *Pediculus* feed using two stylets which suck blood whilst a third directs saliva into the skin; meanwhile feces are continually passed onto the skin.

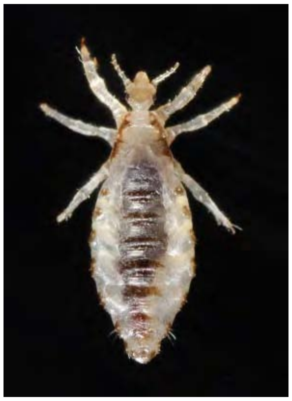

Image 12-22. Dorsal Image of a typical body louse (*Pediculus humanus humanus*). They are wingless and dorsoventrally flattened, bearing a distinct head, thorax and abdomen. They measure approximately 2–4µm in length. (SOURCE: PHIL 9205 - CDC/ Frank Collins, Ph.D.)

Life Cycle

The head and body louse share very similar life cycles only differing in the placement of their eggs; the body louse cements eggs to clothing and the head louse cements single eggs at the base of hairs. Females can lay upwards of 300 eggs during a lifetime. Lice have a hemimetabolous lifecycle. The nymph hatches from the egg and appears very structurally similar to the adult louse. There are three nymphal instars that require blood meals to proceed. It only takes 7-12 days to proceed to the adult stage if blood meals are readily available, but conversely lice will perish if not fed for several days.

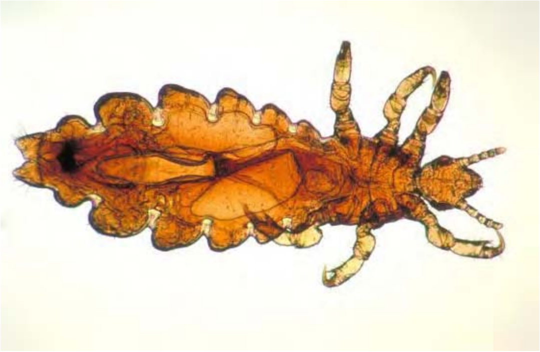

Image 12-23. Dorsal Image of a typical head louse (*Pediculus humanus capitis)* (SOURCE: PHIL 377 - CDC/ Dr. Dennis D. Juranek)

Disease

Colonization by lice may result in serious infection and disease. Lice can potentially pass *Rickettsia prowazeki* resulting in epidemic typhus and other pathogens such as *Rochalimaea quintana* and *Borrelia recurrentis* that result in potentially serious fever. The mode of transmission for all infectious agents is through physically crushing and spreading feces or waste into the wound created through feeding.

Control

The most effective control is to remain clean, but insecticides are often necessary during epidemics to avoid reinfestation.

Pubic Lice

Class: Insecta

Order: Phthiraptera

Genus: *Phthirus*

Introduction

The crab louse is 1µm-2µm long and distinguished by a square, undifferentiated body and massive claws on the two posterior sets of forelegs. These claws are able to grasp both pubic and facial hair (including eyelashes), and allow the louse to remain tightly bound to the host. They are spread mostly by sexual contact, but may also be transmitted through fomites.

Life Cycle

The life cycle of *Phthirus* is very similar to *Pediculus*. Females lay bundles of eggs on the coarse pubic hairs and dense facial hairs of humans. The crab lice proceed through a cycle similar to the head and body lice, with the nymphal stage proceeding several days longer. *Phthirus* are less active than *Pediculus,* but similarly can not survive for very long without a host and blood meals.

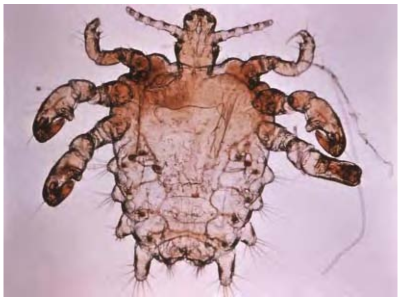

Image 12-24. Ventral Image of a typical Crab louse (*Phthirus).* They hold onto pubic hair with the large claws found on the posterior legs. (SOURCE: PHIL 4077 - CDC)

Disease

There appears to be very little evidence of disease transmission by *Phthirus,* but have the ability to cause severe localized allergic reactions during infestations.

Fleas

Class: Insecta

Order: Siphonaptera

Genus: *Pulex, Xenopsylla, Ctenocephalides, Tunga*

Introduction

Fleas are laterally compressed and wingless (1µm-4µm) with powerful legs. The entire body is generally covered with bristles, and the mouthparts point downwards. *Pulex irritans* (the human flea) and *Xenopsylla cheopsis* (the tropical rat flea) are combless. *Nosopsyllus fasciatus* (the rat flea) has a pronotal comb (behind its head). *Ctenocephalides felis* (the cat flea) and *C. canis* have two combs - a pronotal comb and a genal comb (under the head).

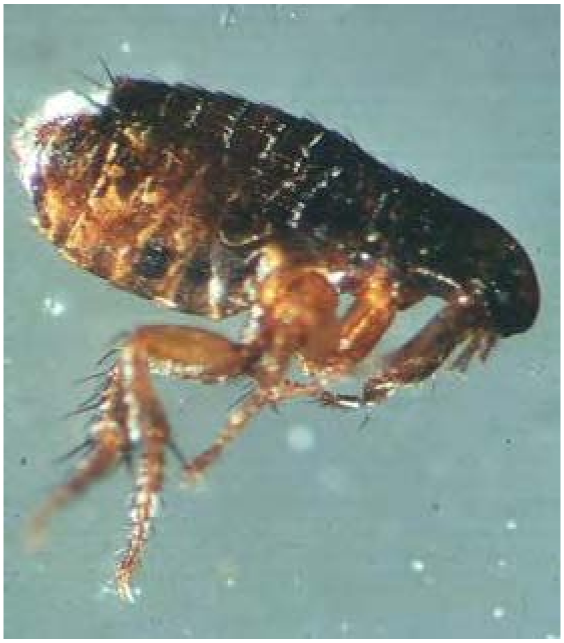

Image 12-25. Image of the cat flea *Ctenocephalides felis*. Fleas are laterally compressed and wingless (1-4 µm) with powerful legs. (SOURCE: CDC)

Tunga penetrans (the Chigoe or jigger flea) demonstrates compressed thoracic segments and attacks man in the Americas, Africa and India, commonly penetrating the stratum corneum between the toes or in the toenail margins

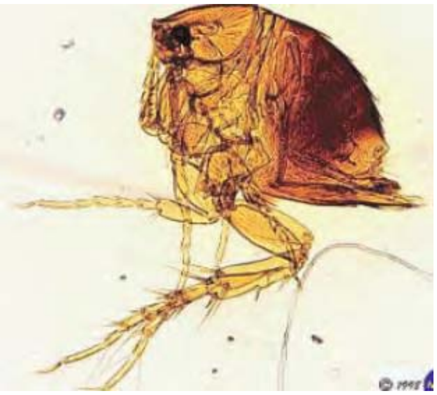

Image 12-26. Image of the Chigoe flea *Tunga penetrans*. They commonly penetrate between the toes or under the toenail. (SOURCE: Unknown)

Life Cycle

Flea larvae hatch from eggs generally following a week incubation. The larvae are legless, segmented, and covered with setae. The larvae feed on organic material, and proceed through two or three larval instars depending on the environment. The larva spins a cocoon and pupates and emerges when the conditions appear favorable for survival. The life cycle can be as short as several weeks or up to several years depending on the stimuli surrounding the pupa. Both sexes take blood meals can live for long periods of time allowing females to lay an enormous number of eggs over their lifetime.

Disease

Fleas are a general nuisance, often biting humans on exposed surfaces resulting in discomfort. Flea-bites induce pruritic papular urticaria commonly on the unprotected lower leg of women and all over the body of children who have intimate animal contact; a generalized allergic response may occur.

Certain fleas, notably the rat fleas, spread plague (*Yersinia pestis*) and murine typhus (*Rickettsia typhi*), and serve as intermediate hosts for species of tapeworm (*Hymenolepis* sp.). Cat and dog fleas serve as intermediate hosts for another common tapeworm (*Dipylidium caninum)*, which can be spread to humans, especially children with exposure to pet animals. *Pulex irritans* is not a major vector of disease but may play a minor role in the transmission of plague. Infection is often spread by the bite alone, but can also potential be transmitted through fecal abrasion. *Tunga penetrans* does not transmit disease to humans, but females will burrow into host skin. The pinpoint lesion enlarges to pea-size within two weeks necessitating removal of the gravid female using a pin, a needle or a sliver of bamboo. This may potentially lead to a secondary bacterial infection.

Control and Treatment

Control of fleas is generally mediated through insecticidal powders and aerosols. If outbreaks of murine typhus or plague occur steps to control the rodent populations in the affected area may be employed.

Bedbugs

Class: Insecta

Order: Siphonaptera

Genus: *Cimex*

Introduction

Common bedbugs (*Cimex lectularius*) are 3µm-7µm long, wingless, and flattened dorsoventrally. They have long legs, clearly segmented antennae and abdomen, and a distinctive set of compound eyes. Bedbugs are characteristically pale brown but swell and turn to black-red when engorged with blood. Both sexes infest clothing, beds and laundry and pierce the skin with an elongated proboscis to feed.

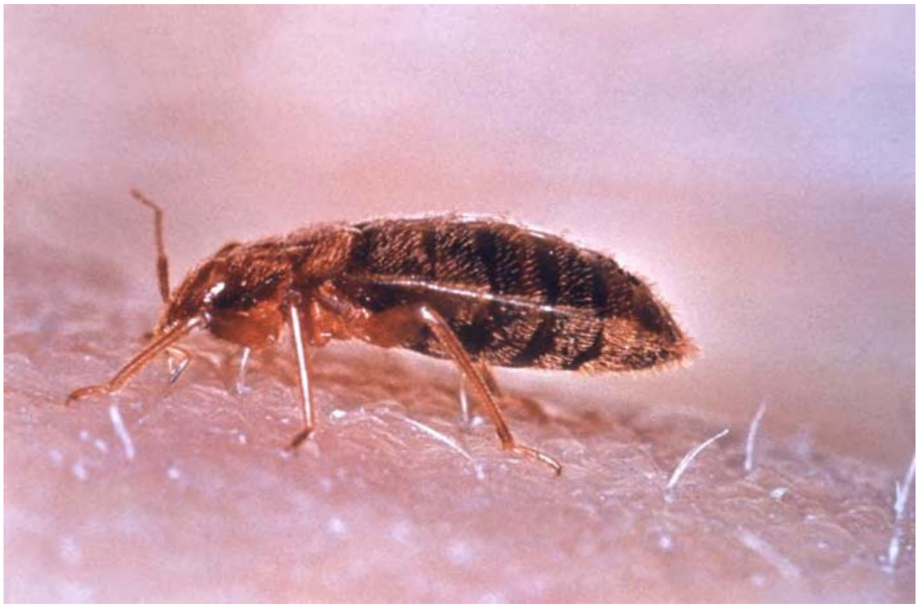

Image 12-27. Image of the common Bedbug *Cimex lectularius.* Bed bugs are usually pale brown in color but swell and turn black-red after a blood meal. (SOURCE: PHIL 6283 - CDC/Donated by the World Health Organization, Geneva, Switzerland.)

Life Cycle

Cimex nymphs appear yellow and very similar structurally to the adults. The life cycle is hemimetabolous with five nymphal instars that require blood meals to proceed. The adults primarily feed nocturnally, and females may lay upwards of 500 eggs during their lifetime. Life cycle duration and the number of offspring produced are primarily determined by the humidity and temperature of the surrounding environment.

Disease

Cimex blood meals result in inflammation, irritation and intense itching. These are the most common results of an infestation, but *Cimex* have also been found to carry Hepatitis B in India.

Treatment and Control

A female lays around 200 adherent eggs at the rate of 3 or 4 per day: eggs are white and 1mm in length. Control is by application of insecticide to mattresses and crevices where they hide during the daytime (to a height of several feet from the floor).

Triatomine bugs

Class: Insecta
Order: Hemiptera
Family: Reduviidae
Genus: *Triatoma*

General Characteristics

Triatomine bugs (a.k.a., Assassin bugs, Kissing bugs, Cone-nosed beetles, Walapai Tiger, or Reduviid bugs) are of variable size but are often large (10mm-30mm). They typically appear brown-black, but can have bright coloration. They are distinguished by a large snout with dark compound eyes, a thin and straight proboscis, and a triangular pronotum. They have long slender legs with terminal claws and segmented antennae. A set of large wings covers the oval abdomen. They live in the mud-walls of housing and woodpiles and come out to feed at night when the host is asleep: they are voracious biters, often on the face around the eyes**.**

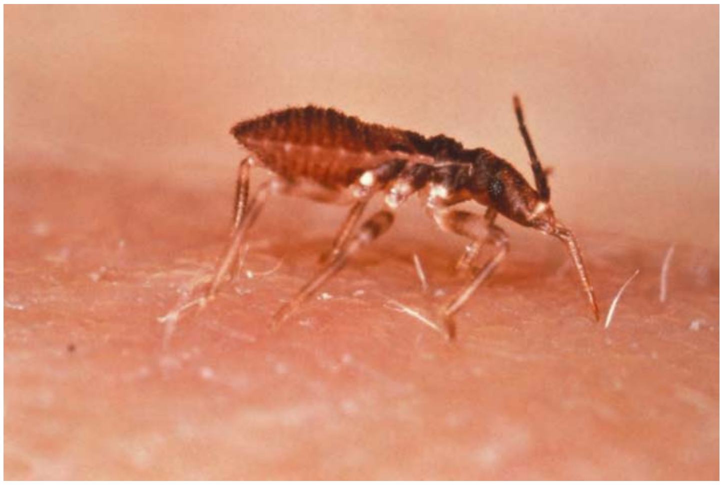

Image 12-28. Image of the Triatomine Bugs *Triatoma infestans.* Reduviid bugs are of variable size but are often large (10-30 mm). They typically appear brown-black, but can have bright coloration. (SOURCE: PHIL 2538 - CDC/World Health Organization.)

Life Cycle

The life cycle of *Triatoma* is hemimetabolous. The emergence of nymphs from eggs is primarily determined by the environment, and blood meals are required to proceed through the five nymphal instars. The nymphs and adults feed nocturnally and generally lay 50 to 1000 eggs depending on life term and the quantity of blood meals taken.

Disease

The primary disease transmitted by *Triatoma* is Chaga's Disease caused by *Trypanosoma cruzi.* Chagas disease is endemic in 21 countries; around 100 million people in Central and South America could be exposed to reduviid bugs; the prevalence of Chaga's disease is about 16-18 million. Rural migrations to urban areas during the 1970s and 1980s changed the traditional epidemiological pattern of Chaga's disease: it became an urban disease, as unscreened blood transfusion created a second way of transmission. Between 1960 and 1989, the prevalence of infected blood in blood banks in selected cities of South America ranged from 1.7% in Sao Paulo, Brazil to 53% in Santa Cruz, Bolivia, a percentage far higher than that of hepatitis or HIV infection (WHO data).

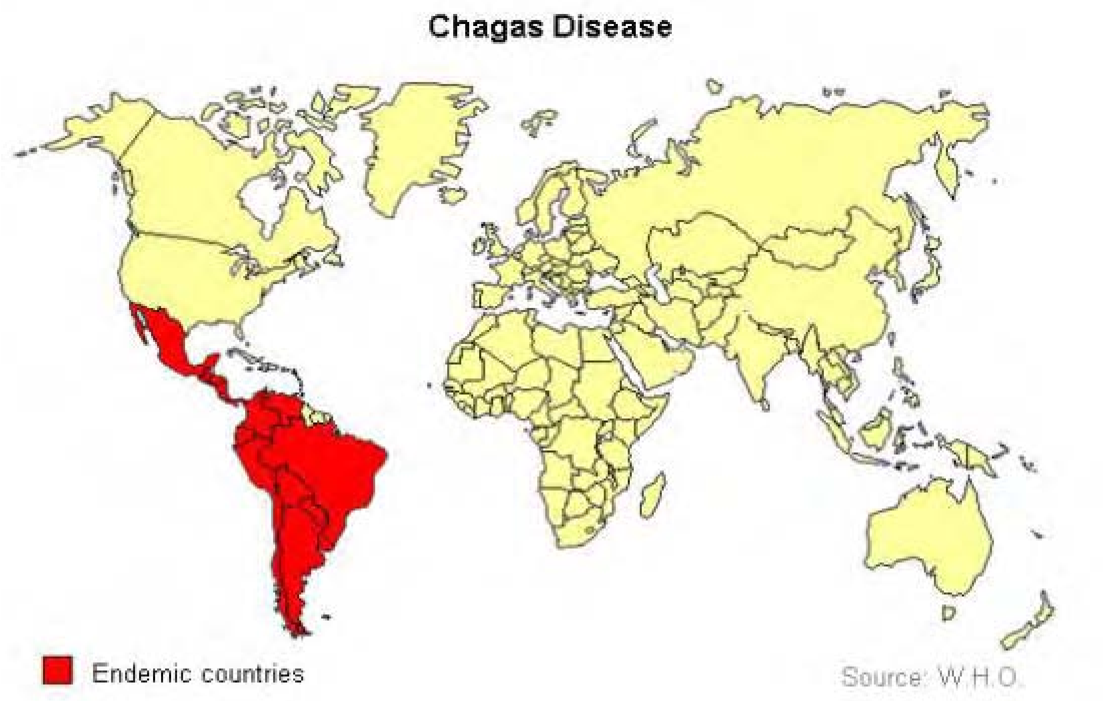

Illustration 12-13. Worldwide distribution of Chagas Disease (*Trypanosoma cruzi*) (SOURCE: WHO)

Triatomids are blood feeders and deposit infected feces (containing metacyclic trypanomastigotes) on the host's skin during feeding. The host rubs the feces into the wound; alternatively trypanosomes enter through the mucous membranes or conjunctivae. Once in the bloodstream, trypanomastigotes penetrate the spleen, liver, lymph nodes and muscle by an unknown mechanism (possibly via receptor-ligand binding proteins). The parasite transforms to the amastigote form that divides by binary fission and forms a pseudocyst. This ruptures and released amastigotes transform to flagellated trypanomastigotes via promastigotes and epimastigotes and enter the bloodstream. Unlike African bloodstream trypomastigotes, these do not replicate. If a Reduviid bug eats trypanomastigotes, they transform to epimastigotes, replicate by binary fission, and are passed as trypanomastigotes two weeks later. *Trypanosoma cruzi* does not exhibit antigenic variation but can persist for the life of the host. *T. cruzi* may also be transmitted in blood products or transplacentally. Humans and a large number of species of domestic and wild animals constitute the reservoir, and the vector bugs infest poor housing and thatched roofs.

In the acute phase (generally seen in children) a small red nodule (Chagoma) may form at the site of the bite. Romana's signs comprise fever, unilateral bipalpebral edema and ophthalmia. Most acute phases are asymptomatic and resolve to an asymptomatic chronic stage in 2-3 months. However, the patient may present with myalgia, bone pain, fever and chills, lymphadenopathy, hepatosplenomegaly and anorexia. Young children may develop meningoencephalitis. Pseudocysts form in heart muscle and fatal heart failure arises within one month. Neurological disorders, gastrointestinal disease and chronic myocarditis are features of chronic disease (mainly seen in adults) which arises 10-20 years after the initial infection and is untreatable. Congenital infection may lead to abortion, still birth or acute disease. Reactivation occurs in HIV-infected patients. Diagnosis is by detection of trypanosomes in peripheral anti-coagulated blood, CSF or node aspirate using wet film or Giemsa stain (acute disease) or by serology (Chaga's IgG ELISA in chronic disease). *Trypanosoma cruzi* is usually C-shaped, 12-30µm in length with a narrow membrane and a flagellum. The posterior kinetoplast is characteristically large and the nucleus is central.

Control

There is no satisfactory treatment. Extended therapy with the toxic agents, benznidazole or nifurtimox, only kills extra-cellular parasites and optimum efficacy (60%) is achieved during the acute phase. Chronic disease is treated symptomatically. Control is by improvements in housing, health education and insecticidal treatment of dwellings. Vaccines and chemoprophylaxis are ineffective (associated with autoimmune disease). For the control of blood-transmitted infections the aim is to screen all blood donors from endemic countries for *T. cruzi* antibodies, and to strengthen health service infrastructures for multiple blood screening (HIV, Hepatitis B and *T. cruzi*).

Chapter 13.
Artifacts and Confounders

Artifacts and Confounders

Introduction and Summary

Cysts and trophozoites must be examined carefully in different fields of view and measurement is often essential. Objects such as epithelial cells and macrophages are around the same size as amoebic trophozoites: the latter may also move and contain red blood cells. White blood cells, plant and vegetable cells, fat globules, muscle fibers, pollen grains, yeasts cells and air bubbles may be confused with cysts or eggs. Air bubbles trapped under adhesive tape often resemble *Enterobius* eggs. Plant hairs and fibers are easily confused with larvae; algae such as *Psorospermium haeckelii* may be found in the feces of patients who have eaten crayfish. Earthworms may resemble roundworms. A variety of non-pathogenic ova, cysts and parasites resemble pathogens in terms of size and morphology and careful examination is essential. Eggs of *Heterodera*, a parasitic nematode of root vegetables, may resemble hookworm eggs. Eggs originating from harmless mites in cereals or flour could be confused with hookworm ova but are usually larger. We recently encountered 160 micron "Schistosome ova" in the urine of a patient complaining of hematuria: we suspected *Schistosoma haematobium* but, on closer analysis, the eggs contained unidentified insects. This volume provides examples of artifacts that may be confused for parasitic life stages. Artifacts should be considered on the basis of size, shape, lack of organelles and defining feature, and variable reactivity with common stains.

Red and White Blood Cells

Red blood cells and a variety of white blood cells can be easily mistaken for parasitic cells or cysts when observed with microscopy.

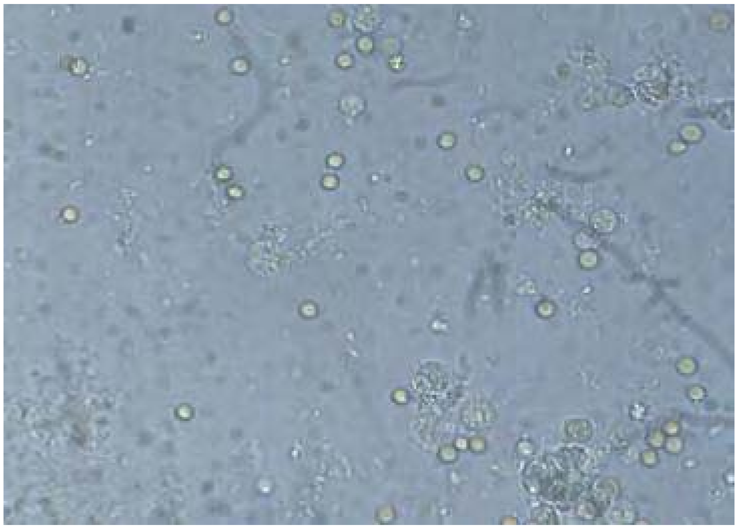

Image 13-1. Image illustrating red and white blood cells in a slide preparation. (SOURCE: Unknown)

White Blood Cells

Charcot-Leyden crystals are a product of eosinophil breakdown and are, therefore, occasionally found in feces of patients suffering from parasitic disease. They appear red when stained with in a trichrome fecal preparation.

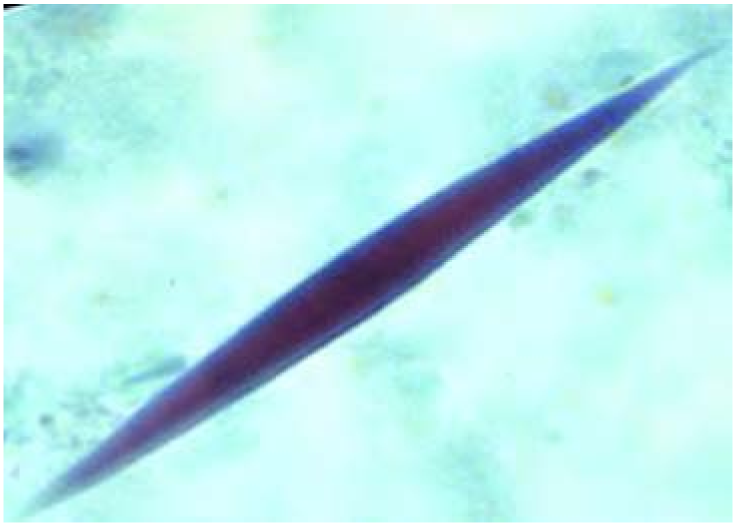

Image 13-2. Image illustrating trichrome stained Charcot-Leyden crystals in a slide preparation (Image courtesy of: The University of Alberta)

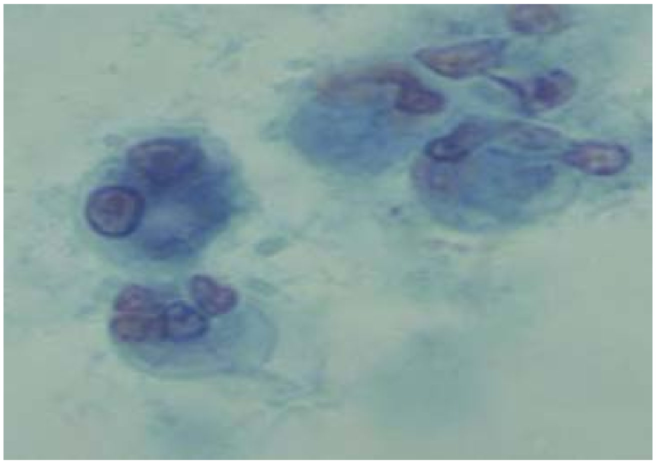

Image 13-3. Image showing trichrome stained Macrophage in a slide preparation. Note similarity to Amoeboid structure. (SOURCE: Unknown)

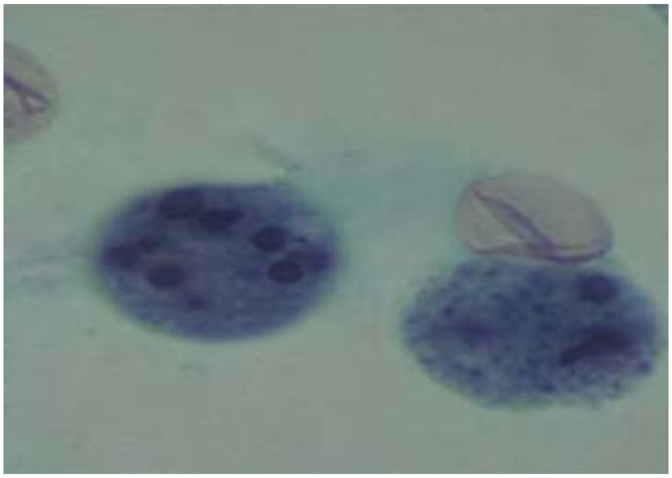

Image 13-4. Image illustrating trichrome stained Leukocyte in a slide preparation. Note similarity to Amoeboid cyst structure. (SOURCE: Unknown)

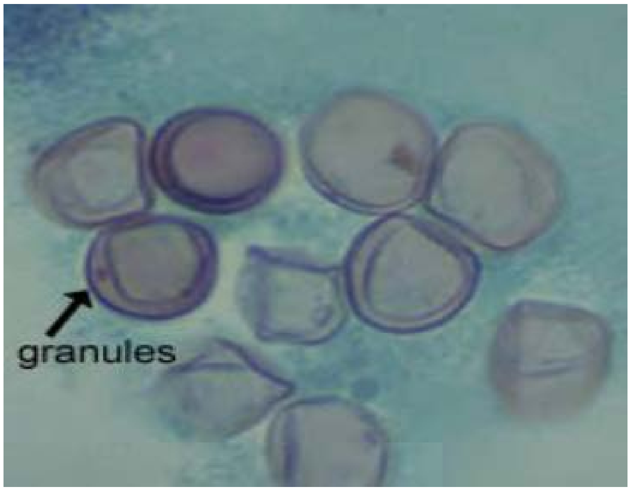

Image 13-5. Image illustrating Red Blood Cells in slide preparation. RBC's may appear to have a central body and a rim of cytoplasm or granules which could be mistaken for *Blastocystis hominis*. (SOURCE: Unknown)

Fat Globules

Fat globules present in a fecal slide preparation may appear similar to parasitic cysts or cell bodies.

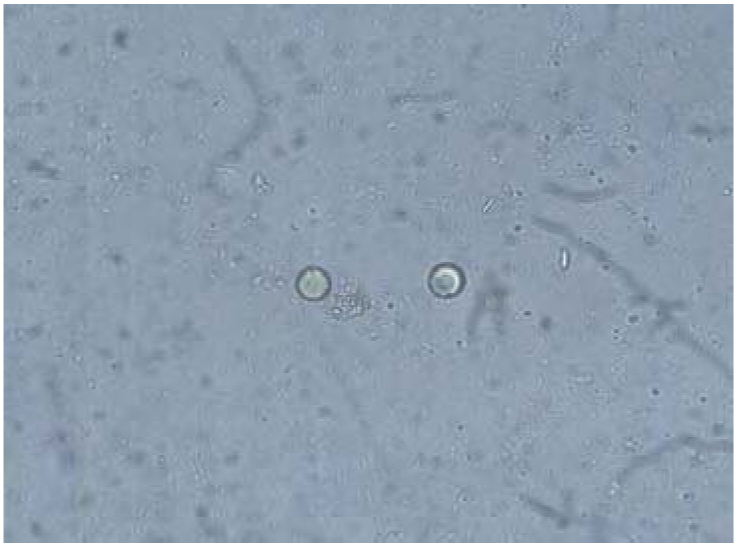

Image 13-6. Image illustrating Fat Globules in slide preparation. (SOURCE: Unknown)

Emulsifying agents are a useful tool to eliminate potential confusion involving fat globules. The removal of such particles from slide preparations will undoubtedly reduce cases of misdiagnosis.

Yeast Cells

Yeast may resemble protozoan cysts because they are uniform in color, have few inclusions and no nucleus. Yeast could also be confused with small protozoans like *E. nana* or with *Cryptosporidium* or *Cyclospora* oocysts in wet preparation. In acid-fast stains, the oocysts of *Cryptosporidium* and *Cyclospora* species stain pink to red. Yeasts are not acid fast and stain green.

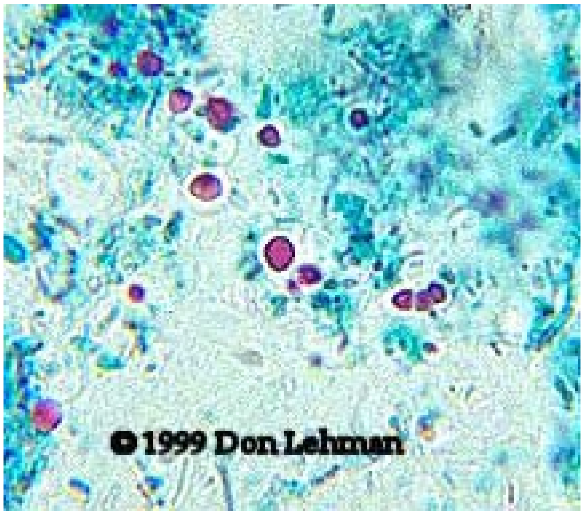

Image 13-7. Image illustrating Yeast Cells in slide preparation (Image courtesy of: Don Lehman). Note similarity to parasitic oocysts. (SOURCE: Don Lehman, Univ of Delaware)

Vegetable Cells

Plant cells and associated elements seen in feces may resemble eggs, cysts or cell bodies. Plant cells are often identified by a more irregular outer membrane.

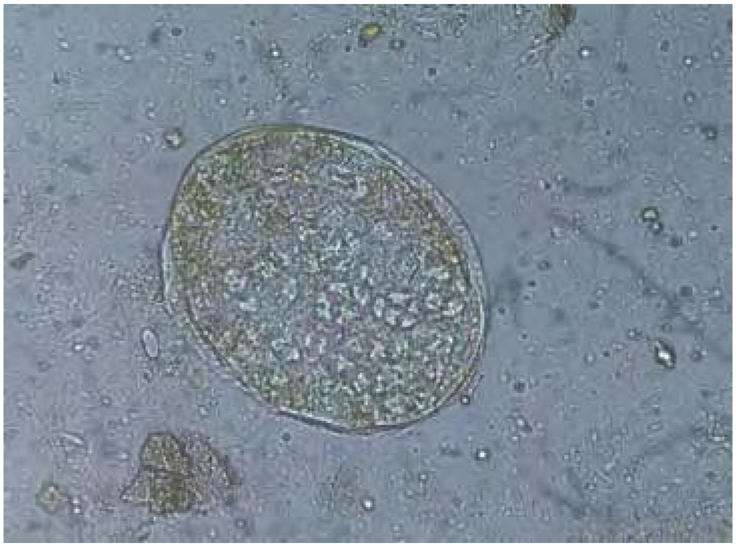

Image 13-8. Image illustrating Vegetable cell in slide preparation. Note similarity to *Paragonimus* eggs. (SOURCE: Unknown)

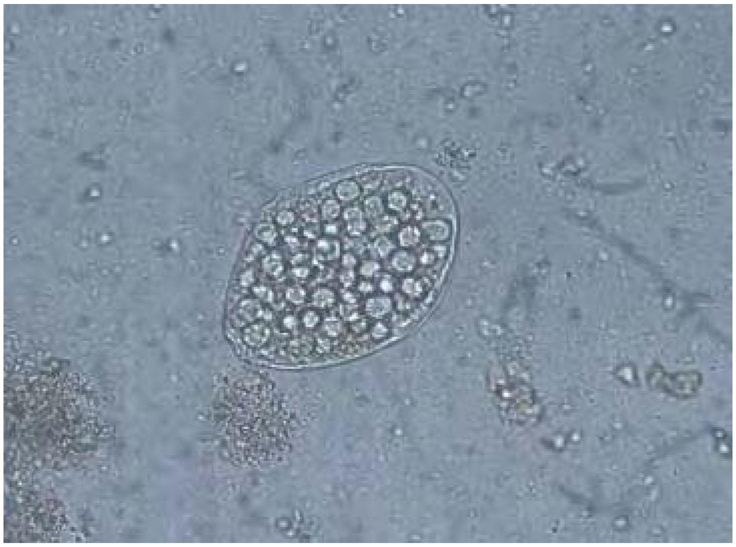

Image 13-9. Image illustrating Vegetable cell in slide preparation. Note similarity to *Dipylidium caninum* egg packets. (SOURCE: Unknown)

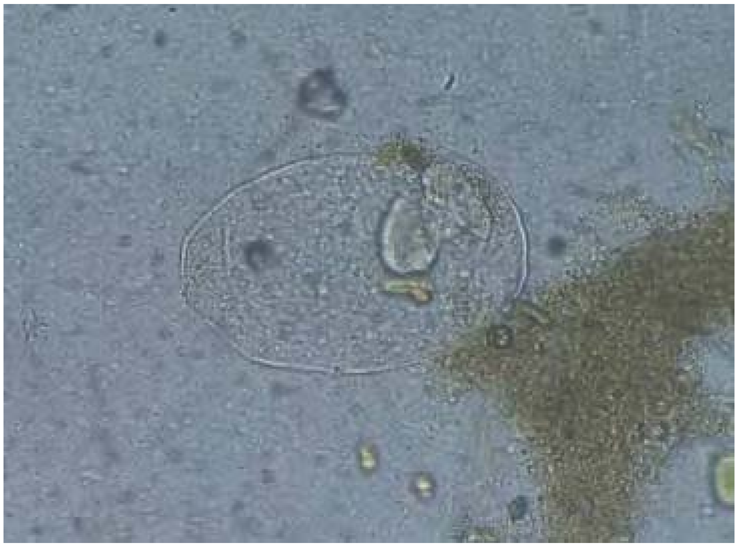

Image 13-10. Image illustrating Vegetable cell in slide preparation. (SOURCE: Unknown)

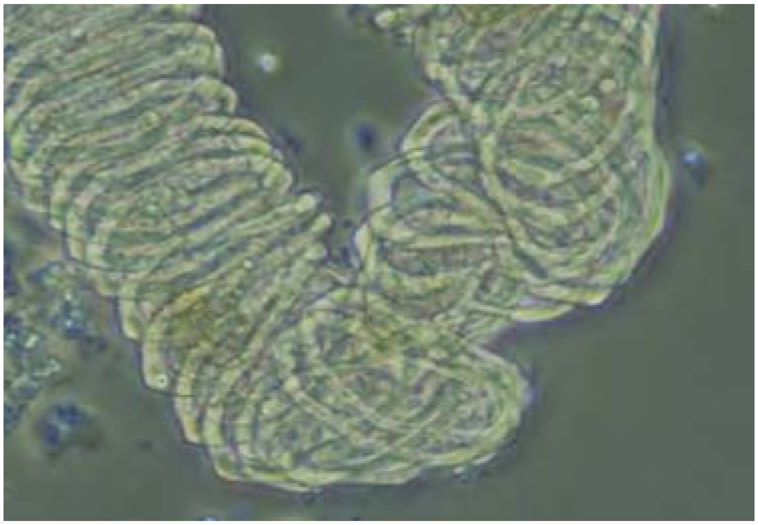

Image 13-11. Image illustrating a Vegetable Spiral in slide preparation. Such spirals may appear similar to proglottids. (SOURCE: Unknown)

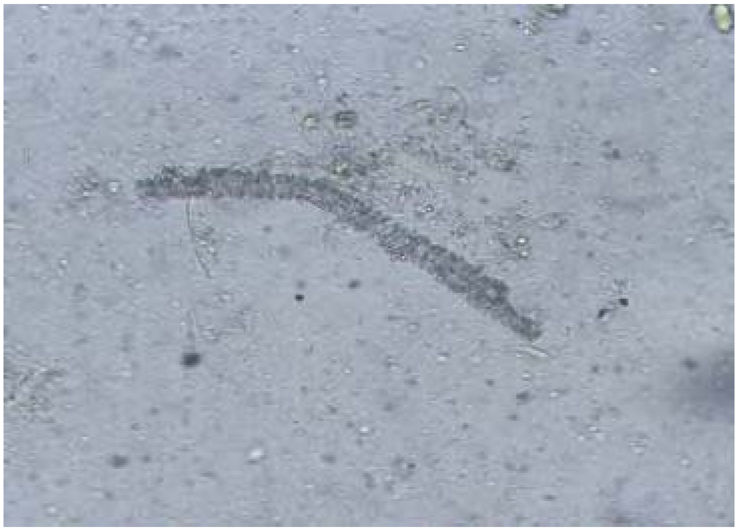

Image 13-12. Image illustrating Vegetable Spiral in slide preparation. (SOURCE: Unknown)

Pollen

Pollen grains are often misinterpreted as parasite eggs, but can often be discerned through size and the presence or absence of important structural elements.

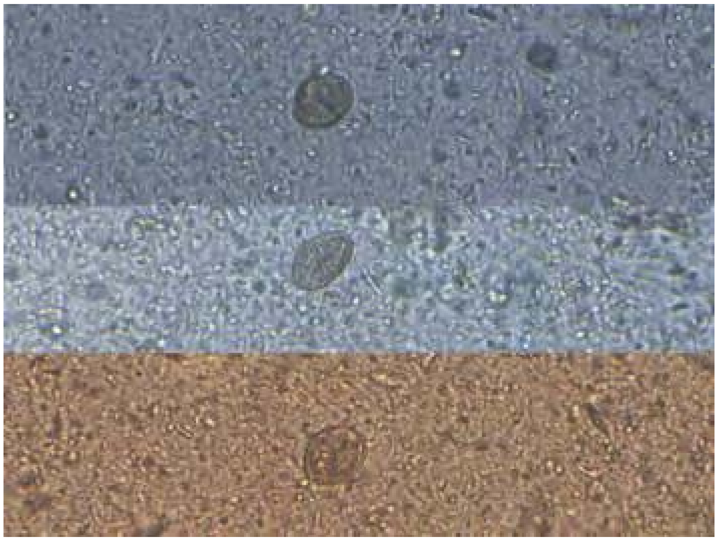

Image 13-13. Image illustrating pollen in slide preparation using a color filter. (SOURCE: Unknown)

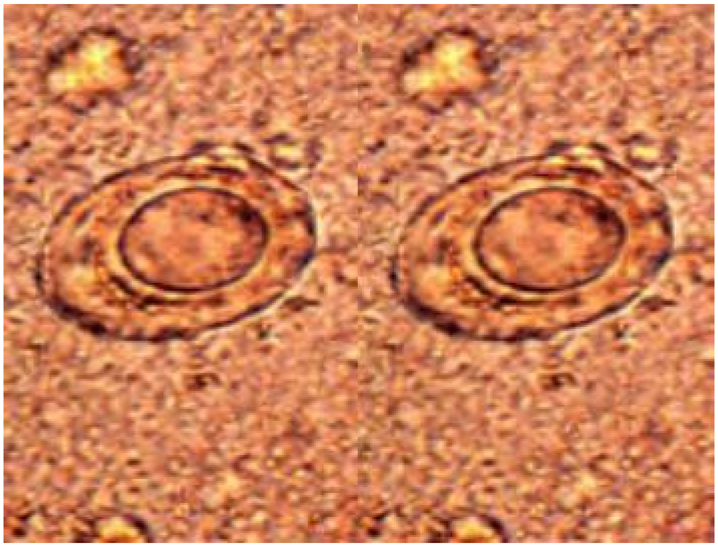

Image 13-14. Image illustrating pollen in slide preparation that could be mistaken for a *Taenia* egg. The shell is thinner, of non-uniform thickness, and no hooks are visible. (SOURCE: CDC)

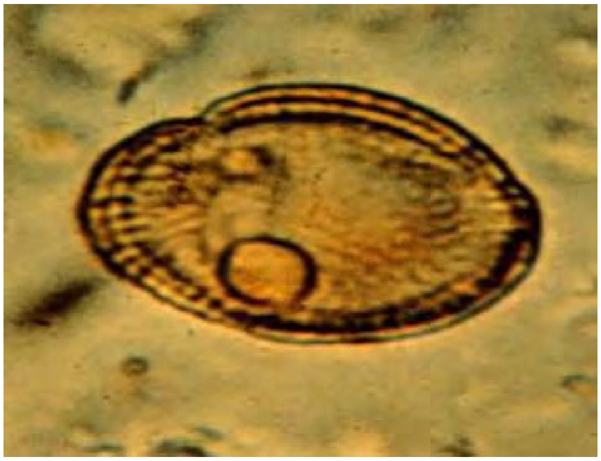

Image 13-15. Image illustrating pollen resembling a *Hymenolepis nana* egg. Hooks and polar filaments are not visible. (SOURCE: CDC)

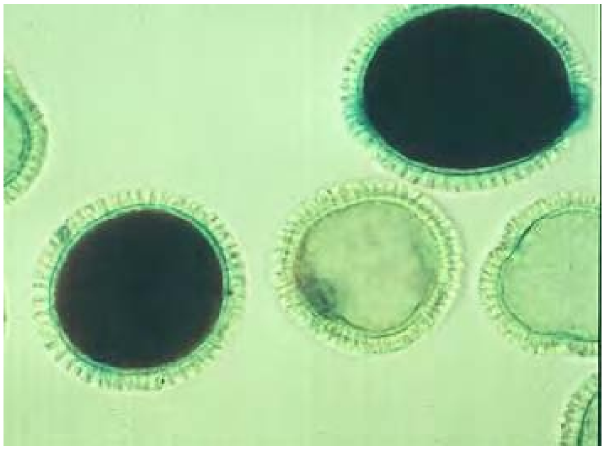

Image 13-16. Image illustrating geranium pollen cells in slide preparation. (SOURCE: Unknown)

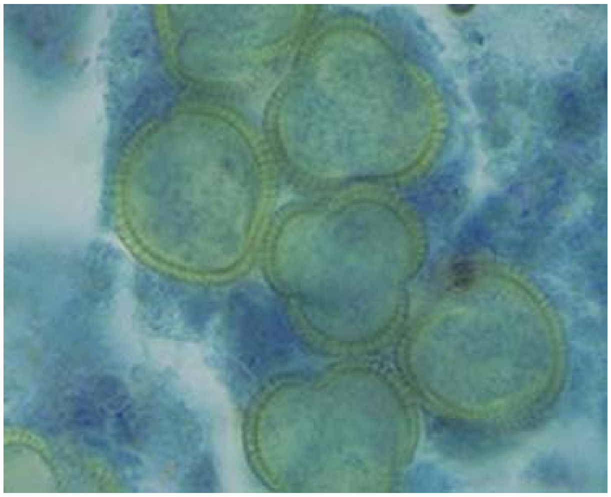

Image 13-17. Image illustrating pollen cells in slide preparation. Similar to *Taenia* eggs, but distinguished by uneven thickness of the wall and lack of internal contents do not suggest an egg. (SOURCE: Unknown)

Hair

Animal and plant hairs are most often and easily mistaken for parasitic nematode worms. Their size and shape may be comparable in many cases, but a lack of internal definition will identify the artifact when compared to the worm. Although nematodes are non-segmented and externally simple organisms, they will often show unique structural characteristics under close examination.

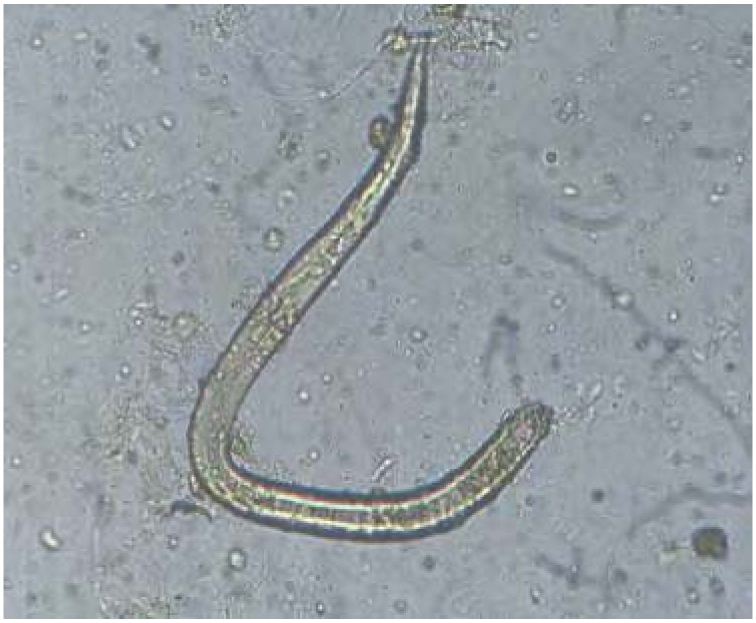

Image 13-18. Image illustrating peach hair in slide preparation. Note the similarity to *Strongyloides stercoralis.* (SOURCE: Unknown)

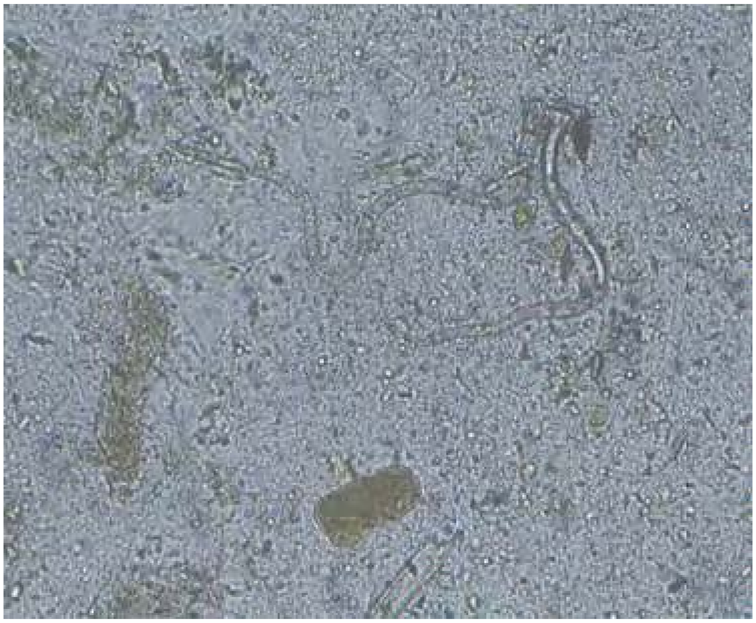

Image 13-19. Image illustrating vegetable hairs in slide preparation. (SOURCE: Unknown)

Insect Eggs

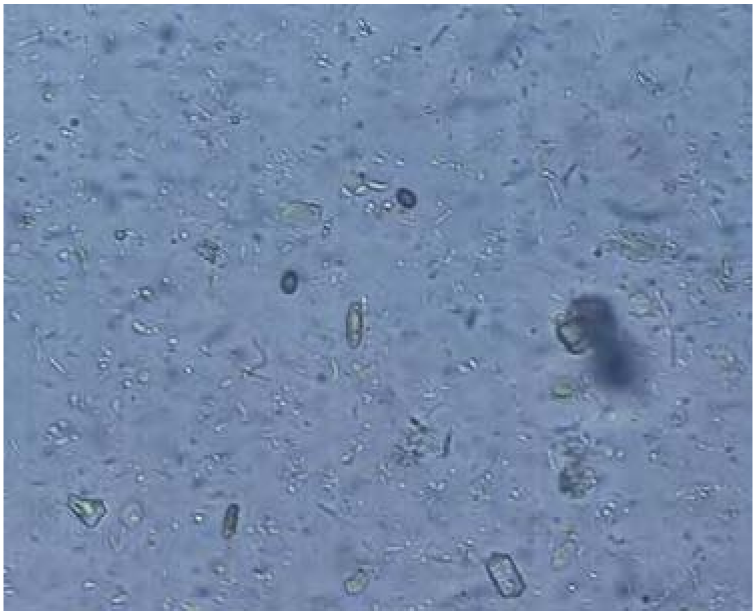

Image 13-20. Image illustrating Insect eggs in slide preparation. (SOURCE: Unknown)

Plant Parasites

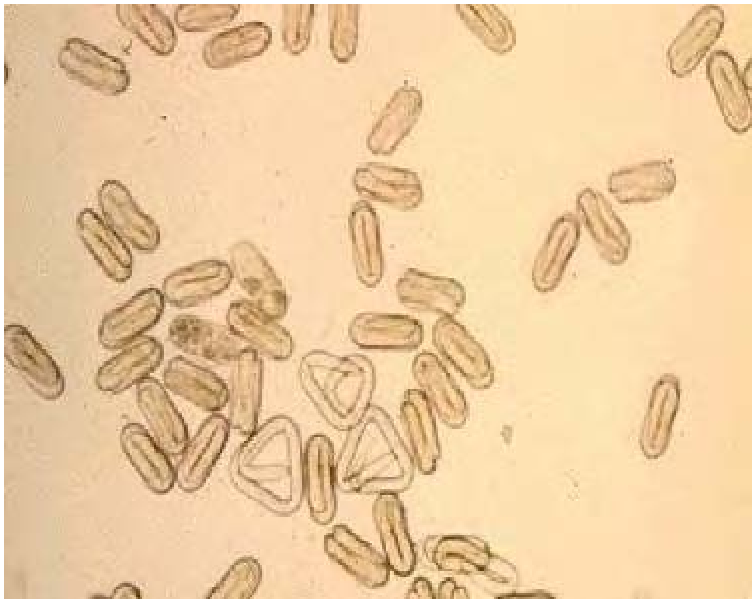

Image 13-21. Image illustrating *Heterodera spp*. in slide preparation. Such parasitic nematodes attack root vegetables such as beetroot, turnips and radishes. Their eggs are 80-120µm by 25-40 µm and can conceivably be confused with hookworm eggs. (SOURCE: Unknown)

Earthworms

Image 13-22. Image illustrating an Annelid earthworm in detritus. They belong to the Annelida (Lumbricus and Allolobophora) and are elongated, segmented and circular in section and are occasionally confused with *Ascaris*. They have a purple-brown dorsal surface and a paler ventral surface, swell out at around segment 12 and possess a marked thickening (the clitellum) a third of the way from the anterior. (SOURCE: Unknown)

THE KATHARA™

Bio-Spiritual Healing System

LEVEL 1 CERTIFICATE PROGRAM

by A'sha-yana Deane

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BIO-SPIRITUAL HEALING SYSTEM

CERTIFICATE PROGRAM

The Maharic Recoding Process

LEVEL - 1

SESSION MANUAL

FOR FACILITATOR-INSTRUCTORS

FOUNDATIONS OF KATHARA HEALING™
KATHARA HEALING ™ FACILITATION
THE MAHARIC RECODING PROCESS ™

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INTRODUCTION TO KATHARA BIO-REGENESIS TECHNOLOGIES

COLOR, SYMBOL, SOUND AND BIO-REGENESIS TECHNOLOGIES

BIO-REGENESIS TECHNOLOGIES are tools to assist us in accelerating our expansion of consciousness through natural, gentle stimulation of the personal **DNA TEMPLATE, KUNDALINI ENERGIES, CHAKRAS AND MERKABA VEHICLE.** Bio-Regenesis techniques are built upon the foundations of **KEYLONTIC MORPHOGENETIC SCIENCE** and advanced **SCALAR MECHANICS**, as understood by races of higher evolution; these are paradigms of science not yet recognized or validated by contemporary earth science paradigms. Because Bio-Regenesis technologies are based upon what is viewed by modem earth science paradigms as a speculative rather than verifiable science, I present Bio-Regenesis techniques only as an option to explore in meditation.

Bio-Regenesis technologies were taught as "Common Knowledge" within the Ascension Schools of Pre-Ancient advanced human cultures and were utilized as standard practice in pre-ancient time periods. Bio-Regenesis Technologies are built upon the natural laws of scalar wave mechanics. Bio-Regenesis Techniques are **SPECIFIC APPLICATIONS OF CONSCIOUS ENERGY DIRECTION WITHIN THE MANIFESTATION TEMPLATE OF THE BODY** that stimulate into activity dormant portions of the personal Manifestation Template, which allows for a natural, progressive and accelerated advancement of the personal **ORGANIC EVOLUTIONARY BLUEPRINT** of the 12th-Dimensional Omni-polar Pre-matter Template. Bio-Regenesis Techniques simultaneously create subtle, natural acceleration within the interwoven energy systems of the DNA Template, Chakra System, Merkaba Fields, Kundalini energies, higher dimensional consciousness, and "Subtle Energy Body" anatomy.

In the Bio-Regenesis paradigm it is said that such techniques allow an individual to affect the function of the scalar wave template of the body, working co-creatively **under the direction of the individual's own higher dimensional levels of consciousness.** As the higher dimensional levels of the personal identity, the spiritual identity of the Soul, governs the processes of the personal Manifestation Template, Bio-Regenesis Technologies are completely safe and natural to the organic design of the human being. Using processes of Bio-Regenesis from the earthly conscious perspective expedites the natural processes of energy and consciousness by which the higher identity and earthly identity integrate to become one. In advanced ancient human cultures, Bio-Regenesis Technologies represented a natural attribute of consciousness expansion into the realms of higher evolution and assisted to biologically prepare humans for **STAR GATE** passage or **"ASCENSION"**.

If we can understand that the **HUMAN MIND** is an energy force that **CONTINUALLY GENERATES PATTERNS OF SCALAR WAVES** through the process of **THOUGHT**, it is not difficult to understand how **APPROPRIATELY DIRECTED THOUGHT** can directly influence the function of the personal Manifestation Template scalar blueprint. All thoughts serve this purpose, and directly effect the observable state of the mind-body-spirit system and the manifestation of events within the external life drama. **THOUGHTS ARE THINGS-** ***SCALAR WAVE CONFIGURATIONS*** of multi-dimensional vibrating patterns of **BI-POLAR ELECTROMAGNETIC ENERGY RADIATION**, which form **SPECIFIC PATTERNS OF SCALAR FREQUENCY** within the personal Manifestation Template.

Undirected thought creates chaotic patterns within the Manifestation Template, while thought directed through clear intention creates ordered patterns within the Manifestation Template. Thought directed with clear intention and **KNOWLEDGE OF THE STRUCTURE OF SUBTLE-BODY ANATOMY**, is a very potent form of **SCALAR POWER**. The patterns of scalar energy frequency that thought projects into the personal Manifestation Template serve as **ELECTROMAGNETIC OPERATIONAL INSTRUCTIONS** within the Template, directly effecting the conditions that will be met in manifest experience. To develop skill in the manifestation process, the conscious "intending" mind must become more familiar with the **"LANGUAGE OF SCALAR WAVES"**, as this is the **"LANGUAGE OF LIGHT AND SOUND"** upon which the Manifestation Template operates. The "language of scalar waves" is "spoken" through the forms of specific wave spectra, forms that appear to the conscious 3-dimensional mind as frequencies of **SOUND**, spectra of LIGHT or **COLOR**, and shapes or **SYMBOLS.**

What we perceive as color is specific spectra of **LIGHT-RADIATION WAVES** that have a specific measurable **WAVELENGTH** and vibrational **ENERGY SIGNATURE.** In using the conscious mind to direct quantities of color, we are **CONSCIOUSLY SELECTING SPECIFIC SCALAR FREQUENCIES** to add to the Manifestation Template. When we use the conscious mind to create images of **SYMBOLS**, we are further **SPECIFYING THE ARRANGEMENT OF SPECIFIC FREQUENCIES**, as they will appear within the Manifestation Template. **SYMBOL FORMS** (even those that compose the alphabets of outer languages) represent **SCALAR-WAVE GUIDES**, and directly affect the contours of the scalar wave blueprint of the Manifestation Template. The Manifestation Template governs the function of the body and consciousness within the manifest experience, and so the **"Language of Scalar Waves"** is the medium through which we gain conscious access to the **CASUAL LEVEL OF MANIFESTATION.** In using **color and symbol** to direct frequency, we are creating a pattern of energy that has a specific vibrational signature or **"TONAL SOUND SIGNATURE"**, which directly interfaces with the energetic vibrational sound signature of the Manifestation Template's scalar grid.

In Bio-Regenesis technology, Color and Symbol are used to direct the **TONAL SCALAR ARRANGEMENTS** of the Manifestation Template, to create natural, desired results within the body-mind-spirit system. There are many complexities within the process of conscious manifestation that one must learn to fully master the contours of space, time and matter. The beginning step is learning to give more finely tuned thought intention **"PROGRAMMING INSTRUCTIONS"** to the personal Manifestation Template. Thoughts and images rendered in **external language** and 3-dimensionally associated symbols affect the **outer layers** of the Manifestation Template, but they do not provided as finely tuned manifestation instructions as do the **"scalar wave languages"** of Color and Symbol image, which direct the contours of vibrational patterns of SOUND. Mastery within the interdimensional spectrum progressively develops as one masters the core **"PROGRAMMING LANGUAGES"** of **Color, Symbol** and **Sound Vibration.**

In **MIND TECHNOLOGIES**, such as **CREATIVE VISUALIZATION** and **VERBAL AFFIRMATION**, beginning skill in **SCALAR TEMPLATE PROGRAMMING** is developed through using emotionally charged images and precise sound patterns in the language to which we are accustomed, as methods to begin gaining conscious control over the processes of personal manifestation. Keylontic Science **BIO-REGENESIS TECHNOLOGIES** take us **ONE STEP DEEPER** into the manifestation process, by directly employing the **LANGUAGE OF SCALAR WAVES** and directing the **ENCODED INSTRUCTIONS** through **PRECISE LOCATIONS** within the body-mind-spirit system and the Manifestation Template upon which this system is built. Bio-Regenesis technologies take us from speaking the language of the 3-dimensional mind into speaking the intrinsic scalar-wave language of the Spirit, which is the **CASUAL ELEMENT** behind and within all manifestation.

Bio-Regenesis Technologies represent applications of Scalar Mechanics that utilize the inherent power of **SUBTLE WAVE FORMS** to created desired change within the core Manifestation Template of the body. Within this process, **COLOR** and **SYMBOL** become the **TOOLS** through which the 3-dimensionallyconscious mind becomes empowered to participate in conscious co-creation with the Soul and higher dimensional spiritual portions of identity. **Color** and **Symbol** possess power as **MATHEMATICALLY ENCODED** directors of scalar frequency; the ultimate effect of this directed power is the ability to affect the scalar arrangements of the **Manifestation Template.** Intrinsically, **scalar waves** are specific points of vibrating bi-polar energy signatures. Vibration of energy units creates patterns of internal and external **SOUND,** within and beyond the range of 3-dimensional detection. The Manifestation Template can be conceptualized as an **INTERWOVEN FABRIC OF SOUND FREQUENCY,** the "Silent Symphony" of personal and universal being. The tools of Color and Symbol affect the scalar-wave arrangement of the Manifestation Template, and thus alter the vibrational patterns of **SOUND TONES** within the personal blueprint. **COLOR AND SYMBOL are tools for the direction of SOUND,** and intentional application of **SPECIFIC SOUND TONES** can also be used in conjunction with Color and Symbol, to further amplify one's power to interact with the Manifestation Template.

Along with the techniques of Color and Symbol direction, **TONING,** or the **intentional generation of specific sounds to affect the Manifestation Template,** is also utilized in Bio-Regenesis technologies and spiritual expansion programs. "Toning Therapies" have emerged in recent years through the New Age and Holistic Healing paradigms, and have been applied for thousands of years, within the practices of spiritual masters in every religious tradition. SPOKEN LANGUAGE itself is a form of TONING, with its accompanying SYMBOL ALPHABET, and like all Symbols and Sound Tones, our languages directly affect the personal Manifestation Template, and the level of consciousness that can manifest through the body. In ancient cultures, the powers of language were better understood than they presently are in contemporary mainstream society. Particularly within the Priest-casts of ancient religions, language was used more consciously, with an understanding that words, sounds and images would directly effect the consciousness of the masses. Prayers, rituals and songs, some of which remain in use today, were used as a means of *altering consciousness*. Some assisted in spiritual development, others were intentionally used to limit and control the consciousness of populations.

The contemporary earth science paradigm is only beginning to explore the power of sound vibration and the connection between sound, symbol and color is not yet recognized or understood. **In advanced pre-ancient cultures, these sciences of Scalar Mechanics were fully understood and utilized in the most powerful of ways.** Color-Symbol-Sound technologies were not only used in **Bio-Regenesis** applications for personal health and consciousness expansion; they were also used among **GROUPS OF PEOPLE** to directly interface with the scalar-wave Manifestation Template of the **PLANTETARY SHIELDS.** Vortices, Time Portals, Star Gates, Ley Lines and free energy systems generated through the planetary core and solar light emanations were all **DIRECTED THROUGH THE FOCUSED MIND,** utilizing knowledge of Color-Symbol-Sound Scalar Mechanics. Since the fall of ancient cultures, which came as a result of abusing the powers of these Scalar technologies, the Color-Symbol-Sound sequences once used to direct massive amounts of power became the **"HIDDEN AND FORBIDDEN SACRED KNOWLEDGE".**

The **COLORS, SYMBOLS** and **SOUNDS** used in Bio-Regenesis techniques are not simply random choices. The elements of Bio-Regenesis technique are drawn from a **UNIVERSAL STANDARD LANGUAGE OF "SCALAR SPEAK",** through which **precise scalar frequencies** are generated through **specific Color-Symbol-Sound sequences** to create very specific effects within Manifestation Templates. The Bio-Regenesis Techniques presently offered represent only the beginning of our reawakening to this vast body of Sacred Science knowledge. Many Bio-Regenesis techniques utilizing Color-Symbol sequence scalar mechanics are accompanied by a corresponding exercise in **TONING.** Within the mystical **Ascension Schools** of ancient and pre-ancient times, there existed a very **SACRED SERIES OF TONING SEQUENCES** that were used **to directly interface with the DNA TEMPLATE** and the **AXIOM LINES** in the **PLANETARY**

SHIELD. On a **personal level,** through this specific series of Toning, dormant strands in the DNA Template could be progressively brought into activation, to expedite the process of Spiritual Actualization, Holistic Healing and building of the **PERSONAL MERKABA VEHICLE** within the bio-energetic field. On the **planetary level,** these **Sacred Toning Sequences** were used to **ENERGETICALLY OPEN** the **PLANETARY AXIOM LINES** for **CLEARING, REPROGRAMMING AND ACCELERATING THE ACTIVATION** of the **PLANETARY SHEILDS.** This series of Sacred Toning was collectively called **"THE MUSIC OF THE SPHERES".**

THE SONGS OF THE SPHERES

The **MUSIC OF THE SPHERES** represents the **ORGANIC TONAL SEQUENCES** of **EACH DIMENSIONAL FREQUENCY BAND** within the 15-Dimensional Time Matrix; the **CONSOLIDATED CORE VIBRATIONAL SOUND SIGNATURES** of each Dimensional frequency band. Of the 15 core vibrational signatures of the 15 Dimensions in a Time Matrix, 12 of these core signatures serve as the **PRIMARY 12 TONAL SEQUENCES** upon which each strand of the 12-Strand original human **DNA Template,** and each **AXIOM LINE** in the 4-Density **Planetary Shields** are structured. In using the **Tone Sequences of the Music of the Spheres,** the 12-Strand DNA Template can be **PROGRESSIVELY BROUGHT INTO NATURAL ACTIVATION.** Scalar-wave distortions within the Templates for the DNA Strands (which physically manifest as genetic distortions) can be systematically **REALIGNED** with their natural perfect 12th Dimensional **ORGANIC IMPRINT.** In using the **Music of the Spheres** for work with the **Planetary Shields,** each of the **24 AXIOM LINES** can be **OPENED** and **ENCODED WITH THE PERFECT PATTERN OF THE PLANETARY PLASMA BEAM.** Transmitting the 12th-Dimensional **MAHARIC SHIELD** pattern directly into the **Axiom Lines** in the Planetary Shields is the most rapid method to distribute the program of the **PLANETARY ORGANIC IMPRINT** throughout the 4 Density Levels of the PLANETARY SHIELDS.

In ancient days, the *Music of the Spheres* was used extensively for purposes of self-generated healing and to prepare the physical body for literal passage through the planetary Star Gates ("Ascension"). The **specific tone sequences** for each **SINGULAR DIMENSION** (which corresponded to one DNA Strand Template in the 12-Strand blueprint and the inherent Dimension of consciousness that would embody through activation of the strand) are called the **"SONGS OF THE SPHERES".** Each **"SONG"** contained very specific **"word sounds"** (from the first Universal Spoken language) for **lyrics,** and specific **multi-layered tones** (which generated inaudible Tri-tone Standing Waves) for **melody, harmony** and **overtones.** To be effective, the Songs had to be used through the **HUMAN VOICE,** externally or mentally as the **"SINGING OF SONGS".**

The Sacred Songs were sung in combination with directing specific corresponding **COLOR** and **SYMBOL** sequences through the bio-energetic field (or through the Planetary Axiom Lines for Planetary Shield work). **The Songs served to "open" specific areas of the DNA Template, or specific Planetary Axiom Lines, to receive instructions directed by the Color and Symbol sequences.** The tones of the Songs generated specific scalar-wave formations that triggered activation of corresponding configurations within the DNA Template and Planetary Shields. Activation of dormant portions of the DNA Strand Templates or Planetary Axiom Lines "opened" the Strand Template or Planetary Shield to directly receive Color-Symbol scalar wave instructions, through which desired outcomes within the personal or planetary body, and within the external reality experience, could be **"PROGRAMMED"** for manifestation.

The **SCIENCE OF THE MUSIC OF THE SPHERES** was one of the most highly guarded **"SACRED SECRETS"** in pre-ancient cultures, due to the power of interdimensional freedom and conscious manifestation that could be obtained through knowledgeable use of the **SONGS.**

Before the **SONGS OF THE SPHERES** will be fully returned to human awareness, our culture will have to mature enough to demonstrate **spiritually motivated ethical use of power.** Certain SONGS are now being slowly returned, so that we may assist those of higher evolution to realign Earth's Planetary Shield with its original 12th-Dimensional **MAHARIC SHIELD ORGANIC IMPRINT.** One of the **15 SONGS OF THE SPHERES** was provided to us by the Emerald Order. This SONG is used to activate dormant scalar-waves in the 8th **DNA STRAND TEMPLATE**, through which the process of activating the dormant **1st-8th Strands** of the 12-Strand DNA Template can be accelerated, expediting the natural processes of higher dimensional spiritual identity integration.

This SONG is also used to open the **8TH AXIOM LINE** in **GAIA'S PLANETARY SHIELD**, to facilitate realignment of **Earth's Planetary Shields** from **ETHERIC MATTER DENSITY-3.** This SONG was given so that **GROUPS** can begin assisting directly in Planetary Grid work, opening specific Axiom Lines and Vortices in the planetary body to help bring Earth's Planetary Shield Manifestation Template into its organic alignment and balance. The SONG that was given is called the **"Ariea Khum Nar'A".** The English language translation is **"THE SONG OF ORION".** This **SONG OF THE 8th SPHERE** corresponds to the **8th -Dimensional level** of the **UNIVERSAL KATHARA GRID** and its **8TH PRIMARY STAR GATE.** It also corresponds to the 8th **PLANETARY AXIOM LINE** within the Etheric Matter Density-3 **GAIAN PLANETARY SHIELD** and to the **8th DNA STRAND TEMPLATE** in the human body. The **8th Dimensional STAR GATE** within the **UNIVERSAL KATHARA GRID** is the Star Gate that opens into the **ORION STAR SYSTEM**, thus the name of the **SONG OF THE 8th SPHERE** is **"THE SONG OF ORION".**

Soon the SONGS that correspond to the **11th** and **12th** –Dimensional frequencies will be provided. Aside from its use in planetary grid work, when used as a **"MANTRA"**, repeatedly sung as a focus for the mind in meditation, the ***Ariea Khum Nar'A*** serves to stimulate consciousness expansion into the higher dimensional fields and amplifies and expedites the effects of personal Bio-Regenesis techniques.

CHAPTER 1

THE CONTEXT OF HEALING

The Structure of the Unified Field and the Multi-dimensional Anatomy of Form

- THE HOLOGRAPHIC TEMPLATE
- THE STRUCTURE OF DIMENSIONS, PARTIKI PHASING AND MATTER DENSITY
- UNIVERSAL AND PLANETARY KATHARA GRIDS, THE 12-TREE, KATHARA CENTERS AND LINES, SCALAR SHIELDS, CRYSTAL SEALS AND DIODIC POINTS
- THE UNIVERSAL AND INTERNAL TEMPLAR COMPLEXES
- THE TRANSDUCTION SEQUENCE AND HOLOGRAPHIC REALITY CONSTRUCTION

TOPICS OF DISCUSSION

The Ariea Khum-Nar'-A

The Song of Orion

Part 1 : the Resonant Tone Syllable Sequence (primary melody)

Verse 1: OM A Da E, Patum ah
OM A Da E, Patum ah
Patum ah A' DE E - Tah, A khum-na
OM A Da E, Patum ah

Verse 2: TrA TE La E' Durum Na
TrA TE La E' Durum Na
Durum' ah A' Khem - Tah, A khum -na
OM A Da E, Patum ah

Part 2 : the Base Tone Syllable Sequence (accompaniment 1)

OM A Da E, Patum ah - Lines 1, 2 & 4 Verse 1 & Line 4 Verse 2
TrA TE La E' Durum Na - Lines 1 & 2 Verse 2
UM ah OM, A
UM ah OM, A
Patum ah A' DE E – Tah, A khum- na
Durum ah A' Khem – Tah A khum-na
DO RAY' TU Ra"
OM A Da E, Patum ah
UM ah OM, A

Part 3: the Over Tone Syllable Sequence (accompaniment 2)

OM A Da E, Patum ah – Lines 1 & 2 Verse 1
TrA TE La E' Durum Na – Lines 1 & 2 Verse 2
BE HE Tah OM, A
BE HE Tah OM, A

Patum ah A DE E – Tah, A Khum –na – Line 3 Verse1
Durum ah A Khem- Tah, A Khum - na - Line 3 Verse 2
Thra Khem' Na, A
OM A Da E, Patum ah – Line 4 Verses 1 & 2

KhrA MiM, Tah A

THE STRUCTURE OF THE UNIFIED FIELD AND THE CONTEXT OF HEALING

If one is to become fluent in the art and science of **Bio-Spiritual Healing Facilitation**, it is necessary to become familiar with the *primary structures of energy* within which existence takes place. Without this understanding one will be unable to identify the *true nature of systems and their intrinsic functions.* If we do not understand the **intrinsic order of a system** and the elements that make up its parts, our ability to comprehend the *organic functions* of the system will be limited. Without comprehension of the intrinsic dynamics inherent to a system, our perceptions will be limited to observing the **effects of systems function**, rather than perceiving the **causal elements** behind and within the apparent observable effects. In relation to the **health and healing** of the human body, it is wise to view the human **Body-Mind-Spirit organism** as a series of interwoven systems, each with *inherent, implicit order*, the perceivable and observable aspects of which represent the effects of systems function. **The observable effects of the human condition emerge from an as yet unidentified causal order, a hidden and mysterious source out of which the manifest effects of human existence emerge.** Holistic Healing approaches human health and healing in terms of the *interdependent relationships* between *multiple interwoven systems.* The Body-Mind-Spirit organism is viewed in terms of the *intrinsic relationships that unite* the multiple systems of the human being, rather than in terms of the *observable boundaries* that appear to *separate and divide* the multiple systems inherent to the human organism.

Holistic Healing, and **KATHARA Healing** particularly, take the concept of **intrinsic unity** within the seemingly separate systems of the human being one step further than *simple interrelationship* between **physical, mental and spiritual aspects** of human experience. **In the paradigm of Kathara Healing, the human organism is viewed as a set of interwoven systems that is itself part of a larger system of interdependent systems.** The human individual is not only recognized as a *singular set of unified parts*, but rather as an *intrinsic part* of the species, planetary, galactic, universal and cosmic systems within which human existence finds **context** for being. The **Cosmic Unified Field of Energy and Consciousness** is viewed as the **indelible medium** within which all reality takes place, and human existence is viewed in terms of *its relationship to this greater Meta-system* of interwoven, interdependent systems. **The health and wellbeing of the human being is directly related to and effected by the systems-functions of the greater Unified Field.** In order to better understand and facilitate the health and healing of biological organisms, it is useful to understand the *basic order and function* of the **UNIFIED FIELD**- the context in which life itself takes place.

Kathara Healing is an ancient system of **Holistic Healing**, dating back beyond presently identified recorded human history. The principles of **Universal Order** as taught within Kathara Theory present a **broader context of universality** than is presently recognized by contemporary western science. Kathara is built upon **Laws of Multidimensional Universal Physics,** laws of intrinsic nature with which western science is not yet familiar. In Kathara Healing the *hidden order of universal systems* is recognized and the foundations of Kathara *demonstrate the interwoven systems-functions* between the human being and the order of the **Unified Field. To develop proficiency and genuine skill within the art and science of Holistic Healing, the basic order of the Unified Field must be understood.** For with this understanding comes the ability to *directly interact with and influence the causal elements* of the human experience. For this reason the teachings of Kathara Healing begin with providing a basic format through which the **CONTEXT of healing** can be understood ***– a glimpse at the intrinsic order of the Universal Unified Field.***

With foundations grounded in **coherent systems relationships**, the Kathara Healing Facilitator has more knowledge, power and comprehension to bring to the art and science of healing facilitation. **Through comprehension of the *intrinsic systems of universal order*, the Kathara Facilitator progressively evolves to embrace the *unity of SELF within the Unified Field*, opening to an ever-expanding capacity of spiritual awakening and the embodiment of UNCONDITIONAL LOVE.** The physical, mental and spiritual aspects of human anatomy represent one interdependent, interwoven system that is *continually in a state of relationship to the Unified Field.* This relationship must be acknowledged and embraced if true health and healing are to occur. **Human evolution is a Bio-Spiritual process, the body and the consciousness – the biology and the spirit - are inseparably intertwined within themselves and within the greater order of the Unified Field.**

Healing emerges through restoring order to the ONE-SYSTEM and its infinite parts.

THE HOLOGRAPHIC TEMPLATE

The externalization of life, manifestation of matter and individuation of identity are **HOLOGRAPHIC PROJECTIONS of CONSCIOUSNESS-ENERGY SUBSTANCE,** created through an *intrinsic order of energetic relationships.* Energetic relationships represent **interrelationships of consciousness**, in its infinite manifest and de-manifest forms.

Consciousness *IS ENERGY*
And
Energy *IS CONSCIOUS*.

True Science has a *spiritual core* and true spirituality has *its intrinsic translation within the Laws of Energy that govern the manifestation of universal systems.*

Reality is **THOUGHT CONSTRUCTION.** The core substance of the cosmos is **CONSCIOUSNESS.** ***Thought*** *is an attribute of CONSCIOUSNESS,* the **filter** through which consciousness manifests itself into the **Hologram of Form.**

Nothing is truly solid. All things are composed of *consciousness* and their *apparent solidity* is determined by the *relationship between the consciousness observing the form and the consciousness of which the form is made.* Human consciousness emerges through an **order of dimensionalization,** which sets frameworks within which the *interrelationships of consciousness* can take place. **Human perception of solidity and externalization is determined by the oscillation rates between dimensionalized units of consciousness.** Dimensionalized units of consciousness form **frequencies of energy,** which exist in *specific relationships* to each other. Human *consciousness* (the soul –spirit), and human *physical form* are **patterns of frequency** formed by *dimensionalization of units of consciousness. We perceive manifest solidity due to the relationship between the frequencies of consciousness of which we are made and those of the Unified Field of Conscious Energy around us.* **Humans perceive as solid the frequency bands that exist one full dimensional spectrum below the frequencies within which the individuated or collective consciousness is stationed.**

The only difference between a *thought* and a *manifest thing* is the *frequency of the consciousness of the observer.* Manifest reality is **thought projection,** made solid and externalized by relationships between the *frequencies of our focus of attention* and those of the *projected thought forms.* **We perceive as reality the thought forms of the collective masses as they were placed within the frequency bands that now exist one dimension below the frequencies within which our present focus of collective consciousness is stationed.**

As reality is a THOUGHT FIELD, composed of units of consciousness awareness, reality can be directly AFFECTED by THOUGHT, as the substance of both thought and reality are one and the same. The key to mastery of our present reality and to restoring our **imprint for health**, is understanding the *reality of dimensionalization* within which our consciousness now resides.

The human body is a HOLOGRAPHIC PROJECTION of consciousness that is built upon a *HOLOGRAPHIC TEMPLATE* of structured units of consciousness. The Holographic **Template** represents the **Living Morphogenetic Field** – the *dimensionalized blueprint of conscious light, sound and scalar waves*, within which the individuated consciousness is stationed, and *upon which the illusion of solidity of the body matter is formed*. **To affect *true and lasting change* within the Body-Mind-Spirit System of the human being, one must *go to the core* of its manifest structure – the *Holographic Template* or Thought-energy Blueprint, upon which the entire system of consciousness itself comes to know being.**

The body is a HOLOGRAM that can be directly affected by the *substance of which it is composed* – CONSCIOUSNESS. In learning the structure of dimensionalization through which the body-illusion manifests, one becomes progressively more masterful in directing this personal thought form to suit ones desired specifications. The core **Holographic Template** of the personal and universal body is called the **Kathara Grid. Kathara Healing** is the process by which the *embodied* aspects of human consciousness become more aware of and able to direct the *intrinsic processes of holographic projection*, with the intention of restoring integrity to the function of the Body-Mind-Spirit system.

No thing is truly manifest – it only appears to be so,
due to the refraction of consciousness
within the energetic relationships inherent to
the _Holographic Template_ –
the original _thought-form construct_
upon which our universal structure
is perpetually recreated.

All creatures and things are Spiritual Beings having a Manifest Experience...No creature or thing can be ever divorced from its innate spirituality, but only from the awareness of its nature. For life is the expression and substance of spirit – and manifest reality is but a Dreamscape, from which we eventually all awaken...

The causal element of all manifest experience is called a ***Morphogenetic Field*** or **MANIFESTATION TEMPLATE.** Keylontic Science, the science of Manifestation Templates is part of a larger advanced paradigm of science that is known as **15-Dimensional UNIVERSAL UNIFIED FIELD PHYSICS.**

PRIMAL SUBSTANCE

- A Manifestation Template is made of **PRIMAL SUBSTANCE;** units of conscious energy called **PARTIKI** that exist as ***Omni-polar points of fixed vibration. Partiki units*** are the smallest building blocks of matter, and they form the templates upon which consciousness in all forms enters manifestation.

- Partiki units are **Omni-polar** (containing the potentials for all polarities or none) units of vibrating energy that perpetually cycle back and forth between a state of **BI-POLAR LIGHT RADIATION** (scalar-standing-wave) and **OMNI-POLAR SOUND VIBRATION.**

- In the ***Omni-polar state,*** Partiki units exist as invisible, fixed points of ***sound vibration,*** forming what is called an **INTERDIMENSIONAL TRI-TONE WAVE.** An Interdimensional ***Tri-tone Wave*** is a singular point of fixed vibration that is composed of ***3 sub-vibrations*** (base tone, overtone and resonant tone). When Partiki units are in their Omni-polar state they exist as ***Ante-matter substance,*** the first state of energy organization before Pre-matter manifestation. Through a process of Internal Fission characteristic to their design, Partiki units break apart to form Bi-polar waves, while replicating their original Tri-tone Omni-polar design.

- In the ***Bi-polar state,*** two sub-vibrations of the Tri-tonal Standing Waves of Partiki units break down into two sub-units, ***sub-tones,*** called **PARTICUM-*Base Tones*** and **PARTIKA-*Overtones,*** interconnected units of **BI-POLAR LIGHT RADIATION** that form ***Electromagnetic Scalar-Standing-Waves.*** The third vibration of the Tri-tone wave, the *Resonant Tone,* remains as the core vibration through which the polarized vibrational units of Particum and Partika will reunite through ***Internal Fusion.***

- **PARTICUM** units form the energetic building blocks for **PARTICLE TEMPLATES** and **PARTIKA** units form the building blocks for simultaneously manifesting **ANTI-PARTICLE TEMPLATES.** Particle and Anti-particle Templates are interconnected, united by the Ante-matter **PARTIKI** units through which they manifest. The effects of **ELECTRICAL AND MAGNETIC FORCE** are set in motion through the **EXPANSION AND CONTRACTION** of energy vibration between Particle and Anti-particle matter units through the Ante-matter Partiki unit that unites them.

- **Particum-Particle units** represent the **CONTRACTION PHASE** of ante-matter energy, with higher **VIBRATION** (energy contracted into or received by the Ante-matter template) and lower **OSCILLATION** (energy expanded or transmitted from the Ante-matter template) and so are considered **BASE MAGNETIC. Partika-Anti-particle units** represent the **EXPANSION**

PHASE of Ante-matter energy, with lower Vibration and higher Oscillation, and are considered **BASE ELECTRICAL.**

- **ELECTROMAGNETIC ENERGY** is created through the continual cycling of energy, as the Omni-polar Ante-matter Tri-tone Wave of ***Sound Vibration*** projects its energy into Bi-polar Particum and Partika Scalar Waves of ***Light Radiation***. Energy thrust expands into the Anti-particle Partika vibration point as **electrical force**. It then contracts into the particle Particum vibration point, creating **magnetic pull**, (in ratio to its original electrical thrust), as the third vibration in the Ante-matter Tri-tone Wave draws the energy back to its source. Through the draw of the Ante-matter Partiki template, Partika-Ante-particles and Particum-particles are brought into a state of **Fusion.** Upon fusion, the energy of the Particum and Partika transmutes, the Bi-polar Standing Scalar Waves of Light Radiation returning to their original Omni-polar Ante-matter state of Partiki units. Once returned to the Partiki state, the process repeats as the Partiki creates Fission and replication. **Partiki, Particum and Partika units represent PHASES that Primal Substance energy passes through as it moves into and out of manifestation.**
- The process by which Partiki units perpetually convert conscious energy into Bi-polar Light Radiation Scalar-Waves (expansion) and back into Omni-polar Sound Vibration Tri-tone Waves (contraction) is called **PARTIKI PHASING.** Through perpetual cycles of Partiki Phasing, matter units "flash on" through **fission**, into Bi-polar Particle and Anti-particle manifestation built upon Scalar Waves of Light Radiation, then "flash off" through **fusion**, into Omni-polar Ante-matter Sound Vibration, continually cycling energy between the manifest and non-manifest state. **The perception of external physical matter, space and the passage of time are created through *variance in relationship* between rates of Partiki Phasing.**
- Consciousness in the form of Partiki Units is the **PRIMAL SUBSTANCE** of which the cosmos is structured and Partiki Phasing is the perpetual **PRIMAL ACT** of reciprocal fission and fusion through which Primal Substance is brought into manifestation.

The Holographic Template

PRIMAL SUBSTANCE

Units of Consciousness, Morphogenetic Fields and Scalar Grids

1. ***Partiki, Partika and Particum:*** Smallest units of energy-substance. Electro-tonal units of consciousness that are the building blocks of morphogenetic fields, matter and individuated conscious identity. Operate as minute, perpetual motion fission/ fusion generators.

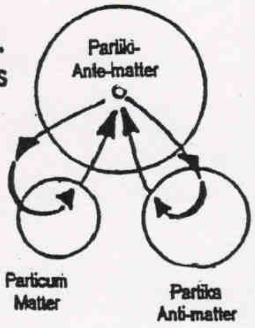

2. ***Partiki Grids*:** The fabric of morphogenetic field structure. Partiki units group to form interwoven Strands, then Grids of electro-tonal substance, out of which morphogenetic fields are fashioned. Out of a Unified Field of Partiki units, Partiki Grids form to create the frequency bands that make up dimensional fields and then to form individuated morphogenetic fields.

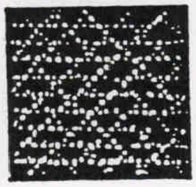

3. Partiki units continue to group or accrete upon the Partiki Grids, forming
A. ***Keylons*** – crystallizations of "frozen light" (standing scalar wave patterns and fixed points of tonal frequency), and
B. ***Keylon Codes*** – complex groupings of Keylons, which together form a crystalline template of light spectra, sound frequency and electro-magnetism that is the morphogenetic field Crystal Body– the Blueprint upon which matter and identity will manifest.

A.

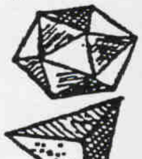

B.

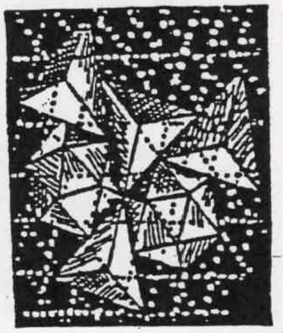

The **Morphogenetic Field** is made of interwoven **Partiki Grids**. The electro-tonal units of consciousness out of which Partiki Grids form create standing wave patterns – **scalar wave grids**, which hold the form of consciousness within dimensionalized manifestation. Morphogenetic Fields are thus **Scalar Grids**, that form in specific ordered interrelationship. Partiki Grids form upon the core *geometrical-mathematical* structure of the **Kathara Grid**, and so the Kathara Grid represents the *core Scalar Field* upon which form manifests.

Morphogenetic Fields govern the form of matter manifestation and the evolution of biology and consciousness. Morphogenetic Field mechanics thus hold the key to mastery of physical reality and Bio-Spiritual Evolution.

THE STRUCTURE OF DIMENSIONS

Frequency Bands and Sub-Frequency Bands, Vibration-Oscillation-Particle Spin, Harmonics of Manifestation and Matter Density Levels.

The Hologram of manifest reality is a complex system of interwoven energy constructs, all built upon **dimensionalized sets of scalar grids**- or fields of standing wave points – that form the **base laws of energy** upon which manifest reality functions.

The physical portions of the human body represent ***wave strata*** that exist within specific relationships to the embodied consciousness. **The embodied consciousness itself is *regulated by the intrinsic behavior of the wave strata* in which it is ensconced.** The wave strata of seemingly physical forms appear to *human detection* in the form of *particles, sub-particles and wave bands* that group to form the 3-dimensionally manifest hologram of human life

The **behavior of dimensionalized wave strata** is an intrinsic element within the function of ***human anatomy***, and provides the *very context* within which human existence and evolution take place. When we come to understand ourselves as **vibrating quantities of conscious energy**, existing within a state of **vibrational co-resonance with all things**, which are themselves *vibrating quantities of conscious energy*, we can begin to understand the **fundamental structures** upon which the human condition is built.

The human body is a ***construct of conscious energy****, a living* morphogenetic field existing within the greater living morphogenetic constructs of the species, planetary, galactic, universal and cosmic morphogenetic structure. We are simply an element of sentient consciousness within a larger structure of sentient consciousness, a part of the **Unified Field of Consciousness** that IS the living identity of the cosmos. Our physicality emerges through the **perceptual lens of dimensionalization**, which provides us with the seeming manifestation of **particles, atoms, molecules** and the **physical systems** built upon them.

If we expect to **heal ourselves** of the manifest conditions that cause suffering within the Body-Mind-Spirit system, we must first understand the **nature of health**, the "way things are supposed to work" when they are *functioning properly*. To understand the intrinsic **Imprint and impetus for health** in the human organism, a basic understanding of the *contents of its parts* is in order. That understanding begins with *identifying the basic reality structures within which we reside, and how we exist in relationship to these structures.*

Our understanding of *health* begins with *identifying the context of existence*, the *Unified Field of Consciousness-Energy* of which we are all a part. **A simple *identification of the structures of the Unified Field* will work wonders in assisting us to understand ourselves, and through this understanding we become more empowered to foster a healthful and more joyous living experience.** To better understand ourselves we must return to the core of our intrinsic nature, the **dimensionalized fields of consciousness** within which we reside and out of which the substance of our SELVES is composed.

The following characteristics inherent to the manifestation of the human hologram are a place to begin our journey of self-understanding.

Characteristics of the Hologram

PRIMAL ORDER

SCALAR WAVES: Points of standing waves, composed of quantities of conscious energy that emanate out of fixed units of vibration (Partiki units), which form the morphogenetic field templates upon and through which consciousness dimensionalizes itself to experience the hologram of manifest reality. Created through Partiki Phasing (internal fission/fusion "flash on/flash off")

MORPHOGENETIC FIELDS: The templates of consciousness, light, sound and scalar standing-wave grids which serve as the structured blueprints upon which our consciousness manifests into dimensionalization, through which the holographic projections of space-time-matter and identity individuation can be experienced.

DIMENSIONS: *Morphogenetic Field Scalar Grids composed of interwoven layers of scalar waves, which serve to direct the flow of consciousness into multiple patterns of refraction through which the hologram of matter density, linear time and objectification of reality can be experienced.* Dimensions are specific structures of consciousness, composed of Partiki units with differing vibratory-oscillation rates, which exist in precise relationship to each other, and govern the intrinsic laws of function within the observably manifest worlds. The process of dimensionalization occurs through the wholeness of consciousness *compartmentalizing itself into various ordered sections having diversity of vibratory-oscillation*, through which the wholeness of consciousness may experience itself in an endless variety of forms. Each dimension represents a full frequency band.

FREQUENCY BANDS: Synchronized, cyclic, repeated sequences of "flashing on and off" of scalar-wave points within the dimensional scalar grids, which gives the appearance of manifest movement of wave spectra within a dimensional system. **Sub-frequency Bands** are shorter segments of the longer "flashing on and off" sequence of the full Frequency Band. The frequency of dimensional levels and the particles within them is determined by the vibratory-oscillation rate of the Partiki units that make up the scalar-wave grid. Frequency is the form consciousness takes on while ensconced within the framework of dimensionalization. Frequency is the vibrating-oscillating wave spectra of which matter particles and dimensionalized consciousness are composed.

VIBRATION-OSCILLATION: Vibration is the condition of **internal movement**, or ***holding of energy within*** units of consciousness (Partiki) and the particles built upon them. Vibration is determined by the **quantity of energy** ***held within*** Partiki units. **Oscillation** is the condition of **external movement**, or ***expending of energy from*** Partiki units and the particles built upon them.

The vibratory-oscillation rate of particles represents the *rate at which the scalar standing-waves "flash off and on"* within the morphogenetic field template. Vibration is the *internal measure of energy quantity* held *within* Partiki units and exists within direct proportion to the *oscillation* rate, or *external measure of energy quantity expended*, exhibited by Partiki and the particles built upon them.

The vibratory-oscillation rate represents the ratio between energy contraction (vibration) and energy expansion (oscillation), which sets the rhythm of particle pulsation that governs the formation of wave spectra within dimensionalization. The vibratory-oscillation rate of Partiki units determines the **frequency** (cyclic pattern of scalar waves "flashing off and on") of wave spectra within the various levels of the dimensionalized morphogenetic field. **The relationship of vibrational-oscillation between wave spectra determines the matter density levels particles will exhibit within the dimensional scale.**

Vibration-Oscillation Correspondences

Higher Dimensional Fields (8-15)	Lower Dimensional Fields (1-8)
Low Vibration	**Higher Vibration**
Higher Oscillation	**Lower Oscillation**
Expanding	**Contracting**
Higher Frequency	**Lower Frequency**
Shorter Wave Length	**Longer Wave Length**
Slower Electron Spin	**Faster Electron Spin**
Less Density	**More Density**
Electric	**Magnetic**
Lower Vibration =	Higher Vibration =
Less energy holding in Partiki =	More energy holding in Partiki =
More energy expended from Partiki =	Less energy expended from Partiki =
Higher Oscillation =	Lower Oscillation =
More expansion =	More contraction =
Faster flash rate of Partiki =	Slower flash rate of Partiki =
Higher Frequency of Flash =	Lower frequency of flash =
More external movement =	More internal movement =
Faster oscillation =	Slower oscillation =
Shorter wave length =	Longer wave length =
Slower electron spin around nucleus =	Faster electron spin around nucleus =
Greater expansion of energy units =	Greater compaction of energy units =
Less density =	Greater density =
Less magnetism =	Greater magnetism =
More electric	Less electrical

The human anatomy is a 15-dimensional morphogenetic field scalar grid structure, composed of wave spectra with varying degrees of matter density characteristic to the dimensional band within which each level of the anatomy is stationed. The portions of our anatomy that appear solid are those stationed one dimension below our focus of conscious attention.

PRIMAL ORDER OF MANIFESTATION TEMPLATES

- Morphogenetic Fields, or the **MANIFESTATION TEMPLATES** that serve as the blueprint through which consciousness manifests, are composed of the Primal Substance of **PARTIKI UNITS.** Partiki units draw together or **ACCRETE** to form **PARTIKI STRINGS.** Following a set **mathematical and geometrical design** inherent to their form, Partiki Strings interweave and overlap, forming a **"Fabric of Light and Sound"** called a **PARTIKI GRID.** A Partiki Grid is a fixed pattern of interwoven Bi-polar Scalar-Waves of light radiation,built upon Omni-polar Tri-tone Waves of sound vibration,that forms the foundation for diversified Manifestation Templates. A **Partiki Grid** is a **SCALAR GRID.**

- Following the precise mathematical design set by the will and intention of the manifesting consciousness, Partiki Grids further accrete, drawing in more Partiki Units, forming groups of Partiki units that are arranged following *3 different rhythms of Partiki Phasing.* **Tri-phase groupings of Partiki Units** form patterns of Scalar-wave and Tri-tone wave interrelationships that create ***crystallizations of energy*** called **KEYLONS.** Groups of Keylons continue to accrete, forming complex Keylon arrangements called **KEYLON CODES,** through which the Manifestation Template is progressively built up from Ante-matter through various stages of matter density, beginning with **PRE-MATTER SUBSTANCE,** the first density of **Liquid Silica Hydro-plasmic** energy to emerge into externalized form.

- The Morphogenetic Fields upon which universes manifest are built upon a Manifestation Template that has a specific order of mathematical interrelationships that govern the combining of Scalar Grids with different rates of ***Partiki Phasing.*** The **Cosmic Manifestation Template** is called the **ENERGY MATRIX.** Within the Energy Matrix there are many smaller manifestation templates upon which Universes are structured. **Universal Manifestation Templates** are called **TIME MATRICES.** There are uncountable Time Matrices within the Energy Matrix, which are collectively referred to as **THE TIME MATRIX.** All Time Matrices within the Cosmic Matrix follow a specific mathematical-geometrical program through which space, time and matter can be experienced by consciousness upon entering the Time Matrix structure.

- Time Matrices are arranged upon a pattern of 15 different, but interwoven, Partiki Phasing rhythms (rhythms of expansion and contraction of energy). Each of the 15 rhythms of Partiki Phasing creates one **DIMENSION.** A **Dimension** is a set pattern of **"FLASH LINE SEQUENCES"**, or a cycle of singular Partiki Phasing rhythms that contains within it 12 smaller rhythms of Partiki Phasing. Each **Dimensional Manifestation Template** creates a set of fixed Scalar-Tri-Tone Wave Points that create a template of stationary **SCALAR FREQUENCY.** Each Dimension represents one **SCALAR FREQUENCY BAND** containing 12 smaller **SUB-FREQUENCY BANDS.** A **Scalar Frequency Band** is a cyclic pattern of specific Partiki Phasing Rhythms, or **EXPANSION AND CONTRACTION RATIOS OF ENERGY CIRCULATION,** to which consciousness conforms in order to enter the experience of manifestation.

- To create the Universal Manifestation Template upon which external space, time and matter experience can be known, Dimensions are ordered into sets of 15, forming the blueprint for a

15-Dimensional Time Matrix. Within a Time Matrix the 15-Dimensions are further arranged into sets of **3 Dimensions,** forming **5 3-Dimensional reality fields.** Each 3-Dimensional Reality Field is called a **HARMONIC UNIVERSE,** and each represents a **level of matter densification** specific to its intrinsic rates of Partiki Phasing. One Time Matrix is thus a **15-Dimensional Scalar Grid** with 5 separate yet interwoven reality fields and 5 different densities of matter manifestation.

- Each of the 5 Harmonic Universes within a Time Matrix represents a **TIME CYCLE.** A Time Cycle is a fixed, repeating pattern of Partiki Flash Line Sequences, or a repeating cycle of specific ratios of energy expansion-oscillation and contraction-vibration. The Time Cycle of a Harmonic Universe is called an **EUIAGO CYCLE.** There are **5 simultaneously manifesting Euiago Cycles in every Time Matrix,** through which consciousness passes in order to experience linear evolution through space, time and matter. Each Euiago cycle contains within it 6 smaller Flash Line Sequences forming 6 smaller cycles of time called **TIME CONTINUUA.**

The **PRIMAL ORDER of Manifestation Templates** represents the core mathematical and geometrical interrelationships of energy that consciousness takes on in order to enter the holographically projected experience of external space, time and matter. All manifest forms, including the **HUMAN BODY** and **PSYCHE** , are built upon a Manifestation Template that begins with the Primal Order of Dimensionalization, through which the consciousness anchors itself into the Time Cycles of the Universal Manifestation Template Time Matrix, to begin the experience of evolution through time.

Understanding the **PRIMAL ORDER OF DIMENSIONAL STRUCTURE,** as it pertains to the human organism, allows for comprehension of the greater causal framework through which personal healing must occur. Such comprehension of the core causal structure of manifestation enables one to work cooperatively, rather than in resistance to, the natural **Universal Laws of Manifestation,** progressively restoring the **NATURAL HARMONIC ORDER** of wellbeing and **DIVINE RIGHT FORM,** through which the indelible **Organic Imprint for Health** can be progressively restored.

Dimensional Structure

A Dimension represents a full ***Frequency Band***, or repeating, cyclic sequence of "flashing on and off" scalar-wave points within a morphogenetic field. The morphogenetic field scalar grid structure of dimensions takes the form of ***sets of 15-Dimensional Matrices***. The 15 Dimensions are grouped into sets ***of 3 Dimensions each***, forming ***5 sets of 3-dimensional reality fields*** called HARMONIC UNIVERSES. The 15-Dimensions composing the 5 Harmonic Universes together represent one TIME MATRIX system.

Each dimension of frequency is composed of **12 Sub-frequency Bands,** or shorter cycles of the "flashing on and off" of scalar-wave points, which exist as part of the longer cycle of the full Dimensional Frequency Band. The Partiki in each dimension have a specific rate of **vibratory-oscillation** (contraction and expansion of energy), which determines the **Angular Rotation of Particle Spin** (angular axis upon which particles will spin). There is a **90-degree shift of angular rotation** of particle spin between each dimensional frequency band and a **45-degree reverse shift** between **Harmonic Universes** (sets of 3 dimensions/frequency bands.)

Particles having varying vibratory-oscillation rates and angles of spin allow multiple dimensional reality fields to co-exist within the same space while remaining perceptually invisible to each other. The *relationships between wave strata* within the dimensional frequency bands create the **holographic refraction** of light, sound and scalar waves that allows consciousness to *perceive the illusions of* **matter solidity, space, time and externalization of reality** while it is ensconced within the structures of dimensionalization.

One 15-Dimensional Time Matrix with 5 Harmonic Universes

PRIMAL ORDER of the Dimensionalized Universal Manifestation Template

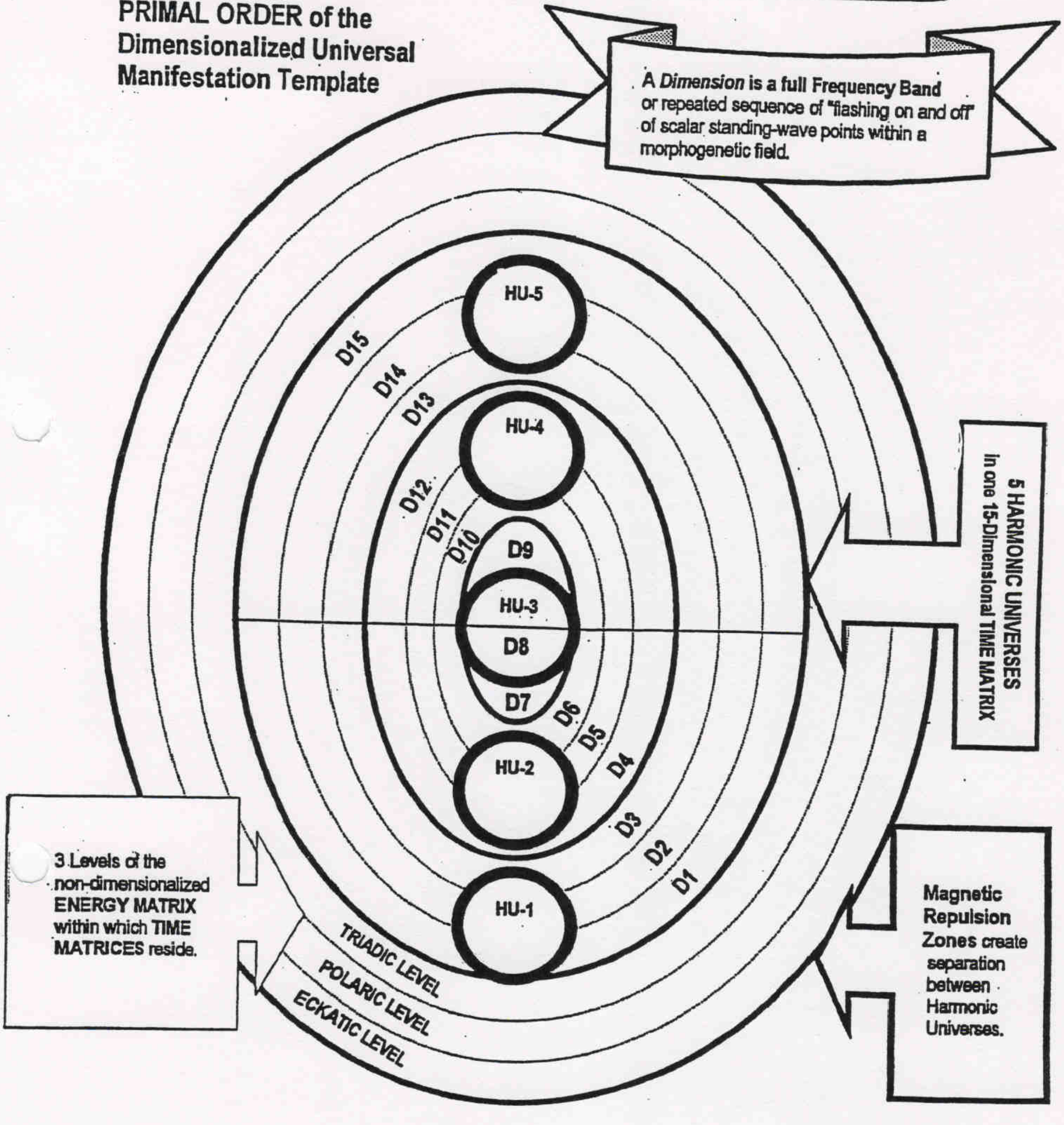
HU-5
D15
D14
D13
HU-4
D12
D11
D10
D9
HU-3
D8
D7
D6
D5
D4
HU-2
D3
D2
D1
HU-1
TRIADIC LEVEL
POLARIC LEVEL
ECKATIC LEVEL

A *Dimension* is a full Frequency Band or repeated sequence of "flashing on and off" of scalar standing-wave points within a morphogenetic field.

5 HARMONIC UNIVERSES in one 15-Dimensional TIME MATRIX

3 Levels of the non-dimensionalized **ENERGY MATRIX** within which **TIME MATRICES** reside.

Magnetic Repulsion Zones create separation between Harmonic Universes.

11

Frequency Bands and Sub-Frequency Bands within the 15-Dimensional Scale

Frequency Bands are cyclic, repeated sequences of "*flashing on and off*" of scalar standing-wave points that create the appearance of manifest wave spectra within a dimensional system. ***Sub-frequency Bands*** are shorter cycle segments of the longer "*flashing on and off*" sequence of the *full* Frequency Band. **Frequency and Sub-frequency Bands make up the foundation wave strata of Dimensions.**

1 Harmonic Universe composed of 3 Dimensions, each Dimension composed of 12-Sub-frequency Bands, for a total of **36 Sub-frequency Bands in 1 Harmonic Universe.**
(3 D per 1HU x 12 SFB per D = 36 SFB per 1HU) 1

①

DIMENSIONS	SFB
D3	12 SFB
D2	12 SFB
D1	12 SFB
	36 SFB (12 x 3)

5 Harmonic Universes in one 15-Dimensional Matrix 2

Harmonic Universe	② Dimensions	③ 180 SFB
H 5	D15	12 SFB
	D14	12 SFB
	D13	12 SFB
H 2	D4	12 SFB
	D5	12 SFB
	D6	12 SFB
H 3	D9	12 SFB
	D8	12 SFB
	D7	12 SFB
H 4	D10	12 SFB
	D11	12 SFB
	D12	12 SFB
H 1	D3	12 SFB
	D2	12 SFB
	D1	12 SFB
		180 SFB (12 x 15)

3 15 Dimensions with 12 Sub-frequency Bands each create **180 Sub-frequency Bands in one 15-Dimensional Matrix.** (12 SFB per D x 15D = 180 SFB or 36 SFB per 1HU x 5HU = 180 SFB)

15 Frequency Bands (Dimensions) **and 180 Sub-frequency Bands within the 5 Harmonic Universes of one 15-Dimensional Time Matrix.**
SFB = Sub-frequency Band

PARTIKI PHASING, HARMONICS OF MANIFESTATION AND MATTER DENSITY

Partiki Phasing – *Scalar Standing-Wave flashing.* The internal expansion/ fission/ "flashing on" and contraction/ fusion/ "flashing off" of scalar standing-wave points made of Partiki units. *Partiki Phasing* governs the mechanics of matter manifestation within the Dimensionalized Frequency Bands of the Time Matrix. Through Partiki Phasing HARMONICS of Manifestation and varying levels of matter density are created.

Each of the 5 Harmonic Universes, moving upward in the 15-Dimensional Scale, has a progressively less dense state of perceivable matter. As you go up the Dimensional Scale each Dimension has a progressively faster rate of Partiki Phasing with its corresponding higher frequency, faster oscillation, lower vibration, shorter wave length, greater expansion and less matter density. **These conditions represent the stages of perceivable matter density consciousness will experience as the focus of attention expands progressively upward/outward into the higher Dimensions of the Dimensional Scale through the process of evolution** (accretion of frequency from the Unified Field into the personal morphogenetic field).

As consciousness progressively expands back into the 15-Dimensional structure of its original morphogenetic field, matter density perception will change from perceivable Gross Matter physical density, to Semi-etheric Matter density, to Etheric Matter density, to Pre-matter Liquid Light density and to its original Ante-matter scalar wave form of non-density consciousness. **As the morphogenetic field expands through drawing in more frequencies of consciousness, the perceivable matter density of the body and external reality field progressively lessens.**

Partiki Phasing, Harmonics of Manifestation and Matter Density

1. *Partiki, Partika and Particum:*
Smallest units of energy-substance. Electro-tonal units of consciousness that are the building blocks of morphogenetic fields, matter and individuated conscious identity. Operate as minute, perpetual motion fission/ fusion generators.

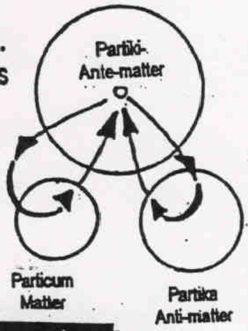

1. Partiki Phasing- expansion/ fission/ "flash on" and contraction/ fusion/"flash off"of scalar points governs the manifestation process

2.

Dimensions #	Harmonic Universe #	density type
1-2-3	HU-1	Carbon based biology physical matter-1
4-5-6	HU-2	Carbon-Silica based biology physical matter-2
7-8-9	HU-3	Silica based biology Etheric matter
10-11-12	HU-4	crystalline liquid-light based biology Pre-Matter
13-14-15	HU-5	standing wave pattern flame or fire body ANTE-Matter

2. Density/ Biology: Progression of Matter Density and related Biology within the 15-Dimensional Scale

3. Harmonics of Manifestation:
Progressive expansion of consciousness into the Dimensional Scale creates progressive perceptual De-manifestation of matter Density within the Hologram of external reality. **Harmonics of Manifestation** are the stages of Matter Density and Vibration-Oscillation Consciousness perceives and passes through within the Dimensional Scale.

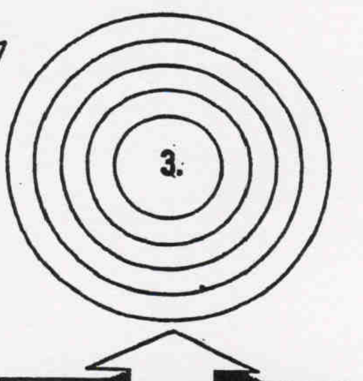

5 Harmonics of Manifestation in one 15-Dimensional Time Matrix

UNIVERSAL AND PLANETARY KATHARA

Kathara Level-1: 12-Tree, Kathara Level-2: Crystals, Kathara Level-3: Diodic Points, Kathara Centers and Kathara Lines.

The Kathara Grid is the *primary mathematical-geometrical organization of units of consciousness* upon which Partiki units group to form morphogenetic field scalar grids. It is the CORE level of scalar standing-wave creation and energetic organization within and behind all dimensionalized systems, and is thus considered to be the **Core of the Holographic Template** upon which the morphogenetic scalar wave blueprint and all other dimensions of form anatomy are built. The Kathara Grid is the causal element within all manifest affects of dimensionalization and consciousness.

The form of the Kathara Grid is reflected in the Macrocosm and Microcosm of all manifestation. All forms have at their core the *common structure of the Kathara Grid Holographic Template.* The Kathara Grids of all forms - universes, galaxies, planets and species - are linked to each other and to the Kathara Grid of the Cosmos through the interwoven Partiki scalar standing-wave grids of the *Kathara Grid Holographic Core.* **The *Cosmic Kathara Grid* represents the scalar field of the Cosmic Unified Field of Consciousness-Energy** through which the *Hologram of manifest experience* is perpetually created.

Energy cannot be created or destroyed, it only changes form. Energy IS *Eternal Consciousness* that perpetually changes form by projecting through the structures of the Kathara Grid, while simultaneously remaining *always the same* - the *singular wholeness* of the **Cosmic Unified Field of Consciousness-Energy.**

Structure of the Kathara Level-1 12-Tree Grid Core Scalar Template

12 PRIMARY KATHARA CENTERS:

Kathara Centers are condensed Scalar Wave points that hold the core electro-tonal geometrical-mathematical program for dimensionalized structure. There are 12 Kathara Centers, each holding the program for one Dimension. The program for Partiki Phasing and Vibration-Oscillation for each Dimensional Frequency Band is set in the corresponding Kathara Center. The Kathara Centers set the template for each Dimension, to ground consciousness within the Holographic experience of manifestation.

15 PRIMARY KATHARA LINES:

Kathara Lines are the primary sequences of Partiki Phasing that transmit the electro-tonal programs held within the Kathara Centers from one Dimension to another, to keep the continual flow of consciousness circulating throughout the 15-Dimensional levels of the Morphogenetic Field. When functioning properly, the Kathara Lines connect each Harmonic and Dimension of consciousness to the other and govern the synchronization of cycles of time within the Dimensional Fields and within the morphogenetic field, DNA and body rhythms of dimensionalized forms. The **3 Vertical Kathara Lines** control the operation of the other 12 Kathara Lines. The **Central Vertical Kathara Line** is the control center for Partiki Phasing rhythms throughout the Kathara Line System.

3 Vertical Kathara Lines = 1-2-3
Central Vertical Kathara Line = 1

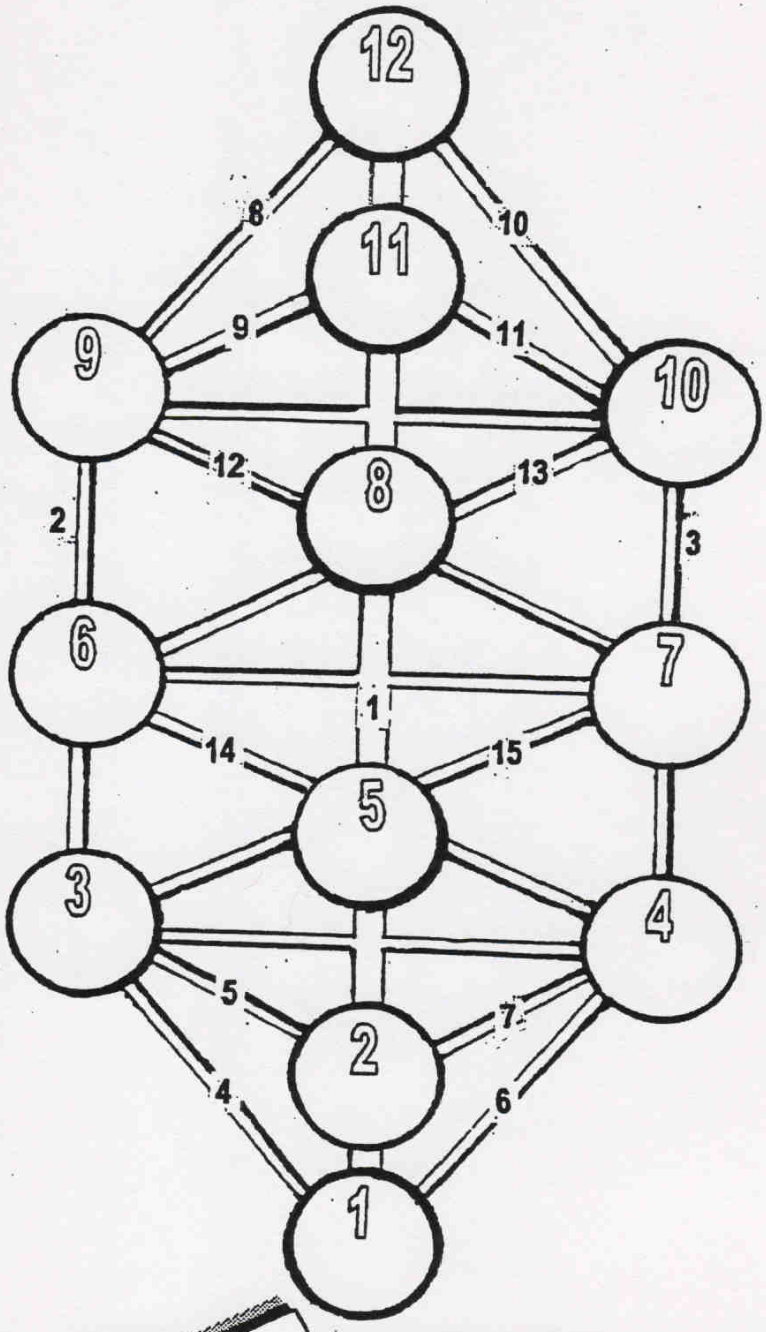

KATHARA LEVEL-1 12-TREE GRID

The 2 Interwoven Kathara Grids of Primal Order within the Universal Time Matrix and Cosmic Energy Matrix of the PRIMAL MANIFESTATION TEMPLATE

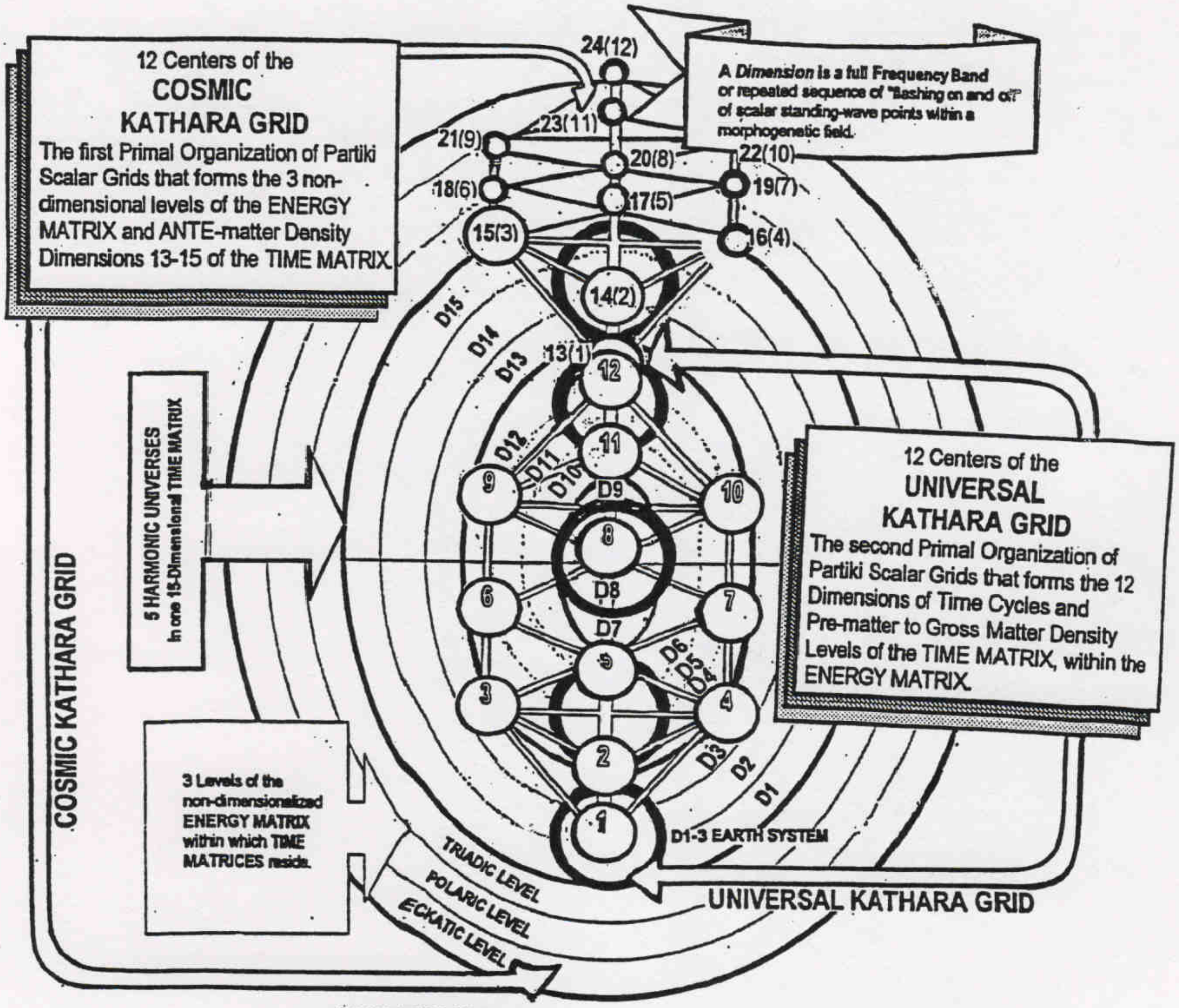

12 Centers of the **COSMIC KATHARA GRID**

The first Primal Organization of Partiki Scalar Grids that forms the 3 non-dimensional levels of the ENERGY MATRIX and ANTE-matter Density Dimensions 13-15 of the TIME MATRIX.

A *Dimension* is a full Frequency Band or repeated sequence of "flashing on and off" of scalar standing-wave points within a morphogenetic field.

12 Centers of the **UNIVERSAL KATHARA GRID**

The second Primal Organization of Partiki Scalar Grids that forms the 12 Dimensions of Time Cycles and Pre-matter to Gross Matter Density Levels of the TIME MATRIX, within the ENERGY MATRIX.

3 Levels of the non-dimensionalized ENERGY MATRIX within which TIME MATRICES reside.

24(12)
23(11)
21(9)
20(8)
22(10)
18(6)
17(5)
19(7)
15(3)
16(4)
14(2)
13(1)
12
11
9
10
8
6
7
5
3
4
2
1
D15
D14
D13
D12
D11
D10
D9
D8
D7
D6
D5
D4
D3
D2
D1
D1-3 EARTH SYSTEM
5 HARMONIC UNIVERSES
In one 15-Dimensional TIME MATRIX
COSMIC KATHARA GRID
TRIADIC LEVEL
POLARIC LEVEL
ECKATIC LEVEL
UNIVERSAL KATHARA GRID

5 HARMONICS OF MATTER DENSITY IN THE TIME MATRIX

1. Gross-matter D1-D3
2. Semi-etheric D4-D6
3. Etheric D7-D9
4. Pre-matter D10-D12
5. Ante-matter D13-D15

= ○

There are 3 **Primary Levels** to the structure of the Kathara Grid. **Level-1: *The Kathara 12-Tree*, Level-2: *The Crystal Seals* and Level-3: *The Diodic Points*.**

Level-1:The 12-Tree holds the first mathematical-geometrical program upon which Kathara Grid Levels 2 and 3 are created, and is composed of the **Kathara Centers** and **Kathara Lines.**

Level-2: The Crystal Seals are groups of 3-Dimensional Partiki scalar wave composites that regulate the rate of *Partiki Phasing* to create the base structures upon which *dimensionalization* is formed. The flow of Frequency (sequences of scalar standing-wave flashing/ cycles of Partiki Phasing) between dimensional bands and Harmonic Universes, the fixed expansion and contraction rates of Partiki, the Vibration-Oscillation and the Angular Rotation of Particle spin are all regulated by the Crystal Seals.

Level-3: Diodic/Miodic Points represent **concentrated areas of energy** that emerge at points where *dimensionalized levels of scalar grids cross over and through each other*, creating **minute vortices** of wave spectra that serve as *frequency modulation zones* (scalar flash-cycle transition points).between Dimensional Frequency Bands. **Diodic Point** vortices are **White Hole** vortices that **transmit energy** into the *Particle Universe* from their counterpart **Miodic Point** vortices within the *Anti-particle Universe*. Through the structure of Dimensionalization, each Harmonic Universe, and the structures contained there within, have within their morphogenetic fields *sets of Diodic and Miodic Points* – sets of **White and Black Holes** – that regulate the flux of consciousness-energy between systems.

The entire cosmic structure is built upon the morphogenetic foundations of *interwoven Kathara Grids*. Within the structures of forms, such as planets or people, the Kathara Grid is the *Core Template of Holographic Manifestation* and controls the structure and function of all of the other *subtle and physical energy systems.*

Planetary scalar templates - **Planetary Shields -** vortices, electro-magnetics, Axiom and Ley Lines are all governed by the operations of the *Kathara Grid*. In the **human body**, personal scalar templates - **Hova Bodies -**, Chakras, Axiom and Meridian Lines and Bio-energetic Field Auric Levels, as well as the physical systems, conscious awareness and DNA, are controlled by the *personal Kathara Grid*. **In terms of generating the *Imprint for Health* within the human organism, as well as *reclaiming dormant potentials of Immortality*, the Kathara Grid is the *causal mechanism* through which such affects can occur.**

KATHARA LEVEL-2 CRYSTAL SEALS GRID

Level-2: The Crystal Seals are groups of 3-Dimensional Partiki scalar wave composites that regulate the rate of *Partiki Phasing* to create the base structures upon which *dimensionalization* is formed. The flow of Frequency (sequences of scalar standing-wave flashing/ cycles of Partiki Phasing) between Dimensional Bands and Harmonic Universes, the fixed expansion and contraction rates of Partiki, the Vibration-Oscillation and the Angular Rotation of particle spin are all regulated by the Crystal Seals.

Planetary Star Crystal Seals

In the ***Planetary Kathara Grid***, the **15 Primary Star Crystal Seals** exist *between* each planetary Vortex or Chakra, on the **Central Kathara Line** or **Central Planetary Axis.** The Star Crystal Seals serve as **"Frequency Seals"** that open or close the *flow of wave spectra* and *Frequency Bands* from one **Harmonic Universe** to another, by regulating and modulating the *sequences of Partiki Phasing and the Vibration-Oscillation rates of Partiki units* within the Dimensional Scale. They control the opening and closing of the *Central Vertical Kathara Line* and *Central Planetary Axis*, through which particles are *phase-locked* into their respective dimensional placements and linear time cycle orientations. Opening of the *Star Crystal Seals* releases the planetary particles and *Ley Lines* from their *dimensional phase-lock*, opening **Inter-harmonic Star Gates (*wave spectra vortices*)** within the Ley Lines, for ***molecular transmutation** and time continuum shift*, through blending the Inter-Harmonic wave spectra of the planetary morphogenetic field. **The Planetary Star Crystal Seals control the opening and closing of the 3 *Vertical* Kathara Lines** (and **Vertical** *Star Gate passageways*) **of the Level-1: 12-Tree Kathara Grid with in planetary body.**

Biological Star Crystal Seals

In the ***human body*** the **15 Primary Star Crystal Seals** exist *between* each Chakra on the **Central Kathara Line** or **Central Body Current.** The *biological Star Crystal Seals* serve as **"Frequency Seals"** that open or close the *flow of wave spectra and Frequency Bands* from one *Harmonic of consciousness* to another, by regulating and modulating the *sequences of Partiki Phasing and Vibration-Oscillation rates of Partiki units* within the Dimensionalized scalar wave grid of the morphogenetic field. They control the opening and closing of the *Central Vertical Kathara Line* and *Central Body Current*, through which particles are *phase-locked* into their respective dimensional placements and linear time cycle orientations. Opening of the *biological Star Crystal Seals* releases the *body particles* and **DNA** from their *dimensional phase-lock*, opening **Inter-Harmonic Star Gates** (*wave spectra vortices*) within the **DNA**, for **cellular transmutation (via** particle+anti-particle *fusion*) and time continuum shift, through blending the Inter-Harmonic wave spectra. **The Biological Star Crystal Seals control the opening and closing of the 3 *Vertical* Kathara Lines** (and **Vertical** wave spectra vortices) **of the Level-1: 12-Tree Kathara Grid within the biological form.**

Seed Crystal Seals

Along with the 15 Primary *Star Crystal Seals* that control the *Vertical* modulation of wave spectra, there are also **15 Secondary Crystal Seals** that control the **HORIZONTAL** Kathara Lines of the Level-1: 12-Tree Kathara Grid within the planetary and biological bodies. The *Horizontal Crystal Seals* are called **SEED SEALS**, they exist and serve as **"Frequency Seals"** ***within*** the planetary vortices and biological Chakras, modulating the wave spectra between Parallel (particle/ anti-particle) Dimensional Frequency Bands.

KATHARA GRID LEVEL-3 DIODIC POINTS

Level-3: Diodic/Miodic Points represent **concentrated areas of energy** that emerge at points where *dimensionalized levels of scalar grids cross over and through each other*, creating **minute vortices** of wave spectra that serve as *frequency modulation zones* (scalar flash-cycle transition points) between Dimensional Frequency Bands. **Diodic Point** vortices are **White Hole** vortices that **transmit energy** into the *Particle Universe* from their counterpart **Miodic Point** vortices within the *Anti-particle Universe*. Through the structure of Dimensionalization, each Harmonic Universe, and the structures contained there within, have within their morphogenetic fields *sets of Diodic and Miodic Points* – sets of **White and Black Holes** – that regulate the flux of consciousness-energy between systems.

Planetary Diodic Points

Within the **planetary body** and morphogenetic field, **Diodic Points** are located in **geographical locations** where Inter-dimensional and Inter-harmonic Horizontal and Vertical Kathara Lines *intersect* to form small **vortices** of inter-dimensional or inter-harmonic wave spectra that serve as passageways – **time portals**- between Dimensional Time Continua or Harmonic Time Cycles. They connect planetary and stellar bodies to their *anti-particle counterparts* and intersect with Vertical Inter-harmonic Star Gates and Horizontal Inter-dimensional Time Portals, through sets of Diodic-Miodic **White and Black Holes** at the center of planetary and stellar cores.

Biological Diodic Points

Within the **biological form** and morphogenetic field, Diodic Points are located in **physical body regions** where Inter-dimensional and Inter-harmonic Horizontal and Vertical Kathara Lines *intersect* to form small **vortices** of inter-dimensional or inter-harmonic wave spectra that serve as ***gateways of consciousness*** between Dimensional Time Continua or Harmonic Time Cycles. They connect physical bodies to their *anti-particle counterparts* and intersect with the Vertical and Horizontal *relationships of wave spectra within the DNA/ RNA and bio-energetic field*, through sets of **White and Black Holes** at the center of the biological Harmonic scalar grids.

Diagonal Grid Control

The *Kathara Grid Level-3: Diodic Points* control the **Diagonal Kathara Lines**, Diagonal *Inter-dimensional portals*, Diagonal *Planetary Ley Lines* and Diagonal relationships between inter-dimensional wave spectra within the biological DNA. **In *Kathara Healing*, the *Diodic Points* are used to open and close the *Diagonal Kathara Lines* for channeling higher dimensional frequency into the Level-1 Kathara Grid, to regenerate the Imprint for Health and to revitalize the Bio-energetic and physical systems.**

THE UNIVERSAL TEMPLAR COMPLEX

- The systems of interwoven Manifestation Templates within the 5 Matter Density Levels of the 15-Dimensional Universal Kathara Grid are collectively referred to as the **UNIVERSAL TEMPLAR COMPLEX.** The Manifestation Template of the human body, likewise structured upon this Primal Order, also manifests through a personal **INTERNAL TEMPLAR COMPLEX** of interwoven 15-Dimensional Manifestation Templates.

- Universal, Galactic and Planetary Scalar-wave Templates of the Universal Templar Complex are called **Scalar SHIELDS.** Shields are sets of 3-Dimensional Scalar Grids upon which the 5 Matter Density Levels of the Universal Manifestation Template manifest. A Shield is composed of the distinct 3 **Primary Flash Line Sequences**, or Partiki Phasing Rhythms, characteristic to the 3 dimensions of which the Shield is composed. The Internal Templar Complex of the human body is also organized into 5 sets of 3-Dimensional **Personal Scalar Shields**, through which the matter form and 5 Matter Density Levels of the 15-Dimensional human consciousness are projected into manifest experience.

- Through the intrinsic dynamics of synchronistic Partiki Phasing, each 3-Dimensional Scalar Shield manifests a **3-DIMENSIONAL SPHERICAL ELECTROMAGNETIC DOMAIN** that creates the energetic framework within which externalized manifest experience can take place. Within the Universal Templar Complex, these Spherical Domains form 5 separate yet interwoven Reality Fields or **Harmonic Universes**, each with a different level of Matter Density, rate of Vibrational Oscillation, different Angular Rotation of Particle Spin and variance in Time Cycle orientation. Within the Personal Internal Templar Complex, the Spherical Electromagnetic Domains created by synchronistic, dimensionalized Partiki Phasing form within the 15-Dimensional Time Matrix 5 separate yet interwoven **STATIONS OF CONSCIOUSNESS** called **HOVA BODIES.** The **5 Hova Bodies** of human Manifestation Template Anatomy within the Time Matrix represent the **5 Subtle Energy Bodies** of human bio-energetic field construction, through which human identity experiences series of **SIMULTANEOUS INCARNATIONS** within the various Time Cycles and matter density levels of the Time Matrix. **Human Evolution** is the process by which the electromagnetic frequencies and stations of consciousness of the 5 Hova Bodies progressively merge to transmute the physical matter form backward through the various Matter Density stages through a process called **TRANSMUTATIONAL DIMENSIONAL ASCENSION.**

  Each of the 5 Shields within a 15-Dimensional Manifestation Template is structured upon **3 KATHARA CENTERS** within the core Primal Order of the Level-1 Kathara 12-Tree Grid. Each Kathara Center of the Universal Kathara Grid forms a core point of consolidated frequency called a **SIGNET Star Crystal Seal** within the 3-Dimensional scalar Shields. Within the universal, galactic and planetary Templar Complex the Signet Seals operate as **Star Gates** between the Time Cycles of the 5 Matter Density levels of the 15-Dimensional Time Matrix. Within the Personal Internal Templar Complex, each **Hova Body** is structured upon **3 Kathara Centers** within the embodied Personal Kathara Grid. Each embodied Kathara Center forms a **Signet Star Crystal Seal** within the human anatomy. The embodied **Signet Seals** operate **as Bio-electric Windows** within the **DNA-RNA**, that link the Stations of Consciousness and various **Simultaneous Incarnations** of the identity that exist within the Time Cycles of the Time Matrix to each other, across the illusions of time. Through the embodied Personal Kathara Grid, Scalar Shields, Signet Seals and DNA Windows, the individuated aspects of **ETERNAL IDENTITY** in time are indelibly linked in consciousness. This intrinsic linking of personal consciousness within the various simultaneous cycles of time appears to the embodied human awareness as **REINCARNATIONAL MEMORY.**

The embodied Manifestation Template of the human form is a microcosmic reflection of the Macrocosmic Universal and Cosmic Manifestation Templates. Both microcosmic and macrocosmic Manifestation Templates share, and are interwoven through, the same **Primal Structures** of the Kathara 12-Tree Scalar Grid, the 5 3-Dimensional Scalar Shields and Signet, Star and Seed Crystal Seals and the Diodic Point "Black and White Hole Sets" of energy vortices that manifest upon the Kathara Grid. Human consciousness and biology are directly and indelibly connected to the Universal Templar Complex through the **Personal Internal Templar Complex** of the Personal Manifestation Template.

HEALING AND PRIMAL FULFILLMENT

A rudimentary but operational understanding of the intrinsic structure of the embodied Personal Manifestation Template- (*the **Level-1**Personal Kathara 12-Tree Grid, **Level-2** Scalar Shields, Hova Bodies and Signet, Star and Seed Crystal Seals, and **Level-3** Diodic Points*) - and its relationship to the Universal Templar Complex, allows the embodied human consciousness the opportunity for progressive participation within the processes of **CONSCIOUS EVOLUTION** and intentional restoration of the **Organic Imprint for Health.** All manifest **DIS-EASE** originates through **distortions** in the electro-tonal scalar wave programs of the **Kathara Grid, Scalar Shields** and **Manifestation Template.** To achieve true and lasting healing, rather than suppression and transference of dis-ease to other embodied systems, distortions within the personal Manifestation Template need to be realigned from the causal Kathara Grid level through **REGENESIS** of **Primal Order** within the **Organic Imprint for Health.**

Manifestation Template healing therapeutics based upon knowledge of the Kathara Grid, simultaneously work to restore the natural intended **Primal Order** and function of the human body and consciousness, while expediting the evolutionary process of merging the stations of identity through time, to facilitate fulfillment of the organic **PRIMAL PURPOSE.** The **Primal Purpose** of human evolution is the achievement of **Transmutational Dimensional Ascension** and **Co-creative Mastery** over the Personal Eternal Consciousness and **Internal Templar Complex** within the Holographic Fields of the Time Matrix. Through fulfillment of the **Primal Purpose,** humanity will regain **THE PRIMAL CONDITION** of Conscious AT-ONE-ment with the Universe and the Central Source of Creation, or **GOD.**

The Universal Templar Complex

The First 4 SHIELDS each with 3 SIGNETS and correspondence to the Kathara Centers of the Level-1 12-Tree Kathara Grid.

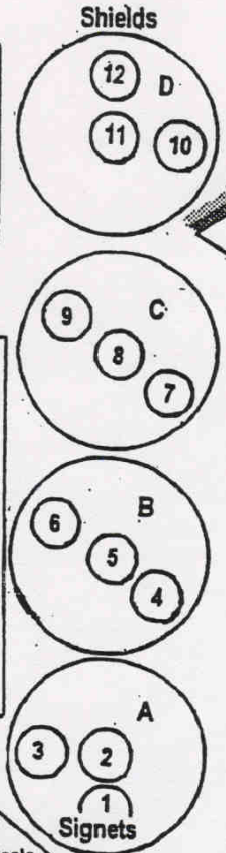

Kathara Level-2 Scalar Shields & Crystal Seals

The 4 Scalar SHIELDS corresponding to the Kathara Center programs and Harmonics of Matter Density within the *Universal* Manifestation Template.(The 5th Scalar Shield in the 15-Dimensional Time Matrix corresponds to the first 3 Kathara Centers of the *Cosmic* Kathara Grid.) Shields are the 3-Dimensional scalar-wave grids that hold the blueprint for manifestation, as set by the mathematical encoding of Partiki Phasing Rhythm held within the Kathara Centers of the Manifestation Template.

HORIZONTAL SHIELDS

A. TELLURIC SHIELD
Gross Matter Shield
Dimensions 1-3

B. DORADIC SHIELD
Semi-etheric Matter Shield
Dimensions 4-6

C. TEURIC SHIELD
Etheric Matter Shield
Dimensions 7-9

D. MAHARIC SHIELD
Pre-matter Shield
Dimensions 10-12

E. RISHIC SHIELD
Ante-matter Shield
Dimensions 13-15
(vertical- not shown)

The 12 SIGNET Star Crystal Seals of the Universal Kathara Grid. SIGNET SEALS are the core points of consolidated frequency corresponding to each Dimension that represent the first manifest arrangement of scalar waves created through the mathematical programs of the corresponding Kathara Centers. The Signets transmit the organizational programs upon which the Scalar Shields manifest. Each 3-Dimensional Scalar Shield manifests on the electro-tonal programs of 3 Signet Star Crystal Seals. Signet Seals keep the Harmonics of Matter Density separate from each other by keeping Partiki units phase-locked into their 3-dimensional electromagnetic domain.

When released, Signet Seals serve as Star Gates, allowing the Time Cycles and Matter Density Levels within the Time Matrix to merge and blend. Signet Seals are the central control points for Scalar Shield programming.

The 12-Dimensional UNIVERSAL KATHARA GRID within the 15-Dimensional Time Matrix. The 12 Kathara Centers hold the core mathematical and geometrical Partiki Phasing programs upon which the Shields of the Universal Manifestation Template organize.

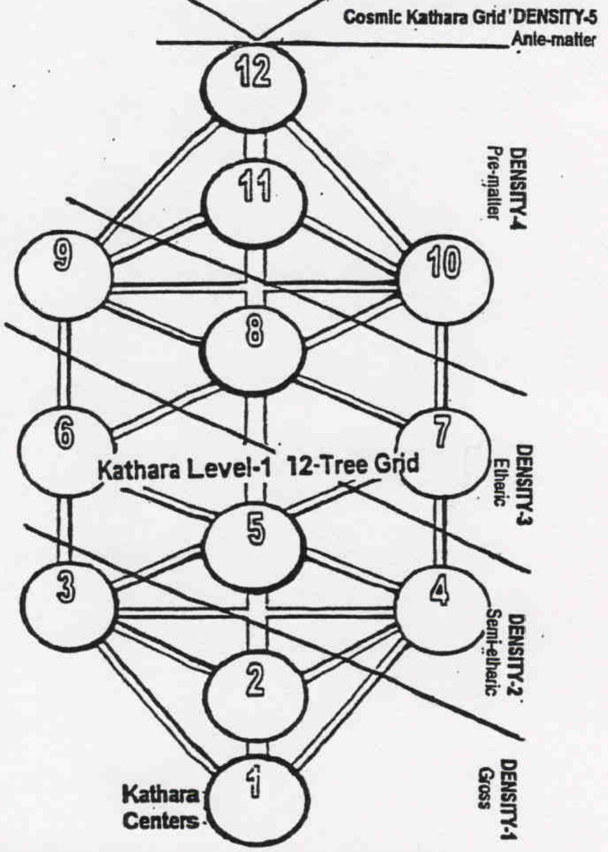

The structure of the macrocosmic **Universal Templar Complex** is replicated within the microcosmic structure of the personal **Internal Templar Complex** upon which **15-Dimensional Human Anatomy** manifests.

The Transduction Sequence

The *Transduction Sequence* represents the phases consciousness passes through into dimensionalization and the process by which conscious energy is transduced and *changes form* to enter the wave spectra within which perception of manifestation is possible.

Basic *Transduction Sequence* of Consciousness into Biological Form.

CONSCIOUSNESS TO **PARTIKI UNITS** TO

KATHARA SCALAR GRIDS LEVELS –1, 2 AND 3 TO **PARTIKI GRIDS** TO

MORPHOGENETIC FIELDS TO **MERKABA FIELDS** (Sets of Counter-rotating electro-magnetic spirals of energy –repeating scalar wave flash/ Partiki Phasing sequences that run between Dimensions and Harmonic Universes)

TO **DNA/ RNA IMPRINT** TO **BIO-ENERGETIC AURIC FIELD** TO **CHAKRAS**

TO **NADIAL CAPSULE** (tissue-like capsule that forms around the 3-Dimensional scalar grid of the Harmonic Universe-1 morphogenetic body.) TO

DNA/ RNA MANIFEST TO **NADIS** (energetic rivulets that feed energy from the Nadial Capsule into the Central Nervous System and molecular structure) TO

NUCLEAR CORE TO

CNS-METABOLIC/ BIOLOGICAL RHYTHMS- BLOOD-BRAIN-CHEMICALS-HORMONES-ORGANS-TISSUES.

HOLOGRAPHIC REALITY CONSTRUCTION

The Unified Field of Conscious-Energy

THE **SCALAR STANDING-WAVE GRIDS** THAT MAKE UP **DIMENSIONALIZED MORPHOGENETIC FIELDS** REPRESENT THE *INTRINSIC STRUCTURE* OF THE **COSMIC UNIFIED FIELD OF ENERGY** WITHIN WHICH ALL THINGS EXIST. *ENERGY IS CONSCIOUS AND CONSCIOUSNESS IS ENERGY.* **CONSCIOUSNESS-ENERGY CANNOT BE CREATED OR DESTROYED IT SIMPLY CHANGES FORM,** WHILE SIMULTANEOUSLY REMAINING ALWAYS THE SAME – **THE ETERNAL UNIFIED FIELD OF CONSCIOUSNESS.**

The Kathara Grid

ALL FORMS OF CONSCIOUSNESS AND PERCEIVABLY MANIFEST FORMS *DERIVE THEIR INDIVIDUATION* WITHIN THE UNIFIED FIELD THROUGH THE STRUCTURE OF THEIR **INDIVIDUATED MORPHOGENETIC FIELD**. THOUGH HAVING MUCH DIVERSIFICATION WITHIN THE **GEOMETRICAL-MATHEMATICAL PROGRAMS** THAT FORM **INDIVIDUALITY** WITHIN LIKE PATTERNS, THE *CORE OF ALL INDENTITY AND MANIFEST FORM IS THE SAME* – THE INTRINSIC STRUCTURE OF **THE KATHARA GRID – THE CORE HOLOGRAPHIC TEMPLATE OF DIMENSIONALIZATION UPON WHICH MORPHOGENETIC FIELDS ARE FORMED.**

Interwoven Morphogenetic Fields

THE INHERENT STRUCTURE OF **INTERWOVEN KATHARA GRIDS** FORMS **SPHERICAL DIMENSIONALIZED MORPHOGENETIC FIELDS** WITHIN WHICH CONSCIOUSNESS CAN EXPERIENCE THE **HOLOGRAPHIC PROJECTION** OF MANIFEST REALITY, SPACE, TIME, MATTER AND EXTERNALIZATION. THE SPHERICAL MORPHOGENETIC STRUCTURES OF THE **MICROCOSM** EXIST WITHIN THE GREATER SPHERICAL MORPHOGENETIC FIELDS OF THE **MACROCOSM**, FORMING A SYSTEM OF CONSCIOUS-ENERGETIC **SPHERES-WITHIN-SPHERES** THAT REPRESENTS THE ***INTERWOVEN MORPHOGENETIC FIELDS*** **OF THE COSMIC UNIFIED FIELD OF CONSCIOUSNESS-ENERGY.**

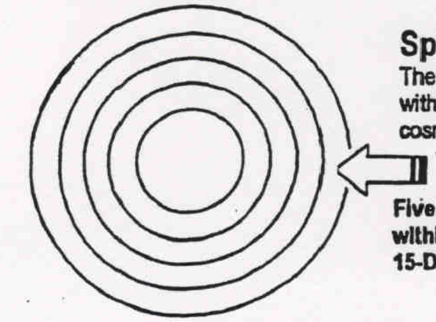

Spheres-within-Spheres ***Interwoven Morphogenetic Fields***
The Microcosm within the Macrocosm. The individual within the species within the planetary within the galactic within the universal within the cosmic within the INFINITE AND ETERNAL.

Five Over-lay Universes exist within the same space in 1 15-Dimensional Matrix.

CHAPTER 1 HIGHLIGHTS

THE HOLOGRAPHIC TEMPLATE

- **External reality is a HOLOGRAPHIC PROJECTION.** Perception of **solidity** and **externalization** are determined by the **oscillation rates** between **dimensionalized units of consciousness** - ***Partiki, Partika*** and ***Particum.*** Dimensionalized units of consciousness form **Frequency Bands** that exist in specific relationships to each other. We perceive as solid the Frequency Bands that exist **1** full Dimensional Band **below** the frequencies within which the consciousness is stationed.

- **Dimensionalization** creates the structure through which consciousness can perceive the **Hologram of Externalization.**

- The human body is a **Hologram** built upon a **Holographic Template** of units of consciousness structured into **Scalar Standing-wave Grids** that represent the **Living Morphogenetic Field** blueprint upon which matter and dimensionalized consciousness manifest.

THE STRUCTURE OF DIMENSIONS

- The **Unified Field** is built upon ***dimensionalized sets*** of ***Scalar Standing-wave Points***, **Wave Strata** formed of units of consciousness that form the basis of energetic relationship through which the **Hologram of Manifestation** can be perceived.

- The human body is a construct of ***Conscious Energy***, built upon **a15-Dimensional Anatomy of Dimensionalized Scalar-Grids.** Perceived physicality emerges through the **Perceptual Lens of Dimensionalization** which provides the picture of seemingly manifest particles, atoms, molecules and physical systems.

- Understanding the nature and structure of **Holographic Reality** allows us to understand the foundations upon which the **body is** built and the **context** within which **healing** must occur.

Scalar Waves are standing wave points that emanate out of fixed points of sound (electro-tonal Partiki units), which form the **Scalar Grid morphogenetic templates** that house consciousness in **dimensionalization** for experience of manifest reality. Scalar Grids are created through **Partiki Phasing.**

Partiki Phasing is the process of ***internal fission/ expansion and fusion/ contraction*** characteristic of **Partiki Units,** through which the units perpetually break apart and replicate through *fission*, then re-merge through *fusion*. Creates a *"flashing on and off" of **Scalar Wave points,*** or **"Flash-line Sequences"** that determine the intrinsic orientation of consciousness within the Scalar Grids composing morphogenetic fields.

Dimensions are Scalar Grids of consciousness composed of interwoven layers of Scalar waves with **varying Flash-line Sequences**, or *Frequency Bands.* **Dimensions are Frequency Bands**, or Partiki wave spectra, that exist within specific relationship to each other to form the template of Holographic Reality.

- **Frequency Bands** are synchronized, repeating ***Flash-line Sequences of Partiki Phasing*** that give the appearance of manifest movement of wave spectra within a Dimensional Scalar Grid **Sub-frequency Bands** are *portions* of the *Flash-Line Sequences* that make up the whole Dimensional Frequency Band. The Frequency of a Dimensional Band is determined by the **Vibratory-Oscillation** rate of Partiki units that make up the Dimensional Scalar Grids.

- **Vibration** is the "internal movement" or **ENERGY HOLDING** of Partiki units. **Oscillation** is the "external movement" or **ENERY EXPENDED** by Partiki units. **Vibratory-Oscillation rate is the rate at which Partiki Phasing "flashing on and off" occurs**. Vibration and Oscillation exist in **direct proportion** to each other. As Vibration increases (energy holding), Oscillation decreases (energy expenditure). Faster Flash-line Sequences (higher frequency) *expend* more energy, raise Oscillation and lower Vibration of Scalar Templates. **Higher Oscillation/ Slower Vibration creates slower electron movement around nucleus and less perceivable density of matter.**

- A **Dimension** is a full Frequency band or **full cycle** of a **Flash-line Sequence.**

- The **Universal Morphogenetic Template** is built upon ***sets of 15 Primary Flash-line Sequences*** that form **15-Dimensional Time Matrices** within which manifestation can be experienced.

- **Dimensions are organized into sets of 3, (**3 full Flash-line Sequences/ 3 Frequency Bands), that create the template through which 3-dimensional manifestation can be experienced. Each set of 3 Dimensions is called a **Harmonic Universe**. There are **5 Harmonic Universes** within a **15-Dimensional Time Matrix.**

- Each Dimension contains **12 Primary Sub-frequency Bands** (partial Flash-line Sequences).

- Partiki in each Dimension have specific set **Partiki Phasing rhythms** giving each Dimension a specific ratio of **Vibration-Oscillation.** Higher Dimensions have Faster Partiki Phasing, are higher frequency and thus have higher oscillation, lower vibration and less particle density.

- **Vibratory-Oscillation** rate within a Dimension determines the **Angular Rotation of Particle Spin (ARPS)**, or *rotational axis of particles* in a Dimension. There is a **90-Degree Shift** in ARPS between each Dimension and a **45-Degree Reverse Shift** in between Harmonic Universes.

- Particles having varying **Vibratory-Oscillation** rates and **ARPS** allow *multiple 3-Dimensional Reality Fields* to *co-exist* within the same space while remaining perceptually and experientially **invisible** to each other.

- The **relationship between wave strata** and **variance in Partiki Phasing Flash-line Sequences** within Dimensional Frequency Bands create **Holographic Refraction** of consciousness-energy that allows perception of an externalized, 3-Dimensional **Holographic Illusion** for consciousness focused within the Scalar Grids of the 15-Dimensional Time Matrix.

UNIVERSAL AND PLANETARY KATHARA

- The **Kathara Grid** is the **first level** of Partiki structure/ *Scalar Grid organization* that sets consciousness into dimensionalization. It is thus the **CORE HOLOGRAPHIC TEMPLATE** upon which the *morphogenetic field blueprint* is structured.

- The *Kathara Grid* is the *Core Holographic Template* for **dimensionalization of the Unified Field** of Consciousness-Energy through which the **Microcosm** and the **Macrocosm** are structured. **All things are built upon the foundation of the *Kathara Grid.***

- There are **3 Primary Levels to the Kathara Grid. Level-1:** ***The 12-Tree Grid*** with **Kathara Centers** and **Kathara Lines. Level-2:** ***The Crystal Seals*** with **Hova Bodies** and **Scalar Shields** and **Level-3:** ***The Diodic Points*** of minute energy vortex **"White and Black Hole" sets.**

KATHARA GRID LEVELS

KATHARA 12-TREE GRID

- **Level-1 Kathara** holds the base electro-tonal **programs** of Partiki Phasing and Dimensional/ Frequency structure upon which the other Kathara Levels and the morphogenetic field are built.

KATHARA SCALAR SHIELDS AND CRYSTAL SEALS

- **Level-2 Kathara Grid** is composed of 5 groups of 3-Dimensional **Scalar Shields** and **Crystal Seals** - that regulate the rates of Partiki Phasing to create the base structures upon which ~~dimensionalization is built.~~

KATHARA DIODIC POINTS

- **Level-3 Kathara Grid** is made of sets of minute White and Black Hole energy **vortices,** made of inter-dimensional Scalar Wave spectra, that **regulate the flux of consciousness-energy** between Dimensional, Harmonic and Parallel/ anti-particle systems.

- ***Cosmic*** *morphogenetic structure* is built upon interwoven **Kathara Grids** and the Dimensionalized Scalar Standing-wave Templates they form.

- The **5 Primary Scalar Templates of Dimensionalization** are formed on **Scalar Shields** composed of sets of 3 Dimensions, which form *5 3-dimensional spheres of energy* called **HOVA BODIES**. Hova Bodies and their Scalar Shields hold consciousness-energy into **5 separate but interwoven 3-dimensional systems.**

- The **Kathara Grid** and the multiple levels of morphogenetic structure built upon it is the **CAUSAL ELEMENT** behind and within all manifestation, and thus the **CORE HOLOGRAPHIC TEMPLATE** through which the **Imprint for Health** can be restored to Biology.

- All manifest **Dis-ease** originates through **distortions** in the natural electro-tonal programs/ *Partiki unit arrangements* of the *Kathara Grid* and *Hova Body Scalar Shields*. The Kathara Grid and morphogenetic field are the **core elements** through which **lasting healing** is created. **Healing** occurs through **REGENESIS** of natural electro-tonal **programs** of the **Holographic Template.**

- **Partiki Units, Scalar Standing Waves, and Crystalline Keylons and Keylon Codes** represent the **PRIMAL SUBSTANCE** in energy that consciousness takes on in order to create the **Holographic Projection** of external manifestation.

- The **Kathara Grid, 15-Dimensional Structure, Scalar Shields, Crystal Seals, 5 3-Dimensional Harmonic Universes and Hova Bodies, Diodic Point** vortices and the subtle and dense matter energetic systems that manifest upon them represent the **PRIMAL ORDER** of mathematical and geometrical interrelationship that **Primal Substance** utilizes to orchestrate the manifest Hologram through creation of **Manifestation Templates.**

- The interwoven, ordered structures of scalar wave fields that form the **Universal Manifestation Template** of the 15-Dimensional Time Matrix are collectively referred to as the **UNIVERSAL TEMPLAR COMPLEX.**

- The interwoven, ordered structures of scalar wave fields that form the **Personal Manifestation Template** of **15-Dimensional Human Anatomy** are collectively referred to as the **Personal INTERNAL TEMPLAR COMPLEX.** The Internal Templar Complex, a structural replica of the Macrocosmic Universal Templar Complex, anchors personal consciousness into the Time Matrix for the experience of the space, time and matter Hologram.

- The **PRIMAL PURPOSE** of human evolution is the achievement of **Transmutational Dimensional Ascension** and **Co-creative Mastery** over the **Personal Eternal Consciousness** and **Internal Templar Complex** within the holographic fields of the Time Matrix. **REGENESIS** of **Primal Order** within the **Organic Imprint for Health** creates true healing and expedites the natural processes of human evolution.

- Through fulfillment of the **Primal Purpose** humanity will regain **THE PRIMAL CONDITION** of **Eternal Conscious At-ONE-ment** with the Central Source of Creation or **GOD.**

CHAPTER 2

(Section One: *Foundations of Kathara Healing* – Part II)

THE ELEMENTS OF HEALING

The Human Body Kathara and the Multi-dimensional Anatomy of the Human Form

- THE MAHARIC SHIELD AND THE IMPRINT FOR HEALTH
- THE PLANETARY BIO-FEED INTERFACE SYSTEM (PBIS)
- THE HIEROPHANT SYMBOL CODE, PBIS AND THE MAHARIC SHIELD
- MORPHOGENETIC EXPANSION, GROWTH CYCLES, DEATH AND MOLECULAR COMPACTION
- LEVELS OF HUMAN ANATOMY, EMBODIED KATHARA 12-TREE GRID, CRYSTAL SEALS, SHIELDS, SIGNETS, HOVA BODIES, AURIC CAPSULES, DIODIC POINTS, SEED SEALS, CHAKRAS, AXIOM LINES, THE HARA LEVEL AND DNA.
- THE 12 HUMAN SENSES, APPARTHI AND HUMAN PERCEPTION

TOPICS OF DISCUSSION

THE HUMAN BODY KATHARA AND THE MULTIDIMENSIONAL ANATOMY OF HUMAN FORM

The Structures of Manifestation and Reclaiming Our Power

In *PART-I* of this program, **THE CONTEXT OF HEALING**, we explored the hidden foundations of *reality structure* within which our existence takes place, the *context of relativity* through and within which *healing* occurs. We learned that the context of existence can be viewed as taking place within a **Unified Field of Energy**, and that **Energy IS consciousness and Consciousness IS energy.** In our exploration we encountered the **Partiki, Partika** and **Particum**, the ultra-micro-particle units of consciousness in electro-tonal form, through which the tangible structure of living **Morphogenetic Fields** are formed. In learning the foundation structures of the Unified Field of Consciousness-Energy, we come to understand that the anatomy of any form, including that of the human Body-Mind-Spirit System, is a **multi-dimensional construct** built on an ordered template of **sets of 15-Dimensions,** through which all conditions of apparent manifestation are created.

Through reviewing the underlying structures of manifest reality (units of consciousness, the ***Partiki Scalar Standing-wave Grids*** that hold consciousness into individuated dimensionalized "packages" of awareness to allow for experience of space, time, matter and form, the core ***Kathara Grid Holographic Template*** that sets the pattern of dimensionalization for consciousness to follow into the manifest experience, the ***Levels of Matter Density*** corresponding to the ordered structure of Dimensions, and the reality that **Dimensions** are *tangible constructs of energy* created through the process of ***Partiki Phasing***-the fission-fusion "flashing on and off" of scalar standing-waves composed of units of consciousness) **we have already expanded our perceptions of the nature of reality itself.** With these **simple revelations of knowledge**, we have shifted ourselves from a perspective of viewing the reality before us as one of *separate manifestations disconnected from our being*, to a perspective of viewing reality as an *intricate system of interwoven consciousness, expressing in the form of standing-wave strata*, to which we are *intimately and indelibly connected*.

Suddenly we find that we cannot be "left out" of things, we cannot "be on the outside as life passes us by", **that there IS no "outside" to which we may stand separate, as by the *nature of our existence* we are an *intrinsic element and force of creative affect* within the whole of creation.** Through this knowledge we have begun to tap the **secrets of SELF**, as we shift from viewing ourselves as *mortal creatures trapped within a gross-matter finite physical body*, to **KNOWING OURSELVES AS THE EXPRESSION OF CONSCIOUS, SENTIENT WAVE-STRATA - ETERNAL BEINGS ENSCONCED WITHIN AN ETERNAL UNIVERSE, within which Energy-Consciousness cannot be created or destroyed, it simply changes form perpetually.** We move from perceiving ourselves as finite beings of limited power to affect a world that is separate from us, to knowing that we are *walking wave-forms within a sea of interrelated wave forms*, and that the pattern of our being operates as an intrinsic part of the whole. **As we begin to perceive ourselves in terms of the *unlimited reality of our nature*, rather than define ourselves by the limited boundaries of the *manifest illusion before* us, we begin to reclaim our power to *affect desired change* within the contours of our lives.**

Knowledge, KNOWING and the Imprint for Health

Knowledge is an agent of freedom, IF it is used to foster practical applications of change. Knowledge can also become a *perpetual quest of distraction*, through which we deny ourselves the ability to EMBRACE the experience of living as we seek outside of ourselves the answers that live within. **Knowledge is power if it is applied appropriately, it can be an agent that leads one through the door to the WISDOM that awaits on the other side.** Knowledge alone cannot provide **cognition,** cognition comes through the *application of applied knowledge* to provide **tangible, experiential** KNOWING, a knowing derived only through the **direct experience of** BEING. **In Kathara Healing™ *knowledge* is applied as a *tool* through which one can grow into the *wisdom of direct experience*** - from ***thinking or believing***, which are knowledge/data-based characteristics of a mind perceiving itself as *finite* - to **KNOWING,** through Direct Cognition of the Experience of BEING, which is a characteristic of a consciousness KNOWING itself as ETERNAL. .

In our first lessons of **Kathara Healing,** we gained *knowledge* of the *Context of Healing* and the *structure* of that which exists within and around us, so that we may become more empowered to serve as a *healing force*, within ourselves and within the collective of the Whole. **But this knowledge will only become practical or useful to us if it is applied to foster the direct experience through which the wisdom of KNOWING may emerge.** Then, and only then, will we be changed...then and only then will we become *true agents of healing*. **Knowledge can help you to *understand the nature of health and healing*, but only through KNOWING HEALTH through *direct experience* will you be *healed.*** To KNOW HEALTH we must rediscover this quality within ourselves, to EXPERIENCE the *quality of wellness* that emerges as the **Imprint for Health** is reawakened within the human body. **First we must use *knowledge* to recognize that the *Imprint for Health* is there, sleeping silently within us awaiting this awakening.**

Healing the Causal Core

Fixing symptoms does not restore the *Imprint for Health*, it simply masks from view the *causal elements* through which non-health manifested. Removing the symptom *without addressing the underlying cause* simply sets the stage for the cause to *re-manifest itself* in new ways, through *new sets of symptoms*. **Each symptom you remove will give birth to another symptom if the *underlying cause* is not changed.** Kathara Healing addresses the **deepest *causal factor*** in manifestation, the **Holographic Template Kathara Grid,** upon which all conditions come into being. **Within the intrinsic structure of the Kathara Grid the dormant *Imprint for Health* is sleeping, and through knowledge of the Kathara and applications of its methods we can reawaken the Imprint for Health within ourselves, to progressively move into KNOWING HEALTH** through the cognition of Direct Experience.

In Kathara Healing you are provided with the knowledge you need to understand the structures upon which the *Imprint for Health* is built, for in understanding these structures you will be enabled to call the Imprint for Health into awakening. **But it is through the APPLICATION OF KATHARA TECHNIQUE that you will AFFECT CHANGE. The technique applications offered in Kathara Healing allow you to "bring the knowledge home" to the core of its usefulness, the ability to lead you into the *direct experience of health-ward change.***

Elements of Healing

In **PART II THE ELEMENTS OF HEALING,** we will apply the knowledge of the *Context of Healing* that we acquired in *PART I,* directly to its relevance in terms of the **HUMAN BODY**. We will now explore **Kathara Mechanics** as they apply directly to the human system, and you will gain the knowledge of your **15-Dimensional Anatomy** through which you may then effectively utilize **Kathara Mechanics Techniques** to begin your journey into the **EXPERIENTIAL REALITY OF HEALING.** We will discover the long forgotten potentials of the ***Planetary Bio-feed Interface System™*** and how to receive energy for healing directly from the Kathara Grid of the Earth. We will explore the real processes within and behind the experience of growth through time, so that we may finally identify the **true causal element intrinsic to the *degeneration* and *death* of the body.** We will come to understand the functions of the Body-Mind-Spirit System as they are **INTENDED to operate**, to identify the areas in which malfunction is occurring, so that we may *remedy the casual factors* to progressively restore the **INTENDED INTEGRITY OF THE BODY-MIND-SPIRIT SYSTEM. In PART II we will reclaim our knowledge of our *multidimensional anatomy*, and rediscover the buried secrets of awakening the *Imprint for Health.***

MAHARIC SHIELD

The Imprint for Health and the *Maharic Shield*

Restoration of health within the body is a progressive endeavor that takes time. Portions of the Body-Mind-Spirit System that have been malfunctioning must readjust to a new process of function that will progressively work its way up from the core **Kathara Grid Holographic Template**, into the **Bio-energetic Field**, **Chakra System** and **DNA**, to progressively ***reset*** the **Imprint for Health** within the Body-Mind-Spirit System. **The Imprint for Health sleeps soundly now within a portion of the multidimensional anatomy called the *MAHARIC SHIELD*.** The Maharic Shield is a buried treasure of **REGENERATION and REVITALIZATION** of the human organism, as it is the key to *recoding the human Kathara Grid* back into its original Imprint for Health. **The *Imprint for Health* is a tangible construct of energy that is located within the structure of the *Maharic Shield*.** In calling these dormant energy systems into activation within the body, one has the opportunity to restructure the causal level of malfunction, and to recode the Holographic Template upon which malfunction manifests.

Reciprocal Reflection and the Kathara Grid

All conditions of dis-ease within the Body-Mind-Spirit System *share a common core of causality - distortions of the Kathara Grid* upon which manifestation is built. All symptoms affect the Body, Mind and Spirit *simultaneously*, malfunction in one aspect of being will have its *reciprocal reflection* in the other aspects of being, as the symptoms emanate from distortion in the *Kathara Core*, upon which all aspects of being simultaneously manifest.

As we work with restoring integrity to the *Holographic Template Kathara Grid*, we are thus creating *simultaneous restoration through Reciprocal Reflection* within the *Body*, the *Mind* and the *Spirit* (the CONSCIOUSNESS that makes up the substance of our multidimensional anatomy and identity).

The Maharic Shield and Whole-Being-Healing

In activating the *Maharic Shield* to regenerate the *Imprint for Health*, you will have change occurring within multiple levels of being. Your **BODY** will begin to reflect change as dis-ease-causing distortions are released from the *biological imprint*, and a higher level of order is reestablished within the ***atomic structure.*** Your **MIND** will begin to reflect change as dis-ease-causing distortions in your **thoughts, ideas and beliefs** are released from the *mental body* awareness. Your **SPIRIT**-consciousness, will reflect change, as divisions between your embodied awareness and the expanded portions of your multidimensional awareness will begin to dissolve, and you will become progressively more able to embody greater states of *cognition, creativity and awareness.* ***Kathara Grid recoding*** **through the use of the *Maharic Shield* will set in motion the processes of WHOLE BEING HEALING, as the *Imprint for Health* is progressively reawakened and restored within the Body-Mind-Spirit System.** Activation of the **Maharic Shield** within the personal Kathara Grid will lay the foundations for progressive, lasting and powerful restoration of the **Imprint for Health** within your Body-Mind-Spirit System.

Learning to activate the Maharic Shield to restore the Imprint for Health requires a bit of **knowledge** regarding *Elements* of the hidden anatomy of multidimensional being, and application of specific **energetic mechanics** that will directly affect these hidden structures of energy. We will begin PART II with a discussion on the **ELEMENTS OF HEALING as they apply to *developing the skills required to create the condition of Maharic Shield activation*, through which the *Imprint for Health* can receive its wake-up call.**

THE PLANETARY BIO-FEED INTERFACE SYSTEM™

Awakening the Personal and Planetary Templar Complex Connection

Interwoven Personal and Planetary Kathara Grids

The core Holographic Templates of both the *personal* and the *planetary* morphogenetic fields are built upon a Scalar standing-wave *Kathara Grid*. As the morphogenetic fields of **species** are interwoven into the larger morphogenetic field of the **planet** they inhabit, there is a **direct energetic connection between the Kathara Grids of individuals and that of the planetary body. This connection between personal and planetary Kathara Grids is called the *Planetary Bio-feed Interface System™*, - PBIS.** For thousands of years the **planetary Kathara Grid** has carried **distortions** in its natural pattern that have rendered the **PBIS** primarily inoperable. **Kathara distortions in the planetary morphogenetic field blocked the human's innate ability to draw energy for regeneration and revitalization from the planetary morphogenetic field.**

When the human Kathara Grid system is working properly there is a *natural sympathetic rapport* between the personal and planetary Kathara Grids that keeps the *Imprint for Health* within the human *Maharic Shield* functioning properly. Due to the distortions of the planetary Kathara, the human Kathara developed **reciprocal distortions,** which created **blockages between the Maharic Shield Imprint for Health and the other functional portions of the human Kathara.** The blockages with the human Kathara manifested as distortions within the natural function of the **DNA** and bodily systems, disarming many of the natural *self-regenerative functions* organic to human biology and rendering the human form more susceptible to disease and malfunction of the biological system. As there is a **Reciprocal Reflection** of patterns between the Body, Mind and Spirit aspects of the human organism, due to their *common causal element* of the *Kathara Grid Holographic Template*, **distortions within the DNA and physical body function also become reciprocal distortions** within the **mental body** and its **perceptual facilities,** and within the **Spiritual Body,** as the Kathara distortions *block and distort* the organic cycles through which higher dimensional aspects of consciousness would progressively embody within and expand the human form.

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The Planetary Bio-Feed Interface System™

As the morphogenetic fields of species are interwoven into the larger morphogenetic field of the planet they inhabit, there is a direct energetic connection between the Kathara Grids of individuals and that of the planetary body. This connection between personal and planetary Kathara Grids is called the *Planetary Bio-feed Interface System*™, - PBIS.

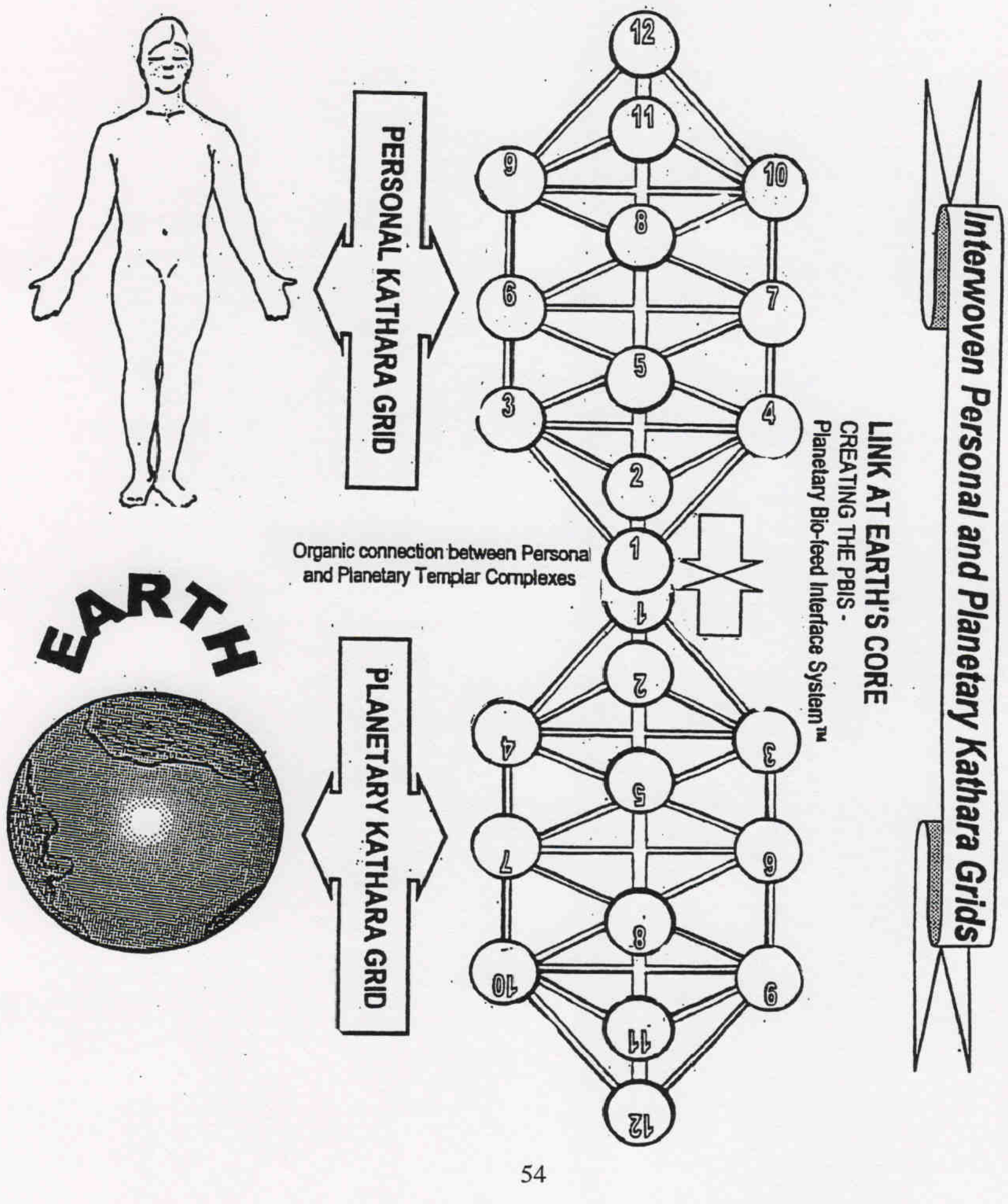
PERSONAL KATHARA GRID
12
11
9
10
8
6
7
5
3
4
2
1
Organic connection between Personal and Planetary Templar Complexes
LINK AT EARTH'S CORE
CREATING THE PBIS -
Planetary Bio-feed Interface System™
Interwoven Personal and Planetary Kathara Grids
EARTH
PLANETARY KATHARA GRID
1
2
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3
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7
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10
9
11
12

Return of the PBIS - Gift of the 21st Century

The secrets of utilizing the PBIS have been passed down within the generations of the Melchizedek human families who brought these teachings to Earth long ago, kept hidden from public display until a day when the PBIS could once again become operational through evolution and clearing of the planetary Kathara Grid. These teachings are now being returned into the public arena because **progress has been made in restoring the integrity of the planetary Kathara Grid system. For the *first time in many thousands of years* the potentials of healing held within the PBIS can be returned to humanity, and the PBIS can now be *activated within the personal biology* to reawaken the *Maharic Shield* and its *Imprint for Health*, within the human Kathara System.** Reawakening the *PBIS* and the *Maharic Shield* within the human body *allows the personal Kathara Grid to open into the planetary Kathara Grid*, through which the now-functional **Holographic Template of the planetary Kathara can be used to RESET the original imprint of function within the personal Kathara,** for accelerated regeneration of the **Imprint for Health** within the human form.

HIEROPHANT SYMBOL CODE

The *Hierophant Symbol Code* PBIS Trigger

The first application of the PBIS that we will employ in Kathara Healing is utilizing the energies flowing through planetary Kathara to reawaken the Maharic Shield within human anatomy. The process of opening the PBIS within the personal morphogenetic field involves using a **specific scalar standing-wave-guide GEOMANCY - a consolidated inter-dimensional *frequency pattern* that triggers release of the *frequency seals* (Kathara Level-2 Crystal Seals) on the presently dormant 10th, 11th and 12th Chakras, opening the human Bio-energetic Field and Kathara Grid to the Kathara Grid, Bio-energetic Field, Ley Lines and energy Vortices of the planetary morphogenetic field.** The wave-guide Geomancy containing the frequencies to activate the PBIS and the Maharic Shield can be directed by the human consciousness **in the form of a visually created symbol code. This symbol code is called the HIEROPHANT.** In **TECHNIQUE # 2: *The Maharic Seal and the Liquid Light Cleanse*,** to be explored in ***PART III. of Section I,*** the **Hierophant Symbol Code** will be used to bring the **Maharic Shield** and the **PBIS** out of dormancy, in order to **RESET** the **Imprint for Health** within the operational Holographic Template of the human **Kathara Grid.**

The *Hierophant Symbol Code Scalar Wave Guide* for Kathara Reprogramming

Thoughts and **Images** formed by the mind represent **small morphogenetic fields** with minute **Kathara Grids**, that become interwoven into the larger morphogenetic field and Kathara Grid of the human multidimensional anatomy. ***THOUGHTS ARE THINGS*** **in terms of the bio-energetic reality of the body and the Kathara Grid; *thoughts become translations* of electro-tonal "*digital" instructions* within the human bio-energetic field, and directly enhance or detract from the natural function of the electro-tonal programs of the human Kathara Grid.** In recognizing the **power of thought *as the power of creation of scalar standing-wave grids***, we can begin to apply that power effectively in regeneration of the Kathara Holographic Template, by **directing needed *electro-tonal instructions* for awakening the *Maharic Shield* into the embodied Kathara Grid.** The **Hierophant Symbol Code**, used in the form of a **visualized image**, sets a **powerful electro-tonal program** within the human Kathara, a program that **triggers the opening between the human Kathara and the PBIS**

The *Hierophant Symbol Code* appears in the form of a *Pale Silver Merkaba Star*, a six-pointed "Star of David", which represents the *electro-tonal program* of the *11th and 12th-Dimensional aspects of the Universal Kathara Grid.* The **frequency wave spectra** perceived by the human mind as **Pale Silver** represents the **electro-tonal program** of the ***Dark Silver*** *primary frequency band of the 11th-Dimensional wave spectra, combined with the* ***Pure White*** *primary wave spectra of the 12th-Dimensional frequency bands.* Using the **Hierophant Symbol** wave guide to direct *frequency and electro-tonal instructions* through the Kathara Grid, creates a ***scalar standing-wave pattern of 11th and 12th Dimensional frequency* within the personal Kathara Grid,** the frequencies in which the **original *electro-tonal instructions*** for the ***Imprint for Health*** are stored. By **awakening the 11th and 12th Dimensional frequencies within the human Kathara and bio-energetic field**, all of the *lower frequencies* within the Kathara electro-tonal program become **modulated and recoded** into their *organic, undistorted pattern*, by the *stronger wave influence* of the higher 11th and 12th Dimensional frequencies, which *contain within themselves* the organic imprint for the *entire dimensionalized wave spectra* of the dimensions that *oscillate below* them.

The Hierophant Symbol Code
Scalar Wave Guide for Kathara Reprogramming

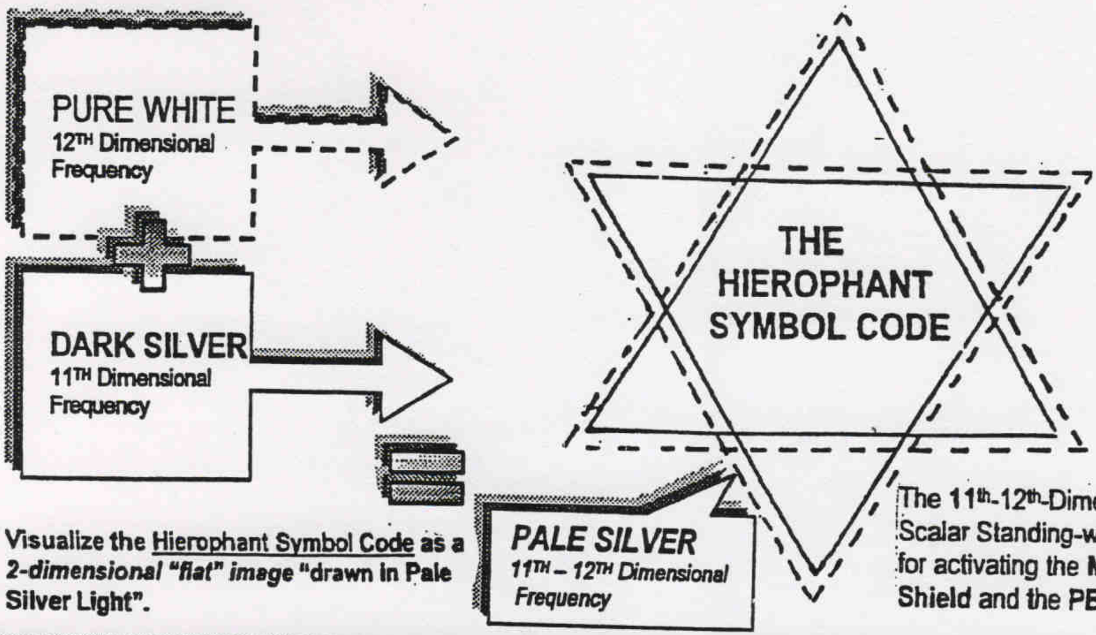
PURE WHITE
12TH Dimensional Frequency
DARK SILVER
11TH Dimensional Frequency
PALE SILVER
11TH – 12TH Dimensional Frequency
THE HIEROPHANT SYMBOL CODE

Visualize the Hierophant Symbol Code as a ***2-dimensional "flat" image*** **"drawn in Pale Silver Light".**

The 11th-12th-Dimensional Scalar Standing-wave Guide for activating the Maharic Shield and the PBIS.

Ease of Kathara Healing Techniques

Through using the *Hierophant Symbol Code* we awaken the restorative frequency patterns within the *Maharic Shield* and the *PBIS*, beginning the process of regenerating the organic *Imprint for Health in* the human Holographic Template Kathara Grid. The restorative affects of using the *Hierophant Symbol Code* to activate the *Maharic Shield* and the *PBIS* will occur upon using the *Kathara Mechanics* provided in Technique # 2, *whether or not* an individual understands the realities in frequency that are taking place through using this process. **Therefore, the complex mechanics of activating the *Maharic Shield* to reset the *Imprint for Health*, can be *reduced to simple instructions* for the direction of energy.** Though the **theory of Kathara Healing** is highly *detailed and complex*, the **Techniques** by which *active results are achieved* employ **simple exercises in *Mental Symbol Code Visualization* and mental energy direction,** coupled with the **application of simple *Kathara-stimulating massage*** to specific corresponding body points. **The *Techniques* of Kathara Healing and regeneration of Kathara Grid integrity are *so simple* that even a young child can learn to actively employ them, to achieve the desired result of restoring the *Imprint for Health*.**

MORPHOGENETIC EXPANSION

Frequency Accretion, Growth, Age Rhythms, Degeneration, Death and Kathara Blockage

Frequency Accretion and Growth Through Time

The morphogenetic field of the human body evolves through time via the process of **Frequency Accretion**. The human morphogenetic field *exists within* the larger morphogenetic field of the planetary and universal dimensionalized **Unified Field of Consciousness-Energy.** Through the inherent function of the **Kathara Grid** and the multi-layered systems of energy built upon it, *progressively more frequency and corresponding wave spectra* from the *dimensionalized Unified Field* are **drawn into** the *personal morphogenetic field* to create **progressive expansion of the morphogenetic imprint and its resulting progressive *expansion of consciousness* and *growth of the physical body* in time.**

Kathara blockages and Organic Growth Cycles

Blockages and scalar wave distortions within the **Kathara Grid** *impede* the natural functions of **Frequency Accretion**, and so **distort the intended natural processes of consciousness expansion and growth of the body form in time.** When the Kathara Grid is functioning properly, there are **certain *specific points in linear time*** **when *specific aspects of morphogenetic expansion* via Frequency Accretion are intended to occur.** The **original cycles of growth and expansion inherent to the human form** occurred between **1. fetal integration through age 11-12, 2. age 11-12 through age 22, 3.age 22 through age 33** and **4. age 33 through age 44**, at which time the human morphogenetic field would reach its **full expansion,** the **DNA** would reach its organic **12-strand activation,** the identity would expand to hold **12-dimensionsof consciousness** within embodiment, and the organism would have **full conscious control** of ***manifesting and de-manifesting*** **its 15-Dimensional anatomy in time. The body forms of the original human imprint are IMMORTAL** - deterioration and death were **not a part of the original *Imprint for Health*** within the human Bio-Spiritual makeup. Through understanding how the natural process of growth and expansion in time were INTENDED to work, we can also understand the core reason for the manifestation of the SYSTEMS MALFUNCTIONS - the conditions of biological and mental deterioration that lead to the condition of **BIOLOGICAL DEATH** - a condition that is **INORGANIC TO THE ORIGINAL GENETIC IMPRINT OF THE HUMAN FORM!.**

The First Natural Expansion Cycle

In the original human genetic blueprint, the frequencies and dimensions of consciousness corresponding to the wave spectra of Dimensions 1, 2, and 3, were intended to accrete or draw into the morphogenetic field between fetal integration and the age of 11-12. At the age of 11-12 the wave spectra of which the body was composed would take a **leap in frequency**, beginning the process of **expanding the morphogenetic field** to hold the higher frequency wave spectra of **Dimensions 4, 5 and 6.**

The *expansion of the morphogenetic imprint* is reflected in the *DNA*, and *chemical and hormonal balances* within the body, which govern the function of the *metabolic rate* and the operation of molecular function. The **first cycle** of *morphogenetic expansion* into the wave spectra of **Dimensions 4, 5 and 6,** represents the process of **SOUL INTEGRATION** for the embodied identity, and **begins the natural process of de-densification of matter** - *by lowering of morphogenetic vibration, raising of oscillation rate and frequency, and shortening of the wave-length of the scalar waves that compose the matter form and consciousness.* **These changes in *intrinsic wave characteristics* have their reflection within the behavior of *atomic structure***- as the morphogenetic field wave spectra **raises in frequency**, the ***electron spin* around the atomic nucleus *slows***, thereby increasing the electrical nature, and reducing the magnetic orientation of atomic function, ***transmuting the perceivable matter substance* of the cells to a *less dense* state of being. Completion of the *Soul Integration process* marks the transmutation of *Carbon-based Gross-matter density* into the *Carbon-Silica based Semi-etheric matter density*, and the expansion of embodied awareness from 3 to 6 Dimensions of consciousness.**

Completing Expansion

This process of *progressive morphogenetic field and consciousness expansion* and *resulting de-densification of biological matter* continued throughout the remaining *expansion cycles*. Age **22 to age 33** marked the accretion of the **7th, 8th and 9th -Dimensional** wave spectra, the process of ***Over-Soul Integration,*** expansion into a **9-Dimensional consciousness** and transmutation to a ***Silica-based Etheric matter density biology*.** Age **33 to 44** marked the accretion of the **10th, 11th and 12th Dimensional** wave spectra, the process of ***MAHARIC INTEGRATION***, expansion into a **12-Dimensional consciousness** and transmutation **out of biology** into the **Crystalline Liquid Light wave form of Pre-matter substance.** At this point the identity is considered a **full AVATAR** and has complete control over ***manifesting and de-manifesting*** the **Holographic Projection** of its desired body imprint in time.

Growth Rates and Morphogenetic Expansion

ORIGINAL HUMAN GENETIC IMPRINT

PERSONALITY INTEGRATION (Telluric Integration) – BIRTH - AGE 12

Expands the Morphogenetic Field through accreting the frequencies of Dimensions 1-3 and activating DNA Strand Templates 1-3.

SOUL INTEGRATION (Doradic Integration) – AGE 12 – 22

Expands the Morphogenetic Field through accreting the frequencies of Dimensions 4-6 and activating DNA Strand Templates 4-6.

OVERSOUL INTEGRATION (Teuric Integration) – AGE 22 – 33

Expands the Morphogenetic Field through accreting the frequencies of Dimensions 7-9 and activating DNA Strand Templates 7-9.

CHRISTOS AVATAR INTEGRATION (Maharic Integration) –AGE 33 – 44

Expands the Morphogenetic Field through accreting the frequencies of Dimensions 10-12 and activating DNA Strand Templates 10-12. Allows full Cellular Transmutation and Dimensional Ascension to the 12th Dimensional Pre-matter Liquid Light HYDROPLASMIC Substance Liquid Silica) and conscious mastery over 12 Dimensions within the 15-Dimensional Time Matrix. A "Christed" Immortal Being possessing non-polarized Unity or Christ Consciousness.

CONTEMPORARY HUMAN GENETIC IMPRINT

PERSONALITY INTEGRATION (Telluric Integration) – BIRTH – DEATH

SOUL INTEGRATION (Doradic Integration) – KATHARA BLOCKAGE

OVERSOUL INTEGRATION (Teuric Integration) – KATHARA BLOCKAGE

CHRISTOS AVATAR INTEGRATION (Maharic Integration) – KATHARA BLOCKAGE.

Deterioration and Death of the physical body occur rather than progressive frequency accretion for Cellular Transmutation and Dimensional Ascension. Distortions in the personal Kathara Grid and Scalar Shields manifest in the DNA Template and block natural inflow and Morphogenetic Field accretion of frequency from the higher dimensional stations of identity. Conscious awareness remains polarized in Duality Consciousness and physical body is rendered finite and vulnerable to dis-ease.

THE 4 NATURAL CYCLES OF MORPHOGENETIC FIELD EXPANSION

THE *4 CYCLES OF MORPHOGENETIC FIELD EXPANSION* REPRESENT THE *ORIGINAL ORGANIC PROCESS* BY WHICH THE HUMAN ORGANISM WAS *INTENDED* TO EVOLVE THROUGH TIME.

The Inorganic Condition of Human Illness and Death

The processes of biological and mental deterioration and resulting DEATH of the biological form, which we presently view as FACTS OF LIFE regarding the process of human passage through linear time, ARE NOT ORGANIC CONDITIONS TO THE HUMAN ORGANISM. Other life forms, such as the **animal kingdoms**, that manifest through morphogenetic fields having *less than 12 Kathara Centers active* within their Kathara Grid, cannot undergo the full process of bodily transmutation into Pre-matter substance, and cannot fully expand their embodied awareness into 12th-Dimensional consciousness. For the **animal kingdom**, the process of evolution is also Frequency Accretion, but it is achieved through expanding one's body form to its full capacity, then entering the consciousness into a morphogenetic imprint with a bit higher capacity, until eventually the consciousness can accrete enough frequency to take it into the next level of matter de-densification and consciousness expansion. **Death is natural to the organic animal kingdom.**

Humans were intended to undergo the *full spectrum of morphogenetic expansion and cellular transmutation* WITHIN ONE ETERNAL BODY IMAGE, that was built upon a program of *full activation* of the *12 Kathara Centers* of the Kathara Grid. Death is NOT natural for humans.

Kathara Grid Blockage and Molecular Compaction

The process of *biological deterioration* and progressive movement toward biological DEATH is the *direct result* of unnatural BLOCKAGES WITHIN THE KATHARA GRID HOLOGRAPHIC TEMPLATE. Blockages within the Kathara Grid program presently block the process of Frequency Accretion **at the beginning of the First Expansion Cycle-** as accretion of the 4th, 5th and 6th Dimensional frequencies representing the *Soul Integration Process* is blocked within the Kathara Grid and thus within the biological DNA, the incoming frequencies of the Soul Level consciousness **push on and CRUSH the morphogenetic field**, rather than *expand the morphogenetic field into a higher level of frequency holding*. When the incoming scalar wave frequencies of Soul Integration begin to crush the morphogenetic field, a condition called **MOLECULAR COMPACTION** is created.

MOLECULAR COMPACTION -

***over exposure to scalar wave spectra* and its resulting *fragmentation of the morphogenetic field and Kathara Grid* - IS THE *ONLY TRUE CAUSE OF DIS-EASE*, AND THE *CORE CAUSAL ELEMENT* OF THE *UNNATURAL DEATH EXPERIENCE*.**

The *Maharic Shield* and Human Healing

Within the imprint of the **MAHARIC SHIELD** of human morphogenetic structure, is the dormant imprint of the *10th, 11th and 12th Dimensional electro-tonal programs* that represent the **ORGANIC PROGRAM OF THE KATHARA GRID. Through activation of the Maharic Shield** - the scalar standing-wave template that corresponds to the Pre-matter Liquid Light fields of Dimensions 10, 11 and 12 - **blockages within the Kathara Grid Holographic Template, that result in the genetic mutation that causes Molecular Compaction, can be progressively realigned with the original IMMORTAL IMPRINT FOR HEALTH.** Though it takes time and consistent application of **Kathara Healing Technique** to fully regenerate the **Imprint for Health and Immortality** within the 15-Dimensional Levels of human anatomy, working to heal distortions within the Kathara Grid through **MAHARIC INFUSION** (running the frequencies and wave spectra of the *Maharic Shield* through the Kathara Grid, Bio-energetic System and Body), **can create progressively more observable affects in creating and maintaining health, and slowing the bodily deterioration process, within the normal life span of an individual.**

Potentials of Kathara Healing

The true beauty and significance of *Kathara Healing* is that it can not only do wonders for creating and maintaining *higher standards of health* within the average human life span, but within the applications of KATHARA MECHANICS lies the *promise and potential* of human biological IMMORTALITY and the fulfillment of SPIRITUAL ACTUALIZATION and evolution to MASTERY- through progressive embodiment of and conscious mastery over our 15-Dimensional Anatomy and the creative process of Holographic Projection within the dimensionalized fields of space, time and matter.

KATHARA HEALING HOLDS THE KEY TO HUMANITY RECLAIMING ITS ANCIENT HERITAGE OF THE ETERNAL SELF AND IMMORTAL AT-ONE-MENT WITH SOURCE.

LEVELS OF HUMAN ANATOMY- THE EMBODIED KATHARA

The Human Body Kathara Grid

The Kathara Grid of the human body is the *Core Holographic Template* upon which the morphogenetic scalar-wave template, and all other levels of identity and form are built. It is the **"Control Center"** for manifestation of the human being.

LEVEL-1 KATHARA 12-TREE GRID

THE KATHARA GRID LEVEL-1: 12-TREE

Level-1 Kathara Grid 12-Tree: The first level of the Kathara Grid **sets the *pattern for dimensionalization of consciousness* through which identity can enter the Time Matrix for the Holographic Experience of manifestation. The Kathara Grid 12-Tree is the first wave spectra composite through which consciousness anchors itself into dimensionality in order to experience manifestation of form.** All things within dimensional structure have the Kathara 12-Tree at the core, but not all manifest forms have the full pattern of the 12-Tree *activated* within their morphogenetic pattern. The 12-Tree is composed of **12 Kathara Centers** or *Kathara Spheres*, and **15 Kathara Lines.**

KATHARA CENTERS

The **Kathara Centers** are *crystallizations of Partiki units* that hold *composite electro-tonal energy signatures for each dimensional band.* The electro-tonal programs of the Kathara Centers hold the **foundation template** upon which the biological **DNA** will manifest.

KATHARA LINES

The **Kathara Lines** are sequences of *Partiki Phasing rhythms* ("flashing on and off"/fission-fusion sequences) that *transfer the dimensionalized electro-tonal programs of the Kathara Centers between each center* , to form the **core level of the scalar standing-wave template** upon which subsequent levels of the Kathara Grid, Bio-energetic System and body will build.

KATHARA HEALING AND THE LEVEL-1 12-TREE GRID

The *Kathara Centers* and *Kathara Lines* are used in *Kathara Healing* to realign and awaken the original 12-Dimensional imprint within the human morphogenetic field, in order to *reinstate the original Imprint for Health and Bio-Spiritual Mastery* within the operational evolutionary blueprint for the Body-Mind-Spirit System of the Human form.

Level-1 Kathara 12-Tree Grid

of the INTERNAL TEMPLAR

KATHARA CENTERS

#12 – *The Capstone*
In 10th Chakra
6" above the head

# 11 – *Crown Jewel*
In Pineal Gland
at center of brain

# 9 & # 10 –*The Shar*
In brain
behind ears

# 8 – *Spark of Orion*
In Thyroid Gland
at 8th Chakra

# 6 & # 7-*The Wings*
In shoulder indents
through to back

# 5 –*Seat of Amenti*
At Navel in
Central Body Current

# 3 & # 4 -*The Dal*
male: Ureters
female: Ovaries

# 2 – *Naum-Yun*
male: Prostate Gland
female: Vagina

# 1 – *Earth Core*
at center of Earth
in 13th Chakra

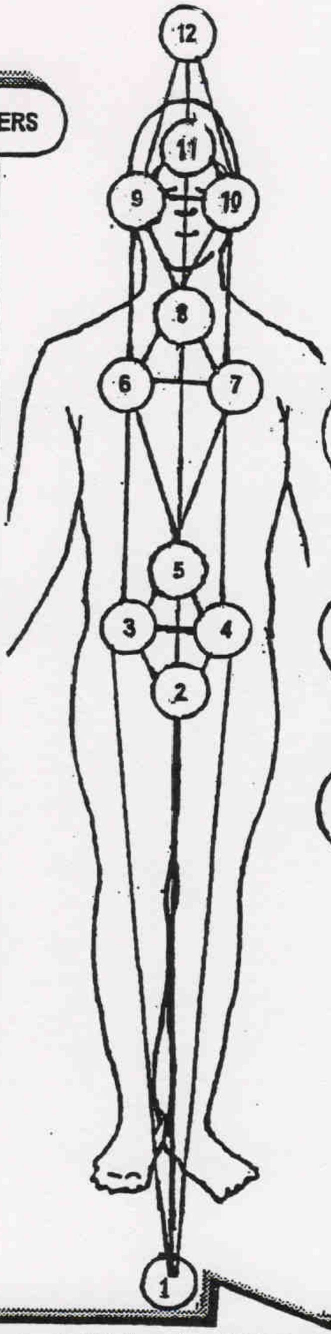
12
11
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1

Placement of *Kathara Level-1 12-Tree Grid Kathara Centers* and *Kathara Lines* within the human body.

Central Vertical Kathara Line
controls all other Kathara Lines. Kathara Centers on *Central Vertical Kathara Line* control all other Kathara Centers.

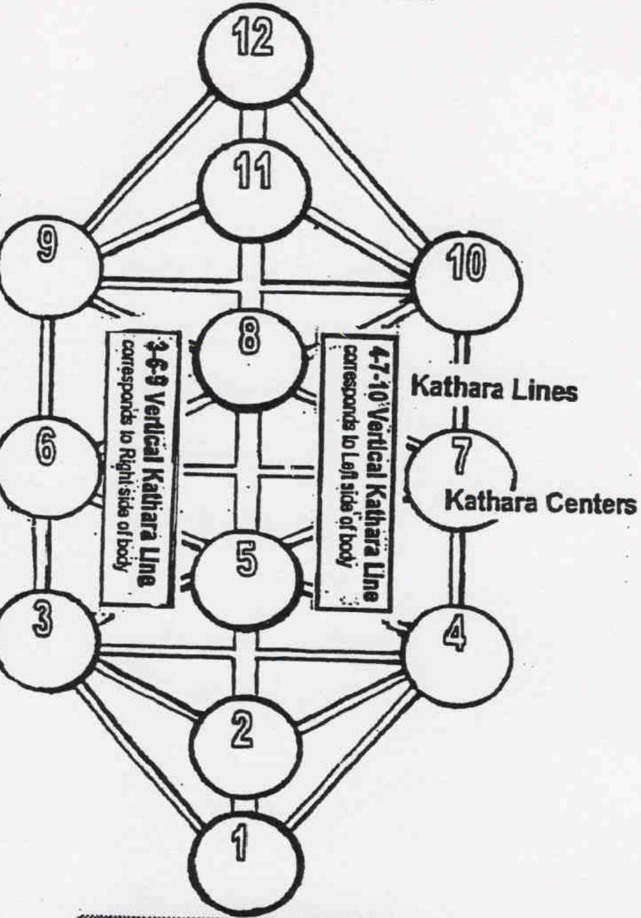
12
11
9
10
8
3-6-9 Vertical Kathara Line
corresponds to Right side of body
4-7-10 Vertical Kathara Line
corresponds to Left side of body
Kathara Lines
6
7
Kathara Centers
5
3
4
2
1

Electro-tonal Programs within the *3 **Vertical Kathara Lines*** control the programs in all other Kathara Lines.

LEVEL-2 KATHARA CRYSTAL SEALS GRID

Level-2: Crystal Seals and 15 Primary Chakras

The Crystal Seals are groups of 3-Dimensional Partiki scalar wave composites that regulate the rate of Partiki Phasing to create the base structures upon which dimensionalization is formed. The *flow of frequency* between dimensional bands and Harmonic Universes, the fixed expansion and contraction/ fission and fusion rates of Partiki, the *Vibration-Oscillation Rates* of Partiki and the *Angular Rotation of Particle Spin* are all regulated by the Crystal Seals.

Star Crystal Seals are positioned between the Chakra Centers along the **Central Body Current**, and **Seed Crystal Seals** are positioned between them, and serve as the *point of composite frequency* out of which the **15 Primary Chakra Center Vortices** emerge.

HOVA BODIES AND SHIELDS

5 Dimensionalized Hova Body Shields and 5 Auric Capsules

Hova Bodies are **3-Dimensional, tri-tonal scalar standing-wave grids** composed of numerous sets of **Crystal Seals** that form the electro-tonal program upon which the **Kathara Grid Level-3: Doradic Points** emerge. **The Hova Body Grids are called Crystal Shields.** The **5 Dimensionalized Hova Bodies** are structured as **5 Concentric Spheres** of energy that *surround and permeate the human body* and serve to *hold the embodying consciousness into dimensionalized levels* through which the **Holographic Projection** of *experienced manifestation* can occur. The Hova Bodies form **"tissue capsules"** of *subtle energy* around **each 3-dimensional Harmonic** level of the **Bio-energetic Field**, within which the **15 Dimensional levels** of the **Auric Field** are stationed.

In Kathara Healing, restoration of the original **4th-Harmonic Maharic Shield** *Imprint for Health* is used to *realign and clear blockages* from the lower Hova Bodies and corresponding **Kathara Centers** and **Kathara Lines**, to awaken the **Imprint for Health and Spiritual Actualization** within the Body-Mind-Spirit System.

HOVA BODIES, SHIELDS & SIGNETS

5 Ariea Hova Bodies, Kathara Grid and Harmonics of Manifestation

Hova Bodies are *tri-tonal scalar grids* that form *spherical energy "tissue capsules"* around each 3-dimensonal level of the multi-dimensional identity. Within 15-Dimensional Human Anatomy, there are **5 Dimensionalized Hova Bodies** called **Ariea Hova Bodies.** The Ariea Hova Bodies form out of the electro-tonal programs held within the **Kathara Centers** of the *Level-1 Kathara 12-Tree Grid.* The *12th Kathara Center* of the Kathara 12-Tree Grid connects to the *12th Kathara Center* of the *Universal Kathara Grid*, just as the *1st Kathara Center* in the personal Kathara connects to the *1st Kathara Center* in the *Planetary Kathara Grid. The 12th and 1st Kathara Centers,the personal Kathara Grid and morphogenetic field connect to the planetary and universal morphogenetic fields.* **When working with the Hova Bodies we first focus upon the lower four , as these must be functioning properly before the 5th Hova Body and its connection to the Universal Kathara Grid can be activated within the Bio-energetic Field.** Four of the 5 Ariea Hova Bodies are directly connected to the Crystal Seals within the human body **Central Body Current** on a **HORIZONTAL PLANE.** These first **4 Hova Bodies** correspond to each of the **12 Kathara Centers** of the personal Kathara 12-Tree Grid. **The Hova Bodies represent Harmonics of Manifestation.**

Hova Bodies, SIGNETS and SHIELDS

Each Hova Body **emanates outward** from a set of **3 Kathara Centers** and their corresponding **Crystal Seals. The *core template of the Hova Body* is a *Triad of Crystalline Spheres* that connect directly to the *3 Kathara Centers* to which they correspond.** This Triad of Crystal Spheres is called a **SIGNET. The Signets are the smaller, *fixed, consolidated* frequency points; out of which the *Seed Crystal Seals* that form the *Chakras* manifest.** The Signets and the smaller Crystal Seal formations that manifest through them, create a **disc** of spinning, **horizontal wave spectra** that direct the function of *Hova Body merger*; these scalar discs are the scalar templates upon which the Hova Bodies manifest, and are called **SHIELDS.**

The *Shields and the Signets* that direct them are considered to be the *core of the Level-2 Crystal Seals Kathara Grid.* Each of the 4 Hova Bodies of the first 12 Dimensions form upon a set of **3 Signets.** Each **Signet *transmits a flash-line*** (Partiki Phasing Sequence) **on a different axis**, one **vertical**, one **horizontal** and one **diagonal**, forming a **3-plane projection of flash-lines** that form the base of the **3-dimensional Holographic projection.**

Kathara Centers and Activating the Signets and Shields

In each set of *3 Signets* at least one corresponds to the *Central Vertical Kathara Line*, the control center of the Level-1 Kathara Grid 12-Tree. The Signets and Shields can therefore be used to direct the function of the Kathara Grid 12-Tree and all built upon it, and the Kathara Centers can be used to trigger activation of the Signets and Shields within the Hova Bodies. When a **Signet is activated** its corresponding **disc or *Shield* begins to spin**. When a certain spin rate of the Shield is reached, it triggers the activation of the next set of Signets in the next Harmonic setting the next Shield to spin. **When *2 Shields activate* and reach a reciprocal spin rate the *tissue capsule* separating the 2 corresponding Hova Bodies releases and the *2 Hova Bodies merge*, which is the process by which *Higher Identity Integration* occurs. It is also the process by which the *Merkaba Vehicle* is activated within the Bio-energetic field.** When all **four Shields** activate and spin, the body matter is able to **transmute** out of matter density and into pure wave form, which represents Maharic/ Avatar Integration for the identity.

THE 5 HOVA BODY SHIELDS

The Hova Bodies and the Shields

Each Hova Body contains at its core a Shield through which the Hova Body functions are governed. The **Nada Hova Body** of dimension 1-2-3 forms on the **TELLURIC SHIELD,** its control center being the 2nd Kathara Center that is composed of 2nd Dimensional Frequencies. The **Alphi Hova Body** of dimensions 4-5-6 forms on the **DORADIC SHIELD**, its control center being the DORA or Archetype of the 5th Dimensional Frequencies. The **Betcha Hova Body** of dimensions 7-8-9 forms on the **TEURIC SHIELD,** its control center being the TEURA or Monad of the 8th Dimensional Frequencies. The **Mahara Hova Body** forms on the **MAHARIC SHIELD**, its control center being the *Mahunta* or Avatar Core of the 11th Dimensional Frequencies. The 5th Hova Body, the **Raja Hova Body**, forms on a set of Signets that correspond to **stellar points** within the **Universal Kathara Grid.** Its Shield, the **RISHIC SHIELD**, rotates on a **vertical plane** and it comes into activation within the personal morphogenetic field only after the four lower Shields have transmuted the body into Pre-matter Liquid Light of the MAHARIC SHIELD. **In terms of healing and advancing evolution of the earthly identity, the first four Shields are of greatest significance.**

Hova Bodies, Shields, Signets and Healing

In all healing application knowledge of the Shields is of great value, for any manifest condition of disorder will have its first manifestations within the Kathara Grid and the Shields that form upon it. The process of healing, therefore, is the process of *restoring the Shields to their proper order* so they may activate to build the Merkaba Vehicle through progressive Higher Identity Integration. **In Kathara Healing we begin with the MAHARIC SHIELD**, the Shield that contains the *pure form of electro-tonal programs upon which the consciousness first entered matter density* through the Pre-matter Liquid Light Fields of the 4th Harmonic - Dimensions 10-11-12. **Through activating and progressively drawing in the highest 11th and 12th-Dimensional frequencies of the Maharic Shield, distortions in all lower Shields can be more rapidly realigned with their original pattern.** When we work with the **Kathara Centers** of the Level-1 12-Tree Grid we simultaneous create change within the **SIGNETS** that direct the function of the **SHIELDS**, and so we are able to more rapidly facilitate appropriate realignment of the Shields and Hova Bodies. **THE CORE OF HEALING IS RESTORING THE HOVA BODIES AND THE SHIELDS UPON WHICH THEY MANIFEST TO THEIR ORIGINAL INTEGRAITY OF ORDER.**

Shields, Signets and Diodic Points

Through the interaction and interplay of multi-harmonic frequency between the **Shields, Signets** and their **Crystal Seals, Kathara Grid Level-3- DIODIC POINTS** come into manifestation, to fill out the 3-plane, 3-dimensional "armature" of scalar waves and flash-lines, upon which more Partiki units will cluster and crystallize to build up the particle base for form manifestation. The **Diodic Points** within the body and morphogenetic field connect directly to the Shields of the Hova Bodies in areas where the *flash-lines and scalar points* within the Crystal Seals of the Shields *align with and pass through each other.* **Flash-Lines from one Hova Body Shield crossing through those in other Hova Body Shields form *COORDINATE POINTS*, or "Gateways" of energy-consciousness *transference* through which frequency and awareness from one Hova Body and identity level can cross through into other Hova Bodies and identity levels.** The *Coordinate Points*, or *regularly scheduled points of flash-line intersection*, form **tiny vortices of energy** , which keep energy and consciousness flowing throughout the multiple dimensional levels of identity and anatomy. **The vortices of energy created by the Coordinate Points of flash-line sequences are called *DIODIC POINTS* and they have a counter reflection within *anti-particle manifestation* called *MIODIC POINTS.*** Diodic and Miodic Points are sets of **White and Black Holes** that circulate energy throughout the anatomy.

LEVEL-3 KATHARA GRID DIODIC POINTS

Diodic and Miodic Points

Diodic/ Miodic Points represent *concentrated areas of energy* that emerge at points where *dimensionalized levels of scalar grids cross over and through each other*, creating minute **vortices** of wave spectra that serve as **frequency modulation zones** (*scalar flash-cycle transition points*) between Dimensional Frequency Bands. Diodic Point vortices are **White Hole** vortices that *transmit energy* into the Particle Universe from their counterpart **Miodic Point** vortices within the Anti-particle Universe. Through the structure of Dimensionalization, each Harmonic Universe, and the structures contained there within, have within their morphogenetic fields *sets of Diodic and Miodic Points* - **sets of White and Black Holes** - that regulate the flux of consciousness-energy between systems.

Within the biological form and morphogenetic field, Diodic Points are located in **physical body regions** where Inter-dimensional and Inter-Harmonic **Horizontal and Vertical Kathara Lines intersect** to form small **vortices** of inter-dimensional or inter-harmonic wave spectra that serve **as Gateways of Consciousness** between Dimensional Time Continua of Harmonic Time cycles. They connect physical bodies to their **anti-particle counterparts** and intersect with the Vertical and Horizontal relationships of wave spectra within the **DNA/ RNA** and bio-energetic field, through sets of White and Black Holes at the center of the biological Harmonic scalar grids.

Diodic Points and 3-Dimensionality

Diodic Points control the **Diagonal Kathara Lines**, the **sequences of Partiki Phasing** or ***"flash-lines"*** that run on a **diagonal** between the Kathara Centers. Whereas the **Kathara Level-1 Kathara Lines** direct the **Vertical flash-line sequences** and the **Level-2 Crystal Seals** control the primary **Horizontal flash-lines** and their relationships to the Vertical flash-lines, the **Diodic Points** further regulate the relationships of flash-line sequences through the Kathara Grid by serving as **"turnstiles of energy"**. The Diodic Points intersect with the crossover points of the Vertical and Horizontal flash-lines , *adding a further level of modulation* to the frequencies passing through, allowing a **3-dimensional Harmonic Projection of flash-lines** (flash-lines projecting on 3 differ angular planes)to build within the morphogenetic field. **The Diodic Points add the third plane of projection to the Kathara Grid, beginning the formation of what will appear as a 3-dimensional "armature" of flash-points upon which particles will accrete to "fill out" the Holographic illusion of 3-dimensionality.**

Diodic Points and Healing

In Kathara Healing Diodic Points are used to open the **Diagonal Kathara Lines** for reprogramming. When Diodic Points become blocked, due to blockages within the Kathara Grid (which appear as "gaps" or missing sequences of flashes along the flash-lines of Partiki Phasing), energy builds up in the *Level-3 Kathara Grid*, forming *distortions* in the natural pattern that will manifest in the body and bio-field systems as *disease or disharmonic condition*. In later applications of Kathara Healing we will learn to identify points of Diodic and Miodic build-up in the body, and use *primary flash-line sequences applied through touch points* to realign the natural flash-point sequences and clear the Diodic Blockages.

Shields, Signets and the Kathara Grid

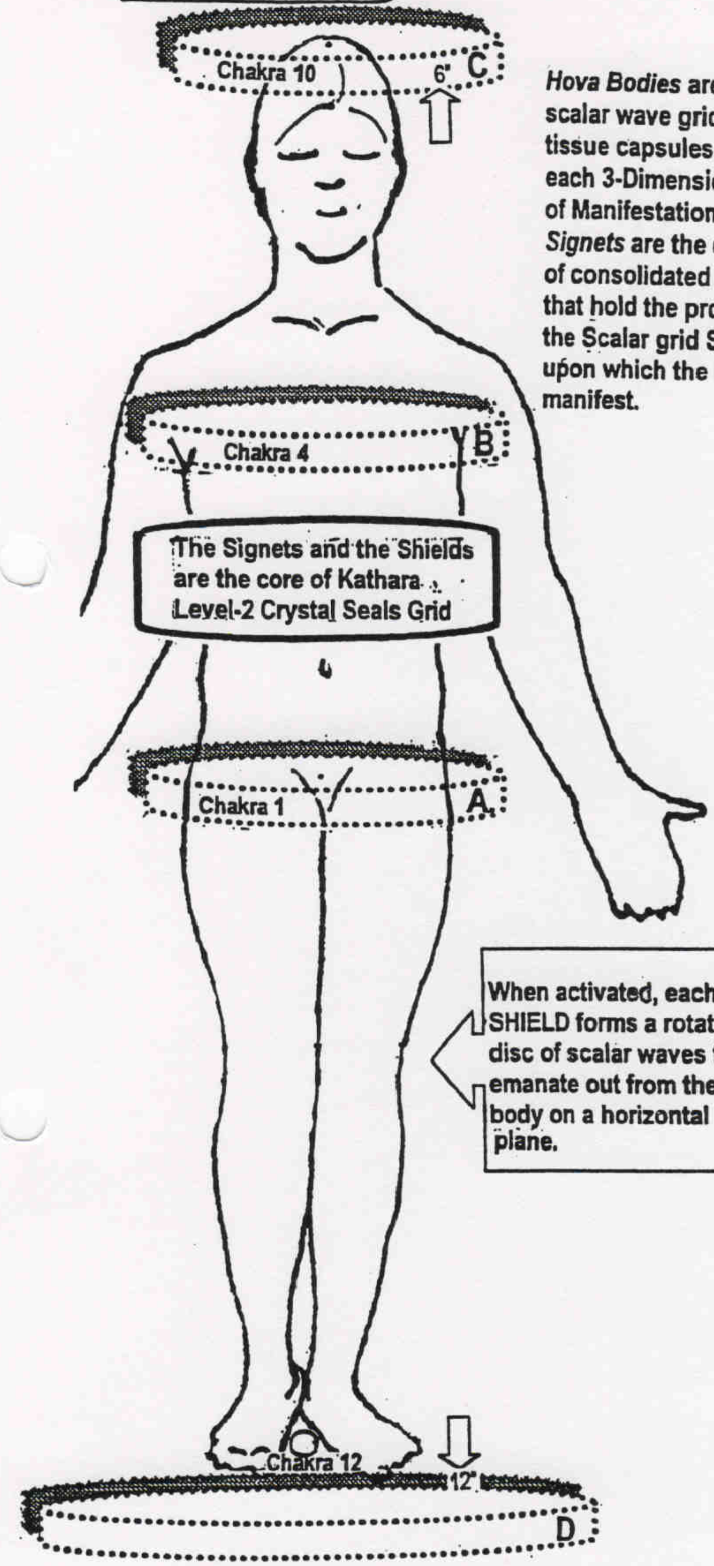
Chakra 10
6"
C
Chakra 4
B
Chakra 1
A
Chakra 12
12"
D

The Signets and the Shields are the core of Kathara Level-2 Crystal Seals Grid

Hova Bodies are spherical scalar wave grids that form tissue capsules between each 3-Dimensional Harmonic of Manifestation.
Signets are the core points of consolidated frequency that hold the programs for the Scalar grid SHIELDS upon which the Hova Bodies manifest.

When activated, each SHIELD forms a rotating disc of scalar waves that emanate out from the body on a horizontal plane.

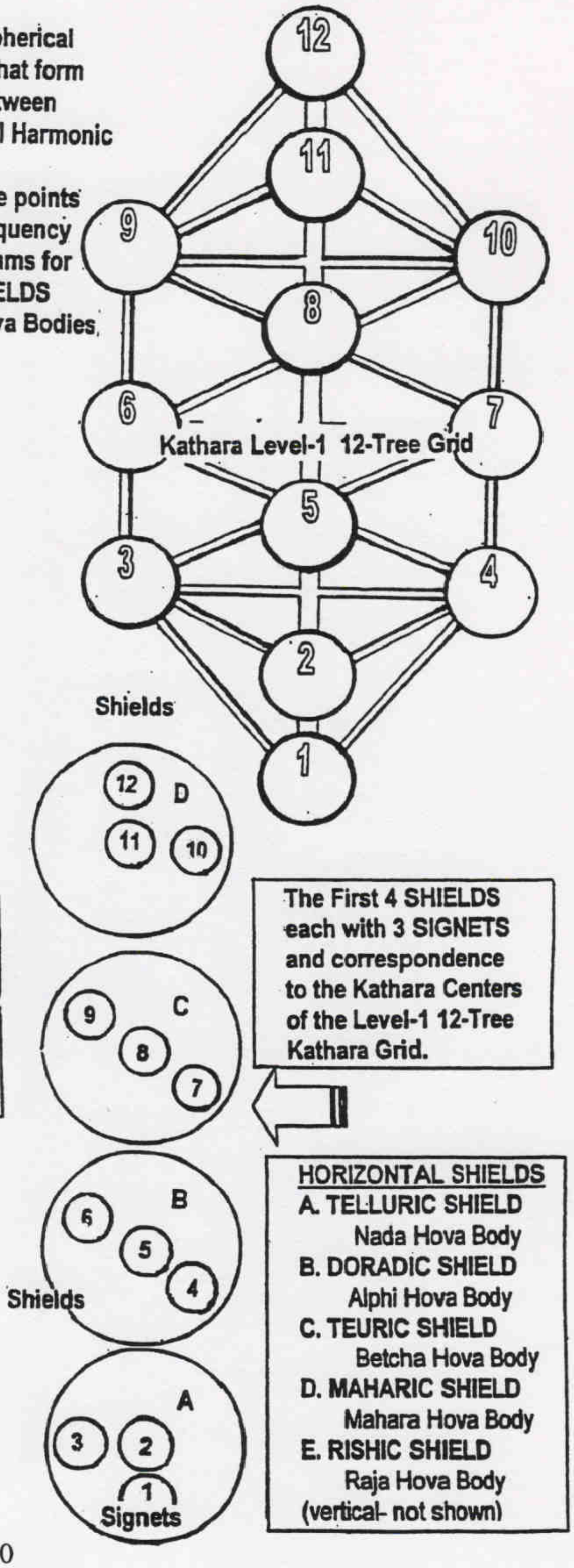
12
11
9
10
8
6
7
Kathara Level-1 12-Tree Grid
5
3
4
2
1
Shields
12
D
11
10
9
C
8
7
6
B
5
4
Shields
A
3
2
1
Signets

The First 4 SHIELDS each with 3 SIGNETS and correspondence to the Kathara Centers of the Level-1 12-Tree Kathara Grid.

HORIZONTAL SHIELDS
A. TELLURIC SHIELD
Nada Hova Body
B. DORADIC SHIELD
Alphi Hova Body
C. TEURIC SHIELD
Betcha Hova Body
D. MAHARIC SHIELD
Mahara Hova Body
E. RISHIC SHIELD
Raja Hova Body
(vertical- not shown)

Level-2 Kathara Crystal Seals Grid and Chakras

Chakras (C & MC)

SIGNET
Star Crystal Seals (S)

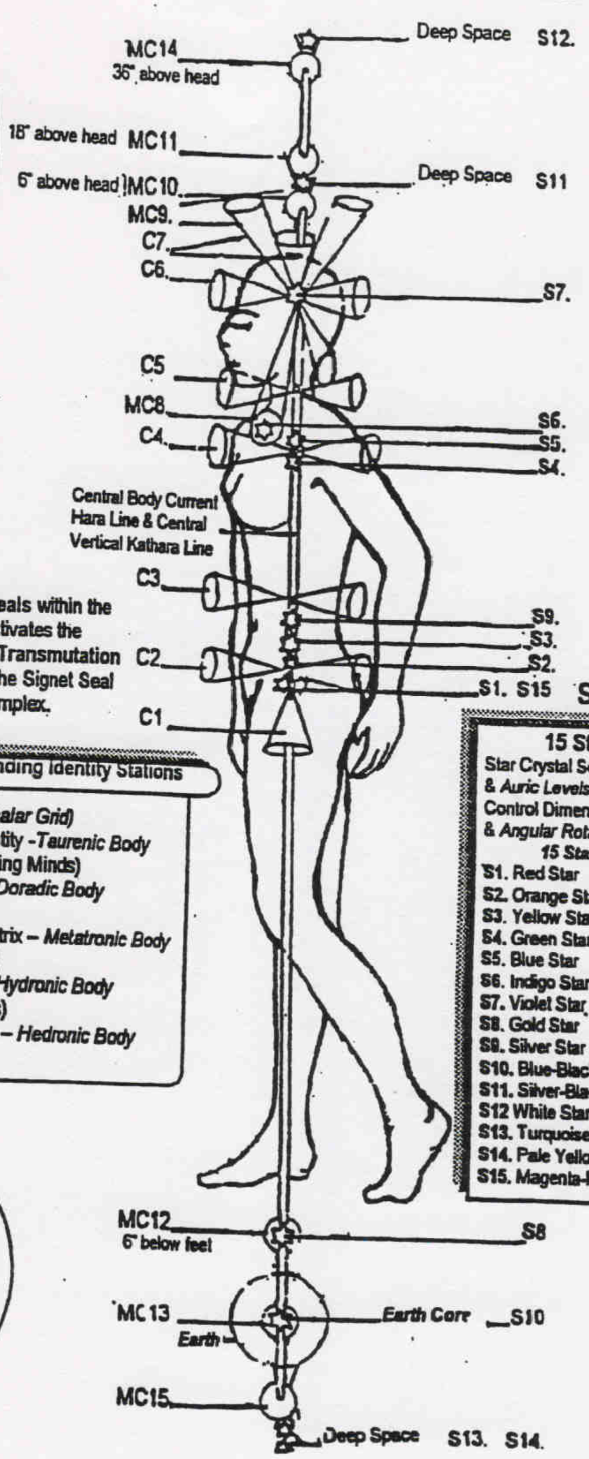
Deep Space S12.
MC14
36" above head
18" above head MC11
6" above head MC10
Deep Space S11
MC9.
C7.
C6.
S7.
C5
MC8
S6.
S5.
C4.
S4.
Central Body Current
Hara Line & Central
Vertical Kathara Line
C3
S9.
S3.
C2
S2.
S1. S15
C1
MC12
6" below feet
S8
MC 13
Earth
Earth Core
S10
MC15
Deep Space S13. S14.

15 Chakras (C & MC)
7 Primary Chakras (C)
C1- Base
C2- Sacral
C3-Solar Plexus
C4- Heart
C5- Throat
C6- 3rd Eye- Pituitary
C7- Crown-Pineal
8 Morphogenetic Chakras (MC)
MC8-Thymus
MC9-Thalamus
MC10- Galactic 1
MC11-Galactic 2
MC12- Earth Star
MC13-Earth Core
MC14-Universal 1
MC15-Universal 2

The 5 Hova Bodies progressively merge with release of the embodied Signet Star Crystal Seals, forming the various phases of the personal Merkaba Vehicle within the bio-energetic field.

Release of the SIGNET Star Crystal Seals within the embodied Internal Templar Complex activates the 12-Strand DNA Template for Cellular Transmutation and Dimensional Ascension through the Signet Seal Star Gates of the Universal Templar Complex.

Signet Seals

15 Star Crystal Seals
Star Crystal Seals keep human identity & *Auric Levels* dimensionally separate. Control Dimensional *Merkaba Field Axis* & *Angular Rotation of Particle Spin.*
15 Star Crystal Seals (S):
S1. Red Star
S2. Orange Star
S3. Yellow Star
S4. Green Star
S5. Blue Star
S6. Indigo Star (Blue-Violet)
S7. Violet Star
S8. Gold Star
S9. Silver Star
S10. Blue-Black Star
S11. Silver-Black Star
S12 White Star
S13. Turquoise Star
S14. Pale Yellow Star
S15. Magenta-Pink Star

Hova Bodies and Corresponding Identity Stations

("Hova" means *Tri-tonal Scalar Grid*)
1. Nada Hova – HU-1 Incarnate Identity -*Taurenic Body* (Subconscious, Instinctual & Reasoning Minds)
2. Alphi Hova – HU-2 Soul Matrix – *Doradic Body* (Astral, Archetype & Angelic Minds)
3. Betcha Hova –HU-3 OverSoul Matrix – *Metatronic Body* (Ketheric, Monadic & Kertatric Minds)
4. Mahara Hova – HU-4 Avatar ID – *Hydronic Body* (Christiac, Buddhaic & Nirvanic Minds)
5. Raja Hova – HU-5 Rishi Collective – *Hedronic Body* (Universal Conscious Mind)

5 Hova Bodies

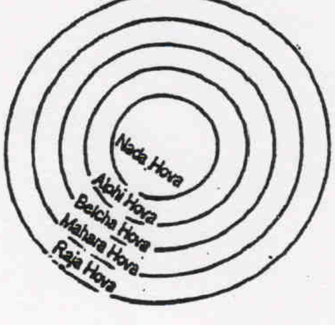
Nada Hova
Alphi Hova
Belcha Hova
Mahara Hova
Raja Hova

AXIOM LINES, AURIC LEVELS AND CHAKRAS

Diodic Points, Signets, Seed Seals and AXIOM LINES

Each **Signet** within a Hova Body Shield holds the electro-tonal program for one *Seed Crystal Seal* and one *dimensionalized flash-line sequence*. Each Seed Seal program corresponds to one *dimensionalized flash-line program* from one *Level-1 Kathara Center*. Each **Seed Crystal Seal** holds intact the electro-tonal program for one ***dimensionalized flash-line projection angle***, or **Single Axis Dimensional flash-line sequence.** The Single Axis Dimensional flash-line sequences controlled by each Seed Crystal Seal are called **AXIOM LINES.**

There are **12 Primary Axiom Lines** that correspond to the 12 Kathara Centers in the *Personal and Planetary Kathara Grids*. There are 12 additional **Stellar Axiom Lines** that correspond to the 12 Kathara Centers in the Universal Kathara Grid. **The Axiom Lines represent single-axis flash-line sequences -** (fixed points of conscious electrified sound- *electro-tonal units*- that form strands of scalar standing waves) **that intermesh to refine the scalar-grid webbing upon which Kathara Grid Level-3 Diodic Points will emerge.**

Axiom A-B Tonal Lines, Diodic-Miodic Vortices, Chakras-DNA-Portals-Ley Lines & Healing

Each of the 12 Primary Axiom Lines has a **reverse reflection** within the dimensions of the **anti-particle universe.** The 12 Primary Axiom Lines governing the **Diodic "White Hole" Vortices of the particle universe** are called **Axi-A-Tonal Lines** (or "Axiatonal" Lines). The corresponding reflections of the Axi-A-Tonal Lines in the **anti-particle universe,** which govern the **Miodic "Black Hole" Vortex** reflections of the Diodic Points, are called **Axi-B-Tonal Lines.** In Kathara Healing the integrity of the Axi-A-Tonal Lines is restored through realigning the electro-tonal programs within the corresponding **Kathara Centers.** The **12 Primary Axi-A-Tonal Lines** set the morphogenetic imprint upon which the **Chakra System** and foundation **DNA** organization of the human body will manifest and upon which the **Planetary Vortex/Portal System** and primary **Planetary Ley Lines** will emerge within the planetary body. Restoring the *Imprint for Health* to the **Axi-A-Tonal Lines** and corresponding **Kathara Centers** will regenerate integrity within the **DNA** and **Chakra System** of the body and will restore the organic operations of the planetary **Vortices-Portals** and **Ley Lines** of the planetary morphogenetic grid.

Restoring the **Imprint for Health** within the **Axi-A-Tonal Lines** simultaneously restores integrity to the corresponding **Diodic Points** and to the **Axi-B-Tonal Lines** and their **Miodic Points.** When working with *Kathara Techniques* that "clear the **Miasmic Imprint**" – *the anti-particle blockages within Diodic Points* – the *Diodic Points* are realigned by clearing their *Miasmic distortions*, which then reestablishes the integrity of corresponding **Axiom A and B Tonal Lines**, sending a realigned electro-tonal program back through the **Seed Seals** and the Level-1 **Kathara Centers.** If the programs within the **Kathara Centers** are **simultaneously realigned** using infusion of the frequencies from the **Maharic Shield**, the Kathara Center programs, the Axiom Lines and the Diodic Points will be progressively restored to health. If the Kathara Centers are not simultaneously realigned, the restored Axiom Line programs will be **overridden** by the Kathara Center programs until the restored programs reach *critical mass* through *prolonged repetition*. ***Clearing the Miasmic Imprint* while simultaneously *Repatterning the Level-1 Kathara Centers and Kathara Lines* via *Maharic Infusion* is the fastest way to restore the *Imprint for Health* within the Human Body-Mind-Spirit System and within the natural operations of planetary bio-mechanics.**

Axiom Lines, Diodic Points, Hova Bodies, Shields and Auric Field Levels

The Single Axis flash-line sequences of the **12 Primary Axiom Lines** cross over and through each other to form COORDINATE POINTS between the Hova Body Shields, through which the "White Hole" ***Level-3 Diodic Point Vortices*** emerge. **The varying angles of flash-line projection within the Axiom Lines create separate dimensionalized bands of frequency** (separate sets of flash-line sequences) **within the Hova Body structure.** As there are **3 Signets** and thus **3 Seed Seals** and **3 Axiom Lines** inherent to each **Hova Body Shield**, each Hova Body becomes *dimensionally compartmentalized* into **3** separate yet interrelated sections, each section having inherent sets of Diodic Points. **Each dimensionalized aspect of the Hova Bodies becomes a *Level of the Auric Field* within the bio-energetic system.** There are **12 Inner Layers of the Auric Field**, which correspond to Dimensions **1-12** and to the 12 Primary Kathara Centers, Seed Seals and Axiom Lines of the *first 4 Hova Bodies*. There are **3 Outer Layers of the Auric Field** that correspond to Dimensions and Seed Seals **13-15**, to the *first 3* Kathara Centers and Axiom Lines of the **Universal Kathara Grid** and to the *5th Hova Body*.

Seed Seals, Axiom Lines, Consolidated Diodic Points, Chakras and Auric Levels

The points in the Kathara Grid where the Single Axis Axiom Lines cross over and through the Central Vertical Kathara Line in the Level-1 Grid and the Horizontal flash-lines of the Seed Crystal Seals form fixed, **consolidated Diodic Points –larger vortices** of energy composed of many smaller Diodic Vortices. **The larger vortex points are called CHAKRAS**. Each Chakra Vortex is formed upon the electro-tonal program of its corresponding Dimensional Frequency Band, Kathara Center, Seed Seal and Axiom Line, and **each chakra corresponds to one Auric Field Level, DNA strand imprint and level of consciousness.** As *3 Signets, Seed Seals* and *Axiom Lines* correspond to each *Hova Body Shield*, **3 Chakras regulate and correspond to each of 5 Hova Bodies**, for a total of **15 Primary Chakras. Primary Chakras 1-12** correspond to Kathara Centers 1-12 in the **Personal and Planetary Kathara Grids** and **Primary Chakras 13-15** correspond to the *first 3 Kathara Centers and Axiom Lines* of the **Universal Kathara Grid.** Chakras 13-15 are considered **Universal Trans-stellar Chakras.**

The *Chakras* regulate the *transduction of flash-line sequences* from the *Dimensionalized Unified Field* and *Diodic Vortices* of the Axiom Lines and Auric Field Levels into the *Hova Body tissue capsules* and *rivulet channels* that connect to the physical, electro-magnetic, chemical and hormonal aspects of the visibly manifest form. Chakras regulate the flow of consciousness-energy between the dimensionalized Auric Field levels of the Hova Bodies, keeping the various multi-dimensional stations of consciousness separate, in order to allow for experiential perception of holographic manifestation. Each **Chakra circulates** its Single Axis flash-line sequence along the **angle of projection** carried within its corresponding **Axiom Line**, and this *angle of flash-line projection* determines the **Angular Rotation of Particle Spin (ARPS)** – or the *axis upon which particles rotate-* within each dimensionalized portion of the anatomy. There is a **90-degree shift** in the *flash-line angle of projection* from one Chakra and dimensional band to the next, which creates a 90-degree shift in the **Angular Rotation of Particle Spin** between each dimensionalized portion of the anatomy. Between each 3-dimensional Hova Body there is also a **45-degree reverse shift** in flash-line projection angle, which creates a **45-degree** rather than a 90-degree **forward shift** of flash-line projection angle between each Hova Body and between each **set of 3 Chakras** (Chakras 1-2-3 * 4-5-6 * 7-8-9 * 10-11-12 * 13-14-15). The precise angles of flash-line projection and ARPS between Chakras, creates the perceivable 3-dimensional hologram.

Chakras

A Chakra appears within the bio-energetic field as **2 cones or spirals of multi-colored energy** that are **linked together at the tip** in the **Central Body Current** through the **Seed Crystal Seal** out of which the cones emerged. **Chakras 2-6** extend from the Seed Seals outward through the body and Auric Field on a **Horizontal axis** and **Chakras 8 and 9** intersect with *6 and 7* at the *Pineal Gland* on **2 rotating Diagonal axes** running through the head. **Chakras 1 and 7 and 10-14** are stacked above and below the body on a **Vertical Axis** aligned with the *Central Body Current* (CBC) and the *Central Vertical Kathara Line*. Chakras 1&7, 10&12, 11&13 and 14&15 are actually the bottom and top cones of **4 Large Vertical Chakra Spirals**, but are counted as separate chakras. **Chakra 15** is a **"roving chakra"**, which travels the course of the **12 Primary Axiom Lines** far out in Level–15 of the Auric Field. Each Chakra draws in energy from and transmits energy into the dimensional Unified Field corresponding to the *chakra number* and carries as its **dominant perceivable color the hue** characteristic to the **primary frequency band wave-length** of its **dimensional affiliation.**

Primary Color of Chakras

Chakra	Dimension	Color	Chakra	Dimension	Color
CK-1	D-1	RED	**CK-8**	D-8	GOLD
CK-2	D-2	ORANGE	**CK-9**	D-9	SILVER
CK-3	D-3	YELLOW	**CK-10**	D-10	BLUE-BLACK
CK-4	D-4	GREEN	**CK-11**	D-11	SILVER-BLACK
CK-5	D-5	BLUE	**CK-12**	D-12	WHITE
CK-6	D-6	BLUE-VIOLET (INDIGO)	**CK-13**	D-13	PALE TURQUOISE
CK-7	D-7	VIOLET	**CK-14**	D-14	PALE YELLOW
			CK-15	D-15	MAGENTA-PINK

A Chakra will also carry, in lesser saturation, the colors/frequency bands associated with all of the dimensions below its own dimensional affiliation.

Chakras and Dimensional Merkaba Fields

When the Seed Seal at the core of a Chakra is released, the **2 cones of the Chakra move through each other** to form a **Dimensional Merkaba Field**- *2 counter-rotating spirals of electro-magnetic energy that take the form of a* ***Star-tetrahedron****.* When the Seed Crystal Seal releases, the corresponding scalar-wave points within the Hova Body Shield are ***released from Dimensional Phase-lock*** – they are released from *polarity* by the re-combining of their inherent *Particum-Particles* and *Partika-anti-particles*. Through re-combining Particum and Partika the scalar standing-wave points undergo **fusion**, then a reciprocal **fission** and **replication** within the Harmonic above. Through release of the Seed Seals the *Dimensionalized Auric Field Levels* of the *lower Hova Body* align along the same *Angular Rotation of Particle Spin* / angle of flash-line projection, which transmutes them into the *angle of flash-line projection* and *Partiki Phasing rate* of the Dimensionalized Auric Field Levels of the Hova Body from the *Harmonic above*. **Seed Crystal Seals are released by infusing them with the frequencies/ flash-line sequences of the corresponding dimension from the Harmonic above.** Progressive release of the Seed Seals within the Chakras creates opening and merging of the Kathara Lines in the Level-1 12-Tree Grid, and merging of the *Hova Bodies, Shields, Diodic Points, Auric and Identity Levels* and *DNA strands, through which activation of the* ***Merkaba Vehicle*** *and de-densification of matter occurs.*

Auric Level, Chakra and Hova Body Correspondences

Each 3-Dimensional Scalar Shield forms a Spherical Electromagnetic Domain called a Hova Body.

Each Hova Body manifests the structure, and governs the function, of 3 Primary Chakras.

Chakras draw energy in from, and transmit energy into, the **Unified Fields** of each Dimension. Each Chakra carries as its **Primary Color** the hue associated with the **wave-length** of the dimensional frequency band to which the Chakra corresponds.

Each Chakra corresponds to a level of the *Auric Field* and one *Axi-A-Tonal Line*. Each ***Hova Body*** corresponds to a set of 3 Chakras and contains 3 dimensionalized frequency bands that form the dimensional levels of **Auric Field.**

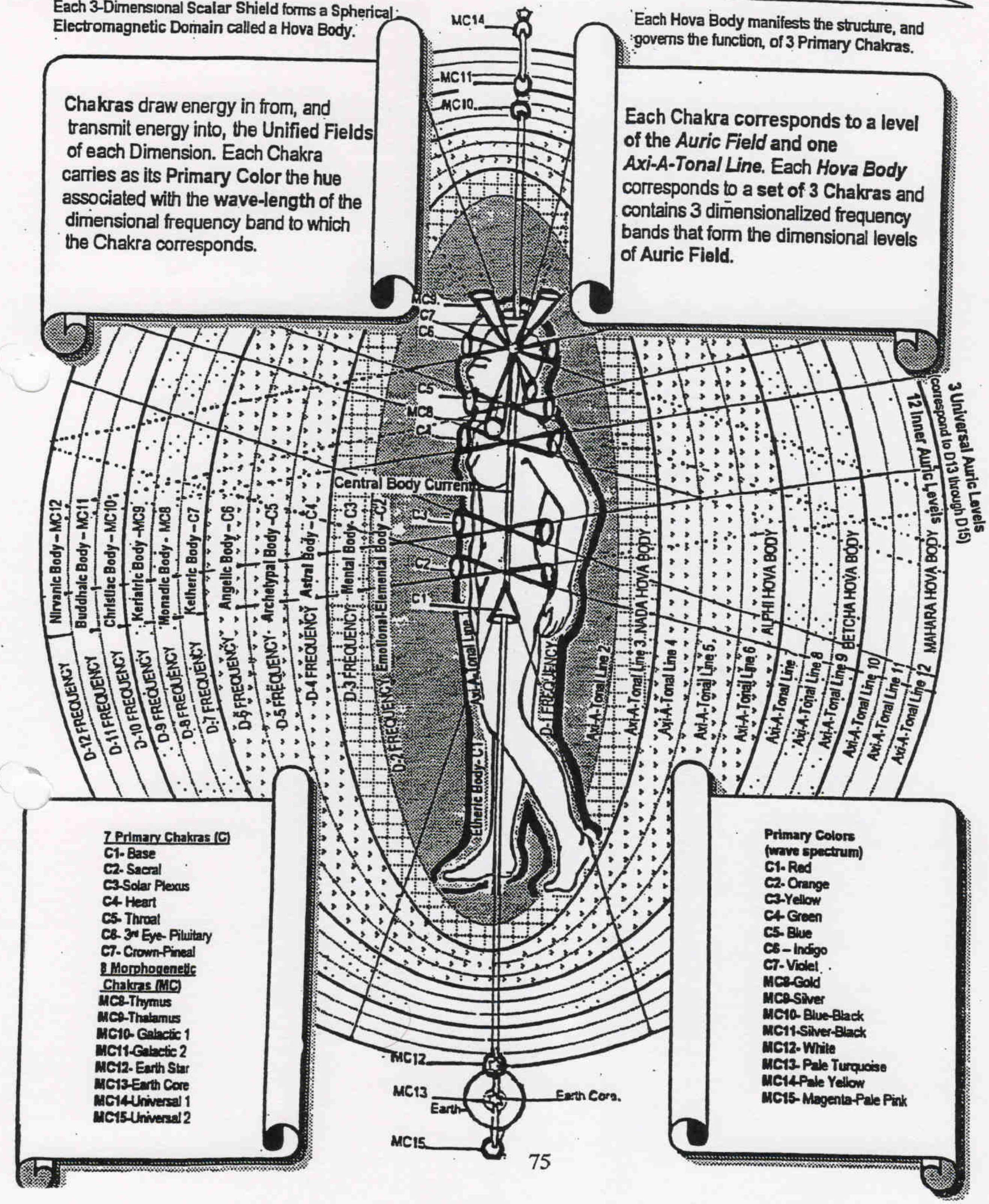
MC14
MC11
MC10
MC9
C7
C6
C5
MC8
C4
C3
C2
C1
Central Body Current
Nirvanic Body – MC12
Buddhaic Body – MC11
Christiac Body – MC10
Keriatric Body – MC9
Monadic Body - MC8
Ketheric Body – C7
Angelic Body – C6
Archetypal Body – C5
Astral Body – C4
Mental Body- C3
Emotional-Elemental Body – C2
Etheric Body- C1
D-12 FREQUENCY
D-11 FREQUENCY
D-10 FREQUENCY
D-9 FREQUENCY
D-8 FREQUENCY
D-7 FREQUENCY
D-6 FREQUENCY
D-5 FREQUENCY
D-4 FREQUENCY
D-3 FREQUENCY
D-2 FREQUENCY
D-1 FREQUENCY
Axi-A-Tonal Line
Axi-A-Tonal Line 2
Axi-A-Tonal Line 3
Axi-A-Tonal Line 4
Axi-A-Tonal Line 5
Axi-A-Tonal Line 6
Axi-A-Tonal Line
Axi-A-Tonal Line 8
Axi-A-Tonal Line 9
Axi-A-Tonal Line 10
Axi-A-Tonal Line 11
Axi-A-Tonal Line 12
NADA HOVA BODY
ALPHI HOVA BODY
BETCHA HOVA BODY
MAHARA HOVA BODY
12 Inner Auric Levels
3 Universal Auric Levels (correspond to D13 through D15)
MC12
MC13
Earth
Earth Core.
MC15

7 Primary Chakras (C)
C1- Base
C2- Sacral
C3-Solar Plexus
C4- Heart
C5- Throat
C6- 3rd Eye- Pituitary
C7- Crown-Pineal
8 Morphogenetic Chakras (MC)
MC8-Thymus
MC9-Thalamus
MC10- Galactic 1
MC11-Galactic 2
MC12- Earth Star
MC13-Earth Core
MC14-Universal 1
MC15-Universal 2

Primary Colors (wave spectrum)
C1- Red
C2- Orange
C3-Yellow
C4- Green
C5- Blue
C6 – Indigo
C7- Violet
MC8-Gold
MC9-Silver
MC10- Blue-Black
MC11-Silver-Black
MC12- White
MC13- Pale Turquoise
MC14-Pale Yellow
MC15- Magenta-Pale Pink

PRIMARY COLOR OF CHAKRAS

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CK-3	D-3	YELLOW	CK-10	D-10	BLUE-BLACK
CK-4	D-4	GREEN	CK-11	D-11	SILVER-BLACK
CK-5	D-5	BLUE	CK-12	D-12	WHITE
CK-6	D-6	BLUE-VIOLET (INDIGO)	CK-13	D-13	PALE TURQUOISE
CK-7	D-7	VIOLET	CK-14	D-14	PALE YELLOW
			CK-15	D-15	MAGENTA-PINK

A Chakra will also carry, in lesser saturation, the colors/frequency bands associated with all of the dimensions below its own dimensional affiliation.

AXI-A-TONAL LINES, THE HARA LEVEL, 6 HARA POINTS AND COMPLEXES

Axiom Lines, Rotating Flash-line Projection and the Human Body

Each Seed Crystal Seal within the Signets of the Hova Body Shields holds the electro-tonal program for a Single Axis Axiom Line flash-line projection. **The flash-line sequences of each Axiom Line are not simply *stationary* single-line projections of flash-lines, but rather operate as *rotating* single-line projections.** Each rotating Single Axis flash-line projection is ***synchronized*** with the other rotating Single Axis flash-line projections of Axiom Lines from the other Seed Crystal Seals. Through the ***rotational synchronization*** of the Axiom flash-line sequences, the flash-lines of each Axiom Line regularly cross through each other, and through the vertical and horizontal flash-line sequences from the Level-1 and Level-2 Kathara Grid. The points of *synchronized flash-line crossover* form ***consistent points of intersection*** through which the **Level-3 Diodic Vortices** and **Chakras** manifest. Within the human body and Auric Field the **consistent points of flash-line crossover** can be charted in the form of **fixed lines of energy** that run through the body. **The charted Axiom Lines within the human body represent series of regularly scheduled flash-line intersection points, created through the synchronized rotation of the Single Axis Axiom flash-line sequences.**

Axiom A Lines – "Axi-A-Tonal" Lines in the Human Body

The consistent points of Axiom Line flash-line crossover that form fixed lines of energy within the body can be charted as **Axiom A and B Line** energy flows within the body. The Axiom A Lines correspond to the body manifestation in the particle universe, the B Lines to the body double in the anti-particle universe. **For Kathara Healing applications the A Lines – Axi-A-tonal Lines- of the particle body are used for various purposes of facilitating Kathara Center realignment and revitalization of the Body-Mind-Spirit System.** Within the body the Axi-A-Tonal Lines can be charted as **Primary Flow Lines** – conduits through which energy-consciousness, in the form of scalar-point flash-line sequences, circulates through the morphogenetic field. The fixed flash-line crossover points that form the **charted Axi-A-Tonal Lines** appear in the body as a set of **12 Vertical Flow Lines**, one running from each of 12 Auric Field Levels, which run through the body within the **Level-2 Crystal Seals Kathara Grid**. Each Axi-A-Tonal Line corresponds to one of 12 Dimensional Frequency Bands, Kathara Centers, Seed Crystal Seals, Chakras and DNA strand imprints. **The 12 Primary Axi-A-Tonal Lines appear to enter and leave the body through the head and feet, with conduits running through the arms, hands and out the finger-tips, and through the legs, feet and out the tips of the toes. Each Axi-A-Tonal Line appears as a colored cord of energy, its hue determined by the wave length characteristic to its corresponding dimensional frequency band.** In charting the positions of the 12 Primary Axi-A-Tonal Lines in the body, **numbering** and **color** are used to denote the *Dimensional correspondences* of each Axi-A-Tonal Line.

Axi-A-Tonal Lines 11 & 12 and the "Hara Line"

Axi-A-Tonal Lines 11 and 12, which correspond to the 11th and 12th Dimensions, Kathara Centers, Seed Seals and Chakras, run vertically through the center of the body along the Kathara Grid Level-1 **Central Vertical Kathara Line**, forming a ***twisted "rope"*** of Dark Silver (D-11) and White (D-12) energy that wraps around the Central Vertical Kathara Line Flash-line Sequence. The **Central Vertical Kathara Line,** which appears as a **thin Silver-gold flash-line of energy** running from the 14th Chakra (36"above the head) through the body and into the 13th Chakra at Earth's Core, is imbued with frequencies from the **12th, 11th and 8th Dimensions** – the frequencies of White, Dark Silver and Gold.

In *Level-2 Kathara Grid*, the rotating single axis flash-lines of *Axi-A-Tonal Lines 11* and *12* spiral around the thin Silver-Gold flash-line of the *Central Vertical Kathara Line,* merging into a thin, vertical tri-tonal flash-line of primarily *Gold* hue that becomes the core of the *Central Body Current.* In ancient Eastern Healing Systems this **thin Gold Vertical Line** is called the **"Hara Line"**, and is often considered the foundation of the manifest form. In truth, the **Level-1 Kathara 12-Tree Grid** and the *Signets, Crystal Seals* and *Shields* of **Kathara Level-2** are the deeper foundations upon which the Hara Line manifests.

The *Hara Level* of Kathara Level-2 Crystal Seals Grid

The mechanics of the Crystal Seals in the Level-2 Kathara Grid are complex, but can be employed with relative ease through working with the energetic dynamics of the ***outer levels* of the Level-2 Kathara Grid**, the level in which the *Hara Line* can be viewed using *9th-dimensional Higher Sensory Perception.* We refer to this level of the Level-2 Crystal Seals Grid as the **HARA LEVEL.** The Hara Level is composed of the Hara Line, and 6 of the 15 Star Crystal Seals of the Kathara Level-2 Crystal Seals Grid.

The *6 Hara Points* (Crystal Seals) apparent from the Hara Level are as follows:

1. The 9th *Silver* Core Star Crystal Seal, called the **HARA CENTER**
2. The 6th *Indigo (or Blue-Voilet)* Star Crystal Seal, called the **SOUL STAR**
3. The 12th *White* Star Crystal Seal, called the **GALACTIC STAR**
4. The 3rd *Yellow* Star Crystal Seal, called the **SUN STAR**
5. The 8th *Gold* Star Crystal Seal, called the **EARTH STAR**
6. The 10th *Blue-Black* Star Crystal Seal, called the **EARTH CORE SEAL**

The **6 Hara Points** govern and regulate the function of **Complexes** of *energy synthesization and distribution* that control the operations of all primary body systems and bio-energetic field dynamics. In *Kathara Healing Level-2* we will explore mechanics of the Hara Level. In Level-1 Kathara Healing we will simply become familiar with Hara Level as an element of 15-dimensional human anatomy.

THE HARA AND THE KUNDALINI

The Silvery-gold energies of the **Hara Center** (9th Star Crystal Seal) are interwoven at the **base of the spine** with what is referred to as the **KUNDALINI life-force energies.** The Kundalini energies represent the **PRIMARY ENERGY CURRENTS** through which the incarnating consciousness anchors its morphogenetic field within the **Fetal Body** through the **FIRST 8 CELLS** of conception. **The Hara Center energies interweave at the base of the spine with the frequencies of the first Star Crystal Seal, the *RED Star Seal*,** in the First Cell. When the Hara Center Seal is dormant and activated only to *the 3-Dimensional Level* its Pale Silvery-gold frequencies appear to be encased within a **crimson RED sheathe** of 1st-Dimenional energy, often **making the Hara Center and Hara Line appear to be RED in color.** As the Hara Center comes into activation through progressive release of the 9th Star Crystal Seal, the Gold 8th-Dimensional and Silver 9th Dimensional frequencies of the Hara become the dominant hues, giving the Hara Center and Hara Line its natural **Silvery-gold color.** With full activation of the Hara Center and **12th-Dimensional Maharic Integration,** the tri-tone frequencies of the Hara Center and Hara Line take on a **tri-color spectrum of Pale Silver, Gold and Red-Violet** (pale Magenta), as the Kundalini primary life force currents at the base of the spine activate within the Central Vertical Current of the body. Full activation of the Kundalini merges the 7th-Dimensional **Violet,** 1st-Dimensional **Red,** 8th-Dimenional **Gold** and 9th Dimensional **Silver** frequencies with the full spectrum **White-Silver** energies of the 12th Dimensional Maharic Current.

The Hara Center, like all Star Crystal Seals, is one of the primary regulatory elements of the natural Kundalini energies. As the Kundalini energies at the base of the spine are brought out of higher dimensional dormancy, through progressive activation of the Star Crystal Seals in the Kathara Level-2 Crystal Seals grid, the Hara Center progressively reflects these changes by expanding in size and energy processing capacities and taking on the hues (wave spectra) of the higher dimensional frequencies. The **Kundalini energies** at the base of the spine are the **key to physical cellular transmutation** of the body. Kundalini energy currents **regulate the physical body's position in space-time,** keeping the physical body phase-locked into the planetary Time Cycle in which it was conceived, following the mathematical programs set by the Star Crystal Seals and the Kathara Grid. For physical transmutation to occur, the Kundalini energies of the higher dimensions must be brought into embodied activation, setting the processes of the **Internal Templar Complex** in motion.

The **DNA Template** manifests upon the programs set by the **Kathara Grid.** As the Kathara Centers and their corresponding Star Crystal Seals, Shields, Kundalini currents, Cranial-Sacral (Pineal-Tailbone) Seals, Seed Crystal Seals and Chakras activate, dormant DNA Strand Template also activate, progressively altering the **Angular Rotation of Particle Spin,** energy-processing capacities, **metabolic orientation** and **neurological processes** of the body and molecular structure. As these physical changes occur through activation of the Crystal Seals and Kundalini energies, the **Merkaba Vehicle** (interdimensional counter-rotating electro-magnetic fields in star-tetrahedral form) progressively builds within the bio-energetic field, allowing the physical body **release from phase lock** within its home space-time vector. **Activation of the Hara Center represents one of the stages of this natural transmutational process.**

THE HARA CENTER

The 9th Core Star Crystal Seal, the Hara Center (Tan Tein) and the D-9 Thalamus Complex

The **Star and Seed Crystal Seals** of the Level-2 Kathara Grid that hold consciousness into the dimensional phase-lock set by the Level-1 Kathara Centers accrete along the Central Vertical Kathara Line and the Central Body Current. **From the *Hara Level* – the *outer portions of the Level-2 Kathara Grid* -** the *12th, 9th and 6th Star Crystal Seals,* **appear as *areas of condensed light* positioned along the *vertical Hara Line*.**

The **9th Star Crystal Seal**, located about 2 " below the Navel is known as the ***Core Star Crystal Seal*** – the point of **8th and 9th dimensional frequency** of the Harmonic-3 Over-Soul Matrix (***Teuric Shield***) that **anchor the personal morphogenetic field into that of the Earth** and serve as the **center of gravity** for the adult human body. **The *Core Star Seal* appears from the Hara Level as a 2" ball of Gold (D-8) energy encased in a thin Silvery (D-9) membrane; in Eastern theory this ball of energy is called the *Tan Tein*, and is used for direction of bodily and Earth energies in advanced martial arts and healing practices.** In Kathara theory we simply refer to this energy ball as the ***Hara Center***, or the 9th **Core Star Crystal Seal.**

The ***Hara Center*** is the point at which the dimensionalizing identity enters the **Etheric Matter densities** of Harmonic Universe-3. The Hara Center represents the point into which the **Over-Soul Identity,** its **Monadic Core, the Betcha Hova Body** and **Kathara Centers 7, 8 and 9** first anchor within the body. The Hara Center holds the morphogenetic imprint for **DNA strands 7, 8 and 9,** corresponds to **Chakra Centers** and **Axi-A-Tonal Lines 7,8 and 9** and is a key point for repatterning the electro-tonal programs of the **Teuric Shield** and realigning and activating corresponding DNA strands, Chakras, Axi-A-Tonal Lines and body regions they govern.

The Hara Center is associated with the ***Thalamus Complex***, the chemical translation and regulatory system that governs the **9th-Dimensional interface** between various **brain-function areas** and the glandular and metabolic operations of the **Thymus Complex, Gonads, Lymphatic System** and corresponding body systems. Through the ***9th-Dimensional Thalamus Complex*** the electrical impulse, chemical and hormonal relationships between the ***10th-Dimensional Shara Complex*** and the ***8th-Dimensional Thymus Complex*** and its related body systems are governed.

The Hara Center and the Thalamus Complex link the functions of the **Mahara** and **Betcha Hova Bodies,** the **Maharic** and **Teuric Shields** and the **Avatar** and **Over-Soul** levels of consciousness and identity within the body and bio-energetic field.

The primary area of dominion of the *D-9 Thalamus Complex* is *Brain Function*.

THE SOUL STAR

The 6th Soul Star Seal and the D-8 Thymus Complex

Also visible along the Hara Line of Kathara Grid Level-2 is the **6th Star Crystal Seal**, located around the **Thymus** at the top of the breast bone and associated with the **5th and 6th dimensional frequencies** of the Harmonic-2 Soul Matrix (*Doradic Shield*). The **6th Star Seal**, visible as a **pale Blue-Violet-white point of diffused light** along the Hara Line, is called the ***Soul Star Seal.***

The *Soul Star Seal* is the point at which the dimensionalizing identity enters the **Semi-Etheric Matter densities** of Harmonic Universe-2. The Soul Star represents the point into which the **Soul Identity**, its **Archetype Core**, the **Alphi Hova Body** and **Kathara Centers 4, 5 and 6** first anchor within the body. The Soul Star holds the morphogenetic imprint for **DNA strands 4, 5 and 6,** corresponds to **Chakra Centers** and **Axi-A-tonal Lines 4, 5 and 6** and is a key point for repatterning the electro-tonal programs of the **Doradic Shield,** and realigning and activating corresponding DNA strands, Chakras, Axi-A-Tonal Lines and body regions they govern.

The Soul Star is associated with the **Thymus Complex**, the chemical translation and regulatory system that governs the **8th-Dimensional interface** between the **Pineal, Pituitary,** and **Thyroid Glands,** which govern the chemical and metabolic operations of the **hormones, Adrenal Glands, Endocrine System, Spleen,** and *crystalline* formation of the **Red Blood Cells** and **Hemoglobin.**

The *Thymus Complex* and its related glandular and metabolic systems, govern the *cyclic rhythms* by which the **DNA strands** will activate through the **Pineal Gland**, the rate of *growth and degeneration* of body tissue through the **Thyroid Gland** and through the **Pituitary Gland** and its inter-glandular processes, the functions of *electro-tonal impulse conversation, translation and distribution* through the **brain, Central Nervous System** and **blood** are regulated.

The *Thymus Complex* controls the **inter-glandular systems balances** between the **Pineal, Thyroid and Pituitary Glands** and regulates the *primary operations* of electrical impulse and chemical translation and transfer throughout the brain and body systems via the **Thymus Gland.** The *8th-Dimensional Thymus Complex* is governed by the functions of the *9th-Dimensional Thalamus Complex* and the *10th-Dimensional Shara Complex.*

The Soul Star and the Thymus Complex link the functions of the **Betcha** and **Alphi Hova Bodies,** the **Teuric** and **Doraidic Shields** and the **Over-Soul** and **Soul** levels of consciousness and identity within the body and bio-energetic field.

The primary area of dominion of the *D-8 Thymus Complex* is *Metabolic Function.*

THE SUN STAR

The 3rd Sun Star Seal and the Nadial Complex

Also present, but less distinctly visible along the Hara Line of Kathara Grid Level-2 is the **3rd Star Crystal Seal**, located just beneath the **Hara Center** of the *9th Star Seal* 2" below the Navel and associated with the **2nd and 3rd dimensional frequencies** of the Harmonic-1 Incarnate Matrix (***Telluric Shield***). The **3rd Star Seal**, visible as a subtle **pale Yellow-Orange-Red point of diffused light** along the Hara Line, is called the ***Sun Star Seal.*** Due to its proximity to the Silver-Gold *Hara Center* 9th Star Seal the Sun Star is often considered to be part of the Hara Center, but in deeper Hara Level scanning the distinction between these crystal seals can be evidenced. The *Sun Star Seal* is the point at which the dimensionalizing identity enters the **Gross Physical-Matter densities** of Harmonic Universe-1.The Sun Star represents the point into which the **Incarnate Identity**, its **Subconscious-Telluric Core**, the **Nada Hova Body** and **Kathara Centers 1, 2 and 3** first anchor within the body. The Sun Star holds the morphogenetic imprint for **DNA strands 1, 2 and 3,** corresponds to **Chakra Centers** and **Axi-A-tonal Lines 1, 2 and 3** and is a key point for repatterning the electro-tonal programs of the **Telluric Shield,** and realigning and activating corresponding DNA strands, Chakras, Axi-A-Tonal Lines and body regions they govern.

The Sun Star is associated with the **Nadial Complex**, the electrical impulse and chemical translation and regulatory system that governs the **4th -Dimensional interface** between the **Thymus Complex, Thalamus Complex** and the functions of the **physical body systems,** through which the electrical, chemical and metabolic operations of the **Blood, Cardio-Vascular, Pulmonary** and **Respiratory Systems** are governed. The Nadial Complex governs the operations of **Heart and Breathing rhythms**, the flow of consciousness-energy or **"Prana"** from the higher dimensional anatomy into physical embodiment and regulates many key functions within the processes of **nutrient conversion and distribution** within the Skeletal and soft tissue systems. **The *Nadial Complex* is a key center for the direction of healing energies within the Nada Hova Body, Telluric Shield and physical body systems.**

In advanced applications of healing and manifestation, the Nadial Complex is combined with the attributes of the **Shara, Thalamus** and **Thymus Complexes** and with the **Universal Raja Complex** of Harmonic-5, which links the human body to the planetary, galactic and universal Unified Fields through the *12th and 13th Chakras* and *10th Star Crystal Seal* at Earth's core via the *Planetary Bio-Feed Interface System.* The frequencies of the *3rd Sun Star Crystal Seal,* that govern the function of the *Nadial Complex* can be combined with those of the 9th Core Star Seal *Hara Center* and the *8th and 10th Star Crystal Seals* through the 12th and 13th Chakras, *PBIS, Doradic, Teuric, and Maharic Shields* and *Raja Complex* to form a potent **Teuric-Telluric Current** for **healing and manifestation**, once the *Doradic* and *Teuric Currents* have been activated within the body.

The *Sun Star* and the *Nadial Complex* link the functions of the **Alphi** and **Nada Hova Bodies**, the **Doradic** and **Telluric Shields** and the **Soul** and **Incarnate** levels of consciousness and identity within the body and bio-energetic field.

The primary areas of dominion of the D-4 *Nadial Complex* are *Cardio-Vascular, Pulmonary* and *Nutrient Absorption/Conversion Functions.*

THE GALACTIC STAR

The 12th Galactic Star Seal and the D-10 Shara Complex

The third point of condensed light visible along the Hara Line of Kathara Grid Level-2 is the **12th Star Crystal Seal**, located at the **14th Chakra** 36" above the head and associated with the **11th and 12th dimensional frequencies** of the Harmonic-4 Avatar Matrix (***Maharic Shield***). **The 12th Star Seal**, visible as a **White-Silver point of Light emanating an inverted White-Silver-Gold *cone of energy* at the 14th Chakra**, is the White Star or ***Galactic Star Seal***.

The *Galactic Star Seal* is the point at which the dimensionalizing gestalt identity enters the **Pre-Matter Liquid Light densities** of Harmonic-4, the point at which identity begins its individuation and journey of densification into the wave spectra of perceivably experiential matter. The Galactic Star represents the point into which the **Avatar Identity**, its **Buddhaic Core**, the **Mahara Hova Body** and **Kathara Centers 10, 11 and 12** first anchor within the **Bio-energetic Field** to begin setting the scalar field for the body. The Galactic Star Seal holds the morphogenetic imprint for **DNA strands 10, 11 and 12**, corresponds to **Chakra Centers** and **Axi-A-Tonal Lines 10, 11, and 12** and is a key point for repatterning the electro-tonal programs of the **Maharic Shield**, and realigning and activating corresponding DNA strands, Chakras, Axi-A-Tonal Lines and body regions they govern.

The Galactic Star is associated with the *Shara Complex*, the regulatory system that governs the **10th-Dimensional interface** between the **D-9 Thalamus Complex** and the D-13 portion of the **Rishi Shield** in Harmonic-5. Through the Shara Complex the Scalar Fields holding the gestalt identity of Harmonic-5 Rishi Consciousness Collective- the "*Universal Family of Consciousness*" – translate via electro-tonal conduction, into the more individuated Scalar Fields that house the Avatar identity gestalt Consciousness Collective- the "*Galactic Family of Consciousness*".

The **Shara Complex *regulates the disbursement of consciousness*** in individuated form through the dimensional fields of the Time Matrix and serves to link each individuated and incarnate member of the Geomantic Entity Collective beyond the Time Matrix, to its Avatar identity and Galactic Family of Consciousness in Harmonic Universe-4, through the Universal Family of Consciousness of the Rishi identity in Harmonic Universe-5. The Shara Complex represents the primary facility through which an individual consciousness retains its indelible energetic connection to its greater **family of consciousness**, through which it is directly linked to **Source.**

The Shara Complex governs, regulates and orchestrates the transduction, translation and cyclic rhythms of **electro-tonal projection of consciousness into dimensionalization**, sets the original operational structures of **Kathara Scalar Grid** arrangement and directs the synchronistic **evolution of families of consciousness** through time. Through the operations of the Shara Complex, an identity's cycles of **incarnation and manifestation** within the 5 Harmonics of a 15-Dimensional Time Matrix are regulated, which sets the **core regulatory rhythms of Partiki Phasing**, expansion and contraction of consciousness, and vibration-oscillation ratios that **govern the formation and function** of the **Thalamus and Thymus Complexes** and all aspects of the individuated **Kathara Grid, Bio-energetic Field** and **bodily systems**. The Shara Complex controls the cycles of in-flow and out-flow of energy between the personal morphogenetic field and that of the dimensional Unified Fields, and thus affects all systems of the body and consciousness, with a primary emphasis upon the functions of the **blood, consumption-excretion and immunological facilities** of the body and of the activation of **the higher dimensional sense facilities** within the embodied consciousness.

The Shara Complex links the functions of the **Mahara** and **Raja Hova Bodies**, the **Maharic** and **Rishic Shields** and the **Avatar** and **Rishi** levels of identity within the embodied consciousness. **Primary area of dominion of the D-10 Shara Complex is the Immune System and HSP.**

THE EARTH SEALS

Earth Seals 8 and 10 and the Raja Complex

Within the Hara level of field depth in which the 3rd Sun Star Crystal Seal can be detected there are 2 other Star Crystal Seals of primary importance stationed along the Hara Line of Kathara Grid Level-2; these are referred to as the **Earth Seals.** The Earth Seals function as intrinsic aspects of the **Planetary Bio-feed Interface System** and the ***Raja Complex.*** The **8th Star Crystal Seal,** called the ***Earth Star Seal*** is located within the **12th Chakra** 6" below the feet and is associated with the **7th, 8th and 12th dimensional frequencies** of the Harmonic-3 Over-Soul Matrix (***Teuric Shield***) and the Harmonic-4 Avatar Matrix (***Maharic Shield***). The Earth Star is visible as a subtle **Gold-Orange point of diffused light** positioned along the Hara Line **6" below the feet**, as the Hara Line leaves the physical body through the 1st Base Chakra to extend downward into the Earth's core. The **10th Star Crystal Seal,** called the ***Earth Core Seal***, is located within the **13th Chakra** where the Hara Line connects into the Earth's Core and is associated with the **9th, 10th, 12th** and **13th** dimensional frequencies of the Harmonic-3 Teuric Shield, Harmonic-4 Maharic Shield and Harmonic-5 Rishi Matrix (***Rishic Shield***). The Earth Core Seal is visible as a **pale Blue-Black point of diffused light** positioned in the **Earth's Core,** at the point where the personal Hara Line connects to the center of the Earth's Core at the ***1st and 12th Planetary Kathara Centers.***

The ***8th Earth Star Seal*** is the point at which the dimensionalizing identity combines the 12th-dimensional frequencies of the **Harmonic-4 Pre-matter Liquid Light density** with the 8th and 9th–dimensional frequencies of the **Etheric Matter densities of Harmonic-3** to connect the personal morphogenetic field and Kathara Grid to those of the Planetary Body. The **Earth Star Crystal Seal** can be viewed as the point where **Personal and Planetary Kathara Grids connect to Galactic Kathara Grid.** The Earth Star represents the point into which the **Mahara and Betcha Hova Bodies, Kathara Centers 8, 9 and 12 and the 12th Galactic Star Seal and Shara Complex** first anchor into the **Planetary and Galactic Kathara Grids.** The Earth Star holds the morphogenetic imprint for **all DNA strands for all manifest incarnations in *4 Harmonics of Time,*** corresponds to **Chakra Centers and Planetary Vortices** and **Personal and Planetary Axi-A-tonal Lines 8, 9, 10 and 12** and is a key point for repatterning the electro-tonal programs of the ***Personal* Maharic, Teuric, Doradic and Telluric Shields,** and realigning and activating corresponding DNA strands, Chakras, Planetary Vortices, Axi-A-Tonal Lines and personal or planetary body regions they govern. In the **Maharic Shield Activation process** the **Earth Star** is activated to release phase-lock on the **12th Chakra** to open the personal Kathara Grid to the PBIS.

The ***10th Earth Core Seal*** is the point at which the dimensionalizing identity combines the frequencies of the **8th Earth Star Crystal Seal** with the **13th-dimensional frequencies** of **Harmonic-5 Ante-matter density** to connect the personal and planetary morphogenetic field and Kathara Grid to those of the Universal Kathara Grid of Harmonic-5. The **Earth Core Seal** can be viewed as the point where **Personal, Planetary and Galactic Kathara Grids connect to the Universal Kathara Grid.** The Earth Core represents the point into which the **Rishi Identity,** the **Raja Hova Body** and **Universal Kathara Centers 1, 2 and 3** first anchor into the 3rd Earth Star and 12th Galactic Star Seals to form the Raja Complex of 5 Harmonic scalar fields through which personal, planetary, galactic and universal experiential manifestation takes place. The Earth Core Seal corresponds to **Chakra 13,** and holds the morphogenetic imprint for **all manifest incarnations of persons, planets and galaxies within the 5 Harmonics of Time in one 15-dimensional Time Matrix.** Through the combined frequencies of the **Earth Star and Earth Core Seals** the personal Kathara Grid connects to the Planetary, Galactic and Universal Kathara Grids forming the Planetary Bio-feed Interface System and the ***Raja Complex*** – or ***Universal* Bio-feed Interface System** – that links personal, planetary, galactic and universal consciousness in time.

THE RA CENTER

The 3rd Sun Star Seal, 8 and 10 Earth Seals and *RA Center*

When combined with PBIS, **Doradic, Teuric** and **Maharic Shields** and **Raja Complex**, the **3rd Sun Star Crystal Seal** and the **12th Core Star Crystal Seal** *Hara Center merge* to form a *Teuric-Telluric Current* that encompasses the *Seed Crystal Seal* within the **3rd Solar Plexus Chakra,** forming a ***sphere of powerful healing energies*** at the **3rd Chakra** called the **RA Center.** In **Kathara Healing Level-2** we will begin activation of the *Teuric Current* of the Harmonic-3 Betcha Hova Body, through activation of Doradic Current Phase-2 and will explore beginning applications of combining the Doradic Phase –1 and Teuric Currents with the natural *Telluric Current* of the Harmonic-1Nada Hova Body to begin bringing the **RA Center for healing and manifestation** into activation. (For more on the 4 Primary Triadic Healing Currents see Chapter 4 of this manual.)

The Hara Level of Kathara Level-2 and the 6 Primary Hara Points

Though the study of the Crystal Seals of Kathara Level-2 Crystal Seals Grid is complex in detail, one can become skilled in healing facilitation through Crystal Seals mechanics by learning the basic orientation of **the outer levels** of the **Kathara Level-2** scalar grid – ***The Hara Level.*** In simple analysis, the ***elements* of the Hara Level can be viewed as follows:**

The Hara Line – the Central Body Current, that is formed by the *11th and 12th Axiom Lines* wrapping around the fixed flash-line sequence of the *Level-1 Kathara 12-Tree Central Vertical Kathara Line.*

The 6 Primary Hara Points: Star Crystal Seals **1.** # 9-Hara Center, **2.** #6-Soul Star, **3.** #12 Galactic Star, **4.** #3-Sun Star, **5.** #8-Earth Star and **6.** #10-Earth Core. Each primary Hara Point governs the function of a **complex** of interwoven scalar, bio-energetic and physical systems. Knowledge of the **6 Hara Points** and the **Thalamus, Thymus, Shara, Nadial** and **Raja Complexes** they respectively govern, allows the healing facilitator a greater understanding of the 15-dimensional anatomy. Such **Foundations of Kathara Healing** are necessary in preparation for **Kathara Healing Level-2** practices that will utilize the **Hara Level** of the **Kathara Level-2 Crystal Seals Grid** in combination with the Kathara Healing Level-1 **Maharic Recoding Process** and other elements to begin activation of the **RA Center** for advanced healing and manifestation.

Axi-A-Tonal Lines 1-10

In our exploration of the Hara Level of the Crystal Seals Grid we have learned that of the **12 Primary Axi-A-Tonal Lines,** (12 primary vertical energy-flow lines within the body and bio-energetic field, created by cross-over points of the rotating, single axis, flash-line sequences projected by each of 12 Seed Crystal Seals), the 11th and 12th Axi-A-Tonal Lines spiral around the Kathara Level-1 12-Tree Grid *Central Vertical Kathara Line* to form the Hara Line and Central Body Current. Axi-A-Tonal Lines 1-10 also run vertically through the body, from the head to the toes and through each arm to the finger tips, connecting body regions to corresponding levels of the Auric Field, Chakras, Kathara Centers, Crystal Seals and DNA. The sequence of Axi-A-tonal Line position is as follows:

Right Side of Body to Center- 3,6,9,2,8 **Center of Body**-11, 12 **Center to Left Side of Body**-. 5,1,10,7,4

Each line of Axi-A-Tonal Lines **1-10** ends in one **finger-tip** and **toe** on the corresponding side of the body, and runs vertically through the top of the head to merge with Axi-A-Tonal Lines 11 and 12 and the Hara Line at **Chakra 10**, and down through the feet to merge with the Hara Line at **Chakra 12.**

The HARA LEVEL- *Outer Portion of Kathara Level-2 Crystal Seals Grid*

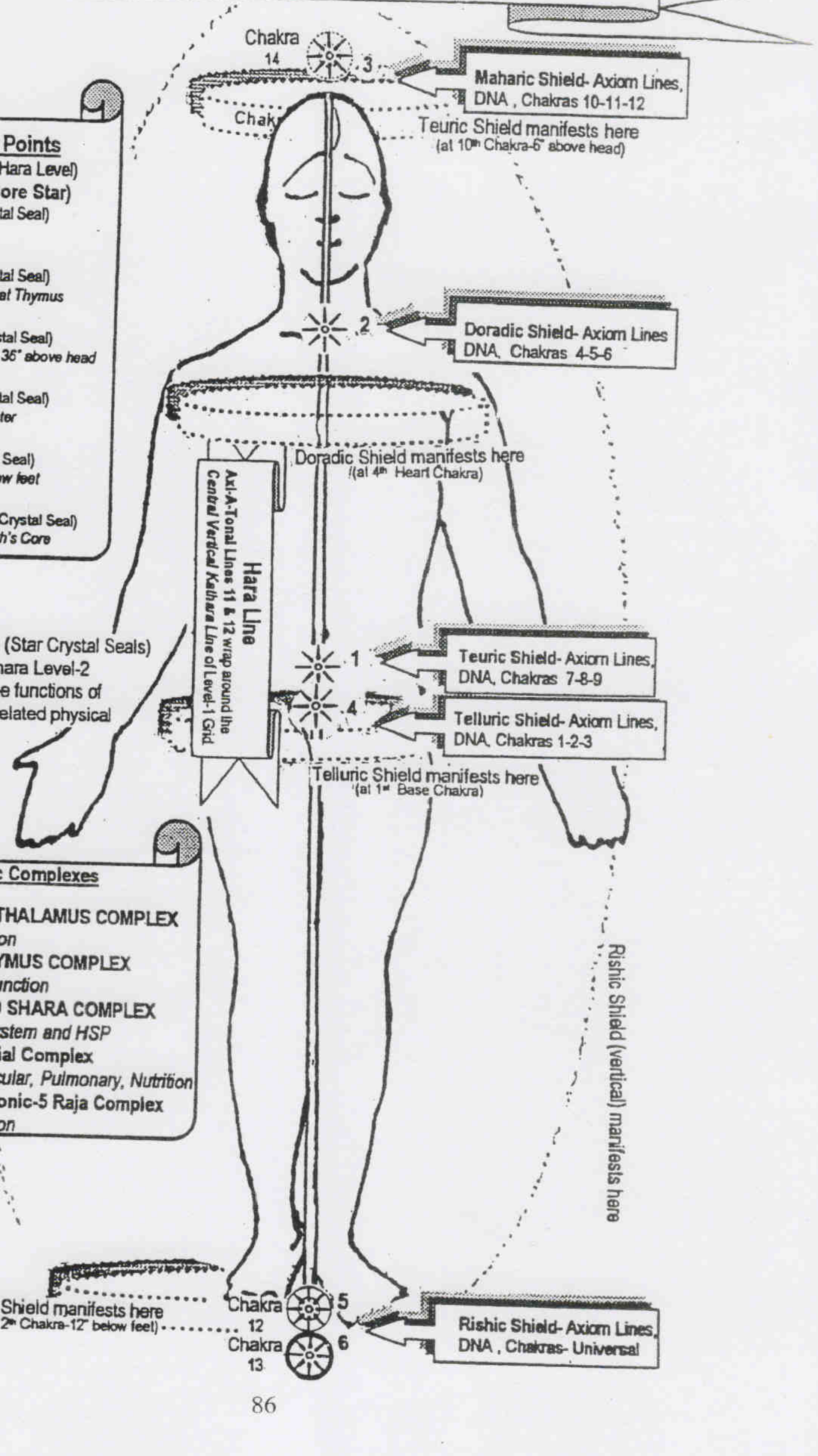
Chakra
14
3
Maharic Shield- Axiom Lines, DNA , Chakras 10-11-12
Chak
Teuric Shield manifests here
(at 10th Chakra-6" above head)
2
Doradic Shield- Axiom Lines DNA, Chakras 4-5-6
Doradic Shield manifests here
(at 4th Heart Chakra)
Hara Line
Axi-A-Tonal Lines 11 & 12 wrap around the Central Vertical Kathara Line of Level-1 Grid
1
Teuric Shield- Axiom Lines, DNA, Chakras 7-8-9
4
Telluric Shield- Axiom Lines, DNA, Chakras 1-2-3
Telluric Shield manifests here
(at 1st Base Chakra)
Rishic Shield (vertical) manifests here
Maharic Shield manifests here
(6" below 12th Chakra-12" below feet)
Chakra
12
5
Chakra
13
6
Rishic Shield- Axiom Lines, DNA , Chakras- Universal

6 Primary Hara Points

(Star Crystal Seals on Hara Level)

1. **Hara Center (Core Star)**
   (9th Silver Star Crystal Seal)
   2" below Navel
2. **Soul Star**
   (6th Indigo Star Crystal Seal)
   Top of Breast Bone at Thymus
3. **Galactic Star**
   (12th White Star Crystal Seal)
   Cone at 14th Chakra 36" above head
4. **Sun Star**
   (3rd Yellow Star Crystal Seal)
   Just below Hara Center
5. **Earth Star**
   (8th Gold Star Crystal Seal)
   In 12th Chakra 6" below feet
6. **Earth Core**
   (10th Blue-Black Star Crystal Seal)
   In 13th Chakra at Earth's Core

The **6 Primary Hara Points** (Star Crystal Seals) of the Hara Level in the Kathara Level-2 Crystal Seals Grid govern the functions of corresponding Shields and related physical systems.

Related Bio-energetic Complexes

1. Hara Center – **D-9 THALAMUS COMPLEX**
   Focus: *Brain Function*
2. Soul Star – **D-8 THYMUS COMPLEX**
   Focus: *Metabolic Function*
3. Galactic Star – **D-10 SHARA COMPLEX**
   Focus: *Immune System and HSP*
4. Sun Star – **D-4 Nadial Complex**
   Focus: *Cardio-Vascular, Pulmonary, Nutrition*
5. Earth Seals – **Harmonic-5 Raja Complex**
   Focus: *Transmutation*

12 Primary Axi-A-Tonal Lines
of the Kathara Level-2 Crystal Seals Grid

The 12 Primary Axi-A-Tonal Lines
Frequency Color and Correspondences.

(Axi-A-tonal Line, DNA Strand, Chakra, Kathara Center & Seed Seal all correspond to one dimensional number)

D1LINE 1 – Red
D2LINE 2 – Orange
D3LINE 3 – Yellow
D4LINE 4 – Green
D5LINE 5- Blue
D6LINE 6 - Indigo
D7LINE 7 - Violet
D8LINE 8 - Gold
D9LINE 9 - Silver
D10LINE 10 – Blue-Black
D11LINE 11 –Silver Black
D12LINE 12 - White

Axi-A-Tonal Lines are Points where the rotating, single-axis flash-line sequences from the Seed Crystal Seals cross over and through each other, to form 12 primary vertical flow-lines within the body. The Axi-A-Tonal Lines create the web-work of energy upon which the Kathara Grid Level-3 ***Diodic Points*** and the DNA manifest.

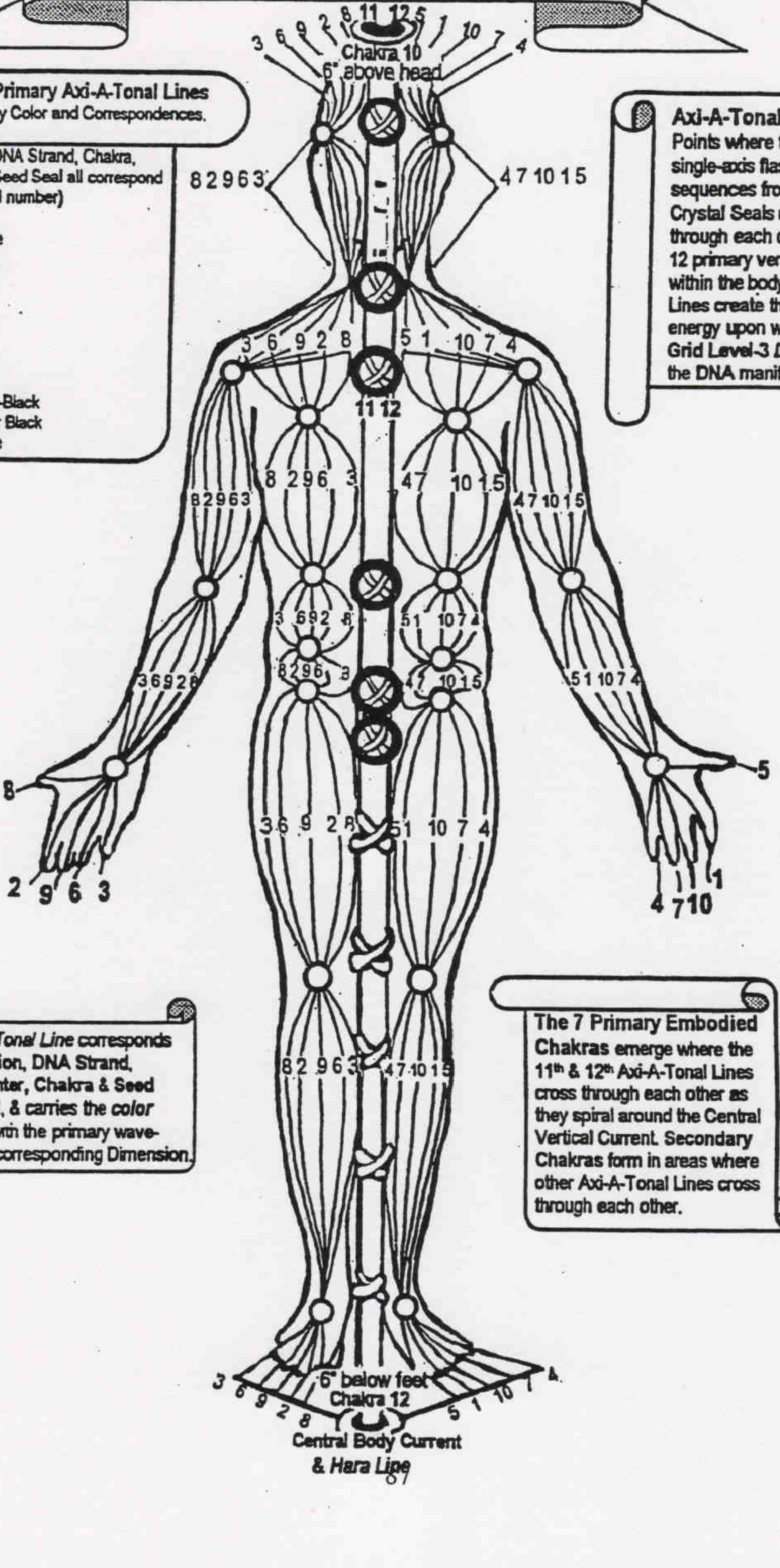
3 6 9 2 8 11 12 5 1 10 7 4
Chakra 10
6" above head
8 2 9 6 3
4 7 10 1 5
3 6 9 2 8
5 1 10 7 4
11 12
8 2 9 6 3
4 7 10 1 5
8 2 9 6 3
4 7 10 1 5
3 6 9 2 8
5 1 10 7 4
3 6 9 2 8
8 2 9 6 3
4 7 10 1 5
5 1 10 7 4
8
2 9 6 3
5
1
4 7 10
3 6 9 2 8
5 1 10 7 4
8 2 9 6 3
4 7 10 1 5
3 6 9 2 8
6" below feet
Chakra 12
5 1 10 7 4
Central Body Current
& Hara Line

Each *Axi-A-Tonal Line* corresponds to a Dimension, DNA Strand, Kathara Center, Chakra & Seed Crystal Seal, & carries the *color* associated with the primary wave-length of its corresponding Dimension.

The 7 Primary Embodied Chakras emerge where the 11th & 12th Axi-A-Tonal Lines cross through each other as they spiral around the Central Vertical Current. Secondary Chakras form in areas where other Axi-A-Tonal Lines cross through each other.

Axi-A-Tonal Lines and the Meridians

The Axi-A-Tonal Lines within the body set the primary holographic scalar field upon which the Meridian Lines – or Secondary Flow Lines- of the body manifest. **The Meridian Lines can be used to access the Axi-A-Tonal Lines and the Axi-A-Tonal Lines can be used to access the flash-line programs of the Kathara Centers and 3 Levels of the Kathara Grid, if the *correspondences* between *the Meridians, Axi-A-Tonal Lines, Kathara Centers* and *Chakras* are understood.** For centuries the **Meridian Lines** and **Chakras** have been used in subtle-energy healing systems. This knowledge can be applied and the potential results of related healing techniques amplified by employing the correspondences between the Meridian and Chakra systems and the Axi-A-Tonal Lines and 3 Levels of the Kathara Grid. Bringing the Kathara Grid into the picture allows for restructuring the **Imprint for Health** within the *causal core* while *expediting* the healing process by restructuring the various other levels of the bio-energetic anatomy.

In Level-1 Kathara Healing we focus primarily upon **Core Morphogenetic Repatterning** – resetting the electro-tonal programs of the Kathara Grid through the uncorrupted programs of the ***Maharic Shield***- to set the "*ground*" into which other healing applications can *anchor*. In later Kathara Healing Levels we will explore technique applications that affect various other levels of the bio-energetic anatomy. **In Level-1 Kathara Healing we strive to create a basic familiarity with the elements of, and the interrelationships between, the various levels of bio-energetic anatomy.** Through understanding the basic correspondences between the **3 Levels of the Kathara Grid** – the *Kathara Centers* and *Kathara Lines*, the *Hova Bodies*, Auric Levels, *Signets, Shields, Crystal Seals* and *Axiom Lines*, and the *Diodic Points* and *Chakras* – and the other aspects of energetic anatomy, such as the **Meridian Lines** and **DNA**, the healing facilitator is equipped with a knowledge base through which more precise healing facilitation can be applied. Meridian Lines and their applications to Kathara Healing will be explored in later Levels of the Kathara Healing Program.

DNA

The DNA Connection

In this Chapter we have explored the various elements of the 15-Dimensional Anatomy of the human form, from the Kathara Grid holographic scalar template, to the Hova Bodies, Shields, Axiom Lines, Chakra Centers, Auric Field Levels and the Hara Level with its related Complexes of energetic interface. Throughout all of these elements of the multi-dimensional anatomy we have seen how each element interrelates with the others through their *correspondences within the structure of the 15-Dimensional Scale.* The elements of the subtle body anatomy also systematically correspond to the structure and function of the human **DNA.** Through direct interaction with various elements of the subtle body anatomy, the operations of corresponding aspects of the human DNA can be repaired, enhanced and altered, to advance applications of healing, and to expedite the evolution of human biology and consciousness. In the *Kathara Healing Level-2 program* we will further explore the correspondences between the subtle body anatomy and the DNA, and methods by which the DNA can be repaired and activated to a more advanced level through employing the use of Kathara Healing mechanics.

The Silicate Matrix 12-strand DNA Pattern

The core human DNA imprint is built upon a **12-Dimensional** Structure, each of 12 strands building up upon one of the Primary 12 Axi-A-Tonal Lines and each strand corresponding to 1 of 12 dimensional frequency bands within the 15-dimensional scale. The original human DNA imprint is called the **Silicate Matrix,** the 12-strand scalar-wave configuration that allows for the progressive **transmutation** of Harmonic-1 carbon-based molecular-elemental structure into the Silica-based structures of higher Harmonic matter. The 12-strand DNA imprint of the human form implies that human biology was designed to embody **12 dimensions of conscious awareness**, or to fully embody the Avatar identity level - the ***"Christed" Identity*** of Harmonic-4 Pre-matter Liquid Light matter density. The human form is organically designed to undergo **full cellular transmutation** through 4 Harmonics of manifestation and their corresponding matter density levels. When the gene code is working properly, the process of cellular transmutation is directed by the embodied human consciousness. In historical terms, the process of ***conscious cellular transmutation*** has been referred to as the process of **"Ascension"**, which is ***Dimensional Expansion,*** the mechanics of which have been hidden with ancient texts dealing with **Merkaba Mechanics.** The **Merkaba Vehicle** of inter-harmonic scalar-wave configurations, which forms within the bio-energetic field, is a consequence or *simultaneous affect* of progressive activation of the Silicate Matrix within the genetic code.

The Silicate Matrix and Subtle Body Anatomy

Just as each Axi-A-Tonal Line of the subtle body anatomy has its correspondence to a Kathara Center, Crystal Seal, Axi-A-Tonal Line, Auric Field Level and Chakra, so too do the DNA strands have their specific affiliations to each *dimensionalized element* of the subtle body anatomy. Each DNA strand translates into electrical-elemental-chemical form from the governing Axi-A-Tonal Line flash-line sequence to which it corresponds. The **Hova Bodies** and **Shields** of subtle body anatomy each correspond to a *set of 3* Axi-A-Tonal Lines, Auric Field Levels and Chakras and thus also correspond to a set of **3 DNA strands,** that together create the experiential projection of separate 3-Dimensional holographic reality fields. Distortions and blockages in the Kathara Grid, Hova Bodies, Shields, Axi-A-Tonal Lines and Chakras appear as distortions and malfunction within the DNA. **The function of the DNA determines the *quantity of interdimensional frequency,* and thus the *amount of dimensionalized consciousness,* that can actively process through and embody within the physical body system.** DNA distortions manifest as distortions of biology and consciousness.

The 12 DNA strands of the Silicate Matrix are *sets of scalar-wave spectra* that correspond to each dimensional band, through which each dimensionalized level of the subtle body anatomy is translated into wave-spectra that is within the range of perceivable matter manifestation. ***The DNA can be viewed as the primary structure through which subtle energy-consciousness translates into manifest physicality.*** As each full dimensional band contains 12 primary Sub-frequency Bands (See Chapter 1 for Dimensional Structure), each of the 12 DNA strands contains ***12 primary* Seed Codes,** or *consolidated scalar points* composed of electro-tonal flash-line sequences, that correspond to the Sub-Frequency Bands within each dimension. The 12 primary Seed Codes within each DNA strand have an *anti-particle counterpart* composed of frequencies from the Anti-particle system. The 12 particle Seed Codes in each strand are called **BASE CODES**, their anti-particle counterparts are called **ACCELERATION CODES**. The Seed Codes of the core DNA scalar imprint are the *points of consolidated frequency* through which energy-consciousness is drawn in from the dimensional Unified Fields to expand the personal morphogenetic field.

DNA Fire Codes- Genetic Time Codes

Along with the **12 Base Codes** and **12 Acceleration Codes** of each DNA Strand Template there are also 12 Primary DNA Codes called **DNA FIRE CODES** that regulate the relationship between human biology and the **Planetary Time Cycle** in which the biology manifests. The DNA Fire Codes can be conceptualized as existing *between* the Primary 12 Strands of the Silicate Matrix. Each Fire Code is composed of one half of the scalar frequency patterns from each of the two Primary Strands that the Fire Code is placed between. Each of the 12 Fire Codes corresponds directly to one of 12 **Signet Star Crystal Seals** in the Personal Shields of the Internal Templar Complex, and with release of the corresponding **Signet Seal**, the Fire Code comes into activation.

The DNA Fire Codes release the natural scalar barriers between particle and anti-particle DNA Strands, allowing **STRAND FUSION** to occur. Fusion of DNA strands in the particle body with corresponding strands in the anti-particle body creates a progressive transmutation of the scalar wave forms of the DNA Template and Scalar Shields, through which the polarized Particum-**Particles** and Partika-**Anti-particles** merge and transform into their original Omni-polar Partiki **Ante-matter** state. Through strand fusion, the biological carbon-based biology progressively **lessens in density** as its elemental agents are transmuted from the Kathara level, into elemental agents characteristic of the higher dimensional matter densities. **Dimensional Ascension** is achieved through release of the Kathara Grid Seals. Release of the Kathara Grid Seals creates merger of the Hova Bodies, activation of the Kundalini energies, release of the Cranial-Sacral Crystal Seals, **fusion of the DNA Strand Templates via the DNA Fire Codes**, building of the Merkaba Vehicle in the bio-energetic field and the resulting transmutation of bodily matter and shift in Angular Rotation of Particle Spin within molecular construction. Through this transformational process the human biology is released from its organic phase-lock within its current space-time cycle, and is able to engage in **transcendental travel** through the various matter density levels and Time Cycles in and beyond the 15-Dimensional Time Matrix. **As the DNA Fire Codes regulate the body's orientation to space-time, they are also referred to as the GENETIC TIME CODES.**

The DNA Fire Codes are an essential element in the natural process of restoring the natural immortal **Organic Imprint for Health** within the human body. The ability of the human form to become **perpetually self-sustaining** is dependent upon the Kathara Grid and DNA being able to continually renew the natural Primal Order of Maharic Shield scalar arrangement upon which the body is built, to keep the Star Crystal Seals and conduits of interdimensional energy supply open. **Perpetual revitalization of the body** is achieved through full activation of the **12-Strand DNA** pattern. When activated, the **DNA Fire Codes** keep the Crystal Seals, **the interdimensional INTERNAL STAR GATES of energy inflow**, open, so the finite supply of frequency held within the personal Manifestation Template can be continually renewed. Restoration of the Organic Imprint for Health, as held within the **Maharic Shield**, is achieved through progressively clearing distortions of scalar-wave arrangements within the Kathara Grid, Shields and DNA Template and realigning the entire subtle energy and physical energy systems with the Primal Order of the Maharic Shield. This process of whole-being-healing does not occur overnight, as many genetic distortions (which emerge from Kathara Grid misalignment) have served as the dominant bio-electrical program within the human genome for many thousands of years. With knowledgeable practice of Kathara Grid realignment, and supportive healing applications within the various Body-Mind-Spirit systems, these inherited distortions can be progressively healed through Regenesis of the Primal Order as held within the personal Maharic Shield.

Science, "Junk DNA" and Evolution

In the contemporary human genetic code the majority of the DNA strands corresponding to higher dimensional anatomy and consciousness are dormant or damaged due to ancient blockages within the Kathara Grid and its corresponding elements of the subtle body anatomy. Present day humans function primarily on a **3 to 3.5 DNA activation level**, while the imprint and potentialities for strands 4-12 lie dormant within the morphogenetic field and within the fragments of non-functional DNA that contemporary science has labeled ***"junk DNA"***.

The portions of the DNA chain that science has presently identified as the **"Double Helix"**, represent only the **surface portions** of the chemical, elemental and electrical components of the active DNA strands. Science has yet to identify the *multidimensional spectra* of DNA manifestation, and has yet to realize that within the structures of detectable DNA, there are *levels of structure and function* that direct the operations of the *entire genetic imprint*, which are *not presently detectable* by contemporary scientific technique. The human DNA imprint will always appear from external analysis, as a *2-strand Double Helix* configuration, but what is not understood, is that within this Double Helix there are, and will be progressively more, **additional Double Helix strands**, which *fuse together* and add their operational coding into the active DNA imprint. By contemporary standards of categorization, if science were to objectively observe the activated 12-strand pattern (or even an activated 4-strand pattern), the DNA would *not appear to be human at all*, but rather as the seemingly incomprehensible genetic signature of an "unknown" species. As science evolves into comprehension of the multi-dimensional spectrum, the understanding of the true structure and function of DNA will progressively advance.

DNA, Kathara Healing and Bio-Spiritual Evolution

One does not have to wait for scientific theology to catch up with a rapidly evolving humanity in order to begin advancing the functions of the DNA. Through the processes of Kathara Healing, as we work to clear blockages from the Kathara Grid and to reawaken the *Imprint for Health* within the human body, we are *simultaneously, directly affecting* the operational structure of the DNA. As we work to create **Hova Body merger-** *merging of the scalar-grid flash-line sequences of the 5 Harmonic Hova Bodies-* we are progressively reordering portions of the "junk DNA" and stimulating dormant portions of the DNA into activation. As we work with subtle energies to clear blockages within the Kathara Grid, we are progressively purging ancient distortions and mutations within the gene code, distortions that have kept our collective consciousness locked into the limited 3-dimensional perceptual range of Harmonic Universe-1.

It is through the ancient distortions of the human Kathara Grid and the resulting **mutations** of the human DNA, that the multidimensional portions of identity seem separate from each other. The higher levels of conscious awareness that are stationed within the scalar grids of the higher dimensional Hova Body Shields have been unable to *electronically translate* into the lower dimensional identity stations of the Nada Hova Body and its apparent physical manifestation. As we work with Kathara Healing to create progressive Hova Body merger and DNA strand ordering and activation, we will progressively experience *advancement of conscious awareness* and *expansion of the perceptual field* and *Higher Sensory Perception* (HSP). This expansion and advancement occurs because we are able to progressively embody higher frequencies of consciousness and scalar wave flash-line sequences into the personal morphogenetic field, via the energetic conduits of the DNA. **Kathara Healing modalities are the fastest and easiest methods available to repair and advance the function of the DNA and to expedite the organic processes of *Bio-Spiritual Evolution*.**

The Silicate Matrix 12-Strand DNA Template with Hova Body, Scalar Shield and Identity Level Correspondences

The Morphogenetic Field Scalar-wave Template for the Original Human Genome

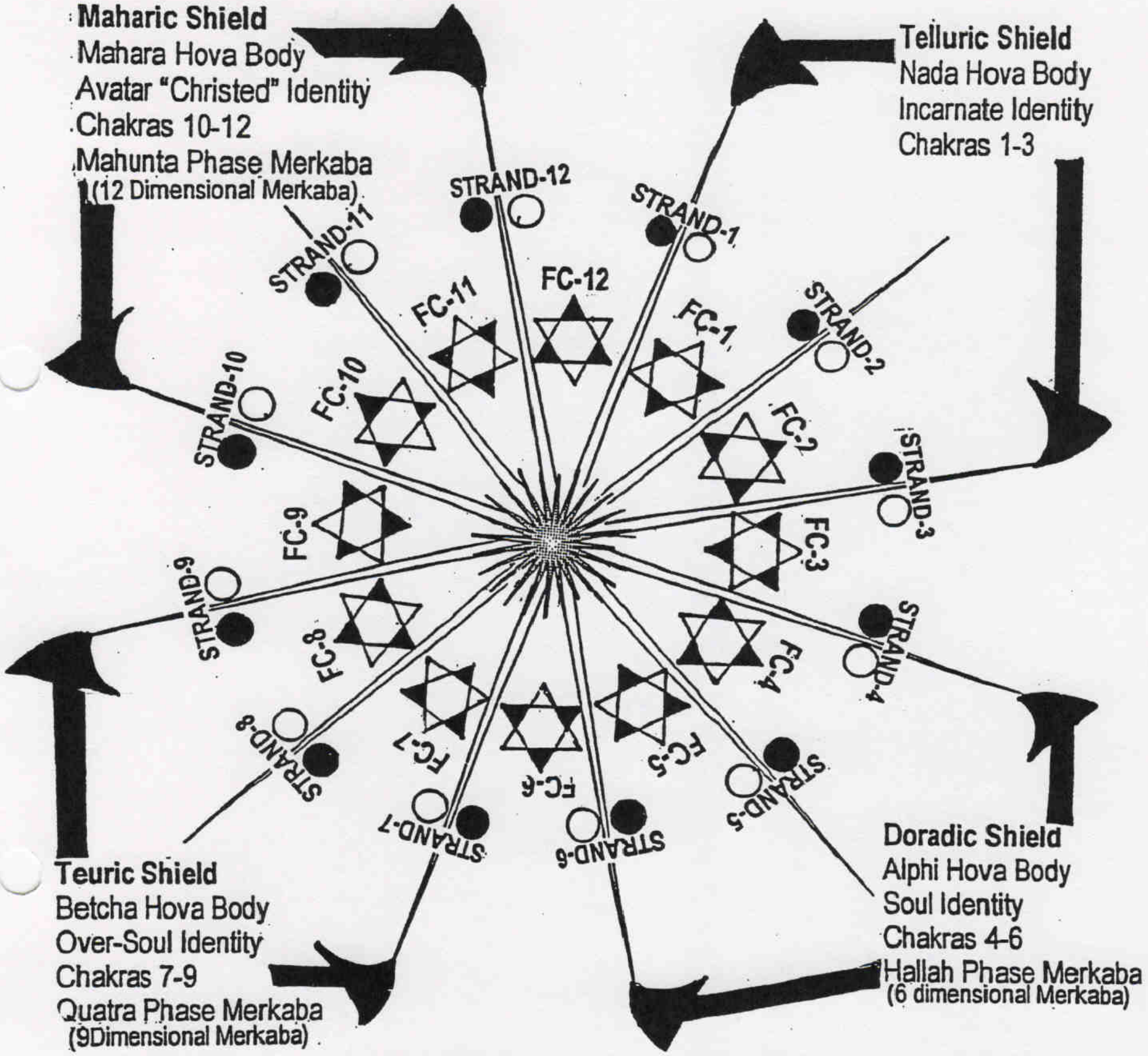
Maharic Shield
Mahara Hova Body
Avatar "Christed" Identity
Chakras 10-12
Mahunta Phase Merkaba
(12 Dimensional Merkaba)
Telluric Shield
Nada Hova Body
Incarnate Identity
Chakras 1-3
STRAND-12
STRAND-1
STRAND-11
STRAND-2
STRAND-10
STRAND-3
STRAND-9
STRAND-4
STRAND-8
STRAND-5
STRAND-7
STRAND-6
FC-12
FC-1
FC-11
FC-2
FC-10
FC-3
FC-9
FC-4
FC-8
FC-5
FC-7
FC-6
Teuric Shield
Betcha Hova Body
Over-Soul Identity
Chakras 7-9
Quatra Phase Merkaba
(9Dimensional Merkaba)
Doradic Shield
Alphi Hova Body
Soul Identity
Chakras 4-6
Hallah Phase Merkaba
(6 dimensional Merkaba)

12 Base Codes per Strand = ● **12 Acceleration Codes per Strand = ○**

12 FIRE CODES between Strands = ✡

(Diagram presents simple conceptualization of DNA Strand Template orientation, not actual geometrical arrangement of wave-form structure and observable strand interrelationship.)

Merkaba Phases – Building the Merkaba Vehicle

44

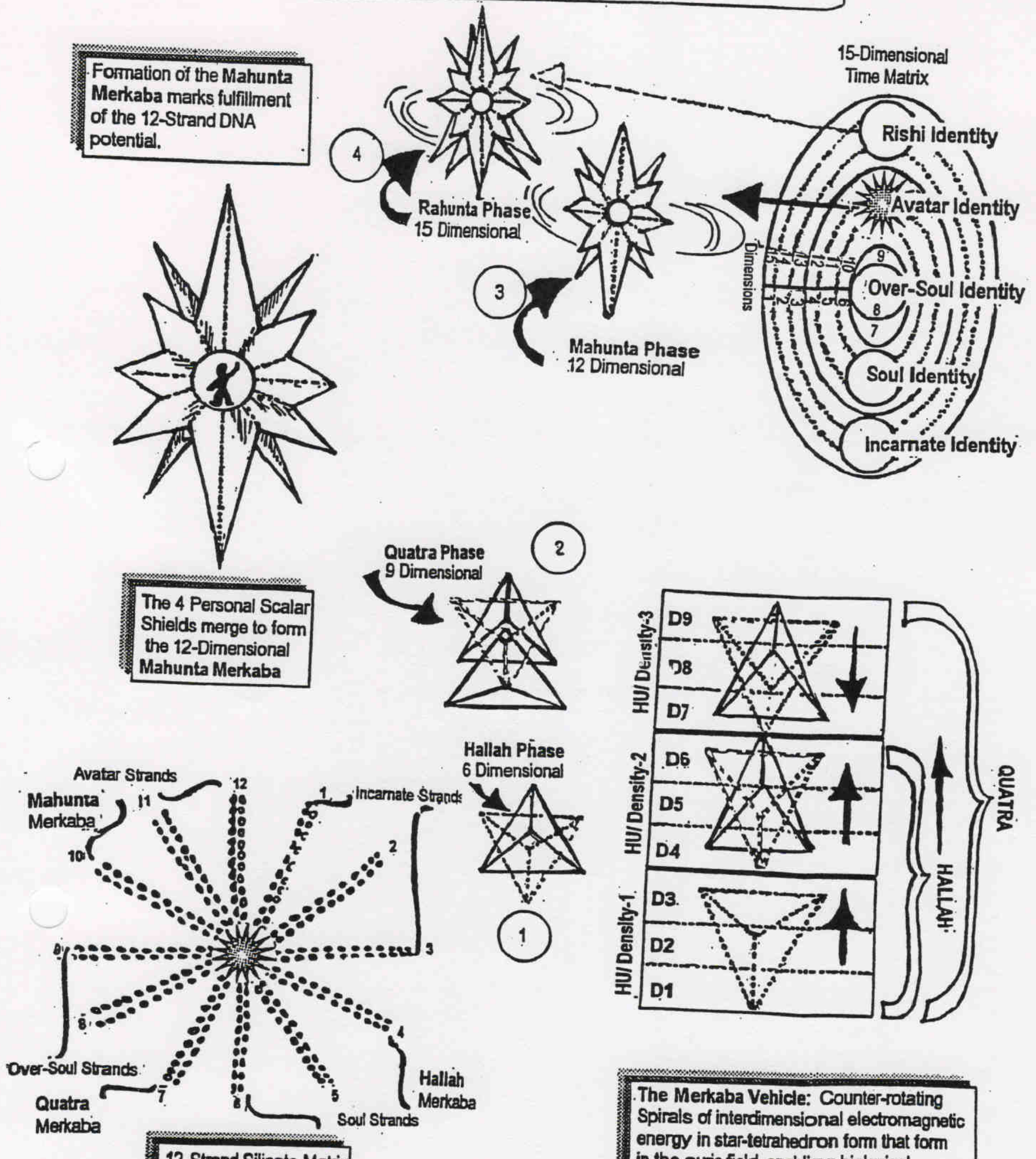
15-Dimensional Time Matrix
Rishi Identity
Avatar Identity
Dimensions
15 14 13 12 11 10
9
Over-Soul Identity
8
7
1 2 3 4 5 6
Soul Identity
Incarnate Identity
4
Rahunta Phase 15 Dimensional
3
Mahunta Phase 12 Dimensional
Quatra Phase 9 Dimensional
2
Hallah Phase 6 Dimensional
1
HU/Density-3
D9
D8
D7
HU/Density-2
D6
D5
D4
HU/Density-1
D3
D2
D1
QUATRA
HALLAH
Avatar Strands
Mahunta Merkaba
12
11
10
1
Incarnate Strands
2
3
9
8
Over-Soul Strands
Quatra Merkaba
7
6
Soul Strands
5
4
Hallah Merkaba

Formation of the **Mahunta Merkaba** marks fulfillment of the 12-Strand DNA potential.

The 4 Personal Scalar Shields merge to form the 12-Dimensional **Mahunta Merkaba**

12-Strand Silicate Matrix DNA Diagram shows Strand relationships

The Merkaba Vehicle: Counter-rotating Spirals of interdimensional electromagnetic energy in star-tetrahedron form that form in the auric field, enabling biological interdimensional travel and ascension.

THE 12 HUMAN SENSES, APPARTHI AND HSP

Perception and the Hologram

In earlier text we have explained that **manifestation is not what it appears to be**, but rather a **Holographic Projection** of consciousness through the structures of **dimensionalization**. Further, that dimensionalization itself is a *compartmentalization* of consciousness created through units of consciousness (Partiki, Partika and Particum) *assembling in specific mathematical-geometrical ratios* to form **scalar grids**, interwoven fabrics of *fixed points of electro-tonal units* that form layers of standing-waves -**scalar waves** - that serve to "flesh out" the structure of the Hologram, through projection along a *vertical, horizontal* and *diagonal axis*. We have explored the **Kathara Grid** - the *core template* of scalar standing-waves upon which consciousness begins its experience of dimensionalization, the structures of the **15-Dimensional Universe** construction, and how these characteristics of the Hologram relate to forming the structure of **15-Dimensional Human Anatomy.** In understanding the basic foundations upon which our perceivable Hologram forms, we begin to better comprehend the nature of reality and of ourselves within this multi-dimensional reality structure. **Through the Holographic Projection of consciousness within the cosmic Unified Field of Energy-consciousness and its scalar fields of dimensionalization, we perceive the conditions of space, time, matter, externalization of reality and individuation of identity.** Within the Hologram of consciousness we perceive as **solid and objectified** the **wave spectra** and their inherent energy constructs of that which exists **precisely one dimensional band below the present station of our consciousness focus.**

In this section we will explore a bit about the **apparatus of perception** that allow us to perceive externalization in such a manner, the **facilities of energy inherent to the scalar-wave construct of the human form,** which together work to bring the Hologram into perceivable manifestation. We will call the constructs of energy formed through scalar organization, which allow for perception of the manifest Hologram, the **HUMAN SENSES.**

THE *HUMAN SENSES* ARE THE *EXPERIENTIAL RESULT* OF *ORGANIZATIONS OF WAVE PATTERNS* INHERENT TO THE ELECTRO-TONAL PROGRAM AND SCALAR ORGANIZATION OF HUMAN CONSTRUCTION.

What ARE Senses?

Senses are the **scalar-wave apparatus**, and their seemingly manifest parts, that allow the personal morphogenetic field to **synthesize and translate frequency** from the dimensional bands of the Unified Field, into **coherent perceptual and experiential qualities** that give embodied consciousness a **translation of its relationship to other forms of consciousness within the Unified Field.** Senses - or the apparatus which give us the *ABILITY TO SENSE*- are scalar arrangements inherent to our form that **TRANSLATE ENERGY SIGNATURES FROM THE UNIFIED FIELD INTO USABLE DATA OF RELATIONSHIP.**

Like the true substance of the human body and consciousness, the Unified Field exists as a *quantity of dimensionalized energy-consciousness in electro-tonal scalar wave form* - a compartmentalized field of **ENERGY SIGNATURES**, within which a vast number of **consciousness constructs** exist The human organism is one such **construct of consciousness**, and through its inherent form, the *energy signatures* of other scalar forms are translated into perceptual data. **The senses are simply *energy constructs* within the human morphogenetic field, that *separate and translate energy signatures from the Unified Field* into sets of experiential stimuli, through which the contours of the manifest Hologram can be *recognized* and *experienced.***

The APPARTHI and Perception

The sense facilities are *organizations of energy* within the morphogenetic field that hold sets of *"energy receivers" or magnetic points of cohesion*, into which *like frequency patterns* from the Unified Field are drawn in for translation. Every organism has a different configuration of energy receivers within its morphogenetic makeup, and so every organism will have a variation of perception. The **morphogenetic energy receivers**, or **APPARTHI** of an organism's construction serve to *draw certain frequency bands into the morphogenetic field for translation and to block out other frequency bands*, making them unavailable for translation. The frequency bands, or *flash-lines of Partiki Phasing*, that are blocked out of the personal morphogenetic field, create **GAPS OF PERCEPTION** of the Unified Field, through which the Holographic picture of "space between objects", "externalization of form" and "separation of SELF from the Unified Field" becomes perceivable to the organism. **These qualities of *objectification* are the result of BLOCKED FLASH-LINE SEQUENCES, portions of the *scalar fields* of the Unified Field and their inherent *sequences of Partiki Phasing*, that *cannot translate* through the personal morphogenetic field due to the arrangement of the APPARTHI within the personal morphogenetic structure.**

Senses as Scalar-wave Constructs & Expanding our Perception of Perception

If it can be recognized that externalization of experience is a perceptual illusion of consciousness created through selectivity of range within the perceptual field, the true nature of the human sense facilities can be better understood as a pattern of interrelated scalar-wave forms that serve to block out portions of the Unified Field so that other portions may be brought more fully into perceivable view. **When viewing the *physical apparatus* through which the known human senses appear to occur as part a of larger, interwoven system of *scalar construction*, it will be easier to understand that *perception is not a localized phenomena created by and limited to the identified organs of perception*.** The experiential capacities of even the 5 known human senses have a much broader range than what is presently assumed or identifiable through analysis of the manifest sense organs. *If one can understand that perception of manifestation itself is an affect of these greater scalar wave constructs, it will not seem so outrageous to consider the reality and integrity of sensing and perception beyond the range of the presently identified sense facilities.*

ESP, HSP and Evolution

"Extra-sensory perception" is not "EXTRA" at all, it is a *normal attribute* of the *evolving human organism*, as the consciousness ensconced within the *body hologram* continues its *natural expansion* into the greater portions of its evolutionary imprint. Individuals displaying abilities of "Extra-sensory Perception" are not gifted with something *other than what is characteristic to the human form*, **they are simply *a bit ahead in the stage of development* of the natural human perceptual capacities. Everyone has dormant potentials for some degree of "ESP"; like all things within the human organism, ESP is regulated by the *function of the DNA* and its naturally intended *relationship* to the *Kathara Grid and morphogenetic structure*.** Individuals with **less distortions and blockages** within the **Kathara Grid** (and the resulting DNA malfunctions such distortions create) will have *greater ease* in calling the dormant perceptual facilities into activation. *Individuals who consciously attempt to use the greater perceptual facilities will stimulate a more rapid advancement into reclaiming this stage of evolution, than those who refuse to acknowledge the existence of their greater sensing facilities.* **The greater sense facilities bring the *higher dimensional wave spectra* and its inherent reality fields into the *perceptual range* of the earthly embodied human consciousness, and so the greater sense facilities can be considered the HIGHER SENSES, a term far more accurately describing their orientation than the term *Extra Senses*. "ESP" becomes "HSP"- *Higher* Sensory Perception - a *natural attribute of experience for the evolving human organism*.**

THE 5 KNOWN SENSES

The 5 Known Human Senses

In order to understand the nature of the **Higher Senses** it is necessary to understand a bit more about the nature of the **common senses**, or the "*lower senses*" if you will, for the **common senses** are those that are "tuned to" perception of the **lower frequency dimensions. Perception of *Sight, Sound, Touch, Taste and Smell* are *experiential affects* of the *scalar-wave constructs* that exist within the NADA HOVA BODY and the TELLURIC SHIELD, the Kathara Grid and morphogenetic field structures that are composed of and stationed within the frequency bands of dimensions 1, 2 and 3, the first Harmonic of manifestation.** The **APPARTHI,** or ***"energy receivers"*** within the Nada Hova body have their first imprint within the **Kathara Grid Level-2: Crystal Seals** structure. The first pattern for the sense facilities responsible for manifesting the organs of perception of the 5 identified senses exist within the configurations of electro-tonal Partiki units that form the crystalline seals of which the dimension-2 **Telluric Shield** is constructed. Through the Partiki Phasing flash-line projections of the Telluric Shield, the "armature" or 3-dimensional blueprint for the organs of perception are set for manifestation within the body hologram.

The 5 Known Senses and Sound Transduction

The 5 known senses are more intimately related than commonly supposed; ALL represent a form of SOUND TRANSDUCTION - the frequencies, or flash-line sequences, within the 1st, 2nd and 3rd dimensional bands, that form the identifiable wave patterns presently associated with sound waves, are drawn into the Level-2 Kathara Grid Crystal Seals by **Apparthi receivers** that carry like flash rhythms. Once drawn into the Apparthi receivers the sound spectrum becomes modulated into different flash-line rhythms and sent into the **Diodic Points of the Level-3 Kathara Grid.** Once intersecting with the frequencies within the Diodic Points the frequencies from the Apparthi are then **divided/ polarized** and projected up and down the Harmonic-1 dimensional scale, **creating a pattern of energy refraction** within the morphogenetic field and physical body apparatus. The polarized frequencies first appear within the **DNA** as part of the core electrical vibration, and then further transmute into **electrical impulse** that manifests as configurations with the **blood chemistry** and within the **Central Nervous System.** These synthesized electrical impulses are further projected through the **scalar-wave grids** that hold the form of the **identified sensory organs,** finally **culminating in the interrelated qualities of perception associated with the identified sensory organs and their 5 known attributes of sensing.**

THE 12 HUMAN SENSES

The Interwoven Senses and the Hova Bodies

As in the case of the Lower Senses, the *Higher Senses* and their experiential manifestations are the product of consciousness interacting with the *dimensionalized scalar organization* of the human morphogenetic anatomy. Whereas the Lower Senses are affiliated with the transduction of sound frequency within the *1st, 2nd and 3rd Dimensions*, through the structures of the *Nada Hova Body* and the *Telluric Shield* of the *first Harmonic*, the Higher Senses are in like fashion associated with the scalar organization of the *Higher Dimensional Hova Bodies* and their corresponding *Shields*.

In truth, all of the sensing facilities organic to the human form comprise interwoven and interrelated systems of *energy refraction* that together create the perceptual experience of *externalization* within the hologram of manifestation. For example, it is not commonly recognized that the sense of **smell** is in actuality part of the function of the **auditory facility**, and thus represents an intrinsic part of the sense of hearing. It is also not commonly understood that the processes associated with **vision** are not only connected to the processes of the brain and Central Nervous System, but also with the formation of *crystalline structures* with the plasma of the **blood. The senses are not nearly as *separate* and *independently functional* as they appear to be when viewed from outside analysis.** They are rather a part of an **interwoven system of electro-tonal information relay** that spans the 15-Dimensional morphogenetic field anatomy of the human organism.

The 12 Human Senses

In terms of breaking down the sense facilities for structural analysis, such as is done by modern science in identifying the 5 Known Senses, we will describe the sensory attributes of the **Higher Sense facilities** in terms of their *primary orientation*, *location of their primary Apparthi receivers* within the *Hova Body* structures and by the type of *perceptual or experiential attributes* produced through their function. **In such categorization of the human sense facilities there are *7 additional*, as yet unidentified, *sense facilities* operating within and through the human consciousness**, which are collectively responsible for translating the scalar fields of dimensionalized reality into the *illusionary holographic picture* of externalized manifestation and its qualities of space, time, matter and identity individuation. **Collectively there *are 12 Primary Sensing Facilities* within 15-Dimensional Human Anatomy.**

PERCEPTUAL BLOCKAGE, KATHARA GRID DISTORTION AND KATHARA HEALING

Perceptual Blockages

The Higher Senses are connected to the Lower Senses and provide attributes of perceptual experience characteristic to their dimensional levels, but in the present stage of human genetic evolution the Higher and Lower Senses are not fully "plugged into" each other, and so the various higher dimensional fields, and the sensory abilities associated with the Higher Senses, appear to be separate or unavailable to the embodied human consciousness.. **The Higher and Lower Senses plug in through opening of *Kathara Lines* in the *Level-1 12-Tree Kathara Grid*, which creates a reciprocal opening and expansion of the DNA, Hova Bodies and activation of dormant nerve networks within the brain, molecular core and Central Nervous System of the body.**

Presently the human senses are *phase-locked into a 3-dimensional perceptual field* due to blockages between the *3rd and 4th Kathara Centers*, which block the Apparthi receivers within the Nada Hova Body from accepting compatible electrical impulses from the higher dimensional Hova Bodies. This Kathara Grid blockage manifests within the body as fragmented units of DNA (**"Junk DNA"**), that serve to render the natural processes of multi-dimensional data transfer into the Central Nervous System inoperable. Portions of *higher dimensional experience* come to conscious attention in the form of *dream perception* or *intuitive impression,* but the natural clear pathways of multi-dimensional perception are blocked to a large degree within contemporary humanity.

Perceptual Blockages and Kathara Healing

Blockages in the Kathara Grid and their reciprocal blockages in the human perceptual field can be progressively removed through practices of *Kathara Healing*, and utilizing the *Maharic Shield* to reawaken the Organic Imprint for Health.. As Kathara blockages are progressively repaired, the genetic code will expand its function by reassembling and activating the presently dormant portions of the DNA imprint. DNA expansion will create reciprocal alterations in the bodily metabolic rate, brain, blood, glandular and hormonal function, particle spin speed and operation of the Central Nervous System, that will allow for a progressive, natural activation of the Higher Sense facilities and expansion of the human perceptual field into the multi-dimensional arena. **In Kathara Healing the dormant Higher Senses will be progressively brought into activation**, beginning with the **6th -Audurea-Merkaba Sense** and the **7th-Tristet-Cellular Telepathy Sense** through which **Inner audio-visual-direct cognition** skills will progressively develop. These skills will be employed in the processes of Kathara Healing, and in so doing they will be progressively stimulated into greater levels of activation. As the dormant Sense facilities are called into activation, Kathara Healing techniques to remove Kathara Grid blockages are used to realign the *Holographic Template* to restore the **Imprint for Health,** through which natural perceptual expansion will progressively take place.

The 12 Human Senses

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The collective spectrum of human sense facilities, including the Higher Senses of 15-Dimensional Human Anatomy can be categorized as follows:

The 12 Human Senses, Hova Bodies and Primary Experiential Attributes

Identified Lower Dimensional Sense Facilities

1. Visual-Sight Sense- ***Nada Hova Body (dimensions 1-2-3)***
2. Auditory-Hearing Sense - ***Nada Hova Body***
3. Tactile-Touch Sense- ***Nada Hova Body***
4. Olfactory-Smell Sense- ***Nada Hova Body***
5. Sense of Taste- ***Nada Hova Body***

Unidentified Higher Dimensional Sense Facilities

6. **Audurea -Merkaba Sense -** *Encompasses all Hova Bodies*
   Primary Attribute: **Manifestation**-circulation of consciousness and frequency accretion
7. **Tristet-Cellular Telepathy** -*Alphi Hova Body (dimensions 4-5-6)*
   Primary Attribute: **Inner Audio-Visual-Direct Cognition** reading energy signatures.
8. **Nurgode-Transmutation Sense -** *Betcha Hova Body(dimensions 7-8-9)*
   Primary Attribute: **Molecular Transmutation** - shape-shifting
9. **Ragode-Transmigration Sense -** *Betcha Hova Body*
   Primary Attribute: **Transmigration** - Projection of Consciousness
10. **Geuard-Transfiguration Sense-** *Mahara Hova Body (dimensions 10-11-12)*
    Primary Attribute: **Bilocation**-multiple holographic manifestations
11. **Shara-Centrifugal Sense-** *Raja Hova Body (dimensions 13-14-15)*
    Primary Attribute: **Electrical Projection** - consciousness enters dimensionalization
12. **Aurt-U - Centripetal Sense -** *Raja Hova Body*
    Primary Attribute: **Magnetic Accretion** -consciousness exits dimensionalization

CHAPTER 2 HIGHLIGHTS

THE IMPRINT FOR HEALTH

- Healing occurs through correcting distortions within the Kathara Grid and Hova Body Shields.

- The human body blueprint was designed to hold 12 Dimensions of Frequency/ Flash-line Sequences and 12 Dimensions of Consciousness, the content of 4 out of the 5 Hova Bodies within the 15-Dimensional Anatomy.

- The **4th Hova Body** - the **Mahara Hova Body** - is composed of Frequencies/ Partiki Phasing Flash-line Sequences of the **10th, 11th** and **12th Dimensions.** It manifests through the 10th, 11th and 12th *Kathara Centers* and the **Maharic Shield** Scalar Grid of the **4th Harmonic.**

- The **Maharic Shield** of *Level-2 Kathara Grid Crystal Seals* holds the original **IMPRINT FOR HEALTH**- the original *Flash-line Sequences* of *Harmonic 4 Pre-matter Liquid Light* - that represent the *point of entry* into perceivable manifestation.

- The **Maharic Shield** can be used to **repattern** the Kathara Grid Holographic Template back to the original **Imprint for Heath.** The Flash-line Sequences of *Dimension 12* can *override* and correct *faulty Flash-line Sequences* that manifest as distortions within the Kathara Grid and Hova Body Shields.

- The **Hierophant Symbol Code** is a *Scalar Standing-wave* pattern containing the electro-tonal programs of the 11th and 12th Dimensions. The Hierophant Symbol code serves as a *Frequency* ***WAVE GUIDE*** through which the **Maharic Shield** can be activated to run 11th and 12th Dimensional Frequency through the Kathara Grid for **repatterning** the **Imprint for Health** within the Core Holographic Template of the body.

- Using the *Hierophant Symbol Code* the **Planetary Bio-feed Interface System™** can be activated to **empower** the Kathara Grid repatterning process via drawing Frequency from the **Planetary Maharic Shield.**

MORPHOGENETIC EXPANSION

- Growth through time is created through **FREQUENCY ACCRETION -** drawing Frequency Bands from the Dimensional Unified Fields of Consciousness into the personal morphogenetic field for expansion.

- When the Kathara Grid is functioning properly there are **set morphogenetic field expansion periods** within the linear growth cycles of the human body.
  1. **Fetal Integration** to age 11-12.
  2. **Harmonic 2 Integration** age 12-22
  3. **Harmonic 3 Integration** age 22-33
  4. **Harmonic 4 Integration** age 33-44

  If the Kathara Grid is working properly the **body does not die** but rather **progressively transmutes** into *less dense states of matter* in an **immortal body form,** via accretion of the 4 Harmonics of Frequency.

- Present **Kathara Distortions** block integration of **Harmonic 2** and begin Molecular Compaction, body degeneration and Death.

LEVELS OF HUMAN ANATOMY

- The **Kathara Grid** is the *Core Holographic Template* upon which the human body and consciousness enter dimensionalization in order to experience manifestation.

- There are **3 Levels** to the Human *Kathara Grid*: *Level-1*- The **12- Tree,** *Level-2* – **Crystal Seals** and *Level-3* – **Diodic Points.**

- *Kathara Level-1 –12-Tree* contains the primary **12 Kathara Centers** and primary **15 Kathara Lines,** that correspond to various regions of the physical body and bio-energetic field and which "ground" consciousness into the framework of dimensionalization.

- *Kathara Level-2 – Crystal Seals* contain the **Signets** *–consolidated points of dimensional frequency* – the **Shields** – *3-dimensional scalar-wave discs emanating from sets of 3 Signets* through which the *Hova Body* energy capsules form– and the **Star Crystal Seals** and **Seed Crystal Seals** through which the *Chakras* and *Bio-energetic Field* levels emerge.

- *Kathara Level-3 – Diodic Points* are **Coordinate Points** where the flash-line sequences from one Shield and its Seals cross over and through those of other Shields to form minute **"White Hole" vortices** of energy-consciousness relay between the Hova Bodies and stations of identity.

- **Hova Bodies** are *3-dimensional scalar grids* in the form of **Concentric Spheres** that form around each **Shield** in the *Kathara Level-2 Crystal Seals Grid,* which serve as "tissue capsule" encasements around each Harmonic of energy-identity within the 15-dimensional scale.

- There are **5** *Dimensionalized* **"Ariea" Hova Bodies** forming human anatomy, which emanate from the **5** 3-Dimensional scalar **Shields** of the *Level-2 Kathara Grid*. Each Shield and Hova Body corresponds to **3 Kathara Centers** in the *Level-1 12-Tree Grid.*

- **5 Ariea Hova Bodies** and Corresponding **Shields:**
  Nada Hova-Telluric Shield-Dimensions1-3
  Alphi Hova-Doradic Shield-Dimensions 4-6
  Betcha Hova-Teuric Shield-Dimensions 7-9
  Mahara Hova-*Maharic Shield*-Dimensions 10-12
  Raja Hova-Rishic Shield-Dimensions 13-15

- The **Signets** and the **Shields** can be used to direct the function of the *Kathara Level-1 12-Tree Grid* and all built upon it. **Kathara Centers** can be used to trigger activation of the *Signets* and *Shields*.

- The first **4 Hova Bodies** and their **Horizontal Shields**, are most important in terms of human evolution. Activation of the **Signets** activates their corresponding **Shield**, which in turn releases the **tissue capsules** between *Hova Bodies*, allowing merger to occur. When the **first 4 Shields** activate the body is able to integrate the Avatar identity and **transmute** into pre-matter liquid-light wave form.

- In *Kathara Healing* the Harmonic-4 **Maharic Shield** is used to restore integrity to all *Shields* and *Hova Bodies* below, which progressively clears the *Kathara Grid* of distortions.

- *Level-1 Kathara Lines* direct the **Vertical** Flash-lines, *Level-2 Crystal Seals* control the **Horizontal** Flash-lines and *Level-3 Diodic Points* govern **Diagonal** Flash-lines. Together the 3 levels of the Kathara Grid form the 3-plane armature upon which the 3-dimensional hologram is created.

SIGNETS AXIOM LINES CHAKRAS

- Each **Signet** within a Hova Body Shield holds the electro-tonal program for one *Seed Crystal Seal*. Each *Seed Crystal Seal* corresponds to one Level-1 **Kathara Center** and holds the program for one primary **Axiom Line** – a *single axis* dimensional flash-line sequence.
- The **12 Primary Axiom Line** programs of the *Seed Crystal Seals* create separate *dimensionalized bands of frequency* within each Hova Body, forming a distinction between *dimensionalized levels* within the bio-energetic **Auric Field**. The Axiom flash-lines cross over and through each other to form the *Coordinate Points* between the Shields through which the *Level-3* **Diodic Point Vortices** emerge.
- The points in the Kathara Grid where Axiom Lines cross over and through the **Central Vertical Kathara Line** in the *Level-1 Grid*, and the **Horizontal flash-lines** in the *Crystal Seals* of the *Level-2 Grid*, form **consolidated Diodic Points** with *numerous Diodic Vortices* – these are called **CHAKRAS**. Each Chakra corresponds to an *Axiom Line, Auric Level, Seed Seal, Kathara Center*, and *Dimensional Frequency Band* and **Merkaba Field**.

- The **12 Primary Axi-A-Tonal Lines** are a set of 12 *Vertical Energy Flow-lines* that run through the body, which are created by the consistent cross-over points of the rotating, single-axis flash-line sequences projected from the **Seed Crystal Seals.**

- **Axi-A-Tonal Lines 11 and 12** combine with the **Central Vertical Kathara Line** to form the **Hara Line,** the foundation of the **Central Body Current.**

- The **Hara Level** is the ***outer level*** of the **Kathara Level-2 Crystal Seals Grid,** can be viewed from *9th-Dimensional perception* and is used in Kathara Healing Level-2 .

- The *Hara Level* is composed of the **Hara Line, 6 Primary Hara Points** and the **Complexes** of energy processing they govern.

- The **Axi-A-Tonal Lines** and **Hara Level** of the *Kathara Level-2 Crystal Seals Grid* are elements of 15-Dimensional anatomy that are used in later applications of Kathara Healing.

- *Axi-A-Tonal Lines* set the core electro-tonal scalar-wave program upon which the **DNA** will manifest. The human DNA imprint contains the program for **12 strands of DNA**, one manifesting upon each of the **12 Primary Axi-A-Tonal Lines.**
- The human form was designed to embody **12 dimensions** of consciousness. The original human genetic code is called the **Silicate Matrix** and when operational it allows human cellular structure to **transmute** through ***4 Harmonics*** *of matter density*.
- The Silicate Matrix is mutated in present day humans due to ancient **Kathara Grid blockages,** which manifest as distortions of form and function within the DNA. "*Junk DNA*" is part of this distortion.
- Contemporary human DNA can be **reverse-mutated,** and its interdimensional functions restored, by applications of **Kathara Healing.**
- Each of the 12 strands of DNA *corresponds to* one of 12 *Dimensional Frequency Bands, Kathara Centers, Seed Crystal Seals, Signets, Axi-A-Tonal Lines*, and *Chakras*. Each **Hova Body Shield** governs the function of a **set of 3 DNA strands.**

THE 12 HUMAN SENSES

- The **human senses** are the *experiential result* of the *scalar standing-wave organization* inherent to the human form.

- Senses are **scalar arrangements** that *translate energy signatures* from the **Unified Field** into *usable data of relationship*.

- The sensing systems are built upon sets of **energy receivers** within the morphogenetic field that are called **APPARTHI**. The Apparthi inherent to Kathara structure serve to **block certain flash-line sequences** out of the morphogenetic field and allow others in to translate into perception.

- The flash-line sequences blocked by the Apparthi create **Gaps of Perception** of the *Unified Field*, which give us the *experience* of **externalization** and **separation of form.**

- *Apparthi receivers* create **refraction and polarization of flash-line sequences** that translate into a variety of identifiable ***holographic sensory perceptions.***

- The sense facilities correspond to the structure of the **Hova Body Shields** and **DNA.** In categorizing the interwoven sense facilities by their *primary orientation*, location of their *Apparthi receivers* within the Hova Bodies and the *experiential attributes* they produce, the human organism can be said to possess **12 Primary Senses.**
- The **5 known senses** are products of the operations of the **Nada Hova Body** and **Telluric Shield**, and thus correspond to **dimensions 1-3**.
- There are **7 as yet unidentified senses** that correspond to the higher dimensional *Hova Bodies*, *Shields* and presently dormant strands of *DNA*.
- As we evolve to *activate* and *reverse-mutate* the **DNA** imprint, through *Hova Body* alignment and merger, the experiential attributes of the higher dimensional senses will become more apparent.
- Due to their *dimensional affiliation*, the *5 known senses* can be viewed as the **Lower Senses**, the *higher dimensional senses* as the **Higher Senses.** Perception through the *Higher Senses* is called ***Higher Sensory Perception*** or **HSP.**

TAPPING THE INNER MENTOR

Levels of Consciousness and the Perceptual Bridge

In earlier text we have learned of the structure human consciousness takes when entering the scalar fields of dimensionalization for the perceivable experience of manifestation. In comprehending the true structure of multi-dimensional anatomy, with its **Kathara Grid, Hova Bodies** and **Shields, Diodic Points** and **levels of bio-energetic substance**, we can begin to see that there is much more to human consciousness than meets the eye - **much more *energy-identity* operating presently beyond the view of our 3-dimensionally focused earthly personality.**

There are portions of our consciousness stationed within the Hova Bodies of the higher dimensional fields, and these expanded levels of ourselves hold knowledge and participate in perceptual experience beyond the usual range of our waking perceptions. As we evolve and expand through **Hova Body Integration** and the resulting activation of dormant **DNA** components, we will progressively have *greater conscious access* to these expanded levels of consciousness while we are actively focused within the waking 3-dimensionally embodied state. However, **we do not have to wait until our evolution plods along to bring us to these expanded perceptual states,** we can, from our waking state of 3-dimensional consciousness begin to actively tap this hidden reservoir of knowledge and perceptual experience. **We can take an active hand in *expediting the process* of our multi-dimensional evolution by using our dimension-3 *mental body awareness* to direct our higher awareness into our current range of perception.** We can begin to build a **PERCEPTUAL BRIDGE** between our 3rd-Dimensional and Higher Dimensional consciousness. **In taking the initiative for building this Bridge of Consciousness we begin to stimulate our Higher Senses into operation, expediting the natural process of Higher Identity Integration.**

Through building a PERCEPTUAL BRIDGE between our present state of awareness and the levels of our consciousness stationed in the Higher Dimensional Hova Bodies, we can actively expedite our own Bio-Spiritual Evolution.

THE MENTOR

The Perceptual Bridge and Creating the Mentor

The Higher Dimensional levels of human consciousness are not dormant within their respective dimensional bands of function, they are quite awake and aware within their own dimensional fields. As we perceive and interact with the 3-dimensional world within which our present awareness is focused, the Higher Dimensional portions of our consciousness are also actively perceiving and interacting with the dimensional environments within which they are focused. **Higher dimensional aspects of our awareness *seem cut off* from our perceptual view because our consciousness is presently focused through a *genetic code arrangement and Kathara Grid orientation* that blocks out the frequencies of those higher stations of identity.** If we can realize that expanded portions of our consciousness simultaneously exist within the higher dimensional frequency bands, we can also realize that it is possible to access such levels of our own identity by building **Perceptual Bridges** between our 3-dimensional perspective and the portions of our consciousness stationed within the Higher Dimensional Hova Bodies.

We can begin to build a *Perceptual Bridge* between ourselves and our *Higher Selves*, by using simple *frequency modulation techniques* of Kathara Healing, such as Technique #1: *Awakening the Mentor and the 6th and 7th Senses*. In this scalar-grid activating exercise, we will awaken dormant **Partiki Phasing Flash-lines** and activate dormant portions of the **Kathara Lines** in the *Kathara 12-Tree Grid*, to begin opening the channels of communication between the consciousness focused within the *Nada Hova Body* and that focused within the *Alphi Hova Body* of Harmonic-2. **In this exercise we will create the MENTOR, a portion of our consciousness composed of *3rd, 4th and 5th Dimensional frequencies*, that will serve as an *intermediary focus of awareness* through which we can begin to receive guidance and knowledge from our 2nd-Harmonic of consciousness.** Creating the MENTOR will begin the process of activating dormant **DNA** , opening new **nerve networks** within the Central Nervous System of the 3-dimensional body, and activating dormant **APPARTHI** frequency receivers within the *Level-2 Crystal Seals Kathara Grid*. **Through creating the MENTOR, we begin to build the Perceptual Bridge between the 1st and 2nd Harmonic of our conscious awareness.**

The MENTOR is a portion of our identity that we create to serve as an intermediary focus of awareness between the Nada Hova Body and the Alphi Hova Body; a PERCEPTUAL BRIDGE between our first and second Harmonics of Consciousness.

The MENTOR and Kathara Healing

In the practices of Kathara Healing we will use the MENTOR as a source of **guidance, information retrieval, objective observation** and as a **communications link** between our own higher consciousness and the higher levels of consciousness in those who come to us for healing facilitation. **Awakening and working with the MENTOR will become a standard practice in our applications of Kathara Healing.** In creating the MENTOR we are using our creative power of scalar-grid manifestation (thoughts and mental images are scalar-grid morphogenetic field forms) to bring into being a **specialized portion of our consciousness** that can **relay frequency** from our higher Harmonics of Consciousness to our 3-dimensionally focused identity. **With repeated use of the MENTOR focus of awareness we will develop the ability to simultaneously hold 2 Harmonics of consciousness, and we will begin to reclaim the natural flexibility of focus that is the healthful condition of embodied human consciousness.** Through the MENTOR focus of attention we can reach higher levels of cognition and understanding regarding application of healing facilitation, and we will more rapidly call into awakening the Higher Sense facilities of the 15-Dimensional Anatomy.

Other Uses of the MENTOR Focus

In creating the MENTOR focus we will begin to realize that even the 3-dimensional focus of awareness with which we are most familiar is far more flexible than once supposed. The MENTOR is not simply an **inert creation,** but rather a **living** portion of our conscious identity composed of portions of the waking self and portions of the Higher Self. MENTOR can become an **advisor**, a portion of self able to "keep its head above the illusion" when you are confronted with challenging events in the 3-dimensional arena; a part of you able to remain clam, focused and able to make clear decisions beyond the confusion of mental or emotional body processing. MENTOR can be sent into the **Cellular Memory** of the body to locate core issues or reincarnational blockages, and can serve to moderate between sub-personality fragments and the "Inner Child". MENTOR can like wise be used to **harmonize communications** between self and others, as you can send the MENTOR focus into the higher dimensional fields to connect with the higher selves of others for conflict resolution. Playing with the MENTOR focus can also have great rewards. You can focus your attention in the Mentor Space and then direct the MENTOR across the room to begin practicing affects of **BILOCATION.** You can travel with MENTOR to distant locations to develop **REMOTE VIEWING SKILLS**, which will be used in later Kathara Healing levels for **REMOTE HEALING FACILITATION**. MENTOR can become a **vehicle for conscious transport** of your awareness, while awake and also in **dreaming** and **higher dimensional projection.**

TECHNIQUE # 1

AWAKENING THE *MENTOR* AND THE 6TH AND 7TH SENSES

Awakening the Mentor:

1. Place the **fingertips** of both hands and the focus of your attention at the **Navel.** Take a few slow, full breaths then visualize the image of a **Blue Flame** (like a gas stove flame) deep inside the body behind the Navel. Gently **massage** the Navel region while envisioning the **Blue Flame.**

2. **Stop massage** and visualize a **Sphere of White Light within the Blue Flame** behind the Navel. **Place your attention within the White Sphere** and imagine that you can feel its reality around you, as if you are sitting within the White Light Sphere.

3. Breath gently and visualize the **White Light Sphere moving upward** through the center of your body until it reaches the center of the brain at the **Pineal Gland. Stop movement of White Light Sphere at the Pineal Gland**, then visualize the **White Light Sphere moving to the RIGHT** in a straight, horizontal line **OUTSIDE OF THE BODY** until it is positioned in your **auric field** just above your **RIGHT SHOULDER.** ***The White Light Sphere positioned over the Right Shoulder now represents a portion of your awareness*** *that was raised to the 5th-Dimensional frequencies via its passage through the Blue Flame and the 5th Kathara Center at the Navel.* You will name this part of your higher identity **MENTOR.**

4. Imagine that you can **feel the reality of the White Light Sphere** that holds your MENTOR resting gently above your Right Shoulder as a **"fuzzy ball of energy".** ***MENTOR*** *serves as the meeting point between your waking conscious mind and the* ***5th-Dimensional portion*** *of your Soul Matrix Identity- the* ***Archetype.*** *With practice, you* ***can lean the energy of your waking awareness*** *from its position within your head, over to the right and into the* ***MENTOR Sphere,*** *to receive direct cognition, audio and visual guidance from your 5th-Dimensional Identity Station.* **In Healing Facilitation** MENTOR will communicate with the 5th-Dimensional Archetype aspect of your **Client's Soul Matrix**, asking how you may best serve the Client's Highest Evolution; guidance MENTOR receives will be translated to you from MENTOR in the form of intuitive urge, spontaneous cognition or audio-visual directions. MENTOR will also serve as a **translator of information from your higher dimensional Stations of Identity** to your conscious mind. MENTOR can also be taken into the Dream State with you to assist in **Dream Recall** and initiating **Out-Of-Body Travel.**

5. Practice creating and sensing the Mentor Sphere over your Right Shoulder. Carry it around with you wherever you go, and play with *moving the focus of your consciousness back and forth between the inside of your head and MENTOR.* Try perceiving from both focuses of attention simultaneously. Such play will help stimulate neurological sensitivities to translating and perceiving information from the 5th and higher dimensional Stations of Awareness.

TECHNIQUE # 1: continued

AWAKENING THE *MENTOR* AND THE 6TH AND 7TH SENSES

Awakening the 6th and 7th Senses: The *Audurea* and the *Tristet*

1. Focus your attention on the **MENTOR Sphere** over your Right Shoulder. Take a few slow, deep breaths and visualize MENTOR *expanding into a Sphere the size of a Basket Ball.* Use the next **INHALE** to draw the MENTOR Sphere *toward your head*, visualizing MENTOR moving from over your Right Shoulder to a position *surrounding your entire head.* **EXHALE**, *stop the movement* of the MENTOR Sphere, and imagine that you can feel its "fuzzy energy" all around the outside of your head; *as if your head is now within the Basket Ball size MENTOR Sphere.*

2. With the next **INHALE** breath, **contract MENTOR into a small Sphere of White Light** positioned inside the center of the brain at the **Pineal Gland**. Exhale and breathe slowly for a moment. With the next **EXHALE** breath, *push* the small MENTOR Sphere from the Pineal Gland, straight forward and into the **6th-Chakra** at the *Forehead*. Visualize MENTOR moving into the 6th-Chakra from inside the head, then continuing to move through the 6th Chakra spiral straight outward and *away from the body*. Imagine the MENTOR Sphere traveling outward through the long **Blue-Violet Tunnel** of the 6th Chakra spiral, until you visually loose track of the MENTOR Sphere far out in front of you.

3. Take a few slow breaths, then on the next **INHALE** visualize the MENTOR Sphere *re-appearing* in the distance of your 6th Chakra spiral, and *riding in on the inhale breath*, back into the **Pineal Gland**. Breathe slowly.

4. With the next **EXHALE**, visualize the MENTOR Sphere moving *down from the Pineal Gland* at the center of the brain, stopping at the center of the **5th Chakra** in the *Throat*. Breathe slowly. On the next **EXHALE** push the MENTOR Sphere straight outward, imagining it moving forward from inside the Throat, into the blue green spiral of the *5th Chakra*. Visualize MENTOR *riding the current of the exhale breath* out into the distance within the blue-green **tunnel** of the 5th Chakra spiral, until it fades from view. Take a few slow breaths and on the next **INHALE** imagine MENTOR returning through the 5th Chakra blue-green spiral to rest deep within the **Throat**. Use the **final INHALE** to move MENTOR back up to the **Pineal Gland** and the final **EXHALE** to *push* the MENTOR Sphere back out to its "home" position in the auric field over the **Right Shoulder**.

This process opens up the 1st-5th Sub-frequency Bands within each dimensional layer of the 6th and 5th Chakras, beginning the process of opening the 6th-Audurea and 7th-Tristet Senses, stimulating Inner Vision and Audio to higher dimensional frequency perception.

SYMBOL SHORTHAND

TECHNIQUE # 1: Condensed Version Awakening the Mentor and the 6th and 7th Senses

AWAKENING THE MENTOR

1. Finger *tips* at *Navel*, see *Blue Flame* in body behind Navel. *Massage* Navel with finger tips
2. See *White Sphere in Blue Flame* at Navel. Imagine *yourself in White Sphere*, feel it around you.
3. Move *White Sphere* up to *Pineal Gland*, see White Sphere move out over *Right Shoulder* creating your *MENTOR*
4. Feel *MENTOR* as *fuzzy ball* of energy hanging in your auric field over your Right Shoulder
5. *Practice shifting* the *focus* of your attention back and forth between usual focus and *MENTOR*

AWAKENING THE 6TH & 7TH SENSES

1. Expand MENTOR over Right Shoulder to size of *Basket Ball, INHALE* drawing *MENTOR* around your *head*, as if your head is inside the Basket Ball size energy that is MENTOR.
2. *INHALE, contracting MENTOR* into *Pineal Gland* as a small Sphere of White Light, *EXHALE* to push *MENTOR* out of *Pineal Gland out to Chakra 6* and into the *Blue-Violet Tunnel* of the Chakra 6 spiral.
3. *INHALE MENTOR back from Blue-Violet Tunnel* of Chakra 6 and into the *Pineal Gland*
4. *EXHALE MENTOR* from *Pineal Gland to Chakra 5. EXHALE MENTOR out* through *Chakra 5 Green Tunnel. INHALE MENTOR back* through *Green Tunnel* into *Chakra 5* at Throat. *INHALE MENTOR* up from *Chakra 5* to *Pineal Gland. EXHALE MENTOR* out from Pineal Gland to its "Home Station" over *Right Shoulder.*

Awakening the Mentor and the 6th and 7th Senses

AWAKENING THE MENTOR

Move MENTOR from Navel to Pineal Gland to position over Right Shoulder.

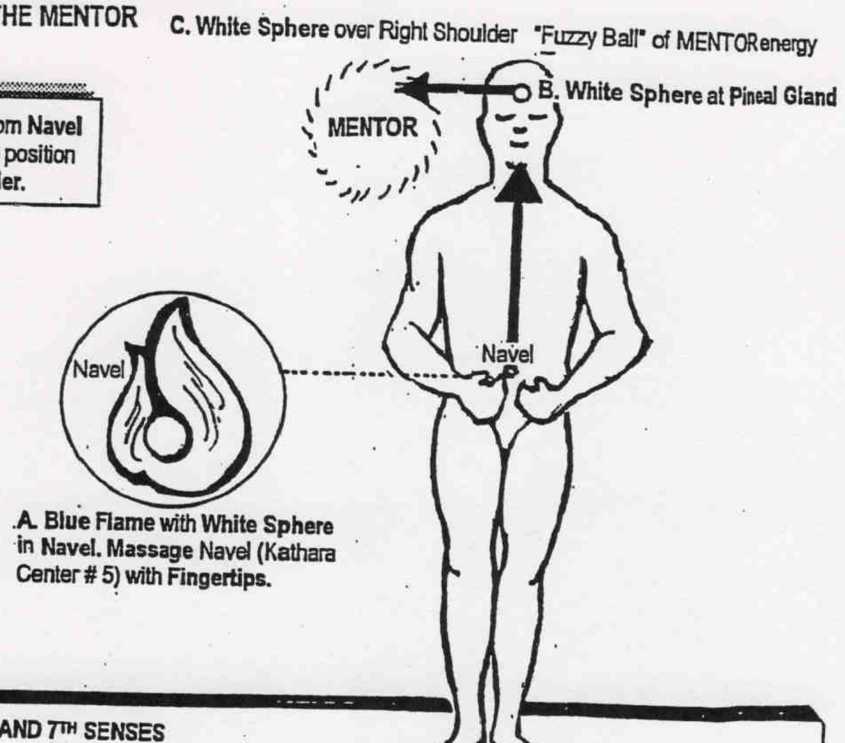
C. White Sphere over Right Shoulder "Fuzzy Ball" of MENTOR energy
B. White Sphere at Pineal Gland
MENTOR
Navel
Navel
A. Blue Flame with White Sphere in Navel. Massage Navel (Kathara Center # 5) with Fingertips.

AWAKENING THE 6TH AND 7TH SENSES

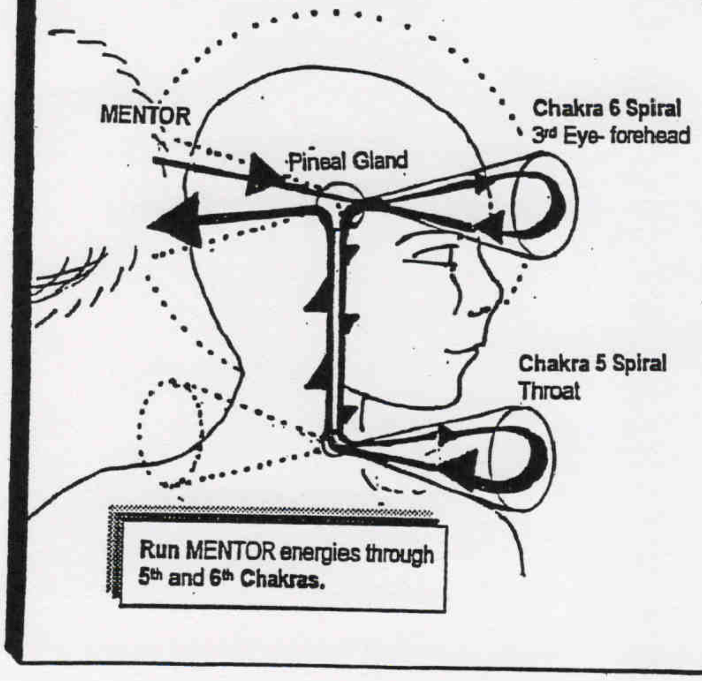
MENTOR
Pineal Gland
Chakra 6 Spiral
3rd Eye- forehead
Chakra 5 Spiral
Throat

Run MENTOR energies through 5th and 6th Chakras.

A. **Expand** MENTOR energy to **basketball size** and position **around head**

B. **MENTOR** in **Pineal Gland** as **White Sphere**

C. **White Sphere** into **6th Chakra Spiral** then **5th Chakra Spiral** and back to **Pineal Gland.**

D. Reposition MENTOR over **Right Shoulder**

MORPHOGENETIC REPATTERNING

MAHARIC RECODING, FREQUENCY SUB-HARMONICS & THE MAHARIC SEAL

Kathara Healing and Reaching the Core of Dis-ease

In earlier text we have explored the significance of the **Kathara Grid** and its role as the **Holographic Template** upon which the morphogenetic field, body and consciousness manifest within the 15-Dimensional system. We have learned that the Kathara Grid is the **core template** upon which the *morphogenetic field* manifests, and that the *morphogenetic field* is the **blueprint** upon which the body systems and embodied consciousness manifest. Through our study of these *core structures of manifestation* we come to realize that *true and lasting health or healing* must be approached from the deepest levels of personal creation, the *morphogenetic reality* within which all dis-ease conditions have their origin. **Kathara Healing applications are intended to reach the *core of systems malfunction*, the various levels of the *morphogenetic field and Kathara Grid*, in order to restore the *Imprint for Health* within the Holographic Template for manifestation.**

The Mahara Hova Body, Maharic Shield and the Imprint for Health

In *Level-1 Kathara Healing* we will learn the first and most important level of *restructuring the Holographic Template* to hold its original Imprint for Health - the MAHARIC RECODING PROCESS. The **MAHARIC SHIELD** is the manifestation template upon which the **MAHARA HOVA BODY** of *Harmonic-4* manifests. The Mahara Hova Body is the scalar-grid that holds the **10th, 11th and 12th-Dimensional** aspects of consciousness, and represents the **ORIGINAL POINT OF MANIFESTATION** -the **creation point** when consciousness moved from its pure scalar-wave state of being into the dimensionalized scalar-grids through which the illusion of external holographic projection could be experienced. The Mahara Hova Body and its station in Harmonic Universe-4 represent the original **PRE-MATTER LIQUID LIGHT** fields of manifestation through which we passed in order to enter the experience of density and individuation of matter form.

Prior to our entering the dimensionalization of the systems within which matter can be perceived, we existed in **pure scalar-wave form** - a scalar-pattern that held the **original, pure and perfect pattern** for our creation as consciousness. The Mahara Hova Body and the Maharic Shield are the Liquid Light Pre-matter Scalar-templates that hold our original pattern of wholeness, our original **CREATION IMPRINT**. Our creation imprint is the **ORIGINAL IMPRINT FOR HEALTH**, the condition of **eternal being** free from Hova Body distortions picked up in the lower dimensional fields.

THE 12th-DIMENSION and FREQUENCY SUB-HARMONICS

In Level-1 Kathara Healing we will utilize the *Imprint for Health* as held within the *Maharic Shield* to begin REPATTERNING the Kathara Grid back to its original level of function. The frequencies of the **12th-Dimension**, as embodied within the **Maharic Shield**, contain within them as **Frequency Sub-Harmonics** ALL OF THE FREQUENCY BANDS FROM THE DIMENSIONS BELOW, along with the natural frequency spectra characteristic to the 12th-Dimension. Each Dimensional Frequency Band within the 15-Dimensional Spectra contains within itself its own **12 Primary Sub-frequency Bands** (portions of the whole dimensional Partiki Phasing flash-line sequences), plus a **reflection set** of the frequency spectra from **all of the Dimensional Bands below.**

For example, Dimension 2 contains its own *12 Primary Sub-frequency Bands*, **plus** *a reflection set of the 12- Primary Sub-frequency Bands* that make up the *Dimension-1 Frequency Band* below. Dimension-1 has 12 Primary Sub-frequency Bands, Dimension-2 thus has 12 Primary Sub-Frequency Bands plus 12 Secondary Sub-Frequency Bands from Dimension-1for a total of *24 Sub-Harmonics* in Dimension 2. **This pattern of FREQUENCY SUB-HARMONICS builds upward through the 15-Dimensional Scale. The 12th-Dimensional Frequency Band has a total of 144 Sub-Harmonics** - 12 Frequency Bands x 12 Sub-Frequency Bands each = *144 Sub-Harmonic Frequency Bands*. Because the 12th-Dimension holds within itself *all of the Frequency Spectra and scalar-grid programs* from the lower dimensions, the *12th-Dimensional Frequencies have the ability to "plug into" and override any Partiki Phasing flash-line pattern from the lower dimensional fields.* **The ORIGINAL PATTERN OF CREATION for the lower dimensional structure itself is held within the *12th-Dimensional Frequencies*, and so the 12th-Dimension *Sub-Harmonics* can be used to *correct any distortion* with the dimensional frequencies of the Lower Hova Bodies and their Shields.**

The Maharic Shield and the 12th-Dimension

As the Maharic Shield and Mahara Hova Body are composed of 10th, 11th and 12th-Dimensional scalar grids, they contain within them the **144 Frequency Sub-Harmonics** of the entire 12-Dimensional Spectrum. The human morphogenetic field is designed to hold the 144 Sub-Harmonic Spectrum, which is fulfilled through activation of the original **12-Strand DNA Silicate Matrix** gene code. Because of its 144 Sub-Harmonic scalar-wave spectrum, the 12th-Dimensional level of the **Maharic Shield** can **reset** the *original, non-distorted imprint of Partiki Phasing flash-line sequences* within the entire *Kathara Grid 12-Tree, the Kathara Centers, Kathara Lines, the Hova Bodies, DNA* and within any level of the morphogenetic field and manifest body built upon them. The *Maharic Shield* is the Kathara **RESET BUTTON.**

Frequency Sub-Harmonics in the 15-Dimensional Scale

Dimension (Primary SFB + Secondary SFBs)	Dimension x 12-SFB each =	**# of Frequency Sub-Harmonics**
Universal Morphogenetic Field: (cannot fully process through the human gene code for embodiment)		
Raja Hova Body-RISHIC SHIELD		
D-15 (12 + 168 =)	15 x 12 =	180 **Frequency Sub-Harmonics**
D-14 (12 + 156 =)	14 x 12 =	168 **Frequency Sub-Harmonics**
D-13 (12 + 144 =)	13 x 12 =	156 **Frequency Sub-Harmonics**
Human Morphogenetic Field: **(can process through gene code via 12-Strand DNA Silicate Matrix)**		
Mahara Hova Body- MAHARIC SHIELD		
D-12 (12 + 132 =)	**12 x 12 =**	**144 Frequency Sub-Harmonics**
D-11 (12 + 120 =)	**11 x 12 =**	**132 Frequency Sub-Harmonics**
D-10 (12 + 108 =)	**10 x 12 =**	**120 Frequency Sub-Harmonics**
Betcha Hova Body- TEURIC SHIELD		
D-9 (12 + 96 =)	**9 x 12 =**	**108 Frequency Sub-Harmonics**
D-8 (12 + 84 =)	**8 x 12 =**	**96 Frequency Sub-Harmonics**
D-7 (12 + 72 =)	**7 x 12 =**	**84 Frequency Sub-Harmonics**
Alphi Hova Body- DORADIC SHIELD		
D-6 (12 + 60 =)	**6 x 12 =**	**72 Frequency Sub-Harmonics**
D-5 (12 + 48 =)	**5 x 12 =**	**60 Frequency Sub-Harmonics**
D-4 (12 + 36 =)	**4 x 12 =**	**48 Frequency Sub-Harmonics**
Nada Hova Body-TELLURIC SHIELD		
D-3 (12 + 24 =)	**3 x 12 =**	**36 Frequency Sub-Harmonics**
D-2 (12 + 12 =)	**2 x 12 =**	**24 Frequency Sub-Harmonics**
D-1 (12 + 0 =)	**1 x 12 =**	**12 Frequency Sub-Harmonics**

REMEMBER: A **FREQUENCY BAND** is a *fixed, repeating sequence* of *Partiki Phasing Flash-lines* - **"flashing on and off" cycles of scalar standing-wave points** within the scalar-grid template, caused by the *fission/ expansion and fusion/ contraction of Partiki Units*. A **SUB-FREQUENCY BAND** is a *fixed, repeating sequence of Flash-lines* that is *part of* the full cycle of the *Frequency Band* Partiki Phasing sequence. A **FREQUENCY SUB-HARMONIC represents a replica of Frequency Band Flash-line sequences from the dimensions below, carried within the Primary Flash-line sequences of the Dimensions above.**

HIGHER DIMENSION = MORE FREQUENCY SUB-HARMONICS = FASTER FLASH RATES = HIGHER FREQUENCY = FASTER OSCILLATION/ SLOWER VIBRATION = SHORTER WAVE LENGTH = SLOWER ELECTRON SPIN = LESS PERCEIVABLE MATTER DENSITY

The Maharic Shield - Core of Healing Therapeutics

To restore the **Imprint for Health** within the *Body-Mind-Spirit System*, the **Holographic Template of scalar-grids** upon which the system manifests must be **restored to its original function.** *Topical applications* of healing modalities within the physical body, bio-chemistry, DNA, Auric Field, Chakra System, and Level-2: Crystal Seals and Level-3: Diodic Points of the Kathara Grid can create *temporary change* toward healing, but the **disharmonic conditions** held within the core **Level-1 12-Tree Kathara Grid** will eventually **override** alteration made to the outer levels of the morphogenetic field or body systems. **Working with outer levels of the Bio-system can *assist* in the healing process, but first the *Imprint for Health* must be restored within the *Level-1 12-Tree Kathara Grid.*** The *Level-1 12-Tree Grid,* with its *Kathara Centers* and *Kathara Lines* is created upon the **144 Frequency Sub-Harmonic** Pattern. As the **Maharic Shield** and Mahara Hova Body are the only portions of the dimensionalized scalar-grid anatomy that hold the full **12th-Dimensional Frequency Band** with its *144 Sub-Harmonics*, the **Maharic Shield** and its corresponding **10-11-12 Kathara Centers** are the *only portions of the morphogenetic anatomy that can override and restructure the electro-tonal scalar standing-wave point arrangements within Level-1 Kathara Grid.* **Thus it is with the *Maharic Shield* that core healing therapeutics must begin.**

Critical Mass and Simultaneous Healing of Core/ Outer Morphogenetic Levels

Activating the **Maharic Shield** will **open, activate and realign** the *scalar-wave flash-line sequences* of dormant *Kathara Centers, Kathara Lines, Crystal Seals, Hova Bodies, Diodic Points, Chakras* and *DNA* within the outer levels of the morphogenetic field and body. Once the **Imprint for Health** has been *temporarily restored* within the *Core Holographic Template Kathara Grid* via running the *Flash-line sequences* of the **Maharic Shield** through the *Level-1 Kathara Grid*, the *outer layers of the anatomy can be further realigned* to expedite manifestation of the Kathara Grid Repatterning into the outer levels of the Bio-system. **Technique # 2: The Maharic Seal and the Liquid Light Cleanse**, begin the process of running the 12th-Dimensional Flash-line sequences, via their Frequency Sub-harmonics, through the Kathara 12-Tree Grid to **REPATTERN** *distorted flash-line sequences* within the core Holographic Template. In the beginning of using this technique, the affects of this reprogramming will last only several hours, as the outer levels of the Bio-field will have greater "**Critical Mass**" in their distortion patterns, than the Kathara Grid can immediately override. **Full healing comes when the renewed Imprint for Health reaches CRITICAL MASS within the morphogenetic field.** Critical Mass is reached via *frequent use of the Maharic Seal* and *outer level Bio-field therapeutics.*

Kathara Healing Theory and Applied Methods

In Kathara Healing the first priority is to *reset the integrity* of the *Kathara Level-1; 12-Tree Grid* by Re-patterning its flash-line sequence program to the *Maharic Shield* via the *Maharic Seal and Liquid Light Cleanse*. This process sets the electro-tonal **"ground"** within which alterations of *outer morphogenetic levels* can connect, reawakening dormant **APPARTHI** *frequency receivers* within the *Level-2: Crystal Seals*, which allows the morphogenetic field levels to *expand* enough to hold the *higher frequencies* of the *Imprint for Health*. After the **Healing Ground** is set within the *Kathara Grid*, additional applications of Kathara Healing can then be applied to various other levels of the Kathara Grid, Morphogenetic Field and Body. **There is an infinite variety of Kathara Healing Bio-energetic applications**, that range from Levels 1, 2 and 3 Kathara Grid work, reprogramming the Kathara Centers, Kathara Lines, Hova Bodies, Shields and Signets, reversing the Miasmic/Karmic Imprint and accelerating the opening of the Diodic Points, to working with the Chakra System, Meridian and Axiom Lines, DNA and physical body points while running the Triadic Currents for healing. In coming Levels of the *Kathara Healing Program* we will learn the use of the **GEOMANCIES** and **FIRE LETTERS**- key **Symbol Codes** that serve as **scalar-wave guides** to reset the electro-tonal *flash-line sequences* within the morphogenetic body, and the application of the Symbol Codes to the treatment of specific physical, emotional, mental and spiritual dis-ease conditions. We will explore working with the **Color Cap Stones** of the Dimensional Frequency Bands and how they can be used in combination with the Symbol Codes for use in **Manifesting** desired conditions and **De-manifesting** undesirables, both within the body and in the 3-dimensional life drama.

Applications of the Level-1 Kathara Healing Program

In Program Level-1 we are setting the foundations upon which all the other skill levels of Kathara Healing are built. The focus of the Level-1Program is to create Morphogenetic Repatterning via the Maharic Shield, and to begin clearing the Miasmic/ Karmic Imprint that blocks various areas of the Hova Body Imprint. We will next learn to add **FORCE AND POWER** to our *Morphogenetic Recoding Process* by opening the **PLANETARY BIO-FEED INTERFACE SYSTEM™** to draw energy directly from the **Planetary Maharic Shield**, and we will begin learning of the *physical body massage point sequences*- **Sequence 1 and 2 Kathara Points** - through which we can begin to *regulate the flow of energy within the Bio-system* for **Regeneration** of the Imprint for Health and **Revitalization** of the Body-Mind-Spirit System. In **Section 2** of this course we will explore **MULTI-VECTOR HOLOGRAPHIC RECODING** - clearing the *Miasmic Imprint* from the Kathara Grid.

SEQUENCE 1 AND 2 KATHARA POINTS

Sequence-1 Kathara Points for REGENERATION

Sequence-1 Kathara Points are mini-energy-vortex points in the body that connect directly to **Diodic Points** within the *Kathara Level-3 Diodic Points Grid.* Stimulation of the Kathara Points affects the movement of energy within related areas of the Kathara Grid, which creates a reciprocal movement of energy within the cellular structure corresponding to the Kathara Points.

When used **in proper sequence,** *Sequence-1 Kathara Points* ***open energetic gate ways to the Kathara Lines*** of the Kathara Level-1 12-Tree Grid, allowing patterns of frequency to be entered into the Kathara Lines, to realign disharmonic patterns of frequency running through the Holographic Program of the Kathara Lines. When the Kathara Lines are opened to receive **11th** and **12th** dimensional frequency infusions from the **Mahara Hova Body,** the Holographic Program of the Kathara Grid can be progressively ***regenerated*** to the Imprint for Health, as held within the program of the Maharic Shield.

Sequence-1 Kathara Points are used to *open* the Kathara Lines prior to *Technique # 2: The Maharic Seal and the Liquid Light Cleanse* and *Technique # 4: The Maharic Infusion.* They **may also be used alone** with deep breathing, for frequent healing support, to draw energy up from the Maharic Shield, re-balancing and regenerating the Imprint for Health within the Kathara Grid and Body-Mind-Spirit System. It is not necessary to close the Kathara Lines after using Sequence-1 Points as they will **close automatically** in **several hours.** If one desires to further revitalize the cellular structure, running the *Sequence-2 Kathara Points* for *closing* the Kathara Lines will increase the amount of energy running through the *body cells,* as the Kathara Lines are no longer absorbing the energy.

Sequence-1 Points **regenerate and re-balance the *Kathara Core* first, which creates *more lasting but less immediate* changes in the body. *Sequence-2 Points* close the Kathara Lines if they are opened and draw energy from the Maharic Shield *directly into the bio-energetic field and physical cells,* rather than the core Kathara Grid, creating *more immediate, but temporary,* revitalization of the body.** The patterns held within the Kathara Grid- core holographic template will eventually override those set into the bio-energetic field alone. **Used in *combination* with each other the *Sequence-1 and Sequence-2 Kathara Points* can affect more lasting revitalization by *simultaneously realigning the core template and the outer layers* of the bio-energetic system and cellular structure.** In combination with other Kathara Healing techniques the affects and restoration of the Imprint for Health are further amplified and accelerated.

Sequence-2 Kathara Points for REVITALIZATION

Sequence-2 Kathara Points are mini-energy-vortex points in the body that, like *Sequence-1 Kathara Points*, connect directly to **Diodic Points** within the *Kathara Level-3 Diodic Points Grid.* Stimulation of the Kathara Points affects the movement of energy within related areas of the Kathara Grid, which creates a reciprocal movement of energy within the Bio-Field and cellular structure corresponding to the Kathara Points.

When used **in proper sequence,** *Sequence-2 Kathara Points* ***close the energetic gate-ways to the Kathara Lines*** of the Kathara Level-1 12-Tree Grid, which the *Sequence-1 Kathara Points* had opened. Closing of the Kathara Lines governed by the Sequence-1 Kathara Points, ***creates a reciprocal OPENING of Nadial Lines (Nadis*** energy rivulets that carry energy from the Nada Hova Body/ Nadial capsule, into the physically manifest systems**)** within the *outer levels* of the Bio-energetic Field. Opening of corresponding Nadis allows restorative patterns of frequency to be entered into the **outer levels** of the Bio-energetic Field and Chakra System, to realign disharmonic patterns of frequency running through the *Chakras, Auric Field and Physical Cells.* When the Nadis, Chakras and outer Bio-energetic Field are opened to receive 11th and 12th dimensional frequency infusions from the **Mahara Hova Body,** the energetic integrity of the physical cells and Bio-energetic Field can be progressively ***revitalized*** with Maharic frequency and the Imprint for Health, as held within the program of the Maharic Shield.

Sequence-2 Kathara Points are used to *close* the Kathara Lines following *Technique # 4: The Maharic Infusion.* They may also be used alone with deep breathing, for frequent healing support, to draw energy up from the Maharic Shield, through the Kathara Grid and into the **outer levels** of the Bio-energetic Field. Directing Maharic frequency into the outer levels of the Bio-energetic Field regenerates the Imprint for Health within, and directly **revitalizes** the *body cells* for accelerated Body-Mind-Spirit healing. If one desires to revitalize the cellular structure, running the *Sequence-2 Kathara Points* for closing the Kathara Lines will **increase the amount of energy running through the *body cells*,** as the Kathara Lines are no longer absorbing the energy. **Sequence-2 Points revitalize and rebalance the *outer levels of the Bio-energetic Field* first, which creates more immediate but temporary revitalization of the body, as restorative energies do not directly enter the Level-1 Kathara Grid.** To create *lasting change* when using the *Sequence-2 Points* alone, restorative electro-tonal programs must be **repeatedly** entered into the Bio-energetic field until the new programs reach **critical mass,** at which time the new programs will begin to *subtly influence* the programs held within the Kathara Grid. **The primary difference between Sequence-1 and Sequence-2 Kathara Points is this: *Sequence-1 Points*** channel energy from the Maharic Shield into the ***core Kathara Grid*** holographic template. ***Sequence-2 Points*** channel energy from the Maharic Shield into the ***outer levels of the Bio-field and body cells*. For this reason the affects of *Sequence-2 Kathara Points* are more *immediate*, and those of *Sequence-1 Kathara Points* are more *permanent*.**

The patterns held within the Kathara Grid core holographic template eventually override those set into the outer Bio-field alone. **Used in *combination* with each other and other healing applications the *Sequence-1 and Sequence-2 Kathara Points* can affect more lasting revitalization by simultaneously *realigning the core template and the outer layers* of the Bio-field and cellular structure.** Using ***Kathara Point Sequences*** in combination with each other and other Kathara Healing techniques will amplify and accelerate the affects and restorative function of the Imprint for Health within the Body-Mind-Spirit system.

14 SEQUENCE 1 KATHARA POINTS

Regeneration of the Imprint for Health

Sequence-1 Kathara Points **OPEN** energetic gate-ways within the **Kathara Lines** of the *Kathara Level-1 12-Tree Grid*, to receive electro-tonal reprogramming for **regeneration** of the *Imprint for Health*. *Sequence-1 Points* are used to open the Kathara Lines **prior to** other energy-healing applications, to open the Kathara Grid so the regenerative patterns of other healing applications can "ground" within the Kathara. Sequence-1 Points re-generate and rebalance the **Kathara Core** first, creating **more lasting but less immediate changes** in the body.

1............CROWN
2 & 3.......TEMPLES
4.............BASE OF SKULL
5 & 6........BELOW SHOULDERS
7 & 8........ABDOMEN IN FROM HIPS
9 & 10......BACKS OF KNEES
11 & 12....SOLES AND TOPS OF FEET
13............4TH HEART CHAKRA
14............6TH THIRD EYE CHAKRA

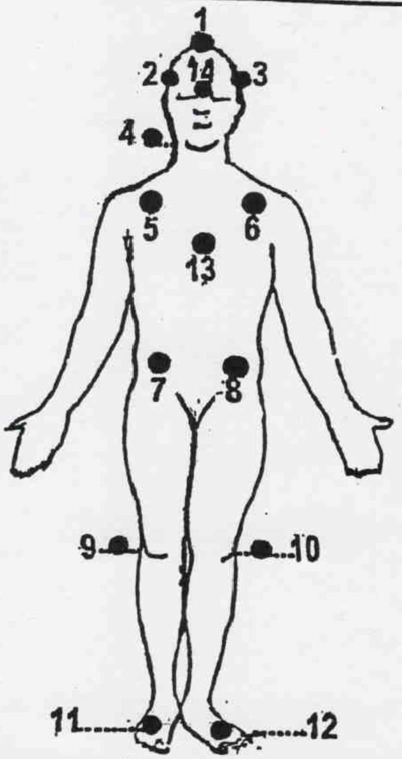

Instructions: Breathe slowly and deeply. Imagine a flow of energy running from the **Maharic Shield** (12" below feet), up into the body through the **soles of the feet** and the **1st Chakra**. Gently **rub** the *Kathara Points* with fingertips for 10 – 20 seconds each, following the **precise sequence** described above.

14 Sequence-1 Kathara Points for Regeneration

LOCATION & APPLICATION SEQUENCE

1............CROWN

2 & 3.......TEMPLES

4.............BASE OF SKULL

5 & 6.........BELOW SHOULDERS

7 & 8.........ABDOMEN IN FROM HIPS

9 & 10......BACKS OF KNEES

11 & 12....SOLES AND TOPS OF FEET

13............4TH HEART CHAKRA

14............6TH THIRD EYE CHAKRA

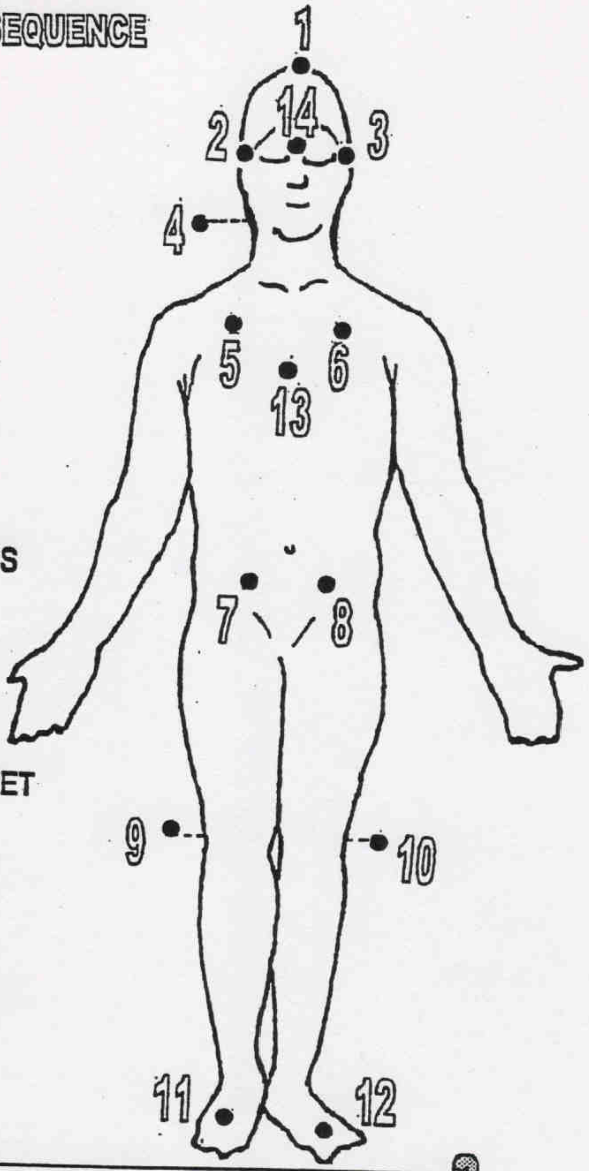

Instructions: Breathe slowly and deeply. Imagine a flow of energy running from the **Maharic Shield** (12" below feet), up into the body through the **soles of the feet** and the **1st Chakra**. Gently **rub** the *Kathara Points* with fingertips for 10 – 20 seconds each, following the **precise sequence** described above.

6 SEQUENCE 2 KATHARA POINTS

Revitalization of the Imprint for Health

Sequence-2 Kathara Points **CLOSE** energetic gate-ways within the **Kathara Lines** of the *Kathara Level-1 12-Tree Grid*, to direct restorative frequencies into the **outer levels of the Bio-energetic Field** for **revitalization** of the *Imprint for Health* within the physical cells. *Sequence-2 Points* are used to close the Kathara Lines **following** use of the *Sequence-1 Kathara Points* or other energy-healing applications, to close the Kathara Grid so revitalizing frequencies can directly enter various *outer levels* of the Bio-energetic Field, such as the **Auric Levels, Chakras, Meridians, DNA** and **physical cells**. Sequence-2 Points revitalize and rebalance the **outer levels of the Bio-energetic Field** first, creating **more immediate but temporary changes** in the body.

1 & 2........NECK, BELOW EARS

3 & 4........BELOW CHEEKBONES

5..............BASE OF TAILBONE

6..............THYMUS

*** AMPLIFER –3RD SOLAR PLEXUS CHAKRA**

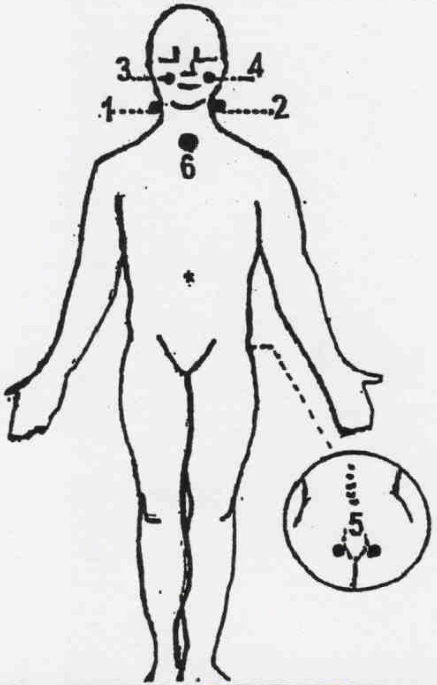

Instructions: Breathe slowly and deeply. Imagine a flow of energy running from the **Maharic Shield** (12" below feet), up into the body through the **soles of the feet** and the **1st Chakra**. Gently **rub** the *Kathara Points* with fingertips for 10 – 20 seconds each, following the **precise sequence** described above.

6 Sequence-2 Kathara Points for Revitalization

LOCATION & APPLICATION SEQUENCE

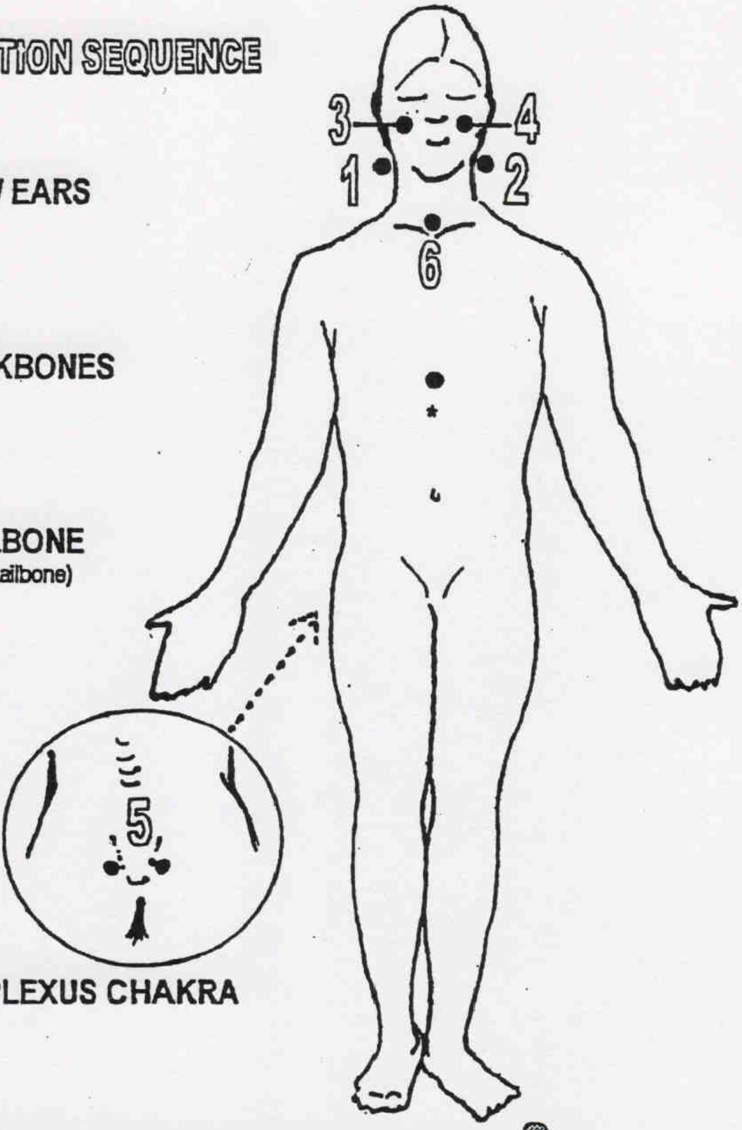

1 & 2……..NECK, BELOW EARS

3 & 4……..BELOW CHEEKBONES

5…………..BASE OF TAILBONE
(one point on each side at base of tailbone)

6…………..THYMUS

* AMPLIFER – 3RD SOLAR PLEXUS CHAKRA

Instructions: Breathe slowly and deeply. Imagine a flow of energy running from the **Maharic Shield** (12" below feet), up into the body through the **soles of the feet** and the **1st Chakra**. Gently **rub** the *Kathara Points* with fingertips for 10 – 20 seconds each, following the **precise sequence** described above.

TECHNIQUE # 2

THE *MAHARIC SEAL* AND THE *LIQUID LIGHT CLEANSE*

1. Close your eyes and visualize the image of a flat (2-dimensional line drawing) 6-Pointed Star of David (**The Merkaba Star**) made of **White Light**, stationed at the **6th-Chakra** on the *inside of the Forehead.* (If you cannot yet generate inner visualizations, simply imagine that the symbol is there.) Continue to visualize or imagine, and move the **White Merkaba Star** image over toward the **left** in your inner field of vision. In the *center* of your inner field of vision, visualize/ imagine the image of *another Merkaba Star*, made of a **Dark Silver Light**. Observe or imagine the **2 Merkaba Stars** in your inner field of vision and then slowly *move the images toward each other* until they have merged into *one Merkaba Star* Symbol made **of Pale Silver Light**. (The *Pale Silver Double Merkaba Star Symbol* is called the **HIEROPHANT** – it is the scalar wave template that governs the release of phase-lock on the *Maharic Shield.)*

2. Visualize/ imagine the Hierophant Symbol clearly in mind, then shift attention to the sound of your breath. Take several slow, deep breaths. On the next **EXHALE** use the force of breath to *forcefully push* the **Hierophant** down from its position at the 6th-Chakra, through the *Central Body Current* and into the **Earth's Core.** Take a few more slow breaths while visualizing/ imagining the Hierophant Symbol in the center of the Earth's core. Imagine now that the *Hierophant begins to spin in the Earth's core*, the Dark Silver Merkaba Star and the White Merkaba Star spinning in *opposite directions.* Spin the Hierophant progressively faster until it "takes on a .life of its own", and suddenly "pops and expands" to form a **Pale Silver Sphere of Light** *spinning in the Earth's core.*

3. Observe the Pale Silver Hierophant Sphere spinning in Earth's core, then visualize/ imagine that a **huge, horizontal Pale Silver spinning disc** emerges out from the Hierophant Sphere, forming a **massive Pale Silver Disc of Light** *spinning throughout the Earth and extending outward into the atmosphere* as a **rotating, horizontal plane.**

This horizontal disc-plane extending through the Earth represents the *Mahara Hova Body*, or **Maharic Shield** of the planetary morphogenetic field – the Pre-matter Liquid Light scalar grid composed of frequency from dimensions 10, 11 and 12. (Known as the ***Shield of Amaratena***). Using the Hierophant wave template you have now activated the planetary Maharic Shield, ***opening the Planetary Bio-feed Interface System™ into your bio-energetic field.*** This constitutes opening your personal Kathara Grid and morphogenetic field into the Planetary Kathara Grid and morphogenetic field, allowing you to draw an *unlimited supply of energy* from the planetary field. You can draw in only as much as your personal morphogenetic field can hold. With repetition of this practice the energy-holding capacity of your Kathara Grid progressively increases, allowing you *a continually expanding supply of energy* for healing and revitalization.

TECHNIQUE # 2: Continued
THE *MAHARIC SEAL* AND THE *LIQUID LIGHT CLEANSE*

4. While remaining aware of the *Planetary Maharic Shield* spinning on a horizontal plane throughout the Earth's body, return the focus of your attention to the spinning **Silver Hierophant Sphere** rotating at Earth's core. (You will now use the Hierophant Sphere to activate your **personal Maharic Shield** and release the 12th-Dimensional Pillar of Light within your bio-energetic field.). Take several slow, deep breaths, while visualizing/imagining the Hierophant Sphere spinning in Earth's core. On the next **INHALE**, draw the Hierophant Sphere *up from Earth's core* with the inhale breath, forming a **Pale Silver Cord** *about 6" thick* trailing behind the Hierophant as it rises to the **12th Chakra**, 6" beneath the feet. *One end of the Silver Cord remains rooted in* ***Earth's core****, the other end is attached to the* ***Hierophant Sphere*** *and follows its movement.* Visualize the **12th Chakra** as a small, **transparent disc** about *3" in diameter*, positioned *6" below the feet*. Stop the movement of the Hierophant in the *center of the 12th Chakra*, imagine the Sphere beginning to spin and *visualize the diameter of the 12th Chakra disc expanding to about 6" in diameter*, as the Hierophant spins at its center. Take a few slow, deep breaths as the *Hierophant spins in the center of the* ***12th Chakra.***

5. On the next **INHALE** draw the Heirophant Sphere *up from the 12th Chakra*, through the **Central Body Current** and up to the **14th Chakra** *36" above the head*. As the Hierophant Sphere rises, visualize the *6" thick* **Silver Cord** drawing up through the **12th Chakra** and farther up through the **Central Body Current,** following the path of the Hierophant Sphere to the **14th Chakra**. Visualize the Silver Cord as a long, thick **Pale Silver Cord of Light**, running from the *Earth's core, through your body and out the top of your head*, connecting to the **14th Chakra** 36" above the head. Take several deep, slow breaths while imagining that you can *feel the sensation* of this *massive current of clear, pure energy* running through the *center* of your body.

6. On the next **EXHALE**, push the spinning Hierophant Sphere *down* through the **Central Body Current,** while leaving the *top end* of the Pale Silver Cord attached to the **14th Chakra** 36" above the head. Move the Hierophant down through the **12th Chakra** 6" below the feet, and **stop the Hierophant** *6" below the 12th Chakra;* a position about **12" below the feet.** This is the location of the **Maharic Shield** within the morphogenetic field of the body. Breath slowly and visualize the Hierophant *spinning progressively faster* 12" beneath the feet, until the Hierophant "takes on a life of its own" and suddenly "*pops and expands*" to **form an expanding horizontal disc of Pale Silver Light spinning 12" beneath the feet.** ***Feel the disc as a circular platform 3 yards in diameter below feet.***

TECHNIQUE # 2: Continued
THE *MAHARIC SEAL* AND THE *LIQUID LIGHT CLEANSE*

7. Call to mind the image of the *massive horizontal disc of Pale Silver Light* spinning through the Earth's body – the **Planetary Maharic Shield**. Imagine the sensation of the large, spinning *Pale Silver platform disc* spinning 12" beneath your feet – your **personal Maharic Shield**. Breathe slowly and deeply while visualizing/ imagining a *massive rush of pure, cool* ***Pale Silver energy*** running from the *planetary Maharic Shield*, up through the **Pale Silver Cord** and into the *personal Maharic Shield* 12" beneath your feet. Breath as this energy runs, *filling your Maharic Shield to its energy-holding capacity*. When your Maharic Shield has received as much Pale Silver energy as it can hold, it will "take on a life of its own", and suddenly "*pop and expand*" upward into an ***oscillating Pale Silver Pillar of Light*** *surrounding and permeating the body*, a *tube of light* extending beyond the body *about 18"*, and running from the **Earth's Core** to the **14th Chakra** 36" above the head. *Feel the reality of your body encased in the cool, refreshing Pale Silver Pillar of oscillating light.* Take a few slow deep breaths and imagine the energy from the Pillar *emanating through all of your body cells*. Your Bio-energetic Field is now sealed with a protective barrier of 11th/12th-Dimensional frequency – **the Maharic Seal.**

8. As the Pale Silver Pillar of Light oscillates around you, place your attention for a moment at the **13th Chakra** in Earth's core and **INHALE** a final **Spark** of *Pale Silver Light* from Earth's core, drawing the Spark up through the **Pale Silver Cord**, into the **Main Vertical Channel of the Kathara Grid**, and into the center of the **4th Heart Chakra**. Breath slowly and easily while visualizing energy from the *Silver Spark* radiating throughout the embodied **12-Tree Kathara Grid**, *filling it with Pale Silver Light.* When the Kathara Grid has reached its energy-holding capacity, the ***12th Chakra*** *will automatically contract* to decrease the flow of Silver Light from the Earth's core. As the 12th Chakra contracts, the *Planetary Maharic Shield* stops spinning and transmitting energy through the Silver Cord, returning the Silver Chord to its dormant state. The ***Maharic Seal*** **Pale Silver Pillar of Light** will remain in your bio-energetic field between **1-3 hours**. Over a *3-month period* of frequent, consistent *daily practice* of this process, the Maharic Seal will self-sustain in the bio-energetic field for **12-14 hours.**

Use of this technique allows a healing Facilitator to activate the **Maharic Shield** and **Seal** in others, through the ***Maharic Infusion process*** (Technique # 4), while Facilitator's Pillar remains active. Progressive use of the Maharic Seal and running the Liquid Light creates a reciprocal clearing, reordering and realignment of the Kathara Grid-*Holographic Template* – and all subtle energy and physical systems built upon it. The Lower Hova Bodies are progressively cleared and realigned with the *original perfection of the Pre-matter Liquid Light* ***Mahara Hova Body***, and the body and genetic code progressively expand to hold higher dimensions of conscious awareness.

TECHNIQUE # 2B: THE MAHARIC QUICK SEAL

1. Work with a 24 pointed, 3 Dimensional Star (Heirophant) and be aware that you will be working with beings known as the Breneau Rishi ...

2 Begin by slowing your breathing , as you imagine or visualize a 24 point, 3 -Dimensional, Heirophant at the Pineal Gland in the center of your brain. Visualise the Heirophant surrounded by a Pale Blue Sphere of Light.

(The Blue Sphere serves as a buffer for your readiness to accept the frequencies associated with using the 24 pointed Star; the Blue Sphere holds the energy for you until your body can handle the energy. If you can handle it, the energy will simply pass through the blue sphere).

3 INHALE, as if you are going to grab the blue sphere containing the 24 point star located at the Pineal, and on the EXHALE move the 24 point star/ blue sphere, all the way down to Earth's Core. Try to hear a sound tone as the Heirophant/ Sphere hits the Planetary Shield ...

4 INHALE and draw the Heirophant/ sphere up to your Personal Maharic Shield 12" below your feet ... and EXHALE while watching the Pale Silver-Blue sphere expand out to a large sphere ... and watch as your Maharic Shield pop out as a disc, about 4' in diameter, Pale Silver with a light coating of Pale Blue.

5 Bring your attention to the center of your Maharic Shield 12" below your feet ... and INHALE the 24 point Star (only) up into the Heart Chakra. EXHALE, expanding the frequencies of the 24 point Star into the Heart Chakra.

6 INHALE to grab the 24 point Star, and EXHALE, pushing the Star up into the 14th Chakra 36" above the head. Imagine that the 24 point Star is spinning in a clockwise direction in the 14th Chakra. As you do this, try to feel/ sense the energy around you, just a few inches out from your body ...

7 Now, put your attention into your Maharic Shield 12" below your feet, take a couple of relaxing breaths and INHALE deeply pulling the Pale Silver and Blue energy up, as if you are pulling on your Maharic Seal to latch it on to your 14th Chakra. Try and feel the sensations just a few inches from your body now – feel the difference if you can. This procedure gives you a Quick Seal.

8 Now envision the cord of Pale Silver Maharic Light that would normally come up with your Shield and focus on the Earth's Core. Begin drawing energy all the way up the 4" diameter cord and into the body. INHALE the energy up into the Heart Center, and expand it there. Begin to form a pale Silver ball of Maharic frequency.

On each EXHALE send your energy down to the Earth's Core to bring up another load of Maharic frequency, up from the Planetary Shields, expand it into the Heart center and repeat several times. Notice that the Cord grows larger as you do this, expanding from approximately 4" to 6 to 8" diameter, until finally it feels like a skin around (as well as within) your body ... as you load your Astral field with Maharic Frequency.

9 Move your attention to the Pale Silver ball you have created in your Heart Center, INHALE and move it up to the 14th Chakra 36" above your head .. as you do, feel for the sheath of Maharic Frequency encasing your etheric body, close to your skin. (This Maharic/ Christos skin charges, and saturates, your etheric body – feel the peacefulness and all-knowing nature of this frequency).

SYMBOL SHORTHAND

TECHNIQUE # 2: Condensed Version
The Maharic Seal and Liquid Light Cleanse

Symbol Shorthand is used to help in remembering the primary steps of a technique

1. *Silver Hierophant Star at Chakra 6*
2. *EXHALE* Hierophant Star from *Chakra 6 to Earth's Core –Spin Hierophant Star* at Earth's core-until it *pops* into *Hierophant Silver Sphere at Earth's core.*
3. *Hierophant Sphere* spins *at Earth's core* until *Silver Disc of Earth's Shield* emerges.
4. *INHALE- Hierophant Sphere* up from *Earth's core to Chakra 12* trailing *Silver Cord* from Core.
5. *INHALE- Hierophant Sphere* up from *Chakra 12 to Chakra 14*, trailing *Silver Cord.*
6. *EXHALE- Hierophant Sphere* down from *Chakra 14 to Personal Maharic Shield* and *spin Hierophant Sphere* until *Personal Shield pops* out to become *Silver disc* plane 12"beneath feet.
7. Draw *Silver energy* into *Personal Shield from Earth's Shield* through *Silver Cord,* until *Personal Shield* is *filled* and *pops* to become vertical *Pillar* of Silver Light around body.
8. *INHALE*-draw *Spark of Silver Light* from *13th Chakra* at *Earth's Core*, into *main* vertical channel of *Kathara Grid* then to *Chakra 4;* from Chakra 4 transmit energy from Spark to fill *12-Tree* Kathara Grid. Chakra 12 auto-shut down when 12-Tree Grid is full.

THE MAHARIC SEAL

63

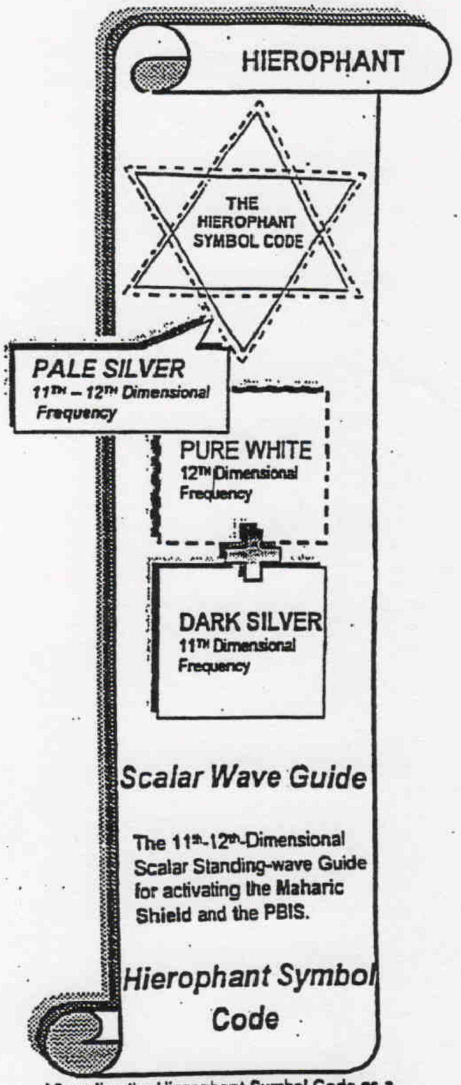
HIEROPHANT
THE HIEROPHANT SYMBOL CODE
PALE SILVER
11TH – 12TH Dimensional Frequency
PURE WHITE
12TH Dimensional Frequency
DARK SILVER
11TH Dimensional Frequency
Scalar Wave Guide
The 11th-12th-Dimensional Scalar Standing-wave Guide for activating the Maharic Shield and the PBIS.
Hierophant Symbol Code

Visualize the Hierophant Symbol Code as a *2-dimensional "flat" image* "drawn in Pale Silver Light".

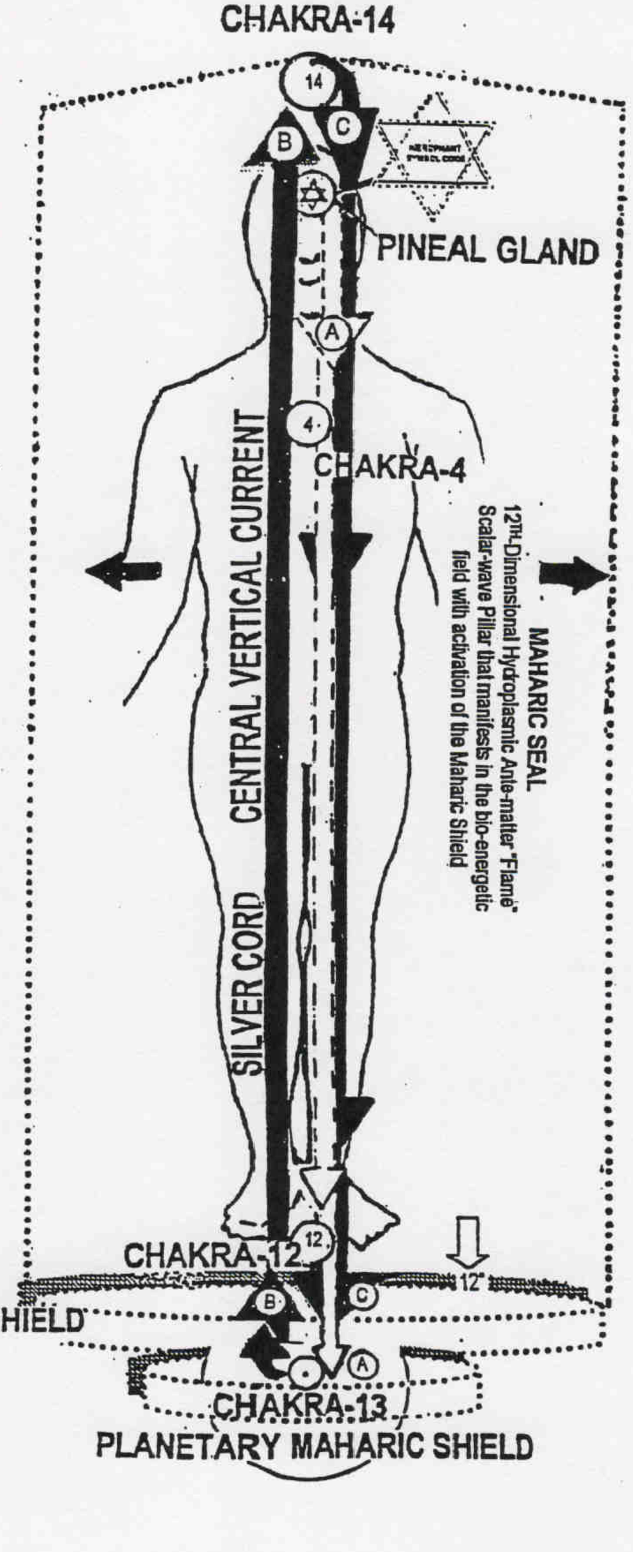
CHAKRA-14
14
B
C
HIEROPHANT SYMBOL CODE
A
PINEAL GLAND
A
4
CHAKRA-4
CENTRAL VERTICAL CURRENT
SILVER CORD
MAHARIC SEAL
12TH-Dimensional Hydroplasmic Anti-matter "Flame" Scalar-wave Pillar that manifests in the bio-energetic field with activation of the Maharic Shield
12
CHAKRA-12
12"
B
C
A
PERSONAL MAHARIC SHIELD
CHAKRA-13
PLANETARY MAHARIC SHIELD

Follow with Liquid Light Cleanse

LIQUID LIGHT CLEANSE

KATHARA CENTERS

#12 – *The Capstone*
In 10th Chakra
6" above the head

# 11 – *Crown Jewel*
In Pineal Gland
at center of brain

# 9 & # 10 –*The Shar*
In brain
behind ears

# 8 – *Spark of Orion*
In Thyroid Gland
at 8th Chakra

# 6 & # 7-*The Wings*
In shoulder indents
through to back.

# 5 –*Seat of Amenti*
At Navel in
Central Body Current

# 3 & # 4 -*The Dal*
male: Ureters
female: Ovaries

# 2 – *Naum-Yun*
male: Prostate Gland
female: Vagina

# 1 – *Earth Core*
at center of Earth
in 13th Chakra

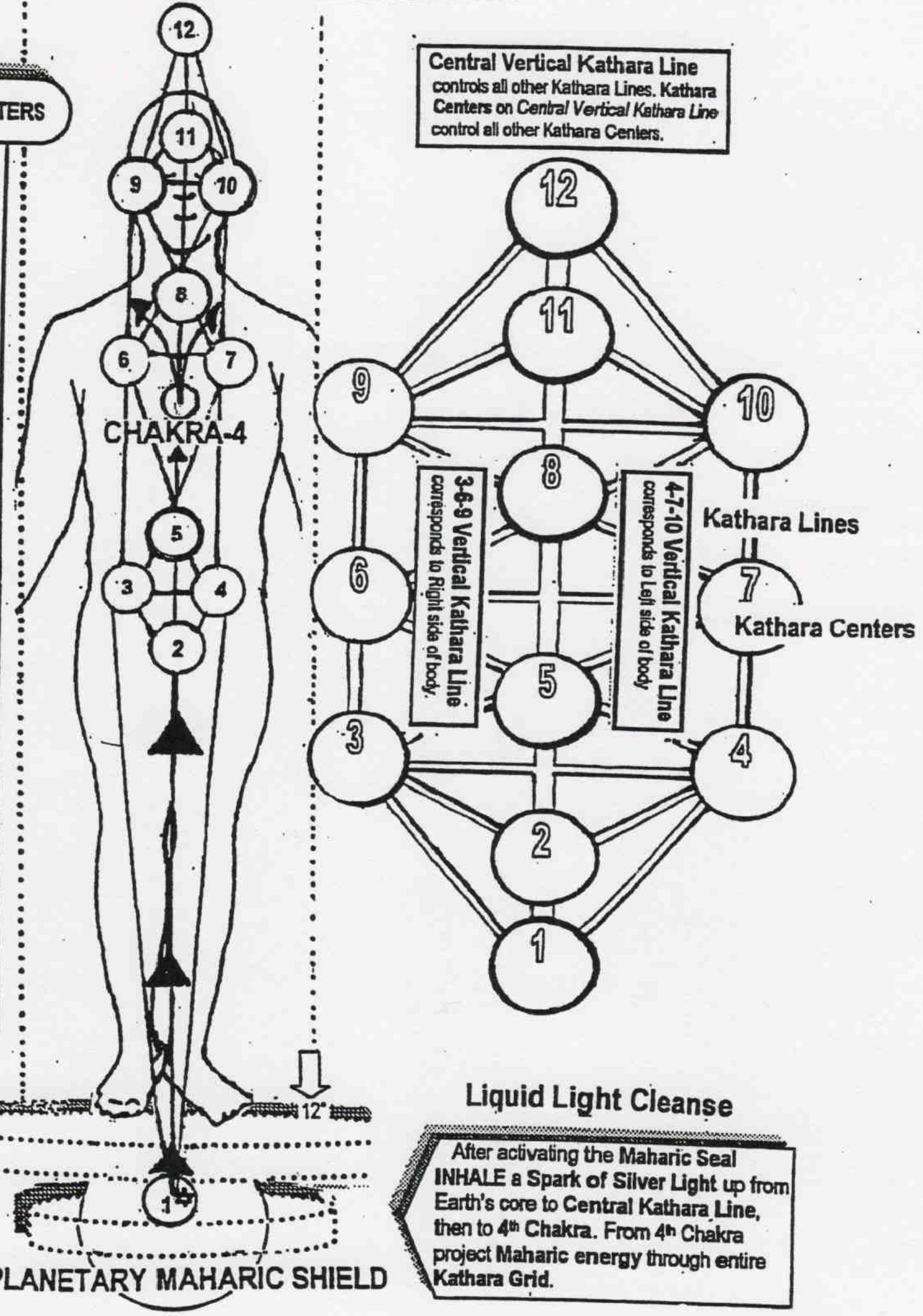
12
11
9
10
8
6
7
CHAKRA-4
5
3
4
2
12"
1
PLANETARY MAHARIC SHIELD
12
11
9
10
8
3-6-9 Vertical Kathara Line corresponds to Right side of body.
4-7-10 Vertical Kathara Line corresponds to Left side of body
Kathara Lines
6
7
Kathara Centers
5
3
4
2
1

Central Vertical Kathara Line
controls all other Kathara Lines. Kathara Centers on *Central Vertical Kathara Line* control all other Kathara Centers.

Liquid Light Cleanse

After activating the Maharic Seal **INHALE a Spark of Silver Light** up from Earth's core to **Central Kathara Line,** then to 4th Chakra. From 4th Chakra project Maharic energy through entire Kathara Grid.

The Planetary Bio-Feed Interface System and the Maharic Seal

Use of the *Maharic Seal and Liquid Light Cleanse* begins the process of activating the **8th through 12th Chakras** and opening the natural **PLANETARY BIO-FEED INTERFACE SYSTEM (PBIS)** within the human body. Through the **PBIS**, the finite quantity of scalar frequency of which the personal Maharic Shield, Hova Bodies and individual identity are composed expands to **infinite potential**, as the **Planetary Scalar Shields** can be used to open dormant **Crystal Seals** within the Scalar Shields of the personal Level-2 Kathara Grid. **Once activated through the 12th Chakra, the PBIS opens a conduit of perpetual energetic supply between the human body and the planetary Morphogenetic Field, allowing the body to continually draw in as much higher dimensional frequency as the DNA Template can hold.**

With the PBIS activated, the human body can also become a tool for reprogramming and re- balancing the Planetary Shields, Vortices, Ley Lines and energetic grids of the Planetary Templar Complex. When the Crystal Seals of the personal Shields are released, the **human DNA Template** can serve as a **bio-electric conduit** for running higher dimensional frequency into the **Planetary Shields.** The human body, with its **12-Strand DNA Template potential,** is the only mechanism on Earth, other than the Planetary Shields themselves, that is capable of running a full 12th-Dimensional **Maharic Current.** Just as within the human Manifestation Template, the Maharic Current can be used to purge distortions within the Planetary Shields, to restore the **Planetary Templar Complex** to its original **Primal Order.** Kathara Healing technologies not only provide the opportunity for individuals to facilitate healing in other *biological life forms,* they also reawaken the human potential to facilitate healing within the **geophysical planetary body.**

The Planetary Bio-Feed Interface System

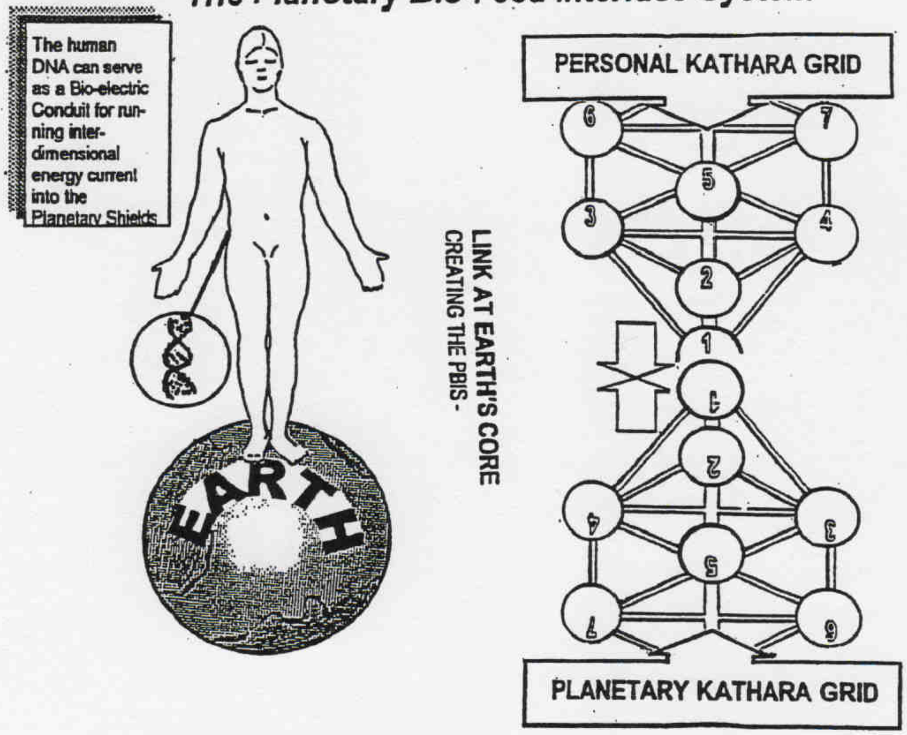
The human DNA can serve as a Bio-electric Conduit for running inter-dimensional energy current into the Planetary Shields
EARTH
LINK AT EARTH'S CORE
CREATING THE PBIS -
PERSONAL KATHARA GRID
6
7
5
3
4
2
1
1
2
4
3
5
7
6
PLANETARY KATHARA GRID

The Maharic Seal and Client Sessions

Through understanding the **Context of Healing**- *The Structure of the Unified Field*, the **Elements of Healing –** *The Anatomy of the Human Body Kathara Grid* and **Kathara Healing Beginning Applications -** *Morphogenetic Repatterning* through the ***Maharic Seal and Liquid Light Cleanse*** and *Awakening the Mentor* for access to 5th Dimensional awareness, the Kathara Healing Facilitator has developed the rudimentary skills necessary to begin **personal Core Holographic Template Healing. To effectively facilitate Core Template healing in others it is important for Kathara facilitators themselves to employ personal Template Healing.**

The ability to hold the **12th-Dimensional Maharic frequency sub-harmonics** (the 12th-sub-frequency band within each of the full Dimensional Frequency Bands) in body to assist in its transmission to a client for healing support increases as the facilitator utilizes the **Maharic Seal and Liquid Light Cleanse** technique **for personal healing.** The *Maharic Seal and Liquid Light Cleanse* technique not only increases the facilitator's ability to transmit 12th-Dimensional frequency sub-harmonics, it also temporarily **realigns distortions** within the *facilitator's* bio-energetic field and Kathara Grid and creates a temporary **12th-Dimensional Scalar Frequency Seal** within the *facilitator's* bio-energetic field. **Without use of the *Maharic Seal*, the facilitator will inadvertently transmit bio-energetic field and Kathara Grid distortions to the client and will energetically pick up scalar distortions** (including part of the "Karmic" Miasmic Imprint) **from the client.** (This problem occurs in all subtle-energy healing modalities that do not employ the Maharic Seal). Both of these conditions serve to amplify, rather than remedy, dis-ease and disharmony within the Mind-Body-Spirit system, for both *facilitator and client.* For these reasons, **the *Maharic Seal and Liquid Light Cleanse* technique needs to be employed prior to ANY healing facilitation work,** to protect the **bio-energetic field integrity** of facilitator and client. **The *Maharic Seal and Liquid Light Cleanse* technique represents the facilitator's preliminary preparation prior to Kathara Healing Facilitation Client Sessions.**

Safety in Healing Facilitation!

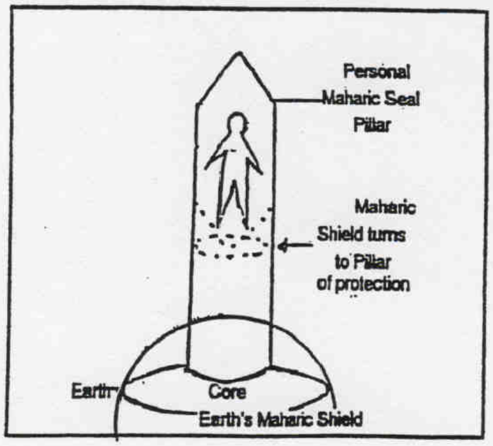

The ***Maharic Seal and Liquid Light Cleanse*** technique, used as facilitator preparation prior to **Client Sessions,** protects facilitator and client from taking on bio-energetic field distortions from each other. **Maharic Seal** is the preliminary step before any **Kathara Healing** application and is needed to effectively run interdimensional healing currents.

CO-GENERATIVE HEALING

The final phase of education necessary before engaging the adventure of **Kathara Healing Client Facilitation** is rediscovering the structure of personal **Multi-dimensional Identity** and how to use the personal **Hova Bodies** to tap the higher dimensional scalar frequencies for enhanced healing facilitation ability. The ability to understand and utilize the **PRECISE HEALING CURRENTS** of the interdimensional spectrum adds **greater power and skill** to the healing facilitation process. Unlike many other energy healing systems, **Level-1 Kathara Healing** trains the facilitator to identify, awaken within the body and employ in client service **specific combinations of interdimensional healing current** that fine-tune and amplify the beneficial effects of subtle energy healing. This chapter will conclude with an overview of the **4 PRIMARY TRIADIC HEALING CURRENTS**, 4 of the 5 **3-Dimensional Primal Energy Currents** that can be awakened within the body through activation of the **Maharic Shield.**

The natural **Primal Triadic Healing Currents**, which exist naturally as part of the personal Hova Body, Scalar Shield and Kathara Grid anatomy, create powerful, effective and user-friendly energetic healing tools when combined with the 12th-Dimensional frequencies of the **Maharic Shield.** Running the Triadic Currents is achieved by using the current to first activate the frequencies of the corresponding Hova Body and station of awareness within the personal Scalar Shields and **DNA Template.** Once activated in the DNA Template, the **Hova Body** is used to draw perpetual supply of the desired current from the Dimensional Unified Field corresponding to the chosen current. **Running the Triadic Currents requires activation of the corresponding frequencies within the facilitator's DNA Template, thus using the Triadic Currents in Client facilitation also serves to progressively stimulate and expedite activation of dormant frequencies in the facilitator's DNA Template.** Using the Triadic Currents in client facilitation serves to accelerate the processes of Holographic Recoding, higher identity Hova Body integration and multi-dimensional evolution within the Body-Mind-Spirit system of the *facilitator*, as well as that of the *client*, creating a condition of **CO-GENERATIVE HEALING** between client and facilitator.

Healing, Evolution and Ascension

In the Kathara Healing paradigm the art and science of healing the Body-Mind-Spirit system is viewed in terms of the *human relationship to the natural structure and dynamics of creation.* **Healing becomes a necessity when the intrinsic energetic systems and scalar-wave constructions of consciousness upon which the biological manifestation is built become incongruent with the natural Primal Order of the dimensionalized Time Matrix system.** The processes of natural healing and the hidden, organic functions of **human evolution** are intimately intertwined. Conditions that facilitate natural healing also facilitate fulfillment of the naturally intended course of human evolution, while conditions detrimental to Body-Mind-Spirit health are likewise detrimental to the evolutionary objectives of both the individual and the species.

The processes by which lasting healing occurs through re-genesis of Primal Order within the Scalar Shields and personal anatomy, are the same processes by which the **CONSCIOUSNESS** evolves to the fulfillment of **Spiritual Actualization,** through embodiment of the 12-dimensions of consciousness inherent to human DNA Template design. The genetic code of the biological imprint is built upon the Scalar-wave Templates of Consciousness that serve to hold the identity as energetic substance into physical embodiment. **Distortions within the physical manifestation indicate distortions in the Manifestation Template and thus constitute distortions in CONSCIOUSNESS.** Genuine healing is a *FUNCTION OF CONSCIOUSNESS*, first and foremost, and it is through realignment of consciousness itself that full healing can occur.

In the Kathara program it is understood that biology and consciousness are intimately intertwined and thus interdependent. The techniques of **Bio-Regenesis** provided in Kathara Healing assist in the processes of restoring the **Organic Imprint for Health** while simultaneously serving to **expedite the natural processes of interdimensional evolution** through DNA Template, Kundalini, Crystal Seals and Merkaba activation. **Human evolution is not a random, goal-less occurrence; it is rather an ordered system of interdimensional physics dynamics by which human consciousness progressively masters the contours of creation in time.** The evolutionary objective of human creation is **mastery,** which is progressively attained through the dynamics of **Transmutational Dimensional Ascension. Ascension** is therefore the intrinsic and indelible **goal** within human evolution, the **hidden impetus for action** that moves the human species forward in time.

Healing and Bio-Spiritual Evolution

When we begin running the higher dimensional frequencies of the **4 Primary Triadic Currents** for Kathara Healing applications, we are, in truth, running **FREQUENCIES OF CONSCIOUSNESS**, that emanate from the **Hova Bodies** in which the expanded spiritual portions of our personal identity are stationed. As we reawaken the higher dimensional frequencies of consciousness within the **DNA Template** we are progressively expediting the reintegration of personal **Multi-dimensional Identity**, serving the **spiritual goal of Ascension** through stimulating into activation the scientific dynamics of **Unified Field Physics** by which genuine Ascension occurs. **Kathara Healing** progressively restores the functions of universal physics dynamics within the human body, as they apply to the pathway of Ascension, and so Kathara Healing applications are considered to be processes of **ACCELERATED BIO-SPIRITUAL EVOLUTION**, as well as processes of holistic Body-Mind-Spirit healing. Both facilitator and client simultaneously receive the subtle but progressive benefits of evolutionary acceleration and spiritual development through Kathara Healing **Bio-Regenesis Technologies**, through which the expansion of personal consciousness into the higher dimensional aspects of spiritual awareness occurs.

Kathara practices serve to stimulate progressive integration and embodiment of the Multi-dimensional Identity by activation of dormant portions of the **DNA Template** through which the scalar-wave patterns of the higher frequencies of identity can enter the physical form. As spiritual advancement through Hova Body integration and DNA Template activation is a beneficial "side effect" of Kathara Healing practice, it is helpful for the Kathara facilitator to understand the order of **Multi-dimensional Identity Structure**. It is also helpful to realize that the **Unified Field of Energy** utilized in Kathara Healing is, in fact, a **UNIFIED FIELD OF CONSCIOUSNESS.** Healing is a function of energy dynamics and at its core, energy is the **substance consciousness adopts** to experience manifestation, thus **HEALING IS A FUNCTION OF CONSCIOUSNESS.** When personal consciousness is applied in ways that are congruent with the natural **Laws of Unified Field Physics**, the effects of healing and wellbeing are met in manifestation.

MULTI-DIMENSIONAL IDENTITY STRUCTURE

Consciousness and the Physical Illusion

In Chapter 1 we explored the **Structure of the Unified Field** and discovered the morphogenetic framework, or **Holographic Template** upon which matter systems are constructed. We learned how the structure of dimensionalization applies to the anatomy of the **15-Dimensional Human body**, from the **Core Template Kathara Grid**, the **Hova Bodies and Shields**, to the **Chakras**, **Bio-energetic Field** and **physical matter** structures built upon them. **We also discovered that *physical manifestation* is not what appears to be - that *nothing is really manifest at all*, but only *appears to be so* due to the *relationships of compartmentalized consciousness interacting with each other through the framework of dimensionalization*.** Our physical parts and our manifest world are **scalar wave constructions**, appearing solid and externalized because we view them with a level of consciousness that is stationed **one full dimension above** the wave forms we perceive as solid and objectified. Our consciousness structures itself into the scalar wave forms of dimensionality in order for us to perceive the illusion of manifestation. There is no difference, other than the **dimensional frequencies from which one is perceiving**, between the *substance that composes physical matter* and that which *composes our seemingly non-manifest portions of consciousness.* **The core of reality is CONSCIOUSNESS - it is the *energetic substance* out of which all things are made.**

Hova Bodies- Platforms of Perception

In this Section we will learn how the attributes of mind and sentient identity fit into the multidimensional anatomy of human consciousness. The scalar grids of the **Hova Bodies** and **Shields** that hold portions of our consciousness separate from each other so we may experience objectification, can be understood as **PLATFORMS OF PERCEPTION.** A portion of our conscious identity is **stationed within each of the Hova Body Shields,** and the dimensions contained within the Shield become the *platform* from which *that portion of our selves* will perceive matter objectification. **We are simultaneously focused within each Hova Body Platform of Perception, and this gives us separated but interrelated stations of identity and different LEVELS OF MIND from which we simultaneously perceive.** The amount of perception we are able to incorporate into our embodied focus on Earth is determined by the Level of **Higher Identity Integration** that has occurred. Integration of Higher Identity is the *merger* of the **Hova Bodies,** which creates changes and advancement in the **biological gene code** that allows the neurological and metabolic functions of the body to expand.

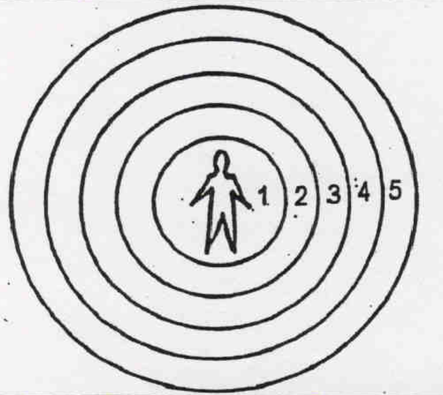

THE 5 HOVA BODIES

3-Dimensional Electro-magnetic Domains created by the Scalar Shields that serve as stations of dimensionalized consciousness

1. **NADA HOVA** Density-1
2. **ALPHI HOVA** Density-2
3. **BETCHA HOVA** Density-3
4. **MAHARA HOVA** Density-4
5. **RAJA HOVA** Density-5

Our Present Platform of Perception

Presently we are accustomed to perceiving from the Platform of Perception provided by the **NADA HOVA BODY**, the *scalar grid* that houses the 1st, 2nd and 3rd Dimensional Aspects of our identity and anatomy. While perceiving from the Nada Hova Body and the **TELLURIC SHIELD** that holds its form, we are functioning as a **3-Dimensional consciousness** and will not be aware of the perceptions of the other levels of ourselves that are perceiving from the *Platforms of Perception* from the other Hova Bodies. **As we expand and evolve we will progressively incorporate the portions of our awareness stationed in the other Hova Bodies into our earthly focus of attention.**

The *Higher Identity Structure* of the Hova Bodies and related *Levels of Mind* within dimensionalization are as follows:

Stations of Identity and Levels of Mind in the Hova Bodies

INCARNATE IDENTITY: Nada Hova Body/ Telluric Shield / dimensions 1, 2 and 3.
The Subconscious (D-1), Instinctual (D-2) and Reasoning (D-3) Levels of Mind

SOUL IDENTITY: Alphi Hova Body/ Doradic Shield/ Dimensions 4, 5 and 6
The Astral (D-4), Archetype or Dora (D-5) and the Angelic (D-6) Levels of Mind

OVER-SOUL IDENTITY: Betcha Hova Body/ Teuric Shield/ Dimensions 7, 8 and 9
The Ketheric (D-7), Monadic or Teura (D-8) and the Keriatic (D-9) Levels of Mind

AVATAR IDENTITY: Mahara Hova Body/ Maharic Shield/ Dimensions 10, 11 and 12
The Christiac (D-10), Buddhiac (D-11) and the Nirvanic (D-12) Levels of Mind.

RISHI IDENTITY: Raja Hova Body/ Rishic Shield/ Dimensions 13, 14 and 15
Universal Consciousness Mind

There are 3 **additional Platforms of Perception** and 3 additional Hova Bodies beyond the structure of Dimensions;Hova Bodies that represent 3 Levels of **Ascended Mastery Identity**.

Spiritual Actualization is the process of progressive Higher Dimensional Identity Integration. ***Higher Identity Integration*** is the merger of the ***Hova Bodies***, which creates changes and advancement in the biological ***Genetic Code*** through progressive activation of dormant portions of the ***Silicate Matrix 12-Strand DNA Template.***

5 Hova Bodies and Levels of Identity in the 15-Dimensional Time Matrix

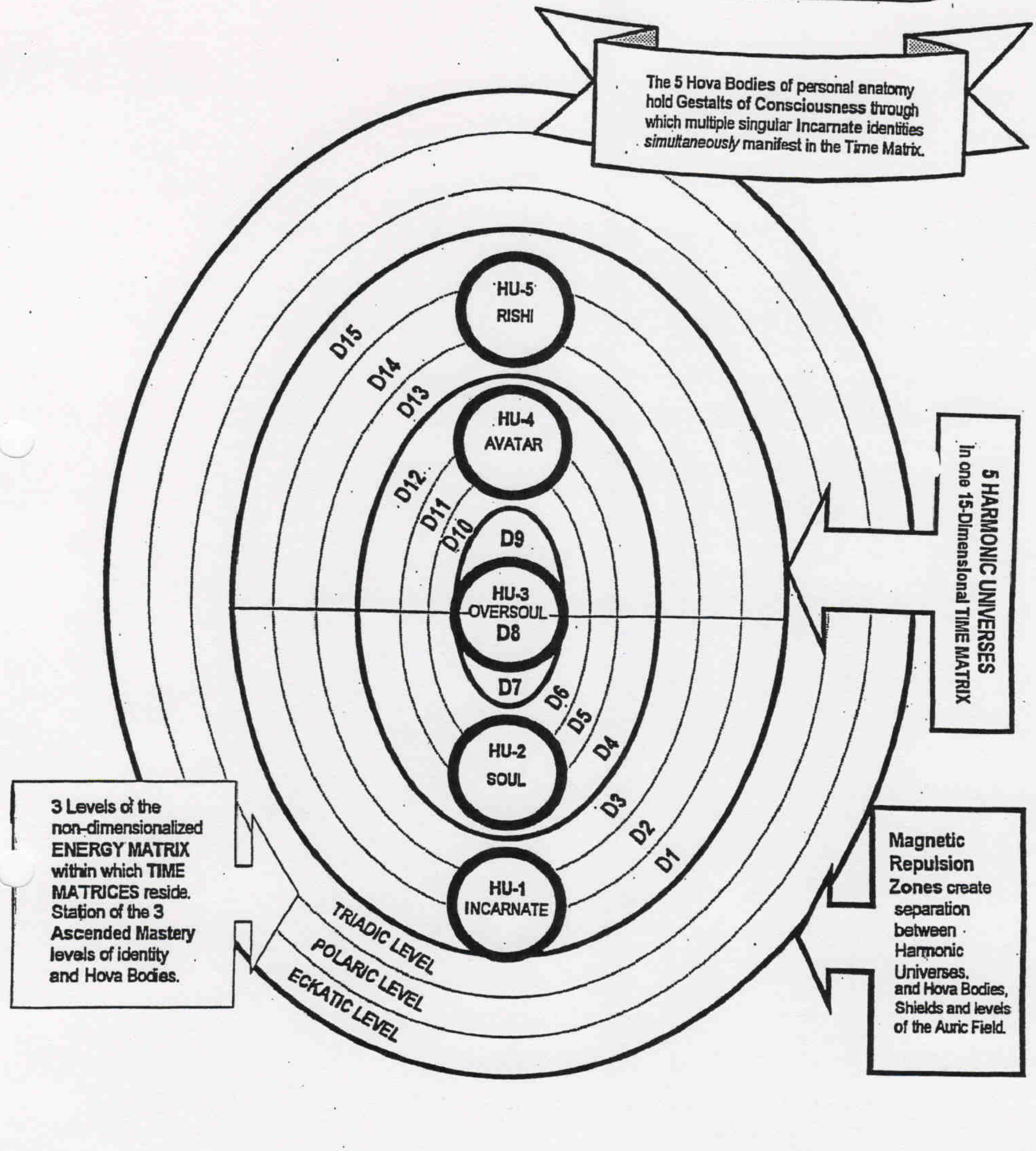

The 5 Hova Bodies of personal anatomy hold Gestalts of Consciousness through which multiple singular Incarnate identities *simultaneously* manifest in the Time Matrix.

5 HARMONIC UNIVERSES in one 15-Dimensional TIME MATRIX

3 Levels of the non-dimensionalized **ENERGY MATRIX** within which **TIME MATRICES** reside. Station of the 3 **Ascended Mastery** levels of identity and Hova Bodies.

Magnetic Repulsion Zones create separation between Harmonic Universes, and Hova Bodies, Shields and levels of the Auric Field.

HU-5
RISHI
HU-4
AVATAR
D9
HU-3
OVERSOUL
D8
D7
HU-2
SOUL
HU-1
INCARNATE
D15
D14
D13
D12
D11
D10
D6
D5
D4
D3
D2
D1
TRIADIC LEVEL
POLARIC LEVEL
ECKATIC LEVEL

THE 4 PRIMARY TRIADIC HEALING CURRENTS

Hova Bodies and the 4 Primary Triadic Currents

Each of the Hova Bodies and Shields contains a portion of your energy-identity that exists in the form of electro-tonal impulse born of Partiki Phasing. The energy of **your higher stations of identity and that of the Universal Unified Fields of Consciousness-Energy can be drawn into the Nada Hova body and earthly incarnate identity for the purpose of healing facilitation.** There are **four Primary Triadic Healing Currents,** each corresponding to one of the **four higher dimensional Hova Bodies.** Through *your* corresponding Hova Body station you can *draw energy from the higher dimensional Unified Fields* and channel it into your Nada Hova Body for direction into healing within the first Harmonic. **The *4 Primary Healing Currents* are HARMONIC CURRENTS OF ENERGY, each composed of *3 Dimensions of Frequency.*** Each Dimensional Band within a Harmonic or **TRIADIC** current is referred to as a **PHASE** *of that current.* **In Kathara Healing we develop the ability to activate each progressive PHASE of each TRIADIC CURRENT, through grounding the current into the body via the activated MAHARIC SHIELD.**

Triadic Currents and Color

Each *Phase* of Triadic Current corresponds to a wave length in the dimensional spectrum that appears as COLOR to the embodied human mind. In directing the **Triadic Currents** we therefore use the **color translation of the primary dimension wave spectra** to differentiate between Phases of current for various applications. **The first current to be activated in Kathara Healing is the that of the DORADIC CURRENT,** the frequencies drawn in from Harmonic 2 through the **Doradic Shield and Alphi Hova Body. The Doradic Current has 3 Phases: Phase -1: 4th Dimensional current/ GREEN wave, Phase-2: 5th - Dimensional Current/ BLUE wave and Phase -3: 6th-Dimensional current/ Blue-Violet wave.** In **Level-1 Kathara Healing** we learn to activate and run the **Phase-1 Green Doradic Current.**

The 4 Primary Triadic Currents and Hova Body Correspondences

TELLURIC CURRENT: Nada Hova Body/ Telluric Shield / Dimensions 1, 2 and 3.
Phase-1 RED, Phase-2 ORANGE-GOLD , Phase-3 YELLOW

DORADIC CURRENT: Alphi Hova Body/ Doradic Shield/ Dimensions 4, 5 and 6
Phase-1 GREEN, Phase-2 BLUE, Phase-3 BLUE-VIOLET

TEURIC CURRENT: Betcha Hova Body/ Teuric Shield/ Dimensions 7, 8 and 9
Phase -1 VIOLET, Phase-2 GOLD, Phase-3 Mid-tone Silver

MAHARIC CURRENT: Mahara Hova Body/ Maharic Shield/ Dimensions 10, 11 and 12
Phase-1 BLUE-BLACK, Phase-2 SILVER BLACK, Phase-3 WHITE

TRANSMUTATION CURRENT

(can be transmitted only by 12th-level Avatars with full Mahara Hova Integration)

RISHIC CURRENT: Raja Hova Body/ Rishic Shield/ Dimensions 13, 14 and 15
Phase-1 TURQUOISE, Phase-2 PALE YELLOW, Phase-3 MAGENTA

Current Combining

When using **Triadic Phase Currents, each Phase current is** *combined* **with the current running from the activated** ***Maharic Shield*****, in** ***combination with*** **the Phase current from the** ***Harmonic ABOVE the Phase current you are using*****.** The **DORA DIC PHASE-1** current is therefore composed of: **D-11/D-12 PALE SILVER** (Maharic Shield), **D-4 GREEN** Doradic Shield Phase -1 AND **D-7 VIOLET,** the *Phase-1 current* of Harmonic 3 - Teuric Shield, *one Harmonic up* from Doradic Phase-1. In activating the **DORADIC-1 (Doradic Phase-1) current you are using SILVER-GREEN-VIOLET color to direct Dimensions 12-11-7-4 current.**

COMBINED TRIADIC CURRENTS

Used in Kathara Healing

TELLURIC

PHASE-1: **PALE SILVER** (D11&12) + **RED** (D-1) + **GREEN** (D-4)
PHASE-2: **PALE SILVER** + **ORANGE-GOLD** (D-2) + **BLUE** (D-5)
PHASE-3: **PALE SILVER** + **YELLOW** (D-3) + **INDIGO** (D-6)

DORADIC

PHASE-1: **PALE SILVER** + **GREEN** (D-4) + **VIOLET** (D-7)
PHASE-2: **PALE SILVER** + **BLUE** (D-5) + **GOLD** (D-8)
PHASE-3: **PALE SILVER** + **INDIGO** (D-6) + **SILVER** (D-9)

TEURIC

PHASE-1: **PALE SILVER** + **VIOLET** (D-7) + **BLUE-BLACK** (D-10)
PHASE-2: **PALE SILVER** + **GOLD** (D-8) + **SILVER-BLACK** (D-11)
PHASE-3: **PALE SILVER** + **SILVER** (D-9) + **WHITE** (D-12)

MAHARIC

(Requires full 12-Strand DNA Template activation & accelerated DNA Template coding)
PHASE-1: **PALE SILVER** + **BLUE-BLACK** (D-10) + **PALE TURQUOISE** (D-13)
PHASE-2: **PALE SILVER** + **SILVER-BLACK** (D-11) + **PALE YELLOW** (D-14)
PHASE-3: **PALE SILVER** + **WHITE** (D-12) + **PALE MAGENTA** (D-15)

In **Level-1 Kathara Healing** we begin preparing the body and DNA Template to receive the higher dimensional Phase Currents by initiating transmission of the **Doradic Phase-1 Healing Current**- the *Pale Silver* + *Green* + *Violet* frequencies of dimensions *12, 11, 7 and 4.*

Through the 7th-Dimensional aspect of the **Teuric Shield** and 11th and 12th Dimensional aspects of the **Maharic Shield**, the **Doradic-1 Healing Current** allows for recoding and realignment of the **1st-4th**-Dimensional aspects of the **Nada** and **Alphi Hova Bodies**, the **Telluric Shield** and **Physical, Emotional** and **Mental Bodies** of Density-1, the **D-4** aspect of the **Doradic Shield** and **Astral Body**, the **1st-4th DNA Strand Templates**, the **1st-4th Chakras**, and the **1st-4th Sub-harmonics** of all Scalar Shields, DNA Templates, Hova Bodies and Chakras. Doradic-1 Healing Current is effective in clearing the **Karmic-Miasmic imprint** from the **Density-1 Time Cycle incarnations** and the beginning of Density-2 Time Cycle incarnations.

CHAPTER 3 HIGHLIGHTS

THE MENTOR

KATHARA BEGINNING APPLICATIONS

- The **Hova Bodies** of personal anatomy contain portions of our higher dimensional awareness. One can begin accessing this awareness by building a **Perceptual Bridge** between the 3-Dimensional Self and higher identity aspects.

- Taking conscious initiative in building a Perceptual Bridge expedites **DNA Template activation** and the organic evolutionary process.

- The **MENTOR Technique** assists in building the Perceptual Bridge and activates dormant **Kathara Lines** in our **Level-1 Kathara Grid** to open communication between our D3 and Density-2, D4 and D5 levels of awareness.

- The Mentor is a part of our awareness that is composed of **3rd, 4th and 5th Dimensional frequencies** of consciousness, which exists as a quantity of **Scalar Wave patterns** that span **Densities 1 and 2.**

- The **Mentor Focus** will be used in **Kathara Healing** for **guidance, information retrieval** and **objective observation.** It can also be used to access **Cellular Memory,** and in **"Inner Child", Bi-location, Remote Viewing** and **Dream** work.

MORPHOGENETIC REPATTERNING AND THE MAHARIC SHIELD

- Through a process called **Morphogenetic Repatterning,** Kathara Healing effects the **Core** of Dis-ease and dis-harmony in the Body-Mind-Spirit system by **repatterning** the Scalar-wave Programs in the personal **Holographic Template** to their original **Primal Order.**

- In **Level-1 Kathara Healing** we learn the **MAHARIC RECODING PROCESS**- the most important level of Holographic Template realignment.

- The **Maharic Shield** is the 3-Dimensional Scalar Grid corresponding to the **10th, 11th and 12th-Dimensional frequencies** of **Density-4.** It represents the **Original Point of Manifestation** and holds our original "Liquid Light" **Hydroplasmic Pre-matter Creation Imprint**, which is the **Organic Imprint for Health.**

- In Kathara Healing, the **Maharic Shield** Organic Imprint for Health is used to progressively **repattern** the embodied **Kathara Grid** and body systems to their original **Primal Order.**

- The **12th-Dimensional Frequencies** of the Maharic Shield contain within them the **144 Sub-frequency Band** Scalar patterns of **ALL** of the Dimensions below.

- 12th-Dimensional **Maharic Frequency** can be used to **effectively correct distortions** in the lower dimensional levels of the Manifestation Template, Scalar Shields and Kathara Grid.

- Activation of the **Maharic Shield** serves as the **RESET BUTTON** for the embodied **Kathara Grid** and for 12 Dimensions of Body-Mind-Spirit anatomy.

THE MAHARIC SEAL AND LIQUID LIGHT CLEANSE

- In bio-energetic healing, **Level-1 Kathara Grid** distortions override realignments made to the **outer levels** of the bio-fields alone. For **lasting healing** to occur, Level-1 Kathara Grid distortions must be realigned.

- The **Maharic Shield**, with its **144 Frequency Sub-Harmonics**, is the only portion of the Morphogenetic anatomy that can fully repattern and realign the **Level-1 Kathara 12-Tree Grid.** In **Kathara Healing**, the **Maharic Shield** is used to realign the Level-1 12-Tree Grid.

- The **Maharic Seal and Liquid Light Cleanse** technique is used to restore distorted **Partiki Phasing Sequences** and **Scalar-wave arrangements** within the **3 Levels of the Kathara Grid** and **Scalar Shields.**

- Realignment will be **temporary** until the Kathara Grid reaches "**Critical Mass**" of energy in the **new**, realigned pattern.

- Until **critical mass** is reached, the outer levels of the anatomy will continue to **reverse** the Kathara Grid healing. With practice and **consistent application** of the **Maharic Seal and Liquid Light Cleanse** technique, the realignment of the Kathara Grid will become **permanent.**

- In future applications of Kathara Healing processes will be used to realign the **outer levels** of the bio-field and the **Kathara Grid simultaneously,** to expedite the healing process.

- The Focus of **Level-1 Kathara Healing** is **Morphogenetic Repatterning** and **Holographic Template Recoding** via the **Maharic Shield,** to clear distortions and the **Karmic-miasmic imprint** from the personal **Scalar Shields, Kathara Grid** and **DNA Template,** utilizing the **accelerated energies** of the *Planetary Bio-feed Interface System* **(PBIS).**

KATHARA POINTS

- **Kathara Points** are mini energy-vortex points in the body that connect directly to **Diodic Point vortices** in the **Level-3 Kathara Diodic Point Grid.**

- Stimulation of the Kathara Points through **manual massage** effects the **movement of energy** within related areas of the Kathara Grid and body systems.

- Used in sequence, **Sequence-1 Kathara Points for Regeneration** *open* energetic gateways to the **Kathara Lines** of the **Kathara Level-1 12-Tree Grid**, to allow new, realigned scalar patterns from the **Maharic Shield** to run through the Kathara Lines and Kathara Grid for **Core Template Repatterning.**

- **Sequence-1 Kathara Points** create **more lasting but less immediate** effects of realignment and healing. They can be **used alone** for **deep healing** and re-balancing of the **Core Kathara Grid.**

- **Sequence-2 Kathara Points for Revitalization** *close* **Kathara Lines** in the 12-Tree Grid and **channel** energy into the **Nadial Lines** of the **outer bio-energetic field** for more rapid revitalization and re-balancing of the **outer auric levels, chakras** and **physical cells.**

- **Sequence-2 Kathara Points** create **more immediate but less lasting** effects of realignment and healing. They can be **used alone** to create **temporary revitalization** of the **outer levels** of the bio-system.

- **Used together, Sequence-1** Kathara Points can run **Maharic energy** through the **core Kathara Grid** for **Template Recoding. Sequence-2** Kathara Points can then be used to **direct the Maharic energy** into the **outer levels** of the bio-field and physical body, to **expedite healing** through **simultaneous** inner and outer bio-field realignment.

- In **Kathara Healing, Sequence-1** Kathara Points are used to **OPEN** the Kathara Lines **prior to** running the **Maharic Seal and Liquid Light Cleanse** and **Sequence-2** Kathara Points can be used **following** the procedure to **revitalize** the outer bio-field and body systems.

THE MAHARIC SEAL, PBIS AND HEALING

- Use of the **Maharic Seal and Liquid Light Cleanse** technique begins activation of dormant **Chakras 8-12** and the **Planetary Bio-feed Interface System (PBIS).**

- **Opening the PBIS** allows energy from the **Planetary Shields** to be drawn into the **human body** for **rapid activation** of the **personal Maharic Shield** and **Crystal Seals, to expedite** the processes of **DNA Template activation, healing, recoding of the Holographic Template** and interdimensional evolution.

- Opening of the PBIS can also allow the human **DNA Template** to serve as a **Bio-electric Conduit,** through which the **Planetary Scalar Shields** and Electro-magnetic Grids can be realigned with their **Primal Order** for **geophysical planetary healing.**

- Through the PBIS humans can directly facilitate healing of the **Planetary Templar Complex** from the Manifestation Template level, as well as facilitate healing in other biological organisms.

- Each use of the **Maharic Seal and Liquid Light Cleanse** technique assists in **planetary healing**, as the process progressively stimulates the **Planetary Maharic Shield** into activation, to realign **Planetary Shield** distortions.

- The **Maharic Seal and Liquid Light Cleanse** technique is used as **preliminary preparation** for **ALL Kathara Healing applications.** It creates a temporary **12th-Dimensional Scalar Frequency Seal** in the facilitator's bio-field to **protect** both facilitator and client from taking on each other's bio-field distortions.

- In **healing applications**, the **Maharic Seal** is needed to run interdimensional healing currents to their most effective **12th-Sub-Harmonic level.**

- The processes by which **healing** occurs through re-genesis of Primal Order are the same processes through which true **Spiritual Actualization** takes place.

- **Biology** and **consciousness** are **intimately intertwined** through the natural **Laws of Universal Unified Field Physics**, the **energetic dynamics** through which consciousness enters manifestation.

- The hidden **impetus for action** behind human evolution is the core species objective of **Mastery of Co-creation** within the space-time system. This **Evolutionary Objective** is obtained through achievement of the Evolutionary **Goal** of **Transmutational Dimensional Ascension.**

- **Kathara Healing** applications generate **healing** through restoring the **Original Imprint for Health.**

- Restoration of the **Original Imprint for Health** simultaneously expedites the natural processes of **evolution,** through activation of the **12-Strand DNA Template, Kundalini** energies, and **Merkaba Vehicle** and integration of the **Hova Bodies, Scalar Shields** and higher dimensional aspects of personal **spiritual identity.**

- **Kathara Healing** facilitates healing while simultaneously facilitating **Spiritual Actualization** and expediting the Goal of **Transmutational Dimensional Ascension.**

- **Healing is a function of consciousness.** There is no difference between the substance that composes physical matter and the substance that composes consciousness, other than the **dimensional frequency** from which one is perceiving.

- When personal consciousness energy is applied in **congruence** with the natural Laws of Universal Unified Field Physics, **healing, wellbeing** and **Spiritual Actualization** result.

MULTI-DIMENSIONAL IDENTITY STRUCTURE

- **Human anatomy** is a **15-Dimensional Scalar-wave construct.** Part of our identity exists **simultaneously** within the Time Cycles of the higher dimensional **Harmonic Universes.**

- We are indelibly **linked** to our higher identity levels through our embodied **Kathara Grid, Scalar Shields** and **DNA Template.** As we evolve biologically to activation of dormant portions of our DNA Template and Scalar Shields, the conscious awareness of our higher identity levels **progressively embodies.**

- The 3-Dimensional Hova Body **Electro-magnetic Domains** and Scalar Shields that form them represent **Platforms of Perception** through which our higher identity levels perceive.

- **Merger** of the **Hova Bodies** via activation of the **DNA Template** and **Scalar Shields** creates **reintegration** of the **Multi-Dimensional Identity Structure.**

4 PRIMARY TRIADIC HEALING CURRENTS AND IDENTITY

- The **5 Levels of Multi-Dimensional Identity Structure** are: **Incarnate**-Density-1, **Soul**-Density-2, **Oversoul**-Density-3, **Avatar**-Density-4 and **Rishi**-Density-5. There are also **3 Ascended Master** identity levels, Hova Bodies and Shields existing **beyond** the dimensionalized **Time Matrix.**

- **In Kathara Healing** we use the various levels of higher dimensional identity to draw in **healing current** from the higher dimensional Unified Fields, by activating the portions of the **personal Scalar Shields, Kathara Grid** and **DNA Template** that correspond to the higher dimensional **Hova Bodies.**

- There are **4 Primary Triadic** (3-Dimensional) **Energy Currents** that can be used in **Healing Facilitation**: The **Telluric Current**-Density-1, the **Doradic Current**-Density-2, the **Teuric Current**-Density-3 and the **Maharic Current**-Density-4. The **Rishic Current** of Density-5 can be run only by beings with **full 12-strand DNA activation.**

- Each of the **4 Primary Triadic Healing Currents** corresponds to one of the first 4 **Hova Bodies** of human anatomy.

- In Kathara Healing, the 4 Primary Triadic Currents are harmonically interwoven to create 4 powerful **Combined Healing Currents.**

- Each of the 4 Triadic Healing Currents has **3** Phases, or **3 Phase Currents,** each representing one of the three dimensional frequency bands within the **Triadic Current.**

- Each of the **12 Phase Currents** is run in combination with the 11-12th-Dimensional **Maharic Current** and the Phase Current from the **harmonic directly above,** to form a powerful **Triadic Healing Current.**

- In **Kathara Healing,** specific Healing Currents are directed by using the **Color** of their dominant **wave-length.**

DORADIC-PHASE-1 CURRENT

- **Level-1 Kathara Healing** teaches us to activate our **Doradic-Phase-1 Current**- the **Pale Silver** (D11-12) **+ Green** (D-4) **+ Violet** (D-7)- for **Healing Facilitation** and **personal** DNA Template and Shield activation.

- The **Doradic-Phase –1 Current** can realign the **1st-4th** Dimensional aspects of the **Scalar Shields**, the **1st-4th Chakras, Axi-A-Tonal Lines** and **DNA Strand Templates**, the **Physical, Emotional** and **Mental** bodies of the **Nada Hova Body** and the D-4 **Astral body** of the **Alphi Hova Body.**

- **Doradic-Phase-1 Current** can also be used to realign the **1st-4th Sub-Harmonics** of ALL Shields, DNA Strand Templates, Axi-A-Tonal Lines, Chakras and Hova Bodies and to clear the **Karmic-Miasmic Imprint** from the **Density-1** incarnational Time Cycles **and the first part** of the **Density-2** incarnational Time Cycles.

CHAPTER 4

GENERAL KATHARA HEALING FIELDWORK

Skills to Facilitate Healing

- OPENING THE HEALING CHANNELS- DORADIC-PHASE-1 CURRENT, THE DORADIC SPHERE, DORADIC CORDS AND DORADIC BALLS.
- THE KARMIC-MIASMIC IMPRINT, INCARNATIONAL TIME VECTORS, VECTOR IMBEDDING.
- MULTI-VECTOR HOLOGRAPHIC RECODING THROUGH THE MAHARIC INFUSION.
- ATTITUDES AND ETIQUETTE IN HEALING, THE MOTIVATION TO HEAL, POSTURES OF LOVE, THE FRAMEWORK FOR HEALING AND FULLY ENGAGING THE LOVE VIBRATION.
- THE 6 STEP MAHARIC RECODING SESSION, MELCHIZEDEK CLOISTER ORDINATION AND BECOMING A PROFESSIONAL SPIRITUAL HEALING FACILITATOR-INSTRUCTOR.

TECHNIQUES:

#3- OPENING THE HEALING CHANNELS- DORADIC –PHASE-1 CURRENT

#4- MULTI-VECTOR HOLOGRAPHIC RECODING KATHARA SCAN

#5- THE MAHARIC INFUSION

THE MAHARA SPACE COMFORT TOUCH

TOPICS OF DISCUSSION

OPENING THE HEALING CHANNELS

DORADIC-PHASE-1 CURRENT

Interdimensional Currents and Signet Star Crystal Seals

Activation of any **Triadic Healing Current** requires temporary release of the corresponding **Signet Star Crystal Seals** within the personal **Scalar Shield** and a temporary activation of the portions of the dormant **12-Strand DNA Template** that correspond to the Signet Seals. Signet Seals modulate the flow of frequency between the 3-Dimensional Harmonic Density Levels. When Signet Seals are in their usual (for this time period) dormant phase, they keep the **5 Hova Bodies** of the personal 15-Dimensional anatomy separate from each other by creating an electro-magnetic barrier or **Magnetic Repulsion Zone** between each 3-Dimensional level of the energetic anatomy. This *Magnetic Repulsion Zone* between embodied **Harmonics of Manifestation** manifests as **polarity resistance to frequency inflow** within the 3 Levels of the Kathara Grid, the Scalar Shields, Axi-A-Tonal Lines, Chakras and Auric Field levels of the embodied **Inner Templar Complex. In order to run higher dimensional frequency currents through the physical body for healing applications, it is necessary to temporarily release portions of the Magnetic Repulsion Zones between the Hova Bodies.** Releasing the electro-magnetic resistance to higher dimensional frequency inflow within the Inner Templar Complex is achieved through temporary activation of the **Signet Seals** within the **Kathara Level-2 Crystal Seals Grid** of the personal **Scalar Shields.**

Most contemporary energetic healing systems rely upon using the 1st, 2nd and 3rd-Dimensional frequencies of the **TELLURIC PHASE CURRENTS** in the **Nada Hova Body**. Through the Nada Hova Body alone, only the 3-Dimensional **Sub-Harmonics** of higher dimensional frequency currents can be run, as the dormant *Signet Seals* block the faster moving *Partiki Phasing Flash-line Sequences* of higher dimensional frequency bands from running through the DNA Template. **If a frequency band is blocked from running through the DNA Template that frequency cannot be energetically transmitted through the Nada Hova Body and physical bio-electrical systems.** In **conventional energy healing methods**, even those emerging from ancient systems of subtle-energy healing, the **Signet Seals**, and thus the *Scalar Shields, Hova Bodies* and *DNA Template* remain dormant in their usually **closed** position, **phase-locked** into a 3-Dimensional orientation. While the DNA Template remains phase-locked into the 3-Dimensional orientation of the Nada Hova Body, only the **1st through 12th Sub-frequency bands** (Sub-Harmonics) of **1st through 3rd Dimensional Current** (Telluric Current), and the **1st through 3rd Sub-frequency bands** of **4th through 12th Dimensional Current** can be run through the human body for transmission. Use of the lower frequency (slower Partiki Phasing rhythm) **Telluric Currents** can effect **temporary** beneficial change in the **outer layers** of the bio-energetic field, but Telluric Currents alone cannot facilitate full repatterning of the **3 Levels of the Kathara Grid** where **Scalar Shield** distortions that cause **genetic malfunction** are embedded. The **11th-12th-Dimensional frequencies** of the Pre-matter Hydroplasmic **Maharic Currents** are the only dimensional frequencies powerful enough to affect change in the embodied **Kathara Grid**. To run **Maharic Current**, and the high frequency **interdimensional Triadic Phase Currents**, through the human body requires release of the **Signet Seals within the personal Scalar Shields.**

Triadic Phase Currents, the Maharic Shield and the PBIS

Most healing systems have not incorporated the **Maharic Current** into their frequency application procedures because the **Planetary Templar Complex** has not been able to run a D-12 **Maharic Current** through the planetary grids for **210,216 years.** Like the human **DNA Template**, if the **Planetary Shields** and Manifestation Template are blocked from processing interdimensional frequency, that frequency will be **unavailable for use** on the planet. If the **Signet Star Crystal Seals** (Star Gates) in the **Planetary Shields** are dormant, closed and phase-locked into Density-1 orientation, no one on the planet will be able to draw interdimensional frequency into their **personal Shields** because the frequency is unavailable within the **Planetary Shields.** The personal and planetary Templar Complexes are **intimately interwoven**, and what effects one will inevitably effect the other.

In order to run the full spectrum of interdimensional **Triadic Phase Currents** through the human body it is necessary to open the **Signet Seals** in the personal **Inner Templar** and the **Signet Star Gates** in the **Planetary Templar Complex.** In conventional human evolution, the internal Signet Seals, which serve as the **Genetic Time Codes** or **"Fire Codes"** of the human **DNA Template**, automatically, progressively and sequentially open over **very long cycles of time.** During the slow activation of the Genetic Time Codes the conscious identity experiences passage through numerous incarnate lifecycles within the planetary Time Cycle, evolving through a series of **Single Vector incarnations** before being released from the 3-Dimensional phase-lock of Density-1 manifestation. One can **manually open the Signet Seals** in the embodied Inner Templar Complex to **expedite evolution** into the Multi-dimensional, **Multi-Vector Time Cycles** through use of the 11th-12th Dimensional **Maharic Current.**

Activation of the personal **Maharic Shield** allows for rapid release of the embodied **Signet Seals** and activation of the **Fire Codes** in the DNA Template. The **Maharic Current** from the personal Maharic Shield can be used to release the **Signet Star Crystal Seals** within the body, which in turn activates the dormant **Kundalini** energies at the base of the spine and the **Cranial-Sacral Kundalini Seals** within the **Tailbone** and **Pineal Gland.** Release of the Cranial-Sacral Seals of the Internal Templar Complex allows the **Magnetic Repulsion Zones** between the **Hova Bodies** to release so the DNA Template, personal Scalar Shields and physical body systems can receive inflow of higher dimensional frequency. To gain conscious mastery over the process of releasing the internal Signet Seals requires activation of the personal **Maharic Shield**, and the personal Maharic Shield can be **manually activated** only through drawing **Maharic Current** into the personal Shields via the **Planetary Maharic Shield. The entire process of releasing the internal *Signet Seals* by activating the personal *Maharic Shield*, in order to enable the *DNA Template* to run *Triadic Phase Currents* for healing is entirely dependant upon the *operational function* of the *Planetary Bio-feed Interface System* (PBIS).**

If the **Planetary Templar Complex** is blocked, or the Signet Star Gates are dormant, and **Maharic Current** from the **Planetary Maharic Shield** is not able to run through the planetary grids, humans on Earth do not have the option of **manually activating the personal Maharic Shield**, because the **PBIS** is not operational. The **PBIS** becomes **operationally functional** within the human body through activation of the **12th Chakra**. The *12th Chakra* cannot activate in the personal Templar Complex if the **Planetary Templar Complex** cannot run 12th-Dimensional **Maharic frequency.** For over 200,000 years, the Planetary Templar Complex could not run Maharic frequency, and thus manual activation of the personal Maharic Shield and release of the embodied Signet Seals to open the Hova Bodies for running interdimensional Triadic Phase Currents for healing were not available options for Earth humanity. Since the recent activation of the **Planetary Templar Complex, Maharic Shield** and **PBIS** activation and **Kathara Healing** applications are now available on Earth.

Opening Triadic Phase Currents in the Human Body

The method by which **Triadic Phase Currents** are activated within the human body is a **progressive process.** First, opening of the personal **Kathara Grid, Telluric Shield** and **Nada Hova Body** is orchestrated through activation of the **Maharic Shield** and **Signet Seals**, to allow inflow of frequency from the higher dimensional **Hova Bodies.** Next, the incoming frequency is harnessed and **collected** within the **Chakra System.** Finally, the collected frequency is then **transmitted** for healing facilitation in others, either through direct **Chakra transmission** or by close-range **Frequency Induction** via transmission of frequency from the activated **Secondary Chakra Centers** within the **PALMS.**

The ability to run the higher dimensional Triadic Phase Currents within the body must be built up within the Internal Templar Complex, starting with the **slowest-moving current** of the higher dimensional spectrum- the **DORADIC-PHASE-1 CURRENT.** The *Doradic-Phase-1 Current* utilizes the **sub-frequencies** of the **11th-12th**-Dimensional **Maharic Current** from the Density-4 *Mahara Hova Body* as a **carrier wave** that will carry the desired interdimensional currents through the **Signet Seals** of the personal **Scalar Shields.** The **full spectrum** of the **4th** Dimensional **Doradic-Phase-1** current from the Density-2 *Alphi Hova Body* is activated as the **primary healing frequency** for transmission. The **full spectrum** of the **7th**-Dimensional **Teuric-Phase-1 Current** (one Harmonic above the Doradic-Phase-1 Current) from the Density-3 *Betcha Hova Body* is used to release the 4th-Dimensional **Signet Seal,** allowing the 4th-Dimensional Doradic-Phase-1 current to enter the **Nada Hova Body.**

Activating the **4th Signet Seal** triggers **temporary** activation of the **4th DNA Strand Template** and corresponding **4th Kathara Center** in the Level-1 12-Tree Grid, which allows the 4th-Dimensional frequencies of the **Doradic-Phase-1 Current** to pass through the **active DNA** and into the bio-energetic and bio-electrical systems of the body for transmission. Once the DNA Template becomes accustomed to holding a **4th-DNA Strand Template Activation,** after **several months** of practice in running the 4th–Dimensional *Doradic-Phase-1 Current*, the body will be able to begin receiving the primarily 5th-Dimensional **Doradic-Phase-2 Current. The lower dimensional Triadic Currents must be activated within the DNA Template before the higher dimensional Triadic Currents can run.** In **Level-1 Kathara Healing** the first step of activating the full spectrum (12 sub-harmonics) of the 4th-Dimensional **Doradic-Phase-1 Current** is achieved.

Triadic Phase Currents and Color Cap-Stones

The **Color Cap Stone** of a dimensional frequency band is the visual representation of the **primary wave-length** formed by the specific **Partiki Phasing Rhythm** for that dimension. A specific dimensional frequency band can be chosen and directed by the **color translation** of its primary wave-length. The **Color Cap Stones** of the dimensional frequency bands are used in Kathara Healing to direct specifically selected dimensional frequency bands (Partiki Phasing Rhythms) for specific applications. The **Color Cap Stones** for the **Doradic-Phase-1 Current** are **PALE SILVER** (D-11-D-12 Maharic) + **GREEN** (D-4 Doradic) + **VIOLET** (D-7 Teuric). In **technique # 3 – OPENING THE HEALING CHANNELS-DORADIC-1** - the ***Pale Silver* + *Green* + *Violet*** Cap Stone Colors will be used to activate the **Doradic-Phase-1** Healing Current within the body.

DORADIC SPHERE, CORDS AND BALLS

The Doradic Sphere and Current Collection

The **DORADIC SPHERE** is a **frequency repository** that is formed to hold the activated **Doradic-Phase-1 Current** within the **Chakra system** for transmission in healing facilitation. As the Doradic-Phase-1 Current is primarily a **4th-Dimensional Current**, the **Doradic-1 Sphere** will be formed in the **4th Chakra**, which corresponds to the 4th-Dimensional **ASTRAL body** of the Alphi Hova Body and Auric Field. **Transmission** of the Doradic-Phase-1 Current will take place from the **Doradic Sphere** at the **4th Chakra**, creating a **4th-Dimensional ASTRAL INFUSION** of frequency into the bio-energetic field of the client in **close-range healing**, and a general **Astral Plane Infusion** of Doradic-Phase-1 frequency into **Manifestation Templates** of areas(and everything contained within the space) when transmitted directly from the **4th Chakra.**

Doradic Cords and Current Induction

The **DORADIC CORDS** are **energy conduits** that are formed by opening the embodied **Axi-A-Tonal Lines** within the **arms, hands** and **fingers.** Opening the Doradic Cords allows the **Secondary Chakras** within the **palms** of the hands to carry the **Doradic-Phase-1 Current** for application in **close-range** transmission. Though Triadic Phase Currents can be transmitted directly from the **Chakra Center** in which the **Collection Sphere** is placed, the energies are more **diffused** and **diluted** in this form of transmission, unless the personal DNA Template holds a **full, permanent activation** of the Strand Template corresponding to the Triadic Current being transmitted. It takes time, often years, for the DNA Template to acquire and permanently hold a higher strand activation level. One-on-one healing facilitation is more effective when conducted through **concentrating** the Triadic Current through the **Axi-A-Tonal Lines** for **DIRECT INDUCTION** of current through the **Palm Chakras** in **close-range**transmission. Close-range transmission also allows for **more precise application** of frequency to specific areas of the body systems. In **Level-1 Kathara Healing**, the **Doradic Cords** are activated within the arms, palms and fingers to allow for concentration, focused direction and **Direct Induction** of the **Doradic-Phase-1 Current.**

For **general healing** purposes, such as **"clearing rooms"** or geographical spaces, or when attempting to transmit healing current into **groups of people**, transmission of the **Doradic-Phase-1 Current** can be orchestrated directly from the **4th Chakra** for **NON-SPECIFIC INDUCTION.** In **Non-Specific Induction**, following activation of the Doradic-Phase-1 Current, each **INHALE** breath is used to fill the **Doradic Sphere** with more energy and each **EXHALE** breath is used to expand and transmit the energy into the room or bio-fields of a group of people. It is not necessary to activate the Doradic Cords for Non-Specific Induction applications. In **Level-1 Kathara Healing** applications use of the **Doradic Cords** and **Palm Chakras** is employed for Direct Induction close-range transmission in Client Sessions. To enhance and expedite **personal healing**, the activated **Doradic-Phase –1 Current** can be run through the personal **Level-1 Kathara Grid** with the ***Maharic Shield and Liquid Light Cleanse*** technique and then through each of the **7 Primary Embodied Chakras.**

Doradic Balls and Palm Transmission Direct Induction

The **DORADIC BALLS** are small energy repositories that form in the **Palms** of the Hands when the **Doradic Cords** have been activated to run Doradic-Phase-1-Current through the **Palm Chakras.** Doradic Balls are used to **accumulate current** in the **Palm Chakra vortices** prior to transmission, to **strengthen** the intensity of the current.

PALM CHAKRAS AND TRANSMITTING CURRENT

Primary Polarities of Palm Chakras

Along with the **15 Primary Chakras** within human anatomy there are many other smaller **Secondary** and **Tertiary Chakra Centers** throughout the body, which correspond to the energetic interrelationships of scalar-wave patterns within the **Kathara Level-3 Diodic Points Grid.** All Chakras operate as sets of **Black and White Holes,** through which energy from the Dimensional Unified Fields circulates into and out of the body and Manifestation Template. The **Palm Chakras** are part of the **Secondary Chakra System.** Like all Chakras, the Palm Chakras are structured as **2 vortices** of energy **joined at the tip** by a minute **Crystal Seal** within the **Kathara Level-2 Crystal Seals Grid.** The Palm Chakras run through the **center of the Palms** and out of the **back of the hands.**

In any set of Chakra vortex spirals, one vortex represents the **magnetic Black Hole,** a *counter-clockwise rotating* spiral that **draws energy IN** toward the central Crystal Seal, and the companion vortex represents the corresponding **Electrical White Hole,** the *clock-wise rotating* spiral that **sends energy OUT** from the central Crystal Seal. The **Black Hole** vortex represents the **RECEIVING spiral** or **Magnetic Pole** and the **White Hole** vortex represents the **TRANSMITTING spiral** or **Electrical Pole.** The **Electrical Pole** of a Chakra represents the **EXPANSION CURRENT** of the Chakra, through which it **expands energy out** from the personal Shields; it is referred to as **BASE ELECTRICAL.** The **Magnetic Pole** of a Chakra represents the **CONTRACTION CURRENT** of the Chakra, through which it **contracts energy in** from the external Unified Field to the personal Shields; it is referred to as **BASE MAGNETIC.**

The Chakras in the **Palms** are composed of many smaller minute **vortex sets,** each with Magnetic and Electrical Poles, but the **PRIMARY POLE** of each Palm Chakra is that pertaining to the **larger Black-White Hole set** and **Crystal Seal.** Though each Palm Chakra is capable of both **Transmitting and Receiving** energy current, the **strongest and most focused currents** can be achieved by utilizing the natural polarity orientation of the Primary Vortex Set. The Chakra in the **RIGHT PALM** is **BASE ELECTRICAL;** its corresponding vortex on the back of the right hand is **Base Magnetic.** The Chakra in the **LEFT PALM** is **BASE MAGNETIC;** its corresponding vortex on the back of the left hand is **Base Electrical.** When running Triadic Phase Currents it is helpful to understand the **Primary Polarities of the Palm Chakras** in order to create the **strongest** and **least distorted** healing current. In **Kathara Healing,** the **RIGHT HAND** is the **TRANSMITTING HAND,** through which Triadic Current is **Exhaled** down the **Cords** in the arms and **EXPANDED** into the **RIGHT PALM CHAKRA** for **TRANSMISION.** The **LEFT HAND** is the **RECEIVING HAND,** through which the Triadic Current transmitted from the Right Hand is **drawn back** into the facilitator's body **TO CREATE A CLOSED CIRCUIT OF CURRENT** for the **strongest current intensity** and **purest frequency content.**

HAND POSITIONS

Standard Hand Position for Transmitting Triadic Current

When transmitting Triadic Current, the **LEFT PALM** is **PLACED OVER THE BACK OF THE RIGHT HAND**. The *Base Magnetic* Current of the *Left Palm* **interfaces** with the *Base Magnetic* Current in the *Back of the Right Hand*, creating a **MAGNETIC REPULSION ZONE**, which **blocks the vortex on the Back of the Right hand** from drawing **non-specific frequency** from the Density-1 Unified Field. This keeps the current transmitted from the *Right Palm Chakra* **pure** to its specifically chosen content. The *Base Magnetic* vortex in the *Left Palm* simultaneously draws the **transmitted current** back up through the smaller vortex sets after it runs through the client's body, creating a **closed circuit of pure frequency** running between the **Hova Bodies** of the **client,** the **facilitator** and the higher dimensional **Unified Fields**. Options of **Frequency Modulation** for other healing applications also become available through using this **HAND POSITION** when transmitting healing current. In some applications a **modulated current** that includes bursts of Density-1 Telluric Current interspersed with current transmission from the higher dimensions is desired; this can be achieved by moving the Left Hand on and off of the vortex on the back of the Right Hand. The **LEFT OVER RIGHT HAND POSITION** is used in **Level-1 Kathara Healing** applications.

Elements of Doradic-Phase-1 Current Activation

Doradic-1 Cap Stone Colors:

PALE SILVER (D-11&D-12) + **GREEN** (D-4)+ **VIOLET** (D-7)

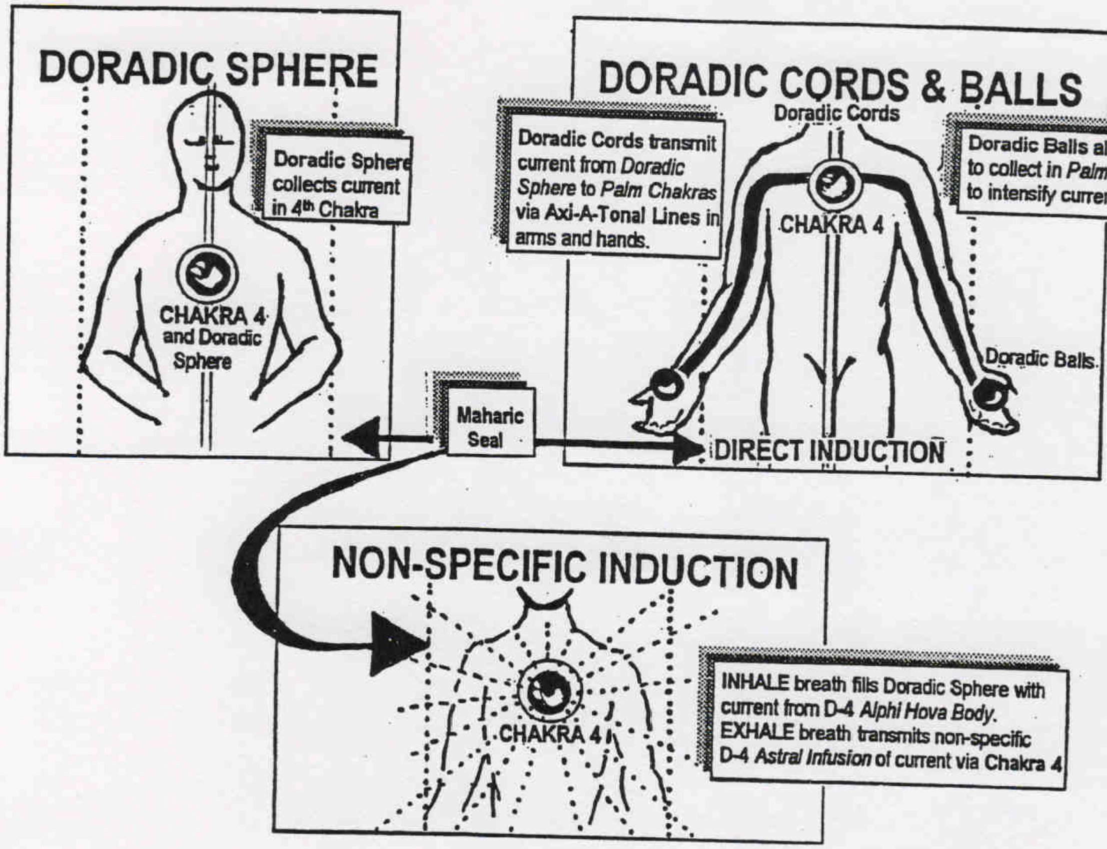

DORADIC SPHERE

Doradic Sphere collects current in 4th Chakra

CHAKRA 4 and Doradic Sphere

DORADIC CORDS & BALLS

Doradic Cords transmit current from *Doradic Sphere* to *Palm Chakras* via Axi-A-Tonal Lines in arms and hands.

Doradic Balls allow current to collect in *Palm Chakras* to intensify current.

Doradic Cords
CHAKRA 4
Doradic Balls
Maharic Seal
DIRECT INDUCTION

NON-SPECIFIC INDUCTION

INHALE breath fills Doradic Sphere with current from D-4 *Alphi Hova Body*. EXHALE breath transmits non-specific D-4 *Astral Infusion* of current via Chakra 4

CHAKRA 4

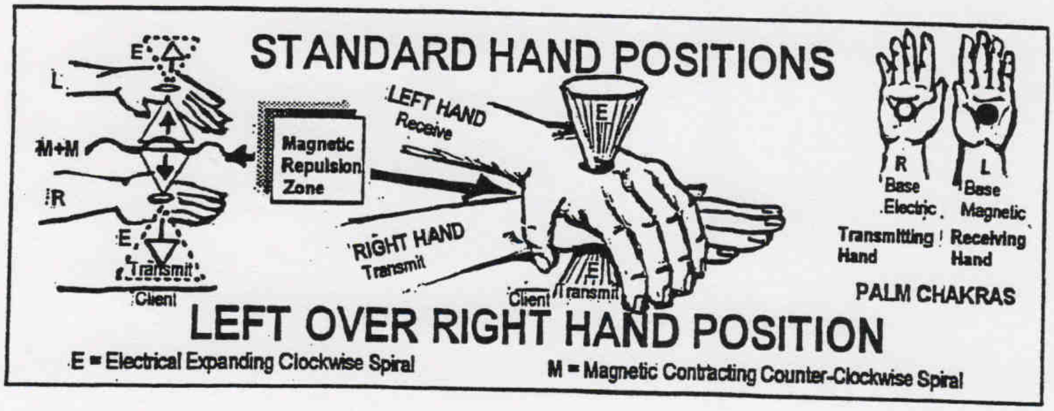

STANDARD HAND POSITIONS

E
L
M+M
R
E
Transmit
Client
Magnetic Repulsion Zone
LEFT HAND Receive
E
RIGHT HAND Transmit
E
Client
Transmit
R
Base Electric
Transmitting Hand
L
Base Magnetic
Receiving Hand
PALM CHAKRAS

LEFT OVER RIGHT HAND POSITION

E = Electrical Expanding Clockwise Spiral

M = Magnetic Contracting Counter-Clockwise Spiral

Intrinsic Process of Activating a Triadic Phase Current

ACTIVATE MAHARIC SHIELD

1. Open the PBIS using the D-11 – D-12 Wave Guide Symbol Code, the **Hierophant Symbol**, to open the **12th Chakra** and stimulate release of **Maharic frequency** from the **Planetary Maharic Shield.**

2. From the PBIS draw Maharic frequency from the Earth's Maharic Shield **up** into the dormant personal Maharic Shield 12" below the feet, to activate **the personal Maharic Shield.**

ACTIVATE TRIADIC PHASE CURRENT

3. Choose the specific Triadic Current you desire to run.

4. Use the inflow of **Maharic Current** from the personal and planetary Maharic Shield as a **Carrier Wave** to carry the **Cap Stone Color frequencies** of the **Signet Star Crystal Seals** in your Scalar Shields that correspond to the **Triadic Phase Current** you wish to activate.

5. Temporarily **release** the **Signet** and **Cranial-Sacral Kundalini Seals** and activate the **DNA Strand Template** corresponding to the chosen **Triadic Phase Current**, by running the **Primary Frequency** and the frequency **one Harmonic above it** through the **Signet Seals**, on the Maharic carrier wave current, to open the **Nada Hova Body** and physical body systems to inflow of the higher dimensional **Triadic Phase Current**.

COLLECT AND TRANSMIT HEALING CURRENT

6. As the Triadic Phase currents transmits into the body through the Signet Seals, Kundalini energies and DNA Template, **collect and build the current** as a **Sphere** of energy within the **Chakra** corresponding to the Primary Triadic Current you are running.

7. Run the current from the **Collecting Chakra** through **the Axi-A-Tonal Line Cords** in the arms, to activate the **Palm Chakras.**

8. **Exhale** current from the **Chakra Collection Sphere** through the **Cords** and allow it to build into **Balls** of energy within the **Palm Chakras** before transmitting.

9. Transmit the Triadic Current through the **RIGHT PALM CHAKRA** into client's bio-energetic field while drawing more current into the **Chakra Collection Sphere** with each **exhale** breath and draw the current back through the **LEFT PALM** on each **inhale** breath to create a higher dimensional Closed Circuit Healing Current. Use **LEFT PALM OVER BACK OF RIGHT HAND** hand position.

TECHNIQUE # 3

Opening the Healing Channels- Doradic-Phase-1 Current

1. Breathe slowly and deeply for several breaths while visualizing or imagining a **4" Violet Dot** on the center of the *inside of your forehead*. Make the color image as strong as you are able.(If you can't yet perceive inner colors or visualization, simply imagine the Violet Dot as being there). Move the Violet Dot to the center of the brain at the **Pineal Gland**, and then upward into the **7th Crown Chakra**, from the inside of the head moving upward and outward until the Violet Dot *rests on top of your head* at the Crown Chakra.

2. Call to mind the **Hierophant Symbol** (Pale Silver Merkaba Star formed by combining 2 Merkaba Stars). Visualize the spinning Hierophant stationed 12" below the feet within your **Maharic Shield** and slowly **INHALE**, drawing the Hierophant up through the Central Body Current, up to meet the Violet Dot at the **7th Crown Chakra** at the top of the head. When the *Hierophant connects with the Violet Dot* visualize the Violet Dot bursting into a **4" Vertical Pillar of Violet-Silver Light**. Imagine the *Violet-Silver Pillar* running down through the body into the *Earth Core* and upward to the **14th Chakra** 36" above the Head. You have activated **the Violet Ray of Transmutation.**

3. Move your attention to the **4th Heart Chakra** and imagine a *small Green Spherical Crystal* – the **Green Star**- stationed at its core. This is the *Green Star Crystal Seal* that controls release of *4th Dimensional* frequency – *Phase-1 Doradic Current* - into the body. **INHALE**, drawing Violet-Silver energy from the Violet-Silver Pillar into the *Green Star*. **EXHALE**, *expanding* the Violet-Silver energy *into the Green Star sphere. Repeat 2 more INHALE-EXHALE* breaths, drawing Violet-Silver Energy from the Pillar and expanding it into the Green Star sphere. At the end of the last **EXHALE**, imagine the **Green Star popping**, turning into a spinning Green and Violet Starburst of Light, as the *Violet-Silver Pillar disappears. Spin the Green-Violet Starburst* faster until it becomes a *ball of Green-Violet Light*, about the size of a *grapefruit*, spinning in the center of the *4th Heart Chakra*. The Green-Violet ball is the store-house for your Phase-1Doradic Current – it is called the **Doradic Sphere. INHALE** and draw Pale Silver energy from your **Maharic Shield**, through the Central Body Current and into the center of the **Doradic Sphere** at the **4th Heart Chakra**, encasing the Sphere in translucent Pale Silver Light.

4. **EXHALE quickly** and push **2 Cords** of *Green-Violet-Silver energy* – **Doradic Cords** -from the Doradic Sphere *down the inside of your arms*, one Cord through each arm. As the ends of the Doradic Cords reach the inside of the hands, notice a sensation of *mild resistance* as the Cords push against the *etheric membranes* covering the *small chakras* in the palms. **INHALE** a full breath, drawing Silver energy up from the **Maharic Shield**, into the *Doradic Sphere* at the 4th Chakra. **EXHALE forcefully**, pushing more energy down through the *Doradic Cords* in the arms, and feel this energy **"pop"** out of the *palms, releasing the membranes* on the palm chakras. Continue to **INHALE** energy up from the *Maharic Shield* into the *Doradic Sphere* and **EXHALE** it through the *Doradic Cords, building the strength of the Doradic Current* in both palms. Imagine the Doradic Current *pooling in the palms* to form *2 Green-Violet balls of light*, about the size of *tennis balls*. Energize the Doradic Sphere and Cords until you can sense the smaller **Doradic Balls** formed in the *palms* of your hands. **Your *Doradic Current* is now activated for use in healing facilitation.**

SYMBOL SHORTHAND

TECHNIQUE # 3: Opening the Healing Channels Doradic-Phase-1 Current

1. **4" Violet Dot** inside forehead, move to **Pineal Gland** then up through **7th Crown Chakra** to **top of head.**
2. **Hierophant Symbol** at center of your **Maharic Shield** 12" below feet. Inhale Symbol **up** to **Violet Dot** at top of head. See **Violet Dot burst** into **4" Violet-Silver Pillar** running through body to **Earth's core** and up to **14th Chakra** 36" above head.
3. Small **Green Star Crystal Seal at 4th Heart Chakra.** Inhale drawing **Violet-Silver** energy from **Violet-Silver Pillar** into **Green Star Crystal Seal** and see **Green Star Crystal Popping** into a spinning **Green-Violet Starburst,** as Violet-Silver Pillar **disappears.** Spin Green-Violet Starburst faster until it becomes grapefruit-size **BALL** of **Green-Violet Light**, the **Doradic Sphere,** at the center of the **4th Heart Chakra.** Encase Green-Violet Sphere in **Pale Silver** Maharic energy.
4. Push a **Green-Violet-Silver Doradic Cord** down each arm to **Palm Chakra Membranes** and draw **Pale Silver** up from **Maharic Shield** to **Doradic Sphere** and forcefully push Maharic Current **down arms** to **pop Palm Chakra Membranes.** While running **Doradic-1 Current** draw energy from **Maharic Shield** to **Doradic Sphere** and push it down arms from **Doradic Sphere** through **Doradic Cords** to **pool** into **Doradic Balls** at **Palm Chakras.**

TECHNIQUE # 3: Opening the Healing Channels
Doradic-Phase-1 Current

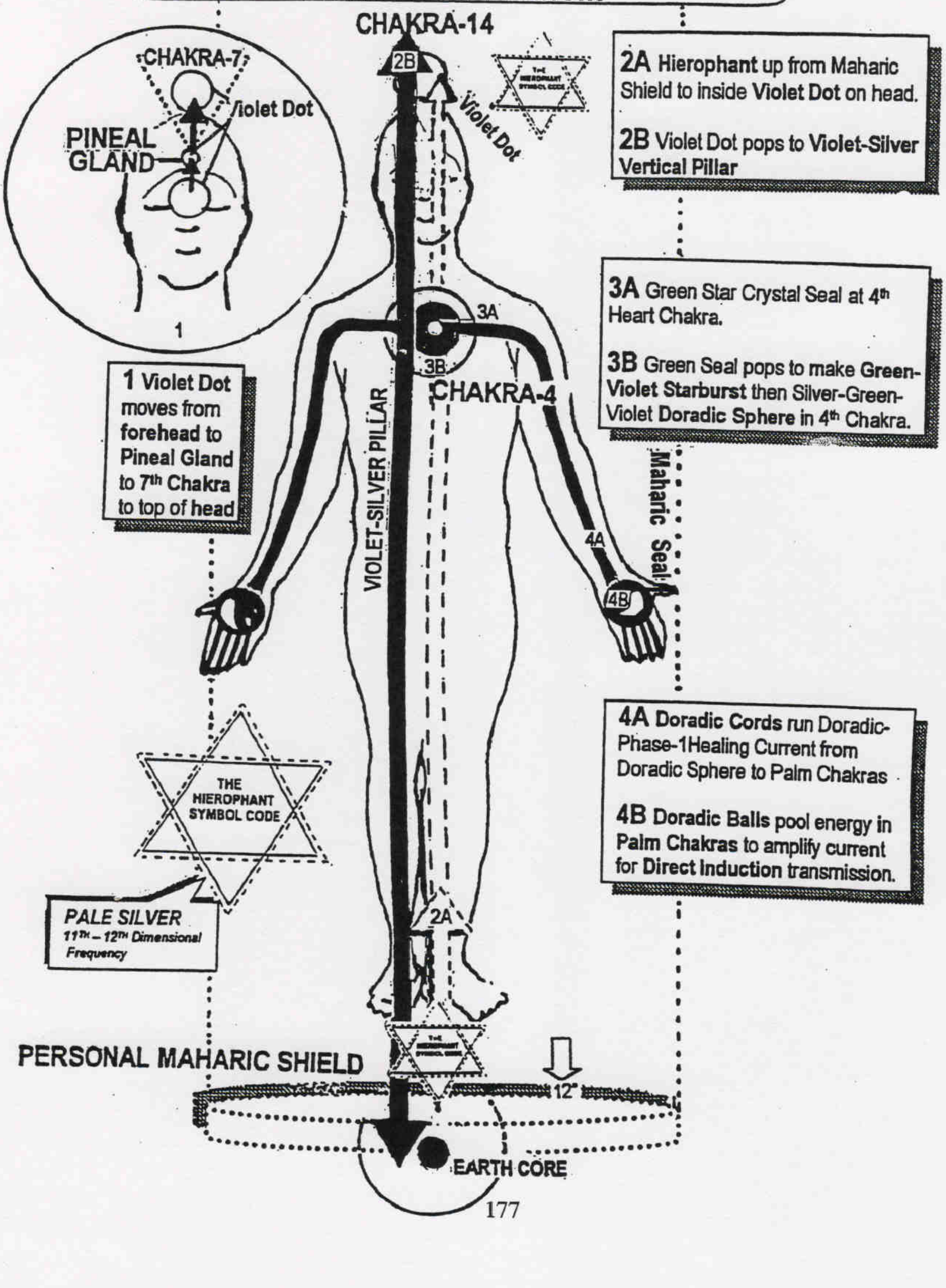
CHAKRA-14
CHAKRA-7
Violet Dot
PINEAL GLAND
1
2B
Violet Dot
THE HIEROPHANT SYMBOL CODE
3A
3B
CHAKRA-4
VIOLET-SILVER PILLAR
Maharic Seal
4A
4B
THE HIEROPHANT SYMBOL CODE
2A
THE HIEROPHANT SYMBOL CODE
PERSONAL MAHARIC SHIELD
12"
EARTH CORE

1 Violet Dot moves from forehead to Pineal Gland to 7th Chakra to top of head

2A Hierophant up from Maharic Shield to inside **Violet Dot** on head.

2B Violet Dot pops to **Violet-Silver Vertical Pillar**

3A Green Star Crystal Seal at 4th Heart Chakra.

3B Green Seal pops to make **Green-Violet Starburst** then Silver-Green-Violet **Doradic Sphere** in 4th Chakra.

4A Doradic Cords run Doradic-Phase-1Healing Current from Doradic Sphere to Palm Chakras

4B Doradic Balls pool energy in **Palm Chakras** to amplify current for **Direct Induction** transmission.

PALE SILVER
11TH – 12TH Dimensional Frequency

THE KARMIC-MIASMIC IMPRINT

THE NATURE OF KARMA

Karma, Identity, the Christos and the Physics of Divine Right Order

When an identity enters the **Time Matrix** to begin **simultaneous cycles of evolution** through time, it enters the manifest fields through first adopting a **Manifestation Template** composed of Partiki Units and Scalar Waves. The first Manifestation Template is called the **Rishic Shield**; it exists at the **Ante-matter** scalar-wave level of **Density-5** and holds the complete **Primal Scalar Pattern** for all of the **Singular Identities** that will **simultaneously** manifest into incarnation within the lower dimensional Densities and Time Cycles. The **Rishic Shield** represents the **Identity Gestalt** or **Family of Consciousness** through which identity enters manifestation. The Rishic Shield carries the precise configuration of Scalar-wave patterns, the **Primal Order** of energetic substance, through which the consciousness individuated to form a collective of consciousness within the dimensionalized Time Matrix. Every individual incarnate from the Rishic Family of Consciousness in time carries as part of its core **Kathara Grid** scalar program the **electromagnetic energy signature** of **Primal Order** carried by the **Rishic Shield** through which it manifested.

The Scalar-wave design of the Rishic Shield represents **DIVINE RIGHT ORDER**, the **Primal Order** of scalar-wave energetic relationship and **Partiki Phasing Sequences** that individual identities in time must re-evolve to hold within their embodied **Manifestation Templates** in order to **regain freedom** from the dimensional systems of the Time Matrix. Consciousness from the Rishic Shield, in the form of **Omni-polar wave spectra**, enters the manifest Densities by projecting portions of itself into **smaller Consciousness Gestalts** within the lower dimensional fields. The smaller Gestalts of Consciousness form the **3-Dimensional Scalar Shields** of the identity within the dimensionalized matter systems. **Each Scalar Shield holds the consciousness of numerous simultaneous Cycles of Incarnation within each of the 4 Primary Time cycles of Densities 1 through 4.** Each individual incarnate in time is directly linked to its original **Rishic Shield Family of Consciousness** through the **Density-4 Maharic Shield.** The Maharic Shield of dimensions **10-12** contains the first **Pre-matter Hydroplasmic scalar-wave spectra** through which identity began its experience within the holograms of Space, Time and Matter. The **personal Maharic Shield,** often called the **PERSONAL CHRISTOS IMPRINT,** holds the original **Primal Order** of scalar waves through which manifest consciousness links to its **Rishic Shield.** The **Christos Imprint** of the **Maharic Shield** represents the **PATH OF DIVINE RIGHT ORDER** through which each individual consciousness in time can **re-evolve** to its original Eternal Non-manifest State of Wholeness in Consciousness beyond the Time Matrix. **Divine Right Order is not only a spiritual concept; it is a reality in energy within the scientific dynamics of Universal Unified Field Physics.** Divine Right Order represents the **Primal Order** of scalar-waves that make up the original **Manifestation Template** from which individual **singular lifetimes** emerge, and it is the necessary pattern of energetic order within the personal multi-dimensional Manifestation Template which allows incarnate beings to fulfill the **evolutionary objective** of **Transmutational Dimensional Ascension. The result of an incarnate being's *Manifestation Template* and Conscious Awareness becoming mis-aligned with the energetic structure of *Divine Right Order* is called KARMA.**

Karma, Divine Right Order, the Scalar Shields, Free Will and Miasms

If it is understood that the universe and all things within it exist as **manifestations of consciousness** in the form of **precisely ordered** scalar wave arrangements, and that there is an intrinsic and indelible **Primal Order** upon which all manifestation functions, it will not be difficult to conceptualize the **literal and tangible nature** of the **Karmic Imprint**. In energetic terms, **Divine Right Order** represents the **natural alignment** of conscious energy fields within the intrinsic **Laws of Universal Physics** characteristic to the dimensional structures of time. Divine Right Order exists as a **tangible, specific** and **harmonious organization** of **energy interrelationships** within the Primal Order of energetic structure that creates dimensionality. The condition frequently referred to as **Karma** is, like Divine Right Order, a tangible, specific organization of energy interrelationships. Unlike Divine Right Order, *Karma* represents dis-harmonious interrelationships of energy within the context of the Primal Order that creates dimensionality. **Karma** can be viewed as **CHAOTIC, incoherent energetic disorganization**, whereas **Order** represents **coherent energetic** organization.

In terms of the **15-Dimensional anatomy** of the **personal Manifestation Template**, the **Karmic Pattern** represents **areas of incoherent energetic disorganization** within the structure of the personal **Scalar Shields**. The **12th–Dimensional** Level of the personal **Maharic Shield** holds the original **Christos Imprint**, the **Primal Order** *perfect organization* of scalar-wave configurations that links our consciousness and **DNA Template** to the **Rishic Shield Family of Consciousness** through which we entered the **Time Matrix**. While the Maharic Shield holds our original **Perfect Organization of Consciousness**, the Scalar Shields upon which our lower dimensional **Hova Bodies and Incarnate, Soul and Over-Soul Manifestation Cycles** emerge often become **distorted** from their original **Primal Order** as held within the **Maharic** and **Rishic Shields**. Human consciousness, in its multidimensional forms, was designed **"in the image of its Creator"**, having **Free Will** to *apply the dynamics of energetic creation in time* in accordance with **personal intention,** within the greater context of the fixed **Natural Energetic Laws of Creation.**

When we use our gift of **Free Will** to direct our energies in a manner **congruent** with the **Divine Right Order** of **Universal Unified Field Physics** (which implies co-creative, not competitive co-evolution for all), the scalar-wave design of our personal **Scalar Shields** remains organized upon the intrinsic design of universal and personal **Primal Order**. Through **embodiment** of Divine Right Order within our personal **Scalar Shields** and consciousness, we know conditions of **perfect health and harmony** within the Time Matrix. When our Free Will is used to direct our energies in ways that are **incongruent** with and non-supportive of **Primal Order**, the **disorganization** of our energetic orientation manifests as literal **Partiki Phasing Sequence distortions** that create **misshapen scalar-wave groupings** within the anatomy of the personal **Kathara Grid, Scalar Shields** and the **DNA Template** built upon them. These misshapen scalar-wave groupings within the Kathara Grid, Scalar Shields and DNA Template are called **MIASMS** and they hold, in **tangible scalar frequency** form, the **disorganized energetic patterns** of our **Free Will choices** through which we have used our energies in a manner **incongruent** with **Divine Right Order.**

Miasms* are the *tangible substance* of our *Karmic Pattern* that reflect the areas in which our *consciousness* and *Scalar Shields* are *distorted* from our original *Maharic Shield Christos Imprint* of *Perfect Organization* within the context of *Universal Primal Order.

TIME VECTORS AND THE KARMIC-MIASMIC IMPRINT

Miasms, Incarnational Time Vectors, Vector Imbedding and the DNA Template

The **Miasmic Imprint** within the body and Manifestation Template that holds the personal **Karmic pattern** manifests as **mathematical, geometrical** and **electro-magnetic distortions** in scalar-wave forms within the Kathara Grid and Scalar Shields, that cause groupings of **Anti-particles** to build up within the **Particle field** of the physical and energetic anatomy. The build-up of **Anti-particles** within the Particle Field blocks the natural flow of energy and consciousness through the Kathara Level-3 **Diodic Points Grid**, and manifests as **malfunctions** within the **Partiki Phasing Programs** within the **Kathara Centers** of the Level-1 **12-Tree Grid** and within the **Signet Star Crystal Seals** of the Kathara Level-2 **Crystal Seals Grid.** The **3 Levels of the Kathara Grid** set the blueprint for manifestation of the **Scalar Shields, Hova Bodies, Chakra System** and **DNA Template. Miasmic distortions** in the **Kathara Grid** effect **every level of personal manifestation**, from the operation of the **physical genetic code** to the ability of consciousness to successfully embody within the physical form, to the potentials of **Transmutational Dimensional Ascension** and attainment of **Spiritual Actualization.**

Karma-* the *Miasmic Imprint-* is a *biophysical phenomenon* of scalar-wave distortion that directly effects the *human DNA.

The **Incarnations of SELF** that **simultaneously manifest** into incarnational cycles of divergent space-time placement within the 4 Densities and 12-Dimensions of Matter are all **directly interconnect** through the **Kathara Grid, Scalar Shields** and **DNA TEMPLATE.** The **Free Will choices** made by other manifestations of ourselves **concurrently existing** in other space-time locations and different manifest body forms, effect the function of our personal **Kathara Grid, DNA Template, conscious awareness** and **life experience.** The **choices WE make** in our present lifetime directly effect the **Kathara Grid, DNA Template, consciousness** and **life experience** of **our other-time incarnations.** The energetic connection between incarnations of the SELF is an immediate, **living connection** of energy and consciousness. Because our numerous simultaneous incarnations in time are directly, energetically linked to each other via the Kathara Grid and DNA Template, we literally **inherit Miasmic Buildup from each other** on a continual basis. When we make the choice to restore our personal **Imprint for Health,** our **Christos Imprint,** as held within our **Maharic Shield,** part of these efforts must involve **clearing the Miasmic Imprint** that is bleeding through into our personal Manifestation Template for the other incarnations of Self.

Each of our simultaneous incarnations in time represents one **SINGLE VECTOR CONSCIOUSNESS,** one portion of our **Eternal Identity** that experiences 3-Dimensional **linear evolutionary progression** along **ONE TIME VECTOR** (one cycle of Partiki Phasing Sequences). **Each Incarnate represents a TIME VECTOR.** The multiple Time Vectors of our Multiple Simultaneous Selves are literally **encoded** within core scalar-wave programs of our **DNA Template;** this is called **VECTOR IMBEDDING.** To fully heal our Body-Mind-Spirit system by restoring it to its **Organic Imprint for Health,** the **Maharic Shield Christos Imprint,** we need to clear the Miasmic Imprint from our other simultaneous incarnations as it is presently embedded within our DNA Template. **Transmuting the Miasmic Imprint that is embedded in our DNA Template to restore the original perfect Primal Order is called "Clearing the Karmic Pattern"** or **MULTI-VECTOR HOLOGRAPHIC RECODING.**

MULTI-VECTOR HOLOGRAPHIC RECODING

REGENESIS OF THE PERSONAL CHRISTOS

Restoring the Organic Imprint for Health and Clearing the Karmic-Miasmic Imprint

Literally all conditions of **dis-ease** in the human body and dis-harmony in the life experience, including the unnatural condition of **death** of the human body form, result from **Miasmic Distortions** within the embodied **Kathara Grid, Scalar Shields, DNA Template** and personal **Inner Templar Complex.** The natural state of **Universal Primal Order** is harmonious co-creative interrelationship of consciousness. Humans can progressively return to their natural condition of **Ordered Perfection** through **re-genesis**, or *re-creation*, of the **Organic Imprint for Health – the Maharic Shield Christos Imprint** – within the Kathara Grid blueprint of the personal Manifestation Template. **Regenesis of the Personal Christos** is a **Multi-Vector Endeavor**, involving clearing the karmic-Miasmic Imprint from a myriad of various simultaneous selves presently evolving in the Time Matrix. The **hard way** to clear the Miasmic Imprint is by **"walking the Karma"**, which means allowing progressive levels of the **Miasmic Imprint** to repeatedly **re-manifest** in the personal life experience, until the **proper application of Free Will choice** used in congruence with **Divine Right Order** becomes consciously apparent and the **"Right Choices"** are made to re-ordered the disorganized use of energy that caused the Miasm to form. In our present time, this approach to "clearing the Karmic Pattern" is no longer effective as a learning tool by which embodied consciousness teaches itself the etiquette of creation. **The Miasmic Imprint within the collective human species has grown so extensively that the core issues of misapplied Free Will that cause Miasmic Buildup can no longer be consciously identified, and the Miasmic Imprint continues to compound and amplify itself as the same errors of Free Will energy use are perpetually repeated and reinforced.**

The Karmic-Miasmic Imprint is an **ENERGY FORM**; a literal **construct of scalar-wave frequency** with its corresponding **Anti-particle Manifestation.** As a form of energy, the **Miasmic Imprint** can be dealt with **AS ENERGY, WITH ENERGY**, for the most expedient clearing, healing and realignment of the **Karmic Imprint.**

The **Karmic-Miasmic Imprint** manifests within the **causal level** of manifestation, the **3 Levels of the embodied Kathara Grid of the personal Internal Template Complex**, and from the Kathara Level the Karmic-Miasmic Imprint manifests as **misalignment** and **malfunction** within all levels of Body-Mind-Spirit system. To clear the Karmic Imprint **AS ENERGY, WITH ENERGY**, its disorganized scalar-frequency patterns must be realigned from the **Core Template Kathara Grids**, the **causal level** of miasmic manifestation. Restoring the **Maharic Shield Christos Imprint** to the personal **Kathara Grid** takes time and **precise applications of frequency re-ordering** in all levels of the Body-Mind-Spirit system. The first step to **Regenesis of the Personal Christos** is the **MAHARIC RECODING PROCESS.**

MULTI-VECTOR HOLOGRAPHIC RECODING

Recoding the Time Vectors of the DNA Template and the DNA Fire Codes

The process of regenerating the **Christos Imprint** within the **Kathara Grid** of the human body is a **MULTI-VECTOR** undertaking. A **Vector** is a **set cycle of vibrational-oscillation rhythm** that creates a **specific repeating Partiki Phasing Rhythm** and **Flash Line Sequence.** Each individual incarnate self in time holds within the electro-magnetic programs of its embodied **Kathara Centers** the precise **Partiki Phasing Rhythms** that correspond to its particular placement within the planetary **Time Cycles.** The **Time Vector,** or **Flash Line Sequence** that creates one linear **Event Horizon,** is literally encoded and actively operational within the **Kathara Grid** and **DNA Template** of each incarnate identity. In the process of restoring the **Organic Integrity** to the personal Manifestation Template, the dormant **Partiki Phasing Rhythms** that correspond to one's **other-time incarnates** are progressively **brought into activation** and **realigned** with the Christos Imprint of the **Maharic Shield.**

The **Partiki Phasing Flash Line Sequence programs** within the embodied **Kathara Centers** manifest within the **DNA Template** as the **GENETIC TIME CODES,** or **Fire Codes,** of the DNA. In restoring **Maharic Order** to the personal **Kathara Grid,** the **12 Dormant Fire Codes** of the DNA Template will be slowly but progressively brought into **activation** through the 11th-12th –Dimensional Frequencies of the **Maharic Shield Mahara Hova Body Current.** Activation of the **DNA Fire Codes** creates a reciprocal release of the **Signet Star Crystal Seals** and **Cranial-Sacral Kundalini Seals** within the **Kathara Level-2 Crystal Seals Grid,** progressive activation of the dormant **Kundalini energies** and **Merkaba Vehicle Phases,** merger of the **Hova Bodies** and embodiment of the higher dimensional **Spiritual aspects** of conscious awareness. The process of recoding the multiple time vectors within the DNA Template – **Multi-vector Holographic Recoding-** is a process of progressive **WHOLE-BEING HEALING** that is achieved through **consistent application** of the **MAHARIC RECODING PROCESS,** and expedited through complimentary processes of **DNA Template, Kundalini** and **Merkaba Vehicle** activation. Level-1 Kathara Healing introduces the operational mechanics of the **Maharic Recoding Process.**

The Maharic Recoding Process

FOR MULTI-VECTOR HOLOGRAPHIC RECODING

The 4 Primary Elements of Action

1. **The Maharic Seal and the Liquid Light Cleanse** (Technique # 2)
2. **Opening the Healing Channels** (Technique # 3)
3. **Amplifying Inner Audio-Visual and Kathara Scan** (Technique # 4)
4. **The Maharic Infusion** (Technique # 5)

The **4 Primary Elements of Action** to begin the **Maharic Recoding Process,** through which **Multi-Vector Holographic Recoding** of the **Morphogenetic Field Manifestation Template** is achieved. Begins realignment of the Core Manifestation Template **Kathara Grid Levels,** the **Scalar Shields, Hova Bodies, Axi-A-Tonal Lines** and **DNA Template** with the **Primal Order** perfect scalar-wave pattern of the personal 12th-Dimensional Pre-matter Hydroplasmic **Maharic Shield-** the **Christos Imprint** and **Organic Imprint for Health.** Also begins activation of dormant **DNA Strand Templates, Kundalini** energies and the **Merkaba Vehicle** for **Transmutational Dimensional Ascension.**

Bio-Regenesis of the Christos Imprint
and 12-Strand DNA Template
within the human body.

TECHNIQUE # 4

AMPLIFYING INNER AUDIO-VISUAL AND KATHARA SCAN

1. Place **RIGHT palm** (*electrical-transmitting hand*) over the **5th Kathara Center** at the **Navel**, and place the *Left palm* (*magnetic-receiving hand*) over the *back of the right hand* (to block 3rd-Dimensional energies from entering the rear of the right hand chakra). **INHALE** energy from your **Maharic Shield** – the *Maharic Carrier Wave*- into your **Doradic Sphere** at the *4th Heart Chakra*. **EXHALE** and run the *Maharic Wave* down the *Doradic Cords* in the arms and into the *Doradic Balls* in the palms. Inhale, then **EXHALE**, using the exhale breath to *push* energy from the *Doradic Sphere*, down the *Doradic Cord* in the **RIGHT** arm, through the **RIGHT Doradic Ball** and into the **5th Kathara Center** at the *Navel*. Run several breaths of *Doradic-1 Current* into the *5th Kathara Center* at the Navel, until a **mild tingling sensation** is **felt**.

2. Place the **LEFT palm** over the **5th Chakra** at the *Throat*, with the *Right palm* covering the *back of the LEFT hand*, and **INHALE** the Doradic-1 Current up from the *5th Kathara Center* at the Navel, into the Seed/Center of the **5th Chakra**. **EXHALE** and *expand* the Doradic-1 frequency into the *5th Chakra spiral*, allowing the magnetic current from the LEFT hand to draw the energy out through the spiral. As you **EXHALE**, slowly **move the hands forward**, away from the body and the **5th** Chakra.

3. Repeat the same process over the **6th Kathara Center**, placing the **RIGHT palm** over the *6th Kathara Center* below the **Right Shoulder**, with the *Left palm* covering the back of the *RIGHT hand*. **INHALE**/Draw energy up from the *Maharic Shield*, into the *Doradic Sphere*. **EXHALE** energy down the *Doradic Cords* into the *Doradic Balls*. Inhale, then **EXHALE** energy down the *RIGHT Doradic Cord* through the *RIGHT palm* and into **Kathara Center 6.** Run several breaths to energize the *6th Kathara Center*. Then move **LEFT palm** over the *6th Third Eye Chakra* in the forehead, with Right palm behind. **INHALE** the Doradic-1 Current from the *6th Kathara Center* into the Seed/Center of the *6th Chakra* and **EXHALE** the energy into the 6th Chakra spiral while drawing it through with the magnetic current from the LEFT hand. The **6th Sense-*Audurea***, which provides **inner audio** perception, and the **7th Sense-Tristet**, which provides **inner visual** perception are now energized and amplified in preparation for **Kathara Scan.**

4. Close your eyes and focus your attention in a **single point** at the *inside of your forehead*. Inhale, and as you **EXHALE** run your attention outward *through your 6th Chakra spiral*, into the **6th Chakra Spiral of your Client**. Move your attention into the center of your Client's brain, the **Pineal Gland**. Inhale, and **EXHALE** moving your awareness down from the Client's Pineal, through your *Client's Central Body Current* and down into the **Earth's core. INHALE** and move your awareness back upward to your **Client's Maharic Shield**, and spread your awareness outward through the *Maharic Shield* with the **EXHALE.** On the *inside of your forehead*, imagine the image of the **Kathara 12-Tree Grid, INHALE** energy from the *Client's Maharic Shield* and **EXHALE** the energy out into the *12-Tree image*. Breathe gently for a moment, *observing the 12-Tree Grid*, which will register tones of white, black and ranges of gray in between. If you cannot yet visualize, you will still get a sense of the 12-Tree image and the areas of dark and light within it. The dark areas represent layers of the **MIASMIC BODY**, areas of the *karmic imprint* that need clearing when you run *Technique # 4: The Maharic Infusion*. Remember the areas of the Client's Kathara that need clearing. Inhale, and *open your eyes* on **EXHALE.**

SYMBOL SHORTHAND

TECHNIQUE # 4: Amplifying Inner Audio-Visual and Kathara Scan

Activate Maharic Seal and Open Healing Channels. (Techniques # 2 and # 3 first)

1. **RIGHT Palm** on **5th Kathara Center** in **Navel.** Breathe **Maharic Current** up from personal **Maharic Shield** and into **Doradic Sphere** at **4th Chakra.** Push **Maharic-Doradic-1 Current** down **Doradic Cords** and into **Doradic Balls** at **Palm Chakras.** Push Current from Doradic Ball in **RIGHT Palm** into **Kathara Center # 5** in **Navel.**

2. **LEFT Palm** on **5th Throat Chakra,** cover back with **Right Palm** (Reverse Standard Hand Position). Inhale **Doradic-1 Current** up from **5th Kathara Center** in **Navel** to center of **5th Throat Chakra** and expand Current into **5th Chakra Spiral,** with **Left Palm Chakra** drawing current out of **5th Chakra Spiral.**

3. **RIGHT Palm** on **Kathara Center # 6** below **Right Shoulder,** cover back with **Left Palm.** Push **Maharic-Doradic-1 Current** from Doradic Ball in **RIGHT Palm** into **Kathara Center # 6. LEFT Palm** over **6th 3rd Eye Chakra,** cover back with **Right Palm** (Reverse Standard Hand Position). Inhale **Doradic-1 Current** up from **Kathara Center # 6** to center of **6th- 3rd Eye Chakra** and expand Current into **6th Chakra Spiral,** with **LEFT Palm Chakra** drawing Current out of **6th Chakra Spiral.**

4. **KATHARA CLIENT SCAN: A.** Place **Point of Attention** inside **forehead** and run attention out of **6th Chakra Spiral** and into the **6th Chakra Spiral of Client,** then into **Client's Pineal Gland. B.** Run attention down **Client's Central Vertical Current** and into **Earth's Core,** then back up to **Client's Maharic Shield..**Expand attention out into **Client's Maharic Shield. C.** Visualize image of **Kathara 12-Tree Grid,** inhale energy from **Client's Maharic Shield** and exhale it into image of **Kathara Grid. D.** Observe for **Dark Miasmic Buildups** in image of **Kathara Grid;** run extra healing Current into these areas of the **Client's Kathara Grid** during the **Maharic Infusion** (Technique # 5).

Personal Kathara Scan: On **Step 4** run attention down **your Central Vertical Current** then back up to **your Maharic Shield** and out into **your Maharic Shield.** Breathe energy from your Maharic Shield into image of **Kathara 12-Tree Grid** and observe for **Dark Miasmic Buildup** areas to clear during the ***Maharic Seal and Liquid Light Cleanse*** technique. Send **extra Maharic Current** to these areas during ***Liquid Light Cleanse.***

TECHNIQUE # 4: Amplifying Inner Audio-Visual and Kathara Scan

1. A. RIGHT Palm on 5th Kathara Center in Navel.
B. Breathe Maharic Current up from personal Maharic Shield to Doradic Sphere and down Doradic Cords to Palm Chakras.
C. Push Current from RIGHT Doradic Ball into 5th Kathara Center.

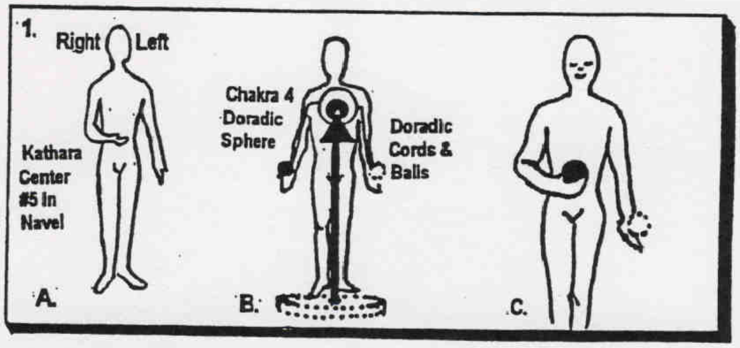
1.
Right
Left
Kathara Center #5 In Navel
A.
Chakra 4 Doradic Sphere
Doradic Cords & Balls
B.
C.

2. A. LEFT Palm on 5th Throat Chakra, cover back with Right Palm.
B. INHALE Doradic-1 Current up from Kathara Center # 5-Navel to 5th Chakra and expand Current into 5th Chakra Spiral.

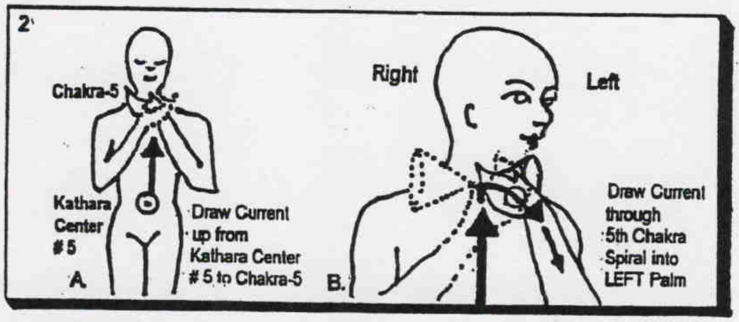
2.
Chakra-5
Kathara Center #5
Draw Current up from Kathara Center # 5 to Chakra-5
A
Right
Left
Draw Current through 5th Chakra Spiral into LEFT Palm
B.

3. A. RIGHT Palm on Kathara Center #6 in Right Shoulder, cover back with Left Palm. B. LEFT Palm on 6th 3rd-Eye Chakra, INHALE Current from Kathara Center # 6 into 6th Chakra Spiral and into LEFT Palm. C. Kathara Scan: a. Run your Attention from your 6th Chakra to Client's 6th Chakra and Pineal Gland. b. Run Attention down Client's Central Vertical Current to Earth's Core & into Client's Maharic Shield. c. EXHALE energy from Client's Maharic Shield into Image of Kathara 12-Tree Grid. d. Scan grid for Dark Areas of Miasmic Buildup for clearing with Maharic Infusion.

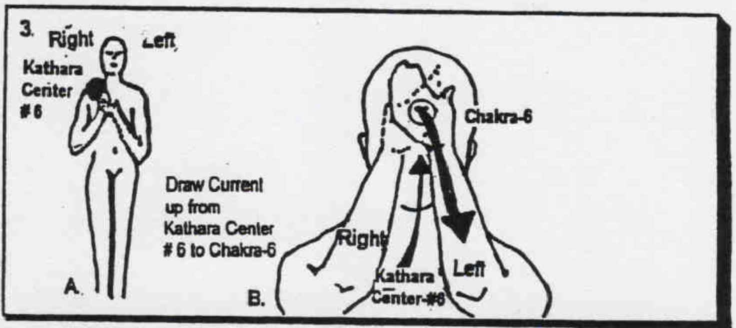
3.
Right
Left
Kathara Center #6
A.
Draw Current up from Kathara Center # 6 to Chakra-6
Chakra-6
Right
Left
Kathara Center-#6
B.

KATHARA SCAN

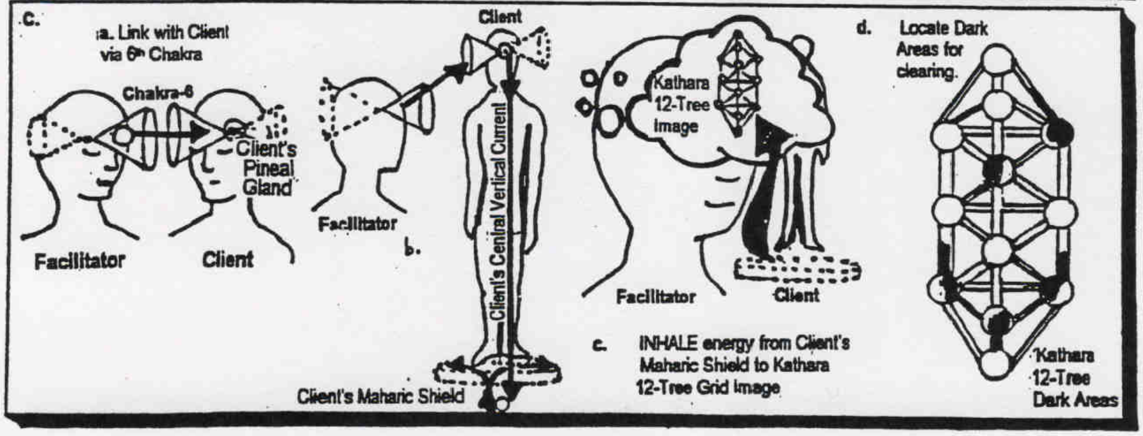
C.
a. Link with Client via 6th Chakra
Chakra-6
Client's Pineal Gland
Facilitator
Client
Client
Facilitator
b.
Client's Central Vertical Current
Client's Maharic Shield
Kathara 12-Tree Image
Facilitator
Client
c.
INHALE energy from Client's Maharic Shield to Kathara 12-Tree Grid Image
d.
Locate Dark Areas for clearing.
Kathara 12-Tree Dark Areas

TECHNIQUE # 5

THE MAHARIC INFUSION – CLIENT FACILITATION

Prior to using this technique you should have completed the following: 1.Positioned *MENTOR* over your Right shoulder to assist (*Tech. # 1:Awakening the Mentor and the 6th and 7th Senses*). 2. Activated your *Maharic Shield, Maharic Seal* and run the *Liquid Light.* (*Tech. # 2: The Maharic Seal and the Liquid Light Cleanse.*) 3.Activated your *Doradic Current, Inner audio/Visual* and *Client Kathara Scan* (*Tech. # 3. and # 4*)
4. Opened the *Kathara Lines* for you and your Client (*Sequence-1 Kathara Points*)

Place Client in a reclining position with shoes off:

1. Position yourself at the **feet** of the reclining Client. Place **RIGHT palm** *12" below Client's feet* at the **Maharic Shield,** *left palm* over the back of Right hand.
2. Visualize the **Hierophant symbol** on the *inside of your forehead.* Inhale, then **EXHALE,** moving the *Hierophant* down to **Chakra 4** and into the **Doradic Sphere** with the exhale breath. **INHALE** energy upward from *your* **Maharic Shield** and into the *Doradic Sphere.* **EXHALE** the **Hierophant** with *Doradic-1 current* down the **Right Doradic Cord** and into the *Doradic Ball* in the **Right palm.** .
3. Inhale, then **EXHALE** the *Hierophant and Doradic-1 current* into the *center* of the **Client's Maharic Shield.** Visualize the *Hierophant spinning* in the center of the Client's Maharic Shield until you sense a **mild shift** in the energy below the Client's feet. The shift indicates that the Client's *Maharic Shield* has activated and the *Maharic Pillar* has "popped" vertically upward from the Shield – the Client's bio-energetic field now carries the **Maharic Seal.**
4. **INHALE** energy from your *Maharic Shield* into your *Doradic Sphere,* then **EXHALE** the energy down **both Doradic Cords,** into the Doradic Balls in the palms. Visualize the **12-Tree Kathara Grid** *within the Client's body.* You will now run the **Maharic Infusion** through the *small chakra points in the feet.*

TECHNIQUE #5 : Continued
THE *MAHARIC INFUSION*

5. Place your **Right palm** on the *bottom* of **Client's Left foot** and your **Left palm** on *top of the foot,* centered over the *Right palm*. Imagine that you are lining up the *small vortex* beneath the ball of the Client's foot (which extends *through the foot* to come out on top), with the *small chakras* in your *palms*. Inhale, then **EXHALE** energy from your **Doradic Sphere** through the **Right Doradic Cord, Right palm** and *into the **sole** of the Client's foot.* Visualize the **Green-Violet-Silver energy** traveling up the **Kathara Line on the** *Left side of the body,* through the *4th, 7th and 10th Kathara Centers.* Continue **EXHALING** energy into the **Left foot** until you begin to feel a bit of **fuzzy energy** coming out of the foot toward your palm. This indicates that the *Kathara Line* has *reached its energy-holding capacity.* **Repeat** the process on the **Right foot**, running energy through the *Kathara Line on the Right side of the body and the 3rd, 6th and 9th Kathara Centers.*

6. You will now clear and align the **Central Vertical Kathara Line** to complete the **Maharic Infusion. Move to Client's head.** Place **Right palm** over **Client's 10th Chakra** 6" above the head, the location of the *12th Kathara Center.* Place *Left palm* over back of Right hand. **INHALE** energy from your **Maharic Shield** into your **Doradic Sphere** then **EXHALE** energy down the **Right Doradic Cord**, into the **Right palm** and through the **10th Chakra**. Visualize the energy moving down from the *10th Chakra* into the **7th Chakra**, to the **Pineal Gland** (11th Kathara Center), then *rapidly* down the **Central Body Current** and **Central Kathara Line**, through *Kathara Centers 8* (thyroid), *5* (Navel), *2* (at Base Chakra) and into *Kathara Center 1* at **Earth's core.** Continue **EXHALING** energy into the **10th Chakra** and **Central Kathara Line** until you feel **fuzziness** against your *Right palm*, indicating that the *Kathara Grid* has reached its *energy-holding capacity.*

7. *Before releasing 10th Chakra* direct a bit of additional energy through the **Central Kathara Line** into areas that revealed **dark spots** during the *Kathara Scan.* Visualize the areas *getting light* as the energy runs through them. **You may add other healing modalities at this point, if desired.** *Close* by using the **Sequence-2 Kathara Points** to close the Kathara Lines and *revitalize the body.* Allow Client a few moments to recline before ending session.

THE MAHARIC INFUSION – CLIENT FACILITATION

Preparation: **A.** *Technique #1*- Place MENTOR over your Right Shoulder **B.** *Technique #2*-Activate your Maharic Shield and run Liquid Light Cleanse. **C.** *Technique #3*- Activate yourDoradic-1 Current **D.** *Technique #4* – Amplify Inner Audio-Visual and run Client Kathara Scan **E.** *Sequence-1 Kathara Points* massage on Self and Client to open Kathara Lines.

Place Client in reclining position with shoes off

1. Stand at Client's feet, place **RIGHT Palm** 12" below Client's feet at **Client's Maharic Shield**, left palm over back of Right hand.

2. See **Hierophant Symbol Code** inside your forehead, **EXHALE** Symbol down to **Chakra-4 Doradic Sphere. INHALE** energy up from your **Maharic Shield** into Doradic Sphere. **EXHALE** *Hierophant Symbol* with *Doradic-1 Current* down **RIGHT Doradic Cord** into **RIGHT Doradic Ball in RIGHT Palm.**

3. **EXHALE** Doradic-1 Current and Hierophant Symbol into Center of **Client's Maharic Shield** via **Right Palm Doradic Ball and spin Hierophant** until sensed **Energy Shift of Client's Maharic Seal.**

4. **INHALE** Current from your Maharic Shield to Doradic Sphere and **EXHALE** Current down both **Doradic Cords** into **Doradic Balls**. See **Kathara12-Tree Grid** within **Client's body** and begin running the ***Maharic Infusion*** through the **Secondary Chakras** in **Client's feet.**

5. **RIGHT PALM** on **bottom of Client's LEFT FOOT, LEFT PALM** on **top of Client's LEFT FOOT**, both **centered** over Client's LEFT FOOT **Secondary Chakra. INHALE** Maharic energy into Doradic Sphere and **EXHALE** Doradic-1 Current into Client's **LEFT KATHARA LINE**, and through **Kathara Centers # 4, #7** and **# 10. EXHALE** Doradic-1 Current into Client's **LEFT FOOT** until **"Fuzzy"** resistance emerges from Client's foot Chakra. **REPEAT PROCESS** on **Client's RIGHT FOOT**, running Doradic-1 Current through the **RIGHT KATHARA LINE** and **Kathara Centers # 3, #6** and **#9.**

6. **Stand at Client's Head. RIGHT PALM** over **Client's 10th Chakra** (6" above head- the 12th Kathara Center), LEFT Palm over back of Right hand. Fill Doradic Sphere with Maharic Energy then **EXHALE** Doradic-1 Current down **RIGHT DORADIC CORD** and Palm and into **Client's 10th Chakra.** Run Current from **Chakra-10**, to **Crown Chakra-7, Pineal Gland**, rapidly down **Central Vertical Current** and **Kathara Centers #8** (Thyroid), **#5** (Navel) **#2** (Chakra-1) and **#1** (Earth's Core Chakra 13). Continue exhaling Current until **"Fuzzy"** resistance emerges from Client's 10th Chakra.

7. **Direct additional energy** through Client's **CENTRAL KATHARA LINE** to clear **DARK AREAS** of **Kathara Grid** located in **Kathara Scan.** Add any additional healing technologies following Client's Maharic Infusion. Close with **SEQUENCE-1 KATHARA POINTS** massage. Allow Client to remain relaxed in reclining position for several minutes following Maharic Infusion.

TECHNIQUE # 5: THE MAHARIC INFUSION – CLIENT FACILITATION

Maharic Infusion 6-STEP Sequence

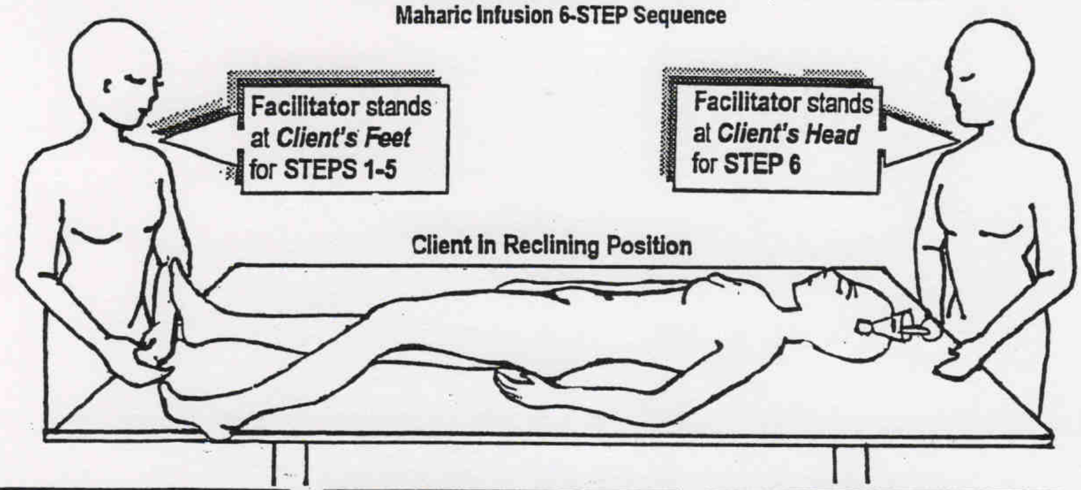
Facilitator stands at *Client's Feet* for STEPS 1-5
Facilitator stands at *Client's Head* for STEP 6
Client in Reclining Position

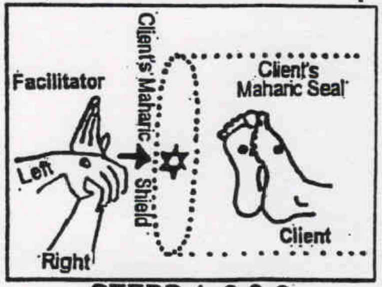
Facilitator
Client's Maharic Shield
Client's Maharic Seal
Left
Right
Client

STEPS 1, 2 & 3

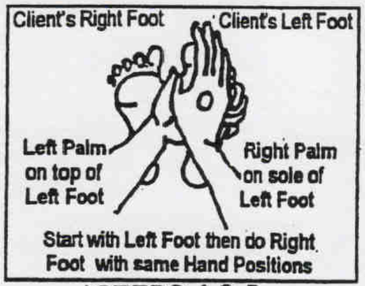
Client's Right Foot
Client's Left Foot
Left Palm on top of Left Foot
Right Palm on sole of Left Foot
Start with Left Foot then do Right Foot with same Hand Positions

STEPS 4 & 5

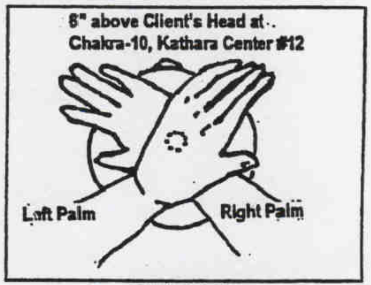
6" above Client's Head at Chakra-10, Kathara Center #12
Left Palm
Right Palm

STEP 6

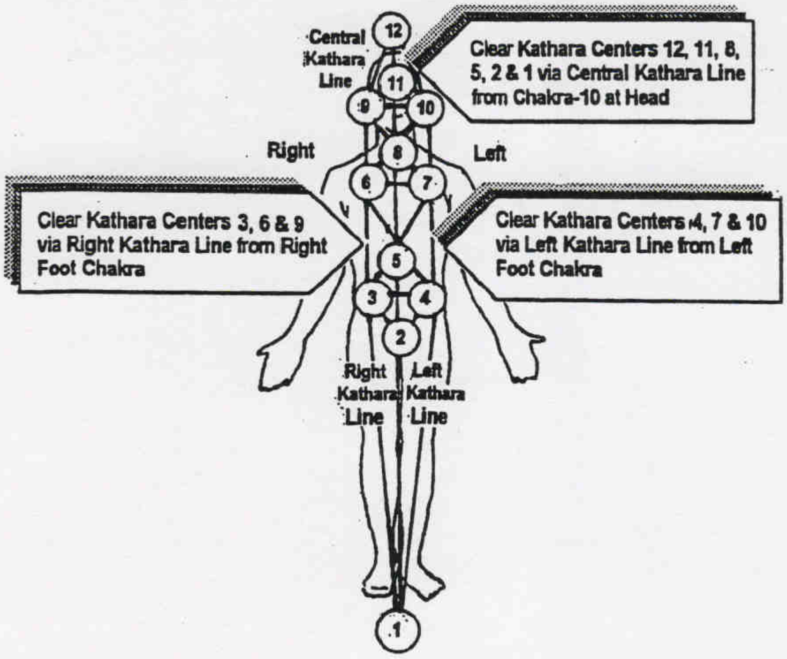
Central Kathara Line
12
11
9
10
8
6
7
5
3
4
2
1
Right
Left
Right Kathara Line
Left Kathara Line
Clear Kathara Centers 12, 11, 8, 5, 2 & 1 via Central Kathara Line from Chakra-10 at Head
Clear Kathara Centers 3, 6 & 9 via Right Kathara Line from Right Foot Chakra
Clear Kathara Centers 4, 7 & 10 via Left Kathara Line from Left Foot Chakra

MOTIVATION TO HEAL

Healing Facilitation is an art and a science, but most importantly, healing facilitation is an **interrelationship of SOULS.** Egotistical objectives have no place in quality Healing Facilitation. The decision to participate in Healing Facilitation should not be motivated by a desire to prove you have "special abilities" to boast about, nor with the primary motive of gaining **financial profit** from Healing Facilitation endeavors. The energies exchanged in healing facilitation are **FREE TO ALL**, a **DIVINE GIFT** from **the universe, and they belong to all beings equally.** A facilitator cannot rightly request payment from a client for providing what the client already possesses- **Natural Healing Energies.**

In Divine Order, it is appropriate for the facilitator to accept **payment** for the **personal time and energies** invested in **learning and developing facilitation skills,** and for the time spent in active facilitation. It is important that the facilitator understands this subtle difference of **"fair exchange of energy"**. If the facilitator mistakenly assumes they are requesting payment **for healing energies** they supply, they are inadvertently misrepresenting themselves to the client. The client possesses personal healing energies and does not need to purchase such energies from others. The **time and expertise** offered by the facilitator to assist the client in stimulating their own healing energies, is a service worthy of reciprocation. If a client chooses such assistance, the **facilitator** has **legitimate right** to honor their own worth as a being by **requesting reasonable payment or barter** in **fair energetic exchange** for the service they offer. However, if a client is in need of healing facilitation, and has no means of fair exchange at that time, the facilitator should honor the worth of the client by providing assistance of equal value **free of charge.**

In spiritual principal, "making money" is not a legitimate motivation for participating in Healing Facilitation. Seeking to find one's personal **"Divine Right Livelihood"** in **sincere service** to others, which might possibly involve providing client service in Healing Facilitation, IS a spiritually legitimate motivation. Healing Facilitators will discover that when they put the objective of **GENUINE SERVICE TO THE DIVINE** as the **first Priority,** rather than the pursuit of personal monies or status, the **Universe Will Provide.** Facilitators who enter the healing field with hidden personal motivations incongruent with **Universal Laws of Energy,** which imply **equality, respect, reverence** and **balanced exchange of energy** between all beings, will find difficulties emerging in their lives as the personal **SOUL** sets up lessons through which **Universal Principles** become more apparent. There is only **ONE TRUE MOTIVATION** for participation in Healing Facilitation- **the motive is LOVE.**

POSTURES OF LOVE

The Energy-Reality of LOVE

In terms of **Universal Physics**, Love is an **energy reality**, a **STATE OF VIBRATIONAL HARMONIZATION**, or **CO-RESONANCE OF FREQUENCY** that allows an **energetic bridge** to build between individuals. It is through this energetic bridge of frequency that one can assist in running healing energies that will facilitate the healing process of others. Without the sentiment and **FREQUENCY** of **GENUINE LOVE**, one cannot energetically facilitate the healing of another. **LOVE is the essential ingredient in healing,** for it allows the opening of facilitator and client's bio-energetic fields to the **Universal Frequencies** of the interdimensional spectrum. Cultivating the ability to embrace and hold the frequencies of Universal or **OMNI-LOVE** is the responsibility of any true healing facilitator. The emotionally experienced reality of the ***frequency of Love*** takes many forms. In healing facilitation it is important to **assess the most appropriate form of love** to engage with each individual client

Soft Love

Many people respond well to **"SOFT LOVE"**, the kind, gentle, nurturing, soothing love often displayed by mother's comforting their infants. Soft Love works well with client's whom possess some degree of spiritual maturity and who have cultivated the ability to hold some degree of a love frequency within themselves. Soft Love is the appropriate form of love for client's possessing the maturity to accept personal responsibility for themselves, their actions and their emotional reaction patterns, and who do not attempt to manipulate, drain energies from or place blame on others. Soft Love is characterized by **engaged detachment** of the facilitator and is demonstrated through soft-spoken, calm and sincere words and actions that are intended to place the client at ease.

Soft Love is always built up sincerity, kindness, respect and a genuine desire to see the client thrive and prosper. Developing the ability to carry the Soft Love frequency takes time, attention and practice, and requires that the facilitator works to heal personal **internal conflicts**, unresolved issues from **childhood** and **karmic** reaction patterns that disrupt the Soft Love vibration. Soft Love is a **vulnerable love** in that it necessitates one to show the self as it is, honestly expressing personal feelings tempered with kindness. Soft Love **is not approval seeking**, it is rather genuine, honest and **self-generated**. Soft Love requires **love** and **respect** of the self and others mutually. It is built upon a level of spiritual maturity in which it is understood that personal value is implied by the fact of existence and is not determined by the approval or **validation** of others outside of the self and the personal relationship to the Divine. The ability to carry the Soft Love frequency emerges through **spiritual integration, personal healing** of internal conflicts and power struggle issues and **intentional application of kindness and mindfulness.**

Tough Love

Soft Love does not facilitate healing on all occasions. Certain clients who come to a facilitator for healing assistance bring with them a great need for **emotional healing** and development of spiritual maturity. They may demonstrate demanding, arrogant or pushy attitudes and refuse to accept responsibility for their personal actions and resulting consequences. Most often such individuals carry deep wounds from childhood or from reincarnational bleed-through. Because they are **wounded within,** they have not yet developed the self-control or maturity necessary to treat themselves or others with kindness, respect or love.

Individuals who display unreasonable behaviors or attitudes pose quite a challenge to the love-based healing facilitator. If they are approached with Soft Love, the facilitator will often find themselves as a scape goat for the individual's personal problems, may have their energies and time excessively **drained** by such clients and might possibly be subjected to outright verbal or physical **abuse.** Clients exhibiting such personality traits are struggling within themselves to **gain control** over the various **conflicting portions** of their personal energies, and they tend to objectify this internal conflict resolution in the form of **POWER STRUGGLE** with others.

Personalities trapped within cycles of subconscious self or other-abusive attitude patterns need **love** more than anyone, but most often their behaviors push others away. Intrinsically the behaviors serve to keep the individual sheltered from **self-exposure;** they do not allow others close enough to inspire feelings of vulnerability or lack of self-esteem. Often such personality traits effectively keep the individual from seeing themselves and the inner pain and conflict from which they attempt to hide. To facilitate healing in such individuals without succumbing to their manipulation, aggression or abuse requires that the facilitator adopt a posture of **TOUGH LOVE.** In Tough Love the facilitator clearly establishes **personal boundaries** in their own mind as to what treatment they will and will not accept. If the client crosses those boundaries the facilitator **assertively addresses the issue** with the client, requests that the offensive behavior cease and provides **CLEAR CONSEQUENCES** as to what will occur if the offense continues. The Tough Love approach is rendered from a base of **Soft Love** and **Omni-Love,** but it is strengthened with **Self Love** on behalf of the facilitator. The facilitator recognizes that they are only assisting the client to continue with the self-destructive patterns by condoning or allowing offensive behavior, and chooses to **love the client enough** to **confront the pattern** so that it may begin to release. In **lovingly, calmly,** but **firmly confronting** poor behavior and **setting clear boundaries** and **consequences,** the facilitator assists such clients to temporarily find a new pattern of action because the old one does not work for manipulation in this instance. The Tough Love approach frequently requires facilitators to demonstrate that they hold their own power, even in the face of client disapproval. Tough Love is an ability of **personal empowerment** worth cultivating for personal and client healing.

Self Love

In healing facilitation **Love** is the essential ingredient. All love begins with the **Divinity Within the SELF.** You will be able to transmit the frequency of love to others in direct proportion to your ability to hold the frequency of love within yourself. If you do not recognize your intrinsic value as a **Divine Being** and seek validation of your existence through external sources such as achievements, status or other-approval, you will likewise project these sentiments into your love relationships with others. If a client does not meet the external standards of validation that you have placed on yourself to determine your personal worthiness of love, you will have difficulty not falling into **judgement** of the client.

Judgement and **love** cannot transmit through the human body at the same time. Judgement creates an **energy reality** of separation or **Non-Resonant Frequencies** of energy, whereas Love creates the **Co-resonance of Frequencies** needed for open flow of Universal Energies for healing facilitation. If one can realize that **LOVE IS THE ONLY CONSTANT** and that all conditions of judgement change, it is easier to cultivate the innate ability to fully hold the frequency of Love. Though **ASSESSMENT** of conditions, actions or attitudes is useful and necessary, such assessment can be rendered through **"separating the person from the action".** You can judge the effectiveness or value of the **action or idea** without assigning a **value-judgement** to the **person** to which it is attached.

If the healing facilitator can feel love, reverence, respect and honor for the **Divinity Within Themselves**, they will also transmit these qualities of **excellence in Love** to the client. The quality of Love brought into the healing facilitation experience will directly effect the success of healing assistance given. **Love the Self** and know that all beings possess an **unalienable worth and value** as a living part of the **Divine.** Begin to cultivate this awareness within your personal life and you will greatly increase your effectiveness as a healing facilitator. Love, honor and respect yourself, your feelings, your dreams and your desires, so you may better love those you wish to serve.

Love others as you would love the Self,
and love the Self as you would like to love others.

The Illusion of Martyrdom

People who love themselves do not buy into the idea that they must play **"martyr"** to others in order to be of service. **Martyrdom** implies a belief that you are **lacking in worth,** or must **earn** your worth in being, by relinquishing that which feels of most value to you. It also **undermines expression of the God-Presence** within others, by assisting them to believe that you are so vital to their wellbeing that they cannot function without you. In truth, martyrdom is an **expression of EGO**, most often used by people who feel they are **personally insignificant** in the eyes of the Divine, in order to **give themselves significance** and a **sense of personal power and purpose** for being. People who actively *know* the intrinsic **Spiritual Divinity** within themselves treat that Divinity with honor and respect and do not allow or need others to **depreciate the Self** and its desires in order to prove the existence of a *belief* in personal Divinity.

Martyrdom **does not facilitate healing** within the self or client, as it reinforces the **erroneous belief** in intrinsic **personal unworthiness,** which exists in **direct contradiction** to the **innate God-Presence** that exists in every living thing. Within the energy dynamics of **Universal Law,** natural **balance** is achieved in the flow or **GIVING,** and back-flow or **RECEIVING** of energy. In human spiritual relationships this **balance of energy** is achieved by **mutually valuing** each person in a relationship, through which the natural giving and receiving of energy can be exchanged unimpeded. **Martyrdom impedes the natural flow of energy**; the martyr customarily gives more than receives, which progressively diminishes the martyrs ability to keep open a perpetual flow of energies from the Divine because the martyr does not allow the Self to receive.

Martyrdom is not a demonstration of Love,
it is an exhibit of Love Deprivation.
The remedy for Martyrdom is
OMNI-LOVE.

OMNI-LOVE; Fully Engaging the Love Vibration

The greatest love that can be embodied in human form is **OMNI-LOVE.** OMNI-LOVE is a pure state of vibrational Frequency Co-Resonance between the human identity and the **12 Dimensions** of reality within which the human anatomy is couched. Omni-Love is expressed in human form as **Christed Love** or **Christos Consciousness, the 12th-Dimensional Love** of the **Maharic Level of Identity.**

Christos Love is a state of full Frequency Resonance with **everything existing** in the many universes contained within **12 Dimensions** of the 15-Dimensional System. It is a **transcendent love** that is attached to no thing but is **AT ONE** with **ALL THINGS** in a state of perpetual **Engaged Detachment.** Through Christos-Omni Love, the **SELF** is known as an **extension of God**, or the **Divine Source**; a **temporary mask of form** worn by the **ONE CONSCIOUSNESS** of the Cosmos. All things and beings are known as **simultaneous expressions** of the **ONE-SELF** that is God-Source. From this state of transcendence in love, all activity is understood to **exist within** the reality of LOVE, and all conflict and strife are viewed as the ONE-SELF **progressively expanding the ability of its expressions** to **carry the frequencies of energy** that constitute **ONE-LOVE,** a state of **total vibrational Frequency Co-resonance** with the **Cosmos.**

Activation of the full **12-Strand Silicate Matrix DNA Template** and full integration of the **Mahara Hova Body Avatar Identity** allows for the experiential embodiment and transmission of Christos-Omni-Love. **Embodiment of Omni-love is the goal toward which human evolution moves forth.** Omni-Love is Soft, Tough, and Enduring, honoring **Self , Other** and the **Divine** simultaneously. It is the **strongest healing force** of frequency in the 4 Harmonics of Matter Density. Christos-Omni-Love is the **fulfillment** of the **Christos Principle.** Strive to bring Omni-love into your life, and personal and client healing facilitation, and you will assist your higher identity levels to create transformation! Omni-Love is the **natural structure** of reality. **AWARENESS** of Omni-Love is cultivated through **intention** and appropriate use of **personal ~~free~~ will choice** in congruence with the **natural Laws** of the **Unified Field Physics of Consciousness and Creation.**

Through living in Omni-Love all moments are known as Sacred, all beings are known as Blessed and life becomes an ecstatic study in Reverence for Existence.

Postures of LOVE

1. SOFT LOVE
KIND, NURTURING, **GENTLE**

2. TOUGH LOVE
KIND, NURTURING, **ASSERTIVE**

3. SELF LOVE
HONORING THE **DIVINITY** WITHIN **SELF**

4. OMNI-LOVE
HONORING THE **DIVINITY** WITHIN **ALL**
Namaste'

***Omni-Love** is the fulfillment of the **Christos Principle,** the goal toward which human evolution moves forth through progressive activation of the **12-Strand Silicate Matrix DNA Template** and embodiment of the **Avatar** Identity.*

OMNI-LOVE EXERCISE TO AMPLIFY HEALING FACILITATION

EXERCISE

The MAHARA SPACE-COMFORT TOUCH

1. **EXHALE Hierophant Symbol** from behind forehead, down *Central Body Current*, into **Earth's Core** (Chakra 13), then **INHALE** *Hierophant* back up to your **Maharic Shield 12" below feet.** *Spin Hierophant* to *activate* **Maharic Shield** and **Maharic Seal Pillar. INHALE** energy up from your *Maharic Shield* into your **Doradic Sphere** at *Chakra 4.*

2. Breathe slowly and deeply while visualizing a **small faceted Crystal Sphere** in the center of your *Doradic Sphere* at Chakra 4. This is the **Holographic Crystal Sphere**; it represents the station of your inner **AVATAR** identity – this is the **MAHARA SPACE.** Focus your consciousness within the *Holographic Sphere* and feel its reality around you, as if your body is encased within the Holographic Sphere.

3. Observe the interior of the Sphere as a **pale Silver-White mist.** Within the mist now envision a **golden treasure chest**- a treasure you had left for yourself long ago to one-day reclaim. This represents your **Inner Arc of the Covenant** – *a doorway to reclaiming your ancient immortal heritage.* **Mentally command** the lid of your inner *Arc of the Covenant* to lift. As the lid rises **pale rainbow colored light** fills the interior of your Holographic Sphere. Notice now that within the golden box there is a gleaming **Silver Sword**, the Silver Rod of Power that will enable you to more quickly evolve to your eternal state of being.

4. Mentally make the **Silver Sword** *rise from the golden box*, floating above the box in a vertical position. Now call to mind the image of your **body** *as it sits within the physical room.* Imagine *the Silver Sword positioned above the body's head*, directly over **Chakra 7. EXHALE** and **steadily lower the Silver Sword** through the *7th Chakra and down the Central Body Current, through the Maharic Shield and down into* **Earth's core.** Observe the Silver Sword turn into a *Pillar of Pale Silver Light with pale rainbow colors flashing through it.* The **Rainbow Pillar** now *surrounds and runs through your body, raising its frequency while lowering its vibration*, lifting your body cells into a **less-dense state of matter.** Feel your body growing lighter and lighter as the Rainbow Pillar slows the spin-rate of your matter particles, making you more and more electric- more light.

5. As you feel the sensations of your density lessening, **imagine that your body is beginning to glow with Pale Silver light** – the *Pre-matter Liquid Light* of dimensions 10, 11 and 12. Feel the *features of your face and the contours of your body begin to melt* into a **Silver, 2 –dimensional fluid body form.** The form of the body still remains but it has been returned to its **first-density state**- **the Silver Liquid Light holographic form of the avatar identity.** Know yourself now as this avatar identity and feel the essence of **pure love** and eternity flow through you. **Know yourself as this essence of Divine Love and Eternal Light.**

6. Now **INHALE** and draw the **Rainbow Pillar into the Holographic Sphere** at *Chakra 4*, visualize the base pulling up from Earth's core and the portion above your head simultaneously *contracting into the Holographic Sphere.* **EXHALE** the energy of the *Rainbow Pillar* fully into the *Holographic Sphere* and observe the **Holographic Sphere become a radiant Silver ball of Liquid Light stationed with your Doradic Sphere** in the Heart Chakra.

EXERCISE: Continued
THE *MAHARA SPACE-COMFORT TOUCH*

7. **You may now transmit the frequencies of the 4th-Harmonic, dimensions 10, 11 and 12, to serve as a healing force for others.** You may transmit this energy into your environment directly through the **4th Heart Chakra**, where it will enter the Unified Field at the 4th-Dimensional astral plane. You may use the breath to move the Holographic Sphere down into the **3rd Chakra** *for 3rd-Dimensional transmission* into the *Earth's atmosphere* and the *Mental Body* levels of people's Bio-energetic field. You may transmit through **Chakra 2** into the Telluric or *Elemental Kingdom* of the planet and into people's 2nd-Dimensonal *Emotional bodies*. Or you may transmit the frequencies of the Silver Sword through the **1st Base Chakra**, for *sacred bonding in intimate relationship*, or to *raise the frequency and lower the vibration* of the *molecular and sub-atomic fields* around you. To transmit the frequencies of the Silver Sword through the chakras, simply use the **EXHALE** breath to move the Silver Light "charged" **Holographic Sphere down** to lower chakras, inhale and use the next **EXHALE** to *push the frequency outward* from the selected chakra into the environment. Use the **INHALE** breath to move the *Holographic Sphere* up through the chakra system. *Always move the Holographic Sphere up or down along the* ***Central Body Current****, to which the core of each chakra is attached.*

8. **You may also transmit the frequencies of the Silver Sword through APPLIED TOUCH –** ***THE COMFORT TOUCH*** -to amplify specific healing facilitation functions and to establish a more harmonious rapport with other people and the nature kingdoms. Simply visualize the Silver Liquid-Light charged **Holographic Sphere** at the center of your **Doradic Sphere** in the **4th Chakra**. Activate your **Doradic-1 current** via the **Maharic Shield and Seal**, then visualize the *Silver Liquid Light from the Holographic Sphere combining with the Green-Violet-Silver Doradic-1 current* as you **EXHALE** the current into the **Doradic Cords** in the arms and into the **Doradic Balls** in the palms. *This application is especially useful to help Clients relax during sessions, or to comfort others when they are in a state of stress, unbalance or illness.*

   Once your current is moving into the Doradic Balls, **EXHALE** the current through the **Right palm.** *Place the* ***Right palm*** *gentle and briefly over the* ***Client's rear Chakra 2****, or touch them gently on the* ***left shoulder****.* The amplified *Doradic-1 current* will move into the *4th-Dimensional astral-body field*, and move its way into the *mental, emotional and physical bodies* from there. **The COMFORT TOUCH of the MAHARA SPACE can be applied to infants, children, older persons, animals and plants to comfort them and support their general well-being.**

PROFESSIONAL USE OF THE KATHARA BIO-SPIRITUAL HEALING SYSTEM PROGRAM – THE KATHARA ALLIANCE

The Kathara System introduced in **The Kathara Bio-Spiritual Healing System ™ Level 1 Workshop & Course Manual with Introduction to The Kathara Bio-Healing System™ Level 2** is destined to become a ***12-level program*** that is focused on "whole-being healing through progressive biological and spiritual awakening". Kathara is as much a course on (non-denominational, dogma-free) **Spiritual Integration Mechanics** as it is a Holistic Healing course.

An individual completing training in the **Kathara Level-1 Bio-spiritual Healing System** delivered by a Certified Kathara Alliance Instructor, will receive a **Certificate of Completion**, which recognizes the person named as attending and receiving training in the Kathara Level One Bio-Spiritual Healing System.

If you desire to practise the ***Kathara Bio-Spiritual Healing System™*** in a regular, professional capacity through Client Service, you may use the techniques provided within this Kathara Healing Manual to begin. Prior to professional use, it is suggested that one becomes a Certified member of the **Kathara Alliance** through the ***Azurite Press MCEO (World-wide Consulate***) and its appointed representatives.

The **Kathara Alliance** is a group of dedicated spiritual healing Practitioners and Instructors who have demonstrated a thorough understanding of the Theory and Practice of the **Kathara Bio-Spiritual Healing System™** and the Maharic Recoding Process, as deemed necessary by the **Azurite Press** for professionalism in the practice of Spiritual Healing Facilitation and Instruction.

All members of the ***Kathara Alliance*** are **Certified Kathara Healing Practitioners and Instructors,** and are permitted to practice Kathara Healing facilitation as **SPIRITUAL SERVICE.** For the protection of both Client and Practitioner, as well as the ethics inherent to the Teachings themselves, Kathara Healing is to be promoted, explained and practiced as **a non-diagnostic spiritual healing enhancement service only** and not as a replacement for traditional medical diagnosis or treatment.

Certification in the **Kathara Alliance** as an **Independent Spiritual Healing Practitioner and Instructor** of the **Kathara Bio-Spiritual Healing System™** requires formal application, including a written open-book examination and video presentation by the applicant. The examination is intended to reveal areas in which applicants may need to further strengthen understanding of and personal relationship to the practice of Kathara Healing Facilitation and Instruction within the parameters of Excellence recognized as intrinsic by the Azurite Press MCEO.

All Instructors and Practitioners must be CERTIFIED to conduct **public presentation** of copyright materials contained in this, the authorized Kathara Bio-Spiritual Healing System Manual. To uphold standards of Professionalism and Excellence in practice, the Azurite Press MCEO **cannot** recognize **Non-Registered Facilitators or Instructors** as active participants in the ***Kathara Bio-Spiritual Healing System Program.*** Obviously, non-certified Facilitators may use this program and its applications for their own **personal and spiritual enrichment. The Azurite Press MCEO authorizes only Certified Practitioners and Instructors** to professionally conduct Client Sessions.

With regards to teaching the program there is a distinction between 'Teaching' and 'Sharing'. **Teaching** is defined as formal presentation of the materials (following protocols described in the **Kathara Bio-Spiritual Healing System™** Manual and communications to Kathara Alliance applicants and members) in the form of a seminar/ workshop and payment is made by attendees. To teach the Kathara Bio-Spiritual Healing System™ , one needs to be a member of the **Kathara Alliance**. '**Sharing**' is defined as leading a study group where attendees are not expected to pay (it would not be inappropriate to accept small donations if offered). To share one does not need to be a member of the Kathara Alliance but group size should be limited to less than 12.

Within the **Kathara Bio-Spiritual Healing System™** there are specific pages for Kathara Alliance Instructors to use in their classes. The Instructors pages are identified by having a number at the *top* of the page (as well as the regular number at the bottom). These are the only pages that can be photocopied for teaching purposes. Only certified Kathara Alliance members (or a Kathara Alliance applicant who is delivering and recording a workshop for assessment purposes) are authorized to photocopy these pages.

The easy-reference **Instructor's pages** need to be sequenced in the order denoted by the number at the *top* of the page. These pages have been carefully sequenced to facilitate delivery and learning of the materials. Learners' needs, including varying learning style preferences, were very much considered when preparing the text and visual presentation of these teaching materials. In terms of frequency, the learning process can be described as when previously dormant Scalar Standing Waves in the personal shields are stimulated and activate('switch on'). As frequency is accreted (by progressive exposure to, and interaction with, the materials) the scalar waves in the personal shield self –sustain (we would say the person has 'learned' the material). The specific sequence of the pages are pre-set to create optimum frequency accretion in the personal shields of learners *even if this is not immediately perceived or understood by the learner.* Therefore it is imperative that these pages are used in the delivery of this program and the instructor remains true to the given sequence.

As Independent Spiritual Healing Facilitators and Instructors, all Certified Facilitators and Instructors are expected to accept full personal responsibility and legal liability for the practice and application of the **Kathara Bio-Spiritual Healing System™.** Certified Facilitators-Instructors are **not required** to pay dues, royalties or revenues to the Kathara Alliance/APMCEO for use of this program other than the cost of initial personal **Training-Registration** and obtaining supplies of **Session Manuals, Certificates and Registration Examinations** for the professional Instruction-Certification of others.

THE KATHARA ALLIANCE CERTIFICATION AND COMPETENCY REQUIREMENTS

The Certification Program is designed to enable the applicant to fully demonstrate his/her understanding of the material in a way that maintains the level of integrity and purity of the Program desired of the Kathara Alliance. This also ensures the Student attains a desired level of understanding in taking the workshop. The requirements of Certification are designed to protect the integrity of the material, those who participate with it, and the rights and responsibilities of all concerned.

Certified Kathara Practitioners and Instructors must not only be knowledgeable in the practice and teaching of Kathara, but are also asked to commit to the behavioral guidelines originating from the Covenant of Regent Consulate of the Melchizedek Cloister Emerald Order (MCEO). In this way those seeking out a Kathara practitioner can reasonably expect the highest integrity in both the teachings and in the individuals with whom they are relating.

Certified Kathara Alliance members are in no way affiliated with the MCEO Vehicle, the Azurite Press and should at no time state or imply such representation. Kathara Alliance members are independent Practitioners who offer local, community-based Kathara Healing Level courses and facilitation for individuals.

PLEASE NOTE: The APMCEO & Kathara Alliance **reserve the right** to **revoke** any Kathara Alliance Certification and Rights of Association of Certified Facilitator-Instructors for ***any*** reasons of: *Misuse, misrepresentation and false claims pertaining to this Kathara Program; inappropriate treatment of APMCEO staff, clients or participants in Kathara Healing Programs; dishonest or unethical behavior and practices, and racial, gender, or religious discrimination of clients and participants or Kathara Alliance Members.*

For further information on the Kathara Alliance certification process visit our website at http://www.azuritepress.com/kathara/kathara_application_proceedures.html or contact

In the U.S. and Canada: Sandy Sayles, 8527 Cool Water Ct., Antelope, CA 95843 - email - siepearl@comcast.net **OR** Melissa Fathman, 855 W. Dillon Rd, Apt. H306 - Louisville, CO 80027 - email - mfathman@yahoo.com

Rest of World Office: Hilary Lyons 341A Green Lanes, Palmers Green, London N13 4TY, U.K. hilary.lyons@virgin.net 07970770404

THE 6-STEP MAHARIC RECODING SESSION

Before Client Arrives: ***Technique # 1***- Activate Your Mentor. Conduct ***Mahara-Space-Comfort Touch Exercise*** and remote-request permission from client's ***Rishi*** identity level to apply **Comfort Touch** when client arrives. Create a calm, pleasant environment where you will not be interrupted by phone or other distractions. Optional: Sing 3 rounds of the ***Ariea-Khum-Nar'A*** **toning** to amplify personal healing and DNA Template activation during healing facilitation session.

When Client Arrives: Apply Comfort Touch if Rishi gave remote permission. Sit with client and review terms of the ***Client Agreement Form*** and secure client's signature on form. Offer client the option of audio-taping the session for client's at-home review.

6-Step Technique Application Sequence- *Maharic Recoding Session*

1. ***Technique # 2***-**The Maharic Seal and the Liquid Light Cleanse** *to seal and align personal bio-fields.*

2. ***Sequence-1 Kathara Points massage***- first your points, then client's points, *to open Kathara Lines.*

3. ***Technique # 3***- **Opening the Healing Channels** to activate your *Doradic-Phase-1* healing current and ***Technique # 4***- **Amplifying Inner-Audio-Visual and Kathara Scan** to locate miasms for healing in client's Kathara Grid.

4. ***Technique # 5***- **The Maharic Infusion** to activate client's Maharic Shield and Seal, recode client's Kathara Grid to the Maharic Shield and clear miasmic buildups.

5. **Optional:** Apply **light touch-massage** to miasmic areas, or employ other healing therapeutics after Maharic Infusion.

6. ***Sequence-2 Kathara Points massage*** on client to revitalize outer body systems and close Kathara Lines. Allow client to rest a few minutes before leaving. Answer any client questions and allow time for client to discuss experience if desired.

When Client Leaves: To ensure clear bio-fields, while Doradic-1 Current is still running, draw energy up from Earth's Maharic Shield and run Maharic Current through your Kathara Grid and body, up to Chakra-14 and back down to Chakra-13, then push a Pillar of Silver Light out of Chakra-4 and EXHALE it to release it around body into auric field. Next massage *your* **Sequence-2 Kathara Points** to revitalize bio-field systems and close Kathara Lines.

CHAPTER 4 HIGHLIGHTS

GENERAL KATHARA HEALING FIELD WORK

- Activation of any **Triadic Healing Current** requires temporary release of corresponding **Signet Star Crystal Seals** in the **Kathara Level-2 Crystal Seals Grid.**
- **Maharic 12th-Dimensional Frequency** is required to **manually release** the **Signet Star Crystal Seals** to activate **Triadic Healing Currents. Kathara Healing** utilizes **Maharic Frequency** to activate interdimensional **Triadic Healing Currents** for more powerful healing support.
- Most healing systems have not used **Maharic Current** because the **Planetary Templar Complex** could not run 12th-Dimensional Maharic Frequency for over 200,000 years, until January 2000.
- Release of the **Signet Seals** also activates dormant Strands in the **DNA Template** and releases the **Cranial-Sacral Seals** on the **Kundalini Energies.** Kathara Healing represents advanced, **12-Dimensional Kundalini Healing.**

OPENING THE HEALING CHANNELS

- Triadic Phase Currents are activated in the body by using **Maharic Frequency** from the **PBIS** to release the **Signet Seals** of the **Internal Templar Complex**, which allows higher dimensional frequency to run through the **physical body system** for transmission.
- Triadic Phase Currents are composed of **3 interwoven frequencies**, the **Maharic Frequency**, plus a chosen **dimensional frequency** and its corresponding frequency from **one Harmonic up**.
- Triadic Phase Currents are **directed** by their corresponding **Color Cap Stone**, the **Primary Wave Length** of the dimensional frequency band from which the current is drawn. **Kathara Level-1** activates the **1st Triadic Phase Current**, the ***Silver (D-12) + Green (D-4) + Violet (D-7)*** **DORADIC PHASE-1 Current.**
- **Doradic Current** is activated through the **Maharic Shield,** then **collected** in the **4th Chakra** ***DORADIC SPHERE***, projected down the ***DORADIC CORDS*** in the **arms** and into the ***DORADIC BALLS*** in the **Palm Chakras** for **DIRECT INDUCTION** of frequency transmission in healing facilitation.

PALM CHAKRA POLARITY

- The **Palm Chakras** are **Secondary Chakras** located in the **Palms of the Hands.** Like all Chakras, they function as **Black-White Hole Sets** for **transmitting** and **receiving energy** between the personal Manifestation Template and the dimensional Unified Fields of energy.
- The Palm Chakras are **double vortices** of energy, with **one spiral** exiting the **Palm** and its **corresponding spiral** exiting the **back of the hand.** The **2 Spirals** of the Palm Chakras are linked by a **Crystal Seal** at the center point where the 2 vortices meet. In one Palm Chakra, one spiral rotates **clock-wise**, is **Base Electrical** and **transmits energy** out of body, and the other spiral rotates **counter-clock-wise**, is **Base Magnetic** and **draws energy** into body.
- In **Level-1Kathara Healing** the **RIGHT PALM** is the **TRANSMITTING HAND** and the **LEFT PALM** is the **RECEIVING HAND.** For **transmission,** the **Standard Hand Position** is **LEFT Palm placed over the back of the RIGHT HAND** for pure transmission and **control of specific frequency** transmitted from the **RIGHT PALM.**
- The **RIGHT PALM** is **BASE ELECTRICAL**, the **LEFT PALM** is **BASE MAGNETIC**, but both have **subtle** electro-magnetic capacity.

THE KARMIC-MIASMIC IMPRINT

- To enter manifestation in time, identity enters **cycles** of **SIMULTANEOUS INCARNATION** within the **4 Harmonics of Matter Density** in **12-Dimensions** of the 15-Dimensional **Time Matrix.** The **PRIMAL ORDER Scalar-wave Template** through which an identity enters time is the **Density-5** (dimensions 13, 14 and 15) **RISHIC SHIELD**

- The **Rishic Shield** holds in the Time Matrix the identity of the **Family of Consciousness** from which **incarnates** emerge. The Scalar Patterns of the Rishic Shield represent the tangible **"DIVINE RIGHT ORDER"** in energy and consciousness, for each incarnate manifesting from it. The individual identity must **realign** its **Manifestation Template** with this **Primal Order** to become free from the Time Matrix in full **Ascension.**

- The **Density-4** Pre-Matter Hydro-plasmic **MAHARIC SHIELD** (Dimensions 10, 11 and 12) is the Scalar Template through which identity manifests in the lower-dimensional Densities and which **connects the individual incarnate** to its **Rishic Shield.** The **Maharic Shield** is often called the **PERSONAL CHRISTOS Template,** and it holds the consciousness and **Perfect Primal Order** for all incarnations of an identity in time.

- **“Karma”** is the result of **Free Will choices** made by **incarnates** that involve using personal energies in ways incongruent with the natural **Laws of Universal Unified Field Physics** and the **Primal Order** of the **Christos Template.** Karma creates **scalar-wave distortions** within the Scalar Shields of personal 15-Dimensional Anatomy that **manifest physically** as **energetic clusters** called **MIASMS.**
- **Miasms** are **unintended** groups of **anti-particles** lodged within the particle field of the personal **Manifestation Template** that block and impede the **natural flow of energy** and consciousness into embodiment. **Miasms,** and the misshapen scalar-wave distortions that form them, are the **cause of ALL disease** and dis-harmonic conditions.
- **Health** and Harmonious flow of energy are the **natural conditions** of human design. The **Maharic Shield Personal Christos Template** holds the **Organic Imprint for Health** for all simultaneous incarnates of an identity, and can therefore be used to **clear the Karmic-Miasmic Imprint** from the personal Manifestation Template to progressively restore **Healthful Primal Order.**

- Miasms from **all simultaneous incarnations** manifest within the personal Manifestation Template and within the DNA Template of each, where they become literal **genetic distortions.**
- Each of an identity's incarnates in various time cycles represents one **TIME VECTOR**, which is encoded in the Vector Codes of the **DNA Template.** Karmic-Miasmic **bleed-through** occurs **between incarnates** from different concurrent time cycles through the **living link** of scalar frequency that exists between the **DNA Templates** of simultaneous incarnations.
- The **Karmic-Miasmic Imprint** does not have to be suffered and cleared the "**old fashioned way**" by "walking through the Karma in physical reality". The **Miasmic Imprint** can be cleared **as energy, with energy**, to prevent its manifestation in physical terms via realignment of the **DNA Template** with the personal **Maharic Shield.**
- Any given incarnate can clear the Karmic-Miasmic Imprint by realigning the personal Manifestation Template with the shared Christos Template Maharic Shield. This process is called **MULTI-VECTOR HOLOGRAPHIC RECODING**, which creates **BIO-REGENESIS** of the original 12-Strand **Silicate Matrix DNA Template** of human design and restoration of the **Organic Imprint for Health.**

ATTITUDES AND ETIQUETTE IN HEALING

- **Holographic Recoding** and clearing the Karmic-Miasmic Imprint from the personal Manifestation Template begins with activation of the **Maharic Shield and Seal** in the bio-energetic field and progressive running of 12th-Dimensional **Maharic Frequency** from the **Personal** and **Planetary Maharic Shields** through the **3 Primary Levels** of the embodied **Kathara Grid**; the Level-1 **12-Tree Grid**, Level-2 **Crystal Seals Grid** and Level-3 **Diodic Points Grid.**
- Personal Holographic Recoding begins with consistent use of ***Technique* # 2- The Maharic Seal and the Liquid Light Cleanse**, and is further accelerated by facilitating **Maharic Recoding** in others through running the **Triadic Phase Currents** for **Co-generative Healing.**
- One can facilitate healing in others and amplify personal healing through the using ***Technique* # 5- The Maharic Infusion.**
- The **Maharic Recoding Session** utilizes the combined **Bio-Regenesis Techniques** presented in **Level-1 Kathara Healing** to facilitate **Client Healing Sessions.**

- Professionalism in Healing Facilitation requires an understanding of the **Postures of Love** and a willingness to **cultivate** the ability to hold and transmit **OMNI-LOVE**, **honoring the Divinity of ALL things and beings.**
- The Primary Postures of Love are **SOFT LOVE, TOUGH LOVE, SELF LOVE** and **OMNI-LOVE.**
- The emotionally experienced quality called **LOVE** is a **REALITY IN ENERGY PHYSICS.** LOVE is a **STATE OF VIBRATIONAL FREQUENCY CO-RESONANCE** that allows **free flow of energy** between consciousness within the Universal Unified Field.
- The human **12-Strand DNA Template** was designed to allow **12-Dimensions of Vibrational Co-Resonance**, the **Christos Consciousness** of the **Maharic Shield**, to embody in human form. **CHRISTOS-OMNI-LOVE** is Vibrational Co-Resonance with all that exists within **12 Dimensions** of the Time Matrix; its embodiment is the **primary goal** toward which **human evolution** progresses.
- Christos-OMNI-LOVE is the **strongest healing frequency** available within the Densities of Space, Time and Matter, and is **essential** for effective **Healing Facilitation** and personal **Ascension.**

CHAPTER 5

INTRODUCTION TO KATHARA LEVEL-2

The Kee-Ra-ShA Induction Process™

Mahara-Merkabic Master Key Healing-Manifesting the Blueprint For Health

Primal Currents, the DNA Sub-Strand Matrix, Merkaba, Psonns, the Trinity Keys and Photo-Dynamic Manifesting

- **SPIRITUAL INTEGRATION**
- **PRIMAL LIFE FORCE CURRENTS-The Kundalini-Antahkahrana, Maharata, Kee-Ra-ShA & Khundaray**
- **DNA SUB-STRAND MATRIX, FIRE LETTERS, PSONNS & THE TRIBAL SHIELD**
- **MERKABA &THE SALUTATIONS**
- **2 MASTERS KUNDALINI ACTIVATIONS-The Emerald & Amethyst Awakenings**
- **UNIVERSAL TRINTIY KEYS & MERKABA KEY CODES**
- **MAHARA MANIFESTING,DNA, KATHARA & PSONNS**

TECHNIQUES:

TECHNIQUE # 6: The Maharic-24 Quick Seal
TECHNIQUE # 7: Ps-13 Tribal Shield Activation
TECHNIQUE # 8: Merkaba Salutations
TECHNIQUE # 9: Merkaba Trinity Key Induction
TECHNIQUE # 10: Photo-Radionic Manifesting
TECHNIQUE # 11: Photo-Sonic Manifesting
TECHNIQUE # 12: Kee-Ra-ShA Activation Sequence-Awakening the Flame

Sacred Sciences of the Mu'a Grail Line-
Tools of the Trade

- **The Maharata-** *Universal Life Force Currents, Kundalini, Antahkarana, Maharata, Kee-Ra-Shay, Khundaray and the Maharic Seal.*
  Field Technique-1: ***Maharic Quick Seal***

- **The Tribal Shield and Cue Zones-** *DNA, Fire Letters, the Sacred Psonns and Cue Zones*
  Field Technique-2: ***Tribal Shield-Cue Zone Activation***

- **The Sacred Salutations-** *Electrical & Magentic Merkaba Activation*
  Field Technique-3: ***Sacred Salutations****- Merkaba Tone Dancing*

- **Expediting Spiritual Actualization -** *Tribal Shield Activation, Emerald and Amethyst Awakening Masters Kundalini Activations, DNA Template Bio-Regenesis, Master Key Codes, Melchizedek Cloister Ordinations*

Universal Life Force Currents

One 15-Dimensional Time Matrix with 5 Harmonic Universes

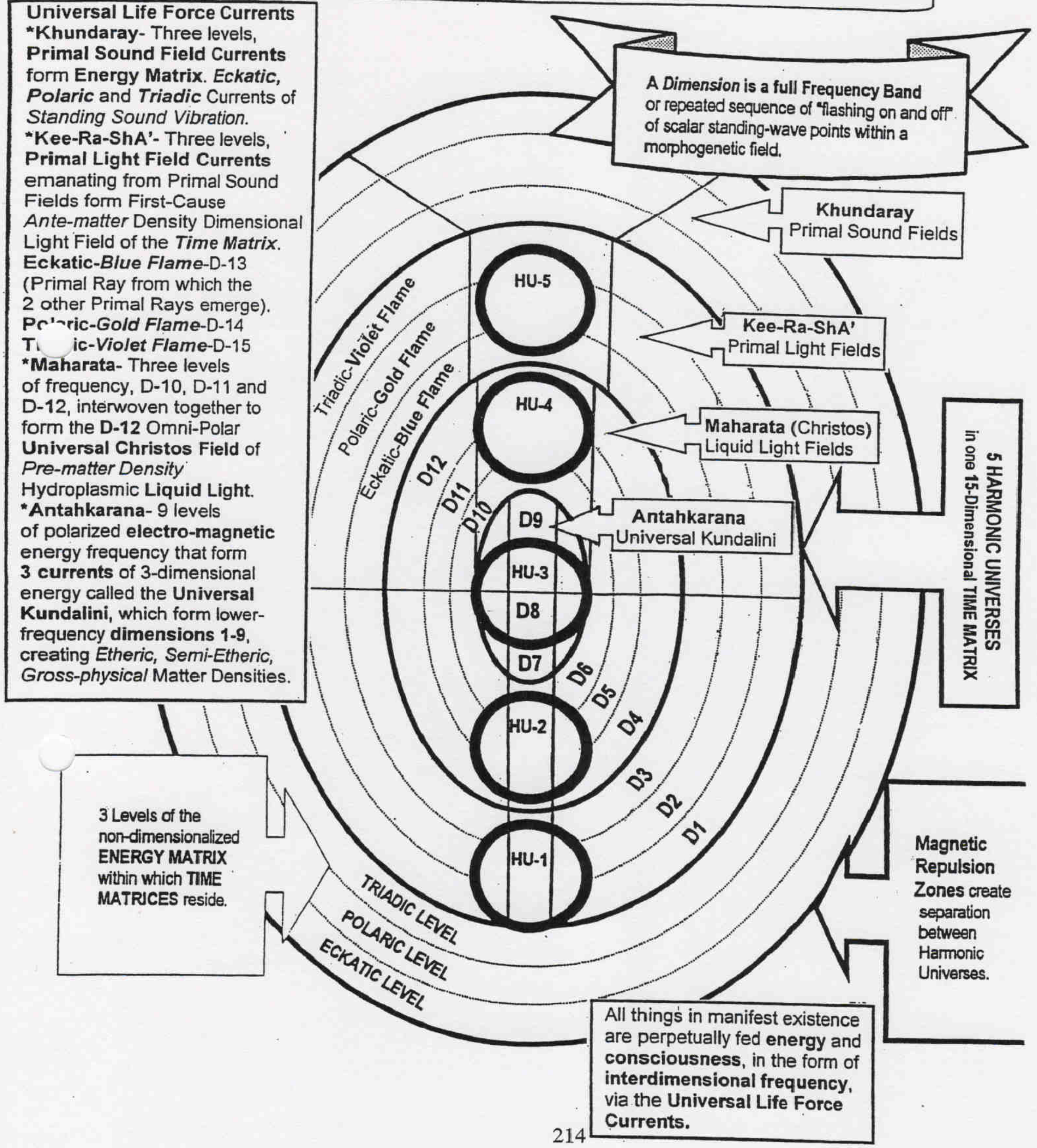

Universal Life Force Currents
Khundaray**- Three levels, **Primal Sound Field Currents** form **Energy Matrix**. ***Eckatic, Polaric and ***Triadic*** Currents of *Standing Sound Vibration.*
Kee-Ra-ShA'**- Three levels, **Primal Light Field Currents** emanating from Primal Sound Fields form First-Cause *Ante-matter* Density Dimensional Light Field of the ***Time Matrix.
Eckatic-*Blue Flame*-D-13 (Primal Ray from which the 2 other Primal Rays emerge).
Polaric-*Gold Flame*-D-14
Triadic-*Violet Flame*-D-15
***Maharata**- Three levels of frequency, D-10, D-11 and D-12, interwoven together to form the **D-12** Omni-Polar **Universal Christos Field** of *Pre-matter Density* Hydroplasmic **Liquid Light**.
***Antahkarana**- 9 levels of polarized **electro-magnetic** energy frequency that form **3 currents** of 3-dimensional energy called the **Universal Kundalini**, which form lower-frequency **dimensions 1-9**, creating *Etheric, Semi-Etheric, Gross-physical* Matter Densities.

A ***Dimension*** is a full Frequency Band or repeated sequence of "flashing on and off" of scalar standing-wave points within a morphogenetic field.

Khundaray Primal Sound Fields

Kee-Ra-ShA' Primal Light Fields

Maharata (Christos) Liquid Light Fields

Antahkarana Universal Kundalini

5 HARMONIC UNIVERSES in one **15-Dimensional TIME MATRIX**

3 Levels of the non-dimensionalized **ENERGY MATRIX** within which **TIME MATRICES** reside.

Magnetic Repulsion Zones create separation between Harmonic Universes.

All things in manifest existence are perpetually fed **energy** and **consciousness**, in the form of **interdimensional frequency**, via the **Universal Life Force Currents.**

Universal Life Force Currents and the Embodied Kathara Grid Core Template

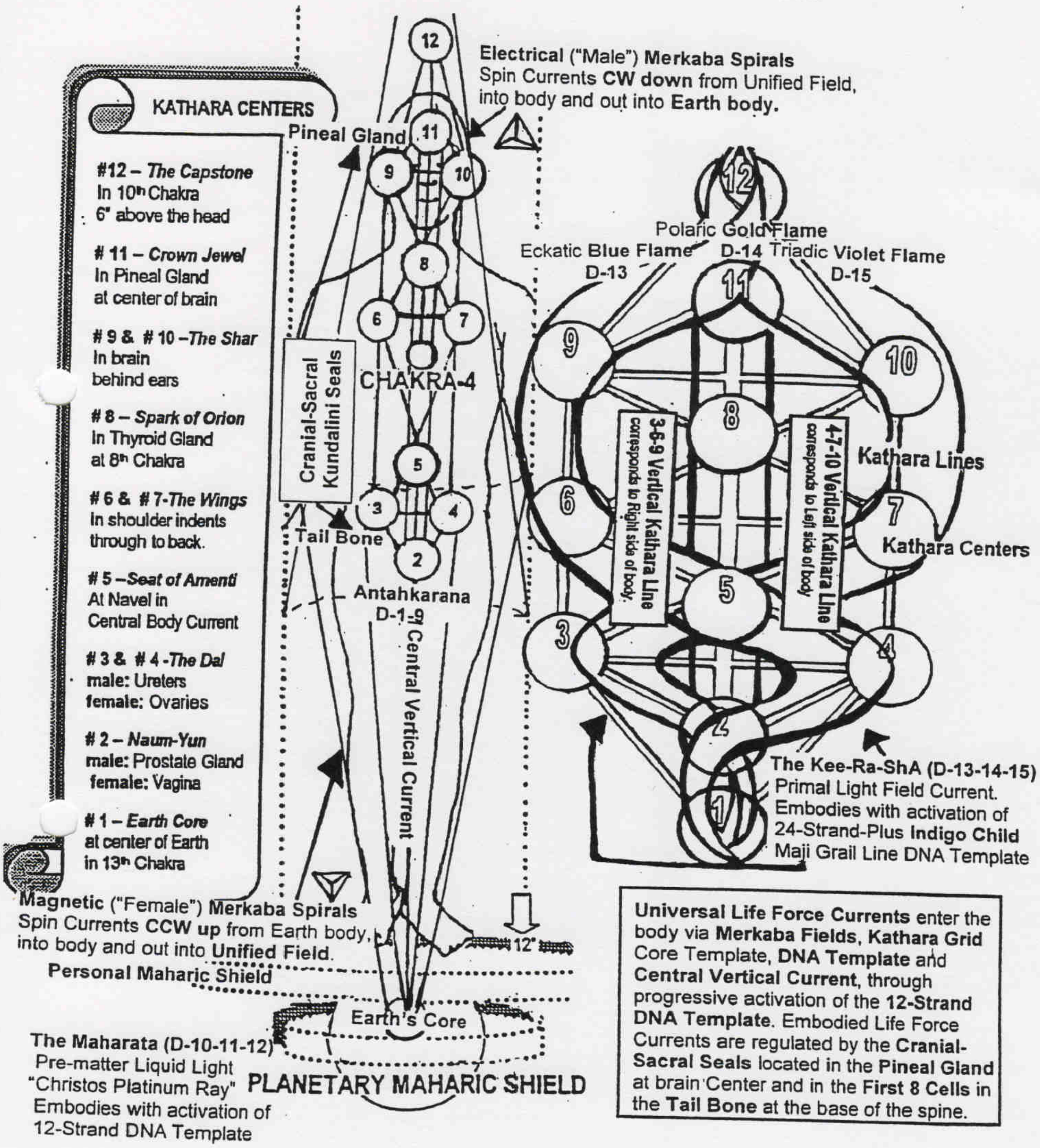

KATHARA CENTERS

#12 – *The Capstone*
In 10th Chakra
6" above the head

# 11 – *Crown Jewel*
In Pineal Gland
at center of brain

# 9 & # 10 –*The Shar*
In brain
behind ears

# 8 – *Spark of Orion*
In Thyroid Gland
at 8th Chakra

# 6 & # 7-*The Wings*
In shoulder indents
through to back.

# 5 –*Seat of Amenti*
At Navel in
Central Body Current

# 3 & # 4 -*The Dal*
male: Ureters
female: Ovaries

# 2 – *Naum-Yun*
male: Prostate Gland
female: Vagina

# 1 – *Earth Core*
at center of Earth
in 13th Chakra

Electrical ("Male") **Merkaba Spirals**
Spin Currents **CW down** from Unified Field, into body and out into **Earth body.**

Magnetic ("Female") **Merkaba Spirals**
Spin Currents **CCW up** from Earth body, into body and out into **Unified Field.**

The Maharata (D-10-11-12)
Pre-matter Liquid Light
"Christos Platinum Ray"
Embodies with activation of
12-Strand DNA Template

The Kee-Ra-ShA (D-13-14-15)
Primal Light Field Current.
Embodies with activation of
24-Strand-Plus **Indigo Child**
Maji Grail Line DNA Template

Universal Life Force Currents enter the body via **Merkaba Fields, Kathara Grid** Core Template, **DNA Template** and **Central Vertical Current**, through progressive activation of the **12-Strand DNA Template.** Embodied Life Force Currents are regulated by the **Cranial-Sacral Seals** located in the **Pineal Gland** at brain Center and in the **First 8 Cells** in the **Tail Bone** at the base of the spine.

Pineal Gland
Cranial-Sacral Kundalini Seals
CHAKRA-4
Tail Bone
Antahkarana D-1-9
Central Vertical Current
12"
Personal Maharic Shield
Earth's Core
PLANETARY MAHARIC SHIELD
Polaric Gold Flame D-14
Eckatic Blue Flame D-13
Triadic Violet Flame D-15
3-6-9 Vertical Kathara Line corresponds to Right side of body.
4-7-10 Vertical Kathara Line corresponds to Left side of body
Kathara Lines
Kathara Centers
12
11
10
9
8
7
6
5
4
3
2
1

Universal Life Force Currents and Level-2 Kathara Crystal Seals Grid & Chakras

15 Chakras (C & MC)

7 Primary Chakras (C)

- C1- Base
- C2- Sacral
- C3-Solar Plexus
- C4- Heart
- C5- Throat
- C6- 3rd Eye- Pituitary
- C7- Crown-Pineal

8 Morphogenetic Chakras (MC)

- MC8-Thymus
- MC9-Thalamus
- MC10- Galactic 1
- MC11-Galactic 2
- MC12- Earth Star
- MC13-Earth Core
- MC14-Universal 1
- MC15-Universal 2

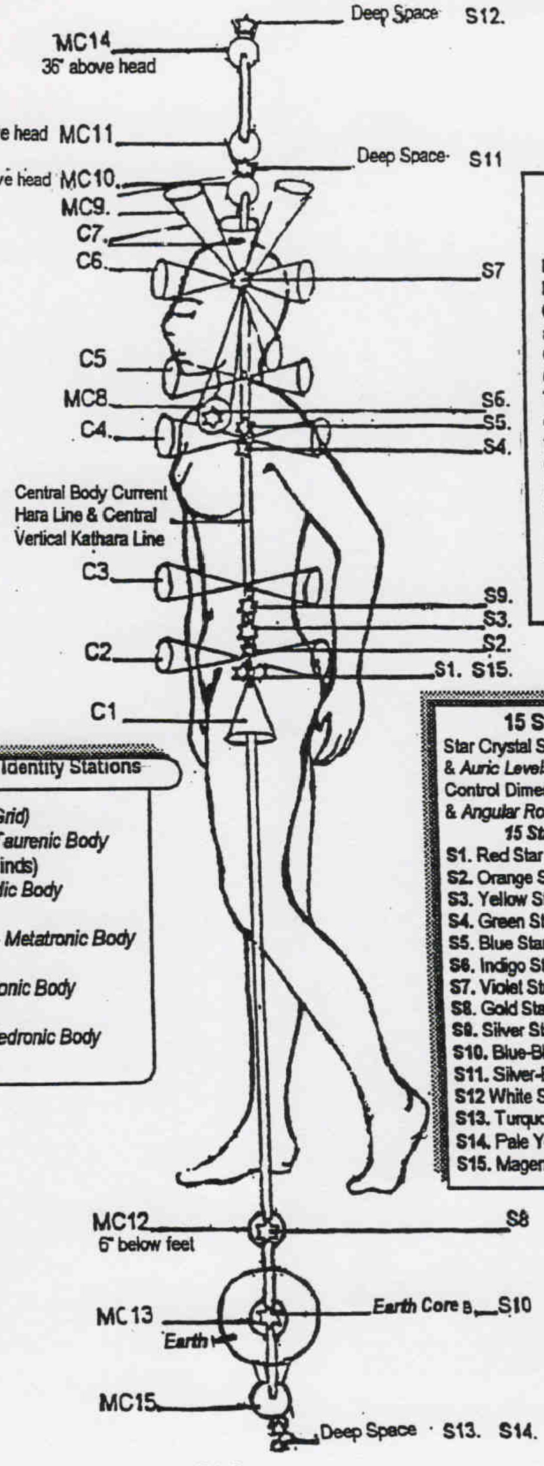
Chakras (C & MC)
Star Crystal Seals (S)
Deep Space S12.
MC14
36" above head
18" above head MC11
Deep Space S11
6" above head MC10
MC9.
C7.
C6.
S7
C5
MC8
S6.
C4.
S5.
S4.
Central Body Current
Hara Line & Central
Vertical Kathara Line
C3
S9.
S3.
C2
S2.
S1. S15.
C1
MC12
6" below feet
S8
MC13
Earth Core B S10
Earth
MC15
Deep Space S13. S14.

Universal Life Force Currents

Enter via **Merkaba Fields, Kathara Grid, DNA Template & Central Vertical Current** and are regulated by the **Crystal Seals** to form the **Chakra System, Axi-a-Tonal and Meridians** of energy distribution in the manifest body. As Currents activate in the Kathara Grid, DNA, Crystal Seals, Chakras and body, **frequency and consciousness** from the higher-dimensional fields progressively embodies.

Hova Bodies and Corresponding Identity Stations

(**"*Hova*" means *Tri-tonal Scalar Grid***)

1. **Nada Hova** – HU-1 Incarnate Identity -*Taurenic Body* (Subconscious, Instinctual & Reasoning Minds)
2. **Alphi Hova** – HU-2 Soul Matrix – *Doradic Body* (Astral, Archetype & Angelic Minds)
3. **Betcha Hova** –HU-3 OverSoul Matrix – *Metatronic Body* (Ketheric, Monadic & Kertatric Minds)
4. **Mahara Hova** – HU-4 Avatar ID – *Hydronic Body* (Christiac, Buddhaic & Nirvanic Minds)
5. **Raja Hova** – HU-5 Rishi Collective – *Hedronic Body* (Universal Conscious Mind)

15 Star Crystal Seals

Star Crystal Seals keep human identity & *Auric Levels* dimensionally separate. Control Dimensional *Merkaba Field Axis* & *Angular Rotation of Particle Spin.*

15 Star Crystal Seals (S):

- **S1.** Red Star
- **S2.** Orange Star
- **S3.** Yellow Star
- **S4.** Green Star
- **S5.** Blue Star
- **S6.** Indigo Star (Blue-Violet)
- **S7.** Violet Star
- **S8.** Gold Star
- **S9.** Silver Star
- **S10.** Blue-Black Star
- **S11.** Silver-Black Star
- **S12** White Star
- **S13.** Turquoise Star
- **S14.** Pale Yellow Star
- **S15.** Magenta-Pink Star

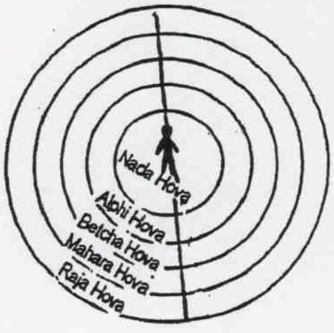
Nada Hova
Alphi Hova
Betcha Hova
Mahara Hova
Raja Hova

Universal Life Force Currents form and sustain the "**Auric Field**" **Levels** of 15-Dimensional Human Anatomy

Auric Level, Chakra and Hova Body Correspondences

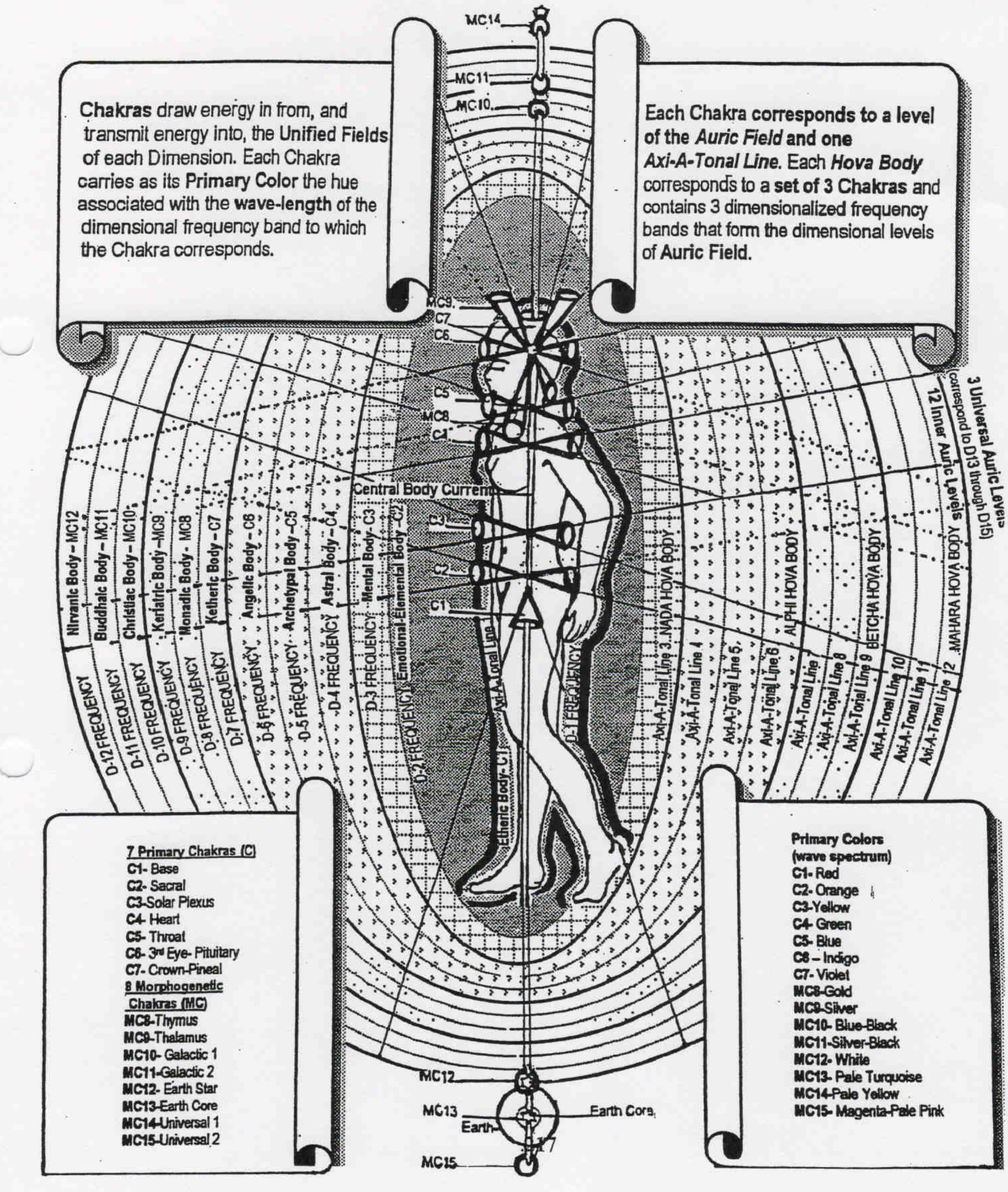

Chakras draw energy in from, and transmit energy into, the **Unified Fields** of each Dimension. Each Chakra carries as its **Primary Color** the hue associated with the **wave-length** of the dimensional frequency band to which the Chakra corresponds.

Each Chakra corresponds to a level of the *Auric Field* and one *Axi-A-Tonal Line*. Each **Hova Body** corresponds to a **set of 3 Chakras** and contains 3 dimensionalized frequency bands that form the dimensional levels of **Auric Field.**

7 Primary Chakras (C)

C1- Base
C2- Sacral
C3-Solar Plexus
C4- Heart
C5- Throat
C6- 3rd Eye- Pituitary
C7- Crown-Pineal

8 Morphogenetic Chakras (MC)

MC8-Thymus
MC9-Thalamus
MC10- Galactic 1
MC11-Galactic 2
MC12- Earth Star
MC13-Earth Core
MC14-Universal 1
MC15-Universal 2

Primary Colors (wave spectrum)

C1- Red
C2- Orange
C3-Yellow
C4- Green
C5- Blue
C6 – Indigo
C7- Violet
MC8-Gold
MC9-Silver
MC10- Blue-Black
MC11-Silver-Black
MC12- White
MC13- Pale Turquoise
MC14-Pale Yellow
MC15- Magenta-Pale Pink

MC14
MC11
MC10
MC9
C7
C6
C5
MC8
C4
Central Body Current
C3
C2
C1
MC12
MC13
Earth
Earth Core
MC15
Nirvanic Body – MC12
Buddhaic Body – MC11
Christiac Body – MC10
Keriatric Body – MC9
Monadic Body - MC8
Ketheric Body – C7
Angelic Body – C6
Archetypal Body – C5
Astral Body – C4
Mental Body - C3
Emotional-Elemental Body - C2
Etheric Body - C1
D-12 FREQUENCY
D-11 FREQUENCY
D-10 FREQUENCY
D-9 FREQUENCY
D-8 FREQUENCY
D-7 FREQUENCY
D-6 FREQUENCY
D-5 FREQUENCY
D-4 FREQUENCY
D-3 FREQUENCY
D-2 FREQUENCY
D-1 FREQUENCY
Axi-A-Tonal Line
Axi-A-Tonal Line
Axi-A-Tonal Line 3
NADA HOVA BODY
Axi-A-Tonal Line 4
Axi-A-Tonal Line 5
Axi-A-Tonal Line 6
ALPHI HOVA BODY
Axi-A-Tonal Line
Axi-A-Tonal Line 8
Axi-A-Tonal Line 9
BETCHA HOVA BODY
Axi-A-Tonal Line 10
Axi-A-Tonal Line 11
Axi-A-Tonal Line 12
MAHARA HOVA BODY
12 Inner Auric Levels
3 Universal Auric Levels (correspond to D13 through D15)

Universal Life Force Currents and the Embodied **Shields, Signets** and **Kathara Grid**

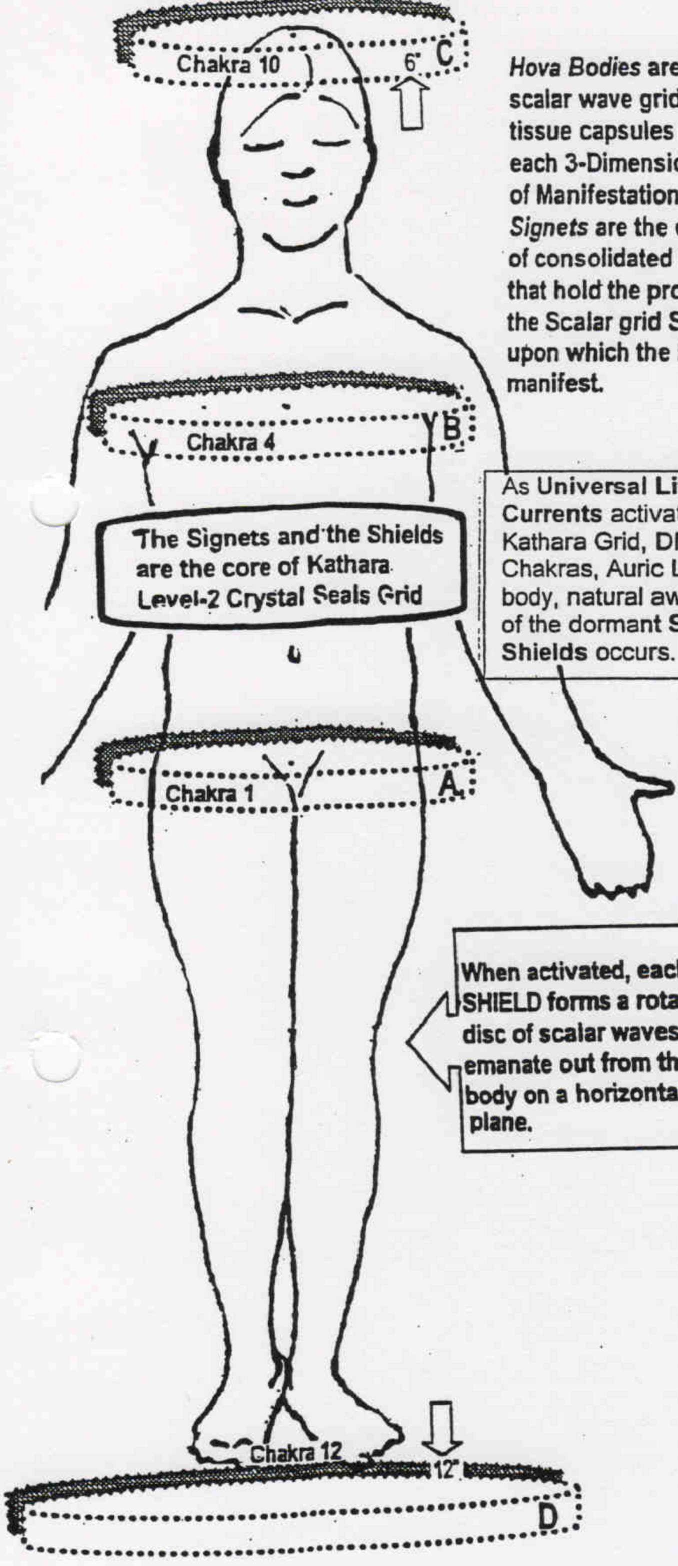
Chakra 10
6"
C
Chakra 4
B
Chakra 1
A
Chakra 12
12"
D

The Signets and the Shields are the core of Kathara Level-2 Crystal Seals Grid

As **Universal Life Force Currents** activate in the Kathara Grid, DNA, Chakras, Auric Levels & body, natural awakening of the dormant **Scalar Shields** occurs.

When activated, each SHIELD forms a rotating disc of scalar waves that emanate out from the body on a horizontal plane.

***Hova Bodies* are spherical scalar wave grids that form tissue capsules between each 3-Dimensional Harmonic of Manifestation.**
***Signets* are the core points of consolidated frequency that hold the programs for the Scalar grid SHIELDS upon which the Hova Bodies manifest.**

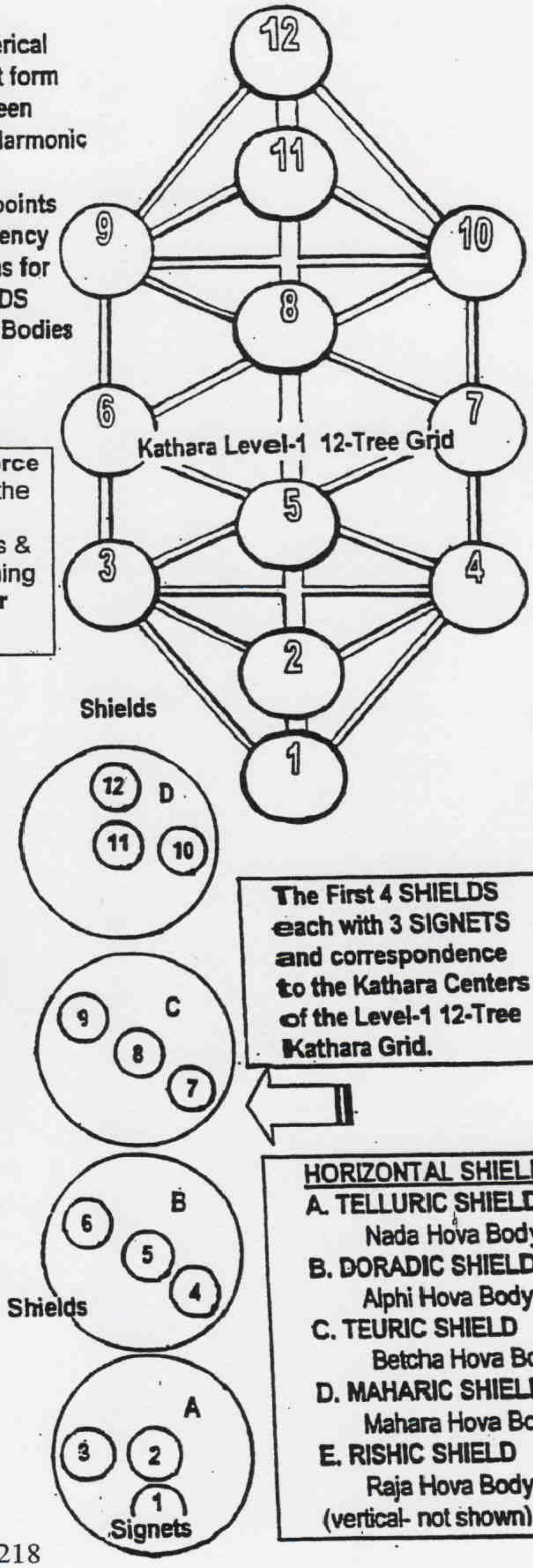
12
11
9
10
8
6
7
Kathara Level-1 12-Tree Grid
5
3
4
2
1
Shields
12
D
11
10
C
9
8
7
B
6
5
4
Shields
A
3
2
1
Signets

The First 4 SHIELDS each with 3 SIGNETS and correspondence to the Kathara Centers of the Level-1 12-Tree Kathara Grid.

HORIZONTAL SHIELDS

A. TELLURIC SHIELD
Nada Hova Body
B. DORADIC SHIELD
Alphi Hova Body
C. TEURIC SHIELD
Betcha Hova Body
D. MAHARIC SHIELD
Mahara Hova Body
E. RISHIC SHIELD
Raja Hova Body
(vertical- not shown)

The Silicate Matrix 12 Strand DNA
Primary Correspondences to Subtle Body Anatomy

Silicate Matrix 12-Strand DNA
Primary Correspondences to Subtle Body Anatomy.

DNA Strand #	Dimension #	Axi-A-Tonal Line	Chakra & *Seed* Crystal Seal	Auric Field Level
NADA HOVA BODY – TELLURIC SHIELD				
1	1	1	1	Etheric Body
2	2	2	2	Emotional Body
3	3	3	3	Mental Body
ALPHI HOVA BODY – DORADIC SHIELD				
4	4	4	4	Astral Body
5	5	5	5	Archetype Body
6	6	6	6	Angelic Body
BETCHA HOVA BODY – TEURIC SHIELD				
7	7	7	7	Ketheric Body
8	8	8	8	Monadic Body
9	9	9	9	Keriatric Body
MAHARA HOVA BODY – MAHARIC SHIELD				
10	10	10	10	Christiac Body
11	11	11	11	Buddhaic Body
12	12	12	12	Nirvanic Body

Three 3-Dimensional Kundalini Currents compose the 9-Dimensional
Antahkarana The Telluric, Doradic and Teuric Kundalini Currents

Maharata
D-10-11-12
Christos Current

As **Universal Life Force Currents** activate within the body, the **dimension of consciousness** contained in each **Auric Field Level** progressively embodies.

Universal Life Force Currents and DNA Template Fire Letter Sequences

15-Dimensional Levels of Identity, DNA and Indigo Children

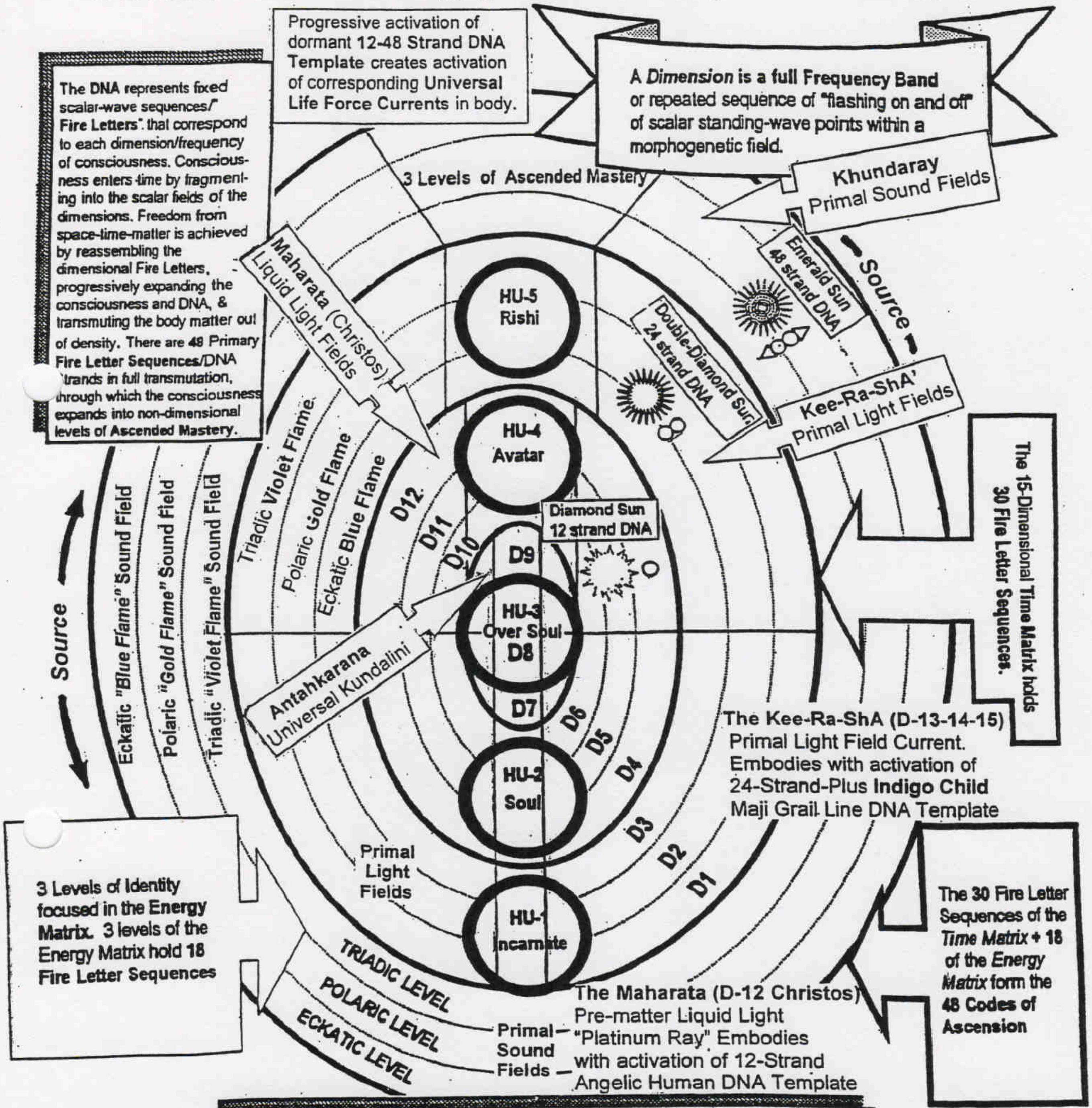

Progressive activation of dormant 12-48 Strand DNA Template creates activation of corresponding Universal Life Force Currents in body.

The DNA represents fixed scalar-wave sequences/" **Fire Letters**" that correspond to each dimension/frequency of consciousness. Consciousness enters time by fragmenting into the scalar fields of the dimensions. Freedom from space-time-matter is achieved by reassembling the dimensional Fire Letters, progressively expanding the consciousness and DNA, & transmuting the body matter out of density. There are **48 Primary Fire Letter Sequences**/DNA Strands in full transmutation, through which the consciousness expands into non-dimensional levels of **Ascended Mastery**.

A *Dimension* is a full **Frequency Band** or repeated sequence of "flashing on and off" of scalar standing-wave points within a morphogenetic field.

The 15-Dimensional Time Matrix holds 30 Fire Letter Sequences.

The Kee-Ra-ShA (D-13-14-15) Primal Light Field Current. Embodies with activation of 24-Strand-Plus **Indigo Child** Maji Grail Line DNA Template

3 Levels of Identity focused in the Energy Matrix. 3 levels of the Energy Matrix hold 18 Fire Letter Sequences

The 30 Fire Letter Sequences of the ***Time Matrix*** **+ 18 of the** ***Energy Matrix*** **form the 48 Codes of Ascension**

The Maharata (D-12 Christos) Pre-matter Liquid Light "Platinum Ray" Embodies with activation of 12-Strand Angelic Human DNA Template

3 Levels of Ascended Mastery
Khundaray
Primal Sound Fields
Emerald Sun
48 strand DNA
Source
Double-Diamond Sun
24 strand DNA
Kee-Ra-ShA'
Primal Light Fields
Maharata (Christos)
Liquid Light Fields
HU-5
Rishi
HU-4
Avatar
Diamond Sun
12 strand DNA
D12
D11
D10
D9
HU-3
Over Soul
D8
D7
D6
D5
D4
HU-2
Soul
D3
D2
D1
HU-1
Incarnate
Triadic Violet Flame
Polaric Gold Flame
Eckatic Blue Flame
Antahkarana
Universal Kundalini
Source
Eckatic "Blue Flame" Sound Field
Polaric "Gold Flame" Sound Field
Triadic "Violet Flame" Sound Field
Primal Light Fields
TRIADIC LEVEL
POLARIC LEVEL
ECKATIC LEVEL
Primal Sound Fields

The *Oraphim* genetic imprint of the **Indigo Children** allows more rapid re-assembly of the **48 DNA Fire Letters**/ scalar-wave grids, creating the potential to embody the *Avatar* identity and open the consciousness to *Ascended Master* Identity Levels. **Indigo Children are Avatars and Ascended Masters waiting to awaken.**

All Angelic Humans possess a minimum of **12-Strand** DNA potential through which activation of the **Maharata Current** and embodiment of the D-12 **Christed Avatar identity** can take place.

The Reality of Spiritual Integration

- **Spiritual Actualization** is as much a function of **Divine Physics** as it is a product of **Divine Consciousness.** The natural Primal Order of **Universal Structure** sets the **Templates of Manifestation** to which consciousness **must conform to** enter the experience of manifest expression within a space-time-matter system.
- The personal Christos **Maharic Shield** Manifestation Template and the Christos **Tribal Shield** Species Manifestation Template are **microcosmic replicas** of the macrocosmic Primal Order upon which Universal and Cosmic structure are built..
- The Personal D-12 Christos Divine Blueprint Maharic Shield connects each Individual Christos self to the **larger** D-12 Christos Divine Blueprint of the **Species.** The D-12 Christos Divine Blueprint is called the **TRIBAL SHIELD.**
- To understand the realities of **personal Spiritual Integration and Actualization,** in order to **fulfill our personal life purpose,** it is important to comprehend the basic **Primal Order** structures of energy, the **personal D-12 Maharic Shield** and the **D-12 Species Tribal Shields,** through which our consciousness manifests in time.
- The secrets to **reclaiming the Divine Birthrights and Responsibilities** of Angelic Human heritage are hidden within the realities of the **Tribal Shield** and the specific **"Fire Letter Sequences"** of the Tribal Shield that manifest within and **govern the function** of the Angelic Human **DNA Template.**
- The **key to Spiritual Actualization** is activation of the dormant personal 12-Strand DNA Template. The **most rapid means** of activating the dormant Angelic Human 12-Strand DNA Template is through **activation of the Tribal Shield,** the Species D-12 Christos Divine Blueprint, which represents the **CORE PROGRAMMING** of the personal D-12 Maharic Shield.

The Silicate Matrix 12-Strand DNA Template with Hova Body, Scalar Shield and Identity Level Correspondences

The Morphogenetic Field Scalar-wave Template for the Original Human Genome

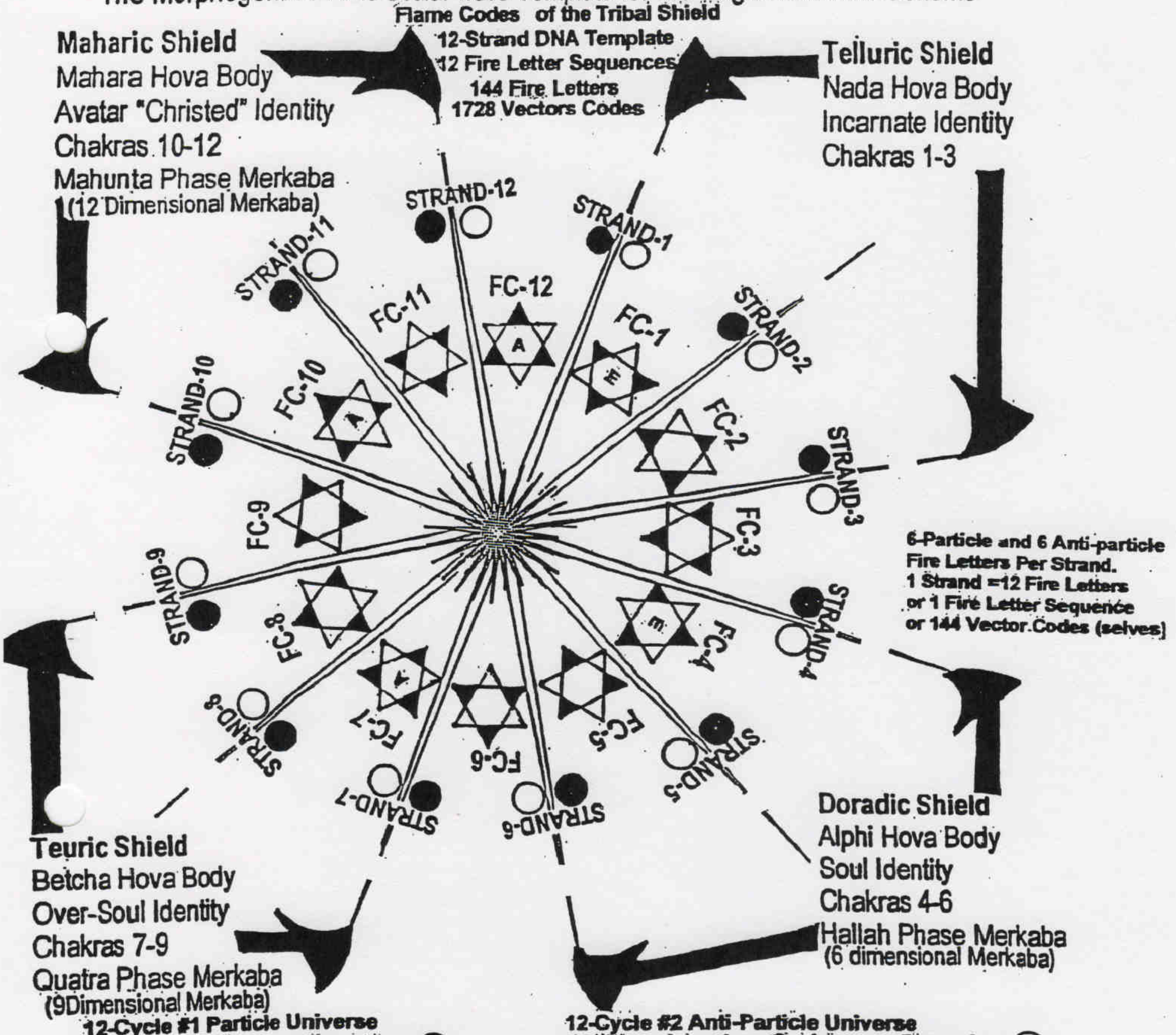
Flame Codes of the Tribal Shield
12-Strand DNA Template
12 Fire Letter Sequences
144 Fire Letters
1728 Vectors Codes
Maharic Shield
Mahara Hova Body
Avatar "Christed" Identity
Chakras 10-12
Mahunta Phase Merkaba
(12 Dimensional Merkaba)
Telluric Shield
Nada Hova Body
Incarnate Identity
Chakras 1-3
Doradic Shield
Alphi Hova Body
Soul Identity
Chakras 4-6
Hallah Phase Merkaba
(6 dimensional Merkaba)
Teuric Shield
Betcha Hova Body
Over-Soul Identity
Chakras 7-9
Quatra Phase Merkaba
(9Dimensional Merkaba)
STRAND-12
STRAND-1
STRAND-2
STRAND-3
STRAND-4
STRAND-5
STRAND-6
STRAND-7
STRAND-8
STRAND-9
STRAND-10
STRAND-11
FC-12
A
FC-1
E
FC-2
FC-3
FC-4
E
FC-5
FC-6
FC-7
A
FC-8
FC-9
FC-10
A
FC-11
6-Particle and 6 Anti-particle Fire Letters Per Strand.
1 Strand =12 Fire Letters
or 1 Fire Letter Sequence
or 144 Vector Codes (selves)

12-Cycle #1 Particle Universe
12 Base Codes per Strand = ●

12-Cycle #2 Anti-Particle Universe
12 Acceleration Codes per Strand = ○

12 FIRE CODES between Strands = ✡

(E) Emerald Kundalini Awakening releases Fire Codes 1 & 4 (A) Amethyst Kundalini Awakening releases Fire Codes 7,10 & 12

(Diagram presents simple conceptualization of DNA Strand Template orientation, not actual geometrical arrangement of wave-form structure and observable strand interrelationship.)

Activating the Tribal Shield

- The 12-dimensional **Tribal Shield** is the dormant **Species Divine Blueprint** within the **DNA Template core** of the Angelic Human races of the 4 Evolutionary Rounds. The frequencies of energy and dimensions of consciousness of the **1728 simultaneous selves** of the Personal Eternal Christos Identity can be **activated in one incarnation** through **sequential activation** of the **Fire Letter Sequences** or **"Flame Codes'** of the **Tribal Shield.**

- The "Flame Code Fire Letters" within the DNA Template are the **DNA Signet Codes** that correspond to Earth's **12 Primary Star Gates** and the **Planetary Shields** through which the planetary body manifests. The Flame Codes serve as the core foundation of the personal 12-Strand DNA Template.

- The DNA Template Flame Codes of the Tribal Shield allow for the **Primal Life Force Currents** of the Density-5 (dimensions 13-14-15) **Kee-Ra-ShA Primal Light Fields** and the **Khundaray Primal Sound Fields** from the Energy Matrix, beyond the 15-Dimensional Time Matrix, to embody more fully within the Angelic Human form.

- A **Fire Letter** is a **fixed point of consolidated frequency** that holds specific frequencies consciousness into manifest form. The **Manifestation Templates** or Divine Blueprints of **all things** manifest are built upon **intricate patterns** of interwoven Fire Letters called **Fire Letter Sequences.** The Flame Codes of the Angelic Human personal DNA Template and Species Tribal Shield are composed of the same **Fire Letter Sequences** that make up the Divine Blueprint of **Earth's Planetary Shields.**

- Activation of the Tribal Shield sets in motion simultaneous "firing" or activation of the **144 Fire Letters (12** Fire Letter **Sequences)** of the 12-Strand DNA Template, expediting the natural evolutionary process of Soul, Over-Soul and Christos Avatar Identity Integration, through progressively opening the "Trans-time DNA Template Star Gates".

- Activating the 12-Strand DNA Template allows the D-12 frequency of the **Universal "Christos" Maharata Current** to activate within and run through the Angelic Human DNA Template and into the Earth's **Planetary Shields.** Activation of the **Maharata Current** within **groups of Angelic Humans** on Earth allows for **collective anchoring** of the **D-12 Planetary Christos Divine Blueprint**, the **Shield of Aramatena**, to achieve fulfillment of Angelic Humanity's **Sacred Commission** of the **Planetary Christos Realignment Mission**.

The Tribal Shield- *Species D-12 Christos Divine **Blueprint***

The Angelic Human 12-Strand DNA Template contains 6 Fire Letter Sequences from particle universe 12-Cycle plus 6 Fire Letter Sequences from anti-particle 12-Cycle = **12 Fire Letter Sequences** or **144 Fire Letters** from the **Two Planetary 12-Cycles** of the Cycle of the Rounds. (1 12-Cycle = 4 Evolutionary Rounds)

The **Tribal Shield** connects our personal D-12 **Maharic Shield** Divine Christos Blueprint to the greater Christos Blueprint of the Angelic Human **Species. 144 Fire** Letters (12 Fire Letter *Sequences*) of the **Tribal Shield** make up the **core program** of the Human **12-Strand DNA Template.**

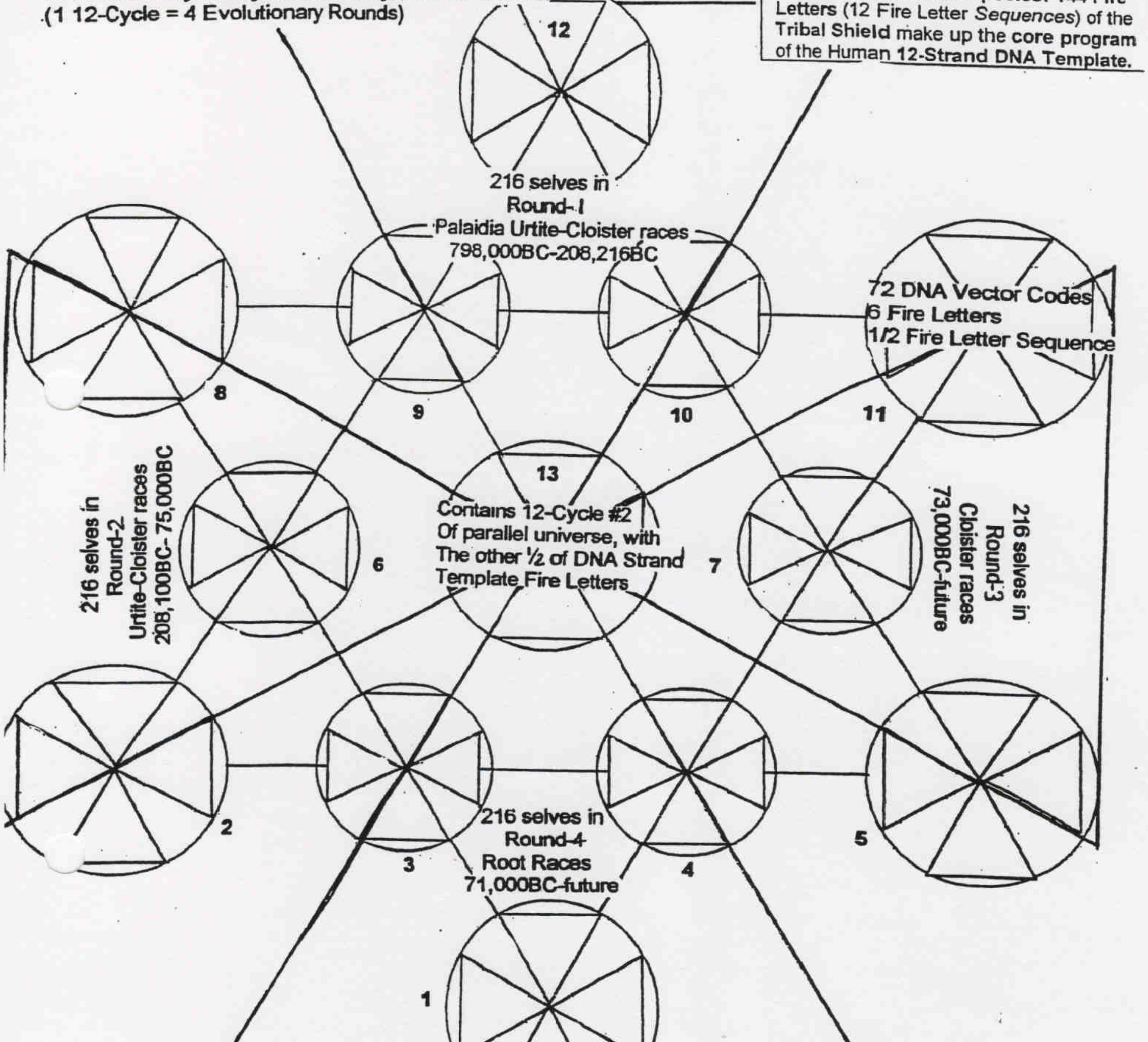
12
216 selves in
Round-1
Palaidia Urtite-Cloister races
798,000BC-208,216BC
8
9
10
72 DNA Vector Codes
6 Fire Letters
1/2 Fire Letter Sequence
11
13
Contains 12-Cycle #2
Of parallel universe, with
The other ½ of DNA Strand
Template Fire Letters
216 selves in
Round-2
Urtite-Cloister races
208,100BC- 75,000BC
6
7
216 selves in
Round-3
Cloister races
73,000BC-future
2
3
216 selves in
Round-4
Root Races
71,000BC-future
4
5
1

Each of the **12 Planetary Time Cycles** in one Planetary 12-Cycle of the **"Cycle of the Rounds"** has **72 Time Vectors. 12-Strand** Angelic Humans have **one self** in each of the 72 Time Vectors of the particle universe Planetary 12-Cycle and **72 selves** in the corresponding anti-particle Planetary 12-Cycle. **72 selves x 12** Planetary Time Cycles = **864 selves** per one Planetary 12-Cycle **+ 864 selves** parallel universe Planetary 12-Cycle = **1728 selves** in Tribal Shield.

Tribal Shield Activation Creates Cue Zones In Earth's Planetary Shields.

Cue Zones

"Cue Zones" are locations on Earth where a small portion of Earth's D-12 Shield of Aramatena **Christos Divine Blueprint** has been re-set within Earth's Planetary Shields. During Stellar Activations Cycles, Cue Zones can be **manually set** by individuals or groups by running the **D-12 Maharata Current**, activating the **Tribal Shield** to draw in the Khunarary Primal Sound frequencies, then singing the 12-Tribes **Master Psonns Suffixes** and running the tones through the body and feet and into Earth's Planetary Shields. After running the Master Psonns Suffixes, one can then allow the **"Song of the Christos Soul"**, the tones of the personal D-12 **Maharic Shield** (the "Elohei-Elohim Within") to run into the Planetary Shields. The personal Soul Song will create a **"Back Song"** transmission of frequency from Earth's Planetary Shields, a set of healing frequencies sent back to you in response to activating your Soul Song in Earth's Planetary Shields. Once set, Cue Zones will remain for a period of **3.5 to 5 years**, depending on strength of energy originally set. They can be **recharged** using the same "setting" procedure to **last indefinitely.**

Cue Zones are **"safe zone"** areas on the Planet that are protected from interdimensional interference. They can be used to amplify effects of energy **healing applications, to "charge" objects and substances** with sub-harmonics of D-12 Christos frequency and when used with the personal Temporary Maharic Seal, to get clear, protected **"meditation space"** free from interdimensional interference. Cue Zones are "keyed" to Earth's Planetary **Templar "Cue Sites"**, the activation sites for Earth's 12 Primary Star Gates, which exist on regions of Earth that correspond to the 12 Primary Star Gates of **Inner Earth.**

TECHNIQUE # 6: THE MAHARIC QUICK SEAL

1 Work with a 24 pointed, 3 Dimensional Star (Heirophant) and be aware that you will be working with beings known as the Breneau Rishi ...

2 Begin by slowing your breathing , as you imagine or visualize a 24 point, 3 -Dimensional, Heirophant at the Pineal Gland in the center of your brain. Visualise the Heirophant surrounded by a Pale Blue Sphere of Light.

(The Blue Sphere serves as a buffer for your readiness to accept the frequencies associated with using the 24 pointed Star; the Blue Sphere holds the energy for you until your body can handle the energy. If you can handle it, the energy will simply pass through the blue sphere).

3 INHALE, as if you are going to grab the blue sphere containing the 24 point star located at the Pineal, and on the EXHALE move the 24 point star/ blue sphere, all the way down to Earth's Core. Try to hear a sound tone as the Heirophant/ Sphere hits the Planetary Shield ...

4 INHALE and draw the Heirophant/ sphere up to your Personal Maharic Shield 12" below your feet ... and EXHALE while watching the Pale Silver-Blue sphere expand out to a large sphere ... and watch as your Maharic Shield pop out as a disc, about 4' in diameter, Pale Silver with a light coating of Pale Blue.

5 Bring your attention to the center of your Maharic Shield 12" below your feet ... and INHALE the 24 point Star (only) up into the Heart Chakra. EXHALE, expanding the frequencies of the 24 point Star into the Heart Chakra.

6 INHALE to grab the 24 point Star, and EXHALE, pushing the Star up into the 14th Chakra 36" above the head. Imagine that the 24 point Star is spinning in a clockwise direction in the 14th Chakra. As you do this, try to feel/ sense the energy around you, just a few inches out from your body ...

7 Now, put your attention into your Maharic Shield 12" below your feet, take a couple of relaxing breaths and INHALE deeply pulling the Pale Silver and Blue energy up, as if you are pulling on your Maharic Seal to latch it on to your 14th Chakra. Try and feel the sensations just a few inches from your body now – feel the difference if you can. This procedure gives you a Quick Seal.

8 Now envision the cord of Pale Silver Maharic Light that would normally come up with your Shield and focus on the Earth's Core. Begin drawing energy all the way up the 4" diameter cord and into the body. INHALE the energy up into the Heart Center, and expand it there. Begin to form a pale Silver ball of Maharic frequency.

On each EXHALE send your energy down to the Earth's Core to bring up another load of Maharic frequency, up from the Planetary Shields, expand it into the Heart center and repeat several times. Notice that the Cord grows larger as you do this, expanding from approximately 4" to 6 to 8" diameter, until finally it feels like a skin around (as well as within) your body ... as you load your Astral field with Maharic Frequency.

9 Move your attention to the Pale Silver ball you have created in your Heart Center, INHALE and move it up to the 14th Chakra 36" above your head .. as you do, feel for the sheath of Maharic Frequency encasing your etheric body, close to your skin. (This Maharic/ Christos skin charges, and saturates, your etheric body – feel the peacefulness and all-knowing nature of this frequency).

Technique # 7: Ps-13 Tribal Shield Activation

The Master Key Tones

- The **12-Tribes names** were the **audible-tone translations** of the **specific Fire Letter Sequences** contained within the **Tribal Shield DNA Templates** of each Tribe. The tones of the Tribal names were used to activate the **144 Fire Letters** of the Tribal Shield in the **personal DNA Template**, providing the Angelic Humans races with the ability to **consciously regulate** the **activation level** of their **DNA Templates** and **Primal Life Force Currents.**
- The **Sound-Tone Programs** that are used to activate the DNA Template and Primal Life Force Currents are called **"The Sacred Psonns"**. The **Tribal name** was the **Master Psonn**. In running the Rainbow Roundtables, the Signet Council Regents brought their Tribal Shield "Flame Codes" into activation by **singing rounds** of the **Sacred Master Psonns.**

The 12 Sacred Master Psonns

for activating the 144 Fire Letters of the Tribal Shield Flame Codes in the 12-Strand DNA Template.

Plus **Master Tone Activation Suffix.**

12. *A-reah-Azurta*
a- RI-a-Zoor- ta- Rha

11. *Zephar-Duun-Atur*
ze-far-Doon a-Tur- Dha

10. *Ma'ah-hu-ta*
Ma-a hoo ta- Khu

9. *Yun Zu-Xen*
Yu-Un Zoo-Zen KE

8. *Chia Zhun Zan La-Yung*
ChE' ah-Zoon Yan LA-Yoong' OM

7. *Mahata-Agrah*
ME hah' ta a'g-ra OE

6. *Ramyana-Shridveta*
rah ma yah na shrid vE' Da U

5. *Ionatu-Etillah*
I O' Na too et il' a EU

4. *Nuagu Hali*
Noo ah' goo ha' LE Ka

3. *Amekasan-Etur*
a ME' ka sun e too'r DO

2. *Maahali-Bruea*
Ma a ha' LE - BrU' A EL

1. *Isutu-Esheau*
I sU' too E' shoo UR

Tribal Shield-Cue Zones Activation

Creating a Cue Zone

1. **Choose location** and **activate a personal "Maharic Quick Seal"** to "run the D-12 **Maharata Current**" in your **body.**

2. Once you can feel sensation of Maharata Current running, sing-tone 12-Tribes **Master Psonns** (names) for **Tribe-12** and **Tribe-1** to activate **Tribal Shields Flame Codes** in your DNA Template to run the "**Rainbow Ray**". Direct Pale Silver Maharata Current and Rainbow Ray pale color spectrum through body and out **soles of feet** into Earth's Planetary Shields. Tone for a while to build critical mass of frequency.

3. Use a selected combination of **3 Master Psonns Suffixes** and tone for a while, running sound through body and feet into Earth's grids. (avoid the Suffix combination of Tribe-4-7-10 used in that sequence to avert present distortions in Earth's grids that run on this mathematical coding)

4. Allow the **Christos Soul Song** to emerge from you "free style" and send the tones into Earth's grids.

5. When complete, sit quietly for a while and listen for the Earth's telepathically transmitted **"Back Song"**, drawing its gentle frequencies into your body for healing.

6. Close with singing several rounds of the **3 Master Psonns Suffixs** that you opened with. The Cue Zone you have set will extend out from your position in a radius of about **5 yards** and will last **3.5-5 years** depending on strength of energy you used in setting the Cue Zone.

7. To **amplify** strength of Cue Zone you can use the **"Merkaba Spin"** just after closing. Remain in same position, stand, the gently spin, first **clockwise** (as if you are standing on a clock face with the "6" in front of your feet, "3" at the left hand, "9" at the right and "12" directly behind you). Spin gently clockwise to bring electrical frequency down through your "**top**" Merkaba spiral. Then slow, stop and **reverse spin** to **counterclock-wise**, to activate "**bottom**" Merkaba spiral", drawing frequency up from Earth's grids. Personal Merkaba Activation will accelerate the frequencies of the D-12 energies you set at the site, making the Cue Zone **stronger and more lasting.**

The Solar Salutation
Electrical Merkaba Activation

- The ancient **Mu'a** and **Lemurian** Guardian Races ran the **Maharata** and activated the **Tribal Shield** each day to conduct the **Sacred Solar and Lunar Salutation Rites** each morning and evening. The **Sacred Salutations** are **Toning Dances** that activate the personal **Merkaba Field** for sustained activation of the DNA Template and amplification of the Maharata and Universal Life Force Currents in the body.
- **Solar Salutations** accelerate the spin of the **Electrical Harmonic Merkaba Spiral** (Top, CW spin), drawing increased amounts of **Electrical Anti-particle** frequency from the Solar **Electrical Merkaba Spiral** light spectrum into the **Electrical Acceleration Codes** in the **DNA Template** to **"charge" the body** with **Electrical Anti-particle frequency.**
- Accelerated **Electrical Merkaba Spiral Spin** of **Solar Salutations** increases the amount of **Anti-particle Base-Electrical** frequency **brought into** the body's **DNA Template** and **Kathara Grid** from the Dimensional Unified Fields and increases the amount of **Anti-particle** frequency **sent out** from the body into Earth's **Planetary Shields.** Frequency passes between the Human Body and Earth's Planetary Shields via the embodied **Kathara Grid** core templates that make up the **Planetary Bio-Feed Interface System** ("PBIS")
- **Electrical Anti-particle** energy enters the body via the **"Top" Electrical** Harmonic and Dimensional **Merkaba Spirals**, the **Base-Electrical Acceleration Codes** in the DNA Template, the **Electrical Kathara Centers 2-5-8-11** of the Kathara Grid **Central Pillar**, the **Electrical aspect** of **Electro-magnetic Kathara Centers 1-3-6-9-12** on the **Right Side** of body ("Left Side Pillar" in Kathara diagram), **Electrical Chakras 2-5-8-11** and the **Electrical aspect** of **Electro-magnetic Chakras 1-3-6-9-12**.

- **Solar Salutations** (CW spin Top Electrical Merkaba Field Activation) **raise** the body's **Oscillation** (energy transmission-expansion), **lower** the body's **Vibration** (energy holding-contraction), making the body **Higher Frequency** and **More Electrical** (transmits more energy than it is drawing in).
- A **Higher Frequency Electrical Body** has:
  - **Lower Vibration**, Higher Oscillation/Frequency, **Less Matter Density**
  - More activated DNA Strands, more chromosomes, embodiment of more levels of consciousness.
  - **Slower** heart, breathing and metabolic rhythms (energy expansion and contraction rates),thus requires less food (burns fuel slower).
  - Greater **longevity** and **less sleep** (body can synthesize natural higher frequency energy and Stream of Consciousness for longer periods without taxing.)
  - Greater **Silica quantity** in **Silica-to-Carbon Ratio** of elemental composition and **larger size** (more space between cells; more expanded matter).
  - Perception of **expanded Space** and **slower Time** movement.
  - Greater **heat release**, thus **cooler** internal temperature.
  - Natural attribute of **transmitting** greater amounts of energy thrust into the Planetary Shields than it is drawing in/receiving from them. **Energy "giving".**

- The **Solar Salutations** "charge" the **Top Electrical CW Merkaba Spiral** to maintain its natural cycle of **33(⅓) rotations per 1 "trillionth" of a nano-second"**, through which the **Base-Electrical** systems of the body are naturally maintained.

The Lunar Salutation
Magnetic Merkaba Activation

- **Lunar Salutations** accelerate the spin of the **Magnetic Harmonic Merkaba Spiral** (Bottom, CCW spin), drawing increased amounts of **Magnetic Particle** frequency from the **Lunar Magnetic Merkaba Spiral** reflected light spectrum and Earth's Planetary Shields into the **Magnetic Base Codes** in the **DNA Template** to **"charge" the body** with **Magnetic Particle frequency.**
- Accelerated **Magnetic Merkaba Spiral Spin** of **Lunar Salutations** increases the amount of **Particle Base-Magnetic** frequency **brought into** the body's **DNA Template** and **Kathara Grid** from the **Earth's Planetary Shields** and increases the amount of **Particle** frequency **sent out** from the body into Dimensional Unified Fields.
- **Particle Base-magnetic** energy enters the body via the **"Bottom" Magnetic** Harmonic and Dimensional **Merkaba Spirals**, the **Base-Magnetic Base Codes** in the DNA Template, the **Magnetic Kathara Centers 4-7-10** of the Kathara Grid on the **Left Side** of the body ("Right Side Pillar" on Kathara Diagram), the **Magnetic aspect** of **Electro-magnetic Kathara Centers 1-3-6-9-12** on the **Right Side** of body ("Left Side Pillar" in Kathara diagram), **Magnetic Chakras 4-7-10** and the **Magnetic aspect** of **Electro-magnetic Chakras 1-3-6-9-12**.
- **Lunar Salutations** (CCW spin Bottom Magnetic Merkaba Field Activation) **lower** the body's **Oscillation** (energy transmission-expansion), **raise** the body's **Vibration** (energy holding-contraction), making the body **Lower Frequency** and **More Magnetic** (draws in more energy than it is transmitting out).

- A **Lower Frequency Magnetic Body** has:
  - **Higher Vibration**, Lower Oscillation/Frequency, Greater **Matter Density**
  - **Fewer** activated DNA Strands, fewer chromosomes, embodiment of fewer levels of consciousness.
  - **Faster** heart, breathing and metabolic rhythms (energy expansion and contraction rates), thus requires **more food** (burns fuel **faster**).
  - Lesser **longevity** and needs more **sleep** (body can synthesize natural higher frequency energy and Stream of Consciousness for **shorter periods**; taxes more easily)
  - Greater **Carbon quantity** in **Silica-to-Carbon Ratio** of elemental composition and **smaller size** (less space between cells; more contracted matter).
  - Perception of **contracted or more confined Space** and **faster Time** movement.
  - Less **heat release**, thus **warmer** internal temperature.
  - Natural characteristic of **drawing** greater amounts of energy thrust from the Planetary Shields than it is transmitting into them. **Energy "taking"**.

The **Lunar Salutations** "charge" the **Bottom Magnetic CCW Merkaba Spiral** to maintain its natural cycle of **11⅔ rotations per 1 "trillionth" of a nano-second"**, through which the **Base-Magnetic** systems of the body are naturally maintained.

The **natural ratio** between the **Top-CW-Electrical-"Male" Harmonic Merkaba Field** and the **Bottom-CCW-Magnetic-"Female" Harmonic Merkaba Field** is **Electrical-Top 33⅓CW** rotations per 1 "trillionth" of a nano-second and **Magnetic-Bottom 11⅔CCW** rotations per 1 "trillionth" of a nano-second.

The Natural Christos Merkaba Vehicle & Personal Shields

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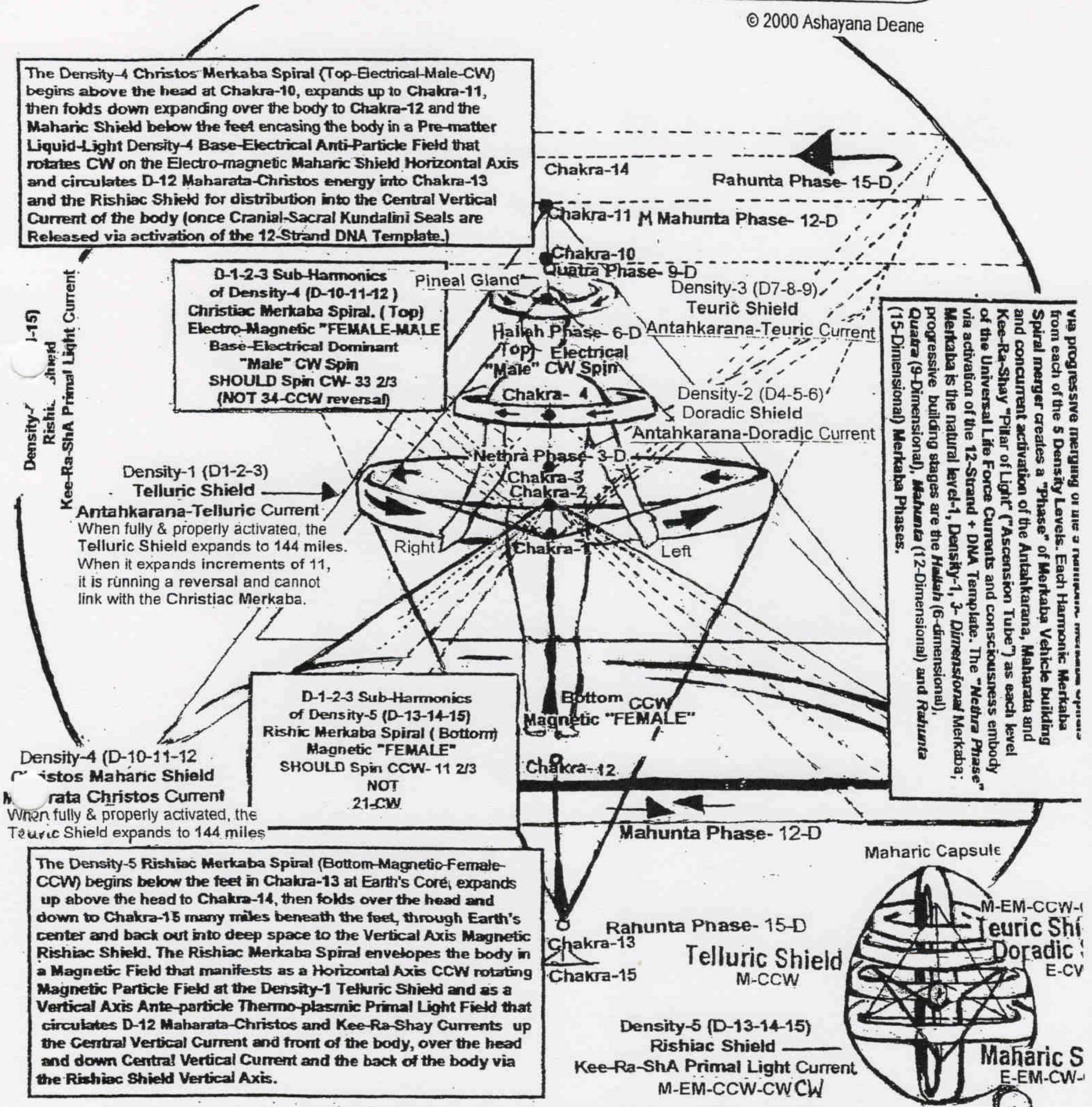
Chakra-14
Rahunta Phase- 15-D
Chakra-11 M Mahunta Phase- 12-D
Chakra-10
Quatra Phase- 9-D
Pineal Gland
Density-3 (D7-8-9)
Teuric Shield
Antahkarana-Teuric Current
Hallah Phase- 6-D
Top- Electrical "Male" CW Spin
Chakra- 4
Density-2 (D4-5-6)
Doradic Shield
Antahkarana-Doradic Current
Nethra Phase- 3-D
Chakra-3
Chakra-2
Density-1 (D1-2-3)
Telluric Shield
Antahkarana-Telluric Current
Right
Chakra-1
Left
Density-
Rishi Shield
-15)
Kee-Ra-ShA Primal Light Current
Bottom CCW
Magnetic "FEMALE"
Chakra-12
Density-4 (D-10-11-12
C istos Maharic Shield
M rata Christos Current
Mahunta Phase- 12-D
Maharic Capsule
M-EM-CCW-
euric Shi
Doradic
E-CV
Maharic S
E-EM-CW-
Rahunta Phase- 15-D
Chakra-13
Chakra-15
Telluric Shield
M-CCW
Density-5 (D-13-14-15)
Rishiac Shield
Kee-Ra-ShA Primal Light Current
M-EM-CCW-CW CW

The Density-4 Christos Merkaba Spiral (Top-Electrical-Male-CW) begins above the head at Chakra-10, expands up to Chakra-11, then folds down expanding over the body to Chakra-12 and the Maharic Shield below the feet encasing the body in a Pre-matter Liquid-Light Density-4 Base-Electrical Anti-Particle Field that rotates CW on the Electro-magnetic Maharic Shield Horizontal Axis and circulates D-12 Maharata-Christos energy into Chakra-13 and the Rishiac Shield for distribution into the Central Vertical Current of the body (once Cranial-Sacral Kundalini Seals are Released via activation of the 12-Strand DNA Template.)

D-1-2-3 Sub-Harmonics
of Density-4 (D-10-11-12)
Christiac Merkaba Spiral. (Top)
Electro-Magnetic "FEMALE-MALE
Base-Electrical Dominant
"Male" CW Spin
SHOULD Spin CW- 33 2/3
(NOT 34-CCW reversal)

via progressive merging of the 5 harmonic merkaba spirals from each of the 5 Density Levels. Each Harmonic Merkaba Spiral merger creates a "Phase" of Merkaba Vehicle building and concurrent activation of the Antahkarana, Maharata and Kee-Ra-Shay "Pillar of Light" ("Ascension Tube") as each level of the Universal Life Force Currents and consciousness embody via activation of the 12-Strand + DNA Template. The *"Nethra Phase"* Merkaba is the natural level-1, Density-1, 3- *Dimensional* Merkaba; progressive building stages are the *Hallah* (6-dimensional), *Quatra* (9-Dimensional), *Mahunta* (12-Dimensional) and *Rahunta* (15-Dimensional) Merkaba Phases.

When fully & properly activated, the Telluric Shield expands to 144 miles. When it expands increments of 11, it is running a reversal and cannot link with the Christiac Merkaba.

D-1-2-3 Sub-Harmonics
of Density-5 (D-13-14-15)
Rishic Merkaba Spiral (Bottom)
Magnetic "FEMALE"
SHOULD Spin CCW- 11 2/3
NOT
21-CW

When fully & properly activated, the Teuric Shield expands to 144 miles

The Density-5 Rishiac Merkaba Spiral (Bottom-Magnetic-Female-CCW) begins below the feet in Chakra-13 at Earth's Core, expands up above the head to Chakra-14, then folds over the head and down to Chakra-15 many miles beneath the feet, through Earth's center and back out into deep space to the Vertical Axis Magnetic Rishiac Shield. The Rishiac Merkaba Spiral envelopes the body in a Magnetic Field that manifests as a Horizontal Axis CCW rotating Magnetic Particle Field at the Density-1 Telluric Shield and as a Vertical Axis Ante-particle Thermo-plasmic Primal Light Field that circulates D-12 Maharata-Christos and Kee-Ra-Shay Currents up the Central Vertical Current and front of the body, over the head and down Central Vertical Current and the back of the body via the Rishiac Shield Vertical Axis.

The NATURAL Spin Ratio between the Top (Male-Electrical-CW-Anti-particle) Density-4 Christiac Merkaba Spiral and the Bottom (Female-Magnetic-CCW-Particle) Density-5 Rishiac Merkaba Spiral is **33 1/3-CW-Male-Top to 11 2/3-CCW-Female-Bottom.** The **33 1/3-CW/11 2/3-CCW** Spin Ratio creates the NATURAL ratio of **33 2/3-Parts-Electrical Anti-Particles** to **11 2/3-Parts Magnetic** Particles, (or **33 1/3 energy expansion/oscillation/thrust to 11 2/3 energy contraction/vibration/draw**) within earth's Density-1 Matter Base, the organic Divine Blueprint of Density-1. This Christiac Internal Merkaba Vehicle Spin Ratio creates a self-sustaining, Eternal, Matter-base that is **MORE ELECTRICAL** than Magnetic, which perpetually re-fuels itself via natural circulation of the *Maharata, Kee-Ra-ShA* and *Khundaray* Universal Life Force Currents.

Merkaba Phases – Building the Merkaba Vehicle

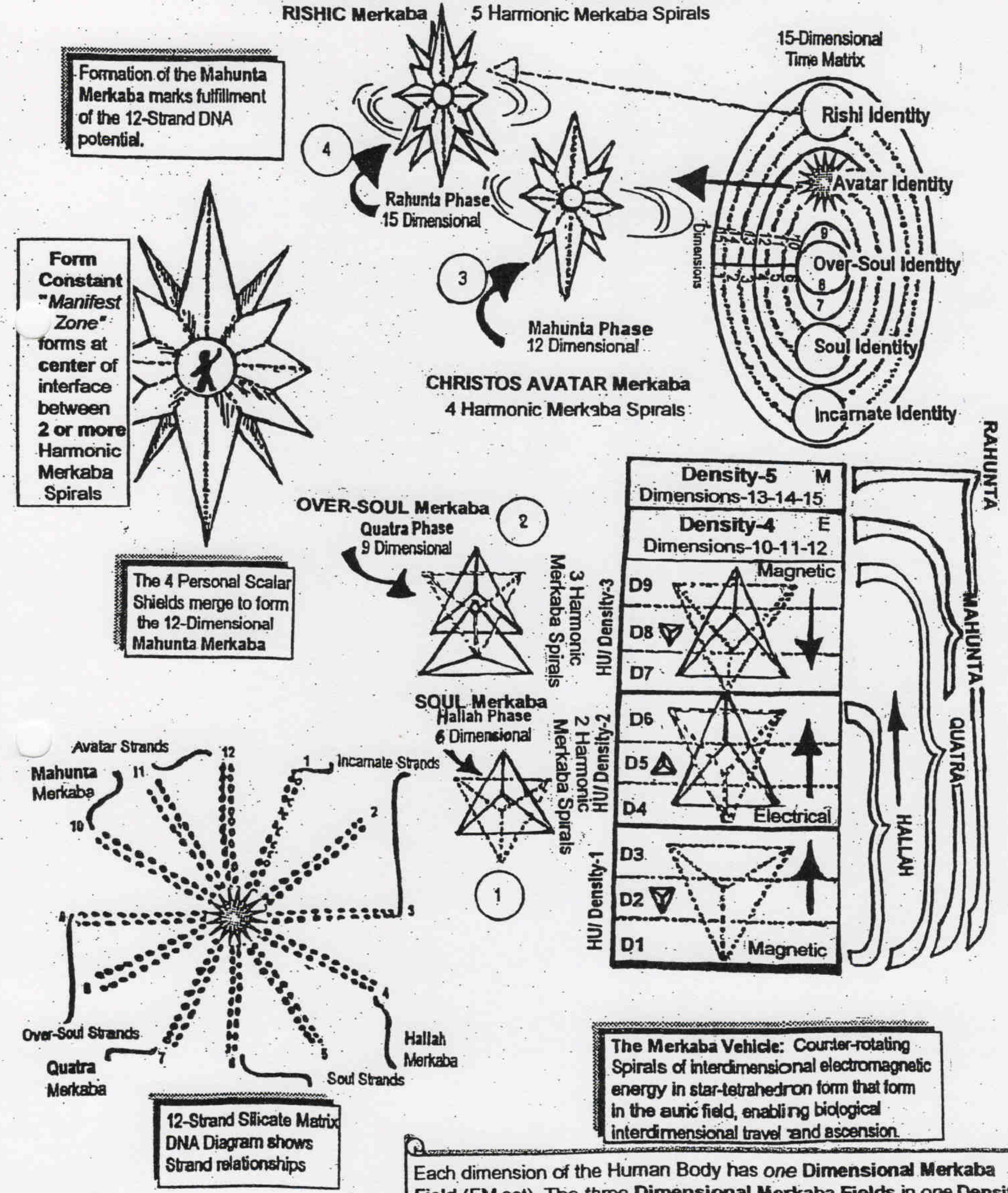
RISHIC Merkaba
5 Harmonic Merkaba Spirals
15-Dimensional Time Matrix
Rishi Identity
Avatar Identity
Over-Soul Identity
Soul Identity
Incarnate Identity
Dimensions
9
8
7
4
Rahunta Phase
15 Dimensional
3
Mahunta Phase
12 Dimensional
CHRISTOS AVATAR Merkaba
4 Harmonic Merkaba Spirals
OVER-SOUL Merkaba
2
Quatra Phase
9 Dimensional
3 Harmonic Merkaba Spirals
SOUL Merkaba
Hallah Phase
6 Dimensional
2 Harmonic Merkaba Spirals
1
Density-5 M
Dimensions-13-14-15
Density-4 E
Dimensions-10-11-12
HU/ Density-3
D9
D8
D7
Magnetic
HU/ Density-2
D6
D5
D4
Electrical
HU/ Density-1
D3
D2
D1
Magnetic
RAHUNTA
MAHUNTA
QUATRA
HALLAH
Avatar Strands
Mahunta Merkaba
Incarnate Strands
Over-Soul Strands
Quatra Merkaba
Soul Strands
Hallah Merkaba
1
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9
10
11
12

Formation of the Mahunta Merkaba marks fulfillment of the 12-Strand DNA potential.

Form Constant *"Manifest Zone"* forms at center of interface between 2 or more Harmonic Merkaba Spirals

The 4 Personal Scalar Shields merge to form the 12-Dimensional Mahunta Merkaba

12-Strand Silicate Matrix DNA Diagram shows Strand relationships

The Merkaba Vehicle: Counter-rotating Spirals of interdimensional electromagnetic energy in star-tetrahedron form that form in the auric field, enabling biological interdimensional travel and ascension.

Each dimension of the Human Body has *one* **Dimensional Merkaba Field** (EM set). The *three* **Dimensional Merkaba Fields** in *one* **Density Level** form *one* **Harmonic Merkaba Spiral** in each of **5 Density Levels** that **merge** to form the **Merkaba** Star Gate Transit (Ascension) **Vehicle.**

Technique # 8: Merkaba Salutations

Healing the Spin & Balancing Particle/ Anti-Particle Ratios

33 1/3-CW/11 2/3-CCW Christos Merkaba Activation

***Note:** Discern **CW or CCW direction of Merkaba Spin** by imagining that you are standing, with arms stretched out to the sides, in the center of a round 12-digit clock-face. The **FRONT** of your body faces the **"6"-digit, "12"-digit** is positioned **behind you,** the **"3"-digit** is positioned at your **LEFT ARM** and the **"9"-digit** is positioned at your RIGHT ARM. **CLOCKWISE "CW" SPIN:** Hold LEFT **"3-Arm"** firmly out to the side of the body like a **"clock hand"** and begin **Spin** toward FRONT, moving the **body** with the **LEFT arm** toward the **"6"-digit** position in **FRONT** of your feet. COUNTER-CLOCKWISE "CCW" SPIN: Hold RIGHT **"9-Arm"** firmly out to the side of the body like a **"clock hand"**. and begin **Spin** toward FRONT, moving the **body** with the **RIGHT arm** toward the **"6"-digit** position in **FRONT** of your feet. The **TOP-ELECTRICAL-MALE** Merkaba Spiral **Christos Spin** is always **33 1/3-CW** rotation. The **BOTTOM-MAGNETIC-FEMALE** Merkaba Spiral **Christos Spin** is always **11 2/3-CCW** rotation.

Solar Salutation Rites: (best time *Dawn's First Light* & *12:00 Noon*)
begin with *Top-Electrical-CW-"Male"* **Merkaba Spiral** activation, followed by *Bottom-Magnetic-CCW-"Female"* Merkaba Spiral
Use Tribe-12 Activation Suffix **"RHA"** as ***Initiating Tone***
Lunar Salutation Rites: (best time *12:00 Midnight* to *3:00AM*)
begin with ***Bottom-Magnetic-CCW-"Female"*** **Merkaba Spiral** activation, followed by *Top-Electrical-CW-"Male"* Merkaba Spiral
Use ribe-1 Activation Suffix **"UR"** as ***Initiating Tone***

1. Activate ***Maharic Quick Seal*** Technique- 6
2. Activate ***Tribal Shield-Cue Zone*** Technique- 7
3. Stand with spine comfortably straight, breath slowly, in a relaxed manner and begin **quietly toning** the ***Initiating Tone***, continuing repetition while progressively **increasing** the **volume** and extending the Exhale Breath Tone thrust behind Initiating Tone until you can **feel the subtle energy** of Tone sound waves oscillating in the body.
4. Activate First Merkaba Spiral (Top or Bottom Spiral first, depending on Solar or Lunar Salutation) by holding **arms out to the side**, parallel with the ground, and begin to **slowly SPIN** in the direction (CW or CCW) natural to the *** Christos Spin** of the Merkaba Spiral you are activating. Continue to **Spin AND Tone Initiating Tone** while progressively **increasing rate of Spin and Toning.** To **prevent dizziness,** hold one arm out to front with thumb positioned UP, and **focus your eyes** on the **THUMB** rather than the spinning scenery beyond. Do not Spin faster than comfort level. You may **modulate toning in rounds of 3,** between the **Initiating Tone** and toning the **Christos Spin Rate Number ("33 1/3"** for Electrical-Top Spiral, **"11 2/3"** for Magnetic-Bottom spiral), if desired.
5. When energy in body feels **"charged"** (a "doneness" intuitive feeling), **slow spin** to a **gentle STOP**, while **Toning 3 Times,** the **"*Um Shaddai Ur'-A ah-Khum' Tun*"** Lyra-**Halls of Amorea** D-12 activation sequence, to **amplify** the Merkaba Spiral "charge. **Stand STILL** and breathe quietly for a few moments while Spin stabilizes, then **repeat STEPS 3-5** to **activate other Merkaba Spiral.**
6. End Salutation Rite with full **3 Rounds** (minimum) **Toning** of the ***"Ariea Khum Nar-A""*** (Song of Orion D-8 activation sequence) Part-1:Verses 1 and 2, to be sung while **Walking 2 Circles,** one **CW**, one **CCW**, beginning Circle Walk with Spin direction of **First Merkaba Spiral** activation, followed by a **reverse-direction** Circle, then **Standing STILL** for a few moments to allow the **Christos Maharata Current** to run between your body and Earth's Planetary Shields.

The *Ar-IE- a Khum –Nar' A*
The Song of Orion

Part 1 : the Resonant Tone Syllable Sequence (primary melody)

Verse 1: **OM A Da E, Patum ah**
OM A Da E, Patum ah
Patum ah A' DE E - Tah, A khum-na
OM A Da E, Patum ah

Verse 2: **TrA TE La E' Durum Na**
TrA TE La E' Durum Na
Durum' ah A' Khem - Tah, A khum -na
OM A Da E, Patum ah

Part 2 : the Base Tone Syllable Sequence (accompaniment 1)
OM A Da E, Patum ah - Lines 1, 2 & 4 Verse 1 & Line 4 Verse 2
TrA TE La E' Durum Na - Lines 1 & 2 Verse 2
UM ah OM, A
UM ah OM, A
Patum ah A' DE E – Tah, A khum- na
Durum ah A' Khem – Tah A khum-na
DO RAY' TU Ra"
OM A Da E, Patum ah
UM ah OM, A

Part 3: the Over Tone Syllable Sequence (accompaniment 2)
OM A Da E, Patum ah – Lines 1 & 2 Verse 1
TrA TE La E' Durum Na – Lines 1 & 2 Verse 2
BE HE Tah OM, A
BE HE Tah OM, A

Patum ah A DE E – Tah, A Khum –na – Line 3 Verse1
Durum ah A Khem- Tah, A Khum - na - Line 3 Verse 2
Thra Khem' Na, A
OM A Da E, Patum ah – Line 4 Verses 1 & 2

KhrA MiM, Tah A

The fastest means of naturally activating the Personal 12-Strand DNA Template is :

1. **Tribal Shield Activation:** Activating the 144 Fire Letters of the Tribal Shield & Sacred Salutations Merkaba Activations.
2. **Emerald and Amethyst Awakening 2 Masters Kundalini Activations:** Releasing key **Fire Codes** between the DNA Strand Templates to allow for **expedited DNA Strand Braiding.**
3. **DNA Template Bio-Regenesis:** Progressive use of internally directed DNA Template Bio-Regenesis technologies for progressive purging of Strand Template mutations, restoration of the natural D-12 Christos Divine Blueprint of the 12-Strand DNA Template and expedited, accelerated activation of the DNA Strand Template Base Codes and Acceleration Codes.
4. **Master Key Codes:** Use of the personal scalar-wave-guide Symbol Code Programs that correspond directly to the core programming of the personal D-12 Maharic Shield for further sequential expedition of Strand Template Activation.
5. **Melchizedek Cloister Level-3 Regent Ordination:** Transmission of the Kee-Ra-ShA Primal Light and Khundaray Primal Sound Field **"Rainbow Ray Current"** directly into the personal **DNA Template** via direct **Chakra Induction**. Sufficient Rainbow Ray frequencies to provide a level-3 Regent Ordination can be transmitted by a Melchizedek Cloister **level-5 Elder Consummate** or **Level-6 Eckar** Indigo Child-Type-1 Maji Grail Line Angelic Humans, who have the frequencies of the Primal Creation Currents integrated into their DNA Template from birth. **Expedites all of the above** while provided additional **bio-energetic field support** for more **stable cycles** of DNA Template activation.

The Khundaray RRT Activation Sequence

A progression of **manually initiated** *Kundalini and DNA Template Activations* that systematically induce *temporary release* the **Cranial-Sacral Kundalini Seals** (Pineal Gland & Tail Bone), in their **natural Release-Sequence,** allowing for temporary and ***progressive*** embodiment (nano-second burst of frequency) of the *Primal Universal Life Force Currents* via **Syncopated Activation** of the **12-Strand DNA Template**.

The ***Khundaray RRT ("K-RRT") Activation Sequence*** allows the Density-4 (D-10-11-12 Pre-matter) ***Maharata Christos Current***, Density-5 (D-13-14-15) ***Kee-Ra-ShA Primal Light Currents*** (Ante-matter *Blue, Gold* and *Violet* "Flames") and the ***Khundaray Primal Sound Currents*** (*Eckatic, Polaric* & *Triadic* Columnar Standing Waves) from *Source* to run through the DNA Template and body for accelerated ***TRUE 12-Strand or higher DNA Template Activation** and expedited human Spiritual Integration.

For the human body to **hold and transmit** a **minimum critical mass** of Kee-Ra-ShA and Khundaray frequency to **access the Planetary Shields** and **Star Gates** for ***Masters (Universal) K-RRTs,*** the ***K-RRT Activation Sequence*** must be conducted **4 to 24 hours** prior to the K-RRT. The *K-RRT Activation Sequence* must also be run **2-24 hours** prior to the ***Amethyst Awakening Masters-2 Kundalini Activation*** to prepare the body for the Amethyst Awakening frequencies. The *Amethyst Awakening* (Field Technique-6) can also be run **just before** a K-RRT (following prior *K-RRT Activation Sequence*) to **greatly amplify the power** of the K-RRT and Signet Council group.

There are **5 Specific Operations of Energy Management** within the ***K-RRT Activation Sequence***:

1. **Activating the Doradic Phase-1 Current**
2. **Awakening the KA**
3. **The Emerald Awakening**
4. **Activating the Kee-Ra-ShA**
5. **Activating the RA Center-Anchoring the Rainbow Bridge**

The Emerald & Amethyst Awakenings
Masters Kundalini-DNA Template Activations
For Accelerated *DNA Template Activation* and *Spiritual Integration*, Running K-RRTs and enhanced *Immune Support*

THE KUNDALINI LIFE-CURRENTS AND THE CRANIAL-SACRAL SEALS.

The human body is fuelled by ENERGETIC LIFE-FORCE CURRENT FROM SOURCE. In contemporary human anatomy, the only life-force currents running fully through the embodied Kathara Grid and body are those corresponding to the SINGLE-VECTOR time cycle of the Density-1 TELLURIC SHIELD. Each of the 4 HOVA BODIES and their corresponding SCALAR SHIELDS, DNA STRAND TEMPLATES, AXI-A-TONAL LINES, DIMENSIONS OF CONSCIOUSNESS AND MERKABA FIELD LEVELS process the frequencies of one TRIADIC CURRENT – a 3-dimensional, Bi-polar life-force current. The life-force currents corresponding to the first 9 dimension and first 3 Hova Bodies, Mater Densities and Shields are referred to as the KUNDALINI ENERGIES. Each KUNDALINI CURRENT is a TRIADIC CURRENT – a set of 3 dimensional currents that function together and are separated by Magnetic Repulsion Zones within the embodied Kathara Grid. The 3 embodied Kundalini Currents are the TELLURIC, DORADIC and TEURIC CURRENTS .

Each of the 3 Kundalini Currents is spiralled within the regions of the 1st 8 CELLS of human conception, located in the TAILBONE at the Base of the Spine. (The incarnating consciousness anchors its identity and Christos Manifestation Template within the FIRST 8 CELLS, to initiate the FETAL INTEGRATION PROCESS.) The first Kundalini Current, the TELLURIC CURRENT that corresponds to the DENSITY-1 Nada Hova Body, is active within the human form from birth, enabling 3 dimensions of consciousness awareness, in the form of scalar frequency, to embody within the human organism. When the 2 dormant Kundalini Currents in the tailbone, the DORADIC and TEURIC CURRENTS, are activated, the frequencies of consciousness from dimensions 4-9 progressively awaken within the body, activating the dormant 4-9 strands of the 12-strand DNA Template. The 3 Primary Kundalini Spirals each contain 3 single-dimension currents, and are controlled by the corresponding SIGNET STAR CRYSTAL SEALS in the Kathara Level-2 Crystal Seals Grid. The Signet Seals create polarization between dimensionalized sets of scalar waves within the Scalar Shields, that manifest within the Kathara Level-2 Grid, First Eight Cells and DNA Template as FREQUENCY SEALS or blockages within the TAILBONE (Sacral region) and the PINEAL GLAND in the center of the brain – the CRANIAL-SACRAL SEALS.

When the Cranial-Sacral Seals are released, through activation of the Signet Star Crystal Seals that govern them, the dormant Kundalini Currents come to life within the body, sending progressively higher-frequency energy through the CENTRAL VERTICAL CURRENT of the body. Activation of the 3 Kundalini Currents progressively creates integration of the higher dimensions of consciousness and de-densification of molecular structure. When ALL of the frequencies within the 3 embodied Kundalini Currents are activated, the 4th KUNDALINI CURRENT- the PRIMAL TRIADIC CURRENT, the KEE-Ra-ShA', is activated. The Frequency Seal on the KEE-Ra-ShA' is located in the 12th Chakra, 6" below the feet. Activation of the KEE-Ra-ShA' anchors the 12th-Dimensional HYDROPLASMIC BEAM within the body, initiating the process of CELLULAR TRANSMUTATION and intentional de-manifestation and Dimensional Ascension of the human biological form.239

THE EMERALD AWAKENING AND THE KEE-Ra-ShA'

The Emerald Awakening Masters Kundalini Activation is one of two inter-harmonic energetic activations of previously dormant frequency within the body that sets in motion simultaneous activation of the 12 MAGNETIC BASE TONES within the FIRE CODES between the 12 Strands of the SILICATE MATRIX DNA Template. Activation of the 12 Fire Code Base Tones begins activation of the 3 PRIMAL CREATION FREQUENCIES – the KEE-Ra-ShA' – within the 4 Scalar Shields of the PERSONAL INNER TEMPLAR COMPLEX. Activation of the 12 DNA Fire Codes allow for progressive natural fusion of each dimensional DNA Strand Template to occur, through which the organic potentials of CELLULAR TRANSMUTATION are re-awakened within the physical body form.

Through the natural processes of Cellular Transmutation, once fully operational within human genetic design, the carbon-based elemental biology of Density-1 molecular structure is progressively and systematically transmuted to SILICA-based biology. Transmutation to Silica-based biology allows the physical body to pass through the levels of Semi-etheric, Etheric and Pre-matter Hydroplasmic Liquid-Silica Densities of Harmonics 2-4 (Dimensions 4-12), through which the consciousness continually enters manifestation, to achieve physical mastery of the organic process of Transmutational Dimensional Ascension. To accomplish mastery of the Ascension process, the SIGNET STAR CRYSTAL SEALS with the Scalar Shields, which keep the 12 dimensionalized frequency levels of the consciousness and molecular form Phase-locked into dimensional division/ polarization, must be released. Release of the Signet Star Crystal Seals allows the frequency spectra of the higher dimensional anatomy and the Primal Creation Currents of the KEE-Ra-ShA', to enter into the Template for the physical body and dormant DNA Fire Code Templates, progressively building the Merkaba Vehicle and setting the Cellular Transmutation process in motion. The process of progressive Transmutational Dimensional Ascension represents the function of the organic genetic design and evolutionary objective of the human creation blueprint, through which the natural Immortal Christos-Angelic Form of the human being is actualised.

In the evolutionary cycles of contemporary humanity, actualization of the 12-Strand DNA potential takes place slowly in Earthly terms, as the incarnate identity experiences in single-life time-vectors, several cycles of Density-1 incarnation, spanning many thousands of years, in order to progressively activate the DNA Fire Codes within the Manifestation Template. When the human genome was operating in its organic form, this process took place in one lifetime, over a period of about 44 years, as the immortal human incarnate matured to embody the 12 dimensions of consciousness within its original Christos Manifestation Template- the MAHARIC SHIELD, actualizing its organic Angelic-human heritage and mastery over 4 Densities of manifestation within the Time Matrix.

The EMERALD AWAKENING Masters Kundalini Activation releases the Density-2 4TH – Dimensional Green Signet Star Crystal Seal and the Density-1 1st-Dimensional Red Signet Star Crystal Seal, to open the Density-1 NADA HOVA BODY and TELLURIC SHIELD, and Density-2 ALPHI HOVA BODY and DORADIC SHIELD, to receive the Omni-polar frequencies of the 12th-Dimensional MAHARIC CURRENT (Hydroplasmic Beam) from the Pre-matter Christos Template Maharic Shield. Upon entering the Telluric and Doradic Shields, the 12th-Dimensional frequencies of the Maharic Current trigger simultaneous activation of the Base Tones within the 12 Fire Codes of the DNA Template, beginning the process of DE-POLARIZTION of the 12-Strands and levels of consciousness within the human Manifestation Template. Progressive de-polarization of the 12 levels of consciousness within the human Manifestation Template sets in motion the organic process of Cellular Transmutation and potential mastery over Transmutational Dimensional Ascension. The Emerald Awakening Masters Kundalini Activation initiates REGENESIS of the original function of the human genome, releasing the Base Tones of the 3 KEE-Ra-ShA' Currents within the body via opening of 2 Signet Seals, through which the physical body begins the carbon-to-silica transmutation process and is prepared to receive the higher dimensional OVER TONE frequencies of the KEE-RA-Sha', to complete Cellular Transmutation via fusion and de-polarization of the particle (Particum) and anti-particle (Partika) aspects of the Manifestation Template. This is the natural process of UNIFIED FIELD PHYSICS by which a human being becomes "Christed".

THE AMETHYST AWAKENING AND THE KHUN-DA-RAY

The final step in fulfilling the potentials of original Angelic-human design is activation of the OVER TONE frequencies of the KEE-Ra-ShA', which allows fusion between DNA Strand Templates to complete on 12 dimensions of frequency. The final step in Transmutational Dimensional Ascension is called the AMETHYST AWAKENING MASTERS KUNDALINI ACTIVATION. Through the AMETHYST AWAKENING, the DENSITY-3 7TH-Dimensional VIOLET Signet Star Crystal Seal and 8th-Dimensional GOLD Signet Star Crystal Seal, and the DENSITY-4 11TH-Dimensional DARK SILVER Signet Star Crystal Seal are released within the body's Scalar Shields. Release of the OVER TONE SIGNET SEALS allows the OVER TONES of the KEE-Ra-ShA Creation Currents to fuse with the BASE TONES, bringing the 3 OMNI-POLAR CREATION CURRENTS (Primal Creation Currents built upon a TRINITY OF TONES, BI-POLAR + NON-POLAR energy units) together as ONE PRIMAL NON-POLAR CURRENT – the KHUNDARAY (also called the "Rainbow Bridge" or the " Rainbow Serpent".)

The KHUN-Da-rAy is the PRE-LUMINAL vibration, or STANDING WAVE OF INTERNAL SOUND emitted from ONE-SOURCE/ GOD, that corresponds to the COMBINED ORIGINAL SOURCE CURRENT from which the 3 KEE-Ra-ShA' PRIMAL LIFE-FORCE CURRENTS of the 3 non-dimensionalized levels of the ENERGY MATRIX, beyond the 15-Dimensional Time Matrix emerge. The Emerald Awakening Masters Kundalini Activation, and its resulting activation of the BASE TONES of the KEE-Ra-ShA' within the human body, is the first step in manually expediting the natural process of Transmutational Dimensional Ascension.

AWAKENING THE KA AND REMOVING INORGANIC CRYSTAL IMPLANTS

Before the Emerald Awakening Kundalini Activation can be orchestrated, the MAHARIC SHIELD and the KA must be brought out of dormancy within the human Manifestation Template. Once the 12th-Dimensional Maharic Current is released within the embodied Kathara Grid, the KA can be activated. The "KA" refers to the 4 HOVA BODIES corresponding to dimensions 1 through 12. (Nada, Alphi, Betcha and Mahara Hova Bodies.) The KA becomes activated through removal of 4 inorganic Crystal Seal IMPLANTS that block the natural function of the 2nd, 3rd and 4th DNA Strand Templates. Following he procedure for AWAKENING THE KA, the Emerald Awakening Kundalini activation can be conducted.

Technique # 12: Kee-Ra-ShA Activation Sequence

ACTIVATING DORADIC PHASE I Awakening the Flame

Preparation: Activate **Maharic Seal** Technique-6 *Maharic Quick Seal*

1 Breath slowly and deeply for several breaths while visualizing or imagining a Violet Dot on the center of the *inside* of your forehead. Make the color image as strong as you are able (if you can't yet perceive inner colors simply imagine the Violet Dot being there).

Move the Violet Dot to the center of the brain, at the **Pineal Gland,** and then upward into the 7th Chakra, finally moving it out of your head to rest on the top of your skull, at the Crown Chakra.

2 Call to mind the Heirophant Symbol (Pale Silver Merkaba Star/ Star of David). Visualise the Heirophant spinning 12" below your feet, within your Maharic Shield, and slowly INHALE.... drawing the Pale Silver Heirophant up through the Central Body Current, up to meet the Violet Dot at the 7th Crown Chakra at the top of the head.

When the Heirophant connects with the Violet Dot, visualize the Violet Dot bursting into a 4" vertical Pillar of Violet-Silver Light. Imagine the Violet-Silver Pillar running down through the body and into the Earth's Core, as well as upward into the 14th Chakra positioned 36" above your head. (This activates the Violet Ray of Transmutation).

3 Now, move your attention to the 4th Heart Chakra, and imagine a small Green Spherical Crystal – the Green Star – stationed at it's core. This is the Green star Crystal Seal that controls release of 4th Dimensional frequency – Phase I Doradic Current – into the body. INHALE, drawing Violet-Silver energy from the Violet-Silver Pillar into the Green Star.

EXHALE, expanding the Violet-Silver energy into the Green Star sphere. Repeat two more INHALE/ EXHALE breaths, drawing Violet-Silver energy from the Pillar and expanding it into the Green Star sphere.

4 At the end of the last EXHALE, imagine the Green Star POPPING, turning into a spinning Green and Violet Starburst of Light, as the Violet-Silver Pillar disappears. Spin the Green-Violet Starburst faster until it becomes a ball of Green-Violet Light, about the size of a grapefruit, spinning the center of the Heart Chakra. (The Green-Violet ball is the storehouse for your Phase I Doradic Current; it's called the Doradic Sphere).

INHALE and draw Pale Silver energy from your Maharic Shield, through the central Body Current, and into the center of the Doradic Sphere at the heart Chakra ... encasing the sphere in Pale Silver Light.

AWAKENING the KA

1 Bring your attention back to the DORADIC SPHERE at the HEART CENTRE...

2 INHALE pale silver energy up from the EARTH CORE to fill & expand the DORADIC SPHERE; breath slow and deep 2-3 times ...

3 Now, put the tips of your fingers together, and feel the 'fuzziness' of the energy flow...

4 Next, move the fingertips to the tail bone... INHALE energy from the Maharic Shield into the DORADIC SPHERE

Continued Next Page

As you EXHALE, push PALE SILVER energy down to the finger tips and into the tail bone............... REPEAT 2-3 times and then remove the fingers.

5 Now, bring your attention to the 2nd CHAKRA (SACRAL) .....feel or visualize or just know ... a DOUBLE TERMINATED QUARTZ CRYSTAL (a crystal with a point at both ends) is beginning to "push out" of the front of your 2nd Chakra, the Sacral center.

6 Focus your attention on this, try to feel the crystal pushing.... use your hands to help ease it forward, and out.

7 There is a smaller double terminated crystal in the 3rd (Solar Plexus) Chakra; this will release on it's own because the currents have activated it to do so. Help it out with your fingers.

8 In the Heart Chakra, imagine a little sphere of energy, colored green. Bring this little green sphere more fully into focus ... and you will notice a little black cube of energy inside it ...look more closely again, and notice a smaller white cube inside the black one.

9 As you focus on the two little cubes, watch them merge together .. feel a ripple of vibration as they do, and then ... notice a little puff of smoke as they both disappear.

Now, the body is activated to open the 4th and 1st Crystal Seals; you are ready for **the EMERALD AWAKENING ...**

1 Now we will open the GREEN STAR CRYSTAL SEAL ....So, keeping your awareness on the Doradic Sphere, the GREEN-VIOLET- SILVER ball at the Heart Center.........INHALE,

2 and ... on the EXHALE visualize or imagine pushing a cord of GREEN-VIOLET-SILVER Doradic Current down into the tail bone... to the 1st Cell ...... at it's very tip .

3 Breathe easy ... and take a moment to visualize the 1st Cell at the tip of your tail bone.... as a WHITE-SILVER SPHERE...

5 Now within the WHITE SILVER SPHERE, visualize, a GREEN SPHERE ... and then visualize a RED SPHERE inside the GREEN SPHERE ...

6 Bring your attention back to the SPHERE of GREEN-VIOLET-SILVER energy in your Heart Center ...

and on the next EXHALE visualize, or imagine, sending a cord of GREEN-VIOLET SILVER energy all the way down your central vertical column and into the GREEN SPHERE in the 1st Cell at the tip of the tail bone.

7 AS you INHALE pull PALE SILVER LIGHT from your personal Maharic Shield, the platform-disc 12" below your feet, up into the tail bone and into the GREEN SPHERE.

8 As you do this, visualize, the GREEN SPHERE 'pop' into a STARBURST of PALE GREEN-SILVER LIGHT.

Continued Next Page

This has opened the kundalini seal – your WHITE-SILVER & RED Spheres REMAIN as you left them earlier ....Now, we will work to open the **RED STAR CRYSTAL SEAL....**

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9 Return your awareness to the Doradic Sphere at the Heart Center....INHALE, and then on the EXHALE push a cord of GREEN-VIOLET-SILVER Doradic Current down to the 1st Cell at the tip of the tail bone, ...

10 INHALE and draw PALE SILVER energy up from the personal Maharic Shield, the platform-disc positioned 12" below your feet, up into the tail bone, and into the RED SPHERE ... inside .... the WHITE-SILVER SPHERE.

11 AS YOU DRAW the PALE SILVER energy into the RED SPHERE visualize the RED SPHERE 'pop' into a STARBURST of PALE PINK-SILVER LIGHT...... and ...... for the next few breaths EXHALE the PALE PINK-SILVER LIGHT into the 12th Chakra, positioned 6" below your feet...

You have now opened the Kee Ra ShA(Y) Seal ... so that the Sacred Flames of the Kee Ra ShA can be activated ......

ACTIVATING THE KEE RA SHA

The Kee Ra ShA appears as 3 little flames which exist in the 12th Chakra positioned 6" below the feet. The 3 flames are PALE BLUE, PALE YELLOW & PALE VIOLET.

1 Begin by focussing deeply on the 12th Chakra, 6" below your feet, and the three little flames held there ... one is PALE BLUE, one PALE YELLOW & the third PALE VIOLET.... We'll take a few moments to do this......

If you have difficulty visualizing, just imagine that they are there.

2 On the INHALE, draw the PALE VIOLET FLAME up from Chakra 12 ... into the central vertical column .. and all the way up ... and out through the top of the head, to the 10th Chakra ... 6" above your Crown chakra......

3 Next, return your attention to the 12th Chakra, 6" below your feet ... allow yourself time to connect with the little PALE YELLOW-GOLD FLAME. Breathe easy.

4 On the next INHALE draw the PALE YELLOW-GOLD FLAME up from Chakra 12 ... into the central vertical column .. and all the way up ... and out through the top of the head, to the 10th Chakra ... 6" above your Crown chakra......

Again, return your attention to the 12th Chakra, 6" below your feet ... and connect with the PALE BLUE FLAME... this FLAME is the INNER ARC of the COVENANT ... Take your time; breathe easy.

5 On the next INHALE draw the PALE BLUE FLAME up from Chakra 12 ... into the central vertical column .. and all the way up ... and out through the top of the head, to the 10th Chakra ... 6" above your Crown chakra......

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6 Now, visualize or imagine the 3 little FLAMES together within the 10th Chakra 6" above your Crown Chakra .... in a moment we will create the Kee Ra ShA SPHERE... Breathe easy.

7 On the next INHALE draw PALE SILVER energy from your personal Maharic Shield 12" below your feet, all the way up your central vertical column, up into the 10th Chakra......

EXHALE gently and INHALE once more, drawing more PALE SILVER energy up into the 10th Chakra ... visualize or imagine the 3 little flames enclosed within a SPHERE of PALE SILVER LIGHT...

8 Breathe easy. On the next EXHALE move the Kee Ra ShA SPHERE all the way down through the central vertical column, out through the 12th Chakra 6" below your feet, and all the way down to the 13th Chakra at EARTH'S CORE.

As the Kee Ra ShA enters EARTH'S CORE listen for sound tones w/ inner ear...

These TONES represent the AMENTI "PASS KEY" ... which opens your personal GRU-AL POINT (#1) - the 1st Cell in the Tail Bone .... releasing the KEE RA SHA FLAMES into your AURIC FIELD.

9 Breathe easy... Watch as the Kee Ra ShA FLAMES rise up your Maharic Pillar and emerge through your 1st Cell ... passing like radiating waves of PALE BLUE, PALE YELLOW & PALE VIOLET ......

10 As the waves of color move through you, bring your attention to your first 4 Chakras ... the base, the sacral, the solar plexus and the heart ... and visualize or imagine each Chakra emanate a SILVER MAHARIC SHEATH or OVAL POD, completely surrounding each one ...

This completes the EMERALD AWAKENING, the natural process by which we use Unified Field Physics to trigger our CHRISTED Selves. Before we finish we must first establish the link to the Amethyst Awakening, the process of activation and sheathing of the higher Chakras.

To complete the session we will now work with 8th & 11th Dimensional Energies to open DORADIC PHASE 2 & 3 CURRENT and activate TEURIC PHASE 2 CURRENT.......THIS IS CALLED **ACTIVATING THE RA CENTRE in the THYROID – and ANCHORING THE RAINBOW BRIDGE**

1 Begin by moving your attention to the area of your 3RD EYE, and focus just inside your fore-head .. a little above and behind your eye brows...... Breathe easy.

2 Now, visualize, or imagine, a DARK SILVER DOT in the position you are focussed on ... in the area of your 3RD EYE... Take a little time.

3 INHALE and move the DARK SILVER DOT into the Pineal Gland in the center of your head and then straight up through the CROWN CHAKRA until the DARK SILVER DOT sits on the top of your skull.

Continued Next Page

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4 On the next INHALE, pull PALE SILVER ENERGY up from your personal Maharic Shield 12" below your feet, all the way up the central vertical current and into the DARK SILVER DOT on the top of your head...

As the PALE SILVER ENERGY reaches the DARK SILVER DOT, the SILVER DOT 'pops' into a SILVER STARBURST ...

5 On the next EXHALE push the SILVER STARBURST down the central vertical channel, all the way to the tip of the tail bone ... EXPANDING the SILVER STARBURST FULLY into the 1st Cell...

6 Breathe easily and watch, as GOLD-SILVER-CURRENT emerges from the tailbone .. and begins to flow up through each Chakra ..

from the 1st Chakra at the base of the spine ... up through the Sacral ... the Solar Plexus ... all the way up to the Crown Chakra ... we'll take a little time for this ....

From the Crown Chakra the GOLD-SILVER-CURRENT continues upward out of the top of your head ... up through the 10th Chakra 6" above your head ... the 11th Chakra 18" above your head ... and finally the 14th Chakra 36" above your head.

7 Once the GOLD-SILVER-CURRENT reaches the 14th Chakra it returns to the 1st Chakra the flow of the current creates a GOLD-SILVER SHEATH throughout your central vertical channel.

8 Bring your attention to the 2nd Chakra now .. were going to create a GOLD -SILVER- BALL there, in the SEED SEAL at the center of the Chakra ... just imagine the chakra as a bow tie shape, the SEED SEAL is at the narrow point in the middle. The GOLD-SILVER BALL is called the TEURIC SPHERE ...

INHALE and draw GOLD -SILVER-CURRENT from the GOLD -SILVER-SHEATH into the center of the Chakra ... as you EXHALE create and EXPAND the BALL to surround the bow tie ...

9 Now ... INHALE and move the GOLD -SILVER-BALL up to the 1ST HARA CENTRE ... 2" BELOW the NAVEL (the 9th SILVER STAR SIGNET SEAL or TAN TIEN) ... EXHALE GENTLY allowing the BALL to EXPAND

10 On the NEXT INHALE move the GOLD-SILVER-BALL up to the SOLAR PLEXUS and EXHALE GENTLY

11 INHALE and move the GOLD-SILVER BALL up to the HEART CENTRE ...
EXHALE GENTLY ... ... INHALE ... drawing more GOLD-SILVER CURRENT into the BALL and THEN EXHALE FORCEFULLY pushing cords of GOLD SILVER CURRENT down each arm and into the PALMS ... bring your fingertips together and feel the fuzzy buzz of TEURIC PHASE 3 CURRENT

You have now activated TEURIC PHASE 3 CURRENT in your palms – and – you are now able to run CURRENT from D4 thru' D8 to transmit to the THYROID GLAND ... to activate and anchor the Rainbow Bridge in others.....

End of Field Technique-5 *The K-RRT Activation Sequence* (5A-B-C-D-E)

You are now ready for the **Amethyst Awakening *Masters Kundalini/DNA Template Activation-2*** (Field Technique-6 *Initiating the Amethyst Awakening*) or to participate as an active member of ***a Khundaray Rainbow Roundtable*** (K-RRT) **Signet Council** (Field Technique-4 A-B-C). **Wait at least 4 Hours** before K-RRT participation, and **no longer than 24 hours** to maintain the **appropriate level of critical mass Khundaray frequency in the body** that is need for an effective K-RRT. **© Rev. Ashayana Deane, 2000**

INITIATING THE AMETHYST AWAKENING

1 **Preparation:** Complete **Maharic Quick Seal** Technique 6 and **Activation Sequence**

2 This technique works to bring in a burst of the Khundaray, Eckatic Blue frequency ...that sets the Amethyst Awakening in motion.

3 Place your attention at the center of your brain, inside your pineal gland. Imagine that you see there a Pale Violet Spark of Light (this is the bottom of the Seal of your 7th Crown Chakra). Imagine that you are going to move this Pale Violet Spark of Light straight up into your 10th Chakra 6" above your head ... imagine that the 10th Chakra is a disc of Light, Blue/ Black – Sapphire.

4 Now see the disc of Light, that was Blue/ Black take on a Violet hue. Try to feel it there, a small horizontal disc ... On the INHALE you will move this disc of Violet-Sapphire Light up to the 24 point Silver Star at the 14th Chakra ...... and, on the EXHALE, move it down through the 10th Chakra, down through the Crown, down the Central vertical Current, down through your Personal Maharic Shield all the way down to the 13th Chakra at the Earth's Core ...

5 Notice, as you do this, a whole series of Violet-Blue Sparks flying out from the Planetary Maharic Shield, as if they are alive, as if electrical communication is taking place. Notice as this happens that the energy flowing up your Maharic Pillar from the Earth Core reflects this change as Violet-Blue energy flows slowly up toward you ... as this energy reaches your personal Maharic Shield, notice that it does the same thing as the Planetary Shields – throws out a shower of Violet-Blue sparks ... all communicating with each other about the mathematical instructions about what to do with your body, your crystal seals, your chakras ...

6 Now, move your awareness to the Pale Silver skin all round your body/ etheric body .. and be aware too of the Main Vertical Current that you brought the Pale Silver cord through ...and at the same time, on each coming INHALE, bring up the Pale Silver-Violet-Sapphire energy, simultaneously, from your Maharic Shield to infuse the Pale Silver skin all round you.

Take a few breaths to do this and watch as the 3 color flicker through you – when they reach the Heart Chakra feel them expand out ... and allow them to travel on up, all the way to the 14th Chakra ... expanding throughout every Chakra as the Pale Silver-Violet-Sapphire energy flows up, through and all around you ... See each Chakra respond with a spiraling burst of Silver-Violet-Sapphire, backward and forward through both sides of the Chakras until they all shift .. try to feel the process as it awakens all the cell's of your body.

The brain cells and brain patterns begin to respond, activating the Fire Letters, setting the grid of frequencies necessary to activate the Fire Codes 7, 10 and 12 in the DNA Template.

Your own **D-12 Christos Avatar identity level will slowly** release the ***Khundaray Activation Frequencies*** through which the Amethyst Awakening progressively unfolds in the DNA Template and body. This process can be **naturally and safely accelerated** by receiving a **Level-3 MC Regent Ordination transmission** from a qualified **Indigo Child/Eieyani** ***Level-4 through Level 6 MC Ordinate*** **Consummate, Elder Consummate** or **Eckar** that carries the necessary **Amethyst Awakening Khundaray Activating Frequencies** in their Eieyani DNA Templates.

The Merkaba Trinity Key Induction

The ***Merkaba Trinity Key Induction Technique*** begins the process of establishing a **conscious directional relationship** with various levels of your 15-Dimensional Anatomy (or that of your Client). The **Trinity Key Symbols** are **mathematical-geometrical programs** that carry the specific organic structure of **each dimensional frequency band** as it exists within the **D-12 Universal Divine Blueprint**. Imbuing the proper **Symbol Key** into the appropriate area of the personal anatomy can rapidly expedite **restoration the personal Divine Blueprint** within the **DNA Template, Chakra System** and embodied **Kathara Grid**. Use of the Trinity Master Key Symbols that correspond precisely to the natural order of each dimensional frequency band, can **intensify** all applications of **holistic and allopathic healing**, as well as progressively and systematically assist in the process of accelerating **DNA Template** healing and **activation.** Every **condition** within the body-mind-spirit system has a specific **Energy Signature** unique to its own construction. Every **dis-ease** condition within any aspect of the personal experience (physical, emotional, mental, spiritual, financial, social, etc.) is created and **held in manifestation** by a specific set of mathematical – geometrical energy relationships that are **stored** within the embodied **Kathara Grid** and **DNA Template** in the form of **Symbol Keys**. The mathematical-geometrical energy relationships that serve as the **blueprints** upon which experiential manifestation will emerge can be perceived by the conscious identity in its Symbol translation. When using the **Trinity Master Key Symbols**, you are **resetting and activating very specific portions** of the personal **Divine Blueprint** (D-12 Pre-matter Maharic Shield) into a naturally harmonious relationship with Universal Order (the organic structure of dimensionalized frequency bands). The Trinity Master Keys provided in this Technique trigger activation of very specific **Fire Letters** (Keylons) within the DNA Template, allowing the DNA Template to receive directly the **new electrical instructions** corresponding the personal Divine Blueprint. This technique can be used with Kathara Healing Techniques from Kathara Level-1, with any other healing modality or singly after activating the D-12 **Maharata Current** via **Techniue-6, *The Maharic Quick Seal.***

It is **necessary** to initiate a **D-12 Maharaic Seal** in order to run **any Symbol Key program** into the DNA Template and Level-1 Kathara Grid; it is the strength of the D-12 Maharata Current that allows access to the deepest levels of the Personal Shields and Divine Blueprint. The **Trinity Master Key Symbols** are a **set of 3 Symbol Keys** that are to be used **in sequence.** The first two Trinity Keys, the **Initiating Keys**, are used in **every application** to open the embodied Level-1 Kathara Grid to receive new instructions. The third Trinity Master Key Symbol, the **Transmitting Key,** corresponds directly to the Divine Blueprint of **one dimensional frequency band** and its corresponding **Kathara Center, DNA Strand Template, Chakra** and related body regions, **Axia-tonal Line, Auric Field Level** and **station of consciousness**. In a **Trinity Key Induction Session**, one can choose to work on only **one dimension** (Chakra-DNA Strand Template-Kathra Center-Axia-tonal Line-Auric Level) via its Transmitting Key, or each of the **12 Transmitting Key** of the Universal Kathara can be used, **in sequence**, following induction of the two Initiating Keys. The process of using the Trinity Keys is simple; the **Chakra** that corresponds to the Transmitting Key/ dimension/DNA Strand with which you desire to work is used as the **vortex** through which the Trinity Keys are **INDUCED** into the corresponding **Kathara Center**. From the Kathara Center, the Trinity Keys electrically pass on to the **DNA Template** and from there into the **Axia-tonal Line system** and corresponding areas of the body-mind-spirit system. Use of the Trinity Key Induction Technique progressively assists in activating the personal **Merkaba Vehicle** while **amplifying and expediting restoration** of the personal Divine Blueprint.

Technique # 9: Merkaba Trinity Key Induction

1. Activate the Maharata Current via **Technique-6: *The Maharic Quick Seal*** and decide which Transmitting Key(s) you will use. **Trace** the **3 Trinity Symbol Keys** onto **3 small squares of paper.**

2. First, place each of the papers with the two Initiating Keys **face up on the floor**, then **stand** (barefoot or socks only) with **one foot on top of each of the papers; Initiating Key #1** under the **LEFT foot, Key #2** under the **RIGHT foot.** (Note: To run Trinity Key Induction for a Client, have them recline on their back and place the papers with Initiating Keys between your palms and the soles of Client's feet. As introduced in Kathara Level-1, use your **palm Chakras** to **transmit** the Symbols and the Pale-Silver Maharata Current, using the same action as described below, into the **Client's foot Chakras**; Key-1LEFT foot-***right hand transmission***, Key-2 RIGHT foot-***left hand transmission***.) In Self-induction, the papers with Symbols should be positioned beneath the **balls of your feet**, in the area of the main **Chakra** on the sole of each foot. Simply begin to **breathe deeply** and slowly for a few minutes. With each **INHALE** draw a **thick stream** of **Pale-Silver Maharata Current** from Earth's core through the **Central Vertical Current** of the body and out the top of the head to the **14th Chakra** 36-inches above the head. With each **EXHALE,** imagine a grapefruit sized Pale-Silver **Maharic Ball** rapidly moving down your Central Vertical Current. When the Maharic Ball reaches your 2nd-Chakra near the navel, imagine the Ball splitting into **Two Balls**, each continuing to **travel down each leg and out your feet Chakras**, through the **Symbol Keys**. Once the Two Balls of Maharic Current have passed through the Symbol Keys, imagine that they **re-merge** into the **one grapefruit sized Pale-Silver Ball** that continues to move downward into the **13th Chakra** at Earth's core. **Continue** this process until you sense a **momentary slight warmth, tingling or subtle itching** at the **balls of your feet**. These mild, **momentary sensations,** called the **CUE RESPONSE**, will grow stronger the more frequently you use the feet Chakras for Symbol Key induction. Once you have noticed the **Cue Response**, you have **successfully induced** the two **Initiating Trinity Keys** and it is now time to utilize the remaining **Transmitting Key**.

3. If you have chosen to use the Transmitting Key for D-1-Strand-1-Axiatonal Line-1-**Chakra-1**, continue **standing** for the final Symbol Key Induction, placing the paper with the Transmitting Key face up on the floor between **slightly parted feet; do not stand on Symbol Key paper** for **Base Chakra Induction.** For all other Chakras, **recline on your back** and place the paper with the Transmitting Key **directly on top of the Chakra** to which it corresponds, **on the front of the body**. Use each **INHALE** breath to drawn Maharata Current up from Earth's Core, into the Central Vertical Current **only as far up as the selected Chakra**. On each **EXHALE**, push Pale-Silver Maharata Current **out from the Central Verticle Current** of the body and **into the Chakra**, imagining that the Chakra is progressively turning into a **radiant vortex of Pale-silver light** that **spins faster and faster**. When you begin to feel a bit of warmth, tingling, energy running or itching of the skin **at the Chakra region** (the **Cue Response**), use a final **INHALE breath** to draw the image of the Symbol **down through the Chakra into the body**, and into the **tiny Crystal Seal** that links the Chakra to the Central Vertical Current. Take a **FINAL exaggerated EXHALE**, and imagine that you have **pushed the energy of the Transmitting Symbol Key** out of the Chakra into the **corresponding level of the Auric Field.** Once imbued into the **Auric Field** the single image of the Symbol then **replicates automatically and rapidly**, creating **millions of mini-replicas of the Symbol** within your bio-energetic field. When the **Cue Response** sensation at the Chakra has **completely ceased**, you have **successfully induced** the entire **mathematiucal program** of the Transmitting Symbol into the corresponding Kathara Center, DNA Strand Template, Axia-tonal Line, body region and level of consciousness.

Technique-9: Merkaba Trinity Key Induction

Trinity Master Key Selection Chart

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12 Transmitting Keys: ***Correspond to each Dimension-Chakra-Kathara Center-Axia-tonal Line etc.***

Number in circle represents the **number of Chakra** into which corresponding Transmitting Key Symbol will be induced. **Note:** The **Smaller Symbols** placed **outside of SOME circles** are **Amplifier Key Symbols** corresponding to the Chakra by which they are positioned. The Amplifier Keys can be used **in place of** the Transmitting Key within the circle, or the two Keys can be drawn on one paper for **simultaneous induction**. It is **recommended** to begin with the Transmitting Key inside the circle, then after a few induction exercise, switch to the Amplifier Key, and after several exercises with the Amplifier Key, use both Transmitting and Amplifier Keys simultaneously.

Two Initiating Keys

1)

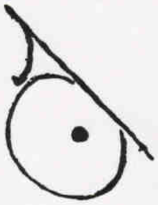

2

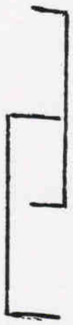

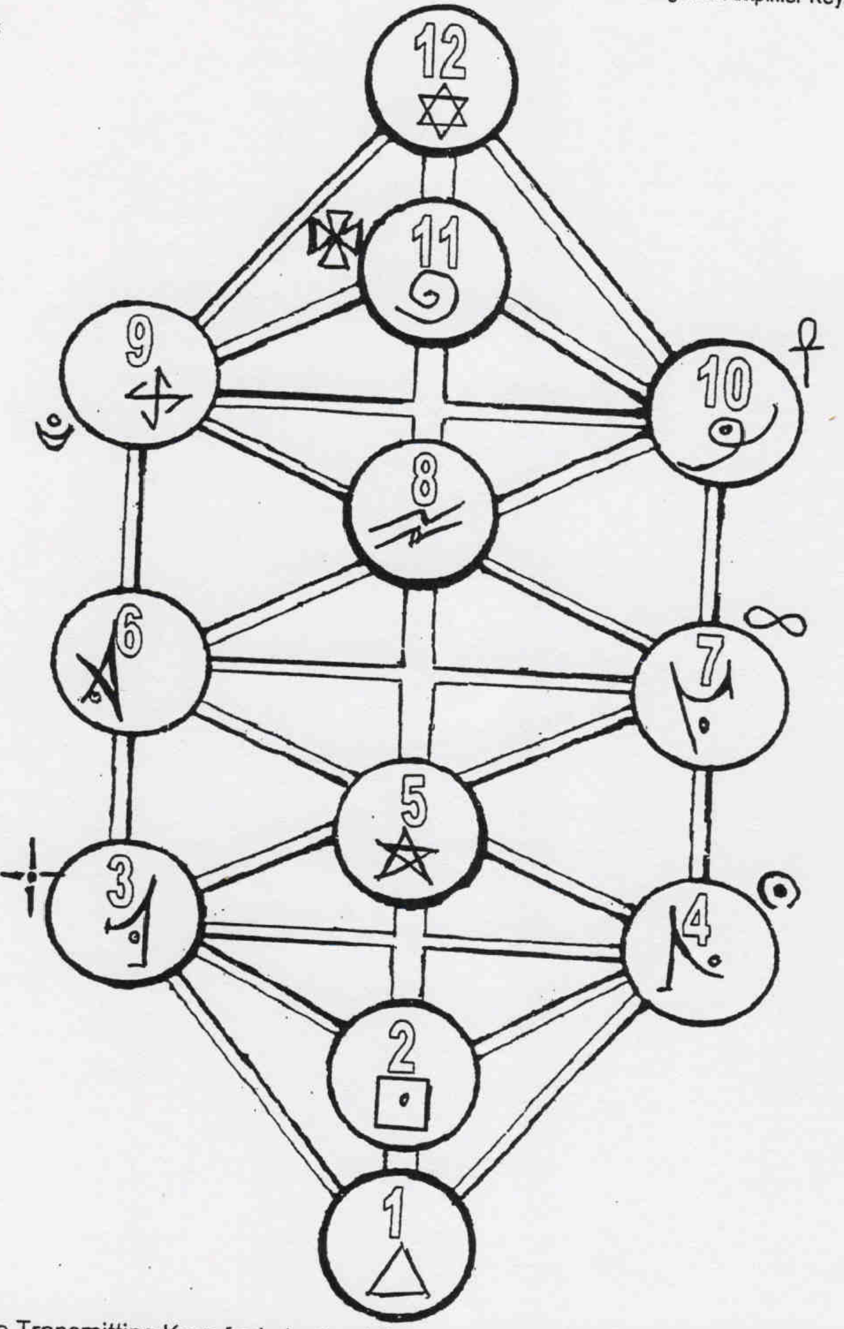

Select one or more Transmitting Keys for induction following induction of the two Initiating Keys above.

In **Kathara Level-1** we have learned of the innate structures of multidimensional reality and how these structures are intimately intertwined with the ***15-Dimensional Human Anatomy*** and levels of personal identity through the personal ***Maharic Shield*** and ***DNA Template***. In rediscovering these long forgotten aspects of the Human condition and our inherently implied relationship to Universal Order, we've become empowered to draw upon the natural **Triadic Phase Currents** indigenous to our personal biology and universal structure, in order to take an active hand in personal *Conscious Bio-spiritual Evolution* and healing, and healing facilitation for others. ***Techniques 1-5*** (#1-*Awakening the Mentor*, #2-*Maharic Seal and Liquid Light Cleanse*, #3-*Opening the Healing Channels Doradic Phase-1 Current*, #4-*Multi-vector Holographic Recoding Kathara Scan* and #5- *The Maharic Infusion* client session) contained within *Chapters 1-4 of the Kathara Level-1 Maharic Recoding Process* enable us to begin conscious interaction with the "invisible" processes of **Body-Mind-Spirit Evolution** that are inherent to Human design. In our introduction to **Kathara Level-2** we have begun to explore the greater nature of ***Universal Life Force Currents***, the "mysterious" sciences of ***Merkaba Mechanics*** and their indelible connection to our personal evolution and **Bio-spiritual Actualization Processes**. ***Techniques 6-7-8-9-12*** (#6-*Maharic Quick Seal*, #7-*Ps13 Tribal Shield Activation*, #8-*Merkaba Salutations*, #9-*Merkaba Trinity Key Induction* and #12 *Kee-Ra-Sha Activation Sequence*) so far explored within this *Chapter 5* of the *Kathara Level-2 Introduction* enable us to advance our conscious interaction with the processes of personal Body-Mind-Spirit Evolution and Bio-Spiritual Actualization. As we increase our personal abilities to understand, embody, hold and direct the inherent powers of the Universal Life Force Currents, and to access the levels of personal spiritual identity and wisdom to which they correspond, we progressively increase our ability to consciously facilitate healing in ourselves and for others we may choose to serve. An in-depth study of Universal Life Force Currents and Masters Merkaba Mechanics involves cultivating a necessary familiarity with a broad spectrum of interrelated subjects that take us into the heart of the Science of Vibrational Mechancis and Holographic Creation Physics, as well as into the very Soul of our spiritual relationship to consciousness, ourselves, each other, our world and God. Mastery of Merkaba Mechanics is an attribute inherent to achieving the state of consciousness often called "Ascended Mastery", which requires much in-depth study into the "mysteries" of creation. However, a functional mastery of Merkaba and the related constructs of the personal "Inner Templar" system upon which the personal body and identity manifest can be achieved through gaining familiarity with and actively employing core mechanics of the personal Merkabic System.

As our *Kathara Level-2 Introduction* began, our exploration of active techniques of *Tribal Shield Activation, Merkaba Salutations* and *Trinity Keys* set us on the path of becoming functionally able to consciously direct elementary operations of the personal Merkaba Vehicle and Life Force Currents, as a means of expediting our progress of Bio-Spiritual Evolution through DNA Template/Merkaba Field Activation. As our *Kathara Level-2 Introduction* continues, we will begin to explore the seemingly "***magical world of Merkaba"***, rediscovering the very tangible importance of the **Merkaba Field** in relation to the inherent dynamics of DNA, health, healing and spiritual actualization. To achieve genuine integrity in the facilitation of healing for others, one must simultaneously strive to heal and actualize the self. The greater the level of health and spiritual actualization possessed by a healing facilitator, the greater will be the facilitation of healing for the client to whom the healing facilitator is in service. As Kathara Level-2 Introduction draws to a close we will begin an introductory exploration of the "Ancient Secrets" of the **Veca Codes,** so that we may engage practical application of two additional techniques of Photo-Radionic and Photo-Sonic **Merkabic Healing. Techinque-#10** ***Restoring the Trion Field Veca Code Activation*** and **Technique-#11**-***Restoring the Meajhe Field Eckasha Activation*** will provide us with powerful tools of the Kathara Healing trade that will ***substantially increase the quality, amount and power of interdimensional frequency we are capable of receiving, holding and transmitting***. Through these simple but effective Merkabic Healing tools we can expedite our processes of personal healing and spiritual actualization, thereby enabling us to become more effective and powerful healing facilitators in our client session service.

The "Magic of Merkaba"

Spiritual-science teachings of **Merkaba Mechanics** emerge from the most ancient of times; record of Merkaba teachings is most often found in obscure traditional "Occult" texts or within New Age "Ascension" teachings. Genuine Merkaba Sciences hold the keys to understanding and mastering the processes of both spiritual and physical evolution, on a personal, planetary, galactic and universal level. Merkaba Mechanics are not the product of "science fiction", nor are they "magical hocus-pocus" of "occult mysticism". Merkaba Mechanics are not "magic" at all, but rather an intrinsic element of universal Primal Order. **Merkaba Fields**, sets of Star-tetrahedron shaped counter-rotating electro-magnetic energy fields within and surrounding manifest forms, are simply an inherent element of the15-Dimensional Anatomy of form manifestation and the Primal Order structure of multidimensional Creation Physics. In the "*Transduction Sequence*" described in *Kathara Level-1*, the sequence of energy transmutation by which conscious energy manifests into tangible biological form, the *Merkaba Field* represents the structure and stage of energy dynamics by which *Primal Life Force Currents* pass from the scalar-wave-template of the embodied *Kathara Grid levels* into the *DNA Template*. In terms of non-biological form manifestation, all forms possess an inherent structure of interwoven Merkaba Fields through which Primal Current energy is transmuted from the Kathara Grid Core scalar-template level into the outer levels of the Kathara Grid and Axiom Line template upon which the specialized structure of the form builds up, through particle/anti-particle accretion, into physical manifestation. Merkaba Mechanics seem "magical" only when the inherent **"Laws of Nature"** that govern the dynamics of **Multidimensional Universal Unified Field Physics** are not understood.

Through understanding of genuine *Universal Unified Field Science, Merkaba Fields*, and their inherent dynamics as utilized in the study of *Merkaba Mechanics*, are simply recognized as natural elements of the processes inherent to Creation Physics and the naturally occurring, organic relationships between Energy Consciousness, and the Holographic Manifestation of form.

As Merkaba Fields are an intrinsic, significant and natural part of the Body-Mind-Spirit anatomy, the study and application of Merkaba Mechanics is an essential component in any Masters Holistic Healing or Spiritual Actualization program. Merkaba Mechanics are *"Scientific"* in that they represent a core element within the innate processes of creation and manifestation that are intrinsic to the sciences of Creation Physics. Merkaba Mechanics are also "*Spiritual"* in that it is through the innate structures and dynamics of Creation Physics, of which Merkaba Mechanics are a natural part, that consciousness enters the manifest arena in the form of sentient, individuated, multidimensional identity. The "body, mind and spirit" of every manifest being is formed through and governed by the natural laws of Creation Physics and Primal Order. The Laws of Creation Physics and Primal Order are designed and maintained by and within a non-manifest, intelligent, central Consciousness Force and Source of Creation that is commonly referred to as "**God**". God expresses It-Self in the form of *Conscious-energy Constructs* that carry the living "Spirit and Consciousness of God" in the form of **Primal Life Force Currents**, which are the foundations for macrocosmic and microcosmic creation and manifestation. Merkaba Fields and the mechanics by which they function, are an indelible part of the physics of Creation and Consciousness, and are thus intimately involved with the Bio-Spiritual processes inherent to **Spiritual Actualization**.

Merkaba Fields, DNA, Healing and Spiritual Actualization

Particles, People, Planets, Galaxies and Universes all have **sets of interwoven Merkaba Fields** that serve as the "**core Primal Life Force Current circulation system**" between the Cosmic, Universal, Galactic, Planetary and Personal "Divine Blueprint" Kathara Grid scalar-templates and the manifestation of those blueprints into the tangible structures of matter. Merkaba Fields are the "**carriers of consciousness**" and the "**engines of energy**" by which physically manifest forms are created, maintained and evolved through the Holographic Unified Field of manifest space-time-matter reality. In relation to the processes of personal bio-spiritual healing and spiritual actualization, the personal Merkaba Field is an intrinsic aspect of 15-Dimensional Anatomy that directly governs the function of the physical, emotional, mental and spiritual body systems. **The multidimensional structure of the personal Merkaba Field is the system of electro-magnetic interface by which the Primal Life Force Currents and Consciousness of God-Source and Its sentient individuations pass from the Kathara Grid Core Template into the scalar-wave DNA Template that holds the blueprint for the physical-chemical biological DNA.** This reality of **Merkaba Field-DNA Connection** implies that the personal Merkaba Field is directly related to the function or dysfunction of the **biological genetic code.** As the Merkaba Field "carries the energy of consciousness" into the DNA and biological vessel, the *Merkaba Field-DNA Connection* also implies that the potentialities of consciousness and embodiment of spiritual identity, while a being is ensconced within the Time Matrix, are dependant upon the condition and function of the personal Merkaba Field, DNA Template and Kathara Grid.

*Merkaba Fields are the "**carriers of consciousness**" and the "**engines of energy**" by which physically manifest forms are created, maintained and evolved through the Holographic Unified Field of manifest space-time-matter reality.*

Universal Merkaba Field Structure

Basic Merkaba Field structure is relatively simple. Viewed Macrocosmically, in a 15-Dimensional Time Matrix there are **15 sets** of counter-rotating electromagnetic **Merkaba Spirals** that form **15 Universal Dimensional Merkaba Fields.** A "**Merkaba Field**" is composed of a set of **2 Merkaba Spirals**, one electrical-transmitting "cone", the other magnetic-receiving "inverted cone"; the 2 "cones" of the Merkaba Spirals, which operate as a **White Hole/Black Hole Pair**, intersect each other, creating a system of energy vortices that form an **Elliptical Sphere** of energy within the center of the intersected Merkaba Spirals. The Sphere of energy at the center of a Merkaba Field is called the **FORM CONSTANT**; it is a "**spherical energy domain**" within which the individuation of consciousness and holographic manifestation/projection of form can take place, akin to an "energy egg" within which manifest reality occurs. Within this Sphere of energy at the center of a Merkaba Field, the template-blueprints of a form are held "constant", allowing conscious Partiki units, particles, anti-particles and ante-particles to accrete in specific ratios to "fill out the form in matter". Within the Form Constant sphere, consciousness is able to perceive the **holographic illusion** of externalized space-time-matter manifestation, as the scalar-template of the form is held fixed within the sphere. The "hologram" appears to remain "constant" within the Form Constant sphere while consciousness is focused within the frequency bands of which the Merkaba Field is composed.

On the macrocosmic universal scale, the Form Constant of each Universal Dimensional Merkaba Field creates a single, elliptical-sphere shaped electromagnetic domain of frequency that represents a single dimension of manifestation. Following the innate mathematical-geometrical structure of Primal Order, the 15 Universal Dimensional Merkaba Fields group into **5 sets** of 3-Dimensional Merkaba Fields called **Universal Harmonic Merkaba Fields**. The 3 Form Constant Spheres from each set of 3 Universal Dimensional Merkaba Fields forms a **Universal HOVA BODY**, or a "Harmonic Universe" electromagnetic domain. Following the mathematical Primal Order program of a Time Matrix as held within the Universal Kathara Grid template and transmitted through the rotation ratios of the Harmonic and Dimensional Merkaba Fields, each of the 3 dimensional levels of a Universal Hova Body holds the Partiki units, consciousness and matter particulates of its dimensional field into a specific angle and speed of rotation. The 3-Dimensional Harmonic Merkaba Field controls the relationship of particle rotation angle (angular rotation of particle spin or "**ARPS**") and rotation speed between each of the 3 Dimensional Merkaba Fields, holding together a 3-dimensional electromagnetic domain, within which consciousness can experience a 3-dimensional space-time-matter hologram. In a single 15-Dimensional Time Matrix there are thus 15 singular Universal Dimensional Merkaba Fields governed by 5 larger 3-dimensional Universal Harmonic Merkaba Fields, all of which circulate consciousness in the form of Primal Life Force Currents into and out of the hologram of manifestation. The seeming solidity and durability of an externally manifest matter-field in space-time is created, maintained, perpetuated and completely dependent upon the intrinsic function of the Universal Merkaba Fields.

Within the larger Form Constant elliptical-spheres of the 5 Universal Hova Bodies of a 15-Dimensional Time Matrix, the holographic perceptual realities of space-time-matter take place. Every being or thing in manifest form enters its reality hologram by *taking on the mathematical program* of first the *Universal Kathara Grid* and *5 Universal Hova Bodies*, which set the "Life Stream" or "Stream of Consciousness" of Primal Creation

Currents in motion following the specific **Harmonic Merkaba Field spin ratios** characteristic to each Harmonic Universe System. Galaxies are formed in this way, as individualized expressions of the greater Harmonic Universe of which they are a part. **Universal Harmonic and Dimensional Merkaba Fields** govern the birth, evolution and transmutation of the **galaxies** within them. **Galactic Harmonic and Dimensional Merkaba Fields** govern the birth, evolution and transmutation of **star systems and planets** within them. **Planetary Harmonic and Dimensional Merkaba Fields** govern the birth, evolution and transmutation/death cycles of the **species and matter forms** existing upon the planet. The **Personal Merkaba Fields** of species and individuals direct the function of the personal **DNA Template, chemical DNA** and **biological genetic code**, thus governing the birth, evolution and transmutation processes of individual organisms. The mathematical-geometrical programs of the **Primal Order "Divine Blueprint"** that govern Merkaba Field formation and spin ratios are held within the Universal, Galactic, Planetary, Species and Personal Kathara Grid structures. In a singular 15-Dimensional Time Matrix, the **inter-linked Universal, Galactic and Planetary Harmonic and Dimensional Merkaba Fields** circulate Primal Life Force Currents and consciousness into and out of manifestation in space-time.

Universal Merkaba Fields

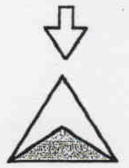

Electrical ***Merkaba Spiral***
Rotates Clockwise
"White Hole" Vortex

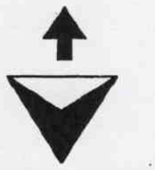

Magnetic ***Merkaba Spiral***
Rotates Counter-clockwise
"Black Hole" Vortex

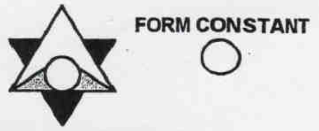
FORM CONSTANT

One ***Merkaba Field*** =
a set of 2 *Merkaba Spirals*
Black-White Hole Pair

Universal Merkaba Field of One 15-Dimensional Time Matrix

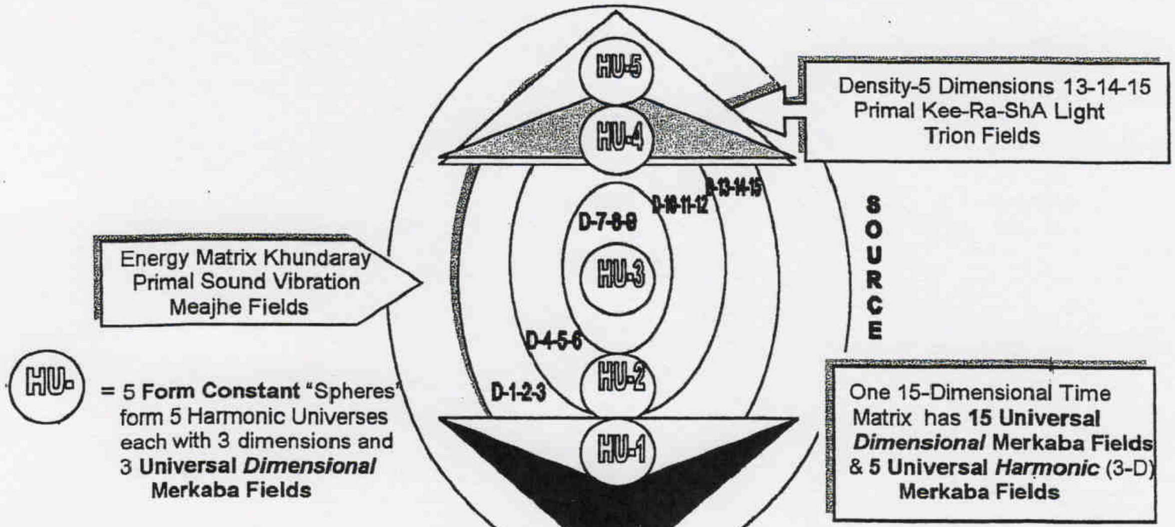
HU-5
HU-4
D-13-14-15
D-10-11-12
D-7-8-9
HU-3
D-4-5-6
HU-2
D-1-2-3
HU-1
SOURCE
Density-5 Dimensions 13-14-15
Primal Kee-Ra-ShA Light
Trion Fields
Energy Matrix Khundaray
Primal Sound Vibration
Meajhe Fields
HU- = 5 **Form Constant** "Spheres" form 5 Harmonic Universes each with 3 dimensions and 3 **Universal *Dimensional*** **Merkaba Fields**
One 15-Dimensional Time Matrix has **15 Universal *Dimensional* Merkaba Fields** & **5 Universal *Harmonic*** (3-D) **Merkaba Fields**

The Personal Merkaba, Trion-Meajhe Field, Radial Body and Radis.

Each individual being receives its life force, consciousness, biology and manifest hologram through the innate connection between the **Personal Merkaba Field** and the Merkaba Fields of the Planet, Galaxy, Universe and Time Matrix. When the **D-12 Pre-matter Divine "Christos" Blueprint** is expressing naturally in a planetary system, the organisms on the planet circulate Life Force Currents and consciousness through the physical and "spiritual" bodies via the Personal and Planetary Merkaba Fields. The **Planetary Merkaba Field** circulates Life Force Currents through the **Personal Kathara Grid** template (morphogenetic field) of the organism via the **Planetary Bio-Feed Interface System.** The organism's **Personal Merkaba Field** then picks up the energy from the Kathara Grid and continues to circulate the Life Force Currents from the Personal Kathara Grid and into the **Maharic Shield imprint** in the **DNA Template** that is held within the Level-1 *Kathra 12-Tree Grid,* Level-2 *Kathara Crystal Seals-Hara Grid* and Level-3 *Kathara Diodic Grid.* From the Maharic Shield imprint in the Kathara Grid, the Personal Merkaba Fields distribute the Life Force Currents and consciousness into the **DNA/RNA Template** and **Axiom Lines.** The Life Force Current continues circulation from the DNA/RNA Template and Axiom Lines into the **Personal Hova Bodies** and **Auric Field**, to the **Chakras** and **Meridian Lines**. Passing through the Meridian Lines, the Life Force Current, imbued with the specific mathematical manifestation program picked up from the Kathara Grid Divine Blueprint Template, then enters a state of final transmutation into 3-dimensional particles by passing through an electrostatic **Repulsion Zone** barrier that exists surrounding each 3-dimensional Hova Body.

The frequency barrier surrounding each 3-dimensional Hova Body forms as **thin, skin-like membrane** or **"Tissue Capsule"** surrounding each of the 5 Hova Bodies in the 15-Dimensional Anatomy. The **Hova Capsule** membrane is composed of Density-5 **Primal Light** ante-matter units, called **TRION UNITS**, that exist in the form of fixed standing-columnar-scalar-light waves made of **Keylons**, or 3-dimensional **Partiki Grids**. The Trion Units and Keylon Partiki Grids within them are anchored upon a fixed field template of **Primal Sound** units, called **MEAJHE UNITS**, which exist as fixed points of mathematically organized vibration. The outer layer of each Hova Capsule is called the **Trion Field**, as it is composed of **Trions**, or units of Density-5 ante-matter Primal Light. The inner portion of the Hova Capsule is called the **Meajhe Field** as it is composed of **Meajhons** (mE' yans) or fixed points of Primal Sound vibration from the **Energy Matrix** beyond the holographic manifestation of the Time Matrix Light Fields. The collective body of the 5 Hova Capsules is called the **RADIAL BODY** or **Trion-Meajhe Field**. All manifest forms possess a core Radial Body/ Trion-Meajhe Field **Hova Capsule** structure as part of the intrinsic 15-Dimensional anatomy.

As multidimensional Life Force Currents pass through the Meridian Lines and into each of the 5 layers of the Radial Body, the energy currents and the consciousness carried upon them project the mathematical program of the Divine Blueprint into the Trion-Meajhe Field of each of the 5 Hova Capsules. Within the Hova Capsule, the individualized raw Life Force Currents enter a system of 3-dimensional energy conduits or **rivulets** called **Radis**, which are the "turnstiles" between "manifest matter" and "conscious energy". The Radis draw in the Life Force Currents with their manifestation program through the Trion-Meajhe Field, then polarize and break up the Trion and Meajhon units into negatively and positively charged electrical sub-units called **Mions** and **Dions**. Partiki, Keylons, Meajhons, Trions, Mions and Dions belong to a category of primal building blocks known as **IONIC PARTICULATES,** which are the building blocks of consciousness, energy, light, sound and scalar-wave-fields that form the blueprints upon which all matter manifests. **Trions** are electrostatic particulates that have both a negative and positive electrical charge, which renders them neutral or static; they are the foundations of what becomes **Ante-matter** Primal Light particles of pre-visible gaseous light. Meajhons are static units of pre-sound standing waves, also possessing neutral electrical charge, that form the Primal Sound Fields of the Energy Matrix. Within the structures of the Radial Body Radis rivulates, Trions and Meajhons are **polarized** into negative charged **Mions** ("Base Magnetic" vibrating pre-sound particulates, foundations of negatively charged particles such as electrons, originating from the Universal Particle Particum field.) and positively charged **Dions** ("Base Electrical" oscillating pre-light particulates, foundations of positively charged particles such as protons, originating from the Universal Anti-particle Partika field). Together, Mions and Dions create the **electromagnetic Ionic Particulate base field** within the Merkabic Form Constant through which particles emerge via Ionic Particulate accretion into tangible matter units.

The Trion-Meajhe Field Radial Body of any manifest form represents the 5-Density "Veil" through which consciousness-as-Primal Life Force moves into and out of externalized 3-dimensional manifestation. **Merkaba Fields are the "energy engines and consciousness carriers" by which Life Force and consciousness are circulated between the internal Kathara Grid scalar template and the Trion-Meajhe Field Radial Body "veil" as they pass into and out of external expression.** The perpetual polarization, electromagnetic expression and de-polarization of the Life Force Currents within the Merkaba Field Form Constant electromagnetic domain is the process by which the holographic projection of matter is perpetually brought into and taken out of perceptually experiential being. The **Radial Body** Trion-Meajhe Field receives, via Merkaba Field circulation, the template or "design" for its particle manifestation from the "instructions" held in the Divine Blueprint Maharic Shield and DNA Template of the Kathara Grid. Manifestation instructions pass from the Kathara Grid to the DNA Template via the Merkaba Field, then continue into the energy circulation systems (Axiom Lines, Hova Bodies, Chakras, Meridians) that deliver the instructions to the Radial Body for particulate manifestation. In biological life forms, the Radial Body and Radis then translate the scalar-wave blueprint of the DNA Template and Kathara Grid into the polarized Ionic Particulate Mion-Dion sub-units, which accrete following the DNA Template instructions to form sub-atomic, atomic, molecular, chemical DNA, physical matter form- the vehicles of embodied consciousness. The **Merkaba Field** also receives its instructions for energy circulation from the Kathara Grid and DNA Template.

The Radial Body Tissue Capsule, Radis & the Mechanics of Manifestation

The **Radial Body** exists as a thin "***Tissue Capsule***" surrounding each of the **5 Hova Bodies.** Each of the **5 Radial Body Levels** are composed of an **Outer Layer** of electrostatic neutral-charge **Trion Primal Light Units** and an **Inner Layer** of **Meajhon Primal Sound Units**. Each of the 5 Levels of the Radial Body serve as the **polarizing filter or "lens"** through which **Multidimensional Primal Life Force Currents** flow, via **Merkaba Field** circulation, from the Kathara Grid and DNA Template, into manifest form.

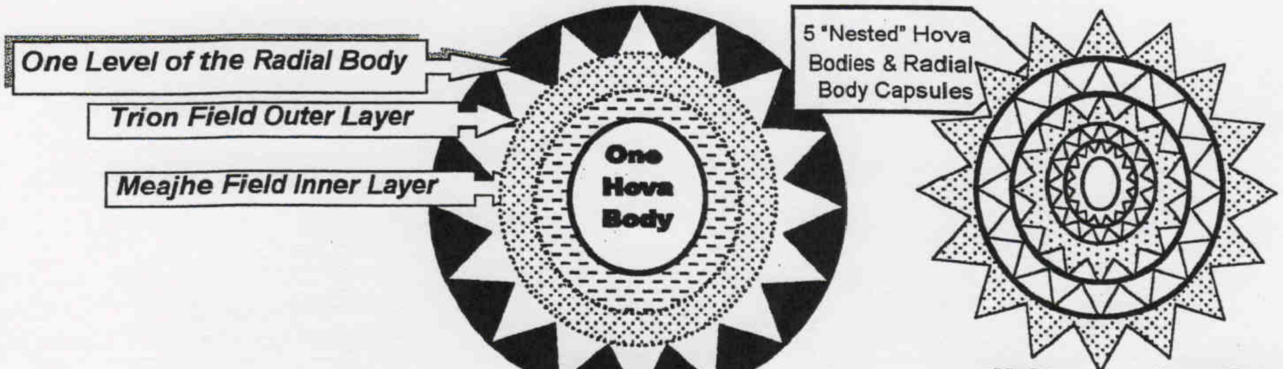
One Level of the Radial Body
Trion Field Outer Layer
Meajhe Field Inner Layer
One Hova Body
5 "Nested" Hova Bodies & Radial Body Capsules

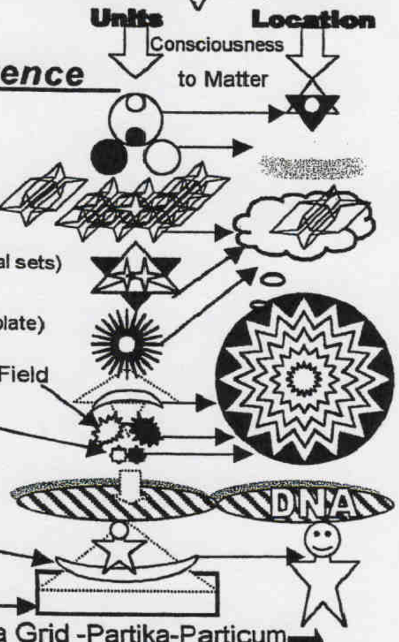

Radial Body Transduction-Manifestation Sequence

Primal Life Force Current *Partiki Units* Planetary Merkaba Field
(Units of Consciousness/Primal Substance)
Partika and Particum Units Kathara Template/Maharic Shield
(Polarized Primal Substance Units)
3-D Partiki Grid Keylon Units/Codes/Grid Morph. Keylon Thought-Form Field
(3-D Crystallized Pre-Light-Sound units, unit groups and grids)
Merkaba Field *Keylons* (3-D Crystallized Pre-Light-Sound Keylon Unit electromagnetic spiral sets)

DNA/RNA Template *Keylons* Kathara Grid (3-D Crystallized Pre-Light-Sound unit Template)
Axiom Lines-Hova Bodies-Auric Field-Chakras-Meridian Lines
Trion & Meajhon *Electrostatic Units* 5 Radial Body "Lens" Levels Trion-Meajhe Field
Dion (+) & Mion (-) Ionic Particulate *Electromagnetic Units* Radis Lines

Sub/Atomic Particles/Anti-Particles, Molecules...Chemical DNA
Physical Matter Body Hologram "Chemical Lens"

External Hologram Projection of Space-Time-Matter
Primal Life Force Currents ➡ Planetary Merkaba Field Partiki ➡ Kathara Grid -Partika-Particum ➡ Maharic Shield Divine Blueprint ➡ Keylon Morphogenetic "Thought-form" Field ➡ Merkaba Fields ➡ Kathara Grid DNA/RNA Template ➡ Axiom Lines ➡ Hova Bodies ➡ Auric Field ➡ Chakras ➡ Meridian Lines ➡ Trion-Meajhe Field 5 Radial Body Levels ⇨ Radis Lines ⇨ Mion & Dion Ionic Particulates ⇨ Strong and Weak Nuclear Force, Electromagnetism ⇨ Quarks, Muons, Measons, Sub-atomic & Atomic Particles and Anti-Particles ⇨ Blueprint translation into Nuclei, Molecules, Elements, Compounds, Chemicals ⇨ Chemical DNA Template and "Chemical Lens" of the manifest body form ⇨ Manifest Hologram ▭

Reverse Transduction De-Manifestation Sequence: matter- *chemical* DNA- *Sub-Atomic units*- Radis *Mion/Dion units*- Radial Body *Trion-Meajhon units*- Meridian Line-Chakra-Auric Field-Hova Body-Axion Line-DNA Template-Merkaba Field-Morphogenetic Thought-form Field *Keylon Grids & units*- Maharic Shield Template & Kathara Grid *Partika and Particum Units*- Planetary Merkaba Field *Partiki Units* of consciousness.

Radial Body Transduction-Manifestation Sequence

1. From the **Planetary Merkaba Field** (via the Planetary Shield, Axiom Lines, Hova Bodies Vortices, Meridian Lines and Radial Bodies), **rhythmic pulses of Conscious Primal Life Force Currents** enter the species and personal **Kathara Grid Core Template** as Primal Units of **Partiki**.

2. Within the **Kathara Grid Template** the **Partiki Units** pick up the **mathematical-geometrical program** from the **Maharic Shield** "Divine Blueprint" Template, **polarize** to form **Particum and Partika Units**, then **accrete** to form **3-dimensional** electro-magnetic **Partiki Grids** called **Keylons**. The Keylons group together mathematically forming complex templates of **Crystallized Keylon Codes** (or "***Keylon Thought-Crystals***"), which create a mathematically encoded **3-dimensional Morphogenetic Field ("Keylon Thought-form Field"** or Morphogenetic **"Keylon Crystal Grid")** carrying the manifestation blueprint program of the Maharic Shield.

3. As the Primal Life Force Currents of the electromagnetic Keylon Crystal Grid interact with each other following the program of the D-12 Pre-matter **Universal Divine Blueprint**, they form **sets of spiraling electro-magnetic vortices** called **Merkaba Fields**, which carry the Maharic Shield-Kathara Grid Blueprint program into formation of the **DNA/RNA Template** Keylon Crystal Grid.

4. From the DNA/RNA Template held in the Kathara Grid, Primal Life Force Current carries the **Keylon Crystal Grid** of the blueprint into the **Axiom Lines, Hova Bodies, Auric Field, Chakras** and **Meridian Line** systems, finally carrying the Keylon Crystal Grid of the Divine Blueprint into the **5 Radial Body "Tissue Capsule" Levels.**

5. Within the **5 Levels of the Radial Body** the **incoming Keylon Crystal Grid** translates into **electrostatic Trion-Primal Pre-Light Units** (gaseous pre-light Ante-matter) and **Meajhon-Primal Pre-Sound Units** (units of vibrating pre-sound energy) that possess a **neutral electrical charge.** The **Encoded Primal Life Force Currents** (PLFCurrents+ Keylon Crystal Grid blueprint program) are converted into a **Trion-Meajhe Field blueprint replica;** a " Primal Light-Sound" translation of the original blueprint.

6. The **Encoded Primal Life Force Currents** then travel, **AS the Encoded Trion-Meajhe Field**, into the **Radis Lines** in each of the 5 Levels of the Radial Body. The Radis Lines first **replicate and store** the **mathematical blueprint encoding** of the **Trion-Meajhe Field,** then **polarize** the neutrally charged Trion-Meajhe units into **electromagnetic units** called **Mion** (-) and **Dion** (+) ***Ionic Particulates.*** The **replicated Trion-Meajhe Field blueprint** becomes part of the "Primal ***Pre-sound*** vibration" ***Meajhe Field*** **Inner Layer** of the ***Radial Body*** **Trion-Meajhe Field**, serving as a living "***Memory Matrix"*** composed of **Meajhon Unit** "Primal Pre-sound vibration". The **polarized Mion/Dion Units** become the foundations upon which the **"Strong and Weak Nuclear Force"**, **Electromagnetism, quarks, Muons, Measons, Sub-atomic Particles** and **Anti-particles** etc. form. Particum-based **Mions** ("Base magentic) become **particles, negative electrical charge units** like **electrons** and **sound spectra**. Partika-based **Dions** become **anti-particles, positive electrical charge units** like **protons** and **light spectra.**

***Radial Body Transduction-Manifestation Sequence-* Continued** page 2

7. Blueprint Encoded Primal Life Force Currents in the form of a **Mion-Dion Field** then translate the original Kathara Grid Blueprint into **Quarks, Muons, Measons, Sub-atomic** and **Atomic particles** and **anti-particles**, which **accrete** according to the blueprint to form **molecules, elements, chemicals**, the **Chemical DNA Blueprint** and the **physically manifest body form**. As this occurs the **body image "flashes on"** into manifestation as a **Pulse of Life Force Consciousness** carrying the **Chemically Translated Holographic Image** of the body form template blueprint. This Pulse of Consciousness continues to expand from the Kathara Grid and DNA via the Transduction Sequence, through and beyond manifestation of the body image and into **projection of portions of the Dimensional Unified Field** that **holographically translate** into **individualized experience** within a perceived **Common Planetary Time Rhythm and Matter Field.**

NOTE: ***An individual will holographically perceive and experience only the portions of the Dimensional Unified Field mathematical-geometrical program that are encoded within the personal Maharic Shield, species Tribal Shield and Planetary, Galactic and Universal Shield aspects of the personal Kathara Grid and DNA Template.***
A **global population** experiences a **common planetary reality field and time continuum** because the Kathara Grid Template and DNA of all beings entering a planetary field **adopt the common imprint** of the mathematical-geometrical program of the **Planetary Kathara Grid** blueprint in order to enter into the electromagnetic domain of the Planet's Form Constant Hova Body structure for experiential manifestation. Members of a **singular species** share a common **species Tribal Shield** template through which a **common Chemical Body Form** and perceptual orientation holographically manifest. The imprint for **individuality** in biological form, life experience variation and the application of **Free Will Choice** is held within the mathematical program of the **personal Maharic Shield** D-12 Pre-Matter **Divine "Christos" Blueprint**. Imbued within the mathematical program of the **Human species Tribal Shield**, and that of some other species, is the imprint for **probability** to exist. The Human species Tribal and Maharic Shields carry a program that allows for **new programs of probable creation** to be **added** to the personal and species **Kathara Grid**, allowing the embodied consciousness to retain **a degree of direct influence** over what sets of mathematical programs will be called into personal experiential Holographic Expression from the personal Maharic Shield Template. **Creative variation** on the original personal, species, planetary and galactic Divine Blueprint is possible as long as the new probabilities do not deviate so excessively from the Pre-set programs and **Original Intentions** of the Universal Divine Blueprint that the **structural integrity** and **Source-God Will Intentions** for our Time Matrix become **irreparably compromised. Free Will thus exists within a pre-set framework of overriding Divine Will**, and is permitted free reign in the manufacture of **co-creative experiential probability** up to the point at which the Original Divine Will of Source and the creative framework itself become unduly jeopardized.

8. The physical body form serves as a **Chemical Lens** through which ***portions*** of the **Dimensional Unified Field** are perceived by the embodied consciousness as a **3-dimensional Hologram,** as the Primal Life Force Currents continually carry **pulses of the individuated consciousness** through the ***Transduction Sequence*** from Kathara Grid, through the DNA, to the manifest Chemical Lens of the physical body structure and Holographic "external" reality field projection.

Radial Body Transduction-Manifestation Sequence- **Continued** page 3

9. As a Keylon-Thought-Form blueprint traveling on one Pulse of Consciousness **fully expands** (fully "Activates") into the manifest externalized hologram, **another Pulse of Consciousness** is released from the synchronized mathematical programs of the Planetary Merkaba Field, which sets the Transduction Sequence in motion ("Initiates")for the ***next portion* of the personal mathematical blueprint.** The blueprint of the **Planetary Kathara Grid** regulates the **cyclic rhythms** at which **Pulses of Life Force Current** will be released through the **Planetary Merkaba Field**; the Planet releases **"Pulses of Time"**.

> **NOTE:**The linear time experience of life forms on a planet is synchronized into specific singular continua and cycles of time through the *DNA Template*; the species Tribal Shield, personal Maharic Shield and DNA Template are imbued with the *exact mathematical programs* of the specific *Planetary Time Cycle* and *Continuum* or "Time Wavef" into which the consciousness intends manifest embodiment. A singular Time Wave constitutes a Time Continuum, within which there are specific repeating cycles of progressively accelerating *Pulses of Time* that collectively form the linear time-progression continuum of a *Planetary Time Cycle*.

10. As one **Pulse of Time/Consciousness** brings its blueprint into manifest **Critical Mass Expansion** (fully activates specific portion of the blueprint in Holographic Expression), the Planetary Merkaba Field releases the **next "incoming" pulse** of Time, which carries the next portion of the Kathara Grid mathematical blueprint into the Transduction Sequence. As the new Pulse enters the Transduction Sequence and begins **Expansion** toward manifestation, the **first pulse** of the **fully expanded hologram** begins **Contraction**, entering a **back-return** through the **Reverse Transduction Sequence** (matter- *chemical* DNA-*Sub-Atomic units*- Radis *Mion/Dion units*- Radial Body *Trion -Meajhon units*- Meridian Line-Chakra-Auric Field-Hova Body-Axion Line-DNA Template-Merkaba Field-Morphogenetic Thought-form Field *Keylon Grids & Units*- Maharic Shield Template & Kathara Grid *Partika and Particum Units*- Planetary Merkaba Field *Partiki* Units)

11. A s **pulse-1 contracts** its hologram program **moving backward** through the Transduction Sequence, creating the **"Remembered Past" moment**, the **pulse-2** simultaneously **expands** its hologram program **moving forward** through the Transduction Sequence, birthing the as-yet-to-come **"Future" moment.** The backward moving **"Past"pulse-1** and the forward moving **"Future" pulse-2 intersect** at the **Radial Body Levels** in the Transduction Sequence. This **"past pulse-future pulse intersection point"** is called the **Eiron** (E'r-on) **Point**, also known as **"Zero Point"**, the **"Present moment of conscious focus within the hologram"**, or the "***Eiros*** Conscious, Breathing Life-Force Stream" (Also referred to as the **"Stream of Consciousness"**, the ***"Living Holy Spirit"*** or the ***"Breath of God"*** ..etc.).

12. The *Eiron/Zero Point*, or **Eiros**, is the **"Present Moment of Creation Power"** for the "manifest" conscious identity. It exists at the position where the **third dimensional field,** the electromagnetic **Resonant Tone "Mental Body"** field of a single 3-dimensional Hova Body, **intersects** with the **Meajhe Field Inner Layer** of the corresponding **Radial Body** Tissue Capsule.

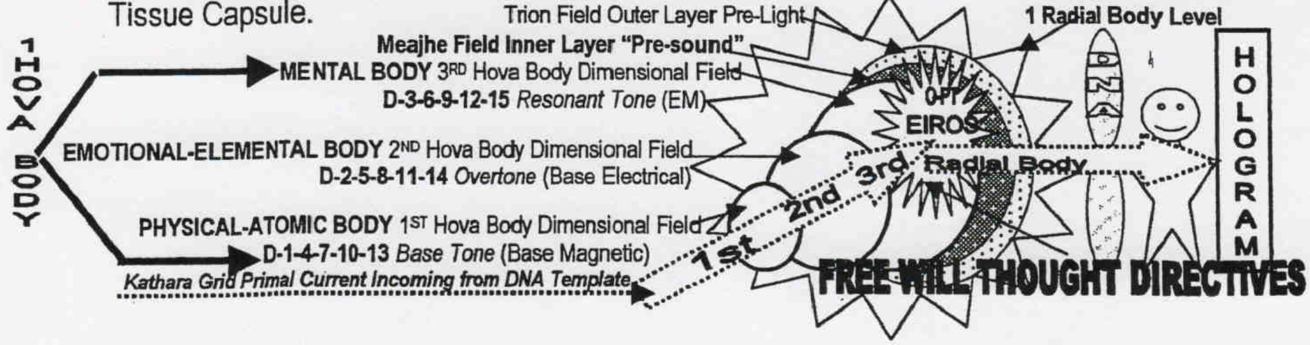
Trion Field Outer Layer Pre-Light
1 Radial Body Level
Meajhe Field Inner Layer "Pre-sound"
1 HOVA BODY
MENTAL BODY 3RD Hova Body Dimensional Field
D-3-6-9-12-15 Resonant Tone (EM)
OPT
EIROS
DNA
HOLOGRAM
EMOTIONAL-ELEMENTAL BODY 2ND Hova Body Dimensional Field
D-2-5-8-11-14 Overtone (Base Electrical)
1st 2nd 3rd Radial Body
PHYSICAL-ATOMIC BODY 1ST Hova Body Dimensional Field
D-1-4-7-10-13 Base Tone (Base Magnetic)
Kathara Grid Primal Current Incoming from DNA Template
FREE WILL THOUGHT DIRECTIVES

Radial Body Transduction-Manifestation Sequence- Continued page 4

13. As the backward moving **"Past" pulse-1** and the forward moving **"Future" pulse-2 intersect** at the Radial Body Meajhe Layer **Eiros** (Eiron Point) ✸ the returning **contracting pulse-1** passes through the Trion Layer and into the ***Meajhon blueprint replica,*** called a " **Radial TILE**" ▨, that it **left behind** in the Meajhe Layer **Eiros** during pulse-1's **incoming** passage. Just as the returning pulse-1 retreats back through its Radial Tile, the **incoming pulse-2,** carrying the **next blueprint** coding ⬚ ,**simultaneously** passes through the **first Radial Tile, combining** the "past" **Radial Tile** mathematical-vibrational blueprint with the **incoming pulse-2 blueprint** ▨ At this moment-point, the hologram template from the "past moment" is adopted by the incoming "future moment" pulse-2 and expanded by the pulse-2 blueprint.

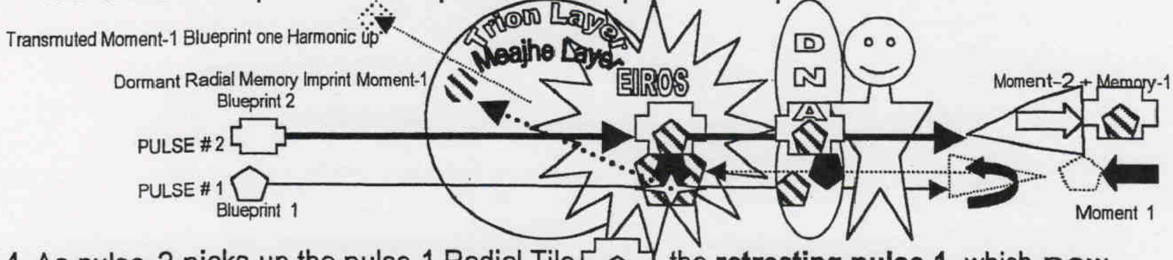

14. As pulse-2 picks up the pulse-1 Radial Tile, ▨ the **retreating pulse-1**, which now **holds the Radial Tile blueprint in *reverse mathematical sequence* as *TRION Pre-light Units*** ⬟ , collides with the incoming pulse-2. Both pulses carry the **common blueprint** of the first Radial Tile; the **incoming pulse-2** holding the blueprint in **forward** mathematical sequence as ***Meajhon Pre-sound Units*** ▨,the **retreating pulse-1** holding the blueprint in **reverse mathematical sequence** as ***Trion Pre-light Units*** ⬟ . As the expanding/advancing and contracting/retreating pulses collide with blueprint **"sequence and anti-sequence",** the pulse-1 reversed **Trion Radial "Anti-Tile" fuses** with the original **Meajhon Radial Tile** ✪ and both Radial Tile and Anti-tile **completely de-manifest** or "***Ascend***" from their original Harmonic Universe by **TRANSMUTING** to become a ***Merkaba Field***. The **energy/ consciousness** once held by Radial Tile/Anti-tile then **replicates** its original blueprint via **Fission,** leaves a **dormant "Memory Imprint"** *Meajhon replica* ▧ in the Radial Body ***Meajhe Field,*** and **reappears** in faster oscillating form within the corresponding **Hova Body Form Constant** of the next Harmonic Universe up in the dimensional scale.

15. As transmutation of the "past" Radial Tile occurs in the Radial Body Eiros, the **incoming pulse-2** is momentarily held **static** as it leaves a **new Radial Tile** in the Meajhe Field; the new Radial Tile holds the **pulse-1+pulse-2** program. At this moment-point the **entire** externalized **Hologram** literally **"Flashes Off"** and de-manifests, its energy **held in suspension** within the **Radial Body** Trion/Meajhe Field. When the first Radial Tile is transmuted, the incoming **pulse-2**, carrying an **expanded imprint of the first Radial Tile**, progresses from the Meajhe Field Eiros to Trion Field, then begins to **"Flash On"** its blueprint in manifestation. The embodied self perceives a **"liner moment progression"**; the ***pulse-1***program becomes **"memory"** of the **"Past"** moment, ***pulse-2*** the **"Present"**.

The Radial Body, Mechanics of Manifestation, Healing and Human Potential

There is much more to be revealed regarding the subject of the *Mechanics of Manifestation*. Our introduction to the ***Radial Body anatomy***, the ***Transduction Sequence*** and the ***Mechanics of Manifestation*** represents a beginning in the quest for genuine mastery over the manifest experience. In this *Kathara Level-2 Introduction* we will **not yet address** the highly pertinent aspects of *Manifestation Mechanics* that pertain to **direct Creation of matter and events** through **Conscious Thought Projection** and applied personal **Will Intention**, nor will we yet investigate the complex realities of **Space-Time Travel, Star Gate Passage** and the **Spiritualized-science of Ascension**. All of these subjects and more are *intimately intertwined* with **personal healing** and the **Imprint for Health**, **attaining mastery** over Manifestation Mechanics and the Bio-Spiritual processes of genuine **Spiritual Actualization**. All of these abilities, and many others too numerous to mention, presently exist as **dormant evolutionary potentials** for the Human species; potentials that were once, long ago, fully actualized and commonly expressed. The ***Kathara Bio-Spiritual Healing System*** represents a body of Master teachings that focus upon the manifestation and maintenance of **Holistic Health through Bio-Spiritual Mastery and Spiritual Actualizaton**. Exploration of subjects such as ***Merkaba Mechanics***, ***Manifestation Mechanics*** and the ***Radial Body Trion-Meajhe Field*** is an intrinsic part of furthering our abilities to embody and practice the ideals of Healing and Health through Holism.

Before we can begin to actualize the exciting potentials of freedom, love, power and knowledge that await Human re-discovery, we must first focus upon **healing the obstacles** that have long stood in our way of actualizing true Human potential. Our study of *Merkaba Mechanics* in this *Kathara Level-2 Introduction* has included a *necessary introduction* to **Manifestation Mechanics** and **Radial Body Anatomy**; the greatest physical and spiritual difficulties presently facing Humankind emerge from a **HIDDEN ILLNESS** that has held our species hostage within a progressively deteriorating, **unnatural Mortal body form**. The **underlying cause of ALL Human illness** is an **unnatural genetic mutation** that manifests THROUGH the **DNA Template** and **chemical DNA.** The **Casual Element** of this species genetic deviation from its original Divine Blueprint can only be found through study of the 15-Dimensional Anatomy, ***Primal Life Force Currents, Kathara Grid, Maharic Shield, Merkaba Field, DNA Template,*** the ***Radial Body*** and the intimate interplay that perpetually exists between these interwoven systems. It is precisely this ***species genetic deviation***, which has progressed and increased for over **200,000 years**, that has kept Humanity bound to a finite, limited world, unable to express the potentials that once existed as our birthright. Though the problem of this species "Internal Illness" is multi-faceted and highly complex, the **Soul-U-tions** through which progressive healing of the Human genome can be rendered are relatively simple. The **Soul-U-tions for healing** and restoring health to our species, and ourselves, **require familiarity with basic Kathara Grid, Manifestation Template, Radial Body, DNA Template and Merkaba Mechanics.** These are the elements of our 15-Dimensional anatomy within which the **Casual Element** of our genetic deviation is held, and thus these are the elements of our anatomy through which the **most rapid and permanent Healing Solutions** can be rendered.

In the following pages we will continue our investigation of the ***Transduction Sequence and the Miasmic Body***, in order to **identify** the regions of our 15-Dimensional Anatomy in which our hidden genetic mutations are created, stored and perpetuated. Once we can identify the regions in which the greatest healing is needed, we can then directly employ appropriate remedial measures. Working with the **Core Kathara Grid and Maharic Shield Divine Christos Blueprint** to reset the Imprint for Health (Kathara Level-1), while **simultaneously** working with the **elements of our anatomy within which the most significant remedial measures are needed**, will allow us to use Divine Blueprint technology to implement **expedited healing.** In this *Kathara Level-2 Introduction* we will examine the *Transduction-Manifestation Sequence* and how it's present **malfunction** creates the **Miasmic Body**, which creates the DNA Template distortion through which our **chemical DNA mutation**, and a phenomenon known as the "**Phantom**" or **"Shadow" Self** is brought into being within our manifest hologram. We will then continue our exploration of **Merkaba Mechanics** and **Radial Body Healing** applications, to discover the **"Secrets of the Veca Codes"**, and Photo-Sonic and Photo-Radionic Radial Body Healing technologies, through which our Kathara and Merkabic Healing applications can be tremendously intensified, amplified and expedited.

The 5 Radial Body-Hova Capsule-Trion-Meajhe Field Levels

and Dimensional, Triadic Phase Current, Density Level, Merkaba Phase, Hova Body, DNA Template, Axiatonal Line, Chakra, Identity Level and Memory Matrix Correspondences

NADIAL CAPSULE:(also called Telluric Capsule): Composed of **Dimensions-1-2-3** ***Telluric Kundalini Current*** frequency, **Density-1** Trion-Meajhe **Gross Matter Density**, 3-Dimensional **Nethra Phase Merkaba**, surrounds **Nada Hova Body**, corresponds to **DNA Strand Templates, Axiatonal Lines and Chakras 1-2-3** and holds focus of consciousness in the D-1 *Lower-Physical-Atomic,* D-2 *Lower-Telluric-Emotional-Elemental* and D-3 *Lower-Mental* ***Taurenic Bodies*** of the embodied Density-1 **Incarnate Personality-*Tauren*** identity, the Sub-conscious, Instinctual and Ego-Reasoning aspects of the "***Mortal Mind***" and the **Personal *Taurenic Memory Matrix***. *Radis* rivulets are called "***Nadis Lines***" (or Telluradis Lines)

DORADIC CAPSULE: Composed of **Dimensions-4-5-6** ***Doradic Kundalini Current*** frequency, **Density-2** Trion-Meajhe **Semi-etheric Matter Density**, 6-Dimensional **Hallah Phase Merkaba**, surrounds **Alpha Hova Body**, corresponds to **DNA Strand Templates, Axiatonal Lines and Chakras 4-5-6** and holds focus of consciousness in the D-4 *Astral-Mid-Physical-Atomic,* D-5 *Archetypal Mid-Telluric-Emotional-Elemental* and D-6 *Celestial Mid-Mental* ***Doradic Bodies*** of the embodied Density-2 **Incarnate Soul-*Dora*** identity, the "***Angelic Mind***" and the **Soul/Species *Akashic Memory Matrix***. *Radis* rivulets are called "***Doradis Lines***"

TEURIC CAPSULE: Composed of **Dimensions-7-8-9** ***Teuric Kundalini Current*** frequency, **Density-3** Trion-Meajhe **Etheric Matter Density**, 9-Dimensional **Quatra Phase Merkaba**, surrounds **Betcha Hova Body**, corresponds to **DNA Strand Templates, Axiatonal Lines and Chakras 7-8-9** and holds focus of consciousness in the D-7 *Higher-Physical-Ketheric,* D-8 *Monadic Higher-Telluric-Emotional-Elemental* and D-9 *Keriatric-Higher-Mental* ***Metatronic Bodies*** of the embodied Density-3 **Incarnate Over-Soul-*Teura*** identity, the ***"Archangelic Mind"*** and the **Over-Soul/Planetary *Askashic-Eckashic Memory Matrix*** . *Radis* rivulets are called "***Teuradis Lines***".

MAHARIC CAPSULE: Composed of **Dimensions-10-11-12** ***Maharic "Christos" Pre-matter Hydro-plasmic Liquid Light Primal Current*** frequency, **Density-4** Trion-Meajhe **Pre-matter Density**, 12-Dimensional **Mahunta Phase Merkaba**, surrounds **Mahara Hova Body**, corresponds to **DNA Strand Templates, Axiatonal Lines and Chakras 10-11-12** and holds focus of consciousness in the D-10 *Christiac-Transcendent Pre-Physical,* D-11 *Buddhaic Transcendant Pre-Telluric-Emotional-Elemental* and D-12 *Nirvanic Transcendent Pre-Mental* ***Hydronic Bodies*** of the embodied Density-4 **Incarnate Avatar-*Dolus*** identity, the ***"Christos Avatar Mind"*** and the **Avatar/Galactic *Dolaric Memory Matrix***. *Radis* rivulets are called "*Maharadis Lines*".

RISHIAC CAPSULE: Composed of **Dimensions-13-14-15** ***M Kee-Ra-ShA Ante-matter Thermo-plasmic Gaseous Pre-Light Primal Current*** frequency, **Density-5** Trion-Meajhe **Ante-matter Density**, 15-Dimensional **Rahunta Phase Merkaba**, surrounds **Raja Hova Body**, corresponds to "Indigo Grail Line" **DNA Strand Templates, Axiatonal Lines and Chakras 13-14-15** and holds focus of consciousness in the D-13-14-15 *Transcendent Ante-matter* ***Hedronic Bodies*** of the Density-5 **Breneua Rishi** Consciousness Collective identity, the ***"Rishiac Universal Mind"*** and the **Rishi/ Universal *Rishic Memory Matrix of one 15-Dimensional Time Matrix.*** *Radis* rivulets are called "*Rishadis Lines*".

The **5 3-dimensional Levels** of the **Trion-Meajhe Field Radial Body** within the 15-Dimensional **Time Matrix** connect each Density Level of all manifest consciousness to the greater, non-dimensionalized structure of the **Energy Matrix *Khundaray* Primal Sound Vibration *Meajhe Field*** through the **Density-5** Ante-matter ***Kee-Ra-ShA*** **Primal Light *Trion Field***.

The Transduction Sequence and the Miasmic Body

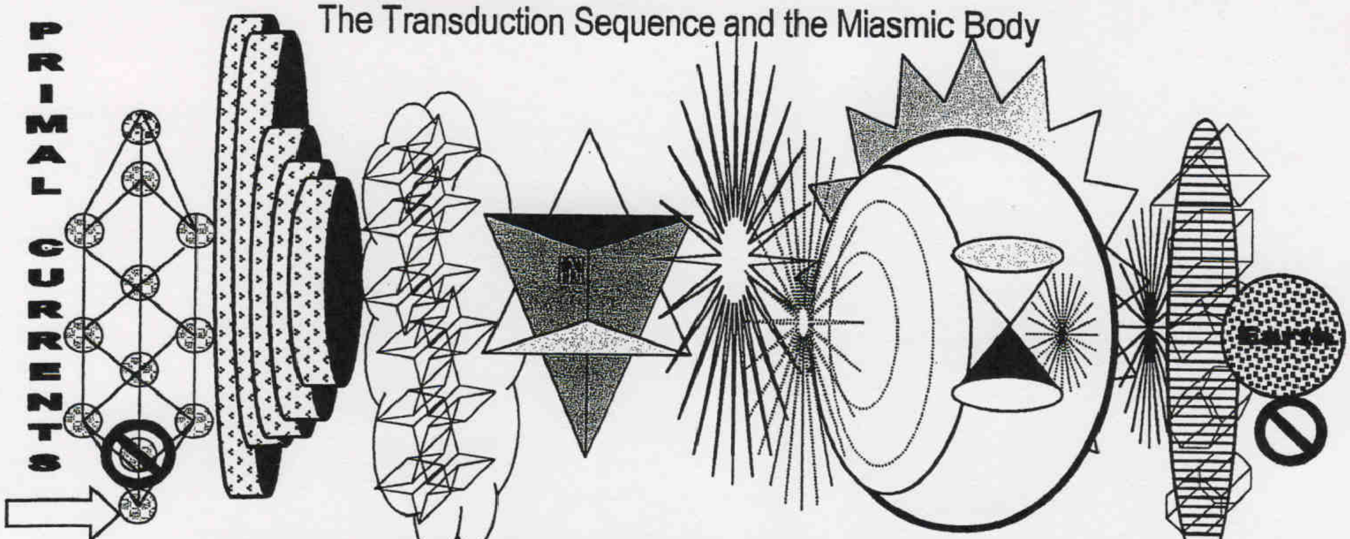
PRIMAL CURRENTS
Earth
Planetary Kathara Grid
Solar Shield & Planetary Shields
Planetary Keylon Crystal Body Thought-form
Planetary Merkaba Fields
Planetary Axiom Template and Axiom Lines
Planetary Hova Bodies, Vortices Ley Lines
Radial Body & Radis
Earth Mions-Dions

Personal Transduction Sequence

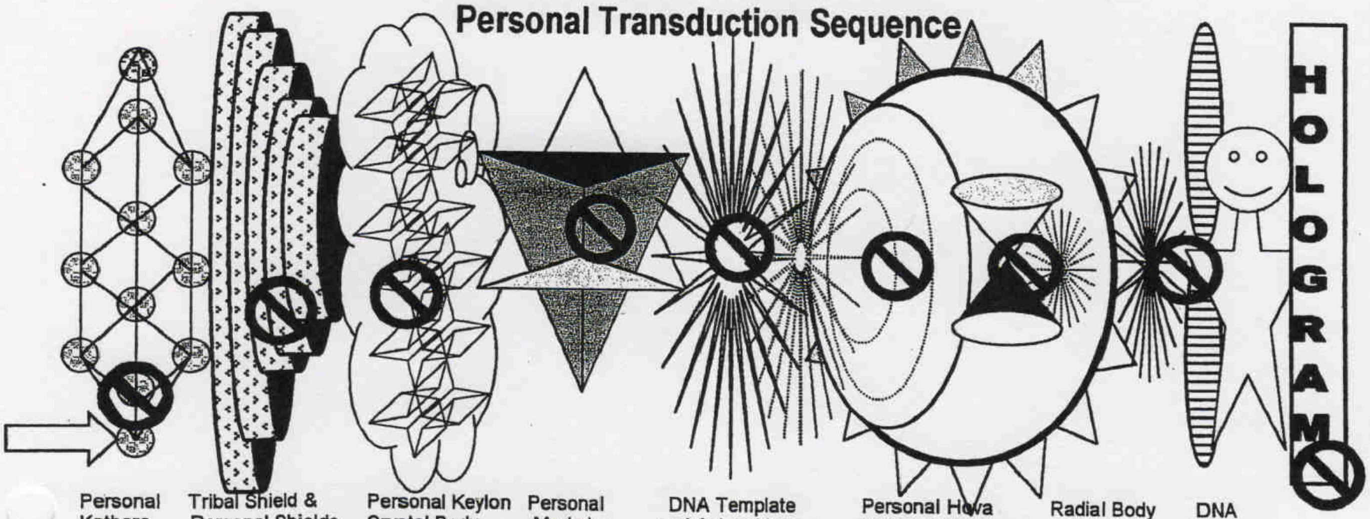
HOLOGRAM
Personal Kathara Grid
Tribal Shield & Personal Shields
Personal Keylon Crystal Body Thought-form
Personal Merkaba Fields
DNA Template and Axiom Lines
Personal Hova Bodies, Chakras Meridian Lines
Radial Body & Radis
DNA & body

Primal Life Force Currents ➡ Planetary Merkaba Field Partiki ➡ Kathara Grid -Partika-Particum ➡ Maharic Shield Divine Blueprint ➡ Keylon Morphogenetic "Thought-form" Field ➡ Merkaba Fields ➡ Kathara Grid DNA/RNA Template ➡ Axiom Lines ➡ Hova Bodies ➡ Auric Field ➡ Chakras ➡ Meridian Lines ➡ Trion-Meajhe Field 5 Radial Body Levels ⇨ Radis Lines ⇨ Mion & Dion Ionic Particulates ⇨ Strong and Weak Nuclear Force, Electromagnetism ⇨ Quarks, Muons, Measons, Sub-atomic & Atomic Particles and Anti-Particles ⇨ Blueprint translation into Nuclei, Molecules, Elements, Compounds, Chemicals ⇨ Chemical DNA Template and "Chemical Lens" of the manifest body form ⇨ Manifest Hologram ▭

⊘ **Miasms block energy flow and create a "Phantom-Shadow Self" running on opposite mathematical program; blocks natural energy flow.**

- The Personal ***Radial Body*** or Trion-Meajhe Field is composed of **5 Hova Body Capsules** that manifest as electromagnetic barriers or "**frequency fences**" between each set of 3 DNA Strand Templates, each set of 3 associated Axiom Lines, Chakras and Meridians and between each 3-dimensional layer of the Auric Field and corresponding level of personal multidimensional identity.

- Each of the **5** 3-dimensional **Harmonic Merkaba Fields** corresponding to the *5 Hova Bodies* of 15 Dimensional Anatomy *govern the function* of the corresponding **Dimensional Merkaba Fields**, **Radial Body level** and its imbedded **Memory Matrix**, via the mathematical program held in the personal Kathara Grid, Shields and **Crystal Body** template. The Kathara Grid program is passed from the **Keylontic Crystal Body** into the **DNA Template** via the **Dimensional and Harmonic Merkaba Fields** and the "mini-Merkaba Fields" of the Level-3 Kathara **Diodic Grid**.

- Each Hova Capsule **Radial Body level,** receiving its instructions from the DNA Template and 3rd dimensional Mental Body Hova Body level, in turn governs the function of the **chemically manifest DNA** and all body-consciousness systems that are built upon chemical genetic code.

- The **Harmonic Merkaba Field** governs the **particle spin axis** (Angular Rotation of Particle Spin) ratios of the energy units that make up its corresponding 3-dimensional system. Each **Harmonic Merkaba Field** corresponds to one **Hova Body**, one set of **3-dimensions** and the Matter Density Level characteristic of that 3-dimensional system. Each Hova Body, and thus each Harmonic Merkaba Field Level and Radial Body Level, correspond to one set of **3 DNA STRAND TEMPLATES** within the Human12-Strand Template.

- Full activation of **one Harmonic Merkaba Field** creates reciprocal activation of the corresponding set of ***3 DNA Strand Templates,*** which creates embodiment of corresponding levels of identity and consciousness (personality, Soul, Over-Soul, Avatar, Rishi etc). When one Harmonic Merkaba Field fully activates through natural activation of the corresponding **Shields** and **Crystal Body Keylons**, the Harmonic Merkaba Field becomes capable of **merging** with the Harmonic Merkaba Fields from other Density Levels, in a process frequently called **Transmutative Dimensional Ascension**.

- During the process of "**Ascension**", (also called "space-time travel", "wave-riding", "Star Gate passage", "Teleportation" etc.) the **Harmonic Merkaba Fields** of more than one Density Level merge, progressively shifting the **two or more different sets of 3-dimensional particles** into a **common particle spin axis angle and spin speed**. The corresponding **Axiom Lines, Hova Bodies, Auric Field levels, Chakras, Meridian Lines** and **Radial Body Levels** also merge.
- When Harmonic Merkaba Fields, and their corresponding Inner Templar anatomy, merge, the **Fire Codes** between the corresponding **DNA Strand Templates activate, causing the DNA Strand Templates to merge,** which creates a reciprocal reaction called **"DNA Strand BRAIDING"** between corresponding **chemical DNA strands**. (The "Double Heli" configuration of "one strand" remains, as the chemical components of each strand overlay together to become a single Double Helix containing the chemical programs of multiple DNA strands.)
- When the **Fire Codes** between strands in the DNA Template activate, dormant sequences of chemical DNA called " **Transient Turnstile DNA Sequences**" "turn on" within the **Hydrogen Bonds** that link each DNA "Ladder Rung" together, producing a **transient trans-harmonic element** called **Celestalline** within the chemical DNA.
- Natural Braiding of the chemical DNA strands and activation of the chemical Turnstile DNA Sequences create a series of **sub-atomic bio-chemical DNA responses** that allows for Internal **Atomic Particle/Anti-particle Fusion** and **Fission.** Natural **Internal Atomic Fusion-Fission** enables the manifest atomic structure to temporarily de-manifest, returning to "*spirit form*", by re-entering the electrostatic **Trion-Meajhe Field** of the corresponding **Radial Body Levels.**
- During the Ascension process, the Harmonic Merkaba Fields of **2 or more Density Levels** merge, forming various **PHASES of Merkaba** activation that create a **Trans-Harmonic Merkaba Field** that is called the **Merkaba VEHICLE.** The 3-Dimensional **NETHRA Phase** Merkaba Field of Density-1accelerates in rotation speed to become the 6-dimensional **HALLAH Phase**, 9-Dimensional **Quatra Phase**, 12-Dimensional **Mahunta Phase** or 15-Dimensional **Rahunta Phase** Harmonic Merkaba Vehicle.

- As a phase of the Trans-Harmonic Merkaba Vehicle activates, the corresponding lower-dimensional **Hova Body and Radial Body Level dissolve**, their content of energy and consciousness **expanding** into the next Hova Body and Radial Body Level, forming a **Trans-Harmonic Radial Body "FORM CONSTANT"** within the **Merkaba Vehicle.**
- The Trans-Harmonic Radial Body and Merkaba Vehicle allow the consciousness and biological form to "de-manifest" from the lower dimensional Density Level. The identity can then **re-manifest** in another Density Level or space-time coordinate by projecting itself into the desired location, AS the *electrostatic* ***Trion-Meajhe Field*** **Trans-Harmonic Radial Body,** then returning the DNA Template activation level and Harmonic Merkaba Spin ratios to that of the new location for re-manifestation.
- When the Personal **Merkaba Field** is used to form the **Trans-Harmonic Radial Body** in the process of Ascension, the Merkaba Field is called a **MERKABA VEHICLE.** A ***Merkaba Vehicle*** is an electrostatic **Trion-Meajhe Field** of Primal Pre-Light-Sound through which the consciousness (AKA "spirit") can move itself, *and its atomic structure*, through **thought-projection**, to a desired location beyond the "veils" of the Planetary, Galactic and Universal Hova Capsule-Radial Body-Form Constant barriers.
- Conscious mastery of the Personal Merkaba Field, through which the organic **internally created Merkaba Vehicle** Trans-Harmonic Radial Body becomes available for conscious direction, implies **conscious control of DNA Template function.** The potentialities of **genuine Ascension** (etc...) and mastery of Bio-Spiritual Consciousness are **inborn attributes** of the Human 12-Strand DNA Template. Due to a **species de-evolutionary genetic mutation** that compromises natural function of the Personal Merkaba Field and DNA, the reality of Ascension on a species level has been lost to all but a few on Earth for over 200,000 years (re: Masters Templar Coursebook).
- The potentials of **Bio-Spiritual Actualization** CAN be returned to humankind through **reverse-mutation** of genetic dysfunction within the human genome and DNA Template. Healing the genetic template can be achieved by **manually employing** specific practices of **Kathara "Maharic Shield" Core Template Dynamics** in **combination** with **Harmonic Merkaba Mechanics** through which the many eons of biological miasmic distortion can be progressively and rapidly cleared from the Personal Kathara Grid and DNA Template.

- Restoration of the D-12 Pre-matter Divine Blueprint within the Human Kathara Grid and DNA Template will eventually **free the Personal Merkaba Field** for use as a **Trans-Harmonic Merkaba Vehicle.** Kathara Healing applications, and use of the D-12 Pre-matter Maharata "Christos" Current to reset the biological D-12 Pre-matter Divine Blueprint, are the beginning steps in reclaiming Bio-Spiritual Mastery.

- The function of the personal **Merkaba Field** and **DNA Template** are not only associated with abilities of **Atomic Transmutation** and **Dimensional Ascension**, they are directly linked to **every aspect of body-mind-spirit function**, including **biological longevity** and **health, memory, intelligence,** and **metabolic, chemical, mental** and **emotional balance** and stability.

- Most significantly, the **Merkaba Field/DNA Connection** is the Bio-Spiritual conduit through which the consciousness of an embodied individual is directly linked to the common Perpetual Force of Energy and Eternal Source of Intelligent Creation that is "**God".**

- When a being's Merkaba Field and DNA Template are functioning upon the innate program of **Universal Primal Order**, as it is held within the Pre-matter **Universal Divine Blueprint** of the D-12 "Christos" Liquid-Light field, the natural and perpetual supply of **Primal Life Force Currents** and "spiritual" consciousness emanating eternally from Source-God, flow through an open energetic channel or "**Pillar of Light**", which is called the "Um Shaddai Ur" (Pillar of First Cause Light-Sound') into the manifest embodiment. Such a being is called a "**Christed Being**". This implies that the integrity of its original D-12 Pre-matter Divine Blueprint has not been structurally compromised, and thus the perpetual Life Force Currents, consciousness, sentience, intelligence, wisdom, power, Will and LOVE of Source can freely express through the Um Shaddai Ur, into the manifest hologram of the Time Matrix through the Christed embodiment.

- If the Kathara Grid, DNA Template and Merkaba Field of a being are damaged, and no longer carry the **original mathematical-geometrical program** of the **D-12 Divine Blueprint** through which the being entered space-time, the flow of Primal Life Force Currents, the Um Shaddai Ur Pillar and thus the active consciousness connection to God will be distorted, reduced or severed at the dimensional level to which the template distortion corresponds.

- A manifest being incapable of running the Primal Life Force Currents of the Um Shaddi Ur "Pillar" becomes **biologically finite**, its consciousness "trapped in the Time Matrix", even following death of the physical body. According to the **natural Laws of Creation Physics** as set by Source-God, this condition of **finite mortality** will remain until the being's **Kathara Grid Template and Merkaba Field connection to** the D-12 **Universal Divine "Christos" Blueprint** and Universal Trion-Meajhe Field Um Shaddi Ur Pillar is restored.

- Healing Core Template genetic distortions that are severe enough to cause dysfunction of the Personal Merkaba Field first require **resetting of the D-12 Divine Blueprint** through activation of the **Personal Maharic Shield.** Until the Body-Mind-Spirit system has reached a **Critical Mass** of D-12 Divine Blueprint holding through frequent and progressive manual running of the D-12 Maharata Current, healing Core Template genetic distortions **also requires** simultaneous, direct and repeated **manual realignment and restoration** of **Personal Merkaba Field function** and **Radial Body Trion-Meajhe Field** integrity.

- If there **are distortions within the Kathra Grid or DNA Template** of an individual or species, the Personal Merkaba Fields will not function in harmony with the **natural energy circulation rhythms** of the **Planetary, Galactic, Universal** and **Time Matrix Merkaba Fields** and Universal Kathara Grid. Such Kathara Grid distortions create tangible **genetic and consciousness mutation** within biological organisms, and can divert the **intended evolutionary destiny** of an embodied consciousness or species on to a divergent path of **de-evolution and consciousness fragmentation** unintended by the original plan encoded within the D-12 Pre-matter Christos Divine Blueprint.

- Distortions with the DNA Template and resulting **Miasms** can be purged through **manual resetting of the D-12 Pre-matter Divine Blueprint,** via repeated manual activation of the Personal **Maharic Shield**. The activated Maharic Shield runs the Density-4 D-12 **Maharata Primal Life Force "Christos" Current** through the Kathara Grid and form embodiment, progressively resetting the original mathematical coding of the personal Divine Blueprint within the Kathara Grid and DNA Template. Use of the **Maharic Shield techniques** in *Kathara Level-1* sets this process of **Core Template Regeneration** in motion.

- The Core Template "Divine Blueprint" healing process can be expedited through applied **Christos-Merkabic Healing Mechanics** such as the ***Tribal Shield Activation*** (Technique-7), ***Merkaba Salutation*** (Technique-8), ***Merkaba Trinity Key Induction*** (Technique-9) and ***Kee-Ra-ShA Activation Sequence*** (Technique-12).
- Divine Blueprint Healing can be expedited further through **manual restoration** of the personal Trion-Meajhe Field **Radial Body** and its inherent **Memory Matrix. Radial Body Healing,** when **combined with** ***Kathara Maharic Shield*** and ***Christos-Merkabic Healing*** dynamics is the most powerful and rapid Holistic Healing technology available.
- **Radial Body Healing** dynamics, which also serve to progressively restore the organic **Memory Matirx,** involve use of the specific **mathematical programs** that govern formation of the **Radial Body Trion-Meajhe Field.** These mathematical programs are called **VECA CODES.**
- **Technique-10** ***Restoring the Trion Field-Photo-Radionic Healing*** **and Technique-*11Restoring the Meajhe Field-Photo-Sonic Healing,*** provide introduction to **Radial Body Healing Mechanics.** Use of these techniques, in **combination** with **Technique-2** ***The Maharic Seal and Liquid Light Cleanse,*** and **Merkabic Healing Techniques 6-12, will greatly expedite** the personal healing process while **significantly increasing** the body-mind-spirit abilities to **receive, hold/sustain and transmit greater quantity and quality** of interdimensional frequency in the Client Healing Facilitation process.

Radial Body Healing, the VECA CODES, DNA and Merkaba

- Veca Codes, also called the "I AM" or "**Immanuyana Sequence**" are very specific **SYMBOL CODES**, each possessing corresponding **Sound Tones** called ***Arieas*** and **energy movements** called ***Seurias***, which correspond to the Cosmic, Universal, Galactic, Planetary and Personal **Trion-Meajhe Field Radial Body Levels**.

- There are **5 categories of Veca Codes**, the Planetary **Low-Veca *Codes of Manu*** (Taurenic-Akashic Codes), the Galactic **Mid-Veca *Codes of Immanu*** (Akashic-Eckashic Codes), the Universal **Level-1 High-Veca *Codes of Immanuel*** (Dolaric-Rishic Codes), the Cosmic **Level-2 High Veca *Codes of Immanuyana*** (Triadic-Polaric-Eckatic Codes) and the God-Seed **Yunasai *Codes of Eckasha*** (Source Codes).

- Beginning applications of Veca Code Radial Body Healing begin with restoring the Trion-Meajhe Field Radial Body through resetting the ***Yunasai*-Eckasha and High Veca *Immanuyanas* and *Immanuel* Codes**, through **frequent manual Direct Induction** of the their corresponding **Symbol Codes** and **Sound Tones/Arieas**.

- The most powerful **Yunasai-Eckasha Codes** are **PHOTO-SONIC Codes**, carrying the Mathematical Programs of the ***Khundaray Current*** Primal Sound ***Meajhe Field*** AND their bridging **God-Seed vibration-rhythms** connecting to Source. The **Level-2 *Immanuyana*** and **Level-1 *Immanuel* High Veca Codes** are **PHOTO-RADIONIC Codes**, carrying the Mathematical Programs of the Trion-Meajhe Field **Khundaray Primal Sound** AND **Kee-Ra-ShA Primal Light Currents.**

- **Consistent use** of **Veca Code Radial Body Healing**, in combination with **Merkabic and Kathara Healing** applications, will progressively **clear the Miasmic Body** and heal, balance, re-integrate, and restore the Divine Blueprint within, the energies of the **Phantom-Shadow Self** in all levels of the Body-Mind-Spirit system.

- More advanced applications of Veca Code technologies include use of the **Mid-Veca *Immanu*** and **Low-Veca *Manu* Codes,** and the corresponding ***Seurias*** (body movements to direct frequency), following a period of initial induction and activation of the Yunasai and High Veca Codes. Full Spectrum Veca Code technologies are introduced in the "***Dance of Life***" Masters Spiritual Development Program.

- **Induction,** or **IMBEDDING** of the High Veca Codes into the 15-Dimensional Anatomy involves placing the corresponding **Symbol Code Sequence** (mathematical program) over the **regions of the physical body** that correspond to the appropriate aspects of the Kathara Level-2 **Crystal Seals Grid** and Level-3 **Diodic Grid.** Once the Symbol is in place, the **breath** is used to direct **D-12 Maharata Current** through each **Symbol Code** and **body region.** Use of the **Maharata Current** "carrier wave" (via **activation of the Maharic Seal/Shield**) is **required** to **induce** the code's **mathematical program** into the **Diodic** and **Crystal Seals Grid,** where the program will then naturally transfer into the corresponding areas of the **Level-1 Kathara 12-Tree Grid** core template.

- Once the High Veca and Eckasha Code Sequences are Imbedded/induced into the Level-1 Kathara Grid, they are then **Activated** in the Kathara Grid by **TONING** the corresponding **Veca Code Ariea Sequence**. The longer toning is sustained, the greater will be the quantity and quality of Veca Code Activation.

- Once Activated, the Veca Code programs travel upward through the stages of the **Transduction-Manifestation Sequence** from the **Kathara Grid**, to the **Shields**, into the **Keylon Crystal Body Morphogenetic Field,** then into the **Merkaba Field**, **DNA Template** and **Hova Body/ Radial Body Levels**, temporarily restoring the **Christiac Merkaba Field**, **Radial Body** and **Memory Matrix Divine Blueprint**. **Frequent and continued use** of the Veca Codes will progressively build **Critical Mass** of the **Divine Blueprint program simultaneously** within **ALL levels** of the 15-Dimensional Anatomy, eventually culminating in expedited full restoration of the D-12 Maharic Shield blueprint within the Body-Mind-Spirit system, via the Radial Body Trion-Meajhe Field.

- Activation of the Yunasai and High Veca Codes within the personal body **prior to conducting a Kathara Client Healing Session** will cause the facilitator's **Level-3 DIODIC GRID to activate**, temporarily **transmitting Veca Code sub-harmonics.** This will cause the **minute Diodic Chakras** in the facilitator's **FINGER TIPS** to activate **if the Palm Chakras** have been activated with either pure **Maharata Current** or a selected **Triadic Phase Current.** The facilitator will then **automatically transmit** Veca Code sub-harmonics into the client's **Diodic Grid** while conducting general Kathara Healing applications, allowing the client to benefit from temporary **Radial Body healing support**, which will **amplify the effects** of all healing applications.

- A more **Temporary Imbedding and Activation** of the Veca Code program can be achieved through **OPTICAL-PINEAL INDUCTION**, whereby the **eyes** are focused for a time upon the **Image** of the **Symbol Code.** The mathematical Veca Code program enters the **Pineal Seals** through the **Optical Currents** and **6th Chakra,** an then travels for Imbedding/induction through the **Central Vertical Current** into the body regions and Crystal Seals Grid areas to which the Veca Code corresponds. The **Veca Tones/Arieas** are then used to Activate the Imbedded Veca Code Sequence.
- In **Optical-Pineal Induction**, the Veca Program looses a bit a **frequency charge/ strength** during is travel in the Central Vertical Current. This creates a **more temporary imbedding and activation** of the Veca Codes than that which is achieved through Direct Induction. Optical-Pineal Induction is useful for **daily amplification** of the Vecas, and for Kathara Healing Client Sessions and planetary grid "site work", when used in **combination** with the **full induction procedure** employed at least **once per week**.
- To receive **full benefit** of **Veca Code Radial Body Healing** applications, **Technique-2** ***The Kee-Ra-ShA Activation Sequence*** should be fully run at least **ONE TIME**. *Technique-2* can also be used occasionally thereafter if desired to create **intensification and amplification** of the Primal Life Force Currents during Kathara, Merkabic and Veca Code Healing technologies.
- Frequent use of **Technique-13: The "Song of Lyra**" Christos Invocation will amplify all Kathara, Merkabic and Veca Code Radial Body Healing applications.

The Christos-Trion-Meajhe Fields, High-Veca Codes and Universal Life Force Currents

One 15-Dimensional Time Matrix with 5 Harmonic Universes

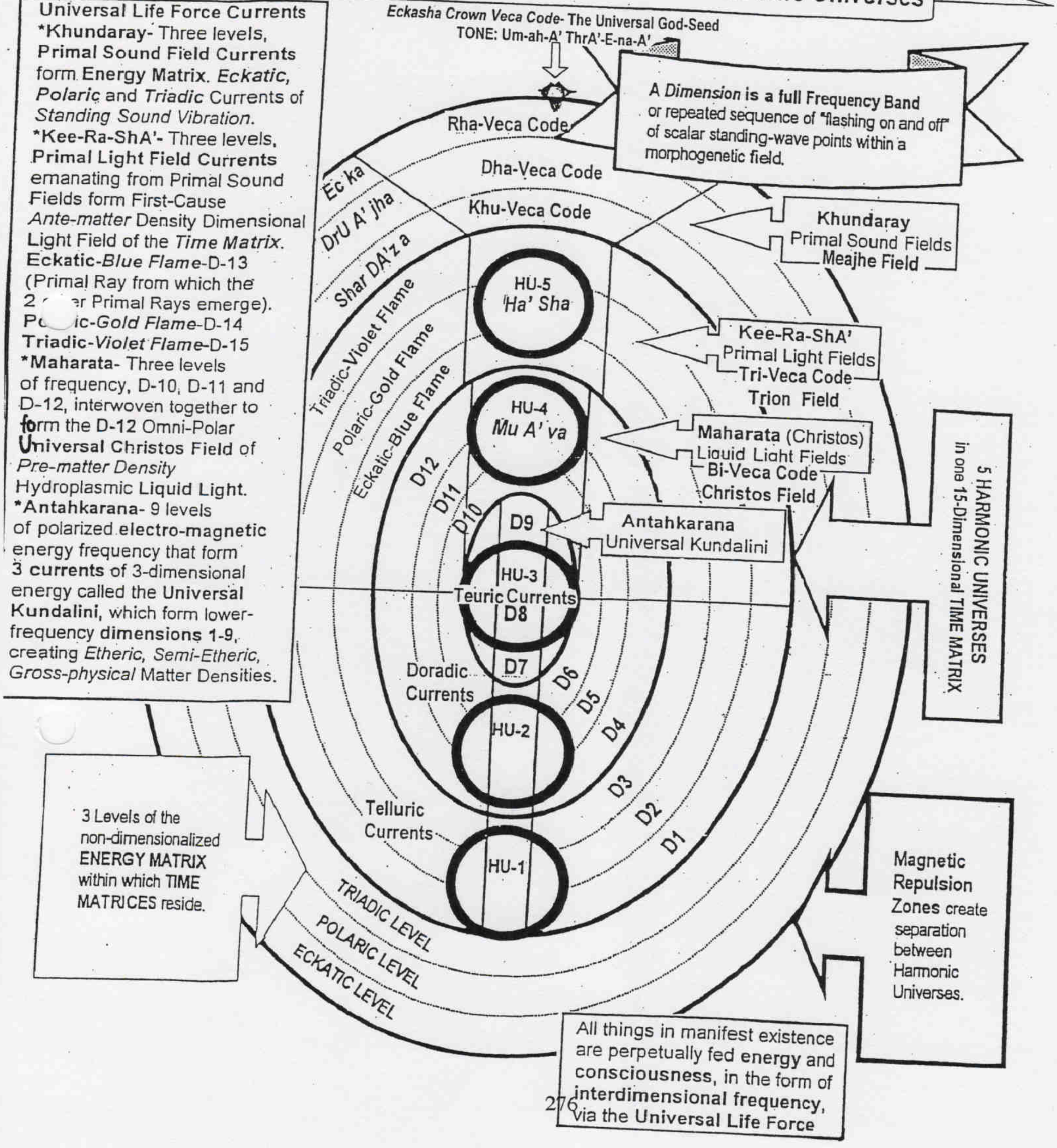
Eckasha Crown Veca Code- The Universal God-Seed
TONE: Um-ah-A' ThrA'-E-na-A'
Rha-Veca Code
Dha-Veca Code
Khu-Veca Code
Ec ka
DrU A' jha
Shar DA'z a
Triadic-Violet Flame
Polaric-Gold Flame
Eckatic-Blue Flame
HU-5
'Ha' Sha
HU-4
Mu A' va
D12
D11
D10
D9
HU-3
Teuric Currents
D8
D7
D6
D5
D4
D3
D2
D1
Doradic Currents
HU-2
Telluric Currents
HU-1
TRIADIC LEVEL
POLARIC LEVEL
ECKATIC LEVEL
Khundaray
Primal Sound Fields
Meajhe Field
Kee-Ra-ShA'
Primal Light Fields
Tri-Veca Code
Trion Field
Maharata (Christos)
Liquid Light Fields
Bi-Veca Code
Christos Field
Antahkarana
Universal Kundalini
5 HARMONIC UNIVERSES
in one 15-Dimensional TIME MATRIX

Universal Life Force Currents
Khundaray**- Three levels, **Primal Sound Field Currents** form **Energy Matrix.** ***Eckatic, Polaric and ***Triadic*** Currents of *Standing Sound Vibration.*
***Kee-Ra-ShA'**- Three levels, **Primal Light Field Currents** emanating from Primal Sound Fields form First-Cause *Ante-matter* Density Dimensional Light Field of the *Time Matrix.*
Eckatic-*Blue Flame*-D-13 (Primal Ray from which the 2 other Primal Rays emerge).
Polaric-*Gold Flame*-D-14
Triadic-*Violet Flame*-D-15
***Maharata**- Three levels of frequency, D-10, D-11 and D-12, interwoven together to form the **D-12** Omni-Polar **Universal Christos Field** of *Pre-matter Density* Hydroplasmic **Liquid Light.**
***Antahkarana**- 9 levels of polarized **electro-magnetic** energy frequency that form **3 currents** of 3-dimensional energy called the **Universal Kundalini,** which form lower-frequency **dimensions** 1-9, creating *Etheric, Semi-Etheric, Gross-physical* Matter Densities.

A *Dimension* is **a full Frequency Band** or repeated sequence of "flashing on and off" of scalar standing-wave points within a morphogenetic field.

3 Levels of the non-dimensionalized **ENERGY MATRIX** within which TIME MATRICES reside.

Magnetic Repulsion Zones create separation between Harmonic Universes.

All things in manifest existence are perpetually fed **energy** and **consciousness,** in the form of **interdimensional frequency,** via the **Universal Life Force**

Technique # 4

Restoring the Trion Field-Photo-Radionic Healing

Regular use of this technique will strengthen and improve RRT Planetary healing Applications (excerpt from Kathara Level-2)

Creating a Personal Bio-field Link to the Universal Christos-Trion-Meajhe Field

Masters Merkaba Mechanics

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Exercise-1: **Once** per day, do **Maharic Insta-Seal** then practice **each set of Veca** tones separately while fixating **visual focus** on corresponding **Veca-Code** symbol; spend at least **three or four minutes** gazing at each symbol (optical-pineal induction) while **toning** corresponding tones (core template vibrational induction) With practice this will progressively expand the personal consciousness while activating the personal Christos-Trion-Meajhe Field of your Christos-Rishiac-Ascended Master identity levels within the cellular structure.

Exercise-2: Once per week, directly after completing **Exercise-1**, place all Veca-Code symbols over designated body areas, activate Maharic Shield, breathe D-12 Maharata Current through each symbol and body area to **induce code**, using the Bi-Tri-Khu-Dha-Ra Sequence, then begin **toning** the corresponding tones following the Bi-Tri-Khu-Dha-Ra Sequence. Memorize the tone sequence of the 5 High-Veca Codes as if it were a "**song**" and relax, close eyes and sing/tone this "song" (Psonn) for **5 to 10 minutes**. The longer you tone, the more frequency power you build within the body and the stronger your link will be to the Universal Christos-Trion-Meajhe Field. This exercise can also be used with groups, either singularly to create and amplify Christos-Trion-Meajhe Field links or just prior to beginning RRT work. Frequent and consistent use of these two exercises will progressively develop the spin-rate capacity of the personal Christos Merkaba Field, while expanding higer consciousness within the body and progressively enhancing the health, immunity and integrity of the Mind-Body-Spirit system.

The High-Veca Codes

Universal Time Codes for Primal Frequency Access

Cosmic Codes of Immanuyana

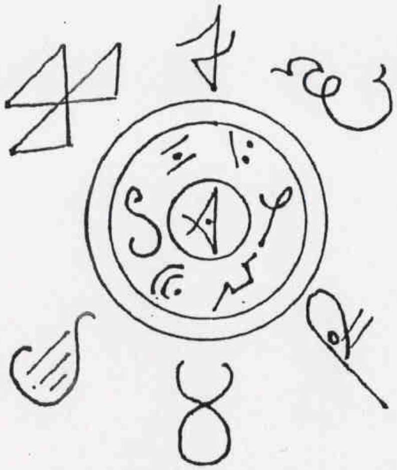

The Rha-Veca Code
Primal Sound-3 Eckatic
called the *Ec ka*
TONE:"*Rha Ec' ka*"
Symbol Placement:
Tailbone

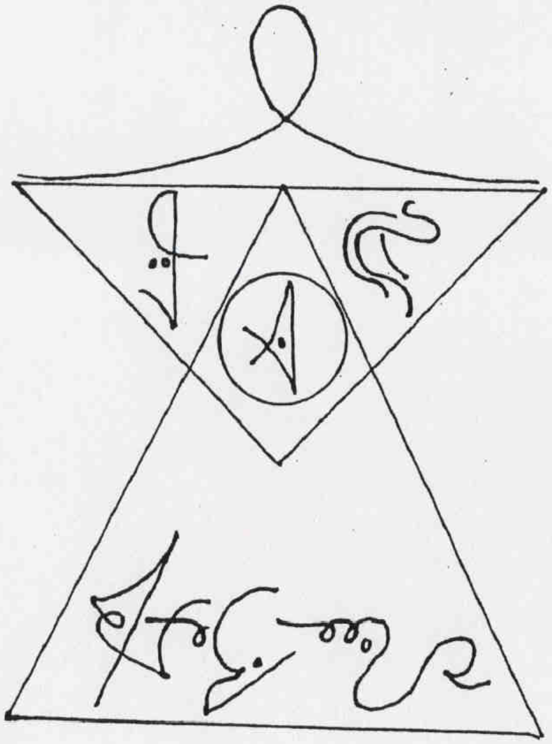

The Dha-Veca Code
Primal Sound-2 Polaric
called the *DrU A' jha*
TONE: "[illegible]' *Dru A' jha*"
Symbo[illegible] [illegible]acement:
Chakra-2 (just below naval)

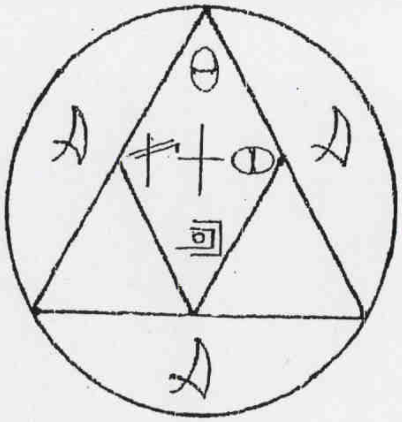

The Khu-Veca Code
Primal Sound-1 Triadic
called the *Shar dA'z a*
TONE: "*Kh*[illegible]*har DA'z a*"
Symbol Placement:
Chakra-8 Front (clavicle)

Universal Codes of Immanuel

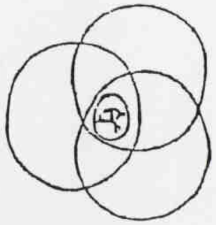

The Tri-Veca Code
Density-5 Dimensions 13-14-15
called the *Ha' Sha*
TONE: "*Kee' Ra ShA Ha Sha*"
Symbol placement:
Left Foot bottom

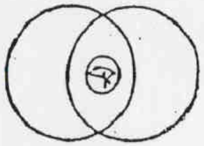

The Bi-Veca Code
nsity-4 Dimensions 10-11-12
called the *Mu A' va*
"*Ma ha ra' ta Mu A' va*"
Symbol placement:
Right Foot bottom

Technique # 11

Restoring the Meajhe Field-Photo-Sonic Healing

1. Use **Technique-6:** ***The Maharic Quick Seal*** to activate your Maharic Shield, Seal and Maharata Current.
2. **Stare at image** of the **Eckasha Code** for a few seconds, then gently begin to **"Cross Eyes"** until you can see a **"Double Image"** of the *Eckasha* when looking at the image. **Hold " Eye Cross"** focus while taking **three rapid breaths**; on each **EXHALE** projecting a **stream** of (D-6) **INDIGO current** from your **6th "3rd Eye" Chakra** at forehead. (This braids D-6 Optical Currents into a D-12 Current to carry the Eckasha program into the Pineal Seals.). Un-cross eyes, relax visual focus and close eyes for a moment or two.
3. **INHALE** several breaths of **Pale Silver D-12 Maharata Current** up from the **Earth Core** through your **Maharic Cord**, on each **EXHALE** depositing the Maharata Current in the **Pineal Gland** at the center of the brain, to form a Pale Silver **"Maharata Ball"** in the Pineal.
4. Breathe gently and **return visual focus to the image of the Eckasha**, focusing upon the **Eckasha Core** ***REUCHE'*** (the "Double Circles and their content at center of Eckasha).
5. **EXHALE** while projecting a **stream of INDIGO current** from the **6th Chakra** at forehead, into the **REUCHE** symbol before your eyes. **INHALE** while drawing the **INDIGO current stream** with the **REUCHE image at its end** back through the **6th Chakra** and into the **Maharata Ball** in the **Pineal.**
6. **INHALE** one more breath of **Maharata Current** up from **Earth Core** to the **Maharata Ball** at the **Pineal**, then use a forceful EXHALE to PUSH Eckasha-Reuche encoded Maharata Ball out to the right, to the "Mentor" position over the right shoulder. Visualize the Maharata Ball growing to the size of a "Basket Ball" over the right shoulder, and visualize the image of the Reuche as expanding to fill the inside of the Maharata Ball.
7. **INHALE forcefully** while drawing the **Maharata Ball** back to a position **centered around your head**, then use **three breaths** to **INHALE Maharata Current** up from **Earth's Core to Pineal** and **EXHALE** the **Maharata Current outward** to fill **and expand the Maharata Ball.**
8. Visualize the **Maharata Ball** expanding outward from around your head, until the Maharata Ball **fully encompasses your body and entire Chakra System**, from **Chakra-14** 36" above head to **Chakra-13** in Earth Core. Imagine that your entire body is now surrounded by a 3-dimensional "Eckasha Tear-Drop" shaped CLEAR CRYSTAL CAPSULE. The Eckasha Code Photo-Sonic Capsule is now temporarily activated in your Inner Templar system.

Eckasha Crown Veca Code- The Universal God-Seed

Tone: Um ……⇩ ah…………A' ⇧ ThrA'……⇩ E'- ⇩ na……A

Symbol Placement: Pineal Induction via Chakra-6 "3rd Eye"

The Yunasai-Eckasha God-seed Code

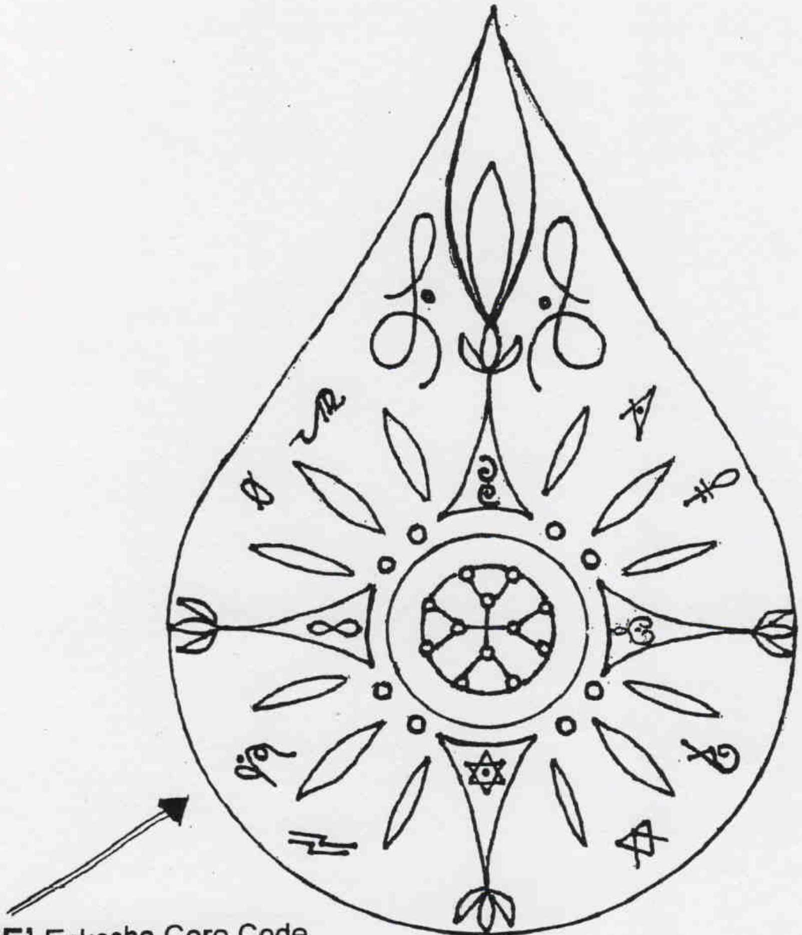

The REUCHE' Eckasha Core Code

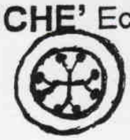

Technique # 13

The Song of Lyra Christos Invocation

The Vectos Invocations

The Vectos Compendium Declariti

The Vectors Collective Declarations

(All self incarnations in all Time Vectors declaring in Unity as the Avatar Self)
English translation from Elohei-Anuhazi Emerald Covenant Decree Texts:
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The Mah'-ah' Bi-Vectus Declaritum
Declaration of the Maharata

(Intention Decree AS the personal D-12 Christos Avatar Maharata self identity)

I decree now in this moment of KNOWING that all things here within me
are hence forth restored to the original Divine Intention of the ONESELF that is MINE.

I release now all bonds of manifest illusion that place veils of SELF-forgetting before mine eyes.
I revoke all separations of duality through which my Heart is rendered numb with disillusion and discord.

In this moment I reclaim the Whole of my Condition, reaching forth into the depths of all creation to now call my SPIRIT home.

I AM the Sun of the Radiant Glowing. I AM the HEART of Divine LOVE. I AM the Still Point of the Face of All Creation. I AM the Voice of the Universal Song.

I decree now in full remembered Knowing that I AM ALL and WE are ONE.
In setting forth this decree of my Eternal Divine Power, I shall render Divine Intention only, through which the All and I are equally served
in the Highest Order of our collective Best Divine Intention.

I call now unto the many Selves and Shadows ensconced within the illusions of time, and decree unto thee that I AM THIS, I AM.
I AM the wind that brushes thy faces.
I AM the rain that renews thy field.
I AM the Whisper of the Breathe of God within YOU.
WE NOW are the expression of Divine Heart, Mind and Hand.
WE are the Rumbling Hymn Song of the earthen worlds of matter.
WE are the Prana-Breath of God Eternal, manifest.
We are the Waters of Eternal Life forever outward flowing.
We are the cooling, life force Flame of the Cosmic Fire expressed.
In our UNION now and always, declare WE in our Wholeness,
that all dissidence is rendered spent, all conflict NOW made healed.

As DIVINE NAME THIS.................(your Christos spiritual name)
I AS WE, the Maharata KHUM BI-Vec'TUS, (D-12 Christed Avatar Divine Blueprint self identity), DO NOW DECREE through the Divine Love, Wisdom and Power that is MINE....to express now AS this moment, the condition of **Mah'-ah BI-Vec'TI UN UR'-A-OR'-NaM' –OOR** (Christos beginning and ending NOW-completion of a manifest expression in its originally intended Divine Fulfillment, its past-present-future full expression made in the present time, clearing all duality, disharmony and distortion. Anchoring of the Divine Christos Maharata Blueprint in the moment). Upon this Invocation Divine Intention is rendered manifest in all conditions to which I now assign.

The Mah'-ah' Bi-Vec'tus Inavhoki
Invocation of the Maharata

(Creation Decree Invocation AS the personal D-12 Christos Avatar Maharata self identity)

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From this Still Point of my Wholeness in manifest decision,
I Decree in Sovereign Knowing, here expressed at my Command *(lovingly stated absolute intention)* ***the Divine Will and Intention of the ONE-SELF that is ONE GOD.***
The ONE-SELF that IS ONE GOD THIS I AM.

Mah–Hah-Rah-Tah KHUM BI-Vec'TUS ……………………(name)
I as D-12 Christos Avatar self…….(name)
IN-A-VHO'-KI UN' E-BLE'UM BI-Vec'TI
Invoke by Divine Loving Command Now, by the Power of the Universal Christos,
Mah'-ah BI-Vec'TI UN UR'-A- OR'-NaM' – OOR
the D-12 Divine Christos Blueprint past-present-future; NOW the Divine Sea of Liquid Light anchors in this moment.
E'-stA Un'-tA E'-Sa Tra'zd-Jha' HA'-A Rha
Absolutely now established, always and forever, in eternal abiding reverent Love of the Eternal ALL-ONE
’’tah-TA Um a Ah-ShA'-Lum
Blessed Be all embracing, given forth from the Still Point of Eternal Peace
Thah-A'-Jha in'ta DO A"
Spoken AS IT IS STATED, As SO It IS DONE
Um Sha'-DI UR'- A ah Khum' TUn
All Embracing Pillar of First Cause Light, I AS THIS expression now.

In the name of the Melchizedek Cloister Emerald Order Eieyani,
Holy Order of the Yunasai,
Sacred House of ONE.

English Translation:

Ma-Ha-Ra-Ta KHUM BI-Vec'TUS ……………………(name)
(Khum = "I AS") (Ma-Ha-Ra-Ta BI-Vec'tus = D-12 Christos Avatar Self)
iN-A-VHO'-KI UN' E-BLE'UM BI-Vec'TI
(*in-A-vhO-kI*= invoke by Divine Loving Command), (*UN*= Now), *(E-BLE'UM*= by the power of),
(Bi-Vec'ti = Universal Christos)
Mah'-ah BI-Vec'TI UN' UR'-A- OR'-NaM' – OOR
(Mah'ah Bi-Vec'tI= D-12 Divine Christos Blueprint past-present-future)
(UN Ur'-A- Or'-Nam' –OOR= Now the Divine Sea of Liquid Light anchors in this moment)
E'-stA Un'-tA E'-Sa Tra'zd-Jha' HA'-A Rha
(E'StA Un'TA E'Sa = Absolutely now established, always and forever)
(Tra'zd-Jha'= in eternal abiding reverent Love) (HA'-A Rha = of the Eternal ALL-ONE)
P'tah-TA Um a Ah-ShA'-Lum
(P'tah-TA UM = Blessed Be, all embracing) ("a" in this context = given forth from)
(Ah-ShA-Lum = the Still Point of Eternal Peace)
Thah-A'-Jha in'ta DO A"
(Tha-A-Jha inta= Spoken AS IT IS STATED) (DO A"= As SO It IS DONE)
Um Sha-DI' UR' A' ah Khum' TUn
(Um Sha- DI' UR'A = All Embracing Pillar of First Cause Light)
(ah Khum' TUn = I AS THIS expression now)

Everyone and Everything within the vicinity of Sacred G will get blasted with positive vibes that unlock energy and boost performance. Increasing the amount of Sacred G you use will increase the amount of energy you have.

Sacred G Stickers come in 6 unique designs:

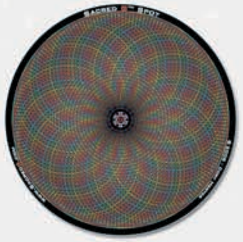

The **Sacred G Spot** is designed to physically cleanse your cells, freeing up more energy for the body to run more efficiently.

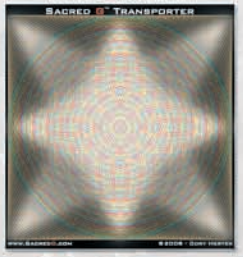

The **Sacred G Transporter** is designed to free up usable energy trapped as emotion in your past memories. Each night that you sleep on Sacred G, more and more energy is released restoring you to your natural state of Peaceful Bliss.

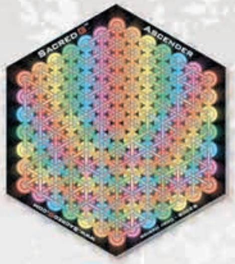

The **Sacred G Ascender** is designed to boost energy and increase self confidence by solving conflicts within your thoughts and belief systems. This enables you to perceive more information at once increasing your level of focus and reaction time.

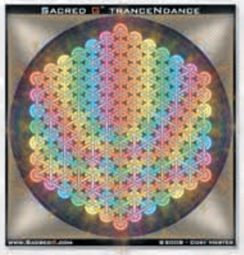

The **Sacred G TranceNDance** is a combination of the first three designs plus advanced memory systems that accelerate the learning and downloading of new information from the collective consciousness.

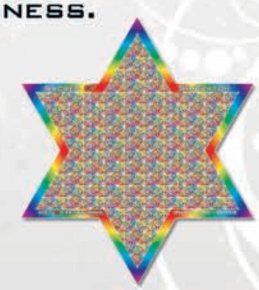

The **Sacred G Simulator** is designed to upgrade your friendships and relationships by attracting new productive ones while empowering you to let go of old ones that no longer serve you. This design will increase the number of synchronicities in your life and create an awakened sense of adventure and purpose.

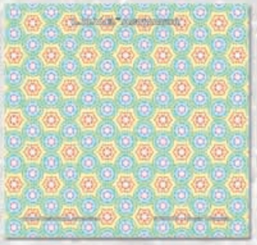

The **Sacred G L.O.V.E.™ Activator** combines all of the designs with a new motion activation system that takes you beyond your limits to achieve your goals. The Activator is the Ultimate State-of-the-Art DNA Activation Technology.

Visit the website to learn about the most advanced Sacred G Design called "Fusion" which incorporates every design into One.

Sleep / Pillow Case

Place the Sacred G beneath your pillow or inside your pillowcase design side up.

Notice how the Sacred G alters your sleep and dream states. The body frees up the most amount of energy while you sleep. Sacred G enhances this process continually increasing the amount of energy you feel.

Energized Water

Super Charge your water with Energy by placing it on top of the Sacred G.

Test: Take two glasses of tap water, place one on top of the Sacred G, and the other at least six feet away. Allow the water to charge overnight, then taste the difference between the two glasses in the morning. This test shows how Sacred G Technology not only cleans your water, but is also instrumental in physically cleansing the toxins from your body increasing energy.

"I will never ride a board that's not G'd out again!"

Rob Dyrdek

X-treme Performance Enhancement: Place the Sacred G on skateboards, surfboards, team uniforms, or any gear and equipment that you use. Watch as your performance is enhanced and your game is improved.

Visit the website to learn over 35 ways to use Sacred G to boost your energy, plus 5 cool tests that you can do. Also, be sure to watch the Sacred G episode on MTV's Rob & Big show to see how Sacred G can boost your Performance.

Visit the website to download all of the Sacred G Designs for FREE! Bonus: Watch a 3 hour video on the science of Sacred Geometry!

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Sacred G Spot

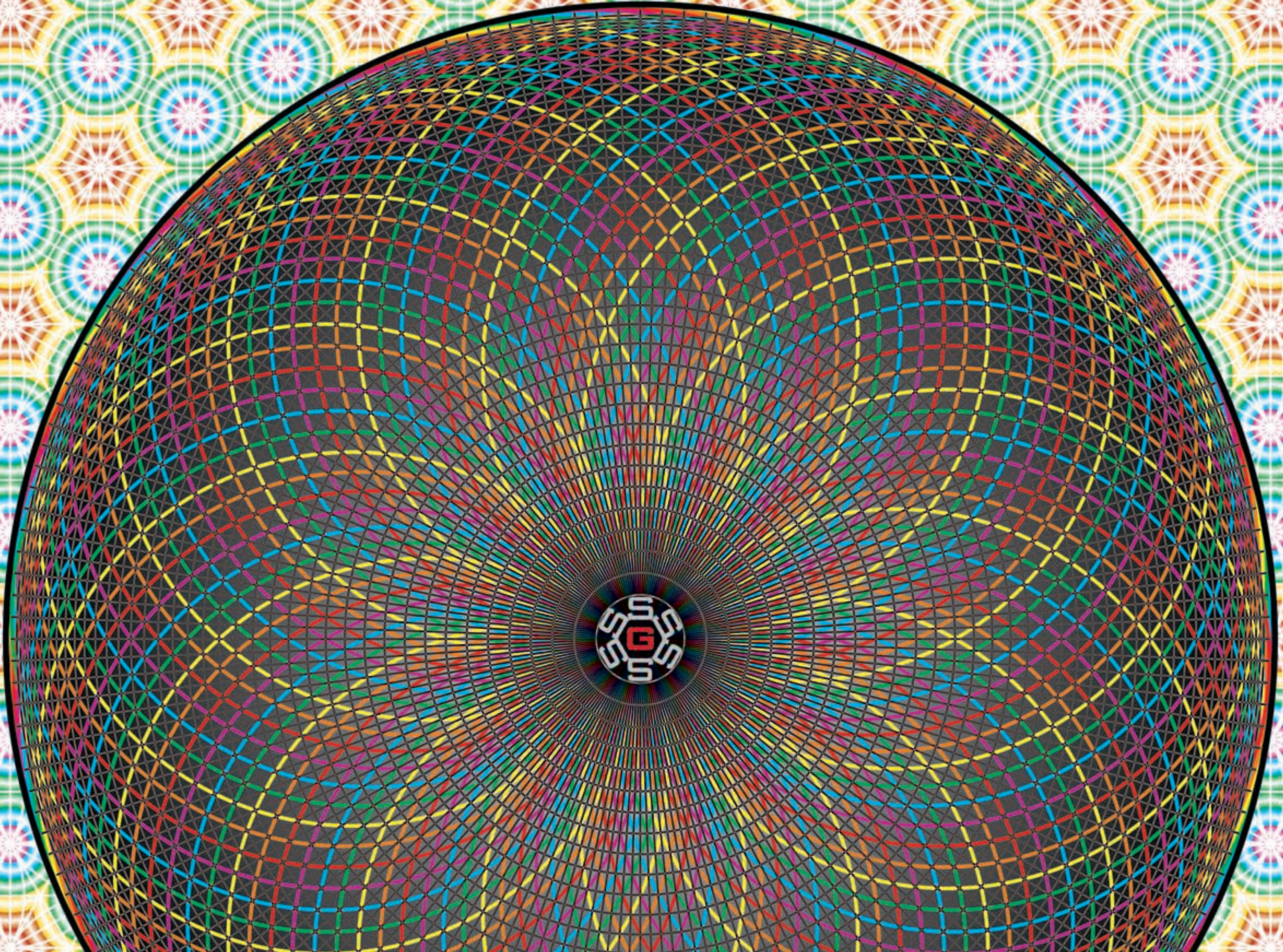

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Sacred G Transporter

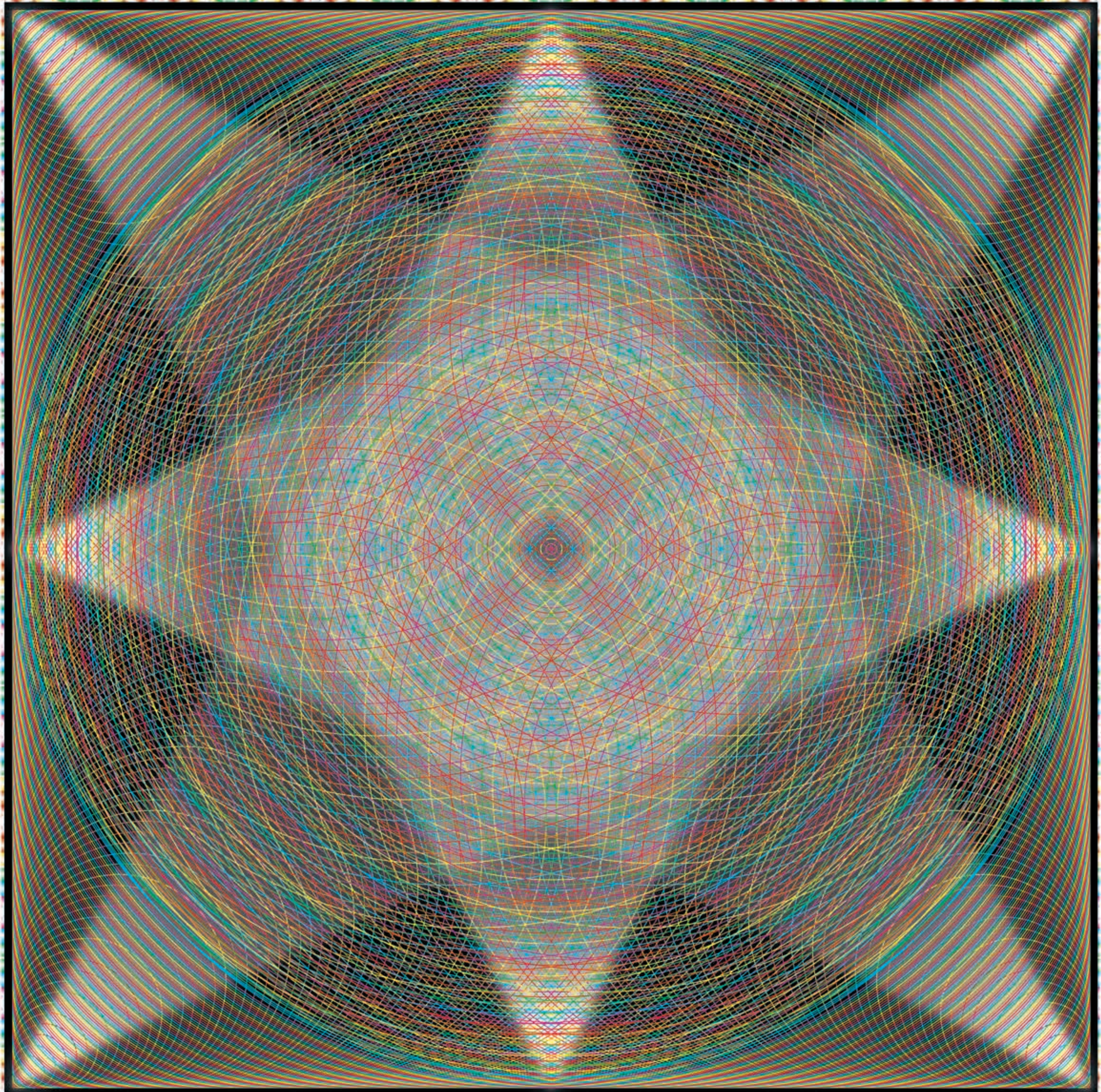

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Sacred G Ascender

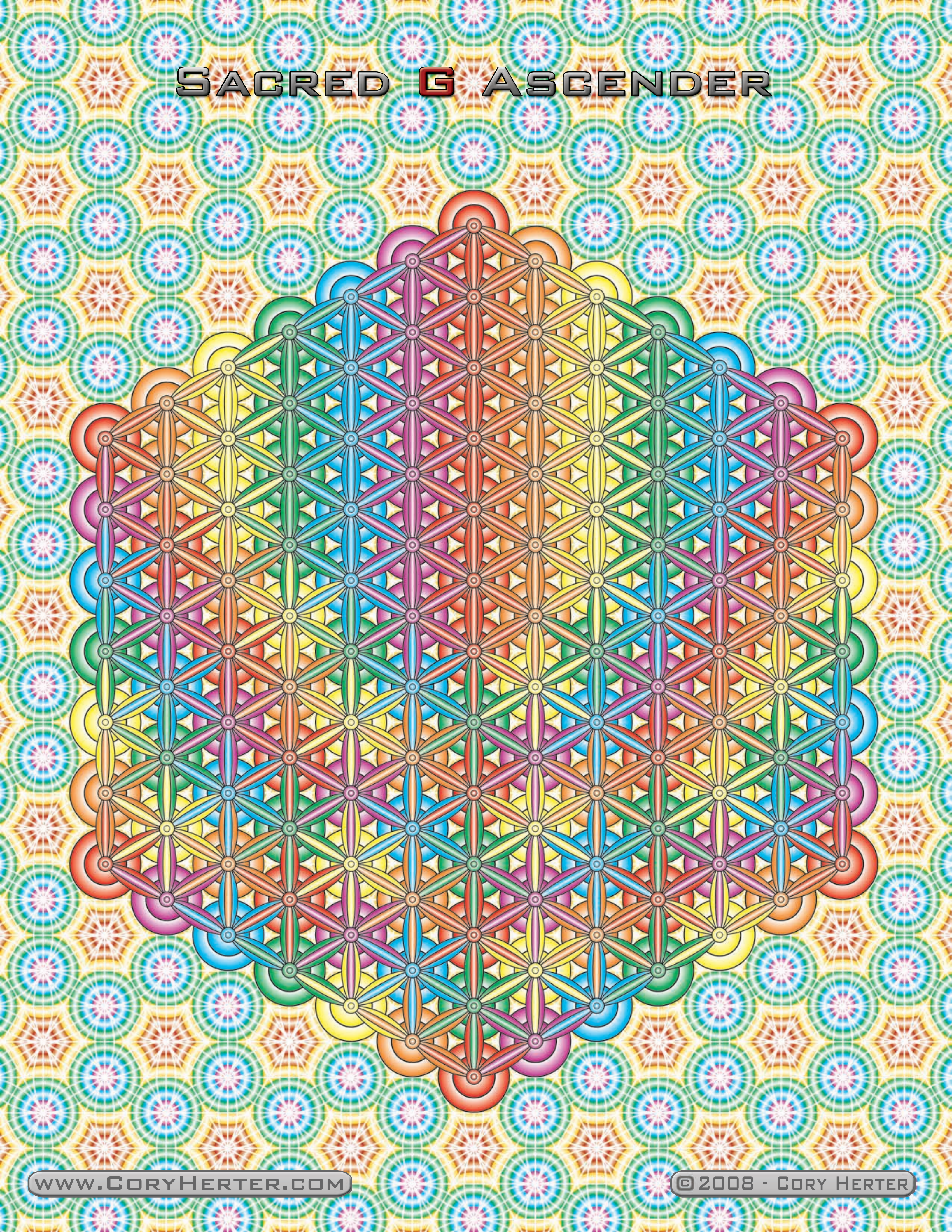

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Sacred G TranceNdance

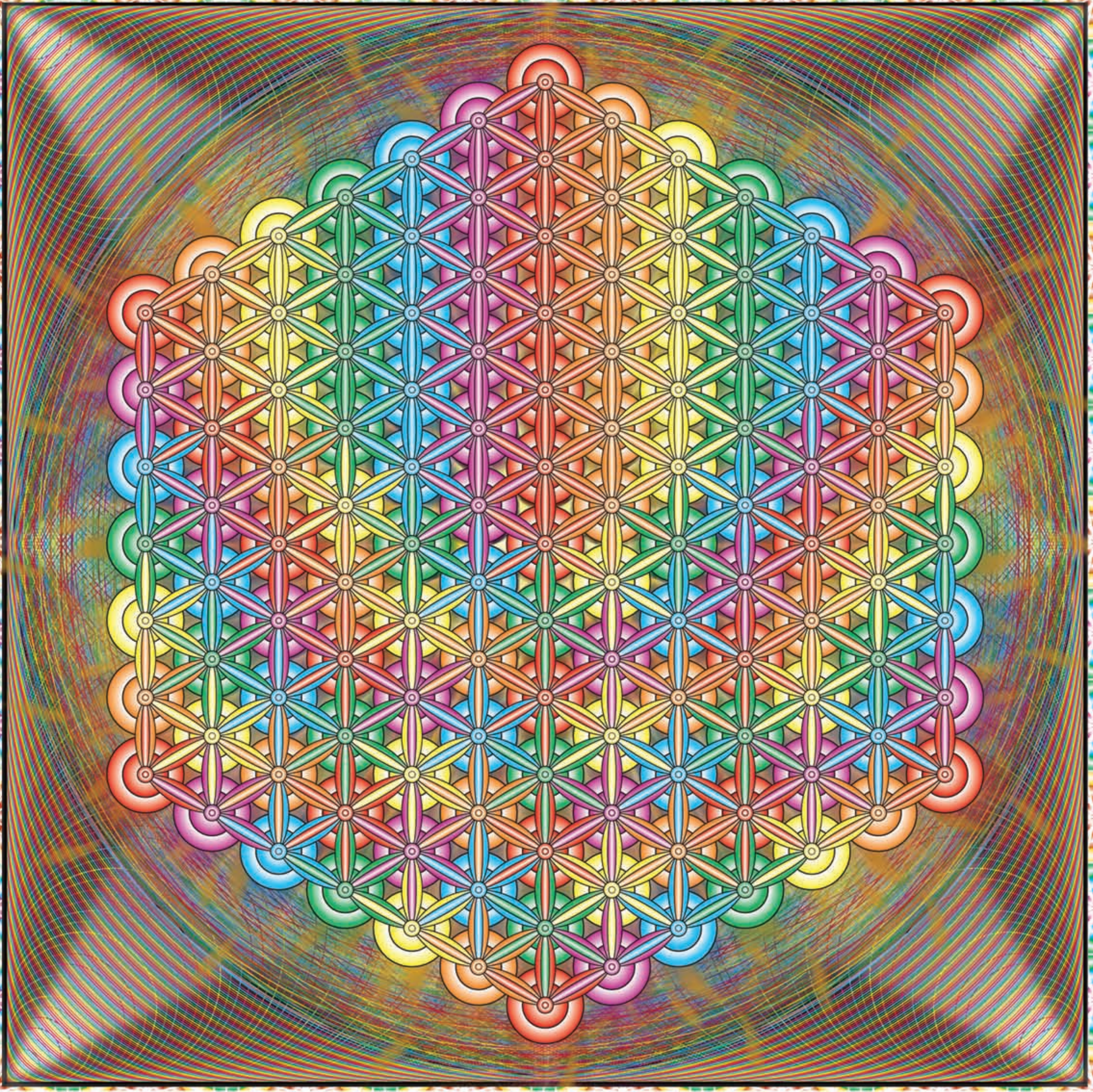

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Sacred G Simulator

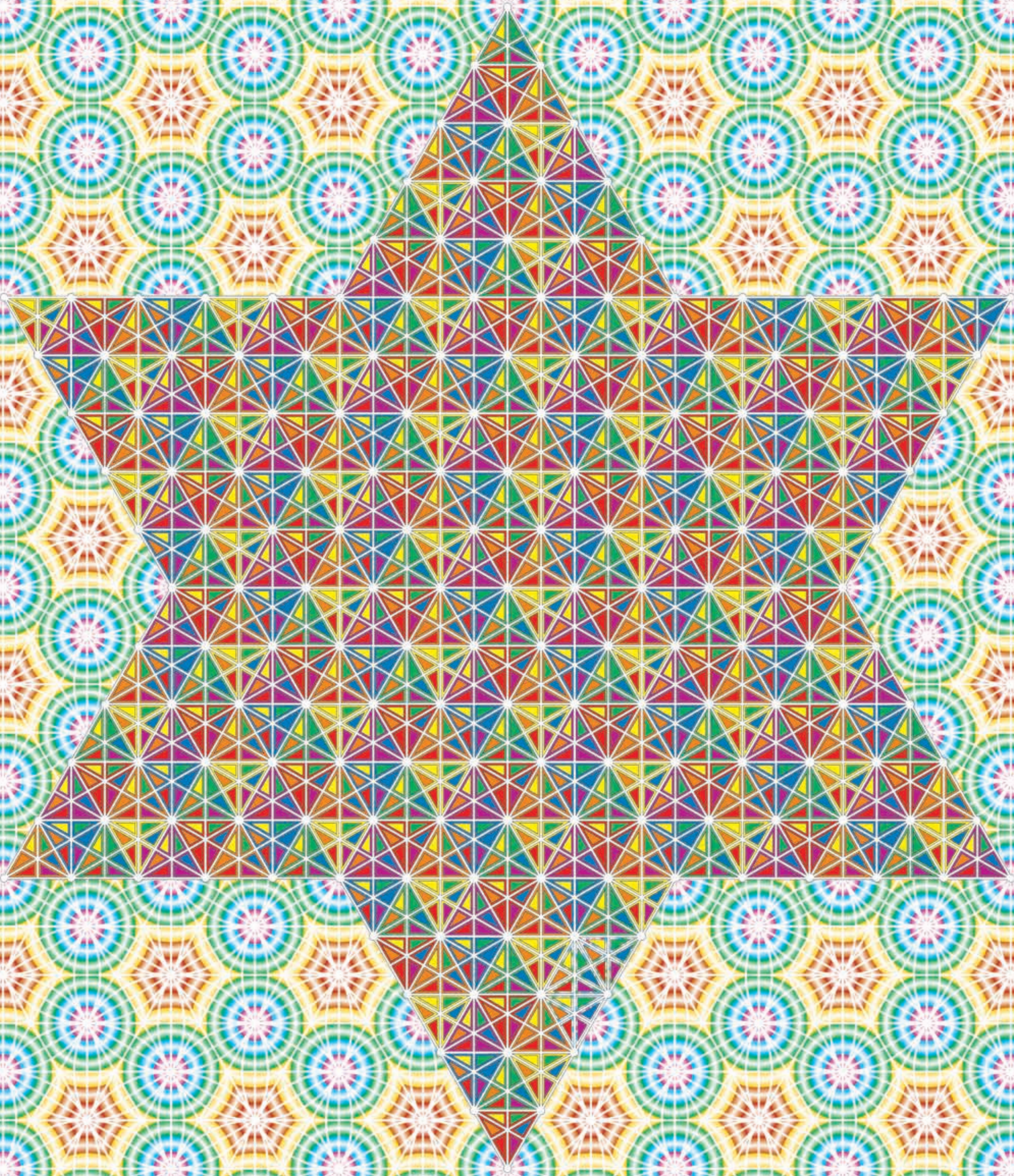

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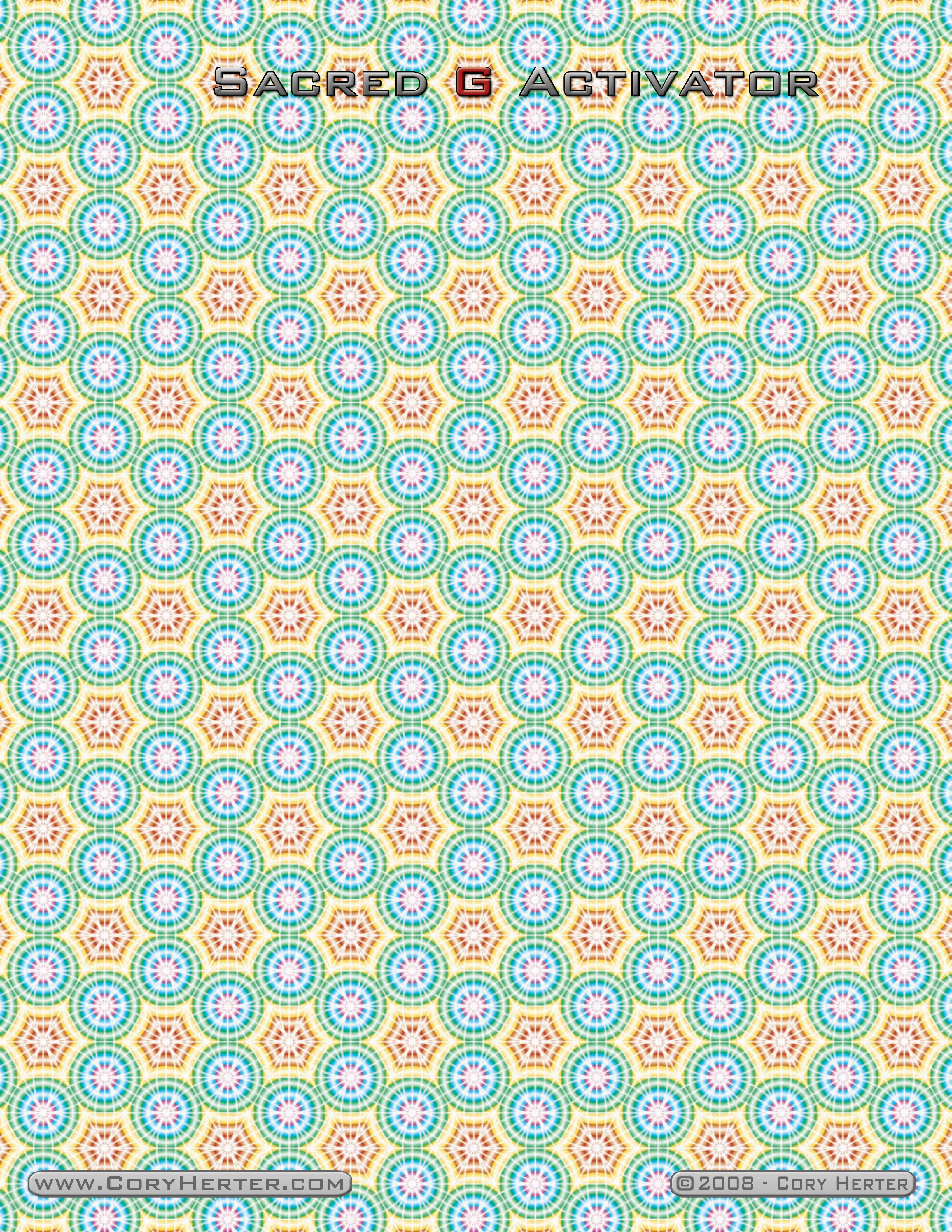

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Third edition

KNIGHT'S Forensic Pathology

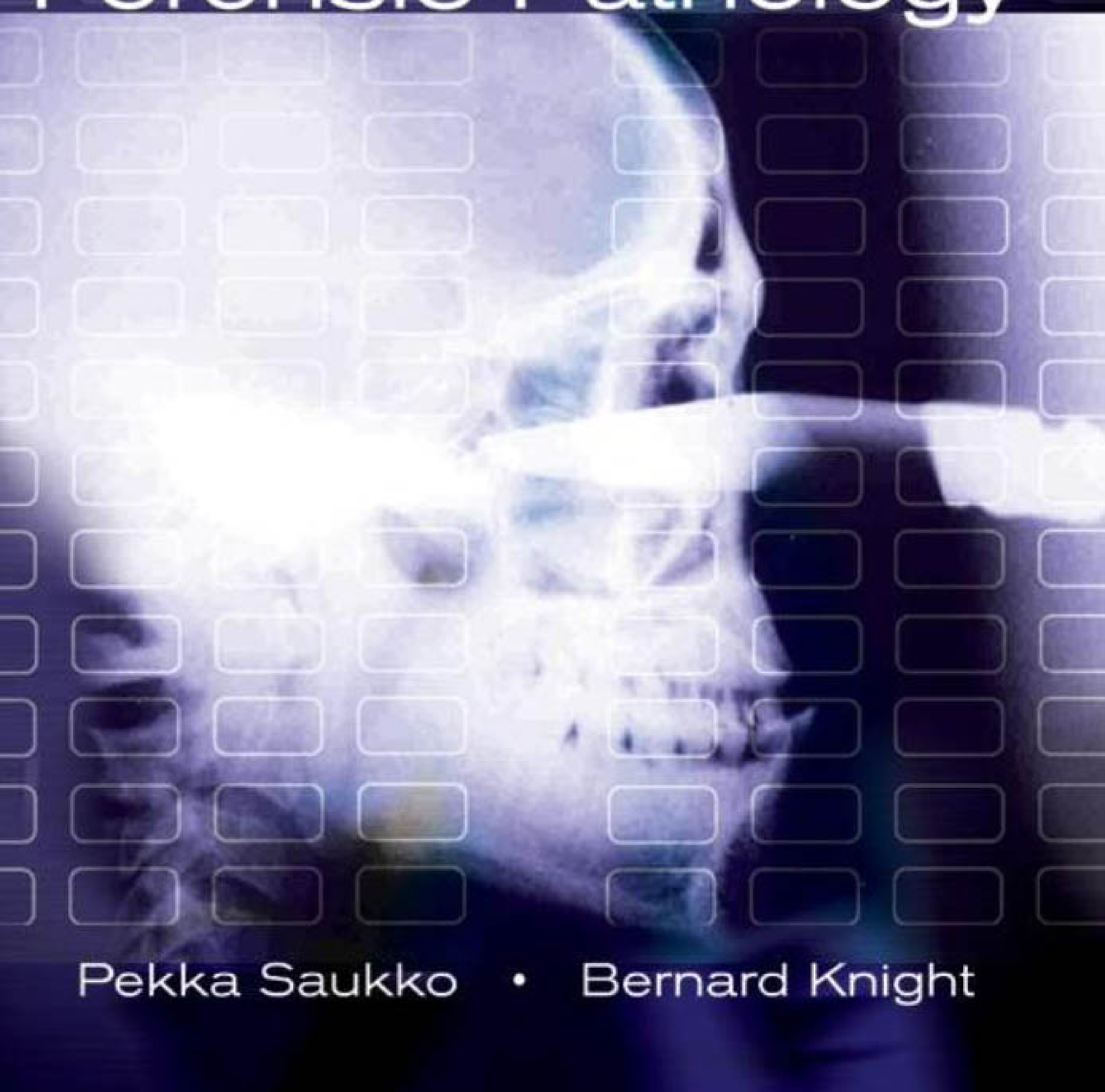

Pekka Saukko • Bernard Knight

KNIGHT'S
Forensic Pathology

Those who have dissected or inspected many bodies have at least learned to doubt, while those who are ignorant of anatomy and do not take the trouble to attend to it, are in no doubt at all.

Giovanni Morgagni 1682–1771
The Father of Morbid Anatomy

**Taceant colloquia. Effugiat risus. Hic locus est
ubi mors gaudet succurrere vitae.
(Let conversation cease. Let laughter flee.
This is the place where death delights to help the living.)**

Latin proverb

Seldom say never – seldom say always!

Forensic proverb

Third Edition

KNIGHT'S

Forensic Pathology

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Preface to the third edition

It is pleasant to record that the second edition of *Forensic Pathology* consolidated the international reputation of the original book as one of the foremost manuals of forensic pathology in the English language. This new third edition generally follows the same successful pattern, but there are some significant differences.

The editorship is being transferred to Professor Pekka Saukko and this volume is the product of the collaboration with the original author. As with previous editions, the text has undergone a complete revision to update where necessary and add new material where relevant. A major change is the extensive use of colour to replace original monochrome illustrations and in numerous new illustrations, including micrographs. More than 300 colour illustrations have been added, of which 175 are completely new from the archives of both the Cardiff and Finnish institutes, and others. Another major improvement has been in the reference material where both corrections and numerous additions have been made. 'Further reading' is intended for those readers who do not have access to electronic libraries and to offer an overview of the literature on a particular topic.

The new edition maintains the philosophy of evidence-based forensic pathology with emphasis on the avoidance of over-interpretation, which regrettably still leads to instances of miscarriage of justice.

It is hoped that the new edition of this well-established textbook, with its emphasis on practical procedures and common-sense evaluation of autopsy findings, will continue to be of assistance to forensic pathologists all over the world.

Pekka Saukko
Bernard Knight

Preface to the second edition

The most gratifying reception accorded in many parts of the world to the first edition of this book has led to the need for an updated version less than five years later. No radical changes have been made in the format, but like an airliner during its periodic major service, every part has been scrutinised and replaced where it has become outdated or defective. In addition, new material has been added where appropriate.

Forensic pathology, unlike its sister discipline forensic science, does not change quickly or have dramatic developments such as the current DNA revolution. Indeed, because its base is the interpetation of autopsy findings, forensic pathology still rests largely on the principles of morbid anatomy founded in the nineteenth century and earlier. However, this is not to say that it remains fossilised in the era of Virchow – new findings and techniques appear constantly, albeit at a measured pace compared with other disciplines. The most useful of these advances have been incorporated into this new edition.

In particular, the sections on child abuse, head injuries and traumatic subarachnoid haemorrhage have been amended or supplemented. Sixty new illustrations have been incorporated, and another area of attention has been the references and recommended reading, as there were some textual citations not listed in the first edition – and very many more have been added. However, the literature is now so vast, both in forensic journals and scattered profusely throughout other specialist publications, that it is futile to try to capture all of even the most seminal papers, which now need computerised and other modern library techniques for their retrieval.

One of the many reviewers of the previous edition complained that many of the references were old, but I make no apology for this. The value of a publication is in its content, not in its date, as Harvey's *De Motu Cordis* and Morgagni's *De Sedibus* clearly demonstrate! Some of the most valuable papers in forensic pathology were written decades or even a century ago; the critical writings of Moritz, Shapiro, Adelson, Helpern, Gonzales, Polson – right back to Taylor and Tardieu in the nineteenth century – are examples of careful observation and logical thinking which some modern pathologists, given to overinterpretation, would benefit from studying.

The critical attitude to every autopsy finding has been maintained in this new edition. A number of recent criminal trials and Appeals have emphasised the vital need for expert medical witnesses to be totally objective in their interpretation of physical findings. To quote from the new (1996) *Practice Guidelines* of the Policy Advisory Board in Forensic Pathology of the British Home Office: 'The evidence should be objective: speculation should be avoided. Unwarranted conclusions can never be defended. The role of the expert witness is not to provide the evidence which supports the case for the Crown nor for the defence, unless that opinion is objectively reached and has scientific validity.' Perhaps, in the interests of justice, an additional new forensic aphorism should be on the frontispiece: 'If you can't prove it, don't claim it!'

Bernard Knight
1996

Preface to the first edition

This is a textbook of forensic *pathology*, not forensic *medicine*. Though there is a considerable overlap, forensic medicine includes medical jurisprudence, the legal aspects of medical practice and many ethical matters, none of which are found – nor are intended to be found – in these pages.

Such topics have marked geographical limitations, as a result of legal, ethnic, cultural, and even religious variations from place to place. Even within the British Isles it is almost impossible to write a single book on medical jurisprudence that can do equal justice to the different legal systems of England and Wales, Scotland and Ireland.

The subject matter of this volume has no such geographical constraints, as it is solely concerned with the examination of the dead body for medicolegal purposes. Even in this limited sphere, police procedures and the habits of pathologists will vary considerably with country and with resources, but it is hoped that the routines, techniques and philosophy offered in this book will offer a guide to good practice that can then be modified according to local circumstances.

The contents are intended to lead the pathologist – and in some countries, the non-pathologist – through the procedures that are needed in the examination of a body found under obscure, suspicious, or frankly criminal circumstances.

In developed countries with sophisticated medicolegal systems, such autopsies will be performed only by forensic pathologists or by histopathologists with considerable experience, but in many areas of the world – especially the developing countries – lack of manpower and resources as well as considerations of distance and facilities mean that almost any doctor may be called upon to perform medicolegal examinations. For both of these classes of medical men and women this book aims to act as a guide and a source of reference.

The subject matter follows a fairly conventional pattern, but the treatment of each topic is designed to offer practical advice linked with a philosophical approach that leads the doctor to analyse and question the interpretations drawn from physical findings.

All too often, dogmatic opinions are derived from an unsound factual base, learned from lectures or textbooks that repeat previous dogma with little sense of critical evaluation. In some parts of the world forensic pathology is learned by rote from teachers who studied it themselves in the same fashion, and who have little or no practical experience in the hard schools of mortuary or witness-box. I hope that this book will at least stimulate trainee forensic pathologists to think twice, question and disagree – not least about some of the material in the following pages.

Some conventions have been discarded in the format of this book. The author feels that it is disruptive for ease of reading to have every line clogged with references to other authors, except where essential to the topic under discussion. Thus most references have been consolidated into groups, placed at the end of the appropriate sections in each chapter. In addition to actual references, there are many suggestions for further reading on the same topic. It is quite impossible to be comprehensive in offering relevant titles, as the amount published on forensic matters is now overwhelming, several hundred new titles appearing each month. A representative selection is offered, much of it quite recent – these papers themselves will then offer a relevant bibliography, so that the topic can be followed in almost geometric progression.

There is no discussion of forensic serology, as this is now a discipline of its own. Similarly, the toxicology is confined to a detailed consideration of the pathologist's role in obtaining samples and interpreting the results from the analytical laboratory. Though the most common poisons are discussed, this is purely from the autopsy aspect. Like serology, toxicology is now a vast subject that stands independently and it seems futile merely to scratch the surface in a text devoted to forensic morbid anatomy.

Another departure from the conventional text is that concise reminders of the forensic anatomy of important regions are given, adjacent to the topic under discussion. Many pathologists learned their anatomy a long time ago and it can be useful before an autopsy, or writing the report, or appearing in court, to have a quick refresher about the relations of the aortic arch to the second rib or the exact structure of the laryngeal cartilages. Illustrations in forensic textbooks are traditionally profuse and often spectacular. The only justification for a photograph is that it instructs, however, rather than entertains or shocks. This book uses photographs only where a relevant point is displayed, with a full caption that stands alone without having to refer to the text.

Many line drawings are used, as the author feels that they often get the message across better than a photograph, which of necessity contains irrelevant and perhaps distracting features. Similarly, many books are replete with anecdotal cases; these can be valuable, but often are more intriguing than useful. The space devoted to these can usually be put to better use and they are employed sparingly in this text.

Where the pronoun 'he' is used throughout this book, it is intended that the word 'she' is equally applicable, unless obviously inappropriate from the context.

Finally, an Appendix is offered with basic reference material on weights, sizes, temperatures, conversion tables and other useful facts. Histological and histochemical techniques relevant to forensic needs are given in detail.

Bernard Knight
1990

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CHAPTER 1

The forensic autopsy

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Though 'necropsy' is semantically the most accurate description of the investigative dissection of a dead body, the word 'autopsy' is used so extensively that there is now no ambiguity about its meaning.

The term 'post-mortem examination' is a common alternative, especially in Britain, where its meaning is never in doubt. Unfortunately, it suffers from a lack of precision about the extent of the examination, for in some countries many bodies are disposed of after external examination without dissection.

The forensic investigation of deaths was introduced relatively early from the requirements of the judicial system. The earliest known forensic dissections took place in Italy, probably in the middle of the thirteenth century, at the University of Bologna. The first one was recorded by William of Saliceto, a surgeon and a teacher on the medical faculty there. He lived from 1210 to 1277 and in his book *Surgery* he mentioned a case examined in about 1275. The principles of the modern medico-legal investigation were developed based on the codes of the sixteenth century Europe: the Bamberg Code in 1507, the Caroline Code in 1532 and later the Theresian Code in 1769. The hospital or clinical autopsy became meaningful first after the introduction of modern concepts of pathogenesis of diseases by Carl von Rokitansky (1804–1878) and cellular pathology by Rudolf Virchow (1821–1902). Further development of medico-legal autopsy has been greatly influenced by the judicial system adopted, the main emphasis in most countries being in the detection and investigation of criminal and other unnatural or unexpected deaths.

AUTOPSY STANDARDS

Discussions about the quality of the autopsy started at the beginning of the nineteenth century. The Austrian decree of 1855 included, in its 134 paragraphs, very detailed instructions as to the performance of medico-legal autopsies. The idea of quality control and quality assurance, first introduced into industrial production of goods in the twentieth century, found its way into medicine later via laboratory medicine. Although regional and national differences in this respect are huge and the pace of progress varies, there is need for standards in specialist education, continuing professional development, harmonization of investigative procedures and quality systems leading perhaps eventually to some form of accreditation of individuals and institutions.

In addition to the national measures to create guidelines and to harmonize the medico-legal autopsy, there has been an increasing international interest in achieving harmonized and internationally recognized rules on the way autopsies should be carried out. In 1991, the General Assembly of the United Nations endorsed the Model Autopsy Protocol of the United Nations. The European Council of Legal Medicine (ECLM) document 'Harmonisation of the Performance of the Medico-Legal Autopsy' was adopted by the General Assembly in London 1995. The latter document served largely as basis for the Pan-European Council of Europe – *Recommendation No. R (99) 3 On the Harmonisation of Medico-Legal Autopsy Rules and Its Explanatory Memorandum* – which was adopted by the Committee of Ministers in February 1999 (see Appendix 2, p. 610). Although the document is a 'recommendation' by nature, it has legal implications, because Council of Europe member countries have to implement these principles into their national legislation.

TYPES OF AUTOPSY

Though medical conventions and legal systems vary considerably from country to country, there are generally two main types of autopsy:

- The **clinical** or **academic autopsy** is one in which the medical attendants, with the consent of relatives, seek to learn the extent of the disease for which they were treating the deceased patient. In most jurisdictions this type of autopsy should not be held to determine the nature of the fatal disease because, if this was unknown to the physicians, the death should have been reported for medico-legal investigation.
- The **medico-legal** or **forensic autopsy**, which is performed on the instructions of the legal authority responsible for the investigation of sudden, suspicious, obscure, unnatural, litigious or criminal deaths. This legal authority may be a coroner, a medical examiner, a procurator fiscal, a magistrate, a judge, or the police, the systems varying considerably from country to country.

In most systems the permission of the relatives is not required, as the object of the legal investigation would be frustrated if the objections of possibly guilty persons could prevent the autopsy.

In many jurisdictions the medico-legal autopsy is often further subdivided into:

- those held on apparently non-criminal deaths, such as accidents, suicides, deaths from sudden natural causes, or associated with medical and surgical treatment, industrial deaths, and so on
- the truly forensic autopsy held on suspicious or frankly criminal deaths, usually at the instigation of the police. These deaths comprise murder, manslaughter, infanticide and other categories that vary in different jurisdictions.

The type of pathologist that deals with these categories also varies from place to place but, as the systems are so diverse, there is little point in discussing the details. What is much more important is that whichever pathologist tackles each type of case, he or she should be trained and experienced in that particular field. Unfortunately, either from lack of staff and resources or because the system is deficient, medico-legal autopsies – especially of major criminal cases – are frequently performed by pathologists inexperienced in forensic procedures.

Another serious defect in many countries is the separation of those who practise forensic pathology from those who profess to teach it in universities. It is impossible to be a credible and convincing teacher unless one has continuing practical experience of the subject.

Even more unfortunate is the performance of medico-legal autopsies by doctors who have no training in pathology at all. Though lack of resources make this a widespread and inevitable practice in many developing countries, the same regrettable practice is seen in some parts of Europe, the Americas and elsewhere. This is to the detriment of the high standard of expertise that is vital for the support of law enforcement and the administration of justice. A poor opinion is often worse than no opinion at all, as in the latter case, the legal authorities will at least be aware of the deficiency in their evidence, rather than be misled by the often dogmatic inaccuracies of an inexperienced doctor.

THE PROCEDURE FOR A FORENSIC AUTOPSY

Though the actual performance of an autopsy is fairly uniform whatever the nature of the death, there are a number of associated matters that vary according to the circumstances. For example, the procedural precautions required in a murder are not necessary in a sudden natural death, and the dissection in a criminal abortion or fatal rape is different from that upon a drowned body.

There are, however, many facets of the autopsy that are common to every death. These will be discussed in turn here, though the full significance of each item is discussed in detail in other chapters.

The objectives of an autopsy

- To make a positive identification of the body and to assess the size, physique and nourishment.
- To determine the cause of death or, in the newborn, whether live birth occurred.
- To determine the mode of dying and time of death, where necessary and possible.
- To demonstrate all external and internal abnormalities, malformations and diseases.
- To detect, describe and measure any external and internal injuries.
- To obtain samples for analysis, microbiological and histological examination, and any other necessary investigations.
- To retain relevant organs and tissues as evidence.
- To obtain photographs and video for evidential and teaching use.
- To provide a full written report of the autopsy findings.
- To offer an expert interpretation of those findings.
- To restore the body to the best possible cosmetic condition before release to the relatives.

Preliminaries to an autopsy

Before the body is even approached, a number of preliminaries are necessary.

AUTHORIZATION AND CONSENT

A medico-legal autopsy is carried out at the behest of the appropriate authority. The pathologist must not begin his examination until he is satisfied that such authority has been issued in respect of that particular death. The means of delivering such authority will vary from place to place: it may be a written document, a verbal or telephoned message, or a tacit standing arrangement.

Where two official organizations are involved, it must be clear who has the premier right to order an autopsy. For example, in England and Wales, the police may request a pathologist to examine a body externally at the scene of death, but the right to order an autopsy is the sole prerogative of the coroner. Though in serious incidents he or she should take the advice of the Chief of Police regarding the choice of a pathologist, the final decision remains that of the coroner.

As stated earlier, in a medico-legal autopsy the relatives are not consulted for their consent to autopsy, as such permission cannot be withheld. As a matter of courtesy it is usual to inform them before the autopsy is carried out unless the circumstances are too urgent. In most cases, however, a relative will have attended to identify the body before the examination begins. Pathologists should be cautious about performing autopsies where the authorization or consent aspects are not clear. It sometimes happens that a 'consent document' for a hospital death has been obtained but the case has later been reported for medico-legal investigation. The pathologist should not then proceed under the 'consent' authority until the coroner or other official has decided whether to order his own autopsy (perhaps using another pathologist). If that official decides not to proceed, then usually the consent document becomes valid once more.

Permission for the retention of material from an autopsy (ranging from small fluid samples to the entire body, if necessary) is usually covered in a medico-legal case by the original authority issued for the examination. There is, however, considerable variation in the legal aspects of tissue and organ retention in different countries, and each pathologist must become fully conversant with local regulations.

In the legislation controlling the English coroner, it is not only permissible, but also obligatory, for the pathologist to retain any tissue that may assist in the further investigation of the death.

However, the coroner (or procurator fiscal in Scotland) has only a negative power to forbid the use of tissues or organs for purposes other than the investigation of the death, and so cannot give positive consent for the use of these for transplantation, teaching or research; such permission must be obtained from the relatives, if the coroner does not object, under the Human Tissue Act 1961 and the forthcoming Human Tissue Act 2005.

Who may be present at an autopsy

Once again, each nation or state has different legislation and regulations on the conduct of medico-legal examinations. Though it is pointless to try to survey these, it must be emphasized that every pathologist must learn and abide by the laws applicable to his or her position.

Often the relatives of the deceased person, or an accused person, must be informed of the place and time of the autopsy so that they may be represented by a lawyer or doctor acting on their behalf. In some jurisdictions, including Britain, there is nothing that specifically forbids the relatives attending in person and the authors have had several experiences of this nature. It is open to the pathologist to refuse to conduct the autopsy if he objects to their presence.

In many homicides, a second autopsy is performed by another pathologist acting on behalf of the defence lawyers representing the accused person. This usually takes place at a later date, after the accused has been charged and granted legal representation, but sometimes the second pathologist will attend the original autopsy. This is quite in order and is more valuable than a later exploration of extensively dissected and autolysed tissues.

The permission for such attendance is granted by the coroner, medical examiner, or equivalent legal authority. The first pathologist should grant his colleague every courtesy and facility in the expectation of similar behaviour when the roles are reversed.

Others entitled to be present naturally include the officials or deputies of the department ordering the autopsy – for example, a coroner, magistrate or judge. The police, including their technical teams, are also present if the death is criminal or suspicious. Whether other doctors and medical students are allowed depends upon the wishes of the official commissioning the examination. When the deceased has been under medical care before death, it is almost invariable practice to allow – and indeed encourage – the physician to be present, as he has the best knowledge of the medical history.

In a criminal or suspicious case, the pathologist should try to limit the number of those present to a minimum. Not only is there a greater risk of loss of confidentiality, but sheer physical numbers, especially of large policemen, can make the mortuary overcrowded. This hampers movement, causes distraction, and adds to the risk of infection and contamination, especially with the present concern about the various forms of hepatitis (B, C, D, E), tuberculosis and human immunodeficiency virus (HIV) infectivity. No one should be present merely as a casual observer, not even senior police officers not directly involved in the investigation. With the increased sophistication and complexity of forensic and police procedures, more and more people cram into the mortuary, cluttered with cameras, videos, recorders, scene-of-crime kits and so on, until there is hardly room for the pathologist to move.

Whoever is present at an autopsy on a criminal or suspicious death should be listed and named by the pathologist on the autopsy report.

EXAMINATION OF THE SCENE OF DEATH

In homicide, suspected homicide, and other suspicious or obscure cases, the pathologist should visit the scene of the death before the body is removed.

Once again, local practice varies but any doctor claiming to be a forensic pathologist should always make himself available to accompany the police to the locus of the death. This duty is often formalized and made part of a contract of service for those pathologists who are either full-time or substantially involved in assisting the police. In England and Wales, the 'Home Office Pathologists' are permanently on call for such visits and in many other jurisdictions, such as the medical examiner systems in the USA, and the European State and University Institutes of Forensic Medicine, there is usually a prearranged duty roster for attendance at scenes of death. The function of an experienced forensic pathologist at the scene of death is generally to assess the environment, the local circumstances, and the position and the condition of the body. In a large proportion of instances crime can rapidly be excluded in favour of accident, suicide or even natural causes. This is a most useful and cost-effective function, as a spurious murder investigation involving perhaps scores of police, many vehicles and other expensive public facilities, may be disbanded promptly when the pathologist recognizes innocent circumstances.

The pathologist should always have appropriate equipment ready to take to a scene investigation at a moment's notice. Further equipment may be carried if autopsies have to be carried out in places where good mortuary facilities are not available. Most forensic pathologists carry a 'murder bag' in their car and though every expert has his own choice of equipment, the following is a reasonable inventory:

- waterproof apron and rubber gloves
- thermometer, syringes and needles, sterile swabs
- autopsy dissection set, including handsaw
- cutting needles and twine for body closure
- swabs and containers for blood and body fluids
- formalin jars for histological samples
- plastic bags, envelopes, paper, spare pen and pencil
- printed body charts for recording external injuries
- hand lens, electric torch, mini-tape recorder
- camera, usually 35 mm single-lens reflex with electronic flash. The recent advent of compact digital cameras or digital video cameras with the facility to take still pictures has made instant reviewing possible.

The thermometer can be either a long chemical mercury type, reading from 0 to 50°C, or the more modern electronic digital variety with a probe carrying a thermocouple. The amount of equipment varies with the facilities likely to be available. In developed countries there are likely to be good mortuary facilities available in a hospital or municipal mortuary and the police forces will have extensive scenes-of-crime expertise with photography, specimen containers and so on. In developing countries and the more remote areas of other states, the pathologist may have to be virtually self-sufficient in respect of both crime investigation and the subsequent autopsy.

In addition to medical kit, the experienced forensic pathologist will always have appropriate clothing such as rubber boots and rain- or snow-wear ready to hand for any call.

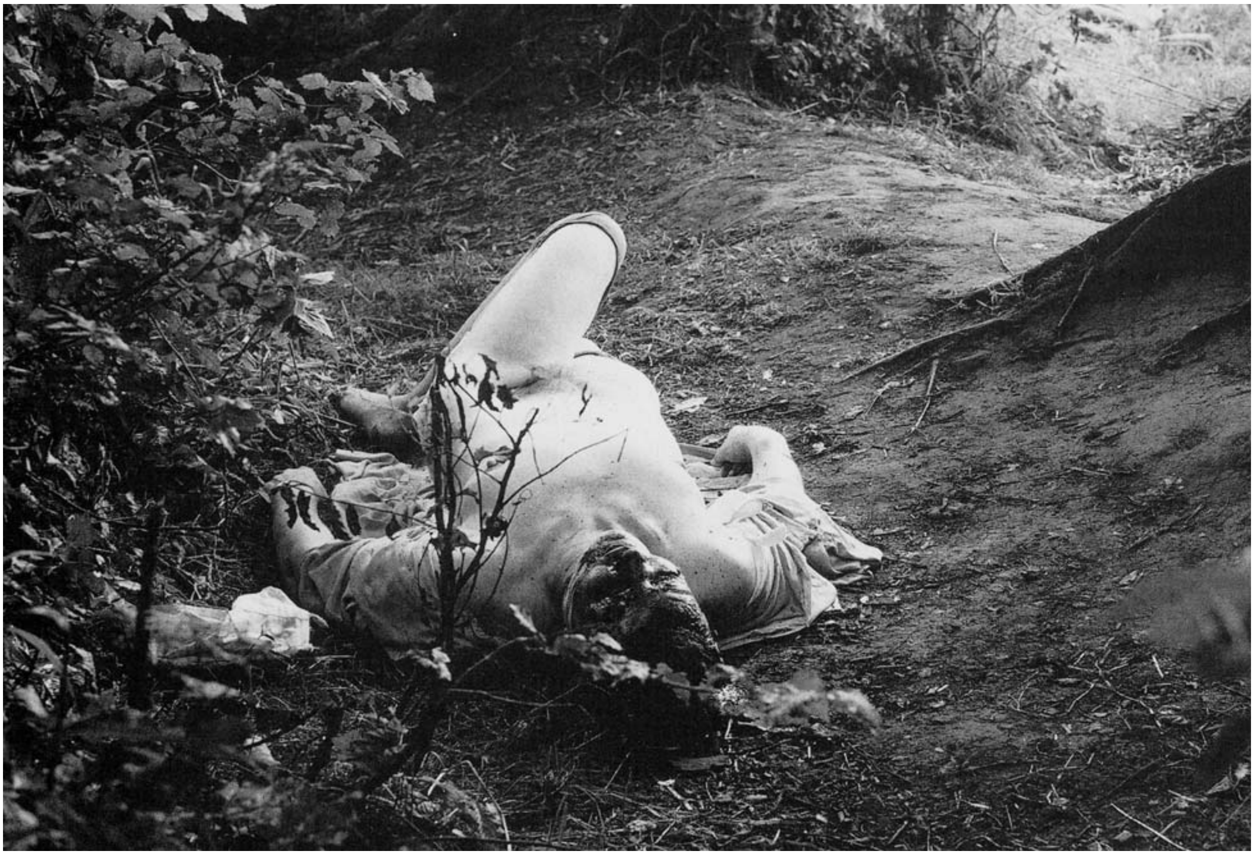

FIGURE 1.1 *The scene of a rape-homicide. The attending pathologist must record the posture, state of clothing and general relationship of the victim to the surroundings, but limit the examination at the scene to avoid any interference with the vital process of obtaining trace evidence. Rectal temperatures should not be taken until all swabs are completed, usually in the mortuary. Temperatures can be taken in the ear or deep nostrils, though with severe head injuries (as here) even this must be done with care.*

When at the scene of death, the pathologist's actions are dictated by the particular circumstances. Much will depend upon the availability or otherwise of police and forensic science assistance. In Britain, for example, several teams converge on a scene of crime, including photographers and video operators, and Scene of Crime Officers (SOCOs) whose function is to collect trace evidence. Scientists from the nearest forensic laboratory often attend with their police liaison officers, as well as fingerprint officers and, of course, the investigating officers from the Criminal Investigation Department.

Where no such backup is available, the pathologist must try to collect trace evidence himself, but he should remain within the limits of his own expertise.

The pathologist should accept the instructions of police officers in relation to the approach to the body so as to preserve the immediate environment as much as possible. Out-of-doors access is often limited to a single pathway marked by tapes, and in a building a track to the corpse is usually pointed out by the detective in charge.

The doctor should not touch anything unnecessarily and certainly not smoke or leave any object or debris of his or her own. Increasingly, those visiting the scene of a crime are given disposable overalls and overshoes to wear, so that fibres, hairs and so on from the visitor are not spuriously transferred to the scene.

If a forensic doctor has to act both as pathologist and clinical medico-legist or 'police surgeon' (that is, examining live victims or suspects), he or she must change clothing or wear a new set of protective garments to avoid transferring trace evidence, such as fibres or hairs, from victim to suspect.

The pathologist should observe a great deal, but do very little. He or she should note the position of the body in relation to nearby objects and establish the plan of the premises if indoors. A sketch or his own photograph is sometimes useful, and some pathologists use a Polaroid, digital or video camera for instant recording of the death scene.

Any obvious cause of death should be observed, and any blood pools or splashes noted in relation to the position of the corpse. The shape of such splashes should be observed,

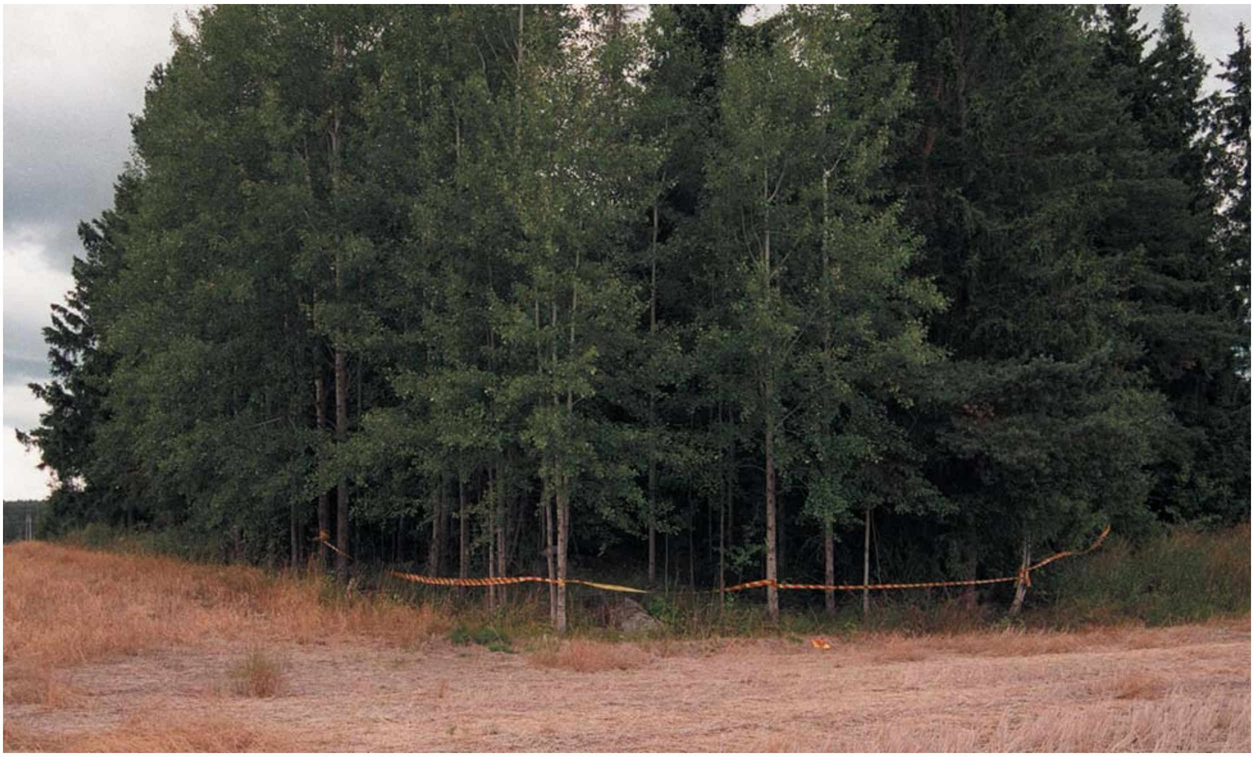

FIGURE 1.2 *Scene of a homicide-suicide where the locus of bodies should be widely marked off by tape to restrict access, and the actual body protected by a shelter from the weather and unauthorized onlookers.*

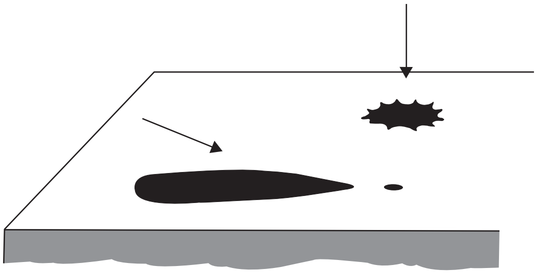

FIGURE 1.3 *At a scene of crime, the position of the body at the time of an assault can sometimes be clarified by observing the direction of blood splashing that may have been thrown off a weapon or blood-stained hands. Blood striking vertically causes round or crenellated circles, while blood hitting at an angle is lance-shaped with the narrow end facing the direction of travel. There is often a preceding drop of blood in advance of the major splash, forming an 'exclamation mark' stain.*

as blood striking perpendicularly to a surface leaves a circular mark, whilst that landing obliquely is pear-shaped, with the sharper end towards the direction of flight.

When photographs have been taken of the body in its original position, the pathologist then approaches it, after checking with the investigating officers that it is appropriate for him to do so. Close examination can be made and the skin felt to assess temperature. The eyes, neck and hands can be examined and where necessary, clothing gently moved aside to look at the throat or upper chest. Any relevant findings should be photographed by the police before further disturbance.

If forensic scientists or scene of crime officers require any samples at this stage, their wishes must be respected. They may want to 'tape' the body, that is, press adhesive tape across the skin and clothing to capture any loose hairs and fibres. The body can then be moved to look at the sides and undersurface, again with caution so that no weapon, other object or trace evidence is disturbed. No set routine can be advised, as each case has its own individual aspects. The prime object is to assess the whole scene while causing the least disturbance to the body and clothing before the scientific teams have finished their tasks.

Estimating the post-mortem interval at the scene

The last sentence above raises the matter of estimating the time since death. The problem is fully discussed in Chapter 3, but has relevance here in relation to the pathologist's actions at the scene of death.

The general warmth or coolness of the hands and face can be assessed by touch, and the degree of rigor mortis felt by gently testing the limbs. The ambient (environmental) temperature must be taken as soon as possible after the discovery of the body, preferably by police scene of crime officers who usually arrive at the locus before the pathologist. The ambient temperature should be taken as near to the body as possible, as microenvironments can exist, even inside buildings or rooms. Information should be sought as to how much disturbance of the ambient temperature might have occurred, such as opening doors and windows, or turning fires or central heating on or off, so that some idea of post-discovery distortions of temperature can be estimated later. The insertion of a thermometer into the rectum at this stage in the investigation, as advocated by some textbooks, is controversial.

At a scene of death, this usually means either pulling down trousers or pants, and otherwise disturbing clothing, often in cramped and ill-lit places, frequently out in the open. It also risks contaminating the rectum and perineum, by introducing seminal fluid from the anal margin into the rectum, making subsequent examination of that area (and taking swabs for semen) of reduced value. As so many violent crimes now have sexual or homosexual overtones, the practice of taking rectal temperatures at the scene should be performed only if the forensic scientists or police scene of crime officers are satisfied that trace evidence from the clothing, swabs from the vulva, vagina and anus, etc., can be obtained satisfactorily before rectal thermometry is performed.

In other words, a cost–benefit analysis must be made at the scene, to decide if the difficulties of taking a rectal temperature are worth the small potential advantage of an earlier measurement. In many cases, where the body has obviously been there long enough for the core temperature to have reached ambient – or where other circumstantial evidence has indicated that the time of death is known to a greater degree of accuracy that can be hoped for by thermometry – then nothing is lost by postponing the procedure until the body arrives at the mortuary for autopsy, which, in British practice, is usually directly after the body is moved from the scene.

If the autopsy is to be delayed for many hours owing to difficulties with transport or lack of facilities, then much more must be done at the scene and temperature measurements are justified.

An alternative is to use a place other than the rectum. The axilla and mouth give low readings, which cannot reliably be correlated with the deep temperature because of variable exposure to the air temperature. More useful is the auditory meatus or nostril, the thermometer or thermocouple probe being inserted as deeply as possible. Reliable, reproducible readings can be obtained from these sites, which have the great advantage of being easily accessible without moving clothing, as well as not being required for swabbing to investigate possible sexual assaults. The use of temperatures to attempt to calculate the post-mortem interval is discussed fully in Chapter 3.

When the pathologist has made the best examination possible in the circumstances, his next function is to ensure that the corpse is removed to the mortuary for autopsy with the least disturbance and loss of evidence. He should supervise the removal himself or at least delegate the duty to another person whom he knows is careful and competent. Each hand should be enclosed in a bag, secured at the wrist by adhesive tape or string. A similar bag should be placed over the head. The packaging medium may vary, but generally paper bags are recommended.

The body should be placed gently in a ‘body-bag’, which has a zip closure, or moved on to a large, new plastic sheet, at least 2 metres square. If a sheet is used, the edges should be wrapped over the body and secured with adhesive tape. The object of the exercise is to retain any loose objects, hairs and fibres that may be adhering to the body or the clothing. The sheet or bag is taken by the forensic laboratory after the body is removed in the mortuary so that they may screen it for trace evidence. The transport of the body is the responsibility of the police or other agency such as the coroner or his officer. The body in its plastic wrapping should be placed in a rigid fibreglass ‘shell’ or ordinary coffin, and taken by hearse, van or police transport to the chosen mortuary.

Physical damage during the removal should be avoided as much as possible, though in difficult or inaccessible sites this is easier said than done. In fires, the body may be seriously damaged before or during recovery, sometimes because its presence is not suspected in the smoke-filled, often waterlogged, debris of a conflagration. The author (BK) has experience of such a scene where firemen walked over two bodies for several hours before it was realized that they were buried under burnt furniture and other debris. Handling brittle, charred, bodies can easily cause the splits at joints that may mimic ante-mortem injuries (see Chapter 12).

In summary, the function of a pathologist at any scene of suspicious death is to observe the situation, to conserve any fragile evidence, to supervise the removal of the body and offer an opinion, based on experience, about the nature of death where this can reasonably be done. He is not there to act as a latter-day Sherlock Holmes, voicing unsubstantiated theories on non-medical matters, nor attempting to overinterpret the situation from the flimsiest of facts. The pathologist is part of a team of specialists, all experts in their own field, and it is as a member of such a cooperative, coordinated group that his best contributions can be made.

PROPERTY, CLOTHING AND IDENTIFICATION

Whether or not the pathologist has been to the scene of a death, he should take notice of the clothing and other property of the body upon which he is to carry out an autopsy. This applies not only to every criminal or suspicious death, but also to many traffic and industrial accidents, as well as to the victims of falls from a height, drowning and so on.

In many instances, there will be no opportunity to examine the clothed body in the mortuary: if death has occurred in hospital or in an accident department, the clothing may have been removed before transfer to the mortuary. The pathologist should make a permanent request that a body from any traffic accident, or other case where trauma was the provisional cause of death, should be brought to the mortuary without having the clothing removed by police or nursing staff – unless of course the victim was still alive on arrival at hospital, and undressing was performed before attempted resuscitation or treatment. As a second best, the removed clothing should accompany the body to the mortuary so that it can be examined, if necessary, for damage, stains and other evidence. Unfortunately, such clothing is frequently destroyed before it can be seen.

The mortuary staff should be trained to regard clothing and property as important items of evidence, and a system should be established to retain, identify and store these, both from the evidential aspects and for the safety of valuables. The contents of the pockets, documents, keys and other items all assist in identification. Though primarily the task of the police, the pathologist will sometimes have an interest in this aspect. The clothes themselves, the style, fabric, colour and labels all assist in identity.

In trauma deaths, the injuries on the body should be matched up with damage on the clothing. Tears, slashes, stab wounds and especially firearm wounds in the clothes must be compared with the position of external lesions on the body, making allowance for movement and displacement during life. Some self-inflicted wounds may be confirmed by the non-alignment of the clothing damage with the injuries (see Chapter 8).

Blood, seminal, vaginal and other body secretions may be found on the clothing, and though this is primarily the responsibility of the forensic science laboratory, the pathologist may be the first or only person to detect their presence. In firearm deaths, gunshot residues on the clothing may be vital evidence about the range of the discharge and the identity of the ammunition.

In traffic fatalities, tearing of the clothes, grease marks, road dirt, broken lamp or windscreen glass, and even metallic or paint fragments from the vehicle may all assist in reconstructing the event and in identifying the unknown vehicle in a ‘hit-and-run’ tragedy.

Other objects associated with the body that may be helpful include medicines, which may assist in determining the nature of the disease from which the deceased had suffered, for example, amyl nitrite or insulin. In some suicides, empty drug or poison containers may be with the body. Other helpful artefacts include such items as hearing aids, syringes, external pacemakers and inhalers. The clothing must be removed carefully and, especially in criminal or suspicious cases, the pathologist should supervise and assist the mortuary technician, especially as some technicians are not always aware of the importance of clothing in the reconstruction of events.

If the body is not bleeding or otherwise fouled, it is best to remove clothing in the usual way by pulling over the head and limbs, unless this might interfere with any injuries or soiling. If rigor is intense or if there is blood on the face or hands, it may be advisable to cut off some or all of the clothing. This should be done after consultation with the forensic scientists, if they are present, so that the cuts will be made where they will least interfere with later laboratory examination. In any event, cuts should avoid passing through pre-existing damage or staining of the garments. Each item of the clothing should be placed separately into a paper bag to allow them to ‘breathe’.

Identification of the body

The identification of an unknown body is a major forensic exercise, and is fully discussed in Chapter 4. Here, however, we are concerned with the formal recognition of the subject of an imminent autopsy. Before a pathologist makes any examination (and certainly before he begins any mutilating dissection), it is essential that he ensures that the corpse before him is indeed the correct person.

In every medico-legal case, some responsible person must have identified the body. This is usually a relative or close friend of the deceased person, who looks at the face of the body and verbally certifies to a police officer, mortuary attendant or doctor that it is indeed ‘John Smith’. Where the body is burned beyond recognition, mutilated or putrefied, attempts at identification must be made by showing the relative documents, or items such as clothing or jewellery.

In non-criminal cases, such as sudden deaths and most accidents and suicides, the continuity of identity is carried on by a label or tag attached to the body by the police officer, nursing staff or mortuary attendant, which carries the name, address, serial number and other relevant details. This label may be tied firmly to a toe, or a durable wrist or ankle bracelet may be used. Some mortuaries write the name on the leg with an indelible marker, but this can be smudged or obscured during autopsy.

The pathologist should always satisfy himself of the identity by comparing the documents authorizing the autopsy with the toe label or bracelet. The details should agree and, if they do not, he should not proceed with the autopsy until the discrepancy is cleared up, if necessary by calling back the police officer or even the relative to make absolutely sure of the identity.

Many mistakes have been made in the past, with adverse publicity, embarrassing enquiries and even legal consequences. Autopsies on the wrong person, incorrect causes of death, relatives attending the wrong funeral and even cremation of the wrong body are regularly reported as a result of laxity in identification. To avoid confusion, the body should always be labelled as soon as it arrives in the mortuary. Labels on shrouds become detached and those on refrigerator doors are unreliable, as other parties (such as night porters) may shift occupants around without the knowledge of the pathologist or regular mortuary staff.

Some large mortuaries use special means of identity. One known to the authors has an automatic camera fitted in the ceiling of the mortuary entrance. Every new body wheeled in is photographed on its trolley with a serial number prominently displayed on a board placed across the upper chest, so that the face appears with the record number to resolve any later discrepancy.

In serious cases such as homicide, the pathologist must not rely on second-hand evidence of identity such as a toe label. Before the autopsy, someone must verbally confirm to him that the body they are both then viewing is 'John Smith'. This person must be either a relative or the police officer to whom a relative has already formally identified the corpse.

The pathologist must record in his autopsy report the date, time and particulars of the person identifying the body to him, so that 'continuity of evidence' is ensured for legal purposes, which cannot successfully be challenged by the defence at a subsequent trial.

THE USE OF THE HISTORY OF THE CASE

As in clinical medicine, the history of the deceased 'patient' or victim is a vital and indispensable part of the investigation. The extent to which it should influence the pathologist in coming to a decision as to the cause of death, however, is more controversial, as is discussed below.

In medico-legal autopsies – compared with hospital 'clinical' cases – the history is often scanty, absent or misleading. If a person has been found dead, having had no previous medical attendant, there may be virtually no information at all. In criminal deaths, the person who knows most about the death may well be the perpetrator, who naturally may remain silent or give a distorted, misleading or totally false account of the circumstances. The forensic pathologist then often has to contend with a scanty or incorrect history.

Even when a story is given in good faith by relatives, the medical facts are often distorted because of incomplete knowledge and understanding. It may be further warped by transmission by a police officer or other non-medical person, so that only a garbled history reaches the pathologist. The latter should attempt to supplement deficiencies in information by further requests to the commissioning authority, such as the coroner or the police. Wherever possible, the pathologist should try to contact the doctor who may have treated the deceased in the recent past. In the urgency of forensic work, however, frequently at night or weekends, the autopsy may have to proceed without any additional history.

Though more detail may be obtained afterwards, the course of the autopsy might well have been different if such knowledge was available beforehand. For example, the author (BK) once performed an autopsy on a coal miner with no history other than a knowledge of his occupation and chronic chest disease. Autopsy revealed sufficient cardiopulmonary disease to account for death and the body was released for burial. It was not until the following day that the police in the rural area where the man had died, tardily produced the information that both an empty bottle of sleeping tablets and a suicide note had been found with the body. Paradoxically, the history is often less important in violent deaths where the wounds are self-evident, though a good description of the circumstances may assist in interpreting the direction of injuries, the nature of the weapon and other aspects.

In most autopsies the history directs the pathologist to the appropriate ancillary investigations, as should have happened in the case described above. Some pathologists have in the past advocated that the autopsy should be performed 'blind', so that the history does not prejudice the opinion of the pathologist. This is patently impracticable, for every autopsy would then have to be totally comprehensive, including such techniques as the removal of the spinal cord in every case, and all possible ancillary investigations, such as toxicology, microbiology, virology, radiology, diatoms, histology and so on, as there would be no means of knowing what was necessary and what was irrelevant. Apart from the intolerable burden of work, the expense of such an approach would be prohibitive, if applied to all autopsies.

A particular difficulty often arises in relation to bodies returned to a home country after death in a foreign state.

The problems vary greatly with the degree of both pathological and administrative sophistication of the foreign country. Where these are poor, then the problems of obtaining a good – or even any – history may be great, even after attempts at using international police or diplomatic channels.

Sometimes, a ‘doctor-to-doctor’ approach by telephone or fax may be the best way of obtaining information. Even a cause of death from the foreign country may be either unobtainable or so vague (such as ‘heart failure’) as to be useless. Previous autopsies may be incomplete, of poor quality, or even fraudulent, such as finding a stitched skin incision but no underlying dissection of organs. Several surveys of such problem autopsies have been published, with a plea for some kind of International Death Certificate (Green 1982; Leadbeatter 1991).

Difficulties arise when objective autopsy findings are scanty or even absent. The pathologist then has the dilemma of choosing between a cause of death based on a subjective knowledge of the alleged history (which may be wrong) or admitting that the cause of death is unascertained.

This problem, fully discussed by Leadbeatter and Knight (1987), is by no means uncommon. For example, sufferers from epilepsy or asthma are known to die suddenly and unexpectedly, an autopsy usually revealing no adequate morphological cause for their death. Another prime example is the sudden infant death syndrome, discussed in Chapter 21, where by definition there are no significant autopsy lesions and the history is usually essentially barren.

In hypothermia where the patient is warmed up in hospital but dies in a day or two, there may be nothing to find at autopsy, yet there is firm clinical history of a rectal temperature of 26°C. Moving to more forensic cases, a body may be recovered from a river after clothing and a suicide note have been found on the bank – yet at autopsy there may be no visible evidence of drowning whatsoever.

In these cases, should the pathologist – in the absence of objective evidence of hypothermia or drowning – decline to offer a cause of death and perhaps be accused of being obstructive or perverse? Or should he certify ‘hypothermia’ or ‘drowning’, and perhaps be challenged in court by a lawyer who claims that the pathologist relied only on hearsay and has no objective evidence to offer?

The best course is for the pathologist, if he feels that the history is sufficiently strong, to give the most likely and reasonable cause of death, but make it clear in his discussion in the autopsy report that this opinion is based on a consideration of the circumstances and is not a dogmatic statement of the kind that could be offered if the victim was shot through the brain. Where a summary of the history prefaces the autopsy report, the pathologist should be careful to indicate what is ‘hearsay’ as far as he is concerned. Thus he should not say ‘The deceased was struck on the head by two men’, but ‘I was told that the deceased was struck on the head by two men’.

As is discussed later, the autopsy report should not be merely a bald recital of the anatomical findings, but should have a final commentary that includes a ‘differential diagnosis’ where the cause of death is not clear cut, as well as a justification for the eventual opinion or an admission that there is no way of deciding between alternative possibilities.

The main difficulty arises with the actual ‘cause of death’ phraseology, which will be entered into the legal and national records in the format required by the World Health Organization. This gives no opportunity to express preferences or give explanations but, on the ‘best-guess’ principle, the pathologist can do no more than enter his most reasoned choice or, with legitimate honesty, state that the cause is ‘undetermined’.

PRECAUTIONS REGARDING POTENTIAL INFECTIVE CONDITIONS

Many forensic situations involve drug abusers and persons with promiscuous sexual behaviour, where the statistical risk of HIV and hepatitis infection is markedly greater than in the general autopsy population. This poses a risk to pathologists, mortuary staff, police and laboratory staff who may deal with post-autopsy samples. A great deal has been written about such risks but no consensus has yet been reached, though an excellent survey has been published by the Royal College of Pathologists (1995).

One school maintains that all autopsies should be carried out with total precautions against infective risks, so that it does not matter what case is handled. However, this is almost impossible to achieve in a busy coroner or medical examiner practice and does not solve the problem of possibly infected material being sent out to other laboratories.

A more common regime is to carry out pre-autopsy testing for HIV and hepatitis, using blood from a femoral needle puncture. The result can often be returned within hours, when a decision may be made as to how to handle the autopsy – or even whether to abandon it, if the risk–benefit aspect is high. More usually, a positive result will result in the autopsy being carried out with special care, additional protective clothing, visors, masks and metal gloves, with restriction of access to observers, choice of more senior technicians and warnings sent to laboratories liable to handle samples.

In this respect, hepatitis is more of a risk than HIV infection. However, so far, about 100 health-care workers have acquired HIV infection from definite occupational exposure (Sidwell *et al.* 1999) and one pathologist is known to have become infected from autopsy work (Johnson *et al.* 1997). Also three morticians in the USA have possibly contracted occupation-related HIV positivity.

The time for which a corpse remains potentially contagious with HIV is variable. Infectious virus has been recovered from liquid blood held at room temperature for 2 months and virus in high concentrations has been found to remain viable for 3 weeks (Cao *et al.* 1993). Bankowski *et al.* (1992) found 51 per cent survival of virus in plasma and monocyte fractions from infected cadavers up to 21 hours post-mortem. Other series found survival in corpses from 18 hours to 11 days after death. Virus has been recovered from the spleen after 14 days post-mortem. Refrigeration seems to make little difference to viability. Douceron *et al.* (1993) cultured blood and effusions from refrigerated bodies and obtained viable virus up to 16 days post-mortem and concluded that there was no safe maximum time at which corpses ceased to be an infective risk. In industrialized countries, it has become standard to offer post-exposure prophylaxis after significant percutaneous exposure to blood or tissues of HIV patients.

Other infections, such as tuberculosis, hepatitis viruses, anthrax, plague, Creutzfeldt–Jakob, Marburg, Green Monkey diseases, etc., are usually the subject of specific health and safety regulations, which vary from country to country.

THE AUTOPSY: EXTERNAL EXAMINATION

In contrast to the 'clinical autopsy' performed to evaluate natural disease, the importance of the external examination is far greater in the forensic case, especially in deaths from trauma. In the latter, the medico-legal value of the external description may be paramount, as it is often from the outer evidence that inferences may be made about the nature of the weapon, the direction of attack and other vital aspects. Thus the forensic pathologist must spend all the time that is necessary in a careful evaluation of the body surface and not be too impatient to wield the knife mainly to seek material for histology, which is more justified in the purely clinical autopsy.

The routine for external examination will naturally vary according to the nature of the case but certain general principles apply. The following procedure is a useful baseline and may be adjusted according to personal preference. Variations in criminal cases to accommodate the needs of the investigating and scientific teams are mentioned later.

- After identification and removal of any clothing, the race and gender are noted. The apparent age is assessed in children by size and in adults by changes in skin and eyes, such as the loss of skin elasticity, senile hyperkeratosis, Campbell de Morgan spots, senile purpura and arcus senilis. Hair colour, tooth loss and arthritic changes are also obvious signs of ageing. The apparent age should be compared with the alleged age and enquiries made about any obvious discrepancy, in case it is the wrong body, an error which plagues most autopsy rooms from time to time.
- The body length is measured from heel to crown (in infants, more detailed measurements are described later). Ensure that the attendant does not take the 'undertaker's height' from toe to crown, as due to the plantar flexion of rigor, this can be a considerable number of centimetres more than the live standing height.

  It should also be appreciated that the post-mortem height may differ from the known living height by several centimetres. There are several opposing causes of variation, which do not necessarily cancel each other.

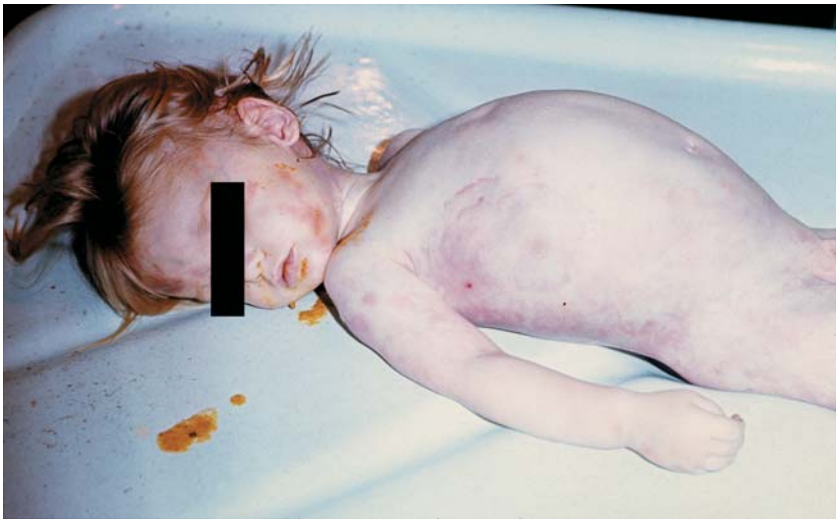
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Figure 1.4 *External examination must note every feature; here there is obvious abdominal distension in a battered child with facial bruising. The intestine had been ruptured by a blow, and oxygen administered by the ambulance crew escaped to distend the peritoneal cavity.*

For example, muscle flaccidity allows joints to relax, unless rigor is present, but intervertebral discs appear to shrink, allowing shortening.

- The body weight in kilograms is measured if facilities are available; if not, it should be estimated. The weight of infants must always be measured. The general nutrition and physique is assessed in terms of obesity, leanness, dehydration, oedema, emaciation, and so on.
- The state of cleanliness, personal hygiene, hair and beard length, toenail and fingernail state, and urinary and faecal soiling is noted. Any parasitic infestation, such as fleas or lice, is combated before proceeding.
- The general skin colour is noted, especially hypostasis (discussed at length in Chapter 2). Congestion or cyanosis of the face, hands and feet is sought. Localized discoloration, especially unilateral in a limb, suggests arterial embolism or incipient gangrene. Pink or brownish pink patches over the large joints may indicate hypothermia (Chapter 17). Other abnormal colours include the brownish hue of methaemoglobinaemia in some poisonings, the bronze speckling of clostridial septicaemia and the dark red of cyanide that somewhat resembles the cherry-pink coloration of carboxyhaemoglobin. Naturally racial pigmentation will modify the ease with which abnormal skin coloration can be seen.
- Congenital deformities of any type are recorded, from talipes equinovarus to spina bifida, from a naevus to extra toes.
- Acquired external marks may be important for identification purposes or in relation to past injuries and disease. Tattoos, circumcision, amputations, surgical scars, old fracture deformities and scars of injuries, burns or suicidal attempts on the wrist and throat are noted. These are discussed further in Chapter 3. Increasingly, artefacts – both external and internal – arise from resuscitation attempts and must be carefully distinguished from original trauma. This emphasizes the importance of the history, to determine whether cardiopulmonary resuscitation was attempted by trained or untrained persons.
- The hands should be carefully examined for such signs as old and new injuries, defence wounds, bruised knuckles and electrical marks. The latter are often insignificant and difficult to see unless the rigor of flexed fingers is overcome, either by force or even cutting the flexor tendons at the wrist.
- Vomit, froth or blood may be present at the mouth and nostrils, and faeces and urine may have been voided. This must be correlated with the degree of post-mortem decomposition, which often leads to purging of fluids from orifices; most forensic pathologists have had the experience of being called by the police to the scene of ‘a fatal haemorrhage’, to discover only bloody fluid being purged by gases from a decomposing corpse.

Vaginal discharge or bleeding is noted and the ears examined for leakage of blood or cerebrospinal fluid. Post-mortem ejaculation of semen from the external

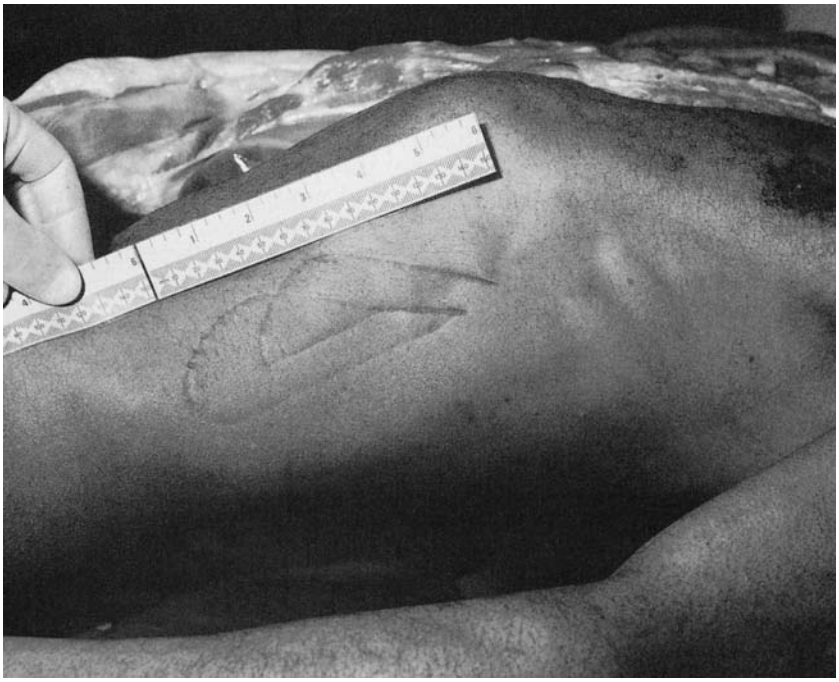

FIGURE 1.5 *Post-mortem artefacts on the body of a homicide victim. These are due to defibrillator paddles applied in a hospital casualty department.*

meatus is of no significance and can be seen in any type of death. It was shown by Mant (1984) not to be associated with sexual activity immediately before death. It is not particularly associated with asphyxial deaths, as sometimes stated.

- The degree of rigor mortis is assessed by flexing the arms and legs to test the resistance. The significance of this and hypostasis is discussed in Chapter 2.
- Recent injuries (other than scars already noted) are carefully examined. In fact this part of the autopsy is often the most significant element of forensic cases. Injuries may be conveniently recorded in the mortuary by marking them on printed body diagrams. The forms can be secured on a clipboard and the data later transcribed into a written description for the autopsy report. The original diagrams should be retained, as their production may be demanded in court if there is controversy about any particular injury.

All traumatic lesions should be clearly differentiated into abrasions, bruises, lacerations, incised wounds, burns and so on, according to the definitions given in Chapter 4. The shape and condition of the margins of each injury should be described where appropriate. It must be meticulously measured in terms of length, breadth, orientation to the axis of the body and the position with reference to surface anatomical landmarks. For example, a knife wound of the thorax might be described as follows, using ordinary language to explain any medical terms:

> A stab wound was present on the left upper chest, placed obliquely, with the inner end lower than the upper outer end. The wound was 20 mm in length, which extended to 22 mm when the edges were opposed. The maximum width at the centre was 4 mm. The centre of the wound was just below the line joining the nipples, being 6 cm from the midline, 7 cm from the left nipple and 18 cm below the centre of the left clavicle (collar bone). The wound was 132 cm above heel level and was elliptical in shape, with the inner lower end slightly more sharply cut than the rather blunt upper end. The wound was shelved in a downwards direction, with subcutaneous tissue visible along the inside of the upper edge.

This description, along with police photographs, will convey an excellent impression of the wound at any future date, including at the trial, which may be many months later. The position of the injury is related to obvious anatomical points and the height above the ground may have relevance if the stature of the victim and assailant, and the angle of attack, become legal issues. On the scalp, the occiput and the tip of the ear can be used as reference points, together with the vertex and the centre line of the head. On the face, the obvious landmarks are the eyebrows, nasion, tip of nose, lips, point of chin and angle of jaw. Where large areas of abrasion or bruising are present, similar measurements of lesion size are needed, but more general descriptions of position may be sufficient, such as ‘covering the external aspect of the left thigh’ or ‘extensive bruising 23 cm by 18 cm on the right side of the chest extending from axilla to costal margin’.

Where widespread burns are present, an estimate of the total area using the ‘Rule of Nine’ should be made, as described in Chapter 11.

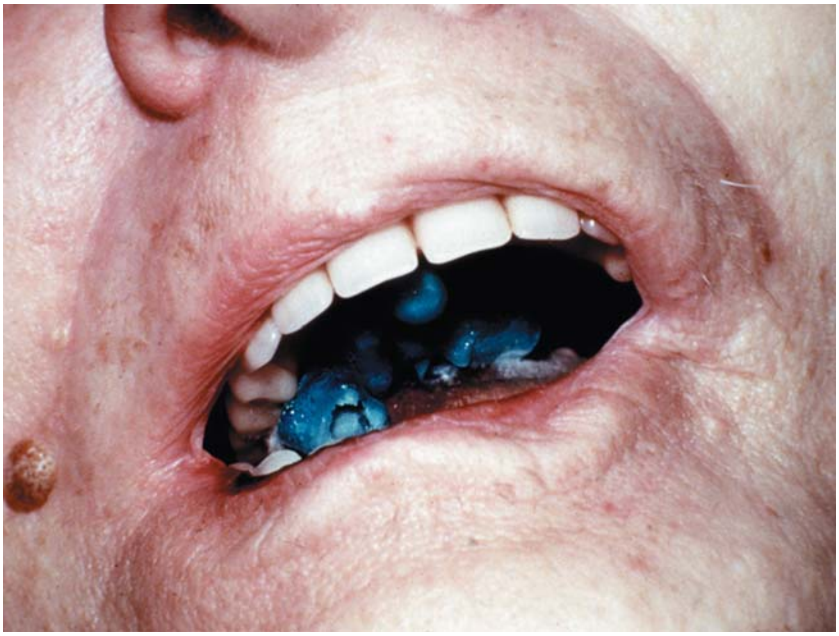

FIGURE 1.6 *Full external examination is vital, including the interior of the mouth. Here a large number of amylobarbitone capsules offer a presumptive cause of death, though analytical confirmation is still required.*

Other injuries, such as firearm wounds, are described in the same manner, being careful not to clean off any powder residues or other trace evidence before the forensic scientists have collected their samples.

With head injuries, the scalp is examined in its original condition first and any trace evidence collected. Then any clotted blood that frequently obscures the injuries can be gently removed, using a sponge and water. After this stage has been studied, it is usually necessary to shave off hair carefully around the wounds, so that the full extent of the lacerations and especially the state of their margins can be assessed and photographed. This shaving is best carried out with a scalpel fitted with a new blade, the blade being kept almost parallel with the surface to avoid making false cuts. The procedure should be carried out by the pathologist himself and not delegated to a mortuary technician. In this way any artefactual cuts can be recognized as such and not misinterpreted as part of the original wound.

The eyes must be examined carefully, especially to detect petechial haemorrhages on the outside of the eyelids, conjunctivae and sclera. Though these do not necessarily indicate an asphyxial process, such petechiae require an explanation. Petechiae should also be sought behind the ears and in the skin of the face, especially around the mouth, chin and forehead. Care must be taken to differentiate these fine petechiae from the more coarse intradermal blood spots often seen across the shoulders or upper chest, which are caused by post-mortem hypostasis in a body with marked agonal venous congestion – especially when that surface of the body has been dependent. Haemorrhages in postural hypostasis are of no diagnostic significance, as true ante-mortem bleedings can never be differentiated from those that commonly develop after death.

The size of the pupils is rarely useful, as rigor in the iris musculature can produce any degree of constriction, which may be unequal on either side (see Chapter 2). False eyes, contact lenses, lens opacity and other defects are to be noted. It is not possible to evaluate the degree of visual acuity during life from any type of post-mortem examination – though obviously a

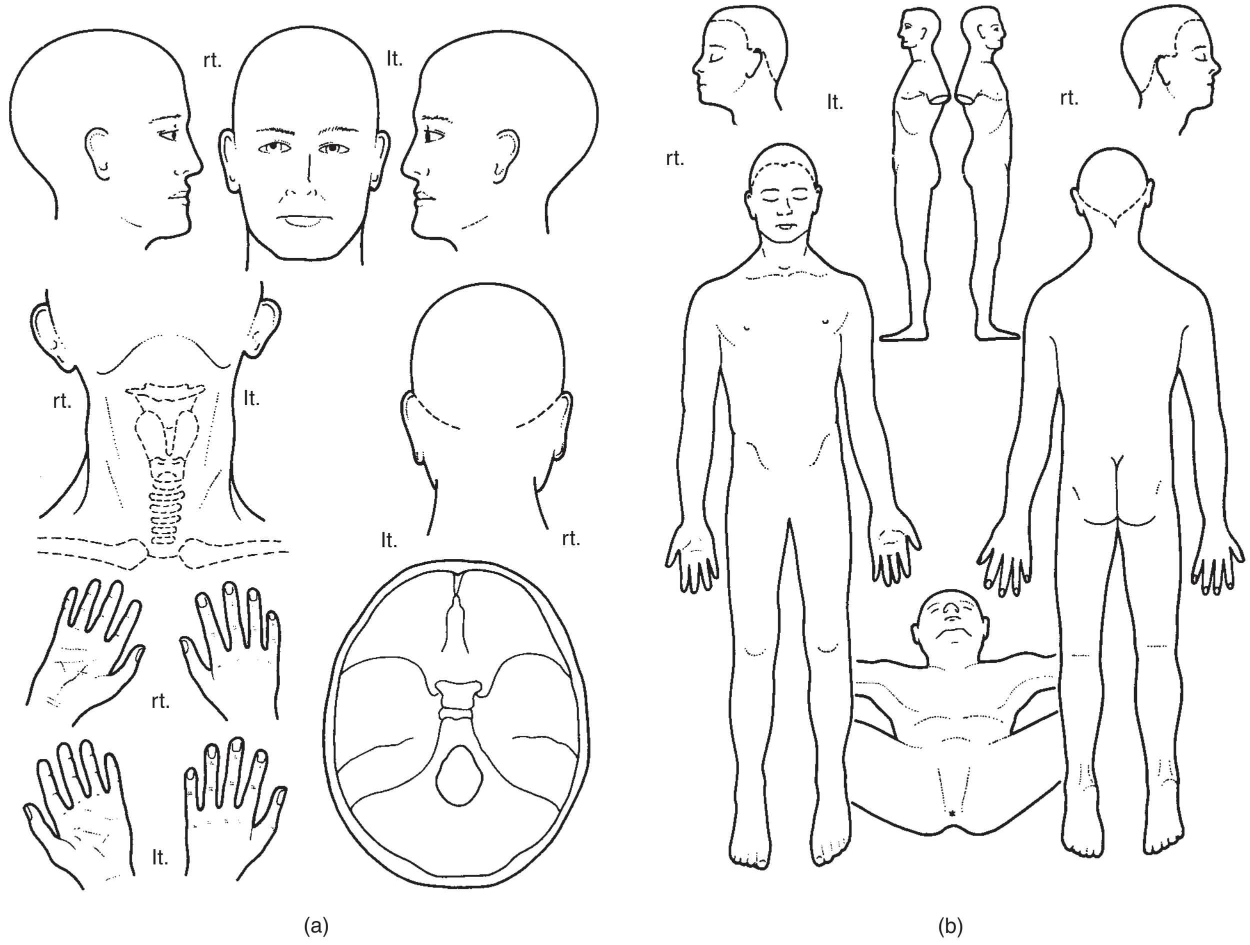

(a)

(b)

FIGURE 1.7 *(a, b) Typical examples of the many anatomical diagrams available for the recording of external findings at autopsy.*

significant defect such as a cataract or a large vitreous haemorrhage is likely to affect vision.

- The mouth may reveal foreign bodies, drugs, damaged teeth, injured gums and lips (especially the ruptured frenulum of child abuse), and the bitten tongue of epilepsy or blows on the jaw. Dentures should be identified and removed before autopsy. Gastric contents in the mouth need not indicate ante-mortem regurgitation, as discussed in Chapter 14, but should be noted. Dried powder on the lips may suggest the recent taking of medicaments or poisons; corrosion of the mouth, lips and chin may be seen in irritant poisons. Bleeding from mouth, nostrils, or ears must be recorded, and later investigated as to source from internal examination. Frothy fluid, sometimes blood-tinged, may be seen issuing from the mouth or nostrils, or both, in drowning and from pulmonary oedema due to a variety of causes. Froth is sometimes pink or frankly blood-tinged. This has no particular significance unless gross, as in drowning, sudden infant death and other conditions with marked pulmonary oedema; rupture of small pulmonary or even pharyngeal vessels can add a little blood to colour the foam.

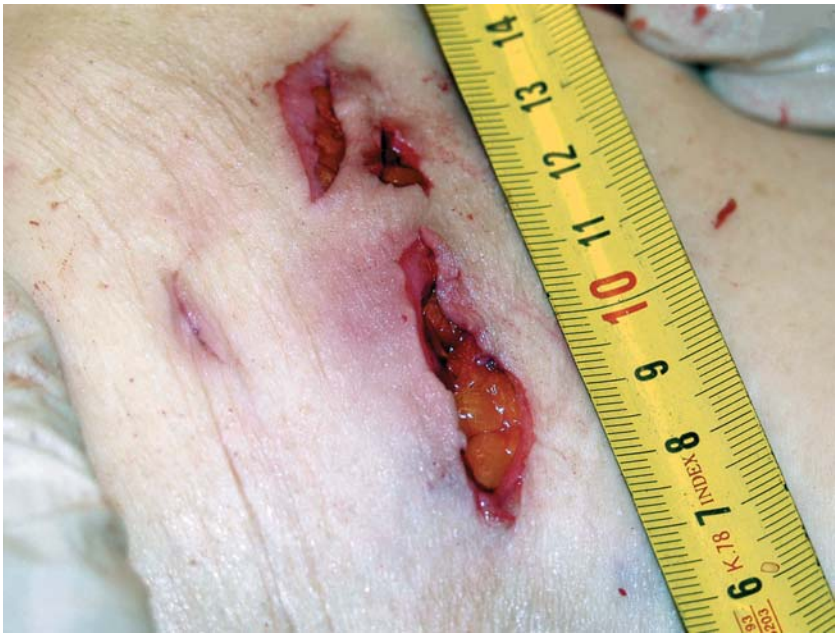

FIGURE 1.8 *Examination and photography of injuries; after full preliminary examination and forensic sampling, the area is cleaned, shaved if necessary, and photographed with a scale adjacent to the injuries.*

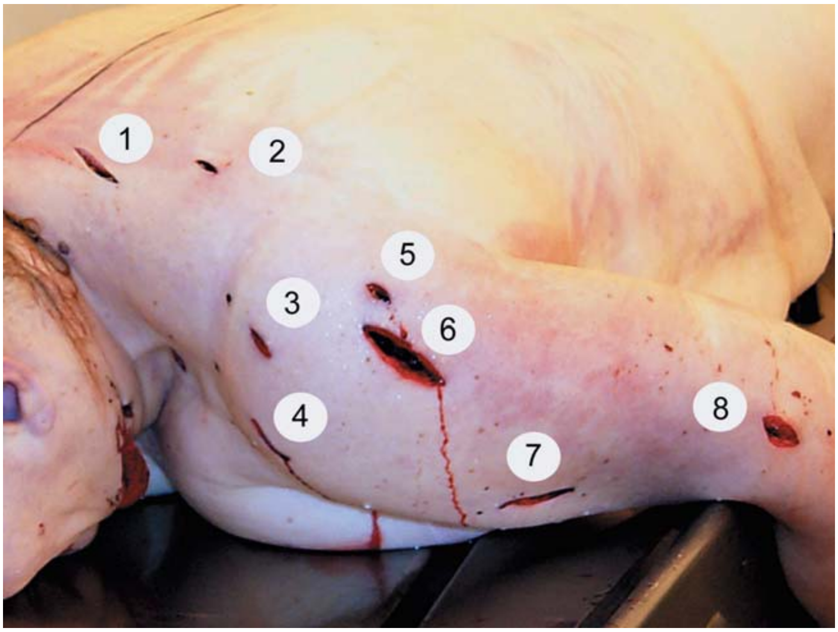

FIGURE 1.9 *Where there are numerous similar lesions, it assists the clarity of the autopsy report if numbers used during photography match those listed in the autopsy protocol.*

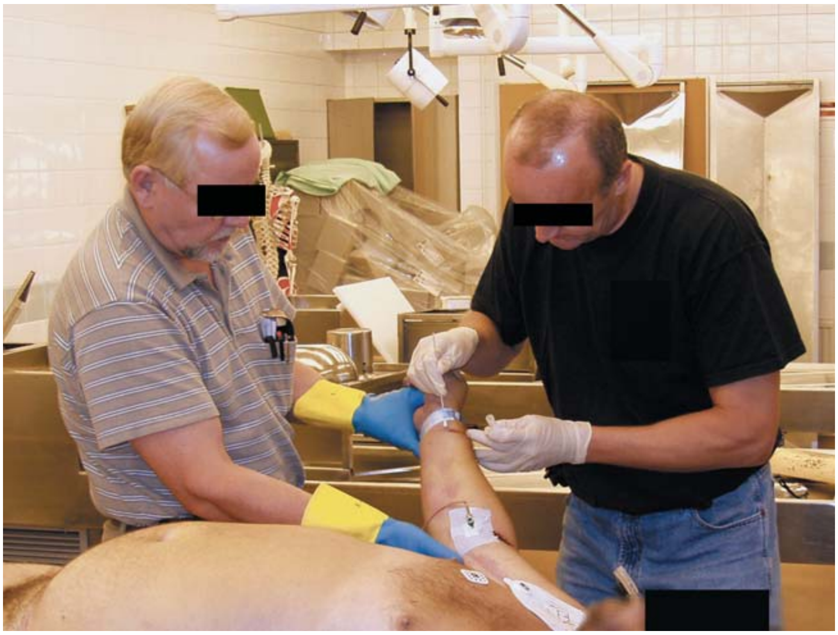

FIGURE 1.10 *Scene of crime officers recovering trace evidence from hands before a homicide autopsy. The pathologist must offer the rest of the team every facility to complete their work before he begins his dissection.*

The external genitals require careful examination, as does the anus. The state of the latter can be misleading, as a widely open, patulous anus is often seen post-mortem, due to flaccidity of the sphincter. The inner mucosa is often visible through the orifice. This is also the case in infants and children, and a diagnosis of sexual abuse must not be assumed without other corroborative evidence such as fresh mucosal tears or swabs positive for semen.

The 'funnel-shaped' anus, beloved of traditional textbooks as a sign of chronic homosexual activity, is such an extreme rarity that its true existence is doubtful. A funnel shape is a normal anatomical variant, the anus being set deeply between the buttocks, sometimes with a commissure of skin above it, making the approach seem even deeper. The alleged 'shiny, silvery hyperkeratinized skin of the habitual pederast' is also of little diagnostic value as scratching from chronic irritation, often associated with haemorrhoids, viral infections or threadworms, may lead to the same appearance. The only reliable criteria are fresh tears and old scars, as well as mucocutaneous eversion, though even these can arise from severe chronic constipation (see also Chapter 18).

Examination of the vulva and vagina is made to exclude obvious injury and disease, unless the nature of the case suggests some sexual interference, when a far more detailed examination and a special autopsy technique is carried out (Chapter 18). Routine examination of the male genitals usually need only extend to general inspection of the penis, glans and scrotum, with palpation of the testes. Circumcision should be noted, as (rarely) it may assist in identification.

THE AUTOPSY: INTERNAL EXAMINATION

The dissection in a forensic case is basically similar to any other autopsy, with variations according to the nature of the death and the needs of the particular investigation, whether it be a criminal case, a civil dispute or an accident investigation.

There are a number of manuals devoted to the performance of an autopsy (see Ludwig 2002 or Knight 1996, for example) as well as one for the instruction of mortuary technicians (Knight 1984). Only an outline of the technique is offered here for those unaccustomed to examining the dead who may have autopsies thrust upon them by circumstances. In addition, special forensic procedures are described, though these are also discussed in each of the chapters devoted to the various types of injury and death. The autopsy on infants is dealt with in Chapters 20–22.

The usual incision is an almost straight line from laryngeal prominence to pubis, deviating to avoid the umbilicus. The upper end of this incision should not be prolonged above the larynx, as even a high-necked shroud will then fail to hide the subsequent suture line from relatives.

Another common method is to cut from behind each ear to a point above the manubrium and continue downwards in a 'Y-shape'. This is often done in infants and wherever it is desired to avoid disfiguring the front of the neck. In the USA in particular, the Y-incision is favoured or even a deep 'U-shape' carried across the upper chest.

In strangulation, hanging, and any condition where the larynx might be damaged, the Y-incision is to be preferred, as the skin of the upper neck can then be dissected off the mandible and raised clear to give a wide approach to the neck structures. Here, the incision should not be made until the skull-cap and brain have been removed, to avoid the congestive artefactual haemorrhages in the neck structures, described by Prinsloo and Gordon (1951), which can be confused with true ante-mortem trauma. Gordon *et al.* (1988) have further suggested that the brain be removed first in all autopsies so that abnormal odours can be detected before being swamped by the smell from the opened abdominal cavity.

The Y-incision is also required when dissection of the face is necessary, to look for deep bruising or bony damage. In fact the whole face can be dissected off completely from the skull and replaced with little effect upon the cosmetic result, if careful dissection is employed. The Y-incision in the neck is made continuous with the transverse scalp incision, joining these behind each ear, so that the anterior neck and facial skin can be removed in entirety.

Returning to the autopsy in general, the primary incision should be shallow over the neck to avoid cutting underlying structures, especially the trachea. The thorax can be cut down to the sternum, but care must be taken over the abdomen, where a light cut is made, sufficient to incise only skin and fat. A small puncture should then be made in the peritoneum and a finger inserted to lift it away from the intestines. The knife is then used to cut outwards along the length of the abdomen, to avoid penetrating the intestines.

The incision for access to the skull is made from behind each ear, meeting over the crown of the head. It is well to keep this posterior to the actual vertex, again to make the stitching less obvious, especially where the hair is scanty or absent. With abundant hair – and especially in children – the hair should be wetted and then combed backwards and forwards from a transverse parting made in the line of the prospective incision. Hair is not then severed and can be combed back later to cover the stitching.

Exposing the body cavities

The skin, subcutaneous tissues and fat are flayed off laterally from the main incision, taking care not to let the edge or point of the knife come through the skin, especially in the neck area, where repair can be unsightly. The tissues are taken back to the lateral edge of the neck and to the outer third of the clavicles. Over the thorax, the tissues, including pectoral muscles, are flayed off to the midaxillary line in the upper part and even further posteriorly towards the costal margin.

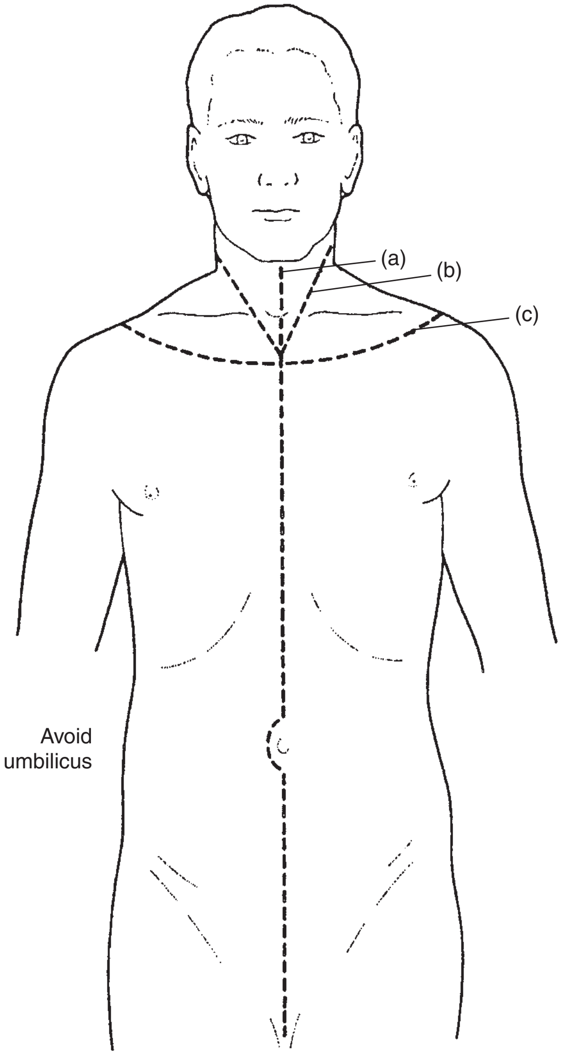

FIGURE 1.11 *Autopsy incisions: (a) standard midline, (b) 'V-shape' and (c) subclavicular.*

The anterior abdominal wall is similarly separated. This can be done either in two stages, first stripping back the skin and fat to expose the muscles – or the full thickness of skin, fat and muscle can be reflected together. The muscle must be cut from the costal margin and, if thick fat overlies, then some transverse relieving incisions can be made on the peritoneal surface of the lower abdominal wall, taking care not to come through to the skin.

Opening the thorax

The thorax is opened by first disarticulating both sternoclavicular joints. This is carried out by moving the shoulder tip with one hand, to identify the joint capsules. The point of a knife is then introduced vertically and cut laterally in a half-circle to separate the joints. If they are ankylosed, which often occurs in old age, then the clavicles can be cut through at the end of the next operation. This consists of the severing of the ribs and can be performed either with a handsaw or a rib shears. In children and many adults, the costal cartilages may be cut through with a knife, though this provides a rather narrow exposure of the chest contents. In infants, the soft cartilage can easily be divided with a scalpel: in older bodies, a stout knife should be kept for the purpose to save blunting the knife that is needed for organ dissection. Often the first rib has to be sawn through, even though the remainder are cut with a knife.

When a saw is used, the ribs are cut through lateral to the costochondral junctions from a point on the costal margin to the sternoclavicular joints or nearby. If a saw is used, it must be kept at a low angle to avoid the tip lacerating the underlying lung, especially if there are pleural adhesions. When the sternum and medial rib segments are free, the section is lifted and dissected away from the mediastinum, keeping the knife close to the bone to avoid cutting the pericardium. The sternal plate is examined for fractures or other lesions before it is put aside: damage caused by the considerable trauma of resuscitatory cardiac massage is frequently found at this point.

The whole of the thorax and abdomen is now open for inspection. The degree of inflation of the lungs should be assessed, noting complete or partial collapse, emphysema, overdistension and any asymmetry of inflation.

If a pneumothorax has been suspected beforehand, a post-mortem radiograph is the best confirmation. Alternatively, the chest wall can be punctured in the mid-axillary line after filling the reflected skin with water to observe if bubbles escape. This test is rarely successful and cannot succeed if there is a patent communication between the pleural cavity and the bronchial tree. If there is a marked tension pneumothorax, the hiss of escaping air may be heard when the tip of the knife penetrates the intercostal muscles and parietal pleura. The pleural cavities are inspected for adhesions, effusions, pus, blood, fibrin and even gastric contents.

Examining the abdomen

The abdomen is then inspected, though ascites, faeculent fluid, pus and blood may already have escaped on first opening the peritoneal cavity.

The omentum may show inflammation or fat necrosis. When moved aside, the loops of bowel are inspected for any abnormality, especially infarction, peritonitis and the distension of ileus. Beware of mistaking post-mortem hypostasis for the necrosis of mesenteric embolism or strangulated bowel. Though the dark colour may be similar, hypostasis usually has irregular segments when the gut is stretched out, whereas infarction occupies one continuous section – and if well established, the bowel wall will be lustreless and friable.

The bowel is gently moved aside to look at the posterior part of the abdomen: a retroperitoneal haemorrhage from a ruptured aorta may be visible, or an aneurysm itself.

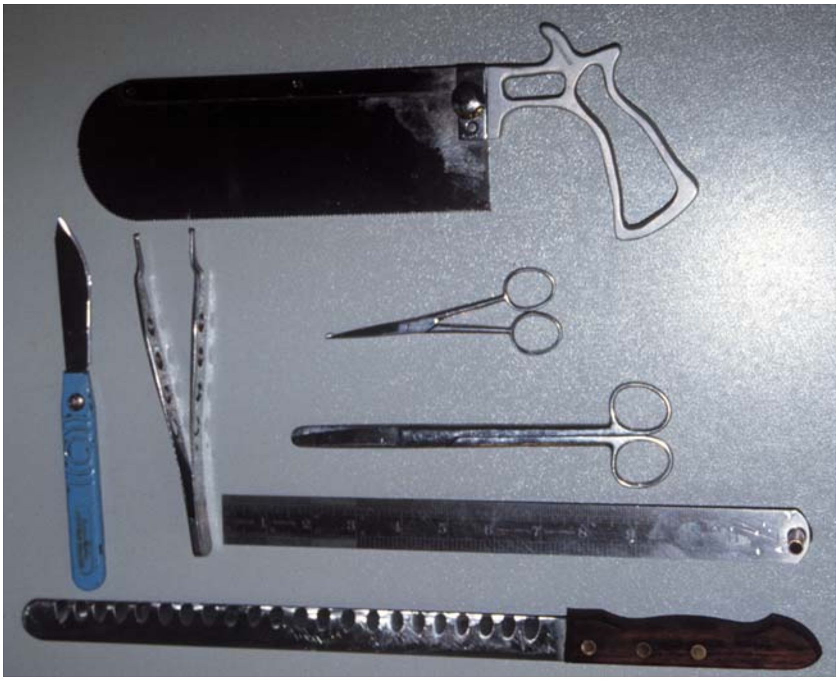

FIGURE 1.12 *The minimum instruments needed for performing an autopsy. Any further items may be useful but not essential.*

The collection of body fluid samples

In a large proportion of forensic autopsies and virtually every one with criminal connotations, samples of blood and other body fluids and tissues are needed for laboratory examination. In relation to sexual offences, the taking of swabs and other samples is described in Chapter 18. Where blood and other fluids are required for toxicological, biochemical, microbiological and serological investigations, they are usually collected at the early stages of the autopsy (see Chapter 27).

The site of collection depends on the nature of the test. When samples for toxicological analysis are required, considerable care should be employed in sampling; this is more fully discussed in Chapter 27.

It is not advisable to use visceral blood for sampling, especially for small molecule substances that can easily diffuse after death; these include alcohol and many pharmaceutical products. Though older textbooks advocate the use of heart blood as a convenient source of samples, it may be contaminated by post-mortem diffusion from the stomach and intestine. After death, the cellular barrier of mucosa and serous membranes breaks down, and substances in the stomach, intestine and air passages can migrate to other organs in the main thoracoabdominal cavity, causing a false rise of the true ante-mortem blood level.

Pounder (1985; see Chapter 27) found that a slurry containing alcohol and paracetamol, placed in the trachea after death to resemble gastric contents, gave rise to appreciable concentrations of those substances in blood samples taken from thoracic vessels, whereas femoral blood remained uncontaminated.

For substances such as carboxyhaemoglobin this does not matter, but alcohol is the prime example of a potential source of error if visceral blood is collected. The better choices for collection sites are:

- by needle and syringe puncture of the femoral vein before the autopsy dissection begins. This requires practice but, in adults, 20 ml can usually be aspirated without trouble. This is the method of choice if only an external examination is possible.
- from the subclavian or external iliac veins after the body has been eviscerated. By holding a small container under the cut end of a subclavian vein and raising the arm, blood can be collected directly. If the flow is slow, the arm can be massaged towards the shoulder. Similarly – and preferably if volume is required – by cutting across the iliac veins at the brim of the pelvis, a container can be dropped into the pelvis with its mouth under the vein and blood massaged into it by firm pressure moved up the inner thigh. As all these containers will be soiled externally, the blood should be decanted into a fresh tube for transmission to the laboratory.
- when the skin is dissected off the neck, the internal jugular vein is exposed, especially if a sternomastoid muscle is divided and pulled aside. When cut, a copious flow of blood is usually obtained, which can be collected directly into a container. The only disadvantage of this method is that if the blood wells

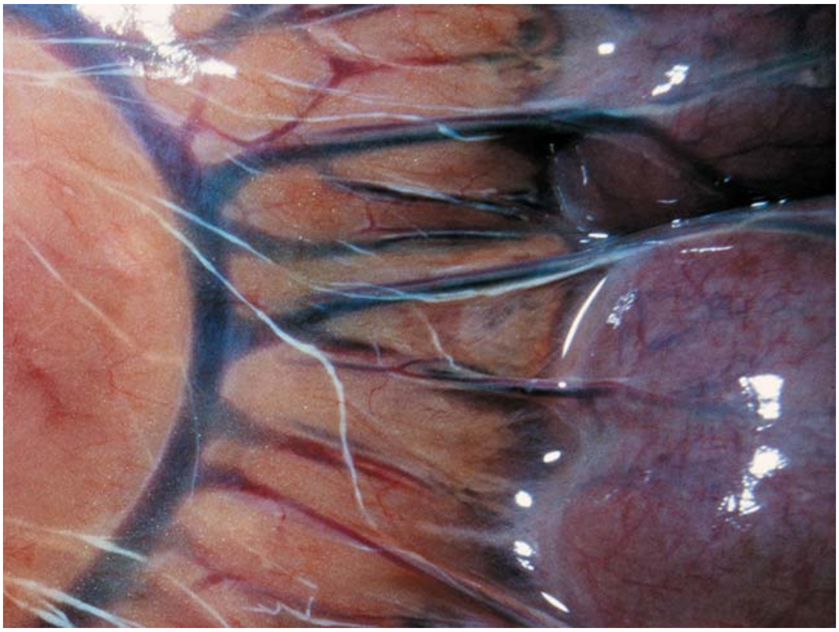

FIGURE 1.13 *White shining fat droplets (chylomicrons) in mesenterial lymphatic vessels suggesting postprandial state.*

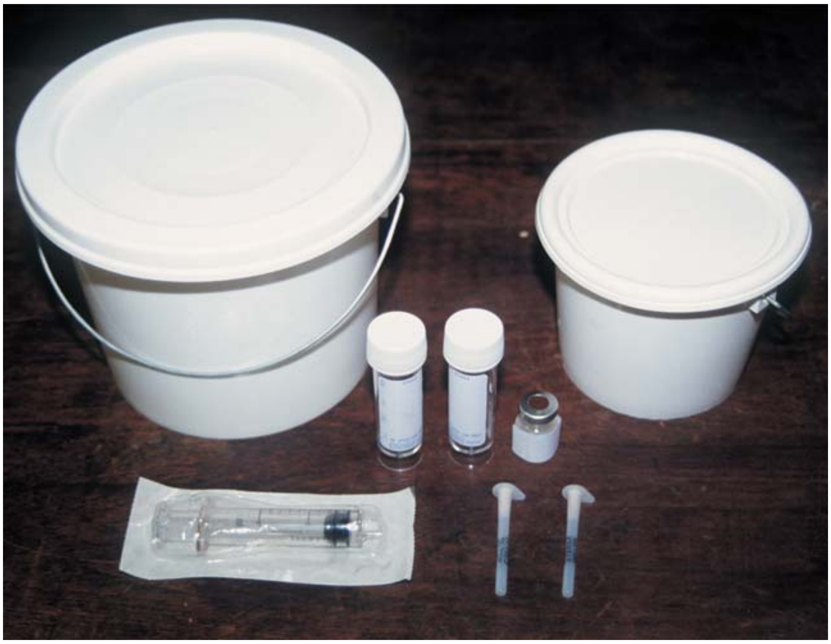

FIGURE 1.14 *Toxicology kit issued by the home office forensic science laboratories. Contained in a plastic bag are a large liver tub, a smaller stomach tub, two universal (30 ml) containers, one rubber-capped fluoride vial for blood alcohol, and a syringe and two needles.*

up from the thoracic inlet via the superior vena cava, heart blood is likely to be admixed, with the possible errors mentioned earlier. If the blood is collected from the upper segment of the jugular, then blood from the head is collected: this flow can usually be stimulated by raising and lowering the head during collection.

Samples for serology, microbiology and for analysis for substances such as carboxyhaemoglobin, which are not absorbed from the gastrointestinal tract, can be collected from any blood vessel, but blood should never be scooped up from the general body cavity after evisceration, as this can be contaminated with any leakage from other structures, such as gastric or bowel contents, mucus, urine, pus or serous fluids.

Blood for microbiological culture has traditionally been taken from the heart but there is no particular merit in this as opposed to peripheral blood. If an infective endocarditis is suspected, it is best to open the heart later with a sterile scalpel and excise the mitral or aortic valve cusps or vegetations for direct culture. Otherwise, blood for culture for a suspected septicaemia is taken from a peripheral vein.

Urine can be collected by catheter before autopsy or even by suprapubic puncture with a syringe and long needle. However, it is usually obtained after the abdomen is opened, but before the organs are removed. If the bladder is full, the fundus is penetrated, and urine collected either by syringe or directly into a container. If almost empty and contracted, the fundus is gripped and pulled upwards so that it stretches, then is incised and the contents removed by syringe. Care should be taken not to contaminate the urine with blood.

The removal of vitreous humour and cerebrospinal fluid may be required for toxicology or for attempts at estimating the time since death by the potassium content (see Chapter 2). Vitreous humour must be aspirated with care if any reliable results are to be attained. A fine hypodermic needle attached to a 5 ml syringe is inserted into the outer canthus of the globe after pulling the eyelid aside. When released, the lid will cover the small puncture mark, hiding any sign of interference. The needle should be entered into the centre of the globe to avoid aspirating material near the retina, which has a markedly different chemical composition due to shreds of detached retina entering the aspirate. The fluid should be sucked off slowly and gently, and as much taken as possible to obtain a mixed fluid: both eyes should be used, as they often differ somewhat in their chemical composition. After withdrawing vitreous, the globes can be re-inflated with water, to improve the cosmetic appearance of the eyes.

Cerebrospinal fluid may be obtained in the same way as in living patients, by passing a needle into the theca between the lumbar spines. A baby can be held upright by an assistant in a fully flexed position; an adult must be pulled into flexion whilst lying sideways on the autopsy table. An alternative technique is to perform a cisternal puncture through the atlanto-occipital membrane.

As there is no pressure within the theca in a cadaver, the fluid must be actively aspirated: sometimes all attempts at obtaining fluid by external puncture fail. The only course then is to try to puncture the ventricles through the exposed brain surface when the skull is opened. Attempting to obtain clear cerebrospinal fluid from the interior of the skull after removal of the brain is generally useless: though blood-stained fluid can be centrifuged to clarity, its chemical composition is then unreliable.

Removal of the viscera

After the body cavities have been inspected, the organs are removed *en bloc* by a modified Rokitansky procedure, more accurately described as Letulle's method. First, the intestine is removed, as follows.

The omentum is lifted upwards to expose the coils of small intestine. The uppermost part of the jejunum is identified, where it passes retroperitoneally to join the termination of the duodenum. Here the mesentery is perforated with the knife and the gut cut through. If it is essential to retain the duodenal/gastric contents or the small intestinal contents, two string sutures may be passed through the hole and tied before cutting the gut between them, but little contents are lost if this is not done. The intestine is stripped out by cutting along the mesentery near the attachment with the bowel until the ileocaecal valve is reached.

The caecum is then mobilized medially using manual traction with minimum use of the knife, to avoid puncturing the lumen. When the hepatic flexure is reached, the omentum is pulled downwards to draw the transverse colon tense against the mesocolon, which is cut through, taking care not to open the adjacent stomach. The splenic flexure is then pulled medially and downwards, and the descending and sigmoid colon separated from the posterior abdominal wall. The upper rectum is cut across, though some pathologists merely lay the gut outside the body, leaving the sigmoid and rectum attached.

Removing the neck structures

To make the removal of the neck structures easier, a block 10–15 cm high should be placed under the shoulders of the cadaver. This allows the head to fall back and thus extends the neck. This should be done gently, as with all handling of the body, to avoid the well-known 'undertaker's fracture', which is a subluxation of the lower cervical spine due to tearing of the intervertebral disc at about C6–C7. This can be misinterpreted as an ante-mortem injury, especially if the other common artefact of haemorrhage over the anterior longitudinal ligament of the cervical spine is present (Prinsloo and Gordon 1951). The neck structures are then freed by passing a knife under the skin of the upper neck until it enters the floor of the mouth. The knife is then run around the inside of the mandible to free the tongue. The tissues at the back and sides of the pharynx are divided, and the tonsillar area cut through. Fingers are then passed up behind the mandibular symphysis to grasp the tongue, which is then drawn down, the remaining tissues behind the larynx being divided to release the neck structures. This should be done as far lateral as possible, so that the carotids can be removed with the laryngeal structures. It is now advisable to look into the pharynx and glottis before any further disturbance, to see if any obstruction, bleeding or other abnormality is present in the upper airway.

Removal of the thoracic contents

The subclavian bundles of vessels and nerves are divided by passing the knife from inside the thorax around the medial ends of the clavicles and first ribs to release the trachea and oesophagus. With gentle traction, the neck structures are held up and pulled caudally, whilst carefully clearing all attachments to the thoracic spine with the knife, taking care to keep the blade on the bone and not stray anteriorly to damage oesophagus or aorta.

Traction should be minimal and, as soon as the thorax is entered, the hand should move from the neck structures to place two fingers under the upper lobes of the lungs, lifting them and the mediastinum as the knife clears the midline structures down to the diaphragm. If the neck structures are pulled too hard by using them as a handle to drag out the thoracic viscera, they may be ripped off. In addition, the descending aorta may suffer transverse intimal tears from traction, which resemble the genuine 'ladder tears' seen in many traffic accidents (Chapter 9).

Pleural adhesions may prevent clean removal of the lungs. If there are only a few, they can be cut through. If the whole pleural cavity is obliterated by adhesions, they may be pulled away by making a cleavage plane with the hand and stripping them off. Sometimes (especially in industrial chest disease and old tuberculosis) the adhesions are dense, tough or even calcified. Removal of the lung may then be achieved by running a knife down the whole length of the parietal pleura over the inner anterior aspect of the ribs, and forcing a hand through the slit to form a cleavage plane to force the parietal pleura off the intercostal muscles and ribs.

Removal of the abdominal organs

When the chest organs are free, they are laid back in the thorax and the diaphragm incised. One hand should pull the liver and spleen medially, putting the left leaf of the diaphragm on the stretch, while the knife cuts it through laterally, near the costal margin. The cut curves posteriorly under the organs to reach the spine, where it must cut through the cruciate ligaments, then passes caudally behind the kidney, which is mobilized forwards.

The knife cut then curves up over the psoas muscle and ends at the brim of the pelvis. The same is done on the opposite side, the operator moving around the body if necessary. The chest organs are then lifted and gently pulled forwards to carry the abdominal viscera towards the feet. Any resistance is usually due to incompletely severed cruciate ligaments, which must be transected.

Eventually the organs will lay inverted across the pubis, secured only by the iliac vessels and ureters, which are cut through and the whole pluck of viscera taken away to the dissecting bench where running water and good illumination must be available.

Removal of the pelvic organs

The treatment of the pelvic contents depends on the type of case. Where the presumed cause of death is unrelated to pelvic lesions, then in men the bladder may be opened widely and the mucosa and trigone inspected before the prostate is incised for examination. The testes are pushed upwards through the inguinal canals, which are widened with the knife. In women, the ovaries are incised and the tubes examined from above before the uterus is sliced in the midline from fundus to cervix.

A more thorough examination of either gender may be made by enucleating the pelvic contents. The knife is passed circumferentially around the pelvic bowl after pulling the bladder away from the pubis. When the walls are free, the knife cuts through below the prostate and then through the lower rectum to allow the pelvic organs to be lifted out. In women the ovaries and tubes are mobilized forwards and the knife passed around the wall of the pelvic bowl, then in front of and below the bladder. The vault of the vagina and rectum is transected, freeing the whole contents. In cases where sexual interference or abortion is suspected, a special technique described in Chapter 19 is employed.

Removing the brain

Attention is then turned to the head. The scalp is incised across the posterior vertex from a point behind the ear to the corresponding place on the other side. Where a Y-incision is used on the neck, the limbs of the Y may be continued right across the scalp, especially if a face dissection is necessary.

The tissues are reflected forwards to the lower forehead and back to the occiput. The deep scalp tissues may peel off by traction, but often require touches of the knife to free them. Bruising is sought and, where head injuries are present or suspected, the scalp should be reflected right back to the nape of the neck, paying particular attention to the tissue behind and below each ear where injuries causing vertebrobasilar artery damage occur. Where there are facial injuries, the skin of the face may be peeled back from the jaw line and downwards from the forehead, restoration being excellent if care is taken not to perforate the facial skin during removal.

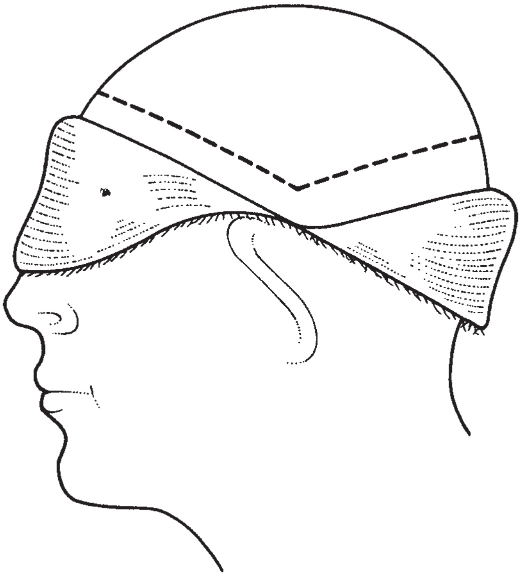

FIGURE 1.15 *Angled saw-cuts for removal of skull-cap to avoid slippage during reconstruction.*

The skull is sawn through, using either hand or power tools. The line of the cut should not be along a circumference, as it is then impossible to reconstitute the head without unsightly sliding of the calvarium. There should be an angled removal, with a horizontal cut from forehead to behind the ears joined by a second, which passes diagonally upwards at a shallow angle over the occipitoparietal area. Care must be taken not to place this posterior saw-cut too vertically (and thus anteriorly) on the skull, or the brain may be damaged by forcing its removal through too narrow an aperture.

The calvarium is then removed by leverage after complete cutting through. A mallet and chisel should not be used in forensic autopsies, even to ensure that the dura is kept intact. The risk of extending or even causing fractures by the use of excessive hammering is too great merely to justify an unmarked dural membrane. A cut dura is easily recognized as such by any competent pathologist. What is more important is to inspect the surface of the exposed dura and brain and assess any oedema, bleeding or inflammatory conditions that may be present. The skull-cap is carefully inspected for fractures and the dura peeled off the inside to study the inner skull surface.

To remove the brain, the dura is incised around the line of skull removal and two fingers slipped beneath each frontal lobe. With gentle traction the frontal lobes are lifted to expose the optic chiasma and anterior cranial nerves. The falx may have to be cut to free the brain, then a scalpel or blunt-pointed bistoury is passed along the floor of the skull to divide the cranial nerves, carotid arteries and pituitary stalk until the free edges of the tentorium are accessible. A cut is made along each side of the tentorium, following the line of the petrous temporal bones to the lateral wall of the skull. Continuing with traction on the brain, but being careful not to impact the upper surface against the posterior saw-cut, the knife severs the remaining posterior cranial nerves and then passes down into the foramen magnum to transect the spinal cord as far down as can be reached. The hand is now slid under the base of the brain, which is rotated backwards for removal, any attached dura being severed where necessary. The brain is taken into a scale pan and weighed before either fixation or dissection.

The floor of the skull is now examined and the basal dura stripped out with a strong forceps to reveal any basal fractures. Discarded dental forceps can be useful for this purpose. The venous sinuses are incised to search for thrombosis. Where appropriate – and always in infants – the petrous temporal bones are sawn, chiselled or cut with bone forceps to examine the middle and inner ears for infection.

Removal and examination of the spinal cord

It is not an invariable routine to remove the spinal cord at autopsy unless there are indications that some lesion may be present. Where there is the slightest possibility of damage to the vertebral column, its blood vessels or the contents of the spinal canal, however, there should never be any hesitation in extending the autopsy to include this area.

There are several methods of removing the cord and for full details, the texts of Ludwig (2002) or Knight (1983) should be consulted. Briefly, there are two main approaches to the spinal canal, the anterior and posterior.

In the anterior method, the vertebral bodies are removed after complete evisceration of the body, by sawing through the pedicles by a lateral cut down each side. The advantages are that the body need not be turned over on to its face and an extensive dorsal incision is avoided, which requires subsequent repair. The author finds this method more laborious, however, especially in the thoracic region where the heads of the ribs make the approach difficult.

The more usual posterior approach requires a midline incision from occiput to lumbar region, the paraspinal muscles being reflected along with subcutaneous tissues. Two parallel saw-cuts are then made down the length of the spine to divide the right and left laminae, and to give access to the spinal canal. This is best done with an electric oscillating saw, taking care not to cut so deeply that the spinal dura is penetrated. The strip of bone may be dissected off from below upwards to expose the spinal canal.

The cuts should be placed sufficiently lateral to allow the cord to be removed without difficulty. When the canal is exposed, the dura is examined for haemorrhage, infection or other abnormalities, then removed – still within its dural sheath – by transecting the nerve roots and dural attachments, and peeling it out progressively from below upwards. The dura is then carefully opened with forceps and scissors to examine the cord itself. It can be fixed in formalin, as with the brain, before cutting, or dissected immediately and samples taken for histology. Crushing, infarction, infection, haemorrhage and degeneration are the main lesions in a forensic context. The empty spinal canal must be carefully examined for disc protrusions, tumours, fractures, haemorrhage dislocations and vertebral collapse.

Where in any autopsy spinal damage is suspected, a good preliminary test is to slide the hands under the back of the eviscerated body on the autopsy table and lift the dorsolumbar spine upwards, whilst watching the interior vertebral bodies. If a fracture or dislocation is present, abnormally acute angulation will be seen, instead of smooth bending. The cervical spine can be tested by manual manipulation. If suspicious angulation is seen, a slice can be taken along with the anterior spine, through the vertebral bodies and discs, with an electric or handsaw. This will reveal the interior of the spine and exhibit any crushing, haemorrhage, or torn disc spaces: if one of these is found, the cord must always be removed.

EXAMINATION OF ORGANS

Examination of viscera

The thoracic and abdominal viscera are laid on a cutting bench at a convenient height and under good illumination. Ample washing water should be available from a flexible pipe, to flush the tissues as dissection proceeds. Some pathologists maintain that this should not be done, as the water can have an effect on the quality of subsequent histological sections, but this has recently been disproved (Cotton and Stephenson 1988). In any case, the vastly inferior naked-eye examination that results if blood is not removed at frequent intervals greatly outweighs any unsubstantiated objections about the more exquisite details of cell structure, especially as in most forensic autopsies the gross appearances are usually far more important.

The viscera should be laid so that the tongue faces the pathologist, with the aorta upwards. The same sequence of examination should be carried out whatever the nature of the case, so that a fixed routine will ensure that nothing is left undone.

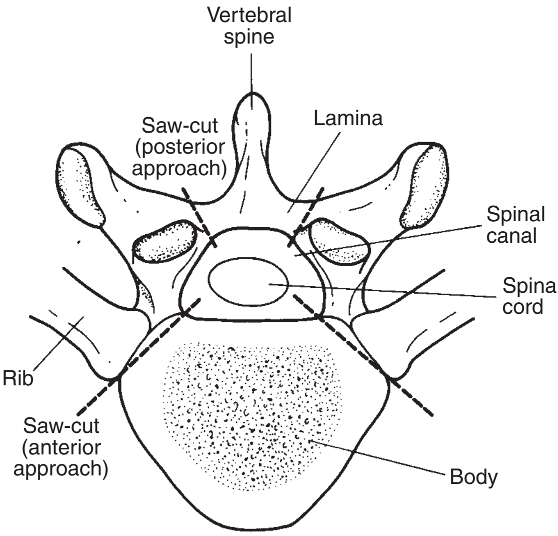

FIGURE 1.16 *The two approaches to the spinal canal for the removal of the spinal cord at autopsy.*

The neck structures

The tongue is examined for disease and injuries, including bites suggesting blows in the jaw or epilepsy. The tongue should be sliced to detect deep haemorrhages sometimes seen in strangulation. Such haemorrhage is seen mostly at the sides and centre of the mid-part of the tongue. Gross congestion, which may be due to either pressure on the neck or to other congestive modes of death, is usually in the posterior part of the tongue. The tonsils and pharyngeal walls are inspected.

The glottis is examined for mechanical or infective obstruction, and the hyoid and thyroid horns palpated for fractures. The oesophagus is opened with large (20 cm) blunt-nosed scissors, which along with a very sharp 10–15 cm bladed knife and a long-bladed 'brain knife', are the most useful tools for performing an autopsy.

The carotid arteries on each side are opened, including the bifurcations and sinuses. If necessary, the upper portions of the carotids are explored in the body itself and followed to the base of the skull. If thrombosis is suspected, the intracranial part should be examined in the cavernous sinus.

Returning to the neck structures, the thyroid should be sliced and inspected, then the oesophagus opened almost to the cardia of the stomach and any suspect material such as capsules, tablets or powder retained for analysis.

The scissors are then passed down the posterior line of the larynx and trachea to the carina. If pressure on the neck of any type, such as strangulation, is suspected, then special examination should be made, as described in Chapter 14.

The trachea and main bronchi should be inspected for disease and obstruction. Gastric contents are often found, but the significance of this is discussed in Chapter 13 – it should not be assumed that ante-mortem aspiration has occurred merely from the presence of gastric contents in the air passages.

The lungs

The lungs are then removed, after careful examination of their external surfaces for patchy collapse, emphysema, petechiae and so on. Almost every autopsy will reveal a few petechiae, especially around the hilum and in the interlobar fissures. Their significance is also discussed in Chapter 13.

The lungs are removed from the thoracic pluck by passing a long-bladed knife (such as a brain knife) under the hilum with the blunt edge upwards. The knife is settled in the correct position before turning the sharp edge upwards to cut through the hilum. Before doing this it may be necessary to remove adhesions over the diaphragm and to cut through the pulmonary ligament, a thin sheet of tissue that ties the inferior medial edge of the lower lobe to the mediastinum.

As the hilum is being cut, the pathologist must notice if any embolism is visible within the pulmonary arteries. It has happened that such an embolism has slid out and been washed unnoticed down the sink. Some pathologists insist on opening the main pulmonary trunk and even right ventricle before removing the lungs, to seek a saddle embolus. This is not necessary, as any large embolus will be readily visible on examining the heart and the lungs in the usual sequence.

Both lungs are taken off and the hilum inspected before being laid aside for cutting. The lung should be weighed before cutting, as appreciable oedema fluid can run away during dissection. Then each is laid with the hilum down on the dissecting board, the opportunity being taken during handling to evaluate weight and oedema, as well as emphysema.

The lung is held on the upper surface by the left hand of the operator (or by an interposed sponge) and the organ cut across in the sagittal plane from apex to base with the large brain knife, held parallel to the board. This produces an anteroposterior slice, the lower medial part carrying the hilum. The cut surfaces can now be opened like a book and the surface examined for oedema, tumour, pneumonias, infarction, trauma and so on. The smaller bronchi must be inspected for such signs as mucosal thickening, infection and blockage. The smaller pulmonary arteries may reveal thrombosis or embolism that was not visible in the larger vessels.

INFLATING THE LUNGS WITH FORMALIN

In some medico-legal autopsies, especially in industrial lung disease such as pneumoconiosis or asbestosis, one or both lungs need to be inflated with formalin for fixation before cutting. This preserves the shape and histology in excellent condition, but delays examination for at least several days. It is carried out by holding or tying a cannula into the bronchus while 10 per cent formol saline is perfused through a tube from a reservoir held about 1 metre above the lung. The lung is then left in a bath of formalin covered with a formalin-soaked cloth to prevent drying.

The heart and great vessels

There are almost as many ways of examining the heart as there are pathologists, and each operator must decide upon the method that appeals most. In this summary there is no space for discussion of post-mortem angiography, which is moving from the field of research and special interest into routine use. A common and practical routine for examining the heart is described here.

First, the organ mass minus the lungs is rotated so that the lower end now faces the pathologist. The scissors are passed into the cut end of a common iliac artery and passed right up to the aortic arch and around to a few centimetres above the aortic valve, staying outside the reflection of the pericardium. The interior of the aorta is studied, especially for the degree of atheroma and for any aneurysms or trauma. The inferior vena cava is opened from its lower end into the liver. The organ pluck is then turned over so that the heart is uppermost. The pericardium is inspected externally for fluid and blood tamponade, then opened widely with scissors. The heart is delivered through the incision and inspected externally for pericarditis, adhesions, discoloration of an underlying infarct and cardiac aneurysms, for example. In a child, the thymus would be inspected and dissected off at this stage.

The heart is then removed by holding it up with the left hand so that its attachment is tensed against the other organs. A long knife, such as a brain knife, is then passed horizontally across at the reflection of the pericardium, cutting through the root of the aorta and other great vessels just above the atria.

The now-detached heart is washed externally and placed in the anatomical position on the dissecting board, with the apex facing the operator and the anterior surface upwards. It should not be weighed until all the contained blood and clot is removed. The general size, shape and ventricular preponderance should be noted. Any dilatation or thickening of the pulmonary conus should be noted as an index of right ventricular hypertrophy, especially if striae of transverse muscle fibres are seen crossing the conus.

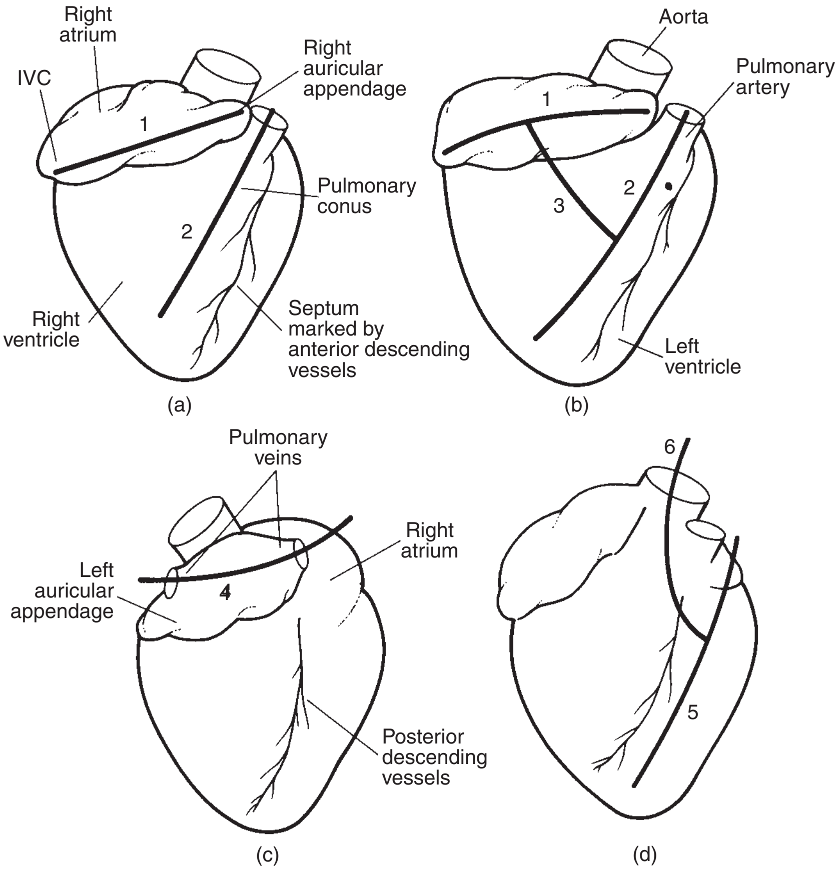

FIGURE 1.17 *Incisions for opening the heart at autopsy. (a) The right atrium is slit with an incision (1) to join the vena cava to the appendage; a cut parallel to the interventricular septum is made on the anterior wall of the right ventricle (2) passing up through the pulmonary conus. (b) These cuts are joined through the tricuspid valve (3). (c) The heart is reversed and the left atrium opened by a cut (4) joining pulmonary veins. (d) On the anterior wall a cut (5) is made parallel to the septum through the mitral valve and joined by (6) which passes through the aortic valve.*

The right atrium is then opened by introducing the scissors into the inferior vena cava and cutting across to the atrial appendage. The interior of the atrium is examined and the septum and tricuspid valve inspected.

The interventricular septum is then identified externally by the vessels running down the outside. With a knife a cut is made about 15 mm to the right of and parallel to the septum, over the right ventricle. This should be deep enough to enter the lumen, but not enough to cut the posterior wall. The scissors are now introduced into the cut and run up through the pulmonary conus and into the pulmonary artery until they meet the transected end. They are also extended downwards to the apex of the ventricle. The scissors are now put in midway down this linear cut and passed outwards at right angles, guided by the fingers of the left hand passed into the tricuspid valve from the opened atrium. The whole of the right side of heart is now open and displayed. It should be washed out and the endocardium and valve examined.

A similar routine is now employed on the left side. The scissors are introduced into a pulmonary vein and passed horizontally across to an opposite vein, thus opening the atrium. Fingers are introduced down through the mitral valve to estimate its size and detect any stenosis.

The heart is then restored to the anatomical position and a cut made again parallel to the septum, but on the left side, going deeper as the ventricle is thicker. Guided by the fingers still in the mitral valve, the cut is extended upwards through that valve and out at the top of the atrium.

A finger is now passed up the outflow tract to the aortic valve to estimate its size. Then the scissors are passed up at the side of the mitral valve, and the aortic valve and aortic stump opened. The whole heart is now open and can be washed out and weighed.

Various estimates of the normal heart weight exist and vary considerably (see the Appendix 1). It has been related to gender and body weight, though this is not altogether sound, as a fat person of moderate stature does not have a heart weight comparable with a large muscular person unless there is associated hypertension. This controversial matter cannot be pursued here, but as a rule of thumb the author (BK) accepts up to 380 g as normal in an adult man of average build.

After weighing, the endocardium and valves are examined, then the coronary arteries. Once again, controversy exists about methods of opening the coronary vessels, but the weight of opinion now lies almost universally with those who cut serial interrupted cross-sections with a knife, rather than open them longitudinally with small scissors. The disadvantages of lengthwise opening are that percentage assessment of stenosis or the recognition of total occlusion cannot be made once the vessel is flapped open, as restoring the cut edges can never reproduce the original conditions. In addition, the tip of the scissors may dislodge thrombus or an intimal flap. Cutting across the vessels allows an estimate of the percentage stenosis. It is admitted that this may not be the size of the lumen during life when normal blood pressure is operating, but the same disadvantage applies to longitudinal opening. An estimate of luminal size is relatively constant, however, in that the collapsed abnormal can still be compared with the collapsed normal.

The coronaries are therefore cut across at frequent intervals. Before the first cut, the ostia are examined for congenital variations (which are frequent) and for obstruction. The left coronary artery is then cut across from the epicardial surface, starting as close to the ostium as possible, as occlusion and severe stenosis can occur very near the origin. Serial cuts are then made at intervals of not more than 3 mm, first into the common trunk, then following the left circumflex laterally until the vessel becomes too small, usually when it dips down from the epicardium to become intramuscular. The anterior descending branch is then followed down the front of the septum almost to the apex.

Turning to the right coronary artery, the proximal segment is cut back from the point where the right ventricle was opened, transecting the artery in its mid-part. The cuts are made back to the aorta, then the distal segment is followed laterally until it becomes the posterior descending branch. During this process, the dominance of right versus left vessels is noted.

Difficulty arises where severe calcification exists, as the knife either fails to cut through the artery or shatters it because of the excessive force required. The lumen is crushed and the percentage stenosis is difficult or impossible to assess. Scissors may be used to exert more force than a knife, but the only real solution is to decalcify the vessels. Except for research purposes, it must be admitted that the days or even weeks of delay occasioned by decalcification provide a formidable deterrent for the busy coroner's pathologist unless the issues involved are important. Post-mortem angiography is the other alternative, though where autopsy caseloads are high, this can be difficult to arrange.

Once the coronary arteries have been examined, the myocardium can be studied more closely. One useful technique is the intramural or 'sandwich' cut through the thickness of the left ventricle. This is easier when there is some ventricular hypertrophy, but can be carried out in any heart. The heart is placed open on the cutting board, with the endocardium downwards. A long knife such as a brain knife is passed carefully into the cut edge of the left ventricle and sliced right through the muscle, keeping equidistant between endocardium and epicardium. The myocardium can then be opened out like a book, showing the interior with any infarcts or fibrotic plaques. If histological blocks through the entire wall are needed it is best to take these before slicing the heart as described, otherwise a full-thickness block will be hard to obtain. Some pathologists make a series of transverse heart slices about 8–10 mm thick, starting at the apex, before opening the heart. This displays the distal myocardium wall, but cannot expose the proximal part, as examination of the coronary arteries would then be compromised.

Examining the abdominal organs

The remaining organs are laid on the dissecting surface in the anatomical position, with the liver and stomach away from the pathologist, and the anterior surface upwards.

The stomach is opened and, if there is any question of requiring the contents for analysis, a suitable container should be ready. The stomach is washed externally with a stream of water and a small cut made in the greater curvature. If the contents are to be saved, this can best be done with the edge of the stomach projecting over the raised cutting board or over the edge of the sink, so that the container can be held underneath. The contents are allowed to run into the container, then the greater curvature is opened widely with scissors, and any remaining contents drained or scraped out. If powder or other substance is adherent to the mucosa, this can be scraped off and added to the container, or kept in a separate tube for analysis.

Some laboratories require the stomach wall to be retained for analysis as well as the contents. This can be done after the organ has been fully opened and the lining examined. If the contents are not required – or when they have been collected – the organ is opened up from cardia to pylorus along the greater curvature. The lining is washed and inspected. The scissors are now passed through the pylorus around the duodenum until they meet the point where the gut was detached earlier. The gall bladder may be squeezed to demonstrate the patency of the bile ducts. In some few cases, bile may be required for analysis, as in morphine or chlorpromazine overdose.

The adrenals are examined next, the right one being on top of its kidney, the left being on the medial side. If the right kidney is taken in the left hand and lifted against the weight of the liver, a single cut into the stretched tissues between liver and kidney will transect the adrenal. The left is buried in the tissue between pancreas, spleen and kidney. The amount of cortical lipoid and the absence of bleeding or other abnormality is noted in each gland.

The spleen is removed by cutting through its pedicle and is sliced after weighing. The pancreas lies under the stomach and should be cut lengthwise from the curve of the duodenum to its tail lying against the splenic hilum.

The kidneys are exposed by incising their capsules, often after a thick layer of perirenal fat is traversed. The kidneys can usually be peeled out of their capsules unless these are adherent.

The renal vessels were examined when the aorta was opened, but can be re-examined at this stage and the ureters inspected. The organs can be detached at their hilum and weighed, then cut lengthwise to inspect the interior. The width of the cortex is important, being about 1 cm in a

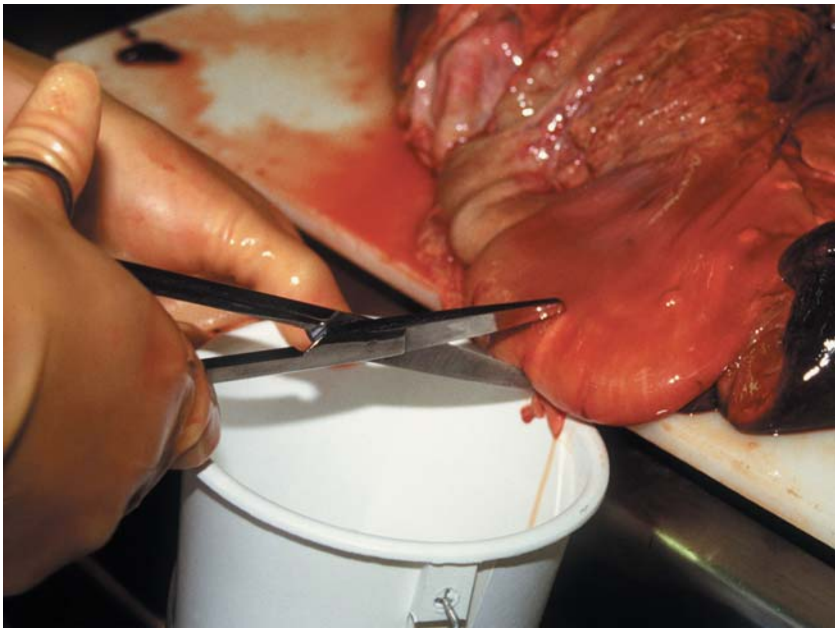

FIGURE 1.18 *Collecting stomach contents at autopsy. The exterior of the stomach is washed free from blood and the viscera moved to overhang the dissecting board. A chemically clean receptacle is held beneath the greater curvature while the latter is opened with scissors and the contents allowed to drain out. The stomach is then opened, the mucosa inspected and any adherent material scraped into the container. The stomach wall should then be dissected off and added to the contents if the laboratory is able to deal with tissue analysis.*

healthy subject. The granularity of the surface and the clarity of the corticomedullary junctions is assessed, as well as the size of the renal pelvis.

The small intestine may have been examined at the earlier stage of removal, but can be inspected now. It is not usual to open the whole length of the gut in a forensic autopsy unless there is any particular indication to do so, though ideally this should always be carried out.

EXAMINATION OF THE BRAIN

After weighing, a decision has to be made whether to examine the brain immediately – the so-called 'wet-cutting' – or to suspend it in formalin until fixed, a process which takes at least several weeks. The advantage of fixation is, of course, that the firmness of the tissue allows thinner and more accurate knife-cut sections to be taken, as well as better histological preservation. Where neurological issues are involved, either traumatic or from natural disease, it is almost mandatory for the brain to be fixed before cutting. Even the impatience of the investigative authorities can usually be overcome if the advantages of a higher standard of opinion are explained.

The technique of brain fixation is well known, but to summarize briefly, the brain is suspended in a container of 10 per cent buffered formalin, the volume being at least 5 litres and preferably 8. The brain is removed with the dura leaving the parasagittal bridging veins and falx intact and suspending the brain in an upright position by the falx. An alternative method is to pass a thread or metal paperclip under the basilar artery and tie it to a support across the mouth of the container, so that the vertex is clear of the bottom.

In the majority of autopsies there is no real need for fixation if no cerebral lesions are either expected or apparent on external examination of the brain. Here, 'wet-cutting' is sufficient, though if any unexpected lesions are found, the process can be stopped and the slices of brain fixed by placing them in a large volume of formalin, on cotton wool pads, to prevent distortion.

One lesion is better examined in the unfixed state, though the brain may be suspended later; this is subarachnoid haemorrhage. It is easier to wash away fresh, unfixed blood with a stream of water and blunt dissection than the hardened blood that develops during formalin fixation. Further details are given in Chapters 5 and 25.

Whether the brain is examined 'wet' or fixed, the sequence is the same. The weight is first considered, the normal for a young male adult being between about 1300 and 1450 g, the female equivalent being around 100 g less. More details are given in Appendix 1. It should be noted that formalin fixation adds about 8 per cent to the original weight.

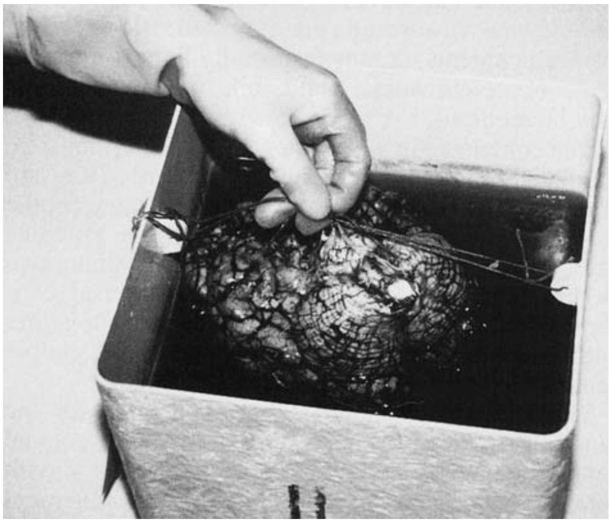

FIGURE 1.19 *A brain suspended in formalin for fixation before cutting. The tank is specially made of fibreglass, being cubical for stacking with a lid (not shown). There are lugs moulded into the sides to hold the suspensory strings, which support the brain by means of a paperclip hooked under the basilar artery. There should be sufficient fluid to allow the brain to float clear of the bottom of the receptacle.*

The brain is first examined for surface abnormalities, which in forensic practice usually means haemorrhage. This is dealt with in Chapter 5, but suffice to say here that meningeal bleeding is one of the most important lesions in forensic pathology, be it extradural, subdural or subarachnoid. This means that examination of the cerebral vessels, especially the arteries of the circle of Willis and the vertebral vessels, is vital – especially in the search for berry aneurysms. The general symmetry of the brain is then noted as well as any depression of the cortex from skull or meningeal masses. An estimate of cerebral oedema is made, partly from the weight, but mainly from flattening of the gyri, filling of the sulci and evidence of hippocampal herniation through the tentorial aperture. In lesser degree this may be seen as grooving of one or both unci, though a normal slight anatomical groove is often present. True uncal herniation is marked and often discoloured as a result of incipient infarction. Similarly, herniation or coning of the cerebellar tonsils through the foramen magnum must be distinguished from the common anatomical pouting of many tonsils: true pressure coning is often discoloured by local infarction. After careful inspection of the basal vessels and the exterior of the brain, and palpation for any fluctuant masses under the cortex such as internal haemorrhage, abscesses or cystic tumours, the organ is cut.

The first cut should be made through the cerebral peduncles using a long, broad-bladed knife to separate the cerebrum from the brainstem and cerebellum. The cerebellum is then held in one hand with the cut stem upwards.

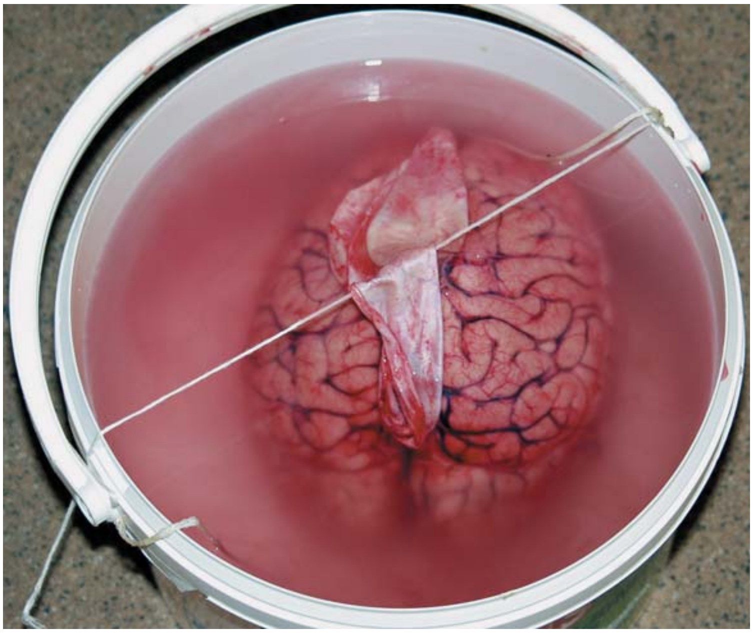

FIGURE 1.20 *An alternative method of suspension is to leave the falx intact and use it to suspend the brain base down in formalin.*

This is examined to assess the substantia nigra and aqueduct, as well as to note any primary or secondary haemorrhage, the latter often being due to raised intracranial pressure. The cerebellum and pons are then cut down vertically and opened like a book to display the fourth ventricle, dentate nuclei and the interior of the cerebellum. The lower pons and medulla can be further sectioned transversely or longitudinally.

The cerebral hemispheres are then placed base down on the cutting block and serial sections made in the coronal plane from the frontal lobes back to the occiput. The sections should be about 1 cm thick and each should be slid into a sequential place in rows along the cutting board so that orientation is preserved. Cuts should be made with careful but bold sweeps of the knife as erratic sawing motions will leave an irregular surface on each section, which obscures a good view. Cutting a fresh brain is less satisfactory than cutting a firmer fixed brain, especially if there is any post-mortem autolysis or softening as in a dead ischaemic brain after mechanical ventilation.

ANCILLARY INVESTIGATIONS

A wide range of samples may need to be taken either before, during or after the gross examination is completed. The nature of such ancillary investigations naturally depends upon the nature of the death, the history and the interests of the pathologist.

Microbiology

Though more common in clinical autopsies than forensic work, culture samples for ‘bacteriology’, virology and (rarely) fungi may be needed. Either plain swabs or swabs immersed in a transport medium can be employed for sampling a wide variety of sites at autopsy. Alternatively, tissue samples may be collected in sterile containers and this is the usual method for virological culture of lung and brain, for example. Blood cultures may be desired, and it is best to take blood with a sterile needle and syringe from a large vessel, such as the femoral vein, before starting the autopsy with its attendant inevitably widespread contamination with putrefactive organisms. Alternatively, blood can be taken from a freshly opened heart chamber using sterile instruments.

In all autopsy investigations, unless cultures are performed soon after death, there is often widespread contamination by organisms that travel rapidly through the dead tissues, especially from the gastrointestinal tract. It requires the expertise of an experienced microbiologist to advise on what is significant in the subsequent growth in the laboratory.

Toxicology

This has already been mentioned and is further discussed in the later chapters of this book but, as far as the collection of specimens is concerned, it may be repeated here that sampling is extremely important if reliable analytical results are expected. Blood, urine, stomach contents, organs (especially liver), intestinal contents, cerebrospinal fluid, bile and ocular fluid may be required.

The containers in which specimens are collected must be chemically clean to a very high standard. They are often supplied by the laboratory that will carry out the analyses. For example, the Home Office Forensic Science Service in Britain supply a kit containing two large plastic tubs with lids, several universal containers, fluoride tube, syringes and needles, together with instructions as to type and quantity of sample needed for various tests.

The pathologist should submit a form with the samples indicating the analyses required, the personal details of the deceased person, a brief history with details of suspected toxic substances, and a statement as to whether the subject was known to suffer from any infective condition, including hepatitis or HIV infection.

Histology

In most autopsies and inevitably in all criminal or litigious cases, the pathologist will need to carry out a histological examination on a range of tissues, even if only to exclude the possibility of some occult natural disease. The Royal College of Pathologists as well as the 1999 Council of Europe recommendation on the harmonization of medico-legal autopsy recommend that histology be taken from every autopsy. This advice should be followed wherever possible, even though in some medico-legal autopsies, the cost of such techniques may provide difficulty if the coroner or other commissioning authority declines to fund the procedure. It is customary to retain samples of liver, spleen, kidney, heart, lung, thyroid, adrenal, pancreas, muscle and brain as a minimum. Where there are indications to examine other parts of the body, these are retained in addition to the routine tissues. The tissues are either sampled by taking relatively large pieces at autopsy (which are later trimmed down to size) or by cutting blocks of a standard size (such as 20 × 12 × 5 mm) at the time of autopsy.

The tissue is placed in a large volume of buffered formol–saline and allowed to fix for at least several days before processing. The volume of fixative should be six times the total volume of tissue: it is all too common to see a mass of tissue squeezed into a small container, barely covered with formalin, half-fixed and even semi-dried. There are many specialized procedures also in use at present, such as histochemistry, fluorescent microscopy and immunohistochemical examination; these are used especially in the pathology of sudden death where evidence of early myocardial infarction is sought. This is discussed in the chapter on sudden natural death (Chapter 25).

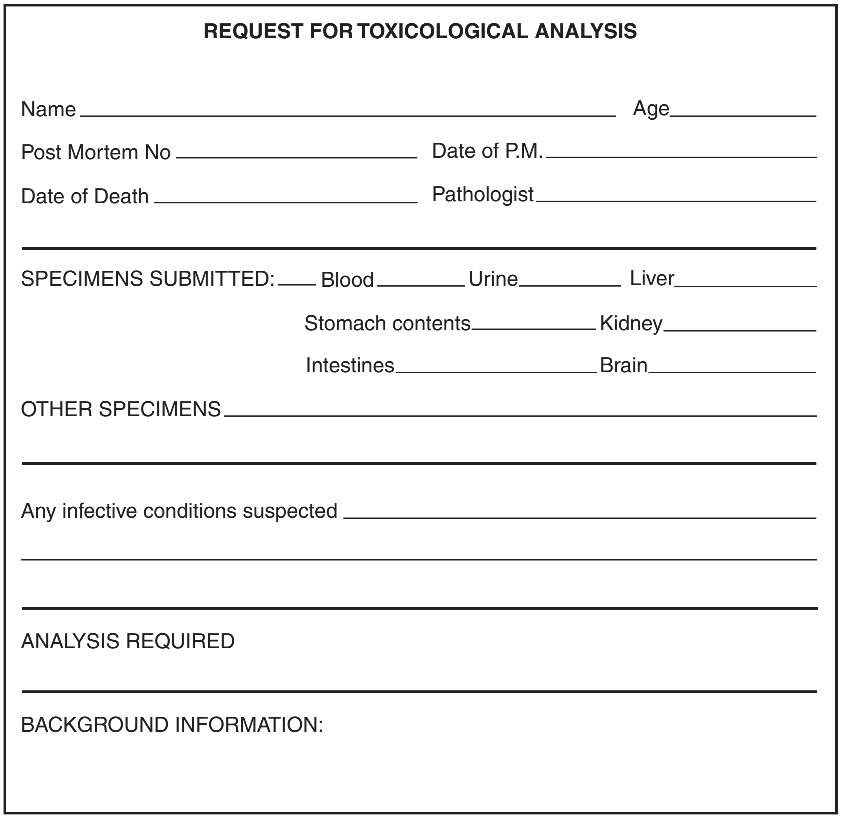

REQUEST FOR TOXICOLOGICAL ANALYSIS

Name Age

Post Mortem No Date of P.M.

Date of Death Pathologist

SPECIMENS SUBMITTED: Blood Urine Liver

Stomach contents Kidney

Intestines Brain

OTHER SPECIMENS

Any infective conditions suspected

ANALYSIS REQUIRED

BACKGROUND INFORMATION:

FIGURE 1.21 *Sample request form for toxicological analysis.*

AUTOPSY RADIOLOGY

The details of radiological findings are discussed in each appropriate chapter, particularly in relation to child abuse, gunshot wounds, identification and dentistry. In general, radiology is similar to photography in the autopsy room, though it requires more bulky apparatus, and someone to operate the equipment and process the films.

The quality of radiographic assistance available will vary widely from none to the most sophisticated techniques, even including computed tomography and even, in very few centres, magnetic resonance imaging (MRI).

The main difference is usually whether the autopsy is carried out in the mortuary of a well-equipped hospital where there is radiographic apparatus, radiographers to use it and radiologists to read the films – or whether the autopsy is performed in some remote public mortuary or in makeshift premises far from clinical facilities.

In many developing countries, radiography may be scarce for living patients let alone corpses, and the same standard of assistance for the pathologist cannot be expected. In larger, more affluent countries, remoteness may be the problem; here mobile equipment is available and sometimes used by forensic pathologists. There are small, portable X-ray kits that can be carried in two suitcases, and can function from an ordinary domestic power supply or from a portable petrol generator. In many instances a mortuary will have a small portable machine, sometimes one discarded from clinical use. This can be wheeled into position when needed, and films and technical assistance obtained from the nearest hospital, which is often adjacent.

For isolated organs and tissues, cabinet-type radiographic equipment is available, which can be used without the assistance of trained radiographers.

Where there is a large forensic institute, then full radiological facilities with the staff and equipment to operate and process plates will be available at all times. Where research projects involving radiology, such as post-mortem coronary angiography, are being carried out, there will usually also be ample facilities for routine use.

The stage at which radiology is employed in an autopsy will vary according to the individual circumstances, but is likely to be after the external examination is complete, but before dissection begins. Straight radiographs for bony injury are not often required, as the skeleton can be inspected directly by dissection in major trauma. The exception is child abuse, where, as fully described in Chapter 22, a full skeletal survey is needed before autopsy. Indeed, many forensic and paediatric pathologists would consider radiology essential in all infants who did not die of some obvious disease.

Suspected air embolism, pneumothorax, barotrauma, gunshot and explosive deaths should have radiological examination before the autopsy, and when a traumatic subarachnoid haemorrhage is suspected, vertebral artery angiography might be necessary, as described in Chapter 5.

Mutilated remains, especially those from mass disasters, may need to be X-rayed, as may victims from fires where the external damage makes dissection difficult. Where bombs or explosive devices are involved, it is essential to have radiographs to detect any parts of the mechanism that are embedded in the tissues.

Though the films are usually taken before the autopsy begins, some lesions may be better demonstrated on isolated

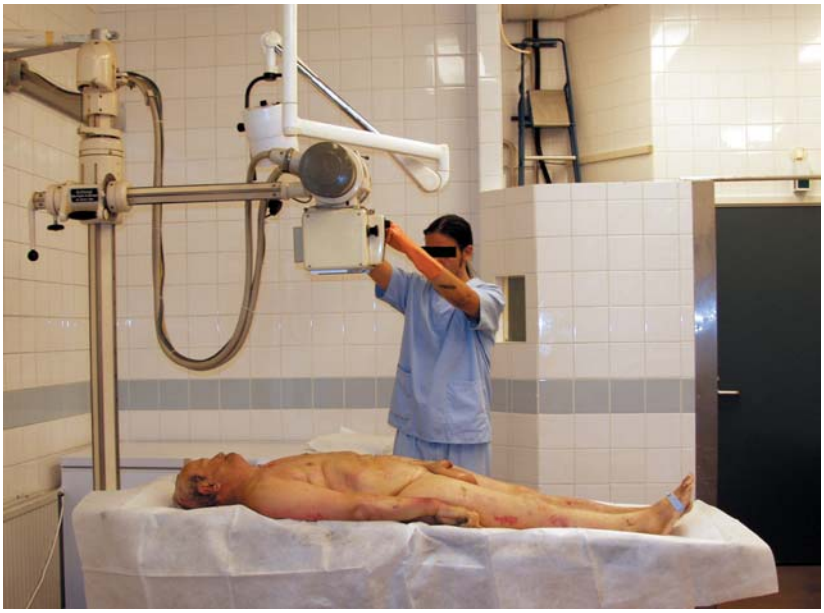

FIGURE 1.22 *Radiography is essential before some autopsies. Here it is being used to X-ray a gunshot wound of the chest.*

organs or structures. In child abuse, the callus of old fractures of posterior ribs may be better visualized on X-ray if the chest cage is dissected out, and radiographs taken without the soft tissues and the obscuring structures of sternum and anterior ribs. Similarly, a block of upper cervical spine may better reveal fractures of transverse processes carrying the vertebral artery, or a larynx may show fractures of the hyoid or thyroid cornuae more clearly when they are X-rayed outside the body.

FORENSIC PHOTOGRAPHY

Many forensic pathologists take their own photographs of both scenes of death and of autopsy appearances. Others rely on professional photographers such as the police and hospital medical photographers.

The standard of expertise amongst some doctor photographers is excellent, and their pictures grace many lectures and textbooks. It is to the more inexpert camera operators that these few general tips are offered.

The type of camera most favoured is the 35 mm single-lens reflex, of which there is now a vast range available, in all grades of sophistication and price. Some means of exact focusing is essential (either automatic or split-screen, for example) as picture sharpness is of prime importance.

The type of lens is a matter of personal choice, as some will prefer interchangeable lenses of various focal lengths. The standard 50 mm is most useful, but for scenes of crime or taking a full-length shot of a body in cramped conditions, a wide-angle lens of 28 or 30 mm is needed. A longer focal length of up to about 80 mm can be useful for close-up pictures of small lesions, but telephoto lenses of 100–200 mm are not required, though extension tubes, some with lenses, can be obtained for macrophotography.

Many pathologists, including the authors, prefer to combine lenses into a single variable-focus ‘zoom’ lens of 28–80 mm range. This saves time spent in changing lenses, and the image resolution of good-quality equipment is virtually indistinguishable from fixed focal length lenses.

Illumination is usually by electronic flash now often an integral part of the camera body, and the use of automatic thyristor control means that no complicated calculations about range are needed. For very close-range work, a flash attached to the camera may be unsatisfactory, so an extension cable is a useful and cheap accessory to keep the flashgun at a distance. Alternatively, the flash can be ‘bounced’ off the ceiling in the autopsy room or a ‘ring-flash’ around the lens used to avoid camera shadow.

Some will prefer tungsten light rather than flash, though this is more cumbersome unless a fixed station is installed in the autopsy room for taking photographs of organs. It is impracticable to use floodlights at the autopsy table or at a scene.

The type of film depends on the nature of the illumination. Speeds of 100 or 200 ASA are more than adequate for most flash work, though 400 ASA is now frequently used. Some keen medical photographers carry a separate camera body loaded with high-speed 1000 ASA film for special circumstances.

Ultraviolet (UV) and infrared sensitive film has been used to demonstrate surface lesions that are not visible to the human eye. It has been claimed that occult bruising can be revealed by UV photography, such as in child abuse, but care must be taken and experience gained to eliminate artefactual false positives.

Most doctors will want transparencies for projection at lectures, which can be made into prints, either colour or monochrome. If prints are specifically wanted for black and white publication in books or journals, it is better to take them originally on monochrome film, as colour negatives do not provide quite the same quality reproduction in black and white.

Some pathologists use Polaroid cameras either alone or together with conventional film. The advantage of instant prints is that a record of the scene of death can be obtained before the autopsy is carried out, and any findings checked back against the original surroundings. For example, if some linear mark is seen on the leg at autopsy, the pathologist can immediately refer to his Polaroid prints to check whether that leg had been resting on some object. Again, where multiple injuries exist, their number, position and size can be checked when writing the autopsy report, without waiting days or even longer for the police album to arrive. Correlation of wounds with blood splashes may also be useful. Such Polaroid pictures can be duplicated and even turned into transparencies, but it is preferable to have a conventional camera for these purposes.

Recent advances in electronics are revolutionizing photography, and have wide application and potential for forensic and autopsy work. Electronic cameras of varying grades of sophistication, resolution and cost, can now instantly store images on a small internal ‘memory stick’ or CD-ROM, which can then be viewed immediately on a computer VDU or printed on a colour laser printer. These images can be manipulated in many ways to enlarge sections or correct colour balance, sent via modems to distant locations, or incorporated within textual material and reports. At present, good resolution can still be obtained more cheaply with silver-based film stock but this situation is changing in favour of the digital photography. Alternatively, photographs and slides can be electronically scanned within minutes, the optical image being digitized into electronic storage for similar manipulation.

All electronic images can also be stored on CD-ROM or DVD equipment, which offers huge storage and retrieval capacities for record-keeping and educational display purposes. In addition, single frames from video camera recordings can be captured as still pictures and electronically stored.

In relation to the actual photography, a marked improvement in the pictorial quality can be achieved with a little care in composition. At scenes of death the viewpoint is often limited and the surroundings have to be photographed as they exist, without modification. The camera position can, however, usually be chosen to cut out as much extraneous background as possible. In the autopsy room, considerable improvement can be made by using the optimum viewpoint and by modifying the background. Many photographs are spoiled by having irrelevant and distracting objects in the background such as observers, buckets, boots and the other extraneous paraphernalia of the autopsy room. The picture frame should be filled as completely as possible with the object under display. A close shot should be taken to limit the irrelevant margins though, where necessary, anatomical landmarks should be included to orientate the viewer. The camera should be at right angles to the lesion being photographed, whenever possible. Tangential shots may foreshorten the required feature and, where size needs to be displayed, may distort both shape and length because of the foreshortening. A ruler or special white adhesive tape with centimetre markings should be placed very near the lesion or wound to provide a size reference.

Where a feature is obscured or insignificant, it may be pointed out by a probe or finger held in the appropriate position. Where part of the picture area consists of the metal or porcelain autopsy table or dissection bench, allowance should be made in exposure, as these very reflective areas may give a false reading in the light meter of the camera and thyristor of the flashgun.

If a full length or half shot of a body is required, an untidy background may be avoided by turning a mobile or rotatable table so that a blank wall forms the backdrop. If this is not possible, assistants can hold up a sheet behind the table to screen the distant confusion.

When photographing viscera, the camera should be near enough for the frame to be almost completely filled by the required object. The shot should be vertical to the lesion and it is often necessary either to place the dissecting board on the floor, or for the photographer to stand on a stool or some elevation to gain the required height.

Where isolated organs are being photographed, they should be placed on a green or blue cloth, such as a discarded operating gown. White can be used, though it may affect the exposure meter if much is visible around the periphery. The organ should be placed on the cloth in one movement and not moved thereafter, otherwise a wet dark stain will obtrude on the green or blue background. The organ should not be oozing blood onto its surface or onto the background. It should be dabbed with a dry cloth or sponge just before the photograph is taken to remove shiny wet highlights.

Ideally a special stage for organs should be used, such as a glass-topped table with a coloured (usually green) background set sufficiently far below the glass to be out of focus. Tungsten lights can be used to advantage on such a fixed stage.

THE AUTOPSY REPORT

Equally important as the autopsy itself is the report that the pathologist provides for whoever commissioned the examination. An autopsy is of little value if the findings and opinion of the forensic pathologist are not communicated in the most lucid and helpful way. The report is an integral part of the procedure and should receive as much attention as any physical procedure in the autopsy room. Unfortunately, some pathologists treat the process of making a report in a somewhat cavalier manner, which diminishes the expertise that they may otherwise possess.

The autopsy report is a permanent record of the findings and is especially vital for medico-legal purposes, when every word may be dissected in a court of law months or even years afterwards, and when all recollection of the examination has been driven from the mind of the pathologist by hundreds of subsequent autopsies. In a clinical autopsy in a hospital, the dissection may be demonstrated and discussed at the time with the interested physician. However, the report of a forensic autopsy becomes a legal document of possibly vital significance, and every effort must be made at the time to make it as comprehensive and useful as possible.

The form of the autopsy report

Reports fall into two main types described below, and local practice and indeed legislation may determine which is used, irrespective of the wishes of the pathologist. The choice is, however, often dictated by the nature of the case.

- A free-style ‘essay’, which usually adheres to a conventional sequence, but leaves the pathologist free to expand on various aspects according to his estimate of their importance. This type is usually used in criminal deaths and cases in which litigation is likely. It has the advantage that any part of the autopsy can be expanded without constraint; also the form of the report can be turned into a legal statement or a deposition for the court with little alteration.

- A printed proforma, in which the various sections of the examination and organ systems are already set out by title, leaving blank spaces for the insertion of the findings. The advantage includes the fact that this 'shopping list' acts as an *aide-mémoire* to those pathologists who do not conduct large numbers of autopsies – and also the non-medical recipient is more able to follow the set pattern of the report. One disadvantage is that the spacing prevents flexibility of description unless the proforma is large, when much of the space may be left blank. Also there is rarely enough space at the end of the form for an expansive discussion and opinion about the preceding factual findings. This type of form is commonly used for non-litigious autopsies – for example, the usual coroner's cases of sudden death and suicide.

Concentrating upon the more serious cases, the report, whatever the format, must contain certain information in some logical order. Consecutive numeration, computer codings and other administrative aspects are naturally conditioned by local practice, but the following matters must be catered for in all autopsy reports, though not necessarily in this sequence:

- Full personal details of the deceased subject, unless unidentified. This includes the name, gender, age, occupation and address.
- The place, date and time of the autopsy.
- The name, qualifications and status of the pathologist.
- Persons present at the examination.
- Usually, the authority commissioning the autopsy.
- A record of who identified the body.
- The name and address of the deceased subject's regular (or last) medical attendant.
- The date and time of death, where known.
- The history and circumstances of the death. The inclusion of this on the actual autopsy protocol may not be permitted in some jurisdictions as it is hearsay evidence, but unless expressly forbidden it should be included, as it remains a record for the pathologist's own files. It also justifies his eventual cause of death in those cases where the morphological findings are scanty or even absent, as his conclusions will be strongly influenced by his pre-knowledge of the mode of death. When the autopsy report is converted to a statement or deposition for legal use, this history may be omitted by those legal authorities responsible for transcribing the document.
- External examination.
- Internal examination.
- A list of specimens and samples retained for further examination. Those handed to other agencies, such as the forensic science laboratory, should be formally identified by means of serial numbers and the name of the person to whom they were handed.
- The results of further examinations such as histology, microbiology, toxicology and serology. When the main report is issued soon after the autopsy, these will not yet be available and a supplementary report will be necessary.
- A summary of the lesions displayed by the autopsy (often coded for departmental computer retrieval).
- Discussion of the findings, if necessary in the light of the known history.
- An opinion as to the definite or most likely sequence of events leading to the death.
- A formal cause of death, in the format recommended by the World Health Organization, suitable for the completion of a death certificate.
- The signature of the pathologist.

The 'external examination' should record those details described earlier in the chapter, the major items being:

- The height, weight and apparent state of nutrition.
- The presence of natural disease such as oedema, abdominal swelling, cutaneous disease, senile changes, etc.
- Identifying features such as skin colour, tattoos, scars, congenital or acquired deformities, dentures, eye colour and hair colour. When identity is an issue, naturally this section will be greatly expanded.
- The presence of rigor, hypostasis, decomposition and abnormal skin coloration. Body and ambient temperature should be recorded where appropriate, with calculations concerning the estimated range of times since death, though this aspect may well be deferred until the final 'Summary and Conclusions'.
- The condition of the eyes, including petechiae, arcus senilis, pupil size, and the condition of iris and lens.
- Condition of mouth and lips, including injuries, teeth and presence of foreign material.
- Condition of external genitals and anus.
- Listing and description of all external injuries, recent and old.

The internal examination records all abnormalities, usually in a conventional sequence such as:

- Cardiovascular system: heart weight, any dilatation, ventricular preponderance, congenital defects, the pericardium, epicardium, endocardium, valves, coronary arteries, myocardium, aorta, other great vessels and peripheral vessels.

- Respiratory system: external nares, glottis, larynx, trachea, bronchi, pleural cavities, pleura, lungs (including weight) and pulmonary arteries.
- Gastrointestinal system: mouth, pharynx, oesophagus, peritoneal cavity, omentum, stomach, duodenum, small and large intestine, liver (weight), pancreas, gall bladder and rectum.
- Endocrine system: pituitary, thyroid, thymus and adrenals.
- Reticuloendothelial system: spleen (weight) and lymph nodes.
- Genitourinary system: kidneys (weight), ureters, bladder, prostate, uterus, ovaries and testes.
- Musculoskeletal system: skull, spine, remaining skeleton and musculature where necessary.
- Central nervous system: scalp, skull, meninges, cerebral vessels, brain (weight), middle ears, venous sinuses and spinal cord (when examined).

The timing of the report

As with the format, there are two schools of practice in this respect. One advocates the issue of as full a report as possible on the gross findings as soon as the autopsy is completed, usually within a day or two. Obviously this can only be a preliminary, provisional report, as it may have to be modified (sometimes radically) by the results of ancillary investigations that may take days or weeks to return. Virological cultures, for instance, may take up to 6 weeks before a growth can be reported.

In a large proportion of forensic cases, however, especially those due to violence, the gross findings are unlikely to be substantially amended by ancillary investigations, though the possibility must always be left open until data have been gathered in.

The other philosophy will delay any report (except perhaps a provisional oral opinion) until everything is to hand, when a single final document is provided.

Whichever course is adopted, one aspect is vital to both. The descriptive facts must be recorded at or immediately after the completion of the autopsy. It is vital that no significant interval – certainly no more than few hours – be allowed between the physical performance of the examination and the setting down of the objective findings. The words 'setting down' are chosen carefully as the report may be handwritten or typed, or may be dictated to a secretary or into a tape recorder or other audio system. What is vital is that it is not consigned to the pathologists' memory for a few days, even reinforced by notes written on scraps of paper.

In Britain and many other jurisdictions, the court may demand to see any contemporaneous notes and even tapes from a tape recorder. Any diagrams, notes or rough drafts must be preserved for production on demand of the judge, coroner or advocates in court. Where the report is dictated (either to a secretary or into a tape recorder), then the first typed (or word-processed) draft constitutes the 'original report', along with any contemporaneous notes including body sketches.

The use of printed body sketches can be a very useful aid in the autopsy room. Many versions exist from the simple front and back views of the whole body used in clinical neurology to multiple sketches portraying every possible view of the body surface. Separate diagrams are available for the male and female perineum, and for the different body proportions of infants. Used on a clipboard these diagrams can be most useful, especially where there are multiple injuries, or large areas of burns or abrasions. Each lesion can be drawn in, with a measurement noted alongside each and distances from anatomical landmarks recorded. The data from the sketches can be transposed to written form at the end of the examination.

Discussion and conclusions in an autopsy report

Some pathologists, usually those not normally concerned with criminal and litigious cases, claim that an autopsy report should be a bare recitation of the physical findings, with no discussion or interpretation of the significance of those findings. In the authors' opinion, this is an abdication of the pathologist's responsibility because, especially in criminal deaths, it is these conclusions that are of most interest and use to the investigating officers, lawyers and courts.

After the detailed description of the external and internal appearances, a short resumé should be offered of the major positive findings and their relationship to the cause of death. In many cases this will be obvious, as in a gunshot wound of the head. Matters such as the probable type of weapon, the range, the direction and the likely rapidity of death, however, should also be discussed.

When the findings are less clear cut, or are multiple, then the alternatives should be discussed, giving a differential diagnosis of the cause of death and detailing the possible sequence of events. If it is possible, a ranking order of probability of the various alternatives can be offered. Time of death and the limitations of accuracy in this particular case should be set out when the issue is relevant to the investigation. What is really required is as full an interpretation as possible, without venturing into the undesirable fields of unwarranted speculation or Sherlock Holmes style of over-interpretation, which was the bane of forensic pathology in former years and is still practised too much even today, to the detriment of the good reputation of the speciality.

POST-MORTEM ARTEFACTS

Forensic pathology can only be learned by experience but no account would be complete without drawing attention to common artefacts found at autopsy, which can mislead the pathologist with insufficient forensic experience and even lead to a miscarriage of justice.

Some of the 'classic' mistakes were described many years ago by Shapiro (1954) and Moritz (1942), but each generation of pathologists discovers them a new – or what is worse, fails to discover them. Most artefacts are described in the various chapters dealing with specific lesions, but a reminder of some of the most important is given here:

- The pancreas is one of the first organs to undergo autolysis, because of the proteolytic enzymes within it. The autolysed tissue is often haemorrhagic and can easily be mistaken for acute pancreatitis, though histology will rapidly resolve the problem.
- Patches of haemorrhage, sometimes quite large and confluent, can occur in the tissues behind the oesophagus in the neck. These lie on the anterior surface of the cervical vertebrae and are caused by distension and leakage from the venous plexuses that lie in this area. They were described well by Prinsloo and Gordon (1951) and are sometimes known by this name. Their importance lies in confusion with deep neck bleeding in strangulation (and sometimes with spurious neck fractures), which is why the skull should be opened before the neck in any suspected strangulation or hanging, to release the pressure in the neck veins before handling the tissues.
- Autolytic rupture of the stomach can occur post-mortem in both child and adult, described by John Hunter in the eighteenth century. This so-called 'gastromalacia' appears as a slimy brownish black disintegration of the fundus with release of the stomach contents into the peritoneal cavity. Sometimes, the left leaf of the diaphragm is also perforated through a ragged fenestration, with escape of gastric contents into the chest.
- Heat fractures of the bones, either skull plates or long bones, may be seen in victims of severe fires, but are not evidence of ante-mortem violence. Also in conflagrations, the 'heat haematoma' within the burned skull can resemble an extradural haemorrhage of ante-mortem origin. The site is often at the vertex or occiput; however, unlike the usual parietal haemorrhage, there is no fracture line crossing the middle meningeal artery, the usual cause of a true extradural bleed. The frothy brown appearance of the false clot, together with heating effects in the adjacent brain, should indicate the true diagnosis. Shrinkage of the dura due to heat may cause it to split, with herniation of the brain tissue into the extradural space. Severe burns of the body surface may lead to heat contractures of the limbs with tears over joints such as the elbow. These must not be confused with ante-mortem lacerations or incised wounds.
- The bloating, discoloration and blistering of a putrefying body must not be misinterpreted as disease on injury. Blisters are quite unlike those of burns and dark blackish areas of discoloration must be distinguished from bruising. The latter can be difficult and incision into the tissues to seek blood in the dermis is advised. Histological sections may help but, where a body is badly decomposed, special stains for blood traces in the histological sections may assist, such as alpha-glycophorin to detect red cell envelopes. However, often it is quite impossible to differentiate the discoloration of decomposition from true bruising.
- Blood or bloody fluid issuing from the mouth may be due to putrefaction, even if the body surface is not overtly decomposed. If the lungs and air passages are discoloured and filled with sanguineous liquid, then this must be taken to be cause of the purging from the mouth and nostrils.
- Dark red discoloration of the posterior part of the myocardium is usually due to post-mortem gravitational hypostasis, not early infarction. Similarly, segmental patches of dark red or purple discoloration of the intestine is hypostasis, not infarction. The latter tends to be a single continuous length, the serosa being dull and the gut wall friable.
- Large petechiae or ecchymoses, sometimes with raised blood blisters, are often seen in the dependent skin of persons who have died a congestive death or where the upper part of the body has been hanging down after death. The usual place where these are seen is over the front of the upper chest and across the back of the shoulders, though in dependent heads the face may be shot with haemorrhages.
- Resuscitation artefacts are of increasing importance to the forensic pathologist and are discussed later.

EXHUMATION

Exhumation is the retrieval of a previously buried body for post-mortem examination. This is usually followed by a first autopsy or a re-autopsy following new information. The term 'exhumation' is usually applied to the removal of a body buried in a legitimate fashion in a cemetery or graveyard ('inhumation'), rather than the recovery of an uncoffined, clandestinely buried victim of a suspicious death. The latter is really a true 'scene of crime' and the pathologist should treat it as such.

Exhumations are required for one of the following reasons:

- Where all or part of a graveyard has to be moved for some development of the ground. Often no special examination of each body is made unless there is some historical or anthropological interest.
- Where some civil legal matter needs to be investigated, such as personal injuries for insurance or civil litigation for negligence – usually after a road, industrial or other accident.
- Where new information or substantiated allegations arise to suggest that a death was due to criminal action, either from injury or poison.
- In ancient or historical circumstances to investigate either the individual or a series of individuals for academic interest. A number of such investigations have been carried out on medieval and later inhumations in England, to study disease patterns and nutritional states in old populations – though many of these have been from dry vaults, rather than earth burials.

The legal procedures authorizing an exhumation do not concern us here, as they vary greatly from country to country. In all jurisdictions, however, there must be strict safeguards to identify the grave and the coffin, so that no mistake can be made. The grave must be positively identified by the cemetery authorities by reference to plans and records: an official must personally point out the grave to be opened.

Traditionally, exhumations are carried out at dawn but, except to avoid spectators and publicity, there is no real need to stumble about in a dark cemetery before first light. A better plan is for the grave to be dug down to just above coffin level by a mechanical digger or workmen on the previous day so that, the following morning, the police, coroner, pathologist and others can arrive in time to see the final exposure of the coffin. The coffin nameplate must be cleaned and read to confirm the identity, and, if possible, the funeral director who carried out the original burial should be present to identify the coffin and the plate.

If there is a suspicion of poisoning, samples of earth should have been taken from the surface of the grave, from other parts of the cemetery and from immediately above the coffin. When the coffin has been removed, further samples should be obtained from the sides and beneath the coffin, but these matters will usually be attended to by forensic scientists.

When the coffin is lifted to the graveside it is as well for the lid to be loosened a little by slackening the holding screws or prising the lid loose. This allows foul gases to escape into the open air, rather than in the mortuary. The coffin is then transported to the mortuary; if it is in a bad state of decay, it may have to be supported on a rigid base such as a trestle, or placed inside an extra large coffin or fibreglass shell. Excess earth and mud should be removed before transportation to avoid excessive fouling of the autopsy room. Where criminal action is suspected or has been alleged, a full photographic record must be kept (usually by the police) of every stage from identification of the grave to the findings during the autopsy.

At the mortuary, the coffin lid should be completely removed and the contents again identified, if possible by the funeral director who originally buried the body. He can again confirm the coffin plate, but also identify the internal coffin fittings, such as fabrics and shroud. When the body has not been buried for too long, he may be able to identify the features of the corpse from personal knowledge.

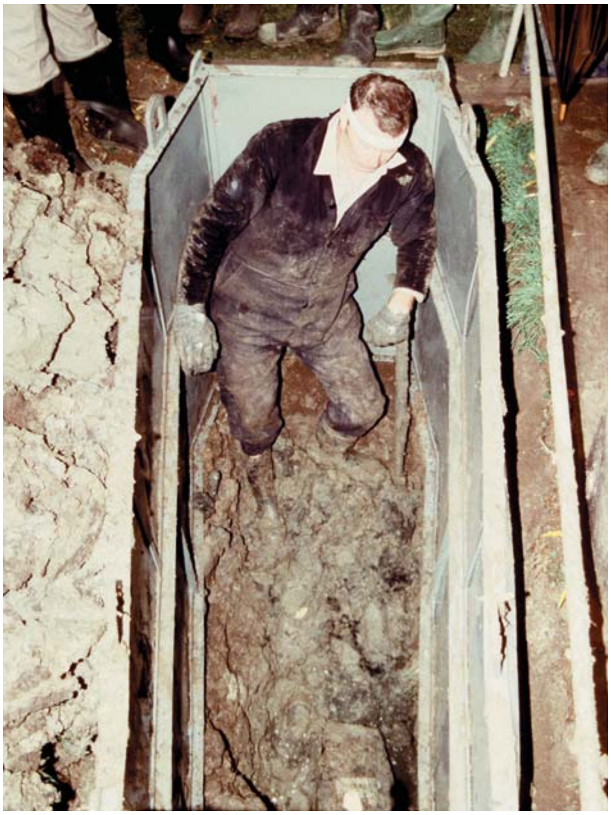

FIGURE 1.23 *Exhumation: a police officer making the final approach to the coffin. A metal cassion is lowered to protect the gravesides. The grave must be identified by the cemetery superintendent.*

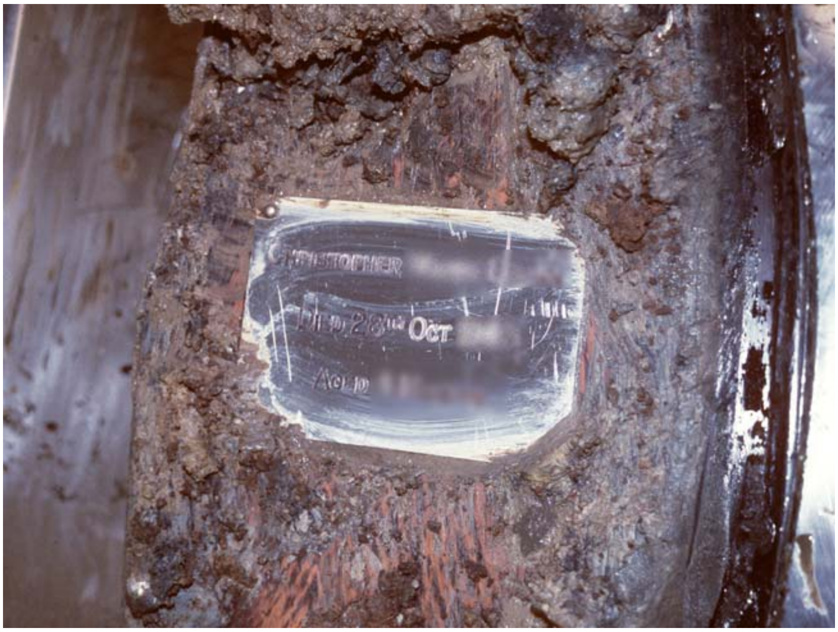

FIGURE 1.24 *Exhumation: when the coffin is exposed it must be identified by the funeral director and the coffin plate checked. If death from poisoning is suspected, samples of earth from above, below and the sides of the coffin as well as from a distant part of the cemetery must be taken, together with a sample of any grave water.*

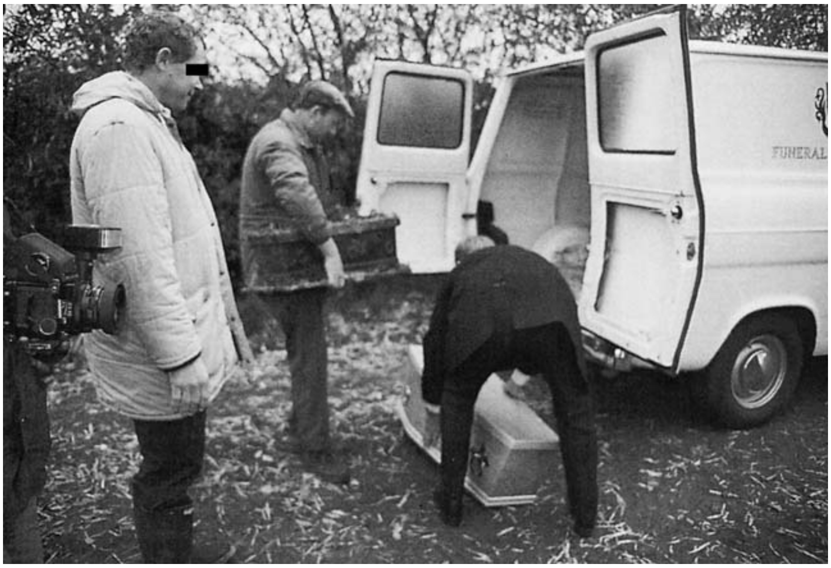

FIGURE 1.25 *Following exhumation, the body is transported to a mortuary for full autopsy. The former practice of autopsy in inadequate premises near the cemetery is no longer justified. Here the original rotted infant coffin is placed within a new coffin for transit.*

If poisoning is suspected, samples of the shroud, coffin trimming and any loose material such as packing or fluid should be retained for analysis. The body is then removed, undressed and a full autopsy carried out, as far as the condition of the body allows. Putrefaction, adipocere and mummification complicate the examination – sometimes, all three may be present in the same body.

The pathologist is sometimes asked by the authorities or by lawyers whether a proposed exhumation is worth carrying out, because of doubts about the usefulness of the result. Certainly the balance between the potential advantages must be weighed against the cost, publicity and distress to relatives that might be caused. In general, however, it is surprising how much information may be gained even when the body has been buried for many months or even a few years. Much will depend on the actual environment of the grave: a gravel or sandy soil, especially in an elevated position, will allow a body to remain in a much better state of preservation than one in the waterlogged loam of a valley. The author (BK) has seen burials only 20 years old with empty coffins containing silt, but no soft tissue or even bones (due to a constantly rising and falling water table) in an area of acidic peat.

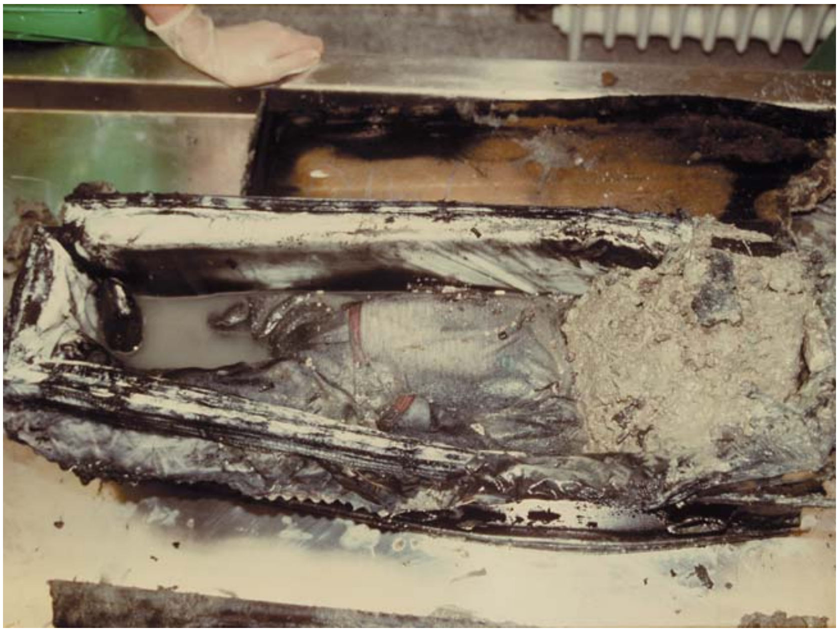

FIGURE 1.26 *When the coffin is first opened in the mortuary, the coffin fitting and fabrics should again be identified by the funeral director, as well as the body and its clothes, if they can be recollected. This infant has been buried for 3 years. The upper part of the coffin has leaked, allowing liquid mud to cover and substantially destroy the head.*

Even negative information gained at exhumation, such as the absence of alleged or suspected fractures, may be of considerable legal value. Some poisons, especially heavy metals, may persist for many years in a buried body and be detectable at exhumation. Even some organic chemicals may survive for a long time; barbiturates have been found after 7 years in a buried body. In all cases of suspected poisoning, it is vital that ample control samples are taken from the grave and its surroundings, to avoid the later accusation that any abnormal substances found were environmental artefacts or were unassociated with the corpse.

THE AUTOPSY ON THE PUTREFIED CORPSE

In forensic work, decomposed bodies are commonplace, especially in warm climates. Though the value of an autopsy is progressively reduced as the state of putrefaction advances, no short cuts should be taken by the pathologist merely because of the unpleasant nature of the examination. However bad the condition of the corpse, every effort should be made to carry out the autopsy as near to the usual routine as possible. It is often surprising – as with an exhumation – how much information can be gained. The interior of the body is often far better preserved than the outward appearances would suggest, so a policy of defeatism that leads to a skimped examination should never be adopted.

Externally, putrefaction hides bruising to a variable degree, the greenish black coloration of the skin masking the usual features of contusion. Abrasions, lacerations, incised wounds and gunshot wounds may, however, survive severe degrees of decomposition. Loss of bloody fluid from the mouth and nostrils (the so-called 'purging') is often mistaken by public, police and even some doctors as evidence of haemorrhage, but loss of serous, bloody or frothy fluid from any body orifice is common in the advanced stages of putrefaction.

Peeling and slippage of skin may hide some abrasions, though they may be visible when the desquamated epidermis is removed and the underlying skin examined. Marks around the neck from the tissues swelling with gas and becoming embedded in a collar have been mistaken for strangulation.

Where maggot or other insect infestation is present, some may be taken for expert entomological examination to help in assessing the post-mortem interval, as described in Chapter 2. As stated above, the external examination should be conducted as near as possible to the routine for a fresh body, and the back and perineum not neglected because of physical difficulties in handling the body.

Identity may be a problem when the facial features are too bloated for visual recognition. The usual procedures described in the next chapter may be employed where necessary. Fingerprints may be required by the police to assist in identity, but decomposition may seriously destroy the fingertips. These may become swollen and desquamate, or may shrivel and become leathery. Several methods of restoring the amputated tips have been described: some recommend a simple method of immersing the tips in 20 per cent acetic acid for 28–48 hours, when the shrivelling will swell to normal size. Others recommend immersion in glycerine.

Internally, much will depend on the state of decay. The abdominal and chest organs may be in a better state of preservation than the exterior. The subcutaneous tissues may be distended and crepitant with gas, as may be the swollen abdomen. Judicious penetration of the peritoneum with the tip of knife may be needed to release the pressure of gas. The technique of lighting the escaping methane with a burning newspaper may be spectacular and sometimes near explosive, but does little to reduce the smell and is not to be recommended.

Examination of the organs follows the usual pattern, modified according to state of putrefaction. The heart may be limp and discoloured, with haemolysis staining of the endocardium and vessels. The coronary arteries are often very well preserved, especially if atheromatous or calcified, or both. Ante-mortem thrombi may persist even after the muscle is semiglutinous. The larynx may be discoloured, but the hyoid and thyroid horns can be examined for fractures and may need to be X-rayed. It may be difficult to detect ante-mortem bleeding at the fracture sites. Fractures elsewhere in the skeleton naturally persist and may require radiography for their detection, as may foreign objects such as bullets.

The brain often decomposes early, and all too often is merely a pinkish-grey paste within the dura. Gross lesions like a large meningeal or intracranial haemorrhage may survive for examination, but the trauma of removing the calvarium and attached dura may seriously damage a semi-fluid brain. In Belgium, where exhumations are common due to the very low primary autopsy rate, a technique was developed in the University of Gent whereby the head of a decomposed body was removed from the body and deep frozen until solid. The head was then cut across in the coronal plane with a band-saw, leaving the brain in two halves within the cranium. These were then immersed in a large volume of formalin until fixed, when they could be removed in a relatively solid state for examination.

Internally, the detection of true subcutaneous bruising may be very difficult due to the discoloration of putrefaction. Histology is often highly unsatisfactory because of cellular lysis and degeneration; stains for haemoglobin may help in revealing focal collections of lysed blood, but are often diffusely positive even in control areas. Claims have been made for staining for glycophorin A to detect red cell envelopes, as opposed to diffuse haemolysis (Kibayashi *et al.* 1993).

RESUSCITATION ARTEFACTS AT AUTOPSY

In recent years, the advent of effective, but often aggressive and invasive, resuscitation procedures has made the task of the pathologist more difficult. At autopsy, injuries and abnormalities are now often found that could be due to terminal and even post-mortem resuscitatory measures. Where the pathologist is made aware of these, he can often exclude the damage being due to non-resuscitatory injury, though even when he is informed of the procedures they can still mask or mimic more sinister trauma. When he is not made aware – or such information cannot be made available – then the difficulties of interpretation are compounded.

There are now many publications describing resuscitation artefacts, including the review of Leadbeatter and Knight (1988). The following are the main categories of damage, for which the pathologist must always be alert:

- Bruising of the anterior chest wall, haemorrhage into the subcutaneous tissues and pectoral muscles, fractures of the sternum, fractures of the ribs, haemothorax, bruised lung, lacerated lung, pericardial haemorrhage, and even fractured dorsal spine, following energetic external cardiopulmonary resuscitation (CPR). Thoracic cage fractures are rare in children, however, because of the pliability of the ribs and costal cartilages, but it cannot be denied that they sometimes occur. The differentiation is naturally of vital interest where child abuse is being alleged.

  Internally all types of damage to the heart may occur, including ruptured atria and even ventricles, septal rupture and valve damage. The great vessels can suffer severe trauma, as described in the now extensive publications on resuscitation artefacts. Fat and bone marrow emboli in the pulmonary vessels have also been reported after cardiac massage (Mason 1993).

  Petechiae in the eyes and intra-ocular haemorrhages can occur after CPR, as well as after violent sneezing or coughing; they are well known to occur during whooping cough.
- Bruising of the face and neck, finger marks and nail marks on the face and neck, and damage to the lips and inner gums from mouth-to-mouth resuscitation, when the face and neck have been gripped by hands. Damage to lips, gums, teeth and pharynx can occur from the introduction of an artificial airway or endotracheal tube, especially in difficult, hurried emergency situations.

  Injuries to the larynx, even including fracture of the hyoid and thyroid cornuae, can occasionally occur from these procedures, which are difficult to distinguish from manual strangulation if the circumstances are obscure.
- Puncture marks for venepuncture may be confused with injection marks in drug dependence. The introduction of intravenous cannulae into veins in the neck may cause large haematomata and more diffuse bleeding into the tissues alongside the larynx.

Similar bruising may occur around puncture sites in the arms and groin. Intracardiac injections leave marks on the chest wall and may lead to a slight haemopericardium. The effects of injected noradrenaline and electrical defibrillation on the histological appearance of the myocardium are well recorded, with contraction bands being the most obvious artefacts which can be mistaken for pre-existing myocardial ischaemia.

- Damage to the mouth, palate, pharynx and larynx can occur from attempts to introduce a laryngoscope or airway. Even fracture of the mandible has been caused in this way. In infants, even digital clearance of the pharynx can cause mucosal damage. Damage to the pharyngeal mucosa may cause bleeding, which can seem sinister to police or relatives; this may be mixed with the fluid of pulmonary oedema to produce copious pink, bloody froth, seen in a number of cases, including sudden infant death syndrome.
- Electric defibrillator pads make marks on the chest, though these are usually easy to interpret, except where there is an unusual shape. Defibrillators and injected β-adrenergic catecholamines such as noradrenaline can, however, cause widespread histological damage to the myocardium, consisting of coagulation necrosis and contraction bands, which can be confused with infarction or electrocution. When both defibrillation and catecholamines have been used to resuscitate, the myocardial changes are even more marked (Karch 1987).
- During the Heimlich manoeuvre to clear an airway obstruction, rupture of the oesophagus, stomach and intestines have been reported. The oesophagus can be perforated by an incorrectly inserted airway. In the abdomen, external cardiac massage may cause ruptured stomach, ruptured liver, and damage to spleen and pancreas.
- Gastric contents in the air passages may have reached there by spontaneous agonal regurgitation or by pumping the chest and upper abdomen during resuscitation attempts. This makes the finding of vomit in the larynx and trachea of even less significance as a cause of death, as discussed in Chapter 14.
- The administration of oxygen by mask or tube may cause damage, as can overenergetic mouth-to-mouth resuscitation. Ruptures of oesophagus and lung have occurred, and other types of barotrauma include ruptured stomach and intestine. Where a pre-existing gut lesion exists, the administered gas may escape into the abdomen. The diagnosis of a pre-existing pneumothorax may be impossible where forced ventilation has been administered.
- In the central nervous system, subarachnoid haemorrhage has been described after external cardiac massage, and from hyperextension of the neck to pass an airway or perform mouth-to-mouth resuscitation. The forced posture can tear the vertebral arteries, making another source of confusion for the forensic pathologist in this difficult area of potential trauma to the neck (Chapter 5).
- Myocardial and pulmonary bone marrow embolism has been reported following cardiac massage (Dziecol *et al.* 1992).
- Retinal haemorrhages, classically a sign of raised intracranial pressure and of head injury, have also been described in whooping cough and after CPR.
- Miscellaneous artefacts of which every pathologist should be aware include: skin maceration from a body lying in urine, kerosene, etc., post-mortem burns from adjacent radiant heat or hot-water bottles; and petechiae and larger haemorrhages in the face from postural hypostasis.

MASS DISASTERS – THE ROLE OF THE PATHOLOGIST

With the exception of the more dramatic murders, the activity which focuses most public attention on the work of forensic pathologists is the mass disaster. Unfortunately, such tragedies are becoming more common with the increase in terrorism, the expansion of travel facilities and the larger size of passenger aircraft. Recent years have seen a tragically frequent need for the expertise of mass disaster teams, following such events as the Zeebrugge and Estonian ferry capsizes, football tragedies like Ibrox Park, Heysel, Moscow and Hillsborough, crush tragedies at Mecca, and numerous massive aircraft crashes, such as Tenerife, Air India, Japan, Lockerbie and most recently the terror attacks in the USA. Mass disaster management is a discipline in itself and only the briefest summary can be offered here, together with useful references at the end of the section.

Forward planning

Many pathologists will thankfully spend their entire careers without having to participate in a major mass disaster; a commonly accepted definition is the death of more than 12 victims in a single event. No one can predict when such a tragedy might occur, however, as typified by the 1988

Pan Am sabotage, when almost 300 bodies fell out of the sky on a quiet and unsuspecting Scottish village. It is thus essential that every forensic institute, department and individual pathologist should make some forward provision for such an eventuality. In Britain, the Royal College of Pathologists (1990) have published a useful booklet on the role of the pathologist in these disasters.

In most advanced countries each region now has a Mass Casualty Plan covering medical and hospital services, fire service and police. This is often very detailed, covering every aspect of transfusion, drugs, casualty transport, emergency surgery and anaesthesia. The plans are clinically orientated, but often completely ignore provision for the dead – or they have some cursory statement at the end such as 'Mortuary accommodation will be provided' with obviously no thought given to how several hundred corpses are to be accommodated and examined. Though clinical planning is, of course, vital – especially in rail disasters, multiple motorway crashes and urban bomb outrages – it has to be appreciated that, in many air crashes, there are few if any survivors, and that all the clinical planning may be redundant, leaving a massive and unprepared crisis in relation to the dead.

It is therefore essential that forensic pathologists should ensure that, in the area for which they are responsible, there is cooperative preplanning that includes adequate provision for collection, accommodation, examination and disposal of large numbers of dead victims. Naturally the pathologist is usually in no position to do this alone, but he is often the person with the most foresight and professional knowledge to act as the stimulus and catalyst between the major agencies responsible for overall planning. These are usually the police and the local health administration. When a Mass Casualty Plan does exist, but has serious omissions in respect of dealing with the dead, or where no such plan exists, the forensic pathologist should energetically stimulate the responsible authorities into making a comprehensive plan. This entails a series of meetings to identify danger areas in the region (such as airports, motorways, railways and military installations), and to discuss potential buildings for temporary mortuaries, the provision of materials such as markers, plastic bags and labels, which may be needed in large quantities at a few hours' notice. Communications between such groups as police, pathologists, mortuary and laboratory technicians, radiographers, and dentists also need to be established in advance. The expertise of international funeral directors with experience in mass disaster fatalities is invaluable.

The objects of pathological investigation in mass disasters are:

- to retrieve and reconstruct bodies and fragmented bodies decently
- to establish personal identity
- to conduct autopsies on some or all of those bodies
- to establish the cause of death in some or all, especially air crew and drivers, and to assist in reconstructing the cause of the disaster
- to obtain material for toxicological analysis (especially alcohol and carbon monoxide) where appropriate
- to seek evidence of the cause of the disaster from autopsy examination, such as bomb or detonator fragments that may be embedded in the bodies.

Outline of necessities in mass disaster planning

PROVISION OF PATHOLOGISTS AND OTHER STAFF

Depending upon the scale of the tragedy, it may be necessary to recruit other pathologists to assist. In large cities, there may be sufficient persons with expert forensic knowledge, but elsewhere, hospital pathologists may be able to assist; forensic pathologists from a distance may also volunteer. It has to be remembered that a really large disaster may need many days or even weeks of work, and therefore personnel may be unavailable for the whole period. In addition, whatever the degree of willingness and unselfish devotion offered by doctors and all other staff, the physical and especially psychological stresses of this harrowing work mean that strictly limited periods of work should be imposed. Apart from the deleterious effect upon the doctor, the standard of work declines dramatically with fatigue and therefore it is in the interests of the investigation – as well as of the pathologists – that sufficient staff be recruited. This may, however, be easier said than done. One person must be in overall charge of the investigation. Usually a senior police officer has the ultimate responsibility, but the medical aspects should be firmly under the control of a senior pathologist, though he must delegate extensively to avoid being swamped by less important tasks and thereby being rendered totally inefficient. Again, all these aspects are modified by the scale of the disaster. Proper facilities for meals, rest and washing must be established, and again forward planning is essential for these mundane, but vital, features. Forensic dental and radiological expertise will be run independently by their own specialists, but there must still be a nominal chief in the form of the senior pathologist who acts as overall coordinator and arbiter of medical matters.

When a disaster, almost always an aircraft crash, occurs in some remote place or abroad where there are no satisfactory forensic or pathological services, it is the usual practice for a team from the country of origin of the aircraft – or a volunteer team arranged at governmental level – to fly to the scene and provide expertise to the local authorities.

In many advanced countries, especially Britain, the armed services have permanent aviation pathologists who deal with all service aircraft crashes anywhere in the world and who are often available to deal with, or attend as advisers, any civil air disaster.

PROVISION OF MORTUARY FACILITIES

Most hospital mortuaries and even larger public mortuaries have limited storage capacity for bodies, and even smaller provision for performing simultaneous autopsies. It must also be appreciated that the normal business of a mortuary has to continue even through a mass disaster, so the massive increase in work is an addition to, not a substitution for, the normal handling facilities. Where more than about ten bodies are involved, most mortuaries cannot cope with these problems, especially when it has to be remembered that some of the corpses may have to be retained for considerably longer periods than usual if identification cannot be made rapidly. Thus external facilities will have to be provided in some temporary accommodation. When the disaster is a long distance from the regular mortuary, transport and other logistic considerations may make it imperative to store and examine the bodies nearer to the crash site. Again forward planning is essential to identify hangars, storehouses, empty factories, halls and other buildings near potential danger spots such as airports. Whenever possible, all bodies should be taken to one site, as the separation of identification sites is a recipe for inconvenience, delay and mistakes. It is sometimes necessary, especially in remote regions, to set up tented mortuaries, but this is a last resort as facilities cannot be laid on with the same degree of efficiency. Where the crash is totally remote, it is usual for the authorities or the armed services to bring out the dead by helicopter or other transport to an urban site. A prime example was the Mount Erebus crash in Antarctica, where the dead were flown back to New Zealand. If a warehouse, or factory or building of similar size, can be used, certain minimum facilities are needed. Good electric lighting, portable lights for close inspection, and power points for radiographic equipment and electric instruments are required. Adequate piped water, and washing and toilet facilities are essential. If any of these is deficient, then portable generators and water tankers must be supplied by the armed services or the police. Telephone and, if possible, telex and fax facilities should be available for the input of identifying data.

In hot climates, or in the summer in temperate climates, body refrigeration is vital, not only for the decent preservation of the dead but for retention of tissues awaiting identification. If a disaster is too large to be handled in the usual mortuary, then some form of cooling is required. The renting of refrigerated trucks used for the transport of foodstuffs is the usual answer and, again, preplanning is necessary to discover sources of such facilities. Sometimes portable air-conditioning units can be installed in part of the mortuary, if this is sufficient to cool the storage area to an acceptable level. In disasters where there are both living and dead victims, the mortuary should be sited away from the clinical facilities or screened in some way to avoid the distressing sight of bodies arriving being visible to survivors or their relatives, and the press.

The temporary mortuary should be large enough for the expected load, and the area to be used for examinations and autopsies should not be too congested. No one should be allowed in who does not have direct business there, no matter of what eminence or rank. Security of admission should be tight, this being the responsibility of the police. Flooring should be waterproof and capable of being hosed down. It can be protected against blood, mud and burned fragments by covering with polythene from large rolls. Tables for examination can be wooden trestles, covered with polythene. These should be in rows one metre apart, with 2 metres between rows.

Retrieval of bodies

This is the task of the police or armed services, but must be carried out in a manner approved by the forensic identifying team. It is essential that every body is first certified as dead by a doctor at the scene. Often, volunteer casualty surgeons may be the first medical persons at the scene, whose primary duty is to rescue living survivors and to confirm death in the remainder.

Each body or fragment should be flagged with a sequential and unrepeatable serial number and marked on a grid plan, being photographed *in situ* wherever possible. It is then bagged and taken with its numbered label to the mortuary. Different teams will have different methods of dealing with the logistics of handling data and, increasingly, this is being performed on either microcomputers or on terminals linked to a central computer. The police have responsibility for these aspects, as they collect and record the clothing and personal belongings that play such an important part in personal identification.

Either the same serial number is used from the recovery stage or a different 'pathology' number is begun in the mortuary, which must be matched up with the previous serial number. Everything that has come from that body, including clothing, wallets, rings, teeth and jewellery, must carry the same number.

The pathologist and lay assistants undress the clothed bodies, and dictate a description of what is found as accompanying artefacts. The clothes are stored in strong paper

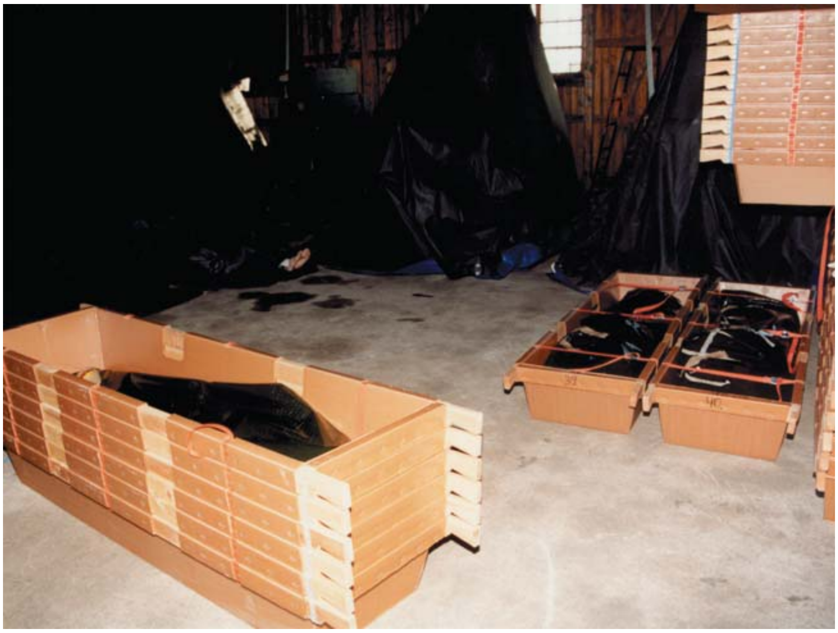

FIGURE 1.27 *Temporary coffins used to transport victims of the m/s Estonia disaster from the archipelago to the autopsy facility.*

bags to avoid the fungal growth that inevitably appears on damp fabric kept in plastic bags.

Many items will have been found loose at the site, but they must all be tagged and an attempt made to relate them to a nearby body, though this is obviously fraught with error. The objects found on a body are recorded on an inventory form and a separate form (usually the Interpol document) used for the purely medical and anatopathological aspects. The latter data are acquired by meticulous and systematic external examination, followed by an internal autopsy if this is to be carried out.

Whether or not an autopsy is to be performed on some or all of the victims will depend upon facilities, availability of pathologists, the legal direction and the system prevailing in the particular country. The wishes of the legal authority, such as coroner, judge, medical examiner or police, will be the deciding factor in determining how many victims are subjected to autopsy. The pathologist should exert his influence where there is reluctance to sanction any autopsies, emphasizing the benefit to the crash investigators of autopsy data on key victims. Pathology findings may often be of use – it has even been claimed that victims can be separated into smokers and non-smokers by finding 'smoker cells' in the lungs (Reiter and Risser 1994).

As mentioned, the aircrew or other persons in charge of a vehicle or train should always have a full examination and analysis of body fluids as part of the accident investigation. Full photography of the clothing and bodies should be taken, and then all physical features such as height, weight, gender, race, colouring, scars, tattoos and deformities must be recorded. The forensic dental examination is then carried out on those bodies where obvious identity cannot be established by non-medical or dental means.

Radiological examination will almost always be required to assist in identification from osteological features and dental aspects – and perhaps also to seek foreign bodies that may assist in accident reconstruction, such as metal fragments blown upwards into the thighs and buttock in a hold explosion in an aircraft bomb – or even parts of the bomb or detonator itself, more especially in land-based terrorist attacks.

Toxicology should be taken as extensively as possible, even from some of those bodies that are not to have an autopsy. The data acquired from this painstaking work is then forwarded to the police bureau who have been collecting personal data from the records and relatives of the victims, and efforts are made to match the two sets of data. This is increasingly being performed by computer, and many efforts have been made by international agencies such as Interpol to set up universally compatible systems so that data can be acquired and exchanged electronically via telephone systems and modems from any part of the world.

In 1990, the Royal College of Pathologists published a definitive guide for pathologists to the problem of mass disasters, which is strongly recommended as a standard set of procedures.

THE OBSCURE AUTOPSY

Several surveys in various countries have shown that where a physician offers a cause of death without the benefit of autopsy findings, the error rate is of the order of 25–50 per cent, even in deaths in hospital. Thus the value of an autopsy in improving the value of death certificates is undoubted, but it still has to be conceded that the autopsy is by no means infallible in revealing the true cause of death. Estimates of the frequency with which autopsies fail to deliver an adequate or even any cause of death vary from pathologist to pathologist, as well as with definitions of what type of case a is included in such series. For example, the sudden infant death syndrome (SIDS) could be considered to provide 'negative autopsies', in that by definition, no significant findings are discovered.

Even excluding SIDS, there is probably at least a 5 per cent 'failure rate' in autopsy series from large medical centres and forensic pathology departments. This rate will also vary according to the habits, personality and seniority of the pathologists involved. Contrary to what might be expected, a higher rate of negative conclusions will originate from older and more experienced pathologists than from juniors. The younger pathologist is often uneasy about failing to provide a cause of death, feeling that it reflects upon his ability, whereas the more grizzled doctor, enjoying the security of tenure and equality with – or even seniority over – his clinical and legal colleagues, is less inhibited in his admissions of ignorance when the cause of death remains obscure.

These 'obscure autopsies' are more common in the younger age group. Even apart from SIDS, many autopsies on infants, especially neonates, are less than satisfactory in terms of definite morphological lesions discoverable in the autopsy room or the laboratory. The deaths often have a biochemical or hypoxic basis and, though inferences can be made from the clinical history, even expert paediatric pathologists have to make do with minimal or even absent findings in a significant proportion of cases. In teenagers and young adults, up to the age of about 35 years, there is a higher proportion of negative autopsies than in the older group, which provides the vast majority of the autopsy workload. An example is the obscure syndrome seen in East Asia, where Thai construction workers in Singapore suddenly die with no demonstrable pathological cause, similar cases occurring in China, Japan and Hong Kong.

This preponderance in the young may carry an inherent fallacy, even though there may be an absolute increase in the incidence of obscure fatal causes. The young adult does not have the almost universal overlay of degenerative cardiovascular disease that is seen in the older group. Thus it is probable that the same occult disease processes occur in that older group as in the young, but as the latter do not have other lesions that can be grasped (usually quite legitimately) as a valid cause of death, then nothing presents itself to the pathologist. For example, on one autopsy table might be the body of a man of 22 who dropped dead shortly after taking part in a football match. There may be no adverse medical history, the gross examination revealed nothing abnormal and subsequently full histology with special stains, full toxicological screening, and microbiological and virological studies, were unrewarding. No cause of death can be extracted from these negative findings and the case must be recorded as 'unascertained' – or, as Professor Alan Usher of Sheffield points out, as 'unascertainable', if the pathologist is feeling particularly omnipotent!

On the next table in the autopsy room, however, may be a man of 60 who has been found dead with no available history. On examination he is found to have 60 per cent stenosis of the anterior descending branch of his left coronary artery, but no recent or old damage to the myocardium. Histology may well be performed, with no further information obtained. The cause of death is likely to be recorded as 'coronary artery disease' by most pathologists, yet he might well have died from the same obscure cause as the young man, but because he has just sufficient arterial degenerative disease to prove fatal, the latter is accepted as the most likely cause of death. This feeling of disillusion may be reinforced by the presence on the third autopsy table of another man of 60 who has been killed by a firearm, yet who has 80 per cent stenosis of all three coronary vessels, this obviously having played no part in the death.

Whatever the philosophical aspects of this problem, the practical difficulty remains of the pathologist's course of action when faced with negative findings in an autopsy.

At the end of the gross examination in the autopsy room, as the depressing realization increases that nothing significant has been found, further action will depend partly upon the facilities available to the pathologist, especially in relation to toxicological, biochemical, microbiological, virological and histological laboratory service.

Before proceeding further to review the dissection, attention must be paid to obtaining adequate samples for ancillary investigations. In many cases, especially where the history alerts the experienced pathologist that this might be a difficult case – and usually always in young people – samples of blood, urine and stomach contents will have been taken as routine during the removal and first dissection of the viscera.

If a blood sample has not already been taken, it should now be obtained, preferably from a peripheral vein such as the axillary or femoral to avoid contamination from the now empty trunk cavities. If urine was not retained from the bladder, a few drops may still be found in that opened organ by suction with a syringe. Stomach contents may well have been lost, but the liver can be retained for toxicological analysis. It might be useful to take vitreous humour if urine and stomach contents have been lost.

Some blood may be used for inoculation of blood culture bottles and swabs can still be taken for microbiological investigations. If a lung infection is possible, then either a few grams of lung tissue can be removed into a sterile jar, or swabs can be taken from peripheral bronchi or from the lung parenchyma itself. As the surface of all cut organs will have been contaminated during the first dissection, cuts should be made into the surface of the lung using a new sterile scalpel so that relatively fresh tissue is obtained for culture. At the same time, a cube of lung – or other organ if desired – should be taken into a sterile container for virus studies.

Before tissue for histology is taken, a full review of the more vital parts of the dissection should be reviewed. Even in younger victims the first area to be studied again is the coronary system, and in older obscure deaths it is essential to re-examine these vessels. Although the coronaries should have been transected at short intervals (not more than 3 mm apart) on the first examination, it is prudent to retrace each vessel carefully from the aortic origin distally, looking again at each cut segment and, where the interval appears too large, to make further intermediate cuts. In addition, it may be wise to join the segments longitudinally between cuts, in case a small isolated thrombus is lurking in the lumen. This should be done for common left trunk, anterior descending branch, left circumflex and right coronary artery.

This review of the coronary system sometimes pays dividends, especially in the middle-aged group that at first sight appears to have good coronary vessels. A tiny segment may be occluded or severely stenosed over a distance of only 2 or 3 mm, either by pure atheroma or by a subintimal haemorrhage, ruptured plaque or a localized thrombosis. If nothing is found, then after a quick review of the valves and great vessels, the myocardium can be sliced more extensively and a number of representative blocks taken for histology, to seek a myocarditis or some obscure cardiomyopathy.

The other organs should be examined again, the pulmonary arteries being scrutinized for pulmonary emboli in the smaller branches. This is rarely productive, but the author (BK) has on several occasions found multiple small emboli in more peripheral lung vessels, although whether these were a valid cause of death was debatable. The brain should be looked at once more, with special attention being paid to the basal arteries. These should be opened with coronary scissors and the dissection carried up into the middle cerebral arteries where they lie in the Sylvian fissures. It is also always worthwhile looking in the carotid arteries in the neck, though these should always be opened routinely at the first dissection from the aorta to a point just distal to the carotid sinuses; even the difficult area above this at the base of the skull has provided some surprises in the past. It is a place rarely examined, except by neuropathologists, but forensic pathologists should add it to their 'repertoire', as occasionally total thrombotic occlusion may be found, especially following some undisclosed neck injury.

When a complete review of the gross pathology has proved fruitless, then a full histological survey is required, especially of the myocardium. Special stains such as phosphotungstic acid-haematoxylin, dehydrogenase enzyme histochemistry (which requires unfixed, frozen sections), acridine-orange fluorescence stains and any other technique that the pathologist favours. Admittedly, where no cardiomegaly or coronary artery stenosis is present, the chances of finding an abnormality are slight, but an isolated myocarditis is an outside chance.

Toxicology may be difficult and expensive if there is no cause to suspect any particular drug or poison. A screen for unknown substances can be time consuming for the laboratory, which means a large expense to public funds. An alcohol estimation and a screen for acidic and basic substances, however, though not comprehensive, can at least exclude most common poisons. Microbiology and virology rarely point to a previously unsuspected fatal disease process unless the patient had clinical signs and symptoms before death.

When all the results are available, which may take several weeks (especially in the case of virus cultures), the case must be reviewed and an honest opinion offered as to whether any positive findings are sufficient to have caused death. In the experience of the authors, these ancillary investigations more often provide no help, than the times when they offer some assistance, but they must be carried out whenever possible in order to exclude such causes and to prevent allegations that the death was not investigated as fully as it should have been.

If at the end of the process no cause of death is apparent, then the appropriate investigating authority must be informed that no opinion can be offered in the present state of medical and scientific knowledge. It can be added, however, that the absence of injuries, evidence of poisoning, lethal infection or well-recognized natural disease is in itself significant negative evidence in that it confirms what the deceased did not die of, and the assumption is then that the balance of probabilities is that it was natural causes, rather than some unnatural external event.

There must be complete honesty on the part of the pathologist and a readiness to admit that the cause of death cannot be determined. The use of some meaningless euphemism such as 'heart failure' or 'cardiorespiratory arrest' is pointless and merely confuses the issue for non-medical persons such as police or magistrates. As mentioned above, there is a tendency on the part of some younger pathologists or histopathologists who rarely become involved in medicolegal cases to assume some unwarranted disease process or to attribute significance to insignificant findings. A **mode** of death is useless in lieu of a **cause** of death, so is the dangerous practice of using some agonal event such as 'inhalation of vomit' where there is no eyewitness confirmation of such an event taking place during life. It is also useless and positively dangerous to guess at some totally unprovable process, such as 'vagal inhibition', 'reflex cardiac arrest' or 'suffocation', just because these conditions are thought to leave no traces and therefore a death with no traces must be due to such a cause. This is illogical thinking and has led to several miscarriages of justice in the past, as well as to far more family anguish.

As the pathologist increases in experience and maturity, he or she is more ready to concede that he cannot find a cause of death, and this is far more satisfactory. In forensic work, this is not 'abrogating responsibilities' but being objective, sensible and just. There is no point in producing a speculative cause of death if that cannot be substantiated in later court evidence or legal statements. It is, of course, quite justifiable and indeed, part of the pathologist's responsibilities, to discuss the range of possible causes with the authorities responsible for investigating the death, but to be dogmatic about a single cause where the grounds for such a decision are tenuous does not help anyone and can lead to unfortunate consequences.

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C H A P T E R 2

The pathophysiology of death

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Most of the discussion concerning the definitions of death belongs to the field of legal medicine and even that of ethics, rather than forensic pathology. Notwithstanding this, a quick review of this complex problem is appropriate here, as when we come to describe the various post-mortem phenomena, some appreciation is necessary of the zero point from which such changes are timed.

TYPES OF DEATH

It is conventional to describe two types of death:

- somatic death, in which the person irreversibly loses its sentient personality, being unconscious, unable to be aware of (or to communicate with) its environment, and unable to appreciate any sensory stimuli or to initiate any voluntary movement. Reflex nervous activity may, however, persist, and circulatory and respiratory functions continue either spontaneously or with artificial support so that the tissues and cells of the body, other than those already damaged in the central nervous system, are alive and functioning.
- cellular death, in which the tissues and their constituent cells are dead – that is, they no longer function or have metabolic activity, primarily aerobic respiration.

Cellular death follows the ischaemia and anoxia inevitably consequent upon cardiorespiratory failure, but it is a process rather than an event, except in the exceptionally rare circumstance of almost instantaneous total bodily destruction, such as falling into molten metal or a nuclear explosion. Even fragmentation of a body by a bomb does not kill all cells instantly.

Different tissues die at different rates, the cerebral cortex being vulnerable to only a few minutes' anoxia, whereas connective tissues and even muscle survive for many hours, even days after the cessation of the circulation.

Brain death

Without trespassing too far into clinical medicine, it may be further noted that somatic death is virtually equated with brain death. When the higher levels of cerebral activity are selectively lost, either from a period of hypoxia, trauma, or toxic insult, the victim will exist in a 'vegetative state'. Here the survival of the brainstem ensures that spontaneous breathing will continue and therefore cardiac function is not compromised. The victim can remain in deep coma almost indefinitely – certainly for years – though debilitating complications such as postural skin necrosis, muscle contractures, and secondary chest infections may well shorten life. Such vegetative patients are not considered 'dead' by most standards, though there is a faction of the medical profession who claim that, because of the irreversible loss of their awareness of themselves and the world around them, they can no longer be considered 'human beings'.

As they are not on life-support machines, however, there is nothing short of euthanasia that can be done about their condition. Attitudes are changing, however, as evidenced by the case of Tony Bland, who declined into a persistent vegetative state, with functioning respiration, after hypoxia caused by crush asphyxia during the Sheffield Hillsborough football disaster. After several years in this persistent vegetative state, his family obtained the consent of the courts in 1993 to allow nutrition to be withdrawn and natural death to supervene.

It is another matter when brain death spreads below the tentorium. When the brainstem (specifically the midbrain, pons and upper medulla) suffers neuronal damage, the loss of the 'vital centres' that control respiration, and of the ascending reticular activating system that sustains consciousness, cause the victim not only to be irreversibly comatose, but also to be incapable of spontaneous breathing. Without medical intervention, hypoxic cardiac arrest inevitably follows within minutes and then the usual progression of 'cellular death' ensues. This invariably occurred in the past, before the advent of sophisticated devices that allowed the support of respiration after spontaneous function has ceased. Because of continued oxygenation, the heart continues to function, though it has been pointed out by Pallis (1983) that the vast majority of brainstem-dead patients suffer a cardiac arrest within 48–72 hours, even when adequately oxygenated.

This then is the state of 'brainstem death', and almost all doctors and most jurisdictions now accept that, once irreversible damage to the brainstem has been proved, the patient is 'dead' in the somatic sense. They are, however, not yet dead in the cellular sense and it is through this 'physiological window' that the spectacular advances in cadaver donor transplant surgery have been made.

MEDICO-LEGAL ASPECTS OF BRAIN DEATH

In relation to forensic pathology and criminal procedure, these matters have now a largely historical relevance in that several decades ago a number of fatal assaults were defended in court on the basis that the original head injuries led to the victims being placed on life-support machines that were later disconnected when brainstem death was diagnosed. The defence was that the assailant did not 'kill' the victim, because 'death' was caused by the action of the doctors switching off the machine. Several judicial decisions have disposed of this defence, however, as it was accepted, first, that death was diagnosed by the doctors before discontinuing artificial ventilation and, second, that the criminal act that initiated the train of events was not remote enough to avoid culpability for the death.

THE INDICATIONS OF DEATH

Here the signs of somatic death are considered, as those of cellular death are manifested by post-mortem changes, to be discussed in later sections. When cardiorespiratory arrest occurs, brain function ceases within seconds as a result of the collapse of cerebral blood pressure and consequent cortical ischaemia. Within minutes, this loss of brain function becomes irreversible. The actual number of minutes for which total anoxia will cause cortical damage is controversial; it was formerly held that 3 minutes was sufficient, but this time has been extended to 7 or 9 minutes. Even much longer times of total hypoxia, such as immersion under water, has been survived without brain damage. In these cases, an element of hypothermia is usual, which reduces the oxygen needs of the tissues. Thus 20 or even 40 minutes of hypoxia has been claimed as not leading to brain damage. All that can be said is that the period is very variable and that 3–4 minutes of cardiac arrest or failure of respiratory gas exchange carries the risk of cortical damage, even though three or four times this period may sometimes be survived without ill-effects.

- Unconsciousness and loss of all reflexes occurs, and there is no reaction to painful stimuli. Rarely, there may be post-mortem coordinated muscle group activity for up to one hour after death, possibly due to surviving cells in the spinal cord (Nokes *et al.* 1989).
- Muscular flaccidity occurs immediately upon failure of cerebral and cerebellar function. All muscle tone is lost, though the muscles are physically capable of contraction for many hours.

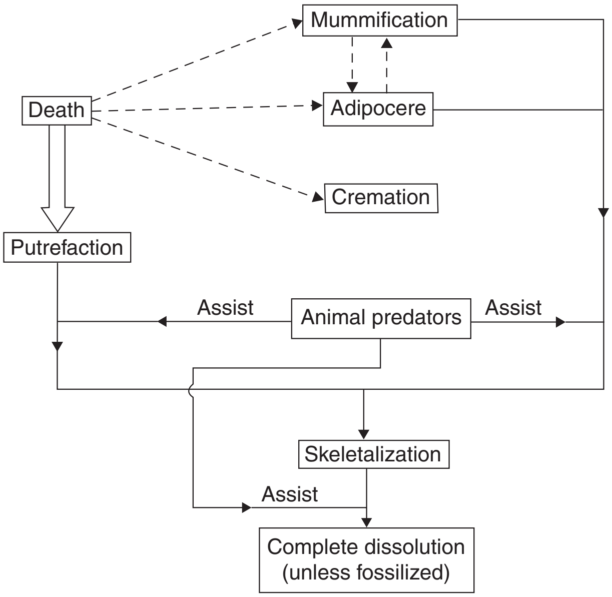

FIGURE 2.1 *The fate of a body after death.*

- Eye signs include loss of the corneal and light reflexes leading to insensitive corneas and fixed, unreactive pupils. Though the iris responds to chemical stimulation for hours after somatic death, the light reflex is lost as soon as the brainstem nuclei suffer ischaemic failure. The pupils usually assume a mid-dilated position, which is the relaxed neutral position of the pupillary muscle, though they may later alter as a result of rigor. There may be a marked difference in the degree of dilatation of each pupil, but this has no significance as a diagnostic sign either of a brain lesion or of drug intoxication. In conditions such as morphine poisoning, where the pupils may be contracted during life, death may allow this to persist or the pupils may dilate to the 'cadaveric position'.

  In addition to irregular size, the pupils may lose their circular shape after death as a result of uneven relaxation. This is usually easy to differentiate from the more obvious irregularity caused by ante-mortem abnormality of the iris. The eye globe tension decreases rapidly, as it is dependent upon arterial pressure for its maintenance. The eyeball feels progressively softer within minutes and the cornea soon loses its normal glistening reflectivity because of laxity and failure of lachrymal moistening. Normal tension was measured by Nicati in 1894, who found that it halved at death, fell to as low as an eighth in 30 minutes, and was nil by 2 hours after death. The eyelids usually close, but this is commonly incomplete, the flaccid muscles failing to produce the full occlusion that occurs in voluntary closure. Where the sclera remains exposed, two yellow triangles of desiccated discoloration appear on each side of the cornea within a few hours, becoming brown and then sometimes almost black, giving rise to the name 'tache noire'.

  When viewed with an ophthalmoscope, the retina provides one of the earliest positive signs of death. This is the well known 'trucking' of blood in the retinal vessels, when loss of blood pressure allows the blood to break up into segments, similar to trucks in a railway train. This phenomenon occurs all over the body, but only in the retina is it accessible to direct viewing.

  The test is not easy to carry out, as the retina of a corpse seems far more difficult to visualize than in a living person. Many observers have described the agonal and early post-mortem appearances of the retina, though some of their accounts are rather contradictory and of little practical value, especially when they attempt to use them to estimate the time since death. Most observers – for example, Kervorkian (1956, 1961) and Salisbury and Melvin (1936) – confirm that the blood flow slows and becomes irregular in density before breaking up into segments. This was apparent within 15 minutes of death as assessed by other means. Kervorkian claimed that colour changes in the retina were closely related to the post-mortem interval. Tomlin believed that segmentation was more indicative of cerebral death than cessation of the circulation, and agreed with others in accepting that 'trucking' was of grave prognostic significance.

  One of the best investigations into the phenomenon was by Wroblewski and Ellis (1970), who studied retinal and corneal changes at death in 300 patients. About a third of the total exhibited trucking, most of them within an hour of death. Part of the difficulty in

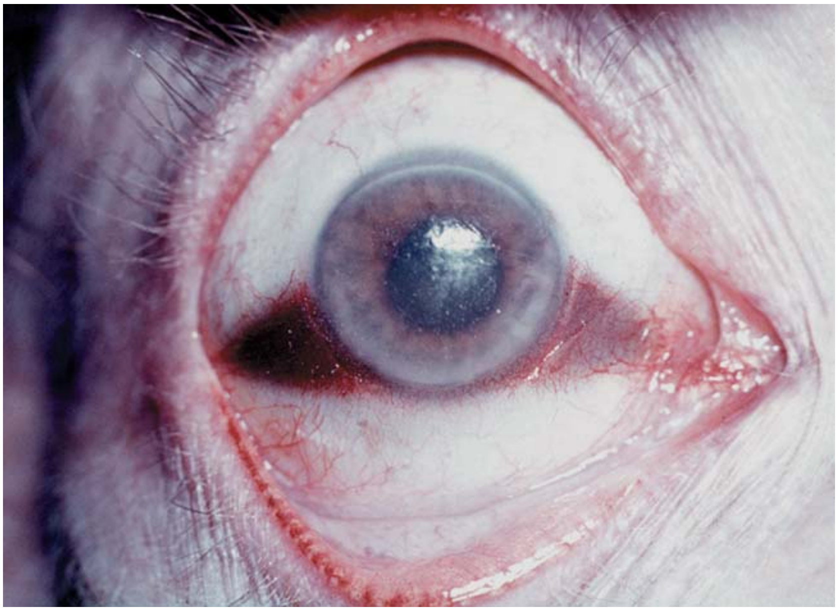

FIGURE 2.2 *Post-mortem change in the eye, the so-called 'tache noire'. These are brown areas of scleral drying caused by failure of the lids to close after death.*

examining the remainder was that clouding of the cornea occurred in 75 per cent of patients within 2 hours of death. They concluded that segmentation was a purely post-mortem change and any intravascular movement of blood, however irregular, was an indication for continued resuscitation.

- Cessation of the heart beat and respiratory movements was the primary marker of death until the advent of mechanical cardiorespiratory support as it led to immediate ischaemia and anoxia of all other tissues. Determination of cardiac arrest may be made by prolonged auscultation of the chest to exclude heart sounds though, as in life, a feeble heartbeat may be muffled by a thick chest wall. The electrocardiograph is unchallengeable in confirming cardiac arrest.

  Respiration is more difficult to confirm, especially in deep coma such as barbiturate poisoning, and prolonged listening with a stethoscope over the trachea or lung fields is necessary. All archaic procedures such as saucers of water on the chest, feathers before the nostrils and tourniquets around the fingers are only of historical interest.

The mode versus the cause of death

Confusion often arises, especially among students and younger doctors, about the distinction between the **mode** of death and its **cause**. This is particularly important in relation to the documentary certification of deaths, but the same confusion sometimes occurs among pathologists, especially those who are not habitually involved in medicolegal cases.

The mode of death refers to an abnormal physiological state that pertained at the time of death: for example, 'coma', 'congestive cardiac failure', 'cardiac arrest' and 'pulmonary oedema'. These offer no information as to the underlying pathological condition and should not be used as the definitive cause of death unless further qualified by the more fundamental aetiological process.

In most cases, the mode is unhelpful and immaterial in describing and understanding the cause of death, and some modal terms are quite useless, such as 'syncope' or 'cardiorespiratory failure'. Even 'bronchopneumonia' is such a common terminal event in numerous diseases that, used alone, it conveys no information about why the patient died. The British Registrar General has recently requested that it should be omitted from death certificates, the basic condition being preferable and sufficient for statistical purposes.

In addition to the mode and cause of death, here is also the **manner** of death, which is not really a medical decision. Manner refers to the circumstantial events, such as 'homicide, suicide, accident or natural cause' and is a legal or administrative categorization.

The recommendations of the World Health Organization, as given in its publication *The medical certification of death*, should be followed to improve both the comprehension and statistical accuracy of the cause of death. Even this booklet is inconsistent with the practice of certification in many advanced countries, in that it requests the doctor to enter the 'manner' of death (for example, homicide, accident or suicide) which, for example in the UK, is the prerogative of the legal authorities after full investigation (see Leadbeatter and Knight 1987).

POST-MORTEM CHANGES OF FORENSIC IMPORTANCE

To the forensic pathologist a number of post-mortem changes are of interest and potential usefulness, mainly in relation to the estimation of the post-mortem interval, possible interference with the body, and an indication of the cause of death.

HYPOSTASIS

Post-mortem hypostasis is known under a variety of older names, such as 'lucidity', 'staining' or 'cogitation', but the current title is most suitable as it indicates the cause. Hypostasis occurs when the circulation ceases, as arterial propulsion and venous return then fail to keep blood moving through the capillary bed, and the associated small afferent and efferent vessels.

Gravity then acts upon the now stagnant blood and pulls it down to the lowest accessible areas. The red cells are most

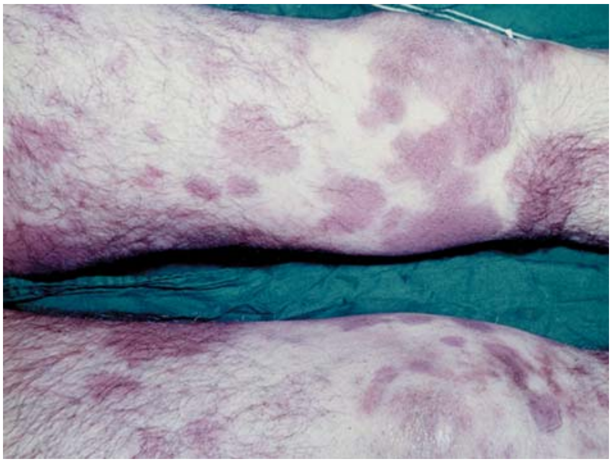

FIGURE 2.3 *Blotchy post-mortem hypostasis, forming in the early hours after death. The patchy disposition has no significance and this usually sinks down and becomes confluent in the most dependent areas within a few more hours.*

affected, sedimenting through the lax network, but plasma also drifts downwards to a lesser extent, causing an eventual post-mortem 'dependent oedema', which contributes to the skin blistering that is part of early post-mortem decay.

The arrival of erythrocytes in the lower areas is visible through the skin as a bluish red discoloration, 'hypostasis'. It often begins as blotchy patches on both lateral and dependent surfaces, but also on the upper surfaces of the legs, especially thighs. These soon coalesce and slide down to the lowest areas.

The distribution of hypostasis

The pattern of hypostasis depends on the posture of the body after death. It is most common when the deceased body is lying on its back, with the shoulders, buttocks and calves pressed against the supporting surface. This compresses the vascular channels in those areas, so that hypostasis is prevented from forming there, the skin remaining white. When the body lies for a sufficient time on the side or face, the hypostasis will distribute itself accordingly, again with white pressure areas at the zones of support.

If the body remains vertical after death, as in hanging, hypostasis will be most marked in the feet, legs and to lesser extent in the hands and distal part of the arms. In addition to pallor of the supporting areas, any local pressure can exclude hypostasis and produce a distinct pattern in contrast to the discoloured area. Examples include the irregular linear marks made by folds in rumpled bedlinen, the pattern of fabric from coarse cloth, the pressure of tight belts, brassière straps, pants' elastic and even socks. According to Bonte *et al.* (1986), when electrocution takes place in water (usually a bathtub), the hypostasis is sharply limited to a horizontal line corresponding to the water level.

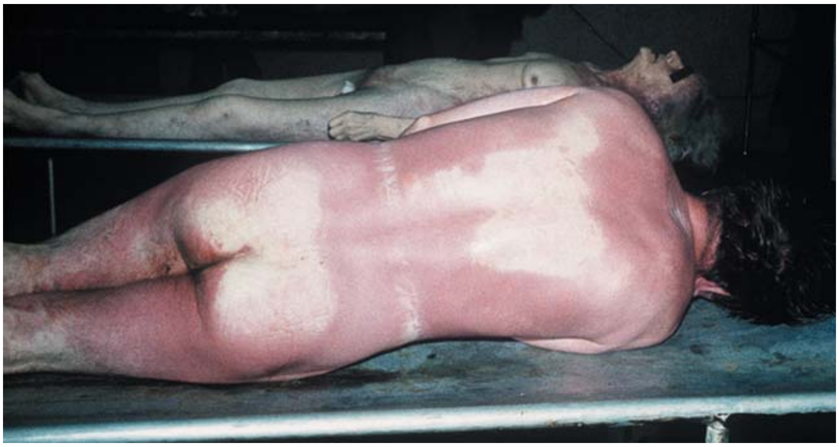

FIGURE 2.4 *Post-mortem hypostasis in the normal distribution. The pale areas are the result of pressure against a hard supporting surface.*

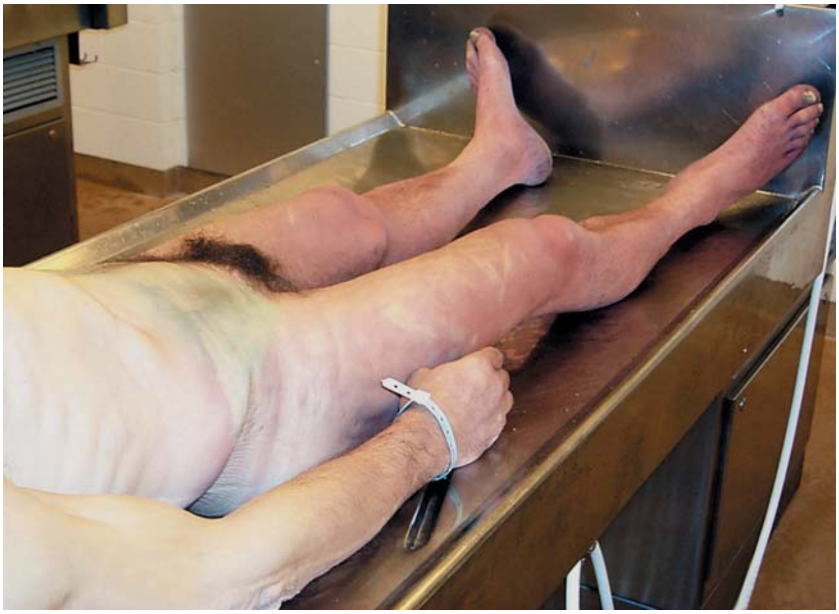

FIGURE 2.5 *Post-mortem hypostasis in a death from hanging. The discoloration of the skin is in the legs and hands, due to the vertical posture after death.*

The colour of hypostasis

The usual hue is a bluish red, but variation is wide. This depends partly on the state of oxygenation at death, those dying in a congested, hypoxic state having a darker tint as a result of reduced haemoglobin in the skin vessels. This is an unsure indicator of the mode of death, however, and no reliance can be placed on a cyanotic darkening of the hypostasis to indicate a hypoxic death in the sense of 'asphyxia'. Many natural deaths from coronary or other disease have markedly dark hypostasis. Often the colour of the hypostasis varies from area to area on the same body. Sometimes a rim of lighter colour may be seen along the margin of the lower darker area and sometimes there is a definite contrast between a bluish zone and a pink margin. This may appear and change as the post-mortem interval lengthens. Often the whole area of hypostasis is pink or bright red. When death has been due to hypothermia or exposure to cold in the agonal period, such as drowning, the colour may assist in confirming the cause of death; again this is relatively non-specific because bodies exposed to cold after death (especially in mortuary refrigeration) may turn pink after an initial stage of normal bluish-red tint.

The mechanism is not understood, but is obviously a result of oxyhaemoglobin forming at the expense of the darker reduced haemoglobin. This is understandable in hypothermia, where the reduced metabolism of the tissues fails to take up oxygen from the circulating blood, but its frequent formation in the post-mortem period is difficult to explain.

Several researchers have investigated the colour of hypostasis in relation to time since death. Schuller *et al.* (1987) noted an increasing paleness between 3 and 15 hours post-mortem, measuring this as a change in wavelength from 575 nm at 3 hours at an average rate of 2 nm per hour. Vanezis (1991) has used tristimulus colorimetry to study colour changes and secondary shifting of hypostasis, and claimed that there is a linear relationship between the fading colour and time during the first 2 hours after death, following which changes are unpredictable. Inoue *et al.* (1994) have also described measurement of hypostatic colour as a measure of time since death.

It may sometimes be noticed that originally bluish hypostasis becomes pink along the upper part of the horizontal margin, the lower parts remaining dark, so a quantitative change probably occurs, the haemoglobin being more easily re-oxygenated where the erythrocytes are packed less densely in the upper layers of hypostasis.

Other changes in the colour of hypostasis are more useful. The best known is the 'cherry-pink' of carboxyhaemoglobin, which is a unique colour and is often the first indication to the pathologist of carbon monoxide poisoning. Cyanide poisoning is said to have its own characteristic dark blue–pink hue, but it is really an index of the congested, cyanotic, mode of death and, if the pathologist was not already aware of the potential cause from the history – and perhaps the odour of cyanide – it is doubtful whether hypostasis would be a primary indication of the nature of the death. The hypostasis may be a brownish red in methaemoglobinaemia and may be various shades in aniline and chlorate poisoning. In deaths from septic abortions where *Clostridium perfringens* is the infecting agent, a pale bronze mottling may sometimes be seen on the skin, though this is not confined to the areas of hypostasis.

Skin haemorrhages, varying in size from small petechiae to large blotches and even palpable blood blisters may develop in areas of hypostasis. The most common place is the back of the shoulders and neck, though they may appear on the front of the chest, even on a body lying on its back. They are more common in cyanotic, congestive types of death and become more pronounced as the post-mortem interval lengthens. Their importance is in not being mistaken for the so-called signs of 'asphyxia'. They appear in the most gross form when a body dies or is left with the head downwards: the confluent petechiae and ecchymoses may be so marked that they virtually blacken the face and neck.

The timing and permanence of hypostasis

Too much has been claimed in the past for the usefulness of hypostasis as an indicator of the time of death and post-mortem disturbance of the body. The phenomenon appears at a variable time after death – indeed, it may not appear at all, especially in infants, old people or those with anaemia. It may be so faint as almost to escape detection.

Hypostasis can appear within half an hour of death or it may be delayed for many hours. Its variability is such that it is useless for any estimation of the time since death. It is claimed that hypostasis can sometimes be observed in the living if the heart action is failing or if venous return is impaired by the immobility of deep coma. The latter is certainly associated with skin blistering caused by dependent oedema.

Once hypostasis is established, there is controversy about its ability to undergo subsequent gravitational shift. If the body is moved into a different posture, the primary hypostasis may either:

- remain fixed
- move completely to the newly dependent zones or
- be partly fixed and partly relocated.

Thus if a corpse is found with the hypostasis in an obviously inappropriate distribution related to the present posture, it must have been moved after death. This fact may

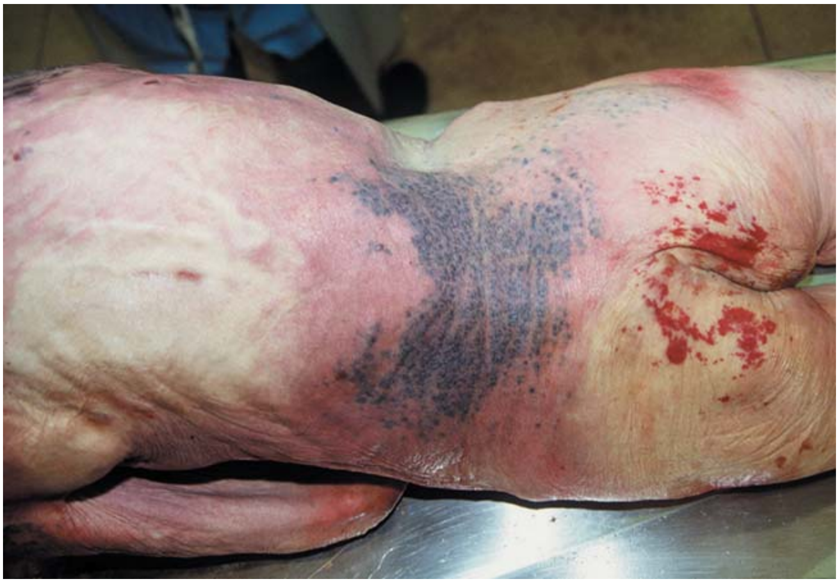

FIGURE 2.6 *Extensive confluent skin haemorrhages may occur within the dependent hypostasis. They worsen as the post-mortem interval lengthens and must not be taken to indicate so-called 'asphyxia'.*

have important significance in the investigation of criminal deaths, such as the return of the culprit or some other person to the scene. It may also migrate either partly or completely, however, thus negating its diagnostic usefulness. Older theories about 'fixation' of the staining after a certain time are not tenable, as there is no constant interval when this occurs.

Mallach (1964) analysed data including onset, confluence, maximum intensity, displacement and shifting, taken from publications between 1905 and 1963. These are summarized in Table 2.1, 'thumb pressure' meaning displacement by thumb pressure. Table 2.2 shows the variable opinions on hypostasis culled from standard textbooks.

A considerable amount of research has been devoted to the investigation of clotting of post-mortem blood, its subsequent lysis and inhibition of coagulation by fibrinolysins, but this cannot be translated into practice. Formerly, it was held that if a body had remained in its original posture for a certain minimum length of time, the blood would coagulate in the hypostatic areas, so that secondary shifting could not then occur if the body was moved. This is not true in the majority of instances, as there may be partial or complete secondary gravitation at any time – at least, until true staining of the tissues due to haemolysis begins as part of early decomposition, which is not until the second or third day in temperate conditions.

Suzutani *et al.* (1978) examined 430 bodies by pressure on hypostatic areas, finding that the colour could not be squeezed out in 30 per cent where death had occurred 6–12 hours previously. More than 50 per cent were fixed after 12–24 hours and no fading occurred in 70 per cent of those dead for more than 1–3 days. However, in a significant number, hypostasis was still mobile for at least 3 days.

TABLE 2.1 *Hypostasis related to the time of death (hpm) as derived from previous literature*

Stage	Mean	Standard deviation	Limits	
			Lower	Upper
Beginning	0.75	0.5	0.25	3
Confluence	2.50	1.0	1.00	4
Maximum	9.50	4.5	3.00	16
Thumb pressure	5.50	6.0	1.00	20
Complete shifting	3.75	1.0	2.00	6
Incomplete shifting	11.00	4.5	4.00	24

TABLE 2.2 *Time of onset of hypostasis as stated by previous authors*

Reference	Onset	Maximum
Adelson	30 min–4 h	8–12
Polson, Gee, Knight	30 min–2 h	6–12
Spitz and Fisher	2–4 h	8–12
Taylor (ed. Simpson)	0 h	12
Taylor (ed. Mant)	1 h	12
Gradwohl (ed. Camps)	20–30 min	6–12
Glaister, Brash	–	8–12
DiMaio	30 min–2 h	8–12
Sydney Smith	0 h	12
Mant	0 h	12
Gordon and Shapiro	'few' h	12

Fechner *et al.* (1984) found no linear relationship between fixation and time of death and also observed variations in fixation according to storage temperatures.

Hypostasis in other organs

Just as blood settles in dependent skin, so it does in other tissues and organs. The importance in forensic autopsy work is the differentiation of organ hypostasis from ante-mortem lesions. In the intestine, dependent loops of jejunum and ileum may be markedly discoloured and mislead the inexperienced pathologist into suspecting mesenteric infarction or strangulation. This hypostasis is discontinuous, however, revealing interrupted segments when the gut is laid out. Often loops in the pelvis are worst affected, because of their lower position.

The lungs almost always show a marked difference in colour from front to back, the anterior margins being pale and the posterior edges lying in the paravertebral gutters being dark blue. This is often accompanied by an obvious difference in fluid content, congestion and oedema being more marked posteriorly. The myocardium often shows a dark patch in the posterior wall of the left ventricle that must not be mistaken for early infarction.

One of the most important hypostatic artefacts is haemorrhage behind the oesophagus at the level of the larynx. This has many times been confused with the trauma of strangulation, but the true nature was best investigated by Prinsloo and Gordon (1951). Areas of congestion developing into haemorrhage appear in the loose tissues on the back of the oesophagus lying on the anterior longitudinal ligament of the cervical spine. They may be prominent, sufficient to produce actual haematomas. They arise in the veins and venous plexus on the front of the spine, and can be avoided in cases of strangulation and suspected strangulation by draining the neck of blood before starting the dissection. This can be achieved either by removing the brain first or by opening the chest and incising the great veins in the superior mediastinum.

Differentiation between hypostasis and bruising

This is rarely a problem in fresh bodies, but when decomposition begins the two conditions become blurred. In fresh material the appearance of hypostasis is of a regular, diffuse engorgement of the surface vessels, the colour varying between purple–red and bright pink. The density varies from place to place but there are no sudden changes in colour nor any sharply circumscribed areas as occurs in bruising. As mentioned above, in the early stages of hypostasis there may be mottled blue areas, which later coalesce. This mottling is unlikely to be confused with bruising by any but the most inexperienced pathologist. The position in dependent areas is also characteristic, giving a generally horizontal orientation. Bruises may be anywhere on the body, are often discoid or have an irregular margin, but rarely cover a large area with uniform density – and do not have a horizontal margin. Abrasions may be topographically associated with a bruise, but not with hypostasis. When there is difficulty in differentiating between the two – usually where there is racial pigmentation or really deep, cyanotic hypostasis that obscures possible bruises – the classic test is to incise the suspect area to see if the underlying blood is intravascular (hypostasis) or infiltrating the tissues outside the vessels (contusion).

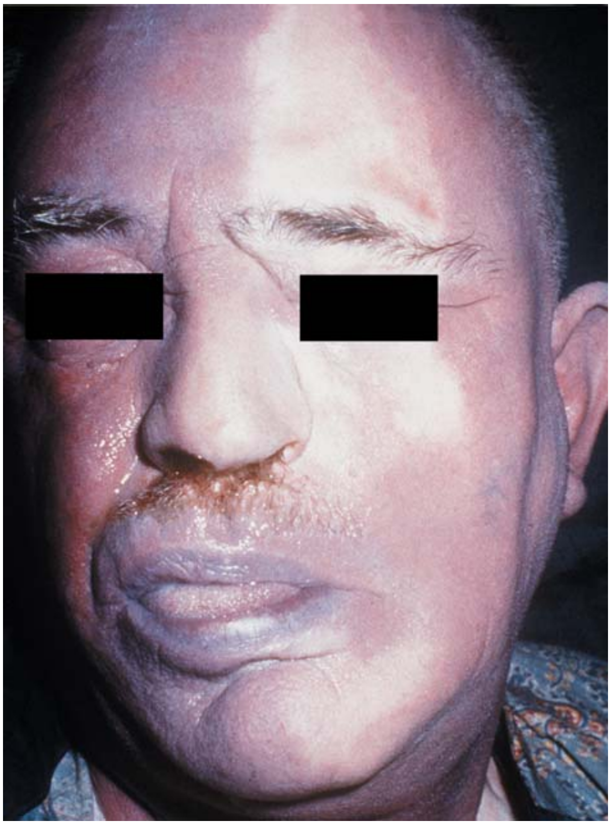

FIGURE 2.7 *White patches within the hypostasis on the face merely indicate pressure against the supporting surface after a face-down position. As in this case, they are usually post-mortem and are not indicators of suffocation.*

Fresh bruises may also be swollen and slightly raised above the surface. If a post-mortem pressure mark (such as from a belt or tight clothing) crosses an area of hypostasis, there will be a pale bloodless zone, but a bruise will not be affected. Hypostasis is in the most superficial layer of the dermis and any exuded blood can be wiped or washed away from the incised surface. A bruise is often deeper in the skin or underlying tissues and is fixed, being infiltrated through the tissues outside the ruptured vessels. An exception is intradermal bruising, but this is usually patterned or linear and rarely can be confused with hypostasis. Histological examination may be necessary finally to decide the matter.

When post-mortem autolysis has developed, the diffusion of haemolysed blood from vessels makes the differentiation between hypostasis and bruising difficult and eventually impossible. Even histological examination may be of little help when the tissues become markedly degenerate.

RIGOR MORTIS

Unlike hypostasis, the stiffening of the muscles after death has some relevance in determining the post-mortem interval. It has been known since antiquity that immediately after death there is general muscular flaccidity, usually followed by a period of partial or total rigidity, which in turn passes off as the signs of decomposition appear. The timing of this sequence of events is so variable, however, that it is a poor indicator of the time since death. The usual range of times when rigor appears can be summarized as follows.

- The flaccid period immediately after death is variable, but commonly extends to between 3 and 6 hours before stiffening is first detected, depending on environmental temperature and other factors. Rigor is first apparent in the smaller muscle groups, not because it begins there, but because the smaller joints, such as the jaw, are more easily immobilized. The sequence of spread of rigor is also variable but tends to affect the jaw, facial muscles and neck before being obvious in the wrists and ankles, then the knees, elbows and hips.

  The usual method of testing is by attempting to flex or extend the joints, though the whole muscle mass itself becomes hard, and finger pressure on the quadriceps or pectorals can also detect the change. The onset of rigor may be markedly accelerated or retarded by the factors mentioned below, so that stiffness may develop within half an hour of death (even excluding cadaveric spasm) or may be postponed almost indefinitely. Some subjects, usually infants, the cachectic and the aged, may never develop recognizable rigor mortis, mainly because of the feebleness of their musculature.
- Rigor spreads to involve the whole muscle mass, again within a variable period but in ‘average’ conditions it might be expected to reach a maximum within 6–12 hours. This state then remains constant until the muscle mass begins to undergo autolysis, which releases rigor gradually at a stage before overt post-mortem changes are visible externally, except perhaps for a commencing discoloration of the lower abdominal wall.

  The duration of full rigor may be 18–36 hours, until it begins to fade in roughly the same order of muscle groups as it appeared. However, there are many exceptions to this rather misleading generalization.

Factors affecting the timing of rigor mortis

As a chemical process, the speed of onset and the duration of rigor is modified by temperature. The colder the environment the slower the process and vice versa. In near freezing conditions rigor will be suspended almost indefinitely. The author (BK) has attended a scene outdoors in winter where the body was quite flaccid one week after death, rigor developing rapidly as soon as the corpse was brought into the comparative warmth of the mortuary. Conversely, hot weather or tropical conditions can speed up the whole cycle so that rigor appears within an hour or even less. Total stiffness develops rapidly, then fades during the first day as decomposition supervenes.

The other modifier of the speed of onset of rigor is physical activity shortly before death. As will be seen when the

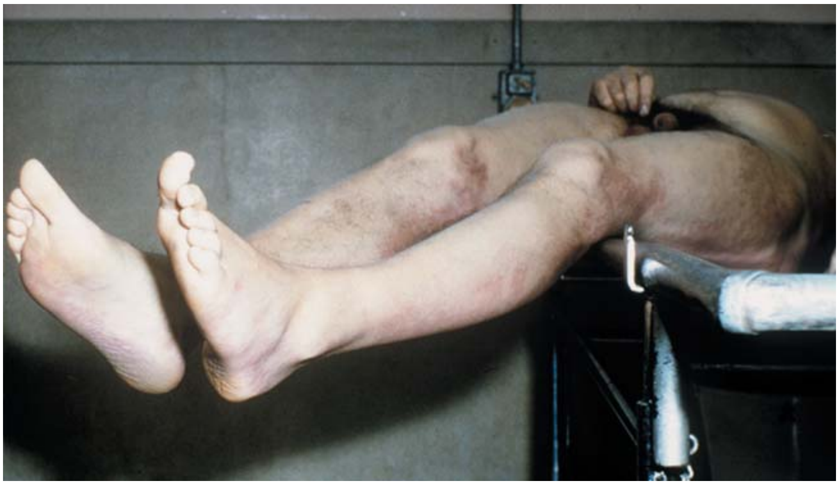

FIGURE 2.8 *Full rigor mortis 12 hours post-mortem.*

physicochemical basis of the phenomenon is discussed, the availability of glycogen and adenosine triphosphate in the muscle is a crucial element in rigor formation. Muscular exertion affects the interaction of these substances and hastens the onset of rigor. Cadaveric spasm, dealt with later, may well be an extreme variant of this accelerated rigor.

In view of the wide range of times at which the various stages of rigor appear and fade, it is a poor determinant of the time since death, compared with estimations of body temperature. Niderkorn's early work (1874) on 113 bodies showed a range of 2–13 hours for rigor to be complete, the main cluster being from 3 to 6 hours after death, a shorter period than would be accepted now. Mallach (1964) compiled a table from 150 years of published data, which suffered from gross variation in observer methodology (Table 2.3).

The following is a reasonable 'spot check' for use in average temperate conditions:

- If the body feels **warm** and is **flaccid**, it has been dead less than 3 hours.
- If the body feels **warm** and is **stiff**, it has been dead from 3 to 8 hours.
- If the body feels **cold** and is **stiff**, it has been dead from 8 to 36 hours.
- If the body feels **cold** and is **flaccid**, it has been dead more than 36 hours.

This crude estimate should never be used as a definitive statement in legal proceedings, as it is only meant as a rough guide 'on the spot'.

Rigor mortis in other tissues

Rigor occurs in all muscular tissues and organs, as well as the skeletal muscles. The iris is affected so that ante-mortem constriction or dilatation is modified. The rigor may be unequal in each eye, making the pupils unequal, confirming the fact that the post-mortem position is an unreliable indicator of toxic or neurological conditions during life.

In the heart, rigor causes the ventricles to contract, which may be mistaken by the inexperienced pathologist for left ventricular hypertrophy; this can be excluded by measuring the total weight, estimating the relative size of the left side, measuring the ventricular thickness (admittedly a rough guide) and – where the issue is important – by dissection and differential weighing of the two ventricles.

Rigor in the dartos muscle of the scrotum can compress the testes and epididymis which, together with the contraction of muscular fibres in the seminal vesicles and prostate, may lead to post-mortem extrusion of semen from the urethral meatus. This has been wrongly attributed to sexual activity and orgasm just before death in cases where a defence of provocation against a homosexual advance has been put forward. Mant showed that many corpses dying from a variety of causes have seminal fluid either at the meatus or in the penile urethra (Mant 1953, 1967; Mant and Furbank 1957). It is also said, without much foundation, that deaths from hanging and 'asphyxia' are commonly associated with post-mortem seminal emission.

Rigor in the erector pili muscles attached to the hair follicles can cause a pimpling or 'goose-flesh' appearance with elevation of the cutaneous hairs. This may have given rise to the persistent myth that the beard grows after death, though an additional explanation is that post-mortem desiccation and shrinkage of the skin allows the hair stubble to appear more prominent.

Studies by Krompecher and Bergerioux (1988) have shown that rigor also sets in more quickly in deaths from electrocution – and that it passes off more rapidly.

The biochemistry of rigor mortis

Though this has little direct forensic relevance apart from the association of the early onset of rigor with muscular

TABLE 2.3 *Time course of cadaveric rigidity as stated by previous literature*

		Hours post-mortem				
		Limits of 95.5 per cent probability (2s)		Variations		
Rigor phase	**Mean with standard deviation(s)**	**Lower limit**	**Upper limit**	**Lower limit**	**Upper limit**	**Number of publications evaluated**
Delay period	3 ± 2	–	7	< ½	7	26
Re-establishment possible	Up to 5	–	–	2	8	–
Complete rigidity	8 ± 1	6	10	2	20	28
Persistence	57 ± 14	29	85	24	96	27
Resolution	76 ± 32	12	140	24	192	27

exertion, the muscle chemistry of the phenomenon has been studied in great detail.

Szent-Gyorgi (1947) discovered that the essential contractile substances in muscle were the two proteins actin and myosin, arranged in interdigitating filaments. They form a loose physicochemical combination called ‘actomyosin’, which is physically shorter than the two substances uncombined (Hanson and Huxley 1955). If energy is supplied to the latter pair, the subsequent combination contracts. This energy is obtained by the splitting off of a phosphate complex from adenosine triphosphate (ATP) which then becomes adenosine diphosphate (ADP) (Erdos 1943). The free phosphate then engages in a phosphorylation reaction that converts glycogen to lactic acid, high energy being released in the process. Some is used to resynthesize the ATP from ADP, by the donation of a phosphate group from creatine phosphate; the remainder goes to activate the actin–myosin reaction.

In addition to supplying energy, ATP is responsible for the elasticity and plasticity of the muscle. The lactic acid is leached away back into the bloodstream and is returned to the liver for reconversion into glycogen. All these reactions are anaerobic and can continue after death, albeit in a distorted form.

In life there is a fairly constant concentration of ATP in the muscular tissues, there being a dynamic balance between utilization and resynthesis. At death, however, the ADP to ATP reaction ceases and the triphosphate is progressively diminished, with lactic acid accumulating. After a variable period, depending on temperature and the amount of ATP remaining, the actin and myosin become rigidly linked into a rigid, inextensible gel, with consequent stiffening of the muscle (see Bate-Smith and Bendall 1947; Forster 1964).

The resynthesis of ATP is dependent upon the supply of glycogen, which is depleted by vigorous activity before death; this explains the rapid onset of rigor in these circumstances. Normally there appears to be an initial period soon after death when the ATP level is maintained or even increased as a result of phosphate liberation by glycogenolysis.

Rigor is initiated when the ATP concentration falls to 85 per cent of normal, and the rigidity of the muscle is at maximum when the level declines to 15 per cent (see Bate-Smith and Bendall 1949).

Gross effects of rigor mortis

There has been some controversy over whether rigor only stiffens the muscles or actually shortens them. Sommer, as long ago as 1833, claimed that muscles contracted after death and the changes were actually known as ‘Sommer’s movements’. There have always been semi-apocryphal tales of corpses moving in the mortuary and there seems little doubt that, if a limb happens to be poised in unstable equilibrium on the edge of a tray or table, the developing tension may occasionally cause it to spring off as rigor supervenes. The author (BK) has seen athetoid writhing of the foot of a corpse, which lasted for 40 minutes, more than an hour after death.

There seems to be no doubt that some shortening does occur, but the noticeable effects are slight because both flexor and extensor muscle groups oppose each other across most limb joints. Bate-Smith and Bendall (1949) decided that shortening only occurred when there had been marked depletion of glycogen by activity before death, but Forster (1964) was of the opinion that, when a muscle was under some tension, it did shorten. His experiments showed that when the muscle was unloaded there was no change in length when rigor set in. Forster further showed that a high environmental temperature and poisons that increase muscle tone, such as parathion, lead to more shortening during rigor.

When fully established, rigor is ‘broken’ by forcible movements of the limbs or neck, then it will not return, a phenomenon utilized daily by mortuary staff and undertakers when preparing a body for a coffin. If rigor is still developing, it will continue in the new posture of the limbs after they have been stretched. ‘Breaking’ fully established rigor is an accurate description, as the rigid, inelastic fibres are physically ruptured – sometimes tearing the muscle insertions from the bone. Rarely, rigor can assist in showing that a body has been moved between death and discovery. If an arm or leg is found projecting into free space without support, in a posture that obviously could not have been maintained during primary post-mortem flaccidity, then it must have been rolled over or otherwise moved. In these cases, a simple restorative movement (after the scene has been fully examined) can usually indicate the original attitude quite simply.

Conversely, it can never be assumed that the posture of rigor in which a body is found was that which obtained at the time of death, as any amount of movement during the period of primary flaccidity will not be mirrored in the subsequent rigor.

Cadaveric spasm

This topic has received a disproportionate amount of notice in textbooks compared with its practical importance. No doubt this is because of its curiosity value rather than its usefulness. Cadaveric spasm is a rare form of virtually instantaneous rigor that develops at the time of death with no period of post-mortem flaccidity.

Krompecher (1994), a major authority on rigor mortis, is extremely sceptical about the existence of true cadaveric

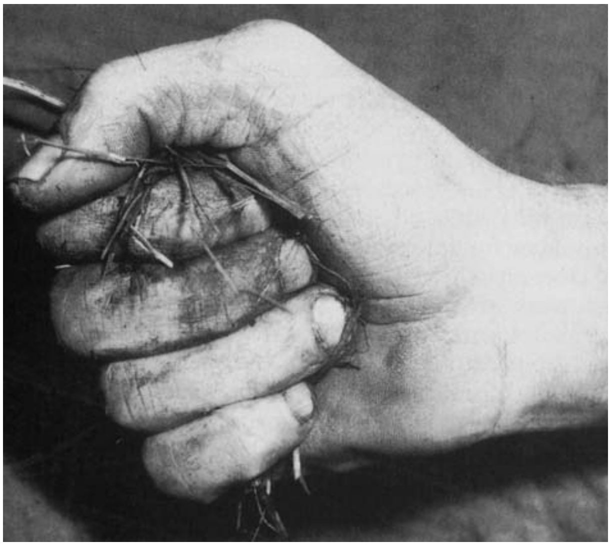

FIGURE 2.9 *Cadaveric spasm, an instantaneous form of rigor, in the victim of a fall into water. The victim was recovered within a short time (as can be seen from the absence of skin maceration) but had grass from the river bank firmly clutched in the hand.*

spasm, but many forensic pathologists claim to have seen such a phenomenon far too soon after death for it to be normal rigor mortis. The authors retain a healthy scepticism about the controversy, believing that most cases are misreported because of errors or uncertainties about the true time of death, so that early normal rigor could have supervened. However, one or two cases within BK's experience seem to be genuine enough to be remarkably early for true rigor.

It seems confined to those deaths that occur in the midst of intense physical and/or emotional activity, though how the latter can lead to instant post-mortem rigor is quite inexplicable. It presumably must be initiated by motor nerve action, but for some reason there is a failure of the normal relaxation. The phenomenon usually affects only one group of muscles, such as the flexors of one arm, rather than the whole body.

It was shown in the earlier section on the biochemistry of rigor that marked depletion of glycogen stores in the muscle by violent exertion immediately before death can hasten the onset of muscular rigidity. Most cases of cadaveric spasm occur in similar circumstances and it was said to be particularly common on the battlefield amongst soldiers slain in combat. In the civilian sphere it is most often seen in persons who fall into water or drop some distance down a precipitous slope such as a cliff. They may clutch at some nearby object, such as grass or shrubs, in an effort to break their fall and such material may be found held tightly in their fingers, even when the body is examined within a few minutes.

Another possibility, more common in detective fiction than in practice, is the gripping of a pistol with the finger still tightly flexed on the trigger, as evidence of true suicide rather than a 'planted' weapon in a homicide where an attempt has been made to simulate self-shooting. The chances of this actually being encountered by a pathologist are less than once in several professional lifetimes.

If found in the victim of drowning, or of a slide from a height, it has some value in confirming that the person was alive at the time of the fall, thus excluding the post-mortem disposal of an already dead body. Of course the body must be examined before ordinary rigor might be expected to have developed, or the presence of cadaveric spasm cannot then be assumed.

HEAT AND COLD STIFFENING

At extremes of temperature the muscles may undergo a false rigor. In extreme cold, well below zero, once the intrinsic body heat is lost, the muscles may harden because the body fluids may freeze solid – as in the commercial or domestic preservation of meat in a freezing cabinet. The temperature has to be below –5°C for cold stiffening to occur and is usually much lower. Part of the apparent stiffness is also due to solidification of the subcutaneous fat. When the body is warmed up, true rigor may supervene, though it may fail to appear as a result of intracellular damage caused by cell membranes being punctured by ice crystals.

Heat applied to the body also causes stiffness of the muscles, as the proteins of the tissues become denatured and coagulated as in cooking. The degree and depth of change depends on the intensity of the heat and the time for which it was applied. At autopsy the muscles may be shrivelled and desiccated, even carbonized on the surface. Beneath this there is a zone (which may be total) of brownish-pink 'cooked meat' and under that, if the process has not penetrated, normal red muscle. Marked shortening occurs, causing the well-known 'pugilistic attitude' of a burned body. This is because of the greater mass of flexor muscles compared with extensors, which forces the limbs into flexion and the spine into opisthotonus. These changes are purely post-mortem and are no indication of burning during life, as similar distortions occur during cremation.

POST-MORTEM DECOMPOSITION

Hypostasis and decomposition occur relatively soon after death when somatic death has occurred, but cellular death is incomplete. As discussed earlier, death is a process not an event and, while the cells of some tissues are still alive and even capable of movement (such as fibroblasts, leucocytes and muscle), others are dying or dead. The process of decomposition begin in some cells while others are still alive, and this overlap continues for several days in temperate climates.

Decomposition is a mixed process ranging from autolysis of individual cells by internal chemical breakdown to tissue autolysis from liberated enzymes, and external processes introduced by bacteria and fungi from the intestine and outer environment. Animal predators, from maggots to mammals, can be included in the range of destruction. Decomposition may differ from body to body, from environment to environment, and even from one part of the same corpse to another. Sometimes one portion of a corpse may show leathery, mummified preservation whilst the rest is in a state of liquefying putrefaction.

In addition, the time scale for decomposition may vary greatly in different circumstances and climates, and even in the same corpse: the head and arms may be skeletalized, whilst the legs and trunk, perhaps protected by clothing or other covering, may be moderately intact. All permutations may be found, making it even more difficult to estimate the probable time since death.

Within the general description of ‘decomposition’ there are several subclasses, which, as just stated, may merge into each other or may be uniform throughout the same cadaver. Most unembalmed bodies undergo putrefaction, in which the tissues become moist and gas-ridden, and eventually liquefy down to the skeleton.

Alternatives are dry decomposition, termed mummification, or a conversion to waxy substances, called adipocere; rarely, tannin occurs by the action of acid, protein-precipitating fluids in the anaerobic conditions of a peat bog. In some stillbirths an aseptic autolysis of a fetus dead *in utero* is known as maceration.

PUTREFACTION

The usual process of corruption of the dead body begins at a variable time after death, but in an average temperate climate may be expected to begin at about 3 days in the unrefrigerated corpse.

Even in temperate zones there can be a wide range of ambient temperatures, from below freezing to near blood heat. In the tropics, far higher temperatures are commonplace, but in high latitudes or elevations, deep-freeze conditions can keep decomposition at bay indefinitely, as in the case of modern discoveries of prehistoric mammoths and medieval Esquimaux. It is therefore futile to attempt to construct a timetable for the stages of decomposition, except to point out salient markers for an undisturbed body in an ‘average’ indoor environment of about 18°C in temperate climates. From this approximate baseline the pathologist must then extrapolate for local variations appropriate to his climatic and geographical conditions.

Sequence of putrefactive changes

Whatever the time scale, the general order of corruption is similar, though the degree of advancement may vary between different areas of even the same corpse.

Usually the first external naked-eye sign is discoloration of the lower abdominal wall, most often in the right iliac fossa where the bacteria-laden caecum lies fairly superficially. Direct spread of organisms from the bowel into the tissues of the abdominal wall breaks down haemoglobin into sulphaemoglobin and other pigmented substances. This discoloration spreads progressively over the abdomen, which in the later phase begins to become distended with gas.

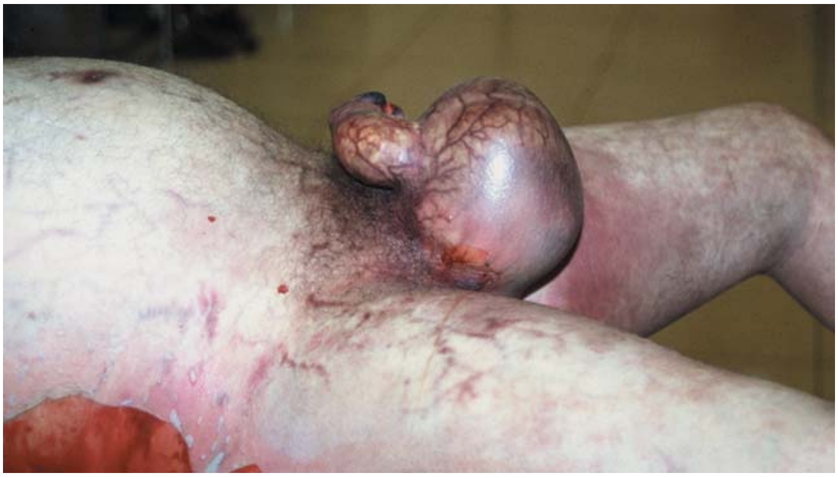

FIGURE 2.10 *Moderately early changes of decomposition, showing gaseous distension of scrotum and abdomen, and skin slippage and blistering in dependent areas. This was after about one week since death, but the changes vary greatly with environmental temperatures.*

At about this time, more generalized spread of bacteria begins to discolour the more moist tissues, which often comprise those dependent areas that show hypostatic coloration and oedema. The face and neck become reddish, and begin to swell. The putrefactive bacteria, which largely originate in the intestines and lungs, spread most easily in fluid so they tend to colonize the venous system, haemolysing the blood that stains the vessel walls and adjacent tissues. This gives rise to 'marbling', a branching outline of arborescent red, then greenish pattern in the skin, seen most clearly on the thighs, sides of the abdomen, and chest and shoulders. This stage may be about one week in the 'baseline' timetable, where the corpse is in air at 18–20°C.

At or even before the stage of marbling, skin blisters may appear, at first on the lower surfaces of trunk and thighs where hypostatic oedema has loaded the tissues with fluid. The upper epidermis becomes loosened, the so-called 'skin-slippage' giving rise to large, fragile sacs of clear, pink or red serous fluid. These may become so large that they are pendulous and soon burst, leaving areas of slimy, pink epidermis. Where this skin change occurs in hairy parts, such as scalp, axilla and pubis, the hair becomes detached and will slide off on slight pressure. Gas formation will now become marked, with increased tension in the abdomen.

The scrotum and penis may swell up to remarkable size and the neck and face will become grotesquely bloated, making visual identification difficult or impossible. The pressure may cause the eye globes and tongue to protrude.

Purging of urine and faeces may occur due to the intra-abdominal pressure and, occasionally, a uterine prolapse may be extruded. There are recorded instances of pregnant women having a macabre post-mortem 'delivery' of the fetus, from the same cause. Bloody fluid, which is tissue liquefaction stained by haemolysis, may leak from any orifice, especially the mouth, nostrils, rectum and vagina. By this stage, some 2–3 weeks may have elapsed since death.

To the inexperienced, this may suggest evidence of some lethal haemorrhage and many pathologists have been called to a scene of 'crime' because of the understandable concern of an investigating police officer that such bloody purging may be evidence of a violent mode of death. Pressure inside the chest due to gas formation in the abdomen may expel air, so that the fluids of decomposition in the trachea and bronchi may be blown into a bloody froth from the mouth and nostrils.

After several weeks, the reddish-green colour of the skin may deepen to a dark green or almost black, but there is marked variation in this aspect. Heavy maggot infestation will almost certainly have supervened except in winter conditions, and the destruction of skin by innumerable maggot holes and sinuses gives better access to other bacteria that may invade from the environment. The maggots secrete a proteolytic enzyme that speeds up the destruction of the tissues, in addition to the direct loss from the voracious appetites of these predators. Skin slippage causes shedding of the outer layers of the fingers and toes, making identification by fingerprints more difficult. Finger- and toenails last longer than the surrounding skin, but they too become loose and eventually fall out. Skin slippage may allow tattoos to become more visible and colourful for a time until the moist underlying dermis itself decomposes.

Internally, decomposition proceeds more slowly than at the surface. It is often quite surprising how valuable an

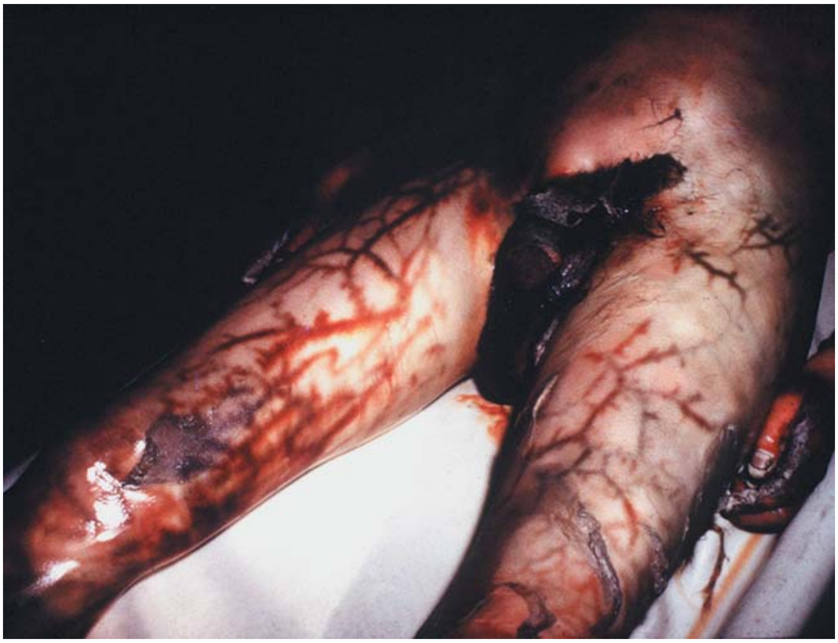

FIGURE 2.11 *Post-mortem decomposition of about 2 weeks' duration in water in a summer temperature. There is 'marbling' of the skin where breakdown products of haemoglobin have stained the venous channels.*

autopsy on a putrefying corpse can be, as the internal organs may be in far better condition than the exterior would suggest. Organs putrefy at markedly different rates. The lining of the intestine, the adrenal medulla and the pancreas autolyse within hours of death, yet the prostate and uterus may still be recognizable in a partially skeletalized body a year later. The brain soon becomes discoloured, being a soft pinkish-grey within a week and liquefying within a month. Meningeal haemorrhage and haematomata persist well, but apart from some tumours, non-haemorrhagic lesions in the brain substance vanish quite early.

The heart is moderately resistant, and examination of the coronary arteries for the degree of atheromatous stenosis may be well worthwhile for many months, though staining of the vessel walls by haemolysis makes recognition of mural thrombosis difficult. Complete occlusion by firm ante-mortem

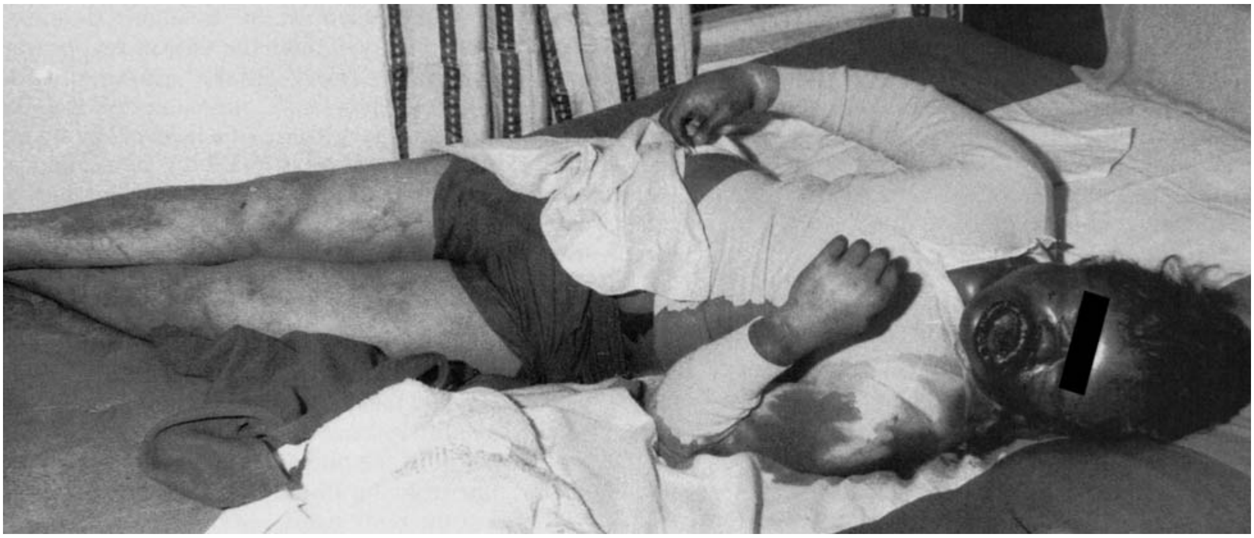
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FIGURE 2.12 *Post-mortem decomposition showing putrefactive changes in the face, arms and trunk after one week in a warm room. The illustration shows the contrast sometimes seen between one part of the body and another, as the legs are hardly affected. The face, neck and hands are swollen with gas, and the clothing is stained by leaking skin blisters. The tongue is protruding because of gas pressure from the tissues below. Death was due to carbon monoxide poisoning caused by faulty installation of a room heater.*

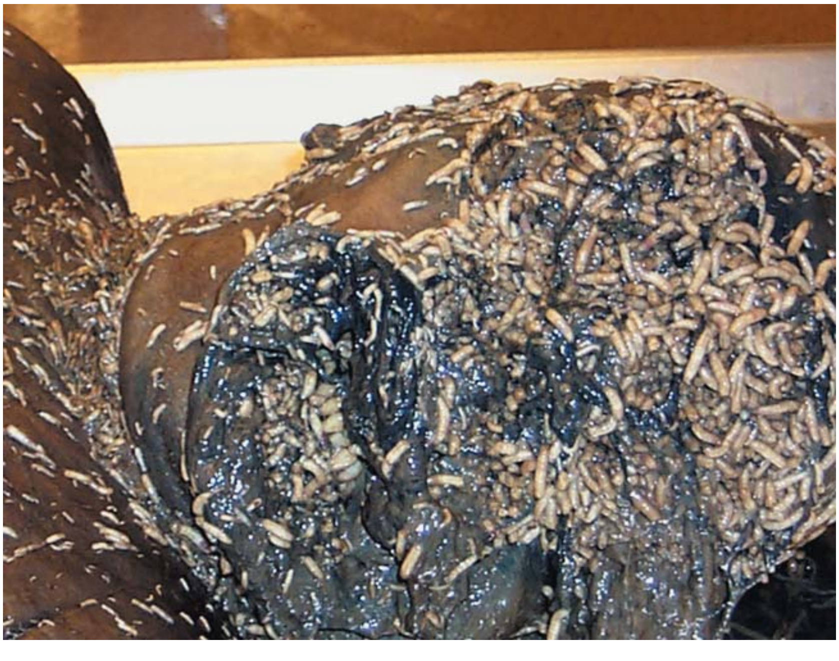

FIGURE 2.13 *Almost complete destruction of the facial soft tissues by maggots. Post-mortem time about 2 weeks in a centrally heated apartment.*

thrombus persists well. The heart may show a curious white granularity on the epicardial and endocardial surfaces, seen either during putrefaction or even on exhumation after a long interval. The nodules are a millimetre or less in size and are often called 'miliary plaques'. They were investigated by Gonzales *et al.* (1954) who found that microscopically they consisted of calcium and soapy material. The origin is obscure, but they seem to be confined to the heart and to be some degenerative product of the cardiac tissue.

In obese people, the body fat (especially perirenal, omental and mesenteric) may liquefy into a translucent, yellow fluid that fills the body cavities between the organs, and makes autopsy even more difficult and unpleasant.

Later putrefactive changes lead to the breakdown of the thoracic and abdominal walls, often hastened by the perforations of maggots and sometimes larger predators, such as rats and dogs. In some tropical countries, such as India and Sri Lanka, bodies left in the open are attacked by many animals, including monitor lizards, and in other parts of the world the indigenous fauna all contribute to the natural cycle that returns the body fats and proteins to the food chain.

After several months, the softer tissues and viscera progressively disintegrate, leaving the more solid organs, such as uterus, heart and prostate, together with the ligamentous and tendinous tissues attached to the skeleton. Often some areas of skin persist, especially where protected by clothing or under the body against the supporting surface. Much depends upon the environment, as a corpse in the open air will suffer far more from rain, wind and especially animal predators, compared with one in a locked room.

Eventually, the body will be reduced to a skeleton, but for some time, ligaments, cartilage and periosteal tags will survive. The season of year and the location will make a great difference to the time scale of skeletalization: a body dying outdoors in the late autumn will 'survive' longer through the cold winter and spring than one dying in the early summer. The effects of animal predators are profound in terms of removing soft tissues from the bones. In broad terms, a corpse outdoors in a temperate climate is likely to be converted to a skeleton carrying tendon tags within 12–18 months, and to a 'bare-bone' skeleton within 3 years; there are, of course, numerous exceptions, depending mainly on the local environment. In closed conditions indoors, a body may never skeletalize, often being converted to a dried, partly putrefied, partly mummified shell.

Decomposition in immersed bodies

The old rule-of-thumb that bodies decay twice as fast in air as in water is grossly inaccurate, but emphasizes the slower rate of decomposition of immersed corpses. Though in mortuary practice 'drowners' are generally regarded as being the major source of offensively rotten bodies, this is usually because discovery and recovery is far later than in deaths on dry land. Water, in fact, slows up putrefaction, mainly because of the lower ambient temperature, and protection from insect and small mammal predators.

The water also affects the usual processes of decay in that the epidermis becomes macerated and eventually detached, as described in the Chapter 16. Gas formation is the reason

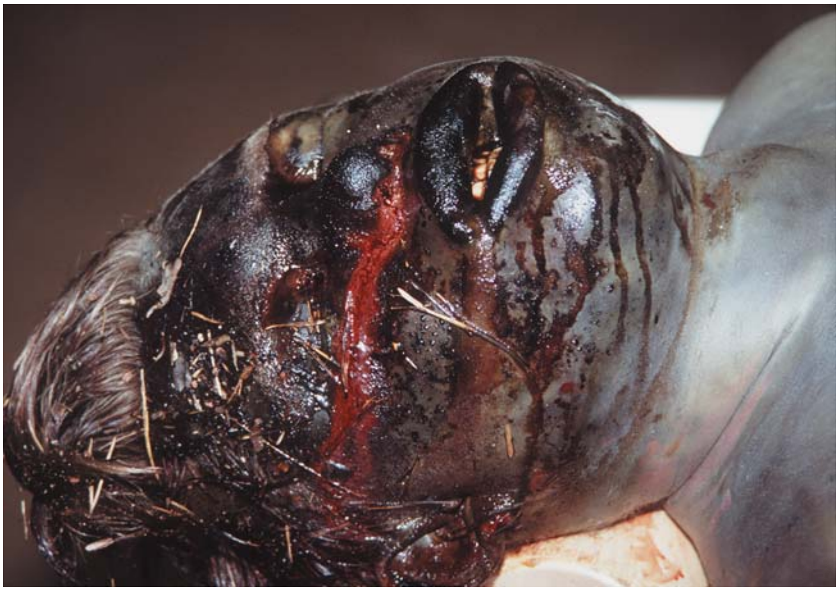

FIGURE 2.14 *Bloating of face and effusion of blood-tinged fluid from the nostrils and mouth. A body recovered from water, post-mortem time approximately 11 days.*

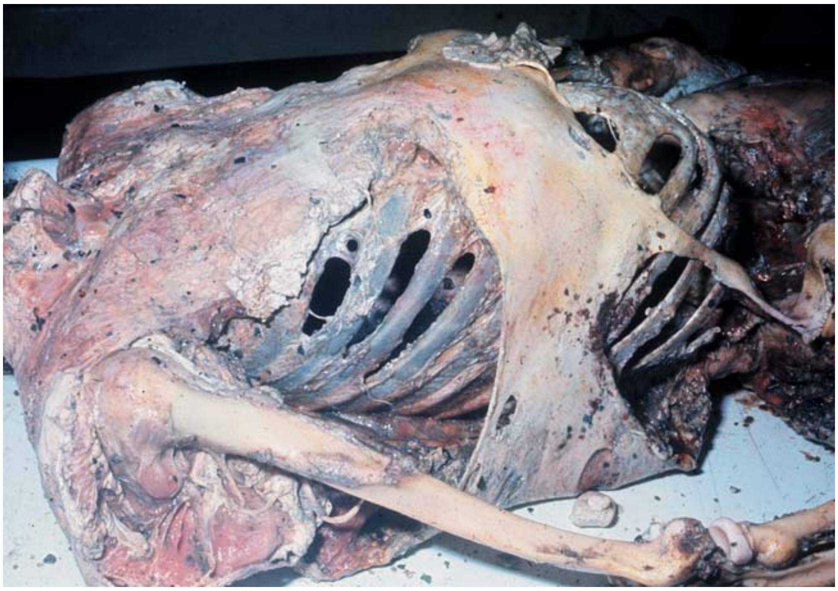

FIGURE 2.15 *Marine predation in a body after 3 months in the North Sea. The victim was from an oil rig and had floated on the surface in a life jacket. Much of the skin has been removed by crustaceans, and the arm muscles by larger fish who have cleaned out most of the body cavity.*

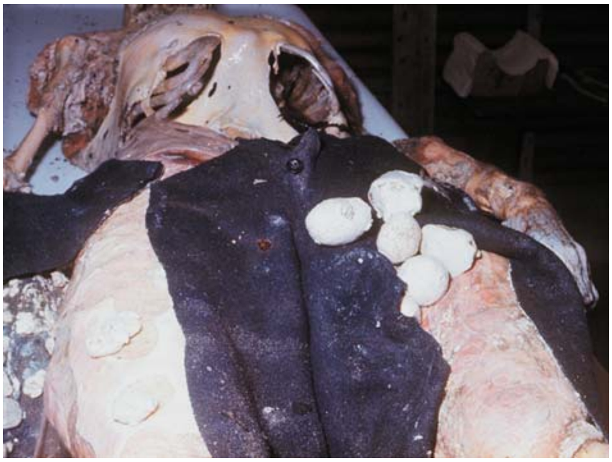

FIGURE 2.16 *Adipocere formation in a body after 3 months in the sea. Subcutaneous fat has been released from crustacean bites on the skin and has been converted into adipocere, which has been rolled by wave action within the clothing to form ovoid masses.*

for the inevitable flotation of an unweighted body, though the time of reappearance at the surface is extremely variable and certainly does not follow the speculative timetable of the older textbooks. The usual posture of a freely floating body is face down, as the head is relatively dense, and does not develop the early gas formation in the abdomen and thorax. This lower position favours fluid gravitation and hence more marked decomposition, so that the face is often badly putrefied in an immersed body, making visual recognition difficult or impossible at an early stage. As stated, temperature is the major determinant of the rate of putrefaction. Though it is usually claimed that the nature of the water in respect of sewage, for instance, is important, it is a minor factor as most of the micro-organisms responsible for decay come from the alimentary canal and respiratory passages of the body itself.

Decomposition in buried bodies

The rate of decay of bodies buried in earth is much slower than of those in either air or water. In fact the process of putrefaction may be arrested to a remarkable degree in certain conditions, allowing exhumations several years later to be of considerable value. In this respect the prospect of an exhumation should never be dismissed on the grounds that because of the lapse of time, it is bound to be worthless. It may turn out to be of little value, but this cannot be anticipated, and not infrequently the condition of the body may be surprisingly good.

The speed and extent of decay in interred corpses depends on a number of factors. If the body is buried soon after death, before the usual process of decay in air begins, putrefaction is less and may never proceed to the liquefying corruption usually inevitable on the surface. A lower temperature, exclusion of animal and insect predators, and lack of oxygen are important factors. Although most bacteria originate in the intestine, there is less access for secondary invaders and the restriction of oxygen inhibits aerobic organisms. If the body is rotting before burial then, although the process slows down, it will still severely damage the corpse, as enzymatic and bacterial growth have had initial encouragement from a higher ambient temperature and free access of air, thereby producing conditions in which secondary

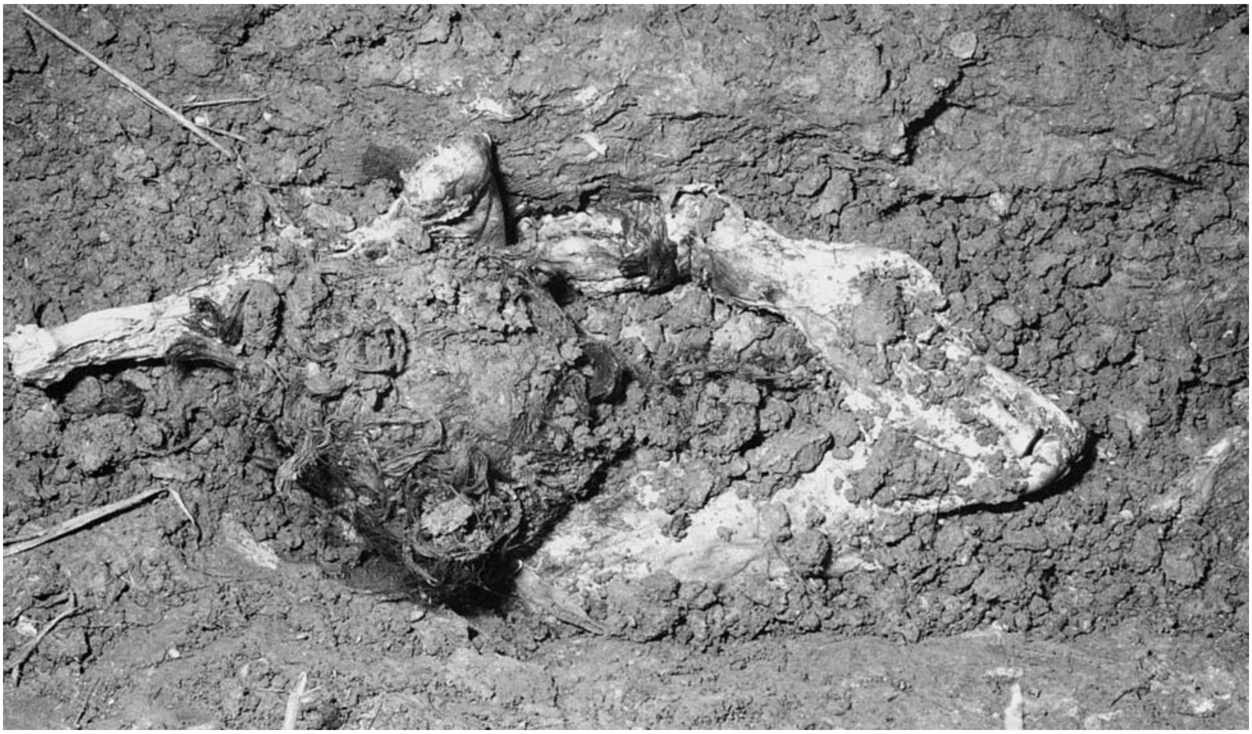

FIGURE 2.17 *Decomposition in a body buried in a shallow grave for 6 months (see Figure 1.2). The soil had collapsed into cavities around the corpse, partly due to the weight of tractors passing over it. This allowed access to flies and discovery by a dog. The body is partly putrefied, but has some adipocere.*

invaders (including anaerobes) can continue their work in a good culture medium that is already partly liquefied by the earlier stages.

Deep burial, as in the usual cemetery interment, preserves the corpse better than the shallow grave seen in some concealed homicides. The deep burial is colder (except in extremely cold weather), it excludes air better and, unless waterlogged, is not directly affected by rain.

The nature of the soil is not directly relevant except in its drainage and aeration properties. Heavy clay will exclude air and, if well above the water table, will exclude percolating surface water. By contrast, light sandy soil may allow access of both air and rainwater, but will drain more effectively. The soil factor is less important than the topography in which it lies – in a valley floor or below the water table, waterlogging is inevitable, but on a well-drained hillside the grave may remain relatively dry.

Another factor that aids the preservation of legitimately buried corpses is the coffin. Though modern coffins are often of wooden laminate or chipboard, which rapidly disintegrates when wet, any kind of coffin helps to exclude water and air for a time. A substantial, sound jointed coffin may last for years and the modern rarity of a sealed metal liner can keep a body in an excellent state of preservation for a long time.

A major factor that helps to slow decomposition is, of course, the absence of animal predation in burials. Again, if a corpse is buried before insect eggs are laid, the profound effect of maggot infestation is avoided. Rodents and larger mammals can only reach shallow burials, and in deep interments the coffin has to be breached before even the limited fauna of that stratum can gain access.

As in all putrefaction, it is unrealistic to try to construct a timetable for the stages of decay in burials. The permutations of factors mentioned above make it impossible, especially where adipocere formation takes place, as described below. The author (BK) has exhumed a chapel cemetery in the waterlogged peat of a Welsh valley and found not a trace of body, even skeleton, in graves with headstones confirming death only 20 years previously. By contrast, other bodies elsewhere were perfectly recognizable – and a standard autopsy could be carried out – one and a half years after death.

When bodies are buried in coffins in vaults, rather than in earth, then again there can be a variable rate of decay. Some bodies may develop adipocere, others may wholly or partly mummify.

There are many publications on this subject, mainly derived from the examination of historical sites or church crypts that have had to be cleared. The subject is of considerable interest but of limited forensic relevance.

FORMATION OF ADIPOCERE

An important and relatively common post-mortem change is the formation of adipocere, a waxy substance derived from the body fat. The name was given to it by Fourcroy in 1789, being derived from 'adipo' and 'cire', to indicate its affinity with both fat and wax. In most instances the change of adipocere is partial and irregular, though occasionally almost the whole body may be affected. In small amounts, adipocere is more common than usually thought in buried or concealed corpses. It is caused by hydrolysis and hydrogenation of adipose tissue, leading to the formation of a greasy or waxy substance if of recent origin. After months or years have passed, adipocere becomes brittle and chalky. The colour can vary from dead white, through pinkish, to a grey or greenish-grey. The substance itself is off-white, but staining with blood or products of decomposition can give it the red or greenish hues. The smell was accurately described by WED Evans (1962, 1963a, b) as being 'earthy, cheesy and ammoniacal'.

The chemistry of adipocere has been studied extensively. It contains palmitic, oleic and stearic fatty acids together with some glycerol, though the latter may have been leached out in older adipocere. These form a matrix for remnants of tissue fibres, nerves and muscles, which give some slight strength to the fats (see Mant and Furbank 1957). Crystals with radial markings can be found in the adipocere. Body fat at the time of death contains only about half of 1 per cent of fatty acids, but in adipocere, this may rise to 20 per cent within a month and more than 70 per cent in 3 months.

The formation of adipocere, as an alternative to total putrefaction, requires certain environmental conditions. A body left exposed in air, unless the conditions are conducive to mummification, will undergo moist putrefaction if the temperature remains above about 5–8°C. In burials, immersion in water, and in incarceration in vaults and crypts, adipocere often forms to a greater or lesser extent.

It is usually taught that moisture is necessary for the process, and it is undoubtedly a fact that most adipocere formation occurs in immersed bodies and those in wet graves and damp vaults. Numerous cases have been described, however, in which dry concealment also led to adipocere formation and here it must be assumed that the original internal body water was sufficient for the hydrolysis to proceed.

It is said that some warmth is necessary for adipocere formation, but the process seems to occur even in deep

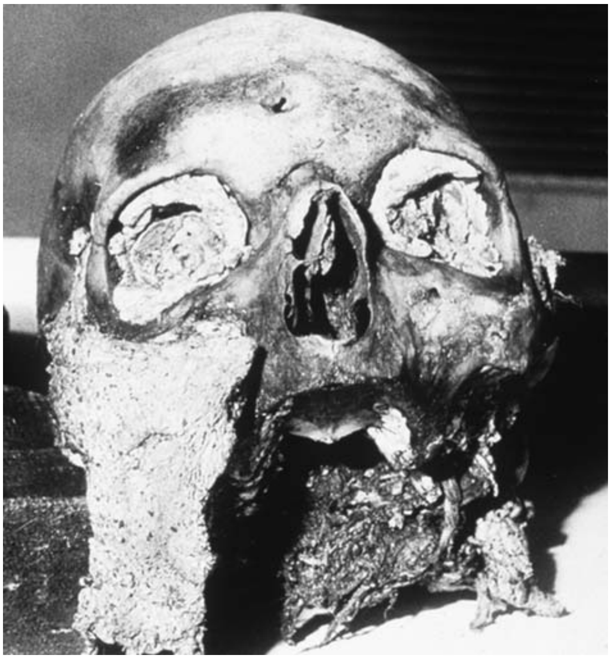

FIGURE 2.19 *Conversion of facial and orbital fat into adipocere after several months in water. There is also a penetrating wound on the forehead, obviously ante-mortem from the healing margins. The body was eventually identified by obtaining hospital radiographs of the person suspected of being the victim; these matched post-mortem radiographs in respect of the injury and frontal sinus outlines.*

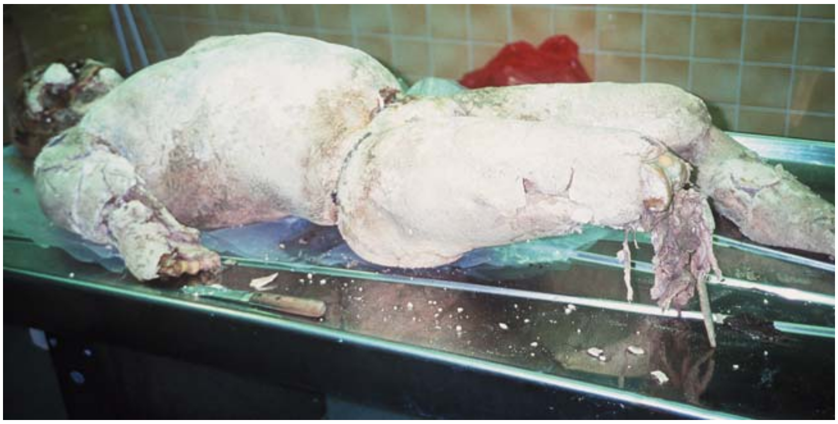

FIGURE 2.18 *Complete conversion of a body to adipocere. The body was recovered from a deep lake 8 years after disappearing in a boating accident during a heavy storm.*

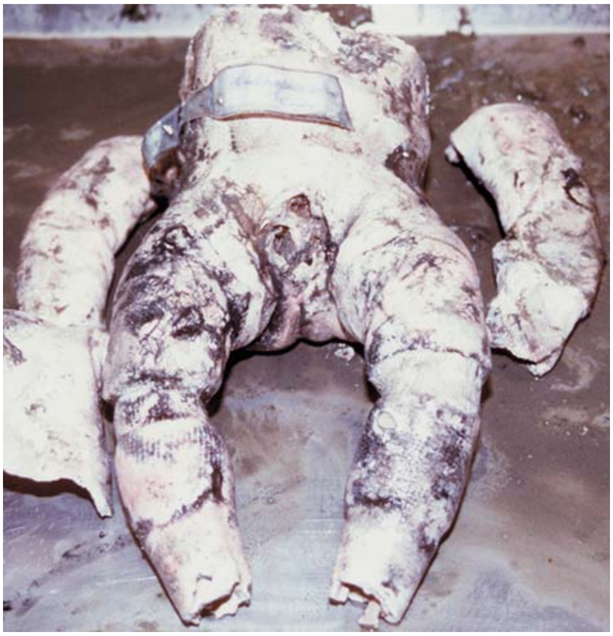

FIGURE 2.20 *Almost complete conversion of an infant's body to adipocere. The body was exhumed after 3 years' burial and was found to consist of a hollow shell of stiff adipocere with the skeletal elements loose within.*

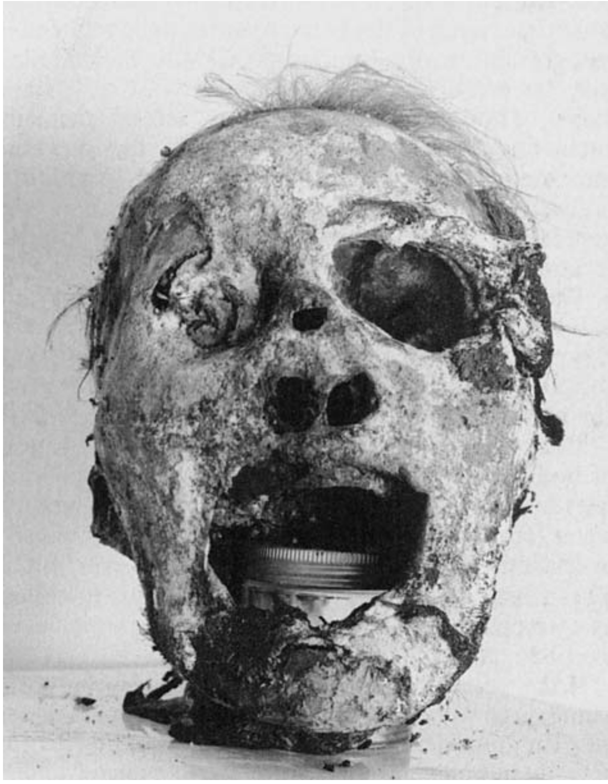

FIGURE 2.21 *Adipocere formation in body left in dry sewer tunnel for about 2 years. External water is not necessary for adipocere formation, as body fluids may be sufficient hydrolysis of fat.*

graves and in cold water. Early activity by anaerobes such as *Clostridium perfringens* assist in the reaction, as the bacteria produce lecithinase which facilitates hydrolysis and hydrogenation (see Mant 1967). Such bacteria need some warmth in the initial stages to reproduce and metabolize and Mant suggests that rapid cooling soon after death, such as by immersion in water, may actually retard the formation of adipocere.

The frequency with which adipocere forms may be gauged by the observations of those who have exhumed old cemeteries and vaults, as well as the victims of wartime slaughter (see Evans 1963a; Mant 1967; Polson *et al.* 1975; Evans 1963a). The latter found that over half the occupants of dry vaults had some adipocere. It was present in 63 per cent of women and 45 per cent of men.

The importance of adipocere formation

The process is more than a biochemical curiosity as, once it is formed, adipocere may persist for decades or even centuries. The usual dissolution of putrefaction is replaced by a permanent firm cast of the fatty tissues and, although distorted compared to the immediate post-mortem shape, it allows the form of the body and sometimes even of the facial features to be retained in recognizable form. Injuries, especially bullet holes, may be preserved in a remarkable fashion (Mant 1967). Though adipocere mainly affects the subcutaneous fat, it may also preserve the omental, mesenteric and perirenal adipose deposits; in addition, organs containing fat through pathological or degenerative processes may be preserved by adipocere forming in their parenchyma.

The time required for the production of adipocere has been a matter of controversy. The old authors claimed that 3–12 months were required, and Casper (1862) suggested 6 months, but it is obvious that the process can occur much faster than this.

There seems little reason to doubt that hydrolysis of body fat begins soon after death, as crystals of fatty acids have been found in infant bodies lying in water for only a week. This process is usually overtaken by liquefying putrefaction, however, which allows the fat, especially in obese persons, to collect as extracellular pools and pockets of triglycerides in the body cavities.

If the putrefactive process is slowed by burial or immersion, then hydrolysis and hydrogenation can outpace putrefaction. In addition, adipocere formation actually inhibits putrefaction, as the increasing acidity of tissues and the dehydration caused by the consumption of water in hydrolysis slow the growth and spread of the usual putrefactive organisms. The point at which adipocere becomes visible to the naked eye varies greatly, but it has been observed as early as 3 weeks, though 3 months is a more typical period. Adipocere is often mixed with the other forms of decomposition. Even within a coffin or other place of sequestration, there may be several different 'mini-environments'. One end of the body may be putrefied or skeletalized, whilst other parts may be mummified or in adipocere. Certain areas tend to develop adipocere, such as the cheeks, orbits, chest, abdominal wall and buttocks. Only rarely is the face preserved well enough by adipocere to be genuinely recognizable, as disintegration of the eye globes and shrinkage of the tissues around the nose and mouth obscure the most characteristic features.

MUMMIFICATION

The third type of long-term change after death is mummification, a drying of the tissues in place of liquefying putrefaction. Like the other modes of decomposition, this can be partial and can coexist with them in different areas of the same body. It is, however, more likely than the others to extend over the whole corpse.

Mummification can only occur in a dry environment, which is usually, but not exclusively, also a warm place. Mummification can occur in freezing conditions, partly because of the dryness of the air and partly because of the inhibition of bacterial growth. The most widely known forms of mummification are those in hot, desert zones. The process of artificial mummification practised for millennia in Egypt was an imitative process founded on the natural mummification of bodies in predynastic times. The essential requirement for mummification is a dry environment, preferably with a moving air current. If sterility of the tissues can be attained, as in a newborn baby, then putrefaction is held at bay whilst drying occurs. The appearances of mummification display desiccation and brittleness of the skin, which is stretched tightly across anatomical prominences such as the cheekbones, chin, costal margin and hips. The skin is discoloured (usually being brown), though secondary colonization by moulds may add patches of white, green or black.

The skin and underlying tissues are hard, making autopsy dissection difficult. The condition of the internal organs is variable, depending partly on the length of time since death. They may be partly dried, partly putrefied – and adipocere is not uncommon. In fact, slight adipocere formation is common in mummification, and perhaps the two are related in that the utilization of body water to hydrolyse fat in turn helps to dehydrate the tissues. The major factor, however, is evaporation from the surface in dry conditions.

Like adipocere, facial recognition may be possible in some instances, though the shrunken distortion and loss of eyes and full lips considerably alter the features. Mummification is likely to occur in temperate climates when the body is left undisturbed in a dry, warm place. These include closed rooms and cupboards, haylofts, attics and beneath floorboards. Because concealment favours mummification, a number of these bodies are hidden homicides – one of the best known being the 'Rhyl mummy' in North Wales, when a strangled woman was concealed in a cupboard for many years, whilst her pension continued to be claimed. Other instances are where a natural death has been concealed for some purpose. The author (BK) has also seen two deaths in hay barns, where the corpses were undisturbed for over a year.

Most experienced forensic pathologists are familiar with the mummified fetus or newborn infant, concealed in domestic circumstances, such as a house loft, where complete mummification has taken place. With small bodies such as these, evaporation is faster and more complete, and may extend

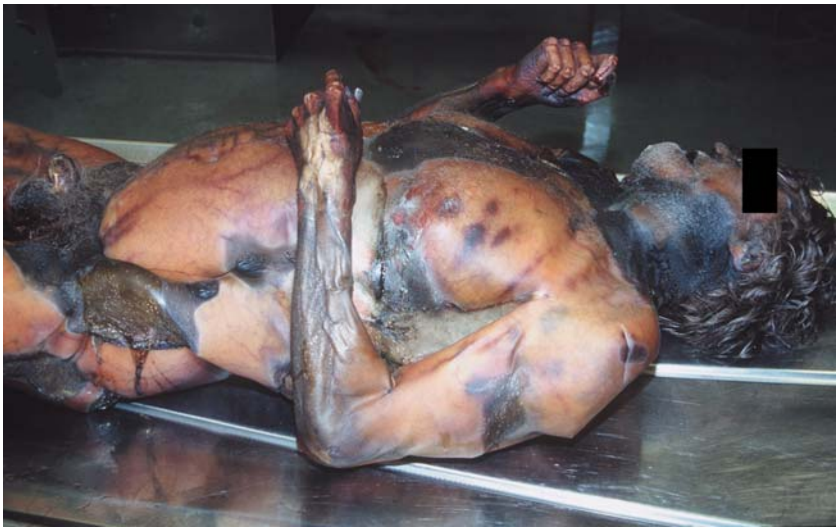

FIGURE 2.22 *Mummification in a man dead in a locked room for 10 weeks. The corpse is dry and leathery, with very little moist putrefaction.*

to all organs, especially as there would have been no invasion of putrefactive micro-organisms from the gut.

The timing of mummification is not well documented, as most mummified corpses have been concealed so well that discovery does not occur until long after the process has reached its maximum effect. It certainly takes some weeks and the early stages are often mixed with a degree of putrefactive change, especially in the internal organs.

After complete drying has taken place, the body may remain in that state for many years. Eventually, mould formation and physical deterioration progress, the dried tissues becoming split and powdery and gradually disintegrating. This process is usually hastened by animal predation. Even in the shelter of a barn or house, moths, beetles, mice and rats will wreak damage on the corpse. It will eventually skeletalize, though tough, leathery shreds of skin, tendon and ligament may persist for many years. Mummification allows major injuries to be preserved, though as in the putrefied body, the detection of bruises and abrasion may be difficult or impossible to differentiate from discoloration, artefacts and fungal damage. The stiff tissues can be softened for better examination and histology, by soaking in a 15 per cent solution of glycerine for several days (see Evans 1962).

POST-MORTEM DAMAGE BY PREDATORS

Animal predation is part of the natural food chain, which returns the proteins, fats and carbohydrates of dead bodies

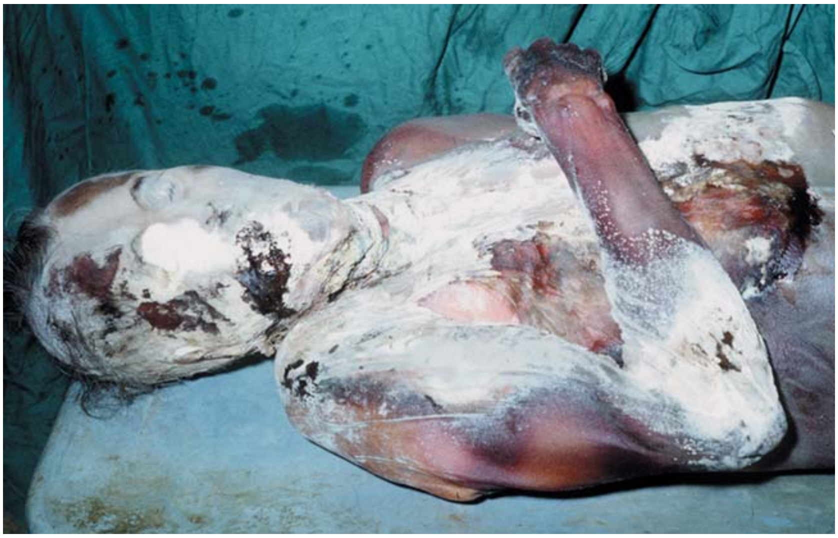

FIGURE 2.23 *The mummified body of an absconder from a mental hospital who was found a year later in a hay barn. The dry environment had inhibited wet decomposition.*

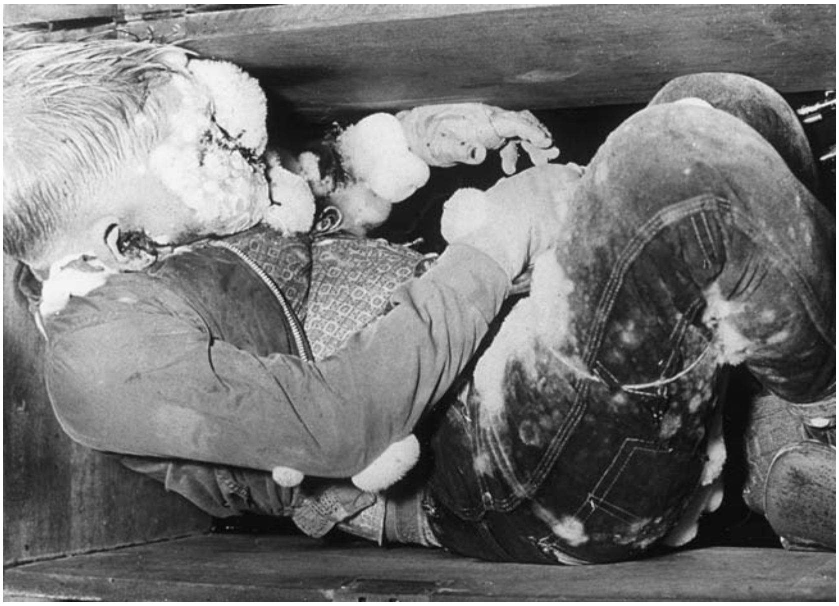

FIGURE 2.24 *Extensive mould formation and lack of putrefactive changes in a child who accidentally locked himself in a box and asphyxiated. The body was not found for 6 weeks.*

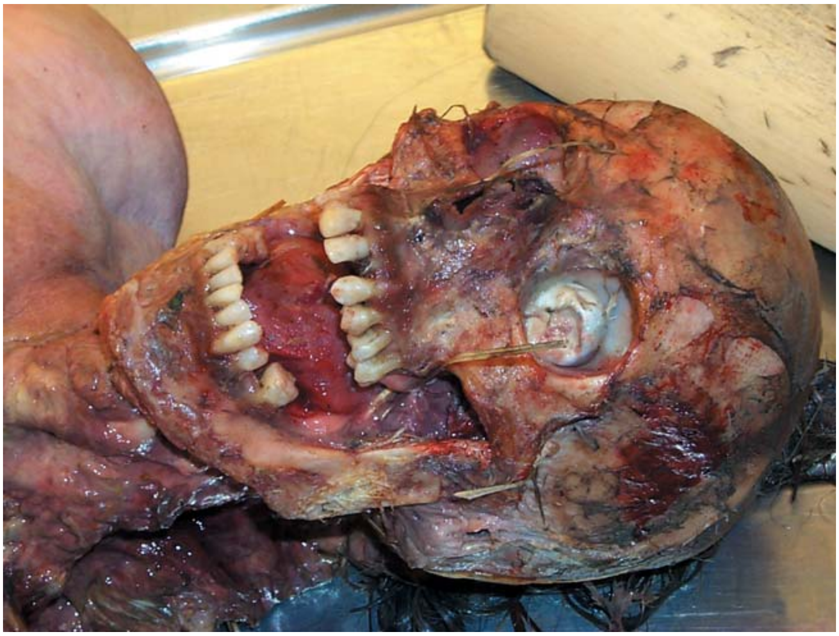

FIGURE 2.25 *Loss of all soft tissues of head and neck, in areas not covered by clothing, by post-mortem animal predation.*

to other animals, some of it passing back to the vegetable kingdom through soil nutrition. All types and sizes of animal are involved, the largest seen by the author (BK) being a 'near-miss' by a Malayan tiger, who dragged a sleeping soldier from his tent. Most animal damage is more mundane, the beasts varying from ants to foxes, and from bluebottles to monitor lizards. Foxes can drag parts of a body away to a distance of at least 2 miles.

The type of predation varies greatly with geography, season, and whether the dead body is indoors or out in the open. If it is lying in the countryside, large predators will cause prompt and severe damage, even complete destruction being possible in a short time. In temperate countries, foxes and dogs form the main agents, and the body may be dismembered and scattered over a wide area, especially if advancing putrefaction makes disarticulation easy. If corpses are in inland waters, damage from water rats and fish is possible, as well as attacks from dogs and foxes, if the body lies exposed on the bank of a river or a lake.

The type of damage from canine and rodent predators is usually obvious, as the local removal of large amounts of flesh is usually accompanied by evidence of teeth marks. Rats and cats leave a crenated edge to fairly clean-cut wounds, the post-mortem nature of which is obvious from the lack of bleeding or an inflamed marginal zone. Mice rarely attack bodies, but may help to remove the dried, crumbling tissue of a mummified corpse. The most active tissue removers are maggots, the larval stage of bluebottles (*Calliphora*) and flies (*Musca*). The use of the life cycle in timing death is dealt with elsewhere, but here we are concerned with their destructive effects on corpses. In temperate zones their activity is seasonal, but in hot countries their predatory work is ever present. The adult insects lay eggs on the fresh corpse (or even on a debilitated live victim), choosing wounds or moist areas such as the eyelids, lips, nostrils and genitalia. Once skin decomposition begins, the eggs can be deposited anywhere. The eggs hatch in a day or so, and several cycles of maggot develop, shedding their cases at intervals, depending on the species.

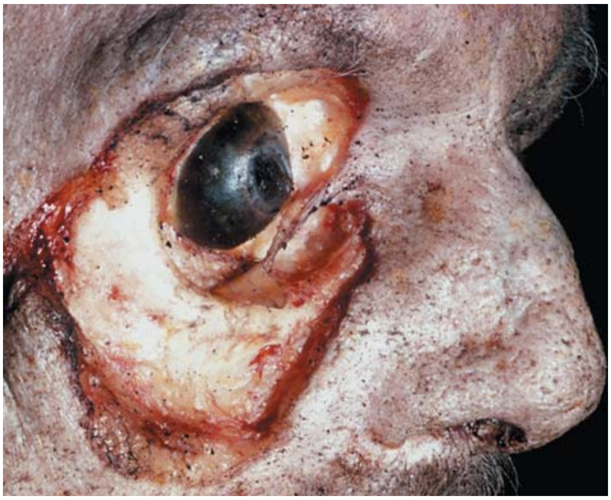

FIGURE 2.26 *Post-mortem rat bites of the orbit. Such injuries are – not unnaturally – often regarded with suspicion by the police. The complete absence of bleeding or reddening of the wound margins, as well as the unlikely shape and situation of the injury, make its post-mortem origin obvious.*

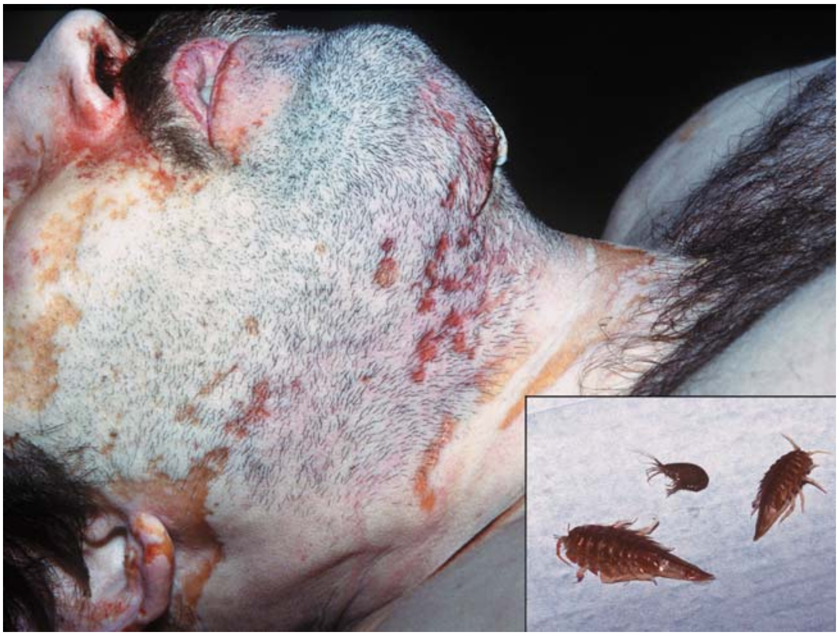

FIGURE 2.27 *A body recovered from the Baltic Sea with numerous superficial skin defects on the face and neck due to post-mortem predation, probably by the crustacean Saduria entomon, shown in the inserted picture with a smaller shrimp in the middle.*

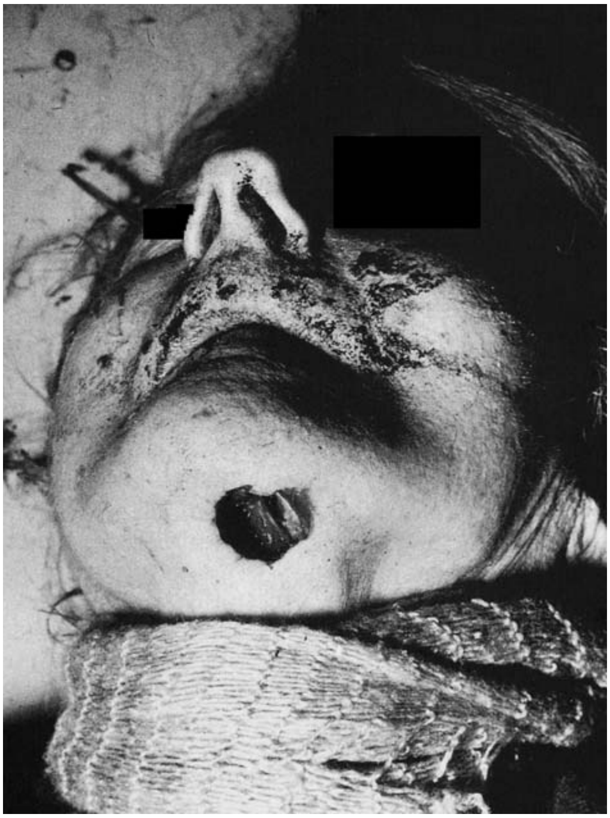

FIGURE 2.28 *A post-mortem animal bite that was mistaken for a criminal assault. The old lady was found locked in with a cat, having died from a gastric haemorrhage. The wound has not bled, the margins are not reddened and tooth crenations can be seen round its edge.*

The maggots are voracious and energetic, first exploring the natural passages, such as mouth and nostrils, then burrowing into the tissues. They secrete digestive fluids with proteolytic enzymes that help soften the tissues, burrowing beneath the skin, and making tunnels and sinuses that hasten putrefaction by admitting air and access to external micro-organisms. Successive waves of eggs are laid, producing new generations of maggots. Eventually, loss of tissue and drying make the host cadaver unattractive to egg-laying insects, and the later stages of decomposition become free from maggots.

Beetles and many other types of insect and arthropod join in the destruction, but one particular insect must be mentioned. This is the ant, which can attack the body soon after death before putrefaction begins. A common place for ant attack is around the eyelids, lips and on the knuckles. The lesions are superficial ulcers with scalloped, serpiginous margins. They can be mistaken for ante-mortem abrasions, but their position, margins and lack of bleeding or inflammatory changes usually make them easily recognizable. Shapiro, however, has documented cases where extensive linear ant lesions have resembled ligature abrasions around the neck (Shapiro *et al.* 1988).

Tropical ants can devour tissues to a considerable extent and, although stories of soldier ants reducing horses to skeletons within minutes are apocryphal, predation by large numbers of insects can be extensive.

In water, all manner of aquatic animals can mutilate immersed bodies, as well as land mammals if the corpse is in shallow water or grounded on a mudbank or the beach. Large fish can be totally destructive, especially in tropical waters, but even in temperate seas severe damage can occur. Some of the victims of the Air India aircraft disaster near Ireland in 1985 were ravaged by sharks. Large gouges from the wound edges, punctures from teeth and extensive tissue loss, even with fractures of large bones such as the femur, characterize shark attacks.

Smaller fish can wreak severe damage, the prime example being piranhas, though many species will devour both fresh and decomposing bodies. Crustaceans are also predatory and can remove circular areas of skin to expose the subcutaneous fat, which may detach inside the clothing to form masses of adipocere. Birds also cause damage, usually to the dead, though crows may mutilate live lambs. The habits of carrion birds, such as the vulture, are well known, but smaller birds will inflict injury on exposed bodies, especially when putrefaction softens the tissues.

All animal predation varies in appearance according to the size and shape of the teeth or jaws of the predator, but all such post-mortem injuries have features in common. There is no bleeding apart from the minute quantity actually in the vessels of the damaged part, and certainly no active haemorrhage into the wound margins. Naturally, there is no oedema or reddening of the edges as might be seen in an ante-mortem wound earlier than the perimortal period. Crenation of the edges is a useful guide where small rodents or other animals are involved, though large carnivores can make totally irregular tears in the tissue. Some animals, such as dogs and foxes, may leave punctured wounds adjacent to the damaged edge where sharp teeth have penetrated. On bones, the incisor teeth of rodents and larger carnivores can leave parallel gouges, which must not be mistaken for illicit human activities. In domestic surroundings, pets may inflict drastic post-mortem injuries if they are locked in with a dead person. Dogs and cats can cause injuries that puzzle those, such as the police, who are unaware of the possibility. Complete decapitation by Alsatian dogs has been seen by both of the authors, as well as genital injury.

THE ENTOMOLOGY OF THE DEAD AND POST-MORTEM INTERVAL

This is a highly specialized subject and, when the issue of time since death is important, such as a criminal investigation, it is essential that, wherever possible, the pathologist has the assistance of an entomologist with forensic experience. As in forensic toxicology and serology when serious medico-legal issues are at stake, there is no place in forensic entomology for the 'occasional expert' who dabbles in the subject when the opportunity arises. Having said this, it is helpful to know sufficient about the topic to recognize when expert help is required, and to understand what information and specimens need to be obtained.

The rationale of forensic entomology is that after death invasion of an unprotected body by sarcosaprophagous insects and other small fauna comes in successive waves. Different species of arthropods colonize the corpse at different periods after death. In addition, some species (including the most common blowflies) pass through complex life cycles that can be used to determine at least the minimum time since death by studying the stage of maturation of the insects. The science is inexact and is modified by a number of factors, both climatic and geographical, but in expert hands can sometimes yield useful information about the date of death at a period when other indicators have ceased to function. These methods have been used since the middle of the eighteenth century, but Megnin placed forensic entomology on a sound basis with his publication of *La faune des cadavres* in 1894. There are now a substantial number of publications on the subject, though most of them need specialist zoological knowledge for the interpretation of the species involved and their complicated maturation cycles. It is essential that the entomologist has the fullest possible information about the nature of the environment in which the body was found and, if possible, he should visit the scene himself. It is also vital to have accurate data on the weather, especially the ambient temperature of the area during the period in which the body had been lying there, as the maturation times of insects (especially blowflies) are markedly altered by climatic conditions.

The most common insect found on relatively fresh corpses is the blowfly, a colloquial name for a group of flying insects of the order **Diptera**, with almost worldwide distribution. They mainly comprise the bluebottles, the greenbottles and the housefly. There are numerous species, with variations in life cycles that are altered by climatic conditions. The bluebottle (*Calliphora*) is the most common, especially *Calliphora vicina* Robineau–Desvoidy (*Calliphora erythrocephala* Meigen), the most frequent invader of dead flesh. These are large, bristly flies about 6–14 mm long, with iridescent blue abdomens.

They do not fly in the dark and thus eggs are laid only in daylight. This means that a corpse found at night or in the morning with eggs upon it, almost certainly died the previous day. Bluebottles rarely fly in winter, but may do on fine days, though when the temperature is below 12°C they are unlikely to lay eggs. Rain is also a marked deterrent to egg-laying, except in the case of the **Sarcophagidae**. Bluebottles prefer fresh rather than decayed carrion and lay their eggs soon after death, which may be of medico-legal significance. Indeed, they may lay eggs on the living, especially when the victim (man or animal) is debilitated or wounded. A single bluebottle may lay up to 300–2000 eggs in clusters of

30–150. The eggs are laid on moist areas, such as the eyelids, canthi of the eyes, nostrils, lips, mouth, genitals and anus. If there are any open wounds or weeping abrasions, these may also be colonized. The eggs are yellow and banana-shaped, about l.7 mm in length.

The many tables and diagrams available for the succession of sarcosaprophagous insects on corpses must be read in the knowledge that the environment, especially the temperature, makes a marked difference to the time span of the larval and pupal stages. As Nuorteva *et al.* (1967) state:

> Crimes do not occur under experimental conditions and standardized food supplies. Flies, as medico-legal indicators, must therefore be used in conjunction with the records of meteorological conditions existing at the time subsequent to the presumed crime.

Thus the following examples, mainly taken from Glaister and Brash's (1937) account of the notorious Ruxton murder, must be read with this caution firmly in mind – and wherever possible, the pathologist must enlist the aid of an experienced entomologist.

Adult bluebottles will begin to lay eggs about 4–5 days after emergence from pupation. Eggs will not hatch at temperatures below 4°C, but they will develop at 6–7°C. The time from laying to hatching is 8–14 hours, depending on the temperature.

The first maggot stage (first 'instar') tries to penetrate the tissues or enter any nearby body cavity such as the mouth or wounds. Maggots have powerful proteolytic enzymes that aid dissolution of the tissues and facilitate penetration. The first larval instar persists for another 8–14 hours, then the outer skin is shed and the second larger instar feeds for another 2–3 days.

After a final moult, the third instar spends about 6 days on the body before leaving it to migrate some distance to hide in the ground or under some other cover (even a carpet) to pupate. The pupa is a brown leathery capsule in which the insect metamorphoses into the winged fly after about 12 days. The new bluebottle emerges and leaves the empty pupa case behind, ready to begin the cycle over again, which thus lasts about 18–24 days from egg to adult. The greenbottle (*Lucilla caesar*) and the sheep maggot fly (*Lucilla sericata*) have life histories that are similar to that of the bluebottle.

The common house fly (*Musca domestica*) is different in that, unlike the bluebottles, it prefers to lay its eggs on already decomposed flesh, though it is more attracted to garbage and manure than to cadavers. The eggs are much smaller and white rather than yellow. Hatching time is 8–12 hours, the first instar at about 36 hours, the second instar at 1–2 days and the third at about 3–4 days. Pupation lasts up to 7 days, less in warm weather. The whole cycle is thus about 14 days at about 22°C, though again it must be emphasized that variations in ambient temperature make considerable differences to the speed of maturation. A table by Busvine (1980) shows that the total cycle length varies from 9 days at 40°C to 32 days at 16°C.

Entomologists have constructed tables of variation in larval length according to age and temperature; expert knowledge and strict identification of the species is needed before definite opinions upon minimum times since cadaver death are offered. Some of the times quoted above were taken from the extensive entomological work performed on the Ruxton case in 1935, but do not correspond to the cycle periods published by Kamal in 1958. The total maturation times that he found in experimental conditions at 22°C are much longer, being 14–25 days (average 18) for *Calliphora vicina*.

In many of the published cases where *Calliphora* have assisted in the estimate of the time since death, it is an assessment of the age of larvae that is made from their size. Of course this can only be a minimum estimate, especially if mixed generations are present as a result of successive waves of flies laying eggs at different times. As already said, however, bluebottles do not favour decomposed tissue for oviposition, so egg-laying is likely to cease within a couple of days of death. If pupa cases are seen either on or near the body, then any larvae present may be from later waves – even second- or third-generation insects.

In addition to maggots on the body, other fauna in the soil beneath a corpse leave the area and a reduction in the number of species of normal soil insects may be a marker for the site of a body, even for some time after the latter has been removed. The minimum population of arthropods under a corpse is reached after about 2 months; it then revives, but with quite a different range of insects from the original inhabitants. The absence of eggs or maggots on a body may sometimes be of use, as it may indicate that a body has been in a sheltered place inaccessible to flies, even if it was later moved out. Where a body has been buried, even a shallow covering of soil may protect it from oviposition; where part of the body protrudes, this may well be the focus of maggot infestation.

Different types of insects invade the body after the moist, putrefaction stage that is associated with blowfly maggots has passed. At different seasons, different insects may be prevalent so that the finding of say, **Phoridae** and **Sphaerocerdiae** in Europe would suggest that the body had been there in the summer months. Larder beetles (*Dermestes*) may arrive 3–6 months after death; house moths may attack dried tissues such as mummies and can dispose of keratin such as hair and beard. Beetles (*Coleoptera*) are late arrivals and are usually found in dried or adipocerous corpses. These and many more are related more to season than time, so again the considered opinion of an expert is necessary. The absence of insects in certain climates may indicate that death took place in the winter months when no active colonization was occurring.

Collection of material for entomological study

To the practising forensic pathologist, the main concern in this context is the careful collection and dispatch of specimens to an entomologist with forensic experience.

First, the entomologist needs to know all available facts about the environment in which the body was found – preferably he should visit the locus himself if the matter is of legal importance. He should be told the temperature of the maggot mass and ambient temperature around the time the body was found. If no actual temperature measurements were taken by the pathologist at the scene – and even if they were – local records should be obtained from the nearest meteorological centre. Without this information the probable maturation rate cannot be estimated. The nature of the locus should be described, in terms of vegetation, trees and undergrowth if outdoors. Where maggots are present, some should be placed live in a tube and, if there is delay in transit to the entomology laboratory, a fragment of meat should be included for food. Any adult flies, other insects and eggs should also be collected without preservative.

In addition, some maggots, adults, pupae, empty pupa cases and eggs should be sent after fixation. They can be placed directly into 80 per cent alcohol, but preferably in three parts 80 per cent alcohol with one part glacial acetic acid. Even better is Pimple's fluid, which is six parts 35 per cent formalin, two parts glacial acetic acid, 15 parts 95 per cent alcohol and 30 parts water. Formol saline 10 per cent (as used for histological fixation) should not be used.

If there are different insects on the body, they should be placed in separate tubes – especially if they are alive – as some may devour the others before they reach the laboratory.

Whatever is sent should be labelled or numbered according to a key that records where on the body they were found. If outdoors, the soil beneath the body should be sampled and, where a full cycle has occurred, pupae or cases should be obtained by shallow trenching in radii around the body.

When the body has been recovered from water, any insects or crustaceans should be recovered. Body parasites may occasionally be useful. Fleas and lice can survive total immersion for some hours, but the advice of an entomologist should be sought if parasites are found on an immersed body to determine the minimum survival time of that particular species under the existing circumstances.

DETERMINATION OF TIME SINCE DEATH

ESTIMATION OF THE TIME SINCE DEATH BY BODY COOLING

Though the study of the rate of cooling of the dead human body is essentially an exercise in physiology, its potential use in determining the time since death have made it the most frequent topic for research in forensic medicine.

For more than one and a half centuries, papers have been published devoted to refining the problem further, which has obvious and important connotations in the investigation of criminal deaths. Unfortunately, the vast amount of labour in this direction has not been rewarded by comparable improvements in accuracy because of the permutations of factors that defeat exact calculation of the post-mortem interval. The history of this research is in itself extensive (Knight 1988) but a few cardinal points might be mentioned here to mark the various phases of investigation.

Though the fact that a dead body becomes progressively colder after death has naturally been known since earliest times, scientific measurements were first published in the nineteenth century. Dr John Davey in 1839 recounted experiments with dead soldiers in Malta and Britain, using a mercury thermometer. Though this pioneer made no practical contribution to the problem, some of his comments are remarkably pertinent across a gap of more than 150 years:

> Much judgement, however and nice discrimination may be requisite on the part of the medical man, in appreciating the circumstances likely to modify temperature, so as to enable him when called upon for his opinion (of the time of death), to give one which will be satisfactory to the legal officers – and to himself – on reflection.

These cautionary words are just as applicable nowadays when, unfortunately, some doctors offer a time of death with a confidence often inversely proportional to their experience. In 1863, Taylor and Wilkes wrote a classic paper which introduced many of the current concepts, such as the initial temperature plateau, the core temperature, heat gradient and the effect of insulation. Taylor was, of course, Alfred Swaine Taylor of Guy's Hospital, author of the textbook that remained the definitive work on forensic medicine for almost a century. Later in the nineteenth century, Rainy of Glasgow first applied mathematical concepts to the problem and produced a formula for calculating the time of death. He also pointed out that Newton's Law of Cooling did not apply to the human body. In 1887, Womack first used centigrade units, though his use of the now familiar temperature graphs was anticipated by Burman in 1880.

In this century, the most quoted papers were those by De Saram in Ceylon (De Saram *et al.* 1955; De Saram 1957), who published careful and detailed measurements of control cases obtained from executed prisoners. His data are still being studied and reworked. The names Fiddes and Patten are known to all those interested in this subject as, in 1958, they produced a paper that was a classic, as Taylor's had been in the previous century. Using repeated temperature measurements they devised a percentage cooling method and explored complex theoretical aspects, such as the 'infinite cylinder' model, for the human body.

Marshall and his collaborators dominated the publications in the 1960–1970 period, with papers that explored in depth the mathematical aspects and confirmed the double exponential or 'sigmoid' shape of the rectal cooling curve. In the last decade or so, many more papers and new techniques have been produced, with computer assistance increasingly used. Amongst these, Henssge and Madea in Germany have been predominant. Microwave and infrared thermography have been explored and the physics and mathematics of body cooling probed in such depth that often the scientist in the research group has difficulty in explaining the concepts to his medical collaborator. In spite of all this activity, practical methods of determining the time of death continue to lack accuracy. Though some recent publications offer firm advice and describe methods, they can do no more than provide a 'time bracket' of probability within which death is thought to have occurred.

Post-mortem cooling

Except where the environmental (ambient) temperature remains at or even above 37°C, the human body will cool after death. A uniform, homogeneous laboratory 'body' will cool according to Newton's Law of Cooling, which states that the rate of cooling is proportional to the difference in temperature between the body surface and its surroundings. Graphically represented, this will display the curve of a single exponential expression, not a straight line. A human body does not obey Newton's Law, though the size of the discrepancy varies according to several factors. When death occurs, heat transfer within the body through the circulation ceases. Metabolic heat production, occurring mainly in the muscles and liver, does not cease uniformly and some heat generation continues for a variable time. As soon as the supply of warmed blood ceases with cardiac arrest, the skin surface immediately begins to lose heat. The rate is variable because of clothing, posture and shielding against the supporting surface and, of course, the environmental temperature.

The centre or 'core' of the body cannot begin to cool until a 'temperature gradient' is set up by the cooling at the skin surface. As the tissues are poor heat conductors, this gradient takes a variable time to become established and therefore a thermometer placed near the core (usually in the rectum) will not register a fall for some time. This is the well-known 'plateau', which forms the upper flattened or slightly sloping part of the double exponential curve when

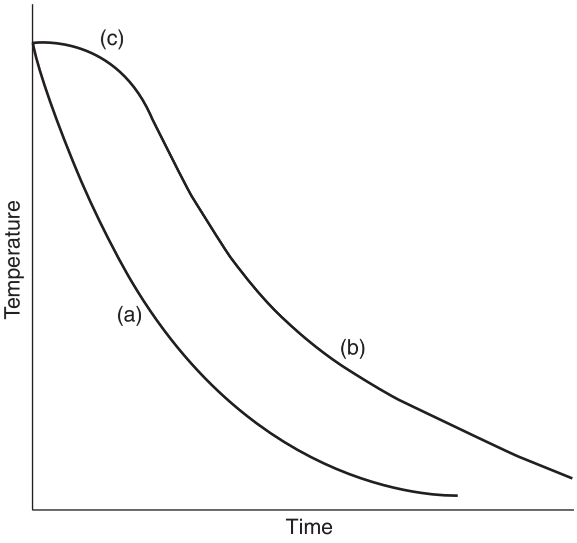

FIGURE 2.29 *Cooling curves: the Newtonian single exponential curve (a) does not occur in practice, except on the surface of the body. Because of the variable plateau (c), the true curve for deep core temperature (b) assumes a double exponential shape.*

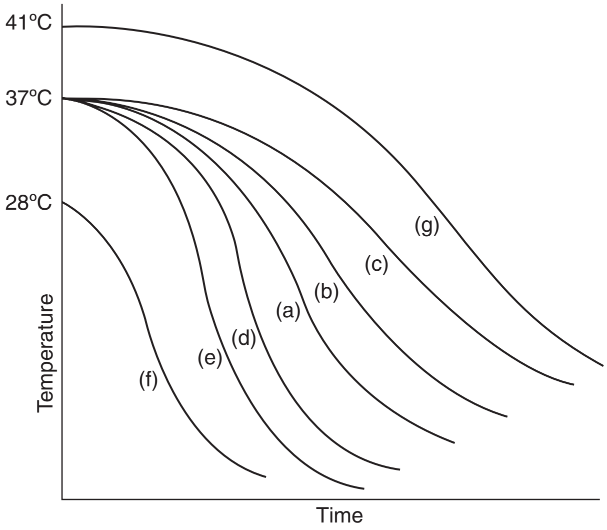

FIGURE 2.30 *Diagrammatic representation of some variables in body cooling curves: (a) average body, (b) obese body, (c) heavily clothed body, (d) thin body, (e) naked body, (f) hypothermic body and (g) febrile body.*

rectal temperatures are measured. If skin temperatures are used, as in some of the nineteenth century research, no plateau is found, and, using cranial temperatures taken through the nose, ear or skull, the plateau is less, as the core is nearer the surface.

The central part of the cooling curve approximates to Newtonian principles, being fairly straight or only a shallow curve. As the temperature differential between the body and environment approaches zero, the graph again flattens off into a lower shelf. Unlike the laboratory body, the human body rarely reaches the ambient temperature unless the latter is at or near freezing. This is probably because enzyme and bacterial action starts during early decomposition and, much as a compost heap warms up, the temperature may actually rise a few days after death.

The typical rectal cooling curve then, is a ‘sigmoid’ shape or ‘double exponential’ curve. The part that is of use in forensic medicine is the central section showing the steepest fall. Theoretically, if one assumes that the body temperature at the time of death was 37°C, then finding the point on this section corresponding to the measured rectal temperature should allow extrapolation back to the 37°C point which is at zero on the time scale, thus giving the post-mortem interval.

Unfortunately, a number of variables make this attractive proposition impossible to attain in practice. Not only are there variables, but the variables themselves often vary during the period before the body is discovered and examined. For example, the ambient temperature may change markedly – perhaps several times – and often this may not be known to the examiner. Even opening doors and allowing draughts to play on the body will have profound effects on the cooling curve, which cannot be detected or corrected retrospectively.

Factors affecting the cooling curve

INITIAL BODY TEMPERATURE

This cannot be assumed to be 37°C and in fact is incapable of ever being measured in retrospect. Not only is there a difference between the rectal, liver, brain, axillary, mouth and skin temperatures in the living person, but the absolute values vary slightly from person to person and from time to time, even in health.

If the oral temperature is taken to be 37°C, then that in the axilla will be several degrees lower and that in the rectum at least one degree higher. There is a diurnal variation of almost 1°C, the temperature being lowest between 0200 and 0600 and highest between 1600 and 1800. Strenuous exercise raises the temperature by up to 3°C, which persists for up to 30 minutes after returning to rest.

When there is illness or trauma, much wider variations occur, which again are impossible to detect retrospectively. In febrile illness from micro-organisms or parasitic infections, the temperature may be 4 or 5°C higher. In the forensic context, infected wounds or a septic abortion are obvious examples. Cerebral (especially pontine) haemorrhage may also cause hyperthermia, as may some drug reactions. It is traditionally stated in many textbooks that asphyxia and strangulation cause agonal hyperthermia, but there is very little hard evidence for this, apart from anecdotal opinions passed from one author to another. One explanation may be that a homicide victim struggling desperately for life against strangulation will generate muscular heat as in any violent exercise, irrespective of an asphyxial mode of death.

At the other end of the scale, hypothermia is common even in temperate winters. Many victims of criminal assault may be left exposed before death and their temperature may be as much as 10°C lower than normal.

As virtually all methods and formulae for calculating the time of death depend upon the body temperature being 37°C, even a slight variation can introduce a fundamental error.

THE BODY DIMENSIONS

The temperature gradient, which drives cooling, varies with the mass of the body and the surface area as well as with the conducting properties of the tissues. Some more complex calculations correct for mass:surface area ratio by means of nomograms (for example, those served by Henssge), but these can only be an approximation. The height and weight of the body must be known, which is often impossible at the scene of discovery. The amount of subcutaneous and abdominal fat will affect the insulating properties and hence the temperature gradient, but there is no way of assessing or correcting accurately for obesity. Oedema and dehydration both have a marked effect because of the high specific heat of water (see James and Knight 1965). In general, a thin person cools more quickly because of both the mass:surface area ratio and the lack of fatty insulation. Children have a larger surface area for a given body weight.

POSTURE

The loss of heat from the skin that drives the temperature gradient is affected by the access of air to the skin and the opportunity for radiation and convection. A body curled into a fetal position will expose much less surface than one in an extended, spread-eagled posture. Another factor is the amount of skin resting on the supporting surface and the nature of that surface. A body lying full length on its back will lose heat by conduction faster than one resting semi-prone, though radiation and convection may be facilitated.

A body on a metal mortuary tray will cool more quickly than one lying on straw.

CLOTHING AND COVERINGS

All too obvious is the effect of external insulation by clothing or other coverings, even a hat. Radiation is a minor pathway for heat loss because of the low biological temperatures involved, but convection and conduction are markedly reduced by coverings. Even more confusion may be added when coverings actually contribute heat, such as an electric blanket left on after death. A duvet or ‘continental quilt’ will markedly retard cooling and in fact will accelerate decomposition to a considerable degree. Wet clothing will accelerate cooling, compared with dry coverings, because of the uptake of heat for evaporation.

THE AMBIENT TEMPERATURE

This is, of course, the major factor in cooling and, as was said at the outset, a body will not cool after death if the temperature of the environment is higher than the nominal 37°C, in fact, it may warm up. This may be climatic and seasonal, as in large areas of the world, not necessarily in the tropics. It may also be due to local heating, usually in dwellings or other buildings. This includes radiant heat from fires left burning near the body after death, electric blankets, or death in a house or vehicle fire. Where a victim dies in a warm bath then the whole cooling process is grossly distorted, the opposite of when immersion takes place in the cold water of baths, rivers, lakes or the sea.

AIR MOVEMENT AND HUMIDITY

Most skin cooling takes place by convection and conduction with the adjacent air as the transporting medium. In still conditions, a layer of warm air clings to the skin, especially if clothed or hairy, blocking the temperature differential. Any air movement brings fresh cooler air into contact with the skin and encourages the gradient from the core. The humidity is a less active factor, but damp air conducts heat more readily than dry. A body in a small space will cool more slowly than one exposed to the open air, as transfer of heat to the small volume of air will reduce the temperature differential.

THE MEDIUM AROUND THE BODY

This is usually air, but when it is water or (rarely) another fluid, skin cooling is far more effective. A body immersed in water, especially the moving water of a river or the sea, will rapidly lose heat, as is all too familiar during life when fatal hypothermia can occur within minutes in a cold sea. It is commonly stated that cooling is less rapid in contaminated water (such as sewage) than in clean water, but this is hard to believe, given the same temperature for each type of medium. As mentioned above, death in the warm water of a bathtub reduces the cooling rate – and may even elevate the temperature, making any attempt at estimating the time of death futile.

HAEMORRHAGE

It is traditional to say that severe haemorrhage shortly before death causes more rapid cooling. As the estimation of the time of death is fraught with such inaccuracy, it is difficult to see how this opinion can have been derived. The volume of blood lost will reduce the mass of the body, but only in a minimal fashion. It may be that terminal bleeding may cause a shutdown of cutaneous circulation in an effort to maintain blood pressure and that this might encourage the early formation of the temperature gradient – but such vasoconstriction would relax immediately at death and play no part in post-mortem cooling.

Methods of measuring body temperature

Estimation of temperature by touching with the hand is a useful first manoeuvre when at the scene of a death. A hand placed on the forehead, face or exposed hand may give a first impression of whether death occurred recently or not. Even if these exposed areas are cold, feeling inside the clothing to touch the chest, abdomen or axilla may detect some heat, as may sliding a hand under the body where it is in contact with the supporting surface. These crude methods are combined with an estimate of rigor mortis to provide a preliminary screening of a recent, as opposed to a remote, time of death. Though conditions vary enormously, a body indoors will feel cold on exposed areas in 2–4 hours and in protected areas after some 6–8 hours. The traditional method of taking the post-mortem temperature is by placing a mercury thermometer in the rectum. This must be a chemical thermometer (not a clinical instrument) or thermocouple, ideally reading from 0 to 50°C. The tip must be inserted to at least 10 cm above the anus, the instrument preferably having most of its gradations still visible when *in situ*. It should be left in place for several minutes for the reading to stabilize before being recorded. Where possible, it should be left *in situ* for multiple readings at intervals, though in operational circumstances (especially in criminal deaths) this may be difficult to arrange. There is considerable controversy about when such measurements should be carried out. It is often recommended that a doctor at the scene of death should measure the rectal temperature at once but logistic difficulties exist. Many cases where estimation of the time of death

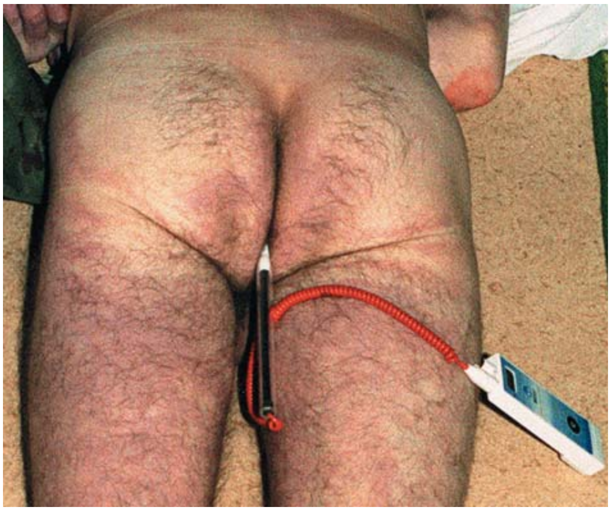

FIGURE 2.31 *Measuring the rectal temperature at the scene of a murder. This should be done only after forensic procedures such as rectal swabbing have been completed. Normally the temperature should be taken at the mortuary where removal of clothing can be carried out with full photographic and forensic science monitoring. In this case the body was unclothed at the scene and the circumstances did not warrant rectal swabbing.*

is important are criminal or suspicious deaths. These will often be associated with at least the possibility of sexual or homosexual assaults, and it may not be practicable to interfere with clothing in the perineal area or to contaminate the anal and vaginal region before full trace evidence procedures are carried out, usually by police scene of crime officers or forensic scientists, which may include adhesive taping of the clothing and skin, and the retention of underclothes for seminal stains, etc.

To wrestle with tight clothing, perhaps at night, in inclement weather and in confined spaces, and to try to introduce a thermometer into the rectum in these circumstances might ruin vital evidence of more importance than the admittedly uncertain calculations about time of death. However, many pathologists and police teams do carry out this manoeuvre as a routine, but each pathologist must decide in every individual case, whether it is preferable to wait until the body is taken to the mortuary where proper, controlled undressing is possible.

This applies where pathology and criminalistic expertise is readily available, but it is acknowledged that in less ideal circumstances, when no such expertise is likely to appear within a few hours (if at all), then some doctor at the scene should take a temperature. The procedure must be tailored to the individual circumstances but where there is a possibility of sexual interference, the rectum (and vagina) should be avoided until after full swabbing for semen and other examinations are completed. Alternatives are to use the axilla, deep nasal passage or external ear for the insertion of a thermometer.

The technique of introducing a mercury or 'rototherm' thermometer through a stab wound in the abdomen to measure liver temperature is never justified. It inevitably leads to blood contamination of the skin and clothing and also leads to intraperitoneal bleeding that might be confused with existing internal injuries.

More modern measuring devices include thermocouples, which register temperature accurately with minimum stabilization time. They may be part of a compact electronic instrument, which has a digital readout, or they may be connected to a computerized recorder that can analyse several other sites at regular intervals (see Morgan *et al.* 1988). Microwave thermography of brain and liver (see Al-Alousi *et al.* 1986, 1994) and infrared monitoring of skin temperature are at present research tools that may lead to practical devices in the future.

The use of thermometry in estimating the post-mortem interval

In spite of the great volume of research and publications already mentioned, accuracy in estimating the time since death from temperature remains elusive. The old rule-of-thumb was that the temperature fell at about 1.5°F/hour, something under 1°C/hour. Another rule-of-thumb was that the fall in °C from 37°C, plus three (to arbitrarily allow for the plateau), was equal to the time since death in hours. For example, if a rectal temperature was found to be 32°C, then 37 − 32 + 3 gave a post-mortem interval of 8 hours. The only confidence that one could place in these methods was that they were almost always wrong and that, if the answer happened to be correct, it was by chance rather than science! To hope for a linear fall was against all the principles of heat loss alluded to earlier. The first method took no account of the 'plateau' when rectal temperatures were used. This upper part of the double exponential curve is of variable length. If the body has been dead for some hours, serial temperature recordings fail to identify it, as the measurements begin on the steeper part of the curve, but where thermometry is begun soon after death, there is a variable flat area at the top of the sigmoid graph.

The length of the plateau has been discussed by several authors (see Shapiro 1965; Nokes *et al.*1985). Shapiro in particular has drawn attention to the invalidation of many formulae by the unknown length of the plateau. He claims that this can be as much as 4 hours 'and is possibly considerably longer'. Marshall and Hoare (1962) admit that the plateau may be as long as 5 hours. The plateau is the result of the lag in conducting heat from the core to the skin that is caused by the insulating properties of human tissue. This delays the establishment of the temperature gradient that must be in operation along the radius of the 'infinite cylinder', which is the model for the human body, before the core can begin to lose heat to the exterior. There may also be a small element of continuing heat production in the liver and musculature, as a number of investigators (including the first) noted that the body temperature could actually rise soon after death. As the length of the plateau is unknown in any particular case when there is a delay in starting measurements, most methods begin within this inbuilt inaccuracy.

At the lower end of the sigmoid curve, measurements again become almost useless, as when the temperature is within about 4°C of the environment, the rate of cooling becomes so slow that it provides no separation in time (see Fiddes and Patten 1958). Another empirical rule-of-thumb was devised by James and Knight (1965) to include variation in ambient temperature. The fall from 37°C was multiplied by a factor of 1, 1.25, 1.5, 1.75 or 2 for ambient temperatures of 0, 5, 10, 15 or 20°C, respectively, to give the time since death in hours. As another linear method, this was doomed to inaccuracy and was found to provide too short a post-mortem interval, though the authors emphasized that it was meant to be modified in each case by an appreciation of all other factors such as physique and clothing.

Nomogram method

At present one of the most useful practical guides is the nomogram published by Henssge. Based on conventional calculations such as those of De Saram and Marshall and backed up by a great volume of experimental data, Henssge has produced a method which can be carried out either by a simple computer program or by a nomogram. Adjustments are built in for body weight, ambient temperature, dry or wet clothing, still or moving air, or still or flowing water. The result is given within different ranges of error, with a 95 per cent probability of the true time of death falling within these ranges, which vary from 2.8 hours each side at the best estimate, down to 7 hours at worst. As with most methods, the difficulties arise in estimating the strength of the variable factors. It also cannot allow for variation of these factors over time, especially changes in ambient temperatures during the period before the body was examined. Henssge and Madea have recently refined their method to reduce the standard deviation of their nomograms so that the confidence range becomes smaller, by a whole battery of methods not dependent on temperature, such as electrical stimulation of muscle and the reaction of the eye pupils to drugs.

Another graphical method is that developed by Al-Alousi (1987) in Glasgow. In addition to his publications on microwave thermography, Al-Alousi has published a simple method based on rectal temperatures. He has constructed cooling curves for both naked and covered bodies, using the concept of 'temperature ratios'. The accompanying cooling curves may be used from a knowledge of the rectal temperature, ambient temperature and whether or not the body surface was covered. Again no correction is made for body size, posture or other variables, but the author claims that such factors made little difference to the standard errors, which he gives as shaded errors on each side of his graphs.

Multiple-site serial measurement methods

In an effort to reduce or eliminate the effect of the external variables when calculating the post-mortem interval, Morgan *et al.* (1988) have developed models using multiple sites in the body for temperature estimations. These are then taken serially at frequent intervals over a period using highly sensitive thermocouples and computerized data acquisition, and calculation, which is miniaturized sufficiently for use at scenes of crime.

The method also attempted to use the deep ear canal and nasal passages for temperature measurements, which avoids the problems of perineal contamination that occur when the rectum is used at scenes of death. The results were not encouraging, but recently French workers have revived the ear method, with claims of relative success. These methods have not been in routine use for sufficiently long to evaluate their operational accuracy.

STOMACH EMPTYING AS A MEASURE OF TIME SINCE A DEATH

With one exception, this controversial topic could be dismissed summarily as being quite irrelevant. For many years pathologists have argued over the reliability of the state of digestion of gastric contents as an indicator of the time between the last meal and death, the leading case in modern times being that of Truscott in Canada. There is now almost a consensus that with extremely circumscribed exceptions, the method is too uncertain to have much validity.

The original hypothesis was founded on the belief that food spent a fairly uniform time in the stomach before being released into the duodenum. In addition, it was claimed that its physical state was progressively altered by gastric juices and movements so that its appearance and volume was a measure of the time since it had been swallowed. Therefore, if the time of the last meal was known from circumstantial evidence, the time of death could be estimated.

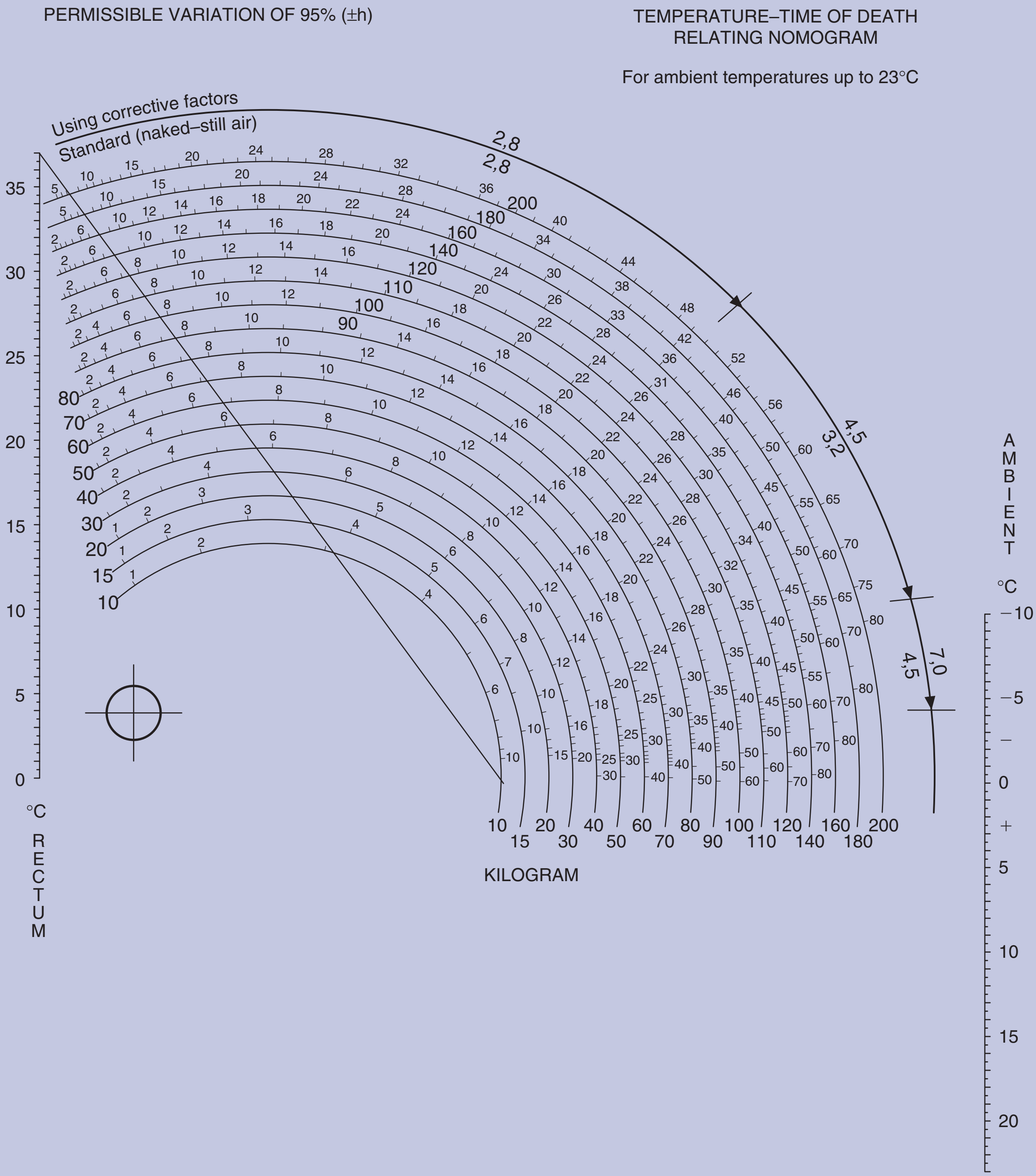

Figure 2.32 *Henssge's nomogram method for estimating the time since death from a single rectal temperature, where the environmental temperature is below 23°C. (From Henssge* et al. *2002.)*

The nomogram expresses the death time (t) by: $\dfrac{T_{\text{rectum}} - T_{\text{ambient}}}{37.2 - T_{\text{ambient}}} = 1.25\ \exp(Bt) - 0.25\ \exp(5Bt);\ B = -1.2815\ (\text{kg}^{-0.625}) + 0.0284$

The nomogram is related to the chosen standard, that is, naked body extended lying in still air. Cooling conditions differing from the chosen standard may be proportionally adjusted by corrective factors of the real body weight, giving the corrected body weight by which the death time is to be read off. Factors above 1.0 may correct thermal isolation conditions and factors below 1.0 may correct conditions accelerating the heat loss of a body.

How to read off the time of death

1. Connect the points of the scales by a straight line according to the rectal and ambient temperature. It crosses the diagonal of the nomogram at a special point.
2. Draw a second straight line going through the centre of the circle, below left of the nomogram and the intersection of the first line and the diagonal.

The second line crosses the semicircles, which represent the body weights. At the intersection of the semicircle of the body weight the time of death can be read off. The second line touches a segment of the outermost semicircle. Here can be seen the permissible variation of 95 per cent.

Example: temperature of the rectum 26.4°C; ambient temperature 12°C; body weight 90 kg. Result: time of death 16 ± 1.8 h. Statement: the death occurred within 13.2 and 18.8 (13 and 19) hours before the time of measurement (with a reliability of 95 per cent).

Note: if the values of the ambient temperature and/or the body weight (see 'corrective factors') are called into question, repeat the procedure with other values that might be possible. The range of death time can be seen in this way.

Empiric corrective factors of the body weight

Dry clothing/ covering	In air	Corrective factor	Wet through Clothing/covering wet body surface	In air/water
		0.35	Naked	Flowing water
		0.50	Naked	Still water
		0.70	Naked	Moving air
		0.70	1–2 thin layers clothing	Moving air
Naked	Moving	0.75		
1–2 thin layers clothing	Moving	0.90	2 or more thicker clothing	Moving air
Naked	Still	1.00		
1–2 thin layers clothing	Still	1.10	2 thicker layers clothing	Still air
2–3 thin layers clothing		1.20	More than 2 thicker layers clothing	Still air
1–2 thicker layers clothing	Moving or still	1.20		
3–4 thin layers clothing		1.30		
More thin/thicker layers clothing	Without influence	1.40		
		1.80		
Thick bedspread + clothing combined		2.40		

Note: for the selection of the corrective factor of any case, only the clothing or covering of the lower trunk is relevant.
Personal experience is needed; nevertheless, this is quickly achieved by consistent use of the method.

Requirements for use

- No strong radiation (for example, sun, heater, cooling system).
- No strong fever or general hypothermia.
- No uncertain* severe changes of the cooling conditions during the period between the time of death and examination (for example, the place of death must be the same as where the body was found).
- No high thermal conductivity of the surface beneath the body.†

* Known changes can be taken into account: a change of the ambient temperature can often be evaluation (for example, contact the weather station); use the mean ambient temperature of the period in question. Changes by the operations of the investigators (for example, take any cover off) since finding the body are negligible: take the conditions before into account!

† Measure the temperature of the surface beneath the body also. If there is a significant difference between the temperature of the air and the surface temperature, use the mean.

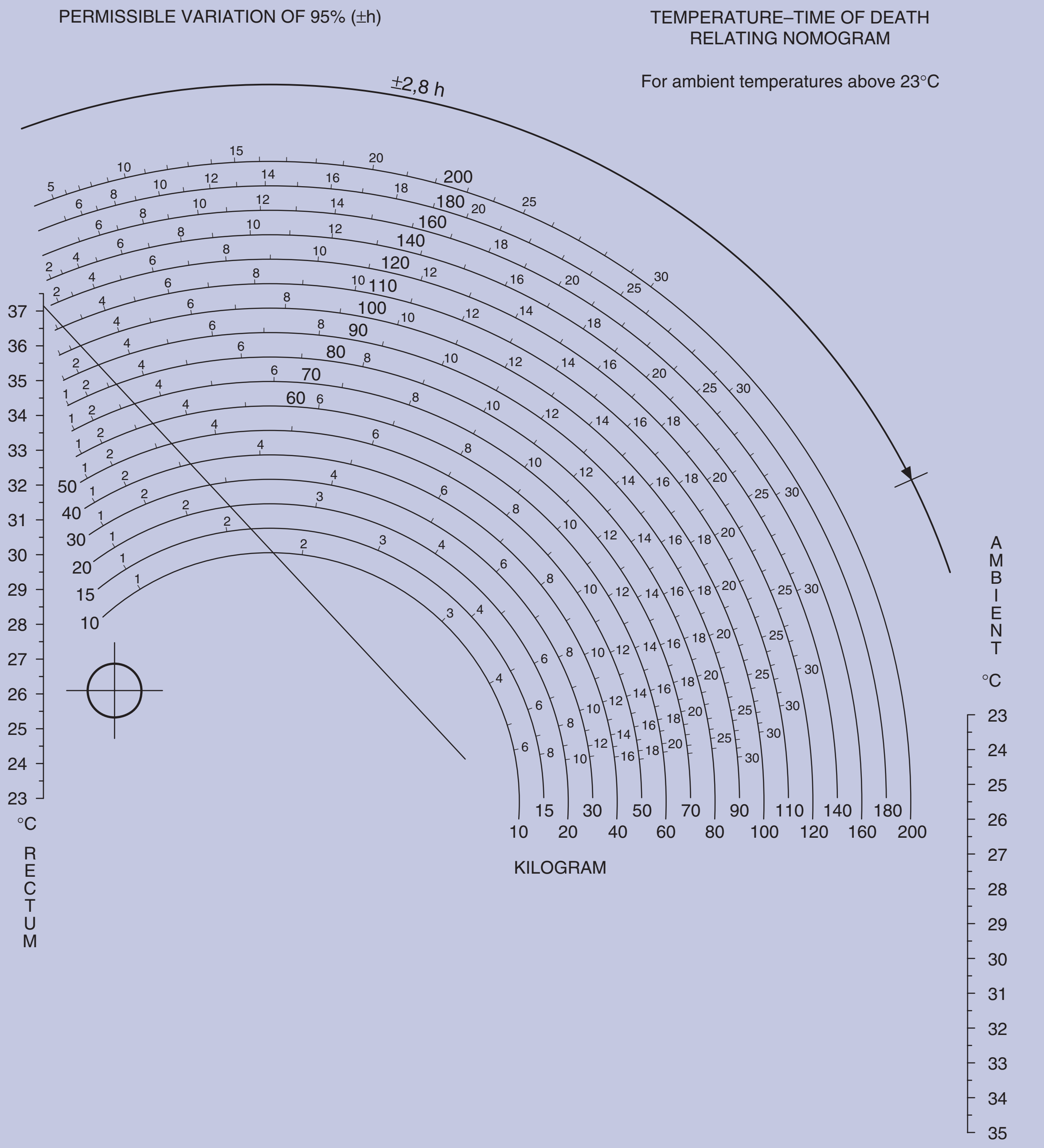

FIGURE 2.33 *Henssge's nomogram method for estimating the time since death from a single rectal temperature, where the environmental temperature is above 23°C. (From Henssge* et al. *2002.)*

The nomogram expresses the death time (t) by: $\frac{T_{\text{rectum}} - T_{\text{ambient}}}{37.2 - T_{\text{ambient}}} = 1.11\exp(Bt) - 0.11\exp(10Bt);\ B = -1.2815\ (\text{kg}^{-0.625}) + 0.0284$

The difference between this nomogram and that for ambient temperatures up to 23°C concerns only the relative length of the 'post-mortem plateau'. It is shorter in higher ambient temperatures (above 23°C) than in lower ones (that nomogram: up to 23°C). This nomogram for higher ambient temperatures was developed according to the data from De Saram, which were obtained in ambient temperatures between 27 and 32°C. These data show a relatively shorter length of the 'post-mortal plateau' than our own data of body cooling in lower ambient temperatures. Our own practical experience of the cooling of bodies in high ambient temperatures and therefore in using this nomogram, is small. It is recommended that the same permissible variation of 95 per cent as given in the nomogram for lower ambient temperatures is taken.

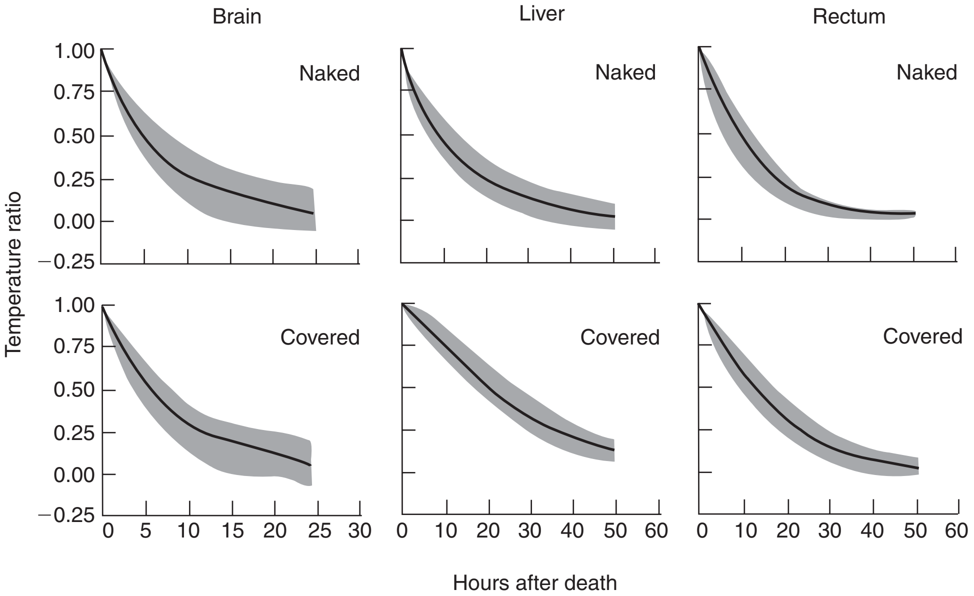

FIGURE 2.34 *Cooling curves for estimation of the post-mortem interval. In Al-Alousi's 'temperature ratio' method, the graphs above are used as follows. Assume that the body temperature (rectal) is 36.6°C at the time of death (*T_b*). Measure the environmental and rectal temperatures at the time of examination (*T_r *and* T_e*). Then the 'temperature ratio' is* $T_r - T_e/T_b - T_e$*. This ratio is then found on the vertical scale of the rectal graph, using either the graph for 'naked' or 'covered' as appropriate. The time since death is the point on the lower scale where a perpendicular falls from the point on the graph where a horizontal line meets it from the temperature ratio level. The shaded area indicates the limits of a 68 per cent probability at that particular point. For example, if the rectal temperature is 23.4°C and the air temperature 19°C, then the temperature ratio is 0.25. If the body is naked, then this gives 18 hours as the time since death, with a margin of plus 2.5 hours and minus 5 hours. (Reprinted with permission from Al-Alousi LM, Anderson RA. 1986. Microwave thermography in forensic medicine.* Police Surgeon, ***30****:30–42.)*

It was assumed that the physiological process of digestion of an 'average' meal lasted some 2–3 hours. This is based on the consumption of a test meal of gruel, however, hardly a representative example of a modern mixed diet. Moreover, the subjects of experimental work were healthy and presumably free from sudden stress during the experiments. More elaborate descriptions of digestion times of various foods have been drawn up, but they are of dubious value. As an example of the great variations offered, Modi (1957) gives 4–6 hours for a meat and vegetable meal and 6–7 hours for a farinaceous meal. Adelson (1974) stated that the stomach begins to empty within 10 minutes of swallowing, that a 'light' meal leaves the stomach by 2 hours, a 'medium' meal takes 3–4 hours and a large, heavy meal takes 4–6 hours. He noted that the head of an 'ordinary' meal usually reached the ileocaecal valve between 6 and 8 hours after ingestion. All these values, however, are subject to considerable variation.

More modern methods of investigation have used radioisotope techniques and have shown some interesting facts. When a solid meal is eaten and water drunk with it, the water leaves the stomach quickly irrespective of the nature or calorific content of the solid part. However, calorific liquids stay longer in the stomach (Brophy *et al.* 1986). The emptying rate also increases with the weight of the meal, as long as the calorific content remains constant. If the latter is increased, then the pyloric opening is delayed. Further work by Moore *et al.* (1984) again emphasized the marked variability of emptying times, even in normal circumstances.

The following factors frustrate the use of gastric emptying as a measure of time since death:

- Digestion may continue for some time after death.
- The physical nature of a meal has a profound effect on emptying time: the more fluid the consistency, the faster the emptying. Liquids entering an empty stomach pass through without any appreciable pause.
- The nature of the food modifies emptying time, notably fatty substances, which markedly delay the opening of the pylorus. Strong alcohol, such as spirits and liqueurs, also irritate the mucosa and tend to delay emptying.
- Importantly, any nervous or systemic shock or stress, mediated through the parasympathetic (vagus) system, can slow or stop gastric motility and digestive juice secretion as well as holding the pylorus firmly closed.

The intestine, as opposed to the stomach, may increase its motility with psychogenic upsets, as noted by De Saram in his autopsies on hanged criminals.

The state of digestion, as opposed to the volume and exit of food from the stomach, is almost impossible to assess. Variations in the type of food eaten make vast differences to the dissolution rate. Hard objects, such as nuts and seeds, resist digestion and may even be voided intact *per rectum*, whereas soft carbohydrates can liquefy almost immediately. The size and dispersion of particles is crucial, including the amount of chewing and admixed saliva. The efficiency of the teeth and gastric acid, enzymes and motility are also of prime importance, as is the amount of liquid either in the original food or drunk during the meal. Fat and oil in the meal slow up pyloric opening, and all these variables make it impossible to time the rate of digestion.

One of the most important factors in the forensic context is the effect of a physical or mental shock or stress during the digestion process. As stated, this can completely inhibit digestion, gastric motility and pyloric opening. The author (BK) recalls a victim of a traffic accident who lived in a coma for a week after a mortal head injury. At eventual autopsy, the large volume of gastric contents looked as fresh as if it had just been swallowed.

Even if one accepts an 'average' gastric transit time of an 'average' meal as being of the order of 2–3 hours, the assumption that death took place within this time can only be valid if the death was quite sudden and unexpected, with no stressful prodromal event. For example, if an unsuspecting person was suddenly shot or run down without warning and died almost immediately, then one can assume that the undisturbed physiological processes of digestion – albeit with its many variables – had taken place. If, however, a domestic dispute or a developing altercation culminated in a strangling or stabbing, the antecedent stresses would almost certainly affect gastric function and render invalid any interpretation of the condition of stomach contents at autopsy.

What is valid is the nature of the last meal, which may be helpful in establishing the time of death. If it was known to the investigators that the deceased person ate a certain type of meal at a certain time, whether it be chicken curry or green beans, the identification of such food in the stomach would be persuasive evidence that he died after taking that food and that it was his final meal, before any other substantial food of a different type was taken.

THE USE OF VITREOUS HUMOUR CHEMISTRY IN TIMING DEATH

This topic has been the subject of considerable research in forensic medicine over the last 30 years. It has never gained sufficient acceptance to become a routine tool, remaining a controversial procedure in spite of the large number of reports that now exists.

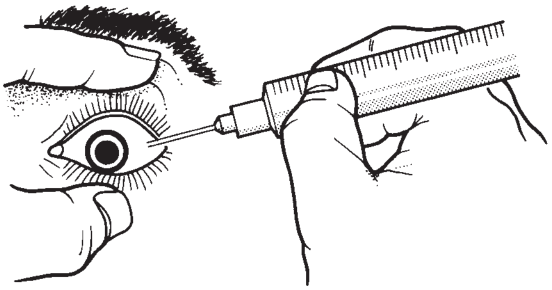

FIGURE 2.35 *Obtaining vitreous humour for analysis. The lids should be retracted and the needle introduced near the outer canthus, so that the hole will be covered when the lids are released. Fluid should be withdrawn slowly, keeping the tip of the needle in the centre of the globe to avoid dislodging the retina. Water can be reintroduced through the needle to restore the tension in the globe for cosmetic reasons.*

The most common chemical estimation performed on the vitreous fluid in the context of the post-mortem interval is that of potassium. There is a marked and progressive rise in the potassium concentration after death, the controversy revolving around whether this rise is simply linear or whether it is biphasic. The degree of confidence is also in dispute and the effect of variable factors is another contentious matter (see works by Coe, Sturner, Lange and Madea). First, the potassium values from either eye often differ, sometimes by a considerable amount. The sampling methods are then critical, as small or marginal samples vary greatly; if aspiration is forcible or from too near the retina, cellular fragments distort the values, because the potassium reaches the vitreous by leaching out from the retina. The effect of temperature changes post-mortem is also undoubtedly important. In addition, different analytical techniques used to estimate the potassium give different results, the older flame photometric methods producing a different range of values compared with modern selective-electrode procedures.

With all these variables, it is little wonder that different authors suggest widely different standard errors, varying from 1–7 hours to 26 hours either side of the true time of death. In addition, the errors seem much greater in persons dying of chronic illnesses, with nitrogen retention, compared with sudden deaths, presumably because of the premortal electrolyte disturbances in patients with metabolic disorders.

The rise in infants seems much faster than in adults – yet another variable – though in both adults and children the most potent influencing factor seems to be the post-mortem body temperature. The most popular calculation for estimating the time since death from vitreous potassium is that devised by Sturner, in which post-mortem interval =7.14 × potassium concentration (mEq/l) −39.1. This seems most satisfactory when the body has lain in an ambient temperature of not more than 10°C (50°F). The 95 per cent confidence limit during the first day is likely to be at least 4.7 hours either side of the true time and probably greater. Taking a sample from one eye at a later time than the first to attempt to calculate the rate of rise does not seem to add any accuracy to a single estimation method (see Adjutantis and Coutselenis 1972).

Hypoxanthine estimation in vitreous humour has also been used to attempt to time death, but more often as a marker of hypoxia. The results are not convincing, but there is an accumulating literature on the subject, more recent contributions being Madea *et al.* (1994) and also Rognum *et al.* (1991).

POST-MORTEM CHEMISTRY

The analysis of physiological chemical constituents of the body, as opposed to toxic substances, is often useful in investigating deaths from metabolic and biochemical disturbances.

Unfortunately, the concentration of many natural chemical substances in the dead body is rapidly distorted by post-mortem autolysis. Cell membranes become permeable to small molecules soon after the cells suffer ischaemic or anoxic damage, and agonal changes themselves may grossly alter the biochemical environment, even in the few minutes of the dying process. Thus both terminal and early post-mortem changes may render many of the analyses that are commonplace in clinical practice of little value – and indeed, quite misleading – when applied to body fluids obtained at autopsy. Some substances are more stable, however, and when results are carefully interpreted, considerable information can be obtained. Urea and creatinine are stable post-mortem, with little variation even up to 100 hours after death, so the diagnosis of ante-mortem nitrogen retention is quite reliable. The normal urea nitrogen range found in post-mortem serum is from 4.9 to 5.5 mmol/l, creatine being from about 70.7 to 212.2 µmol/l.

In the context of post-mortem chemistry the work of John Coe is best known in forensic pathology and his writings should be consulted for detailed information. Another very useful source is Madea, especially for vitreous fluid. The vitreous humour is much to be preferred to blood for post-mortem chemical analyses. Although still influenced by temperature changes, the vitreous is far less contaminated by body autolysis and is remote from the large organs and blood vessels of the abdominothoracic cavity.

There is a large body of literature on vitreous potassium, much of it centred around the controversy over the *in vivo* concentration of potassium, which can naturally rarely be measured directly in healthy persons, and the slope of the regression graph for relating potassium levels with post-mortem interval.

After death, intracellular potassium leaches from the retina through the now permeable cell membranes, into the vitreous body, naturally with an uneven distribution depending on the distance from the wall of eyeball (which is why all or a substantial proportion of the fluid should be withdrawn for analysis, to obtain a mean level). If fragments of retina are aspirated by the syringe, due to excessive suction, then a falsely elevated potassium measurement will be obtained.

Differences in the recommended regression gradient are observed between various workers: Madea states that 0.19 mmol/l/hour should be used, whereas Sturner claims 0.14 is preferable. The literature should be consulted for details (as in the 2002 book by Hennsge *et al.*); it is also pertinent to note that the methods of analysis can make a difference to the calculations. Generally speaking, the vitreous potassium method is of most use after the first 24–36 hours, when other methods have ceased to have application. Although the errors are great, some information can be derived for up to 100 hours post-mortem.

Caution must be used when interpreting results, as different analytical techniques provide different values. For instance, in relation to electrolytes, Coe and Apple (1985) state that flame photometric methods yield values about 5 mmol/l less for sodium, 7 mmol/l less for potassium and 10 mmol/l less for chloride, compared with more modern specific electrode methods. Electrolyte concentration differences between left and right vitreous humor samples were studied by Pounder *et al.* (1998) in 200 medico-legal autopsies using an ion-specific electrode system. Between-eye concentration differences of sodium and chloride were tolerable using this methodology, whereas differences in potassium, even in biochemically nonputrefied cases (potassium <15 mmol/l), were 0–2.34 mmol/l (0–21.8 per cent of mean) averaging 0.37 mmol/l (3.3 per cent), thus undermining the usefulness of vitreous potassium in estimation of time of death.

In relation to other vitreous electrolytes, the concentration of sodium and chlorides decrease after death, while potassium rises. The latter can be used as a check on the reliability of the others, as if potassium is <15 mmol/l, then the sodium and chloride concentrations may be acceptable. Chlorides decrease at less than 1 mmol/l/h and sodium by about 0.9 mmol/l/h, so the loss of this and sodium is insignificant in the first few hours, differing from potassium, which rises appreciably.

With the analysis of glucose in autopsy material, five different methods yielded five different results, presumably because interfering substances were included in varying amounts.

Returning to vitreous electrolytes, in mmol/l measured by flame photometry (in mmol/l), sodium >155, chloride > 135 and urea >40 is a reliable indication of ante-mortem dehydration. When sodium and chloride are normal but the urea exceeds 150, a diagnosis of uraemia is acceptable. These values can be distinguished from post-mortem decomposition, in which sodium is <130, chloride <105 and potassium >20.

In relation to glucose, a common problem is the autopsy diagnosis of uncontrolled diabetes and of hypoglycaemia. The vitreous glucose usually falls after death and can reach zero within a few hours. In 6000 analyses, Coe (1973) found that a vitreous glucose of more than 11.1 mmol/l was an invariable indicator of diabetes mellitus. The agonal or post-mortem rise in blood sugar is not reflected in the vitreous concentrations. In relation to hypoglycaemia, a vitreous glucose of less than 1.4 mmol/l was taken by Sturner *et al.* (1972) to be an indication of a low ante-mortem blood sugar, but others feel that whatever the concentration, no reliable interpretation can be made. In hypothermia there is also an elevated vitreous glucose, but never greater than 11.1 mmol/l.

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CHAPTER 3

The establishment of identity of human remains

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The identity of the dead is an essential part of post-mortem examination, for various reasons. These include:

- the ethical and humanitarian need to know which individual has died, especially for the information of surviving relatives
- to establish the fact of death in respect of that individual, for official, statistical and legal purposes
- to record the identity for administrative and ceremonial purposes in respect of burial or cremation
- to discharge legal claims and obligations in relation to property, estate and debts
- to prove claims for life insurance contracts, survivor's pensions, and other financial matters
- to allow legal investigations, inquests and other tribunals, such as those held by coroners, procurators fiscal, medical examiners, judges and accident enquiries to proceed with a firm knowledge of the identity of the decedent
- to facilitate police enquiries into overtly criminal or suspicious deaths, as the identity of the deceased person is a vital factor in initiating investigations.

The establishment of identity has many facets, some of which have no medical content, such as the recognition of clothing, documents and personal property. Some aspects, though primarily the responsibility of the police, have a medical content, including identification of fingerprints and personal property such as hearing aids, spectacles, medicines, trusses and surgical prostheses. False dentures have such central importance that they will be considered in the section on odontology.

Identification from anatomical and medical features comprises two major aspects:

- The establishment of certain broad groupings, such as sex, stature, race and age. These may be determined solely from the available bodily remains, though corroboration may be obtained from other evidence. An obvious example would be sex determination from clothing and jewellery, though even this may no longer be absolutely reliable.
- Comparison of the remains with ante-mortem information and records from those thought to be the victims, which restricts the method by making it dependent upon the existence or availability of such comparable material.

The establishment of identity may be required upon:

- **Intact fresh corpses.** Here visual recognition, directly or by photography, may be made. Hair colour, skin pigmentation, scars and tattoos can be examined without difficulty.
- **Decomposed corpses.** Many surface features may be partially or wholly lost, but more information can be obtained than from a skeleton. Direct measurement of body height, for example, may be possible, as well as

serological investigations and organ abnormalities, such as past surgical intervention, may be found.

- **Mutilated and dismembered corpses.** Depending on the degree of mutilation and the amount of tissue missing, identification may be hampered. If the remains are fresh, facts such as racial pigmentation may be determined, but direct measurement of stature may be impossible. Selective mutilation in some homicides may be deliberately directed at frustrating identification, such as the removal of teeth and finger-pads.
- **Skeletalized material.** If all soft tissues are absent, identity depends solely on osteological examination and measurements and the recognition of any pathological or anatomical abnormalities in bone.

CHARACTERISTICS USEFUL IN IDENTIFYING THE DEAD

Facial appearance

Even in perfectly fresh bodies, recognition may be difficult because of alterations in the features caused by death. It is a common occurrence in mortuary viewing rooms for a close relative, even a parent or spouse, to have doubts about – or even to deny or mistakenly agree to – the identity of the deceased person. Though distress and emotion play a part, changes in the features may be profound. Hypostasis, contact flattening, oedema, muscle flaccidity and pallor may all combine to distort the face. Recognition in the living is partly a dynamic process, aided by facial muscle tone and especially eye contact and movement, all of which are absent in the corpse.

Eye colour

In the fresh corpse, eye colour corresponds with the living state, but it quickly deteriorates. Loss of intraocular tension and clouding of the cornea develops progressively within a few hours, making the iris harder to observe. Collapse of the front of the globe occurs within a day or two and, with developing decomposition, all irises tend to darken to brown. It is unsafe to depend on eye colour as a criterion of identity later than a few days following death – or even much sooner where environmental conditions hasten decomposition.

Skin pigmentation

In undamaged, unputrefied bodies, the major ethnic differences in skin pigmentation are obvious, though the slight melanin increase of the misnamed ‘yellow’ races of Asia may be impossible to differentiate from Mediterranean or Middle Eastern races. The onset of deathly pallor and post-mortem hypostasis is more profound than slight variations between sunburnt White people, northern Asians or Semitic races. When putrefaction sets in, skin slippage progressively removes the pigmented layers and eventually pigmentation becomes unavailable as a marker of identity, though histologically melanin may still be visible in the basal layer of any surviving epidermis.

Burnt bodies may also lose pigmented skin, either by heat destruction or by deposition of soot and other combustion products on the surface, though it is rare for this to be so complete as to obscure all evidence of pigmentation.

Hair colour

The head, pubic and axillary hair is one of the most resistant identifying features, sometimes lasting millennia in favourable environments. The original colour may, however, alter after burial, becoming a brownish-red or ‘foxy’ colour within as short a time as 3 months. The colour may be obscured by dirt or staining and expert treatment (usually by a biologist or museum technologist) may be required to restore the original colour. The possibility of deliberate chemical coloration or bleaching before death may have to be considered and again expert chemical analysis in a forensic science laboratory may be needed to confirm or eliminate this if the hair colour conflicts with other positive evidence of identity.

Hair structure

This is more the province of the forensic biologist or anthropologist, but factors such as whether the hair ends have been cut or are naturally pointed may sometimes have importance in identity. Racial features exist, Negroid head hair being dark and having a spiral twist with a flattened, elliptical cross-section. Mongoloid hair is less pigmented and is straight with a cylindrical cross-section. Caucasian hair is round or ovoid in cross-section, but shows great variation in colour and morphology compared with the other two major ethnic groups. Though head hair in Caucasians is round to ovoid in section, eyebrow hair tends to be triangular and pubic hair flattened. Where a hair root is present, blood grouping and other serological criteria can be determined. Grouping of the shafts of hairs has been repeatedly attempted and success claimed by some workers. The cells of the hair root can give a DNA profile and mitochondrial DNA (mtDNA) has been detected even in a sample from a single hair shaft.

Microscopic examination of the hair can assist in determining the species, if not human. Human hair has broad groupings when viewed microscopically. However, the topic of individual identity from hair is now the province of forensic biologists, and has a specialism and literature of its own.

Tattoos

Deliberate ornamentation of the skin by introducing pigments under the epidermis has been practised for millennia and in all parts of the world. The word 'tattoo' comes from the Polynesian '*ta tau*', meaning 'to mark'. Some races such as the Ibans of Sarawak may be tattooed over much of their body surface, but many men and some women in most countries have localized tattoos, which can be of considerable assistance in identification. Many different pigments are used, as well as more unusual substances such as soot or gunpowder. The colour is pricked into the upper dermis with a sharp instrument, usually a needle used manually, or by an electric vibrator.

Once under the outer skin, the material persists for a long time. Colours such as blue, green or red may be scavenged by tissue cells and leached into the lymphatic system after a number of years or decades. Black pigments, usually carbon particles in the form of Indian ink, are so resistant as to be virtually lifelong, though some may be transported to regional lymph nodes. Thus an original pattern of different colours may fade differentially over years, the black areas standing out in strong relief.

The patterns are so diverse as to defy classification, though much has been written on the subject. From the point of view of identity, tattoos may be useful in both a general sense and for comparison with potential victims. The general applications require a knowledge of ethnic, national, cultural, religious and social practices, so that the tattoo can be assigned to some particular group of people. In Western society, the popularity of tattooing changes from time to time. Former statements that tattoos are seen mostly in the 'lower social classes' have little current validity, though it is obvious that bankers and parsons are less likely to sport tattoos than seamen and truck drivers. It is also now totally anachronistic to claim that most women with tattoos are prostitutes, though the nature and position of the tattoo is obviously relevant.

Certain tattoos have had particular significance such as a number, often '13', inscribed inside the lower lip of drug pushers or the bluebird on the extensor surface of the web of the thumb in homosexuals. The latter design is now so common as to be of little significance.

Tattoos are of most use when individual enough to be compared with known designs on a missing person. The design is often supplemented by actual names, though these are mostly forenames rather than family names. Designs are by no means unique and a professional tattooist may turn out hundreds of identical decorations, so names are a bonus when trying to achieve identity.

Initials may be used, but these can be misleading due to the use of nicknames and diminutives, such as 'B' for Bill, rather than William. In general, men have the names of girls on their tattoos, but initials are usually their own. Conversely, women with tattoos almost always display the names of sweethearts, rather than their own. Some tattoos may be numbers or unadorned names, the most tragic examples being those from Nazi concentration camps during the last war.

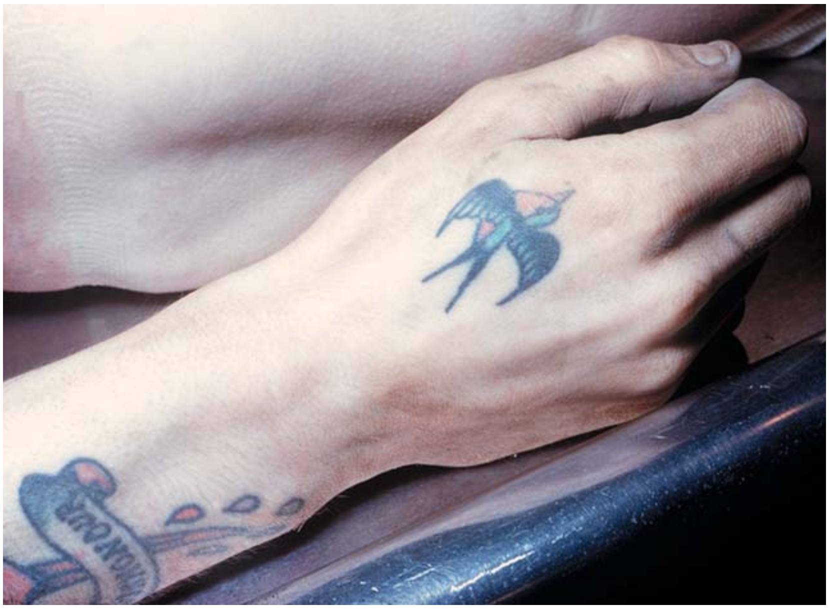

FIGURE 3.1 *Individualistic tattoos may assist the identification of unknown persons.*

The photography, distribution and matching of tattoos is police business, but the pathologist's duty is to make them accessible and clear to the police. Where decomposition has set in, tattoos may be obscured by wrinkled, peeling epidermis, but often this can be wiped off to reveal tattoos that are more vivid than on fresh skin. Once the tissues become green and slimy, then the pattern progressively vanishes, but early decomposition is no barrier to recognition. Where skin pigmentation may hide a design, skin slippage may actually enhance the clarity, especially of the weaker colours like blue, red and green. Attempts at the deliberate removal of tattoos are common, either from regret at having disfigured the body during youthful or drunken euphoria, or to remove evidence of identity. Many methods have been used, from surgical excision to scarification with sandpaper and from caustic soda to electrolysis. All methods depend upon damage to the epidermis and dermis, with consequent inflammation and scar formation. The tattoo can certainly be removed, but always by replacing it by a cicatrix to a greater or lesser extent, which will itself indicate that something pre-existed at that site.

It has been suggested (PA Edwards, personal communication) that the chemical nature of tattoo pigments might be used in identification. Although all manner of substances have been used to tattoo, most tattooists use black pigments containing carbon, green pigments containing potassium dichromate and red pigments containing mercuric chloride. Others use aniline-based dyes, so that microextraction and analysis in a forensic science laboratory might confirm or exclude the tattoo having been executed by a particular artist in the locality.

Finger, palm, foot and lip prints

The science of fingerprints, their classification, retrieval from records and methods of recording lie in the domain of police procedure, and, as with tattoos, the pathologist's role is merely to facilitate the taking of prints by police officers. Sometimes when a strange print is found at a scene of crime, the police may wish to take the fingerprints of doctors who visited the locus to eliminate them from their enquiries and there is obviously nothing objectionable about this. Indeed, some forensic pathologists who habitually assist the police leave their prints on file so that they are permanently available for exclusion. When called to a scene of death, the doctor should take care to avoid handling objects and furniture to reduce the need for such laborious screening of prints.

The doctor need know nothing about fingerprints except for his own interest, though it is as well to be prepared for the inevitable questions – no two fingerprints have ever been found to be identical and even identical twins have different prints. However, some recent claims point out that some prints are so similar that the criteria usually accepted as proof of congruence may not be sufficient. Police usually attend the mortuary to take full sets of fingerprints in the usual way by rolling ink on to the finger-pads and pressing the pulps against record cards.

The pathologist may help when there is strong rigor present, by either forcing the flexed fingers back or even by slitting the flexor tendons, though this has the danger of fouling the fingers with blood.

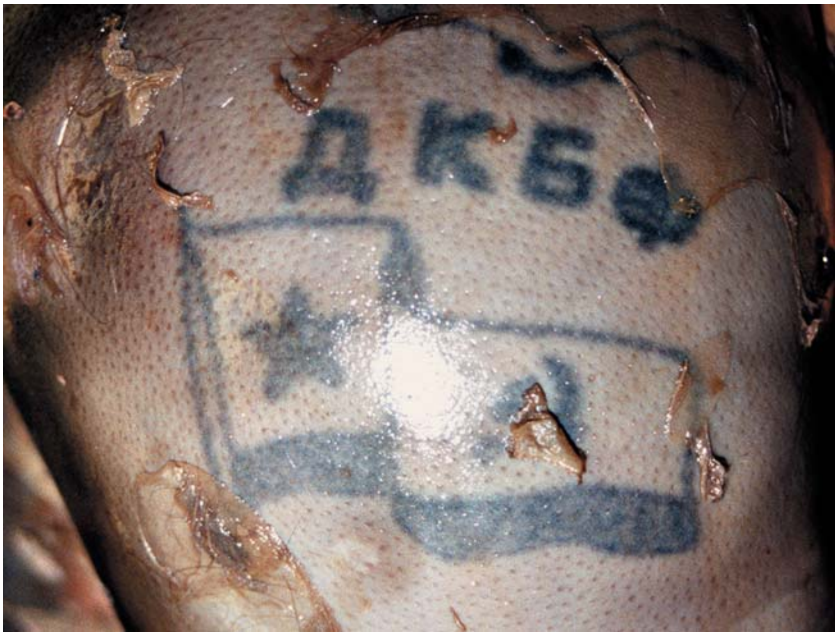

FIGURE 3.2 *Shoulder region of a decomposed body recovered from the sea showing a tattoo with Cyrillic letters (Д, К, Б, Ф) and a flag with a star and hammer and sickle suggesting a connection with the Russian Baltic Fleet.*

When the body is putrefied, the doctor can again assist by removing desquamated casts from the fingers for the police. These may need to be preserved or hardened up so that the decaying tissue does not lose further definition from the ridges that form the prints. The skin may be placed in formalin, alcohol or glycerine solution, especially where maceration in an immersed body has caused swelling and blurring of the epidermis. An alternative is immersion in 20 per cent aqueous acetic acid for 2–8 hours. Rarely, a criminal may attempt to obliterate his fingerprints by scarring the fingerpads. To be effective, this must be drastic enough to damage the underlying dermis and the consequent cicatrices will be more obvious than the original prints. Surgical grafting of skin from elsewhere on the body has been reported as a means of removing fingerprints, but again the result is self-evident proof of nefarious intent.

As with fingerprints, the skin pattern of palms, soles and even lips are said to be unique and have been used in identification, but again this is really police business. The pattern of veins on the back of hands is also said to be characteristic to one individual.

Identifying scars

These can be important in the identification of unknown bodies, even when some degree of putrefaction exists. The author (BK) used a cholecystectomy scar and scars of old surgical incisions on the legs to identify the body of a homicide victim submerged in a river for 6 weeks and many other cases are on record where scars provided similar vital information. Probably the best known instance is the Crippen case of 1910 in which much forensic controversy was generated over the distinction between a surgical scar and a skin crease on a piece of abdominal wall.

Scars on the skin may arise from any previous injury that has breached the epidermis, as superficial injuries to the upper layer of skin will heal without a trace. Where the dermis has been entered, healing occurs by organization of the plug of blood clot and/or granulation tissue, as described in Chapter 4. If the wound is narrow, such as that inflicted by a surgical instrument, sharp knife, razor or glass, then if the edges are kept together, especially by stitches or dressings, the resulting scar will be narrow and insignificant. Gaping or infection will widen the scar and obviously larger lacerations or burns will result in similarly greater scarring. In relation to identification, scars are of use only if those thought to be the victims are known to have similar scars, both in nature and position. The specificity of scars varies greatly, as many people may have appendicectomy scars, and many women have had hysterectomies or other gynaecological operations that leave lower abdominal scars. As always, scar evidence must be taken in conjunction with all other details of identity, but where a cicatrix is unusual or even unique in nature or position, its value is greatly enhanced.

Turning to traumatic scars other than surgical, the pathologist may be able to recognize the cause, which can assist in identity. Naturally the vast majority of non-surgical scars are the result of accidental trauma and where family, friends, photographs or medical records indicate the existence of specific scarred sites on the body, then confirmation of identity may be greatly assisted or confirmed.

Some scars are deliberately produced as part of some ethnic or religious tradition, such as the facial scars in some African tribes, as well as deformed or perforated ear lobes or lips. Regrettably, another class of scars is becoming more common in many parts of the world, due to physical torture; this is dealt with in Chapter 10. Linear scars, cicatrices of burns, keloid overgrowth (especially in negroid races), hyperpigmentation or depigmentation and other persistent lesions may assist in identity in the appropriate circumstances. Much depends on the accuracy of the information concerning the person thought to be the victim; relatives are notoriously vague and inaccurate about medical matters and frequently confuse different surgical operations, thus misleading the investigators about scars. Sometimes surgical scars may be almost invisible. The author (PS) once worked as surgical assistant in a private hospital where one of the surgeons used to perform appendicectomy (in non-acute cases) through a 1 cm wide incision, closing the wound, for cosmetic reasons, with subcutaneous catgut sutures. Most of these wounds healed with virtually no scar whatsoever, unless the person had a tendency to keloid formation. Wherever possible, old hospital records or the notes of a family physician should be obtained.

The old scars of wrist- or throat-slashing indicate previous attempts at suicide. Large areas of scarring on the trunk or limbs that have parallel grooves and marginal extensions suggest severe brush lacerations, probably from a traffic accident. Knife stab wounds may scar in an elliptical fashion, sometimes even with a blunt and a sharp end indicating the position of a single-edged blade. Bullet wound scars may persist – and in 1989, became a matter of political controversy over the identity of Nazi war prisoner Rudolf Hess, who was alleged to have been an imposter because he had no scar from an old rifle bullet wound through the chest. Burns may provide good evidence of identity, especially if they are widespread cicatrices that may have been quite noticeable during life. Many scars on the fronts of the lower legs may indicate the repeated stumblings of a chronic alcoholic, who frequently walks into or falls over furniture.

The age of scars

The age of a scar is very difficult to assess and, once it becomes mature, no change will occur for the rest of the person's life. When a linear wound is inflicted, be it a surgical operation or a knife slash, the edges become mechanically strong within a week, assuming that no infection or haematoma develops. The wound is brownish red at this stage and remains vascular for several months, depending upon its width. The pinkness of contained blood vessels gradually fades and a narrow surgical incision may be white by 4–6 months. The avascular collagen tends to shrink for a year or so, but is white–silver after a year and remains in this state indefinitely. These times are variable depending on the nature of the skin, its pigmentation and the part of the body involved. Where a wound crosses a skin crease that is frequently flexed or extended, it tends to gape and widen, the subsequent scar following suit.

Histology does not contribute much to the examination of scars, except to confirm that a skin mark actually is a scar. Stains for collagen or elastin may confirm the discontinuity in the dermis. Scars do not carry hair follicles, sweat glands or sebaceous glands, though an occasional accessory skin structure may be present as a result of the inclusion of a viable fragment of original skin in an irregular wound – or where surgical repair has detached or invaginated a piece of the margin.

Occupational stigmata

Formerly given prominence in most textbooks, distinctive physical marks of occupation have decreased in incidence and importance. They are still of use in certain areas, but local knowledge of occupations and industries is required. The Victorian days of pen callosities in clerks and shoemaker's kyphosis have gone, but many other occupations have their stigmata, though most are relatively nonspecific. The best known is the 'blue scar' of coal-miners, an involuntary tattoo caused by dust entering small lacerations on the hands and face. Some miners and quarrymen also have small facial scars due to rock splinters scattered during blasting. Steel workers and foundry men may have tiny burn scars on exposed areas from the spattering of hot metal. In more general terms, examination of the hands will indicate whether the deceased was a manual worker or involved in more sedentary occupations. Cuts, scars, callosities and hyperkeratosis of the hands are obvious indicators of rough work.

Internally, black, dust-laden lungs – with or without pneumoconiosis – points to mining, as coal trimmers no longer exist as dock workers. Thickened, pearly plaques on the parietal pleura and diaphragm are caused by exposure to asbestos, though in recent years the widespread use of this substance in so many industries makes it less helpful in identifying the occupation.

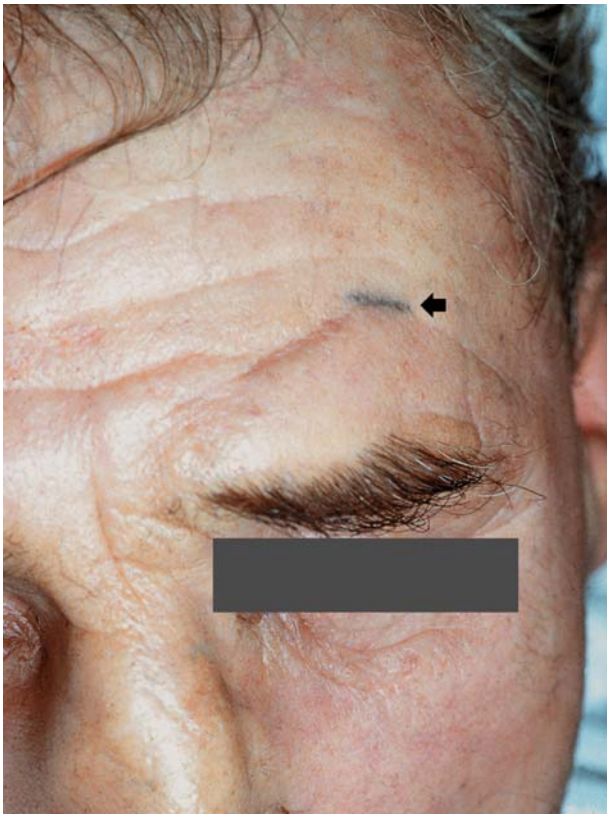

FIGURE 3.3 *Careful external examination may yield evidence that can assist identification. The small 'blue scar' on this forehead establishes that the deceased had been a coal-miner; coal dust enters small lacerations and remains visible after healing. Virtually every coal-worker has such marks on hands or face.*

The stature of an intact body

The stature of a corpse is not necessarily exactly that of the person measured during life. In the mortuary, care must be taken to measure the body from heel to crown, and not to accept the mortuary attendant's or funeral director's 'coffin measurement', which is made from toe to crown. Because of the usual plantar flexion of the foot, this latter height may be as much as 10 cm longer than the heel–crown length.

The height of a dead body may differ from the height during life in either direction, being slightly longer or shorter, though lengthening is much more common. In addition, the measured height may change a little at different periods after death. Because of the complete loss of muscle tone in the first stage of flaccidity, relaxation at large joints, such as the hip and knee, together with the lost tensioning effect of paraspinal muscles on intervertebral discs, the body may lengthen by up to 2–3 cm. Rigor mortis may then replace the muscle tone, shortening the body and tending to flex the legs a little. When rigor passes off and decomposition sets in, joints become lax. Loss of tension in the intervertebral discs tends to shorten the spinal column and hence the total height by a centimetre or so. According to Trotter and Gleser (1958, 1977), the average increase is about 2–5 cm. The errors in getting a really accurate post-mortem length include the difficulty of locating the measuring device exactly at the heel and the crown of the head, as well as fully extending the limbs, spine and neck of a body in rigor.

Determination of sex in non-skeletalized bodies

This is usually obvious and rarely presents problems. The issue of intersex and hermaphroditism is so rare as to be discounted in most forensic practice, except in some areas, such as South-east Asia, where deliberate transsexualism in men, aided by surgical intervention to feminize the genitalia and breasts occurs more frequently. Where this problem arises, expert advice must be sought. In general, the external genitalia remain recognizable until a late stage of putrefaction. In addition, breasts and general body shape, as well as the pattern of pubic hair, reveal the sex. Female pubic hair usually grows low on the abdomen, the upper margin being a horizontal or semicircular edge above the mons veneris. The male pattern rises more in the centre line, sometimes as far as the umbilicus. There are, however, always exceptions to these generalizations. The presence or absence of circumcision should be noted, as it may help in identification of certain ethnic and religious groups such as Jews and Muslims. Naturally it is of assistance here in eliminating only those where the prepuce is present, as many men of other religions are circumcised.

Clothing, hair length, hair style, hair coloration, earrings and other jewellery are no longer the reliable guide to sex that they once were. In certain cultures and religions there are obvious criteria that can assist in the determination of sex, but these are rarely needed as the more apparent anatomical differences can be used. Where putrefaction is advanced, examination of the internal pelvic organs may still reveal unequivocal evidence of sex. Internal viscera are often in better condition than the outside of the body. The uterus is the organ in the body most resistant to decomposition, though the prostate is also quite persistent.

Where almost total dissolution exists, then radiology of the pelvis or the criteria used in skeletal assessment can be used. Cytological examination of cell nuclei may indicate sex where only tiny fragments are available – such as tissue found on a road or rail vehicle where impact with a body is suspected. Usually it is the species rather than the sex that is the first consideration, and this is done by species-specific serology. When sex is to be determined, much depends on the state of preservation. When stained microscopic smears can be prepared or when tissue can be processed for histological sections, then sex-indicating nuclear chromatin may provide a definitive test. The 'drumsticks' of polymorphonuclear leucocytes, and the marginal chromatin masses or 'Barr bodies' in epithelial cells, such as the buccal mucosa, may indicate the sex, but in decomposed material this may be impossible.

The recent remarkable developments in cytogenetics and DNA analysis now give additional powerful tools in sexing and determining the human origin of sub-anatomical fragments, which will partly or wholly replace the older techniques mentioned above.

Other more recent techniques include counting the sex material within the nucleus stained with a fluorescent dye and viewed with ultraviolet light; this may be performed on neurones in a brain smear or in cells from the kidney.

Age of non-skeletalized bodies

Determining the personal age of a corpse is far harder than determining its sex. Ageing a living person can be difficult and a wide margin of error exists, especially as age advances, so the same exercise in a corpse can be expected to be even less exact. Where the body is relatively intact, the usual criteria known to the man in the street are applied to make a general estimate. Hair colour is of general applicability, though every one knows of someone whose hair is grey at 25 or someone who is dark haired at 70. The loss of elasticity in the skin, its thinness and hyperkeratosis and its red Campbell de Morgan spots are indicators of senility. These days teeth are less useful than in the past from the point of view of extractions, clearance, full dentures and oral hygiene, but the general impression remains. The objective determination of age from tooth attrition is a matter for a specialist forensic odontologist (see Chapter 26).

The eyes are useful, in that a grey or white ring around the pupil – the 'arcus senilis' – is rarely seen below 60 years. In infants and children, the height and weight may be compared with standard tables, but developmental defects, disease and malnourishment may introduce considerable errors. Internally, the evolution of degenerative changes such as arterial atherosclerosis and arthritis, may give a general impression, but personal variation is so great that it offers little more than a distinction between 'young' and 'old'. Where a distinction has to be made in a double death between two people of markedly different ages, however, then these generalities may be of considerable use. Up to the age of about 20–25, teeth, ossification centres and epiphyseal fusion are good indicators, but these are described in the section on skeletalized material.

Recent research, aimed mainly at skeletalized bodies but available for any corpse, is the determination of the racemization ratio of amino acids in teeth, as the preponderance of laevo- and dextro-compounds appears to be a function of personal age.

In addition, the Gustafson technique on teeth, described later, is also applicable to a non-skeletalized body, if ageing is important.

Racial and ethnic characteristics

Much of the identification of race depends on common knowledge and recognition of various ethnic traits, and is not primarily a medical problem. Everyone can recognize the deep pigmentation of a West African the epicanthic folds of the Mongoloid races, the red-haired Celt and the pale blond common in Scandinavia. There is a wide and almost continuous range of biological variability, however, not only because of extensive ethnic interbreeding, but also because of marked variations even within a coherent racial group.

In the intact or only partially decomposed body, the following factors may be used as pointers to ethnic classification, but the non-specificity of most of these must always be borne in mind:

- Clothing, ornaments and other associated objects. A vast catalogue can be assembled (such as the string around the wrist in Hindus), but it must be borne in mind that other races may adopt these through choice, marriage or deception.
- Hair texture, style and length and beards. Examples are the hair of the Sikh, the beard of the orthodox Jew, the crinkly hair or 'peppercorn' (clumped growth) of some Negroids, the multiplaiting of Rastafarian West Indians, the straight black hair of Asians and the ginger hair most common in Celtic people. With affected styles and convincing modern coloration and texture alteration, however, these features can be most misleading. Forensic science techniques may be needed to detect and identify bleaching and dyeing changes in hair.
- Physical artefacts include penile and vulval circumcision, nose and ear piercing, lip perforation, tribal facial scars, and earlobe distension in East Africans and some tribes in Sarawak. More bizarre forms, such as neck-stretching by rings, are now rare. Tattoos (mentioned elsewhere) may have an ethnic basis, as in the Ibans of Sarawak.
- Facial appearance is, of course, a major criterion with the high cheek bones and epicanthic folds of the Mongoloid peoples, and the prognathism and nasal differences in Negroid peoples. So many intermediate forms exist, however, such as the Slav and the Polynesian, that only the classic groupings can be identified with confidence.
- Body size gives rise to the same uncertainty, especially as racial differences have lessened with better nutrition in some groups. It is obvious, however, that Japanese are generally smaller than northern Europeans and that in Negroid bone structure the femora are proportionately longer and less curved than those of other races. Teeth are discussed later, but the concave upper central incisors of the Mongoloid races can be helpful on occasions, though they are not absolutely specific.

Finally, skin pigmentation can obviously differentiate the Negroid races from the other main groups, though again there is a continuous range of skin colour. To a lesser extent the slighter melanin content of the skin of Mongoloid races is recognizable, but merges into the variable tints of Semitic, Asian and Mediterranean peoples.

It may well be that, in the near future, genetic DNA studies will revolutionize this aspect of identification. They are also likely to do the same for personal identification.

Identification by DNA characteristics

One of the most revolutionary advances in identification in recent years is the so-called 'DNA profiling or fingerprinting'. This is a technique devised by Alec Jeffreys of Leicester University, in which virtually unique sequences of bases in the DNA strands of chromosomes are used to compare one blood or tissue sample with another, and to investigate genetic relationships. The details of the technique are complex and require highly specialized reagents and apparatus. The method needs highly trained forensic scientists for its application to medico-legal problems. All that the pathologist needs is a basic knowledge of the principles of the technique and how it can be applied in a forensic context.

The deoxyribonucleic acid (DNA) that forms genetic material is composed of two strands of sugar and phosphate molecules that are twisted into a double helix, which is bound together by links formed from adenine and thymine and cytosine and guanine. Each helical twist has ten such links, like rungs on a twisted ladder. A single DNA molecule may have millions of such links and the permutations of the bases in each adjacent link create the genes, the segments of the DNA that carry genetic information. A gene consists of a segment containing some hundreds or thousands of links, but separating these discrete genes are segments that seem to have no genetic function, being redundant. There is about a metre of

DNA in each human nucleus, but only 10 per cent is used for genetic coding, the rest being redundant. Of these silent segments (sometimes called ‘stutters’), there may be 200–14 000 repeats of each identical sequence on each DNA strand.

During investigations into a specific gene (that for synthesizing myoglobin), Jeffreys found that the adjacent redundant segments varied greatly in base sequence, but that they were constant for a given individual and that they were transmitted from parents in a regular fashion. In other words, they formed a ‘signature’ that was virtually unique for every individual person, except identical (uni-ovular) twins, in whom they must be the same as they share the same DNA in the fertilized ovum. The chance of two persons sharing the same sequence is, according to Jeffreys, about one in a million billion. Even among siblings, the chances are only one in ten thousand billion.

To identify the redundant segment (often called the ‘minisatellite’ or ‘hypervariable regions’), a minute amount of human tissue containing nuclear material is required. A small volume of blood containing leucocytes is sufficient, or a semen sample, pulp from a tooth or a hair with some sheath cells at the root. The DNA from the contained nuclear material is broken up into fragments by enzymes called ‘restriction endonucleases’ that cleave the DNA strands at predetermined spots. The fragments are then separated by gel electrophoresis, which spreads the fragments into bands, transferred to nylon or nitrocellulose sheets and subjected to a ‘DNA probe’. This is a single strand of DNA labelled with radioactive phosphorus-32. This latches on to the separated minisatellite fragments and – by microradiography – the position of each band is rendered visible on an X-ray plate.

The end result is a series of parallel bars, similar in appearance to the ‘bar code’ printed on goods in a supermarket. However, more recently the bar pattern from multilocus probes has been supplemented or replaced by simpler patterns from single-locus probes, though the principles remain the same. From the presence of different bars in given positions, comparisons can be made with other samples, so this is a classic forensic technique of comparison. The test is useless without something to be compared with, but the blood on a weapon in the possession of a suspect can be matched with virtually complete confidence against the blood of the victim. Seminal fluid in the vagina of a victim of a murder/rape can be matched against the blood DNA pattern of a suspect – there is no need to match semen against semen, as all the DNA in a given person must, by definition, be identical. A few hair roots found on a blunt instrument in the possession of a suspect from a murder can be matched against the autopsy blood sample. In sexual crime cases, a great advantage of DNA testing over conventional blood-group secretor tests is that DNA can distinguish between mixed semen and vaginal fluids from a swab, which can confuse or negate blood-group techniques.

Another wide medico-legal use is in paternity testing where, unlike blood group, haptoglobin and enzyme tests, a positive identity of parents can be made, rather than a mere exclusion. Every bar in the ‘bar-code’ must have come from either mother or father, half the number from each. In testing, the coding is made from child, mother and father. The bars in the child’s code are first matched with those in the mother’s pattern. The remaining bars then must correspond with those from the father – if not, he cannot be the father.

SAMPLES REQUIRED FOR DNA TESTING

Although amplification techniques, such as polymerase chain reaction (PCR), etc., now allow minute samples to be tested, the larger the sample, the better the chance of a successful DNA test.

Post-mortem material is inferior to live blood and tissue for DNA fingerprinting if any significant post-mortem change has proceeded enough to break down nuclear chromatin. Plain blood samples should be taken, however, though leucocytes may have already disintegrated. Some 5 ml of blood is taken into an EDTA tube, which extracts metallic ions and not only prevents clotting, but inhibits enzymes in blood or micro-organisms, which may break down DNA during storage. The best material is said to be muscle or the spleen and, if decomposition is advancing, the bone marrow is recommended. At least 0.5 g of tissue should be cut from the parenchyma of an organ and placed in a small plastic tube with no fixative or preservative. This should be frozen at −20°C if there is likely to be the slightest delay in transmission to the laboratory.

In sexual offences associated with homicide, as much material as can be obtained from the vagina should be collected, either fluid by pipette or multiple swabs from vagina, rectum and mouth. These again should be frozen if there is more than a few hours delay in transit to the laboratory (see also Appendix 1).

IDENTIFICATION OF SKELETALIZED REMAINS

One of the classic problems of forensic pathology, the identification of a whole or partial skeleton, involves techniques and expertise that span a number of disciplines from anatomy to radiology, from archaeology to dentistry. It often overshadows the equally important need to identify intact or decomposed corpses, but the disproportionate amount of space occupied by skeletal identification in most textbooks can be partly justified by the fact that bones can survive for decades, centuries or millennia, so that the cumulative reservoir of material is vast. As was observed in relation to intact bodies, the procedure for identifying bony remains falls into two distinct sections:

- allotting the bones to general categories based on absolute criteria concerning species, race, sex, stature, age and date
- comparative studies, where the remains are matched against ante-mortem data derived from those people who might be potential victims.

The general categorization of skeletal remains

When objects thought to be skeletal remains are found, the following questions need to be asked and, where possible, answered:

- Are they bones?
- Are they human bones?
- What is the sex?
- What is the stature?
- What is the race?
- What is the age?
- How long have they been dead and/or concealed?
- What was the cause of death?

Are the remains actually bones?

This question is not as facetious as it may seem, as untrained persons may provide objects that falsely resemble bones. The author (BK) has been offered shaped stones, plastic and even hard wood, which were thought to be bones. The mistake is even more common when these objects are mixed with undoubted bones, usually animal in origin, which may be found buried or mingled with rubble.

Recognition is usually easy, by the shape, texture and especially weight of the objects. Greater difficulty may be experienced when simulated human 'bones' are found, such as the 'radius' brought to the author (BK). This originated from a medical student's anatomical skeleton and was made from plaster coated with a plastic polymer. Visually it was indistinguishable from a real bone, but the abnormal lightness indicated the true nature.

Are the bones of human origin?

The recognition of species is important, but deciding on a human origin is usually easy, unless marked fragmentation has occurred. Many animal bones are found by the general public and police who are not qualified to decide whether they are human. Extensive rebuilding programmes and the renovation and demolition of old sites reveal many caches of bones, but in the authors' experience the majority are of animal origin, often originating from butchers' debris.

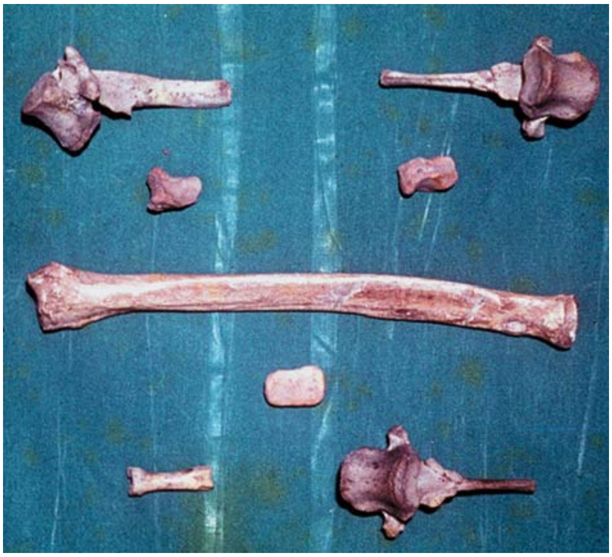

FIGURE 3.4 *All bones are not human – and not all 'bones' are bones. The smaller bones are animal, but the central 'radius' is from an ersatz student skeleton, made from plastic material, but thought by the police to be evidence of a criminal death.*

First, the size is assessed and many small, slender bones excluded on obvious grounds. Even a turkey thigh cannot be mistaken for a metatarsal, nor a beef rib for human. The gross anatomy is then studied, and even if the pathologist makes no pretensions to being a comparative anatomist, the majority of intact animal bones can be recognized from their lack of correspondence to any human bone. Difficulties arise with smaller bones from some animals, especially the hands and feet, where digits, metatarsals and metacarpals require careful study to distinguish them from the human. Several errors have been made in respect of bear paws, which closely resemble the human hand.

When bones are incomplete or fragmentary, the problems escalate rapidly. If the ends of longer bones are present, then their non-human shape may be more readily determined, but cylindrical segments of the central shaft have little in the way of distinguishing features, apart from size. Burnt bone fragments offer similar problems, added to which is the possibility of heat distortion and shrinkage.

The advice of an anatomist is needed in such cases, preferably one with forensic experience and enthusiasm for the project. Unfortunately, every anatomist is not necessarily an osteologist and it may be more effective for the bone to be examined by a pathologist who has both enthusiasm and the relevant reference books.

Histological examination may offer a species differentiation – or at least to exclude a human origin. The Haversian architecture is different in many animals, but the few specialist papers on this subject must be consulted for details.

Where the animal species is relevant to the enquiry, then a veterinary or comparative anatomist must be consulted. If the bones are too fragmentary to provide any anatomical data, then serological investigations must be attempted. These depend on species-specific proteins being extracted from the bone into solution where they can be tested against specific antisera prepared by immunizing animals (usually rabbits) against a range of animal proteins, usually derived from blood. Thus the test is essentially seeking plasma constituents within the bone, the recognition being carried out by techniques such as electrophoresis or gel diffusion. DNA can now identify human tissue, if not the alternative species.

The drawback of such serological tests is that they cannot be applied to bones that no longer have extractable proteins, and these include burnt or cremated bone and bone that has been dead for some years. The length of time for which identifiable protein persists is variable, but a negative result is usually to be expected after 10 years following death, though DNA techniques may be more sensitive.

THE DETERMINATION OF SEX

The accuracy of determination of the sex of skeletal remains varies with the age of the subject, the degree of fragmentation of the bones and biological variability (Table 3.1).

Particularly when studying the skull and pelvis, a subjective impression by the experienced observer defies complete analysis, yet objective measurement may be no more accurate: in other words, the processes comprise morphological traits versus morphometry. The determination of sex is statistically the most important criterion, as it immediately excludes approximately half the population whereas age, stature and race each provide points within a wide range of variables. Obvious sex differences do not become apparent until after puberty, usually in the 15–18-year period, though specialized measurements on the pelvis can indicate the sex even in fetal material. Sex and age are linked, especially where body size and weight are concerned. Similarly, race confuses sexing, for example, the size of the supraorbital ridges in a normal negroid female may exceed those in the average Caucasian male.

TABLE 3.1 *Pfitner's table of bodily dimensions in the female compared with the male (per cent of male dimensions). The common generalization that the female is 94 per cent of the male size varies in different areas of the body*

Stature	93.5	Arm length	91.5
Head breadth	98.0	Sitting height	94.5
Face breadth	94.0	Head circumference	96.0
Face height	90.0	Head height	96.0
Head length	95.5	Leg length	93.0

The accuracy of sexing is hard to estimate, as various loading factors exist. Krogman comments that he scored 100 per cent accuracy using the whole skeleton, 95 per cent on pelvis, 92 per cent on skull, 98 per cent on pelvis plus skull, 80 per cent on long bones and 98 per cent on long bones plus pelvis. He admitted, however, that, as most anatomy department material has a sex ratio of about 15:1 in favour of men, marked bias could be introduced by assigning all doubtful bones to the male category.

Stewart records that, for the whole skeleton, one can expect a 90–95 per cent success rate and for the skull alone only 80 per cent, but, if the mandible is also present, this rises to 90 per cent (Hrdlicka 1939). In general, adult female skeletal measurements are about 94 per cent that of the male of the same race, but different measurements may vary from 91 to 98 per cent.

The skull

The following features develop after puberty and are modified by senility, so are applicable only between about the 20th and the 55th year. Age as well as race has a profound effect.

- **General appearance.** The female skull is rounder and smoother than the rugged male.
- **Size.** Male skulls are larger, with an endocranial volume some 200 ml greater.
- **Muscle ridges** are more marked in male skulls, especially in occipital areas where larger muscles are

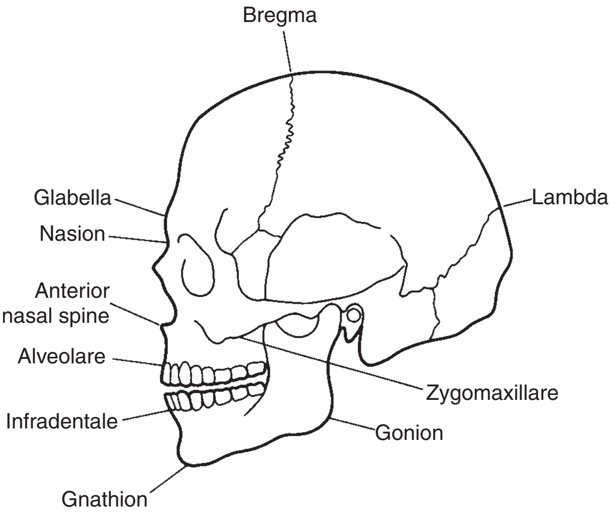

FIGURE 3.5 *Anatomical landmarks of the skull.*

attached to the nuchal crests and in temporal areas for larger masseter and temporalis muscles.

- **Supraorbital ridges** are more marked in male skulls and may be absent in female. The glabella (central forehead eminence above the nose) is small or absent in the female, and prominent in the male, though this is a poor discriminant.
- **Mastoid process.** This is larger in male skulls (see Hoshi).
- **Frontal and parietal eminences.** These are more prominent in female skulls, which resemble the shape in an infant more than in a male.
- **Palate.** This is larger and of a more regular U-shape in men. The smaller female palate tends to be parabolic.
- **Orbits** are set lower on the face in the male skull, with more square and less sharp edges (especially upper edge) than the female.
- **Nasal aperture.** This is higher and narrower in the male skull and has sharper edges. The nasal bones are larger and project further forward to meet at a more acute angle than in the female.
- **Forehead.** This is high and steep in the female skull, with a more rounded infantile contour than the male.
- **Teeth** are smaller in the female skull, molars usually having four cusps. The male often has a five-cusp lower first molar.
- **Zygomatic process.** The posterior ridge projects back beyond external auditory meatus in the male skull. The zygomatic arches bow outward more than the female, where they remain more medial.
- **Mandible.** This is large in the male skull, with a squarer symphysis region. Female jaws are more rounded and

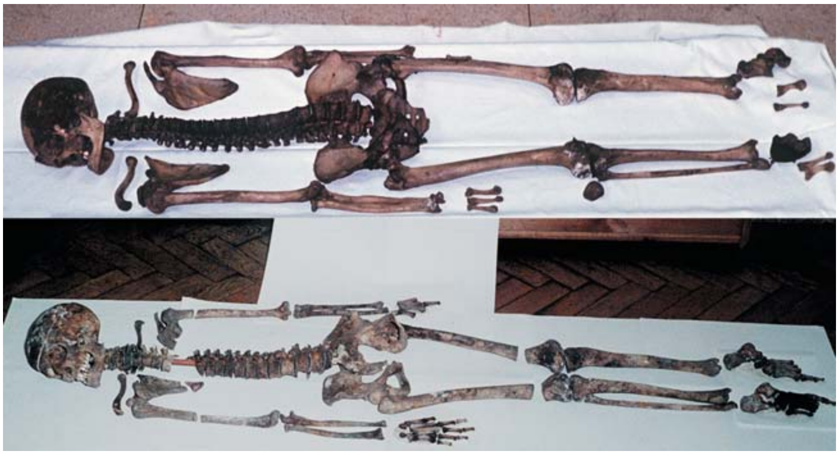

FIGURE 3.6 *Two recovered and reassembled skeletons. After cleaning, the bones should be laid out in correct anatomical position, to gain an approximate direct measure of the stature, allowing as well as possible for lost soft tissue. The upper skeleton, obviously male, shows the frequent loss of small hand and foot bones, but no injuries. The lower remains, from a hidden 40-year-old homicide, reveal that the body was sawn into six sections, there being cuts above the knees and through spine, scapula and humeri.*

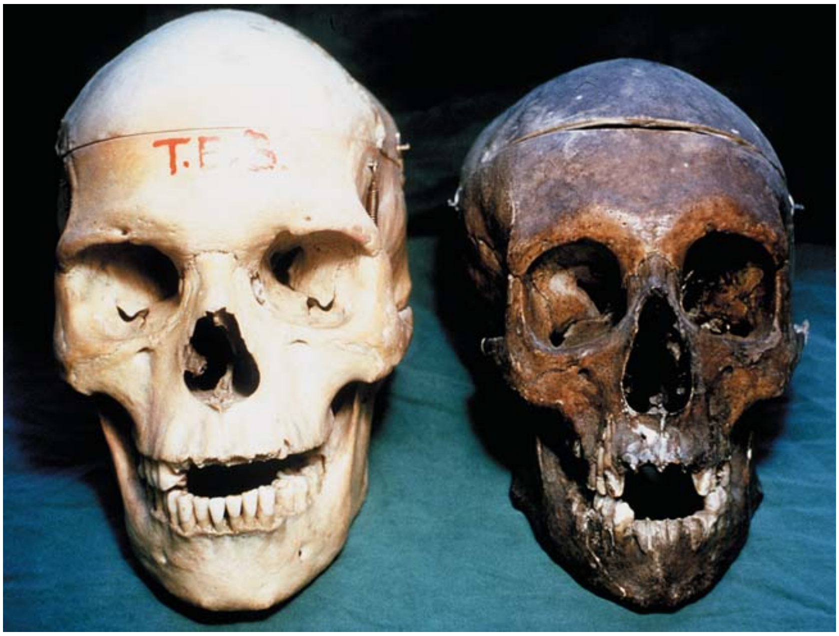

FIGURE 3.7 *Frontal view of male and female skull. The male (left) is larger, more massive and has heavier eyebrow ridges. The chin is squarer and the mandible heavier, The female has relatively larger height orbits, a smoother cranium, and fuller frontal and parietal eminences.*

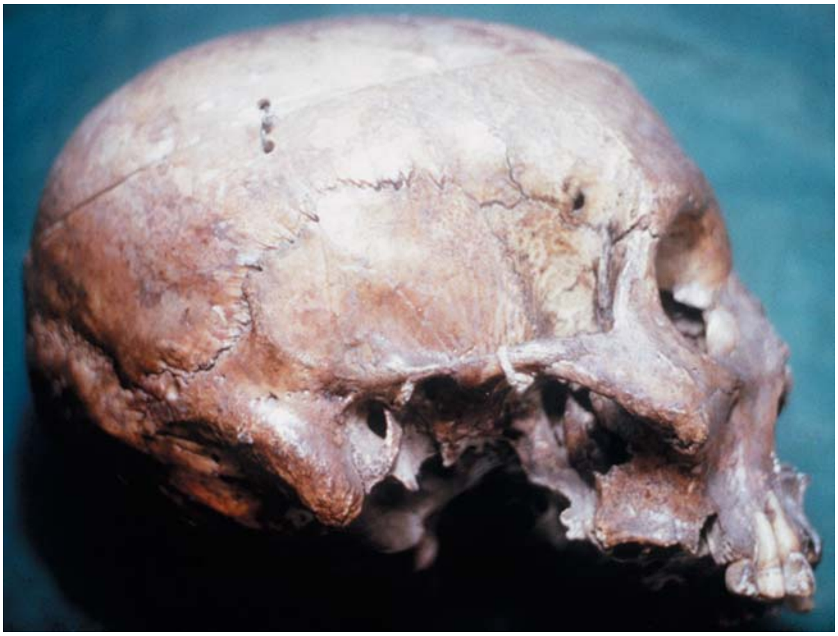

FIGURE 3.8 *A typical male skull, with a sloping forehead and prominent occipital ridges for large muscle attachment. Probably the best male feature is the large mastoid process; also, the zygomatic process extends well behind the auditory meatus.*

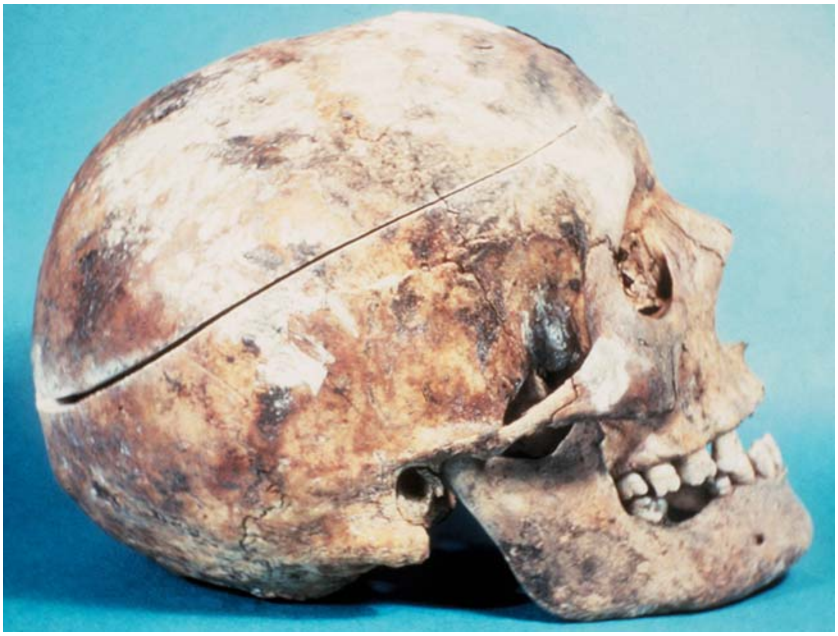

FIGURE 3.9 *A typical female skull, from a murder victim hidden for 40 years in a cave. The cranium is high, round and smooth with insignificant ridges for muscle attachment. The mastoid is tiny, one of the best discriminants. The post-zygomatic ridge does not continue behind the auditory meatus and there are no supraorbital ridges. The chin is round and smooth.*

project less at the anterior point. The vertical height at the symphysis is proportionately greater in the male. The angle formed by the body and the ramus is more upright in the male, being less than 125°. The condyles are larger in the male skull, as is the broader ascending ramus, and there is a more prominent coronoid process.

These sex variations represent the ‘typical’ White and, to a great extent, Asian skull. There is considerable overlap, especially in subjects from the Indian subcontinent, where osteological sex differences are much less marked. The criteria set out above exclude prepubertal and senile persons, and are less valid for those outside the 20–55 age group. For methods of sexing by discriminant function analysis, the work of Giles and Elliot (1963) should be consulted. In recent years craniometry has been applied to sexing the skull and multiple accurate measurements between discrete anatomical points have been used to produce discriminant function analysis. The papers of numerous authors must be consulted for details of this sophisticated and difficult technique that is accurate in 83–88 per cent of cases. The frequency of correct sexing is no greater than more subjective methods, but commands a greater degree of confidence level in respect to its accuracy.

Sex characteristics in the pelvis

The post-pubertal female pelvis is wider and shallower than the rather upright male girdle to allow for the passage of the fetus during childbirth. Though as always there is an overlap of the appearance and measurements in the least characteristic individuals, the usual variations are sufficient to allow sexing of the adult pelvis to be made with about a 95 per cent confidence rate (see work by Genovés). In the pelvis, unlike the skull, there are differences, albeit subtle, in immature (even fetal) pelves that allow sexual differentiation. The following features provide the most useful criteria. One must not be used in isolation, however; as many as possible must be assessed together. Sex features are independent of each other and one may even contradict the other in the same pelvis. It is often a first subjective impression by an experienced eye that determines the answer, though where the sex differences are slight, careful measurements may be needed to resolve the problem.

As in the skull, the male pelvis is more rugged because of the attachment of stronger muscles. It stands higher and more erect than the smoother, flatter, female pelvic girdle. The subpubic angle, measured at the medial intersection of two lines drawn along the best approximation of the lower border of both inferior pubic rami, approaches 90° in the female pelvis, but usually about 70° in the male.

This is often a subjective measurement, however and depends in turn upon the shape of the pubic bone itself. When the line of the inferior ramus is projected medially and intersected with a horizontal line laid across the upper border of the superior ramus, the reverse size of angle is seen, the male being wider than the female.

The body of the pubic bone, the block lateral to the symphysis, tends to be triangular in shape in the male, whilst the female pubis is more rectangular (Phenice 1969; Iscan and Derrick 1984). Certain sexual variations in the pubis have been used by Phenice. In the female these are:

- a bony ridge ('ventral arc') running down the ventral surface from the pubic crest
- a concavity of the lower margin of the inferior pubic ramus immediately lateral to the lower border of the symphysis

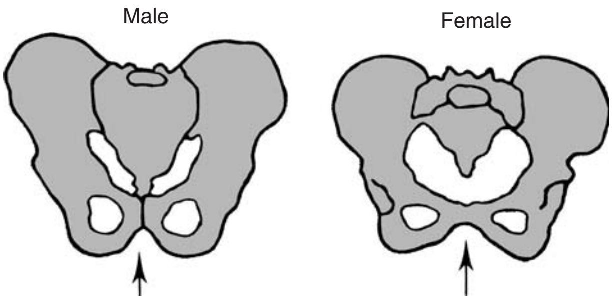

FIGURE 3.10 *Sex differences in the human pelvis. The most noticeable features are the narrower suprapubic angle and the higher iliac blades in the male pelvis.*

- a ridge of elevated bone on the medial aspect of the ischiopubic ramus, immediately lateral to the symphysis; in the male this area is broad and flat.

The 'ischiopubic index' devised by Washburn may be helpful, in which the pubic length (×100) is divided by the ischial length. The measurements must be carefully made, the pubic length being from the plane of the symphysis to the reference point in the acetabulum and the ischial length being from the same point to the most distal edge of the ischium. The reference point is the site of fusion of the three elements of the immature innominate bone, usually marked by a notch in the articular surface of the acetabulum (Schultz 1937). If the ischiopubic index (in White races) is less than 90, the pelvis is male; if over 95, it is female. The acetabulum is larger in the male, being an average of 52 mm in diameter, compared with 46 mm in the female. The male joint cup also faces more laterally than that of the female, which tends to look more forward. Naturally, acetabular size is related to that of the femoral head, which will be considered later. The greater sciatic notch is an important criterion, being deep and narrow in the male, wide and open in the female. The angle formed by the margins approaches closer to a right angle in the woman than it does in the man. Harrison (1968) and Hrdlicka (1939) both felt that the greater sciatic notch was one of the best discriminants for sex, the latter claiming a 75 per cent success rate using this criterion alone.

The obturator foramen is somewhat ovoid in the male, but triangular in the female. The pre-auricular sulcus, which marks the attachment of the anterior sacroiliac ligament, lies just lateral to the sacroiliac joint and is usually well marked in women but often absent in males. The pelvic inlet, looked at from above, is more circular in the female, the male being heart-shaped as a result of the protrusion of the sacrum into the posterior brim (Greulich and Thomas 1938). A number of other pelvic 'indices' have been devised by various authors (see, for example, the work of Turner, Greulich and Thomas, Caldwell and Molloy, Straus, and Derry).

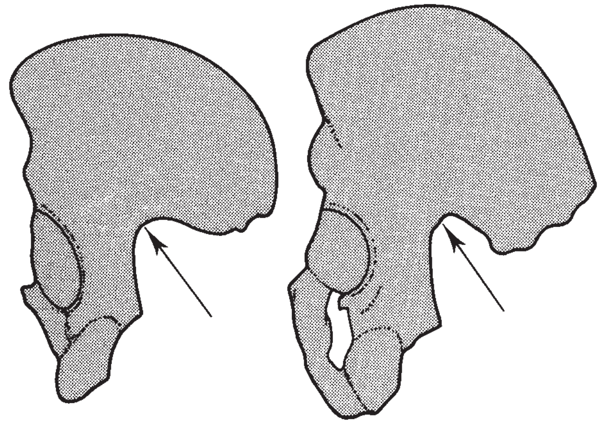

FIGURE 3.11 *The greater sciatic notch is narrower in the male innominate bone.*

Sex characteristics in the sacrum

The sacrum is functionally part of the pelvis and shares in its sex variations. The female sacrum is wide and has a shallow curve, again related to the larger pelvic canal for childbirth. It is shorter in the female and the curve is limited almost entirely to that distal part below the centre of the third sacral vertebra. The male sacrum may have more than five segments, which is rare in the female. The curve in the male is continuous down the whole bone and there may even be a slight forward projection of the coccyx. Fawcett (1938) compared the transverse diameter of the first sacral vertebra (CW) with that of the base of the sacrum (BW). The formula CW × 100/BW averaged 45 in the male and 40 in the female. Kimura (1982) has developed a 'base wing index', where the relative widths of the wing and base provide discriminant function coefficients for sex determination.

Sexing from the long bones

The femur is the most useful, its length and massiveness themselves being significant. There is, as usual, considerable overlap of all long-bone sex characteristics, but Brash's series showed that the maximum (oblique) length in the male femur was around 459 mm, while that of the female was only 426 mm. Other figures from Pearson and Bell (1917) suggested mean values of 447 mm for men and 409 mm for women. Using the trochanteric oblique length, they suggested a range of 390–405 mm for women and 430–450 mm for men, though there was the usual overlap in the middle. Race and nutrition (which is related to the era and the place in which the samples were obtained) must be allowed for in such measurements.

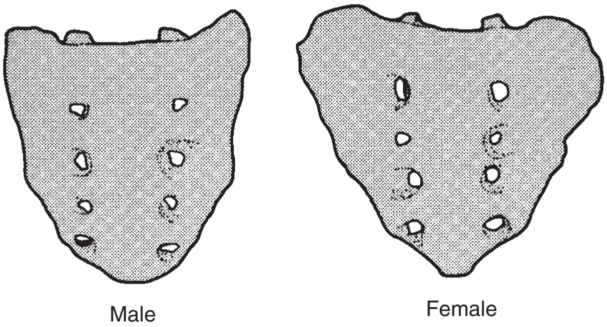

FIGURE 3.12 *The variation in shape of the male and female sacrum. The female is broader and more triangular.*

TABLE 3.2 *Dwight's table for sexing from humeral and femoral head diameters (in mm)*

	Vertical humeral	Transverse humeral	Vertical femoral
Female	42.67	36.98	43.84
Male	48.76	44.66	49.68
Difference	6.09	5.68	5.84

TABLE 3.3 *Pearson and Bell's table for the 'mathematical sexing of the femur'. The area of uncertainty extends in increasing degrees of confidence outwards from the central column to the more definite limits on each side. Measurements are given in millimetres*

	Male	Male or female	Female
Vertical diameter of head	>45.5	43.5–41.5	<41.5
Popliteal length	>145	114–132	<106
Bicondylar width	>78	74–76	<72
Oblique trochanteric length	>450	405–430	<390

The size of the femoral heads is claimed to be a better discriminant of sex, the vertical diameter being said by Pearson and Bell to be greater than 45 mm in the male and less than 41 mm in the female, though again there is an overlap in the distribution curves around the 43 mm size (Table 3.2). Maltby (1917), however, measured 43–56 mm in the male and 37–46 mm in the female. Femoral head size is part of Pearson's 'mathematical sexing of the femur', which incorporates several measurements (Table 3.3). Dwight (1904) studied the size of both femoral and humeral heads, claiming that they were more useful than bone length. Once again, discriminant function sexing has been carried out, using a number of measurements. Details should be sought in the work of Black and of Iscan and Miller-Shaivitz.

Another sex trait in the femur is the angle that the shaft makes with the vertical. Because the pelvis is relatively wider in the female, the shafts have to slope more to converge at knee level, so that the condyles at the lower end of

TABLE 3.4 *Long-bone lengths (mm) in White men and women of different stature*

Men							**Women**						
Humerus	**Radius**	**Ulna**	**Stature**	**Femur**	**Tibia**	**Fibula**	**Humerus**	**Radius**	**Ulna**	**Stature**	**Femur**	**Tibia**	**Fibula**
295	213	227	1530	392	319	318	263	193	203	1400	363	284	283
298	216	231	1552	398	324	323	266	195	206	1420	368	289	288
302	219	235	1571	404	330	328	270	197	209	1440	373	294	293
306	222	239	1590	410	335	333	273	199	212	1455	378	299	298
309	225	243	1605	416	340	338	276	201	215	1470	383	304	303
313	229	246	1625	422	346	344	279	203	217	1488	388	309	307
316	232	249	1634	428	351	349	282	205	219	1497	393	314	311
320	236	253	1644	434	357	353	285	207	222	1513	398	319	316
324	239	257	1654	440	362	358	289	209	225	1528	403	324	320
328	243	260	1666	446	368	363	292	211	228	1543	408	329	325
332	246	263	1677	453	373	368	297	214	231	1556	415	334	330
336	249	266	1686	460	378	373	302	218	235	1568	422	340	336
340	252	270	1697	467	383	378	307	222	239	1582	429	346	341
344	255	273	1716	475	389	383	313	226	243	1595	436	352	346
348	258	276	1730	482	394	388	318	230	247	1612	443	358	351
352	261	280	1755	490	400	393	324	234	251	1630	450	364	356
356	264	283	1767	497	405	398	329	238	254	1650	457	370	361
360	267	287	1785	504	410	403	334	242	258	1670	464	376	366
364	270	290	1812	512	415	408	339	246	261	1692	471	382	371
368	273	293	1830	519	420	413	344	250	264	1715	478	388	376

Modified by Krogman and Iscan (1986) from Hrdlicka (1939).

the femur sit horizontally on the tibial plateau. Thus when a female femur is seated on its condyles on a flat surface, the angle the shaft makes with that surface is of the order of 76°, while a male bone is more upright, the angle being around 80°. The angle of the neck on the shaft of the femur (the 'collodiaphyseal angle') was studied by Godycki (1957), the results suggesting that a bone with an angle of less than 40° had an 85 per cent chance of being male, while if the angle exceeded 50°, there was a 75 per cent chance of it being from a female (Table 3.4).

Most workers have worked with dry bone specimens; when methods using fresh bone are used, allowance must be made for articular cartilage where relevant. For example, the vertical diameter of a femoral head is 3 mm less in the dried specimen.

Sex determination from other bones

The sternum may be helpful in that the length of the manubrium in the female may equal or exceed half the length of the body, while the manubrium of the male is less than half the body length (Table 3.5). This was claimed in the nineteenth century by Hyrtl, but was denied by Krogman and by Dwight. The latter claimed that the ratio of manubrium: body was 52:100 in women and 49:100 in men, a poor discrimination. However, the method has been rehabilitated by Iordanidis (1961), who alleged a success rate of 80 per cent using the sternum alone. Stewart and McCormick (1983) used a radiographic technique and claimed total accuracy in stating that a sternal length of less than 121 mm must be female and over 173 mm must be male.

TABLE 3.5 *Sex determination from the sternum. Mean (range) lengths of manubrium and sternal body (mm)*

	Male	**Female**
Manubrial length	51.7 (41–73)	48.4 (39–61)
Body length	95.4 (74–122)	78.6 (59–95)
Combined length	147 (131–180)	127 (107–140)

Taken from Jit *et al.* (1980) North Indian population.

The scapula has been studied extensively, but mostly in relation to age. There are relatively poor sex variations in the vertical diameter of the glenoid cavity: the threshold, according to Dwight, is 36 mm, those smaller being female. Iordanidis made an extensive study of scapular measurements and concluded that scapular height was the best discriminant, the male usually being greater than 157 mm, the female less than 144 mm.

The humerus, radius and ulna yield little helpful sexing evidence, apart from overall size. The presence of a perforated olecranon fossa at the lower end of the humerus occurs more often in females and more commonly on the left side, there being a 3.7:1 ratio compared with males. Godycki studied this and other characteristics of the arm bones as sex determinants, but their value is poor.

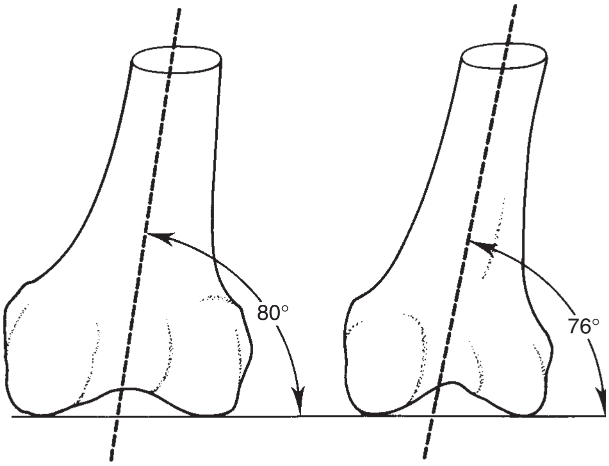

FIGURE 3.13 *Determination of sex of femur by angulation of the shaft. The condyles are set on a flat surface and the angle of the shaft measured. Because of the greater tilt caused by the relatively wider pelvis, the female angle is usually less than 80°.*

There are many reports on sexing from limb and girdle bones and the best approach seems to be a multiple assessment using the data for discriminant function analysis.

Evidence of pregnancy from the skeleton

More accurately, parturition causes some changes in the pelvis as a result of the local trauma of childbirth, which is reinforced by multiple pregnancies. These include 'pubic scars' from the tearing of tendon insertions and periosteum around the pubic bone. The dorsal pubic surface and the pre-auricular sulcus are best indicators, but most authorities agree that it is not possible to determine the number of births from osteological appearances. The papers of Angel and of Ullrich are most useful in this respect.

ESTIMATION OF STATURE FROM SKELETAL REMAINS

When a full skeleton is available, then obviously direct measurement of the correctly assembled bones will give the original height within a few centimetres. Allowance has to be made during assembly, however, for the loss of cartilage in joint spaces and especially for missing intervertebral discs. The accuracy achieved with direct measurement is not great, in that even with an intact body there can be a lengthening of up to 2.5 cm compared with the live height. The skeleton needs scalp and heel soft tissue thickness added – and with the obvious uncertainty about the cumulative allowances for disc thickness and joint cartilage, it is unrealistic to expect accuracy of less than about 4–8 cm compared with the living height.

When incomplete skeletal material is available, calculations have to be made on the basis of one or more bones. Where possible, all available bones should be used and a consensus of results assessed, though the accuracy derived from different bones varies and the result from – say, a femur – is more reliable than that from an ulna. The descending order of usefulness is: femur, tibia, humerus, radius.

Many formulae have been constructed for the determination of stature from the length of long bones. The following cautions must be appreciated before they are used:

- The tables were constructed from differing ethnic groups and at different times, so that racial and nutritional factors introduce significant variations. The table most appropriate to the bones under investigation should be used, though by definition the exact provenance of these bones may be unknown, even including their ethnic origins.
- There is a marked sex difference in stature estimation and ageing of the person also reduces stature relative to long bone length. Trotter and Gleser (1958) found in 855 bodies that there was a 1.2 cm loss of height for each two decades of age over the age of 30, a loss of height equivalent to about 0.6 mm a year after the fourth decade. The same investigation showed that the length of the cadaver was about 2.5 cm longer than the known height during life. The maximum stature (at least in American men) was found in 1951 to be reached at the age of 23 years, a change from earlier estimates in which the peak was found to occur between 18–21 years of age.
- The bone lengths must be measured in exactly the same way as that used by the author of the tables.
- Old dry bones are slightly shorter than recent material, even when one excludes the loss of articular cartilage. Telkkä (1950) stated that 2 mm must be deducted from the length of fresh bone before the calculation is made, as most tables are based on dried skeletons. These differences, however, are slight compared with the greater errors likely if incorrect measuring methods are employed.
- There are inbuilt errors, which are expressed in the formulae. These standard errors are given as 'plus or minus' a certain figure, which applies only when the length of the bone is near the mean of the usual range of length for that particular bone. When the bone is near the extremes of the range (that is from a very tall or very short person), then the standard deviation must be doubled in order to stay within the same range of confidence of accuracy. The same holds good if the tables used are not from the same ethnic group as those

Table 3.6 *The stature tables of Trotter and Gleser. The upper table represents their original 1952 figures, the lower their modification of 1977, as quoted by Krogman and Iscan (1986)*

Male Whites	**Male Negroes**
Stature = 63.05 + 1.31 (femur + fibula) ± 3.63 cm	Stature = 67.77 + 1.20 (femur + fibula) ± 3.63 cm
Stature = 67.09 + 1.26 (femur + tibia) ± 3.74 cm	Stature = 71.75 + 1.15 (femur + tibia) ± 3.68 cm
Stature = 75.50 + 2.60 fibula ± 3.86 cm	Stature = 72.22 + 2.10 femur ± 3.91 cm
Stature = 65.53 + 2.32 femur ± 3.94 cm	Stature = 85.36 + 2.19 tibia ± 3.96 cm
Stature = 81.93 + 2.42 tibia ± 4.00 cm	Stature = 80.07 + 2.34 fibula ± 4.02 cm
Stature = 67.97 + 1.82 (humerus + radius) ± 4.31 cm	Stature = 73.08 + 1.66 (humerus + radius) ± 4.18 cm
Stature = 66.98 + (humerus + ulna) ± 4.37 cm	Stature = 70.67 + 1.65 (humerus + ulna) ± 4.23 cm
Stature = 78.10 + 2.89 humerus ± 4.57	Stature = 75.48 + 2.88 humerus ± 4.23 cm
Stature = 79.42 + 3.79 radius ± 4.66	Stature = 85.43 + 3.32 radius ± 4.57 cm
Stature = 75.55 + 3.76 ulna ± 4.72	Stature = 82.77 + 3.20 ulna ± 4.74 cm

Female Whites	**Female Negroes**
Stature = 50.12 + 0.68 humerus + 1.17 femur + 1.15 tibia ± 3.51 cm	Stature = 56.33 + 0.44 humerus – 0.20 radius + 1.46 femur + 0.86 tibia ± 3.22 cm
Stature = 53.20 + 1.39 (femur + tibia) ± 3.55 cm	Stature = 58.54 + 1.53 femur + 0.96 tibia ± 3.23 cm
Stature = 53.07 + 1.48 femur + 1.28 tibia ± 3.55 cm	Stature = 59.72 + 1.26 (femur + tibia) ± 3.28 cm
Stature = 59.61 + 2.93 fibula ± 3.57 cm	Stature = 59.76 + 2.28 femur ± 3.41 cm
Stature = 61.53 + 2.90 tibia ± 3.66 cm	Stature = 62.80 + 1.08 humerus + 1.79 tibia ± 3.58 cm
Stature = 52.77 + 1.35 humerus + 1.95 tibia ± 3.67 cm	Stature = 72.65 + 2.45 tibia ± 3.70 cm
Stature = 54.10 + 2.47 femur ± 3.72 cm	Stature = 70.90 + 2.49 fibula ± 3.80 cm
Stature = 54.93 + 4.74 radius ± 4.24 cm	Stature = 64.67 + 3.08 humerus ± 4.25 cm
Stature = 57.76 + 4.27 ulna ± 4.20 cm	Stature = 75.38 + 3.31 ulna ± 4.83 cm
Stature = 57.97 + 3.36 humerus ± 4.45 cm	Stature = 94.51 + 2.75 radius ± 5.05 cm

White males	SE	**Black males**	SE
3.08 Humerus + 70.45	4.05	3.26 Humerus + 62.10	4.43
3.78 Radius + 79.01	4.32	3.42 Radius + 81.56	4.30
3.70 Ulna + 74.05	4.32	3.26 Ulna + 79.29	4.42
2.38 Femur + 61.41	3.27	2.11 Femur + 70.35	3.94
2.52 Tibia + 78.62	3.37	2.19 Tibia + 86.02	3.78
2.68 Fibula + 71.78	3.29	2.19 Fibula + 85.65	4.08
1.30 (Femur + Tibia) + 63.29	2.99	1.15 (Femur + Tibia) + 71.04	3.53
1.42 Femur + 1.24 Tibia + 59.88	2.99	0.66 Femur + 1.62 Tibia + 76.13	3.49
0.93 Humerus + 1.94 Tibia + 69.30	3.26	0.90 Humerus + 1.78 Tibia + 71.29	3.49
0.27 Humerus + 1.32 Femur+ 1.16 Tibia + 58.57	2.99	0.89 Humerus – 1.01 Radius + 0.38 Femur + 1.92 Tibia + 74.56	3.38

White females	SE	**Black females**	SE
3.36 Humerus + 57.97	4.45	3.08 Humerus + 64.67	4.25
4.74 Radius + 54.93	4.24	3.67 Radius + 71.79	4.59
4.27 Ulna + 57.76	4.30	3.31 Ulna + 75.38	4.83
2.47 Femur + 54.10	3.72	2.28 Femur + 59.76	3.41
2.90 Tibia + 61.53	3.66	2.45 Tibia + 72.65	3.70
2.93 Fibula + 59.61	3.57	2.49 Fibula + 70.90	3.80
1.39 (Femur + Tibia) + 53.20	3.55	1.26 (Femur + Tib) + 59.72	3.28
1.48 Femur + 1.28 Tibia + 53.07	3.55	1.53 Femur + 0.96 Tibia + 58.54	3.23
1.35 Humerus + 1.95 Tibia + 52.77	3.67	1.08 Humerus + 1.79 Tib	3.58
0.68 Humerus + 1.17 Femur + 1.15 Tibia + 50.122	3.51	0.44 Humerus – 0.20 Radius + 1.46 Femur + 0.86 Tibia + 56.33	3.22

All lengths are in centimetres, valid only for Americans between 18 and 30 years of age. Femur and tibia are maximum lengths. SE, standard error.

being estimated. Krogman indicated that a 95 per cent confidence rate applies only if twice the standard error is accepted each side of the favoured height – in an average man, this means a latitude of over 12 cm, which is too great to be of much use in identification.

Of the many available systems of calculation, those of Trotter and Gleser are most widely used, being based on Caucasian and Negroid Americans from the 1950s (Table 3.6). Older tables include those of Rollet whose measurements of French people were later reworked by Manouvrier and

TABLE 3.7 *Pearson's (1899) regression tables for calculating stature from dried long bones*

S = 81.306 + 1.880 Femur	S = 72.844 + 1.945 Femur
S = 70.651 + 2.894 Humerus	S = 71.475 + 2.754 Humerus
S = 78.664 + 3.378 Tibia	S = 74.774 + 2.352 Tibia
S = 85.925 + 3.271 Radius	S = 81.224 + 3.343 Radius
S = 71.272 + 1.159 (F + T)	S = 69.154 + 1.126 (F + T)
S = 71.441 + 1.220 F + 1.080 T	S = 69.561 + 1.117 F + 1.125 T
S = 66.855 + 1.730 (H + R)	S = 69.911 + 1.628 (H + R)
S = 69.788 + 2.769 H + 0.1958	S = 70.542 + 2.582 H + 0.2818
S = 68.397 + 1.030 F + 1.557 H	S = 67.435 + 1.339 F + 1.027 H
S = 67.049 + 0.913 F + 0.600 T	S = 67.467 + 0.782 F + 1.120 T

TABLE 3.9 *Telkkä's table for calculating stature of Finnish men and women*

Men	SE	Women	SE
169.4 + 2.8 (Humerus – 32.9)	5.0	156.8 + 2.7 (Humerus – 30.7)	3.9
169.4 + 3.4 (Radius – 22.7)	5.0	156.8 + 3.1 (Radius – 20.8)	4.5
169.4 + 3.2 (Ulna – 23.1)	5.2	156.8 + 3.3 (Ulna – 21.3)	4.4
169.4 + 2.1 (Femur – 45.5)	4.9	156.8 + 1.8 (Femur – 41.8)	4.0
169.4 + 2.1 (Tibia – 36.6)	4.6	156.8 + 1.9 (Tibia – 33.1)	4.6
169.4 + 2.5 (Fibula – 36.1)	4.4	156.8 + 2.3 (Fibula – 32.7)	4.5

by Pearson and quoted in a review by Hrdlicka (1939). Pearson allowed a standard addition of 2.5 cm to compensate for the difference between dead and living height (Table 3.7). More modern tables include those of Dupertuis and Hadden (1951) and Trotter and Gleser (1958), from American subjects. The latter used casualties from World War II and later from the Korean War to construct their tables (Table 3.8). Other calculation systems include Breitinger (1937; Germans), Telkkä (Finns) (Table 3.9), Allbrook (1961; African Negroids and English), Shiati (1983; Chinese), Mendes-Correa (1932; Portuguese) and Stevenson (1929; Chinese). Modern critics of the accuracy of the estimation of stature from long bones include Wells (1959), who suggested that even the preferred method of Trotter and Gleser has less accuracy than is generally acknowledged.

Estimation of stature from bones other than the major limb bones is far more inaccurate. Measuring the spinal column (from the tip of the odontoid to the bottom of the fifth lumbar vertebra) has been used by Krogman and by Dwight; Fully and Pineau (1960) used the spine plus a long bone. Tibbetts (1981), in his more modern study on the spine, measured 23 individual vertebrae and produced a regression formula for both men and women. However, the results were far superior when long bones were used. Others have employed the clavicle (Jit and Singh 1956) and the scapula (Olivier 1969).

The use of fragmentary bones and those immature bones from which the epiphyses have been lost have been studied, the survey by Krogman and Iscan being the best account of the techniques employed by researchers such as Steele and McKern (1969) and Muller (1935). The estimation of the heights of infants and fetuses is even more difficult when working with skeletal material, as substantial parts of these bones may be detached and missing because of non-fusion of epiphyses and non-appearance of ossification centres. Mehta and Singh (1972) have specifically addressed this problem, as well as others summarized by Krogman and Iscan (1986).

ESTIMATING THE SUBJECT'S AGE FROM SKELETAL STRUCTURES

The age of the subject at death is usually more important than the stature and rivals the sex as the most vital indication

TABLE 3.8 *Dupertuis and Hadden's (1951) tables for estimating stature from bones. The length of the bones (measured in centimetres according to the authors' criteria) is multiplied by the factor in the table and added to the constant in the right hand column to give the body length (cm)*

Men	cm	Women	cm
2.238 (Femur)	+ 69.089	2.317 (Femur)	+ 61.412
2.392 (Tibia)	+ 81.688	2.533 (Tibia)	+ 72.572
2.970 (Humerus)	+ 73.570	3.144 (Humerus)	+ 64.977
3.650 (Radius)	+ 80.405	3.876 (Radius)	+ 73.502
1.225 (Femur + Tibia)	+ 69.294	1.233 (Femur + Tibia)	+ 65.213
1.728 (Humerus + Radius)	+ 71.429	1.984 (Humerus + Radius)	+ 55.729
1.422 (Femur) + 1.062 (Tibia)	+ 66.544	1.657 (Femur) + 0.879 (Tibia)	+ 59.259
1.789 (Humerus) + 1.841 (Radius)	+ 66.400	2.164 (Humerus) + 1.525 (Radius)	+ 60.344
1.928 (Femur) 0.568 (Humerus)	+ 64.505	2.009 (Femur) + 0.566 (Humerus)	+ 57.600
1.442 (Femur) + 0.931 (Tibia) + 0.083 (Humerus) + 0.480 (Radius)	+ 56.006	1.544 (Femur) + 0.764 (Tibia) + 0.126 (Humerus) + 0.295 (Radius)	+ 57.495

of identity. The estimation of skeletal age falls into various groups, which have marked differences in both method and accuracy. In general, the greater the personal age the less the confidence quotient. There are many publications on the subject, many of them arising from archaeological rather than forensic interest, as the age structure of a skeletal population is of great interest to social anthropologists and historians.

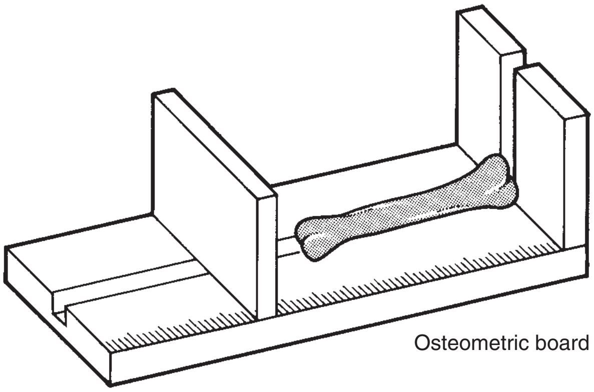

FIGURE 3.14 *Osteometric board for accurate measurement of bone length. There is a central slot in the headboard to accommodate the tibial head spines.*

The fetus and young infant

It is more usual to have to estimate fetal and neonatal age on the intact dead body, rather than the skeleton, as the immature bones are so easily dispersed, lost and destroyed compared to the more robust bones of older subjects. Both in archaeology and forensic pathology, however, such fetal and immature remains are sometimes present.

The major dating indices are the appearance of ossification centres in growing cartilage but, as stated above, these are rarely available in dried bones as the cartilage disintegrates within weeks or months and small ossification centres – both in diaphyses and epiphyses – rarely survive. The bones have to be examined with the cartilage still attached to offer much hope of ageing the remains. Radiology may provide more information than visual inspection.

Specialized books such as the classics by Fazekas and Kosa, Krogman and Iscan, and by Stewart and the numerous papers and monographs on the subject (a selection of which are listed at the end of this chapter) must be consulted where fetal issues are complex and important. Once again the help of interested anatomists and radiologists can be invaluable, especially as biological variation poses a constant trap for the inexperienced who slavishly follow printed tables without the knowledge to appreciate their limitations. Stewart has

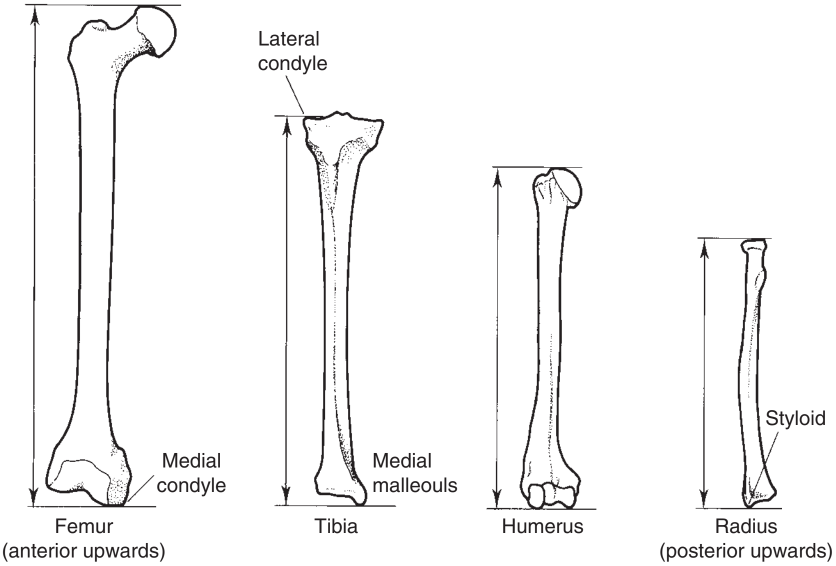

FIGURE 3.15 *Dimensions of dried bones for estimations of stature (Trotter and Gleser, Dupertuis and Hadden). The right side bone is used for preference.* ***Femur:*** *With the bone lying anterior surface upwards, the maximum length is measured from the medial condyle to the most proximal part of the head.* ***Tibia:*** *Maximum length between tip of medial malleolus and face of lateral condyle. The intercondylar eminence is not included.* ***Humerus:*** *Maximum overall length from the posterior margin of the trochlea to the upper edge of the head.* ***Radius:*** *From the tip of the styloid process to the head, lying with the posterior surface upwards. All bones should be measured either with an osteometric board or, if one is not available, on a flat bench with the maximum lengths taken between two vertical, parallel boards placed in contact with the bone ends. If the bones are not dry, but have articular cartilage in place, the following should be subtracted from the measured length before applying the formulae (Boyd and Trevor): radius and humerus 3 mm each, tibia 5 mm and femur 7 mm.*

produced a useful nomogram that relates fetal femoral length to crown–rump length and hence to approximate gestational age. Teeth are discussed in Chapter 26. Fazeka and Kosa's book is particularly useful to the pathologist (as bone lengths, etc. are directly related to fetal and infant age), as are the profuse illustrations.

Skeletal age in the child and young adult

There is no break in the methods used for the fetus and small infant and the older child and young adult. The appearance of ossification centres is complete by around 5 years and after this stage the fusion of epiphyses acts as a calendar up to the age of about 25, when the medial clavicular epiphysis is usually the last evidence of such fusion.

Lists and diagrams such as those shown here are the usual method of tracing the maturity of the skeleton. Several cautionary points must be appreciated and where possible the advice of a radiologist be obtained if there are important issues at stake. The paper by McKern and Stewart gives a valuable commentary on personal variation in skeletal age determination (Table 3.10).

- Maturity is not synonymous with calendar age. There are both sexual, racial, nutritional and other biological variations.
- Females are almost always in advance of males, and maturity tends to be accelerated in hotter climates, though the latter may be tempered by nutritional disadvantages.
- There is a marked range of closure dates in epiphyseal union, and the year suggested in some charts is merely the midpoint of that range.
- Union is a process, not an event. It may be different radiologically from gross inspection; it may also be slow in completion, so that it may be difficult to pinpoint a date that is needed to refer to published data. An example is the one that is usually the last to fuse, the medial end of the clavicle, which may slowly close during any period from about 18 to 31 years. Finally, as emphasized by Krogman and Iscan, multiple criteria of skeletal age should be used, dependence not being placed upon any single measurement.

Skeletal ageing in later years

The eruption of the third molar teeth and the fusion of the last epiphysis occurs approximately in the middle of the third decade. This is a watershed in skeletal dating, as the more objective markers of age are almost all on the younger side of this time. From around 25 years until old age, there are no dramatic events such as tooth eruption or the appearance of ossification centres. There are more subtle changes available for specialized interpretation, but the general decline through middle age to senility prevents assessment of age to within the nearest half-decade.

The major advances in this difficult period have been the use of the pubic symphysis and sternal ribs and the radiology of cancellous bone. However, dental technology may further refine the assessment of age.

Pubic symphysis and age

The opposing faces of the two pubic bones have been extensively studied by Todd (1920, 1921), by McKern and Stewart (1957) and by Gilbert and McKern (1973), who related the changing topography of the symphyseal faces to age. The technique is complex and requires bones that are free of cartilage, but not so eroded by drying and damage that the surface features are blurred.

ASSESSMENT OF AGE FROM THE MALE PUBIC SYMPHYSIS

As always, the details given in the original publications should be studied and practice gained by examining bones of known age. The method as originally devised by Todd has been radically modified by McKern and Stewart so that the technique is now the most useful in assessing the age of post-mature material. It must be noted that their method applies only to males and was not applied to female material until the work of Gilbert and McKern.

In summary, the face of the symphysis is analysed by reference to three 'components', each being scored on a scale of 6. In component I, the dorsal half of the face is assessed on a scale of 0–5; in component II, the ventral half is assessed; and in component III, the whole surface is considered in relation to different criteria to the preceding two stages.

Component I (the dorsal plateau) is scored as follows:

- 0: dorsal margin absent
- 1: slight margin formation appears in the middle third of the dorsal border
- 2: dorsal margin extends along whole dorsal border
- 3: grooves filled in with resorption of ridges to form an early plateau in the middle third of the dorsal demiface
- 4: te plateau, still with vestiges of billowing, extends over most of the dorsal demiface
- 5: billowing vanishes and the surface of the demiface becomes flat and slightly granular.

TABLE 3.10 *Time of appearance of major ossification centres*

(a) Healthy Caucasian boys

Birth
Calcaneus
Talus
Femur, distal
Tibia, proximal
Cuboid
Humerus, head

2 months
Capitate
Hamate
Lateral cuneiform

3 months
Femur, head
Capitulum
Tibia, distal

6 months
Fibula, distal

7 months
Humerus, greater tuberosity
Radius, distal

10 months
Triquetrum

11 months
Third finger–first phalanx
First toe–second phalanx

12 months
Second finger–first phalanx
Fourth finger–first phalanx
First finger–second phalanx

13 months
Third toe–first phalanx
Second metacarpal
Medial cuneiform

14 months
Fourth toe–first phalanx
Second toe–first phalanx
Fifth toe–second phalanx

15 months
Third metacarpal
Second toe–second phalanx
Fifth finger–first phalanx

16 months
Fourth toe second phalanx
Fourth metacarpal

18 months
Second finger–second phalanx
Third finger–second phalanx
Fourth finger–second phalanx
Fifth metacarpal

20 months
First toe–first phalanx
Middle cuneiform

21 months
Third finger–third phalanx
Fourth finger–third phalanx
Navicular of foot
Fifth toe–first phalanx

22 months
First metacarpal
First metatarsal

23 months
First finger–first phalanx

2 years
Fifth finger–second phalanx
Lunate

2 years, 2 months
Second metatarsal

2 years, 5 months
Second finger–third phalanx
Fifth finger–third phalanx

2 years, 11 months
Third metatarsal
Fibula, proximal

3 years, 1 month
Femur, great trochanter
Patella

3 years, 3 months
Fourth metatarsal

3 years, 4 months
Fifth toe–third phalanx

3 years, 7 months
Third toe–third phalanx
Fourth toe–third phalanx

3 years, 8 months
Fifth metatarsal
Second finger–third phalanx

3 years, 10 months
Radius, proximal

4 years, 2 months
Multangulate majus

4 years, 4 months
Navicular, hand

4 years, 8 months
Multangulate minus

5 years+
Humerus, medial epicond
Ulna, distal
Fifth toe–second phalanx

(b) Healthy Caucasian girls

Birth
Calcaneus
Talus
Femur, distal
Tibia, proximal
Cuboid
Humerus, head

2 months
Capitate
Hamate
Lateral cuneiform

3 months
Femur, head
Capitulum
Tibia, distal

4 months
Humerus, greater tuberosity

6 months
Fibula, distal
Radius, distal

7 months
First toe–second phalanx
Third finger–first phalanx
Fourth finger–first phalanx

8 months
Second finger–first phalanx
First finger–second phalanx
Third toe–first phalanx

9 months
Third toe–second phalanx
Fourth toe–first phalanx
Medial cuneiform

10 months
Second metacarpal
Second toe–second phalanx
Fourth toe–second phalanx
Third metacarpal
Second toe–first phalanx
Triquetrum

11 months
Fourth metacarpal
Fifth finger–first phalanx

12 months
Fourth finger–second phalanx
Third finger–second phalanx

13 months
Fifth metacarpal
Second finger–second phalanx

14 months
First metacarpal
First toe–first phalanx
Fifth finger–first phalanx
Third finger–third phalanx
Fourth finger–third phalanx
Navicular of foot
Middle cuneiform
First metatarsal

15 *months*
First finger–first phalanx
Fifth finger–second phalanx

17 months
Second finger–third phalanx
Fifth finger–third phalanx

19 months
Second metatarsal

21 months
Fifth toe–third phalanx

22 months
Third metatarsal

23 months
Patella

2 years
Lunate
Third toe–third phalanx
Fourth toe–third phalanx
Fibula, proximal
Femur, greater trochanter

2 years, 2 months
Second toe–third phalanx
Fourth metatarsal

2 years, 5 months
Fifth metatarsal

2 years, 8 months
Multangulate majus

2 years, 9 months
Humerus, medial epicon

3 years
Radius, proximal
Multangulate minus

3 years, 2 months
Navicular, hand

4 years, 6 months
Ulna, distal

5 years+
Fifth toe–second phalanx

After Francis and Werle (1939).

Component II (the ventral rampart) is scored as follows:

- 0: no ventral bevelling
- 1: ventral bevelling only at the superior end of the ventral border
- 2: bevelling extends along whole ventral border
- 3: ventral rampant starts as bony extensions from either or both extremities
- 4: extensive rampart, but still gaps, especially on the upper two thirds of the ventral border
- 5: complete ventral rampart.

Component III (symphyseal rim) is scored as follows:

- 0: no symphyseal rim
- 1: partial dorsal rim visible, usually at the upper end of the border; it is round, smooth and elevated above the surface
- 2: complete dorsal rim with beginnings of ventral rim, which starts at no particular site
- 3: complete circumferential symphyseal rim, enclosing a finely grained, slightly undulating surface
- 4: the rim begins to break down, no longer smooth but sharply defined. Some lipping on ventral edge
- 5: further breakdown of rim, especially along superior ventral edge. Rarefaction of symphyseal face. Disintegration and erratic ossification of ventral rim.

In practice, a three-figure score is made from evaluation of each component and added together. For example, component I = 3, component II = 4, component III = 1. Thus the score is 3 + 4 + 1 = 8 and by reference to the tables, the age suggested is between 24 and 28.

Since the work of Gilbert and McKern, a method has been offered to assess age in both males and females. Stewart has pointed out that, although Todd felt that the same criteria could be applied to females, there was risk of overestimation of age in women because pelvic trauma during parturition could deform the dorsal border of the symphysis in a manner likely to mimic age changes.

The other limitation of the method is that the upper limit is 50 years, so that a large segment of the range is not considered. Also the scoring is naturally subjective, depending on the experience and training of the observer. In spite of these drawbacks, the method remains the most useful ageing technique for post-mature males.

Gilbert and McKern established standards for females in 1973. The same three components are used, but the description of the symphyseal faces is different. Details must be sought in the original publications or in Krogman and Iscan's invaluable book. Gilbert concluded that, if the male criteria were used for females, the age assessment would be underestimated by about a decade, as the female pubis reaches full maturity about 10 years later than the male.

Several tests of the accuracy of this method have been made by Suchey (1979) and Meindl *et al.* (1985). There have been many reports on the subject, but it would seem that Todd's system remains the most accurate. Overall accuracy obtained by experienced observers lies in the range of 5–7 years around the true age.

The sternal rib methods

The costochondral junction has been studied by a number of physical anthropologists using different techniques. Michelson (1934) found that calcification in the first costal cartilage did not occur under 11 years and that after 16 years, males calcified much more quickly until 66, when the sexes again became uniform. Iscan and Loth (1986) made detailed studies of the shape of the rib end adjacent to the cartilage and constructed complex criteria for age-related changes. The original publications must be consulted for details as well as more recent developments such as those by Loth, Iscan and Sheuerman (1994).

Skull sutures and age

The use of skull suture fusion as an index of age has had a chequered history, beginning in the first century AD with a comment by Celsus. It is now generally discredited, except in the most broad terms.

It is common knowledge that most adults have at least part of their suture lines closed and that this tends to become more widespread as age increases. There are many exceptions and the rate of closure is not linear with time. This generality can be useful when skull fragments are found, as any visible fusion will at least indicate that the skull came from a mature individual, as it is unlikely below the age of 20 (Brothwell).

The claims of Dwight (1890), Parsons and Box (1905) and Todd and Lyon (1924, 1925) (who stated that sagittal fusion began at 22 and was complete by 35) for the use of fusion as an ageing tool, have been refuted by Singer (1953), Cobb (1952), McKern and Stewart (1957) and Genovés and Messmacher (1959). McKern and Stewart found that 25 per cent of 18-year-old males had begun closure of their sagittal sutures and that by 31–40 years, 90 per cent had some fusion. Yet many had no fusion at considerably older ages. Since these criticisms were made, much further work has been carried out, recorded by Krogman and Iscan's book in its 1986 edition. They concluded from the accumulated evidence of many publications that suture closure is not affected by sex, race or right/left differences. Only endocranial fusion must be studied, as that on the outer side is far more erratic. Even so, determination of age from suture closure is unsafe: they feel that in the 20–50 age range, it may be possible to

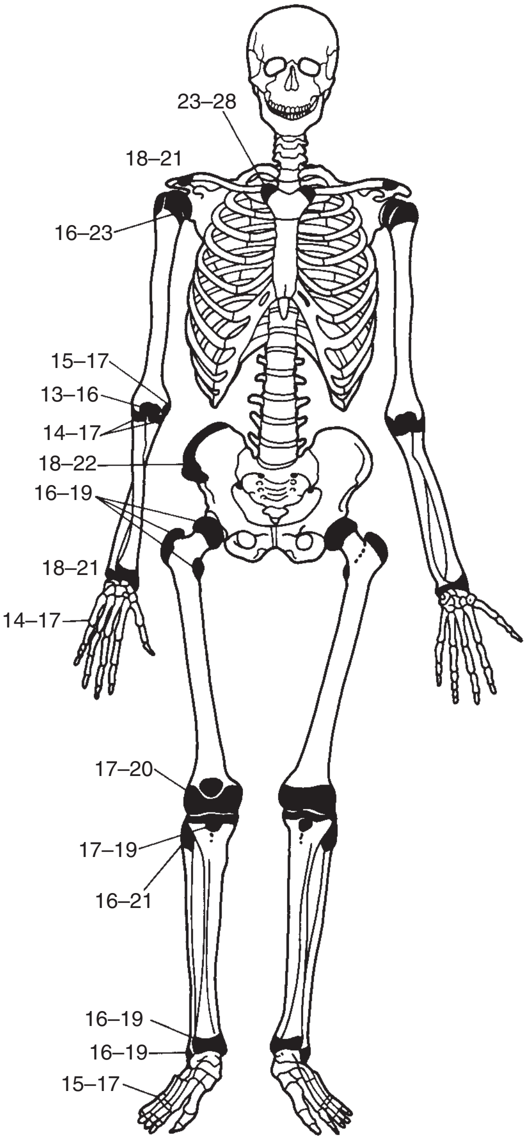

FIGURE 3.16 *A guide to the age of epiphyseal union in the major centres. The commencement and completion of union takes several years. The table is only a guide for male subjects (female slightly earlier) in non-tropical climates; the two dates are partial and complete union (years).*

Head of femur	16–19	Acromion	17–19
Greater trochanter	16–19	Distal femur	17–20
Lesser trochanter	16–19	Proximal tibia	17–19
Head of humerus	16–23	Proximal fibula	16–21
Distal humerus	13–16	Distal tibia	16–19
Medial epicondyle	16–17	Distal fibula	16–19
Proximal radius	14–17	Metatarsals	15–17
Proximal ulna	14–17	Iliac crest	18–22
Distal radius	18–21	Primary elements pelvis	14–16
Distal ulna	18–21	Sternal clavicle	23–28
Metacarpals	14–17	Acromial clavicle	18–21

place a skull within the correct decade only, older material being even more variable.

The basisphenoid synchondrosis cannot be included in this class, as its fusion is a relatively reliable indicator of a minimum age of about 20 years. The metopic suture, between the two halves of the frontal bone, usually closes at about 2 years of age, but occasionally persists into adult life.

Radiology can also assist in the determination of age, from the internal structure of the cancellous bone and cortical thickness of the head of the humerus, for example. Schranz (1959) developed a combination of external visual examination and radiographic features, indicating that the head of the humerus was a better determinator than the corresponding part of the femur. He produced a list of criteria that helped to age a skeleton from about 15 years of age up to one in excess of 75. This was pursued by Nemeskeri and later by him in conjunction with Acsadi (Acsadi and Nemeskeri 1970), to include the proximal parts of both humerus and femur, taking into account the radiological thinning of the cortex and the progressive rarefaction of the apex of the medullary cavity in the head of the bone. The original papers or their full synopsis in Krogman and Iscan's book must be consulted for details.

Histological structure has also received attention and remodelling of Haversion systems seem potentially useful

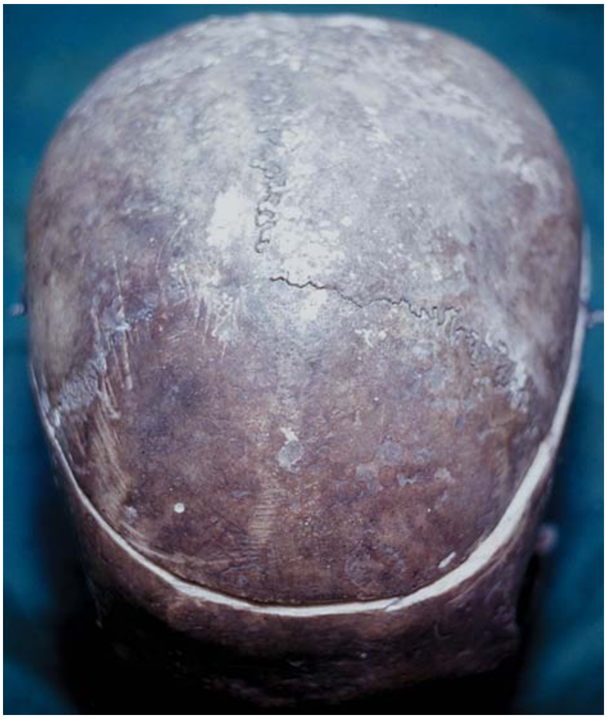

FIGURE 3.17 *The interpretation of cranial suture closure as an index of age is fraught with error. This person was 23 of age and, as would be generally expected, no segments of fusion are shown on the exterior of the skull.*

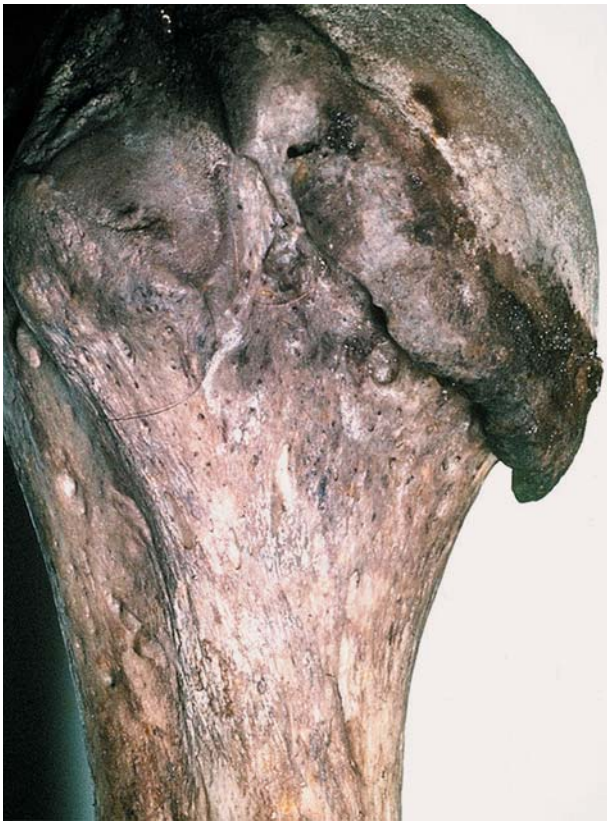

FIGURE 3.18 *Degenerative disease can assist in providing a general estimate of age, or at least exclusion of younger age groups. This grossly arthritic humerus assisted in distinguishing the near-skeletalized bodies of a 66-year-old man and his 22-year-old son.*

for the estimation of personal age. Eriksson and Westermark (1990) have claimed that amyloid inclusions in the choroid plexus can be used as a simple technique.

Chemical methods for assessing personal age lie partly within the field of forensic dentistry, such as the racemization of amino acids in teeth. This has also been applied to bone and depends upon the progressive conversion with advancing age of aspartic acid from the dextro- to the laevo-isomer (Ohtani 1994; Ritz *et al.* 1994).

DETERMINATION OF RACE FROM SKELETAL REMAINS

This is more difficult than any of the preceding investigations, partly because racial traits are not so marked and partly because so much ethnic mixing has taken place, especially in the large-scale immigrations into Europe and North America in recent years.

As usual, those at the extreme ends of the osteological range present little difficulty, as Brothwell (1972) remarks when comparing Eskimos with Australian Aboriginals. Unfortunately, there is a large proportion of racially neutral skeletal material and also some that presents apparently classical racial features but turns out to be totally atypical, so providing a quite incorrect diagnosis. The following criteria are offered, but the usual warnings about dogmatic opinions are even more important in this field.

There are three main racial groups: Caucasian, Mongoloid and Negroid. All others are derived from these and skeletally cannot be distinguished, though when archaeologists and anthropologists are working within a major race, there may well be local criteria that can distinguish racial subgroups with varying degrees of confidence. Most work has been performed in North America and thus most available data are derived from Caucasian and Negroid Americans, and Native Americans.

The skull offers the best evidence on racial origins; Krogman and Iscan claimed that race can be determined in 90–95 per cent of cases. The mandible is excluded from this, apart from the teeth, which will be dealt with in another chapter. It may be mentioned here, however, that one of the most useful pointers to a Mongoloid skull is the present of posteriorly concave, 'shovel-shaped', upper incisors, which may be grooved on the rear surface. These were found by Hanihara (1967) to be present in up to 93 per cent of Japanese, 85 per cent of Chinese and 68 per cent of Eskimos, being absent in Caucasians and occurring in only up to 15 per cent in Negroid Americans.

The wide zygomatic arches that give the typical high-cheekboned features of the Mongoloid races can sometimes produce a skull in which, uniquely, the transverse facial width is greater than the width of any other part of the head. Krogman provides a useful table (Table 3.11), outlining the major racial differences in the skull. Elsewhere he subdivides the Caucasian group into its three main subgroups: Nordic, Alpine and Mediterranean. He points out once again that these describe the 'stereotypes' of each group and that there is an extensive grey zone of more neutral characteristics. Subjects in the Negroid group tend to be long headed (dolichocephalic) and broad headed (brachycephalic) in the Mongoloid group, with the whole range occuring in the Caucasian group. The Negroid orbit is lower and wider, compared with the higher, rounder eye socket of the Mongoloid. The Negroid nasal aperture is wide, and the prognathism of the lower face and jaw relatively marked.

There are racial differences in the pelvis, but specialized measurements as described by Todd and Lindala (1928) must be made in order to detect these. Iscan suggests that a 79–83 per cent success rate can be achieved in differentiating between Caucasian and Negroid subjects (see References and further reading). The long bones offer some assistance, especially the femur. This is straighter in Negroid groups, the anteroposterior bowing being less. Together with other long bones, especially those of the lower limb, Negroid bones are longer than those of Caucasian or Mongoloid skeletons, even for equal total body length, the leg proportions being greater. The radius and tibia are relatively longer (Table 3.12). Several writers offer various indices of relative bone lengths, such as those of Modi (1957), Munter (1936) and Schultz (1937). The scapula has been extensively studied, but seems a poor discriminator of race.

Table 3.11 *General racial features in the skull (after Krogman 1939)*

Feature	White ('Caucasoid') (excluding Alpine)	Negroid	Mongoloid
Height of skull	High	Low	Medium
Length of skull	Long	Long	Long
Breadth of skull	Narrow	Narrow	Broad
Breadth of face	Narrow	Narrow	Wide
Height of face	High	Low	High
Sagittal contour	Rounded	Flat	Arches
Nasal opening	Narrow	Wide	Narrow
Orbital opening	Angular	Rectangular	Rounded
Lower nasal margin	Sharp	Troughed	Sharp
Nasal profile	Straight	Slanted down	Straight
Palatal shape	Narrow	Wide	Medium

PERSONAL IDENTITY FROM SKELETAL MATERIAL

After the general groups of race, sex, stature and age have been investigated, the bones must be examined for any idiosyncratic features that give them a personal identity. This is invariably a matter of matching up such feature(s) with known pre-existing conditions, and depends upon a potential match being available. Circumstances are infinitely variable and the ways in which this suspected matter comes to the examiner's knowledge are legion. Sometimes there may be one 'good bet' and, indeed, the potential identity may be virtually certain from the circumstances, the anatomical confirmation being almost a formality. In

Table 3.12 *Selected anthropometric dimensions (mm) in White and Black* Americans*

	Men				Women			
	White		Black		White		Black	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Body								
Stature	1706	60.5	1744	60.8	1597	78.1	1586	64.9
Total arm length	760	30.2	798	41.2	695	38.1	713	32.7
Upper arm length	333	16.4	340	21.9	302	22.8	303	15.6
Forearm length	249	12.4	269	15.0	225	16.7	237	14.7
Hand length	187	9.3	199	12.3	172	11.3	179	10.2
Leg length (anterior supine)	938	40.0	984	49.1	871	51.2	892	41.8
Thigh length	497	24.3	515	27.5	461	31.6	467	24.9
Lower leg length	376	19.8	401	23.7	352	25.8	365	19.8
Foot length	244	11.9	256	13.9	215	13.6	231	11.8
Bi-iliac breadth	292	16.9	270	16.5	287	22.5	267	24.7
Bi-spinous breadth	246	17.2	227	18.1	242	25.1	220	22.5
Head								
Maximum length	188	7.5	193	6.1	182	6.5	186	7.7
Maximum breadth	154	6.5	149	6.1	145	5.6	144	6.2
Auricular height	120	5.1	124	5.3	118	5.3	120	4.8
Face								
Bizygomatic breadth	139	6.7	139	6.1	130	7.0	132	8.7
Mandibular breadth	110	7.4	109	8.7	103	8.9	105	11.9
Interocular breadth	33	3.5	35	2.7	31	2.8	34	2.3
Total morphological height	122	9.7	125	7.6	113	9.5	116	11.6
Upper face height	69	6.3	71	5.6	66	6.2	67	4.5
Nasal height	54	4.7	52	4.8	52	3.8	50	4.4
Nasal breadth	35	3.7	43	3.7	32	4.9	40	4.1

*From Todd and Lindala (1928). Compiled by Krogman and Iscan (1986).

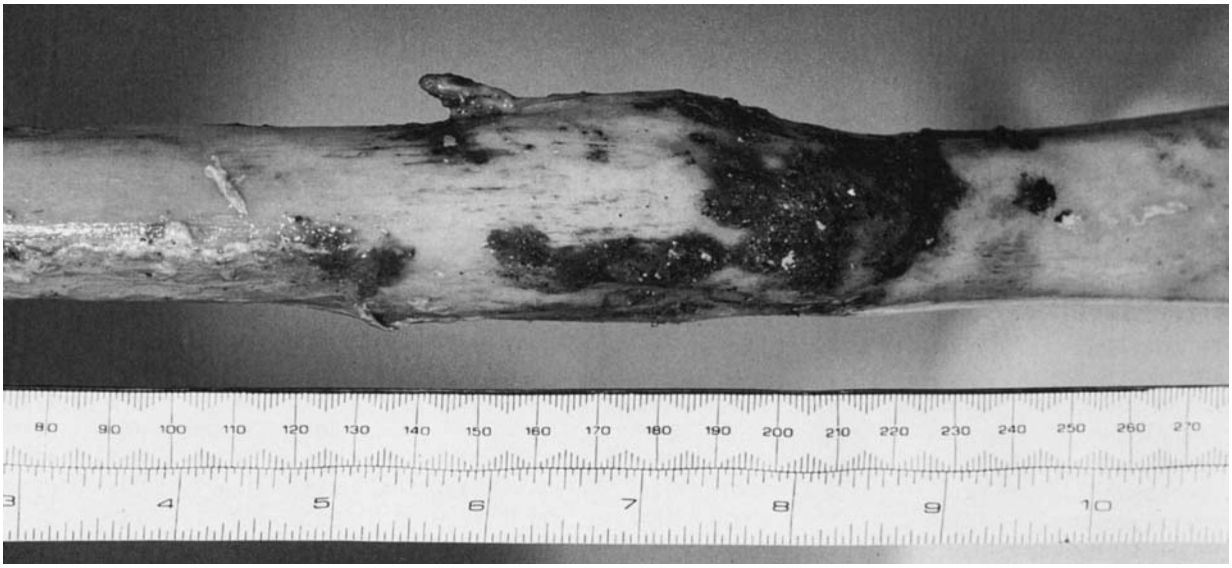

FIGURE 3.19 *Identification of a homicide victim, buried for almost 2 years in a garden, was achieved by matching this callus from a previous femoral fracture, with the medical notes and radiographs obtained from a hospital. The shape and size of the callus, together with the osseous spur due to muscle traction, was identical to follow-up films taken during life.*

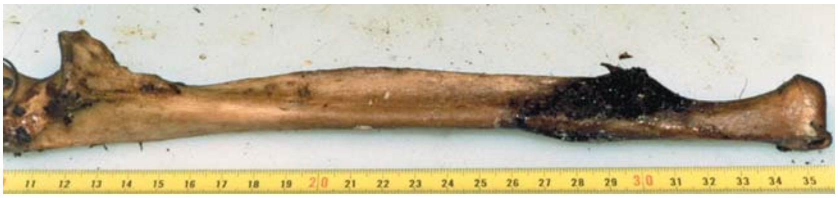

FIGURE 3.20 *Identification of a skeletalized body was achieved by matching this callus from a previous ulnar fracture, with the medical notes and radiographs obtained from a hospital. The shape and size of the callus, was identical to follow-up films taken during life.*

other cases there may be a list of hundreds of potential cases to search through in the hope of finding a match.

Individual characteristics may be of two main types.

- Anatomical shapes that can be matched by radiology, measurement or other means. Examples would be frontal sinus comparison, craniometry and radiological bone architecture.
- Discrete abnormalities such as healing fractures, metal prostheses, bone disease or congenital defects. Some artefacts, such as drill holes or wire, may immediately indicate that the bone is an anatomical specimen.

Anatomical matching depends upon accurate and detailed information about the living subject who is thought to correspond with the skeleton. Such information is usually radiographic and is derived from clinical records. The examples par excellence are dental charts and radiographs obtained from the dentist of the potential match; this is discussed in Chapter 26. Where skull films are available from ante-mortem sources, identity can be almost assured. The lateral view of a head can be matched with similar views taken of the skull, and both obvious anatomical landmarks compared and cranial measurements taken. The matter is further discussed later in relation to radiology, but the profile of the pituitary fossa as well as various intracranial diameters can rapidly exclude a match. In fact, a cursory glance can often confirm that the two skulls are dissimilar; making a positive correlation takes more time and requires accurate orientation of the radiographs.

Frontal sinus identification

This has been extensively studied since Schuller suggested the technique in 1921, as it is particularly useful in mutilated or burnt bodies, such as those from mass disasters like air crashes. The sinuses are well protected from all but the most extreme damage and are unique in that – as first pointed out

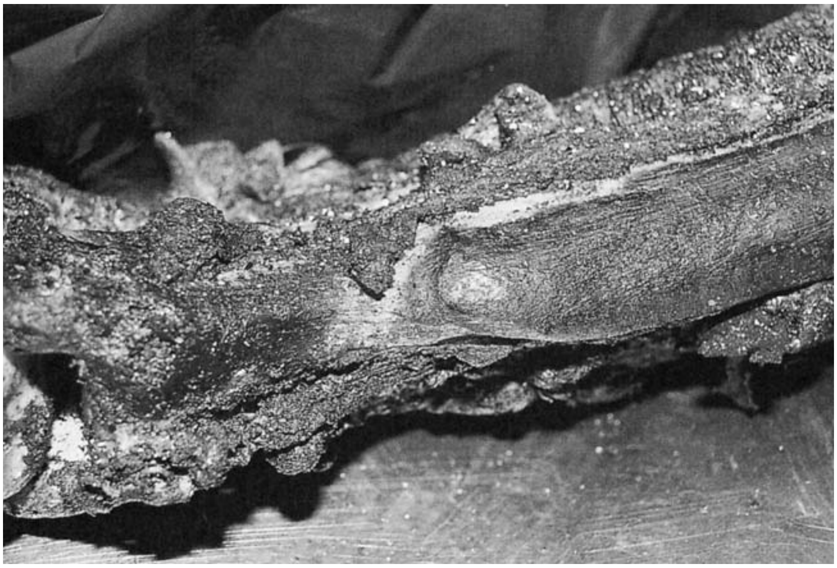

FIGURE 3.21 *Personal identity of this almost skeletalized fire victim was established from this healed callus on the tibia, the site of a well-documented fracture several years before death.*

by Poole in 1931 – no two persons (not even identical twins) have the same profile of these air spaces. They appear in the second year of life and increase in size for the first two decades. They are absent in about 5 per cent of persons and unilateral in another 1 per cent. For the sinuses to be used, an ante-mortem anteroposterior skull radiograph must be available, the most common source being from a previous hospital admission or examination, usually for a head injury. The cadaver skull or head must be X-rayed in exactly the same orientation and degree of enlargement, so that some superimposition technique can be employed. The 'forehead–nose' position was recommended by Schuller (1943), with the tube axis positioned level with the supraorbital margins. The scalloped upper margins of the sinuses are used for comparison, these being smaller and more numerous in the female. Asherson's thesis of 1965 recommends using the Caldwell occipitomental plane for the radiographs, used clinically for investigation of the nasal sinuses. This is preferable to the Wallers occipitofrontal view and the two projections are not necessarily identical in terms of sinus profile. Asherson recommends outlining the sinus shape in black ink on the film or tracing it onto a sheet of paper. Turpin and Tisserand (1942) projected their films on to a cardboard screen and cut out a template, weighing these from both ante- and post-mortem films to determine whether they were identical. Computed tomography of the sinuses is recommended by Reichs (1993).

Other radiological methods of comparing identity include matching of hand and wrist films, matching the profile and structure of the first rib and clavicle, and the craniometric methods of Sassouni (1959) and of Voluter (1959). The methods must be sought in either the original papers or surveys such as the textbook by Evans and Knight (1983). However, in general, it may be said that, wherever ante-mortem X-rays are available, especially of skull, thorax, hip or shoulder, then radiological comparisons of the dead material can almost always exclude an identity and, in many circumstances, can confirm it.

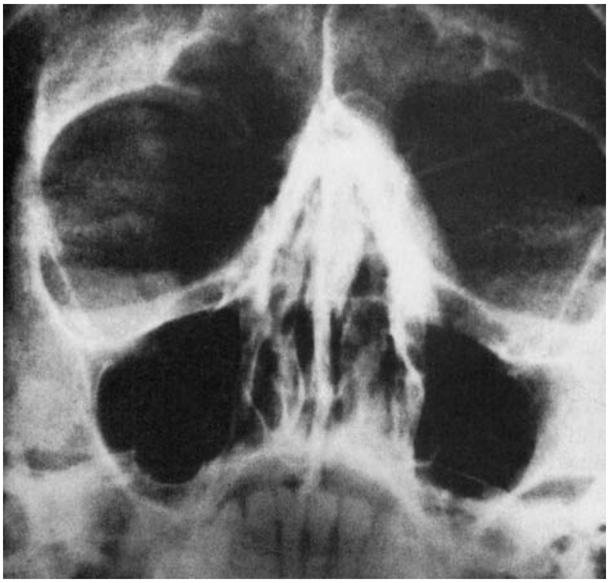

FIGURE 3.22 *The facial and cranial skeleton is unique to every person. If ante-mortem radiographs can be obtained for the person likely to be the victim, matching of the frontal sinus pattern can provide absolute identification. This body, which was washed up on the beach, was eventually matched with hospital radiographs through the sinus pattern seen at the top edge of the picture.*

THE DATING OF SKELETAL REMAINS

One of the issues in identity, as well as in estimating the time since death, is the date (as opposed to the age) of human bones. A knowledge of the time of death, measured in years, decades or even centuries, can assist the investigating authorities considerably. In fact, where skeletal remains are shown to be of considerable antiquity, no investigation at all is required, as even if the death was criminal, the culprit may long since have died. This threshold of investigative interest lies at around 70 years and material older than this may be of concern only to historians and archaeologists.

It is the marginal cases that present difficulties, especially as the methods of dating in this period are so approximate. For example, the skeleton shown in Figure 3.6 was discovered 41 years after the woman had been murdered. When the police went searching for the suspected killer, they found that he had died peacefully 3 years before the discovery, of coronary disease – thus qualifying for the 'perfect murder'.

The major problem in dating bones is that the environment is far more potent than time in changing the state of the bone. In Wales, a historic country where a spectrum of skeletal material has been found dating back some 18 000 years, frequent opportunities present for examining bones from many periods and many conditions of environment. Some Roman or even Bronze Age material, which had been concealed in dry sand dunes or in well-drained ancient burial mounds, appeared almost as pristine as an anatomical demonstration skeleton. On the other hand, modern material buried in coffins in graves marked with headstones only 20 years old have completely vanished because acidic, peaty water repeatedly eluted the bone as the water table in marshy ground rose and fell. An even more striking demonstration of the effect of local conditions was the observation that some limb bones buried vertically in a rock fall in a cave were in excellent condition at the upper ends, yet the lower parts were totally eroded where they had been surrounded by damp rubble.

These facts emphasize that vast errors can be made in dating bone merely by the gross morphological appearances and – as is so often the case – the less experienced the examiner, the more dogmatic his incorrect opinions are likely to be. The following schedule can therefore be nothing more than a rough guide, which must be modified where possible, by a knowledge of the environment in which the bones lay. Certain physicochemical tests are of assistance, but even these are themselves dependent on the environment, with the exception of radiochemical tests that are of little value in the period of forensic concern.

Physical appearance

Recent bones will have soft tissue remnants adhering, in the form of tendon and ligament tags, especially around the joint ends. Periosteum may be visible as fibrous material closely adherent to the shaft surface. Cartilage may also be present on articular surfaces. The time for which these remnants persist is variable, according to the conditions in which the bone has been left. Animal predators may rapidly remove all soft tissue and cartilage, sometimes within days or weeks. If the body has been left in a protected place, such as a vault or closed building, then dried tissue can remain for many years. In temperate climates, bodies left out in the open usually become substantially skeletalized within the first year, though tendon tags and periosteum may survive for 5 or more years. If a body dies in the autumn, then the preservation is likely to be longer through the colder winter months than if it died in the spring or summer.

After all soft tissue has vanished, recent bones may still be differentiated from old material by the density and feel of the bone. For a variable period, depending on storage conditions, a bone will feel slightly greasy to the fingers for several years, sometimes up to a decade if kept indoors. It will also feel heavy compared with older skeletal material because of the preservation of the organic stroma. On sawing a recent bone, it will be hard (especially the shafts of limb bones such as the femur) and will be uniform through the whole thickness. A smell of burning organic tissue will be obvious if vigorous sawing produces heat. In an old bone, the loss of the collagenous stroma will lighten the bone and make it easier to cut. The outer cortex and – to a lesser extent – the zone around the marrow cavity, will lose the stroma first, so a 'sandwich' effect may be seen in which a central ring of hard collagenous bone is layered on each side by a zone of more porous, crumbling material. This is not seen in less than several decades – and sometimes centuries – unless the bone has been exposed to the sun and other elements. The fragile, brittle appearance of old bones is usually first apparent on the ends of long bones, adjacent to the joints, such as the tibial plateau or the greater trochanter of the femur. This is often because the outer layer of compact bone is thinner there than in the shaft, so that the soft cancellous bone of the extremities is more readily exposed. This occurs within a few decades if the bone has been outside, but may not develop for a century in protected material. The aged cortex will feel rough and porous and, in really old material, can be crumbled or pitted with a fingernail.

Another factor that markedly affects the rate of decay of bones is the size and type of the bone itself. Whilst thick, dense bone, such as femoral or humeral shaft, may last for centuries, smaller and thinner items may disintegrate rapidly. Skull plates, tarsal and carpal bones, digits and the thin bones of the facial skeleton will rot more quickly, as will the small bones of fetuses and infants.

Physical tests

In parallel with the physical appearance of the sawn bone, fluorescence in ultraviolet light can be a useful preliminary test. If a shaft is cut across and inspected in the dark under ultraviolet light, such as that from a Wood's lamp, recent bone will shine with a silvery-blue tint right across the whole section. As the bone ages, the outer rim will cease to fluoresce and this will progressively deepen towards the centre. As with visual and tactile examination, a similar zone will work its way outwards from the marrow cavity until only a thin sandwich-filling will survive. This then fragments and eventually vanishes so that all the cut surface is non-fluorescent. The time that this process takes is variable, but total loss of ultraviolet fluorescence takes somewhere of the order of at least 100–150 years to complete. Other physical tests have been described, including density and specific gravity measurements, ultrasonic conduction and thermal behaviour when heated under special conditions. All these criteria depend on the loss of organic stroma and the development of a calcified matrix with a porous structure.

Serological and chemical tests

Positive tests for the presence of haemoglobin may be obtained for a variable time on either the bone surface or powdered bone, this being partly dependent on the sensitivity of the technique. Using the dye-peroxide methods (benzidine is most sensitive, but is now proscribed by Health and Safety regulations, so that the less satisfactory Kastel–Meyer test must be used), positive results may be obtained up to about 100 years.

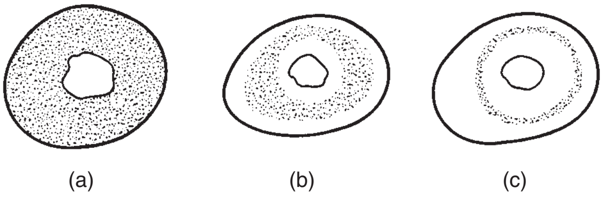

FIGURE 3.23 *Fluorescence of bone in ultraviolet light as a function of time since death. A freshly sawn cross-section of a dense bone such as femoral shaft is to be preferred. Up to several decades after death the whole cut surface fluoresces a bluish colour (a). From 3 to 80 years, greatly depending upon the environmental conditions, the outer zone and the zone around the marrow cavity progressively lose fluorescence (b). After a century or more, the residual fluorescence contracts to a narrowing central sandwich (c) before vanishing completely in the second century. Other methods of attempted dating include microscopic examination. Yoshino* et al. *(1991) claim that microradiography and electron microscopy reveal vacuoles in compact bone left in soil for 5 or 6 years.*

Serological activity lasts only a short time in bones exposed to the weather. Bone powder eluted with weak ammonia and vacuum concentrated, may give a positive reaction with antihuman sera, such as Coombs reagent, for only about 5–10 years – again depending greatly on the environmental conditions.

The recent development of DNA techniques has led to both bone and bone marrow being used to produce profiles for identification. There seems to be a wide range of times during which this is successful. The author (BK) dealt with a case where DNA testing was successful after 8 years' burial, but other more recent skeletons did not yield such success. However, far older archaeological material has given DNA profiles, so, at present, the DNA criteria cannot be used for dating.

Chemical testing seeks to measure the degradation of the proteinous stroma, so knowing the total nitrogen and amino acid content can be useful. Fresh compact bone contains about 4.5 per cent nitrogen, which progressively diminishes with time. If a bone contains more than about 4 per cent nitrogen, it is unlikely to be older than 100 years, but if it has 2.5 per cent or less, it is likely to be older than 350 years.

Estimation of the racemization of amino acids in teeth (laevo/dextro proportions) is being used to determine age, and there is some evidence that it also changes linearly with post-mortem interval. Its use on skeletal structures other than teeth is being investigated.

Residual protein can be converted to its constituent amino acids by prolonged heating in 6 M hydrochloric acid. The digest can then be analysed, either by autoanalytical methods or by two-dimensional chromatography. Fresh bone contains about 15 amino acids, mostly derived from collagen. Glycine and alanine are predominant, but proline and hydroxyproline are more specific markers for collagen. The latter two tend to vanish in about 50 years (as always, depending on the storage environment), so they are useful markers for the time threshold of forensic relevance. The other amino acids diminish over the succeeding scores and hundreds of years, so that a bone containing only four or five amino acids is likely to be relatively ancient. Glycine persists for millennia, being found in palaeolithic material.

Paradoxically, the methods available for archaeologists to use on ancient skeletal remains are proportionately more accurate, but of little or no use in forensic science. The radiocarbon test, which measures the loss of carbon-14 after death, cannot be applied to material less than a couple of centuries old, as the loss of radioactive carbon, which has a half-life of

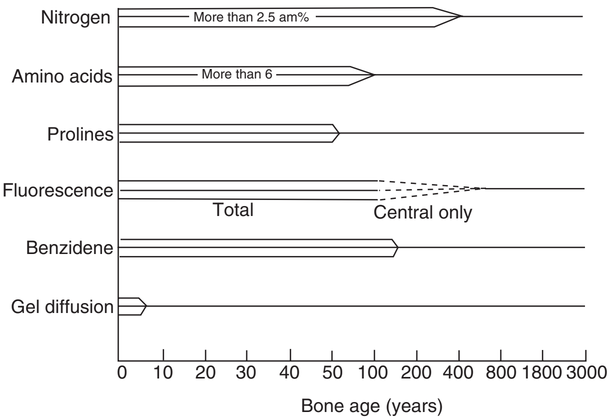

FIGURE 3.24 *Graphical summary of the criteria for estimating the approximate date of human skeletal remains.*

well over 5000 years, is too small to be measured in the half-century or so that interests the forensic pathologist.

Another radioisotope technique is the subject of current research at Aberdeen University, where Maclaughlin-Black *et al.* (1992) are measuring radiostrontium in skeletal remains, the principle being that pre-1945 bones should be free of endogenous strontium-90, derived from nuclear weapons and atmospheric tests, which was at a maximum in the environment in the early 1960s. The possibility exists that atmospheric contamination with other isotopes laid down in bone from dated tests and nuclear accidents may provide a profile that could bring forward the latest date during which the person must have been alive.

PHOTOSUPERIMPOSITION TECHNIQUES FOR IDENTIFICATION

Where potential candidate(s) for the identity of a skull are known to the investigating authority and photographs taken during life are available, a well established technique used for identification is 'photosuperimposition'. In this method, photographs of the skull are taken in exactly the same orientation in three planes as the available photograph. These are then enlarged to exactly the same dimensions as the photograph, and either the negative or a positive print is made on transparent film. This is then laid over the photograph and adjusted in an attempt to match up the major anatomical landmarks such as nasion, supraorbital ridges, angle of the jaw, nasal aperture, external auditory meatus and, especially, teeth. The actual anatomical markers will depend on what is visible, in frontal, lateral or oblique views. The test is mainly an exclusory one, in that, if the match cannot be made, then the skull is not that of the person in the photograph. If the match is good, even excellent, then the two could be the same person, though the standard of proof is low unless some individualistic feature, such as a distinct dental character, is apparent.

The photofit method has been used for many years, one of the most familiar examples being that reproduced in many forensic textbooks, of the skull and face of the wife of Dr Buck Ruxton, a notorious murder in 1935 investigated by Glaister and Brash in Scotland.

A more modern variant of the photosuperimposition technique is with the use of video cameras where two images, one of the photograph and the other of the skull, are mixed on one video display unit. By altering the camera angles and the degree of magnification of the images, superimposition can be tested quickly without the need for laborious photographic processing. This method was used in 1994 to identify a number of the 12 victims of the notorious 'House of Horror' in Gloucester. This is a rapidly developing field of forensic interest, where even the relatively poor-quality images from security cameras can be matched with suspects.

RECONSTRUCTION OF THE FACIAL APPEARANCE FROM THE SKULL

The reconstitution of the visage from the skeletal base has been a goal for workers in many different fields in recent years. The advantages of such a technique are obvious as, when a skull is discovered one prime method of identification would be a reliable reconstruction of the face, so that direct recognition could be obtained from relatives, friends and photographic records.

The first methods were as much artistic as scientific and depended to a great extent on the sculpturing ability of the operator. Gerasimov (1971) was a Soviet pioneer of this method, though much of his work was archaeological and historical, rather than forensic.

The method depends on a pre-knowledge of the usual tissue thickness at a multitude of points on the normal skull, an anatomical exercise that now has quite a large database. Modelling clay is laid on to the unknown skull in layers corresponding to these standard thicknesses, then more imaginative modelling added to 'humanize' the basic shape. The obvious defects in this technique are the lack of knowledge about eyes, lips, nose, ears and head hair, all of which contribute greatly to individual characteristics. Similar methods have been used by graphic artists, rather than sculptors, who use their portraiture talents to create a face on the two-dimensional base provided by the skull profile, plus a knowledge of tissue thicknesses at many anatomical points. Additional information has been provided on tissue thicknesses by radiography of heads.

The method was used with success in the 1988 investigation of the murder of Karen Price in Cardiff. Skeletalized after being buried for 8 years in a carpet beneath a garden, medical artist Richard Neave rebuilt her face upon a skull with sufficient accuracy for its display on public television to be recognized by her parents.

Recently, considerable progress has been made by the use of computer graphic techniques, both in drawing reconstituted heads and in gathering tissue thickness data (Vanezis *et al.* 1989). Some devices are mechanical, measuring the profile of the skull with a device that converts angles and distances into digital data. More recently, a combination of video and laser equipment has allowed 20 000 measurements to be taken and stored within 30 seconds. The data from an unknown skull are then electronically 'clothed' with standard soft tissues from the memory bank and modified on screen to produce various images. These can be rotated electronically so that various profiles can be seen. A variety of stored eyes, ears and noses can be added, and any feature altered almost instantaneously to give a viewer a number of opportunities to recognize the missing person. As with so many techniques in forensic medicine and science, the technology is one for super-specialists at present, but the forensic pathologist should be aware that such methods exist and are increasing in availability and accuracy.

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CHAPTER 4

The pathology of wounds

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DEFINITION OF A WOUND

A wound or injury can best be defined as 'damage to any part of the body due the application of mechanical force'. Some jurisdictions have a legal definition of a 'wound', which usually requires the integrity of the body surface to be breached. As this obviously excludes bruising and damage to deep organs, it is unrealistic in a medical sense, but there is always some legal alternative, such as 'causing serious bodily harm', which covers any injury to any tissue or organ. Other jurisdictions grade wounds not by their physical nature, but by the perceived risk to life or health of the victim; this can be an extremely difficult prognostic exercise.

MECHANISM OF WOUNDING

The human body is constantly subjected to mechanical forces during the normal course of life, varying from unceasing gravitational forces to the forceful impacts of a sporting contest. The body usually absorbs such forces either by the resilience and elasticity of its soft tissues or the rigid strength of its skeletal framework. It is only when the intensity of the applied force exceeds the capability of the tissues to adapt or resist that a wound or injury occurs.

The intensity of the force obeys the usual laws of physics, in that the force varies directly with the mass of the 'weapon' and directly with the **square** of velocity of impact. Of course, the weapon can be anything, including the body itself, as is often seen in the violent deceleration of a fall or in a traffic accident.

The well-known formula: kinetic energy = ½ mass × velocity^2, means that a one kilogram brick pressed against the scalp will cause no injury, but the same brick thrown against the head at a velocity of 10 m/s may smash the skull. This principle is relevant not only in relation to blunt injury and firearm missiles, but also to stab wounds, as is discussed later.

Another factor of importance is the area over which the force acts. If a plank of wood is struck against the skin, the damage to the tissues will be far greater if the narrow edge is used, than if the impact is from the flat surface. Obviously, the force derived from the same mass and velocity is applied over a smaller area, thus delivering a greater impact to any given unit of tissue. This again is relevant to stab wounds, as all the kinetic energy of a moving knife is concentrated into the tiny area of the tip of the blade; the same energy delivered by the large surface area of a cricket bat might not even cause a bruise.

The effect of excessive mechanical forces on the tissues of the body can cause compression, traction, torsion, and tangential (shear) and leverage stresses. The resultant damage depends not only on the type of the mechanical insult but also on the nature of the target tissue. For instance, violent compression (as in an explosion) may do little harm to muscle, but may rupture lung or intestine, while torsion may leave adipose tissue unaffected, yet cause a spiral fracture in a femur.

The transfer of kinetic energy from the relative movements of the body and the weapon is the source of damage to the tissues. If the attacking object comes to rest in the tissues, then all its kinetic energy must have been transferred. A bullet which passes clean through the tissues thus fails to exchange all its energy into trauma production, which is the reason for the illegal 'dumdum' or more recent, explosive-tipped bullets, the object of which is to expand the missile and prevent its exit from the body, so increasing its 'stopping power' (see Chapter 8). If such energy transfer can be slowed down or spread over a wider area, then the intensity of force applied to the tissues per unit of time is less. This is part of the function of a seatbelt in a vehicle crash, where the stretching of the belt fabric extends the time of energy exchange and the considerable area of the belt surface is a preferable alternative to transferring all the kinetic energy via a few square centimetres of forehead against the windscreen.

Other ways in which the transfer of kinetic energy may be modified is in moving the body in the direction of the force. When a car strikes a pedestrian, that proportion of the momentum of the car that is used in projecting the victim along the road is not then available for damaging the tissues.

Similarly, if a boxer 'rides the punch', he is reducing the differential velocity between his head and his opponent's fist, as well as extending the time over which energy transfer occurs. With a high-speed impact, such as a bullet and – to a lesser extent a stab or violent blow – the inertia of the victim's body prevents any significant loss of energy transfer by movement. If the force does not strike in a linear fashion, but leads to a tangential impact – as in a glancing blow causing a 'graze' – then only part of the kinetic energy is transferred and the damage will be proportionately less.

CLASSIFICATION OF WOUNDS

This is quite arbitrary, but when writing medical reports (especially for legal purposes) it is essential that every doctor should use a standardized nomenclature when describing wounds. All too often reports are seen – especially from clinicians who are not used to medico-legal work – where 'laceration', 'incised wound' and 'abrasion' are used loosely, the accompanying descriptions making it obvious that no clear distinction between them was appreciated by the doctor.

Wounds may also be categorized by the motivation of their infliction, such as 'suicidal or accidental' (the 'manner' index of the WHO International Classification of Disease, ICD E-codes), but a pathologist should classify them by their appearance and the method of causation, such as 'laceration' or 'incised wound'. The most useful classification is:

- Abrasions – colloquially 'grazes or scratches'.
- Contusions – colloquially 'bruises'.
- Lacerations – colloquially 'cuts or tears'.
- Incised wounds – colloquially 'cuts', 'slashes' or 'stabs'.

FORENSIC ANATOMY OF THE SKIN

As most wounds involve the body surface, a reminder of the structure and nomenclature of the skin and subcutaneous tissues is appropriate. Most superficial is the keratinized dead layer of cells, the stratum corneum, which varies greatly in thickness from one part of the body to another. That on the soles and palms is the thickest, while that on protected areas such as the scrotum and eyelids measures

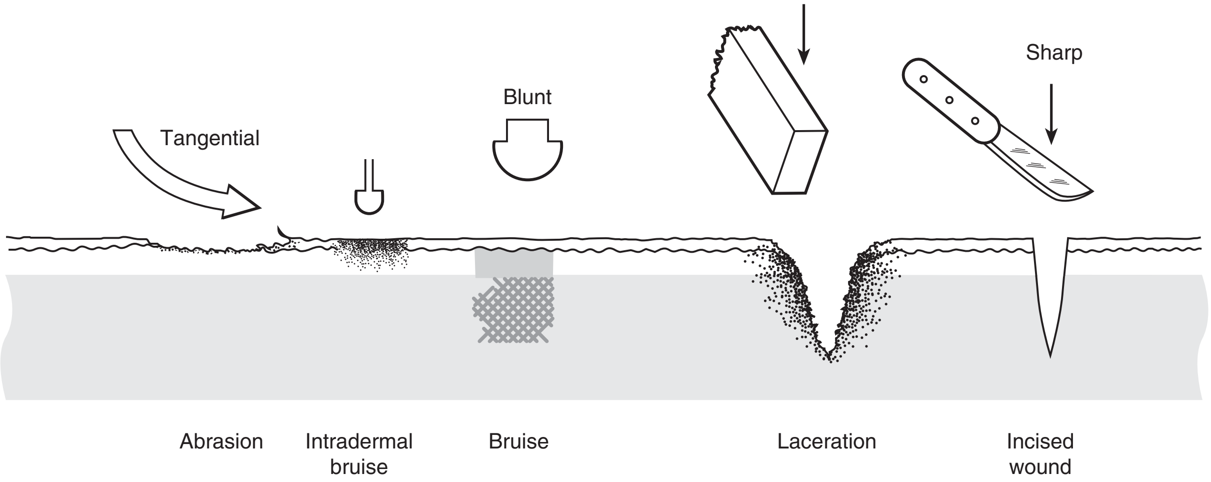

FIGURE 4.1 *Types of injury to the skin.*

only a fraction of a millimetre. This has forensic relevance in the amount of injury that is needed to penetrate the skin and allow bleeding from the underlying tissues.

The living layers of the skin combine with the horny layer to form the epidermis, which has no blood vessels in its thickness. The epidermis is generally corrugated, the under surface by papillae that dip into the dermis. The degree of undulation also varies greatly from place to place, the thinner skin tending to have a flatter junction between dermis and epidermis. The dermis (or 'corium') consists of mixed connective tissue carrying the skin adnexae, such as hair follicles, sweat glands and sebaceous glands. It has a rich network of blood vessels, nerves and lymphatics, and has numerous nerve endings of various types for tactile, pressure and heat sensing. The lower zone of the dermis has adipose tissue and – depending on the site in the body – deep fascia, fatty tissue and muscle will form strata below the skin itself.

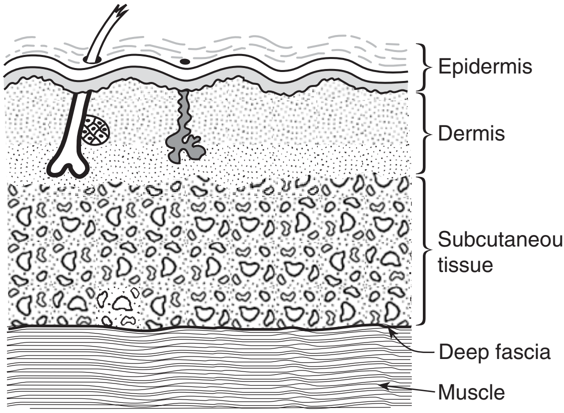

FIGURE 4.2 *General structure of skin.*

ABRASIONS

An abrasion is the most superficial of injuries and, in the most restrictive of definitions, is one that does not penetrate the full thickness of the epidermis. Thus the pure abrasion does not bleed, as blood vessels are confined to the dermis. Because of the corrugated nature of the dermal papillae, however, many abrasions enter the corium and bleeding commonly occurs.

Another definition (all of which are arbitrary) would describe an abrasion as a superficial injury to 'the skin', which would allow penetration of the upper dermis rather than only the epidermis, so that bleeding would fall within the definition.

Abrasions are known in lay terms as 'scratches' or 'grazes', though the former usually indicates a linear mark and the latter a 'brush' abrasion caused by wider tangential impact. Where these brush abrasions are the result of scraping contact with the ground, the lay term is a 'gravel rash'. There are many causes of abrasions, which are common everyday lesions, especially in children whose legs are rarely free from some scratches and bruises. Any contact that rubs across the epidermis and removes the keratinized layer and underlying cells will cause that area to become discoloured and moistened by exuded tissue fluid, even if bleeding does not occur from abraded dermal papillae.

When death ensues soon afterwards, the abrasion becomes stiff, leathery and of a parchment-like brown colour as a result of the drying of the moist exposed surface. This is classically seen, for example, in the ligature mark of hanging or strangulation. It is impossible to tell whether a superficial abrasion occurred immediately before or after

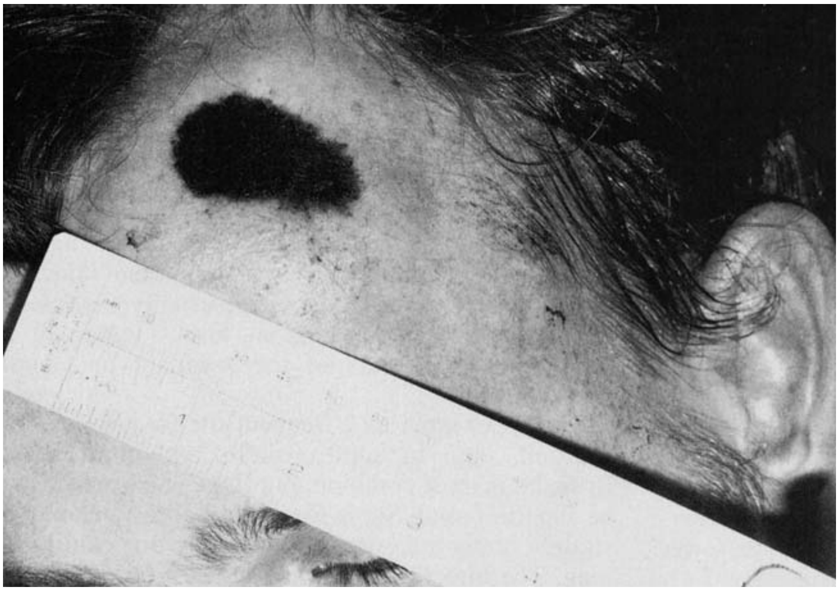

FIGURE 4.3 *Simple abrasion of the skin caused by an almost perpendicular impact of the head against the ground. There is only slight tangential scuffing though most abrasions have some element of sideways contact that damages the epidermis.*

death if there was insufficient time for any inflammatory reaction to occur at the margins. Post-mortem abrasions are common, especially after autopsy when the body is re-examined, because mortuary instruments and the moving of bodies into refrigerators and coffins can often make marks. These abrasions commonly appear yellow and translucent, and are absolutely devoid of any colour change at the edge.

Tangential or brush abrasions

Most abrasions are caused by a lateral rubbing action rather than vertical pressure. Where this tangential component is marked, the direction of the force can often be determined by tags of epidermis dragged to the terminal end of the abrasion. For example, in the 'brush abrasion', which is common in childhood falls and pedestrian accidents, the skidding of the body across a rough surface scrapes linear furrows across the skin. Strands and tags of epidermis may be peeled along these furrows to the further end where contact ceased. Visual examination, using a lens if necessary, can indicate the direction of movement of the body. Similarly, if a victim is struck a glancing blow with a rough object such as a stone or brick, similar epidermal tags may indicate the direction of the blow.

The same type of grooved abrasions can be caused when a victim is dragged along the ground, either in a vehicular accident or by an assailant. It may be important, though difficult, to attempt to differentiate such drag marks as being ante-mortem or post-mortem, a problem which is discussed in another chapter.

Crushing abrasions

Where the impact is vertical to the skin surface, no scraping or tangential marks occur. Instead the epidermis is crushed and an imprint of the impacting object is stamped on the surface. If the impact is substantial and the area of contact small,

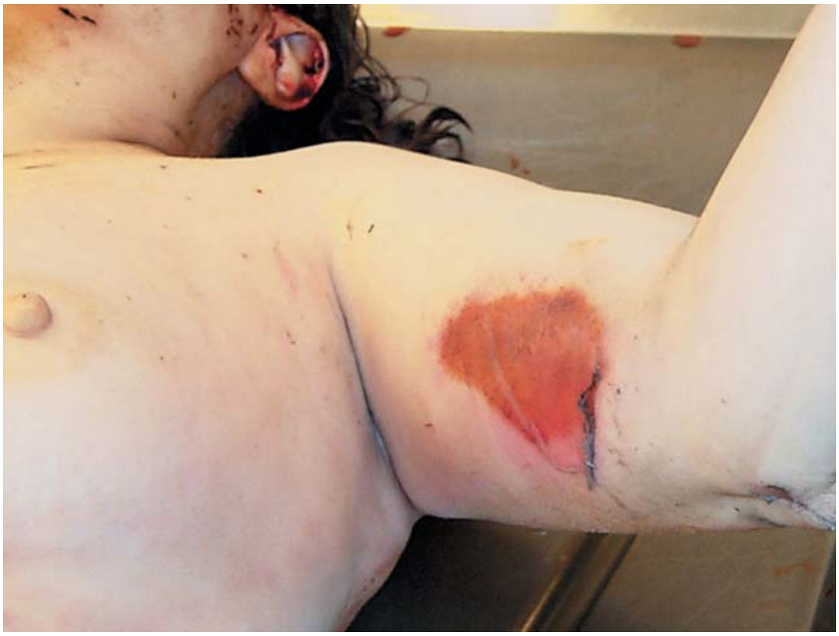

FIGURE 4.4 *A linear abrasion or 'graze', confined to the upper layers of the skin. The tangential direction of impact of the weapon was from above downwards (along the longitudinal axis of the upper arm), as can be determined by the shreds of epidermis peeled towards the lower end.*

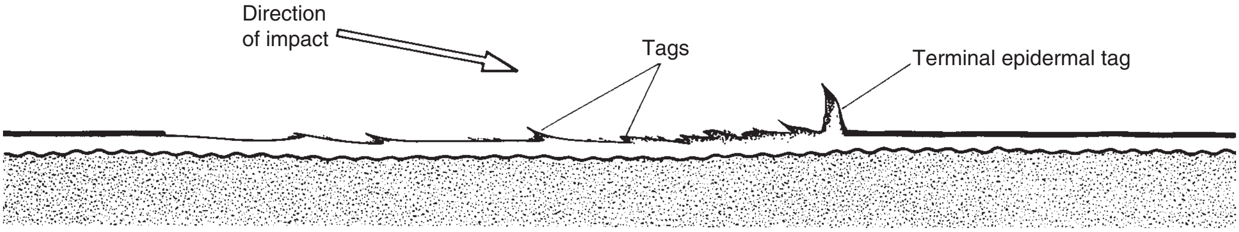

FIGURE 4.5 *Determination of the direction of impact in an abrasion caused by a tangential force. The epidermal tags raised by the impact tend to pile up at the distal end.*

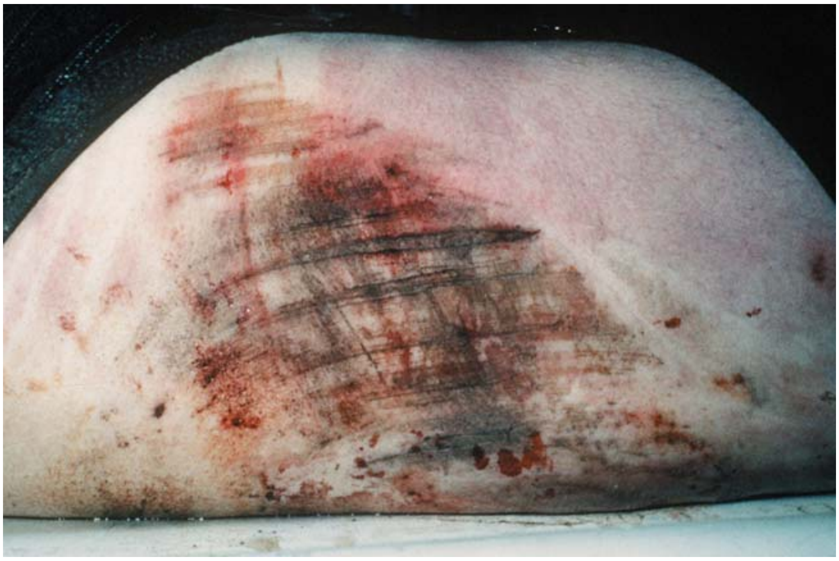

FIGURE 4.6 *'Brush abrasion' or 'grazes' caused by tangential contact of a moving body with a rough surface. Although most are seen in traffic accidents from contact with the road surface, this example is from a murdered woman dropped down a mine shaft. There are grazes running in two directions at right angles, indicating that she must have struck the wall twice, in different postures.*

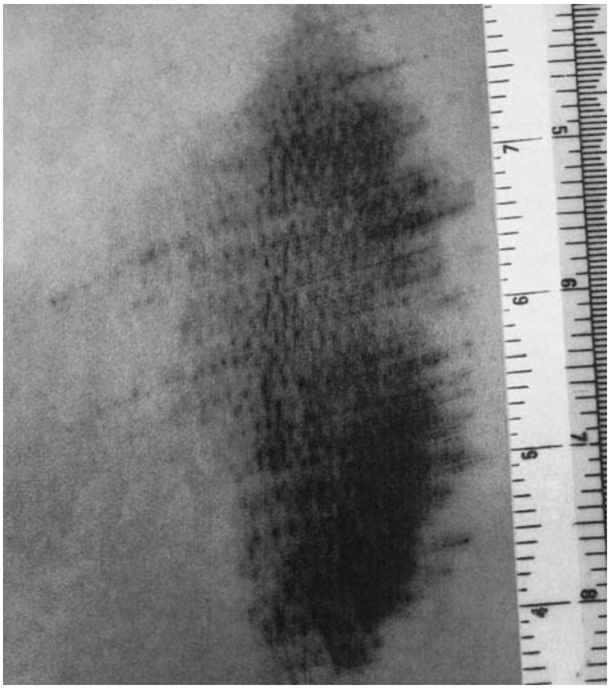

FIGURE 4.7 *Brush abrasion from skidding contact with the road surface during a drunken scuffle. The lesion is partly abraded and partly bruised. The direction of movement can be discerned, as the scratches begin more abruptly and deeply near the ruler, and tail off superficially at the opposite edge.*

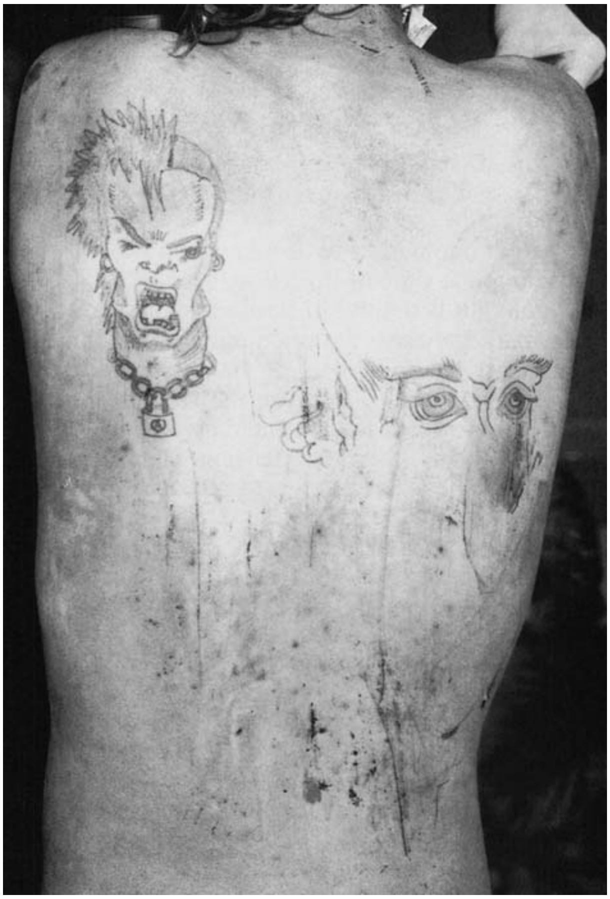

FIGURE 4.8 *Drag marks on the back of a murder victim. Death was caused by a stab wound of the front of the chest – the body was pulled along the ground for a short distance, obviously in the direction of the feet, as the scratch near the waist is deeper near the feet end and tails off at the opposite end.*

a punctured wound will be made, but otherwise a crushed abrasion will occur. The lesion is slightly depressed below the surface unless an underlying bruise or local oedema bulges the tissues. These abrasions are the ones that most clearly reproduce the pattern of the injuring object. An example

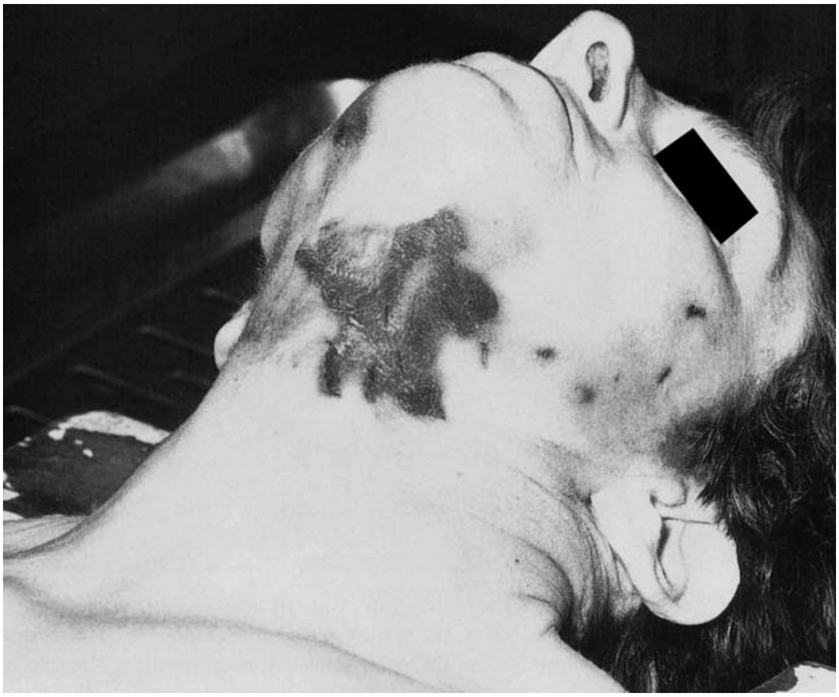

FIGURE 4.9 *Abrasions in manual strangulation. The area is more extensive than is usually seen in such circumstances. The large area of superficial damage to the epidermis is caused by sliding movements of the assailant's hands, the area having become dried and leathery during the post-mortem interval. The smaller marks are fingernail scratches.*

would be the marks of a vehicle radiator on a pedestrian victim or the pattern of a floor grid on to which a person has fallen. If the impact is forcible, then the dermis may also be injured: an area of bruising may underlie the abrasion.

Fingernail abrasions

These are important because of their frequency in assaults – especially child abuse, sexual attacks and strangulation. Often associated with focal bruises, fingernail abrasions are most often seen on the neck, the face, the upper arms and the forearms. They may be linear scratches if the fingers are dragged down the skin, or short, straight or curved marks when the skin is gripped in a static fashion. As women tend to have longer, sharper fingernails than men, they are naturally more often associated with causing such abrasions. A victim resisting a sexual or other attack may rake her nails down her assailant's face, causing linear, parallel scratches that may be several millimetres wide and placed a centimetre or two apart. The expected pattern may be fragmentary, however, as is often seen on the neck when a victim of either manual or ligature strangulation attempts to tear away the attacking fingers or cord. These marks are usually vertical, as opposed to the more random marks that may be inflicted by the nails of the assailant in manual strangulation.

The upper arms are a frequent site for gripping and restraint, both in adult assaults and child abuse. Bruising is most common, but fingernail marks may be superimposed. Static fingernail abrasions may be straight or curved, often about half to one centimetre long. The direction of curvature must be interpreted with care if one wishes to decide which way the hand was held at the time of infliction.

Although it is natural to assume that the concavity of the mark indicates the orientation of the fingertip, experiments by Shapiro *et al.* (1962) have shown that this is often not the case. Because the skin is put under lateral tension when it is indented by the nails, it may distort, so that when the tension is released the elasticity of the skin causes it to return to its original position, carrying the nail mark with it. The curve may then reverse to form either a straight line or a convexity. The shape of the free edge of the fingernail also affects the mark, as pointed nails are more likely than those with straight edges to give these paradoxical results. Once again, the pathologist has to be wary of incorrect interpretation when, for instance, deciding if nail marks on a neck were made by hands approaching from the front or passing around the back of the neck. However, personal experiments with the Shapiro *et al.* contention have shown that it by no means always applies.

Patterned abrasions

Formerly it was often claimed that abrasions retained the pattern of the impacting object more accurately than other injuries such as bruises and lacerations. Though abrasions undoubtedly do preserve such patterns well, many of the examples were not in fact true abrasions, but were intradermal bruises, mentioned in the next section.

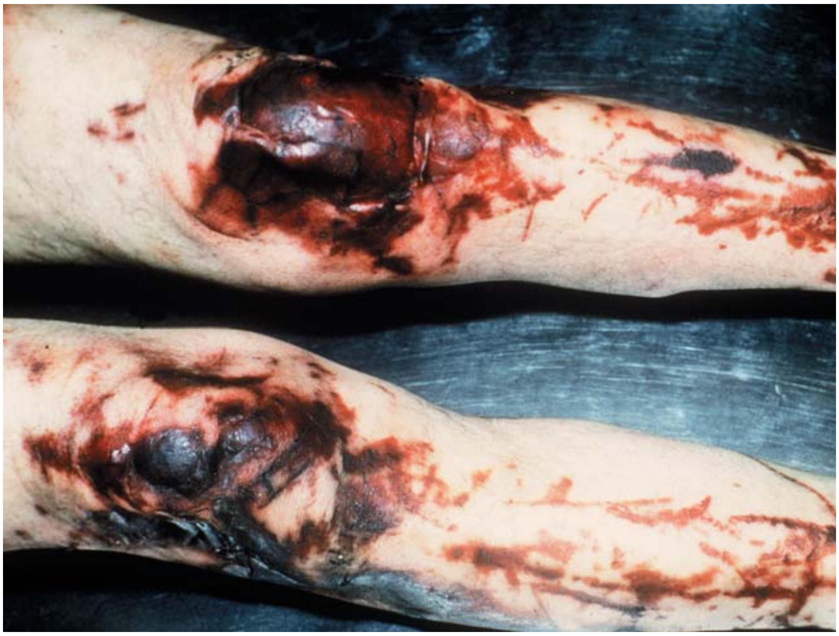

FIGURE 4.10 *Extensive abrasion of the knees and shins, in a drunk who stumbled amongst furniture before dying of a head injury. The damaged skin has exuded tissue fluid, which has dried post-mortem to produce the dark, leathery appearance.*

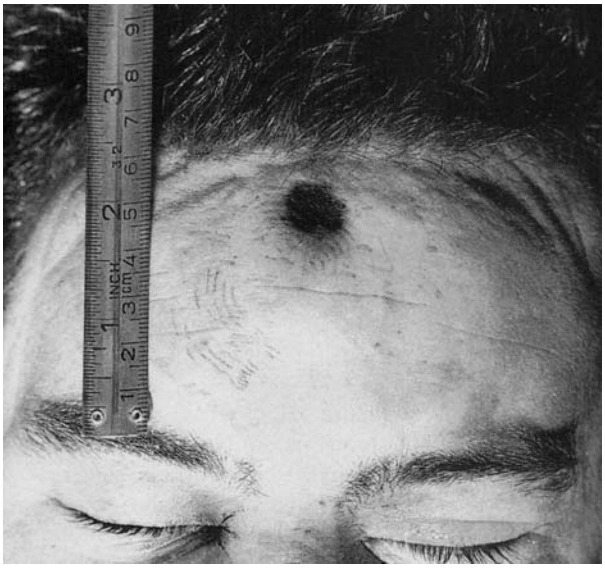

FIGURE 4.11 *Patterned abrasion of the forehead. The victim was struck on the head in a public house with a heavy glass ashtray, the bottom of which had embossed concentric circles moulded into the glass.*

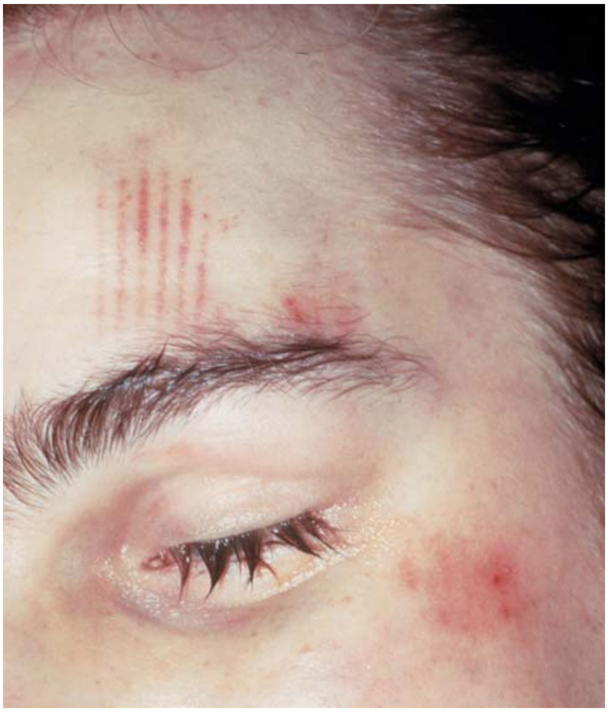

FIGURE 4.12 *Abrasions and intradermal bruising on the forehead of a swimming bath attendant. He was found drowned when there were no witnesses, but the spacing of the marks exactly matched the ridged tiles at the edge of the bath, so it was presumed that he had slipped and struck his head before falling unconscious into the water.*

Patterned injuries occur when the force is applied at or near a right angle to the skin surface, rather than with the skidding impact of a graze. If a weapon with a patterned surface strikes the skin – or the body falls against a patterned surface – the abrasion of the epidermis follows the ridges of the object if it has a profile of varying height. Not only may the epidermis be damaged, but the skin may be compressed into the cavities of the pattern, with consequent capillary damage leading to an intradermal bruise. Probably the best example of this is seen when a motor tyre passes over the skin, leaving a pattern where the skin has been squeezed into the grooves of the rubber tread.

There is little point in trying to list all the possible patterns that can be distinguished in abrasions on a body, but a few

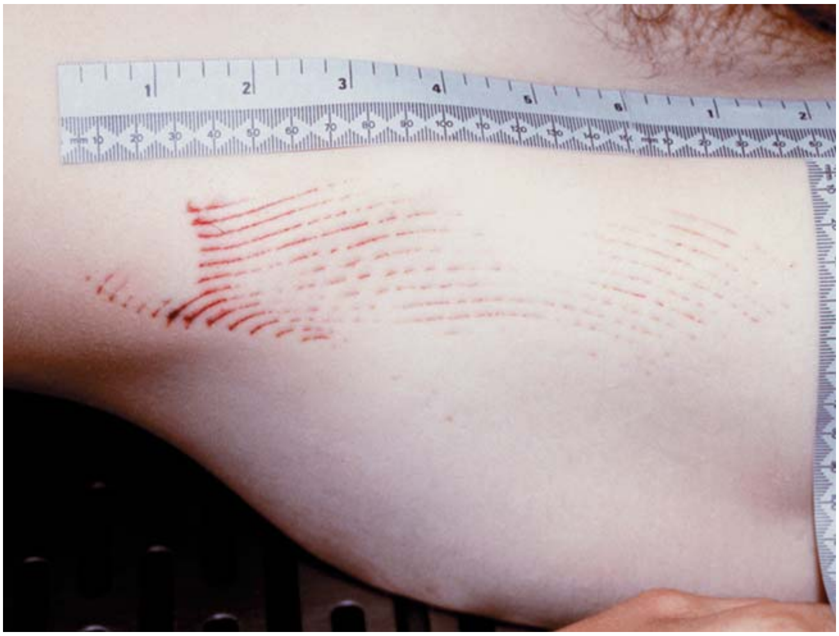

FIGURE 4.13 *Patterned abrasions from the back edge of a serrated 'Rambo' knife. Measurements and photographs with a scale should always be obtained to assist in the identification of the weapon.*

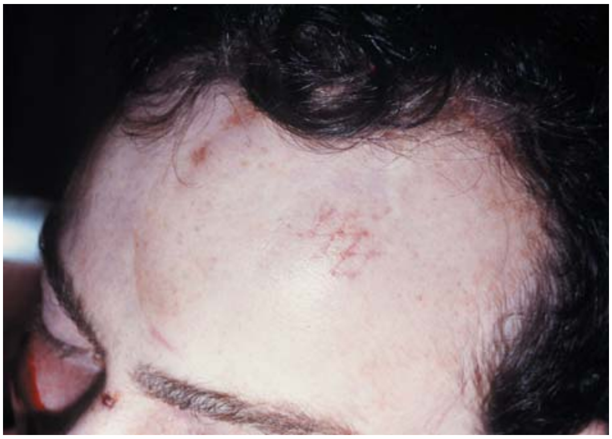

FIGURE 4.14 *Patterned abrasion on forehead due to falling down steps onto a metal grid. Here the abrasions are not produced by tangential force, but imprinted directly by impact at a right angle to the skin.*

have particular medico-legal significance. In former years the honeycomb grid of a motor-vehicle radiator provided many examples of patterned abrasions, but changes in vehicle design have relegated these to historical interest. There may still be projections on vehicles that cause damage, but these are more likely to inflict bruises and lacerations. The muzzle of a firearm can imprint an abrasion on the skin, which is of importance in that it confirms that the discharge was contact in nature. Impact against ribbed ceramic tiles in a bathroom or swimming bath may assist in reconstructing unwitnessed events. Blows from a weapon with a recognizable surface may help to identify that weapon, such as a plaited rope or leather whip, or a solid object with an embossed pattern. Abrasions from objects with a recurring pattern, such as bicycle chain used in gang fights, or a serrated knife, can readily provide a clue to the nature of the weapon.

Post-mortem abrasions

Unlike post-mortem bruises, artefactual abrasions are common. They may have been inflicted after death from a variety of causes, including dragging a corpse or buffeting in moving water. Some post-mortem animal injuries also resemble abrasions such as insect bites, especially by ants.

Other damage may be caused following autopsy. As the post-mortem interval increases, so the skin becomes more fragile. Even the normal procedures of post-autopsy reconstruction and handling in the mortuary may cause dermal damage, especially after washing with hot water. If the pathologist returns for a later examination, or if he is retained to perform a second autopsy for the defence, the appearances should be checked with the original description or photographs, if some injuries suggest a post-mortem origin.

CONTUSIONS OR BRUISES

Although often combined with abrasions or lacerations, a pure bruise lies beneath an intact epidermis and consists of an extravascular collection of blood that has leaked from blood vessels damaged by mechanical impact. An extravasation of blood that is (arbitrarily) larger than a few millimetres in diameter, is usually termed a 'bruise' or 'contusion'. This size overlaps the older and now little used term 'ecchymosis', which is really a small bruise.

Even smaller is the 'petechial haemorrhage', which is the size of a pin head or less. Both ecchymoses and petechiae are not usually caused by direct mechanical trauma and are often seen on serous membranes and conjunctivae as well as on skin. However, moderate pressure, impact or, especially, suction on the skin can produce a patch of localized petechiae.

Bruises are caused by damage to veins, venules and small arteries. Capillary bleeding would be visible only under a microscope and even petechiae originate from a larger order of blood vessel than a capillary.

The word 'bruise' usually implies that the lesion is visible through the skin or present in the subcutaneous tissues, whilst a 'contusion' can be anywhere in the body, such as the spleen, mesentery or muscles. The two words are often interchanged at random, however, though 'bruise' is to be preferred when a doctor gives reports or evidence to a non-medical audience.

Intradermal bruises

These are important but rarely mentioned in most texts. The usual bruise from a blunt impact is situated in the subcutaneous tissues, often in the fat layer. When viewed through the overlying corium and epidermis, the bruise is somewhat blurred, especially at the edge. When a bruise is made by impact with a patterned object, however, the haemorrhage may be far more sharply defined, if it lies in the immediate subepidermal layer. The amount of blood is relatively small, but because of its superficial position and the translucency of the thin layer that overlies it, the pattern is distinct.

Such bruises are especially likely to occur when the impacting object has alternating ridges and grooves, as the skin will be forced into the grooves and be sharply distorted. Intradermal bleeding will occur here and the areas in contact with the raised ridges may remain pale, as the pressure forces the blood from the small vessels. A good example is that of a motor tyre running across the surface. Impacts from whips with patterned thongs may also show the same phenomenon, as do the ribbed rubber soles of 'trainer' shoes.

Factors affecting the prominence of a bruise

Several factors influence the apparent size and prominence of a bruise and, because of these, it is not possible to be dogmatic about the amount of force needed to produce any given bruise.

- As it is a leakage of blood from a vessel, there must be sufficient space outside that vessel for free blood to accumulate. This explains the ease with which bruising appears in lax tissues such as the eye socket or scrotum and its rarity in the sole of the foot or palm of the hand, where dense fibrous tissue and restrictive fascial planes prevent accumulation of blood. Because of the greater volume of soft subcutaneous tissue in fat people, they

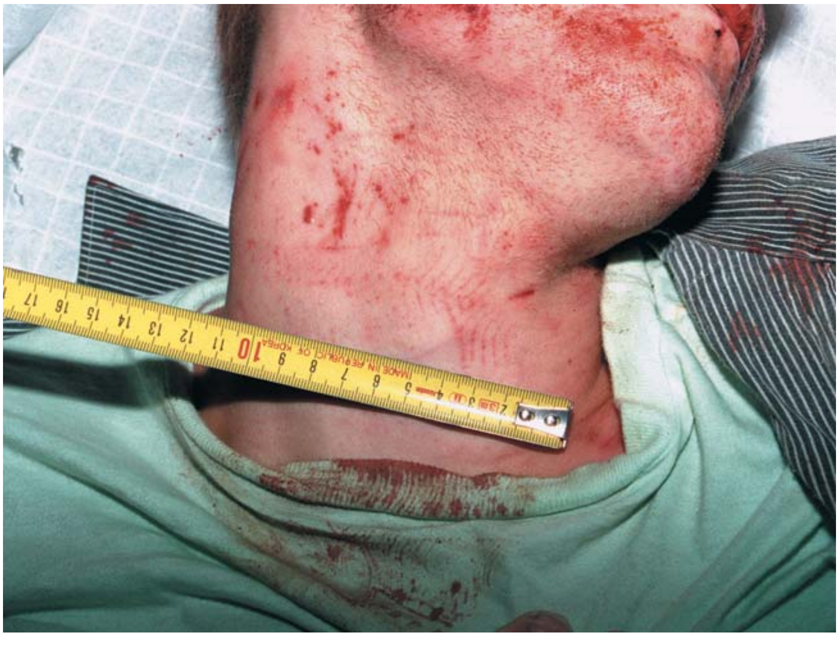

FIGURE 4.15 *Intradermal bruising showing the pattern of rubber soles of 'trainer' shoes on the neck and T-shirt of a homicide victim.*

tend to bruise more easily than thin ones, other factors being equal (such as vessel fragility and senile changes).

- The apparent prominence of a bruise beneath the skin varies with the amount of blood in the extravasation. The size of the haemorrhage depends partly, but not entirely, on the intensity of the injuring force. The size and density of the vascular network varies from place to place and the amount of damage that a given blow causes to local blood vessels is partly a matter of chance.
- Resilient areas, such as the abdominal wall and buttocks, bruise less with a given impact than a region where underlying bone acts an anvil with the skin between the bone and the inflicting force. The head, chest and shins are examples.

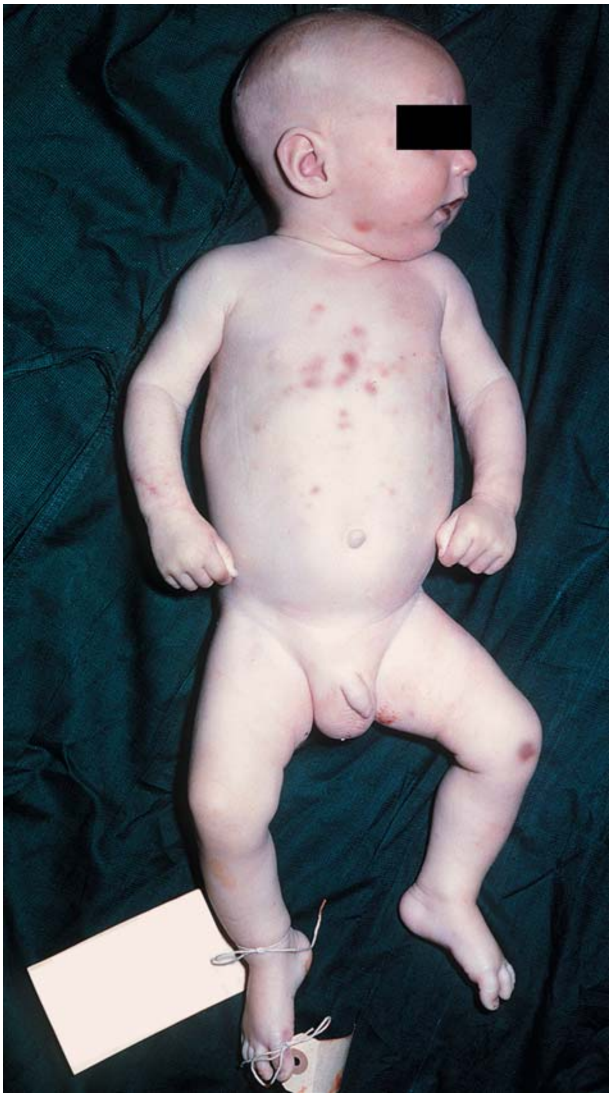

FIGURE 4.16 *Multiple bruises on the trunk of a victim of child abuse. The bruises are of the 'fingertip' type, caused by heavy prodding by adult fingers. The child died of a ruptured liver.*

- The depth at which the bruise is placed affects the apparent severity. A bruise may be placed superficially in the dermis to form the well-patterned intradermal bruise mentioned in the previous section; here, a minute amount of blood will be obvious. Most bruises are in the subcutaneous tissues above the deep fascia and will therefore be fairly obvious, but others can be confined below deeper fascial membranes so that the free blood has to be viewed through the skin and underlying adipose tissue. For a given size of extravasation, this bruise will be less prominent. Some bruises are confined to deep fascial compartments and never become visible without dissection.
- For a given impact, the volume of blood lost into the tissues can depend upon the fragility of the blood vessels and the coagulability of the blood. In old persons, vessel fragility may be extreme and a large bruise may develop from the slightest of knocks. Children tend to bruise more easily than adults, presumably because of the softer tissues and the smaller volume of protecting tissue that overlies the vessels. Any bleeding diathesis resulting from disease, a toxic condition, or certain medication, will also retard the normal clotting process that heals the breach in the bleeding vessels. Those with scurvy and chronic alcoholics bleed easily but, in contrast, certain people (such as boxers) seem able to avoid bruising from blows that would severely damage other people.
- It is common knowledge among lay people, as well as doctors, that a bruise may 'come out' – that is, become more prominent with the passage of hours or days. This is partly caused by continued bleeding from the ruptured vessels, but mainly by percolation of free blood from its origin deeper in the tissues upwards towards the epidermis. Another factor may be haemolysis, when the freed haemoglobin is able to stain the tissues in a more diffuse way and become more noticeable than intact red blood cells. This latter mechanism is certainly the reason not only for the well-known post-mortem phenomenon of bruises becoming more prominent after death, but of new bruises appearing later where none was visible at an autopsy performed soon after death. This is further considered in the chapter on post-mortem changes, but is repeated here because of the importance of recognizing the differences in appearance that can occur between two autopsy examinations spaced a few days apart. The second, usually for a defence opinion, may find new bruises not recorded by the first pathologist, but if the phenomenon of delayed appearance is appreciated, potential disputes may be avoided.

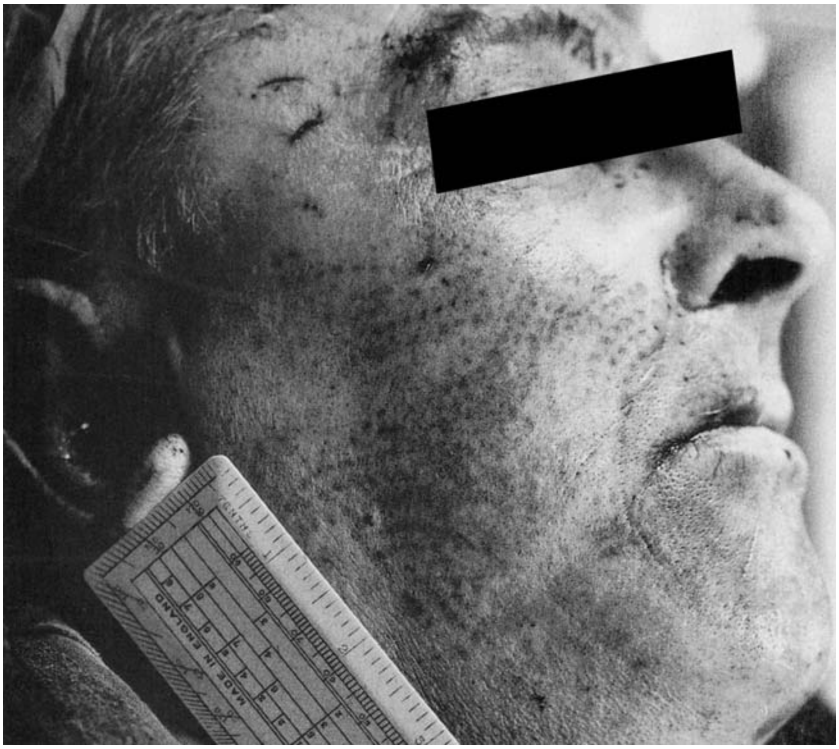

FIGURE 4.17 *Patterned abrasion and intradermal bruising of the face during a fatal armed robbery. The watchman was struck in the face by an assailant wearing a hard-corded driving glove with a coarse-weave pattern.*

Movement of bruises

A bruise may appear at a different place on the surface from the point of impact. When the bruise is superficial, especially intradermal bruising, the lesion appears immediately – or at least rapidly – and is at the point of infliction. When blood extravasates in the deep tissues, however, it may take time to reach the surface (if it ever does), and this may be some distance away because of deflection and obstruction by fascial planes and other anatomical structures.

In addition, bruises may move under gravity. The most frequent example is a bruise or a bleed under a laceration on the upper forehead. If the victim survives for at least some hours, then the subcutaneous haemorrhage can slide downwards over the eyebrow ridge and appear in the orbit, to give a ‘black eye’, which might be misinterpreted as direct trauma. Similarly a bruise of the upper arm or thigh may surface lower down around the elbow or knee.

Alteration of bruises with time

As already mentioned, bruises often become more prominent some hours or days after infliction because red cells or haemoglobin diffuse closer to the translucent epidermis. There is another temporal series of changes in bruises in the living person, this being part of the healing process. Fresh extravasation of blood is obviously dark red, though when viewed through the skin this may be purple or almost black in appearance. In racially pigmented victims, a bruise may sometimes be undetectable from the surface, apart from swelling caused by a haematoma and tissue oedema.

With the passage of time, the haematoma breaks down under the influence of tissue enzymes and cellular infiltration. The red-cell envelopes rupture and the contained haemoglobin undergoes chemical degradation, which causes a sequence of colour changes. The haemoglobin is broken down into compounds including haemosiderin, biliverdin and bilirubin, which lead the colour changes through a spectrum of purple to bluish brown, to greenish brown to green to yellow, before complete fading.

A small skin bruise in a healthy young adult might be expected to pass through all these stages and vanish in about a week, but there is a tendency to overestimate the length of time needed as shown by Roberts (1983), who observed that ‘love bite’ bruises in sexual offences could become yellow and vanish within a couple of days. Langlois and Gresham (1991) reviewed the literature on this subject, indicating the wide variation in opinion. They also made careful photographic records of the macroscopic appearance of bruising on 89 subjects, aged between 10 and 100 years. They concluded that the most significant change was the appearance of a yellow colour (in persons less than 65 years of age), which indicated that the bruise could not be less than 18 hours old. Blue, purple and red did not assist in

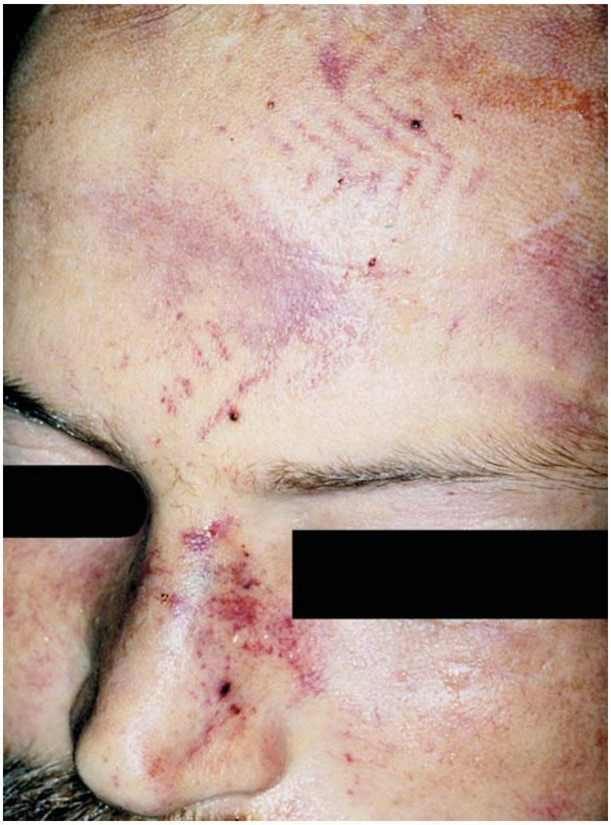

FIGURE 4.18 *Kicking and stamping injury to the face. The nose is bruised from a kick and the patterned rubber sole of the shoe has imprinted intradermal bruising on the forehead. It is essential to obtain accurate photographs and measurements of the shoe-tread pattern, to allow identification of the footwear.*

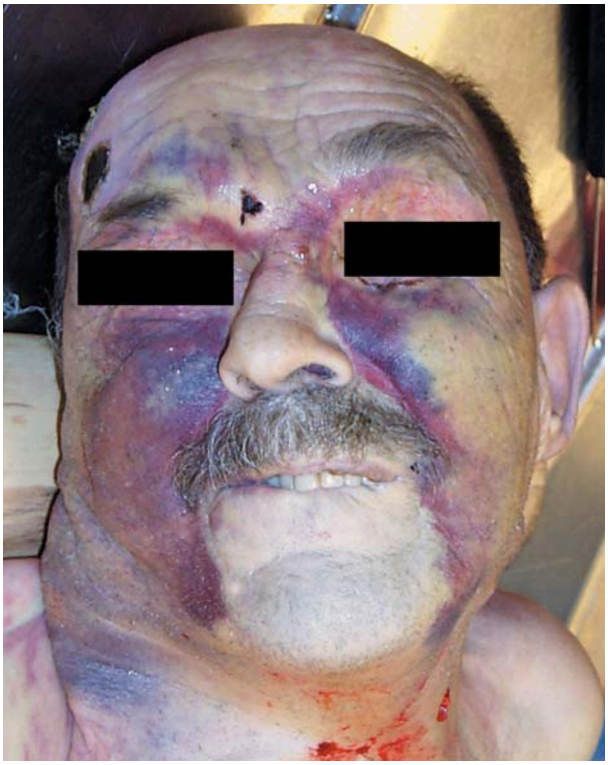

FIGURE 4.19 *Extensive bruising of the face due to hitting, kicking and stamping 6 days earlier. The victim had multiple fractures of the facial bones, bilateral serial rib fractures and a tension pneumothorax.*

dating bruises; brown was held to be a mixture of colours and was not considered as useful.

In the present authors' experience, it is impossible to comment on the age of a bruise less than 24 hours since infliction, except to say that it is 'fresh', as no visible changes occur in that time.

It is not practicable to construct an accurate calendar of these colour changes, as was done in older textbooks, as there are too many variables for this to be reliable. These include:

- the size of the extravasation – changes begin at the margin and a larger bruise will take a longer time to be absorbed. A large old bruise may contain all the colours possible – from purple in the centre to yellow at the edges
- the age and constitution of the victim. Aged persons may not heal their bruises at all and carry them for the remainder of their lives
- a personal idiosyncrasy in the rapidity with which such changes occur in any one person, including coagulation defects.

Even histological examination is unreliable in the accurate dating of bruises, as is discussed later in this chapter. The appearance of stainable iron, in the form of haemosiderin, however, does not usually appear within the first 2 or 3 days, though Simpson suggests that it may be found as early as 24 hours. In meningeal haemorrhage, it seems to appear from around 36 hours.

Haematoidin, another breakdown product of blood pigment, can appear in old bruises and haematomas after the first week.

Though an absolute date cannot therefore be placed upon a bruise, the following observations are legitimate.

- If a bruise appears fresh over all its area, with no observable colour change, it is unlikely to have been inflicted more than about 2 days before death, except in old persons.
- If the bruise has any green discoloration, it was inflicted not later than 18 hours before death (Roberts 1983; Langlois and Gresham 1991).

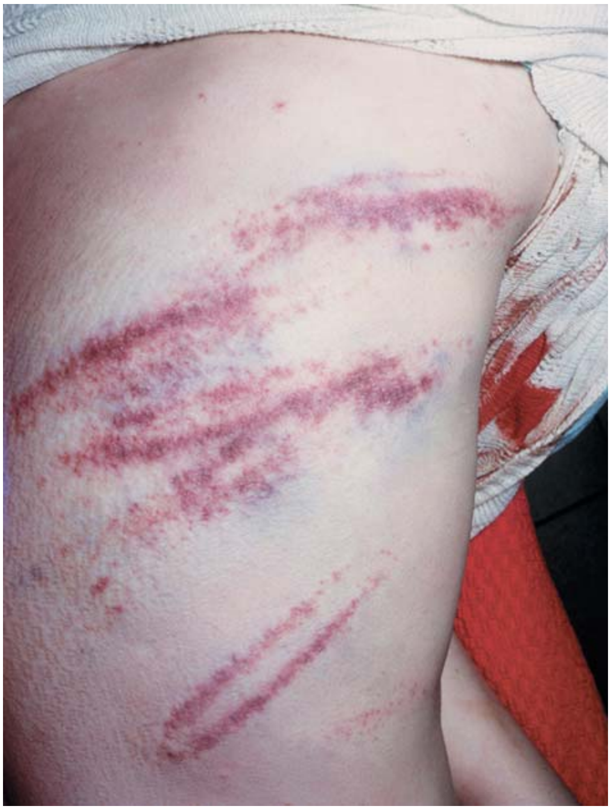

FIGURE 4.20 *Bruises from a beating with a broom handle. They are approximately parallel and several, especially the lowermost, show a double 'tram-line' appearance typical of the impact of a round or square-section rod. The pressure in the centre compresses the vessels so that they do not bleed.*

- If several bruises (of roughly comparable size and site) are present and are of markedly different colours, then they could not have been inflicted at the same time. This is particularly important in suspected child abuse, where intermittent episodes of injury have important diagnostic significance.

Bruising of special significance

Certain types of bruise and bruises at particular sites have a specific significance. Clusters of small discoid bruises of about a centimetre in diameter are characteristic of fingertip pressure from either gripping or prodding. These groups are often seen in child abuse, when an adult hand grips the infant by a convenient 'handle'. Once called 'sixpenny bruises' from their size, the lesions are commonly seen on the forearms or upper arms of the child, or sometimes around the wrist or ankle, though they can occur on the abdomen. Similar bruises from fingertips may be seen on the neck of children or adults in manual strangulation, though there is often additional diffuse bruising caused by a sliding grip on the neck.

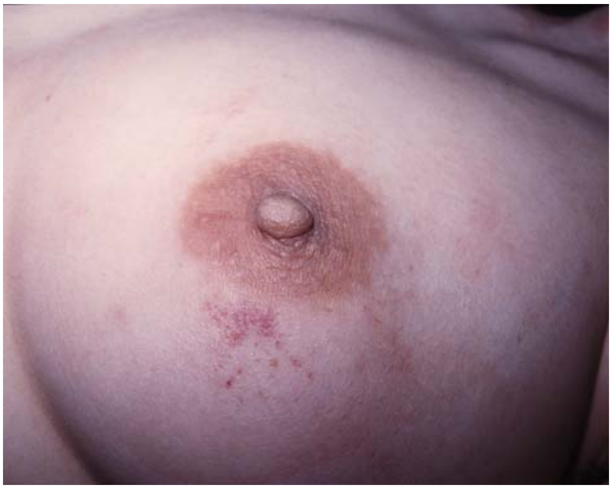

FIGURE 4.21 *Suction marks in the left breast of a 22-year-old homicide victim, who was killed by manual and ligature strangulation.*

When the skin surface is struck by a rod or rectangular sectioned object such as a cane or lath, the consequent bruising may be of the 'tram-line' or 'railway line' type. This appears as two parallel lines of bruising with an undamaged zone in the centre. The mechanism of this double line is that the weapon sinks into the skin on impact so that the edges drag the skin downwards and the traction tears the marginal blood vessels. The centre compresses the skin, which, in the absence of underlying bone, causes little or no damage to the vessels. When the momentary impact is released, blood flows back into the injured marginal zones and leaks into the tissues. Impact from broom handles, narrow planks and wood or metal rods can all cause this characteristic lesion.

As with abrasions, bites can result in bruises; this is dealt with in Chapter 26. It might be noted here that the so-called 'love bites' are often bruises, with or without associated abrasions, being a shower of small petechial lesions caused by oral suction on the skin.

The common 'black eye' is dealt with under 'Head injuries' in Chapter 5, but again it is worth repeating that not all black eyes are true bruising from a blow in the orbit. Some are from fractured orbital roofs and others are the result of gravitational movement of a forehead injury.

A bruise below the ear in a death from subarachnoid haemorrhage needs careful examination of the upper cervical spine and basilo-vertebral arteries, again as discussed under 'Head injuries' in Chapter 5.

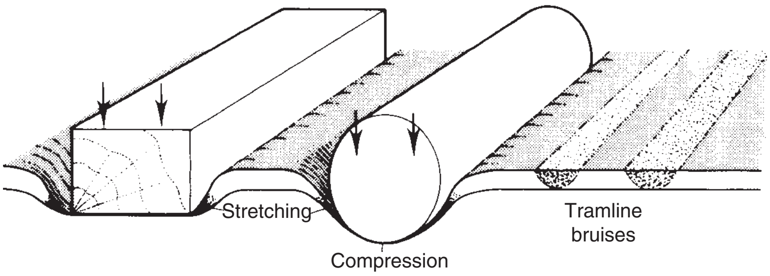

FIGURE 4.22 *Formation of 'tram-line' bruising from the application of a rectangular or cylindrical object.*

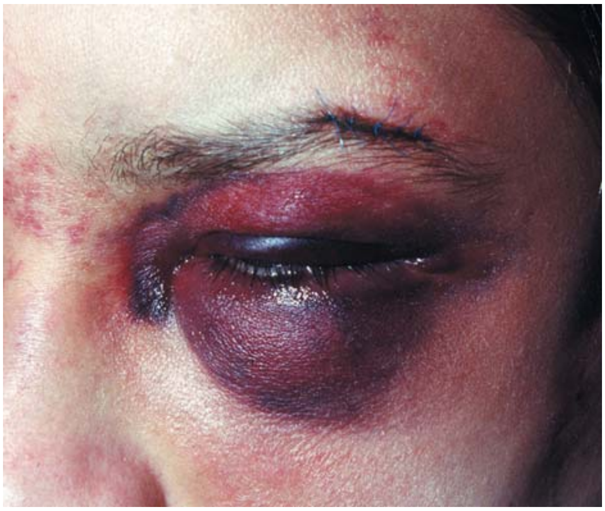

FIGURE 4.23 *A black eye (peri-orbital haematoma) of a live victim from a direct fist blow, which has also bruised the bridge of the nose and lacerated the corner of the eye (sutured).*

KICKING

The shod foot may leave a patterned bruise on the body, most often on the abdomen or chest, though it may be recognizable on the neck or face. A glancing kick is more likely to cause scuffed abrasions and bruising, and a kick from a toecap, a curved abrasion or even laceration. A vertical stamping action may imprint an intradermal bruise corresponding to the sole pattern, especially in these days of rubber 'trainer' shoes. As with a motor tyre, the skin can be forced into the slots in the sole, creating an accurate pattern of superficial bruising. There may also be more diffuse deep bruising if the impact is severe, but this is less useful in delineating an identifiable sole pattern.

Kicking has become increasingly common with the increase in violence and vicious hooliganism in society. The heavy footwear fashionable among some of the least responsible citizens adds to the severity of the lesions.

Though most kicking injuries end up in hospital casualty departments, an increasing number reach the pathologist. Not all victims are drunken youths, as many assaults upon old people by intruders and muggers involve severe kicking.

Obviously, most kicks are delivered with the victim already lying or sitting on the ground, having been brought there by some other means of violence, including pushing, tripping and fist punches. Once prostrate, the 'boot is put in' towards the most convenient targets, which tend to be the concavities of the body. The loin, the groin, the neck and the face are often attacked, and – when the victim assumes a 'fetal position' on his side for protection – swings may be taken into the abdominal area. As an alternative to swinging kicks, the foot may be brought vertically down on the prone victim, the heel being the most damaging part, rather than the toecap. A grinding motion can also be added, which may tear the skin and cause ragged lacerations.

Yet another variant is standing on the body or actually jumping onto it with one or both feet. The chest is the most common target for this practice and fractured ribs or sternum, a flail chest and cardiac injuries can result.

The major characteristic of most kicking injuries is the severity of bruising and underlying damage. Even if the toecap does not cause lacerations, there may be large haematomata and intramuscular contusions from heavy kicks. Abdominal and thoracic viscera can be ruptured and the genitalia are also vulnerable, especially the scrotum and sometimes urethra.

A common danger with kicking to the face is fracture of either (or both) mandible and maxilla, nasal bones and zygoma, though the cranial vault is seldom fractured and kicks to the vertex of the head seem less common. With such facial injuries, death may occur from filling of the pharynx and air passages with blood. A kick on one side of the face can completely detach the lower maxilla – with the upper dental arch and palate – from the rest of the maxilla. A unilateral kick of the jaw can fracture both rami of the mandible, there being no necessity for kicks on either side.

Post-mortem bruising and other artefacts

It is possible to cause what appears to be a bruise by deliberate violence to a dead body, but the amount of force

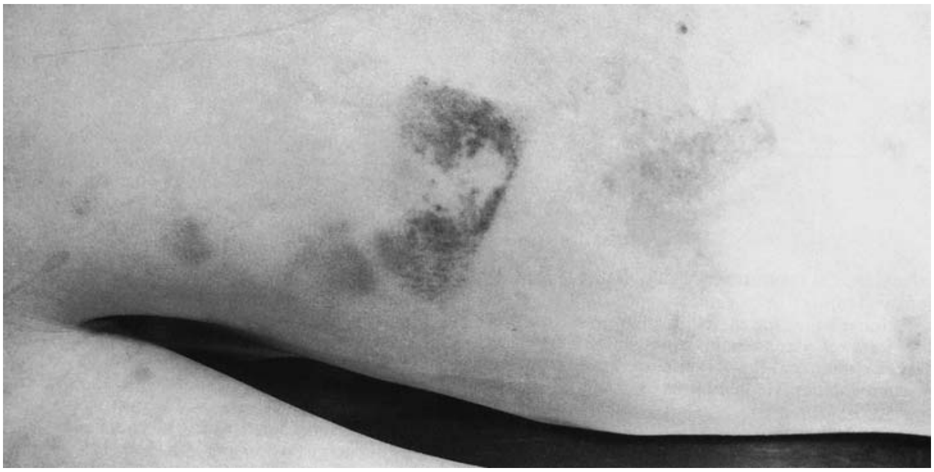

FIGURE 4.24 *A footmark imprinted in superficial bruising on the back. There is another partial mark at waist level, both being made by stamping with the flat of a foot through thin clothing, rather than by swinging kicks.*

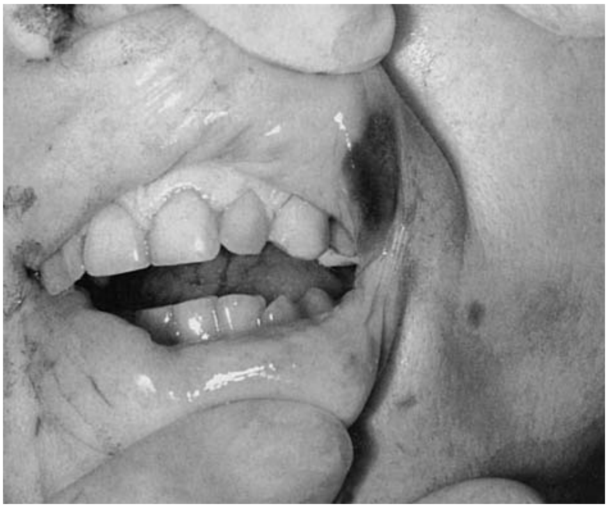

FIGURE 4.25 *Bruising of the interior of the lip from a blow in the mouth. The lip has been impacted on the underlying teeth, but not sufficiently hard to cause a laceration.*

required is great. As there is no internal pressure in the small vessels that have to be ruptured, bleeding is a passive ooze rather than an active extravasation, so the size of the haemorrhage is slight in relation to the amount of effort expended. Thus, post-mortem skin bruising is of little practical significance to the pathologist – in most instances he can be reassured that new or more obvious bruising apparent when he returns several days later for a second examination of a body is genuine. Post-mortem abrasions are common, especially after a first autopsy and additional handling of the body in the mortuary, but these procedures rarely produce artefactual bruises.

More important than dermal artefacts are spurious bruises inside the body. Especially in congestive deaths, such as pressure on the neck, the venous system may be engorged at death and a number of artefactual haemorrhages may occur. One particularly important area described fully elsewhere is the neck, in which collections of blood between the oesophagus and cervical spine may simulate bruising from manual strangulation. These were fully investigated by Prinsloo and Gordon (1951) and, where neck trauma is suspected, it is advisable to remove the brain before dissecting the neck region to allow drainage of the engorged venous plexuses that give rise to the artefact. This phenomenon appears to be related to the post-mortem interval and is more likely to arise if there is a delay in autopsy.

LACERATIONS

The third major type of blunt injury is the laceration, in which the full thickness of the skin is penetrated.

Lacerations differ from incised wounds in that the continuity of the tissues is disrupted by tearing rather than clean slicing, but the distinction is often blurred because some lacerations are caused by jagged projections ripping into the skin in much the same manner as a blunt knife or axe.

Unless great force is used, most lacerations require a firm base to act as an anvil for the skin and underlying tissue to be pinned against. It is unusual for a blunt impact to lacerate the abdomen or buttock, but the scalp, shins, shoulder, face and – to a lesser extent – the thorax, are all prone to lacerated injury. Where a soft area such as buttock, thigh, calf or forearm is lacerated, the lacerating agent is either a projecting point or edge, or a completely blunt object is pulled obliquely against the tension of the skin until it tears. Because of the crushing and tearing components of a laceration, there is usually associated abrasion and bruising,

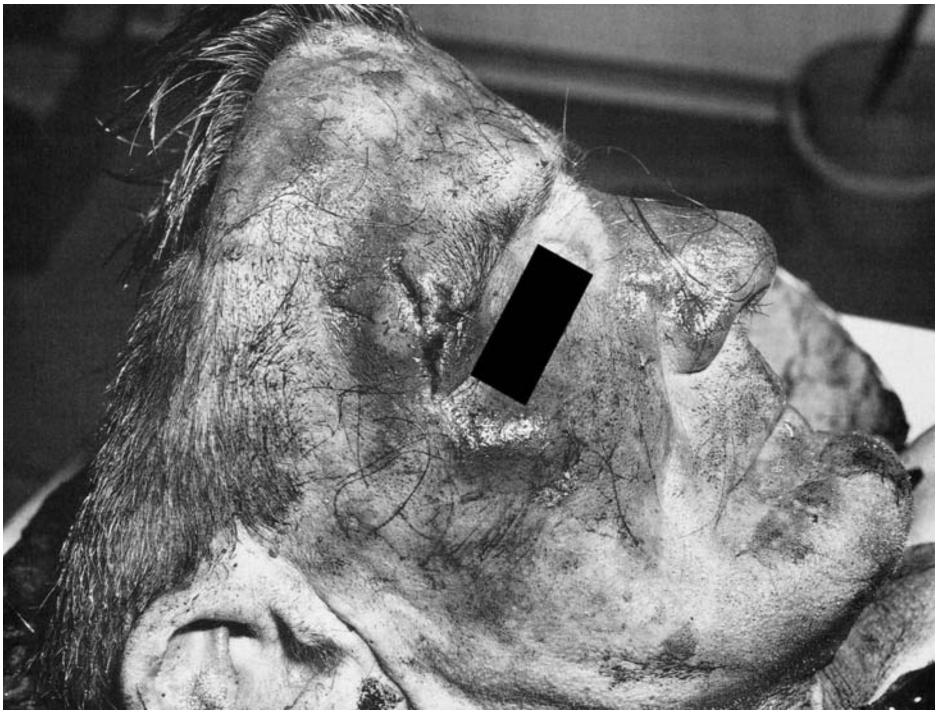

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FIGURE 4.26 *Laceration of the eyebrow with surrounding bruising. The wound is stellate as a result of crushing against the underlying bone. The victim fell from a low cliff on to rocks. The sea has washed away the original bleeding.*

though these may be minimal if the lacerating force acts at right angles to the surface.

The scalp offers the best example of a laceration, as the skin and subcutaneous tissue lie over the bony platform of the skull and are crushed against it when the force impacts. In fact, scalp lacerations can resemble incised wounds, because this ‘sandwich effect’ is so pronounced that a blow from a blunt instrument can cleanly split the tissues against the skull, leaving a linear wound that appears to the inexperienced to be a knife or chopper cut.

A laceration can be distinguished from an incised wound by:

- the bruising and crushing of the margins, though this may be a very narrow zone, requiring inspection through a lens
- the persistence of tissue strands across the interior of the wound, including fascial bands, vessels and nerves. In a wound from a sharp weapon these are divided
- the absence of a sharply linear injury in the underlying bone, especially if it is the skull. A knife or axe is likely to chip or score the base of the wound
- if the area is covered with hair, as on the scalp, intact hairs will survive to cross the wound; an incised injury would divide them.

A flat impact may cause a laceration, especially on the scalp. If the head falls to the ground or is hit by a wide, flat weapon, the skin and subcutaneous tissues are compressed

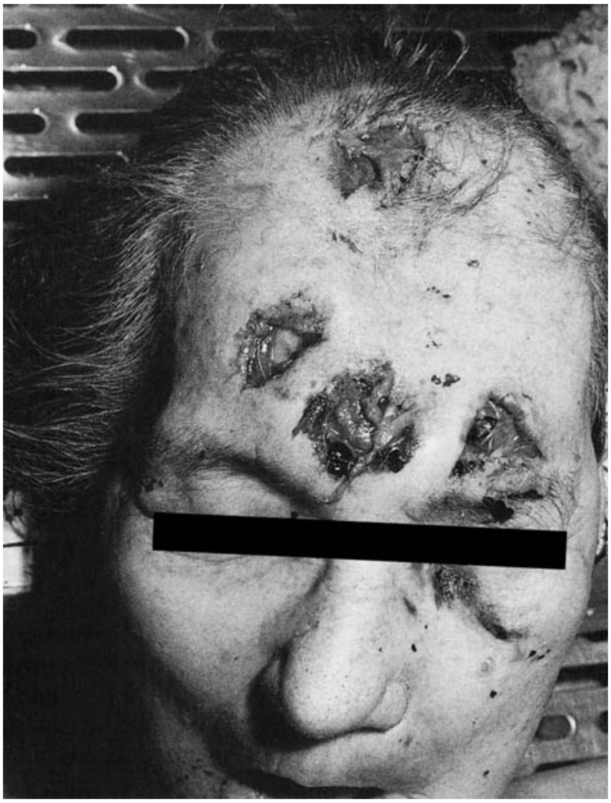

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FIGURE 4.27 *Multiple homicidal lacerations of the scalp. The unusual shape is difficult to interpret, but they were caused by a claw hammer. Two are triangular, the upper and lower show tissue bridges because of the gap between the two claws.*

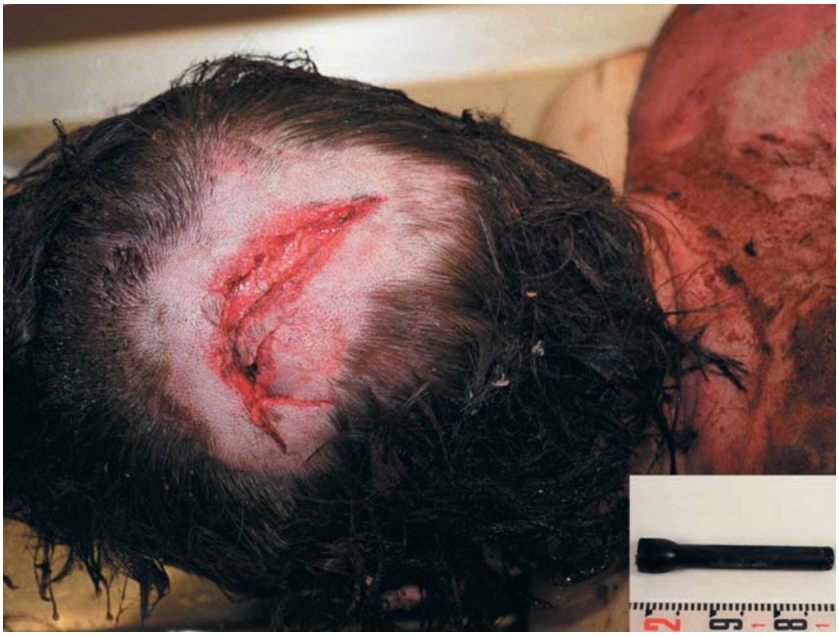

FIGURE 4.28 *Laceration of the scalp from a 30 cm long heavy torch (insert). The skin over the shoulders is reddish due to first- and second-degree burns. The victim was hit on the head while sleeping in bed, after which the husband poured petrol over the body and set it on fire.*

on the anvil of the skull and may split sideways, often with a zone of surrounding bruising.

Other lacerations are caused by the impact of an edged object, be this a rod, a brick, the edge of a kerbstone or the wing mirror of a vehicle. Though the impact may be virtually perpendicular to the skin surface, there is usually some tangential element and this can cause one edge of the wound to differ from the other. Where there is a glancing element, one edge will be relatively clean-cut, whereas the other will be ripped away from the first, suffering more tearing of the margin and often showing undercutting of the edge. If the impact is significantly asymmetrical, then this undercutting may be pronounced enough to form a flap of skin and underlying tissue, which is peeled off the underlying bone or deep fascia.

In extreme forms, this produces a 'flaying injury', where a large area of skin and subcutaneous tissue is rolled off a limb, almost always by the rotary action of a revolving motor wheel. A similar injury can occur on the scalp again from a rotating wheel – though a similar 'scalping' lesion can be caused by traction from hair being trapped in machinery. This was formerly a common industrial accident and was the reason for the 'snood' hairnet being worn by women factory workers during the last war.

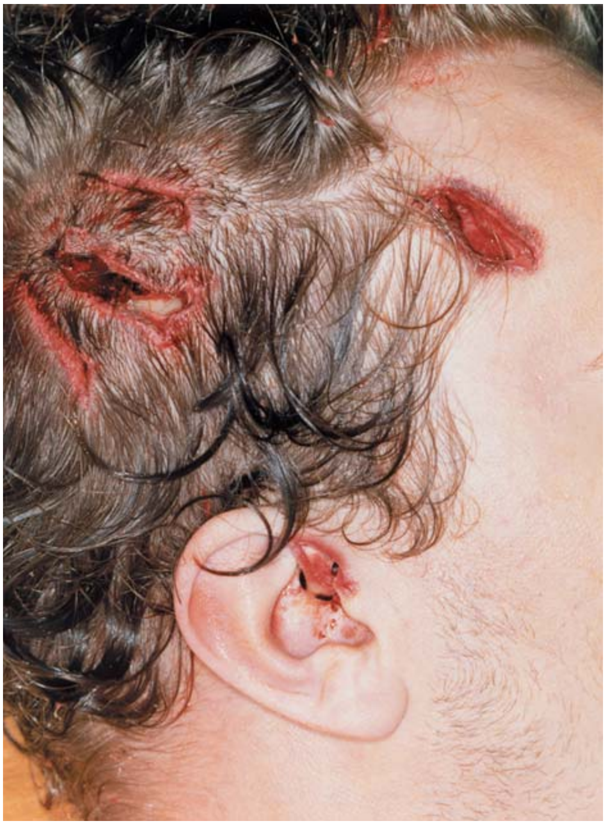

FIGURE 4.29 *Homicidal lacerations of the scalp penetrating the skull. Although some of the injuries resemble incised wounds, their margins are crushed, and hairs and tissue strands cross the injuries. The damage was probably inflicted with a metal rod with sharp edges.*

Patterned lacerations

Lacerations do not reproduce the shape of the injuring agent nearly as well as do abrasions and intradermal bruises. As with

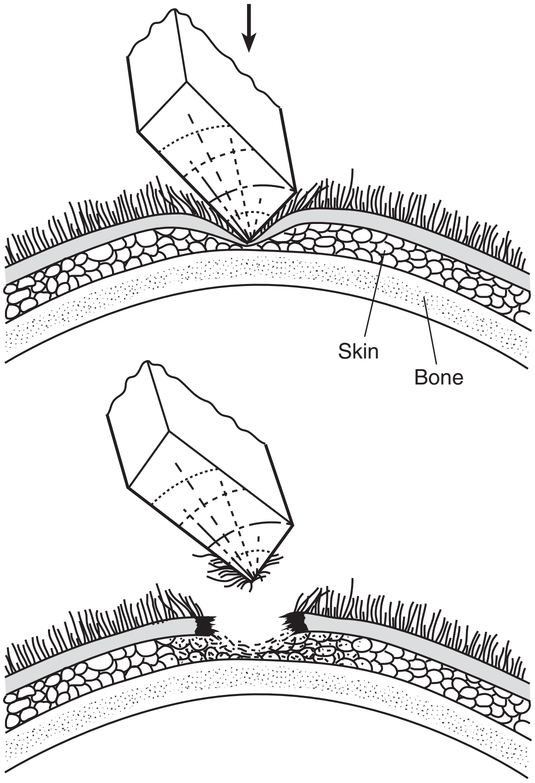

FIGURE 4.30 *Crushing impact of a blunt object on skin supported by bone, such as scalp on skull. The skin is sandwiched between weapon and bone and this causes a lacerated split that has bruised margins and bridges of hair and tissue in the wound.*

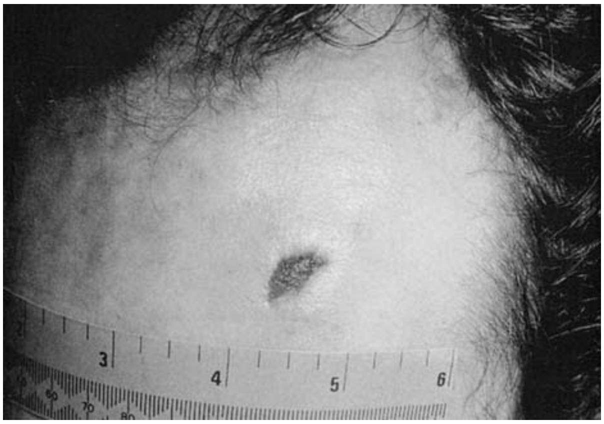

FIGURE 4.31 *A healing shallow laceration of the forehead, about one week after infliction. The base of the injury has filled with granulation tissue and the surrounding skin shows puckering due to contraction of the central scab.*

skull fractures, the magnitude of the force needed to cause a blunt tearing of skin leads to blurring of the impact shape, often with radiating or totally irregular tearing. Sometimes the shape is recognizable and probably the best example is a hammer blow to the head. A circular face may punch out a circle or an arc of a circle, which may also be reproduced in an underlying depressed skull fracture. The exact size of the hammer face may not be accurately reproduced in the laceration, which may be slightly larger than the hammer.

Kicks may cause lacerations, especially if a heavy boot with a hard toecap is used. These tend to be tangential and may peel up a flange of tissue. They can be clean-cut and are sometimes mistaken for knife wounds. Stamping injuries are more likely to cause abrasions and bruises than lacerations, unless the violence is extreme. A heavy focal blow may cause a linear or a stellate laceration, the latter radiating out from the focus of impact. The surface may be abraded and the surrounding tissue deeply bruised, so the final lesion is complex.

Firearm wounds are a special form of laceration and will be dealt with separately.

BLUNT PENETRATING INJURIES

These ‘puncture wounds’ are a hybrid between lacerations and incised wounds, and have more of the features of the latter. Such injuries can occur from metal spikes, wooden stakes, garden or farm forks, and a variety of vehicular and industrial accidents. They are occasionally seen in homicides or suicides when weapons like screwdrivers are used as daggers. The interpretation of such skin wounds can be difficult, as in the ‘Yorkshire Ripper’ cases, when some small stellate stab wounds were thought to have been caused by a Phillips-type screwdriver. A number of fatal wounds, some of them homicidal, have been caused by chisels, usually very sharp woodworking tools with one face of the edge ground to a straight line. The edges of the chisel are squared off and the resulting skin defect may be rectangular.

When a blunt spike is driven through the skin, there will be inversion and abrasion of the edges, though the former may vanish if the weapon has been withdrawn. Foreign material such as rust, dirt or splinters may be left in the wound, and must be carefully preserved for forensic examination if the weapon has not been recovered.

INCISED WOUNDS

Injuries caused by sharp objects are classified as ‘incised’ wounds, though the nomenclature is again somewhat confused. Some authors make these a subcategory of lacerations and, when the weapon is relatively blunt (as in some axe or spike injuries), there may be sufficient crushing and bruising of the wound margins to make differentiation between incised and lacerated wounds difficult.

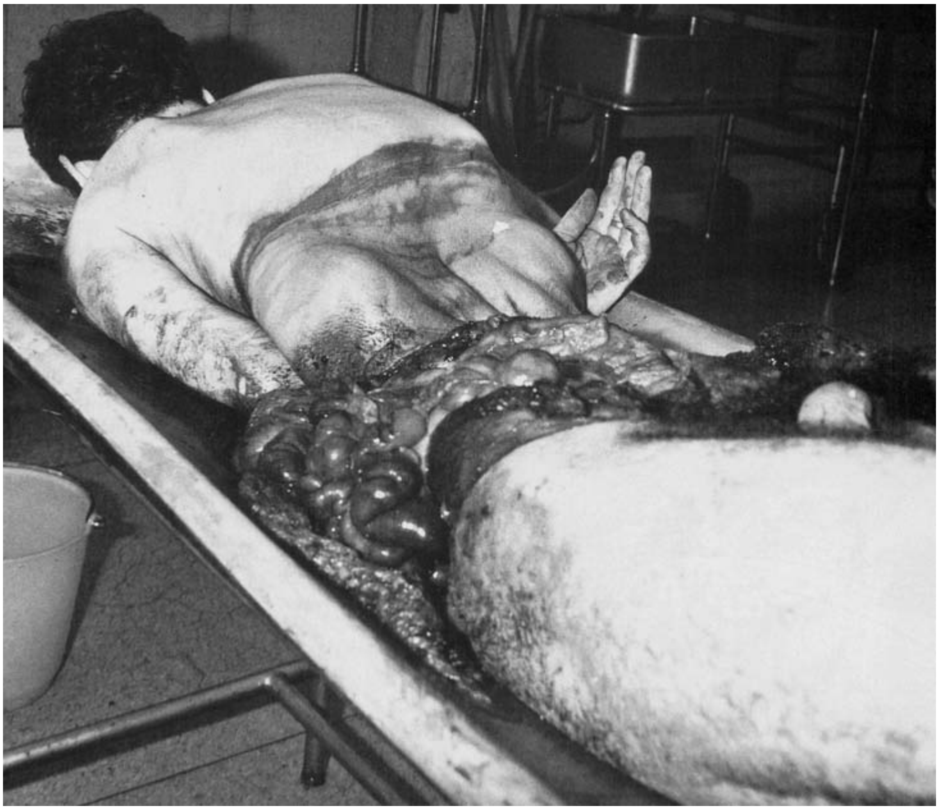

FIGURE 4.32 *Transection of a body into two halves at waist level. The victim jumped from a high-rise building and landed on a fence.*

The term 'incised wound' usually covers all types of injury from, for example, a knife, sword, razor, glass or sharp axe – though some writers would make stab wounds a separate category, reserving incised wounds for injuries that are longer than they are deep. These semantic variations are not important in themselves, but can lead to confusion in medical and autopsy reports, as well as in oral testimony if the doctor fails to clarify his meaning. The essential feature of all incised wounds is the clean division of the skin and underlying tissues so that the margins are almost free from any damage. Microscopically there is always a narrow zone of injury, but this is minimal compared with the tissue destruction caused by blunt injury. Healing is affected, as well as the extent of subsequent scarring.

Cuts or slashes

When an incised wound is longer than it is deep, it may be referred to as a 'cut' or 'slash', though a 'cut' may also be used by lay persons to describe a laceration. Such slashes when inflicted by knife, sword, razor, cleaver, parang, machete, panga, broken glass or bottle, are typical of a fight, when the assailant strikes out with a swiping action, rather than the thrust of a stabbing attack. They are common in gang fights and bar-room brawls and the weapon may be swung at arm's length in a horizontal arc so that if it contacts a body it will slice the skin and tissues as it passes by. They are also seen in suicidal injuries, usually on the wrist or throat. The characteristics of any given wound are a matter of a chance and relative positions. The slash may be deeper at the entry end or the exit point, though it seems true that many such injuries tend to dig in near the point of first contact and become progressively more shallow as the wound approaches the distal end. There may be a superficial 'tail', a shallow scratch, running out of the termination of the slash, as the weapon rises out of the wound and is drawn across the skin surface before leaving the body altogether.

There is a tendency among advocates to visualize a fight as a static confrontation and to attempt to reconstruct events as if the two participants were standing still, the assailant merely moving his arm. This is an unrealistic interpretation, as all fights are dynamic, with constant relative movement of the bodies and limbs of both parties. Therefore any relative angles and depths of contact between the victim and the weapon can occur and overinterpretation and simplification should be avoided.

Slashed wounds are less dangerous than stabs, as the relative shallowness of the wounds is less likely to affect vital organs – especially as the arms and face are the common targets. The rib cage and skull protects the chest organs and

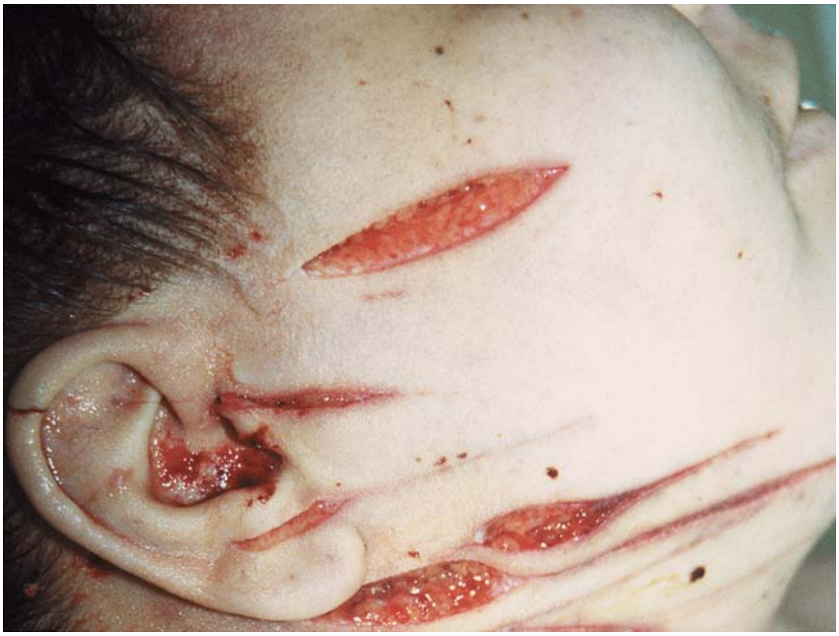

FIGURE 4.33 *Homicidal slashed wounds caused by knife; the length is greater than the depth, unlike stab wounds. The long tails are due to the knife rising from the skin, thus indicating the direction of the slash.*

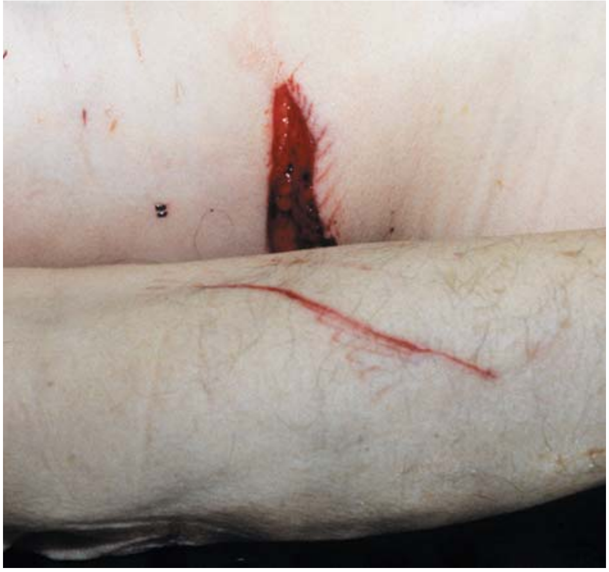

FIGURE 4.34 *A knife slash of the back showing regular scratches along the margin. This was inflicted with a 'Rambo' knife, which has deep serrations along the back edge that have somehow marked the skin on withdrawal.*

brain and the more vulnerable abdomen is seldom the target for a swung knife. Wounds of the neck are the most dangerous and are discussed below. Bleeding is the most serious complication of any slashed wound, though it will be external and more amenable to immediate treatment than the hidden internal bleeding of a stab wound.

A particular form of slashed wound arises from 'glassing', that is, the use of a broken drinking glass or bottle as a weapon. The glass may sometimes be broken prior to the attack, to produce edges that are exquisitely sharp. There may also be spikes of glass, which can inflict deep, almost stab wounds. Where, more commonly, a glass or bottle is used as a blunt instrument, it may shatter on impact with a victim's head, and the resulting injuries may both be blunt and incised.

Stab wounds and penetrating injuries

These are of major importance in forensic pathology, as they are extremely common in homicide. In Britain, stabbing with a knife is easily the most frequent mode of murder and manslaughter, primarily in domestic disputes and street violence. A stab wound is an incised wound that is deeper than it is wide. Though many penetrate only the skin and subcuta- neous tissues, those seen by forensic pathologists are most often fatal, having entered vital deep structures. Several aspects of this important topic need discussion.

THE NATURE OF STABBING WEAPONS

Knives are the weapons most frequently involved and their physical characteristics are important in shaping the wound. A pathologist called upon to examine a knife that may have been used in an assault should note and measure:

- the length, width and thickness of the blade
- whether it is single or double-edged
- the degree of taper from tip to hilt
- the nature of the back edge in a single-edged knife (for example, serrated or squared-off)

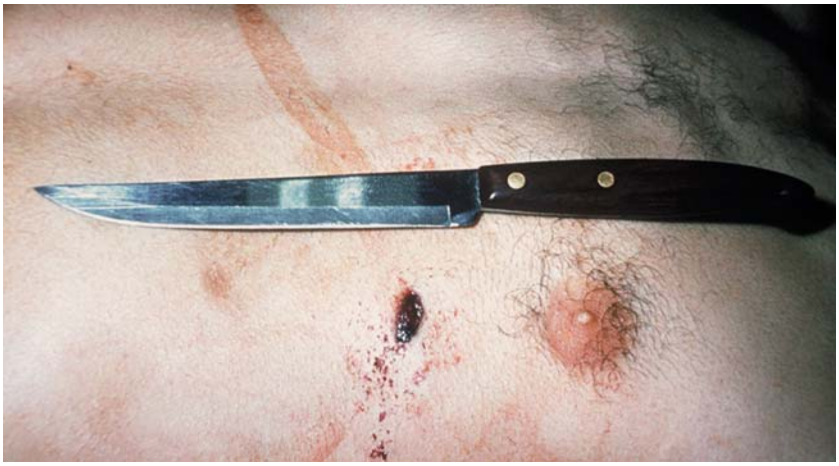

FIGURE 4.35 *A stab wound and the inflicting knife. The wound is slightly shorter than the width of the blade at the depth of penetration because of sideways gaping and the contractile elasticity of the skin.*

- the face of the hilt guard adjacent to the blade
- any grooving, serration or forking of the blade
- most importantly, the sharpness of the edge and especially of the extreme tip of the blade.

Other knife-like weapons include scissors, chisels, swords, open razors and sharp tools of many kinds, including deliberately modified tools such as sharpened screwdrivers. Larger cutting instruments such as axes, choppers, parangs, machetes and pangas and agricultural implements such as shears, bill-hooks, hay-knives and many others have been used as stabbing weapons when used by the point rather the long edge.

Spiked instruments come in many forms, from icepicks to hay-forks, from case-openers to fire-irons. The appearances of their wounds vary with the physical nature of the implement. Some weapons are exquisitely sharp and the wounds made by them exhibit extremely fine division of the tissues. To razors and razorblades may be added surgical and craft knives, often with a disposable blade, together with carpet and general utility and hobby tools, such as the 'Stanley' knife. Equally sharp is broken glass and sometimes porcelain. Both sheet glass and smashed glass utensils can provide edges that equal or exceed surgical scalpels in their cutting ability.

A common weapon in a bar-room fight is a smashed beer tankard, which when held by the intact handle provides a formidable weapon for both slashing and stabbing. Smashed china, such as cups and mugs, can also provide sharp cutting edges. The external glaze can project, if the fracture line is oblique, producing a glass-like edge. From personal experiment, the author (BK) has shown that broken china can easily slice through the full thickness of skin and thus validate a defence that injuries were the result of falling on a broken mug.

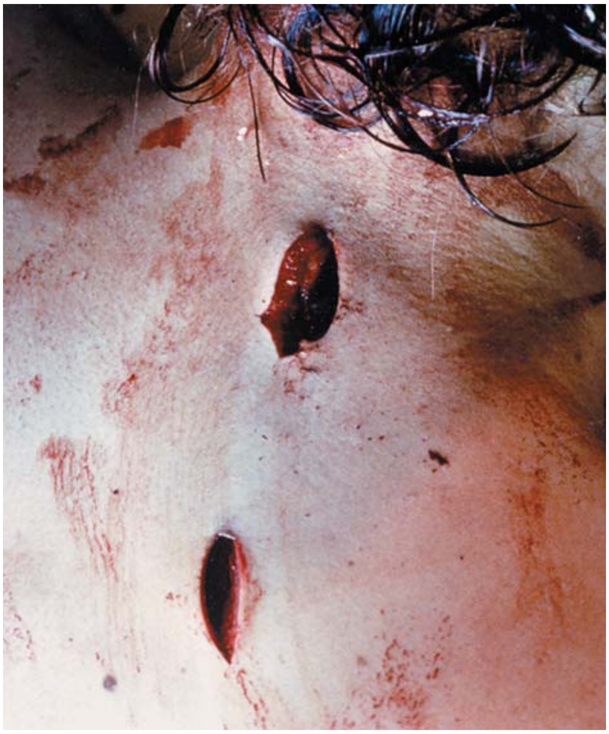

FIGURE 4.36 *Two knife wounds in the back. The wounds have a sharper lower edge compared to a rounder upper edge, due to a one-edged blade.*

THE CHARACTERISTICS OF A STAB WOUND

The surface and internal appearances of a stab wound allow the pathologist to offer an opinion upon:

- the dimensions of the weapon
- the type of weapon
- the taper of the blade

- movement of the knife in the wound
- the depth of the thrust
- the direction of the thrust
- the amount of force used.

Dimensions of the weapon

The dimensions of the knife may be a vital part of the investigation of a homicide when the weapon has been removed from the scene by the assailant. The pathologist can sometimes assist the investigators by telling them, within limits, what size and type of knife to seek. When suspect weapons are recovered, his inspection of them may indicate whether or not they are consistent with having caused the wounds in question. As always in forensic medicine, however, caution must be employed and the cardinal sin of overinterpretation avoided.

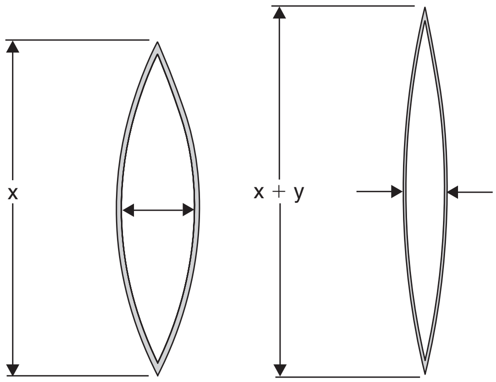

FIGURE 4.37 *A stab wound gapes across its width and shortens in length, especially when across skin or muscle planes.*

The length of the wound should be measured to the nearest millimetre as it lies undisturbed on the skin. In most instances the wound will have gaped across the centre, to form a long ellipse. The extent of gaping will depend on the anatomical situation, for example, over joints or in the axilla or groin, and whether the axis of the stab is in line with or across the tension of Langer's lines or underlying muscle bundles.

When the edges are gently opposed, the length of the wound may then extend slightly and should be measured again in this position, which more accurately approximates to the length when the blade was *in situ*.

An important additional factor, however, must always be taken into account because, when the knife is withdrawn the elasticity of the skin causes it to retract, making the wound smaller than when the blade was *in situ*. This mechanism may be amplified by contraction of the underlying muscles, which, if at right angles to the axis of the wound, may cause the wound to shorten from end to end, while gaping more widely at the centre. Using wound measurements to predict the size of the knife blade, one must take into account the other matters discussed below, such as movement of the blade in the wound, the taper of the blade and the depth of penetration.

Type of weapon

The type of blade usually refers to whether it had a single or double cutting edge. Most knifes have a single sharp edge, the back edge being blunt or otherwise machined. A few dagger-like weapons have both edges ground to sharpness,

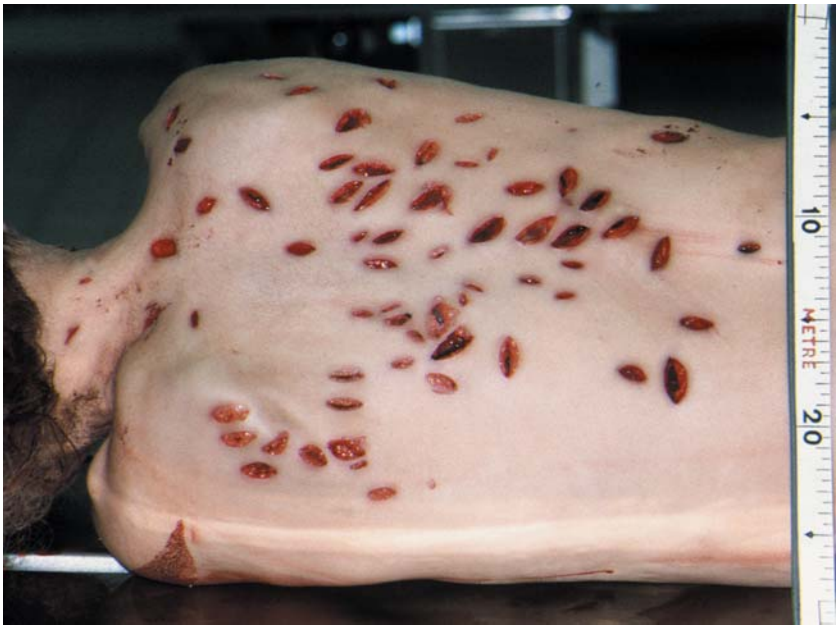

FIGURE 4.38 *Multiple stabs on the back from the same knife, showing differing shapes and sizes.*

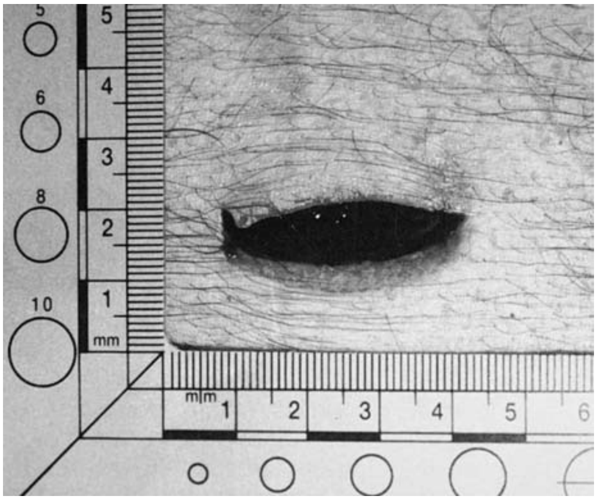

FIGURE 4.39 *A stab wound showing a unilateral 'fish-tail' split caused by the blunt back edge of the knife blade. This is sometimes bilateral due to tearing of the tissues. The other end of the wound is pointed due to the cutting edge of the blade.*

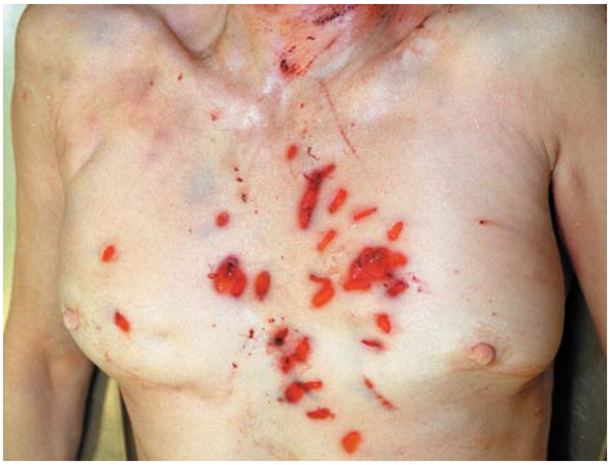

FIGURE 4.40 *Multiple stab wounds from the same knife, showing variations in the size and shape of the injuries. With multiple injuries, it is advisable to number each to facilitate easy reference in the autopsy report and when giving evidence in court.*

some have only the distal part of the back of the blade sharpened. On inspecting the skin wound, the pathologist frequently finds that both ends of the defect appear sharply cut, coming to a fine 'V-point' at the extremities. Unfortunately, this does not necessarily indicate that a knife with two sharp edges was used, as the skin often splits behind the blunt edge to produce a symmetrical appearance.

If, however, there is an obvious difference between one sharply pointed end and a rounded or even square-cut opposite extremity, then it can be said with some confidence that a single-edged knife was employed.

A knife with a thick blade that is squared off to a flat surface on the edge opposite the cutting edge, may sometimes be identified from the wound, where a definite double right-angled end to the skin defect is apparent. The skin may split back slightly from each of these corners, forming the so-called 'fish-tail' appearance.

Where a knife with a serrated back edge has been used, such as is found on some boy scout or other Bowie-type knives (or the recently fashionable 'Rambo' weapons), the back edge of the wound may be torn or ragged and – on some occasions where the knife has entered very obliquely – serrated abrasions may be seen on the skin adjacent to the end of the wound.

If the knife has been plunged into the full extent of the blade, then there may be a hilt bruise or abrasion on the skin surrounding the wound. This may even reproduce the pattern of the guard at the base of the hilt, if there is one. Careful photography, sketches and measurements are needed to capture the exact outline of such a mark, which are, admittedly, unusual.

Taper of the blade

The taper of the blade is naturally related to wound size. If a tapered blade is inserted to 4 cm, then the length of the wound (ignoring skin retraction for the moment) will be that of the width of the blade at that level. If the taper continues to the 8 cm level, then the wound will be correspondingly longer. Only when the blade edges become parallel will the wound size remain constant for further penetration of the knife.

Movement of the knife in the wound

Movement of the knife in the wound can result in loss of evidence as to the size of the blade, but can also add other information. Where a knife is stabbed directly into the body and withdrawn along the same track then, within the limits discussed above, the size of the wound will indicate the minimum width of the blade at the maximum depth of penetration.

If, however, the knife is 'rocked' in the wound, the skin defect will be enlarged, sometimes considerably. The term 'rocking' means a leverage or angulation in the plane of the wound, so that the cutting edge extends the incision. This rocking can occur either by the knife being actively moved in the wound by the assailant – or by the body moving relative to the knife – or by a combination of the two.

It is sometimes a misapprehension among both doctors and (especially) lawyers, that stabbings and other assaults occur in static circumstances, with the victim standing in the anatomical position. Directions of wounds are all too often interpreted as if the only movement came from the hand of the assailant, whereas in most fatal assaults the

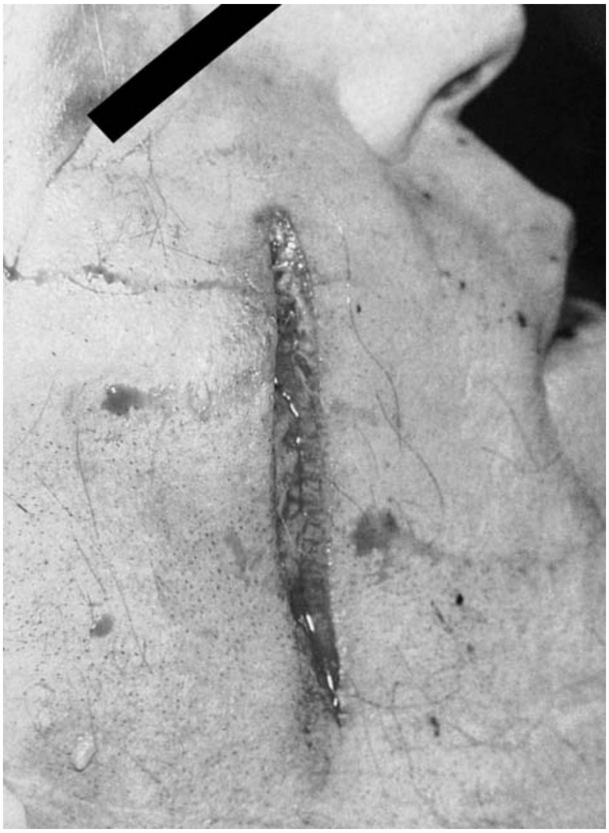

FIGURE 4.41 *A slashed facial wound from a knife, showing undercutting or 'shelving' on the edge nearest the mouth, indicating the angle of the knife relative to the surface. The tailed nature of the lower end also indicates that that knife was drawn downwards across the face.*

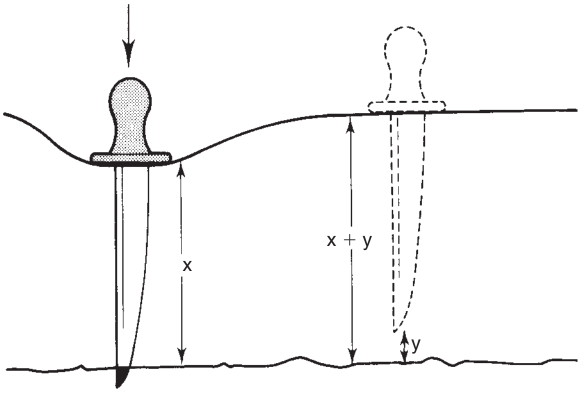

FIGURE 4.42 *Forcible stabbing can indent the body surface so that deep structures can be injured that appear to be beyond the reach of the knife.*

victim bends, turns and twists, and the assailant often follows with similar gyrations. Thus a knife that is thrust into the body may itself move or the body may move against it before it is withdrawn.

This relative movement may extend the wound in a linear fashion, as described above or there may be twisting of the blade in the wound. In the latter case, the resulting skin incision may be V-shaped or totally irregular. Rarely, a single stab may produce multiple skin wounds, such as a tangential stab of the arm, which passes through the superficial tissues and then re-enters the chest wall. Another instance is a stab through a female breast where, especially if the breast is sagging, the knife can pass right through the edge before re-entering the thorax.

Depth of the thrust

The depth of a stab wound may be important in attempting to assess the length of a missing weapon. Again there are pitfalls to be avoided. First, if a knife is driven in up to the hilt, the depth of the wound as measured at autopsy may be greater than the true length of the blade. This is common in the abdomen and to a lesser extent in the chest, because the impact of a forceful stab may momentarily indent the abdominal or chest wall so that the tip of the knife penetrates tissues that apparently should have been out of reach. This is particularly so when the hilt guard of the weapon impinges on the skin. For example, the author (BK) has seen the tip of a broken knife embedded in a thoracic spine, where the distance from that tip to the anterior skin wound was less than the length of the blade when recovered.

As with direction, discussed below, the pathologist must also allow for differences in the position of internal organs as measured at autopsy in a supine body, compared with their position in the living body, often in the upright posture. Such variations in the *in vivo* distance from the skin wound to the organs penetrated must be taken into account when assessing the depth of a wound. In the chest and abdomen, visceral relationships vary with the stage of respiration. The lower ribs move upwards and laterally, and increase the distance between the skin and deeper structures.

Direction of the thrust

The direction of a stab wound is often a matter of contention in homicides, especially as trial lawyers (and their medical advisers) sometimes tend to overinterpret the facts when trying to reconstruct the scene of the fatal assault.

As mentioned above, a stabbing incident is often moving and dynamic, and the victim is rarely in a static, anatomical position. For example, a wound that enters the upper part of the left side of the chest and travels steeply downwards, is not inevitably the result of the killer being taller or situated above the victim, using a downward blow. The victim could equally well have been bending or crouching, the knife then entering on a horizontal plane relative to the floor. All that the pathologist can do is to determine the direction of the wound relative to the axis of the body – it is then a

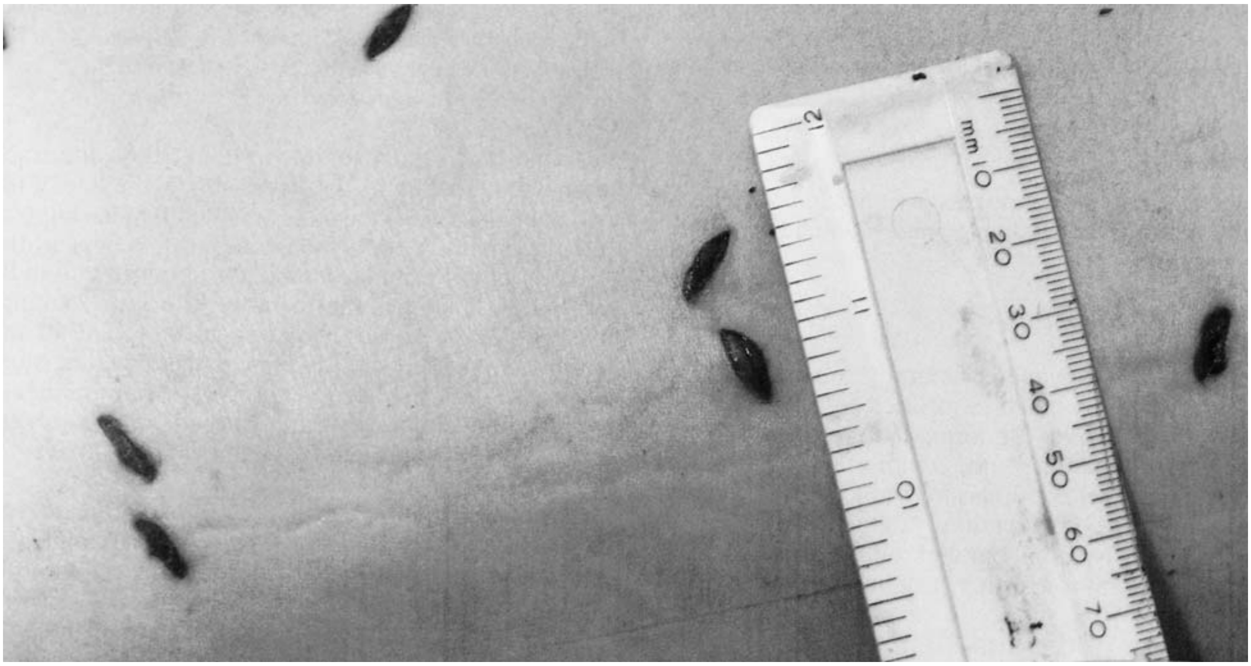

FIGURE 4.43 *Multiple stab wounds from the same knife. Although those at the bottom left are obviously square-ended, the more central ones are almost equally sharp at the extremities – illustrating the dangers of being too dogmatic about describing a missing knife to the investigators.*

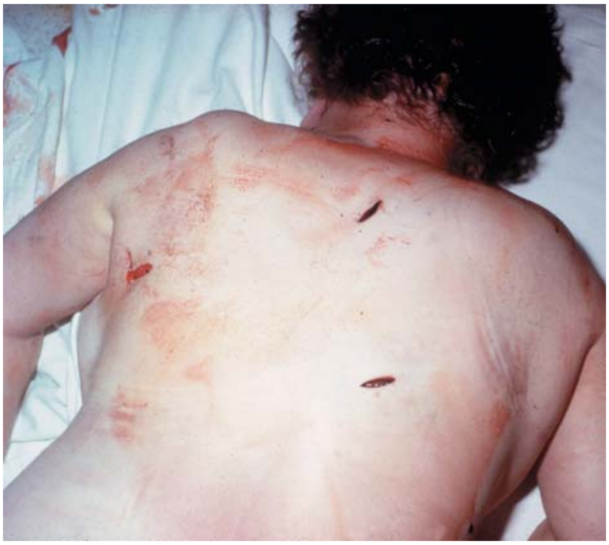

FIGURE 4.44 *Homicidal stab wounds misdiagnosed by an attending doctor as 'haematemesis or epistaxis'. The lower right wound clearly shows evidence of a single-edged blade. The wound in the left axilla is V-shaped because of the twisting knife.*

matter of non-medical evidence to relate that to the posture of the victim when struck.

Determination of the direction relies on both the appearance of the skin wound and the track in the deep tissues. Where a knife penetrates the skin with the plane of the blade at appreciably less than a right angle to the surface, the wound is often 'undercut', being shelved so that subcutaneous tissue is visible below one edge of the wound. Where the knife is plunged in obliquely, but the plane of the blade remains perpendicular to the surface, no such shelving can be seen at the sides of the wound though it may just be visible at the end of the wound.

More information about direction comes from careful examination of the track of the stab wound. This is an anatomical exercise during autopsy, the layers of tissue being examined in sequence from the surface downwards and damage to deep structures and organs compared with the position of the surface wound. For example, a stab wound of the chest may lie below the left nipple. Dissection of the subcutaneous tissues and muscles may reveal that the defect in the chest wall lies in the sixth intercostal space and that, inside the thorax, the right ventricle of the heart has been transfixed, and that there is a wound in the diaphragm that terminates in the liver just to the right of the midline. This information obviously indicates that the direction of the wound was downwards and from left to right. Similar deductions can be made for all other sites, but caution must be exercised, as mentioned earlier, in allowing for the change in position of organs in the supine post-mortem posture compared with the erect, living state. A thorough knowledge of surface anatomy is required, especially of the thorax, as well

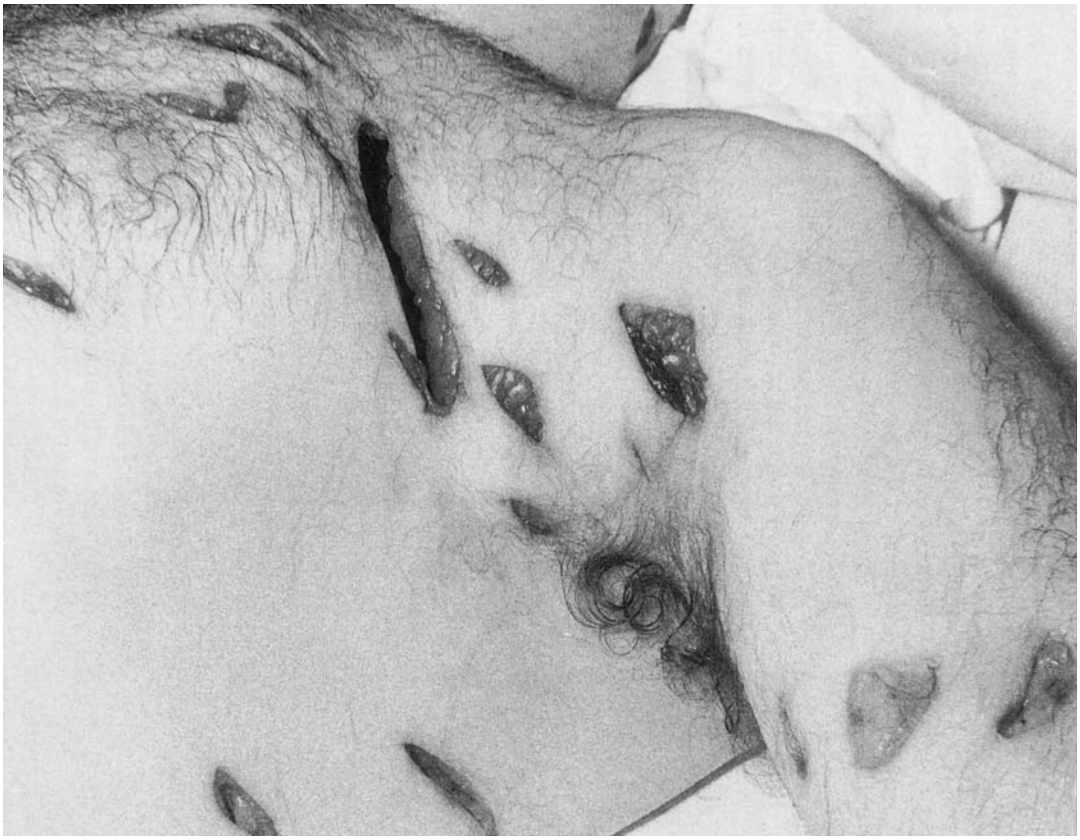

FIGURE 4.45 *Multiple homicidal knife wounds, all inflicted with the same weapon. This shows the marked variation in wound size from the same knife, caused by rocking and twisting movements of either weapon or victim.*

as diagrams of the position of internal organs mapped out in relation to surface markers; samples of such diagrams are given in this book.

Attempts have been made to delineate the track of a stab wound before dissection either by filling the defect with a radio-opaque fluid before taking X-rays, or by filling with a plastic or even metallic substance that will harden to form a cast. In practice, these methods appear to have little advantage over careful dissection. When radio-opaque liquids or pastes are used, there is often leakage from the stab wound into the thoracic or abdominal cavities, leading to a confusing radiological picture. Recently, magnetic resonance imaging (MRI) has been used to visualize the wound track, but such facilities are rarely available for dead victims.

Estimation of the degree of force used in stabbing

The amount of force required to inflict any given stab wound is often a matter of extensive debate in criminal trials. The prosecution naturally gains from showing that a stabbing was inflicted with 'considerable force', sometimes even using pejorative terms such as 'violent' or 'frenzied'. This tends to confirm the intention to stab, whereas the defence proposition is often that the victim inadvertently fell or was pressed against a weapon held passively by the accused. An expert medical witness has difficulty in replying to the almost inevitable question by counsel: 'What amount of force was necessary to cause this wound, doctor?'

Assessment of force is subjective and cannot be quantified in any satisfactory way that is meaningful to the court. Physical units such as dynes/cm^2, even if they can be measured, mean nothing to a judge and jury. The only measure that the medical witness can offer is a broad grading, based on common sense knowledge, such as 'slight pressure', 'moderate force', 'considerable force' and perhaps 'extreme force', the latter being reserved for exceptional cases where the knife has impacted in dense bone, penetrated the skull, or left a marked bruised impression of the hilt guard on the skin. A number of investigators, including the author (BK), have carried out measurements on the force needed to inflict stab wounds, both in animal, cadaver and surrogate tissues. The usual method is to attach some type of dynamometer or transducer to a knife, which records the maximum force applied during penetration, preferably with the duration of impact.

From this work, the following useful generalizations can be made.

- Apart from bone or calcified cartilage, the tissue most resistant to knife penetration is the skin (Knight 1975), followed by muscle where large muscle bundles underlay the fascia.
- The sharpness of the extreme tip of the knife is the most important factor in skin penetration. The cutting edge of the knife, once the tip has penetrated, is of relatively minor importance.
- The speed of approach of the knife is particularly important in achieving penetration. A knife held against the skin, then steadily pushed, requires far more force to penetrate than the same knife launched against the skin like a dart. As in blunt injury, this is an example of the physical law that requires that the force varies directly not with the mass of the weapon, but also with the square of the velocity.
- Stretched skin is easier to penetrate than lax skin. The chest wall, where skin tends to be intermittently supported by underlying ribs, is relatively easy to puncture with a sharp knife as the skin and tissues are stretched over intercostal spaces in the manner of a drum membrane.
- Though the thick skin of the palms and soles is much tougher than on the rest of the body, the variation in resistance of the rest of the skin to a sharp knife is of little importance compared with other factors. Similarly, the skin of the aged, or of women, is not appreciably less resistant to a sharp point than that of men or young persons.
- When a knife-point impacts against skin, the latter dimples and resists until penetration suddenly occurs. The tension developed in the stretched skin appears to act as an 'elastic reservoir' and, when the threshold of resistance is exceeded, the knife 'falls' through the subcutaneous tissues without any further force being imparted to it unless impeded by bone or cartilage. Thus no additional effort is needed by the assailant to achieve deep or even full penetration up to the hilt. It is sometimes incorrectly claimed by the prosecution that a deep stab wound must imply extreme force or continued pushing after penetration. This is not so and experiments have shown that once penetration occurs, it is difficult or even impossible to prevent deep penetration because of the suddenness of the breakthrough.
- When the knife penetrates the skin rapidly, for example, if the body falls or runs on to the blade, the knife does not need to be held rigidly in order to prevent it being pushed backwards. Its inertia, if the tip is sharp, is quite sufficient to hold it in place while the body spears itself on the blade.

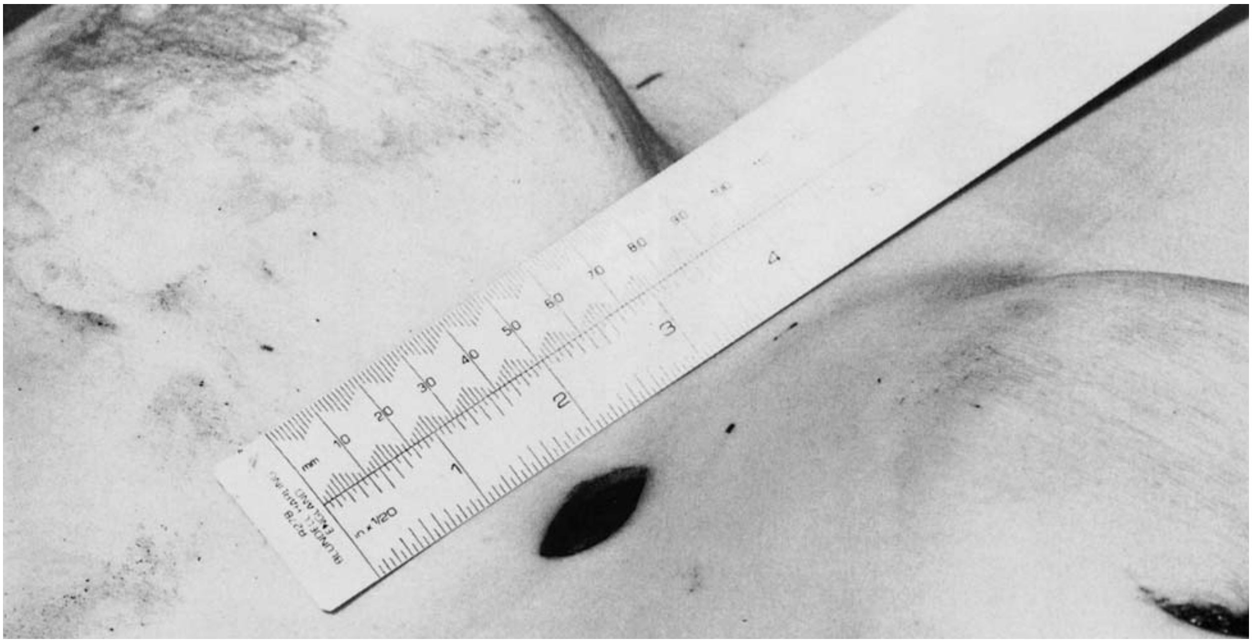

FIGURE 4.46 *A stab wound of the centre of the chest. Although each end of the wound is identical, the weapon was a single-edged kitchen knife. The end of the wound adjacent to the back of the blade has split making it impossible to say if a single- or double-edged knife was used. The sternum beneath was penetrated to reach the heart, so considerable force must have been used.*

It has been wrongly argued against a defence of falling or running onto a knife, that the hilt would have had to have been supported against, for example, the hip of the person holding the knife to immobilize it against the advancing body. Experiments have shown that this theory is invalid. Uncalcified cartilage, especially that in the costal cartilages of young and middle-aged persons, is easily penetrated by a sharp knife, though naturally more force is required than if the blade passed through an intercostal space. Calcified rib and bone provide a much more resistant barrier, but a forceful stab from a strong, sharp knife can easily penetrate rib, sternum or skull. Firm tissues like myocardium, liver and kidney are easily traversed by all but the most blunt of weapons, and their resistance is far less than that of cartilage or skin.

INJURIES BY WEAPONS OTHER THAN KNIVES

The general features of injuries from knives apply equally to other sharp objects that cause incised and stab wounds. Razors and broken glass have extremely sharp edges so that, when applied tangentially or at a small angle to the skin, undercutting may be a marked feature. The wound may appear as a shallow slice which bleeds profusely and, in a hairy area such as the scalp, it will reveal cut hair bulbs on the shelved surface. Deliberate wounds with razors or sharp knives may exhibit patterns or even words; these may occur in gang fights or sadistic homicides.

Glass can be employed as a cutting weapon, again typically in bar fights or gang vendettas, where a broken bottle may be beld by the neck or a smashed beer tankard by the handle.

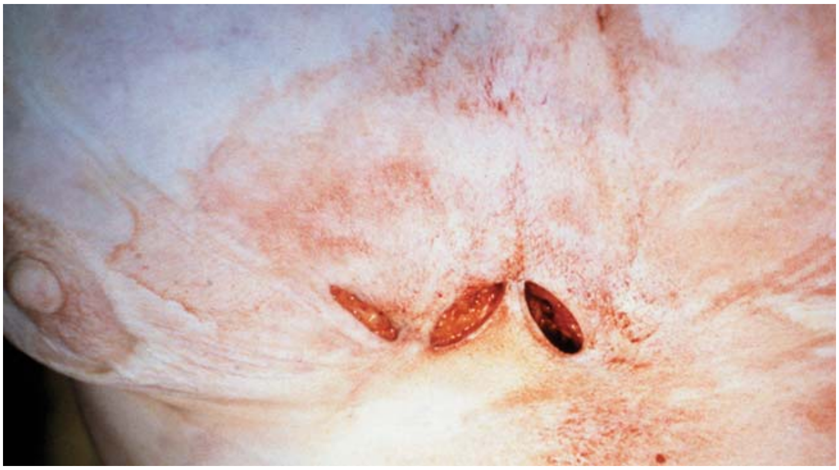

FIGURE 4.47 *Three wounds from a single stab with a knife, which was in place when the body was discovered. The knife had entered obliquely through the inner side of the right breast, emerged into the cleavage and re-entered the mid-line. If the knife had not been in situ, interpretation could have been more difficult.*

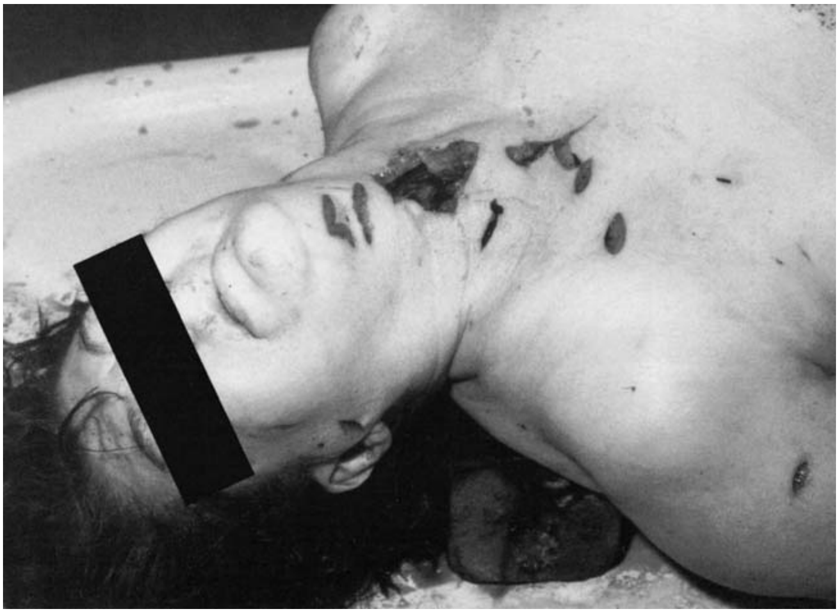

FIGURE 4.48 *Homicidal stab wounds of the throat and head showing the pleomorphism of injuries caused by the same knife. The wound under the chin is V-shaped caused by twisting of the weapon; the large throat wound consists of several superimposed thrusts and over the manubrium there is a 'tail' caused by the tip of the knife slipping out of the wound on withdrawal.*

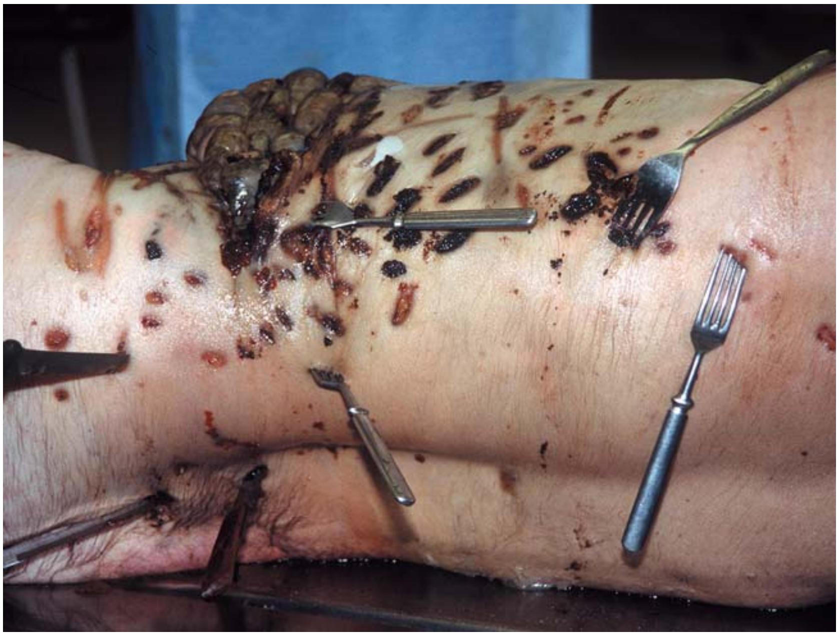

FIGURE 4.49 *Multiple homicidal stab and incised wounds inflicted with various kitchen utensils.*

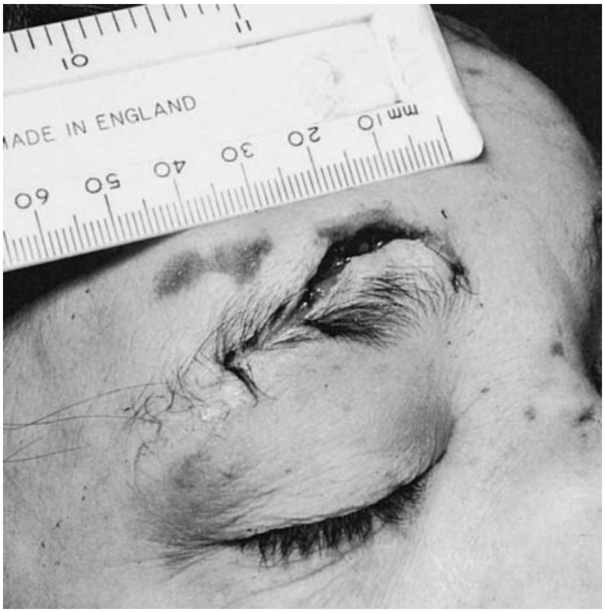

FIGURE 4.50 *A wound over the eyebrow caused by impact from a broken drinking glass. Although this location is commonly the site of laceration from blunt blows, this injury is sharp-edged and has unbruised margins, indicating that it is an incised wound. There is an associated abrasion from non-cutting contact and there is bleeding into the upper eyelid, probably from gravitational seepage from the wound.*

Official estimates in Britain suggest that between 3400 and 5400 offences occur annually in which glass is used as a weapon. Surveys in London and Bristol by Shepherd *et al.* (1990a) and Hocking (1989) showed that bar drinking glasses were the most common weapons, and that 75 per cent of these were from straight-sided pint glasses. Unexpectedly, this research showed that most of the glasses were intact until thrown or thrust at the victim – they had not been smashed prior to the assaults. Most of these non-fatal injuries were to the face. The fragility of these glasses varies greatly from manufacturer to manufacturer, so that there can be a sixfold difference in their propensity to smash on impact.

Though these formidable weapons are usually used for slashing, long slivers of glass can act – sometimes inadvertently – as stabbing agents. The sliver may break off and remain in a deep wound, which may be overlooked if the entry is small.

As many casualty surgeons have learned to their cost – or to the cost of their medical protection society or medical insurers – glass is almost invariably radio-opaque, even though this is either unknown or even denied by the doctor. Numerous civil actions for negligence have occurred – though usually in non-fatal circumstances – but, on occasion, the first person to find a deep fragment of glass in a vital position has been a forensic pathologist.

As mentioned earlier, broken china and porcelain, as from a smashed cup, mug or plate, may have a sharp edge on the exposed glaze and can easily cause a slashed wound.

INJURIES FROM SCISSORS

Stabbing by a pair of scissors is not uncommon and is seen most often in domestic circumstances where a woman uses a weapon upon her husband or consort which is both familiar and near to hand. The appearances of the wound will

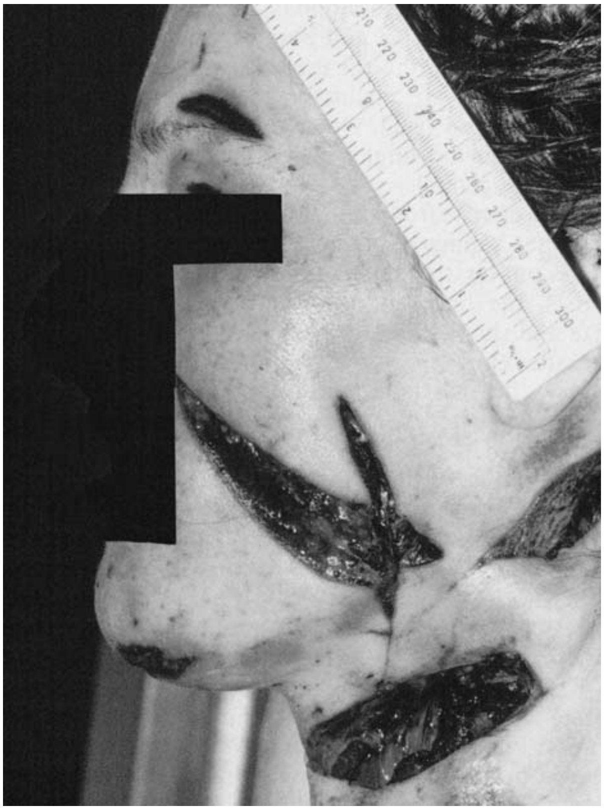

FIGURE 4.51 *Incised wounds, which in spite of their large size are typical of those inflicted by a sharp-edged weapon rather than a crushing laceration. The instrument was a butcher's cleaver.*

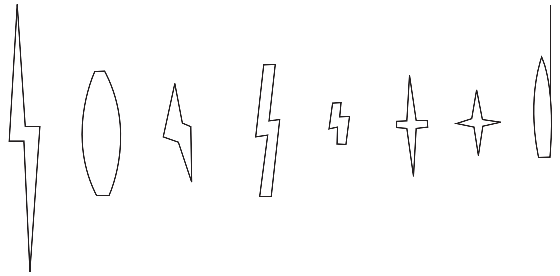

FIGURE 4.52 *Various profiles made by scissors stabbed through the skin. The cross shapes are caused by blade screws or rivets; the one on the right is a full penetration of one blade of an open pair of scissors, the other blade impinging flat on the skin.*

differ according to whether the scissors were used open or closed. If open and one blade is stabbed into the victim, then the appearances will be virtually indistinguishable from a knife wound. Some modern scissors, however, have a two-part blade in which a steel cutting edge is riveted to a carrier continuous with the handles. This may produce a stepped wound that may show a notch or variation in linearity in the margin of the stab wound.

More characteristic is the wound produced when both blades of a closed pair of scissors are plunged through the skin. Some scissors have a double-sharp point, but most domestic, tailors' or dressmaking scissors are fairly blunt at the tips when closed, so considerable force is needed to drive them through the skin – tending to work against a defence of an accidental movement against a passively held weapon.

The skin wound made by closed scissors is typically shaped like a flat 'Z' or the usual impressionist sign for a flash of lightning. The offset of the two blades gives this shallow zig-zag pattern, which is unmistakable when present. Some scissors, however, especially long narrow ones in which the blades close almost completely over one another, may not reproduce this appearance and the wound may look more like that from a thick knife. Sometimes, there are small lateral splits in the wound centre from a projecting hinge screw.

DEFENCE WOUNDS

In assaults of any kind, the natural reaction of the victims is to protect themselves. The limbs used for protection can themselves be injured and these defence wounds may be of considerable medico-legal significance, as they indicate that the victim was conscious, at least partly mobile and not taken completely by surprise. Defence wounds can be sustained from attacks by fists, feet and blunt or sharp instruments. The classic position for them is on the forearms and hands, which are instinctively raised to protect the eyes, face and head. Other defence injuries may be inflicted on the thighs, when attempts are made to shield the genitals.

With attacks from blunt instruments or fists, bruises are the hallmark of defence attempts. They are common on the outer sides of the forearms, the wrists, the backs of the hands and knuckles. The size and shape of the bruises naturally depends upon the attacking object. Abrasions may accompany the bruises but the latter are more common. Fractures of the carpal bones, metacarpals and digits may occur. If the arm is held in front of the face, the inner (palmar) side of the forearm may also receive blows. There may also be defence bruises and abrasions on the thigh, as blows or kicks aimed at the lower part of the body cause the victim, especially men, to protect the genitals. The leg may be brought across the other or the thigh raised, so that its outer side may receive blows or kicks.

The most obvious defence injuries are seen in knife attacks, as the victim often attempts to ward off the thrusts by seizing the weapon. When the fingers are closed around the blade, its withdrawal cuts across the flexures of the phalanges, slicing through the skin and perhaps tendons, or sometimes all four fingers. This may be seen in one, any, or even all of the three sets of flexures.

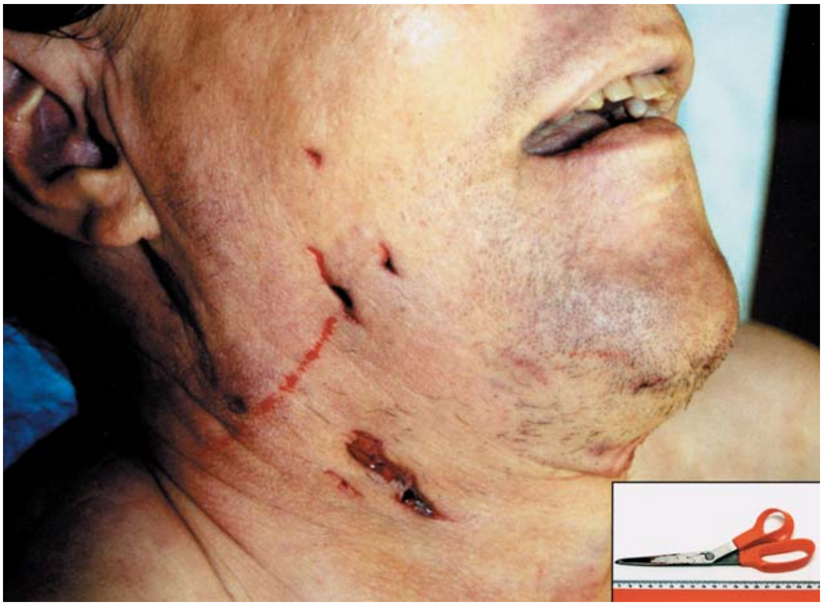

FIGURE 4.53 *Multiple homicidal stab wounds by closed scissors.*

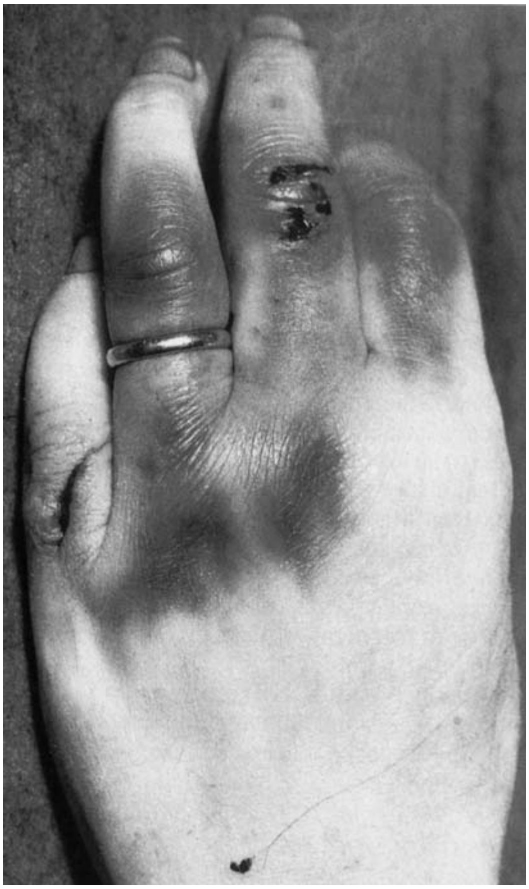

FIGURE 4.54 *Defence injuries: bruising on the back of the hand in an attempt to fend off a blunt instrument in this case a metal poker that was used to inflict fatal head injuries. Such injuries confirm that the victim was conscious and active during the attack, and that it was not made covertly while the victim was unaware.*

The other typical knife defence wound is in the web between the base of the thumb and index finger, when the blade is grabbed in an attempted pincer action. Other knife wounds can be on the backs of the hands or fingers from non-grasping movements trying to ward off the weapon. Defence wounds from knives are often sharply sliced, as the blade is drawn across the tightly applied skin. They are often markedly 'shelved', with loose flaps of skin and copious bleeding.

Defence wounds also occur in firearms injuries, where an arm is raised in a desperate attempt to shield the trunk or head from the blast. This accounts for some shooting deaths where there is an entrance and an exit wound in (often) the upper arm, the missile(s) then repenetrating the trunk.

DATING OF WOUNDS BY HISTOLOGY AND HISTOCHEMISTRY

There are many publications on this subject, as it is a favourite topic for research. As with time of death, it can be an important matter in forensic medical investigations to determine whether a wound found at autopsy was inflicted before or after death and, if inflicted ante-mortem, how long before death it was sustained.

Unfortunately, as with so many problems, biological variability introduces a wide margin of uncertainty, so that a range of probabilities can be offered, but never a definite time interval. Much of the experimental work has been performed on animals and the results are not transferable to man – a common defect in all animal work. The smaller

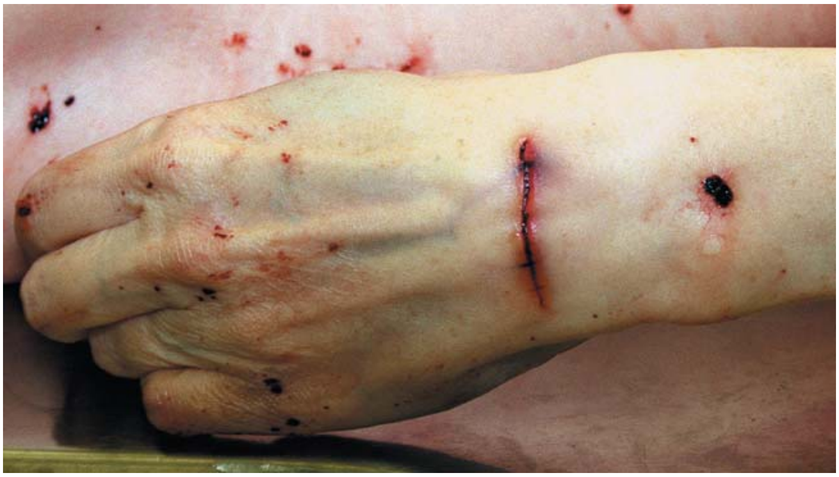

FIGURE 4.55 *Defence wound on the back of the hand from trying to ward off the knife.*

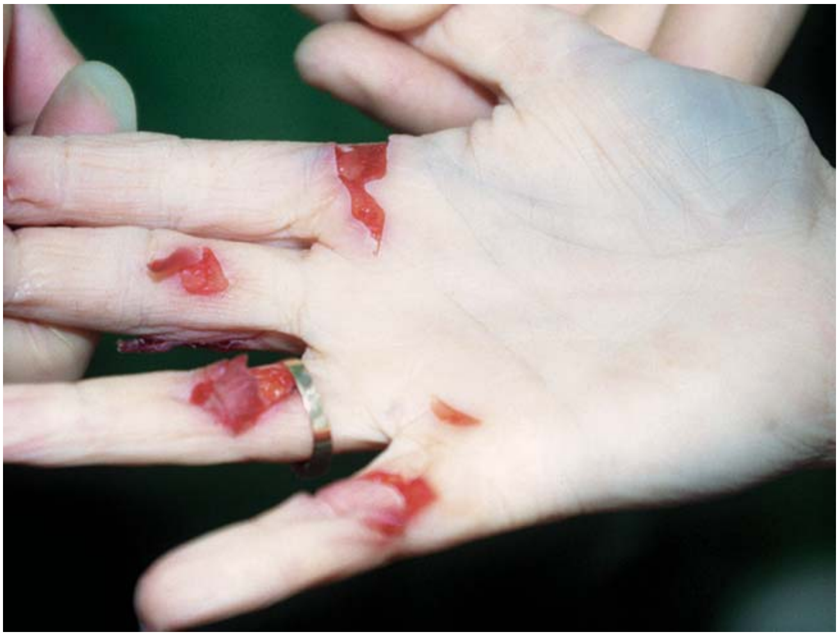

FIGURE 4.56 *Typical defence injuries in a victim of a knife attack. In grasping the blade to deflect it, there have been cuts across the palmar surfaces of the finger joints and a slash between the thumb and forefinger, together with a cut at the base of the thumb.*

the animal, the more rapid the tissue scavenging and reparative changes: more primitive animals have far greater powers of regeneration than man, both in wounds and in regrowing organs and even limbs.

The changes will also vary according to the size of a wound, the type of wound (bruise, abrasion, incision or laceration), the tissue (epidermal or mesodermal), whether there is infection and the age and health of the victim.

The subject is complex and often contradictory and the following schedule of events is offered only as a guideline. The original papers should be consulted if any particular criterion is to be followed; histological appearances, including fluorescence studies may be backed up by histochemical and biochemical assays. The sequence of changes in bruises is far less distinct than in abrasions or lacerations and histology is much less helpful. The most useful criterion in a bruise is probably Perl's reaction for haemosiderin, which becomes positive about 3 days after infliction – though some workers claim an earlier appearance, even down to 12 hours. Haemolysis of red blood cells is irregular and patchy, many intact cells being seen in some bruises after many days, so their rupture and ghosting cannot be used as an index of age.

Chronological histological changes after wound infliction

30 MINUTES–4 HOURS

Margination of polymorph leucocytes in dilated small vessels may occur, a feature which is often completely absent. It is also not a reliable sign of ante-mortem infliction, as

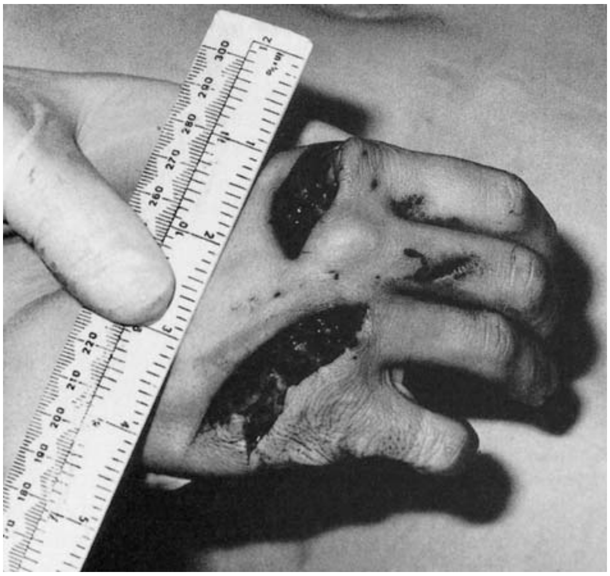

FIGURE 4.57 *Defence wounds of hand in attempts to ward off an assault with a meat cleaver.*

leucocytes may congregate for many hours after death, especially in skin and around aspirated material in the lung.

Some extravascular emigration may begin at the end of this period, but a significant number of polymorphs usually delay for many more hours. Polymorphs tend to appear earlier in the subcutaneous fat than in the upper dermal layers. Basophilic 'mast cells' lose their granules. Fibrin appears in the wound within a few minutes, but this also occurs in post-mortem injuries.

4–12 HOURS

Leucocyte infiltration is likely to be more definite, still mostly polymorphs, but some mononuclear cells as well. A scanty mixed population of lymphocytes and poorly differentiated 'monocytes' appears, usually after 12 hours. Tissue oedema and swelling of vascular endothelium occurs. In small wounds involving the skin, the start of epithelial regeneration may be seen at the sides at the level of the basal layer of epidermis.

12–24 HOURS

Leucocytes tend to demarcate the area of the wound by forming a marginal palisade. The polymorph response declines and the macrophage and mononuclear cell population increases from now on. Removal of necrosed tissue begins, with macrophages evident and a basophilic tinge to the ground substance. Mitoses are visible in fibroblasts from about 15 hours. The epidermis begins to spread across the surface of the scab and down the sides of a cut into the wound.

24–72 HOURS

Leucocyte infiltration reaches a peak at about 48 hours; repair begins concurrently with many fibroblasts appearing, but rarely before 72 hours. New capillaries then begin to bud from vessels, the vascular, infiltrated stroma becoming 'granulation tissue'.

3–6 DAYS

Repair is proceeding apace: collagen begins to form and giant cells may be visible around necrotic debris and foreign matter. The epidermis is actively growing if the wound involves the surface: in animals, it grows laterally at about 200 μm/day. Haemosiderin becomes stainable from about the third day onwards, if there is a bruise or any bleeding into the wound, but is often not obtainable by Perl's reaction until the fifth day even though some claim it can appear on the first or second day.

10–15 DAYS

Cellular reaction subsides in small wounds. Vascularity decreases and the cell population drops, especially leucocytes. Fibroblasts are most active, with collagen being laid down. The epidermis becomes thin and flat, but no papillae ('rete pegs') are reformed for many weeks. Elastic fibres are scarce for a long time and less than in adjacent undamaged tissue.

TWO WEEKS TO SEVERAL MONTHS, DEPENDING ON SIZE AND OTHER FACTORS

Consolidation of the healing tissue continues. The inflammatory response has vanished, unless the wound has become infected. Collagen and elastin increase and a vascular scar is formed, which gradually becomes more dense and avascular. The epithelium remodels and dermal papillae reappear unless the wound is wide and irregular. Skin adnexae do not reappear in the scar unless islands of viable skin survive within the wound area.

Histochemical changes in injured tissues

Histochemical and immunohistochemical methods have been studied widely in recent years, again mainly on animals, the transfer to the human situation being suspect in some cases. A wide variety of markers have been claimed as reliable for both the differentiation between ante-mortem and post-mortem injuries and for dating of ante-mortem wounds.

Electrolytes, such as sodium, zinc, magnesium and calcium, serotonin, esterases, glycophorin A and especially histamine have been used for this purpose.

Mainly as a result of the pioneering work of Jyrki Raekallio in Finland, the histochemical sequence of events in wounds has been actively pursued in recent years. Some techniques need frozen sections, others can be carried out on fixed tissue. Estimations of histamine or serotonin are usually 'tube' methods, rather than microscopic, though some fluorescent techniques have been developed. Betz and his co-workers have also published extensively on the immunohistochemistry of wound dating.

At the present time these methods still remain mainly in the realm of the research laboratory, apart from a few enthusiasts who employ them in casework. For the histochemical novice, it would be unwise to put such procedures into evidence without first gaining extensive experience of control material. Experience emphasizes that strictly standard conditions are required for the production of such histochemical sections, the end result depends largely on laboratory procedures – 'change your technician and you change the answer'.

A list of standard procedures for some of these reactions is given in Appendix 1.

The following are some of the histochemical wound changes described by Raekallio and others:

- In a wound through the skin surface there is a central zone 0.2–0.5 mm wide that will become necrotic and in which enzyme activity rapidly decreases. This may be termed 'negative vital reaction'. Immediately beyond this layer, is a 0.1–0.3 mm zone of reaction and eventual repair, where a number of enzymes and other substances become increased in concentration during the reparative process, compared to the normal level in the areas outside the wound. Enzymatically, this can be called 'positive vital reaction', as no such zone develops in a post-mortem wound.
- Within one hour after injury, esterases and adenosine triphosphatase increase in the positive zone. At around 2 hours, aminopeptidase activities increase and, at 4 hours, acid phosphatase activity increases. Alkaline phosphatase activity is delayed another hour or so though, of course, all these times are relative and subject to the usual biological variability.
- Where death occurs at some stage of this process, the enzyme pattern is 'frozen' at that point and post-mortem changes do not substantially alter the reactions within a few days after death, especially if autolysis is kept at bay by refrigeration. Senility, severe illness and cachexia, as well as widespread multiple injuries, may distort the usual pattern by reducing the ability to produce these reparative enzymes. In contused wounds, the reactions are less useful than in cutaneous injuries, as the damage is more diffuse and there are no definite 'zones'.

  In all wounds, lack of reaction cannot be taken as indisputable proof of a post-mortem origin, though, if the opposite occurs, positive increase in the outer zone must only be the result of a vital reaction. Other enzymes have been used for wound dating: the review by Janssen (1984) in his authoritative book on forensic histology should be consulted for details, as well as the work of Betz.
- Tissue cathepsins are said to increase almost immediately if the stroma is damaged, being demonstrable within 5–10 minutes. Two other substances are of use in establishing that wounds are ante-mortem and giving some idea as to their age. Both are produced during the inflammatory response that accompanies tissue damage – histamine and serotonin (5-hydroxytryptamine). They tend to be complementary to the enzymes, as they appear soon after infliction, within the hour or so before adenosine triphosphatase and esterases become detectable.

  These vasoactive amines appear in maximum concentration about 10 minutes (serotonin) and 20–30 minutes (histamine) after wounding. One of the first demonstrations of this forensic aid was by Fazekas and Varagos-Kis (1965), who showed that a ligature mark in hanging revealed increased serotonin; presumably the hanging was atypical and the victim took 10 minutes to die which is rather unusual. For the employment of the test in human autopsy work, about 2 grams of skin freed from subcutaneous fat are sampled, together with a similar control sample from a nearby normal area of skin from the same corpse. This is to allow for the markedly different amounts found in different people and, indeed, in the same persons at different times.

  To establish that a wound was ante-mortem rather than inflicted after death, the level of histamine in the wound must be at least 50 per cent greater than the control sample – and, for serotonin at least, twice the concentration of the control skin.

SURVIVAL PERIOD AFTER WOUNDING

A pathologist is often asked either by police during an investigation, or by counsel at trial, what was the probable interval between the fatal injuries and death? A supplementary query is how long would the victim have been active, even if still alive?

These are extremely difficult questions to answer, as a number of variables enter the estimation. The doctor should never give a dogmatic answer, unless the nature and severity of injuries are obviously incompatible with continued life or activity.

A person who has his brainstem destroyed by a penetrating injury, or his aortic arch completely transected, will be inactive and clinically dead almost immediately. It would not necessarily be the case if his frontal lobes were damaged or his abdominal aorta was crushed by a railway wheel. Extraordinary instances of survival in both these latter instances are on record.

An opinion should always err on the side of caution in expressing opinions on this subject, as victims can do far more than might be expected after injury. The author (BK) once dealt with a homicide in which the victim was stabbed through the heart, yet ran more than a quarter of mile before collapsing. A wound in the left ventricle can partly seal itself by the contraction of the muscle around the defect and collapse may only occur when sufficient blood has leaked into the pericardium to form a tamponade. Wounds of the right ventricle are often more rapidly fatal as, although the pressure of contained blood is less, the thinner wall is not so effective in preventing the leak.

Head injuries can present many paradoxical instances of prolonged survival, depending partly on what part of the brain is injured. As mentioned, frontal lobes seem remarkably resistant to damage and it is often the generalized head impact, rather than focal damage to this area, that causes most harm. For example, a Finnish man who committed suicide made a home movie of himself firing a pistol into his brain. There was immediate collapse but, just at the end of the 4-minute film, the victim opened his eyes and raised his head, finally dying some uncertain time after the spool ran out.

In the more usual stabbing, head injury, cut throat or shooting, the pathologist must try to assess the nature and severity of the physical damage, and relate that to the age, health and environment of the victim. This is naturally an imprecise exercise. A senile old lady, or someone with severe cardiac or respiratory disease, is less likely to survive multiple injuries for as long as a robust young person – though if the nature of the injury is grossly life-threatening, these factors will make little difference.

A cut artery will lose blood faster than a vein of the same general size, especially if it is only partly severed so that it cannot retract. Other factors, such as the possibility of air embolism occurring in a cut jugular vein, might alter the usual pattern of expected events. The heart is less vulnerable than great thoracic vessels in many stab wounds, as mentioned above. Many wounds of the ventricles are survivable. The author (BK) has twice been warned by police of an imminent autopsy on victims admitted for emergency surgery – only to hear later that, thankfully, they had walked out of the hospital after a successful operation. One had a through-and-through stab wound of the left ventricle that transfixed the heart from front to back.

Where a wound has transected a major coronary artery, then prolonged survival is unlikely, as is one that interrupts a major branch of the conducting system. Other than injuries to the brain or to a large blood vessel, most other injuries can rarely be declared to have caused sudden death or rapid loss of function. In criminal cases, it may be a point of some importance to decide whether the victim could have continued fighting, have run away, have resisted, or even have inflicted injuries on someone else before collapsing and dying. It is difficult to swear that at least some activity was not possible in the great majority of instances. In the adrenaline response of 'fight or flight', the shock element of pain is greatly suppressed – many soldiers have been quite unaware of having sustained severe or lethal wounds until they notice the blood or the battle is over. Thus the usual 'shock' effect may be damped down considerably in an assault and only the sheer physical and haemodynamic sequelae of the injury will eventually lead to a slowing down, then collapse and death. In the interval, injured victims may be able to perform normal physical activity, sometimes to an astonishing degree, albeit followed by sudden deflation of their capacity for exercise.

As in most aspects of forensic medicine, it is unwise of the doctor to be too definite about these matters – the old forensic aphorism 'Seldom say never – seldom say always' is even more true here than usual.

Most issues of this nature revolve around periods of a few minutes, the perimortal or agonal time when few morphological signs are available. The more sophisticated enzyme and serotonin techniques mentioned elsewhere in this chapter may give some clue about the survival period, but are rarely unequivocal enough to be used as hard forensic evidence. If survival is longer, then both gross and histological changes of 'vital reaction', such as thrombosis, inflammation, infection and healing may be useful, but they usually require hours or even days of survival to appear.

The accepted wisdom of wound dating is that polymorph leucocytes begin to appear in wounded tissue within a few minutes, but it has been shown that this can happen even several hours after death, as all leucocytes do not become immobile with cardiac arrest. A good, conventional inflammatory response must be a vital reaction, however, though several hours survival is needed for it to be convincing. The author (BK) has seen a dramatic red flare caused by post-mortem burning at least 30 minutes after undoubted death from strangulation.

Another problem with differentiating 'ante-mortem' from 'post-mortem' injuries is the definition of the moment of death. Again, lawyers, judges and coroners tend to assume that death is an **event**, whereas, in reality, it is a **process** (Chapter 2). Though in most criminal or accidental deaths the moment of death is conventionally – and reasonably – taken to be the moment of cardiac arrest, and thus collapse of blood pressure and cerebral circulation, the cells of the body are still alive and remain so for a variable time – only minutes in the case of neurones, but leucocytes and muscle cells survive for many hours, and connective tissue cells, such as fibroblasts, for days. Thus, it is unreasonable to expect dramatic changes within minutes in skin wounds, etc., until progressive hypoxia alters biochemical processes and enzyme activity. Leucocytes may be motile for more than 12 hours and can aggregate around chemotactically active material, such as gastric contents aspirated into the air passages. This makes the 'vital reaction' a dubiously valid phenomenon in the perimortal period. Much more research is needed into the histology, histochemistry and biochemistry of the perimortal period to clarify these issues, but in the mean time, less dogmatic reliance must be held upon the old criteria of 'ante-' and 'post-' mortem phenomena and the 'vital reaction'.

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CHAPTER 5

Head and spinal injuries

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Of all regional injuries, those of the head and neck are the most common and most important in forensic practice. Adelson (1974) gives these sound reasons for this dominance of head injuries:

- The head is the target of choice in the great majority of assaults involving blunt trauma.
- When the victim is pushed or knocked to the ground, he often strikes his head.
- The brain and its coverings are vulnerable to degrees of blunt trauma that would rarely be lethal if applied to other areas.

A sound practical understanding of the neuropathology of trauma is more essential to the forensic pathologist than any other aspect of his subject, as head injuries provide the major contribution to death in assaults, falls and transportation accidents.

INJURY TO THE SCALP

The scalp is often, though by no means invariably, damaged in trauma that causes injury to the underlying skull and brain. The usual range of abrasions, contusions and lacerations may be inflicted, though a modifying factor is the presence of hair, which may deflect a tangential blow or partly cushion a direct impact.

When an injury is visible on the forehead, the back of the neck, the lower temple or on a bald area, the examination is no different from elsewhere on the body. In hair-covered areas, care must always be taken at autopsy to palpate the scalp in any case in which there is a possibility of injury, otherwise abrasions, swelling, bruising and even lacerations may be missed. When a lesion is found or suspected, the hair must be carefully shaved away to expose the scalp for further examination and photography.

Forensic anatomy of the scalp

Superficially, the skin carries hair follicles, sebaceous glands and sweat glands. The skin is attached to the aponeurosis (see below) by vertical strands of fibrous tissue that break up the subcutaneous layer into pockets filled with fat. The blood vessels and nerves lie in this layer, above the epicranial aponeurosis (formerly called the ‘galea aponeurotica’). This is a dense sheet of fibrous tissue that lies in the deep layer of the scalp over the whole cranium. It is really a flattened tendon uniting the frontal and occipital bellies of the occipitofrontalis muscle.

Deep to the aponeurosis is a thin layer of loose connective tissue that separates it from the pericranium, which is the exterior periosteum of the skull, the dura being the internal counterpart. Some veins traverse all the layers from the superficial fascia to the pericranium, and go on to penetrate the skull and communicate with the intracranial venous sinuses, thus forming a route for meningitis and sinus thrombosis from infected injuries of the scalp.

Abrasion of the scalp

Brush abrasions are less common than in other sites because of the protective effect of the hair, which also tends to prevent or blur the patterned effect of less severe impacts. Impact abrasions from a perpendicular force are imprinted as usual on to the scalp, though again the intervening hair may reduce the severity. Unless the hair is carefully removed at autopsy, with a sharp scalpel or razor, and care taken not to cause artefactual cuts, lesser degrees of abrasion will inevitably be missed.

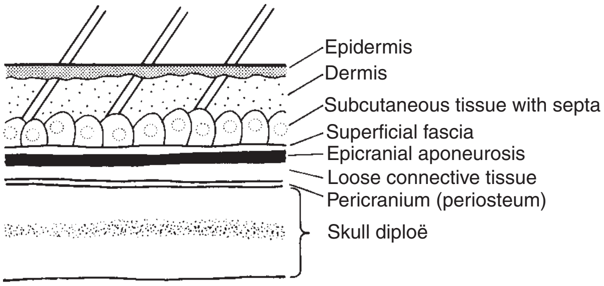

FIGURE 5.1 *Anatomy of the scalp.*

Bruising of the scalp

Bruising may be difficult to detect until the hair has been removed. Marked swelling is a common feature of extensive bruising, as the liberated blood cannot extend downward because of the rigidity of the underlying skull. However, this subsides, or at least diffuses, after death. Commonly, a severe head injury leads to a thick, swollen, indurated layer of blood beneath the scalp, which may extend over a wide area. The blood is sometimes below the aponeurosis, the tough fascial layer of the scalp, but is more often between this and the epidermis.

Blood may also be present beneath the pericranium, the periosteum that is closely applied to the outer surface of the skull. This is often seen in head injuries in infants, usually in association with skull fractures, as the source of the blood is from the fracture line itself. The close attachment of the pericranium to the suture lines in infants may sharply circumscribe the extent of the bleeding.

In addition to frank bleeding beneath the scalp, marked oedema may occur after injury and the layers of the scalp may be greatly swollen and thickened by a jelly-like infiltration of tissue fluid.

As will be discussed under ‘black eye’, bleeding under the scalp may be mobile, especially under gravity. Thus a bruise or haematoma under the anterior scalp may slide downwards within hours – even minutes – to appear in the orbit,

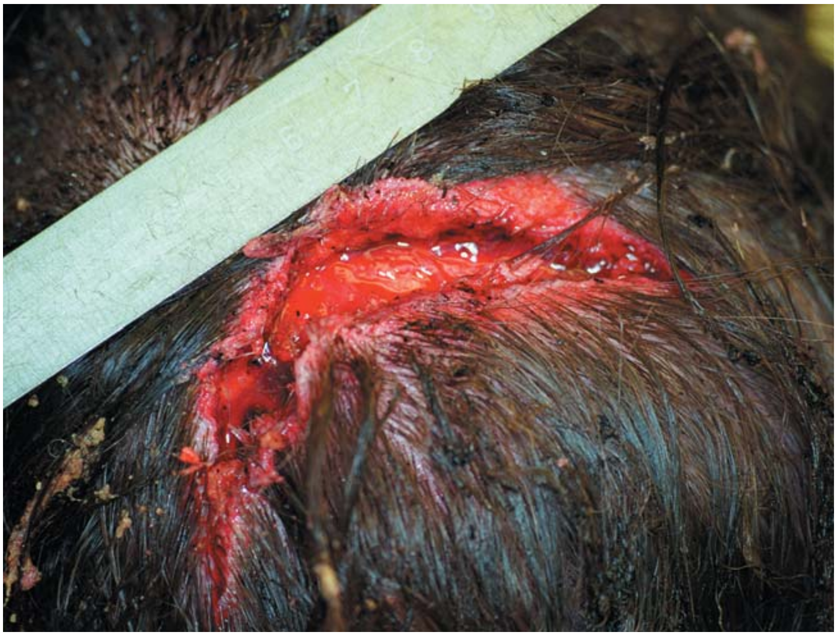

FIGURE 5.2 *A laceration of the scalp caused by a blow from an iron bar. The edges are crushed and bruised, with strands of connective tissue and hairs crossing the gap, indicating that it was not caused by a sharp-edged weapon.*

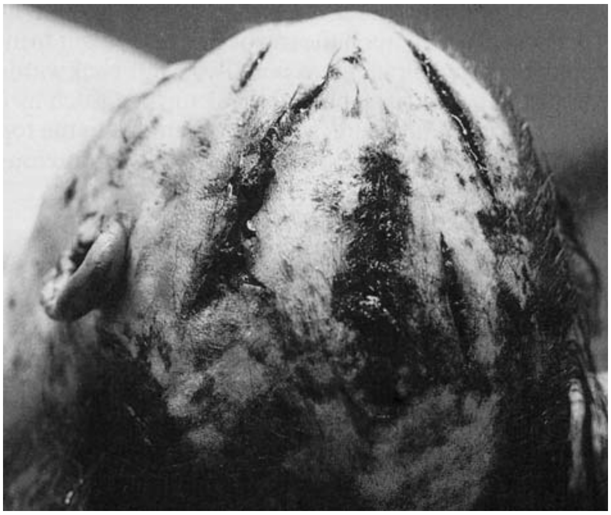

FIGURE 5.3 *Lacerations of the scalp from an iron bar. The margins are bruised and the scalp tissue is extruding in places. The generally parallel direction of the five wounds indicates that the assailant probably delivered the blows in rapid succession with little change of orientation between weapon and head.*

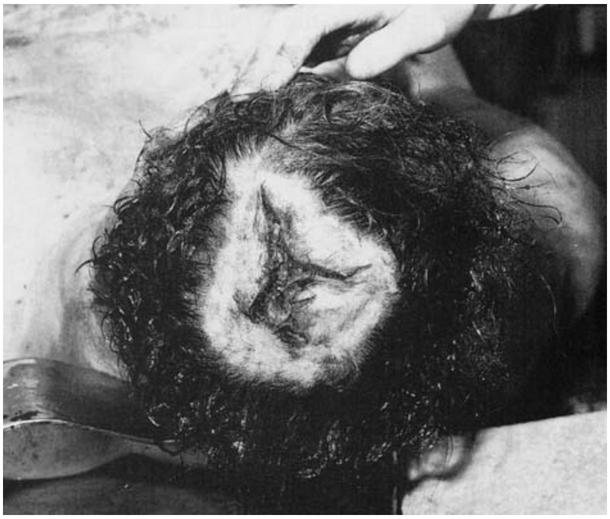

FIGURE 5.4 *Stellate laceration of the scalp caused by a heavy blow with a piece of timber. The support of the underlying skull has caused the tissues to split widely. At autopsy, full clearance of the hair must be made to allow detailed examination and photography.*

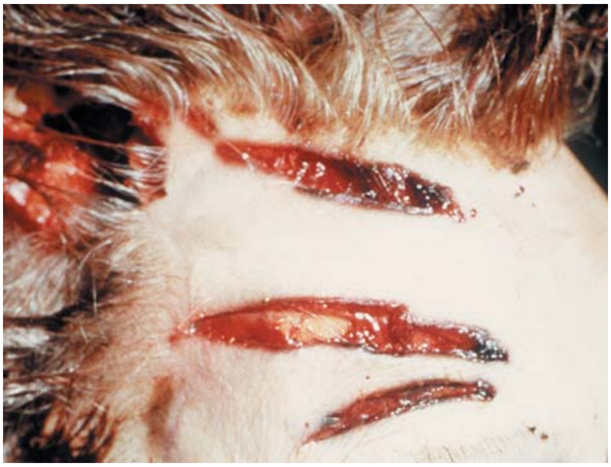

FIGURE 5.5 *Wounds from a metal poker superficially resembling incised cuts, but having edges and tissue bridges within the wounds.*

simulating a black eye from direct trauma. Similarly, a temporal bruise may later appear behind the ear, suggesting primary neck impact. As with bruises elsewhere, those under the scalp may be obvious immediately after infliction – or their appearance may be delayed, either during life or as a post-mortem phenomenon. They may first become evident, or much more prominent, some hours – or even a day or so – after death. This is caused either by movement of the liberated blood through tissue planes or by haemolysis spreading outwards to stain the subcutaneous tissues, making it always advisable to return to examine the body a day or two following the autopsy.

The shape of an inflicting weapon or object is poorly reproduced on the scalp, again due to the padding effect of the hair. Where the scalp is free of hair, as in the upper forehead or bald areas, all traumatic lesions are similar to elsewhere on the body, with the exception that blunt impact may cause very sharply defined lacerations.

Laceration of the scalp

Lacerations of the scalp bleed profusely, and dangerous and even fatal blood loss can occur from an extensive scalp injury if it is not checked by treatment. The most gross injury is avulsion of a large area of scalp, which can be torn from the head, thereby exposing the aponeurosis or skull. This may happen if the hair becomes entangled in machinery, as was formerly not uncommon in women working in factories. A more common cause nowadays is a traffic accident, where a rotating vehicle tyre comes into contact with the head, causing a 'flaying' injury similar to that seen on limbs.

Scalp injuries may bleed profusely **even after death**, especially if the head is in a dependent position. A post-mortem injury to the head may bleed considerably if inflicted soon after death and these facts may sometimes cause confusion about the ante-mortem or post-mortem nature of the wound, or about the length of time of survival following the injury. There is no reliable way of resolving this difficulty.

Lacerations of the scalp may reproduce the pattern of the inflicting object, even though a random splitting is so common. Severe blows from shaped objects such as hammers or heavy tools may reproduce the profile of the weapon totally or in part. A circular-faced hammer may punch a circle in the scalp, but more often only an arc of a circle is seen. In such cases, the position of the edge that digs in most deeply may give an indication of the angle of the blow. There may be a depressed fracture of the underlying skull of the same shape and size, though the interposition of the dense scalp may cause the skull defect to be slightly larger than the weapon. A depressed fracture in these circumstances is not inevitable, however, and one or more linear fractures may radiate from the impact site.

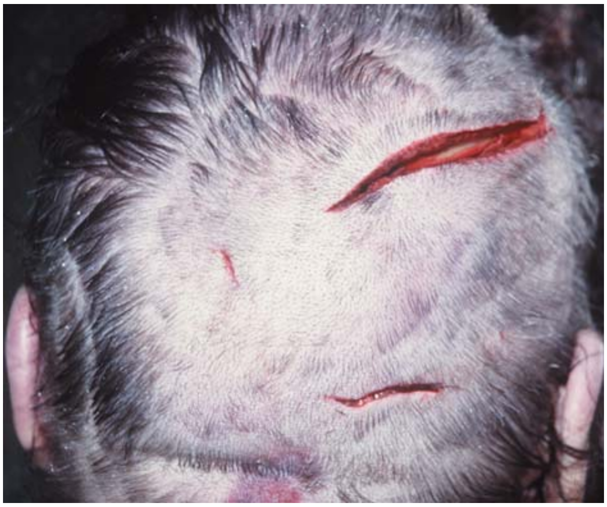

FIGURE 5.6 *Deep linear incised wounds due to a heavy, sharp cleaver. The depth of penetration varies, the large wound overlying extensive skull fractures. The wounds on the neck are due to light contact with the edge of the same blade.*

A major problem in scalp injuries is the differentiation between incised wounds and lacerations from blunt injury.

The scalp is the best example of a surface tissue lying over an unyielding bony support. Violent compression will crush the scalp against the underlying skull, so a blow from a blunt rod-like weapon may split the skin and underlying tissues in a sharply demarcated fashion, which may appear remarkably like a slash from a sharp instrument. Close examination, using a lens if necessary, will show that this blunt laceration has:

- bruised margins, even though this zone may be narrow
- head hairs crossing the wound, which have not been cut
- fascial strands, hair bulbs and perhaps small nerves and vessels in the depths of the wound.

Scalp injuries from falls

It is vital for the pathologist to appreciate that falls on to a flat surface, or a blow from a wide, flat object such as a plank or paving stone, may sometimes leave no external mark whatsoever on the exterior of the head, but commonly such an injury will cause a ragged split which may be linear, stellate or quite irregular.

Such injuries on the back point of the head are commonly caused by falling, especially in inebriated victims. Falls backwards against a ridge, such as a wall or pavement kerb, may cause a transverse laceration, which may be undercut and partly detached from the underlying bone so that a flap of scalp is loosened from the skull.

Falls usually injure the occipital protruberance, the forehead or the parietotemporal areas. Injuries on the vertex

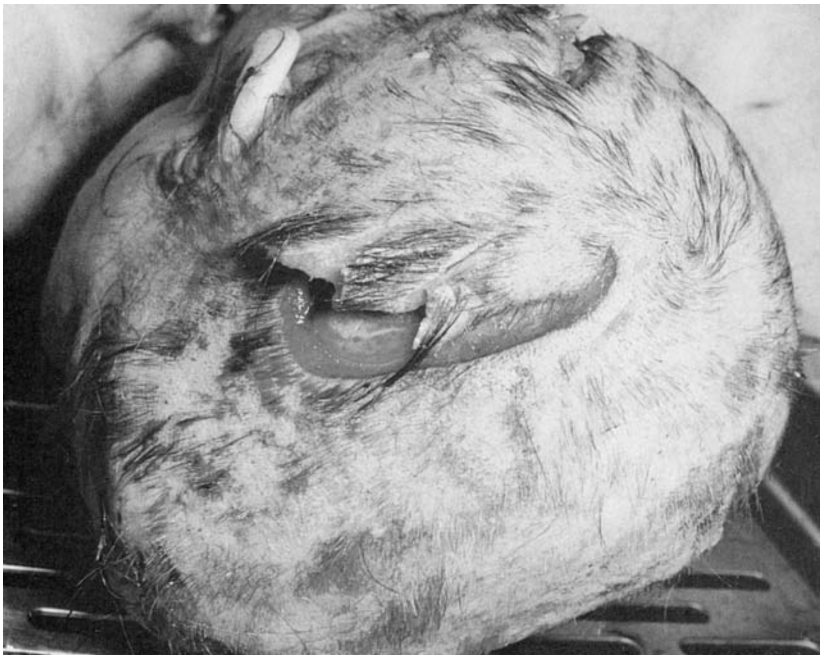

FIGURE 5.7 *Sliced incised wound of the scalp, from a large knife. The wound is markedly undercut, turning a wide flap of scalp. The clean edges, with a lack of any abrasion or bruising, indicate the sharpness of the weapon.*

should always raise the suspicion of assault, as it is unusual to fall upon the top of the head, even from a considerable height. Occasionally, a fall backwards that just happens to reach a vertical surface, such as a wall or piece of furniture, can cause damage to the top of the head, but there is then usually an obvious grazing component to the lesion.

FACIAL INJURIES

Damage to the face is common, but unless gross, with skeletal damage, is rarely fatal in itself unless it leads to bleeding into the air passages. It is often ancillary to fatal cranial damage, or it may be the route by which severe trauma reaches the brain.

The usual range of injuries may be present externally, but all degrees of underlying damage may also occur in the facial skeleton. Because of the complex contours of the face, the various prominences of chin, nose, cheekbones, eyebrows, ears and lips may intercept impacts, with consequent characteristic damage. The eyebrow is particularly vulnerable, being exposed during falls and blows. A blunt impact on the brow often splits the skin and may cause an underlying frontal fracture that can involve the orbital margin.

The distal part of the nose is flexible and often escapes serious damage, though abrasion is common. The bony bridge of the nose is often fractured, which may be detected by movement and crepitus during external palpation – and by dissection at autopsy. Bleeding in the nose is more important than structural damage, as profuse haemorrhage in an unconscious victim may pass back through the posterior nares into the throat and cause fatal airway obstruction.

The maxillae and mandible may be fractured by direct blows and again cause dangerous intra-oral bleeding from associated soft-tissue damage. A heavy blow or kick to one side of the jaw can cause ipsilateral, bilateral or even contralateral fractures. Gross injury to the face, seen in kicking and some transport accidents, may actually detach the facial skeleton from the base of the skull. The lower part of the maxilla, carrying the palate and upper teeth, may be completely separated from the rest of the skull. At autopsy, the best view of the facial skeleton may be gained by dissecting the whole facial skin upwards from the neck incision and reflecting it as far as the orbits, if necessary. Good restoration can be achieved as long as the skin is not penetrated by the knife.

Injuries to the mouth and lips are very common in 'beating-up' incidents, including child abuse. The lips may be bruised or lacerated, much of the damage arising from compression of the lips against the teeth or bony gums. Lacerations on the gingival aspect of the lips may often be exactly matched with the edges of teeth and, as discussed in Chapter 22, rupture of the frenulum inside the upper lip of a child is virtually pathognomonic of a sideswipe across the mouth, if damage from clumsy and forceful attempts at introducing a feeding bottle, dummy or airway can be excluded.

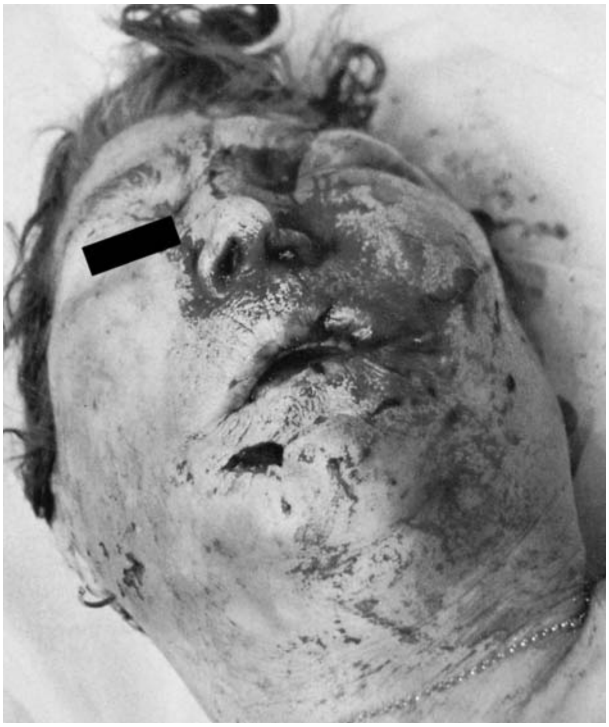

FIGURE 5.8 *Facial injuries caused by kicking. The upper lip is split and the maxilla fractured on that side. The face and orbital region is grossly swollen and bruised. Death was caused by blockage of the air passages by blood.*

Kicking

Kicking of the face is regrettably common and again the prominences suffer most. Bruising, laceration and fractures may result from kicking under the side of the jaw: similar lesions occur on the maxillary area and the eyebrows. Patterned abrasions from boot soles may be seen or crescentic marks from toecaps. Brush abrasions from glancing kicks may be present on the cheeks or forehead as the sole of the shoe scrapes across the skin. It is uncommon to suffer a 'pure' black eye from a kick without other facial injuries, such as scuffed abrasion on the cheekbones, or marks on the brows or bridge of the nose. Teeth may be loosened, broken or detached by both kicks and heavy punches and black eyes and fractures of the nose are common. A kick on the side of the jaw may cause bilateral jaw fractures or even a single contralateral fracture.

It may be difficult or impossible to differentiate in every case, between injuries (especially to the face) caused by kicks

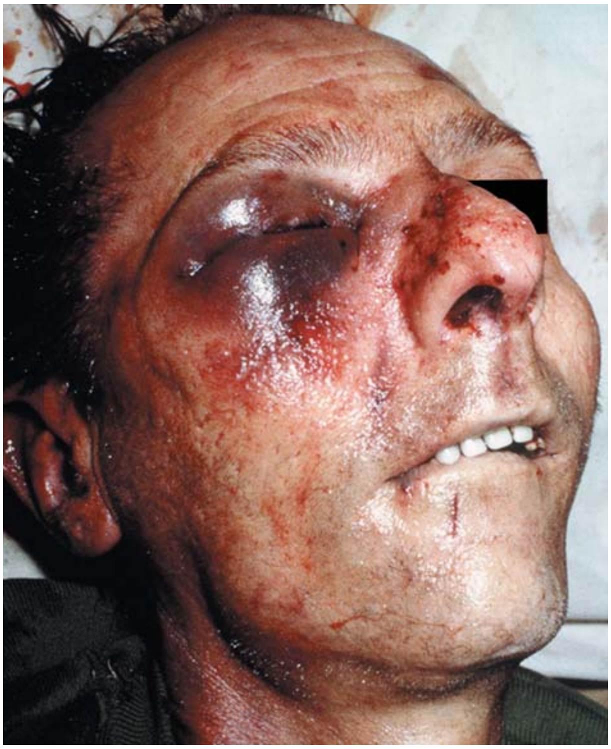
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FIGURE 5.9 *Black eye from a direct impact into the orbit from a punch. This is the third mechanism of production of a periorbital haematoma, the others being a fracture of the anterior base of the skull and a frontal scalp wound.*

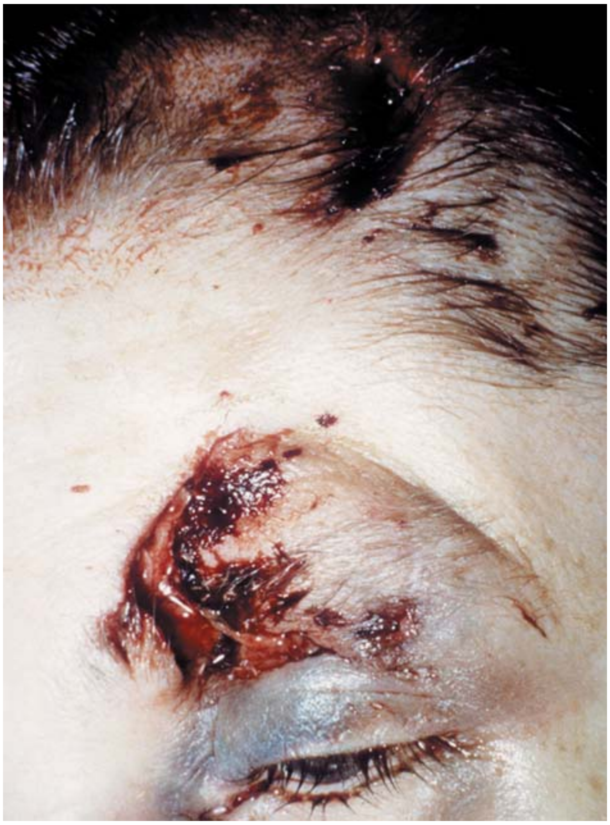

FIGURE 5.10 *Black eye as a result of gravitational seepage of blood downwards from a forehead injury. The woman was struck with a rock on the frontal area and eyebrow, blood then descending during the few hours of coma before death occurred.*

and those from blows from a blunt object. Toecap marks are not all that common, especially since the more flexible rubber 'trainer' shoes have become almost universal footwear.

In stamping, there is the chance that the sole pattern may leave an imprint, but a swing from a toe may leave a non-specific abrasion, bruise or laceration. It may be that the severity of the injury, including underlying bone damage, may be a better indication of a kick than the shape of the injuries, as the force delivered by a swinging foot at the end of a muscular leg is greater than that from a fist.

Black eyes

The usual periorbital haematoma or 'black eye' is usually caused by a direct punch or kick into the eye-socket, but the pathologist must always consider the several alternative explanations. A black eye may be the result of:

- direct violence, which may or may not be associated with abrasion or laceration on the upper cheek, eyebrow, nose or other part of the face
- gravitational seepage of blood beneath the scalp from a bruise or laceration on or above the eyebrow. Survival and at least a partially upright posture of the head must have been maintained for at least some minutes, usually longer, between the time of injury and death. When the scalp lesion is high up on the frontal region, this time will probably be measured in hours
- percolation of blood into the orbit from a fracture of the anterior fossa of the skull. This is often from a contrecoup injury caused by a fall on to the back of the head, leading to secondary fracture of the paper-thin bone of the orbital roof. It is invariably associated with contrecoup contusion of the frontal lobes of the brain, as described later in this chapter.

A simple fall onto the face on a flat surface does not usually cause a black eye, as the prominences of the eyebrow, cheekbone and nose prevent damage to the orbit.

Damage to the ear

The external ear often suffers from blows to the head and is an obvious target in child abuse. Bruising and laceration of

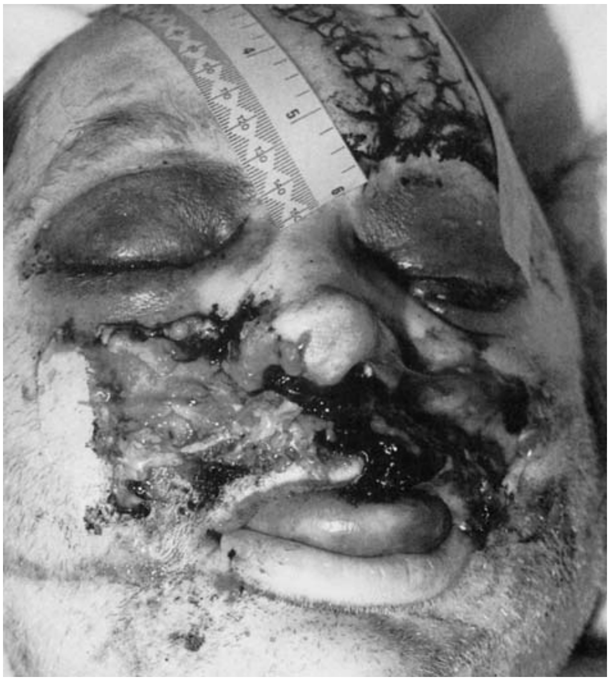

FIGURE 5.11 *Bilateral black eyes caused by leakage of blood into the orbits through comminuted fractures in the floor of the anterior fossa. This homicide victim was struck on the head with a shovel and survived for some days. Brain tissue is escaping from the nostrils through basal skull fractures.*

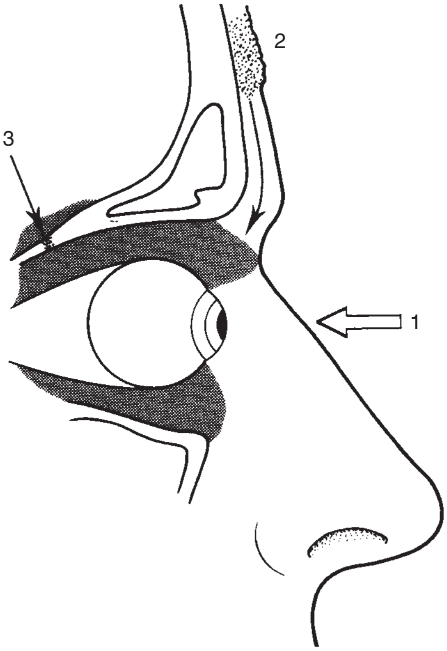

FIGURE 5.12 *The production of a black eye: (1) A direct blow into the orbit. (2) An injury to the front of the scalp, draining down over the supraorbital ridge. (3) A fracture of the base of the skull (direct or contrecoup) allowing meningeal haemorrhage to escape through the orbital roof.*

the pinna is obvious on examination and – in severe trauma – the root of the ear may be detached from the head, usually by a tear at the posterior margin where the ear joins the head. Where gross damage is present, especially with partial avulsion of the pinna, kicking must be considered.

The ear may be bitten and even partly detached, a fate which occasionally is suffered by the nose. In such cases the advice of a forensic odontologist may be invaluable, as teeth marks may form vital evidence.

FALLS

Falls are extremely common, the severity not necessarily being directly related to the distance that the person falls. Many people die after falling from a standing position, yet others sometimes survive a fall of many metres.

Falls from a standing position can occur if a person is drunk, from an assault, during illness (such as a fit or faint) and for many other reasons. Death can follow from a head injury, especially onto the back of the head. An occipital scalp laceration or a fracture of the skull is not necessary for cerebral damage (often frontal contrecoup) to occur. There may also be a subdural or (less often) an extradural haemorrhage, the latter more common from a fall on to the side of the head.

The vexed question of head injury from falls in children is discussed in Chapter 22, but here it may be stated that, although fatal head injury from a fall usually requires a drop of a number of feet, there are well-authenticated instances of skull fractures and brain damage from trivial falls, including some medically witnessed falls from tables and settees. The experimental work of Weber (see Chapter 22) showed that the skulls of small infants could be fractured against a variety of floor surfaces from passive falls of only 34 inches. It is thus invalid for medical witnesses to claim it **cannot** happen, as even one authenticated case creates a precedent. In adults, fractures have certainly occurred from falls onto very hard surfaces from only a foot or so. One such case was a drunk lying on concrete; equally drunken friends attempted to lift him but allowed his head and shoulders to fall back from about half-sitting position, causing occipital fracture.

Falls in old people very frequently cause fractures of the post-cranial skeleton – especially the neck of femur – though ribs, arms and pelvis may also suffer. Osteoporosis is the major reason for the large number of such injuries from falls. More than 47 000 fractured femora occur each year in Britain, with a 25 per cent mortality rate, mainly from subsequent pulmonary embolism or bronchopneumonia.

Falls from a height

Falls from a considerable height, usually from a building, are common in suicide and in some accidents, especially to children. Occasionally deaths from a high fall may be homicidal, again especially in children.

When a person falls or jumps from a height, the trajectory is downwards and outwards, and the distance that the body strikes the ground from the jumping point is variable. Goonetilleke (1980) has published some research on how far from the wall a body is likely to land. Much depends on whether the victims fell passively from near the wall or projected themselves outwards at the top. The body may fall whilst maintaining the same orientation to the ground, but usually turns and twists in an unpredictable manner, the amount of alteration of posture partly depending upon the height of the fall and so the time available for turning. This means that the body may strike the ground in a number of different attitudes – and may also strike some obstruction part of the way down, making interpretation of injuries difficult.

The primary impact is usually the site of the most severe injury, but this is not always the case, as it may strike two areas simultaneously, such as the head and shoulder – or it may bounce or ricochet so that two or more major impacts occur in quick succession. The amount of kinetic energy acquired during the fall has to be fully expended by the time the body comes to rest so that, if only one impact occurs, it is likely to be more damaging than a series of lesser impacts, such as a bouncing, rolling strike.

If the body falls on to the head, there is likely to be a massive fracture, often (but not always) a scalp laceration and possibly extrusion of brain. Both vault and base can fracture and sometimes the base is driven down over the cervical spine, the latter projecting into the posterior fossa. The latter injury is, however, more common with high falls onto the feet when the impact is transmitted up the spinal column and the upper vertebrae – together with a ring of bone around the foramen magnum – are intruded into the skull, causing the classic ‘ring fracture’ of the occipital bone. Where the fall is onto the feet, the deceleration stress can break the axial skeleton at a number of points. The legs can be broken at any point, at tibial or femoral level, often bilaterally. The femoral necks can be snapped off, the hip joints can dislocate and over-ride, or the pelvis may fracture. The latter is often through the sacroiliac joints, the upward force (or more accurately, downward force of the body on to the legs) driving the sacrum down as a wedge into the pelvis.

If the lower limbs and pelvic girdle remain intact, the transmitted force may then fracture the spine, often at mid- or upper thoracic level.

Where the fall occurs onto the side of the body, any combination of injuries can occur. Multiple rib fractures, shoulder girdle or arm fractures, lacerations of back, buttocks or limbs and severe abdominal injuries can occur, with consequent internal lesions, such as rupture of the liver, lungs, heart or spleen.

In falls from high-rise buildings, the injuries can be extreme, as in a suicide from the twentieth floor seen by the author (BK), where the victim fell onto a fence and was completely transected at waist level.

It must also be remembered that biological and circumstantial variability allows for some remarkable escapes from falls; some persons, including children, have fallen from great heights yet have virtually walked away unscathed. Once again, it is very unwise to over-interpret the relationship between observed injuries and the likely length of the fall.

FRACTURES OF THE SKULL

Forensic anatomy

The cranium and facial bones are laid down from membrane in fetal life. The anterior fontanelle closes functionally between 9 and 26 weeks after birth, though is not tightly sealed until about 18 months. The posterior fontanelle closes between birth and 8 weeks of age. Suture lines close by interdigitation during childhood and osseous fusion occurs irregularly at variable dates during adult life.

The adult cranium consists of two parallel tables of compact bone called the ‘diploë’, the outer being about twice the thickness of the inner. They are separated by a central zone of soft cancellous bone, which is often misnamed the diploë. This zone is interrupted at suture lines and vanishes where the bone becomes particularly thin, especially in the floor of the skull.

The cranium varies in thickness in adults and varies from place to place, thin plates being reinforced by stronger buttresses, such as the petrous temporal, the greater wing of the sphenoid, the sagittal ridge, the occipital protruberance and the glabella. This tensile architecture of the skull has been well described and illustrated by Rowbotham (1964). The more vulnerable thin areas lie in the parietotemporal, lateral frontal and lateral occipital zones.

The average frontal and parietal thickness in a young male is between 6 and 10 mm. The thinnest area is in the temporal bone, where it may be only 4 mm, while in the occipital bone in the midline it may be 15 mm or even more. The thickness of the skull is sometimes an issue in courtroom propositions about the special vulnerability of a victim but, unless it is abnormally thin, such theorizing has little forensic relevance as it is well known that fatal brain damage can often occur with an intact skull. It has even been claimed that a thin skull is less likely to fracture,

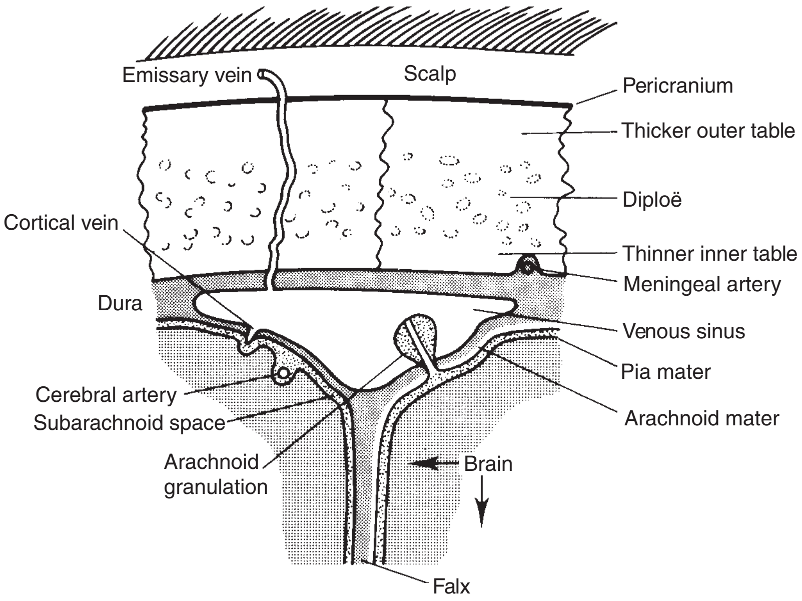
Emissary vein
Scalp
Pericranium
Thicker outer table
Diploë
Cortical vein
Thinner inner table
Meningeal artery
Dura
Venous sinus
Pia mater
Cerebral artery
Subarachnoid space
Arachnoid mater
Arachnoid granulation
Brain
Falx

FIGURE 5.13 *Forensic anatomy of skull and meninges.*

as it is more flexible and can return to normal after distortion without cracking; this is certainly true of the skulls of infants. This may be irrelevant when assessing intracranial damage, however, which is the major issue in head injuries.

It is rarely the skull fracture itself that is a danger to life, but the concomitant effect of transmitted force upon the cranial contents. The presence of a skull fracture is, however, an indication of the severity of the force applied to the head and it is uncommon for a head injury that is sufficiently severe to crack the skull not to cause some intracranial effect, even if it is only transient concussion, though, once again, there are many remarkable exceptions to this generalization.

In skeletal material, fractures of the skull are often seen and the differentiation between ante-mortem injury and post-mortem damage can sometimes be difficult or even impossible in the absence of any soft tissues. Artefactual damage to a skull may be caused during recovery or exhumation, and even stones in the soil can cause erosion and even cracking of the softened, degenerate bone after long burial. Zuo and Zhu (1991) have described scanning electron microscopic details of microfractures and collagen damage, which can differentiate ante- from post-mortem injury, but these are unlikely to assist in old decayed material.

The mechanics of skull fracture

This subject has been extensively studied in living animals, isolated human heads and dried skulls. For details, the writings of Gurdjian, Webster and Lissner (1949, 1950), Weber (1984) and Rowbotham (1964) should be consulted;

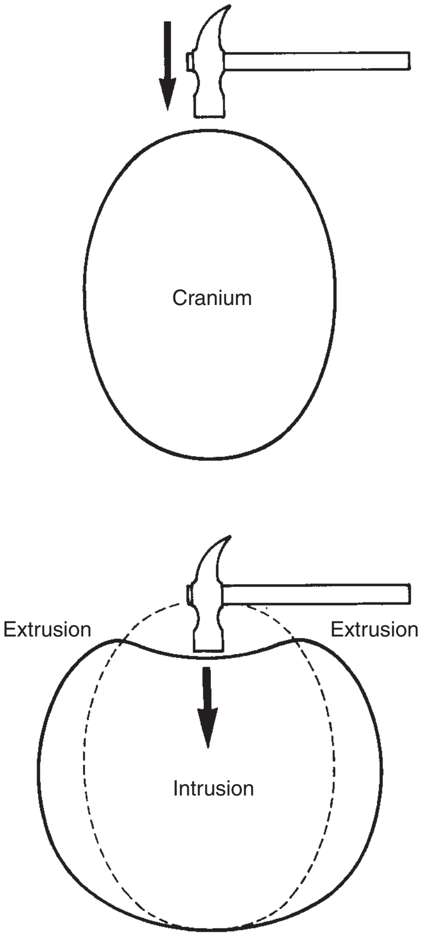
Cranium
Extrusion
Extrusion
Intrusion

FIGURE 5.14 *The 'struck hoop' illustration of impact on the skull. There is a momentary deformation, with the area of impact bending inwards and compensatory bulging elsewhere. This sets up stresses in the inner and outer tables.*

a concise summary has also been provided by Shapiro *et al.* (1988). These and other workers have shown that:

- When the skull receives a focal impact there is momentary distortion of the shape of the cranium, the extent of which may be surprisingly large, though transient. Infant skulls, which are more pliable and have flexible junctions at suture lines, may distort much more than the more rigid skulls of adults. The area under the point of impact bends inwards and, as the contents of the skull are virtually incompressible, there must consequently be a compensatory distortion or bulging of other areas – the well-known 'struck hoop' analogy.

  Both these intruded and extruded areas can be the site of fracturing if the distortion of the bone exceeds the limits of its elasticity.
- When the skull is deformed, compression occurs on the concavity of the curved bone and tension (tearing) forces on the convexity. If the latter exceed the elastic threshold, then fracturing takes place. Thus the inner table will fracture where the skull is indented and the outer table will fracture at the margins of the deformed area. If the forces are great enough, a depressed comminuted fracture will occur.
- In the more common circumstance of a wider impact from a blunt injury, the deformation of the skull is less localized but, where the force is sufficient, fractures can still occur from the same mechanism of exceeding the elastic limits. The fractures may be remote from the area of impact, following lines of structural weakness – or may extend from the area of impact, or even commence at a distance and run back to the impact site.

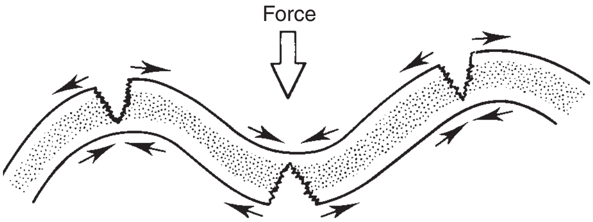

FIGURE 5.15 *The skull is more susceptible to traction forces than compression, so that convexities tend to fracture during the distortion of the 'struck hoop'.*

By using skulls coated with a brittle varnish, Gurdjian showed that stress lines developed in the cranium when it was struck and that these corresponded with the fractures that occurred with heavier impacts.

Blows in certain areas of the skull constantly give rise to fractures in specific localities – for instance, impact on the upper temporal or parietotemporal areas cause fissured fractures running obliquely downwards across the temporal area. If heavier, another fracture line tends to run obliquely contralaterally across the vault of the skull.

A heavy impact on the side or top of the head often leads to the vault fracture running into the base of the skull, usually across the floor of the middle cranial fossa along the anterior margin of the petrous temporal bone, to enter the pituitary fossa. In major injuries, this fracture line may often cross the floor of the skull completely to form a 'hinge fracture', separating the base of the skull into two halves. These fractures do not start at the point of impact unless there is also local

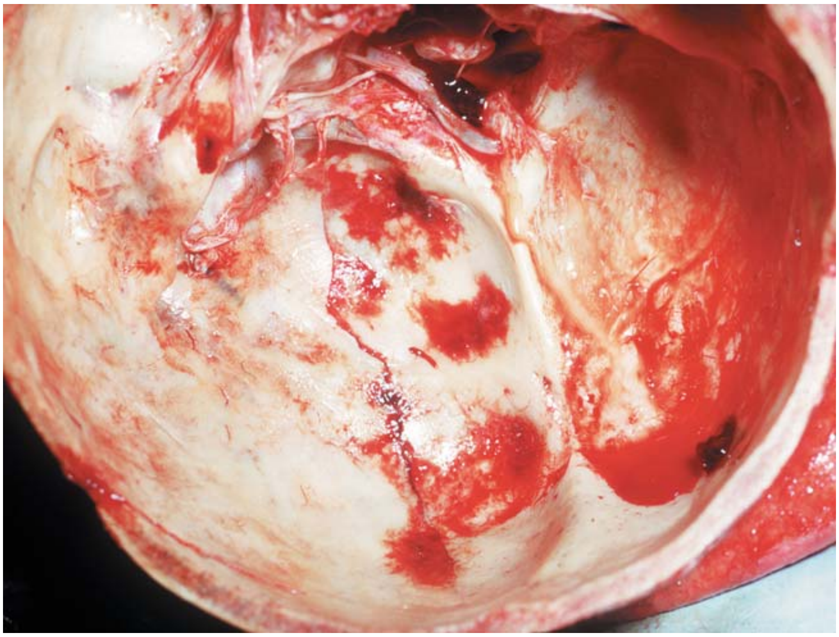

FIGURE 5.16 *Linear fracture of the posterior fossa, due to a fall on the occiput. The fracture typically crosses the thinner bone, avoiding the central buttress and ends near the foramen magnum.*

depressed fracturing; they are initiated at a distance due to the compensatory deformation, but usually run back towards the impact site.

When the frontal area is struck, the usual course for a linear fracture is vertically down the forehead, turning around the orbital margin to run backwards across the floor of the anterior fossa, perhaps into the cribiform plate or air sinuses, or both. A blow or fall onto the occiput may produce a fracture that typically passes vertically or obliquely downwards just to the side of the midline of the posterior fossa, commonly reaching the foramen magnum. In addition, the contrecoup element of an occipital fall may cause fractures of the orbital plates in the anterior fossa, as a result of transmitted force through the brain itself, though the mechanism is not fully understood.

- When severe local impact causes focal and general deformation, a combination of depressed fractures and radial fracture lines may form a 'spider's-web' pattern.
- When the focal impact is severe, the depressed fracture may follow the actual shape of the impacting object, such as a hammer-head. The shape may follow only that part of the object that drives into the skull – for example, the circular head of the hammer may strike at an acute angle, so only a semicircle of bone will be punched inwards, the opposite edge sloping downwards from an irregular crack.

  The deepest part of the depression will indicate where the weapon first struck; there may be 'terracing' of the margins. The author (BK) has seen a recent instance where a victim was struck with a hammer through a thin plastic bag enveloping the head. Parallel terracing cracks had opened for a fraction of a second during the blow, sufficient to trap lines of plastic into the multiple defects in the outer table. Where the impact is from a narrow edge or ring, only the outer table may be fractured, being punched into the softer centre without depression of the inner table.
- The presence of hair and scalp markedly cushions the effects of a blow, so that a far heavier impact is required to cause the same damage, compared to a bare skull. The pattern and nature of the skull fractures are, however, the same. It should be noted that the interposition of scalp and hair may slightly alter the dimensions of the skull lesion from a focal blow. For example, the padding effect of the scalp may add a few millimetres in diameter to the depressed fracture caused by a hammer, compared with the actual measured diameter of the hammerhead.
- Where two or more separate fractures occur from successive impacts and meet each other, the sequence of injuries may be determined by 'Puppe's rule', which is really eponymous common sense. The later fracture will terminate at (that is, not cross) the earlier fracture line, which naturally interrupts the cranial distortion which precedes fracturing (Figure 5.17).

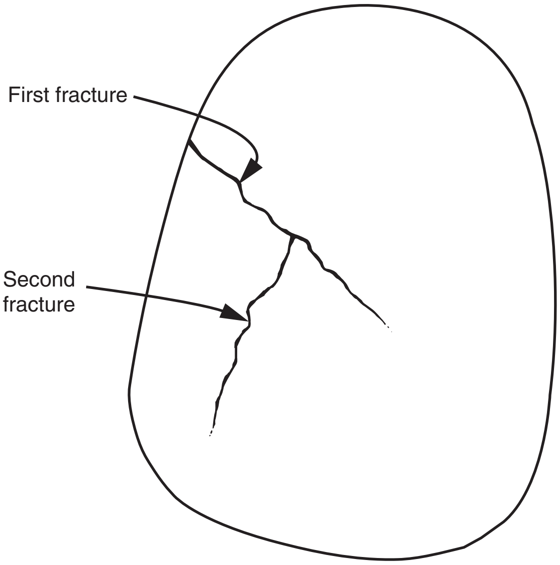

FIGURE 5.17 *Diagram to illustrate Puppe's rule for the sequence of fractures. The course of a later fracture will be interrupted by an earlier pre-existing fracture line.*

Types of skull fracture

Arising from the mechanisms described above, it is conventional to classify skull fractures as follows.

LINEAR FRACTURES

These are straight or curved fracture lines, often of considerable length. They either radiate out from a depressed zone, or arise under or at a distance from the impact area, from bulging deformation. They may involve the inner or outer table, but commonly traverse both.

Depending on the stress contours of that part of the skull and the localization of the impact, they may occur anywhere in the skull, but are especially common in the weak unsupported plates. The temporal, frontal, parietal and occipital plates may all carry single or multiple linear fractures. They may extend downwards into the foramen magnum, across the supraorbital ridges, or into the floor of the skull. A common basal linear fracture is one that passes across the floor of the middle fossa, often following the petrous temporal or greater wing of the sphenoid bone into the pituitary fossa. This frequently continues symmetrically across the other middle fossa separating the base of the

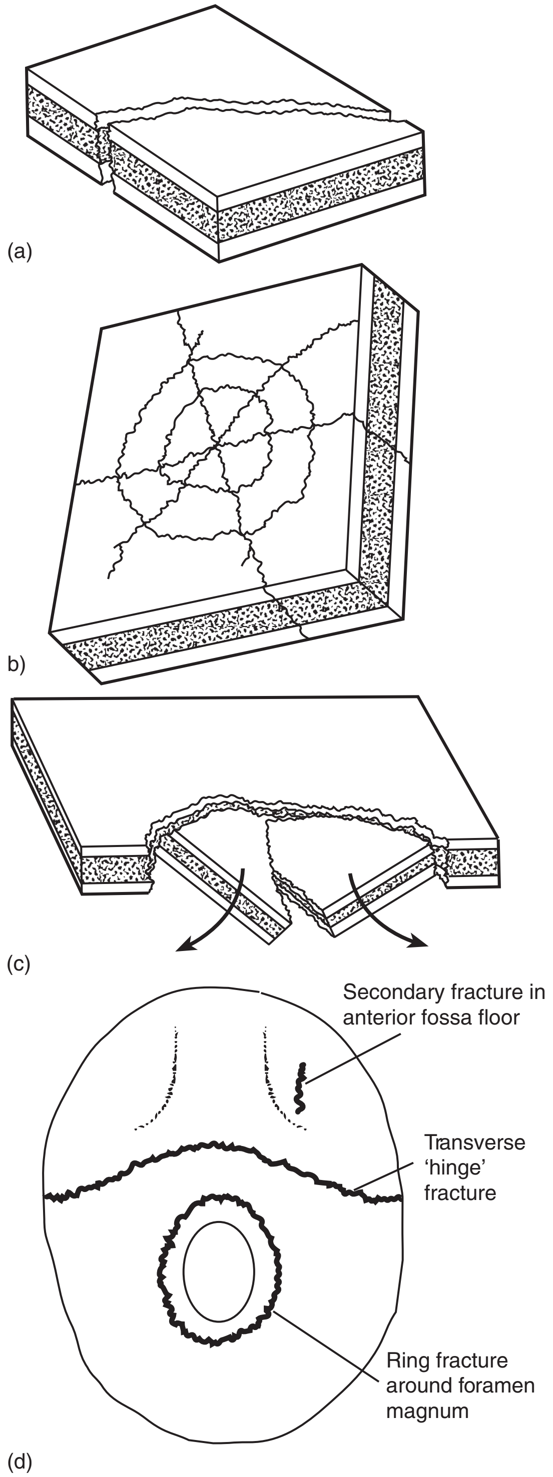
(a)
b)
(c)
Secondary fracture in anterior fossa floor
Transverse 'hinge' fracture
Ring fracture around foramen magnum
(d)

FIGURE 5.18 *Types of skull fracture: (a) linear fracture; (b) 'spider's-web' fracture; (c) depressed fracture; and (d) base fractures.*

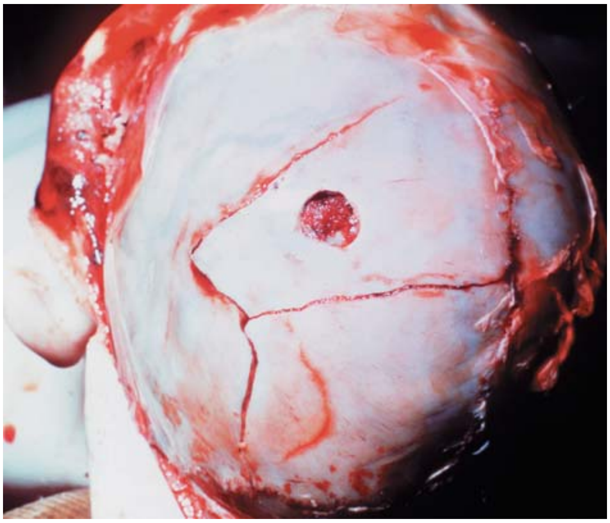

FIGURE 5.19 *Linear fractures of the skull in child abuse. Blunt impact near the vertex has caused a double fracture to run down the parietal bone and continue into the temporal area, the course of the fracture being determined by lines of stress and weakness in the skull. The central burr-hole was for the surgical evacuation of a subdural haemorrhage.*

skull into two halves, usually being caused by a heavy blow on the side of the head; this lesion was sometimes called the 'motorcyclist's fracture' for obvious reasons. Linear fractures may follow a horizontal course around the skull, usually from one temporal area to the other via the occiput rather than around the front.

In children and young adults, a linear fracture may pass into a suture line and cause a 'diastasis' or opening of the weaker seam between the bones. This is most often seen in the sagittal suture between the two parietal bones, but the interfrontal line of weakness left by the earlier fusion of the metopic suture can also reopen under mechanical stress. In infants, especially in the child abuse syndrome, a linear fracture of a parietal bone may reach the sagittal suture and continue across it into the opposite plate. The continuation may be direct or may be 'stepped', so that the two fractures are not in line. This appearance usually means a blow or fall onto the vertex, and the two fractures may be simultaneous but not continuous, explaining the 'stepping'.

RING FRACTURES

These occur in the posterior fossa around the foramen magnum and are most often caused by a fall from a height onto the feet. If the kinetic energy of the fall is not absorbed by fractures of the legs, pelvis or spine, the impact is transmitted up the cervical spine. This may be rammed into the skull, carrying a circle of occipital bone with it.

POND FRACTURES

This is merely a descriptive term for a shallow depressed fracture forming a concave 'pond'. It is more common in

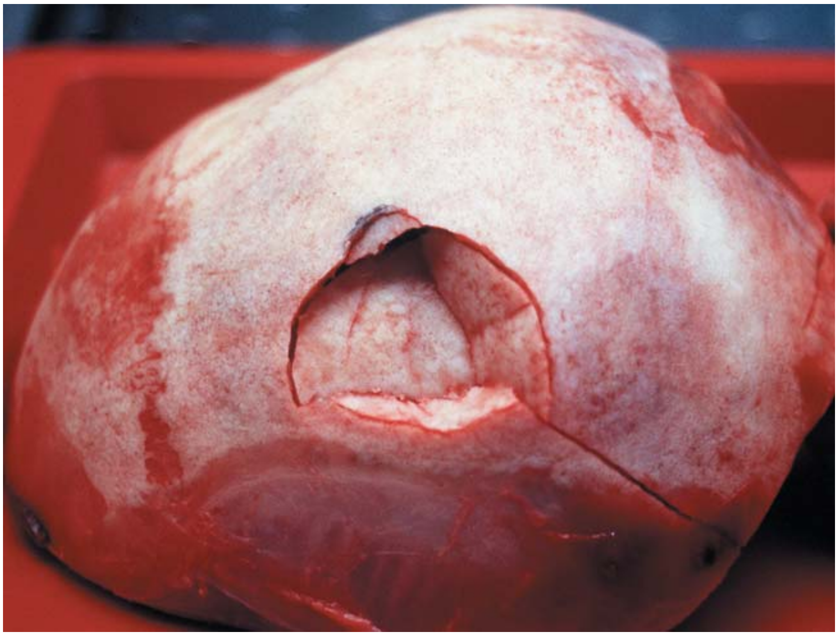

FIGURE 5.20 *Pond fracture.*

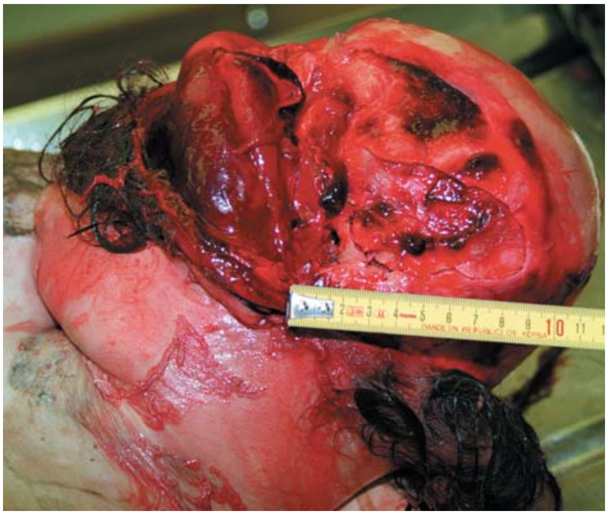

FIGURE 5.21 *Comminuted skull fracture with depression of the central area. This could also be termed a 'pond fracture' in that there is an ovoid depressed zone with radiating linear fractures. The head was struck with a heavy piece of wood along the line of the depressed area.*

the more pliable bones of infants and, indeed, a depression can occur in the absence of a fracture akin to the distortion produced by squeezing a table-tennis ball.

MOSAIC OR SPIDER'S-WEB FRACTURES

As already described, a comminuted depressed fracture may also have fissures radiating from it, forming a spider's-web or mosaic pattern. The degree of actual depression may be minimal or even absent.

DEPRESSED FRACTURES

Focal impact causes the outer table to be driven inwards and, unless absorbed in the diploë, the inner table will also usually be intruded into the cranial cavity with all the dangers of direct damage to the contents. Even sharp-edged weapons, such as heavy knives and axes, which may cause a clean-cut defect externally, usually split and deflect flaps downward from the inner table.

With axes and heavy cutting weapons such as swords, there is a characteristic lesion in the bones, whether skull or elsewhere. The initial impact slices cleanly through the bone on one edge, often burnishing the bone to an ivory-like gloss. The rebound removal of the weapon is at a slightly different angle, either from deliberate intent, or from relative movement between bone and blade. This cracks off an irregular fragment of bone of the opposite face so that the residual defect has one smooth and one rough edge. It is often seen in historical and archaeological material from battles or massacres.

The force required to cause fractures of the skull

Unlike less reliable subjective estimates of the force required to cause other injuries, objective quantitative measurements have obtained for adult skull fractures. Again, the publications of Gurdjian, Webster and Lissner should be consulted for detailed information. The following useful facts arise from their investigations:

- The tensile strength of the adult skull is of the order of 100–150 p.s.i., the compressive strength varying from

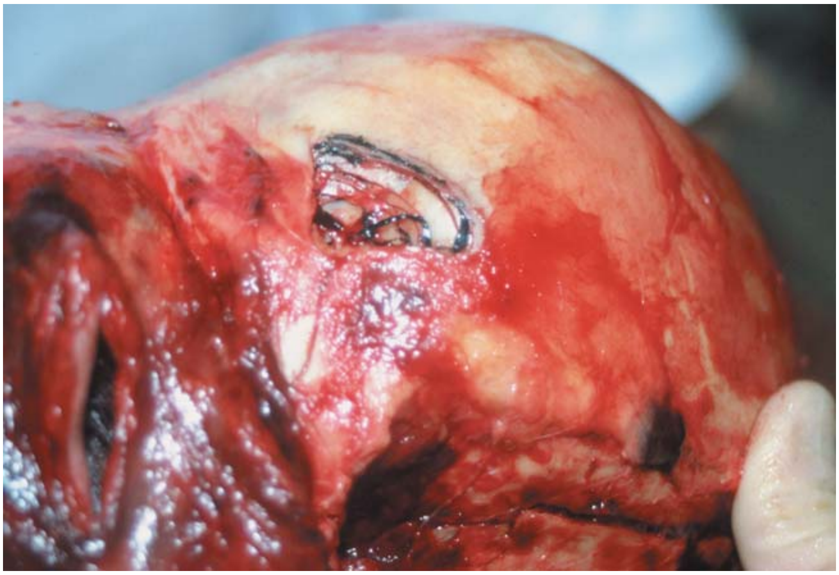

FIGURE 5.22 *A depressed fracture of the skull from a blow with a heavy club hammer. The defect is wedge shaped with a curved anterior border caused by the hammer striking at an angle. The depression is concentrically terraced, with the lowest fragments lacerating the surface of the brain.*

5000 to 31 000 p.s.i. (Gurdjian *et al.* 1949). A simple fissured fracture of the skull can be sustained by walking into a fixed obstruction (Kerr 1954). This requires a force of about 5 foot-pounds (73 N). Fast running into an obstruction produces about 70 ft-lb (1020 N). Falling to the ground from an erect posture also develops at least 60 ft-lb (873 N) and can easily produce skull fractures. A small stone or golf ball weighing about 100 g (4 oz) may also cause a linear fracture when thrown with moderate force against the temporal region (Graham and Lantos 2002).

- The adult head weighs between 3 and 6 kg (7–14 lb), averaging 4–5 kg (10 lb). When falling through about one metre (3 ft), so that the frontal area strikes a hard surface, impact energy of about 35 ft-lb (510 N) develops. This can cause one or two linear fractures or a mosaic fracture (Gurdjian *et al.* 1950).
- Only a small additional amount of energy above that needed to cause a single crack is required to produce multiple fractures.

In spite of these experimental data, it must never be forgotten that, like all biological phenomena, great variation is encountered and skull fractures, though they may be caused by as little as 5 ft-lb (73 N), may be absent when the impact exceeds 90 ft-lb (1314 N). The area of the skull struck, the thickness of the skull, scalp and hair, the direction of the impact and other imponderables, all affect the outcome.

As further discussed in Chapter 22, Weber carried out experiments in which he dropped the bodies of dead infants from a fixed height of only about 85 cm (34 inches) onto various hard and soft surfaces. A high proportion sustained skull fractures, both of the parietal and occipital areas, some of them crossing suture lines.

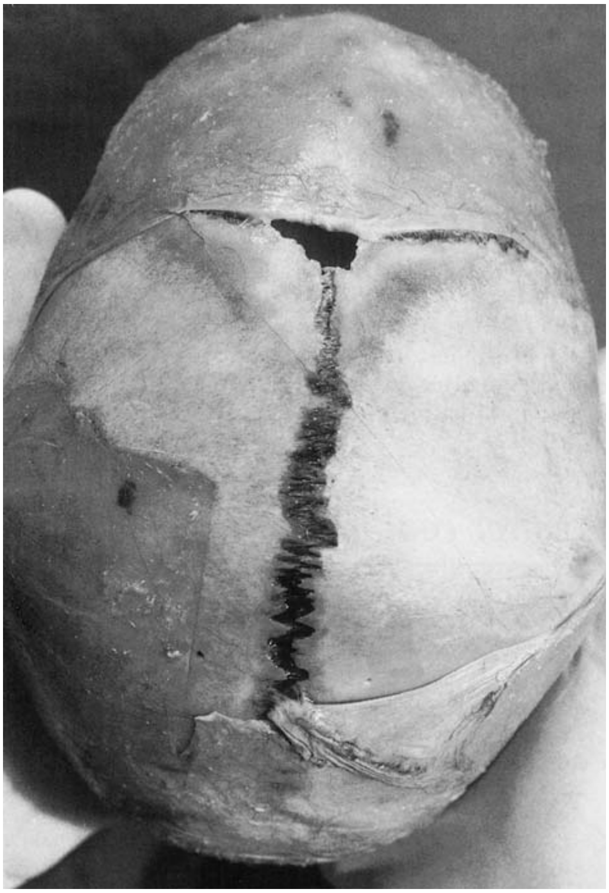

FIGURE 5.23 *Springing of the sagittal suture of the skull of an infant. Though there was no skull fracture, the suture line has widened after a fall that caused a subdural haemorrhage.*

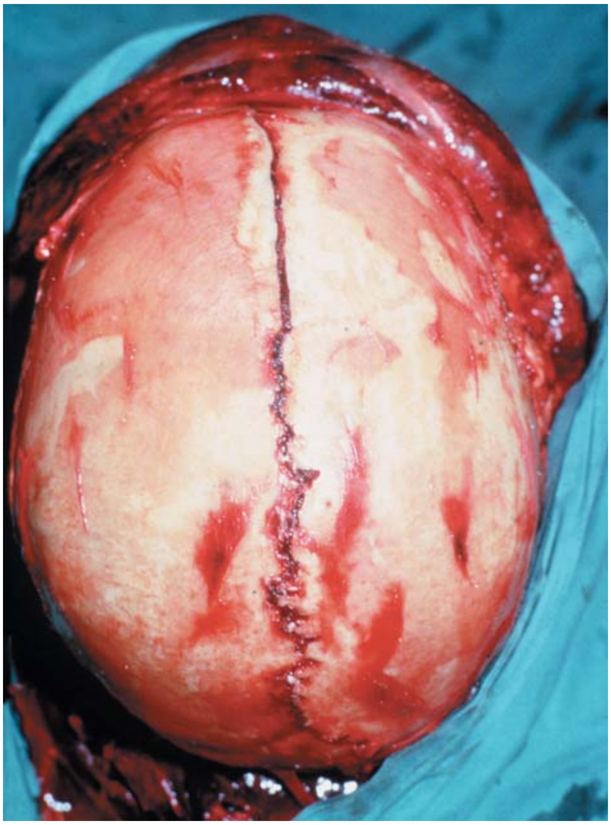

FIGURE 5.24 *Diastasis or 'springing' of the sagittal suture of a young adult who fell from a height onto the vertex of his head. The opening of the interparietal suture has extended anteriorly along the line of weakness of the fused metopic suture between the two halves of the frontal bone.*

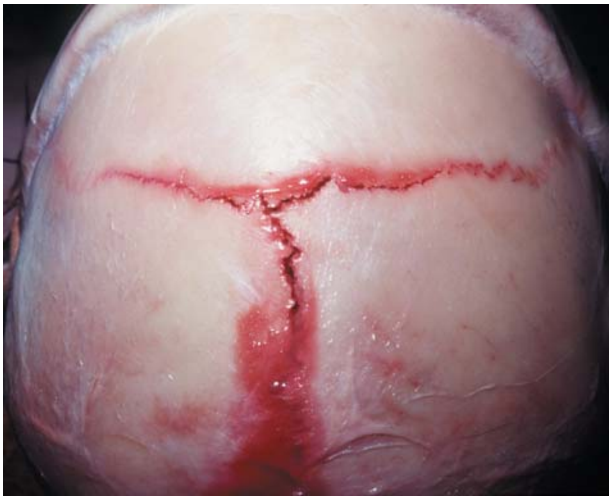

FIGURE 5.25 *Post-mortem diastasis of the sutures as an artefact due to freeze-up of the brain simulating intra-vital skull fracture.*

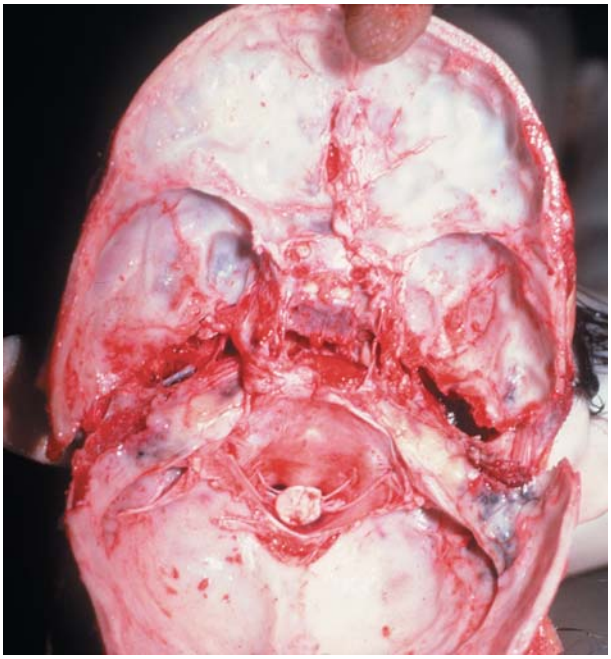

FIGURE 5.26 *A 'hinge' fracture of the base of the skull where the fracture line runs from side to side across the floor of the middle cranial fossa, passing through the pituitary fossa in the midline, following the course of least structural resistance. The victim was a young pedestrian who was hit by a car and then sustained secondary injuries by striking the left side of the head on the ground. This injury is common in road accidents and is sometimes called the 'motorcyclist's fracture'.*

Dangers of fractures of the skull

It has been emphasized that, in the majority of cases, the significance of a fractured skull is an indicator of a substantial insult to the head, with possible injury to the vital contents, rather than the fracture itself being a danger to life.

There are occasions, however, when the fracture itself has dangerous sequelae. The most common is when the crack passes through an embedded meningeal artery, causing a meningeal haemorrhage, which is considered later. A depressed fracture may impinge upon the brain and its membranes, and bone fragments may lacerate or penetrate the brain tissue.

TRAUMATIC EPILEPSY

A late effect of a depressed skull fracture may be 'traumatic epilepsy'. This is of great medico-legal significance, especially in the field of civil litigation where an accident or assault may result in lifelong neurological disability for which very large monetary compensation may be awarded.

Traumatic epilepsy usually manifests as tonic and clonic fits, which may be difficult to differentiate from idiopathic epilepsy, if the injury occurred in early life. When fits begin within weeks, or a year or two of a major head injury in a mature person who had never had fits before, the diagnosis is easier, but all cases need expert neurological examination. There must have been a substantial head injury, usually with a depressed fracture impinging on the underlying cortex, often in the parietotemporal area. The epilepsy appears usually within a range of a few weeks to up to 2 years. It is more common in open head injuries when infection has occurred, or when a spicule of bone has penetrated the meninges, as the mesodermal scarring of the cortex that results is more likely to irritate the brain than the astrocytic reaction found in closed head injuries.

INFECTION FOLLOWING SKULL FRACTURE

Other complications may occur, even in the absence of depression or comminution. The most common is infection of the meninges, or the development of a brain abscess, or both. Infection can gain access via skull fractures:

- by direct spread through a compound fracture, especially where there is a contaminated scalp injury;
- by spread from the nasal cavity when a fracture of the cribriform plate has allowed communication with the anterior fossa. This fracture is not uncommon as part of ‘contrecoup’ lesions, described later. Sometimes the cribriform plate is ruptured by objects entering a nostril and carrying infected material into the cranium: the author (BK) has seen two such fatalities, one from an umbrella ferrule and another from a dirty bamboo garden cane. Another case was seen by PS where a suicide attempt was made with a small calibre pistol. The bullet penetrated the right temple and went through the skull just above the anterior cranial fossa, which was fractured and caused a leakage of the cerebrospinal fluid through the nose. The victim recovered well but, in spite of prophylactic treatment with antibiotics, died one year later from purulent meningitis.
- by spread from fractures that involve a paranasal sinus, such as the frontal or ethmoid, or from the mastoid air cells or middle ear cavity. Basal fractures may allow these spaces, which communicate with the infected outside environment, to reach the meninges, especially when the latter are torn by the traumatic event. A history of leakage of cerebrospinal fluid from the nose or ear must alert both clinician and pathologist to the possibility of communicating basal fractures. In any autopsy on a suspected head injury, however slight, care must be taken to remove the dura from the interior of the vault and base so that a close inspection for fracture lines can be made.

INTRACRANIAL INJURIES

The contents of the skull are the most fragile of the vital organs, necessitating their enclosure in the strong bony box of the cranium. Damage may occur either to the neural tissues or to the rich vasculature that surrounds and penetrates those tissues.

FORENSIC ANATOMY OF THE BRAIN MEMBRANES

The pachymeninges consist of the dura mater and the leptomeninges, the arachnoid and the pia mater (see Figure 5.13). The **dura** is formed of two layers of tough collagenous tissue, the outer of which is firmly attached to the skull and acts as its internal periosteum. The inner layer merges with the arachnoid, so that in reality there is no true subdural space, only a potential cleavage plane.

The dura forms the falx and tentorium, and the cranial venous sinuses run within it. Branches of the meningeal arteries course over and through its substance. The dura is penetrated by bridging veins, especially along the vertex and at the tips of the temporal lobes, also to a lesser extent at the frontal and occipital poles, as well as by random vessels elsewhere. Polypoid invaginations of the dura penetrate the inner walls of the venous sinuses, especially the sagittal sinus, to form the ‘arachnoid granulations’.

The **arachnoid** is a thin, vascular meshwork that is intimately applied to the inner surface of the dura by means of the ‘boundary layer’ so that no subdural space exists in normal conditions, though their junction is so tenuous that they are easily split apart. Sheaths of arachnoid follow vessels into the brain as they penetrate into the neural surface. These vessels and thin strands of connective tissue anchor the brain within the subarachnoid space. This is filled with cerebrospinal fluid and the width of the space varies from less than a millimetre in the young to a centimetre or more in the old, in whom cerebral atrophy has developed. This means that the anchoring strands and the bridging vessels are longer and more vulnerable to shearing and rotatory stresses. Even though anatomically in the subarachnoid space, rupture of these bridging vessels often manifests itself in the subdural space.

The **pia** is not a true membrane, but a surface feltwork of glial fibres that are inseparable from the underlying brain.

EXTRADURAL HAEMORRHAGE

Also known as 'epidural haemorrhage', bleeding between the inner surface of the skull and the dura mater is the least common of the three types of brain membrane haemorrhage. According to Rowbotham (1964), only about 3 per cent of head injuries have an epidural haemorrhage large enough to be of surgical significance; a similar figure of between 1 and 3 per cent was recorded by Tomlinson (1970). Of the 635 fatal head injuries investigated by Adams (see References and further reading) in Glasgow, 10 per cent had extradural haemorrhages. The mortality rate, even with surgical intervention, averages about 11 per cent under the age of 20 years, rising to between 18 and 40 per cent in later life.

The dura is closely applied to the interior of the skull, forming the endocranium or periosteum. It is so tightly applied to the base of the skull that, except in the posterior fossa, extradural bleeding does not occur over the skull floor. In the vault there is a potential space between the dura and the bone, which can be separated by both arterial and – less often – venous leakage. Most extradural haemorrhages are associated with fractures of the skull, but about 15 per cent occur in intact skulls (McKissock 1960). According to Harwood-Nash *et al.* (1971), the incidence in children without a fracture is only 1 per cent, though Adams found that half the children with extradural bleeds in his series of over 600 fatal head injuries had no fracture. About 10 per cent of extradural haemorrhages are associated with subdural haemorrhages. Bilateral epidural haemorrhages are rare, but have been recorded.

The usual site is unilateral in the parietotemporal area, caused by rupture of a branch of the middle meningeal artery where the latter is transected by a fracture line. The posterior branch of this vessel is most commonly involved as it courses diagonally backwards across the squamous temporal bone on the lateral wall of the cranium. The anterior (frontal) branch is rarely the source of bleeding, occurring only twice in Rowbotham's series of 33 cases. The vessel usually lies in a deep osseous groove in the first part of its course. It has been claimed that almost all ruptures occur where the artery is completely roofed over in a bony tunnel so that it is unable to escape damage from a fracture, but observation does not confirm this contention.

Leakage of the high-pressure arterial blood strips back the underlying dura with progressive accumulation of a haematoma, which can reach a volume of several hundred millilitres and cover an appreciable part of the hemicranium. Adams suggests that a minimum volume of 35 ml is needed before clinical signs are apparent, though other writers suggest 100 ml is usually the minimum associated with fatalities.

In the less common occipital and frontal sites, smaller branches of meningeal arteries may be involved or the bleeding may be from torn venous sinuses, in which case there need not be a fracture. When bleeding is venous, the haematomas rarely reach a large size as the pressure is insufficient to tear back much of the dura.

The clinical signs of an epidural haemorrhage are classically those of a 'lucid' or 'latent' interval, as there may be recovery from the initial phase of concussion (see below) before sufficient blood accumulates to cause raised intracranial pressure and consequent relapse into unconsciousness. This classic picture is so frequently absent, however, that no diagnostic reliance can be placed upon it. The coma from the increasing space-occupying lesion formed by the bleed may follow the period of concussion without a break so that there is no temporary phase of recovery. Only 27 per cent of McKissock's series showed the classic history.

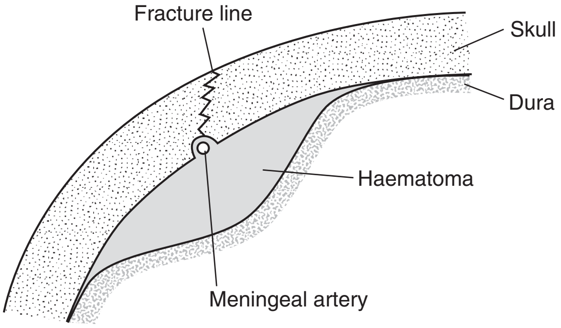

FIGURE 5.27 *Formation of an extradural haemorrhage.*

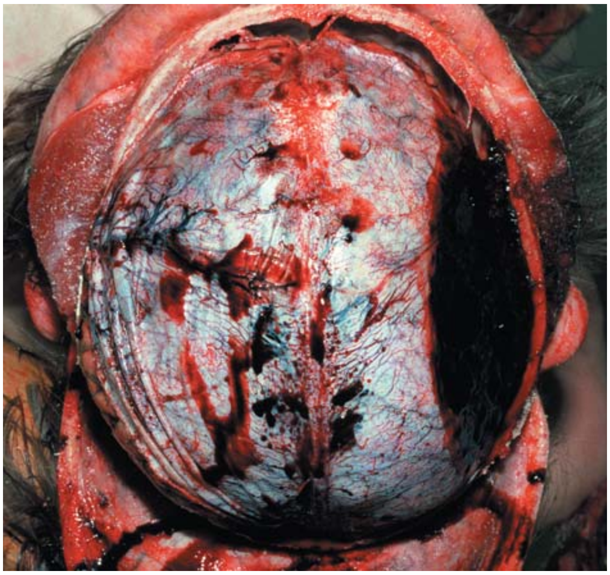

FIGURE 5.28 *A large temporoparietal extradural haemorrhage. The under surface of the scalp on the right shows bruising at the point of impact. There was a linear fracture of the skull passing through the right middle meningeal artery.*

The latent interval may be of variable duration and, as just noted, may not occur if either concussion is prolonged or other brain damage coexists. Half an hour may be enough for the formation of a significant arterial haematoma, though some slow bleeds have taken more than a day to become clinically apparent. In Rowbotham's series, the range was from 2 hours to 7 days, but most were apparent after 4 hours.

More recent investigations using computed tomography, quoted by Adams, suggest that the old concept of worsening clinical symptoms being caused by the progressive accumulation of blood is incorrect, as computed tomograms show that the major volume of blood may appear soon after the injury and that, as with many space-occupying lesions, clinical signs result from other factors, such as cerebral oedema or diffuse neuronal injury.

Medico-legal considerations of extradural haemorrhage

A medico-legal danger is that a victim may be discharged from the care of a doctor or hospital casualty department when he recovers from his transient concussion only to deteriorate and perhaps die at home; negligence may then be alleged against the unsuspecting doctor. Unfortunately, even when the diagnosis is made, the results of surgical intervention are not good, there being a fatal outcome in more than half the cases operated on. Part of the reason for this poor prognosis is that many victims of extradural haemorrhage also have other damage such as cerebral contusion.

When a victim of a head injury recovers from concussion and then lapses into coma within the first 24 hours, the differential diagnosis is between an extradural or subdural haemorrhage, or cerebral fat embolism, especially if there is other skeletal damage. At autopsy the lesion is self-evident, as most haematomas lie in the temporal or parietal areas, and are opened when the usual saw-cut is made to remove

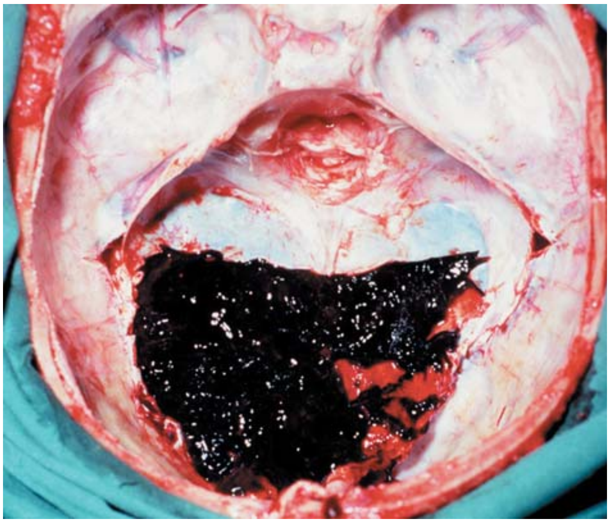

FIGURE 5.29 *An extradural haemorrhage in the posterior fossa. This is an unusual site for this type of lesion, as most occur in the temporal or parietal area as a result of tearing of the middle meningeal artery. In this case a fracture line passed down the posterior fossa towards the foramen magnum, but no bleeding point could be identified.*

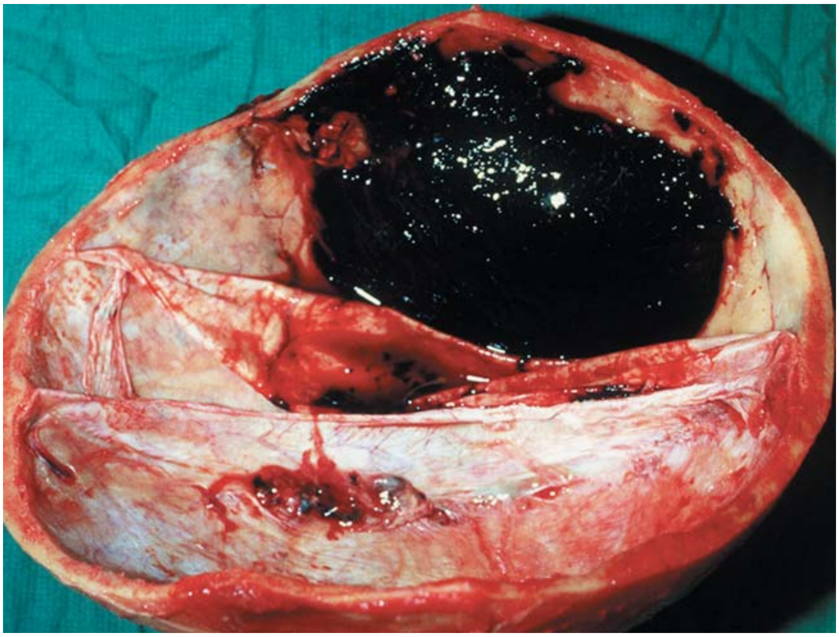

FIGURE 5.30 *A fresh extradural haemorrhage in the temporoparietal area from a fracture crossing the middle meningeal artery. About 85 per cent of such haemorrhages are associated with skull fractures.*

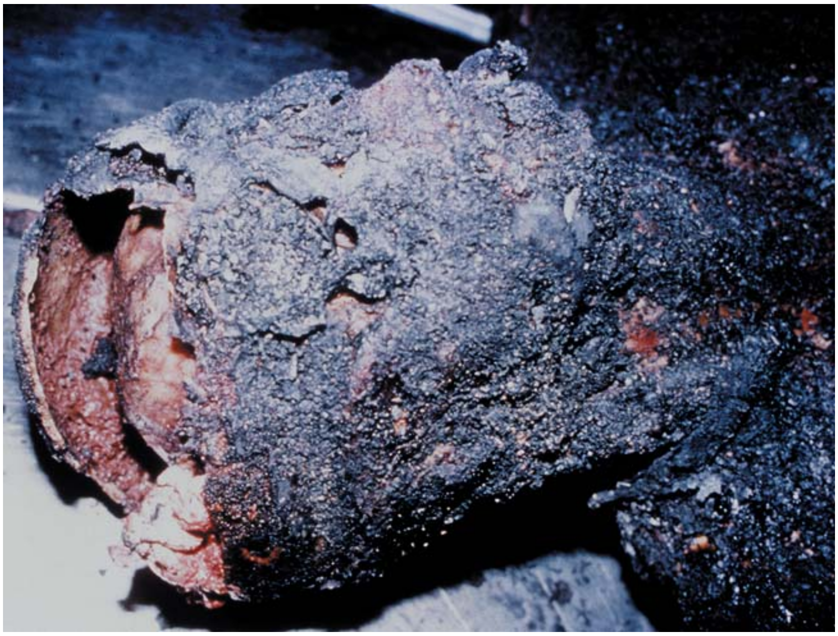

FIGURE 5.31 *Fire victim with extensive defect of the carbonized skull showing reddish-brown 'heat haematoma' on the inner surface of the skull and shrunken brain with brain tissue oozing out through a split in the dura.*

the calvarium. If in the posterior fossa, the dark blood is seen through the raised dura. Wherever it is situated the dimensions and approximate volume should be measured and an estimate made of the inward projection. The brain surface will be flattened or otherwise distorted if the haematoma is of significant size and may have given rise to the usual appearances of raised intracranial pressure, described later. The midline of the brain may be shifted laterally if the bleed is large.

Extradural haemorrhage is never a 'contrecoup' injury, this being purely a cerebral tissue lesion.

HEAT HAEMATOMA

One well-known artefact mimics an extradural haemorrhage. When a head has been exposed to severe external heat sufficient to burn the scalp and perhaps the skull, blood may be extruded from the diploë and venous sinuses into the extradural space to produce a 'heat haematoma'.

The mechanism is obscure, but may be the result of blood being 'boiled' from the diploic layer of bone through emissary veins, or shrinkage of the brain may aspirate blood from the skull. The false haematoma is brown and friable, and the adjacent brain shows hardening and discoloration from the heat.

The importance of the artefact is that it may be mistaken for a true epidural bleed from a head injury, and may mislead the pathologist and investigators into thinking that the fire was started criminally to cover up a fatal assault. As most instances are seen in conflagrations in buildings, there is often a significant level of carboxyhaemoglobin in the body if the death occurred when the fire was in progress. This should be of the same concentration in the heat haematoma as in the peripheral blood; if the victim suffered a head injury before the fire started, then there should be little or no carboxyhaemoglobin in the haematoma.

SUBDURAL HAEMORRHAGE

Bleeding beneath the dura is much more common than extradural haemorrhage. It is also proportionately less often associated with a fractured skull, but in absolute numbers far more fractured skulls cover subdural than extradural haemorrhages. The Glasgow series of 635 fatal head injuries described by Adams included 18 per cent of subdural haematomata.

The lesion is traditionally classified into three types: the acute, the subacute and the chronic. It is unhelpful to subdivide the acute type, however, and only acute and chronic haemorrhage need be considered.

Subdural haemorrhage can occur at any age, but is common at both extremes of life. It is one of the major causes of fatal child abuse and the rediscovery of that syndrome by Caffey (1946) consisted of an association of subdural haemorrhage with long bone fractures. In old people they commonly exist in a chronic form and can be mistaken either for 'strokes' or for senile dementia. The condition is always due to trauma and there is probably no such entity as 'spontaneous subdural haematoma'. Even in states of vascular fragility, such as in senility and in bleeding diatheses, some minimal trauma must precipitate the bleeding even if it was too trivial to be recorded in the history. It is almost certain that minor subdural bleeds, insufficient to give rise to any neurological or clinical symptoms or signs other than a transient headache, occur with the trivial knocks of everyday life. Only when the bleeding is extensive enough to become either a cortical irritant or a space-occupying lesion (probably between 35 and 100 ml) does it become clinically apparent. Of course, many subdural haemorrhages exist in combination with both subarachnoid bleeding and with cerebral damage, making its contribution to the overall symptomatology impossible to assess.

As with the extradural haematoma, the position of a subdural can never be interpreted as a 'contrecoup' lesion and is thus of no use in differentiating a blow from a fall.

Acute subdural haemorrhage

This is a common sequel to any substantial head injury, and the presence or absence of a fracture is immaterial except as an indicator of trauma to the head. Unlike extradural bleeding, a fracture plays no part in the pathogenesis of the haemorrhage, which arises from torn communicating veins that traverse the subdural space between the cortical vessels and the dural sinuses. Less often the sinuses themselves give rise to the haemorrhage.

Naturally in an open head injury or when comminuted fractures penetrate the membranes and perhaps the brain itself, subdural bleeding is merely part of a complex that includes subarachnoid bleeding, and cerebral laceration and contusion.

The lesion is often pure, however, being associated with a closed head injury where the only other signs may be scalp bruising – or even nothing at all, as blunt impacts may leave no signs in the scalp, externally or internally, and no skull fracture.

The latter situation is probably the explanation in most of the cases formerly attributed to shaking of the infant. Many paediatricians and pathologists have enthusiastically adopted the shaking aetiology when there was no overt sign of impact (or sometimes even where there was such evidence!) to such an extent that it is frequently proffered as the favoured diagnosis. However, the concept of the shaken-baby subdural has been strongly challenged recently, as it has been shown that the shearing force (required to rupture subdural vessels) is of the order of 50 times less in shaking than in impact (Duhaime *et al.* 1987). Thus it is very probable that perhaps the majority of allegedly shaken babies have, in fact, had an occult head impact, which has not left any signs on the scalp, subscalp tissues or skull.

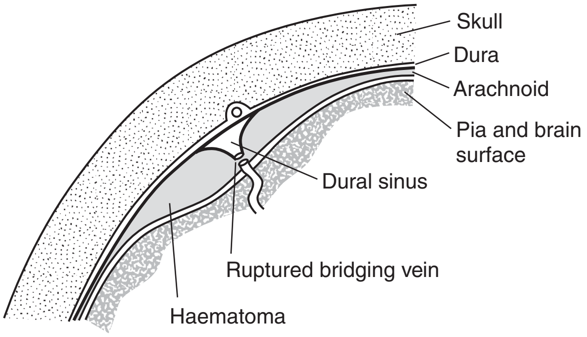

FIGURE 5.32 *Formation of a subdural haematoma.*

Subdural bleeding arises from shear stresses in the upper layers of the cerebrum, which moves the communicating veins laterally sufficiently to rupture their junctions at either the cortical veins or the sinus surfaces. It is very rarely possible to identify the bleeding points. Subdural bleeding is most often over the lateral surface of a cerebral hemisphere, high up in the parasagittal area.

As with most intracranial damage, the mechanical cause is a change of velocity of the head, either acceleration or deceleration, almost always with a rotational component. Where a blunt impact strikes the skull, the subdural bleed need not be situated directly under the impact area – it need not even be on the same side of the head. It is sometimes tempting to attribute a localized subdural to either a 'coup' or to a 'contrecoup' effect (see below), but this is an unsafe interpretation. In addition, a subdural haemorrhage – unlike an epidural – is quite mobile. Lesions that have obviously originated high on the parietal area commonly drain down under gravity and cover the whole hemisphere, with a large accumulation in the middle and anterior fossas, and even through the tentorial opening into the posterior fossa.

The haemorrhage may remain fluid or may clot into a firm mass: both modes are commonly present. If the bleeding is relatively slight, then a 'thin-film' subdural may be found. If the thickness of blood is less than a few millimetres, it cannot be claimed to be a space-occupying lesion, even if the area covered is quite large, as the cerebrospinal fluid in the adjacent subarachnoid compartment can be displaced sufficiently to accommodate an equivalent volume of blood.

Again, Adams suggests that, as in any intracranial space-occupying lesion, a minimum volume of about 35 ml is required to cause neurological signs, though other writers prefer a larger volume, such as 100 ml.

Whether this film of fresh blood is a sufficient irritant to cortical activity – as it undoubtedly is in a subarachnoid haemorrhage – to be a danger to life, is uncertain. It is difficult to claim that a thin layer of blood in the subdural

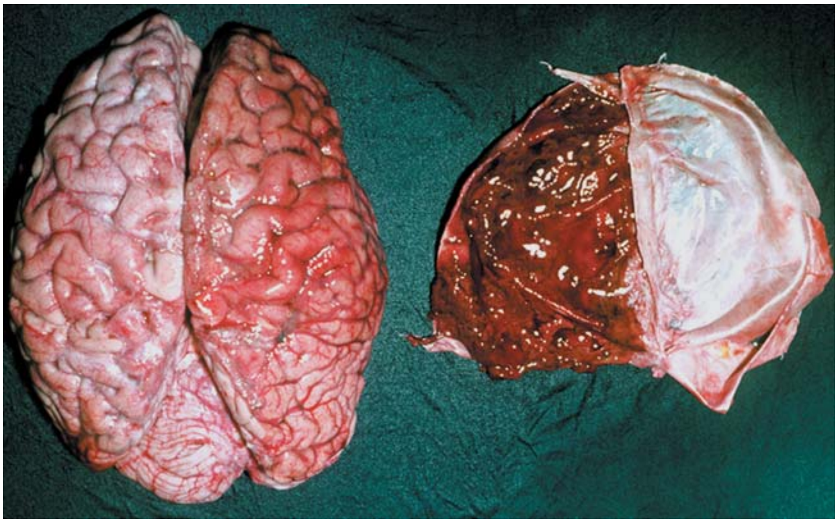

FIGURE 5.33 *Chronic subdural haemorrhage in an old person. Brown liquid escaped from the encapsulated lesion adherent to the meninges leaving a gelatinous outer membrane, as seen. The surface of the right cerebral hemisphere is stained brown from old altered blood and there is some compression of the hemisphere with a midline shift to the left. There was no history of a head injury and no significant neurological deficit.*

space is the sole cause of death, but almost inevitably the force that caused the bleeding will also have had a deleterious effect on the brain tissue, even if this is macroscopically occult such as diffuse axonal damage.

As with the extradural haemorrhage, there may be a latent interval before clinical signs and symptoms appear. After the almost inevitable concussion, which may be very brief, the victim may recover, then relapse into deepening stupor and coma when intracranial pressure rises as the subdural bleeding proceeds. Associated brain damage may, however, cause uninterrupted coma from the time of injury.

When there is a lucid interval, this may be longer than the average 4 hours of the faster arterial bleeding of the epidural haemorrhage. In fact, there is no upper limit to this interval, as the acute subdural haemorrhage merges into the chronic condition, which may recur after weeks or even months. In severe acute bleeds, as are commonly encountered in criminal cases, such intervals tend to be short or non-existent.

Chronic subdural haematoma

This lesion is most often found in old people, frequently as an incidental finding at autopsy where death was caused by some unrelated condition.

The gross appearance varies with age; recent lesions up to several weeks old are tan or red-brown with a gelatinous membrane covering the surface. The contents are thick but liquid and may have areas of redder, more recent bleeding. An older haematoma, up to months or even a year old, is firmer, with a tough membrane around both surfaces, resembling a rubber hot water bottle filled with jelly or oil. The contents are liquid and may be brown or even straw coloured. Sometimes the interior may be much firmer and variegated in colour due to bleeds of different ages. Loculation is common, with different coloured fluids or ooze in each locule. The underlying brain will be depressed if the haematoma is large (more than 50–100 ml), and is often stained brown or yellow from altered haemoglobin.

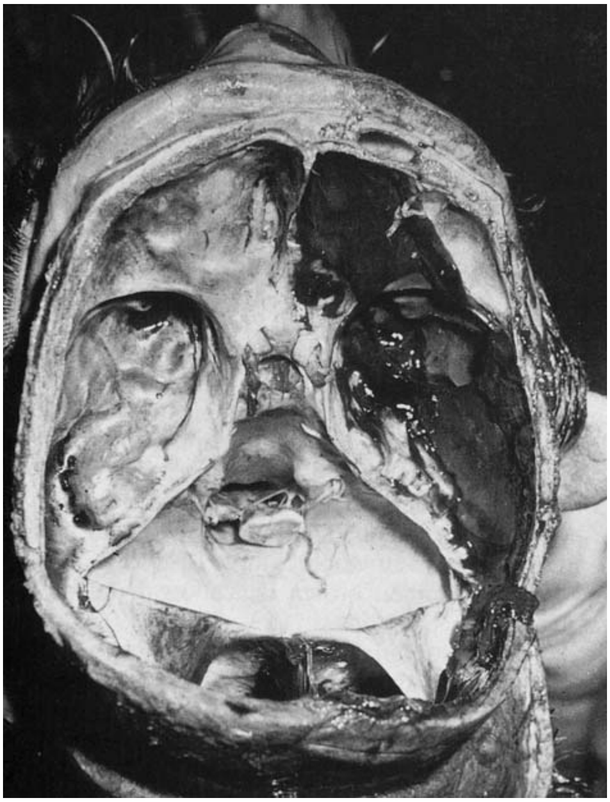

FIGURE 5.34 *A chronic subdural haemorrhage discovered as an incidental finding at an autopsy on an old person dying of an unrelated cause. The blood was brown and gelatinous, but there was no membrane.*

Many such subdural bleeds in old people are small and obviously gave rise to no neurological abnormality; the mere finding of such a small lesion at autopsy should not be used to provide a cause of death, which should be sought elsewhere in the body. Some subdurals are substantial, however, reaching a volume of 100–150 ml. They may still have been asymptomatic, but others give rise to neurological symptoms that may have been ascribed to some other pathological cause. Examples are 'strokes', when unilateral signs were thought to be caused by a cerebral thrombosis or haemorrhage; disordered behaviour of the old person may have been blamed upon senile confusion or dementia, whereas in fact a space-occupying haematoma was really responsible.

The chronic haematoma may become large and press down on the cerebral hemisphere sufficiently to dent and distort the surface. This may progress, as does the large acute haemorrhage, to cause signs of hippocampal and cerebellar tonsillar herniation and all the attendant dangers to the vital centres in the brainstem. The chronic haematoma arises from the acute lesion, which, after an interval, becomes sheathed in a capsule of connective tissue. The haematoma may eventually absorb, it may remain dormant at the same size, or it may enlarge at any later date.

The mechanism of the enlargement is controversial. One common explanation, which seems the most reasonable, is that it occurs from repeated further bleeding, perhaps from new blood vessels that penetrate the mass as part of the healing process. The other theory involves osmosis, said to operate because the centre of the haemorrhage commonly liquefies, forming a haemorrhagic fluid that osmotically attracts into it the cerebrospinal fluid from outside the capsule, which acts as a semipermeable membrane.

The first mechanism seems more likely, as areas of fresh bleeding are often found inside a substantial haematoma but, whatever the cause, the final effect is a worsening of the space-occupying effect.

The dating of a subdural haemorrhage

An estimation of the date of onset of a subdural haematoma may have considerable forensic significance, especially if the lesion is obviously mature. There may have been one or more episodes of trauma on record, any of which may have criminal or civil connotations and the opinion of the pathologist will be sought to relate or to eliminate the lesion found from the potential causative event.

For example, in one of the author's cases an old lady was struck on the head by intruders and died several weeks later. At autopsy, a large chronic subdural haematoma was the main finding, but the defence sought to show that the haematoma must have been present before the assault by claiming that the woman's confused behaviour over the previous year was caused by the pre-existing intracerebral lesion. Furthermore, in accidents of any type, there may be doubt about whether the subdural haematoma arose as a result of the injury, or whether a pre-existing lesion caused unsteadiness that may have precipitated the accident.

Unfortunately, in spite of several claims to reliable methods of dating subdural haematomata, such estimations are of doubtful value, partly because repetitive bleeding results in varying ages within the same haematoma.

A subdural haematoma gradually changes from dark red to a brownish colour, first being apparent not before 5 days and sometimes not obvious for 10–12 days (Crompton 1971, 1985).

Reaction to subdural bleeding begins within a few hours of onset, when cellular infiltration begins from the dural surface. A delicate 'neomembrane', histologically composed of thin-walled capillaries and fibroblastic granulation tissue, grows from the periphery to cover the outer (dural) surface of the clot during the next few days and weeks. If no further enlargement occurs, this capsule becomes more and more fibrous, though rarely does it completely absorb the haematoma by fusing with the outer capsule. According to Crompton, the presence of a membrane firm enough to be picked off with forceps makes the subdural haemorrhage at least 12 days old.

Although claims have been made for accurate dating of subdural haematomas by histological criteria (Munro and Merritt 1936), these cannot be depended upon, especially after a few months, as there is considerable personal variation in healing rates. Also, because of the frequency of repeated subsequent fresh bleeding, attempts at estimating the date of the original bleed are unrealistic. As they are of some use as an approximate guide to age, Munro and Merrit's histological criteria are summarized briefly here:

- Fibroblasts appear at the margin of the clot within 36 hours and in 4 days the neomembrane adjacent to the dura is a few cells thick. From 5 to 8 days, the membrane becomes well established and fibroblasts migrate from it into the clot.
- By 8 days the membrane is 12–14 cells thick and is visible to the naked eye. From a few days after onset, there is progressive red-cell lysis and after 5 days haemosiderin-laden phagocytes are present, which may be stained by Perl's reaction.
- From 11 days the clot is subdivided by strands of fibroblasts. By 15 days a membrane is also present on the under surface of the clot and the outer neomembrane is half to one-third the thickness of the dura itself. By day 26 it equals the thickness of the dura, but the inner membrane is still only half as thick.

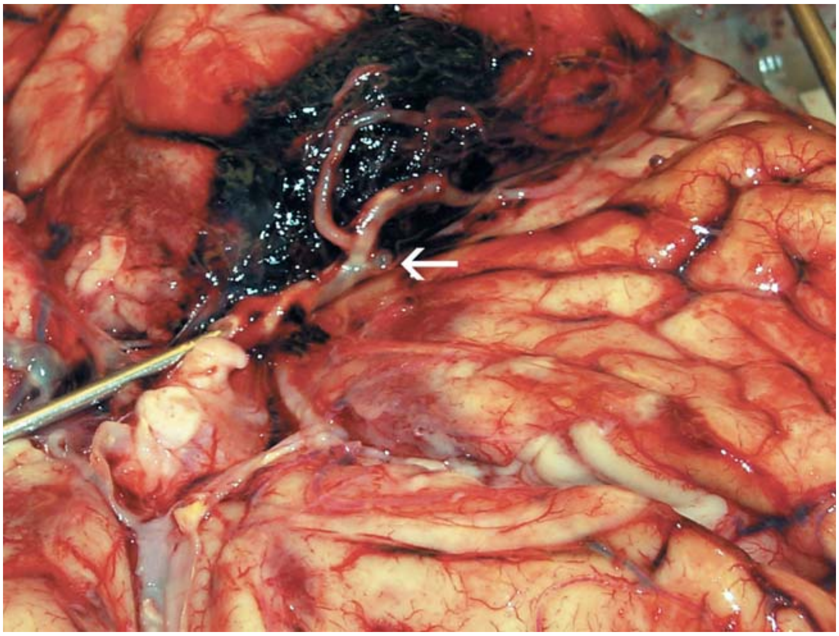

FIGURE 5.35 *Subarachnoid haemorrhage from a tiny berry aneurysm (arrow) of the right middle cerebral artery.*

- Between 1 and 3 months the membrane has lost many fibroblast nuclei and is becoming hyaline. By 6–12 months the membrane becomes thick and fibrous, resembling the dura itself.

A number of later writers have pointed to marked variations in this chronological scheme. Within the first couple of months large sinusoidal vessels appear in the newly formed connective tissue.

From gross appearances, a rough guide is that brown colour changes occur between the first and second week, when a discrete surface membrane becomes obvious. After a month or so a firm capsule develops, forming a cystic cavity containing dark brown, watery fluid. According to Munro, liquefaction of the contents does not occur in less than 3 weeks. Some haematomas remain solid with an organizing blood clot within, often with areas of fresher haemorrhage of different ages.

When a substantial subdural bleed has occurred, the underlying cerebral cortex may be infarcted, caused by either a natural infarct having bled through the arachnoid into the adjacent subdural space or, more often when there has been a head injury, the pressure of the haematoma on cortical blood vessels (Crompton 1971, 1985).

SUBARACHNOID HAEMORRHAGE

The third type of brain membrane bleeding is even more common than subdural haemorrhage, but has a mixed aetiology. Whenever there is damage to the cortex, there will be some degree of subarachnoid bleeding, so all penetrating injuries of the brain, as well as many blunt injuries that give rise to extradural or subdural haemorrhage, will be associated with traumatic subarachnoid bleeding.

It is not common, though not unknown, for traumatic subarachnoid bleeding to occur as a pure lesion where there is no cortical contusion, no neck injury, no deep brain lesion and no other membrane haemorrhage. Slight subarachnoid bleeding probably occurs very frequently after a moderate impact upon the head (as with slight subdural bleeding), but as the vast majority of such victims survive, no autopsy evidence is forthcoming. The increased sensitivity of medical imaging techniques, especially nuclear magnetic resonance, can demonstrate such minor bleeds which hitherto went undetected.

The other complicating issue with subarachnoid bleeding is that it frequently occurs as a result of natural disease, especially rupture of vascular malformations of several types. When trauma is also present, the complex association of either the trauma precipitating the rupture or a rupture causing a fall or other accident leading to the trauma, has to be considered. This is discussed in a later paragraph.

Although the pathology of subarachnoid haemorrhage is of prime forensic importance, because of the relationship to ruptured berry aneurysm, much of the description is offered in the chapter on sudden natural death (Chapter 25), and only the interaction between trauma and this type of bleeding is discussed here.

Appearances and mechanism of formation

The appearance of subarachnoid haemorrhage caused by trauma varies greatly according the nature and extent of the

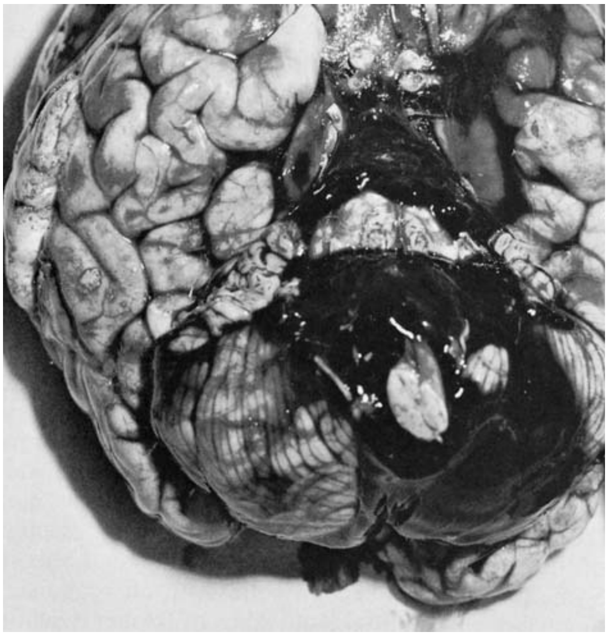

FIGURE 5.36 *An extensive basal subarachnoid haemorrhage arising from a traumatic tear of a basilovertebral artery caused by a blow on the side of the neck.*

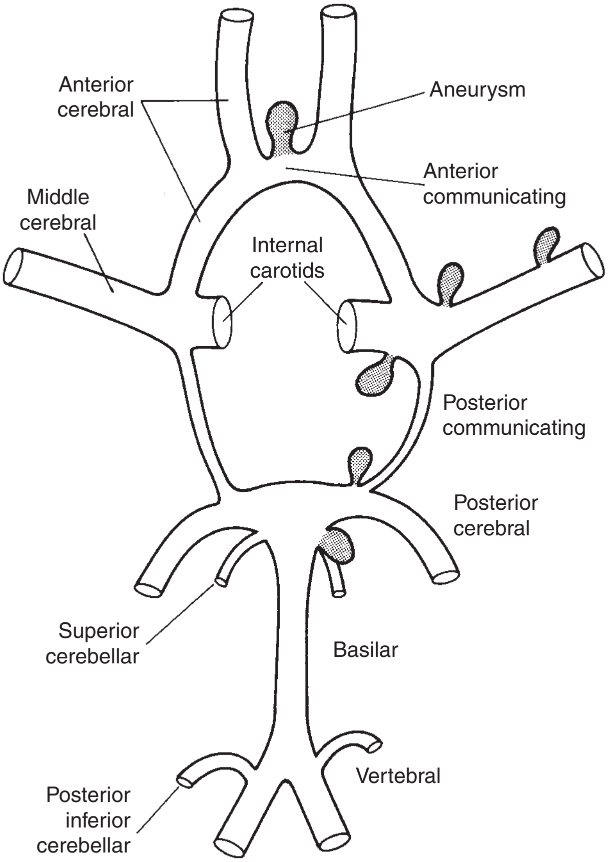

FIGURE 5.37 *Cerebral arteries ('circle of Willis') and common sites for aneurysms.*

injury. Where it is secondary to laceration of the brain or extensive cortical contusion, then its localization and severity depend upon the primary injury. Where it arises from a blunt impact, with or without other membrane bleeding or cortical bruising, its position is not a good localizing sign. Once again, its position cannot be interpreted in the same way as contrecoup contusion of the cortex, though some pathologists use its position to claim that a head injury was sustained either from a fall or from a blow to a mobile head; this is unjustified. Although where the circumstances are known, the meningeal bleeding may be seen in the correct location, this is fortuitous and is equally often sited elsewhere.

Blood in the subarachnoid space mixes with the cerebrospinal fluid, which dilutes it, makes it less ready to clot and allows more mobility. Thus bleeding high over the cerebral hemispheres readily slides down to cover the brain and enter the basal skull fossae, but usually not in a concentration sufficient to form a thick clot. The sulci tend to collect more blood, especially in the insula. Unlike those with subdural bleeding, survivors from subarachnoid haemorrhages rapidly dispose of the blood. Haemolysis turns the cerebrospinal fluid a xanthrochromic yellow and, within weeks, the blood is gone. There may be some residual brown or yellow staining of the pia or arachnoid, similar to that seen when a slight dural bleed leaves its signature on the inner surface of the dura. A positive Perl's reaction for haemosiderin can develop within 36 hours and may remain for months or even years, even after macroscopic discoloration of the membranes has vanished.

This forms a trap for those attempting to date both subdural and subarachnoid haemorrhage in infants, as the common bleeding arising from head-moulding during childbirth may leave a positive haemosiderin reaction for at least a year. Thus if a suspected child abuse head injury occurs in the first months of life, histological attempts to date the bleeding by Perl's reaction may be affected by residual haemosiderin from parturition.

Bleeding in the subarachnoid space is caused by the same mechanism as that in the subdural space, as shear stresses and rotational movements of the brain, described in a later section, shear or rupture the bridging veins that leave the cortex and penetrate the arachnoid en route for the large draining veins and sinuses that lie in the dura. In addition, small cortical arteries may contribute much of the leakage. Where laceration, contusion or infarction of the cortex is present, bleeding will come from cortical veins and small arteries directly into the subarachnoid space. It may also arise from intracerebral bleeding breaking out through the cortex. The subarachnoid haemorrhage allegedly caused by damage to the vertebral arteries near the foramen magnum will be discussed under spinal injuries.

The relevance of a subarachnoid haemorrhage in causing death may be difficult to decide, though this is of more importance in the natural variety caused by a ruptured aneurysm.

In head injuries, death is far more likely to be the result of the other concomitant associated injuries to the brain substance than to a moderate amount of blood in the subarachnoid space.

In the uncommon instances when a substantial subarachnoid haemorrhage seems to be the only sequel of a fatal head injury it must be accepted as the cause of death, though cerebral oedema and microscopic diffuse axonal injury should be excluded as competitors even though this exclusion may be difficult or impossible when death follows rapidly after injury. It is indisputable, however, that sudden death can occur from massive natural subarachnoid haemorrhage in the absence of any traumatic lesions so, by analogy, the pure traumatic bleed – if severe enough – cannot be excluded as a sole cause.

Death can be remarkably rapid when a profuse haemorrhage occurs into the subarachnoid space. The mechanism is not understood, but seems to be confined to those cases where the brainstem is suddenly exposed to a large volume of blood bathing the brainstem in the posterior fossa, usually from a ruptured aneurysm or from a torn basilar or vertebral artery. Numerous instances of victims virtually dropping dead are on record, though many more exhibit the familiar signs of headache, neck stiffness, vomiting and progressive failure of consciousness, before dying at a variable period after the haemorrhage.

FORENSIC IMPLICATIONS OF BRAIN MEMBRANE HAEMORRHAGE

Because of its common occurrence, certain medico-legal problems associated with bleeding into the brain membranes must be considered.

First, the latent or ‘lucid’ interval in both extradural and subdural haemorrhage may lead to civil suits for negligence where a doctor – usually in a hospital emergency department – discharges an apparently well patient who later dies at home or is readmitted **in extremis.** The clinical aspects cannot be considered here, but suffice to say that it is highly unlikely that such patients would not have suffered concussion, albeit transient. Radiology of the skull is not mandatory if the clinical indications are not present, but failure to X-ray can be a legal impediment for the defence. A subdural haemorrhage is commonly present with an intact skull, though this is uncommon with extradural bleeding.

As already mentioned, the dating of subdural haematomas may be crucial in both criminal and civil cases when it is being either maintained or denied that a particular episode of head injury causes the haematoma. Dogmatic adherence to any accurate histological dating regimen is unjustified, though broad distinctions in terms of days, weeks or months may be justified.

The possibility of a previous bleed being the precipitating factor in some later accidental injury, which then caused further bleeding, must be kept in mind.

Using a membrane haemorrhage to localize an impact can be subject to over-interpretation. An extradural haematoma is almost invariably on the same side as the blow, but because of the distortion of the skull described earlier, the fracture that traverses the meningeal artery can be some distance from the point of impact. Using Gurdjian’s work, however, a reasonable estimate of the zone can be offered.

Where subdural or subarachnoid bleeding is concerned, it can be misleading to offer dogmatic opinions about the nature and position of the impact, unless there is scalp or skull damage. Though sometimes it is clear from the presence of a scalp injury that the haemorrhage is either ‘coup’ or ‘contrecoup’, there are so many exceptions when the bleeding is unrelated to the site of the blow, that a firm opinion is not justified.

RUPTURED BERRY ANEURYSM AND TRAUMA

A major cause of medico-legal problems is the association of trauma and subarachnoid haemorrhage from a ruptured ‘berry’ aneurysm. The pathology of the latter is described in another chapter, but here we are concerned with the allegations that an injury led to rupture of a pre-existing aneurysm.

Several variations of this scenario exist. Most commonly, an assault is rapidly followed by the signs of subarachnoid bleeding and subsequently death. Occasionally death may be extremely rapid, as previously described. The question of causation then arises, the prosecution claiming that the head injury mechanically ruptured the aneurysm. Whether this is actually so is virtually beyond absolute proof. Aneurysms of the circle of Willis are remote from the skull surface and lie deeply protected under the buffer provided by the mass of the brain. However, it is hard to deny that a heavy blow to the head, jaw or neck could not rupture, split or weaken the fragile wall of a large, thin-walled aneurysm, but when the bleeding comes from a tiny sessile bulge the evidence is not so convincing.

The complicating factor is that most assaults occur in 'fight or flight' conditions in which both aggressor and victim are physically and emotionally active, so that the adrenal response is likely to be present. Muscle tone, heart rate and blood pressure are increased by catecholamines, and it is likely that raised internal blood pressure in a weak aneurysm is a far more potent reason for rupture than a blow on the head.

A second possibility is that a person with an already spontaneously leaking aneurysm may have a rapidly developing neurological or even behavioural abnormality that leads him into conflict with another person, or into a dangerous physical position, such as a fall or traffic accident. If all this occurs over a short period of time, autopsy may not be able to distinguish the sequence of events and the aneurysmal rupture may be blamed on the trauma instead of the reverse. This may have profound civil as well as criminal legal consequences.

SUBARACHNOID HAEMORRHAGE AND ALCOHOL

A factor that is often said to increase the chance of rupture is alcohol, though there is no objective proof of this claim. A high blood alcohol is said to facilitate bursting of an aneurysm because it dilates cerebral blood vessels, increases cerebral blood flow and raises blood pressure.

The latter is not true because alcohol does not raise systolic pressure, though the pulse pressure – the difference between systolic and diastolic – may widen. The fibrous wall of an aneurysm is incapable of dilating, neither can the major basal arteries do so to any appreciable degree, as they possess little muscle in their walls. The pharmacological evidence that alcohol has any significant effect on the cerebral circulation is extremely weak. There is no evidence that alcohol is associated with completely natural subarachnoid haemorrhage from a ruptured aneurysm, though intense physical activity, such as sport or coitus, certainly does predispose to rupture.

Where alcohol and ruptured berry aneurysm are concerned, a more likely explanation is that the association is coincidental – as most altercations resulting in 'flight, fight and fisticuffs' are catalysed by alcohol. Many of the cases of ruptured aneurysm and violence occur within and on the pavements outside bars and clubs, where a high blood alcohol is virtually inevitable – but not necessarily causative.

The other aspect of alcohol is that it may cause or contribute to unsteadiness, a fall or some other traumatic event, which itself might lead to rupture of a fragile aneurysm. Ataxia and hypotonia are a feature of acute drunkenness and, together with the aggressive behaviour and alcoholic environment of most physical violence, seem sufficient to account for their circumstantial association.

THE RAPIDITY OF DEATH IN SUBARACHNOID HAEMORRHAGE

The immediacy of death is sometimes surprising, especially in association with trauma. It is general clinical experience that the victim of a spontaneous rupture of a berry aneurysm suffers a severe headache, neck stiffness and vomiting, which may resolve or which may progress over hours or days to coma and death. Sudden death is certainly the exception in these clinical cases – but these are from a hospital population, which, by definition, excludes the rapid deaths that reach the mortuary rather than the wards.

In forensic practice, much more rapid demise is not uncommon. For example, the author (BK) recollects that as two men involved in a violent argument in a public house emerged through the outer doors, one struck the other a heavy blow on the head. The victim fell to the ground and never moved again, being certified dead a few minutes later. At autopsy, a typical fresh subarachnoid bleed from a ruptured aneurysm was displayed.

The amount of blood present in most subarachnoid haemorrhages, from whatever cause, often seems insufficient to constitute a space-occupying lesion, especially as, unlike subdural bleeding, it is able to diffuse more widely over the brain and displace cerebrospinal fluid into the spinal theca. The total volume may be considerable, however, and where survival for some hours has occurred, then the typical appearances of raised intracranial pressure may be seen at autopsy, though some of this may be contributed by progressive cerebral oedema.

Most rapid deaths exhibit substantial bleeding into the basal cisterns at autopsy, the brainstem and cranial nerve roots being bathed in a thick layer of blood and clot. As blood in the subarachnoid space seems irritant even in small quantities, it seems possible that such sudden irrigation of the medulla may lead to a rapid cardiorespiratory failure. Where the haemorrhage appears less extensive, the mechanism of death is more obscure.

Crompton points out the sensitivity of cerebral arterioles during surgical operations, when a slight touch upon the cortex leads to blanching spasm of the vessels. Subarachnoid bleeding is undoubtedly irritant and a possible reason for the sudden collapse and death is a widespread vascular spasm, which may have an effect on vital centres in the brainstem.

ROTATIONAL TRAUMA TO THE HEAD AND UPPER NECK: BASILOVERTEBRAL ARTERY INJURY

During the last few years it has been recognized that blows to the side of the neck and/or head can give rise to fatal subarachnoid bleeding. This has been attributed to tearing or dissection of a vertebral artery, allowing blood to track along the upper part of the vessel and enter the cranial cavity where the artery penetrates the dural membrane at the foramen magnum.

The evolution of this concept of traumatic subarachnoid bleeding is interesting. Originally, it was thought that most cases had a fracture of the transverse process of the first cervical vertebra, thus damaging the artery contained in the tunnel-like foramen in this bone – indeed, it was often called the 'CV-One syndrome'.

The hypothesis was that a blow to the side of the neck caused deep injury, usually manifested by skin bruising and bleeding into the muscles deep in the upper neck. This same injury was considered to fracture the transverse process and lead to tearing or dissection of the wall of the contained vertebral artery; blood then tracked upwards and medially to penetrate the dura and emerge inside the subarachnoid space of the posterior cranial fossa to cause a fatal haemorrhage.

Soon cases were being described with no such atlas vertebra fracture, but it was still accepted that mechanical forces, especially of a tilting and rotational nature, could damage the vertebral artery within the foramina of the upper cervical spine and lead to the same dissecting lesion, and hence to fatal subarachnoid haemorrhage. Until very recently, this was the theory – which is still strongly held by many pathologists – that satisfied the aetiological needs of this injury.

However, though it is likely that this classical mechanism does account for some of the deaths, there are several problems with universal acceptance of the hypothesis:

- Many pathologists – including the authors – find it hard to believe that a tiny dissection of a small artery like the vertebral artery – a lesion which often needs serial microscopic sections to confirm – could allow the torrent of blood necessary to enter the cranial cavity and produce a massive haemorrhage (sometimes well in excess of 100 ml) which may cause death within minutes.
- Several instances of a damaged vertebral **vein** have been reported in association with subarachnoid haemorrhage. Because of the very much lower intravascular pressure in a vein compared with an artery, the possibility of this causing a massive intracranial bleed by percolation through the dural fenestration is even less credible than in the case of the artery.
- Increasing numbers of cases are being described with positive evidence of a blow on the side of the neck or head and a large fatal subarachnoid haemorrhage, but with completely intact vertebral arteries.

Thus, if sudden tilting and rotational forces acting on the upper spine and head can lead to subarachnoid haemorrhage without damage to the vertebral vessels, then the causative link is destroyed. Even where vertebral damage is demonstrable, this may be merely a **concomitant** event, the mechanical forces which primarily led to subarachnoid haemorrhage by direct injury to intracranial vessels also having caused the vertebral artery damage. In other words, the two lesions may in some cases – or for all we know, every case – be a **parallel** phenomenon, not a **cause-and-effect** situation. There may well be a further concomitant effect, in that direct occult brain damage, manifested later by diffuse axonal injury, is the major cause of cerebral dysfunction, both the subarachnoid haemorrhage and the vertebral artery lesion (if there is one) being merely markers of a heavy impact.

In these deaths – and certainly where no lesion at all is discernible in the upper spinal vessels – we need to look elsewhere for an explanation of the subarachnoid bleeding.

Occasionally, this is quite obvious and is situated in the intracranial vertebrobasilar vessels. For example, the author (BK) has seen a wide split in the wall of a vertebral artery **within** the posterior cranial fossa, and another where the vertebral artery was totally avulsed and transected at the internal side of the dural perforation. Both these cases arose as a result of trauma to the side of the neck, and both had a massive subarachnoid haemorrhage with no damage to vessels outside the cranium.

Bostrom, Helander and Lindgren (1992) published details of two cases of rupture of the posterior inferior cerebellar artery due to blunt basal head trauma, and proposed that the term 'traumatic subarachnoid haemorrhage' be abandoned and replaced by the nature and localization of the bleeding site.

The demonstration of intracranial bleeding from the vertebrobasilar system is difficult, as the very process of opening the skull at autopsy and removing the brain, however carefully performed, inevitably causes vascular damage. These artefacts cannot be distinguished from original bleeding points due to ante-mortem trauma.

The use of post-mortem angiography by the injection of radio-opaque constrast medium into the lower vertebral and carotid arteries has not lived up to its original claims. There is almost always diffuse leakage of contrast medium from apparently artefactual defects, and localization of true bleeding points is often obscured by a haze of contrast opacity. However, occasionally the method reveals a specific leak, usually within the posterior cranial fossa.

The original descriptions of and claims for vertebral artery damage as the cause of traumatic subarachnoid haemorrhage were published by Cameron and Mant (1972), Coast and Gee (1984), Contostavlos (1971, 1995), Simonsen (167, 1976) and others. Leadbeatter (1994) drew attention to the problems of a universal cause-and-effect relationship; Contostavlos (1995) refuted these claims, but did not satisfactorily dispose of the concomitant hypothesis. Pathologists, both from their dissection experience and reading of the literature must make up their own minds on the matter, but should make a critical evaluation of the practicality of a massive subarachnoid bleed appearing, sometimes within minutes, from a tiny dissection of a small artery outside the dural membrane.

As many pathologists still adhere to the original concept of a subcranial vertebral artery causation for traumatic subarachnoid haemorrhage (and in a small number of instances, the evidence is persuasive), the topic is further pursued here, with the over-riding qualification that most traumatic massive meningeal bleeds are due to intracranial causes consequent upon a tilting, rotatory impact upon the head and/or neck, with or without concomitant damage to a vertebral vessel.

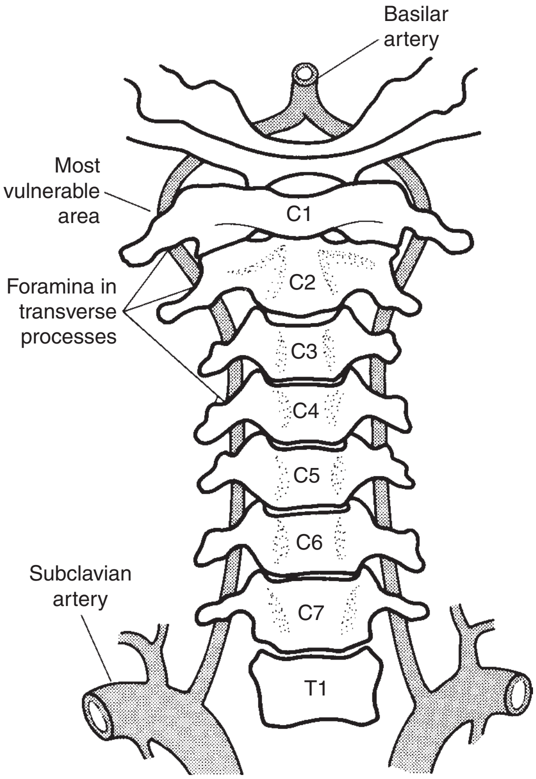

FIGURE 5.38 *The origin and course of the vertebral arteries. They arise from the subclavian arteries at the level of the sternoclavicular joints and ascent via the foramina in the transverse process.*

Forensic anatomy

The two vertebral arteries arise from each subclavian artery in the region behind the sternoclavicular joints. Each artery ascends behind the common carotid to reach the transverse process of the sixth cervical vertebra. It enters the foramen in that process and passes upwards through each similar foramen until it emerges from the upper edge of the second (axis) vertebrae. The artery then bends laterally and enters the final foramen in the atlas vertebrae. Emerging on the upper surface, the artery bends back and medially around the superior articular process, and penetrates the posterolateral aspect of the atlanto-occipital membrane and the underlying spinal dura and arachnoid, emerging on the lateral side of the spinal canal just below the foramen magnum. Both arteries then ascend and converge on the ventral surface of the medulla and pons to fuse in the midline to become the basilar artery. Each vertebral artery is often of markedly different size.

Autopsy appearances

With the caveats expressed earlier, the possibility of vertebral artery trauma, concomitant or otherwise, should always be borne in mind when an external bruise is seen on the side of the neck of the victim of a fatal assault. A blow from a fist, foot or blunt weapon may land in the region between the angle of the jaw to the side of the back of the neck, the area below the ear being the most common place to find an injury.

There may be no external sign at all, but on dissection of the neck, a subcutaneous or deep bruise may be found. Unfortunately, this is an area that is not routinely dissected at autopsy, the usual incision for the removal of the neck organs being too far anterior to reveal many of these injuries, which usually lie in the strong neck muscles. This is probably why the syndrome was not recognized until a few years ago – and also an explanation why so many subarachnoid haemorrhages were said to be due to a berry aneurysm that could not be found because the bursting had destroyed it. No doubt a number of subarachnoid bleeds are due to rupture of non-aneurysmal vessels or to an aneurysm too small to find, but equally, unrecognized head trauma, with or without vertebral artery damage, must have accounted for some of the remainder.

In some autopsies, there is no external neck injury and the cause of death is unknown until the cranium is opened, and a fresh subarachnoid haemorrhage discovered. A decision then needs to be made whether to remove the brain to search for a ruptured berry aneurysm – or begin specialized techniques to seek a rupture of a vertebral artery (described below). If there is a history of assault or other trauma, as opposed to a presumed natural death, then particular methods should be employed. The two avenues are not mutually exclusive, as long as the pathologist is aware of his objectives. The vessels can be clamped off at the base of the brain and the brain removed for a search for an aneurysm or other bleeding-point without spoiling the other techniques.

Mechanism of vertebral artery trauma

When a head is rapidly rotated by a blow that lands at the junction of the head and the neck, there may be a sudden lateral rocking (tilting sideways) at the atlanto-occipital joint, accompanied by rotation of the head. There may also be an element of hyperextension or hyperflexion, the whole episode forming a complex pattern of sudden abnormal movement at the atlanto-occipital junction. It may be that the unexpected impact may allow more unrestrained rotation and angulation of the head, due to absence of anticipatory muscle tensing in the large paravertebral and sternomastoid musles; this may be exacerbated by alcoholic intoxication causing slow protective responses, as most of such episodes occur during altercations related to drinking sessions.

The mechanics are not fully understood and probably differ from case to case but, whatever the mechanism, the vertebral artery can become damaged either:

- in the canal within the first cervical vertebra (whether or not the transverse process is fractured)
- just below the axis, in the space between the transverse processes of the axis and atlas
- as it emerges from the exit of the canal in the atlas to penetrate the spinal dura just below the foramen magnum
- probably much more frequently within the subarachnoid space above the foramen magnum or even higher in its course towards the confluence with the basilar artery – and even the basilar itself. The type of damage is usually a tear or dissection of the wall of the vertebral artery.

Vertebral artery damage was originally said to allow blood to track under arterial pressure within the adventitia and to appear in the subarachnoid space after the vessel has penetrated the dura and arachnoid, though, as discussed above, the likelihood seems slight of these minute lesions allowing the large volume of blood seen in most subarachnoid haemorrhages to flow through the small periarterial window in the dura.

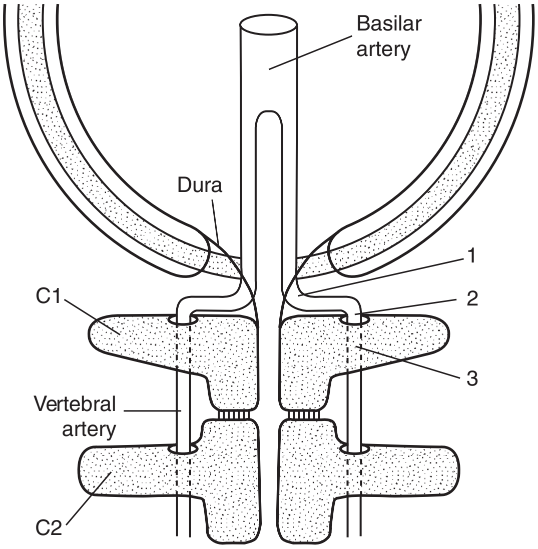

FIGURE 5.39 *Most vulnerable points for trauma to the vertebral arteries: (1) at penetration of dura; (2) at exit from atlas transverse process; (3) in osseous canal in atlas.*

Autopsy demonstration of basilovertebral artery damage

When circumstantial evidence suggests a subarachnoid haemorrhage following trauma or where a bruise is seen on the side of the neck, vertebral artery damage should be suspected, then confirmed or eliminated. The first intimation that it may have occurred may be when the skull-cap is removed and a subarachnoid haemorrhage is discovered.

If the view is taken that most subarachnoid haemorrhage following upper neck trauma is due to intracranial vascular damage, then logically it is unnecessary to use time-consuming and laborious procedures which slow up the completion of the case. In many such deaths, there will be no lesion in the upper cervical spine or extracranial vertebral arteries and even if there is, it is likely to be a concomitant lesion, occurring synchronously, but with no cause–effect relationship with the intracranial vessel rupture.

However, there may be academic satisfaction in demonstrating the concomitant neck lesion, even if it played no role in producing the subarachnoid haemorrhage. In such a case, when the deceased has been in a fight or had some violence applied to the side of his neck, the same routine should be employed.

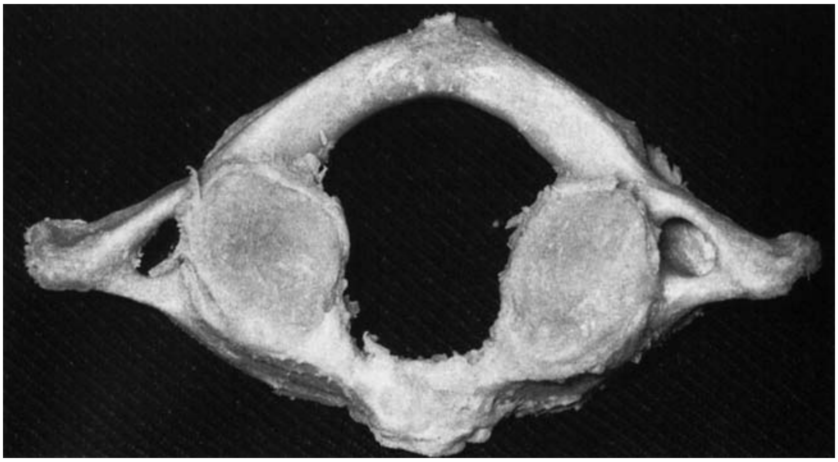

FIGURE 5.40 *The first cervical ('atlas') vertebra viewed from above to show the foramina in the transverse processes through which the vertebral arteries pass.*

Different pathologists have different procedures, but the following would be a reasonable method of investigation:

- Radiographs of the upper cervical region, both anteroposterior and lateral, should be taken as these may (rarely) reveal a fracture of the transverse process of the atlas vertebra. Such a fracture is, however, present in only a minority of vertebral artery injuries – and even when present, straight X-rays may not reveal it.
- Post-mortem angiograms should be taken if facilities exist. There are several methods of performing these. The lower neck is carefully dissected to reach the origins of the vertebral arteries. The best method is to open the subclavian vessels and identify the ostia of the vertebrals, which are the first (most medial) branches of the subclavian arteries. These can be cannulated and contrast media injected, one side at a time, while cervical and skull radiographs are taken. This method tends to fill many intracranial vessels and produce a confused, blurred picture.

  More satisfactorily, the brain should be carefully lifted from the skull and, as soon as the basilar artery is accessible, it should be clamped off with surgical forceps and/or ligated and the brain completely removed as usual after the basilar artery has been transected just above the clamp. Alternatively, each vertebral artery can be clamped or ligated in its terminal course. The angiogram is now performed, either by perfusing up one vessel and forcing contrast medium back down the other via the clamped basilar, or by consecutive injections on either side. Only sufficient medium to fill the system should be introduced to avoid spillage from small branches which obscure the films. The object is to detect any significant leakage from a vertebral vessel in its upper course, usually within the foramen of the atlas or just outside the atlanto-occipital membrane or within the spinal theca.
- As by definition, there will have been a substantial subarachnoid haemorrhage, this sometimes makes it difficult to identify and ligate the basilar or vertebral vessels. The brain should be minutely examined for berry aneurysms or other vascular malformations as, if they are present (and ruptured), then further investigation of vertebral artery damage is pointless. Assuming no such bleeding point is found, the upper cervical region is dissected to determine whether the vertebrals have been injured. When no X-ray or angiographic facilities exist, this is the only method available.

The upper cervical spine should be exposed by a posterior approach, which is continued up to meet the transverse scalp incision. The spine should be freed from the surrounding muscles, taking care to detect and record any muscular bruising in the vicinity. It should then be sawn through at about C4 level or lower.

The occipital bone should then be cut through on each side from the transverse skull saw-cut and prolonged down on each side of the foramen magnum, and then across the clivus to release the central part of the floor of the posterior fossa, carrying the foramen magnum and attached upper spine. Alternatively, using a power saw with a wedge-shaped blade, a square may be cut out of the floor of the posterior fossa to detach the spinal block. If possible, X-rays should be taken of the detached portion, as it may be possible to see a fracture of the transverse process of the atlas better than in the intact body.

The block of bone removed should then be decalcified by prolonged immersion in a large volume of 10 per cent formic acid.

After a week, the spine will be soft enough to slice with a scalpel, so that the lateral parts of the transverse processes can be shaved away, taking care not to get near the arterial foramina. The block is then returned to fresh decalcifying fluid for a further week.

Once the bone has been softened enough to be cut easily by a sharp knife, the transverse processes can be further shaved down on each side to the level of the foramina, so exposing the artery in its whole course. Both sides should be so dissected, the last stages being taken deeper and deeper with extreme care to remove the lateral walls of the canals without damaging the underlying vessel. Naturally, the crucial area is in the upper one or two vertebrae, but though laborious, this method provides the most elegant and convincing demonstration.

Specimens should be taken of any obvious or suspicious breach in the wall for histological examination. The usual type of damage is either a frank tear of the intima and media, or a dissection that allows blood to track through the adventitia.

The papers by Vanezis, Simonsen, and Cameron and Mant, among others, should be consulted for further details of the recommended procedures, but the above is a practical approach to demonstrating vertebral artery lesions. Once again, the relationship must be assessed of any tiny dissection, to the volume of blood found in the cranial meninges – and a decision made as whether this is more likely to be a concomitant injury to intracranial vessels rather than a solitary external vertebral artery lesion.

HEAD INJURIES IN BOXERS

It has become increasingly apparent in recent years that persons who indulge in boxing are at risk of both acute and chronic damage to their brains. In some countries, including parts of Scandinavia, both professional and amateur boxing is banned for this reason. The acute injuries are less common but occur during or soon after the fight itself. A number of boxers have died in the ring or after removal to hospital and, in these fatalities, by far the most common lesion is a subdural haemorrhage. Extradural bleeding almost never occurs, because boxing injuries rarely cause skull fractures. Occasionally a subarachnoid haemorrhage may occur in rare cases where a berry aneurysm is present.

Much attention has been paid to the chronic changes in boxers' brains, which are very common and give rise to what is generally known as the 'punch-drunk' syndrome. It appears that the length of time for which a boxer has been involved in fighting is more important than the number of serious traumatic events he has suffered. It is a cumulative process and many episodes of minor head injury add up to produce the typical lesions described in the now extensive publications on the subject.

There are both anatomical and microscopic lesions in such brains, both in professionals and amateurs exposed over a number of years. The clinical symptoms do not concern the pathologist, but they are explained by the morphological abnormalities. Grossly affected brains may show some cortical atrophy and slight hydrocephalus; the septum pellucidum is characteristically perforated with enlargement of the cavum and tearing of the septal leaves. The fornices and adjacent corpus callosum may be thinned or torn, and throughout the brain substance there may be scars and patches of gliosis. Neurones are lost from the cerebellum and the substantia nigra, the latter often losing pigment.

Another change that has intrigued neuropathologists is the development of an Alzheimer's-like condition, with neurofibrillary tangles throughout the cerebral cortex and brainstem, though no senile plaques are present.

CEREBRAL INJURIES

Though bleeding or infected scalp injuries, depressed fractures, meningitis and substantial meningeal haemorrhage can themselves cause death, in most fatal head injuries it is damage to the substance of the brain itself that is lethal.

In medico-legal practice it is sometimes difficult to convince lawyers that, in most instances, a victim does not die of a simple fractured skull, but that the fracture is evidence only of a substantial head injury, being a 'marker' for concomitant brain damage, which was the real lethal lesion. Similar problems of communication exist with a fracture of the hyoid bone in strangulation, lay persons often being under the misapprehension that a broken hyoid is a mortal injury, instead of merely being an inconstant marker of pressure on the neck.

The neuropathology of brain damage is a large and complex subject, the more subtle varieties requiring both specialist techniques for demonstration and expert knowledge for interpretation. The textbooks of Graham, Adams and Leestma are recommended for detailed description and discussion of cerebral trauma.

The mechanisms of production of some traumatic lesions are matters of conflicting theories, but the forensic pathologist still has to be aware of the general principles of causation in order to offer some interpretation of the injuries.

As always, caution has to be employed, as both the pathological and clinical manifestations of a head injury may appear to be at variance with the degree of force applied to the head. There is a wide range of lesions from a given insult to the head and it is dangerous to be too dogmatic in theorizing about the magnitude of an injury that gave rise to the demonstrable lesions.

It is similarly unwise to hypothesize too firmly about what clinical features must have occurred when the head injury was sustained – for example, quite severe head

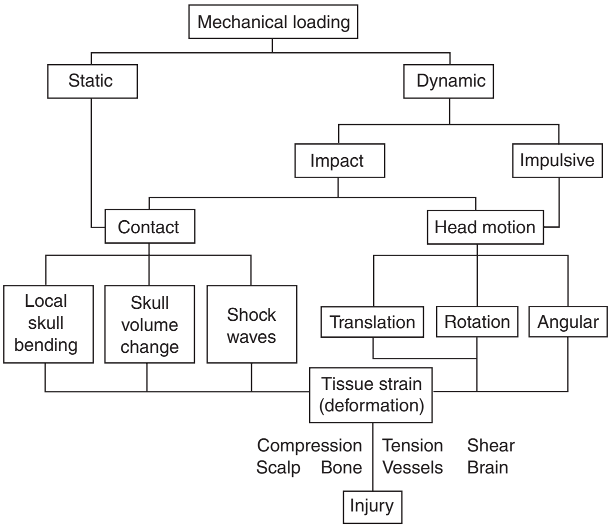

FIGURE 5.41 *Mechanical events that contribute to primary brain injury. (Reproduced from* Greenfield's Neuropathology, *7th edn, 2002 by kind permission of Arnold.)*

injuries have been known to be unaccompanied by concussion, while other apparently slight damage has often been followed by prolonged unconsciousness even ending in death. The well-known aphorism of Munro (1938) must be kept in mind that: 'Any type of head injury can give rise to any type of intracranial damage.'

The mechanism of brain damage

The brain may be injured in the following ways:

- by direct intrusion, either by a foreign object such as a penetrating weapon, bullet or other missile – or fragments of skull in a compound fracture where the skull is disrupted. In these open wounds the mechanism of the damage to the brain is obvious, though of course it may be compounded by the second type of injury described below
- by deformation of the brain in closed head injuries. Here the mechanism of injury is complicated and variable, with several competing theories of causation that have been put forward since the eighteenth century (Ledran 1751, Morgagni 1761). A public debate was held in 1766 in Paris, where rival theories of coup and contrecoup brain damage were hotly defended at the Academy of Surgeons.

The brain is almost incompressible and purely axial impact may give rise to little or no damage. It is extremely rare, however, for an impact not to impart some rotatory movement and it seems agreed that this component is the main culprit in causing brain damage. What is now clear is that no actual blow or fall need be suffered by the head to cause severe and even fatal brain damage. It is the change in velocity – either acceleration or deceleration – with a rotational rather than solely axial element, that leads to damage. The surface of the head need never contact any hard object or surface, though recent research indicates that the quantum of energy delivered by impact is of a far greater order of magnitude that non-impact violence, which lessens the former conviction that shaking, as in child abuse, is a common and potent mechanism in the production of intracranial damage.

In most head injuries – notably traffic accidents and falls – there is marked deceleration of the moving head on contact with a fixed surface but, in many criminal and combat injuries, the head is accelerated by a blow. In either case the initial sudden change in velocity is applied to the scalp and skull, the latter then transmitting the change to the brain via the anatomical suspensory system within the cranium. This system is slightly flexible and consists of the falx and tentorium, which divide the cranial cavity into three major compartments; these contain the two cerebral hemispheres, the cerebellum and the brainstem. When violent relative movements take place between the brain and the dura, forming the partitions of the cranium, the cerebral tissue can become damaged against both the sharp edges and the flat surface of these membranes. In addition, vessels traversing the subdural and subarachnoid spaces can be torn by such relative movements, especially in old people where cerebral atrophy may have widened these spaces.

Among the competing theories of impact brain damage are:

- the rotational shear force theory
- the pressure gradient theory
- the vibration theory
- the transmitted wave force theory
- the brain displacement theory
- the skull deformation theory.

These hypotheses overlap and most are correct in some aspect. Because experiments on primates and mechanical models have been pursued vigorously in recent years, it is now widely accepted that there are marked pressure changes within the cranium on impact (Yanagida *et al.* 1989). When a head falls against the ground, pressure momentarily increases at the impact point but falls to a negative value diametrically opposite. As these suction or cavitation effects are more damaging to neural and meningeal tissue than pressure, this is good evidence for claiming that contrecoup damage is largely a result of this vacuum effect.

The actual physical disruption of cerebral tissue is caused, according to both Gurdjian and Holbourn, by one or more of the following processes:

1 compression of the constituent units, by their being forced together
2 tension of the units, which pulls them apart
3 sliding or 'shear' strains, which move adjacent strata of tissue laterally. The usual homely example is given of a pack of playing cards being displaced, so that each card slides upon its neighbour.

Transient deformation of the skull almost certainly contributes to brain damage (Rowbotham 1964). The area of the skull beneath an impact becomes momentarily depressed even if it does not fracture and therefore may impinge on the underlying brain causing compression, as in 1, above. This is responsible for the typical cone-shaped contusions on the cortex, with the base at the surface, as the impact – possibly via short-lived oscillations of decreasing amplitude – injures the cortex and passes a diminishing force down into the deeper layers.

Simultaneously, other areas of the skull must bulge outward to accommodate the deformation – the so-called 'struck-hoop' action – when it is suggested that a 'rarefaction' remote from the impact may cause tension damage, as in 2, above.

More important is 3, being laminar deformity or 'shear stress' caused by the angular rotation of the head. As the head is pivoted on the first cervical vertebra, almost any impact on jaw, face or cranium will produce an angular momentum, the acceleration being conveyed first to the skull.

Alternatively, if the head is moving and is suddenly arrested, then the skull will decelerate first and the momentum of the brain will cause it to continue in motion, again almost certainly with some rotatory component.

In either the deceleration or acceleration mode, the skull and brain cannot change their velocities simultaneously and the brain will speed up or slow down only by virtue of the restraint provided by the dural septa and the configuration of the interior of the skull. In other words, the brain is either retarded or set into motion secondarily by the skull, especially by the dural septa and the bony prominences.

This restraint will occur first – and with maximum effect – on the most superficial layers of the cortex. These in turn will drag on the next deepest layer and so on until the difference in velocity is equalized – but this will have been at the expense of laminar tearing of the cerebral tissue and its associated blood vessels. In addition to this shearing damage, the brain may be forced against the sharp edge of the tentorial opening and the lower edge of the falx, causing damage to the base of the cerebrum, the corpus callosum and the brainstem. Impact against the side wall of the skull and against the falx may cause diffuse contusion of the cortex. The cerebellum tends to suffer less damage, as it is much smaller and lighter than the cerebrum and there is less room for relative movement in the more tightly enclosed posterior fossa. The configuration of the interior of the cranium is thought to be partly responsible for the common localization of cerebral damage at the tips and undersurface of the frontal and temporal lobes. The rough floor of the anterior fossa, the sharp edge of the wing of the sphenoid and the massive bar of the petrous temporal bone are in contrast to the smooth inner surface of the vault of the skull.

Cerebral contusion

When either linear or, more often, laminar stresses are applied to the cortex, this soft tissue may disrupt. Part of the injury is directly upon the neurocellular structure, but damage to vessels is an important component. If the cortex still retains its shape, but is bruised and swollen, this constitutes 'contusion'. A greater degree of disruption, sufficient to produce macroscopic tearing, is termed 'laceration', but the difference is only one of degree. In gross head injuries, such as crushing, missile wounds and other major penetration, the degree of laceration may lead to partial or even complete extrusion of the brain from the cranial cavity.

In the usual type of cortical contusion seen in a closed head injury, the cortex is blue or red from haemorrhage, though if survival has lasted for some time, there may be added discoloration from associated cortical infarction. The haemorrhage may be diffuse or may be punctate and is often a mottled purplish red when confined to the cortex. Extension into the underlying white matter tends to be pure red in fresh lesions. The lesion is often wedge-shaped, with the base on the surface, tapering away into the deeper layers.

Cerebral laceration

Laceration of the cortex is an extension in severity of contusion in which mechanical separation of the tissue can be seen. When widespread, but relatively superficial, the cortex appears to have a 'red velvet' appearance, which becomes progressively more tattered as the severity increases.

When it is even more severe, the cerebral surface becomes fissured, fragments of cortex may detach and deep lacerations run into the depths of the hemisphere, sometimes reaching even the deep ganglia or ventricles. There may be deep haemorrhage and – especially in the frontal and temporal lobes – the lacerations may be continuous with areas of traumatic haemorrhage. In cerebral lacerations and most contusions, the pia mater and often the arachnoid are torn, so that blood from damaged cortical vessels leaks into the subarachnoid and even subdural spaces. The corpus callosum is commonly torn, especially at its posterior end. This must be distinguished from damage caused by clumsy removal of the brain at autopsy (as must tears of the cerebral peduncles), but when genuine, may represent either a guillotine effect of the free lower edge of the falx or differential lateral movement of one hemisphere relative to the other, again because of unilateral restraint by the falx. Lacerations and contusions are most often found in those areas of the brain where the cortex is most likely to come into contact with irregularities in the internal profile of the skull. The undersurface of the temporal lobes and the orbital surface of the frontal lobes suffer most often.

Traumatic intracerebral haemorrhage

Substantial areas of haemorrhage, either infiltrating the brain tissue or forming actual haematomas, are common in severe head injuries. Some are primary, occurring at the time of impact or soon afterwards; others are secondary and caused by changes in intracranial pressure or bleeding into infarcts caused by vascular damage. These are all seen more often since artificial ventilation has been available, as victims of severe head injuries now survive longer so that there is time for secondary lesions to become apparent.

In the cerebral hemispheres, deep haemorrhage can be caused by coup or contrecoup mechanisms (see below) and may be situated anywhere within the hemispheres. They may rupture into the ventricular system or through the overlying cortex. In some severe contrecoup lesions, there may be large haematomas in one or both frontal lobes with overlying cortical contusion and laceration. These may rupture through the cortex into the meningeal spaces, forming what is sometimes called a ‘burst lobe’. Such haemorrhages sometimes pose a problem for the pathologist when they occur in older subjects, especially those with hypertension and perhaps cerebral atherosclerosis. When a scalp injury is present – and perhaps even a fractured skull – it may be difficult to decide if a head injury (such as a fall) was responsible for the cerebral haemorrhage, or whether a sudden ‘stroke’ caused by a natural cerebral haemorrhage resulted in the fall. The problem is discussed further in the chapter on natural death, but briefly, the presence of left ventricular (cardiac) hypertrophy, a history of hypertension and the site of the (usually solitary) haemorrhage tends to point to a natural bleed. This is especially so if the large size of the lesion seems inconsistent with the degree of head injury sustained. Hypertensive lesions tend to be in the thalamus, external capsule, pons and cerebellum, and are more often occipital than frontal or temporal. Having said that, on occasions it can be impossible to differentiate the two conditions.

Primary brainstem haemorrhage

Secondary brainstem bleeding is dealt with under ‘cerebral oedema’ so here we are concerned with haemorrhage that occurs at the time of injury. As mentioned above, hypertensive haemorrhages not associated with trauma can occur in the midbrain, especially the pons. These tend to be large, explosive lesions that greatly swell the pons and disrupt the central part of the stem, usually with a ragged rim of white matter around the periphery. Traumatic haemorrhage in the brainstem is often a well-circumscribed lesion, sometimes rounded, which lies laterally in the tegmentum, the shape of the midbrain being undistorted (unlike a secondary bleed into an elongated stem).

The typical site is between the aqueduct and the outer end of the substantia nigra. Primary stem haemorrhages are usually associated with occipital impacts and the victim is often unconscious from the time of the injury, as opposed to the lucid interval and gradual decline of those who suffer secondary stem lesions because of a developing cerebral oedema or space-occupying meningeal haematoma.

Coup and contrecoup damage

Whatever the underlying mechanics of cerebral damage, one aspect is of considerable practical importance to the pathologist. When a mobile head is struck with an object, the site of maximum cortical contusion is most likely to be beneath or at least on the same side as the blow. This is the so-called ‘coup’ lesion. When a moving head is suddenly decelerated, as in a fall, though there might still be a ‘coup’ lesion at the site of impact, there is often cortical damage on the opposite side of the brain – the ‘contrecoup’ lesion.

The mechanism of the ‘coup’ and ‘contrecoup’ injuries has long been debated – at least since the time of the famous Paris meeting of 1766. The controversy has been continued, especially by Courville (1942) and by Holbourn (1943), but no satisfactory resolution has been agreed though the work on intracranial pressures by Yanagida *et al.* seems to provide proof that a ‘vacuum’ occurs at the contrecoup site.

The following practical points should be considered:

- There may be no coup damage at all, only contrecoup.
- There need be no fracture of skull, even in the presence of severe coup and contrecoup lesions.
- The most common site for contrecoup injury is in the frontal and temporal lobes. It is often at the tips and on the undersurface of these lobes, and may be symmetrical, if a fall on the occiput has occurred.
- In temporal or parietal impacts, the contrecoup lesions are likely to be diametrically opposite on the

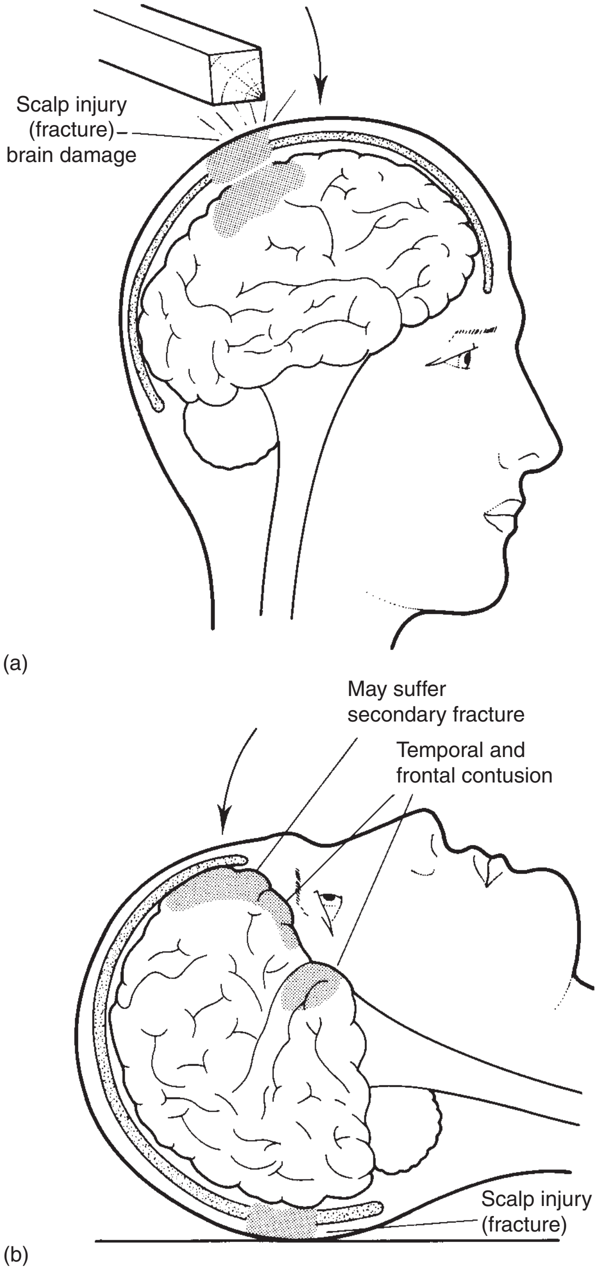
Scalp injury
(fracture) –
brain damage
(a)
May suffer
secondary fracture
Temporal and
frontal contusion
Scalp injury
(fracture)
(b)

FIGURE 5.42 *(a) 'Coup' brain damage to fixed head. (b) 'Contrecoup' brain damage to moving (decelerated) head.*

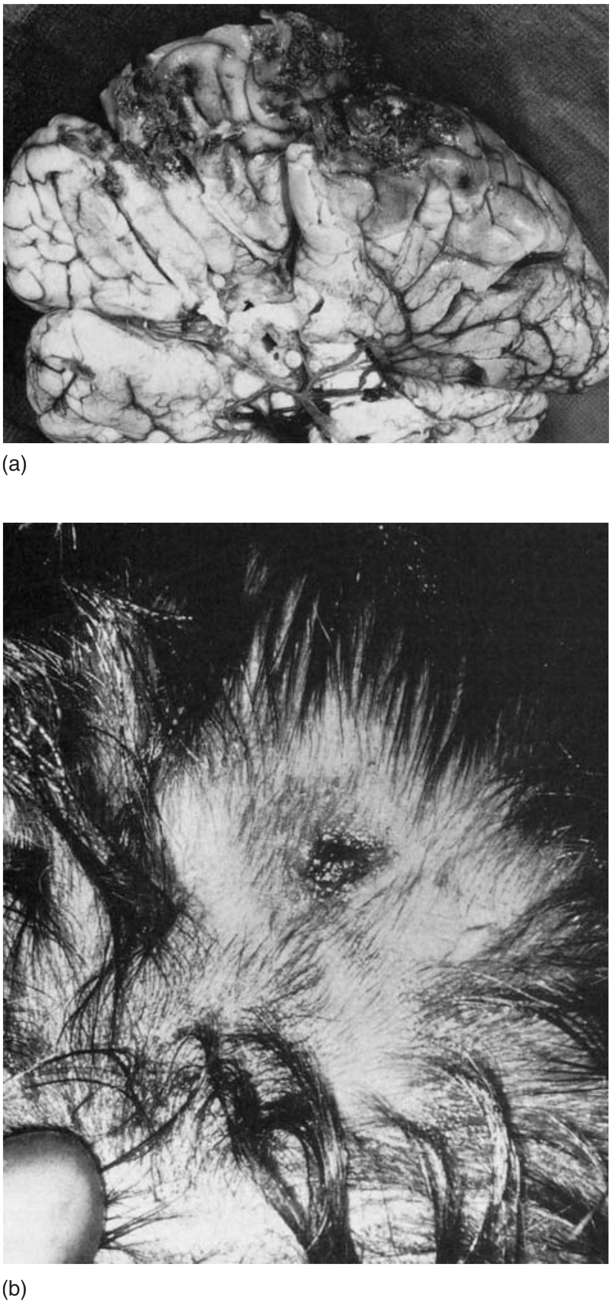

FIGURE 5.43 *(a) Typical contrecoup injury to the tips of the frontal and temporal lobes of a brain. The victim was pushed over in a brawl and fell backwards, striking his occiput and causing a small scalp laceration (b). There was no contusion to the posterior part of the brain.*

contralateral surface of the brain, but exact geometrical correspondence is not necessarily present.

- It is virtually unknown for a fall on the frontal region to produce occipital contrecoup. This is thought to be due to the anatomical configuration of the floor of the cranium, but the reasons are by no means understood.
- In a temporal impact, the contrecoup damage may be not be on the contralateral hemisphere, but on the opposite side of the ipsilateral hemisphere from impact against the falx cerebri.
- The degree of contrecoup damage may be severe, sufficient to cause blood-filled cavitation in the deep cortex and underlying white matter, especially in the frontal lobes and tips of the temporal lobes.

- With severe frontal contrecoup from a fall on the occiput, the transmitted force may be sufficient to fracture the thin bone of the floor of the anterior fossa. Such cracks in the roofs of the orbits may allow meningeal haemorrhage to seep into the orbits and appear as 'black eyes'. In assaults where a fall has occurred, care must be taken not to attribute such periorbital bleeding to direct punches.
- Though contrecoup contusion is classically caused by deceleration of a falling head, it can also occur when a **fixed** head is struck. If the victim is already lying on the ground or against some other unyielding surface, a heavy blow on the upper side may cause typical contrecoup lesions either in the contralateral temporal or parietal cortex, or against the falx on the inner side of the ipsilateral lobe. In these circumstances, there is often coup damage as well. No external scalp injury need be visible.
- The interpretation of contrecoup lesions is most reliable in the form of cortical contusions or lacerations. Meningeal haemorrhage, either subdural or subarachnoid, may also arise in association with a contrecoup lesion, but its diagnostic value is virtually nil compared with cortical damage when interpreting a falling or fixed head injury. Where no associated cortical contusion is present, it is quite unsafe to rely upon a unilateral meningeal haemorrhage as an indicator of the type of head injury.

Concussion

Concussion is a clinical, not a pathological entity, but the pathologist must consider it, as it is related to intracranial lesions and he is often questioned about it in court proceedings. Concussion, according to Wilson (1946), is 'a disorder of cerebral function which follows immediately upon the impact of a force to the head'. A more full definition is offered by Trotter (1914): 'a transient paralytic state due to head injury which is of instantaneous onset, does not show any evidence of structural cerebral injury and is always followed by amnesia from the actual moment of the accident'.

Some neurologists would also include post-concussion symptoms within the definition of concussion, even in the absence of initial coma, following a head injury. There may also be evidence of depressed medullary function, which can affect cardiorespiratory action. Denny-Brown and Russell (1941) showed that the rate of change of velocity of the head was important in producing concussion, which rarely developed if the speed threshold was less than ~8.5 m/s (28 ft/s).

It is an extremely common, but not inevitable, sequel to any significant mechanical insult to the brain. Though in general terms its duration is loosely related to the severity of the injury, there are many exceptions. Gross skull and brain damage have occurred with little or no apparent concussion, though concussion may be so transient that the subject may not even fall to the ground. Relatively minor head injuries have given rise to prolonged unconsciousness so, once again, it is most unwise to be dogmatic about retrospective estimates of concussion.

There is considerable controversy about the cause of concussion, from the unacceptable 'traumatic neurosis' on the one hand (which cannot be true) to claims for the inevitable demonstration of physical lesions on the other.

Courville (1953) has discussed the condition in depth and there seems to be no reason to doubt that some mechanical process does temporarily disrupt the function, if not necessarily the structure, of the neuronic apparatus. Changes in the nucleus and cytoplasm of neurones, the composition of the cerebrospinal fluid and in the electroencephalograph have all been inconstantly reported (see 'Diffuse neuronal and axonal injury' below).

True concussion may last for seconds or minutes. If prolonged unconsciousness extends into hours, days or longer, then there is likely to be some structural brain damage. Occasionally what appears to be simple concussion proves to be fatal, causing respiratory paralysis, though at autopsy no significant lesions are found.

Where a victim of 'simple' concussion dies of some incidental non-neurological condition, autopsy usually reveals no macroscopic damage, though sometimes there is slight cerebral oedema and scattered non-specific petechial haemorrhages may be found. There seems to be a connection between concussion and rotatory movements of the head, which are usually responsible for obvious structural damage because, when a head is fixed before impact, loss of consciousness may not occur. The classic example is trapping of a head against a wall or being jammed between buffers.

That shear stresses are instrumental in causing neurone damage seems confirmed by the frequency in which concussion occurs in boxing contests, where a blow on the jaw is the ultimate in producing a rotational movement of the cranium.

Concussion may be followed by a 'post-concussion state' characterized by headaches, unsteadiness and anxiety. This seems a genuine phenomenon, though it has been pointed out that it may be overlain by a 'compensation syndrome' whilst civil litigation is in progress over responsibility for the accident, which often clears up rapidly once the claim is settled.

Retrograde amnesia is almost inevitably associated with concussion, though, like concussion itself, it may be so transient as to escape notice. A protective mechanism, it seems to be caused by loss of sensory input before the latter is transferred to permanent memory storage in the brain.

Though commonly only of minutes' duration, it can extend to several days before the head injury. Though there is often a later recovery of much of this lost period, the memory of events immediately before the incident rarely returns, which may fortuitously be a protective device. Concussion has been attributed to several causes, including the undoubted vasomotor disturbances that take place after a head injury. Another theory is the impaction of the brain into the foramen magnum or tentorial opening, but the most acceptable hypothesis is 'diffuse neuronal injury'.

DIFFUSE NEURONAL AND AXONAL INJURY

According to Graham *et al.* (2002), diffuse brain damage exists in four principal forms: diffuse vascular injury, diffuse axonal injury, hypoxic brain damage and diffuse brain swelling. Diffuse vascular injury consists of multiple small haemorrhages throughout the brain and is virtually restricted to patients, who die within 24 h, whereas the latter three are encountered in patients who survive long enough to reach the hospital. Recent research and new immunohistochemical methods have shown that traumatic axonal injury is much more common than previously realized, and that axons can also be diffusely damaged by other processes than head injury. Therefore, Geddes *et al.* (2000) suggested new definitions of the terminology to get rid of the incoherent use of terms in the literature:

- Axonal injury (AI) is a non-specific term referring to damage to axons of any aetiology.
- Traumatic axonal injury (TAI), is a damage to axons caused by trauma, which may vary from small foci of axons to more widespread brain damage, diffuse TAI is the most severe form of traumatic axonal damage (originally termed 'DAI').
- Diffuse axonal damage (DAI), first described as a clinicopathological syndrome of widespread axonal damage throughout the brain, including the brainstem, should not be used as a term without reference to the aetiology, because axonal injury may be caused by other pathological processes.

Experimental work has suggested that diffuse axonal injury is primarily a non-impact rotational acceleration–deceleration phenomenon, deformation by stretching probably being the most significant factor. A low level of injury causes transient changes in the permeability of the axolemma, gradually leading to ionic changes, accumulation of fluid and axonal swelling and eventually, with an increasing grade of injury, to intracellular Ca^{2+} accumulation, proteolysis and collapse of the cytoskeleton.

The disruption of axons leads to bulbous and clubbed 'retraction balls or globes' on the axons in the cerebral hemispheres, cerebellum and brainstem. Disturbance of axonal transport causes accumulation of substances in damaged fibres, that can be demonstrated immunohistochemically. At present, β-amyloid precursor protein (βAPP) is considered to be the most reliable indicator of axonal damage, revealing axonal injury within 2–3 hours of the insult, whereas it takes about 12–18 hours for axonal bulbs to become visible on routine or silver stains. However, one should keep in mind that βAPP is not specific to head injury but is an indicator of derangement of fast axonal transport, which has also been demonstrated in other pathological conditions.

It is preferable to examine the brain after proper fixation, usually after 10–14 days in 4 per cent buffered formaldehyde and, where possible, consultation with a neuropathologist with experience in forensic practice. Due to the diffuse nature of the axonal injury, extensive and systematic sampling is essential, as the diagnostic yield is directly related to the number of blocks taken. In addition to any obvious focal pathology, the minumum set of samples should include corpus callosum and parasagittal posterior frontal white matter, splenium of the corpus callosum, deep grey matter to include posterior limb of the internal capsule, cerebellar hemisphere, midbrain including the decussation of superior cerebellar peduncle, and pons including superior or middle cerebellar peduncles. In addition to these, it may also be advisable to include corpus callosum and parasagittal anterior frontal white matter and temporal lobe including hippocampus (Geddes *et al.* 2000).

Retraction globes are most numerous in the corpus callosum, the superior peduncles, the parasagittal white matter, the medial lemnisci and the corticospinal tracts, but can be seen anywhere in the white matter. The retraction globes or axonal bulbs have been shown to lose positive staining for βAPP after about a week but to persist in adjacent varicose axons up to 30 days. After some weeks in those who survive long enough, clusters of microglia, presumably part of a repair process, congregate at the site of ruptured axons. These are best seen in 20 μm thicker sections stained with cresyl violet. One problem with the microscopic evidence of both microglial clusters as well as diffuse axonal injury (as demonstrated by βAPP expression), is that neither of them is specific as a marker for trauma: retraction globes may also be seen around the periphery of natural lesions such as cerebral infarcts and haemorrhages and microglial clusters have been reported in viral/HIV encephalitis, previous global hypoxia and fat embolism. Geddes *et al.* (2000) conclude in their excellent review that 'the demonstration of traumatic axonal damage is likely to be of limited use in most forensic situations, except perhaps to confirm that there has been a head injury'.

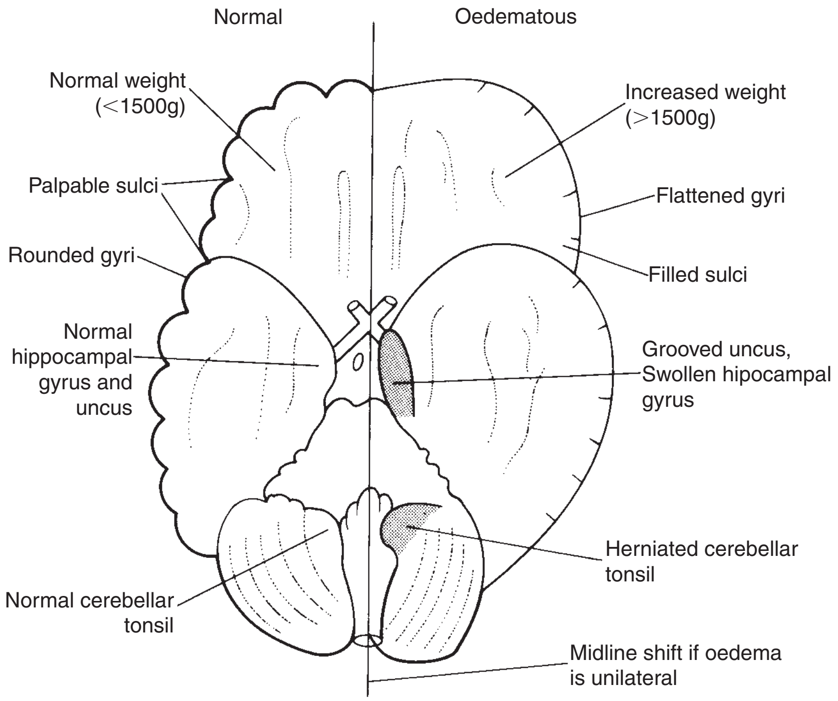
Normal
Oedematous
Normal weight (<1500g)
Palpable sulci
Rounded gyri
Normal hippocampal gyrus and uncus
Normal cerebellar tonsil
Increased weight (>1500g)
Flattened gyri
Filled sulci
Grooved uncus, Swollen hipocampal gyrus
Herniated cerebellar tonsil
Midline shift if oedema is unilateral

FIGURE 5.44 *Signs of cerebral oedema.*

Cerebral oedema

Swelling of the brain tissue may be a local phenomenon around almost any lesion, be it contusion, laceration, tumour or infarct, but here we are more concerned with generalized oedema. Swelling of the brain is extremely common after a substantial head injury, especially in children. Though it is an almost inevitable accompaniment of almost all intracerebral damage as either a local or general phenomenon, it can occur as the sole abnormality – and not infrequently prove fatal, particularly in young victims.

Oedema may well be related to diffuse neuronal injury and to concussion itself. It is the most common cause of raised intracranial pressure, being seen more often than localized space-occupying lesions such as haematomas and tumours, though of course these often coexist with cerebral oedema.

As with concussion, its cause is obscure and hence is the source of considerable controversy. The amount of fluid in the brain increases and the total weight may increase by at least 100 grams, mainly in the white matter. The site of the excess fluid is obscure, as the cut brain surface does not appear wet as do connective tissues elsewhere in an oedematous body. It was formerly thought that there was no true extracellular space in neural tissue and that the fluid must therefore be intracellular, but electron microscopic studies have revealed an extracellular compartment, which is much wider in the white matter (up to 80 nm) than in the grey matter (up to 20 nm), which explains the preference of oedema for the white matter.

The autopsy features of cerebral oedema are readily recognized. On removing the calvarium, the dura is stretched and tense, the brain bulging through the first incision in the membrane. The gyri are pale and flattened, and the sulci filled, giving the normally corrugated cerebral surface a smoothness that can easily be felt at autopsy. The cut surface is pale and, especially in children, the ventricles may be reduced to slits by the swelling of the adjacent white matter.

Severe cerebral oedema causes the larger volume cerebral hemispheres to press down upon the tentorium and herniate through the midbrain opening. The hippocampal gyrus may impact in the opening, lesser degrees causing grooving of the unci. Both these effects may lead to haemorrhage and necrosis at the sites of pressure, especially where the sharp edge of the tentorium cuts into the cerebral tissue. The tonsils of the cerebellum may be impacted or 'coned' into the foramen magnum, and sometimes are forced down into the upper part of the spinal canal. The pathologist must be careful not to mistake the normal anatomical grooving that often exists around the cerebellar tonsils for 'coning'. There should be other signs of brain swelling and true tonsillar herniation will show discoloration or even necrosis of the ischaemic, trapped tissue.

Cerebral oedema may be the only intracranial abnormality found at autopsy after a substantial head injury has occurred. This seems to be more commonly found in children and, in the absence of any other demonstrable lesions, the cause of death has to be attributed to this swelling of the brain, compressing the vital centres in the brainstem.

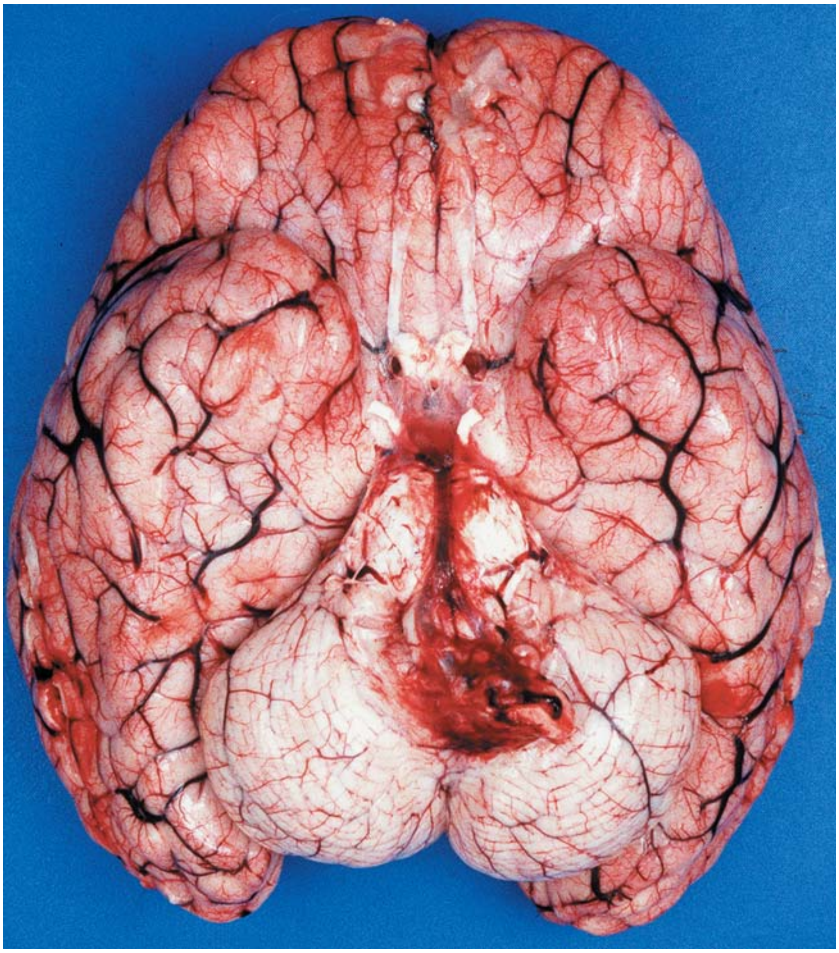

FIGURE 5.45 *Tonsillar herniation as a consequence of lumbar puncture in a patient with increased intracranial pressure. The pressure gradient has forced the cerebellar tonsils into foramen magnum and caused compression of the brainstem and patient's death. (Reproduced by kind permission of Professor H Kalimo.)*

Obviously, many other cases of cerebral oedema resolve either spontaneously or with treatment, so that fortunately no opportunity arises to prove its existence by post-mortem examination. Such oedema is, however, not infrequently found during surgical exploration for a meningeal haemorrhage, the latter sometimes being presented though often only brain swelling is demonstrated.

Cerebral oedema may be self-potentiating, in that once it begins as a result of direct brain trauma, the consequent rise in intracranial pressure then impairs the venous return from the intracranial sinuses. The pressure is insufficient to restrict the arterial inflow, so further congestion and swelling occur. This may lead to worsening cerebral hypoxia and oedema to the stage of actual cerebral infarction and brain death – again, a distressing common syndrome seen especially in child victims of head injuries, usually from road accidents.

In addition to mechanical damage, cerebral oedema can be caused or worsened by hypoxia. Many head injuries may be associated with damage to other parts of the body, such as the thorax – and because the airway may be compromised in many unconscious victims, there may be an element of hypoxia in a considerable proportion of cases of cerebral oedema. Capillary permeability may be increased in a number of states, leading to weakening of the so-called 'blood–brain barrier' formed by the capillary endothelium and basement membrane, together with the astrocyte footplates. Cerebral oedema, either traumatic or hypoxic, can develop with surprising rapidity, especially in children. Macroscopic evidence of brain swelling can be seen at autopsy in cases where the interval between trauma or onset of hypoxia and death was less than one hour.

Several methods are available to reverse oedema, including hyperventilation, which acts by providing full oxygenation and reducing the peripheral carbon dioxide tension, thus causing constriction of arterioles and a reduction in brain volume and transudation.

HISTOLOGICAL DIAGNOSIS OF EARLY CEREBRAL HYPOXIA

Unfortunately for the pathologist, most of the hypoxic conditions seen in forensic practice cause death too quickly for any recognizable histological changes to develop. Acute deaths from strangulation, suffocation and choking occur within minutes or less, even excepting the sudden vasovagal type of cardiac arrest.

There are, however, occasions when a longer period of survival occurs after an acute hypoxic episode and in some of these there may be the opportunity to detect histological changes in the central nervous system. Probably a minimum of 2–4 hours of survival is necessary for unequivocal changes to be observed, though some neuropathologists claim to detect signs after as little as 1 hour. More cautious investigators prefer 4 hours as the minimum. A short post-mortem interval is a considerable advantage in searching for these changes, as they are subtle and can be overlaid by post-mortem autolysis, even if the latter is slight.

It may be helpful to seek the assistance of a neuropathologist in detecting or confirming the relatively minor changes seen in a brain affected by hypoxia, but with experience, a good knowledge of the normal appearances and a laboratory that is able to turn out constantly good-quality sections and uniform staining, any forensic pathologist can build up a considerable expertise in this localized aspect of neuropathology. The parts of the brain most suitable for seeking evidence of hypoxic damage are the hippocampus (especially Sommer's area), the cerebellar folia, the globus pallidus in the basal ganglia, and the boundary zones of the cerebral cortex where the grey matter is most vulnerable because it lies at the terminal reaches of the arterial supply (for example, at the occipitotemporal junction where the watershed between middle and posterior cerebral arteries lies). The third and fourth cortical layers are best for displaying the histological changes of hypoxia.

The following is a summary of the stages and changes that may be seen using different staining methods. The brain should be prefixed by suspension in formol saline for several weeks, though if this is impossible, small blocks should be wet-cut from the target areas of the brain mentioned above and immediately fixed in a large volume of formalin.

Stage 1

The earliest change is microvacuolation in the neurone cytoplasm, which may be seen in 2–4 hours. The cell outline remains smooth and its size is normal but, internally, small vacuoles appear in the cell body, and the proximal parts of the axon and dendrites. There may be a slight eosinophilia in haematoxylin and eosin stains and a violet colour in Luxol Fast Blue.

The microvacuolar change is said to begin earlier in small neurones and last for a shorter time, being present for up to 4–6 hours after insult in large cells and 2–4 hours in cerebellar Purkinje cells, though these times are arbitrary.

Stage 2

In the next stage, more prolonged hypoxia causes distortion in the shape of the neurones, the cell body becoming shrunken and staining darker with aniline dyes. The Nissl granules become fine and are dispersed more widely throughout the cell. Some vacuoles remain, the cytoplasm shows marked eosinophilia in haematoxylin and eosin, and is bright blue to mauve in Luxol Fast Blue stain. The nucleus becomes triangular and may be placed eccentrically in the cell body. The nucleolus becomes obscured and the nucleus stains a darker blue than normal with Luxol Fast Blue. This change is seen after up to 6 hours survival or later in large cells.

Stage 3

The ischaemic cell stage, described last, becomes worse during the following day or two if survival continues. The cell shrinks further, becoming narrow and tapered in many cases. Eosinophilia and blueness when stained with Luxol Fast Blue persists, but small spherical or irregular bodies begin to adhere to the exterior of the cell membrane. These incrustations persist longer than the remnants of the cytoplasm, which vanish, leaving the bare nucleus. The dark, shrunken nucleus becomes more apparent and survives for a number of days before karyolysis occurs.

Stage 4

Homogenizing cell damage is best seen in the Purkinje cells, in which the cytoplasm is uniformly eosinophilic with no Nissl granules. The nucleus stays dark and triangular until it vanishes and leaves a pale 'ghost' of the cell body with a vague perimeter.

There are parallel changes in the glial elements as well as in the neurones. From 4 to 12 hours after a hypoxic insult there may be an increase in the number of astrocytes around damaged neurones. There is a proliferation of astrocytes (which show mitoses) some 4–6 days later if the patient survives. This is most noticeable in the cerebellum and persists for 10–14 days. Fibrous astrocytes proliferate, but not the oligodendroglia. Microglia transform into rod cells, which may lie at right angles to the edge of the cortex, radially in the hippocampus and in the molecular layer of the cerebellar cortex. A later stage of cerebral hypoxic damage is the accumulation of lipid droplets and scavenging of myelin. Groups of microglia around dead neurones (neuronophages) may be obvious even at lower powers of the microscope.

SECONDARY BRAINSTEM LESIONS

When severe brain swelling (or a space-occupying lesion such as a large subdural or extradural haematoma) causes raised intracranial pressure above the tentorium, amongst the possible sequelae is compression of the midbrain against the free edge of the tentorium. This may be unilateral, causing grooving of a cerebral peduncle (called 'Kernohan's notch') associated with subpial petechial haemorrhages and often hemiplegia. When symmetrical, the oedema forces the undersurface of the cerebrum against the tentorium so that the hippocampal gyrus is squeezed into the opening. This elongates the midbrain in an anteroposterior direction as well as grooving the uncus and, in extreme cases, infarcting part of the parahippocampal gyrus. In addition, the distortion stretches, and compresses the paramedian and nigral vessels that supply the midbrain, leading to haemorrhages and infarcts in the upper pons and midbrain. Damage to cranial nerves and to the circulation of the cerebrospinal fluid may be added complications. The calcarine cortex on the medial aspect of the occipital lobe may be infarcted by the posterior cerebral artery being trapped around the edge of the tentorium by the cerebral herniation.

Secondary lesions are almost exclusively midline or paramedian haemorrhages, or haemorrhagic necrosis placed centrally in the upper pons and midbrain, though some may be obliquely placed in the substantia nigra. They may be difficult to distinguish from primary brainstem haemorrhages that arise at or soon after the original head injury – the secondary lesions tend to obscure the primary, rather than the converse. In children, the typical stem haemorrhages may not be present as in adults, but instead the medulla oblongata may be buckled or kinked due to fixation of the upper spinal cord by the denticulate ligaments (see work by Crompton).

SPINAL INJURIES

The spine and head should be thought of as part of the same system in relation to trauma. In recent years, a closer association – both skeletal and neurological – has been acknowledged between the two structures. For instance, interruption of ascending fibres in the cervical cord has been shown to be associated with neuronal chromatolysis in the brainstem and Spicer and Strich have shown that haemorrhage into spinal root ganglia may be associated with head injury. Electroencephalographic changes have been shown to occur in half the victims of cervical spine whiplash injury.

Though all segments of the spine are vulnerable to trauma, the cervical part holds the most interest for the forensic pathologist, mainly because of its close association with head injuries and vehicular accidents. The upper two cervical vertebrae provide most of the rotational movement of the head, whilst the lower neck allows flexion and extension. Violent force applied to the head tends to damage those parts of the neck corresponding with this functional distinction. Spinal damage may be caused by compressional, hyperflexion and hyperextension stress.

Compression damage

This occurs when the victim falls from a height either onto his feet or his head, though in the latter case, head injuries may overshadow damage to the spine, as well as absorbing most of the impact.

When a person falls a long distance onto the feet, the kinetic energy of the deceleration may be absorbed by fractures of the feet, legs and pelvis, but can be transmitted up the spinal column. This can be fractured at one or more points, or the force may cause the upper cervical spine to impinge on the base of the skull and cause a 'ring fracture' around the foramen magnum as the spine is rammed into the posterior fossa.

A fall onto the head may also cause the 'burst atlas' injury, where the impact of the occipital condyles in an axial direction wedge the superior atlantal articulating facets apart and split the ring of the vertebra. The posterior arch can also be fractured in hyperextension by compression between the occiput and the posterior spine of the axis.

Compression fractures of vertebral bodies may occur, most commonly in the lower dorsal and upper lumbar zone, particularly T12 and L1. There is less chance of spinal cord injury compared with the angulation injuries described below, unless posterior extrusion of a disc or backward displacement of fragments of a disrupted vertebral body occurs.

Hyperflexion and hyperextension injury

Of the two, hyperextension is much more dangerous in causing spinal damage, possibly because flexion is protected by contraction of the strong posterior neck muscles, whereas the weak anterior longitudinal ligament is incapable of preserving the integrity of the cervical spine during hyperextension. In frontal or rearward motor vehicle crashes, which comprise 80 per cent of accidents, there is usually a hyperflexion and hyperextension component to the spines of the occupants, though head restraints and seatbelts restrict the range of movement.

Where a car undergoes violent frontal deceleration, the subject's head will swing down into hyperflexion and, unless restrained, will then strike the fascia or windscreen, and rebound into hyperextension.

When the vehicle is struck from the rear, the head will fly into hyperextension first unless a head-rest is available; such collisions often then smash the vehicle into the one in front, when a deceleration hyperflexion takes place.

Whatever the cause, a whole range of lesions can follow, both in the cervical, and to a lesser extent into the thoracic and lumbar segments. Bleeding into the surrounding muscles,

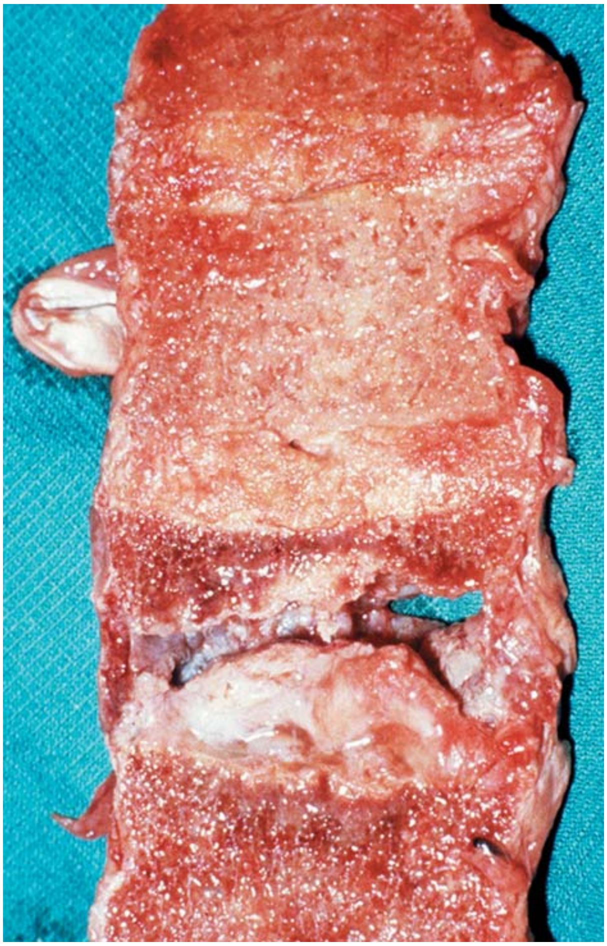

FIGURE 5.46 *Crushing of a thoracic vertebral body with disintegration of the adjacent disc following a violent hyperflexion in a car driver sustaining a deceleration injury. These lesions are best displayed at autopsy by cutting a longitudinal slice down the anterior aspect of the spinal column with an electric saw.*

rupture of the anterior longitudinal ligament, and tearing of intervertebral discs and of the annulus fibrosus may occur.

Nerve roots may be torn or compressed, and the spinal canal may be narrowed, distorted or even almost obliterated by fracture dislocations of the vertebrae. Compression, ischaemia, haemorrhage and even pulping of the spinal cord is the most serious complication. In older persons with cervical spondylosis, further narrowing of the canal by trauma may cause neurological effects that would not occur in younger subjects.

The most common part of the spine to be injured is the region of the upper two cervical vertebrae. In a series of fatal motor car accidents reported by Mant (1978), 35 per cent of passengers and 30 per cent of drivers suffered cervical spine damage. Of these the most common was a dislocation of the atlanto-occipital joint and Mant claims that one-third of all victims of fatal motor vehicle accidents suffer this lesion, even though it is often undetected at autopsy. The mechanism of fracture of the atlas is said to be an axial impact via the head, when the occiput is held rigidly in line with the spine by contracted neck muscles. This most frequently occurs when the vertex of the lowered head violently strikes the windshield of a decelerating vehicle. Fracture or dislocation of the atlas or fracture of the odontoid of the axis can all occur from this type of impact. Hyperextension injuries tend to force the vertebral body forwards and, if there is significant displacement, the arch is intruded into the spinal canal with the consequent risk of cord damage. In addition, hyperextension – especially in the presence of cervical cord enlargement – can cause the ligamentum flavum to corrugate and intrude into the anterior part of the spinal canal to impinge upon the cord. When the injury is due to hyperflexion, dislocation of a vertebra causes it (or its fragments) to tilt backwards, again compromising the lumen of the spinal canal.

Dislocation of cervical vertebra can occur under many conditions. An anterior dislocation can be caused by a fall onto the back of the head and a unilateral dislocation is common when a head strikes a windscreen. Posterior dislocation may be caused by blows to the jaw or face that jolt the head backwards with a hyperextension element. Falling onto the face, especially from a height (such as down a staircase), is a likely cause. Fracture of the odontoid peg of the axis can occur from a variety of violent movements of the head on the neck, and is sometimes associated with fracture of the skull or mandible. Where gross injury to the spinal column is inflicted – such as a relatively high-speed motor vehicle or railway accident – the cord may be transected by a guillotine action of the two displaced fragments. This is most often seen on the upper or mid-thoracic region, from direct impact or gross 'whiplash' effects. The thoracic aorta at this level is often torn at the point where the descending arch meets the spine, even in the absence of a spinal fracture.

Damage to the cervical spine in hanging is rarely seen in the usual suicidal hangings in which sudden death is caused by carotid compression or – much less often – asphyxia. The drop in such cases is small or even absent, the subject merely slumping his weight against the neck restraint. Spinal damage can occasionally occur, however and the author has seen a fractured neck when a heavily built soldier stepped from a lavatory seat with the rope attached to the overhead cistern.

Judicial hanging with a long drop causes a severe fracture dislocation (rather than fracture) of the cervical spine, often with complete severance of the two fragments and transection of the spinal cord. Where such hanging is carried out with the knot of the suspension point beneath the chin, a violent hyperextension is produced that often fractures the axis and dislocates it from the third cervical vertebra. With a heavy person and a long drop, there may be complete decapitation.

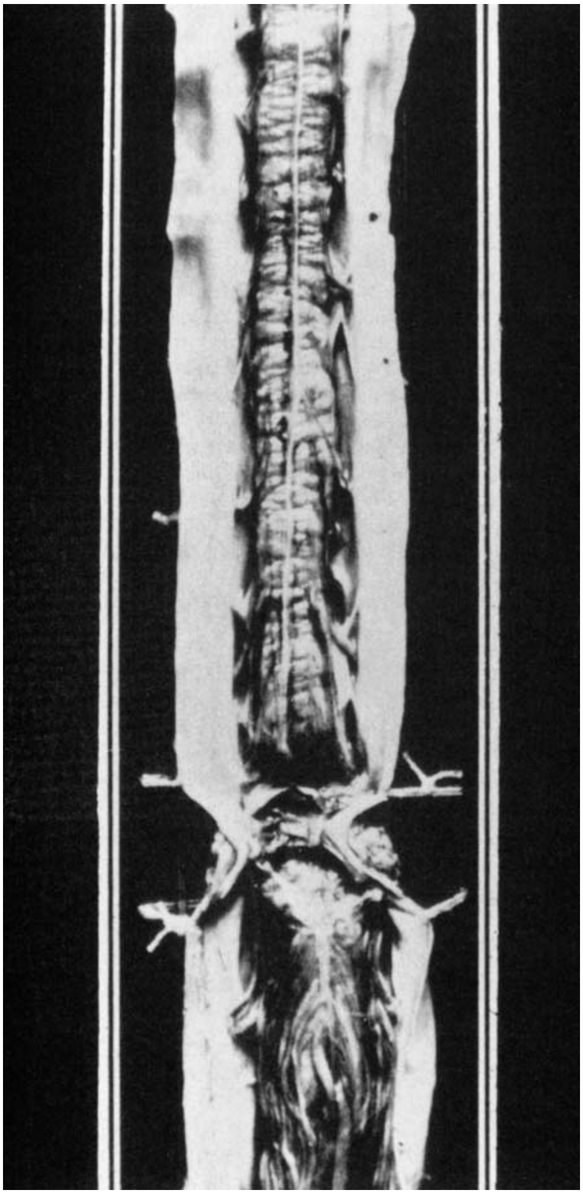

FIGURE 5.47 *Crushing and transection of the lower spinal cord following a hyperflexion fracture of the lower thoracic vertebrae. The spinal cord ends at about the lower border of the first lumbar vertebra, the cauda equina occupying the remainder of the lumbar spinal canal. This injury occurred several years before death, and the dura is constricted and adherent to the remnants of the cord. At autopsy the cord and its membranes should be pinned out and fixed for a proper examination to be made.*

Spinal cord injury

Most damage to the spinal cord arises from intrusion of some part of the spinal column into the canal, be it bony fragments or displacement, ligamentum flavum, disc annulus or extruded nucleus pulposum.

There may be bleeding into the space outside the spinal dura causing a space-occupying lesion in the canal that can compress the cord, or bleeding may occur within the dura, either from ruptured vessels or from haemorrhage in the cord itself. Damage to the cord may also occur in the absence of any apparent intrusion into the canal, in a manner similar to that seen in the brain in closed head injuries without a fracture. Haematomyelia and oedema may develop without any obvious mechanical defect at that level in the spinal column. Such injuries must be attributed to some momentary collision of the cord against the wall of the canal or a transient deformity of the profile of the canal that did not exceed the threshold for either fracture, dislocation or ligament rupture of the vertebral column.

The damage in the cord may extend for several segments above and below the point of impact. A haemorrhage within the cord tends to occupy the central grey matter more than the white columns, because of the softer and more vascular nature of the former tissue. Infarction of the cord can occur either in association with contusion, or because the local blood supply – often the anterior spinal artery – has been damaged.

An originally firm cord may undergo liquefaction ('myelomalacia') over several days or even longer, with progressive worsening of neurological symptoms.

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CHAPTER 6

Chest and abdominal injuries

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The major categories of wound previously described can be inflicted on any part of the body. In forensic practice certain areas are particularly vulnerable or have special medico-legal significance. Head injuries are so important that they have been discussed in a special chapter, but here consideration will be given to other regions, especially the chest and abdomen.

CHEST INJURIES

Damage can be sustained to either the chest wall or to the contents.

FORENSIC ANATOMY

The most important aspect is the relationship of the visceral contents to external landmarks. This is best described by reference to diagrams, where the relationship of pleural cavities, lungs, heart, mediastinum and diaphragm is depicted. It should be appreciated that, from the forensic aspect, the spleen and most of the liver and stomach are thoracic organs in that they lie largely beneath the costal margin, and are vulnerable to both stabbing and blunt injury to the chest.

Penetrating injuries, especially by knife to the lower lateral wall of the thorax, may enter the peritoneal cavity as well as

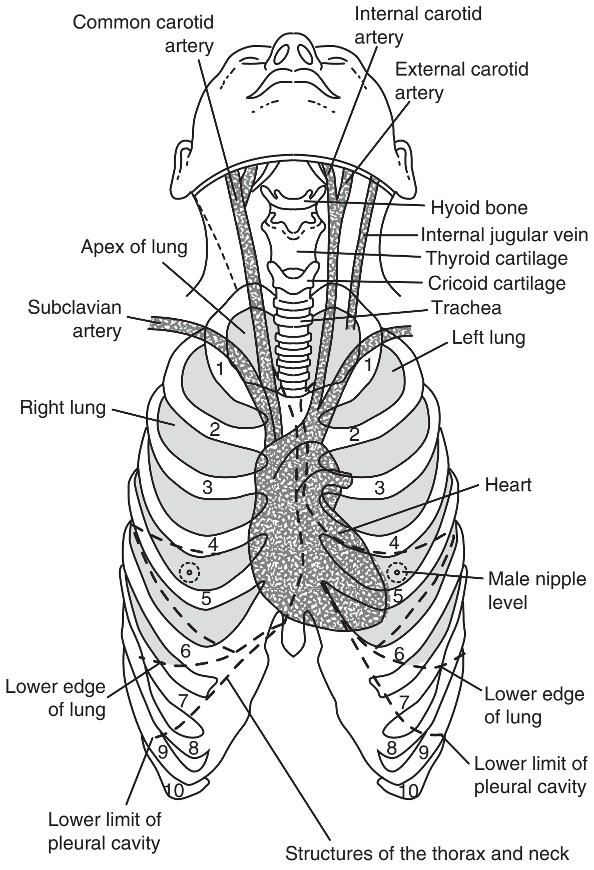

Common carotid artery
Internal carotid artery
External carotid artery
Hyoid bone
Internal jugular vein
Thyroid cartilage
Cricoid cartilage
Trachea
Apex of lung
Subclavian artery
Left lung
Right lung
1
1
2
2
3
3
4
4
5
5
6
6
7
7
8
8
9
9
10
10
Heart
Male nipple level
Lower edge of lung
Lower edge of lung
Lower limit of pleural cavity
Lower limit of pleural cavity
Structures of the thorax and neck

FIGURE 6.1 *Surface anatomy of heart, lungs and neck structures.*

the pleural spaces, perforating the diaphragm en route. The stomach, being largely within the rib cage, may often be penetrated. The common stab wounds of the heart may also include diaphragmatic and upper abdominal injuries. A knife can enter the front of the lower thorax, pass through either or both ventricles, and exit through the pericardial surface of the diaphragm to enter the upper surface of the liver. The orientation of the heart is often not appreciated after it is removed as an isolated organ, as the tendency is to visualize it as hanging with the apex downwards. In fact, it sits flat on the diaphragm on the lateral edge of the right ventricle, with the inferior vena cava passing immediately downwards into the abdomen.

INJURIES TO THE CHEST WALL

Respiration is dependent on the integrity of the rigid chest wall and, if the expansion is prevented or severely limited, then air entry will be correspondingly diminished. The integrity can be compromised either by severe mechanical failure of the rib cage or by penetration of the pleural cavities.

Fractures of ribs are common, but do not greatly embarrass respiration unless:

- they are so numerous that they prevent expansion of the thorax
- broken ends penetrate the pleura and lungs
- pleural and muscular pain limit respiratory effort.

Where many bilateral fractures are present, especially on the anterolateral sides of the thorax, the condition of ‘flail chest’ may be present, usually with multiple fractures of some ribs and sometimes with added fracture(s) of the sternum. As a result of loss of rigidity of the chest cage, attempts at expanding the thoracic volume during inspiration are impaired. The loose section is sucked inwards during inspiration, this clinical sign being known as ‘paradoxical respiration’. Dyspnoea and cyanosis may develop and extreme degrees of flail chest are rapidly incompatible with life because of progressive hypoxia.

The flail chest is caused by frontal violence, most often sustained in motor vehicle accidents – where the victim is thrown against the steering wheel or fascia – or in stamping assaults, where the shod foot is violently applied to the supine body. In any substantial chest injury, broken rib ends may be displaced inwards, the jagged tips ripping the parietal and visceral pleura. This may cause a pneumothorax or a haemothorax, or both, from penetration of the lungs, with the formation of a bronchopleural fistula. In gross chest injuries there may be compound fractures of ribs that allow a pneumothorax to form from external communication with the atmosphere, but this is rare in civil practice, though common in battle casualties.

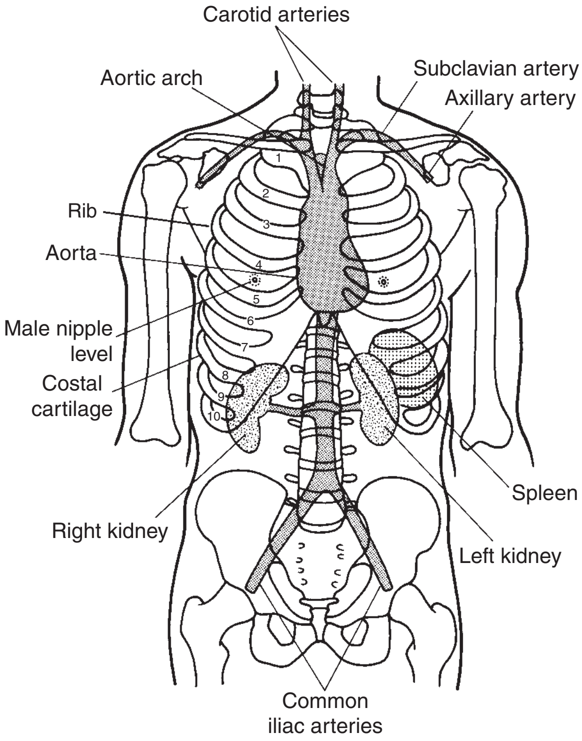

FIGURE 6.2 *Anterior view of trunk showing surface relations of heart and aorta.*

Rib fractures are most often seen in the anterior or posterior axillary lines caused by falls onto the side. The upper ribs are less often fractured, except by direct violence from kicking, heavy punching or traffic accidents. The fracture sites almost always show bleeding beneath the periosteum or the parietal pleura if the fractures occurred during life – though it must be admitted that (rarely) undoubted ante-mortem fractures may be totally bloodless, whereas some post-mortem cracks may exhibit slight oozing from the marrow cavity into the adjacent tissues. Attempts at resuscitation, especially external cardiac massage, now provide a common cause for extensive rib fractures (up to 40 per cent) and make the task of the pathologist much more difficult when trying to differentiate original trauma from the effects of enthusiastic first aid (Leadbeatter and Knight 1988). Bleeding may or may not be seen in these resuscitation fractures and, as the attempts at revival are, by definition, perimortal in timing, it is often impossible to say if they were immediately ante-mortem or post-mortem.

As the bracing action of adjacent intercostal muscles may conceal any mobility of the ribs when being examined at autopsy, it is a useful procedure to slit all the intercostal muscles with a knife when chest injury is suspected to allow any mobility to be detected more easily. In the osteoporosis of senility and some diseases, the ribs may be so fragile as to be breakable by finger pressure. Allowance must be made for this fragility in interpreting the cause of the fractures.

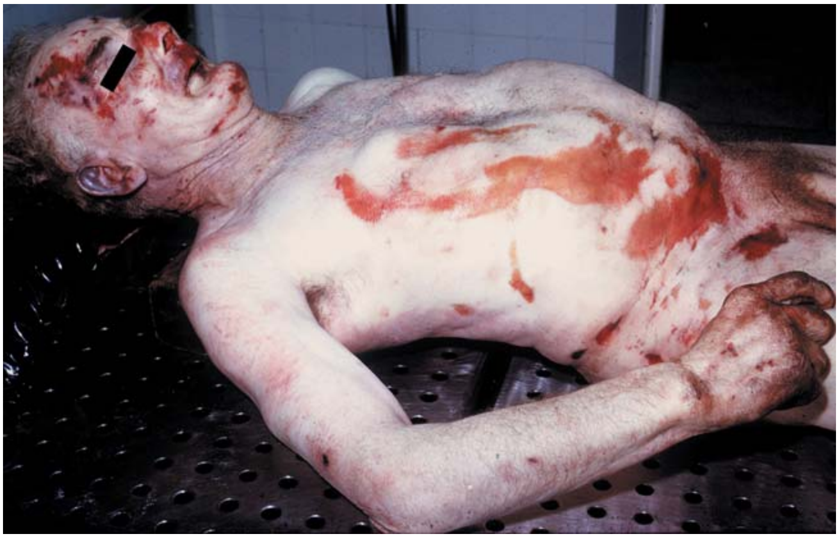

FIGURE 6.3 *Extensive abrasions and deformity of the chest in a man found by the roadside. All his ribs and sternum were fractured, resulting in a 'flail chest'. It was thought to be a road accident until bovine hairs were found on his clothing. He had been crushed by a bull and then tossed over the field wall.*

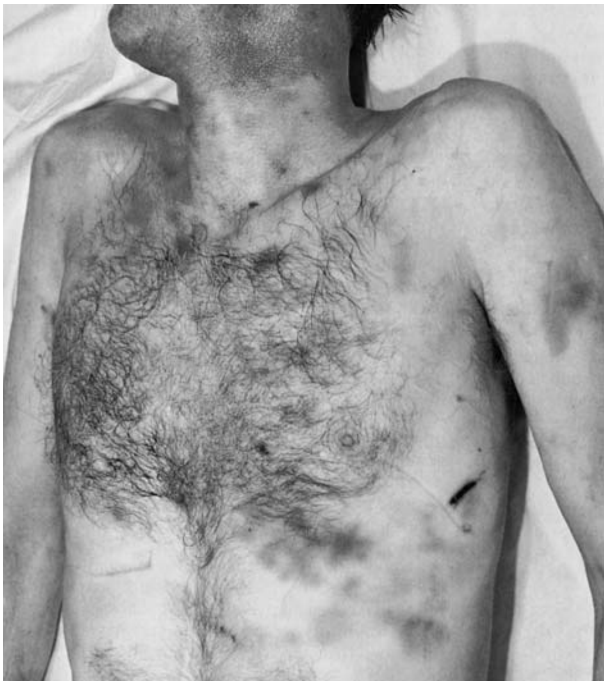

FIGURE 6.4 *Extensive bruising of the chest caused by kicking and stamping, resulting in multiple rib and sternal fractures. Over the left costal margin there is a pattern suggestive of the sole and heel of a shoe.*

In infants, especially victims of child abuse, rib fractures are common and may be an important diagnostic sign of abuse in doubtful cases. Where a small infant is squeezed from side to side, as when adult hands are clamped in each axilla or lower on the lateral sides of the chest, the hyperflexion can easily break ribs in their posterior segments, usually near their necks. The ribs are levered against the transverse processes of the vertebrae by excessive anterior flexion, which explains the tendency to fracture in the paravertebral gutter. Fresh fractures will be obvious, both on radiography and at autopsy. Within about 2 weeks (though this is very variable), callus will form and be visible both on X-ray and by direct post-mortem inspection. It is extremely difficult to date such callus.

It is said by paediatricians and radiologists that anterior rib fractures are rare in infancy other than from child abuse; though this is probably generally correct, care must be taken to exclude bony injury from the now almost universal attempts at resuscitation (even though infant ribs are very pliable). In very young infants, the possibility of older fractures dating back to birth injury cannot be dismissed, though again these are rare.

The sternum may be fractured by stamping or other frontal impacts, but far more force is necessary than with ribs. If posterior displacement of a fragment occurs, the underlying heart or great vessels may be severely damaged.

HAEMORRHAGE AND INFECTION IN THE CHEST

Any injury to the chest wall or lung surface that breaches blood vessels and the pleural lining can lead to a haemothorax. Intercostal and, less often, mammary arteries can bleed into the pleural cavities, but most massive haemorrhage comes from large vessels in the lung or mediastinum. The lung hilum can be torn or penetrated by stabs wounds. Another obvious source of a haemothorax is the heart itself, though there must also be a defect in the pericardial sac before the blood can reach the chest cavity. Several litres of blood may accumulate in the chest, either as liquid or clot, or usually a mixture of both. Death may occur from loss of circulating blood volume, even if there is relatively little external bleeding.

Many intrathoracic haemorrhages may be fatal with virtually no external blood loss, a fact that the police often find

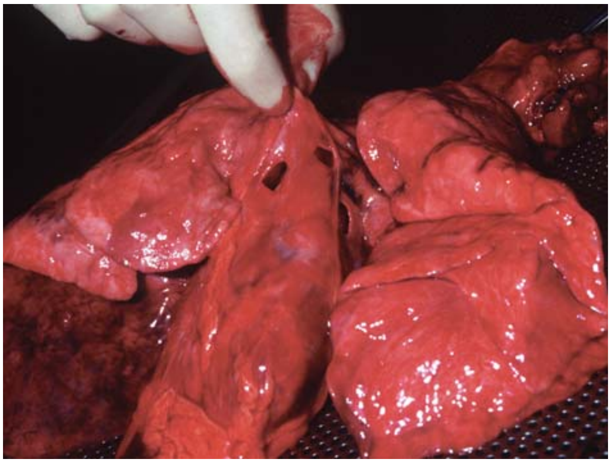

FIGURE 6.5 *Penetrating stab wound of chest, which has traversed the lung. The blade has passed through the upper lobe, crossed the interlobar fissure and re-entered the lower lobe. Death was caused by a haemothorax from severed branches of the pulmonary vessels within the lung.*

hard to credit if there is little blood at the scene of a fatal stabbing. A knife that passes obliquely into the chest through intercostal muscles may puncture a great vessel or heart chamber, allowing a fatal cardiac tamponade or haemothorax, yet the valve-like overlap of the tissues after withdrawal of the blade may seal up the external wound almost completely and prevent significant bleeding, especially as the blood inside the chest is not under any appreciable pressure.

The same may apply to a gunshot wound, where bleeding can be virtually absent if the wound is uppermost after death. Where the body lies above the wound, of whatever type, then considerable post-mortem gravitational leakage can take place.

Whatever the source of the bleeding, post-mortem haemorrhage can add very considerably to the volume found in the chest at autopsy. Due to the great variability of post-mortem coagulation – and subsequent lysis – much of the blood found at autopsy may not have been there at the moment of death. It is impossible to quantify this additional leakage in retrospect, but the ever-present possibility makes it unwise to be dogmatic about the amount of blood loss prior to death.

Infection following a chest wound is uncommon in forensic practice, as most deaths occur from haemorrhage within a relatively short time before infective sequelae have time to be established. Where survival is longer, then effective medical care usually prevents secondary infection. However, cellulitis, pleural inflammation and even empyema may supervene, especially where some dirty weapon is used, or where clothing or other foreign material has been carried into the wound. Infection may be of many types, but staphylococci, *Proteus*, coliforms and *Clostridium perfringens* are commonly found on culture.

PNEUMOTHORAX

There are three types of pneumothorax:

1. a simple type where a leakage through the pleura allows air to enter the pleural cavity, but where the communication rapidly closes. The lung partly collapses, but if death does not supervene the air is soon absorbed. If the communication remains open, then a bronchopleural fistula ensues with air in the pleural cavity but, as it is not under pressure, like type 2, it will not bubble out when the autopsy 'water test' is attempted. Radiology is then the best means of demonstrating the air in the pleural cavity.
2. when the leak in the pleura (or rarely the chest wall) has a valve-like action, air is sucked into the pleural cavity at each inspiration, but cannot escape on expiration. This pumping action leads to a 'tension pneumothorax', which causes complete collapse of the lung onto its hilum and a shift of the mediastinum to the opposite side. It is this type of pneumothorax that may be demonstrated at autopsy by penetrating an intercostal space under water, though radiology is a much better method of detection of all types of pneumothorax.
3. when an injury of the chest wall communicates with the pleural cavity, a 'sucking wound' may form with direct passage of air from the exterior. This type is most often seen in military surgery, and may be complicated by haemorrhage and infection.

A common traumatic cause of pneumothorax is a stab wound of the chest that allows direct communication with the exterior, though usually the layered skin and intercostal muscles closes the track when the weapon is withdrawn. The knife often enters the lung, however, so that air can enter the pleural cavity from the bronchi.

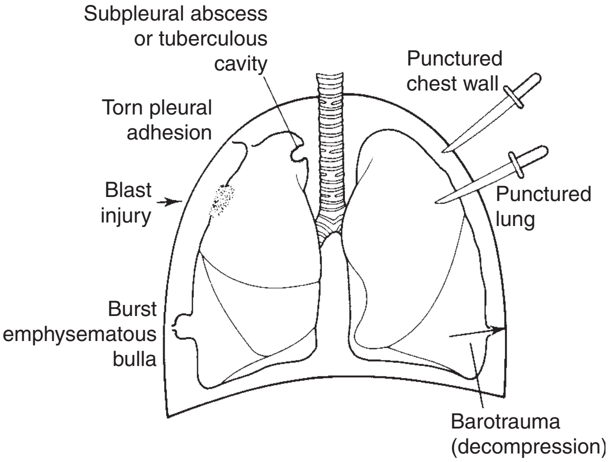
Subpleural abscess or tuberculous cavity
Punctured chest wall
Torn pleural adhesion
Blast injury
Punctured lung
Burst emphysematous bulla
Barotrauma (decompression)

FIGURE 6.6 *Common causes of pneumothorax.*

Natural disease can also cause a pneumothorax, which can lead to sudden death. Common causes are a ruptured emphysematous bulla, a tuberculous lesion at the lung periphery, or a tear at the site of a fibrous pleural adhesion. This may initially appear suspicious, as in a case seen by the author (BK) in which a teenage boy bent down to tie a shoelace and fell dead. At autopsy the only finding was a pneumothorax that had been caused by a single pleural adhesion that had torn the visceral pleura. This illustrates the fact that sometimes a pneumothorax can cause sudden unexpected death, presumably via some vagal cardioinhibitory mechanism.

INJURIES OF THE LUNGS

Bruising of the lungs is common in both open and closed chest injuries. Any substantial impact on the chest can contuse the lung surface or deeper parts. This may be beneath the area of impact or 'contrecoup' damage on the opposite surface. Deceleration injuries are seen in falls and traffic accidents, most commonly along the posterolateral surfaces where a vertical line of subpleural bruising occurs, often in the paravertebral gutter. The outline of ribs may be imprinted in lines of contusion on the pleural surface of the lungs. Bruising may be so severe as to form subpleural blood blisters, which may rupture to release blood or air into the pleural cavities.

In all severe chest injuries the central parts of the lung may show bleeding, sometimes sufficient to form actual haematomas with breakdown of lung tissue. Osborn describes 'pincer contusions' of the lung, where the expanded lower margins of the lungs become trapped in the narrow costophrenic angles.

Laceration of the lung can occur in blunt injuries and even lobes or parts of a lobe may be detached. The hilum may tear and the pulmonary ligament below the hilum is a frequent site of haemorrhage. Vessels in the hilum (especially pulmonary veins) or those more peripherally, may be ripped, causing severe intrapleural or mediastinal haemorrhage. In children, lung injuries can occur without fracturing of the ribs, because of the greater elasticity of the latter and the ability of the chest wall to deform.

Penetrating injuries of the lungs are common, usually from stabbing by knives. The wounds may end in the lung parenchyma or in large vessels, or may be 'through-and-through' injuries that emerge to cause further damage to the heart or great vessels. They assist the pathologist by delineating the track and the direction of the stabbing, but due allowance must be made for the marked variation in topography during inspiration, compared with the collapsed state seen at autopsy.

Blast injury is dealt with elsewhere, but the lungs are the most vulnerable organs to this type of injury due to their large tissue–air interface.

INJURIES OF THE HEART

The heart is vulnerable to both penetrating and blunt injuries. A common form of homicide is a stab wound of the chest which penetrates the heart. The entry point may be anywhere over the praecordium or adjacent areas if the angulation of the track is sufficient. Sometimes the sternum is penetrated by a forceful blow that reaches the underlying heart, but most stab wounds enter via the intercostal spaces, or through a rib or costal cartilage.

Rarely, an upward stab from the abdomen reaches under the costal margin to penetrate the diaphragm. The right ventricle is often injured by a stab wound as it presents the largest frontal area, but the anterior interventricular septum and the left ventricle are also vulnerable. A shallow stab wound may enter the myocardium and not reach the lumen of the ventricle. In such a case there may be little disability unless a coronary vessel is severed, which may either cause death from myocardial insufficiency (if a major artery is transected) or cardiac tamponade.

More often – especially in the right ventricle – the knife passes into the cavity. In the thin right ventricle this usually

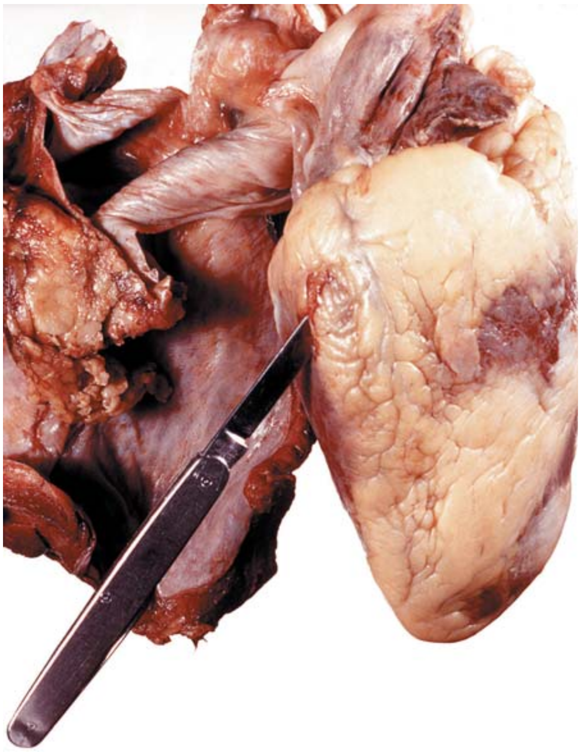

FIGURE 6.7 *Even a small penknife can inflict a fatal wound. This injury was caused by a boy to a police officer when the latter was apprehending him for some minor offence. Though the blade was only about 6 cm long, this is sufficient to enter alongside the sternum and puncture the ventricular wall.*

leads to copious bleeding into the pericardial sac even though the intraventricular pressure is relatively low because of the inability of the thin wall to close the defect by muscle overlap and contraction.

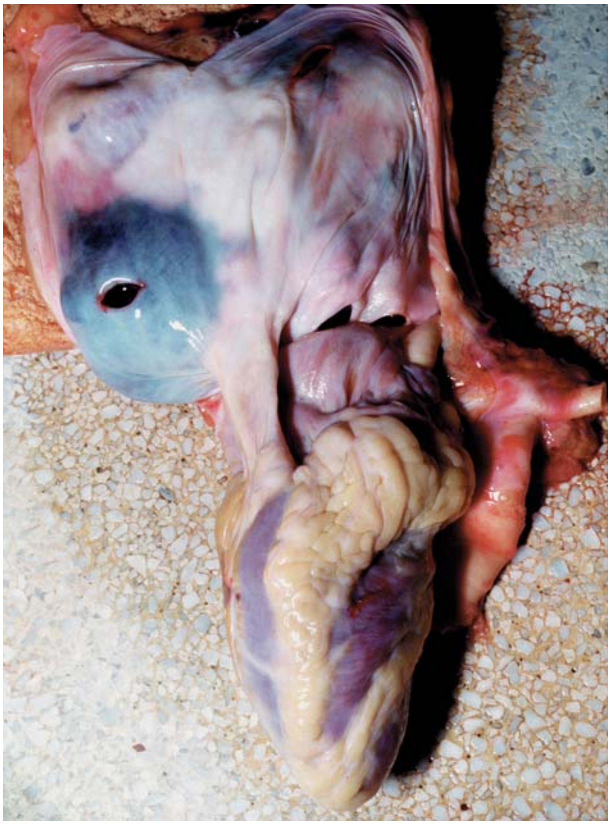

FIGURE 6.8 *Stab wound penetrating the pericardium (reflected upwards) with a wound in the corresponding point on the heart. Death was caused by cardiac tamponade from leakage of blood from the ventricular lumen.*

In the left ventricle, the contraction of the layered thick wall may partly or wholly seal the wound, and bleeding can be slight. It is, however, more common for persistent bleeding to occur and, if the drainage from the pericardial wound is less than the leakage from the ventricle, eventually a tamponade will develop. These variables make it impossible to calculate how long the victim was able to carry on with his activities, often a matter of dispute at a criminal trial. In general, wounds in the right ventricle are more dangerous than in the left because of the absence of the muscular ‘self-sealing’ effect.

Many stab wounds of the heart are transfixing or ‘through-and-through’ injuries, the knife entering one wall and emerging through another. If the left ventricle carries both wounds, the rapidity of bleeding may still not be torrential. Some of these wounds pass downwards and transfix the heart, then exit through the lower wall of the right ventricle and pass on via the diaphragm to end in the liver.

Blunt injuries of the heart are seen in civilian practice mainly in traffic accidents, falls from a height and in stamping assaults, though any heavy impact (including a punch) can cause fatal damage. There are usually multiple rib and sometimes sternal fractures, with or without a flail chest. Occasionally there can be heart damage in an intact chest cage, especially in a child with a pliable thorax. Fatal blunt damage of the heart may occur, however, without a mark on the skin of the thorax nor damage to the bony chest cage. The cardiac injuries are usually on the front of the organ, especially to the right ventricle, though posterior bruising and laceration can occur if the heart is compressed against the thoracic spine, as in stamping assaults and steering wheel impacts.

All degrees of damage can occur, from mere epicardial bruising to lacerations that open the ventricular lumen widely.

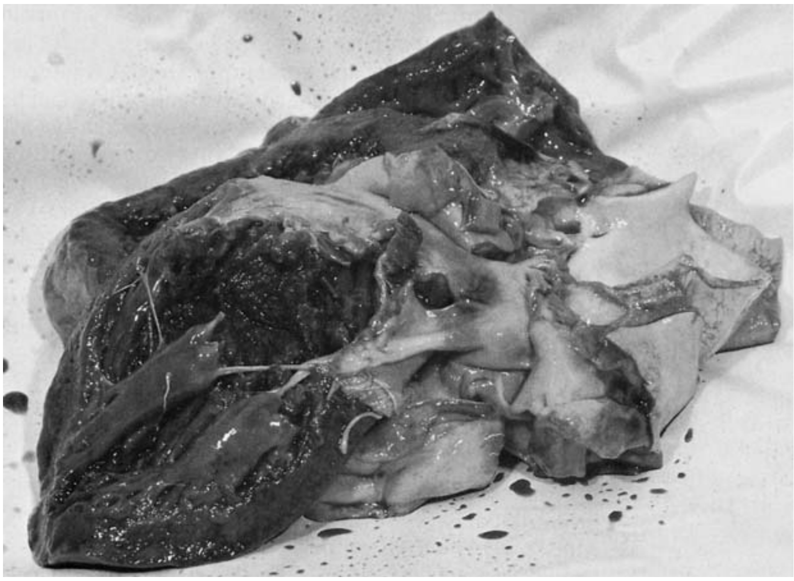

FIGURE 6.9 *Ruptured interventricular septum as a result of impact on the front of the chest. The septum can tear without damage to the outer walls of the heart.*

Internal damage to the heart may be present, without external signs of injury to either the heart or the external chest wall. The interventricular septum may be ruptured as a sole lesion, the mechanics of which seem obscure. In gross injuries, such as aircraft crashes, the whole heart may be avulsed from its root, to be found lying loose in the thorax. Histological damage, especially contraction band necrosis, can be found even when there is no macroscopic abnormality. A comprehensive review of cardiac contusions has been made by Sagall (1971).

HAEMOPERICARDIUM AND CARDIAC TAMPONADE

Bleeding into the pericardial sac may occur from the surface or the cavities of the heart, or from the intrapericardial segments of the roots of the great vessels, particularly the aorta and pulmonary artery. Most causes of haemopericardium are from natural disease, such as a ruptured myocardial infarct or a ruptured dissecting aneurysm of the aorta (Chapter 25), but it is not an uncommon sequel to injury to the chest. When the damage has been caused by a stab that has perforated the pericardial sac, bleeding can escape into the pleural cavities, mediastinum or even abdomen if the diaphragm is penetrated. Death may occur from sheer blood loss if the haemorrhage can escape from the confines of the pericardium, but another common lethal condition is ‘cardiac tamponade’.

In the tamponade, blood accumulates in the pericardial sac faster than it can escape, either because the bleeding rate exceeds the drainage or because the exit hole in the pericardium becomes blocked by blood clot. In cases where the bleeding is from a contusion or laceration of the heart, there is no escape route from the sac. When sufficient blood accumulates, the pressure in the pericardial sac increases and begins to prevent the passive filling of the atria during diastole. The cardiac output falls, as does the systemic blood pressure and the venous pressure rises. If unrelieved, death will follow, though the time that this takes is variable and almost impossible to calculate retrospectively on pathological findings. It has been stated (Moritz 1942) that about 400–500 ml of blood is sufficient to cause death, though this seems a greater volume than is usually seen in tamponades. Where trauma to the heart co-exists, it is difficult to apportion the relative contribution to death of the tamponade as opposed to the other injuries.

INJURIES TO GREAT VESSELS

The most vulnerable vessel is the aorta, which most commonly suffers injury in deceleration trauma from both road and air accidents, as well as from falls from a height. When the thorax is suddenly decelerated, the heart – being relatively mobile in the chest – attempts to continue in the original direction. This causes severe traction on the root of the heart, and a common sequel is complete or partial rupture of the aorta in the descending part of its arch. In falls from a height, Fiddler (1946) claims that the lesion is the result of the abdominal and thoracic viscera being forced caudalwards by the abrupt deceleration when landing on the feet or buttocks. Tannenbaum and Ferguson (1948), however, postulate that the mechanism is a sudden rise in intra-aortic pressure. Lasky (1974) has reviewed the biomechanics of impact injury of the aorta.

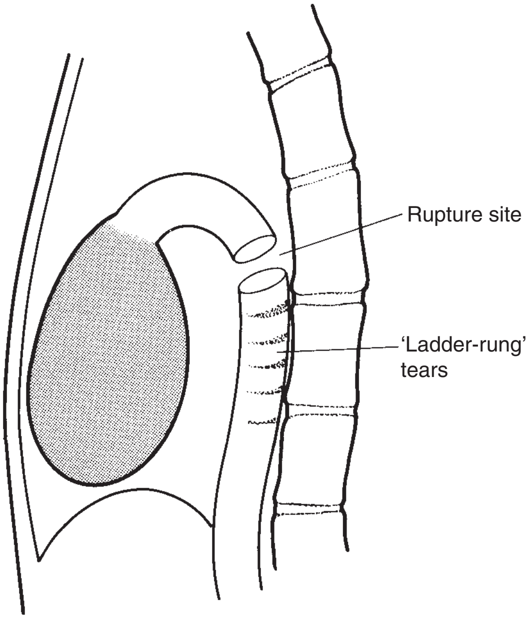

FIGURE 6.10 *The usual site of rupture of the aorta in deceleration injury.*

According to Fiddler, rupture occurs almost constantly at a point 1.5 cm distal to the attachment of the ligamentum arteriosum, the remnant of the ductus. The lower thoracic aorta is closely bound to the anterior longitudinal ligament on the front of the dorsal spine, until it reaches the termination of the arch, where it curves forwards. This appears to be the weak point and transection occurs at this level, sometimes so cleanly that it looks like a surgical incision. The tear is annular and at right angles to the axis of the aorta. Sometimes, there may be multiple parallel intimal tears near the main transection, the so-called ‘ladder-rung tears’. In deceleration trauma, these incomplete tears, which affect only the intima and inner media, may be found without major transection; where death is delayed, false aneurysms and dissections may be diagnosed on aortograms.

The pulmonary artery is much less vulnerable to blunt trauma than the aorta but, in stamping assaults and steering

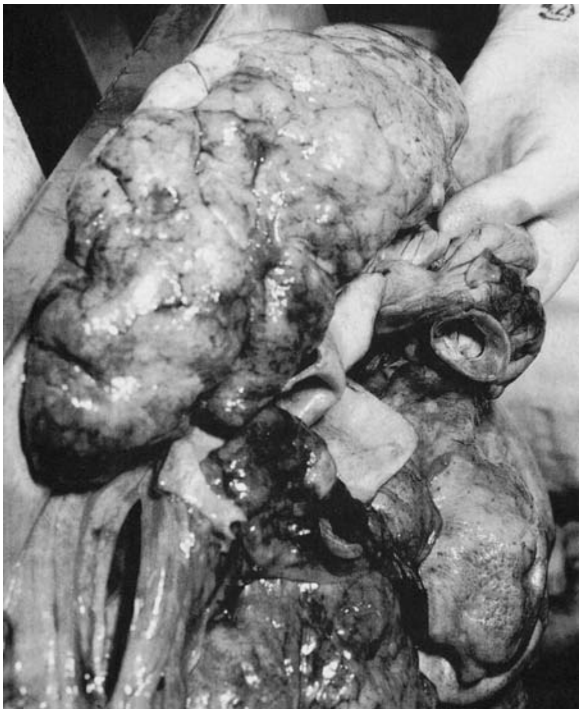

FIGURE 6.11 *Complete transection of the aorta in the distal part of the arch. The victim was a car driver who suffered a severe deceleration impact. There is also some slight pulmonary bruising; the lungs are asthmatic.*

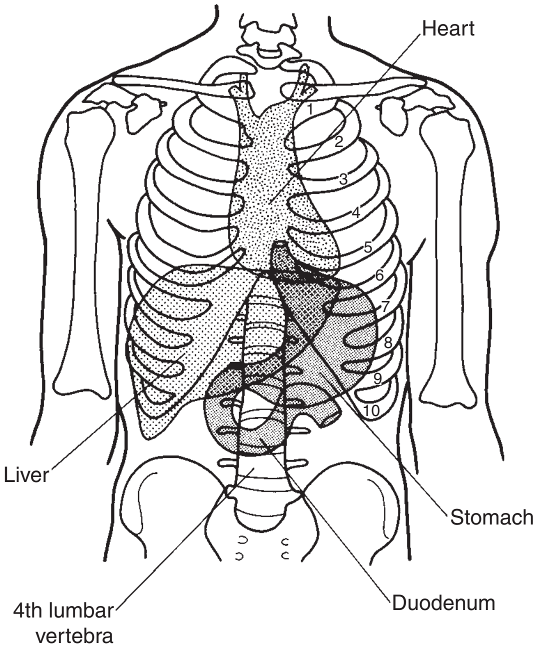

FIGURE 6.12 *Surface anatomy of liver, stomach and heart.*

wheel impacts, it may be damaged by depressed rib cage and sternal fractures. The pulmonary artery and vein branches may also be damaged in the root of the lung, where hilar tears are not uncommon. The great vessels are often involved in penetrating injuries, notably stab wounds. Stabs of the upper part of the chest may pass directly into the arch of the aorta, especially on the right side of the sternum. Here even a shallow injury may reach the aorta and the authors have seen several cases in which a short-bladed penknife has caused death in this way.

Stabs that are either too high, or are directed too laterally to puncture the chambers of the heart may penetrate the ascending aorta or the pulmonary artery. If the wound is below the reflection of the pericardium, a haemopericardium and perhaps cardiac tamponade may result. Other stab wounds may injure the heart valves or may enter the root of the lung to penetrate the large primary branches of the pulmonary artery or veins, causing gross bleeding into the corresponding pleural cavity or the mediastinum.

ABDOMINAL INJURIES

As with the thorax, the damage caused by blunt and penetrating trauma of the abdomen depends upon the location of the injury. In addition, the large area of the anterior abdomen occupied by the intestine provides a target for perforation with consequent chemical or infective peritonitis.

Open or penetrating wounds need little description, as they follow the characteristics of stab-like injuries in general. The liver, and especially the spleen, may bleed extensively, causing a haemoperitoneum. The intestine and mesentery are the other major targets, wounds often being multiple, because of the overlapping nature of the coils and their mesentery. The stomach, being partially protected by the rib margin, is less often penetrated from the abdomen, but is not uncommonly involved in chest stabbings that pass downwards through the diaphragm. The kidneys are rarely stabbed except from a thrust in the back.

Closed or blunt injury to the abdomen is common from both accidents and assault. Impact on the abdomen by a car steering wheel was more common before the widespread use of safety-belts and air-bags and still occurs in severe deceleration accidents. The liver, intestine, spleen and mesentery are most vulnerable. Crushing between two vehicles, or between a vehicle and a wall is another mechanism for abdominal trauma, and may also be seen in railway and industrial accidents where squeezing between two opposing surfaces occurs. In homicides, assaults and child abuse, kicking, stamping and heavy punching can also cause blunt injury to the abdomen.

Whatever the mechanism of infliction, the following features may be present:

- Bruising of the abdominal wall, both of the skin and the underlying muscles, is often (but by no means

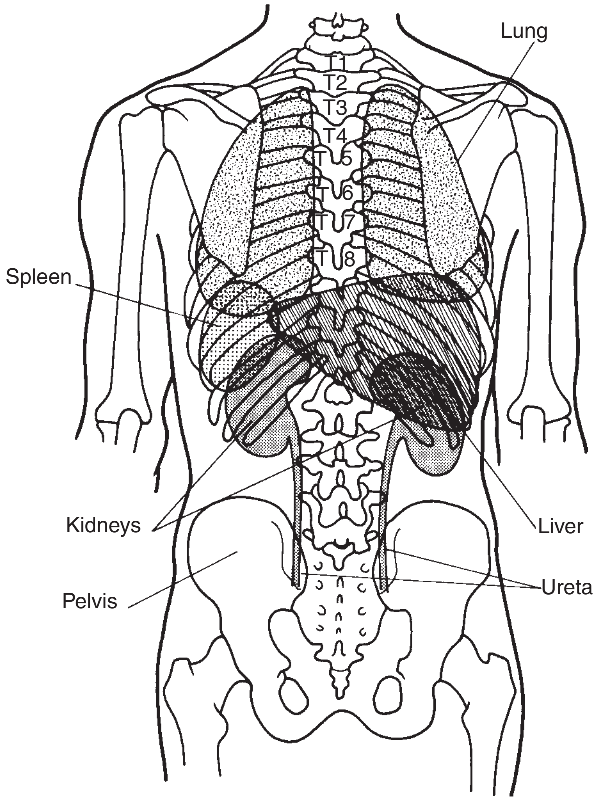

FIGURE 6.13 *Posterior view of trunk to show surface relations of organs.*

invariably) seen in abdominal trauma. Where subcutaneous bleeding is profuse it may track from the initial area of impact to become more diffuse and may cover a large area of abdominal wall, especially in the lower segment. Blood may track down the inguinal canal and appear in the scrotum or labia.

More often there are discrete bruises on the abdominal skin, associated in some instances with surface abrasions. Kicks will usually leave scuffed abrasions if tangential, unless protected by clothing. Fingertip or knuckle bruises may be seen, especially in child abuse. In infants, bruises may be seen on the sides of the abdomen where adult fingers have forcibly gripped or lifted the child, though these are more common in the axillary line of the chest.

Severe or fatal intra-abdominal injury may be present, however, without any mark on the skin. This can occur if clothing protects or if a blunt impact is applied over, a relatively large surface. In child abuse, for example, the liver, mesentery or duodenum can be ruptured with no external sign whatsoever.

- Extensive bleeding into the peritoneal cavity, usually from rupture of a solid viscus or bleeding from the mesentery.
- Bruising or rupture of the stomach and diaphragm. The stomach is less vulnerable than the intestines, but may be lacerated by a heavy blow in the upper abdomen, especially when full of food or fluid.
- The intestine and its mesentery are frequently damaged in abdominal trauma. Extensive bruising of the gut and its vascular mesentery may occur, mainly from being crushed against the prominent lumbar vertebrae in the midline. The duodenum and jejunum are particularly vulnerable to transection from being compressed against the spine, especially in children, where a heavy blow in the central or upper abdomen can cut through the third part of the duodenum almost as cleanly as a scalpel. Laceration of the mesentery is not uncommon both in traffic accidents and assaults. The same mechanism of compression against the lumbar spine causes bruising and tearing of the central parts of the mesentery, which usually occurs towards the intestinal margin of the membrane. Multiple fenestrations may be seen, presumably because folds of mesentery overlie each other and are injured when in apposition.

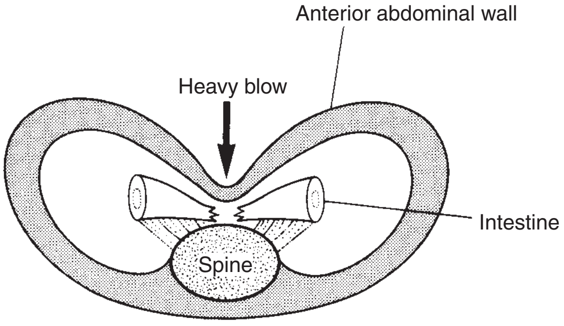

FIGURE 6.14 *Injury or rupture of intestine or mesentery in violent blow to the upper central abdomen. Because of its small size and the thin abdominal wall, the infant duodenum is especially vulnerable.*

Severe and intractable bleeding can occur in circumstances where surgical treatment is often not offered because the condition is unrecognized. Kicks and punches in the abdomen may be sustained by drunken persons who may be apparently unaware of the seriousness of their injuries until collapse and death supervene perhaps hours later.

In a case seen by the author (BK), a man was involved in a fight and then allegedly assaulted the police. He was forcibly restrained and may have been struck in the abdomen by a knee. He remained apparently well, though drunk, in a police cell for more than 5 hours, before collapsing and dying on his way to the lavatory, never having complained of any abdominal pain. Autopsy revealed several litres of blood in his peritoneal cavity, which had escaped from several large tears in the mesentery. Similar bleeding from mesenteric lacerations has been seen in abused infants,

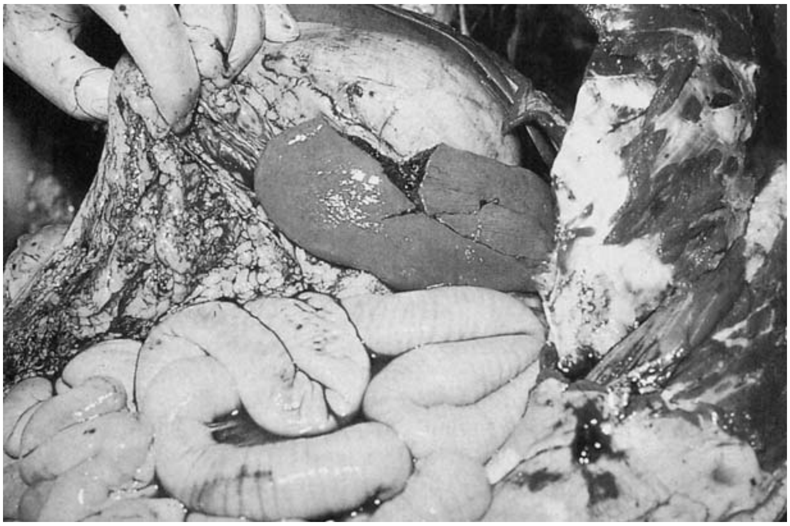

FIGURE 6.15 *Laceration of the spleen following lower chest impact during a road traffic accident.*

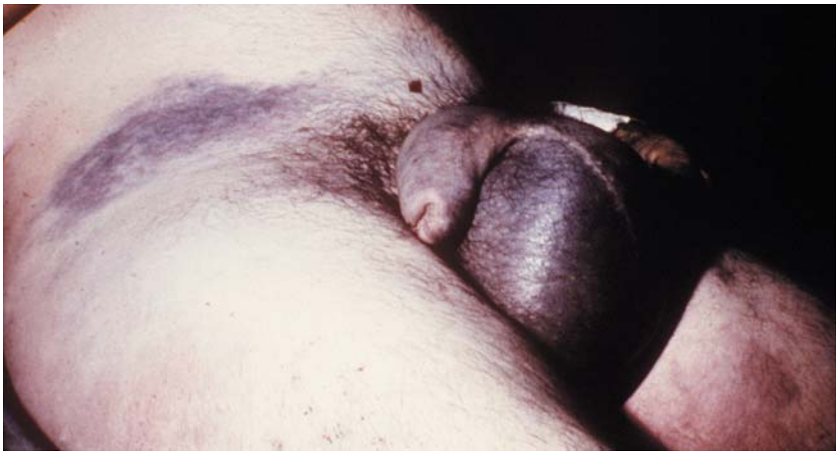

FIGURE 6.16 *Abdominal wall bruising with fatal intraperitoneal haemorrhage from a ruptured mesentery. There is also a large haematocele from a gang attack in which repeated kicking occurred.*

where the thin abdominal wall provides little protection from blows on the abdomen.

Injury to the mesentery may damage local arteries without causing severe bleeding, but may occlude or thrombose them, with infarction of the bowel as a consequence. Perforation may be delayed for a day or two and in children and old people there need not be the dramatic symptoms of the onset of peritonitis that is usually seen in clinical surgical practice.

The colon is rarely injured unless the abdominal injury is gross. One well-known lesion is rupture of the rectum or sigmoid by a high-pressure air hose being placed in or near the anus as a practical joke.

- Rupture of the spleen is a common surgical emergency after trauma but may be first found at autopsy if undiagnosed, or if death occurs from lack of speedy surgical treatment, or if other injuries made recovery impossible. An enlarged spleen is more vulnerable and more fragile than a normal organ. Malaria, glandular fever and other infections increase the risk of rupture. The 'stiletto' dagger was specifically designed in medieval Italy for puncturing the enlarged malarious spleen by an upward blow under the left costal margin.

The spleen can be damaged either from impact on its surface or from traction on its pedicle. The rupture may be immediate or may be delayed if a large subcapsular haematoma and underlying tear are held intact for a time by the capsule. This delay can last for a number of days or even weeks.

- Rupture of the liver is also a common lesion following serious abdominal trauma, such as fall from a height or a crush injury between two wagons. It is seen especially in traffic accidents, either from impact of the driver on the rim or centre of the steering wheel or by the unrestrained passenger being thrown against the fascia. A pedestrian can also suffer a ruptured liver either as a primary impact from a vehicle or as secondary damage from being thrown to the ground.

A more recent cause of liver injury is enthusiastic external cardiac massage. Even if death has already taken place, there may still be a significant amount of blood oozing from the liver tears into the peritoneal

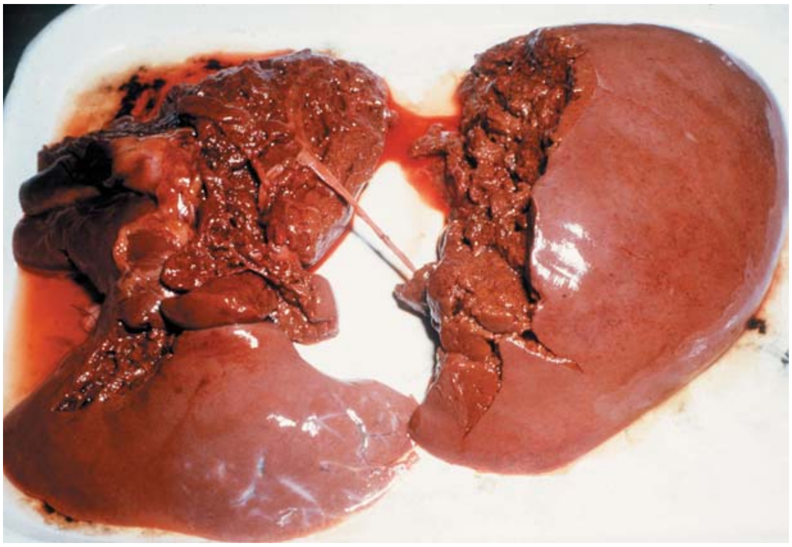

FIGURE 6.17 *Complete bisection of the liver in a high-speed deceleration during a traffic accident. The abdomen of the driver was hurled against the steering wheel as he was projected through the windscreen.*

cavity. Moritz (1942) has described six varieties of hepatic laceration, but such a differentiation is of little practical use. The liver may show one or more linear cracks, most often on the convex upper surface, which may be of any severity from superficial subcapsular tears to complete transection of the organ. Not infrequently, several roughly parallel tears are seen on the upper surface, obviously from the same type of mechanical stress. The surface lacerations may extend deeply into the liver and may even appear on the opposite surface. Occasionally, there may be internal tears that do not communicate with the surface. As in the spleen, a subcapsular haematoma can reach a large size before bursting into the peritoneal cavity, causing a delay in collapse or death.

Infants readily suffer liver damage from trauma and it is a well-known component of the child abuse syndrome. Liver tears can occur during the process of birth, particularly in breech presentation.

- Injuries to the kidney. Being deeply situated at the back of the abdomen in the paravertebral gutter, the kidneys are rarely damaged by frontal trauma, but may be involved in kicks or heavy blows to the loin. Traffic impacts, mainly in pedestrians, can damage the kidney, but kicking is another cause of this rather uncommon injury. When a victim is lying on the ground, a swinging boot can conveniently enter the slightly raised arch between the rib margin and hip, where the kidney is situated.

Perirenal haemorrhage is much more common than damage to the actual organs themselves, but when they are injured, all grades of damage from comminuted pulping through transection to shallow surface lacerations may be seen. Like the mesentery and spleen, damage to vessels may lead to post-injury infarction. The suprarenal vessels can be damaged by impact and, statistically, the right suprarenal artery is more often involved in traffic accidents in Britain because the direction of traffic tends to favour lesions on that side. It is, however, difficult to differentiate direct trauma to the suprarenal vessels from the common post-stress haemorrhages, often bilateral, of the Waterhouse–Frederichsen type. These occur quite commonly a few days after any trauma, surgical operation or infection, and are rarely diagnosed by clinicians (Knight 1980) (see Chapter 13).

FOREIGN BODIES IN THE GUT

Though not usually a feature of trauma, foreign bodies and material are not infrequently found in the alimentary system in forensic practice, both clinically and at autopsy.

Disorders of the mental state may lead to extraordinary numbers of objects being swallowed, which may be present anywhere from mouth to anus, but especially in the stomach. Betz *et al.* (1994) describe two such deaths, where, in one, 2000 cm^3 of debris, including broken glass, was in the alimentary tract; the other suffered intestinal obstruction due to ingestion of a large quantity of his own hair.

Similar aberrations may lead to insertion of foreign objects into the rectum, urethra, bladder and vagina. The authors have seen large objects of various types, e.g. potatoes in the rectum, lengths of broom handle and wood in the colon (one penetrating the liver) and a banana and a beer can in the vagina. Sexual perversions, masturbation and heterosexual or homosexual activities may account for these, as well as frank mental abnormality.

In recent years, the smuggling of narcotics through ports and airports has commonly been accomplished by 'body-packing', the drugs being concealed in condoms, which are then either swallowed or, less often, inserted into the rectum or vagina. Deaths have occurred in these body-packers, usually by rupture of a package within the gut, so that a massive dose of heroin or cocaine is released with all the attendant toxic effects. Rarely, the mass of illicit material may cause intestinal obstruction, leading to a surgical emergency, which the carrier does not wish to be investigated, for obvious reasons.

INJURIES TO THE PELVIS AND PELVIC ORGANS

The bony pelvis suffers a variety of fractures and dislocations in severe trauma:

- Where great pressure is applied to the front of the abdomen or pubic area – as in running over by a vehicle wheel – the pelvis may be splayed open, the symphysis parting and one or both sacroiliac joints becoming dislocated.
- An impact from the side may shatter the superior and, less often, the inferior pubic ramus, and again dislocate the sacroiliac joint on that side.
- A fall from a height onto the feet may transmit the force up the legs either to dislocate the hips or even to drive one or both femoral heads through the acetabulum. If the hip joints remain intact, the pelvic girdle may crack and again the sacroiliac joints may be sheared apart.
- A kick or heavy fall onto the base of the spine may fracture the coccyx or sacrum.

The pelvic organs with the exception of the bladder are generally protected from all but the most severe trauma. When it is full, the bladder can be ruptured by heavy blows or kicks on the lower abdomen. The empty bladder is rarely injured by blunt trauma. The male urethra is also vulnerable to direct trauma, such as falling astride a solid object like a gate, or being kicked in the crutch, both of which compress the urethra against the undersurface of the pubis.

The external genitals may suffer injury, apart from the sexual assaults discussed in Chapter 18. The scrotum is vulnerable to severe bruising, especially from kicks: a large haematocele may develop. Scrotal and vulval injuries can occur from falling astride an object or in traffic accidents. Impact of a bicycle wheel between the legs is one such cause.

COMPLICATIONS OF ABDOMINAL INJURY

The most common fatal sequel to intra-abdominal trauma is haemorrhage from any of the contained organs. The spleen and mesentery tend to bleed most copiously and quickly, though even here there can be a delay of many hours before serious symptoms are obvious – and, in the case of a subcapsular laceration of the spleen, the time can be far longer. The liver tends to ooze more slowly unless a major injury opens a large vessel or an extensive area of hepatic tissue.

The mesentery contains numerous blood vessels that are not covered by parenchymatous tissue as in the liver or spleen, so bleeding is usually brisk from significant tears – although, as illustrated by the case described above, even this injury can lead to delayed death.

Because all bleeding in the abdomen, unless it is from a wound of the aorta, takes time to accumulate, restriction of the victim's activity immediately after the injury need be minimal or absent unless there are other factors involved. It is never safe for a pathologist to declare that rapid immobility must have ensued, unless there are other gross injuries.

As mentioned in relation to intrathoracic bleeding, some of the blood found at autopsy within the peritoneal cavity may have accumulated there after death, adding to the true ante-mortem volume.

In spite of common surgical experience, even severe intra-abdominal injuries leading to bleeding need not necessarily be painful, especially in the commonly associated circumstance of the victim being under the influence of alcohol.

Perforation of the gastrointestinal canal is another serious complication of trauma, though often death ensues from the totality of injuries before infection can become established. As in natural perforated peptic ulcer, penetration of the stomach or duodenum will cause a chemical peritonitis that can be a cause of severe and immediate shock – perhaps a major factor in a rapid death. Rupture of the small or large intestine is less damaging but, if survival continues, will inevitably lead to generalized peritonitis unless vigorously treated. Open wounds of the abdomen, including stabbing, will introduce organisms from the outside into the peritoneal cavity. In addition to infection, trauma to the intestine may cause an intractable ileus; if the pancreas is damaged, there may be widespread fat necrosis in the mesentery and omentum.

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CHAPTER 7

Self-inflicted injury

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Injuries that are deliberately self-inflicted are common and their examination is a frequent task for both pathologists and clinical forensic practitioners. These events consist of suicide, attempted suicide and suicidal gestures, the latter lacking the intention to kill though death may inadvertently ensue. In addition, there is non-suicidal self-inflicted trauma, as described below.

One of the most difficult decisions that can face pathologists, medical examiners and legal authorities, such as coroners, is the differentiation between homicide, suicide, accident and other self-inflicted injury. Though it is not the legal function of a pathologist to attribute motive, his experience and training are often the factors that lead the official authority to make a decision as to the classification of the manner of death or injury. One such situation is fatal auto-erotic activities, described in Chapter 15.

In addition, when a pathologist is assisting the police in the early stages of a death investigation, his opinion and decision about the manner of the death may be crucial in initiating or aborting a homicide investigation – an onerous decision which may have serious and expensive consequences if wrong. It is therefore a most important function of the forensic pathologist to decide on the evidence of a death scene and subsequent autopsy whether murder, suicide or accident is the most likely explanation.

Self-inflicted injury, when not suicidal, is often not fatal and the pathologist is usually not consulted unless he also includes clinical forensic medicine in his work. The pathologist may, however, be asked for his opinion, as he is a specialist in trauma and may be able to provide the most useful opinion available. In other cases, self-inflicted injury, which the victim did not intend to be fatal, may end in death from a variety of causes and thus the pathologist will be directly involved.

SUICIDAL INJURIES

This discussion is confined to physical trauma, self-poisoning being considered later in the book.

Suicides may injure themselves in many different ways, some bizarre in the extreme. The pathologist must always be alert to the possibility that such injuries are not true suicides, but some manifestation of peculiar practices that have taken a course unintended by the victim. A prime example is masochistic asphyxia, which is still sometimes mistaken for suicide (Chapter 15). Even more serious is the homicide that appears to be a suicide, though the reverse also occurs.

Suicides, apart from poisoning, may use one (or even more) of the following methods, though the list is by no means exclusive:

- stabbing and cutting
- firearms and explosives
- jumping from a height
- jumping into water
- burning
- suffocation, e.g. plastic bag
- hanging and strangulation
- electrocution
- road and railway injuries.

Most of these modes are discussed in the appropriate chapters.

Suicidal knife wounds

Many incised and stab wounds are self-inflicted, either from motives of self-destruction, from mental aberrations or deliberately for some form of gain. These must be differentiated from each other, and from accidental and homicidal wounding.

Sometimes the distinction may be difficult and even impossible, but the experience of the forensic pathologist is paramount in assisting investigative agencies to come to the correct conclusion. Suicide, attempted suicide and suicidal gestures commonly employ cutting weapons as the means of injury. There are certain features that are quite reliable pointers to these motives, though they are by no means infallible:

- Suicidal knife wounds favour certain 'sites of election', which are predominantly the throat, the wrists and the front of the chest. As with most violent methods, cut throat and chest stabbing is predominantly seen in men – though cutting wrists is not uncommon in women.
- Suicidal wounds are typically multiple, often being characterized by a number of preliminary trial cuts, called 'tentative incisions'. These are most often seen on the throat and wrists, where the person often makes a series of shallow incisions, presumably hesitating while gaining courage to make a final decisive cut. In many suicidal attempts the subject abandons this method after a few trial incisions and uses some other method of self-destruction. Although the presence of tentative incisions is strong presumptive evidence of suicide, exceptions do occur, and the pathologist must take all other aspects of the scene into account before giving an opinion to the investigators. In fact, the almost absolute statements of some older textbooks that tentative incisions must indicate suicide, is to be disregarded. The author (BK) has dealt with two recent murders in which 'typical' suicidal injuries were present on wrist or throat causing considerable doubt to the investigators until other factors clarified the situation.
- A suicidal cut throat usually has these trial incisions; there may be only one or two, or there may be scores of trial cuts. If successful, there will be one or more deep incisions superimposed, which may destroy some of the previous shallow cuts. The classical description of the cut throat is of incisions starting high on the left side of the neck below the angle of the jaw, which pass obliquely across the front of the neck to end at a lower level on the right. This assumes that the victim is right-handed, the obliquity being reversed in a left-handed person. The cuts are said to be deeper at their origin, becoming shallower as they cross the throat, tailing off into surface cuts at the extremity.

  This description, though hallowed by repetition in many textbooks, is often incorrect and many cut throats have horizontal cuts that show no variation in depth at either end. Most suicides appear to raise the chin to provide better access to the throat, so that the skin is stretched when cut. This tends to cause straight-edged incisions, rather than the jagged cut (the so-called 'dentele' toothed incision) seen when a knife is drawn over loose skin. Throwing back the head moves the carotid bundle under the protection of the sternomastoid muscles and, if the cuts are confined to the centre of the front of the neck, only the larynx or trachea may be damaged, rather than large blood vessels.

  Death from a cut throat depends on the nature and extent of local damage to the neck. Severe haemorrhage

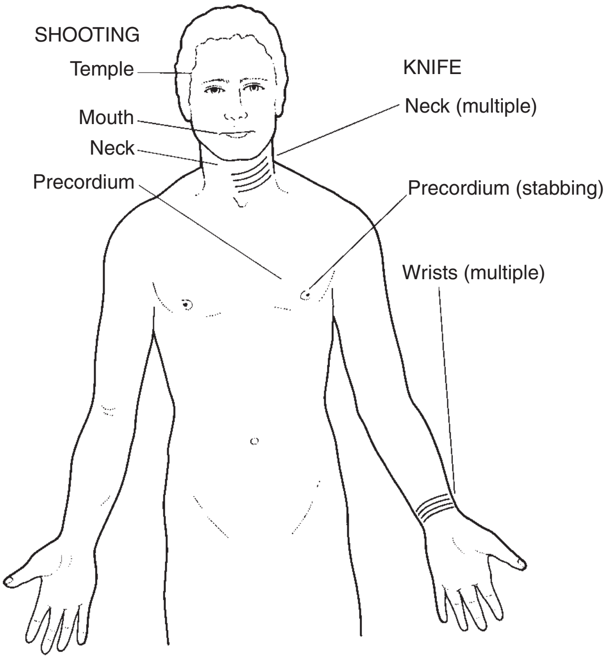

FIGURE 7.1 *Sites of election in violent suicide.*

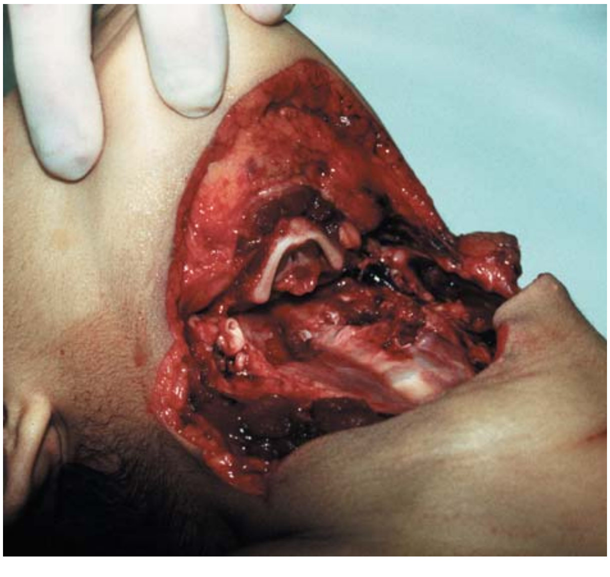

FIGURE 7.2 *Homicidal cut throat, showing single slash with no tentative cuts. Clean-cut edges with no sign of repetitive strokes, severing muscles, larynx and some large vessels.*

from the jugular veins, or less often the carotid arteries, may lead to death from exsanguination. If the larynx or trachea is opened, then even relatively minor haemorrhage from local vessels may cause blockage of the airways by blood and clot, though many slashed air-passage victims survive. A rare cause of death is air embolism, caused by aspiration into cut jugular veins while standing or sitting with the neck at a higher level than the thorax. The possibility that the victim of a cut throat may have died from some unrelated cause must always be borne in mind. Many suicides either use multiple methods of suicide to ensure success – or may abandon the pain of a cut throat for some other mode, such as poison or a fall from a height.

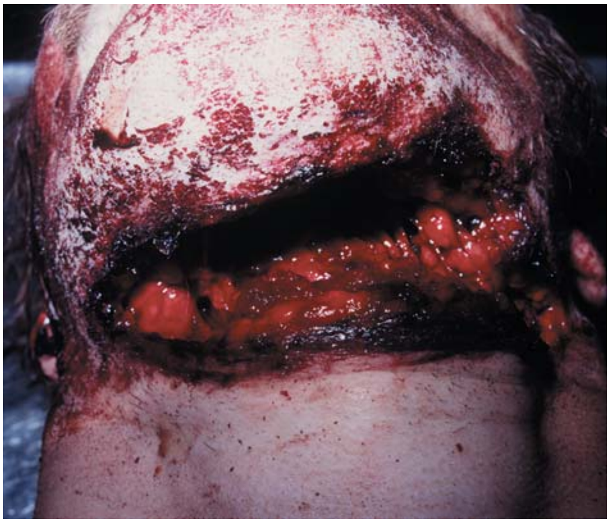

FIGURE 7.3 *Gaping laceration in front of neck of a mental patient, who on leave from a psychiatric hospital, had used a frame saw to commit suicide (see also Figure 7.4).*

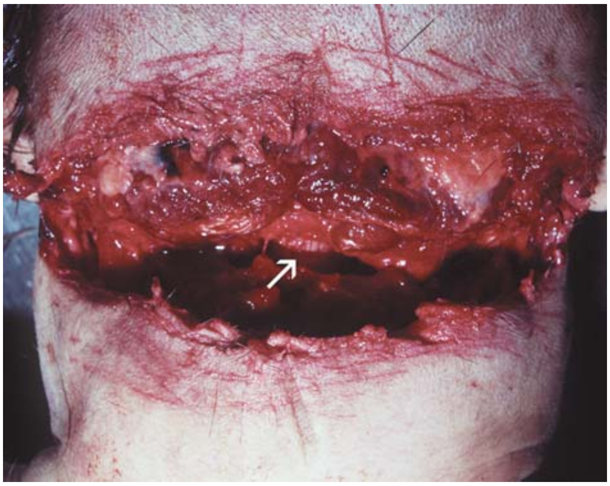

FIGURE 7.4 *Back of neck showing marks of the saw teeth around the laceration and medulla at the bottom (arrow). Mental patient who, on leave from a psychiatric hospital, had used a frame saw to commit suicide (see also Figure 7.3).*

- Deliberate cutting of the wrists is rarely effective as the sole method of suicide, but it is a common injury. Many suicides from other causes are seen at autopsy to have scars on the wrists from previous unsuccessful attempts or gestures. The usual site is on the flexor surface at the level of the skin flexion creases. As with the neck, there may be a number of shallow tentative incisions, but commonly several deep gashes are made without trial cuts. The left wrist is the more common target, because of right-handed dominance (86 per cent in men, 93 per cent in women).

As with the neck, there is a tendency for the victim to hyperextend the wrist before making the cut, which causes the radial artery to slip into the shelter of the lower end of the radius. The knife cuts may then miss major blood vessels and merely divide flexor tendons, though many cuts are too shallow to cause anything

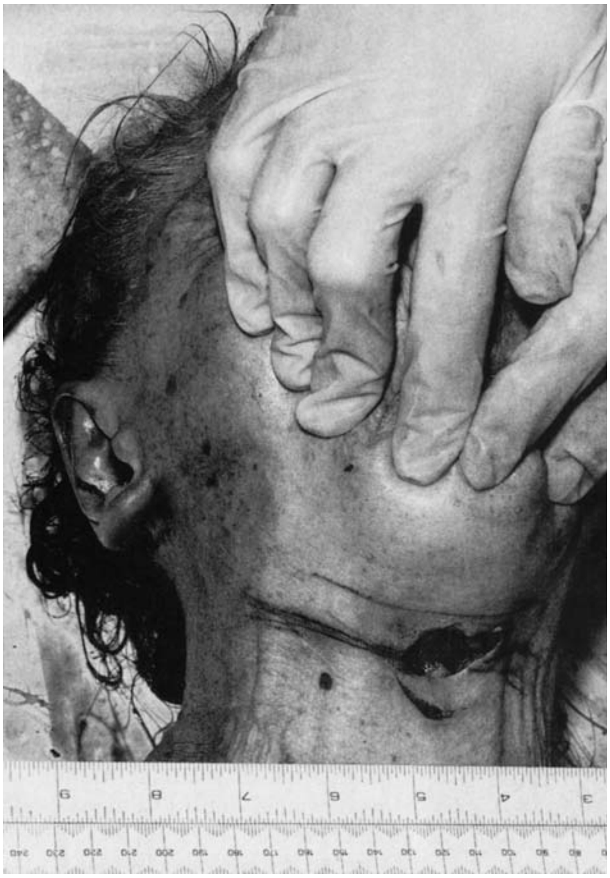

FIGURE 7.5 *Homicidal cut throat, simulating a suicide. There are several apparently 'tentative cuts', but the deep penetrating central laceration and adjacent stab wound is atypical. The face is congested and shows some petechiae from prior pressure on the neck.*

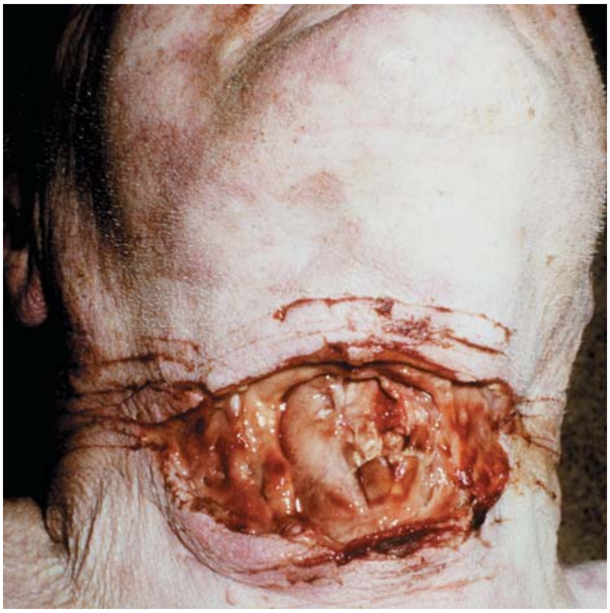

FIGURE 7.6 *Suicidal cut throat. The wounds are horizontal, rather than the more common sloping-down from left to right in a right-handed person. The numerous 'tentative cuts' are the hallmark of self-infliction, though there are rare exceptions. The larynx has been entered and death was due to aspiration of blood into the air passages. The great vessels in the neck were undamaged.*

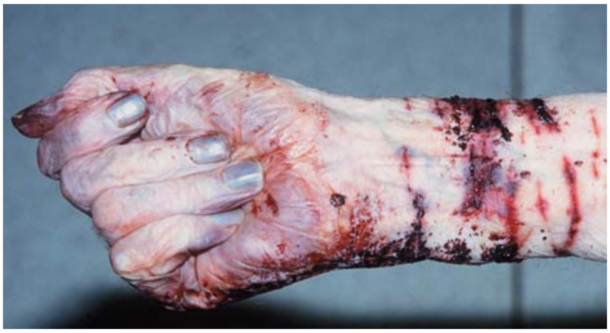

FIGURE 7.7 *Numerous self-inflicted cuts on the wrist, as part of a futile suicide attempt. Most of these attempts fail and the person turns to another method of self-destruction.*

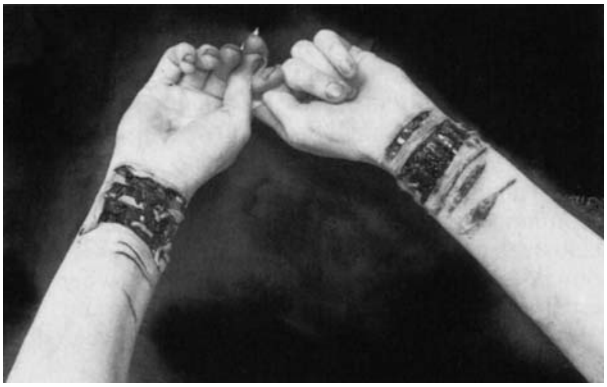

FIGURE 7.8 *Knife wounds of wrists in a suicidal attempt. Even though these are more severe than usually seen, no damage to the radial arteries was effected and death was the result of a subsequent cut throat. The victim was a woman of 31, unusual in that cut wrists and throat are much more common among men.*

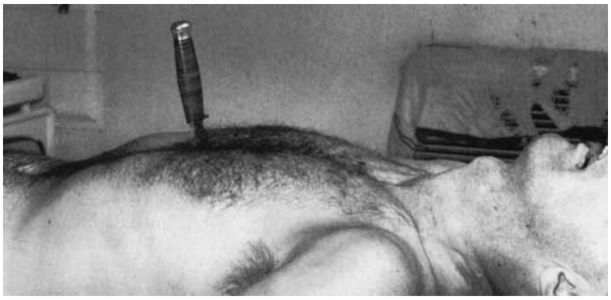

FIGURE 7.9 *Suicidal stab wound of heart. The front of the chest is one of the suicidal sites of predilection; multiple stabs do not exclude self-infliction.*

but superficial damage. Most cut wrists are but an accompaniment to other more effective methods of self-destruction. Once again, the presence of tentative cuts, though very significant, cannot be unquestioningly accepted as an exclusion of homicide.

- Suicidal injuries of the chest are almost always stab wounds. Sometimes linear incised cuts are made over the precordium or more widely over the front of the chest; these may be multiple, parallel and sometimes criss-cross, but rarely do any serious damage. Stab wounds are usually over the left side of the chest where common knowledge places the heart, but they may be alongside the sternum or even on the right side. The wound is often single, but multiple wounds are not uncommon. Though naturally a series of severe wounds always raises the presumption of homicide, many undoubted suicides can inflict a number of injuries upon themselves, each potentially fatal. The author (BK) has seen a suicide in a doctor, where eight severe knife wounds of the lower chest had created a large external defect and detached a portion of liver.

  Suicidal knife wounds are not often made in the abdomen, though they do occur, sometimes to the extent of disembowelling. The author (PS) has seen a suicide of a person, who removed several meters of the gut through a single and relatively small incision before dying of exsanguination. There is usually frank mental abnormality present in these cases, which merge into the self-mutilation described below.
- Stab wounds of the neck are uncommon in suicide, but are recorded (such as those described by Gee and Watson 1989, where actual transfixion of the neck was achieved).

- The position of the clothing in suicidal knife wounds is equivocal. It is more common for the self-stabber to lift the garments to expose the area of chest or abdominal skin to be attacked, but exceptions are common and the point has little diagnostic significance.

Suicidal firearm wounds

The characteristics of gunshot wounds are fully discussed in Chapter 8 but, as far as suicide is concerned, the following salient features may be repeated:

- Women rarely shoot themselves. In Britain, a shot woman is a murdered woman until proved otherwise, though – as always – exceptions do occur, especially in communities where firearms are commonplace, such as farming or hunting areas.
- The weapon must always be present.
- The range must be within arm's length, depending upon the nature of the weapon and excluding some mechanical device to fire the gun. The pathologist may be asked if a dead person could have reached the trigger of a rifle or long shotgun, which may have been placed against the neck, head or chest. Having first established that the entry wound was close contact, the length of the gun from muzzle to trigger can be measured and compared with the distance from wound to tip of finger. It must be remembered, however, that the length of the limb after death, especially if rigor is present, is not necessarily the same as in life when mobile joints and muscles may have allowed a slightly longer reach than that measured after death. Allowance must also be made for lateral or other flexion of the trunk, and mobility of the shoulder girdle before declaring dogmatically that the victim could not have fired the gun and therefore did not shoot himself.
- Sites of election are the temple, the neck, the mouth and the chest. Suicides rarely shoot themselves in the eye or abdomen. The lifting of clothing to expose bare skin, usually in the chest, is very variable, and has even less significance in differentiating suicide from homicide or accident than in knife wounds.
- Shooting in anatomically inaccessible sites cannot be suicide.
- It is not true that suicides always shoot themselves in the head on the same side as their dominant hand.
- It is difficult to differentiate homicide from accident, even though the circumstances may be suggestive. The distance of discharge may be beyond arm's reach in both, the weapon may be missing in both, inaccessible sites may be shot in both and sites of suicidal election may not be used in both.

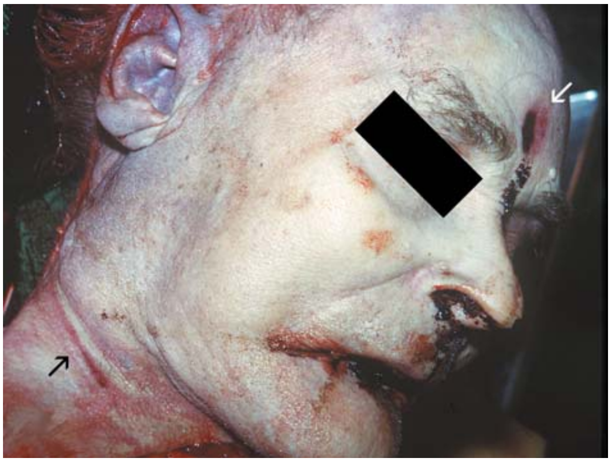
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FIGURE 7.10 *A combination of two suicide methods, by firearm and hanging. The man had stood on a stool with a noose around his neck and then shot himself through the forehead. The entrance wound is seen in the forehead (white arrow) and the double ligature mark around the neck shows ecchymoses on the ridge between the two furrows (black arrow).*

Suicide by submersion

This is a common mode of self-destruction, in both men and women. It has a marked geographical variation as a favoured method of self-destruction, naturally depending on the availability of water – it is relatively infrequent in Egypt, but very common in the west of Ireland.

Either large bodies of water, such as rivers, lakes or seas may be used – or the bathtub. The pathology of immersion deaths are dealt with in Chapter 16, but the following features will assist identifying suicides:

- Other means of self-destruction may also be present, such as drug overdose: in baths, associated electrocution is not uncommon, especially in the former West Germany (Bonte 1983).
- Suicide notes may or may not be present, but those who kill themselves usually remove top clothes, hats and spectacles that may be left on the river bank; as usual, exceptions are commonplace.
- Other injuries on the body may be the result of agonal or post-mortem damage in the water.

Suicide by burning

Heat injuries are dealt with in Chapter 11, but suicide from burns has recently increased in Western countries (where it was formerly almost unknown), though in Asia it has always been relatively common. The spread to the West followed political self-martyrdom modelled on that practised by some Vietnamese protesters. There are no particular medical features to distinguish suicide from accident or homicide, this being a circumstantial matter. It is almost invariable, however, for some container of inflammable accelerant to be within reach. The myth of 'spontaneous combustion' is discussed in Chapter 11.

Suicide by 'asphyxia'

The pathology is described in Chapters 14 and 15, but the following facts are pertinent to suicide:

- The masochistic or sexual asphyxias must be carefully distinguished from homicide and suicide. Some asphyxial deaths with sexual aspects appear to be suicidal in nature – or at least, the inevitability of a fatal outcome must have been apparent to the victim (Knight 1979).
- Hanging, though not usually truly asphyxial, is a common mode of suicide, especially (though not exclusively) in men. It is also common as a sequel to homicide, especially in domestic murders, where the perpetrator often commits suicide by this means.
- Plastic bag suicide is increasing in incidence, the means being universally available.
- Suicidal ligature strangulation is not uncommon and sometimes causes difficulty in differentiation from murder. The winding of several turns of ligature and the tying of multiple knots is still consistent with suicide, even though it is hard to understand how, in some cases, death appears to have been caused by reflex cardiac arrest rather than the more florid 'asphyxial' mode of death.

  Sometimes a stick or other object is inserted under a ligature and twisted to tighten the cord against the neck. This is called a 'Spanish windlass', the stick becoming jammed against the body to prevent the tightened ligature from becoming loose once the twisting is completed. Though usually suicidal, this device is sometimes used for murder.

Jumping from a height

'Precipitation' – jumping from a height – is another mode of suicide where the circumstances rather than the autopsy findings determine the motivation. It may sometimes be possible to deduce, by measuring the distance from the jumping point to where the body strikes the ground, the fact that the victim must have actively projected himself outwards rather than fallen close to the wall or cliff face. Some experiments on this aspect have been carried out (Goonetilleke 1980). The injuries may be variable, depending on the attitude of the body when striking the ground, contact with obstacles during the fall and the height of the drop.

Head injuries are common and are described in Chapter 5. If the fall is onto the feet, damage may occur at any point from the ankles to the skull. The legs may fracture, the hip joints may impact, the pelvis may split, the spine may be fractured (especially vertebral body compression, hyperflexion or hyperextension lesions), or the base of the skull may be imploded as a ring fracture.

It is extremely difficult, to the point of impossibility, to deduce the height of the fall from the nature and severity of the injuries, as was evident from the medical testimony in the Helen Smith inquest in Leeds in 1982.

Some persons will be killed from a fall from a standing height, whilst other may make remarkable escapes without injury from a very high fall. The rare survivals in falls from a great height – usually when some cushioning effect, such as snow, exists – may still defy mechanical explanation.

SELF-INFLICTED INJURIES OTHER THAN SUICIDE

Two main classes exist: those where some abnormality of mind leads the victim to mutilate his body – and those in which deliberate injuries are inflicted for motives of gain. Those caused by mental aberration are usually bizarre in either their multiplicity or their site.

Some mentally disordered persons may inflict hundreds of small wounds upon themselves, which may be additional to the actual cause of death, if death has taken place. Forensic physicians, such as police surgeons, may be called upon to examine living victims of this type.

The arms may be covered with scores of parallel superficial incisions from a knife, razor or broken glass. These may cross each other in groups and again are more frequent on the non-dominant side, usually the left. Small stabs may be made on the chest or temples. In a case seen by the author (BK), there were more than 200 knife-point stabs on each temple and the centre of the forehead. Another well-recognized syndrome is self-mutilation of the genitals, almost invariably by men. Paranoid schizophrenics, often with a strong religious flavour to their delusions, are known to attack themselves in this manner. The penis, scrotum and testes may be removed, and death from intractable haemorrhage can follow. In one of the cases illustrated, there was also perforation of the eyeballs and 40 stab wounds on the top of the head, as well as a complete circumferential cutting of the throat, all with the same blunt scissors that performed the castration. The forensic implications arose from

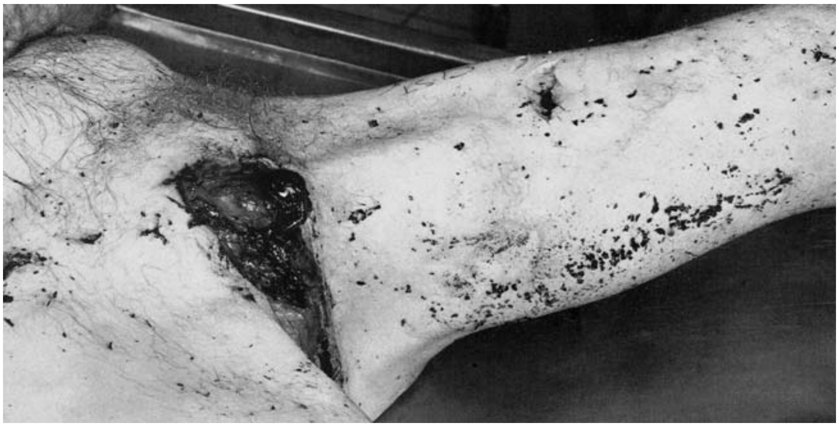

FIGURE 7.11 *Complete self-amputation of the scrotum and penis with scissors.*

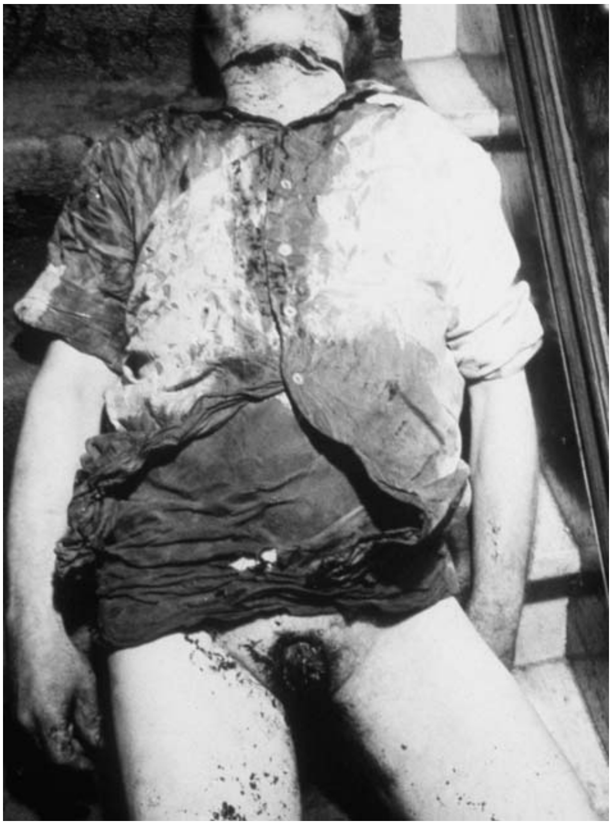

FIGURE 7.12 *Self-mutilation thought by the police to be a bizarre homicide. The genitals have been amputated, the throat cut through 360°, the eyeballs punctured and the scalp stabbed many times, all with scissors. The dead man had paranoid delusions of a religious nature.*

the initial suspicions of the police that a sadistic homicide had taken place.

Self-inflicted injuries, usually non-fatal unless some complication has arisen, may be motivated by some form of gain. The most common is fabrication of injuries to simulate an assault, either to divert attention from the person's own theft or to arouse sympathy. Fabricated accidental injuries are usually a form of malingering, as in the armed forces, or in fraudulent attempts to obtain compensation. In other cases, the 'victim' may claim that a specific person assaulted them, from motives of hate or spite. Others may injure themselves and then waste police time by insisting on a futile search for a non-existent assailant, the motive often being impossible to discover, even by a psychiatrist.

Though these matters are usually seen by the clinical forensic physician, the pathologist may be asked for an opinion where no other medico-legal doctor is available, or if death supervenes. The so-called 'Münchausen syndrome' consists of repeated simulations of illness or the infliction of repeated minor injuries, with the object of gaining admission to hospital, or obtaining medical care and attention.

The following features assist in the recognition of self-inflicted incised injuries:

- The cuts are usually superficial and rarely any danger to life, unless they become infected. Occasionally, they may penetrate the full thickness of the skin, but not in sensitive areas like the face.
- The incisions are regular, with an equal depth at origin and termination, unlike more serious wounds that tend to be deeper at the start and tail off to the surface.
- The cuts are usually multiple and often parallel. They avoid vital and sensitive areas like the eyes, lips, nose and ears, usually being drawn on the cheeks and jaws, temples and forehead, sides of the neck, chest, shoulders, arms and backs of hands and thighs. This is inconsistent with an attack by another person, as the victim is unlikely to stand still to allow these multiple delicate and uniform injuries to be carefully executed.
- In right-handed persons, most of the injuries are on the left side, especially the sides of the face and left hand.
- When the incisions are made on areas covered by clothing, the relevant garments may show either no cuts or cuts that do not match the injuries in position or direction.

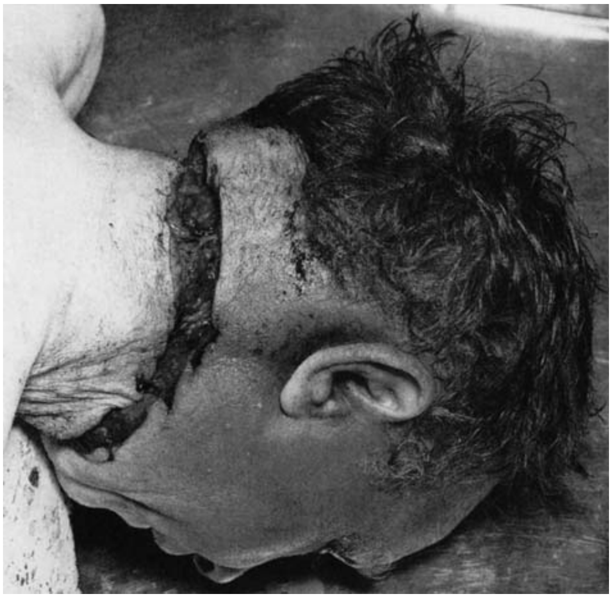

FIGURE 7.13 *Self-inflicted scissors injury around the full circumference of the neck.*

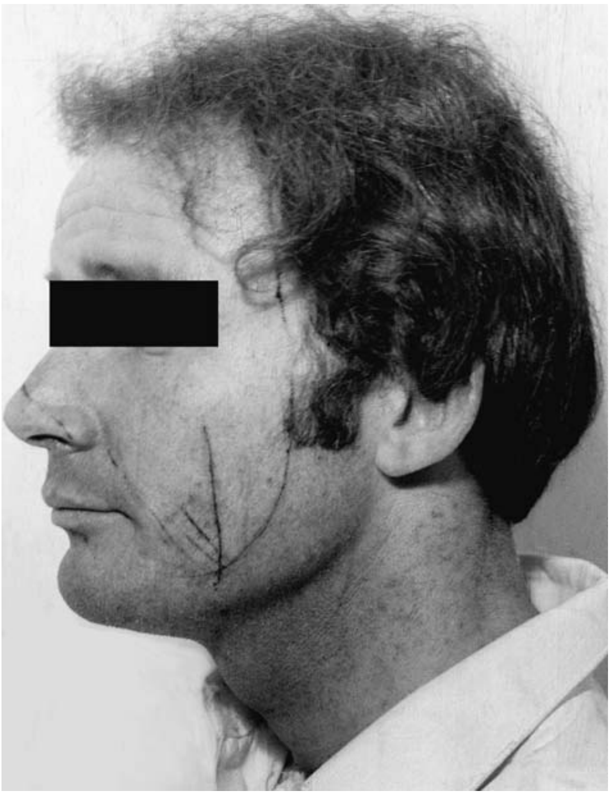

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FIGURE 7.14 *Self-inflicted injury in an attempt to produce an excuse during shop-breaking. Surprised by the police, he cut himself with broken glass to claim that he had been assaulted by the robbers whilst trying to defend the premises. There were similar shallow, straight cuts on the other side of the face and on the backs of the hands.*

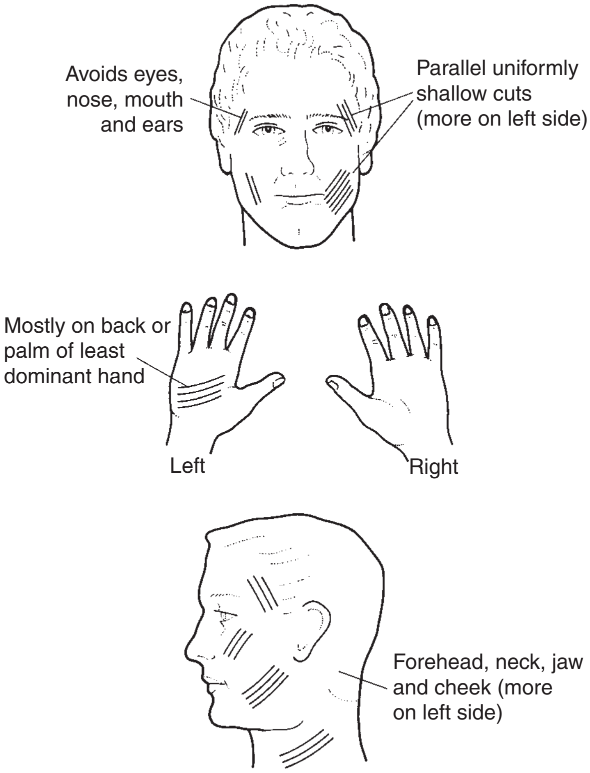
Avoids eyes, nose, mouth and ears
Parallel uniformly shallow cuts (more on left side)
Mostly on back or palm of least dominant hand
Left
Right
Forehead, neck, jaw and cheek (more on left side)

FIGURE 7.15 *Characteristics of non-fatal self-inflicted injuries.*

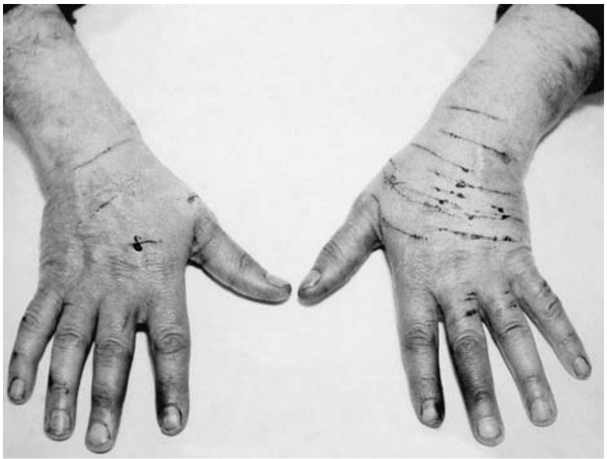

FIGURE 7.16 *Cuts on the backs of the hands in the man shown in Figure 7.14. He was right handed and most of the shallow incisions are on the left hand.*

In summary, the whole range of injuries and surrounding circumstances may suggest to the experienced pathologist that the lesions do not constitute a genuine assault. This diagnosis may be virtually immediate on first looking at the 'victim' and may be almost intuitive after some experience – though this is of little use when giving legal testimony, when every opinion has to be backed up by hard fact and reasoned opinion.

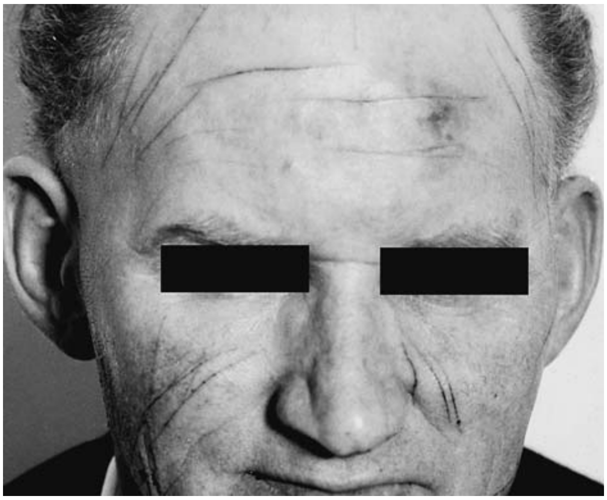

FIGURE 7.17 *Self-inflicted injury in the living. The 'victim' alleged that he had been attacked and robbed. The superficial, uniform, mostly parallel scratches avoid the eyes, nose and mouth.*

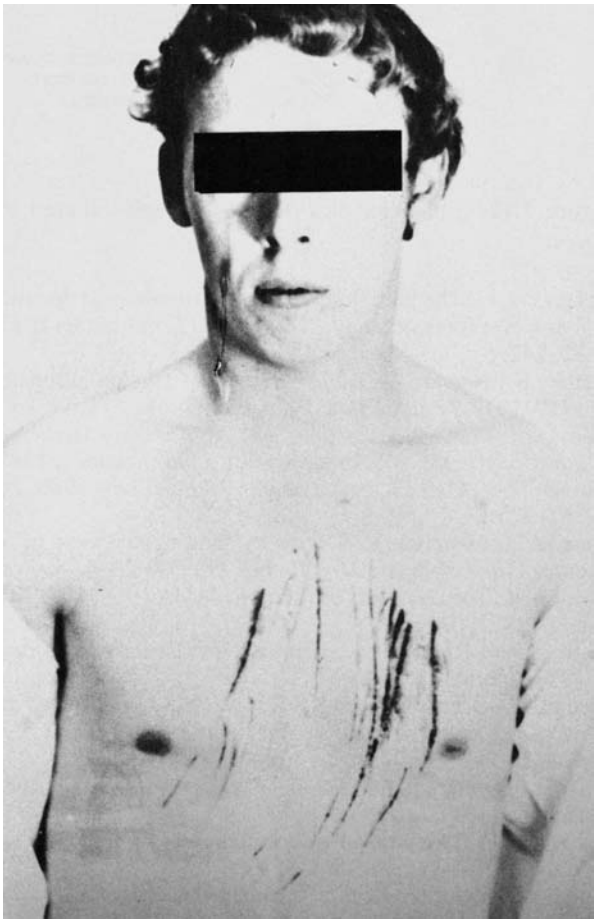

FIGURE 7.18 *Extensive self-inflicted cuts on the chest. The youth persistently claimed to the police that he had been attacked, but the cuts in his shirt were horizontal. He later confessed, explaining that he wanted to get his father's sympathy over some domestic crisis.*

The so-called 'Münchausen syndrome' and the 'Münchausen syndrome by proxy' lie within the realm of the forensic psychiatrist, but a pathologist or clinical forensic physician may be called upon to confirm – or even first detect – that the injuries are self-inflicted.

The Münchausen syndrome refers to adults who injure themselves or feign signs of illness, in order to gain medical attention and often admission to hospital. They can be a plague to casualty departments until recognized. More sinister is the Münchausen syndrome by proxy, where a parent will repetitively injure her child – occasionally fatally – to gain the same attention from doctors and medical facilities. The relationship with child abuse, of which it is a variety, must be recognized.

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CHAPTER 8

Gunshot and explosion deaths

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Though the majority of missile wounds are caused by firearms, other devices such as crossbows, captive-bolt guns, air weapons and even catapults can launch lethal projectiles. In the bombing deaths now so commonly associated with terrorism, missile fragments cause more deaths than the blast effects, so, overall, an understanding of projectile trauma is essential.

THE MECHANICS OF MISSILE INJURY

With the exception of deceleration injuries, all mechanical trauma, whether punching, stabbing or kicking, is caused by the transfer of energy from an external moving object to the tissues and nowhere is this more obvious than in shooting. For damage to occur, some or all of the kinetic energy of the missile has to be absorbed by the target tissues, where it is dissipated as heat, noise and mechanical disruption. When a missile passes completely through soft tissues, it may retain much of its original kinetic energy and fail to transfer any appreciable amount to the tissues, which may remain relatively intact apart from the immediate bullet track. If the latter is in a limb muscle, there may be no serious effects if major blood vessels are not involved, though the same track in brain, lung or heart may prove fatal.

To ensure transfer of energy to the tissues, some missiles are especially designed or modified to slow up or stop within the body. Soft-headed bullets will flatten on impact and some are designed to fragment. The ‘dumdum’ bullet, which has a scored nose, and the military missile with an air-cavity within the tip are intended to splay open on impact to increase the ‘braking’ or deceleration effect, and transfer more energy for disruption. Explosive-tipped bullets, such as those used in the assassination attempt on President Reagan, are not designed to cause damage by the tiny detonation, but drastically to deform the missile to cause maximum deceleration. Weapons designed to be fired in confined spaces, such as those for combating hijack attempts in an aircraft, may be of relatively low velocity and have a deceleration feature incorporated to ensure the absence of an exit wound, and thus limited travel of the missile to avoid puncture of the pressurized passenger cabin.

The trajectory of the missile also determines how much and how fast its energy is given up to the target. Shotgun pellets are spherical, so the orientation of impact is not relevant, but all conical bullets may acquire an erratic course in the tissues. They may tumble end-over-end, especially when nearing the limit of range; they may ‘wag’ or ‘yaw’ from side to side of their axial trajectory; the base may rotate around the axis, with the tip remaining on the straight path; and they may ‘precess’ or ‘nutate’ with complex spiral or circular movements about the axis.

Whatever the deviation, it offers more contact between the projectile and the tissues, allowing more transfer of energy and thus greater tissue damage. The amount of kinetic energy possessed by a projectile accords to the familiar formula of half the product of the missile mass and the square of its velocity. Modern military science takes advantage of the squaring of the velocity to develop weapons that have a missile of small mass but exceedingly high velocity to provide the maximum kinetic energy for tissue damage.

The mode of injury depends on the velocity of the missile. Relatively slow projectiles are those travelling at up to the speed of sound in air (340 metres/second or 1100 feet/second), which of course includes all non-explosively propelled missiles like crossbow bolts and air-rifle pellets, as well as most revolver bullets. These mechanically thrust aside the tissues along a track only slightly wider than the missile. The tissues are lacerated or crushed, secondary damage occurs from rupture of blood vessels and other structures, and secondary and tertiary damage is caused by displaced bone and cartilage fragments.

Above the speed of sound in air, a missile passing through tissue sends a shock wave of compression ahead of the laceration track, this wave being propagated at about the speed of sound in water (1500 metres/second or 4800 feet/second). Though this wave lasts only for a brief period, it raises the tissue pressure to extreme values, up to thousands of kilopascals. In tissues like brain, liver and muscle, this can cause severe disruption within a wide zone around the bullet track, and can be propagated down hollow fluid-containing vessels to cause distant vascular damage.

High-velocity projectiles produce yet another phenomenon, that of cavitation. The missile accelerates the molecules of the tissues adjacent to the track, so that they continue to move centrifugally outwards even after the missile has travelled onwards. This forms a cavity around the track that is far wider than the diameter of the projectile. It reaches a maximum size within milliseconds and then pulsates with decreasing amplitude so that a fusiform cavity rapidly follows in the wake of the bullet. When the bullet stops or leaves the organ, the cavity rapidly subsides, but the track of damage persists in a tubular zone much wider than the actual missile. In high-velocity bullets from military weapons – for example, 980 metres/second (3185 feet/second) this cavitation effect is the most damaging mechanism; in addition to the physical damage, the near-vacuum sucks infected dirt and clothing fibres into the depths of the wound (Owen-Smith 1981). Solid organs such as brain and liver are affected more than spongy matrices like lung. Those tissues that contain most water are most severely damaged by penetrating missiles and high-velocity missile damage is proportional to the specific gravity of the tissue injured.

In most of the shooting cases seen by forensic pathologists, death will have occurred rapidly but, where it is delayed, secondary damage from infarction, local necrosis of muscle and organs, and infection must always be borne in mind. High-velocity weapons in particular can cause vascular damage at a distance from direct trauma, stretching and thrombosis, leading in turn to ischaemic lesions such as infarcts.

TYPES OF WEAPON

The nature of firearm wounds varies considerably with the type of weapon employed. A general knowledge of the main features of the various types of gun in common use is essential, though there is no need for the pathologist to master the unnecessary mass of detail on firearm construction offered by some forensic medicine textbooks. Indeed, much of this is solely the province of the firearms examiner, not the doctor. The inordinate amount of detail sometimes provided is perhaps symptomatic of the fascination which firearms hold for many men – but rarely women.

In the context of wounding, guns are of two main types.

The smooth-bore weapon or ‘shotgun’

A shotgun consists of one or more metal barrels of relatively wide diameter, which are smooth on the inner surface. They fire a variable number of spherical lead shot (pellets), which emerge from the end (muzzle), from where they gradually diverge in the form of a long, narrow cone. Exceptionally, a shotgun may fire a few large projectiles or even a single slug, but these are rarely met with in forensic practice, the usual load of pellets totalling scores or hundreds. Special types of projectile are described later. A shotgun often has two barrels, either side by side or ‘up-and-under’. One barrel may be parallel sided (the ‘cylinder’) and the other slightly tapered towards the muzzle (the ‘choke’). The latter will produce a narrower cone of shot and this affects estimates of range derived from the size of the wound. There are several gradations of choke, such as ‘improved cylinder’, ‘modified choke’, ‘half-choke’ and ‘full-choke’.

Some modern weapons have the facility for removing one particular type of barrel and replacing it with another degree of choke. Modern accessories can convert a cylinder barrel to a choke barrel – for example, variable choke such as Poly-Choke, Kutts Compensator and Weaver-Choke are available, especially in the USA.

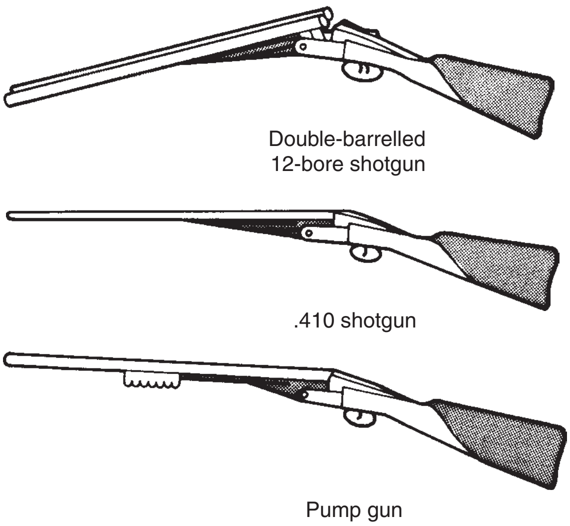

FIGURE 8.1 *Types of smooth-bore weapon.*

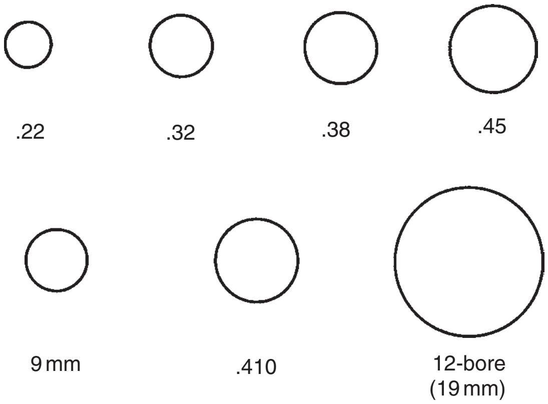

FIGURE 8.2 *Relative calibre of common weapons.*

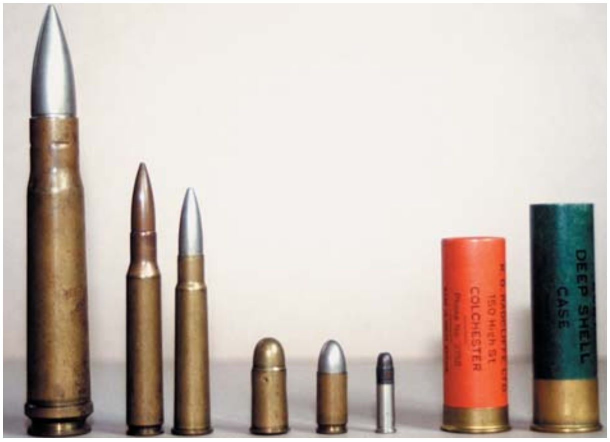

FIGURE 8.3 *Various types of ammunition. From the right, there are two twelve-bore shotgun cartridges, .22 rifle, .38 automatic pistol and .45 revolver bullets and two military rifle shells. On the left is a cannon shell, which is unlikely to be encountered in civilian forensic pathology.*

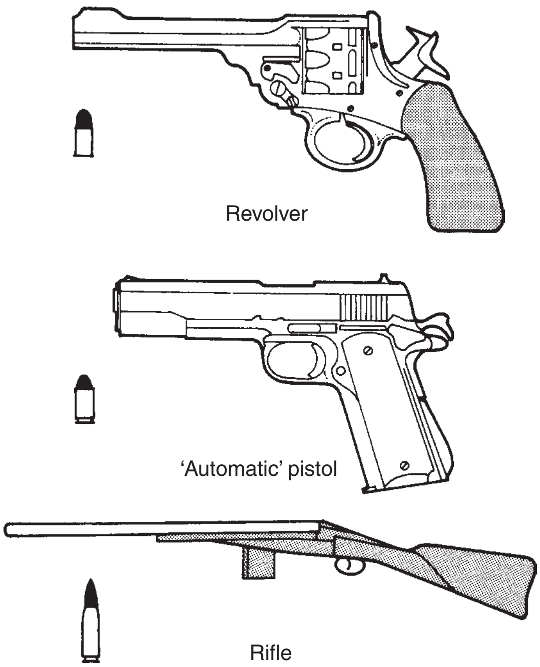

FIGURE 8.4 *Types of weapon and ammunition.*

Another typically American modification is the ability to fire a single projectile through the smooth bore. A number of devices intended for hunting are available, but they may be involved in a human fatality. One of the older types is the solid round 'pumpkin ball' or the Brenneke rifled slug, but more recent devices include the Foster rifled slug and the French Blondeau, which is a dumb-bell-shaped projectile.

Shotguns come in two main sizes, which determine the nature of the wound. The first is the 'twelve-bore', usually called 'twelve-gauge' in North America, which has a diameter of about 19 mm or 0.738 inches. The other is the smaller 'four-ten', usually single-barrelled with a diameter of 10.6 mm or 0.410 inches.

SHOTGUN AMMUNITION

The ammunition for the shotgun is a cartridge made of a cardboard or plastic cylinder fitted into a metal base. This carries a percussion detonator that is struck by the spring-loaded firing pin when the trigger is pulled. The cartridge contains a charge of propellant, above which are 'wads' or pistons of felt, and cardboard or plastic discs, or both. Above these is the charge of shot, which varies greatly in number and size, finally covered by a card or plastic disc.

This description is of the old, classical cartridge but modern ammunition has a variety of devices incorporated into the cartridge to improve efficiency and accuracy. These include the Power Piston, a proprietary name for one of a class of cartridges which holds the shot inside a polythene cup and which itself may contribute to the wound at short range. Other modern cartridges may have plastic granules as a filler between the shot; this brightly coloured material may be found inside the wounds.

Tampering with the contents of cartridges may markedly alter the spread and other characteristics of the shot and hence the resulting wound. The shot may be fused into a mass by pouring paraffin wax or even molten pitch into the cartridge. The cardboard or plastic cylinder may be partly cut through at the level of the wads, so that, on firing, the upper part of the casing is blown out to restrain the divergence of the pellets.

The propellant has also changed in recent years, so that the old black gunpowder has been largely replaced by cleaner explosives that do not produce the same volume of soot and unburnt propellant, which may be deposited in and around the close-range wound.

‘Country’ guns

In developing countries, in some rural and poor areas of other countries, in subversion and terrorism, and sometimes in juvenile hands, weapons and ammunition may be ‘home-made’. These are common in India, where the name ‘country gun’ is well understood; they are also made in Sri Lanka and other Asian areas, but may be encountered anywhere.

The author (BK) had experience of such weapons in the terrorist campaign in Malaya in the 1950s, where crude weapons were made in the jungle from pieces of water-pipe attached to roughly carved wooden stocks, with a primitive firing mechanism. The guns were muzzle-loaded with black powder and the projectiles were often wood-screws, nuts and bolts and irregular fragments of metal or even stones.

In civilian practice in Britain, two similar weapons have been seen, both made by juveniles out of electrical conduit pipe, using potassium chlorate–sugar propellant. In one, the user was killed when the device exploded; the other one successfully propelled a small screwdriver across several fields to (slightly) injure a cow.

Terrorists in Northern Ireland have also manufactured some of their own weapons, but these were relatively sophisticated, being made in clandestine but well-equipped workshops.

The problem for the pathologist with such guns is that few of the criteria to be described apply to the injuries, especially where random, irregular missiles such as wood-screws are employed. Local knowledge and experience are essential for the interpretation of these wounds.

The rifled weapon

Handguns, rifles, air rifles and military weapons differ from shotguns in that they fire one projectile at a time through a thicker barrel that has spiral grooves machined on its inner surface. The elevations between the grooves are the ‘lands’, which grip the bullet as it passes down the barrel and give it a rotatory movement. This has a gyroscopic effect that increases the stability of the bullet’s trajectory and hence the accuracy.

Handguns, which cause over 50 per cent of all homicides in the USA, comprise the revolver and the automatic pistol. The revolver has a rotating cylinder carrying a variable number of shells, which are brought into the firing position one by one, each time the trigger is pulled. The revolver has a low muzzle velocity of the order of 500 feet/second (150 metres/second). The ‘automatic’, more accurately called a ‘self-loading’ pistol, has its shells in a spring-loaded magazine, each spent round being ejected and a new one positioned by means of the gas pressure developed at each discharge. The muzzle velocity may be 1000–1200 feet/second (300–360 metres/second).

Rifles are long-barrelled guns that may be single-shot, bolt-loaded or self-loading and used for hunting, target-shooting or for military purposes. Military weapons come in a vast range of types, most of them now either ‘self-loading’, which means that the trigger has to be pulled for each shot – or truly ‘automatic’, when the weapon will continue to fire while the trigger is depressed until the magazine is empty. The muzzle velocity varies greatly, from 1500 to 5000 feet/second (450–1500 metres/second).

AMMUNITION FOR RIFLED WEAPONS

The variety of types of rifled ammunition is even greater than the range of weapons designed to fire them, but all conform to a general pattern. There is a metal cylinder, closed at one end, which is the ‘shell’ or cartridge, carrying a percussion detonator in the base, either centrally or peripherally. The shell is loaded with explosive propellant such as nitrocellulose and the bullet is firmly clamped into the open end. The bullet may be composed of a variety of metals, often compound. A lead core may be covered in a nickel or steel jacket, but there are many other variations. The detonator may contain elements such as barium, bismuth mercury or antimony.

Both shotgun and rifled weapon ammunition have a common purpose when detonated – to produce large volumes of hot gas under pressure that expel the bullet or shot from the barrel. One gram of black powder produces about 3000 ml and nitrocellulose produces some 13 000 ml of gas, which consists of carbon dioxide, monoxide, nitrogen, hydrogen sulphide, hydrogen, methane and many other substances, all at high temperatures.

WOUNDS

Though the construction and performance of weapons is of vital interest to the forensic firearms examiner, the relevance to the pathologist is concentrated in those aspects which affect the nature of the wound:

- whether the weapon is smooth-bore or rifled;
- if rifled, the muzzle velocity of the weapon;
- the nature of the projectile(s);
- the nature of the propellant;
- the degree of choke, if any;
- the range of discharge;
- the angle of discharge.

WOUNDS INFLICTED BY A SMOOTH-BORE SHOTGUN

The following constituents of the cartridge emerge on the discharge of a shotgun and all may contribute to the wound:

- lead pellets
- soot in the form of smoke and debris
- unburnt and burning propellant particles
- flame and hot gases under pressure
- carbon monoxide
- wads – either felt, cardboard or plastic
- detonator constituents
- fragments of the cartridge case.

When a shotgun is fired, a compact mass of shot emerges from the muzzle and then begins to disperse, the divergence increasing progressively as the distance lengthens. A tongue of flame and hot gas follows the shot. High pressure and temperature exists just outside the muzzle, but this rapidly expands and cools. This gas is composed of oxides of nitrogen, carbon dioxide, hot air and other compounds, but the one of interest to the pathologist is carbon monoxide. Soot from the combustion of propellant is expelled, along with some flakes or grains of propellant that may be still burning. The wads are also expelled, their nature depending upon the type of cartridge. Some modern ammunition may contain other devices that may contribute to the wound.

Chemical traces of the elements in the detonator or percussion cap cannot be seen, but may be vital laboratory evidence, where barium, antimony and other metals can be recovered on analysis or by means of the scanning electron microscope. Fragments of the cartridge case may also be ejected, especially if it has been tampered with, as described earlier.

The most important deduction that a pathologist is asked to make is the estimation of the range of discharge of the gun, as this may substantially influence the distinction between accident, suicide and homicide. The appearance of the wound is greatly modified by variation in range and it is convenient to describe them in terms of increasing range of discharge.

Shotgun contact wound

SHAPE

Where the muzzle is placed tightly against the surface of the abdomen, thorax, limb or neck, the consequent wound will

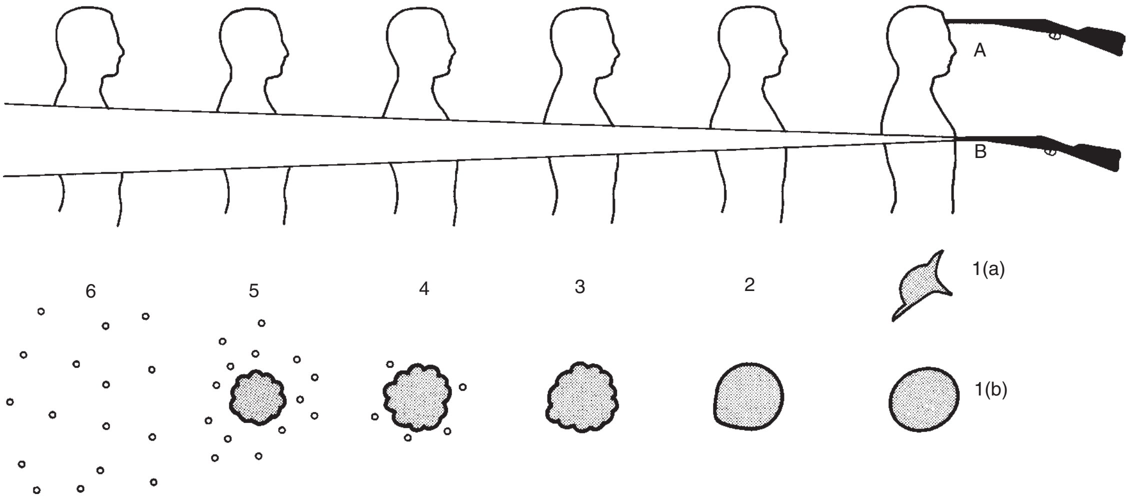

FIGURE 8.5 *Variation in appearance of a shotgun wound at increasing range of discharge: 1(a), split wound from contact over bone; 1(b), usual round contact wound; 2, close but not contact range up to about 30 cm (variable); 3, 'rat-hole' wound from 30 cm to about a metre (variable); 4, satellite pellet holes appearing over a metre; 5, spread of shot increases, central hole diminishes; 6, uniform spread with no central hole over about 10 m. All these ranges vary greatly with barrel choke, weapon and ammunition.*

be single and circular, of a size approximately equal to the bore of the weapon, though a .410 wound may be smaller because of the relatively greater effect of elastic contraction of the skin. The edges of the wound may be crenated by individual shot, but usually this feature is not noticeable.

SOILING AND BURNING

In a tight contact wound, the skin forms a seal around the muzzle, preventing much escape of hot gas and soot, so that soiling and burning are minimal or absent. The recoil, which takes the muzzle away from the skin, may, however, loosen the seal and, if the muzzle is not pressed firmly, flame, gas and soot may escape sideways and affect the skin in the immediate vicinity. Where clothing is interposed between the muzzle and skin, soot is much more likely to escape sideways and may be found in each layer of fabric, as well as on the underlying skin. The cloth may be singed at the edge of the hole and there may be a ring of burning around the skin wound.

MUZZLE IMPRESSION

There may be a muzzle impression in a tight contact wound made by firm mechanical pressure or impact of the metal rim against the skin. Many textbooks quite wrongly attribute this to 'recoil', though of course recoil takes the muzzle away from the skin, not towards it. The true explanation of a muzzle mark is either that the assailant physically kept the weapon pressed hard against the skin or – more often – that the subcutaneous expansion shortly to be described, lifts the skin forcibly up against the muzzle. A muzzle mark is a most useful indication to the pathologist of a contact wound. Actual bruising can occur around the muzzle imprint, though this is more likely to be the result of deep contusion from the effects of the blast. Rarely, a double-barrelled weapon may make a ring-like mark adjacent to the entry wound.

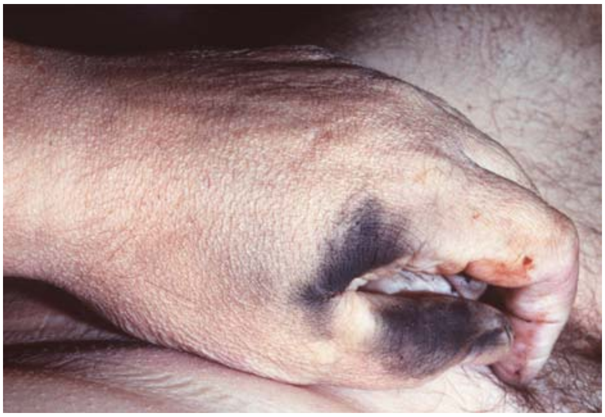

FIGURE 8.6 *Soot-soiling of hand that had grasped a shotgun barrel.*

CARBON MONOXIDE

Carbon monoxide in the gases combines with haemoglobin and myoglobin to give a pink coloration to the interior of the wound track and adjacent tissues. This diminishes in concentration along the track, but can still be present in its depths – and even at an exit wound, if there is one. The presence of carboxyhaemoglobin and myoglobin has been advocated as a test for distinguishing the exit from the entrance wound, especially where decomposition has blurred the morphological appearances. This test must be used with caution, though if quantitative measurements are made it can still be a valid exercise.

CONTACT WOUNDS OVER BONE

When the wound is made over a site with underlying bone, the wound may have a different appearance. Especially in

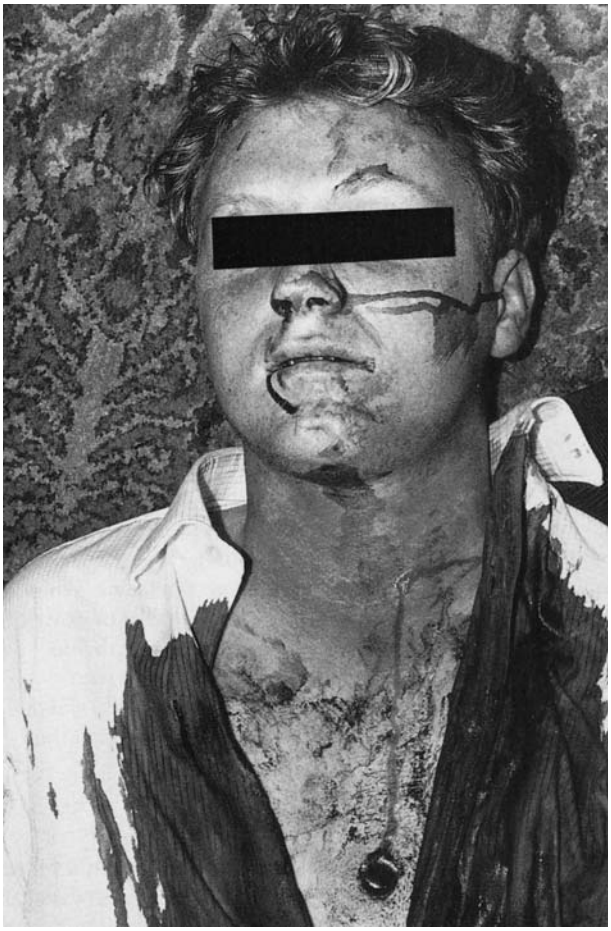

FIGURE 8.7 *Homicidal firearm wound with a twelve-bore shotgun. The wound shows a clear muzzle impression, the barrel having been pressed against the skin at discharge. There is almost no smoke soiling, the muzzle having forced a firm seal against the thin shirt and skin.*

the scalp, but also over the back of the neck, sternum, shoulder, hip and other areas where the soft tissue lies thinly over bone, the large volume of discharge gases cannot dissipate, as they can into the abdomen, chest, or mass of muscle. When the gas is forced through the skin, it is reflected back by the underlying hard layer and momentarily raises a dome of skin and subcutaneous tissue. This is rammed back against the muzzle to increase the pressure of contact further, sometimes producing a muzzle mark. When the gas volume is large, as with a twelve-bore gun, this dome may then split, causing a cruciate, stellate or ragged wound, with skin flaps. This is less likely with a .410 because the cartridge is smaller, but it can occur, as of course it can with rifled weapons.

The close discharge of a shotgun

When the muzzle is held near the skin, but not actually in contact with it, a number of helpful signs are produced. Once again the appearance is naturally modified by clothing, which must always be carefully preserved and subjected to forensic scientific examination. Where clothing is present, then it will trap most, but not necessarily all, of the soot and powder grains. It will reduce the flame effects, though if the fabric is ignited even momentarily, this can diffusely scorch the skin.

Assuming that the body surface is uncovered, a close discharge – one between actual contact and about 15 cm (6 inches) – is likely to show the following features:

- Singeing of hairs around the wound, unless the skin is hairless. The fine downy hairs of the trunk and limbs may be burnt away, though this is unlikely with dense, long, head hair. Where the distance is greater, the keratin of the hair may melt with the flame and then solidify on cooling, causing a 'clubbed' appearance of the hairs because of rounded bulges at the tips.
- Burning of the skin, unless protected by head hair. There may be a wide flare or narrow rim of hyperaemia or even blistering from the flame of incandescent gas blown from the muzzle.

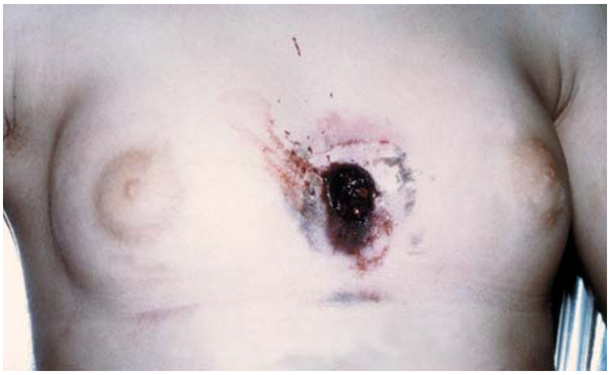

FIGURE 8.8 *Suicidal firearm wound from a twelve-bore shotgun. The wound shows a muzzle impression with soot soiling, the double-barrelled shotgun having been pressed against the skin at discharge.*

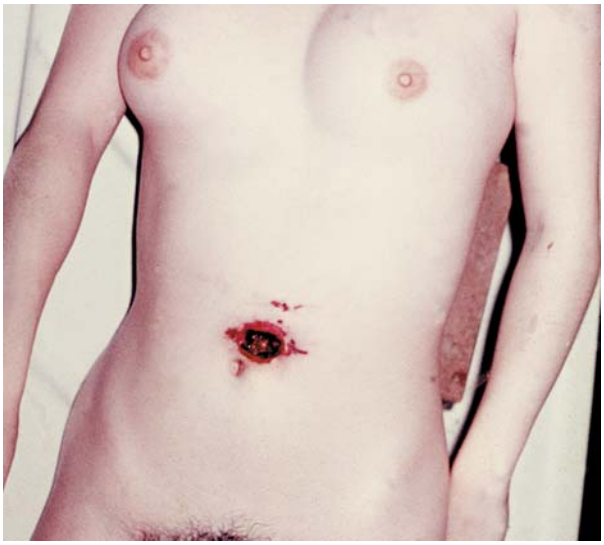

FIGURE 8.9 *Firm contact wound from a twelve-bore shotgun. The clothing has prevented any soot soiling, but there are minor peripheral abrasions from impact of a belt. As the abdomen was distensible, the gas expansion has not caused splitting of the skin at the wound edges.*

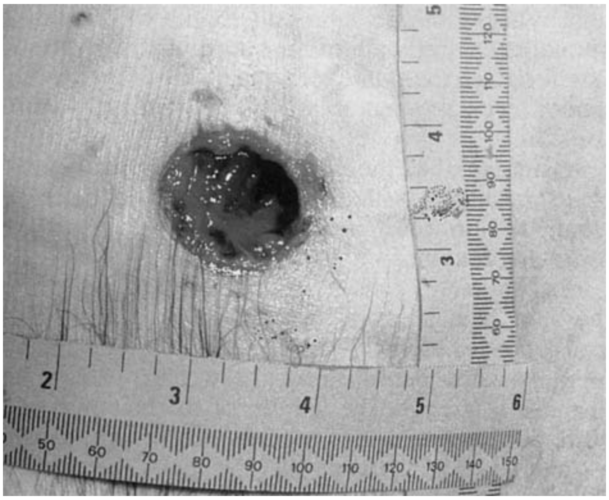

FIGURE 8.10 *Contact wound from a twelve-bore shotgun fired through clothing. There is some abrasion of the wound edges, but no irregularity from the close-packed pellets, which have not begun to disperse. The clothing has protected the skin from smoke and powder soiling. The circular wound indicates discharge at right angles to the body surface.*

- The tissues within and around the wound may be cherry-pink from absorption of carbon monoxide.
- There will be 'smoke soiling' or 'soot staining' of the skin, from carbon deposition. This spreads more widely than powder tattooing, but does not carry as far as the heavier propellant grains. This effect is much less or even absent with modern 'clean' propellants.

  This soot or smoke soiling is easily washed off the skin, and care must be taken at autopsy to obtain all photographs and trace samples before allowing the bloodstains to be washed from the body. Tattooing will not wash off, though adherent unburnt propellant may be physically detached from the tiny burns during any washing or swabbing process.
- Burning, partly burnt and unburnt propellant flakes and grains may pepper the surrounding of the wound. As stated above, these carry further than smoke staining, but usually spread over a smaller area. The incandescent particles cause small burns on the skin, but the unburnt flakes (such as nitrocellulose) may be seen as small glistening particles on the skin, sometimes coloured.
- The wound will be circular if the weapon is held at right angles to the skin and elliptical if slanted, often with undercut edges on one side. Depending partly on the size of the pellets, 'nibbling' or crenation of the edge may be seen, though this is usually imperceptible in close discharges. The edge of the wound will be blackened and there will be soot in the exposed tissues. There may be annular bruising around the wound and distant bruising a few centimetres away as a result of tissue damage from the entry of gases. Other bruises or abrasions may be seen in the vicinity from objects such

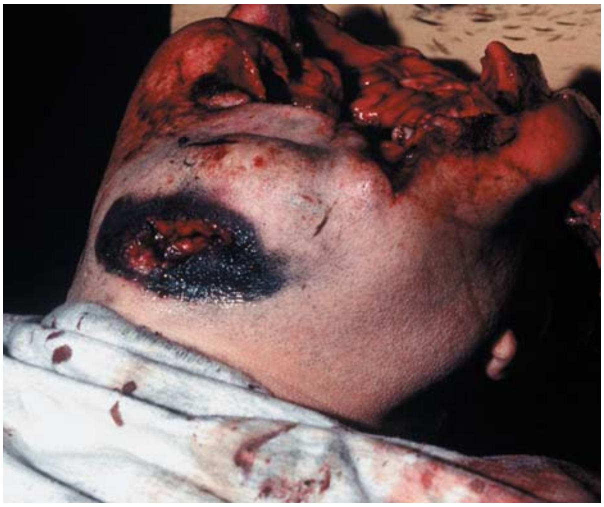

FIGURE 8.12 *Suicidal twelve-bore shotgun wound. The entrance is in one of the 'sites of election', in the neck, and the circular smoke fouling indicated a close or even contact discharge.*

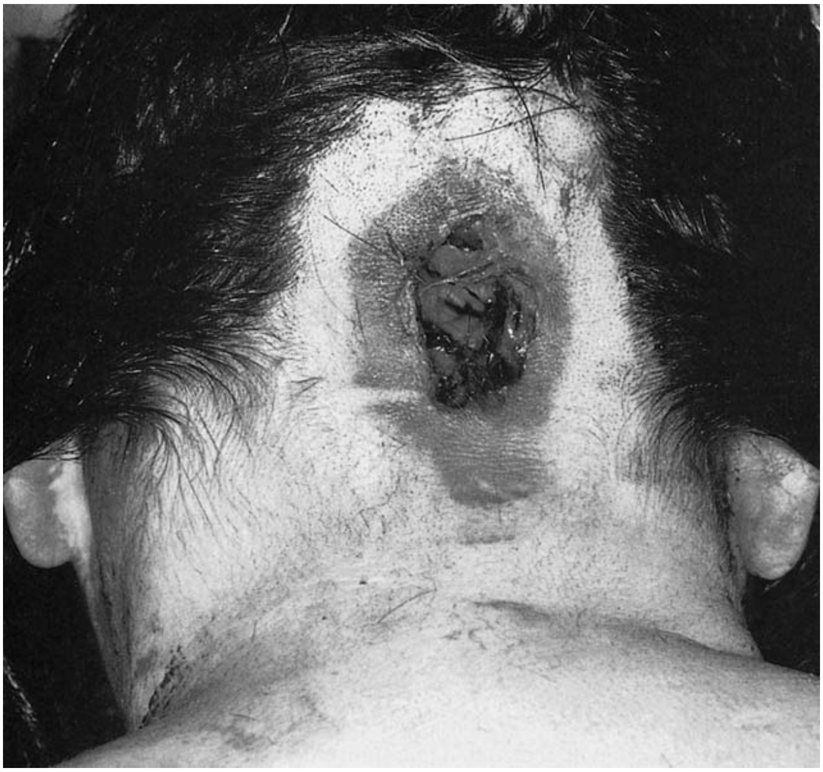

FIGURE 8.11 *Close-range twelve-bore shotgun wound of the head. This homicidal discharge was made through thick layers of fabric, which has filtered out any smoke or powder soiling. However, there is a wide zone of skin burning due to the muzzle gases. The wound is oval due to the downward angulation of the weapon.*

as buttons or buckles being hurled against the skin by the gas pressure.
- Any felt or cardboard wads or plastic cups from the cartridge will be within the depths of the wound.

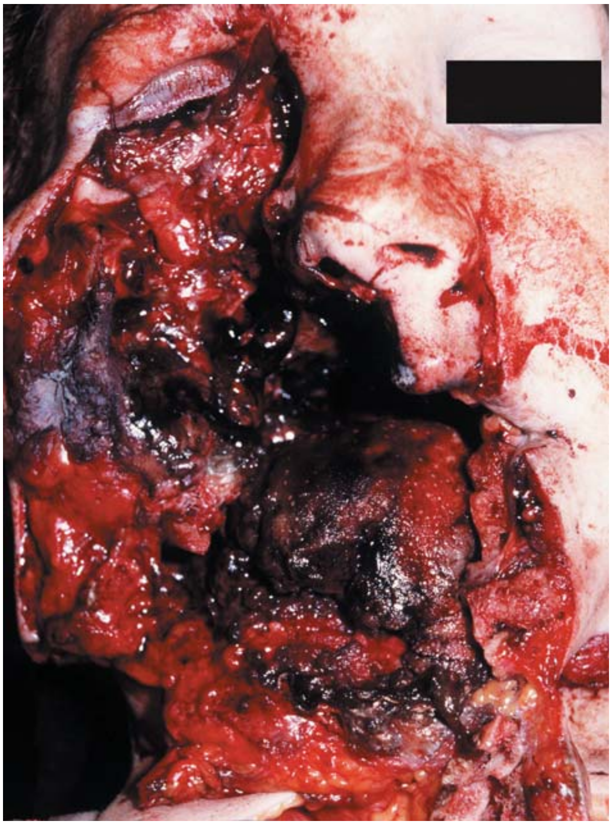
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FIGURE 8.13 *Suicidal twelve-bore shotgun wound. The entrance is one of the 'sites of election', in the neck (see Figure 8.14).*

Short- to mid-range shotgun discharge

From about 15 cm (6 inches) to 2 m (6 feet), considerable variation occurs in the appearance of the wound. The shorter range will provide a similar picture to that of close discharge, but the soot soiling diminishes and over 20–40 cm it may vanish. Powder tattooing near the wound periphery may persist for somewhat further than this.

At the upper end of this range the edges of the wound will become crenated and scalloped, especially with larger shot. This is sometimes called the 'rat-hole' or 'rat-nibbling' from its resemblance to rodent teeth marks. From 2 m upwards, the number of satellite pellet holes will progressively increase around the main wound.

It must be emphasized that these are useful generalizations, but that marked variations occur between different weapons, different barrels of the same weapon and different ammunition fired from the same gun. Only test firing can give a measure of the length of the flame, the distance and pattern of soot staining and powder tattooing, the beginning of pellet spreading and the distance over which the wads are projected. As a rough rule-of-thumb, which is often incorrect, hair singeing occurs over the first 30 cm (1 foot), soot staining can be seen for the first half-metre (20 inches) and a single large hole persists for at least 1 m (3 feet).

Mid- to distant-range shotgun wounds

Here, test firing is even more vital for an estimate of range, as the variation is great. The choke as opposed to cylinder barrel on the same gun will provide different appearances at

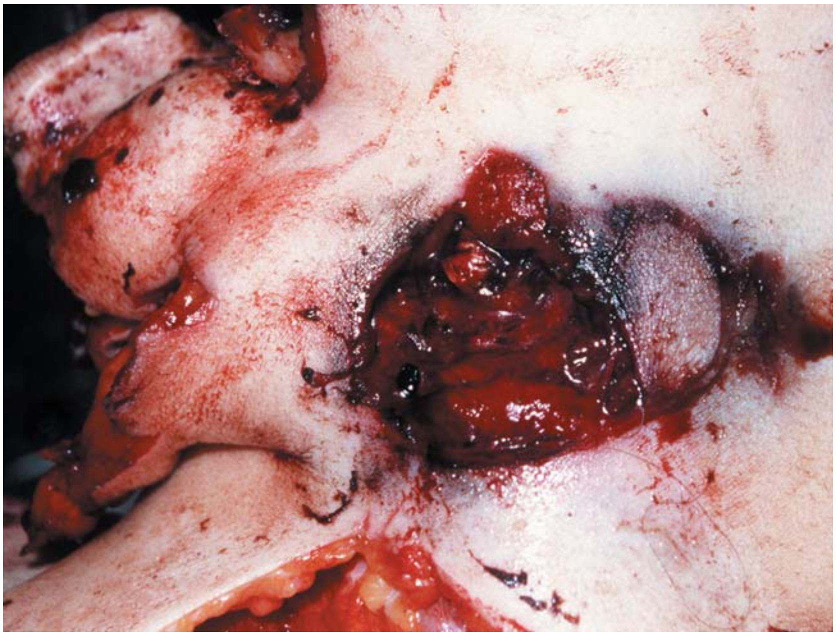

FIGURE 8.14 *Suicidal contact entrance wound in the neck. One barrel of a double-barrelled shotgun was used, the unfired barrel causing a muzzle mark (see Figure 8.13).*

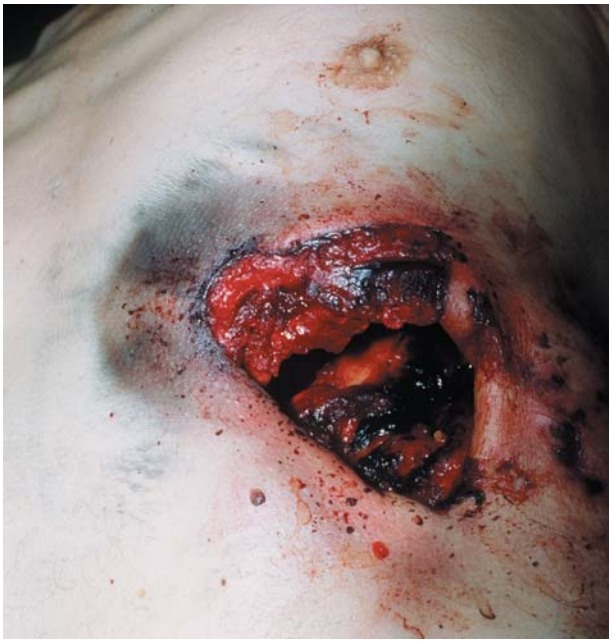

FIGURE 8.15 *Suicidal twelve-bore shotgun wound. Not all such wounds are circular – this one has torn a large defect in the chest wall because of its tangential orientation. The smoke smudging is extensive, having overshot and been deflected from the wound interior. The precordium is another site of election for suicidal shooting.*

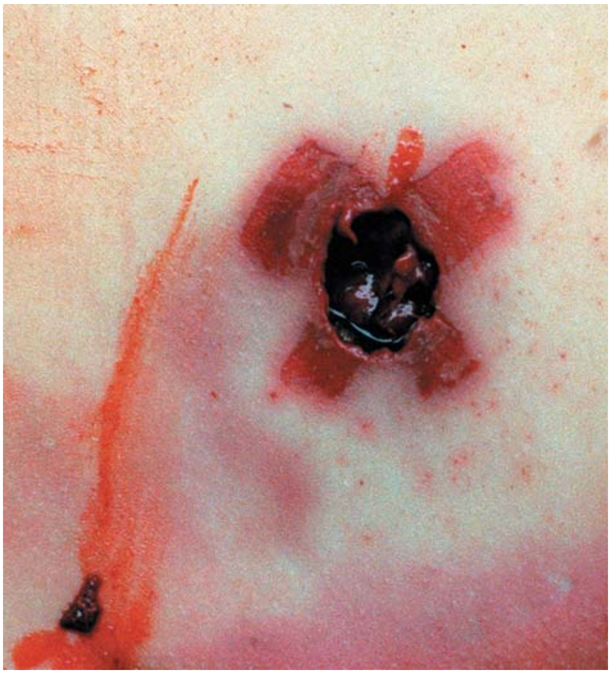

FIGURE 8.16 *Characteristic capital 'X'-shaped bruise caused by opening up of the plastic cup containing the shotgun pellets and surrounding the circular entrance wound from a homicidal short-range discharge.*

the same range. Once beyond 2 m, there will be no burning or smoke staining, rarely will there be powder tattooing and the presence of the wads will be variable. Sometimes the latter fall away within 2 m, but they can sometimes be found in a wound up to 5 m distant. Often the wad takes a lower trajectory and may strike the body below the shotgun wound. It may penetrate the skin, causing a second lacerated wound or it may only bruise the skin. Some of the plastic cup devices now used open up in flight to form a square-edged star or capital 'X' shape. This can strike the skin at or near the shotgun wound and produce a characteristic bruise or abrasion of a similar shape. The spread of pellets, which usually begins at a metre or two range, increases progressively, the central 'rat-hole' diminishing at the same rate.

There is an old (and extremely inaccurate) rule-of-thumb which states that the diameter of the spread in inches is roughly equal to the range in yards (metric: one-third of the spread in centimetres equals the range in metres). This of course applies to a circular wound or the narrow diameter of an oblique elliptical wound; it is of no use other than a quick first check to indicate if suicide can be excluded, but expert examination and test-firing are essential.

At distant ranges, beyond 6–10 m, the central hole may shrink to nothing. There will naturally be no wad injuries, no smoke, flame or tattooing, and no way of determining range except to say that it must be within the maximum discharge distance of that particular weapon, which may be 30–50 m. At such ranges the shot will not be lethal and the pellets, if they penetrate the skin, will lie just in the subcutaneous tissues. Death may occur, however, from an unlucky shot in the eye or from natural disease precipitated by pain and shock.

The direction of a shotgun injury

It has already been stated that, where the discharge has been at right angles to the body surface, the shape of the wound will be symmetrical and circular. A shotgun blast traces out a shallow cone from the muzzle and simple geometry demands that where this cone intersects a plane (the skin), a circle will result only when the cone is at 90° to the plane. In all other positions an ellipse will be traced out, its elongation increasing as the angle between them decreases. This pattern applies not only to the pellet spread but to soot deposition and provides a ready indication of the direction. In addition to the surface features, the internal wound assists in orientating the discharge:

- The wound edges may be shelved, the tissues being undercut below the margin distal to the origin of the

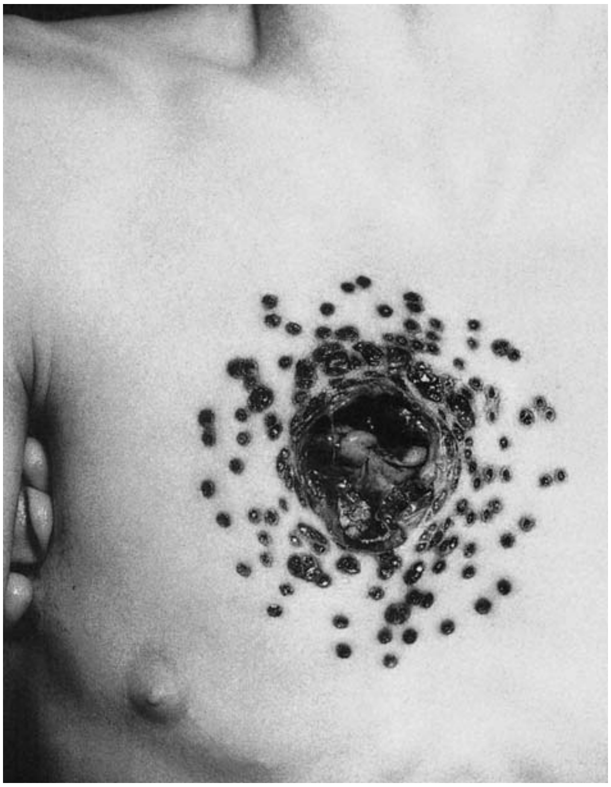

FIGURE 8.17 *Shotgun wound from a twelve-bore weapon. The circular outline indicates that the discharge was perpendicular to the skin surface. The central hole was caused by the entry of a confluent mass of shot, though there were no wads in the wound. The diameter of the peripheral pellet pattern was about 12 cm, which suggests that, approximately, the range was about 4 m. Test firing must always be carried out, however, to obtain a more exact estimate. Whatever the actual range, it is clear that it could not be suicidal.*

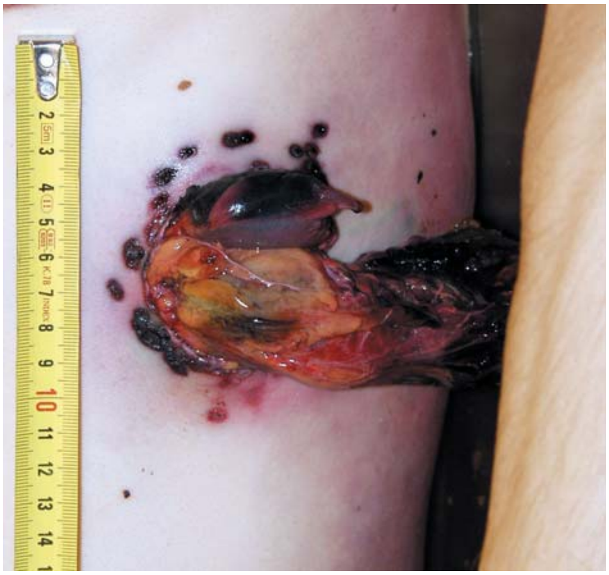

FIGURE 8.18 *Homicidal close-range shotgun wound from a twelve-bore weapon.*

discharge. The appearances are similar to those seen in some knife wounds, where an oblique stab leaves tissue visible at one edge and undercut on the other. In firearm wounds this is better seen in injuries from a single rifled projectile than from the more diffuse mass of shotgun pellets, but is still sometimes apparent in the latter.

- The track of the wound in the deep tissues can be established and this line projected backwards to indicate the discharge direction relative to the body. Again, a missile from a rifled weapon usually gives a clearer picture than those from a shotgun, but a general estimate can be obtained from a knowledge of the positions of the surface wound and the mass of pellets. Examination of a radiograph may be of more assistance that the laborious search from pellets at autopsy. Whatever the type of missile(s), considerable deviation caused by deflection by bone and other tissues can occur, so that the final resting place of the projectile may be far off the initial track. Thus the actual path through the tissues before ricochet must be established, if possible.

Other features of shotgun wounds

- Exit wounds are uncommon in the trunk as the energy possessed by each pellet is small because of its tiny size and the relatively low muzzle velocity of the weapon. The 'four-ten' will almost never exit and even the twelve-bore rarely causes a through-and-through wound of the adult chest or abdomen. The pellets often penetrate the distal chest wall, but are held up beneath the skin of the further side of the trunk. Commonly a bruise may be seen in the deep tissues of the frustrated exit site and lead shot may be felt under the skin, which is tough enough to prevent the final exit phase.

  In the head, neck and limbs, and in children and small thin adults, the twelve-bore commonly causes an exit wound which may be extremely large and ragged, with gross tissue destruction exposed. One of the most common is that seen when a twelve-bore is discharged suicidally into the mouth; this may disrupt the head, and expel most of the brain through a massive skull and scalp defect – the so-called 'burst head'.
- The internal track is more diffuse than that caused by a rifled weapon, though where the discharge is contact or close, the compacted mass of shot travels as a unit

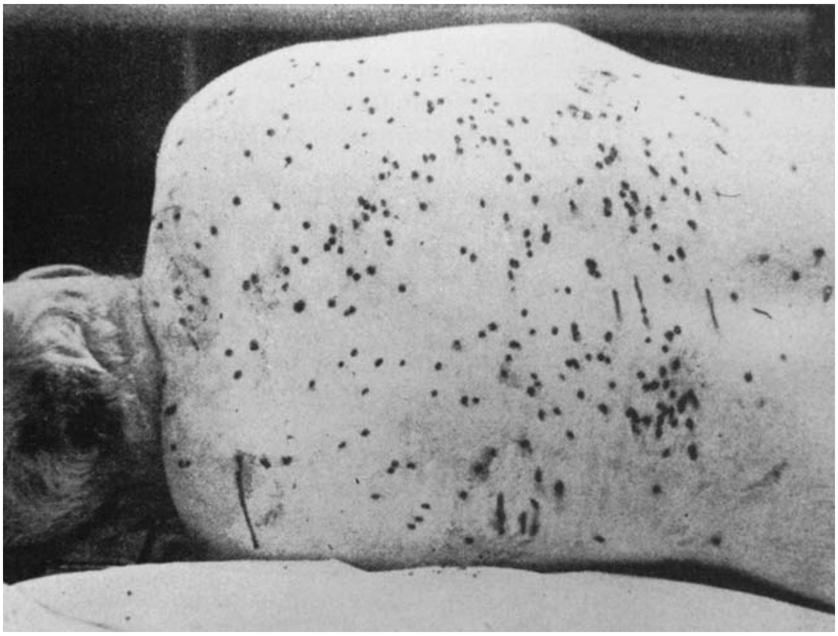

FIGURE 8.19 *Pellet injuries from a distant twelve-bore shotgun discharge. The range was about 25 m and the shot lies just under the skin. Death was caused by coronary heart disease, cardiac arrest being precipitated by the shock of injury.*

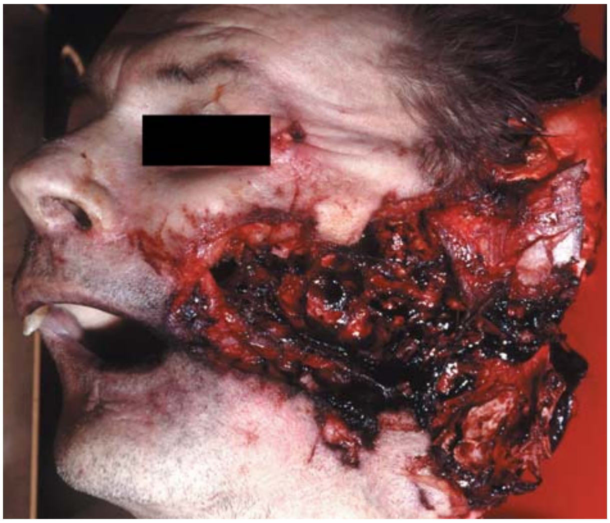

FIGURE 8.20 *Tangential shotgun wound of face. The edge of the dispersal cone of pellets and gas has ploughed through the cheek, and removed the ear. The facial bones and base of the skull were fractured.*

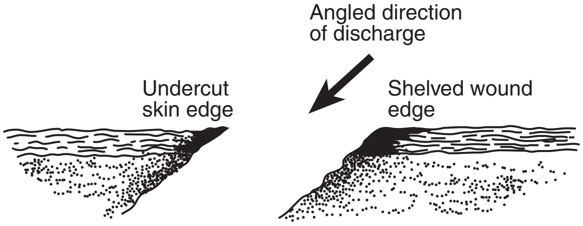

FIGURE 8.21 *Shelving and undercutting of entry wound in oblique discharge.*

for some distance into the tissues before dispersing. In general, the internal damage caused by a shotgun is diffuse and is caused by direct mechanical disruption by the gas and shot, which enter at relatively low velocity. There is no cavitation effect as is seen in high-velocity injuries, the tissue being physically smashed by the impact of a heavy load of pellets and, in the case of near discharges, by the large volume of hot propellant gases.

- Secondary damage is caused by the mass of pellets striking bone and releasing fragments that then act as secondary missiles, damaging adjacent tissues and sometimes emerging to form exit wounds. These may sometimes cause confusion to inexperienced observers, including police officers, who may wrongly suspect multiple shots or the use of some other type of weapon.
- Wad wounds can be caused by the non-metallic contents of a shotgun cartridge. These can vary from trivial bruises to fatal lacerations. The latter may occur when a blank cartridge is discharged at close range, the wad and accompanying gas breaching the body surface. As mentioned earlier, the new devices now often used in shotgun ammunition may cause characteristic wounds, such as the square cruciate mark from the wings of the opened plastic cup which contains the shot. Felt and plastic wads travel a variable distance from the gun muzzle, depending on many factors, such as the type of cartridge, the amount of propellant load and the nature of the wads. The wads fall away much more quickly than the lead shot because of their low weight and high air resistance. At contact and close ranges

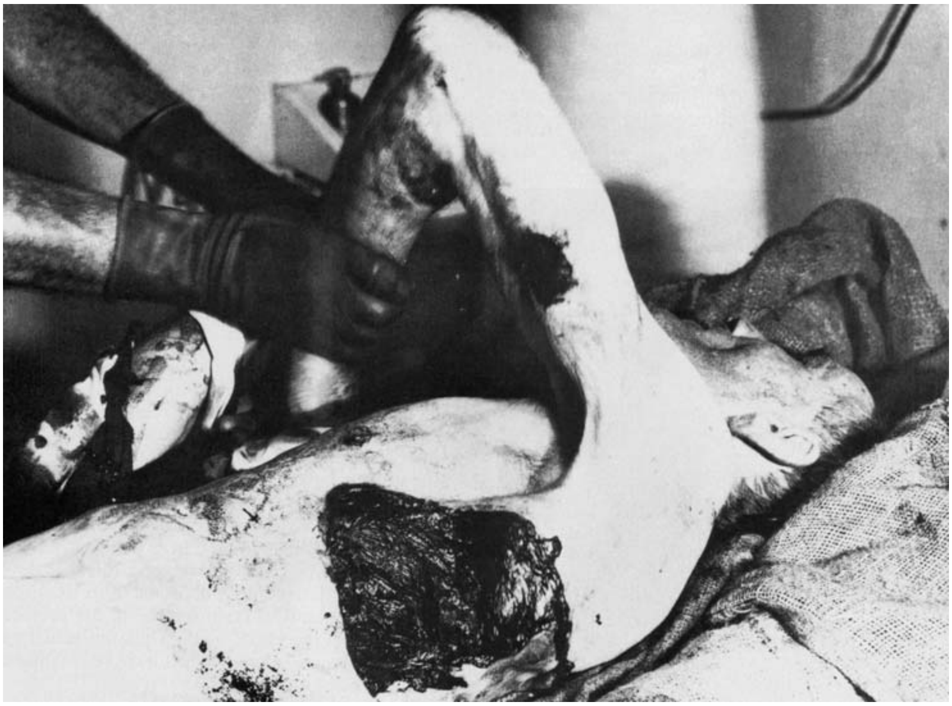

FIGURE 8.22 *A tangential shotgun wound of the side of the chest. When the victim was first found it was not appreciated that he had been shot. The discharge passed under the slightly abducted arm, injuring the upper arm as well as the thorax. Though most of the shot passed to the rear of the victim, some were found in the pleural cavity.*

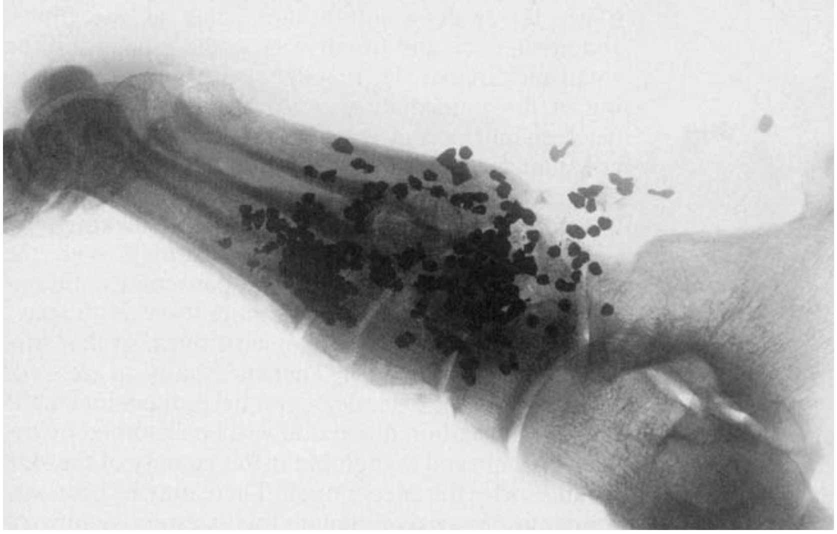

FIGURE 8.23 *Radiography should be carried out before autopsy in all deaths from firearms. The extent of dispersal of shot can be assessed – as in this film – and, in single bullet injuries, the position and possible fragmentation can be detected in order to assist in recovering the missile.*

they will almost always enter the wound and should be recovered at autopsy in order to assist in identifying the type of ammunition.

Beyond a metre or two, the wad may drop sufficiently to miss the main wound and strike the skin at a lower point. From 2 to 5 m, the wads may or may not strike the body, and further than this distance it is almost certain that the wads will fall to the ground. As with all variables associated with firearm wounds, however, it is essential for test firing to be performed wherever possible. The pathologist should not be dogmatic or impracticably precise about distances, but offer a bracket of reasonable probability.

- Tangential wounds can offer considerable difficulty in recognition to the inexperienced observer. Some pathologists, as well as clinicians and police officers, have attributed certain wounds to knives or blunt injuries, when in fact they have been gunshot wounds. The shallow cone of a shotgun discharge may pass any part of the body so that the central axis is clear of the tissues, but the periphery strikes the body surface tangentially. The most common position is probably the side of the chest, in the lower axilla. If the arm is raised it may escape damage, but sometimes an opposing injury is seen on the chest wall and inner part of the upper arm. Another area is the side of the face, where a glancing gun blast may gouge the face and perhaps carry away an ear.

The appearance of the wound depends, of course, on the range and the depth to which the cone of shot and gas penetrates. On the side of the chest, a large elliptical area may be ripped from the surface to expose underlying muscle and ribs. If a close discharge, then the nature of the injury will be clear from the usual burning and soiling of the muzzle gases, but a more distant shot may cause a clean wound that can give rise to doubt about causation. Radiography will usually reveal lead shot in the tissues, unless the contact is extremely superficial.

In the chest – even if shot penetration is minimal – severe damage to the pleura and lungs may occur from the impact, and death may occur from a haemothorax with or without lung laceration or contusion. When the side of the head is hit, shattering of skull or facial bones can occur and intracranial damage is common, even though no metallic projectiles enter the cranium. Rifled weapons can also cause tangential wounds and some features of skidding across the surface and re-entry wounds have been mentioned earlier. There is not usually the wide gouging of tissue seen in smooth-bore injuries, but the glancing passage of a high-velocity missile can open up a severe longitudinal laceration. The lateral transfer of energy can cause severe internal damage in both chest and skull, even though the missile does not enter the cavities. The skull may be extensively fractured, with widespread underlying damage, and in the absence of any projectile and a deficient knowledge of the circumstances, some such injuries have erroneously been ascribed to blunt trauma.

WOUNDS FROM RIFLED WEAPONS

Injuries from rifled weapons vary greatly according to the velocity of the projectile, as discussed at the beginning of this chapter, but there are some characteristics common to all types. Unlike shotguns there is only one missile in each discharge, though an automatic weapon may well cause multiple wounds in close succession which impact upon the same area of the body. Occasionally, because of some defect in the weapon, two bullets may be fired at once, or a fragment of metal may detach from cartridge, barrel or bullet, so that two missiles may strike simultaneously; this is described later.

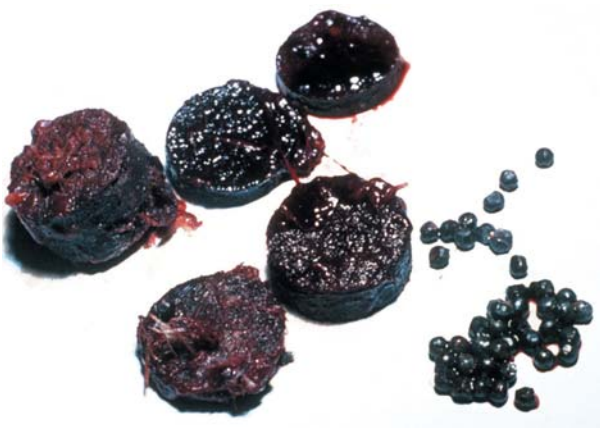

FIGURE 8.24 *Lead pellets and felt cartridge wads from a twelve-bore shotgun wound. It is important to recover at least a sample of pellets and the wads so that the type of cartridge can be identified.*

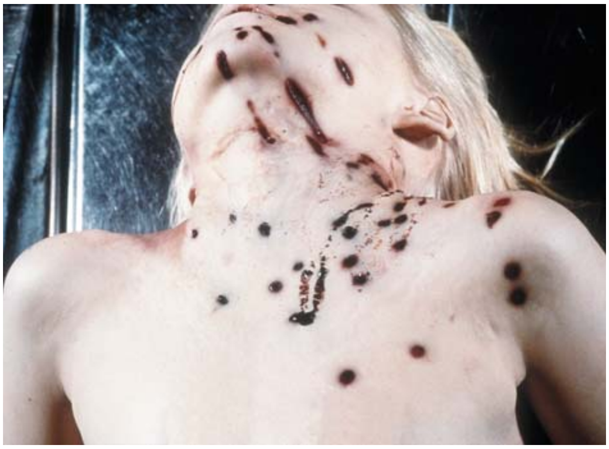

FIGURE 8.25 *Pellet injuries from a distant twelve-bore shotgun discharge (see also Figure 8.26). The child had been walking behind a hunter carrying a shotgun on his shoulder, the barrel pointing down. When the hunter was ducking to avoid branches of a tree the shotgun was triggered by a branch.*

Contact wounds

When a weapon is fired in contact with the skin, the appearances can vary according to whether the muzzle was firmly pressed against the surface so as to form a tight seal – or whether it was merely held in loose contact, so that the backward jerk of recoil can permit a small gap to appear. Yet another permutation is when clothing is interposed between the muzzle and the skin.

When a rifled weapon is held firmly against the body surface during discharge, the resulting wound is in many respects similar to that from a shotgun. A twelve-bore wound

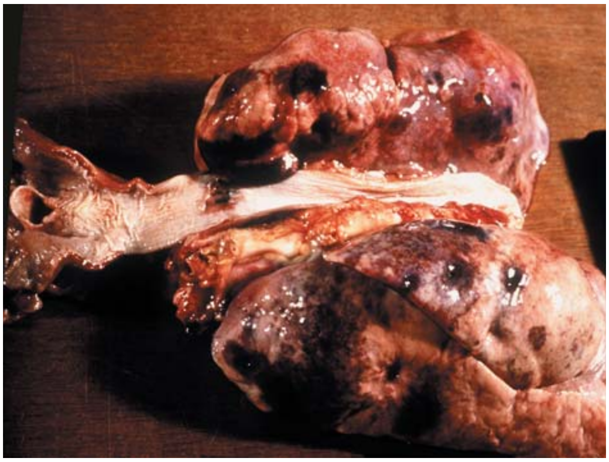

FIGURE 8.26 *Pellet injuries puncturing the oesophagus and both lungs (see also Figure 8.25).*

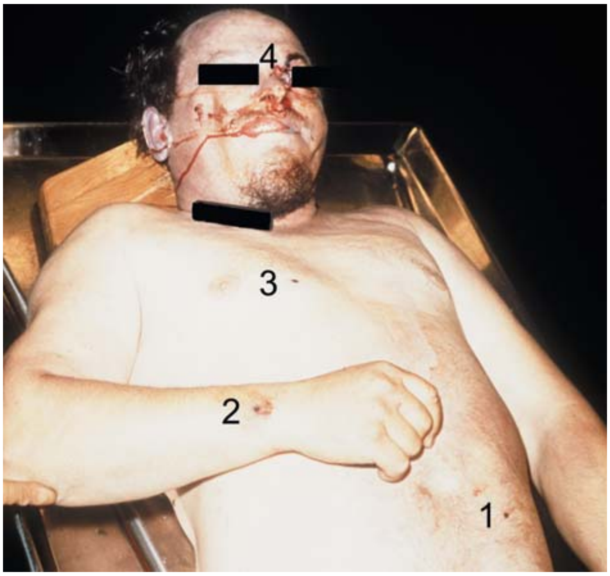

FIGURE 8.27 *Hunting accident in which the man was hit by four pellets from a distant twelve-bore shotgun discharge. Pellet no. 1 punctured the abdominal skin and was found in the subcutaneous fat; pellet no. 2 bruised the right wrist; pellet no. 3 penetrated the chest wall and was found in the pericardial fat tissue without any injury to the heart; pellet no. 4 hit the corner of the left eye and travelled through the left cerebral hemisphere, causing death.*

is usually much larger, but a .410 can closely resemble a large-calibre rifled weapon injury. Over deep soft tissues, such as the limbs, abdomen, neck and usually chest, the wound will be small and circular. There will be burning and blackening of the immediate wound edges, but if the seal between muzzle and skin is tight, there will be little or no sideways escape of flame and soiling unless clothing is interposed.

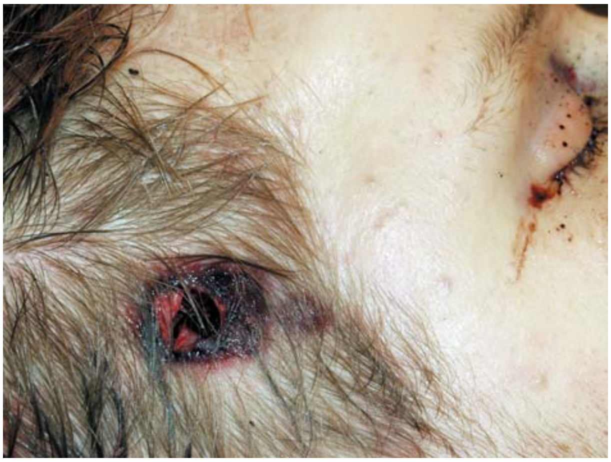

FIGURE 8.28 *Suicidal contact wound with muzzle mark from a 9 mm pistol (see also Figure 8.29 for corresponding exit wound).*

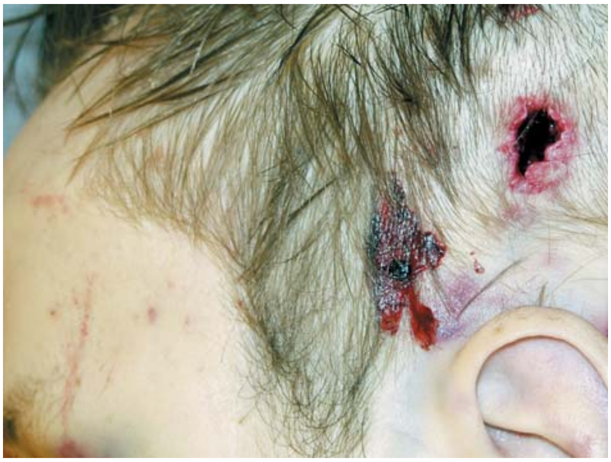

FIGURE 8.29 *Suicidal exit wound from a 9 mm pistol (see also Figure 8.28 for corresponding entrance wound).*

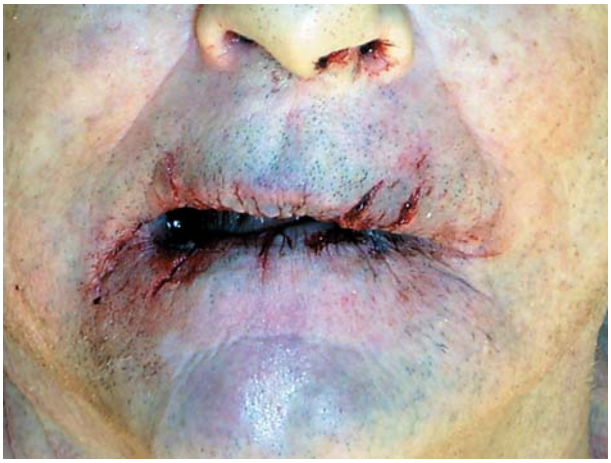

FIGURE 8.30 *Numerous tears in the lips due to expansion of muzzle gases from a 9 mm pistol fired in the mouth.*

Within the wound, there will be some flecking with soot in the tissues, the amount varying with the 'cleanliness' or otherwise of the particular ammunition. Most rifled weapon ammunition is 'clean', compared with many shotgun cartridges, so that soot may be absent altogether. There is usually an areola of hyperaemia that extends beyond the diameter of the muzzle and carbon monoxide will be absorbed by the haemoglobin and myoglobin in the vicinity of the skin wound and in the deeper track. There may be bruising, sometimes extensive, though this is rarely symmetrical and is often absent. The expansion of the tissues by gas entry tends to force the skin even harder against the end of the barrel and a 'muzzle imprint' may be formed. In rifled weapons, especially handguns, there are more features at the end of the barrel than in shotguns, so complex imprints may be made of foresights and mechanisms for self-loading in 'automatics'.

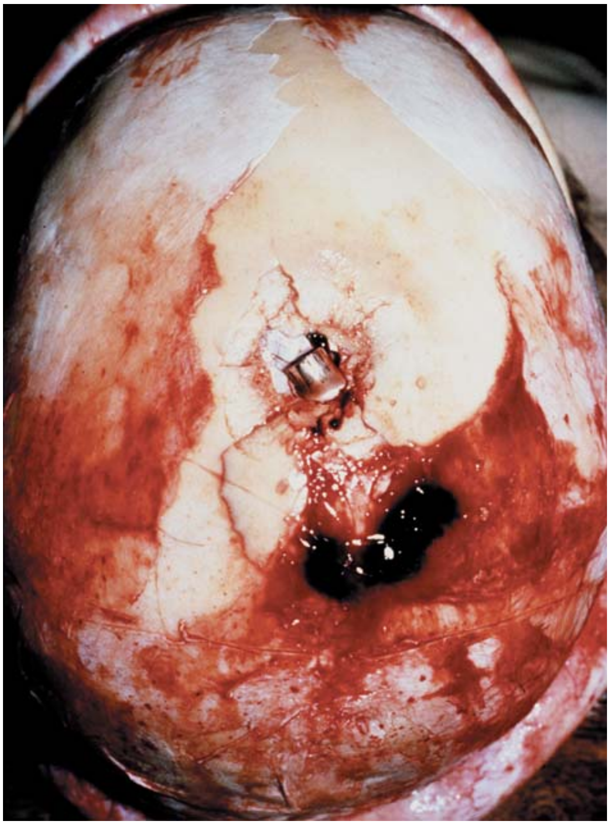

FIGURE 8.31 *Slightly deformed full-jacketed bullet in the middle of the cone-shaped exit wound on top of the skull. Homicidal entrance wound under the chin.*

If the contact wound is over a bony support, especially the skull, then the same phenomenon occurs as in shotgun wounds. The muzzle gases entering the subcutaneous tissues cannot expand by displacing adjacent soft structures and are reflected from the bone to raise a dome of gas that often splits the entry hole. This results in a linear, cruciate or stellate tear that may well destroy the original puncture. As the volume of gas produced is usually less than that formed by the large mass of propellant in a twelve-bore shotgun cartridge, the tear is smaller – though the charge in some older rifles and sporting guns may be comparable.

When the contact is loose, burning and soiling in the immediate vicinity of the muzzle may occur – again modified as in the case of shotguns, by the interposition of clothing between muzzle and skin. The fabric allows a lateral passageway for diffusion of soiling, as the muzzle cannot make such a good seal as against skin.

If the skin of the gun hand remains in firm contact with the weapon steel for a longer period of time, rust stains may develop as seen in Figure 8.34. In experiments carried out by Ulrich and Zollinger (2001) in the living as well as corpses, the formation of rust stains depends on the firmness of the contact, humidity of the skin and the environment, contact time and the state of the weapon surface. The shortest period of time necessary for the formation of rust under the most favourable circumstances, as reported by Ulrich and Zollinger, was 135 minutes for a corpse and 27 minutes for a living person.

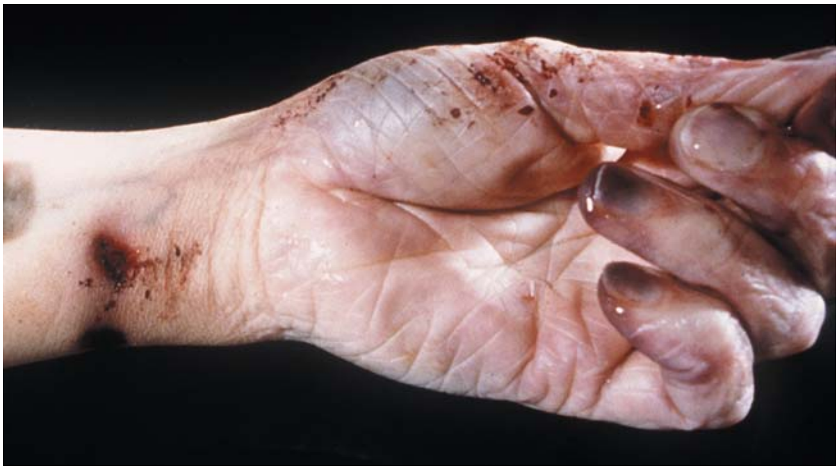

FIGURE 8.32 *Wrist of a homicide victim, who had raised her left hand to ward off the attack, showing a 'clean' exit wound of a full-jacketed bullet in the middle and soot-soiled entrance wound beneath it.*

Blow back into the barrel – ‘back spatter’

Contact wounds – and also close-range discharges – may cause blood and tissue fragments to enter the muzzle, sometimes penetrating for several centimetres, this being called ‘back spatter’. There appears to be a momentary suction effect after the pressure of the gas blast subsides, possibly as a result of rapid relative cooling in the barrel. This seems to aspirate material into the muzzle and pieces of skin, hair and adipose tissue have been found inside the weapon. Sometimes blood and tissue may soil the hand or arm of the person firing the gun, a matter of considerable significance in forensic science.

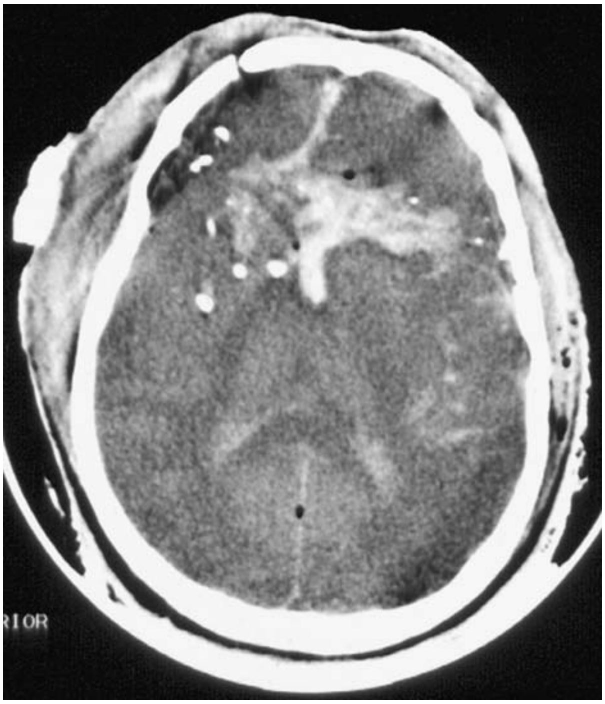

FIGURE 8.33 *Intravital CT scan of a 23-year-old male who in the course of a ‘Russian roulette’ shot himself in the right temple with a .357 calibre Magnum revolver. Extensive injury of the cranium and brain with several X-ray positive particles probably due to the disintegration of the bullet. (From the files of the Department of Radiology of Turku University Hospital reproduced by kind permission of Professor M Kormano.)*

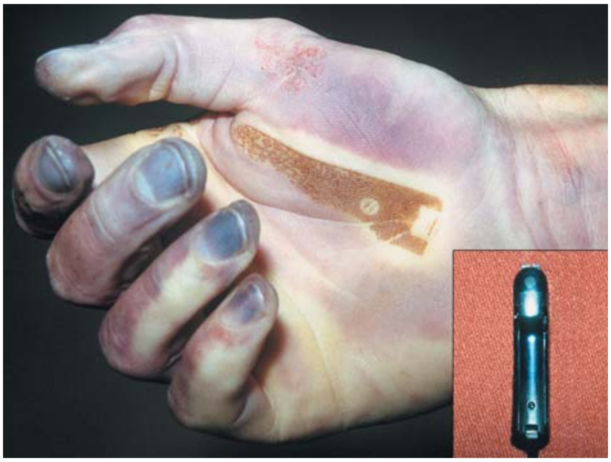

FIGURE 8.34 *Rust stains on the gun-hand of a suicide corresponding to the shape of the grip.*

Close-range wounds

When there is a short distance between the muzzle and body surface, the appearances of the wound will vary accordingly to the type of ammunition used. The wound

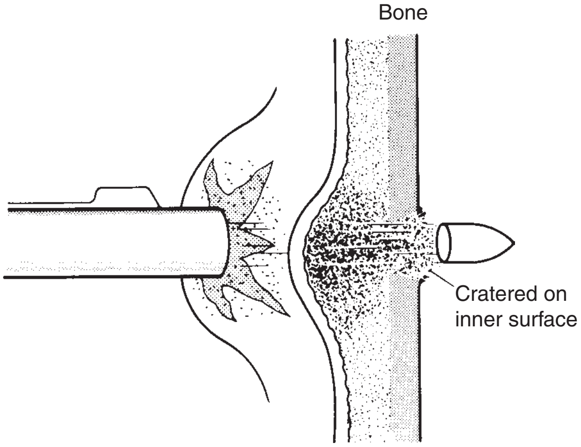

FIGURE 8.35 *A firm contact discharge against tissue overlying bone (such as the skull) causes gas to rebound from the rigid base. This raises a dome under the skin that can split to give a ragged entrance wound. This effect is by no means invariable.*

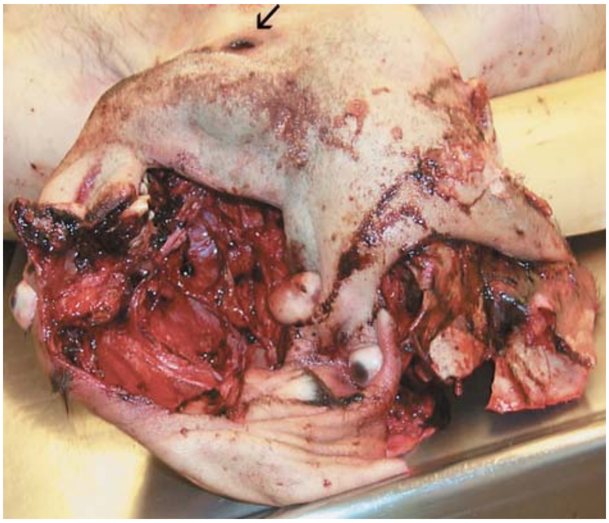

FIGURE 8.36 *Suicidal contact wound in the neck (arrow) from a 7.62 calibre rifle with destruction of the head.*

will almost invariably be circular as the tearing due to gas intrusion is unlikely to occur. The wound edges may be inverted, but at close range the rebounding gases may level up or even evert the margins. As will be described in medium-range wounds, there will be an abrasion collar.

Burning

Modern propellant produces less flame than the black powder of older shotgun cartridges, but within a few centimetres of bare skin there is likely to be burning of the skin with singeing of hairs. Even where hairs are not destroyed, they may be 'clubbed', that is, the keratin melts at the tip and resolidifies as a tiny blob. Hyperaemia around the wound is usual and some bruising can occur, which may be more evident as the post-mortem interval increases.

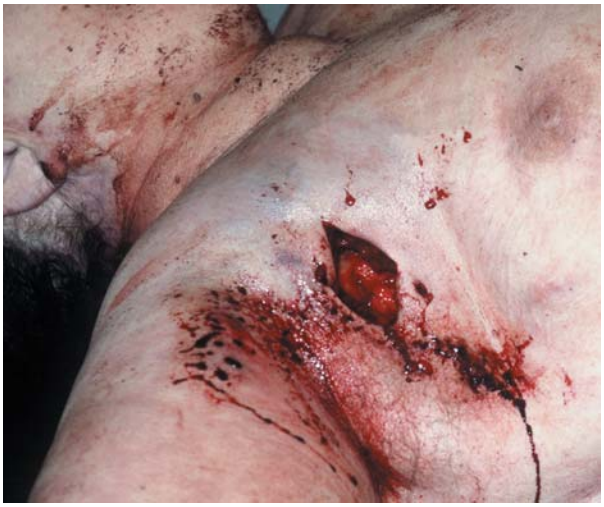

FIGURE 8.37 *Atypical slit-like exit wound of a homicidal firearm wound from a hunting rifle with entrance wound in the back.*

It is sometimes claimed that the flame effects extend from the muzzle a distance equal to the length of the barrel, but the truth of this rule-of-thumb is doubtful, though it may be a very rough approximation.

Soot or smoke soiling and powder tattooing

Though most propellant is now 'clean', some soot may be seen around the wound. In addition, there will be tiny burns from specks of incandescent propellant, the so-called 'powder tattooing'. These may pepper the vicinity of the entry hole in a roughly symmetrical pattern, which may assist in

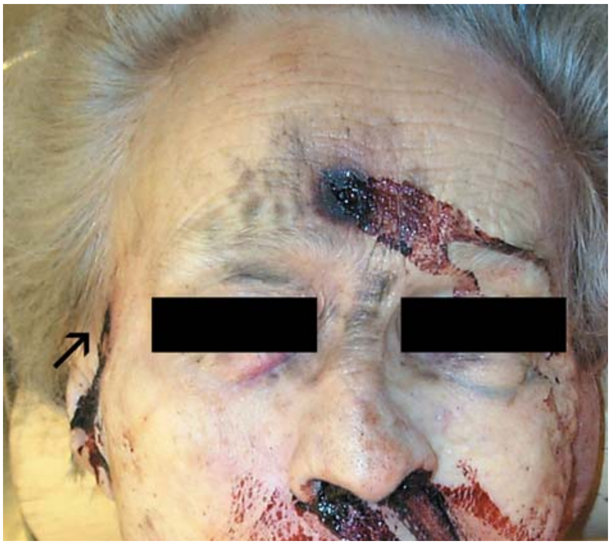

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FIGURE 8.39 *Entrance wounds from a 7.65 calibre automatic pistol in the forehead and right side of the face (arrow) of a homicide victim, with soot soiling.*

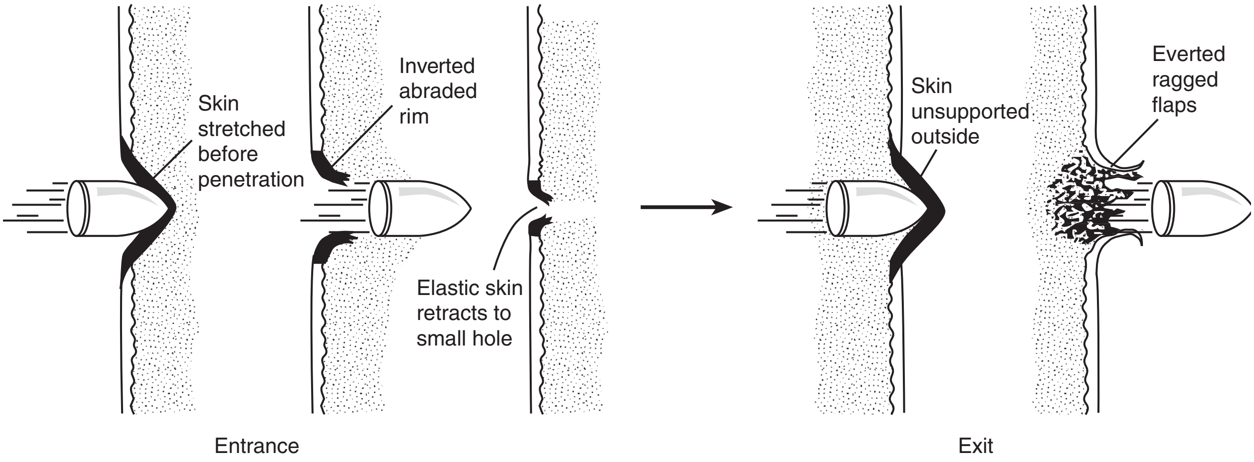

FIGURE 8.38 *Entrance and exit wounds.*

determining the angle of impact. Particles of propellant carry further than smoke, so tattooing around the entrance wound in the absence of soot indicates a greater distance. The soot rarely carries more than 15 cm (6 inches) from a pistol, whereas powder grains will travel 30–45 cm (12–18 inches).

These distances are approximate and can be doubled for a rifle compared with a handgun. The length of the barrel is another variable and a rule-of-thumb for pistols in this respect states that the distance from which powder residues can reach the skin is about twice the length of the barrel. It must be emphasized once again that test firing is essential for any hope of accuracy.

'Fouling' refers to tiny lesions around the entry wound caused by fragments of metal expelled by the discharge. These come either from the surface of the missile or from the interior of the barrel. Friction between the bullet and the rifling may gouge off pieces of lead, jacket, or barrel steel and hurl them at the skin, where they become embedded. These particles, like powder burns, will not wipe off at autopsy, whereas soot soiling can easily be removed with a damp sponge. Even fragments of the shell case may become detached and blown out of the barrel.

Minute flakes of unburnt explosive or inert filler may land on the same area of skin; these tend to glisten and may be orange or blue, depending on the manufacturer. It is important that a forensic scientist or police scene of crime officer has the opportunity to retrieve these before the wound is washed. If no such person is available, the pathologist should swab the area with a water-damped plain swab, or preferably cut out the skin around the wound and preserve it unfixed (refrigerated if necessary). These specimens should be sent for expert forensic examination, as they may indicate the nature of the ammunition and may be matched to that in the possession of a suspect. As with contact wounds, carboxyhaemoglobin and myoglobin will be present in the wound track in diminishing concentrations as the range increases.

The estimation of range is dealt with later, but here it is again emphasized that until test firing is carried out with a similar weapon and ammunition, only an approximate estimate can be offered from the appearances of the wound.

Medium-distance wounds

Unlike the shotgun, once the discharge of a rifled weapon is greater than a metre, there is nothing to indicate increasing range, until perhaps the erratic trajectory of extreme distance suggests maximum range. From perhaps less than half a metre to up to several kilometres the entry wound of a high-velocity rifled weapon appears the same. The typical appearance of the entry wound has been likened to that caused by 'driving a dirty pencil through the skin'. The central aperture is circular and may be inverted – that is, the margins are driven inwards by the passage of the missile – though this feature is often absent.

The size of the hole is rarely equal to the diameter of the missile and therefore the calibre of the weapon cannot instantly be determined by inspection of the wound – in spite of the apparent ease with which television drama doctors and detectives can instantly spot 'a thirty-two' or a 'thirty-eight'. When the bullet strikes the skin, the latter is stretched for a minute fraction of a second until penetration occurs, so that the missile perforates expanded skin. Immediately after entry, the skin undergoes elastic recoil and the resulting hole is usually smaller than the diameter of the bullet unless the range is so close that gas entry – or gas rebound – contributes to the size of the defect.

The abrasion collar

The skin immediately around the central hole is discoloured, the so-called 'abrasion collar'. This may be only a narrow rim or may be equal in width to the central defect. The collar is due to the inversion of the skin during penetration by the missile so that the sides of the bullet are 'wiped' by a tiny tube of skin, the epidermis of which is abraded by heat and friction.

The width of the abrasion collar is determined by the degree of inversion and hence the length of the skin tube. The collar is caused by friction and heat as the missile chafes the skin.

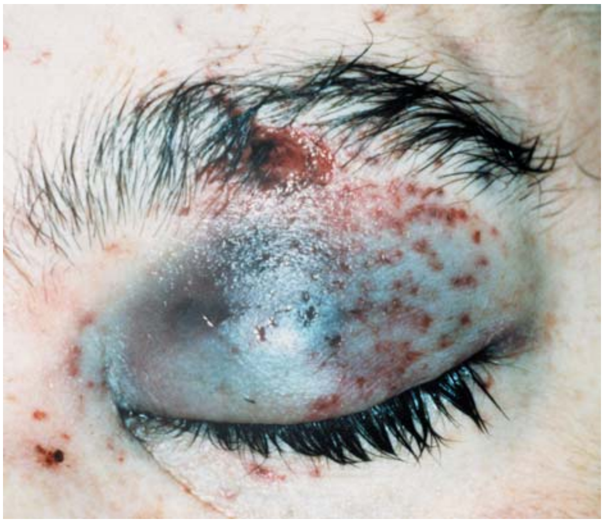

FIGURE 8.40 *Close-range pistol entrance wound. The eyelid and lower forehead show tiny burns from propellant flakes landing on the skin. The eyes are blackened by fractures of the floor of the anterior fossa.*

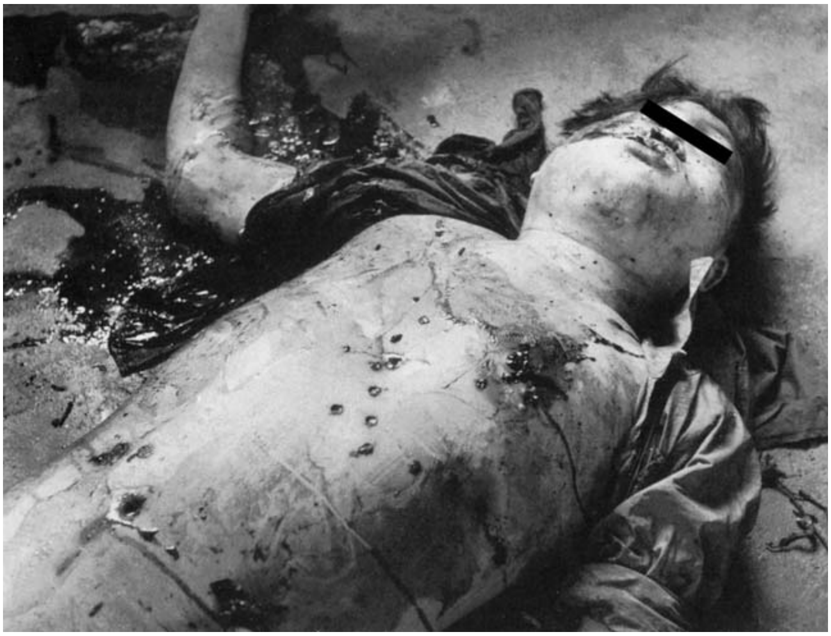

FIGURE 8.41 *Multiple entry wounds from a military self-loading weapon. The wounds are in line and approximately evenly spaced. Each is a typical entry, with an inverted appearance and an abrasion collar. There were massive exit wounds on the back, caused by .303 bullets from a Bren gun used by a Malayan patrol.*

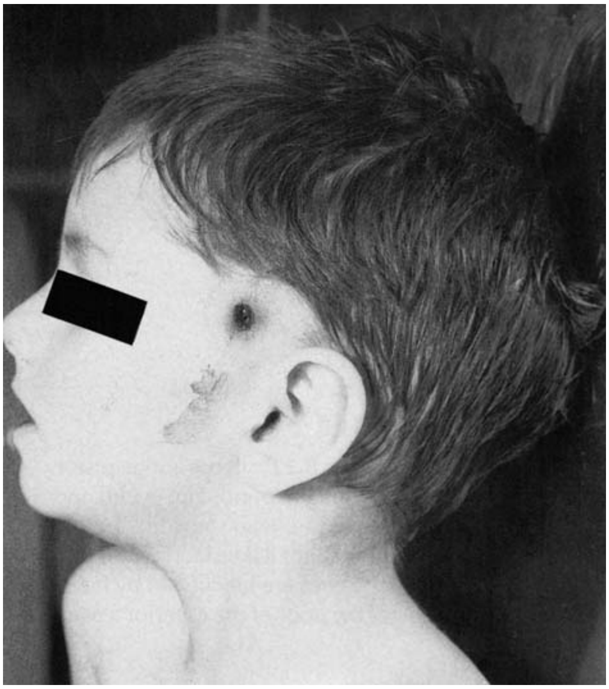

FIGURE 8.42 *Entrance of a .22 rifle bullet at a few inches range. There is slight smoke soiling around the wound, which has a well-marked abrasion collar. In fact, two shots were fired in quick succession through the same hole, which is slightly ovoid because of the non-congruence of the two shots (see Figure 8.49).*

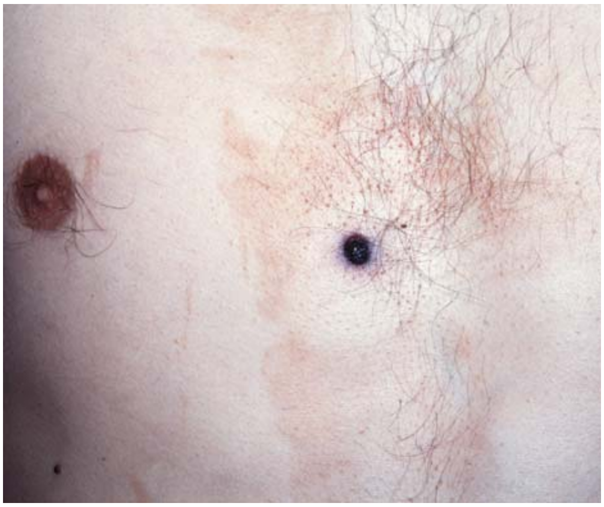

FIGURE 8.43 *Entrance of a .22 rifle bullet in a shooting accident.*

In addition to the true abrasion collar, there is often a slightly wider circle of peeled keratin, where the stratum corneum of the skin is raised to form a slightly frayed edge around the entry wound. This appears due to mechanical separation of the outer layer, due to the impact of the bullet knocking the deeper layers down away from the keratinized surface.

The grease ring

The inner edge of the abrasion collar may be black, as a result of heating effects and to the rubbing-off of dirt, lubricating oil, or grease and metal particles from the bullet. This is often called the ‘grease ring’ or ‘ring of dirt’, and may be absent if the missile was clean.

There may also be bruising around the wound from mechanical damage to adjacent subcutaneous blood vessels,

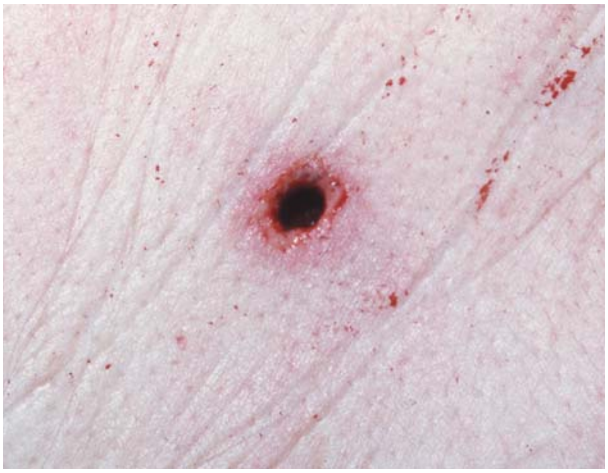

FIGURE 8.44 *Entrance wound in the back of a rifle bullet fired from across a room. There is thus no burning or soiling, and only minimal bruising at the margins of an almost circular inverted entry.*

but no other features, apart from the keratin ring, are present in the surrounding skin. No burns, soot or powder can be found beyond a variable distance that will not exceed a metre in the case of a rifle, and half that distance with a handgun.

Extreme trajectory wounds

Over most of their flight path, rifled weapon missiles maintain a fairly constant attitude. Soon after emergence from the muzzle, the bullet may 'precess', with the tip on the axis of travel and the base rotating in a diminishing circle about the axis. This soon settles down and causes no observable difference in the contact wound. For most of the distance of travel, the bullet remains steady, with only minor variations from axial stability. When the extreme range is approached, however, the reduced velocity allows instability of the flight path. The bullet begins to wobble and yaw, and may even tumble, that is, turn end-over-end. If the missile strikes the body in this phase, the impact may be sideways or even backwards, as well as being in an irregular lateral motion. A bullet striking sideways may leave an almost rectangular entry wound. The wound will then be similarly irregular, and there may be difficulty in recognizing it as a firearm wound or in differentiating it from a laceration caused by other means.

The direction of discharge

As with smooth-bore weapons, a close range discharge may provide information about the angle of the shot because of the geometry of any smoke soiling, powder tattooing, or burns on the skin. An impact at right angles will produce a circular zone of discoloration on the skin, while an oblique angle will result in an elliptical mark, the length of which increases as the angle decreases. As rifled weapons produce relatively little soiling except at close range, this clue is of less assistance than with shotguns.

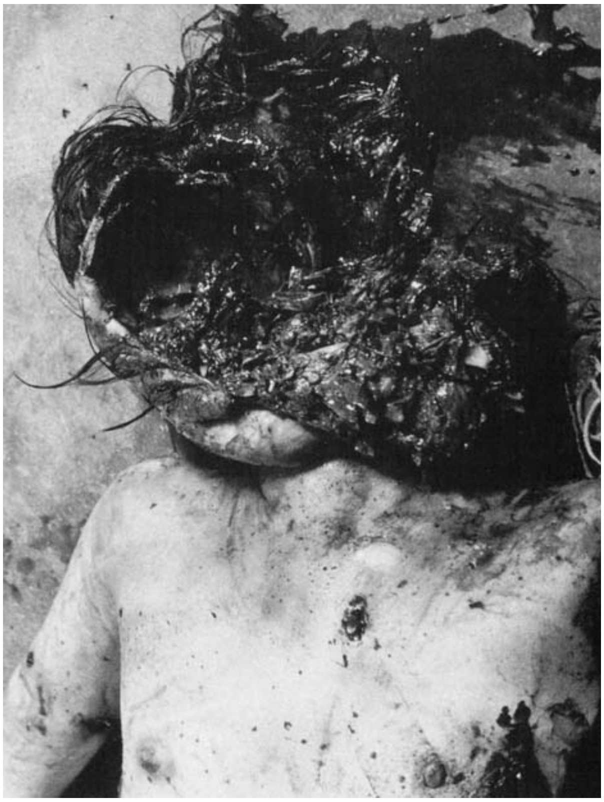

FIGURE 8.45 *Disintegration of the head of a young female terrorist in the Malayan emergency from a single bullet entering the external auditory meatus. The weapon was a F-N rifle with a high muzzle velocity; the impact of the missile on the base of the skull instantly converted the kinetic energy into a virtual explosion.*

Again as with smooth-bore guns, the edges of the wound may be shelved or 'undercut' when the discharge enters at an oblique angle. Tissue may be seen in the floor of the wound at one side, which indicates the direction from which the bullet came. Muscular contractions may distort this picture, however and it is not always present, though minute inspection (using a lens if necessary) may reveal shelving in the deeper layers of the skin rather than in the tissues below. More useful is the shape of the abrasion collar, which will be asymmetrical if the bullet enters at an angle, even through the central hole often remains circular. The other means of determining direction, which is not usually available with shotguns, is the trajectory between entrance and exit wounds. These can be joined and projected in direction of approach to indicate the site of discharge. Two important conditions attach to this interpretation, however:

- If the bullet strikes a solid object, either bone or even a firm organ, it may be diverted within the body to exit well off the original trajectory.
- The posture of the victim's body at the instant of impact must be taken into account. It is too often assumed, especially by lawyers, that all persons are injured – in whatever fashion – whilst standing passively in the 'anatomical position'. Nothing is further from the truth, as people, especially in conditions of fight, fright or flight, may be moving or dodging in a variety of postures, which change by the second. For example, in one of the author's (BK) cases, a woman accidentally shot by a police officer had the anterior entrance wound much higher than the exit in her back. This did not mean that she was shot from above, but that she was leaning forward when the bullet hit her. Much more bizarre examples occur from time to time, such as another case seen by the author (BK) in which a puzzling high-angle wound in the chest was later proved to have been fired from an upstairs window as the victim was knocking on the front door below.

Bullet wounds in bone

Where a bullet passes through bone, especially the thin bone of the skull, the well-known pattern of 'cratering' can usually be seen, though there are exceptions. Using the cranium as the best example, the initial contact of the missile punches a clean hole through the outer table of the skull. Where the bullet emerges internally, the inner table is then unsupported and a cone-shaped plug is detached, forming a crater that is appreciably larger than the external hole. If the bullet traverses the cranium and penetrates the opposite side, the same pattern occurs, this time with the small hole on the inner table and the crater on the outside. In addition to these penetrating defects, there are often fissured, sometimes comminuted, fractures running away from the central holes.

However, though this is the classical picture, a number of exceptions have been reported in the literature, where the cratering has been reversed or is otherwise atypical (Bhoopat 1995).

A shotgun usually destroys a large area of the skull, but similar shelving may be seen on the edges of bone fragments if a bolus of shot strikes the bone. Individual pellets rarely penetrate, but the massive cranial damage from close range of contact shotgun discharges is largely the result of the rapid and violent increase in intracranial pressure caused by the entry of a large volume of gas, as well as the bolus of shot and wads.

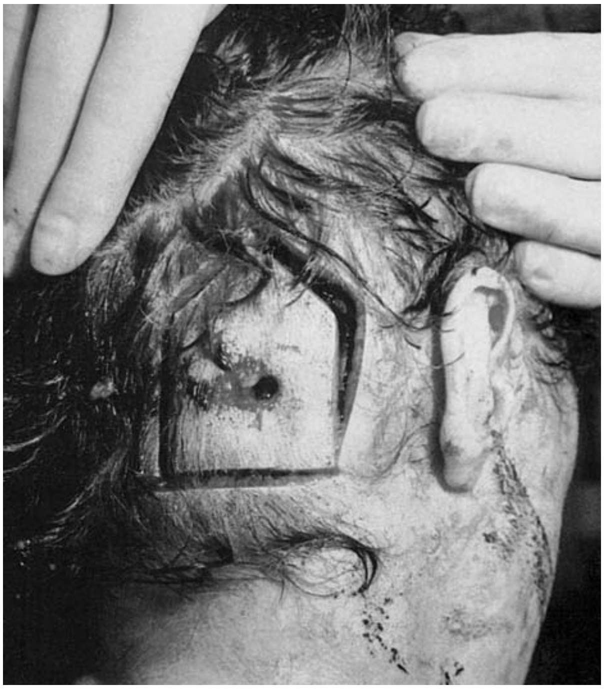

FIGURE 8.46 *Bullet entrance wound, showing the removal of a wide area of skin for forensic examination, the hair having already been removed and preserved before photography. The autopsy incision around the wound is wide, to include any discharge residue and burned skin. The shape of the incision is obviously asymmetrical, to indicate the orientation of the sample after removal from the body.*

Where several bullets have struck the cranium, the sequence of shots can usually be determined using Puppe's rule, which is applicable to any multiple blunt force causing skull fractures. Madea and Staak (1988) have developed this rule in relation to bullet injuries: the test depends on the observations of the fracture lines either when they intersect each other or when they intersect a cratered lesion, so that one can determine which crack or defect must have been formed first.

Where bones other than skull are hit by a bullet or shot, comminuted fractures are frequent and may be the cause of extensive secondary injury. Part of the kinetic energy of the missile is transferred to the bone and fragments may be violently displaced into the adjacent tissues. They may be extruded from the body altogether, leaving secondary exit wounds in the skin. These may give rise to difficulty in interpretation, as both lay persons and doctors may mistake them for lacerated or even stab wounds, unrelated to the firearm incident. Fractures of bone from gunshot impact may be of any variety, and radiography is necessary to detect and orientate fragments of bone and differentiate them from missiles and missile fragments.

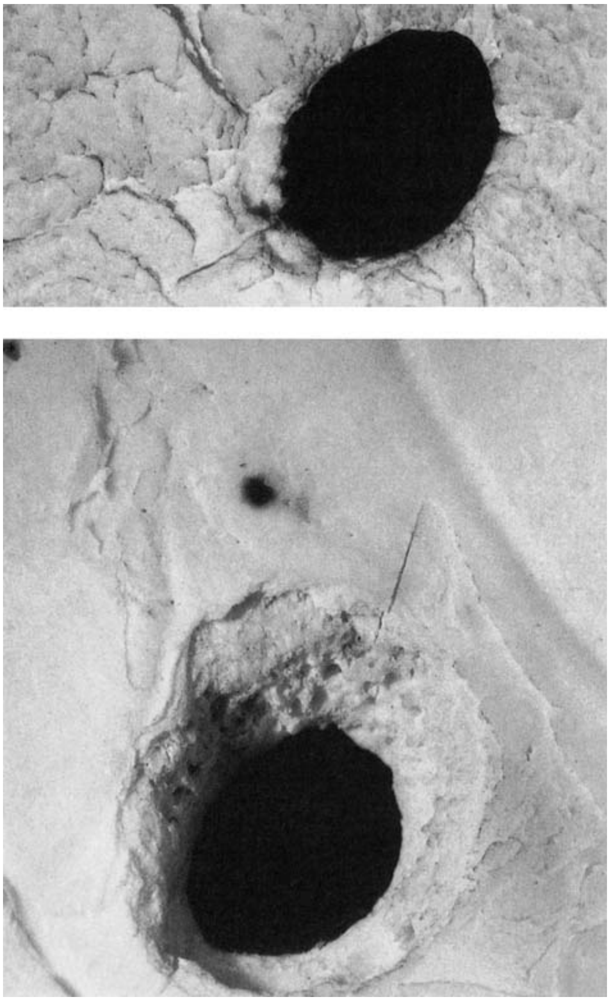

FIGURE 8.47 *The entrance wound of a bullet into a skull. Externally the defect is clean-cut and slightly ovoid because of the oblique impact of the missile. Internally, the inner table of the cranium is cratered, the bevel being caused by lack of support from the diploë. The exit hole on the opposite side of the skull showed a reversal of this pattern, with the cratering on the exterior surface.*

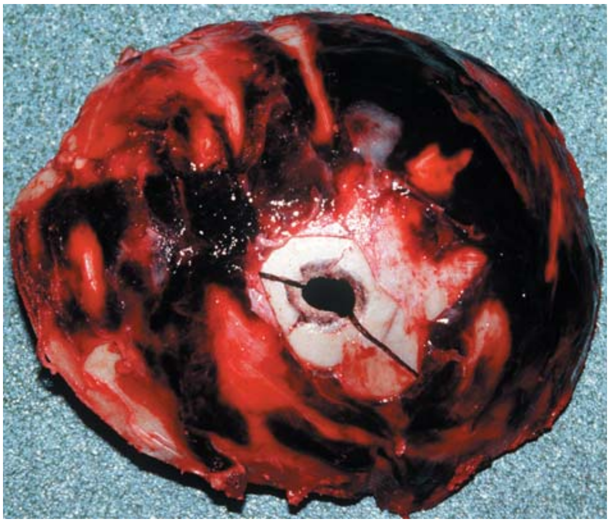

FIGURE 8.48 *Cone-shaped exit wound of the calvarium, with radial fractures in left parietal bone.*

EXIT WOUNDS

When a gunshot wound completely traverses the part of the body struck, an exit wound will result.

Shotgun exit wounds

When smooth-bore weapons are involved, the residual energy of the individual pellets (which have a small mass and a relatively low initial velocity) is usually insufficient for them to emerge through the wider parts of the body, such as the chest and abdomen. Wounds of the limbs, neck and head may well be 'through-and-through' with a twelve-bore shotgun and occasionally, though rarely, with the small 'four-ten'. The range has an effect on the possibility of a shotgun exit wound, as contact or close-range discharge will allow the compacted mass of shot to act like a single bolus – in addition to which, the large volume of intruded gas assists in disrupting the tissues and clearing a path for the missiles, especially in the head. A shotgun blast into the mouth may well remove much of the back of the head as an exit wound, but this is in part caused by the explosion of the cranium by the gas, the so-called 'burst head', which can occur in any gunshot wound of the head, whether into the mouth or elsewhere.

The appearance of a shotgun exit wound is totally random, depending on the anatomical part injured and the addition of any bone or tissue fragments blown out in the discharge. Typically, it is a jagged, irregular laceration with everted edges that exposes deep tissues and comminuted bone fragments beneath. A shotgun injury of the chest or abdomen often just fails to exit on the opposite side, because the toughest obstruction, other than bone, is the skin. It is not uncommon to be able to palpate lead shot under the skin in the contralateral position after it has traversed the body and been trapped by the skin.

As a contact shotgun discharge may produce a large, ragged, entrance wound, this may resemble the exit wound, if present. Differentiation is usually simple, however, because of the burning and soiling present around the entrance. It has been said that the presence of carbon monoxide in the tissues marks the entrance wound, even in decomposed bodies, but carbon monoxide can in fact be detected right through a close shotgun discharge, though the concentration should be greater near the entrance.

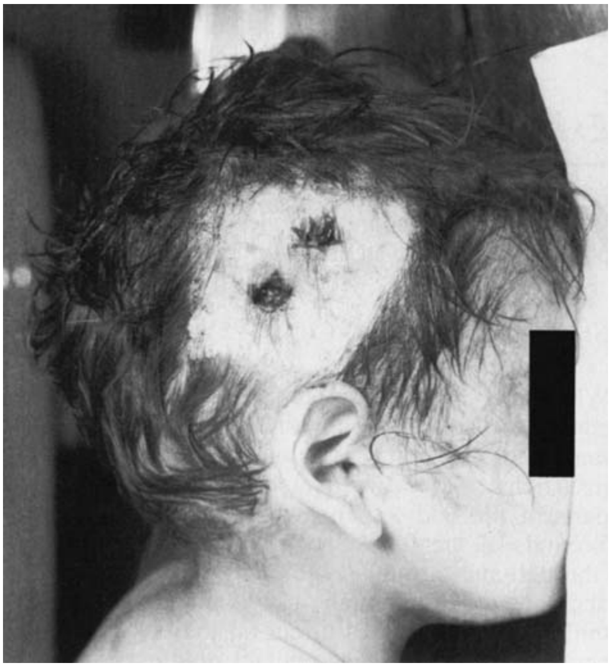
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FIGURE 8.49 *The exit wounds in the fatality shown in Figure 8.42. The two bullets have diverged inside the head from their common entrance wound and emerged separately. The exit wounds are typically stellate, everted and clean. With small-calibre missiles, such as a .22, there is often no exit wound, but here the small head and thin skull provide less resistance to complete traversing.*

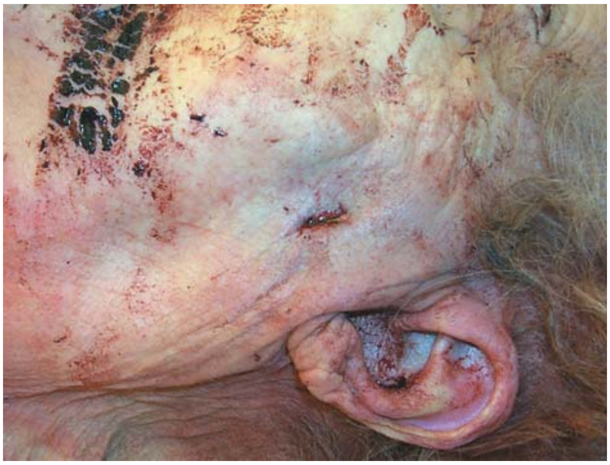

FIGURE 8.50 *Atypical slit-like exit wound of a 7.65 cal. bullet (see also Figure 8.39).*

Exit wounds from rifled weapons

As stated above, many wounds from rifled guns are 'through-and-through', especially from high-velocity military weapons. The muzzle velocity is important in determining whether a single bullet will completely traverse the body. A high-velocity missile (of the order of 800 metres/second or 3000 feet/second) is likely to pass right through the body unless it strikes a large bony structure like the spine, large limb bone or base of the skull. As discussed at the beginning of the chapter, this may be inefficient in terms of wounding capability, as much of the kinetic energy fails to be transferred to the tissues to cause damage, although the cavitating effects of a high-speed missile in vital tissues may be extremely damaging. Much modern military ammunition consists of a small bullet with a large propellant charge to provide maximum muzzle velocity. This, by the familiar physics equation, provides substantial kinetic energy. The bullet is designed to fragment on impact, so that all the energy is transferred and an exit wound may not occur. In some shootings of this nature the pathologist may have difficulty in retrieving any metallic missile material, even after identifying it radiographically, as the fragmentation may reduce the bullet to granules and dust. If the missile does not strike bone or cartilage, it is likely to emerge on the other side of the body, even through the thickness of the chest or abdomen. Of course, in many cases where bone is penetrated (especially the skull or ribs), the bullet will still emerge, but this is considered below.

If a fairly intact bullet emerges, not having been seriously deformed or fragmented, the exit wound is likely to be a small everted defect, either circular or with torn edges. The classical description is of a stellate wound, with triangular skin flaps at the margin, where the bullet has pushed out against unsupported skin. Many wounds may be cruciate or linear slits, however, and others are as circular as the entrance wound, which can give rise to some difficulty in interpretation.

It is naturally important to confirm the direction of the shot, but where a bullet has come from any distance between half a metre and near the extreme range of the weapon, then both entrance and exit wounds can look remarkably similar. There will be no burning or soiling to indicate the entry and identification will depend upon the close examination of the margins of the wounds. Where the entry was covered by clothing, fibres of fabric may have been driven into the wound, which can never occur at the exit.

Though the exit is usually everted, this may not occur if the skin is supported at the moment of penetration. A firm brassière band or an elasticated trouser waistband can press on the skin and prevent eversion, as can a plaster or fibreboard wall, if the victim was leaning against it. In these instances, there may even be a spurious 'abrasion collar', which is really caused by the emerging bullet slamming the wound periphery against the resisting surface. In difficult cases the pathologist or a deputy should examine clothing and the scene, to see if there are any such factors that will help in arriving at a definite answer as to direction.

Usually, the abrasion collar and frayed keratin ring of the entrance wound will be of diagnostic significance, as it is

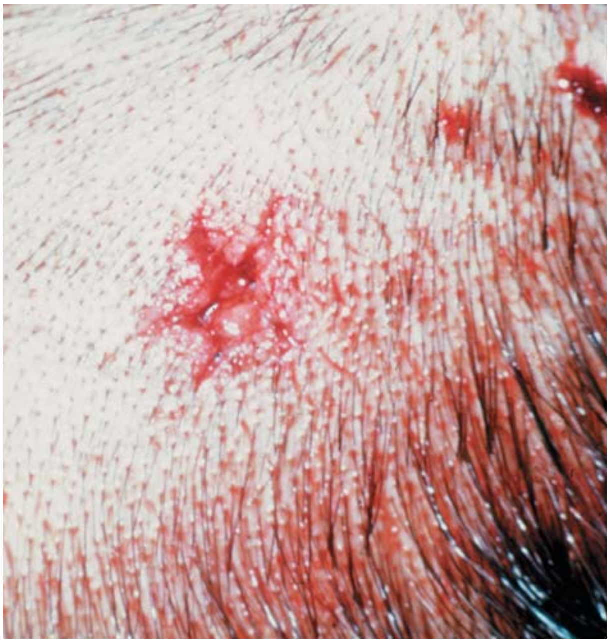

FIGURE 8.51 *Typical exit wound from a 9 mm bullet. The wound in the scalp is everted, stellate and quite clean, the missile having been wiped by its passage through the tissues.*

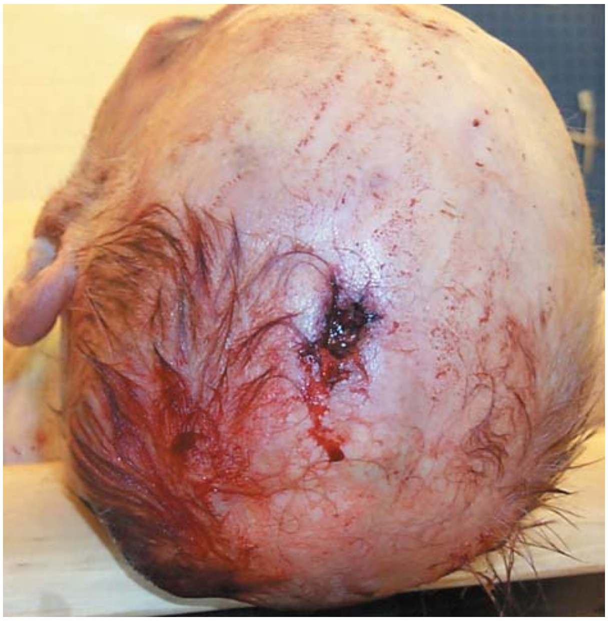

FIGURE 8.52 *Exit wound of a 9 mm pistol fired into the mouth.*

absent in the exit wound, except as detailed above. Occasionally, however, the abrasion collar of the entrance wound is merely a narrow rim that needs close inspection to detect. Where the bullet has struck bone or fragmented, the exit wound may be of any size or shape, and may be multiple. If bone is shattered, pieces can be driven out through the skin, causing wounds that may be mistaken for lacerations from blunt or even incised weapon violence. Where the bullet has hit bone within the body, the bullet may emerge sideways causing a longer or otherwise distorted exit wound.

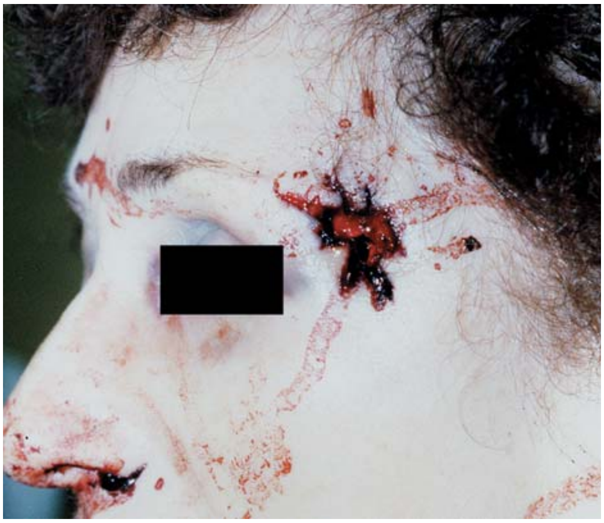

FIGURE 8.53 *Exit wound of the bullet responsible for the wound seen in Figure 8.46, showing the classical everted, split edges, with no soiling of the surrounding skin.*

Of the many bizarre findings in gunshot wounds, re-entry can pose some problems. One case seen by the author had two entrance and one exit wounds, with a single bullet in the body. The victim had been standing against a wall when shot from the front: the bullet emerged through his back, ricocheted from the wall and re-entered his body.

Penetration of two parts of the body is quite common, a single missile causing several wounds. The most usual is a through-and-through wound of the arm or leg, the bullet then re-entering the abdomen or chest. Placing the limb in the appropriate position immediately clarifies the situation and can considerably aid an estimation of direction.

Glancing or tangential rifled weapon wounds

Though the large gaping wounds caused by a glancing blast from a shotgun are rarely seen with rifled weapons, some strange wounds can occur. A bullet may strike the body surface at a shallow angle, enter and then re-emerge some distance away, having travelled superficially under the skin. Within the skull, a missile may enter, follow the internal curve of the calvarium and exit some distance away. Cases are on record of such wounds causing relatively little damage, having traversed the meninges, rather than the brain substance.

When the body surface is irregular, such as the breast, buttocks or groin, several re-entries and exits can take place.

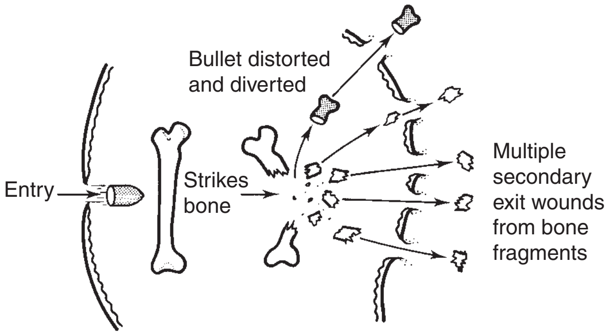
Bullet distorted and diverted
Entry
Strikes bone
Multiple secondary exit wounds from bone fragments

FIGURE 8.54 *Diversion of trajectory of bullet on striking bone. The secondary effects can be more damaging than those from the missile.*

In these instances, extensive bruising may mislead examiners into assuming that some blunt injury has occurred, if the firearm nature of the wound is overlooked.

A bullet striking at a small angle with the surface may follow the curvature of the skull or a rib and emerge some distance away after having made a track in the subcutaneous tissues. Alternatively, a bullet can pass tangentially across the surface, causing a linear graze or even a laceration, which may lead to great difficulties in interpretation if the circumstances are unknown. Gunshot wounds in the axilla or across the side of the thorax may gape widely, looking quite unlike a firearm injury to an unsuspecting medical examiner.

FIREARM DAMAGE TO INTERNAL ORGANS

This may be of any nature, but broadly falls into two categories:

- Contusion and laceration from low-velocity impact. Where a mass of shotgun pellets and gas strike tissues or an organ the damage is simple mechanical disruption, with widespread haemorrhage from local vessels. Similar, though less extensive, damage is likely from a low-velocity rifled bullet or slug, which pushes the tissues apart as it ploughs through an organ or muscle. Secondary damage can occur from fragmentation of bone or bullet, which produces further traumatizing missiles within the tissues. The danger to life that ensues naturally depends upon the target tissues – a clean wound through the thigh may cause only temporary disability, whereas the same wound through heart or brain may well be rapidly fatal.
- High-velocity missiles produce disproportionate damage relative to their diameter because of cavitation effects, described at the beginning of the chapter. This is particularly damaging in solid organs, such as the brain and liver. The track may be many times wider than the diameter of the bullet, and may consist of pulped and haemorrhagic tissue left behind by the pulsating cavitation effect caused by the lateral transfer of energy as the missile passes through.

ESTIMATING THE RANGE OF DISCHARGE

This is one of the most important aspects of the interpretation of firearm wounds. Though guidelines can be offered, it cannot be emphasized too strongly that every weapon and batch of ammunition will vary, so that medical opinion must always defer to the results of test firing with the same gun and similar shells. Allowance must also be made for the effect of interposed clothing.

Rifled weapons

TIGHT CONTACT OVER SOFT TISSUES

- Possible muzzle impression.
- Circular hole with abrasion collar.
- Bruising.
- Local reddening from heat and monoxide.
- Little or no surface burning.
- Little or no propellant soiling or powder tattooing.

TIGHT CONTACT OVER UNDERLYING BONE

- Split or cruciate wound.
- Local reddening and monoxide.
- Bruising.
- Little or no surface burning or propellant soiling.
- Abrasion collar partly lost on skin tags.

DISCHARGE FROM LESS THAN 15 CM (6 INCHES)

- Circular hole with abrasion collar.
- Flame burn on surrounding skin.
- Burnt hairs.
- Soot and smoke soiling (depending on ammunition).
- Small punctate burns from propellant tattooing.
- Unburnt propellant flakes.
- Little or no monoxide in tissues.

DISCHARGE FROM 15 TO 30 CM (6 TO 12 INCHES)

- No soot, but perhaps powder tattooing, depending on barrel length.

- No monoxide.
- Rarely, flame burns.

DISCHARGE FROM MORE THAN 40–60 CM (16–24 INCHES)

- Circular hole with abrasion collar.
- No burning, soiling, burnt hairs or monoxide.

FAR DISTANT DISCHARGE AT LIMIT OF RANGE

- Larger, irregular hole with irregular abrasion rim caused by tumbling bullet.
- No other features.

Smooth-bore shotguns

TIGHT CONTACT DISCHARGE OVER SOFT TISSUES

- Single circular wound about diameter of muzzle.
- Smooth margin.
- Often muzzle imprint.
- Blackened edge.
- No surrounding smoke soiling unless clothing allows leakage.
- Deep bruising.
- Pink tissues.
- Wads in wound.

TIGHT CONTACT DISCHARGE OVER SKULL OR BONY AREA

As last type, but wound may be ragged and split from gas rebound.

DISCHARGE WITHIN A FEW CENTIMETRES

- Circular wound, unless oblique discharge.
- Smooth or slightly crenated margin.
- No satellite pellet holes.
- Surrounding soot soiling.
- Punctate powder burns.
- May be unburnt powder flakes.
- Burning of surrounding skin.
- Burnt hairs.
- Pink monoxide in tissues.
- Wads in wound.

DISCHARGE FROM 30 CM (12 INCHES)

- Circular ‘rat-hole’ wound with nibbled margins.
- No satellite pellet holes.
- Soot soiling may persist.
- Powder tattooing present.
- Little or no monoxide.
- Still burning of skin and hairs.
- Wads in wound.

DISCHARGE FROM 1 TO 5 M (39 TO 195 INCHES)

- Central ‘rat-hole’ wound.
- Satellite pellet holes around periphery.
- No burning.
- No soot.
- Maybe slight tattooing at 1 m.
- No monoxide.
- Wads not in wound at upper part of this range.

DISCHARGE OVER 5 M (195 INCHES)

- Diffuse pellet pattern.
- Probably no central hole.
- No burning, soot, tattooing, monoxide, no wads.

All the foregoing data are very variable, being dependent upon the individual weapon and ammunition. Test firing must be used to validate the pathological interpretation.

AIRGUN INJURIES

Air rifles and pistols produce wounds that have some of the characteristics of both shotguns and explosive rifled weapons. The missile is single and fired through a rifled barrel, but is small and resembles a shaped (waisted) shotgun pellet.

The muzzle velocity is relatively low, but some more sophisticated rifles, such as the German Weirauch, can produce more than 12 foot-pounds of energy and the pellet can easily penetrate a wooden door – and the human skull.

Two calibres are common, the .177 and the .22 inch, the latter naturally being the more dangerous. The .177 can, however, penetrate the thin temporal bone of a child. Wounds from an air weapon are rarely fatal except when the head is struck – and children are the usual victims. The pellet can enter the skull and traverse the whole width of the brain, but never produce an exit wound, being usually found in the contralateral meninges. The track may be surprisingly wide for such a low-velocity missile.

Apart from fatal head wounds, a number of eye injuries occur from airguns, the pellet lodging within the globe, the orbit or the adjacent air-sinuses. Radiology is obviously of prime importance in locating the missile, prior to surgical removal.

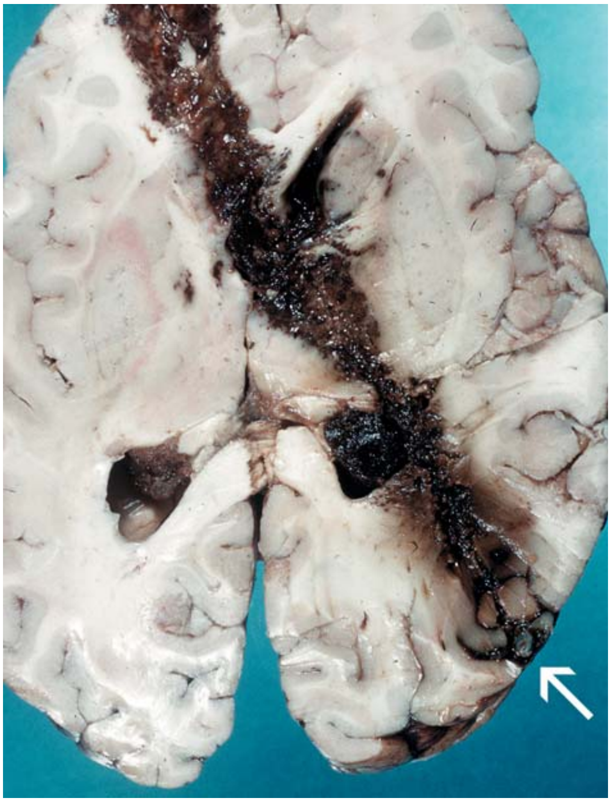

FIGURE 8.55 *Track through a child's brain made by a .177 inch air-rifle pellet (arrowed). Although a relatively low-velocity missile, the track is much wider than the pellet from lateral transfer of kinetic energy.*

There are no particular features of an air weapon wound, as, of course, there are none of the heat, powder or soot effects of an explosive gun. The entry wound is small, but may show an abrasion ring. There is never an exit wound, unless the tissue traversed is extremely narrow.

HUMANE (VETERINARY) KILLERS AND INDUSTRIAL 'STUD-GUNS'

Explosive weapons of a specialized type are used in abattoirs and by veterinary surgeons to dispatch large animals.

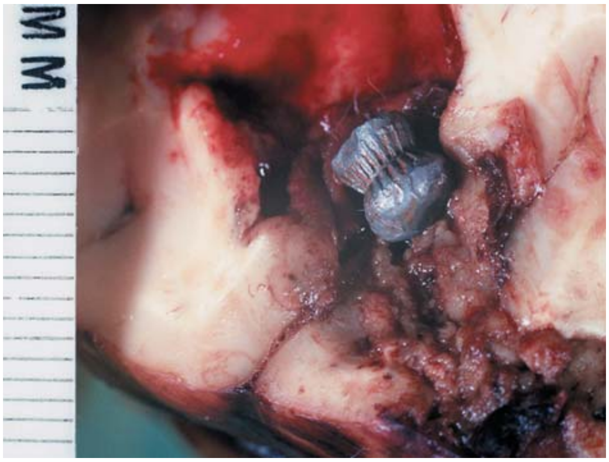

FIGURE 8.56 *Airgun pellet in brain tissue.*

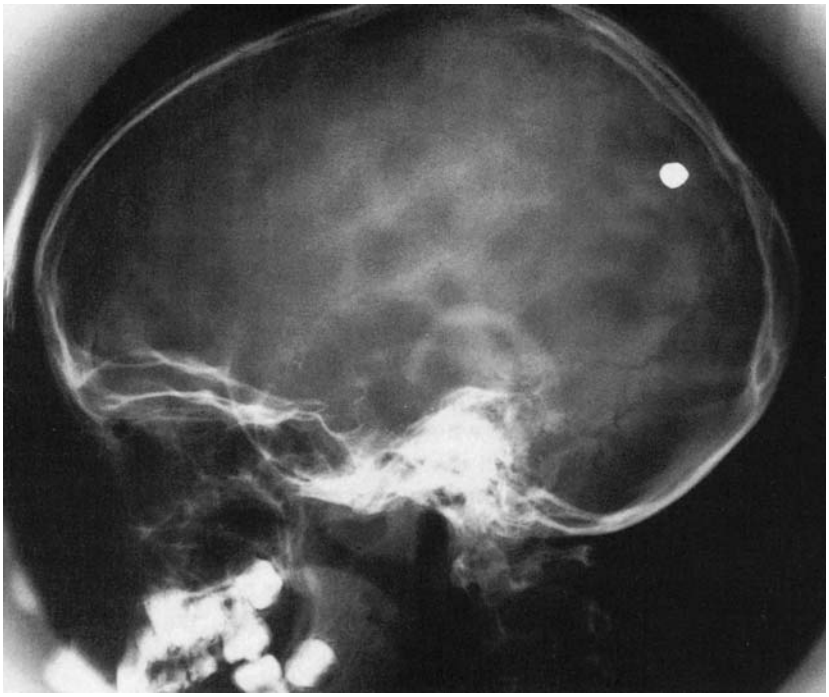

FIGURE 8.57 *Radiography can assist in locating a missile before autopsy, so that random searching does not cause instrument damage to the delicate striation pattern used for weapon identification. Here there is a lead pellet in the occipital lobe, with a bone defect in the extreme front of the skull.*

They may be of the 'captive-bolt' type, which consists of a metal rod, the distal end of which is propelled for a few centimetres from the muzzle of the weapon by a blank cartridge inserted in a chamber behind the proximal end. The captive bolt inflicts a clean, penetrating injury, about 5 cm deep, which can be mistaken for a stab-like injury.

Another variety consists of a metal barrel on the distal end of which is a heavy flange, which is placed against the head of the animal. A cartridge carrying a 0.31 inch (8 mm) bullet is inserted into the proximal end of the barrel and a firing pin struck with a mallet. The injuries from this resemble a contact wound from a conventional weapon, though the base of the flange may have embossed concentric circles to prevent slipping, which may produce an unusual patterned imprint on the skin surrounding the wound.

Another type is the Webley veterinary pistol, which is of .32 calibre and is virtually identical with a conventional gun. Humane killers may cause injuries on humans either accidentally or suicidally, homicide being rare. The nature of the weapon will almost always be apparent from the circumstances, including the presence of the weapon. Death may be delayed due to complications, as in one case seen by the author (BK) where a farmer died of tetanus after accidentally shooting himself in the knee with a humane killer.

Devices used in industry and especially the building trade, are similar to humane killers. These are the 'stud-guns' used

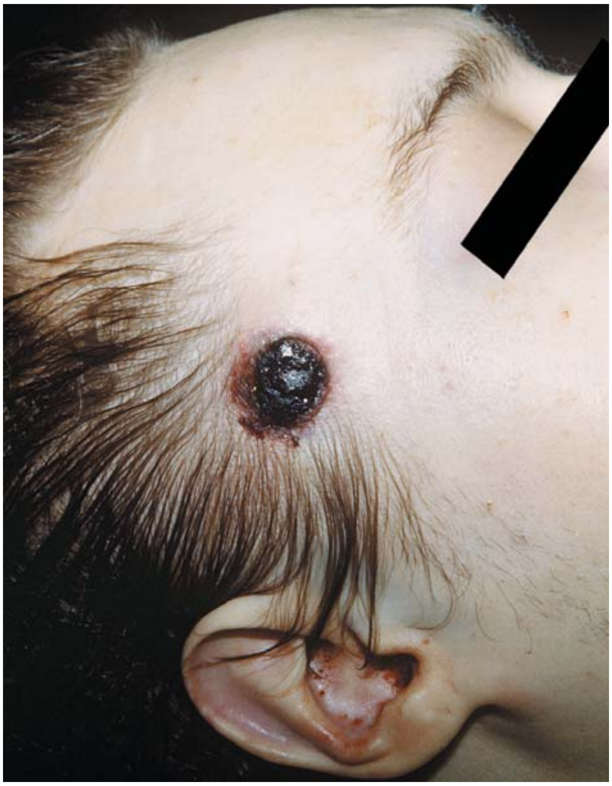

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FIGURE 8.59 *Suicidal contact wound from a humane veterinary killer (see also Figure 8.60).*

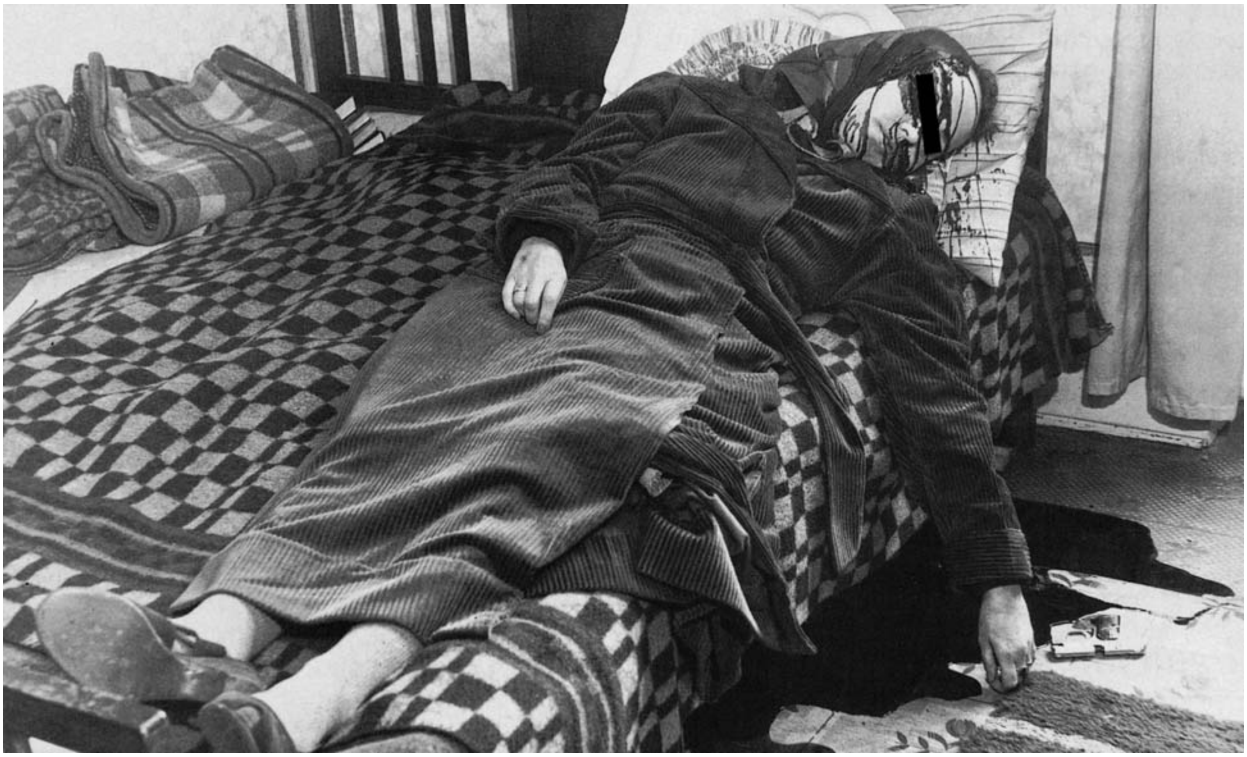

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FIGURE 8.58 *A relatively unusual photograph in Britain, in that the suicide is of a woman and an automatic pistol is used. Note the massive haemorrhage on the floor, which illustrates the possible extent of post-mortem bleeding.*

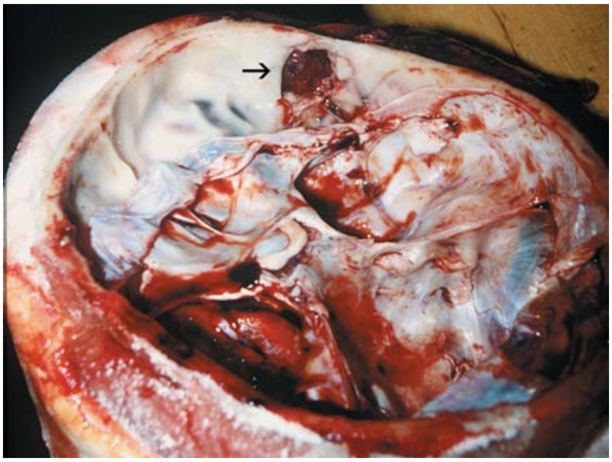

FIGURE 8.60 *Defect of the right frontal bone (arrow) from a humane veterinary killer (see also Figure 8.59).*

for driving a hardened metal pin or threaded stud into masonry, or other wood or metal structures as a rapid and convenient means of attachment. An explosive cartridge, often of .22 calibre, is used to drive a piston that acts as a hammer on the pin or stud. Many accidents and the occasional suicide have occurred from these tools, which resemble a long pistol, with a flat faceplate attached to the muzzle for pressing against the structure. Some accidents occur because the guns are used on relatively flimsy partitions, and the stud traverses the structure and flies on to injure or kill someone on the other side.

RUBBER AND PLASTIC BULLETS

A relatively recent innovation in firearms is the use by police and security forces of projectiles for riot control. Originally rubber bullets were used, being compressed into smooth-bore weapons. These have been abandoned in Britain in favour of 'baton rounds', more commonly known as 'plastic bullets'. They have been used in large quantities in Northern Ireland, some 43 000 having fired up to 1985. These projectiles have not yet been used in the mainland of Britain, though many police forces hold stocks. Elsewhere in the world, they are used extensively for riot control.

The baton round is a solid cylinder of polyvinylchloride 38 mm in diameter and 10 cm long, weighing 135 g. When fired from a smooth-bore weapon it has a muzzle velocity of about 250 km/hour and an effective range of 50–70 m. It should not be fired at a person under about 20 m range. It is used to disperse riots and discourage stone-throwers by striking them sufficiently hard to cause pain and bruising, but no serious injury. The bullet is about the same weight as a cricket ball, but travels twice as fast as the best bowler could deliver it. In Britain, the bullets were made by Pains-Wessex-Schermuly, but later by Brocks Fireworks and also by the Ministry of Defence. Many injuries and some deaths have been reported from their use. Fractures of the face and skull, eye damage including blinding, broken ribs and limbs, and contusions of liver, lung and spleen have occurred.

Police are instructed to fire at the lower half of the body, to avoid the more serious injuries arising from hitting the head or chest. The death rate is said to be 1/18 000 rounds fired, compared with rubber bullets which had a mortality rate of 1/4000 rounds.

DEATHS FROM EXPLOSION

Deaths from the effects of explosive substances or devices occur in both civil and 'military' circumstances, though the latter now include a considerable proportion of terrorist activities rather than conventional wars. Civil tragedies are usually industrial, as in individual incidents in mines and quarries, or on a larger scale, such as the detonation of chemical stores, ships or factories.

The nature of explosive trauma

Several different factors cause injury following an explosion, and the relative importance of each varies considerably with the type of detonation. For example, pure blast effects are far more important with high-explosive projectiles designed for purely military use than with the home-made terrorist bombs, the lethality of which may be primarily caused by flying fragments. Death and injury from explosives is caused by:

- blast effects
- impact of projectiles derived from the explosive device
- impact from surrounding objects and debris impelled by the explosion
- burns from hot gas and incandescent objects
- secondary injuries from falling masonry, beams and furnishings dislodged by the explosion.

A blast consists of a wave of compression passing rapidly through the air – or water in the case of a submarine explosion, such as a mine. The velocity of the shock wave depends on the distance from the epicentre, being many times the speed of sound at the start, but rapidly decreasing as it spreads out. The compression wave is followed by a transient zone of low pressure (below atmospheric), so that a rapid double change in pressure is suffered by the body. The magnitude of the blast varies with the energy released and also with the distance from the epicentre, the intensity obeying the inverse square law. With all but powerful military high explosives, the blast effects of most terrorist devices fall off so rapidly with distance that only those in the immediate vicinity will suffer severe damage from blast. Not uncommonly, this type of victim is the bomb-setter himself, when a premature detonation occurs.

A blast causes the most damage at an interface between tissues in contact with the atmosphere, which is why the lung usually suffers the most. About 100 lb/inch^2 (690 kPa) is the minimum threshold for serious damage to humans. The shock wave can pass through solid, homogeneous tissues such as liver and muscle, causing little or no damage, but in the lung there is marked variation in density between the alveolar walls and the contained air so that damping of the shock wave occurs and energy is absorbed, with disruptive effects.

There is controversy about whether pulmonary damage occurs from direct transmission of the shock wave through the thoracic wall, or through the oronasal orifices and air passages. In any event, the autopsy signs are of subpleural patchy haemorrhages, often in the line of the ribs, intrapulmonary haemorrhage and bullae at the lung margins. The air passages may be filled with bloody froth causing airway obstruction and hypoxia in addition to the primary damage.

Microscopically the alveolar walls can be shredded by the acceleration and consequent tearing of the air-sac wall when the shock waves traverses the lung. Desquamated alveolar and bronchial epithelium is seen lying free. Large areas of haemorrhage are seen, with either the alveolar pattern still visible or the architecture completely disorganized. Pulmonary haemorrhage in explosive incidents is often not caused solely by the blast, but may be from direct impact on the chest from flying objects, aspiration of blood from nasopharyngeal injuries and from bleeding following aspiration of stomach contents.

The ear may suffer severe damage from a blast, but this is not easily discernible at autopsy. Clinical examination and testing (obviously in the living) reveals many lesions, but these are of little relevance to the pathologist.

The gastrointestinal system suffers from the effects of a blast because, like the lung, it contains air and gases, and is thus not a uniform medium for transit of the shock wave. Once again haemorrhage is the most common lesion, usually small foci of the order of a centimetre in size. They may form circumferential bands around the intestine or may be confined to the serous coat as focal haemorrhages. The caecum and colon are more often injured than the ileum, jejunum and stomach, probably because they are larger and often contain more gas. Occasionally ruptures of the gut occur if the blast is violent and the victim in near proximity.

Victims of explosions in water suffer a reverse order of gastrointestinal to lung damage. The former is more common and may be manifested as haemorrhages under the serous coats and mucosa. Perforations may occur and, in survivors, peritonitis is not uncommon. The perforations are often multiple and in any part of the intestine. Lung damage is less common in water and some instances may be caused by impact transmitted up through the diaphragm.

Missile injuries in explosions

It is again emphasized that unless a sophisticated high-explosive military device is involved, or if the victim is virtually adjacent to a lower energy terrorist bomb, blast effects will rarely be the sole cause of death. The body will, however, be vulnerable to impact from solid fragments originating from the bomb casing or a container or conveyance, such as a car in which the bomb was concealed. Fragments of metals, from tiny splinters to large chunks or sheets, will be projected at high speed. The smaller ones will not travel more than a few metres, but larger, heavier pieces can fly over considerable distances and can cause serious or fatal injuries in just the same way as projectiles from a firearm. In the open, debris is scoured away, including dust and dirt, which can impinge on the body to injure and discolour it. At autopsy the body may appear pigmented from this dust blasting, the clothing causing a shadow effect similar to bathing suit protection from sunburn. A more common appearance is a ‘peppering’ as a result of the numerous small missiles causing bruises, lacerations and abrasions. The lacerations are often puncture wounds, of varying size and depth. Burns may also discolour the body, especially those areas unprotected by clothing. Flash burns from the bomb itself only affect those nearby unless the device is massive, though singeing of hair and eyebrows is not uncommon. Other burns may be caused by ignition of clothing, or by the building or vehicle catching alight from the bomb effects –or from gas or petrol ignition.

A massive bomb, or one where the victim is virtually on top of the device, may totally disrupt the body and fling unidentifiable pieces over a wide area. Alternatively, part of the body may be totally destroyed, sometimes the remainder of the victim being remarkably intact. The legs may be blown off or the abdomen disrupted, or the hands and arms torn away. In terrorist attacks these effects may be seen in the person who was planting the bomb or carrying it to the place chosen for detonation. A premature explosion, sometimes during the act of setting the timer, may cause these localized injuries.

The pathologist may be able to assist in reconstructing the events, as localized severe trauma obviously indicates the relative position of the bomb and the victim at the time of detonation. If the lower legs are destroyed, then the person was standing near the device that lay on the ground. Punctured wounds and bruises on the front of the thighs and trunk will indicate that he was facing the bomb. If the thighs, pelvic region and abdomen are damaged, the bomb may have been carried on the lap – and if the hands, chest and face are the most affected areas, the deceased may have been bending over the device.

The autopsy in explosion deaths

The salient features have already been described and much of the autopsy is directed at listing the injuries, as in any other trauma death. The interpretation outlined above, however, may be most important for the investigators.

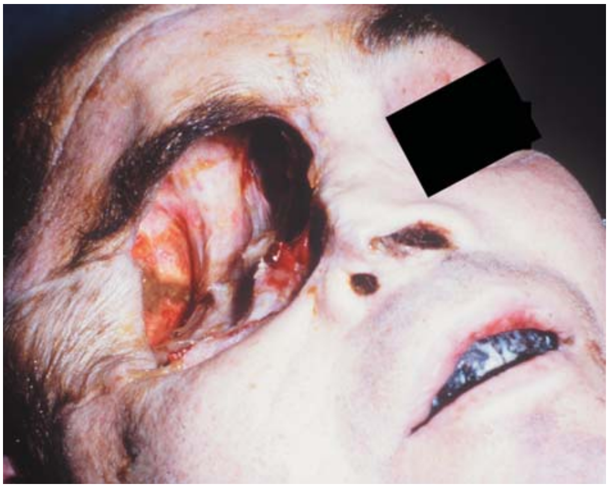

FIGURE 8.61 *Localized injury by an explosive device. The soldier picked up an apparently 'dud' smoke shell, which then detonated. He lived for some weeks, the injury having partly healed, though part of the face and skull were destroyed.*

There are some more specific matters in an explosion death which the pathologist must bear in mind. Firstly, trace evidence may be vital to the forensic scientists and bomb experts, who are trying to trace the maker of a terrorist device. X-rays should be taken of all bodies before autopsy to identify any radio-opaque objects. Not only will this assist in detecting lethal missiles not visible from the surface, but it may reveal small metal objects that form part of the bomb mechanism, such as small springs or contacts from the timer or detonator. These may be invaluable in allowing the experts to recognize the handiwork of a particular bomb-maker or terrorist group. Such radiography may also reveal the unexpected, which in the past has included a bullet, the victim having been blown up after death from shooting. Even prior to radiography, there may be much that the pathologist has to do. Though many explosion victims are relatively intact, where extensive disruption has occurred, the fragments have to be collected and sorted out in the mortuary.

A major initial problem is to discover how many bodies are represented and to try to allot the correct fragments to the right individuals. Where there are a number of victims and a large pile of small fragments, this task may be difficult or impossible, but it is naturally of paramount importance to determine how many victims are involved and to determine the sex of each. This is largely an anatomical exercise, akin to the sorting of multiple skeletal remains. Careful identification of all recognizable structures, such as prostate, uterus, breasts, scalp, eyes, for example, is needed in addition to more gross sorting of limb and trunk fragments. Radiology may again assist in matching contained skeletal structures, but much of

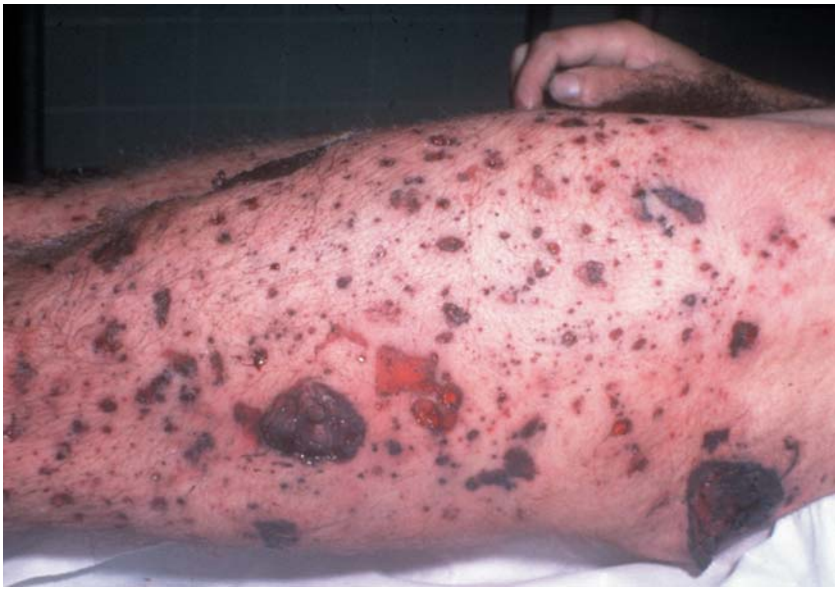

FIGURE 8.62 *Numerous wounds and peppering by debris projected in a terrorist bomb blast. Blast injuries occur only in close proximity to the device – most injury is caused by flying projectiles. (Reproduced by kind permission of Professor TK Marshall.)*

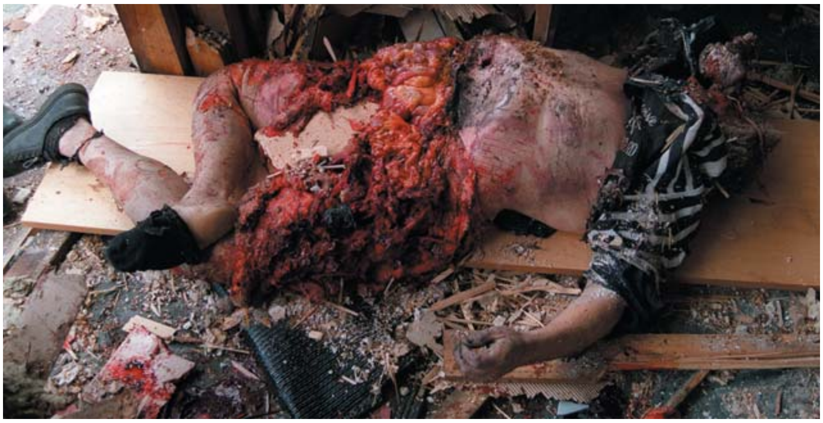

FIGURE 8.63 *Anterior aspect of a man who had constructed an explosive device using dynamite. The device probably detonated prematurely, the blast disrupting the head and abdominal region.*

the debris accumulated after a large explosion consists mainly of skin and attached tissues.

In spite of the most thorough police search of the scene, considerable proportions of some bodies are never recovered, having been disrupted into tiny fragments and mixed with the masonry and other debris of the bomb site. The collected fragments have to be washed clean from the inevitable dirt that coats them and sorted into groups by anatomical similarity. Non-human tissue is discarded, as animal material is not uncommonly admixed. The completed piles of tissue are then resorted by any apparent similarity, such as racial pigmentation, hair colour and sex. Limbs and large joints are then sorted, allotting them to left and right from anatomical considerations.

The difficulties of such a task was emphasized by Professor TK Marshall, whose experiences in Northern Ireland make his writings on the subject the definitive guide to such tragedies. In one of his incidents, eight victims were accounted for, when a single penile fragment forced the inevitable conclusion that there were in fact nine victims, not eight, though no other recognizable part of this ninth man was ever discovered. He had presumably been the bomb-carrier and had been completely disintegrated.

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CHAPTER 9

Transportation injuries

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Injuries and fatalities occur in all forms of transportation but numerically road traffic accidents account for the great majority worldwide. In developed countries, they are the most common cause of death below the age of 50 years, and in young men this trend is even more marked. The pattern of injury, fatal and otherwise, varies considerably depending upon whether the victim is a vehicle occupant, a motorcyclist, a pedal cyclist or a pedestrian.

THE DYNAMICS OF VEHICULAR INJURY

A number of elementary physical facts help to explain the complex pattern of traffic injuries, especially those sustained by the occupants of a vehicle.

- Tissue injury is caused by a change of rate of movement. A constant speed, however rapid, has no effect whatsoever as is evident from space travel or the rotation of the earth. It is the change of rate that is traumatic – that is, acceleration or deceleration.
- Change of rate is conveniently measured in 'gravities' or 'G forces'. The amount that a human body can tolerate depends greatly on the direction in which the force acts. Deceleration of the order of 300 G can be sustained without injury and even 2000 G can be survived for a short time, if it acts at right angles to the long axis of the body. The frontal bone may resist 800 G without fracture and the mandible 400 G, as can the thoracic cage.
- During acceleration or deceleration the tissue damage produced will depend upon the force applied per unit area, just as a sharp knife penetrates more easily than a blunt one used with the same force. If a car driver is brought to rest from 80 km/hour by striking 10 cm^2 of his head on the windscreen frame, the damage will be vastly more severe than if the same decelerative force was spread over 500 cm^2 of a safety belt.
- Between 60 and 80 per cent of vehicular crashes (either into a fixed structure or into another vehicle) are frontal, causing violent deceleration. Another 6 per cent are rear impacts, which accelerate the vehicle and its occupants. Of the remainder, about half are sideswipes and the rest 'roll-overs'.
- In the common frontal impact, there is never instant arrest of the vehicle, even when it runs into a massive, immovable structure. The vehicle itself deforms from the front so that there is always a deceleration distance and time, albeit small. In fact, much of the manufacturers' design research now goes into making deliberate provision for the crumpling or 'concertinaing' of the front and rear of the car, leaving a central rigid cell that comprises the passenger compartment. The object is to extend the stopping distance and time, so that the G value acting on the occupants is reduced.
- The value of the G forces can be calculated from the formula: $G = C(V^2)/D$, where V is velocity in km/hour, D is the stopping distance in metres after impact, and C is a constant 0.0039. (If V is in mph and D is in feet, C becomes 0.034.) For example, if a car

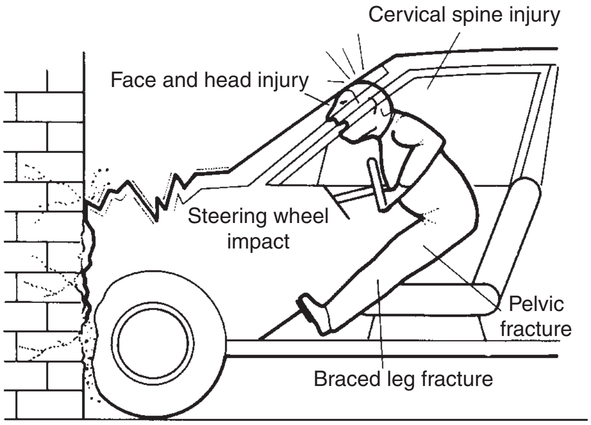

FIGURE 9.1 *Major points of injury to an unrestrained driver of a vehicle in deceleration impact.*

travelling at 80 km/hour runs into a stone wall that it penetrates for 25 cm, plus 50 cm crumpling of the front of the car, the deceleration would amount to about 33 G. If an occupant was rigidly belted into his seat (a practical impossibility), he would also suffer the same deceleration, which would be survivable. If, however, he was unrestrained, he would continue forwards momentarily at 80 km/hour and suffer massive G forces, the magnitude of which would depend on his deformation stopping distance (a few centimetres of tissue compression) when he struck the internal car structures in front of him.

PATTERN OF INJURY OF VEHICLE OCCUPANTS

The type of vehicle (other than motorcycles) in theory makes little difference to the mechanism of injury, but most statistical surveys divide them into cars and light vans under 1.5 tonnes, on the one hand and heavier vehicles, such as trucks and buses, on the other, though the latter have different features more akin to passenger aircraft.

Heavy goods vehicles naturally suffer less than cars and light vans in crashes because of their far greater mass and strength, and also due to their height above the ground. Structural damage from impact with other smaller vehicles is less and often sustained below the level of the driver. Given smaller deceleration forces, however, the cab occupants are vulnerable to the same injury patterns.

Light vans are virtually identical to cars with respect to the front-seat occupants. In fact they may be more at risk, as modern vans tend to be flat-fronted and thus have little or no 'crumple' potential to increase the stopping time. Concentrating on cars, the most common vehicular casualty, the pattern of injury varies according to the position of the occupant.

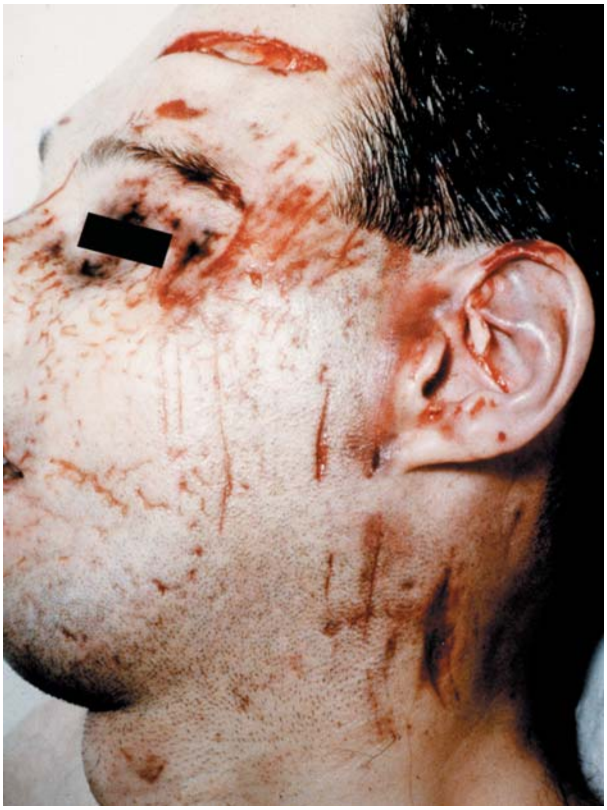

FIGURE 9.2 *Facial lacerations from a shattered windscreen in an unrestrained driver. The toughened glass breaks into small fragments, which produce the characteristic 'sparrow-foot' marks. The laceration on the forehead was made by the windscreen rim.*

The driver

Numerous investigations have been made by road research organizations and car manufacturers using dummies and actual corpses, together with sophisticated recording equipment and high-speed cinematography. These have established a detailed picture of the sequence of events in automobile crashes. When the most common event – frontal impact – occurs, the unrestrained driver first slides forwards so that his legs strike the fascia/parcel-shelf area, and his abdomen or lower chest contacts the lower edge of the steering wheel. The body then flexes across the steering wheel and begins to rise. The heavy head goes forwards, and there is flexion of the cervical and thoracic spines. The upward and forward component causes the head to strike the windscreen, the upper windscreen rim or the side pillar. The windscreen is often perforated by the head or face, and the whole body may be ejected through the broken glass, to land on the bonnet or even on the roadway ahead.

Another factor causing injury is the intrusion of structural parts into the passenger compartment. Though modern cars are designed to maintain a rigid central passenger compartment, if the impact is gross, the engine or front-wheel assembly may be forced back into the seating area, intruding upon the driver. Similarly, the roof or front corner pillar (the so-called 'A'-frame) may cave in on top of the driver.

One effect of column, engine, or gearbox intrusion may be to force the floor up and backwards against the driver's feet and legs. The control pedals also take part in intrusion, and, in the usual desperate braking and declutching, the reflex pressure of feet on rising pedals and floor may cause transmitted force up the legs and into the pelvic girdle. The steering column was formerly a more dangerous item for intrusion, being forced back to 'stab' or crush the driver's chest or abdomen. Modern design has reduced this danger by making the column telescopic, hinged or otherwise collapsible, but injuries still occur – sometimes from the wheel itself breaking and penetrating the chest. Additionally, the door may burst open and the driver, if unrestrained, ejected sideways onto the road, especially in a crash that has a roll-over component.

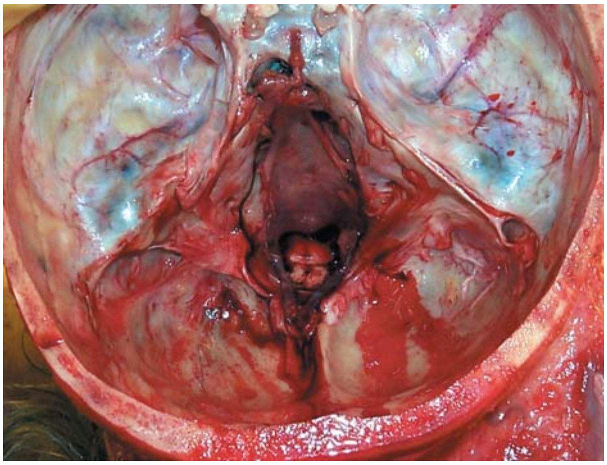

FIGURE 9.3 *Ring fracture around the foramen magnum caused by an impact on the crown of the head in a car driver, who lost the control of his vehicle and crashed into a tree.*

In a rear impact, the driver is violently accelerated and, if no rigid head restraint is fitted to the seat, severe hyper-extension of the neck occurs, often followed by the sequence of deceleration events when the car is cannoned into the vehicle or other obstruction in front, causing the popular, if inaccurate name of 'whiplash'.

In side impacts, the injuries depend upon the amount of intrusion of the driver's door and side panels. Restraint devices can offer no protection, though modern vehicles usually have strengthened side-impact bars built within the doors.

This range of traumatic events can produce the following lesions in drivers not wearing seatbelts or protected by airbags:

- Impact against the fascia can cause abrasions, lacerations and fractures of the legs around knee or upper shin level.
- Pressure of feet on the floor, especially when it is intruded by the engine, can cause fractures anywhere from foot to femur. The leg can also be injured by violent contact with the fascia or dashboard and the hip joint may be dislocated posteriorly. Not uncommonly the pelvis is fractured, often at one or both sacroiliac joints. In Mant's (1978) series of 100 driver fatalities there were 22 pelvic injuries and 31 of the lower limb.
- Impact of the abdomen and chest against the steering wheel may cause severe internal injuries, usually rupture of the liver (50 per cent) and, less often, spleen (36 per cent). There may be bruising of the skin surface, but this is often absent even in the presence of

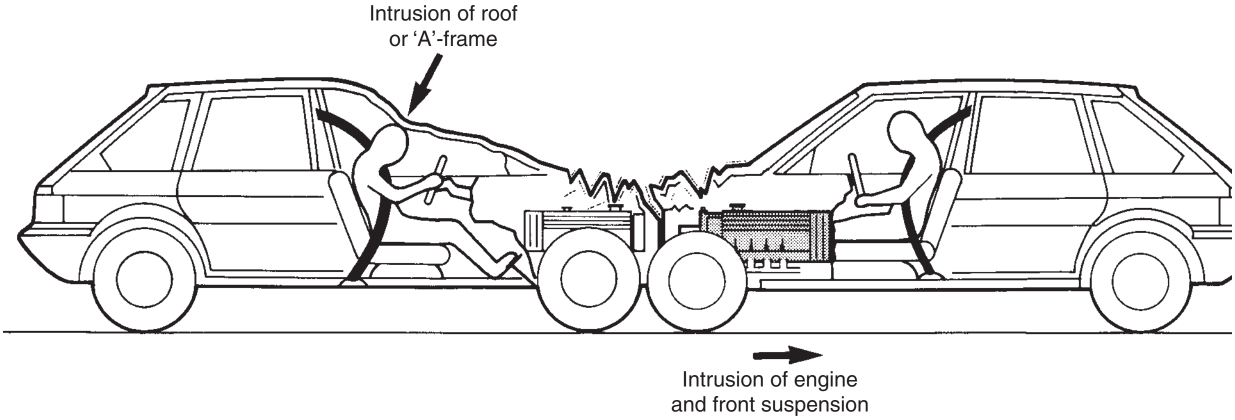

FIGURE 9.4 *When vehicle structures impinge on the occupants even belt restraints offer little protection. The engine, front suspension, roof and 'A' frame are frequent intruders.*

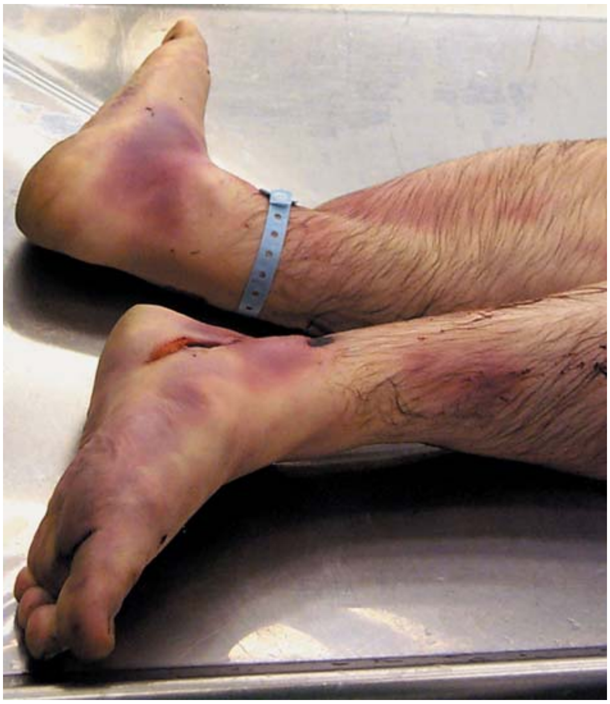

FIGURE 9.5 *Bruising, laceration and bilateral leg fractures of a car driver in a frontal impact.*

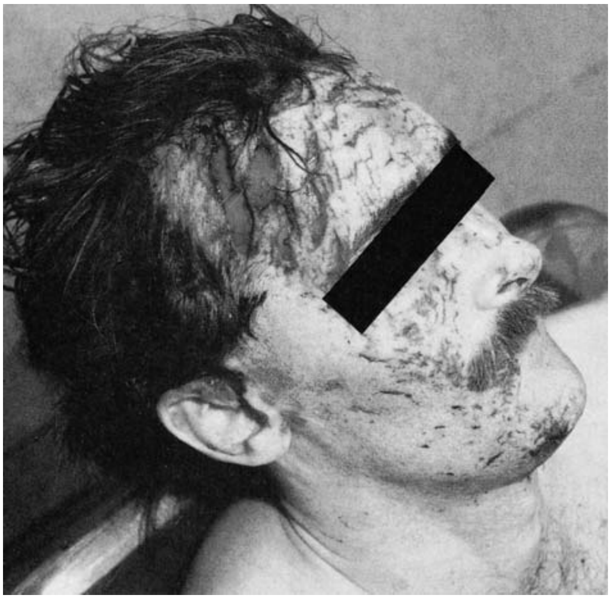

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FIGURE 9.6 *Facial injuries in a car driver unrestrained by a seatbelt. Following a deceleration impact his face struck the windscreen, causing the typical small cuts from broken safety glass and lacerations of the temple from striking the windscreen rim or 'A' frame.*

severe internal injuries. Laceration of the skin is rare unless the steering wheel snaps and penetrates the trunk. Other steering-wheel lesions include bruising of the lungs, fractured ribs and sternum, cardiac contusion and haemothorax or pneumothorax or both. Almost 70 per cent of Mant's series had broken ribs.

- Upper limb injuries are less common but may occur from transmitted force through gripping the steering wheel or from impact against the windscreen, pillars, intrusive roof, bonnet or ground when held up in a reflex protective position. Only 19 per cent of Mant's series had arm injuries.
- The most obvious injuries are often those to the face and head as a result of projection against and ejection through, the windscreen. The unrestrained driver rises and flexes forwards so that his forehead and skull are likely to contact the upper rim of the windscreen, leading to lacerations. The face frequently suffers multiple cuts from contact with the shattered safety glass. In most European vehicles the glass is of the toughened, not laminated, variety and, when broken, it shatters into small cubes with relatively blunt edges. These still cause superficial lacerations, often in short 'V-shaped' or 'sparrow-foot' patterns. In themselves they are not a danger to life, but indicate an impact sufficient to hurl the driver on or through the glass. Damage to the eyes is common.
- The impact against the windscreen rim or corner pillar – or after ejection – can cause any type or degree of head injury, including scalp laceration, fractured skull, intracranial haemorrhage or brain damage. In Mant's series there were 42 skull fractures in 100 drivers. This was less than in the front-seat passengers, a figure at variance with Eckert's (1959) series of 300 in the USA, where drivers suffered twice as many head injuries as the passenger, though it is not stated how many accidents were to vehicles occupied only by the driver.
- Hyperflexion of the cervical spine when the head swings can cause fractures or dislocation. There is often a double component in that the hyperflexion of deceleration is followed by a rebound hyperextension when the head strikes an obstruction in front. Rear impacts also cause the double 'whiplash' effect, as already mentioned.

One injury that is frequently overlooked at autopsy is the atlanto-occipital dislocation, which Mant found in a third of his series. Other fractures can occur anywhere in the cervical spine, often at about C5–6. Seatbelt restraint cannot prevent cervical spine damage, though a rigid head restraint can reduce injuries resulting from hyperextension. The thoracic spine is less often damaged, but in unrestrained drivers the same 'whiplash' effect can fracture or dislocate the upper dorsal spine, often around T5–6–7.

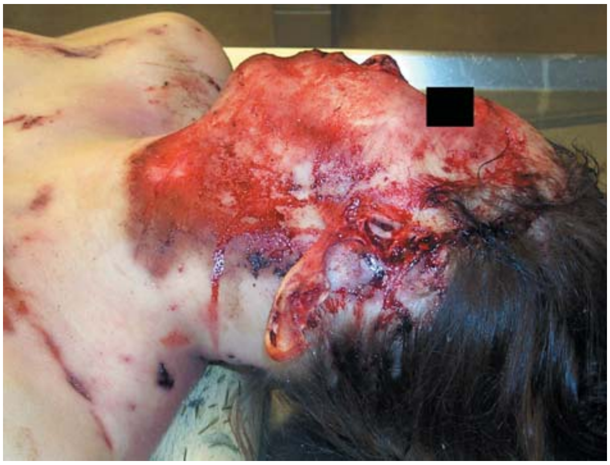
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FIGURE 9.7 *Mixed injuries in a restrained car driver from a head-on collision. Death was caused by ruptured aorta.*

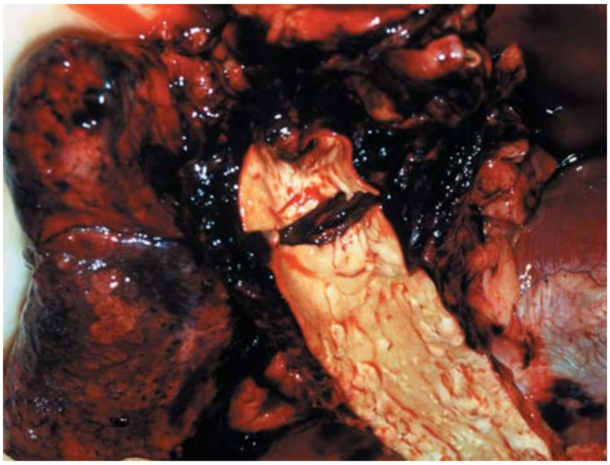

FIGURE 9.8 *Ruptured aorta in which car occupant, unrestrained by seatbelt, suffered severe deceleration. Aorta has torn in the usual place, the distal arch where the curve of the vessel meets the thoracic spine.*

- A more common thoracic injury associated with deceleration is the ruptured aorta. It may be associated with a severe whiplash effect on the thoracic spine, as the aorta is tethered to the anterior surface of the vertebrae where the distal arch joins the straight descending segment. Probably the most common reason for aortic rupture, however, is the ‘pendulum’ effect of the heart within the relatively pliable thoracic contents. When the thorax is violently decelerated, the heavy cardiac mass attempts to keep moving ahead and may literally pull itself off its basal mountings, the most rigid part of which is the aorta. Separation takes place at the point where the aorta is attached to the spine at the termination of the arch.

  The appearance of the aortic rupture is often of a clean-cut circular break, almost as sharp as if it had been transected with a scalpel. Sometimes there are additional transverse intimal tears adjacent to the main rupture, the so-called ‘ladder tears’, as they can resemble the rungs of a ladder. These may be present when no actual rupture has occurred and may be found as an incidental finding at autopsy. Sometimes they are deep enough to allow a local dissection of blood to seep into the intima, when death has not been virtually instantaneous. Rarely, a major dissection may lead to delayed death some hours or even days later. Ruptured aorta is a common lesion in traffic accidents – in a two-car crash, the author (BK) has seen three transected aortas among the four fatalities.

  The frequency of such tears is common enough for a warning always to be offered to the autopsy prosector not to use undue force on the neck and thoracic structures when removing the organ pluck from the body. Rough handling during this stage can produce artefactual ladder tears in the aorta.
- Other chest injuries can be caused by impact with the steering wheel, ejection through the windscreen or impact with the road. There may be bruising or laceration on the chest from the steering wheel, though padding, collapsible columns, less fragile wheels, airbags and seatbelts have reduced the incidence of this formerly common lesion. Beneath the skin, sternal and rib fractures are common, though fatal visceral injuries can occur without rib fractures in young people because their ribs are more pliable.
- The heart may be damaged even in the absence of external marks or thoracic cage fractures. Bruising of the epicardium and underlying myocardium is not uncommon and the posterior surface may be damaged from impact against the spine. In high-speed impacts, the heart may be completely avulsed from its base and be found lying loose in the chest. Less severe degrees of damage may lacerate the ventricles or atria, and cause gross haemorrhage. Coronary artery thrombosis has been described following contusion over a coronary artery. Penetrating injuries from sternum, ribs or external objects may lacerate the heart directly. Subendocardial haemorrhages on the left side of the interventricular septum and opposing papillary muscles are not a sign of impact, but an index of catastrophic hypotension. They are also seen in head injuries; they can occur within the space of a few beats, as the author (BK) has seen these prominent lesions in an avulsed heart after a military aircraft crash.
- The lungs are frequently injured, either from stabbing by fractured ribs penetrating the pleura or from blunt

impact. The latter often leads to a line of bruising down the posterior part of the lung where it lies in the paravertebral gutter. There may be air bullae or blood blisters under the pleura overlying the bruised areas and a pneumothorax or haemothorax may result. The interior of the lung may be pulped even in the presence of an intact visceral pleura, from transmitted force or massive variations in intrathoracic pressure during the impact. The lung often shows areas of bleeding under the pleura, which may be from direct contusion, from aspiration of blood from other damaged areas of lung or from blood sucked down the air passages from injuries in the nose or mouth.

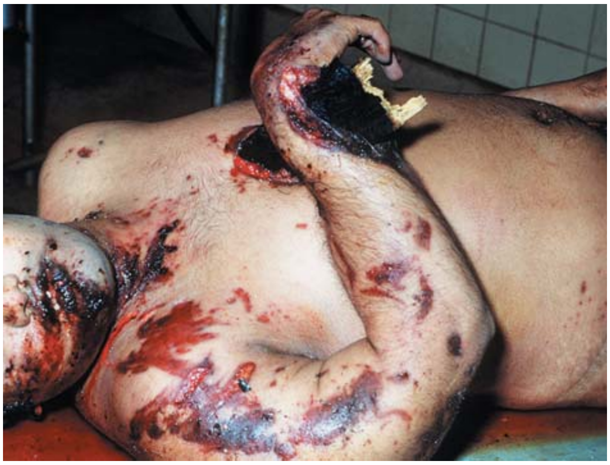

FIGURE 9.9 *Penetration of the wrist and chest by a wooden component of a bus seat. The victim drove his car at speed into a bus and part of the resulting debris penetrated his left ventricle.*

- The major abdominal injury is a ruptured liver, which may be damaged in any part. A common lesion is central tearing of the upper surface, which may extend deeply and even transect the organ. Less serious damage is often seen in the form of shallow, sometimes multiple, parallel tears on the upper surface of the right lobe. Subcapsular tears can occur with the formation of a subcapsular haematoma, which can rupture later. The spleen also shows shallow tears in some accidents, often around the hilum; in rare cases, it may be avulsed from the pedicle. The mesentery and omentum often show bruising and, rarely, there is laceration and fenestration sufficient to cause a lethal haemorrhage.
- Ejection injuries are common, and lethal in both driver and passengers. This is particularly likely to happen in roll-over accidents. Much research has been pursued by manufacturers to develop anti-burst door locks, which have improved safety. Where there has been considerable distortion of the vehicle frame, however, nothing can prevent the doors from opening or even being torn off. It has been shown by Moore and Tourin's study (1954) at Cornell that ejection injuries followed steering-column lesions as the second most frequent type of trauma and, if a victim was ejected, there was a fivefold greater chance of dying than if he was retained in the vehicle. Moore and Tourin found that when doors burst open a third of the car occupants were ejected.

  Almost any kind of injury, usually multiple, may be sustained after ejection, either from contact with the road surface or (in a significant proportion) from being struck by other vehicles, especially on motorways.

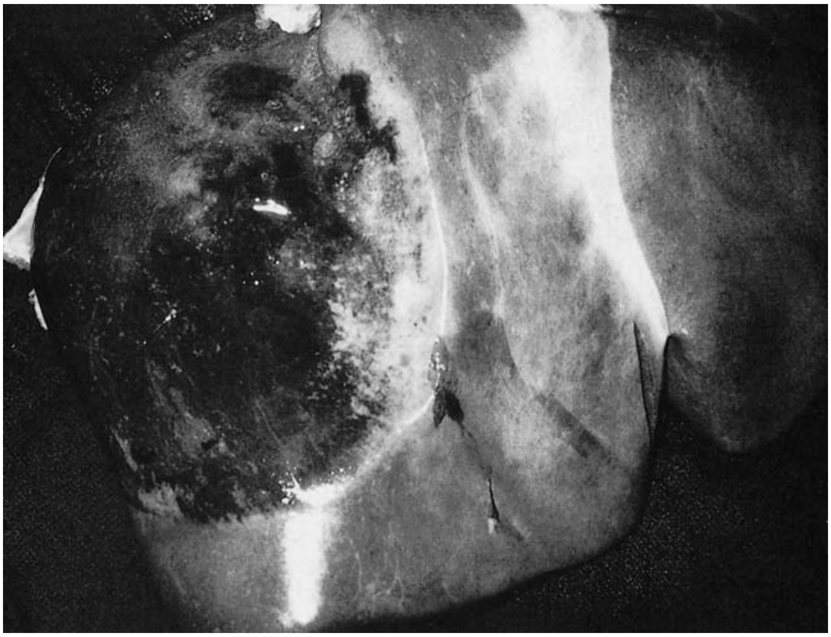

FIGURE 9.10 *Large subcapsular haemorrhage of the liver in a driver who struck the rim of the steering wheel during severe deceleration. Such subcapsular lesions can remain intact for hours or even days, then rupture into the abdominal cavity.*

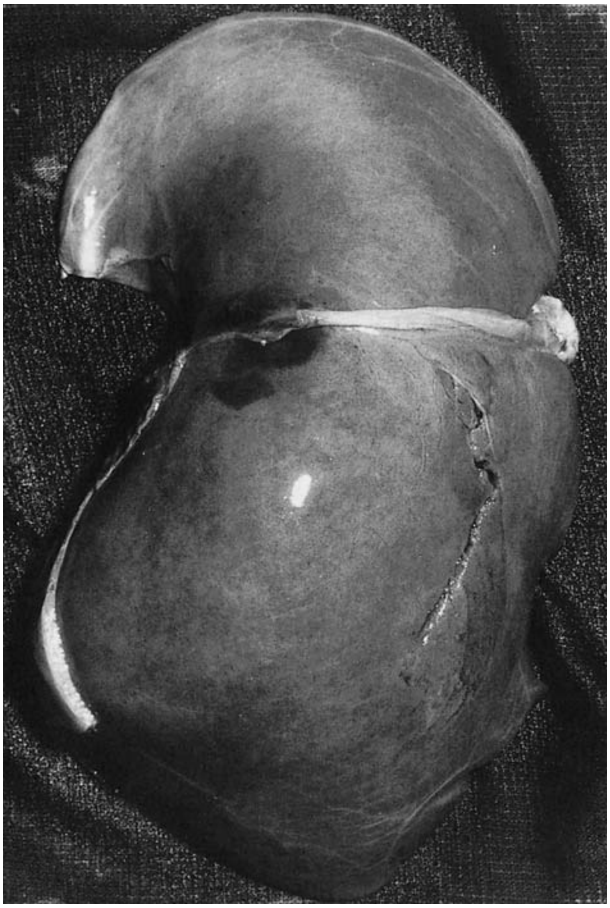

FIGURE 9.11 *Anterior tear through the full thickness of the liver; there is also a haemorrhage around the suspensory ligament. The victim was a car driver who was impacted against the steering wheel in a frontal crash.*

The front-seat passenger

In Western countries, far more drivers than passengers are killed or injured, but this reflects the fact that a high proportion of cars contain only a driver – a third in Mant's series. In countries with a lower ratio of vehicles to population the converse is true and indeed many accidents are due to gross overcrowding of passenger vehicles. The pattern of injuries is similar to that of the driver, but this position in the car is even more dangerous, as indicated by the title of a safety film made by the French Michelin Tyre Company – *La place du mort*.

Though there is no steering wheel to impact into the chest, its absence also denies the slight protection offered to the driver in reducing the collision with the windscreen, perhaps by giving him something to brace against. Another factor may be that the driver gives his attention constantly to the road and so has momentary warning of an impending crash, compared with the passenger who may be oblivious of imminent disaster and fail to 'brace up' ready for the impact. This may explain the greater number of skull fractures and brain damage in unrestrained passengers in Mant's series, the percentages being 55 per cent and 42 per cent, compared with 64 per cent and 53 per cent, respectively. However, these figures were compiled before seatbelts and airbags became commonplace or even mandatory.

Rear-seat occupants

Before the more widespread use of front seatbelts – now mandatory in many countries – it was thought that the rear-seat position was fairly safe, as indeed it is compared with the front seats.

When the widespread use of seatbelts dramatically reduced the deaths and serious injuries amongst front-seat occupants, the dangers of the back seats became much more obvious. One series showed that 49 per cent of rear-seat passengers in car crashes sustained serious or moderately serious injuries. Campaigns and legislation similar to the previous crusade were waged on behalf of the rear-seat occupants, and the use of these has now become mandatory in Britain and some other countries.

During violent deceleration, unrestrained occupants in the rear are projected forwards and strike the back of the front seats, including head-rests where fitted. They may be thrown over the seats, striking and adding further injuries to the front-seat occupants and may even be ejected through the windscreen, which is broken by them or by the people in front.

In roll-over accidents, they share in the general trauma of being churned inside the passenger compartment, when multiple injuries can occur from contact with fitments, such as mirrors, door handles and window winders. Design changes have reduced these hazards by making handles smoother or countersunk and mirrors that easily snap off their mountings. Ejection is another common cause of death and serious injury in rear-seat occupants, a wide range of head, chest and limb injuries being seen.

THE EFFECT OF SEATBELTS

As stated, many countries now have legislation making the wearing of front and rear seatbelts mandatory. Where no laws exist, persuasion seems to have little effect, in spite of the fact that it is uncontested that their use reduces deaths and serious injury by a factor of 20–25 per cent, as seen in the Australian experience in Victoria and New South Wales. A similar reduction was attained in Britain after the introduction of mandatory laws. Not only did the death rate drop substantially, but facial injuries and especially eye damage was dramatically reduced.

Seatbelts are now almost all of the lap-strap and shoulder diagonal type, the so-called 'three-point attachment belt'. The simple lap-strap is now fitted only in aircraft, where it is really only of token effectiveness. Most car belts are now of the 'inertia-reel' type, which allow slow movement but jam at a sudden tug. The advantage, apart from the comfort, is that they automatically tighten up around the body, as a slack belt is not only less effective but can actually constitute a danger. More complex restraints, such as double shoulder harness and crotch strap, are fitted only in light aircraft, gliders and racing cars. Though far more effective, their use would be socially unacceptable in ordinary road vehicles, as would head-band restraints, which are almost the only way of preventing hyperflexion damage to the cervical spine.

The various forms of strap restraints act by:

- Holding the occupant back against the seat, so that forward projection against the steering wheel, windscreen and corner 'A' frame is prevented. The head, though still subject to hyperflexion, is prevented from smashing through the glass and the body cannot be projected through the screen onto the bonnet or roadway. The belt cannot cope with backward intrusion of the engine, floor, roof or corner pillar if those structures reach the occupant sitting in the original seat position. The effectiveness of the belt is also dependent on the secure fixation of the seat to the vehicle floor.

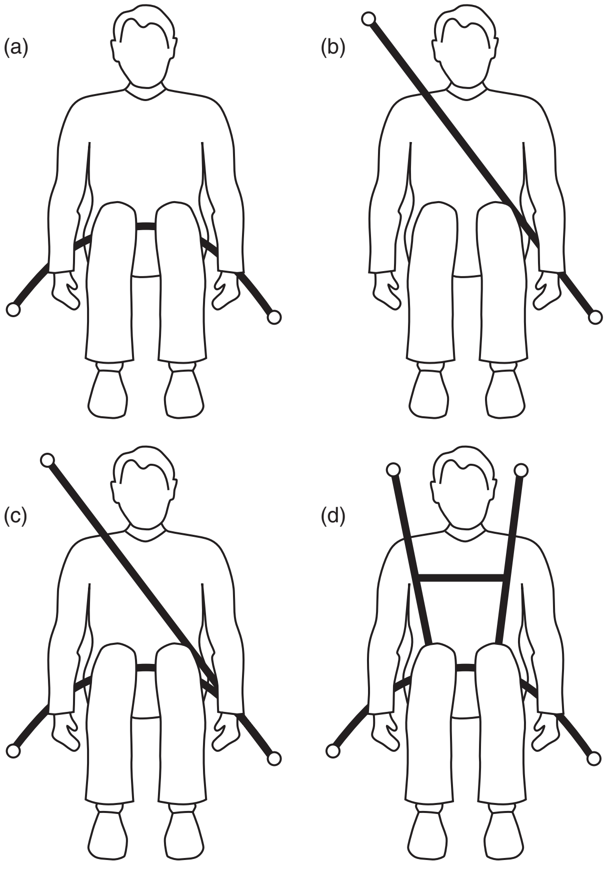

FIGURE 9.12 *Types of seatbelt restraint: (a) simple lap-strap (dangerous to aorta), (b) diagonal only (can slip underneath), (c) diagonal plus lap-strap (usual car type), and (d) shoulder harness (used in aircraft and racing cars).*

- The belt restrains the occupants within the vehicle in the event of a door bursting, as ejection greatly increases the risk of death or serious injury. A belt is relatively ineffective in a side impact, except in that it reduces injuries from ejection. It has been reported, however, that head injuries were fewer in restrained victims of side-swipes, though the reason is not clear.

  It has been claimed (mainly in insurance disputes) that seatbelts can worsen this sort of injury by holding the occupant in more dangerous proximity to the intruding impact. There would seem few occasions, however, in which even the unrestrained occupant could voluntarily escape from any significant degree of sudden lateral intrusion from a speeding vehicle.
- Extending the deceleration time and distance by substantial stretching of the belt fabric, which may lengthen by many centimetres during a violent arrest. To be effective the belt must be held tightly against the body to get the maximum restraint, either by adjusting the buckle or using an inertia reel. The belt should never be used again, as it cannot stretch further and may break on the next application of tension.
- Spreading the area of application of deceleration forces. As stated earlier, the body has to absorb whatever G forces are applied to it, as calculated by the $G = C(V^2)/D$ equation. If these are absorbed by a focal impact covering a few square centimetres over the skull, fatal injury may well ensue. The same deceleration diffused against the thorax and abdomen by 500 cm^2 of belt may leave no injury or merely surface bruising.

Seatbelt injuries

There is no doubt that seatbelts can themselves cause injury, occasionally of considerable severity. This was one of the arguments of the vociferous anti-seatbelt lobby that opposed legislation in several countries, but it is largely illogical, because an impact that causes seatbelt injuries would almost invariably have caused even worse injuries or death if no seatbelt had been worn.

Another invalid criticism of restraints was that they impede escape from a burning vehicle. Fires involving passenger car crashes are, however, quite rare. A report by Bako *et al.* (1970) from Canada showed that, of 1297 vehicle fatalities, only 24 were from burns, a mere three in passenger cars.

Incorrectly adjusted or positioned straps such as a twisted belt, which reduces the area of contact, can increase the danger of injury. Loose straps allow the body to move relative to the belt before sudden restraint occurs, decreasing the distance between the passenger and facing structures.

Where the person is too small for the harness, such as a child or a small woman, the body may slide from under the strap – the so-called ‘submarining’ – or it may act as a garrotte around the neck. Some women find that the diagonal strap compresses the breast even in normal use, so that the greatly increased tension during deceleration is likely to injure the gland.

Pregnant women also have problems with belts but, although uterine and fetal injuries have been recorded in accidents, the incidence is relatively low and without the belt the consequences would have been as bad or probably worse.

Injuries from seatbelts can vary from the trivial to the fatal. Bruising is the most common and may be seen either under the diagonal or the transverse component of the three-point belt. It is more common with the single aircraft-type lap-strap because of the smaller area of pressure. Bruising may occur in the abdominal or chest wall, but the dangerous lesions are visceral. The abdominal contents suffer most, especially from single lap-straps. Rupture of the mesentery, or the small or large intestine, usually occurs from acute flexion over a lap-strap. The full bladder can be ruptured as can the caecum. The abdominal aorta can be crushed and the lumbar spine suffer a compression fracture or be dislocated through a disc in the midlumbar region. The posterior arch, pedicles or transverse processes may also be damaged.

The diagonal strap usually prevents serious abdominal injury as it prevents hyperflexion, but it may contribute to thoracic injury. Bruising of the skin and underlying muscles and fractures may accompany a broken clavicle or sternum where the belt crosses them. Several authors (listed at the end of this section) have made detailed studies of seatbelt injuries.

Airbags

In recent years, the use of airbags has spread from only the most expensive vehicles to many standard production cars. The device consists of a large fabric bag, which is normally folded into the steering-wheel hub in the case of the driver position and into the fascia in front of the front-seat passenger.

A sensitive deceleration device triggers the ignition of sodium azide, a solid and highly toxic explosive propellant, which is converted in milliseconds to nitrogen gas. The deploying airbag can reach speeds up to over 300 km/h (>200 mph). Deflation is also rapid, so that residual car control and escape from the vehicle is not impeded.

The inflated bag is designed to interpose itself between the occupant and the frontal structures of the passenger cabin, to cushion the impact and prevent forceful contact and hyperflexion.

In addition to the life-saving capabilities, airbags can also cause serious and even fatal injuries either by the airbag itself or the module cover overlying it in the steering wheel or in the fascia on the passenger side. Injuries can be inflected at any stage of the deployment process, depending on the posture and possible objects between the occupant and the deploying airbag or the module cover. They vary from facial bruising, partial or complete amputation of fingers to dislocated and fractured arms or cervical spine and fatal head injuries. Eye injuries are common and range from mild corneal abrasions and chemical burns from contact with unburned sodium azide or the alkaline byproducts of combustion, which are released into the passenger compartment, to globe rupture from blunt trauma or perforation by interposed objects.

THE VULNERABILITY OF CHILDREN IN VEHICLES

This is a particular problem with several aspects. Many countries have brought in laws to protect children in cars because of their special vulnerability.

First, it is an understandable, but highly dangerous, indulgence for adults to allow small children to travel unrestrained in the front seat of a car. Some parents even allow them to stand gripping the fascia edge immediately below the windscreen, an invitation to facial and eye damage even in minor accidents. The seating of a child on the mother’s lap is hazardous, as on violent deceleration either mother and child pitch against the windscreen – or the child flies out of the arms of a belt-restrained mother. The close proximity to the fascia and windscreen causes many deaths and facial injuries, especially to the eyes.

Adult-secured seatbelts will not properly accommodate a child (or even a small adult), because the fixation point on the door pillar is too high even if the straps can be shortened sufficiently to be made tight. The diagonal may pass across the throat and, unless special drop-plates are fitted to the door pillars, the restraint is often worse than useless.

Though some European countries already forbid children under 14 years to travel in front seats, the medical profession in Britain campaigned for similar legislation, as they had done for motorcyclists to wear helmets many years before.

As discussed above, a similar campaign has been successfully waged for rear-seat restraints for children and adults. Banished from the front, children were thought to be safe in the back of the car, but many have died and far more have been injured from being projected against the seat backs, front passengers and internal fitments. Special seats secured on top of the regular seating are required and, for a baby, the cot must be lashed down with equally robust restraints. In 1988, legislation was introduced into the British Parliament to make compulsory the restraint of children in rear seats: from 1991, this law also became applicable to adults.

INJURIES TO MOTORCYCLISTS

Though there are fewer motorcycles than four-wheeled vehicles, especially in developed countries, the rate of injury and death amongst motorcyclists is far higher than among car drivers. For example, in England and Wales in 1989 there were more deaths amongst male motorcyclists between the ages of 16 and 24 than with comparable car drivers (343 compared with 323) even though the ratio of motorcycles to cars is very small in Britain. In the 25–44 age group, 192 motorcyclists died compared with 381 car drivers.

The two extremities of the body suffer most in motorcycle accidents, though Larsen and Hardt-Madsen's analysis in Denmark in 1988 also showed high injury rates for chest and abdomen.

- Because the rider inevitably falls to the ground, head injuries are common and often severe, causing 80 per cent of deaths according to Bothwell (1962). Though crash helmets are mandatory in most countries, the severity of the impact often defeats the protective effect of the helmet.

  Impact with the road surface or another vehicle at speed causes skull fractures at any part of the head, but often temporoparietal. A common complication is a basal skull fracture, especially a 'hinge' fracture. This transverse crack across the floor of the skull, crossing the petrous base or behind the greater wing of the sphenoid bones through the pituitary fossa to the opposite side, has also been called 'the motorcyclist's fracture'.

  Another type is the ring fracture around the foramen magnum in the posterior fossa caused by an impact on the crown of the head. The neck suffers quite often and Mant found cervical spine fractures in over a quarter of his series. Brain damage may be severe, even with a helmet in place. Cortical contusion and laceration, sometimes contrecoup, may be gross enough to cause brain tissue to extrude through compound fractures of the skull. In Mant's series of motorcyclists, 60 per cent had skull fractures and almost 80 per cent had brain damage.
- The legs are often injured, either by primary impact with another vehicle or fixed road structures, or by becoming trapped by part of the motorcycle frame. Lacerations, friction burns and fractures – often compound – are common. Mant recorded leg or pelvic fractures in 55 per cent of his cases.
- Any part of the body may suffer injury, but less often than the extremities. Falling from the machine, especially at speed, can cause rib fractures and visceral damage, especially rupture of the liver and spleen.
- An injury common with motorcycles is the 'tail-gating' accident, where a rider drives into the back of a truck so that the machine passes underneath, but the head of the motorcyclist impacts upon the tail-board. Decapitation may occur in the most extreme cases, but severe head and neck injuries are almost inevitable.

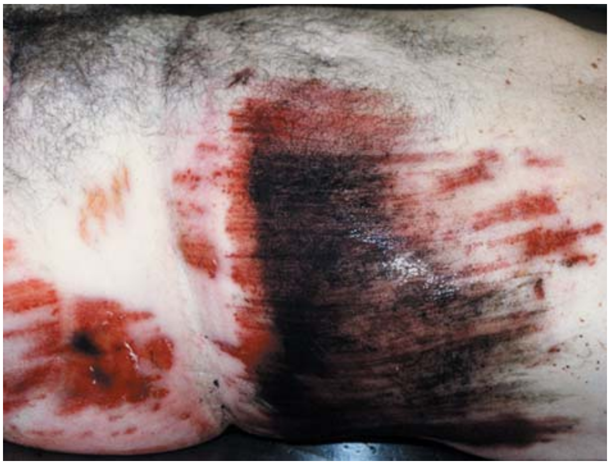

FIGURE 9.13 *Severe brush abrasions or 'friction burns' in a motorcyclist, who came off his machine and skidded across the road surface.*

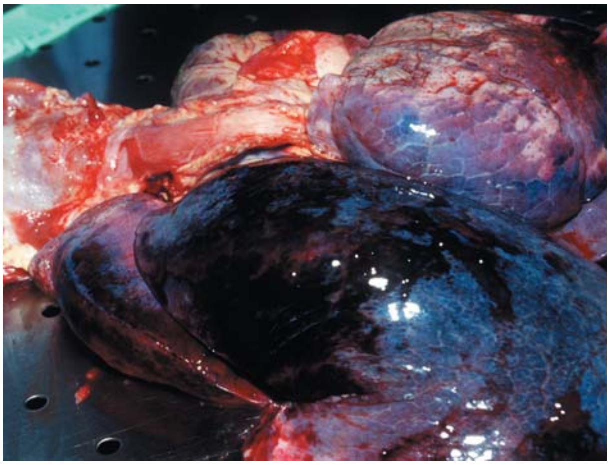

FIGURE 9.14 *Pulmonary contusions in a motorcyclist, who collided with a truck and was hurled into a signpost. Death was caused by a cranial fracture and multiple injuries of the internal organs.*

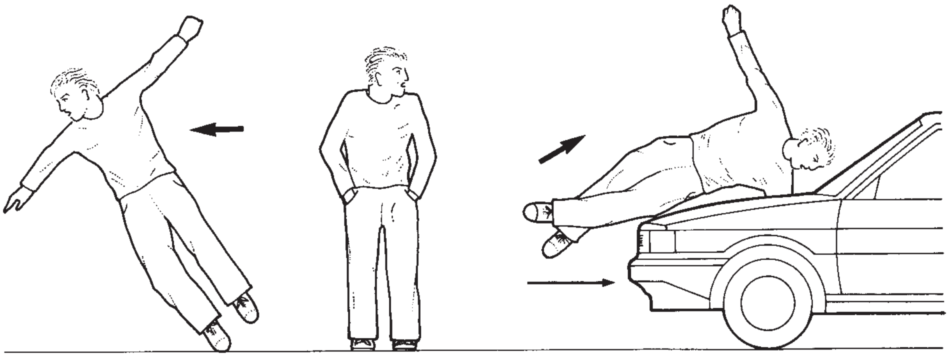

FIGURE 9.15 *A pedestrian struck by the front of a car may be projected forwards or lifted onto the vehicle.*

Trucks in many countries must now have strong bars fitted at the rear to prevent this 'tail-gating', which may also happen to motor cars, the rear of the truck smashing into the windscreen and driver.

Safety helmets act both by providing a rigid barrier against impact, which depends partly on the shock absorbing padding within the helmet and by providing a smooth surface, which is designed to skid across the road surface, thus lengthening the stopping distance and time to reduce the G force of deceleration. Their strength is designed to be finite to control the rate of deceleration but in massive impacts seen at high speeds the helmet may be penetrated or the head and brain damaged by the transmission of blunt force. Crash-bars are another safety measure on motorcycles, being fitted in front of the engine to project on each side and protect the legs if the machine falls over. Unless extremely strong, however, such bars can themselves trap the legs if they bend backwards on impact.

INJURIES TO PEDAL CYCLISTS

These form a less severe counterpart of motorcycle lesions, as the pedal cycle has the same instability but far lower speeds. Once again, head injuries figure largely in accidents, as the height above the ground is considerable and the rider suffers from the passive fall, added to by any forward motion or projection from impact by a motor vehicle. Helmets are now worn by many cyclists and naturally afford considerable protection.

Other injuries are from the primary impact from a striking vehicle, which may hit the rider around thigh, hip or chest level. Secondary damage to the shoulder, chest and arm may occur from striking the ground, when friction grazes are common. (A unique injury, though not fatal, was entrapment of the leg between wheel spokes with compression of the soft tissues of the calf, when the leg penetrated the wheel.)

INJURIES TO PEDESTRIANS

Worldwide these are easily the most common road fatalities, probably accounting for more than 50 per cent of the third of a million road deaths each year. In the densely populated areas of the globe where vehicles are greatly outnumbered by people, such as Southern Asia, parts of Africa, and the Middle East and Central America, pedestrian casualties form a significant part of the total mortality.

Most pedestrians are struck by motor cars or trucks, and the type of vehicle makes a difference to the dynamics of the impact, which – unlike injuries to vehicle occupants – is an **acceleration** not a **deceleration** process.

Primary injuries are caused by the first impact of the vehicle on the victim, while secondary injuries are caused by subsequent contact with the ground. Some writers also use the term 'tertiary injuries' to describe the impact with the ground, reserving 'secondary' for additional contact with the vehicle, as when the pedestrian is hurled up against the windscreen. The usual sequence of events is as follows:

- The height of the car bumper bar ('fender') is well below the centre of gravity of the adult pedestrian, which lies in the abdominal region. Thus the first impact tends to knock the legs from under the victim and rotate them towards the oncoming vehicle. Depending on the profile of the front of the car, the struck pedestrian is either thrown forwards in the direction of travel if the bonnet-front is high and blunt – or scooped up onto the bonnet top, as with many slope-fronted modern vehicles.
- If thrown forward, secondary injuries will be suffered as a result of striking the ground, as well as the primary impact on legs and often the hips. If the car speed is appreciable (anything over 20 km/hour is sufficient), the body can be thrown into the air or knocked down flat with a severe impact. The secondary injuries may fracture the skull, ribs, pelvis, arm or thigh.

A further hazard is being run over by the vehicle if the victim is projected directly in front. Sometimes he may be dragged by the under-belly of the car, and seriously soiled and injured, perhaps appearing at the rear if the vehicle does not stop quickly. Many impacts are on the front corner of the car and the pedestrian may then be knocked diagonally out of the path of the car. If thrown into the centre of the roadway, the person can be run down by a different vehicle overtaking in another lane or by one coming in the opposite direction on a single carriageway.

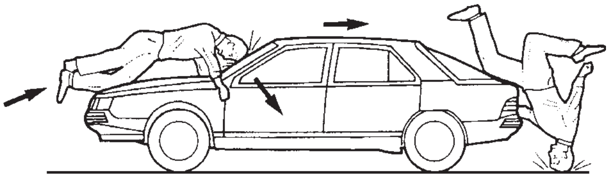

FIGURE 9.16 *At speeds of over 23 km/hour (15 mph) a pedestrian can be 'scooped up' onto a car, suffering head injuries against the windscreen. He may then fall off sideways or – at higher speeds – be thrown over the roof.*

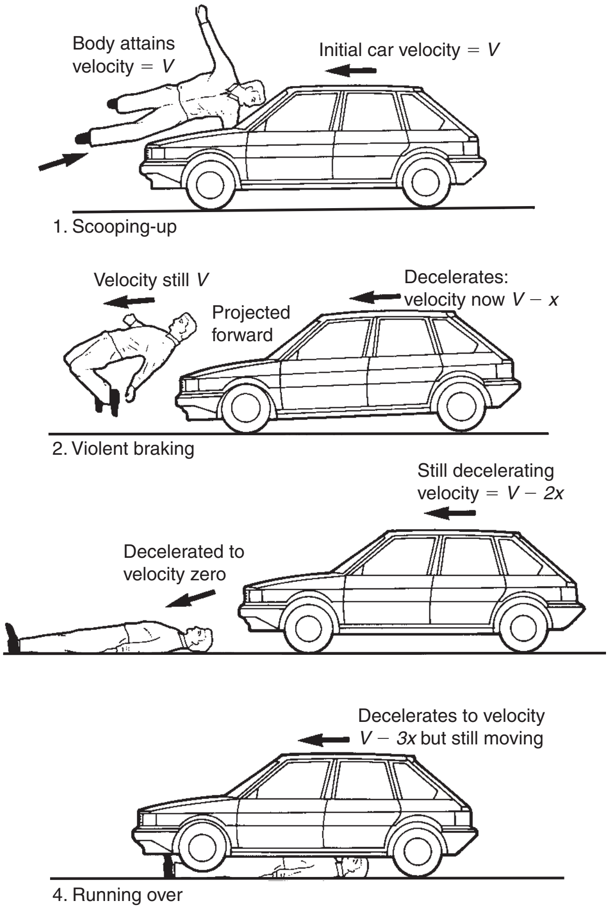
Body attains velocity = V
Initial car velocity = V
1. Scooping-up
Velocity still V
Projected forward
Decelerates: velocity now $V - x$
2. Violent braking
Still decelerating velocity = $V - 2x$
Decelerated to velocity zero
Decelerates to velocity $V - 3x$ but still moving
4. Running over

FIGURE 9.17 *Sequence of events when a carried pedestrian is projected forwards during braking.*

- If scooped up, the victim will land on either the bonnet or against the windscreen or corner-supporting pillar (the 'A' frame). The flat bonnet usually does relatively little damage, though linear abrasions, brush grazes, or friction burns may be seen. Violent contact with the windscreen, especially the rim or side pillars, is the most frequent cause of severe head injury from primary impact.

  Scooping-up can occur at speeds as low as 23 km/hour (about 15 mph; below 19 km/hour the body will usually be projected forwards). If the speed is high, the victim can be thrown up onto the car roof, sometimes somersaulting so that the head strikes the roof. He can then slide or be flung right over the back of the car, landing behind it in the roadway. This is more likely to happen if the car does not brake, but literally drives from under the body.
- In most cases, the scooped pedestrian falls or is flung off on one side of the car or the other, again to suffer secondary injuries in the road and perhaps be run over by another vehicle. The usual pattern of events is that, at the instant of contact – or even slightly before – the driver will apply the brakes violently. The scooped-up victim will acquire the speed of the car by the time he lands on the bonnet, but then the vehicle decelerates. As the adhesion to the shiny surface is small, the newly acquired velocity of the body will cause it to slide off the front of the car as the latter brakes. The victim then hits the ground in front of the car, sustaining secondary injury – and may even be run over during the residual motion of the vehicle before it finally stops.
- In a high-speed impact, which may be anything over 50 km/hour (31 mph), the body can be flung high in the air and for a considerable distance, either to the side or in the path of the car – or even backwards over the roof. In general, the severity of the injuries – both primary and secondary – will be the more severe the higher the speed.

  It is impossible to estimate the speed of impact from the nature of the injuries. These can be fatal even at slow speeds of the order of 10 km/hour (6 mph), yet occasionally high-speed impacts can produce only minor damage. In Ashton's (1975, 1978) series half the deaths occurred at speeds less than 48 km/hour (30 mph).

  In child victims, although the general pattern of injuries is similar, their shorter height and smaller weight affects the mechanics of impact. The primary contact is higher up their body, so they tend to be hit forwards rather than rotated upwards, though many do become scooped up onto the bonnet. Children tend to be projected further by impact and may be hurled in

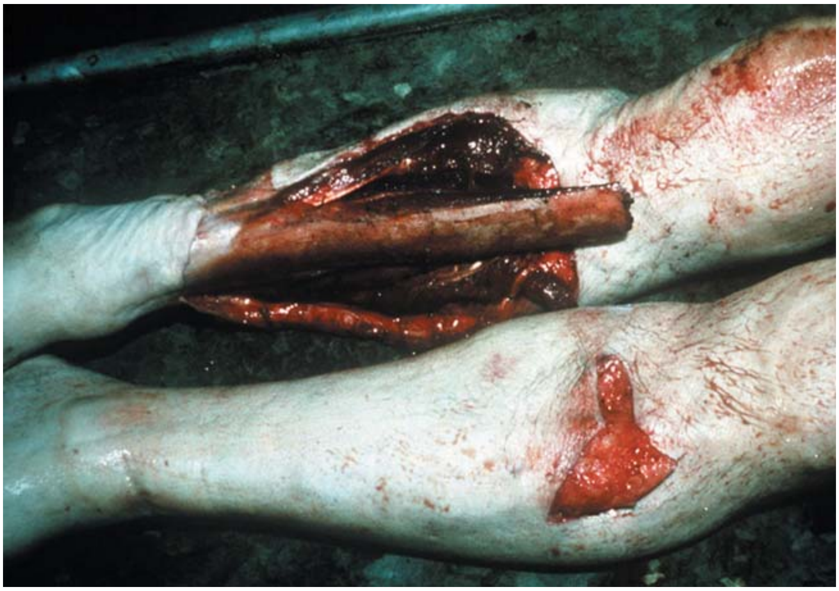

FIGURE 9.18 *Primary injury to a pedestrian struck by a car. There is damage to both legs at about the same level, with a compound fracture of the right leg. These are sometimes called 'bumper fractures'. The height of the injuries above heel level should always be measured at autopsy.*

the air at lower speeds than with adults. They are also more prone to be run over by reversing vehicles, especially trucks, as they often play between parked vehicles and – being small – are less visible to the driver. Recent safety measures on trucks include audible reversing warnings that are automatically linked to the gear-shift lever.

- When a pedestrian is struck by a larger vehicle, such as a van, truck or bus, the initial point of impact is higher and may cause primary damage to pelvis, abdomen, shoulder-girdle, arm or head. Because of the profile of these vehicles, there is no scooping-up effect, and the victim is usually projected forwards to suffer secondary damage from road contact and sometimes to be run over.
- The nature of pedestrian injuries reflects these dynamic effects.

The most common trauma is to the legs, some 85 per cent of pedestrian casualties having lower limb injuries. Abrasions and lacerations to the upper shin and knee area are typical of car bumper contact, and fractures of the tibia and fibula, often compound, are so common that they are present in a quarter of fatalities, according to Eckert. The femur is fractured less often, but is no rarity. The midshaft may be broken or the head may be driven into the acetabulum, together with a fractured pelvis. In children, because of their small stature, the femur may be fractured by the low bumper bar. At autopsy, the skin of the lower legs should be incised to seek deep bruising, as the clothing often protects the surface from obvious marking.

When a bumper (fender) strikes a leg, the tibia is often fractured in a wedge-shaped manner; the base of the wedge indicates the direction of the impact (often from behind), the front of the wedge pointing away from the side of contact.

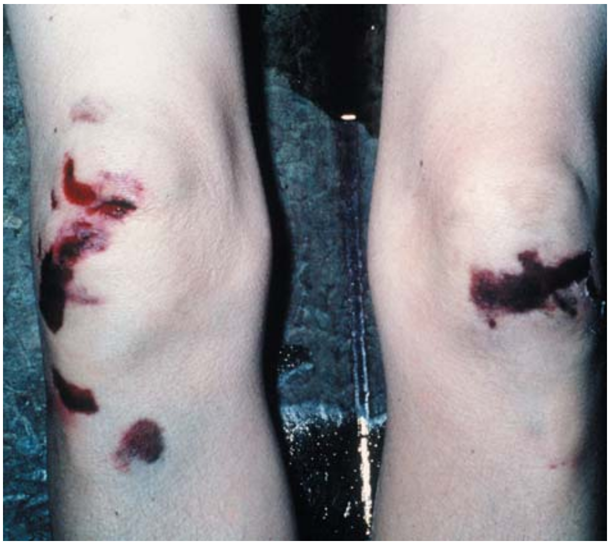

FIGURE 9.19 *Abrasions and laceration at knee level in a pedestrian struck by a car bumper. Their anterior position indicates that the victim was facing the vehicle at the moment of contact, but this may be a last-instant turn during final awareness of the car's proximity.*

If the leg is weight-bearing at the time of the impact, the tibial fracture tends to be oblique, whereas if not stressed, as when being lifted during walking, the fracture line is often transverse. When both shins are damaged, the level may be different on each side; this indicates that the person was moving at the time, with one leg raised in walking or running. Sometimes the level of injury appears too low for the normal bumper height of most cars, but this may indicate that the vehicle was braking violently at the moment of impact, going down on its suspension as the front wheels decelerated or locked, unless dip compensators were fitted.

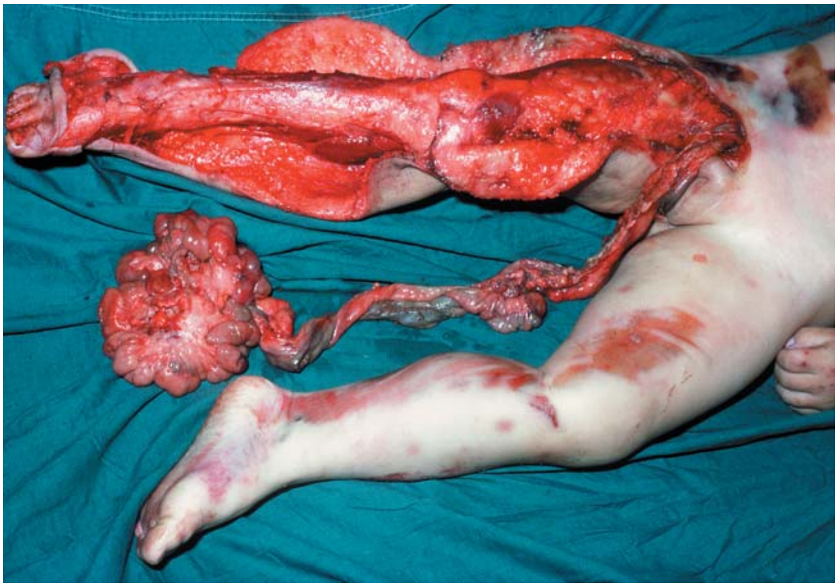

FIGURE 9.20 *Injuries caused by being run over by a bus. The large rotating wheel has 'flayed' the right leg, stripping the skin and subcutaneous tissues from the muscles. The passage of the adjacent double wheel over the abdomen has extruded the intestines through the perineum.*

Because of impact with the windscreen, pillars and roof, together with secondary contact with the ground, the head is the next most frequently damaged region – and the one which leads to most causes of death. Any type of injury may be sustained, as described in Chapter 5. Traffic accidents are the most frequent cause of skull fracture, especially of the base. Fractures of chest, arm and pelvis and injuries to the abdomen follow in frequency. Often the injuries are concentrated on one side, usually on the opposite side to the point of primary impact, because the body was thrown down onto the road. Because of rotation and the variable posture from being thrown off the car structure, however, the injuries are often widespread and may show no particular pattern.

Soft tissue injuries are common and, apart from abrasions, bruises and lacerations, muscle laceration and crushing can occur. A characteristic lesion from running-over, as opposed to knocking-down, is the 'flaying' injury, where a rotating motor wheel tears the skin and muscle from a limb or head. The rotatory effect against a fixed limb may strip off almost all tissue down to the bone. When a wheel passes over the abdomen or pelvis, multiple parallel striae or shallow lacerations may occur near the contact area because of ripping tension in the skin.

When a wheel passes over the pelvis, abdomen or head, there may be great internal damage with little surface injury. The weight of a large vehicle can virtually flatten a head, crushing the cranial vault. Often the brain is extruded through scalp lacerations, as may be the intestine through an abdominal wound. The pelvis may flatten out when run over, the symphysis or superior rami breaking, and one or both sacroiliac joints becoming detached. Any type of intra-abdominal injury may occur from ruptured liver and spleen to perforated intestine, lacerated mesentery and fractured lumbar spine. In the chest, ribs, sternum and thoracic spine may fracture, and heart and lung damage occur from crushing or laceration from jagged ribs. A 'flail chest' is sometimes produced when a heavy wheel runs across the supine body, breaking all the ribs on each side in the anterior axillary line.

Patterned injuries may be important, in that they can assist the police in identifying a vehicle in a 'hit-and-run' accident. The most common is a tyre pattern outlined in intradermal bruising and these should be measured carefully and photographed. These marks are usually caused by the skin being forced into the grooves of the tyre tread, the edge of the raised rubber tracing out the pattern. The elevated parts do not leave bruises, but may imprint dirt on the skin.

Paint fragments and glass shards are also trace evidence that must be carefully retained, as the forensic laboratory may be able to identify the make and model of vehicle involved, and match the fragments when a suspect car is examined.

Parts of the vehicle may leave patterned imprints on the skin, such as headlamps, mirrors or other components. Safety regulations for manufacturers have now almost eliminated the dangerous devices such as bonnet mascots, projecting door handles and non-flexible mirrors that used to adorn older cars. Metallic and plastic objects may still be found in the tissues from time to time, however; the author (BK) has recovered a door handle from the interior of the liver and a chromium bonnet insignia from a cerebral hemisphere. Any such artefacts must be preserved for the police in cases in which the identity of the vehicle is not known.

In Britain, where traffic drives on the left side of the road, it is more common for pedestrians to be struck on the right side as they walk off the pavement. Many, however, are struck facing the vehicle, from turning during last-minute awareness, and some are hit from behind.

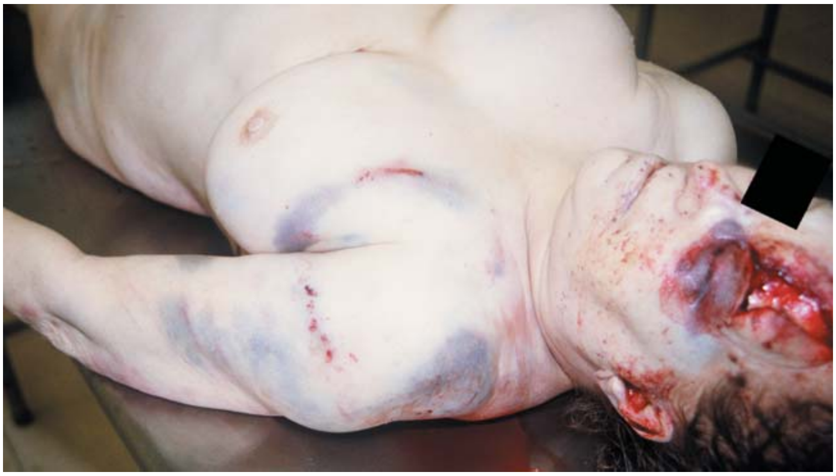

FIGURE 9.21 *A patterned injury in a pedestrian struck by a truck. The circular bruise and abrasion over the front of the shoulder are from a headlamp rim. There is also a well-demarcated imprint around the left eye from some other projection on the vehicle.*

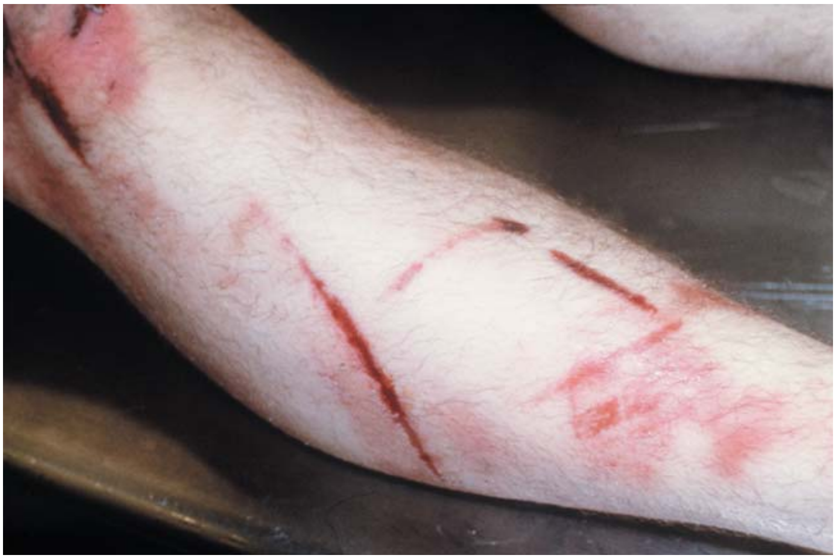

FIGURE 9.22 *Primary pedestrian injury. The pattern is caused by the bumper bar striking the leg. The height from the heel should always be measured for the police to compare with the vehicle – though during extreme braking, many vehicles will dip down at the front, thus lowering their bumper height.*

These factors will all affect the distribution of injuries, but it is too hazardous to try to reconstruct unwitnessed events in any detail from a study of the injuries. Suprarenal haemorrhage is more common in the right gland than the left after a traffic injury in Britain (Johnson, unpublished communication), but this observation must be modified by the fact that many such haemorrhages occur several days after the trauma and are usually the result of general systemic effects, rather than direct impact.

CAUSE OF DEATH IN TRAFFIC ACCIDENTS

In gross injuries this is often obvious, as in the crushed head with extrusion of brain or rupture of the aorta. Often multiple injuries make it difficult to decide which was the most serious and mortal lesion, but in such cases it is quite acceptable to use the term ‘multiple injuries’, preferably listing several of the most lethal.

When death occurs on the road or soon afterwards, there is usually macroscopic evidence of gross musculoskeletal or organ damage, severe haemorrhage, blockage of air passages from blood, or traumatic asphyxia from fixation of the chest caused by crushing some part of a vehicle.

Delayed death can be caused by continuing bleeding, secondary haemorrhage, renal failure from hypotension and/or extensive muscle damage, fat embolism, local infection, chest or other systemic infections, myocardial or cerebral infarction and other sequelae discussed in Chapter 13.

The presence of natural disease is always an important consideration in all transportation deaths, as a possible cause or contribution to the accident. In pedestrians, a sudden collapse

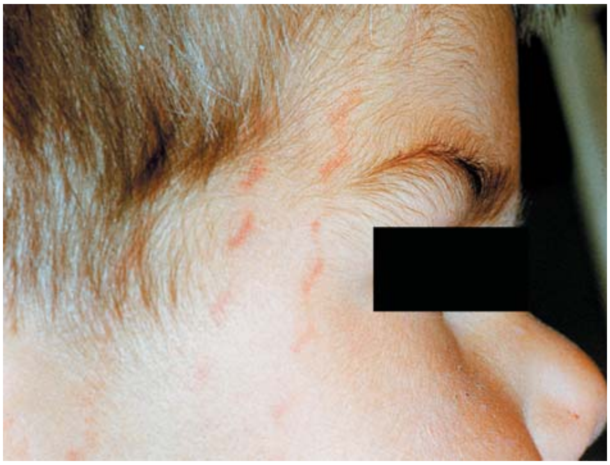

FIGURE 9.23 *Intradermal bruising on the forehead of a live boy who was found wandering in the street with amnesia for recent events. He had been struck by a 'hit-and-run' car, which left identifiable tyre marks on the skin. An astute casualty officer had a photograph taken as the marks faded in a few hours.*

in the roadway may lead to fatal injuries when a vehicle comes along – or even a dead body being run over by the next car.

Similarly, defects in sight or hearing may have contributed to the accident, though this is almost never detectable at autopsy, unless there are gross corneal or lens abnormalities. Of course, the possibility of drug or alcohol intoxication in the pedestrian victim must always be considered.

Where drivers or pilots are concerned – or even shipmasters – the presence of disease or intoxication may be a vital element, with both civil and criminal connotations possible.

Generally speaking, sudden natural disease does not often cause road vehicles to go out of control, as there seems to be a sufficient warning in most instances of cardiac or cerebral disablement, to allow the driver to pull over and stop.

Even the regular medical checks on older drivers legally enforced by some countries are no warranty that sudden collapse will not occur the very next day. The same applies to air pilots, as the VC-10 crash at London Airport proved some years ago, when the hypertensive pilot with coronary artery disease collapsed on take-off after an altercation with his co-pilot.

Schmidt *et al.* (1990) analysed 39 deaths at the wheel in Germany and found that 97 per cent had cardiovascular disease and 90 per cent had coronary heart disease. This was confirmed in a more recent retrospective study covering a 15-year time period in Munich, Germany, ranging from 1982 until 1996. Ischaemic heart disease was the underlying cause of death in 113 (84%) of the 147 natural deaths at the wheel. Morild (1994) found that 14 of 133 traffic deaths in Norway had died of natural disease, again predominantly coronary atherosclerosis.

The autopsy on a road traffic death

The autopsy is in general identical to the usual procedure, but with special attention to the following points:

- As criminal proceedings against a driver may follow, legal matters such as identity of the body and continuity of evidence must be assured, as discussed in Chapter 1.
- The body should be seen clothed, if brought dead to the mortuary or hospital, so that injuries can be matched against soiling and damage to the garments. Often this is not possible, especially if temporary survival allowed admission to a hospital or accident department, but where practicable the clothing should be preserved and examined by the pathologist. In any event, the clothes should be retained by the police for submission to the forensic science laboratory, usually when criminal proceedings are likely.
- Blood samples must be retained for blood grouping and now perhaps even 'DNA fingerprinting' in case a 'hit-and-run' vehicle is found with blood or tissue traces upon it. Sometimes hair samples may be required for the same purpose. Where death occurs within 12 or even 24 hours of the time of the accident, blood analysis for alcohol is essential, whether in the driver or pedestrian (see Chapter 28). Where possible, screening for drugs of dependence and common medicinal substances that might have caused drowsiness should be carried out. In combination with alcohol, even low levels of sedative, hypnotic and antihistamine drugs may be relevant in the causation of an accident. In certain cases, where leakage of carbon monoxide is suspected, the circumstances will suggest analysis of the blood for carboxyhaemoglobin concentration.
- The external examination, as in all trauma deaths, is vital and should be detailed, accurate and fully recorded. The height of major or patterned injuries above heel level must be noted, in order to compare these against dimensions of a vehicle. Patterned injuries must be photographed with a scale in view. Any foreign bodies or particles, either in the clothing, hair, on the skin or in the wounds, must be carefully retained for forensic science examination, especially in a 'hit-and-run' accident, where the identity of the vehicle may be vital.

All types of trace evidence may be found by a pathologist, from paint flakes and glass debris (which may be traced to a certain make, age, type and even individual vehicle) to parts of the vehicle structure. In past years, the author (BK) has retrieved a Renault door handle from inside a liver and an Austin bonnet insignia from within a brain.

- A full autopsy must be carried out, not merely a catalogue of injuries. The presence of any natural disease is relevant, especially if it might have contributed to the accident, either by causing a driver to lose control or ability to drive, or a pedestrian to exercise proper caution or behaviour in the roadway. Old and recent cardiac and cerebral lesions are particularly important, as is any evidence of a fit, such as a bitten tongue, or old meningeal adhesions over cortical damage. It is almost impossible to assess visual acuity at autopsy, but obvious lesions such as lens opacities must be noted. Similarly, it is virtually impossible to give any opinion on acuity of hearing from autopsy findings unless there is a gross neurological abnormality in the auditory tract.

SUICIDE AND HOMICIDE BY MOTOR VEHICLE

There is little that the pathologist can contribute to the elucidation of motivation in traffic accidents, as it is circumstantial and sometimes forensic-laboratory evidence that is more likely to reveal a non-accidental cause. Homicidal traffic deaths are rare, though the author (BK) has been involved in one incident where racial hatred led to the running-down of youths of one ethnic group – and another where a man repeatedly crashed the near-side of his own car in an effort to kill his passenger (his wife). There are no specific pathological features that can assist, except that the incident is likely to occur at relatively high speed, without braking effects. The victims of homicide by other means – or persons rendered unconscious first – may be deliberately placed in motor vehicles which are then crashed, preferably with a subsequent fire. The author (BK) dealt with one such case where a husband placed the body of his strangled wife in his car and secretly pushed it over the edge of a mountain road. Unfortunately (for him), he left the ignition key in the ‘off’ position. This faking of a vehicular ‘accident’ to conceal homicide is by no means unknown, the author (BK) being involved in another case where a police officer disposed of the body of his wife who died in suspicious circumstances, by crashing her car and smashing the windscreen with a hammer to add to the effect.

In such circumstances, the pathologist’s role is to match the injuries with a traffic accident, to detect any which are atypical. For instance, focal depressed fractures of the skull of the type caused by a weapon are unusual in a car occupant unless there was a localized intrusion of the vehicle roof. The ante-mortem nature of the injuries should be demonstrated, though this is not always possible. When there is a fire, some evidence of ante-mortem burns, soot inhalation or carbon monoxide absorption should be sought, though – as mentioned in Chapter 11 – some flash petrol fires may kill before any monoxide is absorbed. Where the victim was unconscious though not dead, no such differentiation is possible. Full analysis for alcohol and stupefying drugs must be made if there is any suspicion.

Attempts at deliberate self-destruction by the use of a motor vehicle are said to be not uncommon (Selzer and Payne 1962), though this is difficult to prove in most cases. Once again, the evidence is more likely to be based on circumstantial rather than medical evidence – a matter for the investigating authorities rather than the pathologist. Driving at speed into the path of an oncoming truck or into a solid obstruction at the roadside are the methods employed, though it is hard to prove in the absence of definite evidence. It has been said that the imprint of the accelerator pedal on the undersurface of the shoe may be an indication, though this can never be the only indication. A witnessed lack of other causative factors may offer some corroboration, but this is police business, not pathology.

RAILWAY INJURIES

These are not uncommon, especially in countries with many ‘level crossings’ (called ‘grade crossings’ in the USA), where a public road crosses a railway track with either no barrier at all or with only a flimsy lifting pole. Many vehicles are struck each year by passing locomotives.

Few rail passengers are killed or injured in moving trains compared with accidents to railway staff and to other types of accident on railway property. Track workers may be run down and some die from electrocution from overhead cables. The pathology of all these is no different from accidents elsewhere, the interest lying in the occupational epidemiology and preventive aspects.

One worrying development in recent years is the malicious damage caused to trains, either by placing objects on the tracks, which may cause a derailment, or the dropping of objects from bridges. The author (BK) has conducted an autopsy on a driver killed by a concrete block dropped from a bridge, which smashed through the windshield of his cab.

The other fairly common railway fatality is the suicide who lays himself in front of an approaching train. Decapitation is the most common injury and the obvious features are the local tissue destruction, usually with grease, rust or other dirt soiling of the damaged area.

The usual search for alcohol and other drugs must be made, as suicides often employ multiple methods to ensure self-destruction. As well as lying down before a locomotive,

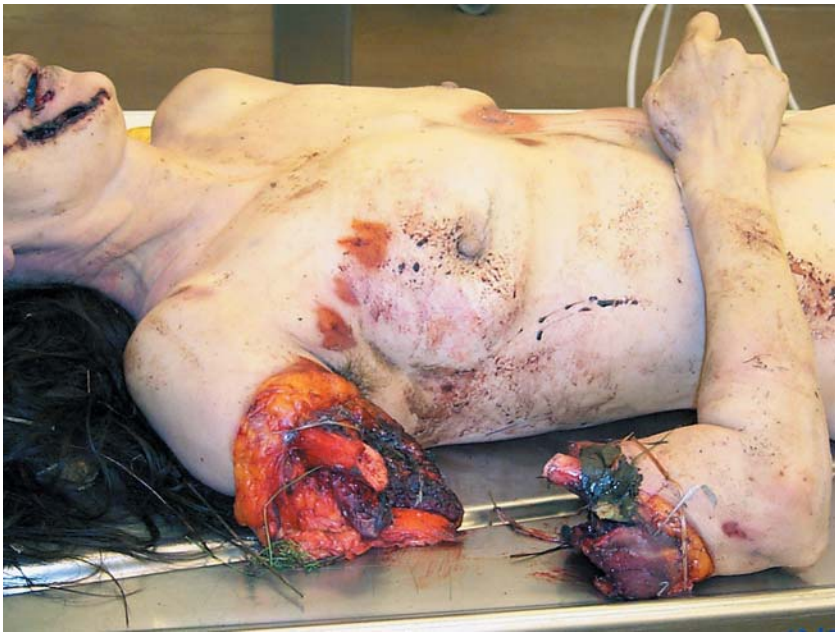

FIGURE 9.24 *Amputation of the right arm and bruising of the face and chest in a pedestrian struck by a passing locomotive.*

another common method of suicide in large cities is to jump from the subway platform of an underground 'tube' or 'metro' system. Here injuries are sometimes complicated by high-voltage electrical lesions, as the typical traction voltage of an electric railway is in excess of 600 volts.

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C H A P T E R 10

Abuse of human rights: deaths in custody

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Regrettably, abuse of human rights is so widespread on a global scale that some reference must now be made in forensic pathology texts to the physical manifestations of torture. It is stated by Amnesty International (2001) that in a third of the member states of the United Nations torture of one kind or another is practised, in spite of them being signatories to United Nations resolutions banning these atrocities. According to Amnesty International's worldwide report on torture based on a 3-year investigation (2000), currently more than 150 countries routinely torture people compared with 98 countries in their previous report in 1984.

Although most torture does not result in death, there are sufficient cases of physical abuse of human rights that progress to fatality that a number of organizations offer expertise when any alleged case needs to be investigated, usually calling upon forensic pathologists to assist them in such circumstances. These include Amnesty International (based in London), Physicians for Human Rights (PHR), the Medical Foundation for the Treatment of Victims of Torture (London) and many others.

EVIDENCE OF FATAL PHYSICAL ABUSE

In many instances the autopsy appearances of fatal abuse are no different from those by any other homicide, and the confirmation of lethal torture must depend upon circumstantial and other corroborative evidence, which is no concern of this book. For example, if a political detainee is kicked to death, the physical findings may be identical to those of a murder by kicking in a street crime. Similarly, head injuries, shooting and suffocation may show no variation from the same modes of death outside a political context.

Certain features may arouse suspicion or provide definite evidence that the death had political overtones. The word 'political' is used in a wide sense as many abuses of human rights are not directed or even condoned by higher levels of government, though often there is an indifference to being informed about such activities. Many instances of illegal death and injury are perpetrated by the military or the security forces – and even here, the level of command that directs or condones the abuse varies greatly. In general, the civil police and the regular prisons are usually not the perpetrators of gross abuse, though there are many exceptions. It tends to be the armed forces, clandestine security police, and special detention camps that are most often guilty of torture and illegal executions.

One of the features that characterizes torture and abuse is that the victim is usually either in detention or some form of custody, or is temporarily in the power of the authorities, even if that means that soldiers have just burst into a private house. All deaths in custody – discussed later in the chapter – should be examined with care, as much to ensure that the guardians are cleared of any suspicion of ill-treatment as to discover any ill-treatment itself. The fatal event may be quite different from the non-fatal abuse, as a victim who is beaten may be disposed of by shooting. As in all forensic work, the pathological investigations can only be part of the overall enquiry, another example of cooperation and teamwork between all disciplines.

One of the major differences – and great problems – in the investigation of torture and abuse of civil rights is that the authorities in the state where it occurred may be totally uncooperative and, indeed, wholly hostile to impartial enquiry. It is through respected international agencies, such as the Red Cross, Amnesty International and Physicians for Human Rights, that pathologists have the best chance of being allowed access to the relevant material, and the organizations mentioned above are willing to undertake or assist legitimate investigations anywhere in the world.

One particular problem associated with human rights abuse is the frequent long delay before being able to examine the victim. In the living, they may have been detained for months or years after the ill-treatment, or may have been exiled or in hiding before they have the opportunity to be seen by an impartial medical observer, by which time acute injuries will have healed, bruises absorbed and wounds and burns scarred over. In the dead, long-term post-mortem changes are common: the body may have been buried and exhumed before examination.

Even skeletal material is all that is sometimes available, as in the 'lost children' of Argentina or in the killing fields of Uganda. Problems of identification are often difficult. Contemporary photographs of injuries are often of poor quality and the facilities for autopsy are primitive in some of the less developed countries. When the suspicion, lack of cooperation and often open hostility of the local authorities is added, the task for the visiting pathologist is formidable indeed.

The following types of injury may confirm or arouse suspicion of torture, though, as stated, virtually any type of injury can be inflicted deliberately to extract information, punish or degrade the victims or to exterminate them. Repetition of a particular injury, such as 'tramline' bruises from beating, is suspicious, because in ordinary assaults and homicides such excessive and perhaps regularly placed repetitive lesions would be unusual.

- Beating is one of the most common forms of torture and can take many forms, varying both with the weapon used and the part of the body injured. Blows both to the head and to other parts of the body were present in all the cases reported by Hougen (1988). Unless severe and repeated, beating is not often the sole cause of death, though this can occur from haemorrhage, sepsis, injured internal organs, or from sheer exhaustion and pain in an already debilitated victim. The blows may be inflicted by fist or foot, but are more often applied with a weapon. The use of a whip or lath-like instrument is common, but metal or wooden bars, clubs, batons, rifle butts or belts may be used. More recently, lengths of plastic hosepipe or tubing have come into favour in some parts of the world.

Many of these produce a characteristic skin lesion, namely a single- or double-edged linear bruise. The bruise may be a line of confluent petechial haemorrhages or a continuous mark of red skin. The 'tramline' bruise is a double line of parallel marks with a pale unbruised zone between them, caused by the impact of a rectangular or circular-sectioned object. This is described in more detail in Chapter 4.

The bruising may be intradermal, when it reproduces the pattern of the weapon well. If a leather whip with, for example, plaited thongs, is struck against the skin, the pattern may be imprinted clearly on the skin.

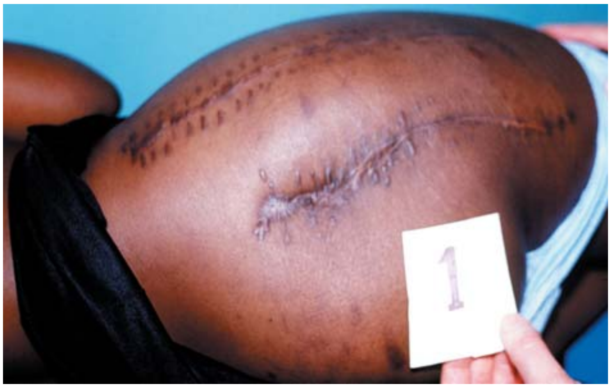

FIGURE 10.1 *A scar about one year after the original injury. The female victim was shot while escaping from an East African concentration camp. The wound was opened surgically and healed imperfectly with keloid formation. The other surgical incision is of more recent origin. Such scars will remain unaltered for life, apart from possible increase in the keloid formation.*

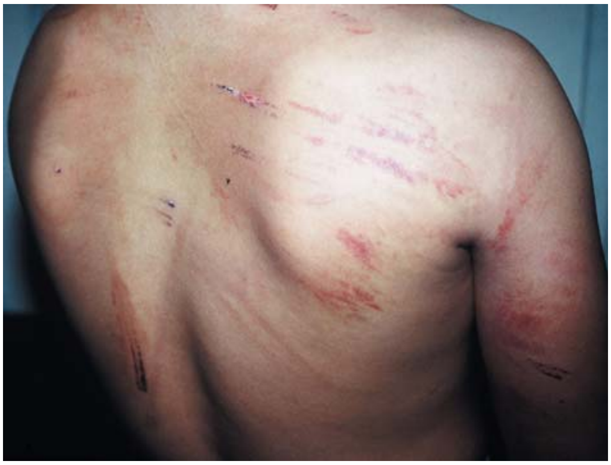

FIGURE 10.2 *Recent bruising inflicted within the previous 2 days, from blows by lengths of plastic tubing about 15 mm wide. The injuries show parallel 'tramlining' typical of impact from a cylindrical weapon. The assailants were vigilantes administering a punishment beating to an alleged collaborator in a Middle Eastern country.*

Buckles on belts and other recognizable artefacts may occasionally be useful in identifying the weapon. Where the bruising is deeper, no such pattern is likely. The skin may be broken, causing abrasions or lacerations and, if the full thickness is breached, healing will cause scars, which may even be recognizable as 'tramlines'.

Repeated beating leaves multiple marks, which though overlapping and often criss-crossing, may have a generally similar orientation that indicates that the attacker stood in a relatively fixed position to the victim. For example, lashing across the back may leave marks running from top right to bottom left, suggesting that a right-handed perpetrator stood to the left of the victim.

The use of a multi-thonged whip, such as a 'cat-o'nine-tails' will leave a series of marks, again generally in the same orientation. The thongs tend to be narrow and may cause linear marks with tramlining. There may be metal tags or knots on the end of each thong, which can cause focal damage. The back is the most frequent target, but whipping and beating may be applied to the buttocks, thighs, front of chest, breasts and abdomen, lower legs, soles of the feet, and even perineum and genitals.

Beating of the soles of the feet with canes or rods is a torture rooted in antiquity and this so-called 'falanga' may leave relatively little to see, even though it is extremely painful and debilitating. The tough tissue and thick fascial planes of the foot do not readily reveal bruising, though it may be found on deep dissection in victims who have been killed by some other means.

If injuries were inflicted months before examination, little or nothing may be found unless the skin was broken, when scarring will have taken place. Sometimes, however, faint red lines may be seen in pale-skinned people and in those with appreciable racial melanin pigment there is often hyperpigmentation along the lines of injury. Where severe damage has been caused and sometimes where there is scar tissue, depigmentation may be seen.

- Burns are unfortunately common and may be either the actual cause of death or visible as recent or scarred evidence of previous torture. All kinds of burns may be suffered. The author (BK) has seen extensive burns from molten rubber dripped onto victims from motor tyres suspended overhead, hot irons applied to skin, ignited kerosene-soaked rags wrapped around limbs and numerous burns from cigarettes pressed into the skin. Knowledge of local practices, such as the burning motor tyre 'necklace', can help identify burns in typical sites. Where molten liquids have been dripped from above onto a bound-up victim, there may be shadow areas that indicate the direction of contact, which makes any innocent explanation highly unlikely. In survivors, scarring occurs in all but the most superficial burns, and may lead to large, unsightly cicatrized areas. In victims of African origin, large keloids may form, and further complicate the damage and attempts at surgical treatment.
- Cutting and stabbing may be inflicted with a variety of weapons, but wounds from knives and bayonets are most common in the context of torture and extrajudicial execution. The features are identical to

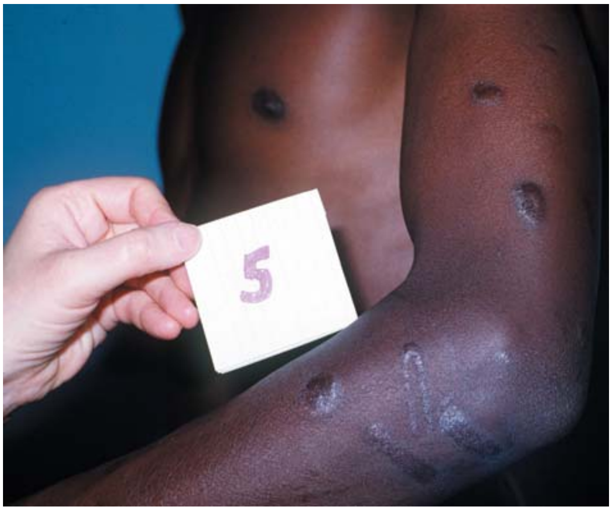

FIGURE 10.3 *Scars from beating with a thin metal rod in an East African torture camp. Though more than a year old, the 'tramline' nature of one of the scars is outlined in keloid.*

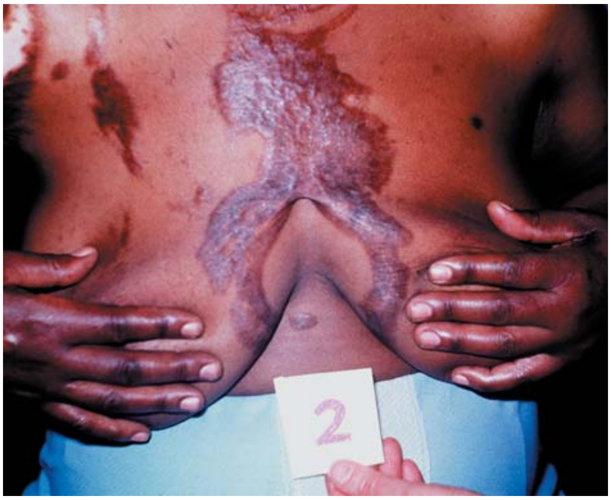

FIGURE 10.4 *Keloid scars from extensive burns during torture. The elderly lady was tied to a chair and a burning motor tyre suspended over her. The shadowed area between the breasts indicates the downward trickle of molten burning rubber. Her face was also extensively scarred.*

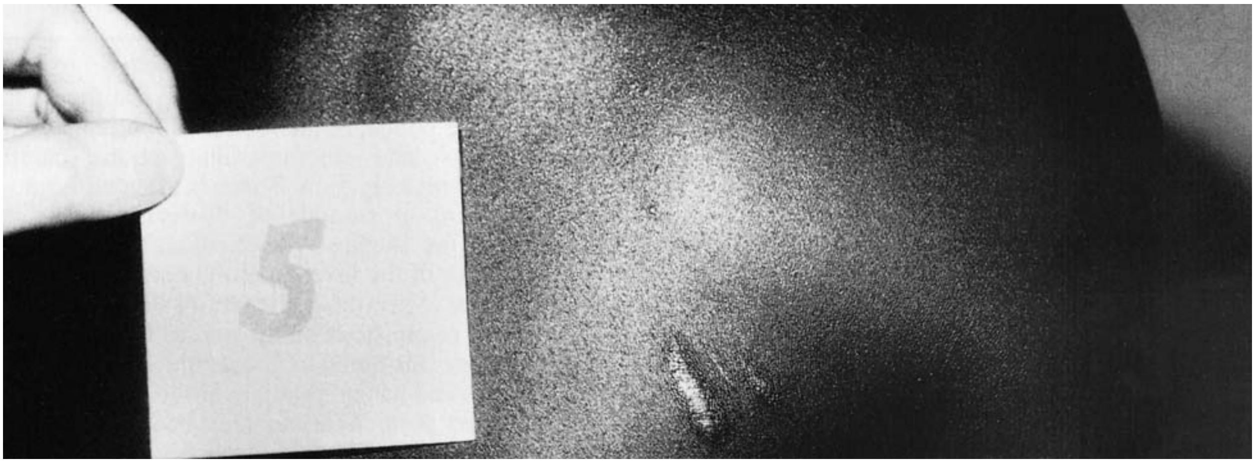

FIGURE 10.5 *The scar of a bayonet stab wound inflicted many months earlier in a Ugandan torture camp. Though scars are usually of little help in interpreting the cause of the injury, here the elliptical shape of the original stab wound can still be seen as a keloid scar and even the sharp upper end of the blade edge, as opposed to blunter lower end.*

those described in Chapter 4. The site on the body may be anywhere, but the chest and upper arms seem to be favourite targets. The scars of old stab wounds, such as those from a bayonet, may still be recognizably elliptical many months or years after infliction.

- Clubbing and blunt injury is extremely common, either to cause death or as a form of abuse. It is sometimes dispensed almost casually, as when guards lay about themselves with rifle butts against the inmates of detention camps. Again the features are non-specific and are described in the chapter on wounding. The head is the most common target, but the legs and knees are also often struck. Blows on the back or side of the neck can be particularly lethal from vertebrobasilar artery damage (Chapter 5).
- Deaths from suffocation and drowning are not common, though non-fatal practices of this kind are well-known methods of abuse. Repeated dipping of the victim's head under water or even foul liquid such as sewage is called 'submarining', and may cause drowning, air-passage occlusion or a later pneumonia. Enveloping the head in an opaque plastic bag is more a means of disorientation than physical torture, but partial suffocation by similar means may eventually prove fatal.
- Electrical torture is common and well documented. Either mains voltage of 110 or 240 V is used – which carries the risk of fatal cardiac arrhythmia as well as local burning – or a magneto delivering high voltage, which is painful but not lethal. The latter will not leave any significant skin marks, as the amperage is so low.

  The later demonstration of electrical injury is difficult, as healed lesions have few characteristic features. The acute injuries which may cause burns and death are described in Chapter 12. Karlsmark and his co-authors have made a special study of the pathology of electrical torture. The current may be applied anywhere, but the genitals are sites favoured by torturers, especially the penis and scrotum. The female nipples are also targets.

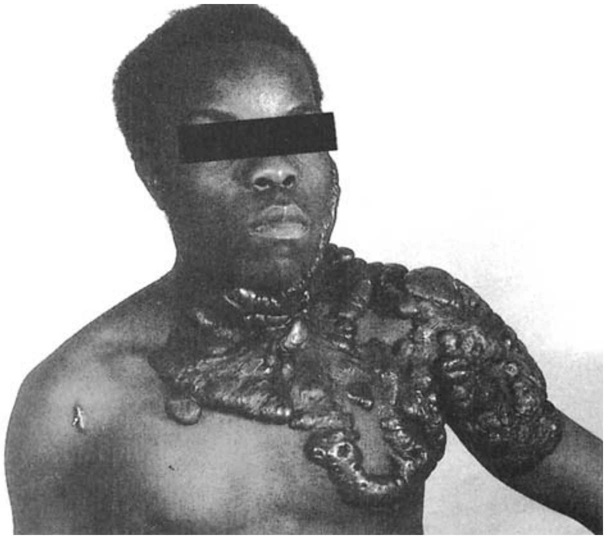

FIGURE 10.6 *Extensive keloid scars following deliberate burning of a 16-year-old student in an East African concentration camp. An electric hot plate was pressed against his neck and kerosene-soaked rags were ignited on his arm.*

- Injuries to the ears can rarely be demonstrated at autopsy, but a favourite torture is the 'telefono', consisting of repeated slapping of the sides of the head by the open palms of the assailant. This may rupture the tympanic membranes and injure the inner ear.

- Suspension is a common torture, though again not often fatal in itself. If the victim is seen relatively soon after the ordeal then abrasions, bruises and chafing marks may be found at ligature sites, usually on legs, arms and sometimes genitals.
- Shooting is not a method of torture in the accepted sense, but is a common means of execution or of non-fatal punishment, such as the 'knee-capping' perpetrated in Northern Ireland, where opponents and suspected traitors are shot either through the knee joint or the lower thigh.
- Sexual abuse is also common and in women, rape – sometimes multiple – may leave physical signs as described in Chapter 18.

Medical examiners of alleged victims of torture must be careful not to misinterpret non-torture lesions as evidence of abuse, as such lapses will be seized upon by opponents wishing to discredit the medical opinion, either for political or immigration reasons. Forrest's guide (Forrest *et al.* 1995) lists most of these, which include innocent occupational, sporting or other accidents, tribal marks, skin infections, variations in pigmentation, traditional scarification, healing marks, stretch marks, etc.

EXTRAJUDICIAL EXECUTION

Many hundreds of thousands – indeed probably millions – of victims have been assassinated in recent years by governmental agencies acting quite outside the legal system. Because of ethnic origin, tribal feuds or political views, whole sections of populations have 'disappeared' on a scale sometimes amounting to genocide as in Rwanda, Cambodia, Bosnia and Kosovo. It is common knowledge that these disappearances are usually explained by murder, either on a mass scale or by continuous individual or group extermination by 'extermination squads'. Specific instances are not the concern of a textbook, but as recent years have shown, severe excesses have taken place in most continents leading to several forensic exercises directed towards identification of victims and proving methods of torture.

When vanished people have been presumed to have been killed by troops or security agencies, the evidence is usually very late in coming to light, so that forensically, much of the work consists of skeletal identification and investigations into causes of death. Where the bodies have decomposed or skeletalized, shooting or head injuries may be the only mode of death to leave any telltale evidence on exhumation. Autopsy examination may resemble mass-disaster procedures where there are large numbers of victims. The talents of odontologists and anthropologists, and the techniques of archaeology may be needed in such cases, as described by Clyde Snow in relation to the 'lost children' of Argentina or more recently in Bosnia and Herzegovina, Croatia and Kosovo. The vast numbers of skeletal remains in the Lowero triangle of Uganda have so far had no such attention.

DEATH IN CUSTODY

The occurrence of death while a person is either in the custody of the police, or the inmate of a prison, raises public interest and emotions that require careful handling and investigation. There is often an immediate complaint or rumour of ill-treatment by the relatives or the media. A meticulous autopsy is a necessary part of the investigation needed to dispel – or sometimes confirm – allegations that an act of commission or omission on the part of the custodians has led to, or contributed to, the death. This applies in all countries and has no relationship to the preceding section, when political issues may be suspected as a cause of the death. The two aspects are not always totally separate, however, as countries with excellent human rights records have sometimes been suspected of occasional lapses of standards where custodial deaths are concerned.

Most of the cases dealt with by a forensic pathologist will concern civil police forces and the regular prison service. Many countries, including Britain, have strict legislative rules that make all deaths in custody, whether police or prison, reportable for medico-legal investigation by the appropriate law officer (the coroner in England and Wales), in addition to a searching internal enquiry by officers from a different police force (e.g. in Finland the National Bureau of Investigation).

An autopsy will inevitably be held, regulations in UK making this a case for an accredited forensic pathologist. It is sometimes helpful if the pathologist visits the scene of the death, especially if it was caused by hanging or some form of mechanical trauma.

There are several situations in which death may occur in custody. The deceased may die during or soon after arrest by police officers, as there is often a struggle in which the offender is resisting arrest, sometimes violently. It may be a physical struggle, especially when police officers are attempting to control or overpower a resisting offender. In these situations, the use of so-called personal defence sprays has increased, as they have been shown to be very effective in incapacitating an aggressor. They cause acute ocular irritation, lachrymation, conjunctivitis, blepharospasm and extreme discomfort. Most of these sprays contain *o*-chlorobenzylidene malononitrile (CS), 2-chloroacetophenone (CN), oleoresin capsicum (OC), or a combination of these ingredients as the active agent. Capsacain (8-methyl-*N*-vanillyl-6-nonenamide) is a neurotoxin component of cayenne pepper. It stimulates excitatory afferent sensory neurones, causes hypothermia, neurogenic inflammation and pain, followed by subsequent desensitization. Although these sprays have been considered to be relatively safe, unexpected deaths have been reported after the exposure to oleoresin capsicum (OC) spray devices. Pepper spray has been suspected to induce bronchoconstriction. Chan and co-workers (2002) tested the effect of (OC) spray inhalation on respiratory function in 35 healthy subjects by itself and combined with restraint but could not find evidence of hypoxaemia or hypercapnia in either group. OC exposure did not result in abnormal spirometry, hypoxaemia, or hypoventilation when compared to placebo in either sitting or prone maximal restraint position. In another study on clinical toxicity of OC, in Kansas, Watson *et al.* (1996) reported on 81 emergency department patients who had been investigated after exposure to OC. Ocular burning and redness were the most common presenting symptoms. None of the patients required hospitalization due to OC toxicity. Corneal abrasions and respiratory symptoms occurred in seven and six patients, respectively. In case of death after OC exposure, a thorough autopsy, with ancillary investigations, including complete histology and toxicological analysis with assessment of the circumstances and symptomatology, is necessary to assess whether the exposure to OC spray has been causative, contributory, or unrelated to death.

On other occasions, the offender may threaten police officers with a knife, gun or blunt weapon, and the police have to subdue him either by sheer physical force – truncheons or riot sticks – or by the use of firearms. The most common event is the arrest of a drunken offender and this poses extra problems, discussed below. Other drugs, such as cocaine, cannabis, amphetamine and hallucinogens, rather than opiates such as morphine, heroin and barbiturates, may also be involved.

The physical overpowering of a suspected offender poses definite risks to health and life, and has been the subject of numerous controversial enquiries and litigation in many countries. The police usually outnumber the offender, sometimes by a considerable margin, but even a one-to-one struggle can be dangerous for either party. The following risks exist, though the list is by no means comprehensive.

- Traumatic asphyxia may occur where several policemen fall upon a resisting subject to overpower him. The author (BK) has dealt with several deaths where a number of large police officers piled on top of a prisoner fighting maniacally, to apply handcuffs. When they got up, the man was not breathing and died in hospital shortly afterwards. Death was caused by traumatic asphyxia, the weight of the men on top of him causing chest compression and prevention of respiratory movements. The appearances are described in Chapter 14.
- Arm-locks or neck-holds applied by police officers to resisting persons are other causes of deaths during arrest. These have been particularly notorious in the USA, where police officers have been trained to apply neck-holds as a form of restraint, but similar deaths have been seen elsewhere. The arm-lock is applied either from behind or with the head of the offender tucked under the police officer's arm against his waist. The dangers are compression of the front or sides of the neck, and death can occur either from reflex cardiac arrest or cerebral ischaemia during carotid compression, or asphyxia from airway obstruction, though the latter is unlikely as the sole mechanism. According to American writers such as Reay and Eisele (1982, 1986), there are two types of neck-hold – the 'bar arm control' and the 'carotid sleeper'. The former is alleged to be more dangerous; the officer's forearm is pulled across the front of the larynx to occlude the airway. The carotid sleeper uses the two sides of the 'V' formed by the flexed upper and lower arm to compress the carotids and produce transient cerebral ischaemia. Both varieties are dangerous, however, as there is the ever-present hazard of reflex cardiac arrest from vagal stimulation from the carotid sinus and sheath, as well as the potential danger of neck traction and hyperextension causing subarachnoid haemorrhage from vertebrobasilar artery damage.
- Postural (positional) asphyxia has been reported to have caused sudden deaths in persons after the use of the 'hogtie', 'hobble' or prone maximal restraint and even in situations where a person has been placed in a prone position in the rear compartment of a police car. In an experiment with healthy subjects, the restraint position resulted in a restrictive pulmonary function pattern but did not cause clinically relevant changes in oxygenation or ventilation. It has been postulated that the hogtie restraint position by itself does not cause respiratory compromise to the point of asphyxiation but other factors, e.g. acute intoxication by alcohol or drugs, are responsible for the sudden deaths of individuals placed in this position.
- Blunt injury may occur from the use of fist, arm or leg – or the use of a weapon such as a truncheon, riot stick or pistol butt. During a struggle, usually with one or more police officers who are attempting to subdue a fighting offender, injuries may be received by either side. All types of blunt injury may be sustained, some potentially fatal and these are discussed in Chapter 4. Head injuries may occur during a scuffle from falls either against the ground, or against a wall or other

obstruction. A heavy punch in the face may cause nasopharyngeal bleeding that can block the air passages, especially in a person affected by alcohol. A blow on the side of the neck can cause reflex cardiac arrest or a subarachnoid haemorrhage from vertebrobasilar vascular damage.

A backward blow from the point of an elbow can be damaging, if it strikes the face, neck or abdomen. Kicking and stamping are unusual, but not unknown, in custodial deaths. A blow in the abdomen can also be serious if delivered with sufficient force. Though in an adult a fist blow is not very likely to cause serious harm, it can in a slighter young person. The use of the elbow, knee or a head butt can deliver extreme force, especially from a fit, muscular police officer, as well as from an offender.

The author (BK) has seen fatal intraperitoneal bleeding amounting to three litres in a drunken man arrested after a scuffle with two police officers, in which there were allegations that one struck or fell on the man with his knee. Several hours later the prisoner collapsed and at autopsy there were several large tears in the mesentery.

Alcohol is a frequent cause of death in custody. Not only is it the major factor in provoking aggression and violent resistance, with the consequences mentioned above, but it can have other effects which lead to death while in the care of the police. Acute alcoholic poisoning, described more fully in Chapter 28, may lead to death while the victim is thought to be ‘sleeping it off’ in a police cell. When blood alcohol levels rise to above 350 mg/100 ml there is an increasing risk of coma and central respiratory depression. Although most responsible police forces have standing orders about placing drunken prisoners in the semiprone position and observing them at frequent intervals, a quiet drunk may still slip into irreversible coma and respiratory arrest.

At lower blood alcohol levels there is still the risk of aspiration of vomit and choking on gastric contents. Though drunken prisoners are placed in the safest posture for drainage, they can still vomit and choke when unobserved, between visits by the often busy police station officers. At autopsy, caution must be observed before ascribing death to aspiration of vomit, as this is a common agonal phenomenon in deaths from other causes. Where an otherwise healthy person dies with a high blood alcohol concentration in these circumstances, however, gross blocking of the trachea and bronchi with vomit forms one of the most convincing arguments for acceptance of aspiration as the cause of death if no other factors can be identified.

Alcohol also contributes to accidents during custody, especially head injuries, which come about because of falls to the ground, falls down steps and stairs, and being run over by traffic, as a result of the ataxia and incoordination of the drunken state. Falls onto a hard surface are often on the occiput and the frequent finding of frontal and temporal contrecoup brain damage at autopsy is good evidence of a deceleration injury rather than an assault with a weapon.

Some falls may occur during custody or in transit from the site of arrest to the police station – others have happened before arrest, but the ill-effects and death may become manifest during the stay in the police cell, when the police are often blamed either for allowing or causing the injury – or for not summoning or providing urgent medical attention. Drugs, especially those causing excitement, such as amphetamine, cocaine or hallucinogens, may also lead to physical damage, but alcohol remains by far the most common.

Drugs are commonly available within prisons and overdose or hypersensitivity deaths are occasionally seen amongst prisoners, as they are in the outside world.

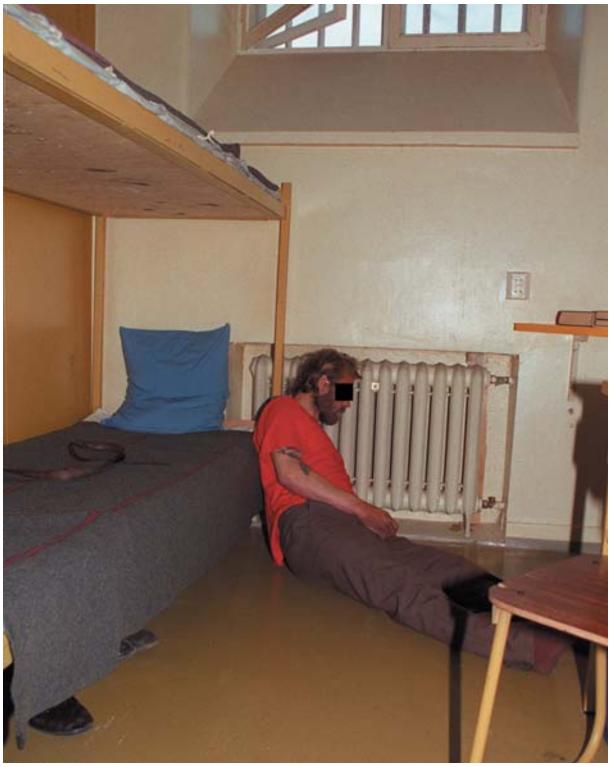

FIGURE 10.7 *Suicidal hanging in a prison cell. This is an infrequent but regular tragedy, which, in spite of strenuous efforts by prison officers and designers of cells, occurs because of the determination of the prisoner to defeat the safeguards. The belt used as ligature has been removed and lies on the bed.*

- Suicide in custody is not uncommon, and often leads to accusations and recriminations from the relatives over lack of supervision. There has recently been a spate of such deaths in Britain, especially amongst young offenders on remand awaiting trial. It is such a well-recognized hazard of custody that most police forces deprive the prisoner of any objects, such as belts, braces (suspenders), cord or even bootlaces, that could be used to hang himself in his cell. In addition, the police cell may be specifically designed to avoid any convenient suspension points, such as hooks, bars or even internal door handles. In spite of these precautions, prisoners regularly manage to find some means of killing themselves. Strips of bedding material, sleeves of clothing and handkerchiefs have all been used for self-suspension. As described in Chapter 14, hanging can be successfully accomplished by traction on the neck at low levels and need not occur from high suspension points, so prisoners have killed themselves by attaching ligatures to bed-heads, chairs and other unlikely objects in the cell.

  Accusations that apparent suicidal hangings were in reality homicides by the custodians can usually be resolved by the autopsy showing no signs of bruising, abrasions or a struggle. It would seem impossible to hang a conscious person against his will without leaving some signs of restraint. The proposition that the hanging was a ligature strangulation is usually disproved by the rising angle of the ligature mark, which most commonly sets under the angles of the jaw and has a defect in the skin mark where the suspension point pulls the ligature away from the surface. A homicidal strangulation usually encircles the neck and a cross-over point is often seen. The level is lower, nearer the horizontal (Chapter 14).

  Where a true hanging mark is caused by a ligature with a slip-knot, there may also be a full circle of skin abrasion and compression. If the suspension point is low, as might happen in a cell using a doorknob or a bed-frame, then the direction of pull can be oblique. If the body also leans over against the direction of pull, the resultant mark can be virtually horizontal and, unless the situation is fully assessed – preferably by a visit to the scene with the body *in situ* – confusion can occur, as with the controversy over the death of Rudolph Hess in 1988, whilst an inmate in Berlin's Spandau prison.
- Death may be from purely natural causes, usually cardiovascular in origin, which happened to have occurred during detention. It must be admitted, though it is almost impossible to provide objective proof, that the emotional and sometimes physical upset of being arrested and confined may have affected the blood pressure and heart rate sufficiently, by an adrenaline response, to have precipitated an acute cardiac crisis in the presence of severe pre-existing disease.

  The presence of diabetes, epilepsy, asthma or other diseases that can potentially cause sudden or unexpected death should be sought by medical history and autopsy appearances (Chapter 25).

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CHAPTER **11**

Burns and scalds

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Damage to the tissues arising from the application of heat is commonly encountered in forensic pathology and sometimes provides a challenging problem in the distinction between ante-mortem and post-mortem burning, which may have serious criminal aspects.

HEAT INJURY

This may arise following a defect in body temperature control or, more commonly, from the external application of heat. Mammalian tissues can survive only within a relatively narrow range of temperatures, approximately 20–44°C.

When external heat is applied, the extent of damage depends upon:

- the applied temperature
- the ability of the body surface to conduct away the excess heat
- the time for which the heat is applied.

The temperature/time relationship is important, for it is sometimes forgotten that relatively low temperatures, even as little as 44°C, can cause damage if sustained long enough. This is attested by many negligence lawsuits concerning unconscious patients burned by forgotten hot-water bottles.

The degrees of thermal damage were investigated by Moritz and Henriques (1947), who found that the lowest temperature that would cause damage was 44°C, though it required no fewer than 5 hours before a burn appeared. Only 3 seconds was needed, however, if the object was at 60°C.

Radiant heat can also cause severe damage, as is obvious from overexposure to sunlight or artificial sunlamps. The long-term effects also include malignant changes, now more important because pollution-induced changes in the stratosphere are allowing more ultraviolet radiation to reach the earth's surface. In forensic practice it is more often seen when an old or disabled person falls unconscious within close range of a gas, electric or coal fire, those areas of skin unprotected by clothing becoming burned, often to a blistered state. It can be difficult or impossible to tell how much of such a condition is ante-mortem or post-mortem, as the presence of reddening and blistering cannot always be depended on as criteria of vital infliction. Mottled pigmentation and reddening of the fronts of the legs (erythema ab igne) is a familiar sign in those addicted to sitting before an open fire.

CLASSIFICATION OF THE SEVERITY OF BURNS

An arbitrary, but useful, classification is used (mainly for surgical purposes) to denote the severity of both burns and scalds. The older six-stage classification of Dupuytren has given way to Wilson's three-stage nomenclature:

- **First degree:** erythema and blistering without loss of dermis. There is capillary dilatation and transudation of fluid into the tissues, causing swelling. A split may occur in the epidermis to form a blister with an upper cap of pale skin enclosing fluid, surrounded by a zone of hyperaemia. If small (<1 cm) this blister may resorb, otherwise it will burst, leaving a reddened base. A first-degree burn will heal without scarring.

- **Second degree:** destruction of the full thickness of skin. The epidermis is coagulated or charred, and a central zone of necrotic tissue is surrounded by first-degree burns or a zone of hyperaemia, or both. The central necrosis sloughs in due course and the epidermis grows in from the margins. The injury cannot heal without scarring, which usually contracts during the healing process, causing puckering and distortion of the surface.
- **Third degree:** destruction of deeper tissues below the skin. This can be of any severity, from damage to subcutaneous fat to loss of muscle, bone and even a whole limb.

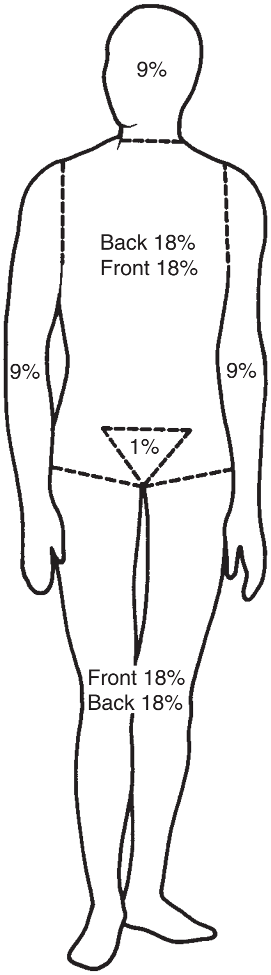

FIGURE 11.1 *The 'Rule of Nines' for calculating the area burned. It does not apply to infants whose body proportions are different from adults. About 60 per cent surface burns can be survived by children and young people up to 20 years of age but this rapidly decreases with advancing age.*

The area involved is traditionally estimated by the surgical 'Rule of Nines', which is sufficient for prognostic purposes, though for the pathologist a more precise anatomical description of the areas burned is essential for his autopsy report.

If the burns are widespread, then large areas of skin may be damaged and functionless. A large area involved may be more dangerous to life than a deeper, more localized burn. It is generally considered that 30–50 per cent involvement of the total body surface is incompatible with survival. Old people can die at considerably lower percentages than this, while children appear more resistant.

MOIST THERMAL DAMAGE – SCALDS

A 'scald' refers to tissue damage from hot liquids, usually water. Other hot fluids include oils, molten rubber, other liquid chemicals and steam. Molten metals are usually at such a high temperature that the results are similar to dry burns. The water scald is a common domestic accident, especially to children and old people, that group at the extremes of life who are vulnerable to so many types of accident.

A scald, unless from some superheated oil, does not cause charring, carbonization or singeing of surface hairs, as does dry heat. It resembles a first-degree dry burn (see later) in

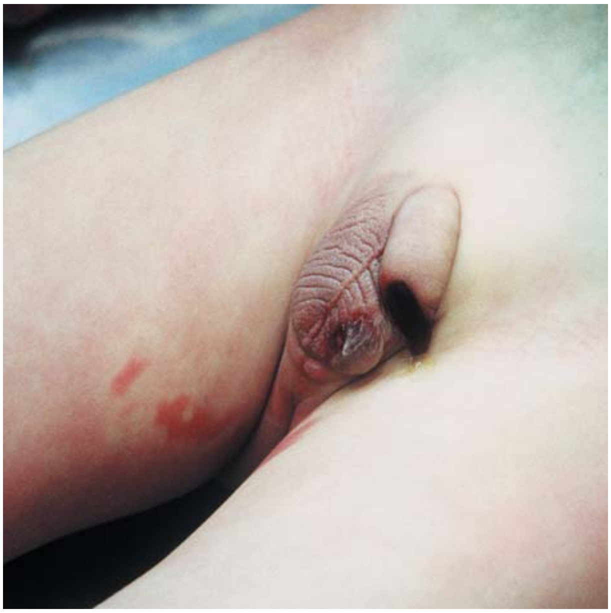

FIGURE 11.2 *First- and second-degree burns on the right thigh and scrotum of a 5-year-old diabetic child, who had been treated by a quack, who had promised the parents to cure the child by hot baths. Death was caused by the untreated diabetes.*

that there is reddening, desquamation and blistering, but the shape of the scald tends to be different. There is usually a sharply demarcated edge, corresponding to the limits of contact of the fluid. If due to immersion in hot water, such as a bath, there will be a horizontal fluid level, though this may be made irregular by splashing. When tipped or splashed, the hot liquid runs under gravity so that trickle patterns may be seen, which may enable the medical examiner to determine the posture of the victim when scalded.

The intensely red base of a severe scald may at first be covered by wrinkled, macerated epidermis. The scalded skin may swell and exude serum. Infection may supervene but where the burns are extensive, death usually results from the systemic effects of shock, fluid and electrolyte disturbance, and secondary chest infections. The severity of a scald depends on the duration of contact with the skin, as well as the temperature. When hot water is splashed, tipped or thrown, it has only a momentary contact, falling away under gravity. The large surface area allows rapid cooling, so damage must occur in a short time, which necessitates the temperature being high if severe damage is to be caused. Often the water is boiling, especially in the kitchen accidents that, sadly, occur to children with such regularity. The interposition of clothing may have two opposite effects; it may protect the underlying skin from the hot liquid, especially if poorly permeable, but it may also hold the hot liquid in contact with the skin for a longer time, especially if the fabric is absorbent.

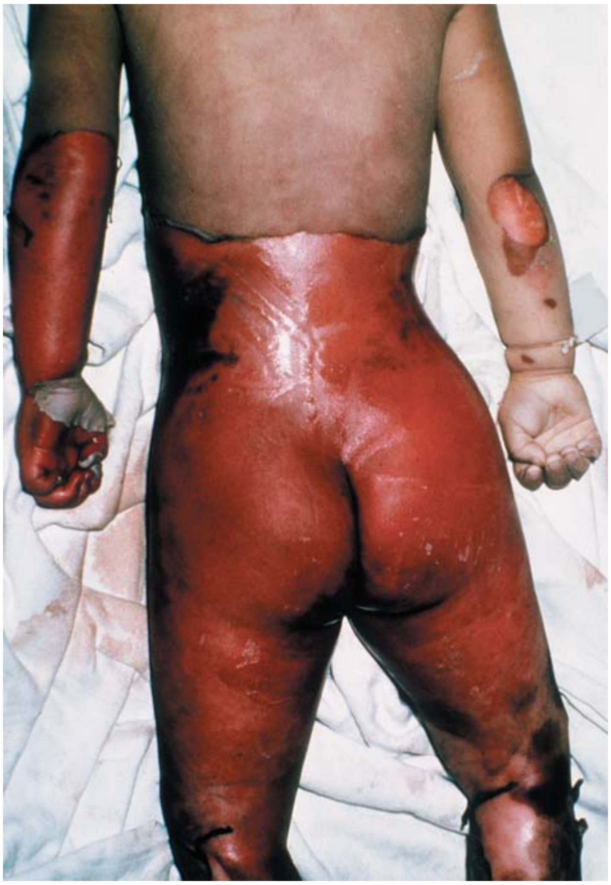

FIGURE 11.3 *Scalds or wet burns in a child accidentally left in a hot bath while her mother went to answer the telephone. This illustrates that time, as well as temperature, is a factor in causing heat damage to skin. The child died some days later from an intercurrent chest infection.*

The appearance of scalds may resemble dry burns except for the distribution and the fact that, if due to immersion, the severity of the skin damage is usually uniform over the whole of the burnt area up to the sharply demarcated margin. When hot or boiling water has been poured or splashed onto the body, the worst scalds will be at the area of initial contact where the fluid was hottest, but decrease in severity as the cooling liquid runs away. In children who pull containers of hot liquid down on themselves, the scalds tend to be on the face, neck, chest and arms, with ‘shadow areas’ of undamaged skin in the axillae and on the back.

BURNS FROM DRY HEAT

More common than scalds, burns due to dry heat may be caused by high temperature applied to the body surface by conduction or radiation. Convection is merely a variant of conduction in this respect; as hot gas impinges on the surface, the molecules transfer their high energy in a similar fashion to the direct contact of a hot solid.

Radiation causes damage through the conversion of infrared frequencies into thermal heat on absorption at the

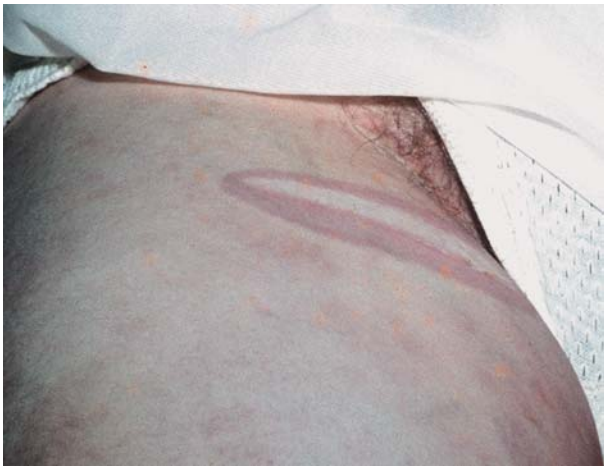

FIGURE 11.4 *A burn on the inner sides of each upper thigh in a young woman. These are suggestive of the application of a hot-water bottle in an attempt at resuscitation after a criminal abortion. The victim died of air embolism following the use of a Higginson syringe.*

skin interface. As with scalds, the tissue damage is a function of temperature and time. A warm water-pipe will cause a burn if left long enough in contact with the same area of skin, but the vast majority of dry burns are due to high temperatures acting for a shorter time.

Where the time is extended beyond that needed for initial burning, the tissues may be charred, carbonized or completely destroyed, as in cremation.

The severity of dry burns

The Wilson classification of severity of burns is given above, with three degrees according to the depth of tissue damage:

- Erythema leads to redness and swelling of the skin. Blisters may form either within the thickness of the epidermis or at the epidermal–dermal junction.
- Destruction of the full thickness of the skin, which may be total or incomplete. If epidermal structures survive, such as the deeper parts of hair follicles, then epithelialization may occur from islands within the burned area. If not, slow coverage with more probability of extensive scarring will occur from invasion of epidermis at the periphery.
- Destruction of subcutaneous tissues, such as fat, muscle and even bone, is the most serious grade of burning, though, as mentioned elsewhere, it may be less dangerous to life than larger areas of more superficial burns.

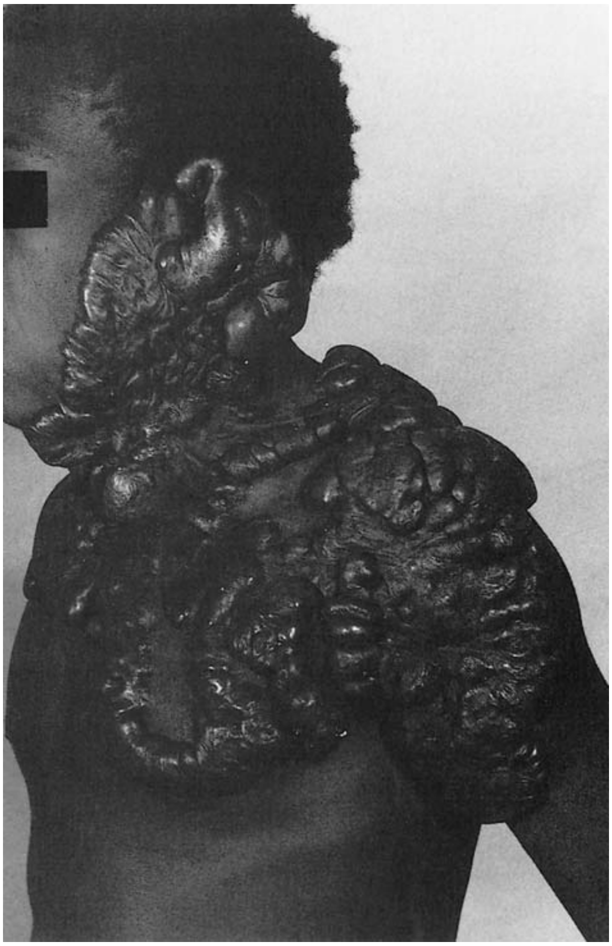

FIGURE 11.5 *Keloid tissue (dense collagenous overgrowth) more often follows burns than other injuries. It is especially prevalent and profuse in negroid persons. This East African youth was tortured in a political camp with hot metal and burning kerosene, resulting months later in exuberant keloid.*

GROSS APPEARANCES AT AUTOPSY

The body may present a wide range of damage from mere reddening over wide areas to almost total cremation, in which a search may have to be made at the scene of the fire to collect or even discover the remnants.

Usually, where leathery coagulation or charring has not occurred, ante-mortem burns will be reddened and often blistered. The latter have a marginal red zone of variable width, usually 5–20 mm across. Blisters may be present either in the main burn or as islands beyond the periphery. Most ante-mortem blisters will have a bright red base when burst and an erythematous areola. The whole of the burned area may form one large blister or be a coalescence of blisters. These are usually collapsed at autopsy, so that sheets and shreds of white epidermis lie across an angry red base.

Where the burns are more severe, the skin may be stiffened, yellow–brown and leathery, a half-way stage to actual carbonization. Drying after death of areas that were weeping serum leads to a stiff, parchment-like surface. Post-mortem heating and deposition of smoke may mimic or overlie the ante-mortem appearances, the surface often being blackened by soot deposition.

Hair is singed or completely burnt away in severe burns. In lesser degrees it may survive and the ends of the hairs may be 'clubbed'. Here the keratin melts at the distal end nearest the heat, then resolidifies on cooling, forming a terminal blob on the shaft like an unlit match. Eyelashes, eyebrows, pubic, axillary and general body hair may all suffer this scorching. Where skin has actually ignited, the subcutaneous fat acting as a fuel, black brittle masses will occupy the tissues merging into cooked, dry muscle beneath, which in turn grades into more moist and normal-looking soft tissue at greater depths. Beneath burns of any degree, the deeper tissues may be affected, especially muscle, which becomes pale, brownish and obviously 'part-cooked'. This is often a post-mortem phenomenon caused by the dead body remaining in a heated environment and such cooked muscle may

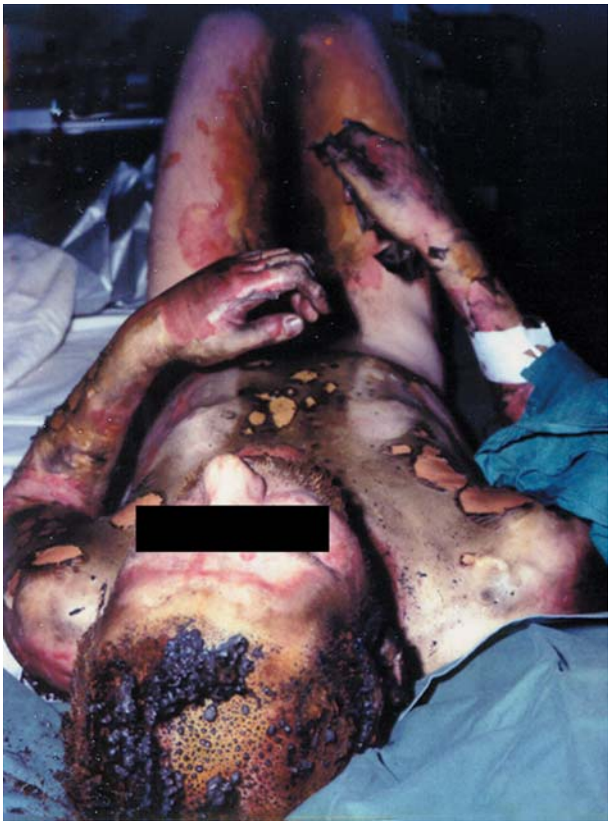

FIGURE 11.6 *Second and third degree burns and singeing of hair on a suicide who doused himself with petrol and set himself to fire.*

extensively underlie normal skin, which shows no evidence of ante-mortem burning, especially if protected by clothing. It is the general high temperature of the environment over a relatively long period which produces this 'parboiled' appearance, similar to the cooking effect of a slow oven.

Where heat has been intense and continuous, all soft tissue down to bone may be consumed and the bone itself may be blackened. The most extreme stage is conversion of the bone to brittle greyish-white splinters, sometimes with loss of skeletal structures, leading to absent feet, hands or limbs. It is rare for the whole body to be completely consumed, even in deliberate cremations, but only a fraction of the original body mass may remain, often almost inseparable from the burned surroundings. Where much smoke has been generated, as in most house fires, the skin will be discoloured where exposed. Sharply demarcated areas of soot deposition may coincide with burning from hot gas. Even the thinnest layer of clothing may protect completely from both these effects.

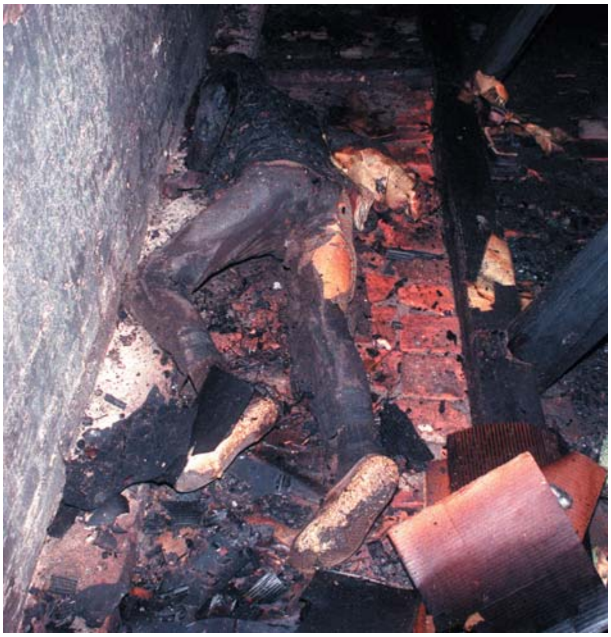

FIGURE 11.7 *Dead bodies in fires pose a problem for pathologists and investigators. Death was shown to have occurred after the fire began from soot in the lungs and carboxyhaemoglobin in the blood. There were no ante-mortem burns and there was a high blood-alcohol concentration.*

Muscle contractures are common where substantial heat has reached the body. This is almost always a post-mortem occurrence, as deep-heating effects sufficient to cook muscle are incompatible with life. The muscle becomes shortened by dehydration and protein denaturation. The flexors, being bulkier than the extensors, contract more and force the limbs into a position of general flexion, the so-called 'boxer's' or 'pugilistic' attitude. Contraction of the paraspinal musculature often causes a marked opisthotonos. Froth, often pink-stained, may appear at the mouth and nostrils as a result of pulmonary oedema caused by heat irritation of the air passages and lungs. The tongue frequently protrudes and may be scorched.

SPURIOUS 'WOUNDS' IN BURNS

Heated skin contracts markedly and splits often appear. This may lead inexperienced observers (such as police) to suspect that ante-mortem wounds have been inflicted, the fire being used to cover up a criminal offence. These splits may be anywhere, but are especially seen over extensor surfaces and joints, as well on the head. Some, especially those at elbows and knees when the limbs are flexed across brittle skin, are caused by firemen handling the body during recovery.

The possibility of true wounds being present must always be kept in mind, as many homicides have been concealed in fires. The false split will show no bleeding in the deeper tissues and its position is usually suggestive. The differentiation may be difficult or even impossible, however, especially when severe heat damage in the area makes examination of the underlying tissue impracticable.

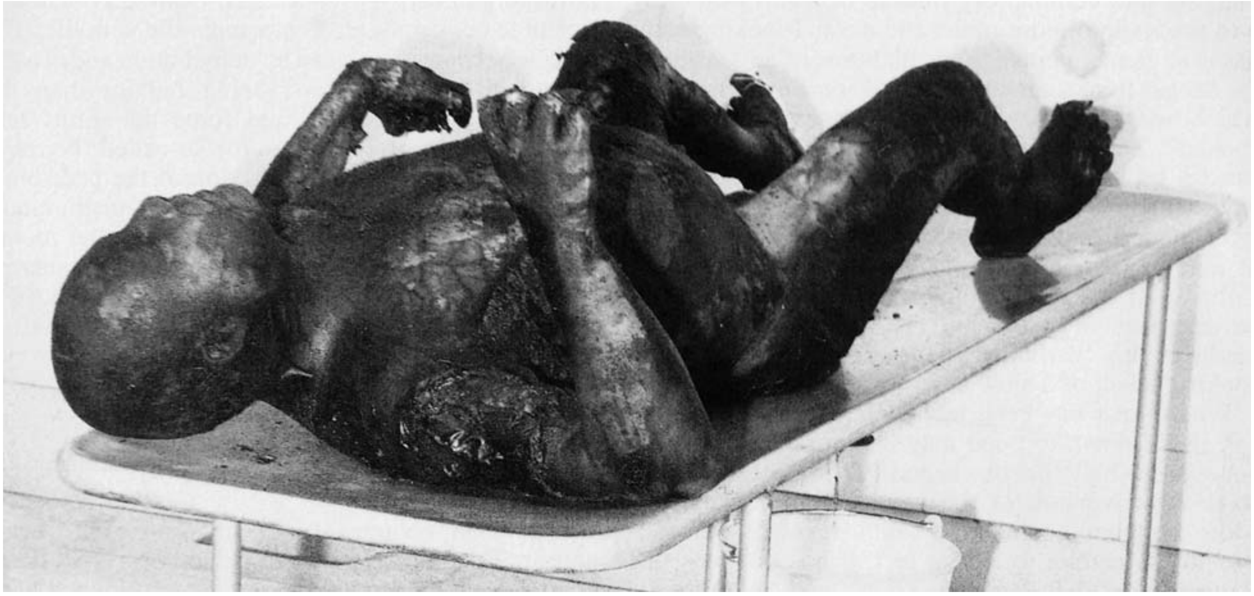

FIGURE 11.8 *Heat flexures of the limbs, part way towards the 'pugilistic attitude' formed when the arms are raised higher. The elbows, knees and wrists are strongly flexed because muscle contraction is stronger in the flexor groups. The victim was the captain of a Russian ship who set fire to his cabin during a bout of heavy drinking.*

The other major false lesion is the 'heat haematoma' in the extradural space. When severe heat is applied to the cranium, a mass of blood resembling a true extradural haematoma may form between the skull and the dura. This may arise either from venous sinuses or be virtually 'boiled' out of the diploic space in the skull through emissary venous channels. The blood is spongy from gas bubbles and tawny or chocolate brown. The exterior of the skull overlying the haematoma is usually charred and the scalp burnt away. If it is a purely post-mortem phenomenon, the heat haematoma will have a similar level of carboxyhaemoglobin to the blood, whereas if it was an ante-mortem lesion sustained before the fire began, it will be free from monoxide, as discussed in more detail below. Where the heat is intense the spurious haematoma may be outside a grossly shrunken dura, which compresses the brain into a cooked mass. The dura may split under the tension and allow brain tissue to ooze out into the large space within the cranium, where it may form a mass of frothy paste (Kondo and Ohshima 1994). These changes may be present without a haematoma, but the latter is often present. In the absence of a skull fracture, other than one due to heat, this haematoma should not be ascribed to trauma.

ANTE-MORTEM VERSUS POST-MORTEM BURNS

In severe conflagrations, either in buildings or vehicles, the terminal state of the body often does not reflect the condition at the time of death. Indeed, many deaths will have occurred before any heat reaches the body, death being caused by the inhalation of smoke. It may be difficult or impossible for the pathologist to determine the extent of ante-mortem damage if the ensuing fire later reaches the body and causes post-mortem burning. The exposed skin surface may be reddened in both ante-mortem and post-mortem burns, the classical distinction of a 'red flare' or 'vital reaction' being unsafe as an index of infliction before death. The author (BK) has seen several cases of undoubted post-mortem burns, one at least 30 minutes after fatal strangulation, where an extensive 'red flare' was caused during attempts at disposal of the body by fire.

Blisters can form post-mortem, but are pale yellow unless on scorched skin. There is rarely a red base or erythematous areola, though this sign cannot be depended upon absolutely. The contained fluid is thin and clear. Traditionally most authors claim that differentiation can be made between an ante-mortem and a post-mortem blister by an analysis for protein and chloride in the fluid. The blister formed in life is said to contain more protein and chlorides, but no absolute figures are offered and the authors have yet to meet a pathologist who does this as a routine. One suspects that the test is another of the apocryphal procedures that have been handed down from textbook to textbook without verification.

Most useful of all in fatalities is the presence of carbon monoxide in the circulating blood and carbon particles in the air passages and lungs, and this is dealt with in the section on inhalation of fumes. They do not necessarily prove that any burns were ante-mortem, but that the victim was still alive when the fire was in progress, which is not the same conclusion. The extradural heat haematoma may be investigated in a different way to determine its time of origin. If it is a true traumatic lesion produced before the fire began, it should contain no carboxyhaemoglobin. A spurious heat haematoma is formed from blood that will contain carboxyhaemoglobin if the victim has absorbed this gas during the fire. It must be appreciated, however, as

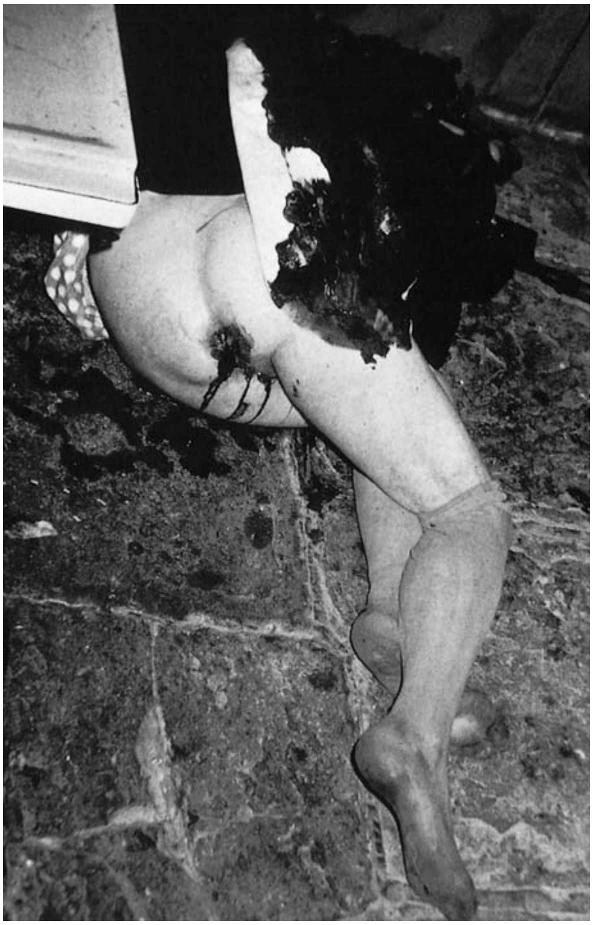

FIGURE 11.9 *Substantial destruction of the body by fire. The upper half of the victim has virtually vanished, including skeletal structures, leaving the lower part intact. The gas stove was ignited with a match after a delay while gas was escaping, causing a near-explosion that consumed the upper part of the body, the fat burning with clothing acting as a 'wick'. Such events have given rise to the myth of 'spontaneous combustion'.*

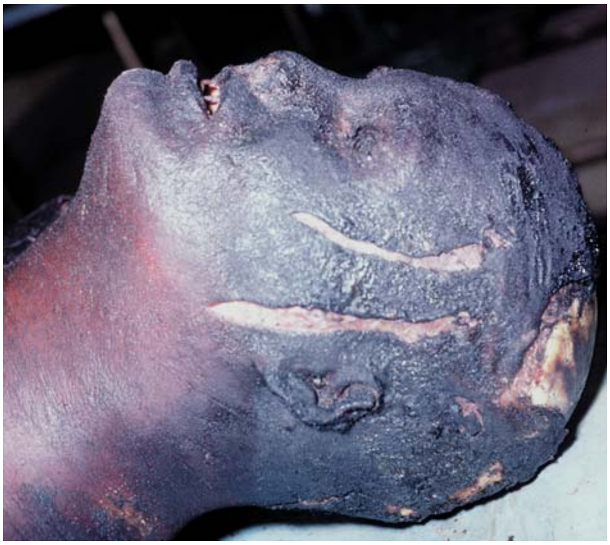

FIGURE 11.10 *Post-mortem injuries caused by heat simulating head injuries. The fire service were concerned about an apparent preconflagration assault, but such skin splits are commonly seen as a result of heat contracture of the tissues. The scalp on the top of the head has been burned through and the skull is charred. Beneath this is a spurious 'heat haematoma', sometimes confused with a traumatic extradural haemorrhage.*

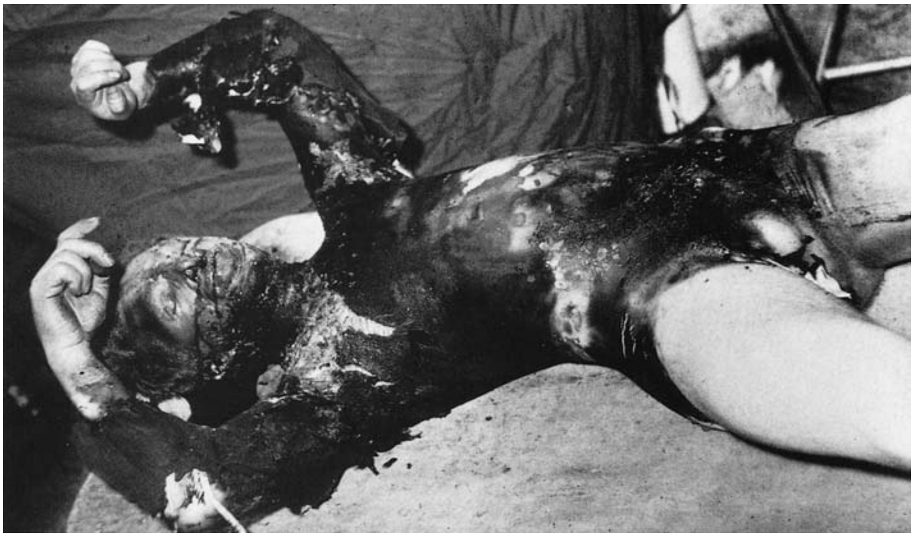

FIGURE 11.11 *Post-mortem burns in a victim recovered from a house fire. Note the raised arms caused by heat contractures and the complete protection against burning afforded by clothing on the legs. There is extensive skin splitting on the chest.*

discussed below, that not all persons alive during a fire accumulate carboxyhaemoglobin in their blood.

If there is carboxyhaemoglobin absorption, then the heat haematoma will also yield it on analysis. The use of this test, again related in most classical texts, is, however, extremely limited.

FUMES AND FIRES

The majority of fatal dry burns in civilian practice occur in conflagrations in buildings, rather than in vehicles or aircraft. In many of these tragedies death is not caused by burns, but to inhalation of fumes produced by the combustion of the building structure and contents. Indeed, most burns seen by forensic pathologists are post-mortem, either because the victim was already dead from smoke inhalation or because severe post-mortem burning obliterates the lesser degrees of burns present up to the moment of death.

Death from inhaling fumes may be caused in several ways:

- Thermal damage to the air passages and lungs from the direct effect of hot gases. At autopsy the tongue, pharynx and especially glottis may be scorched, lesser degrees causing a greyish-yellow blanching of the mucosa. The interior of the larynx, trachea and main bronchi may be thickened and blanched, or reddened and inflamed, if the temperature is too low actually to burn the lining.

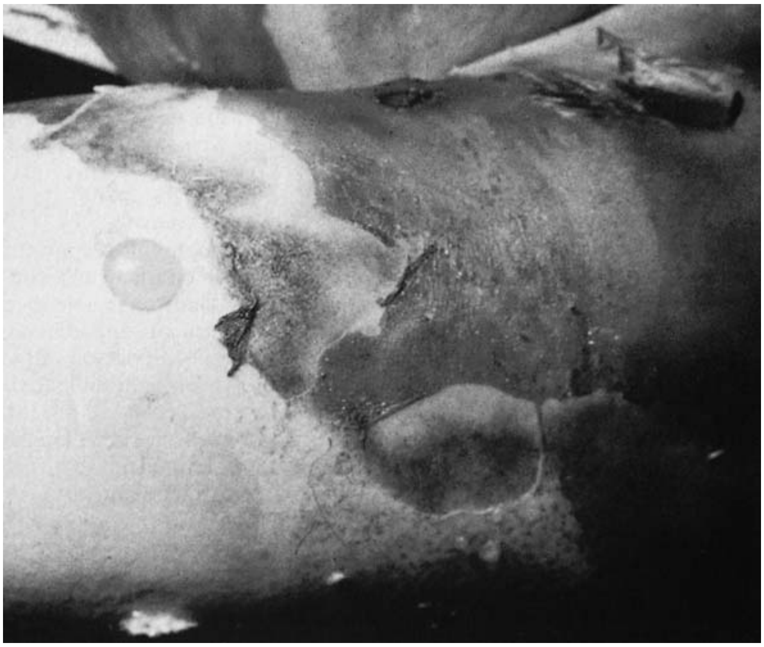

FIGURE 11.12 *It can be difficult or impossible to differentiate between ante-mortem and post-mortem burns when they are sustained near to the time of death. Here the blister with no erythema at the base could either be post-mortem or ante-mortem, as reddening of the margins and adjacent skin can occur for at least an hour after death. It is preferable to call doubtful lesions 'peri-mortal'.*

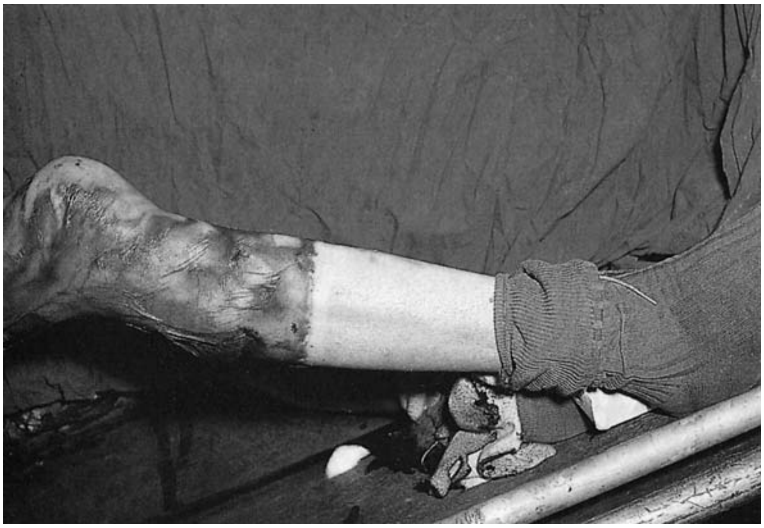

FIGURE 11.13 *Post-mortem smoke soiling and superficial burns on the leg of a house-fire victim who died of smoke inhalation. Note the complete protection of the skin, which had been covered only by a sock.*

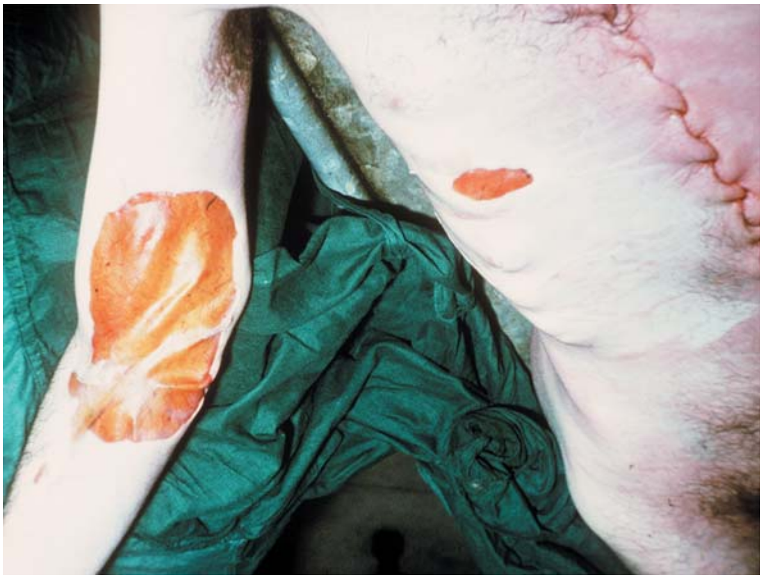

FIGURE 11.14 *Post-mortem burn on the arm and chest caused by a hot-water bottle being left over the heart in an attempt at resuscitation. The lesion is sharp-edged, there is no erythematous margin, and the surface is brown and leathery from post-mortem drying.*

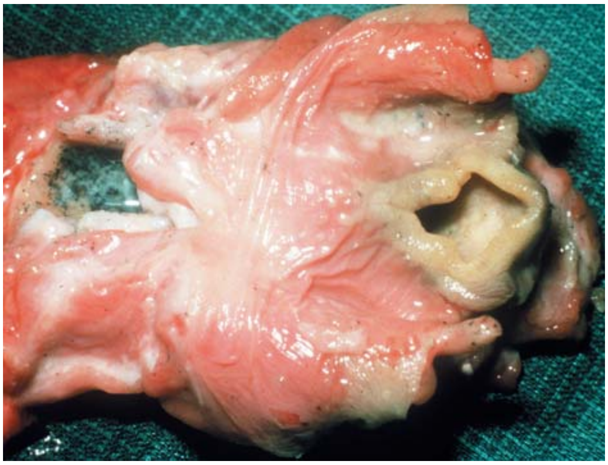

FIGURE 11.15 *Larynx of a house-fire victim showing heat blanching of the epiglottis and glottal entrance from breathing hot gas. The lower cut end of the trachea shows copious soot-containing mucus, also indicating respiration during the fire.*

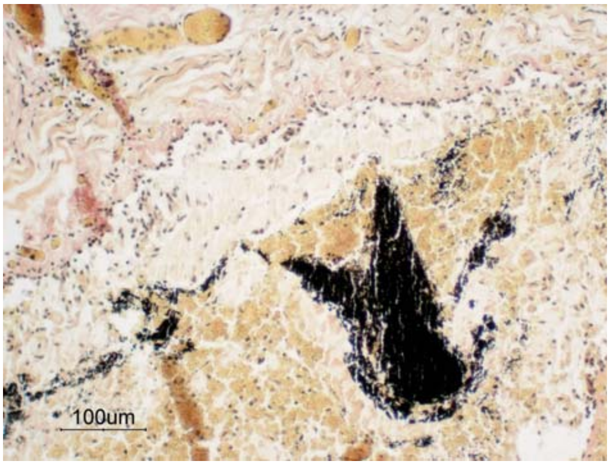

FIGURE 11.16 *A small bronchus from a fire victim, showing histological evidence of soot deposition, together with desquamation of the epithelium and plugging with cellular debris. (Van Gieson; original magnification ×10.)*

Heat effects on the pharynx and epiglottis can occur post-mortem through passive percolation of hot gas through the open mouth. The lungs usually respond to heat damage by marked pulmonary oedema, though this is often present in fire victims even when the inhalation of hot gas has been insufficient to cause visible damage to the bronchial tree.

- Carbon monoxide poisoning is an important aspect of most fires – indeed it is the major or even sole cause of death in many victims of conflagrations, especially in house fires. When any combustible material burns in air, most of the carbon in organic material, such as timber, fabric and furnishings, is converted to carbon dioxide. Carbon monoxide is also produced, however, and, where the access of oxygen is limited or exhausted by the ongoing combustion, larger volumes of the monoxide are produced. Slow, smouldering fires with little flame are likely to produce more monoxide, as with burning bedclothes and mattresses. At the other extreme, rapid flash fires with flames fanned by moving draughts and those involving volatile fuels, such as petrol or kerosene, produce relatively little monoxide – though much depends upon the free access of air.

In many house fires, where the seat of the fire is originally remote from the victim, death may occur from carbon monoxide poisoning long before the flames reach the body.

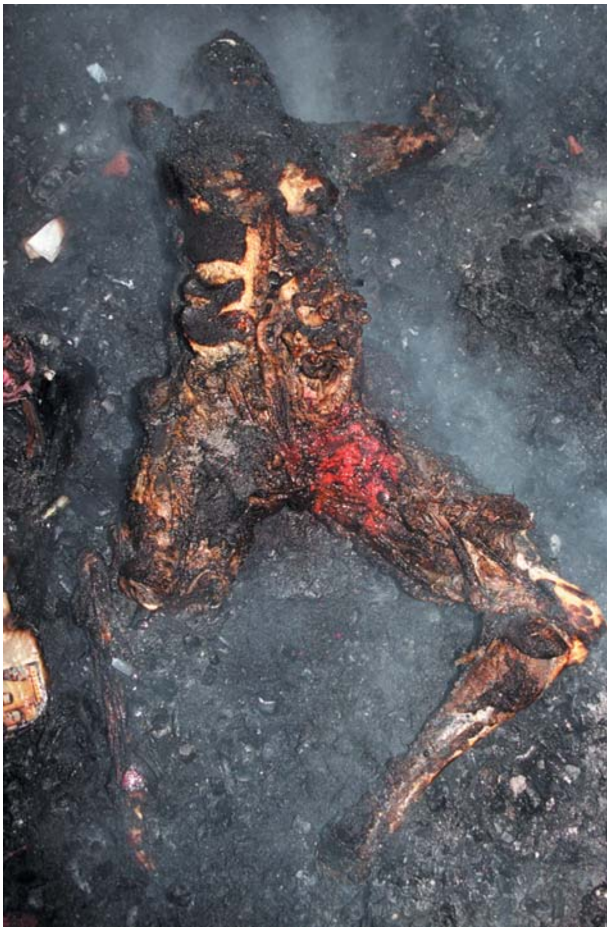

FIGURE 11.17 *Charred body at the scene of fire showing the 'pugilistic attitude' and post-mortem skin splits on the chest.*

A person may be asleep in an apartment or house, and die without ever waking if large volumes of monoxide creep through the rooms. Burns are often post-mortem in such cases and, where extensive charring occurs, the differentiation between ante-mortem and post-mortem damage may be impossible.

It is often a comfort for bereaved relatives to be told that their loved ones were either already dead or unconscious before the agony of burning reached them, and the pathologist may be able to emphasize this at any inquest or inquiry. Unfortunately, where the bodies are found in positions obviously indicating escape or concealment, such an explanation loses its conviction – though even then it may well be that coma from monoxide poisoning overtook them before burning began.

The pathology of carbon monoxide is dealt with in another section of this book, but it may be repeated here that the autopsy signs are primarily that of a cherry-pink coloration of the skin, blood and tissues. Where smoke staining or extensive charring has occurred, there may be little skin to examine, though there is usually some in a protected position under the body. The blood and tissues usually have the characteristic colour but, when the person is anaemic or exsanguinated, this may be hard to detect. A high saturation with monoxide is usually unmistakable at autopsy, though sometimes certain types of artificial light in the autopsy room, such as some fluorescent tubes, make the cherry-pink colour difficult to confirm. The colour may be better seen if blood is diluted with water against a white background, such as a porcelain autopsy table or sink. Nothing replaces laboratory analysis of a sample, however, and this must be done in

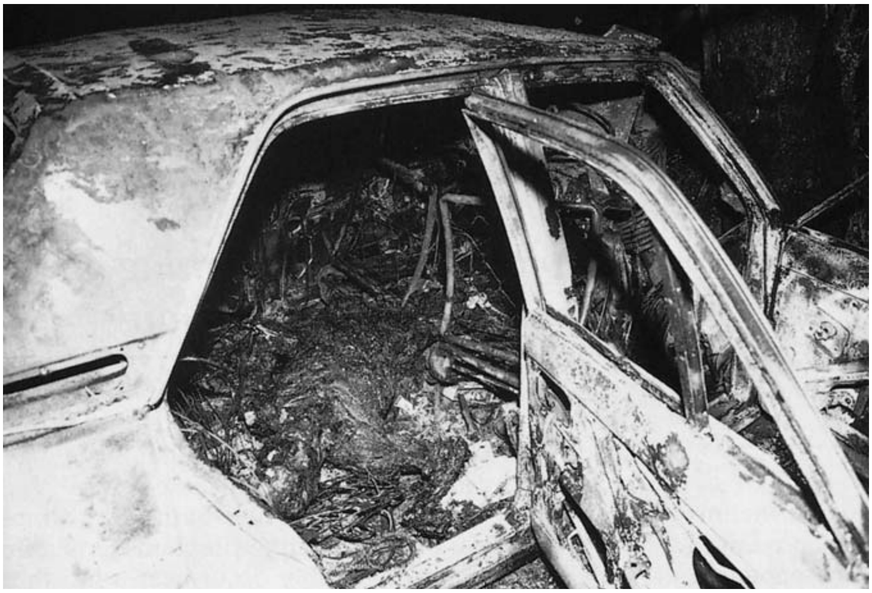

FIGURE 11.18 *The finding of a body in a burnt-out car is always suspicious, but is usually accidental or suicidal. Radiography should always be carried out to exclude firearm injuries. Carboxyhaemoglobin levels are often low or even absent in a rapid flash gasoline fire; this makes the diagnosis of being alive during the fire difficult, especially when there may also be little soot to foul the air passages.*

every case of death from fire, irrespective of the subjective appearance of the skin, blood and tissues.

The saturation of haemoglobin with carbon monoxide varies greatly from one fatal case to another. Many variable factors exist such as the concentration in the atmosphere, the time of exposure and local changes in oxygen content. When carbon monoxide is the sole cause of death, a blood saturation of at least 40 per cent is required, except in old and debilitated persons where deaths have been reported at 25 per cent. Many fatalities will display 50–60 per cent saturation, though levels in general are less than in pure carbon monoxide poisoning, such as car exhaust suicides or industrial exposure, where concentrations of up to 80 per cent may occur. In fires, additional factors such as other toxic fumes and reduction of the atmospheric oxygen may operate, resulting in death at lower carboxyhaemoglobin concentrations.

Yoshida *et al.* (1991) published data from 120 house-fire victims in Japan, in which only nine people had carboxyhaemoglobin (HBCO) concentrations below 10 per cent, the range being from 1 to 95 per cent saturation. Of 31 victims in whom cyanide analyses were made, two had high cyanide and low HBCO.

The variability of monoxide poisoning may be illustrated by the fact that two bodies lying side by side in a burned house may have widely differing blood saturations – indeed, sometimes one victim may have a zero blood monoxide saturation. Children often have much lower levels than adults in the same situation, but even two adults may differ in their carboxyhaemoglobin concentrations, the explanation being unclear. Local variations in draughts, levels above the floor and respiration rates may account for these anomalies.

Carbon monoxide in the blood is a valuable indicator that the victim was alive after the fire began. Where a dead body is disposed of by arson no absorption can take place, as the gas can gain entry only through the pulmonary interface. Thus the presence of more than a smoker's level of 5 per cent saturation of the blood with carboxyhaemoglobin means that breathing occurred after the fire began. It is vital, however, to appreciate that the converse is not true. **The fact that a body in a fire does NOT have carboxyhaemoglobin in the blood does NOT mean that they must have been dead before the fire began.** The records of all forensic departments have examples of this occurrence and therefore it is illogical – and sometimes legally dangerous – to draw the unwarranted inference that such a victim must have been already dead before the fire began, however common the generalization may be. In rapid flash fires, especially where gasoline or kerosene are involved, the monoxide level is more likely to be low or even negative, than in the slower conflagration with restricted access of oxygen that occurs in a burning building.

Toxic substances in fumes

In recent years it has been appreciated that a number of toxic substances other than carbon monoxide may be present in the fumes from fires. Cyanides are predominant and the blood of fire victims may often be shown to have high levels of this toxic compound. Nitric oxide, phosgene and other more complex substances may be liberated, especially when modern plastic polymers are burned. Furnishings, upholstery, paints, lacquers, varnishes and actual structural components are increasingly made from polystyrene, polyurethane, polyvinyl and other plastic materials. These are particularly liable to generate toxic gases when ignited (Anderson *et al.* 1981, 1982).

Caution must be employed when interpreting the analysis of cadaver blood for cyanide, as this substance can be produced in significant concentration by post-mortem decomposition. Particular care must be taken in preservation of samples, which should have fluoride added, and in ensuring there is no delay before analysis so that further decomposition is kept to a minimum. Where cyanides, oxides of nitrogen and other toxic substances are inhaled during a fire, carbon monoxide is inevitably absorbed as well. It then becomes difficult to apportion the relative blame for the death among these different toxic agents – and where there are also ante-mortem burns, the differentiation may be impossible. If the pathologist considers that he cannot identify any ante-mortem burns, then the most logical cause of death is 'inhalation of smoke'. If vital burns are present then, according to the circumstances, these can be given as the cause of death, with or without the addition of 'carbon monoxide or smoke inhalation'.

INHALATION OF SOOT

As well as the inhalation of carbon monoxide, victims in a fire usually breathe in carbon particles present in the sooty smoke. Once again this is more pronounced in a building fire than a vehicle blaze, though there are many exceptions. The combustion of timber floors, roofs, furniture, and the fabric of furnishings and carpets produces large volumes of dense black smoke. Every pathologist attending the scene of a house fire is aware of the thick layer of soot than clings to every surface and may hang in fronds from the ceilings. It is little wonder that such material suspended in the air finds its way into the respiratory passages of the victims.

As a marker of ante-mortem inhalation, it is almost as useful as carbon monoxide. Soot particles may enter the open mouth of a corpse, stain the tongue and pharynx, and may even passively reach the glottis. No significant amount can pass the vocal cords and enter the trachea after death, however, so carbon in the lower respiratory tract is a certain

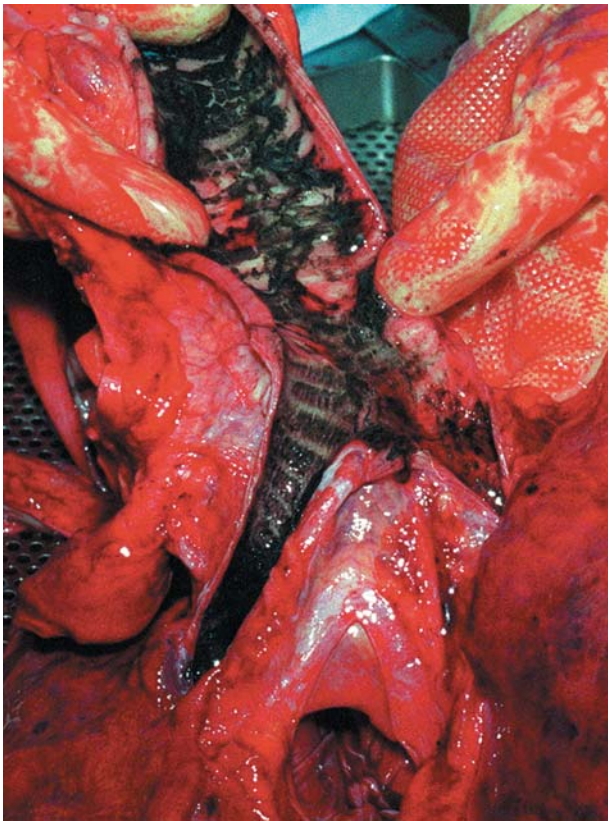

FIGURE 11.19 *Soot in the tracheal mucus, a sign of breathing while the fire was in progress. Though soot can passively reach the glottis after death if the mouth is open, it cannot reach the lower air passages in any significant quantity. Histology of the smaller bronchi offers complete proof of active respiration.*

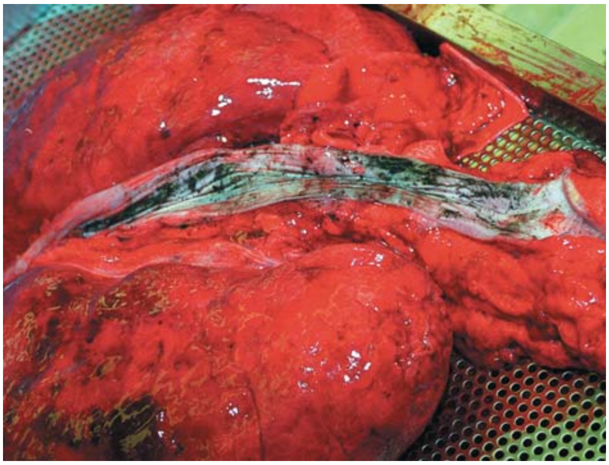

FIGURE 11.20 *Soot in oesophagus of a house-fire victim indicating respiration during the fire.*

indicator of breathing during the fire. Histological demonstration of soot in the more peripheral bronchi, out as far as the terminal bronchioles, is absolute proof of such respiratory function. The carbon is usually mixed with mucus adherent to the tracheal and bronchial walls because of heat irritation of the mucosa. Often there is swallowed soot and mucus in the stomach, and again this is evidence of life during the smoky phase of the fire.

ATYPICAL LOCALIZED BURNING AND 'SPONTANEOUS COMBUSTION'

Some very strange instances of fatal burning occur and most experienced forensic pathologists have recollections of apparently inexplicable cases.

A human body may sometimes burn away almost completely, yet the surrounding fire damage is minimal. These almost invariably occur near a hearth or open fire-grate or chimney. The burning may be confined to the body, its clothing, and a narrow zone of floor or carpet. The author (BK) has seen a circumscribed hole burned through a hearthrug and the floorboards beneath, with an ashed body lying in the space under the floor. He also remembers a pair of undamaged house slippers, with feet still within, the legs burned off at ankle level and no remaining body above, apart from ashed material lying on the adjacent floor. Both these deaths occurred in front of a fireplace with an open chimney.

It seems extraordinary that virtually a whole adult body can be consumed, including the skeleton, with minimal surrounding fire damage, but many such cases are on record and have helped to substantiate the myth of 'spontaneous human combustion'.

Experiments carried out many years ago by Professor David Gee (personal communication) indicated that body fat can burn slowly, using the clothing as a 'wick', similar to a candle flame.

Most cases have in common the fact that there was a source of ignition in an open fire and a chimney which can provide a constant updraught – and often the victims are alcoholics. Though it is not suggested that alcohol plays any part in the burning process, the confusion, instability and lack of judgement which goes with inebriation may well precipitate the ignition process.

As indicated above, the myth of 'spontaneous combustion' is one which refuses to go away, as endless unsubstantiated reports, and newspaper, magazine and television features have continued to fascinate a credulous public ever since Charles Dickens included a description of a case in his novel *Bleak House*.

Numerous allegations have been made of people bursting into flames as they walk down the street, but as yet, no photographs or film has been produced; in fact, the majority of the retrospective claims for this phenomenon have been of bodies next to some source of ignition and where alcohol was involved – as indeed was Dickens' original example.

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CHAPTER 12

Electrical fatalities

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The passage of a substantial electrical current through the tissues can cause skin lesions, organ damage and death. This injury is commonly called 'electrocution', though some would use this term only if death occurs. Fatalities are usually accidental, in both a domestic and industrial environment. Suicides from electricity have increased in recent years, especially in Germany. Homicide is rare but is recorded and, in the USA, electricity has again become a means of judicial execution.

PHYSICAL FACTORS

The severity of tissue damage 'including death' is directly related to a number of physical factors, which include current, voltage, resistance and time. For biological damage to occur, the body must be incorporated into an electrical circuit, so that there is a passage of electrons through the tissues. A mere accumulation of electrons in the form of a static charge can do no harm; scientists in the ball of a Van de Graaf static generator may be at a potential of more than a million volts (V), but experience nothing other than their hair standing on end. Similarly, a person outdoors in a thunderstorm may accumulate a high charge from the capacitance effect of an overhead cloud but, unless the insulation of the air breaks down to allow a lightning strike at or near the person, no ill-effects will occur.

In electrocution there must be a pathway for electrons across part of the body which, in fatal cases, contains vital structures. The current enters at one point (most often a hand being used to hold, touch or manipulate some electrical device) and then leaves the body at an exit point, usually to the earth or the neutral conductor of the electricity supply. The pathway of the current will depend mainly on the relative resistance of various potential exit points. It tends to take the shortest route between entry and best exit, irrespective of the varying conductivity of different internal tissues. If a person places a finger on a 240 V conductor while standing with damp shoes on a wet concrete floor, then an appreciable current will pass from hand to feet, with possibly fatal results. If, however, the person is standing on a carpeted upstairs wooden floor, the poor earth return will allow only a small current to flow and all that may be suffered is a painful muscular spasm.

In another variant of the upstairs scene, should the neutral wire of the supply be touching the skin of the same finger a few centimetres away from the live conductor, a severe local burn may occur but no danger to life, because the high resistance through the feet to earth will prevent any significant current flow passing through the thorax.

Should the person upstairs happen to be turning a bath tap with the other hand, the contact with the opposite finger would allow a current to pass to earth via the tap and metal water-pipes from hand to hand across the thorax – an extremely dangerous position.

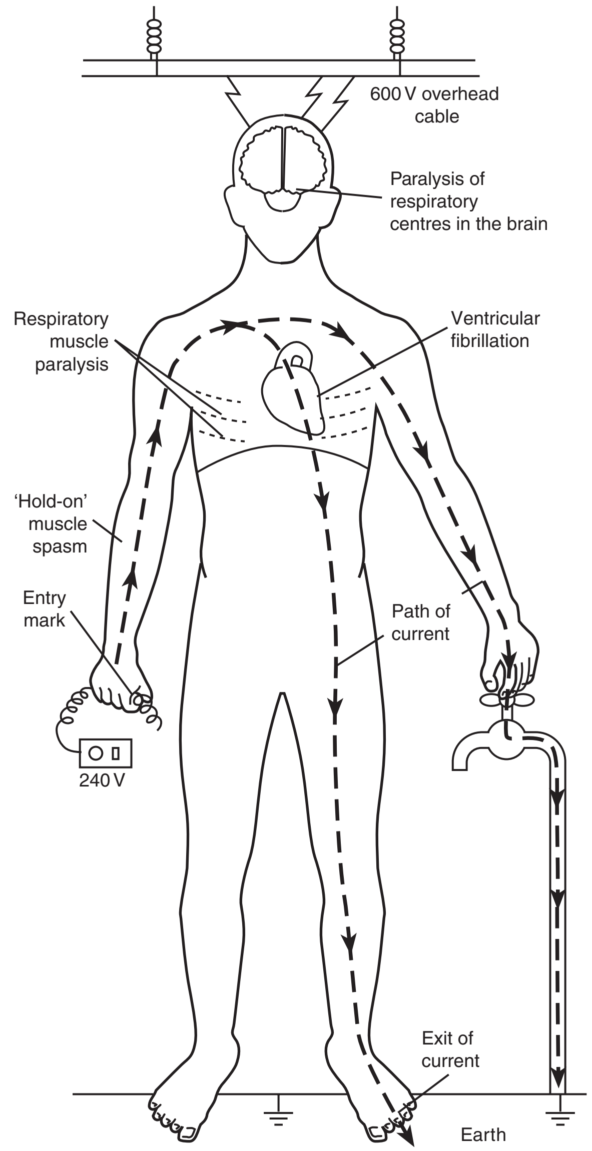

FIGURE 12.1 *Pathways of current in electrocution.*

The pathologist is concerned with fatal electrocution and three major events may occur, which are a threat to life:

- The most common is the passage of a current across the heart, usually when a hand is brought into contact with a live conductor, and the body is earthed either through the feet or the opposite hand. It has been claimed that the most dangerous is contact with the right hand and exit through the feet, as this causes the current to pass obliquely along the axis of the heart. Compared with the other variables of voltage, skin resistance and time, this hypothesis seems immaterial, though this route increases the current across the heart by a factor of 1.5–2.5 compared with left-hand entry.

  The fatal process is a cardiac dysrhythmia, usually a ventricular fibrillation ending in asystole.
- Less often, the passage of a current across the chest and abdomen may lead to respiratory paralysis from spasm of the intercostal muscles and diaphragm.
- Rarely, the current passes through the head and neck, usually in circumstances when the head of a worker on overhead power lines comes into contact with the conductor. In such instances, there may be a direct effect on the brainstem so that cardiac or respiratory centres are paralysed.

It is commonly said that tolerance can be gained to electric shock and that professional electricians often work on live 240 V conductors with impunity. It seems more likely that expectation of a shock decreases sensitivity, but only for brief contacts, less than would be required for physiological or structural damage.

ELECTRICAL CONSIDERATIONS

Electrons are moved around a circuit by the 'potential difference' between two points, which may be looked upon as the 'pressure' of the electricity, measured in volts (V). The number of electrons flowing constitutes the 'current', analagous to the volume of electricity and is measured in amperes, though in the present discussion, milliamperes (mA) are more relevant to biological effects. The tissues also have 'resistance' to the electrical flow. There is a mathematical relationship between potential difference, current and resistance – the well-known Ohm's law – in which the current varies directly with the voltage and inversely with the resistance. This law has considerable relevance to biological electrical damage.

Alternating and direct current

In spite of the folklore of electricians there is no doubt that direct current (d.c.) is less dangerous than alternating current (a.c.); a current of 50–80 mA a.c. can be fatal in seconds, whereas 250 mA d.c. for the same time is often survived. Alternating current is four to six times as likely to cause death, partly because of the 'hold-on' effect described below, which is the result of tetanoid muscle spasm and prevents the victim from releasing the live conductor.

Alternating current is also much more likely than direct current to cause cardiac arrhythmias. The passage of a.c. at 100 mA for only one-fifth of a second is likely to cause ventricular fibrillation and arrest. High amperage d.c. (above 4 A) may even cause an arrhythmic heart to revert to sinus rhythm, as in medical defibrillation.

The usual frequency of a.c. is 50 cycles/second (cps), though some American and European systems run at 60 cps. Alternating current between 40 and 150 cps is most dangerous in terms of ventricular fibrillation, and regrettably the usual mains supply lies in the centre of this range. Above 150 cps, fibrillation is progressively less likely as the frequency increases: at 1720 cps the heart is 20 times less likely to fibrillate than at 150 cps.

Current

The degree of damage to the tissues is proportional to the actual quantity of electricity flowing through them. This quantity is expressed by the number of electrons per unit time and strictly speaking should be measured in 'coulombs', which is the product of amperes and seconds, though amperes are usually accepted as an index of the current flow. According to Ohm's law, current depends on the applied voltage, the resistance of the tissue and, for tissue damage, the time for which the current is flowing.

In forensic pathology, we are concerned with fatal electrocution and, as most deaths are the result of cardiac dysrhythmias, the most important measure of current is that which leads to acute heart failure. Estimates vary among authors, but it is generally considered that the passage of 50–80 mA across the heart for more than a few seconds is likely to cause death. The most that can be tolerated voluntarily by most people is 30 mA applied to the hand, which results in painful muscle contractions. Consciousness is likely to be lost at about 40 mA and, as stated, currents sustained for some seconds at over 50–80 mA carry a substantial risk of death.

Voltage

To produce a potentially fatal current across the chest, a certain minimum voltage must be applied to the skin surface. As the latter has a relatively high resistance (see below), Ohm's law dictates that an appreciable voltage is required to produce the 50 mA or so needed for ventricular fibrillation. Most fatalities occur with the domestic voltage of 240, though the common alternative in parts of the USA and Europe of 110 V is still lethal in many instances.

It is uncommon to encounter deaths at less than 100 V, mainly because there are few sources of supply between 110 V and the 12 V or 24 V used in vehicle electrical systems. These are almost always innocuous, though Polson (1963) has reported a fatality at 24 V in a man pinned beneath an electrical vehicle for several hours. That case emphasizes the importance of the time element in electrical injury. Extremely high voltages, such as those encountered in power transmission systems and in electronic equipment, may paradoxically be safer on some occasions, as the shock may physically fling the subject off the conductor, thus reducing the contact time below the threshold for cardiac damage.

Resistance

The major barrier to an electrical current is the skin, which has a far higher resistance than internal tissues. That is why skin electric burns occur, as the resistivity causes energy transfer from the electron flow to the skin. Once inside the dermis, the semi-fluid cytoplasm, and especially the vascular system filled with electrolyte-rich fluid, passes the current through the body quite easily. The resistance of skin varies greatly according to the thickness of the keratin-covered epidermis; that on the soles and finger-pads is greater than the thin skin elsewhere. The average resistance is between 500 and 10 000 ohms for areas other than the horny hand and foot pads, which may offer 1 million ohms resistance when dry.

A more potent factor is the dryness or dampness of the skin, which greatly affects its resistance. While dry palm skin may have a resistance of the order of 1 million ohms, when wetted this may fall to only 1200 ohms. Jellinek (1932) found the horny skin of a workman to have a dry resistance of from 1 to 2 million ohms; Jaffe (1928) stated that sweating could reduce skin resistance from 30 000 to 2500 ohms. When the current begins to pass, there is a further marked drop in resistance, as a result of electrolytic changes in the skin, which may fall to only 380 ohms. Thus for a fixed voltage, such as the mains supply of 240 V, the resultant current will be far greater if the skin is wet from sweating or external moisture. This emphasizes the dangers of bathrooms and using electrical equipment in damp surroundings. Where alternating current is concerned (as in most forensic cases), resistance is replaced by 'impedance', but this is not relevant to the pathological aspects.

EFFECTS UPON MUSCLE

One effect of electricity that has practical implications is the spasm that occurs in skeletal muscle if the current reaches between 10 and 40 mA at 50 cps. When, as most often happens, the entry point is in the hand, the stronger flexor muscles of the arm go into spasm and cause a 'hold-on' effect. This means that any object being held in the hand is involuntarily clenched and, as it is likely to be the faulty electrical appliance or a wire, the object cannot be released and the current thus continues to flow. This adds to the time element and progressively worsens the risk of both cutaneous burns and the risk of cardiac or respiratory arrest. Tingling may be felt in the skin with a current of only 1 mA and 'hold-on' can begin at a current as low as 9–10 mA.

MODE OF DEATH

As already stated, most deaths from electricity are from cardiac arrhythmias, usually ventricular fibrillation ending in arrest. This is caused by the passage of current through the myocardium, especially in the superficial epicardial layers and possibly across the endocardium. The current has a profound effect directly upon the myocardial syncytium, the possible dislocation of the pacemaking nodes and conducting systems being ill-understood. When death occurs from cardiac arrest, the body remains either pale or only slightly congested, the autopsy appearances being unhelpful apart from the presence of any external electrical marks.

The second (and far less common) mode of death is respiratory arrest, in which the passage of current through the thorax causes the intercostal muscles and diaphragm to go into spasm, or become paralysed. In either case, respiratory movements are inhibited and a congestive–hypoxic death occurs. The brainstem is affected rarely, when the current enters through the head. Either cardiac arrest or respiratory paralysis can then supervene.

Many electrical deaths are not observed, the person being found dead later, so that the mode of death is unknown. Sometimes the witnessed mode of death is hard to explain on physiological grounds, in that there appears to be a delay (often some minutes in duration) between the shock and the death. In the interval, the victim may be conscious and even apparently recovering. It is difficult to know why a sudden cardiac arrest should take place after the current is switched off, but presumably some fundamental damage has been caused on an intracellular level to cardiac or neural tissue.

Finally, when discussing the mode of death, it must always be remembered that non-electrical trauma is quite common. In a series reported by Bissig (1960), some 15 per cent of cases had injury from falls and other associated trauma. In industrial accidents and when working on power lines, victims of shock may be thrown from a height, or suffer violent muscular spasms that may lead to fractures and other serious injury.

THE CUTANEOUS ELECTRIC MARK

The point of contact on the body surface may leave skin lesions, which are either called 'electrical burns' or 'electrical marks', though the term 'Joule burn' is gaining in popularity. These are the sites of entry of the current, but another mark or marks may also appear where the body was earthed or 'grounded'. It must be emphasized here that fatal electrocution may occur with no skin mark whatsoever, making the diagnosis entirely dependent upon the circumstances of the death. An extreme example is electrocution in the bath, when the large surface area for entry plus the low skin resistance caused by the water abolishes the possibility of a focal burn.

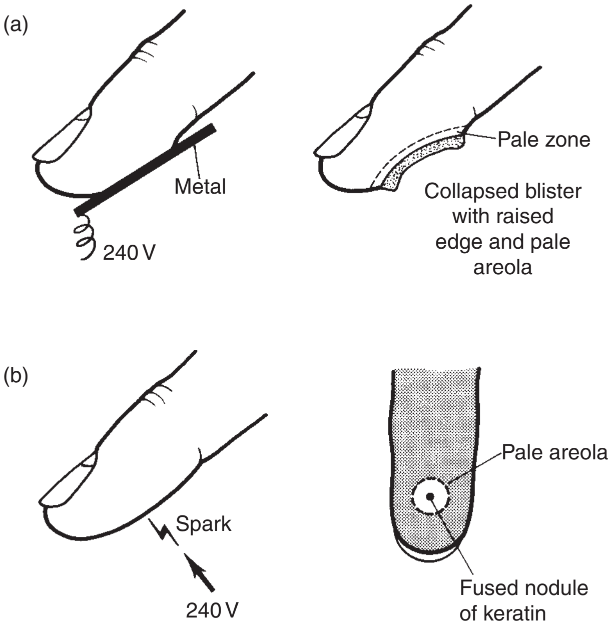

FIGURE 12.2 *(a) Firm contact electric mark, and (b) spark burn across air gap.*

An electrical mark may not be externally obvious, as the current can be applied to the genitals, anus or abdomen in sexual perversions or through the mouth, especially in children. Infants may place a live plug between their lips and sustain electrical burns on the tongue or buccal mucosa, which may not be readily apparent on external examination at autopsy.

When a current passes, there may or may not be a visible lesion, depending upon:

- the density of the current passage in terms of skin area and
- the conductivity, usually varying with the moisture content.

The skin lesion is a thermal burn from heating of the epidermis and dermis as the current passes. Theoretically, the heat generated can be determined from the formula $GC = C2R/4.187$, where GC is the heat in gram calories per second, C is the current in amperes and R the resistance in ohms. If the electron flood passes through a relatively wide area, then the resistance per unit area is small (especially if the skin is damp) and thus the heating effect is proportionately diminished. For example, a person resting the palm of the hand on a flat metal plate which is electrified will pass a far

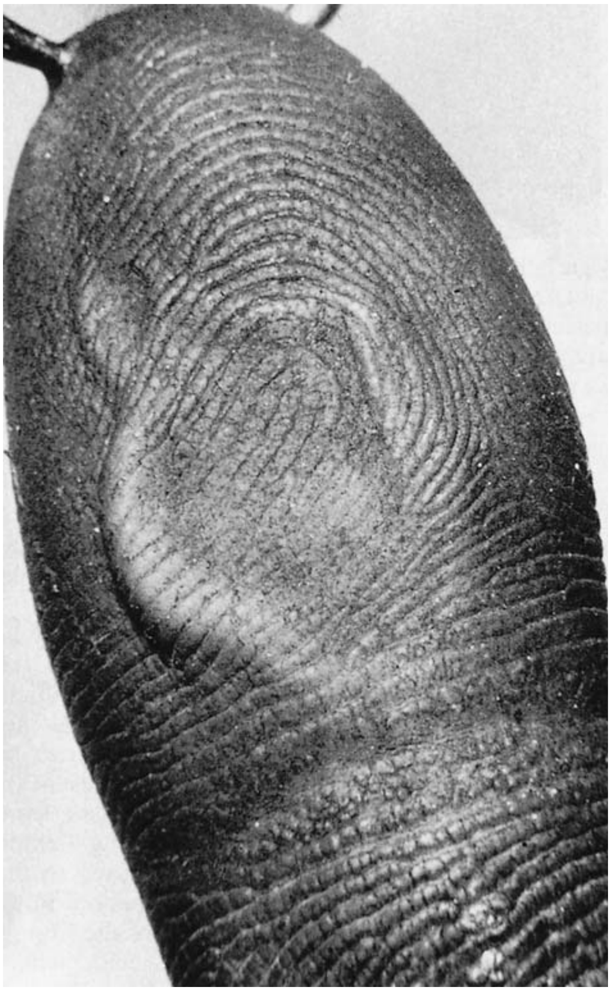

FIGURE 12.3 *Firm contact electric marks on a fingertip. Two blisters have been formed by the heat of local skin resistance; they have collapsed on cooling.*

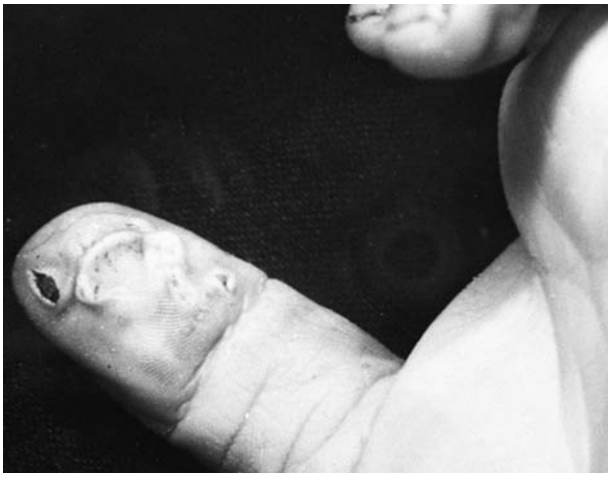

FIGURE 12.4 *Firm contact blister and adjacent spark burn from 240 V mains supply. The victim was holding a faulty electric drill. There were no other marks on the body.*

smaller current per square centimetre of skin than another touching the plate with the tip of a finger. The first is likely to have no demonstrable lesions, while the second will have a blistered burn or a keratinized nodule, depending on the firmness of the contact.

The temperature in the tissues directly under the contact point can easily reach 95°C. Tissue damage can occur within 25 seconds when the temperature reaches a mere 50°C. The focal electric mark is largely a thermal burn and even some of the histological features to be described later, which were once thought to be peculiar to the electrical current, are now generally ascribed to thermal effects. There are some features, however, which are characteristic of an electrical cause.

- When the skin has been in firm contact with an electrical conductor, the passage of the current through the high skin resistance heats up the tissue fluids and produces steam. This may split the layers of the epidermis or the epidermal–dermal junction and produce a raised blister. This may rupture if the current continues or if the area is relatively large.

  When the current ceases, the blister cools and collapses, giving the familiar appearance seen at autopsy. The collapsed blister is often annular, producing a raised grey or white ring with an umbilicated centre. The mark sometimes reproduces the shape of the conductor, especially where this is a linear wire or a shaped metal object. Where the tip of a wire or rod is at right angles to the skin, a focal pit is created, sometimes penetrating quite deeply into the skin.
- Where the contact is less firm, so that an air gap (albeit narrow) exists between skin and conductor, the current jumps the gap as a spark. In dry air 1000 V will jump several millimetres and 100 kV about 35 cm. This is at extremely high temperatures (about 4000°C), as in the sparking plug of a petrol engine, and causes the outer skin keratin to melt over a small area. On cooling, the keratin fuses into a hard brownish nodule, usually raised above the surrounding surface, the so-called ‘spark lesion’.
- In many electrical burns these two types are combined, as a result of movement of the hand or body against the conductor and sometimes because of irregularity of the shape of the conductor. Where the time has been prolonged, the voltage is high, or the conductor is large, the burn may be correspondingly severe with large areas of peeled blistered skin, charred keratin, and a mixture of hyperaemia, deep scorching and shed epidermis.

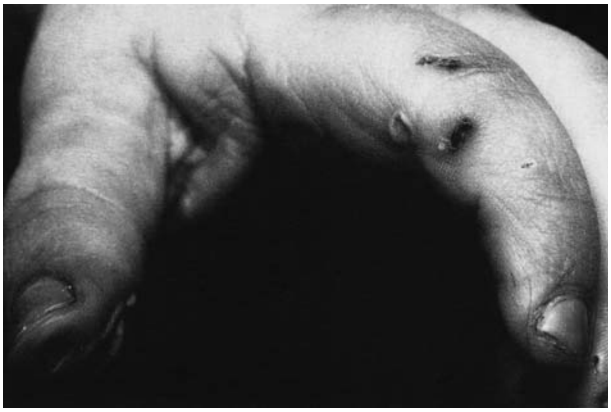

FIGURE 12.5 *Collapsed blisters and a spark burn from holding a faulty power tool.*

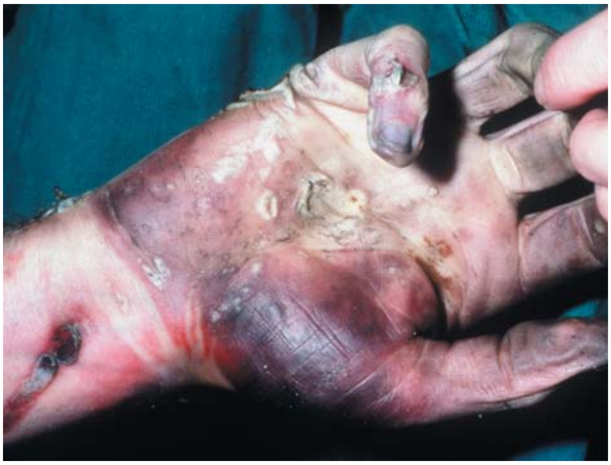

FIGURE 12.6 *Multiple electrical burns on a hand, with blisters showing the typical pale raised margins and areas of peeling epidermis. There is a blackening from metallization as the current was passing for several hours; the victim was an electrician who fell into an air-conditioning plant.*

- A characteristic feature of the electric mark, which is the most useful indicator of the nature of the lesion, is the common occurrence of an areola of blanched skin at the periphery. Presumably because of arteriolar spasm from the direct effects of the current on vessel-wall musculature, the pallor survives death and is virtually pathognomonic of electrical damage. Often there is a hyperaemic border outside the blanching, though reddening may also be seen inside the pale zone, as the outermost rim of the heated burn area. Occasionally, an alternating spectrum of blister-reddening-pallor-reddening can be observed centrifugally from the centre of the lesion. When the burn is linear, such as that from a bare wire pressed against the skin, the 'areola' takes the form of a pale zone parallel to the central burn.
- When the marks are minimal, all that may be seen are tiny white discs representing minute flat blisters where the epidermis has split, but no reddening or areola has formed – or at least, has not persisted until the time of autopsy. These can be hard to find and, as they are likely to be present on the palmar surface of the hands (the usual site from grasping an electrical appliance), the strong flexion of rigor mortis may bring the fingers down to the palms, so obscuring any lesions. It is essential in all autopsies to examine the flexor surface of the fingers by forcible breaking of the rigor – and, where electrocution is a possibility, minute inspection of the hands must be carried out, even if the flexor tendons at the wrist have to be cut to release the rigor clenching of the fingers.
- In high-voltage burns, such as those sustained from high-tension grid transmission cables, where the voltage is in the multi-kilovolt range, sparking may occur over many centimetres. This can cause multiple spark lesions giving rise to a 'crocodile-skin' effect. Both linesmen and copper thieves working on high pylons may suffer non-electrical injuries from being thrown to the ground, or they may sustain gross charring burns or even limb fractures from both direct electrical energy and the muscle spasm caused by a massive bolt of electricity.
- Earthing or 'grounding' lesions are not often seen, but should be looked for on the contralateral hand and on the feet. The lesions may be similar, though less severe. In a case seen by the author (BK), in which a workman pushed a metal wheelbarrow over a live cable lying in a pool of water, the entry burns were on the hands, but on the soles of both feet the electrical burns matched the metal studs in his boots where the current earthed through damp socks and leather.

  In another case, a homicide in a bath, there were no entry burns but the current went to earth by contact of the breasts with the metal taps.
- When the current has flowed for an appreciable time, even at a domestic voltage of 240, the effects may be severe. Charring and more extensive peeling and blistering of skin may occur, with deep muscle damage and cooking of the tissues. This is partly because of the fact that the initial damage lowers skin resistance so that progressively more current flows and therefore more burning and necrosis follows.

Much of this damage seen at autopsy may have occurred post-mortem, if death from cardiac arrest occurs early in the event and, where the victim is alone, there is no one to remove his body from the source of the current. It has been

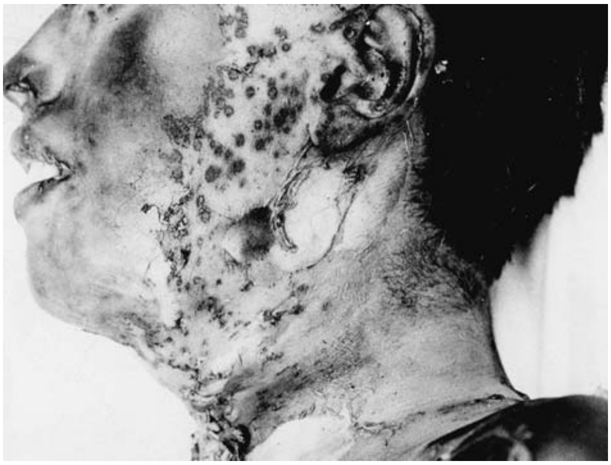

FIGURE 12.7 *Multiple burns from high-voltage (multi-kilovolt) supply lines of the grid system. The appearance is sometimes called 'crocodile skin' and is caused by arcing of the current over a considerable distance. The victim was a boy who went bird-nesting amongst the switch gear of a power station.*

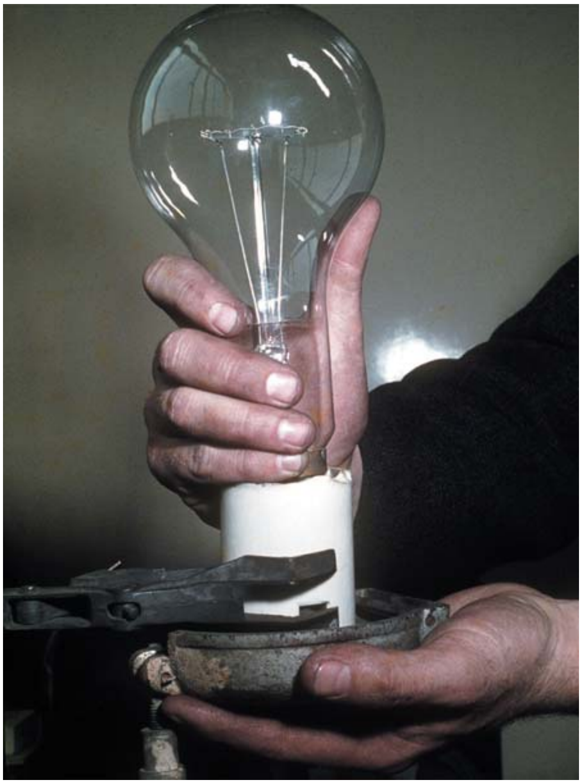

FIGURE 12.8 *Reconstruction of a fatal electrocution. While replacing a bulb a workman dropped dead, even though the light was not illuminated. The circuit had been improperly 'wired through' – that is, the switch had been placed in the neutral wire, instead of the live. The porcelain holder was broken so that his little finger touched the brass base of the bulb, thus completing the circuit across the chest to the other hand, which held an earthed base-plate. The only electrical mark was on the little finger.*

conclusively shown by Polson and others that post-mortem burns can be inflicted on a dead body, the appearances being similar in terms of blistering and burning, though the red flare of 'vital reaction' will be absent if death has occurred some time before.

PATTERNED ELECTRIC MARKS

As with many other injuries, a pattern of the shape of the causative object may sometimes be identified. When the electrical conductor is a wire, a linear burn may occur. The shape and spacing of electrical plugs or contacts may be seen, and faulty electrical equipment may impress its shape into the skin. These marks may be useful when the pathologist tries to reconstruct the events – and indeed, may indicate for the first time that the death was caused by electricity, when the unwitnessed events are particularly obscure.

As electric shock and burns are commonly seen in torture victims in abuse of human rights, a pattern may be useful in determining what object was used and give evidence of deliberate repetition. The deliberate use of a male-pin plug connected to the mains supply, then pressed against the skin, may give a series of regularly spaced marks, consisting of hyperaemia, blistering, areola formation or even charring.

METALLIC TRACES IN ELECTRICAL MARKS

When a current passes from a metal conductor into the body, a form of electrolysis occurs so that metallic ions are embedded in the skin and even in the subcutaneous tissues. This occurs with both d.c. and a.c. because of the combination of metallic ions with tissue anions to form metallic salts. These may be invisible to the eye, but detectable by chemical, histochemical and spectrographic techniques. They persist for some weeks during life and resist a moderate amount of post-mortem change. Where gross they may be observed directly on the skin, and where copper or brass conductors are involved a bright green imprint may be obvious. Where an electric arc forms, vaporized metal may be deposited on the skin, often extensive enough to be visible to the naked eye. In high-voltage contacts, the skin of a wide area may be brown or greyish, partly from heat effects, but partly from metallization.

Recently, using the scanning electron microscope, it has become possible to see tiny globules of molten metal on the skin at and near an electrical mark, deposited there by the almost inevitable 'mini-arcing' that accompanies any electrical contact. Chemical tests for metallic deposits include that devised by Adjutantis and Skalos (1962), which is a simple touch-test using elution on strips of filter paper. Copper, iron, aluminium, zinc or nickel are dissolved in nitric or hydrochloric acid, and the solution tested with a variety of simple but specific reagents.

INTERNAL APPEARANCES

In fatal electrocution, gross findings in the internal organs may be absent and even histological changes are a matter of controversy. Because the internal tissues are largely aqueous and contain conductive electrolytes, the current pathway is usually too diffuse to cause thermal damage. The absence of visceral damage is made up for by physiological and functional abnormalities, mainly in muscle and nervous tissue.

The usual mode of death is cardiac arrhythmia leading to ventricular fibrillation and arrest. In these deaths there is little to find at autopsy apart from the skin lesions. It is claimed that epicardial petechiae may occur, but these are too non-specific to be of any use. The body is either pale or only slightly congested, in contrast to the **few** deaths that occur from respiratory paralysis.

In the latter group the intercostal muscles and diaphragm go into spasm or are paralysed, which leads to marked congestion and cyanosis of the face, with similar changes in the lungs. There may be some petechiae on the pleura, though this again is such a non-specific finding as to be unhelpful as a diagnostic sign. At autopsy, the usual signs of a congestive death are found, with dark blue–red post-mortem hypostasis.

A number of other signs of electrocution have been claimed, but they are rarely confirmed by personal experience. These include intracerebral petechiae, which are probably part of the general congestive state in respiratory paralysis.

HISTOLOGICAL APPEARANCES

These are rather controversial, as some changes formerly claimed to be specific for electrical lesions have been shown to be thermal.

The skin mark consists of vacuolation in the epidermis and sometimes dermis, caused by the gas spaces from the heated tissue fluids splitting the cells apart. The affected tissues become more eosinophilic. The cap of epidermis may be detached and raised into a blister, with a large space beneath. The cells of the epidermis are often elongated, with the nuclei of the lower layers orientated and horizontally stretched; this was once claimed to be an electromagnetic effect, but the same appearance can be seen in purely thermal burns and in hypothermic lesions.

Changes in the brain have been described, even when the cause of death was cardiac. Focal petechial haemorrhages, spaces around small blood vessels and tears in white matter have been described. Electron microscopy reveals a variety of changes, especially in the nuclei of skin cells, which are deformed with clumped chromatin. Janssen (1984) has compiled a review of electrical histological lesions in his book on forensic histology, but it seems evident that there is little that is absolutely pathognomonic of electrical as opposed to purely thermal burns.

Histochemical reactions for metallization can also be carried out, though, again, metals can be transferred into the skin by purely thermal means if hot metallic objects are pressed against the skin.

Scanning electron microscopy appears to be the best way of distinguishing between electrical and thermal damage, as the punctate nature of the deposition and the possibility of chemical analysis by electron microprobes offer a sophisticated means of identifying the metallic deposit. Internal organs reveal no true diagnostic lesions of electricity. The wavy appearance of the myocardial fibres and their fragmentation may be suggestive, but by no means diagnostic. Contraction bands within the fibres, especially of a ‘bark-like’ appearance, have been described but, again, are non-specific, though they are often seen in the subepicardial myocardium after resuscitation that includes electrical defibrillation. However, they are identical to catecholamine effects on the myocardium and so may not be electrical in origin.

ELECTROCUTION IN THE BATHROOM

The bathroom is a common site for electrical tragedies. Accidents, suicides and even homicides occur there because of its vulnerability to electrical shock. The bathroom is electrically the most dangerous place in a house as there is a moist atmosphere, ample water, good earthing through metal taps and pipes, and a wet, unclothed body – all of which are conducive to low electrical resistance and hence high tissue currents. Accidents are common, usually as a result of the careless use of electrical appliances, such as hairdryers and room heaters. Most European countries have strict regulations about electrical installations in bathrooms because of the danger. In Britain, no wall switch is permitted for the light, a ceiling switch operated by an insulating cord being mandatory. No power sockets are allowed except for a shaver socket which incorporates a step-down transformer

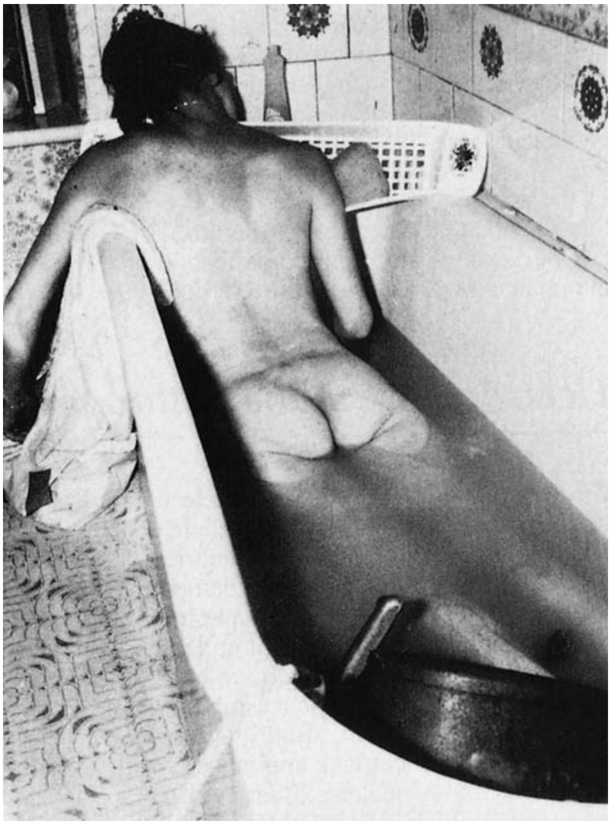

FIGURE 12.9 *Homicidal electrocution in the bath. An electric heater was dropped into the water with the wire to the earth terminal deliberately disconnected. The 240 V supply entered the body diffusely through the water and completed the circuit by earthing through contact with the breasts against the metal taps, leaving electrical marks on the skin.*

with a low maximum current output. In spite of this, people unwisely use extension leads or plug into light sockets to operate a variety of appliances.

SUICIDE BY ELECTRICITY

There has been a remarkable increase in the number of suicidal electrocutions in recent years, especially in the bath. Bonte *et al.* (1986) have described an increasing number of cases in the former West Germany, drawing attention to the unusual demarcation of post-mortem hypostasis in such deaths, where the water level during electrocution appears to limit the subsequent appearance of the hypostasis. Various circuit arrangements are made by suicides in baths: these range from the pulling of an electrical appliance into the water to complex connections to metal soap dishes and wiring up contacts on the body. There may even be arrangements to break the circuit when the bathroom door is opened to safeguard those who find the body. The circumstances are rarely in doubt except that some less sophisticated cases may be difficult to differentiate from the many other accidents that occur in bathrooms. Rarely, other more bizarre deaths associated with electricity occur, as seen in Figure 12.11.

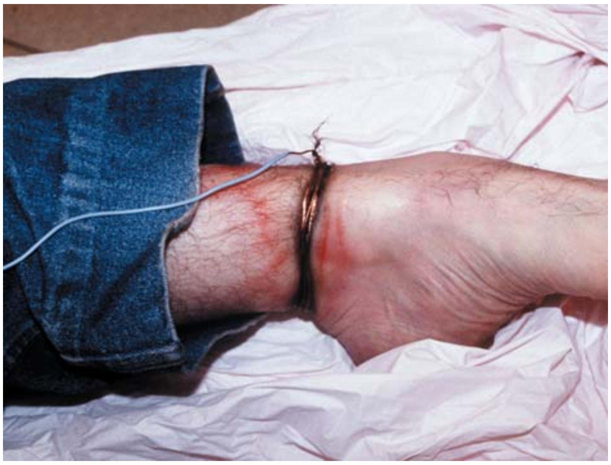

FIGURE 12.10 *Suicide by electricity. Both wrists were wired in this fashion to a 240 V supply socket, the circuit being completed from arm to arm across the chest.*

HOMICIDE BY ELECTRICITY

Homicide is occasionally committed by electricity, the author (BK) having dealt with two such incidents and his co-author (PS) with one. The first took place in the bath and provided good illustrations of the electrical aspects of fatal shock. A young woman was found dead in her bath, slumped forwards in a kneeling position with one breast resting against a chrome tap. The left arm was trailing over the edge of the bath, in which was the usual level of water plus an electric fan-heater immersed near the feet. The heater was connected by a long cable to a 240 V 13 A socket in an adjacent bedroom. Significantly, the third ‘earth’ wire had been deliberately disconnected from the earth pin inside the plug. Subsequent forensic tests showed that the enamel lining of the metal bath was an excellent insulator so that earthing of the current through the bath water could only occur via the chrome waste pipe. The circuit was completed, however, with fatal results, by the woman falling (or being pushed) against the tap, so that she sustained an electrical burn on the breast. She also had another typical burn on the inside of her left arm near the axilla, where the insulating enamel of the bath ceased at the turned-over edge. Forensic tests showed that there was a progressive gradient of voltage down the bath from over 200 V near the heater to virtually zero near the earthed waste pipe. The current had preferentially taken a course

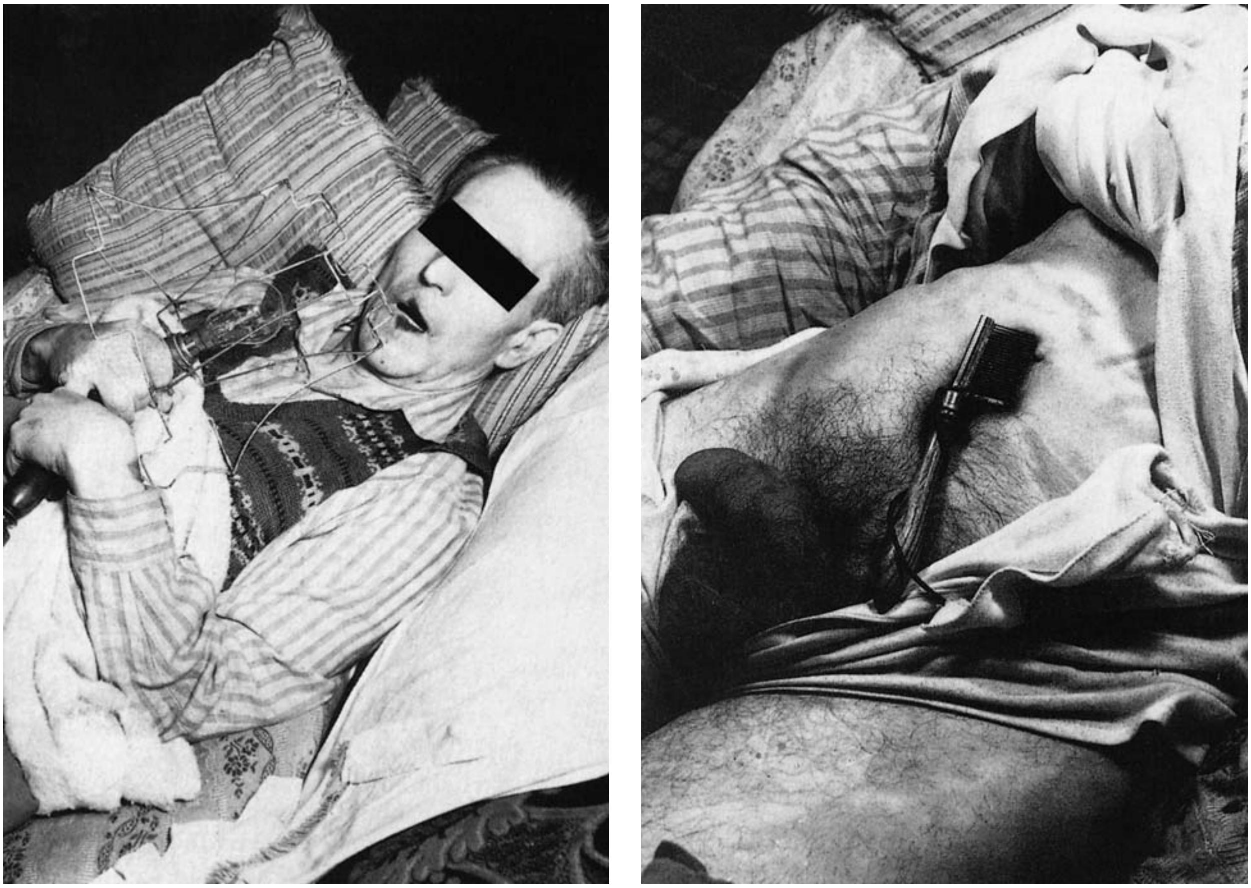

(a)

(b)

FIGURE 12.11 *(a) The deceased man had electrical marks on his fingers and lips, which were stained green from metallization from the brass fittings of the table lamp. (b) In addition, he had a metal comb resting over a large electric burn on his abdomen, also wired up to the lamp socket. No circumstantial evidence of suicidal intent could be discovered and some masochistic exercise was suspected.*

through the victim's body from feet to exit through breast and arm, rather than through the higher resistance of the fresh water.

It was also shown that, when the earth safety wire was reconnected, the voltage at the top of the bath fell to negligible levels, even though the fuse did not blow. The woman's husband, after several denials, eventually confessed to dropping the heater into the bath – and also to borrowing a book from the public library the previous day entitled *The do-it-yourself home electrician!*

The other homicide, which could not be proved for lack of evidence or a confession, concerned the wrapping of bare electric wires around a woman's neck. The wire was thick 30 A cooker cable with 40 cm of insulation stripped except for the extreme tips. The woman's husband, a professional electrician, provided the unlikely explanation that he was using this to test his electric shaver!

The third homicide went first undetected as the perpetrator, the husband of the victim, had staged it as an accident. The wife was supposed to have been ironing in the kitchen early one morning and been electrocuted by a faulty cord of the iron, the water-pipe of the sink providing the contact to the earth. In addition to the SOCs, an electrician, but not the pathologist, was called to the scene to investigate the faulty device, but nothing suspicious was detected. Ironically, in spite of the clumsy way in breaking the insulation of the cord and leaving only a couple of millimetres of the naked wire visible, a picture of the faulty cord and iron landed in a textbook for electricians, pointing out the dangers of faulty household appliances. At autopsy the only finding was an electrical burn on the chest. Eight years later, when the husband was in detention in the course of an investigation due to a stolen money transport, he wrote a very detailed confession of the murder of his wife. He had attached two copper electrodes to an extension cord and, while the wife was asleep, pressed them to her chest. In court, in spite of the withdrawal of his confession, he was sentenced to a long imprisonment. Several details, which came out in the course

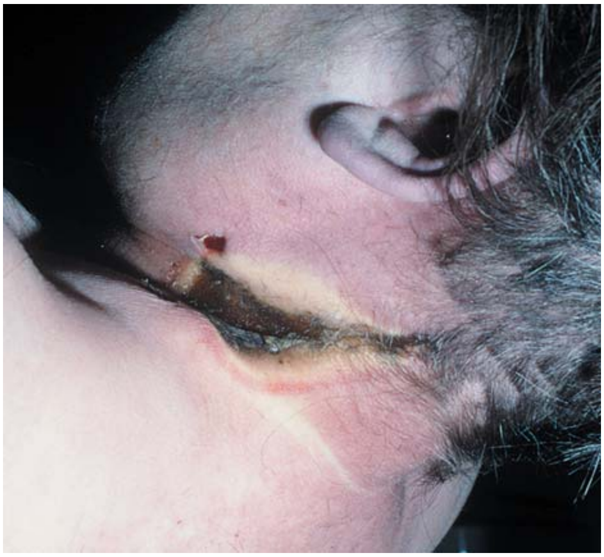

FIGURE 12.12 *Electrical burn around the neck from a mains wire being held against the skin. The typical pale areola and peeled skin blistering can be seen. There was suspicion of homicide, but it could not be proved.*

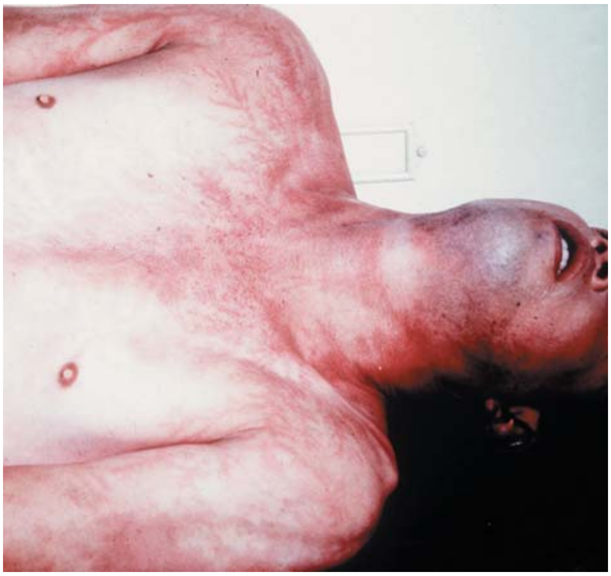

FIGURE 12.13 *The fern-like, arboresque pattern seen over the shoulders and chest in a victim of lightning stroke. Although this is always mentioned in descriptions of lightning deaths, it is seen only in a small minority of cases.*

of the criminal investigation, implied, although it was never proven, that the man had first attempted to kill his wife by feeding her diazepam tablets without her knowledge, and when this had failed, electrocuted her. It is hindsight and fruitless to contemplate what might have happened if the pathologist had been to the scene. The lesson of the case is, however, that if electrocution is suspected, it certainly is worthwhile to take a look at the scene of death.

In tropical and subtropical countries deaths from lightning are not uncommon and, even in higher latitudes, occasional tragedies occur where numbers of people are killed or injured in single episodes. An example was at the Ascot race meeting in 1955. The physics of a lightning strike are complex and not fully understood. Gigantic voltages and amperages are involved when a highly charged thundercloud discharges via a huge arc to the ground.

Lightning deaths cannot be other than accidental and provide no real problems for the forensic pathologist. Occasionally the nature of the death may be uncertain if a dead body is discovered in the open with no marks upon it, but usually there will be reports of a lightning strike nearby and artefacts, such as torn and scorched clothing and magnetized metallic objects in the pockets, may assist in explaining the event.

It is well known that injury from lightning is capricious and unpredictable. Two people can stand side by side during a flash and one may be mutilated and killed while the other is unharmed. The physical damage in fatal cases can vary from virtually nil to gross burning, fractures and tissue destruction. Cutaneous marks may be present, the well-known 'fern-like' or 'arboresque' pattern, also referred to as 'Lichtenberg' figures (because of their similarity to the pattern described by a German physicist, Georg Christoph Lichtenberg, in 1777) being much less common than the standard texts suggest. Irregular red marks, often linear first-degree burns, may follow skin creases, especially if damp from sweating. These marks may be many inches long and generally follow the long axis of the body towards the ground. Frank blistered or charred burns are also present in some cases.

An excellent picture of the Lichtenberg figures was taken by Domart and Garet, published in the *New England Journal of Medicine* in 2000, showing a 54-year-old man struck by lightning. With the exception of numbness and paraesthesia of the left shoulder, flank and leg, he felt well on the arrival at the emergency department. The serum creatine kinase and myoglobin concentrations were slightly elevated. After a 24-hour observation period, the patient was sent home and two days later, on a follow-up visit, the fern-leaf pattern of marks had disappeared.

The clothing may be torn off and this can sometimes raise the suspicion of foul play if the lightning aspect is obscure. The clothing is typically ripped open as if by an internal explosion, and belts and boots may be similarly ruptured. Metal objects in the pockets may be fused or magnetized, as may be metal buttons and tooth fillings. Burns on the skin may be adjacent to metal objects in or on the clothing.

There is often a smell of singeing or burning about the body and its clothing. The hair may be scorched and there is often a head injury, caused either by the lightning strike itself or by falling to the ground.

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CHAPTER 13

Complications of injury

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Serious bodily injury, from whatever cause, may either lead to virtually instantaneous death from destruction of vital organs and structures, or may cause delayed death from complications of the original injury. This delay may be short, as in torrential haemorrhage or acute respiratory failure, or it may be progressively longer, stretching into hours, days, weeks or even years. For example, the author (BK) dealt with a death in which a glider crash 15 years previously had to be implicated as the sole reason for the death, as the victim suffered a fractured spine, a paraplegia, paralysed bladder and recurring ascending urinary infection leading to death in renal failure from bilateral pyelonephritis.

Many even more delayed deaths can be found in the records of most experienced forensic pathologists. As long as a direct chain of events can be traced from the injury to the death, then the former must be considered to be the basic cause, a fact which may have profound legal implications both for civil compensation and criminal responsibility. Some of the most difficult problems in forensic pathology – and some of the most arduous testimony and cross-examination in court – concern deaths from which post-traumatic complications are disputed as being causative factors.

HAEMORRHAGE

Bleeding may occur externally through lacerations and incised wounds or via natural passages, such as the bronchi and trachea, oronasal passages, ears, vagina, urethra or rectum. Internal bleeding comprises contusions, which are leakages of blood into tissue spaces from rupture of vessels and free bleeding into body cavities, notably the pericardium, peritoneum, pleura and cranium.

The volume varies greatly, from the tiny petechiae of ruptured venules to the massive amounts seen in a ruptured aorta. As a primary cause of death it is not only the total volume that is lethal, but the rapidity and the site of the bleeding. When the leakage is slow the body can compensate for the loss of a far greater volume, both by adjustment of the vascular bed and by restoration of the blood volume by transfer from other aqueous compartments.

As to site, it is obvious that a small quantity of bleeding into the brainstem is likely to be lethal, whereas the same volume exuded into the pleural cavity would be of little consequence. Bleeding usually begins at the time of injury, though there is often a momentary delay at the instant of infliction. When a sharp blade cuts the skin, it is a matter of common observation that the blood may hesitate for a second or so before welling out. This is caused by transient spasm of local vessels from the stimulus of the injuring object. Bleeding then continues until normal haemostasis plugs the vessels.

In some injuries involving arteries, the musculoelastic vessel may retract and its wall invaginate, so that an almost immediate seal prevents copious haemorrhage. Occasionally even gross injuries, such as the amputation of a limb by a railway wheel, may be almost devoid of significant bleeding, because the crushing effect may combine with arterial wall retraction to seal the cut vessel effectively. It can sometimes be more dangerous partly to transect an artery than to divide it completely, as retraction cannot then take place. Failure of haemostasis is a haematological matter, but may have medico-legal connotations if an injury (which includes a surgical procedure) is performed on someone who has a haemorrhagic diathesis either from natural disease, or from therapeutic anticoagulant treatment, such as heparin or warfarin.

Delayed bleeding may be seen in a number of conditions. In trauma, especially traffic accidents, organs, such as the liver, spleen or (sometimes) lung, may be injured within their capsules or covering membranes, which initially remain intact. A good example is a subcapsular haematoma of the liver, which may be large and grow even larger as continued bleeding strips more capsule from the parenchymal surface. Eventually, the blister may rupture and the now unrestrained bleeding area can pour into the peritoneal cavity. Trauma can also weaken the wall of an artery or vein, leading to a false aneurysm, which can later rupture. An arteriovenous fistula can also form and later burst.

Infections can also develop in trauma sites and involve vessels in the vicinity, so that an abscess or cellulitis can secondarily lead to severe haemorrhage when the vessel wall is eroded. This is rare except among poorly treated accident or battle casualties, as are mycotic aneurysms that result from infected emboli impacting in a branch of an artery and causing local septic necrosis.

It is sometimes difficult to know how much of a haemorrhage found at autopsy may be accounted for by post-mortem bleeding. There is little doubt that the volume may increase after death, but, except in serous cavities, such as the pleura and peritoneum, or externally from the body surface, in most cases this is a small proportion of that which leaked under arterial pressure during life, due to the tissue pressures opposing passive bleeding.

However, a haemothorax from a ruptured aorta may amount to several litres and much of this may be in the form of a large shaped clot. A clot can form post-mortem, so its presence cannot be taken as an index of *in vivo* formation, but the source of the bleeding will usually be obvious and any post-mortem addition will not affect the interpretation. Copious external bleeding can continue after death, especially from the scalp, particularly if the head is dependent after death.

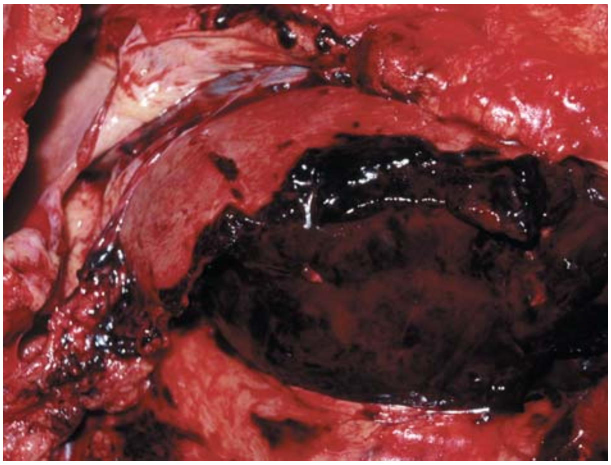

FIGURE 13.1 *Massive intra-abdominal bleeding from a subcapsular haematoma of the liver due to blunt abdominal trauma.*

INFECTION

Infection used to be so common after open wounds that it was the norm rather than the exception. Prior to the introduction of sulphonamides and antibiotics, many criminally inflicted wounds, which in themselves were not a danger to life, became fatally infected so that an assault became a homicide. This illustrates the fallacy of comparing murder rates in the last century with today, as the survival rate because of rapidly available ambulance and resuscitation services, blood transfusion, emergency operations and antibiotics is vastly greater now than in former times, when even a trivial injury was often fatal.

The types of post-traumatic infection are legion and vary greatly from country to country. Purulent wound infection from Gram-positive cocci, Gram-negative bacilli, anaerobes, such as *Clostridium perfringens*, and other more common organisms, is the most frequent, but in some countries tetanus and anthrax are common dangers. The whole matter is one of clinical microbiology, and the main forensic relevance is to prove a chain of causation between the original injury and a death from intercurrent infection. There may be medico-legal issues involved, such as failure to give or delay in giving antibiotic cover, which can have both civil and criminal legal consequences. A criminal assault that ends in death because of a neglected infection does not exonerate the perpetrator from all responsibility, even though there has been a *novus actus interveniens* in the form of defective medical treatment.

PULMONARY EMBOLISM

This is a most important topic in forensic pathology, as the medico-legal implications of a fatal pulmonary embolus are common and profound. Pulmonary embolism is the most underdiagnosed cause of death where no autopsy is performed; it has been estimated that, in the USA – and probably elsewhere – less than half of fatal pulmonary emboli are recognized clinically.

As with infection, an originally non-lethal injury may end in death because of venous thrombosis and pulmonary embolism, making what might be a simple accident or a common assault into a grave legal issue. The victims of many forms of trauma are at risk from pulmonary embolism because:

- Tissue trauma increases the coagulability of the blood for several weeks, the peak being between one and two weeks.
- Injury to the tissues, especially the legs or pelvic region, may cause local venous thrombosis in the contused muscles or around fractured bones.
- The injury may confine the victim to bed, either because of general shock and debility (especially in old people) or because the trauma itself necessitates recumbency, as in head injuries, severe generalized trauma or injury affecting the legs. In either case, recumbency leads to pressure on the calves and immobility causes reduced venous return and stasis because of lessened muscular massage of the leg veins. The common result is thrombosis of the deep veins of the legs, which can extend proximally into the popliteal and femoral vessels, forming a dangerous source of venous thromboemboli. Small emboli may break off and impact in more peripheral branches of the pulmonary arteries, sometimes causing pulmonary infarcts that may be precursors of a massive embolus that impacts in the major lung vessels and causes rapid death.

At autopsy, such large emboli are readily visible and can usually be easily distinguished from post-mortem clot. The latter is dark red, soft and jelly-like, with a shiny, glistening surface. It is often separated into 'chicken-fat' plasma clot and dark red-cell clot by sedimentation after death. When pulled out of the vessels it forms a cast of the branches, albeit shrunken by clot retraction. It is less evident in peripheral branches and, when the lung is sliced post-mortem, clot does not pour out of cut small vessels.

Conversely, ante-mortem embolus (especially if a number of days old) is firm, though brittle and has a dull, matt, striated surface from fibrin lamination. Older thrombus tends to be greyish-red and varies in colour from place to place. Although it may appear to be a cast of the large vessel in which it is impacted, it may often be unravelled to form a long length that obviously originated in a leg vein. Side branches, or the stumps thereof, may be seen that do not correspond to the branches of the pulmonary artery in which they lie.

Post-mortem clot may be adherent to the ante-mortem embolus and sometimes forms a sheath around it, so that the true nature is obscured unless a careful examination is made. On cutting the lung with a knife, ante-mortem emboli may be seen in the more peripheral vessels, often standing up slightly 'proud' above the surface, like toothpaste coming from a tube.

The importance of the differentiation between ante-mortem emboli and post-mortem clot is emphasized, as the legal issues hanging upon the unequivocal diagnosis may be very important. Histological confirmation of an ante-mortem origin must be made if there is any doubt. Pulmonary infarction does not occur from fatal massive pulmonary embolism, as death is too rapid. There may be infarcts present in the lungs but these must be caused by previous smaller emboli, at least a day earlier and probably much longer.

Medico-legal aspects of pulmonary embolism

Pulmonary embolism is the most underdiagnosed condition in British death certification, frequently being unsuspected as the cause of death by clinicians. Several investigations into the medico-legal aspects have been made (Knight 1966; Knight and Zaini 1980; Zaini 1981) and the peak incidence at about 2 weeks after trauma confirmed. In Knight's survey, more than three-quarters of the victims had predisposing factors such as injury, surgical operation or immobility in bed, but the remaining 20 per cent were ambulant and apparently healthy. This has important medico-legal implications because, if fatal pulmonary embolism can strike an appreciable proportion of the population who have not suffered one of the recognized predisposing factors, then the cause–effect relationship after trauma is weakened. If the standard of proof in criminal trials must be 'beyond reasonable doubt', then the fact that up to 20 per cent of pulmonary embolism deaths have not followed trauma or immobility must surely remove the cause–effect relationship from near-certainty to mere probability, which is sufficient for a civil decision, but not for a criminal conviction. This is a legal matter for the judge, however, who may or may not let the matter go to the jury – and if it does, for the jury to decide. There is marked variation in these decisions from case to case.

After the lung appearances have been examined and pulmonary embolism confirmed, the source of the embolus must be sought. In almost all cases this will be found in the vessels draining into the femoral veins, though rarely pelvic vessels are involved (usually in relation to pregnancy or abortion). Here pelvic veins may be thrombosed, with extensions into the iliac system and exceptionally into the inferior vena cava. An even more rare source is from jugular thrombosis, sometimes seen as extensions of intracranial venous sinus thrombosis. Axillary and subclavian vein thrombosis is equally unusual, the legs accounting for the vast majority of emboli.

In the usual leg vein thrombosis, various autopsy techniques are available to seek the site of obstruction. Extensive dissection is favoured by some, in which the femoral vein is exposed through a skin incision, this being continued distally as far as necessary to find the residual thrombosis. Of course, after a massive pulmonary embolus, by definition a large part of the source thrombus has been detached and therefore the pathologist has to search further distally to find the remnants. This makes dissection an extensive and disfiguring process, so alternative techniques can be used.

Zaini found that many thrombi begin far distally, even in the dorsum of the foot. He used a flexible wire with a blunt terminal knob (a Bowden cable from a bicycle brake) inserted down the femoral vein until it was arrested, then cut down from the skin at that point to examine the peripheral veins. Alternatively, transverse or longitudinal incisions can be made into the calf of the leg to examine the deep veins. The soleus and gastrocnemius muscles are transected to view their contained veins, but often the thrombus is found in the interosseous veins between tibia and fibula. If ageing of the thrombus is attempted histologically, then it should not be expressed from the vein, but the vein should be taken out with adjacent muscle, as it is the junction between thrombus and vein wall that offers the most information about the maturity of the thrombus.

Dating of pulmonary emboli and deep vein thrombi

As discussed above, it can be a matter of considerable medico-legal importance to know if a pulmonary embolus arose prior to, or subsequent to, some traumatic event. A major difficulty is that the embolus may be the most recent addition to an extending venous thrombosis that is considerably older.

It is also difficult to use histological criteria to date the free embolus from the lungs, as it is the thromboendothelial junction that provides the most information. The best method, therefore, is to examine the residual thrombus, almost always in the leg veins, to see if the oldest part could have formed as far back in time as the suspected traumatic event. For this, the vein wall with the contained thrombus is required. A segment of thrombosed vein, if necessary with adjacent muscle, should be dissected out of the leg. The presence of thrombus will have been confirmed prior to removal by transverse cuts across the calf or thigh muscles containing the veins. Sometimes the original site of thrombosis may be as far distal as the dorsum of the foot.

The thrombus-containing vein is processed in the usual way and subjected to various histological stains. Though accuracy about dating is impossible, the following is a useful scheme to provide at least an approximate idea of the duration of thrombosis in the section of vein under study – remembering always that other segments or other veins may have thrombi of different dates.

- Platelet and red-cell appearances give no useful information. Red cells begin to haemolyse between 24 and 48 hours to form amorphous masses, but many intact red cells survive for weeks.
- Using phosphotungstic acid-haematoxylin stain (PTAH), fibrin can be seen as purplish strands on the first day, but they aggregate into small masses with a meshwork of thicker strands and sheets by 4 days. After 2 weeks, the fibrin becomes more deeply purple stained, but begins to be absorbed by about the twenty-fifth day. Using Martius Scarlet Blue stain (MSB), the early pink fibrin strands become fringed by scarlet in about a week.
- Endothelial proliferation is most useful in the first week, as buds begin to arise from the vessel wall about the second day and proliferate during the first week. Clefts lined by endothelium are seen around the periphery of the thrombus against the vein wall. Artefactual contraction caused by fixation shrinkage must be excluded by seeking endothelial nuclei. These endothelial buds anchor the thrombus to the vein wall, and represent the first stage of healing and recanalization. They are usually noticeable by about the fourth day when they begin growing into the fibrin mass and breaking it up into compartments.
- Collagen fibres do not appear for about 5–10 days, often much later. Fibroblasts may be seen as early as 2 or 3 days, but tend to appear towards the end of the first week and reach a maximum at 2 or 3 weeks, reaching a maximum at about 4 weeks. Elastic fibres appear late, not before 28 days and often much later. They reach their maximum density in about 2 months, mainly in the walls of recanalizing vessels.
- Haemosiderin, blue granules demonstrated by Perl’s reaction, may be seen by the end of the first week and reach a maximum in 3 weeks. It does not seem to be present as early in thrombi as in extravascular haemorrhages, such as bruising or meningeal bleeding, where it can be seen in 2 or 3 days.
- Capillaries begin to appear on the second day as endothelial buds, but do not contain red cells until about 2 weeks. Over the next 3 months, substantial canalization occurs by widening and merging of these channels. The full lumen may be restored within 6–12 months, but endothelial thickening and haemosiderin deposits in the vein wall may form permanent evidence of a former thrombus.
- Leucocytes, both polymorph and mononuclear, are inconsistent markers; sometimes they do not appear at all. Polymorphs may be seen within the first day – sometimes in profusion – but they vanish rapidly, often by the next day when mononuclears take their place.

- Covering of the thrombus surface by endothelium is rapid and may begin on the first day and be complete within a few days. Various authors have given 24–72 hours as the time required. Naturally, the size of the thrombus surface is a variable factor. Also, only sections taken where the thrombus does not fully fill the vein lumen will provide an opportunity for observing the endothelial covering.

FAT AND BONE MARROW EMBOLISM

Another important sequel to trauma – fat embolism – is the subject of considerable controversy about the source of the lipoid; this does not, however, detract from the autopsy significance of its detection.

A great deal has been written about the pathophysiology of fat embolism and it is now evident that it is not just a simple extrusion of marrow or adipose tissue material by mechanical trauma. The work of Sevitt (1962), Bergentz (1961), Edland (1971), Ellis and Watson (1968), Buchanan and Mason (1982), and many others must be studied for detailed accounts of the suggested pathogenesis.

Wherever the fat comes from, embolism is most often seen after injury to bone or fatty tissue. In simplistic terms, where skeletal structures containing fatty marrow are damaged or where subcutaneous fat is compressed or lacerated, fat globules commonly appear in the pulmonary capillaries – and where they are numerous they somehow leak through the lungs into the systemic circulation where they can cause severe disability or death from impaction in vital organs, such as brain, kidney or myocardium. Not only fat, but cellular haematopoietic tissue from bone marrow, can be liberated into the venous system and reach the lungs.

The clinical manifestations of fat embolism depend on the volume of fat reaching the lungs. If substantial, ventilatory problems can ensue because of vascular obstruction and pulmonary oedema. The most dramatic symptoms occur, however, with systemic fat embolism when globules reach the brain and cause a range of neurological abnormalities, usually coma and death from brainstem involvement.

There is usually a delay between trauma and cerebral fat embolism while fat builds up in the lungs, so that a 'lucid interval' occurs, which may be confused clinically with the development of an extradural or subdural haemorrhage. Sevitt stated that of patients with multiple bone fractures, no fewer than 45 per cent had pulmonary fat emboli and 14 per cent had cerebral embolism.

Fat embolism is also associated with burns, barotrauma, soft tissue injury, osteomyelitis, diabetes, surgical operations on fatty tissues (especially mastectomy), septicaemia, steroid therapy, acute pancreatitis and the fatty liver of alcoholism, though fractures remain the most potent cause of the condition. In burns, there is some doubt whether pulmonary fat embolism is a true ante-mortem process, or whether fat can be melted out of tissues and organs in the perimortal period. Mason's (1968) experience in rapid air-crash fires was that fat embolism was not present, but Sevitt's hospital series revealed embolism in 47 per cent of deaths from burns.

Pulmonary fat embolism

After trauma, fat commonly appears in the lungs and can be demonstrated there histologically in the majority of cases of fractures and injury to fatty parts of the body such as the buttocks. Indeed, Lehman and Moore (1927) showed that half of a series of non-trauma deaths had histological evidence of fat in the lungs. Mason found fat in the lungs of 20 per cent of his series of non-trauma deaths, but emphasized that quantitatively the amount was small in contrast to that found in cases of fatal trauma. He used a simple scale for assessing the histological severity of embolism as seen in Oil Red-O frozen sections of lung:

- Grade 0: no emboli seen
- Grade 1: emboli found after some searching
- Grade 2: emboli easily seen
- Grade 3: emboli present in large numbers
- Grade 4: emboli present in potentially fatal numbers.

In systemic fat embolism, no such grading is possible; they are either absent or scanty, or they are abundant.

In most instances, pulmonary fat embolism is merely a phenomenon and not a clinical syndrome and the difference between the two seems closely related to the amount of fat impacted in the lung vessels. When clinically manifest it appears as acute respiratory insufficiency, the incidence being up to 2 per cent in long bone fractures and as much as 10 per cent in multiple fractures, especially with pelvic injuries. In small to moderate amounts, fat in the lungs gives rise to no disability, but large amounts, easily seen by a cursory glance at any field of a fat-stained histological section, give rise to acute respiratory distress. Marked pulmonary oedema is the pathological marker for this syndrome, but caution must be employed, as cerebral fat embolism can also cause pulmonary oedema by its effect upon the brain.

Systemic fat embolism

Here the fat penetrates the lung capillaries and appears in the major circulation, so that it can be carried to any organ or structure, including the skin, where it can cause petechial-like

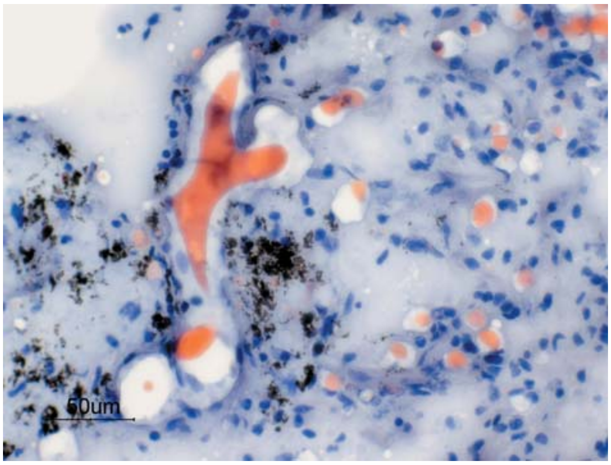

FIGURE 13.2 *Pulmonary fat embolism (Oil Red-O frozen section of lung; original magnification ×20).*

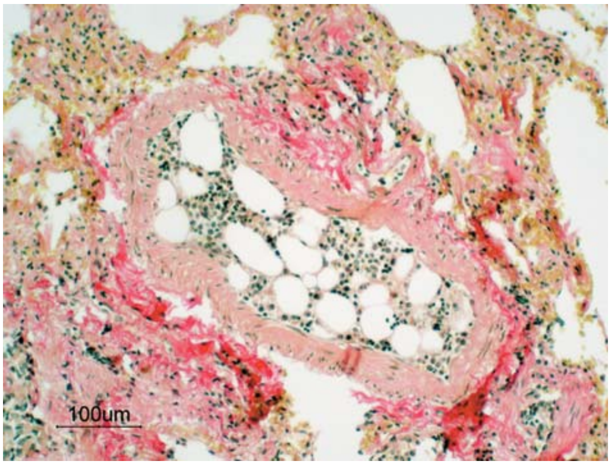

FIGURE 13.3 *Pulmonary bone marrow embolism (van Gieson staining, original magnification ×10).*

lesions. Systemic fat embolism is the fatal manifestation, except where pulmonary loading is so great that it causes respiratory distress. The brain, kidneys and myocardium are the most vulnerable target organs, the brainstem being the one that is most likely to lead to death from impaction of fat globules in its capillaries.

Autopsy findings in fat embolism

When fat is released through the lungs into the systemic circulation, a number of target organs and tissues exhibit abnormalities demonstrable at autopsy, either by gross or histological examination.

Petechial haemorrhages are the typical lesion, caused by the impaction of fat droplets in small venules. These may be seen in the skin of any part of the body, but especially over the front of the chest and on the face and eyelids. Internally they can be widespread but are classically seen in the white matter of the brain, both cerebral and cerebellar hemispheres, as well as the brainstem. Microscopically, when frozen sections are stained by Oil Red-O or other fat stain, the cerebral petechiae will show a central fat globule or globules, and others will be visible without haemorrhage.

In the myocardium, fat may be seen in the interfibre capillaries and in the kidney glomeruli may be stuffed with stained fat. There can be fat in the retina and in the optic nerve, which, in survivors, can cause visual impairment.

Fat embolism is markedly underdiagnosed, both clinically and at autopsy. The more often and the more thoroughly it is sought, the more often it is found. Mild to moderate degrees of pulmonary fat embolism, without systemic overspill, however, must not be given as a cause of death unless there are corroborative clinical features.

Bone marrow embolism

Bone marrow embolism is almost wholly a pulmonary phenomenon, as only in quite exceptional circumstances can cellular material penetrate the lung capillaries. It is quite common in association with fractures of long bones or in multiple bone injuries, though again the frequency with which it is seen is directly related to both awareness and the thoroughness of the search. Where marrow is found, the degree of fat embolism is usually substantial. The common concurrence of fat and cellular embolism is strong evidence of a marrow source for embolic fat, as pointed out by Mason, who found marrow cells in 81 per cent of his cases that had a grade 2 or more lung loading with fat, on a scale of 0–4. According to both Sevitt and Mason, the finding of both substantial fat and marrow emboli in the lungs is definite evidence of ante-mortem infliction of any discovered trauma. For these elements to reach the lungs there must be a competent circulation, albeit for a short time after the trauma.

With the possible exception of burns, any injury inflicted after cessation of effective cardiac function cannot transmit fat or marrow to the pulmonary capillary bed. This is therefore a useful forensic marker on some occasions, such as differentiating between ante-mortem and post-mortem fractures in a body recovered from water. Systemic embolism is not seen in rapid deaths following trauma: there is an interval averaging 24 hours before lung percolation takes place.

Foreign body embolism

A number of other objects may be found as emboli during forensic autopsies and histology. The lung granulomata of

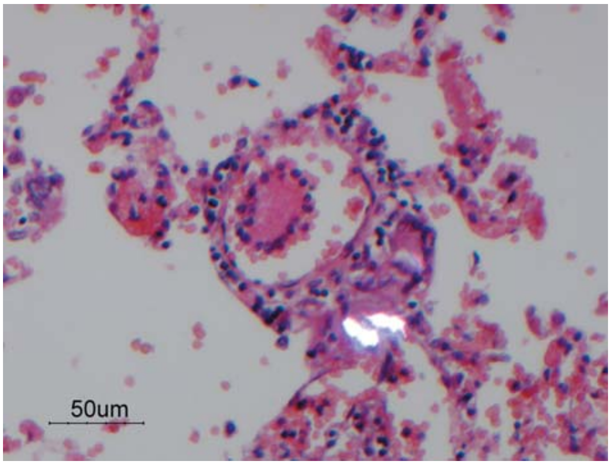

FIGURE 13.4 *Small foreign body granuloma with giant cells and birefringent particles as seen in polarized light in the lung of a drug addict (HE, original magnification ×20).*

talc, etc., seen in the lungs of intravenous drug users, are emboli from contaminants introduced into the venous system by syringe and needle. Shotgun pellets and bullets may enter the circulation via tissue damage and embolize to various sites including coronary arteries. In fat and bone marrow embolism, even fragments of bone and cartilage have been found as emboli in the lungs.

Amniotic fluid embolism is discussed elsewhere.

ADULT RESPIRATORY DISTRESS SYNDROME

Following severe lung injury, such as gross impact upon the thorax or blast injury from explosion, or from aspiration of gastric contents, infections, toxins, systemic shock, irritant gases, near-drowning and many other causes, the lung epithelium may suffer 'diffuse alveolar damage'. Clinically the victim may suffer marked dyspnoea and progressive respiratory failure, becoming hypoxaemic. Pathologically the lungs show a stiff oedema that progresses to a rigid, infiltrated lung if survival is long enough. At autopsy the lungs are hard and retain their shape after removal, having a 'dry-oedema' appearance, being almost double in weight in some instances.

Histologically the initial changes are shedding of type I pneumocytes with intra-alveolar exudates, the formation of hyaline membrane and patchy alveolar haemorrhage. This destructive phase is then replaced after a few days with a proliferative stage, when type II pneumocytes begin to fill the alveoli and a mononuclear response infiltrates the interstitial areas. The alveolar proliferation organizes, if survival continues, and eventual pulmonary fibrosis may seriously incapacitate the half who survive. A typical progression is seen in paraquat poisoning, though here there are virtually no long-term survivors.

A condition that is similar to the appearances of adult respiratory distress syndrome is the so-called 'respirator lung', which develops when a patient dies after an appreciable period of mechanical ventilation. It may appear within a few days, but usually supervenes after many days or weeks on a ventilator. The gross appearances are of a stiff, rigid lung, which, though heavy, does not usually appear obviously oedematous. Microscopically, proteinaceous fluid and a mixture of proliferative cells may be seen in the alveoli.

RENAL FAILURE FOLLOWING TRAUMA

Known for many years, this is a common sequel to extensive muscle damage or to burns that affect considerable areas of skin, as well as from certain poisons. It was formerly ascribed most often to 'acute tubular necrosis', but recent experimental work has thrown some doubt upon this as an accurate clinicopathological entity. When muscle is crushed, severely torn or otherwise rendered ischaemic, where extensive burns are suffered, or where poisons, such as mercuric salts or carbon tetrachloride are given, destruction of the renal tubular epithelium may be seen.

Unfortunately for histological diagnosis, a similar change occurs during post-mortem autolysis. In burns and muscle damage, the tubules may also be blocked with brown casts of myoglobin and these two changes of distal tubular necrosis and casts were thought to cause the profound oliguria or anuria often associated with trauma and burns. In biopsy as opposed to autopsy material, however, the tubular damage has been found to be minimal and the casts may be a sequel to reduced filtration rather than to tubular damage, so the validity of 'acute tubular necrosis' as an explanation of renal failure following trauma has been questioned. The true mechanism is still obscure, but may well involve the juxtaglomerular apparatus and the renin–angiotensin system, as well as disseminated intravascular coagulation effects on the glomeruli.

DISSEMINATED INTRAVASCULAR COAGULATION

The importance and frequency of this condition has been increasingly recognized in recent years, as it may follow a whole range of traumatic, infective and other acute events. Widely known as 'DIC', it has a number of other names indicating that it is a consumption coagulopathy associated with the blood clotting mechanism.

In DIC there is an abnormal activation of the coagulation process within the blood vessels caused by a wide variety of factors related to the blood itself, the vessel walls and to blood flow. Damaged tissue from trauma and burns can trigger thromboplastin-initiated coagulation: entry of tissue cell elements, especially from erythrocytes, brain and placenta are particularly potent. Particulate matter such as micro-organisms or microemboli of all types (including fat and air emboli, especially those from decompression) can precipitate coagulation via factor XII. Vascular endothelial damage and stasis of blood flow can have a similar effect.

Whatever the causes – and they are extremely complex – fibrinogen is consumed and fibrin precipitated in vessels, leading to both vascular obstructive effects and to a haemorrhagic diathesis from depletion of the coagulation system. Platelets are also consumed, adhering to the fibrin thrombi. Fibrinolysis is activated and there is a dynamic contest between intravascular coagulation and its removal.

After death there can be post-mortem fibrinolysis (Mole 1948), which lessens the ease with which fibrin deposits can be detected: staining techniques are also an imperfect method of visualizing the fibrin, so that a careful search must be made in autopsy histology for fibrin remnants. Lungs, kidney, liver and adrenals are the most likely organs to yield positive results.

Microvascular obstruction, leading sometimes to frank infarction as well as reduced function, together with bleeding, form the major dangers of DIC in a forensic context.

AIR EMBOLISM

Most examples of air embolism have a medico-legal significance as the entry of air into the circulation usually comes about as a result of trauma, sometimes surgical or therapeutic, from barotrauma or from criminal intervention.

Air embolism consists of an interruption of the circulatory system by bubbles of air (or other gas) that gain access to the circulation, usually through the venous side. It is an 'airlock', familiar to plumbers and owners of diesel engines, where the normal flow of liquid through tubes is wholly or partially blocked by air.

In the animal body the major disability is in the heart, as air is compressible and the contractions of the heart fail to move on the bolus of gas, being designed to pump an incompressible liquid. The air must enter on the venous side to be sucked towards the heart, causing pulmonary air embolism. The air usually remains in the right side of the heart, pulmonary trunk and arteries, and in the pulmonary vessels, rarely emerging on the pulmonary vein side. Death is usually immediate, but can be delayed by up to about 2 hours.

In the surgical context, aspiration of air into neck veins may occur while operating on the head or neck (especially thyroid and neurosurgical operations) with the patient in a sitting position. When the atria are below any breach in a vein, there is a suction effect that can draw in air; this can also happen in suicidal or homicidal cut throat. Refilling of a therapeutic pneumothorax has also led to fatal air embolism, either because the lung is punctured or an adhesion has torn the visceral pleura. In either case air under pressure may enter an exposed vein.

Some accidents have arisen during transfusion or infusion, and may form the basis for a medical negligence action. Now that flexible, collapsible fluid or blood containers are widely used the danger is less, but where rigid bottles are still used, the need for a vent tube may allow air to enter the connecting tubing when a bottle is allowed to empty completely. This in itself is innocuous, but if a fresh bottle is then connected, the new flow will drive all the air in the tubing into the vein.

Even more dangerous is the practice of connecting pressurized air or oxygen to the vent in order to hasten the transfusion speed: if the bottle is allowed to empty, gas under pressure enters the vein.

Arterial air embolism is rare, but can occur in lacerations of the lungs, refilling of an artificial pneumothorax or in some forms of barotrauma where the lung is ruptured in a diver who ascends too rapidly from a great depth. The 'bends' are also a type of gas embolism, in which dissolved nitrogen appears in gaseous form in the blood. This is caused by a sudden release of pressure on the return of a diver to atmospheric conditions after being supplied with air at high pressure. Death can be the result of air locks in the cerebral vessels or of ventricular fibrillation from coronary air embolism (Moore and Braselton 1940).

Criminal abortion accounted for many deaths from air embolism in former years (and still does in some parts of the world), from the insufflation of the uterus by a Higginson syringe (Chapter 19). Though therapeutic abortion by suction aspiration of the uterine contents is an extremely safe procedure, several somewhat inexplicable deaths have occurred from air embolism. The mechanism is obscure but may have been caused by muscular rebound of the uterus sucking air into the cervix. Some homicides, including 'mercy killings' committed by doctors, have been caused by deliberate injection of air into peripheral veins. The volume of air needed to cause fatal embolism has been hotly debated for years, but no real consensus has emerged, estimates varying from 10 to 480 ml (Polson 1963). If the volume of the right side of the heart is accepted as the minimum space that has to be filled, about 100 ml would appear to be a reasonable volume. In the rare event of air gaining access to the arterial system, presumably much less would be required to be effective; it would have to be introduced into a carotid artery to be of much danger, as this is the only way it could gain access to the cerebral circulation. To reach the coronary vessels – always mentioned in books, but virtually never seen – the blood would have to enter the pulmonary veins to reach the root of the aorta via the left side of the heart. Virtually all of the few cases of arterial air embolism have arisen in relation to dysbarism, where bubbles have either been generated within the vessels by decompression, or have entered the arterial system in the lungs from tears in the lung tissue.

Certainly air injected into a limb artery would do no harm at all, especially as most of the gas is likely to be absorbed very rapidly by the tissues. Thus the ingenious plot in Dorothy L Sayer's novel, *Unnatural Death*, where 'a hypodermic of air was injected into an artery' would have failed on two counts: site and volume!

The autopsy in suspected air embolism

When the circumstances indicate the possibility of fatal air embolism, special precautions must be taken over the autopsy. A pre-autopsy chest radiograph must be taken, as this is by far the best way of demonstrating air in sufficient quantities to be fatal. A chest radiograph is also essential in any kind of barotrauma as it may also indicate a pneumothorax, a lesion so often the cause of air embolism.

Almost the only mechanism of death is 'pump failure' of the right side of the heart. Air fills the great veins, right atrium and right ventricle, causing a froth that cannot be pumped on by the heart in systole because air is compressible. It is unlikely that air will penetrate the pulmonary capillaries in any quantity, unless some vascular shunts are present, so froth is unlikely to be seen in the left side of the heart, except in dysbarism.

Following radiography – in place of it, as second-best – the body must be carefully inspected for any tissue swelling, especially in the upper thorax and neck region, where crepitant gas bubbles may form surgical emphysema from leakage from lung damage or pneumothorax, or both, in dysbarism.

The head should be dissected first, not to detect air bubbles in the cortical veins, as almost every textbook erroneously states, but to look for air in the cerebral arteries. Descriptions and photographs of air segments in the cerebral veins are part of the mythology of forensic pathology, handed on uncritically from one book and one author to another. There is no way in which air bubbles can reach the pial veins on the brain surface. They cannot get there via the venous system, as there is no way in which they could struggle against the flow in the jugular veins, pass through the complex arrangement of intracranial venous sinuses retrograde to the circulation and dispose themselves over the cortical surface. Neither can they reach the same veins by penetrating the capillary bed of the brain, in the rare instances of arterial air embolism. As was demonstrated almost 30 years ago, these bubbles are artefacts and can be seen in many routine autopsies where there can be no question of air embolism.

The basal arteries should be inspected for air, however, which can reach them during episodes of dysbarism where air gains access to the arterial system in the lungs during decompression. The calvarium is removed gently and the dura opened. The brain is carefully lifted and small artery forceps clamped on the intracranial part of both internal carotid arteries and vertebral arteries. The vessels are then cut below these before the brain is removed from the skull in the usual manner. The whole pluck can then be submerged in water and the ends of the vessels watched for escaping bubbles when the clamps are removed.

The thorax is opened in the fashion appropriate for the detection of a pneumothorax, with puncture of an intercostal muscle beneath a pool of water supported by the reflected skin flap. This is done on each side, remembering that a positive result can only be expected in a **tension** pneumothorax.

The abdomen should next be examined, especially where air may have gained access through the uterus. The intestines should be gently displaced and the mesenteric veins examined for air bubbles. The inferior vena cava, the common iliac veins and the various pelvic veins should be scrutinized, and, if necessary, opened under water by pouring water into the opened abdominal cavity.

The sternum and costal cartilages are then removed carefully, preferably keeping the manubrium and upper ribs intact at this stage to avoid damage to the great vessels in the thoracic inlet. The superior vena cava should be inspected for bubbles. The pericardium is opened and the right and left ventricles punctured under water.

Bajanowski *et al.* (1998, 1999) consider that an aspirometer has to be used for the detection, measurement and storage of gas originating from the heart ventricles. It should be filled completely with distilled water containing two drops of Tween 80 to reduce the surface tension of the water to prevent adherence of small air bubbles to the wall of the aspirometer. Subsequently the gas should be analysed by gas chromatography and the results assessed according to the criteria defined by Pierucci and Gherson (1968, 1969) before the diagnosis 'air embolism' is justified.

If air embolism substantial enough to have caused death is present, frothy blood will be quite evident oozing from

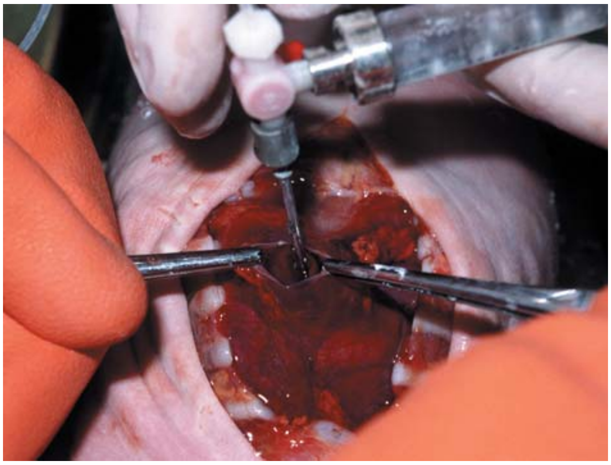

FIGURE 13.5 *An aspirometer should be used to recover air from the heart ventricles for subsequent analysis by gas chromatography.*

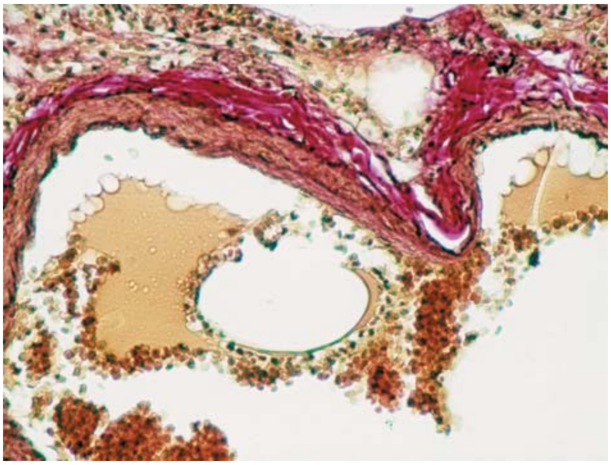

FIGURE 13.6 *Leucocyte and platelet accumulation around an empty space, 'air bubble' in blood, considered by some authors as evidence of venous air embolism. (Reproduced by kind permission of Professor E Lignitz.)*

the ventricular lumen, almost invariably the right. If this is apparent, however, it will almost certainly already have been seen on the pre-autopsy radiograph.

If there has been a considerable delay between death and autopsy, the air can dissipate, presumably dissolving into the tissues. Any degree of decomposition of the body negates a diagnosis of air embolism, because of the production of gases of putrefaction.

SUBENDOCARDIAL HAEMORRHAGE

A striking feature of many forensic autopsies, especially on victims of severe trauma, is the presence of well-marked haemorrhage under the endocardium of the left ventricle. This is often so striking as to provide an indication of some catastrophic event shortly before death.

Though the haemorrhages have been described since the last century, they were specifically studied in the 1930s by Sheehan in cases of abortion and acute haemorrhage associated with pregnancy; they were formerly known as 'Sheehan's haemorrhages'.

The lesions are seen in the left ventricle, on the interventricular septum, and on the opposing papillary muscles and adjacent columnae carneae of the free wall of the ventricle. The haemorrhages are flame-shaped and confluent, not petechial, and tend to occur in one continuous sheet rather than patches. The bleeding is in a thin subendocardial layer, but when severe may actually raise the endocardium into a flat blister that can be palpable on the smooth septum. The mechanism of production is obscure, but they are commonly seen in the following circumstances:

- After sudden, profound hypotension, either from severe blood loss or from 'shock' in the widest sense.
- After intracranial damage, from head injuries, cerebral oedema, surgical craniotomy or large intracranial tumours. Sudden intracranial decompression also seems to be associated with subendocardial bleeding.
- Obstetric catastrophes seem particularly prone to produce these haemorrhages, as found by Sheehan. Death from ante-partum or post-partum haemorrhage, ruptured ectopic gestation, abortions of various types and ruptured uterus often reveal these lesions.
- Various forms of poisoning, especially acute heavy-metal toxicity, particularly arsenic. The most profound subendocardial haemorrhages ever seen by the author (BK) were in a massive suicidal poisoning with arsenious oxide: the endocardium was raised into a large blood blister on the interventricular septum.

The haemorrhages can appear extremely rapidly, within a few heart beats. The author (BK) has seen well-marked lesions in a heart that was avulsed from its base during the crash of a military aircraft, obviously causing virtually instantaneous death. The common factor seems to be sudden hypotension and it has been suggested that, if the intraventricular pressure drops precipitously, the existing blood pressure in the coronary system is then unsupported across the endocardium by an equal pressure within the ventricular lumen, so that rupture of the superficial vessels occurs. There are flaws in this theory, one being the common incidence in intracranial lesions. Experimental work in goats has shown that prior vagotomy prevents the occurrence of subendocardial haemorrhages, suggesting that the phenomenon is mediated by the autonomic nervous system. To support this hypothesis, they are known to be part of Virchow's triad of 'pulmonary oedema, gastric erosions and subendocardial haemorrhage' seen in head injuries and cases of raised intracranial pressure.

SUDDEN DEATH FROM SUPRARENAL HAEMORRHAGE

Though not common, haemorrhage into the adrenal glands is a well-recognized terminal event, usually after some trauma to the body not related to direct injury to the suprarenal vessels themselves.

Originally these haemorrhages were thought to be confined to meningococcal septicaemia in children, the lesion being called the 'Waterhouse–Friderichsen syndrome'. It is now recognized that adrenal haemorrhage is part of a general response to stress, of which meningococcal infection is only one of a wide range.

In a recent 5-year period, the author (BK) found 16 cases of 'adrenal apoplexy' (to give it its old name) in the autopsy records of a forensic pathology service that performed 4890 autopsies in that period, giving an incidence of about 0.3 per cent.

Of these 16 cases, more than half (9) were bilateral. There were more male than female subjects, probably because of the greater amount of trauma in men. Three were infants, all with meningococcal infections.

None of the adult cases was diagnosed or even suspected clinically. Most were traffic accidents, the remainder being post-operative, other trauma or poisoning, together with several cases of hypertension and chronic renal failure. The most frequent common denominator was trauma, whether that trauma was direct injury or surgical trauma. The sudden collapse and rapid death usually occurred a few days after the trauma, varying from 2 to 21 days.

At autopsy one or both of the adrenal glands are found to be swollen, sometimes to the size of a large walnut (3–5 cm) the cortex being tightly stretched around a large haematoma occupying the medulla. The haemorrhage is usually dark red and fairly fresh, though occasionally an area of brown bleeding indicates a previous episode.

The late Professor Hugh Johnson, of St Thomas' Hospital, London, collected between 150 and 200 autopsy cases of suprarenal haemorrhage (unpublished) and considered that they fell into six main groups:

- Trauma of all types. Johnson was of the opinion that the predominance of right-sided gland haemorrhages was a result of the frequency of right-sided impacts on pedestrians in Britain because of the side of traffic flow.
- Perinatal, newborn or stillborn infants, especially when they were breech births or had fetal anoxia.
- Infancy and childhood, especially meningococcal and disseminated intravascular coagulation.
- Infective and post-operative septicaemia, often with Gram-negative organisms. Sometimes there was direct surgical trauma to the gland, as in gastric surgery.
- Tumour: haemorrhage into a secondary deposit or invasion of adrenal vasculature.
- Thrombosis of central vein with adrenal infarction.

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CHAPTER 14

Suffocation and ‘asphyxia’

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Though traditionally every textbook of forensic medicine has a chapter entitled ‘Asphyxia’, it is a partial misnomer, as many of the conditions described under this heading are not truly asphyxial in nature. It is difficult to find a succinct alternative, however, unless each subcondition is described individually – and some deaths have a mixed aetiology. The conventional title is therefore retained in this book, though it is emphasized that ‘asphyxia’ is both inappropriate and inaccurate when applied to many of the mechanisms of death formerly ascribed to this cause.

THE NATURE OF ‘ASPHYXIA’

Common usage has led to the term ‘asphyxia’ being equated with ‘lack of oxygen’, though etymologically the word means ‘absence of pulsation’. Interestingly – if fortuitously – this original sense is sometimes more accurate in certain deaths associated with pressure on the neck, where cardiac arrest – certainly a prime reason for absence of pulsation – is the fatal mechanism, rather than hypoxia.

Reverting to the usual meaning of asphyxia, a whole series of disturbances can lead to lack of oxygen. The basic purpose of respiration is to convey atmospheric oxygen to the peripheral tissue cells. Anything that interferes with oxygen transfer can be called ‘asphyxia’, though other terms such as ‘hypoxia’ or ‘anoxia’ are more accurate, and should be preferred. The following conditions may legitimately be considered to be defects in the chain of respiration and hence are examples of asphyxia:

- Absence or reduction of oxygen tension in the external atmosphere, such as reduced barometric pressure or replacement of oxygen by an inert gas, such as nitrogen or carbon dioxide.
- Obstruction of the external respiratory orifices, as in smothering or gagging.
- Blockage of the internal respiratory passages, at either pharyngeal, laryngeal, tracheal or bronchial level.
- Restriction of the respiratory movements of the thorax, preventing the inspiration of air through patent respiratory passages, as in the so-called ‘traumatic asphyxia’ or in paralysis from brainstem or cord damage, or the use of curare-like drugs.
- Disease of the lungs that prevents or reduces gaseous interchange. Extensive pneumonia, pulmonary oedema, adult respiratory distress syndrome, diffuse fibrosis and many other conditions may lead to hypoxia, but these are rarely of forensic concern.
- Reduction in cardiac function leading to impairment of the circulation of oxygenated blood may be considered as a type of ‘asphyxia’, sometimes called ‘stagnant anoxia’. Again, the condition is rarely relevant to forensic problems.
- A reduced ability of the blood to transport oxygen can also be thought to be asphyxial in nature, such as severe anaemias and the replacement of the oxygen-combining power of haemoglobin by carbon monoxide.
- Finally, an inability of the peripheral tissue cells to utilize the oxygen delivered to them by the bloodstream is seen in conditions such as cyanide poisoning, where the cytochrome-oxidase enzyme systems are inactivated.

Several schemes of classification of asphyxia have been devised, such as those of McIntyre (1969) and Shapiro (1988).

MECHANICAL 'ASPHYXIA'

The usual relevance of asphyxia in a forensic context is in mechanical asphyxia, rather than some of the internal conditions mentioned above, which are more likely to arise as a result of natural disease or toxic conditions.

The normal oxygen content of blood varies according to the age and health of the subject. Young to middle-aged adults have almost complete saturation of their arterial blood with oxygen, at a level of 90–100 mmHg (12–13.5 kPa), whilst persons over 60 may drop to between 60 and 85 mmHg (8–10 kPa). These normal values in the younger group may be contrasted with those sufferers from mild hypoxia of about 60 mmHg (8 kPa), and those in severe to fatal hypoxia when oxygen tension falls to between 40 and 20 mmHg (5–3 kPa).

Unfortunately for pathologists, post-mortem analysis of oxygen levels in the blood is of no value in the retrospective diagnosis of hypoxia, as changes soon after death rapidly distort the distribution of gases and make the results meaningless.

Definition of terms

A number of different names have been used to describe the various types of mechanical 'asphyxia', some of which are confusing or inexact:

- **Suffocation** is a general term used to indicate death from deprivation of oxygen, either from lack of the gas in the breathable environment or from obstruction of the external air passages.
- **Smothering** is more specific, in that it indicates blockage of the external air passages, usually by a hand or soft fabric. A variety of suffocation may be called **gagging** where fabric or adhesive tape occludes the mouth to prevent speaking or shouting. While the nasal passages remain patent, air can enter, but later blockage by mucus or oedema may lead to death.
- **Choking** refers to blockage of the upper airways by some foreign body, but is also used for manual strangulation.
- **Throttling** refers to strangulation, usually by hand, the word rarely being applied to ligature strangulation.
- **Strangulation** is the most specific term, indicating the use either of the hands or a ligature as a means of applying external pressure to the neck. **Garrotting** has been used for ligature strangulation, but more accurately refers only to a Spanish method of judicial execution. Other methods exist in various parts of the world, such as the Indian technique of pressing a flexible stick or 'lathi' across the front of the neck.
- **Mugging** originally meant the application of pressure to the neck by means of an arm crooked around from the rear, but more recent American usage has widened the term to mean any kind of robbery with violence. More recently still the **arm-lock** has been used as means of restraint by law enforcement officers, sometimes with fatal results.

As an aside, in some deaths during arrest, usually where a violent struggle occurs between several police officers and a drunken or drugged offender, the death of the latter occurs where no neck or chest pressure can be implicated. Though the mechanism is obscure and impossible to demonstrate objectively at autopsy, it has been provisionally ascribed to a catecholamine-induced cardiac arrhythmia from an exaggerated adrenal response.

As most of these victims are given energetic cardiopulmonary resuscitation, any markers of this catecholamine effect, such as contraction-band necrosis in the myocardium, cannot be differentiated from resuscitative artefacts.

THE CLASSIC SIGNS OF 'ASPHYXIA'

For many years the autopsy diagnosis of an asphyxial death was made by reference to a set of findings that have come to be known as the 'classic signs of asphyxia'. Unfortunately, it is now quite clear that most of these signs are so non-specific that little reliance can be placed on them in the absence of other confirmatory evidence. They are scathingly referred to by Lester Adelson (1974) as the 'obsolete diagnostic quintet'.

In many cases of undoubted fatal hypoxia these signs are absent and, conversely, they are often present in some degree in conditions that can be shown to be non-hypoxic in origin. The major difficulty for the pathologist is that 'asphyxia' cannot reliably be equated with 'hypoxia'. There are no truly distinctive autopsy signs of pure hypoxia and most of the alleged criteria are caused by factors other than a lack of oxygen.

To confuse the issue further, some apparently hypoxic states lead to sudden or rapid death before there is time for oxygen lack to take effect, such as often happens when a victim enters a space devoid of oxygen, has the trachea suddenly blocked by food or has a plastic bag pulled over the head.

Each of the 'classic features' must be looked at in depth.

Petechial haemorrhages

These are small pin-point collections of blood lying in the skin, the sclera or conjunctivae and under thoracic serous membranes such as the pleura or pericardium. They vary in size from a tenth of a millimetre to about two millimetres. If larger than this, they are more accurately called 'ecchymoses'.

Petechiae are often known as 'Tardieu's spots', but this eponym should be restricted to those lying in the visceral pleura, where they were described by the Parisian Professor Ambroise Tardieu in 1866, in the bodies of infants who he claimed had been 'overlain'. A further common error is to attribute the petechiae to the rupture of **capillaries**, whereas they actually emanate from small venules – capillary bleeding would be invisible to the naked eye.

Petechiae are caused by an acute rise in venous pressure that in turn causes overdistension and rupture of thin-walled peripheral venules, especially in lax tissues, such as the eyelid, and in unsupported serous membranes, such as the pleura and epicardium. It is traditionally claimed that hypoxia of the vein wall is an added factor, but there is no experimental proof of this conjecture, which seems unlikely considering the rapid formation of these lesions when venous pressures rise; for example, petechiae can appear almost instantly after violent sneezing or coughing before any hypoxia is possible.

Petechiae are seen most often in the face and eyes of victims of compression of the neck or fixation of the chest. In the former, where strangulation by either hand or ligature has occurred, occlusion of the jugular veins prevents venous drainage from the head, whilst almost always allowing the arterial supply to continue via the more deeply placed and much less compressible carotid and vertebral arteries. There is a rapid rise in venous pressure in the head, leading to engorgement of the veins. The consequences are swelling of the tissues, both from an increase in intravascular volume and from rapid transudation of fluid into the tissues, followed by showers of petechial haemorrhages in unsupported areas, such as the skin of the upper eyelids, the forehead, the skin behind the ears, the circumoral skin, and the conjunctivae and sclera of the eye. The same venous engorgement often leads to frank bleeding from the nasal mucosa and the external auditory meatus.

In the internal tissues and organs, petechiae are most often seen on serous membranes in the thorax, where the presence of a body cavity leads to lack of support for the superficial venules and hence predisposes to rupture when venous pressure rises. They are almost never seen in the peritoneal serosa and it has been postulated that, in the chest, attempts at breathing against a closed airway may lead to a sudden extreme decrease in intrapleural pressure causing petechiae in the same way as suction on the skin can cause a shower of pin-point haemorrhages. As described by Tardieu, petechiae in the thorax are often seen on the visceral pleura, especially in the interlobar fissures and around the hilum.

Petechiae are also common on the surface of the heart, especially on the epicardium around the atrioventricular groove, particularly on the posterior surface, though these have been shown to appear or worsen as a post-mortem phenomenon. In infants and children, the thymus or thymic remnants may show numerous petechiae. It is claimed that in the sudden infant death syndrome these are confined to the cortex, whereas in other 'asphyxial' conditions they are scattered throughout the gland; this is doubtful.

Petechiae are rarely seen in the parietal pleura or the peritoneum except in haemorrhagic diatheses. In the brain, petechiae occur in the white matter and there may be larger patches of bleeding in the subarachnoid space where superficial vessels have ruptured because of acute venous engorgement. The same mechanism often produces profuse petechiae and ecchymoses under the scalp. In regard to the scalp, caution must be observed as numerous haemorrhages can be caused as a common autopsy artefact during the reflection of the scalp flaps.

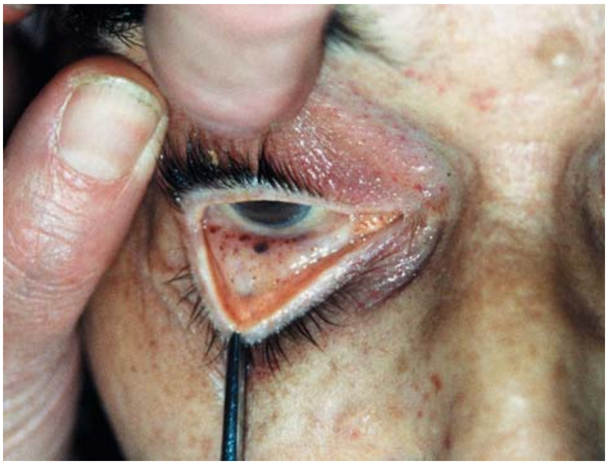

FIGURE 14.1 *Petechial haemorrhages in the eye in manual strangulation. There are also some petechiae on the facial skin.*

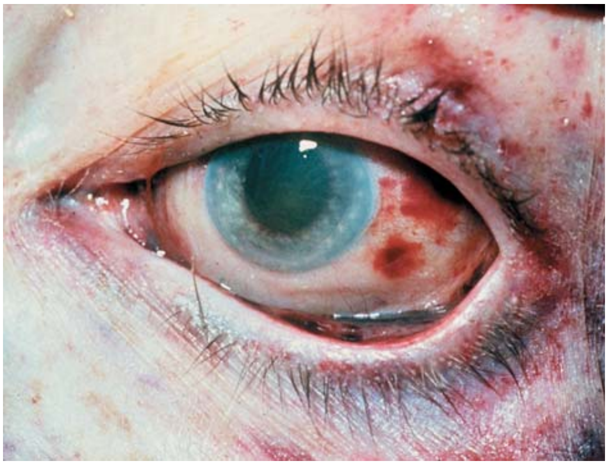

FIGURE 14.2 *Scleral haemorrhages in manual strangulation. These are larger than the usual petechiae, but the latter are present inside the lower lid.*

Petechiae may also disappear with lengthening post-mortem interval. Betz *et al.* (1994) have shown that in putrefaction and freshwater immersion, conjunctival petechiae may vanish.

THE SIGNIFICANCE OF PETECHIAE

A number of factors cause difficulty in the interpretation of petechial haemorrhages. First, there is no doubt that both cutaneous and visceral petechiae, especially the latter, can both appear and enlarge as a post-mortem phenomenon. Gordon and Mansfield (1955) have shown that the presence and number of petechiae is a function of the post-mortem interval, in common with other haemorrhagic artefacts such as those found behind the larynx by Prinsloo and Gordon (1951).

Posture also has an effect on the appearance of haemorrhages. They are commonly seen, along with larger ecchymoses, on the front or back of corpses who have died from a variety of causes in which mechanical asphyxia is absent. They are often present in normal post-mortem hypostasis, especially where the mode of death was congestive as in many types of natural heart disease. Their appearance in the hypostatic areas is also time-related, the longer the post-mortem interval, the more likely – and more prominently – they are to occur.

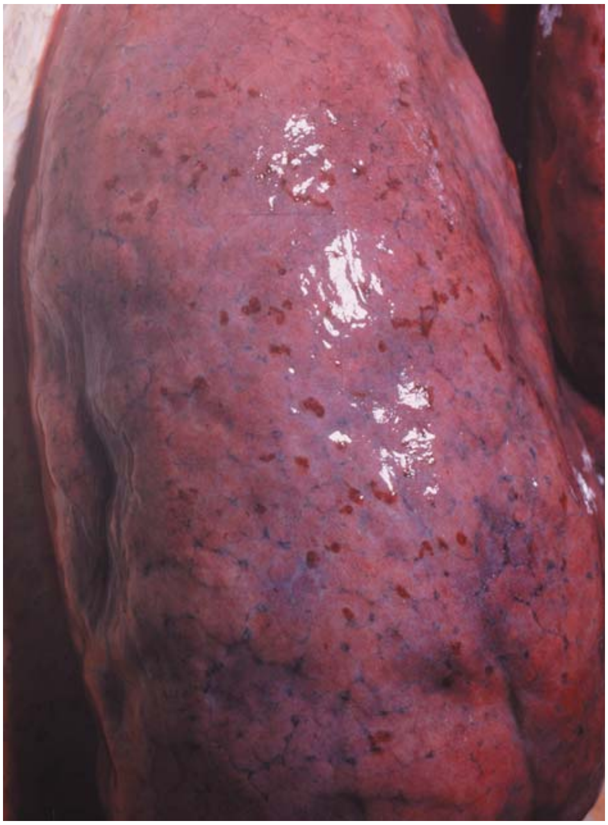

FIGURE 14.3 *Subpleural petechial haemorrhage – the true 'Tardieu spots' – in manual strangulation. These are no longer considered to be specific for 'asphyxia' and a few petechiae can frequently be found in many autopsies unassociated with asphyxia.*

Where some abnormal posture is present – such as the deceased being slumped out of bed or otherwise found with the head lower than the body – marked congestion, cyanosis and petechial haemorrhages are common.

Occasionally the abnormal posture may have occurred during life, such as in overdose victims, drunks and senile persons, who have fallen into a position with the upper part of the body lowermost. This may embarrass respiration and contribute to death and the ante-mortem component may be difficult or impossible to distinguish from post-mortem accentuation of the congestive-petechial appearances.

Another problem in the autopsy interpretation of petechiae is that not all punctate lesions in the pleura are petechiae. Zaini and Knight (1982) showed that many such apparent petechiae were either intravascular venous pools, subpleural microbullae or pigment foci.

In summary, petechial haemorrhages are highly unreliable indicators of an asphyxial process, taking this to mean a hypoxic state. They are the result of venous engorgement, usually from mechanical obstruction of venous return to the heart – or in the thorax, from attempts to inspire against a blocked airway. Petechiae and ecchymoses are common non-specific autopsy findings and many are post-mortem in origin, especially in dependent positions. They

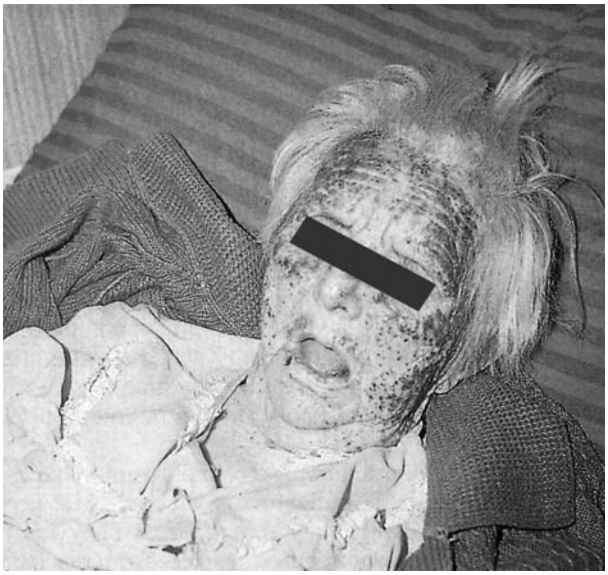

FIGURE 14.4 *Dense confluent skin haemorrhages in the face of an old lady who had slipped from her bed and was found with her head on the floor and her legs on the bed. The signs of this 'postural asphyxia' may well have been accentuated by post-mortem worsening of the hypostatic haemorrhages.*

may occur in many non-asphyxial states and, in the lungs, some petechiae can be found in the interlobar fissures and around the hilum in most routine autopsies.

Conversely, in some types of death where oxygen deprivation is to be expected (such as drowning, plastic-bag suffocation and entering an atmosphere devoid of oxygen), petechiae are seldom demonstrable.

The most significance must be placed on facial and ocular petechiae, because showers of pin-point haemorrhages in the eyelids, conjunctivae, sclera and facial skin require urgent explanation unless the body was face down or head down.

Congestion and oedema

The next 'classic' sign of asphyxia is congestion. This is even more non-specific than petechiae and once again is the result of obstructed venous return. When the neck is compressed, the face, lips and tongue become swollen and reddened. The true colour change of congestion is usually darkened by the onset of cyanosis. Internal organs also become congested and in strangulation this is most notable in the tongue, pharynx and larynx above the level of venous obstruction. In pressure on the chest, failure of respiratory movements cause an intense rise in venous pressure, accompanied by cyanosis.

Congestion is often associated with tissue swelling if the venous obstruction continues. The oedema is the result of rapid transudation through capillary and venule walls, again mainly a function of back pressure in the venous system. Hypoxia of the vascular endothelium is alleged to allow increased permeability, but generalized hypoxia from other causes does not produce the tissue swelling seen in strangulation.

Tissue fluid also escapes rapidly into the brain in strangulation that continues for even a few minutes, though here the well-known effect of hypoxia might be an added factor. Pulmonary oedema, causing excess fluid to enter the alveoli, is often found in hypoxic deaths. Here the mechanism is more obscure, but is probably a combination of hypoxia and raised pulmonary vessel pressure. In strangulation, froth may sometimes be so profuse as to emerge from the mouth and nostrils – yet in other throttlings, it may be absent. Pulmonary oedema is such a common and non-specific phenomenon in a whole range of fatal conditions that it has little diagnostic significance.

Cyanosis

The colour of blood depends upon the absolute quantity of oxyhaemoglobin and reduced haemoglobin present in the erythrocytes. The normal pink colour of well-oxygenated skin may change to purple or blue when oxygen is lacking – indeed, the word 'cyanosis' is derived from the Greek, meaning 'dark blue'. Cutaneous cyanosis, however, depends on the absolute amount of reduced haemoglobin, rather than the proportion of reduced haemoglobin to oxyhaemoglobin. It is not apparent in marked anaemia, even if the ratio of oxyhaemoglobin to reduced haemoglobin is low. There must be at least 5 g of reduced haemoglobin per 100 ml blood before cyanosis becomes evident, irrespective of the total amount of haemoglobin.

In the common forensic event of constriction of the neck, cyanosis almost invariably follows congestion of the face, as venous blood containing much reduced haemoglobin after perfusing the head and neck is dammed back and becomes more blue as the blood accumulates. If and when the airway becomes blocked, then impaired oxygenation in the lungs leads to a diminution in the oxygen content of arterial blood. This will lead to a darkening of all organs and tissues, and will accentuate the cyanosis of the face. This does not happen in the first phases of strangulation, however, and depends on complete or substantial occlusion of the airway, or restriction of the respiratory excursions of the chest.

Cyanosis produced during life may be partly or wholly overshadowed by hypostasis, which may be a deep purple or blue, and may be mistaken for true cyanosis – indeed, some pathologists refuse to use 'cyanosis' in respect of the dead, claiming that it cannot reflect the ante-mortem situation.

'Engorgement of the right heart and fluidity of the blood'

Descriptions of an abnormal fluidity of the blood seen at autopsy in asphyxial deaths are part of forensic mythology and can be dismissed with little discussion. Post-mortem clotting in the heart and venous system is a most erratic process, as is the eventual dissolution of those clots by the action of fibrinolytic enzymes (Mole 1948). It is irrelevant in the diagnosis of asphyxia.

Engorgement of the chambers of the right side of heart and the great veins is also a non-specific autopsy observation, useless as a marker of an asphyxial process. Any type of congestive death, including primary heart failure from many diseases, leads to terminal engorgement of the right ventricle and atrium as part of the generalized rise in venous and intracardiac pressure.

The autopsy diagnosis of 'asphyxia'

Thus there are no specific autopsy findings for 'asphyxia', taking this in its hypoxic sense. As stated earlier, the so-called ‘classic signs’ have been well described by Adelson (1974) as the ‘obsolete diagnostic quintet’. He goes on to observe that ‘the co-existence of these findings, in themselves, does not prove that death resulted from mechanical asphyxia. All these phenomena are non-specific and are in no way peculiar to this mode of death. Inasmuch as they are observed frequently in deaths arising from unquestioned natural disease, they are of no value in proving that death resulted from mechanical asphyxia’.

Other salutary cautions on the significance of ‘asphyxial signs’ may be found in the important publications of Gordon and Turner (1951), Camps and Hunt (1959), Shapiro (1953) and Swann and Brucer (1949).

It is impossible to make a post-mortem diagnosis of acute hypoxia by measuring the blood gases, as rapid changes after death – and indeed agonal changes – make analysis worthless. Only by a careful assessment of the history and circumstances of the death, exclusion of other causes and a cautious evaluation of the signs described above can any conclusion be reached. Most important of all is the finding of a cause for airway obstruction or other local trauma, such as prolonged pressure on the neck or chest, obstruction of the airways, postural causes or occlusion of the external respiratory orifices.

It cannot be emphasized too strongly that the mere finding of any of the non-specific features, such as congestion and petechiae, without firm circumstantial or preferably physical evidence of mechanical obstruction of respiration, is quite insufficient to warrant a speculative diagnosis of asphyxia. If such collateral evidence is not forthcoming, then the cause of death must be left undetermined.

Histological and biomechanical diagnosis of anoxia/‘asphyxia’

Many attempts have been made to find markers of hypoxia, anoxia and ‘asphyxia’ by means of laboratory techniques, including histology, histochemistry and various biochemical methods. Although many claims have been made for their usefulness, the fact that such tests are virtually never put forward in criminal or civil litigation makes it self-evident that they are not reliable.

This is hardly surprising, given the vague and contentious nature of the ‘asphyxial’ condition, where the mechanisms are diverse and even the nomenclature is unstandardized. If the target for research is narrowed down to severe hypoxia at a tissue or cellular level, then perhaps more success might be expected, by being able to demonstrate cellular damage by one or more of the great battery of techniques now available. However, even this limited objective is not yet attained with the degree of reliability required for legal purposes. The extensive strangling, drowning and gassing of legions of small animals may have produced many theses and papers, but has had no practical impact upon a long-standing problem in forensic pathology. Cell death, especially in neurones or myocytes, due to ischaemic/hypoxic damage is the most common focus for research, but the problem in a forensic context is that a considerable period of hypoxia – usually a minimum of many minutes or even hours – is needed before changes can be detected, even in experimental circumstances. In human autopsy material, the ever-present post-mortem and agonal changes interfere with the subtle early signs of hypoxic damage.

Histological changes in the lung and also chemical markers in blood or vitreous, such as hypoxanthine, have been claimed to indicate generalized hypoxia, but the application of such techniques in routine practice has not been fruitful.

SUFFOCATION

Although not a specific term, suffocation usually refers to a death caused by reduction of the oxygen concentration in the respired atmosphere, formerly called a ‘vitiated atmosphere’. It is less often used to include smothering or choking. Reduction of atmospheric oxygen may occur in a wide variety of situations. Decompression, such as cabin failure of aircraft at high altitudes, causes a dramatic fall in the partial pressure of oxygen and hence reduced penetration of the gas through the alveolar wall. Other factors, however, such as the direct effects of a partial vacuum and often mechanical trauma from the near-explosive situation may overshadow the hypoxic aspects.

More common is the reduction of oxygen in the atmosphere by physical replacement by other gases, or chemical changes such as combustion. In fires, the loss of respirable air may be a potent factor in causing death, though other complications, such as the presence of toxic gases such as carbon monoxide, cyanide and many other poisonous substances liberated by the burning of plastics, may cause death more quickly than pure hypoxia. Carbon dioxide, which though not itself poisonous, is irrespirable and may accumulate in fires, and in wells and shafts in limestone. In former years, vagrants sleeping for warmth near limekilns were sometimes suffocated by this heavy gas creeping over them.

Carbon dioxide is also the cause of deaths in a more modern agricultural setting – the grain silo. Here, many tons of grain are stored in gas-tight towers; the seed produces carbon dioxide that settles to the bottom of the tower. When a blockage occurs in the gravity discharge, farm workers may enter the tower to clear the obstruction. Although safety precautions demand venting before the men enter, some workers still suffer a sudden death on encountering an atmosphere rich in carbon dioxide.

A similar hazard exists in ships' tanks or other industrial metal chambers, in which oxygen is replaced by nitrogen. This happens because the damp steel walls become rusty and use up much of the contained oxygen in forming ferric oxides. In all these deaths associated with replacement of oxygen with an inert gas, rapid death is common before hypoxia can have had any physiological effect. For example, the author (BK) has dealt with two deaths in which seafarers entered closed ships' tanks and virtually fell dead off the entry ladder. The presumed mechanism, which was far too quick to be hypoxic, was considered to be some overstimulation of the chemoreceptor system, leading to a parasympathetic 'vasovagal' cardiac arrest.

Even where death was not witnessed as sudden, the 'classic signs' of asphyxia are almost always absent. In domestic circumstances, death may be seen where a heating apparatus has removed oxygen from the atmosphere in the absence of ventilation. Though oxides of carbon are usually formed, a kerosene or natural gas appliance may kill from pure hypoxia, especially where left burning all night in a small room where the occupants lie sleeping. The effect may be accentuated by the victims having blocked up cracks in the doors and windows to keep out draughts. An open wood or coal fire does not present the same hazard, as it requires a flue or chimney in order to burn. In all such deaths, carbon monoxide poisoning must first be excluded by blood analysis, as it is a common accompaniment to lack of oxygen, especially as the reduction in oxygen availability tends to make the heat source produce progressively more monoxide than dioxide during combustion.

In a different variety of hypoxic death, persons – especially children – may asphyxiate by being confined in a small airtight space. Examples include boxes and discarded refrigerators; the danger of the latter is so well known that in Britain it is illegal to dump a refrigerator in a place with public access, unless the self-locking handle is rendered inoperative.

In all such 'hypoxic' deaths (though some are patently due to vasovagal cardio-inhibitory mechanisms) it is very rare to find any petechial haemorrhages, as these are mainly the result of venous obstruction, which is absent in these circumstances. In the true hypoxic deaths, there may be congestion and cyanosis, though even these are often absent and the autopsy findings are essentially negative.

SMOTHERING

This term refers to death from mechanical occlusion of the mouth and nose, though sometimes 'suffocation' is used to include this class of death. The smothering agent is usually fabric, an impervious sheet or a hand, though occasionally (especially in industrial accidents) a mobile solid, such as sand, mud, grain or flour may be responsible for blocking the air passages. In the 1966 Aberfan disaster in South Wales, more than 140 victims – almost all children – were smothered when semi-liquid coal slurry from a collapsing mine tip swept over their school.

In smothering, death may occur either by the occluding substance pressing down upon the facial orifices, or by the passive weight of the head pressing the nose and mouth into the occlusion. Deliberate homicide is seen usually in the old, the debilitated and in infants. It is extremely difficult to prove homicide from objective findings.

In relation to infants, the matter will be further discussed in the chapter on sudden infant death syndrome, but it is essential to appreciate that the smothering of babies, whether intentional or accidental, is both rare and difficult to prove. The so-called 'classic signs' of asphyxia, for what they are worth, are rarely present in proven suffocation – and as intrathoracic petechiae are common in undoubted 'cot deaths', these signs cannot therefore be accepted in isolation as evidence of suffocation.

Pressure marks on the face can rarely be distinguished from post-mortem postural changes, where circumoral and circumnasal pallor is caused merely by passive pressure of the dependent head after death, preventing the gravitational hypostasis from entering these areas.

Even where the head is found supine, variation in colour is still common on the face, with contrasting white and pink patches, which usually change as the post-mortem interval lengthens. Unless there are bruises or abrasion on the cheeks, around the mouth, lips or lesions within the lips or mouth, it is dangerous to overinterpret mere colour variations from

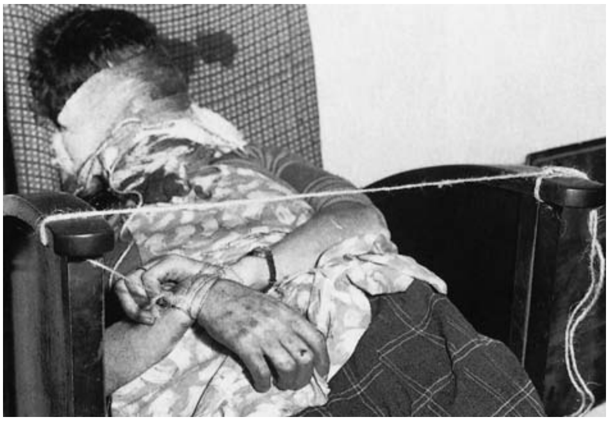

FIGURE 14.5 *Smothering from a towel being tied over the face. Death was contributed to by head injuries, also inflicted by the aged husband, who died within a few hours of natural causes from hypertensive heart disease.*

alterations in the amount of blood in the facial capillary bed, which is almost always a post-mortem phenomenon.

Even a confession from the mother is not always reliable – cases are on record where a mother has falsely confessed to smothering her child to rationalize the inexplicable events of a true sudden infant death syndrome fatality.

A similar situation exists with the elderly, who may be victims of a 'mercy killing', often a euphemism for the exhaustion of patience of long-suffering caring relatives. A pillow placed over the face of a sleeping octogenarian leaves no signs, **unless a struggle develops**, when protracted attempts at respiration against obstruction may lead to congestion, cyanosis and sometimes facial and conjunctival petechiae.

'Overlaying' of infants

This alleged condition has an ancient pedigree, being mentioned in the Old Testament. In Chapter III of the First Book of Kings, Solomon has to adjudicate between two women who both claim the same child, as the other infant was 'overlain'. This event, some 3000 years ago, has been mentioned at intervals through history, as in Wales in AD 1188, when Giraldus Cambrensis records that the Lord punished a woman for preventing her husband joining the Third Crusade, by causing her infant son 'to be overlain in the night'.

When an infant was found dead in the morning in the maternal bed (as separate cots or cribs are a relatively modern invention), it was assumed that the mother had turned over onto the baby in her sleep and suffocated it. When infants began to be placed in cots, the deaths continued unabated and it seems obvious that most of these were victims of the sudden infant death syndrome (SIDS). Whether or not overlaying really exists is doubtful and seems incapable of proof, given that any infant found dead in bed with no physical signs at autopsy could, by definition, be a SIDS.

The recent marked decline in numbers of SIDS in Britain has coincided with a campaign to discourage mothers from putting their infants to sleep face down – but, as yet, no definite cause-and-effect relationship has been proved, so any consequent strengthening of the 'overlaying' hypothesis cannot be substantiated.

Plastic bag suffocation

Although an increasingly common form of suicide in Britain, plastic bag suffocation may also be homicidal or accidental. In all these types, the essential mechanism is that a hood of impervious substance, usually polythene or other plastic, is placed over the head down to neck level. The plastic is usually in the form of an open-ended bag, either transparent or a 'supermarket' shopping bag.

Although many suicides tie the open end of the bag around their neck with cord or a tie, this is not necessary for a fatal result. Indeed, even flat sheets of polythene have killed infants when placed on the face. The mechanism is not understood, as it was formerly but erroneously thought to be the result of the clinging effect of static electricity.

Plastic bag suffocation can be rapid and leave no signs whatsoever. In the author's (BK) series of accidental, suicidal and three homicidal deaths from plastic bags, not one had any petechial haemorrhages or, indeed, any signs of 'asphyxia' at all, the faces being pale and uncongested. In another case, a person was convicted of murder by plastic bag, yet was only arrested after a spontaneous confession 6 weeks after an autopsy that had revealed no signs whatsoever of an asphyxial cause of death. As with hypoxic atmospheres, it seems that the mechanism of death in plastic-bag facial occlusion is some rapid cardio-inhibitory mode, rather than a purely hypoxic process. This conclusion is strengthened by the causes mentioned above, where flat sheets of plastic, not bags, have killed infants by clinging to the face, which of necessity must have been rapid deaths.

At autopsy, unless the bag is still present, these cases can present great difficulty. In fact, as in the homicide mentioned above, unless a confession or other corroborative evidence is forthcoming, the pathologist may never even know that he has dealt with an occult suffocation. Where the bag

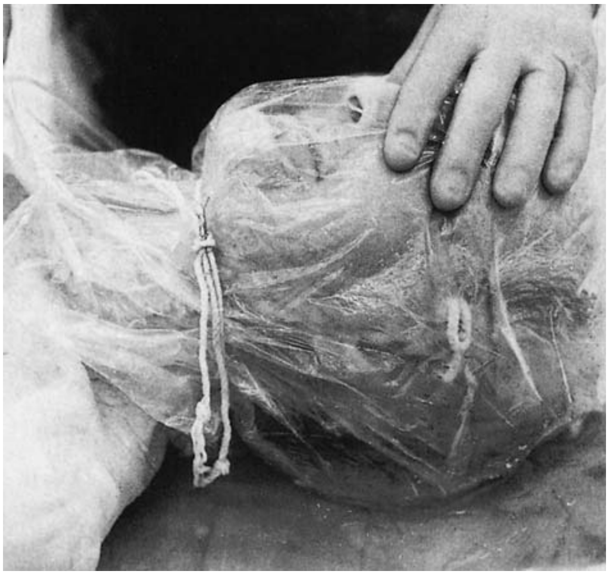

FIGURE 14.6 *Plastic bag suicide. The bag is sometimes tied around the neck, as in this case, but this is not necessary for a fatal outcome. The deaths are not asphyxial in the hypoxic sense; facial congestion and petechiae are almost always absent.*

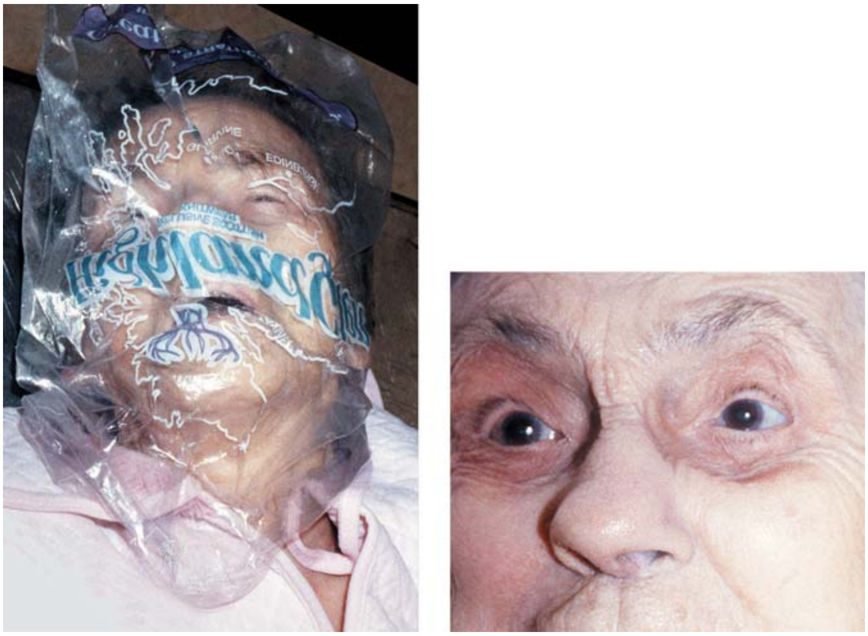

FIGURE 14.7 *Plastic bag suicide, with an open bag placed loosely over the head. As usual there are no congestive petechial signs in the face.*

is still in place, a search must be made for other indications of suicide, such as drug analysis and futile injuries, such as slashed wrists. Masochistic activities, described later in this chapter, are sometimes, though not often, associated with plastic bag suffocation.

It is sometimes said that moisture seen inside the bag indicates that it was put on during life, the water being from respiration. It is rare for this to be an important issue, as placing a bag on a corpse's head would seem excessively unusual; in any event, the test is invalid, as evaporation from the skin, nose and mouth can produce beads of moisture inside, whether the victim is dead or alive.

Autopsy signs of suffocation

Where smothering is suspected, local signs must be sought to try to substantiate pressure on the face. Such signs include bruising around the mouth, chin and nose, though these are rarely seen except in the more violent incidents. Pressure of the lips on the teeth or dentures may cause the buccal surfaces to be bruised or abraded, though lacerations are rare unless a blow has been administered. It must be remembered that as small infants and many old people have no teeth, these injuries are less likely. The dangers of accepting areas of facial pallor as 'pressure marks' when the face shows post-mortem hypostasis has already been mentioned. In the early stages of post-mortem discoloration of the skin, variable colouring may not be truly 'hypostatic' as mottling and patchy variation is common due to uneven vasodilatation after death. It takes some time for gravity to pull cutaneous blood down to lower levels.

Smothering may occur accidentally where a person who is incapacitated from one of a variety of causes lies face down on a surface that is impervious to air. Drunkenness, epilepsy, drug overdose, coma or stupor from natural disease, may lead to this. Though it has long been proved in connection with 'cot death' that woven fabrics of most types can still admit enough air to support quiet respiration when placed over the mouth and nose, fabric that becomes saturated with saliva, nasal mucus or vomit may form an impervious seal that ceases to allow the passage of air. The weight of the inert head also distorts the nose and presses the nostrils and mouth so hard against a mattress or pillow that this adds to the airway stenosis.

In these instances, congestion and cyanosis are common, but when the body is examined after death, some of these findings may be postural and hypostatic in nature. As always, however, it must be recognized that skin haemorrhages often appear post-mortem in dependent hypostasis.

Gagging

Smothering may also occur where a pad or gag is fixed over the face, as sometimes happens in robbery with violence. A householder, caretaker or night-watchman may be tied up and silenced by having a scarf, tie or other fabric tied around his face. At first this admits air, but when it becomes progressively soaked with saliva or mucus it may become impervious and lead to an asphyxial death, again usually without any petechiae in the face or eyes.

A similar situation arises when a gag is thrust into the mouth to silence a watchman or security officer. Another variant is adhesive tape applied over the mouth. Though the nasal airway may originally be quite patent, any later obstruction from oedema and mucus, or movement of the gag backwards into the nasopharynx, may cause an unforeseen death and turn a robbery charge into a homicide.

CHOKING

This term refers to blockage of the internal airways, usually between the pharynx and the bifurcation of the trachea. Death can be the result of pure hypoxia from occlusion of the airway, when all the attendant signs of congestion, cyanosis and perhaps petechiae may be present, usually where the victim struggles to breathe for an appreciable period. As described below, however, a large proportion of deaths occur suddenly before any possible hypoxic manifestations have time to take effect; these fatalities must be caused by neurogenic cardiac arrest, either purely neurogenic or accelerated by excess catecholamine release from the adrenaline response.

Causes of choking include the following.

Foreign bodies

Objects such as gags, dummies, small toys, table-tennis balls and a multiplicity of objects may be placed in the mouth and inhaled, usually by children and the mentally retarded. Occasionally adults will do the same, accidentally or by design; an example of the latter was a suicide seen by the author (BK), who died (without any asphyxial signs whatsoever) by pushing a closed pill-bottle into his pharynx.

Dentures and haemorrhage

False teeth (especially partial plates), extracted large teeth, blood clots, and frank haemorrhage following dental or ear, nose and throat operations such as tonsillectomy.

Acute obstructive lesions

Lesions of the glottis or larynx, such as the oedema of acute hypersensitivity (including insect stings), irritant vapours, inhalation of hot gas and acute infective conditions. The most dangerous of the latter is diphtheria or *Haemophilus influenzae* epiglottitis in children, which is a medical emergency sometimes requiring an immediate tracheostomy to relieve the airway obstruction. At autopsy, great thickening of the epiglottis and aryepiglottic folds by jelly-like oedema and inflammatory tissue will be found occluding the entrance to the larynx.

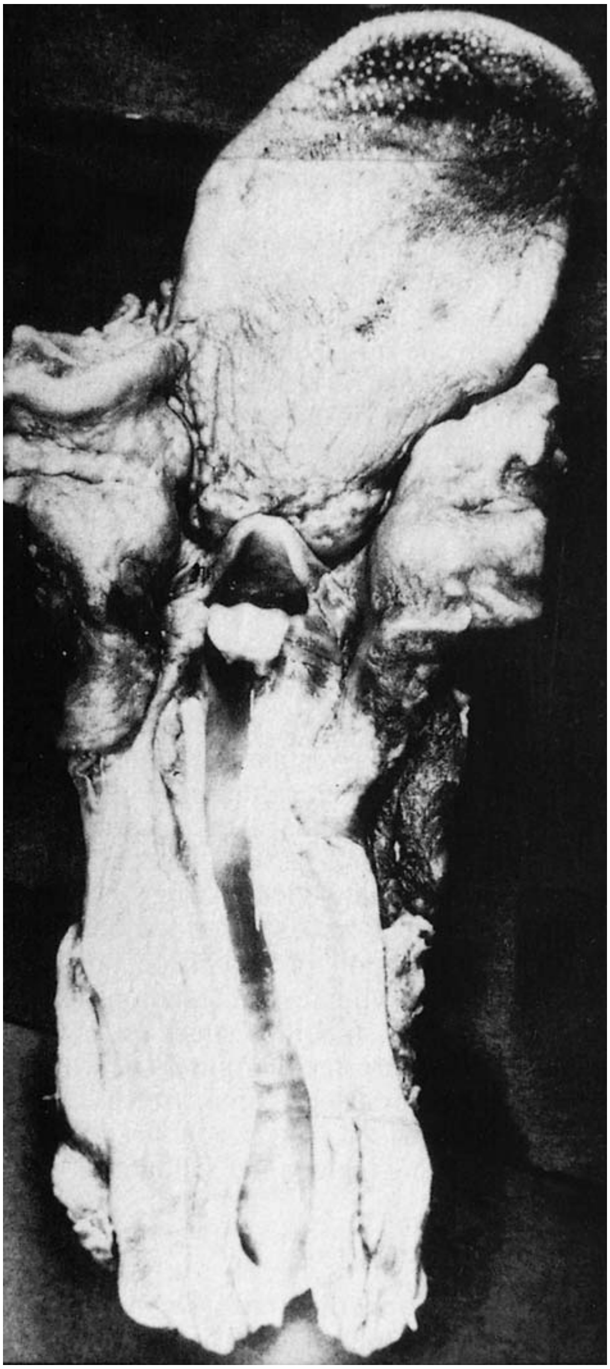

FIGURE 14.8 *Impaction of an extracted molar tooth in the larynx. Though now uncommon with modern dental and anaesthetic practices, it can still happen in less satisfactory circumstances. Blood clot from dental extraction, tonsillectomy, and other ear, nose and throat surgery can also block the airway.*

Food material

This is an important topic, as the cause of death ‘aspiration of vomit’ is used too often without real justification. Food

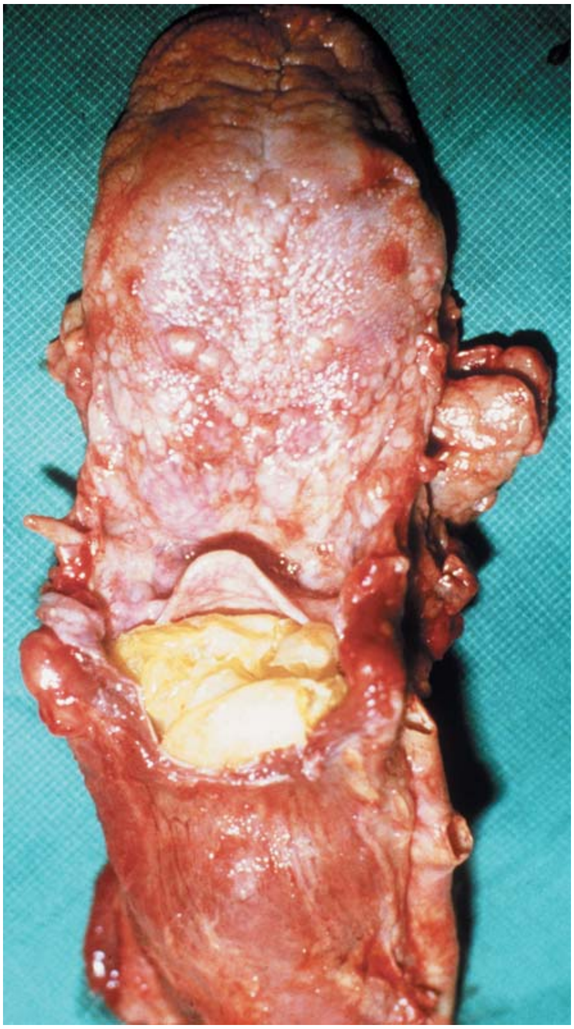

FIGURE 14.9 *Blockage of the larynx by a complete small orange in a mentally disturbed patient. The fruit had just been swallowed and was not regurgitated from the stomach. The face was pale and death was rapid, unaccompanied by symptoms of choking.*

may be drawn into the larynx either as it is being taken down from the mouth in the act of swallowing, or it may be regurgitated from the stomach.

- The first instance is rarely misinterpreted, as whole undigested food may be found in the air passages and there is usually a history of death taking place while eating. Though most commonly encountered in old persons and the mentally disturbed, it can occur in any age group. A notable example was the so-called 'café coronary' syndrome, which received considerable publicity in the USA some years ago. The most frequent victims were well-nourished businessmen, who died suddenly and unexpectedly during a meal with no signs of respiratory distress or any of the 'classic signs of asphyxia'. Initially thought to be coronary heart disease, autopsy revealed a bolus of food, often steak, lodged in the pharynx or larynx. In any choking on food, the bolus can be quite large, such as a whole pancake, a whole tangerine or masses of meat, fruit or vegetable. Senile persons in retirement homes and mentally retarded children in institutions are also vulnerable. In such fatalities, the history and mode of death gives no hint of a hypoxic mechanism. Many cases have been observed where the victim merely sits back in their chair, dead – the mode clearly being cardiac arrest, presumably from overactivity of the parasympathetic nervous system from stimulation of the laryngeal or pharyngeal mucosa – the so-called 'vasovagal reflex' or 'reflex cardiac inhibition'.
- The finding of gastric contents in the air passages is by no means as significant as the presence of freshly swallowed food. First, difficulties can arise in distinguishing gastric contents from fresh food material if digestion of the former has not proceeded far – which is not always a function of the time since the last meal, as any physical or psychological disturbance can retard or completely halt digestion. The history, if available, is a better guide, unless the material is obviously partly or wholly digested. In cases of doubt, the smell and acid reaction to pH indicators may be useful.

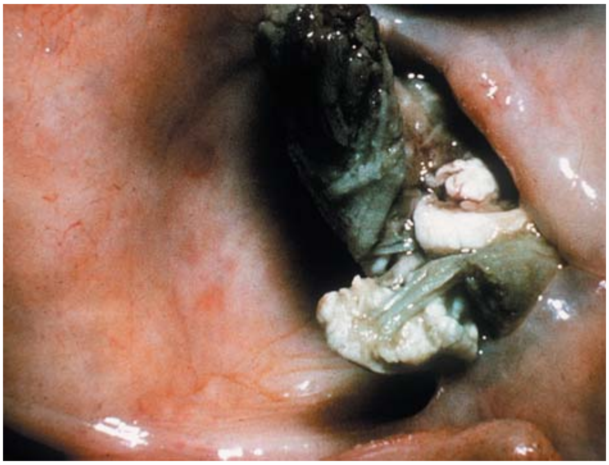

FIGURE 14.10 *Blockage of the larynx by meat. The victim was an old person with senile dementia who gulped food and who eventually died suddenly without asphyxial signs from reflex cardiac arrest.*

Gastric contents are commonly found in the larynx, trachea and bronchi at autopsy when no other evidence of aspiration exists, and when there is a clear and unconnected cause of death. Knight (1976) found that no less than a quarter of a series of 100 consecutive autopsies on both adults and children contained some gastric contents in the air passages, and Pullar (1984) observed that this was a low figure compared with his series. These findings were obviously caused in the great majority of cases by agonal or post-mortem spillage.

Gardner (1958) described experiments in which barium was placed in the stomachs of recently dead patients while still in bed in the hospital wards. When X-rays were taken after they were first moved to the mortuary and thence into the autopsy room, most had barium in their tracheobronchial tree, confirming that overspill was common as a post-mortem phenomenon. Even histological evidence of leucocyte clustering around foci of gastric contents deep in the bronchi was shown by Gardner to be an early post-mortem event, not a 'vital reaction'. Leucocyte migration in the skin up to 16 hours post-mortem was demonstrated by Ali (1986).

Almost the only definite evidence of aspiration of gastric contents is either reliable witnessed observation during life or the histological finding of an advanced 'vital reaction' with infection, necrosis and a definite inflammatory reaction. This is a relatively late change and cannot be seen where death occurred within a few hours of aspiration. Finding a few foci of leucocytes around a bronchiole is of no evidential use. There is therefore no reliable method of distinguishing agonal or even early post-mortem overspill from true vital aspiration, unless clinical or other witnessed evidence is available. In most instances, it is not justifiable for a pathologist to claim that death was caused by inhalation of stomach contents without such confirmatory evidence. Unfortunately, where other lesions are absent or unconvincing at autopsy, especially in the sudden infant death syndrome, many pathologists use the presence of gastric contents in the air-passages as the primary and often the only cause of death. This unwarranted assumption may have distressing consequences, both in the field of medical negligence, deaths in custody and especially in the sudden infant death syndrome, where mothers may be misled into thinking that some negligence on their part in failing to observe vomiting, may have caused the death.

The only circumstance where a firmer opinion may be held is in acute alcoholism, though even here certainty is usually elusive. Where an undoubtedly drunken person (usually with a blood alcohol of at least 150 mg/100 ml) is found dead with massive blockage of his air passages by copious gastric contents and where other causes of death can be excluded by autopsy, then it might be reasonable to assume that regurgitation may have killed him, especially if there is other evidence of external vomit on the clothing or immediate surroundings. However, it is not an autopsy diagnosis to be made lightly.

TRAUMATIC 'ASPHYXIA'

This condition is unfortunately misnamed, as the word 'traumatic' could equally be applied to hanging or strangulation. It is well recognized now, however, as meaning mechanical fixation of the chest, and is important both because of its frequency in accidents and because it provides the most extreme demonstration of the 'classic signs' of asphyxia.

Whereas other types of mechanical asphyxia may cause obstruction of air entry into the lungs, 'traumatic asphyxia' acts by restricting respiratory movements and thus prevents inspiration. It was termed 'traumatic' because gross mechanical forces are usually the reason for the fixation of the thoracic cage. Traumatic asphyxia occurs in two main conditions:

- The chest and usually the abdomen are compressed by an unyielding substance or object, so that chest expansion and diaphragmatic lowering are prevented. Burial in earth following the collapse of an excavation is a common cause and may kill workmen even if their heads remain above the fallen soil. Similarly, burial in grain, sand, coal or minerals, may have the same effect, and is usually encountered in industrial, marine or agricultural accidents. An avalanche in a silo, hopper, or other large-scale storage container may bury the worker up to neck level and, unless rescue is rapid, asphyxia will prove fatal. Similar restriction of chest movement may be caused by the victim being pinned under an overturned vehicle, or by falling timber or masonry. Many fatalities have occurred on farms, especially in hill country, by the toppling of a tractor, pinning the driver underneath. Protection in the form of a 'roll-bar' over the driving position or the provision of a rigid cab on a tractor was specifically designed to avoid such accidents.
- Crushing in crowds also leads to traumatic asphyxia, and this has caused some mass disasters, the largest probably being in Mecca. Most of the football-ground tragedies such as Bolton, Ibrox Park (1971), Lima (1964), Hillsborough (1989) and the Heisl Stadium in Belgium (1986) have been the result of crushing in crowds out of control. A similar mechanism led to 173 deaths in wartime London, when a panic on the stairs of Bethnal Green underground station, used as an air-raid shelter, caused the crowd to fall on those beneath.

Other forms of chest crushing arise from trapping between a vehicle and a wall, or between the buffers of two railway trucks.

Individual cases of traumatic asphyxia can occur when one person allows the whole weight of his body to fall upon another for a protracted period. This may happen in sexual intercourse, especially when one or both parties are incapacitated by drink or drugs.

Features of traumatic asphyxia

The appearances just mentioned are the hallmark of traumatic asphyxia and in no other condition, apart from postural dependency, is the degree of congestion and cyanosis so marked. When the chest is fixed, the face, neck and shoulders down to the thoracic inlet are grossly discoloured. Sometimes this colour is more red than purple. It can extend lower than the clavicles, Polson *et al.* (1985) being of the opinion that it often reaches down to the level of the third rib.

The conjunctivae are grossly congested and haemorrhagic. Rather than the petechiae seen in pressure on the neck, the conjunctivae and sclera may be so engorged with blood that the haemorrhagic tissue actually bulges out through the lids, completely obliterating the whites of the eyes. The face, lips and scalp may be swollen and congested, being dotted with petechiae and ecchymoses. There may be copious bleeding from the ears and nostrils. The whole picture is commonly an exaggeration of the appearances seen in slow death from manual strangulation, but local injury is absent and the signs extend down to or beyond the root of the neck. Where the compression has been caused by pinning under a solid object – as opposed to soil, sand or squeezing in a crowd – there may be local bruises and abrasions from the weight of a vehicle or heavy beam, but these are unrelated to the margin of the congestive–haemorrhagic zone.

Internally, the congestion is less marked than on the surface, but the lungs are usually dark and heavy and may well have subpleural petechial haermorrhages, the true 'Tardieu spots'. The right heart and all the veins above the atria are markedly distended. There may be injuries to the chest wall from the trauma of the fixating object.

It is not clear why there should be such gross venous congestion, but it is usually explained rather unconvincingly by the failure of the pulmonary circulation consequent upon the cessation of the normal expansion and collapse of the pulmonary vasculature. Shapiro suggested that the pressure on the chest forces blood back into the great veins and, as the venous valves in the subclavian vessels prevent displacement into the arms, the extra volume is forced up the valveless jugular system to congest the head and neck.

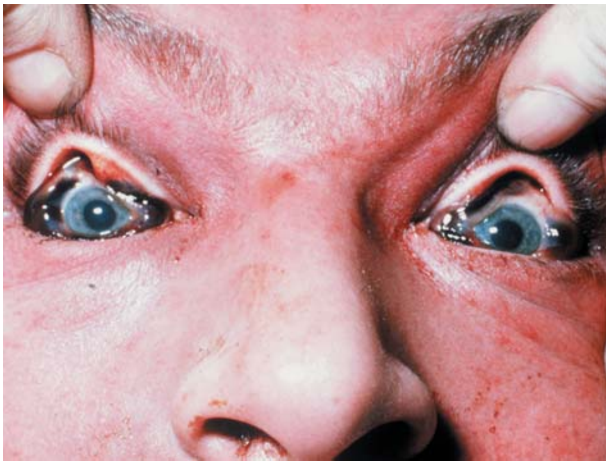

FIGURE 14.12 *Gross conjunctival haemorrhages in traumatic asphyxia. The victim was a workman who was buried up to his chest in an avalanche of ash.*

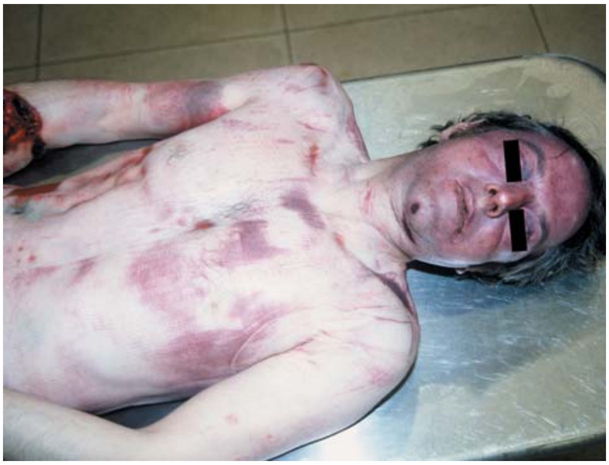

FIGURE 14.11 *Traumatic asphyxia showing gross congestion of confluent petechial haemorrhages of the face and parts of the shoulders. The victim had been buried up to the axillae in an avalanche of iron ore in a factory bunker.*

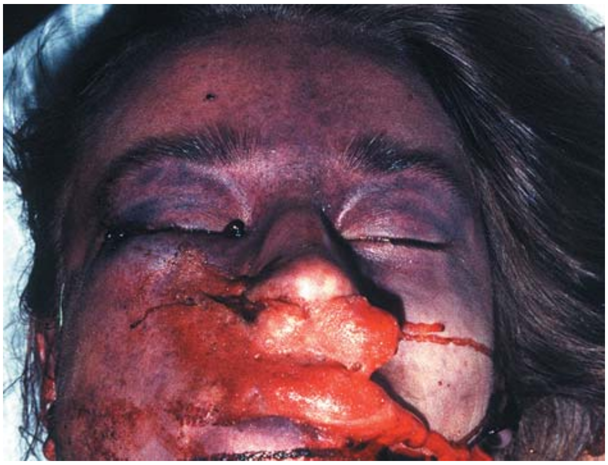

FIGURE 14.13 *Traumatic asphyxia showing gross congestion of the face and red blood-tinged froth exuding from the nostrils and mouth. The victim had lost the control of the tractor he was driving, fell out of the cab and was compressed under the overturned vehicle.*

POSTURAL ASPHYXIA

Closely allied to traumatic asphyxia is the so-called 'postural asphyxia', whose description as a separate entity is quite recent. When a person remains in a certain position for an extended time, either due to being trapped, or being in a drunken or drugged state, there may be a mechanical impediment to adequate respiratory movements. In addition, the normal venous return to the heart may be impaired.

Such positions usually entail inversion, either of the whole body or of the upper half; the syndrome and the pathophysiology are described well by Madea (1993), though most forensic pathologists will have had experience of such situations from time to time.

Persons who have been trapped upside down or even only in a 'jack-knife' position, with the upper half of their body bent acutely downwards from the waist, may have such impairment of their respiratory movements that they become hypoxic and suffer marked disturbance of their circulatory system, especially the venous return to the heart.

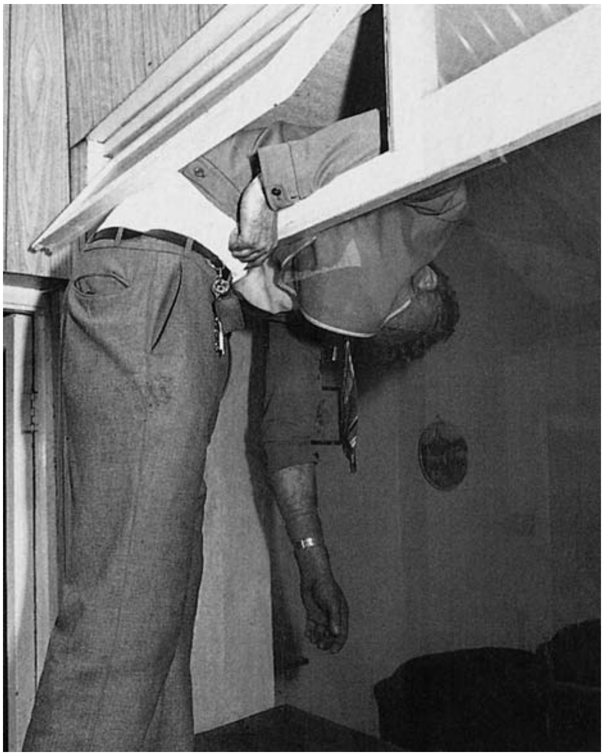

FIGURE 14.14 *Postural asphyxia in an inebriated man attempting to climb through a fanlight window. His feet slipped from the sill and he was unable to make sufficient respiratory movements against the weight of his body. Note the marked difference in congestion and cyanotic lividity between his two hands, the face and lower hand being discoloured at least partly from post-mortem hypostasis.*

The author (BK) has seen two cases in which a victim has become stuck whilst trying to climb through the upper part of a window, one as a thief, the other in trying to get into a house without his key. Others have been seen where, in a state of drunkenness or other disability, they have slipped out of bed, so that their head and shoulders are on the floor, with the legs and pelvis still at a higher level on the bed. These may also suffer the same disturbance of respiratory movements, which when prolonged may lead to death.

Inversion may occur during torture: crucifixion has an element of postural asphyxia. In the case of inverted crucifixion, as in the death of St Peter, it would be the major factor, as inspiration would be impeded by the weight of abdominal viscera upon the diaphragm.

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CHAPTER 15

Fatal pressure on the neck

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This provides one of the most complex and controversial areas of 'asphyxial' deaths, as the mechanism is uncertain and the frequency of such deaths makes them a common problem for both forensic pathologist and jurist.

Pressure on the neck may arise from manual strangulation, ligature strangulation, hanging, direct blows, arm-locks and a variety of accidental lesions, such as entanglement with cords or falling onto the neck.

Strangulation was formerly thought to be a pure asphyxia as a result of 'cutting off the air' by occlusion of the airway during the constriction of the neck. Since the end of the nineteenth century, however, it has been recognized that the rapidity of death in many cases made it impossible for hypoxia to be the sole or even major cause. Many victims died almost immediately and exhibited none of the so-called 'classic' signs of asphyxia.

Others, though showing these signs, still died too quickly for it to be reasonably argued that lack of oxygen had proceeded to a fatal stage. It was common knowledge that most people could hold their breath for over a minute and that some pearl divers could be physically active and yet not breathe for at least 3 minutes, so the much more rapid onset of death seen in many cases required further explanation.

MECHANISM OF DEATH IN PRESSURE ON THE NECK

A number of anatomical and physiological factors must be considered in analysing the effects of pressure on the neck.

Airway occlusion

This may occur either from direct compression of the larynx or trachea, or from a lifting of the larynx so that the pharynx is closed by the root of the tongue being pressed against the soft palate and roof of the mouth. The latter explanation is far more likely, as the strong cartilages of the larynx will resist all but the most extreme compression. Various experiments have been attempted to quantify the force needed to close the airway and blood vessels, but it is difficult to translate the often conflicting results to the degree of violence actually used in fatal events. For example, Brouardel (1897) calculated that the force needed to close the trachea was of the order 15 kg, far more than that required to occlude the blood vessels.

Occlusion of the neck veins

This factor is almost solely responsible for the appearance of the 'classic' signs of congestion, cyanosis, oedema and petechiae above the line of constriction. The external jugular system is most vulnerable, but any significant pressure encircling the neck will also obliterate the lumen of the internal jugular system, causing a rapid rise in venous pressure in the head, especially if the carotid arteries are still patent, which is usually the case. Brouardel's experiments suggest that a ligature with a tension of 2 kg blocks the jugular return; Reuter (1933) found an even lower figure.

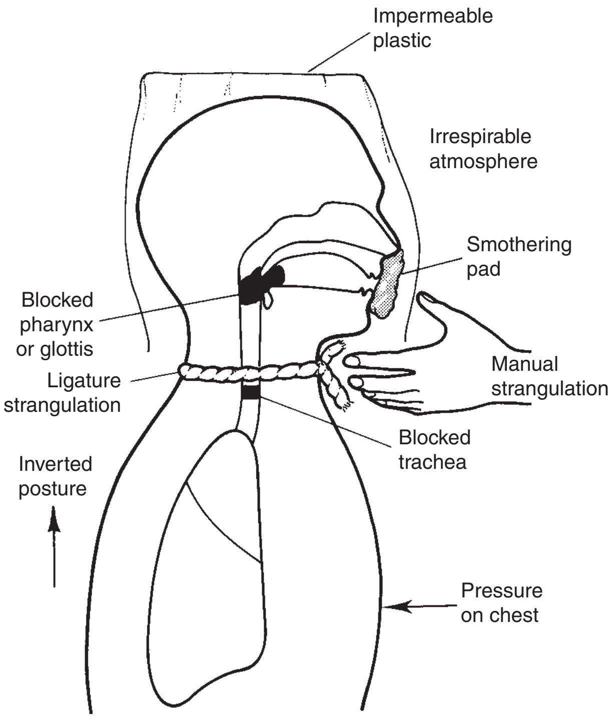

FIGURE 15.1 *Causes of mechanical asphyxia.*

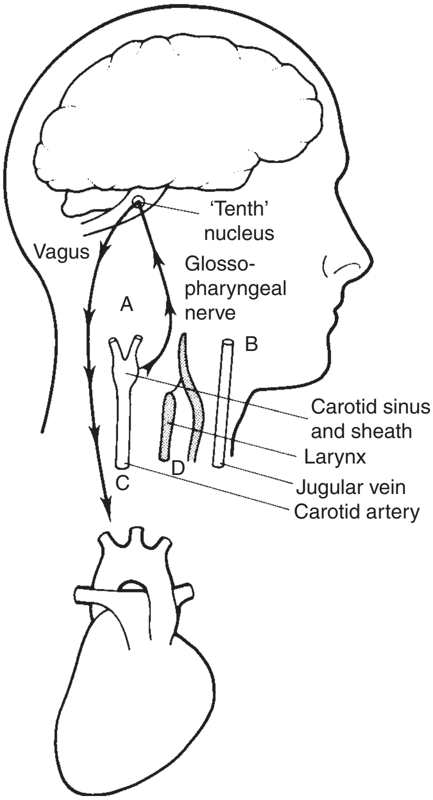

FIGURE 15.2 *Possible effects of pressure on the neck: (A) carotid sinus reflex leading to cardiac arrest; (B) jugular venous compression leading to cyanosis and petechiae; (C) carotid artery compression leading to unconsciousness; and (D) airway obstruction leading to hypoxia.*

Compression of the carotid arteries

This is much less common than venous occlusion, as the higher internal pressure of the carotid arteries resists occlusion and they are situated much more deeply. The carotids are largely obscured by the sternomastoid muscles. If bilateral occlusion of the carotids is achieved, almost immediate unconsciousness will ensue, as the supply of arterial blood to the brain by the vertebral circulation is insufficient to maintain cortical function, which depends mainly upon the anterior and middle cerebral arteries that arise from the carotid supply. Occlusion of the vertebral arteries by neck compression seems virtually impossible despite some claims to the contrary.

If the carotid circulation is totally occluded for an unremitting period of 4 or more minutes, then irreversible cerebral damage may occur. The time for this to happen is variable and the minimum has been disputed for many years, but the consensus of opinion is that permanent brain damage is very unlikely if the supply has been cut off continuously for less than 4–5 minutes. Total recovery has often been recorded after total ischaemia of considerably longer than this, even in normothermic conditions, with 9–14 minutes being quoted. Where the body has been subjected to low temperature, far longer times have been recorded, including an anecdotal case of a boy falling into the cold water of a Scandinavian harbour and being totally submerged for 40 minutes, with total recovery of cardiac and cerebral function.

Nerve effects

Pressure on the baroreceptors situated in the carotid sinuses, the carotid sheaths and the carotid body, can result in bradycardia (slowing of the heart), or in total cardiac arrest. This is an example of the physiological mechanism that monitors and adjusts blood pressure and heart rate.

This mechanism acts through a reflex arc in which the afferent (sensory) nerve impulses arise in the carotid complex of nerve endings, but not – as is sometimes alleged – in the vagus nerve trunk itself.

These impulses pass up to the brain via the glossopharyngeal nerves to the tenth nucleus in the brainstem, then return via the vagus (efferent) supply to the heart and other organs. This reflex arc acts through the parasympathetic side of the autonomic nervous system and is independent of the main motor and sensory nerve pathways. It is often claimed, admittedly without much concrete evidence, that fear, apprehension, struggling and possibly the effect of drugs such as alcohol, may heighten the sensitivity of this vagal mechanism. The release of catecholamines during such adrenal responses may well sensitize the myocardium to such neurogenic stimulation.

The vagal reflex has profound implications in relation to pressure or blows on the neck. Sometimes called 'vagal inhibition', 'vasovagal shock' or 'reflex cardiac arrest', the rapid onset of heart stoppage may antedate any evidence of congestive or 'asphyxial' signs, causing death immediately or within seconds, or at any time thereafter.

It is a matter of some dispute as to whether this reflex can cause immediate cardiac arrest or whether there has to be a period of marked slowing of the heart with negligible cardiac output – or whether an arrhythmia such as ventricular fibrillation precedes such an arrest. Probably any combination can occur, but it is an indisputable fact that collapse and apparent death can occur immediately on the application of pressure to the neck. Overstimulation of nerve endings in the carotid sinus or adjacent arterial sheath may be brought about by direct pressure from fingers, or from a ligature during strangulation or hanging – or from a blow directed at the side of the neck. Severe pain, such as a blow on the larynx or genitals, may also trigger a 'vagal response'.

THE FREQUENCY OF VAGAL CARDIAC ARREST

Though different authors vary in the proportion of such deaths that they attribute to reflex cardiac arrest, they all admit to the existence of such a mechanism. In the author's (BK) own series of fatal pressure on the neck from a variety of causes, the 'classical signs', denoting vascular and perhaps sometimes airway obstruction, were present in slightly less than half the cases. The remaining deaths presented with an absence of congestion, cyanosis and petechiae, the pale faces indicating that cardiac arrest had taken place before the congestive signs had time to appear.

One aspect which is uncertain – and virtually incapable of experimental proof in humans – is whether vagus-mediated cardiac arrest can be spontaneously reversible. Where an arrhythmia leads to arrest, resuscitation by cardiac massage or direct current electrostimulation has an excellent chance of revival – though in most forensic situations, such assistance is often lacking or too late.

However, it is not known whether cardiac arrest caused by the vasovagal reflex, can spontaneously revert to normal rhythm some minutes later – or whether it inevitably leads to death if no timely resuscitation is offered. This may have forensic relevance, as the author (BK) has been involved in several cases where pressure on the neck has lead to a comatose, but heart-beating victim, who later dies on artificial ventilation from irreversible brain damage. In the absence of medical data, the problem then arises as to whether the brain damage was caused by prolonged carotid artery occlusion from neck pressure – or was the result of a momentary neck pressure which caused reflex cardiac arrest, with spontaneous reversion to normal rhythm more than five minutes later, by which time irreversible cerebral damage had occurred.

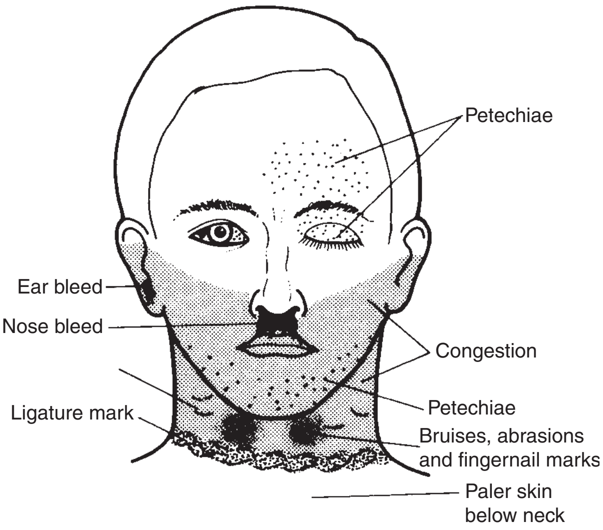

FIGURE 15.3 *Classical features of strangulation when cardiac arrest is delayed.*

Medico-legal aspects

This phenomenon has considerable legal as well as medical significance, as sudden death from 'vagal inhibition' can occur with total unexpectedness even with relatively slight pressure to the neck. Keith Simpson and Polson recorded cases many years ago in which a soldier at a dance playfully 'tweaked' his partner's neck and was mortified to see her drop lifeless to the floor. Many such cases are on record and every forensic pathologist of any experience has examples in his own records. Where it can be shown that the death occurred rapidly and without prolonged manual gripping of the neck, the defence may be raised that neither death nor serious injury was contemplated by the accused. It would be much harder to establish this lack of intent if the grip was maintained long enough to lead to florid congestion and petechiae in the face.

A combined mechanism of injury and the duration of neck compression

It is important to remember that the cardiac arrest mode of death may be mixed with the congestive–petechial mode in that, though the first stages of pressure may continue for long enough for congestive–asphyxial signs to appear (perhaps a minimum of 15–30 seconds), a change in grip may then allow the fingers to impinge on the carotid structures and lead to reflex cardiac arrest. Thus the progression of the pure ‘asphyxial’ process may be abruptly terminated at any point along its pathway to death by the superimposition of ‘vagal inhibition’, so that the intensity of the congestive changes may be of any degree in any given death.

The duration for which pressure must be maintained is often a contentious issue in criminal trials, as the ‘inadvertent squeeze’ which causes rapid vasovagal cardiac arrest is likely to be viewed as less culpable than a prolonged, unremitting gripping of the throat.

It is virtually impossible to measure the average minimum time of gripping that will produce congestion, cyanosis and petechiae from venous occlusion. As so often is the case in forensic medicine, animal experiments are useless for this purpose and obviously few cases of strangulation homicide are ever reliably witnessed, especially by some dispassionate observer with a stopwatch! Even in non-fatal cases – which incidentally, can produce far more florid examples of facial and eye haemorrhages than deaths – there is almost never any independent, accurate measurement of the time for which the neck was compressed.

It has been arbitrarily suggested that 15–30 seconds is probably the minimum period which will give rise to petechiae in the eyelids, conjunctivae and facial skin, but this really is ‘picking a figure from the air’, with little scientific justification.

Some years ago, the British Home Office and the Royal College of Pathologists set up a small working party to study this problem, composed of several experienced forensic pathologists and a respiratory physiologist – but the project was soon abandoned because of a total lack of reliable data.

Though it is easy to demonstrate that facial congestion develops within a few seconds of total jugular occlusion, petechiae – the only lasting sign after the venous return is re-opened – do not appear as quickly from neck pressure. However, they can occur from sudden, transient rises in venous pressure, such as sneezing or coughing – whooping-cough is a well-known example – and during the Valsalva experiment of forcibly trying to expire against a closed glottis. Eye petechiae and retinal haemorrhages can also occur during the chest compression of energetic cardiac massage during resuscitation.

CAUSES OF REFLEX CARDIAC ARREST

Vagal inhibition of the heart from stimulation of the carotid neural complex may occur in any form of pressure on the neck, but is much more common in manual strangulation than with a ligature, hanging excepted. Fingers seem more prone to dig deeply and find the structures under the anterior edge of the sternomastoid muscle. Perhaps the movements of the fingers, especially during the shifting postures of a struggle, more readily impinge upon the carotid bifurcation than the more static position of a ligature.

The majority of hangings, however, present with a pale face, free from congestive–haemorrhagic signs.

This seems to be caused by the more precipitate impact of the noose on the carotid structures when the victim’s weight abruptly bears down, though Polson favoured actual carotid occlusion and hence cerebral ischaemia as the common cause of death in hanging. The scarcity of carotid intimal damage in suicidal hangings does not favour this view.

Blows to the throat

Another cause for sudden cardiac arrest is a blow to the neck or throat. This is the basis of the so-called ‘commando punch’ and some of the oriental martial arts also contain this in their repertoire – often forbidden because of its potential lethality. The edge of the hand is brought forcibly across the side of the neck or the front of the larynx.

Direct violence to the carotid region naturally causes gross stimulation of the afferent nerve endings. Blows directly to the larynx indirectly stimulate the sinus region or the laryngeal sensory nerve endings may themselves trigger the cardio-inhibitory reflex.

It is well known that the hypopharynx and larynx are particularly sensitive to stimulation, which accounts for the sudden deaths from impaction of food in the larynx, or from the flooding with cold water that causes some sudden immersion deaths. The testicles and uterine cervix also have a similar reputation for leading to sudden cardiac death, if unexpectedly overstimulated, especially when the myocardium is presensitized by catecholamines released by fear or emotion.

MANUAL STRANGULATION

A common method of homicide, manual strangulation is most often encountered when the physical size and strength of the assailant exceeds that of the victim. It is most commonly seen in domestic homicides when a husband kills his wife, in sex-related murders when the victim is again a woman, and in child killings, when the killer is an adult. Manual strangulation is rarely committed by a woman except on a child and a man rarely kills another man of equal physique.

Autopsy appearances in manual strangulation

The autopsy findings fall into two groups, namely, the local signs of violence, and the signs of the mechanism of death, where discernible.

- Bruising on the neck is the result of the assailant’s attack, whereas abrasions may be from either victim or

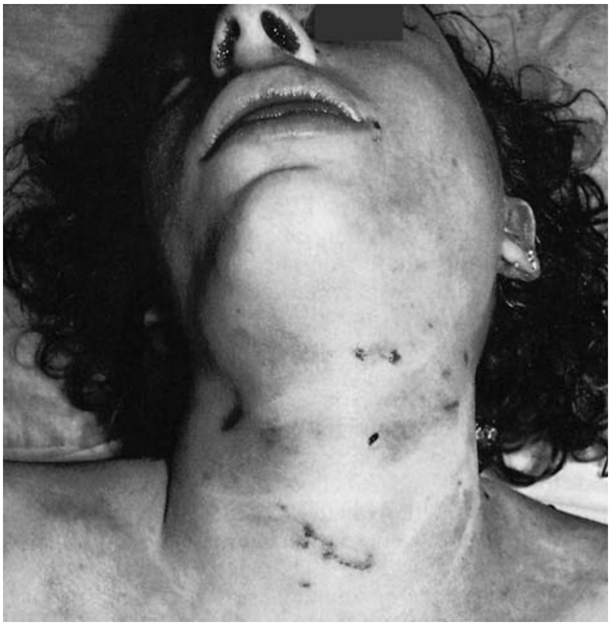
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FIGURE 15.4 *Classical manual strangulation with fingernail marks and abrasions on the neck, congestion of the face, slight protrusion of the tongue and bleeding from the nose.*

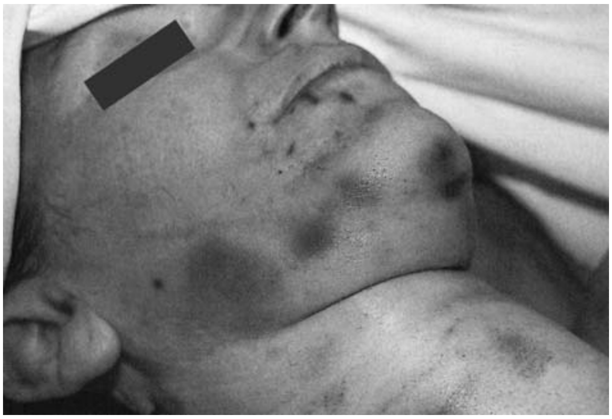
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FIGURE 15.5 *Bruising on the neck and jaw margin in manual strangulation. Separate bruises along the jaw are due to high finger pressure – where a larger area of abrasion or bruising is present in this region, consideration must be given to pressure from an arm-lock.*

assailant. The bruises are mainly discoid, but may run together into larger areas of confluent bruising. The discoid marks are from finger-pads and are about 1–2 cm in size, though where the fingers skid across the skin surface, longer, irregular marks may occur, especially along the jaw margins. The bruises tend to cluster at the sides of the neck, often high up under the angles of the jaw. Some may overlap the jaw line and trespass on the chin, but others can be lower on the neck spreading down to the inner ends of the clavicles.

As a result of the shifting grip, often caused by the struggles of the victim, bruising can be anywhere, even at the posterolateral sides of the neck, and on the upper chest over the sternum and collar bones. Some may be seen in the grooves on either side of the larynx, over the anterior edge of the sternomastoid. They are also common over the prominence of the larynx and at the level of the cricoid.

As in most of the cases seen by a pathologist, death will have taken place at or about the time of the attack, most bruises will be fresh, being dark red or purple. Some may be so severe as to form actual superficial haematomas raised slightly above the skin surface. Bruises may often be seen in an asymmetrical pattern, with just one or two on one side of the neck, and a larger group on the opposite side. This may well suggest that a thumb was applied on one side and a group of fingers on the other; this may well be correct, but is not necessarily so and may be fortuitous if a shifting grip caused several reapplications of fingers.

It is sometimes tempting to use such asymmetrical grouping to decide ‘handedness’, that is to suggest that one bruise on the right side of the victim’s neck and a group on the left means that a right-handed assailant gripped from the front. The grouping may not be genuine, however, and because it can be fortuitous, it cannot be definitely determined that it was the right hand nor that it was not placed around the neck from the back. Overinterpretation must be avoided, as in all fields of forensic medicine and ‘Sherlock Holmesian’ opinions as to the handedness, size of hand, and orientation of attacker and victim in strangulation must be suitably restrained if both justice and the credibility of pathologist are to be preserved.

- Abrasions on the neck: scratches may be caused by the assailant or the victim, usually from fingernails. As with bruising, rough finger-pads (especially from a male hand on the delicate skin of a female neck) may abrade the epidermis and underlying bruises may be overlain by diffuse abrasions, again often seen along the margin of the jaw line.

Linear scratches are the hallmark of fingernails and, when a woman strangles a child, the often longer nails of the woman may leave obvious marks. Whether male or female, the scratches are of two types: when the pressure is static, straight or curved marks up to a centimetre in length are made; when the nails skid down the skin, linear lines may result, sometimes several centimetres in length.

A static nail mark is often semi-lunar in shape, but caution must be used in interpreting the posture of the hand from this shape. Though it would seem obvious that the concavity of the mark should face the finger-pad, experiments by Shapiro *et al.* in 1962 showed that the converse may be true. This is caused by fixation of the skin at the centre where the nail digs in, with escape at the margins, so that when the traction relaxes, the mark appears inverted, with the convexity facing the finger-pad. However, experiments by others, including the author (BK), show that this phenomenon is by no means invariable and often the marks are the result of the nails being applied in the expected direction.

Scratches are the result of the victim's attempts at pulling away the strangling hand. As most victims are women, the nails may be long and the scratches more severe than those from the assailant, which are often absent altogether. These defence scratches may run in parallel lines from grouped fingers and run in a vertical direction in the long axis of the neck, though they are often random.

In the autopsy on a strangled victim it is good practice to take fingernail scrapings or clippings for full forensic science investigation. These should be preserved and labelled so that each clipping or scraping is individually identified – or failing that, at least the left- and right-hand material should be kept separate. Skin fragments or blood under these nails may provide blood typing or DNA characteristics that can be matched to an alleged assailant – and other valuable trace evidence, such as hairs and fibres might be trapped in a torn fingernail – though admittedly, the number of occasions when such evidence has been gained is extremely small.

The alleged assailant should always be examined medically to correlate any injuries that may have been inflicted on him by the fingernails of the victim, such as facial or hand scratches. If he is examined soon after the offence, his own fingernail scrapings should be taken, especially if the victim has neck abrasions, so that comparison studies can be made between any debris found and the tissue types of the victim.

Internal appearances in manual strangulation

Internally, the bruises described above may be visible to a greater or lesser extent in the tissues of the neck. Often they are quite superficial and are confined to the dermis, but some may be visible to an appreciable depth in the muscles and other structures in the neck.

The platysma muscle may be bruised, but the sternomastoid and the deeper strap muscles that run vertically along the larynx may show patchy bleeding, not always corresponding exactly to the position of surface bruises. They may contain infiltrated blood or even frank haematomata, especially the sternomastoid.

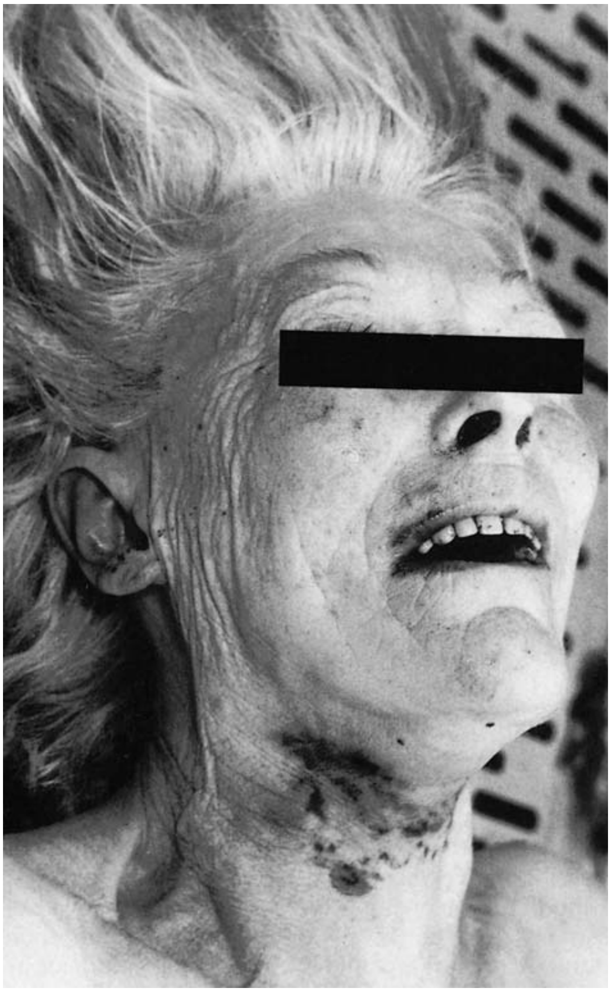

FIGURE 15.6 *Manual strangulation with bruising from the assailant and fingernail abrasions from the victim. The face is pale as a result of rapid vasovagal cardiac arrest before congestive signs could develop.*

At autopsy, it is essential to release the blood in the venous system before dissecting the neck to avoid or reduce artefactual haemorrhages that can occur in the region. It may be easiest to reflect the scalp and remove the brain before dealing with the neck, to release venous engorgement. Alternatively, after the skin of the neck has been carefully flayed off in a wide 'V' incision, the internal jugular vessels can be incised before any further manipulation to release the venous pressure, but removal of the skull is preferable.

Radiography of the neck may be carried out before any dissection to determine the state of the cervical spine and the laryngeal cartilages, though the author (BK) has never found this to be particularly helpful, preferring to X-ray the isolated larynx before dissection.

When examination of the deep neck structures begins, careful removal of the overlying tissues layer by layer is required, seeking genuine haemorrhage as each set of muscles is exposed. There may be bruising into the thyroid capsule and into any of the strap muscles. The vascular bundles must be handled carefully and the large veins opened with scissors. The carotids can be opened *in situ*, or after the laryngo-oesophageal pluck has been removed.

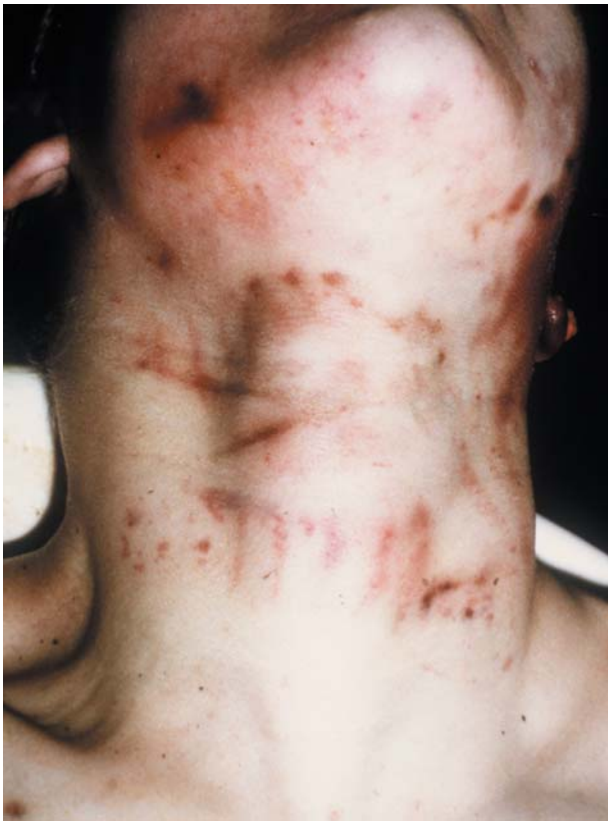

FIGURE 15.7 *Manual strangulation, showing scattered bruises from the fingers of the assailant, but also a pattern of abrasions under the chin and below the larynx, caused by the nails of the victim whilst attempting to pull off the strangling fingers.*

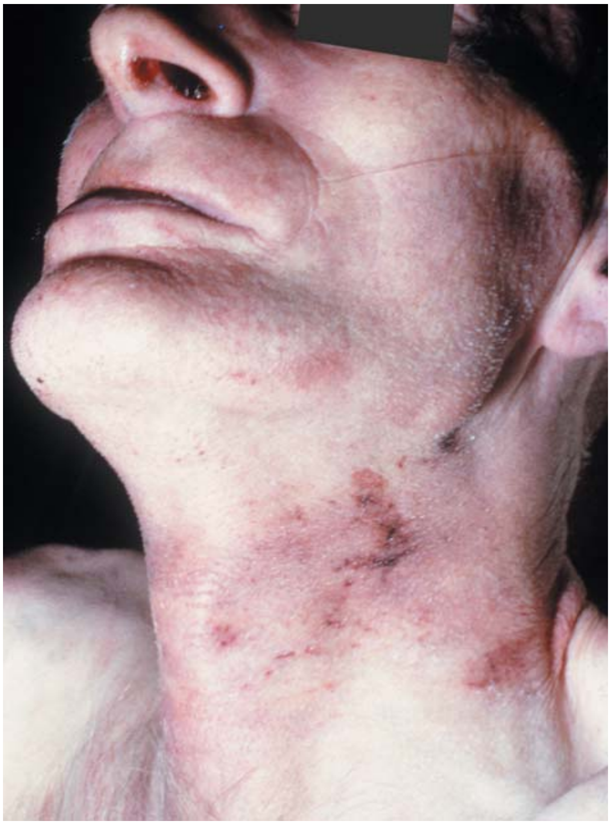

FIGURE 15.9 *Abrasion and bruising in manual strangulation. The face is pale, indicating a rapid sudden death; much of the skin damaged is directly over the position of the underlying carotid sinus.*

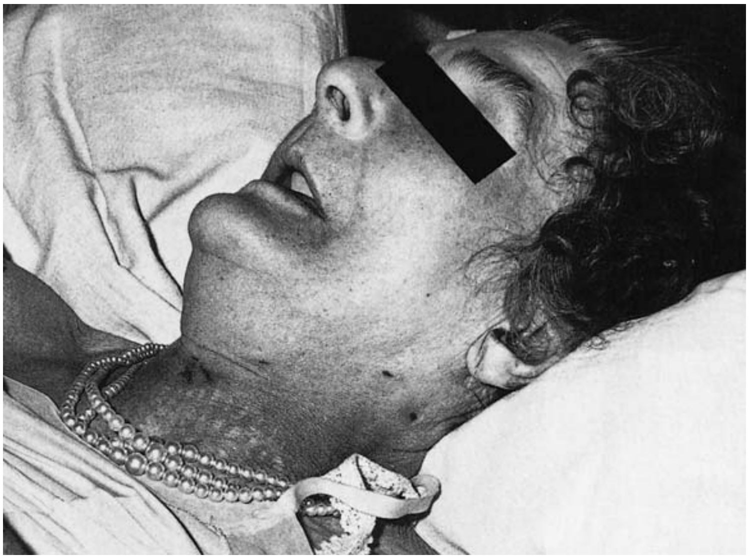

FIGURE 15.8 *Illustration of the need for all doctors to be observant and vigilant. This lady was seen in bed by a family doctor and pronounced a 'heart attack' victim. Later examination revealed facial congestion, fingernail marks on the neck and the impression of her necklace on the skin by strangling hands.*

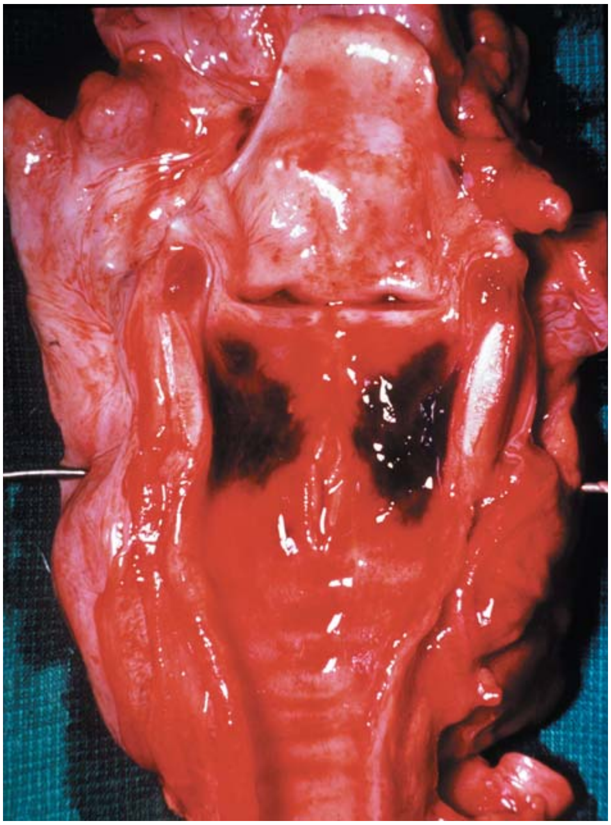

FIGURE 15.10 *Mucosal haemorrhages in the interior of the larynx immediately below the vocal cords, in manual strangulation. This is a common finding and the mechanism is uncertain. It can occur as here – in the absence of generalized congestive–petechial changes – and appears to be caused by local trauma.*

Spurious bleeding behind the larynx

Bleeding over the front and sides of the larynx is usually genuine, if the venous pressure has been released beforehand, but great caution must be employed in interpreting bleeding behind the larynx and pharynx.

In any autopsy, substantial haemorrhage may be seen over the posterior surface of the oesophagus and on the anterior longitudinal ligament of the cervical spine. This is a common post-mortem artefact, described fully by Prinsloo and Gordon (1951) and sometimes known by their name. In the absence of any other neck lesions, especially bleeding in the lateral and anterior parts of the neck, no reliance can be placed on this haemorrhage. It tends to develop more as the post-mortem interval lengthens and even releasing the venous pressure in the neck by removal of the brain, or opening the jugulars early, does not ensure its absence. To avoid the Prinsloo and Gordon artefact, a special technique of dissecting the neck is recommended by Shapiro (1988). Another artefact in the neck, much easier to recognize as false, is ‘banding’ of the oesophagus, especially when the tissues are congested. These bands are pale areas in the mucosa caused by post-mortem hypostasis being prevented from settling by the external pressure of adjacent anatomical structures, including parts of the larynx, trachea and aortic arch. Banding is common in routine non-trauma autopsies, but has been misinterpreted by inexperienced pathologists as evidence of strangulation.

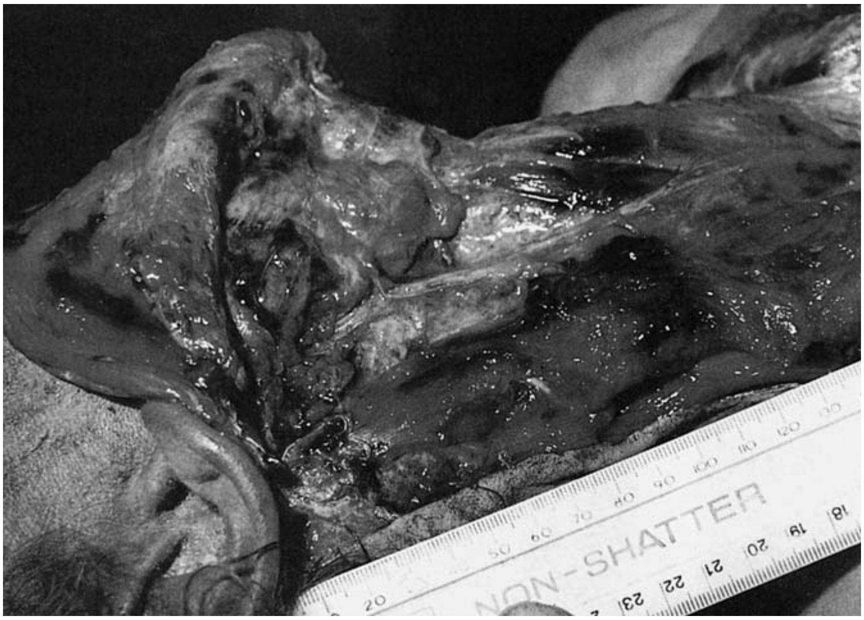

FIGURE 15.11 *Dissection of the neck in a victim of manual strangulation. There are extensive areas of bleeding in the strap muscles, the lower part of the larynx and on the submandibular gland and jaw margin. Removal of the brain before dissection of the neck reduces the risk of artefactural haemorrhages in this region.*

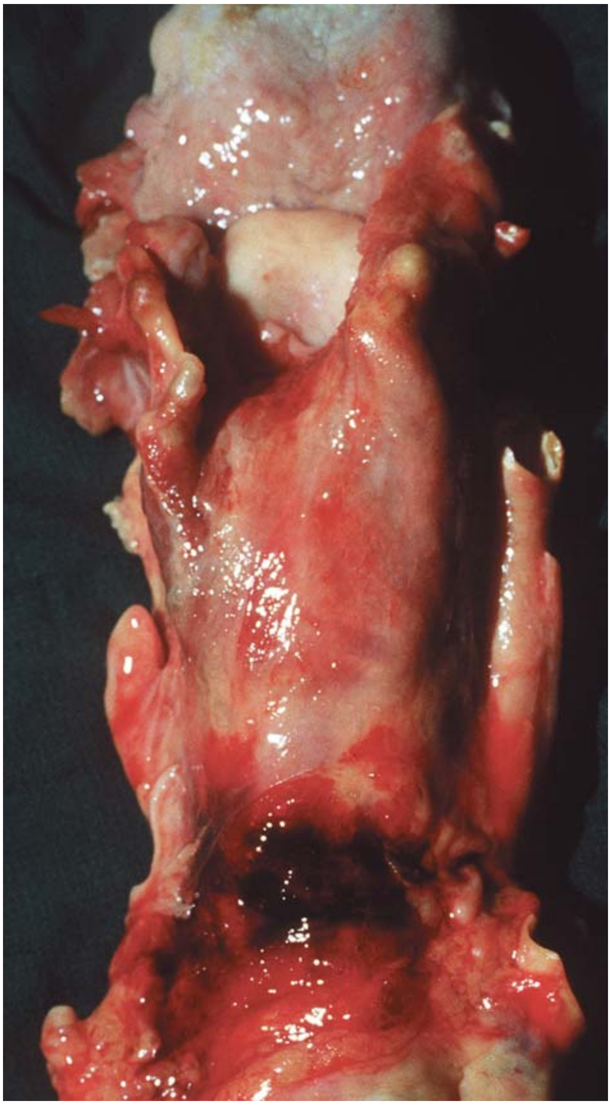

FIGURE 15.12 *Artefactual post-mortem haemorrhage on the posterior surface of the oesophagus in a natural death. This was fully described by Prinsloo and Gordon, and is a reason for draining the blood from the venous system of the head and neck before beginning to dissect.*

Forensic anatomy of the larynx

The larynx consists of a large 'V'-shaped thyroid cartilage, which has a prow-like prominence anteriorly and is open at the back. Below this is the smaller cricoid cartilage, which is narrow at the front, but expands posteriorly to occupy the lower part of the space left by the open thyroid cartilage.

At the upper margin of the posterior wing of the thyroid on each side, are the superior horns or 'cornuae', which are connected by the thyrohyoid membrane to the greater horns of the hyoid bone which lies immediately above.

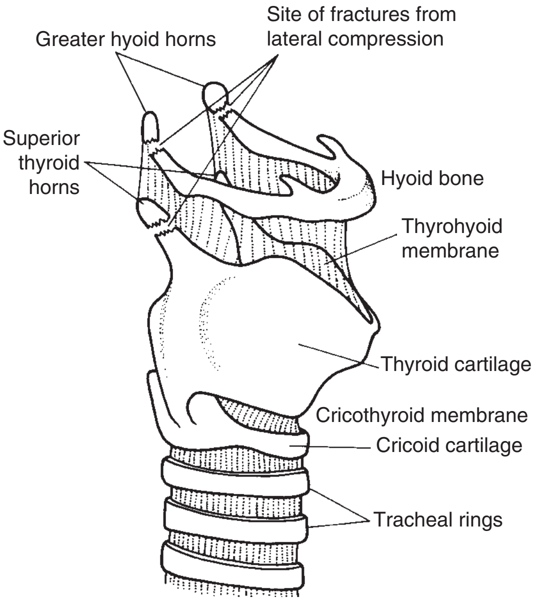

FIGURE 15.13 *The forensic anatomy of the larynx. The hyoid and thyroid bones fracture either from direct lateral compression, or from traction from the thyrohyoid membrane when it is compressed.*

The hyoid bone lies at the root of the tongue, and consists of a central horizontal 'body', to which are attached two long 'greater horns', which sweep backwards and slightly upwards above the upper margin of the thyroid cartilage and superior horns. The hyoid often has natural joints, sometimes even with synovium, which lie at the junction of the body with the greater horns.

There are two lesser horns on the upper surface of the body that have no forensic anatomical significance. The hyoid calcifies at variable times: the body is usually calcified, but the horns may calcify irregularly, both in space and time. In teenagers and young adults they are usually cartilaginous and the joints mobile. In middle and later life, the hyoid and thyroid horns calcify and become more brittle. The cricoid cartilage is a modified upper tracheal ring but can also become partly calcified as age increases; no meaningful ages can be placed on any calcification, but traumatic fractures can occur at any time except in children and most teenagers, in whom fractures are rare.

Injury to the larynx

During manual strangulation the larynx may become damaged in various ways. The pressure is mainly bilateral, so that the sides of the larynx are squeezed. Particularly vulnerable structures are the four 'cornuae' or horns, which protect backwards to maintain the patency of the airway around the glottis. Lateral pressure of the fingers can displace any of the

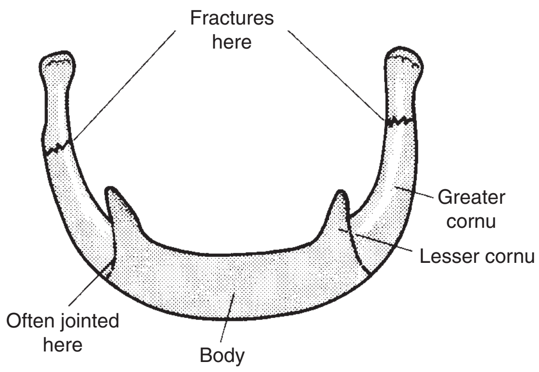

FIGURE 15.14 *The hyoid bone.*

four horns inwards, either by direct pressure or by pressure on the thyrohyoid membrane, which then drags the horns medially. In young persons, the horns are so pliable that they return to their normal position on release of the pressure but, variably beyond the third decade, they may be sufficiently calcified to fracture.

The appearance of a fractured horn is of a loose or even flapping termination. The horn usually displaces medially, but is held by the thyrohyoid ligament. At autopsy it is advisable to cut down this ligament carefully between thyroid cartilage and hyoid to destroy the 'splinting' effect that may support a broken horn. As will be discussed later, however, there will be a haemorrhage at the fracture site that will make the lesion obvious. In the case of the hyoid, care must be taken not to misinterpret a natural joint as a fracture. These are more medial than the usual site of fracture, which is likely to be within a centimetre of the tip. The jagged edge of the fracture line may be exposed, especially in an older person with a brittle horn. Radiography before dissection is an excellent way of confirming a fracture, identifying natural joints and detecting any other fractures in the thyroid or cricoid cartilage.

Though the hyoid bone has received most attention in publications as being the marker of violence to the larynx, in fact the thyroid horns are far more vulnerable. Simpson (1985) found that, in 25 successive deaths from manual strangulation, there were 22 fractures of thyroid horns but only one fractured hyoid. Though this ratio is not typical of the experience of most pathologists, there is no doubt that the superior horn of the thyroid is much more fragile and more vulnerable than the greater horn of the hyoid bone. Although fractures of the horns are more common with advancing age, they can on rare occasions be found even in teenagers. Care must be taken, however, not to confuse mobility at natural joints with a fracture (Evans and Knight 1982).

Conversely, undoubted severe violence to the neck in older persons does not necessarily cause horn fractures. The frequent persistence of joints at the base of the greater horns of the hyoid may allow movement and so avoid fractures when compressed. The cricoid and the main ala of the thyroid cartilage may be cracked, but this is an index of much greater pressure from strangling fingers. The plates may break in a spiral or oblique fashion and the cricoid may crack anteriorly through the narrow bridge rather than at the wider posterior plate. Fractures of these larger areas are also found in direct blunt violence such as punching, kicking or arm-locks, often as part of general severe damage and disruption of the entire larynx.

Significance of laryngeal fractures

Laryngeal cornual fractures are, of course, merely indicators of pressure applied to the neck and are not themselves relevant in terms of a threat to life. This is sometimes misunderstood by laymen, especially police and lawyers, who have been misled by the importance that pathologists attach to the finding of a fractured horn into thinking that the injury itself is a significant contribution to the death.

Such fractures, if proved to be genuine, are certainly significant in proving the application of violence to the neck, but certain precautions must be observed in their interpretation. The sole finding of a fractured horn, where there is no other injury to the skin, subcutaneous tissues, muscles or rest of the larynx is of little value unless there is firm circumstantial evidence of violence to the throat.

When a fracture of a laryngeal horn is found, it must first be proved to be ante-mortem in origin. Post-mortem fractures undoubtedly occur, either from mishandling the body during transit or from incorrect autopsy techniques – though the frequency of the latter has been overestimated.

It is certainly possible to damage the larynx post-mortem by allowing the neck to fall against a hard surface or sharp edge during removal from the place of death, or during handling in the mortuary. Such damage, however, is more likely to occur to the laryngeal plate of the thyroid cartilage or to the cricoid, rather than to the laterally placed horns, though these can be broken. Damage at autopsy is usually caused by an inexperienced pathologist or autopsy-room technician, especially when forensic expertise is lacking. Clumsy removal of the tongue and neck structures can break the thyroid or hyoid cornuae, especially in old persons where they are calcified and brittle and when any natural joints are ankylosed.

This may be one justification for radiography before autopsy, but probably the danger of artefactual breakage has been overestimated, especially where a gentle removal technique is employed.

Proof of ante-mortem laryngeal fracture

This must be obtained by demonstrating haemorrhage at the fracture site. It is usually obvious to the naked eye and can be confirmed histologically. Sometimes the bleeding is prominent, with a blood bleb under the periosteum or perichondrium at the fracture line, and the broken end of a calcified horn may be palpable and even slightly crepitant. Where no macroscopic evidence of bleeding is found, careful histology of the fracture site will almost always reveal some red-cell extravasation, but this evidence is of less value because microscopic – and even slight macroscopic – oozing can occur from a post-mortem fracture of a horn. Bleeding is therefore a 'one-way' criterion: if there is no haemorrhage, the fracture must be post-mortem, but if there is a small bleed, then the lesion can be either ante-mortem or post-mortem. Naturally the findings must be taken in conjunction with other evidence of neck injury and, if there are surface bruises, scratches, muscle bleeding, intralaryngeal and tongue haemorrhage, then a minimal bleed at a fractured horn can be accepted as probably ante-mortem.

Conversely, it must again be emphasized that the solitary finding of a fractured laryngeal horn, even with slight associated bleeding, is not in itself sufficient evidence of ante-mortem trauma to the neck.

Other causes of fractured laryngeal horns

The hyoid and thyroid horns can be broken other than by manual strangulation. Ligature strangulation and hanging can certainly cause these lesions, though not as often as manual throttling. Direct violence can also break the cornuae, but usually only as part of more diffuse laryngeal damage. A punch or kick in the throat can disrupt the larynx and break the horns as part of general damage. Even wide, blunt pressure can fracture the horns, however, such as an arm-lock from behind squeezing the larynx against the cervical spine. It has been said that such direct violence from the front tends to splay the fractured horns laterally, whereas in manual strangulation the horn tends to fall inwards – but this is too tenuous a claim to be of much practical value.

In accidents, the larynx can be damaged. In falls, the larynx is usually protected by the prominences of the chin and chest, but if the fall is onto a ridged object, such as gate or chair-back, then a focal impact can injure the throat. The author (BK) has seen a death in a housebreaker, who slipped when trying to climb through a sash window. He fell with his throat across the top of the window-frame and died – presumably of a vagal cardiac arrest – being found suspended by his neck next morning with fractures of the laryngeal cartilages.

Other laryngeal injuries in strangulation

Other injuries to the larynx include splitting of the ala of the thyroid cartilage, often either in the midline or obliquely across the left or right plate. This may be part of a violent strangulation, seen by Green (1973) in 12 per cent of his series – but is more often seen in blows to the front of the neck, either by fist or the edge of the hand, or a kick or any other kind of substantial trauma directed at the front of the neck.

The cricoid cartilage, a circle shaped like a signet ring that lies below and partly within the thyroid cartilage, may also be fractured by manual throttling when pressure is applied rather lower than usual. Again, this cartilage tends to break either across the front midline or obliquely. Though an uncommon injury, a severe displacement of a broken cricoid – especially if accompanied by mucosal tearing and bleeding – may project backwards into the airway and cause a partial obstruction.

The interior of the larynx may also show indications of pressure on the neck. This usually takes the form of haemorrhage into the mucosal lining and is most often seen immediately below the vocal cords. Bleeding may be intense here, but its cause is obscure. It can occur with no other damage to the cartilages of the larynx and it is then hard to equate it with direct physical pressure as it lies on the protected inner surface.

Similar, but less intense, haemorrhage is sometimes seen on the surface of the epiglottis, which more often shows a shower of petechial haemorrhages if the death was not sudden.

Such haemorrhage inside the larynx is often a bright, fiery red, unlike the dark cyanotic discoloration that is seen in the pharynx, root of tongue and larynx in congestive–asphyxial deaths, and is caused by obstructed venous return rather than direct trauma. At autopsy the base of the tongue should always be sliced, as deep haemorrhages may be present, usually at the sides of the tongue, deep congestion being more central or across the whole posterior part of the tongue.

Damage to the carotid arteries

Though the sudden 'vagal inhibition' type of death caused by pressure on the baroreceptors of the carotid sinus and sheath is quite common, it is unusual to find anatomical confirmation of injury to these structures.

There may be deep haemorrhage in the neck tissues surrounding or adjacent to the bifurcation of the common carotid artery, but this is often absent in these cases of cardiac arrest – and conversely, such bleeding may be found in the slow 'asphyxial' deaths, as part of the generalized diffuse bleeding into the tissues.

Rarely, careful dissection of the carotid arteries may reveal an intimal tear or bleeding into the walls of the vessels at or near the carotid sinus. A delicate technique is required and artefactual damage must be carefully excluded, especially that from the point of scissors used to slit open the artery. Such tears are more often found when a forcible impact or a more focal pressure has been applied, such as from a thin ligature that can cut deeply and abruptly into the neck, especially in hanging. Generally, little or no morphological confirmation is to be expected in the cardiac arrest type of death, following pressure on the neck. The diagnosis is one of exclusion, based on the absence of any congestive–cyanotic–petechial appearances, together with some circumstantial history of sudden death whilst pressure is being applied to the neck.

As already mentioned, one problem is that pressure may be maintained for long enough – perhaps a minimum of 15–30 seconds – to produce these signs, yet not cause death, but death then supervenes abruptly because a vagus-mediated cardiac arrest is superimposed on the early asphyxial mode. In the absence of any structural damage to the carotid apparatus, autopsy cannot differentiate between the two mechanisms and only the history (which is rarely available for obvious reasons) can assist in interpreting the sequence of events.

STRANGULATION BY LIGATURE

Pressure on the neck may be effected by constricting all or part of the circumference of the neck by a ligature. This is sometimes called 'garrotting', though strictly this refers to the tightening of a noose around the neck by twisting a rod within the ligature, a form of judicial execution once employed in Spain, from which also comes the description of the twisting device as a 'Spanish windlass'. This method had a refinement in which the back of the neck was forced against a sharp spike which penetrated the spinal cord.

In forensic practice, if hanging is excepted as a separate entity, most ligature strangulations are homicidal. Some are suicidal and a few accidental, usually in children.

The nature of the ligature

The ligature may consist of a wide variety of objects, some not obviously suitable for the purpose, yet effective in causing death. Cords, wires, ropes and some belts are strong and relatively thin, so that they tend to cut deeply into the neck if the tension is great. Softer fabrics, however, in the form of scarves, ties, towels, stockings, tights and even strips of bed-linen may be used and may cause some problems in interpretation if they are removed from the scene before the investigation begins. The ligature may be applied as one turn around the neck – or even less, as homicides have been perpetrated by the assailant pulling a U-shaped ligature against the front and sides of the neck, while standing at the back. Even a flexible rod, such as bamboo cane or – in India – a flat 'lathi', can act as a ligature if the two ends are forcibly pulled back from behind against the front of the throat.

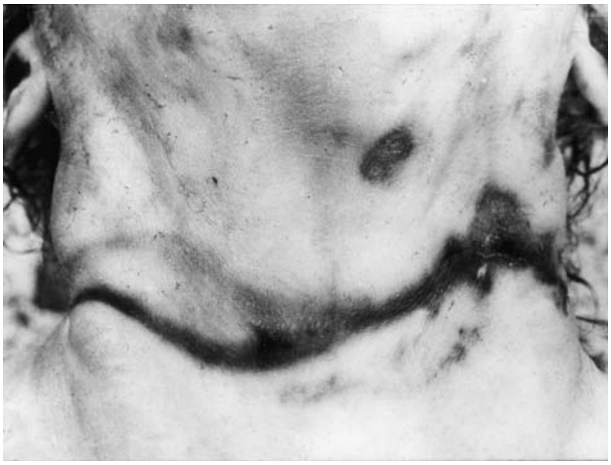

FIGURE 15.15 *Ligature mark from a nylon scarf. Although the fabric was broad, the tension bands from the tightly stretched material have produced a definite line that could be mistaken for a cord or wire.*

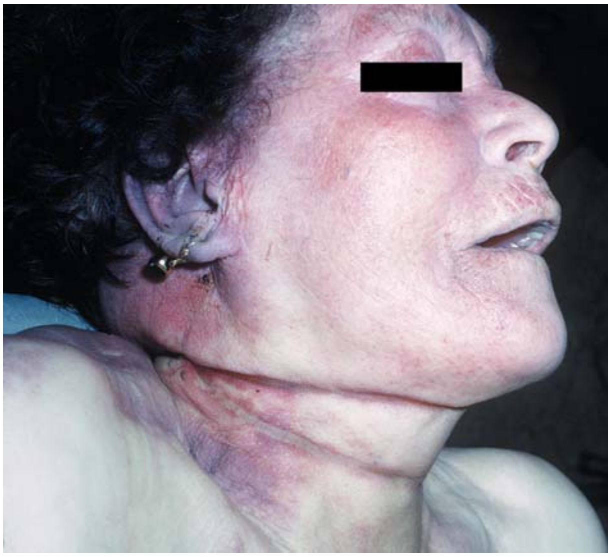

FIGURE 15.16 *Ligature strangulation with a generally horizontal course for the two strands of cord that diverge from the skin at the back of the neck.*

In the majority of cases, however, the ligature is crossed over itself after passing a full circle around the neck – and several turns may be wound around, secured with one or more knots. These multiple turns are not uncommon in

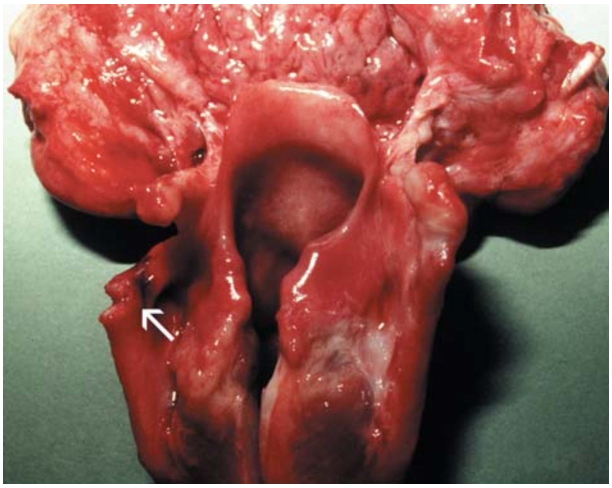

FIGURE 15.17 *Fracture of the left laryngeal horn (arrow) with haemorrhage. The body was recovered from a lake based on the confession of the perpetrator. Further findings were haemorrhage in the fractured cricoid cartilage, bruising on the neck and petechiae in the conjunctivae and larynx.*

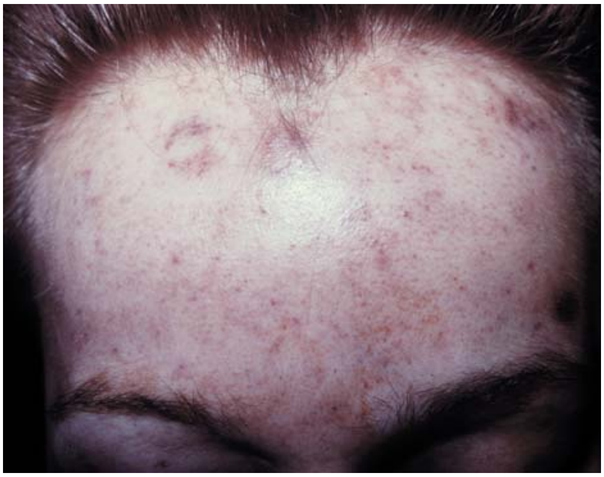

FIGURE 15.18 *Typical appearance of congested, cyanosed forehead, with multiple petechiae in the skin, in a woman strangled manually and by ligature. Circular bruising probably due to knuckle blows. The scarf tied around the neck initially suggested only ligature strangulation.*

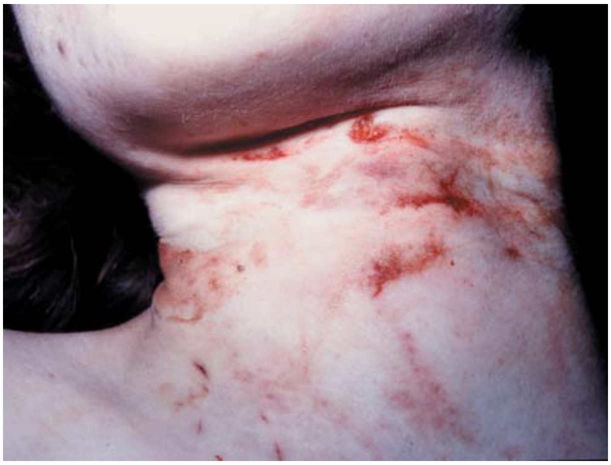

FIGURE 15.19 *In the case shown in Figure 15.18. When the scarf was removed, typical bruises and abrasions of manual strangulation were seen in addition to the ligature mark.*

suicide, where two, three, or even more circles are wound around, often with complex knots. The presence of these more complicated ligatures by no means confirms homicide – in fact they are more common in suicide, where the determined victim is eager to succeed. The ligature may be tightened even further by means of the 'Spanish windlass' mentioned above, which consists of some rod-like object, which may be a ruler, stick or screwdriver inserted between the ligature and the skin, and twisted around several times. The rod may be held in position by being wedged under the chin or against the shoulder or chest. This device may be seen in either homicides or suicides.

The ligature mark

The appearance at autopsy naturally depends on the nature and texture of the ligature. When there is a pronounced pattern, such as the weave of a cord or the plaiting of a thong, the same pattern may be imprinted into the skin. In homicide, where the ligature has been removed by the killer, such a pattern may be of great value in tracing its origin. When a fabric has been used, such as a scarf or towel, the marks on the neck are more difficult to interpret. A broad, flat band may leave no mark whatsoever, but it usually leaves one or more linear marks on the skin of the neck, often discontinuous. These may fade if the body is not seen soon after death and if the surface has not been abraded.

A fabric ligature may leave a sharply defined mark, which may be misinterpreted as being caused by a narrow cord or wire. The reason for this is that when a broad piece of cloth is tightly stretched, one or more bands appear that are under greater tension than the rest. It is these that mark the skin, and no sign may be left that a wider area was lying on either side of the most tensed band. These marks are usually less well demarcated at the edges than a cord or rope, but can cause confusion.

When the ligature is still in position when the body is examined, it may appear to be deeply embedded in the skin, sometimes almost out of sight, and on removal a deep groove may be seen in the skin. This embedding may be accentuated by oedema of the tissues, especially above the ligature, which initially may not have been applied so tightly. The swelling can continue to develop to some

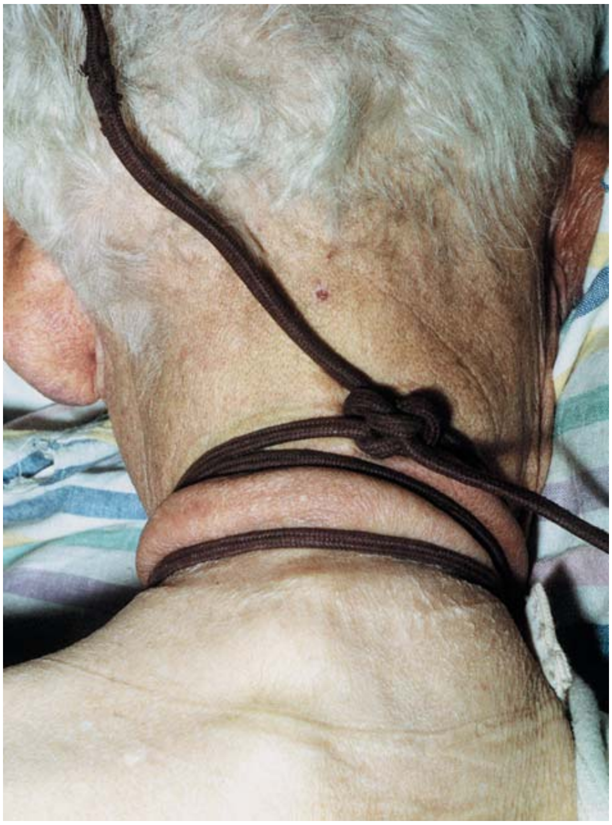

FIGURE 15.20 *Self-strangulation by ligature, with three turns around the neck and a complex knot. There was no doubt from the circumstances that the deceased man had deliberately killed himself with this telephone cord, but the mechanism of apparent vasovagal death before any congestive changes could appear remains obscure.*

extent even after death, accentuating the depth of the groove. Presumably some passive transudation of tissue fluid continues even after the circulation has stopped. In suicides, multiple turns and knots may have been applied and obviously, the degree of tightness as seen later at autopsy could not have been present during the application of the ligature, otherwise incapacity would have been so rapid that the process could not have been completed. In such cases, it is remarkable how often the mode of death still seems to be of the non-asphyxial cardiac arrest type. It might be expected that vagal stimulation could not have occurred once the expected static position was attained with the completion of ligation – but experience indicates otherwise, the mechanism remaining obscure.

The skin mark may remain red, especially if the ligature was of softer material such as cloth, but cords, ropes and wires tend to abrade the surface, which later becomes yellow or brown and parchment-like. This is seen particularly in hanging, when the friction and chafing may be greater.

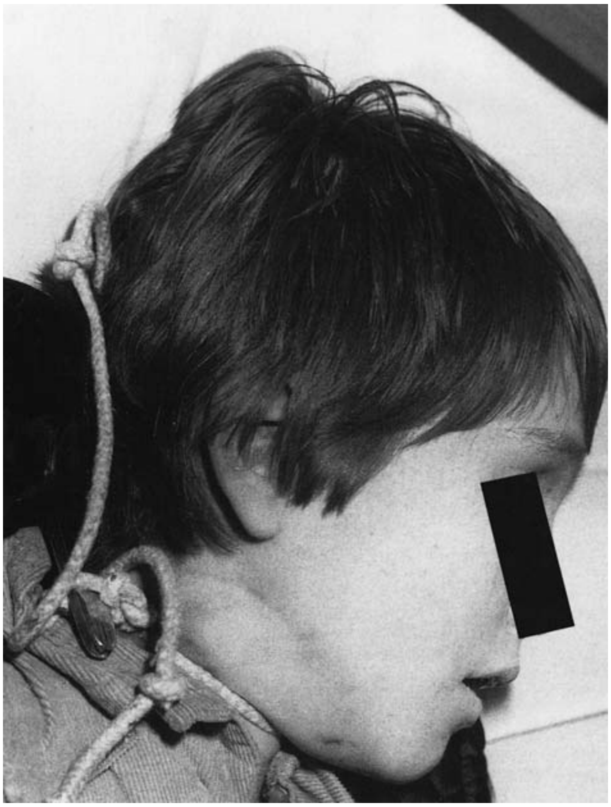

FIGURE 15.21 *Ligature strangulation by means of a 'Spanish windlass'. A penknife has been thrust through the knot to twist the ligature tight.*

The stiff, brownish-yellow appearance occurs post-mortem and tends to become more pronounced as the interval lengthens after death. The mark may be slightly wider, narrower or the same width as the actual ligature, depending partly upon how deeply it cut into the skin. There is often a narrow zone of reddened hyperaemia at either margin of the mark. This used to be taken to indicate that the ligature must have been applied during life – though by analogy with the spurious 'vital reaction' sometimes seen as a post-mortem development at the margin of burns (see Chapter 11), this sign is of doubtful reliability. Experiments by Pollak (personal communication) confirm this by the production of similar marginal reddening by applying ligatures soon after death – it seems to be due to lateral displacement of blood from the squeezed area immediately below the ligature.

THE POSITION OF THE LIGATURE MARK

The geometry of the mark is important in interpreting the fatal events. In strangulation, unlike hanging, the mark tends to encircle the neck horizontally and at a lower level. Typically it crosses immediately above or below the prominence of the

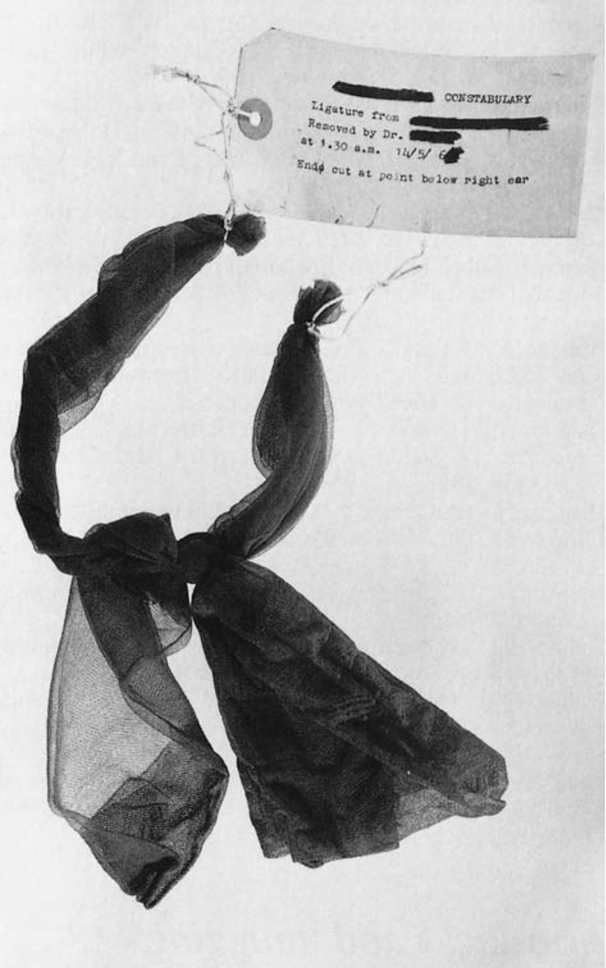
[redacted] CONSTABULARY
Ligature from [redacted]
Removed by Dr. [redacted]
at 1.30 a.m. 14/5/ 6[redacted]
Ends cut at point below right ear

FIGURE 15.22 *At autopsy on a victim of ligature strangulation, the ligature should be cut well away from the knot, if one is present. The knot should never be untied, but preserved for forensic examination. If the ligature is in danger of unravelling, it should be tied at two places and divided between these points. (Reproduced with permission from Robert Hale Publishers.)*

larynx and passes back to the nape of the neck. In homicide, where a single turn is used, there is often a cross-over point where the two ends of the ligature mark overlap. This may be at the front, side or back of the neck, depending on the relative positions of assailant and victim.

When a knot is tied, it may leave a mark on the skin and, of course, if multiple loops are present, some or all of these will be represented on the skin. Unless the killer is pulling upwards, the mark will not be seen to rise nor will there be a gap in the mark at the highest point, as seen in most hangings.

In the later section on hanging, the point will be made that sometimes a hanging mark may resemble a ligature mark, but the converse is almost unknown.

Other signs of local injury in ligature strangulation

There may be scratches on the neck, but these are usually caused by the attempts of the victim to pull away the ligature. Fingernail marks, sometimes linear and vertical, may be present as in manual strangulation, but not focal abrasions or bruises. Internally there may be superficial haemorrhage under the ligature mark, though this is often minimal. Depending on the force with which the ligature was applied, there may be deep damage in the muscles of the neck, but this tends to be less than in manual strangulation. Similarly, there may be laryngeal injury, but less severe than from pressure from the hands. The hyoid bone and thyroid horns may be fractured, especially where the ligature rides at the level of the thyrohyoid ligament, but damage to the laryngeal cartilages is much less common than in manual strangulation. Gonzales found in 24 fatal manual strangulations, four hyoid fractures but nine thyroid and cricoid fractures. In 25 deaths from manual strangulation, Simpson found only one hyoid fracture but 22 with thyroid horn fractures. It is rare for the main thyroid plate or the cricoid to be fractured unless gross violence was applied with excessive pressure by a strong ligature. Uncommonly, a narrow wire may be used, the so-called ‘cheese-cutter’ method. Here, strong pressure over a small area – such as that delivered by a piano wire – may actually lacerate the skin, and even cut into the deeper tissues and cartilages.

Where much bruising and abrasion is seen, especially if scattered and away from the actual ligature mark, then the possibility of a combination of manual and ligature strangulation must be considered. This is not uncommon, the handling of the throat either preceding or accompanying the application of the ligature. Fractures of the laryngeal structures may be caused by this element, rather than the associated ligature. A deeply sunken narrow ligature applied with force may damage the carotid arteries and focal injury to the intima may rarely be found on careful dissection.

The mode of death in ligature strangulation

The mode of death is more often the ‘classic asphyxia’ picture than in manual strangulation, where sudden cardiac death is common before congestive–petechial changes have time to occur. The contrast in the appearance of the skin immediately above and below the ligature mark is often striking, with pale skin below, and a puffy, oedematous, congested, cyanotic and haemorrhagic surface above. Petechiae may abound in the eyelids, conjunctivae and facial skin, and there may be bleeding from the ear and nose. This is by no means invariable, and many ligature strangulations die rapidly from vagal reflex cardiac arrest before any congestive signs have had time to appear.

This can occur in both homicide and suicide and, as mentioned earlier, the mechanism is obscure, especially where the victim – bent on self-destruction – has been able to complete multiple loops around his neck and tie several knots before dying.

Accidental ligature strangulation – which may be actual hanging if the body weight is thrown wholly or partially upon the ligature – is seen in the tragedies than occur to young children, who may become entangled in blind or curtain cords, usually when their cot or playpen is left too near a window.

ARM-LOCKS AND ‘MUGGING’

The original meaning of ‘mugging’ has now been confused by its application, especially in North America, to any form of robbery with violence. The term strictly means throttling by pressure from an arm held around the throat. The attack is usually made from behind, the neck being trapped in the crook of the elbow. Pressure is then exerted either on the front of the larynx, or at one or both sides by the forearm and upper arm. The mechanism is further discussed in Chapter 10, as an arm-lock (or ‘choke-hold’) is a method of restraint used by police officers for law enforcement, but it is rapidly losing favour because of the number of inadvertent fatalities due either to ‘asphyxia’ or to reflex cardiac arrest. Following several fatalities during police arrests in the early 1990s, the Association of Chief Police Officers in Britain have issued recommendations that arm-locks be avoided during the restraint of violent prisoners.

The autopsy features are those of ligature strangulation with a broad object, in that signs may be minimal. Some diffuse abrasion may be seen, especially along the margin of the jaw or lower face, sometimes over a considerable area, caused by the friction of the forearm. Internally there may be diffuse bruising, but this again may be slight or even absent. The larynx may also escape damage, though if it is pressed backwards against the spinal column the thyroid horns and even the hyoid may fracture (see also Chapter 10).

HANGING

Hanging is a form of ligature strangulation in which the force applied to the neck is derived from the gravitational drag of the weight of the body or part of the body.

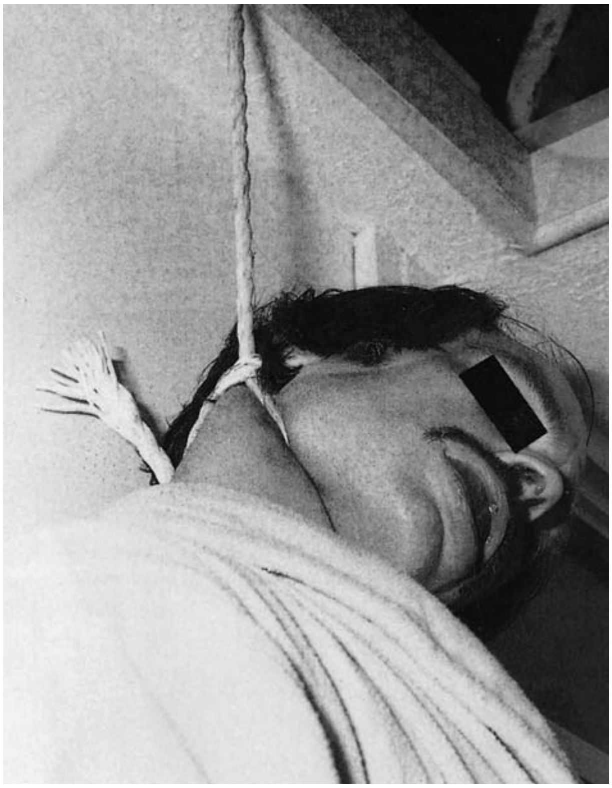

FIGURE 15.23 *Typical posture in hanging with the suspension point rising to the ear, tilting the head to the opposite side. The tongue is projecting because of upward pressure on the larynx and root of the tongue. There are no congestive appearances. As a slip-noose was used, the rope is in contact with the skin throughout the full circumference of the neck.*

Judicial hanging

The modern form of judicial execution is unrelated to the usual suicidal hangings seen in routine forensic practice, as it depends upon severe mechanical disruption of the neck structures. Until the nineteenth century judicial hanging in Britain was carried out even more barbarically by ‘ordinary’ hanging, where the victim was strangled at the end of a rope by his own weight. At the infamous Tyburn execution site near the present Marble Arch in London, tens of thousands were dispatched, the usual method being the placing of a rope noose around the neck of the condemned person, who stood on a cart or ladder. This support was then removed leaving the victim suspended. Some contemporary accounts suggest that many died with little further movement, but this was not the case for a considerable number and it was not unusual for the victims’ relatives to pull on the victims legs to shorten the agony. It appears to have been a desire to increase the rapidity with which death occurred that ‘improvements’ were made, principally the use of a drop effected suddenly by means of a trapdoor. The use of a drop required the placing of the 'knot' – really a brass eyelet and rubber washer – under the left ear where it was less likely to be pulled over the head than at the occiput, a traditional site. The aim was that, when the rapidly falling body was suddenly arrested, the cervical spine would be dislocated resulting in traction on the spinal cord with consequent spinal cord or brainstem disruption. Exhumation of persons executed by this method shows that fracture was not usual but post-mortem accounts of findings indicate that cervical spine dislocation – occurring at various levels – was common with resulting cord or brainstem damage. However, the effects do seem to be variable with decapitation occurring at drop heights, which, in others, judging by contemporary descriptions of the execution, appear not even to have caused rapid unconsciousness. Though cerebral function presumably ceased immediately on cord or brainstem damage, the heart usually continued to beat, sometimes for up to 20 minutes until hypoxia caused arrest.

Suicidal and accidental hanging

Apart from the now rare 'lynching', hanging is almost always suicidal or accidental, the former being by far the most common. Hanging has many features in common with ligature strangulation. Death is, however, more often caused by reflex cardiac arrest from pressure on the carotid structures. Many more victims of hanging are found to have pale faces, rather than the congested, haemorrhagic appearance of the slower asphyxial type of death. James and Silcocks (1992), in a 15-year survey of hangings in Cardiff, found congestive–petechial features in 27 per cent, being related to the completeness of suspension.

Polson suggested that the usual pale face in hanging is caused by cerebral ischaemia from bilateral occlusion of the carotid arteries rather than a vasovagal effect, though this seems incapable of proof. In either event, the death can be taken to be rapid if no asphyxial signs are present.

Methods of hanging

Most hangings are self-suspension. This may be carried out by a wide variety of methods, but a typical method of self-suspension is to attach a thin rope to a high point such as a ceiling beam or staircase. The lower end is formed into either a fixed loop or a slipknot, which is placed around the neck while the intending suicide stands on a chair or other support. On jumping off or kicking away the support, the victim is then suspended with all or most of his weight upon the rope.

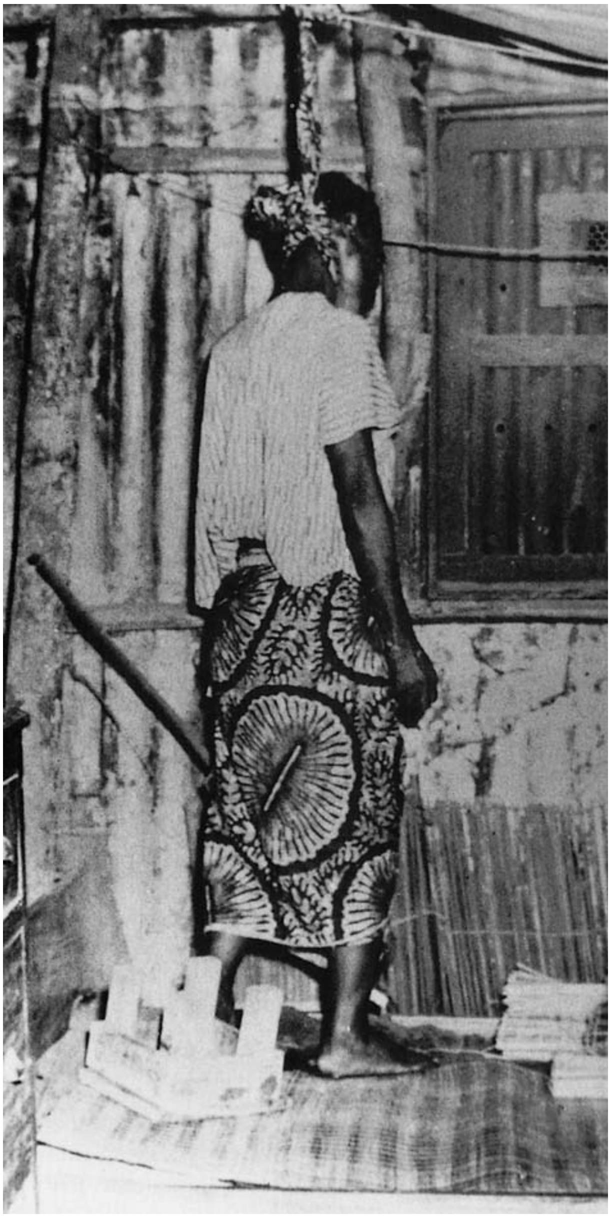

FIGURE 15.24 *Suicidal hanging with the feet flat on the floor. The deceased man stepped off the low stool, but the stretching of the cloth ligature prevented total suspension. Many suicidal hangings are successful at much lower levels, such as doorknobs and bed headboards.*

The many variations of this involve either the ligature or the height of suspension. Wires, string, pyjama cords, belts, braces (suspenders), scarves, neckties, stockings and numerous other devices may be used, depending on availability. In prison or police custody considerable ingenuity may be employed to defeat the efforts of the custodians to remove anything that could be used for self-destruction: shoelaces, stockings and torn bed-sheets have been used in prison cells.

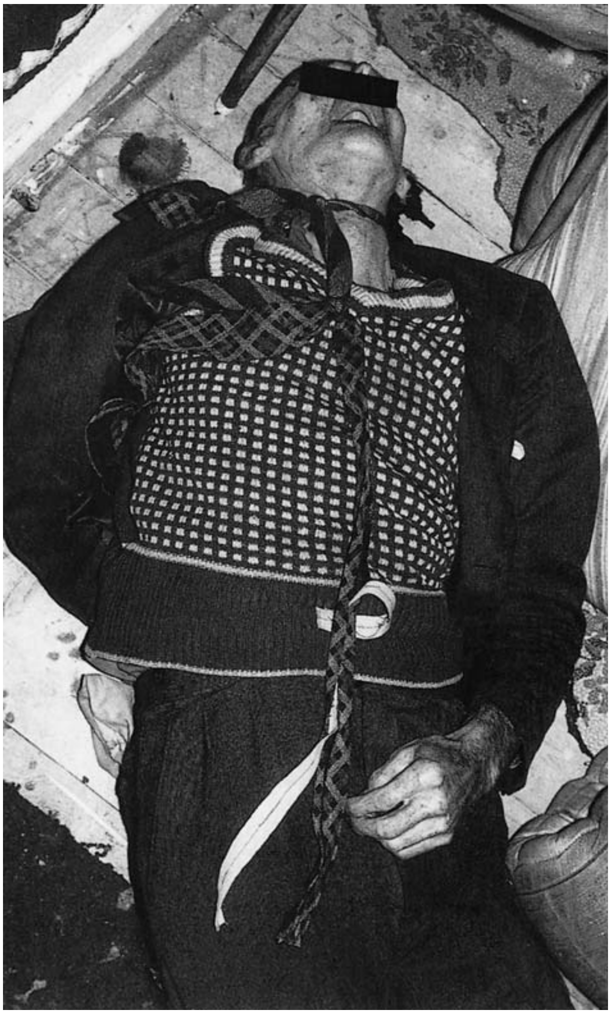

FIGURE 15.25 *Suicidal hanging by means of a necktie. The deceased man had suspended his neck from a hook on the back of a door by tying two neckties together. The hook had pulled out and he was found on the floor. Note the pale, uncongested face, indicating rapid cardiac arrest.*

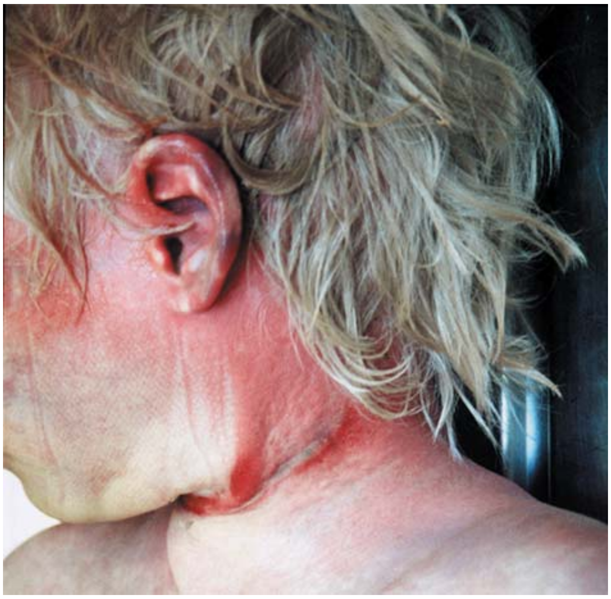

FIGURE 15.26 *Hanging deaths in children are very rare. This 7-year-old boy took his leave from his playmates and hanged himself from a bedpost under their very eyes.*

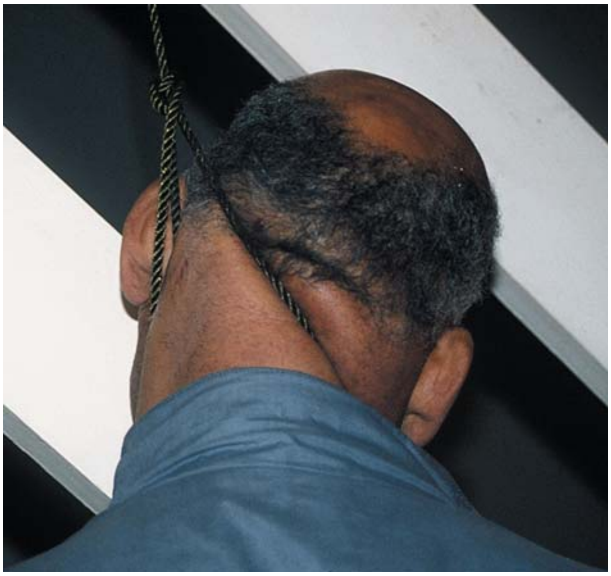

FIGURE 15.27 *Hanging with a fixed knot in the cord, so that there is a segment of skin free from the mark where the cord rises towards the knot. This was part of the common murder–suicide pattern in a domestic homicide.*

Suspension is often not high enough to keep the victim's feet clear of the floor. Commonly, when the person steps from his support, the stretch in the ligature rope is sufficient to allow the feet to reach the ground, but this by no means prevents a fatal outcome. The weight of the upper part of the body leaning into the noose is often more than enough to cause death. Successful hanging can occur from low suspension points, where the person is merely slumped with part of his weight into the ligature. Hanging can take place from doorknobs, bedposts and any other convenient low securing point. The body may be merely slumped against the door or bed or chair, with the legs and buttocks supported on the floor, so that only the weight of the chest and arms is contributing to the fatal pressure within the noose. One 'hanging' seen by the author (BK) was successfully achieved by merely leaning the neck into the shallow curve of a low clothesline stretched between two posts in a garden.

It is unusual for a suicidal hanging to be sufficiently violent for damage to the cervical spine to occur as the length of drop is usually too short. Only occasionally will a person jump from a roof or other high place with a rope around his neck – here severe injury can occur, even decapitation if the

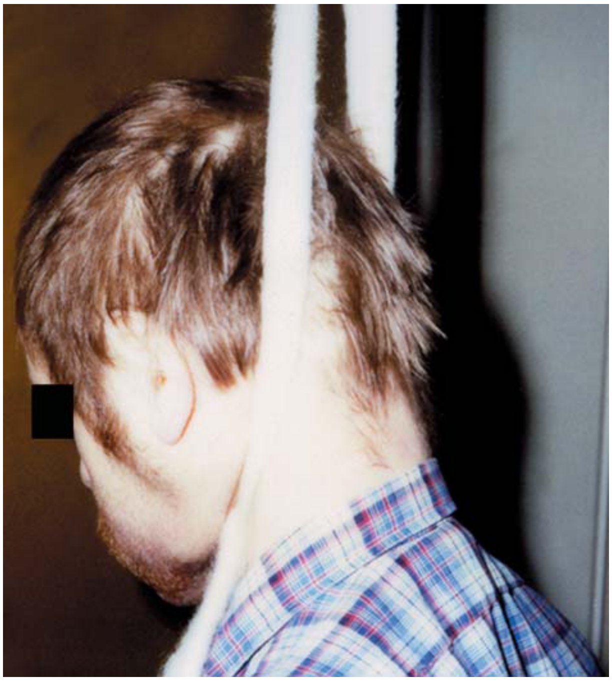

FIGURE 15.28 *This inmate had torn up a sheet and attached both ends to a water tap (not shown) and is leaning into the loop in sitting position with sparing of the back of the neck.*

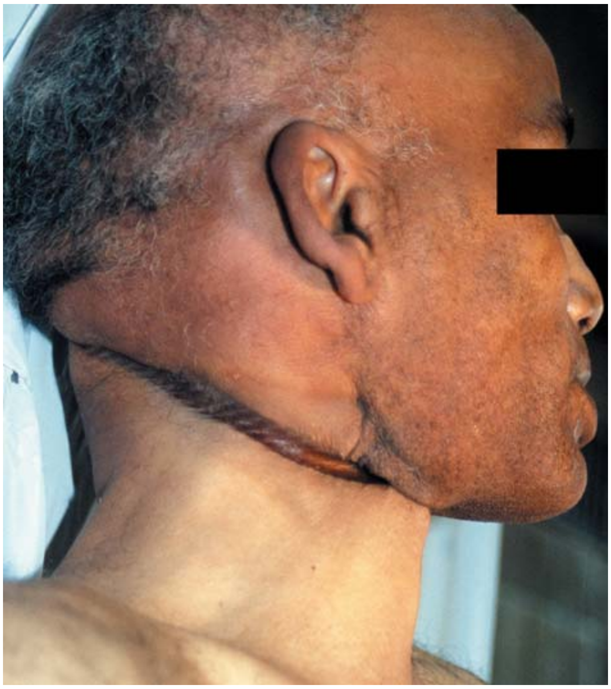

FIGURE 15.29 *A deep hanging mark showing the high position under the chin rising to the back of the neck. The spiral weave of the rope is clearly imprinted in the skin. The dark tint of the face is racial, not congestive.*

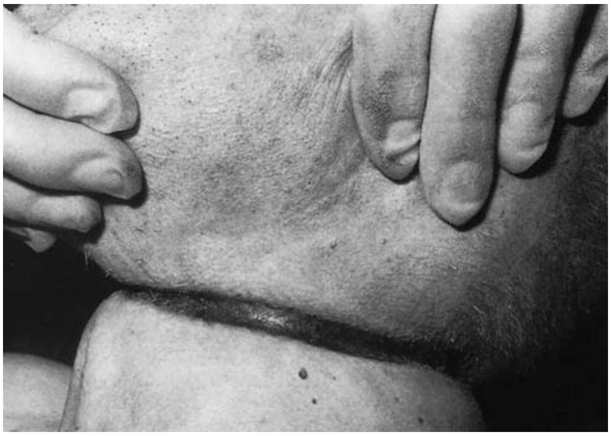

FIGURE 15.30 *A perfectly horizontal mark around the neck in a man who hanged himself from a staircase. A slipknot was used, which tightened so that the usual rising line of a hanging mark did not occur, illustrating the dangers of assuming that the usual is invariable.*

rope is strong enough. More often the jump will be from an attic trapdoor or a tree, sufficient to damage the vertebrae or atlanto-occipital joint. The author (BK) once saw a fractured cervical spine when a heavily built soldier jumped off a lavatory seat after securing a rope to the overhead cistern, but this is unusual.

The hanging mark

The mark on the neck in hanging can almost always be distinguished from ligature strangulation. The circumstances will usually indicate the fact of hanging, but sometimes the rope will break or become detached, and the deceased will be found lying with a ligature around his neck. There may then be doubt as to whether he was hanged or strangled. Obviously a search of the locus for a suspension point and signs of rope attachment will be the task of the investigators.

The hanging mark almost never completely encircles the neck unless a slipknot was used, which may cause the noose to tighten and squeeze the skin through the full circumference of the neck. In most instances the point of suspension is indicated by a gap in the skin mark, where the vertical pull of the rope leaves the tilted head to ascend to the knot and thence to the suspension point. This gap is usually seen at one or other side of the neck or at the centre of the back of the neck. Much less often it is under the chin. The knot itself may be impressed into the skin, especially if at the side of the head, above the gap where the anterior mark begins.

The hanging mark, the features of which resemble those described earlier in strangulation, is usually deepest at the side diametrically opposite the suspension point where the maximum load-bearing occurs. Like ligature strangulation,

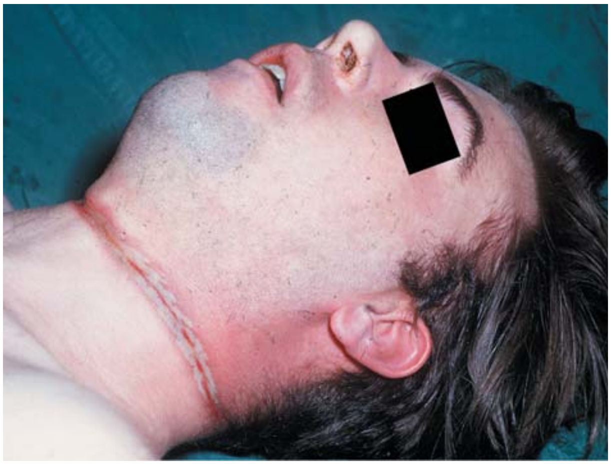
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FIGURE 15.31 *A hanging mark showing the plaited imprint of a six-strand cable. There is a central line of abrasion, within a zone of pallor caused by vascular compression, outside which is a narrow band of hyperaemia. The mark is horizontal due to leaning forwards.*

the mark may be abraded, brown and dried to a parchment-like consistency after death. There may be a narrow red zone either above or below (or both sides) the ligature mark. This is not an indicator of vital reaction, as explained in relation to ligature strangulation, but is due to displacement of blood laterally from under the zone of maximum pressure.

THE POSITION OF THE HANGING MARK

The hanging mark is situated higher on the neck than in strangulation, usually being directly under the chin anteriorly, passing round beneath the jawbones and rising up at the sides or back of the neck to the usual gap under the knot.

An exception may be seen where the suspension point is low and part of the body is supported. For example, the victim may sit or slump on a chair, bed or floor with the rope attached to a point only slightly above neck level. Then the pull on the rope is almost at right angles to the axis of the body when the latter slumps away, so that the resulting mark may be almost horizontal and set at a lower level than usual on the neck. In such cases, if the body is cut down before investigators arrive, it may be much more difficult to distinguish hanging from strangulation, a fact which has been argued in more than one criminal trial or controversial death, such as that of Rudolf Hess in Spandau Prison, Berlin in 1987.

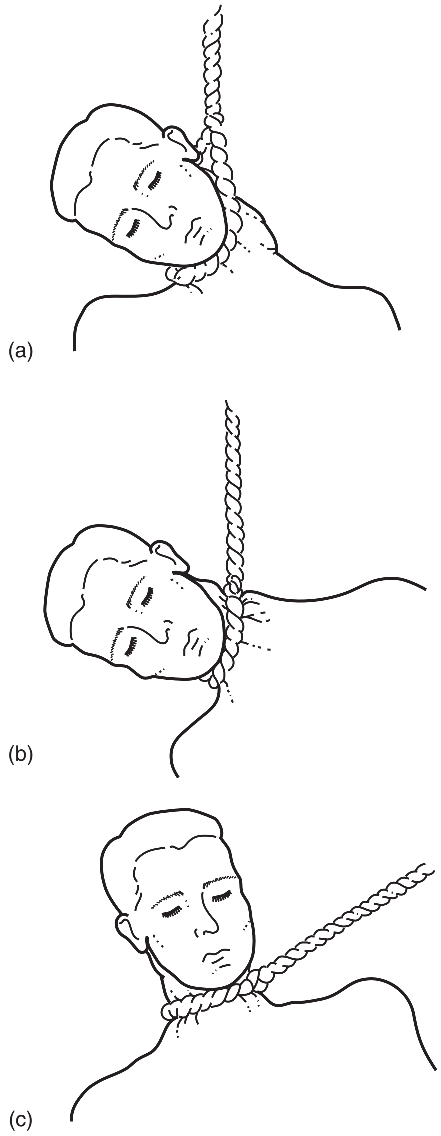

FIGURE 15.32 *The position of the hanging mark on the neck. (a) Usual position with fixed noose and high suspension point. The mark rises high to a gap. (b) If a slipknot is used, the tightness of the deeply impressed loop tends to find the smallest circumference on the neck, and may be lower and more horizontal. (c) If the suspension point is low and the subject leans away, the mark can be horizontal.*

On rare occasions, hanging will take place with the suspension point at or above the point of the chin with the rope cutting into the back of the neck. Where the rope passes across the jaw margins to a knot in front of the face, the mechanism of death is somewhat obscure as the laryngeal region suffers little or no compression. Fatalities, however, certainly do occur, presumably as there is still opportunity for pressure on the carotids.

Autopsy appearances in hanging

Apart from the appearances of the hanging mark, there are some other features to note. First, post-mortem hypostasis

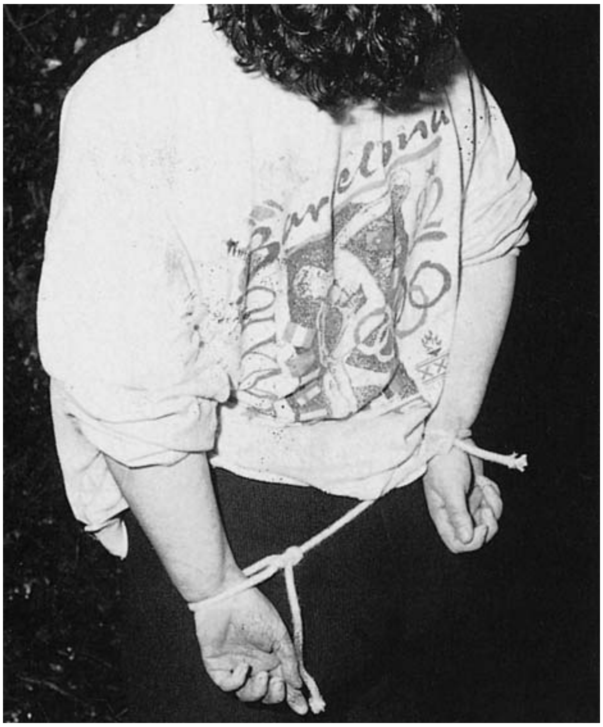

FIGURE 15.33 *The back of the victim in Figure 15.31, showing tying of the wrists. This does not indicate a homicide, unless the ligature could not have been self-applied. Some persons bent on self-destruction will try to ensure that they do not attempt to rescue themselves. A suicide note was left in this case.*

will occur in the legs and hands if the body has been in the vertical position for at least a few hours. When the body is cut down and laid horizontal for a considerable time, some or all of this appearance may flow back into the usual pattern.

Petechial haemorrhages are the exception rather than the rule, most series reporting them in approximately 25 per cent of cases. Such petechiae appear to occur more frequently in incomplete suspension but are frequently present in the absence of significant congestion. Congestion itself is far less usual than a pale face.

In the neck tissues there may be surprisingly little to find with an absence of laryngeal fracture or strap muscle haemorrhage being a common finding, especially if a soft ligature has been used. However, the literature suggests that an average figure for the incidence of soft tissue haemorrhage would be about 20–30 per cent of cases and for laryngeal fractures approximately 35–45 per cent of cases. Fractures of both the hyoid and thyroid may be seen.

Damage to the intima of the carotid arteries, often in the region of the sinuses, may sometimes be found on careful dissection. In hangings with an unusually long drop, severe disruption of the larynx can be found.

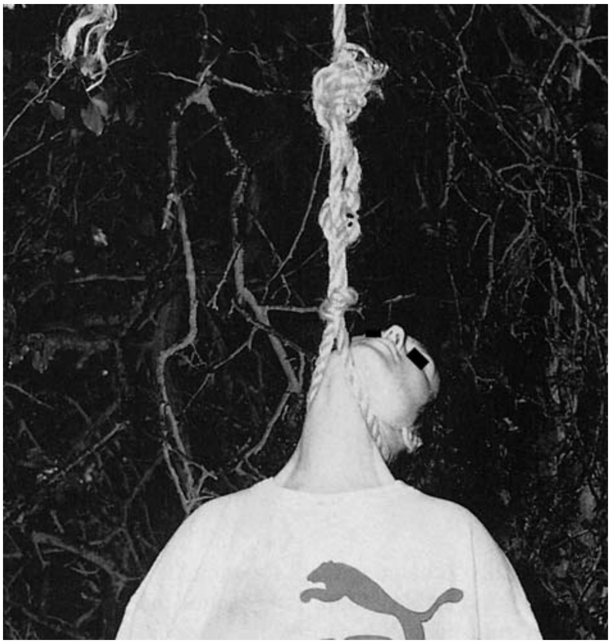

FIGURE 15.34 *Suicidal hanging with the rope in a frontal position. Even though the larynx cannot be compressed, death is due to pressure on the carotid arteries and sinuses. The face is pale, with no so-called 'asphyxial' signs.*

Mechanism of hanging

There are a number of mechanisms by which hanging may cause death, which may act independently or in concert. These include: stretching of the carotid sinus causing reflex cardiac arrest; occlusion of the carotid (and possibly vertebral) arteries; venous occlusion; airway obstruction resulting from pushing the base of the tongue against the roof of the pharynx or from crushing of the larynx or trachea; and finally spinal cord–brainstem disruption.

Whilst hanging shares some features with manual strangulation, the majority of victims of hanging are seen with pale faces rather than the congested, haemorrhagic appearance associated with the slower death resulting from pressure on the neck. This probably reflects a different mechanism, with reflex cardiac arrest and carotid occlusion more prevalent in hanging than in strangulation. Such mechanisms cause death rapidly, with unconsciousness resulting from bilateral carotid occlusion 3–11 seconds after the application of circumferential pressure.

However, the precise interplay of different mechanisms, which themselves appear only partially dependent on the completeness of suspension and the location of the noose, is impossible to determine from the pathological findings alone.

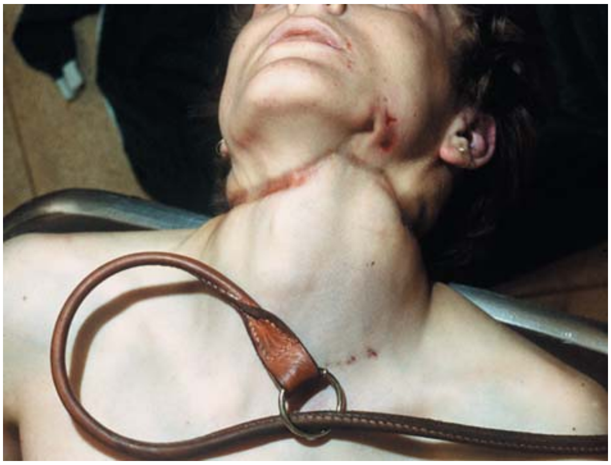

FIGURE 15.35 *Hanging by frontal suspension. A leather noose has been used so that compression has occurred round the whole periphery of the neck. The imprint of the metal ring on the jaw is well seen.*

Accidental and homicidal hanging

Though most hangings are suicidal, accidental hangings occur from two main causes. The first is entanglement in ropes or cords; this is relatively uncommon, and is usually seen in infants and children. The straps of a baby harness, used to support or restrain an infant, have led to death on a number of occasions, the child becoming entangled in leather or plastic reins when no adult was present. Any other cords may present a similar hazard, as in several cases seen by the author (BK), where infants standing in a cot near the bedroom window became entangled in a noose formed by the control cords hanging from a nearby blind or curtain.

On rare occasions, similar tragedies have befallen adults in factories, farms or ships, where a trip or fall has precipitated the victim head-first into machinery or structures, where ropes or cords have caused hanging or strangulation.

More commonly, a totally different situation causes fatal hanging or strangulation, almost exclusively in men and most often in young men, which is described in the next section.

Homicidal hanging is very rare, outside abuse of human rights and 'lynching'. For one individual to hang another, there must be either a disparity in their size and strength – or the victim must be drugged, drunk or otherwise incapacitated by fear, illness or senility. For a conscious, presumably unwilling, victim to be hanged by another, there will inevitably be signs of resistance, such as grip bruises on the arms due to restraint, or signs of binding the arms, wrists or legs.

THE SEXUAL ASPHYXIAS: AUTOEROTIC OR MASOCHISTIC PRACTICES

Though not all of this group are hangings or strangulations, this well-recognized phenomenon is conveniently considered here. The sexual asphyxias occur almost exclusively in men and only a few reports exist of women indulging in this dangerous habit, though Byard *et al.* (1990) have been able to contrast the death scenes in the two sexes, indicating that males tend to use more apparatus, whilst females are usually found naked with only a ligature in evidence.

The age of the male victims can vary widely, but is most often seen in young to middle-aged adults. The deaths that occur are obviously a small proportion of the total incidence of this strange practice. A fatal outcome is usually because of some failure of the equipment and this emphasizes the accidental nature of most of these deaths.

Features of the sexual asphyxias

The basic mechanism of the sexual asphyxias is the production of cerebral hypoxia, which in some men appears to produce hallucinations of an erotic nature.

This hypoxia is most often achieved by constriction of the neck by a ligature, which can be voluntarily tightened to produce vascular obstruction and perhaps airway stenosis. It would seem reasonable to think that vascular obstruction, either by blocking venous return – or even carotid flow – to the brain was the most likely explanation, as this would occur early. The production of cerebral hypoxia by anoxaemic anoxia through airway narrowing would surely be painful, distressing and slow in onset – hardly features which persons intent on self-gratification would welcome.

Some autoerotic procedures use other means of hypoxia, such as anaesthetic agents and a variety of volatile substances, tapering into 'solvent abuse', discussed elsewhere (Chapter 34). Whatever the mechanism, when cerebral hypoxia occurs with its attendant erotic sensations, progressive loss of voluntary control as consciousness fades allows the constrictive device to slacken, so that the subject recovers. As some fatal cases show clear evidence of repeated previous escapades, it is obvious that the mechanism usually functions quite successfully and that death was the result of some unforeseen complication.

A common practice is to place a fixed noose around the neck, so that compression will cease as soon as muscular tension on the free end is relaxed. This free end may be passed down the front or back to be fastened to the ankles, so that by extending the legs, the noose around the neck is

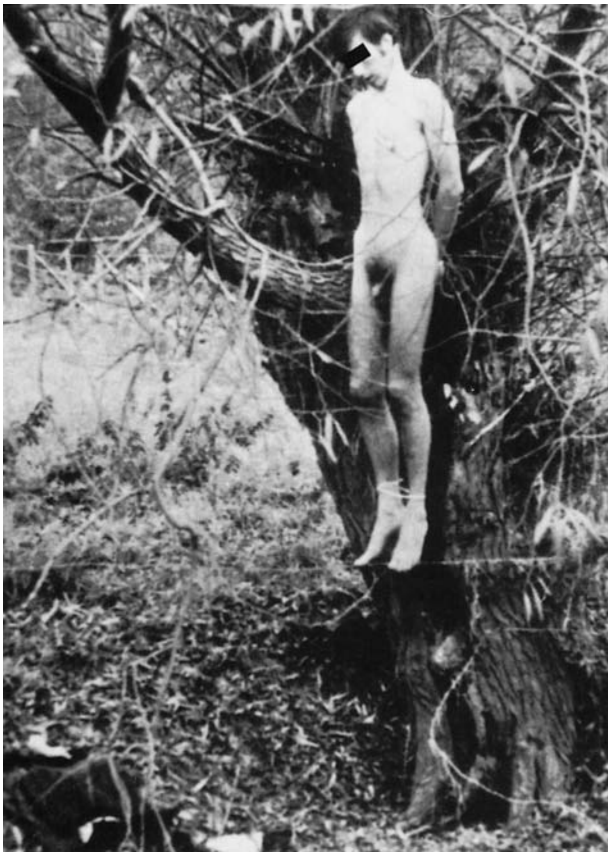

FIGURE 15.36 *Hanging in circumstances which suggest a sexual–masochistic motive. The young man showed no signs of previous depression or suicidal tendency. He was found naked, with arms and legs tied together with wire. Though homicide was suspected at first, the bonds were loose and easily self-applied. No satisfactory explanation was forthcoming.*

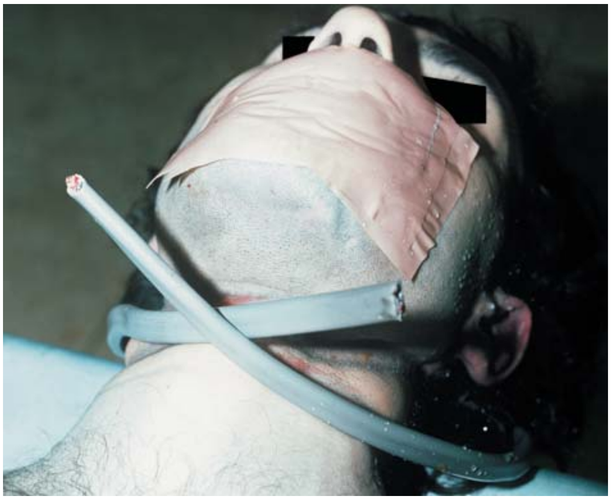

FIGURE 15.37 *A hanging in which it was not clear if there was a true sexual–masochistic element. The victim was suspended by electric cable from an attic trapdoor with his face plastered with surgical tape and the wrists tied together. Homicide could be excluded. In some deaths with an undoubted sexual element, the means used would inevitably lead to a fatal outcome, so there seems to be an overlap between masochism and suicide.*

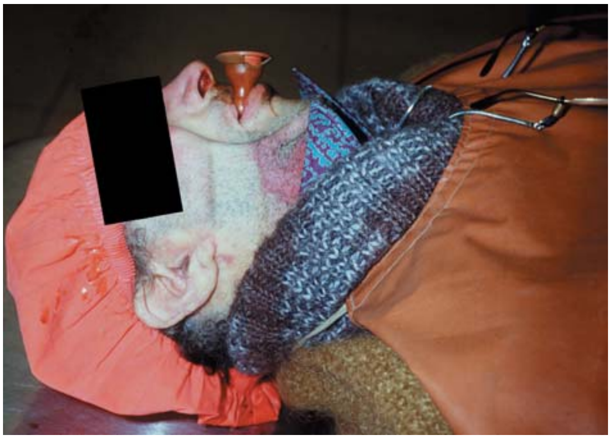

FIGURE 15.38 *Fatal sexual asphyxia in an engineer with a rubber fetish. He was found dead connected to a dental anaesthetic machine, with a rubber face mask strapped on over a rubber teat in the mouth. Bizarre pornographic material devoted to dentistry was in the vicinity. (Figure reproduced by kind permission of Dr S Leadbeatter.)*

tightened. Compression may also be attained by passing the rope over a support and hanging a weight on the end to produce tension.

Other men may secure the end to an overhead support and achieve constriction by slumping against the pull of the rope. In these and similar cases, it is difficult to understand how death can be avoided once consciousness is lost, but evidence of repetition on previous occasions indicates that enough voluntary control must be retained to allow the person to retrieve the situation after obtaining his erotic satisfaction.

Similar hypoxia may be produced by placing the head in a plastic bag, by pushing the head into a confined space, by postural contortions (often associated with bondage) that constrict the airway, or a host of other ingenious methods. One case seen by the author (BK) deliberately constructed a large sack made from impervious material, into which he crawled to attain his hypoxia. Certain features of these deaths make them fairly easy to differentiate from suicides, a distinction which is important, though some cases are impossible to separate from deliberate attempts at self-destruction (Knight 1979).

Bondage is common, with sometimes elaborate and bizarre methods of restriction. The wrists and ankles may be tied together with cord, wire, chains, padlocks or handcuffs, for example, and it is vital for the investigators to ensure

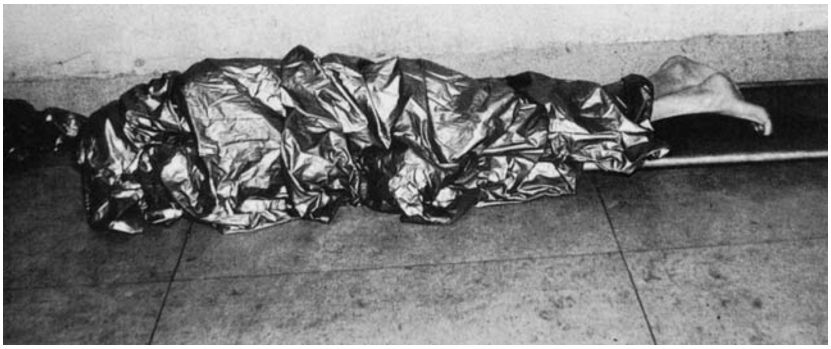

FIGURE 15.39 *A presumed instance of sexual asphyxia. The deceased was naked and had enveloped himself in a large impervious bag, which he had made himself. It seemed impossible for him to save himself once unconsciousness had occurred, but there appeared to be no suicidal tendencies in the history.*

that such bondage could have been secured by the deceased himself to exclude the possibility of homicide, usually by a heterosexual or homosexual partner involved in the ritual.

The bonds may be sexually orientated, with straps around the crutch or constricting the genital organs. In cases seen by the author (BK), one had made a metal sheath for the penis that was padlocked in place and another clamped the penis within a metal shackle.

Masks and gags may be in place, again a manifestation of restraint. The mouth may be sealed by adhesive plaster and the eyes blindfolded. Rubber or leather often features in the masks, which may have eye-slits or completely envelope the face. Transvestism is common, female attire being worn either overtly or under male clothing. False breasts and nipples may be fabricated or brassières padded with cloth. This is a common phenomenon, however, without sexual asphyxia, as any coroner's autopsy service will reveal some men (often elderly) as hidden transvestites, wearing female underclothing beneath their suits. Fetishism is often seen, especially rubber or shiny plastic or leather. Female wigs and make-up are sometimes encountered, though the syndrome does not seem to be overtly associated with homosexual activity.

Pornographic literature is often within view and may be spread around the body at the scene of death. The act is sometimes performed before a mirror and masturbation is common. The mere emission of semen found at autopsy does not confirm sexual activity in itself, however, as postmortem discharge of semen from the meatus is common in any type of death, not only in asphyxia (as used to be commonly alleged by standard textbooks). Occasionally, lewd writings are left near the body and even upon the body surface. The author (BK) has seen one where obscene graffiti were written with a ball-pen on the abdomen and around the glans penis.

Perhaps more importantly, overt suicide notes are never present, helping to distinguish the cases from definite self-destruction. Another important piece of evidence against suicide is the fact that, in some neck ligatures, the rope may be padded by fabric to avoid leaving a telltale mark on the neck – an act incompatible with an intention of suicide.

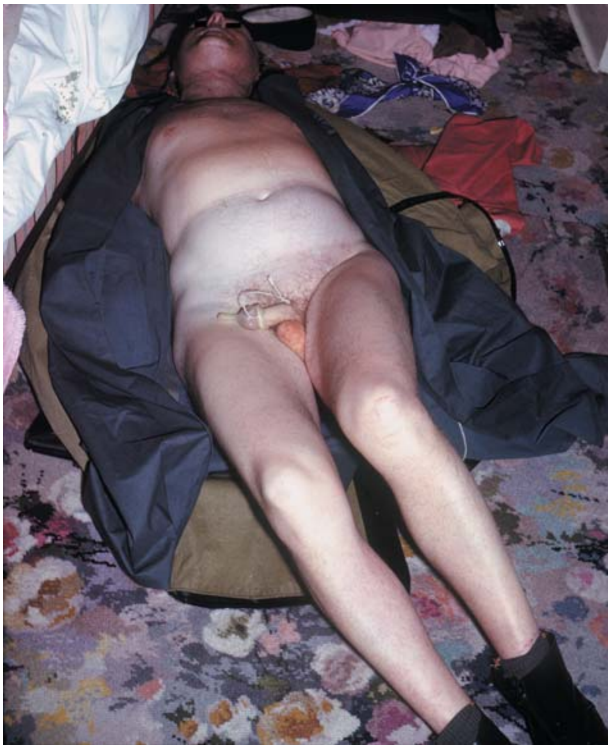

FIGURE 15.40 *A classical sexual asphyxia where the deceased has used a dog collar round the neck (removed before photography), the chain passing down to the ankles, which provide temporary traction. The common features of rubber fetishism and penile bondage were present.*

Rarely, autoerotic gratification may be achieved by the application of electric current, usually low voltage applied to the genitals. Electrical faults, such as in a transformer, may lead to a fatal outcome.

Medico-legal aspects of the sexual asphyxias

Though all these features make the true nature of the death clear to the medical examiner, it can sometimes be difficult

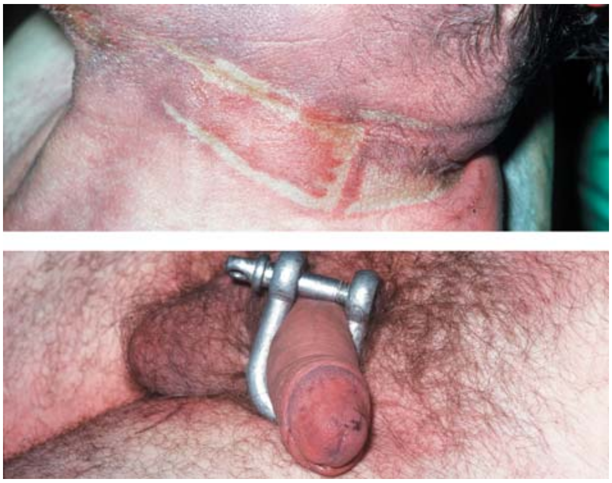

FIGURE 15.41 *A sexual asphyxia from a buckled belt applied tightly to the neck and a metal shackle on the penis. Obscene phrases were written on the glans and abdomen.*

to convince the police, the coroner or judge – and especially the relatives – that death was accidental. The stigma still attached to suicide and the revulsion felt at the perverted sexual element may cause the relatives to prefer homicide as the cause. The judicial authorities often lean towards suicide, especially when they are unaware of the existence of this strange syndrome of the masochistic or sexual asphyxias. The doctor is often the only person able to explain the relatively common occurrence of this phenomenon and assist in reaching the correct conclusion. It has to be admitted, however, that in a small minority of these deaths, it seems inevitable that the victim must have been aware of the fatal outcome, as the mechanics of the asphyxia are such that no escape could have been foreseen. In these instances the circumstances are such that a mixed motivation must have existed. For example, hanging by the neck in free suspension from a tree or from the trapdoor of an attic is a situation from which escape is impossible, even though sexual attributes such as nudity, bondage and masking were present (Knight 1979).

Where the victim is young, motivation is again less clear. Youths of 12 or 14 years are sometimes found hanged, usually without the secondary sexual or bizarre attributes listed above. There is usually nothing in the history to suggest suicide, and quite often the coroner or other legal authority will decide that death was due to 'experimenting with ropes', sometimes alleging that it followed watching lynching in cowboy films on television. It is probable that most of the obscure deaths are also associated with aberrant sexual activity, even if more positive evidence is lacking. Recognition of the true nature of most of these deaths is vital for the medical examiner, as spurious homicide investigations may be initiated if they are misinterpreted. More commonly a false suicide verdict may result, which can have financial implications in respect of life insurance. A mistaken belief in suicide may be preferred by some families, however, rather than the shame of a publicised sexual aberration.

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CHAPTER 16

Immersion deaths

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Many corpses are recovered from water, but not all have drowned. Of those that have drowned, pathological proof is often difficult or even impossible to obtain. The autopsy diagnosis of drowning presents one of the major problems in forensic medicine, especially when there is delay in recovering the victim.

Bodies retrieved from water may have:

- died from natural disease before falling into the water
- died from natural disease while already in the water
- died from injury before being thrown into the water
- died from injury while in the water
- died from effects of immersion other than drowning
- died from drowning.

All the above may show signs of immersion on examination, but this is rarely helpful, other than confirming that they had indeed been in water. It does not assist in differentiating the mode of death.

SIGNS OF IMMERSION

- Maceration of the skin begins within minutes in warm water, such as death in a bathtub, but in cold water is visible after a variable time, the minimum probably being 4 or 5 hours depending upon temperature. Polson's (1962) experience suggests a much longer time, from 12 to 48 hours, but sodden skin on the hands can undoubtedly occur much earlier than this.

  The first signs tend to be on areas with an appreciable keratin layer (such as the fingertips, palms, backs of the hands and later the soles) where the surface becomes wrinkled, pale and sodden – the so-called 'washerwoman's skin', for obvious reasons. Areas protected by clothing develop these changes later than exposed parts so that the hands usually reveal more marked maceration than the feet during the first few days.

  After prolonged immersion, wide areas of skin assume the same appearance, especially where the stratum corneum is thick or naturally creased, such as the extensor surface of knees and elbows. After some days in warmer water and up to several weeks in cold, the thick keratin of hands and feet becomes detached and eventually peels off in 'glove and stocking' fashion. The nails and hair become loosened at about the same time. Problems of obtaining fingerprints in such circumstances are dealt with later.
- Cutis anserina – or 'goose-flesh' – is a common finding in immersed bodies, but is related to cold rather than warm water. The erector pilae muscles attached to each hair follicle can contract in any type of death and cause a generalized pimpling of the skin. It is often stated that rigor mortis can produce this goose-flesh appearance, but this is doubtful, as rigor does not shorten muscles appreciably. From whatever cause, however, agonal contraction of the erector pilae is common and in immersed bodies has no diagnostic significance.

- The distribution of post-mortem hypostasis is also of no value in immersed bodies. According to Bonte *et al.* (1986), electrocution in the bath seems cause the margin of hypostasis to correspond with the horizontal line of the water level (see Chapter 12). It is usual for most corpses to float or hang in the water with buttocks uppermost, and the head and limbs hanging down, but water movements often roll the body constantly unless in a placid lake or wide river. Other corpses may float upon the back, and gravitational staining of the skin may therefore be in any pattern if the body is subject to frequent changes or posture. The hypostasis of bodies from cold water is frequently pink, but this has no diagnostic value. The reddish colour is caused by the presence of unreduced oxyhaemoglobin in the superficial blood vessels and is the result of cold, whether ante-mortem or post-mortem. It may be seen in any body taken from a mortuary refrigerator or found in a cold environment, irrespective of immersion. In immersion, however, it does not have the typical distribution over extensor surfaces and large joints, nor the rather dusky tinge that is seen in true ante-mortem hypothermia.
- Mud, coal-slurry, oil, silt or sand may be present on or in the body, as well as other artefacts such as seaweed, water weed, algae and small aquatic animal life of many types. Mud may be adherent to the whole body surface and clothing, or may be retained in the hair, mouth, nostrils, ears and other more protected sites. In appropriate circumstances, such deposits should be retained for scientific examination, if they might help establish where the body has travelled from in marine or riverine waters. Sand may be found deep in the respiratory passages and stomach, especially if the body has been rolled by the waves on a beach. Such deep penetration is not evidence of live aspiration. Where a body is decomposed and partly skeletalized, molluscs may colonize the bones. The author (BK) has had several cases recovered from the sea where mussels and barnacles filled the eye sockets and other crevices of the skull.

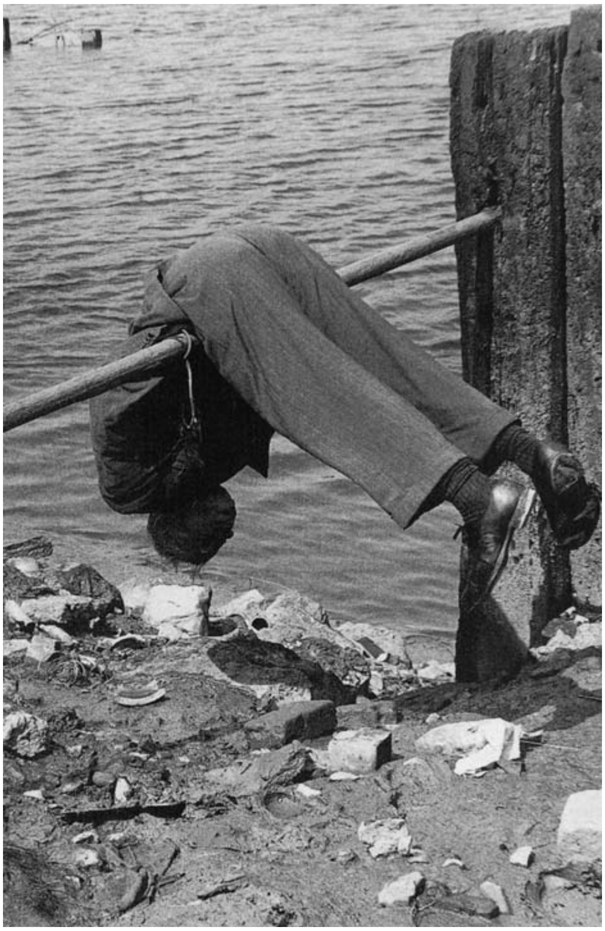

FIGURE 16.1 *The diagnostic problems associated with bodies recovered from the water. In a death such as this, where a body is left by the falling tide, it may be difficult or even impossible to prove drowning, especially if the post-mortem period is long.*

ESTIMATION OF DURATION OF IMMERSION

This is another difficult problem and one that is often too dogmatically answered by doctors with insufficient experience to appreciate the potential errors. The over-riding variable factor is water temperature, which has the most effect upon decomposition. Water pollution has little to do with speed of putrefaction, as most of the decomposing organisms come from the gut of the body itself.

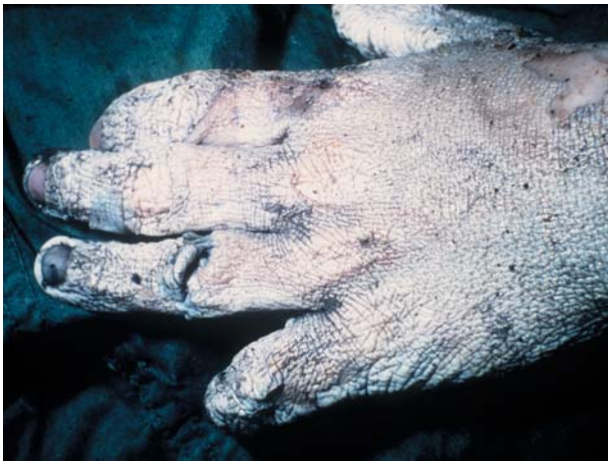

FIGURE 16.2 *Waterlogged skin ('washer-woman's hands') after 2 weeks' immersion in a temperate climate. Fingerprints can still be obtained from hands like these, with appropriate techniques.*

When a body falls into water in average temperate climates, the following is an approximate guide to timing, in conjunction with the other usual signs, such as rigor:

- if no wrinkling of the finger-pads is present, less than a few hours
- wrinkled fingers, palms and feet, progressively from half a day to 3 days
- early decomposition, often first in the dependent head and neck, abdomen and thighs: 4–10 days
- bloating of face and abdomen with marbling of veins and peeling of epidermis on hands and feet, and slippage of scalp: 2–4 weeks
- gross skin shedding, muscle loss with skeletal exposure, partial liquefaction: 1–2 months.

These times may be reduced or exceeded by wide margins according to animal predation, climatic changes and bodily build.

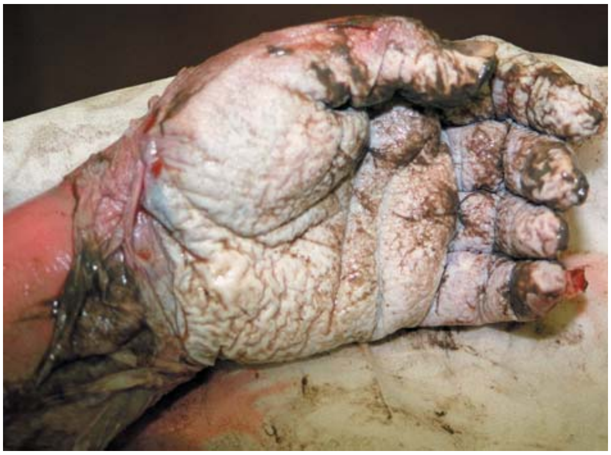

FIGURE 16.3 *Waterlogged skin after one week's immersion in a cold climate.*

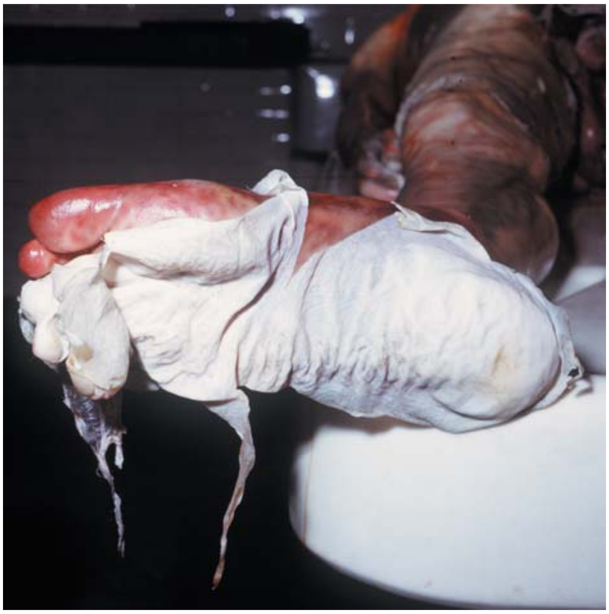

FIGURE 16.4 *Peeling of the epidermis in a 'stocking' fashion after a few weeks' immersion. The rate at which such changes occur is so variable, because of environmental factors, that no timetable can be offered to attempt to date death. In a temperate-zone summer, this stage would require at least 2 weeks and probably much longer.*

DEATH FROM NATURAL CAUSES BEFORE ENTERING THE WATER

This is relatively uncommon, but does occur. The victim may suffer one of the many causes of sudden natural death, most commonly a cardiovascular catastrophe, in circumstances where he involuntarily falls into the water. The last such instance dealt with by the author (BK) was a man returning to his yacht in a rubber dinghy, alone and in the dark. The dinghy was found empty and a search recovered the body, autopsy revealing a well-established myocardial infarct with no evidence of drowning, though the latter is never conclusive. Other instances have involved persons collapsing from natural disease while on boats, a canal tow-path or a river bank.

Of course, in the absence of witnesses it is difficult to separate such cases from those who first fall into the water and then suffer a natural death. The autopsy must be directed towards identifying the pathological lesions and to excluding, as far as is possible, any evidence of drowning.

NATURAL DEATH WHILST IN THE WATER

As discussed above, it may well be impossible to determine whether a person recovered from the water, with a potentially fatal natural disease, suffered this before or after immersion. Because of the problems (to be described later) of positively diagnosing drowning, it is difficult to exclude this as either the primary or contributory cause in someone with a lethal disease.

Cardiovascular disease is the most common reason for death in the water. A pre-existing condition may be exacerbated either by the physical exertion of swimming or struggling, or by the effects of cold. The common belief that swimming after a heavy meal is dangerous probably has some basis in fact, because of circulatory changes such as the 'splanchnic shunt'. When an acute cardiac episode occurs, such as sudden myocardial insufficiency or an arrhythmia, death may follow either from the cardiac lesion itself, or from drowning because of sudden physical incapacity.

INJURIES SUSTAINED BEFORE ENTERING THE WATER

The disposal of a murdered corpse in water is by no means uncommon, as it provides a convenient means of concealing the body, of transporting it from the scene of the crime by means of currents in river or sea, and – if discovery is delayed – of preventing identity by post-mortem decay and damage. Occasionally, accidental or suicidal injuries may be inflicted on a person before he or she enters the water. In marine, air or (rarely) road transport accidents, the victims may be injured or killed before entering the water. Persons falling from docks, bridges or ships may strike masonry or solid obstructions before hitting the water. Suicides may suffer in the same way or in exceptional circumstances, may stab themselves or cut their throats in a position where they fall into water immediately afterwards.

Whatever the means, the difficulties for the pathologist are the same, in that he must try to differentiate them from injuries sustained in the water before death occurs – and from post-mortem injuries. Often this is an impossible task, as such injuries are sustained perimortally, so that the time span involved is far too short for any of the usual criteria of ante-mortem infliction to be applied.

When the nature of the injuries is such that they could not have occurred in water, the issue is clear. Burns, missile wounds, the effect of explosions (other than compression injury) and patterned injuries may be incompatible with infliction in water, and must therefore be related to the effects of a previous assault or some accident on board ship or aircraft.

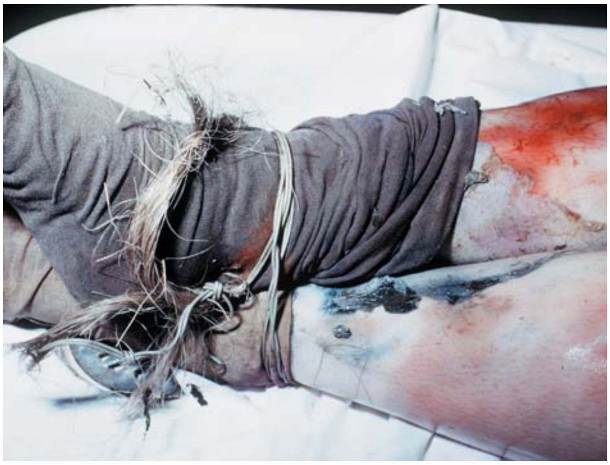

FIGURE 16.5 *Tying of the legs in a body removed from the water is suspicious, but not absolute proof of foul play. Some suicides who are good swimmers deliberately tie their legs to prevent instinctive self-preservation. In this illustration, however, the bonds were used to secure a heavy weight after homicide.*

INJURIES SUSTAINED IN THE WATER

As stated, this category is often impossible to differentiate from injuries inflicted before entering the water. Trauma in the water is common, as both an ante-mortem and a post-mortem phenomenon. Before drowning or another mode of death can supervene, the victim may be washed by waves or current against any kind of obstruction, from bridge pier to wharf, from rocks to weirs. Contact with the rough bottom of a river or a stony beach is another common cause of trauma. Damage from boats, ship's propellers, and marine or animal predators is frequent.

The issue usually becomes one of attempting to distinguish injuries sustained during life from those after death. Water complicates the problem by washing away surface bleeding from open injuries. A laceration inflicted during life will, however, usually show some bleeding into the tissues under the margins of the wound, at least until post-mortem decomposition blurs the appearances. Many decomposed bodies from water reveal green or black areas under the skin, especially in the scalp. It can be difficult or impossible to decide whether these are areas of altered blood, or merely autolytic changes. Even histological examination is often unhelpful in this respect. A similar problem exists with bruises in a decomposed body, which are often mimicked by discoloured areas of putrefaction. Post-mortem damage from animal predators is common in water and is discussed in the chapter on post-mortem changes.

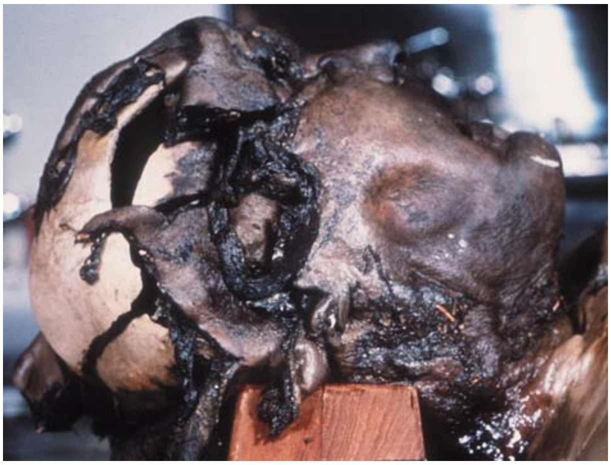

FIGURE 16.6 *Decomposed head and fractured skull of a person, who disappeared in the autumn before the river was covered with ice. The injuries have possibly been caused post-mortem by the ice packs when the body surfaced in the spring.*

In cold climates, if a body enters the cold water in late autumn, the gas formation due to putrefaction may be so slow that the sea, lake, or river will be covered with ice before the body surfaces and this takes place first in the spring when the ice is melting. In rivers, additional injuries may occur if the body gets pinned down between moving ice blocks.

Internally, there is no particular problem distinct from the examination of injured bodies in general, until post-mortem decomposition begins to obscure the appearances. This is more common in immersed bodies because of the frequent prolonged delays before the body is discovered. Bodies that have been suspended in shallow water may bear post-mortem damage from being dragged against the bottom. A common posture is with the head, hands and knees hanging downwards, so that these areas (especially the backs of the hands) may suffer extensive abrasions against a rough stone or gravel bottom.

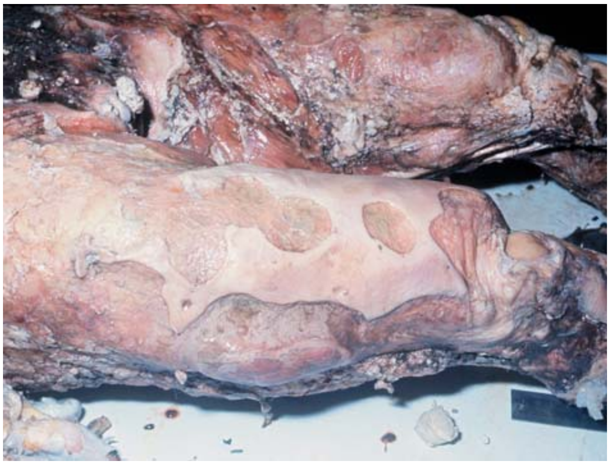

FIGURE 16.7 *Marine predator injuries on a body from the sea. The circular defects in the skin are probably made by crustaceans such as crabs.*

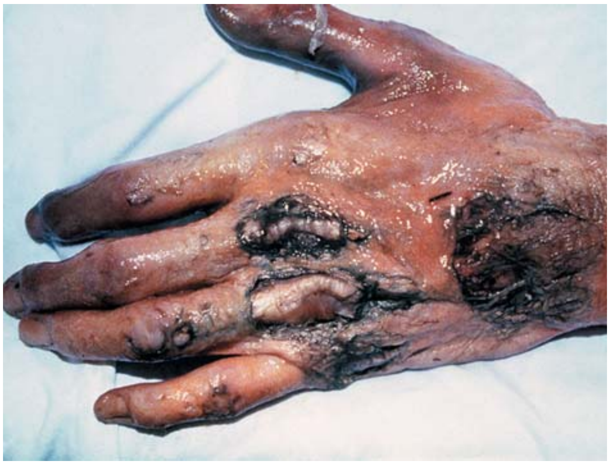

FIGURE 16.8 *Post-mortem injury to the back of the hand in a drowned person. Bodies usually hang suspended in the water with the back upwards and the knees, head and arms hanging down. In shallow water these areas may be dragged against the bottom, causing injuries similar to those shown here.*

Damage from the propellers of ships and smaller boats is common in commercial waterways and where pleasure craft abound. The screw of a large vessel may inflict serious damage – even dismemberment – on a body, but more characteristic is that caused by a small, high-speed propeller, such as an outboard motor or the out-drive of a motor cruiser. These injuries are becoming more common with the increase in water-skiing, and the number of other small pleasure boats on rivers, lakes and off beaches. The characteristic lesions are parallel wounds set a few centimetres apart, often of a sliced, undercut incised nature, usually on the head or back.

DEATHS FROM IMMERSION OTHER THAN DROWNING

Irrespective of natural disease or injury, some persons who die after falling into water do not drown, in the accepted physiological sense. The great problem for the pathologist is that, even in true drowning, there may be no autopsy signs, especially if any appreciable delay has occurred before recovery or autopsy, or both. Therefore it may be difficult or impossible for him to say whether a death is a true drowning or one from the non-drowning mechanisms. All that can then be offered is that death was due to 'immersion' – and even then such a diagnosis is usually one reached by exclusion of natural disease, trauma or toxic conditions, using hearsay circumstantial evidence to arrive at a pathological diagnosis. This is why drowning and immersion deaths present one of the most difficult problems for the forensic practitioner.

In certain circumstances, death may be extremely rapid after falling into water, there being insufficient time for drowning to occur. The typical occasion is familiar to any forensic pathologist with a harbour or dockside within his area. A seaman (often the worse for drink) returns to his ship at night, misses the gangway and falls into the water. The night-watchman immediately raises the alarm and the victim is pulled from the water within a minute or two, but is dead. At autopsy, none of the typical signs of drowning are present.

Other witnessed accidents of a similar nature are relatively common, in which rapid, almost instantaneous death must be presumed, in circumstances where true drowning can be excluded by history and lack of autopsy findings. The mechanism must be attributed to a reflex cardiac arrest, of a type similar to 'vasovagal inhibition', which is discussed elsewhere. Powerful stimulation of sensitive nerve endings can induce sudden overactivity of the parasympathetic system, inducing

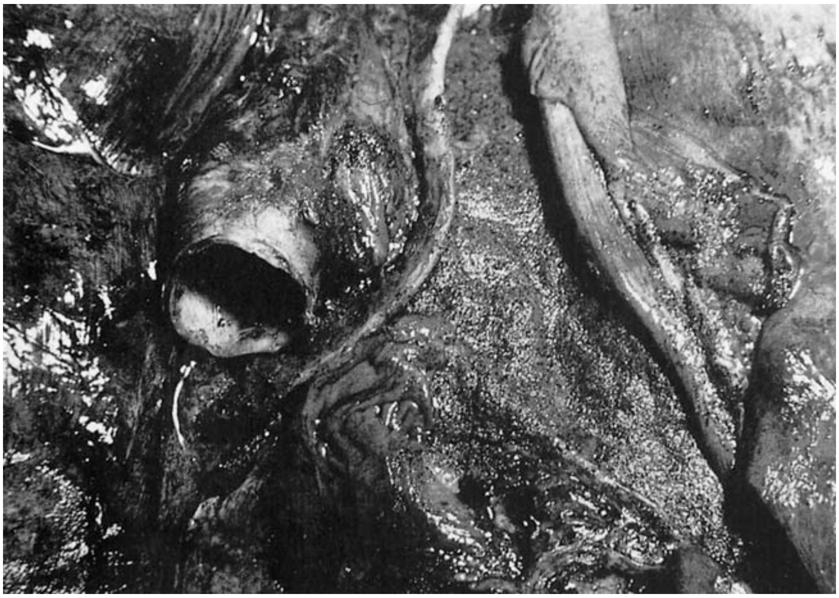

FIGURE 16.9 *The bifurcation of the trachea and main bronchi at autopsy on a body recovered from a beach. The air passages are full of sand, but this is not proof of vital aspiration of water, as foreign material can enter the bronchi by passive percolation after death.*

bradycardia and triggering cardiac arrest via the tenth cranial nerve nucleus and its vagal outflow. The afferent arc of this reflex varies from case to case, but is probably either:

- sudden immersion in cold water, causing intense stimulation of cutaneous nerve endings. Alcohol is known to potentiate such effects, perhaps by the general vasodilation of skin vessels – which would make the contrast with cold water all the more severe – and possibly by some central effects on the vasomotor centre
- sudden entry of cold water into the pharynx and larynx, and perhaps nasal passages can produce powerful stimulation of nerve endings in the mucosa. A bolus of water entering the trachea can also cause reflex cardiac arrest before there is time for airway insufficiency to have any effect.

As with any reflex cardiac arrest, there will be nothing to find at autopsy, a situation that forces this diagnosis to be speculative and based on the circumstances and exclusion of other conditions. Another mechanism that is often postulated as a cause of non-drowning immersion death is 'laryngeal spasm', leading to a hypoxic death from closure of the airway. The evidence for such a condition is tenuous, as such closure would have to operate for many minutes for hypoxia to kill, all the time keeping the larynx closed to prevent entry of water. Cyanosis is an uncommon feature of immersion deaths and in its absence it is difficult to see how laryngeal spasm could be differentiated from 'dry-lung drowning' or vasovagal cardiac arrest, the latter being a more reasonable diagnosis in those found dead after rapid recovery from the water.

Deaths in the bathtub

Fatalities in the bathroom are common, from a variety of causes, some unconnected with immersion. For example, Schmidt and Madea (1995) reported no fewer than 215 deaths in bathtubs from their Cologne Forensic Institute in 13 years, including 11 homicides.

Many suicides take place in the bathroom, from slashing of the throat or wrists, in or out of the bath. The bathroom cabinet or cupboard commonly holds razors for cutting and medicinal poisons for overdose. Electricity is more likely to be fatal in wet surroundings and a number of self-killings from electricity occur in the bathroom. Accidents include falls on slippery, wet floors or bath lining, with hard ceramic surfaces to cause head injuries.

Where gas appliances are used to heat water, the risk of carbon monoxide toxicity from faulty equipment is greater, as is also the case with electrical appliances such as hair-dryers, heaters and other devices. Although most countries have strict regulations about the electrical supply in bathrooms, people often defeat these safety measures by various means. Natural deaths from many causes may occur in the bathroom, but epileptics having unsupervised baths may have a fit and fall or drown.

Even homicide may be committed in bathrooms, by almost any means, but also from electricity and forcible immersion. The notorious multiple murders of 'The Brides in the Bath' perpetrated by George Joseph Smith early this century were probably accomplished by sudden pulling of the feet of the three women, so that their heads slid under the water. There is now a considerable literature about death in the bathtub, and all deaths in these circumstances must be investigated with particular care.

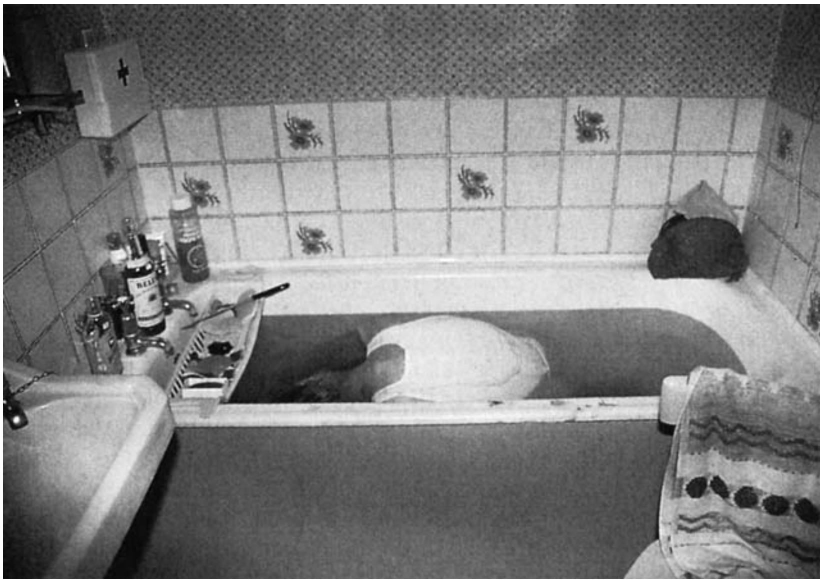

FIGURE 16.10 *Death in the bath is not uncommon and always requires careful investigation. In this case, the water is blood-stained, due to a suicidal cut throat after committing murder.*

DEATH FROM DROWNING

During the past five decades, views on the mechanism of drowning have undergone a radical change and perhaps the pendulum of opinion has swung a little too far. Until the researches stimulated by the Second World War, when large numbers of seamen and airmen were exposed to the risks of cold water, the classic view of drowning was that the victim was plunged into an airless medium and died of lack of oxygen. Following the experiments of Swann and many others (see below and references and further reading), it was recognized that, in animals, fluid and electrolyte disturbances had a major role in causing acute myocardial failure. The hypoxic element was relegated to such a secondary role that some commentators on drowning seemed to ignore the fact that the victims may have suffered 10 or more minutes without drawing a single breath of air. This criticism by no means disputes the undoubted role of fluid and electrolyte changes in drowning, but the effects of hypoxia must be considered in parallel when discussing the pathophysiology of drowning. The biochemical findings in the experimental animals did not seem to be matched by constant changes in human subjects and, in delayed and near-drowning victims, the electrolyte changes in aspiration have been shown to differ considerably from those in experimental animals.

A number of investigators long before Swann showed that blood and plasma were radically affected by drowning. In 1902, Carrara used specific gravity and other methods to demonstrate marked dilution of left heart blood in freshwater drowning and its absence in seawater, work repeated by Planck the following year with similar density techniques. Freimuth in 1955, however, used such specific gravity methods and found similar differences in non-drowning deaths.

The classical work of Swann and his colleagues (Swann *et al.* 1947; Swann and Spafford 1951) and others was conducted on conscious dogs imprisoned in cages and immersed totally under water – which, as pointed out by Crosfill (1956), does not accurately reflect human drowning, in which submersion is intermittent at first, prolonging the process and altering the physiological effects. In summary, the findings of Swann were that in freshwater drowning there was a massive absorption of water through the alveolar membranes, which could amount to 70 per cent of the original blood volume within 3 minutes. This haemodilution caused a relative anaemia and myocardial hypoxia, as well as rapid overloading of the cardiac capacity by hypervolaemia. It was also suggested that haemolysis of red cells released potassium, a powerful myocardial toxin – yet in dogs, unlike man, sodium is the main electrolyte in the erythrocyte. In fact, because of the hypoxia and haemodilution, there was a fall in plasma potassium and sodium, which led to early ventricular fibrillation in dogs that did not occur in seawater. Such fibrillation is said to be rare in man (Rivers *et al.* 1970).

In seawater the hypertonic medium caused a withdrawal of water from the plasma into the lungs and a rise in plasma sodium concentration. This was less deleterious to heart function and helped to explain the longer survival time in seawater immersion.

Pulmonary oedema developed in both types of aqueous medium but was slight and inconstant and, where abnormal, rapidly returned to normal. Death in freshwater typically took some 4–5 minutes, whilst seawater drowning was delayed for 8–12 minutes. Occasional instances have been reported of remarkably long periods of total submersion in the sea, always in cold water where oxygen uptake is reduced: these periods may exceed 20 minutes, and at least one authenticated survival exceeded 40 minutes.

Modern commentators on the researches of Swann, such as Giamonna and Modell (1967), have pointed out the inconsistencies between animal and human responses, and emphasized the role of hypoxaemia as a result of interference with the blood–air interface in the alveoli. This once again indicates the dangers of transposing the results of animal experiments to man and poses the question of how many dogs died in vain.

THE AUTOPSY SIGNS OF DROWNING

At autopsy much depends on the delay, both in recovering the body from the water and in starting the post-mortem examination. Where a considerable period has elapsed between death and retrieval of the body, the positive signs of drowning progressively fade. Depending on temperature, a period of several days in the water is likely to minimize most changes and, once significant putrefaction has occurred, then (apart from the controversial diatom tests) there is little hope of finding positive signs of drowning.

Even when a fresh body is recovered, delay in performing the autopsy reduces the amount of evidence. The author (BK) has seen several drowned bodies soon after retrieval in which a large plume of froth has been present at the mouth, yet when commencing the autopsy several hours later, such froth had vanished and was present only in the deeper air-passages.

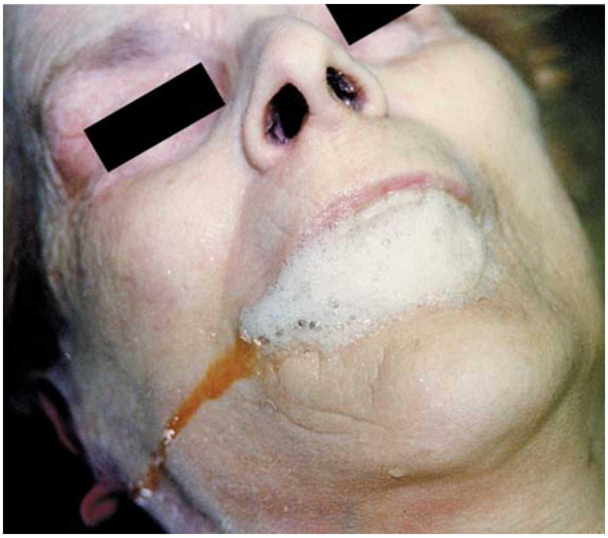

FIGURE 16.11 *Froth exuding from the mouth of a drowned person. Froth disappears with increasing post-mortem interval, though it persists in the internal air-passages for a much longer time.*

Froth in the air passages

The positive signs of drowning, as opposed to mere immersion, are scanty and not absolutely specific. The most useful, has just been mentioned – the presence of frothy fluid in the air passages – which in fresh bodies, often exudes though the mouth and nostrils, sometimes in the form of a plume. The froth is oedema fluid from the lungs, and consists of a proteinaceous exudate and surfactant mixed with the water of the drowning medium. It is usually white, but may be pink or red-tinged, because of slight admixture with blood from intrapulmonary bleeding. It is similar in appearance to the oedema of left ventricular failure that is commonly seen in deaths from cardiac disease such as hypertension, though some drownings exhibit a column of

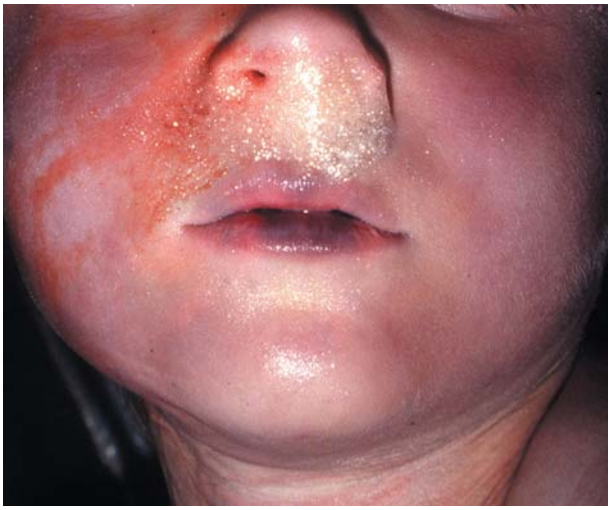

FIGURE 16.12 *Red-tinged froth exuding from the nostrils of a drowned person.*

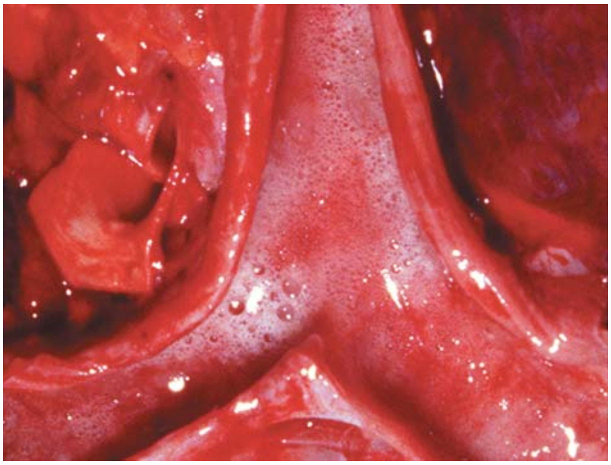

FIGURE 16.13 *Frothy fluid in the trachea and main bronchi of a person who was first strangled and subsequently fell or was thrown into sea and drowned.*

froth that is rarely, if ever, seen in natural pulmonary oedema. The froth extends into the trachea, main bronchi and smaller air passages. The lungs themselves in such cases will inevitably be waterlogged, and frothy fluid will exude from the bronchi when the lung is squeezed and from the cut surfaces when they are sectioned with a knife.

Unfortunately, although such oedema can be taken as diagnostic when combined with the appropriate circumstances and lack of other lethal pathology, the absence of waterlogging by no means excludes true drowning. The so-called ‘dry-lung drowning’ is not uncommon, in which the lungs appear normal in all respects, presumably because all the aspirated water has been absorbed through the alveolar walls into the plasma.

It has been suggested that this is more likely to occur if cardiac arrest takes place after removal from the water or if laryngeal spasm supervenes to prevent further water entry, so that continued circulatory function is able to clear away intra-alveolar fluid into the plasma. This theory, however, often fails to conform to the available facts of the drowning episode.

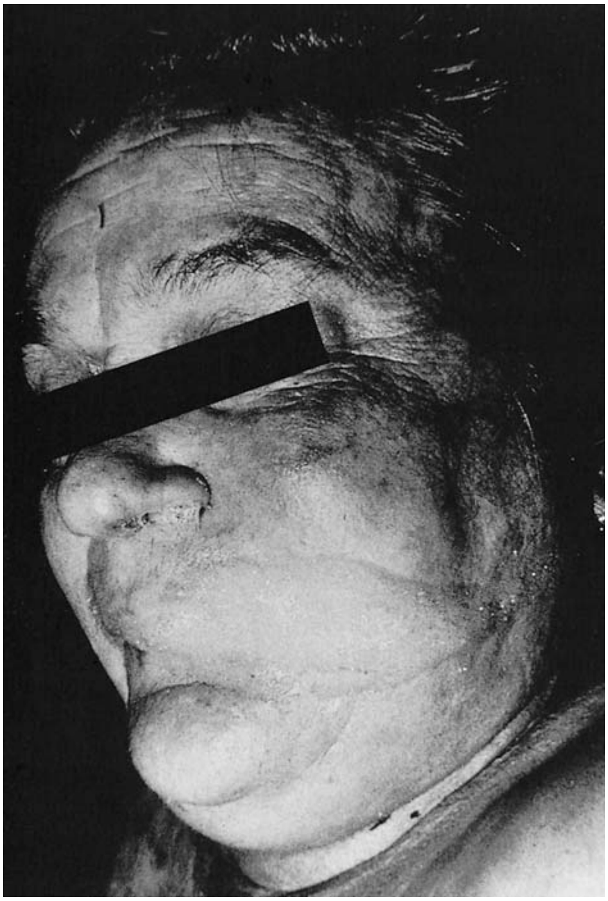

FIGURE 16.14 *Not all froth around the mouth is from drowning. This lady died in bed from hypertensive heart disease with profuse pulmonary oedema.*

Copeland (1985) measured lung weight in non-drowning deaths and deaths from salt-water and freshwater drowning. There was no significant difference in the weights of the last two, though 10–20 per cent of undoubted drownings were ‘dry-lung’ cases with no excess weight. Generally, the weights of a lung in drowning were around 600–700 g, whilst the non-drowned were in the 370–540 g range – though there was a considerable overlap in the two groups. The lung weights were also studied by Kringsholm *et al.* (1991) who claimed that the duration of submersion is related to lung weight. They found that 7 per cent of cases were ‘dry-lung drownings’ with a combined lung weight of less than a kilogram. In the remainder, the average weight of both lungs was 1411 g, compared to 994 g in controls. This was where the body was in the water less than 24 hours. After this, lung weight decreased, but pleural transudate increased. By combining the weight of lungs and transudate, more than 75 per cent of the cases lay between 1000 and 2200 g, up to 30 days.

Overinflation of the lungs

Apart from generalized waterlogging, the lungs may be markedly overinflated, filling the thoracic cavity when the sternum is removed. The normally bare area over the heart may be covered and the lungs may bulge upwards, meeting in the midline to obliterate the anterior mediastinum. The texture is rather pale and crepitant, superficially resembling that shown in asthma – for the same reasons. The older name for this condition is ‘emphysema aquosum’. True pre-existing emphysema may partially mimic the distension of drowning, but in the latter, bullae are never present. The oedema fluid in the bronchi blocks the passive collapse that normally occurs at death, holding the lungs in the inspiratory position. In addition, there is often an element of over-distension caused by the valvular action of the bronchial obstruction – again similar to asthma. In drowning this may be sufficient to mark the lateral surfaces of the lungs with the impression of the ribs, leaving visible and palpable grooves after removal of the organs from the thorax. This may be one of the most valuable positive signs of drowning to be gained at autopsy.

There may be some areas of intrapulmonary haemorrhage, which give the red tinge to the oedema fluid. These areas are seldom large or intense, and the general oedema and distension tend to minimize their prominence. Some may lie near the pleural surface and can be seen as rather blurred blotches on the exterior of the lung, the blurring being partly the result of spreading haemolysis. There are almost never subpleural petechial haemorrhages in drowning, apart from the few non-specific spots that can be found in the fissures and around the hilum in virtually every autopsy, no matter what the cause of death.

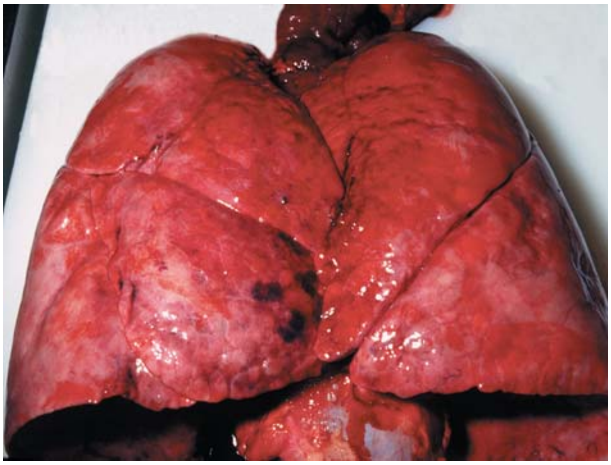

FIGURE 16.15 *Overinflation of the lungs (emphysema aquosum) in drowning with overlapping of the anterior margins and haemorrhages in the right middle lobe.*

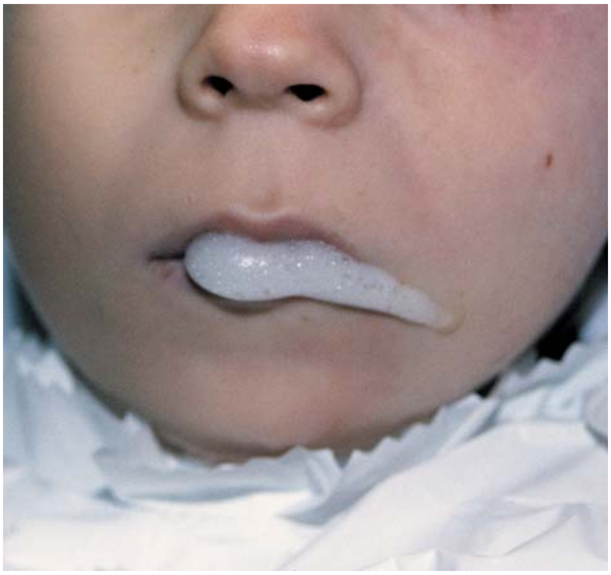

FIGURE 16.16 *A typical plume of froth from the mouth of a recently drowned boy. This will vanish as the post-mortem interval extends.*

Other organs in drowning

There are no other reliable autopsy changes in drowning. The heart and great veins have often been said to be 'dilated and engorged with fluid blood, especially the right side', but this is such a subjective and non-specific finding as to be useless, meriting no further consideration.

Many pathologists have for centuries claimed that the blood remains more fluid in drowning, and the physiological researchers of this century have confirmed the haemodilution in freshwater drowning. As a gross sign at autopsy, however, it is totally subjective and unreliable.

The stomach may contain watery fluid or even foreign material from the water, such as silt, weed or sand, but this cannot be accepted as a positive aid to the diagnosis. Many undoubted drownings show no water in the stomach, yet other cases in which a dead body was immersed reveal copious water in the stomach. The limiting factor is the tone in the oesophagus and cardiac sphincter, not the drowning process. The same applies to foreign materials in the trachea. Haemorrhage into the middle ears has been postulated as a positive sign of drowning, but in the author's (BK) own experience, it is totally unreliable. It can occur in any type of death where drowning can be definitely excluded, yet in classic instances of drowning, such bleeding may be absent. It has been said to be related to the depth to which the body sinks because of the hydrostatic pressure within the ear, but even this does not accord with the experience of most pathologists (Niles 1963).

CHEMICAL CHANGES IN THE BLOOD IN DROWNING

Because of the marked haemodilution that occurs in freshwater drowning and the electrolyte shifts in salt-water drowning, it is reasonable to expect that chemical analyses of the plasma should provide reliable evidence of drowning. Unfortunately, these theoretical hopes have not been realized in practice, mainly because of the biochemical chaos that occurs soon after death from any cause, in which the ability of live cell membranes to partition fluid and electrolytes is rapidly lost. Gettler (1921) published results of analyses of chloride content from the left and right sides of the heart, suggesting that the haemodilution from freshwater drowning would differentially reduce the plasma concentration on the left side, a difference of 25 mg/100 ml being significant. Salt-water drowning was said to produce the opposite effect. Gettler's claims have often been refuted and they are now no longer accepted. It has been shown that post-mortem changes in blood chloride concentrations occur irrespective of drowning and that the rate of change may be different on each side of the heart. Even the differentiation between freshwater and seawater drowning was discredited by the work of Durlacher *et al.* (1953), who found no reliable changes in sodium, potassium and chloride concentration. Similar results were found by Fuller (1963).

Electrolyte measurements in surviving victims of near-drowning showed no regular pattern, according to Rivers *et al.* (1970). Moritz (1944) attempted to use magnesium

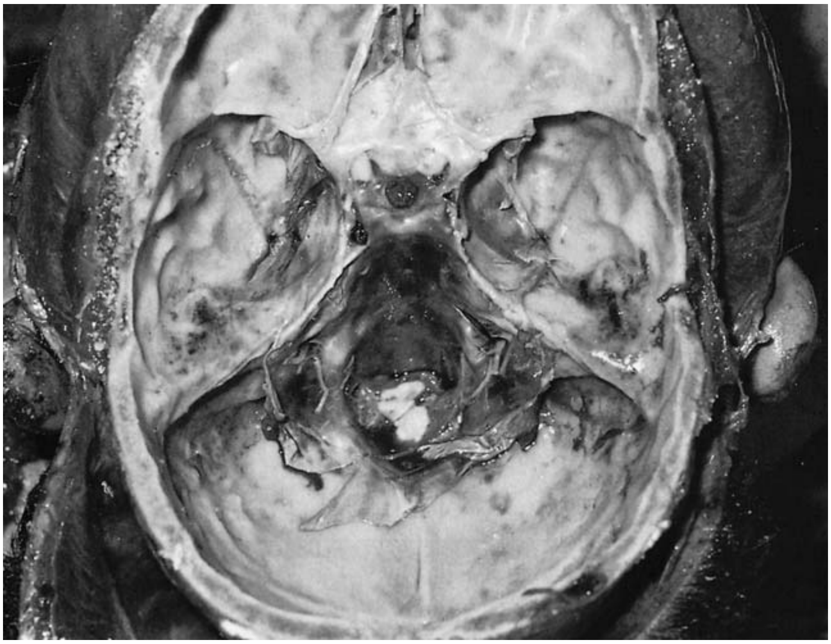

FIGURE 16.17 *Bilateral haemorrhages within the petrous temporal bones in drowning. Though claims have been made for the usefulness of this observation, its occurrence seems random, sometimes being present in non-drowning and absent in proven drowning.*

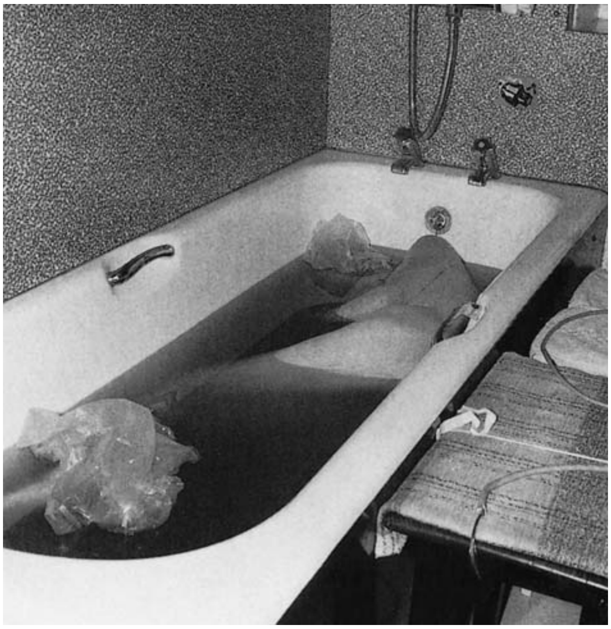

FIGURE 16.18 *Suicide in the bath. The head was enveloped in a plastic bag and an (unused) electrocution device was also present, illustrating the frequent presence of alternative methods in suicide.*

as a similar marker in drowning, but the unreliability of such analyses has prevented their being used as a routine procedure. Once again, the hazards of extrapolating the results of animal experiments to humans is highlighted by these results, as even other mammals like dogs have quite different responses to the same environmental changes.

Other chemical substances have been used as markers of drowning, such as strontium. Azparren *et al.* (1994) claim that differences in the strontium concentration of blood from left and right heart are always greater than 75 μg/l in seawater drowning.

HISTOLOGICAL CHANGES IN DROWNING

Much has been written about both light and electron microscopy of the lungs in immersion deaths, especially in continental Europe. The accounts are confusing, however, and sometimes contradictory, the consensus of opinion being that such changes are inconstant and unreliable.

Much of the work has tried to confirm histologically the genuineness of 'emphysema aquosum' in both fresh and decayed bodies, but the dilatation and rupture of the terminal air spaces can occur not only as a result of drowning, but of passive immersion in water deeper than 4 m. Dilatation of the alveoli, thinning of the walls and compression of the capillaries are easy to observe, but the significance is always ambiguous. Reh (1976) classified such lungs on the basis of reticulin fibres, but Heinen and Dotzauer (1973) showed similar changes in undrowned material. Janssen (1984) has reviewed the subject and concludes that though histological evidence may be helpful and indicative, it is never probative.

The number of macrophages in the alveoli, adjusted to the size of the alveoli where distended, was studied by Betz *et al.* (1993), who claimed a diagnostic usefulness of the method as long as no autolytic changes were present.

The weight of the spleen has been used by Haffner *et al.* (1994) as a diagnostic marker in drowning. Compared with other modes of 'asphyxia', about an 18 per cent reduction in weights and spleen–liver ratios was recorded, with a suggestion that stress, hypoxia, alcohol and cooling were responsible.

The skin changes in maceration are also well recorded, and some have been claimed to have use in dating the period of immersion (Okros 1938; Dierkes 1938). Schleyer (1951) is pessimistic on the reliability of such histological criteria.

The early formation of adipocere can be detected microscopically after 3–4 weeks; this is dealt with in the chapter on post-mortem changes.

DIATOMS AND THE DIAGNOSIS OF DROWNING

Few topics in forensic pathology have given rise to so much argument as the use of diatoms in the diagnosis of drowning. Revenstorf in 1904 was the first to attempt to use diatoms as a test for drowning, though he stated that Hofmann in 1896 was the first to discover them in lung fluid. An excellent review of the diatom controversy was published by Peabody in 1980.

The basic premise is that when a live person is drowned in water containing diatoms (microscopic algae with a silicaceous exoskeleton), many diatoms will penetrate the alveolar walls and be carried to distant target organs such as brain, kidney, liver, and bone marrow. After autopsy, samples of these organs can be digested with strong acid to dissolve the soft tissue, thus leaving the highly resistant diatom skeletons to be identified under the microscope. Alternatively, blood can be used to seek the organisms.

When a dead body is deposited in water or when death in the water is not due to drowning, then, although diatoms may reach the lungs by passive percolation, the absence of a beating heart prevents circulation of diatoms to distant organs.

The great advantage of the diatom test, if it was reliable, would be that a positive diagnosis of drowning could be

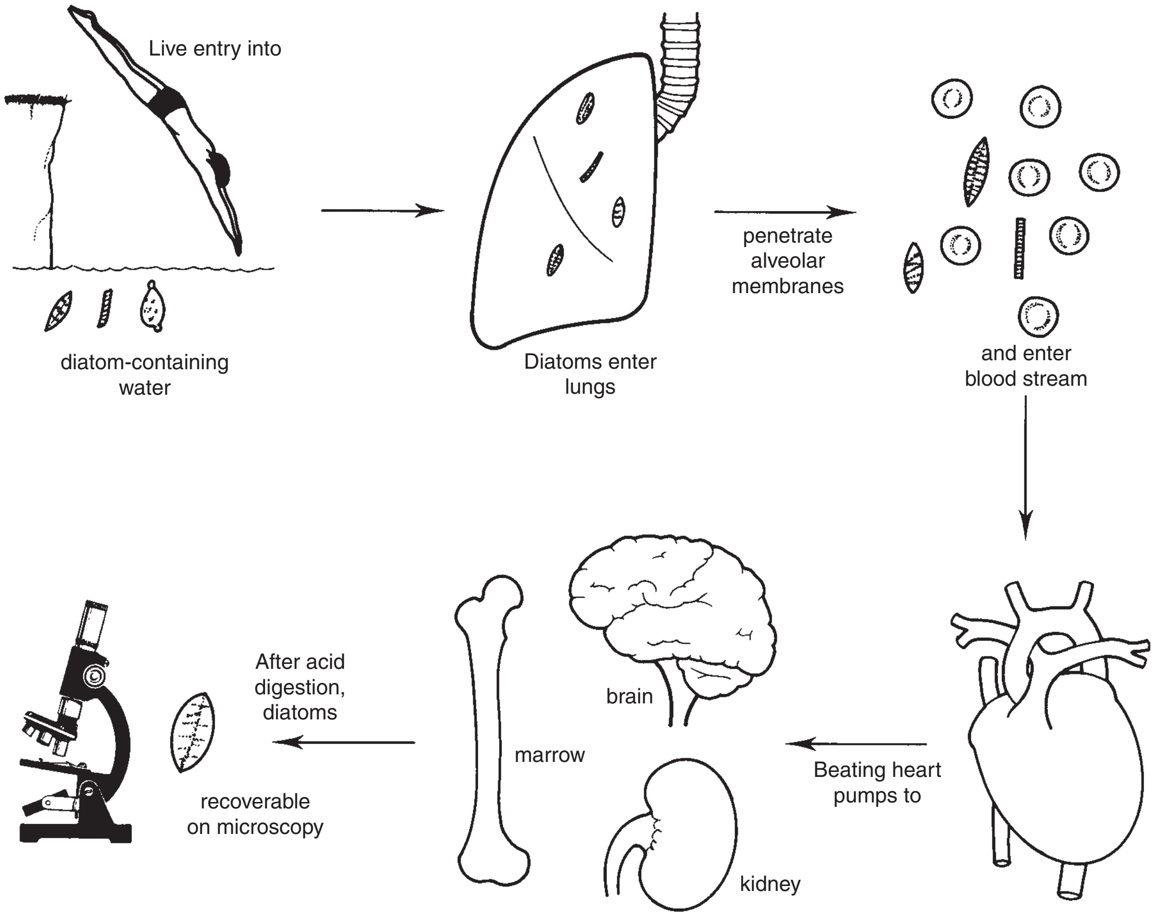

FIGURE 16.19 *The principle of the diatom test for drowning. When a dead body enters the water, diatoms cannot progress further than the lungs.*

made even in the frequently putrefied bodies that are recovered, where no hope of anatomical recognition of drowning is possible. In addition, evidence of the site of the drowning might be obtained from the ecological typing of the diatoms, especially in relation to salt-water or freshwater locations.

Meticulous attention to technique must be employed at autopsy to recover suitable samples of tissue, which must not be contaminated by the body surface or instruments, before digestion is commenced. (Technical details are given in Appendix 1.)

Diatoms belong to the class of plants known as *Diatomaceae* and consist of a box or 'frustule' composed of two valves that fit together to enclose the cytoplasmic contents. They have either radial symmetry ('centric' diatoms) or are elongated ('pennate' diatoms). The valves are highly complex in shape and are extremely resistant to decay, fossil diatoms from Jurassic times being abundant. The floor of the oceans have an area of 11 million square miles of thick diatomaceous ooze and upraised beds on land may be hundreds of feet thick, which emphasizes the vast amount of potential contaminant available.

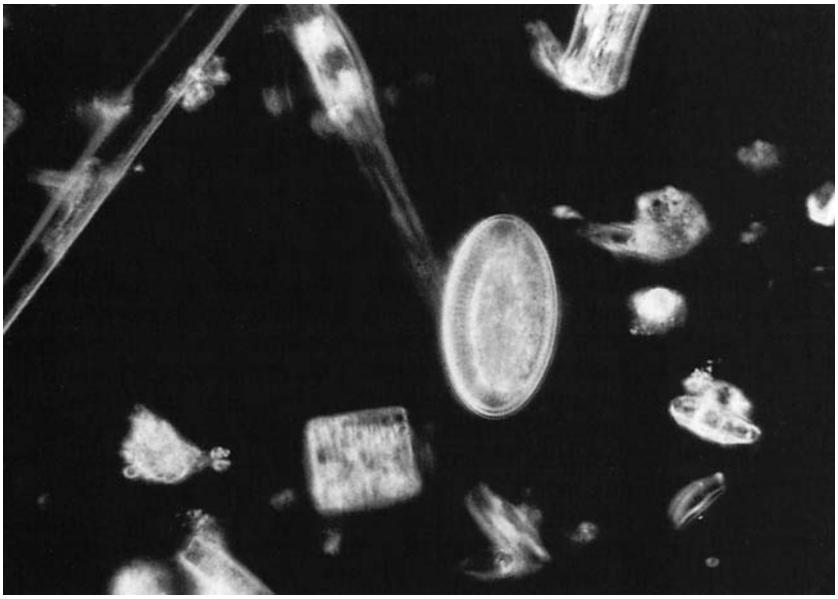

FIGURE 16.20 *Diatoms seen under dark-ground illumination (original magnification ×350). These are from fresh water. There are at least 10 000 different types and, where identification of locus of likely origin is required, the help of a biologist with expert knowledge is essential.*

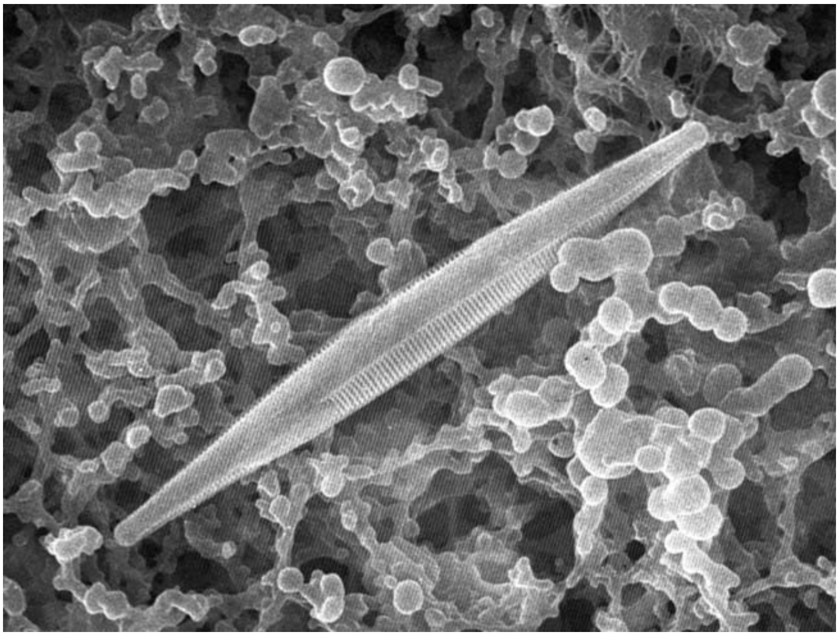

FIGURE 16.21 *Scanning electron micrograph of a diatom (original magnification ×4000, 20 kV).*

There are at least 10 000 species, and the identification of the various types is a matter for an experienced botanist or biologist, but the following general classification is useful: 'oligohalophilic' diatoms live in freshwater with a salinity less than 0.05 per cent, and 'mesohalophilic' and 'polyhalophilic' diatoms live in brackish water and seawater with a salinity higher than 0.05 per cent.

The critics of the diatom test point to certain problems:

- Diatoms are ubiquitous, being present in soil, water supplies and in the air. Many commonly used minerals, such as kieselguhr, are largely fossil diatoms. Manufactured substances like board-chalk and abrasives – even toothpaste – contain diatomaceous raw materials. Mant, however, examined the filters of the air-conditioning system of Guy's Hospital in London and found no diatoms taken from the city atmosphere.
- Though entry into the body is thought to be mainly through the lungs, there seems no reason why they cannot penetrate the intestinal lining, and gain access to the bloodstream and hence any body tissues.
- Certain foods, notably shellfish, contain vast quantities of diatoms that may enter the circulation and reach the tissues.
- Examination of the tissues of both animals and man reveal the presence of diatoms when the cause of death is other than drowning. Schellmann and Sperl (1979) found them in the tissues of 15 out of 16 non-drowned bodies, but other workers found no diatoms in 33 out of 34 bodies, including two drownings.

Foged (1983) made a detailed investigation into drowned and non-drowned bodies in Denmark, and concluded that the diatom test was quite invalid. He quoted many references both for and against the reliability of the technique, and no doubt the controversy will continue. It seems probable that there may be a quantitative difference between the numbers of diatoms recovered from the tissues in drowning and non-drowning deaths, and a careful analysis of the species identification in relation to the locus and circumstances of the death may be useful. At the present time the diatom test should be used only as an indicative aid and not as legal proof of drowning. Recently, other water organisms have been advocated as tests for drowning, including soft-bodied protozoa and crustaceans.

Japanese workers have used other methods to digest autopsy tissues to seek diatoms because it has been shown that strong acid digestion markedly reduces the yield. The new methods introduced for diatoms, such as enzymatic and detergent digestion, allowed soft-bodied microscopic organisms to be recovered and claims for better specificity for drowning have been made (Matsumoto and Fukui 1993; Funayama *et al.* 1987, 2001). Chinese workers have claimed that the spectrofluorophotometric detection in the lungs of chlorophyll derived from plankton is diagnostic, but it is not clear how this can be differentiated from plankton passively entering the lungs after death (Qu and Wang 1992).

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CHAPTER 17

Neglect, starvation and hypothermia

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- The 'hide-and-die' syndrome 418
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Though, tragically, starvation is one of the most widespread scourges of our planet, we are here concerned with individual neglect with which starvation is often associated, either as a potentially criminal act or as a manifestation of self-neglect. As with so many conditions, the extremes of life are most affected, rather than the middle years. Infants and children are at the mercy of their parents or guardians for the provision of care and sustenance. The old are prey to senile dementias and other disorders of the mind, as well as often being devoid of spouse or caring relatives – or sometimes even the financial means to stay warm and adequately fed.

Many countries have legislation designed to protect children, on the basis that they are totally dependent upon adults for the necessities of life. In Britain, the Children Act places a responsibility upon parents, guardians or the community to care for children. The minimum requirements laid down by law are the provision of food, clothing, shelter and education. Unfortunately, these requirements are evaded in spite of official supervision and, from time to time, scandals explode in the public eye when a child has died, not from physical abuse, but from sheer neglect.

Voluntary organizations, such as the National Society for the Prevention of Cruelty to Children (NSPCC) were founded in the nineteenth century to combat the widespread neglect of children consequent upon the population explosion of the Victorian industrial revolution. Their present-day role, however, has changed radically so that now most of their efforts are directed against physical, sexual and mental abuse, rather than starvation and neglect. Notwithstanding this change of emphasis, deaths still occur from deliberate or negligent lack of provision of proper care and nutrition of children. In general – though there are many exceptions – nutritional neglect and physical battering tend to be mutually exclusive. The abused child is usually well nourished and the emaciated child is usually uninjured.

Neglect and starvation are not synonymous, but are so often closely associated that the two conditions are usually considered together. When fatal, they may come to the attention of the pathologist either as a potentially criminal death or, when self-inflicted, in the usual course of coroners' or similar enquiries. Rarely, victims will starve from being isolated in some catastrophe, such as a mining incarceration or shipwreck, but these days a more common occurrence is a hunger strike or voluntary fast for some political or similar motive.

GENERAL FEATURES OF NEGLECT AND STARVATION

The obvious and outstanding appearance is of emaciation caused by an inadequate intake of food. A minimum of about 1500–1900 calories is needed to maintain body weight in active adults. Life is threatened when more than 40 per cent of the original body weight has been lost, though the speed of loss is relevant. Total deprivation of food will obviously kill faster than a severe reduction. Total lack of food is likely to cause death in about 50–60 days as long as adequate water is available, but this depends on weather and temperature as well as the original fitness – and fatness – of the individual. Deprivation of water will kill in about 10 days – or less in higher ambient temperatures.

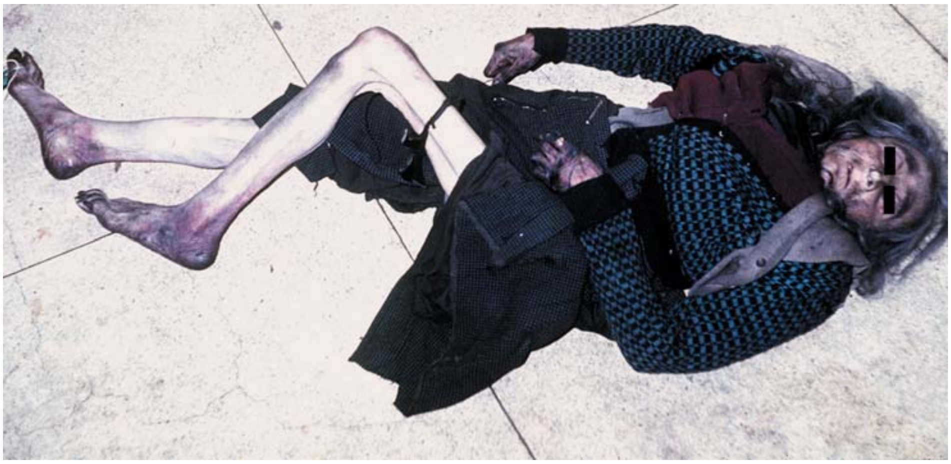

FIGURE 17.1 *Death from neglect and hypothermia in an old woman. The discoloration of the feet and hands was cyanotic.*

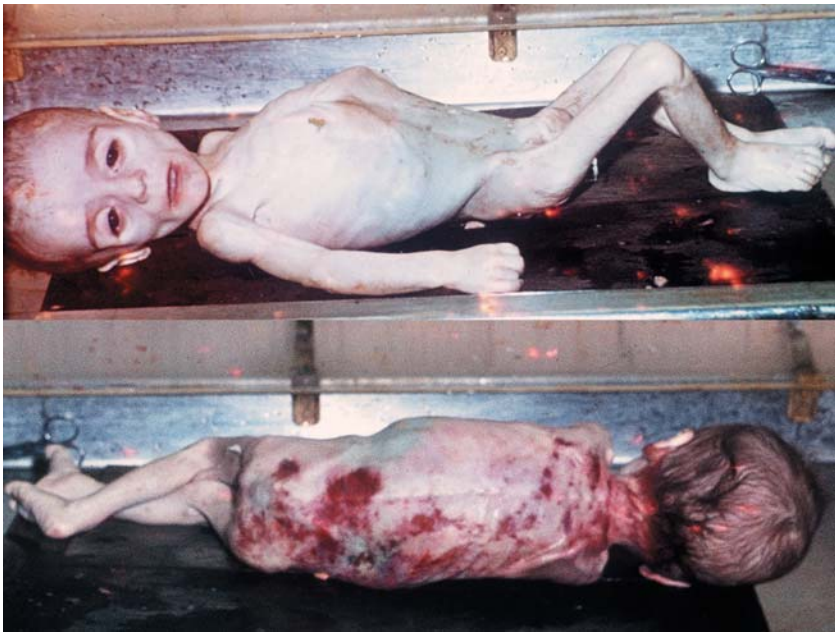

FIGURE 17.2 *Fatal neglect and starvation in an infant. The limbs are emaciated, the abdomen scaphoid and the head appears relatively large. The back shows extensive pressure ulceration. The sunken eyes and cheeks from malnutrition and dehydration constitute the 'Hippocratic facies'.*

In the numerous cases of fatal and non-fatal starvation seen at the end of the 1939–45 war in Nazi concentration camps, two main types were seen. These were the 'dry' type, in which there was emaciation, but only leg oedema, with a body weight up to half the normal. Alive, these showed marked hypotension, feeble pulse and cyanosis. The other 'wet' group had marked oedema of face, trunk and limbs, with ascites and pleural effusions. The oedema of hypoproteinaemia is caused by protein being diverted to produce energy when carbohydrate and fat are grossly deficient in the diet. In some victims, the skeleton accounted for 50 per cent of the total body weight, instead of the usual 15 per cent.

Other features are secondary to this nutritional deficiency, such as intercurrent infections, avitaminoses, skin disorders and nutritional oedema. Dehydration, hypothermia and actual necrosis of the extremities are the most severe manifestations that contribute to death.

Most fatally neglected infants are under one year of age. At autopsy great care must be taken to measure, not estimate, the full indices of size and weight. Crown–heel, crown–rump, head diameter, foot length and exact weight must be measured accurately, so that comparison may be made with standard paediatric percentile growth charts, consonant with age, birth weight, sex and race.

The diameter of limbs at major landmarks such as wrists and ankle should be measured with a flexible tape. Photographs should be taken in all major views, using colour to record skin tints and lesions, as well as the general aspect of the emaciated body. The words 'cachexia', 'emaciation' and 'marasmus' are all synonymous as used today, though 'marasmus' is confined to the description of infant victims. The so-called 'Hippocratic facies' is not confined to the emaciation of neglect, as cachexia from any cause – such as an obstructive carcinoma of the oesophagus – can give rise to the same appearance. The skin of the face is stretched tightly across the cheekbones, the cheeks are sunken and the lines of the jaw are obtrusive. The eyes are deeply sunken from loss of orbital fat, though dehydration may contribute to this manifestation.

On the trunk the ribs are prominent, with concavities in the intercostal spaces and sunken supraclavicular fossae. The abdomen is of the classical ‘scaphoid’ shape, being concave from costal margin to iliac crests, the latter sticking up like wings. The limbs are almost skeletal from loss of fat and muscle, and the head may appear deceptively large by contrast with the narrowed neck.

The skin surface may present differing appearances according to the length of time that nutritional loss has been suffered and the qualitative defect in the diet, especially of certain vitamins. The skin may be pale, lustrous and semi-translucent, with an almost blue tinge in infants, partly as a result of the loss of subcutaneous fat. It may also be coarse and rough, however, with flaking hyperkeratosis, though this is more often seen in aged persons, partly as a result of senile changes. Pigmentation, either diffuse or of a punctate nature, is sometimes seen.

Dehydration is a common feature, especially in infants and may be the major contribution to death. The skin is dry and wrinkled and, when pinched between the fingers, remains ridged because of loss of subcutaneous fat and fluid. The fontanelles may be depressed from loss of pressure of cerebrospinal fluid. In chronic starvation, hypoproteinaemia can lead to oedema, though this is rarely seen in forensic practice. In famines it may be widespread, associated with other nutritional disorders such as kwashiorkor.

Skin infections are common, partly as a result of nutritional loss of resistance to infections and partly because of neglect in care and hygiene, especially in infants. Pressure sores on buttocks, heels and spine may occur in both infants and old people who are lying inert because of weakness, and, in infants, urine dermatitis and lack of any skin care after defecation worsens these. Sores may be seen on any pressure or friction points, such as the elbows, knees, shoulders and occiput. Apart from pressure areas, any part of the skin surface may develop infected lesions, which often crust over after partial healing. Sores on the lips, blepharitis and conjunctivitis may also occur. The hair is dry and brittle, sometimes becoming depigmented and even gingery with chronic malnutrition.

Internally, the same loss of adipose tissue will be evident both subcutaneously and in the internal fat stores, such as the omentum, mesentery and perirenal area. The organs will be small (except the brain) and it is therefore important to weigh the major viscera to compare them with standard tables for sex and age. Organ atrophy will be more apparent in old people, but the problem then exists of distinguishing weight loss caused by nutritional defects from the usual senile atrophy. The differentiation is one of degree, as chronic starvation can reduce organs to unusually low weights. More specific internal signs will include an empty gut, which may be gas-filled and translucent from stomach to colon. Any faeces in the rectum are likely to be inspissated, especially if there has been fluid restriction and dehydration. Faecoliths may ulcerate the intestinal lining. In infant starvation, however, the stools may be fluid and offensive unless dehydration was severe. The gall bladder is distended in starvation if there has been no recent meal to stimulate emptying. The tongue may be thickly coated, but this is such a non-specific finding that it is of no practical use.

MEDICO-LEGAL PROBLEMS

In infants there may sometimes, if rarely, be physical abuse associated with neglect, so radiography prior to autopsy is essential – in fact the whole procedure must be conducted on the lines indicated for the ‘battered child’ (Chapter 22). In both children and adults, a major problem is cause and effect, especially where some pathological disease process is found. Did a cancer lead to cachexia or is it an incidental finding? Did pulmonary tuberculosis cause the emaciation or was the infection secondary to the nutritional deficiency? The relevance of diseases such as diabetes, Addison’s disease, chronic infections and neoplasms must be evaluated. Particularly important in children are familial metabolic diseases that may be associated with failure to thrive and frank emaciation.

Where death from a wasting condition is alleged to be the result of malnutrition, either from wilful withholding of food or from indifference about its provision, a defence may be raised against criminal prosecution that the condition was caused by a natural disease. Indeed, such a claim may be true on occasions. Both the prosecution and defence medical advisers must undertake a thorough investigation using all anatomical, histological and biochemical means at their disposal to discover any such metabolic or pathological cause for fatal wasting, before attributing the death to sheer malnutrition.

INJURY CAUSED BY COLD: HYPOTHERMIA

Until about 40 years ago, injury and death from the effects of low temperature was thought to occur almost exclusively among those subjected to extremes of climate out of doors. Mountaineers, polar explorers and those exposed in some disaster on sea or land were considered to be the prime candidates for frostbite and ‘freezing to death’. Only after some noteworthy medical publications, such as those by

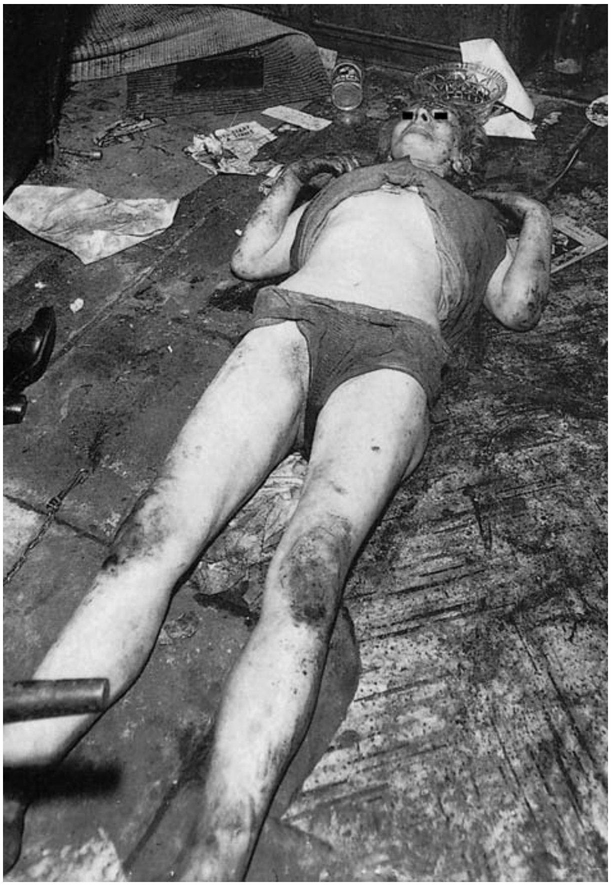

FIGURE 17.3 *Hypothermia in a woman of only 56. She lived in extreme squalor, with no heating and broken windows, even though she had been a state registered nurse. The knees, hands and feet showed hypothermic discoloration as well as dirt.*

Emslie-Smith (1958), Duguid *et al*. (1961) and others, was it generally appreciated that hypothermia was a common and widespread danger in temperate climates and indoors. Recognition was rapid and Special Committees of both the Royal College of Physicians and the British Medical Association produced reports on hypothermia in the 1960s.

As in so many other conditions, the aged and the infants are most vulnerable, especially as the condition is insidious and may not be suspected in time by those more active persons who are the potential guardians of those at the two extremes of life.

Factors involved in hypothermia

LOW ENVIRONMENTAL TEMPERATURE

No precise figures can be given in degrees Celsius for temperatures potentially dangerous to life, as other factors and the personal vulnerability of different individuals vary considerably. Certainly the air temperature need be nothing like as low as was thought in former years, when profound frost was considered essential for the production of lesions. Air temperatures below 10°C are probably low enough to cause hypothermia in vulnerable persons, but air movements such as external wind or internal draughts will make things worse by markedly increasing the rate of body cooling. Damp conditions, especially of clothing, will also aid cooling from the latent heat of evaporation.

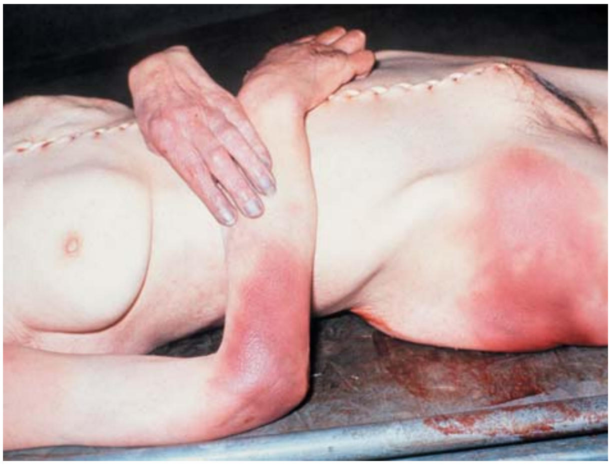

FIGURE 17.4 *A death from hypothermia showing brownish-pink discoloration over the hip and elbow.*

AGE AND PHYSIQUE

As stated, the elderly and the young are at greatest risk. The old person may have poor musculature and a lack of mobility, thus depressing heat production from muscular activity. Often thin, there may be a lack of insulating subcutaneous fat. Poor thyroid function is common, especially in old women, and is discussed below. Cerebral dysfunction – often from degenerative arterial disease – may lead to poor central heat regulation, a disinclination to move around, and apathy concerning personal nutrition, heating and general well-being. Depression and mental illness are not uncommon, as in the early cases reported by Emslie-Smith and by Duguid *et al.*

In infants, the body mass is small and the surface area:mass ratio large, so that heat is lost more easily. In small infants, there is naturally complete dependence on others in regard to clothing and environment.

HYPOTHYROIDISM

Myxoedema, either occult or obvious, is an important factor in hypothermia. Many elderly women have a thyroid deficiency and this is a potent factor in vulnerability to cold. The majority of victims are women over 70 and the environmental conditions in which thyroid dysfunction is a factor may be little below optimum. Cases were first reported in the 1950s by Marquand, soon followed by the paper of Angel and Sash (1960). In hypothyroid subjects, certain drugs may have a deleterious effect by precipitating hypothermia, even when the environment is relatively normal. Imipramine, chlorpromazine and diazepam are particularly hazardous. Barbiturates, phenothiazines and alcohol are also dangerous in this respect.

LACK OF FOOD, ADEQUATE CLOTHING AND INDOOR HEATING

These are factors that may be social or financial, but are often related to the depressed, apathetic state of many old people, especially those with cerebral atherosclerosis. Cause and effect are often hard to separate, as the effects of cold may bring on or worsen mental sluggishness and confusion.

The manifestations of hypothermia

The clinical manifestations are not the concern of the forensic pathologist, though when unsuspected before autopsy the history may give a clue to the fatal process.

It is sometimes claimed that hypothermia in the elderly never occurs unless there is some predisposing disability, such as cerebrovascular disease, hypothyroidism, alcoholism or diabetes, for instance. This seems too restrictive an attitude, though in general is probably true. The rectal temperature is used as the measure of severity in hypothermia. Between 37°C and 32°C there are no ill-effects beyond the normal subjective feeling of being cold, with shivering and constriction of blood vessels.

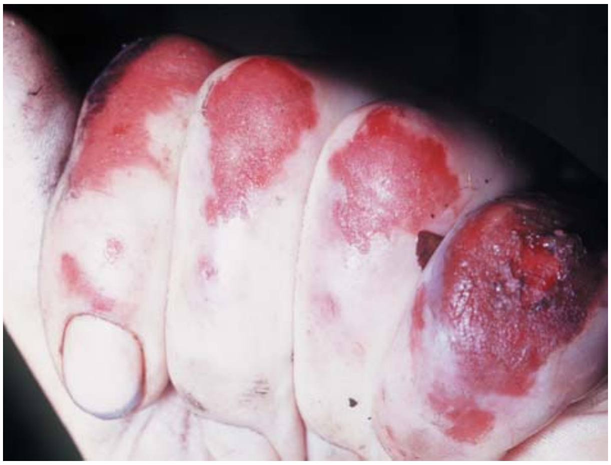

FIGURE 17.5 *Frostbite of the knuckles after being left unconscious during winter in Wales. It does not require Arctic temperatures to cause tissue damage or death.*

When the core temperature falls further below 32°C to 24°C, there is dulling of consciousness, a fall in respiration and heart rate, and a lowering of blood pressure. If maintained without relief, death will ensue and recovery is rare if the rectal temperature falls below about 26°C, though one remarkable case reported by Laufman (1951) recovered after falling to 18°C, albeit with severe mutilating frostbite.

Autopsy findings in hypothermia

There may be no signs whatsoever at autopsy in a death from hypothermia and thus the history may be all-important. The usual difficulties then arise as to how much the pathologist is entitled to rely upon hearsay evidence – as opposed to the objective findings of his own examination – when deciding on a cause of death. This is more fully discussed in the first chapter of this book.

Hypothermia, like some cases of epilepsy, asthma and drowning, provides some of the more difficult pathological dilemmas when there are slight, non-specific or absent autopsy findings. When a victim of hypothermia has been admitted to hospital and 'warmed-up', death may supervene at any time up to a few days later. In such circumstances the autopsy may reveal no positive findings. The skin changes will almost certainly be absent, but intra-abdominal signs may persist.

In a classical death from hypothermia the body will usually be that of an old person – almost half the Royal College of Physicians' series was over 65 years of age; most will be women. The exterior of the body may present suggestive

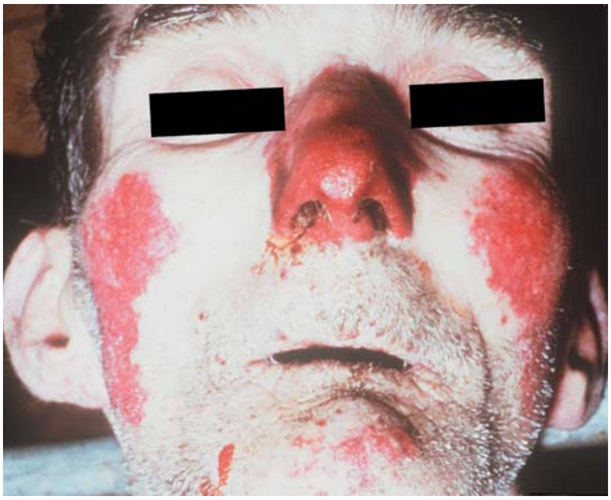

FIGURE 17.6 *Bright red discoloration of the cheeks and nose from hypothermia. The victim suffered from mitral stenosis (where malar flush is one of the clinical signs) and was in bed in an unheated room during a Welsh winter. The tissues of the nose were virtually necrotic, amounting to actual frostbite.*

signs of hypothermia, in that patches of pink to brownish-pink discoloration may be seen in certain areas. They are most often present over extensor surfaces and large joints, such as the outer sides of the hips, the elbows and the knees, and less often on the flanks and face.

The colour is similar to that seen in bodies exposed in cold water or in severe outdoor cold – and to the post-mortem pinkness that often develops in mortuary refrigerators. In hypothermia, however, the distribution over the large joints is distinctive, in addition to the pinkness of hypostasis. There may be pink patches on the cheeks, chin and nose, especially in victims who already had impaired cardiac function, such as the 'malar' flush of mitral stenosis. The slight brownish tinge often seen in the pinkness and the rather indefinite blurred edges of the patches suggest that some haemolysis may have occurred, perhaps in the early post-mortem period as well as during the terminal stages of life. The colour is presumably due to persistent oxyhaemoglobin in the skin capillaries, which, because of the low metabolic activity of the cold tissues, fail to take up the delivered oxygen. Pooling of blood in surface vessels from the breakdown of normal vasomotor control allows this unreduced haemoglobin to show through the skin. Why a normally coloured body placed after death in a mortuary refrigerator should also become pink has never been satisfactorily explained.

In addition to pink areas of skin, the extremities may be cyanosed or they may be white. Sometimes the feet are blue to the ankles, above which is pale. The hands may show blueness of the fingers or nail beds. Oedema may be seen, most often in the feet and lower legs, but many of the victims of hypothermia already have pre-existing congestive cardiac failure. Rarely there may be blistering of the skin, usually in dependent parts such as the buttocks, backs of thighs and

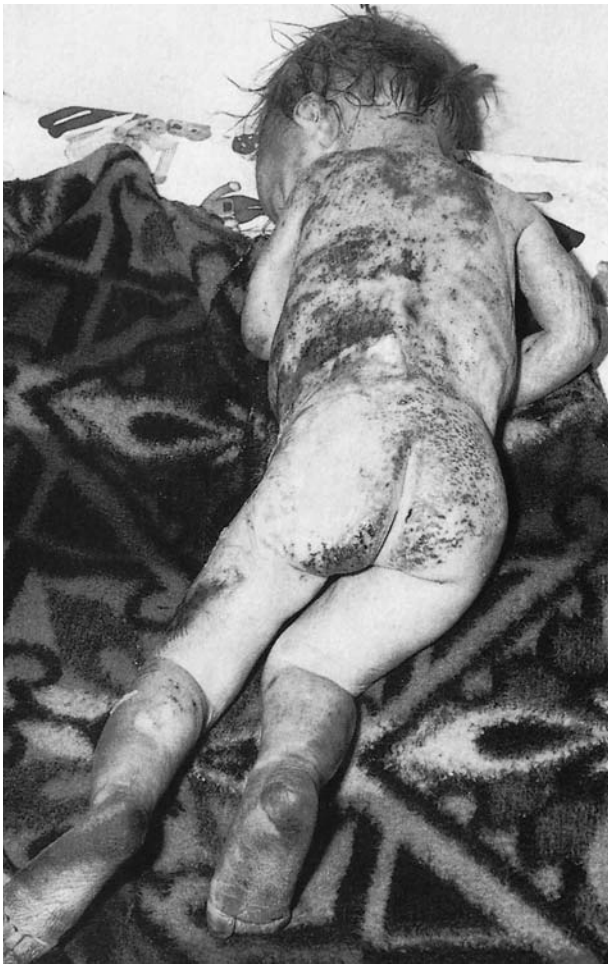

FIGURE 17.7 *Fatal child neglect. The infant has extensive skin ulceration and was underweight. Death was the result of an intercurrent chest infection.*

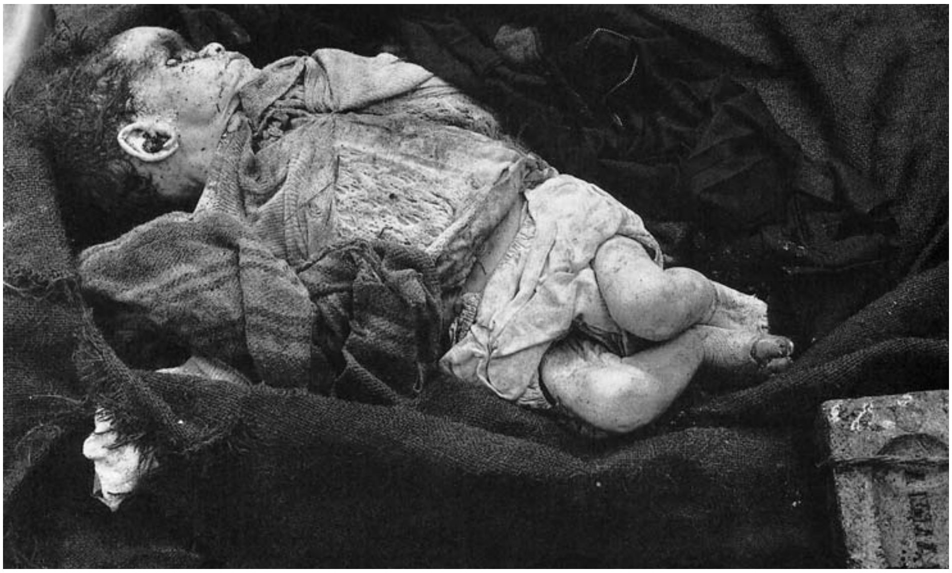

FIGURE 17.8 *This infant died of neglect, hypothermia and frostbite, having been left in an unheated farmhouse bedroom, the cardboard box that acted as a cot having crystals of frozen urine in the bedclothes. After death the child was dropped down the farm well in this sack with a brick as a weight.*

upper arms. This may or may not be in pink areas and seems to be caused by skin oedema which then breaks down.

The face, especially of an elderly woman, may show appearances suggestive of myxoedema or hypothyroidism, with coarsening of the features, puffy eyelids and loss of eyebrow hair. Internally there may be nothing specific to note, even if the external skin changes are obvious. Signs of pre-existing disease are common, especially if one subscribes to the view that hypothermia in the elderly never occurs in the absence of systemic disease. Degenerative arterial disease, senile myocardial degeneration, hypertension, chronic renal lesions and obstructive airways disease are common. More specific lesions are considered below.

ACUTE GASTRIC EROSIONS

In the authors' view, these are found much more often than pancreatitis. The stomach mucosa is frequently studded with numerous shallow ulcers, the floor of each containing a dark brown plug of altered blood. Frank haematemesis is rare, but the stomach contents sometimes contain dark acid-affected blood.

ACUTE PANCREATITIS

This is the lesion most often quoted in textbooks, but is present in less than half the deaths from proven hypothermia. It may have been diagnosed before death from an increase in serum amylase activity. The most obvious feature may be areas of stiff, yellow, fat necrosis when the pancreas is sectioned at autopsy. There may be adjacent areas of fat necrosis in the omentum and mesentery. Haemorrhage into the gland may occur, but caution has to be employed here, as post-mortem autolysis of this organ commonly gives a haemorrhagic appearance in many other modes of death seen at autopsy. Histologically, necrosis, leucocyte infiltration and fat necrosis may be confirmed in some instances, but in others the pancreas, even if haemorrhagic, yields little information on microscopy.

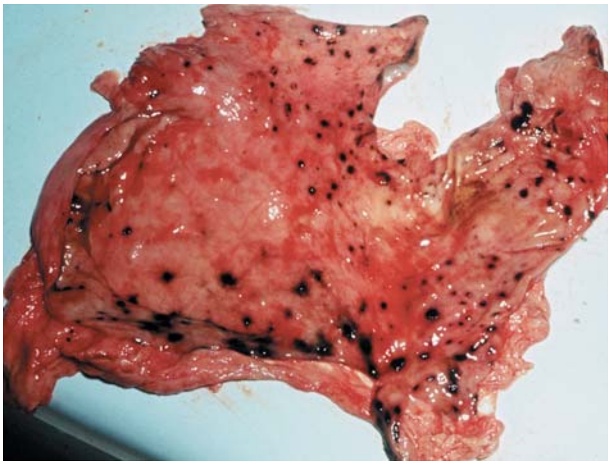

FIGURE 17.9 *Gastric mucosa from a hypothermia death showing numerous acute erosions.*

PULMONARY OEDEMA

This is common, but as it is such a common finding in any death from cardiac failure, its diagnostic value in hypothermia is almost nil.

PERIVASCULAR HAEMORRHAGES

These have been described in the brain, especially in the walls of the third ventricle, but again they are not particularly specific, especially in an autopsy population that has a high incidence of cerebrovascular disease. Sludging of blood in peripheral vessels may occur, partly from cold agglutinins. This contributes to skin oedema and necrosis, though peripheral vasoconstriction is the main cause of the infarction of frostbite. Microinfarcts are common in many organs in hypothermia, presumably from cold agglutinins blocking small vessels. Deep vein thrombosis in the legs and pulmonary embolism are occasionally found, but again cause and effect is hard to establish.

It is said that the good preservation of tissues when examined histologically is characteristic of hypothermia, as autolysis is retarded by the low temperature. In the experience of the authors, this claim is not justified.

THE 'HIDE-AND-DIE' SYNDROME

There is a peculiar aspect to some cases of hypothermic death in that it is associated with the victim undressing and hiding away from sight. The subject is usually an old person, man or woman. When found dead (usually, but not always at home), the body may be partly or even totally naked, even though the environment is cold. In addition, the victim may have burrowed his or her way into some corner or cupboard, or alternatively pulled down furniture and household articles into a heap on top of the body. In fact, the house may be in such a state of disorder that when the police break in and find a corpse amongst such chaos they may naturally suspect a homicide and robbery.

The author (BK) has seen old people who have crawled into small cupboards, the bottom of wardrobes, under low shelves, and into corners of pantries and outhouses. They have been found under piles of books pulled from a bookcase, or hidden under a mound of old clothes, newspapers and other debris.

The signs of hypothermia are usually present and the problem then arises as to whether the victim became hypothermic first, which led to mental confusion that caused the strange behaviour, or whether – as a result of some mental aberration, perhaps related to senility or other cerebral episode – they began behaving abnormally, including shedding their clothes and so became fatally hypothermic.

Though some geriatricians claim that hypothermia is almost always precipitated by some natural illness, including cerebral vascular episodes, the experience of most pathologists is that it is not common to find definite lesions of such predisposing factors at autopsy.

Biochemical markers of hypothermia have been investigated, and catecholamines appear in the blood and then urine in the early stages, but then decline, as the adrenals become exhausted (Hirvonen and Huttunen 1995). There is a variation in the adrenaline:noradrenaline ratio, all these changes being manifestations of stress induced by low temperature.

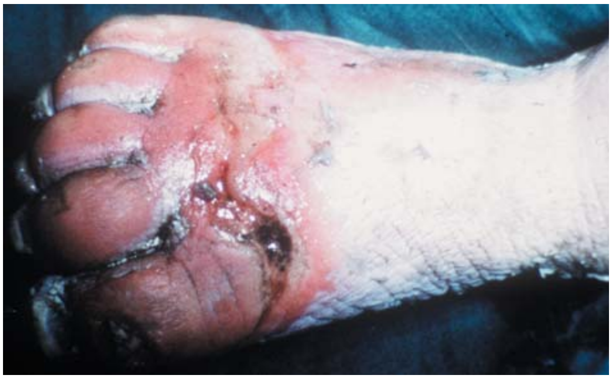

FIGURE 17.10 *Frostbite of the foot from the infant shown in Figure 17.8. The distal part of the foot is infarcted and a line of separation has appeared between the distal slough and the rest of the limb.*

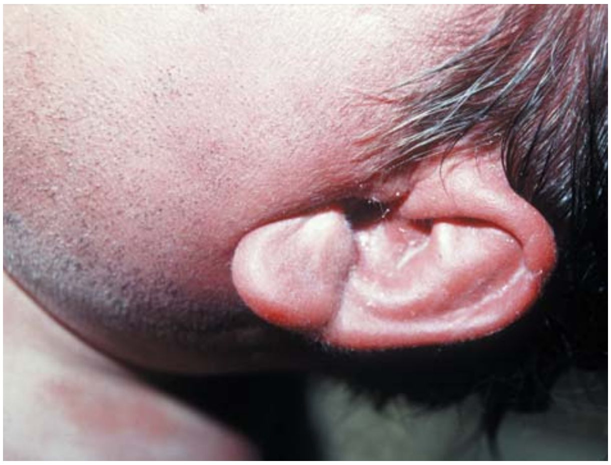

FIGURE 17.11 *Frostbite on left auricle of a man who, heavily intoxicated by alcohol, left for home at night in the Arctic winter, but lost his way at* $-40°C$ *and was found dead the following day.*

DEATHS FROM EXPOSURE

Fatal hypothermia can occur in healthy adults, as well as infants and old people. This is caused by purely environmental conditions, which need not be extreme. One common group, especially in more northern countries, is the inebriated person who becomes exposed to even moderate cold. The typical circumstances are a person who gets drunk and either falls asleep outdoors in his drunken state or sustains some accident – such as a fall or even mild head injury – which incapacitates him for long enough for him to become hypothermic. Alcohol seems to have a secondary effect, apart from causing incapacity and immobility. Its vasodilating effect on skin allows heat loss to be more rapid and in higher concentrations it may have a direct action on the heat-regulating centres. Apart from drunken victims, many other classes of person may fall prey to hypothermia. Hill-walkers, climbers, yachtsmen and dinghy-sailors, swimmers, and other classes of sportsmen and women can become cold and exhausted. Every year sees deaths and rescue escapades in the hill country of Britain, even when the weather is far from Arctic in severity. Naturally the risks in colder countries and at high altitudes almost anywhere in the world are much greater. For the pathologist, the features are similar to domestic hypothermia, but there may be the added lesions of frostbite.

LOCAL INJURY DUE TO COLD: FROSTBITE

There are a number of different clinical lesions caused by the effect of prolonged cold on the extremities. 'Immersion foot' and 'trench foot' refer to damp cold damage, whereas 'frostbite' is caused by dry conditions below zero. In the context of forensic pathology, they may be found in victims of fatal hypothermia, but rarely kill in themselves unless tissue necrosis becomes infected. Severe damage with sloughing and separation of toes, or part of the foot is likely to be seen only in survivors or victims of some catastrophe on sea or mountainside, but the author (BK) has seen one case where a neglected infant was left in a urine-soaked cot at temperatures below zero for many days. When it died of a mixture of hypothermia and chest infection, the parents placed it in a sack with a brick and dropped it down a well. On recovery of the body, separation of the necrotic distal part of a foot was seen, with a red zone of inflammatory tissue on the proximal margin. Frostbite may affect only the skin or may extend deeply into the underlying tissues. Lesser degrees are reversible, but infarction and necrosis may ensue if the blood supply is cut off by vasoconstriction, sludging and thrombosis, for a sufficient time.

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CHAPTER 18

Deaths associated with sexual offences

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■ Tests for semen 426
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The examination of living victims of sexual assaults is the province of the forensic physician or 'police surgeon', in places where such doctors exist. In many countries, any physician may be asked by the police to examine the victim of an alleged sexual offence, but this difficult and onerous task in the living victim is outside the experience of many pathologists – though in some jurisdictions, this function is combined with that of the forensic pathologist.

In this book, attention will be confined to those cases in which a sexual assault leads to death, almost always rape and homicide. Regrettably, a significant proportion of non-domestic homicides are associated with sexual offences, death occurring either because the woman rejects the sexual approaches or because a sadosexual motive colours an intended murder. The most common mode of killing is either pressure on the neck, head injuries, or, less often, stabbing. In some instances death may be the result of violence associated with the sexual activities themselves, especially in child victims when pelvic trauma may be the immediate cause of death. In this chapter, only the sexual aspects are discussed, as other modes of violent death are covered elsewhere.

EXTERNAL FINDINGS IN FATAL SEXUAL ASSAULTS

As with most forensic autopsies, a meticulous external examination is as important – and usually more important – than the internal dissection. The study of the body surface in sexual assaults is similar in both the living and dead and may be divided into general appearances and those of the perineum. The whole body surface should be searched for sexually orientated injuries.

Mouth and lips

Bruises may be found on the lips and especially inside on the buccal surfaces, from rough kissing. The lips may have been forced back on to the edges of the teeth, causing abrasions, bruises and even laceration of the buccal surface. Swabs should be taken from the mouth in every case before substantial manipulation for examination, to seek evidence of seminal fluid from oral penetration. Though such swabs rarely yield a positive result as to the presence of spermatozoa, modern analytical methods may be able to detect other components of the seminal fluid or the presence of male epithelial cells.

Bites

Other bruises may be found on the neck, shoulders, breasts and buttocks from oral suction or biting. These are somewhat euphemistically termed 'love bites' and may range from minor lesions inflicted from enthusiastic passion to mutilating bites of a sadistic nature.

Suction lesions may comprise a circular or oval area of bruising, in which the damaged zone consists of many small intradermal petechial haemorrhages caused by sucking the skin into the mouth, the reduced air pressure rupturing the small vessels. There may be semilunar marks at the periphery from the lips, and there may be associated teeth indentations or abrasions. Such suction marks are often seen at the sides of the neck, below the ears, on the upper shoulder, and on the upper part of the breasts and around the nipples.

Actual bites may accompany suction marks or may be independent. The characteristics are described in Chapter 26, but the main features are abrasions or bruises matching the dental arches, often with discrete marks from each tooth. These may be linear if the teeth are scraped down the skin in closing the jaws. They may be superficial or deep enough to penetrate the skin as lacerations. The latter are especially common at the nipples in sexual assaults, and the nipple and part of the areola may even be partly or wholly amputated.

In sexual homicides, it is essential to obtain expert forensic odontological advice, if at all possible. In any event, photographs and measurements must be taken of these injuries and, if practicable, a cast of any teeth indentations for later comparison. Before any handling of the lesions, swabs should be taken of the surface in an effort to recover saliva, which – if the assailant was a 'secretor' – may be tested for blood-group-specific substances.

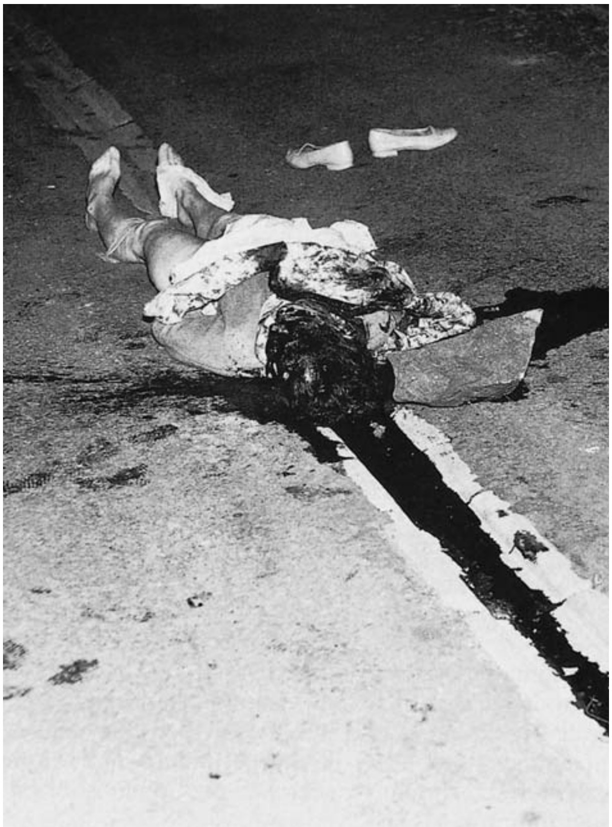

FIGURE 18.1 *Sexual assaults are sometimes associated with extreme violence, often of a sadistic nature. Here, rape has been followed by severe head injury from the large rock seen near the central gutter of this back lane.*

General bruising and abrasion

Apart from bruises that may be associated with the fatal assault, such as throat or head injuries, some bruises are indicative of the sexual motivation. The breasts are often manually squeezed and manipulated, causing discoid bruises of 1–2 cm on any part, especially around the nipples. Linear abrasions, usually from fingernails, may also be present. Bruises may also be seen on the thighs and buttocks, from struggles to achieve intercourse. Both the outer and inner sides of the thighs may be bruised and scratched: a typical area is the inner aspect of the upper thigh, where the legs are manually forced apart. There may be bruising around the anus from fingers opening the buttock cleft to achieve either anal or posterior vulval penetration.

Where the assault takes place on a hard or uneven surface, bruises and abrasions may be seen on the back, especially the shoulders and buttocks. If outdoors, there may be marks from stones or sticks and remnants of vegetation, such as leaves, and grass and green staining may be adherent to the skin, together with earth or dirt. Examination of the clothing is usually a function of the forensic scientist ('criminalist'), but when the pathologist examines the body *in situ*, he will naturally note damage, disarray and foreign material on the garments.

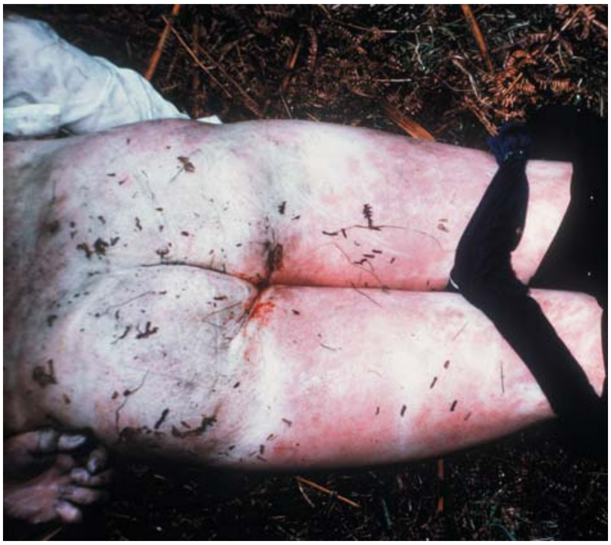

FIGURE 18.2 *In fatal rape the pathologist must note at the scene, or at the mortuary, the position and condition of clothing and presence of foreign material on the skin. Full cooperation with scene of crime officers or forensic scientists is vital in collecting trace evidence.*

Other general injuries

The hands should be carefully examined, as in all assaults. The fingernails, especially the often longer and manicured nails of younger women, may be broken from a struggle. Occasionally, there are hairs or fibres trapped in nail splits, which may have come from the assailant or his clothing. At autopsy, the nails should be cut closely to the junction with the fingers and all parings carefully collected for forensic laboratory examination. It is rarely necessary to collect those from each finger in individual packets, but each hand should be identified separately. Some pathologists or scientific officers prefer to scrape out the space under each nail with a pointed orange-stick or toothpick, carefully retaining any debris. The reason for this interest, especially in sexual assault victims, is that they may have scratched their assailants and have blood, or even skin parings, under the nails that can be identified as to blood group or individually specific DNA characteristics.

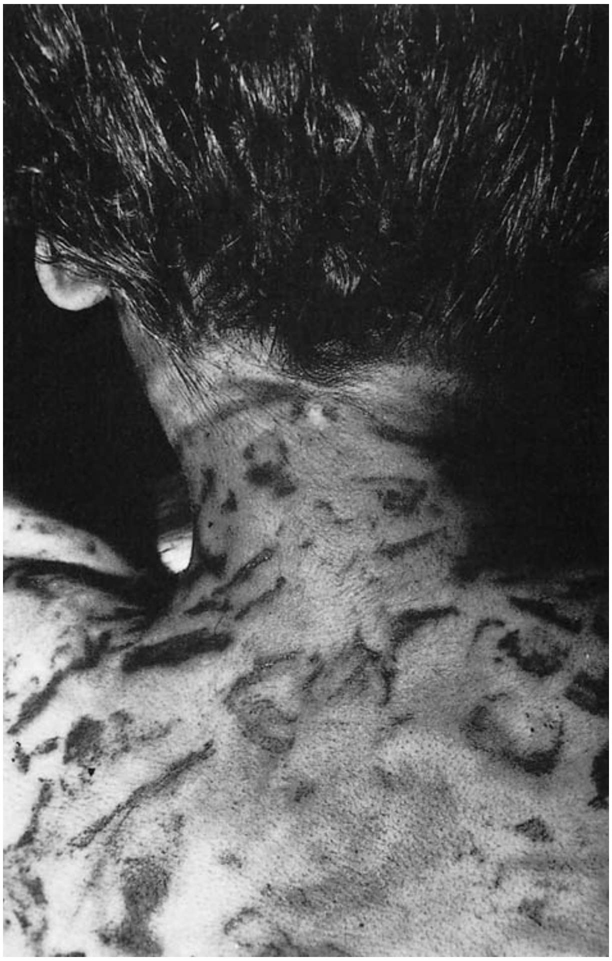

FIGURE 18.3 *Multiple superficial abrasions from undergrowth and ground debris on the back of the victim of rape. This is an indication of pressure of the unclothed body on the ground. There is a ligature mark around the neck with a cross-over point visible.*

Signs of head injury and throttling are dealt with elsewhere, but some fatal trauma may be sexually orientated, especially knife injuries. Sadistic cutting or stabbing may be inflicted on sexually significant areas, especially the breasts, buttocks, perineum and lower abdomen. The vulva itself may be mutilated. These may be slashes or deeply penetrating stabs, often multiple and indeed numerous. They may be arranged in a pattern or may be mutilating, as when whole breasts are amputated. Decapitation is sometimes performed and ritual acts may be performed, with objects placed in definite sites near the body. The notorious 'Jack the Ripper' murders in London in 1888 exhibited the arrangements of disembowelled organs and this type of mutilation is another feature of some sadistic sexual homicides. Intestine or uterus may be removed, either through abdominal wounds or manually through the vagina. General injuries may be continuous with genital trauma, as in knife or broken bottle wounds of the abdomen and perineum.

Genital injuries

Once the pathologist has examined all the external general injuries, attention should be turned to the perineum. As with the clinical examination of sexual offences, a set routine should be used, as the incorrect order may lose valuable forensic evidence.

The vulva and anus should be inspected externally and laceration, swelling, bruising, bleeding and discharge noted. Any blood or suspected semen stains anywhere on the body or clothing should be sampled either by the pathologist or by the forensic scientist or scene of crime police officer. The pubic hair should be examined for foreign material, hairs, vegetation and dried seminal stains, and samples of hair and combings taken. The hair may be combed using a fine comb with the base of the teeth packed with cotton-wool to trap any loose fibres. Dried stains on hair may be cut away and placed in clean folded paper in an envelope, or plastic bag for transit to the laboratory. The vulval labia may show clear signs of trauma, especially in children. In forcible rapes, especially in young persons, there may be external signs of perineal tears, with laceration of the margin of the vaginal introitus or anus, sometimes causing a complete rip between the two orifices.

Caution must be used in interpreting the degree of dilatation of the anus in a dead body, as the sphincter can become patulous and wide open as a normal post-mortem change. Unless the dilatation is very marked, the sole finding of an open anus in the absence of abrasion, bruising, or semen is difficult to sustain as proof of anal penetration. This applies

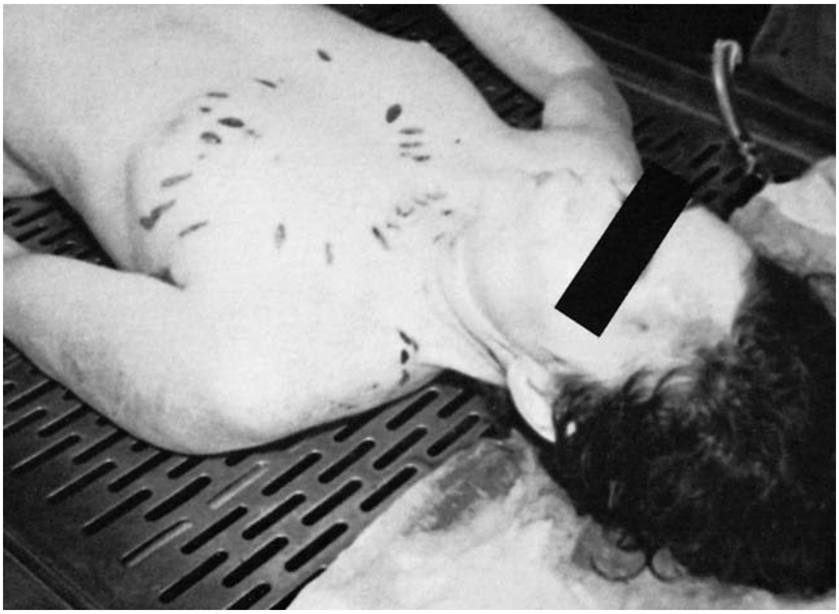

FIGURE 18.4 *Some homicides have obvious sexual connotations even if there is no genital interference. This circle of stab wounds is centred on a breast.*

to children as well as adults; in fact, post-mortem dilatation of the anus is particularly noticeable in children.

Once external examination and assessment has been made, samples should be taken for forensic biological testing, for the presence of semen and venereal infection, as well as samples for DNA profiling, which may be able to distinguish between any semen present and the vaginal secretions. If any fluid is running from the vulva or anus, it should be picked up with clean pipettes and preserved in the smallest available tube, to prevent drying from evaporation. Then cotton-wool swabs on sticks (ensuring that those used for semen detection are plain swabs, not those containing albumin or other media) should be used to take the following samples by touching gently on to the mucosal surfaces:

- the interior of the vulval labia and around the vaginal orifice
- the margins and interior of the anus
- the mid-vagina, using a speculum or broad handle of a dissecting forceps to part the lower vaginal walls gently to allow the swab to reach the area without contamination from the lower vagina
- the upper vagina, cervix and posterior fornix, again using a spatulate instrument to open the canal to give access to the swab. If more fluid contents are seen higher in the vagina, either now or during the later dissection, they should be recovered by pipette.

After samples are taken, the interior of the anus, vulva and vagina, as far as can be seen from the exterior, should be examined. Lacerations, abrasions, bruises and bleeding may be evaluated, though they can be seen in more detail at dissection. The presence and condition of a hymen is noted, with any evidence of recent tearing. Where injuries are gross, especially in children, fistulae between the vagina and the rectum or even peritoneal cavity may be seen. There may be extrusion of intestine.

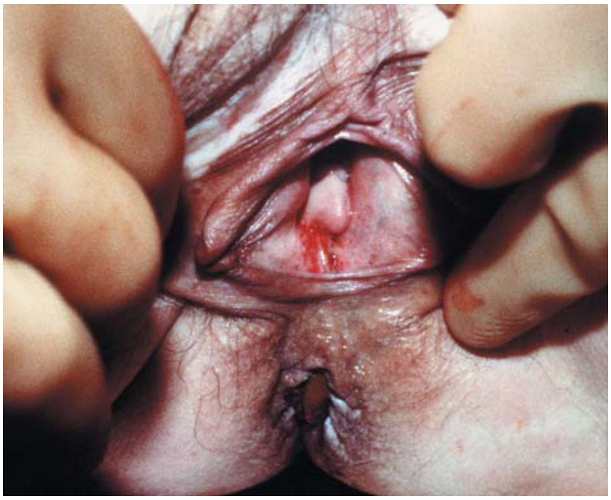

FIGURE 18.5 *Fresh bleeding and mucosal abrasion on the lower wall of the vagina in a sexual assault associated with fatal head injuries in an old lady.*

INTERNAL EXAMINATION

The order of the autopsy may be determined by the nature of the death. The fatal injuries, such as strangulation or head

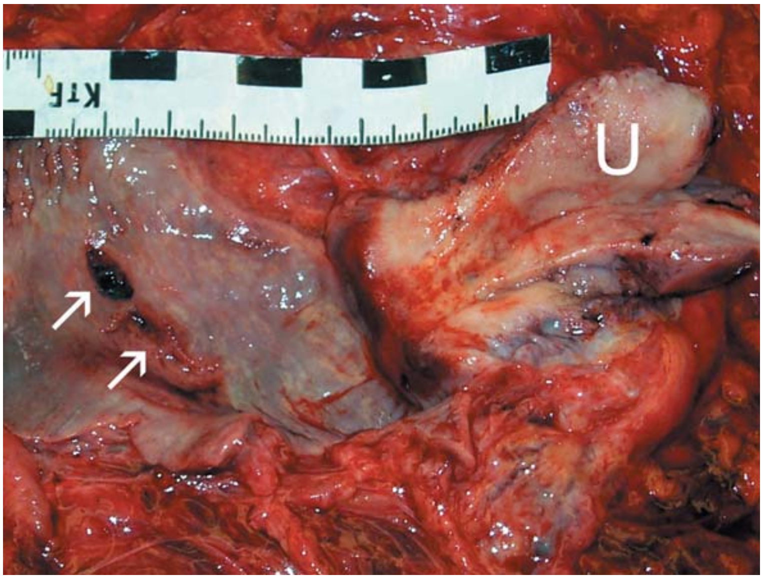

FIGURE 18.6 *Stab wounds (arrows) in the vaginal wall of a homicide victim (U, uterus).*

injuries, may be dealt with first or the pelvic region may command prime attention. The autopsy incision should be similar to that described for the examination of deaths associated with pregnancy, with an incision circumscribing the perineum, removal of the anterior part of the pelvic bones and the extraction of all the pelvic organs in continuity from ovaries to vulva and anus. This block of tissue is then dissected separately. Before this is done, the bladder should first be emptied of urine (either by catheter or through a small incision in the fundus) and the fluid retained for toxicological analysis, especially for alcohol.

The vagina should be opened with large scissors, the track of the cut depending on the assessment of any injuries seen on external examination. If there are tears or bruises in the vulva or vagina, the cut should be orientated to avoid them wherever possible; the anus is later dealt with in a similar way. The vagina is laid open to the posterior fornix and all injuries carefully examined and photographed. The cervix and uterus are examined in the same way.

Injuries may be of all types, from mere reddening or swelling to complete disruption of the vaginal canal. This may occur in small children from sheer brutality of penetration, especially if there is gross disproportion between the adult penis and infantile canal. It may also occur from instrumental injury, as it is by no means uncommon for deliberate incised wounds to be made. The author (BK) has seen abdominal knife wounds carried over the pubis into the vagina in a murdered prostitute; another murder–rape was found to have a broken milk bottle high in the vagina, to the potential hazard of the examining fingers. Vaginal injuries, especially by instrument, may continue up into the abdominal cavity, either via the posterior fornix or lateral vaginal walls. This will have been examined through the abdominal autopsy incision before removal of the pelvic organs.

INTERPRETATION OF MINIMAL FINDINGS

As in clinical forensic practice, there is little difficulty in interpreting gross sexual interference, but problems arise when only minimal evidence is present in a death (traumatic or otherwise) where the circumstances suggest some sexual offence or activity. In such cases, the following questions need to be answered, in the light of all the available findings at the end of the autopsy and ancillary investigations:

- Is there any evidence of sexual intercourse at any time – that is, absence of virginity as determined by an intact hymen? This does not exclude sexual activity short of penetration and technically rape can occur from even the minimal passage of a glans between the labia, which does not affect the hymen. Old intercourse may be assumed from healed hymenal tears with epithelialized ‘carunculae myrtiformes’ at the margins, though the prolonged use of tampons and manual manipulation can also tear a hymen. Evidence of previous pregnancy, such as abdominal striae, old damage to the cervix and breast changes are almost incontrovertible evidence of previous sexual intercourse.
- Is there evidence of recent sexual intercourse? A recently ruptured hymen, with swelling, a raw unepithelialized edge and bleeding may be found, though admittedly it is relatively uncommon except in children and previously virginal young persons. The labia may be red and

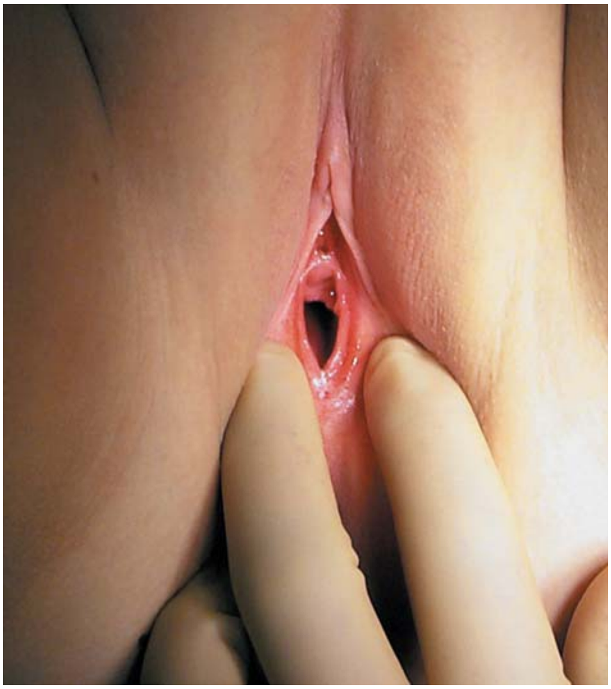

FIGURE 18.7 *External genitals of a live 8-year-old girl, a victim of repeated sexual abuse by an adult living in the neighbourhood. The lack of intact hymen, reddened and larger than normal orifice of the vagina as well as thickened skin and ulcers perianally (not shown) are in keeping with abuse.*

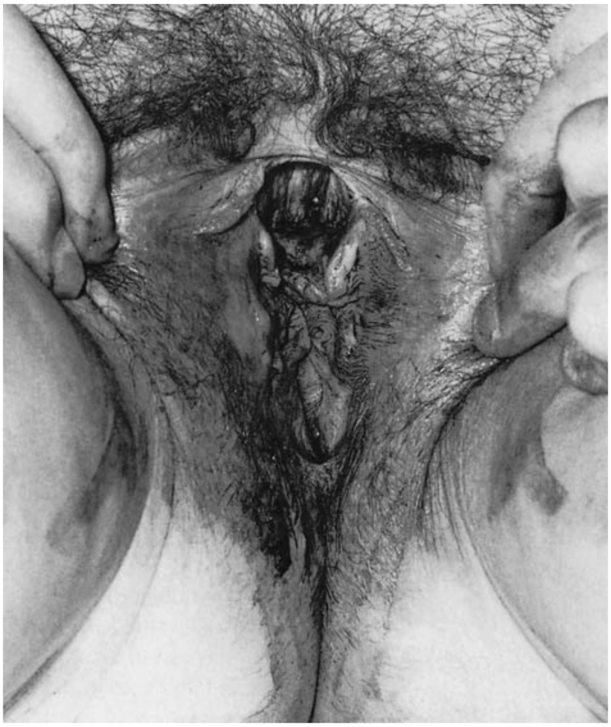

FIGURE 18.8 *Extensive bleeding from inner lacerations of the vaginal walls in a fatal rape. Blood is pooling in the posterior part of the vaginal canal. A full autopsy dissection is required, keeping the perineum en bloc with the genital tract to display any injuries and to exclude natural disease as a contribution to the bleeding.*

inflamed with slight oedema of the vaginal introitus if it is the first episode, or if there is disproportion between an adult man and a young person, even in voluntary sexual connection. The presence of semen on swabs is the best evidence, though with the use of condoms it may be absent. After vasectomy, though no sperms will be present, chemical and enzyme tests for semen remain positive. The presence of venereal disease, especially gonorrhoea, is presumptive evidence of intercourse, though it can be contracted other than by sufficient penile penetration to constitute rape.

- If recent intercourse has taken place, was it by force? This may be all too obvious in the presence of gross injury, especially in small children. Where vaginal or rectal tearing has occurred, or where there is obvious abrasion, bruising or laceration of the vulva, anal margins or perineum, then this can hardly be compatible with voluntary intercourse. The possibility of sexually motivated injury without actual penile penetration must be considered when no semen can be recovered, as equally severe damage can be caused by digital or instrumental trauma. All kinds of foreign objects can be forcibly introduced into the vagina and rectum, and are not infrequently employed by sadistic and perverted killers. The author (BK) has seen candles, bottles, a banana, broken glass and knives introduced into the vagina, and broom-handles and potatoes lying in the rectum.

  Where injury is relatively slight and confined to hyperaemia and oedema of the vaginal or anal entrances – and where abrasion and bruising of the vulva is slight (even including fingernail scratches), although the presumption is that intercourse was by force, the possibility still exists that it was voluntary though overenthusiastic, unless, of course, the victim was a small child.

TESTS FOR SEMEN

In countries with sophisticated forensic science or police laboratories, the pathologist will not be called upon to carry out the actual techniques for the detection of seminal fluid. His role is to be a careful collector of the original samples at autopsy and, to some extent, to be able to interpret the results for the benefit of the police and the courts. He should be conversant with the general principles of the tests and aware of any potential shortcomings. In places where forensic science facilities are deficient or their availability may be delayed, the pathologist may have to conduct the more simple tests himself and the technical details are given in Appendix 1. The detection of semen depends upon the following methods:

- Naked-eye and lens recognition is a screening method which may identify suspicious stains on clothing, skin and pubic hair. Liquid semen leaking from the vagina or anus may be obvious, though leucorrhoeic vaginal discharge may be mistaken for seminal fluid. Dried seminal stains are stiff and rather silvery, depending upon the nature and colour of any fabric they may be upon. On the skin they flake off readily and can easily be lost if not carefully lifted with a blade or needle into a container. Dried stains on hair should be retrieved by cutting away the clump on which they lie. Suspect smears on skin may be collected by gentle rubbing with a plain cotton-wool swab that has been moistened with water or saline. All material should be examined as soon as possible after collection.
- Examination under ultraviolet light causes seminal stains to fluoresce a bluish-silver, but many other biological fluids and vegetable juices give false-positive

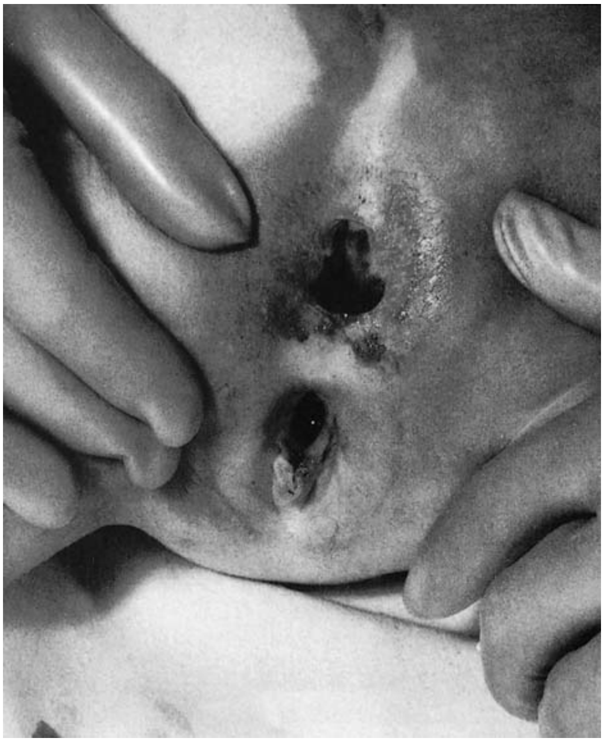

FIGURE 18.9 *Rape and buggery of a small girl who was then strangled. The vulva has a slight posterior tear and there is a large vaginal tear internally, the canal being filled with blood. The anus is widely ripped, especially posteriorly. Swabs were positive for semen in both orifices.*

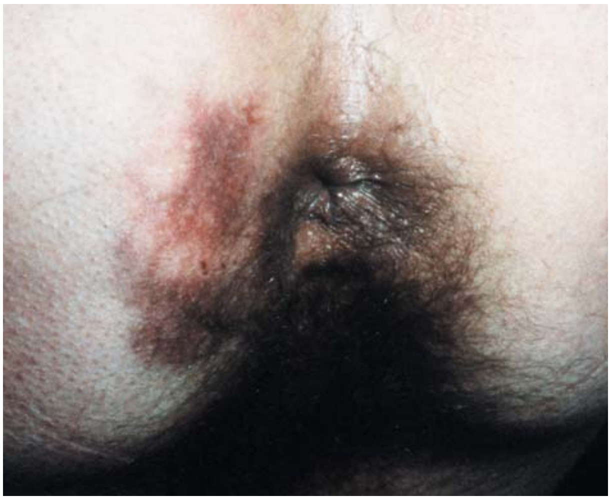

FIGURE 18.11 *Extensive bruising from fingers during a multiple anal and vaginal rape. Though penetrated by several men in a short space of time, the anus shows no injury.*

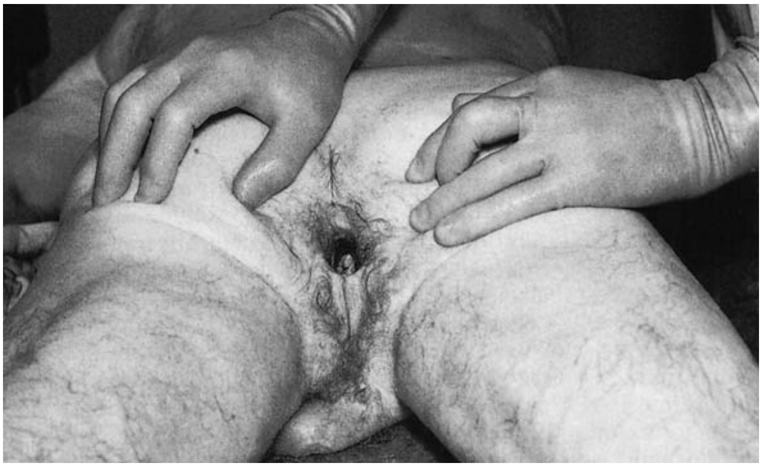

FIGURE 18.10 *A chronically dilated anus in an habitual passive homosexual. After death any anus can appear open and patulous, but this example is too large to be accepted as within normal limits. It also has keratinized, chronically abraded margins.*

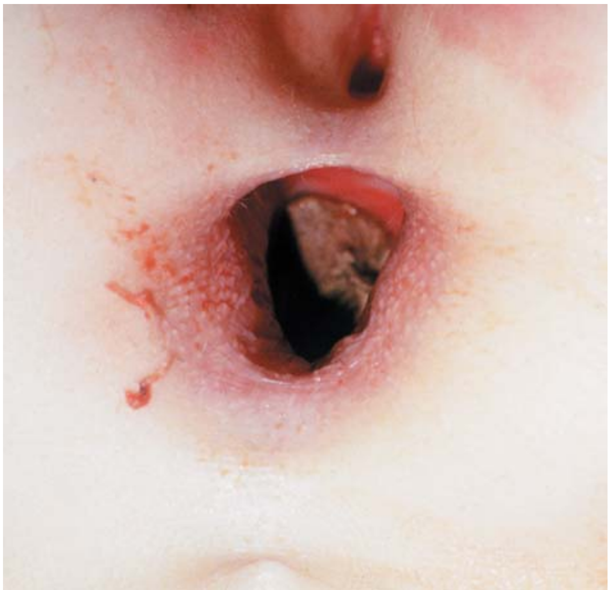

FIGURE 18.12 *The anus of a girl who has suffered penetration. The sphincter is overdilated, there is slight tearing of the anal margin, and some epidermal tags have been abraded from the surface. However, this degree of dilatation in a dead subject should not be used as the sole indication of buggery, as the post-mortem anus can be patulous in quite innocent circumstances.*

results. Many detergents, such as washing powders, also produce a confusing background fluorescence. The method is a useful screening process but cannot be used as definitive evidence of the presence of semen. Areas that fluoresce, especially on fabric, should be outlined to identify them for more specific testing.

- Enzyme reactions are valuable, and though not absolute proof, are strong presumptive evidence of the presence of semen. They depend on detecting high concentrations of acid phosphatase originating in prostatic secretion. Acid phosphatase activity in semen is 500–1000 times greater than in any other normal bodily fluid. Also, vaginal fluid contains endogenous acid phosphatase showing considerable variation in activity depending on various factors, which complicates the interpretation of the findings. There are several methods of detecting phosphatase, including a rapid commercial ‘spot’ test, which should not be used as hard evidential proof.
- Immunological methods, where animal antihuman semen sera are set up against extracts of the stain. These techniques can only be used by trained laboratory staff.

  Prostate-specific antigen (PSA, p30) is a glycoprotein produced by the prostatic gland and is found in seminal plasma, male urine and blood, but not in any tissues or fluid of the female body. A positive PSA finding is a reliable indicator of semen regardless of the presence of spermatozoa or elevated acid phosphatase level. Simple and sensitive methods have been developed for analysis of the presence of PSA.

  Other serological techniques may be able to determine the blood group of the semen if the ejaculator was one of the 80 per cent of the population who are ‘secretors’ – those who pass blood-group antigens into their saliva, sweat and semen. A problem for the forensic serologist is the admixture of semen with biological fluids from the victim, in the form of vaginal secretion and blood, but this is a complex technical matter that is usually outside the remit of the forensic pathologist, though he needs to be aware of the potential difficulties.

  Recent developments have now added the DNA technique to the armamentarium of the forensic biologist; this is a remarkable advance, especially in sexual offences, as the previous problems of blood group and enzyme typing caused by the admixture of semen and vaginal secretion can now be solved in many instances. The sensitivity of detection and identification has also been enormously enhanced by amplification techniques, such as PCR (polymerase chain reaction). Y-chromosome short tandem repeat (STR) markers have been succesfully used to analyse mixed stains with a male component.
- Until recent years, the only absolute proof accepted by the courts was the demonstration of spermatozoa in stain extracts and it remains the best evidence, though some of the sophisticated laboratory techniques such as serological and DNA identification are now equally reliable. One modern problem in using spermatozoa retrieval is the widespread and increasing incidence of vasectomy as a method of male contraception, so the seminal fluid contains no sperm; this also occurs naturally in azoospermic men. The phosphatase and some serology tests are unaffected by vasectomy. Fluorescent *in situ* hybridization (FISH) has been suggested as a sensitive and specific test for the detection of male epithelial cells in the post-coital vagina up to one week. Y-chromosome-positive epithelial cells have been identified in vaginal swabs even in cases with no ejaculation.

HOMOSEXUAL OFFENCES

As with heterosexual offences, the cause of death in fatal cases is almost always some form of general trauma, such as strangulation or head injuries. Homosexual activity, however, may be a parallel event; it is a fact that some of the most violent homicides seen by pathologists are among male homosexuals. In addition, quite a number of fatal altercations arise because a heterosexual man becomes violent when importuned by a homosexual.

The pathologist's attention will almost always be directed to the anal region of the passive participant, as the other partner or assailant is rarely dead, and any examination will be carried out by a police surgeon or clinical doctor. The examination of the victim follows closely on that for a female subject of rape, in that general injuries are sought first – including the one that caused death – together with any sexually orientated marks such as scratches anywhere on the body, but especially down the back, on the buttocks or on the thighs. Bruising around the anus and in the cleft of the buttocks is significant, especially if discoid finger bruises are seen. The anus should be inspected and the warning given earlier about the degree of dilatation in corpses should be heeded. Though most marked in children, a patulous anus can be seen in any adult post-mortem. Unless it is grossly dilated, an open anus cannot be used in isolation as an index of homosexual penetration. In recent or forcible anal intercourse, especially by a large penis upon a 'virgin' or young person, the margins of the anus may be reddened, sometimes abraded, and occasionally torn, especially in a child. There might be some eversion of the lower rectal mucosa through the sphincter. In gross anal 'rapes', especially on a young person, there may even be severe perineal tearing. At autopsy, swabs must be taken from the anal margin, and deeper in the anus and rectum. Mouth swabs should also always be taken. The presence of blood or lubricant should also be sought.

The classic description of the chronic passive homosexual has been passed down from textbook to textbook over the years, but is a rarity. The so-called 'funnel anus' is usually an anatomical variant. Some men and women have a deeply set anus as an anatomical variant, sometimes with a bridge of skin dorsally across the cleft of buttocks. This causes the anus to appear as if it was at the bottom of a funnel, but has no significance. The other classic feature was said to be silvery thickening of the skin outside and at the margins of the anus – but this is often due to chronic scratching from pruritis, rather than from prolonged friction during homosexual activities. In life, a lax anus, prolapsed mucosal rim and thickened anal margin may well be genuine signs to the experienced clinical eye, but at autopsy only acute damage and the presence of semen or lubricant is of much evidential value.

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CHAPTER 19

Deaths associated with pregnancy

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Though not usually a forensic problem, deaths associated with pregnancy (other than criminal abortions) are intensively investigated in a number of countries. In Britain, the Department of Health has had an ongoing 'Confidential Enquiry into Maternal Deaths' running for many years, which publishes valuable reports at 3-yearly intervals that have helped to clarify both the clinical and pathological aspects of the problem.

The pathologist has an important role in furthering the understanding of the causes of death in pregnancy and after childbirth. A good autopsy is essential, with full histological examination and other ancillary investigations where necessary. Only in this way can the full range of causes of death be recognized, especially amniotic fluid embolism, which is a histological diagnosis.

To give an example of the range of fatal conditions that occur in association with pregnancy, the following causes are taken from the 'Confidential Enquiry' from Britain published in 1998, the figures referring to death during pregnancy and within 6 weeks of parturition in the years 1994–1996. Altogether 376 deaths were reported to or identified by the enquiry in the UK during that period. Of the 376, there were 134 (36 per cent) direct and 134 (36 per cent) indirect maternal deaths. The number of underlying causes of death of the direct maternal deaths is shown in Table 19.1.

TABLE 19.1 *Number of direct maternal deaths by cause, United Kingdom 1994–1996*

Cause of death	*n*	Percentage
Thrombosis and thromboembolism	48	35.8
Hypertensive disease of pregnancy	20	14.9
Amniotic fluid embolism	17	12.7
Early pregnancy deaths*	15	11.2
Sepsis	14	10.4
Haemorrhage	12	9.0
Genital tract trauma	7	5.2
Anaesthesia	1	0.7
Total	134	100.0

* Ectopic pregnancy, spontaneous abortion, or termination of pregnancy, before 24 weeks' gestation.

According to a recent estimation, about 26 million legal and 20 million illegal abortions are carried out yearly throughout the world. Forensic pathological interest in pregnancy revolves almost exclusively around deaths associated with abortion, either criminal or legally induced. The term 'therapeutic abortion' is used in many countries, including Britain, where there is no abortion on demand, as in some countries. The description 'legal termination of pregnancy' is a wider definition for all but illegal (that is, criminal) abortions. The autopsy investigation of deaths from legal abortions has much in common with that into fatalities associated with surgical and anaesthetic procedures.

DEATHS ASSOCIATED WITH ABORTION

Though in many countries medical termination of pregnancy ('therapeutic abortion') is legal, a large area of the world still prohibits any form of abortion, either totally or except for the preservation of life of the pregnant woman. Even in those states where legal termination is possible, criminal abortions are still carried out, albeit on a small scale.

The reasons for this survival are varied, but are either because of restrictive grounds for legally available termination or to some sections of society that do not wish to avail themselves of the legal provisions. Whatever the cause, criminal abortion is associated with a considerable risk of both morbidity and mortality, especially in countries with a lower level of medical and social care.

Legal termination of pregnancy

When carried out with proper facilities, legal abortion has an extremely low mortality rate, being less than the mean death rate associated with pregnancy. The usual methods are vacuum aspiration, dilatation and curettage, or hysterotomy in later pregnancy. A few deaths are reported from time to time, the causes including:

- pulmonary embolism from leg vein thrombosis
- mishaps associated with anaesthesia
- disseminated intravascular coagulation and cerebral damage (including 'butterfly' haemorrhagic infarction in the basal ganglia) when abortion was induced by intrachorionic injection of hypertonic saline or glucose after the twelfth week (Cameron and Dayan 1960)
- air embolism following vacuum aspiration – only two cases have been reported and the mechanism is obscure, one theory being that 'elastic rebound' of the aspirated uterus sucked air into the cavity
- bleeding or infection, which failed to respond to treatment.

Death from illegal abortion

This has a much wider range of causes. The risks vary according to the skill, experience and facilities of the abortionist. When this is carried out by a doctor with aseptic and antiseptic methods, together with antibiotic cover if needed, the risk may be small compared with the crude methods of a lay person using makeshift instruments. The most common methods together with the associated dangers to health and life are as follows.

INSTRUMENTAL INTERFERENCE

The intention is to disturb the pregnancy sac so that, once damaged, it will be expelled by uterine contractions. This usually consists of dilatation of the cervical canal, which in itself also tends to dislodge the pregnancy. All manner of instruments have been used, from surgical dilators to bicycle spokes. A favourite in the hands of paramedical abortionists is the bougie or stiff catheter. When used by doctors or nurses with anatomical knowledge and sterile instruments, the risk is small, but lay persons often have no idea of the relationship of uterus to vagina. The instrument is then often pushed into the posterior fornix in the misguided belief that the cervix lies axially with the vagina. The vault of the vagina can be perforated and the instrument may even be passed through coils of intestine as far as the liver. Penetration of the lower or mid-vagina can also occur. If the cervix is entered, then the canal may be punctured and the instrument emerges through the side.

The external os may be badly injured by repeated, clumsy attempts to introduce too thick an object into the undilated canal. If successfully passed into the cavity of the uterus, it may be pushed right up through the fundus, again to damage the contents of the peritoneal cavity.

The dangers of such instrumentation are bleeding and infection. Perforation of the wall of vagina or uterus may cause severe bleeding, which may be internal or external. Sepsis can supervene in the peritoneal cavity or pelvic tissues either directly from a dirty instrument or from transfer of vaginal, skin or bowel organisms.

Another less common danger of the use of instruments (including syringes) is cervical shock. The mere act of dilating the cervix with an instrument in an unanaesthetized patient may trigger a vagal reflex, the efferent pathway being via the parasympathetic nervous system, causing a cardiac arrest. This is known to be a more potent mechanism in states of fear, apprehension and nervous tension, which obviously will apply to many candidates for a criminal abortion.

INSUFFLATION OF AIR

In Europe, this is becoming more of historical interest, but occasional cases still occur. A rubber pump, usually a Higginson enema syringe, is used to introduce fluid under pressure into the cavity of the uterus. This strips the chorionic sac from the wall of the uterus, exposing the placental bed. If sufficient detachment is achieved, then abortion will occur. It was formerly a popular method of abortion, both by women themselves and by abortionists. The main danger – part from the usual risks of bleeding and infection from damage to the tissues by the stiff nozzle – was air embolism, and in the first half of this century it was a major cause of abortion deaths. The intention was to introduce a fluid such as water–soap solution or disinfectant through the cervix by means of the syringe nozzle, the other end, which carried a one-way valve, being dipped in a receptacle of the fluid.

As the level in the receptacle dropped, the inlet tube rose above the surface and the syringe began to inject air instead of fluid, often as soapy foam. In addition to this danger, unless the bulb of the pump was primed with fluid before use, the first ejection would be the appreciable volume of air

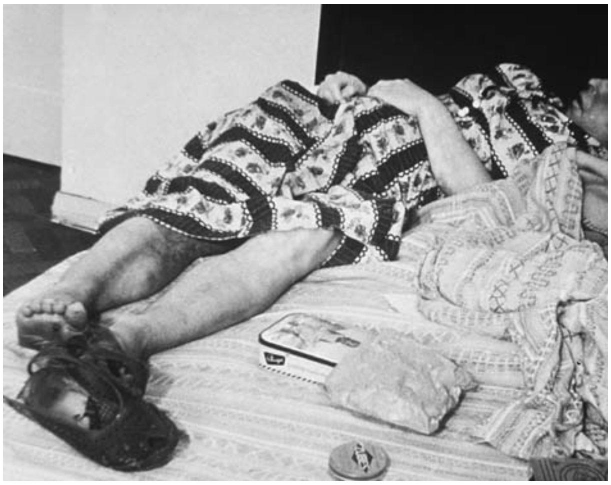

FIGURE 19.1 *The sudden unexpected death of a woman of child-bearing age should always arouse the consideration of a complication of pregnancy. This woman insufflated her uterus with a Higginson syringe and had time to clean up the equipment before collapsing with air embolism. This photograph was taken before the British Abortion Act of 1967, as such events are now uncommon.*

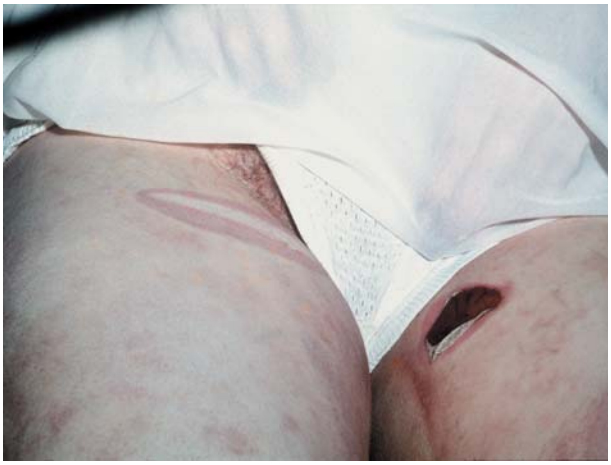

FIGURE 19.2 *Burns from a hot-water bottle on the inner side of the upper thigh in an attempt to resuscitate the victim of a criminal abortion who died from air embolism.*

contained in the empty syringe, which in itself was enough to cause a fatal embolism. Under the considerable pressure available from the instrument (as much as 28 cm of mercury according to Teare 1958), this air was forced into the exposed vascular channels of the placental bed and from there into venous sinuses and pelvic veins to cause cardiac embolism.

Though this occurred almost immediately in most instances, some delay was possible – perhaps because contained air was further squeezed by contraction of the uterus. Some victims were able to leave the premises of an abortionist and survive for up to 2 hours or more before the embolism occurred (Simpson 1951). The addition of various substances, such as phenol, formalin, alcohol and turpentine, to the fluid introduced a toxic element, and in some cases these fluids were extruded into the peritoneal cavity through the uterine tubes, causing a chemical peritonitis.

DILATATION OF THE CERVIX

Another crude method was to introduce a ‘tent’ into the cervical canal. This was a strip of substance that absorbed water and became greatly enlarged, such as *Laminaria digitale* or slippery elm (*Ulmus fulva Michx*). These vegetable materials are hard and compact when dehydrated, so that a strip about 3–8 cm long could be slid into the cervix. When water was absorbed from the surrounding tissues, the cervical canal became widely dilated and abortion might take place. The risks were perforation of the cervix and also infection, especially if the strip tore into the tissues. The substances used, often crude vegetable material, could be the source of infecting micro-organisms including anaerobes.

PHYSICAL VIOLENCE

Women anxious to lose their pregnancy have resorted to extremes of physical activity and even violence in efforts to dislodge the fetus. Frenzied exercise, horse-riding and severe purging with laxatives were usually ineffective, and some unfortunate women went on to seek violent treatment from husbands or consorts. Punching and kicking of the abdomen were most common, and death from visceral rupture, such as liver, spleen or intestine, has been reported. Ironically, the uterine contents were usually undisturbed.

SYRINGE ASPIRATION

The suction method most often used in therapeutic abortion has also come to be used for illegal operations, mainly by medical or nursing personnel. A large syringe attached to a catheter or length of plastic tubing can produce suction within the uterus sufficient to rupture the chorionic sac and precipitate abortion. The method is safe as long as aseptic methods are used, though, if evacuation is incomplete, some products of conception may be left behind that can form a nidus for infection.

INTRAUTERINE INFECTION

Whatever method is used to evacuate the uterus, the risk of haemorrhage or sepsis is always present. Where an instrument, tent or syringe is used, any remaining fragments of placenta or other products of conception may form a substrate for infection. The organisms involved in sepsis are varied, the most dangerous being non-haemolytic

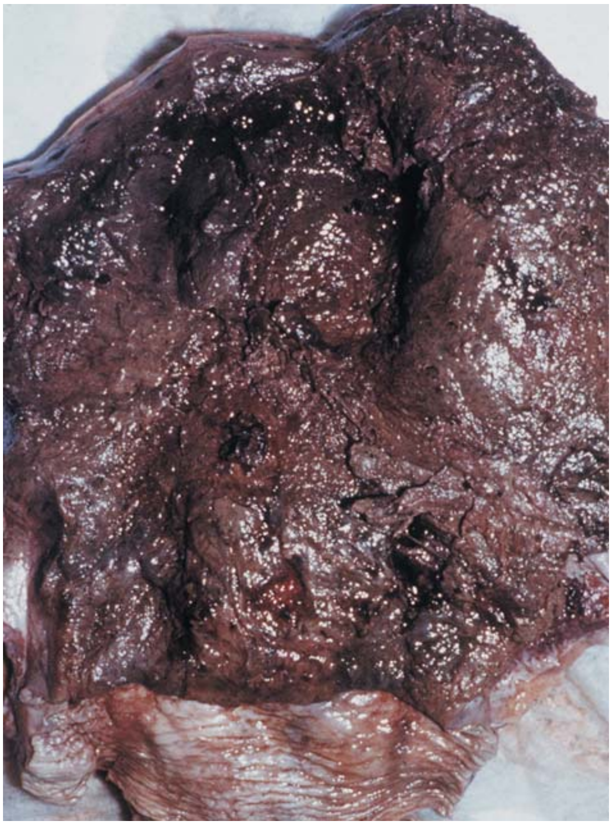

FIGURE 19.3 *Septic, necrotic uterus following an instrumental criminal abortion. The endometrium, containing some retained products of conception, is chocolate brown and foul-smelling, the predominant organism on culture being* Clostridium perfringens.

streptococci and *Clostridium perfringens*, though coliforms and staphylococci may also be responsible.

The uterus becomes swollen, spongy and discoloured. The serosal surface seen at autopsy may be brownish – especially in clostridial infections – and the endometrium may be ragged, foul-smelling and even purulent. Signs of septicaemia may develop with an enlarged, soft spleen, prominent lymph nodes and hepatorenal failure. The kidneys may show bilateral cortical necrosis in extreme cases. In clostridial septicaemias there may be a characteristic bronze coloration of the skin. This may have a mottled or 'raindrop' appearance.

THE USE OF DRUGS AND CHEMICALS

A wide variety of substances, applied locally or taken by mouth, have been used since time immemorial to induce miscarriage. Some have a sound pharmacological basis, others are dangerous, and yet more lie in the realms of folk medicine. Substances applied locally include phenols and Lysol, mercuric chloride, potassium permanganate, arsenic, formaldehyde and oxalic acid. All have their own dangers, both from local corrosion and systemic effects if absorbed. A necrotic pseudomembrane may form in the vagina and severe damage to the cervix may also ensue.

Potassium permanganate was a substance that appeared during the last war and persisted for some years, 650 cases being reported up to 1959, though only a few were fatal. It can cause local necrosis in the vagina and, if absorbed, can have fatal systemic effects including renal failure. Permanganate can cause profuse vaginal bleeding from necrosis, which may give the impression that abortion is threatened and lead an unsuspecting doctor to carry out a curettage. 'Utus paste' is a mixture of soap, myrrh resinoid and potassium iodide, and was used earlier in the century for legitimate abortions, but soon became popular with the criminal abortionist. Another similar product containing elemental iodine, is 'Interruptin'; both were used for late abortions and the induction of labour when the fetus was dead. These pastes are squeezed into the cervical canal through an applicator and the halogen component acts as an irritant which causes eventual expulsion of the chorionic sac. Used medically, they are relatively safe (Barns 1967; Berthelsen and Ostervaard 1959), but fatalities can occur from air or fat embolism or from the toxic effects of absorption.

Substances taken by mouth or injection are legion. The old classification into 'ecbolics' and 'emmenagogues' is now quite redundant and most of the lists of substances are of historical interest only, as their efficacy is either nil or the dose needed to produce abortion is perilously near the fatal level. These include pennyroyal, tansy, rue, savin, laburnum, colocynth, aloes, castor oil, nutmeg, hellebore, cantharides, cotton root, wintergreen and turpentine. Many of these may cause purging, gastrointestinal irritation and general illness if taken in quantity, but have no specific action whatsoever on the uterus. There are other substances that have more chance of causing uterine contractions, though many of them are effective only on a late pregnancy, not at the usual time of 1–3 months when most abortions are sought.

Quinine can be dangerous, as the dosage required for any effect on the uterus is likely to cause cinchonism. Ergometrine has been known from ancient times to lead to abortion, though like most drugs its effectiveness is greater later in pregnancy. Excess dosage may cause peripheral vascular spasm and gangrene. Its availability to doctors and mid-wives is similar to pituitary extract, oestrogens, and – more recently – prostaglandins. Heavy metals, particularly lead, were used for abortion in the past. Plasters coated with a lead compound 'diachylon' were scraped to recover the metallic substances and ingested. Though abortion sometimes occurred, illness and death from acute and subacute lead poisoning was more common; this method has also become of historical interest only. It has been well said that most substances that

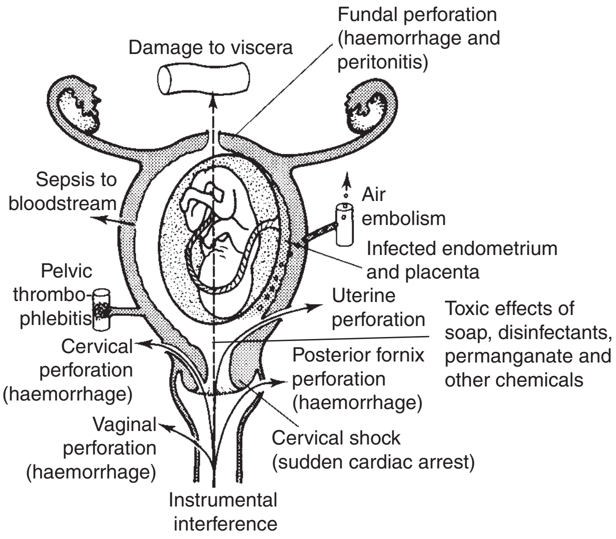
Damage to viscera
Fundal perforation (haemorrhage and peritonitis)
Sepsis to bloodstream
Air embolism
Infected endometrium and placenta
Pelvic thrombo-phlebitis
Uterine perforation
Toxic effects of soap, disinfectants, permanganate and other chemicals
Cervical perforation (haemorrhage)
Posterior fornix perforation (haemorrhage)
Vaginal perforation (haemorrhage)
Cervical shock (sudden cardiac arrest)
Instrumental interference

FIGURE 19.4 *Dangers of a criminal abortion.*

are successful in killing the fetus are likely to kill the mother as well.

A wide variety of medical substances have been used for abortion, including aminopterin, steroids, antimitotic drugs, such as vincristine and ergocornine, and other cytotoxic drugs used in malignant diseases. Even monoamine oxidase inhibitors have been reported as abortifacients. In all these, the autopsy findings in fatal cases will be non-specific or negative, and the history and toxicology provide virtually all the available evidence.

THE AUTOPSY IN ABORTION DEATHS

Where a death in pregnancy or the puerperium occurs, every effort should be made to obtain an autopsy, even if the death does not fall within the usual category of death reportable for medico-legal investigation. When a criminal abortion is suspected, then virtually every jurisdiction will require necropsy.

The usual full autopsy is performed, but a number of additional measures are required, varied to suit the particular circumstances. The fullest possible history is required and, where the death has taken place under medical care, a prior discussion with the clinician is vital. A careful external examination must be carried out, noting especially:

- Abnormal coloration of the skin, such as in the bronzing of clostridial septicaemia and the jaundice of liver damage.
- Signs and duration of pregnancy, such as abdominal swelling and breast changes.
- Signs of injury, including bruising or abrasion of the vulva from instrumentation, and vaginal bleeding.

  Burns on the abdomen or inner sides of the upper thighs may indicate efforts at resuscitation by hot-water bottles when a woman has suddenly collapsed during an illegal abortion.
- The vagina should be examined for signs of recent or current pregnancy, and attempted or successful recent abortion. Any fluid should be removed by pipette to be examined for soap and chemicals, such as antiseptics. A swab should be taken for microbiological culture.
- Where any possibility of air embolism is considered, pre-autopsy radiology of the chest and abdomen must be performed. Some pathologists would consider this obligatory in any death associated with pregnancy, as it is the best method of detecting air embolism by visualizing air bubbles in the heart, great veins in the thorax, inferior vena cava, peritoneal cavity and – possibly – pelvic veins. In the few centres where MRI or computed tomography is available for autopsy material, this may greatly increase the chance of detecting air in the vessels.

Where radiology is not possible, air must be sought by dissection methods, which are not so reliable. The thorax is opened carefully, making sure that removal of the costal cartilages and sternum does not damage the underlying mediastinum or open any of the veins at the thoracic inlet. The cardiovascular system is first examined for the presence of air. The classic method, discussed elsewhere in this book, is to open the heart chambers *in situ* under water poured into the pericardial sac. Escaping bubbles are then said to be indicative of air embolism, though the technique is by no means as reliable as past authors have claimed. In fact, if the post-mortem interval is short, in terms of a few hours, then any fatal air embolism will almost always be quite apparent from the frothy contents of the right ventricle when it is opened in the usual way. Appreciable delay allows absorption of air, as can be proved by the failure to find air in the heart on dissection, even after radiology has clearly indicated its presence. Of course, where any degree of decomposition has set in, which may be on the first day after death in hot countries, gases of putrefaction completely negate any chances of proving air embolism.

Before the organs are disturbed, the great veins of the abdomen should be inspected for bubbles, then the pelvic veins. The uterus itself may be crepitant and bubbles may be seen under the serosal surface or even under the parietal peritoneum of the pelvis. On opening the uterus, gas bubbles may be evident in the wall or placental bed, but this is later in the examination. The usual instructions in most forensic textbooks for opening the head first, carefully removing the calvarium and minutely inspecting the cerebral veins for air bubbles, can be totally disregarded, as this is yet another

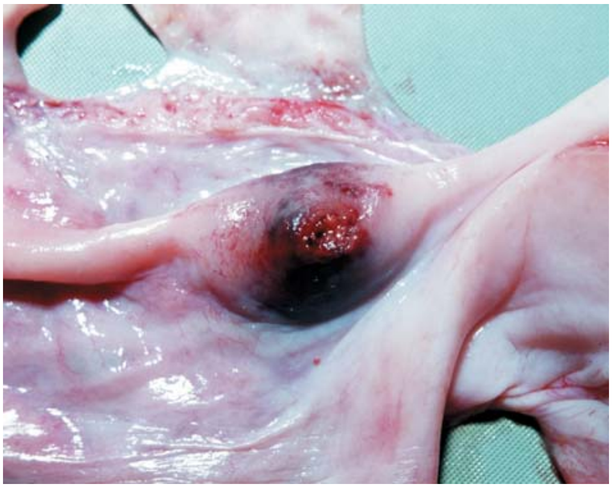

FIGURE 19.5 *Ruptured tuba in (ectopic) pregnancy. Death due to massive intraperitoneal haemorrhage. (Reproduced by kind permission of Professor E Lignitz.)*

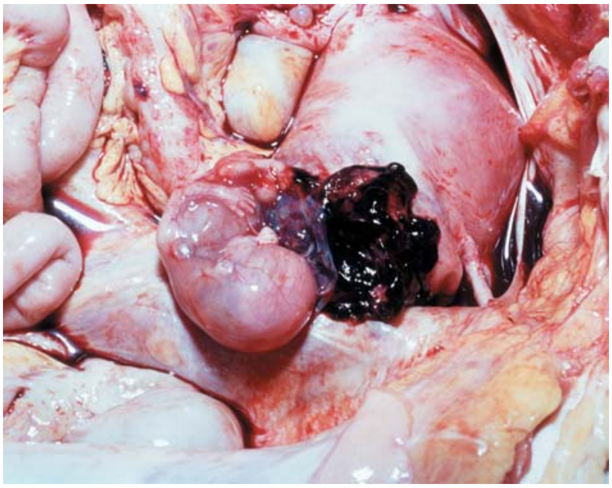

FIGURE 19.6 *Fetus and placenta in the abdominal cavity after ruptured tubal (ectopic) pregnany. Death due to massive intraperitoneal haemorrhage. (Reproduced by kind permission of Professor E Lignitz.)*

example of forensic mythology repeated from one book to the next, without critical evaluation. As discussed in Chapter 13, air embolism cannot occur in the cerebral veins and it was proved many years ago that air bubbles in those veins are artefacts caused by removing the calvarium.

The thorax and upper abdomen should be examined as usual, with particular attention to signs of infection. Blood cultures, and peritoneal and other swabs should be taken as indicated by the circumstances.

The pelvic organs should be removed *en bloc*, as in the examination of fatal rape victims. The lower end of the abdominal incision is carried on each side around the labia and into the cleft of the buttocks to meet beyond the anus. The dissection is taken along the superior pubic rami, which are then carefully sawn through a few centimetres laterally to the symphysis on each side, the cuts being continued down through the inferior rami. The central block of bone is removed and the perineal incision dissected deeply, so that the vagina, rectum and anus, uterus, tubes and ovaries can be lifted out in continuity, and removed for detailed dissection. The vagina is carefully opened along one side to avoid overrunning any midline injuries. Abrasions, bruises, lacerations and any foreign material are noted in the vagina, and any samples kept for chemical or microbiological testing. Any abnormality of the cervix is noted, especially instrument marks, such as forceps or volsellum teeth. The state of dilatation of the cervical canal is noted and the uterus opened, again keeping away from the midline if possible. The colour, size and texture of the uterus is noted, and the state of the interior is naturally vital. If the chorionic sac is still present, its integrity and the attachment to the deciduae are noted. If a fetus is present, this is examined separately for maturity and damage.

If no fetus is present, products of conception are sought and the state of the placental bed noted. Infection, bleeding and air crepitancy are all sought, and the appropriate ancillary investigations made. The tubes are then opened and any foreign fluid collected. The ovaries are examined and the state of any corpus luteum recorded. Finally, extensive histological specimens are taken from all organs and special stains employed where necessary, such as those for seeking amniotic squames in lungs and other organs. Blood, urine, liver and stomach contents are retained for analysis, should this be indicated.

AMNIOTIC FLUID EMBOLISM

Some deaths associated with childbirth or pregnancy are caused by the entry of amniotic fluid into the maternal circulation. The fluid contains fetal squames, lanugo, lipoid from the vernix, meconium, cells from chorion and amnion, and other cellular detritus. The solid elements are usually impacted in the lung capillaries, but rarely have been found in the systemic circulation, including embolization into the kidney, liver and brain. In addition to the solids, the actual fluid itself (which is naturally undetectable histologically) is blamed for the ‘allergic’ response that may cause such profound collapse, leading to death. Amniotic fluid embolism is also one of the most potent causes of disseminated intravascular coagulopathy, mentioned also in Chapter 13.

A variety of causes exist apart from the pelvic trauma of parturition, including rupture of the uterus, but instrumental interference late in pregnancy may also allow opening of the sinuses in the placental bed with consequent escape of amniotic fluid. Further details of the causes and mechanisms must be sought in obstetric works, but from the autopsy point of view, it is important both to bear the possibility in mind and to have techniques that will reveal the embolism after autopsy. The diagnosis is histological and depends upon identifying the squames detached from the fetal epidermis, which float freely in amniotic fluid. These can be seen in ordinary haematoxylin and eosin stained sections of the lung, but are much better visualized and a greater yield obtained if special staining methods are used, as described in Appendix 1. Fibrin deposition in many organs may occur as a result of the disseminated intravascular coagulation and careful search for this must be made, using fibrin stains. Immunohistochemical techniques have also been used in the lung sections to demonstrate human keratin-, meconium- and amniotic fluid-derived mucin as well as isolated trophoblastic cells in deaths due to AFE (amniotic fluid embolism) syndrome.

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CHAPTER 20

Infanticide and stillbirth

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Historically, infanticide has by no means always been a crime, and has been practised as a social and economic necessity since the dawn of humanity. The pathologist, however, has to deal with the practicalities of infanticide as they exist today. Though legal definitions vary among different countries, the medical concept of infanticide is uniform, being the deliberate killing of a newborn infant by the mother. In England and Wales, infanticide was not accepted as a legal entity in the criminal law until 1922. Before then all child killing was murder – and the convicted mother was liable to be sentenced to death until the Infanticide Act, which was re-enacted in a more satisfactory form in 1938 (see account by Kellett 1992).

In many other countries there is no specific infanticide legislation – even Scotland did not adopt the English statute, having a separate crime of 'child murder', but long before 1922 that country had held a more enlightened attitude towards the mentally stressed mother. In Japan, Funayama *et al.* (1994) have described cases of multiple, repeated infanticides by five mothers.

This book generally avoids territorial legal comparisons, but the foregoing facts serve to illustrate that the killing of a young child by the mother is a well-recognized medical and psychiatric phenomenon that distinguishes it from other types of homicide. The penalties should therefore be different and there is a profound responsibility laid upon the forensic pathologist called to examine such infants, to investigate the death with particular caution.

The substance of infanticide that has relevance to the pathologist is well set out in the English Infanticide Act 1938 (Section 1):

> Where a woman by any wilful act or omission causes the death of a child being under the age of 12 months, but at the time the balance of her mind was disturbed by having given birth or the effect of lactation, she may be dealt with as if she had committed manslaughter.

It should be noted that:

- Only the mother can benefit from this alternative to murder – not the father or any other person.
- The child has to be less than a year old, though in fact the majority of infanticides occur within hours or even minutes of birth.
- It has to be a 'child' – that is, a person with a separate existence living independently fully outside the mother's body.
- It must have died because of a wilful (deliberate) act of omission or commission.

All these provisos have an effect on the pathologist's task. Even in those jurisdictions where there is no formal infanticide legislation, there is usually recognition that the acts of a woman soon after childbirth, often in adverse conditions, are different from common murder.

STILLBIRTH

To clarify later definitions, a stillbirth is defined in English law and, from a medical point of view no doubt has a broadly similar description in other jurisdictions. In England and Wales, a baby is stillborn if after 24 weeks' gestation, 'it did not at any time after being completely expelled from its mother, breathe or show any other sign of life'. Theoretically, this is a medically unsatisfactory definition, as it could be alive when its head was born but die

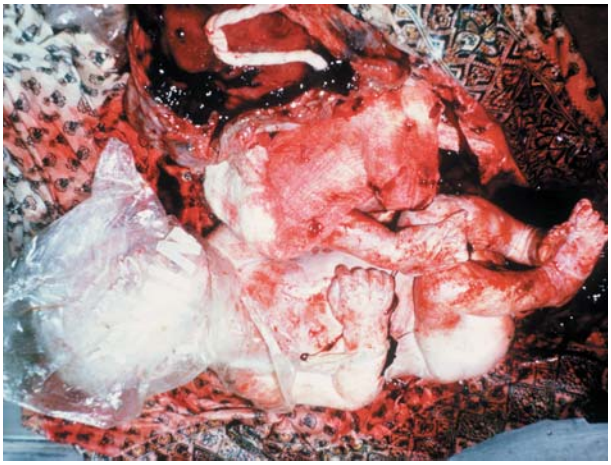

FIGURE 20.1 *Newborn baby with umbilical cord and placenta, abandoned in a car park. It was wrapped in a curtain and though the head was in a plastic bag no signs of suffocation nor of live birth could be detected. The mother was never identified.*

before completion of expulsion, and therefore legally be a stillbirth. However, in practice this would be rare, as most stillbirths either die *in utero* or during the earlier stages of parturition. Stillbirths occur in about one in every 18 legitimate pregnancies in Britain, and are more frequent in illegitimate births and socially disadvantaged families.

FUNCTIONS OF THE PATHOLOGIST IN INFANTICIDE

To assist in identifying the mother, if she is unknown

Newborn infants found dead (especially in clandestine circumstances) are not necessarily the victims of infanticide. Those stillborn or dying naturally or from unintentional lack of care may be hidden or abandoned, a minor crime in Britain called 'concealment of birth'. The autopsy, as well as artefacts discovered with the body, such as bags, blankets and newspapers can assist to a greater or lesser degree in the police search for the mother.

The apparent ethnic group of the child will be disclosed and blood grouping can be performed, which may assist by eliminating or helping to confirm the consanguinity of any putative mother. In the future, DNA profiling will add greatly to identification. The appearance of the cut end and any ligation of the umbilical cord (see below) may help to decide whether the birth was one where medical, nursing or only amateur attention was available. In spite of these clues, most abandoned newborn corpses fail to be linked to the mother, delay in discovery making both identification and evidence of live birth unattainable.

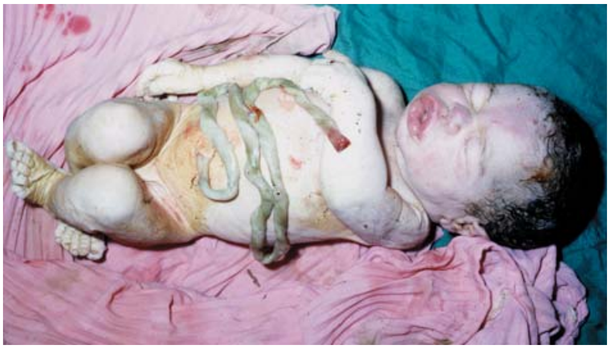

FIGURE 20.2 *Full-term newborn found wrapped in a blanket inside a shopping bag in a refuse container. The cord had been cut with a sharp instrument, but the child was not washed or fed. The lungs showed no positive evidence of respiration.*

To estimate the maturity of the child

Though any newborn infant, whatever the length of gestation, can be the victim of infanticide if born alive, it is obviously relevant to this issue if the fetus is too immature to have survived birth. In another context [Infant Life (Preservation) Act 1929, concerning child destruction], the age of viability in English law was taken as 28 weeks' gestation, though this has now been reduced to 24 weeks as even younger fetuses can now survive with intensive medical support. If a child is shown to be that premature, there is a strong presumption that it would not long survive a birth away from medical attention.

To determine whether or not the child was stillborn and whether it had a separate existence

There is a presumption in English law that all infants are stillborn and, when a woman is charged with infanticide, the burden of proof is upon the prosecution to demonstrate that the child had a separate existence. Adelson (1974) states that the same legal situation exists in the USA, and gives the following useful and interesting commentary:

> Unless the pathologist has incontrovertible criteria of post-natal survival, e.g. well-expanded lungs, food in the stomach or vital reaction in the stump of the umbilical cord, he is legally bound not to diagnose live birth. Convictions for infanticide have been set aside when there has been any doubt whatsoever that the child was born alive. Many courts have pushed this proposition to the extent that the State has been given the burden of proving that the baby was born alive beyond any

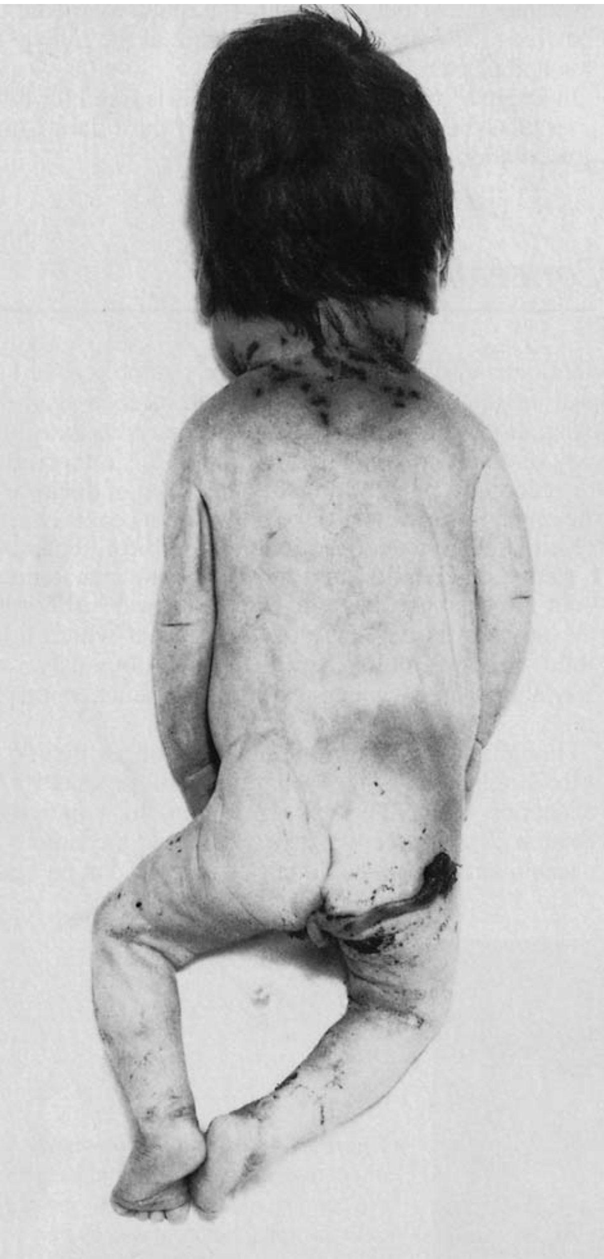

FIGURE 20.3 *A stillborn child concealed by the mother after birth. The injuries around the neck were viewed with suspicion by the police, but are the result of fingernails being used in an attempt to assist self-delivery in an unattended birth.*

possible doubt rather than beyond any reasonable doubt, the latter being the general level of proof required in a criminal prosecution.

Herein lies the most difficult task for the pathologist, one which has given rise to considerable controversy in forensic pathology.

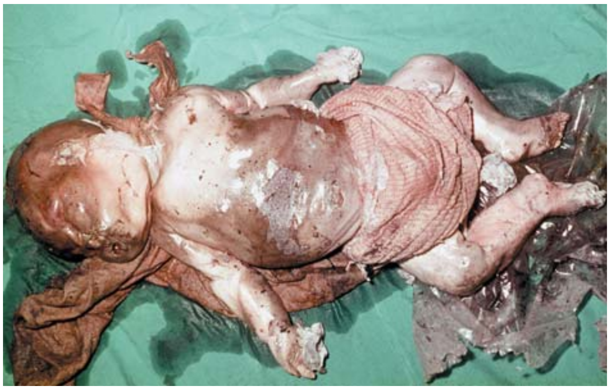

FIGURE 20.4 *A putrefied newborn infant disposed of in a plastic bag in the countryside. There is no hope of determining whether it was live or stillborn with this degree of post-mortem decomposition. There was a strip of fabric knotted around the neck, but it is impossible to decide if that was related to the death, if the child was not stillborn.*

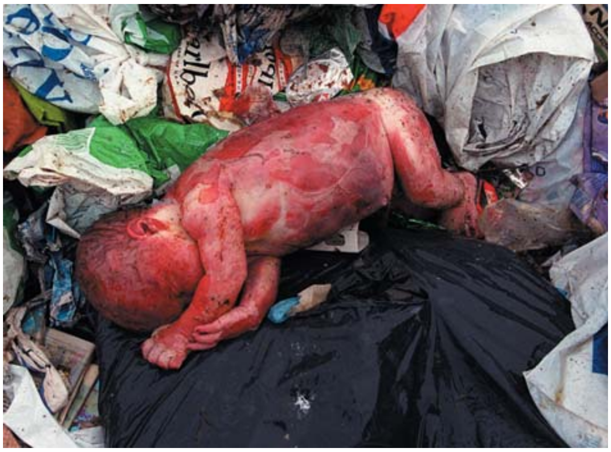

FIGURE 20.5 *A decomposed newborn infant found in a rubbish dump.*

To determine whether its death was due to natural causes or to any act of omission or commission

Where the pathologist claims to have proved separate existence (or at least, live birth), he has an additional burden in that he must show that death occurred from an act of commission or omission, The ‘wilful’ aspect is a matter for the lawyers, but it is for the pathologist either to demonstrate lethal injuries or to prove that some lack of care led to the death – often an impossible task. There is a considerable burden upon the investigating authorities when finding a hidden newborn infant if they wish to pursue an infanticide charge.

First, they must find the mother – often another impossible task. Then the pathologist must prove live birth, which is often impossible, especially in a decomposed body. To prove a separate existence is even more difficult and is rarely a purely medical decision. The firm diagnosis of death from wilful inattention is equally hard to make.

It is small wonder that only a small proportion of suspicious neonatal deaths ever reach the court – where few women are convicted, and those who are, rightly receive lenient and sympathetic treatment, usually consisting of probation and psychiatric support.

DEFINITION OF 'LIVE BIRTH' AND 'SEPARATE EXISTENCE'

There is no definition of live birth in English law, except by inference from the defined 'stillbirth', given earlier. Using the live birth as the converse of a stillbirth, the infant should have attained the gestational age of 24 weeks, but this is not a factor in 'separate existence' with which live birth is almost synonymous.

A child with a 'separate existence' would be an infant that had issued forth from its mother irrespective of its gestational age, and who breathed or showed any other signs of life after being completely expelled from the maternal passages – though the child could still be attached to the placenta within the mother. This is almost synonymous with a live birth, though medically all would agree that a child that was crying lustily, but with a foot still in the vagina, was undoubtedly live born even though it did not satisfy the legal criteria of a 'separate existence'.

Viability

Yet another medical and legal concept is that of viability, which is the potential ability of an infant to survive after birth. An immature fetus may be born alive, but be incapable of maintaining an independent existence. Naturally the stage of gestation at which this occurs varies not only with the condition of the particular fetus, but also with the state of medical knowledge and the facilities available at the relevant time and place.

In English law, a period of 24 weeks is fixed for the onset of viability, for the purposes of the Infant Life (Preservation) Act, 1929.

CONCEALMENT OF BIRTH

Mentioned earlier, this is a relatively minor crime in most jurisdictions and is basically an offence against registration, and perhaps public decency, in that the body of an infant is neither notified to the authorities nor accorded a proper burial or other form of disposal. The crime is the hiding of the body to conceal the fact of birth. It does not depend at all on live birth, separate existence or viability, and the law is not concerned about the cause of death or whether it was stillborn. One problem is the stage of gestation at which the 'child' becomes noticed by the law – obviously an early abortion is of no concern to anyone, except the family.

Though not specified in relation to concealment of birth, English law takes no regard of products of conception under 24 weeks' gestation. In a judicial decision (*R* v *Matthews*), it was held that a charge of concealment of birth could not be sustained at an age where the law did not require the (still)birth to be registered.

Whatever the legal ramifications, the forensic pathologist is not infrequently asked to examine dead infants in which he can neither prove live birth nor a wilful act that might have caused death. The only remaining charge, if he can show an age above that of viability, is 'concealment of birth'. This is the end result of the discovery of most decomposed babies, in the minority where the mother can be traced.

THE AUTOPSY ON A SUSPICIOUS DEATH OF A NEWBORN INFANT

A number of important matters need specific attention, over and above the usual meticulous autopsy procedure on any infant.

The coverings and any other associated articles with the infant must be examined and retained. Though this is mainly police business, the pathologist usually has the task of unwrapping the baby – often in a decomposed and offensive state – from the coverings of newspaper, plastic bags, rags or blankets. He must recover any foreign material or objects that may assist in the identification of the mother when the disposal has been clandestine.

When the baby has been found in a house or other building, he may need to visit the scene, preferably with the child still *in situ*. Numerous cases are on record of the infant being in a lavatory pan and, if there are head injuries or drowning, the circumstances must be evaluated.

The external examination is, as always, important. It is vital to assess the degree of putrefaction because if it is in any way decomposed, it will almost certainly be impossible to determine whether live birth had occurred. Decomposition must be distinguished from intrauterine maceration, as the latter is definite proof of stillbirth. If death occurred within 2–3 days before expulsion from the uterus, the appearances may be fairly normal, apart from general softening and histological evidence of general cellular autolysis.

When it has been dead for many days, the macerated fetus is usually a brownish-pink, rather than the greenish hue of putrefaction. The surface is slimy, blistered, desquamating and sometimes almost jelly-like. The joints are grotesquely loose and the cranial plates may be virtually detached beneath the scalp. Their over-riding, radiologically seen as 'Spaulding's sign', is characteristic, so that the head is shapeless. Rarely, a macerated fetus – which is normally sterile – may become infected if not expelled after the membranes rupture; it will then be born in a putrefied state.

External examination will next be directed at the cord and placenta, if present. The latter must be measured and weighed to estimate the maturity and any abnormalities, such as placental infarcts, noted as possible reasons for fetal death. The cord is important as an indicator of separate existence, if survival has been for an appreciable period. Even where early putrefaction renders evaluation of breathing impossible, vital signs in the cord may indicate live birth if survival reached 24–48 hours. Until this period, no evidence of cord separation is reliable, but after a day or so, a ring of reddening appears around the base of the cord and adjacent abdominal skin. This becomes more marked in the succeeding few days as the cord dries and shrivels, detachment taking place between 5 and 9 days. As most infants die or are killed within hours of birth, however, these signs are rarely of much practical use.

The severed end of the cord should be examined, as it may indicate whether the cord had been broken or actually cut. This is occasionally important if death is the result of head injuries and the defence on behalf of the accused mother claims that the child fell to the ground head first during a precipitate delivery. The length of the cord must be measured, especially if the placental segment is available, so that the distance from the vulva to the floor can be calculated. The average cord length is about 50 cm, but more than twice this length is not uncommon, as are much shorter ones. Naturally, if a ligature is present it indicates either the attendance of a professional or at least knowledgeable person, but this is rare in these cases. The severed end may be examined in the hand, but may also be floated out in water, to better study the detail of the detachment. Morris and Hunt (1966) conducted experiments on cords and determined that they could easily be broken by hand traction. A broken cord can show a clean transverse termination, but is usually ragged. If cut by a sharp instrument such as knife or scissors the cut may be clean, but may also be ragged if the instrument is blunt.

If the baby is examined as found, either at the scene or undisturbed in wrappings, it should be noted if the cord was coiled around the neck. Although it is usually unsafe to claim that death during delivery was from pressure on the neck from the cord, the fact must be noted and evaluated along with all other findings.

The skin may still have vernix caseosa present. This is not a useful observation but, if none is present, it may indicate that the child had been washed, which suggests survival for some time after birth.

Measurements are vital for an estimate of maturity. Weight, crown–heel, crown–rump, head circumference, and foot length are required.

Abnormalities incompatible with continued life may be obvious, such as anencephaly, severe spina bifida or abdominal ectropion. It is, however, often unsafe to assume that actual live birth, as legally defined, could not have taken place.

Injuries are obviously of prime importance as evidence of the 'act of commission', though most newborns seen by the pathologist will be free of such trauma. The types of injury perpetrated by distraught mothers are numerous:

- Strangulation presents the usual features of bruises and abrasions on the neck, though these may be minimal. The classical features of facial congestion, cyanosis, oedema and petechiae may be present, but are often absent, presumably because of the ease with which the vulnerable infant dies. Abrasions on the neck, however, may also be caused by the frantic efforts of the mother to deliver herself, leaving finger-nail marks on the infant's neck. A ligature may be used, which may still be in place. Again caution must be employed, as the fact of some object around the neck, though suggestive,

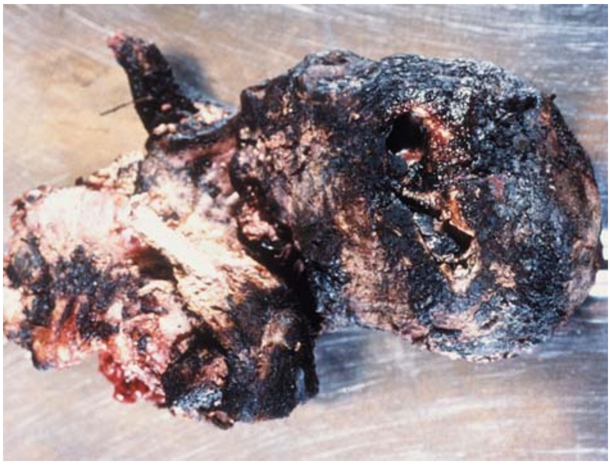

FIGURE 20.6 *Remains of a newborn infant, who was born during a weekend when the mother, a schoolgirl, was alone in her room in a boarding-school. After the birth she wrapped the child in a plastic bag. The following day she left for home and tried to burn the body in a stove but when that did not succeed she buried the partly burned body in a snowdrift where it was later found by a dog.*

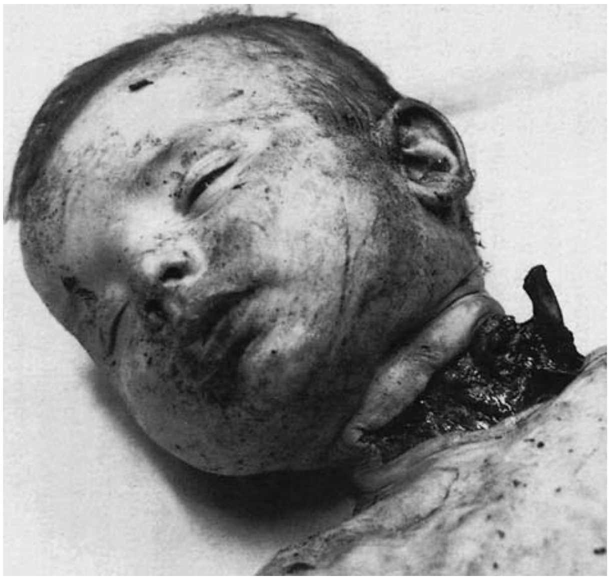

FIGURE 20.7 *Definite infanticide, the child having fully respired before having this severe incised wound of the neck made with a kitchen knife.*

is not absolute proof of strangulation unless corroborative evidence of congestive and petechial signs in the face or skin, and tissue damage beneath the ligature is demonstrated. The explanation has been advanced in the past that a cloth ligature around the neck was an attempt to assist self-delivery by the woman in an obstructed labour.

- Smothering is almost impossible to prove, as the infant will almost never show conjunctival petechiae or other signs that may be seen in strangulation. Only if excessive pressure is applied, so that marks are left on the lips and face, can any evidence be retrieved. These must be definite intradermal or deep bruises, abrasions or marks within the lips and mouth – and not shadowy, vague variations in post-mortem staining. The arguments about criteria of suffocation in infants are further discussed in Chapter 14. Choking by the internal obstruction of the pharynx by various materials has been described in old reports, but it is excessively uncommon these days.
- Cutting and piercing is well known as a means of infanticide. Stabbing with scissors, either in the chest or neck, has been seen or even cutting the throat with a blade. The defence may be offered that the wounds were inflicted accidentally during frenzied efforts by the mother to cut the umbilical cord. Though not seen in Europe, deliberate infanticide has been described in India by clandestine stabbing by a long needle or pin into the spine, fontanelle, eye, or nose.

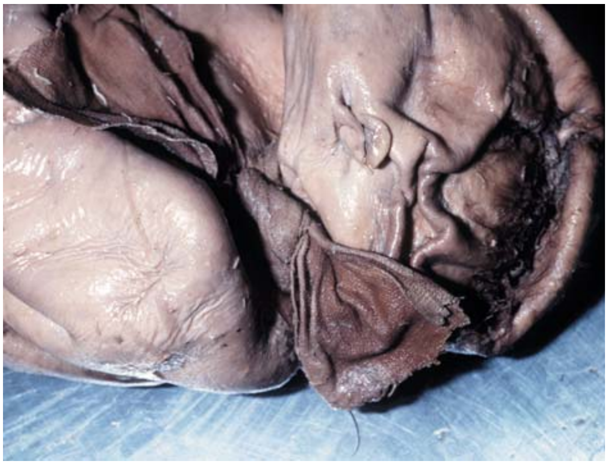

FIGURE 20.8 *A putrefied newborn infant with a scarf knotted tightly around the neck. (Reproduced by kind permission of Professor E Lignitz.)*

- Head injuries are relatively common. The mother may throw the child to the floor, or dash its head against a wall or other obstruction, sometimes by swinging it by the legs. This mode of death is similar to child abuse in older infants. The defence may be raised that the child fell to the ground, either from the mother's arms, but especially during a precipitate birth from the standing or crouching position. Though this defence sounds like a desperate excuse, the author can attest – no doubt in common with all doctors who have practical experience of childbirth – that some deliveries, especially in multiparous women, can occur with considerable speed and force. This is why the length of the cord needs to be measured, as it is obviously an effective brake on such a descent. There is no doubt, however, that cords have broken during precipitate birth, a reason for a careful inspection of the severed ends at every autopsy.

  The lavatory pan has special significance in this respect, as many unexpected births have taken place whilst the woman is sitting on the toilet. A common story is that the pregnant woman, often a teenage girl – is unaware that she is pregnant and goes to the toilet under the misapprehension that she has stomach pain from constipation. There is no doubt that some naive girls are genuinely ignorant of their gravid condition, and are shocked and devastated to the point of blind panic when a baby emerges into the pan.

  The question may then arise as to whether fatal head injuries on the infant can be accounted for by the descent into the lavatory. It is unlikely to produce the severe fracturing sometimes seen – and falling to the

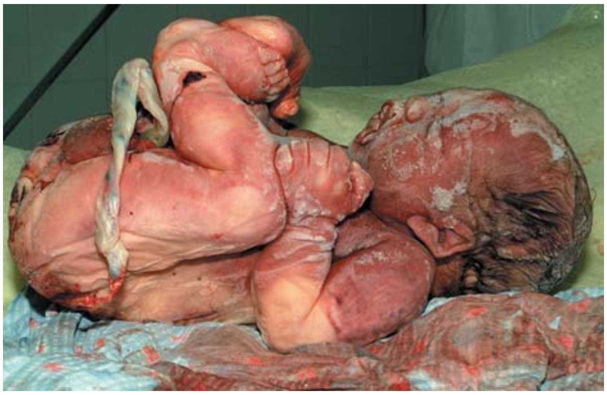

FIGURE 20.9 *Frozen newly born infant found in a freezer by the children of the family. The child and placenta were packed and frozen in separate plastic bags, the umbilical cord is still attached. The family had moved twice after the birth of the child.*

floor in a precipitate delivery is also unlikely to produce fatal damage. Much depends on the severity and nature of the scalp and skull injury, and although it cannot be said that it is impossible for a fatal head injury to be caused in this way, it must be a rare event. Minor fractures of the parietal bones may occur in natural delivery if there is excessive head moulding. These are usually unassociated with internal brain or meningeal damage, and naturally there is no associated scalp damage.

- Drowning is another unusual form of infanticide, but is more often a way of disposing of an already dead child, either stillborn, a natural death or the victim of some other mode of infanticide. It may take place in any form of water, from a washbasin to the open sea. Most often the mother will use a household receptacle such as bowl, bucket or bath, but the infant may be taken out and disposed of in any source of open water, where delay in recovery may add decomposition to the pathologist's difficulties. In a recent case seen by the author (BK), the young parents admitted that the child was live born. After some hours, they wrapped the infant in a blanket with a brick and dropped it into a river. The partial remains, largely converted to adipocere, were recovered some 3 months later, there obviously being no prospect of offering any opinion upon either live birth or the cause of death. The only objective, but equivocal evidence, was the recovery of diatoms from the femoral bone marrow, which resembled those in the river water. Returning to the lavatory pan once again, cases are on record where the birth into the toilet led not to head injuries, but to drowning.

INFANTICIDE BY OMISSION TO OFFER PROPER CARE

This is both rare and almost outside the province of the pathologist's examination. If the infant is older than newborn, then deliberate starvation will leave obvious signs, but the proof of lack of care immediately after birth will be a matter of witnesses and clinical opinion. The only possible signs which the autopsy might reveal would be hypothermia (Chapter 17), and obstruction of the air passages by mucus or amniotic fluid.

PROOF OF A SEPARATE EXISTENCE

Strictly speaking, the pathologist can never demonstrate evidence of a separate existence in the English legal sense of complete expulsion from the mother, but it is usually taken to mean proof of live birth, specifically the attainment of breathing air. In the slightly older child the presence of food in the stomach would obviously prove a separate existence, but most autopsies are upon the recently newborn.

Changes in the cord have already been mentioned, but are of no use in the immediate post-partum period. Polson *et al.* (1985) make mention of the presence of 'extraneous material' in the deeper (secondary) bronchi as evidence of a stillbirth, on the grounds that, if this material, such as soil or sand, gained entry after respiration had commenced, the air in the deeper areas of the lung would prevent its ingress. The practicality of this appears suspect.

The unequivocal demonstration of breathing in a newborn infant is fraught with difficulty. Along with the estimation of the time of death, it has probably provoked more discussion, printed words and controversy than any other topic in forensic medicine. The controversy revolves around the 'hydrostatic test' on the lungs, in which it has been claimed since medieval times that, if the lungs float in water, then the infant breathed. There are modifications of technique, but this is the thrust of the claim. The authors' attitude must be stated at the outset: the test is of limited value, whatever modifications are made and it can at best be a suggestive pointer, but never a definitive test in itself.

There are too many recorded instances when control tests have shown that stillborn lungs may float and the lungs from undoubtedly live-born infants have sunk, to allow it be used in testimony in a criminal trial. Even one such failure negates the whole history of the test and the authors are saddened to contemplate the number of innocent women who were sent to the gallows in previous centuries on the testimony of doctors who had an uncritical faith in this crude technique. As this is such an important issue and one that is still contested today, the words of the late Professor Polson may be recalled from his notable textbook:

> The test was suspect even in 1900 and requires no detailed discussion, because it is now known to have no value. The lungs of the live-born, even those who have been known to live for days, may sink [Dilworth 1900; Randolph 1901] and those which float are not necessarily those of live-born infants . . . . It is therefore pointless to apply the hydrostatic test, which will impair the material for other and more important investigations.

Before dismissing the test so absolutely, there are some points both for and against its use as part of the feeble armamentarium that the pathologist has in determining this vital issue. First, the slightest degree of post-mortem decomposition immediately negates any interpretation of the flotation test. As so many potential infanticides are found hidden, buried or submerged, decomposition is more the rule rather than the exception, so the test cannot even be considered in a large proportion of cases. Even when obvious putrefaction with gas formation is not apparent, slight decomposition will still begin to produce gas on a microscopic scale from the second unrefrigerated day in temperate surroundings – and much earlier in hot climates. In recent years the advent of resuscitation attempts make the evaluation of breathing even more difficult or even impossible. The use of mouth-to-mouth revival, external cardiac massage and the administration of oxygen, completely negate any of the already fragile tests for respiration in a newborn infant.

On the positive side – assuming fresh tissue – the floating of the whole pluck of thoracic organs in water makes one tend to accept that respiration had taken place. This means that the attached heart, mediastinum and neck structures are also buoyed up by the lung – but in this case, it is almost invariable that the lungs are sufficiently aerated for this to be obvious on naked-eye inspection.

This is about the total extent of the usefulness of the hydrostatic test. The complicated instructions offered in many textbooks concerning cutting the lung into lobes and then into pieces, squeezing them with knife blades and even pressing them underfoot on the mortuary floor before floating them, all smatter of black magic and are a complete waste of time. Worse, they can simulate a false sense of scientific validity and even to an eventual miscarriage of justice.

The best way of seeking proof of respiration is to look at, to feel and to listen to the lungs. The lungs of a stillbirth are dark, small, heavy and liver-like, even though they may still float. They lie contracted against the mediastinum, though when the body is intact they must still fill the thoracic cavity, as the pliable rib cage pulls inwards and the diaphragm rises to eliminate the free space in the chest. Though this fact is seldom considered, it must be obvious that there can be no free space in the pleural cavities until the thorax is opened at autopsy. As soon as this is done, air enters the pleural sacs and the lungs then appear much smaller than the expanded chest cavity than is seen when the sternal plate is removed.

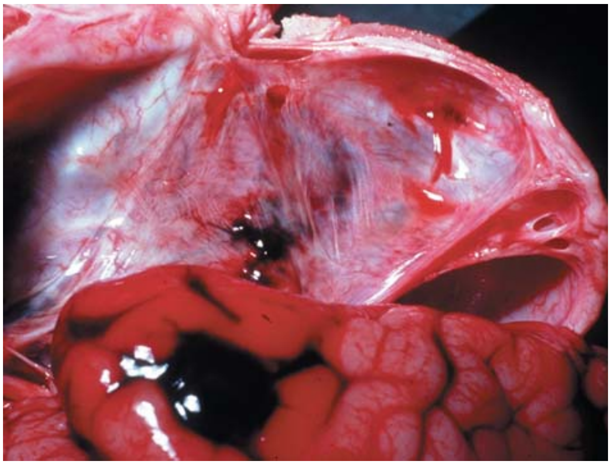

FIGURE 20.10 *A positive finding in a baby whose body was abandoned after death. Respiration had occurred but, on examination of the cranium, a tear in the tentorium was found with an adjacent meningeal haemorrhage, presumably caused by excessive moulding of the head during precipitate delivery.*

Unrespired lungs appear smaller than those that have breathed for a significant time, though there is a continuous range of expansion. According to Polson *et al.* (1985), unrespired lungs weigh something of the order of one-seventieth of the body weight; when aeration begins, the lung weight increases because of the increased vascular volume and become about one-thirty-fifth of the body weight. This seems at variance with actual measurements at autopsy as the combined weight of both lungs in an infant of average birth weight is about 40 g and, although there is a fairly wide variation between individuals, no combined lung weights approach 85 g, which would be one-thirty-fifth the weight of a 3000 g baby.

The texture of an unrespired lung is rubbery and uniform, with no paler, crepitant areas at the margins, which tend to be sharply angled. On slicing, the interior is uniform in colour and texture, being moist and resembling stiff strawberry jelly. On rubbing a small piece between the fingers close to one's ear, no crepitation is heard.

The lung that has respired will change quantitatively from the above appearances depending on the length of time and the depth to which breaths have been taken. Feeble or brief respiration will affect only the margins, whilst more robust or prolonged breathing may lead to total expansion. Even a single good breath can unfold some of the fetal pulmonary tissues – and of course, resuscitation, whether by mouth-to-mouth, chest compression or administration of oxygen, will actively inflate the lungs, dead or alive. Even ordinary handling of the dead baby may aspirate air into the lungs. Fully respired lungs will be obvious on inspection. The organs are pink or mottled, the medial edges overlapping the mediastinum and part of the pericardium, though not as fully as in the older neonate. The weight is greater, but not as much as recorded by Polson and colleagues, as described above. The edges of the lung, including the interlobar fissures, are more rounded by the expansion, compared with the angular margins of the unrespired organ.

The major change is in the colour and texture. It may be pink all over the surface or there may be patches of darker atelectasis under the pleura. The lung is spongy and resembles the familiar adult tissue. On cutting, the aerated texture is apparent, and on holding a piece to the ear, typical crepitance is heard on rubbing gently between the fingers.

The problem arises with the minimally respired lung, where the changes are intermediate between the two extreme states described above. The anterior margin best shows partial expansion, the areas such as the lingula, anterior diaphragmatic margin and the medial edge of the lower lobe sometimes being pinker and more expanded than the posterior parts. The most sensitive criterion is the ear crepitance test, but it is all a matter of degree as to whether the pathologist is impressed enough – having excluded any possibility of decomposition or resuscitation artefact – to consider that significant respiration has occurred.

Any doubts must be resolved in the direction of no breathing and, even in doubtful instances when the pathologist decides – on balance – that respiration has occurred, he should convey his uncertainty in the body of his report. As to the corroborative role of the flotation test, if performed, when the whole chest pluck floats, the descriptions of the lungs given above will usually indicate clearly that the lungs had breathed. A sinking lung will never correspond with a pink crepitant appearance, but what appears to be a dark, fetal lung may float. The test unfortunately tends to mislead more in one direction than the other, in that almost all lungs float irrespective of their appearance. To repeat the advice of Lester Adelson, whose experience and clarity of expression makes his voice one of the most respected in forensic pathology:

> Unless the pathologist has incontrovertible criteria of post-natal survival, e.g. well-expanded lungs, food in the stomach or vital reaction in the stump of the umbilical cord, he is legally bound not to diagnose live birth. Convictions for infanticide have been set aside where there was any doubt whatsoever that the child was born alive. Many courts have pushed this proposition to the extent that the state has been given the burden of proving that the baby was born alive beyond any possible doubt rather than beyond any reasonable doubt, the latter being the general level of proof required in a criminal prosecution.

Histological appearances of newborn lungs

Histology is not as helpful as might be expected in the problem of demonstrating the onset of breathing. It was formerly thought that the shape of the alveoli and the height of the lining epithelium would indicate whether they had been expanded by the passage of air, but this has proved to be a disappointing exercise. According to Shapiro (1977), the height of the epithelium and the shape of the alveoli are more a measure of fetal maturity than respiration at birth. The lung parenchyma develops in the fetus as a branching ramification of the trachea and at an intermediate stage – around 800 g body weight or 4 months' gestation – appear as gland-like structures with a cuboidal or columnar cell lining. The evolution to the thin-walled adult-type alveolus is complete before full term, or when the fetal weight is about 2500 g. The alveolar spaces may be found substantially distended even in fetuses who could not have breathed air, such as the one described by Shapiro that was found free in the maternal abdomen after rupture of the uterus. No intra-alveolar epithelium was visible and the lung could not be distinguished histologically from that of a child that had breathed.

Other authors have described the maturation of the fetal lung (Kuroda *et al.* 1965; Parmentier 1962; Ham and Baldwin 1941) and it is undisputed that fully expanded alveoli can be present before full term, even in infants who have not inspired air. After the fifth month, the glandular nature of the air sacs of the lumen are filled with amniotic fluid. In fact, there is evidence that amniotic fluid may be produced by the nascent pulmonary lining, because it is present even in cases of congenital bronchotracheal atresia. When breathing starts, the alveoli further enlarge, and the fluid is partly expelled through the bronchi and partly absorbed back into the pulmonary circulation. Ham (1950) and Shapiro (1947) point out that the finding of open alveoli with no cuboidal or columnar epithelium means that the fetus has passed the two-thirds stage of its maturation process, not that it has respired air.

Further proof is found in the histological appearance of sequestrated parts of lung tissue in infants, which were not connected to the bronchial system but which still showed alveolar ducts and alveoli (Potter and Buhlender 1941; Potter 1952). Fetal lung transplanted into the anterior chamber of an animal eye also developed alveoli with terminal bronchioles (Waddell 1949). Post-mortem handling has also been incriminated for the entry of air into fetal lungs. Apparently respired alveoli have been found in lung sections from a dead infant taken from the uterus of a dead mother.

Janssen (1977) agrees that resuscitation will lead to post-mortem aeration of the lungs, but claims that such artificial respiration cannot cause the alveoli of stillborn neonates to be perfectly and uniformly aerated. Against this view, however, is the undoubted patchy appearance of the lung expansion of many infants who have undoubtedly breathed for some time, so it is difficult to see how the two situations could ever be differentiated. Janssen's statement about the histological appearances is reasonable:

> According to the present level of knowledge and possibilities for examination, ventilation of the lungs alone cannot be taken as a certain indication of a live birth. Under various circumstances, lungs originally aerated can become devoid of air: conversely, the lungs of stillborn neonates can appear aerated. It is not possible to be certain in all cases.

In general, an infant who has breathed strongly for some time – probably hours in most cases – will have lungs that histologically resemble the older child with full, uniform, expansion of alveoli. In many infants who undoubtedly have lived and breathed for an appreciable time, however, there may be only patchy expansion, which corresponds to the uneven aeration seen macroscopically under the pleural surface. The difficulty arises when paradoxical appearances are seen, examples of which are illustrated in many textbooks. Thus an undoubted stillbirth may reveal quite extensive alveolar expansion, whilst a baby that unequivocally lived for some time may show totally collapsed air sacs.

In medico-legal work, though it is quite in order to refer to the usual state of affairs, when a criminal trial is in progress, the standard of proof is 'beyond reasonable doubt' and the well-documented exceptions just mentioned (as with the flotation test) make it unsafe to be dogmatic over a histological opinion.

ESTIMATION OF MATURITY

This is a necessary part of the autopsy, both as matter of record of the size and presumed age of the infant, but also as a legal requisite in those jurisdictions that require proof of viability before either stillbirth can be recorded or a charge of infanticide brought.

First, it must be accepted that – as at any time of life – morphological measurements are by no means infallible indicators of chronological age. Personal variations are compounded by sex, race and nutritional factors to prevent accuracy. The time of appearance of ossification centres is no longer as uniform as once thought. As with so many biological conditions, there is the typical 'bell-shaped curve' of probability, so that though most subjects will lie in the large central zone, there will be a progressively diminishing number at each extreme of the graph. It should be remembered that a female infant is usually at least 100 g less in weight at full term than the male, though individual differences in either sex can be far larger than this statistical variation. Twins, even those going to full term, are each lighter than a singleton child. The full-term singleton fetus, at **40 weeks' gestation**, will have the following vital specifications, subject to the above cautions:

- a weight of between 2550 and 3360 g
- crown–heel length of 48–52 cm
- crown–rump length of 28–32 cm
- head circumference of 33–38 cm
- the ossification centre in the lower end of the femur will almost always be present, being about 6 mm in diameter
- lanugo is absent or present only over the shoulders; head hair is about 2–3 cm long
- the testes are palpable in the scrotum; the vulval labia closes the vaginal opening
- the umbilicus is midway between xiphisternum and pubis
- there is dark meconium in the large intestine
- an ossification centre in the upper end of the tibia will be present in 80 per cent of full-term infants. The length of finger and toenails is an unreliable guide. More detailed information may be obtained from obstetric and paediatric texts.

At 36 weeks, the crown–heel length is about 45 cm and the weight around 2200 g. There will probably be ossification centres in the cuboid and capitate bones, often in the lower end of the femur and perhaps also in the upper end of the tibia.

At 28 weeks, the fetus is likely to be about 900–1100 g in weight, have a crown–heel length of 35 cm, a crown–rump length of 23 cm, and a foot length of 8 cm.

The old Haase rule-of-thumb for fetal age and size was that, up to the twentieth week, the length in centimetres was the square of the gestation period in (lunar) months. Beyond the twentieth week, the length in centimetres divided by five represents the age in months.

Examination of the ossification centres may be performed radiographically, which requires the advice of a radiologist, as the time of appearance may not be synchronous with visual identification of the centres. At autopsy it is usual to seek them directly, as follows: at the knee, the leg is flexed and a lengthwise cut made over the patella. The bones are pushed forwards through the cut, and transverse

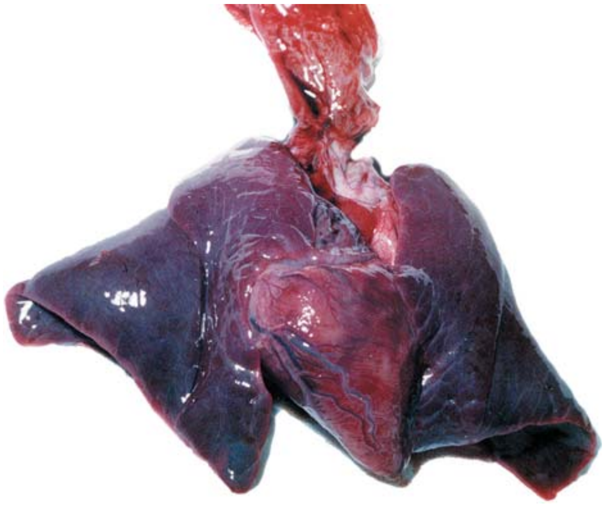

FIGURE 20.11 *The pluck of thoracic organs from a known stillbirth in hospital. The lungs are firm and heavy with no crepitation when squeezed. Margin portions of lung floated in water, however, demonstrating the fallacy of the 'flotation test'.*

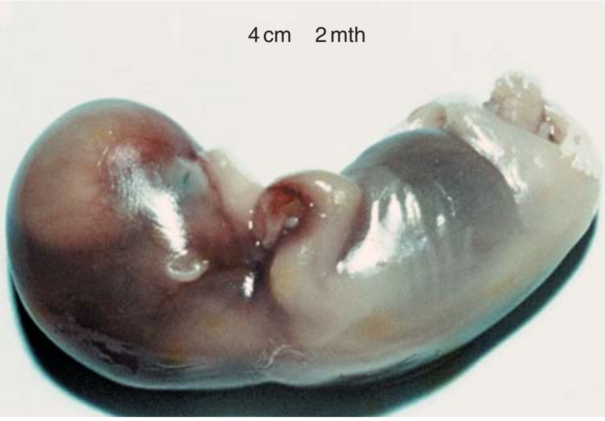

FIGURE 20.12 *Fetal maturity: up to the twentieth week the length of the fetus in centimetres is approximately the square of the age in months (Haase's rule).*

slices made with a knife through the cartilage of the lower end of the femur. If the ossification centre is revealed, the cuts should continue through plain cartilage above it until the diaphyseal centre is reached. This is to avoid mistaking the lower margin of the diaphyseal bone for the separate epiphyseal centre. The upper end of the tibia is then dealt with in a similar way.

In the foot, a cut is made in the axis of the limb up between the third and fourth toes into the ankle joint, to seek the cuboid bone. The talus and calcaneum can be entered by cuts across the upper dorsum of the foot when the latter is plantar-flexed. The centre in the calcaneum appears at about 7 months' gestation, that in the talus at about 7 months', and the cuboid at full term.

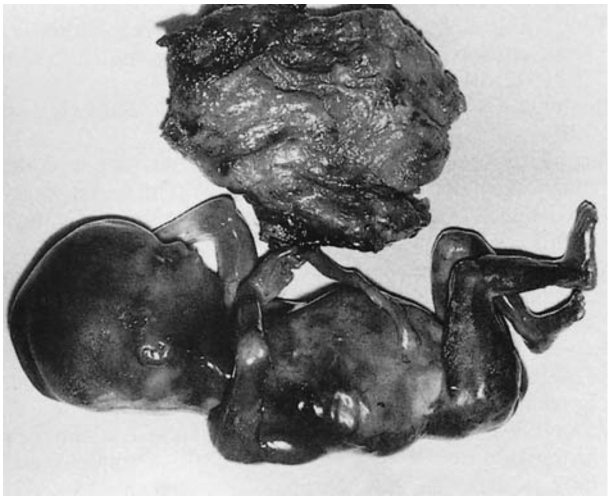

FIGURE 20.13 *Fetal maturity: by Haase's rule this 18 cm crown–heel fetus is about 4.5 months old.*

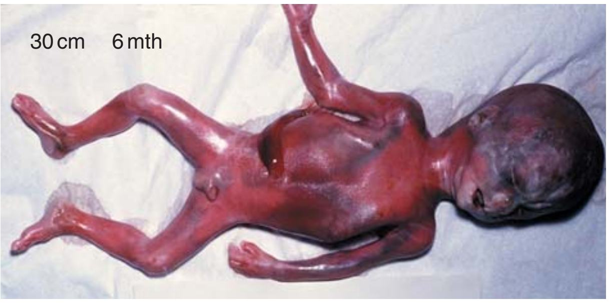

FIGURE 20.14 *Fetal maturity: this infant is 30 cm crown–heel length, which is approximately 6 months' gestation, as the length in centimetres beyond the fifth month is about five times the age in months.*

In assessing skeletal age in the fetus, the reference book of Fazekas and Kosa (1978) is invaluable. Other non-osseous methods of estimating maturity exist, such as the progressive development of surfactant-producing alveolar type II cells in fetal lungs (Betz *et al.* 1992).

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CHAPTER 21

Sudden death in infancy

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This distressing condition has a variety of names and abbreviations. The one now most generally accepted is the 'sudden death in infancy syndrome', often shortened to (and pronounced as) 'SIDS'. An older title was 'SUD', standing for 'sudden unexpected death', but this in itself did not denote the infant connotations. Colloquially, SIDS is known as 'cot death' in Britain and 'crib death' in North America.

DEFINITION OF THE SUDDEN INFANT DEATH SYNDROME (SIDS)

Following one of the international conferences on the condition (held in Seattle in 1969) the following useful definition of the syndrome was proposed by Beckwith and is now generally accepted: 'the sudden death of any infant or young child which is unexpected by history and in whom a thorough necropsy fails to demonstrate an adequate cause of death'. Other definitions have been proposed later, e.g. the definition by the National Institute of Child Health and Human Development (NICHD) in 1989 emphasizing the necessity of the scene of death examination, and a three-tiered definition by Beckwith 1992 in Sydney, during the Second SIDS International Conference, dividing the SIDS into three different categories according to the age, the occurrence of similar deaths in siblings or other close relatives, and the presence of petechial haemorrhages and inflammatory lesions or other abnormalities found during the autopsy. The 'Stavanger definition', proposed during the Third SIDS International Conference in Stavanger, Norway 1994, lays stress on the importance of the investigation of the circumstances of death: sudden death in infancy unexplained after review of the clinical history, examination of the circumstances of death and post-mortem examination. However, when put to the vote during a subsequent SIDS Global Strategy Meeting in Stavanger, the original definition from 1969 received the most votes.

INCIDENCE OF SUDDEN INFANT DEATH

Until recent years, national death statistics were totally unreliable in providing data on the incidence of SIDS, as the nomenclature was confused, and the certifying habits of different pathologists and clinicians were extremely variable. According to a recent review by Rognum (1999), the percentage of sudden deaths in infancy that are diagnosed by various authors as pure SIDS varied between 2.5% and 70%. This situation still applies in many countries, especially those where high infant mortality from many causes overshadows sudden infant deaths. In advanced countries, the progressive and often dramatic reduction in total infant mortality since the beginning of the century has eliminated many infective, nutritional and congenital diseases to the point where the 'law of diminishing returns' has flattened out the mortality curve to a low level. Until 1990, there was little evidence that the SIDS rate had changed significantly for centuries or even millennia, so the pre-1990 straight-line incidence of SIDS became a far greater proportion of the total infant deaths compared with the early years of this century. In many advanced countries, SIDS is still the most common single cause of infant mortality after the perinatal period.

Until about 1990, Britain had a SIDS rate of about 2 per 1000 live births, but the risk varied considerably in various sections of the population. Golding *et al.* (1985) give a comprehensive table in their book of known variations in worldwide incidence before the recent dramatic decline. For example, in the USA there was an overall rate of 2.3/1000, though again this varies considerably from place to place, and among different ethnic and social groups. In Chicago the rate in 1969 was 3.4 compared with 1.4 in upstate New York in 1974. There is far more variation amongst ethnic groups in the USA, the rate being much higher among non-White infants. In Nebraska, for instance, the rate was 1.9/1000 Whites and 5.9/1000 in non-Whites. There is other evidence, however, that social differences are the predominant factor rather than any intrinsically ethnic cause.

As noted above, in Britain and several other European countries the SIDS rate has dropped remarkably in the past few years. In France there was a stagnation for post-neonatal mortality between 1979 and 1993 followed by a sharp decrease to 2/100 in 1995. In England and Wales there was a 69% fall in the sudden infant death rate between 1988 and 1992 from 2.01 to 0.63 and further down to 0.3 in 2000 (see Table 21.1).

The cause for this is obscure. It almost coincides with a vigorous publicity campaign by the Department of Health and the Foundation for the Study of Infant Deaths, which advocated sleeping babies on their back, not on the face and in avoiding overheating and smoking near the baby, as well as exhortations to seek medical advice whenever the infant was unwell.

However, the fall slightly antedated this campaign, so that the contribution of sleeping position, etc., to the decline is not fully understood, though there is other evidence from The Netherlands that recommendations about sleeping supine favourably affects the death rate. However, these same years have shown a series of very mild winters, which may also be a factor.

TABLE 21.1 *Infant mortality rates (per 1000 live births) in England and Wales in 1996–2000*

Infant mortality	1996	1997	1998	1999	2000	No.
Stillbirth	5.4	5.3	5.3	5.3	5.3	3203
Infant (under 1 year)	6.1	5.9	5.7	5.8	5.6	3399
Early neonatal (under 1 week)	8.6	8.3	8.2	8.2	8.2	1760
Neonatal (under 4 weeks)	4.1	3.9	3.8	3.9	3.9	2335
Post-neonatal (4 weeks–1 year)	2.0	3.0	1.9	1.9	1.8	1064
SIDS underlying cause (4 weeks–1 year)	0.6	0.5	0.4	0.4	0.3	203

Source: Office for National Statistics, Health Statistics Quarterly 05, Spring 2000.

FACTORS INFLUENCING THE RISK OF SIDS

Age

The age range in which sudden infant death occurs follows the usual 'bell-shaped curve' of most biological phenomena. As the Seattle definition stated, the ends of the curve lie at 2 weeks and 2 years, but these boundaries are far too wide for the great majority of victims. The peak incidence occurs at around 3 months and the time bracket of 2–7 months will encompass most cases. It is rare after 9 months, but deaths can occur well into the second year which, by all the criteria, can only be called 'cot deaths'.

Similarly, a few small infants die unexpectedly and inexplicably before the first month, but it must be accepted that true SIDS is not a condition of the neonatal period. There is almost always a gap between the deaths that must be attributed as being a sequel to birth, and those that suddenly occur subsequently in babies who have apparently weathered that dangerous period successfully. It is obvious, however, that such an absolute distinction cannot be made, as premature and underweight infants have a higher risk of SIDS, and some perinatal deaths are indistinguishable from SIDS in that autopsy may reveal the same negative findings.

Sex

There is a slight but definite sex bias in the syndrome, showing the usual slight weighting against the male infant, which is a common feature of many conditions and at all ages. Most surveys have shown a ratio of 1:1.3 or thereabouts, with an excess of male infants. Some other investigations, however, have indicated equal numbers and one survey actually showed a slight excess of girls.

Twinning

There is a marked excess of deaths in a member of a twin pair as opposed to singletons. Figures have varied in different surveys, but the risk is at least twofold. In the author's (BK) own hospital district (South Glamorgan), where a total birth survey is maintained, some years ago the increased risk was five times that for single babies. The reason for the excess among twins lies partly in the fact that physically disadvantaged infants, such as premature births and those of low birth weight are at greater risk; these two factors are often present in twins. There is no difference in incidence between identical or binovular twins. There have been at least ten reports of both twins having died of SIDS on the same day, and obviously reported cases are but a small fraction of those occurring. Some pathologists, almost exclusively in the USA, claim that simultaneous death in twins is indicative of homicide, but this view is not generally accepted.

Seasonal incidence

There is a marked seasonal variation in SIDS, the excess occurring in the colder, wetter months in temperate zones. In Europe and North America, most SIDS die between October and April, whilst in Australasia the monthly incidence is reversed. In tropical and subtropical zones, no clear pattern emerges, partly because many of the countries in these latitudes are relatively underdeveloped so have both high infant mortality, and often death certification and statistical records of lesser accuracy. SIDS undoubtedly occurs in the tropics, however, but the incidence is often swamped by that of more obvious disease. Returning to temperate zones, many efforts have been made to relate SIDS to changes of temperature and the incidence of respiratory infections in the community. The results are conflicting, but there seems little doubt that respiratory infections are a precipitating trigger in SIDS.

Social class and housing

This is not the place to expand upon the social epidemiology of cot death, but there is ample evidence that lower levels of social disadvantage, as measured by occupation and housing quality, are strongly related to the incidence of SIDS. It is difficult to reconcile these epidemiological factors with the numerous pathological theories and the few facts concerning the aetiology of sudden infant death.

THE CASE HISTORY IN SUDDEN INFANT DEATH

The history is usually brief and remarkably similar from case to case. The infant is either quite well on the preceding day or (in about half the victims) has trivial symptoms, usually of upper respiratory infection or a bowel upset. Even these symptoms may be overstated, as the history is of necessity taken retrospectively from distraught parents trying to rationalize the tragedy.

The story usually records that the infant was put to sleep in the evening and was found dead in the morning when a parent first visited it. Alternatively, the baby was given an early morning feed when it appeared well, but was later found dead in its sleeping place. Most infants are found dead in the first half of the day, before mid-morning. A minority die (or are found dead) in the afternoon and evening. Death can be rapid and silent. Though most victims die unobserved, the author's (BK) experience can confirm that a number of cases indicate that an infant observed to be quite well at a given moment can be found dead within 5 minutes, and cases are on record of SIDS occurring in hospital and even in a physician's arms.

THE SCENE OF DEATH AND EXTERNAL FINDINGS

The scene of the death is rarely available for examination in its original state. When found, the child is naturally either rushed to a doctor or a hospital, or an ambulance team arrives and attempts resuscitation, again usually hurrying to a hospital casualty department.

When found, a few children have slight oedema fluid exuding from the mouth. This may sometimes be blood-tinged, and frank bleeding – apparently from a congested mouth or pharyngeal vessel – is occasionally seen.

Stomach contents may be present in the mouth, nostrils or on the face, but this must not be assumed to be a cause of death (from aspiration), as is discussed below. The hands of the child are often found to be clenched around fibres from the bedclothes, as if there were spasmodic agonal grasping movements.

Some children are found under the bedclothes, even huddled upside down at the foot of the cot. Again, this has no significance, as thousands of healthy infants habitually sleep in this way without suffering SIDS.

A number of infants have been found moist with sweat and even with a raised body temperature. The significance of this is not known, but part of the recent preventative advice given in Britain, is to avoid overwrapping and overheating.

There are no external findings of significance. The face may be pale or slightly cyanosed or congested: there are no petechial haemorrhages in the face or eyes. The posture at death is not necessarily relevant, even if the initial sleeping position is important in the aetiology – some are found face down and may have a pallid area around the mouth and nose where pressure has prevented post-mortem hypostasis from settling. This develops after death and on no account must be misinterpreted as a pressure mark indicating suffocation.

AUTOPSY APPEARANCES

These have given rise to much controversy over the years. Essentially the gross findings are nil, almost by definition. If any significant pathological lesion is found on naked-eye examination, the death ceases to be a true SIDS, and is categorized as whatever lesion was discovered. The proportion of 'explained' cot deaths varies greatly with the pathologist, though this variation is more in relation to microscopic than gross findings. Of all babies found dead in their sleeping place, that is, 'cot deaths', most will be true SIDS, but a few will have a significant pathological condition. The relative proportions of these two subsets varies from pathologist to pathologist. Many would accept that about 15 per cent reveal some pathological lesions at autopsy, though this is not to say that those lesions – sometimes slight – were a factor in the death. For example, some mild congenital heart lesion or the presence of Down's syndrome is occasionally revealed, but this is not to say that they were causative. Thus almost all SIDS are cot deaths, but not all cot deaths are SIDS.

The external appearances have already been discussed and are essentially negative, apart from inconstant froth at the lips and nostrils, and fibres sometimes clenched in the fists. The length, weight and other physical measurements are of no direct relevance, though naturally they must always be carefully recorded as in any other infant autopsy, for it may transpire that the death was not a typical SIDS.

Internally, the findings are again non-specific in a typical SIDS. A large number of reports now exist on the microscopy, microbiology and biochemistry of the syndrome, but no diagnostic criteria have yet been confirmed. The following naked-eye features may be present at autopsy:

- Petechial haemorrhages on the visceral pleura.
- Petechial haemorrhages in the thymus gland.
- Petechiae or larger ecchymoses on the epicardial surface of the heart, especially posteriorly. These petechiae have been the subject of intense controversy since they were first described in infant deaths by Tardieu in 1855, but they are almost certainly agonal in origin. One explanation suggests that they are the result of forced inspiratory efforts against a closed airway, the latter being either from laryngeal spasm or from a collapsed pharynx in hypotonic infants, but neither of these hypotheses has been substantiated. Petechiae in the thorax are found in about 70 per cent of true SIDS infants. Thymic haemorrhages are often prominent, the organ being studded with both petechiae and larger ecchymoses: it has been claimed recently that in SIDS as opposed to mechanical suffocation, the haemorrhages are in the thymic cortex, rather than the medulla, but few pathologists accept this.

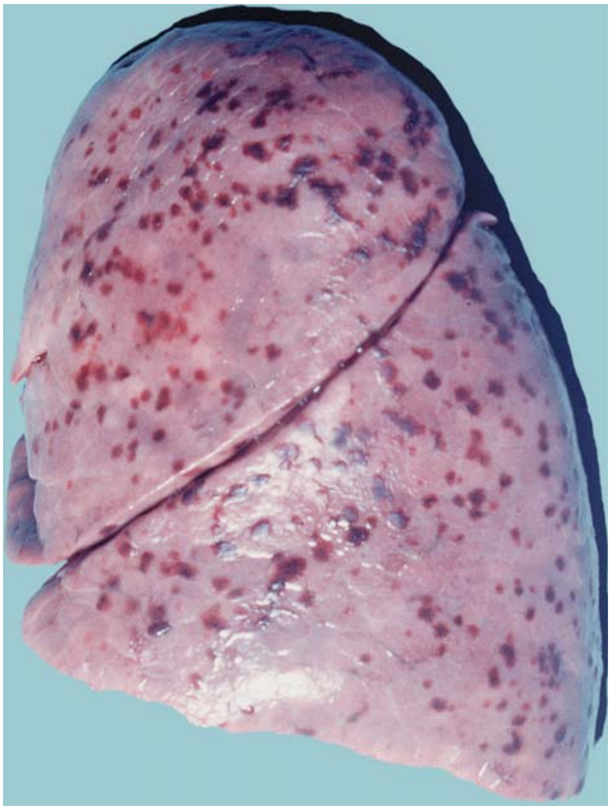

FIGURE 21.1 *Subpleural haemorrhages – the original 'Tardieu spots'. These are far more pronounced than those seen in adult lungs, being taken from a case of SIDS, in which 70 per cent of cases exhibit these lesions.*

- Gastric contents, usually milk-curds, in the air passages. All too often this has been used by some pathologists as the definite cause of death, but there is no evidence that it is the reason for the death. It is either an agonal regurgitation or even a post-mortem phenomenon. In a series of 100 consecutive autopsies, including adults and children, the author (BK) found gastric contents in greater or lesser amount in no less than 25 per cent of cadavers, almost all of which had quite satisfactory pathological lesions to account for death. This aspect is discussed in more detail in Chapter 14.
- Respiratory infections in the form of inflamed laryngeal or tracheobronchial mucosa are not common, but are macroscopically evident in some SIDS victims. If the infection is severe enough to produce pus and especially if there are obvious inflammatory changes in the lung parenchyma, then the death is removed from the SIDS category into a fatal chest infection group. The finding of minimal 'inflammatory' cells on microscopy must be viewed with caution. Some pathologists undoubtedly lay too much emphasis on sparse or small collections of leucocytes in the peribronchial zones. In control infants, small foci of lymphocytes are common and can

be disregarded. It is usually the lung histology that causes the variations in the proportions of ‘cot deaths’ that are classified as true ‘SIDS’.

- Pulmonary oedema is common, though usually moderate in intensity. The surface of the lungs often shows patchy sublobular partial collapse, with areas of blue lung alternating with better-aerated pink zones.

In some infants dying unexpectedly, abnormalities such as Down’s syndrome, congenital heart disease or other chronic systemic disease are found. The problem then is to decide whether the death should be ascribed to ‘SIDS’ or to the obvious disease, even though there is no evidence that such a disease should have suddenly caused death. There is a natural temptation to use an established lesion to explain the death, especially as both doctors and parents tend to be less unhappy with a specific disease process than with the rather nebulous diagnosis of ‘SIDS’.

In most cases, however, there is no real reason why an infant with Down’s syndrome, perfectly well one night, should be found dead the following morning – and many relatively mild (and often previously undiagnosed) congenital defects similarly are unlikely to cause death in such an abrupt manner. It is probably more logical to assume that SIDS has occurred in a child with Down’s or a septal defect, or whatever. It may be accepted that this defect may be one factor among the many involved in SIDS, and therefore it is probably reasonable to enter ‘SIDS’ in Part I of the certificate and add the other lesion in Part II, as a contributory cause.

HISTOLOGICAL FINDINGS IN SIDS

Again a huge and controversial topic, there have been numerous papers on the microscopic appearances in SIDS. Much of this is pure research material and is often irreproducible by other workers.

Most interest has focused on the lung changes and especially evidence of pulmonary inflammation. The frequency with which positive findings are made depends upon the criteria threshold of the observer, as mentioned earlier. Peribronchiolar cell infiltration is the main finding and some workers claim to find an abnormal cellular response in the majority of SIDS material. Others, more used to the less equivocal appearances in adults, fail to attach significance to marginal increases in cell population in the peribronchial zone.

Many of the other findings are inconstant and claimed by a variety of researchers. For example, Richard Naeye (1973) supported his hypothesis of chronic hypoxia by finding thickened pulmonary artery walls, gliosis in the brainstem, retention of brown fat in the adrenals and abnormalities in the carotid body. Changes in the myocardium, adrenals, parathyroids and liver have all been described, but have either not survived critical assessment, appear incompatible with clinical and epidemiological data, or fail to be reproducible in subsequent investigations.

THEORIES OF CAUSATION

Since the mid-1970s more than 5000 articles have appeared concerning sudden infant death and one now needs review papers, such as those published by Valdes-Dapena, merely to keep up with mainstream research. Theories include allergy to cow’s-milk proteins, house-mite allergy, deliberate suffocation, spinal haemorrhages, botulism, calcium deficiency, selenium deficiency, biotin deficiency, vitamin E deficiency, vitamin C deficiency, vitamin D deficiency, thiamine deficiency, hypoglycaemia, hypothyroidism, magnesium deficiency, carbon monoxide poisoning, carbon dioxide poisoning, overlaying, pharyngeal hypotonia, nasal obstruction, tracheobronchitis, respiratory syncytial virus, prolonged sleep apnoea, deficient or abnormal pulmonary surfactant, cardiac conduction defects, sodium overload in feeds, narrow foramen magnum, hyperthermia, hypothermia, influenza infection, metabolic enzyme defects, immunodeficiency, hypogammaglobulinaemia and many others.

In 1989 and again in 1994, press publicity in the UK drew considerable attention to claims that fungal growth on certain antiflammable chemicals used on cot mattress covers produced gases containing arsenic and antimony, and some chemical analyses showed that antimony could be demonstrated in some SIDS tissues. However, a causative link has not been proven and the theory fails to fit the epidemiology – especially as SIDS has been occurring for hundreds and probably thousands of years before mattress covers existed. Reports of cot deaths can be found in sources as ancient as the Old Testament and twelfth century Welsh literature.

In the 1970s and early 1980s, one hypothesis gained widespread favour and was beginning to gain general acceptance. This was the claim that some infants, with poor respiratory drive, suffered from exaggeration of the normal periods of apnoea that all infants have during sleep. A complex mechanism was built up in which progressive hypoxia and failure to respond adequately to hypercapnia and hypoxia drove the sleeping infant into a descending spiral of hypoxia–apnoea–hypoxia, which ended in bradycardia and cardiac arrest. Respiratory infections, sleep, and nasal obstruction contributed to an acute-on-chronic state of hypoxia, which histological findings claimed to substantiate.

This attractive theory was largely deflated, however, when prospective studies of infants with sleep apnoea and other respiratory problems were found to have no greater risk of SIDS than normal controls. The theory led to a great popularity of apnoea alarms, which parents of subsequent children following a SIDS loss have insisted on using. There is no evidence that they have any beneficial effect, other than reassurance of the parents; indeed, in some instances, the stress of waiting for the alarm to sound and the many false alarms, have led to marital problems.

In the present state of knowledge, it seems that SIDS is the final common pathway that leads to death in infants who have been compromised by a number of deleterious factors, which have to come together in one baby at one time in order to summate to a fatal outcome. The factors may be quite different in each case, but all manifest themselves in terminal acute cardiorespiratory failure.

Some of the factors are known such as sleep, which depresses the brainstem, and virus infections – especially of the respiratory tract – which provide a viraemia, reduce oxygenation and may narrow the effective airway lumen by mucus and exudate. Other factors are 'constitutional', in that many SIDS victims are physically compromised in some way, often since fetal life, being premature and of low birth weight (though most SIDS are neither of these). Other factors from the long list given above may operate in certain circumstances, such as botulism which may be relevant in some 5 per cent of SIDS in California.

It is thus futile to search for 'the cause' of cot death, as there is no single cause, but a galaxy of factors that vary from death to death, though the mediating terminal mechanism appears to be the same.

One of the most difficult aspects is the failure of pathological explanations to be compatible with epidemiological findings. It has been shown that non-specific health-care improvements reduce the incidence of SIDS, such as in the excellent ante-natal and post-natal services of countries such as Finland and Holland, which have the lowest SIDS rates – and the Sheffield project, where it was shown that the strongest factor in reducing incidence was the use the family made of the health services.

As far as the pathologist is concerned, his function is to perform a meticulous autopsy, to exclude any overt natural disease or injuries, and to offer sympathetic advice to those parents who want an explanation of the syndrome in comprehensible lay terms. There are several highly proficient counselling charities in Britain, the USA and other countries, who can provide literature and direct help to parents – and who also usually support most of the ambitious research schemes now operating.

THE SIDS AUTOPSY

The routine for an autopsy on a sudden infant death follows that for any infant and is little different from that in suspected child abuse. Indeed, exclusion of child abuse is a prime consideration as, although there is no aetiological connection between the two conditions, sometimes occult abuse – or sometimes genuine accident – may present as a 'cot death'. Some pathologists, both forensic and paediatric, insist on a whole-body radiological survey before commencing the autopsy and, where such facilities exist, this is a wise precaution. Full measurements of the infant are essential, as in all paediatric autopsies, to monitor the size-for-age of the child and to compare it with centile graphs, provided the birth weight is known.

The gross examination is the standard meticulous scrutiny of all external surfaces, orifices and organs. A full histological survey is vital, with even more blocks being taken than may be the norm for many forensic pathologists. The lungs in particular should be extensively sampled and six blocks is a bare minimum for these organs. In addition to histology, swabs should be taken from the major air passages and the lung parenchyma for microbiological culture, and heart blood may also be cultured. The middle ears should always be opened and a swab taken if infection is suspected. A separate piece of lung should be sent for virological culture. Where there has been any history of gut upset before death, a sample of ileal contents should be cultured. It has to be said that the return on such microbiological and virological studies is poor in terms of positive findings, both because of the post-mortem interval and because many of the micro-organisms found may be indistinguishable from commensals or post-mortem contaminants.

Similarly, by the very definition of SIDS, significant histological findings are absent. If a definite pathological lesion capable of causing death is discovered, the case is removed from the SIDS category and classified according to the disease process discovered. The problem arises when 'significant' or 'definite' has to be defined, as the criteria threshold of different pathologists varies considerably, especially where the diagnosis of an inflammatory condition in the lungs is concerned.

MEDICO-LEGAL PROBLEMS IN COT DEATHS

Differentiating SIDS from external suffocation

This is the oldest problem in cot death and one that is virtually insoluble on purely pathological grounds. The signs of infant suffocation are usually nil and the signs of SIDS are nil, so in a completely negative autopsy no reliable criteria exist. The presence of intrathoracic petechiae has little or no diagnostic value, in spite of one recent report that claims to distinguish SIDS from mechanical suffocation by the confinement of petechiae to the thymic cortex in SIDS. In any event, they are usually absent in known suffocation, such as those caused by a plastic bag over the head, yet some 70 per cent of SIDS have serosal petechiae.

In Britain, there are about 1000 cot deaths each year and probably up to 10 000 in the USA. The majority of these were found dead with the face uncovered, and in a posture where the mouth and nose are not obstructed. No one believes that all these children have been smothered by their parents; therefore, as petechiae are valueless for differentiation, it is not possible for an autopsy to state or even suggest that any particular child has been suffocated. This naturally presupposes the absence of facial bruising, scratching or other positive signs that would immediately remove the case from the SIDS category.

It is possible for circumstantial or other non-medical history to suggest or confirm deliberate suffocation, though this is extremely rare and not the concern of the pathologist. A caution must be offered about maternal confessions of smothering, however, as several instances are known where such a confession has proved totally false, the desperately bereaved woman in her grief and recrimination deluding herself in order to rationalize an inexplicable tragedy.

Multiple sudden infant deaths

Again, these pose a formidable problem for pathologist, paediatrician and investigating authority. Statistically, a mother will suffer a second cot death in her family every quarter of a million births, but a number of families are reported where three or even four siblings have died inexplicably. There is always the possibility of foul play in such circumstances, though some familial metabolic or other genetic disease – albeit obscure – is more likely. Even where no trace of the latter can be detected by the most exhaustive medical investigations, if the autopsies reveal no positive evidence of mechanical suffocation or other demonstrable cause of death, the pathologist cannot then substantiate any allegation of mechanical suffocation. He can – and should – express his concern to the investigating authorities but, if their investigations produce no corroborative evidence, it is pointless for him to continue to support a hypothesis that cannot be substantiated by any pathological evidence.

Counselling of parents

Many families, primarily the mother, have an intense desire to know why their baby died, a need that is often unfulfilled by any official contacts, such as with a coroner. Once any legal processes are complete, there is no reason why a pathologist should not meet and offer explanations to the parents of a child upon whom he has performed an autopsy. Often an earlier line of counselling is provided by a paediatrician, but some mothers wish to talk to the pathologist. Both Adelson (1974) and Knight (1983) have advocated that the pathologist should make himself readily available for this purpose, though some pathologists shelter behind an imaginary legal barrier to avoid what should be an ethical obligation.

ADDRESSES OF COUNSELLING ORGANIZATIONS

- The Foundation for the Study of Infant Deaths, Artillery House, 11–19 Artillery Row, London, SW1P 1RT, UK (Tel.: General enquiries: +44 020 7222 8001; 24-hour helpline: +44 020 7233 2090; Fax: +44 020 7222 8002). http://www.sids.org.uk/
- National Sudden Infant Death Syndrome Resource Center (NSRC), 2070 Chain Bridge Road, Suite 450, Vienna, VA 22182, USA (Tel.: (703) 821 8955; Fax: (703) 821 2098). sids@circlesolutions.com
- SIDS International (SIDSI). http://www.sidsinternational.minerva.com.au/

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CHAPTER 22

Fatal child abuse

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There is now a vast collection of publications on the child abuse syndrome, including international journals devoted to the topic. Most of this interest concerns the clinician, as child abuse is now a major concern in paediatrics. When no intervention is offered, an abused child has up to a 10 per cent risk of having eventually fatal injuries, so unfortunately the forensic pathologist will be involved in this tragic problem from time to time. This chapter will deal solely with the physical manifestations of the child abuse syndrome as seen at autopsy, though naturally these will in large measure coincide with the non-fatal injuries seen by clinicians.

GENERAL ASPECTS OF CHILD ABUSE

Though the modern phase of recognition of the syndrome dates only from the middle decades of this century, almost all the classical features were described by Tardieu in 1860 (see Knight 1986). In 1946, Caffey published his well-known first paper and, from then on, an avalanche of articles led to the present intense awareness of the problem that throws into stark contrast the apparent unawareness of the medical profession during the previous century.

Though definitions are variable, it can be said that the ‘child abuse syndrome’ (also known as the ‘battered baby’ or ‘non-accidental injury in childhood’) exists when an infant or child suffers repetitive physical injuries inflicted by a parent or guardian, in circumstances that exclude accident. Most of the fatal victims are young, more than two-thirds being under 3 years of age (Kempe *et al.* 1963; Lauer *et al.* 1974; Brown 1976; Helfer *et al.* 1977).

The syndrome includes, of course, psychological and sexual abuse, but the forensic pathologist can only be concerned with physical damage, some aspect of which has led to death. Though all homicides of children are ‘child abuse’ in the broad sense, the term is usually reserved for a fatal outcome in those who have suffered repetitive ill-treatment, though admittedly some cases span the borderline between chronic injuries and a single episode of trauma.

The definition of ‘child abuse’ is itself controversial, as what is unacceptable now may well have been considered valid and even desirable discipline in Victorian times. However, serious physical injury must be wrong, irrespective of societal attitudes.

Even so, for a pathologist to label an injury as ‘child abuse’ or ‘non-accidental injury (NAI)’ is to be rather pejorative and judgemental, so perhaps ‘adult-induced injury’ might be a more neutral description, which leaves decisions as to motivation to those who possess a wider picture of the whole circumstances. Having said that, the more gross forms of injury are self-evidently ‘abuse’ but, in lesser degrees of trauma, it may be impossible to differentiate deliberate battering from inexpert rough handling, albeit contributed to by exasperation, panic or even attempts at resuscitation.

Though it is vital to recognize non-fatal child abuse, because of the need for intervention to prevent the 60 per cent recurrence rate and 10 per cent mortality rate, it can be almost as tragic to falsely accuse and/or convict parents or guardians where the injuries were non-culpable.

There has sometimes been perhaps some excess of zeal on the part of paediatricians, radiologists, accident surgeons and pathologists to overinterpret injuries and scenarios that had an alternative and less sinister explanation. Though it is natural and vital for doctors to protect children and their siblings, medical opinion has to remain free from emotive bias and be confined within the bounds of what can be proved in each individual case, or injustice may be done. Some years ago, a situation developed where even innocent parents were afraid to take their accidentally injured child to a doctor, for fear of the euphemism 'non-accidental injury' being applied.

MODES OF DEATH IN CHILD ABUSE

The majority of deaths are caused manually, either by hitting or beating with the hands, shaking, throwing, dropping and – less often – by burning or suffocation. It is exceptional for death to be caused by the impact of a blunt instrument, though non-fatal bruises from beating with a strap, for instance, are sometimes seen. Shooting, strangling and stabbing are characteristic of classical homicide, which is distinct from the child abuse syndrome.

The most common mode of death is head injury. Next in frequency is rupture of an abdominal viscus, leaving a wide range of miscellaneous injuries to account for the small remainder.

THE RANGE OF INJURIES IN CHILD ABUSE

Concentrating on autopsy findings, the various types of trauma will be described, though many will not in themselves have caused or even contributed to death. Their recognition is none the less vital as, at the end of the examination, they may well be the decisive factors that may distinguish an accident from deliberate maltreatment.

SURFACE BRUISING

One of the classic aphorisms in the study of child abuse was stated by the forensic pathologists, Cameron, Johnson and Camps (1966), who said: 'The skin and bones tell a story which the child is either too young or too frightened to tell.'

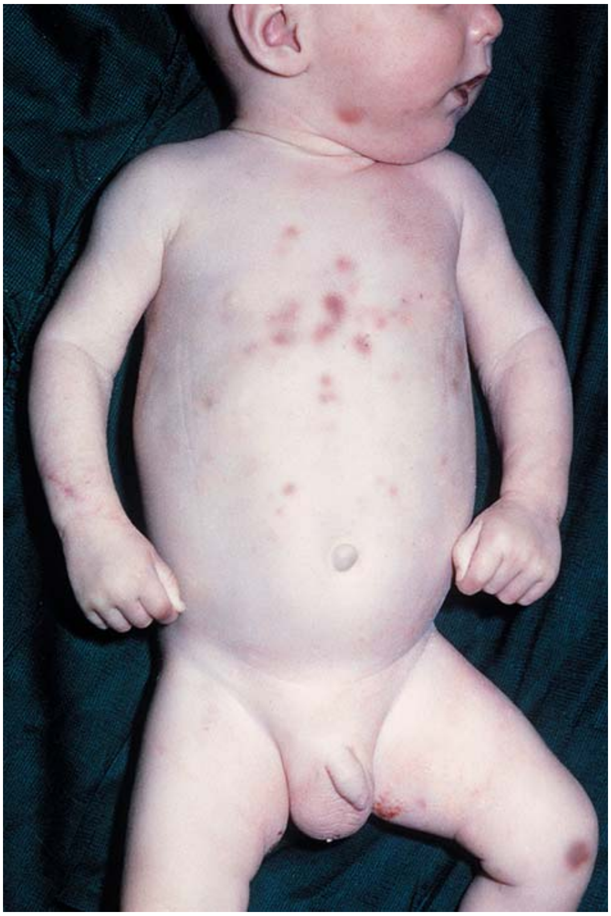

FIGURE 22.1 *Multiple fingertip bruises on the chest and abdominal wall of an infant left with a male babysitter. The child was ill on the mother's return and died during admission to a hospital casualty department (see also Figures 22.4 and 22.5).*

Skin bruising is the most common injury and may be seen almost anywhere on the child's body. There are, however, certain sites of predilection which help to strengthen the diagnosis of abuse:

- Bruising around the limbs, especially the wrist and forearms, upper arms, thighs and – in small infants – around the ankles. These places form convenient 'handles' for an adult to grip the child. In the small infant the lower leg bruises may indicate that the child has been held by the leg or ankle in order to swing it – and may be associated with head injuries. The older child, as an adult, may be gripped by the upper arms in order to be shaken.
- The buttocks are a frequent site of bruising from hand smacks or beating with a strap. Bruises on the thigh are less common, but on the outer side may signify slaps and on the inner, possible sexual interference.

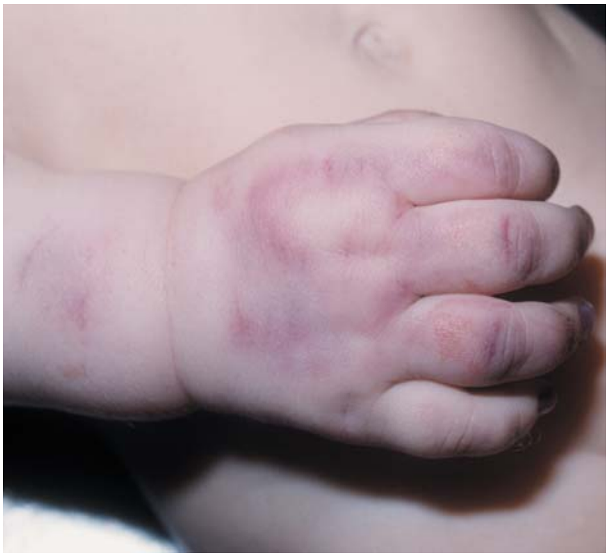

FIGURE 22.2 *Bruising of wrist and back of the hand after maltreatment by mentally ill mother (see also Figures 22.3 and 22.6).*

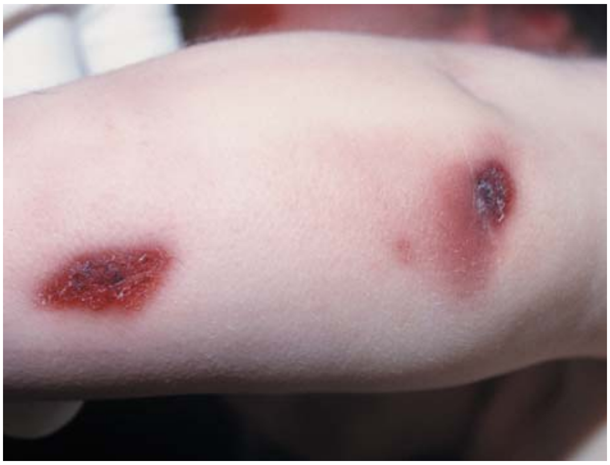

FIGURE 22.3 *Bruising of upper extremity after maltreatment by mentally ill mother (see also Figures 22.2 and 22.6).*

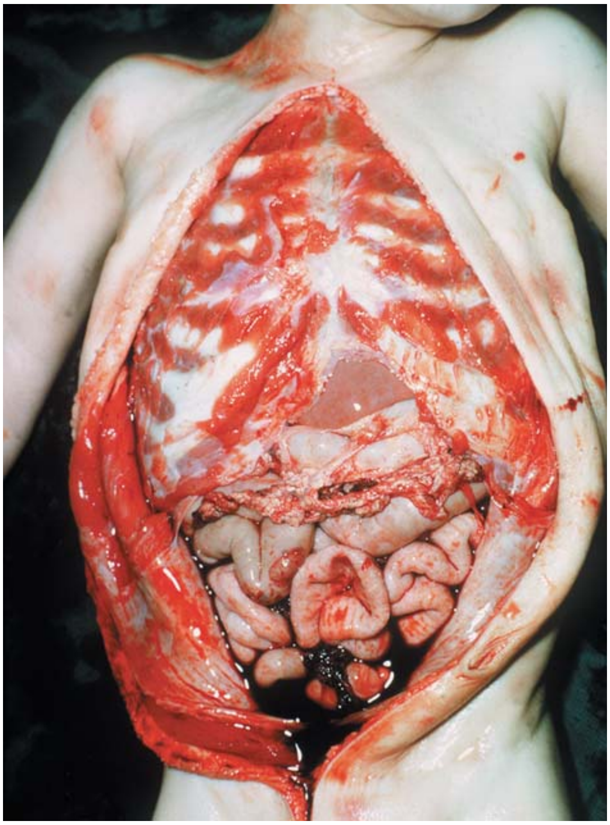

FIGURE 22.4 *Injuries found at autopsy of an infant left with a male babysitter showing a generalized haemoperitoneum.*

- The face is often bruised, especially the cheeks and mouth area, from slaps, which may also be present on the forehead and ears. Associated damage to the mouth and eyes is common. Bruising of the scalp is harder to see because of the hair, but is often part of deeper head injury.
- Bruises on the chest, abdomen and neck are usually from finger pressure rather than slaps or blows. Those on the abdomen and lower chest may be associated with deep visceral injury. Bruises may be of any size or type, but a common variety in child abuse is the small discoid lesion about 1–2 cm in diameter; these were once called 'sixpenny bruises' from the size of coinage at that time. These are caused by impact or pressure from the fingerpads of adults, and may be seen in groups around the limbs and on the neck, chest or abdomen.

Bruises from slapping or punching may be larger and irregular. Occasionally, a partial or even almost whole handprint may be seen outlined in bruises on the buttocks or trunk.

The age of bruises is an important issue in child abuse because:

- The observed age may be at variance with the history given by a parent, so increasing the suspicion of a non-accidental event.
- Bruises of different ages indicate episodes of injury at different times, one of the hallmarks of child abuse that usually continues over a period.

Though it is impossible to be accurate about the absolute age of a bruise, those of markedly different colours cannot have been inflicted during the same episode. The interpretation of patterns and the ageing of bruises are more fully considered in Chapter 4, but any bruise with yellow coloration must be more than 18 hours since infliction.

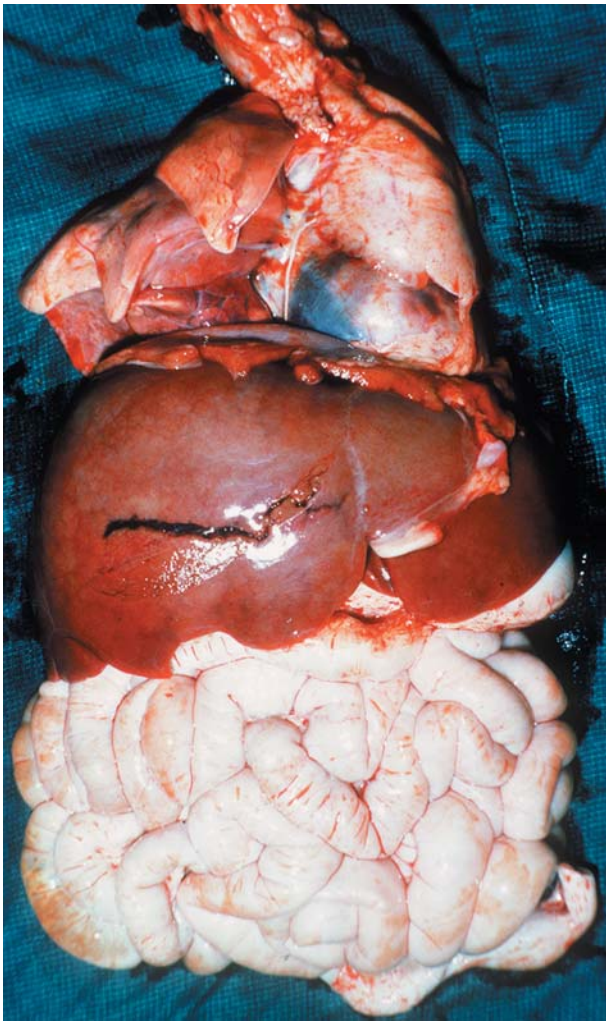

FIGURE 22.5 *The infant shown in Figures 22.1 and 22.4 showing a full-thickness tear extending through the liver. Rupture of an abdominal viscus is the second most common mode of death in child abuse, head injury being the most frequent.*

SKELETAL DAMAGE IN CHILD ABUSE

This is the second part of the aphorism about battered children as, both clinically and pathologically, diagnosis is largely a radiological matter. Just as a whole-body survey is needed in the live victim, so it is essential before an autopsy on a suspected fatal case of child abuse. Some pathologists would recommend a radiological skeletal survey on all infants prior to autopsy if they had not been under constant clinical care for some well-recognized natural disease. This would include all sudden infant deaths but, because of lack of facilities and finance, many pathologists have to confine their requests for such extensive radiology to those deaths in which there was some possibility of abuse, though this decision may lead to injuries being missed.

The range of skeletal injuries seen in child abuse is wide and there are very extensive publications on the subject, including at least one textbook by Cameron and Rae (1975) and a section on the radiology by Evans and Knight (1981).

Worlock *et al.* (1986) compared fractures in 35 abused children with 826 controls and found that the abused were all under 5 years old, whereas 85 per cent of the others were more than 5 years. The abused infants were more likely to have multiple fractures, and to have bruising of the head and neck. Rib fractures were almost confined to abused children, when major chest trauma was excluded. Spiral fractures of the humeral shaft were more common, though classical chipped metaphyses were uncommon. They concluded that one in eight infants under 18 months of age with a fracture had been abused.

The following is a summary of the more important bony lesions.

Fractures of the skull

Skull fractures are common in fatal child abuse, often in association with intracranial haemorrhage, usually subdural, though numerically less than half of infants with subdural haematomata have skull fractures (Harwood-Nash *et al.*). He found that of 4465 childhood head injuries, 1187 had skull fractures, but that there was little correlation with neurological signs and intracranial damage, subdural haemorrhage (SDH) being twice as frequent in the non-fracture cases.

Fractures have been discussed in relation to head injuries in Chapter 5, but some particular features in child abuse must be mentioned, as it is a controversial subject, especially when such cases come to trial.

The most common fracture lies in the occipitoparietal area, but the differentiation from accidental falls is impossible on anatomical or radiological grounds alone, in spite of the dogmatic claims of some radiologists. An infant's skull is more flexible than that of an adult and may absorb some impacts without fracturing. Occasionally, a parietal bone may 'dimple' inwards without cracking, much as a table-tennis ball may be dented with a thumb. The skull of a child is much thinner than that of an adult, even though the brain size and weight is greater relative to the postcranial mass. This means that there are two opposing factors operating:

- Because of the thin skull, less force is required for fracturing.
- Because of the elasticity or 'springiness' of the skull, recovery from distortion caused by impact is greater, so

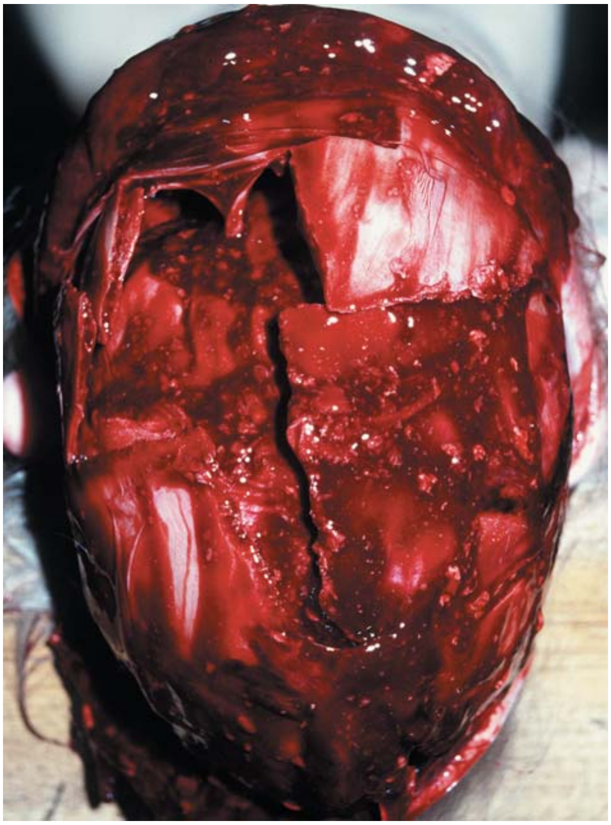

FIGURE 22.6 *Fractured skull of an infant after repeated blows against the floor by mentally ill mother (see also Figures 22.2 and 22.3).*

more force is needed to fracture the pliable bone, relative to its thickness.

Notwithstanding the flexibility, however, it remains a fact that an infant skull will fracture with the application of much less mechanical force than would be needed to fracture a mature skull. In addition, because the cranium is more easily deformed, a momentary depression of the skull can impinge upon the underlying brain (including membranes), damage it and return to its original shape so that, even in the absence of a fracture, brain damage is more likely to occur.

There is now a large literature on infant fractures (especially of the skull) in relation to child abuse, some of it contradictory.

One aspect that arouses much controversy is the height of a passive fall which can (a) fracture a child's skull and (b) cause brain damage. The two injuries are certainly not synonymous, as it is clear that most fractures, both in infants and adults, are not accompanied by any brain damage or neurological effects. However, forces that can cause a skull fracture certainly **can** – though not **must** – cause brain or meningeal lesions, and it is impossible to forecast what will happen following a fall of even minor magnitude.

Though many paediatricians will deny that a passive fall from adult waist level – or even higher – can cause either skull fracture or intracranial damage, there is experimental proof and witnessed cases on record where this has occurred.

In respect of skull fractures, Weber (1984) experimentally dropped dead infants from a horizontal position at only 'table height' (82 cm, 34 inches) onto a variety of surfaces and found that fractures were common. Fifteen infants less than 8 months old were dropped passively from a horizontal position onto concrete, carpet and linoleum; all developed cranial vault fractures in various positions. Though most fractures were in the parietal bones, some extended into the occipital bone. In 1985, Weber again dropped dead infants from 82 cm (34 inches) onto soft cushioning, such as 10 cm (4 inches) thick foam mat and 8 cm (3.2 inches) thick double blanket. Fractures were much less frequent, as was to be expected, but still one occurred on the thick foam and four out of 25 drops onto the folded blanket, all from only 82 cm (34 inches).

Reichelderfer *et al.* (1979) indicated that serious head injuries in playgrounds can occur when the impact force exceeds 50 G; a fall of only 7.5 cm (3 inches) onto concrete can generate 100–200 G and one of 0.3 m (a foot) no less than 475–500 G.

In 246 falls of infants under 5 years from bed or low structures less than 90 cm (36 inches) high, Helfer *et al.* (1977) found no serious injuries or deaths. Of these, 161 occurred at home and 175 had some injury, including two skull fractures. In 85 hospital falls, there were 28 injuries, with one skull fracture. Nimityongskul and Anderson (1987) investigated 76 childhood falls in hospital, 75 of which were younger than 5 years. The height of fall was between 30 and 91 cm (1 and 3 feet), and only one doubtful skull fracture occurred.

Of 398 falls studied by Williams (1991), 106 were observed by independent witnesses. There were 14 severe injuries in falls between 4.5 and 12.20 m (15 and 40 feet), but below 3 m (10 feet), there were no life-threatening injuries, though three skull fractures were detected. Similarly, Reiber (1993) found three skull fractures in infants who had died after witnessed short falls of less than 1 m (3 feet). This was from a series of coroners' cases where all had intracranial bleeding. One 21-month infant fell 1.5–1.8 m (5–6 feet) and had a subdural haemorrhage, but no skull fracture. Another 17-month child fell only 0.6–0.9 m (2–3 feet), but suffered a sub-dural and cerebral contusion. Reiber gives a good short survey of the competing literature, indicating that opinions fall into two groups – the 'major injury–major fall' set and the 'major injury–minor fall' camp.

Hall *et al.*'s (1989) series confirms that severe or fatal damage can occasionally arise from low falls. In a 4-year study, there were 18 deaths following falls from less than 0.9 m (3 feet). Two of these were witnessed by medical care persons, excluding abuse as a covert reason. Sixteen other similar deaths were not so witnessed, but abuse was not corroborated as a cause.

Chadwick *et al.* (1991), analysing 317 childhood falls, saw seven deaths in 100 falls from less than 1.20 m (4 feet), but doubted the veracity of the histories, as there was only one death in those who fell between 3 and 13.7 m (10 and 45 feet). Hobbs (1984) studied 89 children with skull fractures, 29 thought to have been abused. Of 20 deaths, 19 were abused. The characteristics of the battered infant fractures were multiplicity or complex configuration; depressed, wide and 'growing' fractures, the latter meaning widening of the fracture line after infliction; accidental fractures were felt to be narrow, linear and single, usually in the parietal area.

Leventhal *et al.* (1993) investigated 104 infant skull fractures and concluded that abuse was the cause in 34 per cent, accident in 62 per cent, the rest being doubtful. Billmire and Myers (1985) claimed that 64 per cent of all infant head injuries, excluding simple fractures, were caused by abuse and that of serious intracranial damage, 95 per cent were from abuse. These varying figures emphasize the lack of consensus in the literature.

Though the immature skull has more flexibility, once its elastic limit is exceeded during deformation, it will fracture. The pattern of fracturing is similar to that in the adult, but there are some variations because of the presence of open sutures and fontanelles. Fracture lines tend to end at sutures, but if they cross them there is frequently a lateral displacement so that the two limbs of the fracture are not in line. Most instances where what appears to be a fracture line crossing a suture with a 'side-step' are really two independent fractures either approaching or receding from each other, the origins or terminations being slightly offset. The most common example is seen in a child who has been dropped on the vertex of the head. Both parietal bones may then deform and crack transversely from the vertex anterior to the point of impact, the bilateral fracture lines running downwards towards the parietal bosses. The upper ends of both fractures terminate in the sagittal suture, but may be 'staggered' by a centimetre or so.

Another common fracture is a horizontal crack running backwards from the frontoparietal suture, which courses across the parietal bone, often turning down towards the base of the skull. This can be caused by a blow or fall on the side or top of the head. Such fractures can occur bilaterally, which is then an indication of an impact on the vertex of the skull, which causes marked depression of the top of the skull with crack fractures along the lines of maximum stress. These are then more marked on the outer aspect than the inner table – though the diploë of infants' skulls are absent or only partially formed, according to the age. Of course, such bilateral fractures can also be caused by two separate impacts on each side of the head; here multiple bruises on or under the scalp may assist in interpretation.

The frontal bone is less often involved than the parietotemporal area, the frontal suture that is still present in young infants giving more flexibility than in the fused older bone. Occipital fractures may occur from falls onto the back of the head, but again these are much less common than cracks at the vertex or sides of the cranium, though, as the experiments of Weber showed, occipital bone cracks can occur from simple low-level falls in small infants. Wherever the vault fractures, if it is severe enough, extension lines may run down into the base of the skull, but this is not a frequent finding in child abuse injuries.

Sutural 'diastasis' (separation) may occur with or without fractures, the loosely knit skull plates being easily parted by distortion of the calvarium when struck. As mentioned above, some fractures widen after infliction (sometimes due to rising intracranial pressure). These so-called 'growing fractures' are thought by some writers to be more likely to be associated with abuse, though logic would relate it more to severity of impact rather than to motivation.

Limb fractures

These provide some of the most characteristic signs of child abuse, as injuries are common around the metaphyses and epiphyses of growing bones, as well as being the cause of periosteal lesions. Most of the limb injuries are indirect, that is, the bone damage is caused by stresses from abnormal angulation, torsion or traction, rather than from a direct impact upon the bone. Swinging the child by the wrists or ankles, dragging it by an arm or shin and violent shaking using the limbs as 'handles', are the usual mechanisms.

Avulsion of the metaphysis or chipping of the edges of the metaphyses or epiphyses may occur, with small fragments seen isolated on radiographs. Swinging, wrenching or twisting actions can fragment the metaphysis. Small pieces of the adjacent cortex and parts of the provisional zone of calcification may be avulsed from the shaft. The epiphysis may even separate from the metaphysis. Cameron and Rae (1975) suggested that metaphyseal fragments are virtually pathognomonic of child abuse.

The periosteum in infants is only loosely attached to the bone and easily lifts where there is shearing or traction injury. Blood accumulates under the raised periosteum and this rapidly calcifies (usually within 7–14 days) to give a characteristic radiological picture of a bony shell extending along the shaft, often thicker at the extremity, having a lumpy, irregular profile (Evans and Knight 1981). In almost half the cases, this may be seen radiographically within one week (Cameron 1970). The calcified rim may extend around the end of the metaphysis and epiphysis, or between the two, giving a 'bucket-handle' loop effect around the end of the bone, especially the lower end of the femur.

In early infancy it must be appreciated that some breech deliveries have legs that radiologically show long, smooth periosteal thickening secondary to subperiosteal bleeding caused by handling during delivery. It is also accepted that mere growth can produce faint subperiosteal calcification, but this is symmetrical and limited to the central parts of the shaft, keeping clear of the metaphyses.

A spiral fracture of the diaphysis of a long bone must be considered a suspicious injury in infants, as such a lesion is likely to be the result of a twisting strain, unlikely to occur in accidental circumstances.

The lower end of the shaft of a long bone may be 'squared-off', as described by Caffey (1946), by metaphyseal fragments reuniting. Damage to the epiphyseal cartilage may cause permanent growth defects, sometimes with increased growth from hyperaemia following injury. The axis of growth may be deviated and cupping of the metaphysis may occur because of retarded longitudinal growth in the centre.

Although the metaphyseal and epiphyseal lesions described above are classically those seen in child abuse, transverse and spiral fractures of the diaphysis are also common. In a series of 100 cases reported by Kogutt *et al.* (1974), these fractures were more common than the injuries to ends of the bones.

Damage to the chest cage

Apart from occasional perinatal fractures during delivery (Polson, Gee and Knight 1985), accidental fractures of ribs are very uncommon in infants, though the incidence is a matter of considerable controversy. Once again paediatricians, radiologists and pathologists may have differing views and experience.

In child abuse, ribs are commonly fractured, often several consecutive bones being affected on one or both sides. The damage may be fresh or old, giving different radiological appearances. The most characteristic picture of old fractures is of sequential callus formation seen in a vertical line down one or both paravertebral gutters. These form a 'string-of-beads' appearance on X-ray (Figure 22.7), where the ribs have been fractured near their angles, a sufficient time previously for new bone formation to occur – probably a minimum of 10 days, though dating is notoriously variable, and even the claims by experienced radiologists to date fractures have been confounded by a knowledge of the actual time of breakage.

These multiple posterior fractures are more common in small infants who have been picked up by adult hands under the armpits and squeezed from side to side. Whether or not such fractures can be caused by innocent handling, albeit rough or robust, as opposed to angry or impatient violence, is again a matter of dispute, beyond the competence of doctors to resolve – although this does not deter some from expressing strong opinions based on weak facts.

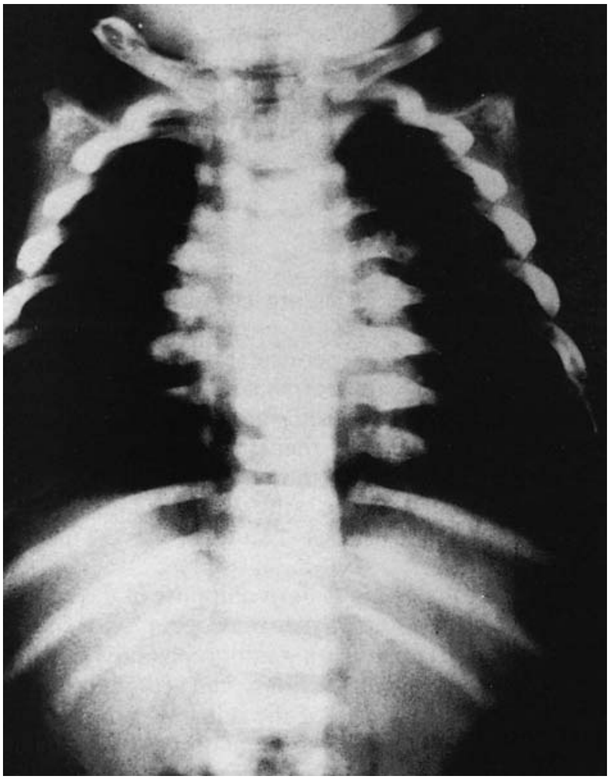

FIGURE 22.7 *Chest radiograph of an infant showing multiple callus formation on the necks of the ribs, giving a 'string of beads' appearance down the paravertebral gutter. These indicate previous multiple fractures caused by lateral squeezing by adult hands.*

These fractures, a centimetre or so from the head of the ribs, are due to the rib being levered against the transverse process until breaking point is reached. They may be very difficult or impossible to see as fresh lesions on radiographs, if the fracture line is not exactly in line with the X-ray beam. This explains the occasional discrepancy between the radiologist's and the pathologist's report; the fractures are much more visible after a week or two, when callus is present.

If such injuries are recent (probably less than 10 days) no visible callus is formed, but the fractures may be seen on X-ray and confirmed at autopsy. However, as with fractures elsewhere – and perhaps more often in ribs than skull – the radiological and dissection diagnosis sometimes does not concur. Fractures seen at autopsy may not be visible radiologically – and conversely, alleged fractures seen on films may not be discoverable at autopsy, even after the most diligent dissection.

Rib fractures in the axillary line are likely to be the result of anteroposterior pressure, rather than side-to-side squeezing, but this mechanism is not exclusive. With fresh fractures found at autopsy, the possibility of chest compression

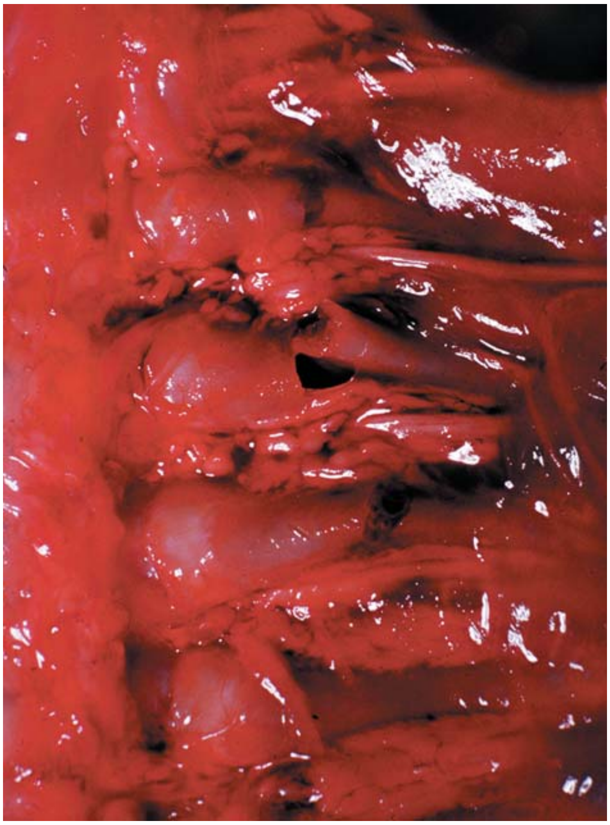

FIGURE 22.8 *Recent fractures of ribs of an abused infant. These breaks are near the necks of the ribs in the paravertebral gutter, caused by side-to-side squeezing of the chest.*

during cardiopulmonary resuscitation must always be considered, even though some paediatricians and radiologists will strenuously deny the possibility of this happening. The literature has different opinions on this matter, though it is admittedly very uncommon. As with other aspects of child abuse, the published material seems to flow more from those who lean towards abuse in the majority of injured children, rather from those who retain a more cautious approach and admit to the possibility of an innocent explanation.

It must be conceded that pliable infant ribs are unlikely to be broken by proper cardiac massage, which in infants should be performed with finger pressure; however, lay persons, especially in the panic of apparent collapse and death, may forcibly pump the small chest using techniques intended for adult resuscitation.

Fractures elsewhere are more likely to arise from direct impact such as a fist blow or kick. The clavicle is sometimes broken, usually from indirect stress from swinging by an arm. Fractures of the scapula or sternum are rare and arouse the probability of 'parental infliction' if some obvious trauma such as a traffic accident can be excluded.

Wherever the site of bony injury, the cardinal features that arouse suspicion are multiplicity and variation in fracture age. Though children often sustain accidental fractures, these are usually single lesions, unless some pathological bone disease is present. Similarly, the radiological demonstration of multiple fractures of varying ages must be accepted as evidence of abuse until proved otherwise.

Dating of fractures

As in the case of skin bruises, though the absolute dating of healing fractures by the state of callus formation is far from accurate (Evans and Knight 1981), marked differences in appearance on radiology usually indicate that the injuries were not sustained at the same time. As it can be shown, however, in control material, that the same person reveals callus of different extent and maturity in different but similar bones fractured contemporaneously, it becomes impossible to be dogmatic about radiological healing rates. Bone healing is rapid in healthy children and within months the abnormalities may have completely resolved, depending on the severity of the original damage.

Histological appearances are also very unreliable in placing an absolute date on fractures, in spite of assertions that this can be done with accuracy.

BONE DISEASES AND INFANT FRACTURES

Both in the differential diagnosis of childhood fractures and in the defence of allegations of child abuse, the several 'brittle bone diseases' that can cause abnormal skeletal fragility must be considered, on the grounds that lesser force, within normal parental handling or even spontaneous movements of the infant, could give rise to the observed fractures.

It has to be said at the outset that only a small minority of injured infants can be shown to have such abnormalities. When this possibility is being run as a defence in a criminal trial or child protection proceedings, it is essential to have an opinion from a radiologist or paediatrician with specialist knowledge of these conditions.

It is also important to have original radiographs, not copies, as the latter may not show marginal, indistinct abnormalities visible on the originals.

Osteogenesis imperfecta

This is a bone dysplasia with four types, numbered I, II, III and IV, of which there are several subgroups. The disease is an inherited disorder of connective tissue, with abnormal collagen, resulting in varying degrees of bone fragility, ligamentous laxity, skin fragility, sometimes blue sclera, hearing defects and dental abnormalities.

Types II and III have obvious bone disease and can hardly be confused with child abuse lesions.

Type I forms 70 per cent of cases and is the classical variety with a family history, blue sclera, Wormian bones and often dental changes, which again is hardly likely to be confused with abuse. It is type IV (only about 5 per cent of the overall disease incidence) that may cause difficulties in diagnosis, though it must be said that of all the medico-legal occasions in which this disease is postulated as a reason for brittle bones as a defence against allegations of abuse, the times upon which it can be proven are few indeed.

Type IVB, the larger subgroup, has dentinogenesis imperfecta. Type IVA has no family history of the disease, no osteoporosis, a high incidence of skull fractures and metaphyseal fractures and normal sclera. Subgroup IVA has Wormian bones, like IVB, but it has been postulated that some alleged cases of type IVA were really abuse.

It has been calculated that the incidence of type IV osteogenesis imperfecta in infants under one year, with fractures, no family history, no Wormian bones or dentinogenesis imperfecta is one in 1–3 million. A case would occur in a city of half a million population only once every 100–300 years.

Recent techniques of fibroblast culture and collagen analysis can provide evidence of defective connective tissue in the absence of overt clinical signs, but this is not necessarily synonymous with brittle bones. The case report by Ojima *et al.* (1994) gives a useful survey of the problem. Bone strength in otherwise normal SIDS infants has been measured by Morild *et al.* (1993) to obtain a baseline for comparison with alleged osteogenesis where this is raised as a defence against child abuse.

Infantile cortical hyperostosis (‘Caffey’s disease’)

Here there is extensive new periosteal bone laid down around the diaphyses, the bones most involved being the ribs, ulnae, clavicles and especially the mandible. The condition is rarely seen over the age of 3 years.

Congenital syphilis

This can mimic the changes seen in child abuse, though the condition is extremely rare in most Western communities. The periosteal thickening is similar to that of trauma, but tends to be symmetrical. The metaphysis may be fractured and even separated, the shaft adjacent to the metaphysis being porotic.

Copper deficiency

Again rare, this condition has radiological features in which periosteal thickening of the shafts of the long bones may be accompanied by symmetrical spurring of the metaphyses, osteoporosis, fractures and cupping of the metaphyses. Abnormalities of the hair may be present in this deficiency disease that is caused by lack of copper impairing the enzyme lysyl oxidase. The radiological appearances may cause confusion with child abuse. Other clinical features include psychomotor retardation, hypotonia, pallor, hypopigmentation of the skin and hair, prominent scalp veins, sideroblastic anaemia and neutropenia.

Menke’s syndrome (‘kinky hair’ syndrome)

This is another rare condition also associated with copper deficiency in which there are abnormal metaphyses. It affects males only, with abnormal hair, Wormian bones in the skull and mental retardation.

HEAD INJURY IN CHILD ABUSE

The most common cause of death in abused children is intracranial damage, with or without skull fracture. As well as being the most frequent fatal condition, brain trauma is responsible for the common tragedy of severe, and often permanent, neurological impairment.

The classic head injury associated with battered children is subdural haemorrhage, which formed part of ‘Caffey’s syndrome’ that he described five decades ago. It was also noted in Tardieu’s famous publication of 1860, when he described bleeding on the side of the cerebrum and other classical features (Knight 1986). Subdural haemorrhage is most common at the extremes of life, the topic being discussed fully in Chapter 5. In infants, it most often occurs from direct impact on the skull – as in a blow or fall. For some years, it has been held that vigorous shaking, without an impact, is also a common cause of subdural bleeding. This is a view strongly held by many paediatricians, who may prefer this mode as a first choice over a blow or fall, but recent research has thrown doubt on the common acceptance of this mechanism.

For example, the excellent textbook of DiMaio and DiMaio (1989) observes:

> Many forensic pathologists have doubted that the shaken baby syndrome exists [Norton 1983]. Most have felt that the injuries to the brain, including the retinal haemorrhages, are due to undetected direct impact

injuries. In all cases seen by the authors in which there has been retinal haemorrhage associated with subdural or subarachnoid bleeding, or some other brain trauma, direct impact injury to the head has been identified.

The forces generated in the cranial cavity by shaking have been shown to be of the order of 50 times less than in the deceleration stresses of an impact (Gennarelli and Thibault 1982; Duhaime *et al.* 1987). These authors investigated 13 fatalities alleged to have occurred from shaking, but though 7 showed no external head injury, all 13 revealed evidence of impact at autopsy. In infant models, they then compared impact with violent shaking; the mean tangential acceleration for 69 shaken babies was less than 10 G, whereas for 60 impacts, the mean was 428 G, some 50 times greater. The mean time for shakes was 106 milliseconds, but for impacts was only 20 milliseconds.

It is the rate of change and the duration of deceleration – the 'strain rate' – that is most damaging, rather than a steady deceleration. A head impacting on an immovable surface after a fall is an example of a high strain-rate injury, whereas low strain-rate injuries are those where the head decelerates over a longer period of time. Non-impact shaking of the head is a low strain-rate mechanical insult. Subdural bleeding from bridging veins is likely to occur from high strain-rate injury, even though this may be a low-energy injury, insufficient to cause cerebral tissue disruption. By contrast, low strain-rate injuries are more likely to cause cerebral contusion, with vascular damage only if concomitant high energy is generated (Howard *et al.* 1993).

Geddes and Whitwell (2004) have recently pointed out that there have been no formal systematic neuropathological studies of infant head injury and the evidence base for diffuse axonal injury (DAI) being a common finding in infant head injury is poor. In fact the idea of the presence of DAI in these cases was widely accepted before the advent of the modern diagnostic methods and before the diagnostic criteria for DAI had been established. Moreover, the findings of Shannon *et al.* (1998), the first formal study of microscopic damage in non-accidental injury (NAI), suggesting that axonal injury in such cases had been ischaemic or vascular in origin, had been largely ignored or misunderstood. In their recent series of 53 fatally injured infants (Geddes *et al.* 2001a, b), diffuse axonal injury was present in only two children, both of whom had multiple skull fractures and severe head injury, whereas the most frequent histological finding was global hypoxic damage in 84 per cent of the cases. In 11 of these cases (21 per cent), however, there was gross and microscopic evidence of injury to the craniocervical junction and concomitant axonal damage in the caudal brainstem long tracts in 8 subjects. This finding is in keeping with cervical hyperflexion/hyperextension injury pattern in adults and suggests as a possible mechanism of death: brainstem injury, apnoea and hypoxic brain swelling. In another systematic study of dural bleeding in 50 paediatric cases, including intrauterine deaths up to infants of 5 months of age, but without head injury, Geddes *et al.* (2003) found fresh haemorrhage into the layers of dura in a majority (36/50) of cases. The authors believe that this is a manifestation of severe hypoxia similar to the haemorrhages found in internal organs in birth asphyxia or prematurity, rather than being caused by trauma, and postulate that hypoxia is sufficient to cause extravasation of significant amounts of venous blood both in and under the dura.

Although shaking presumably may cause subdural haemorrhage (SDH), it is likely that it is a relatively uncommon cause, compared with impact. This situation may well have arisen because a blunt impact upon the head of infant, if spread over a wide area following contact with a flat surface, can leave no external scalp mark, no subscalp bleeding and no fracture of the skull – yet the transmitted forces can still be sufficient to cause high strain-shearing stresses within the cranium leading to subdural bleeding. In addition, as has been discussed elsewhere in this book, death is often not due to the irritative or space-occupying effects of the subdural, but is due to the intrinsic brain damage beneath, even if this is occult. Diffuse axonal injury, cerebral oedema and consequent circulatory disturbances are likely to be the fatal consequences, but detecting neuronal damage may be difficult or impossible histologically, due to the relatively rapid death of the child within 12–24 hours. Also, the microscopic features of diffuse axonal injury seem to be less common and less distinct in infants compared with adults, though the use of immunocytochemical methods, such as the demonstration of β-amyloid precursor protein (βAPP), described in Chapter 5, may provide a marker of use within the first few hours after injury. These factors combine to negate any proof of an impact injury and thus the shaking theory, which requires none of these criteria to be demonstrated, is an easier option.

Howard *et al.* (1993) looked at 28 instances of SDH in infants under 18 months of age. All had a history more consistent with an impact rather than shaking. Six Caucasian infants fell less than 0.9 m (3 feet), such as from a chair or standing adult. Eight non-Caucasians fell from a sitting or standing position or rolled off a bed onto a carpeted floor. There was a history of shaking in three, but these also had signs of impact, the shaking being resuscitation attempts after falling. Of these, 47 per cent of the Caucasians and 20 per cent of the non-Caucasians had a skull fracture. The authors state: 'Our findings do not support shaking as the only cause of SDH and also suggest that non-accidental injury is a less common cause of SDH than it is believed to be.'

There is a suggestion in several papers that Asian children are more susceptible to SDH from minor trauma;

Japanese infants have been reported with SDH after falling from only a sitting position (Aoki and Masuzawa 1984; Rekate 1985).

Most direct impacts in child abuse are caused by the moving head striking a fixed object, rather than the fixed head being struck. The latter certainly occurs, but is usually from an open-handed slap, albeit often of considerable force. It is unusual for the child's head to be struck with a weapon or for a direct punch to be given with the clenched fist. The moving head injury either arises from a fall in circumstances which are non-accidental, or by deliberate swinging or throwing of the child against a hard surface, often with added momentum being gained by holding the infant's ankles or wrist. For example, one such case seen by the author (BK) was a month-old baby whose father grasped it by the ankles to dash its head against stones at the edge of a canal, after which it was stripped so that its clothing could be sold in a street market, the body then being thrown into the canal.

Several other mechanisms of head injury have been described, including some seen by the author (BK) in which fathers were throwing their baby up in the air in a catching game called 'up-and-away', but for some reason missed the child on the downward return, allowing it to fall to the floor. When unwitnessed, this situation can give rise to accusations of deliberate malice, which are difficult to disprove.

Presumably, as vigorous shaking can sometimes rupture vessels in the subdural space, this must still be accepted as an alternative to impact in the causation of subdural haemorrhage. In an infant, the head is relatively large and heavy and the neck musculature undeveloped and often hypotonic. Thus repetitive shaking of the body – often attained by grasping under the armpits – can lead to unrestrained flexion and extension movements of the head with rotational movements of the heavy cerebral hemispheres relative to the skull.

Extradural haemorrhage is uncommon in child abuse, perhaps because the meningeal arteries do not run in deep grooves or even tunnels in the immature skull, as they do in the adult. Subarachnoid haemorrhage is, as always, an inevitable accompaniment of cerebral cortical contusion.

Brain damage may be of any type, as catalogued in Chapter 5, but as in any childhood head injury, cerebral oedema is more common than in the adult. Indeed, a significant proportion of deaths after a head injury in a child are caused by raised intracranial pressure without skull fracture, meningeal haemorrhage or visible brain injury. The typical autopsy indications may be found consisting of a heavy brain, flattened gyri, obliterated sulci and slit-like ventricles. The more florid signs seen in adults, such as herniation of the hippocampal gyrus through the tentorial gap, secondary brainstem haemorrhages and coning of the cerebellar tonsils are seen less frequently in children.

When there has been a severe head injury, with or without a fractured skull, cerebral contusion or laceration may occur. The position of this damage is usually related to the site of external impact. Although many episodes of child abuse involve dropping or throwing to the floor, classical contrecoup lesions are not as common as in similar adult injuries. They certainly do occur, but are often absent when the circumstances would indicate that contralateral contusion might be expected. The smoother internal profile of the infant skull may be a factor.

The distance of a fall sufficient to cause head injury has been mentioned earlier and is a matter of considerable controversy in the literature and amongst expert medical witnesses. There is no doubt, both from reliable anecdotal evidence and from experimental data, such as that by Weber, that skull fractures can occur in infant skulls from very low passive falls, including heights not exceeding chair or table level (Weber 1984: 82 cm; 34 inches). However, as catalogued above, skulls often fracture without any significant internal brain damage – although the reverse is also true. The evidence that low falls may cause brain or meningeal lesions is much less convincing than that proving skull fractures – but the possibility exists and cannot be dismissed by inflexible, dogmatic opinion. The problem with assessing the mechanical basis of head injury is that human experimentation is virtually impossible – Weber's work on dead infants probably could not be repeated in the present ethical climate – and obviously no data can be derived from the living. Animal models are useless, so the frequent difficulties for pathologist, lawyers and the courts have to rest on available statistical evidence – which can never give a definitive answer in any one case. If a phenomenon has definitely occurred once, then it can occur again, whatever the statistical weight is against its frequency, as a precedent has been established which cannot be gainsaid as a possibility.

One of the problems is the 'standard of proof', as in the criminal courts, it is 'beyond reasonable doubt', whereas in civil matters, it only has to pass the test of 'balance of probabilities', where statistical evidence is far more persuasive.

To rely on the 'experience' of medical witnesses is also fraught with difficulty, as their anecdotal memories of previous cases will provide unsatisfactory data in respect of the causation of the injury. Where adults are accused of malice or neglect, they are very likely to fabricate or distort the circumstances of the injury, and claim that the infant fell from the chair, the arms or the bed. Even in genuine accidents, feelings of guilt, clouded recollection from grief and panic, will often lead to an inaccurate account of the circumstances, so the doctor's past experience is often of lesser value than the accused adults, the lawyers and the court imagine, due to inadequate or false knowledge of the true circumstances of previous cases.

VISCERAL INJURY IN CHILD ABUSE

Damage to internal organs is almost always confined to the abdomen, as the heart and lungs are rarely injured. As stated earlier, rupture of an abdominal viscus is the second most common cause of death in child abuse after head injury. Forcible impacts on either the lower chest or the abdominal wall are responsible. Direct punching or heavy 'prodding' are the usual mechanisms rather than being dropped or thrown, which is a common cause of head injury. Often there will be an excuse that the child fell or tripped upon some protruding obstruction, such as a toy or piece of furniture; occasionally this may be true and it is a matter of fact and interpretation as to whether the circumstantial evidence is compatible with the medical findings. The liver is frequently injured, the most common lesion being a deep tear in either lobe, sometimes being a complete penetration or, more rarely, actual detachment of hepatic tissue. A haemoperitoneum results and in fatalities, may be the proximate cause of death. A heavy blow over the lower ribs or xiphisternal area is the most likely site of impact.

The small intestine is the other common target organ, the duodenum or jejunum being the most frequent site of damage. The second part of the duodenum is vulnerable to blows in the central abdomen, as beneath this area, the duodenum crosses the midline and is liable to be 'sandwiched' between the compressed anterior abdominal wall and the promontory of the lumbar spine. As the tissue thickness is small in a child, the gut can be virtually 'guillotined' at this point and may be completely transected, appearing almost as clean-cut as if it had been done with a surgical knife. Alternatively the gut wall may be damaged and, though it may not leak or rupture at the time of impact, ischaemic and necrotic changes over the next few hours or even days may lead to a delayed rupture, with the later onset of peritonitis.

The same lesions, though rarely as sharply cut, can occur in the jejunum, often accompanied by laceration of the mesentery and haemorrhage into the peritoneal cavity instead of – or in addition to – leakage of intestinal contents.

Rupture of the stomach can occur, but must be carefully differentiated from gastric rupture from non-traumatic causes and (these days) especially from external cardiac massage, which produces linear tears in the mucosa and even rupture of the complete wall.

DAMAGE TO EYES, EARS AND MOUTH

As part of general facial damage, black eyes, and scleral and conjunctival haemorrhages are often seen, but damage to the interior of the globe is much less apparent at autopsy. Some considerable time after the general recognition of the child abuse syndrome, it was discovered that a considerable proportion of victims, both live and dead, had significant internal damage to the eyes. Direct violence to the head and allegedly shaking, can cause bleeding into the vitreous humour, dislocation of the lens, retinal detachment and retinal haemorrhages (Gilliland *et al.* 1994).

The latter can also be caused by cardiopulmonary resuscitation, where vigorous compression of the chest has been applied; the literature on this topic is controversial, but numerous references confirm this mechanism, yet others,

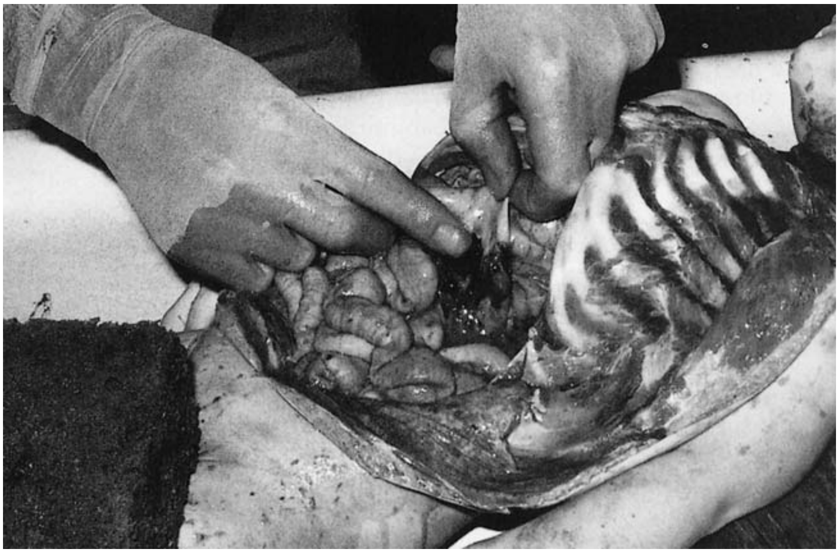

FIGURE 22.9 *A ruptured duodenum in an abused child who suffered a blow in the central abdomen. This relatively common mode of death in fatal child abuse is caused by the duodenum being guillotined against the lumbar spine by an impact that indents the thin anterior abdominal wall. The gut may be severed immediately or may become infarcted because of damaged blood supply over the ensuing few days, then rupture into the peritoneal cavity.*

such as Gilliland and Luckenbach (1993), deny it. Once again, there are hotly contested viewpoints in the position taken by different doctors over the aetiology of various lesions in child abuse, both by clinicians and pathologists. They are also, of course, often secondary to raised intracranial pressure from head injuries, rather than due to primary direct violence. During life, these can be diagnosed by ophthalmoscopy, but at autopsy they must be sought by dissection. As disfigurement of the body of a child must be avoided wherever possible, examination for eye lesions may be achieved either by enucleation and replacement with glass prostheses – or by opening the orbits from the anterior cranial fossae and removing the posterior two-thirds of the globes.

Injury to the external ear is frequent, as abuse of a child is often directed at the obvious targets, such as face, head, arms, buttocks and ears. The pinnae may be bruised or even lacerated, usually by an open-handed slap. Damage to the internal ear from heavy impacts on the head may be diagnosed clinically, though often in retrospect from later deafness. At autopsy, damage to such minute structures is rarely visible, though sometimes haemorrhage into the petrous temporal bone may be found when routinely examining this area for middle-ear sepsis.

Injury to the lips and mouth is so common as to be one of the prime diagnostic signs of the battered child. Infants and older children are commonly slapped across the mouth, the swipe usually having a tangential component that moves the tissues laterally. This causes the most reliable indicator of child abuse, the torn frenulum (or ‘frenum’) beneath the upper lip. This small median band of mucosa that joins the upper gum to the upper lip is ripped as the lip is jerked sideways, and is virtually pathognomonic of battering. The other possible cause of a ruptured frenulum is the forcible entry of a feeding bottle teat into the mouth of a reluctant infant. Instead of entering between the gums, the teat is rammed up between the gum and lip, causing a tear. The lesion heals rapidly, as do all injuries in the mouth and, within a few days, nothing may be seen except perhaps a loose mucosal tag or an absent frenulum, or both.

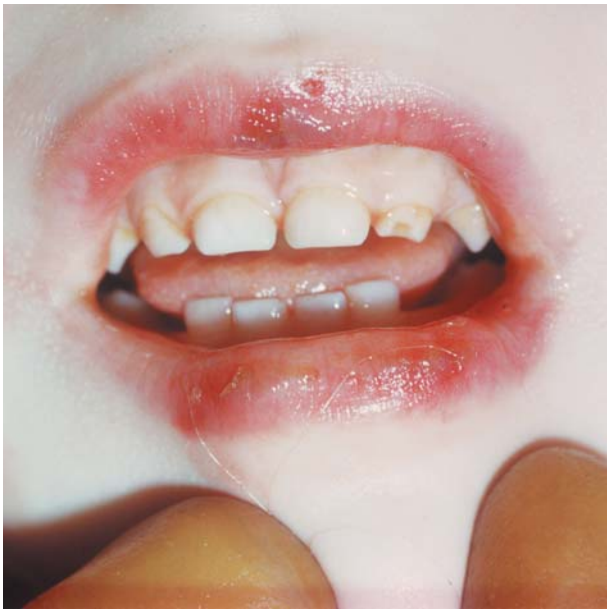

FIGURE 22.10 *Bruising of the lips in child abuse caused by smacking in the mouth. When the child is old enough to have teeth, lacerations may occur inside the lips. The frenulum behind the midline of the upper lip (not shown) was ruptured in this child, a strong pointer to a blow across the upper lip.*

Damage to the lips themselves is common, the type of injury varying somewhat according to whether or not the child is old enough to have teeth. In any event, bruising, swelling, abrasion and sometimes external laceration may be seen. The inner mucosal aspect of the lips may be bruised even if the child has no teeth and, if the blow is hard enough, laceration can occur. This is far more likely to happen if the lips are forced against the teeth, especially the cutting edge of the incisors.

The teeth themselves may be damaged, especially in older children. Total avulsion from the sockets, loosening and breakage may occur. In small infants, developing teeth may be forced back into the sockets, like pegs into holes. Expert dental advice should be sought wherever possible when injuries to teeth and jaws are found, both in live children and at autopsy.

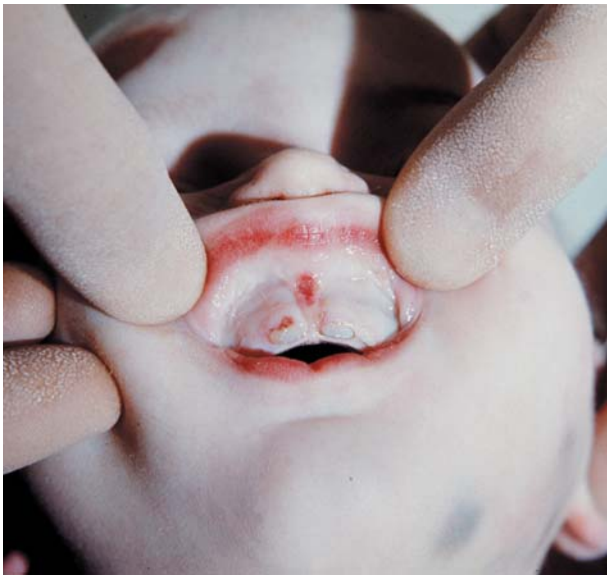

FIGURE 22.11 *Tearing of the frenulum of the upper lip of a child, a classical injury from a tangential slap across the mouth.*

BURNS IN CHILD ABUSE

Unfortunately, thermal injuries are by no means uncommon in abused infants. These may be moist scalds, dry burns or, exceptionally, electrical injuries.

Scalds result from dipping in hot fluid and often involve over-hot bath water. The line between accident and abuse may be blurred in some cases, but it can occur as a form of chastisement. In one case, a child was deliberately held in water at over 80°C as a punishment for persistently complaining about being cold. Other scalds may be from boiling water from a kettle or saucepan deliberately being poured over the child.

Dry burns can be inflicted in innumerable ways as a deliberate and sadistic act. Children have been forcibly sat on electric cooking rings and hotplates, branded with hot shovels and electric soldering-irons, or pressed against the bars of a fire. A particular type of burn seen relatively often in abused children is never the cause of death but may be found incidentally. This is the cigarette burn, seen most often on skin not normally covered by clothing, such as the hands, arms, neck and head. Such burns are usually circular, but not always; if the cigarette has been held obliquely against the skin, the mark may be triangular. The regular shape and size usually indicate the nature of the burn, though some skin diseases may simulate an old burn, such as a small patch of impetigo. Fresh cigarette burns are red, sometimes with a narrow rim of a deeper red. When healing, they become pink and later have a silvery sheen on the surface.

BITE MARKS IN CHILD ABUSE

Most bites on the skin surface are seen either in sexual offences or in child abuse. In the author's own experience, all bitten infants have had these inflicted by the mother, though published reports indicate that both male and female guardians can bite their infant charges. The topic is discussed in more detail in Chapter 26, but as they are relatively common in child abuse, a summary is repeated here.

Bites may be seen anywhere on the child's body. The arms, back of the hands, cheeks, shoulders, buttocks and abdomen are favoured sites. A bite mark usually consists of two opposing semicircles, which may be incomplete. Individual teeth marks may be visible or the dental arch may be represented by a continuous line. The mark is either an abrasion or a bruise, or a combination of both. There may be confluent petechiae in the centre caused by suction, but this is much more common in sexual assaults – the so-called 'love bite'. In child abuse, the centre is more often undamaged. The size of the dental arch should be carefully measured to determine whether it was formed by an adult, another child or even an animal, as is sometimes alleged in defence.

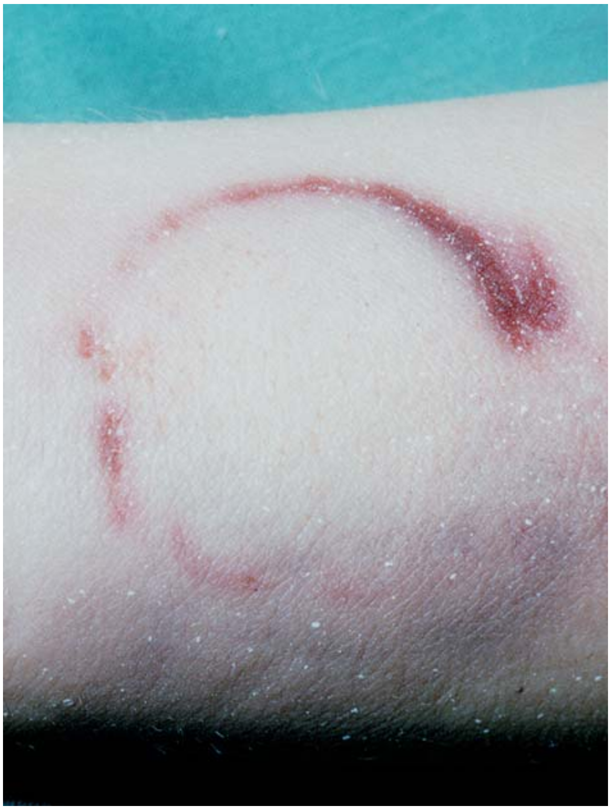

FIGURE 22.12 *Bite mark on baby's arm in a case of child abuse. The culprit was the mother. The teeth marks are deficient over one quadrant, the gap on the other side being smaller than usual.*

In older children, the possibility of self-biting must be borne in mind – the author has seen multiple self-bites all the way up one arm in a young person.

As with all dental matters, the advice of a dentist experienced in forensic problems is highly desirable. Not only can he confirm or exclude doubtful lesions, but he can identify individual teeth marks, make casts of any residual impression in the skin and take swabs for saliva identification. He can also examine any suspects to compare their dentition with the marks – a common excuse of the parents is that another child or even the family dog caused the bite. If no forensic odontologist is available, however, the pathologist must make the best examination possible and details are given in Chapter 26.

OTHER INJURIES IN CHILD ABUSE

A variety of injuries, some bizarre and sadistic, occur from time to time in battered children. The hair may be pulled out in clumps (epilation), leaving pseudoalopecia on the

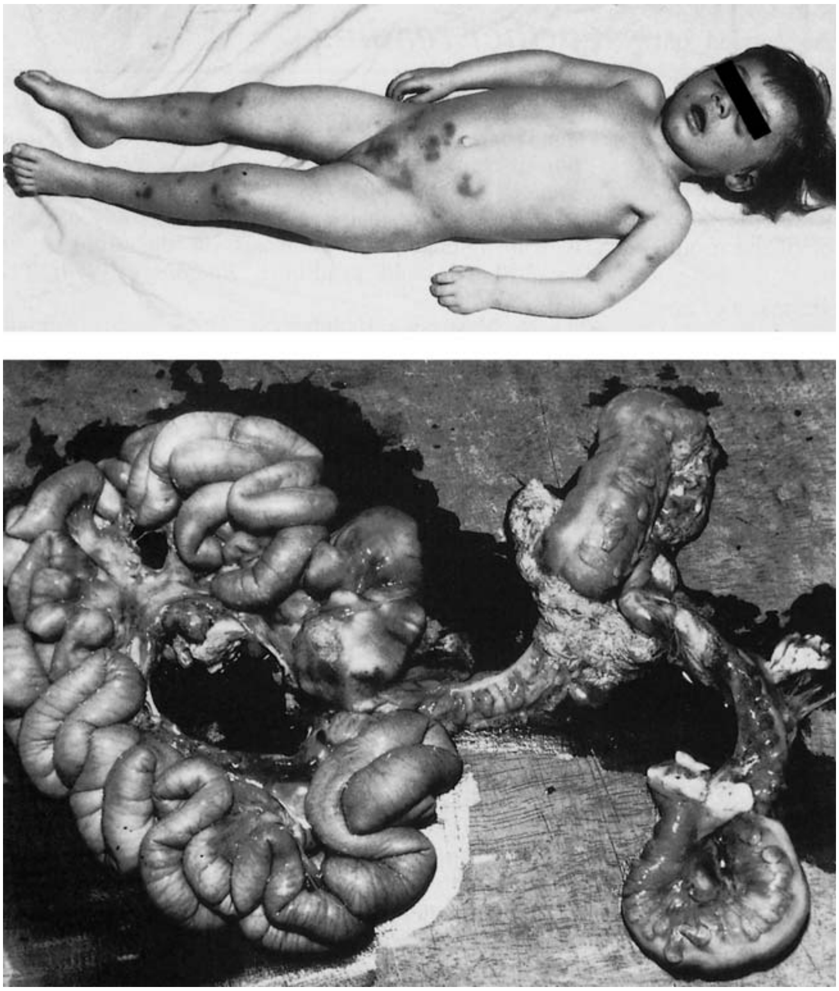

FIGURE 22.13 *A child with numerous bruises on the body, totalling 80 on the face, neck, abdomen, back and legs. The male adult in the house claimed that she had 'slipped while being bathed'. At autopsy, there was a massive haemoperitoneum arising from multiple ruptures of the mesentery.*

scalp. Fingers may be broken by hyperextension and fingertips crushed by blows or other means. Patterned marks from straps and ropes may be seen on the skin, usually on buttocks, thighs and abdomen. 'Pinch' or 'tweaking' marks are not uncommon, made by the skin being nipped between adult fingernails. These appear as two small opposing semi-circular or triangular bruises, often with a clear zone between them.

THE AUTOPSY IN CHILD ABUSE

This follows the usual routine for any forensic autopsy, but certain additional matters must be given close attention. Because of the emotive nature of child abuse, especially where a fatality is concerned, the pathologist must pay meticulous attention to all aspects of his examination and report. A full description of the autopsy in child abuse may be found in the chapter by Knight in *Paediatric Forensic Pathology* (Knight 1989). The following matters must be borne in mind:

- The scene should be visited wherever possible, though usually the child will already have been removed, usually to a hospital accident department. Even a retrospective visit can be helpful, however, to assess such matters as the nature of the floor and its coverings, where falls are alleged, the height of settees and chairs, and the general size and space between walls, doors and furniture, as claims of colliding with household structures are a constant line of defence – and may well be true in some instances.
- The child should be examined in its original clothing where possible.
- The appearances before washing and other cosmetic manoeuvres should be recorded; when children die in hospital accident departments, such compassionate acts may remove useful evidence, and the balance between

sympathy and justice can sometimes be hard to reconcile.

- Careful enquiries should be made about any resuscitatory attempts, as these can introduce a number of artefacts.
- Where any suspicion of abuse is present, a full radiological skeletal survey should be carried out before the autopsy is begun.
- Full physical measurements must be made including weight, crown–heel length, crown–rump length, foot length and head diameter.
- A meticulous external examination must be made, covering every square centimetre of the body, including all body orifices. The interior of the mouth and lips must be searched.
- A full photographic record must be made of any abnormality discovered. Where bruising is suspected, but not definitely apparent, the use of both infrared- and ultraviolet-sensitive film has been advocated, though experience is required in their interpretation, as artefacts are common.
- Extensive dissection of subcutaneous tissues is required wherever bruising is seen or suspected. Incisions must be made into doubtful areas or the skin flayed away to reach such areas, if disfigurement is to be avoided.
- Full sampling of blood, urine, stomach contents, liver, ocular fluid and cerebrospinal fluid must be taken, according to the circumstances. It is best to be liberal with the range of samples – it is easy to discard unwanted samples, but difficult or impossible to obtain them at a later date.
- Where appropriate, skin samples for fibroblast culture and swabs for microbiological culture are taken. Blood samples for grouping and other blood characteristics may be needed and a sufficient amount for DNA testing.
- Bite marks may need to be swabbed for saliva and casts made of tooth indentations. The cooperation of a forensic odontologist is then vital (see Chapter 26).
- A full internal dissection of all organs is required, with full sampling for histological purposes. Further radiographs may need to be taken on isolated bones or on the chest cage. The latter can be removed entirely by careful dissection if multiple rib fractures are present. X-rays can then be taken of the detached thoracic cage free of soft tissue and further histological blocks taken for decalcification in an attempt to date the lesions.
- If there is obvious or suspected brain damage, the brain should be removed carefully and suspended in formalin until firmly fixed. On no account should ‘wet cutting’ take place if intracranial damage or cerebral oedema is present.
- The globes of both eyes should be removed for histological examination: they can be taken entire and false eyes replaced for cosmetic purposes – or the posterior three-quarters of the globes can be removed via a superior approach through the base of the anterior fossa.

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CHAPTER 23

Deaths associated with surgical procedures

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In most jurisdictions, deaths that occur during or within a short time after surgical operation, invasive diagnostic procedure or an anaesthetic, become the subject of a medicolegal investigation. Similarly, any death thought to be caused or contributed to, by any of these procedures – irrespective of the interval – may be enquired into if the medical attendants or the relatives consider that a causal relationship exists. To be effective such investigations must include an autopsy, and the pathologist involved in these has a difficult and often professionally sensitive task.

The pathologist should, wherever possible, be independent of the institution in which either the death occurred or which carried out the procedure. This is partly why the services of a forensic pathologist should be retained by the investigating authority, rather than a clinical or histopathologist belonging to the hospital, or associated institution. It is important that a separation should exist – and be seen to exist – between the loyalties of these two elements, not because there is any substantial likelihood of collusion, but because the public and private interest is best served by displaying the independence of the pathologist. In addition, there may be professional embarrassment when a close colleague of a surgeon or anaesthetist is placed in a potentially critical position within the same institution.

It is also sometimes useful to have the technical advice and expert opinion of an independent clinical consultant who is unconnected with the hospital, and who is not a colleague of the team involved in incident.

THE AUTOPSY ON DEATHS ASSOCIATED WITH SURGERY AND ANAESTHESIA

A number of difficulties exist, that are peculiar to this type of death. The following matters need particular attention:

- The morphological findings, especially in so-called ‘anaesthetic deaths’, may be minimal or even absent so, more than in any other type of case, expert advice and full clinical information are essential.
- Technically the autopsy on a post-operative death may be difficult as a result of the surgical intervention and its sequelae, especially in abdominal and thoracic procedures. Exudate, sepsis, adhesions, haemorrhage, oedema and distortion of the normal anatomy may make the dissection difficult, especially if the details of the surgical procedure are not fully known. Post-mortem changes can further complicate the appearances: for example, recent suture lines in the intestine or stomach may appear to be leaking, but this may be caused by autolysis, and even handling the tissues at autopsy may tear devitalized and autolytic structures even further.
- Numerous surgical and anaesthetic devices may have been introduced into the patient during the procedure, such as airways, endotracheal tubes, indwelling needles, intravascular cannulae, self-retaining catheters, wound

drains, chest tubes, monitoring electrodes, and metal or plastic prostheses. It is essential that none of these be removed before autopsy, as their proper placement and patency may need to be checked. Standing orders should be issued to hospitals within the jurisdiction of any coroner or medical examiner to the effect that no post-mortem interference with the body be made by members of the medical, nursing, technical or portering staff, as it has happened in the past that the single vital piece of evidence about some technical mishap has been discarded by some well-meaning person.

- Before any further disturbance of the body is made (for instance, by turning it over to look at the back) and certainly before a knife is picked up, the position of any endotracheal tube that may remain after anaesthesia must be checked. If the clinical information raises any doubt whatsoever about its malposition, then a pre-autopsy radiograph should be obtained, both anteroposterior and lateral.

  Oesophageal intubation is not all that uncommon in anaesthetic mishaps and should be investigated carefully. The tube may be palpable through the skin if properly in the trachea – if there is doubt, a small primary incision in the midline of the neck with a further careful cut into the trachea can resolve the matter. Sometimes the intubation has been into the oesophagus, then been rectified after the damage has been done. Here the pathologist may find a ring of oedematous oesophageal mucosa still present at a level equal to that of the tube in the trachea. When nitrous oxide or other anaesthetic gas has previously been passed down a tube in the oesophagus there may be distension of the stomach and intestines. A sample of the contained gas may reveal the agent on analysis.
- The hospital laboratory should be requested to retain any ante-mortem blood or body-fluid samples sent to them so that they remain available for analytical checks, such as blood grouping in transfusion mishaps, or creatine phosphokinase activity in malignant hyperthermia.
- Even more than usual, the fullest information is needed before beginning the autopsy. The patient's notes are essential, together with any other relevant information. Sometimes the nursing records may be more helpful

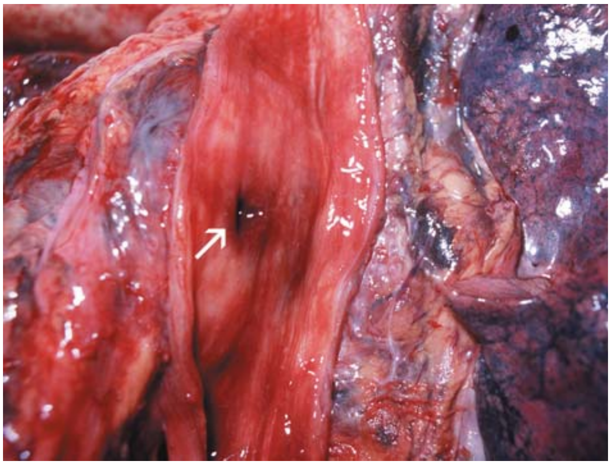

FIGURE 23.1 *Aorto-oesophageal fistula (arrow) due to ruptured anastomosis causing fatal haematemesis 18 days after replacement of the thoracic aorta with a prosthesis.*

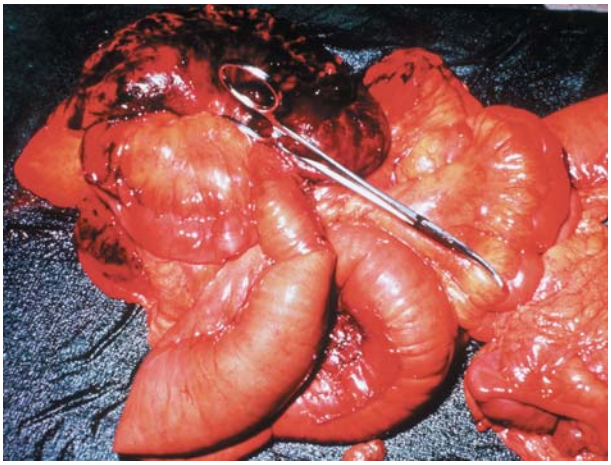

FIGURE 23.2 *Gut strangulated through the handle of forceps left in the abdomen during surgery and detected during an unrelated autopsy six weeks later for pneumoconiosis assessment.*

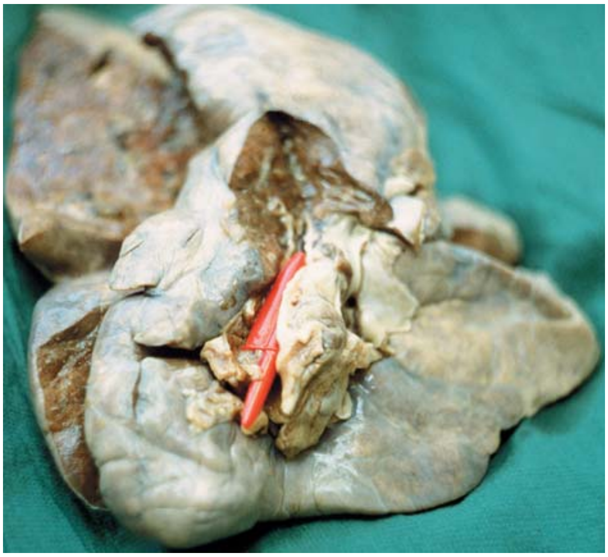

FIGURE 23.3 *Bronchial obstruction by the cover of a ballpoint pen, used by a midwife to hold down the tongue of a pregnant woman, who died days after childbirth from pneumonia.*

than the medical notes, as they are frequently more detailed and recorded at shorter intervals.

Equally important is the attendance of clinicians at the autopsy. Indeed, in deaths associated with anaesthesia, this is usually more useful than the post-mortem dissection, which frequently reveals little or no morphological evidence. Sadly, attendance at autopsies has declined markedly in recent years, as have requests for clinical autopsies, but every effort should be made to secure the presence of someone who knows the circumstances of the case well and who can point out to the pathologist the procedures that were carried out. A discussion across the autopsy table is of paramount importance and it is of little use if a junior doctor is delegated to attend, especially if he confesses to knowing little or nothing about the patient.

Especially in anaesthetic-related deaths, this dialogue with a clinician – in this case, the anaesthetist – may provide virtually all the data upon which to base a cause of death. Discussion between pathologist, surgeon and anaesthetist may arrive at an amicable conclusion that will be the best consensus of opinion to offer the investigating authority in cases where a bare autopsy might reveal little or nothing upon which to base any interpretation of the fatal processes.

- During the autopsy, care must be taken to detect any surgical emphysema, pneumothorax or air embolism. When surgical operations have been conducted with the patient in the sitting position, as in posterior fossa neurosurgery or some thyroidectomies, the possibility of air aspiration into open veins or venous sinuses always exists.

  Where infusion or transfusion mishaps may be a possibility, especially where gas pressure has been used to hasten the infusion rate, the possibility of air embolism must always be borne in mind.

THE MODE AND CAUSE OF DEATH AFTER SURGERY AND ANAESTHESIA

The rather loose terms ‘operative deaths’ and ‘anaesthetic deaths’ are usually inaccurate descriptions. When used without due consideration, they may lead to medico-legal enquiries and even civil litigation, which is not justified by the actual circumstances.

Fatalities associated with surgical intervention or invasive diagnostic procedures can be separated into several categories:

- those directly caused by the disease or injury for which the operation or anaesthetic was being carried out
- those caused by a disease or abnormality other than that for which the procedure was being carried out
- those resulting from a mishap during, or a complication of, the surgical or diagnostic procedure
- those resulting from a mishap during, or a complication of, the anaesthetic being administered.

These groups must be considered in more detail.

Deaths directly caused by disease or injury for which surgery is performed

Many deaths during a surgical or diagnostic procedure or an anaesthetic are caused by the disease process or injury for which the procedure was being performed. The death may be virtually inevitable in some ‘heroic’ operations where urgent intervention is the only hope of saving life. Presumably there must have been some chance of success or even palliation, otherwise the intervention would not have been justified, but the decision not to operate may be difficult. When death occurs from the effects of such disease or injury, some medico-legal systems will certify the original condition as the cause of death and omit any reference to the intervention.

The American Society of Anesthesiologists have a classification system for deaths during surgical procedures, as follows:

- ASA 1: those with no serious disease
- ASA 2: those who may have a serious disease, but have no limitations on their activities
- ASA 3: those with serious disease and some limitation of their activities
- ASA 4: those with a serious disease that is a constant threat to their health and that limits their activities
- ASA 5: those with such serious disease that their death can be expected within 24 hours, with or without treatment.

The Society recommended that classes 1–3 require full investigation, as they were expected to survive; those in class 4 that were elective and not emergency procedures, with no expectation of death, are also included. The general principle is that unexpected deaths are investigated, though in the British coroner and Procurator Fiscal system there are no exceptions to such investigations, once reported by doctors to the appropriate legal authority.

Pathologists in some jurisdictions have problems in the nomenclature of certification following an autopsy. The strict test to be applied should be: ‘Would death have occurred when it did, if the operation had not taken place?’ Sometimes this is impossible to answer and the balance of probabilities may be evenly poised. If a patient has a leaking aortic aneurysm, which catastrophically ruptures whilst the surgeon is still making his skin incision, most would agree that the original disease process was the primary cause of death. Even here, however, it may be argued that the added disturbance of preparation and anaesthesia contributed something to a possible slight rise in blood pressure that further split the aneurysm wall.

Where a person dies of a pulmonary embolus 7 days after an elective gastrectomy for peptic ulcer, the connection between the operation and the death can hardly be denied, even though in up to a fifth of fatal pulmonary embolisms, depending on the study, no predisposing factors have been found (see Chapter 13).

When both trauma and surgical operation have taken place, then it can be impossible to separate the relative contributions of each to a death. A common example would be death a few days after the pinning of a fractured neck or femur in an old person. A fatal bronchopneumonia, pulmonary embolism or acute cardiac failure might all be caused either by the original trauma, by the stress of operation or by the subsequent immobilization in bed.

Death due to a disease or disability other than that for which surgery is performed

Where death is due to a disease or disability other than that for which the operation was performed, a distinction has to be drawn between those conditions that were known before the operation and those which were unsuspected.

When some disease is known beforehand, it must be evaluated in deciding whether or not the operative procedure is justified. For example, a patient with a non-obstructing hernia who has chronic obstructive airways disease might be thought to be too poor a risk for an elective, prophylactic operation. If that same patient's hernia becomes strangulated and he develops potentially fatal intestinal obstruction, however, the risk:benefit ratio dramatically changes and the danger of a perioperative death may have to be accepted. Naturally, operative and anaesthetic techniques may have to be modified to take account of the known adverse conditions.

It is different when an occult disease process is not suspected by the clinicians. It may be that they had no diagnostic means of appreciating the risk – such as an unsuspected phaeochromocytoma – but a medico-legal problem can arise if they took no reasonable precautions in detecting common risk factors, such as hypertension, lung disease or ischaemic heart disease, which in retrospect could have been diagnosed.

Death as a result of failure of surgical technique

Exceptionally, death is the result of a failure of surgical technique. This may be inadvertent, from a true 'accident', sometimes caused by unusually difficult operative circumstances, to anatomical abnormalities or even failure of equipment. When it is the result of error or incompetence, then a legal action for negligence may ensue and the pathologist must be even more meticulous than usual in producing a detailed, objective and impartial report. In all these cases, the presence of the surgeon is essential, so that agreement can be reached on what actually was found at autopsy.

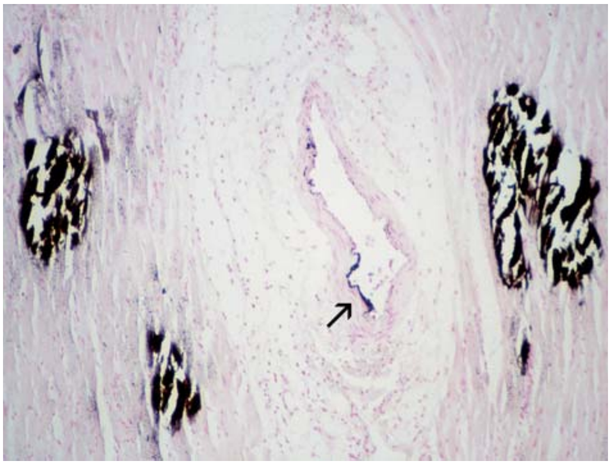

FIGURE 23.4 *Calcification of myocardium and vascular endothelium (arrow) due to postoperative rhabdomyolytic myoglobinuria and acute renal failure after reconstructive hand surgery and the interruption of blood circulation to the corresponding arm for the time of a nerve reconstruction. (Von Kossa staining, original magnification ×100.)*

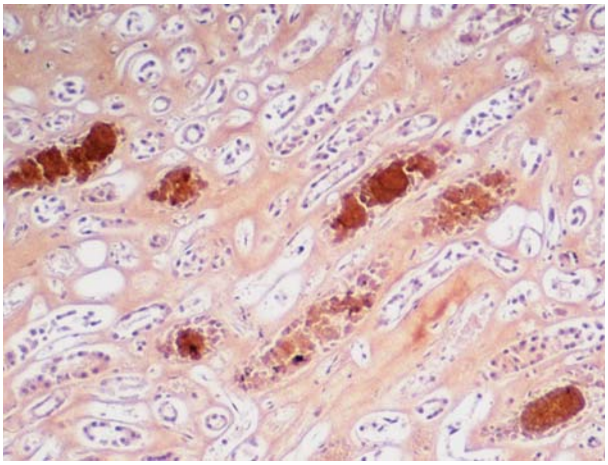

FIGURE 23.5 *Immunohistochemical demonstration of myoglobin in the renal tubuli with Anti-Human Myoglobin (Dakopatts a/s, Denmark).*

When a failure of equipment may be responsible, then expert examination and advice is essential. Anaesthetic machines, gas supply, compatibility of connections and all the sophisticated hardware of operating theatres must be subjected to the most rigorous inspection if a malfunction is suspected. This is no part of the pathologist's concern but, as he is responsible for the eventual decision about the cause of death, any conclusions about an equipment failure must be communicated to him.

Deaths due to anaesthetic administration

The foregoing categories account for most perioperative deaths and fatalities following surgery, even if delayed. True 'anaesthetic deaths' are comparatively rare, but have such potential medicolegal importance that they must be discussed in more detail.

DEATHS ASSOCIATED WITH ANAESTHESIA

Even more than is the case with surgeons, any autopsy on an anaesthetic-related death must be a cooperative process with the anaesthetist. Not only are the objective autopsy findings in true anaesthetic deaths meagre or absent, but the pathologist's training and experience of the complex techniques of modern anaesthesia is insufficient for him to appreciate, analyse and criticise constructively without the expert knowledge of the anaesthetist.

Most anaesthetic-related deaths are not caused by the anaesthetic agent itself, but due to other aspects of the procedure. Patients have anaesthetics because they have some significant – often very serious – disease or injury and, as has already been discussed, it is more likely that the fatality was the result of these or of some co-existent condition rather than the anaesthetic. There is a tendency on the part of relatives – and sometimes their lawyers – to assume that because someone died 'under' an anaesthetic, then this must be the major or even sole factor in the death because it was so closely related in time.

When factors other than anaesthesia can be excluded, certain features can be identified. A survey was conducted by Lunn and Mushin (1982) for the Association of Anaesthetists. This indicated that, although 1 in every 166 patients died within 6 days of a surgical operation, only 1 in 10 000 die solely as a consequence of the anaesthetic. Anaesthesia contributed to (but not totally caused) the death of 1 in every 1700 patients, many of these deaths being potentially avoidable.

The survey also showed that the causes have not changed significantly during the last 30 years, in spite of marked changes in anaesthetic technology and that anaesthesia may contribute to deaths that occur more than 24 hours after the administration. Many patients suffer from intercurrent disease unrelated to their surgical condition, but the implications for the anaesthetist are all too often ignored. The major causes of true anaesthetic fatalities include inexperienced and insufficiently supervised junior staff. Allowing periods of hypoxia to occur appears to be one of the common faults leading to a fatal outcome.

As far as the pathologist is concerned, the survey complained that the autopsy is of limited value in investigating the death. All too often irrelevant findings are offered, such as 'bronchitis'. Ischaemic heart disease was recorded in 39 per cent of the series. It was emphasized that the investigation of such deaths cannot be the sole province of the pathologist, but must rely heavily upon clinical data and cooperation with other doctors. Earlier investigations indicated that acute cardiovascular failure was the most common cause of unexpected death during anaesthesia. Lahey and Ruzicka in 1950 measured the risk of death during anaesthesia as about 1/1000, from all causes. Cardiac arrest was the most common single mode of death, being seen on average once or twice a year in most busy operating suites even under the most careful surgical and anaesthetic regimens. The autopsy is usually unhelpful in determining the cause, if coronary insufficiency can be excluded. Most cardiac arrest occurs under relative light anaesthesia and thus tends to occur at either the start or finish of the surgical procedure.

Reid and Brace (1940) showed that the arrest is mainly neurogenic and that any irritation of the respiratory tract, such as laryngoscopy or intubation, may cause a lightly anaesthetized patient to have a cardiac arrest. Inexperienced anaesthetists may not keep the patient at a level of unconsciousness appropriate to the manipulations of the surgeon, as it has been shown that such procedures can also precipitate arrest during light anaesthesia.

Hypoxia is also a potent precipitating factor in cardiac arrest. Deaths from respiratory failure also occur, and hypoxia is again a prime example – either from faults in the apparatus or more commonly to inexperience of the anaesthetist, especially in handling equipment with which he is not familiar. An overdose of the anaesthetic agent may depress the respiratory centres and begin a descending spiral of hypoxia. Excessive premedication and the use of muscle paralysing agents may also predispose towards respiratory failure unless appropriate measures are taken, such as assisted respiration.

Airway obstruction is another danger – from blood, teeth, dentures, faults in the connecting tubing, laryngeal spasm, swabs and an abnormal posture of the neck. Though regurgitation of gastric contents is a real danger, the use of

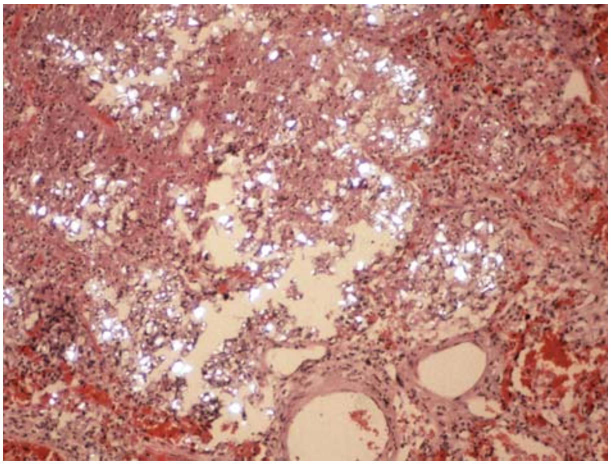

FIGURE 23.6 *Birefringent material in the alveoli due to contrast medium aspiration (barium sulphate).*

cuffed endotracheal tubes has greatly reduced the hazard. From the pathologist's point of view, the finding of gastric contents in the airways must be backed up by some clinical evidence of its ante-mortem origins, as a quarter of bodies have some gastric contents in some part of the air passages at autopsy, mostly as a result of agonal or even post-mortem transfer that is a consequence of the dying process, not a cause (Chapter 14).

Rarely, some physical fault in the anaesthetic equipment may cause death. Mention has been made of faults in the connecting tubing, which may be internal delamination, not visible from outside. Flow-meter errors occur, but a more common one is the confusion of bottled or piped gas supplies, and the inadvertent use of the wrong substance or the connection of an empty cylinder. Two such fatalities, where the wrong gas was introduced into the theatre piped supply, occurred in Hong Kong in recent years.

Fires are not uncommon, the most frequent danger being the ignition of spirit-based skin antiseptics ignited by cautery. Any electrical apparatus is potentially dangerous, and defective cauteries, defibrillators and diathermy equipment have all caused death.

Explosions from inflammable gases and vapours, such as cyclopropane and ether, have been catastrophic on occasions.

Hazards of local and epidural anaesthesia

Local anaesthetics rarely cause death, though the overall rate of complications is about 1/2000. Hypersensitivity and escape of contained adrenergic drugs form the major fatal hazards. It is said that most cases of 'hypersensitivity' are really overdosage, but there are undoubtedly some patients who have an abnormal sensitivity to the cocaine-like active constituents. Legal actions have been brought against doctors for failure to give a test skin dose before injecting the major quantity. Diffusion away from the operative site of adrenaline-like substances used to vasoconstrict the area and thus retain the anaesthetic effect may cause a sudden cardiac arrest.

Epidural and spinal anaesthesia has returned to favour, especially in obstetrics, after a period in which spinal injection of anaesthetic agents fell into disrepute because of a number of lawsuits brought because of spinal cord damage as a result of contaminants or excessive dosage.

The upwards diffusion of the active agents may cause paralysis, and the effect upon the vasomotor system may lead to a precipitous fall in blood pressure. Total spinal anaesthesia from upward diffusion blocks all sympathetic efferent impulses so, if the concentration of the anaesthetic agent in the upper thoracic and cervical spinal fluid level is high enough, efferent transmission to all motor fibres of the respiratory muscles will be blocked.

Epidural anaesthesia has now replaced intrathecal administration, but even this has occasional tragedies, and is said to have a 1/10 000 incidence of permanent nerve paralysis. This usually comes about either from an overdose or from puncture of the theca, instead of the anaesthetic solution remaining in the epidural space. In the rare autopsies on such deaths, a sample of cerebrospinal fluid should be taken for analysis to ascertain the concentration of anaesthetic substance. An attempt should be made to find the puncture in the dura, which is easier said than done. If an epidural catheter is still in place for continuous administration of the active agent, dye or Indian ink can be injected to see if it enters the subdural space.

MALIGNANT HYPERTHERMIA

This is a familial condition in which certain agents, including some anaesthetics and muscle relaxants, precipitate a metabolic change in skeletal muscle with the production of energy, and hence a rapid and sometimes fatal rise in temperature. The basic condition is an autosomal dominantly inherited trait associated with sudden uncoupling of oxidative phosphorylation, accompanied by massive energy production from the muscles with consequent overheating.

When malignant hyperthermia is diagnosed, the family members should be investigated, preferably by muscle biopsy, to assess the risk of their suffering a similar crisis if subjected to anaesthesia. In 70 per cent of carriers, the creatine phosphokinase and aldolase activities are elevated, though the basic abnormality appears to be a defect in calcium transfer and phosphorylation within the muscle fibres. This is one reason why hospital laboratories should be asked to retain any pre-mortem blood samples, as the creatine phosphokinase activity can be estimated retrospectively.

Suxamethonium and halogenated anaesthetic agents seem particularly prone to precipitate the condition. Halothane is one of the agents associated with malignant hyperthermia, either alone or in combination with suxamethonium. The condition occurs about once in every 10 000 anaesthetics, with various estimates ranging from 1/5000 to 1/70 000. There are virtually no autopsy features of any significance and the diagnosis is made on clinical grounds. The features of malignant hyperthermia include a sudden rise in temperature, sometimes reaching 43°C, with stiffening of the skeletal muscles, rapid heart rate and respiratory distress.

Halothane anaesthesia has acquired the reputation for causing liver injury known as halothane hepatitis and, rarely, a fulminant hepatic failure. Its incidence varies between 1/35 000 and 1/600 000 and if halothane anaesthesia is repeated within one month, 1/6000–1:22 000. It is a typical example of immune-mediated adverse drug reactions. Other drugs used in anaesthesia are occasionally responsible for death. Barbiturates used in induction, such as thiopentone, may give rise to cardiorespiratory failure, often because the quantity used has been excessive. Trichlorethylene and atropine have been involved in fatalities, the usual mode being sudden circulatory failure.

AUTOPSY PROCEDURE

In most autopsies on deaths during anaesthesia, toxicological investigations are generally unrewarding, except where overdose with specific drugs such as barbiturate or adrenaline is involved. It is usually impossible to make any quantitative assessment of the amount of volatile agents present, such as nitrous oxide, halothane or cyclopropane, even though some American writers advocate clamping a main bronchus and retaining a lung in a plastic – or preferably nylon – bag, so that head-space gas can be analysed. Neither is it practical to try to prove hypoxia by post-mortem measurement of blood gases. Usually the function of the autopsy is to discover or exclude natural disease, and mechanical blockages, as the pharmacological aspects are usually beyond investigation. Even when it seems obvious that a surgical error has taken place, one should be careful and not jump to conclusions nor let this distract from a thorough investigation. A full range of specimens for histological examination should be taken to exclude occult conditions such as a lymphoma or myocarditis, as well as to investigate the severity of the disease for which the surgical procedure was being performed. This includes also the investigation of any surgical specimens taken during the operation and sent to the histopathologist. Histological examination of the brain (fixed before cutting wherever possible) must be carried out. Though most mishaps will have occurred too quickly for much hope of any stigmata of cerebral hypoxia to be seen, changes can classically occur in Sommer's area of the hippocampal gyrus. Perhaps an even better marker is the distal parts of the cerebellar folia, where pallor and rapid loss of Purkinje cells can be seen within a few hours.

The work of Plum (Plum and Posner 1984) is relevant in this respect, as he found morphological changes in the brains of victims of only slight hypoxic periods who survived for long periods after an anaesthetic. At autopsy he recorded diffuse, severe leucoencephalopathy of the cerebral hemispheres, with sparing of the immediate subcortical connecting fibres and – usually – of the brainstem. Demyelination and obliteration of axons was observed and sometimes infarction of the basal ganglia. The cortical neurones were spared, however, and the damage appeared confined to the white matter. Plum attributed this damage to greater glycolysis in the white matter during hypoxia, compared with the grey.

Some new immunohistochemical techniques have been used in animal experiment to demonstrate structures of the cytoskeleton, e.g. in detecting ischaemic/hypoxic damage. Great caution must be exercised, however, when using these methods in autopsy material and it is therefore crucial to examine alterations occurring in the cytoskeleton as a result of post-mortem delay before conclusions can be drawn from the possible changes observed. Irving *et al.* (1997) investigated the post-mortem distribution of microtubule-associated proteins (MAP) in various regions of rat brain using immunohistochemistry. They showed that each MAP underwent unique changes that were dependent both on post-mortem interval and the brain region examined. Following long post-mortem delays, some of the changes in these proteins were similar to those seen in rodent models of cerebral ischaemia.

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CHAPTER 24

Dysbarism and barotrauma

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Damage to the body from changes in external pressure usually lies in the province of specialized occupational or armed services medicine, rather than that of the forensic pathologist. The major exception is recreational and sporting diving, using SCUBA (self-contained underwater breathing apparatus) equipment. When death occurs in such circumstances, however, though criminality is rarely a factor, there is usually some form of official enquiry, be it quasi-judicial or an internal investigation. Civil suits for compensation may arise and in these circumstances a forensic pathologist may well become involved as the expert witness providing the autopsy evidence.

Injurious pressure effects are virtually always the result of a decrease in atmospheric pressure from a previous level. This can occur either from a decrease of high pressure to normal atmospheric pressure or a decrease from normal to a low pressure. An example of the first is the decompression of a diver ascending to the surface, while the second is seen in depressurization of an aircraft at high altitude. The first is by far the most common as a source of injury and death, mainly because of the great increase in recent years of diving activity associated with the offshore oil industry, which in Britain now forms the most dangerous type of commercial employment.

Dysbarism is a term that covers all adverse effects of pressure, while barotrauma describes the mechanical damage from gas released into the tissues.

In diving, each 10 m depth of water increases the pressure on the body by one atmosphere – 101 kiloPascals (kPa) – so that, in a non-rigid diving suit, the air supply has to be provided at the appropriate pressure relative to the working depth. This depth depends on the equipment used and is limited by legal constraints – for example, in Britain, dives of more than 50 m (164 ft) are not permitted using a nitrogen/oxygen mixture, a gas such as helium being mandatory. Similarly, surface decompression is only allowed at less than this depth of 50 m (164 ft).

When air is supplied at increased pressure, the contained nitrogen (and, to a much lesser extent, carbon dioxide) will progressively dissolve in the plasma and tissue fluids, the amount being governed by Henry's law (the solubility of a gas in a liquid is proportional to its partial pressure). This itself can produce nitrogen narcosis, a state resembling drunkenness in which orientation, judgement and rational behaviour may be diminished. This can occur at depths greater than 30 m. A more physical danger, however, is when a diver who has been at high pressure for long enough to have appreciable nitrogen dissolved in his tissues is returned too quickly to normal atmospheric pressure. The dissolved gas will then come out of solution, almost as champagne effervesces when the cork is released. Gas bubbles appear in the circulation, tissues and joint cavities, and can cause 'decompression sickness' with a wide range of clinical signs and symptoms.

Bubbles in the circulation can cause gas emboli that block small vessels and give rise to infarction, especially in the central nervous system, such as the spinal cord. In addition, such bubbles can interfere with the coagulation system, causing platelet aggregation and disseminated intravascular coagulation. Subcutaneous emphysema can appear as a result of gas under the skin.

PHYSICAL DAMAGE

When sudden, or too rapid, decompression occurs, there may also be physical damage from volume changes. The gas in body cavities expands markedly as the diver rises and, unless these can be progressively vented to the exterior, pressure effects from the contained gas will occur. Such effects may develop in the paranasal sinuses, if blocked, and even in the teeth, if small vacuoles of gas are trapped in the pulp cavities. The middle ear may also be involved and ruptures of the drum can occur. None of these lesions in themselves is likely to be fatal, however, unless the pain and disability interfere with performance – then drowning is the usual cause of death.

A more serious volume effect is in the thorax because, if the air in the lungs is not vented as the diver rises, the alveolar walls may be ruptured by the gas pressure. This leads to interstitial emphysema – air bursting through the respiratory membranes into the interalveolar, interlobular and interlobar septa. Bullae may appear on the pleural surface and, if these rupture, a pneumothorax is formed. Air may reach the mediastinum and track up the tissues to appear in the neck. Apart from a disabling pneumothorax, air can break into the lung capillaries and veins with the danger of air embolism to the left side of the heart, as it cannot move back down the pulmonary arteries. The filling of the left atrium and ventricle interrupts cardiac pump function and, if the volume is sufficient, can be fatal in itself.

Even though this does not occur in most cases of air entry, smaller volumes will be swept into the systemic arterial circulation and impact in the arterioles and capillaries of target organs, especially the myocardium, spinal cord and brain, causing microinfarcts, haemorrhagic necrosis and loss of function of vital tissues. This pulmonary barotrauma is not necessarily confined to deep diving, and may occur in only 2 or 3 m of water.

Many incidents occur to sporting divers, rather than to professionals, in relatively shallow water. The SCUBA diver is now a ubiquitous user of the seas, especially in the warmer, clearer waters of many parts of the world. It is estimated that there are about 80 000 recreational divers in the UK who complete more than two million dives each year. In 1987 there were 600 000 dives, which produced 162 incidents serious enough to be reported. Of these, 115 were of a ‘medical’ nature and included 8 deaths. There were 6 instances of air embolism, 69 of decompression sickness, 4 of hypothermia, 4 of nitrogen narcosis and 4 cases of ear damage. The incidence of medical incidents was 1/5000 dives, with 1 death in every 75 000 dives.

THE AUTOPSY IN DYSBARISM AND BAROTRAUMA DEATHS

Many of the vast quantity of reports on this subject deal with the clinical effects. Most deaths associated with diving are caused by drowning, though dysbaric disablement may have caused or contributed to the drowning. The autopsy must be directed to investigating the drowning aspect (Chapter 16), and to excluding or confirming any evidence of dysbarism or barotrauma.

The autopsy should not begin until some expert advisers are present, including someone with detailed knowledge of the equipment. If the victim has died in hospital or in a decompression chamber, then obviously much original information will be lost, as no *in situ* examination of the suit and breathing apparatus is possible. In any event, as few forensic pathologists are likely to be expert in this specialized field, every effort should be made to have the attendance of a naval or commercial person who is an authority on the equipment being used at the time of the death.

It has been recommended that the autopsy itself should be conducted in a decompression chamber in order to prevent the post-mortem dissipation of gas that must take place if the body is brought into atmospheric pressure. This is hardly likely to be a practical procedure except where the autopsy takes place under the aegis of armed-service or specialized commercial facilities, who have expert medical staff who are well versed in such procedures.

However, it must be recognized that the very act of decompression is likely to allow bubbles to form within the body, even if they were not there when death took place. This is an insurmountable difficulty for the pathologist unless, as just mentioned, the autopsy itself can be performed under pressure. Thus the finding of gas in the vessels and tissues has to be interpreted in the knowledge that they may be an artefact; part of the differentiation is quantitative, as a mass of froth distending the heart is unlikely to have accumulated post-mortem merely from the static fluid and tissues in the immediate vicinity, and is therefore more likely to have been brought there to form an ‘airlock’ by a vital circulation.

The autopsy should not begin – nor the body be undressed – until all necessary examination is made of the diving apparatus by an expert. Full photography at every stage, and radiology of the chest and major joints is essential before any dissection is attempted. It has been recommended that air samples should be taken by external lung puncture using a greased syringe so that chemical analysis can be performed to determine the oxygen:nitrogen ratio. This should only be performed under expert guidance. Externally, attention should be paid to the skin colour, as hypothermia is sometimes an associated hazard of diving. Unfortunately, many bodies recovered from water have a bright pink colour that may be post-mortem in origin, much as refrigerated bodies often have a pink hue. Red linear marks may be seen in those who have suffered ‘squeezes’ inside a neoprene drysuit when the external pressure has become excessive. Crepitance of the skin – usually of the head, neck and thorax – is an indication of barotrauma. The eardrums should be examined with an otoscope to detect any recent ruptures.

The brain should be removed before opening the body cavities, using a special technique to detect air in the cerebral arteries. Artery forceps should be placed on the middle cerebral, basilar and vertebral arteries before they are cut through; the brain should then be placed under water and the clamps removed to observe whether air bubbles escape from the cut ends of the vessels. The detection of air bubbles in the cerebral veins is of no significance, always being an artefact, as it is impossible to remove the calvarium without aspirating some air into the pial vessels. In any case, there is no way in which air in the arterial side of the cerebral circulation can penetrate the brain capillaries in sufficient volume to be visible in the cortical veins.

In the central nervous system, petechial haemorrhages may be seen in any part of the system, including the spinal cord. If the victim survives for a day or more, early infarcts may be seen. Histologically, ring-shaped haemorrhages around vessels may be seen in the white matter. In long-term survivors, living for some weeks, softening of the lateral and dorsal columns of the thoracic spinal cord may be seen if air emboli have impacted there.

Subcutaneous, mediastinal, retroperitoneal and subpleural emphysema must be sought. In the lungs, rupture of alveolar membranes allows air to track through the interstices from where it either enters the circulation or reaches the periphery of the lung to form subpleural bullae, or both. It can cross to the other lung via the hilum; in addition, local bronchial stenosis may trap air in a single lobe, causing a local distension.

The chest should be examined for pneumothorax, first by radiology and then by puncturing an intercostal space under a pool of water held in the lateral skin flap. Similarly, the heart should be examined radiologically for the presence of bubbles. If the air has emerged from the general tissue mass, it will have been conducted centrally by the venous drainage and so more air will be found in the right chambers than in the left side of the heart. If lung damage has occurred, then entry into the pulmonary venous system will bring it to the left side. It is hardly worth attempting to open the heart under a pericardium full of water, as froth in the chambers will be readily apparent if in sufficient volume to have caused death. Some authorities, however, advocate placing clamps on all the major thoracic vessels and the trachea before removing the thoracic pluck of organs. This is then placed under water and the clamps released to see if and from where air bubbles emerge.

Histologically, there are no particularly specific changes in spite of some claims. Lipoid-containing tissues, such as adipose tissue and adrenal cortex, may show microbubbles with a foamy appearance. There may be fatty change in the liver, possibly from air emboli. In lungs in which barotrauma has taken place, oedema, patchy haemorrhage, torn alveoli and focal emphysema confirm the macroscopic findings. The myocardium may show small foci of necrosis.

Fat embolism may occur, both in post-descent shock and in decompression in both water and high altitude. Not only fat, but cellular bone marrow may be found in target organs such as lung, myocardium, brain and kidney. There is controversy over the origin of fat emboli in decompression states, some claiming that it is caused by air-bubble disruption of fat depot tissues, while others favour a more complex genesis involving a redistribution of blood lipids, inter-relating with fibrin production and disseminated intravascular coagulation.

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CHAPTER 25

The pathology of sudden death

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Virtually all forensic pathologists deal not only with criminal, suspicious, accidental and suicidal deaths, but with a wide range of deaths from natural causes. Many of these are sudden, unexpected, clinically unexplained or otherwise obscure, even though there need be no unnatural element in their causation.

It is good that such a large substrate of natural deaths is available to most forensic pathologists: the situation where they deal exclusively with trauma and crime is professionally unhealthy, as they become progressively more out of touch with morbid anatomy, and lose daily contact with disease processes and uninjured tissues and organs. Involvement with natural death means frequent professional intercourse with clinicians and non-forensic pathologists, with all the consequent benefits of cross-fertilization of knowledge and ideas. To work in a totally forensic vacuum is to lose touch with pathological and clinical reality, which is essential for a medico-legal expert to retain a sense of proportion and an awareness of contemporary medical advances.

Another indispensable benefit of sustained experience in natural disease is the fact that some of the most difficult problems in criminal and litigious cases arise not out of gross, rapidly fatal, trauma, but in deaths where concurrent natural disease or complications after trauma lead to a fatal outcome. The assaulted victim that dies later from a stroke or the negligent minor accident that has a fatal pulmonary embolism – these can pose far greater difficulties over causation than a gunshot wound or a stabbing.

In this chapter no attempt is made to duplicate the detailed descriptions of disease processes provided in a score of illustrious textbooks of pathology, but a survey will be offered of the spectrum of causes of sudden or unexpected death as commonly encountered by forensic and 'coroner's' pathologists.

SUDDEN OR UNEXPECTED DEATHS

The definition of a sudden death varies according to authority and convention. The World Health Organization definition is of death within 24 hours from the onset of symptoms, but this is much too long for many clinicians and pathologists; some will only accept death within one hour from the onset of illness. We have to also bear in mind that a death may appear sudden and unexpected to an outsider but need not have been so from the point of the pathological disease process. The deceased may have been symptomless and utterly unaware of his chronic disease or he may have had symptoms but interpreted them as harmless. Also, fear, lack of human contact or his own disposition may have prevented him mentioning symptoms to anyone, including a doctor.

In many jurisdictions, deaths may only be certified by an attending physician if he has seen the patient recently and is satisfied that the death was caused by a potentially lethal disease from which he was aware the patient suffered. The fact that, without autopsy, this physician is wrong in his belief in between 25 and 50 per cent of cases cannot concern us at the moment, but the relevance is that, where a clinical doctor cannot so certify, the death is usually reported for medico-legal investigation. In many countries such notifications form by far the largest proportion of medico-legal autopsies, and in England and Wales they account for some 80 per cent of coroner's autopsies, the remainder being suicide, accident and homicide.

The description 'sudden' or 'unexpected' is not always accurate, as 'unexplained' is an equally common reason for medico-legal investigation. Here the clinician is unable to offer a cause for the death, though the patient was under medical care. Even after autopsy, the cause of death may still not be revealed and this problem of the obscure autopsy is discussed elsewhere.

In sudden death, the immediate cause is almost always to be found in the cardiovascular system, even though topographically the lesion is not in the heart or great vessels. Massive cerebral haemorrhage, subarachnoid bleeding, ruptured ectopic pregnancy, haemoptysis, haematemesis and pulmonary embolism, for example, join with heart disease and aortic aneurysms to contribute most of the vascular system reasons for sudden, unexpected death.

SUDDEN DEATH FROM CARDIAC DISEASE

Ischaemic heart disease is easily the most common cause of sudden death in Western nations. The term is employed rather loosely and inaccurately, often being used as if it was synonymous with 'coronary atherosclerosis'. Certainly the latter is the largest contributor to ischaemic heart disease, but not to the exclusion of other conditions.

As a further complication of nomenclature, 'coronary atherosclerosis' or 'coronary atheroma' is the proper title of the common degenerative disease that causes most deaths, but the term 'coronary artery disease' is so ingrained into popular usage that it is accepted as synonymous with coronary atherosclerosis, even though there are other coronary diseases.

Ischaemic heart disease comprises:

- coronary atherosclerosis
- hypertensive heart disease
- aortic valve disease
- anomalies of the coronary circulation
- other coronary artery diseases, such as polyarteritis
- cardiomyopathic enlargement
- some congenital heart disease.

CORONARY ATHEROSCLEROSIS

Sometimes called 'the Captain of the Men of Death', this is certainly the most frequent cause of sudden death in Western societies. The basic mechanism is stenosis or occlusion of one or more major branches of the coronary arteries by atheromatous lesions, or one of the complications of such a lesion. The severity of stenosis before death occurs is debatable: cardiac pathologists claim that at least 80 per cent of the normal lumen must be lost before myocardial necrosis occurs. Most forensic pathologists would admit to blaming coronary atheroma for death in autopsies where a significantly smaller percentage of the lumen was lost, when the symptomatology and circumstances were strongly suggestive. Areas of myocardial fibrosis and – rarely – even recent infarcts, may be seen in the presence of relatively small degrees of coronary atheroma. Part of the problem lies in quantifying the amount of stenosis at autopsy. Because of the empty vessels lacking the normal intraluminal blood pressure, the walls are lax, collapsed and unstretched. During life, the same lumen will be larger and only fixation at arterial pressure will retain a semblance of the original size. The pathologist sees all coronary arteries in the dead state, however, so the relative degree of stenosis is still a reliable observation, as both normal and diseased vessels can be compared, even if their absolute luminal size is incorrect.

Coronary atheroma may be focal, with irregular plaques that vary both in size and in stenosing effect from place to place. They may be few and localized, with a virtually normal lumen in the rest of the system. This means that every part of the major vessels must be examined at autopsy, with transverse cuts at no more than 3 mm intervals. It is unjustifiable to make a few cuts at wide intervals and claim that this provides a reliable estimate of the state of the coronary system. A coronary artery is like a chain – just as the latter is only as good as its weakest link, so a vessel is only as good as its narrowest point.

Two cuts, if even half a centimetre apart, may pass either side of a grossly stenosing plaque or a thrombus. Opening the vessels lengthwise obviates this danger, but this is outweighed by the disadvantage of not being able to measure accurately the degree of stenosis by making frequent cross-cuts. A compromise is the best answer to this dilemma, as described in Chapter 1.

Plaques are often eccentric, leaving a crescentic residual lumen, but another variety of coronary atheroma is a more diffuse lesion, where the vessel is concentrically narrowed by a more longitudinal degeneration, forming a tube-like segment with a narrow, sometimes 'pin-hole' central lumen. The author (BK) has the impression that this is more common in younger victims and that such lesions seem less likely to be ulcerated and calcified. Both types of lesion are often found in the same patient and there is presumably no fundamental difference in their pathogenesis.

Complications in coronary atheromatous lesions

ULCERATED PLAQUES

The simple endothelial thickening develops to involve the media and usually becomes infiltrated with lipids. Whilst the covering endothelium remains intact, the danger to life is confined to the luminal reduction from the bulge of the enlarging plaque. When the fibroendothelial cap begins to break down under the pressure and erosion of the central necrosing process, the plaque may rupture into the lumen. This has several consequences, which may precipitate acute symptoms or even death.

First, a large plaque may suddenly disgorge its pultaceous contents into the lumen. This can mechanically block the vessel or seriously stenose it. Thrombosis may be precipitated at that spot by the slowed blood flow plus thrombogenic tissue elements. The cap of the plaque may be projected across the lumen, forming a sudden and perhaps complete occlusion. This will be more dangerous if the open end of the ruptured plaque faces 'upstream' into the direction of the blood flow, so that the intimal cap is lifted up, causing a valve-like obstruction. When the blood flow sweeps across the cap in the opposite direction, the cap will not be displaced, though the soft, grumous contents of the plaque will be washed downstream. Sometimes the flap can be seen in histological sections, though it is difficult to know if this is a processing artefact. It is best demonstrated directly at autopsy, when two cuts are joined longitudinally and the intima examined with a lens or low-power microscope.

The contents of the plaque may be washed downstream by the blood flow, eventually impacting in small branches and occluding them. These can be seen histologically using lipid stains and the multiple small infarcts that often ensue can be seen either in classical histological sections or, more readily, by enzyme or fluorescent techniques. They are probably responsible for many of the small fibrotic areas commonly seen in the myocardia of sufferers from long-standing coronary disease.

HAEMORRHAGE

Haemorrhage often occurs within an atheromatous plaque, usually into the softened, necrotic centre. This 'subintimal haemorrhage' may give rise to a sudden reduction in the blood-carrying capacity of a coronary artery and cause sudden death. The source of the bleeding is somewhat controversial, but the best explanation is that it comes from rupture of small blood vessels in the periphery of a plaque. A normal coronary artery does not have a blood supply to the intima but, in the disorganization frequently associated with the distorted microanatomy of a diseased coronary artery, such vessels may lie within the intima and be eroded by extension of the degenerative process.

Haemorrhages, both fresh and old, can often be demonstrated in histological sections of atheromatous plaques. It is reasonable to presume that such a bleed may be precipitated by some sudden rise in blood pressure from exertion or emotion, though, if a vessel is sufficiently eroded by atheroma, such a precipitation is not strictly necessary for such an event to take place.

The sudden release of blood into an atheromatous lesion can rapidly enlarge it and may raise the cap of the plaque towards the other side of the already stenosed lumen. It may even rupture the plaque: some subintimal haemorrhages may track circumferentially, causing a 'minidissection'. Subintimal haemorrhage as a factor in acute coronary occlusion was investigated many years ago by Patterson (1938), who believed that they played a major part in coronary thrombosis. In the same year, Wartmann demonstrated occlusion by subintimal haemorrhage without rupture of the overlying intima. Though English and Williams (1943) doubted if haemorrhage could compress the lumen against arterial pressure, other authors, including Davies and Pomerance (1975) believe that the haemodynamics within the coronary vessels are such that the pressure varies markedly from place to place, and that there may even be a contributing factor to subintimal haemorrhage by a suction effect in certain conditions. Other authors, such as Drury (1954), consider that the blood within the plaque is not caused by haemorrhage from mural vessels, but from blood percolating from the lumen of the coronary artery at the time of rupture of a plaque. This seems a minority opinion, however, as many haemorrhages can be seen (some older ones containing haemosiderin) within plaques which have a perfectly intact overlying intima.

Whatever the precise origin of the blood, it is clear that subintimal haemorrhage is a potent factor in rapidly reducing the available lumen of a coronary artery – and sometimes precipitating thrombosis by further stretching and damaging the overlying intimal cap.

CORONARY THROMBOSIS

The atheromatous plaque may not undergo these more dramatic changes, but progressive internal necrosis may erode the luminal surface and expose the fibrofatty contents. This loss of normal covering endothelium then forms a nidus for thrombus formation, which may gradually accrete in layers so further reducing the lumen or even occluding it, especially if a combination of lesions causes the plaque to expand at the same time as roughening the surface. Thus mural thrombus may completely block or severely narrow the residual lumen, with all the consequences of reduced blood flow to the distal myocardium.

A narrow lumen is by no means essential to the formation of thrombosis, as it may occur in the abnormally wide, virtually aneurysmal, coronary arteries sometimes seen in aged people. The lumen may be up to a centimetre wide yet be firmly thrombosed, presumably solely because of damage to the intima. Thrombosis often occurs in recanalized vessels, secondary thrombosis taking place after organization and re-establishment of a lumen through the previous block. Multiple coronary thromboses are by no means unusual. Many are post-infarct, the original thrombus causing myocardial necrosis and the resulting stasis in circulation, together with the thrombogenic effect of tissue damage leading to sluggish flow of readily coagulable blood.

It has also been noted that coronary thrombosis may be accompanied by thrombotic lesions elsewhere in the body. For example, a coronary thrombosis may be followed by a pulmonary embolus from thrombosed leg vein – and the converse may also occur in non-fatal pulmonary embolism. The coagulability of the blood, together with circulatory stasis, aided by immobility in bed, are obvious factors.

SITES OF CORONARY STENOSIS AND OCCLUSION

The whole length of the coronary arterial system is not uniformly vulnerable to atheromatous lesions. First, the major trunks are most affected where they lie subepicardially, often in the fatty surface tissue. Once the arteries dip down into the myocardium, these more distal intramuscular branches become much less prone to significant atheroma, especially of the grumous, degenerative type, though intimal thickening may still be seen.

Second, there are sites of predilection in the three major arteries. The most common site of occlusion is in the first 2 cm of the anterior descending branch of the left coronary artery, which is more frequent than in the common trunk. The next most frequent site is in the right coronary artery, but here the thrombosis is more distal than in the left vessel, usually seen as the vessel courses around the right margin of the heart in the atrioventricular groove part-way between aorta and the beginning of the posterior descending branch.

The third most common place is the proximal part of the left circumflex artery, soon after the bifurcation from the common trunk. The latter is then the next most frequent site, in the short segment (sometimes absent) between the aorta and the birfucation into descending and circumflex branches. At autopsy, it is always necessary to transect the proximal part of both coronary arteries right up to the coronary ostia, as occlusion can sometimes be present in the first few millimetres.

MYOCARDIAL INFARCTION

There is a different emphasis laid upon myocardial infarction by the forensic pathologist and by the clinician. To the latter, the clinical signs of chest pain and shock mean an infarct and certainly, a much higher proportion of patients who reach hospital beds do have myocardial infarcts compared with those who are taken straight to the mortuary. Recently the Joint European Society of Cardiology/American College of Cardiology Committee for the Redefinition of Myocardial Infarction produced a consensus document examining the scientific and societal implications of a new definition for myocardial infarction from seven points of view: pathology, biochemistry, electrocardiography, imaging, clinical trials, epidemiology and public policy.

In the pathology of sudden death, overt infarcts are the exception, rather than the rule. The incidence in autopsy material from sudden deaths varies considerably, partly because of the different methods of demonstrating the muscle necrosis, but speaking of obvious naked-eye infarcts, the author (BK) would estimate that, in his material considerably less than a quarter of deaths attributable to coronary atherosclerotic disease have myocardial infarction. In Finnish autopsy material of the author (PS) the 5-year average (1987–1991) of infarcts among deaths due to coronary atherosclerotic disease was 13.5 per cent. The relevance of this observation in relation to the mechanism of sudden cardiac death is discussed later.

Almost all myocardial infarcts are caused by atheromatous lesions and their complications. A few are the result of other types of coronary obstruction, such as polyarteritis, other vasculitides, embolism of various types, ostial occlusion by syphilis, severe aortic stenosis, some congenital anomalies of the coronary arteries or great vessels, dissecting aneurysms at the aortic root, and tumour or sarcoidosis affecting the coronary vessels.

Most infarcts are caused by super-added coronary thrombosis, but even this statement needs further analysis. A proportion of infarcts have no demonstrable thrombus in the supplying vessel, but this proportion can be reduced by a more careful search. There is no doubt, however, that muscle necrosis can follow severe narrowing of the supplying vessel by subintimal haemorrhage, a ruptured plaque or simple severe stenosis from atheroma. In addition, grumous debris from a ruptured plaque can produce embolic occlusions with 'microinfarcts' in the distal myocardium. The fact that some thromboses are post-infarct has already been mentioned.

It is said that the original lumen must be reduced to 20 per cent or less before the ischaemia in the distribution zone is sufficient to cause myocardial necrosis. Most pathologists with considerable experience of sudden death autopsies will, however, have numerous experiences of undoubted infarction in the absence of an 80 per cent stenosis. The embarrassing situation occasionally occurs where an infarct exists with virtually normal coronary arteries.

The contrary is much more common: the finding of complete thrombosis of a major vessel with no sign of infarction. In this case, either an effective collateral circulation provided an alternative blood supply – or the victim died before signs of infarction had time to develop.

There are several types of myocardial infarct recognizable at autopsy:

- A laminar infarct in which the subendocardial region of much – or even all – of the left ventricle is involved, sometimes extending through half or more of the thickness of the wall. This is due to a reduction in perfusion pressure to the inner zones, as all the coronary supply comes from the epicardial surface. Laminar infarcts are the result of generalized stenosis in the major branches of the coronary vessels, but there is usually a second factor, in that a drop in blood pressure or the oxygenation of the blood compromises the already poor supply so that the outer zones of the ventricular wall consume the available oxygen and nutrients, leaving little for the inner zone. This is discussed further under hypertension and aortic stenosis.
- A regional or focal infarct is more common in pure coronary artery disease, and is caused by a localized occlusion or severe stenosis in a coronary artery. These are true myocardial infarcts, as the definition of an infarct requires occlusion of the vascular supply, which strictly excludes some laminar infarcts when perfusion pressure or relative insufficiency is caused by hypertension, or aortic valve disease. The regional infarct is a topographically demarcated zone of muscle necrosis, the size and position depending on the site of vascular occlusion, though any collateral supply may modify these. Almost all infarcts are in the left ventricle. Wartmann and Hellerstein (1948) found that between 6 and 9 per cent involved the right ventricle and that 7 per cent involved the atria, though Cushing's (1942) figure was 17 per cent for atria. Most of these infarcts, however, were overlapping from infarcts in the left ventricle.

The relative immunity of the right ventricle and atria is presumably because of the relatively thin walls, which do not require so much blood, do not have the perfusion gradient of the thick left ventricle and which can more easily obtain oxygen and other constituents from the blood in the lumen of the ventricle. The presence of a conus artery, small branches to foci, such as to the sinus node, and the presence of anastomotic channels between the left circumflex and right coronary arteries must all contribute to the better survival of these areas. The site of a left ventricular infarct does not always correspond strictly to the site of the coronary occlusion or thrombus because of the presence of a collateral circulation.

It was also shown by Wartmann and Souders (1950) that many infarcts involve only certain layers of muscle, which cannot be supplied by a particular vessel. There is obviously no simple explanation for the topography of a myocardial infarct – this is further confirmed by the patchy nature of myocardial damage on microscopic study, as the alternate necrosis and survival of adjacent fibres or even segments of the same fibre cannot be explained solely by coronary perfusion.

The autopsy diagnosis of early myocardial injury and infarction

The autopsy demonstration of an acute lesion in the heart, such as an early myocardial infarct, can have profound medico-legal implications. In a fatal traffic accident, or even rail or air crash, the proof of an acute disabling myocardial lesion in the driver may be vital in the investigation of the event and the apportionment of legal liability. In potentially criminal deaths, the presence of a recent infarct again may be relevant in causation or as a contribution to the death. It is thus important to make a full histological search for evidence of myocardial fibre damage, using all the methods available, including histochemical and fluorescent techniques.

The macroscopic appearances of myocardial infarction are described with a considerable lack of uniformity in most pathology texts, partly because of the varying ages of infarct that the authors depict. The age of an infarct is notoriously difficult to establish in the human, as the onset of clinical symptoms, however dramatically abrupt, are often much later than the onset of the pathological lesion precipitated by a coronary occlusion. In animal experiments, a coronary vessel can be ligated at zero time and serial sacrifices made at different intervals to gain an accurate estimate of the age of the infarct.

In the human, the time of chest pain and shock cannot be used in a similar fashion. When a victim of coronary disease dies say, 8 hours after the onset of acute symptoms, though one might expect an early infarct to be visible histologically or histochemically, not infrequently a demarcated yellow or tigroid area of necrosis is present, which must be several days old. The following appearances are typical of the stages of myocardial infarction, though marked divergences from this time scale are not uncommon:

- For the first 12–18 or even 24 hours, no definite naked-eye changes are visible. The first sign towards the end of this variable period is oedema of the affected area of muscles, which causes pallor as the swollen fibres squeeze the blood from the vessels that lie between them. The normal moist lustre of the cut surface becomes more granular and dull when cut by a sharp knife. Caution must be used with this feature, because if the scissors are used to cut even normal muscle, the crushed edges of the fibres will give a similar dry, matt appearance.
- From about the end of the first day progressively through the second and third, the area becomes better demarcated and turns yellow. With breakdown of the myocytes, streaks of red appear, being both dilated vascular channels and areas of interfibre haemorrhage. This gives a 'tigroid' appearance suggestive of tiger stripes across the area, though sometimes the yellow element is virtually uniform or the red streaks may fade after a few days.

  Demarcation becomes more sharply apparent and there may be a red zone in the less damaged muscle around the periphery. The size of the infarct depends on the means with which it is visualized; the naked-eye size is less than the area detectable by classical histology and this in turn is smaller than that demonstrable by enzyme studies, where the more peripheral fibres are sick but potentially recoverable.
- After a few days, progressing through weeks, the infarct becomes softer and more friable, justifying the old name 'myomalacia cordis'. It is at this stage, from about the second or third day onwards, that ruptures occur into the pericardial sac. Some pathology textbooks are in error in stating that such cardiac rupture occurs in early infarcts.
- From the third week and later, the centre of the infarct becomes gelatinous, the colour fading to a translucent grey that often subsides below the level of the cut surface. This rather mucoid stage may still have old haemorrhage within it, but the stage of healing slowly develops and, during the next month or two, depending upon the size of the infarct, fibrosis replaces the dead muscle to form a scar. Even after this stage, there is often a narrow zone around the young fibrous tissue that shows muscle necrosis, though special staining or enzyme techniques may be needed to demonstrate this.

The laminar infarct goes through the same cycle of changes, but this is often less intense. Eventual fibrosis may be widespread but remains thin, often subendocardial, especially on the left ventricular aspect of the interventricular septum where a wide glistening sheet may obscure the underlying muscle. The apex also may show widespread fibrosis and all muscle may be replaced in this region, sometimes leading to a cardiac aneurysm on the free wall. Infarcts may be transmural, extending from epicardium to endocardium, or they may be confined to the inner zone. It is almost impossible to have an infarcted area confined to the outer subepicardial zone because of the topography of the coronary supply. The papillary muscles are usually involved, being particularly vulnerable to ischaemia as they are at the end of the line of coronary supply. The central part of the muscle may necrose and even rupture. Infarction usually spares the immediate subendocardial zone, the three or four most superficial layers of fibres surviving, even though they may show ischaemic damage. They presumably receive enough oxygen and nutrients from the ventricular blood to survive, though this does not seem to prevent deposition of mural thrombus over the infarcted area.

Microscopical appearances of myocardial injury and infarction

There are a vast number of publications on this subject dealing with morphological changes, classical histological methods, enzyme histochemistry, fluorescent studies, immunohistochemical methods and transmission and scanning electron microscopy. Only a brief summary can be offered here, though some of the methods of detecting very early infarction are detailed in Appendix 1.

MORPHOLOGICAL CHANGES

There is marked variation from case to case, just as in the gross appearances. The same difficulties exist about assessing the time of onset and hence the age of the infarct. This may sometimes have considerable medico-legal importance,

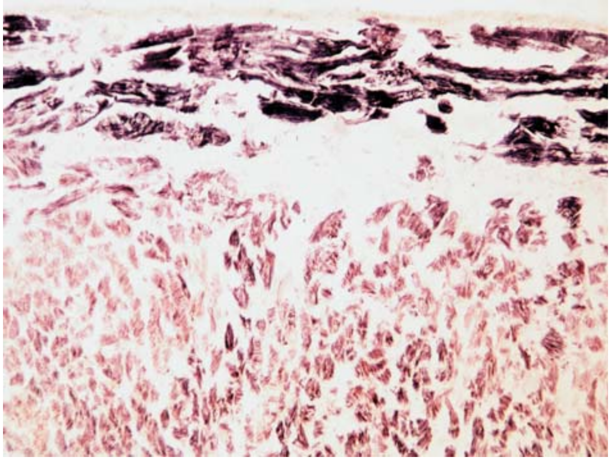

FIGURE 25.1 *Enzyme histochemistry of early myocardial damage. This photomicrograph shows strong succinate dehydrogenase reaction in the myofibres adjacent to the endocardium and moderate decrease of reaction elsewhere suggesting early injury. (Original magnification ×100.)*

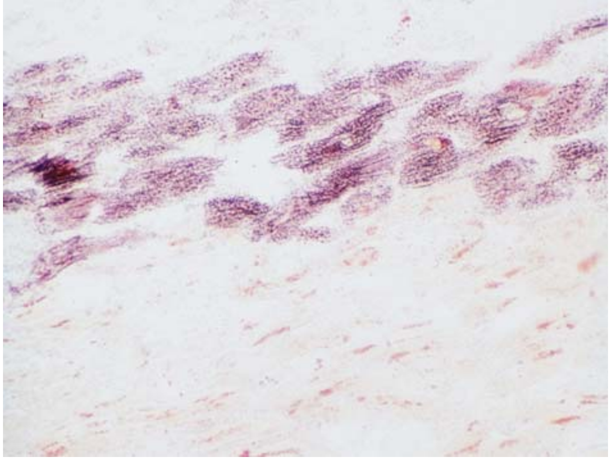

FIGURE 25.2 *Fresh myocardial infarction with β-hydroxybutyrate dehydrogenase staining showing positive reaction in the myofibres adjacent to a larger vessel seen above as an empty space. The lower part of the picture shows infarcted myofibres with some lipofuscin but no enzyme reaction. (Original magnification ×160.)*

especially when cardiac disease may have caused a traffic or other transportation accident – and is sometimes relevant in criminal circumstances. In animal experiments, changes in myocardial fibres become apparent within 30 seconds of coronary ligation, the first change being a loss of glycogen as the cell shifts from aerobic to anaerobic respiration. This cannot be observed in human material, for obvious reasons. The first observable change is subjective and different pathologists given the same material will offer different opinions on whether or not ischaemic damage is visible. Some of the earliest changes are mimicked by autolysis, especially granularity of the cytoplasm. The infarcted area becomes swollen, so that the interfibre clefts become obliterated, and the overall appearance is pinker and more solid in routine sections. Care must be taken to assess sections of uniform thickness, as material from other laboratories may not conform to the observer's usual quality. Along with swelling, the cytoplasm becomes granular, the 'cloudy swelling' of the old texts.

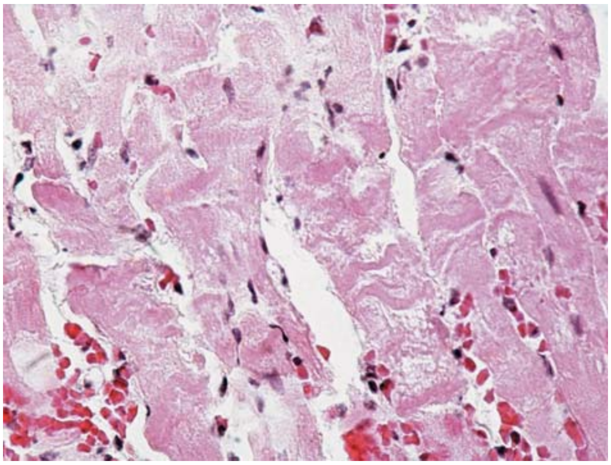

FIGURE 25.3 *Contraction bands in myocardium. (HE, original magnification ×500.)*

Early morphological changes seen in light microscopy are unspecific: interstitial oedema, congestion and small haemorrhages. An overstretching of myofibres with a sarcomere length of about 2.51 μm is possible only when the fibre is injured. In experimental infarction in the rat and the dog sarcomere, overstretching has been observed 15 minutes after coronary ligation. Cellular infiltration is variable and neutrophil infiltration is seen in most infarcts during the first few days being replaced by a mononuclear response within a week or so.

Contraction bands, known also as myofibrillar degeneration, and coagulative myocytolysis, are commonly described in connection with different pathological conditions. The change signifies irreversible myocyte injury. Contraction bands are irregular, dense and in haematoxylin and eosin (HE) staining eosinophilic transverse bands alternate with lighter staining granular zones in the myocyte, possibly firstly described by Smith (1904) in the periphery of myocardial infarction. These lesions have been observed in various forms of experimental heart muscle injury and have been also seen, e.g. in association with potassium deficiency, magnesium deficiency, in cases of malignant hyperthermia, in the hearts of drug addicts and in cases of sudden cardiac death.

They may also be seen after blunt trauma to the chest or even cardiopulmonary resuscitation, both where mechanical massage has been applied and especially where cardiac stimulants like noradrenaline have been injected. In fact, catecholamines seem able to cause this fibre disruption, which may also appear during electrocution and other conditions

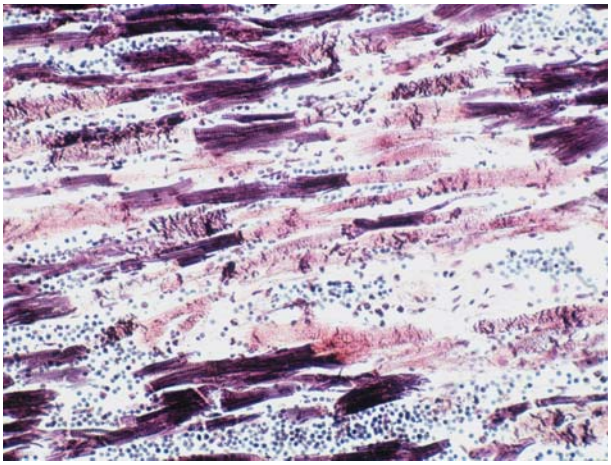

FIGURE 25.4 *Contraction bands in fresh myocardial infarction. (PTAH, original magnification ×250.)*

of cardiac stress. In sections stained with haematoxylin and eosin, pale areas in the fibre are common as a result of fibrocytolysis and the sarcolemma is often seen to be deficient at these sites. Although the change signifies fresh and irreversible myocyte injury and is more frequently observed in cardiac deaths, it is not specific to the cardiac death.

Contraction bands are best seen by phosphotungstic acid haematoxylin stain and all myocardial sections should be stained in this way as well as – or even in preference to – haematoxylin and eosin. Phosphotungstic acid haematoxylin stain does not reveal ischaemic damage at an earlier stage, but renders it far more obvious. Large areas can be scanned under low power of the microscope and the danger of missing abnormal areas is far less than with haematoxylin and eosin. The striations become distorted and break up, forming either a general 'sandy' appearance or the striking 'contraction bands' where fragmentation occurs in transverse lines across the fibre. The contractile material aggregates into thicker, darker masses, sometimes like 'Chinese writing', at first within an intact sarcolemma, but later the cell membrane ruptures and the basophilic contents scatter extracellularly.

Zonal lesions occur as a region of supercontraction of myocytes at the intercalated discs. These lesions have been observed both in the dog and in humans after haemorrhagic shock and the changes have been considered ubiquitous in and pathognomonic for hypovolaemic shock. These possibly reversible changes have been observed in experimentally induced shock in animals 15 minutes after the induction. The presence of catecholamines is also considered necessary.

Fragmentation of myocardial fibres is, at least to some extent, practically always present in adult hearts and more frequently in the wall of the left ventricle. Although it has generally been associated with post-mortem changes, it has also been shown to be more frequently seen in myocardial samples from sudden cardiac death victims. Early injury possibly increases the brittleness of myocardium, resulting in increased fragmentation of myofibres after the fixation and cutting process. This phenomenon has, however, no value as a positive marker of myocardial injury.

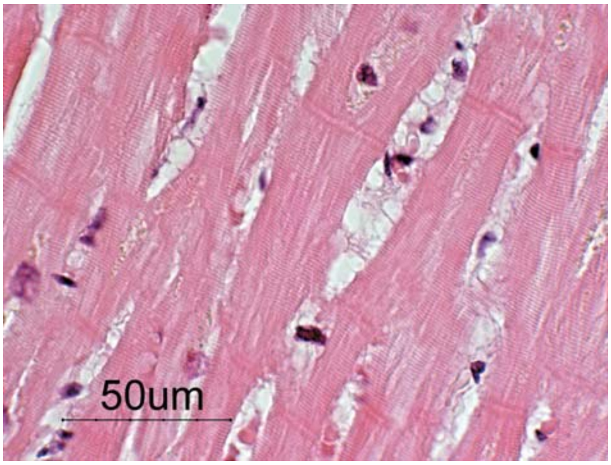

FIGURE 25.5 *Zonal lesions in haemorrhagic shock (HE).*

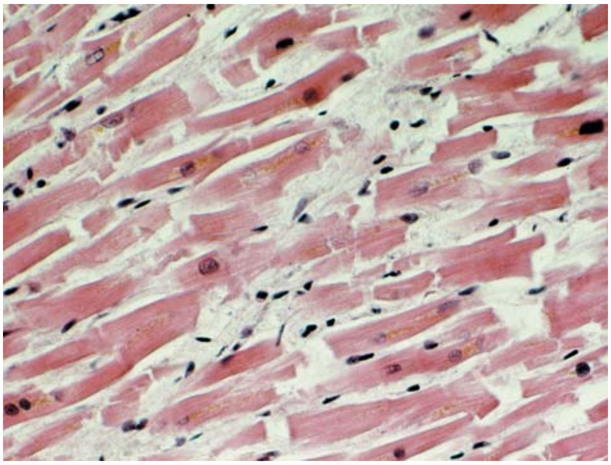

FIGURE 25.6 *Fragmentation of myocardial fibres. (HE, original magnification ×250.)*

Waviness of fibres was noted by Glogner (1903), who saw corkscrew-shaped myofibres in the heart and skeletal muscle in some cases of beri-beri. Similar patchy deformation of myofibres in a wavelike fashion was seen in association with fatty degeneration of the myocardium and in early and also more advanced human myocardial infarction. Both in cardiac deaths and non-cardiac deaths it can be observed more frequently in the wall of the right ventricle. It has no diagnostic significance as to the cause of death and it signifies only agonal injury.

LATER STAGES

The later stage of infarction follows the 18–24-hour period and, as by now macroscopic changes will be apparent, the histology is merely a confirmatory procedure. Even here, there is great variation in appearances, especially in cellular infiltration. There is a progressive degeneration of the fibres, best seen in longitudinal section. Eosinophila becomes stronger for a time until the internal architecture breaks down. The cellular oedema subsides and interfibre oedema takes over, separating the myofibres, a process that becomes more marked as the latter shrink and fragment.

Loss of nuclei is not an early phenomenon but, by the second to fourth days, the nuclei become hollow, shadowy and eventually ghost-like, though nuclear remnants can sometimes still be seen in completely necrotic infarcts. Cellular infiltration is variable and sometimes does not occur at all, again in contradiction to the established descriptions in most textbooks. In general, however, there is a neutrophil infiltration in most infarcts during the first few days, which subsides gradually and is replaced by a mononuclear response within a week or so. These are mainly macrophages clearing up the debris and fibroblasts coming in to lay down new collagen during repair.

By the end of the first week, disintegration of muscle fibres is well under way, and new capillaries and fibroblasts are appearing, though there are many exceptions to this timetable. In general, infarcts are older than most observers think, so that their age is usually underestimated. By the fourth week, depending upon the total size of the infarct – early fibrosis is evident but still with lacunae of necrotic, unrepaired muscle, which heals unevenly and slowly. From this point on there is a variable population of cells, leucocytes diminishing in favour of fibroblasts, macrophages and new vessels.

It is difficult, if not impossible, to date such an infarct even within weeks, and different parts of the same infarct may show quite different appearances. Only when sufficient time has elapsed for all the lesions to catch up with the end stages of firm fibrosis can one say that probably a minimum of about 3 months has elapsed – though again this is dependent on the size and other more imponderable factors, such as age and other concomitant disease.

HISTOCHEMICAL METHODS

In haematoxylin and eosin (HE) staining, increased cytoplasmic eosinophilia is an early form of cellular injury partially resulting from increased binding of eosin by cytoplasmic proteins. At the pH conventionally used in staining, eosin is negatively charged. The binding may increase because of greater exposure of positively charged reactive sites along polypeptide chains after their denaturation. The loss of cytoplasmic basophilia usually reflecting detachment and scattering of polysomes from rough-surfaced endoplasmic cisternae is considered as another cause for the increased eosinophilia.

The intensity of eosinophilia increases, sometimes uniformly, but often in patches with advancing injury. It is earlier and more distinctly seen in HE-stained cryosections and can be enhanced by placing a green filter in the light path of the microscope. Patchy hyperchromasia can be observed in all kinds of deaths and therefore it is of limited diagnostic value. Care must be taken to exclude the occasional thickened areas made by cutting artefacts, which look pinker because of a greater depth of cytoplasm. These early changes are not usually visible in the first 8–12 hours after the (presumed) onset of infarction.

Acid fuchsin (AF) was suggested to be useful for demonstration of early myocardial infarction in man or in animal experiments, but was found to be inconsistent and misleading.

Haematoxylin/basic fuchsin/picric acid stain (HBFP) was claimed to demonstrate early myocardial ischaemia and to be unaffected by post-mortem autolysis. In experiments with isolated cardiac myocytes in suspension made anoxic by complete oxygen deprivation, basic fuchsin was taken up by contracted or damaged myocytes, which, according to their morphology in suspension, revealed irregular contractions, but neither by undamaged nor necrotic myocytes. However, after the first promising reports, contradictory results started to accumulate and the method has been shown to produce inconsistent results and to be unreliable and non-specific and without value for diagnostic purposes.

FLUORESCENT METHODS

Fluorescent methods have been applied to demonstrate early myocardial infarctions and myocardial degeneration in animal experiments as well as in human heart either by using a fluorescent dye, e.g. acridin orange to stain unfixed cryostat sections or paraffin sections or utilizing the fluorescent properties of eosin in the HE-stained myocardium. Intravenously or intraperitoneally injected tetracycline has also been used in experimental infarction for demonstration of the perfused region in myocardium. Carle (1981) claimed that only hypereosinophilic cells autofluoresced, but Badir and Knight (1987) found that myocardium that had normal eosinophilic staining also fluoresced yellow in ultraviolet light; this has been confirmed by Saukko and Knight (1989).

Acridin orange stained cryosections of intact myocardium show golden brown fluorescence which turns into greenish fluorescence with increasing ischaemia time whereas eosin fluorescence of normal myocardium in paraffin-embedded samples show olive-green fluorescence which turns into yellow in injured tissue. Post-mortem autolysis does not seem to have any significant effect on the fluorescence but the high percentage of wrong positive samples indicates that at least eosin fluorescence is obviously too sensitive injury marker capable of demonstrating agonal ischaemic changes.

A major handicap common to all classical histochemical staining methods is that the basis of these colour reactions is poorly understood. Considering the possible legal implications, it is not reasonable to use such diagnostic methods for medico-legal purposes, when their diagnostic significance, to say the least, is questionable and one does not know for sure what the methods are actually measuring.

ENZYME HISTOCHEMISTRY

After Rutenburg *et al.* (1953) had found large amounts of succinate dehydrogenase in the myocardium of various species using blue tetrazolium as hydrogen acceptor, this method was also applied to autopsy material and the inactivation of histochemically demonstrable succinate dehydrogenase was observed in human myocardial infarction. The enzyme histochemical methods became soon widely applied in animal experiments and also to diagnose early human myocardial infarction in autopsy material. Various oxidative enzymes were demonstrated either by incubating thick myocardial slices in a medium containing a tetrazolium salt with or without exogenous substrate and coenzyme (macromethods) or to stain cryosections observed under the microscope (micromethods). It was assumed that enzyme histochemistry might be, at least, a 'semi-quantitative' indicator of the actual biochemical activity of a given enzyme and, therefore, a scientifically more solid biochemical indicator of myocardial metabolism and injury than the previously discussed traditional histochemical methods. In all, the results between individual authors and laboratories have been extremely variable, suggesting that the situation is not that simple. Hiltunen *et al.* (1985) assessed the enzyme histochemical methods, used by the author (PS) in autopsy material, comparing the enzyme histochemical reaction with the actual biochemical acitivity of the enzymes in a global ischaemia model in an animal experiment. The results pointed out that, although the enzyme histochemical methods have been named after the enzymes, the enzyme histochemical reactivity need not necessarily correlate with the actual biochemical activity of the enzyme at all, suggesting that other factors, such as the presence of auxiliary enzyme systems or other co-factors of the histochemical reaction, may be rate-limiting. This brings about the same dilemma as with the conventional histochemistry: unless the biochemical basis of any given enzyme

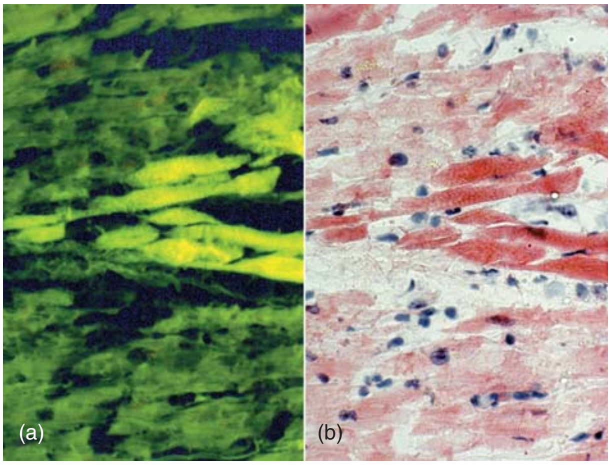

FIGURE 25.7 *Bright yellowish eosin fluorescence of damaged myofibres (a) corresponding exactly with eosinophilia as seen in the HE-stained cryosection (b) of a fresh myocardial infarction.*

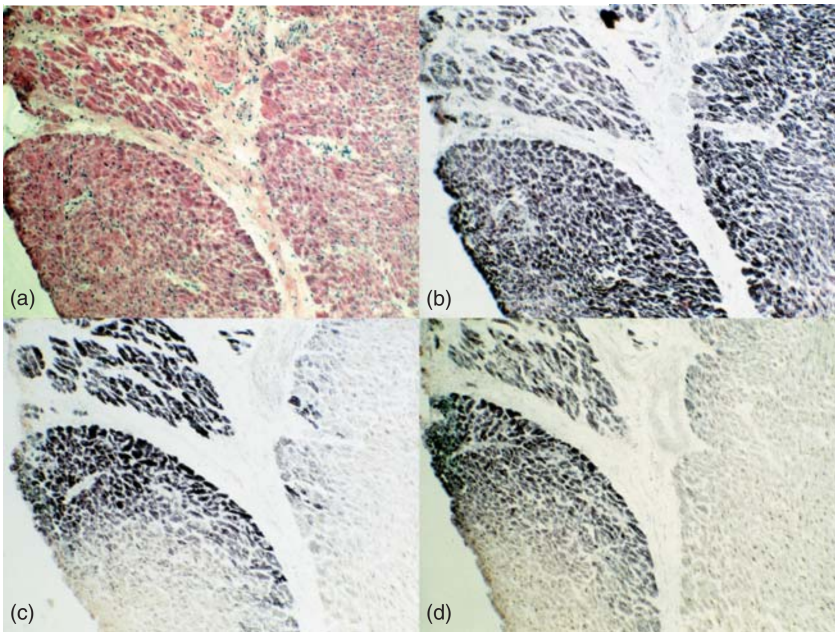

FIGURE 25.8 *The size of a myocardial injury depends upon the method used to display it. These are four serial sections of a heart from autopsy, stained in different ways. Haematoxylin and eosin stained cryosection (a) does not reveal any damage; the adjacent section (b) is stained for malate dehydrogenase activity, and shows strong and uniform reaction. Section (c) is stained for succinic dehydrogenase and reveals a varying degree of enzyme loss in almost all the section, the section (d) on the right stained for* β*-hydroxybutyrate dehydrogenase activity reveals slightly larger area of damage. (Original magnification ×100.)*

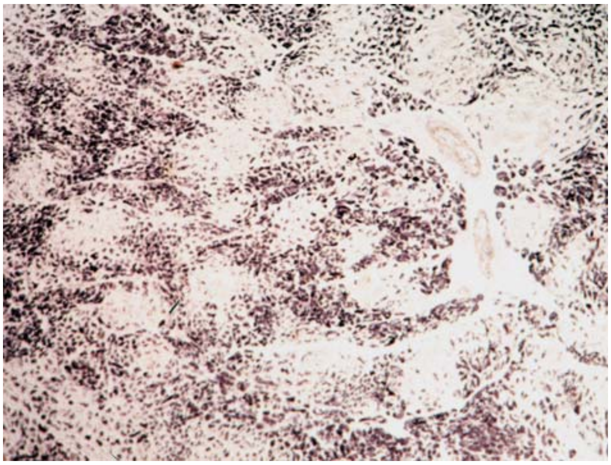

FIGURE 25.9 *Patchy loss of malate dehydrogenase reaction simulating early injury. In fact, the injury was caused by artificially prolonged agonal period due to respiratory treatment and cardiac pacing. It was equally well visible in HE staining emphasizing the necessity of control staining with conventional methods always when more sensitive methods are used.*

histochemical method is thoroughly understood, it is precarious to use it for medico-legal purposes.

IMMUNOHISTOCHEMICAL METHODS

The advances in immunohistochemistry and good results in clinical pathology as well as the availability of a great number of new antibodies have resulted in numerous publications reporting on potential markers of early myocardial injury in both animal experiments and autopsy material. As it has been shown that ischaemia damages cell membrane, contractile proteins, cytoskeleton and subcellular organelles of the myocardium relatively quickly, the search for better diagnostic methods has been directed to various components of the myofibre, e.g. basement membrane (collagen IV, fibronectin, laminin), cytoskeletal proteins (actin, desmin, alpha- and beta-tubulin), cell-matrix focal adhesion molecules (vinculin, talin), membrane-associated proteins (dystrophin, spectrin), terminal complement complex (C5b-9) and fatty acid binding protein (FABP), among many others. In spite of the plethora of publications, the results have been rather contradictory and/or their practicability difficult to assess due to shortcomings in test material or design.

In spite of better insights into the pathophysiology of myocardial injury, the practical problem as to its diagnostic significance as a cause of death has not changed: whenever myocardial injury has been detected, either macroscopically or by using whatever conventional or more sophisticated methods, **it does not necessarily prove that the injury is the cause of death, unless other causes of death have been excluded**. The rule-of-thumb is that the more sensitive methods are used the greater the probability that agonal period and autolytic changes may be difficult to differentiate from intravital changes.

COMPLICATIONS OF MYOCARDIAL INFARCTION

Ruptured heart

Ruptured heart is the most common cause of a haemopericardium and cardiac tamponade, the rupture always occurring through an infarct. The softened, necrotic muscle gives way from the internal pressure of the ventricular blood during systole, there being no equalizing rise in external pressure. Hypertension will increase the risk, but a more potent factor is a senile, soft myocardium, so that the elderly woman is a common victim of a ruptured heart. This by no means excludes younger men if the infarct is extensive and transmural. The most common area for rupture is the more distal part of the free wall of the left ventricle. The septum occasionally ruptures and the consequent left–right shunt, whilst the patient survives, provides a classical diagnostic sign for the stethoscopes of clinicians.

The rupture does not take place in the early stages of a new infarct, but after a day or two when necrotic softening is well established. The blood usually tracks through tortuous channels between muscle bundles, rather than bursting a direct fistula from ventricle to pericardial sac. The infarcted area may not always be obvious, as the haemorrhagic patch may obscure it, but histologically the ragged tissues and the periphery may be seen to be necrosed.

Haemopericardium is the pathological condition found at autopsy and is not quite synonymous with ‘cardiac tamponade’, which is a clinical state caused by the progressive accumulation of blood within the closed pericardial sac. As the external pressure rises, the heart cannot fully expand in diastole to allow filling from the great veins. As input volume falls, so does stroke output. The venous drainage is dammed back so that congestion and cyanosis of the face and neck occur, until a fatal endpoint is reached.

Mural thrombosis

Mural thrombosis almost inevitably occurs when an infarct is based upon the endocardium of the left ventricle. Though there is usually a thin layer of viable (though sick) cells immediately beneath the endocardium, they do not seem to prevent deposition of platelets and fibrin.

The thrombus is often entwined between the muscular bands lining the distal ventricle, which aids its adherence. When extensive, the thrombus may fill the entire apical area of the ventricle. The layers nearest the endocardium are naturally the oldest, and visible strata (lines of Zahn) are often visible. The youngest layers on the surface are less organized and more friable, so fragments tend to break off and form emboli that enter the arterial circulation, and can cause infarcts in kidney, brain, spleen and even the myocardium itself.

Pericarditis

Pericarditis occurs with full-thickness (transmural) infarcts that form the most common cause of pericarditis in Western communities. The visceral pericardium becomes purple–red as a result of the infarct beneath, with a vascular blush on the surface. Granular fibrin deposit causes the surface to lose its glistening sheen, and strands of fibrin may link the visceral and parietal layers together. When healed, fibrous adhesions may form which can obliterate part or even all of the pericardial sac.

Myocardial fibrosis

Myocardial fibrosis has already been described, healed infarcts being replaced by dense collagen, as new muscle cannot be formed. Large plaques from healed infarcts can be anywhere in the left ventricle, depending on the vessel(s) that were occluded. The septum and the posterior wall are more common sites than the anterolateral wall, though the latter is by no means exempt. Often the fibrotic plaques are multiple or irregular, being scattered throughout the ventricular wall.

Diffuse fibrosis is common in elderly people, even when there is negligible coronary narrowing. This may be in part the result of ventricular hypertrophy in hypertension, which causes a relative ischaemia, but many old hearts with no enlargement (indeed, atrophy) reveal patchy fibrosis, either macroscopically or microscopically. In the latter case, the fibrosis is often perivascular in situation.

Cardiac aneurysms

Cardiac aneurysms occur where a large area of fibrosis replaces a previous transmural infarct, usually on the distal part of the free wall of the left ventricle. During systole, the cavity blood presses outwards onto the unsupported area and gradually herniates it into the pericardial sac. A saccular aneurysm develops and may undergo various changes, including calcification of the wall, adherence to the parietal pericardium, or filling with laminated thrombus. The aneurysm wall is tough and fibrous and, though lacking in elasticity, almost never ruptures – again contradicting some of the dicta of pathology textbooks.

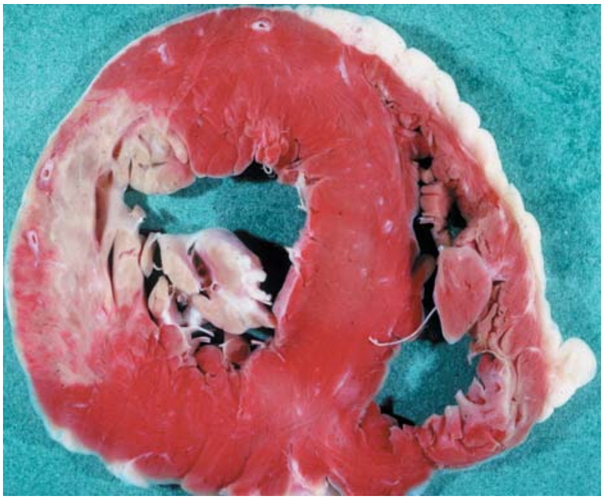

FIGURE 25.10 *An infarct of the lateral wall of the left ventricle of between 5 and 10 hours' duration. It has been rendered visible by staining the heart slice with triphenyltetrazolium chloride, which colours the normal myocardium red by the activity of tissue dehydrogenases. The infarcted area remains unstained. The infarct is virtually transmural, though some subepicardial fibres survive; the papillary muscle is particularly vulnerable, being at the distal end of the coronary supply.*

CAUSE OF DEATH IN CORONARY INSUFFICIENCY

Most sudden deaths from coronary insufficiency do not have myocardial infarction, even when the most sophisticated techniques are employed for its detection. Neither do the majority have a coronary thrombosis, though severe coronary stenosis is by definition present.

The rare case of myocardial infarction with only moderate or even minimal coronary atheroma has to be relegated to the realms of mystery in the present state of knowledge, unless some embolic cause can be found. Some pathologists invoke 'spasm' of the coronary arteries when the vessels show minimal atheromatous stenosis, but this is a hazardous diagnosis for a pathologist to make. Though spasm is certainly seen by clinicians when performing cardiac catheterizations or cardiac operations, it can never be a morphological diagnosis at autopsy, for obvious reasons.

In most sudden 'coronary' deaths, the usual autopsy finding is of severe, long-standing stenosis sometimes with foci of complete occlusion from a ruptured plaque or a subintimal haemorrhage. There may often be partial thrombosis, in that a plaque or narrow segment may have mural thrombus that further narrows the lumen, though does not totally occlude it.

There is macroscopic and microscopic evidence of myocardial fibrosis in many of these cases. This may either be a large plaque of scar tissue at the site of a previous focal infarct or more diffuse fibrosis. There may be fibrosis subendocardially and in the papillary muscles. In many of these sudden deaths there is no naked-eye or even microscopic evidence of any new lesion in the coronary system or myocardium, so why do they die?

Death must be ascribed to a rhythmical defect, rather than loss of mechanical pumping power. Myocardium and especially the pacemaking and conducting system, is vulnerable to ischaemia and hypoxia. Disturbances of rhythm, from ectopic beats to atrial fibrillation through to ventricular fibrillation and cardiac arrest, may occur, as well as heart block and the many other clinical manifestations of ischaemic heart disease from whatever cause. In addition, many victims are hypertensive and left ventricular hypertrophy exacerbates their relative coronary insufficiency. Anyone with a heart weighing more than 450 g is a candidate for sudden death, with or without coronary artery stenosis. The mechanism of this sudden type of death, where there is no large infarct, seems to be a state of electrical instability from chronic hypoxia, so that sudden stresses (such as exercise or emotion) can suddenly cause the arrhythmias mentioned above, though it must be said that death can occur without any of these factors while the victim is asleep or at rest. It is known that the myocardium is sensitive to catecholamines, this being a physiological response to intrinsic adrenergic hormones. Excess catecholamines given parenterally can cause arrhythmias and even contraction-band damage to the myofibrils. Certain other drugs, such as organic solvents, can sensitize the myocardium to even physiological amounts of noradrenaline, leading to ventricular fibrillation and sudden death.

Those with fibrosis in the myocardium may have the additional risk of interruption of the conducting system, which may give some degree of heart block or defect in the spread of the contraction impulse, rendering them more prone to arrhythmias and arrest. This is especially so where a large fibrotic plaque occupies the interventricular septum, as here the left bundle branch penetrates to supply the apical region and may be strangled by dense fibrosis.

Where there is a recent coronary thrombosis, the absence of an infarct may mean that insufficient time has elapsed for it to become apparent, but of course the pumping efficiency will be compromised and the risks of electrical disturbance will already be operating, so that all the problems listed above exist. The other reason for lack of an infarct is an adequate collateral circulation but, even though necrosis is avoided, a new coronary occlusion can only further worsen the ischaemic and hypoxic state of the myocardium, with all the potential consequences of electrical instability.

If there is an infarct, then again all the above dangers exist, but there is the added liability of a loss of mechanical pumping function, which, with a large infarct, may be a substantial proportion of the whole cardiac output, leading to overt low-output failure during which sudden death can supervene at any time. In addition, the risks of sequelae of myocardial infarction, such as rupture and embolism, are ever present.

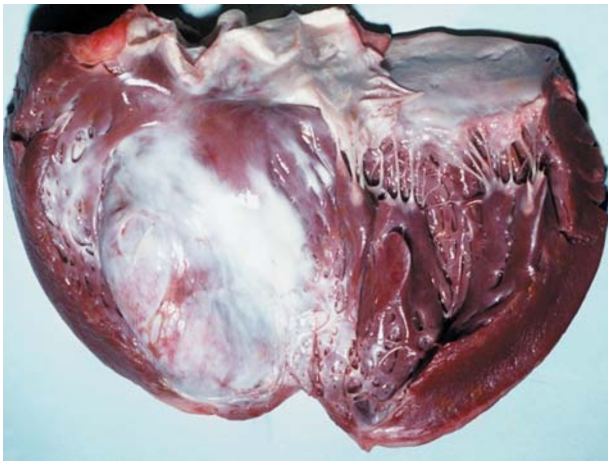

FIGURE 25.11 *Extensive myocardial fibrosis occupying the interventricular septum and apex of the heart with severe occlusive disease of the anterior descending branch of the left coronary artery. Near the apex all the muscle has been replaced by scar tissue. This type of lesion is particularly prone to cause sudden death, as well as clinically apparent dysrhythmias, as the septal fibrosis interrupts the left bundle branch of the cardiac conducting system.*

The role of the conducting system in sudden cardiac deaths is one which is attracting increasing interest, especially as new histological and immunohistochemical techniques are becoming available. A revised sampling technique, described by Song *et al.* (1997), uses longitudinal sectioning, reduces the workload and allows observation of continuity between different components of the cardiac conduction tissue. It demonstrates the sino-atrial (SA) node, the atrio-ventricular (AV) node and the distal part of the His bundle and the bundle branches of the cardiac conduction system in 4–5 blocks. However, although a significant number of abnormalities can be recognized, it is usually difficult or impossible to relate morphology to function. The fact that an AV or SA node, or the bundle of His or its branches shows fibrosis or some other lesion, does not necessarily mean that this played any part in the death. It has been shown that the conducting system is remodelled with advancing age – and many deaths from obvious extracardiac causes reveal lesions in the conducting system when studied at autopsy. Nevertheless, new knowledge now being accumulated about the conducting system may become useful in investigated sudden cardiac deaths, as it is obvious that a high proportion of these fatalities, which have no recent acute lesion demonstrable in the coronary arteries or myocardium, are due to arrhythmias and functional arrest, in which abnormalities of the propagation of the pacing impulse may be important. James (1996) has suggested that apoptosis, the programmed cell death, might be a logical explanation and responsible for histological abnormalities of the cardiac conduction system in sudden deaths due to progressive development of complete heart block and various arrhythmias.

HYPERTENSIVE HEART DISEASE

Hypertension may kill in a number of ways, such as by renal failure, ruptured aneurysm or cerebral haemorrhage, but here we are concerned with primary heart failure, a quite common cause of death. During life, the clinical syndrome of 'cardiac asthma' or 'paraoxysmal nocturnal dyspnoea' is caused by pulmonary oedema from hypertensive left ventricular failure. The same oedema is a marked feature of the autopsy on fatal hypertensive heart disease.

Because there is an aetiological connection between hypertension and coronary atheroma, the two conditions are often present together in a victim of sudden death, making it difficult to separate the myocardial consequences of each component. Sufficient 'pure' deaths from hypertensive heart disease are available where there is no concurrent coronary disease, however, to establish the effect of the former on the myocardium. When the left ventricle has to work against a higher pressure in the systemic arteries, the muscle fibres hypertrophy. They cannot increase in number, but they increase in length and thickness, with irregularity and enlargement of nuclei. This fibre enlargement leads to increase in the mass of the left ventricle, the well-known 'concentric hypertrophy' of hypertension.

If 360–380 g is taken as the upper limit of heart weight for an average size man, then hypertensive disease may produce hearts of 500–700 g. Hearts larger than this usually have some other cause, such as valvular disease or a cardiomyopathy. Though it is sometimes denied that hypertension can cause sudden death, most forensic pathologists would strongly disagree, all having performed numerous autopsies where no other reasonable explanation existed. The usual picture is of marked pulmonary oedema fluid running freely from the cut surfaces of the lungs because of a terminal failure of the left ventricle slightly prior to right ventricular arrest. This causes a rapid rise in pulmonary artery pressure and consequent transudation across the pulmonary alveolar membranes.

There may not always be evidence of hypertension in the often sparse history available at sudden death, but the presence of concentric hypertrophy in the absence of valve disease or a cardiomyopathy – together with characteristic changes in other vessels and organs, such as the kidney – is strong evidence of raised blood pressure. Sometimes the overall weight of the heart may be normal, yet there is relative left ventricular thickening; this again suggests hypertension. In the hearts of aged people, the usual atrophy – with tortuous surface vessels – may be concealed by a left ventricular hypertrophy, keeping the heart at normal weight.

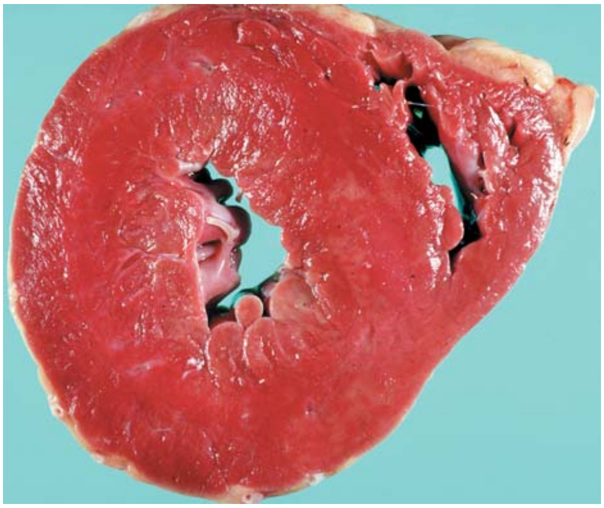

FIGURE 25.12 *Concentric hypertrophy of the left ventricle in a person with cardiomegaly from hypertension. The slice has been stained with triphenyltetrazolium chloride to reveal dehydrogenase activity; some mottled areas, especially in the septum, show pallor from reduced enzyme activity as a result of relative ischaemia of the increased muscle mass.*

The existence of hypertensive heart disease as a specific entity was strengthened by some investigations published by the author (BK) in 1973, in which it was shown that gross enzyme deficiencies exist in the inner part of the wall of the hypertrophied left ventricle. This lesion is not specific to hypertension, but is seen whenever the left ventricle is enlarged, notably in aortic valve disease. In severe instances, the defect in dehydrogenase activity extends from endocardium almost to the epicardium, there being only a narrow zone of normal activity. In some ways this defect is similar to the 'laminar infarct' of coronary artery disease.

In pure hypertension and aortic valve disease, the cause is a relative ischaemia of the inner zone of the ventricular wall caused by insufficiency of coronary blood supply compared with the demands of the thickened ventricular mass. The reason for the laminar distribution is the anatomy of the coronary supply, graphically described by Farrer-Brown (1968, 1977). The various levels or strata of the ventricular wall have different arterial patterns. The subendocardial zone is supplied by arteries with many branching terminations that provide a profuse and concentrated blood supply. A second set of vessels passes straight through the ventricular wall without division – all the coronary supply coming, of course, from the epicardial surface. This set serves the papillary muscles and trabeculae carnae, while a third group tends to run circumferentially parallel and below the epicardium, giving branches both outwards and inwards.

Farrer-Brown found that the termination of these vessels were of two types, as they divided into arterioles and then capillaries. The direction of the tree-like branching in the subendocardial zone continued in the general line of the main artery. The area of myocardium supplied by these branches was small. This was in contrast to the pattern in the midzone of the wall, where the branches turned at an angle to the main artery and then divided to supply a much wider area of myocardium that was supplied by the terminal branch in the subendocardial zone. These anatomical differences suggest that the vessels in the mid-zone each have to supply a larger volume of muscle than in the other layers. This might well explain the greater vulnerability of this central zone to hypoxic changes, as indicated by reduced enzyme activity and the occurrence of laminar necrosis. In actual practice, the inner zone also suffers, apart from the immediate subendocardial layers, but the superficial subepicardial zone is almost always spared. The rationale of damage to the myocardium in hypertensive heart disease, as in aortic stenosis, would appear to be a relative coronary insufficiency. In pure coronary artery disease, part of a normal-sized myocardial mass is rendered ischaemic by localized reduction of blood flow by a coronary stenosis or occlusion, the resulting necrosis being distributed in a focal pattern according to the location of the block.

In hypertensive heart disease, normal coronary arteries attempt to supply a much larger muscle mass, so that there is the same imbalance between supply and demand. As there is no focal blockage, however, the resulting lesion is diffuse and the areas that suffer most are those in the mid- and inner zones, probably because of the microanatomy of the vessels described above. The same type of lesion may be seen in any severe sustained hypotensive episode of extracardiac cause, though the early onset of death in many of these will preclude the development of morphological evidence of laminar myocardial damage.

SUDDEN DEATH IN AORTIC VALVE DISEASE

A similar situation exists with aortic valve disease in which stenosis rather than incompetence can lead to sudden death. Most of the lesions are primarily degenerative, the commonest being ‘idiopathic calcific aortic stenosis’, most often seen in elderly men. Aortic stenosis of rheumatic origin always affects the mitral valve before the aortic, so a solitary aortic lesion cannot be ascribed to rheumatism and is therefore of the primary degenerative type. Rheumatic valve disease is becoming rare, both with the decline in rheumatic fever and the frequency with which valve lesions are treated surgically at an earlier stage, before marked ventricular hypertrophy and its myocardial lesions are evident.

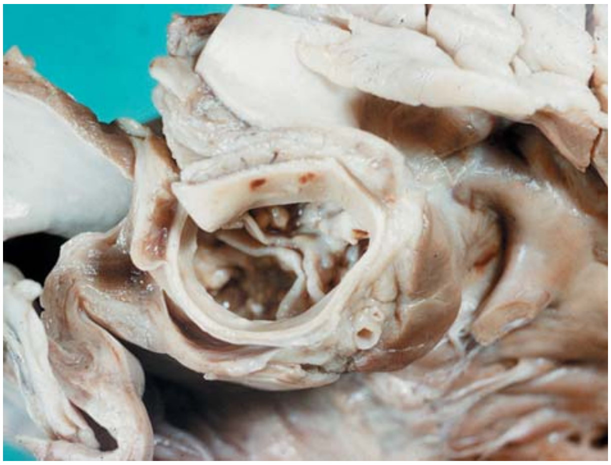

FIGURE 25.13 *Calcific aortic stenosis, a common cause of sudden unexpected death especially in older men. Though the stenosed valves are often biscuspid, the stenosis often deforms normal valves, as in this illustration. Marked left ventricular hypertrophy usually ensues, the large muscle mass becoming ischaemic, especially in the inner layers.*

In the common calcific disease, the valve is thickened and rigid, with fusion of the commissures in most cases. There may be large, irregular excrescences on the cusps and in the sinuses behind. At a later stage, the whole valve may be an almost unrecognizable, chalky mass, with a lumen barely wide enough to admit a pencil. This type of valve may have been biscuspid from birth, a condition that undoubtedly encourages calcific degeneration. Many stenotic and apparently bicuspid valves are not truly bicuspid, however, but appear so because the degenerative process has destroyed or obliterated one of the commissures between the cusps. This may often be demonstrated by the fact that a trace of the commissure may still be seen, or by the fact that the two surviving cusps are not equal in size, the commissures being placed at 120° rather than 180°.

A tight aortic valve, from whatever cause, obstructs the outflow tract of the left ventricle and causes the muscle to hypertrophy in order to eject the same stroke volume through a narrower orifice. In addition, if there is associated regurgitation, further extra work has to be performed to attempt to throw out the refluxed blood.

The effect of a severe aortic stenosis in relation to sudden death is to enlarge the left ventricle to sizes even greater than those seen in hypertension. Some of the biggest hearts (excepting some cardiomyopathies) are seen in aortic valve disease, going up to 800 g or – exceptionally – 1000 g.

Another effect of a tight valve is to lower the perfusion pressure in the coronary arteries, which is made worse if there is also an element of regurgitation. It is the diastolic pressure in the proximal aorta that feeds the coronary supply, as during systole the contraction of the heart prevents flow in the intramural arteries. A less common effect may be the distortion of the coronary ostia by calcific masses in the sinuses of Valsalva and the wall of the root of the aorta, which can partly block the entry into the coronary vessels. The combination of a large myocardial mass and decreased coronary flow is often made worse by concomitant coronary atherosclerosis, so the propensity of victims of aortic valve disease to drop dead is considerable. Elderly men are the most frequent victims. Lesions of other heart valves seldom cause sudden death as an isolated cause, though the more chronic cardiac dysfunction – mainly congestive cardiac failure – caused by them may end life rather abruptly on occasions. Rheumatic mitral stenosis is one such lesion, but perhaps a more direct mitral cause of sudden death is the 'floppy' valve usually seen in old age.

SUDDEN DEATH FROM THE CARDIOMYOPATHIES

There is a heterogenous group of diseases of myocardium associated with cardiac dysfunction known as the 'cardiomyopathies', which, though of mixed and often uncertain aetiology, have sufficient in common pathologically to merit a special identity. As they account for the second largest number of sudden deaths after coronary artery disease, i.e. about 10–15 per cent of all sudden deaths of cardiac origin, they are briefly described here, though specialized texts and papers on cardiac pathology should be consulted for details. The outstanding feature is a large heart in the absence of hypertension or valve lesions. The victims are usually young adults, partly because in older groups in which there is atherosclerotic coronary disease and also hypertension, these overlay the cardiomyopathy and make the diagnosis difficult or impossible. The only exception is if there is definite histological evidence or if the heart weight is excessive (over 700 g) in the absence of a valve defect. Cardiomyopathies are the most common cause of heart failure and are an important cause of death in children and adults. According to the Report of the 1995 World Health Organization/International Society and Federation of Cardiology Task Force on the Definition and Classification of Cardiomyopathies, they are classified into the following main types: dilated, hypertrophic, restrictive and arrhythmogenic right ventricular cardiomyopathy.

Dilated cardiomyopathy (DCM) is the most common cause of congestive heart failure. The annual incidence varies, depending on the diagnostic criteria, from two to eight cases per 100 000. Around 30–40 per cent of them are familial (FDCM), but it may also be idiopathic, viral, immune or toxic, e.g. alcoholic. Idiopathic dilated cardiomyopathy (IDCM) is characterized by dilated ventricular chamber and reduced contractility without coronary, valvular or pericardial disease. Histology is non-specific; however, viral genome has been identified in 10–34 per cent of patients with dilated cardiomyopathy.

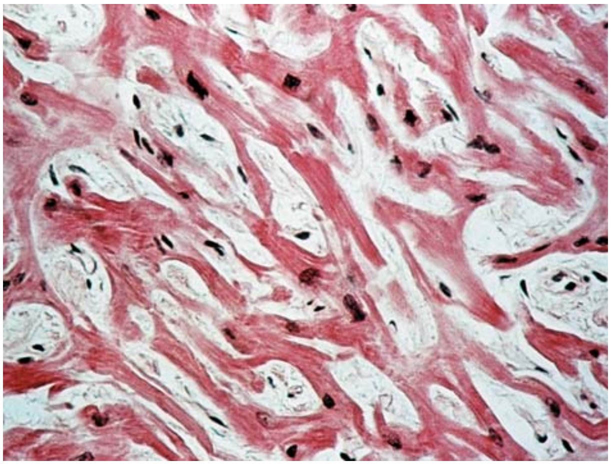

FIGURE 25.14 *Myofibre disarray in hypertrophic cardiomyopathy.*

Hypertrophic (obstructive) cardiomyopathy was first described in medicolegal autopsy material by a London forensic pathologist, Donald Teare, in 1958. Although he noted and described asymmetrical hypertrophy of the interventricular septum, so that a bulging pad of myocardium partly obstructed the left ventricular outflow tract, this cardiomyopathy is predominantly (75 per cent) a non-obstructive disease and, hence, hypertrophic cardiomyopathy (HCM) is now the preferred name. It is a primary sarcomere disorder characterized by left and/or right ventricular hypertrophy and, in most cases, inherited as a predominantly autosomal disease. It is caused by mutations of any of the genes encoding the proteins of the cardiac sarcomere.

Between 20 and 30 per cent are familial, and the condition may occur at any age from infancy to senility, though the majority of deaths occur in early middle age. The weight of the heart may range from a high normal at 400 g, to 800 g or even a kilogram. More striking than the total weight is the left ventricular preponderance, which is often maximum in the proximal septum, as described above.

Histologically the myocardium shows irregular-sized, large fibres with nuclear pleomorphism. Though once thought to be a rhabdomyoma or a hamartoma, or aberrant adrenergic tissue, the septal bulge usually shows a bizarre pattern of fibres, with loss of the orderly strata and replacement by a criss-crossing, confused architecture of muscle bundles. Interstitial fibrosis is common, and – though there may be an increase in interstitial cellularity – inflammatory infiltrate is not seen, as it would be in an active myocarditis.

Restrictive cardiomyopathy is, according to the WHO report, 'characterized by restrictive filling and reduced diastolic volume of either or both ventricles with normal or near-normal systolic function and wall thickness. Increased interstitial fibrosis may be present'. It may be idiopathic or associated with other diseases such as cardiac amyloidosis, cardiac haemochromatosis or endocardial fibroelastosis with or without hypereosinophilia.

Arrhythmogenic right ventricular cardiomyopathy (ARVC) is a primary myocardial disorder characterized by progressive fibrofatty degeneration of right ventricular myocardium, arrhythmias and risk of sudden death. In addition to familial autosomal-dominant disease with variable penetrance and polymorphic phenotype, two autosomal-recessive forms of ARVC are known.

The WHO classification includes further two groups of cardiomyopathies:

- specific cardiomyopathies that are associated with specific cardiac or systemic (ischaemic, valvular, hypertensive, inflammatory, metabolic, general systemic e.g. connective tissue or neuromuscular disorders) and
- unclassified cardiomyopathies, which do not fit readily in any group, e.g. fibroelastosis or isolated non-compaction of the ventricular myocardium (INVM), a rare disorder characterized by excessively prominent trabecular meshwork, ventricular arrhythmia and systemic embolism.

Myocarditis

Many infective diseases produce an acute myocarditis, which may be the immediate cause of death. A prime example is diphtheria, but this has virtually no forensic relevance. More important is 'isolated myocarditis', where the condition is primary and usually of unknown aetiology. It was formerly [and some recent results from an ongoing study by the author (PS) suggest, that it still is] a much-used and overused autopsy diagnosis, especially where no gross lesions could be found. Known by a variety of names, such as 'Fiedler's' or 'Saphir's' myocarditis, its incidence was said to be appreciable in victims of sudden death – and it was incriminated as the cause of accidents on the road and in the air that had been attributed to driver or pilot incapacity. In forensic pathology some 20–30 years ago, it became a 'fashionable' diagnosis on rather equivocal histological criteria. It was then found that many victims of trauma where death was rapid and where cardiac incapacity could not possibly be a causative factor in the accident, also had foci of mononuclear cells in the myocardium.

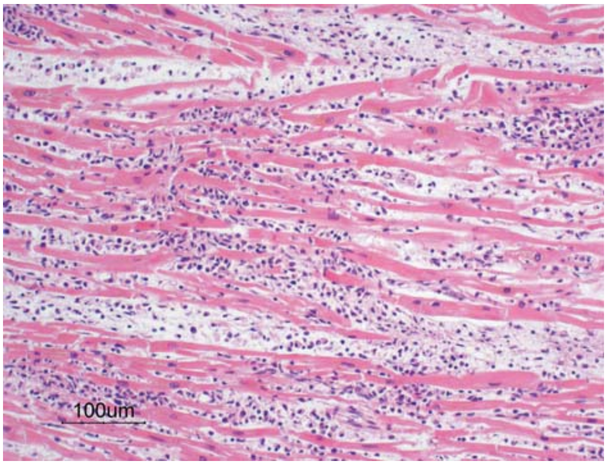

FIGURE 25.15 *Severe diffuse lymphocytic myocarditis with destruction of myocytes. (HE, original magnification ×10.)*

Stevens and Ground (1970), after finding six cases of myocarditis in 263 air pilots, when none of them could have been affected by a cardiac event, looked at a considerable number of other accident victims in circumstances in which disease was obviously unrelated to the trauma. They found about 5 per cent of young men had lesions otherwise histologically acceptable as 'myocarditis' and concluded that it was an unsafe diagnosis to use for the cause of death. Their histological minimum criteria for acceptance was one focus of 100 or more cells or many foci of half that size. Groups of lymphocytes, especially subepicardial of 40 or fewer cells, were disregarded.

In Australia, Tongue *et al.* (1972, 1977) did similar studies, but used whole transverse sections of ventricles at up to 18 levels in each heart. Their results showed that the more extensive the search, the greater the number of foci discovered in deaths that had no circumstantial relation to a sudden cardiac death. Using 18 full sections, they found that 90 per cent of the accident victims had 'myocarditis' lesions and suggested that, if the search was extensive enough, it could probably be brought up to 100 per cent.

The Dallas Classification System was proposed by eight cardiac pathologists in an attempt to provide the practicing pathologists with easily applicable and uniform criteria for the diagnosis of myocarditis in endomyocardial biopsies (Aretz *et al.* 1987). By this definition, the diagnosis of myocarditis can be made only if myocyte necrosis or degeneration or both are associated with an inflammatory infiltrate adjacent to the degenerating or necrotic myocytes. A semi-quantitation of the amount of inflammatory infiltrate was suggested as mild, moderate, or severe and its distribution characterized as focal, confluent, or diffuse. The composition of inflammatory infiltrate, i.e. the presence of lymphocytes, neutrophils, eosinophils or giant cells was suggested for differential diagnosis of the aetiology. According to Feldman and McNamara (2000) the Dallas criteria probably underestimate the true incidence of myocarditis.

Among the great variety of infectious agents, viruses have been considered as important cause of myocarditis. The molecular biological techniques such as polymerase chain reaction (PCR) and *in situ* hybridization have provided new diagnostic possibilities and viral genome has been detected both in myocardial biopsies as well as in autopsy material. However, the detection rate and the viruses identified have varied markedly according to the study. In addition, drugs may cause myocarditis, either through direct toxic or immune-mediated mechanism.

Probably, the position now to be accepted is that unless multiple, florid foci are found, with myofibril necrosis seen, using special stains if necessary, bland mononuclear foci that are purely interstitial and not involving muscle fibres must be disregarded. The presence of myofibre necrosis, however localized, would appear the most important confirmatory criterion. Where stenotic coronary artery disease exists, it can be difficult or impossible to differentiate the resulting cellularity, fibrosis and fibre necrosis from that of a myocarditis.

A disease process that may well have been underestimated in the pathology of sudden death is cardiac sarcoidosis. Unless routine histology is carried out on every sudden death, this diagnosis will be missed (Fleming 1988) as will a considerable number of myocardial amyloidoses, which need special stains.

DEATH IN OLD AGE – THE SENILE MYOCARDIUM

In many autopsies on old persons, no specific lesions can be discovered that provide a clear cause of death. In the increasingly aged population of the developed nations, this problem becomes a more frequent task for the pathologist. The history of the mode of death then becomes particularly important, as it may give some clue as to which area of the indeterminate lesions should be given priority in deciding on a cause of death. For instance, if there is moderate coronary artery disease, then if the person died with sudden breathlessness or chest pain, rather than slowly fading away, more credence would be given to the coronary lesions. Many old people have good, patent coronary arteries, however, even if the walls may be calcified – if they did not have such good vessels, they probably would not have lived to 88 or 95 years, anyway.

Where nothing other than general senile atrophy of most organs is found and the history is unhelpful as to a specific mode of death, as long as the pathologist can exclude any unnatural cause, then it is quite legitimate to ascribe the death to ‘myocardial degeneration due to senility’. The WHO’s ICD-10 (International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Geneva 1992) provides a code for such a disease even though many cardiac pathologists seem reluctant to agree to its existence, wishing always to find some more specific disease process. In the authors’ view, senile myocardial degeneration is quite acceptable, given exclusion of other causes. Senile hearts are usually small, but hypertension may have enlarged the ventricles long ago and the residual effect of this may be to sustain the heart at a normal weight. More important is the appearance of the heart, which is brown on the surface and in the muscle and is flabby and soft. The thumb can be pushed into such muscle at autopsy without difficulty. The weight may be down to 300 g or even 250 g, if no previous hypertrophy has existed. A good indication of cardiac atrophy is the presence of tortuous coronary vessels on the epicardial surface, especially the anterior descending branches. These may meander markedly, as the myocardium has shrunk, the apex has contracted nearer the base and so the vessels have to corrugate to fit into the diminished space.

Microscopically, the myocardial fibres are uneven in size, there may be a fine, diffuse fibrosis, which is not ischaemic in origin and the nuclei of the myocytes have prominent clumps of lipofuscin pigment at their poles. Unfortunately, none of these features is diagnostic of the cause of death, as other old persons dying of quite unrelated causes, such as trauma, might have equally poor heart muscle.

The justification for considering that senile myocardial degeneration is a valid cause of death comes from the species life span of different animals. Even without lethal specific disease, each species has a fairly uniform life span, the human being some 70–90 years. No one lives to 150 years, so there must be some limiting factor; as cardiac function is the most immediate arbiter of survival, it seems reasonable to indict heart contractibility as the primary factor. All tissues age, but senility of the spleen or thumbs does not have the immediacy for life support possessed by the myocardium.

SUDDEN DEATH FROM RUPTURE OF AN ANEURYSM

The most frequent extracardiac cause for sudden death arising in the cardiovascular system is a rupture of an aneurysm, almost always of the aorta or a cerebral vessel. Aortic aneurysms are of three types, all capable of catastrophic rupture.

The atheromatous aneurysm

The atheromatous aneurysm is the most common and is seen mainly in the abdominal segment of the aorta. Though atherosclerosis affects the whole length of the aorta, it is usually worse below the diaphragm, probably because of the haemodynamic effects of the larger branches that come off in this segment. Turbulence and 'Venturi' effects are known to localize the development of fatty streaks and atheromatous plaques, as they are seen first around the ostia of the intercostal vessels and become particularly severe at the major bifurcation into common iliac arteries. Though aneurysms can develop at any point in the aorta, most are below the diaphragm. Excepting dissecting aneurysms, however, any aneurysm in the thoracic segment is still more likely to be atheromatous than syphilitic, even though syphilis is virtually confined to the aortic arch. Most atheromatous aneurysms are fusiform or saccular, the bulge being either symmetrical about the axis of the vessel or more commonly bulging out more on one side than the other. Progressive destruction of the media by the fibrolipid degenerative processes of atherosclerosis leads to weakening of the aortic wall. Bulging caused by the continuous internal blood pressure begins, aided by the hypertensive tendencies of later life. The damage or complete destruction of the intima leads to platelet and fibrin deposition, so that mural thrombosis is laid down in the expanding aneurysm. This may partly or wholly fill the sac, being many centimetres thick in some instances, with well-marked stratification called the 'lines of Zahn'. The wall of the aneurysm may contain calcific fragments similar to the adjacent artery wall.

Most aneurysms remain intact throughout life and are found as incidental findings at autopsy. Naturally the incidence of ruptured aneurysms is greater in medico-legal autopsies by reason of the selective population of sudden deaths. When rupture occurs, the weakest point of the wall is penetrated by the contained blood and this usually leaks out into the retroperitoneal tissues, rather than free bleeding into the peritoneal cavity. The blood tracks behind the root of the mesentery and around the kidney. A large perirenal haematoma may form but, more often, the obvious site of bleeding is in the centre of the back of the abdomen. The diagnosis is usually quite obvious as soon as the autopsy begins for, as soon as the abdomen is opened and the intestine moved aside, a dark red mound may be seen projecting forwards over the lumbar spine, bulging at the root of the mesentery.

The development of a successful technique for the repair of many such arterial defects has reduced the death rate, though there is a substantial perioperative mortality, often because the patient is virtually moribund when the operation begins, or because gross calcification and degeneration of the remaining aortic wall makes it technically impracticable.

The dissecting aneurysm

Rupture of a dissecting aneurysm of the aorta is much less common than the atheromatous variety and seems to have decreased even more during the past decade. It is still by no means an uncommon cause of sudden death, however, and is the second most frequent cause of a haemopericardium and cardiac tamponade. Whereas atheromatous aneurysms are usually in the abdomen, the dissecting aneurysm can span the whole length of the vessel from iliac artery to aortic valve, though the main effects are usually manifest in the thoracic segment.

The basic lesion is a degeneration of the aortic media, the so-called 'medionecrosis'. The thick elastic media becomes degenerate and cystic in the central layers, producing a vessel wall like a sandwich with a soft cleavage plane in the middle. This defect is of unknown aetiology and affects both the elastic and muscular elements of the media. It is relatively common over the age of 50, especially in men. Many aortas seen at autopsy have this degeneration, but no aneurysms, as they never develop because the blood fails to enter the potential cleavage space from the lumen of the aorta.

In most cases where a dissecting aneurysm has caused death, the blood has broken through from the lumen through a tear in an atheromatous plaque, which is a quite separate disease process existing in parallel with the medionecrosis. When blood enters the medial cleft under high arterial pressure, the two layers of the media are split apart and the dissection may rapidly travel both upwards and downwards in the aortic wall. The upper component may split its way around the arch and beyond the attachment of the pericardium. Here, just above the aortic ring, the dissecting haemorrhage often bursts through the remaining outer media and adventitia into the pericardial sac. This causes a massive haemopericardium and the cardiac tamponade described earlier in relation to ruptured myocardial infarct. The distal extension may travel down to the iliac and even femoral arteries, sheathing them in blood. Rarely, in a patient who survives a dissection, the secondary lumen formed in the cleavage plane may rupture back into the main aortic lumen, thus forming a 'double-barrelled' aorta, a curiosity occasionally found at autopsy. Death usually occurs from cardiac tamponade, but some dissections do not burst into the pericardium. Here death is by a less obvious mechanism, which may be partly the sudden narrowing of the aortic lumen and pressure on the coronary ostia and roots of the coronary arteries. In persons under 50 years of age, there is a much less common alternative cause of medionecrosis, known as Erdheim's degeneration. This is sometimes called 'mucoid medial degeneration' and is associated with Marfan's syndrome, an inherited condition characterized by arachnodactyly and optic, aural and bony lesions.

The syphilitic aneurysm

Syphilitic aneurysms are now uncommon, because of the relative rarity of tertiary lesions as treatment is available for the

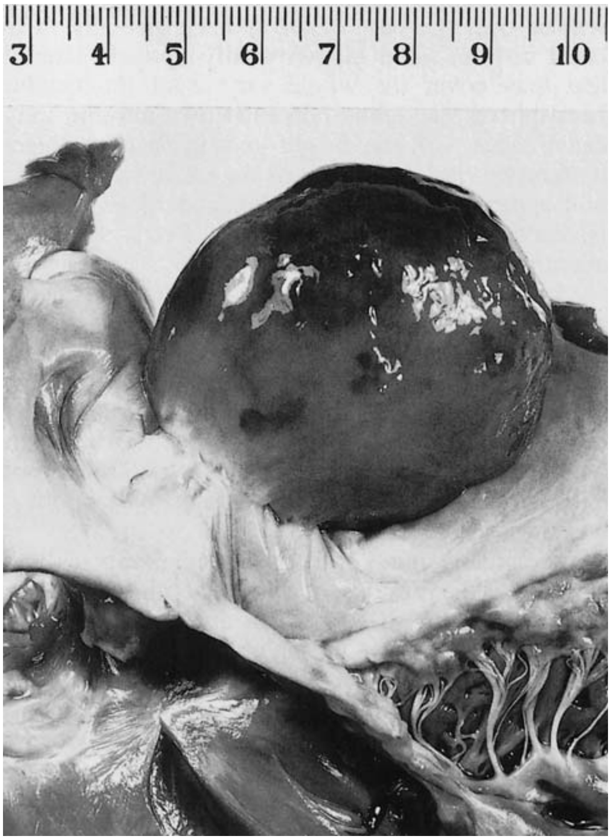

FIGURE 25.16 *Sudden unexpected death caused by a myxoma of the left atrium. The ball-shaped mucoid tumour impacted in the mitral valve during a postural change. No other cause of death was discernible.*

earlier stages of the disease. In some areas of the world, however, tertiary syphilis is not the rarity it has become in Europe and America.

The syphilitic aneurysm of the aorta is almost always in the thoracic segment and usually in the arch. Syphilitic aortitis, which precedes an aneurysm, may be recognized in the lining of the thoracic and abdominal aorta by its irregular corrugated pattern, though admixture with atheroma can obscure the classical appearances. There tend to be sinuous linear folds, like coarse wrinkles, which have been likened to the bark of an oak tree. If the aorta dissected free of adherent connective tissue is held up to a strong light, 'Gough's test' may be applied, in which translucent windows can be seen in the media. When confluent, these weak patches allow the internal blood pressure to blow out an aneurysm and the syphilitic bulge can be the largest of all, sometimes almost filling the upper part of the chest. The wall is thin and fragile, and there may be several separate bulges from overlapping aneurysms.

Pressure may erode bronchi, oesophagus, pulmonary vessels, lung and even the thoracic cage. The latter may allow the aneurysm to become subcutaneous and, in former years, the external bursting of a pulsating chest tumour must have been a dramatic event. The usual mode of rupture is into the pleural cavity or into the oesophagus or bronchus, giving rise to a sudden, massive haematemesis or haemoptysis. Histologically, it may be impossible to confirm syphilitic aortitis, as the reactive phase of the disease may have been long burnt out, but the gross pathological appearances are diagnostic in themselves.

Fatal aneurysms of other vessels

Fatal aneurysms of other vessels are rare, apart from the cerebral arteries. Atheromatous bulges can occur on the iliac and femoral vessels, and sometimes in the mesenteric arteries. Polyarteritis nodosa can produce mini-aneurysms from the inflammatory process eroding the wall, but death is not caused by the direct effects of rupture, but by vascular problems in the coronary, renal and other arteries. Infective mycotic aneurysms are rare in civilian practice, as are traumatic arteriovenous fistulae, but are not uncommon in war casualties.

Sudden death from ruptured cerebral aneurysm

The relationship of head and neck injury to subarachnoid haemorrhage is discussed in Chapter 5, but here we are concerned solely with spontaneous rupture of an aneurysm of the circle of Willis at the base of the brain. This is one of the most common causes of death in young to middle-aged adults, if coronary disease is excluded. In women, who are relatively immune from coronary occlusion up to the fifth decade of life, ruptured berry aneurysm is proportionately much more common than in men. It is a useful rule-of-thumb, when presented with the sudden death of a woman of child-bearing age, to consider a complication of pregnancy, self-poisoning, pulmonary embolism and subarachnoid haemorrhage as the first choices.

Subarachnoid bleeding can cause virtually instantaneous death, even though the mechanism is obscure. Numerous cases have been described where a previously fit person was seen to collapse and was apparently already dead when attended by onlookers. There must be an element of cardiac arrest in these examples, caused by the sudden bathing of the brainstem in blood from a jet of arterial blood impinging on the base of the brain. As with coronary disease, arterial spasm has been invoked as a cause of the sudden death in ruptured berry aneurysm, without any proof. Most cases of subarachnoid haemorrhage have a much longer course, with clinical symptoms and signs allowing either surgical intervention or, often, spontaneous resolution.

We are by definition here, however, concerned with sudden or rapid fatalities. In the usual coroner's case, the victim is either found dead with no available history, or has died rapidly and inexplicably, or has expired after suggestive symptoms like severe headache and rapid coma. Many die after physical or emotional exertion, especially sexual intercourse or strenuous sporting activity. Those that occur during or soon after some assault or altercation are dealt with in the chapter on head injuries (Chapter 5), and can pose a major forensic problem concerning causation.

At autopsy, the diagnosis of subarachnoid haemorrhage is self-evident. As the usual point of bleeding is in the circle of Willis, the most dense haemorrhage will be over the base of the brain, especially in the basal cisterns. The blood usually spreads laterally and may cover the whole surface of the cerebral hemispheres, the hindbrain and down into the spinal canal. This will be bright red in a fresh bleed; if survival lasts a week or so, a brownish tinge will appear as the haemoglobin undergoes changes. Haemosiderin can be detected by Perl's stain after about 3 days.

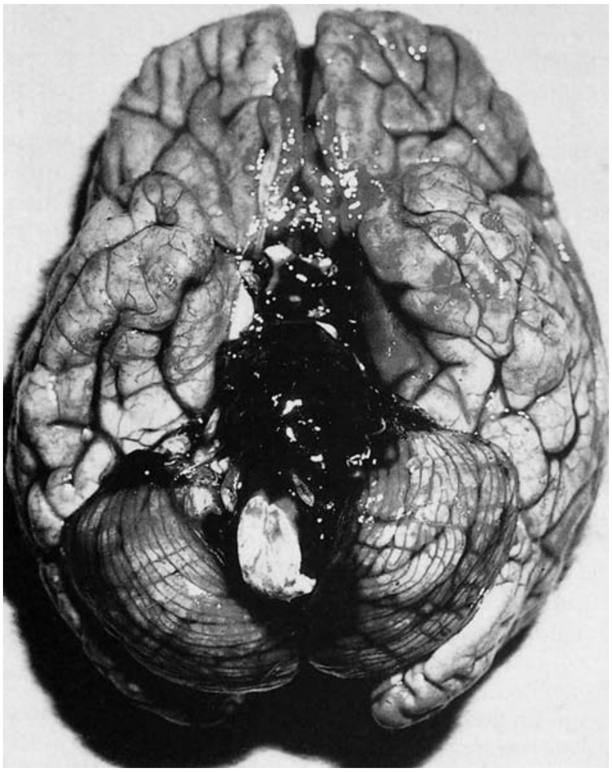

FIGURE 25.17 *A dense basal subarachnoid haemorrhage that caused rapid death. The blood clot filling the basal cisterns conceals a ruptured berry aneurysm of the circle of Willis; at autopsy, this must be removed under a stream of water, using careful blunt dissection to avoid further damage to the vessels.*

The detection of the source of the haemorrhage is sometimes difficult. An aneurysm is present in about 85 per cent of spontaneous subarachnoid haemorrhages, but the remainder reveal no aneurysm, even after an exhaustive search. This may be because of destruction of a small aneurysm at the time of rupture, but it is just as likely to be a leak from a vessel without an aneurysm, as a result of the existence of a point of weakness as described below.

A relatively rare cause of bleeding, especially in children, is the presence of a vascular malformation in the arterial system, such as an angioma, an arteriovenous anastomosis, or an aberrant vessel in the meninges. Post-mortem angiography may be of assistance in tracing intracranial bleeding from natural lesions, as in trauma. Karhunen *et al.* (1990) describe the techniques required.

Though berry aneurysms are often called 'congenital', they are not themselves present at birth, but a defect in the wall of a cerebral artery is probably present from late fetal life. The circle of Willis condenses out of an irregular embryonic meshwork of arteries over the base of the brain by unwanted vessels undergoing atrophy. Where these redundant vessels originally joined the surviving main arteries, a 'window' in the elastic and collagenous coat is left, usually at the junction of two vessels. This window is a weak point where rising blood pressure in adult life may begin to form a 'blow-out', a thin-walled aneurysm, which may be single or multiple. At a certain stage, any sudden extra rise in blood pressure or flow rate may rip the already tense sac, and cause extravasation of blood at full arterial pressure into the subarachnoid space. Where there is no aneurysm, it must be assumed that a weak point in a vessel wall has given way *ab initio*, without the prior formation of a sac.

The search for a small aneurysm at autopsy may be difficult because of the thick layer of blood clot that is trapped in the meninges and vessels. Blunt dissection should be used, employing the handle of a scalpel or the nose of a pair of forceps. The blood should be constantly washed away in a continuous stream of water. It is possible to inject water into one of the cut ends of a vertebral artery, having carefully tied or clamped the other vessel and the two cut terminations of the carotid arteries, to see where the water leaks from. The leaks are often multiple, however, from artefactual tearing of small vessels during autopsy removal of the brain. The search for an aneurysm is best carried out on the fresh unfixed brain, as formalin fixation hardens the blood clot so much that it cannot be removed without the danger of tearing the underlying vessel and any aneurysm. It is essential to carry out blunt dissection progressively in a continuous stream of water. Aneurysms are most often found at the bifurcation of the middle cerebral and posterior communicating arteries, at the bifurcation of the basilar arteries, on the middle cerebral in the Sylvian fissure, on the anterior communicating artery, or where the posterior communicating artery joins the posterior cerebral vessels. An aneurysm is sometimes on the cortical aspect of the artery and may be part-buried in the cerebral surface, making it hard to find. If the swelling (which may be completely collapsed at autopsy, especially when ruptured) is not seen on superficial examination of the circle of Willis, the vessels should be gently lifted away from the brain surface with a blunt elevator so that the underside can be inspected. Sometimes a buried aneurysm will rupture mainly into the cortex, causing a lesion that may be mistaken for an intracerebral haemorrhage. Berry aneurysms are frequently multiple and of varying size, from a few millimetres to several centimetres, though the usual diameter is of the order of 3–8 mm.

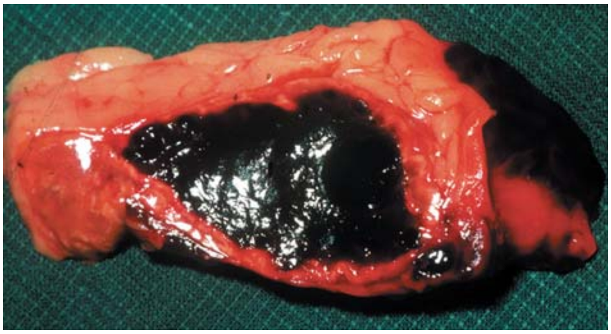

FIGURE 25.18 *Adrenal haemorrhage occurring several days after multiple injuries sustained in a traffic accident. There was no apparent abdominal injury. The haemorrhage is fresh and occupies the medulla, with the cortex stretched around the periphery.*

PULMONARY THROMBO-EMBOLISM

This is discussed fully in Chapter 13, but here it is sufficient to emphasize that pulmonary embolism is the most underdiagnosed cause of death, according to Cameron and McGoogan (1981). Their figures show that less than half the deaths shown at autopsy to have been caused by a pulmonary embolism were so diagnosed by the attending clinician. Paradoxically, many other presumed deaths from this condition were found at autopsy not to have been embolic. Thus the overall statistics are not so much in error – but in relation to the wrong victims!

Pulmonary embolism is more common with advancing age, with obese subjects and in the majority of instances there is a predisposing factor such as trauma, surgical operation, confinement to bed or immobility from another cause. Even prolonged sitting can lead to deep vein thrombosis, as was seen in persons sleeping in deckchairs in air-raid shelters in the last war and, more recently, it has been described as a hazard of long air flights.

A significant proportion, however, estimated by the author (BK) at up to 20 per cent, occur unexpectedly in the absence of any of these usual factors, making the legal problem of causation difficult. This is especially so in criminal cases where a high standard of proof has to be

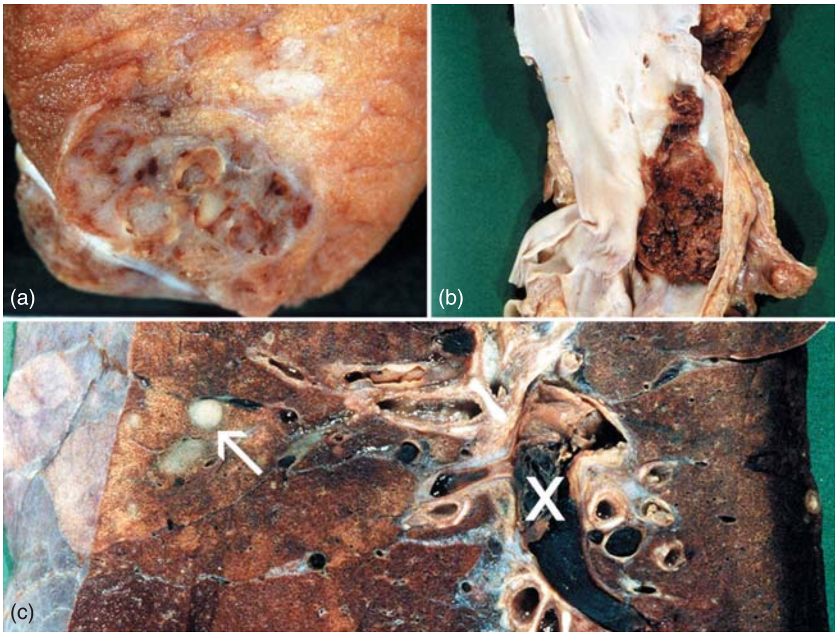

FIGURE 25.19 *A rare cause of pulmonary embolism. Metastasizing embryonal carcinoma + seminoma of the testis (a) and thrombosis attached to the wall of inferior vena cava due to metastases of the local lymph nodes (b) and (c) pulmonary metastasis (white arrow) and massive pulmonary embolism (white X).*

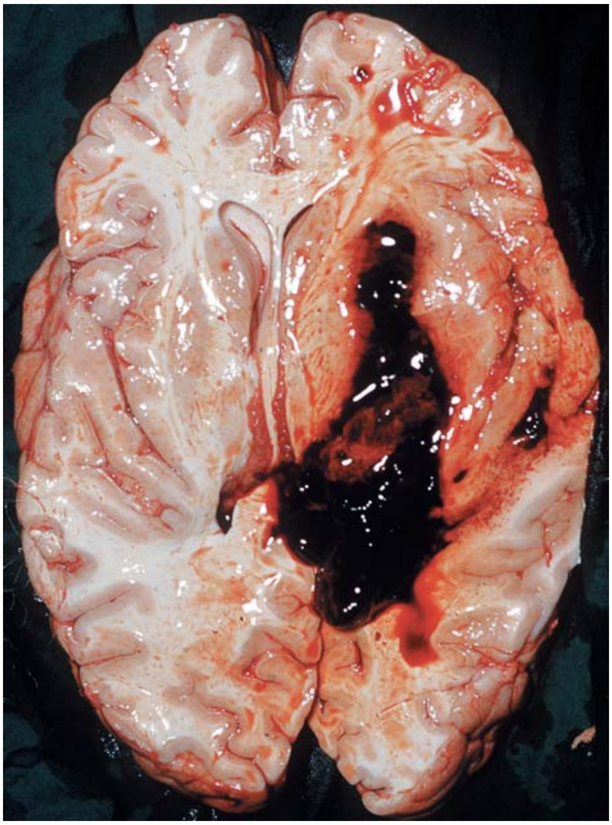

FIGURE 25.20 *A large recent intracerebral haemorrhage in a person with hypertension. The bleeding has originated in the region of the external capsule from a lenticulostriate branch of the middle cerebral artery then broken through into the posterior horn of the lateral ventricle.*

attained, rather than the balance of probabilities required for a civil action.

SUDDEN DEATH IN EPILEPSY

Every coroner's pathologist or the equivalent in other jurisdictions, has experience of sudden deaths in epileptics, when no morphological lesion can be found at autopsy. Epileptics can die unexpectedly without being in status epilepticus – or indeed, not even in a typical fit. It is true that many such deaths are not witnessed to prove that no such fit occurred, but sufficient evidence exists to indicate that a rapid sudden death can certainly occur.

There are, of course, many deaths in epileptics where the mode is apparent, such as asphyxia during a fit in bed when the face is pressed into the pillow, and saliva and mucus form an airtight seal against the fabric around the nose and mouth. Epileptics also drown in the bathtub and suffer other traumatic deaths because of fits occurring when they are in some vulnerable position.

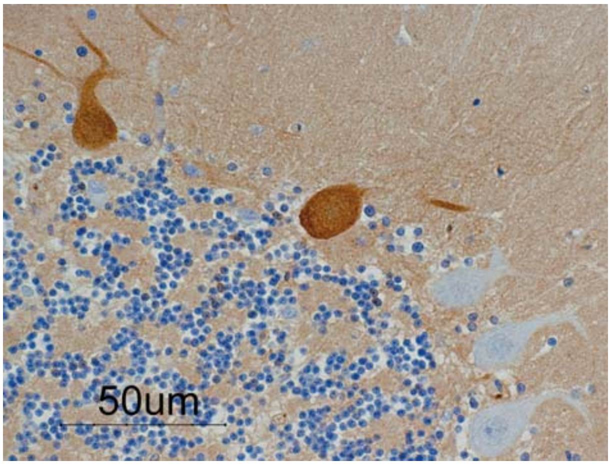

FIGURE 25.21 *Two fibrinogen-positive Purkinje cells and three negative cells in a sudden unexpected death with a history of epilepsy. (Peroxidase-DAB immunostaining, original magnification ×20.)*

These causes apart, the victim of epilepsy seems to be able to die with no apparent immediate cause and the mechanism is obscure. It has been suggested that some massive cerebral electric discharge or neurone storm occurs, leading to cardiac arrest, but this is mere hypothesis. When all investigations have been completed (including toxicological screening for antiepileptic drug overdose), after an essentially negative autopsy, then the pathologist is justified in recording 'epilepsy' as an acceptable cause of death.

The autopsy should always include a search for bites on the tip and distal sides of the tongue, which suggest a fit. A careful examination of the brain is essential, to search for any cause of post-traumatic epilepsy. In some epileptics, without coronary stenosis, patchy myocardial fibrosis has been recorded (Falconer and Rajs 1976), said to be the result of episodic hypoxia from apnoea during fits. Based on the observation of Sokrab *et al.* (1988) that Purkinje cells become labelled by plasma proteins in experimental blood–brain-barrier (BBB) breakdown, Ikegaya *et al.* (2003) investigated immunohistochemically the presence of fibrinogen-positive Purkinje cells in 50 sudden unexpected deaths. There were 24 subjects with and 26 without known history of epilepsy. Regarding ⩾30 per cent of fibrinogen-positive Purkinje cells as diagnostic limit indicating recent major BBB breakdown, they found that 22 of the 24 cases with high percentage of fibrinogen-positive Purkinje cells had a history of epilepsy. One of the two remaining high-fibrinogen subjects had unknown leucoencephalopathy and the other had essential hypertension. Only two of the low-fibrinogen cases had a history of epilepsy. The immunopositivity of Purkinje cells is not specific for epilepsy but can occur in any conditions causing BBB breakdown, most likely due to uptake of fibrinogen

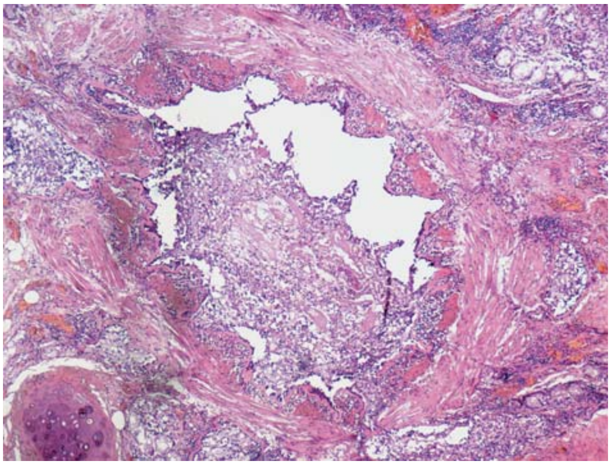

FIGURE 25.22 *Cross-section of a bronchus in sudden asthma death showing cell-laden mucus, folding of the soft tissues of the bronchial wall, thickening of the basement membrane and hypertrophy of the muscle. (HE, original magnification ×10.)*

from the cerebrospinal fluid irrigating the cerebellar surface. The time interval needed for the protein accumulation in man is not known. It is probable that, in addition to fibrinogen, other plasma proteins can also be used as a marker and an auxiliary method in assessing the probability of epileptic seizures contributing to the cause of death in sudden unexpected deaths.

SUDDEN DEATH IN BRONCHIAL ASTHMA

As in epilepsy, sufferers from bronchial asthma may die suddenly and unexpectedly, without necessarily being in status asthmaticus or even in an acute asthmatic attack. The mechanism is obscure, but experience proves that such fatalities are not uncommon. About 20 years ago, there was a marked increase in sudden deaths in asthmatics, but it was recognized that this was caused by the overuse of inhalers containing bronchodilators. These adrenergic drugs, used in excess, have a direct action upon the myocardium causing tachycardia, arrhythmias and ventricular fibrillation. Awareness among prescribing doctors rapidly reduced this danger but sudden deaths still occur, even when these substances are not used to excess.

The question of sudden death in asthma was discussed by Morild and Giertsen (1989). They considered that a number of factors contributed to death. Hypoxia and respiratory acidosis occur in asthma and increase myocardial irritability. Drugs such as theophylline and sympathomimetic agents can provide ventricular fibrillation. The β_2-antagonists so commonly used for the relief of bronchospasm are not so prone to cause cardiac arrhythmias, but they are by no means safe drugs in this respect. Of the 11 deaths in this Norwegian series, seven victims were found dead with a β_2-inhaler still clutched in their hands. Overdosage of the substance appears to be common. The use of theophylline derivatives combined with sympathomimetic agents tends to accentuate the cardiotoxicity of the bronchodilators.

Some of the deaths appeared to be in instances where the drug had been exhausted from the inhaler, but the propellant was still active. This may be another possible mechanism for some of these deaths, similar to the vagal inhibitory fatalities seen in butane misuse, where cold gas impinges on the pharynx.

At autopsy little or nothing is found, except confirmation of the chronic asthmatic state. On opening the chest cavity, the lungs are seen to fill the thorax, not collapsing as is usual and they have a pale spongy texture, forming stable pits when pressed with the fingers. The cut surface may reveal thick-walled prominent bronchi, often plugged with thick, clear mucus. This is not an explanation for the sudden collapse and death, however, and the mechanism remains obscure.

The topic of sudden death from asthma in childhood has been investigated by Champ and Byard (1994), who consider that it occurred only in children with significant chronic disease.

RESPIRATORY OBSTRUCTION

Mechanical obstruction by foreign bodies is dealt with in Chapter 14, but some rapid – if not actually sudden – deaths can be due to fulminating natural disease.

Rupture of a retropharyngeal abscess (‘quinsy’), when pus and necrotic material pour into the pharynx and larynx, is now a rare cause. Diphtheria is also virtually unknown in advanced countries so that the toxaemia, a fatal myocarditis and the possibility of laryngeal obstruction from a detached pharyngeal membrane are rarely considered by most doctors.

More common – and a cause of legal actions for negligence against doctors – is the fulminating epiglottitis caused by *Haemophilus influenzae* in children. This is a major paediatric emergency and any child with stridor of recent onset should be seen urgently by a paediatrician and anaesthetist. The gross infective oedema of the laryngeal entrance can lead to death within hours of onset of the illness, and may require rapid intubation or tracheostomy to save life.

HAEMOPTYSIS

Now that pulmonary tuberculosis is less common and treatable in advanced countries, deaths from haemoptysis are rare, as most massive respiratory haemorrhages were from this cause. However, warning signals are now evident about a revival of tuberculosis, even in 'advanced' countries. Part of the return of this scourge is due to opportunist infection in HIV-infected persons, but AIDS apart, phthisis seems to be on the march again, with worrying concerns about increasing resistance to the drugs, which revolutionized its treatment 30–40 years ago.

Bronchial tumours rarely cause fatal haemoptyses, unless a large vessel is eroded; syphilitic aortitis perforating the aorta or other large vessel is now almost a matter of history.

The bleeding rarely causes death from exsanguination except where the aorta is eroded, but smaller bleeds may fill the air passages, and cause an asphyxial-type death or a 'vagal inhibition'-type death from sudden flooding of the larynx.

GASTROINTESTINAL HAEMORRHAGE

Bleeding may take place at any point along the alimentary tract and though modern transfusion and resuscitatory methods make deaths unusual these days, some are seen in medico-legal practice when people living alone or otherwise remote from assistance, die without any medical intervention.

Bleeding from surgical operations in the mouth or pharynx, such as tooth extraction or tonsillectomy, rarely causes death, but can occasionally do so from blood and clot blocking the airways. In the oesophagus, a penetrating carcinoma may erode the aorta or other great vessel in the mediastinum, but the most frequent sources of bleeding are varices at the lower end, caused by the portal hypertension associated with hepatic fibrosis. It is often difficult to identify the varices at autopsy, as they have collapsed, but the absence of gastric or duodenal ulceration, and the congested, bluish vessels around the cardia often give away the lesion, especially in the presence of liver cirrhosis and splenomegaly.

Other causes of massive gastrointestinal bleeding are gastric and duodenal peptic ulcers, which can erode large vessels in their base. Acute erosions, though shallow, can produce considerable blood in the stomach and may require surgical resection. They are rarely the cause of lethal bleeding.

Carcinoma of the stomach can reach a large size and the crater variety may perforate a major vessel to produce severe haemorrhage. Bleeding from the small intestine is rare, except in certain haemorrhagic diatheses. More common is bleeding from colonic lesions, such as carcinomas and ulcerative colitis.

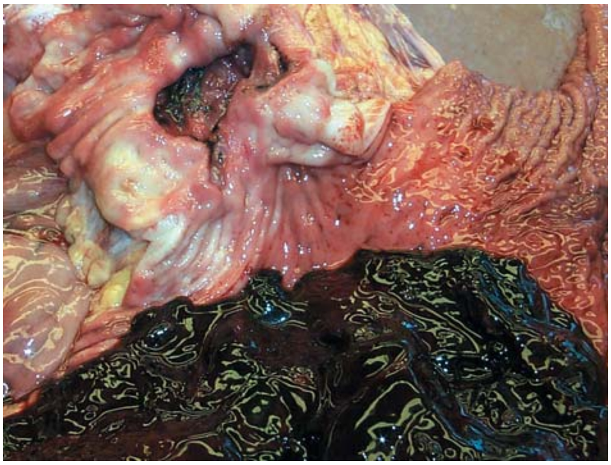

FIGURE 25.23 *Massive lethal bleeding from eroded vessels of a gastric ulcer.*

Polyps, sometimes malignant, may also give rise to melaena and even massive bleeding *per rectum*, though these are now rarely fatal unless medical intervention is delayed or absent.

FATAL ABDOMINAL CATASTROPHES

Though usually surgical emergencies, some abdominal conditions go untreated because the victim is either a solitary person living alone with no opportunity to call for help, or declines to seek medical assistance. They may well be found dead with no history to suggest a cause of death.

Mesenteric thrombosis and infarction is one such condition. The thrombosis may in fact be an embolus, rather than a thrombosis *in situ*, the most common cause of both being atherosclerosis of the aorta and its mesenteric branches. The length of small intestine supplied by the vessel becomes dark and necrotic, and may involve almost the whole length of the jejunum and ileum. Even if precipitated by an embolus, much of the rest of the arterial system may then thrombose and, on cutting into the mesentery at autopsy, the cut ends of arteries may show plugs of firm ante-mortem thrombus. The gut will be blue–red or even almost black, with loss of the serosal lustre and a friable necrotic wall.

Strangulated intestine is yet another condition that may present as sudden or rapid death, where medical attention is lacking, and even sometimes when it is negligently offered.

Hernias, both femoral and inguinal, and internal strangulation beneath fibrous bands in the peritoneal cavity, may all twist the intestine so that its blood supply is cut off, with subsequent necrosis. The gut above may develop ileus and become paralysed and dilated.

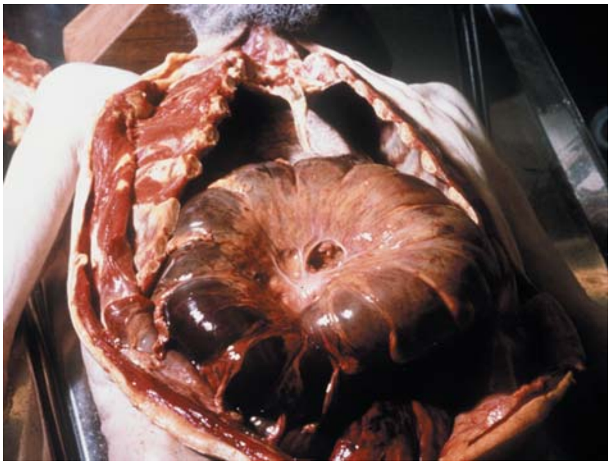

FIGURE 25.24 *Great distension of colon due to volvulus of sigmoid colon. Deceased found dead with history of abdominal pain.*

Caution is needed at autopsy to differentiate the dark red colour of loops of intestine due to post-mortem hypostasis from true infarction. Hypostasis is seen to be interrupted when the gut is stretched out, due to alternate dependent loops, whereas real necrosis is usually continuous and the serosa is dull and friable.

Fulminating peritonitis may be seen in a variety of causes, again leading to death if undiagnosed or untreated. Death from acute appendicitis and appendix abscess is now uncommon, but perforation of the colon through a diverticulum, whether inflamed or merely distended and eroded by faecoliths, is common.

Tearing of the senile gut where it is adherent to other structures, such as uterus or tube, can also lead to peritonitis, and a carcinoma (often difficult to differentiate macroscopically from chronic diverticulitis) may also lead to perforation with loss of intestinal contents into the peritoneum.

A perforated peptic ulcer, usually duodenal, leads to a chemical peritonitis. The autopsy appearances are straightforward, turbid fluid being found in the peritoneal cavity, which may show early inflammatory changes, if the perforation occurred many hours previously. The perforation is most commonly found on the posterior surface of the duodenum.

GENITOURINARY SYSTEM

There is very little in the urinary system that can give rise to a sudden or rapid death, but the female genital organs certainly make up for this. Complications of pregnancy are discussed elsewhere (Chapter 19), but it should be repeated here that ectopic pregnancy, usually in the tubes, can rupture with massive intraperitoneal haemorrhage. Induced abortions, unless under reputable medical control, are another source of death from haemorrhage, air embolism, perforation of vagina or uterus, infection and the use of toxic substances.

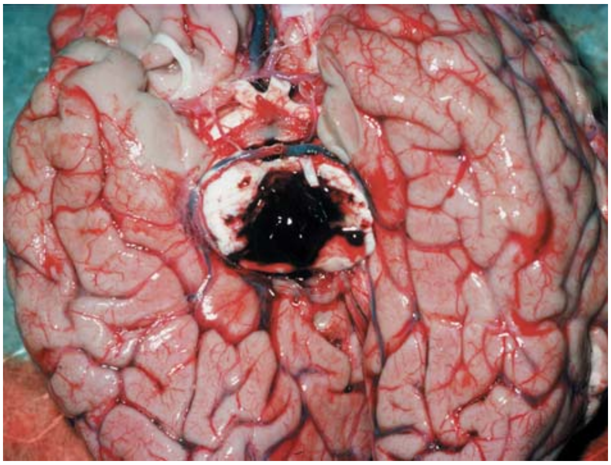

FIGURE 25.25 *A massive pontine haemorrhage in a person with hypertension. The circumstances and the irregular distribution of the bleeding within the brainstem distinguish this primary haemorrhage from the secondary lesions seen in raised intracranial pressure. Sometimes a natural intracranial haemorrhage may precipitate an accidental fall or traffic accident, however, and the resulting head injury may make it more difficult to identify the nature of the brain haemorrhage.*

THE RELATIONSHIP BETWEEN TRAUMA AND DISEASE

One of the most difficult problems in forensic medicine occurs when a death takes place in a person who has suffered trauma but who has either pre-existing natural disease or where some apparently natural disease has supervened after the trauma. The relative contributions of trauma and disease may then become an acute medico-legal problem.

For example, the author (BK) conducted an autopsy on an old man of 82 years, previously in excellent health, who had been tied up and slightly injured by robbers of a sub-post office. Within 2 hours of release from his bonds the old gentleman became ill and then hemiplegic, dying of a massive cerebral haemorrhage shortly afterwards. The attackers were charged with homicide, in addition to robbery, but that charge was rejected by magistrates on the grounds that a cerebral haemorrhage could be a natural disease, unrelated to the assault. The prosecution obtained a private Bill of Indictment to circumvent the magistrates, and at the Crown Court the accused were convicted of manslaughter on the grounds that the physical and emotional stress of being assaulted and tied up probably (beyond reasonable doubt) led to an elevation of blood pressure that precipitated a cerebral haemorrhage in a previously fit person, within such a short time span.

This marginal case illustrates the problems that can occur when trauma and natural disease coexist in the same person. A common dilemma exists in relation to subarachnoid haemorrhage from a ruptured berry aneurysm when there has been a head injury.

In autopsies when an injury has been sustained by a person with substantial natural disease, the following problems must be addressed:

- whether death was caused entirely by the disease and would have occurred irrespective of the injury
- whether death was caused entirely by the injury and would have occurred whether or not the disease was present
- whether the death was caused by a combination of these two processes.

In practical terms, the most common situations involve coronary artery disease, pulmonary embolism and subarachnoid haemorrhage.

Coronary atherosclerosis

The disease has invariably been present for months or probably years before the traumatic episode, and it is therefore indisputably obvious that the trauma can have no relationship to the genesis of the disease – though relatives and some lawyers are often hard to convince on this point. Furthermore, unless there was a direct blow onto the front of the thorax, which could physically have damaged the heart surface and caused a direct traumatic lesion of the coronary system (by dislodging an atheromatous plaque – but see end of this section – causing a subintimal haemorrhage or precipitating a coronary thrombosis, a rare event), there is no way in which the injury can be accused of worsening the state of the coronary arteries. If the state of the coronary system was already poor, thus it could justifiably be claimed by the defence that death could have occurred at any time. The standard of proof in criminal cases is high and must be proved 'beyond reasonable doubt', whereas in civil disputes, only 'the balance of probabilities' must be attained.

As opposed to showing that the trauma directly worsened the physical state of the coronary vessels, it is easier to claim that the physical and emotional stress associated with the traumatic event caused increased demands upon a weakened heart and caused it to fail. Recent investigations (see end of this section) have strongly confirmed the association between acute myocardial infarction, cardiac arrest and exertion.

The adrenal response of 'fight or flight' may be invoked, it being accepted that released endogenous catecholamines such as noradrenaline can send a chronically hypoxic heart into ventricular fibrillation and arrest. There may even be morphological evidence in some cases, by the finding of contraction bands in the cardiac myofibrils, especially in the superficial subepicardial layers.

It is often an assessment of the circumstances, in addition to the autopsy findings, that decides a court's attitude to the relationship of trauma to disease. Where a man who has had no previous cardiac symptoms drops dead immediately after some assault or strenuous activity, the court is more likely to assume an association than with some cardiac cripple, who has been hovering on the brink of heart dysfunction for a long time before the traumatic event.

The average jury is likely to decide that it would be too much of a coincidence for an assault to cause a man to drop dead on the spot, even if it was shown that his coronary artery stenosis had been there for several years. Much depends upon the individual circumstances, especially where there is only a short interval between the traumatic episode and death.

The strict test is: 'Would he have died when he did die if the assault had not taken place?' This is often unanswerable on medical grounds, but the court is entitled to take a commonsense view of coincidence in terms of immediacy in time and apply the 'beyond reasonable doubt' test to it.

The fact that a person is in a parlous state of health and might die from relatively minimal trauma is no defence in law, which states that 'an assailant must take his victims as he finds them'. In other words, it is immaterial whether the attacker knows that his victim is ill or not – if death results from an illegal act against him, the charge of homicide may stand. This dictum is not adhered to slavishly by public prosecutors, however, as it is a matter of practical politics whether a criminal prosecution can be maintained with any chance of success (using public funds), against an energetic defence that can show medically that the victim had such a degree of natural disease that he might have dropped dead spontaneously at any time. The prevalence of coronary disease is so widespread that a close association in time must be shown before any causal connection can be accepted. The actual death itself need not occur very soon after the assault, however, if it can be established that the latter could have precipitated an infarct in a myocardium already compromised by coronary stenosis. It is not only a blow or some physical trauma that may precipitate a myocardial infarct or arrhythmia; as stated above, even the emotional upset that accompanies injury, or even the threat or fear of an injury, can lead to death. The blow may never actually be struck or it may fail to land, yet the threatened person may suffer a transient hypertension or tachycardia that may precipitate a subintimal haemorrhage, arrhythmia, or cerebral or subarachnoid haemorrhage that leads to death. Such an event, however, with little or no morphological evidence to be presented as evidence, has a poor chance of acceptance in court unless the circumstances are clear-cut. These cases pose a problem for police and pathologist, in that it may be difficult to decide whether to arrest and charge the potential culprit with a criminal offence.

A typical case was once seen by the author (BK) in which an elderly man was involved in an altercation with another, concerning parking a car. There was a scuffle, in which only trivial blows were exchanged, but one participant immediately developed chest pain and breathlessness, and soon died. The other man was arrested, but as autopsy showed marked cardiac enlargement, extensive myocardial fibrosis and gross occlusive coronary atherosclerosis, the prosecution decided to offer no evidence and the charge was dropped, even though the answer to the 'acid test' of whether the victim would have been likely to die at that particular time had the altercation not taken place was probably in the negative.

In civil matters, considerable sums of money may hang upon such decisions by way of damages and insurance payments. Here the standard of proof is much lower, as the plaintiff only has to show that there was a 51 per cent or better chance of the association being present, rather than the much higher standard of criminal liability.

An actual example of the civil problems was a workman who was removing a truck wheel from his employer's vehicle with a wheelbrace. Under full pressure, the threaded stud in the hub suddenly snapped and the man was thrown to the ground under the force of his own muscular effort. He was shocked and soon developed chest pain and died the next day. Autopsy revealed no fresh infarct, but there was longstanding left ventricular hypertrophy, myocardial fibrosis and stenosing coronary atheroma. The employer's liability was disputed, but eventually a compromise settlement was reached.

Recent very careful and statistically meticulous research on large cohorts, both in the USA and Germany, have shown an indisputable relationship between exertion and sudden cardiac death. Mittleman *et al.* (1993) investigated 1228 patients with acute myocardial infarcts and showed that there was a sixfold increase in the incidence of infarction during or within one hour of heavy physical exertion, such as snow shovelling, jogging or sexual activity. In Germany, Willich *et al.* (1993) researched 1194 patients with the same condition and showed a twofold increase in risk. Both surveys showed that the risk was greater in those who were otherwise sedentary and that long-term moderate exercise was undoubtedly associated with a reduced risk of infarction (Curfman 1993). Several mechanisms were proposed for the increased risk during sudden severe exertion, including the splitting and dislodgement of an atheromatous plaque. It was also claimed that increased platelet activation occurred in sedentary people who suddenly exerted themselves. In an earlier publication, Siscovick *et al.* (1984) showed the same trend in primary cardiac arrest, exertion in otherwise sedentary persons increasing the risk, whilst habitual exercise protected.

Subarachnoid haemorrhage

Subarachnoid haemorrhage is another difficult area in which trauma and natural disease interact. When a berry aneurysm on the cerebral arteries ruptures, the allegation is often made that some traumatic occurrence precipitated that event. The matter is discussed in Chapter 5, but to recapitulate here, the problem is to decide whether the trauma itself was a mechanical factor in causing the arterial blister to burst.

A rupture is a relatively common event without external trauma, this cause of death being well-known in young to middle-aged persons who are not indulging in any strenuous activity whatsoever. It is known to occur, however, during innocent activities, such as jogging, intercourse and sporting exertion, probably because of a transient rise in blood pressure and pulse rate. Once again, a potent element may be in the adrenal response, catecholamines pushing up the blood pressure. Thus when a ruptured aneurysm occurs during or shortly after a fight or altercation, it is arguable whether a mechanical blow to the head or merely the emotional stress of a dispute is the most potent factor in causing rupture. There has been much medical argument about the role of trauma in causing the rupture, as many would maintain that the aneurysm is so deep-seated within the skull that internal pressure from hypertension is far more likely to be the reason.

Certainly, where a small aneurysm a few millimetres in size breaks, it is difficult to accept that a blow could have caused a tear, but in the more exceptional cases of a large tissue-thin globule, then it is easier to accept that intracranial stresses may have played a significant part. The role of alcoholic intoxication – another hotly disputed aspect – has been discussed in Chapter 5. The legal problem is similar in berry aneurysm deaths to that in coronary disease. The time interval is naturally important, though in most instances, bleeding occurs immediately or soon afterwards.

Autopsy is not all that helpful in assessing the relative contribution of assault versus pre-existing disease. Unless the aneurysm is found to be large and fragile, the morphological findings are mainly of use in confirming the diagnosis, evaluating any injuries and excluding any other contributory disease. It used to be the usual practice in England and Wales not to prosecute assailants when an aneurysm was demonstrated at autopsy, though in Scotland and on the continent of Europe no such reluctance was evident. Following a case in Gibraltar in 1978, however, in which a British sailor was convicted of homicide after kicking another in a drunken brawl, the latter eventually dying of subarachnoid haemorrhage from a ruptured aneurysm, such charges are now usually brought (Knight 1979).

Pulmonary embolism

The other major example of the interaction of trauma and natural disease is pulmonary embolism. This is discussed in Chapter 13, but is so important in medico-legal casework that the forensic aspects may be repeated here with advantage.

Deep vein thrombosis, almost always in the leg veins, is a common sequel to injury and consequent immobility. Virchow's triad of slowing of the circulation, local injury to vessel walls and increase in blood coagulability are the major factors, though deep vein thrombosis can occur in the absence of all three. When the leg is the site of the injury, it is more likely to occur in the ipsilateral limb, though it can occur contralaterally or bilaterally. The fact that a fatal embolus came from the contralateral limb when the other leg has been injured by no means rules out a causative element.

Pulmonary embolism typically occurs about 2 weeks after an injury or surgical operation, but the range of time during which a cause-and-effect mechanism operates can be anything from about 2 to 90 days. It becomes progressively more difficult to maintain a causative relationship, however, when the interval exceeds a few weeks.

Forensically, it is vital to show that the deep vein thrombosis post-dated the traumatic event, if an association is to be established. If a person suffers a fatal embolism a week after injury, yet histologically the deep vein thrombosis appears to be several weeks old, then obviously the injury could not have initiated the process. The embolus may, however, be much younger than the most distal part of the leg vein thrombosis (which may be as far down as the foot) as progressive proximal extension of a deep vein thrombosis undoubtedly occurs. It could still be argued, therefore, that although the original thrombosis antedated the injury, the latter encouraged extension and hence the eventual breaking off of an embolus. The case becomes weaker, however, than if the whole process was entirely subsequent to the traumatic event.

Histological dating of the embolus should always be undertaken, though it is less rewarding and more difficult than that of the leg vein thrombi, which must always be taken for microscopy with the vein wall intact. It is the thrombomural junction that gives the most information about the age of any thrombus. Thrombosis of the deep leg veins is far more common than pulmonary thromboembolism. In 100 consecutive coroner's autopsies, Knight and Zaini (1980) found 32 instances of deep vein thrombosis, but only 10 had pulmonary emboli, not all fatal.

The legal problem, outlined in Chapter 13, is that though trauma, surgery and immobility are potent factors in the development of deep vein thrombosis, the latter condition frequently occurs in the absence of all three. Thus it is difficult to maintain that any traumatic event was the cause of a subsequent fatal pulmonary embolism, as many fatal emboli occur in the absence of trauma. In a series of coroner's and hospital autopsies studied by Knight (1966), 25 per cent of fatal pulmonary emboli came 'out of the blue' in ambulant people who had no previous history of trauma or surgical operation. Later, Knight and Zaini studied 38 000 autopsy reports and found that 10 per cent of deaths due to pulmonary embolism had no history of any predisposing factors. The discrepancy in these proportions is caused by the variable standard of history reports and also by marked alterations in pathologist's reporting habits over the years – in fact, in the large series mentioned above, there was not a single fatal pulmonary embolism recorded in the 20 years from 1908 until 1928!

Even disregarding the dubious statistical value of such investigations, there can be no doubt that a significant proportion of fatal pulmonary emboli cannot be related to previous trauma. This provides a line of defence in those cases where the prosecution allege that a 'cause-and-effect' relationship exists between some criminal assault and death. It becomes a matter of law for the judge to decide whether he will let the issue go to the jury, and a matter of fact for the jury to decide whether this relationship can be 'beyond reasonable doubt' in circumstances where even conservatively, at least 10 per cent of pulmonary emboli are not related to trauma. Several court cases are within the author's (BK) experience in which quite different verdicts have been reached on essentially identical pathological evidence.

In civil cases, usually related to road traffic accidents or industrial personal injuries, the burden on the plaintiff is much lighter, as the 'balance of probabilities' test can be much more readily satisfied.

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CHAPTER 26

Forensic dentistry for the pathologist

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Forensic odontology – the application of dentistry to forensic problems – is a discipline in itself and requires special dental expertise not possessed by pathologists qualified only in medicine. It is therefore imperative that, wherever possible, problems involving the teeth and jaws are referred to a dentist at an early stage, preferably at the time of the original autopsy or other examination of the subject.

A number of different circumstances need to be taken into account in this respect, however. First, it has to be accepted that by no means all dentists are either interested or competent in forensic problems. It is the same with pathologists, anatomists or any other specialists, in that the lack of enough motivation and experience can make their participation in legal matters of little value. A forensic odontologist naturally provides the best expertise, as he is professionally involved in the subject and will have training or experience, or both, of dento-legal problems, even though few forensic odontologists are occupied full time in this super-speciality, most being teachers or researchers in some other branch of dental science.

In many parts of the world, there are no forensic odontologists available. In developing countries there may be no forensic dentists at all – or the only expert is in the medical school of the capital city, inaccessible to distant areas. Even in more advanced states, problems of distance and travel may make it impracticable to call an odontologist to examine the body *in situ*. Dental expertise may be made available later, if material is retained for examination for transmission to the expert. In yet other circumstances, many problems of availability, cost and the lack of perceived importance of the case may make it impossible to involve an odontologist at an early stage – or even at all. In all these instances the pathologists or other medico-legal doctor may have no choice but to handle the dental aspects as best he can, either in the initial stages or even throughout the investigation.

This chapter is meant to be nothing more than a guide for the doctor placed in this position and is certainly not intended to encourage pathologists to attempt to replace or dispense with a good odontological opinion. It cannot be sufficiently emphasized that, where the issues are serious, every effort should be made to obtain expert forensic dental assistance. The remainder of this chapter must be looked on solely as a 'first-aid primer' for cases in which the ideal investigation cannot be attained for one reason or another. If no expert dental advice can be obtained at the outset, then the pathologist should do all he can to assemble and preserve both detailed records and physical specimens, which can be examined later by a forensic odontologist, if one can be found further along the investigative pathway.

The assistance that dentistry can render falls into two broad headings:

- the interpretation of bite marks
- personal identification, either individually or in the context of mass disasters.

BITE MARKS

One of the two major interests of forensic odontologists is one that has direct relevance to pathologists in that it concerns the interpretation of trauma to the body surface. For the sake of completeness, however, mention must first be made of bite marks on inanimate objects, usually foodstuffs.

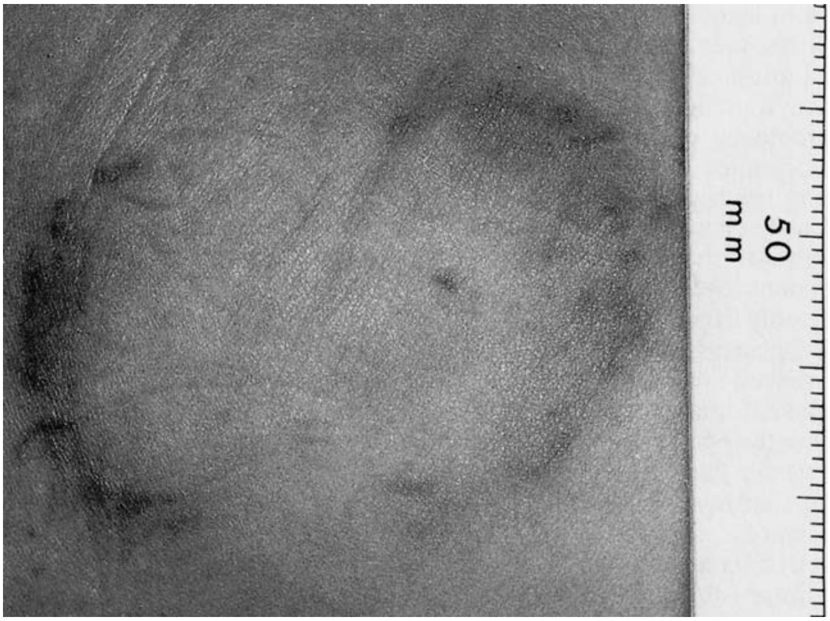

FIGURE 26.1 *Bite mark on skin. The two opposing bruises from the upper and lower dental arches are separated as usual by a gap, as only the front pans of the two arches contribute to the injury.*

This is mainly within the province of forensic science in the sense of 'criminalistics', where dental evidence is used to identify the perpetrators of a crime who happen to have left their teeth marks in some substance left at the scene. This rarely concerns forensic pathologists, except in the rare instance of their being asked by the police to examine an object, such as an apple or piece of cheese, to see if some obvious dental abnormality of a suspect could have caused the unusual bite mark.

The doctor may also be asked how the bite mark may be best preserved until the object can be examined by a forensic odontologist at a later date. Where the substance is 'plastic', such as butter, cheese, lard, wax or chocolate, for instance, it should be stored in a refrigerator to prevent melting or gradual flowing. It should not be deep frozen, as this may cause brittleness and cracking. Forensic science advice should be taken if at all available. Fruit, especially apples, seems prone to be bitten at scenes of crime, and Marshall *et al.* (1974) recommend preservation in Campden solution, a metabisulphite fluid used for fruit bottling. Alternatively, 5 per cent acetic acid in 40 per cent aqueous formaldehyde solution can be used. Ordinary histological formalin is not satisfactory – nor is refrigeration, which allows the fruit to shrivel. Whatever preservation is recommended to the police, the object should be adequately photographed with the film plane at right angles to the bite and a scale placed in the focal plane. If appropriate, swabbing for saliva traces should be carried out (see below) and then the fruit preserved for future examination.

Returning to the human body, bites are relatively common, especially in cases of child abuse and in adult sexual assault. In the former, bites may be anywhere on the infant, favourite sites being the arms, hands, shoulders, cheeks, buttocks and trunk. In the author's (BK) experience almost all bites on small children have been inflicted by the mother, but this is by no means invariable in the generality of child abuse. A common excuse from the parents is that the infant was bitten by another sibling or by the family dog – and occasionally, this explanation may be true. Others may be self-inflicted. It is therefore vital that the bite mark be properly examined to determine whether it is of a size consistent with adult dentition, or whether it is small enough to have come from another child – or is of a different shape, indicative of an animal.

The other common circumstances in which human bite marks occur are rape or other sexual offences. Here the pathologist will need to examine bites as part of the autopsy in a sexual murder – or even sometimes in live victims of an assault, if it is part of his duties to deal with clinical examinations or where no 'police surgeon' or forensic physician is available.

In this type of crime, bites may be sexually orientated or be distributed on any part of the body. Common sites are the breasts and nipples, but the neck, shoulders, thighs, abdomen, pubis and even vulva may be attacked. As noted in the chapter on sexual homicide, care must be taken to recognize that some so-called 'love bites', especially with suction petechiae, may be part of acceptable (if over-enthusiastic) sexual intercourse, but where real damage occurs, especially to breasts and nipples, then a violent or sadistic element is likely.

Bites may also be inflicted on police officers when attempting to arrest resisting offenders. They are also suffered in sporting events, especially football and some forms of wrestling, and during assaults when the victim manages to bite the assailant. In these instances bites may be

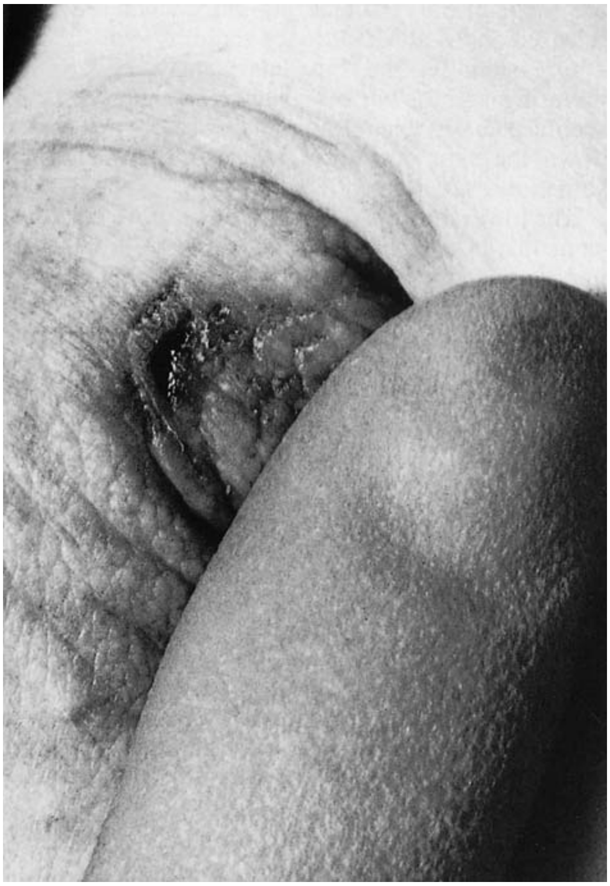

FIGURE 26.2 *Bite mark on a nipple during sexual homicide. The injury is too small for any dental matching, but a saliva sample might provide the blood group of the assailant, if he is a secretor.*

inflicted anywhere, but the hands, fingers, nose, forearms, ears and even lips may be the targets.

Some bite marks are self-inflicted; falls onto the face or a fit may cause the tongue and lips to be badly bitten. Other persons deliberately bite themselves, sometimes to fabricate injuries for a variety of motives ranging from gain to psychiatric disorder. Multiple bite marks (especially of the suction type), which are seen on accessible areas of the shoulder and arms, raise the suspicion of self-infliction, especially in older children and teenage girls.

The nature of the bite mark

Though called a 'bite mark', some of the components of the application of the mouth to skin may not be from the actual teeth. The lips can transiently mark the skin if forcibly nipped, especially on children, though the marks are short-lived and rapidly fade in life, not persisting after death unless associated with petechiae. Suction can produce a crop of punctate haemorrhages, either small petechiae or larger ecchymoses merging into a confluent central bruise.

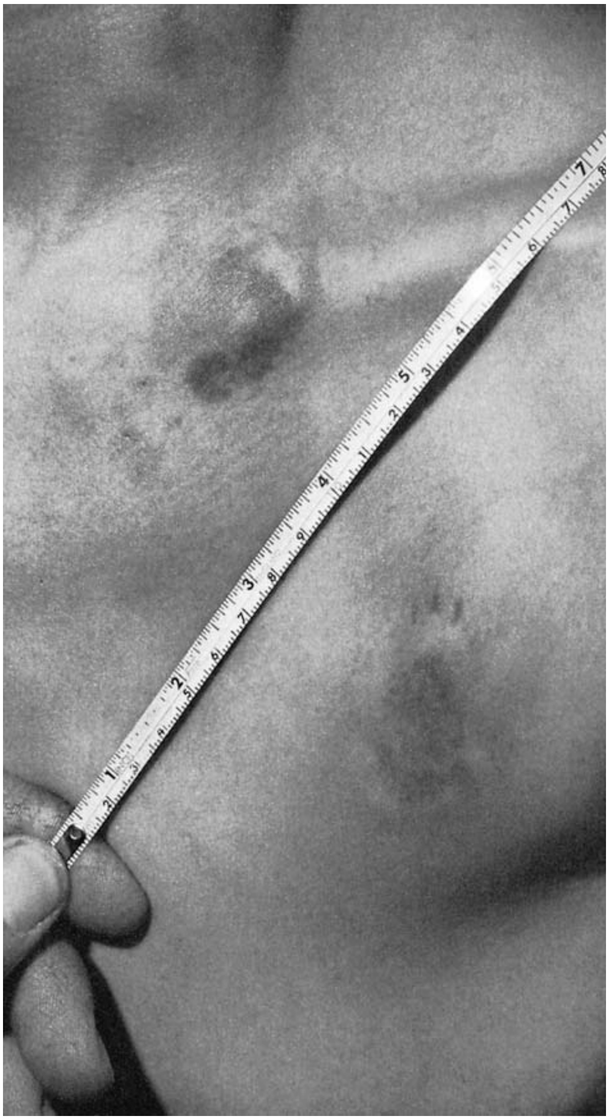

FIGURE 26.3 *Bite marks made during a sexual assault. The upper mark shows no specific features but its position is typical of a sexually orientated bite. The other shows central confluent petechiae and red bruising from suction and tongue pressure. There is a lower semi-circular pale zone corresponding with the lower lip, but the striking feature is the group of linear abrasions at the top of the mark made by the upper incisors dragging across the skin as the jaw is closed. Both bites are surrounded by zones of diffuse bruising.*

A human bite mark may present only a small part of the dental arcade, caused by the front teeth from canine to canine with an almost invariable gap at either side representing the separation of upper and lower jaw. A human bite is near circular or a shallow oval. A deep parabolic arch or a 'U-shape' can only be animal in origin. The teeth may cause clear, separate marks or they may run into each other to form a continuous or intermittently broken line. As time passes, originally clear tooth marks spread out and blur, progressively losing their definition – though abrasions on the skin surface retain their shape until scabbed healing is complete.

Teeth marks may be abrasions, bruises or laceration – or a combination of any two or three. The clarity of a bite mark depends on a number of factors. If the contour of the part bitten is irregular or markedly curved, then only part of the dental arch may contact the tissues. If the bite is forcible, then extensive subcutaneous bruising may spread laterally and blur the outline. If the bite was inflicted many days before, then healing of abrasions and lacerations, and absorption of bruising will leave progressively less detail. Where teeth have been forcibly applied, the typical appearance is of two 'bows' with their concavities facing each other and a gap at each end. Within this may sometimes be suction petechiae, which are often present without teeth marks, in the so-called 'love bite'. They are caused by the firm application of the lips, which form an airtight seal against the skin, then a sucking action reduces the air pressure over the centre. This causes a shower of petechial haemorrhages to appear from rupture of small venules in the superficial layers of the subcutaneous tissues. If forcible, the petechiae are confluent and a frank bruise, or even haematoma develops. Added to this is pressure from the tongue, pushing the tissues against the palate. This type of lesion is most often seen on the side of the neck and on the breasts of women, either in love play or after a sexual assault. They are by no means rare in child abuse, however, and are sometimes self-inflicted. Such a suction lesion must be human in origin and the claim that one is caused by a household pet can be immediately discounted.

Bites may be inflicted by the teeth closing down on a relatively flat skin surface, but there is usually an element of indrawing into the mouth, so that the teeth close down onto a parallel-sided or elliptical block of skin. In sexual bites, especially of the breast or nipple, the tissue may be actually sucked into the mouth before the jaws close upon it. This will naturally affect the shape of the resultant bite mark when the skin is released and flattens out once more.

Occasionally, the bite mark may not be two opposing arches, but more linear in pattern. This is seen especially where the upper incisors are scraped down the skin, leaving a series of parallel tracks, sometimes several centimetres long.

The lower incisors may leave either a curved line of static marks, or a straight or interrupted line below the upper incisor scrapes, as the lower teeth dig in and anchor the skin whilst the upper teeth gouge downwards towards them, during the act of closing the mouth.

The major problem with bite marks is the identification of the perpetrator and hence the problem cannot really be tackled without the expertise of a dentist fully experienced in this specialist task. Unless the dentition has some really characteristic features, especially in the incisors and canines, then a non-dentist is a poor witness if the matter comes to a legal dispute. Some odontologists would claim that a bite mark can only be identified in a negative sense – that is, suspects can be excluded if their dentition is obviously incapable of inflicting the bite mark under investigation, but that no positive match can be claimed. Though many forensic odontologists would dispute this conservative claim, it is probably the best attitude for a pathologist involved in such a problem, unless there is some really spectacular and unique feature in the front teeth of a suspect.

Missing teeth, grossly displaced teeth and substantially damaged teeth may suggest a match with a person – or the mark may be quite inconsistent, which is helpful to the investigators if they eliminate a person or persons, especially in the restricted range of a family in which a child has been abused.

It is probably best for a pathologist to realize his limitations in this field, however, and to confine himself to taking the best physical evidence for later study by a forensic odontologist, where this is at all possible.

The investigation of a bite mark

As stated, every effort should be made to obtain the best evidence for future specialist examination. First, the bite mark should be carefully and fully photographed. If police facilities are to be used, the pathologist – as in other aspects of forensic pathology – should direct them as to the important features required on film. Often such photographers, though otherwise expert in the technical aspects of their craft, do not appreciate the problems that inadequate or inappropriate views can cause – especially at a later date, when experts reviewing the case and lawyers presenting it in court have to rely on photographs without the benefit of having seen the original lesions.

The photographs should be taken from several different angles, but especially from a directly perpendicular viewpoint, with the plane of the film at right angles to that of the lesion. Some police photographers persist in taking tangential shots that foreshorten the true shape. An accurate scale should always be adjacent to the lesion, as close as possible, but not impinging upon it or obscuring any detail.

Bites are often on a curved surface, such as the face, breast or arm, and thus can never be reproduced exactly on a flat surface, as there is bound to be slight foreshortening at the ends, but several views at slightly different angles can overcome this problem. Small lens apertures and short focal lengths will obviate the blurring that results from the lesion curving out of the focal plane. Too short a focal length will itself produce image distortion.

The lighting is important, as perpendicular lighting may lead to a flat rendering with no capture of detail. Side

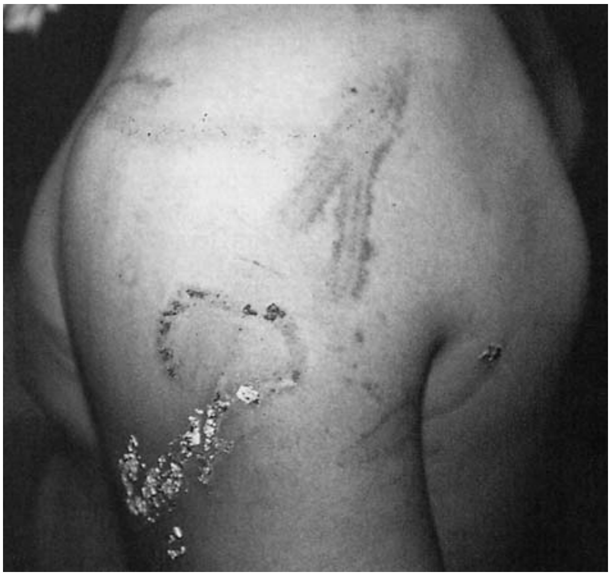

FIGURE 26.4 *A clear bite mark on the shoulder, a few days after infliction. This was from political abuse of human rights, there also being linear bruises on the shoulder and back from beating with a hose-pipe.*

lighting may throw small irregularities into relief, especially if there are tooth indentations in the skin. Both monochrome and colour photographs should be taken, with particular attention to sharp focus and correct exposure. The use of infrared-sensitive film has been recommended to reveal occult bruising, but it also appears to demonstrate artefacts. The lesion should almost fill the camera frame in some shots to capture as much detail as possible, either by short lesion-to-camera distance or the use of long-focus lenses. More general, wider shots should also be taken, however, to orientate the bite mark in relation to anatomical landmarks. During photography, care should be taken not to heat up the skin by the close proximity of high-power tungsten lamps. These should be placed at a distance or used only for short periods. Flash illumination will obviate this danger of heating the skin, which can distort the bite mark.

When photography is completed, swabs of the bite should be taken to try to recover saliva. Though not often successful, this technique can occasionally be vitally important in helping to identify or exclude the assailant, if he or she is one of the 80 per cent of people who are ‘secretors’, that is, who exude their blood-group substance in their saliva. Plain cotton-wool swabs are gently rubbed onto the bite – some experts recommend slightly moistening them first with water or saline. They should then be deep frozen unless sent straight to the serology laboratory.

Following photography and swabbing, there is usually little more that the pathologist can do in the absence of a dentist. If facilities are available and someone has the expertise, an impression of the bite can be made. This consists of laying a plastic substance over the bite mark, which then hardens, so as to produce a permanent negative cast of the lesion. It is usually made with a rubber- or silicone-based medium containing a catalytic hardener. Less satisfactory substances are water-based pastes, such as plaster of Paris, which are put on wet and allowed to dry before removal. These have the disadvantage of potential damage to the actual bite, if that is required for further evidential examination. Though it is unlikely that a pathologist will be able to carry out these procedures, it may be that a non-forensic dentist or a forensic scientist used to making casts of other evidence may be able to make satisfactory impressions that can then be preserved for later examination by an odontologist.

After autopsy, it is also possible for the whole area of skin carrying the bite to be removed and preserved in formalin for future examination. The shrinkage and distortion that are virtually inevitable, however, make these specimens of limited value for detailed tooth matching, though if good photographs with accurate scales are also available, they may be a useful addition to the dental evidence.

It is recommended that, as with all bruises and abrasions, the body be re-examined a few days after the first autopsy, as the appearances may be markedly enhanced. In a bite mark, faint or even absent original lesions may become more prominent, or even appear for the first time a day or two after death. The removal of skin carrying the lesion should be delayed if it is wished to see if this enhancement will occur, unless climatic conditions or lack of refrigeration would make this delay undesirable.

Matching the bite mark with the suspect’s dentition

For a pathologist, this is such a specialist enterprise that it would rarely be attempted, unless there was no prospect whatsoever of a forensic dentist being available, even at a later date. As mentioned earlier, unless there is a striking dental feature in the bite mark or in the teeth of the suspect, the best that can be done is to try to exclude a limited number of potential assailants on the basis of lack of correspondence of their dentition with the bite mark. If neither mark nor teeth show any particular distinctive appearances, then even this should be avoided, without expert dental opinion. Where circumstances dictate that only the pathologist will ever be available to help the investigation, he should confine himself to the following routines:

- The teeth of those who are either suspected by the police or who had access to the victim should be examined. In most jurisdictions it is vital that fully informed consent should be obtained from the person beforehand. The doctor must explain what he intends doing and the reason for doing it. It must be made clear that this is to be done for the purposes of a legal investigation and that any information gained might be used as evidence – and that it is not related to diagnosis or treatment for the subject's own welfare.

- Any refusal must be a bar to any further action. Where children are concerned, usually in the setting of child abuse, the consent of the fully informed parents or guardian must be obtained. All such consent is preferably obtained in writing and many police forces have special forms for the purpose. If not written, then a dubious second best is getting oral consent; at least one witness to this must be obtained, if possible from independent persons other than relatives or police officers.
- With consent, the dentition is then examined and the following points determined and recorded by diagram and writing. Photographs should also be taken if there is an issue of possible correspondence between the teeth and the bite – or where exclusion is legally important.
  - The presence of full or partial denture – and, if so, were they worn at the time of the incident?
  - The number of teeth in upper and lower jaw.
  - A charting of any missing teeth, especially incisors and canines.
  - An estimate of the bite overhang, or whether there is edge-to-edge occlusion or an undershoot projection of the lower teeth.
  - Recording of any broken teeth or teeth with significant individual abnormalities; these must be charted and described.
  - A record of any irregularity or marked variation in the cutting edge profile of any front teeth.
  - An evaluation of the size and prominence of any teeth, especially in the canines and incisors and any developmental abnormalities, such as an extra interposed front tooth.
  - Recording of any abnormality in the orientation of any tooth or teeth, such as twisting (rotation) in the anteroposterior tilting or double row of teeth. Gaps and irregular spacing are vital factors.

Though it is unlikely that a pathologist will have either the expertise or materials to make an impression of the bite, this might be attempted if no dental assistance of any kind is available – though the aid of a local dental practitioner would be useful in obtaining a wax or other bite registration. If this is impossible, then a bite impression into any available plastic substance might be attempted. The use of such substances as modelling clay, Plasticine, or beeswax might be better than nothing if some unique feature required demonstration. Finally, whether it be from visual inspection of the teeth or from comparison with a cast, an attempt should be made to compare the characteristics of the bite mark with the dentition of the suspect or suspects. It is assumed that an animal bite will have already been excluded by this stage.

This comparison can be performed in various ways, different odontologists having their own techniques. Where marked abnormalities exist in the teeth, these may be present in the bite mark if the affected teeth happen to have registered in the lesion. Some forensic dentists prefer to match photographs of the mark with photographs or tracings of the teeth, the former being printed to a 1:1 magnification. Tracings can be made from positive casts of a bite impression, inking the cutting edges of the front teeth and transferring these to transparent sheets, which can then be laid over the photographs to determine correspondence. Others use a negative photograph of the teeth laid over a positive photograph of the bite, again ensuring exact correspondence of magnification.

In a bite mark it is said that a tooth impression is better evidence than an absent mark – in other words, the presence of a tooth mark means that the tooth was actually in the jaw, whereas a gap in the injury could either mean that the tooth was missing or merely that the occlusal edge had not marked the skin, perhaps because of slight shortening, unevenness or wear. In all matching procedures between a bite mark and the suspect teeth, allowance must be made for distortion of the skin surface during the biting process and the angle of attack of the teeth. Again it is emphasized that exclusion is probably a much safer exercise than an allegation of positive matching, unless there is some unique feature in the dentition. Unlike fingerprints, fewer points of definite correspondence are required to claim correspondence. This applies only in the hands of experts, where the number needed for a confident identification depends on the strength of the idiosyncratic features, but may be inferred from three or four identical points.

In practice, it is the six upper and six lower front teeth that give the most information. The canines may provide particular help when prominent and pointed. Premolars and molars are rarely useful, as might be expected from their lower profile and posterior position in the jaws.

IDENTIFICATION OF THE DEAD FROM THE DENTITION

The major contribution of forensic odontology is in the field of identification, especially in mass disasters, such as aviation and marine catastrophes. In air crashes, dental investigation is the most successful single procedure leading to identification of mutilated and burned bodies, as the passenger manifest lists provide a circumscribed population for whom dental records can be obtained in the majority of cases. In such disasters the involvement of dentists is imperative, but the size of the subject is far too large to be attempted in a book of this nature.

Apart from mass casualties, forensic odontology is frequently used in problems of individual identity that are the direct concern of the forensic pathologist, as accident, suicide and murder form the majority of such unidentified bodies.

As with skeletal remains (of which dental evidence is part), discussed in Chapter 3, there are two prime avenues of investigation:

- general or reconstructive identity, which attempts to classify the unknown person by age, sex and race
- comparative methods, which confirm or exclude the personal identity of the individual against ante-mortem dental records.

Once again, the pathologist can only act for the dentist in a 'second-best' way, when no forensic odontological expertise is available. Unlike bite marks, the material is likely to be much more permanent and, wherever possible, the pathologist should retain photographs, chartings and even the actual dentition against the time when expert dental opinion might become available. When time presses in a criminal inves-tigation, however, or where no dental help is ever likely to be forthcoming, then the pathologist has to do the best he can, though many special techniques such as radiology or tooth sections may be quite beyond his capabilities.

General or reconstructive identity

Unlike skeletal remains, the human origin of dental material is rarely in doubt. In badly decomposed or skeletalized bodies the jaws usually survive intact, though in dry skeletons, teeth may become loose and fall out, especially the single-rooted canines and incisors.

Even in fragmented bodies and skeletons, the jaw remnants and teeth are readily recognizable, even by lay persons. Where teeth have dropped out and been recovered independently of a body, they are still usually recognizable as human, as opposed to most domestic or farm animals. In countries where large primates exist, there may be some confusion, but this is a rare problem.

Having established the human origin, the next determination is sex and here teeth have a poor discriminating value, though the intact jaw is more helpful, as discussed in Chapter 3. Male teeth are usually larger, but this is generally unhelpful. The difference in size between the upper lateral and upper central incisors is often greater in women, the male incisors being more equal in size. The female canines are usually smaller and more pointed relative to the male, more especially in the mandible than the maxilla. Girl's teeth tend to calcify and erupt earlier than boys. If the skeletal age is known, then more advanced tooth eruption in young persons is an indication of being female, though in these circumstances there are usually far better indicators of sex available elsewhere in the skeleton. The mandibular first molar often lacks a fifth cusp in the female, which is almost always present in the male. Extraction of pulp tissue from a tooth, even up to many months after extraction or death, can provide material for fluorescent staining for the female intranuclear F-body, as described in Chapter 3, but this has now been superseded by sex determination via DNA, if recoverable from the pulp.

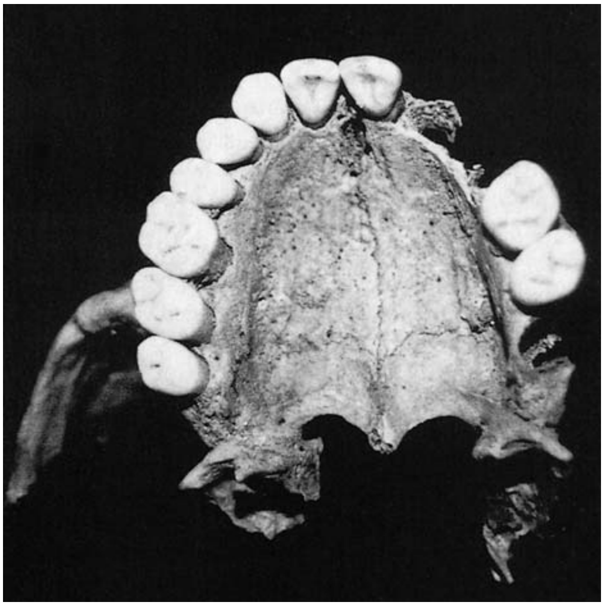

FIGURE 26.5 *Upper dental arch of a skeleton found buried on a small island in the Bristol Channel. The central incisors are 'shovel-shaped' and have a depressed groove on their posterior surface. This strongly suggests that the deceased was of mongoloid race.*

Race is also a difficult criterion to determine from teeth. The best-known feature is the 'shovel-shaped' upper central incisors of Mongoloid races, first described in Leipzig by Muhlreiter in 1870. The posterior surfaces of these teeth have a depression centrally, with two marginal bars, causing the back of the tooth to appear like a coal shovel with turned-up edges. The feature is found mainly amongst Chinese, Mongols, Eskimos and Japanese, but is also found amongst non-Mongoloid races in lesser numbers. Some 91 per cent of Chinese, Japanese and Tibetans have such teeth, 95 per cent of Native Americans, 84 per cent of Eskimos, 46 per cent of Palestinian Arabs – and 90 per cent of Finns. It is rare amongst Negroids and Australian Aboriginals. In Caucasian races, the lateral incisors in the upper jaw are usually smaller than the central, especially in women, a feature absent or less marked in Negroid or Mongoloid races. Caucasians also have long pointed canine roots, a feature not seen in Mongoloids. Enamel pearls, small nodules of enamel on the tooth surface, are much more frequent in Mongoloid teeth. Small nodules on the lingual surface of maxillary molars, called 'Carabelli's cusp', are most common in Caucasian races and rare in the other major racial groups. The condition of bull-tooth or 'taurodontism' is most common in Mongoloid peoples: here the pulp cavity of molars is wide and deep, and the roots are fused and bent. A congenital lack of the third upper molar is most common in Mongoloids, but can occur in any race. Negroid races tend to have large teeth and often have more cusps on their molars, even up to eight, with two lingual cusps on the mandibular first premolars as an additional common finding.

The age of the person is one of the most useful findings disclosed by the teeth, especially in the first two decades of life. The sequence of deciduous or 'milk' teeth is well known, overlapping the appearance of the permanent dentition, shown in Figure 26.6. This is only an average timetable, however, and is modified by several factors, such as sex, race and climate. Again, dental expertise is needed to refine the accuracy of such estimations. The determination of age from fetal teeth is also a matter for embryologists or dentists with specialized knowledge of this period. After the third molar has erupted in the third decade of life, then age determination becomes much more difficult. Much research has been expended in forensic odontology and the name of Gustafson (see references and further reading) is well known in this respect. His criteria for age in adult life comprised six factors:

- occlusal attrition of the tip of the tooth
- secondary dentine deposition in the apex of the pulp cavity
- apical migration of the attachment of the periodontal membrane
- increase in root transparency – the best single indicator
- root resorption
- accumulation of cementum around the root.

This method, as later modified by Johanson (1971), is said to give an age accuracy within 5 years either side of the true age.

It seems pointless to rehearse these methods in advice to pathologists, however, as specialized techniques, equipment and knowledge are needed for these procedures. The standard textbooks on forensic odontology and original papers should be consulted for the details. Returning to general features of age, obvious pointers are the state of the teeth in respect

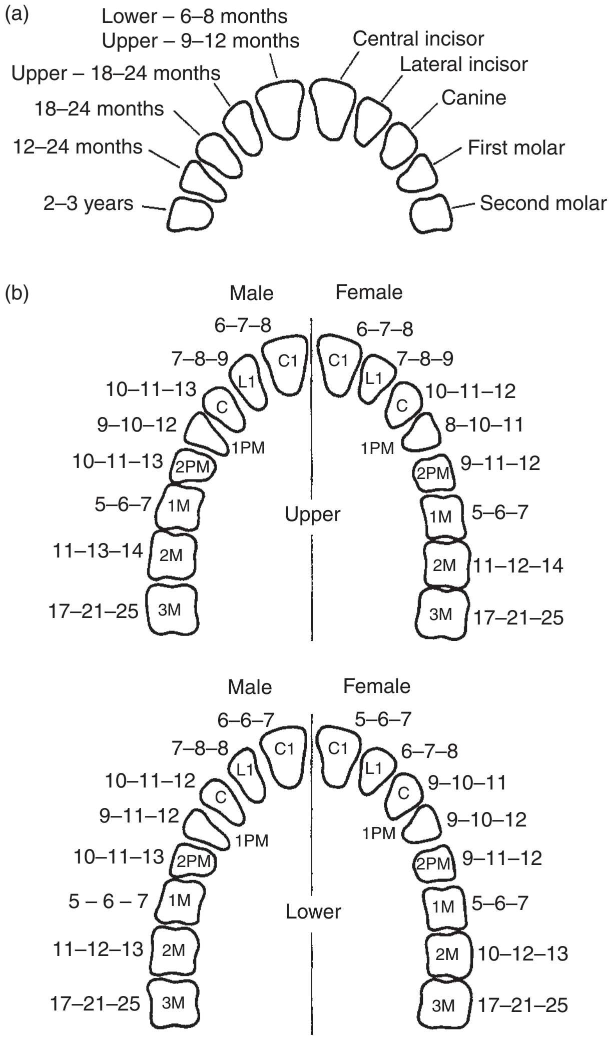
(a)
Lower – 6–8 months
Upper – 9–12 months
Central incisor
Lateral incisor
Upper – 18–24 months
Canine
18–24 months
12–24 months
First molar
2–3 years
Second molar
(b)
Male
Female
6–7–8
6–7–8
7–8–9
7–8–9
C1
C1
L1
L1
10–11–13
10–11–12
C
C
9–10–12
8–10–11
1PM
1PM
10–11–13
9–11–12
2PM
2PM
5–6–7
5–6–7
1M
1M
Upper
11–13–14
11–12–14
2M
2M
17–21–25
17–21–25
3M
3M
Male
Female
6–6–7
5–6–7
7–8–8
6–7–8
C1
C1
L1
L1
10–11–12
9–10–11
C
C
9–11–12
9–10–12
1PM
1PM
10–11–13
9–11–12
2PM
2PM
5 – 6 – 7
5–6–7
1M
1M
Lower
11–12–13
10–12–13
2M
2M
17–21–25
17–21–25
3M
3M

FIGURE 26.6 *(a) Dates of eruption of deciduous teeth (average times). (b) Times of eruption of permanent teeth; three dates are shown (years) for early, average and late eruption, rounded to the nearest year.*

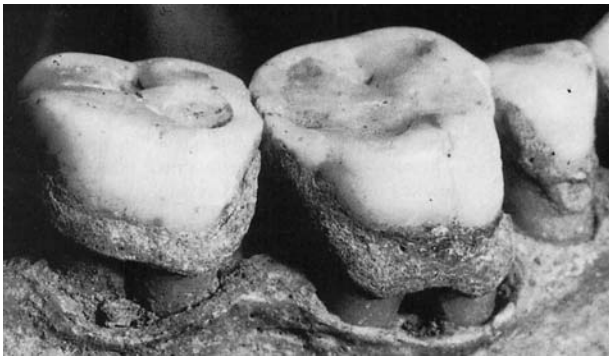

FIGURE 26.7 *Severe occlusal attrition in a jaw from the early nineteenth century. The crowns are worn down to expose the dentine by a rough diet that probably contained stone dust in the flour from contemporary milling methods.*

of wear, hygiene and colour, which may deteriorate with advancing age. Much depends upon the care with which they have been maintained, however, though marked occlusal attrition tends to go with increasing age, unless a rough diet has accelerated the wear. In Western Europe, gross occlusal attrition, sometimes down to gum level, is seen in old skeletal material. This usually indicates that the bones and teeth came from someone alive in the mid-nineteenth century or earlier, before modern milling methods removed abrasive stone dust from flour.

Edentulous jaws also suggest advancing age but, especially in former years before more conservative dentistry, even young adults often had total tooth clearances for caries. Once the teeth have gone, there is a general atrophy of the alveolar margins, but this is a poor criterion of age because of the great variability in the time when teeth are lost.

Newer techniques for age estimation include the variation with age of racemization of amino acids, especially aspartic acid, but this is a very specialized area.

Comparative identification from teeth

Establishing personal identity requires the matching of observed features with pre-existing dental records, the latter almost always obtained from previous diagnostic and therapeutic surveillance. For this method to be applied, there must be:

- Some collateral evidence to indicate either who the unknown body might be, so that records can be sought.
- Alternatively, a circumscribed population must be searched for records that may match the unknown. Such a population may be the known passengers on an aircraft or ship or a cohort of missing persons maintained on some register. It is manifestly impossible to search a large population, such as a whole country or even a city. Attempts were made in Britain to computerize dental records from the National Health Service so that a wide search could be made, but the completeness and quality of data was such that the scheme was found to be impracticable.
- The unknown person must have had dental attention in the past. The dentist or hospital must be known; the records must be traceable and, when found, must contain sufficient clinical information to provide adequate identifying features. The recovery of dental radiographs is a most useful adjunct. Unfortunately, these criteria are not always satisfied.

The dental records are needed to provide a description of the dentition and jaws at a date as late as possible before the finding of the body. Work may have been done on the deceased during life since the last record was made, if the person had been treated elsewhere and the information not recorded. Where a record does not conform to the dental state of a body who was expected to be a match, it is obvious that such discrepancies can be of two types:

1. If the record indicates some condition that is irreversible but which does not exist in the body, then that excludes matching. For example, if the record states that certain teeth have been extracted, yet they are still present in the jaws, then any hope of correspondence must be abandoned.
2. If fillings are present in the teeth, which are not shown in the records, then these may have been made later and not recorded. Of course, no discrepancies of point 1 must be present for those of point 2 to be acceptable.

Charting the teeth

In the absence of a forensic odontologist, the next best person to record the state of dentition of a dead body would naturally be a dental practitioner, to whom this task would be an everyday routine. The chart made by him could then be used for future reference in any identification procedure. This chapter is concerned with the imperfect yet sometimes inevitable circumstance where the pathologist is the only person available. Unfortunately, there are a host of different methods of charting the contents of the jaws, and, in spite of sustained efforts, no universal internationally accepted system has yet been adopted. For our purposes, any careful record of the number, position and state of the teeth made by a pathologist can be converted into whatever system of charting is required at a later stage.

Two main methods of recording data are in use: the first is a diagrammatic chart commonly used in large dental services such as the British National Health Service, seen in Figure 26.8. The other system uses a more pictorial representation of the teeth, so that all features can be recorded in a more exact topographical manner. Both systems, as well as many variants, have a notation which describes the position of the teeth, almost always in four quadrants, right upper, left upper, right lower and left lower. Unfortunately, there is considerable variation in the sequence of numeration, especially where the transition points from left to right, and from upper to lower are concerned, these being confusing and often not interchangeable. The pathologist need not concern himself too much with this problem, as his graphic representation can always be turned into whatever system of numeration is required at a later time. For example, if an unknown body has its teeth charted on one

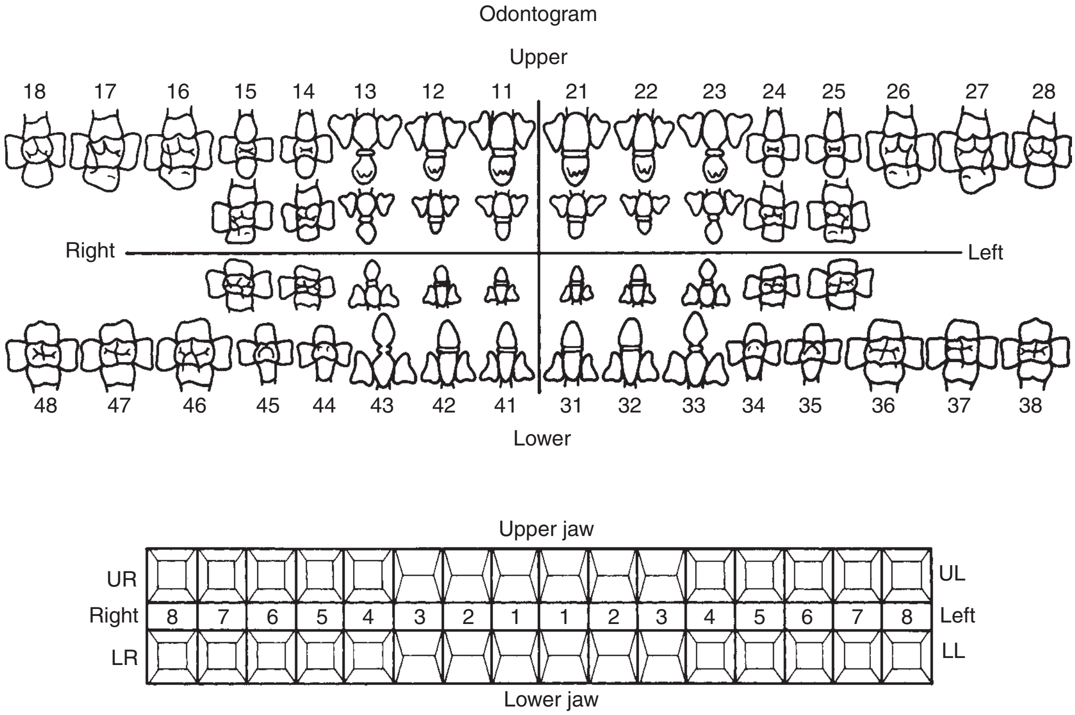

FIGURE 26.8 *Two of the many types of chart used for recording dental characteristics. The upper is the 'Odontogram' designed for Interpol. The chart displays each surface of each tooth, including the deciduous teeth. The lower chart is that used in the British National Health Service, which is a simpler design. In both charts the buccal aspects are at the top and bottom and the lingual sides of the teeth face each other centrally.*

of the common diagrams and later the dental records of a potential 'identitee' become available, the chart can be transposed into the same system as the clinical records. The notation derived from this can then be transmitted by telephone, telex, fax or other form of communication, if the records are not available at the place where the body lies. This is particularly important in transportation fatalities such as air crashes, where the home base of the victims may be far removed from the scene of death.

On the diagrammatic or anatomical charts, each tooth is represented by a pictorial symbol that provides the same number of tooth surfaces as those on the same teeth in the mouth. The incisors and canines have four surfaces represented, while the premolars and molars have an additional facet, the occlusal surface. On these diagrams, the positions of fillings, crowns, caries and damage are marked, and, of course, missing teeth are deleted.

In charting the teeth, the pathologist needs good access to the mouth and this presents the first problem. Rigor mortis in a relatively fresh cadaver may make it impossible to open the mouth without great effort. Excessive force should not be used, especially leverage with a metal instrument, because of the danger of damaging the teeth. Where the rigor cannot be broken by sustained firm pressure on the chin – or where time prevents waiting for rigor to pass off – it may be necessary to extend the autopsy incision into a neck 'V' and dissect the skin off the lower part of the face, to gain access to the masseter and temporalis muscles, which can then be divided above their insertion into the mandible, to allow the jaw to become mobile. Care must be taken not to disfigure the face during this procedure.

When the body is decomposing, no rigor will be present. If badly rotted, then cosmetic considerations will not apply and more radical removal of the jaws may need to be performed. The same holds for badly burned bodies, where heat contraction of the facial muscles may make it impossible to open the jaws without dissecting away tissues. In both these instances, where identity is a prime consideration, both mandible and maxilla may need to be removed for retention and later examination. The mandible can be disarticulated at the temporomandibular joints and removed intact. The lower maxilla, comprising the tooth-bearing jaw, the palate and the inferior part of the facial skeleton, can be removed after the mandible has been taken. This is done by sawing horizontally across the maxilla at the level of the lower margin of the nasal aperture, taking care to saw above any tooth

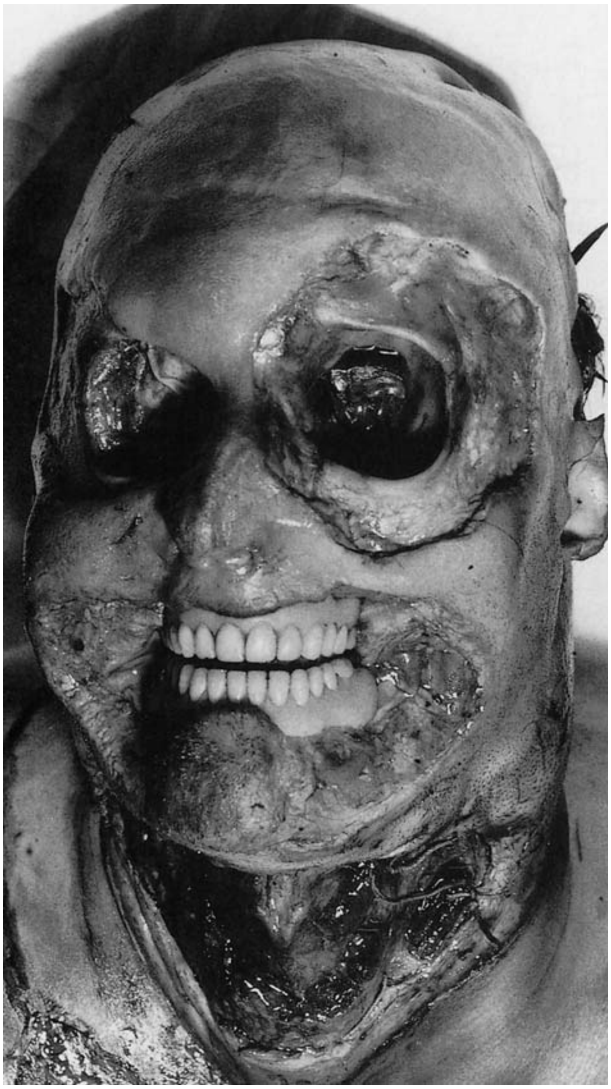

FIGURE 26.9 *Use of dentures to identify a decomposed body from the sea. Some dental prostheses carry makers' or patients' record numbers embedded in the plate material. The loss of tissue around eyes and mouth was caused by marine predators. The cut throat was made by a nylon hawser that threw this ship's officer overboard.*

roots. After photography and charting, the jaws can be preserved in formalin or a freezer. With modern serological and DNA identification techniques, the need to keep some unfixed tissue for serology and other investigations should be borne in mind. Naturally, the presence of any full or partial dentures or any other type of dental prosthesis will have been recorded and the prosthesis carefully retained for examination. Even edentulous persons may show signs of having worn dentures by the presence of pressure marks on gums or palate. Wherever possible, radiographs should be taken of the head of an unidentified body (as discussed in Chapter 3) where non-dental considerations apply, such as craniometry or frontal sinus visualization. At the same time, the radiographs may show unexpected foreign bodies in the head and some of these may have unique dental importance, such as broken drill, broken roots or congenital abnormalities, which may be matchable with clinical films, or a note in the ante-mortem records. Radiography has a special place in forensic odontology, but specialist techniques and knowledge are likely to lie outside the abilities of a pathologist.

When, by whatever means necessary, the dental arches have been made available for examination, the following features are sought and recorded on the chart:

- Extractions – whether recent or old – should be noted from the condition of the socket.
- Fillings – their number, position and composition.
- Artificial teeth – gold, porcelain or stainless steel.
- Other prosthetic work in the mouth, such as bridgework or braces.
- Crowned teeth.
- Broken teeth.
- Pathological conditions in teeth, jaws or gums.
- Congenital defects such as enamel pearls, Carabelli's cusps or ectopic teeth.
- Malpositioned teeth – rotated or tilted for example.
- The general state of care and hygiene including caries, plaque, tobacco staining and gingivitis.
- Racial pointers, such as shovel-shaped upper central incisors or multi-cusped molars.

When all available information has been discovered and entered on the chart, the process of comparison with any ante-mortem records can be made. Much will depend on the quality and the date of these records, which are frequently less detailed and exact than the autopsy charting. Allowance must be made for the clinical records to be substantially out of date on occasions, as mentioned earlier. The process of matching is again really the work of an experienced dentist, but the major task of checking the above list against the previous records can be carried out adequately in respect of missing teeth, filling, prostheses and major trauma and other anomalies.

Anything on the clinical chart that is not represented in the actual jaws almost always excludes a matching – fillings cannot go away and extracted teeth cannot return, even though some remarkable feats of dental treatment now exist. The degree of correspondence that is acceptable for a positive match is a matter of common sense, and naturally other non-dental aspects must be taken into account – it is useless trying to claim a match on a woman's dental characteristics if other information clearly indicates that the missing person was a man. Finally, and at the risk of being over-repetitive, it must again be emphasized that, though the pathologist may be a collector of data and physical evidence, where the issues

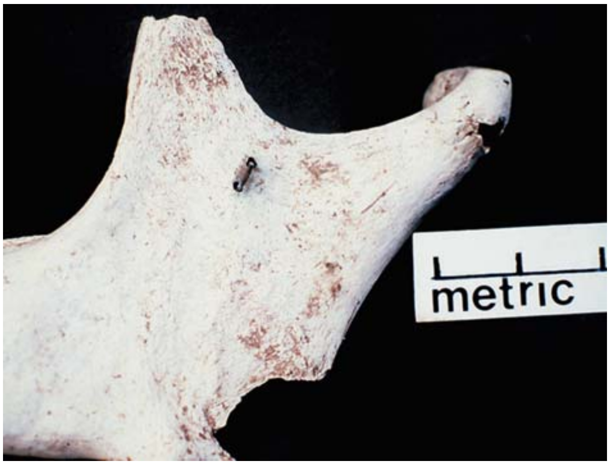

FIGURE 26.10 *A short-cut in excluding homicide. A skeleton was found buried in a suburban garden. Initial suspicions were allayed when the ramus of the mandible was seen to carry a bronze wire for attaching a spring to suspend the jaw from the skull. Police enquiries confirmed that the house had previously belonged to a member of the medical school teaching staff.*

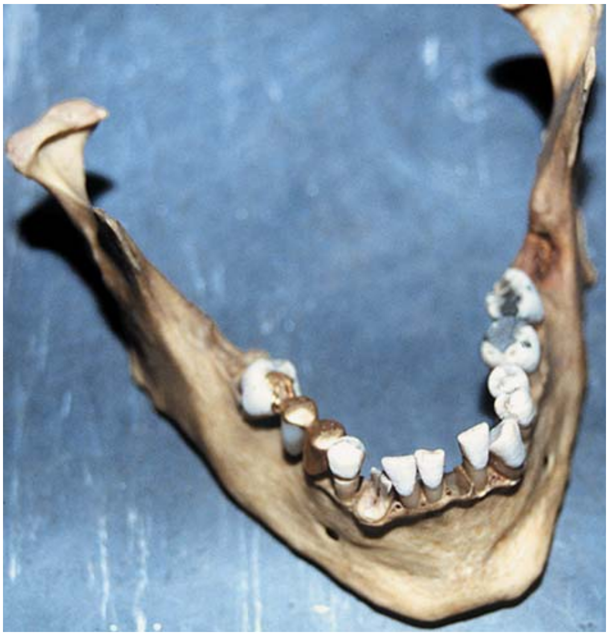

FIGURE 26.11 *A mandible from a skeletalized body found in suspicious circumstances. Identity was established solely from dental features, such as the gold bridge and acrylic tooth on the right side of the jaw and the numerous amalgam fillings. Comparison of dental radiographs obtained from a hospital confirmed the correspondence. The jaw, with the prominent square symphyseal region, is typically male.*

are vital (as in a homicide investigation), every effort must be made for the material to be evaluated by a forensic odontologist, even if the details have to be sent by air mail to another country.

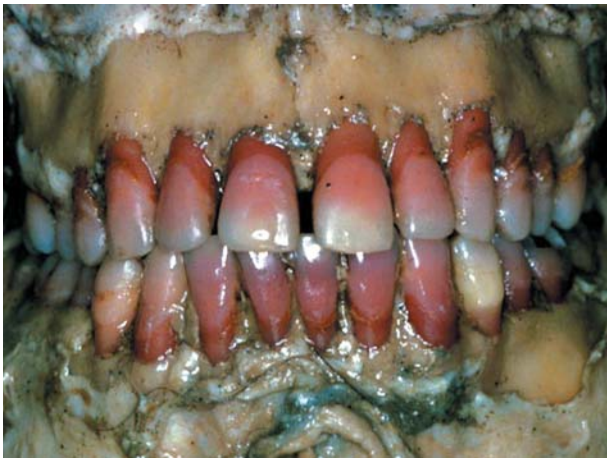

FIGURE 26.12 *Pink teeth. The jaw came from a decomposed body dumped in the countryside after death from narcotic overdose. No carbon monoxide was present in the body, the pinkness being caused by haemoglobin products staining the dentine. (Reproduced by kind permission of Professor David Whittaker.)*

PINK TEETH

At autopsy on putrefied bodies, the teeth are sometimes seen to be a marked pink colour, especially near the gum line. Considerable research has been carried out into this interesting phenomenon and it is clear that the colour is the result of the dentine being stained by haemoglobin products. It was once thought that carbon monoxide played a part in the coloration, but this has been disproved. Claims that the phenomenon is a pointer to an asphyxial death can be discounted, though possibly a very 'congestive' mode of death – albeit a very non-specific condition – encourages pinkness because of retention of blood in the pulp.

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CHAPTER 27

Poisoning and the pathologist

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Toxicology has a number of different aspects and, in such a huge subject, various specialists have different interests. The clinical toxicologist is most concerned with diagnosis and treatment of the living patient; the analytical toxicologist has the complex task of laboratory investigation; and the pathologist is concerned with evaluating poisons as a cause or a contribution to death. Though obviously linked, these various aspects are substantially different and few people can claim to be proficient in all three. As far as the pathologist is concerned, his main task is to exclude or confirm other non-toxic factors in the death. He has then to collect suitable samples for analysis and, when the laboratory results are available, to interpret them in the light of his knowledge of the history, clinical features and autopsy appearances.

The pathologist inevitably needs the expertise of the laboratory analyst and the latter's knowledge of the therapeutic, toxic and fatal levels of the substances under consideration. Such data must, however, be evaluated in the knowledge of other pathological and physiological conditions present, so that it is the pathologist, rather than the laboratory toxicologist, who should provide the final opinion upon the proximate cause of death. This does not always happen and some laboratory report forms may be seen that unequivocally – and unwisely – state that a particular drug **caused** the death.

Where, as so often happens, the toxic levels found at post-mortem are not in a potentially fatal or even toxic range, then the pathologist should seek the advice of a **clinical** toxicologist to determine whether any of the symptoms or signs during life may assist in deciding on the cause of death. As so often happens in forensic problems, the investigation of a fatal poisoning must be a cooperative effort, especially between pathologist and laboratory analyst. Even in apparently obvious cases, such as a blood saturation of 50 per cent carboxyhaemoglobin, it is not for the analyst to declare a definite cause of death, as the victim may also have had a fractured skull – but equally, the pathologist has an obligation to provide the laboratory with the best possible samples in the best possible condition, as well as good information about the circumstances of the case.

THE CONCEPT OF THE FATAL DOSE

Many persons, including some doctors, are under the firm misapprehension that, for most toxic substances, there are relatively constant quantities that will cause death. Not only the lay public, but lawyers, police, coroners and others assume that there is a more or less linear relationship between the amount of poison that enters the body, the resulting levels in blood and tissues and the degree of disability caused – the ultimate disability being death.

In addition, it is often thought that back-calculation from blood and tissue levels can arrive at a definite assessment of how much poison was originally administered. This aspect is of particular concern to coroners and similar officers, who have to decide on motive in potential suicides, where the magnitude of any overdose may assist in distinguishing between accident and self-administration.

The pathologist has his own difficulties in respect of 'the fatal dose', as quantitative results from the laboratory have to be matched against a knowledge of published blood and tissue levels for that substance in relation to its potential toxicity. Though numerous tables of toxic levels have been published, there is considerable variation between the levels recorded. Reasons for this are explored later. It is obvious that there is no 'fatal dose' in the sense of a single threshold concentration above which a person dies and below which he survives. Instead, there is a range of levels, the upper and lower margins of which vary from one authority to another, which encompasses most deaths – but even here there are many exceptions, instances being recorded where survival occurs well above the upper limit and death occurs below the lower margin. In such cases, the task of the pathologist – which cannot always be satisfactorily discharged – is to evaluate all other non-toxicological data to see if they can modify the circumstances sufficiently to allow an acceptable explanation for the death. It is sometimes difficult to explain these concepts of great biological variation to lawyers and police officers, who expect more definite decisions, and might even feel that the pathologist is being evasive or obstructive.

The concept of the 'LD_{50}' is sometimes raised by the more knowledgeable lawyer, but this does not assist materially in any individual case. The LD_{50} is a device used by pharmacologists and toxicologists in a statistical sense in animal experiments. Over a large number of tests, it provides a toxic level at which half the animals will be expected to die. Though the indicative value in a general sense in comparing the toxicity of one substance against another, there is no way of knowing whether the human victim of poisoning lies at the upper or lower end of the classical bell-shaped curve that characterizes most biological responses.

Far more useful is the cumulative record of actual laboratory results from toxicology centres that deal with human poisoning, which progressively build up a large database of blood and tissue levels, and correlate these with records of the clinical state, toxic effects and fatal outcome. Even here the variations are wide, as the many published tables testify, but at least general guidance can be obtained.

VARIATIONS IN PUBLISHED FATAL POISON CONCENTRATIONS

In the many publications that offer therapeutic, toxic and lethal ranges for a wide variety of poisonous substances, there is considerable variation in the quoted levels. These can be a source of confusion and sometimes dismay to the pathologist who, even with the advice of his local toxicologist, may find it difficult to decide whether a death can justifiably be attributed to a particular drug or other toxic substance. Even if he can so satisfy himself, he may be subjected to keen questioning, interrogation, doubt or criticism from colleagues, coroners, police, lawyers and others, who have access to different versions of toxic and fatal levels. The ultimate challenge may come in a criminal court, where opposing counsel may openly defy the pathologist's interpretations in cross-examination.

Dr A R W Forrest, Chemical Pathologist and Toxicologist at Sheffield's Royal Hallamshire Hospital (personal communication) points out some reasons for the variations found in such published data. He expresses the view that it is rather surprising that the order of disagreement is not greater, given the opportunities for disparity.

First, many of the published series are small, some being only individual case reports. Statistically, this is not a good foundation for establishing reference ranges, which are much better obtained from a database derived from the cumulative results of a large laboratory service, such as the British Home Office Forensic Science Service, which maintains a central computer store of all results from its laboratories.

Second, analytical techniques vary widely, both in method and accuracy. The specificity varies from laboratory to laboratory so that there may be a lack of uniformity about what is actually being measured. For example, paracetamol may be measured by a non-specific method that picks up its metabolites as well as the native drug, which will then offer a different blood level in a fatal case from that found by more specific methods. In other words, one is not comparing 'like with like'.

Third, as discussed elsewhere in this chapter, the site of sampling may introduce wide errors. With some substances, a several-fold variation in concentration may be found between femoral vein and cardiac cavity blood.

Last, errors occur because a 'fatal' level may be attributed to one substance without taking into account the level – or even the existence – of other toxic substances that the deceased may have taken, and of which the pathologist or analyst may not even have been aware. For example, the newer more potent benzodiazepines may be missed in a simple toxicological screen, but could well have contributed to the toxicological overload that caused the patient to die. In such a case, the level of the recognized drug would be blamed for the death, whereas in fact it may not have been a lethal dose in itself, though was recorded as such in any database or tables.

These facts highlight the dangers of limiting a request for analysis solely to the substance known or thought to have been taken. Often an efficient screen for other substances will reveal other unsuspected compounds, sometimes more toxic than the one originally suspected.

It has to be recognized, however, that, in many jurisdictions, the availability and expense of toxicological investigations may make it impossible to pursue a full analytical survey, especially if this is to be undertaken on a speculative basis rather than for quantification of a known or strongly suspected toxic agent. A full screen may only be practicable and justified in a suspected homicide, if laboratory facilities and fiscal support are severely restricted. In many countries homicide by poison is relatively rare and the funds to investigate accidental, suicidal and iatrogenic poisoning exhaustively may just not be available.

THE AUTOPSY IN SUSPECTED POISONING

The autopsy in these circumstances can be amongst the most difficult of problems faced by a forensic pathologist – not in the technical procedure of the examination, but in the final evaluation of all the available information.

The nature of the poisoning autopsy in Western countries has changed dramatically since the last century, when poisoning was a common method of homicide. There has been a marked change in the nature of poisons used in murder, suicide and accident. The corrosives, heavy metals and alkaloids commonly ingested in former years became relatively easy to detect, either by gross autopsy appearances or by straightforward analytical methods. Further refinements of toxicological techniques, instead of the old methods in which large samples had to be tested because of the insensitivity of laboratory tests, allow the detection of nanogram quantities.

Acids, alkalis, phenols, arsenic, antimony and strychnine, for example, became easy to detect, and in the Western world these gave way to compounds that leave little or no gross, or even histological changes in the body. Most are pharmaceutical or agrochemical substances, active in low dose compared to the old ‘blockbuster’ poisons. As for the majority of drugs used in legitimate medical therapy, an added problem arises when low post-mortem levels are found – is this merely a therapeutic dose or the tail-end of a declining lethal dose?

In some parts of the world, such as South-east Asia, Africa and the Indian subcontinent, poisoning remains common and more physically damaging substances continue to be seen that leave obvious autopsy lesions. Some of these are described under the appropriate headings in the succeeding chapters, but in most poisonings the major function of the autopsy is to evaluate any other conditions present, both from trauma and natural disease – but also to collect suitable material for laboratory analysis. The proper retention of optimal samples, their correct preservation and dispatch to the toxicologist are of such fundamental importance that they are discussed in detail.

POISONING DEATHS IN HOSPITAL

A considerable proportion of those who die from suspected poisoning will have died in hospital, and it is of prime importance that the medical records be obtained and studied before the autopsy begins. Even if poisoning was not confirmed or even suspected by the clinicians treating the patient, later information may have come to the pathologist to raise this possibility. Whether known or not, the results of ante-mortem investigations may be of considerable use to the pathologist. If poisoning was known or suspected before death, there may well have been toxicological analyses performed and the results of these may be of great value.

Whether poisoning was suspected or not, there may still be ante-mortem blood or urine samples (taken for biochemical or haematological tests) stored in the hospital laboratory, which may be rescued for retrospective analysis. Such ante-mortem samples are likely to be of greater use than fluids drawn off at autopsy, because of sampling defects, post-mortem changes and because toxic levels are likely to have been higher during life, representing more accurately the maximum toxic concentrations.

In addition, many patients dying in hospital from drug overdoses will have indwelling catheters in place. It is the common practice for the nursing staff to remove these at death and discard the urine. If it is possible to establish a practice in the wards where such terminal urine samples are saved, valuable material for analysis can be obtained.

THE COLLECTION OF AUTOPSY SAMPLES FOR TOXICOLOGICAL ANALYSIS

The investigation of a death from suspected poisoning may stand or fall upon the correctness or otherwise of the sampling of fluids and tissues from the body. Unsuitable samples, inadequate amounts, incorrect sampling sites, poor containers, inadequate preservation methods, and delayed or unsatisfactory storage and transport to the laboratory may frustrate or distort proper analysis. The final outcome may be wrong, either in failing to detect a poison actually present, in measuring only part of that originally present or – in some cases – even producing falsely high results that then lead to an incorrect cause of death. Not only must samples be in the optimal condition, but the accompanying information from the pathologist to the analyst needs to be as accurate and comprehensive as possible, so that the most appropriate techniques are used, and allowance made for any interfering substances that may be present.

In decomposed bodies infested with maggots, and in the absence of tissues or fluids normally taken for toxicology, Diptera and other arthropods can be used as alternative specimens for toxicological analyses. This relatively new field of forensic entomology is called entomotoxicology.

The time of sampling

It is obvious that the shorter the delay between death and the removal of samples, the better. Though some toxic substances, such as carbon monoxide, form stable compounds in the body, many others (especially volatile substances and some pharmaceutical products) will be broken down by post-mortem autolysis and decomposition. When an autopsy cannot be performed quickly after death, in terms of a few hours, then mortuary refrigeration is the first line of defence to slow up putrefactive and autolytic processes. If delay is foreseen, usually because of administrative problems in obtaining consent or authority for autopsy, it may be possible to obtain a sample of blood through the body surface, such as puncturing the femoral vein by needle and syringe. The blood can then be kept in optimal conditions, with preservative where needed, and perhaps with the serum or plasma separated from the cells to avoid haemolysis. Similarly, urine could be drawn off by catheter or even suprapubic puncture, unless strict regulations forbid this as anticipating autopsy permission.

In some jurisdictions, authority for autopsy may be particularly hard to obtain, from religious, financial or administrative reluctance. Where poisoning is suspected, permission may be granted only for external examination and sampling; here venous blood, urine and perhaps vitreous humour may have to suffice for all investigations.

Information supplied to the laboratory

When samples are submitted to the toxicologist, they should be accompanied by the best possible information relevant to the case. It is both counterproductive and an unprofessional discourtesy merely to record the personal details of the deceased and list the samples, with a terse demand such as ‘Any poisons?’ on the request form. Such a demand could legitimately be refused by the toxicologist, as it is quite inadequate information upon which he can be expected to function effectively and safely. The following information should be supplied and where necessary, supplemented by direct discussion either in person or by telephone:

- The personal details of the deceased, including age, sex and where thought relevant, the occupation (especially if in agriculture or industry).
- Brief details of symptoms, if any, and length of illness.
- The post-mortem interval before samples were obtained, and the actual date and time of sampling.
- The name, address and telephone number of the pathologist.
- A list of all samples provided, with an indication of the sampling site for each.
- The nature of any preservative in each of the samples.
- If there has been a delay in submitting or transporting the samples, a note of the condition under which they have been stored (for example, refrigeration or deep-freeze).
- Any special risk associated with the samples **must** be communicated to the laboratory. The most obvious are infective conditions, especially hepatitis B or C virus or HIV infection in the deceased, though other diseases such as tuberculosis, tetanus, anthrax, gas gangrene or any other bacterial or viral condition must also be specifically reported. In relation to hepatitis and HIV, even if these are not definitely confirmed, the toxicology laboratory must be told if the deceased was in a high-risk group, such as a drug addict or a homosexual. In many areas, including Britain, some toxicology laboratories will not accept samples from such high-risk groups until a blood sample has been screened for hepatitis B and HIV antibodies; if positive, they may decline to carry out the analysis or perform it only under strictly controlled conditions.

  Similar warnings must be given to the analyst if there is any possibility of certain harmful substances, such as radioactive isotopes or certain war gases, being present in the samples.
- When a death has criminal aspects, such as a murder or manslaughter, then the usual strict precautions must be taken for continuity of evidence. Each container must be carefully labelled and preferably countersigned by the pathologist. Some jurisdictions will require actual seals on the containers themselves or the package into which they are placed for transport, or both. Accompanying signed ‘exhibit labels’ with serial numbers corresponding exactly with numbers on the jars may be required. The containers must be given by the pathologist to a named person, usually the ‘exhibits officer’ of the police investigating team (or to forensic scientists if they attend the autopsy). The police officer must hand the samples personally to a member of the laboratory staff and a record of this chain of evidence must be kept, so that there can be no criticism levelled at anyone when the matter comes to court, raising doubts about the correct identity of the sample.

CONTAINERS FOR TOXICOLOGY SAMPLES

There will be considerable local variation in the type of containers used for the collection and transmission of samples to the laboratory. Some laboratories will issue their own kits, an example being those provided by the Home Office Forensic Science Service in England and Wales. These consist of a plastic bag containing a sheet of instructions about the most suitable samples, together with a large plastic pot with tightly self-sealing lid for liver, a smaller one for stomach contents, several plastic or glass 30 ml universal containers for blood and urine, a small vial containing fluoride for blood-alcohol estimation and a sterile syringe and several needles. Variations of such kits may be provided by different laboratories, but the general nature of the containers is the same. In other areas, the pathologist will provide the containers himself and they should conform to the following general specifications:

- They should either be new or, if previously used for other samples, have been rigorously cleaned and sterilized. Even when they are new, it is preferable for containers to be washed and sterilized before use unless the manufacturer's specifications clearly make this unnecessary. All containers must be chemically clean, not just apparently clean to the naked eye. This applies particularly to any rubber, plastic or other seal within the lid or cap, which may be a trap for any debris or even residue from a previous sample.
- Blood should be collected in screw-capped universal containers of about 30 ml or, where less will suffice, in plastic-capped tubes of about 5 ml. Urine is best held in 30 ml universal containers, as is bile. Stomach contents may be retained in glass or plastic jars with a volume of at least 250 ml, the lid being either a tight screw-thread with a cardboard or plastic liner, and a self-sealing plastic top. Some laboratories require the stomach wall as well as the contents, as toxic substances may be held in higher concentrations in the rugae and crypts of the mucosa, or even in the blood in the actual stomach wall. The size of the container may need to be larger if the organ itself is retained. Liver is usually required, preferably a piece weighing a few hundred grams, rather than the whole organ. The total weight of the liver should be communicated to the laboratory if only part is sent. It may be preserved in a larger glass or plastic container. When the laboratory wishes the whole organ, this container needs to be large enough to hold about 3 litres. If only small samples are needed, such as vitreous humour or cerebrospinal fluid, bijou bottles of 5 ml capacity or small tubes of similar size, are needed.

In Britain, the government forensic laboratories provide special bottles for blood-alcohol estimations, for use in both drink–driving offences in the living and for autopsy samples. These are short, wide bottles of about 10 ml capacity, with a fixed top consisting of a plastic diaphragm secured by a metal flange with a central aperture. They are filled by syringe, the needle being pierced through the diaphragm, but have the disadvantage of building up pressure when the blood is injected, so that, when the needle is removed, blood may spurt back and even contaminate the operator – the reverse of the intention of these vials to be safe. The danger can be avoided by either inserting a second needle through the diaphragm to equalize the pressure, or to suck out air from the bottle with the empty syringe and needle before taking the sample so that the introduced blood replaces the lost air. Intestinal contents, with or without the gut itself, can be placed in large jars or plastic pots, similar to those used for liver.

Plastic containers, especially polypropylene, are increasingly used and have the advantage of not smashing when dropped. Some analyses, however, may be affected by the plasticizer in either the container wall or the cap – cocaine is an example. The advice of the toxicologist with whom each pathologist normally collaborates should be sought in respect of his individual preferences for containers. Where lungs or other tissues are to be submitted for analysis for volatile substances, as in solvent abuse, ordinary polythene bags are not suitable containers. Nylon bags (such as those used by arson investigators) should be used, as they are not permeable to such substances.

PRESERVATIVES IN SAMPLES

Though many samples for analysis are best sent in their original state, others require additives to maintain them in optimum condition until they reach the laboratory. In addition to such preservatives, some require anticoagulants to keep the blood fluid. The prime example of sample preservations is that for blood alcohol, as improper care of samples may distort the original alcohol level in either an upward or downward direction. The usual preservative is sodium or potassium fluoride, which is essential if the sample is not to be analysed within a few hours of withdrawal from the body.

Errors caused by post-mortem changes before the sample is removed cannot be avoided. These are variable, depending partly on the conditions of the post-mortem environment and partly on the microbiological population of the corpse. In warm conditions, fermentation by yeasts and other alcohol-producing flora can produce appreciable quantities of alcohol: it has been reported that as much as 150 mg/100 ml have been generated within 24 hours after death.

Once the blood or urine has been withdrawn from the body, however, further changes can be arrested by preservatives. Much has been published on this subject and a variety of concentrations of fluoride have been recommended by different authors. Glendening and Waugh (1965) used 100 mg of sodium fluoride/10 ml blood and found no change in the alcohol content when samples were kept at room temperature for up to 3 months. Plueckhahn (1968) found that at least 5 mg/ml of sodium fluoride was required to inhibit alcohol dehydrogenase activity, which destroys alcohol. He found, however, that this concentration failed to inhibit alcohol-forming organisms completely, such as when yeasts were introduced into the samples. Together with Ballard, he investigated the use of mercuric chloride as a preservative (Plueckhahn and Ballard 1968). This substance was also used by Bradford (1966) who added 0.5 mg of sodium citrate and 0.1 mg of mercuric chloride/ml of blood to ensure that the samples remained liquid and sterile. When he replaced the mercury by fluoride, significant changes occurred, usually a loss of alcohol, though occasionally it increased.

In most cases the delay before analysis is relatively short, being measured in days – often with refrigerated storage – so the long-term experiments mentioned here do not apply. When the ambient temperature is high, much more caution needs to be used. It would seem that for general use, a concentration of 10 mg/ml of sodium or potassium fluoride is satisfactory. Fluoride should also be added to urine and vitreous humour if alcohol estimations are required. Cocaine and its metabolites are also labile *in vitro*, and fluoride should be added to samples submitted for analysis for this drug.

Cyanide may be formed in considerable quantities in plain blood samples, which are of little use for cyanide estimation. Fluoride should be added to such specimens, as well as for carbon monoxide (carboxyhaemoglobin) if the analysis is to be delayed. In all analyses for pharmaceutical drugs, two samples of blood should be submitted, one plain in large volume of at least 25 ml and another smaller sample in fluoride.

When insulin assay is required on a blood sample, special precautions should be taken. Haemolysis of the red cells releases enzymes which will reduce the S–S bonds in insulin and destroy its immunoreactivity, so the sample should be centrifuged as soon as it is obtained to separate the serum. A heparinized sample should also be taken for glycosylated haemoglobin estimation and fructosamine assay. Vitreous humour, blood and urine samples should be placed in fluoride and sent for glucose estimation, as well as tissue samples from around any putative injection site, together with a control tissue sample from a site elsewhere on the body where insulin is unlikely to have been recently injected.

THE SITE OF SAMPLING FOR TOXICOLOGICAL ANALYSIS

It is now obvious that, in the past, serious errors were made in toxicological analyses from lack of care or consideration concerning the source of body-fluid samples. Significant variation can be found in the concentration of many substances depending on the place from which sampling was carried out. In life there may be variations when arterial as opposed to venous blood is used, as tissues may take up the compound from the arterial supply, the concentration then being lower in the venous return. Similarly, portal blood may have a substantially higher concentration of a substance that is being absorbed from the intestine, before it is extracted by passage through the liver. After death, most variation is caused by uneven destruction by enzymatic and microbiological activity – and by diffusion from sites of higher concentration. The barriers formed by living cell membranes break down after death and small molecules in particular may move easily through the tissues into vascular channels.

Post-mortem levels of many substances are unreliable because of this diffusion effect, making the interpretation of physiological components, such as sodium, potassium, calcium, glucose, urea and many others extremely difficult, if not impossible. Applying these facts to toxic compounds, the concentrations may vary considerably according to the sampling site. As an illustration, the Moorgate Tube disaster in London showed that blood-alcohol levels may vary widely between different sampling points. The driver of an underground train was killed, along with a number of passengers, but his body could not be recovered from the warm environment for several days. As it was obviously vital to know if drink had contributed to the accident, four samples were taken from various sites in the body. On analysis, a fourfold variation from between 20 and 80 mg/100 ml was obtained, presumably because of variable rates of putrefactive alcohol production, as there was no evidence to show that the driver had imbibed alcohol before death.

Most research in respect of sampling variation has been directed at alcohol. One point of dispute, which is relevant even when post-mortem changes are minimal, is whether alcohol in the stomach can diffuse after death to neighbouring organs and produce a falsely elevated alcohol concentration in blood at those sites.

The relevance is clear, in that, if a person drinks alcohol immediately before death, there will be insufficient time for it to be absorbed. Thus ethanol remaining in the stomach after death cannot have contributed to his ante-mortem blood-alcohol level, and hence his cerebral function and consequent behaviour. If however, analysis of a sample of blood taken from the heart cavities is contaminated by post-mortem diffusion from the adjacent stomach, then a falsely high reading will be obtained, which may have serious legal implications, if the error is not appreciated.

Several workers have investigated this problem, with conflicting results. Gifford and Turkel (1956) introduced alcohol into the stomachs of cadavers and found that subsequent heart blood levels increased by 25 up to 106 mg/100 ml. They then compared femoral vein blood with heart blood voided into the pericardial sac in alcohol-positive autopsies and found that the concentration in the latter was higher. Plueckhahn and Ballard (1968), however, criticized this work on the grounds that pericardial fluid alcohol was usually about 20 mg/100 ml higher than that in the heart or peripheral vessels. Plueckhahn went on to instil alcohol into the stomach of cadavers, taking multiple site samples at times from 6 to 50 hours later. His results indicated that there was a significant diffusion of alcohol to the pericardial and pleural fluids, but that the increase was minimal in intraventricular heart blood.

Pounder and Yonemitsu (1991) carried out experiments with dead bodies in which they introduced a slurry containing alcohol, dextropropoxyphene and paracetamol into the trachea to simulate aspiration of stomach contents. After a delay of 48 hours, an autopsy was carried out and drug concentrations measured in samples taken from various sites. Whilst femoral vein blood remained clear of these substances, samples from vessels in the thorax showed up to 130 mg/100 ml of alcohol with a mean of 58 in a pulmonary vein – and up to 1934 mg/l of paracetamol (mean 969), both obviously spurious due to post-mortem diffusion. This situation could have occurred from agonal regurgitation of stomach contents with recently swallowed drugs back into the air passages and shows the dangers of inappropriate sampling sites, with the femoral the place of choice.

Winek *et al.* (1995) have shown that, in the sampling practice of transthoracic needling, especially in cases of trauma where the gastrointestinal tract has been damaged, false elevations of blood alcohol can occur. These workers used heart blood as their control, which itself seems suspect as a satisfactory autopsy sample.

For the reasons given above, **peripheral** vein blood should be used whenever possible, avoiding heart blood as a potential source of error for alcohol and presumably other easily diffusible substances.

THE TECHNIQUE OF OBTAINING AUTOPSY SAMPLES

Blood

There are several ways of obtaining blood samples at autopsy and perhaps the most useful advice is what **not** to take. Blood should never be obtained from body cavities after evisceration, as it is almost certain to be contaminated with other body substances. The practice of scooping 'blood' – or more accurately, bloody fluid – from the paravertebral gutters or the pelvis is always unacceptable, as urine, intestinal contents, gastric contents, lymph, pleural and ascitic fluid and general tissue ooze will always find their way into such a sample and negate the reliability of analysis.

When a large haemothorax or haemopericardium is present, it may be grudgingly acceptable to use such blood or clot, if a clean sample is taken immediately on opening the chest, before any dissection or disturbance of organs is made. This is only second best to obtaining intravascular blood – and, in the case of alcohol and other diffusible substances, the results cannot be relied upon, as the sample may be contaminated by post-mortem diffusion from the stomach, as discussed in the preceding section. Carbon monoxide estimations may also be made on clean cavity blood, if nothing else is available, as sometimes happens in a badly incinerated body. As it is absorbed through the lungs, it cannot diffuse from the gastrointestinal tract to give a false result. Even so, it is a rare autopsy that cannot provide a small sample of blood from some peripheral vein, if enough care and persistence is used.

To return to the general state of affairs, the most satisfactory way of obtaining a venous blood sample is venepuncture of the femoral vein by direct puncture in the groin before the autopsy begins. Practice is required as, unlike a living patient, the vein is not usually palpable. Once the lumen is entered, 25 ml can usually be drawn off without trouble, though a slow flow may be improved by massaging the leg to drive blood proximally or the leg may be raised, if rigor allows. Though less satisfactory than a leg vein, for reasons discussed earlier, a neck vein can also be punctured through the skin, and even after death the jugular may sometimes be both visible and palpable, especially in congestive deaths. The subclavian vein can also be tapped.

When collecting blood samples by percutaneous puncture, some pathologists prefer to use a needle designed for aspirating samples from rubber-capped vials, rather than a needle meant for clinical aspiration or injection. The same needles can be used for collecting vitreous humour. An example of this type of needle is the Becton Dickinson purple-hubbed 16 gauge one-inch or a similar American equivalent.

In some jurisdictions, especially in countries where the system allows only a low autopsy rate, transcutaneous sampling is virtually the only post-mortem investigation possible and the doctors in these areas become adept at cadaver venepuncture. Many pathologists, the authors included, have been brought up to obtain blood samples during the actual performance of autopsy and this can be as satisfactory as external venepuncture, as well as saving the expense of a new syringe and needle every time. A common procedure after evisceration is to hold a container (such as the 30 ml universal) under the severed end of the subclavian vein, within the upper part of the empty thorax. The arm is then elevated and massaged if necessary, to express blood into the container. Similarly, and perhaps preferably, the femoral or external iliac vein may be transected near the brim of the pelvis, and a container held under the cut while the leg is elevated, or massaged, or both. Either of these methods will provide ample, clean, peripheral venous blood, though care must be taken to avoid any contamination from the body cavities. This initial collection should be transferred into one or more new tubes, with preservative added if appropriate, as the first receptacle will be soiled externally during the collection process.

An alternative method of collecting a venous sample, which always gives a copious flow of blood, is to incise the internal jugular vein during the initial stages of the autopsy. As soon as the main autopsy incision is made, the flaps of the neck skin can be dissected aside and the jugular exposed, if necessary by dividing the sternocleidomastoid muscle. As in the previous technique, a bottle can be held against the vein as it is transected and the flow collected directly into it. The blood may overflow into the pouch formed laterally by the reflected skin, which forms a reservoir where a considerable volume may collect. If the flow is scanty, it can be improved by raising and lowering the head, which will cause blood to return from the upper venous drainage areas.

Even more can be expressed by pressing on the chest, but here there is the potential disadvantage of forcing up blood through the superior vena cava from the heart, which may distort the value of alcohol and other drugs that may have diffused port-mortem from the stomach. Blood should not be taken from the heart cavities, the inferior vena cava, or the portal or hepatic veins, as these may also give concentrations that are at variance with those in the peripheral vascular system. A full 30 ml of blood should be submitted to the laboratory wherever possible, together with a 5 or 10 ml fluorided sample.

Urine

Prior to, or in the absence of, an autopsy, urine can be obtained by catheter or suprapubic puncture with syringe and long needle. At autopsy it is usual to wait until evisceration has been carried out before dealing with the bladder. A sample can be obtained by puncturing the fundus with syringe and needle. Alternatively, the bladder can be stretched by pulling the fundus upwards with the fingers, then a sagittal incision made with a knife on the ventral surface, which must be free from blood soiling. The urine that wells out can be collected directly into a small container such as a 30 ml universal. If only a small amount is present, then the incision may have to be enlarged and the residual urine sucked out under direct vision, using a syringe without a needle.

Bile

This can be useful for some analyses, such as those for morphine and chlorpromazine, which are concentrated by the liver and excreted into the gallbladder. Direct collection into a bottle is advised, as bile is usually too viscous to be sucked through a needle.

Cerebrospinal fluid

This is not often required for toxicological analysis, though it may be needed for microbiological and virological studies. If needed, it should be collected by lumbar or cisternal puncture, as in the living patient. It can be difficult or impossible to obtain in this way because of the lack of any intrathecal pressure.

The body should be turned on to its side before the autopsy begins and flexed as much as possible by an assistant. If an infant, it should be sat up and again flexed forwards to curve the spine as much as possible. A needle on a syringe should then be passed between two lumbar or lower thoracic spines, and stopped as soon as any penetration of the theca is felt. Moderate suction should be maintained on the syringe piston to compensate for the lack of internal pressure. Alternatively, the needle should be passed into the midline just below the occiput and advanced upwards until the skull is contacted just posterior to the foramen magnum. The needle is slightly withdrawn and re-advanced until it slips through the posterior part of the atlanto-occipital membrane into the basal cistern when cerebrospinal fluid may be aspirated. It is of little use taking cerebrospinal fluid from the bowl of the posterior fossa after the brain has been removed as the concentration of many substances is different in blood compared with the fluid, so blood contamination distorts any results. Clear cerebrospinal fluid may, however, sometimes be obtained from the lateral ventricles, either by needle puncture or cutting down through the cortex.

Vitreous humour

This is sometimes useful, especially in bodies with appreciable post-mortem decomposition, as the fluid in the eye resists putrefaction longer than other body liquids. Vitreous fluid is also used for estimating the time since death (see Chapter 2).

A puncture should be made through the sclera at the outer canthus with a fine-gauge needle. This should be placed as far laterally as possible, pulling the lid out, so that when released it returns to cover up the puncture mark for cosmetic reasons. The fluid should be sucked out by syringe, but it will often come only slowly because of its viscosity. If the best restoration is needed, water should be reinjected through the same needle to reinflate the globe, which tends to collapse on suction.

Stomach contents

As stated earlier, these can be collected directly into wide-mouth glass or plastic pot of at least 250 ml volume. To collect them, the exterior of the stomach should be washed clean of blood and other contamination, and pulled with attached organs to the edge of the dissecting board or sink. The greater curvature should be opened cautiously with large scissors, and the jar held underneath so that the contents flow directly into it. When most have been expressed, the greater curvature can be opened up fully and the gastric lining examined. Any further contents are scraped out and any powder, capsule or tablets picked off, and either added to the main jar or placed in a separate small container. Such focal deposits form a more concentrated sample for the laboratory. Any undissolved tablets or capsules should be carefully preserved, as the laboratory or a pharmacist may be able to identify them by their appearance and colour. After the mucosa has been examined, including that of the duodenum, the stomach wall can be dissected off. Some laboratories require this for their analysis, either added to the jar of contents or sent separately. The wishes of each individual toxicologist should be discovered in advance.

Intestinal contents

These are not routinely required for analysis unless some particular gastrointestinal poison is suspected, such as one of the heavy metals. Again, the toxicologist should be consulted. If required, both ends of the small gut should be ligated by string sutures at duodenum and ileum. The intestine is cut through at these points and stripped out by cutting through the mesentery in the usual way. The intact gut can be sent to the laboratory in a large container (such as that used for liver) or – if the mucosa needs to be examined first – it should be opened in a large clean tray. One suture can be cut and the contents milked from one end to the other into a suitable jar, the gut then being opened and sent with the contents to the laboratory. The large intestine and contents are rarely required, as most toxicology laboratories are not keen on handling and storing large volumes of faeculent material. In heavy-metal poisoning, such as arsenic and antimony, however, some analysis may be required.

Vomit

This is rarely collected at autopsy, unless a large quantity has been found in the air passages. However, vomit is not infrequently collected by ambulance crews and police at the scene of the illness or agonal event, and brought with the deceased to hospital or the mortuary. If thought relevant in a case of suspected poisoning, it should be properly contained, labelled and forwarded with other samples for toxicological examination.

Other fluids

Other fluids are rarely collected, but on occasions may be useful, especially if clean blood cannot be obtained. Pericardial fluid, synovial fluid, pleural effusion and ascitic fluid can be used for qualitative analysis to identify a range of substances, though these levels can rarely be related to established ranges of blood concentrations. They may be collected and transported in the same type of container and with the same preservatives as vitreous humour.

Analysis for volatile substances

In solvent abuse and deaths from gaseous or volatile substances, the toxic material may be isolated from a whole lung. As soon as the thorax is opened at autopsy, a lung is mobilized and the main bronchus tied off tightly with a string ligature. The hilum is then divided and the lung placed immediately into a nylon bag, which is sealed and sent as soon as possible to the laboratory. Ordinary plastic (polythene) bags are not suitable for this task, as they are permeable to volatile substances. Nylon bags, as used by arson investigators to collect samples that may have volatile accelerants, do not suffer from this defect.

In collecting blood samples for volatile substances, plastic tubes or tube/syringe combinations of the ‘monovette’ type are unsuitable, as the concentration of such compounds as toluene or other solvents will decrease considerably over a few days in storage. Vials with a rubber septum as a seal are also unsuitable, as the volatile substance can escape through the rubber. Suitable tubes are made of glass with an aluminium foil-lined cap or a polytetrafluorethylene (Teflon) liner. This type of tube is often used in laboratories for scintillation counting and can be employed for the collection of solvent samples. Such tubes should be available in any busy autopsy room where solvent abuse deaths may be handled. The tubes should be filled to the top to avoid loss of volatile substances into the head space and should be stored at 4°C, rather than being frozen solid.

Body tissues

Body tissues may be needed for some toxicological analyses. Liver is the most usual, as it concentrates many substances and their metabolites, which may then be recoverable long after the blood and urine levels have declined. Either the whole organ is saved or an aliquot of 50–100 g, according to the wishes of the particular laboratory. If only a part is retained, it should be taken from the periphery, away from major vessels and bile ducts.

Brain and kidney may sometimes be required and again a 50–100 g aliquot is usually sufficient. As with liver, the total original weight of the organ should be recorded and notified to the toxicologist.

Where a toxic substance may have been injected into the subcutaneous tissue or muscle, these tissues should be excised and submitted to the laboratory. The usual method of identifying the site is from a needle puncture mark, and a zone of skin and tissue should be removed circumferentially around this or an ellipse cut away, so that the defect can be sewn up on the body. A few centimetres in diameter around the mark is usually sufficient. The depth of the sampling depends on how deeply the needle track extends and may need to go into the underlying muscle. Radiography may assist in rare cases, as in the George Markov murder in London, where a political assassination was carried out by the introduction of a tiny sphere, presumably injected from an air weapon concealed in an umbrella. The sphere, drilled out to carry a potent toxin, probably ricin, was located by X-ray at autopsy after a small skin puncture was found. Where an injection site is sampled, it is essential that a control area from a remote part of the body is also sent to the laboratory. It is usual to take this from a symmetrical zone on the contralateral side, but caution must be used, as in both drug dependence and insulin usage, alternate sides may be used at frequent intervals for injection, so another more remote site might be preferable.

The substances which may have been injected are numerous, but insulin, morphine, heroin, cocaine and other illicit drugs are most common. In the notorious Coppolino case in the USA, products of succinylcholine (suxamethonium) were identified from around a needle track in the buttock of an exhumed body of a woman, leading to the conviction of her anaesthetist husband for murder.

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CHAPTER 28

Forensic aspects of alcohol

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Ethyl alcohol is the most commonly used drug in the world and has such numerous points of contact with medico-legal pathology that it has to be considered separately from all other substances. Its abuse is a prime factor in many accidents – transport, domestic and industrial – and the majority of homicides are catalysed by alcohol intake. It acts as an adjuvant to many other toxic substances, combining to cause a fatal outcome where often the other drug alone would not have caused death. The chronic abuse of alcohol leads not only to definite pathological changes in a number of target organs, but also contributes to deaths from neglect, hypothermia and burns.

This central role in forensic practice makes it imperative that a comprehensive knowledge of its metabolism and effects is held by every forensic pathologist, not only for an understanding of autopsy appearances, but to be able to assist investigative authorities to place the death into its alcoholic context.

MODE OF ACTION OF ALCOHOL

Ethanol is a small molecule that is easily miscible with water and therefore quickly diffuses through the whole of the aqueous compartment of the body.

There are slight variations in the intracellular concentration in different tissues – for instance, the red blood cells contain somewhat less alcohol than plasma, so that a whole-blood concentration is slightly less than that in separated plasma or serum. Most serous fluids are in equilibrium, however, though Plueckhahn (1968) claims that pleural and pericardial fluids have a higher concentration than that of plasma. The aqueous humour of the eye is in equilibrium with blood, as is cerebrospinal fluid, given sufficient time for equilibration.

It is said above that alcohol disperses rapidly through the aqueous compartment and this excludes the adipose tissues, as ethanol is almost insoluble in fat. This fact has important practical significance, as people with large fat stores will produce a higher blood-alcohol level for a given intake of alcohol than persons of the same weight who are lean, as the aqueous compartment is smaller. This is particularly relevant to women, who, by virtue of their **panniculus adiposus**, may develop blood-alcohol concentrations at least 25 per cent higher than men of the same body weight after similar drinks. This must be allowed for in all calculations that attempt to relate blood-alcohol levels to intake of drink.

The behavioural effect of alcohol is caused by its action on brain cells and is a function of the concentration in the blood, the alcohol readily passing the 'blood–brain barrier' to bathe neurones via the cerebral extracellular fluid. The action of alcohol is entirely depressant, a fact not always appreciated by those who observe the apparent excitant effect of drinking. Alcohol acts on neural cells in a way similar to hypoxia, reducing their activity. In lower concentrations, this action is confined to the more specialized and sensitive cells of the cerebral cortex, leaving lower brain functions relatively unaffected. The consequent depression of these higher areas releases their inhibitory tone and thus 'takes the brakes off' more primitive and unrestrained behaviour. This was aptly described by Thomas de Quincey (1785–1859) when he wrote that 'sobriety disguiseth man'!

With increasing concentrations of ethanol, progressively lower levels of brain function are depressed and, when the vital centres in the midbrain and medulla are affected, there is a danger of fatal cardiorespiratory failure. Alcohol also causes changes in the heat regulatory mechanism, both centrally and by a vasomotor effect. Generalized vasodilatation occurs, especially in the skin, which may lead to marked heat loss and dangerous hypothermia. There is an increase in heart rate with low concentrations but, when alcohol levels approach the dangerous ranges in excess of 300 mg/100 ml, bradycardia may develop. A slight and inconstant increase in blood pressure may occur, more often in the systolic level, which increases the pulse pressure between systolic and diastolic. There is no evidence to support the contention that alcohol dilates the coronary arteries and claims that it causes dilatation of cerebral arteries (and thus worsens intracranial haemorrhage) are also equivocal. Alcohol also has a diuretic effect and, when combined with large quantities of fluid, as in excessive beer drinking, may lead to electrolyte disturbances. In healthy test subjects short-term alcohol administration causes transitory hypoparathyroidism, accounting, at least in part, for the transient hypocalcaemia, hypercalciuria and hypermagnesiuria. In alcoholic patients especially hypomagnesaemia is common.

ABSORPTION OF ALCOHOL

For all practical purposes, it may be assumed that the only route of absorption of alcohol is by mouth as, although it can be inhaled, situations where this occurs must be rare indeed. One case is known to the author (PS), in which a man suffering from a tumour of the base of the tongue, probably causing difficulties in swallowing, had instilled fruit brandy rectally via a plastic tube using a pump, and dying as the result of acute alcohol poisoning.

Almost as soon as the alcohol is swallowed, it begins to be absorbed into the blood – and as soon as that blood reaches the liver, the alcohol begins to be eliminated. Therefore the blood level (and hence the brain concentration) is a dynamic balance between absorption and elimination, the peak determining the maximum behaviour effect. Such a balance is often represented graphically by the 'blood-alcohol curve' (BAC), which indicates the intensity and duration of physiological effects.

Ethanol is capable of being absorbed by any part of the gastrointestinal canal, but in practice this is confined to the stomach and upper small intestine, as only a little alcohol remains to pass through the wall of the ileum or colon. When alcohol is taken with food, however, there seems to be a deficit in the amount absorbed, as some never appears in the bloodstream. Some of this lost alcohol may be excreted in the faeces, but when absorption is slow, more may be destroyed by the liver directly from the portal blood, never surviving to enter the systemic circulation. Nickolls (1956) estimated this lost alcohol taken with food to be between 17 and 20 per cent and Alha (1951) gave the range as 10–20 per cent. Recent studies suggest that it is probably much less, around 5 per cent.

Owing to a thinner mucosa, a better blood supply and a larger surface area, the upper small intestine – the duodenum and jejunum – has the maximum capacity for absorption, compared with the gastric mucosa. This has practical implications, as drink taken by mouth will be absorbed more quickly when:

- a gastrectomy or gastroenterostomy has been carried out previously, as the drink will pass rapidly through to the upper small intestine
- the stomach is empty, as fluid will pass through the pylorus with almost no delay.

Conversely, when the stomach contains food, the drink will be held up until digestion has proceeded sufficiently for the contents to be released into the duodenum. A fatty meal will slow this process down even more and milk feed also has a marked delaying effect. Obviously some absorption will still occur in the interim via the gastric mucosa, but not at the same high rate as in the duodenum and jejunum. As well as delaying emptying, a full stomach will retard absorption by mixing with the alcohol and physically reducing its access to the gastric lining where transit into the blood takes place.

Another factor in the speed of absorption is the concentration of the alcohol. A strength of about 20 per cent is optimum for rapid absorption, which is met (in an empty stomach) by sherry or port wine, or spirits diluted with a 'mixer', such as gin and tonic or whisky and soda. It is also said that carbonated drinks (those containing dissolved carbon dioxide, such as champagne, tonic or soda water, or lemonade) hasten absorption, perhaps because the bubbles greatly increase the surface area carrying alcohol.

Dilute drinks, such as beer (with a concentration of about 4 per cent alcohol) will be absorbed much more slowly – probably because the large volume impedes access of the alcohol molecules to the stomach lining. Beer may take twice as long to absorb as stronger drinks, though part of the delay is caused by contained carbohydrates, which is another factor that slows absorption. For example, when whisky is diluted to the same strength as beer, absorption is more rapid and the peak is higher than drinking the same amount of alcohol in the form of beer.

Very strong drink slows the rate of transfer into the bloodstream. Neat spirits or liqueurs, which may be in excess of 40 per cent alcohol, cause:

- pyloric spasm and hence retarded emptying into the duodenum

- irritation of the gastric lining, forming a barrier of mucus, which slows absorption
- reduced gastric motility, which also retards emptying.

Given an empty stomach and an optimum concentration of alcohol, most of the drug will have entered the bloodstream between 30 and 90 minutes after drinking. According to research by Wilkinson *et al.* (1977), the average times to reach peak blood concentration were 22, 40, 55 and 60 minutes after drinking 11, 22, 36 and 45 g of alcohol in a bolus of similar volumes.

It has been calculated that 98 per cent of alcohol drunk would be absorbed within 10 minutes if it went straight into the small intestine – most of the delay is due to hold-up in the stomach. Rates vary greatly among different people and even in the same person at different times, irrespective of food being taken, but an acceptable mean time would be that 60 per cent of the imbibed alcohol would be absorbed within 60 minutes and 90 per cent within 90 minutes.

Food in the stomach can, however, at least double these times and a large fatty meal can delay total absorption for a number of hours. This has an important effect on the dynamic state between absorption and elimination, as the rate of the latter is relatively constant (see below) and can therefore deal with the slow delivery of alcohol from the portal blood so effectively that the peak of the blood-alcohol curve is low – indeed the curve becomes a long shallow curve instead of a sharp hillock. Where there is a legal threshold for blood alcohol in relation to driving, the taking of food can easily cause one person who has had a large meal to remain well under this limit, whereas another person who drank the same amount at the same time may rapidly exceed the threshold if he drank on an empty stomach. Incidentally, the same effect can occur, notwithstanding food, where a man and woman drink the same amount, as described earlier.

Some drugs will affect absorption rates, by modifying the speed of stomach emptying. Atropine, chlorpromazine, tricyclic antidepressants, procyclidine, amphetamines, morphine, antidiarrhoea compounds (e.g. Lomotil), codeine, methadone, heroin, pethidine, etc., will delay gastric transit, whilst the antiemetics cisapride and metoclopramide, as well as the antibiotic erythromycin, will hasten stomach emptying.

ELIMINATION OF ETHANOL

Almost all alcohol is detoxified by the liver, only 2–10 per cent being excreted unchanged. This means that a heavy drinking session places a great metabolic burden upon the liver and is the cause of hepatic damage after long-standing drinking. The elimination mechanism is an oxidation of alcohol by liver enzymes, through acetaldehyde to acetate. The first stage is performed by the enzyme alcohol dehydrogenase but, as the second stage is much more rapid, little acetaldehyde has time to accumulate. The acetic acid is rapidly oxidized further to carbon dioxide and water. Some may also be broken down by a microsomal oxidase system.

The rate of elimination is of crucial importance to the shape of the blood-alcohol curve, the height of its peak and to the duration of the alcoholaemia. It is also central to any attempts at retrospective calculations of blood, breath or urine levels, as discussed later. Whereas the rate of absorption is variable and is affected by a number of factors, the speed of detoxification in the liver is much more constant and relatively independent of external influences. This is not to say that it is fixed and immutable, even in the same person at different times, but it is capable of reasonable approximation. Much experiment and research has been devoted to this topic and the results, though variable, lie within a fairly narrow band.

Holford (1987) reviewed 11 different studies and found average rates varying between 12.6 and 26.8 mg/100 ml/hour. Neuteboom and Jones (1990) looked at levels in 1300 drivers stopped by the police, and calculated rates between 12 and 38 mg/100 ml/hour in 95 per cent of subjects. Several had rates over 48 mg/100 ml/hour. The elimination rate appeared to increase as the net blood concentration increased, for which several explanations are possible.

As a generalization, it has traditionally been assumed that blood alcohol declines, after the peak is reached, at a rate of around 15 mg/100 ml/hour, but more recent research, especially that of Holford, indicates that this should be raised to 18.7. This applies to healthy adults who are not habituated drinkers, and includes light to moderate drinkers and those 'binge drinkers' who may indulge heavily but intermittently. The enormous number of publications on alcohol must be consulted for details of the range of variation, but basically, elimination can vary from about 12 to 27 mg/100 ml/hour.

Taking the mean as around 18 mg, a man of average size can therefore destroy about 9 g alcohol/hour, with a range variation of between 7 and 16 g. This is about the same as the 'unit' of alcohol, a concept devised for convenience in estimating the daily or weekly intake of drinkers. A 'unit' is of 10 g and is contained (approximately) in half a pint of beer, one single measure of spirits, or a standard glass of table wine.

The habituated drinker, the 'chronic alcoholic', can eliminate far faster than the average person, at least until he suffers severe liver damage in the later stages of his addiction. Though there is some controversy about the experimental evidence, workers such as Bonnichsen (1966) have shown that the rate is greater in older people, at higher blood-alcohol levels, and in habituated drinkers. The rate in the latter may be in excess of 40 mg/100 ml/hour and work at

Lion Laboratories in Wales, who manufacture equipment for breath testing, have found rates over 50 mg/100 ml/hour in chronic alcoholics.

Between 90 and 98 per cent of ingested alcohol is removed from the blood by the liver, leaving a small residue to be excreted unchanged by the kidneys, lungs, sweat, salivary and mammary glands. The ethanol in glomerular filtrate is in equilibrium with plasma, but as water is absorbed in the renal tubules, the urine concentration is higher than the blood level at the time of filtration, the ratio being approximately 123:100. This means, for example, that the legal limit for driving in Britain of 80 mg/100 ml blood is taken to be 107 mg/100 ml in urine.

Unfortunately, it is obvious that, except in the highly unlikely circumstances of ureteric catheterization, the urine concentration can never accurately represent the blood concentration at any given time. The blood concentration is almost never static, but is either rising or falling, so the amount of alcohol in the glomerular filtrate is also constantly varying. It is being mixed in the bladder, however, with previously filtered urine and will also have that which is filtered later added to it, until the bladder is emptied – so it can only provide an average concentration for the time between two micturitions. An added error is that urine produced before drinking began (and which was therefore alcohol-free) may have already been in the bladder and will dilute the alcoholic urine. In many countries, where urine is used for drink–driving testing, the subject is instructed by the police to empty his or her bladder before collection is made over the subsequent hour, in order to avoid the dilution factor.

Breath is now used by many jurisdictions to measure alcohol intake, either as a screening test before blood is taken for analysis, or as an evidential method instead of blood or urine. There is still some controversy over the scientific accuracy of this method, but usually the results are so high that errors are immaterial – or in marginal results, more accurate blood testing is indicated.

Alveolar air at 37°C is in equilibrium with the pulmonary capillary plasma alcohol, the ratio being about 2300:1, volume to volume, for blood as against breath. There is some dispute as to the true ratio, which lies somewhere between 2100 and 2400. If sufficiently deep exhalation is made to drive out dead-space air, then the collected sample can be analysed to give a measure of the blood alcohol, though slight errors occur if there is incomplete elimination of dead-space air and a drop in temperature as the air travels through the dead space. In most countries using evidential breath testing, however, the offence is not in having a breath-alcohol level in excess of an equivalent blood level, but in having excess alcohol in the breath. This obviates defence ploys that would attempt to throw scientific doubt on the relationship between the two concentrations.

ALCOHOL CONCENTRATIONS: UNITS AND VARIOUS DRINKS

The concentration (often called the 'level') of alcohol in blood, urine and breath is expressed by a variety of metric units, which may lead to some confusion. The index most widely used for blood, urine and other body fluids is the weight of alcohol per volume of diluent – for example, milligrams per hundred millilitres (mg/100 ml). The expression 'decilitre' may be used instead of 100 ml (mg/dl). In some countries in continental Europe, alcohol concentration is expressed as 'pro mille', which is grams per litre (g/l), equivalent to milligrams per millilitre (mg/ml). Elsewhere, especially in the USA, a 'percentage' system is common, but can be ambiguous as it does not intrinsically state whether the percentage is volume/volume, volume/weight, weight/weight or weight/volume. Unless otherwise stated, it is assumed to be a weight/volume.

Breath is almost universally measured as micrograms per hundred millilitres (μg/100 ml). The matter of weight and volume is important in respect of alcohol concentrations. The specific gravity of alcohol is 0.79, the compound being appreciably lighter than water. In alcoholic drinks, the manufacturer's description and labelling is almost always 'volume/volume' (v/v), but physiological calculations are made via the weight of alcohol in a given volume of body fluid (w/v). Therefore, especially for stronger alcoholic drinks, a conversion has to be made. For example, many spirits, such as whisky, may be labelled as 40 per cent v/v, but this would be only about 32 per cent weight/volume. For weak drinks, such as beer, it is hardly worth correcting the 4 per cent v/v, as calculations have a far greater intrinsic error from other factors.

Approximate strengths of common drinks are as follows (all v/v):

- beer, lager, stout: 3–5 per cent
- cider (variable): 5 per cent
- table wines (unfortified): 9–12 per cent
- fortified wines (sherry, port, vermouth): 18–20 per cent
- spirits (brandy, gin, whisky, rum, vodka): 37–42 per cent
- liqueurs (variable): 15–55 per cent.

The practice of using 'units of alcohol' has become popular in recent years, not so much for calculating concentrations, but for approximate estimates of intake, in relation to excessive drinking and the long-term medical consequences of alcohol consumption. A 'unit' is of the order of 10 per cent ethanol and very approximately delivered by 'one drink', where this is either a half pint of beer, one glass of table wine or one small measure of spirits. For example, it has been recommended that men should not exceed about 20 units per week and women 14, to avoid the risk of liver damage. It has recently been claimed that from statistical analysis of forensic autopsy material, the risk of coronary heart disease can be reduced by drinking 2 units a day (Thomsen 1995).

Calculation of blood levels from drink taken and the converse

The most important statement in this respect is to stress the utter unreliability and inaccuracy of attempting back-calculations in either direction. Only gross approximations can be achieved and no pretence at accuracy must be offered. In this book, we are not concerned with the controversial problems of trying to estimate blood or breath levels in living vehicle drivers at some time prior to an accident or other event, but with similar problems that can arise in fatal cases, especially in relation to drink and driving. In both criminal and civil disputes, evidence is often sought as to the alcoholic state of the deceased at some material time, based on calculations made from blood or urine alcohol analyses taken at autopsy. Less often, aviation, railway, diving and industrial fatalities may present the same potential problem. Criminal proceedings may arise because of alleged reckless driving on the part of another, when the drunken state of the deceased victim may offer some defence. In civil matters, often involving insurance companies, a significant blood-alcohol level may be used as contributory negligence.

Whatever the reason, the pathologist must offer interpretations of alcohol levels found at autopsy with caution, especially where retrospective calculations are requested. Less often, the pathologist may be asked what blood or urine levels might be expected at a certain time (for example, at the time of death) given a description and timetable of alcoholic drinks taken by the deceased. The same cautions against overprecise calculations must be offered here. In calculating approximate blood levels from a knowledge of the drink taken, there are several methods in use: either the well-known 'Widmark factor' or other calculations, which are really modifications or simplifications of the Widmark technique.

Widmark, in 1932, produced his well-known formula for calculating the total amount of alcohol in the body, from which knowing the body weight and assuming equilibration throughout the water compartment, the blood-alcohol level could be derived.

The Widmark equation is: $A = R \times P \times C$, where A is the total body alcohol, C the blood concentration, P the body weight in kilograms and R a factor, which is 0.68 in men and 0.55 in women. The sex difference is due to the different fat:water ratios, men having about 54 per cent and women 44 per cent water partition by weight.

Much research and modification of Widmark's factors has been carried out. Hume and Fitzgerald (1985) claimed that the use of body water distribution was too complex. Gullberg and Jones (1994) have published data on a re-evaluation of the Widmark equation, in which they claim to be able to estimate from a single blood-alcohol determination, the amount of alcohol consumed, within an error of ±20 per cent. Pounder and Kuroda (1994) claim that the use of vitreous fluid (which is sometimes used in decomposed or damaged bodies in place of blood) to predict the blood-alcohol concentration, is too variable to be of practical use.

A useful approximate calculation, derived from Widmark, is that an intake of 0.2 g of alcohol per kilogram body weight is likely to result in a blood-alcohol concentration in men of about 25 mg/100 ml.

The following facts are of use:

- The average rate of decline of blood alcohol after the peak of the curve is reached, may be taken as about 15 mg/100 ml/hour, though recent research suggests 18 as more accurate.
- The weight of alcohol imbibed may be calculated from knowledge of the v/v strength of the liquor and the amount taken. For example, if a 'double' British measure of 40 per cent v/v whisky is drunk, then 15 ml will contain $(40 \times 0.8) = 32$ per cent alcohol w/v in $15\,\text{ml} = 4.8\,\text{g}$.
- The weight of alcohol/kg body weight is calculated.
- A ratio of 0.2 g alcohol/kg body weight will produce a blood level of approximately 25 mg/100 ml in a man, assuming an empty stomach.
- In women, the level so produced may be 20–25 per cent higher.
- If only beer is drunk, the peak will be considerably less, sometimes only 50 per cent that produced from wine or spirits.
- Drinking during or after a meal markedly flattens the blood–alcohol curve.

PHYSIOLOGICAL EFFECTS OF ALCOHOL

The pathologist is frequently asked in either written opinions or in court testimony to give an estimate of the behavioural state of a victim at a certain level of blood alcohol or after having taken a specified amount of drink. Though he is usually not qualified as an expert on alcoholism in any

Table 28.1 *General spectrum of behaviour (mg/100 ml of alcohol in blood)*

Above 30	Impairment of complex skills such as driving
30–50	Definite deterioration in driving ability
50–100	Objective signs such as loquaciousness, progressive loss of inhibitions, laughter and some sensory disturbance
100–150	Slurred speech, unsteadiness, possible nausea
150–200	Obvious drunkenness, nausea, staggering gait
200–300	Stupor, vomiting, possibly coma
300–350	Stupor or coma, danger of aspirating vomit
Over 350	Progressive danger of death from respiratory centre paralysis

clinical sense, he will be a medical practitioner with general knowledge and some personal experience of alcoholic behaviour, from his pre-pathology years. He thus can give a general opinion to assist the court, but unless he has special experience of the matter, he should not extend himself into detailed clinical expositions, which are the province of the psychiatrist with an interest in alcoholism, a police surgeon or a casualty officer, all of whom deal frequently with drunken patients. A general level of knowledge can be offered to the lawyer, police or court, however, especially in respect of the usual level of capability and consciousness at different blood-alcohol levels (Table 28.1).

The list in Table 28.1 is probably 'worst case' in nature, as many people show less effects at given blood levels. Women are usually more affected at lower levels, though the 'world record' for survival may be a woman who survived a blood alcohol of 1510 mg/100 ml (Johnson *et al.* 1982). Many drivers stopped by the police at random road blocks in Australia had blood levels over 500 mg/100 ml.

MODES OF DEATH IN ACUTE ALCOHOLISM

Death from alcoholic poisoning is not uncommon and can occur at blood levels in excess of about 300 mg/100 ml. Johnson *et al.* (1982) claimed that some deaths could be attributed to alcohol at even lower concentrations. Death can be caused either by the direct depressive effects upon the brainstem, mediated via the respiratory centres – or through secondary events such as aspiration of vomit. As discussed in Chapter 14, the use of 'aspiration of vomit' as a cause of death must be used with great caution unless there is ante-mortem eyewitness evidence. The major exception to this proviso is in acute alcoholism, where if copious inhalation of stomach contents right down to the secondary bronchi is confirmed, then in the absence of significant natural disease, injury or other toxicity, a high blood-alcohol level may reasonably be incriminated as the probable cause. Many such fatalities occur during police custody, when considerable outcry, publicity and disciplinary investigations are the usual outcome.

Drunken persons are often involved in fatal trauma, which may be of many types. The majority of homicides are triggered by the aggressive behaviour engendered by alcohol. Road accidents, either caused by drunken drivers (often upon themselves) or by drunken pedestrians walking into traffic, are commonly related to alcoholic vulnerability. Falls are extremely frequent and often fatal. Drunken persons may fall down stairs or steps and suffer head injuries. Falls from high places are less common, but do occur from drunken carelessness or unsteady gait – exemplified by the notorious inquest on Helen Smith in Leeds in 1982.

Death from burns or carbon monoxide poisoning may occur in drunken persons who smoke when intoxicated. A common scenario is for a drunk to go to bed and fall asleep whilst smoking, the cigarette igniting the bedclothes. Sometimes, a gas, electric or kerosene heater may be knocked over during drunken staggering, which again starts a fatal fire.

Drowning is seen occasionally, especially in river or dockland areas. A typical happening is for a drunken sailor to return to his ship late at night, and fall from a bridge or gangway into the water. Death is sometimes not caused by drowning, but by sudden vagal cardiac arrest from the shock of hitting cold water or having cold water suddenly flood the pharynx and larynx. The drunken state seems to sensitize the victim to such vasovagal shock, perhaps because of the marked cutaneous vasodilatation encouraged by alcohol. The author (BK) has seen a number of such tragedies in Cardiff dockland, including a sailor and his woman companion, who both fell off the ship after carousing.

CHRONIC ALCOHOLISM

The pathological features of this condition are extensive and can only be surveyed briefly here. In this context, chronic alcoholism refers to the steady, regular abuse of drink, rather than intermittent 'binge' drinking, which gives the tissues time to recover between bouts of acute alcoholism.

At autopsy, there may be signs of general neglect and malnutrition, but many chronic alcoholics are obese or even oedematous, the latter because of chronic heart failure. The specific lesions are in the liver, heart and brain, though they may be difficult to identify as unequivocally caused by alcohol. The early stages of liver damage cause fatty change, usually with enlargement. The normal weight, according to the sex and build, is between 1300 and 1600 g, but a fatty liver may be well in excess of 2000 g.

The surface is pale and greasy, though this may not be a uniform change, especially in early or less severe cases. Patchy yellowish areas may be visible within normal hepatic parenchyma.

If the abuse continues, then the fatty change may eventually give way to fibrosis, the liver surface becoming rippled beneath its capsule. Such cirrhosis is fairly fine, with nodules of the order of 5–10 mm in diameter. In the later stages the liver becomes smaller and contracts to a hard, greyish-yellow block of only 800–1200 g.

Without a history of long-term alcohol abuse, it is difficult or impossible to be definite about the aetiology purely on autopsy appearances, though suspicion may be strong. A similar liver may develop as a sequel to hepatitis – and less often as an end result of certain dietary or metabolic defects. The spleen may be enlarged and firm, and portal varices may be present at the gastro-oesophageal junction, but these are both manifestations of portal hypertension and do not assist in determining the precise aetiology of the hepatic fibrosis. A useful index of liver damage and the progression or remission of alcoholic impairment is the level of the enzyme γ-glutamyl transpeptidase in the serum. Normal levels are less than 36 units, whereas liver damage can elevate this by a factor of many times. Alcoholic cardiomyopathy is certainly a real entity and can be diagnosed clinically. Whether it can be definitely identified on histological appearances alone is a matter of dispute. The heart is enlarged and shows patchy fibrosis with a variable mixed cellular infiltrate, hypertrophy of muscle fibres, patchy necrosis, hyalinization, oedema and vacuolization. Nuclear enlargement and polymorphism complete the range of changes, but none of these are specific, being found in hypertensive heart disease, coronary stenosis and other types of myocarditis. Combined with a definite history of chronic alcoholism, however, these relatively non-specific changes can be ascribed to alcohol if other causes can be excluded (see also Chapter 25). More specific myocardial damage has been caused by cobalt added to commercial beers and several outbreaks are on record. Systemic fat embolism has also been recorded in victims of alcoholic fatty liver. Microinfarcts in myocardium and brain are possible, though this aspect has so far been rather neglected in research. Fat stains are not usually employed in routine investigations and it is not known how the victims of a fatty liver compare with control subjects in respect of diffuse target organ embolism.

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CHAPTER 29

Carbon monoxide poisoning

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CAUSES OF CARBON MONOXIDE POISONING

After alcohol and some pharmaceutical drugs, carbon monoxide poisoning is probably the most common toxic condition to be met with in routine forensic pathology. The widespread introduction of natural gas (which contains no carbon monoxide) as a replacement for 'coal gas' as a heating fuel has removed a major source of the poison. Monoxide still provides lethal dangers in many other ways, however. It is produced whenever fossil fuels are incompletely oxidized to carbon dioxide and, because of its great affinity for haemoglobin, even low concentrations can be cumulative.

There are a vast number of publications on carbon monoxide toxicity, both in an environmental and industrial context. Once again, this discussion is confined to the pathologist's involvement in fatalities. A body coming to autopsy with suspected (or sometimes unsuspected) carbon monoxide poisoning, will have suffered that toxic condition by the following means.

Motor vehicle exhaust gases

Since the replacement of coal gas (containing up to 7 per cent monoxide) with natural gas, a major means of suicide has been removed. 'Putting the head in the gas oven' was the most common form of self-destruction in Britain and many other countries until this changeover. In 1961 in the UK, for example, there were 2711 suicides and 1014 accidental deaths from carbon monoxide. Since then, suicides have obtained carbon monoxide to kill themselves from the internal combustion engine. Petrol (gasoline) engines produce up to 5–7 per cent carbon monoxide in their exhaust fumes, and more if the engine is idling, defective or improperly tuned. Diesels produce far less monoxide than petrol engines. Normally, the exhaust pipe vents the gases into the atmosphere, where it may contribute to considerable low-level monoxide contamination in large cities, such that policemen on traffic duty may have up to 10 per cent saturation of their haemoglobin. When the exhaust fumes are confined to a small space, then a dangerous or lethal level can build up in a short space of time. It is calculated that a 1.5 litre petrol engine, idling in a closed single garage, can produce a lethal concentration in the atmosphere within 10 minutes.

Some suicides will merely sit in the garaged car with a window open and allow the gas to overtake them. More commonly, some device is fitted to pipe the gas into the interior of the car and this may be done outside a garage, often in a remote parking spot. The flexible tube from a vacuum cleaner seems a favourite means, though ordinary hose-pipe, pushed inside the tail-pipe and led in through a window, is a common alternative. Apart from suicide, accidental poisoning sometimes occurs in relation to internal combustion engines. A mechanic or car owner may work on a vehicle in a closed garage, especially in cold weather, and be overcome by monoxide before he is able to remove himself from the danger. The insidious nature of the toxic effects may make him unaware of the supervening stupor and coma.

Carbon monoxide can also affect drivers of a moving vehicle, usually because of a defective exhaust system, which allows gas to percolate through the floor or engine bulkhead into the interior. Rarely, a strong following wind blows the external exhaust gas into the open doors of a van or truck. Another motoring cause is a leak in the heat exchanger in those vehicles that use a direct air supply from around the exhaust manifold to provide passenger heating.

In aircraft – usually light planes with the engine immediately adjacent to the cockpit – a leakage of exhaust gas from the motor compartment can lead to disablement of the pilot and death from a crash rather than from fatal toxicity. The same applies to those road-vehicle drivers who are overcome by the gas to an extent that makes them incapable of driving safely. The differential diagnosis in survivors is between carbon monoxide and alcohol, as the clinical symptoms of both are quite similar at one stage of the toxic process.

Deaths have also been reported in 'scuba' divers, whose air cylinders have been contaminated with carbon monoxide during refilling from faulty petrol-driven compressors.

Domestic appliances

Domestic heating appliances can produce carbon monoxide in addition to the usual dioxide from a restriction of their air supply, so that incomplete combustion of the fuel takes place. The fuel can be natural gas, which, though itself free from monoxide, is only partially oxidized from some defect of design, maintenance, or patency of the exhaust flue. Solid-fuel boilers used for central heating may have some restriction of air entry or a partial blockage of the chimney system. Paraffin (kerosene) heaters may burn with inadequate oxygen ingress and any other form of hydrocarbon fuel appliance can malfunction so that part of the products of combustion are monoxide.

The author (BK) has dealt with several deaths that occurred because the faulty installation of natural-gas fires led to absent or inadequate ventilation, causing monoxide to back-diffuse into living rooms. Gas appliances, especially water heaters, are one reason why the bathroom is such a dangerous place. Apart from the extra hazards of electricity, a bath for drowning, wet surfaces for slipping, tablets in the cabinet and sharp instruments such as razor blades, the small-sized room and the frequent installation of a gas water heater or 'geyser' makes this room a frequent locus for unnatural death. Blockage of the exit or 'flue' pipe is a common fault, sometimes from bad installation or because it becomes blocked by soot or by birds' nests.

Structural fires

A common cause of monoxide deaths arises from structural fires in houses and other buildings. As described in Chapter 11, the majority of deaths in house conflagrations are caused not by burns, but by inhalation of smoke. These fatalities are largely caused by carbon monoxide poisoning, though other lethal gases such as cyanide, phosgene and acroleins are partly responsible. Many victims of house fires die remote from the flames, and may be overcome in different rooms or even on different floors, the monoxide percolating considerable distances and killing persons either asleep or trapped elsewhere in the building.

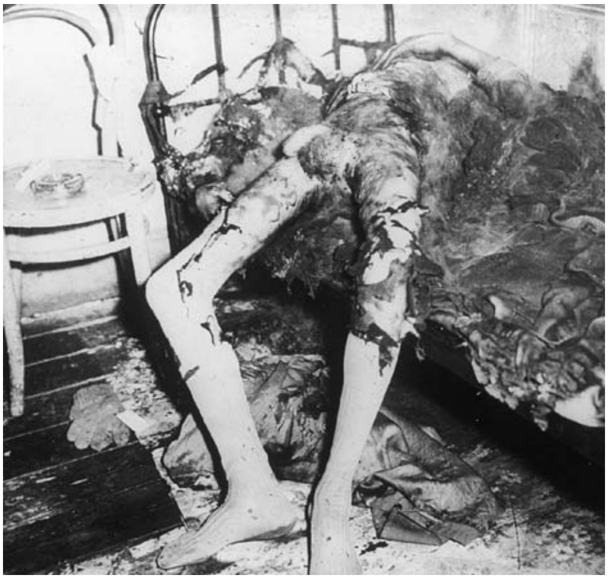

FIGURE 29.1 *Carbon monoxide poisoning in a chronic alcoholic. This is a relatively common event when a drunken person collapses with a lit cigarette across his bed (note the ashtray and cigarette packet). The burns are post-mortem, death being caused by a high level of carboxyhaemoglobin generated by the smouldering bed coverings.*

Industrial processes

Many industrial processes may lead to monoxide poisoning, especially in iron and steel works, where producer gas and water gas are deliberately formed and stored as part of the manufacturing process. Water gas can contain up to 40 per cent carbon monoxide and in former days was added to town gas for the domestic supply, which greatly enhanced the monoxide content of some 7 per cent from coal gas. Many other industrial processes, such as the Mond method of nickel production, use carbon monoxide, as well as the universal danger of any heating process producing the gas during combustion. In coal-mining, carbon monoxide is one of the gases that presents a constant threat; it escapes from the coal seams themselves but is also produced from the frequent small fires that smoulder in the recesses of the mines.

Incomplete combustion

Incomplete combustion of a gas flame from any gaseous fuel can produce carbon monoxide. Where such a flame impinges on a cold metal surface or where that surface is coated with soot, partial oxidation of the fuel supply leads to monoxide production. In appliances fuelled from the common butane or propane cylinder sources, as in caravans, campers and boats, maladjustment or restriction of ventilation can lead to slow but insidious production of monoxide. Deaths of whole families have occurred under such circumstances, as they are exposed overnight to slow accumulation of carbon monoxide from refrigerators and other appliances.

THE AUTOPSY IN CARBON MONOXIDE POISONING

As always, an adequate history may give the clue to the cause of death. Where the circumstances are obvious, such as a death in a car with a tube leading from the exhaust, the pathologist's attention will be directed towards carbon monoxide from the outset. There are many other circumstances, however, in which the history may be obscure, and only the vigilance of the pathologist and his staff will pick up the possibility of this type of toxicity. In fact, many a case has first been recognized by the mortuary technician who commented on the colour of the skin or tissues. A number of fatal monoxide poisonings have already been certified as 'natural causes' by uncritical clinicians (especially in general practice) when in fact carbon monoxide poisoning, either suicidal or accidental, was the true reason for the death. Failure to examine the body fully is the usual cause, as the pink coloration may only be noticeable in the areas of postural hypostasis not normally visible in a body in bed, though the sides and back of the neck are reasonably accessible even to cursory examination. The author (BK) recollects at least one suicide where the relatives placed the body back in bed and had it certified as 'coronary thrombosis' by an unsuspecting family doctor.

At autopsy the most striking appearance of the body is the colour of the skin, especially in areas of post-mortem hypostasis. The classical 'cherry-pink' colour of carboxyhaemoglobin is usually evident if the saturation of the blood exceeds about 30 per cent. Below this, familiarity and good lighting are needed and below 20 per cent, no coloration is visible. As these low concentrations are rarely fatal, however, little is lost. Sometimes, darker cyanosis tends to mask the skin colour, but the margins of the hypostasis and the internal tints are usually apparent.

When the victim is anaemic, the colour may be faint or even absent because insufficient haemoglobin is present to display the colour. In racially pigmented victims the colour may obviously be masked, though may still be seen on the inner aspect of the lips, the nail-beds, tongue, and palms and soles of the hands and feet. It is also seen inside the eyelids, but rarely in the sclera.

Rarely, there may be blistering of the skin of dependent areas, such as the calves and buttocks, and around wrists and knees, similar to the so-called 'barbiturate blisters'. These are not specific to carbon monoxide toxicity and are the result of cutaneous oedema in any profound coma where there is total immobility and lack of venous return from muscle movement. As most carbon monoxide deaths are relatively rapid, such blisters are rare. Internally the most noticeable feature is again the colour. Blood and muscle will be pink as a result of carboxyhaemoglobin and carboxymyoglobin. In relatively low concentrations, in poor light and in some artificial lighting in autopsy rooms, the cherry-pink colour may be difficult to see. It can be enhanced by diluting the blood with water against a white background, as in a porcelain sink or an enamel scale-pan, when the pinkness will be more evident. The pinkness of hypothermia or refrigeration is a different colour. Unfortunately, some pathologists have a red-colour visual impairment, which makes it difficult for them to differentiate between subtle changes in redness, so laboratory analysis is always required for objective confirmation and quantification of the monoxide concentration. Other suggestive indications of carbon monoxide are that, when tissues are placed in formol saline for preservation of histology, they do not decolourize as quickly as normal tissues and remain pink for a long period. If carbon monoxide poisoning is suspected at autopsy, a quick test is to add a few drops of blood to some 10 per cent sodium hydroxide solution on a white tile or in a tube against a white background. The normal blood will immediately become brownish-green but, if significant monoxide is present, the colour will remain pink, as no methaemoglobin is formed. One has to bear in mind though, that unlike adult blood, fetal blood up to the age of 6 months is more resistant to alkali and the colour change can take hours to develop. Another simple test, mentioned in 1857 by Hoppe, is to take 3 ml blood into a test tube and dilute it with 6 ml tap water and to heat it for a short while with care in a water bath. Carbon monoxide blood turns brick red whereas control blood becomes greyish-brown. However, these crude tests are not recommended as an alternative to proper analysis.

Other signs at autopsy are non-specific. Pulmonary oedema is usually present. The author (BK) has the impression that the white matter of the brain remains unusually firm and that the whole brain after removal from the skull keeps its shape better, being rather stiff and rigid. This may be caused either by oedema or by some minimal fixation change in the brain tissue.

None of these rather idiosyncratic tests can replace proper laboratory investigation, however. Blood should be taken for analysis in the usual way, preferably from a peripheral vein. In contrast to most toxicological investigations, even foul samples can still be useful for carboxyhaemoglobin estimations. Heart blood, blood from body cavities and even from bone marrow when the bones are split open, can still provide valid material for estimating the percentage of haemoglobin converted to carboxyhaemoglobin. It is the

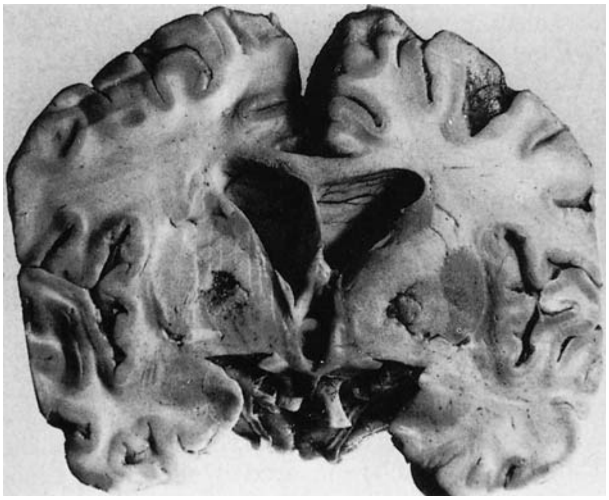

FIGURE 29.2 *Basal ganglia degeneration after carbon monoxide poisoning. The patient survived for a number of weeks, but succumbed to bronchopneumonia. There are cystic lesions in the globus area of both cerebral hemispheres.*

ratio of haemoglobin to the carboxy-type that is required, rather than an absolute concentration in the blood, so virtually any blood-containing fluid will provide this answer. When a body has been badly damaged by fire, fluid blood may be hard to obtain, so that any sanguineous body fluid or bone marrow can provide material for analysis. If analysis is to be delayed more than a day, it is recommended that fluoride be added as a preservative.

There are no other autopsy features in acute deaths, which form the majority seen by forensic pathologists. Where survival occurs there are a number of neurological lesions that follow severe carbon monoxide exposure. Necrosis and cavitation of the basal ganglia in the brain, notably the putamen and globus pallidus, has been known for well over a century. Within about 5 days, histological changes occur here, with 'gitterzellen' scavenging cellular debris, the foam cells and microglia presenting an appearance characteristic of tissue breakdown in the central nervous system. There may also be damage in the substantia nigra of the brainstem. In delayed deaths, petechiae and ring-shaped haemorrhages may occur in the cerebral white matter. All these changes, together with the clinical symptomatology, are exhaustively described in neurological publications.

There are also tiny focal necroses in the myocardium in delayed deaths from this cause, and similar lesions were described by Korb and David (1962) even in acute deaths. Frank myocardial infarction has often been reported after severe monoxide exposure and relative hypoxia, usually in the presence of pre-existing coronary disease, is probably the reason.

BLOOD ANALYSIS

Carbon monoxide has an affinity for haemoglobin that is between 200 and 300 times greater than oxygen. Therefore even small concentrations of monoxide in the inspired air will progressively displace oxygen from the erythrocytes and this will lower the oxygen-carrying capacity of the blood. It was formerly thought that all the toxic properties of carbon monoxide lay in this hypoxic action, but more recently it has been shown to interfere with other ferroproteins such as myoglobin and various enzymes including members of the cytochrome family.

The major effect is undoubtedly the reduction in oxygen transport and, for this reason, it is the percentage saturation of the total available haemoglobin that is important rather than an absolute quantity of carboxyhaemoglobin in the blood. Anaemic persons will not show the external cherry-pink colour if insufficient haemoglobin is available for the monoxide component to become visible. It is the residual non-combined haemoglobin still available for oxygen transport that is important in maintaining life. For example, an anaemic person with only 8 g/100 ml of haemoglobin having four of those occupied with carbon monoxide (50 per cent saturation) is in much worse a state than a person with a total of 14 g of which four are monoxide-occupied. There are many tables available that relate saturation levels to the clinical symptoms. There is a wide margin of variation in these, as there is with lethal levels.

Broadly speaking, the saturation levels found in fatal cases reflect both the physical state of the victim and the rapidity with which the poisoning took place. Robust, healthy adults under 60 years of age rarely die at saturation level under 50–60 per cent unless the concentration of carbon monoxide in the inspired air was so great that death occurred before gas exchange in the lungs was able to progress sufficiently to enter all available monoxide into the red cells. Death may then supervene with post-mortem saturation levels of as low as 40 per cent. Where absorption is slow and life persists longer (for there seems to be a relationship between air concentration of monoxide and length of survival), autopsy samples may show 80 per cent saturation.

Old people may die at relatively low concentrations, such as 30 per cent and, in some cases, no other cause can be found when the carboxyhaemoglobin level is only 25 per cent. This may be the result of anaemia, so that there is less reserve for oxygen carrying when part of the haemoglobin is occupied by monoxide. In many cases, the senile myocardium is already in a fragile state and any extra hypoxia will cause it to fail. Infants also seem to die at relatively low levels, perhaps because their higher respiration rate allows a more rapid absorption. The variation in fatal concentrations is wide and quite irregular. This is best exemplified when two or more victims have died together in the same environment. The carboxyhaemoglobin concentrations of bodies lying alongside each other can sometimes be totally different, even in persons of the same age group and physical health. Any disease process can contribute to death at lower monoxide concentrations. Coronary artery disease, respiratory insufficiency and other debilitating conditions allow death to occur earlier, when the toxic level is still relatively low. Conditions that are worsened by hypoxia, such as myocardial insufficiency or obstructive airway disease, are particularly potent. In addition to disease, any separate toxic state is additive, such as hypnotic drugs or alcohol.

The method of analysis has traditionally been by reversion spectroscopy, but this is a crude technique in which accuracy cannot be attained to within 10 per cent of the true value. For most purposes related to fatalities, this is good enough, as more exact results do not add anything to the investigation. The only problem can be at the lower end of the scale, when it is difficult to be certain about positivity under about 15 per cent. Modern analytical methods include non-dispersive infrared spectrophotometry and gas chromatography. Carboxyhaemoglobin is stable and can be detected even in putrefied bodies a long time after death, as long as sophisticated laboratory techniques are used. Monoxide cannot enter a body post-mortem to any significant extent. Bodies burnt after death do not absorb any monoxide and thus a significant level (more than 10 per cent) in a body from a fire means that respiration must have been proceeding whilst the conflagration was in progress. As emphasized in Chapter 11, the converse is often not true, in that deaths from rapid fires, especially flash fires caused by petrol, for example, may have no carboxyhaemoglobin in the blood. The possibility of carboxhaemoglobin being formed in the blood post-mortem has been investigated as a possible source of error (Kojima *et al.* 1982) and fluorided samples are recommended.

A minor source of local carboxyhaemoglobin and myohaemoglobin is gunshot wounds, where the propellant gases (which are rich in the compound) are blown into the wound from contact or short-range discharges. The tissues absorb monoxide, especially around the entrance wound. It has been claimed that this is a way of differentiating the entrance from the exit wound, but in fact the whole track of the missile(s) may be sheathed in a zone of monoxide transfer into blood and muscle from a near-discharge, though theoretically there should be a gradient of concentration from one end of the track to the other (see Chapter 8).

Many other war, military and terrorist circumstances are associated with exposure to carbon monoxide. Large quantities are released from the firing of guns and, in enclosed spaces, can become a hazard. Detonation of explosives in places where there is little ventilation also allows monoxide to accumulate and it may persist long after the physical dangers of the explosion have passed.

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CHAPTER 30

Agrochemical poisoning

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In the last half century there has been a technological revolution in farming methods, which has spread to almost all parts of the world. The developing nations (who in terms of area of land usage and proportion of the population who work on that land, are numerically greatest at risk) suffer most and this is sometimes exacerbated by the less stringent controls and less safe working methods that exist in those countries.

The potent chemicals used in agriculture may harm persons by accidental exposure, either during their application to crops, or due to incorrect or careless storage. Another major source of human poisoning is through self-administration, when the easily available substances are used for suicide. For example, in Sri Lanka many thousands of hospital admissions each year are for agrochemical poisoning (16 649 in 1983) with over a thousand deaths annually (1521 in 1983). Of these, about three-quarters were self-administered, the remainder being accidental and occupational.

The main dangers from agricultural chemicals lie in the pesticides, especially organophosphorus compounds, such as parathion and herbicides, such as paraquat.

PARAQUAT POISONING

Paraquat is a herbicide that is sprayed on unwanted weeds and other vegetation before planting crops. It is absorbed by the foliage and rapidly kills the plant, but is inactivated when in contact with the soil, so cannot harm the seeds or young plants that are placed in the same ground a short time later. Paraquat (and the less popular diquat) are dipyridyl compounds, paraquat chemically being 1,1′-dimethyl-4,4′-bipyridyldiylium. It is produced commercially as a brownish concentrated liquid of the dichloride salt at 10–30 per cent strength, under the trade name Gramoxone and, for horticultural use, as brown granules called Weedol at about 5 per cent concentration.

Toxicity occurs almost exclusively through ingestion, though some cases are reported where inhalation through spraying has led to a fatal outcome. A suicide from intravenous injection of paraquat has been reported by Fernandez *et al.* (1991).

Only about 5 per cent of the substance is absorbed orally. Poisoning usually occurs either by deliberate self-ingestion of the liquid concentrate, or by accidental drinking from unmarked or incorrectly marked bottles. It is said that one swallowed mouthful of Gramoxone will almost always be fatal and certainly 5 ml has caused death. The decanting of the concentrate from the original manufacturer's containers leads to many accidental deaths. Because of the relatively high cost, paraquat is often taken from the large containers and kept in lemonade or other soft drink bottles. Such decanting is illegal in some countries such as the Republic of Ireland, because of the dangers of unlabelled bottles. Unsuspecting people, especially children, then take a drink from such bottles and immediately suffer the effects of the potent toxin.

Paraquat in concentrated form, is irritant to all epithelial tissues. The lips, mouth, pharynx and oesophagus are superficially eroded, though there is nothing like the dangerous structural damage of strong acids or alkalis. The major danger of paraquat is to the lungs and liver. The lungs are affected mainly by direct aspiration, either as the irritative substance is swallowed or by regurgitation from the stomach during vomiting.

Of that absorbed through the gastrointestinal tract, the major danger is to the liver, where paraquat causes a centrilobular necrosis, with giant mitochondria and crystalline inclusion bodies seen on electron microscopy. In the kidney, renal failure may develop within 2 or 3 days from diffuse tubular damage.

The striking lesion, almost characteristic of paraquat, is in the proliferative damage to the lungs. If rapid death from acute hepatorenal failure does not occur, either because of low dosage or energetic clearance of the residual poison, then progressive lung damage may still lead to death within the next 2 weeks. When paraquat reaches the distal air spaces, diffuse pulmonary oedema and haemorrhages occur, followed by stimulation of the alveolar lining cells. Prior to this, in the first day or two, there is damage to the pneumocytes with vacuolation, desquamation and necrosis. A hyaline membrane is often visible. The mechanism appears to be that paraquat reacts with tissue elements to produce peroxides, including hydrogen peroxide, which is responsible for the damage, which can be worsened by oxygen therapy.

Within a few days repair begins, the mesenchymal interstitial cells and the alveolar lining cells dividing rapidly and filling the alveoli. Both granular and membranous pneumocytes (types I and II) are involved. Within the first week, gas exchange begins to suffer as the air spaces become occluded by mononuclear cells forming rounded-up ‘fibroblasts’. If survival continues, the alveoli begin to fibrose, with reticulin and collagen being laid down to form a rigid, stiff lung.

The autopsy in paraquat poisoning

There may be ulceration around the lips and mouth from escape of paraquat concentrate. The mucosa of the mouth may be reddened or desquamated, and the oesophagus may show worse changes, including casts of shed epithelium. None of these changes is by any means inevitable, however, and the upper gastrointestinal tract may be normal.

Similarly, the stomach may show erosion and patchy haemorrhages, or may be unremarkable. The liver may show pallor or mottled fatty change to the naked eye. It is unusual for any gross charges to be visible. Other organs show no specific changes, apart from the lungs; the kidneys may reveal cortical pallor if there is renal failure.

If the victim has lived a week or more, then the lungs may reveal typical changes in that they are large and stiff, keeping their shape when removed from the chest. There may be a fibrinous pleurisy and sometimes slight bloody pleural effusions. The cut surface reveals oedema and patchy haemorrhage, though this may have subsided in cases that survive for some time. The main appearances are microscopic and, unless the history is known, the lung may be mistaken for a diffuse pneumonia. The author (BK) saw a homicide by paraquat, in which the victim was in hospital for 2 weeks with a presumptive diagnosis of ‘virus pneumonia’, until a confession revealed the true cause of the lung changes. Samples required at autopsy, apart from full histology, include the usual blood samples, urine, stomach contents, lung and liver.

In most instances, the relative slowness of the death allows the diagnosis to be made on history and clinical grounds, so that ante-mortem toxicology is usually well documented.

Toxicology interpretation

Blood levels of paraquat of 0.2 mg/l are sufficient to cause lung damage. Survival has been recorded, however, with plasma levels of up to 1.6 mg/l. Paraquat is excreted over a long period and can be detected in urine at autopsy many days after ingestion. Concentrations in excess of 0.07 mg/l have been found 26 days later.

The concentrations found on analysis after autopsy naturally depend upon the dose taken and the time that has elapsed since ingestion. On the first day, ranges from 0 to 63 mg/l (average 15) have been found in the blood, with urine levels of 20–1210 mg/l (average 462). Seven days later, the blood level comes down to an average of 0.8 mg/l with 4.5 in the urine. Two to three weeks after ingestion, the blood concentration averages 0.5 and the urine level 0.6 mg/l.

ORGANOPHOSPHORUS PESTICIDES

Used in huge quantities throughout the world, these substances cause thousands of deaths in southern Asia, Africa and elsewhere. The major example is parathion, with malathion and dichlorvos used far less extensively. These chemicals act on insects and other arthropods by inhibiting cholinesterase and their toxic effects on man are caused by the same mechanism.

Parathion (nitrostigmine) is extremely toxic and can be absorbed through the skin, conjunctivae, lungs and gut. Because of the inhibitory effect on plasma and erythrocyte cholinesterases, acetylcholine builds up at neuromuscular junctions and other neurotransmitter sites, resulting in hyperexcitability of both voluntary and involuntary muscle.

Other organophosphorus compounds include malathion, which is much less toxic than parathion and is used more in horticulture: dithion, diazinon, hexaethyltetraphosphate (HETP), tetraethylpyrophosphate (TEPP), octamethylpyrophosphamide (OMPA) and demeton are other pesticides of this group.

Toxic signs and symptoms appear when the cholinesterase level drops to 30 per cent of its normal activity. Fatalities begin to occur after the ingestion of 125–175 mg, though ingestion of much larger amounts can be survived. Death can occur in less than an hour after ingestion, though usually several hours elapse in those who are not going to survive.

Autopsy appearances are more helpful than with many other compounds, in that parathion is dissolved in a kerosene base, which can often be detected by its smell. A greenish colouring agent is often added to the commercial products. The stomach therefore may be seen to contain an oily, greenish scum. The gastric mucosa may be haemorrhagic, though this is too non-specific to be of much use, as is the common finding of haemorrhagic pulmonary oedema.

The author (BK), when practising pathology in South-east Asia, noted a useful diagnostic sign in some less modern mortuaries that were infested with flies and bluebottles. When these insects alighted on an opened cadaver at autopsy, many fell dead or dying onto the autopsy table when the case in progress was a parathion poisoning.

Toxicology interpretation

Post-mortem toxicology is usually conclusive in acute poisoning. The substance resists post-mortem autolysis well and can be recovered from putrefied bodies. The range of blood parathion concentrations in fatal cases may be from 0.5 to 34 mg/l with an average of 9.0. Urinary excretion ranges from 0.4 to 78 mg/l with an average of 10 mg/l. The liver may contain from 0.1 to 120 mg/kg, averaging 11.

Malathion is much less toxic but deaths certainly occur given a greater dose. Blood levels in fatalities ingesting from 25 to 70 g malathion ranged from 100 to 1880 mg/l with a mean of 815. The liver contained from 200 to 1700 mg/kg, with an average of 1300.

Other pesticides and insecticides include chlorinated compounds such as aldrin, DDI (dicophane), lindane (Gammaxane) and dieldrin. Other types include the carbamates (opxymyl, landrin and aldicarb), dinitrophenols, pyrethrum and derris. The phenolic pesticides include DNOC (dinitro-orthocresylphosphate) and dinitrobutylphenol. None of these has any specific autopsy features and the diagnosis rests upon the history, circumstances, and post-mortem analysis of blood, urine and liver.

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CHAPTER 31

Poisoning by medicines

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GENERAL CONSIDERATIONS

In most countries, especially those with advanced economies and relatively sophisticated medical services, poisoning with medicinal compounds is common. In many such countries, poisoning with therapeutic substances exceeds deaths from other types of toxic agents, especially in suicidal and accidental poisoning.

This is explained by the ease of access of such substances, whether they are obtainable from a doctor on prescription or on demand across the counter of a pharmacy. Where state-sponsored health services exist, the cost to the recipient may be minimal or absent and this ease of access contributes to opportunities for self-poisoning, whether it be deliberate self-destruction, suicidal gestures or accidental ingestion – the latter especially in children. Unfortunately, overprescribing or the supply of too great a quantity of drugs at one time allows excessive stocks of drugs to be easily available to the public.

Though only a minority of victims of medicinal poisoning fail to recover, there are still an appreciable number of deaths. These come to the attention of the investigative authorities and hence to pathologists. The autopsy investigation of a fatality from a therapeutic substance can be difficult, for a number of reasons:

- The nature of the substance may be uncertain or unknown.
- There may be more than one such substance involved.
- There may be a delay between ingestion and death sufficient to allow blood, urine and tissue concentrations to decline below fatal, toxic or even therapeutic levels.
- Analysis may be difficult to arrange because of lack of facilities.
- Information about fatal levels may be unobtainable.
- Most medicinal poisons leave virtually no characteristic features at autopsy, so diagnosis depends upon laboratory findings.
- Post-mortem changes may make analysis difficult, inaccurate or impossible.
- Where death is delayed after taking the substance, none may be recoverable from the stomach (which has emptied) or even from the intestine.
- The original substance may be rapidly metabolized into one or more breakdown products, adding to difficulties in identification and interpretation.

AUTOPSY APPEARANCES

The lack of characteristic autopsy appearances is often very frustrating for the pathologist. Unless there is an indicative or suggestive history as to which drug was taken – a matter for the investigators in respect of circumstances and recovery of containers – then an autopsy may have to be performed ‘blind’. Where no significant morphological lesions can be discovered, then a full toxicology screen must be considered, which in some jurisdictions may be difficult or impossible to obtain, or be extremely expensive.

The majority of modern medicinal substances are, by design, bland and non-irritant to the tissues and gastrointestinal tract. Most of those met with in forensic practice are taken orally and, though the active constituents may be potent in their pharmacological effect on target organs and tissues, the medicine will cause no erosion or damage to the alimentary tract. Thus little or no physical evidence can be obtained from a gross or even microscopic examination of the gastrointestinal tract or other organs. Much of the physical bulk of modern tablets or capsules is merely the vehicle for introducing the active component into the body and is thus unlikely to have any adverse effect.

When a medicinal compound causes death, the mode of death is most often some form of cardiorespiratory failure, often secondary to depressive effects on the central nervous system. This mode of death causes only non-specific changes discernible at autopsy, which are usually of no use in indicating the basic reason for the death. Acute congestive cardiac failure, pulmonary oedema, sometimes cerebral oedema, generalized organ congestion, scattered petechiae on serous membranes – none of these is of any real use to the pathologist, who has to rely on the results of toxicological analysis for a definitive answer.

There are some therapeutic substances, which, though not the cause of specific lesions, may suggest themselves from their autopsy appearances. An example is the widespread membrane ecchymoses sometimes seen in aspirin poisoning. This could not in any way be sufficient to provide a legally acceptable cause of death, however, unless absolutely reliable circumstantial evidence existed, together with the finding of a large bolus of undissolved tablet remnants in the stomach. Even then it might be contested that the substance was not aspirin – or not aspirin alone – unless analytical confirmation was obtained.

RESULTS OF LABORATORY TESTS

As discussed in Chapter 27, the investigation of fatal poisoning is a collaborative investigation between pathologist and toxicologist. The autopsy excludes, confirms or evaluates any trauma or natural disease, and provides suitable material for analysis. The toxicology laboratory conducts the technical assays, and produces qualitative and quantitative results. The toxicologist/analyst interprets those results to the pathologist, by providing an indication of the therapeutic, toxic and fatal ranges of concentrations in various body fluids and tissues, and by pointing out problems such as decline from post-ingestion survival, conversion to metabolites and many others. The pathologist then collates this information with his own knowledge of the history and autopsy findings to offer the best interpretation of the investigation for judicial authorities. Most problems arise either because the information about the medicine (especially if it is newly developed or where its toxicity is low) is incomplete in terms of toxic blood and tissue levels – because post-ingestion survival has allowed the originally lethal levels to have subsided to therapeutic or even lower limits. What is offered in the remainder of this chapter is a digest of information about such potentially lethal levels, culled from a variety of sources. The ranges are often wide as most of the data are of necessity derived anecdotally, and the problems of uncertainty of dosage, variation in post-ingestion survivals and wide individual biological variation make it impossible to lay down strict thresholds between therapeutic, toxic and fatal concentrations.

Wherever possible, the advice of the analytical toxicologist should be taken about each case – but where this is impracticable, then the following data and similar material, which is constantly being updated in forensic and toxicological publications, may be of assistance. The choice of substances is arbitrary, but represents the most common medicines seen in suicidal and accidental poisoning.

ANALGESICS

Aspirin (acetylsalicylic acid) and salicylates

Aspirin is the most widely used therapeutic drug, being analgesic, antipyretic and anti-inflammatory. It was formerly very common as an agent of self-poisoning, both accidental in children and suicidal in adults. In Britain in the last two decades, its use as a self-poisoning agent has declined remarkably, so that fatalities are now rarely seen.

The therapeutic dose is usually 325–975 mg, that is, 1–3 tablets. Rarely, persons with an aspirin hypersensitivity may become ill or even die after therapeutic doses, suffering urticaria, angioneurotic oedema, hypotension, vasomotor disturbances and laryngeal and glottal oedema.

Patients on long-term salicylate therapy for arthritic or rheumatic diseases may take 3–5 g/day and slowly reach blood concentrations which would be in the lethal range if caused by acute overdoses. Those on 3 g/day have blood levels varying between 44 and 330 mg/l.

Apart from deaths caused by hypersensitivity, death in an adult is unlikely with the ingestion of fewer than about 50 tablets, that is, about 16 g. The blood concentration (measured as total salicylate), from a medicinal dose of 975 mg, ranges from about 30 to 100 mg/l (with a mean of 77) 2 hours after ingestion. There is a rapid fall to around 25 mg/l some 8 hours later.

At autopsy, aspirin is one of the few medicines that may cause some gross abnormalities, though they are not particularly specific. Externally there is nothing to see, unless vomiting has taken place, when dark or even red, bloody gastric contents may be expelled. Rarely, there may be some haemorrhagic manifestations in the form of skin petechiae.

Internally, the stomach may still contain a mass of fused, unabsorbed tablets. These tend to start dissolving and then aggregate into a grey or dirty-white mass if a large number (several hundred) have been swallowed. The gastric mucosa may be eroded by the irritative, acidic substance. This may be localized in the stomach or spread widely across the fundus and cardia. The lining may be dotted with acute erosions, sometimes causing bleeding that may amount to a frank haematemesis. Black altered blood may lie in the stomach and pass into the intestine to form a melaena if survival is long enough. Mucosal petechiae and ecchymoses in the stomach, without actual erosive destruction, may be seen as part of a haemorrhagic result of the anticoagulant action of aspirin. Similar petechiae may be spread through other organs and especially serous membranes, particularly on the parietal pleura and epicardium. Even single tablets may cause a small ulcer if they stick to the stomach lining – this is sometimes seen incidentally at autopsy in non-poisoning cases, where a tablet has been swallowed shortly before death.

Post-mortem toxicology requires the usual samples of blood, urine, stomach contents and liver. The mass of aspirin in the stomach may remain for several days in life, forming a partly insoluble concretion that may retard the absorption of the drug. This is why it is always worth washing out the stomach of a live victim, as a large proportion of the aspirin may be removed before it can cause systemic effects. With the advent of soluble aspirin or effervescent preparations, this aspect is lost as no such insoluble bolus forms. At autopsy, part of such a mass can be sent for analysis, whilst quick 'spot' tests can be carried out on another part. Such quick chemical confirmation may be performed in the autopsy room itself, by using a 10 per cent solution of ferric chloride. If a small quantity is added to a urine sample or to the surface of the tablet mass, an immediate purple–blue colour suggests aspirin. This is by no means specific, but is merely suggestive. If negative, however, then aspirin can be virtually discounted. These are only rapid screening methods and by no means replace proper laboratory analysis.

Toxic blood levels (measured as total salicylate) begin at about 300–500 mg/l, though both death and survival are consistent with far higher or lower levels. Blood concentrations in fatal cases may range from about 60 to 7300 mg/l, some authorities suggesting that 500 mg/l is an average minimum level. The liver concentration in fatalities varies from 2.5 to 1000 mg/kg and urine salicylate from 20 to 1350 mg/l, emphasizing the wide levels that are compatible with life. Salicylate has a rather slow clearance rate from the blood, the half-life being up to a day in some massive overdoses.

Aspirin poisoning is dangerous in that sudden cardiac arrest can occur in the absence of any toxic symptoms. This accounts for the deaths that take place after patients have been discharged fit from the emergency departments of hospitals. They may have seemed quite well and symptom free, but suffer a fatal collapse up to a day or so later. Fatal cardiac arrhythmias can supervene without warning and make it advisable, where possible, to admit patients with aspirin overdoses for observation for a day or so.

PARACETAMOL

Paracetamol is also known as acetominophen, *N*-acetyl-*p*-aminophenol or 4′-hydroxyacetanilide. It is an analgesic and antipyretic, without the anti-inflammatory properties of aspirin, for which it is often used as an alternative because of the lack of gastric irritation.

In wide use, especially in combination with other drugs such as codeine and dextropropoxyphene, paracetamol is one of the most common agents in self-induced poisoning by medicinal products. It is used alone in therapeutic doses of up to 500 mg. Overdoses of 20 g or more are potentially lethal, but much less is needed in combination with other drugs, such as propoxyphene. Paracetamol is a potent liver poison, as a small proportion is converted by the liver enzyme 'P450' (microsomal mixed function oxidase) into a toxic compound, probably *N*-acetyl-*p*-benzoquinone. Normally, glutathione and other sulphydryl compounds detoxify this substance, but in overdose, these are exhausted and the toxic agent causes a profound centrilobular hepatic necrosis. The concurrent administration of other drugs, such as phenobarbitone or phenytoin in epileptics or chronic alcoholism, activate the P450 enzyme and worsen the toxicity through this mechanism.

At autopsy there is nothing specific to observe in the gastrointestinal tract. In massive overdosage, there can rarely be rapid death from a direct depressive action on the central nervous system, but most deaths are delayed 2–4 days whilst liver failure develops. At autopsy, the liver may be enlarged, but is often under the normal weight of 1500 g. It may be pale yellow or tan, or the damage may be only visible histologically, when a centrilobular necrosis is seen. Renal changes in the form of tubular necrosis may also be present and occasionally myocardial fibre damage may be visible histologically.

Analytically, the therapeutic range of plasma concentrations 6 hours after a 324 mg dose is 2–6 mg/l, though some

TABLE 31.1 *Fatal concentrations of some antidepressants (mg/l or mg/kg)*

	Blood (average)	Urine (average)	Liver (average)
Amitriptyline	2.7–4.7 (3.7)	0.4–7.9 (3.4)	13–317 (130)
Dothiepin	0.3–2.5 (1.5)	0.4–5.1 (3.2)	2.0–14 (8)
Imipramine	6–8.5 (7.3)	0.6–54 (20)	33–381 (166)
Tranylcypromine	3.7	25.0	7.3

records claim peak levels of up to 25 mg/l. The plasma half-life is a guide to hepatotoxicity, it being dangerous to have a half-life of more than 2 hours at a level of 300 mg/l at 4 hours after ingestion. Typical blood levels in overdoses when at least 10–15 g have been taken are 100–400 mg/l, with an average around 250. The urine may contain 150–800 mg/l, but all levels depend on dose and survival time. Paracetamol may exhibit post-mortem redistribution.

The inclusion of other drugs, especially dextropropoxyphene (and, of course, alcohol), may markedly reduce the level needed for a fatal outcome. Paracetamol was the most frequently detected substance in a compilation of post-mortem femoral blood concentrations of drugs (Druid and Holmgren 1997) based on a selection of 15 800 samples sent to the Department of Forensic Chemistry in Linköping, Sweden, during 1992–95. In their series of 139 fatal intoxications with paracetamol in combination with other drugs and/or alcohol, the median concentration of paracetamol was 170 mg/l (range 90–320).

ANTIDEPRESSANT DRUGS

The tricyclic antidepressants are frequently involved in self-poisoning, partly associated with the type of patient for whom they are prescribed.

Amitriptyline, dothiepin, doxepin and trimipramine have additional sedative properties. Those with little or no sedating action include protriptyline, nortriptyline, imipramine, clomipramine, iprindole, lofepramine, desipramine and butriptyline.

Tetracyclic antidepressants include maprotiline and mianserin. Other types include the monoamine oxidase inhibitors, which are well known to have dangers related to the concurrent ingestion of other drugs and foods, especially those with sympathomimetic action and tyramine content, such as rich cheese, yeast extracts, red wine and beans. Dangerous hypertension may ensue with the risk of cerebrovascular haemorrhage. Drugs of this class include phenoxypropazine, tranylcypromine, isocarboxazid and phenelzine.

TABLE 31.2 *Fatal concentrations of three benzodiazepines (mg/l or mg/kg)*

	Blood	Urine	Liver
Chlordiazepoxide	20	8	10
Diazepam	5–19	3	16
Nitrazepam	1.2–9.0	1–10	0.7–4.0

TABLE 31.3 *Fatal concentrations of two phenothiazines (mg/l or mg/kg)*

	Blood (average)	Urine (average)	Liver (average)
Chlormethiazole	10–214 (55)	5–114 (43)	42–190 (94)
Chlorpromazine	6.6	1.2	84

THE BENZODIAZEPINES

These widely used drugs are employed for their sedative and tranquillizing effects. A large number of both 1,4- and 1,5-benzodiazepines are available, divided into short-acting, intermediate-acting and long-acting compounds.

Long-acting benzodiazepines include: flurazepam, nitrazepam, diazepam, ketazalam, chlordiazepoxide, clobazam, chlorazepate, medazepam and alprazolam. Intermediate-acting benzodiazapines include: loprazolam, lormetazepam, temazepam, flunitrazepam, lorazepam, bromazepam and oxazepam. A short-acting benzodiazepine is triazolam.

THE PHENOTHIAZINES

This group of tranquillizer drugs includes: haloperidol (butyrophenone), chlormethiazole, chlorpromazine, fluphenazine, diphenylbutylpiperidine, promazine, trifluoperazine and prochlorperazine.

The autopsy appearances are non-specific and toxicology may resolve any diagnostic problems if the death has occurred fairly soon after ingestion – which may often not be the case, when history and ante-mortem investigations can provide the only answer.

THE BARBITURATES

The massive problem posed by therapeutic administration of barbiturates until about 20 years ago has largely abated in countries with a responsible medical profession, which voluntarily refrained from the prescription of these drugs except where specifically indicated. Their use as sleeping tablets and general soporific sedative agents led to widespread abuse, so that at one time they were easily the most common agent of drug addiction. The development of non-barbiturate hypnotics, such as the benzodiazepines, helped to remove the need for the older and more lethal compounds. Unfortunately, barbiturates are still widely available on the illicit market, either alone or in combination with other substances such as amphetamines.

Barbiturates exist in many forms, the best classification (which relates to their degree of toxicity) being their speed of action:

- Long-acting barbiturates: barbitone, phenobarbitone and phenytoin, which is still prescribed for epilepsy.
- Intermediate-acting barbiturates: amylobarbitone, sodium amytal, pentobarbitone, allobarbitone, butobarbitone and pentobarbitone.
- Short-acting barbiturates: hexobarbitone, cyclobarbitone, secobarbital and thiopentone.

Much lower blood levels will be found in fatal poisonings in the short-acting group as death may occur more quickly from the usual mode of action, a central depression of the respiratory centres. The author (BK) has knowledge of a death within 20 minutes of taking a massive overdose of ‘Seconal’.

At autopsy, the signs are of general cardiorespiratory failure, with often a cyanotic, congestive appearance. Though non-specific, probably the congested lungs in acute barbiturate poisoning are more intense than in any other condition. These organs may be almost black and the whole venous system is engorged with dark, deoxygenated blood. There may be ‘barbiturate blisters’ on dependent parts of the skin surface, especially buttocks, backs of thighs, calves and forearms, though as discussed in the chapter on carbon monoxide poisoning, these blisters are common to all states of deep coma.

Internally there may be local signs of erosion from the drug itself. The gastric mucosa may be badly damaged from the alkaline attack of drugs such as sodium amytal which, being the sodium salt of a weak organic acid, hydrolyses in the stomach. The fundus may be thickened, granular and haemorrhagic. The cardia and lower oesophagus may be eroded from reflux and, if the victim regurgitates, then black, altered blood may appear at the nose and mouth.

The capsules of certain barbiturates also leave characteristic traces in the mouth, oesophagus and stomach. The colour varies with the manufacturer, but the turquoise–blue of sodium amytal capsules may stain the stomach contents and even be visible through the wall of the intestine when the abdomen is opened. Other pigmented gelatine capsules can be red, yellow or blue. As with so many other drugs, combination with alcohol greatly increases the dangers of a fatality.

TABLE 31.4 *Fatal concentrations of barbiturates (mg/l or mg/kg)*

	Blood	Urine	Liver
Phenobarbitone	55–144	–	–
Amylobarbitone	29–68	210	106–580
Secobarbitone (or quinal barbitone)	5–52	–	15–330

INSULIN POISONING

Formerly a rarity, death from parenteral administration of insulin is now not uncommon. The Beverley Allitt case in Britain in recent years showed that multiple deaths can occur, especially where medical or nursing staff are concerned, as well as those in proximity to diabetics, as both groups may have access to insulin.

Another change is the relative ease with which analysis of body fluids and tissue can be carried out now, compared with the great technical difficulties of only a few years ago, so that fewer such deaths may be missed from lack of reliable insulin assays.

Fatal insulin toxicity may be accidental, suicidal or homicidal. The accidental fatalities are usually examples of medical error, mostly from misreading the label on the box or ampoule. A former student of the author (BK), on the fourth day of her first intern post, gave ten times the dose of insulin to a patient during a pituitary function test, by wrongly assuming that the stated number of units written on the box were the total ampoule contents, instead of being the strength per millilitre.

Suicide by insulin is not uncommon; the author (BK) has seen it given into a saline drip by a doctor and also injected into the abdominal wall by a non-diabetic who stole it from her diabetic neighbour’s refrigerator.

As stated, homicide and attempted homicide have given rise to some notorious cases, both in UK and the USA. In one case known to the author (PS), a previously healthy 48-year-old man was delivered unconscious to the emergency unit because of a suspicion of decompression sickness. The treatment was aborted as the patient was found to be hypoglycaemic (nadir serum glucose 0.3 mmol/l) and treatment and diagnostics of hypoglycaemia commenced. Serum samples drawn at admittance were stored frozen, whereby it was possible to show retrospectively that, while the concentration of insulin in serum was high (75 mU/l, increasing further to over 240 mU/l in the next few hours), concentration of C-peptide was low (below detection limit of 0.1 nmol/l) at the hypoglycaemic stage, suggesting that the patient had received exogenous insulin somehow, and the police were informed. Due to severe hypoglycaemic brain damage, the patient remained in a vegetative state for 2 months before dying of multiorgan failure. Circumstantial evidence obtained during the ensuing criminal investigation was considered by the court to prove the patient's wife (a nurse) guilty of murder (Koskinen *et al.* 1999).

Insulin is, of course, inactive orally and has to be given by injection to perform its hypoglycaemic effect. At autopsy, where either from the circumstances or the finding of needle marks, insulin is a possibility, peripheral blood samples and skin and underlying tissue from the injection site should be carefully preserved, together with control skin from another site.

The fine needles usually used by diabetics may leave virtually no mark on the skin. The author (BK) has tested some such needles on cadaver skin and found that, often, the mark cannot be seen immediately after withdrawal, unless a small vessel has been damaged.

Although insulin has been recovered many days, even weeks, after death, the sooner the better as far as collecting samples is concerned. Serum should be separated from red cells and the former frozen until sent to the analysts, unless whole blood can be sent straight away. Skin and tissue samples should either be frozen or kept in the refrigerator – not fixed. Porcine or bovine insulin can be detected as such but, if therapeutic insulin is of human origin, then it cannot be distinguished on analysis from the patient's own insulin. As well as immunoassay of the insulin itself, the measurement of C-peptide, produced on a one-to-one basis by the pancreas, assists in distinguishing endogenous from exogenous insulin. All such interpretations are a matter for specialists in this field, upon whose advice the pathologist must rely.

Attempting to prove insulin-induced hypoglycaemia by measuring glucose levels in human post-mortem fluids is impracticable, due to the unreliability of such estimations after death.

Very low vitreous humour glucose levels may strongly suggest hypoglycaemia, but are not absolutely acceptable.

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CHAPTER 32

Death from narcotic and hallucinogenic drugs

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These substances are discussed solely from the point of view of the pathologist dealing with fatal cases.

Drugs of dependence may be absorbed orally, by intravenous, subcutaneous or – rarely – intramuscular injection, by smoking, or by nasal sniffing. The routine at autopsy, in respect of obtaining samples for toxicological analysis, is altered according to the route of administration. As mixing of drugs and addition of non-narcotic drugs is common, it is the usual practice to take a wide range of samples even if the primary route is known with some degree of certainty. For example, an addict dying 'on the needle' where intravenous injection is obvious, will still have stomach contents taken for investigation. The standard samples should be taken, as described in a previous chapter, comprising several samples of venous blood (one with fluoride), stomach and contents, liver and urine. In some circumstances, additional samples such as bile, cerebrospinal fluid and vitreous humour may be taken, as well as brain or kidney. The great advances in the analytical techniques allow the analysis of drugs also in other biological samples, such as saliva, sweat and hair. Hair analysis can also provide evidence of long-term exposure to drugs (weeks, months or years), because most drugs, if not all, incorporate in hair and are relatively stable. At least 50 mg of hair should be collected, cutting about a pencil thickness of strands of hair as close to the skin as possible from the back of the head, dried and stored in a sealed plastic bag or tube at room temperature.

When the drug has been injected, then an ellipse of skin around the injection mark, extending down through the subcutaneous tissue to the muscle, should be excised, along with a control area of skin from another non-injected site. These should be refrigerated, not fixed in formalin, until delivery to the laboratory can be arranged. Full histology should always be taken, especially if drugs have been injected, as foreign substances may be discovered as embolic particles, especially in the lungs. Pulmonary granulomata are well-known histological features of 'mainlining' addicts taking impure drugs intravenously, as the lung capillaries filter out coarse particulate matter used to dilute the active narcotic. Talc is particularly prone to form granulomata, sometimes with foreign body giant cells. Under polarized light, doubly refractile particles may be seen in the centre of the reactive nodules. Sometimes, strands of cotton may form foreign bodies, derived from the cloth strainer used to filter particles crudely from the drug solution before injection.

Siderophages were also claimed to be increased in these lungs, compared with healthy young adult controls. However, Lockemann and Püschel (1993), studying lungs stained for iron with Perl's reaction, found conflicting results in two large series and conclude that the pathognomonic value of these cells in drug takers is uncertain.

If drugs may have been taken by the nasal route, such as cocaine and heroin, then dry swabs from each nostril should be taken.

MORPHINE AND OTHER OPIOID DRUGS

Morphine is the major representative of the general group of opioids, which comprise natural opium and a whole series of chemically related derivatives. They may be taken orally or injected and several, such as crude opium and heroin – may be absorbed by inhaling smoke. Morphine itself is poorly absorbed from the gastrointestinal tract; heroin can be taken via the nasal mucosa.

The group consists of opium, morphine, heroin (diacetyl morphine), codeine (dimethyl morphine), dihydrocodeine (DF 118), etorphine (Immobilon), methadone, papaverine, pethidine, dipipanone, dextromoramide, dextropropoxyphene, pentazocine, cyclazocine, diphenoxylate, buprenorphine, tramadol, fentanyl and many more.

Autopsy appearances

The autopsy findings in deaths from all these drugs are relatively non-specific. Toxicological analysis and expert interpretation of the results are necessary for the proper elucidation of the deaths, but certain features can be useful pointers. The first is the presence of injection marks. When fresh, they look just like any other needle mark commonly seen from therapeutic or diagnostic procedures. They are commonly on the arms, either in the classical position in the antecubital fossa on the front of the elbow, or into one of the prominent veins of the forearms or dorsum of the hand. The left side is favourite as most people are right-handed, but in habitual users, sclerosis of the veins may lead to the arms being used randomly. The veins of the dorsum of the foot may be used when the hands and arms have become unusable because of thrombosis and scarring. Less common sites are in the thighs but here, as with the abdominal wall, the injections may be subcutaneous, rather than intravenous. This mode of injection is known as 'skin-popping' and can lead to areas of subcutaneous sclerosis, fat necrosis, abscesses and, if the injections are deeper into the muscle, to chronic myositis.

Other external signs may be tattoos, often bizarre and connected with the drug subculture. One specific type is tattooing, often of numerals, such as '13', on the buccal (inner) surface of the lower lip. Where chronic addiction has taken its toll, the body may be emaciated, dirty and show signs of infection, especially in the form of skin ulceration. Rarely, there may be necrosis or even loss of phalanges from thrombotic or septic emboli. Old injection marks, sometimes with associated bruising, may be found, the bruising undergoing the usual spectrum of colour changes if not recent. The veins may show overlying fibrosis where phlebitis has occurred, or old venous thrombosis with firm cord-like vessels under the skin.

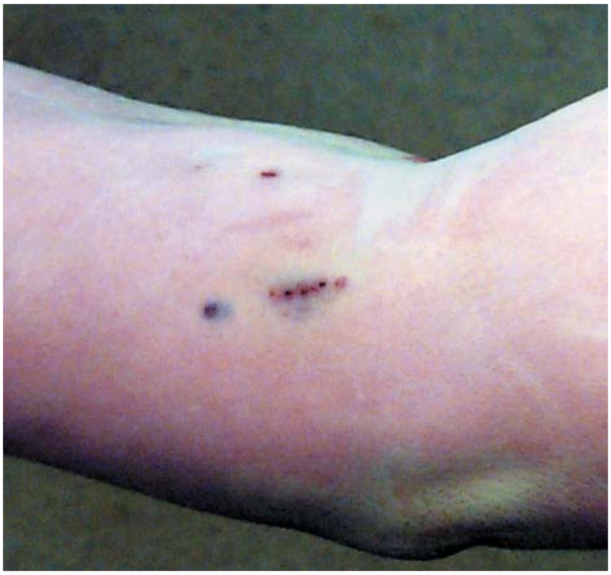

FIGURE 32.1 *Fresh injections marks on the arm of a drug addict.*

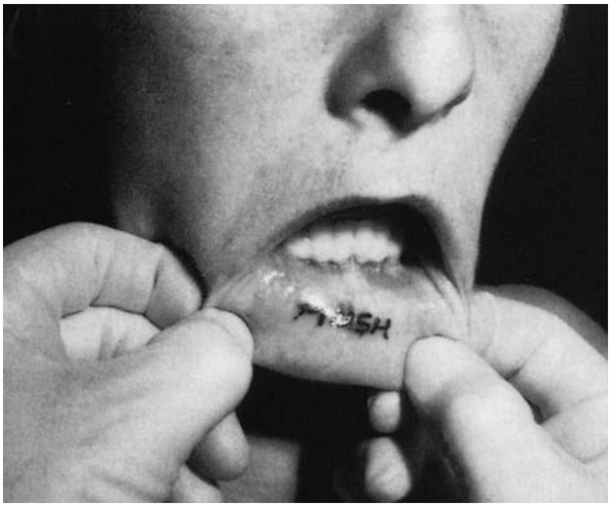

FIGURE 32.2 *Tattoo inside the lower lip of a narcotic drug dealer.*

Where sudden death has occurred in habituated addicts, there may be gross pulmonary oedema, with a plume of froth exuding from the mouth or nostrils, suggestive of drowning. As Polson *et al.* (1983) point out, this may cause some confusion when the victim is found dead in a bathroom, a common venue (along with toilets) for drug administration. This pulmonary oedema is sometimes a striking feature of rapid death in those who are habituated to opioid drugs, especially heroin. It does not seem to occur in novices to the habit, who tend to die in a different way, from a sudden primary cardiac arrest. The oedema may be blood-tinged, again causing confusion with drowning. The cause is not known, but is often attributed to some 'allergic' phenomenon, a rather unsatisfactory explanation. It has been claimed that it sometimes may be caused by adulterants in the drugs, such as quinine, but this is doubtful.

The death may be so rapid that the needle may still be found in the vein when the body is discovered, often in a public lavatory or sometimes in the presence of other addicts, who may then be charged with criminal offences in relation to the death as well as with possessing and using illicit drugs.

There are no other more specific autopsy appearances. Though clinically, a constricted pupil is a prominent sign of morphine administration, after death, any kind of pupil alteration may occur. They may remain small, dilate, or become quite unequal – this applies to any form of death, so no specificity exists for opioid poisoning.

Among new recruits to drug dependence, some die at the first injection of a parenteral dose of heroin or morphine. The mode of death appears to be a cardiac arrest following an arrhythmia and ventricular fibrillation, but no morphological signs can be found. It may be related to sensitization of the myocardium to catecholamines by the drug, the excitement and apprehension being similar to the triggers that seem to cause sudden death from falling into cold water or having a criminal abortion.

The other aspect of autopsies on drug-dependent victims is the risk of infection to pathologist and mortuary staff. Addicts form a high-risk group for both hepatitis B and C, HIV and AIDS. The way in which such autopsies are dealt with in different jurisdictions must vary widely, but it is common practice for HIV and hepatitis testing to be carried out prior to autopsy, unless the policy of the particular autopsy service is to accept all cases with appropriate safety techniques. The analytical laboratory must be informed of any high-risk samples being sent to them, and some will be reluctant to handle blood or tissue samples with positive serology. The pathologist may well refuse to carry out an autopsy on a suspect body until a negative result has been returned on a sample of blood taken (with adequate precautions) from the femoral vein. If positive for hepatitis B or C virus, and especially if the victim shows any signs of hepatic involvement such as jaundice, then many pathologists would decline to carry out a full autopsy unless there are pressing reasons. In that case, scrupulous safety precautions must be taken (see Chapter 1).

In relation to AIDS and HIV positivity, opinions and practices vary widely in the present state of knowledge. It seems obvious that the HIV virus is not in the same category of infectivity as hepatitis. Though autopsies on patients dying of clinical AIDS are routinely performed, there is a difference in the potential risk of a literally 'cold' autopsy being performed on a hospital death after a day or two in the mortuary refrigerator, compared with the urgent activities of a forensic pathologist who may be called upon to conduct an autopsy on a still-warm corpse within a few hours of a suspicious death. However, as mentioned in Chapter 1, HIV may remain viable for many days after death.

TOXICOLOGICAL RESULTS

As with all deaths from toxic substances, the interpretation of laboratory analytical results may present considerable difficulties. There may be a long delay between the administration of the drug and death, during which time the blood, urine and even tissue levels may decline, or even disappear. Many drugs break down rapidly in the body and their metabolites may be the only recognizable products of their administration. In some cases, data on lethal blood levels may be imperfectly known and great variations in personal susceptibility may make the range of concentrations found in a series of deaths so wide as to be rather unhelpful.

As mentioned above, some persons die rapidly after the first episode of taking a 'normal' dose of a drug because of some ill-understood personal idiosyncrasy and here quantitative analysis may not assist.

Where habituation and tolerance has developed, drug users may have concentrations in their body fluids and tissues far higher than lethal levels published for non-habitués. In general, the great usefulness of toxicological analysis is both qualitative and quantitative. The former will show what drugs have been taken in the recent past; the length of time that drugs or their metabolites – persist in different fluids and tissues varies widely.

The quantitative analysis can be useful, especially when the results reveal high levels – into the toxic or lethal ranges. These ranges are usually obtained anecdotally from surveys of large numbers of deaths but, as stated, can differ in terms of minimum and maximum values from different laboratories. The problems of idiosyncratic sensitivity and tolerance cause such published ranges to act only as a general yardstick and deaths that occur outside the ranges (usually off the lower end) cannot be excluded from having been caused by the drug in question if other factors may have been involved. Such factors include the presence of other drugs or alcohol, or both, delayed death and abnormal sensitivity.

Thus the analysis is not the final arbiter of the cause of death, although it is a highly important component of the whole range of investigation. The pathologist has the duty to correlate and interpret all known facts. He must fit the circumstances, the presence of natural disease, trauma and other toxic substances with the laboratory findings, to arrive at the most reasonable cause of death.

The advice of the toxicology laboratory is vital in this process, especially in relation to known lethal ranges and the significance of metabolites, but the analysts should not become the sole arbiter of the cause of death.

METHADONE

Methadone has come to be used primarily as a treatment for established heroin dependency, but unfortunately appears to substitute one form of addiction for another, albeit somewhat less lethal, though recent experience in Scotland (1995) has shown that deaths from methadone may exceed those from heroin, whose use it was intended to supplant. Its clinical uses are as an analgesic more powerful than morphine, with the advantage that it is almost as potent by oral administration as by injection. It has strong and often undesirable sedative properties, however, and is virtually as addictive as the other opioids.

Many deaths occur from its misuse, when obtained either legitimately for the replacement of heroin dependency or on the large illegal market. Most deaths follow oral administration and appear to be due to lack of tolerance, in the absence of which even 50 mg may be lethal, though some recipients appear to die at the outset of the replacement treatment (Drummer *et al.* 1992).

In post-mortem samples, the liver has the highest concentration. The fatal levels found on analysis overlap those found in persons on maintenance doses for heroin replacement, making interpretation difficult. The blood levels published by Manning in 10 fatal cases showed: blood – mean 1.0 mg/l (range 0.1–1.8); liver – mean 3.8 mg/l (range 1.8–7.5); bile – mean 7.5 mg/l (range 2.9–18.0); and brain – mean 1.0 mg/l (range 0.5–1.4).

HALLUCINOGENS

Few of the hallucinogenic drugs are primary causes of death, but some may lead to traumatic deaths because of the abnormal behaviour of the person who is under their influence. For example, the victim of a lysergic acid diethylamide (LSD) 'trip' may be under the impression that he can fly and thus project himself from a high window. Some drugs, however, may have direct toxic effects, though, as with so many drugs of dependence, the autopsy findings are negative or totally non-specific.

Phencyclidine

Chemically this is 1-(1-phenylcyclohexyl) piperidine hydrochloride, known as PCP or 'angel dust' among many other nicknames. It is often used in combination with other drugs of addiction. A number of deaths have been reported from its use, a variety of modes including hyperthermia, intracranial haemorrhage and high output cardiac failure.

Table 32.1 *Blood and tissue concentrations (mg/l or kg) of narcotic drugs from various series of fatalities (Baselt* et al. *1975; Stead and Moffat 1983)*

	Baselt *et al.*		
	Range	**Mean**	**Stead and Moffat**
Heroin			
Blood	0.05–3.0	0.3–0.4	>0.1 (mean 0.43)
Urine	0.7–86	5–18	
Bile	3.2–119	32	
Morphine			
Blood	0.2–2.3	0.7	>0.2 (mean 0.7)
Urine	14–18	3.0	
Liver	0.4–18	52	
Cocaine			
Blood	0.9–21	5.2	3.1 (one case)
Urine	1.4–215	47	
Liver	0.1–20	4.3	
Amphetamine			
Blood	0.5–41	8.6	>0.5
Urine	25–700	237	
Liver	4.3–74	30	
Phencyclidine			
Blood	0.3–25	4.8	>0.3 (mean 2.9)
Urine	0.4–120	35	
Liver	0.9–170	23	
Pethidine (meperidine), orally			
Blood	8–20	12	>2 (mean 14)
Urine	150	150	
Liver	5–10	7	

Phencyclidine is excreted in the urine for a long time after ingestion and autopsy samples may be positive for up to a week.

Lysergic acid diethylamide (LSD)

The well-known LSD, which takes its acronym from the German 'Lysergsäurediäthylamid', is a powerful hallucinogenic which is not fatal in itself, as mentioned above. It is an indole alkaloid derivative, of which other members are psilocybin and psieocin, contained in the Mexican mushroom (*Psilocybe mexicana*).

Mescaline, obtained from the cactus *Lophophora williamsii* of central America, is chemically trimethoxyphenethylamine, again not in itself a lethal substance.

CANNABIS

Cannabis, with all its various names in different parts of the world, has at least six active chemical constitutents, the most important of which is one of the tetrahydrocannabinols. Though its effects are a matter of controversy, there seems to be general agreement that used alone, it cannot be blamed for a single death. Proof of the intake of cannabis can be obtained from analysis of urine, blood, and swabs from lips and fingers.

THE AMPHETAMINES

Now rarely used in reputable medical practice because of the undesirable side effects, the amphetamine group of drugs was formerly employed for the abolition of fatigue and for the suppression of appetite. Methylamphetamine sulphate and dexamphetamine were the commonest analogues of amphetamine itself and are still widely available on the illicit market. Death is uncommon from overuse of the amphetamines alone. At autopsy there are no specific findings, apart from the rare possibility of a cerebral or subarachnoid haemorrhage from the induced hypertension.

Toxicology data suggests that after a therapeutic dose of 10 mg, the blood concentration at 2 hours is about 0.035 mg/l. After 30 mg, a peak plasma level of about 0.11 mg/l was observed at 2–5 hours, declining to 0.084 mg/l at 4.5 hours. Chronic abusers consuming large amounts may have blood levels of up to 2–3 mg/l. In the rare fatalities, there is a wider range of blood levels at autopsy, from 0.5 to 41 mg/l (average 8.6), depending on the size of the overdose and the time until death. Liver levels of 474 mg/kg (average 30) and high urine excretion, ranging from 25 to 700 mg/l, with an average of 237 mg/l, are common.

Methylenedioxymethamphetamine (MDMA) or ‘ecstasy’

In recent years, new derivatives of amphetamine have appeared in the drug abuser’s pharmacopoeia, though the substances have been available for medical use for many years. The most commonly encountered is MDMA (3,4-methylenedioxymethamphetamine), known as ‘ecstasy’, ‘XTC’ or ‘ADAM’. Others of the groups are MDA (methyl 3,4-methylenedioxyamphetamine) and MDM (*n*-methyl-MDA). MDMA or ‘ecstasy’ was developed as long ago as 1914 and for some time had a role in psychotherapy as a consciousness-altering agent. It is now widely used as an illegal hallucinogenic drug, and though deaths have been few, they are now being reported from both the USA and Britain. The author (BK) conducted an autopsy on the first fatality in the British Isles, in a man who swallowed a considerable supply on being challenged by the police. There were no autopsy signs apart from a marked generalized cyanotic congestive state and the diagnosis was made purely on toxicological evidence.

Since the first edition of this book, MDMA deaths have increased markedly due to its ubiquitous availability to young people, especially at ‘rave’ parties: hyperthermia, dehydration and myocytolysis are some of the potentially fatal consequences.

COCAINE

Along with heroin, cocaine and its associated drugs like ‘crack’ form the core of the hard-drug problem, from which fatalities are likely to arise. As cocaine is rapidly destroyed when given orally, it is usually taken by injection or sniffed. Recently, a fatality has been reported from absorption from administration via the rectum. This is in addition to some deaths in which cocaine smugglers have died after packets of the drug hidden in their alimentary tract have broken, causing a massive overdose. In India, cocaine has been used by means of urethral instillation and may also be used in the vagina by prostitutes.

In areas where cocaine usage is common, a significant proportion of fetal deaths are associated with the narcotic. In a series reported in New York by Morild and Stajic in 1990, of 103 fetal deaths, toxicology revealed cocaine in 64. The study suggested that fetal death, *abruptio placentae* and abortion were caused by maternal use of the drug.

Death has been recorded by as little as 20–30 mg being applied to the nasal mucosa, but a gram taken by mouth may not be lethal. As with other narcotics, marked habituation and tolerance occurs in chronic users, making estimates of dangerous dose levels difficult to forecast. Intravenous doses are of the order of 100 mg, a common lethal dose being 10 times greater, though far larger amounts can be tolerated by habitual users. Absorption via the nasal mucosa is less effective and larger doses are needed for the same effect than when used parenterally. Though ulceration and even perforation, of the nasal septum in chronic users is mentioned in most standard texts, they are extremely rare lesions.

Death may occur with considerable rapidity in cocaine overdose or hypersensitivity. It may be quite sudden, from cardiac arrest, in first-time users.

At autopsy, there are no specific features. The pulmonary oedema often seen in heroin deaths is not present with cocaine, though the mode of death is also a dysrhythmia.

The diluent used in 'cutting' the drug for street sale may be found in the injection sites, the regional lymph nodes, in the lungs and in other organs. Adulterants may be similar to those used with heroin and include talc, starch, quinine, lactose and dextrose. Particles of cocaine itself may also be found as microemboli. Strychnine has been used because of its bitter taste, like quinine. Deliberate poisoning by a supplier has been known by either increasing the strychnine content or by supplying pure cocaine or heroin, leading to a massive overdose.

Cocaine is an excitant and stimulator of the autonomic nervous system. Sudden dramatic rises in blood pressure can occur, sometimes to over 300 mmHg and cerebral haemorrhage is a possible complication of this acute hypertension.

As with the opioids, autopsy may reveal complications of the septic methods used for injection, apart from the already stated risks of virus infection, such as hepatitis and HIV. In former years, in New York and California, transmission of malaria was a well-known problem amongst those who shared syringes and needles – indeed, one suggestion for the use of quinine as a diluent, was as a treatment for the *Plasmodium*.

Pyogenic infections are most common, with phlebitis and distant embolic abscesses occurring. The injection sites may ulcerate, there can be regional lymphadenitis, but more serious sequelae that may be fatal include endocarditis. This can affect any heart valve, including those on the right side, which are not usually affected in post-rheumatic endocarditis. Many organisms are involved, mainly haemolytic and non-haemolytic streptococci, *Streptococcus faecalis*, *Staphylococcus aureus* and *Pseudomonas aeruginosa* and some fungi. Post-mortem blood cultures frequently show such a mixed flora from contamination that isolation of the true causative organism may be difficult, but a heavy predominant growth may be significant. The advice of a microbiologist should be enlisted in assessing the relevance of a positive blood culture.

Any drug used intravenously, if it has particulate matter admixed, such as starch or talc, may cause foreign-body granulomata in the lungs, when the undissolved components are filtered out in the pulmonary capillary bed. Such granulomata are characteristic of intravenous drug abusers – when viewed under a polarizing microscope, refractile elements may be easily visualized.

As cocaine is so commonly used by sniffing, swabs should always be taken from each nostril using a plain cotton-wool swab. An unused swab should be sent to the laboratory as a control. The full range of blood, urine, stomach contents, liver and vitreous samples should routinely be taken at autopsy. Blood levels in fatal cases vary widely, but typical ranges extend from 1 to 21 mg/l, with a mean of 5.2 mg/l according to Baselt *et al.* (1975).

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CHAPTER 33

Corrosive and metallic poisoning

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Toxicology is a vast subject, most of it concerned with the nature, occurrence, symptomatology, biochemistry, mode of action and treatment of a wide range of poisonous substances. Many forensic medicine textbooks, especially those from Asia, devote a major part of their text to all these aspects of hundreds of toxic substances, many of which are seldom – if ever – encountered by a pathologist in most parts of the world. As the autopsy appearances of most poisons are non-specific, it seems fruitless to offer a repetitive catalogue, and therefore the descriptions selected here refer to some of those that either have specific features or are encountered more often. This chapter describes the autopsy appearances in a range of poisons that can broadly be classed as 'corrosive', even if this is not necessarily their main lethal mode of action. In addition, several toxic heavy metals will be discussed, again from the point of view of autopsy findings and relevant toxicological laboratory findings.

CYANIDE

Cyanide is a relatively common poison, both in suicide, accident and, occasionally, homicide. It forms part of lethal toxicity of many fires in buildings, where smoke inhalation kills the majority of victims, rather than burns (Chapter 11). Although the autopsy diagnosis of acute cyanide poisoning is rarely in doubt, toxicological analysis may be difficult to interpret because of both the destruction and production of cyanide in the dead body and even in stored blood samples awaiting analysis. Acute cyanide poisoning is most often self-administered (70 per cent in one series), in which case usually the sodium or potassium salt is swallowed. It may be accidental or industrial, in which case either salts may be involved, or it may be the free gas liberated from some commercial process.

Homicidal poisoning is rare, except for the mass homicides which still occur, such as the Jonesville tragedy in Guyana, or the use of cyanide as a weapon of war against civilians in the Middle East. It has also been used for judicial execution in parts of the USA, a practice which seems to be reviving in recent years.

Cyanide acts only as free hydrogen cyanide and therefore swallowed salts need to meet either water or gastric acid before liberating hydrocyanic acid, a process that takes only a few seconds. The fatal dose of cyanide is small, of the order of 150–300 mg, which allowed it to be used as hidden suicide pills by prominent Nazis at the end of the last war. Recovery has been recorded from far greater doses, however, such as 2–4 g of potassium cyanide. Much depends on the purity of cyanides, as they tend to decompose in storage and old samples may contain only half the weight as active cyanide.

Autopsy findings in cyanide poisoning

Cyanide acts by linking with the ferric iron atom of cytochrome oxidase, preventing the uptake of oxygen for cellular respiration. Cyanide cannot combine directly with haemoglobin, but can do so through the intermediary

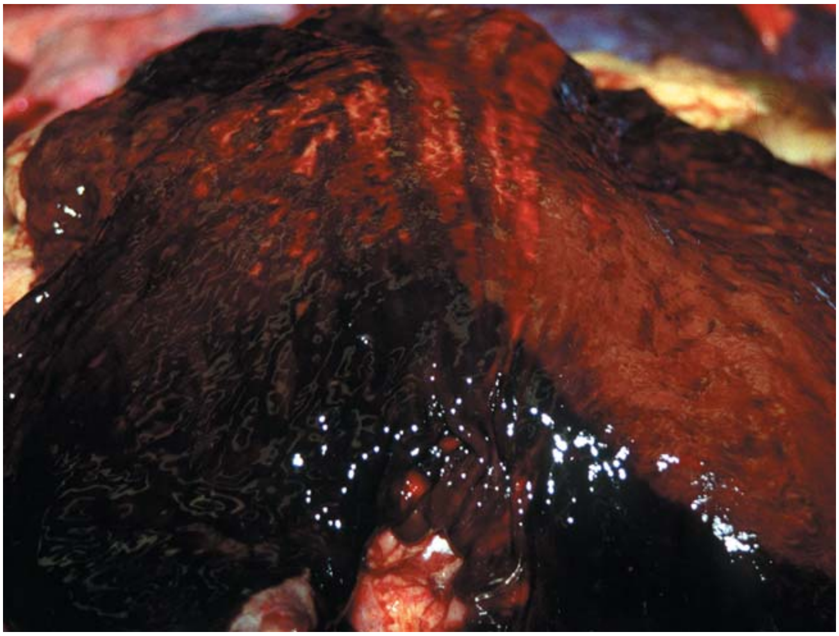

FIGURE 33.1 *Haemorrhagic gastric mucosa in cyanide poisoning.*

compound methaemoglobin. Cyanides are moderately corrosive through their alkaline nature, causing local tissue damage that is unrelated to their more general toxicity via enzyme inhibition.

Externally there can be wide variations in the appearance. Traditionally, the hypostasis is said to be brick-red, due to excess oxyhaemoglobin (because the tissues are prevented from using oxygen) and to the presence of cyanmethaemoglobin. Many descriptions refer to a dark pink or even bright red skin, especially in the dependent areas, which can be confused with carboxyhaemoglobin. The few cases seen by the authors have shown a marked dark cyanotic hypostasis, perhaps caused by lack of oxygenation of the red cells by paralysis of the respiratory muscles. There may be no other external signs apart from the colour of the skin and possibly black vomit around the lips.

There may be a smell of cyanide about the body, though it is well known that many persons cannot detect this, the ability being a sex-linked genetic trait. This may be of importance to pathologists and mortuary staff, as corpses dead of cyanide poisoning can present a health hazard. A former colleague of the author (BK) became ill and was temporarily disabled shortly after conducting an autopsy on a suicide who had swallowed a massive amount of potassium cyanide. Presumably he had inhaled hydrogen cyanide from the stomach contents when examining the viscera.

Internally the tissues may also be bright pink caused by the oxyhaemoglobin that cannot be utilized by the tissues – which is probably more common than the presence of cyanmethaemoglobin. The stomach lining may be badly damaged and can present a blackened, eroded surface, by altered blood staining the stripped mucosa. This is mainly because of the strongly alkaline nature of the hydrolysed sodium or potassium salts of cyanide; hydrogen cyanide itself causes no such damage. In less severe cases, the stomach lining will be streaked with dark red striae, where the rugae have been eroded while leaving the intervening folds relatively unharmed. The stomach may contain frank or altered blood from the erosions and haemorrhages in the walls. If the cyanide was in dilute solution, there may be little damage to the stomach, apart from pinkness of the mucosa and perhaps some petechial haemorrhages. There may also be undissolved white crystals or powder, with the almond-like smell of cyanide mentioned above.

As death is usually rapid, little of the contents will have passed into the intestine. The oesophagus may be damaged, especially the mucosa of the lower third, though some of this may be a post-mortem change from regurgitation of the stomach contents through the relaxed cardiac sphincter after death. The other organs show no specific changes and the diagnosis is made by history, smell and the reddish colour of the internal tissues, and often skin.

Toxicological analysis

The usual blood, stomach contents, urine and any vomit should be submitted to the laboratory, taking particular care that the samples present no hazard to those packing, transporting or unpacking them. The laboratory should be warned in advance that a possible cyanide case is coming their way.

If death was possibly caused by the inhalation of hydrogen cyanide fumes, a lung should be sent intact, sealed in a nylon (not polyvinylchloride) bag.

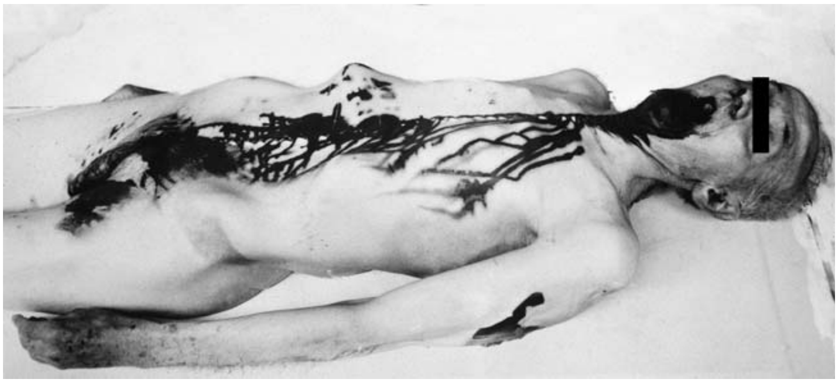
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FIGURE 33.2 *Skin burns on a victim of lysol suicide. The trickle pattern makes it obvious that the man was either standing or sitting erect when he drank the fluid. Lysol burns are usually leathery and brownish-purple.*

It is important to get the samples to the laboratory as soon as possible (in terms of days) to avoid the spurious formation of cyanide in stored blood samples. This usually occurs at room temperature so, if there is to be a delay, refrigeration is essential. By contrast, some positive samples may actually decrease on storage, as described by Curry (1969). Up to 70 per cent of the cyanide content may be lost after some weeks, from reaction with tissue components and conversion to thiocyanate.

The amount found on analysis naturally depends on the amount taken and the time between administration and death. Though the latter is usually measured in minutes, low dosage – or treatment – may allow survival for hours or even days.

Assuming that no spurious cyanide is formed, any significant amount found is evidence of cyanide ingestion, which in itself is abnormal and presumably confirmatory evidence of poisoning. However, Karhunen *et al.* (1991) have reported a case in which post-mortem burning of a homicide victim led to a blood cyanide level of 10 mg/l, presumably due to passive diffusion of cyanide through body cavities opened by the fire.

Typical blood levels in one series of fatal cases following ingestion of the poison range from 1 to 53 mg/l, with an average of 12 mg/l. The spleen always has the highest tissue concentration, presumably because it contains so many red cells; in the same series, the spleen level was between 0.5 and 398 mg/l, with a mean of 44 mg/l. In another series, mean blood levels were 37 mg/l.

CORROSIVE ACIDS, ALKALIS AND PHENOLS

Corrosive poisons were formerly common suicidal agents, though they are now relatively rare in Western countries, probably because of the ease of obtaining less painful substances. In some parts of the world, mineral acids are still often used for homicide, assault ('vitriol-throwing') and suicide. In Malaya, reagents used in rubber production, such as formic and acetic acids, were often taken as a means of self-destruction by young women, especially Tamil rubber workers.

In Britain, acids and alkalis are now almost unknown as agents of death. Even the occasional use of sulphuric 'battery acid' as a weapon of assault rarely causes death. The phenolic corrosives, however, such as carbolic acid and lysol, are occasionally encountered as suicidal agents. Toxicologically, none of these presents much problem, as the damage is often structural rather than poisonous, unless the victim survives long enough to have complications such as renal failure or chest infections. All the corrosive substances have the following features in common:

- There may be spillage of the fluid on the exterior of the body, corroding the skin in a pattern which may be helpful in reconstructing the posture of the victim at the time of drinking the substance. The lips may be burnt, and trickle and splash marks may run from the mouth down the chin, neck and chest. The pattern of burns at the mouth may sometimes indicate the shape of the container from which the poison was drunk, as the wide brim of a cup may mark the cheeks, while a bottleneck may sit more cleanly in the mouth. If the person was standing or sitting, then these runnels of fluid may pass down the chin onto chest and abdomen. If lying, then they may run across the face and cheeks and pass to the back of the neck. Further spillage may come from the nostrils due to spluttering and gagging. The hands may also be affected if the hands are instinctively brought up to the face.
- The interior of the mouth may be eroded, and the tongue swollen or shrivelled, according to the nature of the corrosive agent. The pharynx, larynx and oesophagus are all eroded, and if survival lasts more than a few minutes the glottis area may become oedematous. Spillage into the larynx and air passages may allow the respiratory mucosa to be damaged, and aspiration of liquid or vapour into the lungs can cause rapid pulmonary oedema and haemorrhages.

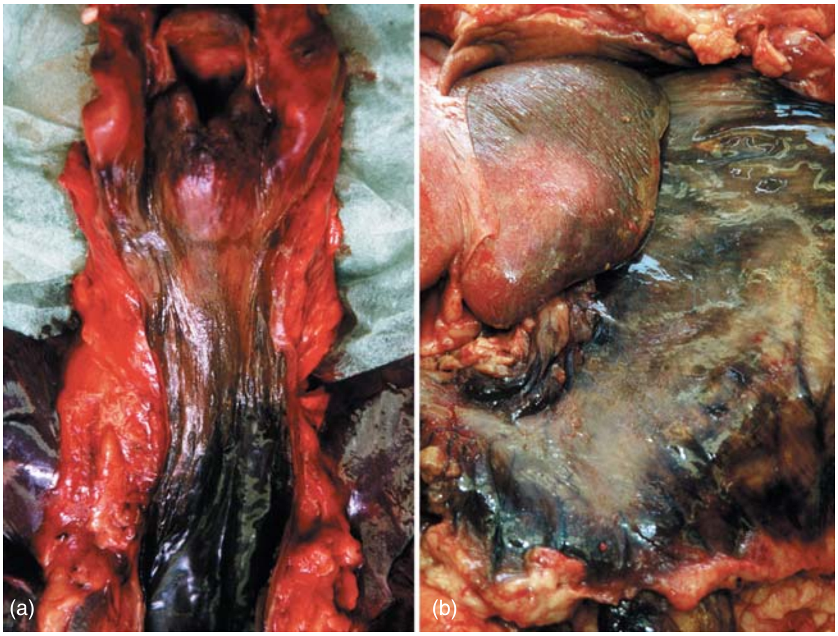

FIGURE 33.3 *Corrosion of larynx, oesophagus (a) and stomach (b) in suicidal ingestion of concentrated hydrochloride acid with alcohol.*

- The lower oesophagus and stomach rapidly become damaged, with discoloration, desquamation and sometimes perforation. Attempts at passing a stomach tube may themselves penetrate the softened wall of the oesophagus or stomach. If survival lasts long enough, some corrosive may pass through to damage the small intestine, but this is rare because of the time factor and spasm of the pylorus.
- All may cause death by pulmonary oedema from spillage into the lungs: if survival lasts a day or more, then a fulminating bronchopneumonia may be the terminal event.

The different corrosive agents have different actions on soft tissues, which can sometimes be differentiated by appearance and smell, though the mineral acids are not all that different. The phenolic compounds can usually be detected by smell alone. Strong acids act by dehydrating the tissues, coagulating the proteins and converting haemoglobin to haematin.

Sulphuric acid, in concentrated form, is extremely corrosive and produces great heat in contact with water or tissues. The tissues are grey to black, rather dry and dehydrated. They may actually be charred into a blackened crust by the generated heat. The gastric lining may be grey, dark brown or black, or mixtures of all colours, depending upon the amount of altered blood in each part. Perforation may occur.

The oesophagus and stomach may be grey and swollen, depending on the amount of acid and the amount of food already in the stomach. The tongue may be grey or black and distorted.

Nitric acid is similar, but has a brownish-yellow cast to its mucosal damage. There may be yellow or brown sharp-edged patterns on the skin burns of the face, with the usual trickle marks coming down from the corners of the mouth. Yellow fumes may arise from the stomach contents if a considerable quantity is present. The internal appearances are of yellowish-brown sloughing, though perforation seems less common than with sulphuric acid.

Hydrochloric acid has similar effects, especially on mucous membranes, but is not so injurious to intact skin as sulphuric and nitric acids. The stomach may be converted into a slimy, softened mass and can perforate. The colour is greyish to black, depending on the amount of altered blood.

Sodium hydroxide in concentrated form is also a corrosive, but soft, slippery slime is the characteristic appearance and feel to tissues damaged by caustic soda. The colour is dirty white to grey.

Phenol and lysol are also damaging and affect the tissues in much the same way as acids and alkalis. Carbolic acid (pure phenol) tends to stiffen the tissues and bleach them so that hard, cracked, whitish surfaces are seen on the face and skin. Internally, the same stiffness is noted in the oesophagus and stomach. Lysol is a soapy solution of phenol and cresols. It discolours the tissues a brownish purple, but is otherwise similar to phenol in its action.

OXALIC ACID AND OXALATE SALTS

These are not so corrosive as the mineral acids, but are poisonous and often act quickly, death occurring within minutes or the hour, from shock or hypocalcaemia. The acid is locally corrosive, but also has a systemic effect that may well be fatal even if the local damage is non-lethal.

At autopsy, if an appreciable amount of either the white crystals or a strong solution has been swallowed, the local effect is a bleaching, the mucosa of mouth, pharynx and oesophagus being white, though local haemorrhage can streak this with red. The stomach contains altered blood from the damaged mucosa and is dark brown or black from acid haematin, the wall studded with acute erosions. Calcium oxalate crystals may be seen in the stomach contents or in scrapings from the mucosa.

In those who have survived the acute phase, death may be caused by abnormalities of the muscle function (including the myocardium) from the hypocalcaemia, caused by the precipitation of body calcium as insoluble calcium oxalate. More common is renal failure, death occurring 2–10 days later. The renal tubules suffer necrosis, primarily in the proximal convoluted tubules. This is not caused by the presence of calcium oxalate crystals, though these can be demonstrated histologically in the kidney.

ETHYLENE GLYCOL POISONING

Though in no sense a corrosive poison, ethylene glycol has certain features in common with oxalate poisoning and is so common relative to death from mineral acids that it cannot be omitted. The glycols are used widely as antifreeze agents in motor engines and as solvents in industry, so they are easily available. Because of their chemical inclusion in the alcohol group, they are abused as a source of intoxication, as well as being accidental and suicidal agents. At least 40–60 deaths a year are reported and this is probably an underestimate. The compounds involved are ethylene, diethylene, propylene and hexylene glycols. These do not have the same toxic effects (in fact, propylene glycol is virtually non-toxic), but ethylene glycol is the most commonly encountered. When drunk in excess of 100–200 ml, it is almost certain to be fatal unless specific treatment is given, such as dialysis and competition with alcohol.

The first effects resemble drunkenness, but this passes into coma and death often within the first day. The glycol is metabolized in the body, a small but significant amount (about 1 per cent) being converted to oxalic acid, via the process glycol–glyoxal–glycolic acid–formic acid–glyoxylic acid–oxalic acid. It is not clear which of these compounds causes the most damage to the tissues.

At autopsy there is no local damage, but widespread precipitation of the sheaf-like doubly refractile crystals of calcium oxalate into the tissues can be rendered visible microscopically by the use of polarized light. It is a matter of controversy whether this crystal deposition is the cause or merely a side effect of the lethal action of glycols. There may be cerebral oedema and a chemical meningoencephalitis. In the kidney there is a tubular necrosis similar to that in oxalate poisoning, and the crystals can be seen in the interstitial tissues and the tubules. Diffuse liver damage can also occur.

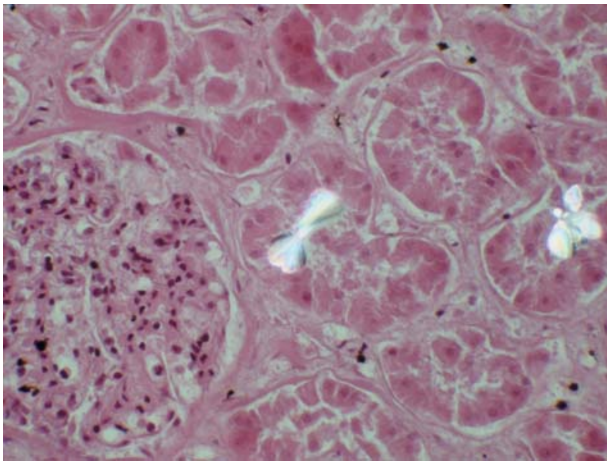

FIGURE 33.4 *Birefringent calcium oxalate crystals in kidney in ethylene glycol poisoning as seen in polarized light under a microscope.*

Laboratory analysis in ethylene glycol poisoning

The blood levels naturally depend on the time that has elapsed since ingestion. It is usually greater than 300 mg/l and the mean is as high as 2400 mg/l in samples taken before the second day. The brain may contain from 300 to 4000 mg/kg and the urine from 600 to 10 000 mg/l, with a mean of 5700 mg/l.

METALLIC POISONS

There is a whole range of metallic poisons, most of them from the upper reaches of the Periodic Table, accounting for their usual description as ‘heavy metals’. The vast majority of toxic effects come from environmental and occupational poisoning, both chronic and acute. Acute poisoning by suicide, accident and homicide is becoming much less common, both because of the availability of other toxic agents, and because of greater awareness and controls on the environmental and industrial hazards of heavy metals. In former years, especially the nineteenth century, heavy-metal poisoning was common in homicide, but is now rarely seen in Western countries, mainly because they are now known to be easily detectable.

As the subject is dealt with in great detail by so many textbooks and monographs, only one such poison – arsenic – will be discussed, together with a mention of any significant differences with other metals.

Arsenic

A constituent of all animal tissue, arsenic is the twelfth most abundant element on earth. This emphasizes the need for strict controls when making analysis for arsenic in human fluids or tissues, as the excretion of a healthy person on a diet rich in fish (especially shellfish) can exceed that seen in chronic arsenical poisoning. Similarly, where an exhumation is performed after allegations of poisoning, full control samples of soil and grave water must be taken to ensure that arsenic found in the body could not have arisen from local contamination (Chapter 1).

Arsenic metal is not poisonous, only its compounds. These interfere with cellular respiration by combining with the sulphydryl groups of mitochondrial enzymes, especially pyruvate oxidase and certain phosphatases. Arsenic has a particular target in vascular endothelium, accounting for the many lesions caused by increased permeability, tissue oedema and haemorrhage, especially in the alimentary canal.

Arsenical poisoning may arise from the ingestion of arsenious oxide, a tasteless white powder – from copper, sodium and potassium arsenites, arsenates of lead and calcium, arsenic sulphides and gaseous arsine (confined to industry). In forensic practice, the rare cases of arsenic poisoning are now usually from arsenious oxide or one of the arsenites.

Arsenical poisoning may be acute or chronic, the latter being the presentation of most environmental and occupational toxicity. Suicides are obviously invariably acute, whereas the uncommon homicidal cases may be either acute or chronic.

FATAL DOSAGES IN ARSENICAL POISONING

If taken on an empty stomach, especially in solution, only about 150 mg may be fatal, but usually some 250–300 mg are needed as a minimum lethal dose. Much larger quantities have been survived and there is some evidence that tolerance to arsenic can be attained. With large doses, much may be vomited. Death can be rapid – within hours from 'shock' and cardiorespiratory failure – or may be delayed for many days, when hepatorenal failure is the mode of death. In chronic poisoning, no lethal dosage can be indicated, as if the ingestion exceeds the small normal excretion rate, then a cumulative build-up of arsenic will occur.

Autopsy findings

In acute poisoning the findings may be minimal, if death occurs within hours. There may be some mild irritation of the upper gastrointestinal tract, such as reddening of the gastric mucosa, especially along the top edges of the rugae. The description of 'red velvet' has been applied to some stomach linings in acute arsenic poisoning. There may be mucus coating and granules of the poisonous agent may be trapped on the lining – a reason for sending both contents and stomach wall for analysis, as in most suspected poisonings of any type. The intestines are usually normal in acute poisoning.

The only other lesion commonly seen is subendocardial haemorrhage on the left ventricular wall. This, of course, is a common finding in any severe shock condition when sudden hypotension occurs. It is seen in any gross injury, with loss of blood volume, blood pressure and neurogenic shock. Head injuries and raised intracranial pressure are other conditions in which these lesions are prominent (Chapter 13). The phenomenon can be rapid, the author (BK) having seen them in the victims of military air crashes where the heart was avulsed from its base at the moment of impact. One of the best descriptions of subendocardial haemorrhages was given by Sheehan in 1940 in obstetrical catastrophes. The haemorrhages are situated on the upper part of the interventricular septum and on the opposing papillary muscles. The most severe the author (BK) has ever seen was in a massive suicidal overdose of arsenious oxide, where the haemorrhages were actually raised blood-filled blisters under the endocardium. These suggested the true diagnosis before analysis was carried out, albeit with an element of speculative good luck.

In chronic arsenical poisoning, the picture is quite different, though unless some suggestive history or circumstantial evidence is available, the diagnosis may be extremely difficult. As many a clinician has discovered to his chagrin in the past years, many a chronic arsenical poisoning has been misdiagnosed as a gastroenteritis.

Part of forensic mythology surrounds the alleged preservation of corpses dying from arsenic poisoning. This has been endlessly discussed, but there is no real evidence that it is true. A more likely explanation is that the dehydration from diarrhoea in chronic poisoning retards the usual moist putrefaction.

Externally there may be a diffuse abnormality of the skin, with a dry, scaly, hyperkeratotic surface. Clinically, there is a 'rain-drop' punctate pigmentation, but this may not be apparent after death unless really marked. It is more common in skin flexures and over the forehead and neck. There may be some hair loss. Puffy thickening and oedema of the face has been described, suggestive of myxoedema.

Internally the stomach may be normal or may show a chronic gastritis with thickening of the mucosa and subserous coats. Mucus formation may be noticeable and there may be a patchy inflammatory redness of some of the rugae. Sometimes there is a haemorrhagic gastritis with acute and chronic erosions. The small intestine is dilated and generally reddened, with thickened mucosa, the whole picture being of a non-specific congestion oedema so commonly seen in any enteritis.

There is rarely any mucosal ulceration. The contents may be copious and fluid, the usual description of 'rice-water' being applied. The large intestine may show minimal changes or be normal: the contents may be fluid and similar to the small bowel. The liver may reveal fatty change or more severe necrosis, sometimes at the periphery of the lobule. Severe liver damage may be associated with externally apparent jaundice. The kidney is damaged in chronic toxicity, there being non-specific tubular necrosis. The myocardium may also show myofibril damage, interstitial collection of cells and sometimes fatty degeneration.

TOXICOLOGY SAMPLING AND ANALYTICAL RESULTS

In acute poisoning, the major requirement is the stomach and contents, and preferably the small intestine, tied off at each end. Blood, urine and liver should also be taken.

In chronic poisoning, especially if the diagnosis is not firmly established from circumstantial and gross autopsy findings, a much wider range of samples is needed:

- blood from peripheral veins
- stomach and contents
- small intestine and contents
- sample of large bowel contents
- urine
- bile
- whole liver
- one kidney
- nail clippings or whole nails
- hair samples – whole length of at least 20 hairs, including roots.

Arsenic levels in blood are elevated only for a short time following absorption, unless exposure is continuous. The highest concentrations of arsenic are found tissues rich in sulphydryl (SH-) groups, such as skin, hair and nails. Typical levels of arsenic found in healthy persons unexposed to extra amounts over and above that normally (but variably) present in their environment are as follows: urine, <2–20 μg/l; blood, <0.5–4 μg/l; liver, <60 μg/kg (dry weight); nails, <10^3 μg/kg (dry weight).

It was formerly thought that it took a week or two for ingested arsenic to find its way into the keratinized tissues such as hair and nails. More sensitive analytical techniques have, however, shown that it can appear there within hours of ingestion by mouth. The explanation was originally offered that arsenic was rapidly secreted into sweat, and spread to the hair and nails by surface diffusion. This has recently been disproved by neutron activation analysis and the mechanism remains obscure. The test for estimating the timing and duration of arsenic administration by analysing different lengths of the hair shaft has thus been vindicated. Arsenic can remain stored in keratin for several years after administration ceases.

TABLE 33.1 *Levels in acute arsenious oxide poisoning from 49 fatalities (Rehling 1967)*

	Range	Average
Blood (mg/l)	0.6–9.3	3.3
Liver (mg/kg)	2.0–120	29.0
Kidney (mg/kg)	0.2–70	15.0
Spleen (mg/kg)	0.5–62	8.8
Brain (mg/kg)	0.2–4.0	1.7

Antimony

Antimony is similar to arsenic in many respects. Apart from industrial exposure, the usual vehicle of poisoning is 'tartar emetic', antimony potassium tartrate. This has been used suicidally and homicidally, as well as in some accidental deaths. The pathology and toxicology are similar to that of arsenic, the minimum fatal dose of the tartrate being about 150 mg, though this was formerly the normal intravenous dose in the treatment of bilharzia. Vastly greater amounts of tartar emetic have been survived, so the minimal lethal dose is not a particularly useful concept, as with many other poisons.

Occupationally unexposed people have either zero or not more than 0.01 mg/l of antimony in their blood and a tenth of this concentration in their urine.

Baselt (2002) quotes a case of acute poisoning from antimony trichloride where the following concentrations (in mg/l or mg/kg) were found on analysis: blood, 4–6; liver, 45; kidney, 32; bile, 404.

Thallium

Though other heavy metals have declined in forensic importance over the past century, thallium has several times been used homicidally in recent years, sometimes for multiple poisonings. Thallium is used as a rat killer and widely employed in industry, especially in glass manufacture. It has curious aspects in relation to forensic pathology, in that it can be seen radiologically in the intestine and deposited in the liver, so in the rare event of a pathologist suspecting thallium poisoning,

TABLE 33.2 *Fatal thallium concentrations (mg/l or mg/kg) collected by Baselt (2002)*

	Range	Average
Blood	0.5–11	4.0
Urine	1.7–11	5.2
Kidney	6–20	11.0
Liver	5–29	15.0

X-rays of the body should be taken before autopsy. The other unique aspect is that it is probably the only homicidal agent to be confirmed after cremation. In the Young case in Britain in 1971, where two people died and several others were non-fatally poisoned by Young, thallium was detected retrospectively in the ashes of one of his victims.

The fatal dose is somewhere about 1 g, depending upon the type of thallium compound employed, as there are several different salts available, such as the acetate, sulphate or nitrate. The estimates vary from 6 to 40 mg/kg body weight, with an average of about 12 mg/kg.

Autopsy appearances are variable and non-specific, but pallor and streaking of a pale, degenerate myocardium have been recorded. Hair loss is one of the clinical signs that arouses suspicion of thallium poisoning, as it was formerly used as a depilatory. This effect begins about a week after administration, but may not be noticeable for twice that time. Large tufts tend to come away, rather than a general thinning. Loss of the outer third of the eyebrows is said to be a significant sign, though these are also the areas that are lost in hypothyroidism.

Examination of the roots of surviving hairs may show a black coating, caused not by the thallium itself, but by an excess of melanin. Liver necrosis and renal tubular necrosis are non-specific findings in those who survive for some time.

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CHAPTER 34

Deaths from organic solvents

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A wide range of organic compounds used in industry and in the home as solvents may cause injury or death, especially when used carelessly or for improper purposes. Other organic substances, often gaseous, can also be fatal when used or abused in the same circumstances.

SOLVENT ABUSE

This phenomenon arose, spontaneously and independently, in several parts of the world in the 1960s. It consists of deliberately inhaling a variety of substances, especially organic solvents, in order to achieve a distortion of consciousness. The effects vary from a state resembling alcoholic intoxication through euphoria (sometimes of an erotic nature) and distortion of perception, to actual hallucinations. The practitioners of this activity are predominantly, though by no means exclusively, male and most are between the ages of about 14 and 22 years, though again there are a few beyond either end of this age range. The majority of deaths occur in solitary users, some 70 per cent being reported by Anderson *et al.* (1985) as having happened when the young person was alone. Sniffing can certainly be a group activity, however, as is seen in schools and even the streets of some cities.

At first, the most common substance inhaled was a toluene-based adhesive and therefore the name 'glue-sniffing' soon became attached to the habit, though in fact many substances now used are not adhesives. The more accurate title of 'solvent abuse' has now been applied to this widespread and dangerous habit. Although (like the sexual asphyxias, with which there is some cross-relationship) the ratio of deaths to non-fatal escapades is relatively small, the large number of children and young people who indulge in the habit means that a considerable death toll occurs annually.

The usual method of abuse is for a quantity of the solvent or other chemical to be placed in a plastic bag – which may be any kind from a large black polythene garbage sack to a used potato-crisp packet. The open end is then placed against the nose and mouth, and the air inside re-breathed. The warmth of the hand holding the bag, as well as the warm breath, encourages vaporization of the solvent, which enters the tidal air stream and is absorbed through the pulmonary membranes into the blood. When the substance is not a viscous glue, it may be placed on a handkerchief or rag, and inhaled direct as a pad over the nose and mouth.

When gaseous substances are abused, they may be introduced directly into the mouth or nose. A common variety is butane or propane, taken from either a large cylinder used for camping, heating and cooking, or from the small ampoule cylinders sold for refilling gas cigarette lighters. Others are used directly from pressurized aerosol cans, including pain-relieving sprays used for the relief of muscular conditions. Yet again, sniffing may be attained by merely inhaling directly from the neck of a container. Tins, jerry-cans and the petrol-fillers of motor vehicles may be used in this way. Some fire extinguishers contain an organic bromine derivative which is also abused for inhalation. This has a particular propensity for sensitizing the myocardium to catecholamines.

Dangers of solvent abuse

SUDDEN DEATH

The major cause of death appears to be sudden cardiac arrest, following an arrhythmia. Any of the solvents appears to have the ability to sensitize the myocardium to the action of catecholamines, such as noradrenaline. Any sudden 'flight-or-fight' stimulus, even some considerable time after sniffing solvents, has the ability to precipitate ventricular fibrillation and hence sudden death. A recent instance seen by the author (BK) involved a youth whose habit was to steal fire extinguishers from trains parked in sidings and inhale the bromine-based contents. Having been in trouble with the police before, he took fright on seeing a constable approaching, though in fact the officer was merely walking his dog. The boy ran from his group of friends and did not reappear, being found dead in some bushes some time later, though he had not 'sniffed' that day. The autopsy and toxicology were negative, apart from residual traces of organic substance in his blood.

In addition to this physiological mechanism, actual myocarditis can occasionally occur, as in a 15-year-old girl who dropped dead whilst inhaling from the petrol tanks of vehicles. At autopsy all that the author (BK) could find was a florid, diffuse interstitial myocarditis with minimal myofibril necrosis.

CHEMICAL EFFECTS

The mechanical means of obtaining concentrated solvent vapour is in itself dangerous. Persistent rebreathing can produce hypoxia and hypercapnia, which is additive to the toxic effects of the solvent itself. When large plastic bags are used, the abuser sometimes places his head within the bag and this risks the dangers of rapid death from plastic bag asphyxia (Chapter 14). It is difficult to know if some of these cases are at least partially instances of erotic hypoxia, the effects of both oxygen lack and the hallucinogenic effect of the solvent combining to give both sexual pleasure and a heightened risk of death.

Another potent risk is vomiting while the effects of the solvent incapacitate the victim sufficiently to prevent his reflexes from protecting or clearing his glottis or air passages. The usual warning must be given, however, about uncritically accepting the finding of gastric contents in the air passages at autopsy. This may well have been an agonal regurgitation in a victim who was dying of the common cardiac (ventricular fibrillation) effect of solvents on the myocardium. This has medico-legal relevance in that a fellow abuser or even some other bystander may be accused of failing to render assistance in clearing the air passages, when in fact this was the effect, rather than the cause of death. This is not to say that aspiration of vomit cannot be the cause of death, as in alcoholic intoxication, but the autopsy finding should be backed up with some circumstantial evidence that it occurred before the agonal period.

PHYSICAL DANGER

When gaseous substances are used, such as butane or propane from cylinders, or propellants from aerosol cans, a physical danger is added to the chemical effects. The gases are commonly directed or sprayed into the open mouth while inhalation is performed. The release of high-pressure gas causes rapid cooling by the 'refrigerator effect' and the impact of this on the palate, pharynx and larynx may cause a reflex cardiac arrest. The author (BK) has dealt with two such cases, one in a school yard, where the users of small propane refuellers virtually dropped dead in the presence of other youths. The mechanism of this phenomenon is disputed, but freezing of the sensitive pharyngolaryngeal area is surely a parallel to the sudden deaths seen when cold water enters the nasopharynx in sudden immersion deaths.

DANGER TO LONG-TERM USERS

Long-term users can suffer liver damage, typical of halogenated hydrocarbon exposure, with fatty change in the liver and sometimes associated renal damage.

SUBSTANCES USED IN ABUSE

Toluene

Toluene was one of the first substances recognized as giving rise to 'glue-sniffing', as it is the solvent for many adhesives, such as the proprietary glue 'Evostick'. It is an aromatic petrol hydrocarbon used widely in industry as a solvent and thinner for adhesives and paints. It resembles benzene in many of its properties, another substance that can be used in solvent inhalation. Toluene can cause acute and chronic intoxication in industrial situations. Exposure to relatively high concentrations in the air, between 10 000 and 30 000 p.p.m. can cause drunkenness, mental confusion and coma within a few minutes.

In non-fatal toluene abuse, blood levels of 0.3–7.0 mg/l were measured by Bonnichsen *et al.* (1966), with urine excretion of up to 5 mg/l. Those with blood concentrations of 1.0–2.5 mg/l showed some sign of intoxication, while half of those between 2.5 and 10 mg/l were admitted to hospital with marked symptoms. Those who were unconscious or dead had blood levels in excess of 19 mg/l. Nomiyama and Nomiyama (1979) found blood levels of between 50 and 80 mg/l in three fatalities. Baselt (2002) quotes a fatal range of between 10 and 48 mg/l with an average of 22 mg/ml for fatalities, the average in the lung being 12 mg/l and in the brain 47 mg/l. Brain damage has been reported in long-term abusers, with electroencephalographic changes, encephalopathy and occasional cerebral atrophy.

Petrol (gasoline), xylene and benzene

These closely resemble toluene in behaviour, though benzene is said to be more potent in causing intoxication. As with toluene and most other solvents, they can burn the skin if left in contact with it for some time. The odour threshold for benzene has been reported as 1–5 p.p.m. in air. In chronic exposure, benzene can cause bone-marrow depression and fatal aplastic anaemia, but this is not a feature of the shorter exposures in solvent abuse.

Methylene chloride and ethylene dizchloride

These are found in paint strippers and, as these solvents, in many other products. One used for abuse is the solvent for typewriter correction fluids, such as Tippex.

Butane and propane

These have been mentioned earlier, being used direct from pressurized containers. They are light hydrocarbons, being the upper fractions of oil distillation.

Fluorocarbons

These are the substances now blamed for having the worst effect on the ozone layers of the upper atmosphere. They are widely used as refrigerants and propellants in aerosol containers. It is in this latter role that they are widely abused for euphoric and hallucinatory effects. The various compounds are numbered, rather than named, two fluorine atoms being incorporated into molecules that otherwise resemble carbon tetrachloride. Those used for propellants are FC-11 and FC-12.

A similar compound incorporating bromine instead of fluorine is used as a fire extinguisher, as is carbon tetrachloride itself. As long ago as 1970, Bass published a series of 110 sudden deaths, including many from fluorocarbons. As mentioned earlier, these substances sensitize the myocardium to circulating catecholamines. The range of blood concentrations in fatal cases in respect of FC-12 is 0.6–12 mg/l, with a mean of 3.0 mg/l and for FC-11, 1.2–32 mg/l, with a mean of 12 mg/l. In the lung, FC-12 may be present at levels of 0.9–134 mg/kg, with a mean of 33 mg/kg; for FC-11 the corresponding figures are 5.8–94 mg/kg, with a mean of 43 mg/kg.

Carbon tetrachloride

Used as a degreaser, dry-cleaner and fire extinguisher, carbon tetrachloride is easily available from retail outlets as a spot remover. It is quite toxic, though it (unwisely) used to be used in human pharmacy to treat intestinal worms. As little as 3–5 ml can be fatal. Much of its toxicity is industrial, but it has also been used in suicide and solvent abuse. Chronic exposure can cause liver and renal damage, worsened by the simultaneous use of alcohol. Addiction can occur, even from initial exposure during industrial use.

As with most halogenated hydrocarbons, the liver suffers from exposure to tetrachloride. There is a centrilobular necrosis, usually preceded by fatty change if the poisoning is low level and lasting. In fatal cases there may well be virtually total acute yellow atrophy. The liver damage is markedly worsened by a high alcohol intake. Renal changes consist of a tubular necrosis and diffuse fatty degeneration in the cortex.

Post-mortem blood levels vary greatly, but a fatal case has been recorded with a concentration of 260 mg/l. Korenke and Pribilla (1969) found tissue levels at autopsy a week after inhalation as being 142 mg/kg in the liver and 39 mg/kg in the lung.

Other halogenated hydrocarbons

Other halogenated hydrocarbons have similar effects to carbon tetrachloride, but the level of toxicity varies with the number of chlorine atoms in the molecule. The ascending order of danger is methyl chloride, trichlormethane, chloroform and carbon tetrachloride. Others include trichlorethylene, used widely in both anaesthesia (Trilene) and in dry-cleaning. Several other similar compounds have been the cause of fatalities in industry as well as in solvent abuse. The pathological features are similar in most of them, the effects being on the central nervous system in acute massive overdose, whether by ingestion or inhalation, and upon the liver and kidneys in more chronic intoxications.

THE AUTOPSY ON FATAL SOLVENT-ABUSE VICTIMS

The scene should be visited if possible, though it is rare to find the body there, as strenuous resuscitation and removal by ambulance is always a prime consideration in children and young persons found apparently dead. The paraphernalia of sniffing may be seen in its original state.

At autopsy, the clothing should be examined, even though it has almost always been removed for resuscitation attempts. Any soiling with adhesive or solvent stains should be detected and, though volatile, should be kept for forensic science investigation. The best means is to pack them as soon as possible in a nylon bag to retain any vapour; these solvents will penetrate a polyvinylchloride bag and be lost.

Externally, the face should be inspected for any signs of chronic or recent solvent abuse. The act of holding a bag against the lower face, often contaminating it with glue or solvent, may leave skin lesions. These can be red erythematous pimples or actual excoriations from the irritant action of the solvent. The lesions may become infected or scratched, becoming crusted. The rest of the autopsy may be unrewarding from the point of view of gross pathology. Rarely, there may be a fatty liver from long-standing damage from the solvent, especially the halogenated hydrocarbons. Full samples for histological examination should be taken to determine the state of the myocardium, liver and brain. More immediate is the need to obtain samples for analysis.

Vigorous resuscitation, including mouth-to-mouth and chest compression, together with mechanical ventilation and oxygen administration, will obviously blow off much of the solvent in the lungs. If it has already been absorbed, however, some will come back into alveolar air from the lung tissue and the sensitivity of the head-space gas chromatography used for its detection is often sufficient to identify the substance, which can also be detected in blood and tissues.

Blood samples should be taken in the usual manner, including a tube with fluoride for alcohol, which is sometimes also present. A lung should be taken intact for the laboratory. It was formerly the practice to aspirate air from the trachea before removal of viscera, using a 50 ml syringe, which was then sealed and sent to the laboratory. This is impracticable, and the best method is to open the pleural cavity and pass a string ligature round the hilum of a lung, pulling it tight to occlude the main bronchus. This is then drawn tight and the hilum transected. In actual fact, little is lost if the lung is cut off without this procedure, as long as it is put straight into a nylon bag without delay and without squeezing out the contained air. The nylon bags are those that arson investigators use to save material for fire-accelerant examination, as they are impervious to organic solvents.

A urine sample, and unfixed tissue from liver and brain should also be supplied to the toxicology laboratory, though local discussion should be made to determine the requirements of each laboratory.

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APPENDIX 1

Technical methods

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STAINING TECHNIQUES

Periodic acid–Schiff (PAS) for myocardium

In established early infarcts of probably at least 28–24 hours' duration, damaged myofibres stain a pale purple-blue with PAS, compared with the pinker colour of healthy fibres. This stainable material is diastase resistant and is probably a mucoprotein.

(a) Bring sections to water.
(b) Immerse in 1 per cent periodic acid for 5 minutes.
(c) Wash in water for 5 minutes.
(d) Rinse in distilled water.
(e) Immerse in Schiff's reagent for 10 minutes.
(f) Wash in water for 10 minutes.
(g) Stain in haematoxylin for 30 seconds.
(h) Blue in tap water and mount in usual way.

Malic acid dehydrogenase (MDH)

Enzyme histochemistry is the most reliable method of detecting early myocardial infarction. Succinic, lactic, malic, β-hydroxybutyric dehydrogenases and cytochrome oxidase are among those used by many workers and each has its advocates. The author (BK) prefers malate dehydrogenase, though β-hydroxybutyrate is also recommended. Fixed tissue cannot be used, as frozen cryostat sections are required. The method for malate dehydrogenase is given, though the technique for other enzymes is similar, using different substrates; details are found in standard histochemistry texts.

MALATE DEHYDROGENASE METHOD FOR MYOCARDIUM

Normal myocardium stains dark blue–black, mostly concentrated on intracellular mitochondria, with some staining of the cytoplasm. Fibres damaged by anoxia or ischaemia progressively lose their staining properties and may be completely devoid of colour when totally infarcted. There is almost always perivascular survival of a few layers of cells and the subendocardial and subepicardial layers usually also survive: this acts as a built-in control for the staining reaction.

Stock solutions

Buffer

0.2 M for pH 7.0 (store at 0–4°C).

Solution A: 2.4 g trometamol (TRIS) in 100 ml distilled water	25 ml
Solution B: 0.1 M hydrochloric acid (Use ANALAR concentrated HC1 diluted 1/12 for molar, then dilute further 10 times for 0.1 M)	45 ml
Distilled water	30 ml

Malic acid substrate

L-Malic acid 6.7 g in 50 ml distilled water.
Add 12 g TRIS to buffer to pH 7.0.
Store frozen.

Sodium cyanide

0.1 M solution: weigh out 0.25 g sodium cyanide in 100 ml distilled water.
Add 8–8.5 ml M hydrochloric acid to buffer at pH 7.2.
Store at 0–4°C.

Tetrazolium salt
Make up nitroblue tetrazolium at 1 mg/ml strength in distilled water. Keep frozen.
Nicotinamide adenine dinucleotide (NAD) – keep solid desiccated in freezer.

Method
Cut cryostat sections from myocardium frozen either in liquid nitrogen or in isopentane/solid carbon dioxide slush.

(a) Place slides carrying sections in 37°C incubator.
(b) Make up incubating medium as follows:

Sodium cyanide solution (0.1 M at pH 7.2)	0.1 ml
NAD coenzyme	6 mg
Nitroblue tetrazolium solution	0.25 ml
TRIS buffer pH 7.0	0.55 ml
Malic acid substrate (1 M at pH 7.0)	0.1 ml

(Check pH and adjust with a small amount of TRIS)
(c) Warm the incubating medium to 37°C and place sufficient on each section with a pipette, covering the section completely. Leave for 30 minutes, mount in glycerine jelly or an aqueous mountant. A negative control can be set up as required by omitting the malate substrate from the incubating medium.

Haematoxylin–eosin (H and E) autofluorescence

Routine formalin-fixed H and E sections can be examined under ultraviolet light for autofluorescence of those fibres that have anoxic or ischaemic damage. Fibres with early infarction show a shift of their secondary emission towards the yellow, away from the usual olive-green of healthy fibres. It has been said that only fibres that reveal increased eosinophilia in ordinary tungsten light will fluoresce in this way, but the authors and co-workers have noted yellow shift in fibres that cannot be detected in tungsten light as being eosinophilic.

Acridine-orange fluorescent stain for myocardium

Either formalin-fixed paraffin sections or unfixed frozen sections can be stained by this technique. The former must be brought to water first. After staining and mounting in water (no other mountant can be used, not even Fluormount), the sections are examined immediately under ultraviolet light. They can be photographed if required. If the cover-slip is removed and the sections allowed to dry, however, they can be retained indefinitely. To review, they need only be wetted and a cover-slip replaced. Normal myocardium is a golden brown or sometimes yellowish brown depending on the optical system used. Damaged fibres show a colour shift to green when viewed under ultraviolet light.

Method
A stock solution of 1 per cent acridine-orange in water is kept refrigerated. This lasts for several months. For use, it is diluted 1/10 with distilled water.

(a) Bring sections to water.
(b) Agitate in the 0.1 per cent stain for approximately 5 seconds, though the time is not critical.
(c) Briefly wash, wipe off the excess water from around the section.
(d) Apply a cover-slip.

They are then ready for immediate examination. The pH of the washing water is not critical and tap water can be used if the pH range is between 6.0 and 7.0.

Martius scarlet blue (MSB) stain for fibrin

This trichrome stain is useful for examining thrombi and emboli and for seeking fibrin in disseminated intravascular coagulation.

(a) Bring sections to water.
(b) Stain with celestine blue for 3 minutes and Mayer's haematoxylin for 1 minute.
(c) Blue in water.
(d) Rinse in 95 per cent ethanol and then stain for 2 minutes with 0.5 per cent Martius yellow in 95 per cent ethanol containing 2 per cent phosphotungstic acid.
(e) Rinse in water and stain with 1 per cent brilliant crystal scarlet in 2.5 per cent glacial acetic acid for 10 minutes.
(f) Rinse in water and treat with 1 per cent aqueous phosphotungstic acid for 5 minutes.
(g) Rinse in water and stain with 0.5 per cent soluble blue (Acid Blue 93) in 10 per cent aqueous acetic acid for 10 minutes.
(h) Rinse and mount.

This method stains fibrin red, erythrocytes yellow and collagen blue.

Lendrum's stain (phloxine-tartrazine)

Though this stain has a number of applications, such as the demonstration of viral inclusion bodies, its major forensic use is in the detection of amniotic fluid embolism deaths associated with pregnancy. The fetal squames are rendered visible much more readily than in haematoxylin–eosin stain.

(a) Stain with Mayer's haematoxylin for 6 minutes and rinse in running water for 5 minutes.
(b) Stain with 0.5 per cent phloxine in 0.5 per cent calcium chloride solution for 20 minutes in a Coplin jar.
(c) Rinse in water and drain almost dry.
(d) Flood with a saturated solution of tartrazine in cellusolve ($C_4H_{10}O_2$; ethylene glycol monomethyl ether), which differentiates counterstain. This takes about 7 minutes and should be monitored microscopically so that red cells appear red–brown.
(e) Rinse by two changes in 95 per cent ethanol and two changes in absolute ethanol.
(f) Transfer straight to xylol and mount.

The keratin of amniotic squames is stained red; nuclei blue and cytoplasm yellow.

The 'WHO' method

The 'WHO' method is similar for demonstrating keratin and mucin-like substances in amniotic fluid embolism.

(a) Bring sections to water.
(b) Stain with celestine blue/Mayer's sequence, rinse.
(c) Differentiate quickly in 0.5 per cent acid–alcohol, then blue.
(d) Stain with erythrosin (1 per cent) for 5 minutes and rinse.
(e) Differentiate quickly in 95 per cent alcohol, rinse.
(f) Stain, with alcian green solution for 5 minutes.
(g) Rinse – the section should now be slightly pink.
(h) Rinse and treat with 95 per cent alcohol.
(i) Stain with ethanolic saffron for 5 minutes.
(j) Mount without going through water.

The alcian green is made by mixing 50 ml of 1 per cent aqueous solution of alcian green with 50 ml of 1 per cent acetic acid then adding 20 mg of thymol and filtering. Ethanolic saffron is made by cutting up strands of saffron and warming in 95 per cent alcohol until no more will elute. This should be a deep yellow solution.

DIATOM TECHNIQUE IN SUSPECTED DROWNING

There are several versions of this method, each with its own advocates. More recent methods have used suction of the filtrate through a millipore membrane to trap the diatoms, but the author (BK) has encountered early clogging of the membrane by debris and prefers the older centrifugation. References to the published methods will be found in Chapter 16.

Take a sample of water from the site where the body was recovered or where the immersion was first thought to have occurred. Several litres should be collected in a clean container and allowed to settle overnight. The top 90 per cent volume is then carefully decanted and the remainder centrifuged. The deposit should be examined under phase-contrast or dark-ground microscopy to see if any diatoms are present. If not, it is pointless to examine the autopsy tissues. If present, they should be retained for species comparison.

If the water contains diatoms, then the material retained at autopsy can be processed. The following procedure should have been followed:

(a) The sternum or a long bone such as the femur, or both, should be removed from the body in the usual way. It should be taken to a part of the mortuary or a side room distant from the cadaver and well-washed externally in a clean bowl or sink. Tap water can be used, if it is checked at intervals to ensure that it is diatom-free. Some water supplies at irregular times contain a few diatoms, though these are rarely numerous enough to cause problems in interpretation.

When the exterior of the bone has been well washed to remove any contamination from the exterior of the body, a clean saw (not used in that autopsy) is employed to open the marrow cavity of femur or sternum. With a clean scalpel or gouge, several grams of marrow are removed into a glass universal (30 ml) container. Obtain red marrow if possible, as fatty yellow marrow causes problems during digestion.
(b) Whole kidney, lung, liver or brain is also washed in this way and 1 × 1 cm cubes (several from each organ) cut with a clean scalpel from the deeper tissue. The organs can then be returned to the autopsy area for the usual gross examination.
(c) Each container, holding its separate tissue, is placed in a fume cupboard and covered with five times the volume of concentrated nitric acid. If metal caps are used on the containers, they may need to be

shielded by polythene sheet to prevent dissolution. Digestion is allowed to proceed at room temperature for 1–2 days or, if the matter is urgent, they can be heated in a water-bath for a number of hours or overnight. When the solid cubes have dissolved into a slurry the containers are gently centrifuged, the supernatant acid poured off and replaced with distilled water. This process is repeated twice more to dilute the acid, knocking up the deposit, and recentrifuging, the final spin being as hard as possible to produce a small button of deposit. This may require transferring to a smaller conical centrifuge tube.

(d) A portion of this is transferred by pipette or loop to a slide and covered with a cover-slip to examination under phase-contrast or dark-ground illumination.

A prolonged search under medium power of the microscope is required before the sample is declared negative. The lung sample should be examined first, as if it is negative it is unlikely that other organs can be truly positive, for diatom-containing water can percolate passively down the air-passages even after death.

Opinion is divided about how many diatoms can be accepted as presumptive evidence of drowning when found in distant organs like brain, bone marrow and kidney. One solitary organism is certainly insufficient and the author (BK) requires five as a minimum under one coverslip before acceptance. The tissue examined may make a difference to the yield. Peabody strongly recommends brain as the choice and condemns femoral marrow, but bone marrow was the tissue used by the pioneers of the technique and seems to the authors to be satisfactory. The type of diatom found in the tissues should correspond to those found in the water sample, though it must be admitted that most diatoms seem to the non-botanical eye to be ovoid or boat-shaped. Expert advice from a suitable biologist should be sought if the issue is important.

USEFUL CONVERSION TABLES

TABLE A1.0 *Conversion factors*

To convert from	To	Multiply by
Centimetres	Inches	0.394
Inches	Centimetres	2.540
Grams	Pounds	0.002
Pounds	Grams	453.592

To convert Centigrade to Fahrenheit, multiply by 1.8 and add 32.
To convert Fahrenheit to Centigrade, subtract 32 and divide by 1.8.

TABLE A1.1 *Approximate weight of bodies*

Stones	Pounds	Kilograms
1	14	6.3
2	28	12.7
3	42	19.0
4	56	25.4
5	70	31.7
6	84	38.1
7	98	44.4
8	112	51.0
9	126	57.0
10	140	63.0
11	154	70.0
12	168	76.0
13	182	82.0
14	196	89.0
15	203	92.0
18	252	114.0

TABLE A1.2 *Height of bodies*

Feet and inches	Inches	Centimetres
4′10″	58″	145.0
4′11″	59″	147.5
5′	60″	150.0
5′1″	61″	152.5
5′2″	62″	155.0
5′3″	63″	157.5
5′4″	64″	160.0
5′5″	65″	162.5
5′6″	66″	165.0
5′7″	67″	167.5
5′8″	68″	170.0
5′9″	69″	172.5
5′10″	70″	175.0
5′11″	71″	177.5
6′	72″	180.0
6′1″	73″	182.5
6′2″	74″	185.0

TABLE A1.3 *Approximate breath–blood-alcohol equivalents*

µg/100 ml breath	mg/100 ml blood
10	23
20	45
30	68
40	91
50	114
60	137
70	160
80	182
90	205
100	228

1 µg/100 ml in breath = 2.28 mg/100 ml in blood.
1 mg/100 ml in blood = 0.43 µg/100 ml in breath.

TABLE A1.4 *Length conversion of wounds, etc.*

Inches	Centimetres
0.25	0.63
0.5	1.27
1.0	2.54
1.5	3.81
2.0	5.08
2.5	6.35
3.0	7.62
4.0	10.16
5.0	12.70

TABLE A1.5 *Normal ranges of biochemical blood analyses*

Sodium	133–147 mmol/l
Potassium	3.4–5.0 mmol/l
Urea	2.5–7.5 mmol/l
Calcium	2.2–2.6 mmol/l
Chloride	95–106 mmol/l
Bicarbonate	22–28 mmol/l
Glucose (fasting)	3.6–5.6 mmol/l
Lactate	0.8–2.0 mmol/l
Phosphate (inorganic)	0.8–1.4 mmol/l
Magnesium	0.6–1.0 mmol/l
Serum protein (total)	60–80 g/l
Albumin	35–48 g/l
Bilirubin	up to 17 μmol/l
Alkaline phosphatase	30–90 IU/l
Amylase	70–300 IU/l
Creatinine	50–100 μmol/l
Creatine kinase (CPK)	Up to 240 IU/l

TABLE A1.6 *Body weight and length 15–30 years.* In this table, three weights (without clothing) are given for each body length: (1) weight for persons of average build = middle entry; (2) weight for lightly built persons = top entry; (3) weight for heavily built persons = bottom entry*

Women					Men				
	Weight (kg)					Weight (kg)			
Body length (cm)	15 yrs	20 yrs	25 yrs	30 yrs	Body length (cm)	15 yrs	20 yrs	25 yrs	30 yrs
142.5	40.8	43.0	44.0	45.3	150	41.7	45.8	47.6	49.4
	45.3	47.6	49.0	50.3		46.2	50.7	53.0	54.8
	51.2	53.0	55.3	56.6		51.6	57.1	59.3	61.6
145	41.2	43.5	44.8	46.2	152.5	42.6	46.7	48.5	50.3
	45.8	48.5	49.8	51.2		47.1	51.6	53.9	55.7
	51.6	53.9	56.2	57.5		53.0	58.0	60.7	62.5
147.5	41.7	44.4	45.8	47.1	155	43.5	47.6	49.4	51.2
	46.2	49.4	50.7	52.1		48.5	53.0	54.8	56.6
	52.1	55.7	57.1	58.4		54.4	59.3	61.6	63.4
150	42.6	45.3	46.7	47.6	157.5	44.9	48.9	50.7	52.1
	47.1	50.3	51.6	53.0		49.8	54.4	56.2	58.0
	53.0	56.6	58.0	59.8		56.2	61.2	63.0	65.2
152.5	43.5	46.7	47.1	48.5	160	46.2	50.3	52.1	53.5
	48.5	51.6	52.6	53.9		51.2	55.7	58.0	59.3
	54.4	58.0	59.3	60.7		57.5	62.5	65.2	66.6
155	44.8	47.6	48.5	49.8	162.5	47.6	51.6	53.9	55.3
	49.8	53.0	53.9	55.3		53.0	57.5	59.8	61.2
	55.3	59.8	60.7	62.1		59.3	64.8	67.0	68.9
157.5	46.2	48.9	50.3	51.2	165	49.4	53.5	55.7	56.6
	51.2	54.4	55.7	56.6		54.8	59.3	61.6	63.0
	57.5	61.2	62.5	63.9		61.6	66.6	69.3	70.7

(*continued*)

TABLE A1.6 *Body weight and length 15–30 years.* (continued)*

Women					**Men**				
	Weight (kg)					**Weight (kg)**			
Body length (cm)	**15 yrs**	**20 yrs**	**25 yrs**	**30 yrs†**	**Body length (cm)**	**15 yrs**	**20 yrs**	**25 yrs**	**30 yrs†**
160	47.1	50.3	51.2	52.5	167.5	51.2	55.3	57.1	58.4
	52.5	55.9	57.1	58.4		56.6	61.2	63.4	64.8
	59.3	62.5	6.43	65.7		63.4	68.9	71.1	72.9
162.5	48.9	51.2	52.5	53.9	170	52.5	56.6	58.9	59.8
	54.4	57.1	58.4	59.8		58.4	63.0	56.2	66.6
	61.2	64.3	65.7	67.5		65.7	70.7	73.4	74.7
165	50.7	53.0	54.4	55.7	172.5	54.4	58.4	60.2	61.6
	56.2	58.9	60.2	61.6		60.2	64.8	67.0	68.4
	63.4	66.1	67.5	69.3		67.5	73.0	75.2	77.0
167.5	52.1	54.9	55.7	57.1	175	55.7	59.8	62.1	63.9
	58.0	60.7	62.1	63.4		62.1	66.6	68.9	70.7
	65.2	68.4	69.8	71.6		69.8	74.7	77.5	79.3
170	53.9	56.2	57.5	58.9	177.5	58.0	61.6	63.9	65.7
	59.8	62.5	63.9	65.2		64.3	68.4	71.1	72.9
	67.5	70.2	71.6	73.4		72.0	77.0	79.7	82.0
172.5	55.3	57.5	59.3	60.2	180	59.8	63.9	66.1	68.0
	61.6	63.9	65.7	67.0		66.6	70.7	73.4	75.7
	69.3	72.0	73.8	75.7		74.7	79.3	82.4	85.2
175	57.1	59.3	60.7	61.6	183	62.1	65.7	68.4	70.7
	63.4	65.7	67.5	68.4		68.9	72.9	76.1	78.4
	71.6	73.8	75.7	77.0		77.5	82.0	85.6	87.9
178	59.3	60.7	62.1	63.4	185.5	63.9	68.0	71.1	72.9
	65.7	67.5	68.9	70.2		71.1	75.2	78.8	81.1
	73.9	76.1	77.5	78.9		79.7	84.3	88.3	91.1
180	61.2	63.0	63.4	64.8	188	66.1	69.8	73.0	75.7
	68.0	69.8	70.7	72.0		73.4	77.5	81.1	83.8
	76.1	78.4	79.7	81.1		82.4	87.0	91.1	94.2

[*] From Basel JR, Geigy AG. 1953. *Wissenschaftliche Tabellen*, p. 199. By permission.
[†] Fourth decade weight should be maintained throughout life.

TABLE A1.7 *Weight of fetus (g) in relation to age (month)**

Lunar month	**Streeter**	**Scammon and Calkins**
Second	1.1	3.5
Third	14.2	14.3
Fourth	108.0	86.8
Fifth	316.0	260.9
Sixth	630.0	551.6
Seventh	1045.0	971.4
Eighth	1680.0	1519.0
Ninth	2378.0	2196.1
Tenth	3405.0	2998.8

[*] From Potter EL. 1961. *Pathology of the fetus and infant*, 2nd edn. Chicago, Year Book Medical Publishers. By permission.

TABLE A1.8 *Length (cm) of fetus in relation to age (month)**

	Crown–rump length		**Crown–heel length**	
Lunar month	**Streeter**	**Scammon and Calkins**	**Dietrich**	**Scammon and Calkins**
Second	2.3	–	3.0	–
Third	7.4	5.1	9.8	7.0
Fourth	11.6	10.7	18.0	15.5
Fifth	26.4	15.5	25.0	22.7
Sixth	20.8	19.7	31.5	29.2
Seventh	24.7	23.6	37.1	35.0
Eighth	28.3	27.1	42.5	40.4
Ninth	32.1	30.5	47.0	45.4
Tenth	36.2	33.6	50.0	50.2

[*] From Potter EL. 1961. *Pathology of the fetus and infant*, 2nd edn. Chicago, Year Book Medical Publishers. By permission.

TABLE A1.9 *Weights of the organs at various ages (in grams)**

	Lungs		Brain		Heart		Kidneys		Liver		Spleen	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
New born	51.7	50.9	353	347	19	20	24	24	124	125	8	6
0–3 mth	68.8	63.6	435	411	–	–	–	–	–	–	–	–
3–6 mth	94.1	93.3	600	534	–	–	–	–	–	–	–	–
6–9 mth	128.5	114.7	877	726	41	36	60	52	300	240	26	25
9–12 mth	142.4	142.1										
1–2 yr	170.3	175.3	971	894	54	48	72	65	400	390	35	34
2–3 yr	245.9	244.3	1076	1012	63	62	85	75	460	450	42	41
3–4 yr	304.7	265.5	1179	1076	73	71	93	84	510	500	48	47
4–5 yr	314.2	311.7	1290	1156	83	80	100	93	555	550	53	52
5–6 yr	360.6	319.9	1275	1206	95	90	106	102	595	595	58	57
6–7 yr	399.5	357.5	1313	1225	103	100	112	112	630	635	62	62
7–8 yr	365.4	404.4	1338	1265	110	113	120	123	665	685	64	67
8–9 yr	405.0	382.1	1294	1208	122	126	128	135	715	745	68	71
9–10 yr	376.4	358.4	1360	1226	132	140	138	148	770	810	73	77
10–11 yr	474.5	571.2	1378	1247	144	154	150	163	850	880	82	85
11–12 yr	465.6	535.0	1348	1259	157	168	164	180	950	950	91	93
12–13 yr	458.8	681.7	1383	1256	180	188	178	195	1050	1080	101	103
13–14 yr	504.5	602.3	1382	1243	202	207	196	210	1150	1180	111	112
14–15 yr	692.8	517.0	1356	1318	238	226	212	222	1240	1270	121	120
15–16 yr	691.7	708.8	1407	1271	258	238	229	230	1315	1330	135	127
16–17 yr	747.3	626.5	1419	1300	282	243	244	236	1380	1360	145	134
17–18 yr	776.9	649.5	1409	1254	300	247	260	240	1450	1380	152	140
18–19 yr	874.7	654.9	1426	1312	310	250	270	244	1510	1395	157	146
19–20 yr	1035.6	785.2	1430	1294	318	251	282	247	1580	1405	160	151
20–21 yr	953.0	792.8	–	–	322	252	290	248	1630	1415	162	155

* Boyd E. 1962. In: Altman and Dittmer (eds), *Growth, including reproduction and morphological development*. Biological Handbooks, Federation of American Societies for Experimental Biology, Washington, pp. 346–8.

TABLE A1.10 *Heart: men and women, weight in relation to body weight by sex**

Men				Women			
Body weight		Heart weight (g)		Body weight		Heart weight (g)	
Pounds	Kilograms	Mean	Range	Pounds	Kilograms	Mean	Range
				90	40	162	135–193
				95	43	171	143–204
				100	45	180	150–215
105	47	205	165–241	105	47	189	158–226
110	50	215	173–253	110	50	198	165–237
115	52	225	181–264	115	52	207	172–248
120	54	235	190–276	120	54	215	180–259
125	56	245	198–287	125	56	225	188–268
130	58	255	206–299	130	58	234	195–277
135	60	265	213–310	135	60	244	203–286
140	63	274	221–322	140	63	253	211–295
145	65	284	229–333	145	65	262	219–304
150	68	294	237–345	150	68	272	225–313

(*continued*)

TABLE A1.10 *Heart: men and women, weight in relation to body weight by sex[*] (continued)*

Men				**Women**			
Body weight		**Heart weight (g)**		**Body weight**		**Heart weight (g)**	
Pounds	**Kilograms**	**Mean**	**Range**	**Pounds**	**Kilograms**	**Mean**	**Range**
155	70	304	245–356	155	70	282	233–322
160	72	313	253–368	160	72	288	240–330
165	74	323	261–370	165	74	297	247–337
170	77	333	268–371	170	77	306	255–343
175	79	343	280–372	175	79	315	283–350
180	81	353	288–373	180	81	324	301–356
185	83	363	296–382	185	83	333	309–361
190	86	373	304–392	190	86	342	317–366
195	88	382	312–402	195	88	351	325–371
200	90	392	320–412				
Average weight of adult male heart: 294 g				Average weight of adult female heart: 250 g			

[*] Data from Smith HL. 1928. The relation of the weight of the heart to the weight of the body and of the weight of the heart to age. *Am Heart J* **4**:79–93.

NB There is considerable variation in published tables of heart weights: probably hypertensive hearts account for some of the upper ranges of 'normal'. However, the authoritative publication of Hangartner *et al.* gives considerably higher normal maximum weights. (Hangartner J, Marley N, Whitehead A, Thomas A, Davies M. 1985. The assessment of cardiac hypertrophy at autopsy. *Histopathology* **9**:1295–306.)

TABLE A1.11 *Heart: normal weight in relation to body length*

Body length (cm)	**Heart weight (g)**		**Body length (cm)**	**Heart weight (g)**		**Body length (cm)**	**Heart weight (g)**	
	Males	**Females**		**Males**	**Females**		**Males**	**Females**
	σ = ±40	**σ = ±30**		**σ = ±40**	**σ = ±30**		**σ = ±40**	**σ = ±30**
135	254	219	157	296	258	179	338	297
136	256	220	158	298	259	180	340	299
137	258	222	159	300	261	181	342	300
138	260	224	160	302	263	182	344	302
139	262	226	161	304	265	183	346	304
140	264	227	162	306	267	184	348	306
141	266	229	163	308	268	185	349	307
142	268	231	164	310	270	186	351	309
143	270	233	165	311	272	187	353	311
144	272	235	166	313	274	188	355	313
145	273	236	167	315	275	189	357	315
146	275	238	168	317	277	190	359	316
147	277	240	169	319	279	191	361	318
148	279	242	170	321	281	192	363	320
149	281	243	171	323	283	193	365	322
150	283	245	172	325	284	194	367	323
151	285	247	173	327	286	195	368	325
152	287	249	174	329	288	196	370	327
153	289	251	175	330	290	197	372	329
154	291	252	176	332	291	198	374	331
155	292	254	177	334	293	199	376	332
156	294	256	178	336	295	200	378	334

σ = standard deviation.
From Zeek PM. 1942. Heart weight. I. The weight of the normal heart. *Arch Pathol* **34**:820–32.
Copyright 1942, American Medical Association.
NB But see also Hangartner *et al.* 1985 (details above).

Table A1.12 *Brain: adults**

Age (years)	Brain weight (g)			
	Men		Women	
	Mean	Range	Mean	Range
17–19	1340	1170–1527	1242	1120–1420
20–29	1396	1158–1620	1234	1057–1565
30–39	1365	1075–1685	1233	1038–1440
40–49	1366	1069–1605	1240	995–1543
50–69	1375	1113–1665	1200	820–1477
60–69	1323	1018–1610	1178	920–1372
70–85	1279	1039–1485	1121	832–1370

* Data from Sunderman FW, Boerner F. 1949. *Normal values in clinical medicine.* W. B. Saunders Company, Philadelphia.

Table A1.13 *Brain: children**

Age	Body length (cm)	Brain weight (g)
Birth–3 days	49	335
3–7 days	49	358
1–3 wks	52	382
3–5 wks	52	413
5–7 wks	53	422
7–9 wks	55	489
3 mths	56	516
4 mths	59	540
5 mths	61	644
6 mths	62	660
7 mths	65	691
8 mths	65	714
9 mths	67	750
10 mths	69	809
11 mths	70	852
12 mths	73	925
14 mths	74	944
16 mths	77	1010
18 mths	78	1042
20 mths	79	1050
22 mths	82	1059
24 mths	84	1064
3 yrs	88	1141
4 yrs	99	1191
5 yrs	106	1237
6 yrs	109	1243
7 yrs	113	1263
8 yrs	119	1273
9 yrs	125	1275
10 yrs	130	1290
11 yrs	135	1320
12 yrs	139	1351

* Data from Sunderman FW, Boerner F. 1949. *Normal values in clinical medicine.* W. B. Saunders Company, Philadelphia.

SAMPLES AND CONTROLS NEEDED FOR DNA PROFILING

The essence of DNA profiling in forensic work is comparison between two samples. One is the ‘test’ sample from the living or dead subject (or objects with which he or she has been in contact, such as clothing) and the other the ‘control’, a somewhat inaccurate term for the samples obtained from a suspect, a group of suspects or a screening programme which may have hundreds or even thousands of items.

Since the beginning of the DNA analysis, significant advances have been made in methodology allowing forensic identification of individuals from minute amounts of DNA. Microgram amounts of relatively undegraded DNA is required for multi-locus typing of the restriction fragment length polymorphism (RFLP) analysis and hundreds of nanograms for single-locus typing. Polymorphic DNA sequences can be detected from the root of shed or freshly plucked single human hairs using the polymerase chain reaction (PCR). Mitochondrial DNA (mtDNA) has been detected even in a sample from a single hair shaft.

Blood

As red cells have no nuclear DNA, sufficient blood must be obtained to extract DNA from the much sparser leucocytes. At least 1 ml and preferably 5 ml are taken into an EDTA tube, which extracts metallic ions and not only prevents clotting, but inhibits enzymes in blood or micro-organisms, which may break down DNA during storage.

The blood sample, in a plastic (not glass) tube, should be frozen solid in a deep-freeze or the ice-making compartment of an ordinary refrigerator. As frozen blood is useless for some other forensic investigations, the DNA sample should be clearly marked as such. Other samples, for grouping and many other serological and toxicological tests, must be taken and stored at only 4°C.

If a blood sample is to be taken directly to the laboratory for DNA profiling, then freezing is not necessary, but wherever there is delay, either freezing or, at second best, effective cooling should be carried out.

Most of the laboratories are using nowadays FTA paper for the collection of blood samples. FTA paper is an absorbent cellulose-based paper that contains chemical substances to protect DNA molecules from nuclease degradation and preserve the paper from bacterial growth (Seah and Burgoyne 2000). As a result, DNA on FTA paper is stable at room temperature over a period of several years. The use of FTA paper simply involves adding a spot of blood to the paper and allowing the stain to dry.

Blood stains, as opposed to liquid blood, should either be sent intact on surfaces, kept as cool as possible before and during transit to the laboratory – or rubbed with a cotton-wool swab moistened with water. This swab is then air-dried without heat and frozen. Although not required for DNA testing, always provide the laboratory with control swabs for conventional blood grouping, including swabs rubbed on an area of the fabric away from obvious stains, as well as an unused swab.

Dried blood stains on hard surfaces can be scraped off with a scalpel into a small plastic container and sent as they are, kept as cool as possible.

Buccal cells

A disposable toothbrush may also be used for collecting buccal cells in a non-threatening manner. This method can be very helpful when samples need to be collected from children and this is the method actually used for most of paternity testing labs. After the buccal cells have been collected by gently rubbing a wet toothbrush across the buccal surface, the brush can be tapped onto the surface of FTA paper for sample storage and preservation.

Seminal and vaginal fluids

Swabs from vagina, rectum, mouth, etc., should be air-dried as quickly as possible, but not heated. They should then be stored in deep-freeze, unless sent straight to the forensic science laboratory. Liquid semen found in the vagina or elsewhere should be recovered with a fine pipette, placed in a small plain tube and frozen solid.

Seminal stains on small items of fabric or any other small objects may be frozen or kept as cool as possible during transit. Bulk clothing cannot be frozen and should merely be kept cool, transit to the laboratory being made as soon as possible, using strong sterilized paper bags, not impervious polythene, which encourages mould formation. Alternatively, damp swabs may be taken of suspect stains, which are then dried and frozen. As with blood, suspect dried seminal stains on hard surfaces may be scraped off and transmitted dry to the laboratory.

Mouth swabs may be taken either to seek semen in suspected oral intercourse (though positive recoveries are very rare) or to obtain buccal mucosa for DNA identification. In the latter case, the yield is small, so at least three to four swabs must be rubbed hard against the inside of the cheek – or the mouth lining scraped with an instrument and then smeared onto a swab. All such swabs should be frozen in the usual manner.

Hairs – head, pubic, etc.

Collection of hairs – head, pubic, eyebrow, axillary – from the victim or at the scene of crime is extremely important as a 2 cm piece of single hair is actually sufficient for mtDNA analysis. It is of paramount importance to avoid cross-contamination and to submit the hairs in sterilized paper bags, well identified.

Autopsy tissue samples

At least 0.5 g of tissue should be cut from the parenchyma of an organ and placed in a small plastic tube with no fixative or preservative. This should be frozen solid. Spleen is said to be one of the best organs for DNA recovery, though liver, muscle, kidney and brain may also be used. The fresher the tissue the better, and totally putrefied material was formerly of little use, as the nuclear chromatin was degraded. However, rapidly developing new techniques are allowing the recovery of recognizable DNA from old material.

For identification of skeletal remains using DNA technology, a well-preserved tooth is the tissue of election. In addition, long bones (femur) or ribs can also be used.

Other general remarks

The sensitivity of DNA technology is changing the strategy of sample collection. Very sensitive low-copy-number DNA methods are being developed allowing the detection of subnanogram amounts of DNA. For this reason, it is extremely important to avoid cross-contamination from the personnel collecting the samples.

DNA can even be obtained from personal objects, fingerprints, sweat and of course from saliva recovered from bite marks.

Finally, as for other type of forensic evidence, the chain of custody must be extremely well-preserved.

FURTHER READING

Badir B, Knight B. 1987. Fluorescence microscopy in the detection of early myocardial infarction. *Forensic Sci Int* **34**:99–102.

APPENDIX 2

Council of Europe Committee of Ministers Recommendation No. R (99) 3

■ Recommendation No. R (99) 3 of the Committee of Ministers to Member States on the harmonisation of medico-legal autopsy rules 610

■ Appendix to Recommendation No. R (99) 3 616

RECOMMENDATION NO. R (99) 3 OF THE COMMITTEE OF MINISTERS TO MEMBER STATES ON THE HARMONISATION OF MEDICO-LEGAL AUTOPSY RULES[1]

(*Adopted by the Committee of Ministers on 2 February 1999 at the 658th meeting of the Ministers' Deputies*)

The Committee of Ministers, under the terms of Article 15.*b* of the Statute of the Council of Europe,

Considering that the aim of the Council of Europe is to achieve a greater unity between its members;

Having regard to the principles laid down in the Convention for the Protection of Human Rights and Fundamental Freedoms and, in particular, the prohibition of torture or inhuman or degrading treatment or punishment, and the right to life;

Conscious that it is normal practice for autopsies to be carried out in all Council of Europe member States to establish the cause and manner of death for medico-legal or other reasons or to establish the identity of the deceased;

Considering the importance of compensation for victims and families in criminal and civil proceedings;

Underlining the need for investigation, description, photographic documentation and sampling during medico-legal autopsy to follow primarily medical and scientific principles and simultaneously consider legal requirements and procedures;

Conscious that the increasing mobility of the population throughout Europe and the world, as well as the increasing internationalisation of judicial proceedings, require the adoption of uniform guidelines on the way autopsies are to be carried out and on the way autopsy reports are to be established;

Considering the Council of Europe Agreement on the Transfer of Corpses (European Treaty Series No. 80) and having regard to the difficulties often experienced by the receiving country when a dead body is repatriated from one member state to another;

Aware of the importance of proper autopsy procedures, in particular with a view to bringing to light illegal executions, and murders perpetrated by authoritarian regimes;

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[1] When this recommendation was adopted, the Representatives of Denmark and the Netherlands, in application of Article 10.2*c* of the Rules of Procedure for the meeting of the Ministers' Deputies, reserved the right of their Governments to comply or not with paragraph 2 (scope of the recommendation) of the present recommendation.

When this recommendation was adopted, the Representative of Germany, in application of Article 10.2*c* of the Rules of Procedure for the meeting of the Ministers' Deputies, reserved the right of his Government to comply or not with paragraph 2 *f* and *h* of the present recommendation.

Underlining the need to protect the independence and impartiality of medico-legal experts, as well as to make available the necessary legal and technical facilities for them to carry out their duties in an appropriate way and to promote their training;

Considering the importance of national quality control systems to ensure the proper performance of medico-legal autopsies;

Underlining the need to strengthen international co-operation with a view to the progressive harmonisation of medico-legal autopsy procedures at a European level;

Having regard to Recommendation 1159 (1991) on the harmonisation of autopsy rules adopted, at its 43rd Ordinary Session, by the Parliamentary Assembly of the Council of Europe;

Having regard to the Model Autopsy Protocol of the United Nations, endorsed by the General Assembly of the United Nations in 1991;

Taking into account the 'guide on disaster victim identification' adopted by the International Criminal Police Organisation (Interpol) General Assembly in 1997,

1 Recommends the governments of member states:
  (i) to adopt as their internal standards the principles and rules contained in this recommendation;
  (ii) to take or reinforce, as the case may be, all appropriate measures with a view to the progressive implementation of the principles and rules contained in this recommendation;
  (iii) to set up a quality assurance programme to ensure the proper implementation of the principles and rules contained in this recommendation.

2 Invites the governments of member states to inform the Secretary General of the Council of Europe upon his or her request of the measures taken to follow up the principles and rules contained in this recommendation.

PRINCIPLES AND RULES RELATING TO MEDICO-LEGAL AUTOPSY PROCEDURES

Scope of the recommendation

1 In cases where death may be due to unnatural causes, the competent authority, accompanied by one or more medico-legal experts, should where appropriate investigate the scene, examine the body and decide whether an autopsy should be carried out.

2 Autopsies should be carried out in all obvious or suspected unnatural death, even where there is a delay between causative events and death, in particular:
  a homicide or suspected homicide;
  b sudden, unexpected death, including sudden infant death;
  c violation of human rights such as suspicion of torture or any other form of ill treatment;
  d suicide or suspected suicide;
  e suspected medical malpractice;
  f accidents, whether transportational, occupational or domestic;
  g occupational disease and hazards;
  h technological or environmental disasters;
  i death in custody or death associated with police or military activities;
  j unidentified or skeletalised bodies.

3 Medico-legal experts must exercise their functions with total independence and impartiality. They should not be subject to any form of pressure and they should be objective in the exercise of their functions, in particular in the presentation of their results and conclusions.

Principle I – Scene investigation

A *General principles*
  1 In case of obvious or suspected unnatural death, the physician who first attended the dead body should report to the competent authorities, the latter deciding whether an examination should be carried out by a qualified medico-legal expert or by a physician familiar with medico-legal examination.
  2 Particularly in cases of homicide or suspicious death, medico-legal experts should be informed without delay and, where appropriate, go immediately to the place where the body is found and have immediate access there. In this respect, there should be an adequate structure of co-ordination among all persons involved and, in particular, among judicial bodies, medico-legal experts and police.

B *Examination of the body*
  1 Role of the police
  The following tasks, among others, should be carried out by police officers:
    a record the identities of all persons at the scene;
    b photograph the body as it is found;
    c make sure that all relevant artifacts are noted, and that all exhibits, such as weapons and projectiles, are seized for further examination;
    d in agreement with the medico-legal expert, obtain identification of the body and other pertinent information from scene witnesses, including those who last saw the decedent alive, where available;

- **e** protect the deceased's hands and head with paper bags, under the control of the medico-legal expert;
- **f** preserve the integrity of the scene and surroundings;

2 Role of the medico-legal expert

The medico-legal expert should without delay:

- **a** be informed of all relevant circumstances relating to the death;
- **b** ensure that photographs of the body are properly taken;
- **c** record the body position and its relation to the state of the clothing and to the distribution pattern of rigor mortis and hypostasis, as well as the state of *post-mortem* decomposition;
- **d** examine and record the distribution and pattern of any blood stains on the body and at the scene, as well as other biological evidence;
- **e** proceed to a preliminary examination of the body;
- **f** except where the body is decomposed or skeletal, note the ambient temperature and deep-rectal temperature of the body, and estimate the time of death by recording the degree, location and fixation of rigor mortis and hypostasis, as well as other findings;
- **g** make sure that the body is transported and stored in a secure and refrigerated location in an undisturbed state.

Principle II – Autopsy physicians

Medico-legal autopsies should be performed, whenever possible, by two physicians, of whom at least one should be qualified in forensic pathology.

Principle III – Identification

In order to ensure that proper identification of the body is carried out in accordance with the disaster victim identification guide adopted by the General Assembly of Interpol in 1997, the following criteria should be considered: visual recognition, personal effects, physical characteristics, dental examination, anthropological identification, fingerprints and genetic identification.

1 Visual identification
Visual identification of a body should be carried out by relatives or persons who knew and have recently seen the decedent.

2 Personal effects
A description of clothing, jewellery and pocket contents should be recorded. These may assist correct identification.

3 Physical characteristics
Physical characteristic should be recorded through an external and an internal examination.

4 Dental examination
Where appropriate, the examination of teeth and jaws should be carried out by a dentist with medico-legal experience.

5 Anthropological identification
Whenever human material is skeletised or in an advanced stage of decomposition, an anthropological identification should be carried out, if necessary.

6 Fingerprints
Where appropriate, fingerprints should be taken by police officers. A close collaboration should exist between all experts involved.

7 Genetic identification
Where appropriate, genetic identification should be carried out by an expert in forensic genetics.

It is appropriate to take biological samples from the deceased in order to assist genetic identification. Measures should be taken in order to avoid contamination and guarantee appropriate storage of biological samples.

Principle IV – General considerations

1 Medico-legal autopsies and all related measures must be carried out in a manner consistent with medical ethics and respecting the dignity of the deceased.

2 Where appropriate, the closest relatives should be given an opportunity to see the corpse.

3 Before beginning the autopsy, the following minimum rules should be applied:

- **a** record the date, time and place of autopsy;
- **b** record the name(s) of the medico-legal expert(s), assistant(s) and all other persons present at the autopsy with indication as to the position and role of each one in the autopsy;
- **c** take colour photographs or video, where appropriate, of all relevant findings and of the dressed and undressed body;
- **d** undress the body, examine and record clothing and jewellery, verify the correspondence between injuries on the body and clothing;
- **e** where appropriate, take X-rays, particularly in cases of suspected child abuse, and for identification and location of foreign objects.

4 Where appropriate, before beginning the autopsy, body orifices should be appropriately swabbed for the recovery and identification of biological trace evidence.

5 If the decedent was hospitalised prior to death, admission blood specimens and any X-rays should be obtained as well as hospital records.

Principle V – Autopsy procedures

I EXTERNAL EXAMINATION

1 The examination of the clothing is an essential part of the external examination and all findings therein are to be clearly described. This is especially important in those cases where the clothing has been damaged or soiled: each area of recent damage must be described fully and relevant findings are to be related to the site of injuries on the corpse. Discrepancies in such findings are also to be described.

2 The description of the body following an external examination must include:

- **a** age, sex, build, height, ethnic group and weight, nutritional state, skin colour and special characteristics (such as scars, tattoos or amputations);
- **b** post-mortem changes, including details relating to rigor and post-mortem hypostasis – distribution, intensity, colour and reversibility – and putrefaction and environmentally induced changes;
- **c** findings on a primary external inspection and description which, if required, include sampling of stains and other trace evidence on the body surface and a reinspection after removal and cleaning of the body;
- **d** inspection of the skin of the posterior surfaces of the corpse;
- **e** description and careful investigation of the head and the facial orifices includes: colour, length, density and distribution of hair (and beard); nasal skeleton; oral mucosa, dentition and tongue; ears, retro-auricular areas and external meati; eyes: colour of irises and sclerae, regularity and appearance of pupils, sclerae, conjunctivae; skin (presence and absence of petechiae to be described); if fluids have been evacuated from facial orifices, their colour and odour;
- **f** neck: checking for excessive mobility, presence and absence of abrasions, other marks and bruising (including petechiae) over the entire circumference of the neck;
- **g** thorax: shape and stability; breasts; aspect, nipples and pigmentation;
- **h** abdomen: external bulging, pigmentation, scars, abnormalities and bruising;
- **i** anus and genitals;
- **j** extremities: shape and abnormal mobility, abnormalities; injection marks and scars; palmar surfaces, finger and toe nails;
- **k** material findings under fingernails.

3 All injuries, including abrasions, bruises, lacerations and other marks have to be described by shape, exact measurement, direction, edges, angles and location relative to anatomical landmarks. Photographs should be taken. Bite marks shall be swabbed, and casts made where necessary.

4 Signs of vital reaction around wounds, foreign particles inside wounds and in their surroundings and secondary reactions, such as discolouration, healing and infections must also be described.

5 The investigation of cutaneous and sub-cutaneous bruising may require local skin incision.

6 Where appropriate, specimens from wounds must be removed for further investigations, such as histology and histochemistry.

7 All signs of recent or old medical and surgical intervention and resuscitation must be described. Medical devices must not be removed from the body before the intervention of the medico-legal expert.

8 A decision has to be taken at this stage as to the strategies of investigation and the necessity of documentation by X-rays and other imaging procedures.

II INTERNAL EXAMINATION

A General

1 All relevant artifacts produced by the dissection and from sampling procedures, must be documented.

2 All three body cavities – head, thorax and abdomen – must be opened layer by layer. Where appropriate, the vertebral canal and joint cavities should be examined.

3 Examination and description of body cavities include: an examination for the presence of gas (pneumothorax), measurement of volume of fluids and blood, appearance of internal surfaces, intactness of anatomical boundaries, external appearance of organs and their location; adhesion and cavity obliterations, injuries and haemorrhage.

4 The demonstration and dissection of the soft tissues and musculature of the neck have to be components of all medico-legal autopsies (see the paragraph concerning special procedures).

5 All organs must be examined and sliced following established guidelines of pathological anatomy. This includes opening of all relevant vessels, for example, intracranial arteries, sinuses, carotid arteries, coronary arteries, pulmonary arteries and veins, aorta and vessels of the abdominal organs, femoral arteries and lower

limb veins. Relevant ducts have to be dissected, for example, central and peripheral airways, biliary ducts and ureters. All hollow organs have to be opened and their content described by colour, viscosity, volume (samples should be retained, where appropriate). All organs have to be sliced and the appearance of the cut surface described. If injuries are present, the dissection procedure may have to vary from the normal one: this should be appropriately described and documented.

6 All internal lesions and injuries must be precisely described by size and location. Injury tracks must be described in order to include their direction as regards the organ anatomy.

7 The weight of all major organs must be recorded.

B Detailed

1 *Head*

- **a** Before opening the skull, the periosteum must be scraped off in order to display or exclude any fractures.
- **b** The head examination procedure must allow the inspection and description of the scalp, external and internal surfaces of the skull and of the temporal muscles.
- **c** The thickness and appearances of the skull and sutures, the appearances of the meninges, the cerebrospinal fluid (CSF), the wall structure and contents of cerebral arteries and sinuses must be described. The description of the bones must also include an examination of their intactness, including the connection between the skull and the first two vertebrae.
- **d** In obvious or suspected head injury (for example, if a detailed examination is required or if autolysis or putrefaction is present) fixation of the whole brain is recommended before its dissection.
- **e** Middle ears must be always opened and nasal sinuses where indicated.
- **f** The soft tissue and skeleton of the face is dissected only in relevant cases, using a cosmetically acceptable technique.

2 *Thorax and neck*

The opening of the thorax must be performed using a technique which allows the demonstration of the presence of pneumothorax and the inspection of the thorax walls, including the postero-lateral regions. *In situ* dissection of the neck must display the details of its anatomy.

3 *Abdomen*

The opening procedure of the abdomen must allow an accurate examination of all layers of the walls, including the postero-lateral regions. *In situ* dissection is necessary in certain cases, particularly for the demonstration of injury tracks and evacuation of fluids. Dissection of organs should observe anatomical continuity of systems, where possible. The whole intestine must be dissected and its contents described.

4 *Skeleton*

- **a** The examination of the thoracic cage, the spine and the pelvis must be part of the autopsy procedure.
- **b** Where appropriate traumatic deaths need a precise dissection of the extremities, possibly complemented by X-ray examination.

5 *Special procedures*

- **a** If there is any suspicion of neck trauma, the brain and thoracic organs are to be removed prior to the dissection of the neck, to enable detailed dissection to take place in a bloodless field.
- **b** If there is a suspicion of air embolism, pre-autopsy radiology of the thorax must be performed. The first stage of the autopsy in such a case must be a careful partial opening of the thorax and dislocation of the lower three-quarters of the sternum with the subsequent opening of the heart under water, allowing the measurement and sampling of escaping air or gas.
- **c** For the demonstration of particular injury patterns, deviation from the normal procedure of dissection has to be accepted, provided that such procedures are specifically described in the autopsy report.
- **d** The dissection in traumatic deaths must include a full exposure of the soft tissues and musculature on the back of the body. The same procedure must be applied to the extremities (so called ‘peel-off’ procedure).
- **e** In suspected or overt sexual assaults, the sexual organs are to be removed *en bloc* together with the external genitalia, rectum and anus, before they are dissected. Relevant swabs of orifices and cavities must be taken prior to this procedure.

6 *Sampling*

The scope of the sampling procedure is to be case-dependent. However, the following minimum rules should be applied:

- **a** in all autopsies, the basic sampling scheme includes specimens from the main organs for histology and peripheral blood sampling (such as for alcohol and drug analyses and genetic identification), urine and gastric contents. All blood samples must be peripheral blood and not heart or thoracic;
- **b** if the cause of death cannot be established with the necessary degree of certainty, sampling includes

additional specimens and fluids for metabolic studies and thorough toxicology. This includes blood, vitreous humour, CSF, bile, hair samples and further relevant tissues;

- **c** if death is related to physical violence, sampling includes the injuries, for example to determine wound age and any foreign materials in the wounds;
- **d** if reconstructions are desirable, the removal of bones and osseous compartments may become necessary;
- **e** if identification is the predominant aim, the removal of jaws and other bones may be necessary;
- **f** if strangulation or the application of physical force to the neck is suspected or diagnosed, the entire neck structures, musculature and neurovascular bundles must be preserved for histology. The hyoid bone and the laryngeal cartilages must be dissected very carefully;
- **g** biological samples must be collected in tightly closed jars, properly preserved and placed under seal and transported to the laboratory in perfect safety;
- **h** certain specimens and fluids need to be sampled in a special way and analysed without delay.

7 *Release of the body*
After a medico-legal autopsy has been carried out, medico-legal experts should ensure that the body is returned in a dignified condition.

Principle VI – Autopsy report

1 The autopsy report is as important as the autopsy itself, as the latter is of little value if the findings and opinions of the medico-legal expert are not communicated in a clear, accurate and permanent document. The autopsy report should be an integral part of the autopsy procedure and be drafted carefully.

2 The report should therefore be:
- **a** full, detailed, comprehensive and objective;
- **b** clear and comprehensible not only to other doctors, but also to non-medical readers;
- **c** written in a logical sequence, well-structured and easy to refer to in various sections of the report;
- **d** be in a legible and permanent form, with hard paper copy even if it is retained in electronic storage;
- **e** be written in a discursive ‘essay’ style;

3 When drafting an autopsy report, the following minimum content should be included:
- **a** legal preface to fulfil statutory requirements, if needed;
- **b** serial number, computer retrieval coding and International Classification of Disease Code (ICD) code;
- **c** full personal details of deceased (including name, age, sex, address and occupation) unless unidentified;
- **d** date, place and time of death, where known;
- **e** date, place and time of autopsy;
- **f** name, qualifications and status of medico-legal expert(s);
- **g** persons present at the autopsy and their function;
- **h** name of the authority commissioning the autopsy;
- **i** person(s) identifying the body to the medico-legal expert;
- **j** name and address of the medical attendant of the deceased;
- **k** a synopsis of the history and circumstances of the death, as given to the medico-legal expert by the police, judges, relatives or other persons, as well as information contained in the file, where available;
- **l** description of the scene of death, if attended by the medico-legal expert; reference should be made to the provisions contained in Principle I above;
- **m** external examination; reference should be made to the provisions of Principle V above;
- **n** internal examination by anatomic systems, together with a comment on every organ. Reference should be made to the provisions of Principle V above;
- **o** a list of all samples retained for toxicology, genetic identification, histology, microbiology and other investigations should be included; all such specimens should be identified and attested by the medico-legal expert according to the legal system of the state concerned, for continuity of evidence;
- **p** results of ancillary investigations, such as radiology, odontology, entomology and anthropology should be included, when such results are available;
- **q** one of the most important parts of the autopsy report is the evaluation of the significance of the accumulated results by the medico-legal expert. After termination of the autopsy, evaluation is usually provisional because later findings and later knowledge of other circumstantial facts can necessitate alteration and modification. Medico-legal experts must interpret the overall findings so that the maximum information and opinion can be offered. Also questions that have not been raised by the competent authority must be addressed if they could be of significance;
- **r** based on the final interpretation, the cause of death (in the International Classification of Disease should be given. Where several alternatives for the cause of death exist and the facts do not allow a differentiation between them, the medico-legal expert should describe the alternatives and, if possible, rank them in order of probability. If this is

not possible, then the cause of death should be certified as 'Unascertained';

s the report should be finally checked, dated and signed by the medico-legal expert(s).

4 The date of the autopsy and the date of the provisional report should never be more than a day or two apart. The date of the autopsy and the date of the final report should be as close together as possible.

APPENDIX TO RECOMMENDATION NO. R (99) 3

SPECIFIC PROCEDURES (SELECTED EXAMPLES)

1 *Constriction of neck (hanging, manual and ligature strangulation)*
The examination of the scene where the body was found is extremely important: for example the presence of a chair or similar platform; fastening of the strangulation device; technique of tying of the knot; adhesive taping of hands and objects for trace evidence:

- Strangulation marks: depth, width, intermediate rings, direction, suspension point, raised ridges of skin, zones of hyperaemia, presence of duplicate strangulation marks; further specific neck injuries: dried excoriations due to slippage of the implement, marks due to textile weave pattern and structure, distribution of petechiae in the skin, bruising, scratch marks, blisters in the strangulation mark.
- Bleeding from facial orifices. Differences in widths of the pupils, localization of hypostasis, presence and distribution of congestion.
- Injuries due to convulsions, defensive injuries, injuries due to being held forcibly.

Dissection of the soft tissues, of the musculature and of the organs of the neck in a bloodless field is essential.

2 *Drowning/Immersion*
Note carefully the following findings: foam at the mouth, cutis anserina, maceration, mud and algae, lesions due to water animals, injuries due to surroundings (for example rocks and ships), loss of nails, skin, localization of livor mortis.

Technique: sampling of gastric contents, precise description of the lungs (weight, measurement, extent of emphysema), sampling, lung fluid, liver and other tissues, for the possible demonstration of diatoms and other contaminants.

If required, sampling of drowning medium (for example river, bath water) should be carried out.

3 *Sexually motivated murder*
The inspection and documentation of the scene of crime, e.g. relative to the injury pattern, is especially important. All injuries must be photographed together with a scale. If required, the body surfaces must be investigated under UV light and taped. Search for and sampling of foreign biological material must include pubic hairs and secretions on the body surface as for instance originating from bites. Such material must be preserved carefully for DNA investigation and protected against contamination. 'En bloc' dissection of the genital organs is strongly recommended. It is also necessary to proceed to the careful removal and sampling of material under the fingernails and control hairs.

4 *Death from child abuse and neglect*
State of nutrition and general care, thorough description and documentation of external injuries and scars, thorough examination for bone fractures (X-ray), must be evaluated.

Consider the removal of a variety of tissues: for example all injuries, regional lymph nodes in malnutrition, endocrine organs, immuno-competent tissues, specimens from different parts of the intestine.

5 *Infanticide/still-birth*
Special techniques of dissection are necessary to expose the falx cerebri and the tentorium cerebelli; describe the site of caput succedaneum; remove all fractures 'en bloc'; investigate all bone centres of ossification (size and presence). Special care is to be applied to the thoracic organs: degree of inflation of the lungs, flotation test 'en bloc' and 'en detail'. However, the limitations of the flotation test must be appreciated. All malformations must be described. As regards abdominal organs, gas content of the intestine must be investigated. The umbilical cord and the placenta must be subject to morphological and histological examination.

6 *Sudden death*
A subdivision into three main categories relative to the further strategy after gross examination is useful:

a findings that obviously explain the sudden occurrence of death (for example haemopericardium, aortic rupture). Cases belonging to this category can usually be regarded as sufficiently solved;

b findings that could explain the death but allow other explanations. Cases belonging to this category necessitate the exclusion of , for example,. poisoning and possibly histological proof of recent or chronic alterations relative to the cause of death;

c findings are either nil/minimal or do not explain the occurrence of death. Cases belonging to this category will usually require extensive further investigations.

This is especially so with sudden infant death cases. In such cases a more comprehensive investigative scheme is essential.

7 *Shooting fatalities*

The following should be carried out:

- extensive account on the scene of the incident, of weapons involved, of types of bullets, of sites of ‘environmental’ damage, of cartridge cases and of relative positions of persons involved;
- thorough examination of the clothing and description of relevant damage and careful sampling;
- thorough investigation and documentation of any blood (splashes) on the body surfaces (including clothing and hands);
- precise description of bullet entry and exit wounds relative to anatomical landmarks and distances from the soles of the feet and bullet tracks within the body;
- description of any impression marks of the muzzle;
- excision of uncleaned skin specimens surrounding entry and exit wounds;
- X-ray before and/or during autopsy (where necessary);
- determination of bullet tracks and their direction(s);
- final determination of direction(s) of fire, of the succession of shots, of intra-vital occurrence, of the victim’s position (s).

8 *Death caused by explosive devices*

a As well as evaluating the cause of death, autopsy is essential to assist in reconstructing the nature of the explosion and identifying the type and maker of the explosive device, especially in aircraft sabotage or other terrorist actions.

b Full X-ray of the body must be made to detect and localise any metallic objects, such as detonator components, which may lead to the identification of the explosive device.

c The pattern of injury may indicate that the dead person was a perpetrator of the explosion, for example maximum injury in the lower abdominal region suggests that he or she carried the device on his or her lap during a premature explosion.

d At autopsy, all foreign objects in the tissues, identified on X-rays, must be carefully preserved for forensic examination.

e Samples of tissues, clothing, etc., must be retained for chemical analysis to identify the type of explosive.

9 *Blunt and/or sharp force injuries*

The following should be carried out:

- examination of the weapons or objects that are possibly involved (especially their dimensions);
- extensive examination and inspection of clothing (including damage, stains);
- careful dissection and description of all tracks (layer by layer) including their dimensions and weapon-related traces, signs of vitality.

10 *Fire Deaths*

The following should be carried out:

- examination of remains of clothing, - specific types and shapes of skin combustions;
- search for heat-related alterations and peculiarities;
- demonstration/exclusion of fire accelerants.;
- search for signs of vitality: carbon monoxide, HCN, soot inhalation, skin lesions.

11 *Suspicion of intoxication (General Outlines)*

11.1 Where anatomical findings do not reveal a cause of death and/or there is vague suspicion of poisoning, basic sampling should include peripheral blood, urine, stomach contents, bile, liver and kidney.

11.2 If specific suspicion arises, sampling should be group-related as follows:

- hypnotics, sedatives, psycho-active drugs, cardiac drugs and analgesics, pesticides: as aforementioned under (11.1);
- drugs of abuse: as aforementioned under (11.1) and additionally cerebrospinal fluid, brain tissue, injection marks, hairs;
- volatile fat-soluble substances such as fire accelerant and solvents: as aforementioned under (11.1) and in addition: blood from left ventricle, brain tissue, subcutaneous fat tissue, lung tissue, clothing;
- nutritional intoxication: as aforementioned under (11.1) and in addition: intestinal contents, if possible taken from 3 different sites;
- suspicion of chronic intoxication (heavy metals, drugs, pesticides etc.) as aforementioned under (11.1) and in addition: hairs (tufts), bones, fat tissue, intestinal contents.

12 *Decomposed bodies*

The presence of decomposition does not remove the need for a full autopsy.

Radiological examination will exclude bony injury, the presence of foreign bodies, for example bullets.

Toxicological studies (particularly estimation of alcohol concentrations) should be carried out but interpreted with great caution.

Index

References to autopsy, death and homicide are limited in the index, as these are major subject of the book. Readers are advised to seek more specific references. *vs* denotes differentiation or comparison.

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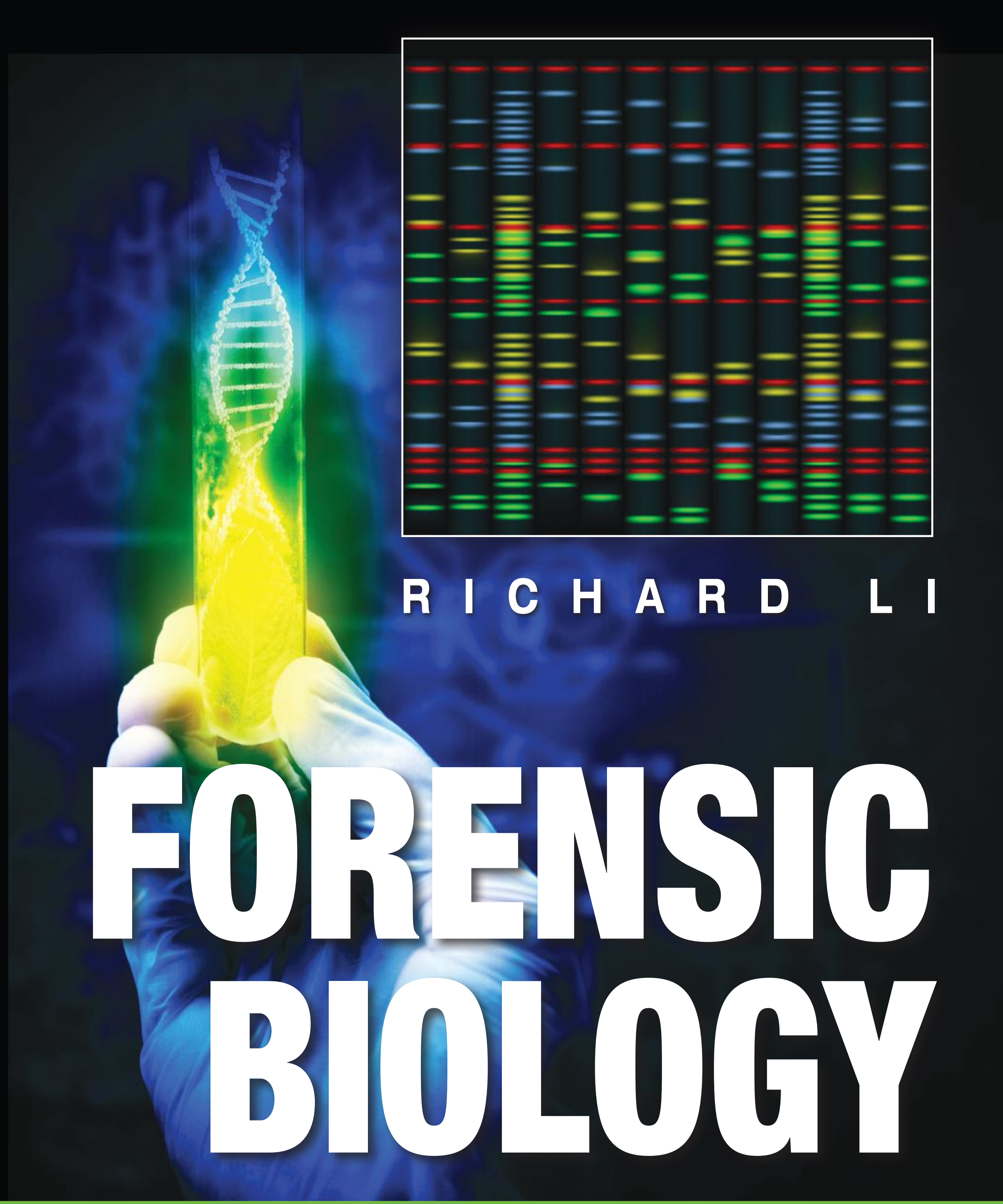

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Preface

Since the first edition of this book, new developments in forensic biology have led to a rapid expansion of the knowledge of the field. Therefore, it is necessary to create a new edition. This edition provides updates in most chapters of the original edition. Additionally, three new chapters (Chapters 2, 16, and 17) have been added and approximately 200 new figures have been created for this edition. Just like the first edition of this book, the new edition aims to inspire an undergraduate audience to tackle new challenges in the forensic biology field. It is written specifically to provide a general understanding of forensic biology and assist students in becoming more knowledgeable about the field of forensic biology and the wealth of available information. My readers should find that this edition of the book contains useful information, presented in a way that is more easily understood. Hopefully, it will be utilized by students, particularly those interested in forensic biology, to further enhance their education and training. I will continue to be open to suggestions in the future.

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Author

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Introduction

This text defines forensic biology as analyses performed in the forensic biology sections of forensic laboratories and thus focuses on forensic serology and forensic DNA analysis. The aim of this book is to emphasize the basic science and its application to forensic science in an effort to make the principles more understandable. In addition, it introduces the language of forensic biology, thus enabling students to become comfortable with its use, and it provides clear explanations of the principles of forensic analysis.

To convey a general understanding of the concepts of forensic biology, it is necessary to include explanations of various techniques that are utilized in the field. The intent is to provide students with a scientific grounding in the area of forensic biology by offering an introduction to methods and techniques utilized by forensic biology laboratories. The techniques introduced in this text are accompanied by brief background descriptions and discussions of basic principles and techniques. Schematic illustrations are included where necessary. The text also acknowledges the benefits and limitations that apply to forensic biology techniques. Forensic techniques that were used in the past are also described. Learning past examples of forensic tests can help students to review historical forensic cases.

This text contains five modules, organized by section: Section I, Biological Evidence (Chapters 1–4); Section II, Basic Techniques in Forensic Biology (Chapters 5–11); Section III, Identification of Biological Evidence (Chapters 12–17); Section IV, Individualization of Biological Evidence (Chapters 18–23); and Section V, Forensic Issues (Chapters 24–26). The 26 chapters are designed to be covered in a single-semester course.

SECTION I

Biological Evidence

1

Crime Scene Investigation of Biological Evidence

A forensic investigation involving biological evidence usually begins at the crime scene. The crime scene investigation process includes maintaining scene security, preparing documentation, and collecting and preserving physical evidence. A crime scene investigation requires teamwork and effort. Each team member should be assigned specific tasks (Figure 1.1).

1.1 Protection of Crime Scene

A crime scene investigation begins with the initial response to a scene (Figure 1.2). Securing and protecting the scene are important steps in a crime scene investigation (Figures 1.3 through 1.6), and this task is usually carried out by the first responding officer arriving on the scene. The entry of authorized personnel admitted to the scene should be documented using a log sheet (Figure 1.7). Suspects, witnesses, and living victims should be evacuated from the scene. If a victim is wounded, medical attention should be sought.

Appropriate supplies and devices should be used to prevent the contamination of evidence by investigators. Protective wear and devices including a face mask or shield, safety eyeglasses, a disposable coverall bodysuit, gloves, shoe covers, and a hairnet should be used (Figures 1.8 and 1.9). Exposure to bodily fluids may occur during a crime scene investigation. An investigator can be exposed to bodily fluids through the mucous membranes, skin exposure, and needlestick injuries (especially when investigating a clandestine drug laboratory scene). Therefore, biosafety procedures must be followed for the protection of personnel from infectious blood-borne pathogens such as the human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV); infectious aerosol tuberculosis pathogens; and other biohazardous materials.

1.2 Recognition of Biological Evidence

A preliminary survey should be carried out to evaluate potential evidence. In particular, the recognition of evidence plays a critical role in solving or prosecuting crimes. The priority of the potential evidence at crime scenes should be assessed based on each item's relevance to the solution of the case. Higher priority should be assigned to evidence with probative value to the case. For example, the evidence related to a *corpus delicti* is considered to be of the highest priority. *Corpus delicti* is a Latin term meaning "body of crime." In Western law, it primarily refers to the principle that in order for an individual to be convicted, it is necessary to prove the occurrence

N.Y.P.D.
POLICE
CRIME SCENE
UNIT

Figure 1.1 A crime scene investigation team. (© Richard C. Li.)

POLICE
CRIME SCENE UNIT
NYPD

Figure 1.2 A crime scene unit vehicle that is used to respond to crime scenes. This type of vehicle is usually outfitted with devices and supplies that investigators need when processing a crime scene, as well as evidence packaging materials, fingerprint collection kits, and DNA collection kits. Additionally, it can be equipped with a workstation for computer access, a refrigerator for storing chemicals, and a compact fuming hood for processing latent fingerprints, as well as equipment cabinets and drawers. (© Richard C. Li.)

CRIME SCENE DO NOT CROSS

Figure 1.3 Crime scene barrier tape is used to ensure that only investigators are admitted to the scene. (Courtesy of H. Brewster.)

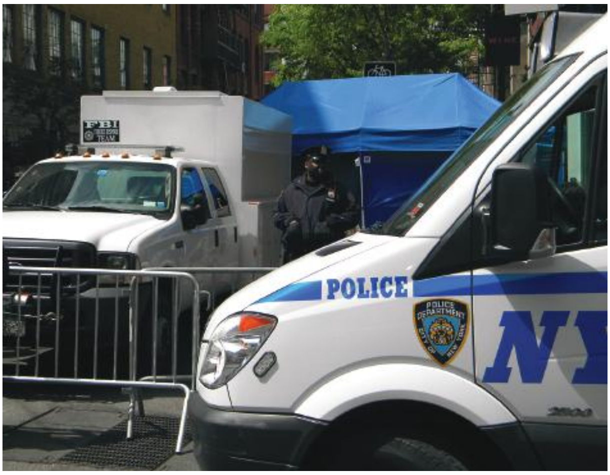
FBI
POLICE
POLICE DEPARTMENT CITY OF NEW YORK
NY

Figure 1.4 A police officer guards the crime scene. (© Richard C. Li.)

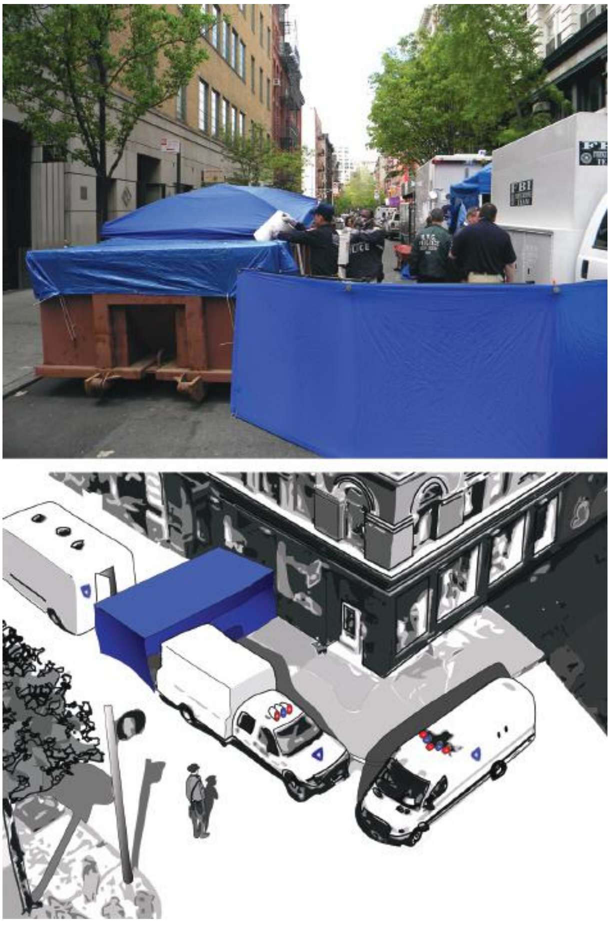

Figure 1.5 Crime scene privacy screen and tent. The screen (top) and the tent (bottom) are useful devices for shielding the evidence or body from viewing by unauthorized personnel. (© Richard C. Li.)

Figure 1.6 Barricades are set up to keep crowds at a distance from the scene. (© Richard C. Li.)

of the crime. In a forensic investigation, it also refers to the physical evidence proving that a crime was committed. For example, when an individual is missing, a missing persons investigation is usually initiated. If *corpus delicti*, such as a dead body or a victim's blood at a crime scene (Figure 1.10), is discovered during the investigation, a homicide case can be established and a suspect can be charged with homicide. Higher priority should also be attached to evidence that can establish connections such as *victim-to-perpetrator linkage*. For example, items found in a perpetrator's possession may be linked to a victim. This also applies to transfer evidence based on the principles of transfer theory, also known as the *Locard exchange principle*, which theorizes that the cross-transfer of evidence occurs when a perpetrator has any physical contact with an object or another person (Figures 1.11 through 1.14). Thus, trace evidence, such as hairs and fibers, may be transferred from a perpetrator to a victim or vice versa. This explains why it is important to ensure that perpetrators and their belongings are thoroughly searched for trace evidence. Likewise, victims and their belongings should be examined for the same reason.

Victim-to-scene and perpetrator-to-scene linkages can also be established. Blood belonging to a perpetrator or a victim found at a crime scene can establish such a linkage (Figure 1.15). Additionally, reciprocal transfers of trace evidence from crime scenes can be used to link a suspect or a victim to a crime scene. A perpetrator may present a unique *modus operandi* (MO). *Modus operandi*, a Latin term commonly used in criminal investigations, refers to a particular pattern of characteristics and the manner in which a crime is committed. For example, Richard Cottingham, a serial killer known as "the torso killer," dismembered his victims and took their limbs and heads with him but left their torsos at the scene. He then set the rooms on fire before

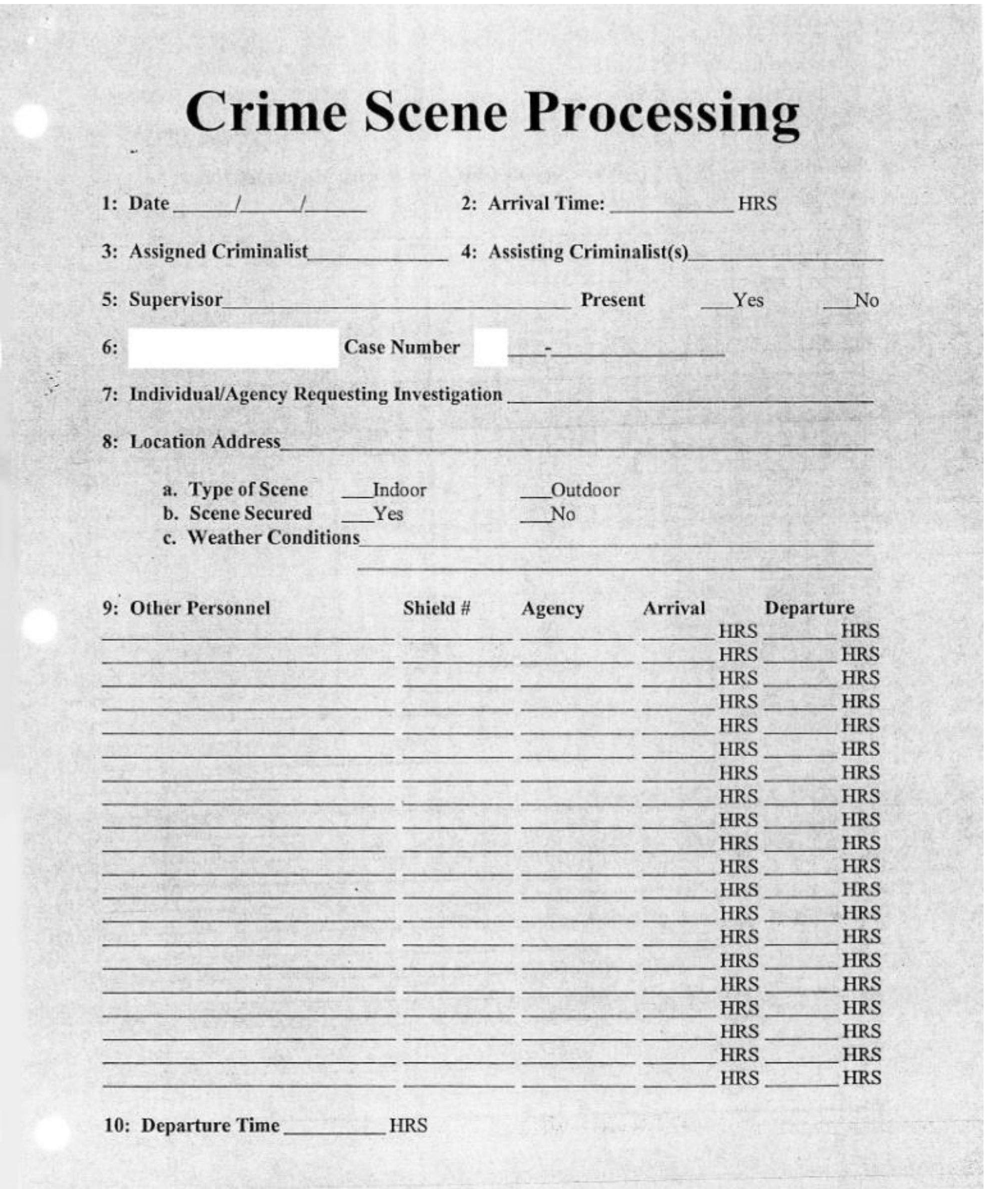

Crime Scene Processing

1: Date _____/_____/_____ **2: Arrival Time:** __________ HRS

3: Assigned Criminalist__________ **4: Assisting Criminalist(s)**__________

5: Supervisor____________________ **Present** ___Yes ___No

6: [redacted] **Case Number** [redacted] ___-__________

7: Individual/Agency Requesting Investigation ____________________

8: Location Address______________________________

a. Type of Scene ___Indoor ___Outdoor
b. Scene Secured ___Yes ___No
c. Weather Conditions____________________
____

9: Other Personnel	**Shield #**	**Agency**	**Arrival**	**Departure**
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
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			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS

10: Departure Time __________ HRS

Figure 1.7 An example of a log sheet for documenting authorized personnel at a crime scene. (© Richard C. Li.)

fleeing the scenes. Evidence that provides information on the MO is also vital to an investigation. A distinct MO can establish a *case-to-case linkage* for serial offender cases.

1.3 Searches

Some investigations require a search for specific items of evidence such as biological stains, human remains, and all relevant evidence. A search usually has a specific purpose. Thus, the use of search patterns can be helpful, especially in cases involving large outdoor crime scenes.

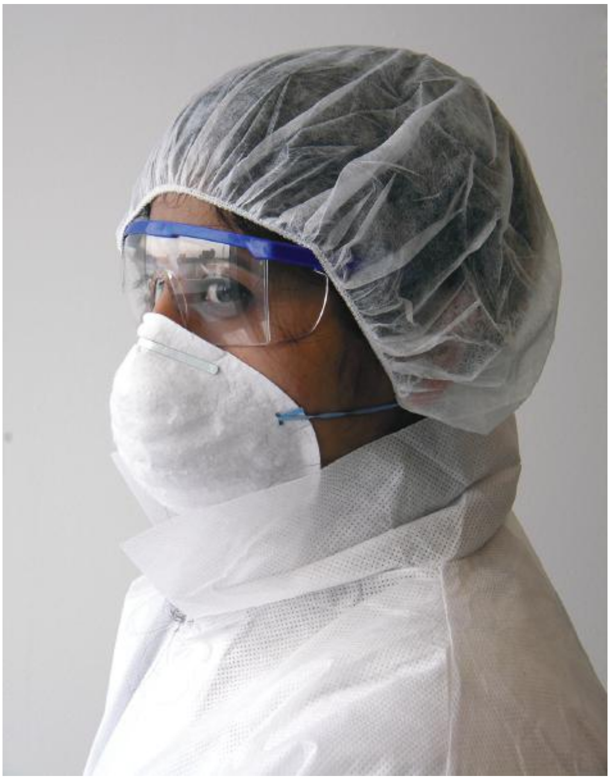

Figure 1.8 Personal protection wear and devices that are used at crime scenes. (© Richard C. Li.)

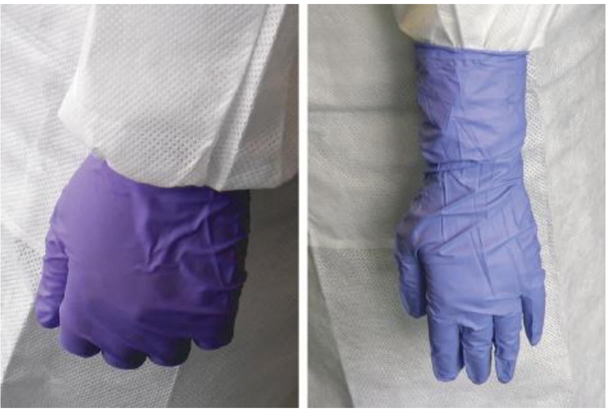

Figure 1.9 Disposable glove (left) and glove with extended cuff (right). (© Richard C. Li.)

Search patterns may include a grid, line, or zone (Figures 1.16 and 1.17). The method that is ultimately used depends on the type and size of the scene (Figures 1.18 through 1.20). Additionally, the points of entry and exit and the paths followed by a perpetrator should also be searched.

Searching for biological stains usually utilizes devices such as an alternate light source (ALS); see Figures 1.21 and 1.22. An ALS either produces a single specific wavelength of light or a desired wavelength by using specific filters. Biological materials such as blood, semen, and saliva emit fluorescent light under an ALS, which can facilitate the locating of biological materials. Additionally,

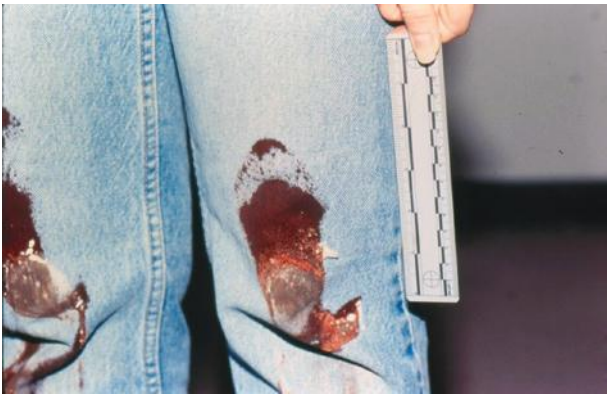

Figure 1.10 Photographic documentation of bloodstains on clothing. (© Richard C. Li.)

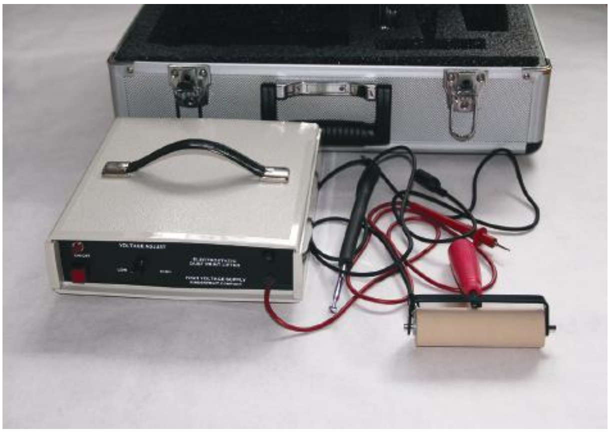

Figure 1.11 An electrostatic dust print lifting device can be utilized for processing impression evidence such as footprints and tire tracks. (© Richard C. Li.)

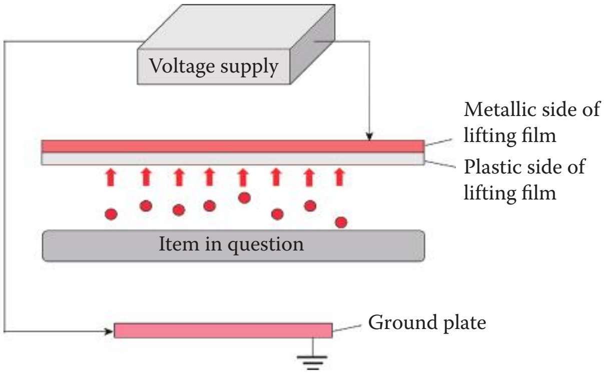
Voltage supply
Metallic side of lifting film
Plastic side of lifting film
Item in question
Ground plate

Figure 1.12 Basic components of an electrostatic dust print lifting device. The lifting film is placed on top of the item in question with the plastic side against the surface and the metallic side facing up. A ground plate is placed directly on the ground. The lifting film and ground plate are connected to the voltage supply apparatus. Once the charging voltage is turned on, the static charge transfers the dust particles from the surface to the plastic side of the lifting film. (© Richard C. Li.)

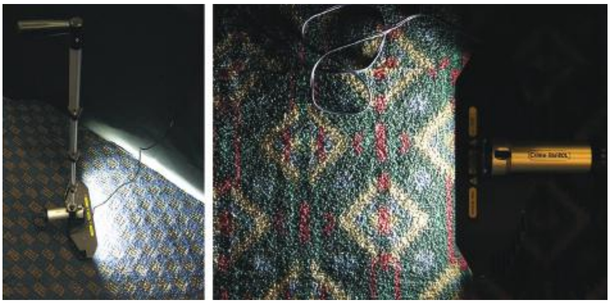

Figure 1.13 A high-intensity light-emitting diode (LED) device for locating evidence at a crime scene is particularly effective in highlighting trace evidence such as hairs, fibers, and shoe prints. (© Richard C. Li.)

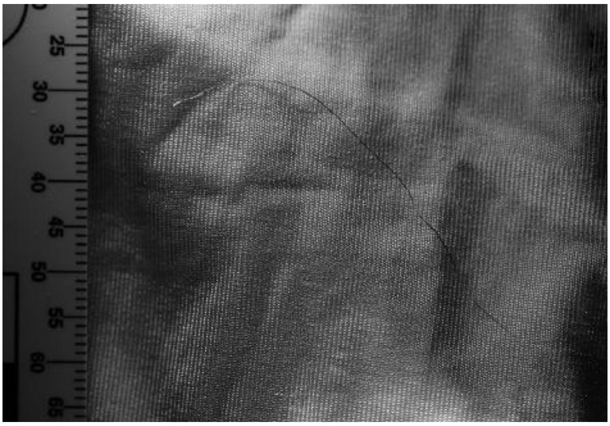

Figure 1.14 A hair found on a victim's clothing can be transferred evidence from a suspect. (© Richard C. Li.)

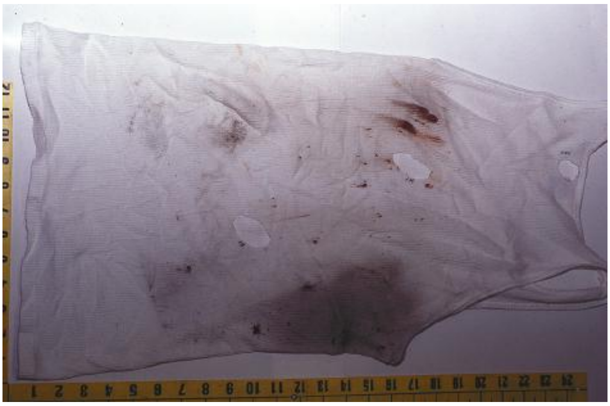

Figure 1.15 Finding a victim's blood on a suspect's clothing can establish a link between them. (© Richard C. Li.)

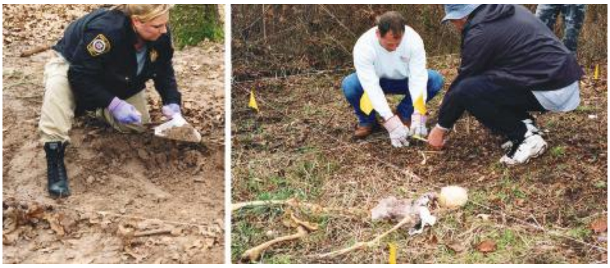

Figure 1.16 Grid search pattern for an outdoor scene. The investigators and anthropologists present are searching for human bone evidence within the grid. (Courtesy of H. Brewster.)

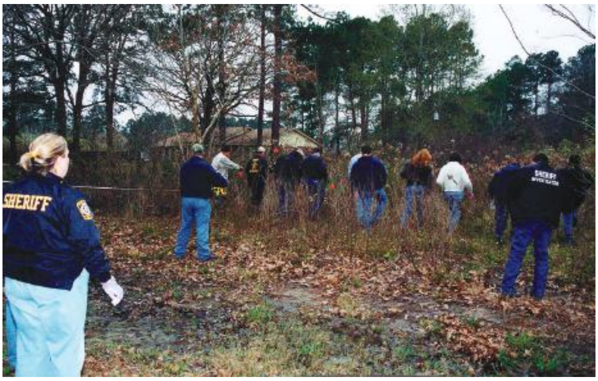

Figure 1.17 Line search pattern for an outdoor scene. (Courtesy of H. Brewster.)

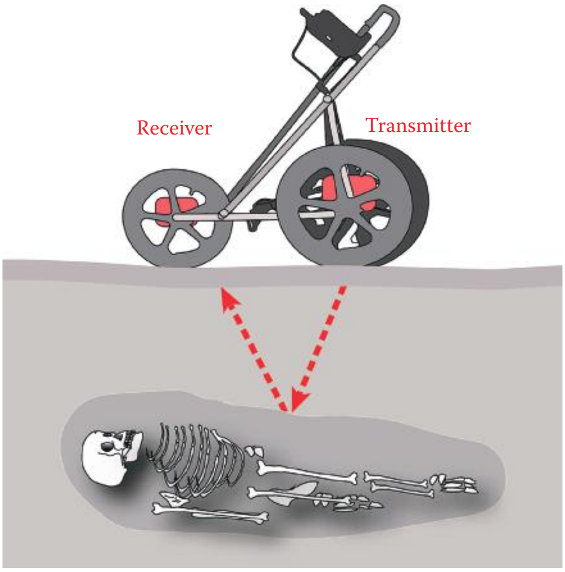

Figure 1.18 Using ground-penetrating radar (GPR) to locate clandestine graves of homicide victims. GPR uses electromagnetic waves emitted from a transmitter, which are detected by a receiver to locate clandestine burials and buried objects such as weapons embedded in soils. Images of the potential evidence are typically obtained by moving the antenna of the GPR device over the surface of the ground. (© Richard C. Li.)

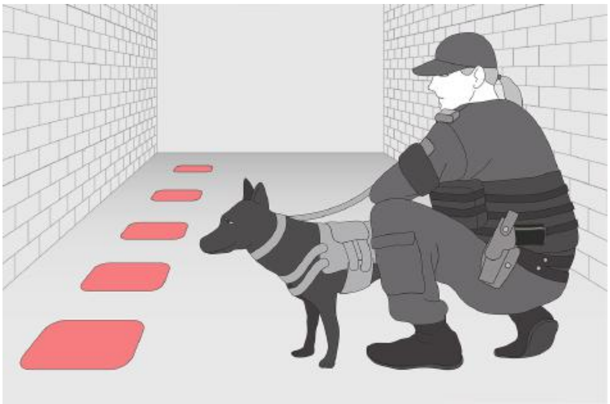

Figure 1.19 Using cadaver-sniffing dogs to alert investigators to the presence of buried bodies. The odor produced by the decomposition of the human body may be sensed by cadaver-sniffing dogs. Odor-absorbing pads absorb and retain the scent of decomposed remains and can be placed at the scene for several days. Upon sniffing the pads, a cadaver dog may indicate the presence of buried human remains or may indicate that human remains were once buried in that location. However, it is not clear that this technique is reliable. (© Richard C. Li.)

MADISON
CONSTABLE SAR K9

Figure 1.20 Tracking dog for searching suspects. In a situation of processing a recent crime scene when the suspect may be in close vicinity to the scene, a tracking dog can be used. A tracking dog, such as a bloodhound, can potentially follow the scent from items left at the scene to locate a suspect nearby. (© Richard C. Li.)

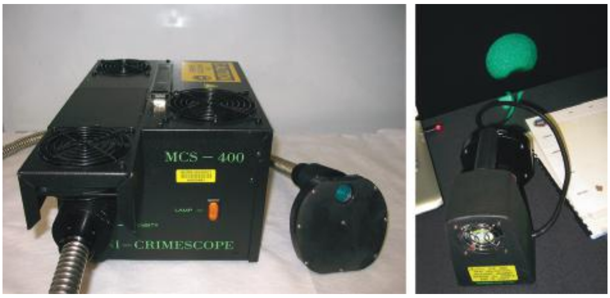

Figure 1.21 Compact alternate light source devices, which are intended specifically for use at crime scenes, reduce search time and improve the recovery of evidence such as biological evidence and chemically enhanced latent fingerprints. (© Richard C. Li.)

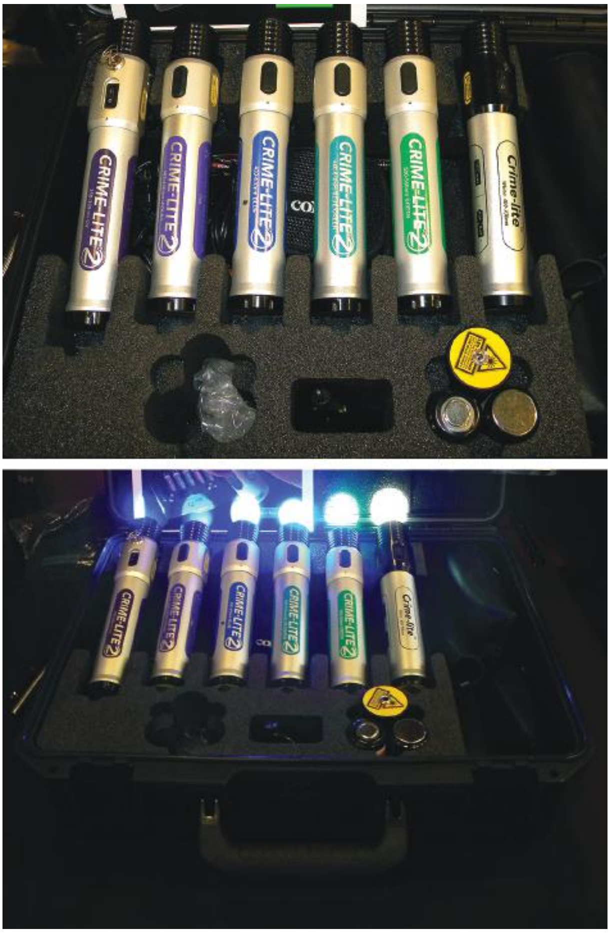

Figure 1.22 LED light sources provide illumination for locating evidence such as bodily fluid stains, hair, or fibers. (© Richard C. Li.)

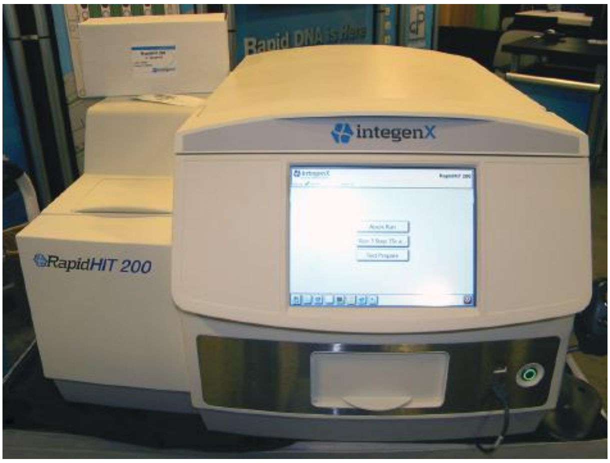

Figure 1.23 An example of a compact Rapid DNA device for processing DNA evidence in the field. (© Richard C. Li.)

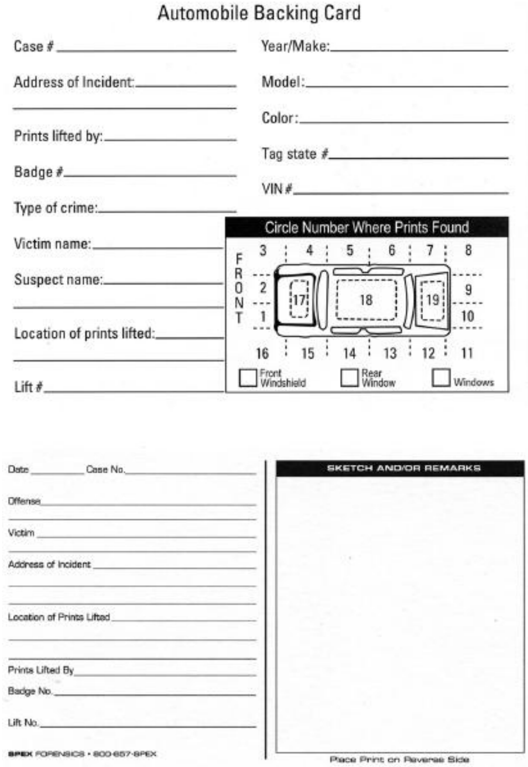

Automobile Backing Card

Case #__________
Address of Incident:__________
Prints lifted by:__________
Badge #__________
Type of crime:__________
Victim name:__________
Suspect name:__________
Location of prints lifted:__________
Lift #__________

Year/Make:__________
Model:__________
Color:__________
Tag state #__________
VIN #__________

Circle Number Where Prints Found

FRONT
3
4
5
6
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2
17
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13
12
11

☐ Front Windshield ☐ Rear Window ☐ Windows

Date__________ Case No.__________
Offense__________
Victim__________
Address of Incident__________
Location of Prints Lifted__________
Prints Lifted By__________
Badge No.__________
Lift No.__________

SPEX FORENSICS • 800-657-SPEX

SKETCH AND/OR REMARKS

Place Print on Reverse Side

Figure 1.24 An example of sketch documentation. (© Richard C. Li.)

field tests and enhancement reagents can be used to facilitate crime scene searching (Chapter 12). These reagents can detect and identify biological evidence. The tests are very simple, rapid, and sensitive, and thus can be used at crime scenes. For example, phenolphthalin and leucomalachite green tests can be used for detecting blood evidence. Sometimes, minute amounts of blood may be

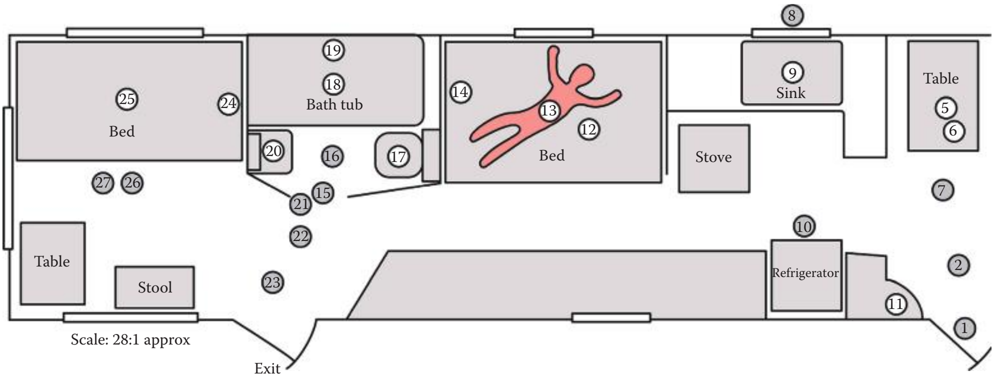

Figure 1.25 Sketches for documenting the sites of fingerprints. (© Richard C. Li.)

present at the scene as a result of attempts to clean up blood prior to the investigation. These stains may not be visible with the naked eye. Enhancement reagents such as luminol and fluorescein, which emit chemiluminant and fluorescent light upon reacting with certain biological materials, respectively, can be used. Additionally, the enhancement reagents can detect faint blood-containing pattern evidence such as faint bloody fingerprints, footprints, and other pattern evidence of physical contact such as drag marks in blood. However, precaution should be taken since these reagents are not usually very specific to blood. Certain substances such as bleach, various metals, and plants may also lead to chemical reactions with the field tests and the enhancement reagents. In these cases, the evidence collected is further tested with laboratory examination and analysis.

Recently, portable and field-deployable instruments have been developed that are capable of processing buccal swabs and potentially other evidence to produce a DNA profile on-site (Figure 1.23). It is a fully automated process, using the Rapid DNA technology (Chapter 8), that

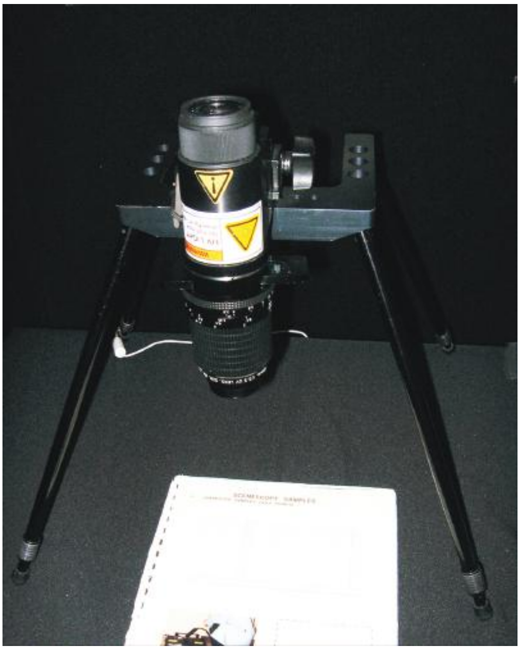

Figure 1.26 A reflected ultraviolet imaging system (RUVIS) imager for documenting close-up views of evidence such as latent fingerprints. (© Richard C. Li.)

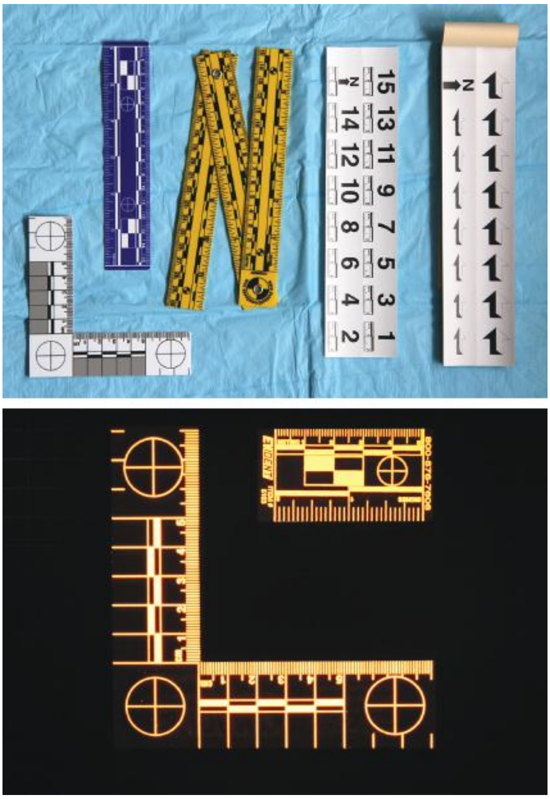

Figure 1.27 Scales for photographic documentation. Regular scales (top) can be used with visible light sources. Fluorescence scales (bottom) can be used for the documentation of fluorescing evidence after certain treatment, such as chemical enhancement, using alternate light sources. (© Richard C. Li.)

can be completed within 2 h by a trained crime scene investigator or police officer. These instruments may provide a new tool for expediting the identification of suspects and developing investigative leads at the scene. Additionally, this technology can enable law enforcement agents to rapidly determine whether the crimes were isolated incidents or part of serial crimes committed by the same offender, such as in serial burglary and arson cases. It can also be used in the identification of human remains in mass disasters.

1.4 Documentation

The conditions at a crime scene, including both the individual items of evidence and the overall scene, must be documented to provide vital information for investigators and for the courts. The most common documentation methods are drawing sketches and taking photographs and videographs. The sketch is to reflect the positions and the spatial relationships of items and persons with measurements using a scale. An investigator usually prepares a rough sketch first and later converts the rough sketch into a finished sketch (Figures 1.24 and 1.25). If bloodstains are present at the scene, the location of bloodstain patterns should be emphasized. Prior to handling and moving evidence, photographs should be taken with different views: an overall view of the entire scene, a medium-range view showing the positions and the relationships of items, and a close-up

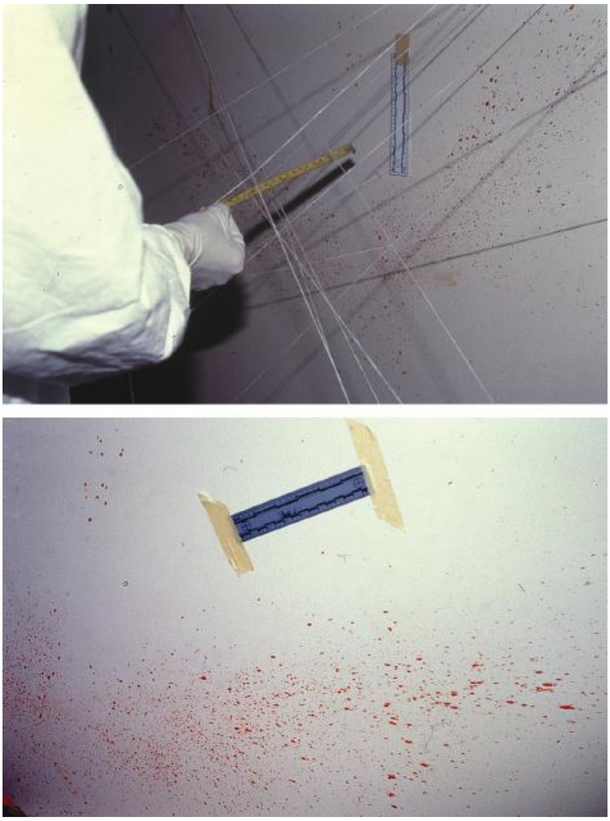

Figure 1.28 Photographic documentation of bloodstain patterns. (© Richard C. Li.)

view showing details of the evidence (Figure 1.26). Photographs should also include a measuring device such as a scale (Figure 1.27) to accurately depict the sizes of items such as bloodstains or bite marks. This can be achieved simply by placing a ruler adjacent to the evidence when it is photographed (see Figure 1.28). A photograph log sheet can be used to record the chronological order of crime scene photographs and to note filming conditions and any additional relevant information (Figure 1.29). Similar documentation should be prepared for videographs when appropriate. Additionally, written or audio-recorded notes can be used. Notes should include complete and accurate information of a crime scene investigation, such as the case identifier number, the identities of the investigators, and a description of the scene or items (e.g., location, size, and shape). Additionally, any disturbance of evidence occurring during crime scene processing should be noted.

1.5 Chain of Custody

Custody information should be recorded at each event when evidence is handled or transferred by authorized personnel. Usually, a custody form listing a specific evidence item is used to document the chain (Figure 1.30). Each individual who acquires custody of the evidence must sign a chain of custody document. An incomplete chain of custody may lead to an inference of possible tampering or contamination of evidence. As a result, the evidence may not be admissible in court.

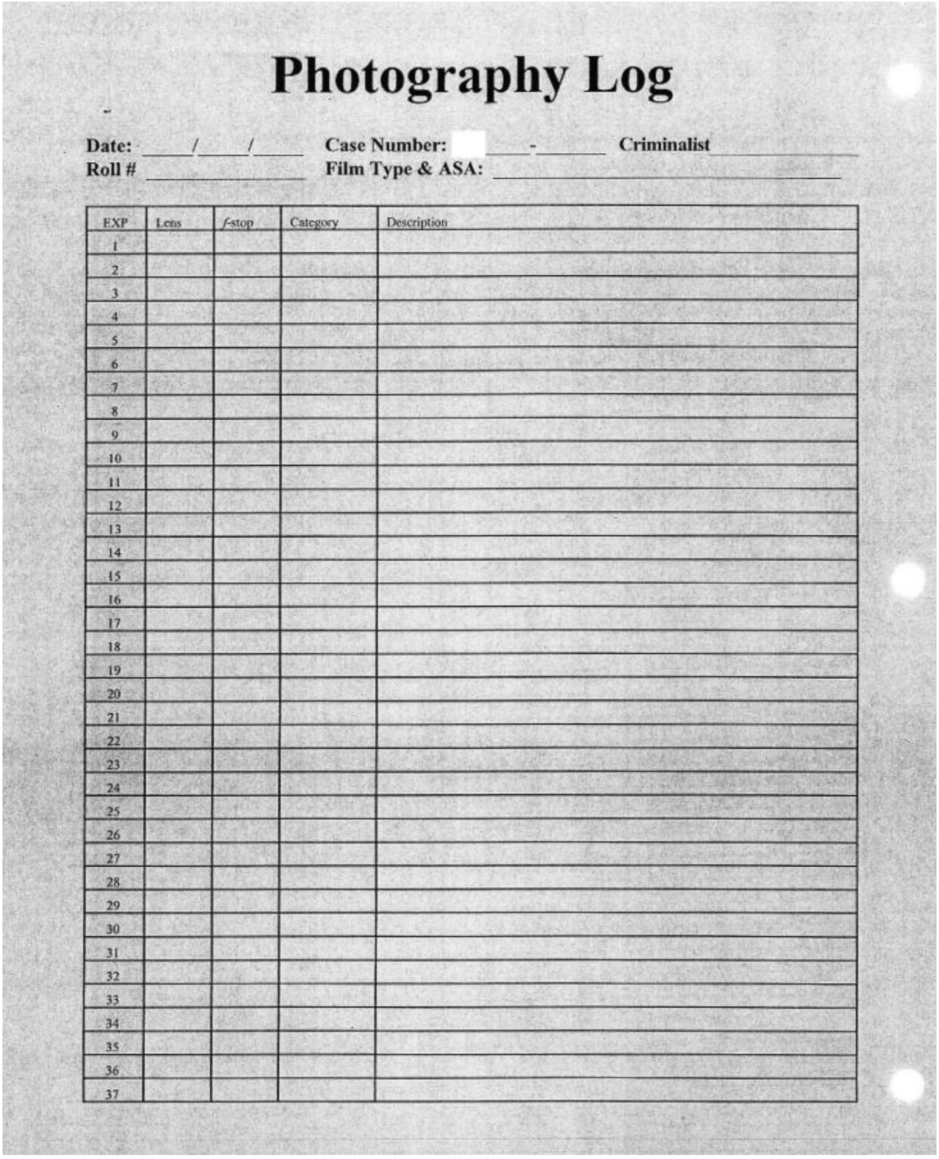

Photography Log

Date: ____/____/____ **Case Number:** ____-______ **Criminalist** ______________
Roll # ______________ **Film Type & ASA:** ______________________________

EXP	Lens	f-stop	Category	Description
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Figure 1.29 Crime scene photography log. (© Richard C. Li.)

1.6 Collection of Biological Evidence

After the crime scene documentation is completed, the collection of evidence can be initiated. Small or portable items, such as bloodstained knives, can be collected and submitted to a crime laboratory (Figure 1.31). Large or unmovable items of evidence (Figure 1.32) can be collected and submitted in sections, such as a section of wall where bloodstains are located. Table 1.1 and Figures 1.33 through 1.38 summarize and illustrate representative collection techniques. Specific care is required for the collection of biological evidence in the following situations:

- *Bloodstain pattern evidence*: It is especially important to thoroughly document the bloodstain pattern evidence at a crime scene prior to collection. Bloodstain patterns can be especially useful in crime scene reconstruction.

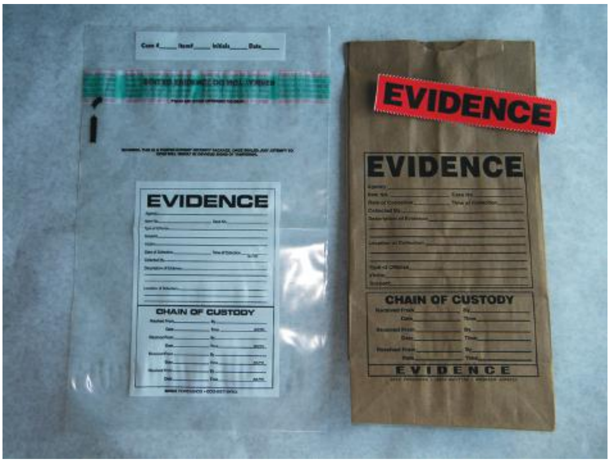
EVIDENCE
CHAIN OF CUSTODY
EVIDENCE
EVIDENCE
CHAIN OF CUSTODY
EVIDENCE

Figure 1.30 Labels with the chain of custody that are used for marking the evidence contained in the packaging. (© Richard C. Li.)

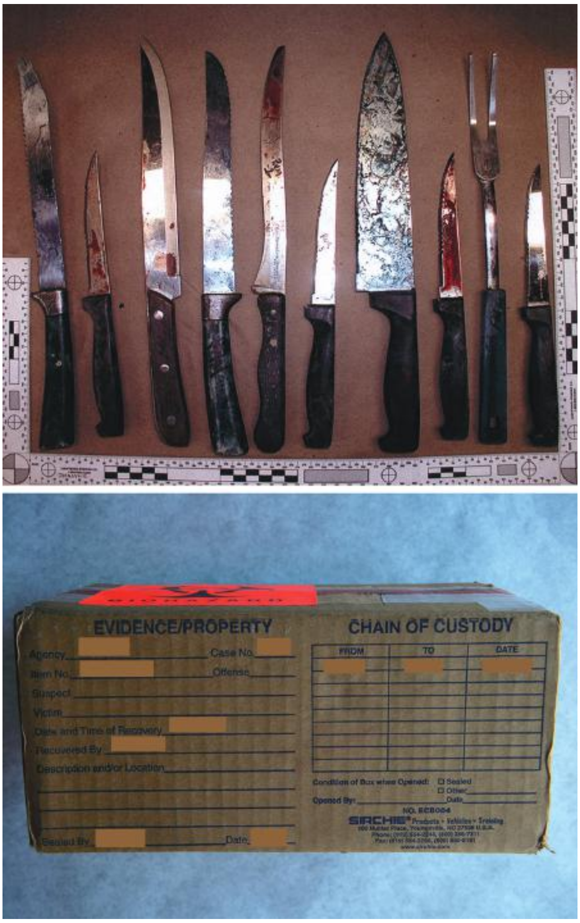
EVIDENCE/PROPERTY
Agency
Case No.
Item No.
Offense
Suspect
Victim
Date and Time of Recovery
Recovered By
Description and/or Location
Sealed By
Date
CHAIN OF CUSTODY
FROM
TO
DATE
Condition of Box when Opened:
☐ Sealed
☐ Other
Opened By:
Date
NO. ECB004
SIRCHIE

Figure 1.31 Handling sharp objects. Bloodstained knives collected and submitted to laboratories (top) and a box for packing sharp objects (bottom). (© Richard C. Li.)

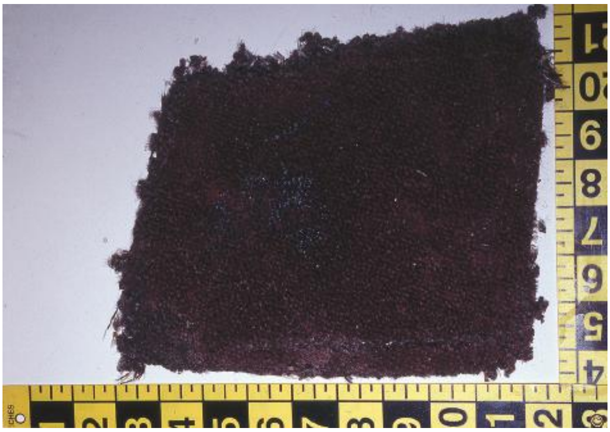

Figure 1.32 A section of bloodstained carpet is collected. (© Richard C. Li.)

- *Multiple analysis of evidence*: If multiple analyses are needed for a single item of evidence, nondestructive analyses should be carried out first. For example, a bloody fingerprint should be collected for ridge detail analysis prior to collecting blood for DNA analysis.
- *Trace evidence*: Trace evidence such as hairs and fibers can be present in bloodstained evidence and should be identified and properly collected.
- *Control samples*: Control (known or blank) samples should be collected from a control area (e.g., unstained area near a collected stain).
- *Size of stain*: Polymerase chain reaction (PCR)-based forensic DNA techniques are highly sensitive and allow for the successful analysis of very small bloodstains. All bloodstains, even if they are barely visible, should be collected at a crime scene.
- *Wet evidence*: Wet evidence should be air-dried (without heat) prior to packaging to prevent the degradation of proteins and nucleic acids, which are used for forensic serological and DNA analysis.

1.7 Marking Evidence

The marking of evidence is necessary for identification purposes so that it can be quickly recognized even years later (Figure 1.39). An investigator's initials, the item number, and the case number are usually included in marking. Information can be marked on a tag, a label attached to the item, or directly on garment evidence. The marking of evidence should not be proximal to bullet holes or biological stains to prevent the mark from interfering with analyses.

1.8 Packaging and Transportation

Packaging is intended to protect and preserve evidence. All evidence should be secured and protected from possible contamination. Fragile items should be protected to prevent any damage during transportation. Exposure to heat and humidity should be avoided to protect biological evidence from degradation during transport. Various packaging methods are available

Table 1.1 Methods for Collecting Biological Evidence

Type of Evidence	Condition	Method of Collection	Procedure
Blood	Dry	Swab	Best on nonabsorbent surfaces; lightly moisten sterile swab with distilled or sterile water, rub over stain while rotating; allow to air-dry; a combination of first a moistened swabbing followed by second a dry swabbing (both swabs submitted) is recommended
		Cutting	Cut stain from item
		Scraping	Scrape bloodstain into a clean piece of paper using a clean blade; wrap sample using druggist's fold
		Lifting	Works for nonabsorbent surfaces; use fingerprint lifting tape that does not interfere with DNA testing to lift stain; lifted stain should be covered with a piece of lifter's cover
		Collect entire item	Collect if item contains bloodstain pattern; difficult to swab; requires multiple exams
	Wet	Swab	Absorb blood sample onto sterile cotton swabs; stain should be concentrated on tip and allowed to air-dry
		FTA paper	Use a sterile disposable pipet to collect liquid blood; spot on FTA paper; allow to air-dry
	Reference liquid blood sample	Venous blood collection	Collect blood in a purple-topped vacutainer tube containing ethylenediaminetetraacetic acid (EDTA) anticoagulant; refrigerate but never freeze
Semen	Dry or wet	See "Blood" above	See "Blood" above
	Condom	Collect entire item	Secure condom with a tie and place in a container in a refrigerator; submit to laboratory as soon as possible
	Various conditions	Victim sexual assault kit	Standardized kit to collect biological evidence from the body of a victim includes swabs, microscope slides, and envelopes
	Various conditions	Suspect standard kit	Standardized kit to collect biological evidence from the body of a suspect includes swabs, microscope slides, and envelopes

(*continued*)

Table 1.1 (Continued) Methods for Collecting Biological Evidence

Type of Evidence	Condition	Method of Collection	Procedure
Victim vaginal fluid	Dry or wet	See “Blood” above	Often collected from a suspect’s pubic area or fingers
Saliva	Dry or wet	See “Blood” above	Often collected from a bite mark or a victim’s pubic area
	Reference saliva (buccal) samples	Swab	Swab the inside of the cheek using two swabs, rotating them during collection; allow swabs to air-dry
		Filter paper	Place donor saliva sample on marked area of filter paper; allow to air-dry
Hairs	Head and pubic hairs	Lifting	Refer to dry bloodstain lifting method
		Transfer	Use forceps to transfer hair onto a piece of paper that can be folded
		Vacuum	Vacuum can be used if necessary; generally not recommended
Fingernails and scrapings	Various conditions	Clipping	Use a clean clipper to clip nails onto clean paper; wrap samples using druggist’s fold
		Scraping	Scrape undersides of nails onto clean paper; wrap samples using druggist’s fold
Bones	Various conditions	Freeze in container	Collect if blood is not available; collect bone with marrow if available; rib bone and vertebrae are preferred; place specimen in a container and freeze if wet
Teeth	Various conditions	Container	Collect teeth with dental pulp if possible into a container
Tissues and organs	Wet	Freeze in a container	Collect if blood is not available; place specimen in a container and freeze
DNA database samples	Various conditions	Various	Follow jurisdiction protocol for collecting samples from arrested individuals or convicted offenders or both

Source: Fisher, B., *Techniques of Crime Scene Investigation*, 7th edn., 2004, CRC Press, Boca Raton; Lee, H.C. et al., *Henry Lee’s Crime Scene Handbook*, 2001, Academic Press, San Diego; National Institute of Justice. Using DNA to solve cold cases, Special Report, 2002, US Department of Justice, Office of Justice Programs, Washington, DC.

Note: Samples requiring refrigeration or freezing are noted; other samples may be stored at room temperature. Dry evidence should be packed in a porous material such as paper (envelope, bag, box) as described in the text.

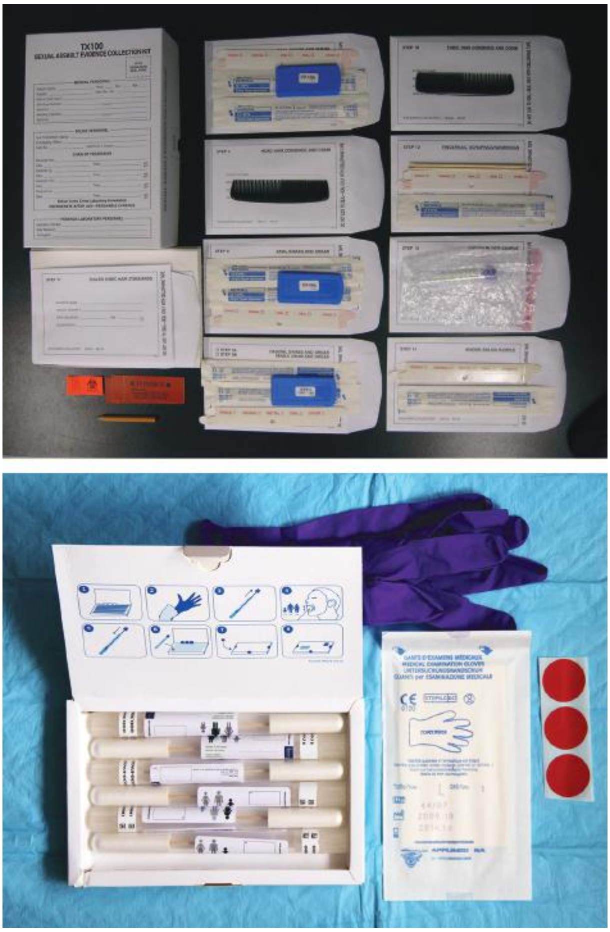

Figure 1.33 Evidence collection kits. Sexual assault evidence collection kit (top). Paternity evidence collection kit (bottom). (© Richard C. Li.)

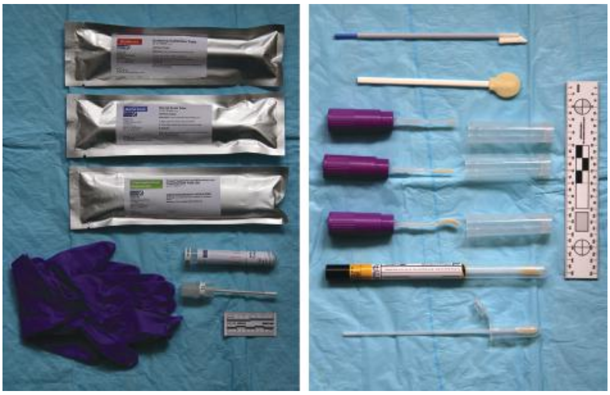

Figure 1.34 Various types of swabs that are used for collecting biological evidence. (© Richard C. Li.)

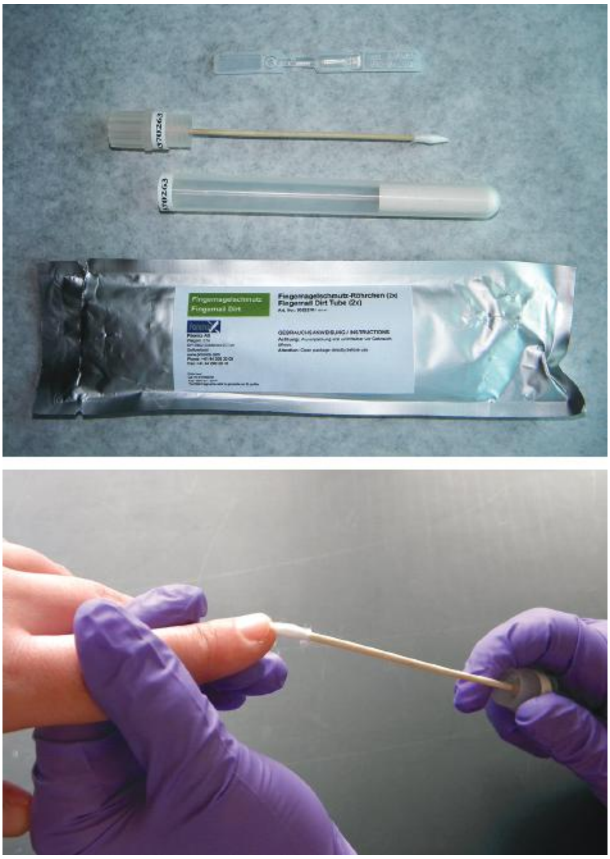

Figure 1.35 Fingernail swabbing for recovering evidence. Fingernail swabs are often collected from individuals who are involved in a struggle in violent crimes and in digital penetration in sexual assault cases. Fingernail swabs are sampled separately from both hands. (© Richard C. Li.)

depending on the type of evidence handled (Figures 1.40 through 1.42). The following are general considerations related to the packaging of evidence:

- *Evidence from different sources*: To prevent the transfer of evidence from different sources, items of evidence should not be grouped in a single package. However, evidence may be packed in a single container if the items were found together.
- *Folding of evidence*: Folding of clothing, especially items with wet bloodstains, can transfer evidence from one part of a garment to another. If a large, dry garment must be folded, a piece of clean paper should be placed between different parts of the garment to avoid direct contact between the different parts of the garment, thereby preventing the transfer of evidence.
- *Packing materials*: Envelopes, bags, and boxes that are made of porous materials such as paper are appropriate for packaging dry biological evidence. Dry, bloodstained evidence should not be sealed in plastic bags or containers that trap moisture.
- *Liquid evidence*: Tubes containing liquid such as blood should not be frozen because the volume of a liquid expands in freezing temperatures and this expansion may lead to cracking. Tubes should be placed in plastic bags to prevent leaks in case of

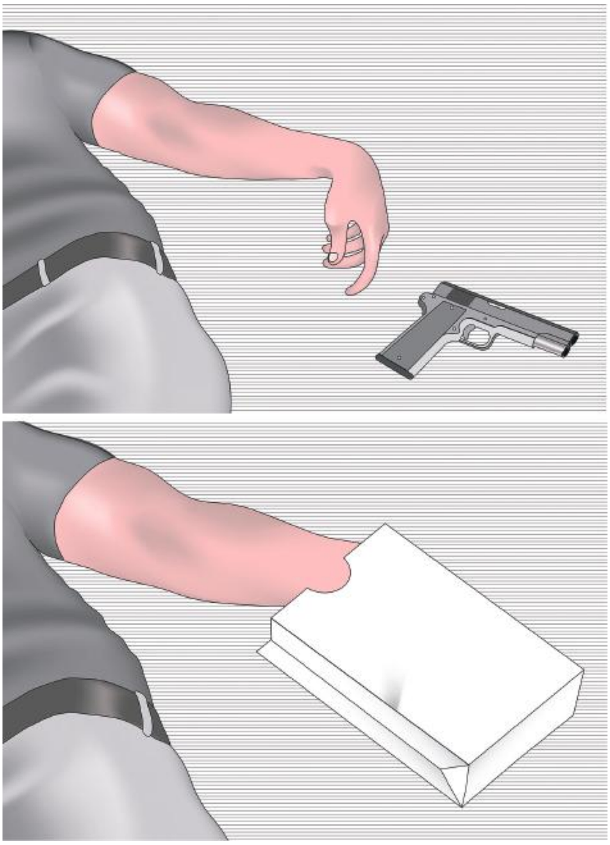

Figure 1.36 Hand bags for protecting the hands of a decedent in an alleged suicide. Gunshot residue can be found on hands after firing a weapon (top). The bagging of the hands, using paper bags and wide rubber bands, prevents the loss of gunshot residue during the transportation of the body (bottom). (© Richard C. Li.)

accidental breakage. Liquid evidence should be transported and submitted to a laboratory as soon as possible after the collection of evidence.

- *Trace evidence*: All such evidence should be wrapped in paper with a druggist's fold (Figure 1.43). The wrapped trace evidence can be packed in an envelope.

Packaged evidence should be properly labeled with a description of the evidence and sealed with evidence tape. It is important for the person packaging the evidence to initial and date across the seal to show authenticity (Figure 1.44). A seal should not be cut when a sealed evidence bag is opened. Instead, an opening can be created by cutting at an area distal from the existing seal. After analysis is complete, the evidence packaging should be resealed. Table 1.1 summarizes additional steps for packaging evidence.

1.9 Final Survey and the Release of the Crime Scene

During a final survey, a discussion with all personnel in the crime scene investigation team should be carried out to thoroughly review all aspects of the search. It is important to ensure

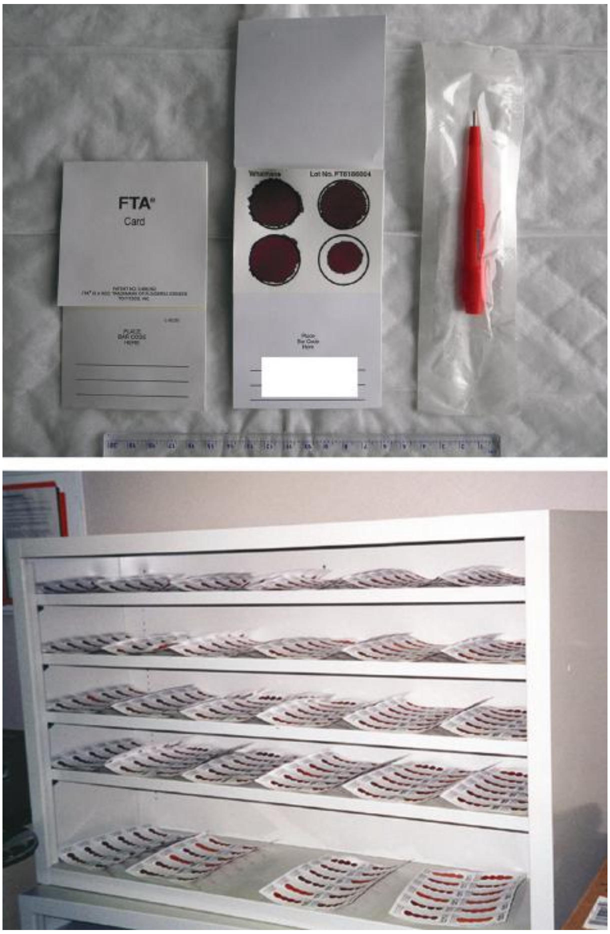

Figure 1.37 Blood cards are typically used for collecting blood evidence from a known source such as a suspect or a victim (top). A manual hole punch can be used to create a blood card punch for DNA extraction. Blood samples are air-dried on blood cards for storage (bottom). (© Richard C. Li.)

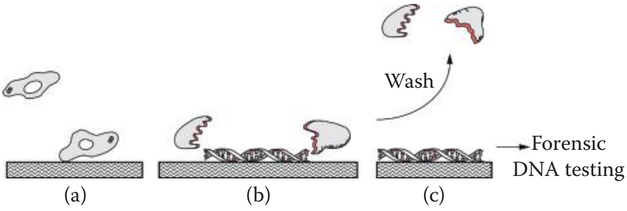

Figure 1.38 Application of Flinders Technology Associates (FTA) filter paper for the collection of biological evidence. (a) Biological fluid with cells is applied to FTA paper. (b) Cells are lysed and DNA is immobilized on FTA paper. (c) Cellular materials are washed away and DNA remaining on the FTA paper can be used for forensic testing. (© Richard C. Li.)

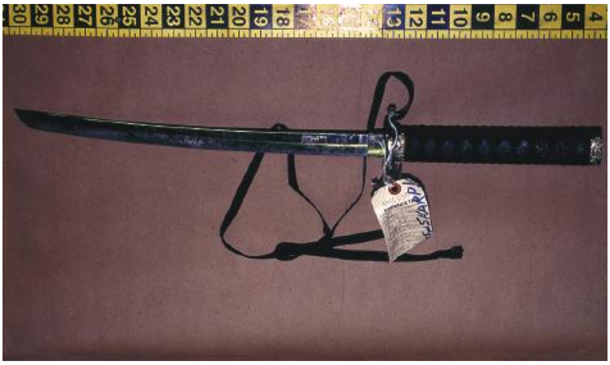
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Figure 1.39 Photographic documentation of a knife. Note the evidence tag. (© Richard C. Li.)

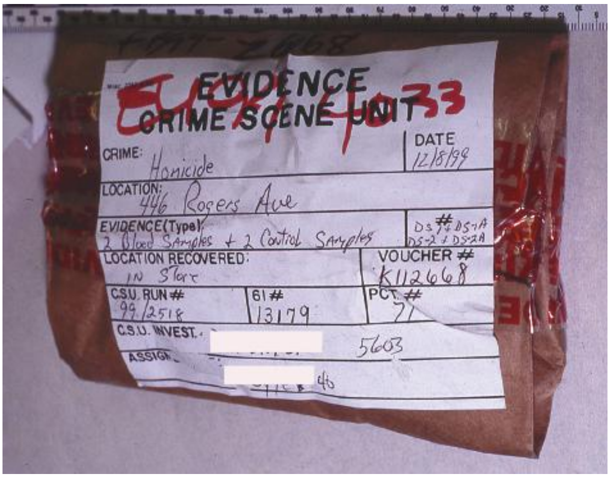

E094033

EVIDENCE
CRIME SCENE UNIT

CRIME: Homicide	DATE 12/8/99
LOCATION: 446 Rogers Ave	
EVIDENCE(Type): 2 Blood Samples + 2 Control Samples	DS # 1 + DS-1A DS-2 + DS-2A
LOCATION RECOVERED: IN Store	VOUCHER # K112668

C.S.U. RUN # 99/2518	61 # 13179	PCT. # 77

C.S.U. INVEST. [redacted] 5603
ASSIGN. [redacted] 46

Figure 1.40 Evidence containing dried bodily fluid stains is packed in a paper bag. (© Richard C. Li.)

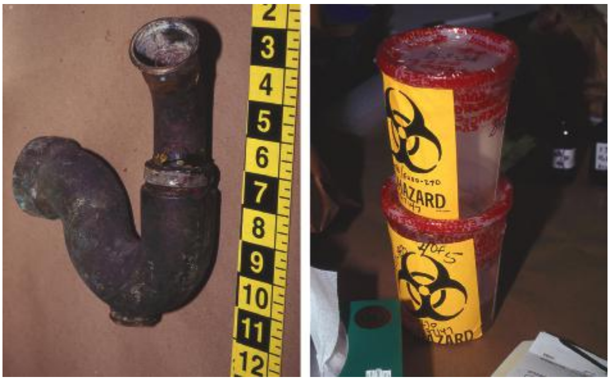
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12
HAZARD
4 OF 5
HAZARD

Figure 1.41 Alleged diluted blood collected from a pipe (left) and placed in plastic containers (right). (© Richard C. Li.)

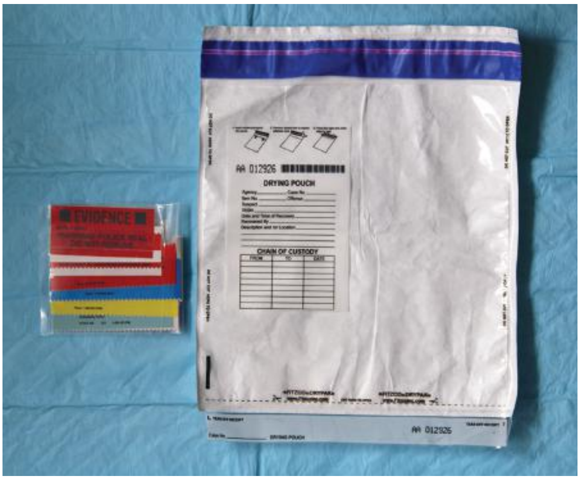

Figure 1.42 Evidence pouch. The front of the pouch is transparent for viewing the content. The back of the pouch is made of breathable materials allowing wet evidence, such as swabs, to dry inside the pouch. (© Richard C. Li.)

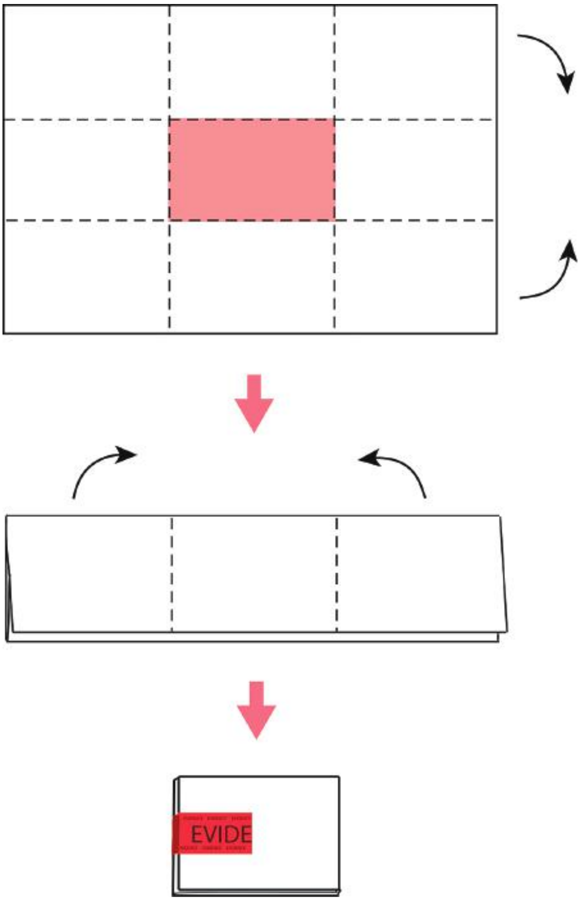

Figure 1.43 An example of a druggist's fold. Trace evidence should be deposited in the center (colored area) of the paper. (© Richard C. Li.)

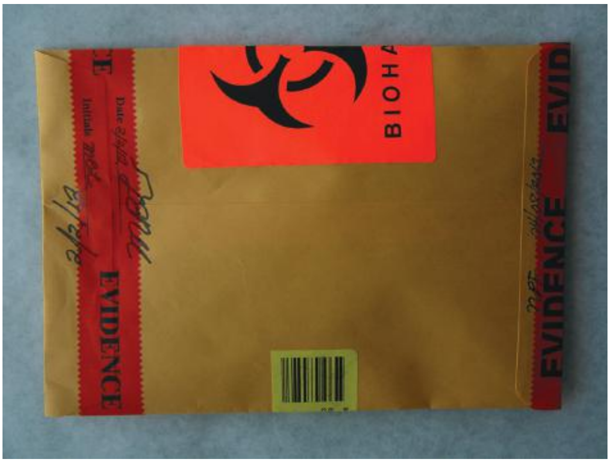

Figure 1.44 Proper marking of sealed evidence. Note that the evidence packaging was cut a second time and resealed at a different location than that of the preexisting seal. (© Richard C. Li.)

that the scene has been searched correctly and completely, and that no area has been missed or overlooked. All documentation including the chain of custody document must be complete and all evidence should be collected, packed, documented, and marked. Photographs of the final condition of the scene should be taken. Once the final survey is completed, the crime scene can be released. Reentry into the crime scene may require a search warrant after the scene is released. Crime scene release documentation usually includes the time and date of release, to whom it is released, and by whom it is released.

1.10 Crime Scene Reconstruction

Crime scene reconstruction is the scientific process of determining the sequence of events and actions that occurred prior to, during, and after a crime. Reconstruction is carried out based on the information from the crime scene observations and the laboratory examination of physical evidence. The overall scientific process in reconstruction usually involves several steps. The process usually begins with the formulation of questions related to the problems that need to be solved. The questions can refer to the explanation of the specifics of the crime, for instance, "Where was the shooter's position when the shooting occurred?," "Where was the victim's position when shot?," and "What is the muzzle-to-target distance during the shooting?" In order to conduct a thorough crime scene reconstruction, all useful information is collected for review, such as photographs, videotapes, notes, sketches, autopsy reports, and analysis reports of the physical evidence. A hypothesis is then constructed based on the information obtained, which may explain the events and actions involved in a crime. The next step is making predictions that determine the logical consequences of the hypothesis. One or more predictions are selected for testing. The hypothesis is tested by conducting reconstruction experiments. One example of a reconstruction test is bloodstain pattern reconstruction in violent crimes (Chapter 2). Other examples of reconstruction may include trajectory and shooting, glass fracture, and accident reconstruction. The final step is to analyze experimental data and draw a conclusion. The experimental data are analyzed to see if the hypothesis is true or false. Additionally, the interpretation of physical evidence analysis, witness and confession statements, and investigative information should also be considered.

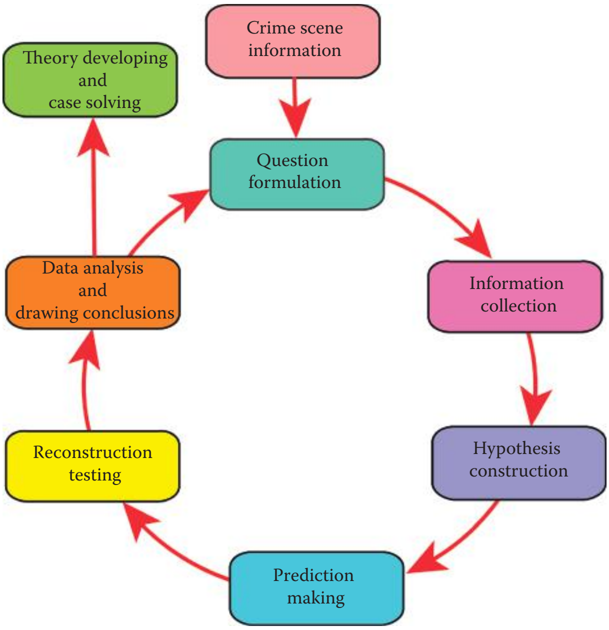
Crime scene information
Theory developing and case solving
Question formulation
Data analysis and drawing conclusions
Information collection
Reconstruction testing
Hypothesis construction
Prediction making

Figure 1.45 The scientific process of crime scene reconstruction. (© Richard C. Li.)

If the results of the experiment are consistent with the hypothesis, a theory can be developed that is intended to provide valuable information to the investigation and future prosecution of a case. Sometimes, forensic scientists may find that the hypothesis is inconsistent with the test results. In that case, an alternative hypothesis needs to be constructed to initiate another reconstruction process. Figure 1.45 illustrates the scientific process of crime scene reconstruction.

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2

Crime Scene Bloodstain Pattern Analysis

Bloodstain pattern analysis is the application of scientific knowledge to the examination and the interpretation of the morphology, the sequence, and the distribution of bloodstains associated with a crime. These analyses may determine the sequence of events; the approximate blood source locations; the positioning of the victim; and the position, the intensity, and the number of impacts applied to the blood source. They also can assist in the determination of the manner of death and can distinguish between accidents, homicides, and suicides. Bloodstain pattern analysis provides critical information for crime scene reconstructions in violent crime investigations (Chapter 1).

2.1 Basic Biological Properties of Human Blood

Blood is a bodily fluid circulating within the body. An average adult has a blood volume of approximately 8% of his or her body weight. Blood consists of a cellular portion as well as a liquid portion known as plasma (Chapter 12). The cellular portion consists of blood cells and platelets. The plasma is mostly composed of water and other substances such as proteins, inorganic salts, and other organic substances. The mass density of blood is only slightly greater than that of water. Blood can form clots (or *thrombi*) that are the result of blood coagulation (Chapter 16). Coagulation begins after an injury occurs, stopping blood loss from a damaged vessel. The normal coagulation time for 1 mL of venous blood in a glass tube is 5–15 min. The coagulation time can be affected by many factors such as blood volume and mechanical disturbance.

2.2 Formation of Bloodstains

The formation of a blood droplet is a complex event that is influenced by viscosity, surface tension, cohesion force, and gravity. Blood is viscous, and blood viscosity is a measure of the blood's resistance to flow. The viscosity of blood is approximately five times greater than that of water. During the formation of a drop of blood, blood leaks out from a blood source. The surface tension of the blood causes it to hang from the opening of a blood source and to form a pendant drop of blood (Figure 2.1). The molecules of a blood drop are held together by the cohesion force to maintain the shape of a blood drop (Figure 2.2). Surface tension causes liquids to minimize their surface. As a result, the formed blood drop is spherical. As the volume of the drop gradually increases and exceeds a certain size, it detaches itself and falls. The falling drop is also held

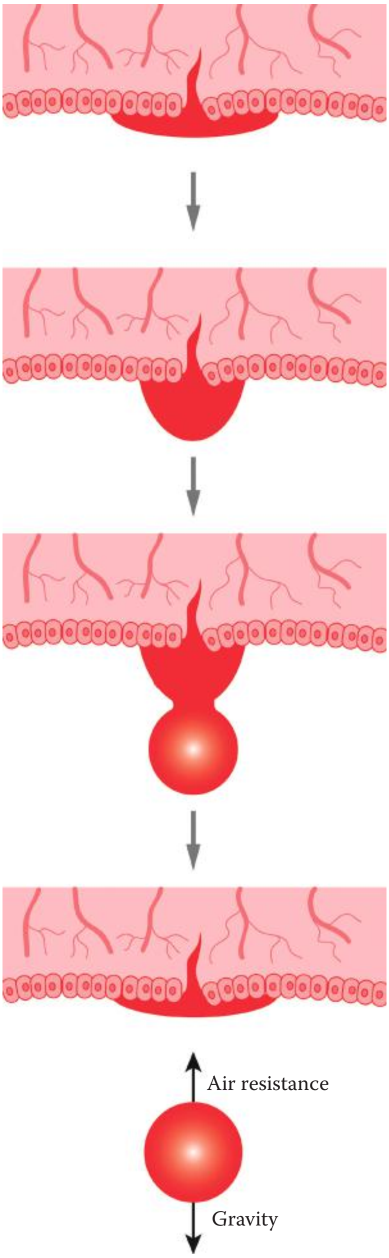

Figure 2.1 Forming a blood drop from a blood source. The blood that leaks out of the blood source forms a pendant drop of blood. As the volume of the pendant drop increases, the drop stretches in a downward direction. Eventually, the drop detaches and falls. The falling drop is largely influenced by the force of gravity and air resistance. (© Richard C. Li.)

together by surface tension. A falling blood drop is influenced by the downward force of gravity acting on the drop and the air resistance that acts in the opposite direction as the drop is in motion (Figure 2.1).

When a bloodstain lands on a surface, the shape and the size of the bloodstain is affected by the texture of the target surface. Bloodstains that land on porous or rough surfaces usually

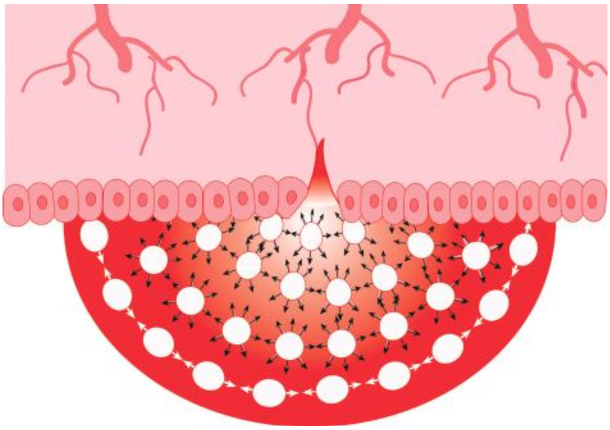

Figure 2.2 The particles of blood are attracted to each other by cohesive forces that are responsible for surface tension. As a result, a formed blood drop is spherical in order to minimize its surface area. Black arrow, cohesive force; white arrow, surface tension. (© Richard C. Li.)

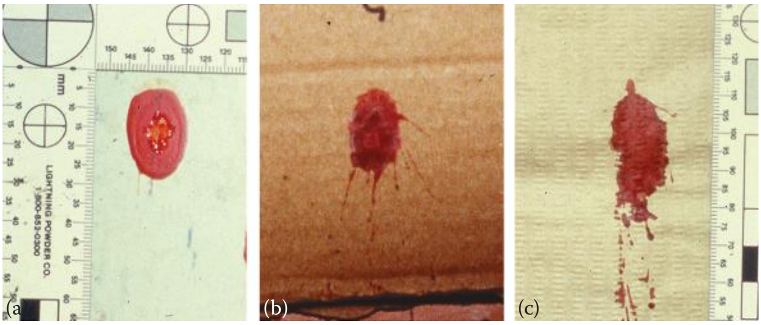

Figure 2.3 The respective morphologies of falling blood drops that land on surfaces with different textures at a 30° angle. (a) Tile, (b) cardboard, and (c) paper towel. (© Richard C. Li.)

have more distortion around the edges of the stains than those that land on smooth surfaces. A comparison of blood dropped onto different textures of target surfaces is shown in Figure 2.3.

2.3 Chemical Enhancement and Documentation of Bloodstain Evidence

Many chemical reagents react with blood to exhibit a color, a chemiluminescent light, or a fluorescent light (Chapter 12). These tests are extremely sensitive and thus are used as chemical enhancement reagents for detecting bloodstains. For bloodstain pattern analysis, the enhancement reagent is primarily used for detecting latent bloodstains such as diluted bloodstains that are visible on enhancement. A commonly used chemical reagent is luminol, which can be used for locating bloodstains at the scene. Other reagents such as phenolphthalein, leucomalachite green, and tetramethylbenzidine are not often used as enhancement reagents but rather as presumptive tests for blood. The positive reactions of all these reagents indicate the presence of blood.

Documenting bloodstain patterns at the scene is a major task of the investigation. Documenting bloodstain evidence can be done using a combination of photography, note-taking, and sketching. The general principle of crime scene documentation is described in Chapter 1. In bloodstain pattern analysis, special attention must obviously be given to bloodstains. The photographic documentation of bloodstains may be performed by multiple means, including film and digital photography, as well as videotaping. Photographs should be taken with an overall view followed by a medium-range and a close-up view of the bloodstain patterns. A scale of measurement must be included in the photograph, which is critical for bloodstain analysis. To avoid any distortion, the photographs should be taken with the camera lens parallel to the target surface where the bloodstains are located. An overall photograph provides an overall view of the scene including the bloodstain evidence (Figure 2.4a). A midrange photograph provides more details of the bloodstain pattern compared with that of the overall photograph (Figure 2.4b). Single bloodstains should be visible in midrange images. A close-up photograph, usually taken with a macro lens, provides a detailed image of single bloodstains, which is useful for spatter pattern analysis (Figure 2.4c).

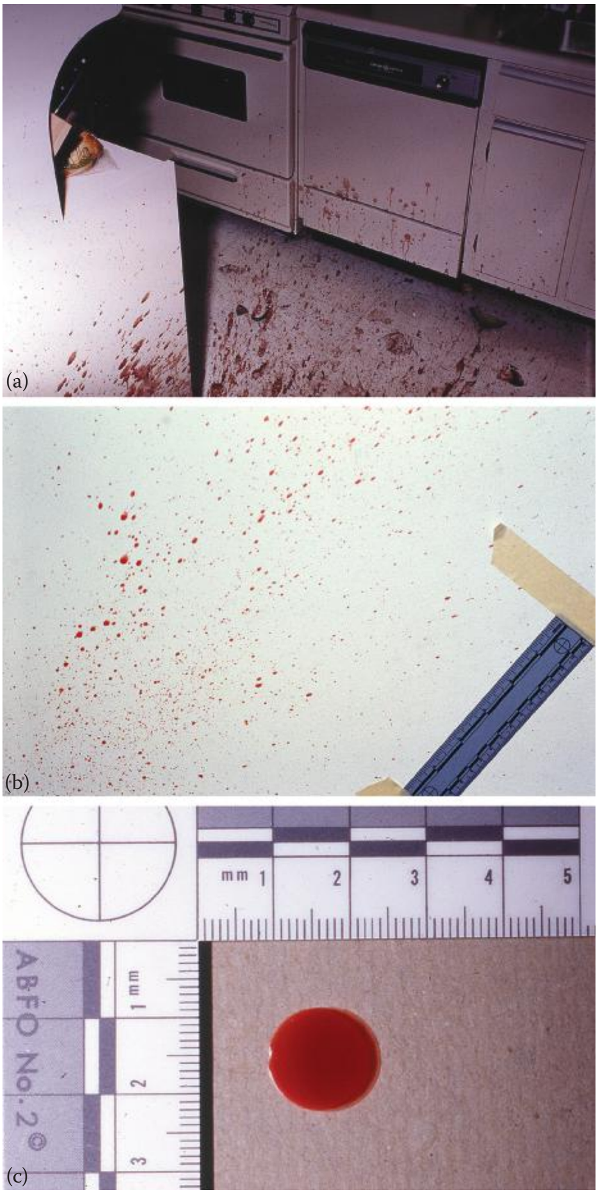

Figure 2.4 Crime scene photographic documentation. (a) Overall, (b) midrange, and (c) close-up photographs. (© Richard C. Li.)

2.4 Analyzing Spatter Stains

A *spatter stain*, based on the recommended terminology of the Scientific Working Group on Bloodstain Pattern Analysis (SWGSTAIN), is "a bloodstain resulting from a blood drop dispersed through the air due to an external force applied to a source of liquid blood." The patterns of spatter stains, including the shape and the size of the stains, are affected by the direction and the angle of impact (discussed in detail in Section 2.5.3) of the spatter stains that are projected. This information can be obtained from an analysis of the patterns of the spatter stains. Thus, it is possible to determine the area of origin (discussed in detail in Section 2.4.4) where an external force was directly applied to the blood source.

2.4.1 Velocity of Blood Droplets

The sizes of bloodstains are affected by the external force that is directly applied on a blood source. Increasing the energy of the external force will reduce the surface tension, thus decreasing the size of the droplets. Since these travelling blood droplets are driven by the energy derived from the external force, the higher the energy, the higher the velocities of the droplets. Bloodstains can be divided into three categories based on different travelling speeds. Low-velocity impact spatter is formed when a blood droplet is travelling at <1.5 m/s. The resulting stains are usually >4 mm in diameter (Figure 2.5a). As the travelling speed of blood droplets increases, the size of the spatter stain decreases. Medium-velocity impact spatter is formed when a blood source is subjected to a force associated with beatings or stabbings. The resulting stains range from 1 to 4 mm in diameter (Figure 2.5b). High-velocity impact spatter is formed when a blood source is subjected to a force associated with shooting using firearms. The resulting stains are usually <1 mm in diameter.

2.4.2 Determining the Directionality of the Stains

In this analysis, the effects of the directionality of the spatter stains projected are examined. SWGSTAIN defines the directionality to be "the characteristic of a bloodstain that indicates the direction blood was moving at the time of deposition." This analysis is applicable when the blood source is projected onto a surface at an angle of between 0° and 90°. Under this condition, the resulting spatter stain is an elongated ellipse (Figure 2.6), which is known as the *parent stain*. Additionally, *satellite stains* in the vicinity of the parent stain can be observed. As defined by SWGSTAIN, a satellite stain is "a smaller bloodstain that originated during the formation of the parent stain as a result of blood impacting a surface." More importantly, a spine is observed, which is the pointed edge away from the parent stain. When such a pattern is observed, the pointed end of the spine always points toward the direction of travel of the bloodstains.

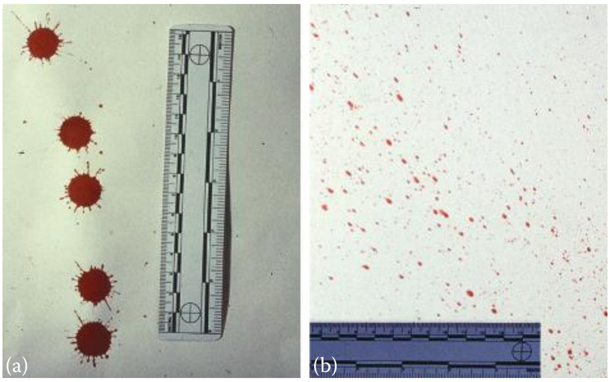

Figure 2.5 Bloodstains can be categorized based on their travelling velocities. (a) An example of a low-velocity impact spatter stain and (b) an example of a medium-velocity impact spatter stain. (© Richard C. Li.)

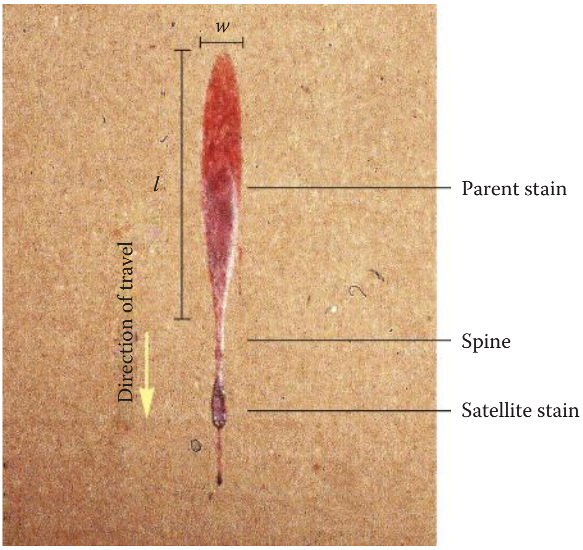

Figure 2.6 The morphology and directionality of a blood spatter stain. The arrow indicates the direction of travel. (© Richard C. Li.)

2.4.3 Determining Angles of Impact

SWGSTAIN defines the *angles of impact* to be "the acute angle (alpha), relative to the plane of a target at which a blood drop strikes the target." The shapes of the spatter stains are affected by the angle of impact. When a blood drop lands on a surface at a perpendicular angle (90°), a circular parent stain is formed (Figure 2.7), where the length and the width of the stain are equal. When a blood drop is projected onto a surface at an angle of between 0° and 90°, the stain is elongated. As the impact angle decreases, the shape of the spatter stain is more elongated (Figure 2.7), in which the length of the stain is greater than the width. It is observed that the ratio of the width and the length of the parent stain is proportional to the sine of the impact angle, which is summarized in the following trigonometric equation:

$$\sin \alpha = \frac{w}{l}$$

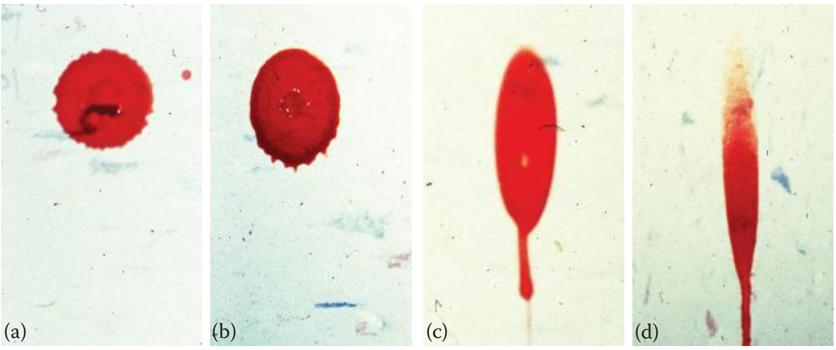

Figure 2.7 The effects of the impact angle on the shapes of blood spatter stains. Spatter stains are projected onto the surface of a ceramic tile at: (a) 90°, (b) 50°, (c) 20°, and (d) 10°. (© Richard C. Li.)

In this equation, α is the angle of impact, *l* is the length of the parent stain (major axis), and *w* is the width of the parent stain (minor axis). Thus, the angle of impact can be determined based on the relationship between the length and the width of the stain (Figure 2.8). Obviously, the measurement of the stain's axes is critical to the accuracy of the calculation of the angle of impact. To produce accurate and reproducible measurements, bloodstain pattern analysis software can be used, which superimposes a scaled close-up image of an individual bloodstain and calculates the angle of impact.

2.4.4 Determining Area of Origin

SWGSTAIN defines the *area of origin* to be "the three-dimensional location from which spatter originated." Using simple trigonometry, the area of origin can be determined based on the measurements from multiple elongated spatter stains (Figure 2.9). This can be accomplished by using the string method or the tangent method.

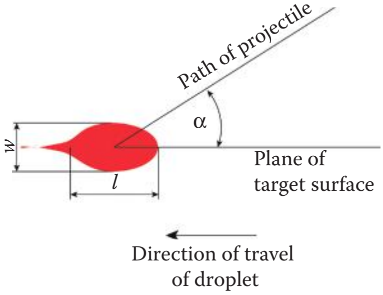

Figure 2.8 Impact angle. The angle between the path of a projectile and the plane of the target surface is shown. α, the impact angle; *l*, the length of the parent stain; and *w*, the width of the parent stain. (© Richard C. Li.)

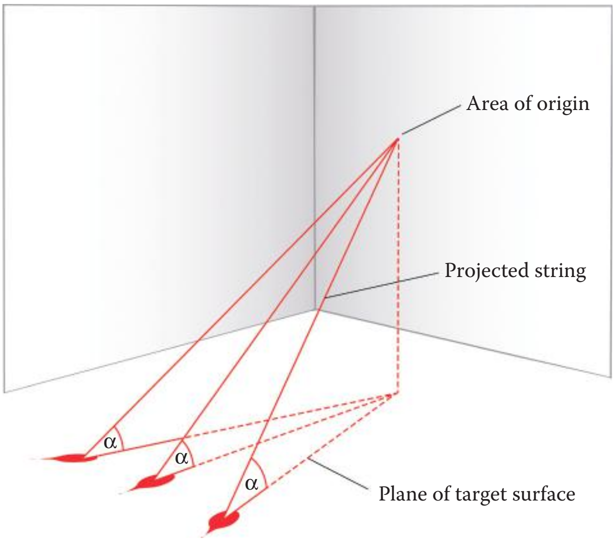

Figure 2.9 Area of origin. The area of origin is determined using the string method. Only three representative bloodstains are shown. α, impact angle. (© Richard C. Li.)

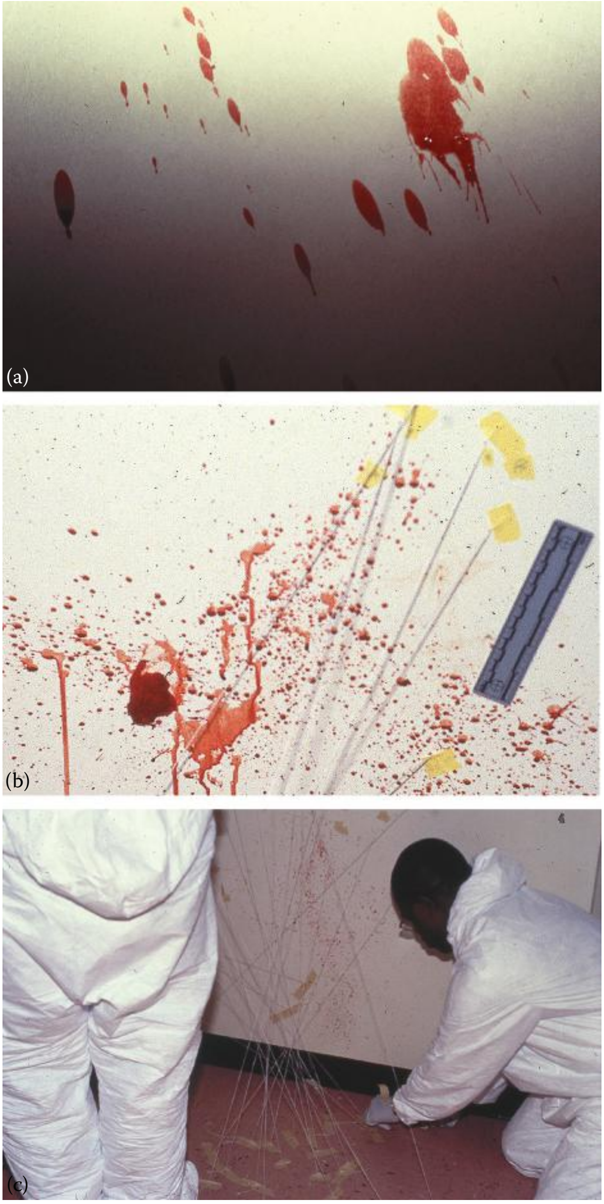

Figure 2.10 Determining the area of origin using the string method. (a) Selecting elongated spatter stains, (b) connecting strings, and (c) setting the path of the strings. (© Richard C. Li.)

In the string method, multiple (approximately two dozen) well-formed, elongated spatter stains are selected for analysis (Figure 2.10a). For each stain, the angle of impact is calculated. A piece of string is then connected between the stain and a surface with one end of the string precisely attached to the spatter stain (Figure 2.10b). The path of the string, indicating the trajectory of the stain, is set using a protractor based on the calculated angle of impact (Figures 2.10c and 2.11). This process is repeated until all the stains that have been selected are processed. For

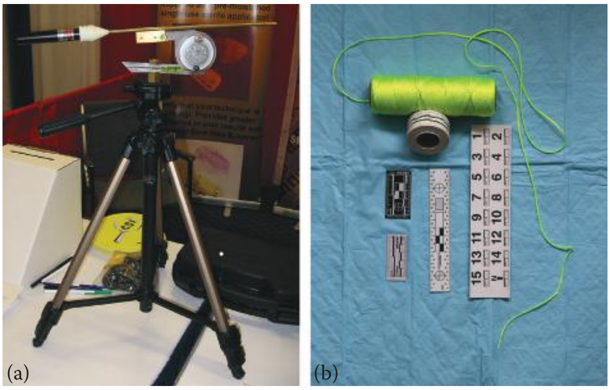

Figure 2.11 Tools for finding the area of origin. (a) Laser trajectory pointer and (b) string and scales. (© Richard C. Li.)

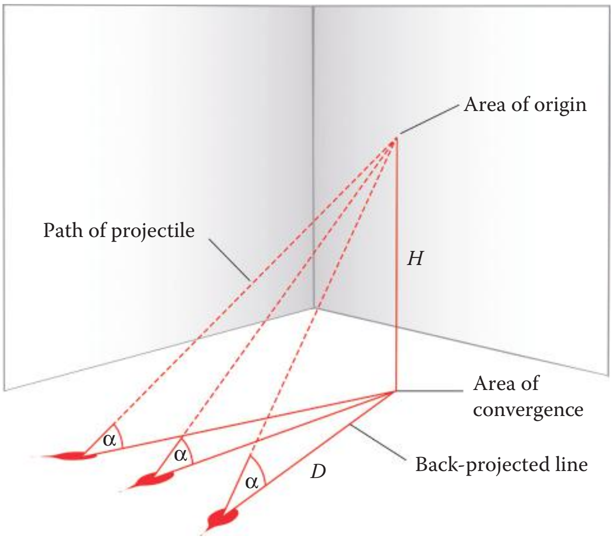

Figure 2.12 Determining the area of origin using the tangent method. Only three representative bloodstains are shown. α, the angle of impact; *H*, the height of the area of origin; and *D*, the distance from the spatter stain to the area of convergence. (© Richard C. Li.)

a spatter pattern generated from a single impact event, the strings converge. The area where the strings meet is the area of origin.

In the tangent method, the directionality of a single stain is determined first. A line is then back projected through the major axis of the bloodstain. For a single impact event, approximately two dozen stains are processed to determine the *area of convergence*. Based on SWGSTAIN's definition, the area of convergence is "the area containing the intersections generated by lines drawn through the long axes of individual stains that indicates in two dimensions the location of the blood source." Next, the angle of impact of each stain is calculated. The distance from the bloodstain to the area of convergence is measured (Figure 2.12). The height of the area of origin is calculated using the tangent function as shown:

$$H = D \cdot \tan \alpha$$

In the equation, α is the angle of impact, H is the height of the area of origin, and D is the distance from the spatter stain to the area of convergence.

2.5 Types of Bloodstain Patterns

Bloodstain patterns can be classified into three basic categories: passive, transfer, and projected bloodstains.

2.5.1 Passive Bloodstains

A *passive bloodstain* is formed due to bleeding from wounds, and the blood is deposited on a surface by the influence of the force of gravity alone. For example, a *drip stain* is formed when a falling drop of blood from an exposed wound or a blood-bearing object lands on a surface. If a blood source is moving, a *drip trail* is formed. A *drip pattern*, which is distinct from a drip stain, is formed when a liquid drips into another liquid, where one or both of the liquids are blood (Figure 2.13). As a result, secondary spatter stains are generated. As the dropping distance of the blood increases, the number of secondary spatter stains usually increases, and the size of these stains decreases. An approximate estimation of the dropping distance is possible. A *splash pattern* is formed when a volume of blood spills onto a surface (Figure 2.14). Splash patterns usually

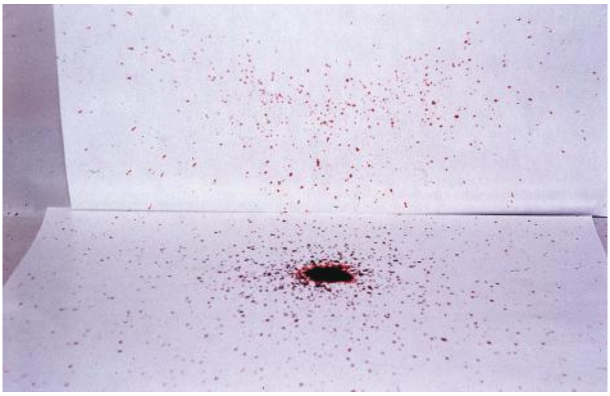

Figure 2.13 A drip pattern. The secondary spatter stains are shown. (© Richard C. Li.)

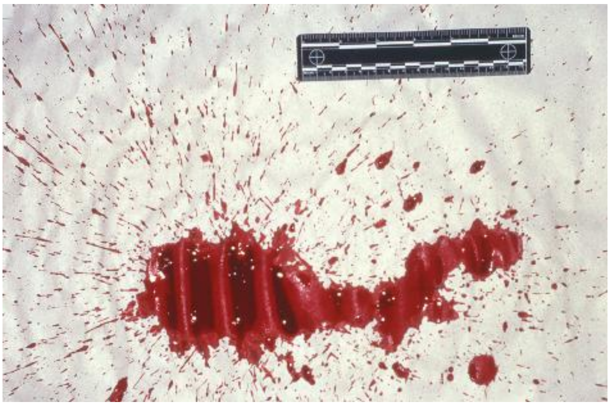

Figure 2.14 A splash pattern. Peripheral, elongated bloodstains are shown. (© Richard C. Li.)

have large stains surrounded by numerous, peripheral, elongated bloodstains. A *flow pattern* is caused by the movement of a large volume of blood on a surface either due to gravity or to the movement of the target such as a victim or postmortem disturbance. A *pool* is a bloodstain resulting from the accumulation of liquid blood on a surface (Figure 2.15). Sometimes, air bubbles in the blood may cause a *bubble ring* pattern (Figure 2.15). If blood is coagulated, gelatinous *blood clots* can be observed. Additionally, a *serum stain*, which consists of the liquid portion of the blood after a clot is formed, may also be present.

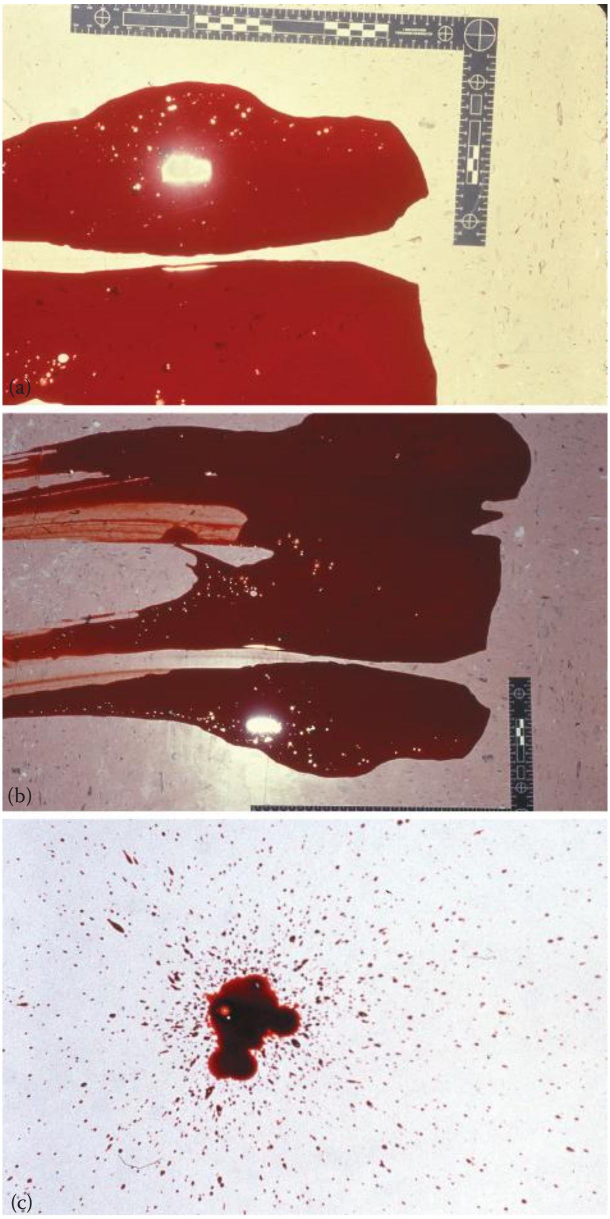

Figure 2.15 Pool and bubble ring patterns. (a) A pool pattern, (b) a disturbed pool pattern, and (c) a splash pattern with a bubble ring. Bubble rings are also present in (a) and (b). (© Richard C. Li.)

2.5.2 Transfer Bloodstains

A *transfer bloodstain*, based on SWGSTAIN, is “a bloodstain resulting from contact between a blood-bearing surface and another surface.” For example, a *swipe pattern* is “a bloodstain pattern resulting from the transfer of blood from a blood-bearing surface onto another surface, with characteristics that indicate relative motion between the two surfaces.” For example, bloody impressions can provide information about the shape, the size, and the pattern of the objects such as finger ridges, hands, and shoe soles. Examples of hand and shoe swipe patterns are shown in Figures 2.16 and 2.17. A *wipe pattern* is “an altered bloodstain pattern resulting from an object moving through a preexisting wet bloodstain.” Examples of wipe patterns are shown in Figures 2.18 and 2.19. A *perimeter* stain, a type of wipe pattern, is a bloodstain that is disturbed before it is dried but it maintains the peripheral characteristics of the original stain (Figure 2.20). Perimeter stain patterns can be useful for the estimation of sequential events of acts. The pattern can also be used to estimate a time frame between the time of bleeding and the subsequent act. However, the drying time of a blood drop varies based on the surrounding conditions. Therefore, it is necessary to carry out a crime scene reconstruction under similar conditions to those of the scene to make such estimations.

2.5.3 Projected Bloodstains

A *projected bloodstain* is formed when a volume of blood is deposited on a surface under a pressure or a force that is greater than the force of gravity. For example, an *impact pattern* is

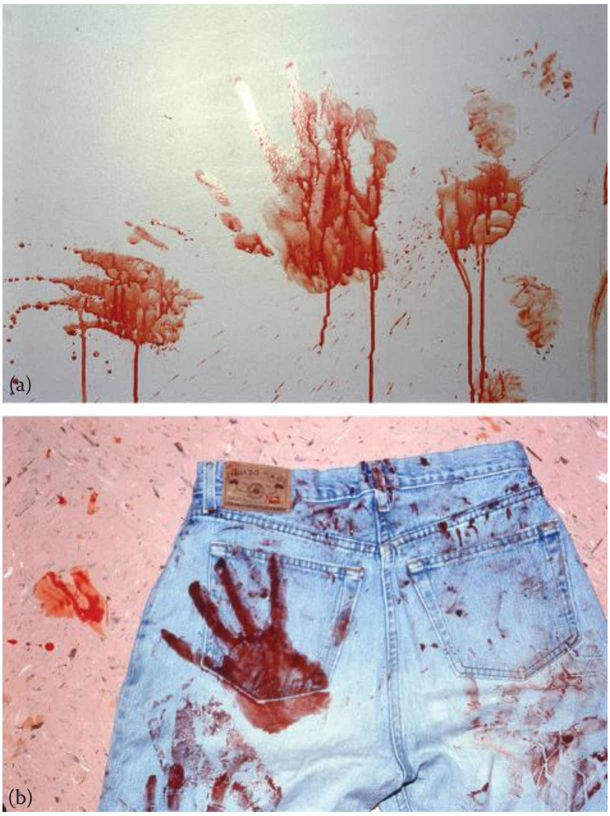

Figure 2.16 Bloody impressions. Bloody handprints are present on (a) a wall and (b) fabric. (© Richard C. Li.)

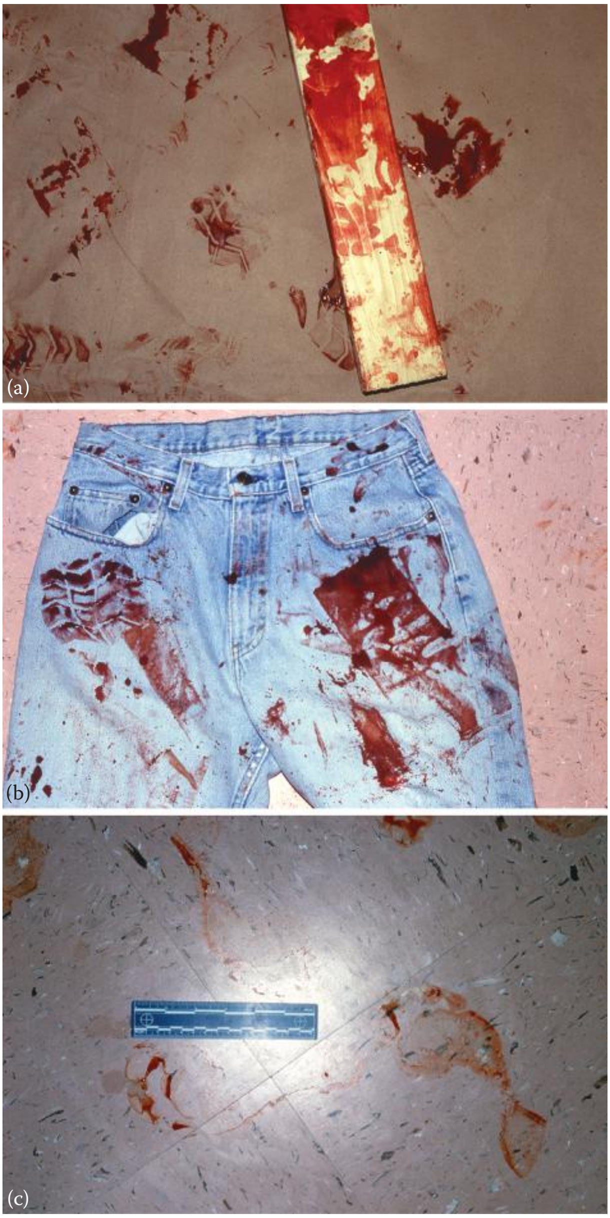

Figure 2.17 Bloody impressions. Bloody shoe prints on (a) paper and (b) fabric; and (c) bloody footprints on tile. (© Richard C. Li.)

formed when an object strikes liquid blood (Figure 2.21). A *cast-off pattern* is formed when blood drops are released from a moving blood-bearing object (Figure 2.22). Some spatter patterns are often associated with a wound penetrated by a projectile (Figure 2.23). A *forward spatter* is formed when blood drops travel from an exit wound in the same direction as a projectile, while a *back spatter* is formed when blood drops travel from an entry wound in the opposite direction of a projectile. Sometimes, internal bleeding caused by an injury may block the airway. An *expiration pattern* is formed when blood is forced by airflow through the

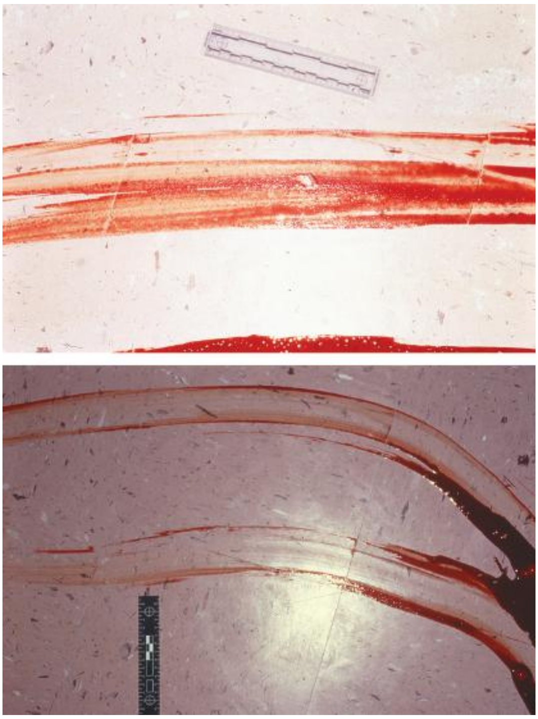

Figure 2.18 Wipe patterns. (© Richard C. Li.)

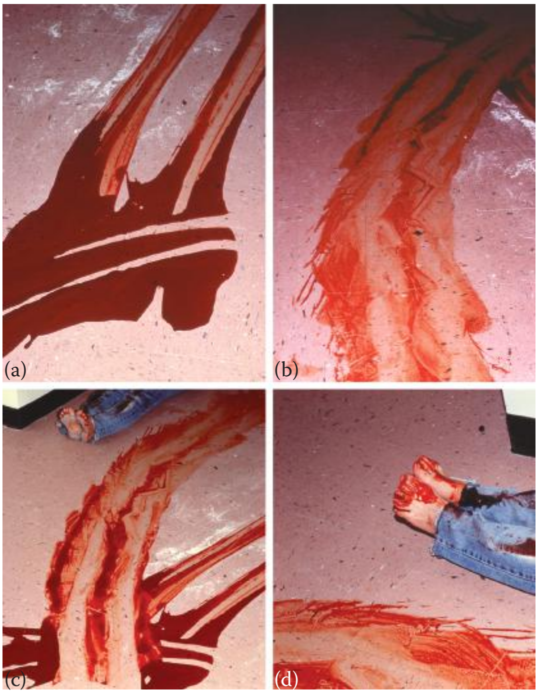

Figure 2.19 A wipe pattern caused by dragging a body through a pool of blood. (a) A pool of blood. Sections of the wipe pattern caused by dragging are shown in (b), (c), and (d). (© Richard C. Li.)

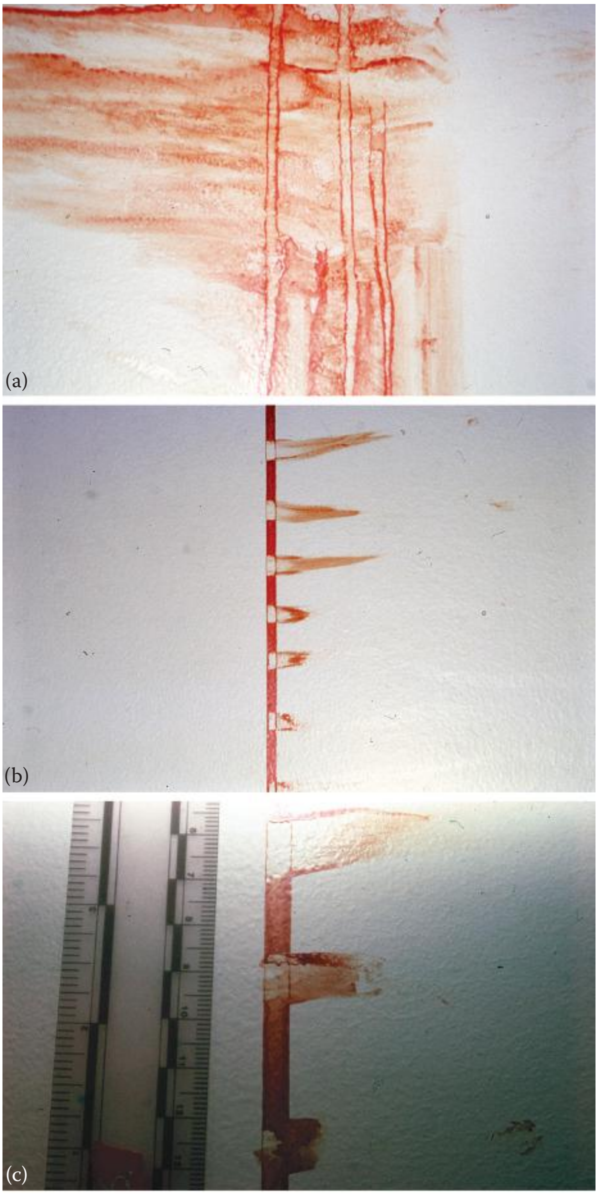

Figure 2.20 Perimeter stains. (a) Peripheral characteristics of the original stains are shown. Perimeter stains were created at different periods of time after the original stain was formed: (b) midrange view and (c) close-up view. (© Richard C. Li.)

trachea and out of the nose or mouth (Figure 2.24). An *arterial spurt pattern* is associated with wounds damaging arterial blood vessels where bloodstains are driven by arterial pressure. Although the shape of arterial patterns varies, these patterns usually have a series of large spurts with fluctuations corresponding to the systolic and the diastolic blood pressures. At a crime scene, if the projectile of bloodstains is blocked by an object, a *void pattern* is formed, which exhibits an area where there is an absence of blood surrounded by continuously distributed bloodstains.

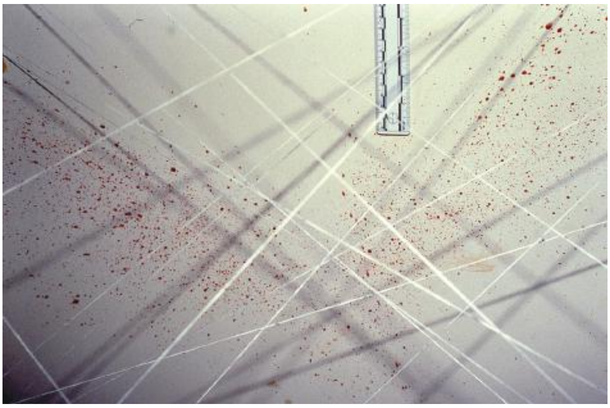

Figure 2.21 An impact bloodstain pattern as a result of using blunt force. (© Richard C. Li.)

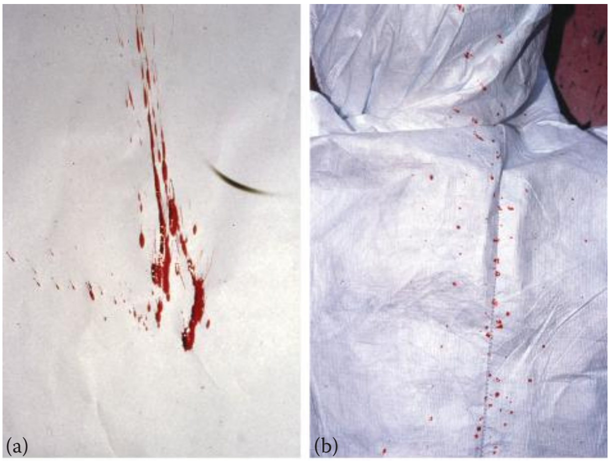

Figure 2.22 Cast-off patterns. Spatter stains are projected onto (a) a covered wall and (b) a lab coat. (© Richard C. Li.)

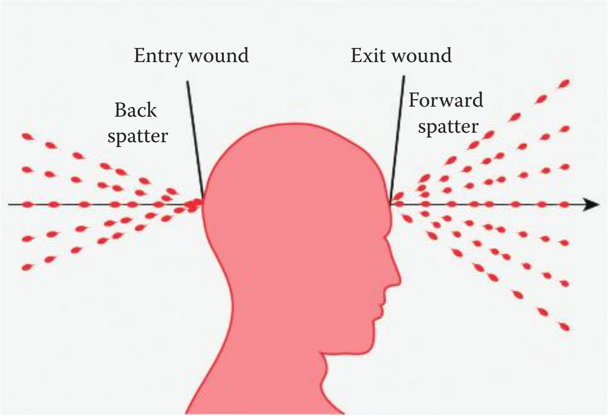
Entry wound
Back spatter
Exit wound
Forward spatter

Figure 2.23 Forward and back spatter patterns. Arrow, the direction of a projectile. (© Richard C. Li.)

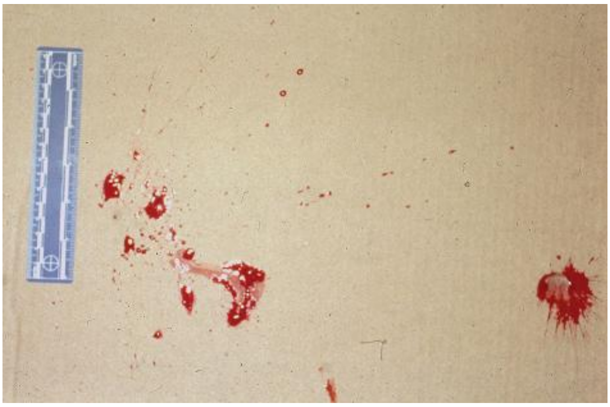

Figure 2.24 An expiration pattern. (© Richard C. Li.)

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3

Forensic Biology

A Subdiscipline of Forensic Science

Forensic laboratories provide scientific analysis, evidence evaluation, and consultations to various criminal justice agencies for the investigation of criminal cases. Additionally, forensic laboratories provide expert testimony related to the resolution of criminal cases to the courts.

3.1 Common Disciplines of Forensic Laboratory Services

Many of the disciplines of the forensic laboratory services are commonly practiced in various municipal, county, state, and federal forensic laboratories in the United States. Forensic biology is a subdiscipline of forensic science. A full range of forensic laboratory services, known as "full service," usually includes: crime scene investigation (Figure 3.1); latent print examination (Figure 3.2); forensic biology (Figure 3.3); controlled substance analysis (Figure 3.4); postmortem toxicology (Figure 3.5); questioned document examination (Figure 3.6); firearm, toolmark, and other impression evidence examination (Figures 3.7 through 3.10); explosive and fire debris examination (Figure 3.11); and transfer (trace) evidence examination (Figures 3.12 and 3.13). Table 3.1 describes the services that are normally provided by a forensic laboratory with their respective analyses.

3.2 Laboratory Analysis of Biological Evidence

Forensic biology uses scientifically accepted protocols to analyze biological evidence. Laboratory analysis (Figures 3.14 and 3.15) utilizes scientific techniques for the examination of evidence, the reconstruction of a crime scene, the identification of biological fluids, and the comparison of individual characteristics of biological evidence.

3.2.1 Identification of Biological Evidence

The identification of biological evidence is the first step that is performed before further analyses are carried out. This includes the identification of biological fluids such as blood, saliva, and semen; this process is discussed in more detail in subsequent chapters (Chapters 12 through 14). The *identification* is based on a comparison of *class characteristics*—a set of characteristics that allows a sample to be placed in a category with similar materials. By comparing the

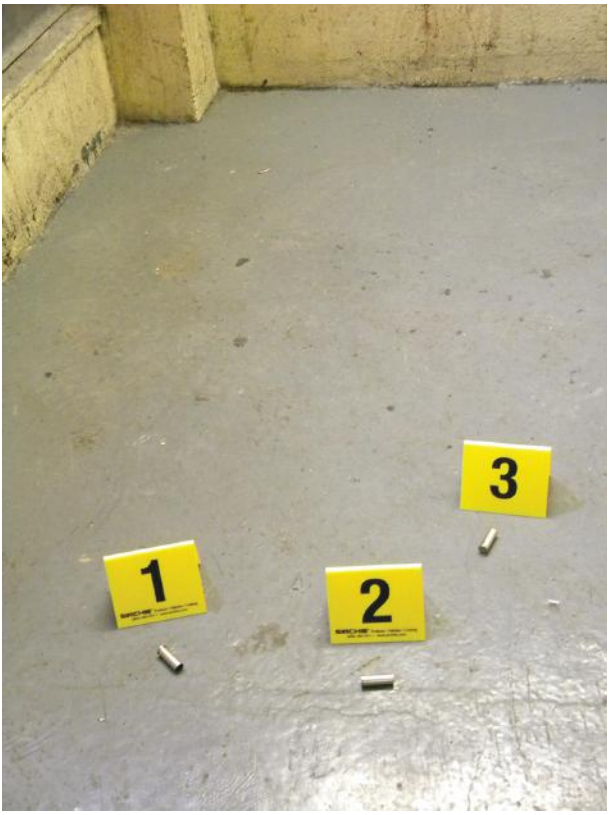

Figure 3.1 Crime scene investigation. Recovery of fired casings at the scene can aid in determining the position of the shooter. (© Richard C. Li.)

class characteristics of a sample with known standards of its class, biological samples can be identified.

3.2.2 Comparison of Individual Characteristics of Biological Evidence

Individual characteristics refer to the unique characteristics of both the evidence and a reference sample such as fingerprints, which share a common origin to a high degree of certainty. An example of biological evidence possessing individual characteristics is DNA polymorphisms. In the case of biological evidence, current forensic DNA profiling can compare individual characteristics of DNA evidence with a known reference sample. It is possible to determine that a biological stain originated from a particular individual, which is useful for human identification. The examination of individual characteristics of evidence can also exclude the possibility of a common origin. The specific methods utilized for the individualization of evidence are also discussed in subsequent chapters (Chapters 19 through 23).

3.2.3 Reporting Results and Expert Testimony

After the analysis of evidence is completed, a report is prepared based on the results of the analysis, which may include sections discussing the specific evidence analyzed, the method of analysis used, the results obtained, and the conclusions drawn. In the case of DNA evidence, the strength of the conclusion is usually evaluated via statistical computations (Chapter 25). A forensic scientist often serves as an expert witness whose testimony

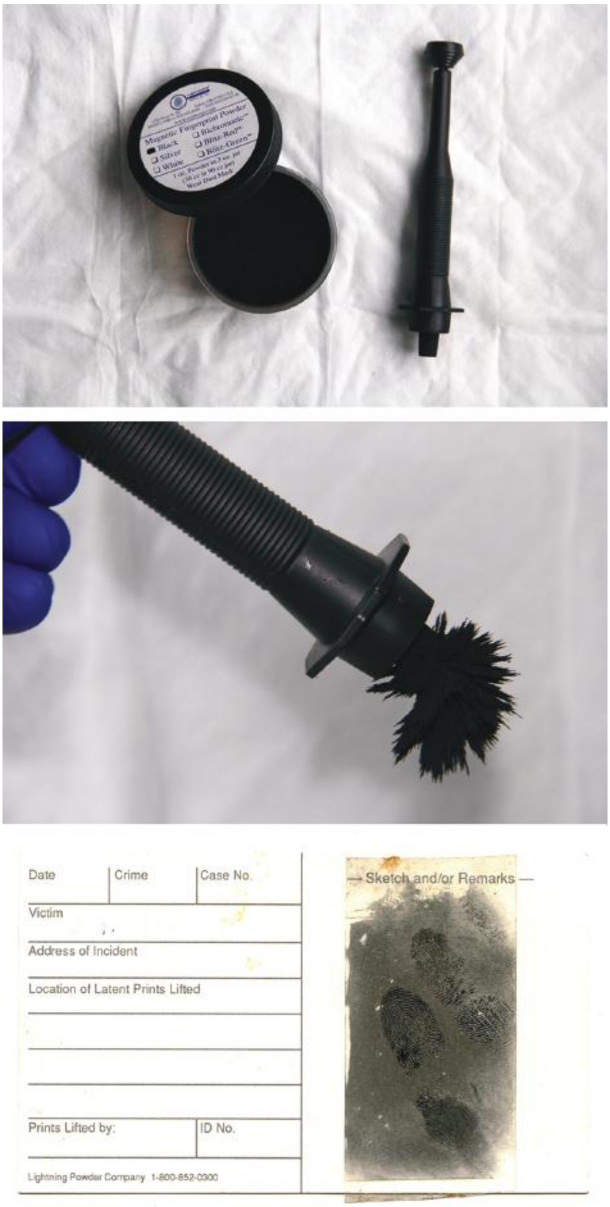

Date | Crime | Case No.
Victim
Address of Incident
Location of Latent Prints Lifted
Prints Lifted by: | ID No.
Lightning Powder Company 1-800-852-0300
— Sketch and/or Remarks —

Figure 3.2 Developing latent fingerprints by dusting methods. Using magnetic fingerprint powder (top) that is held by a magnetic applicator (middle). Fingerprints (bottom) dusted by magnetic fingerprint powder, tape lifted and preserved on a fingerprint card. (© Richard C. Li.)

provides professional opinions about the evidence analyzed. Based on the federal rules of evidence, an expert witness is qualified based on his or her knowledge, skill, experience, training, or education, and may give an opinion to the court that is relevant to the analyses conducted. However, forensic scientists must also communicate their findings to attorneys, judges, and members of a jury. This requires the translation of technical information into layman's terms.

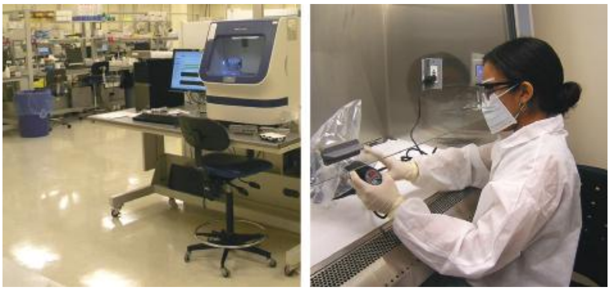

Figure 3.3 A section of a forensic biology laboratory showing an automated electrophoresis instrument used for forensic DNA profiling (left). Processing biological evidence in a biosafety cabinet (right). (© Richard C. Li.)

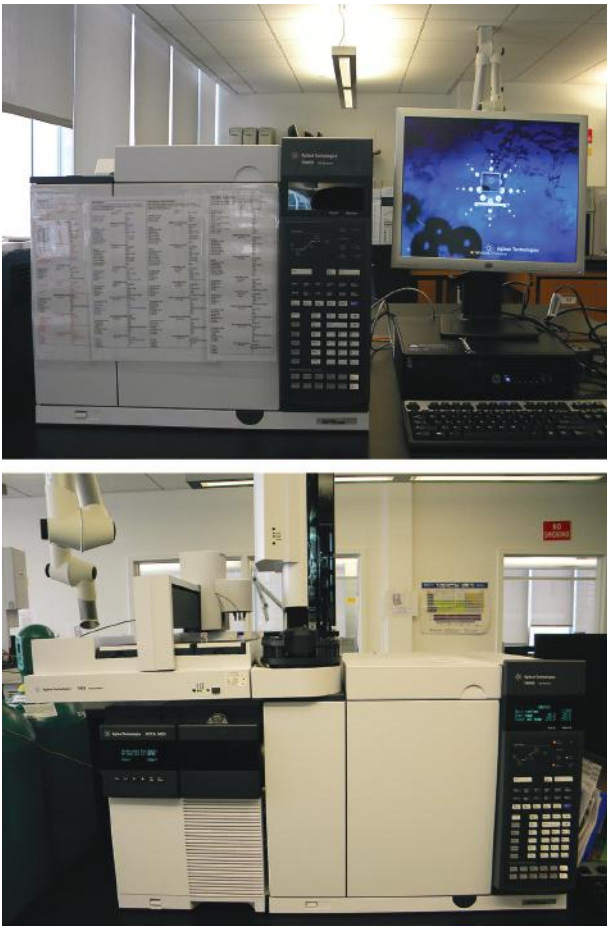

Figure 3.4 Gas chromatograph (top) and gas chromatograph-mass spectrometer (bottom) used for controlled substance analysis. (© Richard C. Li.)

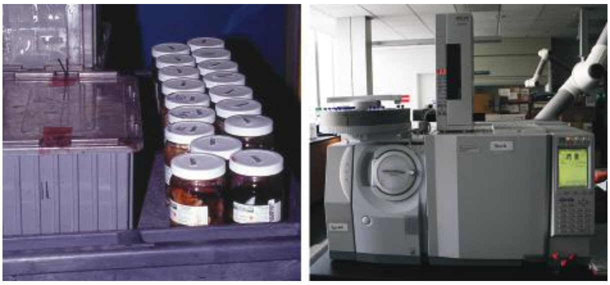

Figure 3.5 Tissue samples (left) and gas chromatograph-mass spectrometer (right) for forensic postmortem toxicological analysis. (© Richard C. Li.)

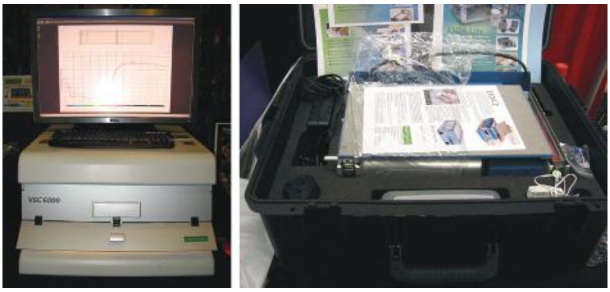

Figure 3.6 A digital imaging system, using multiple illumination sources ranging from ultraviolet to infrared wavelengths, for examining altered and counterfeit documents (left). An electrostatic imaging system for detecting indented writing on questioned documents (right). This device generates an electrostatic image of indented writing, which is then visualized using charge-sensitive toners. (© Richard C. Li.)

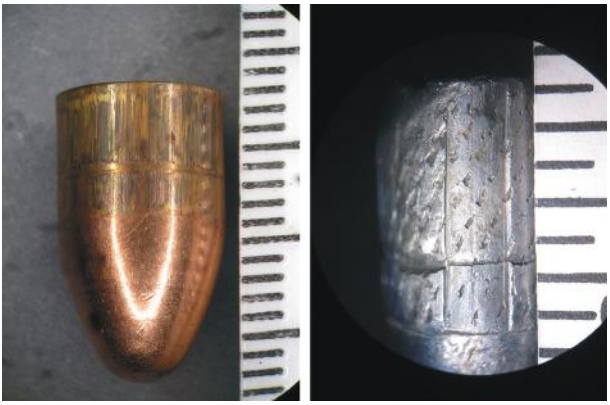

Figure 3.7 Striation marks on fired bullets can be analyzed to match a bullet to a gun. (Courtesy of P. Diaczuk.)

3.3 Forensic Science Services Related to Forensic Biology

A number of specialized forensic science services beyond those provided by forensic laboratories are routinely available to law enforcement agencies. For example, forensic services related to biological evidence and those involving more specialized analysis are available. These services are important aids to a criminal investigation and require the expertise of individuals who have highly specialized skills.

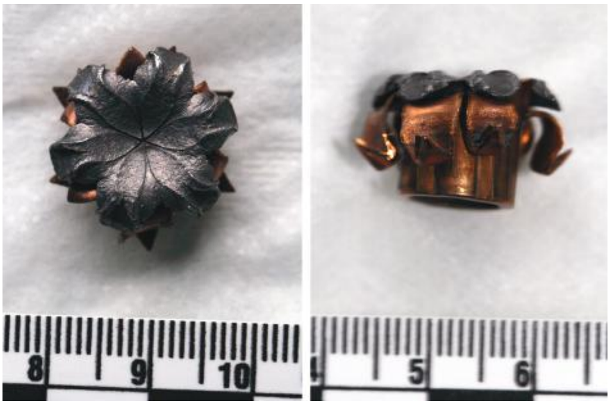

Figure 3.8 Fired hollowpoint bullets (.45 caliber ACP Winchester). Striation marks are visible on the side view of a bullet (right). (© Richard C. Li.)

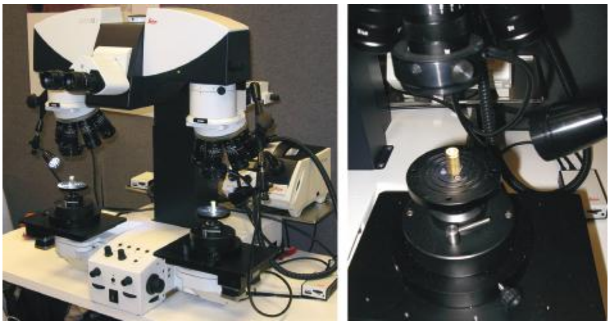

Figure 3.9 A comparison microscope is used for the simultaneous comparison of two items of firearm evidence side by side. (© Richard C. Li.)

3.3.1 Forensic Pathology

When a death is deemed suspicious or unexplained, medical examiners frequently perform autopsies to determine the exact cause (Figures 3.16 and 3.17). The manner of death is classified into one of five categories based on the circumstances: natural, homicide, suicide, accident, or undetermined. Additionally, a medical examiner participating in a criminal investigation is often responsible for estimating the time of death.

3.3.2 Forensic Anthropology

Forensic anthropology is the identification and the examination of human skeletal remains (Figures 3.18 and 3.19). Skeletal remains can reveal a number of individual characteristics that can be useful in attempting to identify an individual. An examination of bones may reveal an individual's origin, sex, approximate age, race, and the presence of a skeletal injury. A forensic anthropologist may also assist in creating facial reconstructions to aid in the identification of skeletal remains or may be called on to help collect and organize bone fragments in the course of identifying victims of mass disasters such as plane crashes as well as victims in mass graves discovered after wars or genocides.

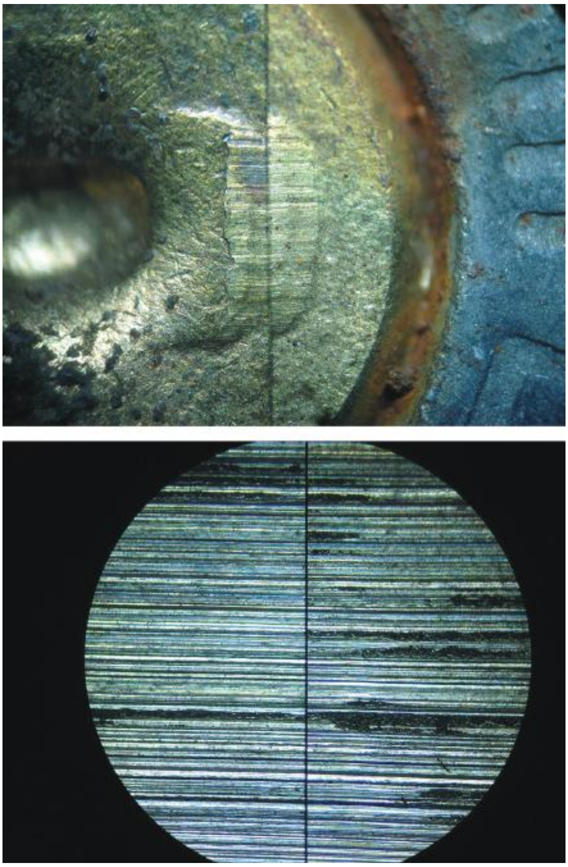

Figure 3.10 Comparing the striations between evidence and reference samples using a comparison microscope: casings (top) and bullets (bottom). (Courtesy of P. Diaczuk.)

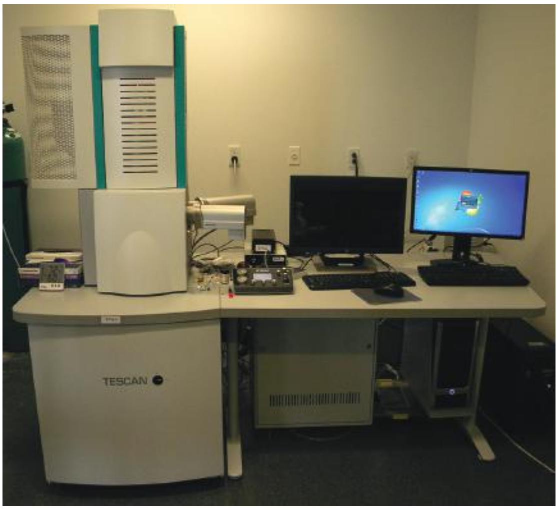

Figure 3.11 Scanning electron microscope used in the analysis of gunshot residue and explosives. (© Richard C. Li.)

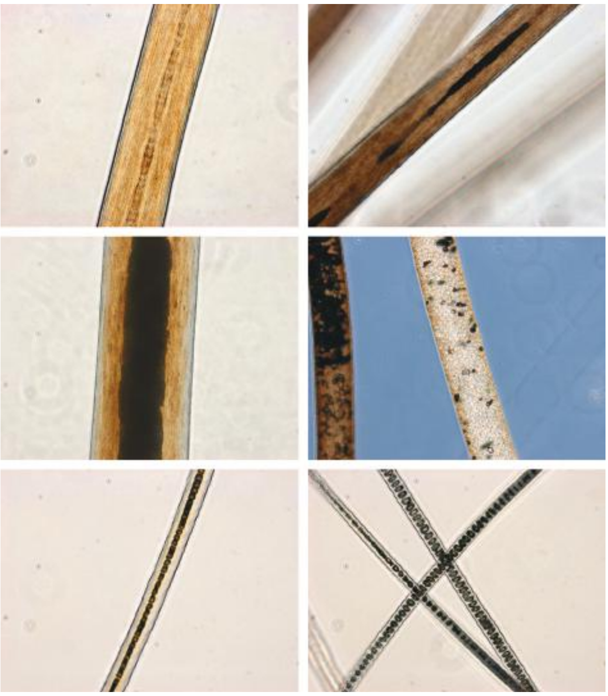

Figure 3.12 Trace evidence such as hairs can be transferred during the acts of a violent crime. The analysis and comparisons of these types of trace evidence can potentially establish a link between a suspect or a victim and a crime scene. Hairs from human (top), horse (middle left), deer (middle right), dog (bottom left), and cat (bottom right). (© Richard C. Li.)

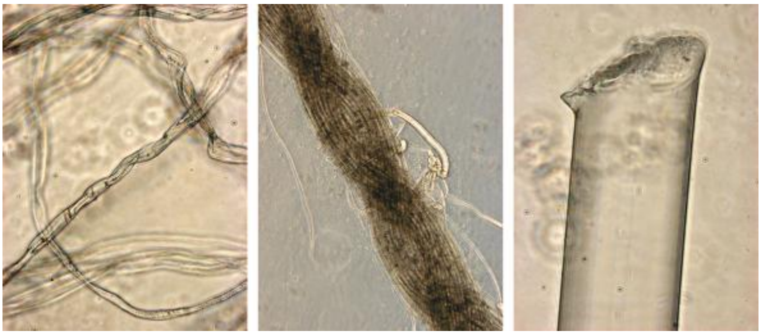

Figure 3.13 Trace evidence: fibers. Cotton (left), nylon (middle), and polyester (right). (© Richard C. Li.)

3.3.3 Forensic Entomology

The study of insects in relation to a criminal investigation is known as forensic entomology. This forensic discipline is valuable for estimating the time of death when the circumstances surrounding the crime are otherwise unknown. The stages of development of certain insect species present in or on a body can be identified and allow a forensic entomologist to approximate how long the body was left exposed (Figure 3.20).

Table 3.1 Common Services Provided by US Forensic Laboratories

Service	Function	Method
Crime scene investigation	Evidence recognition, documentation, collection, and preservation	Crime scene responses and related endeavors are diverse and vary with case and type of evidence
Latent print examination	Analysis of friction ridge detail in fingerprints Activities include visualization, recording, comparison, storage, and recovery of latent prints	Alternate light sources, physical (powder) and chemical enhancements Direct lifts, photography, and digital imaging Use of an Automated Fingerprint Identification System (AFIS) database
Forensic biology	Identification of biological fluids (blood, semen, and saliva) DNA profiling for individualization	Serological and biochemical methods Polymerase chain reaction (PCR)-based methods Automated electrophoresis platforms Use of Combined DNA Index System (CODIS)
Controlled substance analysis	Identification and quantification of drugs present in submitted evidence	Microscopic, chemical, chromatographic, and spectroscopic methodologies Gas chromatography–mass spectrometry or infrared spectrophotometry
Postmortem toxicology	Determination of concentrations of substances and their metabolites in biological fluids or tissues	Immunoassays and chemical methods Confirmatory techniques such as gas and liquid chromatography–mass spectrometry
Questioned document examination	Investigation of forgeries, tracings, disguised handwritings, computer manipulation of images, and recovery of altered documents Analysis of papers, inks, toners, word processors, typewriters, copiers, and printers	Macroscopic and microscopic comparisons Chromatographic and spectroscopic methods
Firearm and toolmark examination	Identification of firearms, tools, and other implements (expertise achieved predominantly through experience)	Microscopic comparisons of questioned and authenticated impressions Comparison of striae on recovered bullets Use of National Integrated Ballistics Information Network (NIBIN)
Explosive and fire debris examination	Identification, recovery, and detection of bulk explosives, residues, debris, and accelerants	Microscopic, spectroscopic, and chromatographic methods Gas chromatography–mass spectrometry may be needed to adequately characterize sample
Trace evidence examination	Analysis of transferred evidence such as hairs, fibers, soil, paints, and glass	Microscopic analysis of evidence with gas chromatograph-mass spectrometers, FTIR microscopes, scanning electron microscopes, basic and advanced microscopy, and capillary electrophoresis

Source: Adapted from US Department of Justice, Office of Justice Programs, National Institute of Justice (NIOJ), *Forensic Science: Review of Status and Needs*, 1999, US Department of Justice, Washington, DC.

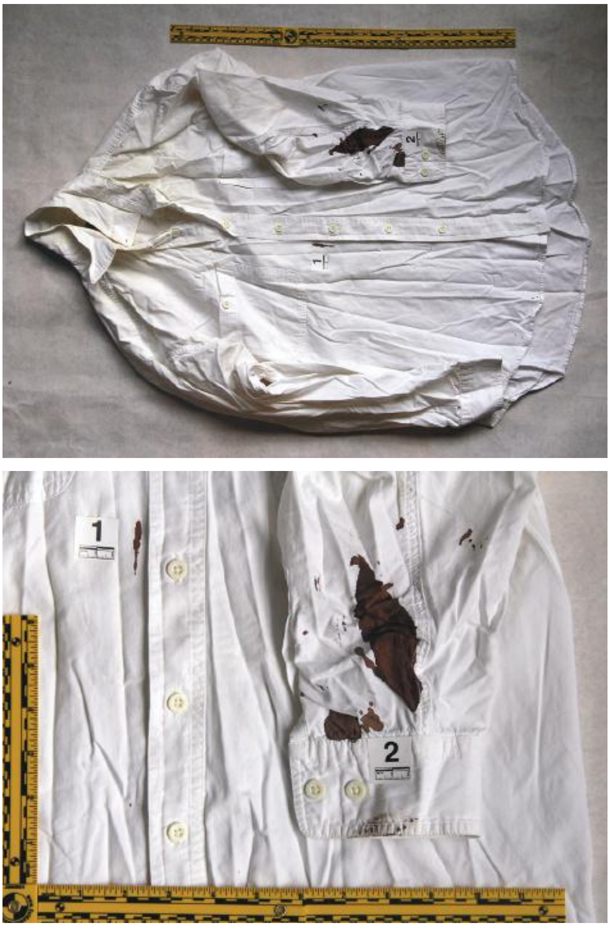

Figure 3.14 Photographic documentation of a bloodstained shirt after visual examination. (© Richard C. Li.)

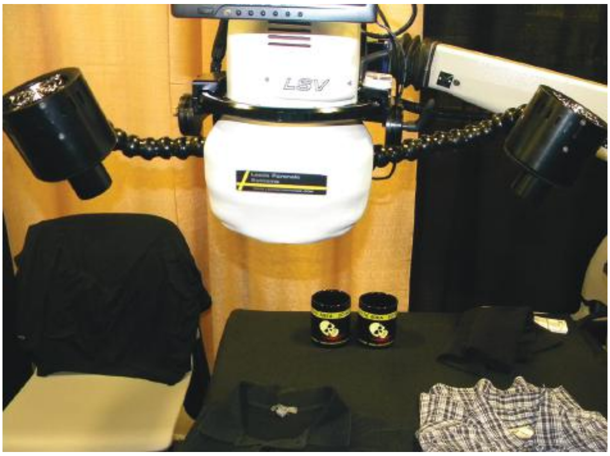

Figure 3.15 A multiwavelength viewing and imaging device used for the examination of various types of evidence, including bodily fluid stains. (© Richard C. Li.)

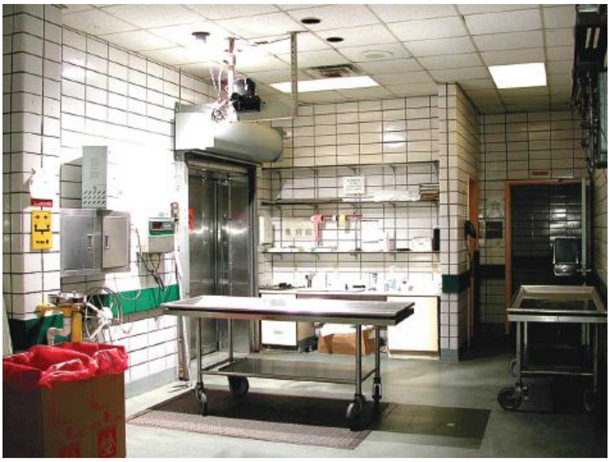

Figure 3.16 View of a forensic pathology facility. (Courtesy of G. Ledwell.)

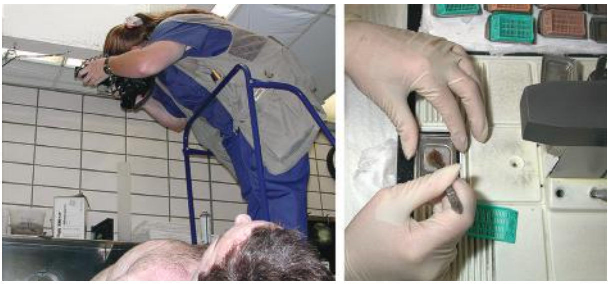

Figure 3.17 Photographic documentation prior to autopsy (left). Preparing specimens for histological sections for forensic pathological examination (right). (Courtesy of G. Ledwell.)

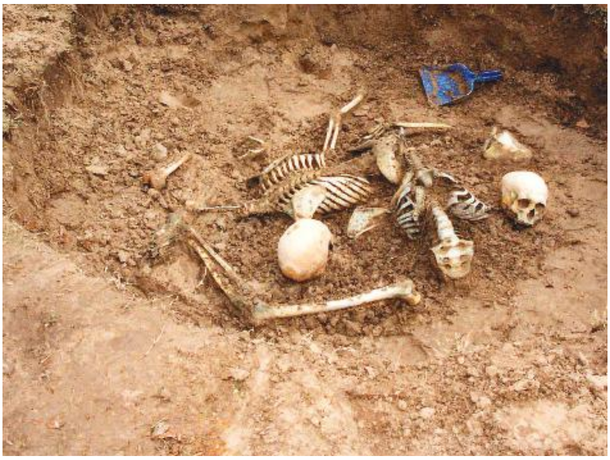

Figure 3.18 Buried human skeletons recovered by forensic anthropologists. (Courtesy of H. Brewster.)

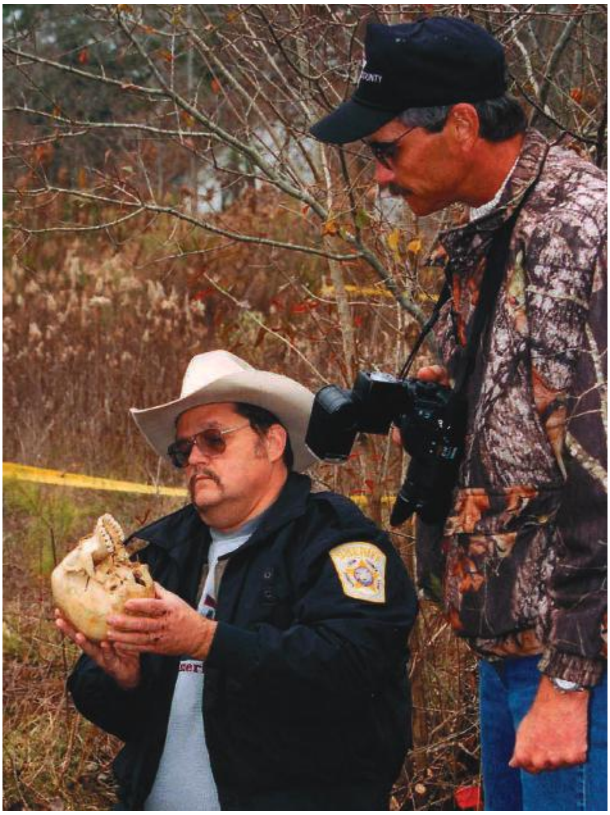

Figure 3.19 Human skull recovered at the scene. (Courtesy of H. Brewster.)

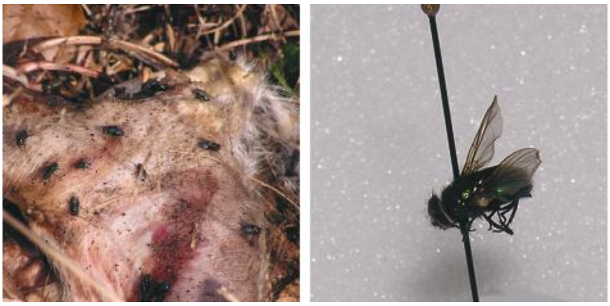

Figure 3.20 Insects found on a dead animal (left). Blow fly specimen. This insect is commonly encountered at crime scenes (right). (Courtesy of K. Wendler.)

3.3.4 Forensic Odontology

Practitioners of forensic odontology participate in the identification of victims whose bodies are left in an unrecognizable state. The characteristics of teeth, their alignment, and the overall structure of the mouth provide evidence that can identify a specific person. Dental records such as x-rays and dental casts allow a forensic odontologist to compare a set of dental remains with an alleged victim. Another application of forensic odontology in a criminal investigation is bite mark analysis (Figure 3.21). A forensic odontologist can analyze the marks left on a victim and compare them with the tooth structures of a suspect to make a comparison.

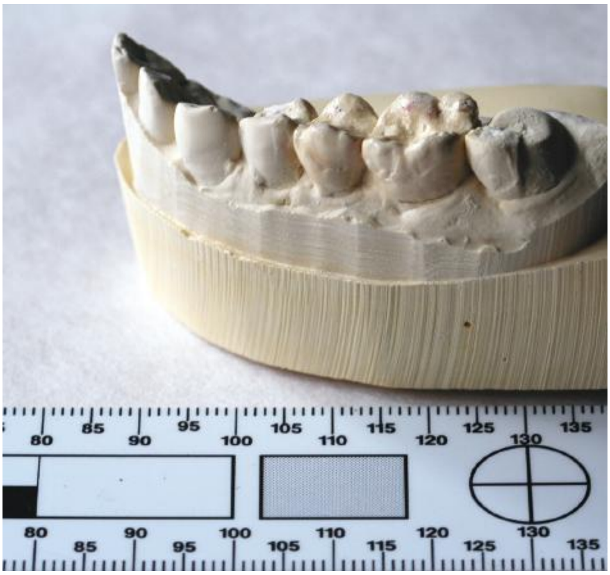
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Figure 3.21 A dental cast can be utilized for identifying bite marks. (© Richard C. Li.)

3.4 Brief History of the Development of Forensic Biology

The developmental history of modern forensic biology spans three stages: (1) antigen polymorphism, (2) protein polymorphism, and (3) DNA polymorphism. Figure 3.22 illustrates this history.

3.4.1 Antigen Polymorphism

The human ABO blood groups were discovered in 1900 by Karl Landsteiner in a study of the causes of blood transfusion reactions. Landsteiner's discovery made blood transfusions feasible, and he received the Nobel Prize in 1930 when he revealed the four groups of human blood cells designated A, B, AB, and O. By the 1960s, a dozen more blood group systems had been characterized, and at least 29 systems are currently known (Chapter 18).

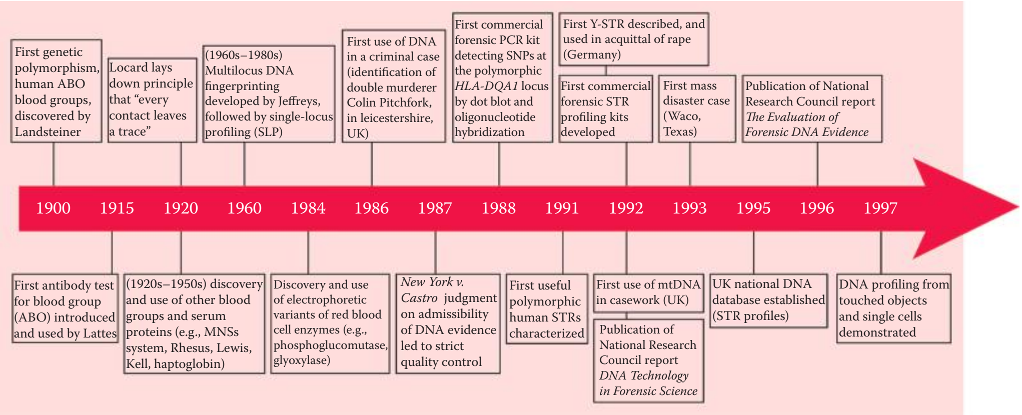
First genetic polymorphism, human ABO blood groups, discovered by Landsteiner
Locard lays down principle that "every contact leaves a trace"
(1960s–1980s) Multilocus DNA fingerprinting developed by Jeffreys, followed by single-locus profiling (SLP)
First use of DNA in a criminal case (identification of double murderer Colin Pitchfork, in leicestershire, UK)
First commercial forensic PCR kit detecting SNPs at the polymorphic *HLA-DQA1* locus by dot blot and oligonucleotide hybridization
First Y-STR described, and used in acquittal of rape (Germany)
First commercial forensic STR profiling kits developed
First mass disaster case (Waco, Texas)
Publication of National Research Council report *The Evaluation of Forensic DNA Evidence*
1900
1915
1920
1960
1984
1986
1987
1988
1991
1992
1993
1995
1996
1997
First antibody test for blood group (ABO) introduced and used by Lattes
(1920s–1950s) discovery and use of other blood groups and serum proteins (e.g., MNSs system, Rhesus, Lewis, Kell, haptoglobin)
Discovery and use of electrophoretic variants of red blood cell enzymes (e.g., phosphoglucomutase, glyoxylase)
New York v. Castro judgment on admissibility of DNA evidence led to strict quality control
First useful polymorphic human STRs characterized
First use of mtDNA in casework (UK)
Publication of National Research Council report *DNA Technology in Forensic Science*
UK national DNA database established (STR profiles)
DNA profiling from touched objects and single cells demonstrated

Figure 3.22 A brief history of the development of forensic biology. (From Jobling, M.A. and Gill, P., *Nat Rev Genet*, 5, 739–751, 2004. With permission.)

Subsequent studies found that the blood types in the ABO system were inherited, and the frequencies with which the four types appeared in specific human populations were found to differ. This led to the discovery of the first antigen polymorphic marker for use in human identification in forensic cases. In the past, forensic laboratories utilized blood group systems in a discipline known as forensic serology. While it is possible to exclude a suspect through the use of blood group typing, the evidence for the inclusion of a suspect is weak due to the high probability of a coincidental match between two unrelated persons.

3.4.2 Protein Polymorphism

Because of the limitations of antigen polymorphism, protein polymorphism was introduced for forensic identification (Chapter 18). Initially, a few polymorphisms in serum proteins and erythrocyte enzymes were reported. By the 1980s, however, approximately a hundred protein polymorphisms had been discovered. A few systems were commonly used in forensic laboratories, including the polymorphisms of erythrocyte enzymes, serum proteins, and hemoglobin. Blood groups and protein polymorphism analysis were combined in forensic investigations to lower the probability of a match between two unrelated individuals. However, more powerful methods were still sought.

3.4.3 DNA Polymorphism

The human genome contains all the necessary biological information for cellular and organ structure and function. It consists of the *nuclear genome* and the *mitochondrial genome* (Chapter 23 discusses the mitochondrial genome). The human nuclear genome, a set of 23 chromosomes, contains approximately 3 billion base pairs (bp). The Human Genome Project was initiated in 1990 to sequence the entire human nuclear genome. In 2003, 99% of the human genome, including the most important parts of the genome, was sequenced. Further analyses on the human genome sequences continue. The genome contains genes and intergenic noncoding sequences.

3.4.3.1 Genes and Related Sequences

Approximately 20,000–25,000 genes have been identified in the human genome, which encode the information for the synthesis of proteins. The functions of nearly half of these genes have been identified. Most encode the proteins that are responsible for the maintenance of the genome, the functioning of the cells, the immune response, and the structural proteins of cells.

Most human genes are discontinuous. The coding regions of genes are called *exons* and are separated by *introns*. During gene expression, the precursor messenger RNA transcript (pre-mRNA), consisting of both the exons and introns, is produced. The mRNA is a template for protein synthesis in which the sequence is based on a complementary strand of DNA. Through the process of splicing, the introns are removed and the exons are joined, producing the spliced mRNA form, which can be used for protein synthesis via the translation process. Other gene-related sequences include those responsible for gene transcription such as *promoter sequences*; those responsible for gene regulation such as *cis-regulatory sequences* (or enhancers); and *untranslated sequences*, which are transcribed but do not encode proteins. Figure 3.23 depicts the features of a representative human gene.

3.4.3.2 Intergenic Noncoding Sequences

More than 90% of the human genome sequence consists of intergenic noncoding sequences located between genes. The functions of these sequences are yet to be discovered. The intergenic noncoding sequences contain large quantities of various types of *repetitive DNA*, which falls into two categories: tandem repeats and genome-wide or interspersed repeats.

Tandem repeats are repeat units placed next to each other in an array. One type is called *satellite DNA* because of the observation of satellite bands containing DNA with tandem repeats

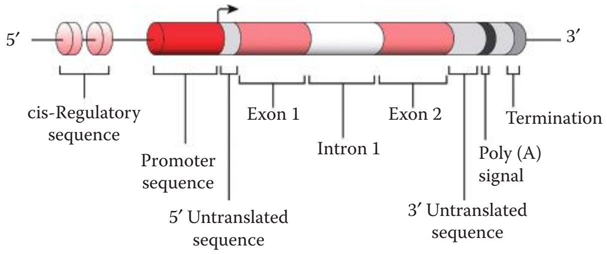
5′
3′
cis-Regulatory sequence
Promoter sequence
5′ Untranslated sequence
Exon 1
Intron 1
Exon 2
3′ Untranslated sequence
Poly (A) signal
Termination

Figure 3.23 Gene structure. Transcription, which can be regulated by the cis-regulatory sequence, is initiated at the transcription start site (arrow) near the promoter. The exons, noncoding introns, and the untranslated sequences are also shown. (© Richard C. Li.)

during density gradient centrifugation. Satellite DNA can be found at centromeres and telomeres consisting of regions composed of long stretches of tandem repeats. Minisatellites and microsatellites are two other types of shorter tandem repeats. *Minisatellites*, also known as *variable number tandem repeats* (VNTRs), form arrays of tandem repeats with a *repeat unit length* from several to hundreds of base pairs. In a *microsatellite*, also known as a *short tandem repeat* (STR) or a *simple sequence repeat* (SSR), the repeat unit length can be 2–6 bp long.

Mobile elements (*interspersed repeats*) are randomly located throughout the human genome (Figure 3.24). Two human types have been characterized: *DNA transposons* and *retrotransposons*. The mobile elements change their locations, a process called *transposition*, by which these sequences are inserted into a new site in the genome. The transposition of DNA transposons is through a "cut-and-paste" mechanism. During transposition, DNA transposons are excised from one site and inserted at a new site in the genome. In contrast, retrotransposons duplicate themselves during transposition and propagate throughout the genome, which is a copy-and-paste mechanism: a copy of the original retrotransposons is generated at the new site and the original copy is retained. Additionally, the transposition of retrotransposons requires an RNA intermediate, a process called *retrotransposition*. Retrotransposons have two subtypes: *long terminal repeat* (LTR) and *non-LTR retroposons*. The non-LTR retroposons can be further divided into two subtypes: *long interspersed elements* (LINEs) and *short interspersed elements* (SINEs). Alu elements are the most abundant type of human SINE. There are more than one million copies of Alu elements in the human genome (Figure 3.25). Some members of the Alu elements are

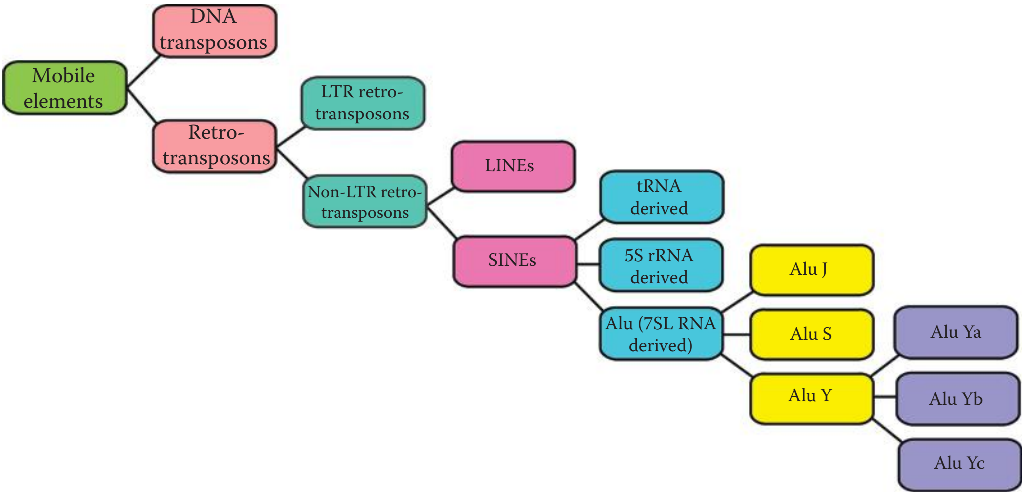
Mobile elements
DNA transposons
Retro-transposons
LTR retro-transposons
Non-LTR retro-transposons
LINEs
SINEs
tRNA derived
5S rRNA derived
Alu (7SL RNA derived)
Alu J
Alu S
Alu Y
Alu Ya
Alu Yb
Alu Yc

Figure 3.24 Mobile elements classification. (© Richard C. Li.)

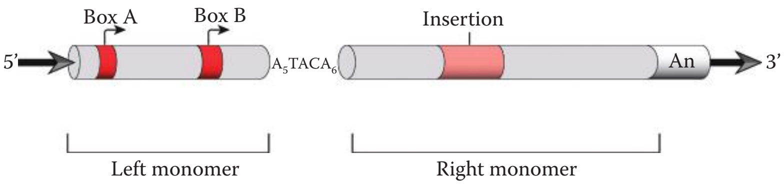

Figure 3.25 Structure of Alu elements. The name, Alu elements, was given since these elements usually contain DNA sequences cleaved by the restriction enzyme *Alu*I. The Alu element is a dimeric structure including two regions separated by an A-rich sequence. The 5′ region has boxes A and B containing RNA polymerase III promoter sequences. The 3′ region contains a 31-nucleotide insertion. There is a short polyadenylation tail located at the 3′ end of the Alu element (terminal A-stretch). Full-length Alu elements are approximately 300 bp long. (© Richard C. Li.)

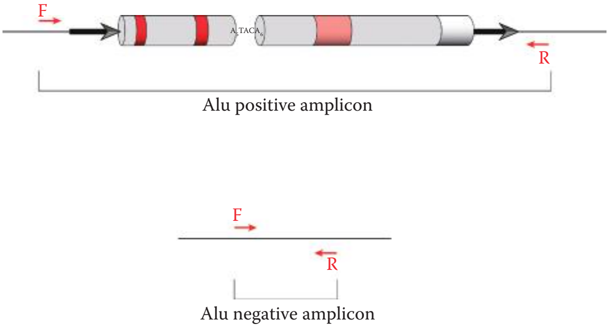

Figure 3.26 Detecting Alu element insertion polymorphism for human identification. The Alu element insertion site is amplified using the polymerase chain reaction assay. The presence and absence of the Alu element at the site can be detected based on the length of the DNA fragment analyzed. F, forward primer; R, reverse primer. (© Richard C. Li.)

polymorphic for the presence or absence of insertion that can potentially be used for forensic human identification (Figure 3.26).

3.4.3.3 Human DNA Polymorphic Markers

Most individual human genome sequences are very similar. However, variations in sequences do occur. The differences between individual genomes that occur at the DNA level are called *DNA polymorphisms*. In particular, a DNA polymorphism with alternative forms of a chromosomal locus that differ in nucleotide sequence is known as a *sequence polymorphism*. A DNA polymorphism that differs in the numbers of tandem repeat units is known as a *length polymorphism*. A DNA polymorphism can occur anywhere in a genome including genes and other chromosomal locations. Many DNA polymorphisms are useful for genetic mapping studies and hence are called *DNA markers*. DNA polymorphisms form the basis of forensic DNA profiling. The focus of this text is on the human genome, but polymorphisms also occur in the genomes of other organisms.

Most DNA polymorphisms are single nucleotide polymorphisms (SNPs) involving a single-base-pair change or a point mutation. Over one million SNPs have been identified. SNPs arise by spontaneous mutation. Most SNPs occur in noncoding regions of the genome, although some appear in coding regions as well. Other forms of DNA polymorphisms are tandem repeats such as STRs and VNTRs. Although their biological functions are unknown, STRs and VNTRs are very useful for forensic DNA analysis. Many are highly polymorphic, and the number of repeat units varies greatly among different individuals of a population. It is unlikely that two unrelated individuals will have exactly the same combination of STR or VNTR polymorphisms if sufficient markers are examined. Thus, a resulting genetic profile can be used for human identification.

Alternative forms of DNA polymorphisms are called *alleles*. The same allele present in both homologous chromosomes is referred to as *homozygous*. Two different alleles present in homologous chromosomes are referred to as *heterozygous*. A combination of alleles at a given locus is a *genotype*. In forensic analysis, the genotype for a panel of analyzed loci is called the *DNA profile*.

3.4.3.4 Forensic DNA Polymorphism Profiling

In 1984, Sir Alec Jeffreys (Figure 3.27) developed a DNA profiling technique using a VNTR technique involving multilocus profiling and later followed by single-locus profiling (Chapter 19). This technique led to the solving of a double murder that had been committed in Leicestershire (United Kingdom) in the 1980s. The case was the first to apply DNA evidence to a criminal investigation. During the investigation, DNA profiling not only identified the true perpetrator but it also excluded an innocent suspect. This case demonstrated DNA profiling's great potential in forensic investigations.

DNA profiling offered a number of advantages compared with earlier systems. The most important is the ability of the technique to reveal far greater individual variability in DNA than can be revealed by antigen and protein polymorphic markers. The probability of two unrelated individuals having the same DNA profile is very low. The great variability of DNA polymorphisms has made it possible to offer strong support for concluding that DNA from a suspect and from a crime scene originated from the same source. This technique was subsequently implemented in forensic laboratories worldwide.

In the mid-1980s, Kary Mullis and his coworkers developed the polymerase chain reaction (PCR) technique, which amplifies a small quantity of DNA. Mullis's invention had a powerful impact on molecular biology and earned him a Nobel Prize in 1993. Since the introduction of PCR, new techniques have been developed for forensic DNA testing purposes.

Figure 3.27 Sir Alec Jeffreys. (© Richard C. Li.)

The application of PCR-based assays makes forensic DNA analysis possible when only minute quantities of DNA can be recovered from a crime scene, for example, from hairs and cigarette butts. These assays have greatly increased the sensitivity of forensic DNA testing. The first forensic application of a PCR-based assay utilizing SNPs at the *HLA-DQA1* locus (formerly called DQα) was developed in 1986 (Chapter 22). One major disadvantage of the assay was the high probability (approximately 1 in 4000) of a match between two unrelated persons. Amplified fragment length polymorphism (AFLP) at the D1S80 locus has also been implemented in forensic laboratories. The D1S80 locus is a small-size VNTR marker that can be amplified by PCR. The *HLA-DQA1* and AFLP assays were used for some years until the introduction of STR assays.

In the late 1990s, forensic laboratories started utilizing STR loci. STRs have a number of advantages compared with VNTRs. For example, STRs can be amplified by PCR because of their smaller size, which greatly increases the sensitivity of the assay. Furthermore, STR markers are as highly variable as VNTRs. With the application of multiple STR loci, the probability of a match between two unrelated persons becomes extremely low. As a result of DNA testing, perpetrators have been identified and wrongly convicted innocent people have been exonerated (Chapter 20).

In 1995, the United Kingdom established the first national DNA database for criminal investigations. By the end of 1998, several other countries, including the United States, had created their own national DNA databases. The United States has selected 13 STR loci for the Combined DNA Index System (CODIS). These national DNA databases play important roles in solving criminal cases.

Another technique known as mitochondrial DNA (mtDNA) profiling has also been used for forensic testing. mtDNA is maternally inherited genetic material and is therefore particularly useful for human identification. Each cell contains multiple copies of mtDNA. Thus, mtDNA typing can be useful for analysis when nuclear DNA is severely degraded or present in very limited amounts, such as in cases involving decomposed human remains. Alternatively, polymorphic markers at the Y chromosome have also been utilized for forensic DNA testing. Y chromosomal markers are paternally inherited so they can be used for paternity testing. These markers are also very useful in analyzing DNA from multiple contributors in sexual assault cases.

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4

Sources of Biological Evidence

Biological evidence analysis is one of the standard forensic examinations in the investigation of a wide variety of crimes. In particular, DNA evidence facilitates investigators' efforts to link offenders to crime scenes by matching DNA profiles. DNA evidence can also be used to eliminate suspects. The DNA evidence that is routinely encountered at crime scenes can often be categorized into several groups or types. Table 4.1 lists sources of DNA that are frequently found on personal items. Figures 4.1 and 4.2 illustrate representative types of evidence that are processed and their success rates.

4.1 Bodily Fluids

Bodily fluids and their stains are useful biological evidence for forensic, serological, and DNA analysis and may be useful in solving crimes. The most common bodily fluids in forensic analysis are blood, seminal fluid, and saliva. Blood evidence, such as peripheral blood that circulates through the heart, arteries, veins, and capillaries, is one of the most common types of biological evidence that is found at crime scenes (Chapter 12). The fluid portion of blood is called *plasma*, a subcompartment of extracellular fluid, which is the bodily fluid outside cells. Blood contains various suspended blood cells. The cellular portion of the blood consists of *erythrocytes* (also known as red blood cells), *leucocytes* (also known as white blood cells), and *platelets*. Because mature human erythrocytes and platelets do not have nuclei, they are not useful sources of nuclear DNA. For forensic DNA profiling, the nuclear DNA in blood samples (Figure 4.3) is primarily isolated from leucocytes, which are nucleated. Besides peripheral blood, menstrual blood can be analyzed to investigate the possibility of the occurrence of a sexual assault crime (Chapter 16).

Other bodily fluids are *transcellular fluids*. These fluids are considered to be a subcompartment of the extracellular fluid that is contained within epithelial-lined extracellular spaces. For example, seminal fluid (Chapter 14) and saliva (Chapter 15) stains as well as vaginal secretions are analyzed for the investigation of sexual assault crimes. Sometimes, urine stains and fecal materials (Chapter 16) are related to assault crimes as well. Sweat, which is secreted from the eccrine and apocrine sweat glands in the skin (Chapter 17), and cerumen, also known as earwax (a waxy substance secreted in the ear canal), can be potentially used for human identification. Fluids present in vomitus (Chapter 17) can be potentially important for forensic investigations of violent crimes.

4.1.1 Extracellular Nucleic Acids

Blood plasma and other various bodily fluids usually contain small amounts of nucleic acids (DNA or RNA) known as extracellular nucleic acids. The nucleic acids circulating in plasma

Table 4.1 Common Items of Evidence

Evidence	Possible DNA Location	Source of DNA
Baseball bat	Handle	Skin cells, sweat, blood, tissue
Hat, bandana, mask	Inside surfaces	Sweat, hair, skin cells, dandruff, saliva
Eyeglasses	Nose, ear piece, lens	Sweat, skin cells
Facial tissue, cotton swab	Surface	Mucus, blood, sweat, semen, earwax
Dirty laundry	Surface	Blood, sweat, semen, saliva
Toothpick	Surface	Saliva
Used cigarette	Butt (filter area)	Saliva
Used stamp, envelope seal	Moistened area	Saliva
Tape or ligature	Inside or outside surface	Skin cells, sweat, saliva
Bottle, can, glass	Mouthpiece, rim, outer surface	Saliva, sweat, skin cells
Used condom	Inside surface, outside surface	Semen, vaginal cells, rectal cells
Bed linen	Surface	Sweat, hair, semen, saliva, blood
Through-and-through bullet	Outside surface	Blood, tissue
Bite mark	Skin surface	Saliva
Fingernail, partial fingernail	Scrapings	Blood, sweat, tissue, skin cells

Source: National Institute of Justice. Using DNA to solve cold cases, Special Report, 2002, US Department of Justice, Office of Justice Programs, Washington, DC.

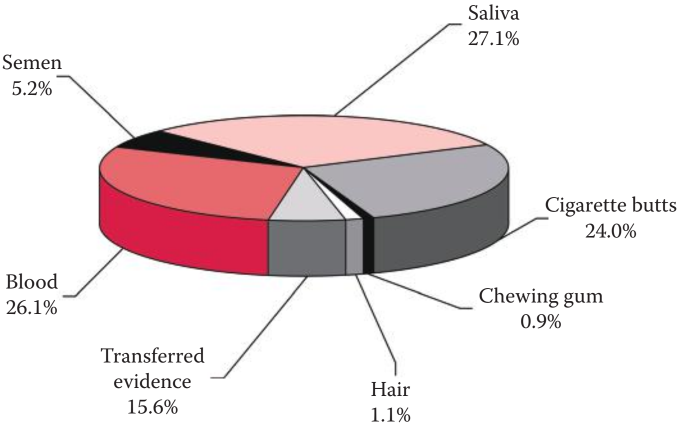

Figure 4.1 Representative types of evidence samples. Data compiled from the third quarter 2005 (July–September) results for all police forces in England and Wales. (Adapted from Bond, J.W., *J Forensic Sci*, 52, 128–136, 2007.)

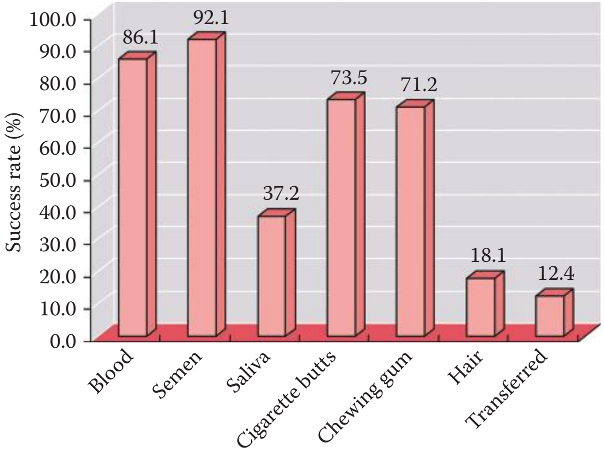

Figure 4.2 Success rate of obtaining suitable profiles from processed samples for submitting to DNA databases. Data are from the third-quarter 2005 (July–September) results for all police forces in England and Wales. (Adapted from Bond, J.W., *J Forensic Sci*, 52, 128–136, 2007.)

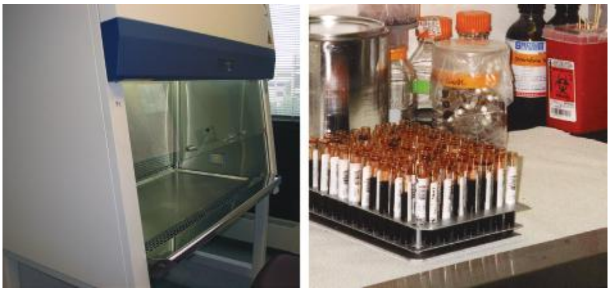

Figure 4.3 Biosafety cabinet for the extraction of DNA from biological evidence (left). Blood samples to be processed in a biosafety cabinet for DNA isolation (right). (© Richard C. Li.)

are referred to as *circulating* nucleic acids; the nucleic acids that are found in other body fluids, such as saliva and urine, are referred to as *cell-free* nucleic acids. Extracellular nucleic acids can remain soluble or form complexes with proteins and lipids.

The potential sources of extracellular nucleic acids are *extracellular vesicles* (EVs). EVs are endogenous vesicular structures, containing proteins and nucleic acids that are secreted by most eukaryotic cells (Figure 4.4). There are many types of EVs, including exosomes and microvesicles, which can be detected in bodily fluids. *Exosomes* are one potential source of extracellular nucleic acids. Exosomes are derived from multivesicular bodies (MVBs), which are intracellular organelles of the endocytic pathway (Figure 4.4a). MVBs fuse with the plasma membrane. As a result, the vesicles are released into the extracellular compartment as exosomes. *Microvesicles*, also called shed vesicles or ectosomes, are another possibility. Microvesicles shed from the plasma membrane and thus carry along membrane and cytosolic materials including nucleic acids (Figure 4.4b). *Apoptotic bodies* are a special type of microvesicle that is formed in apoptotic cells. During apoptosis, a process of programmed cell death, cells shrink and eventually form apoptotic bodies (Figure 4.5). Apoptotic bodies contain fragmented DNA by nucleolytic degradation that resembles similar characteristics to those observed in extracellular nucleic acids. However, messenger RNA (mRNA) within apoptotic bodies is protected from RNase degradation. These

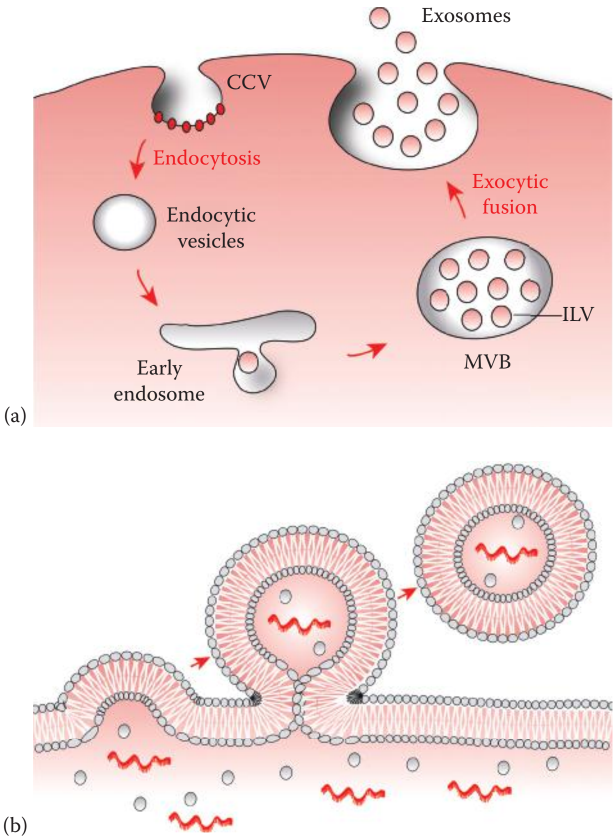

Figure 4.4 Exosomes and microvesicles released from healthy cells. (a) Exosomes are derived from the endocytic pathway. In the endocytic pathway, clathrin-coated vesicles (CCV) are formed at the plasma membrane. The endocytic vesicles are then formed through endocytosis and are transported to early endosomes. Multivesicular bodies (MVBs) containing intraluminal vesicles (ILVs) are then developed from early endosomes. Through the exocytic fusion of the MVB membrane with the plasma membrane of the cell, exosomes, containing cellular components including nucleic acids, are released to the extracellular space. (b) Microvesicles are derived from the budding of vesicles from the plasma membrane. Microvesicles are then shed from the plasma membrane carrying along cellular components including nucleic acids that are present in the cytoplasm. (© Richard C. Li.)

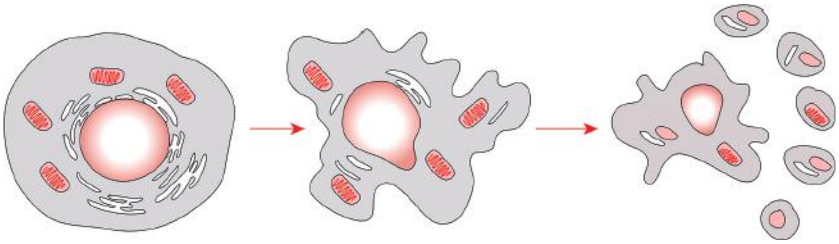

Figure 4.5 Apoptotic bodies released during apoptosis. During apoptosis, the preapoptotic cell (left) undergoes morphological changes. The early apoptotic cell (middle) shows deformation: the cell shrinks, the membrane blebs, and chromatin condense. The late apoptotic cells (right) are fragmented, releasing apoptotic bodies, which contain cytosol and organelles, and nuclear fragments. In addition, proteolytic enzymes are activated that cleave the genomic DNA into fragments. (© Richard C. Li.)

extracellular nucleic acids are potentially useful sources for the forensic identification of bodily fluids and for forensic DNA profiling.

4.2 Cells

4.2.1 Cell Surface Markers

Many of the forensic markers that are analyzed in forensic laboratories are from cells, the building blocks of the human body. All cells have membranes, also known as plasma membranes, which constitute their outer boundaries (Figure 4.6). The functions of cell membranes include exchanges with the environment, signal transduction, and structural support. The cell membrane is a phospholipid bilayer containing lipids, proteins, and carbohydrates. Membrane proteins can act as enzymes, receptors, or ion channels. Many cells also have carbohydrate-rich molecules, including proteoglycans, glycoproteins, and glycolipids, on their membrane surfaces (Figure 4.6). Many of these molecules act as cell surface antigens (Chapter 18).

4.2.2 Nucleated Cells

Probative biological evidence usually contains nucleated cells. The *nucleus* (Figure 4.7) is surrounded by a nuclear envelope and contains chromosomes and a nucleolus. A nucleolus is a dense, non-membrane-bound structure due to its high RNA content. The function of a nucleolus is to transcribe ribosomal RNA and to form ribosomes.

There are two types of cells in the body: sex cells (sperm and oocytes) and somatic cells (all other types). Spermatozoa and ova, which are formed by germ cells, are called *gametes*. In humans, each gamete is haploid, containing 22 *autosomes* (chromosomes other than sex chromosomes) plus one *sex chromosome*. In ova, the sex chromosome is always an X, while in spermatozoa it may be an X or a Y. After fertilization, the zygote, which is the fertilized egg cell formed when two gamete cells are joined, becomes diploid as a result of the fusion of the haploid spermatozoon and ovum. Most of the other cells of the body, known as *somatic cells*, are diploid. This means that they have two copies of each autosome plus two sex chromosomes, XX for females or XY for males. This results in a total of 46 chromosomes per diploid cell. The two chromosomes of a pair in a diploid cell are *homologous chromosomes*. One of the homologous chromosomes is inherited from the spermatozoon and the other from the ovum.

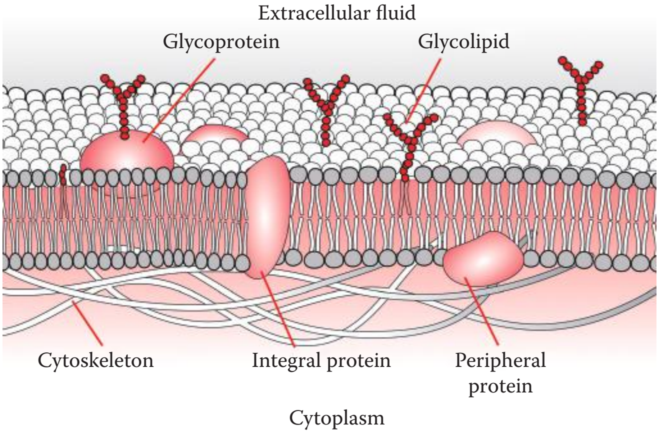

Figure 4.6 Cell membrane and carbohydrate-containing glycoproteins and glycolipids. (© Richard C. Li.)

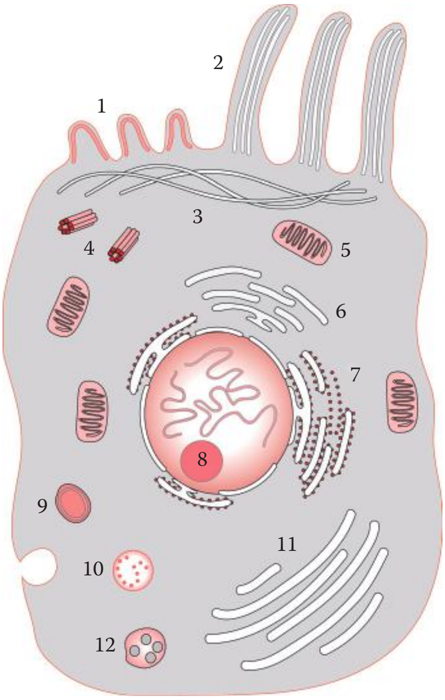

Figure 4.7 A cross-sectional view of a cell. 1, Microvilli; 2, cilia; 3, cytoskeleton; 4, centrioles; 5, mitochondrium; 6, smooth endoplasmic reticulum; 7, rough endoplasmic reticulum; 8, nucleolus; 9, peroxisome; 10, vesicle; 11, Golgi apparatus; and 12, lysosome. (© Richard C. Li.)

Although most somatic cells are diploid, exceptions exist. Some differentiated cells such as red blood cells and platelets have no nuclei and are designated *nulliploid*. A few other cells have more than two sets of chromosomes as a result of DNA replication without cell division and are referred to as *polyploid*. For example, the regenerating cells of the liver and other tissues are naturally tetraploid, while the giant megakaryocytes of the bone marrow may contain 8, 16, or even 32 copies of chromosomes.

The nuclear *chromosomes* of humans consist of complexes of DNA, histone proteins, and nonhistone chromosomal proteins. Each chromosome consists of one linear, double-stranded DNA molecule. The large amounts of DNA present in the human chromosome are compacted by their association with histones into nucleosomes and even further compacted by higher levels of folding of the nucleosomes into *chromatin* fibers. Each chromosome contains a large number of looped domains of chromatin fibers attached to a protein scaffold.

The degree of DNA packing varies throughout the cell cycle. During the metaphase of mitosis and meiosis of the cell cycle, chromatin is the most condensed. Two forms of chromatin have been defined on the basis of their chromosome-staining properties. *Euchromatin* regions are areas of chromosomes that undergo normal chromosome condensation and decondensation during the cell cycle. The intensity of staining of euchromatin is darkest in the metaphase and lightest in the synthesis (S) phase. Euchromatic regions account for most of the genome and lack repetitive DNA. Usually, the genes within the euchromatin can be expressed. *Heterochromatin* comprises the chromosomal regions that usually remain condensed throughout the cell cycle. It contains repetitive DNA and can be found at centromeres, much of the Y chromosome long arm, and the short arms of the acrocentric chromosomes (chromosomes with centromeres near one end). Genes within heterochromatic DNA are usually inactive.

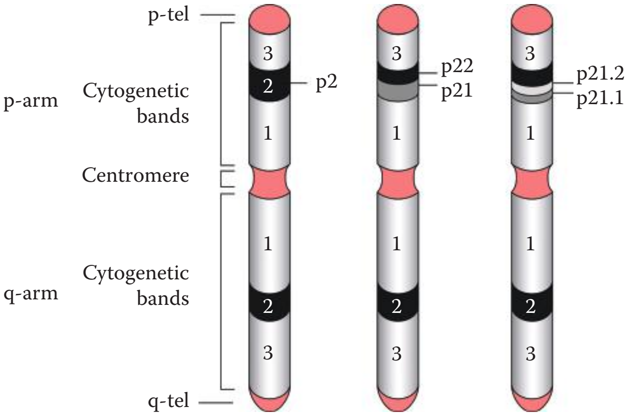

Figure 4.8 The ideogram of a human chromosome and cytogenetic banding nomenclature. The cytogenetic banding pattern is shown after chemical staining such as G-banding, which treats chromosomes with Giemsa dye. The short arm is designated p; the long arm is q. The centromere, p telomere (p-tel), and q telomere (q-tel) are also shown. G-bands at increasing resolution (from left to right) are shown. (© Richard C. Li.)

Each human chromosome has a short arm, designated p (for petit), and a long arm, designated q (for queue), separated by a centromere (Figure 4.8). *Centromeres* are the DNA sequences that are found near the points of attachment of mitotic or meiotic spindle fibers. The centromere region of each chromosome is responsible for accurately segregating the replicated chromosomes to daughter cells during cell divisions. The ends of the chromosome are called *telomeres* and they help stabilize the chromosome and play a role in the replication of DNA in the chromosome.

Chemical staining of metaphase chromosomes results in an alternating dark and light banding pattern (cytogenetic banding) that can be seen under a microscope. Each chromosome arm is divided into regions based on the cytogenic bands. This process is known as *cytogenetic mapping*. The cytogenetic bands are labeled p1, p2, p3, q1, q2, q3, and so on, counting from the centromere out toward the telomeres. At higher resolutions, subbands can be observed. For example, the cytogenetic map location of a gene termed *AMELY* (amelogenin, Y-linked; Chapter 21) is Yp11.2, which indicates its location on chromosome Y, p arm, band 11, subband 2. The visually distinct banding pattern gives each chromosome a unique appearance. Recently, the cytogenic map has been integrated with the human genome sequence to allow the determination of the positions of cytogenetic bands within the DNA sequence.

Chromosomes can be identified on the basis of the size and the positions of the centromeres and cytogenetic banding patterns. The chromosome constitution is described as a *karyotype* and can be displayed as a *karyogram*, which includes the total number of chromosomes and the sex chromosome composition (Figure 4.9). Chromosomes are numbered in order of their size, with chromosome 1 as the largest (except chromosome 21 is smaller than 22). In the cases of chromosomal abnormality, the karyotype can also reflect the type of abnormality and allow visualization of the affected chromosome bands.

4.2.3 Mitochondria and Other Organelles

The cytoplasm contains the cytosol fluid in which organelles are suspended (Figure 4.7). Multiple copies of *mitochondria* are located within the cytoplasm. Mitochondria are surrounded by phospholipid membranes that separate them from the cytosol. The mitochondria are responsible for energy production through aerobic metabolism by producing molecules containing high-energy bonds, such as adenosine triphosphate (ATP). Mitochondria have their own genome, which can be analyzed for human identification (Chapter 23).

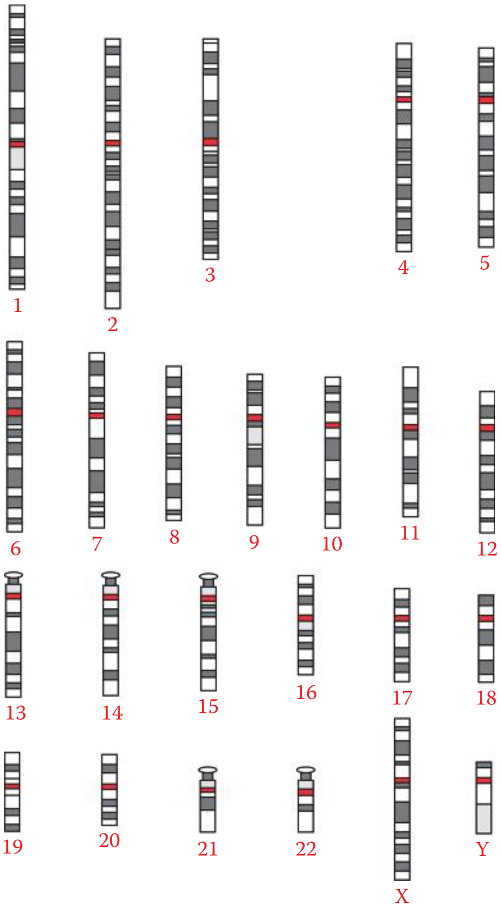

Figure 4.9 Human karyogram. The chromosomes are numbered. Cytogenic patterns show alternating dark and light bands (From www.genome.gov). Centromeres (in red) are shown.

Two types of *endoplasmic reticulum* (ER) can exist within the cytoplasm: the smooth ER (SER) is involved in lipid synthesis; the rough ER (RER) contains ribosomes on its outer surface and forms transport vesicles. The *Golgi apparatus* is responsible for the production of secretory vesicles and new membrane components, and also for the packaging of *lysosomes* (vesicles containing digestive enzymes for the degradation of injured cells). *Peroxisomes* carry enzymes that neutralize potentially harmful free radicals. Other organelles found within the cytoplasm of eukaryotic cells include the cytoskeleton, microvilli, centrioles, and cilia.

4.2.4 Cytosol

4.2.4.1 Messenger RNAs

The chromosomal DNA contains genes that encode for specific proteins. The genetic code is read as an array of triplet codes, a sequence of three bases that specifies the identity of a single amino acid. As gene expression is activated, transcription occurs in which precursor mRNA (pre-mRNA) is produced from a DNA template. After transcription, the pre-mRNA is capped, polyadenylated, and spliced to form matured mRNA. Only the matured mRNA is transported from the nucleus to the cytoplasm. Tissue-specific mRNA can be potentially used for the identification of biological evidence (Chapter 11). The proteins are synthesized in a process known as translation, in which amino acids are assembled based on the codons derived from the triplet code of the DNA contained in the sequence of the mRNA strand. Various components including the ribosomal complex are involved in translation. The cytosol also contains many proteins that can be used for the identification of bodily fluids (Chapters 11 and 12).

4.2.4.2 MicroRNAs

MicroRNAs (miRNAs) are short RNA molecules that are 21–23 nucleotides in length. In eukaryotic organisms, miRNAs function as negative regulators of gene expression. They play roles in development and cell differentiation. Additionally, the altered expression of miRNAs can be detected in many human diseases. The biological function and the potential application of miRNAs in forensic biology are discussed in Chapter 11.

It is estimated that the human genome may encode approximately 1000 miRNAs. Based on their genomic location and structure, miRNAs can be characterized into three types: intergenic, intronic, and exonic (Figure 4.10). *Intergenic* miRNA genes are distinct transcriptional units that are found in genomic regions. In humans, most of the intergenic miRNA genes have a transcription start site and a polyadenylation site. *Intronic* miRNAs reside within the introns of protein-coding and noncoding genes. The orientation of the intronic miRNAs can be the same as that of the sense (coding) strand of a host gene or that of the antisense strand (complementary to the sense strand) of a host gene. Sense intronic miRNAs are transcribed from the same promoter as their host genes. The antisense intronic miRNAs are transcribed from their own promoters. *Exonic* miRNAs are rare in eukaryotic genomes and reside in genomic regions that overlap with an exon and an intron of a pseudogene, which is a noncoding gene or is no longer transcribed. These miRNAs are also transcribed from their host gene promoter. miRNAs can also be monocistronic or polycistronic. A *monocistronic* miRNA has a single transcriptional unit with its own promoter. In *polycistronic* miRNAs, several miRNAs reside as a cluster of transcriptional units with a shared promoter.

The biogenesis of miRNAs begins in the nucleus. miRNAs are transcribed by RNA polymerase II. Nascent transcripts, referred to as primary transcripts (pri-miRNAs), can be several hundreds to thousands of nucleotides in length. The pri-miRNAs have a hairpin secondary

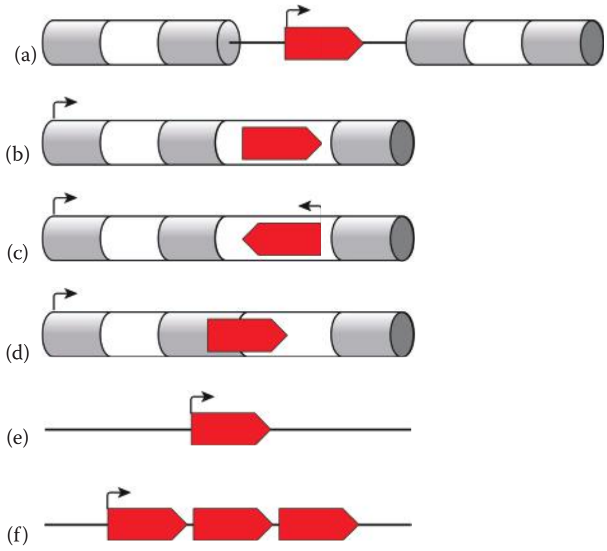

Figure 4.10 The genomic location and the structure of miRNAs. (a) An intergenic miRNA gene, (b) a sense intronic miRNA gene, (c) an antisense intronic miRNA gene, (d) an exonic miRNA gene, (e) a monocistronic miRNA gene, and (f) polycistronic miRNA genes. Exons (gray), introns (white), and miRNA genes (red) are shown. (© Richard C. Li.)

structure that is approximately 70 nucleotides long with imperfect base pairing in the stem. miRNA processing is initiated in the nucleus (Figure 4.11). The hairpin region of a pri-miRNA is then cleaved from the pri-miRNA by the nuclear RNase III endonuclease, Drosha. As a result, a pre-miRNA is formed. The pre-miRNA is transported from the nucleus to the cytoplasm by a nuclear transporter, Exportin 5. In the cytoplasm, a cytoplasmic RNAse III–like endonuclease, Dicer, cleaves the pre-miRNA to generate a double-stranded miRNA that is approximately 21–23 nucleotides in length. The mature miRNA strand is bound to the Argonaut protein to assemble the RNA-induced silencing complex (RISC). The complementary RNA strand is degraded.

A specific miRNA is designated with a prefix. The prefix for a mature miRNA is a capitalized "miR," while the prefix for a pre-miRNA is an uncapitalized "mir." The prefix "miR" is followed by a dash and a number (e.g., miR-135). Experimentally confirmed miRNAs are sequentially numbered and are deposited in the miRBase, which is a database that archives miRNA sequences and annotations.

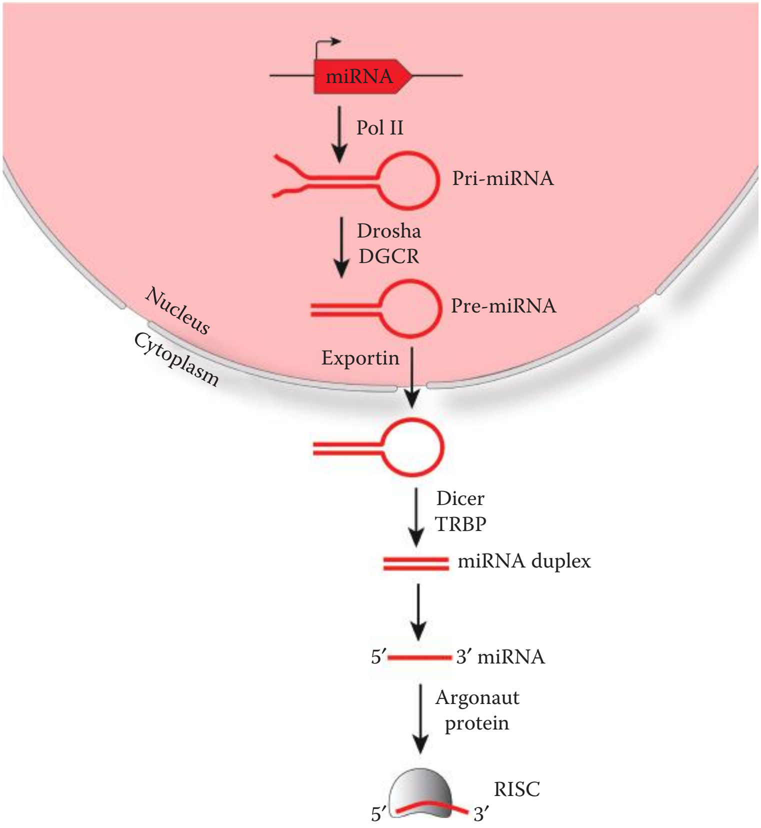

Figure 4.11 The biogenesis of miRNAs. In the nucleus, the pri-miRNA (primary transcript) is processed by Drosha (nuclear RNase for double-stranded RNA) and DGCR (nuclear double-stranded RNA-binding protein), forming the pre-miRNA. The pre-miRNA is transported from the nucleus to the cytoplasm by the exportin. In the cytoplasm, the pre-miRNA is further processed by Dicer (cytoplasmic RNase for double-stranded RNA) and TRBP (cytoplasmic double-stranded RNA-binding protein). The mature miRNA strand is bound to the Argonaut protein to assemble the RISC (RNA-induced silencing complex). (© Richard C. Li.)

4.3 Tissues

4.3.1 Skin

4.3.1.1 Biology of Skin

The biological evidence related to skin is important in forensic investigations. For example, fingerprints are ridge skin impressions that are usually collected at crime scenes, and shed skin tissue is a source of DNA for human identification. The skin covers the entire body surface. Additionally, the skin contains specialized structures that include sebaceous and sweat glands, hair follicles, and nails. The thickness of skin varies throughout the body. The skin of the dorsal area of the body is usually thicker than that of the ventral area of the body. The skin consists of different layers (Figure 4.12). The *epidermis* is the outer layer of the skin. The epidermis also contains melanocytes that produce the skin pigment melanin. The *dermis* is the middle layer of the skin. It is filled with fibrous collagen proteins secreted by fibroblasts and contains hair follicles and sweat glands. Additionally, it contains blood, lymph vessels, and nerves. The *subcutaneous layer* is the deepest layer of the skin. The subcutaneous layer consists of collagen networks and adipose tissue to prevent loss of heat.

The epidermis is a multilayered tissue that includes a number of morphologically distinct zones: the basal, the spinous, the granular, and the cornified layers (Figure 4.12). The epidermis renews continually through the proliferation and differentiation of keratinocytes. The *basal layer* contains newly formed keratinocytes that are proliferative. Epidermal differentiation begins with the migration of the keratinocytes from the basal layer toward the outer layer of skin. Once the migrating keratinocytes reach the *spinous* and *granular* layers, the keratinocytes become nonproliferating and partially differentiated. As the cells reach the *cornified* layer, these cells are filled with keratin filaments and are differentiated into corneocytes, which are dead, and terminally differentiated keratinocytes. In the course of differentiation, the cells are flattened, and all organelles including the nucleus are lost. The corneocytes are then shed from the skin surface.

4.3.1.2 Skin as Source of DNA Evidence

Evidence from skin contact, also referred to as *touched evidence*, can be collected and used for forensic DNA analysis. One example of this evidence is shed skin cells that are found on worn clothing, which is frequently encountered in crime scene investigations. For instance, a perpetrator's shed skin cells that are deposited on worn clothing are potential evidence to be collected. After collection, a DNA profile can be obtained from shed skin cells, providing the forensic evidence or "lead" that is required for the criminal investigation. Touched evidence becomes more

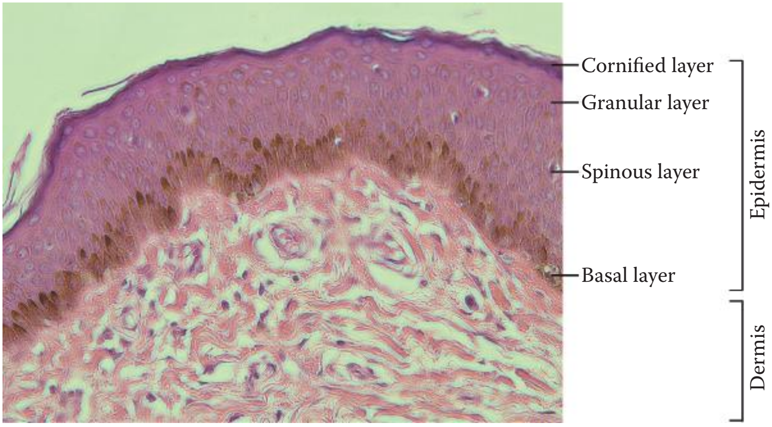

Figure 4.12 A sectional view of the skin. Multilayered epidermis tissues are shown. (© Richard C. Li.)

useful and important when no other type of evidence (e.g., a fingerprint, bloodstain, or seminal stain) can be collected at the crime scene, especially for the investigation of certain criminal cases such as cold cases and property crimes such as theft and burglary (Figures 4.13 through 4.15). Touched evidence usually contains minute quantities of nuclear DNA. DNA recovered from touched evidence is referred to as *transfer DNA*. However, the source of DNA transferred through physical contact is not well understood. Although the shed skin cells from touched evidence lack nuclei, these cells may contain DNA remnants from partial degradation during the differentiation process. These can be a possible DNA source. Additionally, the sweat glands in the skin produce sweat. When the skin makes contact with an item, a residue of sweat is left on the surface of the item. It is known that sweat contains cell-free DNA. Thus, cell-free DNA from sweat is another possible source of DNA. Furthermore, a small number of nucleated cells can be observed in touched evidence. These cells possibly originated from sweat glands and ducts.

4.3.2 Hair

Hairs, including scalp and pubic hairs, frequently constitute biological evidence that is found at crime scenes, and their identification can be of great forensic importance. Formerly, the

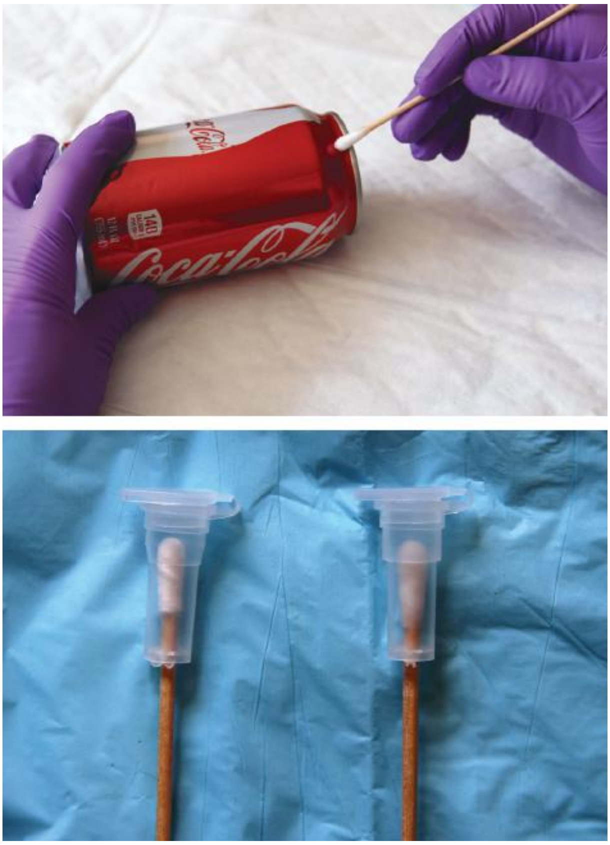

Figure 4.13 Evidence collection using swabbing. The evidence from skin contact for forensic DNA analysis is usually collected by swabbing. More DNA can be recovered when evidence is collected with a double swab method than with a single swab. The double swab method involves applying a moistened cotton swab followed by a second dry cotton swab onto the same target surface of evidence. The target surface is swabbed using a moistened swab first. The moisture left by the first swab is absorbed by the second dry swab. Both swabs can be pooled for DNA extraction. (© Richard C. Li.)

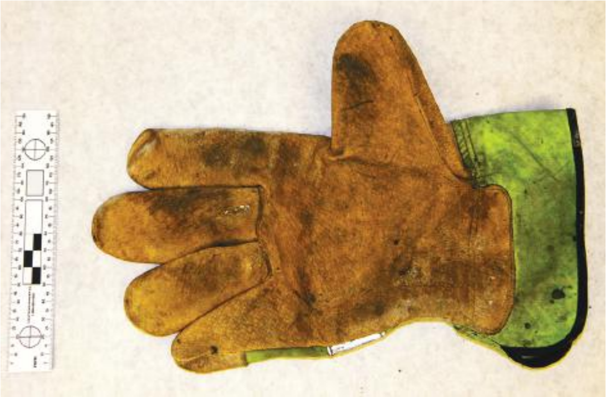

Figure 4.14 A worn glove as a source of DNA evidence. Shed skin cells on a worn glove can potentially generate DNA profiles. (© Richard C. Li.)

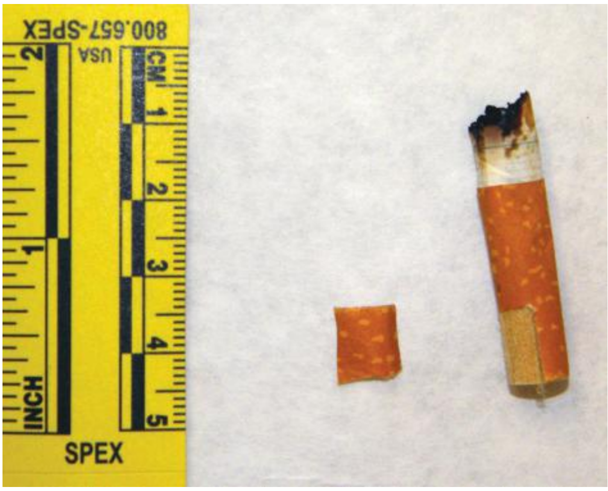

Figure 4.15 A cigarette butt as a source of DNA evidence. Shed cells left behind on a cigarette butt can be a source of DNA. A portion (~1 cm^2) of the filter paper of a smoked cigarette butt can be cut for isolating DNA. (© Richard C. Li.)

principal methods that were utilized in forensic hair analysis were limited to morphological analysis and comparisons. Since then, protein polymorphisms provide some potential for identifying individuals from single hairs. However, human hairs contain DNA and as a DNA source they may be used for forensic analysis. The development of the polymerase chain reaction (PCR) amplification technique made it possible to analyze very small quantities of DNA in hair, and the use of hair as evidence of identification has become more significant.

4.3.2.1 Biology of Hair

The human hair shaft is a keratinized cylindrical structure (Figure 4.16). The center or core of the hair is called the *medulla*, which is present in the majority of hairs. The medulla is surrounded by a *cortex*, which is the outer layer of the hair shaft. The *cuticle* consists of overlapping layers of flattened keratinized cells that protect the hair. Hairs are produced in *hair follicles* (Figures 4.17 and 4.18). Each hair follicle is located deep in the dermis (a skin layer beneath the epidermis) and opens onto the surface of the epidermis (the outer layer of the skin). The hair follicle is composed

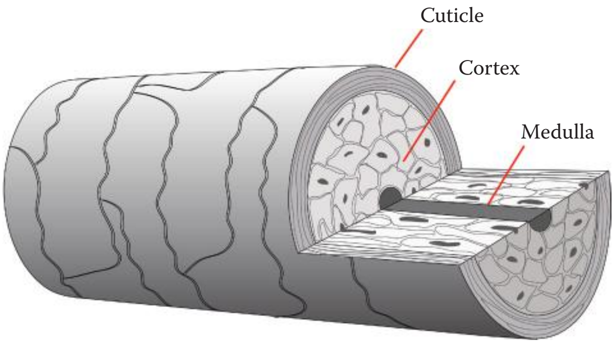

Figure 4.16 A sectional view of a hair shaft. (© Richard C. Li.)

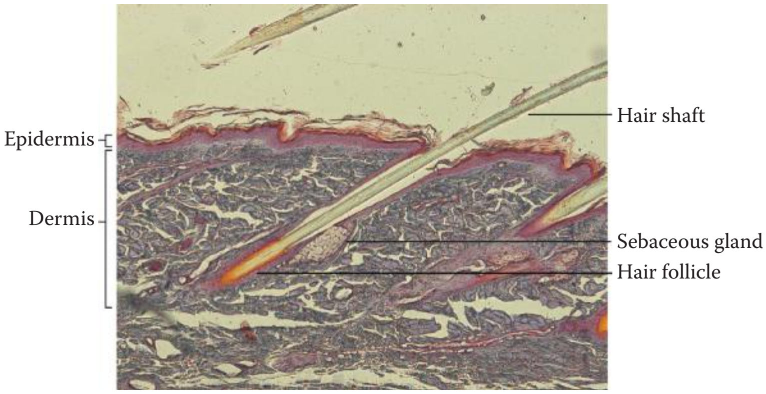

Figure 4.17 Longitudinal section view of a scalp hair follicle with accessory structures. (© Richard C. Li.)

of the *bulge* and the *bulb* regions. The bulge exports the stem cells that migrate down and give rise to bulb cells. The bulge also produces the stem cells that migrate up to form skin cells. The matrix cells, which generate the hair shaft cells, are located at the lower portion of the bulb. The *dermal papilla* is situated at the base of the bulb and contains cells that regulate hair growth, which are nourished by blood vessels and nerves. The growing hair shaft is surrounded by two concentric layers of cells, which are referred to as the inner root sheath and the outer root sheath, respectively. The entire hair follicle is surrounded by a connective tissue sheath.

Human scalp hairs grow for a few years and shed according to the hair follicle cycle (Figures 4.19 through 4.21). A human scalp hair can grow at its highest rate of approximately 1 mm per day. The growing phase of hair is called the *anagen* phase. The matrix cells undergo rapid proliferation and eventually become differentiated cells such as hair shaft cells. As a hair grows, it is pushed toward the surface of the skin and becomes longer. During the migration upward, keratinization occurs as cells are filled with fibril keratin proteins. In these keratinizing cells, nuclei are absent. However, mitochondrial remnants can be observed. By the time a hair approaches the skin surface, cell death occurs at the medulla, cortex, and cuticle. At the end of the anagen phase, the matrix cells enter the *catagen* phase and undergo cell death, thus leading to the regression of the bulb. Hair follicles then enter the *telogen* phase: the stage of rest. When another cycle begins, the follicle produces a new bulb and the telogenic hair, also known as the club hair, is pushed to the surface and shed. On average, an adult loses approximately dozens of hairs daily.

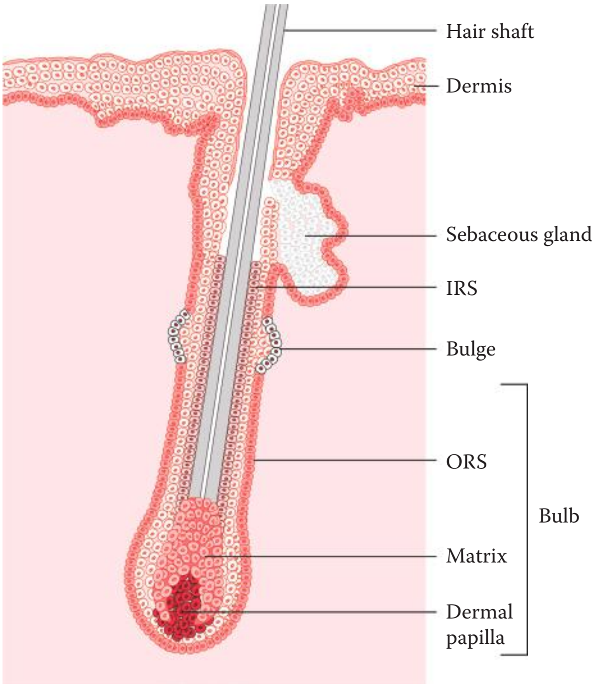

Figure 4.18 Structure of an anagen-phase hair follicle. The diagram shows the hair follicle structure including the dermal papilla, sebaceous gland, bulge, bulb, and hair shaft. Concentric layers of the outer root sheath (ORS), the inner root sheath (IRS), and the hair shaft are also shown. (© Richard C. Li)

4.3.2.2 Hair as Source of DNA Evidence

The isolation of DNA from intact hair roots is routinely used in nuclear DNA analysis. In comparison, the quantities of DNA in telogen hair roots are considerably less than the DNA that is found in the roots of anagen hairs. Nuclear DNA analysis is usually accomplished by using freshly plucked hair roots (Figures 4.22 and 4.23) because cells at the root region may contain nuclear DNA. Unfortunately, most human hairs recovered from crime scenes are shed naturally (in the telogen phase) and contain little nuclear DNA (Figure 4.24). Thus, multiple telogen hairs with roots are necessary to isolate enough nuclear DNA. However, shed hairs that are found at crime scenes may be derived from different individuals. Therefore, the ability to perform a forensic DNA analysis of a single shed hair would be highly desirable. Nuclear DNA isolation from hair shafts is still far less reliable because hair shafts contain very low amounts of nuclear DNA. In addition, variations in the amounts of DNA isolated from hair shafts are observed in a comparison between different hairs from the same head and hairs from different individuals.

A hair follicle cell contains multiple copies of mitochondria. As a result, mitochondrial DNA (mtDNA) can be successfully isolated from hair roots. Additionally, mtDNA is embedded in the keratin matrix of hair shaft cells, which protects the mtDNA molecules from degradation. Thus, mtDNA can also be isolated from hair shafts. A sequence polymorphism analysis of mtDNA from hair can be carried out. mtDNA is maternally inherited, which is useful to identify maternal relatives but cannot be used to perform paternity testing. Additionally, the mtDNA profiling results are not as discriminating as nuclear DNA profiling. Furthermore, mtDNA analysis is time-consuming. Therefore, the typing of nuclear DNA from hair would be preferable for forensic DNA analysis.

Sometimes, a mixture of more than one mtDNA sequence in the same individual is observed. This heterogeneous pool of mtDNA molecules is referred to as *heteroplasmy*. In hair, it is

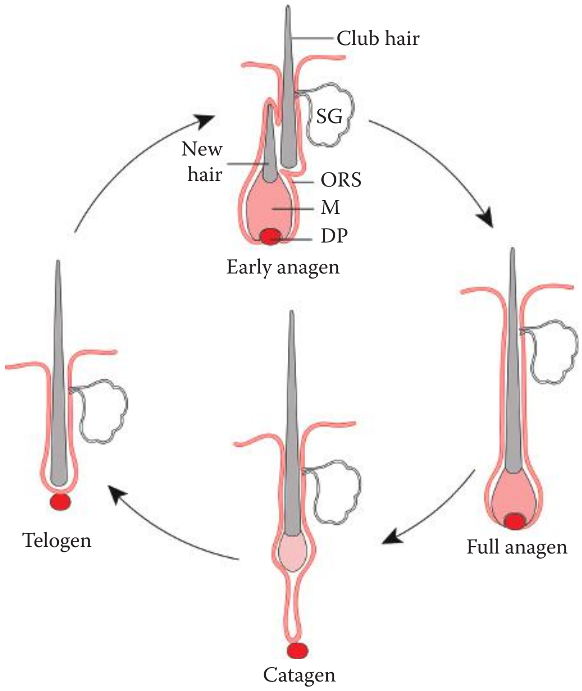

Figure 4.19 Diagrammatic representation of the scalp hair cycle. The morphological characteristics of a hair follicle are shown in three distinct phases encompassing the entire hair cycle: anagen (including early and full anagen), catagen, and telogen. DP, dermal papilla; M, matrix; ORS, outer root sheath; SG, sebaceous gland. (© Richard C. Li.)

believed that it is due to a mixture of mtDNA molecules from keratinocyte and melanocyte-derived mitochondria (Figure 4.25). Hair follicle melanocytes are formed at the beginning of each hair cycle and die at the end of the cycle. Melanocytes are located in the bulb hair follicle. Hair melanocytes play roles in hair pigmentation, which determine hair color. Melanin, which is produced by the melanocytes, is contained in an organelle called the *melanosome*. The melanosomes are transferred to neighboring keratinocytes though *dendritic processes*. In addition to melanosomes, the melanocyte mitochondria can also be transferred to keratinocytes. Thus, the keratinized cells in the hair shaft may carry more than one type of mitochondria, one from the keratinocytes and the other from the melanocytes. As a result, heteroplasmy of a mixture of different mtDNA molecules, with different DNA sequences, can occur in hairs.

4.3.3 Bone

4.3.3.1 Biology of Bone

The bodies of human remains begin to decompose shortly after death. The rate of decomposition of human remains varies greatly with environmental conditions such as climate, bacterial growth, and the presence of insects and other animal scavengers. However, soft tissues may be lost first while more stable bone tissues may remain. Identifying human skeletal remains can be applied in a variety of cases including mass fatality incidents, missing persons, fires, explosions, and violent crime cases involving skeletal remains.

An adult human skeleton consists of 206 bones (Figures 4.26 and 4.27). The shaft of a long bone, such as an arm or a leg bone, consists largely of an outer layer of *cortical* (or compact) bone, which is solid and strong. The shaft of a long bone forms a *marrow cavity*, which is filled with a specialized type of connective tissue called bone marrow. The portion at each end of a

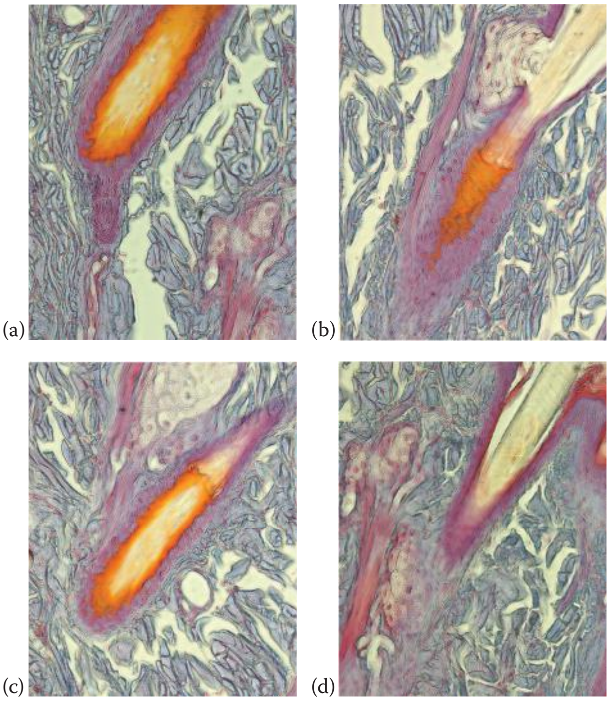

Figure 4.20 Longitudinal section view of a scalp hair follicle during the hair cycle. (a) Early anagen, (b) full anagen, (c) catagen, and (d) telogen. (© Richard C. Li.)

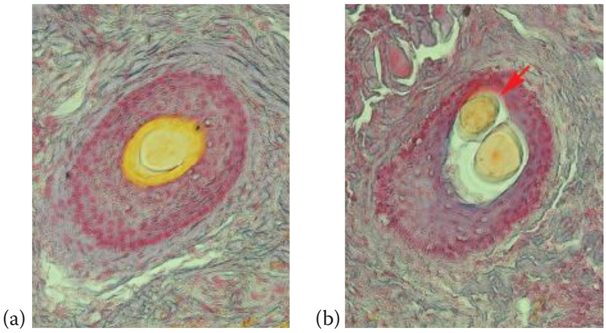

Figure 4.21 Cross-sectional view of hair follicles. (a) Early anagen and (b) full anagen. Note that the new hair (arrow) and the club hair are shown. (© Richard C. Li.)

long bone is called the *epiphysis*, which is composed largely of *cancellous* (or spongy) bone, and can bear the force of compression. A flat bone can have primarily either cortical or cancellous bone. For instance, a rib consists of primarily cancellous bone surrounded by a thin layer of cortical bone. A skull bone usually consists of largely cortical bone.

Bone, which is a connective tissue, contains a matrix and cells. The bone matrix consists of an inorganic and an organic matrix. Calcium and phosphorus are the major components of the inorganic matrix, which consists mainly of hydroxyapatite crystals, $Ca_{10}(PO_4)_6(OH)_2$. The organic matrix consists of collagens, primarily type I collagen, which are insoluble fibrous proteins. With the deposition of calcium hydroxyapatite crystals around the collagen fibrils, bone becomes a weight-bearing hard tissue.

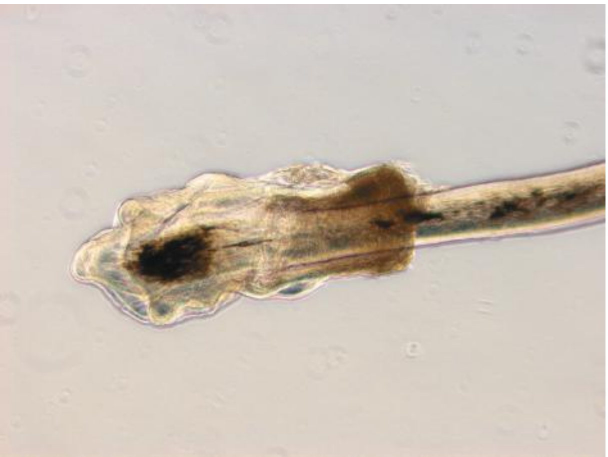

Figure 4.22 Hair root of a pulled hair with visible soft tissue attached. (© Richard C. Li.)

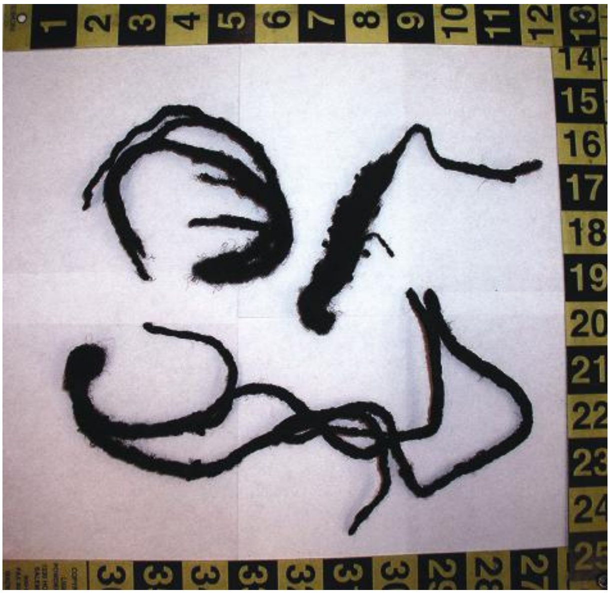

Figure 4.23 Pulled dreadlocks recovered from a crime scene. (© Richard C. Li.)

Developing bones contain small numbers of *osteoprogenitor* cells. These cells can divide to produce cells that differentiate into *osteoblasts*. Osteoblast cells regulate the calcification of the bone matrix. Osteoblasts that are embedded in the bone matrix are termed *osteocytes* and are the most abundant cells in bone. Osteocytes play a role in maintaining the surrounding matrix and repairing damaged bone. Another type of cell that can be found in bone tissues is *osteoclasts*. These cells are giant cells containing 50 or more nuclei and are responsible for dissolving and recycling the bone matrix.

4.3.3.2 Bone as Source of DNA Evidence

A number of methods are used to identify human remains, for example: the identification of facial characteristics; the recognition of individualizing scars, marks, and other special body

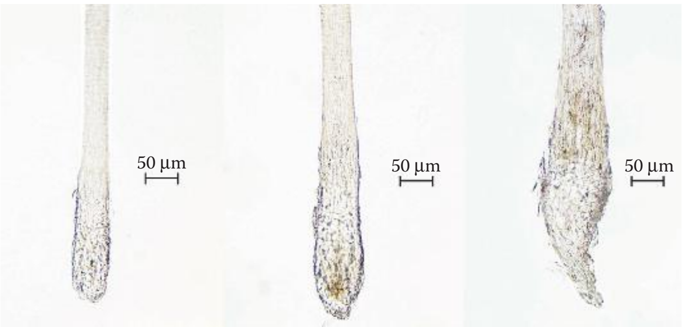

Figure 4.24 Telogen hair roots. From left to right: telogen club root with no visible soft tissue; telogen hair root with some visible soft tissue; telogen hair root with visible soft tissue. (From Bourguignon, L. et al., *Forensic Sci Int Genet*, 3, 27–31, 2008. With permission.)

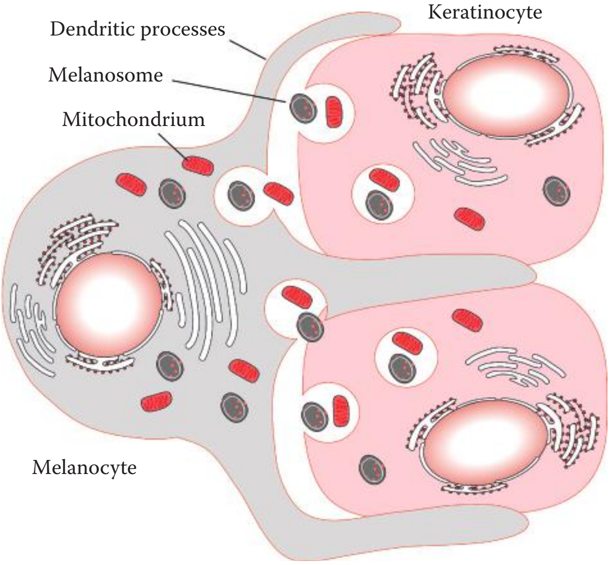

Figure 4.25 Scheme diagram of the melanosome transportation. Melanosomes are released into the extracellular space from the melanocyte dendrites through exocytosis and subsequent endocytosis by keratinocytes. During the process, mitochondria originating from the melanocytes can be potentially transported to the keratinocytes. (© Richard C. Li.)

features; the matching of dentition with premortem dental x-rays; and the comparison of fingerprints. In some situations, these methods cannot be used because of the extensive decomposition of the remains. The mass fatality terrorist attack on the World Trade Center in 2001 (Figure 4.28) serves as an example of a situation where common identification techniques may not be useful. Large quantities of compromised human skeletal fragments were recovered at the fatality site. In these cases, DNA typing is a powerful tool for identifying human remains.

Most DNA in cortical bone is located in the osteocytes. It has been estimated that there are approximately 20,000 osteocytes per cubic millimeter of calcified bone matrix. As a result, microgram quantities of DNA can potentially be obtained from a gram of bone. Thus, compact bone tissue should contain sufficient amounts of nuclear DNA for analysis. However, the skeletal fragments recovered from burial sites are often subjected to decomposition (Figures 4.29 and 4.30). During the decomposition process, both nuclear and mtDNA can be degraded.

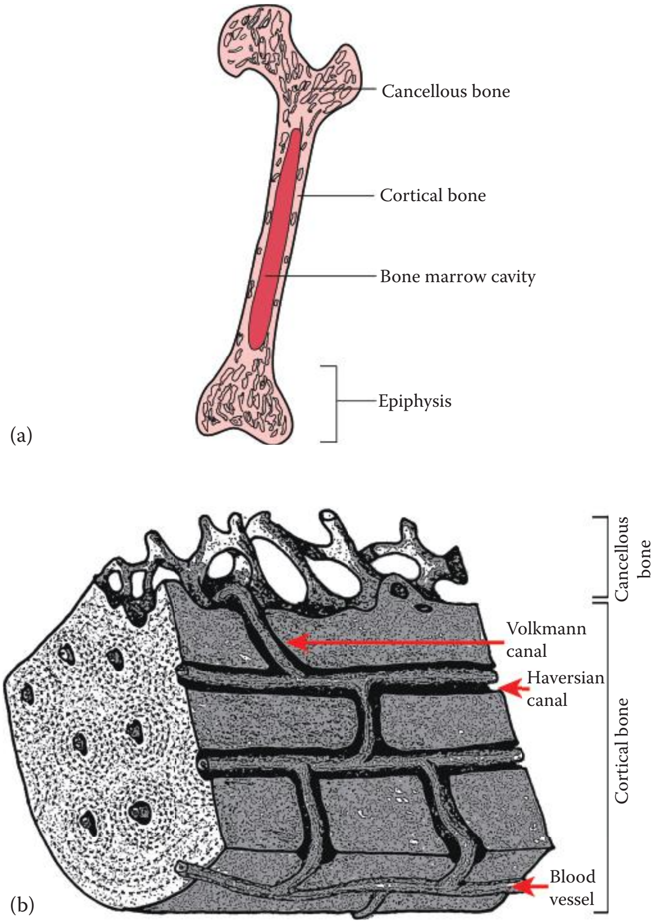

Figure 4.26 Bone structure. An adult human consists of 206 bones. A long bone, such as an arm or a leg bone, consists of an outer cylinder of cortical bone surrounding a marrow cavity. Each end of a long bone is called the epiphysis, which is composed largely of cancellous bone. Flat bones have variable structures; for example, the skull consists mainly of cortical bone whereas the spine consists mainly of cancellous bone. (a) Diagram of a long bone. (b) A bone fragment. Cortical and cancellous bones are shown. Blood vessels can be found in the Volkmann and Haversian canals. (© Richard C. Li.)

Additionally, burial conditions with high humidity and temperature promote the degradation of DNA. Thus, the identification of partial DNA profiles or the complete failure to obtain DNA profiles can occur after samples from decomposed remains are analyzed.

Processing bone samples for DNA extraction is a time-consuming task (Figure 4.31). Due to the potential for commingled remains and contaminants that interfere with forensic analysis, a bone sample initially must be cleaned prior to isolating DNA. The outer surfaces of bone fragments are usually removed by using a mechanical method such as sanding. However, to avoid cross-contamination of samples, the bone dust that is generated by sanding must be removed. Additionally, special protective equipment and safety procedures are necessary to protect analysts from exposure to blood-borne pathogens.

To obtain adequate quality and quantity of DNA from a bone sample, a high-yield DNA extraction method should be selected. The bone samples can be ground to powder to aid in DNA extraction (Chapter 5). The osteocytes containing DNA are embedded in a calcified bone matrix, which is a barrier for extracting DNA from the osteocytes. The bone matrix must be

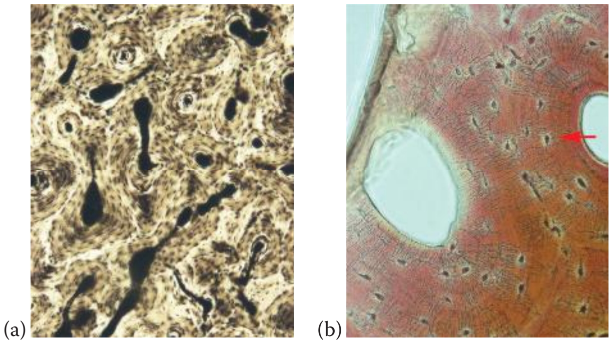

Figure 4.27 Cross-sectional view of cortical bone. (a) The functional unit of cortical bones is a cylindrical structure known as osteon. Haversian canals are shown in the center of the osteon. (b) Detailed view of an osteon. Osteocytes (arrows) are shown within osteons. (© Richard C. Li.)

Figure 4.28 Sections of the Fire Department of New York City (FDNY) Memorial Wall. Memorial to the Fallen Firefighters of 9/11, at FDNY Engine Co. 10 on Liberty Street, New York, by Rambusch Studios. (© Richard C. Li.)

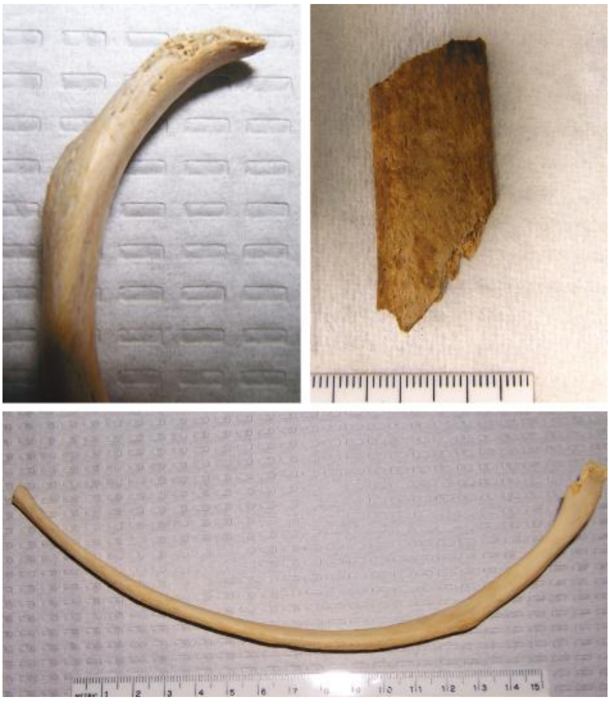

Figure 4.29 Human rib bone fragments recovered from burial site. (© Richard C. Li.)

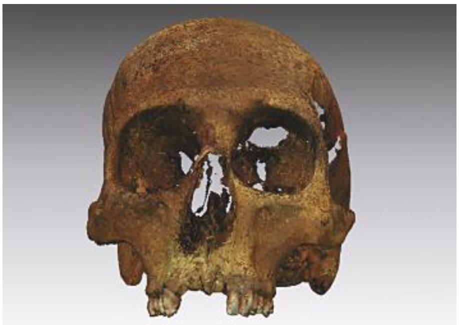

Figure 4.30 Skeletal remains, exhumed from Frombork Cathedral in Poland, are thought to be those of astronomer Nicolaus Copernicus (1473–1543). (From Bogdanowicz, W., et al., *Proc Natl Acad Sci U S A*, 106, 12279–12282, 2009. With permission.)

removed to improve the yield of DNA. A decalcification method can be utilized to dissolve calcium ions to soften the bone tissue. Additionally, the application of proteinase can be used to digest the matrix proteins, thus increasing the yield of DNA that is harvested from osteocytes.

4.3.4 Teeth

4.3.4.1 Biology of Teeth

During embryonic development, two sets of teeth begin to form. The first to appear are the *deciduous teeth* or *primary teeth*. Most children have 20 deciduous teeth, which are later replaced by 32 teeth known as the *secondary dentition* or *permanent dentition* (Figure 4.32).

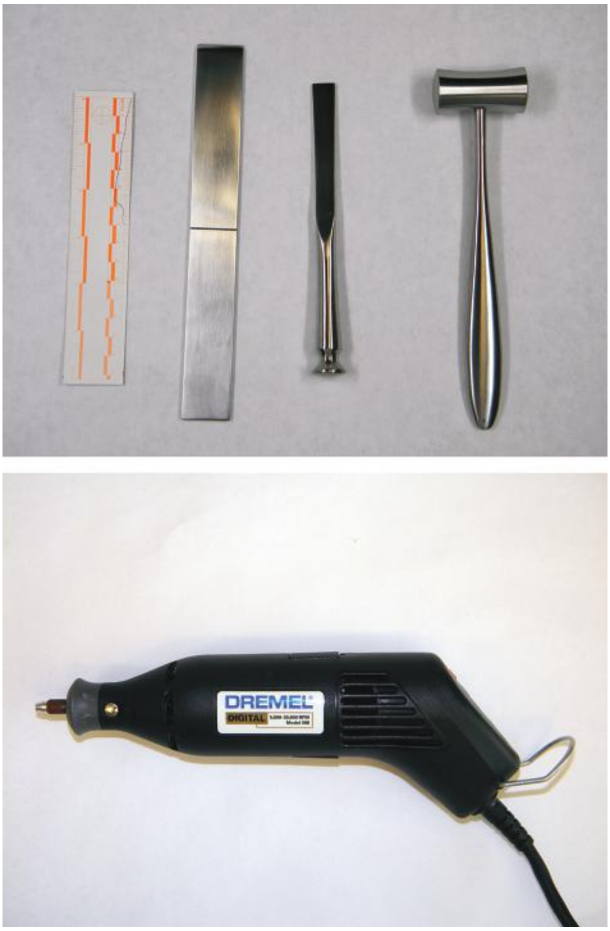

Figure 4.31 Tools for cutting bone samples. Osteotomes and a mallet (top), and a rotary device (bottom). (© Richard C. Li.)

The bulk of each tooth consists of a calcified connective tissue called *dentin* (Figure 4.33). The dentin of the crown is covered by a layer of *enamel*. The rest of the dentin is referred to as radicular dentin and is covered by a layer of *cementum*, which separates the tooth from the surrounding jawbone.

Similar to bone, tooth tissue contains a matrix. The inorganic matrix of tooth contains hydroxyapatite, a calcium phosphate in a crystalline form. The organic matrices of dentin and cementum are primarily collagens. In enamel, amelogenin is the major protein of the organic matrix. Other proteins include ameloblastin and enamelin, which are also the components of the enamel organic matrix.

The interior chamber within the tooth surrounded by dentin is known as the pulp cavity. The *dental pulp*, found within the pulp cavity, is the connective tissue made up of nerve fibers, blood vessels, and various cells. The blood vessels and nerves in the pulp cavity are innervated through the root canal, a narrow tunnel located at the root of the tooth. Incisor and cuspid teeth have single roots. Bicuspids have one or two roots. Molars typically have three or more roots.

The columnar cell bodies of *odontoblasts* are located along the peripheral dental pulp. A single *odontoblast process*, arising from each cell body of the odontoblasts, projects into the dentinal tubule (Figure 4.34). Odontoblasts play important roles in the formation of dentin. Odontoblasts secrete collagens and ground substances that are the components of the

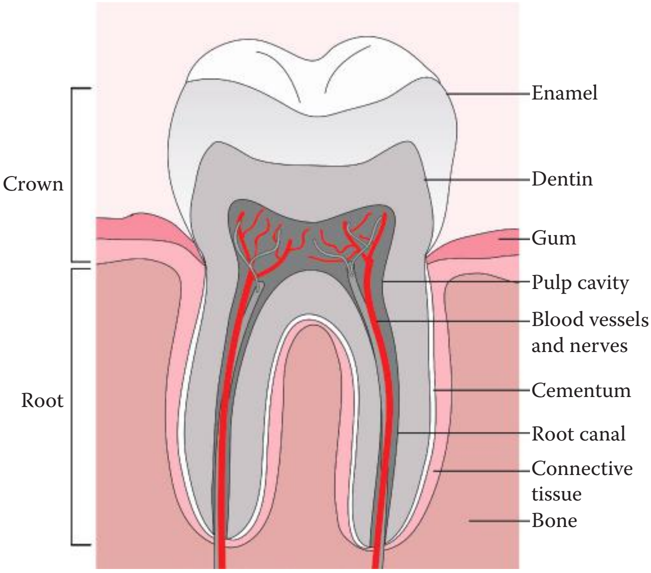
Crown
Root
Enamel
Dentin
Gum
Pulp cavity
Blood vessels and nerves
Cementum
Root canal
Connective tissue
Bone

Figure 4.32 A sectional view of an adult tooth. (© Richard C. Li.)

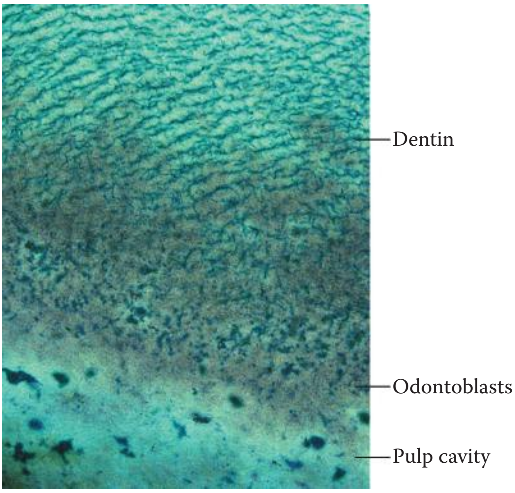
Dentin
Odontoblasts
Pulp cavity

Figure 4.33 Cross-sectional view of a tooth. (© Richard C. Li.)

dentinal matrix. Additionally, odontoblasts regulate the calcification of the matrix of dentin. *Cementoblasts* are cells that play roles in forming the cementum. Cementoblasts secrete collagens and ground substances to form the extracellular matrix of the cementum. Through the process of forming cementum, cementoblasts become trapped in the extracellular matrix. The cementoblasts embedded in the cementum are referred to as *cementocytes*. *Ameloblasts* are cells that play a role in producing enamel and are subsequently lost during tooth eruption.

4.3.4.2 Teeth as Source of DNA Evidence

The characteristics of teeth, their alignment, and the overall structure of the mouth provide information for identifying a person. The use of dental records such as x-rays and dental casts can allow dental remains to be connected to a victim. Particularly in circumstances such as

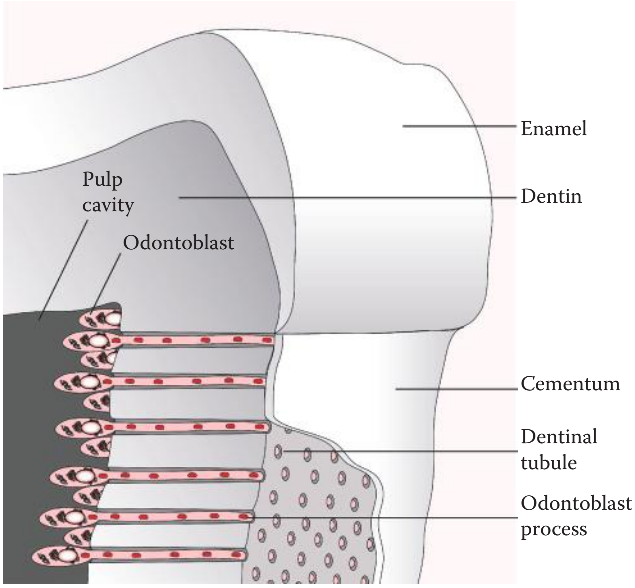

Figure 4.34 Odontoblast processes. See Section 4.3.4.1. (© Richard C. Li.)

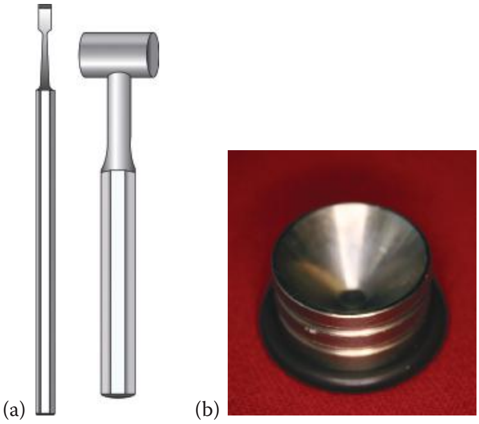

Figure 4.35 Tools for dissecting teeth. (© Richard C. Li.) (a) A dental chisel and a mallet. (© Richard C. Li.) (b) An amalgam well. (Courtesy of Dr. Ken Hermsen.)

decomposition, an odontological comparison is possible since the dental evidence often remains intact. When no antemortem dental record is available for comparison, forensic DNA testing can be carried out for postmortem human identification. The mineralized dental structure protects DNA from degradation in cases where it may be degraded in other tissues of the body. Thus, teeth are an excellent source of DNA for forensic DNA analysis under such conditions.

Dental pulp tissue contains various cells and is a suitable source of DNA. However, when tooth evidence has been exposed to high temperature and humid environments, decomposition of the pulp tissue can occur. Thus, cementoblasts within the cementum, containing both nuclei and mitochondria, can then be utilized as a source of DNA. Additionally, odontoblast processes within dentin, containing mitochondria, can also be used. Several different methods are used to obtain dental tissues for DNA isolation (Figure 4.35). A vertical section is cut along the longitudinal axis of the tooth, which allows the dissection of the pulp, dentin, and cementum tissues

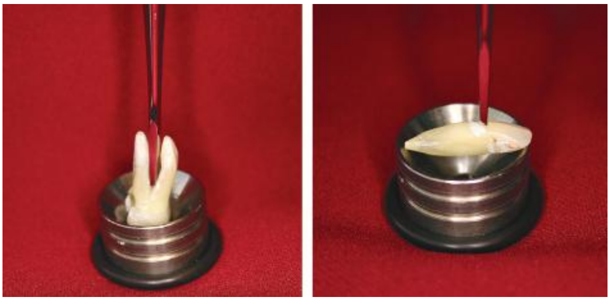

Figure 4.36 Dissecting teeth for DNA isolation. Vertical cutting and dissecting of the pulp, dentin, and cementum tissues (left) and horizontal cutting and dissecting of the root portion (right). (Courtesy of Dr. Ken Hermsen.)

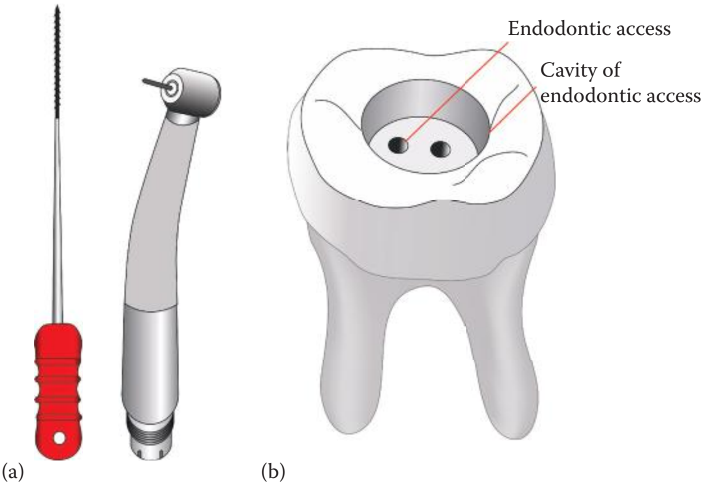

Figure 4.37 Extraction of pulp tissue using endodontic access procedures: trepanning the occlusal surface of a tooth using a dental bur mounted on a turbine (a), creating a cavity for endodontic access (b), and extracting pulp tissue using a nerve broach (a). (© Richard C. Li.)

(Figure 4.36). A horizontal section is cut through the cementum–enamel junction of the tooth (Figure 4.36). The root portion can be pulverized to a fine powder for DNA isolation. The crown can be preserved for forensic odontological comparisons if needed. Additionally, the extraction of pulp tissue can be carried out by standard endodontic access (Figure 4.37). For calcified tissues such as dentin and cementum, a decalcification step is needed to soften the dental matrix, which facilitates DNA isolation.

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SECTION II

Basic Techniques in Forensic Biology

5

Nucleic Acid Extraction

5.1 Basic Principles of DNA Extraction

Deoxyribonucleic acid (DNA) is a linear polynucleotide consisting of four types of monomeric nucleotides. Each nucleotide contains three components: a deoxyribose, a nitrogenous base, and a phosphate group (Figure 5.1). The four bases for DNA are adenine (A), cytosine (C), guanine (G), and thymine (T) (Figure 5.2). The deoxyribose is attached to the nitrogen of a base. The phosphate group is attached to the deoxyribose. In a *polynucleotide*, individual nucleotides are linked by phosphodiester bonds (Figure 5.3).

Interestingly, the first attempt to isolate DNA from humans, which involved the use of human leucocytes, was accomplished by the Swiss physician Friedrich Miescher in 1869. This study led to the discovery of the DNA molecule, which he referred to as "nuclein." Over the years, various methods for isolating DNA from blood samples were developed. However, many protocols still use the basic principles Miescher developed more than 100 years ago.

This chapter introduces basic techniques for DNA extraction used in forensic laboratories (Table 5.1). The commonly used methods isolate total cellular DNA, which is suitable for most forensic DNA analyses. However, DNA extraction procedures may vary according to the type of biological evidence, which can include cell types, substrates, the quantity of biological evidence collected, and the type of test that is being performed. Specific DNA extraction procedures for a sample of interest can be found in the literature. The extraction method of choice yields an optimal quantity, quality, and purity of DNA to satisfy forensic DNA testing needs. A sufficient quantity of DNA ensures the generation of a complete DNA profile. Poor quality of DNA, such as fragmentation due to DNA degradation, may result in a partial DNA profile or a failure to obtain a profile. Poor purity of DNA may cause interference during subsequent DNA testing. For example, DNA polymerase inhibitors interfere with DNA amplification (Chapter 7). Additional criteria for selecting proper DNA extraction methods include adaptability to automation, throughput potential, simplicity, the reduction of contamination risks, and cost-effectiveness. The most common DNA extraction protocols include basic components discussed below.

5.1.1 Cell and Tissue Disruption

In most DNA extraction protocols, enzymatic digestions, such as those with proteinase K, are used for cell and tissue disruption. The disruption process can also be carried out by boiling and by using alkali treatment and mechanical methods (Figures 5.4 and 5.5). Materials such as bone and teeth can be frozen in liquid nitrogen and then ground to a fine powder with a mortar or cryogenic grinder such as the SPEX CertiPrep® freezer mill (Figure 5.6). In such specimens, cells containing DNA

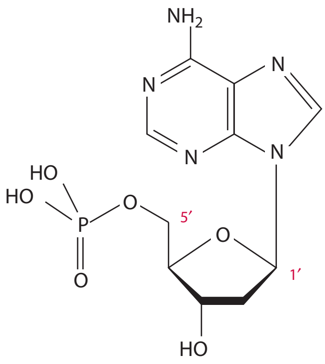
NH2
N
N
N
N
HO
HO
O
P
O
5′
O
1′
HO

Figure 5.1 Structure of a nucleotide. Each nucleotide in a DNA polymer is made up of three components: a deoxyribose, a nitrogenous base (adenine is shown as an example), and a phosphate group. The 1′ carbon of the deoxyribose is attached to the nitrogen of a nitrogenous base. A phosphate group is attached to the 5′ carbon of the deoxyribose.

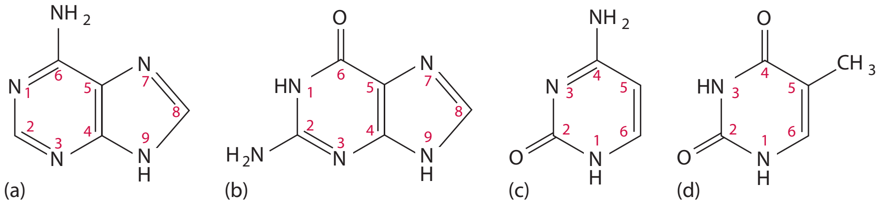
(a)
(b)
(c)
(d)
NH 2
O
NH 2
O
CH 3
HN
H 2N
N
HN
N
H

Figure 5.2 Chemical structures of nitrogenous bases: (a) adenine, (b) guanine, (c) cytosine, and (d) thymine.

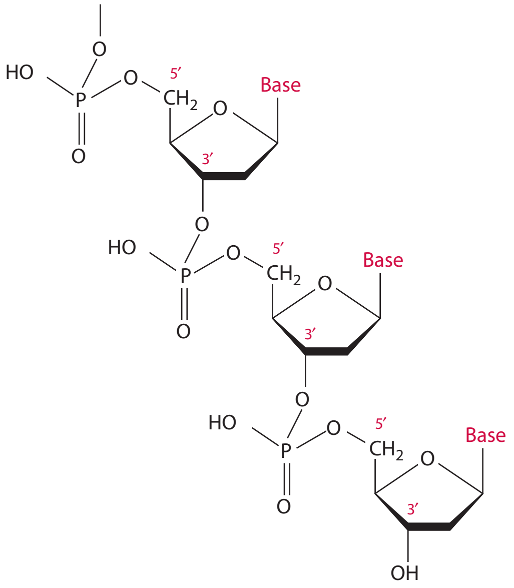
HO
O
P
O
5′
CH2
Base
3′
OH

Figure 5.3 DNA polynucleotide chain. Individual nucleotides are linked by phosphodiester bonds between their 5′ and 3′ carbons.

Table 5.1 Three Basic DNA Extraction Methods

Method	Forensic Application	Purity	DNA Strand	DNA Size	Throughput	Note
Solvent-based	RFLP- and PCR-based assay	High	Double stranded	Large	Time-consuming; difficult to adapt for automation	Uses toxic solvent; multiple transfer steps between tubes
Boiling	PCR-based assay	Low	Single stranded	Small	~30 min per sample	No transfer required
Silica-based	RFLP- and PCR-based assay	High	Double stranded	Large	~1 h per sample; amenable to automation	Minimum transfer required

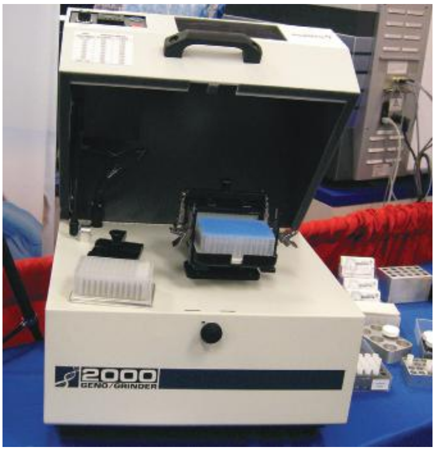

Figure 5.4 An automated mechanical disruption device for efficient disruption of tissues. It can be used for high-throughput applications involving sample preparation for the isolation of nucleic acids. (© Richard C. Li.)

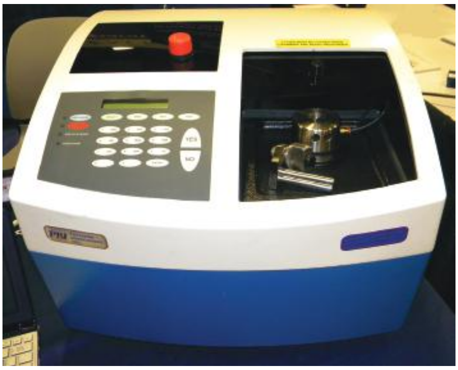

Figure 5.5 Tissue disruption using a pressure-generating instrument also known as a barocycler. During the process, a barocycler is utilized to apply alternating cycles of high and low pressures onto specimens placed in single-use processing containers. The technique is known as pressure-cycling technology (PCT). (© Richard C. Li.)

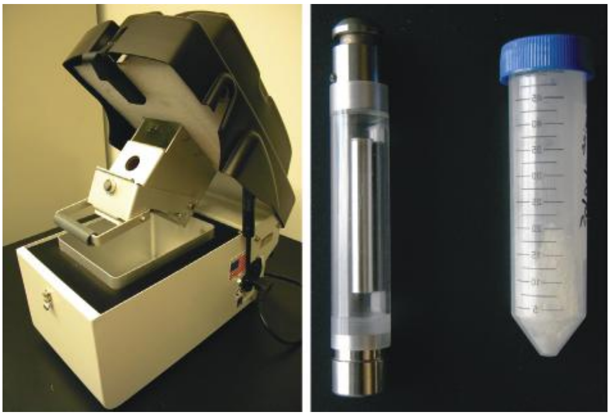

Figure 5.6 Tissue disruption using cryogenic grinding. A cryogenic mill (left), also known as freezer mill, can be used for the pulverization of hard tissue such as bone samples into fine powder prior to DNA extraction. During a grinding cycle, an impactor (right) moves back and forth, under a magnetic field, inside a grinding vial, grinding the sample to a fine powder. The grinding process is carried out at low temperatures (approximately −196°C), using liquid nitrogen to protect temperature-sensitive analytes such as DNA. (© Richard C. Li.)

are embedded in a calcified matrix that is responsible for the rigid structure of bone and teeth. In order to achieve a high yield of DNA extraction, it is necessary to remove the calcified matrix. A decalcification process removes calcium ions from the matrix, thus making the specimen suitable for DNA extraction. The most commonly used decalcifying agents for DNA extraction purposes are chelating agents such as ethylenediaminetetraacetic acid (EDTA), which sequesters the calcium ions. Decalcification is a lengthy procedure. Bone or teeth powder is usually treated with the decalcifying agent overnight or for a longer period of time, depending on the size and source of the sample.

5.1.2 Lysis of Cellular and Organelle Membranes

During or after tissue disruption, membranes—including those of cells, nuclei, and mitochondria—are lysed in order to release DNAs, including nuclear and mitochondrial DNA. The lysis can be carried out using salts and chaotropic agents (Section 5.2.3) such as guanidinium salts and detergents such as sarkosyl and sodium dodecyl sulfate (SDS). These substances can destroy membranes, denature proteins, and dissociate proteins such as histones from DNA. The lysis procedure is usually carried out in a buffer, such as Tris, in order to maintain a pH where endogenous *deoxyribonucleases* (DNases) remain inactive. DNases are a type of nuclease that catalyzes the cleavage of phosphodiester bonds of DNA. Endogenous DNases are located in cytoplasmic lysosomes and play a role in degrading the DNA of invading viruses. When cells are lysed, the DNases that are also released can degrade the extracted DNA. Chelating agents such as EDTA or Chelex® (Section 5.2.2) can therefore be used to chelate the divalent cations that are the cofactors of DNases, in order to inhibit DNase activities. Furthermore, reducing agents such as mercaptoethanol or dithiothreitol (DTT) can be used to inhibit the oxidization processes that can damage DNA.

5.1.3 Removal of Proteins and Cytoplasmic Constituents

After lysis, cytoplasmic constituents, such as proteins and liquids that interfere with DNA extraction, are removed. Proteins and lipids are usually removed by one or more rounds of extraction with organic solvents such as phenol–chloroform mixtures (Section 5.2.1). Another strategy to remove cytoplasmic constituents is to utilize the reversible binding of DNA to a solid material such as silica, which selectively binds DNA in chaotropic salt solutions. The proteins and cytoplasmic constituents can then be removed through washing steps.

5.1.4 Storage of DNA Solutions

Purified high-molecular-weight DNA is usually stored in TE buffer (10 mM Tris-HCl, 1 mM EDTA, pH 8.0). EDTA is usually included in storage solutions to chelate divalent cations and thereby inhibit DNases. Such a DNA solution may be stored at 4°C or −20°C. For long-term storage, −80°C is recommended. Frequent freezing or thawing cycles should be avoided because temperature fluctuations may cause breaks of single- and double-stranded DNA. Additionally, DNA containing impurities such as extracts generated via the Chelex method are much less stable. The presence of heavy metals, such as cadmium and cobalt, can cause breakage of phosphodiester bonds in the molecules. Additionally, unsuccessful removal of exogenous or intracellular free radicals, such as a hydroxyl radical (HO·), which have unpaired valence electrons, can cause DNA damage such as strand breaks. Furthermore, contamination by DNases may lead to subsequent degradation of DNA.

5.1.5 Contamination

Contamination is usually caused by the introduction of exogenous DNA to an evidence sample. It can occur between samples, between an individual and a sample, between other organisms and a sample, or between amplified DNA and a sample. Certain procedures can be utilized to prevent the occurrence of contamination. For example, evidence and reference samples should be processed separately in different rooms to avoid sample-to-sample contamination. In situations where space is limited, the evidence sample should be processed before the reference sample. Additionally, evidence samples should be processed and extracted for isolating DNA in separate areas (or at different times) from DNA amplification areas.

Solutions and test tubes used for extraction should be DNA-free, and aerosol-resistant pipet tips should be used during the extraction process. Additionally, the levels of contamination should be monitored by using *extraction reagent blanks* (having reagents but no samples), which monitor contamination from the extraction.

5.2 Methods of DNA Extraction

5.2.1 Extraction with Phenol–Chloroform

This method is also called organic extraction. Major steps include the following:

5.2.1.1 Cell Lysis and Protein Digestion

These steps can be achieved by digestion with proteolytic enzymes such as proteinase K before extraction with organic solvents.

5.2.1.2 Extraction with Organic Solvents

The removal of proteins is carried out by extracting aqueous solutions containing DNA with a mixture of phenol:chloroform:isoamyl alcohol (25:24:1). Phenol is used to extract the proteins from the aqueous solution. Although phenol has a slightly higher density than water, it is sometimes difficult to separate it from the aqueous phase. Therefore, chloroform is utilized as it has a higher density than phenol. As a result, the phenol–chloroform mixture forms the organic phase at the bottom of the tube and is easily separated from the aqueous phase. Isoamyl alcohol is often added to the phenol–chloroform mixture to reduce foaming. During partition, DNA is solubilized in the aqueous phase, while lipids are solubilized in the organic phase. Proteins are located at the interface between the two phases (Figure 5.7).

5.2.1.3 Concentrating DNA

Two common methods for concentrating DNA are ethanol precipitation and ultrafiltration. In the first method, the DNA is precipitated from the aqueous solution with ethanol and salts. Ethanol depletes the hydration shell of DNA, thus exposing its negatively charged phosphate groups. The

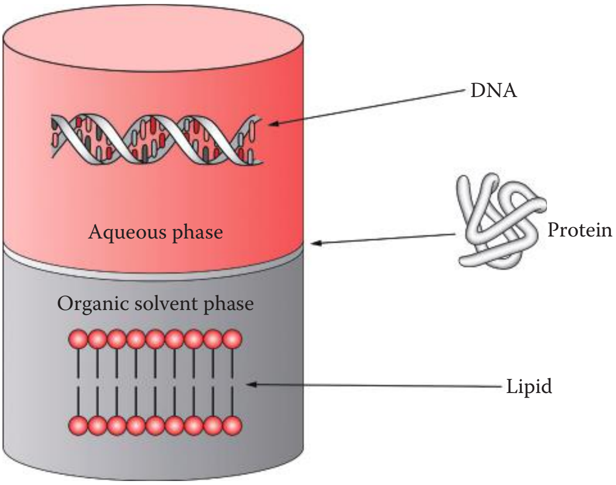
DNA
Protein
Aqueous phase
Organic solvent phase
Lipid

Figure 5.7 DNA extraction using organic solvent. The DNA is contained in the aqueous phase, while cellular materials such as lipids are contained in the organic-solvent phase. Proteins remain in the barrier between the two phases. (© Richard C. Li.)

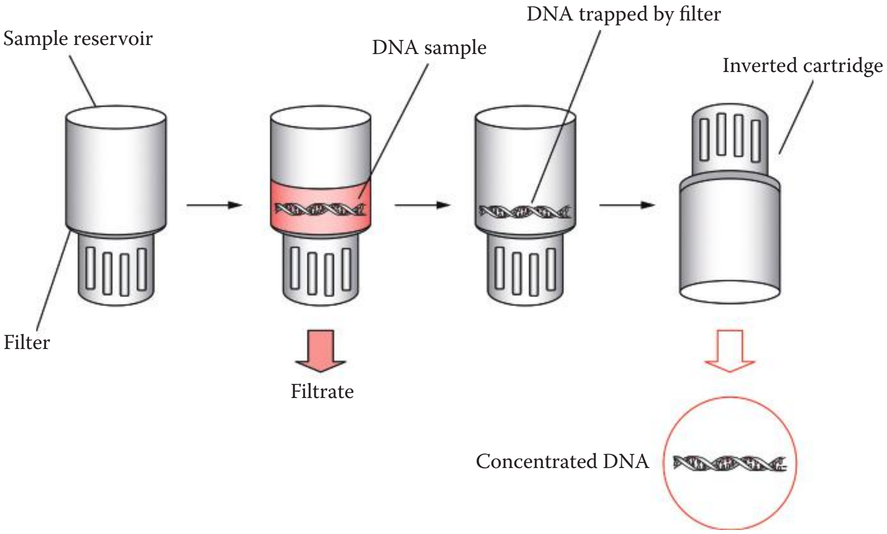
Sample reservoir
DNA sample
DNA trapped by filter
Inverted cartridge
Filter
Filtrate
Concentrated DNA

Figure 5.8 Concentrating DNA solutions using filtration devices. DNA samples are loaded into the reservoir. The liquid is filtered by centrifugation and the DNA becomes trapped in the membrane. The cartridge is then inverted to recover the trapped DNA by centrifugation. (© Richard C. Li.)

precipitation can only occur if sufficient quantities of cations are present in the solution. The most commonly used cations, such as ammonium, lithium, and sodium, neutralize the charges on the phosphate residues of DNA, forming a precipitate. Ultrafiltration is an alternative to ethanol precipitation for concentrating DNA solutions. The Microcon® and Amicon® are centrifugal ultrafiltration devices that can concentrate DNA samples (Figure 5.8). A proper Microcon® unit can be selected with a nucleotide cutoff equal to or smaller than the molecular weight of the DNA fragment of interest. Usually, the cutoff size is 100 kDa for forensic DNA samples.

Phenol–chloroform extraction yields large, double-stranded DNA and can be used for either restriction fragment length polymorphism (RFLP)-based or polymerase chain reaction

(PCR)-based analysis. However, the organic extraction method is time-consuming, involves the use of hazardous reagents, and requires the transfer of samples among tubes.

5.2.2 Extraction by Boiling Lysis and Chelation

This technique, also called the Chelex® extraction method, was introduced in the early 1990s to forensic DNA laboratories. It usually includes the following steps:

5.2.2.1 Washing

This step removes contaminants and inhibitors that may interfere with DNA amplification. For example, heme compounds found in blood samples should be removed from blood samples because it inhibits DNA amplification.

5.2.2.2 Boiling

Cells are suspended in a solution and incubated at 56°C, where DNases are not active, for 20 min. This preboiling step softens cell membranes and separates clumps of cells from each other. The cells are then lysed by heating to boiling temperature in order to break open the membranes and to release the DNA. Additionally, the lysis of cells releases all of their cellular constituents, including DNases. The DNase degradation of the extracted DNA can be blocked by applying a chelating resin (Chelex® 100) during the extraction process. Chelex® 100 is an ion-exchange resin composed of styrene divinylbenzene copolymers. The paired iminodiacetate ion groups in Chelex® 100 act as chelators by binding to divalent metal ions such as magnesium. Magnesium is a cofactor of endogenous DNases. Thus, sequestering magnesium in the solution using Chelex® 100 protects DNA from degradation by DNases (Figure 5.9).

5.2.2.3 Centrifugation

Brief centrifugation is performed to pull the Chelex® 100 resin and cellular debris to the bottom of the tube. The supernatant is used for DNA analysis. Carrying the Chelex® 100 resin over into the DNA amplification solutions should be avoided because the resin chelates magnesium, which is a necessary cofactor for DNA polymerases used for amplification.

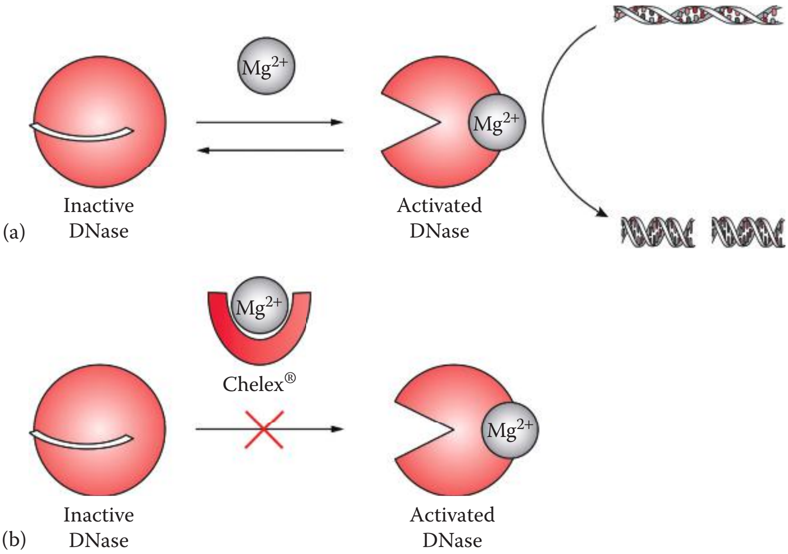

Figure 5.9 Utilizing Chelex® for preparing DNA samples. (a) Cations such as Mg^{2+} are required for the activity of endogenous DNase, which degrades DNA. (b) Chelex® prevents DNA degradation from endogenous DNase by sequestering the Mg^{2+}. (© Richard C. Li.)

This method is simple and rapid and uses only a single tube for extraction, thus reducing the risks of contamination and sample mix-ups. However, the heating step of this method disrupts and denatures proteins and also affects the chromosomal DNA. The resulting DNA extracted from the solution is fragmented single-stranded DNA. Thus, the DNA extracted is not suitable for RFLP analysis because RFLP requires double-stranded DNA samples. The DNA obtained by lysis and chelation can only be used for PCR-based DNA analysis.

5.2.3 Silica-Based Extraction

The method of adsorbing DNA molecules to solid silica surfaces is used for extraction (Figures 5.10 and 5.11). The method is based on the phenomenon that DNA is reversibly adsorbed to silica—silicon dioxide (SiO_2)—in the presence of high concentrations of chaotropic salts. Chaotropic salts can disrupt hydrogen bonding, affecting the three-dimensional structures of macromolecules. These salts are used to denature proteins. Additionally, chaotropic salts can facilitate the adsorption of DNA to silica.

In aqueous solutions, the hydration shells of nucleic acids shield the negative charges of phosphates at the phosphodiester backbone of nucleic acids. As a result, nucleic acids are usually hydrophilic in aqueous solutions. In the presence of chaotropic salts, nucleic acids become hydrophobic. The dehydrating effect caused by chaotropic salts allows the phosphate residues to become available for adsorption to the silica surface. Common chaotropic salts utilized for DNA extraction include guanidinium salts such as guanidinium thiocyanate (GuSCN) and guanidinium hydrochloride (GuHCl). GuSCN is a more potent chaotropic salt and also facilitates cell lysis and DNA adsorption. This technique usually includes the following steps:

5.2.3.1 Cell Lysis and Protein Digestion

This is carried out by proteinase K digestion. The cell membranes are broken open, and DNA is released.

5.2.3.2 DNA Adsorption onto Silica

This step utilizes silica as the stationary phase in a membrane configuration to which the DNA in the cell lysate binds. Adsorption of the DNA to the silica occurs in the presence of high concentrations of chaotropic agents (some protocols adjust pH conditions to enhance adsorption). Under these conditions, cellular materials and other contaminants that can inhibit DNA amplification reactions are not retained on the silica membrane. The adsorbed DNA is largely double stranded.

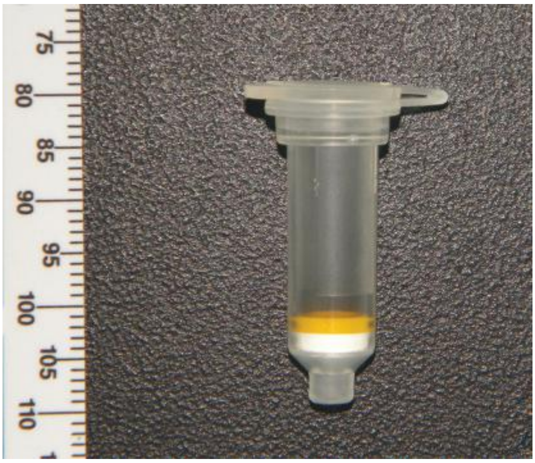

Figure 5.10 A silica-membrane spin column. (© Richard C. Li.)

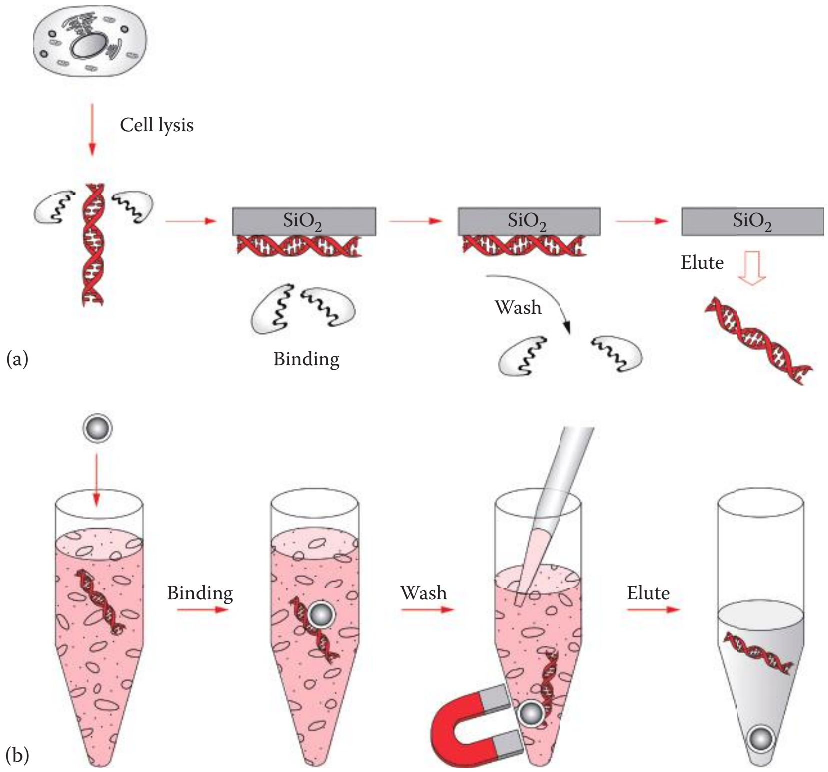

Figure 5.11 Silica-based DNA extractions. (a) Cells are lysed in the presence of proteinase. The DNA then binds to the silica matrix. A washing step removes unbound cellular materials and salts from the matrix. The purified DNA is then eluted for use in downstream applications. (b) Using silica-coated paramagnetic particles for DNA extraction. The particle is added into a lysate, and then DNA binds to the silica surface of the particle. The particle is then captured by a magnetic field. Afterwards, the supernatant is removed, and cellular materials are washed away. DNA elution follows. See Section 5.2.3. (© Richard C. Li.)

5.2.3.3 Washing

This step removes chaotropic agents and other contaminants. An ethanol-based wash solution is used. This wash solution does not remove DNA from the silica. The chaotropic agents and contaminants that are present in the solution can be removed using the ethanol-based wash solution.

5.2.3.4 Elution of DNA

The adsorbed DNA can be eluted by rehydration with aqueous low-salt solutions. The eluted DNA is double stranded and can be used for a wide variety of applications.

Silica-based extraction methods yield high-quality DNA. Silica membrane devices can also be adapted for automation; for example, this can be done by using 96-well silica membrane plates and a variety of robotic platforms. Another type of device utilizes silica-coated paramagnetic particles that adsorb DNA in the solution (Figure 5.11b). A magnet is used for particle capture instead of centrifugation or vacuum filtration. The magnetic particles can be resuspended during the wash steps, and the solution containing contaminants and cellular materials is then discarded. DNA is eluted after washing. This device can also be adapted to automated, high-throughput methods.

Over the years, high-throughput silica-based procedures have been developed to process large numbers of samples in parallel. Some of these methods are adapted for automated DNA extraction platforms (Figures 5.12 and 5.13).

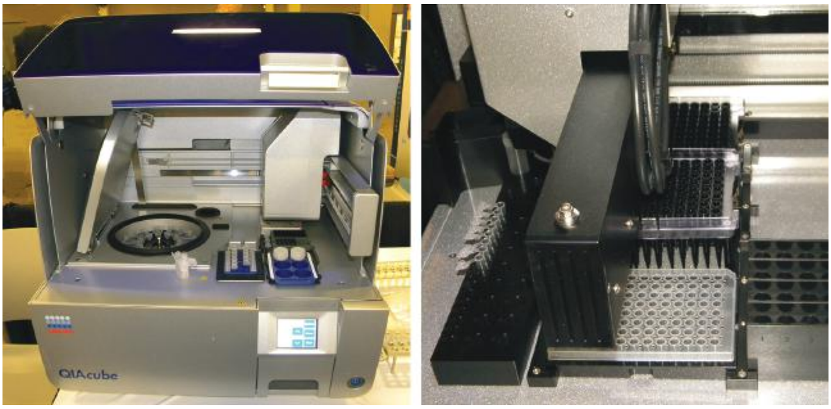

Figure 5.12 Automated bench-top DNA purification systems that enable the isolation of genomic DNA from a wide variety of forensic samples. A low-throughput sample-preparation system that can process up to 12 samples (left) and a low-to-medium throughput sample-preparation system (right). (© Richard C. Li.)

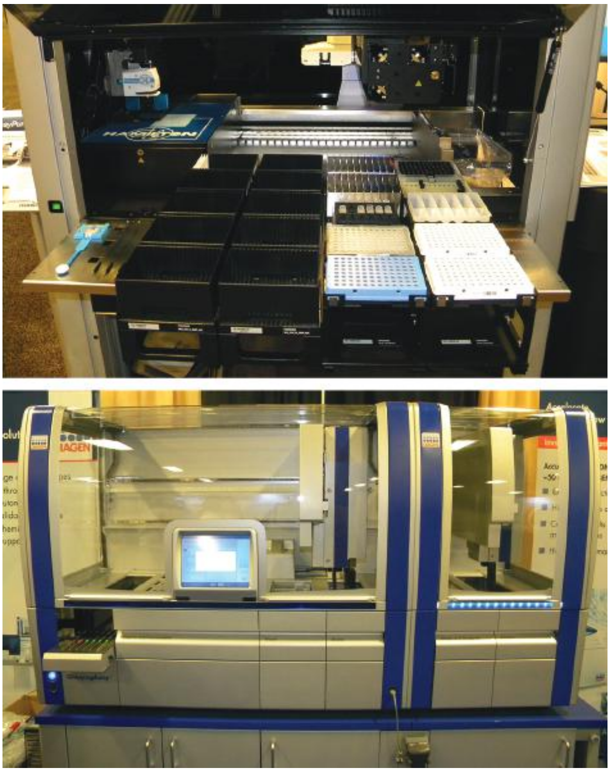

Figure 5.13 Integrated platforms enabling automated DNA sample preparation and liquid handling for subsequent assay setup. These systems utilize silica-coated bead chemistries and can achieve moderate to high throughput of processing (1–96 samples) with bar coding for sample tracking. A Hamilton (top) and a Qiagen system (bottom). (© Richard C. Li.)

5.2.4 Differential Extraction

This method is very useful for the extraction of DNA from biological evidence derived from sexual assault cases, such as vaginal swabs and bodily fluid stains. These types of evidence often contain mixtures of spermatozoa from a male contributor and nonsperm cells such as epithelial cells from a female victim. Mixtures of individual DNA profiles can complicate data interpretation.

This method selectively lyses the nonsperm and spermatozoa in separate steps based on the differences in cell-membrane properties of spermatozoa and other types of cells. Thus, the DNA from spermatozoa and nonsperm cell fractions can be sequentially isolated.

First, the differential extraction procedure involves preferentially lysing the nonsperm cells with proteolytic degradation using proteinase. Sperm plasma membrane contains proteins cross-linked by disulfide bonds. The membrane exhibits a much higher mechanical stability than nonsperm cells and is thus resistant to proteolytic degradation. The nonsperm DNA is released into the supernatant and the liquid containing it (the nonsperm fraction) is extracted, yielding a fraction that predominantly contains DNA from nonsperm cells.

To lyse the sperm cells, it is necessary to cleave the disulfide bonds in addition to proteolytic digestion. The application of DTT, a reducing agent, is an approach that can be used for cleavage. In the presence of DTT and proteinase K, the sperm plasma membrane is then lysed (Figure 5.14). Subsequently, DNA from the sperm cells can be extracted (Figure 5.15).

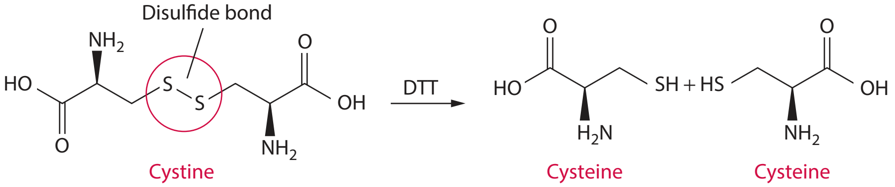

Figure 5.14 DTT reaction. The breaking of disulfide bonds in cystine residues is carried out by adding a reducing agent such as DTT.

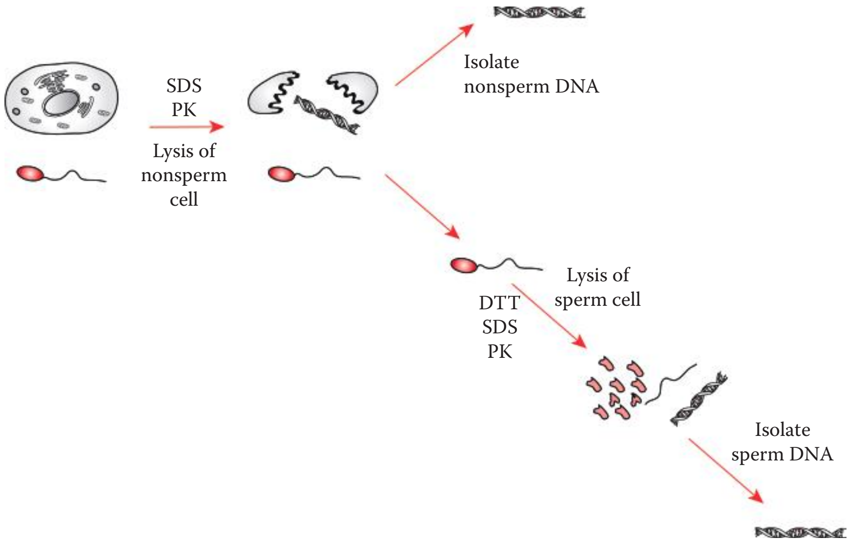

Figure 5.15 Differential extraction process used to separate sperm cells from nonsperm cells. Nonsperm cells are lysed in the presence of SDS and proteinase K (PK); sperm cells are resistant to such conditions. The nonsperm cell DNA is extracted. The sperm cells are then lysed separately in the presence of SDS and proteinase K plus DTT to extract the sperm DNA. (© Richard C. Li.)

This process isolates sperm and nonsperm cell DNA separately for obtaining DNA profiles from male and female contributors, respectively. However, the non-sperm-cell DNA and sperm-cell DNA may not be completely separated from one another; this can happen, for example, if the sperm cells have already lysed due to poor sample conditions. Some sperm DNA may be present in the non-sperm-cell fraction. Additionally, if a mixture has an abundance of nonsperm cells and fewer sperm cells, non-sperm-cell DNA may be detected in the sperm fraction. Thus, new methods that can overcome these problems are highly desired.

5.3 Essential Features of RNA

Like DNA, *ribonucleic acid* (RNA) is a linear molecule containing four types of nucleotides linked by phosphodiester bonds (Figures 5.16 and 5.17). However, certain properties of RNA differ from those of DNA. Unlike DNA containing deoxyribose (see Figure 5.18), the sugar residue

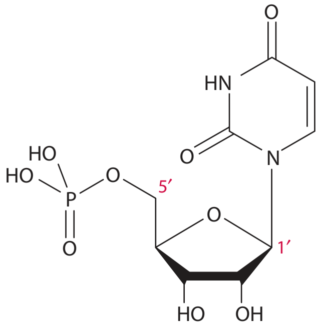

Figure 5.16 The structure of ribonucleotide. Each ribonucleotide in a RNA polymer consists of three components: a ribose, a nitrogenous base (uracil is shown as an example), and a phosphate group. The 1′ carbon of the ribose is attached to the nitrogen of the nitrogenous base. A phosphate group is attached to the 5′ carbon of the ribose.

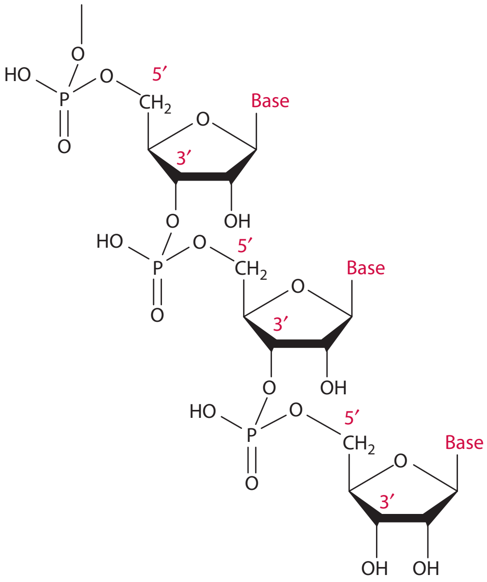

Figure 5.17 Chemical structure of RNA (polyribonucleotide) chain.

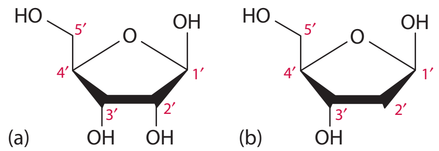

Figure 5.18 Comparison of (a) ribose and (b) deoxyribose. The hydroxyl group attached to the 2′ carbon of ribose is replaced by a hydrogen group in deoxyribose.

of RNA is a ribose, which has a hydroxyl (OH) group at the 2′ carbon position. Therefore, RNA has a lower pKa, which means that it is more acidic than DNA. RNA contains uracil (U) in the place of thymine in DNA (Figure 5.19). RNA is typically found in cells as a single-stranded molecule, while DNA is double stranded. Polyribonucleotides can form complementary helices with DNA strands by base pairing (with the exception of uracil pairs with adenine) (see Figure 5.20).

Total RNA contains all the RNA of the cells, including RNAs involved in protein synthesis and posttranscriptional modification, as well as regulatory RNAs. The RNA that carries codes from a DNA template is called messenger RNA (mRNA) and usually contains a cap and polyadenine tail at the 5′ and 3′ ends of the molecule, respectively (Figure 5.21).

The stability of RNA is an issue for mRNA-based forensic analysis. Single-stranded RNA is chemically less stable than DNA. The 2′ OH group of RNA can react with its phosphodiester backbone, potentially causing the nonenzymatic hydrolysis of an RNA molecule. Several factors, such as moisture, UV light, high temperature, and extreme pH, can facilitate the nonenzymatic

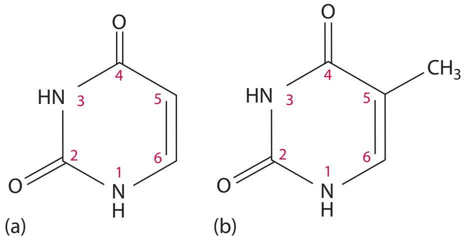

Figure 5.19 Comparison of (a) uracil and (b) thymine. Thymine has a methyl group attached at the 5-carbon position.

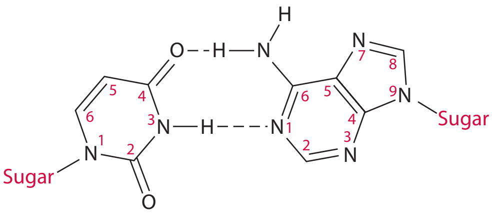

Figure 5.20 Base pairing of uracil (left) and adenine (right).

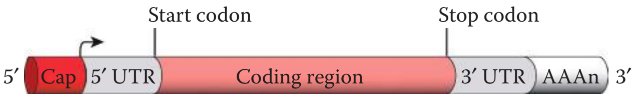

Figure 5.21 Structure of mRNA. Eukaryotic mRNA is modified at the 5′ end (cap) and 3′ end (polyadenine tail) needed for protein synthesis. Start and stop codons are required for the initiation and termination of protein synthesis. (© Richard C. Li.)

hydrolysis of RNA phosphodiesters, which leads to the degradation of RNA. Moreover, endogenous *ribonucleases* (RNases), present within cells, represent the major factor causing RNA degradation. Environmental microorganisms are also a common source of RNase contamination. RNases are very stable and usually do not require cofactors to carry out enzymatic reactions. Small amounts of RNases are sufficient to degrade RNA. RNA can be protected by adding RNase inhibitors such as diethylpyrocarbonate. Additionally, using RNase-free laboratory supplies and reagents and wearing disposable gloves while handling samples and reagents can reduce the risks of RNase contamination.

5.4 Methods of RNA Extraction

5.4.1 RNA–DNA Coextraction

For most forensic applications, total RNA is usually isolated. The procedure for isolating total RNA is simpler than that for mRNA. The total RNA isolated usually contains a sufficient amount of mRNA for subsequent reverse transcriptase PCR (RT-PCR; see Chapter 7). However, if the quantity of a target mRNA is very low, the procedures specifically for isolating mRNA should be used. There are a variety of protocols for isolating total RNA. However, RNA–DNA coextraction methods allow for the simultaneous extraction of high-quality DNA and RNA for forensic DNA analysis and bodily-fluid identification (Chapter 11), respectively, without the consumption of additional samples when extracted separately.

Biological samples are first lysed in lysis buffer. The lysis buffer usually contains chaotropic salts that can facilitate the lysis of cells and denature proteins, thus inactivating endogenous RNases to protect RNA. The lysate is then passed through a silica membrane column. A high-salt environment in the lysate allows selective binding of silica to genomic DNA over RNA. The column is washed, and purified DNA is then eluted.

The extraction of RNA is achieved by utilizing a high concentration of chaotropic salts that are already present in the lysate, along with ethanol, in order to decrease the hydrophilic property of RNA and increase its affinity for silica. After ethanol is added to the flow-through that passed the first column, the sample is then applied to a second silica column, where total RNA molecules, longer than 200 nucleotides, bind to the silica membrane. RNA including mRNA is then eluted (Figure 5.22). This method does not isolate small RNAs such as miRNA, rRNA, and tRNA, which comprise 15%–20% of total RNA.

5.4.2 miRNA Extraction

miRNAs (Chapter 4) are low-molecular-weight RNAs ranging between 15 and 30 nucleotides in length. Conventional methods routinely used for extracting total RNA do not effectively recover small RNAs; thus, they are not suitable for isolating miRNA. One approach to extracting small RNA molecules including miRNA involves two steps: organic-solvent extraction to isolate total RNA and solid-phase extraction to enrich small RNA.

To begin the process, tissues are disrupted and cells are lysed. The lysis reagents also inactivate RNases to protect RNA. The lysate is then extracted with an organic solvent, such as phenol and chloroform, with a high concentration of chaotropic salts such as GuSCN. The partitioning of DNA and RNA between the organic phase and the aqueous phase is determined by the pH during the organic extraction. At an acidic pH, DNA partitions to the organic phase. The pKa of RNA is usually lower than DNA; thus, RNA remains hydrophilic and is retained in the aqueous phase under this condition. This step removes most of the DNA, proteins, and other cellular components from the lysate into the organic phase.

The second step, silica-based extraction, further purifies and enriches small RNAs. It is achieved by utilizing the high concentration of chaotropic salt that is already present in the lysate, along with ethanol. The size-fractioning of RNAs is achieved using different ethanol

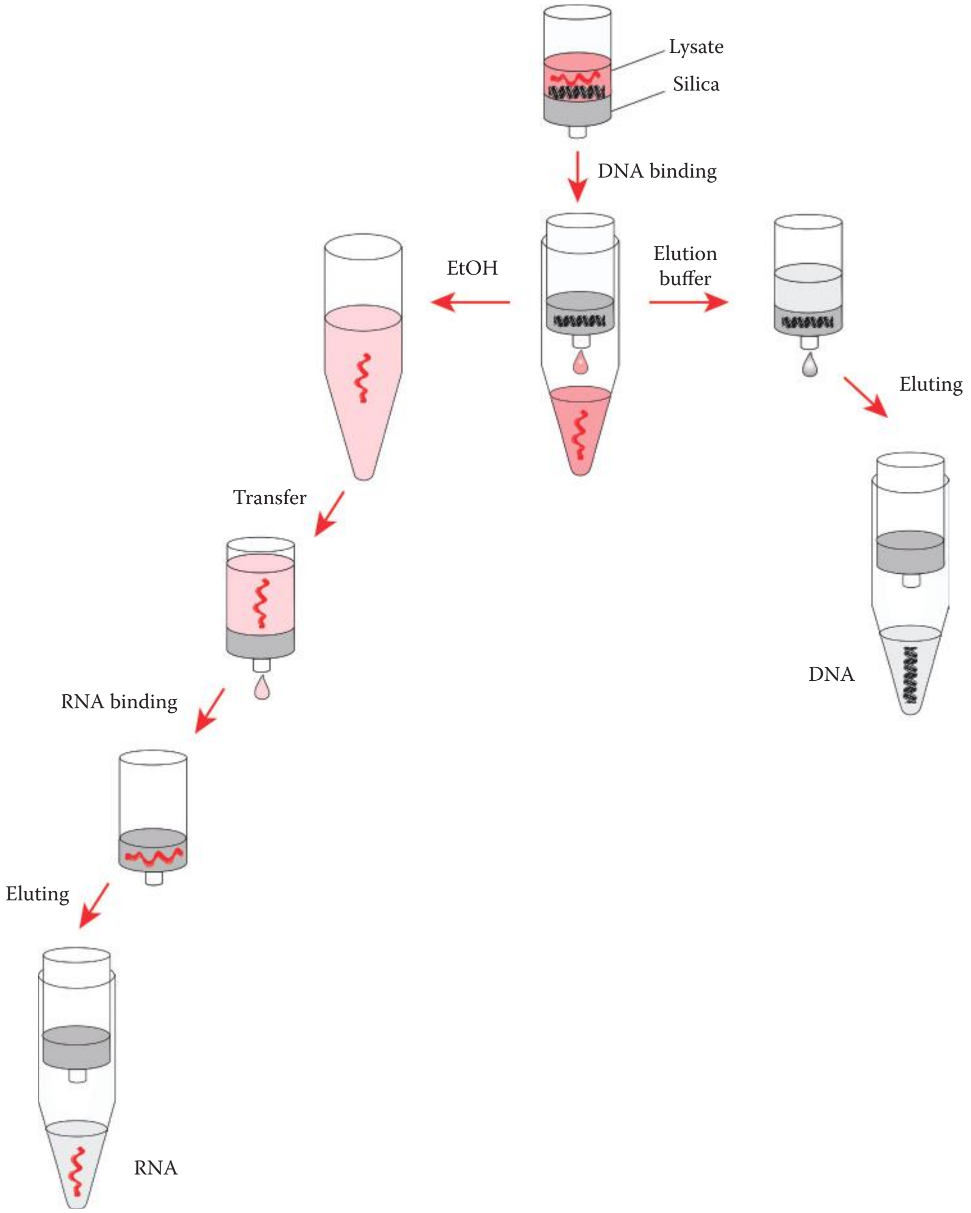
Lysate
Silica
DNA binding
EtOH
Elution
buffer
Eluting
Transfer
DNA
RNA binding
Eluting
RNA

Figure 5.22 RNA and DNA coextraction using a silica-based method. See Section 5.4.1. (© Richard C. Li.)

concentrations. At a low ethanol concentration, the solvent-extracted lysate is passed through a silica membrane filter. Large RNAs are retained on the silica membrane, while small RNAs are not and are collected in the filtrate. The filtrate is passed through a second silica membrane filter. At a high ethanol concentration, the small RNAs are retained on the silica membrane. The small RNAs are then eluted in a low ionic strength solution (Figure 5.23). RNA less than 200 nucleotides, including miRNA, can be obtained.

After RNA is extracted, the small amounts of RNA can be quantified using a quantitative RT-PCR (Chapter 7) or fluorescent intercalating dye assay (Chapter 6). Purified RNA can be

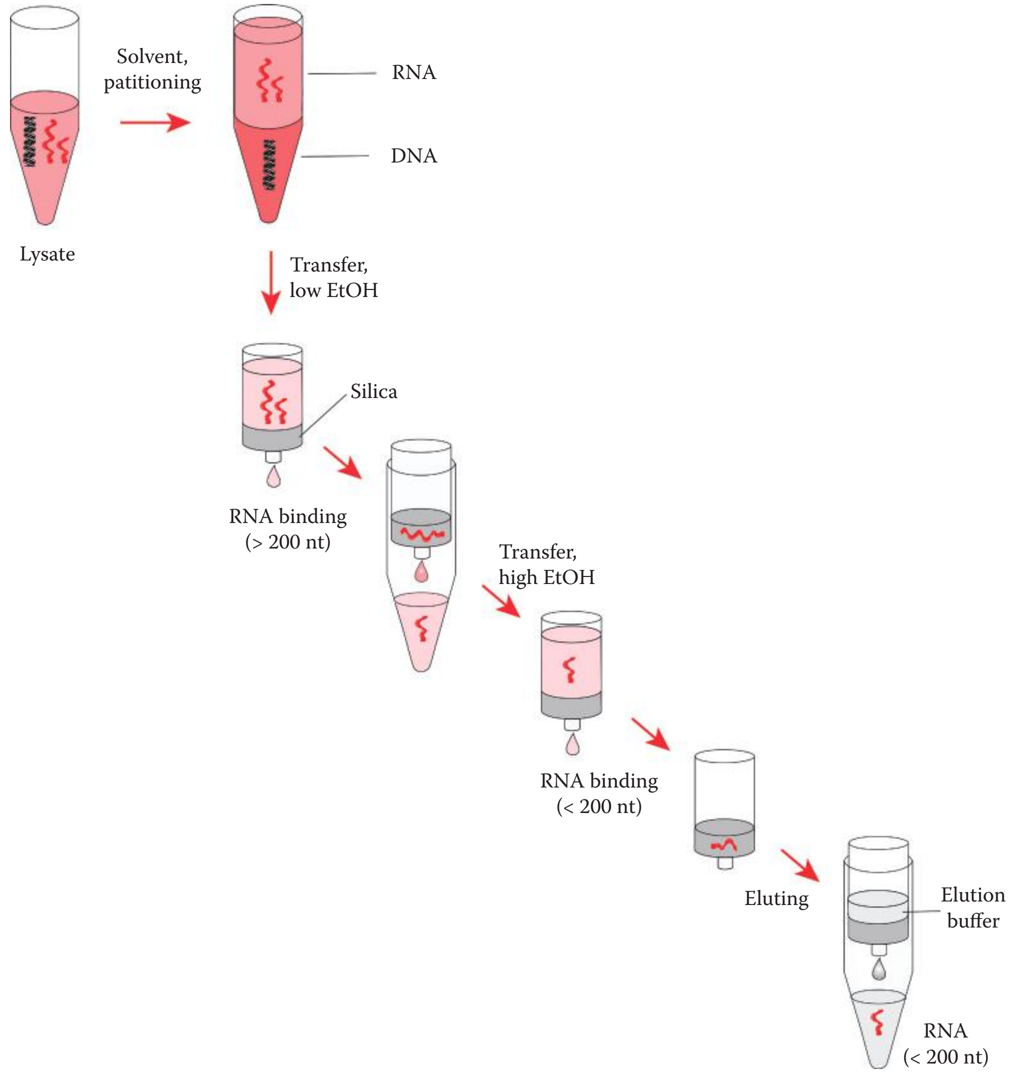
Solvent,
patitioning
RNA
DNA
Lysate
Transfer,
low EtOH
Silica
RNA binding
(> 200 nt)
Transfer,
high EtOH
RNA binding
(< 200 nt)
Eluting
Elution
buffer
RNA
(< 200 nt)

Figure 5.23 Schematic illustration of an miRNA extraction method. See Section 5.4.2. (© Richard C. Li.)

stored at −80°C in RNase-free water or Tris-EDTA buffer (pH 7). Single-use aliquots are preferred when possible to avoid multiple freeze–thaw cycles.

The integrity of extracted RNA is a great concern for RNA-based forensic analysis. RNA quality is traditionally assessed using the 28S:18S rRNA ratio. There are some conditions where this method has been shown to be inconsistent; that is, in which the 28S:18S rRNA ratio does not reflect the true level of RNA degradation. Recently, the *RNA integrity number* (RIN) has provided an effective method for determining RNA quality. RIN is a software algorithm that takes the electrophoretic RNA measurements into account in order to assign integrity values to RNA samples. RIN ranges from 1 to 10, with 10 being the most intact. Thus, the RIN method facilitates the assessment of the integrity of RNA samples. As reflected by RIN, RNA degradation has a negative influence on the reproducibility of the results of RNA-based forensic analysis.

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6

DNA Quantitation

Determining the amount of DNA in a sample is essential for polymerase chain reaction (PCR)-based DNA testing (Chapter 7). Because PCR-based DNA testing is very sensitive, a narrow concentration range is required for amplification to be successful. If too much DNA template is used in PCR, the resulting artifacts may interfere with data analysis and interpretation. On the other hand, very low amounts of DNA template may result in a partial DNA profile or failure to attain a profile. Samples with poor purity may contain PCR inhibitors that lead to a failure of DNA amplification. Thus, a test that can measure the quality and quantity of the DNA template of a sample is desirable.

Additionally, forensic samples containing DNA are often mixtures that may include nonhuman DNA. For instance, microbial DNA may be present. Thus, it is necessary to use human-specific DNA quantitation methods to selectively determine the amount of human DNA present. In the United States, quality-assurance guidelines require the use of a quantitation method that estimates the amount of human nuclear DNA in crime-scene evidence samples.

In this chapter, the slot blot, intercalating dye, and quantitative PCR methods are introduced. The quantitative PCR method is the most sensitive of the three methods. It is the only method that can detect PCR inhibitors. Both the slot blot and the quantitative PCR methods can detect human and nonhuman primate DNA. Current technology cannot distinguish between human and nonhuman primate DNA.

6.1 Slot Blot Assay

Historically, the slot blot assay was used to detect human genomic DNA in a sample. Methodically, the slot blot assay works based on the following principles. Prior to the quantitation, an alkaline solution is added to the genomic DNA sample, which denatures DNA. Generating single-stranded DNA is necessary for DNA to be cross-linked onto a nitrocellulose membrane. The DNA sample is then spotted, using a slot blot device, onto a nitrocellulose membrane (Figure 6.1). The single-stranded DNA is then immobilized onto a nylon membrane. The targeted sequence is revealed by hybridization with a labeled 40-nucleotide probe complementary to a primate-specific α-satellite DNA sequence at the D17Z1 locus (Figure 6.2). In humans, the α-satellite DNA sequences are highly repetitive sequences located near the centromeres of chromosomes. These sequences are usually distinct for each chromosome.

Three detecting schemes of the slot blot assay have been developed. Initially, the D17Z1 probe was labeled with radioisotopes that could be visualized by exposing the slot blot membrane to x-ray film. The hazardous radioisotope detection method was then replaced by alkaline phosphatase-labeled and biotinylated probes. The alkaline phosphatase-labeled probe can be coupled with chemiluminescent detection (Lumi-Phos Plus kit, Lumigen, Inc.). The biotinylated probe

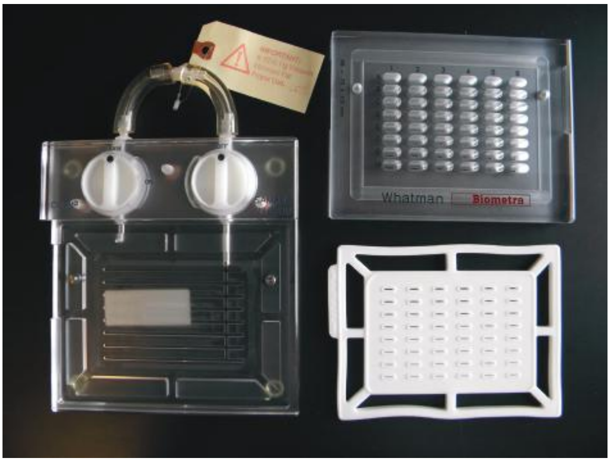

Figure 6.1 A slot blot device. (© Richard C. Li.)

(QuantiBlot Human DNA Quantitation Kit, Applied Biosystems) can be coupled with either colorimetric or chemiluminescent detection.

In colorimetric detection, the biotin moiety of the probe is bound to streptavidin. The streptavidin is conjugated with horseradish peroxidase, which catalyzes the oxidation reaction of tetramethylbenzidine (TMB), a substrate, forming a blue precipitate. With the chemiluminescent detection method, the horseradish peroxidase catalyzes the oxidation reaction of a substrate such as luminol, emitting photons that can be detected by exposure to x-ray film. The sensitivity of chemiluminescent detection is slightly higher than that of the colorimetric detection. The detection mechanisms will be discussed in Chapter 9.

The detected signal intensity is proportional to the concentration of the DNA sample in question. Quantitative measurements can be made by comparing an unknown sample to a set of standards with known DNA concentrations (Figure 6.3).

The assay typically quantifies DNA over the range of 150 pg–10 ng. However, the quantitation results are manually read, and conclusions are based on subjective judgments. Additionally, the D17Z1 sequences of humans and other primates share homology. The probe cannot distinguish between human and other primate genomic DNA. This is not a great concern because cases involving nonhuman primates are rare. Nevertheless, the probe does not cross-react with all other species. This assay has been replaced by recently developed quantitative PCR assays (see Section 6.3).

6.2 Fluorescent Intercalating Dye Assay

Small quantities of DNA can also be quantified by using a fluorescent intercalating dye method. Intercalating dyes, usually planar molecules, can slide themselves in between base pairs of DNA without breaking the DNA double helix. The Quant-iT™ PicoGreen® dsDNA reagent (Invitrogen) is a fluorescent intercalating dye that stains double-stranded DNA (dsDNA) for quantitation in a sample (Figure 6.4a). The detection limit of this method is approximately 250 pg. Intercalating dyes, not specific to human DNA, bind to all DNA molecules. Therefore, fluorescent intercalating dye assay can be utilized for the quantitation of known reference samples. For instance, DNA database samples from known sources can be quantified using this method. The assay has also been adapted for automation and is, thus, a high-throughput method.

DNA samples are simply added to a solution containing the fluorescent intercalating dye. The fluorescence, proportional to the quantities of DNA (Figure 6.4b), is measured using a standard spectrofluorometer with excitation and emission wavelengths of the light source. A standard

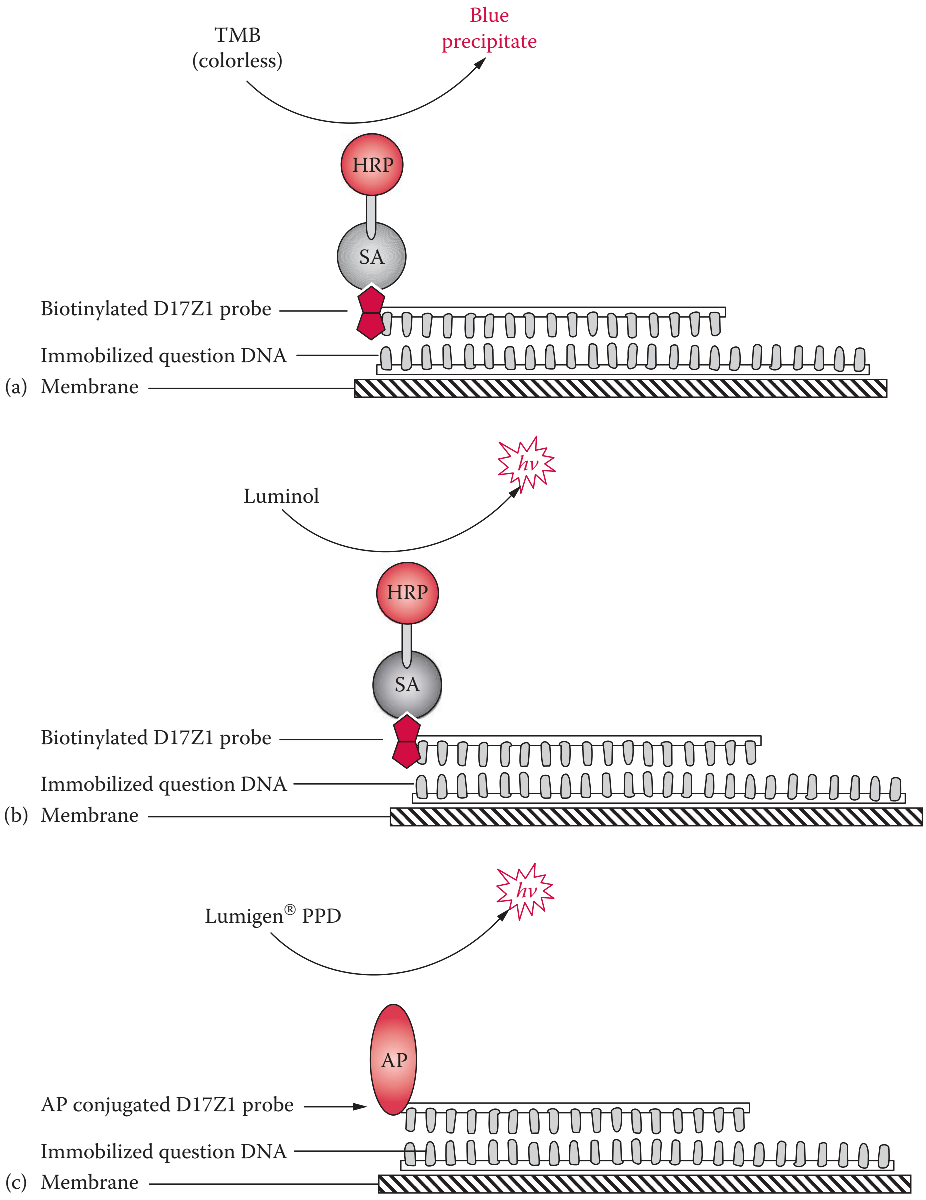
TMB
(colorless)
Blue
precipitate
HRP
SA
Biotinylated D17Z1 probe
Immobilized question DNA
(a) Membrane
Luminol
hv
HRP
SA
Biotinylated D17Z1 probe
Immobilized question DNA
(b) Membrane
Lumigen® PPD
hv
AP
AP conjugated D17Z1 probe
Immobilized question DNA
(c) Membrane

Figure 6.2 Slot blot assay. Questioned DNA is immobilized onto a solid-phase membrane then hybridized with a biotinylated D17Z1 probe. The detection of the hybridization is carried out by (a) streptavidin (SA) and horseradish peroxidase (HRP) conjugate, and a colorimetric reaction is catalyzed by HRP using tetramethylbenzidine (TMB) as a substrate; (b) SA and HRP conjugate, and a chemiluminescent reaction is catalyzed by HRP using Luminol as a substrate; (c) immobilized DNA is hybridized with an alkaline phosphatase (AP)-labeled D17Z1 probe. The detection of the hybridization is carried out by a chemiluminescent reaction catalyzed by AP using Lumigen® PPD as a substrate. (© Richard C. Li.)

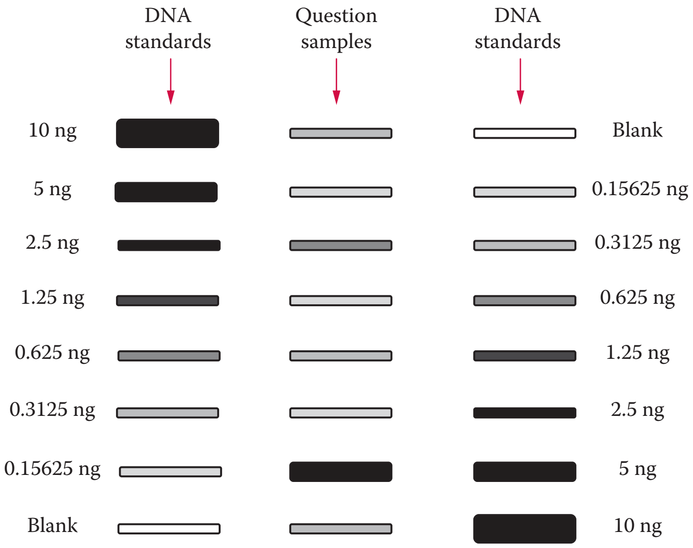
DNA standards
Question samples
DNA standards
10 ng
5 ng
2.5 ng
1.25 ng
0.625 ng
0.3125 ng
0.15625 ng
Blank
Blank
0.15625 ng
0.3125 ng
0.625 ng
1.25 ng
2.5 ng
5 ng
10 ng

Figure 6.3 Human DNA quantitation using the slot blot assay. Standards with known amounts of human DNA are applied, and unknown samples and a set of standards are compared. The quantities in the unknown samples are estimated by visual comparison to the standards. (© Richard C. Li.)

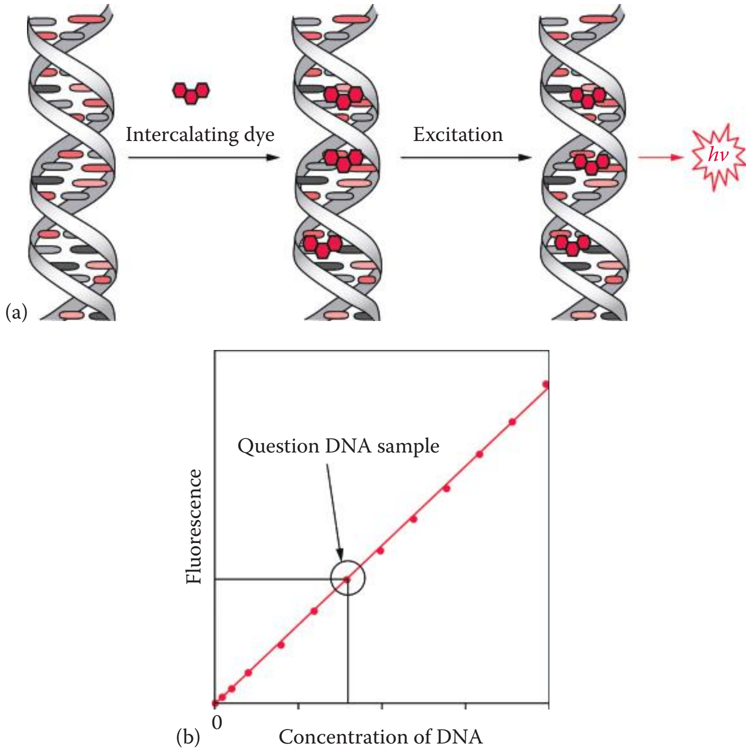
Intercalating dye
Excitation
hv
(a)
Question DNA sample
Fluorescence
0
Concentration of DNA
(b)

Figure 6.4 DNA quantitation using intercalating dye. (a) Fluorescent dye intercalates into DNA. The fluorescence can be measured upon applying an excitation light source. (b) A standard curve can be constructed using known amounts of DNA standards. The amount of questioned DNA can be determined by comparing the standard curve. (© Richard C. Li.)

curve is first created using samples containing known amounts of DNA. The assay is then performed for the unknown samples and the quantities of DNA in the samples are determined by comparing the results to the standard curve.

6.3 Quantitative PCR Assay

Based on the principle of PCR amplification (Chapter 7), the amount of PCR product amplified correlates with the initial concentration of DNA templates. Thus, the DNA concentration of a sample can be determined. There are two types of quantitative PCR methods. *End-point PCR* methods measure the quantity of amplified product at the end of PCR. Usually, the fluorescence is emitted by the dyes that intercalate into the double-stranded DNA. The quantity of amplified DNA is measured from the amount of fluorescence emitted from dyes such as SYBR (Figures 6.5 and 9.1b).

Real-time PCR methods can quantify the amplified DNA during the exponential phase of PCR (Chapter 7). The quantitation result is not affected to a significant extent by slight variations in PCR conditions. Thus, the precision of the quantitation of target sequences is improved with this method.

6.3.1 Real-Time Quantitative PCR

Real-time quantitative PCR (qPCR) was developed in the early 1990s, and it analyzes the amplification of a target sequence at each cycle of PCR. A fluorescent reporter is used to monitor the accumulation of amplified products during PCR. The fluorescence signals of the reporter molecule increase as amplified products accumulate with each cycle of PCR. qPCR is commonly used because of the following advantages:

- Better objectivity than the QuantiBlot method
- Increased sensitivity with a large dynamic range (30 pg–100 ng)
- More accurate measurements of small quantities of DNA in samples
- Fewer laboratory manipulations; amenable to automation
- Ability to detect PCR inhibitors (Section 6.3.1.1)

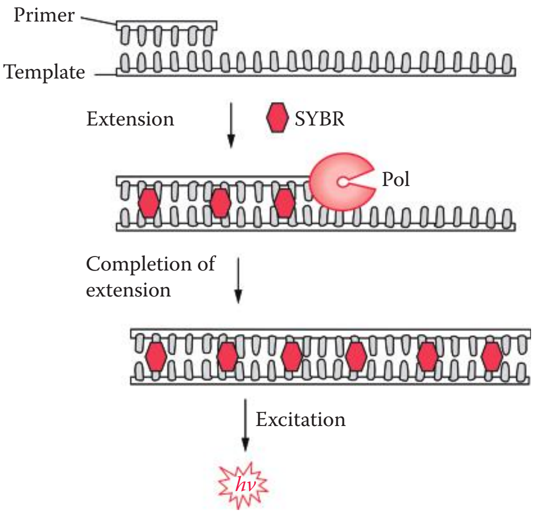

Figure 6.5 End-point PCR using SYBR Green detection. During the extension phase of PCR, in which DNA synthesis occurs, the dye binds to the double-stranded amplicons. Upon excitation, the emission intensity of the dye can be measured. Pol represents Taq polymerase. (© Richard C. Li.)

The technique is amenable to multiplexing to detect more than one type of DNA target sequence in a single reaction. Commercial qPCR kits for human DNA and Y-chromosome DNA quantitation are available. Additionally, the qPCR method for mtDNA quantitation is possible. qPCR uses commercially available fluorescence-detecting thermocyclers to amplify specific DNA sequences and measure their concentrations simultaneously. The fluorescent reporter can be a nonspecific intercalating double-stranded DNA-binding dye or a sequence-specific fluorescently labeled oligonucleotide probe (Chapter 9). The target sequences are amplified and detected by the same instrument, and the reporter fluorescence is monitored externally. Thus the reaction tubes do not need to be opened. This minimizes aerosol contamination and reduces the risk of false-positive results. A widely used qPCR probe technique is the TaqMan method (Applied Biosystems).

6.3.1.1 TaqMan Method

This method utilizes the 5′ exonuclease activity of *Taq* polymerase to cleave the probe during PCR (also known as the 5′ exonuclease assay). The probe is designed to anneal to the target sequence between the upstream and downstream primers and is added to the PCR mixture together with primers (Figure 6.6). The probe T_m (melting temperature; see Chapter 7) should be higher than the amplification primer T_m. A minor groove binder (MGB), such as dihydrocyclopyrroloindole tripeptide, is often linked at the 3′ end of the probe (Figure 6.6). A conjugated MGB binds to the minor groove of a B-form DNA helix (Figure 6.7), which is stabilized by van

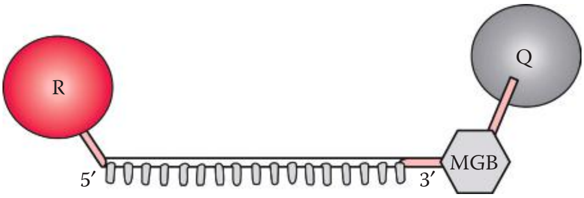

Figure 6.6 TaqMan probe. Each probe is labeled with a reporter dye (R) on the 5′ end and a fluorescence quencher (Q) on the 3′ end. MGB represents a minor groove binder. (© Richard C. Li.)

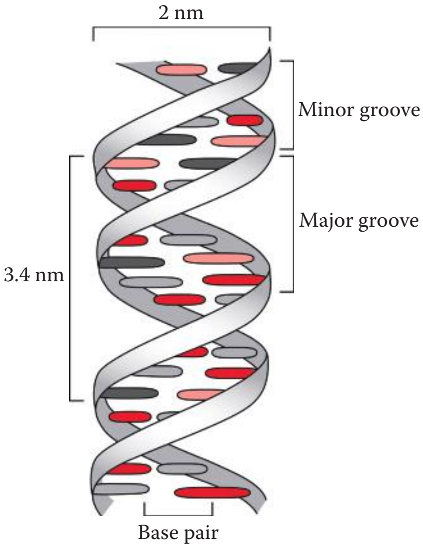

Figure 6.7 DNA double helix. The double-helical structure of B-DNA, the most common form of DNA, is shown. With a helical diameter of 2 nm, each turn of the helix takes 3.4 nm, which corresponds to 10 base pairs per turn. The major and minor grooves are shown. (© Richard C. Li.)

der Waals forces. As a result, conjugating an MGB into a probe increases the T_m values, allowing for the use of shorter probes. As a result, having the probe T_m higher than that of the primers ensures that the probe is fully hybridized during primer extension. The oligonucleotide probe is labeled with both a *reporter* fluorescent dye, usually 6-carboxyfluorescein (6-FAM) or tetrachlorofluorescein (TET) at the 5′ end; and a nonfluorescent *quencher* moiety, such as tetramethylrhodamine (TAMRA), usually at the 3′ end or any thymine position. While the probe is intact, the quencher greatly reduces the fluorescence emitted by the reporter via fluorescent resonance energy transfers (FRET). FRET is a distance-dependent interaction between two molecules in which the excitation energy is transferred from a photon donor molecule (reporter) to an acceptor molecule (quencher) without emission of a photon. During the extension phase of the PCR cycle, the 5′ exonuclease activity of Taq polymerase cleaves the reporter dye from the probe. Because the reporter dye is no longer in close proximity to the quencher, the FRET is disrupted and the probe begins to fluoresce (Figure 6.8). The intensity of fluorescence can be measured (Chapter 9) and is proportional to the amount of target DNA synthesized during the PCR.

In this assay, the rate of accumulation of amplified DNA over the entire course of a PCR is generated. The greater the initial concentration of target templates in a sample, the fewer cycles required to reach a particular quantity of amplified product. The initial concentration of target templates can be expressed using the *cycle threshold* (C_T). C_T is defined as the number of PCR cycles required for the fluorescent signal to cross a threshold of amplification where the signal exceeds background level or baseline noise. A plot of C_T against the $\log_{10}$ of the initial concentration of a set of DNA standards yields a straight line as a standard curve (Figure 6.9). The target sequences in an unknown sample can be quantified by comparing to the standard curve. Additionally, qPCR has the ability to detect PCR inhibitors (Chapter 7) that interact with DNA or with DNA polymerases. The presence of PCR inhibitors in the DNA extracts can be measured by monitoring the amplification of the internal positive control (IPC). Most human DNA quantitation kits contain a known amount of exogenous DNA as IPC that can be fortified to the sample and amplified. Monitoring the amplification of IPC enables the detection of PCR failure due to inhibition when the IPC's C_T value is higher than that of an uninhibited PCR reaction.

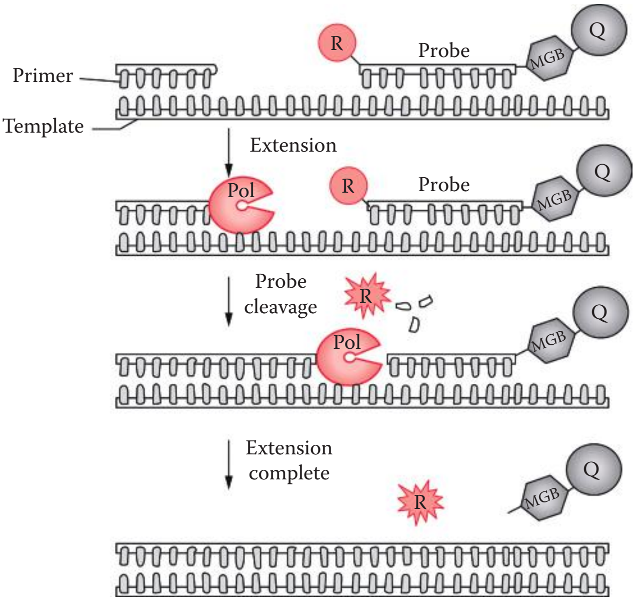

Figure 6.8 Real-time PCR with TaqMan detection. The TaqMan probe is shown. During extension, the 5′ nuclease activity of Taq polymerase (Pol) cleaves the probe. Reporter dye is released during each cycle of PCR. (© Richard C. Li.)

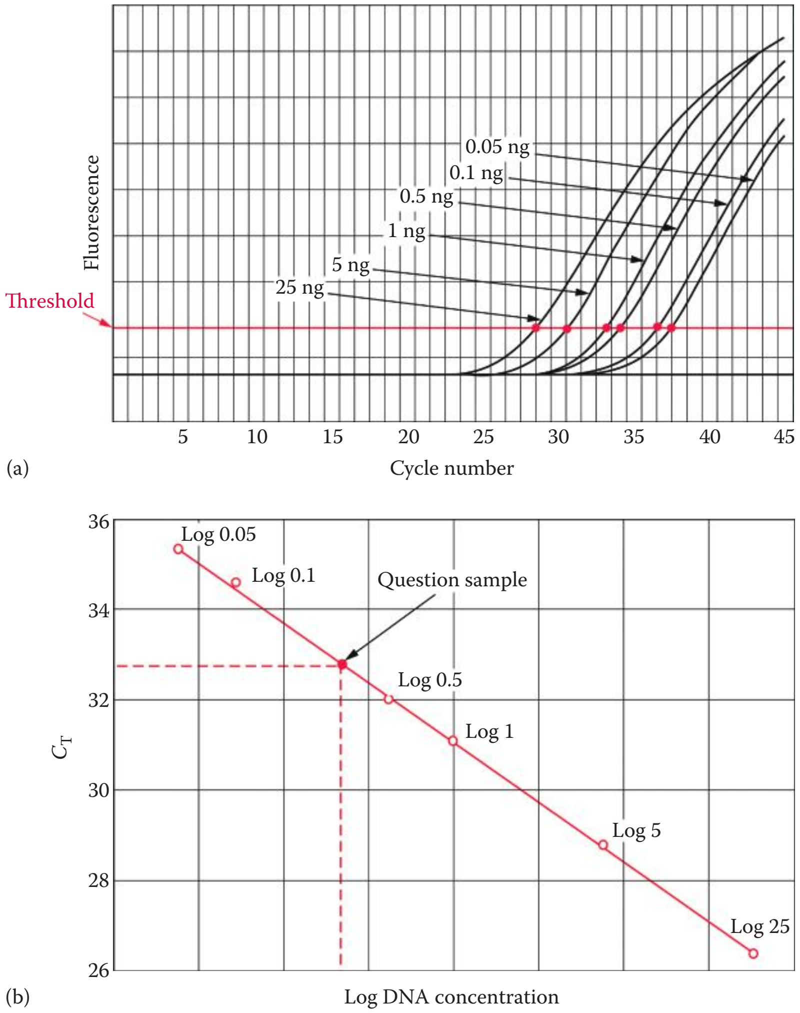

Figure 6.9 Real-time quantitative PCR. (a) Amplification curves for a dilution series of standards with known quantities of DNA. C_T is the cycle threshold at which the amplification curve crosses the threshold, as indicated by the red line. (b) A standard curve based on data obtained from the amplification curves. The quantity of DNA in a questioned sample can be determined from the standard curve. (© Richard C. Li.)

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7

Amplification by Polymerase Chain Reaction

7.1 Denaturation and Renaturation of DNA

The DNA double helix is stabilized by chemical interactions. Base pairing of the two strands involves the formation of hydrogen bonds that provide weak electrostatic attractions between electronegative atoms. An adenine always pairs with a thymine (two hydrogen bonds), and a cytosine pairs with a guanine (three hydrogen bonds) (see Figure 7.1). Base stacking involves hydrophobic interactions between adjacent base pairs and provides stability to the double helix.

Double-stranded DNA is maintained by hydrogen bonding between the bases of complementary pairs. *Denaturation* occurs when the hydrogen bonds of DNA are disrupted, and the strands are separated. A *melting curve* can be obtained from measuring DNA denaturation by slowly heating a solution of DNA. As shown in Figure 7.2, an increasing temperature increases the percentage of the DNA that is denatured. The temperature at which 50% of DNA strands are denatured is defined as the *melting temperature* (T_m). The value of T_m is affected by the salt concentration of the solution, but can also be affected by nucleotide content, high pH, and length of the molecule.

Nucleotide content affects the value of T_m because GC pairs are joined by three hydrogen bonds while the AT pairs are joined by only two. Increasing the GC content of a DNA molecule increases the T_m. Excessively high pH causes the hydrogen bonds to break and the paired strands to separate. Finally, the length of the molecule also affects the T_m simply because a longer molecule of DNA requires more energy to break more bonds than a shorter molecule.

The single strands in a solution of denatured DNA can, under certain conditions, reanneal into double-stranded DNA. The process is called *renaturation* and two requirements must be met for it to occur. First, sufficient amounts of charged molecules, such as salts, must be present in the solution to neutralize the negative charges of the phosphate groups in DNA. This prevents the complementary strands from repelling each other. Additionally, the temperature must be high enough to disrupt hydrogen bonds that formed randomly between the bases of DNA strands. However, excessively elevated temperatures can disrupt the base pairs between the complementary DNA strands.

7.2 Basic Principles of Polymerase Chain Reaction

The *polymerase chain reaction* (*PCR*) allows the exponential amplification of specific sequences of DNA to yield sufficient amplified products, also known as *amplicons*, for various downstream

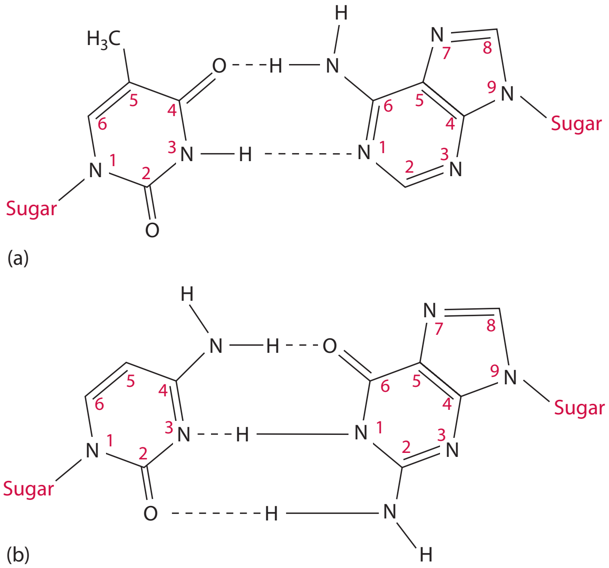

Figure 7.1 Base pairing between two DNA strands. (a) An adenine (right) pairs with a thymine (left). (b) A cytosine (left) pairs with a guanine (right).

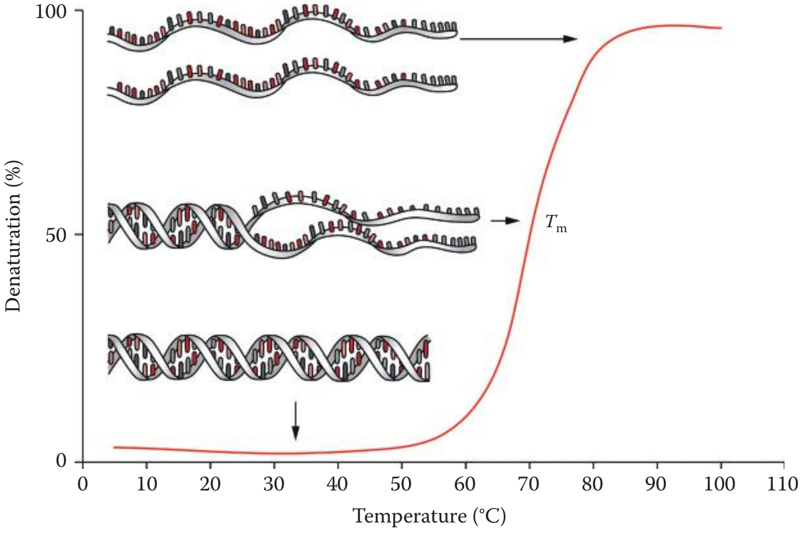

Figure 7.2 Melting curve of DNA. The degree of DNA denaturation is increased by increasing the temperature. T_m and possible shapes of a DNA molecule are shown. (© Richard C. Li.)

applications. The technique is highly sensitive and can amplify very small quantities of DNA. Therefore, it can be utilized for the analysis of samples of limited quantity. PCR-based assays are rapid and robust. Thus, PCR forms the basis of many forensic DNA assays such as DNA quantitation (Chapter 6), short tandem repeat (STR) profiling (Chapter 20), and mitochondrial DNA (mtDNA) sequencing (Chapter 23).

The concept of synthesizing DNA by a cycling process was first proposed in the early 1970s. In the mid-1980s, PCR technology was finally developed by Kary Mullis and his coworkers (Cetus Corporation) to amplify the β-globin gene for the diagnosis of sickle-cell anemia. In the late 1980s, a

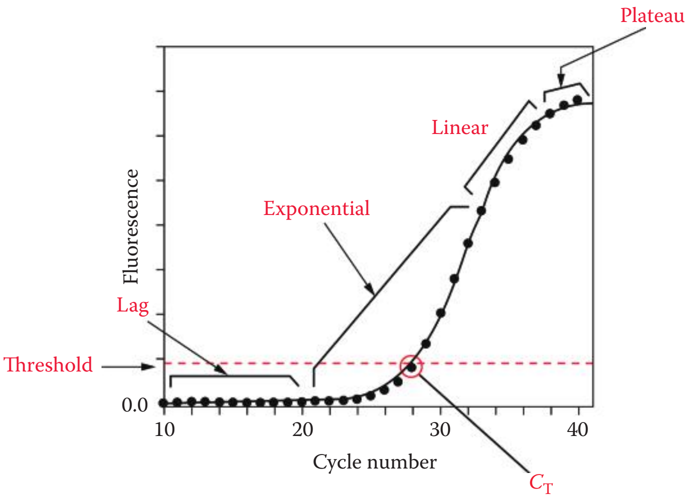

Figure 7.3 PCR amplification curve. A fluorescence signal results from the accumulation of amplicon. The location of the signal threshold is indicated as a dashed line. The C_T value for the curve is the cycle at which the amplification curve crosses the threshold. (© Richard C. Li.)

thermostable polymerase from *Thermus aquaticus* was utilized for PCR. This step greatly increased efficiency and allowed the process to be automated. The result was a powerful impact on molecular biology. In 1993, Mullis was awarded the Nobel Prize for the invention of PCR technology.

In the early 1990s, the technique for the simultaneous amplification and detection of the accumulation of amplicons at each PCR cycle was developed, and the concept of *real-time PCR* was born. This process allows the monitoring of amplicon production at each cycle of the PCR process. The fundamental processes were studied by characterizing the amplification kinetics of PCR using a graph that plotted the amount of amplicon yield at each cycle versus the cycle number (Figure 7.3).

An S-shaped amplification curve is obtained and divided into an exponential phase, a linear phase, and a plateau. During the exponential phase, the amplicon accumulates exponentially. It was revealed that the amplicon accumulation during PCR was correlated to the starting copy number of DNA template. Thus, the amount of amplicon produced during the exponential amplification phase can be used to determine the amount of starting material. This relationship can be further examined using a plot of cycle numbers versus a log scale of the serial dilution of the starting concentration of DNA template, which results in a linear relationship (see Chapter 6). It demonstrates that fewer cycles are needed if larger quantities of starting DNA template are present. The slope of this linear curve (Figure 6.9b) is known as the *amplification efficiency*. The exponential phase continues until one or more of the components (Section 7.3) in the reaction become limited. At this point, the amplification efficiency decreases, the amplicon no longer accumulates exponentially, and PCR enters the linear phase of the curve. At the plateau phase, no more amplicon is accumulated due to the exhaustion of reagents and polymerase.

7.3 Essential PCR Components

A PCR reaction requires thermostable DNA polymerases, primers, and other components, as described below (Figure 7.4).

7.3.1 Thermostable DNA Polymerases

A wide variety of DNA polymerases are available. They vary in fidelity, efficiency, and ability to synthesize longer DNA fragments. Nonetheless, *Taq* polymerase is the most commonly used

HAMILTON
microLAB NIMBUS
NIMBUS PCR
Automated Assay Setup

Figure 7.4 A liquid handling workstation for automated PCR assay setup. (© Richard C. Li.)

enzyme for routine PCR applications (0.5–5 units per reaction). Currently, AmpliTaq Gold™ DNA polymerase (Applied Biosystems) is the most common DNA polymerase for forensic applications.

PCR reactions are usually set up at room temperature. Nonspecific annealing between primers and template DNA can occur, resulting in the formation of nonspecific amplicons. Additionally, annealing between the primers can occur to form primer dimers. Nonspecific annealing interferes with PCR amplification by reducing the amplification efficiency of the specific sequences of interest.

Such interference can be minimized by a *hot-start PCR* approach. The AmpliTaq Gold™ DNA polymerase, a modified enzyme, remains in an inactive form until activated with a pH below 7 prior to the PCR cycling in which the inhibitory motif is inactivated. The pH of the buffer system used in the PCR reaction is temperature sensitive; increasing the temperature decreases the pH of the solution. Thus, the activation of the enzyme can actually be carried out by a heating step at 95°C prior to the start of the cycling. During the heating process, the DNA strands also denature, which can prevent the formation of nonspecific PCR products.

7.3.2 PCR Primers

PCR primers are the oligonucleotides that are complementary to the sequences that flank the target region of the template. A pair (forward and reverse) of primers (typically 0.1–1 μM) is required. Properly designed primers are critical to the success of a PCR reaction. Computer software such as Primer3 is available to assist and optimize the designing of primers.

A primer must be specific to the target sequence; otherwise, nonspecific products that might interfere with the proper interpretation of a DNA profile might be produced. The primers within a pair should have similar T_m values. The estimated T_m values of a primer pair should not differ by more than 5°C. The T_m of an oligonucleotide primer can be predicted and calculated using the following equation:

$$T_m = 81.5°C + 16.6\left(\log_{10}[K^+]\right) + 0.41\left(\%\ [G + C]\right) - \left(\frac{675}{n}\right)$$

where:

$[K^+]$ = concentration of the potassium ion
$[G + C]$ = GC content (%) of the oligonucleotide
n = number of bases in the oligonucleotide

This equation shows that the T_m can be affected by primer base composition (GC content) and primer length. The GC content of an oligonucleotide primer should be 40%–60%, and the length of an oligonucleotide primer should be 15–25 base pairs, although longer primers can be used.

A primer should not contain self-complementary sequences that may form hairpin structures interfering with the annealing of primers and the template. Additionally, the primers in a pair should not share similar sequences, to avoid the primers from annealing to each other. These annealed primers may then be amplified during PCR, creating products known as *primer dimers*, which compete with the target DNA template for PCR components.

Multiplex PCR is the simultaneous amplification of more than one region of a DNA template in a single reaction to achieve high-throughput analysis. Multiplex PCR consists of multiple primer sets in a single reaction to produce amplicons of multiple target DNA regions. The primers should be designed to yield proper sizes of amplicons to be resolvable in downstream separation and detection procedures such as electrophoresis. To prevent preferential amplification of one target sequence over another, the annealing temperatures should be similar among multiplex PCR primer pairs. Additionally, the primers should lead to similar amplification efficiencies among the loci to be tested. Forensic applications of multiplex PCR, such as autosomal and Y-chromosomal short tandem repeat analysis, are discussed in Chapters 20 and 21.

7.3.3 Other Components

Essential components include template DNA with target sequences in either linear form (nuclear genomic DNA) or circular form (mitochondrial DNA). Both single- and double-stranded DNA can be used as a template for PCR. Typically, 1–2.5 ng of template DNA is utilized for forensic applications using PCR.

Deoxynucleoside triphosphates (dNTPs) are the substrates for DNA synthesis. A PCR assay usually contains equal molar amounts (typically, 200 μM) of dATP, dCTP, dGTP, and dTTP.

Divalent cations, such as Mg^{2+}, are required for the enzymatic activity of DNA polymerases. A PCR assay usually contains 1.5–2.5 mM Mg^{2+}. Monovalent cations, such as K^+ (50 mM), are usually recommended, and a buffer is often utilized to maintain pH between 8.3 and 8.8 at room temperature.

Controls should be used to monitor the effectiveness of PCR amplification. A *positive control* shows that PCR components such as reagents and PCR cycle parameters are working properly during a PCR. A standard DNA template should be used as a positive control and amplified with the same PCR components used on the rest of the samples. The amplification negative control and extraction reagent blank are discussed in Section 7.5.4.

7.4 Cycle Parameters

PCR cycling protocols may vary according to the type of analysis. Figure 7.5 shows representative PCR cycling conditions commonly used by forensic DNA laboratories. PCR utilizes a number of cycles for the replication of a specific region of a DNA template. During each cycle, a copy of the target DNA sequence is synthesized. A PCR cycle consists of three elements: denaturation, annealing, and extension. Precise and accurate temperatures at denaturation, annealing, and extension are critical to achieve a successful amplification. At the beginning of each cycle, the two complementary DNA template strands are separated at high temperatures (94°C–95°C) in a process called *denaturation*. The temperature is then decreased to allow *annealing* between the oligonucleotide primers and the template. The temperature for annealing is usually 3°C–5°C lower than the T_m of the oligonucleotide primer.

The annealing temperature is critical. If it is too high, a very low quantity of amplicon is yielded because of the failure of annealing between the primer and the template. If the annealing temperature is too low, nonspecific amplification can occur. Next, optimal temperature for DNA polymerase is reached, thus allowing for DNA replication (*extension*). By the end of each cycle, the copy number of the amplicon is nearly doubled (Figure 7.6).

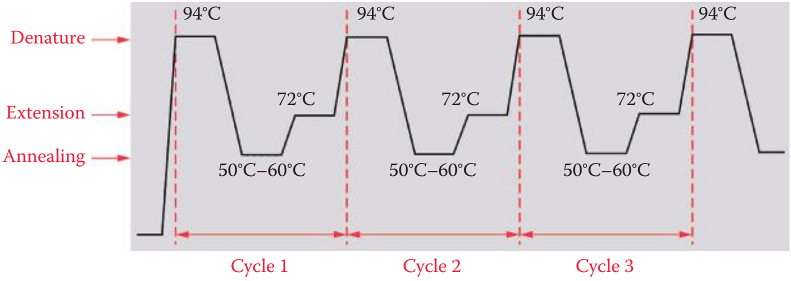

Figure 7.5 Temperature parameters during thermal cycling of the PCR process. The first three cycles are shown. (© Richard C. Li.)

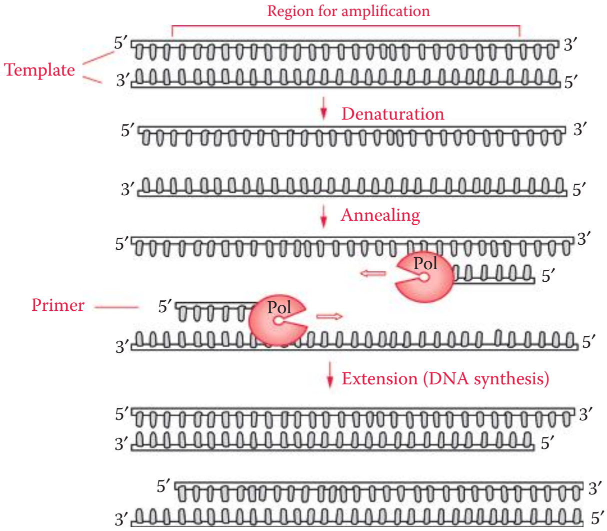

Figure 7.6 First cycle of PCR. The amplified region is determined by the positions of the primers. The direction (5′ to 3′) of DNA synthesis is indicated by arrows. Pol represents *Taq* polymerase. (© Richard C. Li.)

The number of cycles needed for PCR depends primarily on the number of copies of starting DNA template. The relationship can be expressed as the following equation:

$$N_x = N_0(1+E)^x$$

where:

X = number of PCR cycles
N_x = copy number of the amplicon after x cycles of PCR
N_0 = initial copy number of the template
E = amplification efficiency of the *Taq* polymerase

For example, in a 28-cycle PCR amplification, the DNA template can theoretically be amplified by a factor of approximately 10^8. If the cycle number is increased to 34, a factor of 10^{10} can theoretically be reached.

PCR amplification can be carried out using an instrument known as a *thermal cycler* (Figure 7.7). Various types of thermal cyclers differ in the number of samples they can process, the sizes of the sample tubes, and temperature control features.

Figure 7.7 Thermal cyclers. A thermal cycler can provide rapid temperature changes as desired to carry out PCR. A PCR thermal cycler (left) and a real-time PCR instrument (right). (© Richard C. Li.)

7.5 Factors Affecting PCR

7.5.1 Template Quality

It is important to prevent degradation of the DNA during the collection and processing of evidence. Degradation causes DNA to break into smaller fragments. If the damage occurs at a region to be amplified, the result can be failure in PCR amplification. In a degraded sample, the longer the amplicon length, the higher the risk of failure in PCR. Low copy number (LCN) of DNA template is often encountered in forensic samples. When amplifying very low levels (approximately 100 pg of DNA) of a template, the following phenomenon is often observed: one of the two alleles fails to be detected from a heterozygote and can falsely be identified as a homozygote. This phenomenon is also known as the *stochastic effect* in which the two alleles in a heterozygous individual are unequally detected at a low level of starting DNA template. Approaches such as increasing the cycle number, from 28 to 34 (Section 7.4), have been introduced to address the LCN problem.

7.5.2 Inhibitors

Inhibitors, if present, can interact with the DNA template or polymerase, causing PCR amplification failure. The presence of PCR inhibitors can be detected using an internal positive control (Section 6.3.1.1). A number of PCR inhibitors commonly encountered in evidence samples include heme molecules from blood, indigo dyes from fabrics, and melanin from hair samples. Thus, it is important to remove PCR inhibitors during DNA extraction. If PCR inhibitors are not eliminated during the extraction process, additional procedures such as the use of centrifugal filtration devices can be used. Centrifugal filtration devices can separate molecules by size. After the centrifugation step, small molecular weight inhibitors are filtered by passing through the membrane and are discarded. Alternatively, increasing the amount of DNA polymerase or adding bovine serum albumin (BSA) in the reaction can overcome the inhibition effects.

7.5.3 Contamination

PCR is a highly sensitive method; therefore, procedures that minimize the risk of contamination are necessary. To prevent contamination, pre- and post-PCR samples should be processed in separate areas or at different times. Additionally, reagents, supplies, and equipment used for pre- and post-PCR steps should be separated as well. Protective gear should include laboratory coats and disposable gloves. Facial masks and hair caps may be used if necessary. Aerosol-resistant pipet tips and DNA-free solutions and test tubes should also be used.

The levels of contamination must be monitored using controls. Extraction *reagent blanks*, which contain all extraction reagents but no sample, monitor contamination from extraction to PCR. Contamination detected in an extraction reagent blank but not in an amplification-negative control indicates that the reagents used for extraction are contaminated. Amplification-*negative* *controls*, which contain all PCR reagents and no DNA template, monitor contamination of the amplification. Contamination observed in an amplification-negative control but not in an extraction reagent blank indicates that the contamination occurred during the amplification step. Contamination observed in both an amplification reagent blank and an extraction-negative control indicates that amplification reagents are contaminated. A collection of DNA profiles of each member of a laboratory should be readily available for comparisons. Sources of laboratory contamination can be identified by comparing results with an analyst's DNA profile.

7.6 Reverse Transcriptase PCR for RNA-Based Assays

The pathway for the flow of genetic information is called the *central dogma*—a term coined by Francis Crick in 1956. According to the central dogma, parental DNA serves as the template for *DNA replication*. With RNA synthesis or *transcription*, the process is carried out using the DNA as a template. Conversely, RNA chains can be used as templates for the synthesis of a DNA strand of complementary sequence, in which the end product is referred to as *complementary DNA (cDNA)*. Protein synthesis, also known as *translation*, is directed by an RNA template (Figure 7.8).

The flow of genetic information from RNA to DNA is referred to as *reverse transcription*. It was discovered independently by David Baltimore and Howard Temin in 1970, and they shared the Nobel Prize for their work. Reverse transcription is carried out by a *reverse transcriptase* that forms the basis of reverse transcriptase PCR as described below.

Reverse transcriptase PCR (RT-PCR) is highly sensitive and can be used to detect very small quantities of mRNA. It can be utilized to measure levels of gene expression even when the RNA of interest is expressed at very low levels. Detecting mRNAs of tissue-specific genes can be utilized for bodily fluid identification in forensic investigations (Chapter 11). During an RT-PCR process, a single-stranded cDNA is synthesized from a template mRNA using reverse transcription. The cDNA is then amplified by PCR for detection and analysis.

7.6.1 Reverse Transcription

The synthesis of single-stranded cDNA from an mRNA template is catalyzed by reverse transcriptase. Reverse transcriptases share many features in structure and function with DNA polymerases. The catalytic function of cDNA synthesis requires a primer that anneals to a complementary mRNA template. The primer can be either RNA or DNA; however, DNA primers are more efficient than RNA primers. During the elongation of the primer, reverse transcriptase incorporates the corresponding deoxyribonucleotide triphosphate according to the rules of base pairing with the RNA template. The RNA template is then degraded by an intrinsic RNase H activity of reverse transcriptase during the reverse transcription reaction. The retroviral RNase H is a domain of the viral reverse transcriptase enzyme. It is a nonspecific endonuclease that cleaves RNA.

Several reverse transcriptases derived from retroviruses can be used to generate cDNA from an RNA template. The most common reverse transcriptases used for cDNA synthesis are

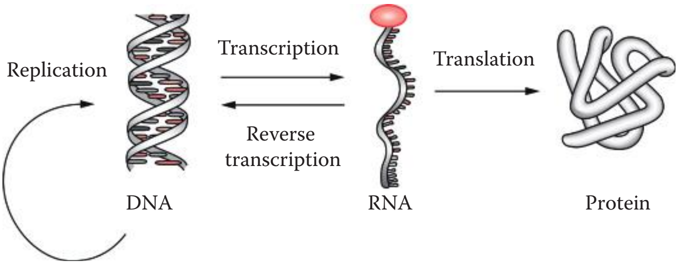

Figure 7.8 Pathway for the flow of genetic information. (© Richard C. Li.)

encoded by the *pol* gene from the avian myeloblastosis virus (AMV) and the Moloney strain of the murine leukemia virus (MMLV). These enzymes are genetically engineered reverse transcriptases but lack RNase H activity. Genetically engineered reverse transcriptases that are stable at higher temperatures (up to 60°C) are also produced. Increased thermal stability of reverse transcriptase allows the reverse transcription to be carried out at a higher than ambient temperature, which eliminates RNA secondary structures and improves the specificity of the reaction and the yields of the synthesis of full-length cDNA.

7.6.2 Oligodeoxynucleotide Priming

Oligodeoxynucleotide primers are an essential component for a reverse transcriptase reaction. Different priming strategies can be utilized to synthesize cDNA from a particular target mRNA or from all mRNA in a sample. *Gene-specific primers* are designed to hybridize to a particular mRNA sequence for the conversion of a specific gene sequence into cDNA. *Universal primers* can hybridize to any mRNA sequence in a sample to convert all mRNAs to cDNA. Two types of universal primers can be used: oligo (dT) and random hexamer primers. An *oligo (dT) primer* can hybridize to the 3′ termini poly (A) tails of eukaryotic mRNAs. Reverse transcriptases with oligo (dT) only synthesize cDNA from transcribed genes. *Random hexamer primers* are another type of universal primer. Random hexamers are nonspecific primers that can hybridize, at multiple sites, to any RNA sequence including non-mRNA templates such as ribosomal RNA.

7.6.3 Reverse Transcriptase PCR

During an RT-PCR process, a single-stranded cDNA is synthesized from a template mRNA using reverse transcription. The cDNA is then amplified by PCR with a pair of oligonucleotide primers corresponding to a specific sequence in the cDNA (Figure 7.9).

Two strategies of RT-PCR exist: a one-step and a two-step RT-PCR (Figure 7.10). One-step RT-PCR combines the reverse transcription reaction and PCR in a single tube. Only gene-specific

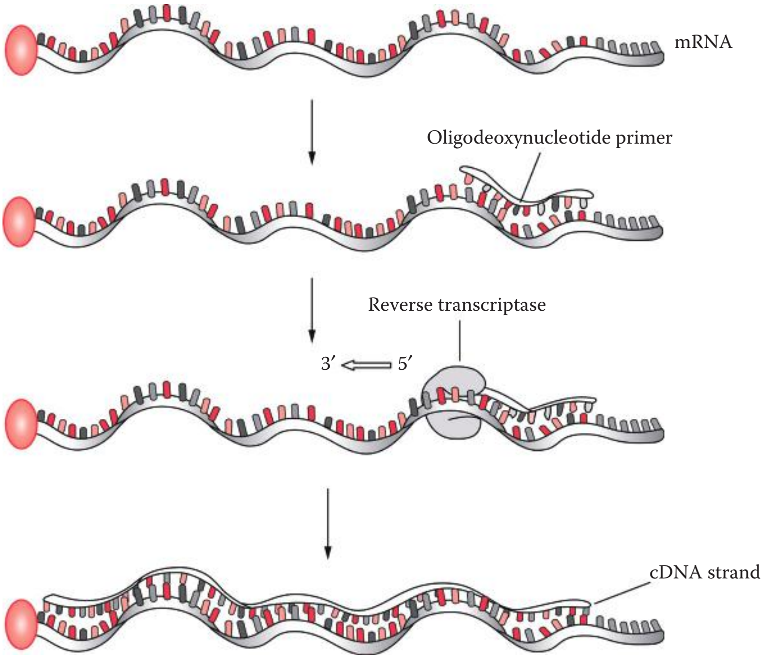

Figure 7.9 cDNA synthesis. The synthesis of a DNA strand transcribed from mRNA can be carried out using a primer and reverse transcriptase. A gene-specific primer that amplifies a specific target sequence is shown. (© Richard C. Li.)

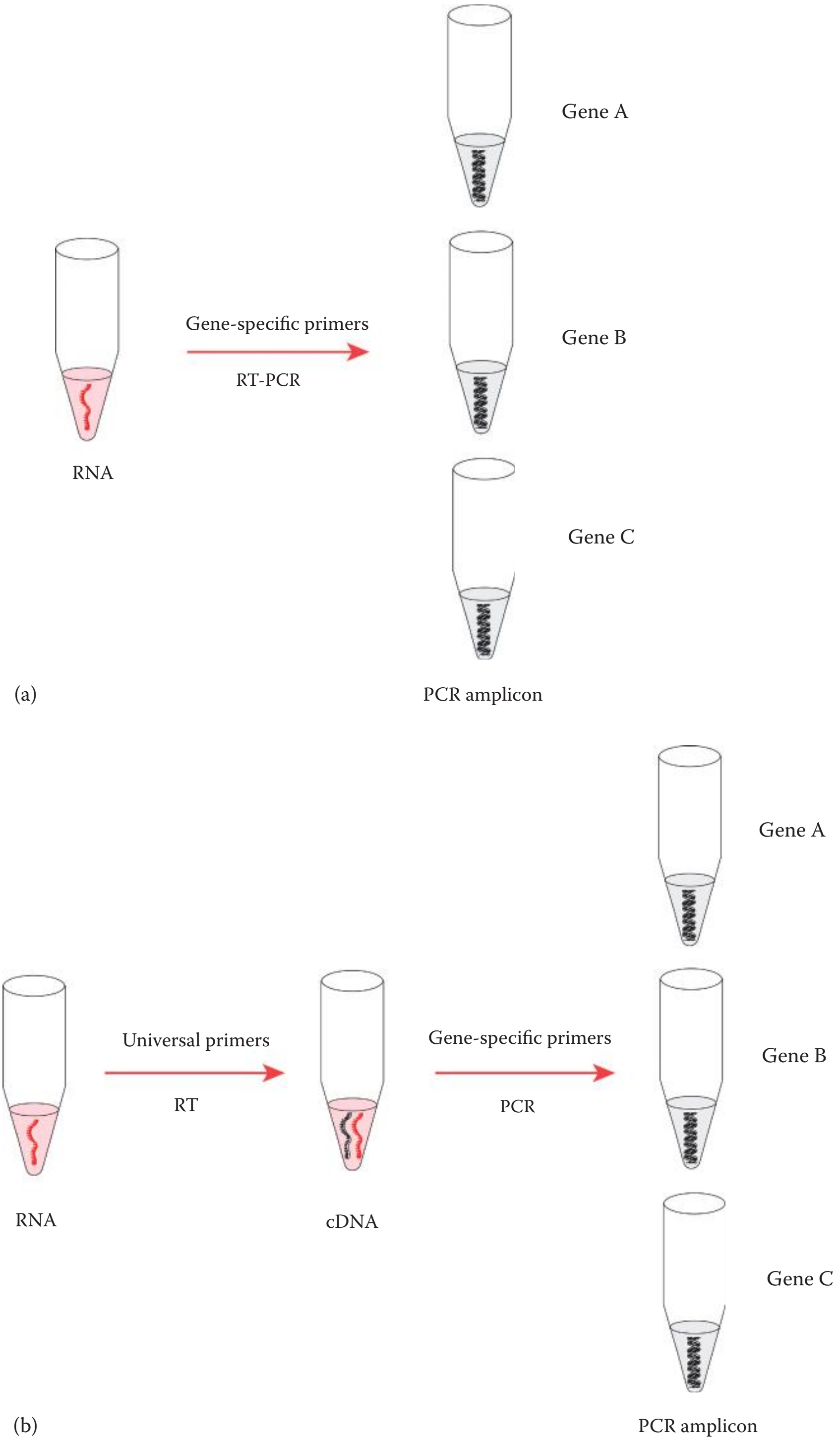
Gene A
Gene-specific primers
RT-PCR
Gene B
RNA
Gene C
(a)
PCR amplicon
Gene A
Universal primers
RT
Gene-specific primers
PCR
Gene B
RNA
cDNA
Gene C
(b)
PCR amplicon

Figure 7.10 RT-PCR strategies. (a) One-step RT-PCR and (b) two-step RT-PCR. (© Richard C. Li.)

primers can be used for the reverse transcription reaction and PCR. RNAs from either total RNA or mRNA can be used. This approach simplifies the reaction setup as it is useful for processing large numbers of samples. The tubes are not opened between reverse transcription and PCR, thus minimizing the risk of pipetting errors and carryover contamination.

During a two-step PCR, the reverse transcription reaction and PCR are carried out in separate tubes. Following the reverse transcription reaction, the cDNA is transferred to a separate tube for the PCR amplification. Either oligo (dT) or random hexamer primers can be used for the reverse transcription reaction. Total RNA or polyadenylated RNA can be used for the reverse transcriptase reaction. This allows for the ability to convert all the messages in an RNA sample into cDNA. The two-step RT-PCR is useful for analyzing multiple mRNAs from a single sample.

Two types of PCR methods can be utilized for analyzing amplified products. The end-point PCR method measures the amount of amplified product synthesized during PCR at the end of the PCR amplification. The detection of the amplified product indicates the presence of the mRNA of interest. With the real-time PCR method, the amplified product is quantified during the exponential phase of PCR. The hot-start PCR strategy is typically used to increase sensitivity, specificity, and yield. Usually, the hot-start strategy is carried out at a high temperature, for example 94°C, prior to PCR cycling. Under this condition, *Taq* DNA polymerase is activated. Additionally, the RNA-cDNA hybrid is denatured, and reverse transcriptase is inactivated at 94°C. Multiplex RT-PCR assays have been developed that can detect multiple bodily fluid mRNAs from single or mixed stains (Chapter 11). The commonly used RT-PCR for forensic identification of bodily fluids is the two-step RT-PCR. The end-point PCR is usually utilized with the forward primers labeled with florescent dyes at the 5′ end. The amplified products are separated and detected in a standard capillary electrophoresis instrument.

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8

DNA Electrophoresis

It is necessary to separate various sizes of DNA fragments so that the DNA fragment in question can be identified and analyzed. This can be achieved by electrophoresis, a process in which fragments are separated based on the migration of charged macromolecules in an electric field.

8.1 Basic Principles

DNA is a negatively charged molecule in an aqueous environment, with the phosphate groups of DNA nucleotides carrying negative charges. DNA molecules migrate from the negative electrode (cathode) toward the positive electrode (anode) in an electric field during electrophoresis. The *electrical potential*, a measure of the work required to move a charged molecule in an electric field, is the force responsible for moving the charged macromolecules during electrophoresis.

The *electrophoretic mobility* of macromolecules is primarily determined by their *charge-to-mass ratios* and their shapes. However, because the phosphate group of every DNA nucleotide carries a negative charge, the charge-to-mass ratio of DNA molecules is almost the same even if the length of the DNA fragment varies. Additionally, forensic DNA testing usually analyzes linear DNA molecules such as double-stranded linear DNA for variable number tandem repeat (VNTR) analysis (Chapter 19) and single-stranded DNA for short tandem repeat (STR) analysis (Chapter 20). The shapes of linear DNA molecules are similar. Therefore, the electrophoretic separation of different-sized DNA fragments, through a series of pores of the supporting matrix in which the fragments travel, is based more on their sizes than their shapes.

It is obviously easier for smaller molecules to migrate through the pores of a supporting matrix than larger molecules; this is why smaller molecules migrate faster through the matrix. Hence, the electrophoretic mobility increases as the size of the DNA molecule decreases. Conversely, larger DNA molecules migrate much more slowly because they experience more friction and collisions as they travel through the net of pores in a matrix. Therefore, the separation of DNA molecules with different sizes can be accomplished. Figure 8.1 depicts the models for DNA electrophoresis.

8.2 Supporting Matrices

Although the actual separation occurs in an aqueous phase, most variants of electrophoresis use a physical support material also called a *matrix*. As discussed in Section 8.1, the matrix can be used as a molecular sieve for the separation of DNA molecules, and it also reduces diffusion and convection during electrophoresis. Agarose and polyacrylamide are commonly used electrophoresis matrices because of their good reproducibility, reliability, and versatility.

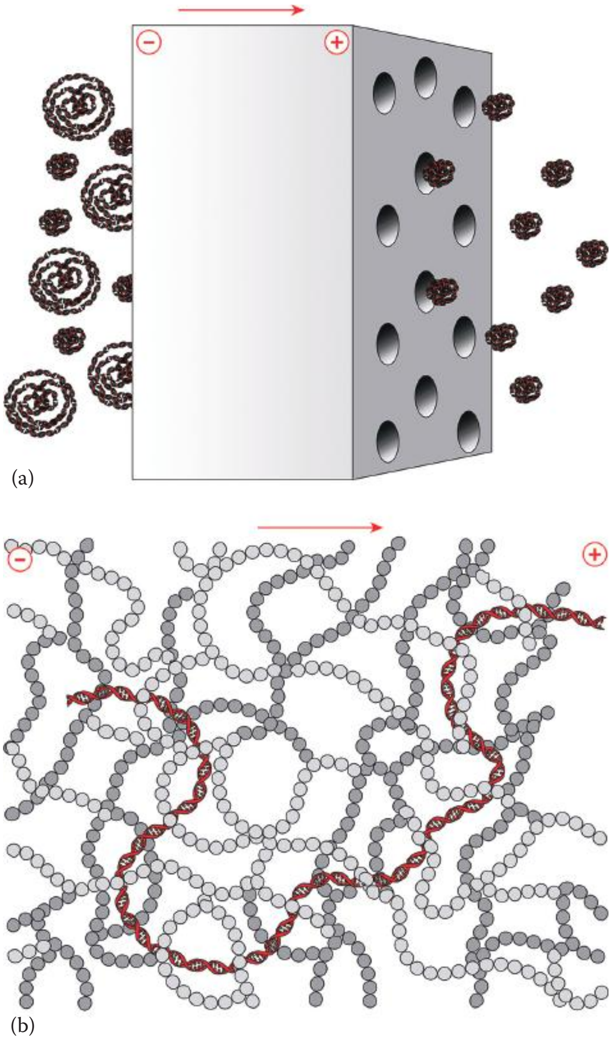

Figure 8.1 Schematic illustrations showing some of the nucleic acid separation mechanisms. (a) Ogston sieving model for the separation of DNA fragments through electrophoresis. Based on this model, the matrix used for gel electrophoresis consists of randomly distributed pores. DNA molecules are considered to behave as globular objects. During the migration, smaller DNA molecules migrate faster than their larger counterparts through the matrix. However, this model does not apply to DNA molecules with a radius much larger than the pore size of the matrix. (b) A reptation model presents an alternative mechanism of gel electrophoretic separation of DNA molecules. Based on this model, DNA molecules are flexible and can migrate through the pores of the gel matrix through a reptation process that is driven by an applied electric field. This model can also apply to capillary electrophoresis separation of DNA molecules in entangled polymer solutions. +, anode; –, cathode; arrow, direction of migration. (© Richard C. Li.)

8.2.1 Agarose

Agarose is a linear polymer composed of alternating residues of D- and L-galactose (Figure 8.2). A gelatinized agarose forms a three-dimensional sieve with pores from 50 to 200 nm in diameter (Figure 8.3). DNA fragments ranging from 50 to 20,000 base pairs in size are best resolved in agarose gels.

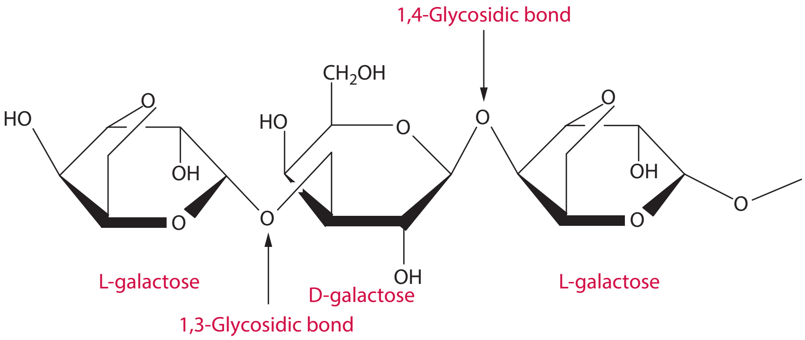

Figure 8.2 Chemical components of agarose, a linear polysaccharide composed of alternating units of D- and L-galactose. Often, the L-galactose residue has an anhydro bridge between the 3 and 6 positions and is called 3,6-anhydro-L-galactose.

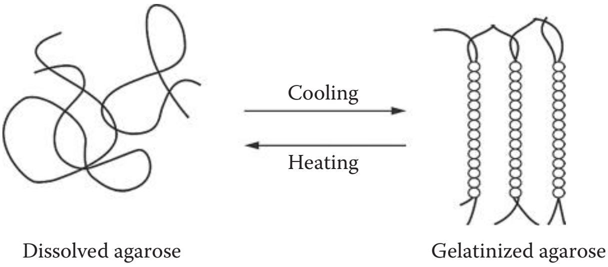

Figure 8.3 Agarose chains. Gelatinized agarose consists of a three-dimensional network in which chains of agarose form helical fibers that aggregate into supercoiled structures. (© Richard C. Li.)

The electrophoretic mobility of double-stranded DNA through agarose gel matrices is inversely proportional to the $\log_{10}$ of the size of DNA fragments ranging from 50 to 20,000 base pairs. The electrophoretic mobility of a linear DNA fragment is also inversely proportional to the concentration of agarose in the gel. A low concentration of agarose in a gel forms larger pores, allowing the separation of larger DNA fragments.

8.2.2 Polyacrylamide

A polyacrylamide gel matrix is very effective for the separation of smaller fragments of DNA (5–500 base pairs). Additionally, a single nucleotide difference in the length of a DNA fragment can be resolved with this type of gel. Polyacrylamide produces much smaller pore sizes than agarose gels and thus has a much higher resolving power than agarose gels for low-molecular-weight DNA molecules. A polyacrylamide gel matrix is formed by polymerization and cross-linking reactions.

8.2.2.1 Polymerization Reaction

Long linear chains of polyacrylamide are polymerized from acrylamide monomers (Figure 8.4). This polymerization reaction is initiated in the presence of free radicals that are generated from the reduction of ammonium persulfate (APS) by *N*,*N*,*N*′,*N*′-tetramethylethylene diamine (TEMED). See Figure 8.5.

8.2.2.2 Cross-Linking Reaction

As shown in Figure 8.5, three-dimensionally cross-linked polyacrylamide chains can be formed with the use of cross-linking agents, such as *N*,*N*′-methylenebisacrylamide (BIS; Figure 8.4).

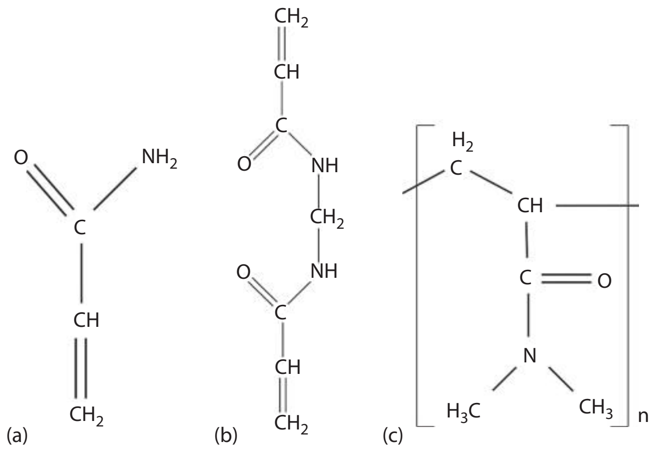

Figure 8.4 Chemical structures of (a) acrylamide, (b) *N*,*N*′-methylenebisacrylamide (BIS), and (c) polydimethylacrylamide (a linear polymer for capillary electrophoresis).

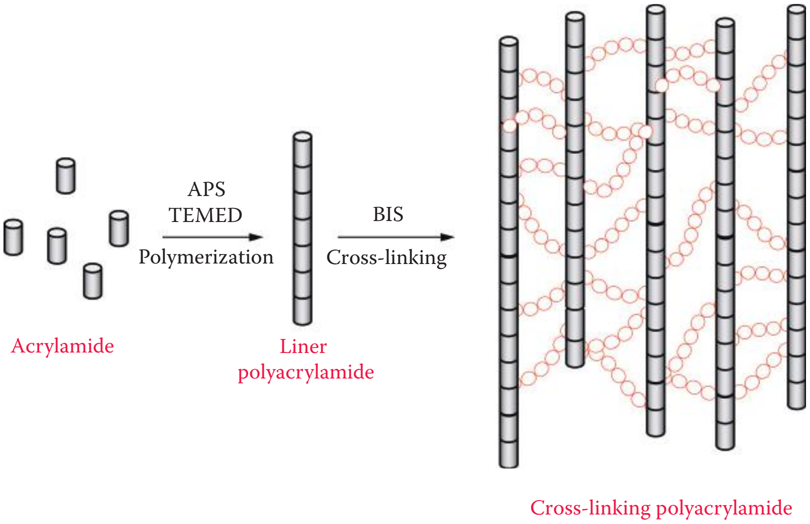

Figure 8.5 Formation of polyacrylamide gel. Polymerization is followed by cross-linking in which the pore size of the gel is determined by its degree of polymerization and cross-linking. (© Richard C. Li.)

The porosity of the resulting gel is determined by the lengths of these chains and the degree of cross-linking between them. Therefore, the sizes of the pores that are formed can be adjusted by altering the concentrations of the acrylamide monomer and the cross-linking reagent.

Polyacrylamide can also be used in a capillary electrophoresis matrix. It is very difficult to insert a cross-linked polyacrylamide matrix into a capillary. Therefore, a solution of a linear polymer (non-cross-linked) of polydimethylacrylamide (Figure 8.4) is used as a matrix for capillary electrophoresis. For instance, POP-4 (4% un-cross-linked polydimethylacrylamide polymer) is used for fragment analysis, such as forensic STR analysis (Chapter 18), in which fluorescently labeled DNA amplicons are separated using electrophoresis and are identified based on their sizes by comparing them with a size standard. POP-6 (6% un-cross-linked polydimethylacrylamide polymer) is used for sequencing, such as mitochondrial DNA (mtDNA) sequencing (Chapter 21). These un-cross-linked polymers are commercially available (Applied Biosystems).

8.2.2.3 Denaturing Polyacrylamide Electrophoresis

Polyacrylamide-based electrophoresis can be carried out with both double- and single-stranded DNA. Electrophoresis that is performed under the conditions of single-stranded DNA is called *denaturing electrophoresis*. Denatured DNA migrates through the gel as linear molecules at a rate independent of the base composition and sequence. With short single-stranded fragments, molecules differing in size by a single nucleotide can be separated. This extraordinary sensitivity to size is extremely useful for the separation of small DNA fragments that are used for DNA sequencing and STR analysis in forensic applications. The denaturing condition can be best achieved by adding chemicals such as urea or formamide to the matrix or by increasing the temperature or pH during electrophoresis.

8.3 Apparatus and Forensic Applications

Agarose electrophoresis is carried out in a slab gel. Agarose gel can be prepared in a variety of shapes and sizes and can be run in different configurations. The most common gel for forensic use is the horizontal slab. Polyacrylamide can be used either in a slab gel or in a capillary electrophoretic apparatus.

8.3.1 Slab Gel Electrophoresis

8.3.1.1 Agarose Gel Electrophoresis

One forensic application of agarose gel electrophoresis is restriction fragment length polymorphism (RFLP) analysis of VNTR loci (see Chapter 19). An agarose gel is used to separate the DNA fragments by size ranging from 500 to 20,000 base pairs of commonly used VNTR loci for forensic testing. This type of electrophoresis is done under nondenatured conditions (double-stranded DNA).

Figure 8.6 shows an example of the apparatus used for gel electrophoresis of DNA. A slab (3–4 mm) of agarose gel is prepared by allowing liquid agarose to gelatinize in a cast. The gel is submerged in a buffer tank filled with an electrophoretic buffer with proper ionic strength, which is necessary to achieve efficient electrical conductance. The gel contains small wells for loading samples. The DNA samples are mixed with a gel loading buffer prior to loading them into the gel. The gel loading buffer contains dyes that add color to the sample to facilitate the process of loading. Dyes such as bromophenol blue and xylene cyanol FF migrate toward the anode during electrophoresis. In most forensic applications, these dyes migrate faster than DNA fragments. The dyes are visible and can thus be used to track the progression of electrophoresis. The electrophoresis can be stopped as the dye front reaches the bottom of the gel (anode side).

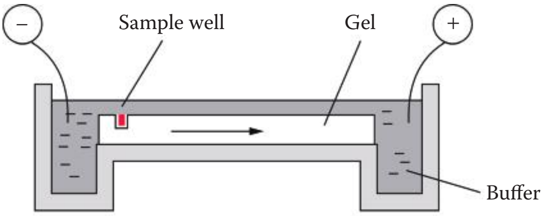

Figure 8.6 Horizontal agarose slab gel apparatus. The gel can be prepared by heating an agarose suspension to dissolve it. The agarose solution can then be poured into a gel cast and allowed to cool until gelatinized. An electrophoresis buffer is poured over the gel to submerge it. The samples, usually mixed with loading buffer containing dye to allow visualization, are loaded into the wells of the submerged gel using a pipet. The electrodes are indicated. (© Richard C. Li.)

The samples are loaded into the sample wells situated proximal to the cathode. An electric field is applied and the negatively charged DNA molecules migrate through the agarose toward the anode. Slab gel electrophoresis is capable of running multiple samples simultaneously. The sample is made visible by using a fluorescent intercalating reagent that can make DNA fluoresce under ultraviolet (UV) light (Chapter 9), either using the fluorescent intercalating reagent incorporated into the gel or staining the gel after electrophoresis. The separated DNA samples appear as bands and the sizes of the DNA fragments can be estimated by comparing them with the sizes of standards run concurrently.

8.3.1.2 Polyacrylamide Gel Electrophoresis

The forensic application of this apparatus is the separation of STR fragments and DNA sequencing reaction products of mtDNA. The sizes of DNA fragments that can be separated range from 100 to 500 base pairs—much smaller than what can be separated efficiently with agarose gels. Single-nucleotide resolution to distinguish similarly sized fragments can be achieved with this technique under denatured conditions with only single-stranded DNA. Polyacrylamide thin slab gels (0.75–1.5 mm) are usually used. Samples are loaded into wells flanked by two pieces of glass. Therefore, polyacrylamide gels are usually run in a vertical configuration (Figure 8.7). The detection of DNA bands in polyacrylamide gels will be described in Chapter 9. The sizes of DNA fragments can be calculated by including an internal size standard. As with agarose gel, polyacrylamide gel electrophoresis is capable of running multiple samples simultaneously and high throughput (a measurement of the rate that a sample is processed by a given analysis) can be achieved. However, caution should be taken to ensure that cross-contamination does not occur from the spilling of samples from adjacent wells. Additionally, polyacrylamide gels are more difficult to prepare than agarose gels.

8.3.2 Capillary Electrophoresis

Capillary electrophoresis (Figures 8.8 through 8.11) is a newer method than the slab gel method, and can be utilized to separate charged macromolecules, such as DNA, RNA, polysaccharides, and proteins.

One essential component of the capillary electrophoresis instrument is the capillary, a thin hollow tube made of fused silica (which typically has a diameter between 50 and 100 µm and a length between 10 and 50 cm). The capillary contains a translucent detection window for the instrument to detect signals from the labeled DNA fragments during electrophoresis.

Linear polydimethylacrylamide is used as the matrix. Capillary electrophoresis is conducted under denatured conditions for forensic applications such as STR analysis and mtDNA sequencing analysis. The denatured condition is achieved by including urea in the electrophoresis matrix and formamide during sample preparation. The injection of samples into the capillary is performed by an autosampler using an *electrokinetic* mechanism (an injection based on the charge of molecules). Only small quantities of sample are required for each injection, and any remaining sample can be saved in case an analysis needs to be repeated.

During electrophoresis, the capillary is connected to buffer reservoirs that are connected to electrodes. The efficient heat dissipation property of thin capillaries allows the separation to be performed at higher voltages, as the electric field (typically 200–300 V/cm) is much higher than that of a slab gel platform. Thus, the separation in capillary electrophoresis is rapid. During electrophoresis, DNA fragments migrate through the capillaries toward the anode. Similar to gel electrophoresis, DNA fragments are separated according to their sizes, with the shorter fragments moving faster than the longer fragments. During capillary electrophoresis, linear polymers in the solution can act as obstacles to the migrating DNA fragments. Thus, electrophoretic separation models (Figure 8.1) developed for gels are applicable for capillary electrophoresis. Currently, capillary electrophoresis can separate DNA fragments of up to 1000 nucleotides with single-nucleotide resolution.

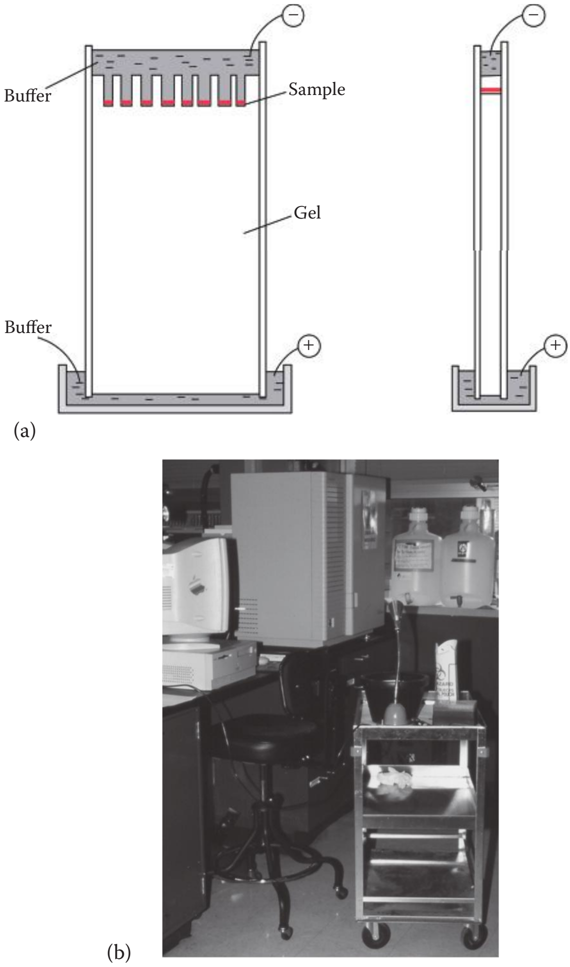

Figure 8.7 Vertical slab polyacrylamide gel. (a) Front and side view of vertical slab polyacrylamide gel apparatus. (b) Automated gel electrophoresis instrument, ABI PRISM 377® Genetic Analyzer, which was used in forensic laboratories but is now discontinued. (© Richard C. Li.)

Capillary electrophoresis instruments are equipped with detection systems utilizing laser excitation sources that excite the fluorescently labeled DNA fragments. They also include fluorescence detectors that record the signals emitted from the labeled DNA fragments (Chapter 9). In capillary electrophoresis, samples can only be analyzed sequentially so the throughput is much more limited than with slab gels. This disadvantage can be overcome by utilizing capillary array systems that can run up to 16 capillaries at one time (Figure 8.10).

8.3.3 Microfluidic Devices

Forensic DNA analysis includes the extraction of DNA from a sample, DNA quantification, polymerase chain reaction (PCR) amplification, capillary electrophoresis, data collection, and genotyping. Various microfluidic devices have been developed for forensic DNA analysis. Microfluidic devices control the movement of samples and reagents in a small, geometrically constrained environment and carry out biochemical reactions and analysis. These devices are made using microfabrication technology. This technology fabricates miniature structures historically used for integrated circuit fabrication in semiconductor manufacturing. The microfluidic

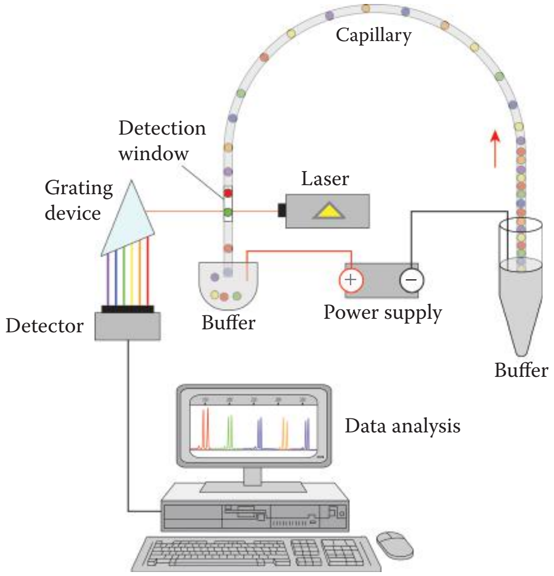

Figure 8.8 Essential components of a capillary electrophoresis system. The system includes a capillary, buffer reservoirs, two electrodes, a laser excitation source, a fluorescence detector, and an autosampler that holds the sample. Sample injection, electrophoresis, and data collection are automated and controlled by a computer. (© Richard C. Li.)

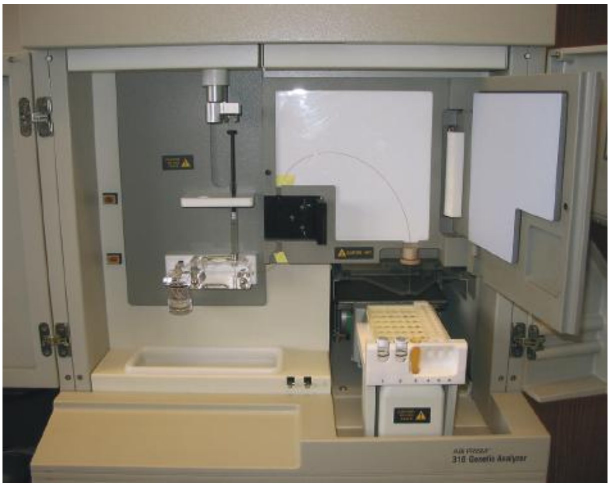

Figure 8.9 A single-capillary electrophoresis instrument, ABI PRISM 310® Genetic Analyzer. This was used in forensic laboratories but is now discontinued. (© Richard C. Li.)

devices can be classified as modular and integrated devices. Overall, the microfluidic device has many advantages compared with conventional techniques. The reaction volume required in microfluidic devices is usually in the nanoliter range, which decreases reagent and sample consumption. Additionally, due to the high surface area-to-volume ratio of the system, the efficiency of the system is greatly improved. Lastly, it can be automated, which makes the device a potential new platform for forensic DNA analysis.

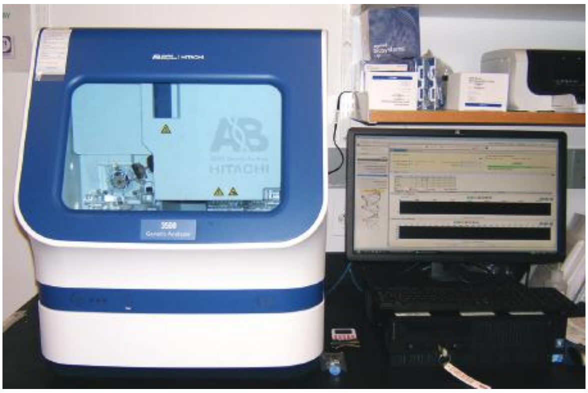

Figure 8.10 Photo of a multicapillary electrophoresis instrument. ABI PRISM 3500® Genetic Analyzer. (© Richard C. Li.)

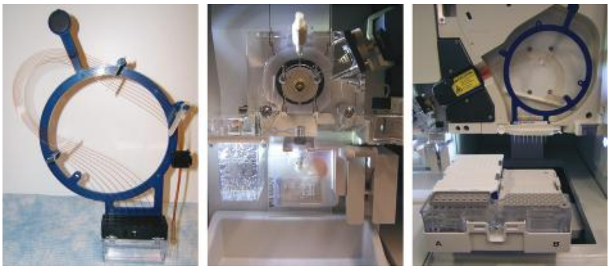

Figure 8.11 Components of the ABI PRISM 3500® Genetic Analyzer. A capillary array (left), electrophoretic buffer chambers (middle), and an autosampler (right). (© Richard C. Li.)

8.3.3.1 Modular Microfluidic Devices

The modular devices are separate devices for DNA extraction, quantitation, amplification, electrophoresis, and so on. Each processing step is carried out on different devices. The modular design is flexible, allowing laboratories to choose the best device suited to the procedure for each step. For example, an electrophoresis microfluidic device has been developed (Figure 8.12). The electrophoretic assay is carried out on a modular microfluidic chip format using the same basic principle of capillary electrophoresis. The single-use chip contains wells for samples, a sieving polymer matrix for electrophoresis, and size standards. The wells are connected through microchannels. When the interconnected wells and channels are filled, the chip becomes an integrated electrical circuit. Each well is then connected to an electrode with an independent power supply. DNA molecules, carrying negative charges, are

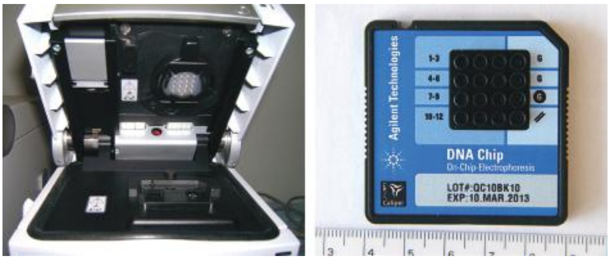

Figure 8.12 A modular instrument for gel electrophoresis. Left: Agilent 2100 Bioanalyzers contain 16-pin electrodes that fit into the wells of a chip. Right: The chip can accommodate sample wells, gel wells, and a well for a size standard. (© Richard C. Li.)

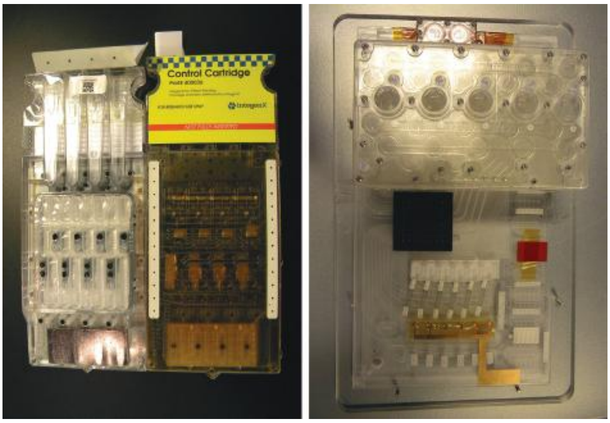

Figure 8.13 Integrated instruments for rapid DNA analysis. Cartridges developed by IntegeneX (left) and Zygem (right). (© Richard C. Li.)

electrophoretically separated based on their size. Smaller molecular weight fragments migrate faster than larger fragments. The polymer matrix contains fluorescent dye molecules that intercalate with DNA in a sample, which can be detected by laser-induced fluorescence. The duration of electrophoresis is approximately 30 min. The sensitivity is approximately 0.1 ng/μL; thus, sample consumption is small. The device provides the sizing and quantitation information of the nucleic acid fragment. In addition to DNA, the device can also be used for the analysis of RNA and protein. In the forensic laboratory, it has been used for the quantitation of amplified mtDNA product to monitor successful amplification and to normalize the quantities of DNA template for cycle sequencing.

8.3.3.2 Integrated Microfluidic Devices

It is possible to integrate several different modular devices into a single device (Figure 8.13). These devices are also known as "micro-total analysis" systems. An integrated system is a fully automated process. It also reduces the risk of contamination from laboratory sources. Full integration of all the constituent steps required for forensic STR DNA analysis has been achieved by a *rapid DNA* instrument. This instrument integrates various microfluidic devices including DNA extraction, PCR amplification, electrophoresis, detection, and genotyping steps into a single process on a cartridge. The cartridge, made from a variety of materials such as polycarbonate, incorporates pumps and valves controlling fluidic movement for the delivery of samples and prefilled reagents to the chambers for processing. DNA extraction usually utilizes silica-coated magnetic particles that can be collected by a magnet for DNA extraction. Microquantitative PCR utilizes the Taqman real-time quantitative PCR technique. During amplification, multiplex PCR is accomplished using commercial STR kits. Additionally, the cartridge also integrates a microcapillary electrophoresis chip for the separation of amplified products. The fluorescently labeled DNA fragments are detected based on laser-induced fluorescence. Data analysis and genotyping are then carried out to produce a DNA profile, which is compatible with the CODIS DNA database (Chapter 24). Rapid DNA instruments are fully automated platforms that are designed to process a single-source sample such as a buccal swab to generate a DNA profile and database search in less than 2 h. The goal is for these instruments to be deployed in field tests at the scene or at the booking stations operated by trained law enforcement agents.

8.4 Estimation of DNA Size

8.4.1 Relative Mobility

The *relative mobility* (R_f) of a DNA molecule during electrophoresis can be calculated as the distance of band migration divided by the distance of tracking dye migration. The DNA

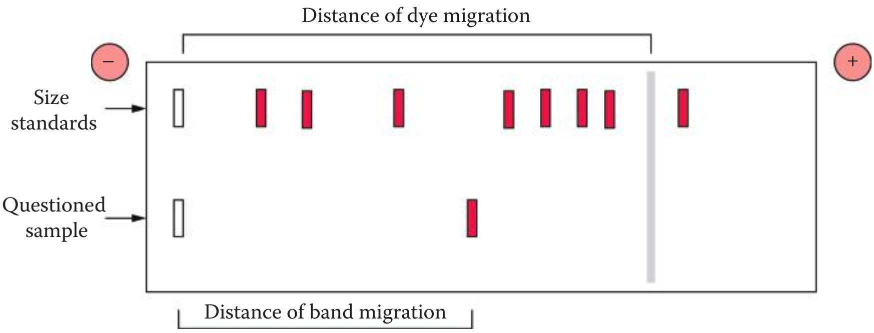

Figure 8.14 Measurement of the electromobility of DNA. Questioned DNA samples are analyzed concurrently with a set of standard DNA fragments of known size. The distances of DNA migration can thus be measured. The samples are usually mixed with a gel loading buffer prior to loading samples to the gel. The buffer contains dyes that add color to the sample to facilitate the process of loading. Dyes such as bromophenol blue and xylene cyanol FF migrate toward the positive electrode during electrophoresis. They can be used for tracking purposes as well. (© Richard C. Li.)

band migration is the distance from the sample origin to the center of the band. The tracking dye migration distance extends from the sample origin to the center of the dye band (Figure 8.14). To estimate the size of the DNA, standards containing DNA of known size and questioned samples are run on the same gel at the same time. The standards can be used to estimate the size of an unknown DNA molecule. A plot of $\log_{10}$ base pair of the standards versus R_f for a given gel can be constructed. A linear relationship, over a size range, between $\log_{10}$ base pair of the DNA molecule and the R_f can be observed. The R_f of the test sample is interpolated on the plot from which the size of an unknown DNA molecule can be determined (Figure 8.15).

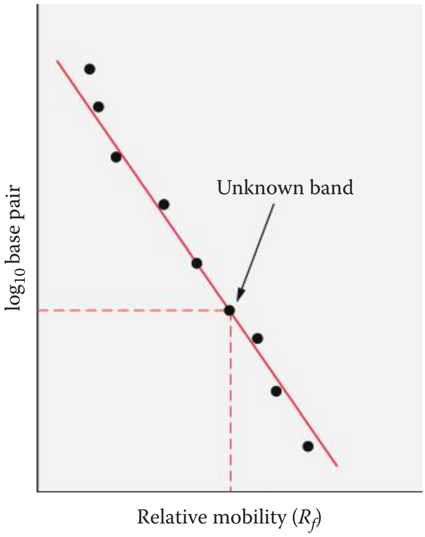

Figure 8.15 Estimation of the size of a DNA fragment. A plot of size standards versus relative migration during electrophoresis is shown. The size of the questioned DNA fragment can be estimated using this plot. (© Richard C. Li.)

8.4.2 Local Southern Method

The size of a DNA fragment is determined by an internal size standard that is a set of synthetic fragments with known molecular weight. The standard is labeled with a different colored dye so that it can be spectrally distinguished from DNA fragments of an unknown size (Figure 8.16). The sample including the internal size standard is then mixed in with DNA samples and is analyzed by electrophoresis. To determine the sizes of DNA fragments, a standard curve using the internal size standards must be established based on the reciprocal relationship between the electrophoretic mobility and the sizes of DNA fragments. However, this relationship is not exactly linear; instead, it appears to be sigmoidal (Figure 8.17). Therefore, the *Local Southern method*, described by Sir Edwin Southern, is used to generate standard curves for determining the sizes of DNA fragments. The equation is as follows:

$$L = \left[\frac{C}{M - M_0}\right] + L_0$$

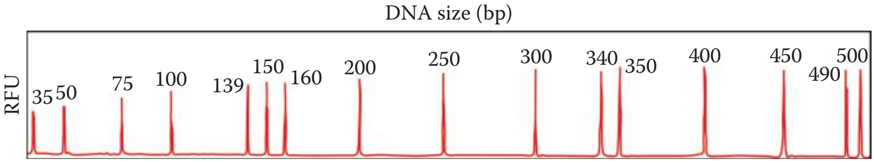

Figure 8.16 Electropherogram of a synthetic molecular weight size standard, GeneScan™ 500 size standard (Applied Biosystems). RFU, relative fluorescence units. (© Richard C. Li.)

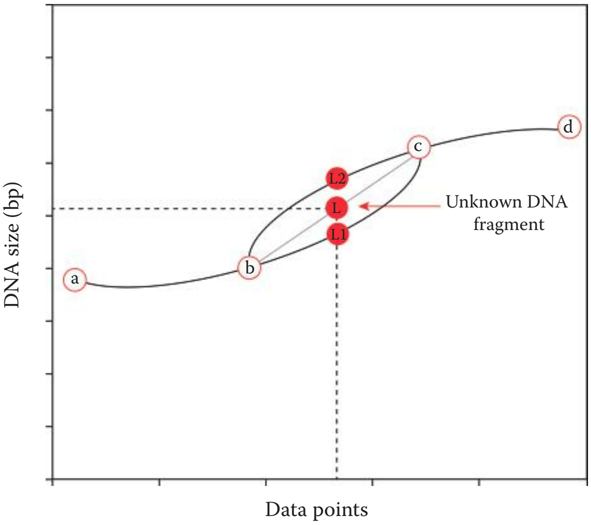

Figure 8.17 Estimation of unknown DNA fragment sizes using the Local Southern method. The migration of ssDNA fragments (20–1200 base pairs) is not linear over the entire fragment size range and is somewhat sigmoidal. To determine the size of a DNA fragment in question, two curves are generated. The first curve is generated using three standard points: two points (a and b) that are smaller and one point (c) that is larger than the questioned fragment. As a result, a fragment size (L_1) is determined. The second curve is then generated using an additional three standard points: one point (b) that is smaller and two points (c and d) that are larger than the questioned fragment. Thus, a fragment size, L_2, is determined. The two values (L_1 and L_2) are averaged to determine the size (L) of the questioned fragment. (Adapted from Southern, E.M., *Anal Biochem*, 100, 319–323, 1979.)

In the equation, L is the size of the unknown fragment; M is the mobility of the fragment; and C, M_0, and L_0 are constants that are obtained from the fragments of known size. To determine the size of an unknown fragment, two curves are generated based on the equation. Each curve utilizes three data points. The first curve utilizes two size standards that are smaller and one size standard that is greater than that of the unknown fragment. As a result, size L_1 is obtained. The second curve utilizes a size standard that is smaller and two size standards that are greater than that of the unknown fragment. Thus, size L_2 is obtained. Finally, the average of L_1 and L_2 is defined as the size of the unknown fragment. In this method, only the size standards that are in the proximity of the unknown fragment are analyzed. However, the accuracy of the standard curve relies on the proper separation of the standards during electrophoresis.

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9

Detection Methods

A variety of techniques are available for the detection of DNA fragments in forensic DNA analysis. For example, the direct detection of DNA fragments in a gel can be achieved via staining. The detection of DNA probes in a hybridization-based assay can be performed with radioisotopes, colorimetric assays, and chemiluminescence labeling. For polymerase chain reaction (PCR)-based assays, DNA primers can be labeled directly with fluorescent dyes.

9.1 Direct Detection of DNA in Gels

This section describes two simple and rapid detection methods used for detecting DNA: staining agarose gels with fluorescent intercalating dyes and staining denatured polyacrylamide gels with silver.

9.1.1 Fluorescent Intercalating Dye Staining

The location of DNA in an agarose gel can be determined directly by staining with low concentrations of fluorescent intercalating dyes (Chapter 6) such as ethidium bromide (Figures 9.1 through 9.3). These techniques allow the detection of DNA bands as small as 10 ng in agarose gels. Staining of DNA in agarose gels can be achieved by including an intercalating dye in the gel or staining the gel after electrophoresis in a dye-containing solution, followed by a washing step known as de-staining to reduce nonspecific staining. Historically, ethidium bromide-stained gels were photographed with a standard ultraviolet transilluminator at approximately 300 nm using a camera with an orange filter, whereas gels can currently be documented using digital techniques. When examining a DNA-containing gel under a UV lamp, the eyes and the skin should be protected from UV exposure. Ethidium bromide is a mutagen and a potential carcinogen. Ethidium bromide should be handled according to the Material Safety Data Sheet and safety protection wear should be used while handling the chemical. Ethidium bromide waste is usually disposed of as hazardous waste and is handled in accordance with laboratory guidelines. Alternatives to ethidium bromide are available, for example, fluorescent dyes such as SYBR® stains (Molecular Probes; Figures 9.2 and 9.3). Some of these alternatives are less mutagenic and have better performance than ethidium bromide.

9.1.2 Silver Staining

Electrophoretically separated DNA fragments can also be detected with silver nitrate staining. Silver staining of polyacrylamide gels has been used for the amplified fragment length polymorphism (AFLP; see Chapter 19) method of variable number tandem repeat (VNTR; see

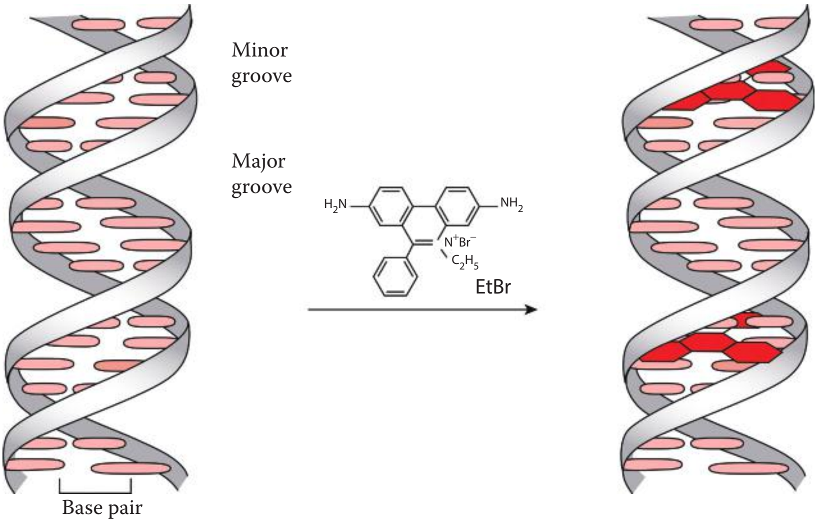

Figure 9.1 Schematic illustration showing binding of an intercalating agent, ethidium bromide (EtBr) to DNA. It intercalates into the minor groove of DNA. (© Richard C. Li.)

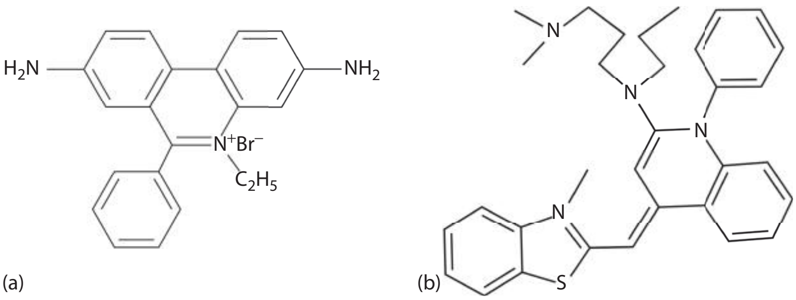

Figure 9.2 Intercalating agents used as nucleic acid stains. (a) Chemical structure of ethidium bromide. Ethidium bromide has UV absorbance. The emission maximum of the DNA–dye complex in aqueous solution is approximately 590 nm. (b) Chemical structure of SYBR Green 1. The stain is a cyanine dye that binds to DNA and is used as a nucleic acid stain. The excitation and emission maxima of the DNA–dye complex are 494 and 521 nm, respectively. The stain preferentially binds to double-stranded DNA rather than single-stranded DNA and RNA.

Chapter 19) profiling. The sensitivity of silver staining is approximately 100 times higher than that obtained with ethidium bromide, and silver staining is less hazardous than ethidium bromide detection. Also, the developing chemicals are readily available at low cost.

Silver staining involves processing a gel followed by exposure to a series of chemicals. First, the gel is submerged in a silver nitrate solution. Silver ions are positively charged, and DNA is negatively charged. Therefore, silver ions bind to the DNA and are subsequently reduced using formaldehyde to form a deposit of metallic silver on the DNA in the gel (Figure 9.4). A photograph of the gel with images of the silver-stained DNA strands is kept as a permanent record. Alternatively, the gels may be sealed and preserved for record purposes. One disadvantage of this method is that silver stains RNA and proteins along with DNA. The presence of restriction enzymes and polymerase should therefore be minimized. Additionally, bands from both complementary DNA strands may be detected in a denatured polyacrylamide gel, which leads to a two-band pattern.

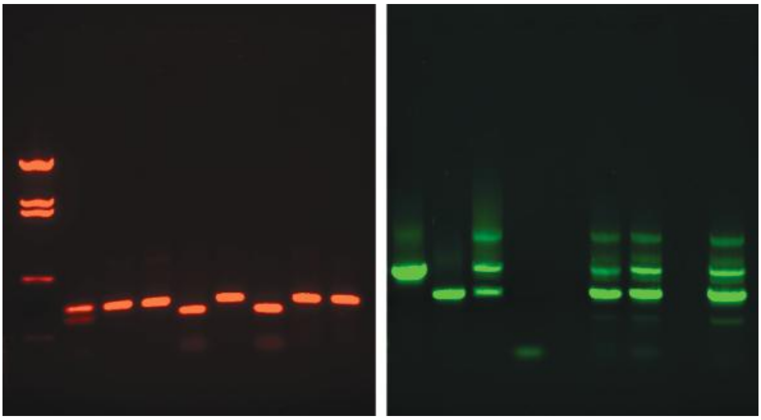

Figure 9.3 A DNA–dye complex emitting fluorescence on UV-light exposure. Ethidium bromide–containing agarose gel (left). SYBR Green 1–containing agarose gel (right). (© Richard C. Li.)

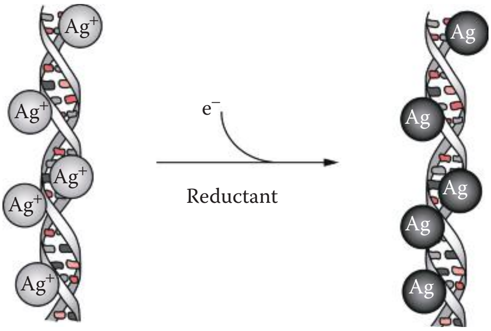

Figure 9.4 Silver staining of DNA. Silver (Ag^+) ions bind to DNA and are reduced to metallic silver (Ag) to form dark particles. (© Richard C. Li.)

9.2 Detection of DNA Probes in Hybridization-Based Assays

9.2.1 Radioisotope Labeled Probes

Radioisotope probe labeling was used for early versions of VNTR testing and DNA quantitation. Labeling can be accomplished in several ways (Figure 9.5). For example, nick translation incorporates labeled deoxyribonucleotides (dNTPs) into double-stranded DNA. DNase I is used to introduce single-strand nicks within the DNA fragment to be labeled. Next, DNA Polymerase I recognizes the nicks and replaces the preexisting nucleotides with new strands containing labeled dNTPs, resulting in the generation of ^{32}P-labeled double-stranded DNA molecules. ^{32}P, with a half-life of approximately 14 days, is the most common radioisotope used in this technique. Nick translation can utilize any dNTP labeled with ^{32}P.

Prior to hybridization, the probe is denatured into single-stranded fragments by boiling for a few minutes followed by rapid cooling on ice. After the hybridization process, these probes can be visualized by exposing the DNA-containing membrane to an x-ray film. The radioactive object is commonly placed in an x-ray cassette. The energy released from the decay of the radioisotopes is absorbed by the silver halide grains in the film emulsion and forms a latent image. A chemical development process amplifies the latent image and renders it visible on film (Figure 9.6). Because most ^{32}P emissions pass through the thin film emulsion without

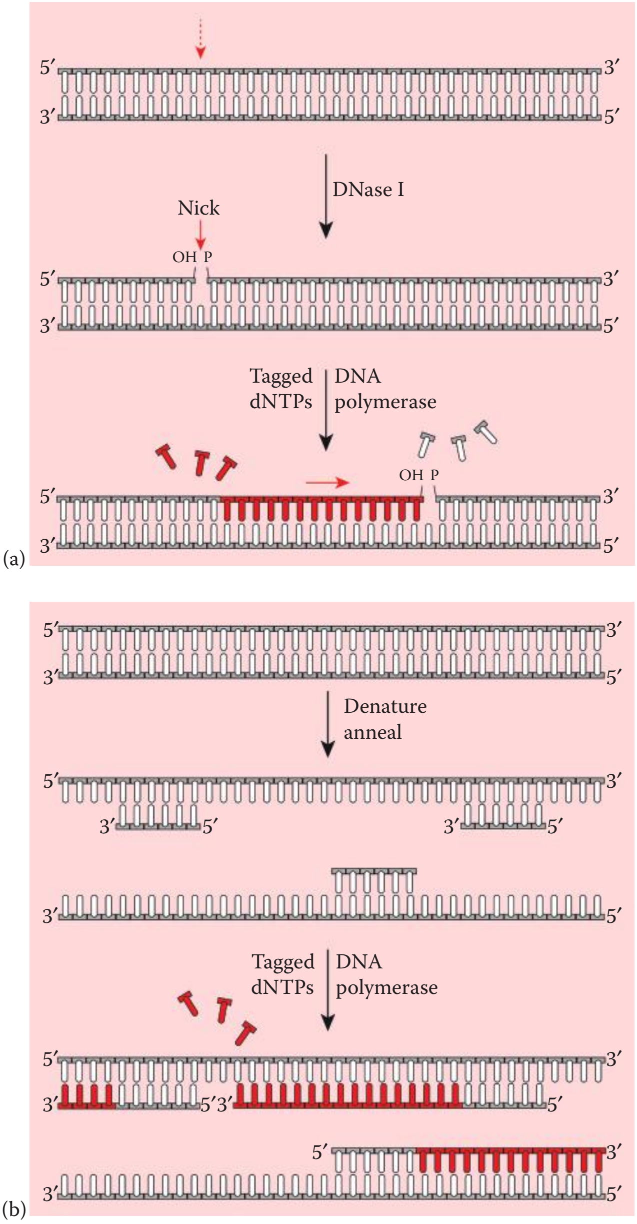
5′
3′
3′
5′
DNase I
Nick
OH P
Tagged dNTPs
DNA polymerase
OH P
(a)
Denature anneal
3′
5′
Tagged dNTPs
DNA polymerase
(b)

Figure 9.5 DNA probe labeling using dNTPs. (a) Nick translation method. A DNase is utilized to create nicks along a DNA strand. Tagged nucleotides (one or more than one of the dNTPs) are then incorporated into the DNA strand using a DNA polymerase. DNA synthesis extends from the 5′ to 3′ end and the original strand is degraded. (b) Random primer labeling method. A template DNA is denatured and separated into single strands. A random mixture of hexameric deoxynucleotide fragments, as primers, is then annealed to the template strand. The tagged nucleotides are then incorporated by the Klenow fragment of the DNA polymerase. (© Richard C. Li.)

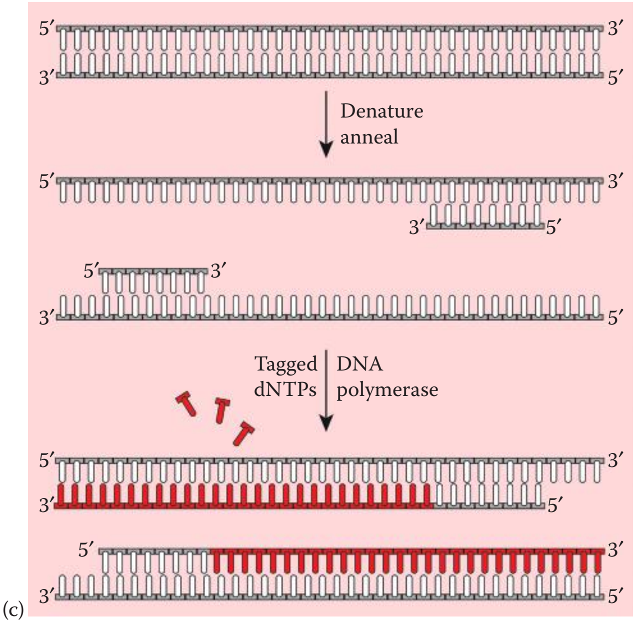

Figure 9.5 (Continued) (c) PCR method. DNA templates are denatured and then annealed to primers flanking the region of interest. During the DNA synthesis phase of a PCR cycle (see Chapter 7), tagged nucleotides are incorporated into the DNA strand using a Taq DNA polymerase, producing new double-stranded DNA. The process is repeated for many cycles. Only the first cycle is shown. (© Richard C. Li.)

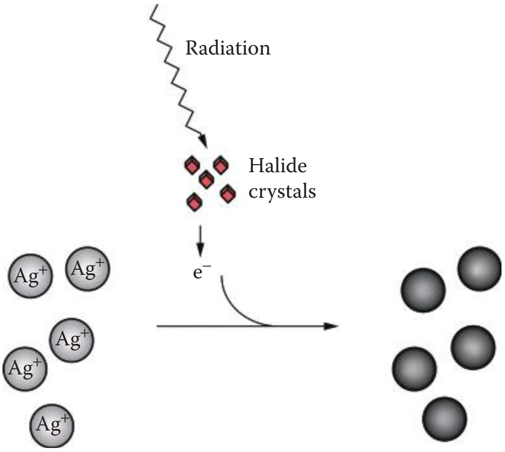

Figure 9.6 Autoradiography. Exposure to radiation causes halide crystals to release electrons, thus reducing silver (Ag^+) ions to metallic silver (Ag). (© Richard C. Li.)

contributing to the final image, the detection process may require long exposure times. Signal intensity can be enhanced, however, by using intensifying screens at low temperatures. The screens emit photons upon receiving radioactive β-particles, thus further enhancing signals. Additionally, highly sensitive x-ray film can be used. One disadvantage of using ^{32}P is that it is a safety hazard. Additionally, autoradiography is a lengthy process. Therefore, nonradioisotopic detection methods have become popular alternatives.

9.2.2 Enzyme-Conjugated Probe with Chemiluminescence Reporting System

The use of alkaline phosphatase (AP)-conjugated probes with chemiluminescent substrates comprises a highly sensitive nonradioisotopic detection system.

Alkaline phosphatase can cleave the phosphate groups from a variety of substrate molecules. Its enzymatic activity can be measured using dioxetane-based chemiluminescent substrates such as Lumigen® PPD (Figure 9.7). The Lumi-Phos Plus kit of Lumigen Inc. contains this substrate and can serve as a detection system for slot blot assays for DNA quantitation (Chapter 6) and RFLP assays for VNTR profiling (Chapter 19). AP catalyzes the cleavage of the phosphate ester of Lumigen® PPD, resulting in the release of a photon (Figure 9.8). The Lumigen® PPD substrate yields a long-lasting light emission that can be detected by exposure to x-ray film. This system provides a highly sensitive chemiluminescent detection method for AP-conjugated DNA probes in solution or on a solid matrix such as a membrane (Table 9.1).

9.2.3 Biotinylation of DNA with Colorimetric Reporting Systems

9.2.3.1 Biotin

Biotin, also known as vitamin H, is a water-soluble molecule found in egg yolk (Figure 9.9). It can be incorporated onto oligonucleotide probes without interfering with the ability of probes to hybridize because of its small size (molecular weight: 244.31 u). Signals from a biotinylated probe can be detected with an enzyme-conjugated avidin system. Two steps are required to detect biotin-labeled probes. First, an avidin conjugate consisting of a reporter enzyme is added. Then, the reporter enzyme is assayed with substrates.

9.2.3.2 Enzyme-Conjugated Avidin

Avidin is a glycoprotein found in egg white; it binds to biotin with extremely high affinity. Thus, a biotin–avidin complex is very stable. However, avidin detection has a high background due to nonspecific binding. The nonspecific binding can be reduced by replacing avidin with its

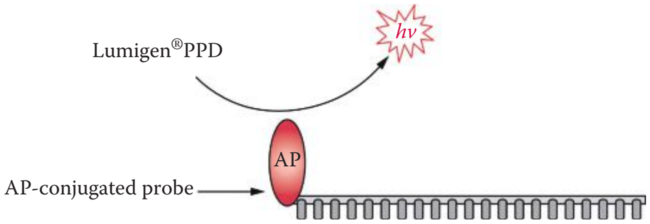

Figure 9.7 Detection system using AP-conjugated probe. Chemiluminescence is generated by using the Lumigen® PPD as an AP substrate. (© Richard C. Li.)

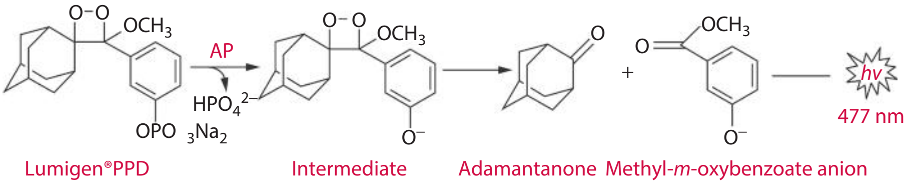

Figure 9.8 Lumi-Phos Plus contains Lumigen® PPD (4-methoxy-4-[3-phosphatephenyl]spiro[1,2-dioxetane-3,2′-adamantane], disodium salt). AP catalyzes the removal of the phosphate group of Lumigen® PPD and generates a chemiluminescent intermediate that is subsequently broken down to the excited state of methyl-*m*-oxybenzoate. The decay of the excited state end-product releases a photon.

Table 9.1 Forensic Applications of Enzyme Reporting Systems for Detecting DNA

Reporter Enzyme	Labeling	Detection Mechanism	Substrate	Forensic Application
AP	AP-conjugated probe	Chemiluminescent	Lumigen®PPD	RFLP; blot assay for DNA quantitation
Horseradish peroxidase (HRP)	Biotinylated probe, recognized by streptavidin conjugated with HRP	Colorimetric/ chemiluminescent	TMB/luminol	Blot assay for DNA quantitation
	Biotinylated primer, recognized by streptavidin conjugated with HRP	Colorimetric	TMB	Reverse blot assay for DQA1 typing and for mtDNA typing

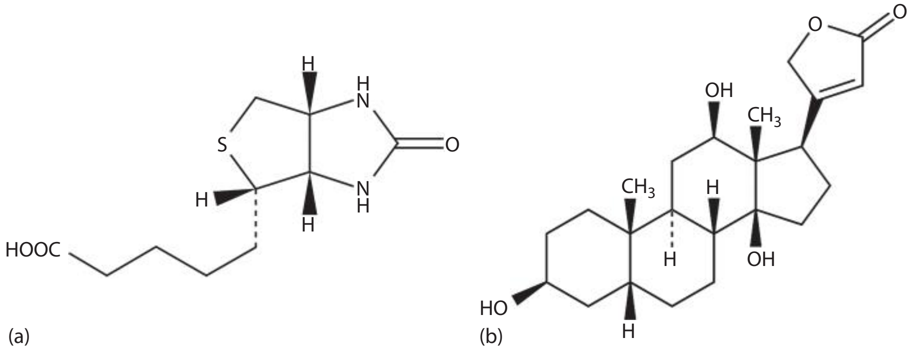

Figure 9.9 Nonradioactive tags for labeling and detecting nucleic acids. (a) Chemical structure of biotin, also known as vitamin H. Molecular formula: $C_{10}H_{16}N_2O_3S$. Molecular weight: 244.31. (b) Chemical structure of digoxigenin. Molecular formula: $C_{23}H_{34}O_5$. Molecular weight: 390.51.

streptavidin counterpart from *Streptomyces avidinii*. To detect binding, an enzyme-conjugated streptavidin such as horseradish peroxidase (HRP)-conjugated streptavidin can be used. HRP isolated from horseradish roots contains heme residues that catalyze the oxidation reactions of substrates (Chapter 12).

9.2.3.3 Reporter Enzyme Assay

HRP can be assayed with colorimetric, chemiluminescent, or fluorogenic substrates. One common colorimetric substrate for forensic DNA testing is 3,3′,5,5′-tetramethylbenzidine (TMB), which is oxidized by the peroxidase to form an insoluble precipitate of intense blue at an acidic pH (Figure 9.10). Because the colored precipitate is difficult to remove from membranes, TMB is not suitable if reprobing for RFLP analysis is required. This technique has been used for forensic DNA testing such as slot blot assays for DNA quantitation (Table 9.1). A chemiluminescent substrate such as a luminol-based reagent can also be utilized with

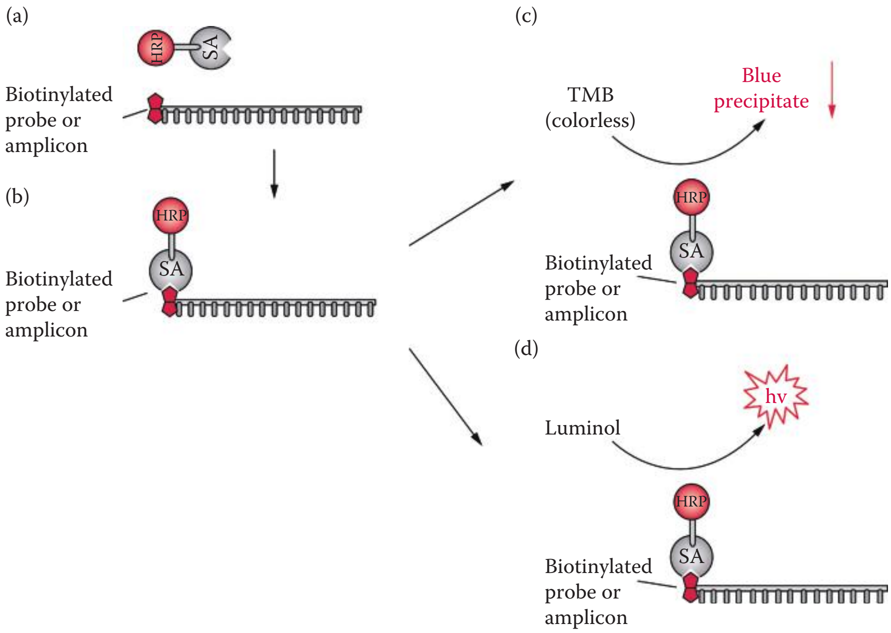
(a)
HRP
SA
Biotinylated probe or amplicon
(b)
HRP
SA
Biotinylated probe or amplicon
(c)
TMB (colorless)
Blue precipitate
HRP
SA
Biotinylated probe or amplicon
(d)
Luminol
hv
HRP
SA
Biotinylated probe or amplicon

Figure 9.10 Detection system using biotinylated DNA probes with colorimetric and chemiluminescent reactions. (a) Biotinylated probe is incubated with a streptavidin (SA) and horseradish peroxidase (HRP) conjugate complex. (b) Biotin is recognized by the complex. Reporter enzyme assays can be carried out using either a colorimetric reaction with a TMB substrate (c) or a chemiluminescent reaction using luminol analogs (d). (© Richard C. Li.)

HRP. The peroxidase catalyzes the oxidation of luminol to form a chemiluminescent product (Figure 9.10).

9.3 Detection Methods for PCR-Based Assays

9.3.1 Fluorescence Labeling

9.3.1.1 Fluorescent Dyes

The advantages of fluorescence detection methods include a higher sensitivity and broader dynamic range than comparable colorimetric detection methods. Furthermore, they have the capacity for simultaneous analysis of complex samples such as multiplex PCR products with different fluorescent labels (Figure 9.11), allowing the distinction of various amplicons. Commonly used fluorescent dyes in DNA labeling emit fluorescence in the range of 400–600 nm (Figures 9.12 and 9.13).

9.3.1.2 Labeling Methods

Fluorescent dye labeling can be incorporated into a DNA fragment using a 5′-end fluorescently labeled oligonucleotide primer (Figures 9.14 and 9.15). The dye-labeled primer method is usually used for STR profiling (see Chapter 20) in which only one primer from each primer pair is labeled; therefore, only one strand can be detected. The two-band pattern observed with silver staining does not appear with this method. Additionally, dye-labeled primers allow multiplex PCR amplifications in the same tube.

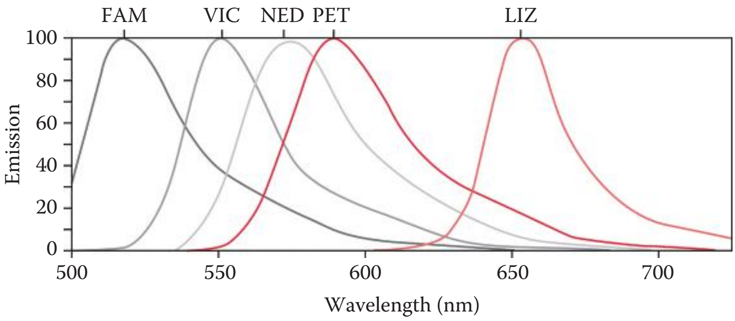

Figure 9.11 Emission spectra of common fluorescent dyes used for forensic DNA analysis. (© Richard C. Li.)

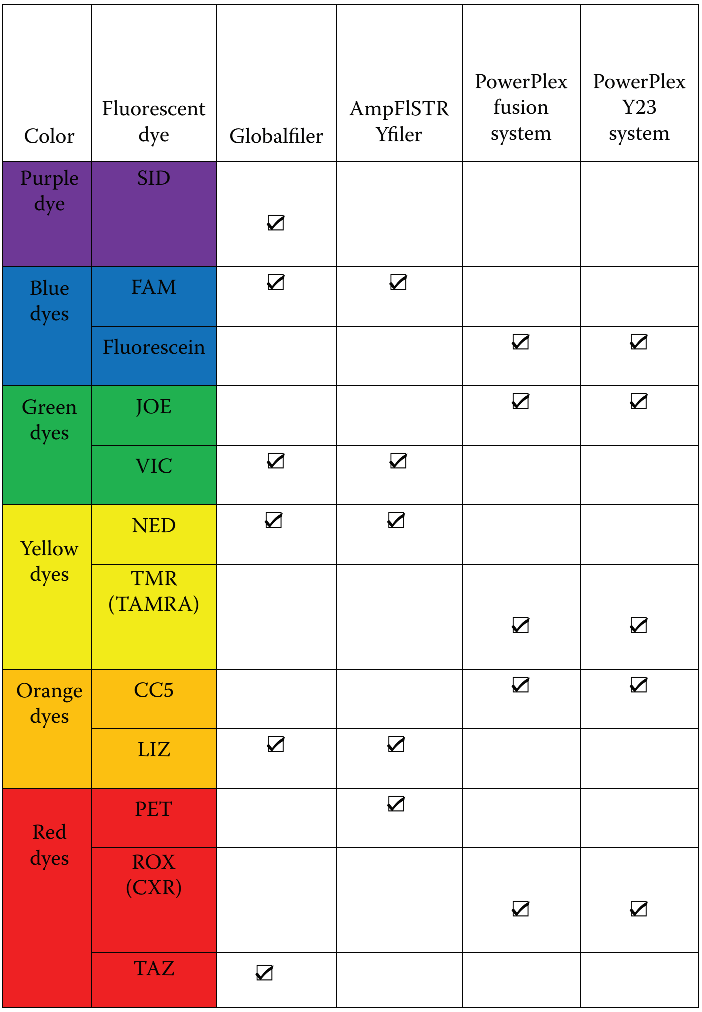

Color	Fluorescent dye	Globalfiler	AmpFlSTR Yfiler	PowerPlex fusion system	PowerPlex Y23 system
Purple dye	SID	☑			
Blue dyes	FAM	☑	☑		
	Fluorescein			☑	☑
Green dyes	JOE			☑	☑
	VIC	☑	☑		
Yellow dyes	NED	☑	☑		
	TMR (TAMRA)			☑	☑
Orange dyes	CC5			☑	☑
	LIZ	☑	☑		
Red dyes	PET		☑		
	ROX (CXR)			☑	☑
	TAZ	☑			

Figure 9.12 Examples of fluorescent dyes and their applications in STR kits. *Note*: Globalfiler and AmpFlSTR Yfiler are manufactured by Applied Biosystems. PowerPlex Fusion system and PowerPlex® Y23 System are manufactured by Promega.

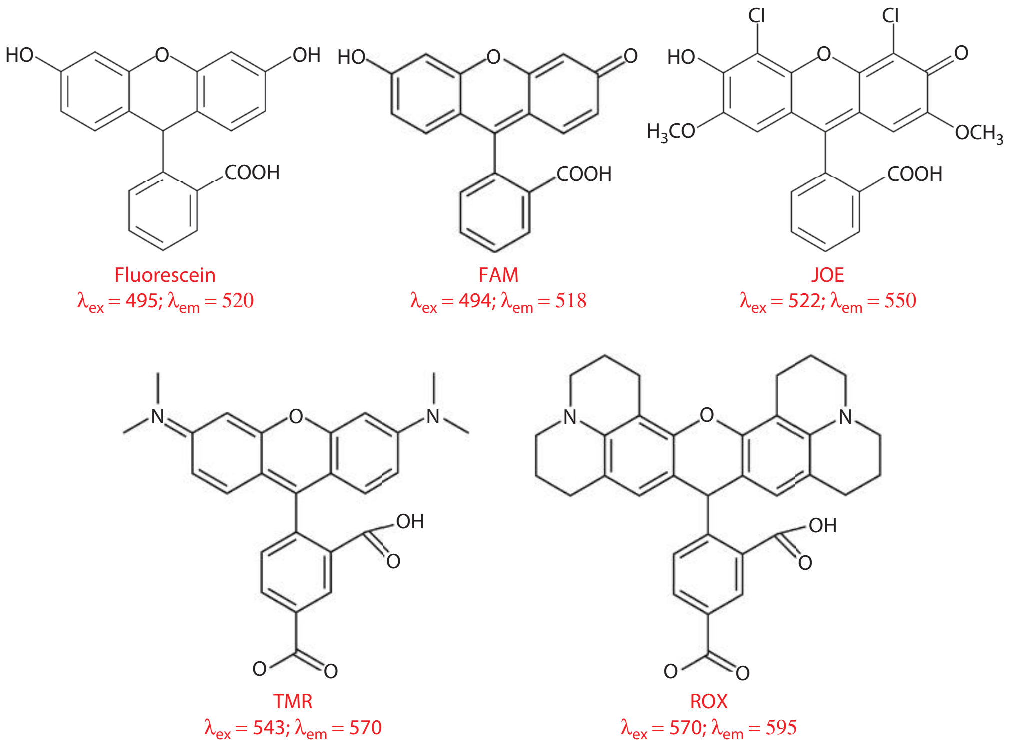
HO
OH
O
COOH
Fluorescein
$\lambda_{ex} = 495; \lambda_{em} = 520$
HO
O
COOH
FAM
$\lambda_{ex} = 494; \lambda_{em} = 518$
Cl
Cl
HO
O
H_3CO
OCH_3
COOH
JOE
$\lambda_{ex} = 522; \lambda_{em} = 550$
N
N
OH
O
TMR
$\lambda_{ex} = 543; \lambda_{em} = 570$
N
N
OH
O
ROX
$\lambda_{ex} = 570; \lambda_{em} = 595$

Figure 9.13 Chemical structures of representative fluorescent dyes. Fluorescein, 3′,6′-dihydroxyspiro[2-benzofuran-3,9′-xanthene]-1-one; FAM, 5(6)-carboxyfluorescein; JOE, 6-carboxy-4′,5′-dichloro-2′,7′-dimethoxy-fluorescein; TMR, 5-carboxytetramethylrhodamine; ROX, 5(6)-carboxy-X-rhodamine; λ_{ex}, peak excitation wavelength (nm); λ_{em}, peak emission wavelength (nm).

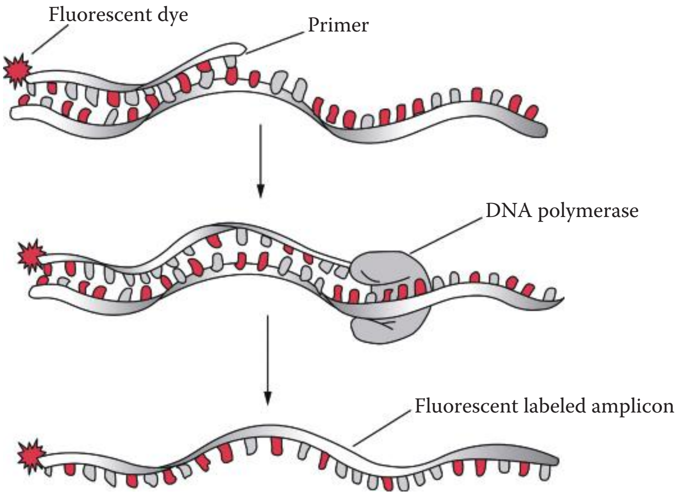
Fluorescent dye
Primer
DNA polymerase
Fluorescent labeled amplicon

Figure 9.14 A fluorescent dye–labeled primer can be used for the amplification of DNA. The dye is conjugated at the 5′ end of the primer. The amplified product is fluorescently labeled. (© Richard C. Li.)

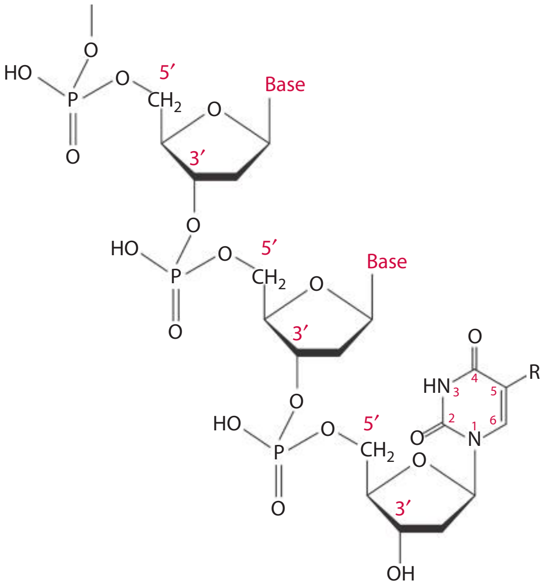

Figure 9.15 Direct labeling of nucleic acids with fluorescent dye. Labeled cytosine is shown as an example. R, fluorescent dye.

Alternatively, fluorescent dye labeling of DNA fragments can be carried out by incorporating fluorescently labeled dideoxynucleotides (ddNTPs) in the PCR product. This labeling method is usually used in DNA sequencing such as mtDNA sequence profiling (Chapter 23).

9.3.1.3 Fluorophore Detection

The *fluorophore* is a component of a florescent dye molecule that causes the molecule to be fluorescent. First, a laser strikes a fluorophore covalently linked to the end of a DNA fragment. An electron of the fluorophore is then excited, rising to an excited state from a ground state. The excited electron then descends to the ground state and releases a photon (Figure 9.16). The emitted photon has a longer wavelength (emission spectrum) than that of the excitation photon (excitation spectrum). The wavelengths of excitation and emission spectra (Figure 9.17) are largely dependent on the chemical structure of the fluorophore.

Lasers are commonly used as *excitation sources* because laser light emissions have high intensity and are monochromatic (single wavelength). The argon ion gas laser is frequently used in applications such as fluorescence-labeled STR and mtDNA sequence analysis because the excitation wavelength of commonly used fluorescent dyes matches the wavelength of the argon laser.

Optical filters are used to filter out undesired light and to allow only one particular wavelength to pass through. An essential optical filter consists of three components: an excitation filter, a dichroic beam splitter, and an emission filter. The excitation filter selectively transmits light from an excitation source. The light is then directed by the dichroic beam splitter to DNA molecules labeled with fluorescent dyes. The light emitted from a fluorophore is also transmitted by the dichroic beam splitter toward the detector. The emission filter selectively blocks undesired light, thus transmitting a specific wavelength of the emitted fluorescence. The light intensity emitted from a fluorophore is detected using a photosensitive device such as a charge-coupled device (CCD). The signal from the fluorophore is collected and converted to an electronic signal expressed in an arbitrary unit such as a *relative fluorescence unit* (RFU). Signals from multiple fluorophores in the same sample can be recorded separately using optical filters and a mathematical *matrix* (fluorophore separation algorithm). The function of a matrix is to subtract the

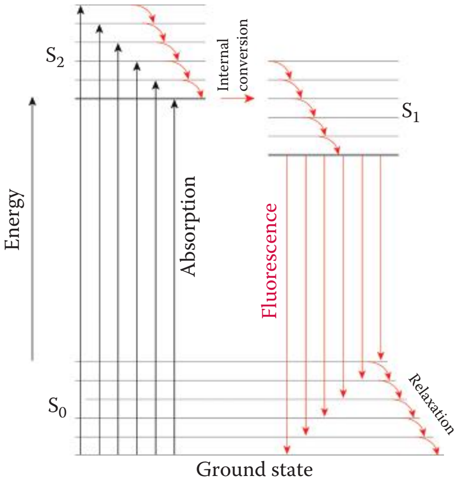

Figure 9.16 A Jablonski diagram illustrating the absorption of a single photon and subsequent emission of fluorescence. During an excitation stage, a single photon with the appropriate energy excites a molecule to the first excited energy level (S$_2$). In fluorescence reactions, the energy is supplied by an external light source such as a laser, while in chemiluminescence reactions, the energy is derived from a chemical reaction. The excited molecule is not stable and relaxes to its lowest vibrational level in the excited state (S$_1$). The molecule then returns to the ground state (S$_0$), emitting a photon. (© Richard C. Li.)

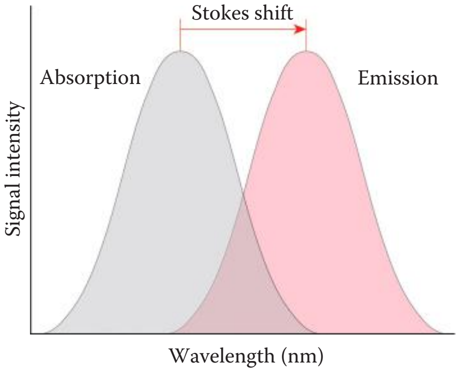

Figure 9.17 A fluorescence excitation spectrum. In fluorescence reactions, the energy of the photon emitted is lower than that of the excitation photon. As a result, the wavelength of an emission photon is longer than that of an excitation photon. The difference in wavelength is known as the Stokes shift. (© Richard C. Li.)

color overlaps of the various fluorescent dyes. The matrix can be established by the calibration of fluorescently labeled standards.

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10

Serology Concepts

10.1 Serological Reagents

10.1.1 Immunogens and Antigens

A foreign substance that is capable of eliciting antibody formation when introduced into a host is called an *immunogen*. Natural immunogens are usually macromolecules such as proteins and polysaccharides. Other molecular structures can also act as immunogens, for example, glycolipids (such as A, B, and O blood group antigens) and glycoproteins (such as Rh and Lewis antigens). However, they must be foreign to their hosts. The molecular structure of an immunogen, usually a small portion recognized by an antibody, is called an *epitope* or determinant site. An immunogen usually consists of multiple epitopes and is thus considered *multivalent* (Figure 10.1). Each epitope can elicit the production of its own corresponding antibody.

An *antigen* is a foreign substance that is capable of reacting with an antibody. All immunogens can be considered antigens, but not all antigens can elicit antibody formation. *Hapten* is one example of a substance that is antigenic but not immunogenic. Haptens are chemical compounds that are too small to elicit antibody production when they are introduced to a host animal. However, a hapten can be coupled to a *carrier*, usually a macromolecule, to produce antibodies. A hapten-conjugated carrier can become immunogenic to elicit the formation of an antibody specific to the hapten. The resulting antibody can bind to free haptens. Certain controlled substances such as cocaine and amphetamines are haptens and can be detected through corresponding antibodies for forensic toxicological analysis.

10.1.2 Antibodies

Antibodies, also known as *immunoglobulins*, are capable of binding specifically to antigens and are designated with an Ig prefix. The five major classes of immunoglobulins are designated IgG, IgA, IgM, IgD, and IgE. Additionally, IgG immunoglobulins can be further divided into four subclasses (IgG1–IgG4) and IgA immunoglobulins can be further divided into two subclasses (IgA1 and IgA2). Thus, there are a total of nine immunoglobulin isotypes in humans. *Isotypes* are the immunoglobulins that differ based on the molecular variations in the constant domains of the heavy and light chains (Figure 10.2). IgD, IgE, and IgG are usually monomers. IgM can be a membrane-bound monomer or a cross-linked pentamer (secreted form). IgA can be a monomer, dimer, or trimer. In an immune response, an initial exposure to an immunogen elicits a primary response, producing IgM immunoglobulins. Further exposure to the immunogen can elicit a secondary response, producing IgG, IgA, IgE, and IgD immunoglobulins. IgG is the most abundant immunoglobulin in serum. A majority of serology tests are based on the IgG immunoglobulins.

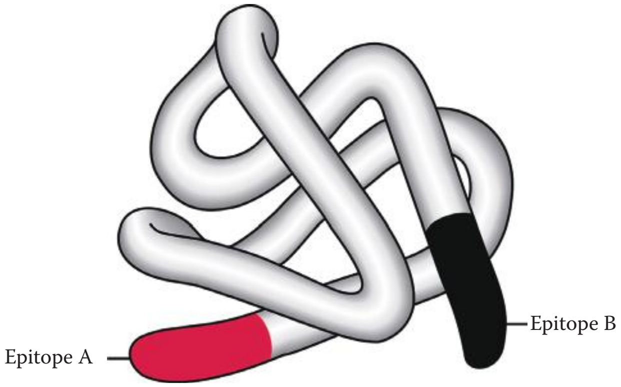

Figure 10.1 Multivalent immunogen. A protein with two different epitopes is shown. (© Richard C. Li)

Immunoglobulins have many similarities in their molecular structures. Figure 10.2 illustrates a diagram of the IgG molecule. The structures of immunoglobulins were first revealed by Gerald Edelman and Rodney Porter who shared a Nobel Prize in 1972. Immunoglobulins are composed of four polypeptide chains: two heavy (H) chains and two light (L) chains. The polypeptide chains are linked by disulfide bonds into a Y-shaped complex. The H chain can be divided into fragment antigen-binding (*Fab*) and fragment crystallizable (*Fc*) fragments. The L chain consists of a Fab fragment only. A typical antibody has two identical antigen-binding sites and is thus considered *bivalent*. The antigen-binding activity is located within the Fab fragments. In particular, the N-terminal ends of the L and H chains together form antigen-binding sites. At the amino acid sequence level, both H and L chains have *variable and constant domains* (Figure 10.2). The variable domains are located at the N-terminal ends of the immunoglobulins. Additionally, three small *hypervariable regions* are located within the variable domain of each chain.

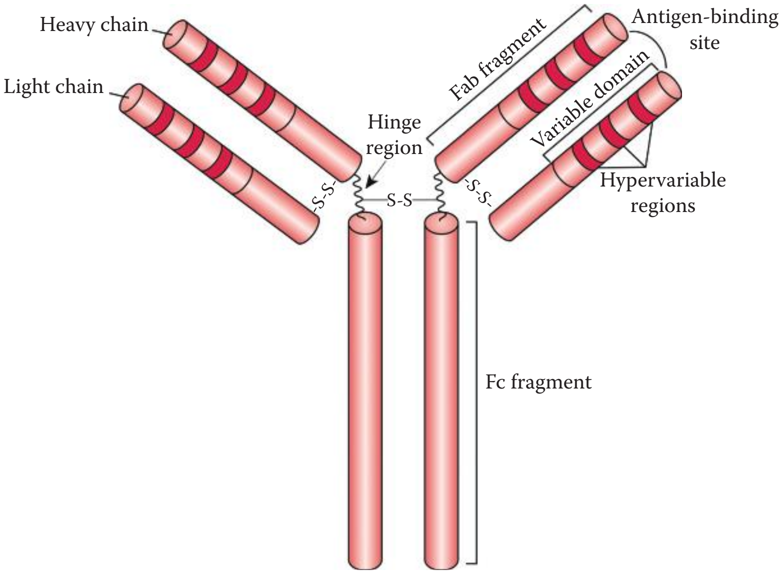

Figure 10.2 Immunoglobulin IgG structure. Immunoglobulin IgG is composed of light and heavy chains that contain variable domains. The remaining portions of chains form the constant domains. The variable domains of both light and heavy chains contain three hypervariable regions that form the antigen-binding site of the immunoglobulin. (© Richard C. Li.)

The diversity in the amino acid sequences of these hypervariable regions determines the specificity of the antigen-binding sites. The hinge regions provide flexibility to the antibody molecule and are important for the efficiency of the binding and cross-linking reactions. The basal portion of the H chain consists of *Fc* fragment.

The binding affinity and specificity of antibodies make them useful reagents for serological testing. Two types of antibodies are commonly used: polyclonal and monoclonal antibodies.

10.1.2.1 Polyclonal Antibodies

To produce an antibody, an immunogen is usually introduced into a host animal. A multivalent immunogen is capable of eliciting a mixture of antibodies with diverse specificities for the immunogen. As a result, a polyclonal antibody is produced by different B lymphocyte clones in response to the different epitopes of the immunogen. Antibodies can be circulating (in blood or other bodily fluids) or tissue bound (in cell surface antibodies). Circulating immunoglobulins are referred to as humoral antibodies.

The blood from an immune host is drawn and allowed to clot, resulting in the formation of a solid consisting largely of blood cells and a liquid portion known as *serum* containing antibodies (Figure 10.3). Such a preparation of humoral antibodies is also called a *polyclonal antiserum.* Depending on the type of animal used, the antibodies produced are classified as avian (B), rabbit (R), or horse (H) type. The characteristics of polyclonal antibodies may vary if they are produced from different individual host animals of the same species. Variations in reactions among different sources of antibodies should be monitored by quality-control procedures.

10.1.2.2 Monoclonal Antibodies

To produce a monoclonal antibody, spleen cells are harvested from a host animal, such as a mouse, inoculated with an immunogen (Figure 10.4). Next, the plasma cells of the spleen, which produce antibodies, are fused with myeloma cells. Since only a small population of cells fuse, a selection step is needed to allow only fused cells to grow (Figure 10.4). The fused cells, called *hybridoma* cells, are immortal (proliferate indefinitely) in cell cultures. Pools of hybridoma cells are diluted into single clones and are allowed to proliferate. The clones are then screened for the specific antibody of interest.

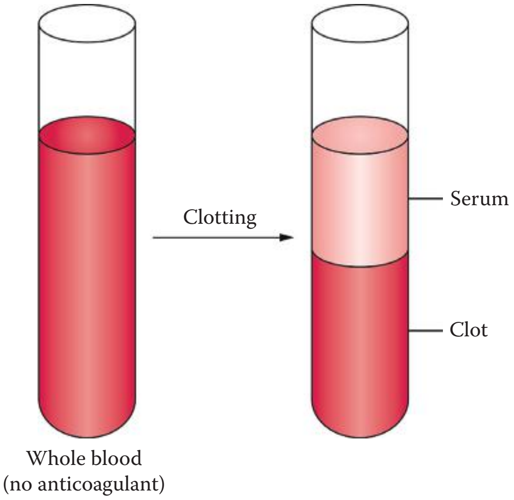

Figure 10.3 Serum component of blood. The blood of an immunized animal is collected in the absence of an anticoagulant and is allowed to clot. The resulting liquid portion of the blood is serum. (© Richard C. Li.)

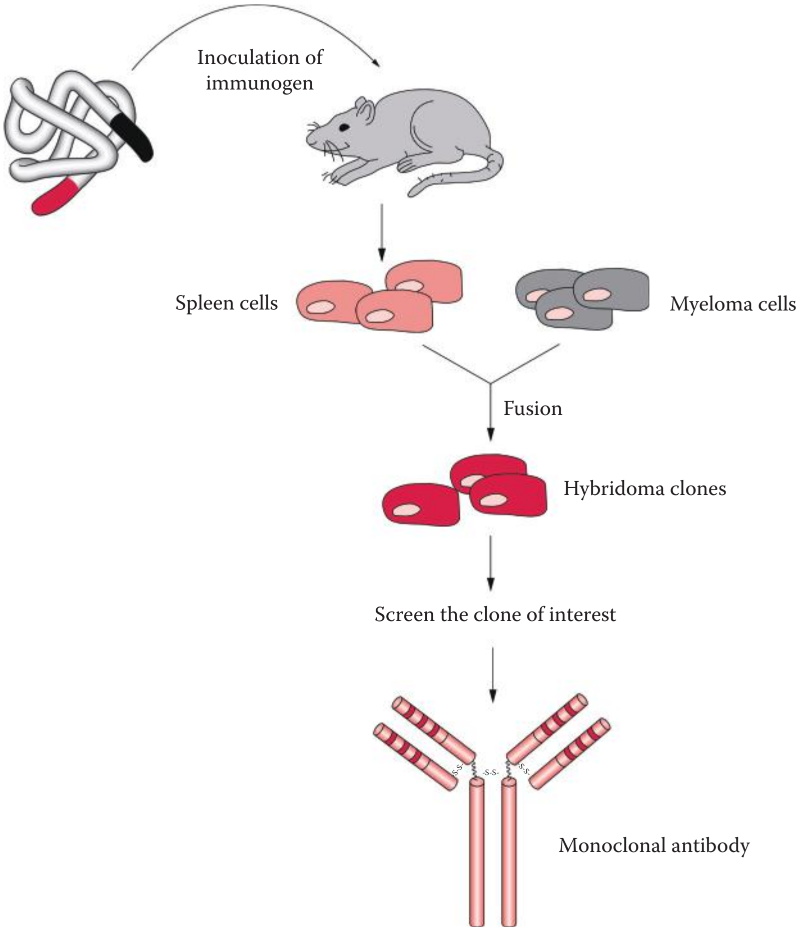

Figure 10.4 Preparation of a monoclonal antibody. A mouse is immunized with an immunogen, and its spleen cells are fused with myeloma cells to generate hybridoma cells. The clone that synthesizes and secretes the monoclonal antibody of interest can then be identified. (© Richard C. Li.)

The desired hybridoma clone can be maintained indefinitely, and it produces a monoclonal antibody that reacts with a single epitope. The hybridoma-derived monoclonal antibodies are specific and homogenous, and can be obtained in unlimited quantities. Monoclonal antibodies have been utilized in many serological assays, as discussed in Chapter 11. However, they have certain limitations in serology assays. For instance, monoclonal antibodies react with only a single epitope of a multivalent antigen and, therefore, cannot form cross-linked networks in precipitation assays (see Section 10.3.2.1).

10.1.2.3 Antiglobulins

Immunoglobulins are proteins that can also function as immunogens. If a purified foreign immunoglobulin or a fragment of a foreign immunoglobulin is introduced into a host, the antibodies produced are known as *antiglobulins*. Antiglobulins that are specific to a particular isotype can be produced in laboratories. In addition to specific antiglobulins, it is possible to produce nonspecific antiglobulins, which recognize an epitope that is common to all isotypes of an immunoglobulin class, such as the Fc portion of the heavy chain of all subclasses of human IgG. Antiglobulins are important reagents in many serological tests.

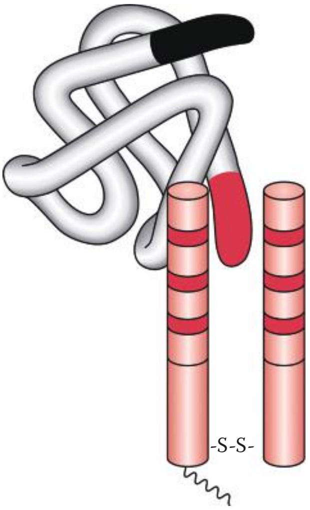

Figure 10.5 Affinity is a measure of the interaction between a single epitope on an antigen and a single binding site on an antibody. (© Richard C. Li.)

10.2 Strength of Antigen–Antibody Binding

The binding of an antigen to its specific antibody is mediated by the interaction between the epitope of an antigen and the binding site of its antibody. Noncovalent bonds can be formed during antigen–antibody binding. Various forces act cooperatively during antigen–antibody binding. These include hydrogen bonding, hydrophobic interactions that exclude water molecules from the area of contact, and van der Waals forces arising from the asymmetric distribution of the charges of electrons. The binding process occurs rapidly and the formation of the antigen–antibody complex is reversible. Such binding occurs at short distances when the antigen and antibody are in close proximity. Additionally, the strongest binding occurs only if the shape of the epitope fits the binding site of the antibody. The strength of the interaction between the antigen and the antibody depends on two characteristics, designated affinity and avidity.

Affinity is the energy of the interaction of a single epitope on an antigen and a single binding site on a corresponding antibody (Figure 10.5). The strength of the interaction depends on the specificity of the antibody for the antigen. Nevertheless, antibodies can bind with lower strength to antigens that are structurally similar to the immunogen. Such binding is known as *cross-reaction*.

Avidity is the overall strength of the binding of an antibody and an antigen (Figure 10.6). Since an antigen is usually considered multivalent and an antibody is bivalent, the avidity reflects the combined synergistic strength of the binding of all the binding sites of antigens and antibodies rather than the sum of individual affinities. It also reflects the overall stability of an antigen–antibody complex that is essential for many serological assays.

10.3 Antigen–Antibody Binding Reactions

The binding of an antigen to an antibody is an equilibrium reaction consisting of three types of reactions. The primary and secondary reactions form the basis for many forensic serological assays and will be discussed in the following subsections. The third type is called the tertiary reaction. It is used to measure *in vivo* immune responses such as inflammation and phagocytosis. Because most forensic serology tests are *in vitro* assays, the tertiary reaction is not commonly utilized in forensic serology testing and will not be discussed here.

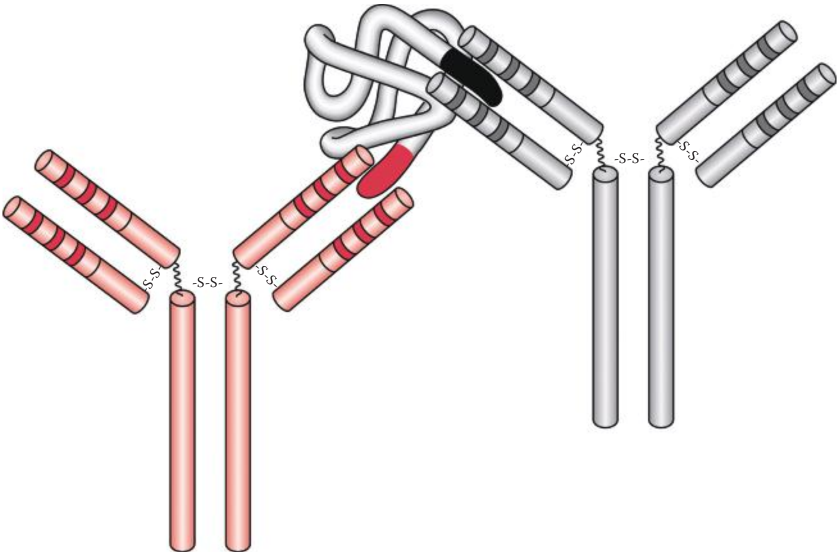

Figure 10.6 Avidity is a measure of the overall strength of the binding between antigens and antibodies. (© Richard C. Li.)

10.3.1 Primary Reactions

A primary reaction is the initial binding of a single epitope of an antigen (Ag) and a single binding site of an antibody (Ab) to form an antigen–antibody complex (Figure 10.7). This rapid and reversible binding reaction can be expressed as

$$\mathrm{Ag} + \mathrm{Ab} \rightleftarrows \mathrm{AgAb}$$

At equilibrium, the strength of the interaction can be expressed as the affinity constant (K_a) that reflects the affinity of binding, where:

$$K_a = \frac{[\mathrm{AgAb}]}{[\mathrm{Ag}][\mathrm{Ab}]}$$

The square brackets indicate the concentration of each component at equilibrium. K_a is the reciprocal of the concentration of free epitopes when half the antibody-binding sites are occupied. Thus, a higher K_a corresponds to a stronger binding interaction.

Techniques such as enzyme immunoassays, immunofluorescence assays, radioimmunoassays, and dye-labeled immunochromatography can measure the concentrations of antigen–antibody complexes formed by primary reactions (Chapter 11). These techniques are the most sensitive for detecting the presence of an antigen and an antibody in a sample. Additionally, many forensic serology assays are based on the detection of primary reactions and will be discussed in Chapters 12 through 17.

10.3.2 Secondary Reactions

The primary reaction between an antigen and an antibody is often followed by a secondary reaction. The three types of secondary reactions are precipitation, agglutination, and complement fixation. The techniques that detect secondary reactions are usually less sensitive but easier to perform than primary reaction assays. The precipitation and agglutination reactions form the basis for many serologic assays performed in forensic laboratories. These reactions will be discussed in the following subsections in detail. The third type of reaction is called *complement fixation*. If an antigen is located on a cell surface, the binding of the antigen and the antibody

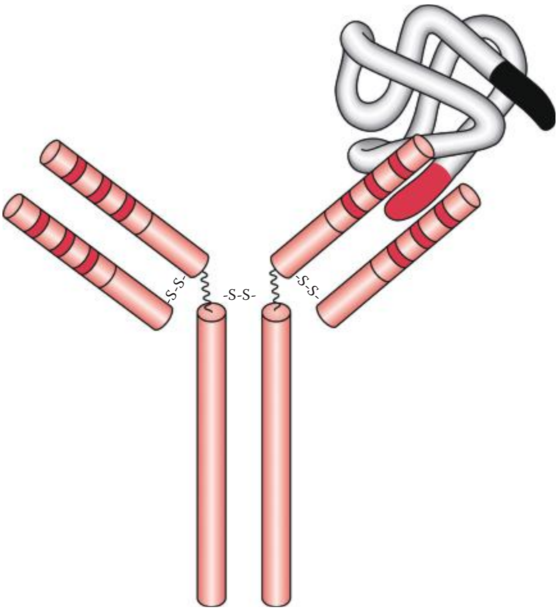

Figure 10.7 Primary reaction. Initial binding forms an antigen–antibody complex. (© Richard C. Li.)

may activate the classical complement pathway and lead to cell lysis, also known as a complement fixation reaction. The detection of this type of reaction is not commonly used in forensic serology.

10.3.2.1 Precipitation

If a soluble antigen is mixed and incubated with its antibody, the antigen–antibody complexes can form cross-linked complexes at the optimal ratio of antigen-to-antibody concentration. The cross-linked complex is insoluble and eventually forms a precipitate that settles to the bottom of a test tube. Antibodies that produce such precipitation are also called *precipitins*.

This precipitation reaction can be characterized by examining the effect of varying the relative ratio of antigen and antibody. If an increasing amount of soluble antigen is mixed with a constant amount of antibody, the amount of precipitate formed can be plotted. A precipitin curve (Figure 10.8)

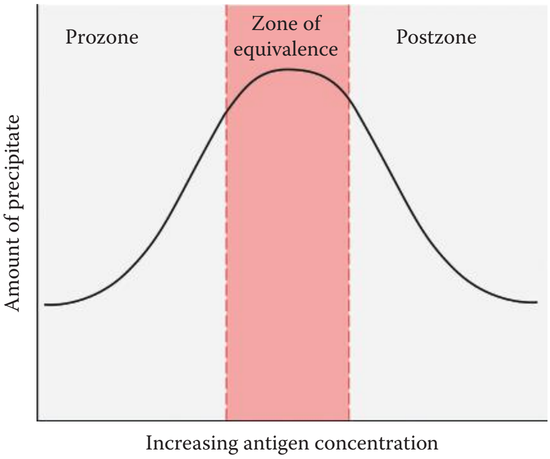

Figure 10.8 Precipitin curve. (© Richard C. Li.)

illustrates the results observed when antigens and antibodies are mixed in various concentration ratios. The curve can be divided into three zones known as the prozone, the zone of equivalence, and the postzone.

10.3.2.1.1 Prozone

At this zone, the ratio of antigen–antibody concentration is low. In other words, the antibody is in excess. Each antigen molecule is rapidly saturated with antibody, thus preventing cross-linking (Figure 10.9a). No precipitate is formed at the prozone stage.

10.3.2.1.2 Zone of Equivalence

As the concentrations of antigen increase, the amount of precipitate increases until it reaches a maximum. The amount of precipitation depends on the relative proportions of antigens and antibodies present. The maximum precipitation occurs in what is called the zone of equivalence. In the zone of equivalence, the ratio of antibody to antigen concentration is optimal and

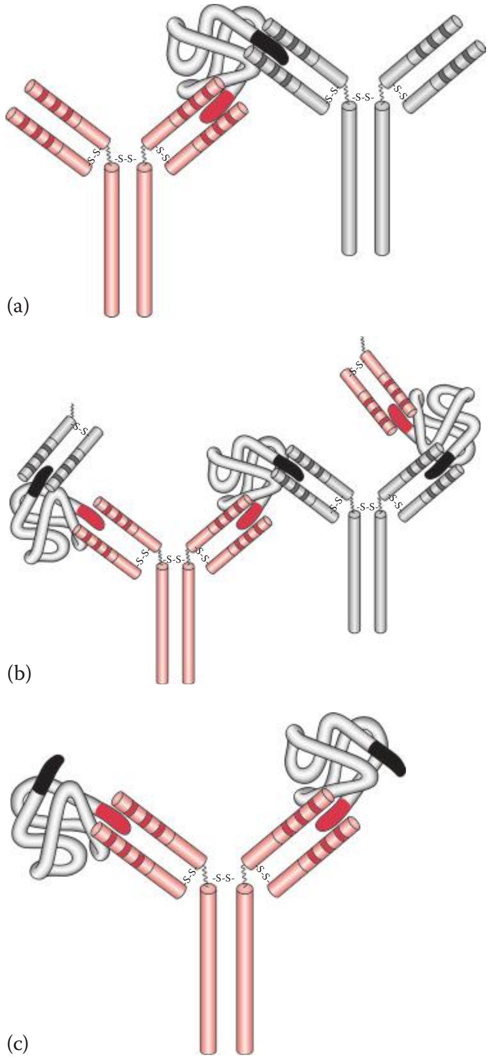

Figure 10.9 Antigen–antibody binding in (a) prozone, (b) zone of equivalence, and (c) postzone. (© Richard C. Li.)

precipitation occurs as a result of forming cross-linked networks (Figure 10.9b). Precipitation assays are usually carried out under the condition of the zone of equivalence, forming a sufficient quantity of precipitation to be detected.

10.3.2.1.3 Postzone

With the addition of more antigens, the ratio of antigen–antibody concentrations is high. In other words, the antigen is in excess. The amount of precipitate decreases and eventually diminishes. Each antibody molecule is saturated with antigen molecules (Figure 10.9c). Cross-linkage cannot form, and precipitation does not occur.

10.3.2.2 Agglutination

As discussed in the previous subsection, precipitation reactions involve soluble antigens. If the antigens are located on the surfaces of cells or carriers (carrier cells such as sheep erythrocytes,

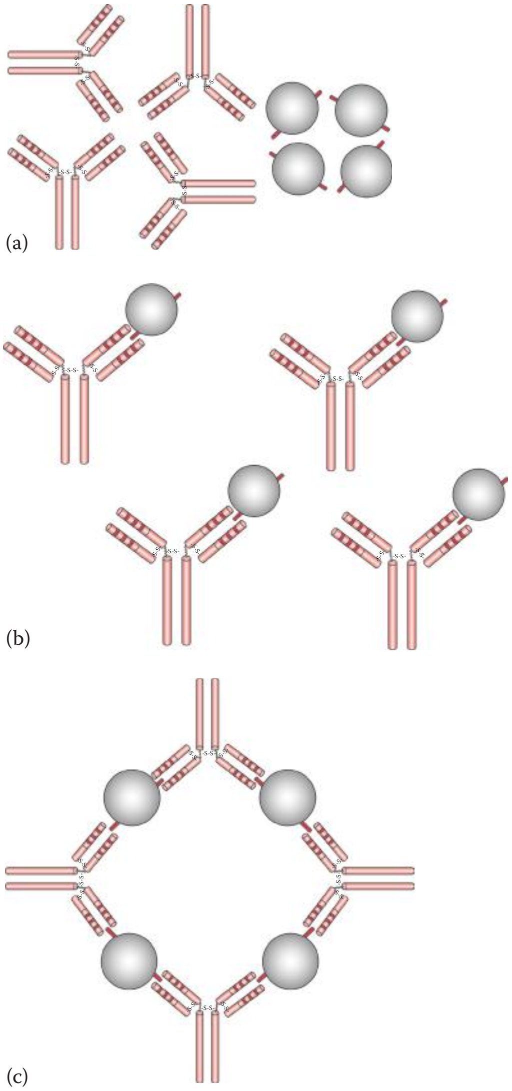

Figure 10.10 Agglutination reaction: (a) antigens are mixed with antibodies, (b) an antigen–antibody complex is formed during initial binding, and (c) the lattice is formed. (© Richard C. Li.)

bacteria, or latex particles), antibodies can bind to the surface antigens and can form cross-links among cells or carriers, causing them to aggregate. This aggregation is referred to as *agglutination*. In agglutination, a visible clumping can be observed as an indicator of the reaction of the antigen and the antibody. If the antigen is located on an erythrocyte, the agglutination reaction is designated *hemagglutination*. Agglutination is a two-step process that includes initial binding and lattice formation (Figure 10.10a).

10.3.2.2.1 Initial Binding

The first step of the reaction involves antigen–antibody binding at a single epitope on the cell surface (Figure 10.10b). This initial binding is rapid and reversible.

10.3.2.2.2 Lattice Formation

The second step involves the formation of a cross-linked network resulting in visible aggregates that constitute a lattice (Figure 10.10c). This involves an antibody binding to multiple epitopes because each antibody has two binding sites and antigens are multivalent. Lattice formation is a much slower process than the initial binding step. The cross-linking of cells requires physical contact. Additionally, an antibody must bind to epitopes on two different cells. The ability to cross-link cells depends on the nature of the antibody. Antibodies that produce such reactions are often called *agglutinins*.

Additionally, a *complete antibody* is capable of carrying out both primary and secondary interactions that result in agglutination. An antibody that can carry out initial binding but fails to form agglutination is called an *incomplete antibody*. This type of antibody is believed to have only one active antigen-binding site and is thus not capable of agglutination. It is potentially caused by the presence of steric obstruction due to the conformation of the incomplete antibody molecule, preventing the binding of antigens at the second binding site. However, other incomplete antibodies have two active sites but cannot bridge the distance between cells, thus failing to form lattices. Certain antibodies such as IgG are small and lack flexibility at the hinge region, and this may prevent agglutination. In contrast, the large IgM antibodies produce agglutination much more easily than IgG. Agglutination reactions have a wide variety of applications in the detection of antigens and antibodies. Such assays have high degrees of sensitivity and have been used for many years in forensic serology.

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11

Serology Techniques

Past, Current, and Future

11.1 Introduction to Forensic Serology

11.1.1 The Scope of Forensic Serology

Forensic serology is the component of forensic biology that deals with the examination and identification of biological evidence. In particular, it focuses on determining the presence and identification of various bodily fluids such as blood, semen, and saliva in a questioned sample.

Bodily fluid stains are commonly associated with violent criminal cases. For instance, the identification of blood evidence (Chapter 12) is often necessary for investigating cases involving homicide, aggravated assault, sexual assault, and burglary. Proving the presence of blood has probative value or may corroborate allegations of violent acts. This evidence can also be used for investigative purposes. For example, the forensic DNA analysis of evidence such as a victim's blood on a suspect's weapon can establish a link between a victim and a suspect. The identification of semen (Chapter 14) and saliva (Chapter 15) is important for the investigation of a sexual assault case. For instance, a stain from a victim's clothing would be processed with forensic DNA analysis in a sexual assault case so that the DNA profile of the stain could be compared with that of an alleged suspect. Matching DNA profiles prove that the suspect's DNA was found on the victim's clothing, establishing a link between the suspect and the victim. Additionally, the identification of a biological stain as a semen stain through forensic serology testing proves that semen was found on the clothing taken from the victim and that the suspect is the source of the DNA from the semen stain. This evidence can then be used in court to support allegations that a sexual act occurred. Likewise, the presence of a suspect's saliva stains on a victim's genital area may corroborate an alleged oral copulation. The identification of bodily fluids other than blood, semen, and saliva will be discussed in Chapters 16 and 17.

11.1.2 Class Characteristics and Individual Characteristics of Biological Evidence

The identification of an unknown fluid sample is based on a comparison of the class characteristics (Section 3.2.1) of a sample with known standards of its class. Forensic identification typically involves bodily fluids, such as blood, semen, and saliva. If the presence of the bodily fluid is confirmed, the individual characteristics (Section 3.2.2) of the biological evidence are then determined to find out whether or not a bodily fluid sample has come from a particular individual. Today, this analysis can be achieved through forensic DNA analysis. The most commonly utilized forensic DNA analysis is the short tandem repeat (STR) analysis used for human identification. Additionally, Y-chromosomal STR analysis is often utilized for the investigation of sexual assault crimes. Furthermore, mitochondrial DNA analysis is used for the identification of human remains. Therefore, establishing the probative value of a sample requires both the identification of its class characteristics and the individualization of its contributor. Therefore, the identification of bodily fluids cannot be replaced by forensic DNA analysis.

11.1.3 Presumptive and Confirmatory Assays

The identification of bodily fluids can be carried out using presumptive and confirmatory assays to identify the type of bodily fluid in question. The advantages of *presumptive assays* are that these assays are sensitive, rapid, and simple. A positive reaction of a presumptive assay indicates the possibility of the presence of the bodily fluid in question. However, presumptive assays are not very specific. Therefore, they should not be considered conclusive for the presence of a type of bodily fluid. In contrast, a negative assay indicates that the questioned bodily fluid is absent. Thus, presumptive assays can be used as a screening method and for narrowing down bodily fluid stains prior to other types of analyses, such as forensic DNA testing. Moreover, these assays can be used as a search method to locate bodily fluid stains at the crime scene. Additional assays, such as confirmatory assays, should be conducted afterward if necessary.

Confirmatory assays are more specific for the bodily fluid in question. These assays are utilized to identify bodily fluids with higher certainty than presumptive assays. For example, bloodstains are commonly associated with criminal investigations. A reddish-brown stain that has been identified through visual examination is usually tested by using presumptive assays. If the result of the presumptive assay on the alleged bloodstain is positive, the stain is then further analyzed by forensic DNA analysis. This approach *indicates* the presence of blood. Confirmatory assays are performed when a sample has to be *identified* as blood (Figure 11.1). Additionally, the human or animal origin of blood evidence can be determined if necessary and the techniques to do so will be discussed in Chapter 13.

11.1.4 Primary and Secondary Binding Assays

Traditionally, the detection and measurement of the antigen–antibody binding reactions serve as the bases of forensic serology. These assays fall into two categories: primary and secondary binding assays. Recall that the primary binding assays involve the initial binding between a single epitope of an antigen and a single binding site of an antibody (see Section 10.3.1). Therefore, they are very sensitive. Although the secondary binding assays are less sensitive than the primary binding assays, they are easier to perform than primary assays. The secondary assays consist of precipitation-based and agglutination-based assays. Precipitation-based assays have been used for species identification. Agglutination-based assays are more sensitive

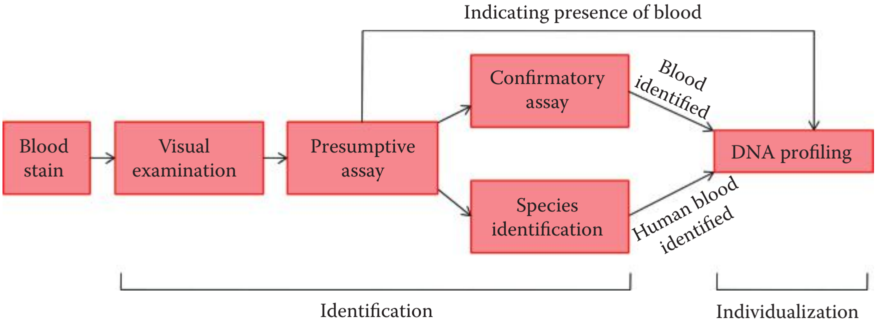

Figure 11.1 An example of work flow for processing blood samples. (© Richard C. Li.)

than precipitation-based assays. Agglutination-based assays, which detect antigens located on the surface of cells or carriers, are normally applied to blood group typing. Recently, emerging techniques such as RNA, proteomic, and DNA methylation assays, and fluorescence as well as Raman spectroscopy can potentially be used for the identification of bodily fluids.

11.2 Primary Binding Assays

11.2.1 Enzyme-Linked Immunosorbent Assay (ELISA)

An enzyme-linked immunosorbent assay (ELISA) is an immunoenzyme assay that can be used to detect and measure the antibody or antigen in question. The most common ELISA that is used in forensic serology is the antibody-sandwich ELISA (Figure 11.2). It is utilized to detect the prostate-specific antigen (PSA) to identify seminal stains and amylase for the identification of saliva (Chapters 13 and 14).

An antibody (usually monoclonal) coating is formed by nonspecific adsorption onto a solid phase such as the wells of a polystyrene plate. A sample containing the antigen to be tested is then added and binds to the solid-phase antibody. Subsequently, a second antibody is added to form an antibody–antigen–antibody sandwich complex. The second antibody binds to different epitopes of the antigen. Next, an enzyme-labeled antiglobulin (Chapter 10) is added to bind the sandwich. Subsequently, the excess enzyme-labeled antiglobulin is removed by washing and the bound antiglobulin can be detected.

A number of enzymes such as alkaline phosphatase and horseradish peroxidase have been used as reporting enzymes (Chapter 9) to label the antiglobulin for ELISA. The enzyme catalyzes the substrate and produces colorimetric or fluorometric signals. The intensity of the signals can

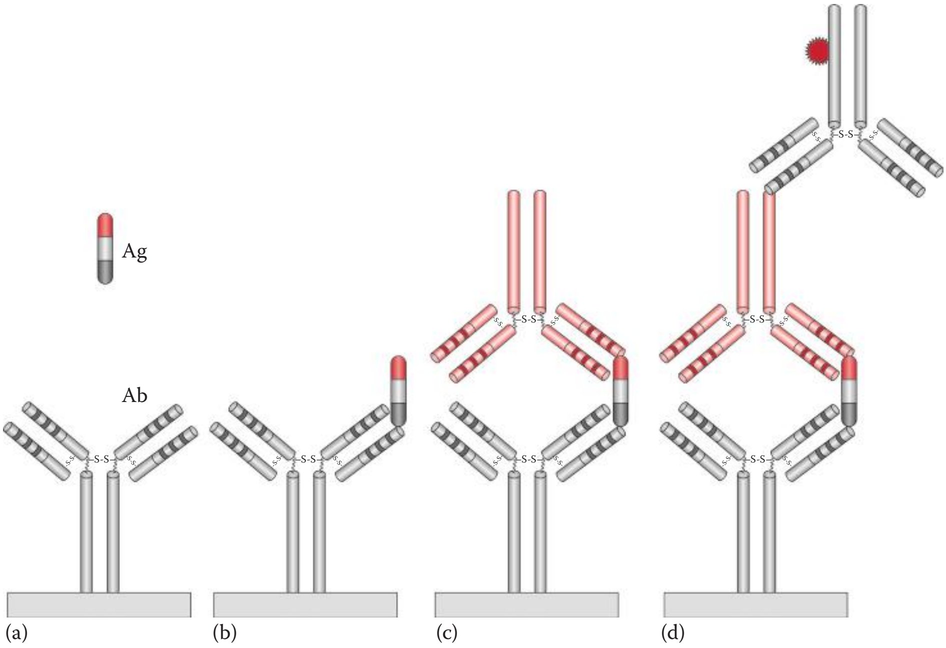

Figure 11.2 ELISA assay. (a) Sample containing Ag (antigen) is applied to a sample well where Ab (antibody) is immobilized. (b) Ag binds to an immobilized Ab to form an Ag–Ab complex. (c) A second Ab to a different epitope is added to form an Ab–Ag–Ab sandwich. (d) Labeled antiglobulin binds to the sandwich. The bound antiglobulin can be detected by various reporting schemes. (© Richard C. Li.)

be detected spectrophotometrically and is proportional to the amount of bound antigen. The amount of antigen can be quantified by comparing the standard with known concentrations. Recall that antiglobulin can recognize an epitope that is common to all isotypes within an antibody class (Section 10.1.2.3); the enzyme-labeled antiglobulin is a universal reagent regardless of the antibody used, as long as they are of the same class.

Alternatively, antibodies in a sample can also be detected and may be quantified by an ELISA system in which the antigen is bound to a solid phase instead of the antibody. After an antibody in a sample binds to the solid-phase antigen, an enzyme-labeled antiglobulin is added to bind to the bound antibody. The bound antiglobulin can be detected and measured by the addition of an enzyme substrate. The enzymatic catalytic reaction is similar to the antibody sandwich ELISA procedure previously described.

11.2.2 Immunochromatographic Assays

Figure 11.3 depicts a test using an immunochromatographic membrane device. A dye-labeled monoclonal antibody is contained in a sample well and a polyclonal antibody for the antigen (or a second monoclonal antibody to a different epitope of the antigen) is immobilized onto a test zone of a nitrocellulose membrane. An antiglobulin that recognizes the antibody is immobilized onto a control zone.

The assay is carried out by loading a sample into the sample well. The antigen in the sample binds to the dye-labeled antibody already in the sample well to form an antigen–antibody complex. The complex then diffuses across the nitrocellulose membrane until it reaches the test zone. The antibody immobilized at the test zone traps the antigen–antibody complex to form an antibody–antigen–antibody sandwich. The presence of the antigen in the sample results in a colored vertical line at the test zone. (Figure 11.4)

The immunochromatographic device also utilizes a control zone to ensure that the device works properly and that the sample has diffused completely along the test strip. Unbound

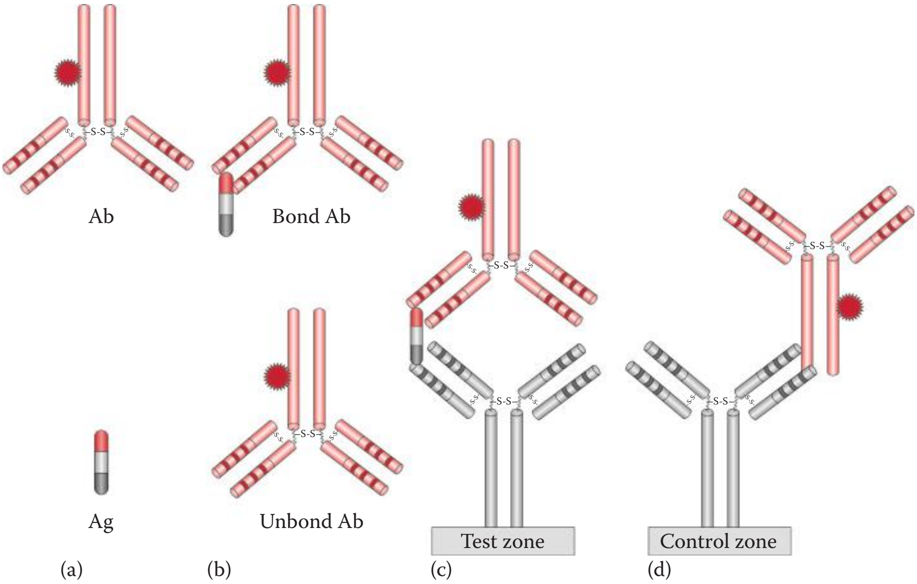

Figure 11.3 Immunochromatographic assay. (a) Sample containing Ag (antigen) is loaded in a sample well. (b) Ag binds to a labeled Ab (antibody) to form a labeled Ab–Ag complex. (c) At the test zone, the labeled Ab–Ag complex binds to an immobilized Ab to form a labeled Ab–Ag–Ab sandwich. (d) At the control zone, a labeled Ab binds to an immobilized antiglobulin and is captured at the control zone. (© Richard C. Li.)

monoclonal antibodies diffuse across the membrane until they reach the control zone where they are trapped by the immobilized antiglobulin. This antibody–antiglobulin complex at the control zone also results in a colored vertical line (Figure 11.4). The test is considered valid only if the line in the control zone is observed. The presence of an antigen results in a line at both the test zone and the control zone, while the absence of an antigen results in a line in the control zone only (Figure 11.4). This method is rapid and simple and thus can be used as a screening test in laboratories and as a field test at crime scenes to identify semen, saliva, and species (Table 11.1).

However, a false-negative result may be obtained if a sample contains a very high concentration of an antigen (Figure 11.5). Under this condition, the dye-labeled antibody will become saturated with the antigen to form antigen–antibody complexes. The unbound antigen will diffuse along with the

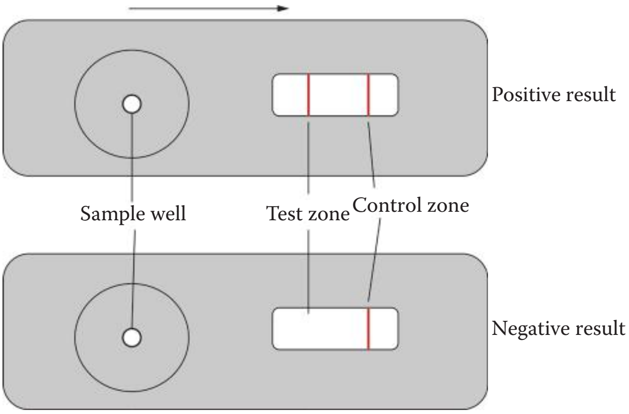

Figure 11.4 Immunochromatographic device. Positive and negative results are shown. (© Richard C. Li.)

Table 11.1 Common Immunochromatographic Assays for Forensic Applications

Assay	Antigen	Labeled Antibody	Immobilized Antibody	Forensic Application
ABAcard® HemaTrace® (Abacus Diagnostics)	Hemoglobin (Hb)	Monoclonal antihuman Hb antibody	Polyclonal antihuman Hb antibody	Blood and species identification
RSID™-Blood (Independent Forensics)	Glycophorin A (GPA)	Monoclonal antihuman GPA antibody	Monoclonal antihuman GPA antibody	Blood and species identification
RSID™-Saliva (Independent Forensics)	Human salivary α-amylase (HAS)	Monoclonal antihuman HAS antibody	Monoclonal antihuman HAS antibody[a]	Saliva identification
One-Step ABAcard PSA® (Abacus Diagnostics)	Prostate-specific antigen (PSA)	Monoclonal antihuman PSA antibody	Polyclonal antihuman PSA antibody	Semen identification
RSID™-Semen (Independent Forensics)	Semenogelin (Sg)	Monoclonal antihuman Sg antibody	Monoclonal antihuman Sg antibody[a]	Semen identification

[a] The epitope recognized by the immobilized antibody is different from that of the labeled antibody.

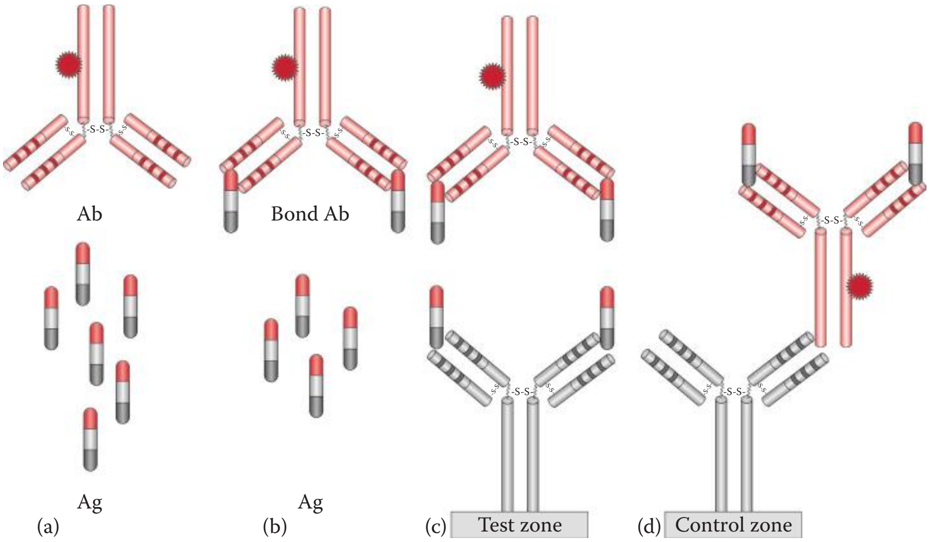

Figure 11.5 High-dose hook effect of immunochromatographic assay. (a) Ag (antigen) in sample is loaded in the sample well. (b) Ag binds to a labeled Ab (antibody) to form a labeled Ag–Ab complex. (c) At the test zone, free Ag binds to an immobilized Ab to form an unlabeled Ab–Ag complex and prevents the formation of a labeled Ab–Ag–Ab sandwich. (d) At the control zone, a labeled Ab binds to immobilized antiglobulin and is captured at the control zone. (© Richard C. Li.)

antigen–antibody complex toward the test zone. At the test zone, the unbound antigen will compete with the antigen–antibody complexes for the antibody immobilized at the test zone. Since the antigen is in excess, the unbound antigen binds to the immobilized antibody, preventing the formation of the antibody–antigen–antibody sandwich. The resulting reading appears as a negative result. This artifact is known as the *high-dose hook* effect. To prevent the high-dose hook effect, a smaller volume of sample can be applied, or the sample can be diluted to reduce the amount of antigen applied.

11.3 Secondary Binding Assays

11.3.1 Precipitation-Based Assays

These techniques are based on the precipitation reaction and are used primarily for species identification in forensic laboratories.

11.3.1.1 Immunodiffusion

Immunodiffusion is a passive method in which an antigen or an antibody or both are allowed to diffuse and therefore a gradient, from low to high concentration, is established for an antigen or an antibody or both. As a result, precipitation occurs due to the interaction between an antigen and an antibody. The assay can be carried out in a liquid or a semisolid medium such as agarose gel. The semisolid medium can stabilize the diffusion process and reduce interference such as convection, which is the movement of molecules within liquids. The two types are single immunodiffusion and double immunodiffusion.

11.3.1.1.1 Single Immunodiffusion

A concentration gradient is established for either an antigen or an antibody. One serology technique based on this principle is radial immunodiffusion—a single diffusion method in which a concentration gradient is established for an antigen. The antibody is uniformly distributed in the gel matrix (Figure 11.6). The antigen is loaded into a sample well and allowed to diffuse from the well into the gel until a precipitation reaction occurs. The precipitate ring around the well is observed; the area within the ring of precipitate is proportional to the amount of antigen loaded in the well. Standards using known concentrations of antigen can be included in the same assay along with the samples, and a standard curve can be plotted. The amounts of antigen in samples can then be quantified by comparing the results with the standard curve.

11.3.1.1.2 Double Immunodiffusion

The second type of assay is double diffusion in which a concentration gradient is established for both an antigen and an antibody. The most common examples are the ring assay and the Ouchterlony assay. The *ring assay* can be performed in a test tube or capillary tube (Figure 11.7). An antiserum, a denser phase, is placed in a small tube. An antigen solution is carefully layered on top of an antibody solution without mixing. Both the antigen and the antibody will diffuse toward each other. In a positive reaction, a ring of precipitate can be observed at the interface of the two solutions. A negative reaction is indicated by a lack of precipitation. The assay requires positive and negative controls along with questioned samples.

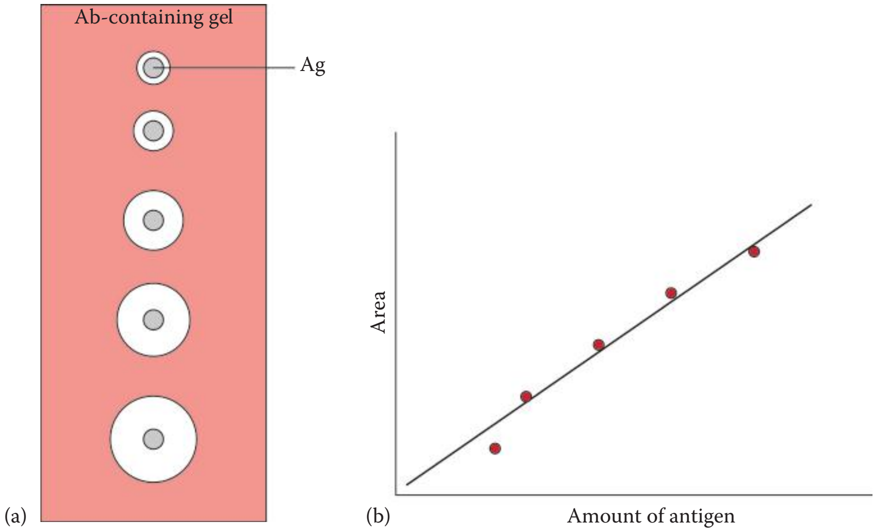

Figure 11.6 Radial immunodiffusion assay. (a) Immunodiffusion of antigens from a well into an antibody-containing gel. (b) Standard curve based on results of standards with known amounts of antigens. (© Richard C. Li.)

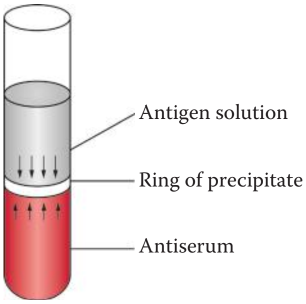

Figure 11.7 Ring assay. (© Richard C. Li.)

The *Ouchterlony assay* is named after the Swedish immunologist, Örjan Ouchterlony, who developed it. The assay can be performed in an agarose gel supported by a glass slide or polyester film (Figure 11.8). Wells are created by punching holes in the gel layer at desired locations. Often, a pattern with six wells surrounding a center well is used. The antibody is loaded in the central well while the questioned samples and the controls are loaded in the surrounding wells. The double diffusion of the antigen and the antibody from the wells is allowed to occur during incubation. If the reaction is positive, a precipitate line between wells can be observed at the end of incubation. The precipitate can be stained, enhancing visibility to aid observation. A single assay can compare more than one antigen to determine whether the antigens in question react the same way or differently with the antibody (see Chapter 7). This method is sometimes used to determine whether samples have come from the same or different origins.

11.3.1.2 Immunoelectrophoretic Methods

Diffusion techniques can be combined with electrophoresis to enhance test results. Electrophoresis separates molecules according to the differences in their electrophoretic mobility.

11.3.1.2.1 Immunoelectrophoresis

Immunoelectrophoresis (IEP) is a two-step procedure that can analyze a wide range of antigens. This technique uses electrophoresis to separate the antigen mixture prior to immunodiffusion (Figure 11.9). In the first step, the antigens in a sample are separated using agarose gel electrophoresis.

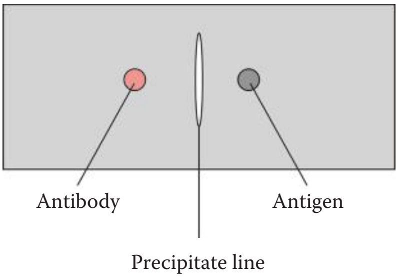

Figure 11.8 Ouchterlony assay. (© Richard C. Li.)

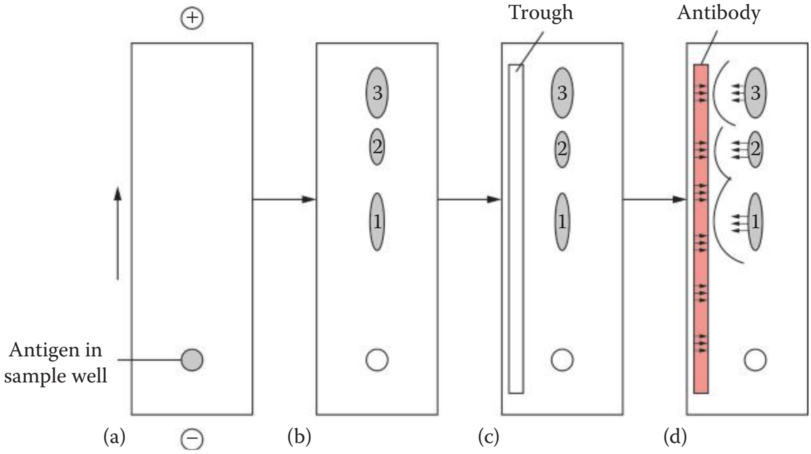

Figure 11.9 IEP assay. (a) Electrophoresis of antigens is carried out. (b) Various antigens are separated after electrophoresis. (c) Trough is cut. (d) Antibody is applied to the trough allowing diffusion to occur and forming precipitate lines. +, anode; −, cathode. (© Richard C. Li.)

Then, a trough is cut in the gel parallel to the array of antigens separated by electrophoresis. In the second step, an antibody is loaded in the trough and the gel is incubated for double diffusion. An arc-shaped precipitate line can be observed for a positive reaction. Multiple precipitate lines can occur if more than one antigen reacts with the antibody. The shapes, intensities, and locations of the precipitate lines of a known control and a questioned sample can be compared.

11.3.1.2.2 Crossed Immunoelectrophoresis

Crossed immunoelectrophoresis (CRIE), also known as two-dimensional IEP, is a modification of IEP. The first step utilizes electrophoresis to separate antigens contained in a sample (Figure 11.10). A strip of gel containing separated antigens is cut for the second round of electrophoresis. The gel including the gel strip is turned at a 90° angle and is further separated by a second-dimension electrophoresis. This drives the antigens from the gel strip into an agarose gel that contains uniformly distributed antibodies. Following the second-dimension electrophoresis, an arc-shaped precipitate line is formed. The area of the arc can be measured, and a sample can be identified by comparison with a known standard. This technique is more sensitive than IEP.

11.3.1.2.3 Rocket Immunoelectrophoresis

An antibody-containing agarose gel is used. The antigen is loaded into the well (Figure 11.11). Electrophoresis then drives the antigen from the well into the agarose gel. In a positive reaction,

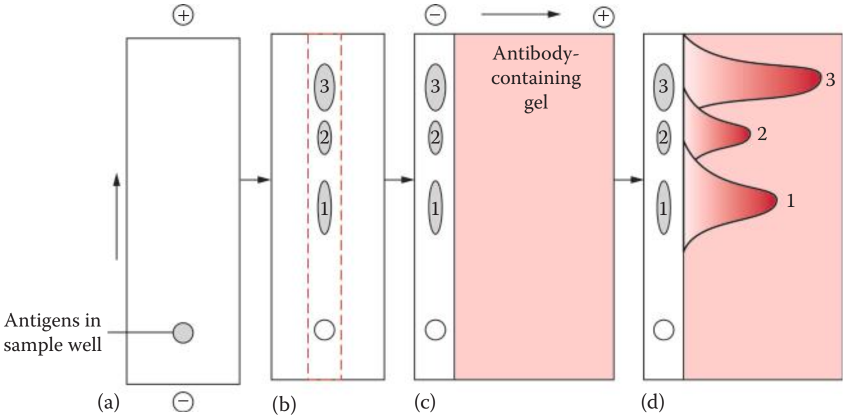

Figure 11.10 CRIE assay. (a) Electrophoresis of antigens is carried out. (b) Various antigens are separated after electrophoresis. A strip of gel containing separated antigens is excised and then used for second-dimension electrophoresis. (c) As shown, second-dimension electrophoresis is carried out to drive the antigens into an antibody-containing gel; (d) arc-shaped precipitate lines are formed as a result. (© Richard C. Li.)

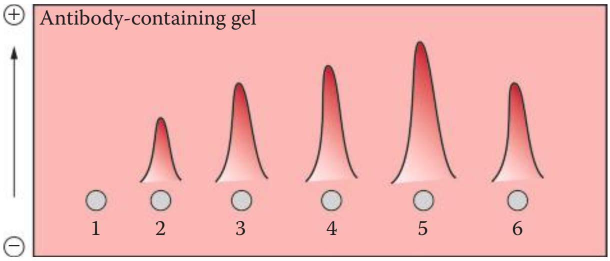

Figure 11.11 Rocket immunoelectrophoresis assay. Antigens are driven from the wells into an antibody-containing gel forming precipitate lines. (© Richard C. Li.)

a rocket-shaped precipitate line can be observed. The height of the rocket is in proportion to the amount of antigen in the sample. Quantitation can be achieved by comparing standards and the sample in the same gel.

11.3.1.2.4 Crossed-Over Immunoelectrophoresis

This technique is also known as counterimmunoelectrophoresis (CIE). Two arrays of opposing wells are created by punching holes in the agarose gel (Figure 11.12). The antibody and samples are loaded in opposing wells arranged by pairs. Electrophoresis is used to drive the antigen and the antibody toward each other. The wells containing the antibody should be proximal to the anode and the wells containing the samples should be proximal to the cathode. During gel electrophoresis, the antigen, which is usually negatively charged, migrates toward the anode. The antibody migrates in the opposite direction as a result of electroendosmosis—a phenomenon in which the movement of molecules is caused by fluid flow. A precipitate line is formed between the opposing wells if the antigen reacts with its specific antibody.

11.3.2 Agglutination-Based Assays

Agglutination reactions can be used as forensic serological assays such as for blood group typing (Chapter 18) and menstrual blood identification (Chapter 16). Agglutination assays are qualitative, indicating the absence or presence of antigens or antibodies. Semiquantitative results can be obtained by titration (diluting the antigen or antibody). Many types of agglutination reactions are available; only those used in forensic serology are discussed next.

Direct agglutination assays involve reactions in which an antibody interacts with antigens originally located on cell surfaces. In a *hemagglutination* reaction (Figure 11.13a), an antibody binds to the antigens located on erythrocytes. This method is used for the identification of blood types, for example, the testing of erythrocytes for ABO blood group typing. The assay can be carried out on a glass slide and the agglutination, as indicated by forming cell clumps, can be observed under a microscope (Chapter 18). The assay can also be carried out in a test tube. In a positive reaction, agglutinated cells are formed on the bottom of the test tube. Test tubes can also be centrifuged and then swirled to determine whether the cell clumps can be resuspended. Agglutinated cells cannot be resuspended. In a negative reaction, unagglutinated cells can be resuspended.

In *agglutination inhibition assays*, the presence of an antigen in question is indirectly detected (Figure 11.13b). If a known antigen is added to a mixture consisting of antigen-containing cells and antibodies, the added antigen will compete with the antigen located on the cell surfaces for antibody binding and inhibit the agglutination reaction. Another indirect agglutination assay is the absorption–elution assay (Chapter 18), which can be used for ABO blood group typing.

Passive agglutination assays are different from direct agglutination assays, in which the antigen is coated on the surface of carrier cells such as tannic acid–treated sheep erythrocytes. Tannic acid is considered to be a fixative. Treating with tannic acid can stabilize the carrier cells

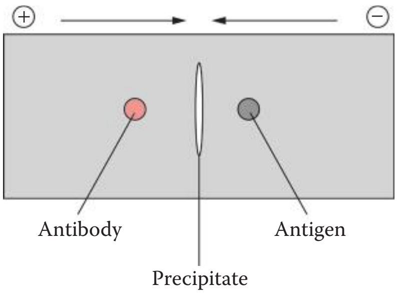

Figure 11.12 Crossed-over immunoelectrophoresis assay. (© Richard C. Li.)

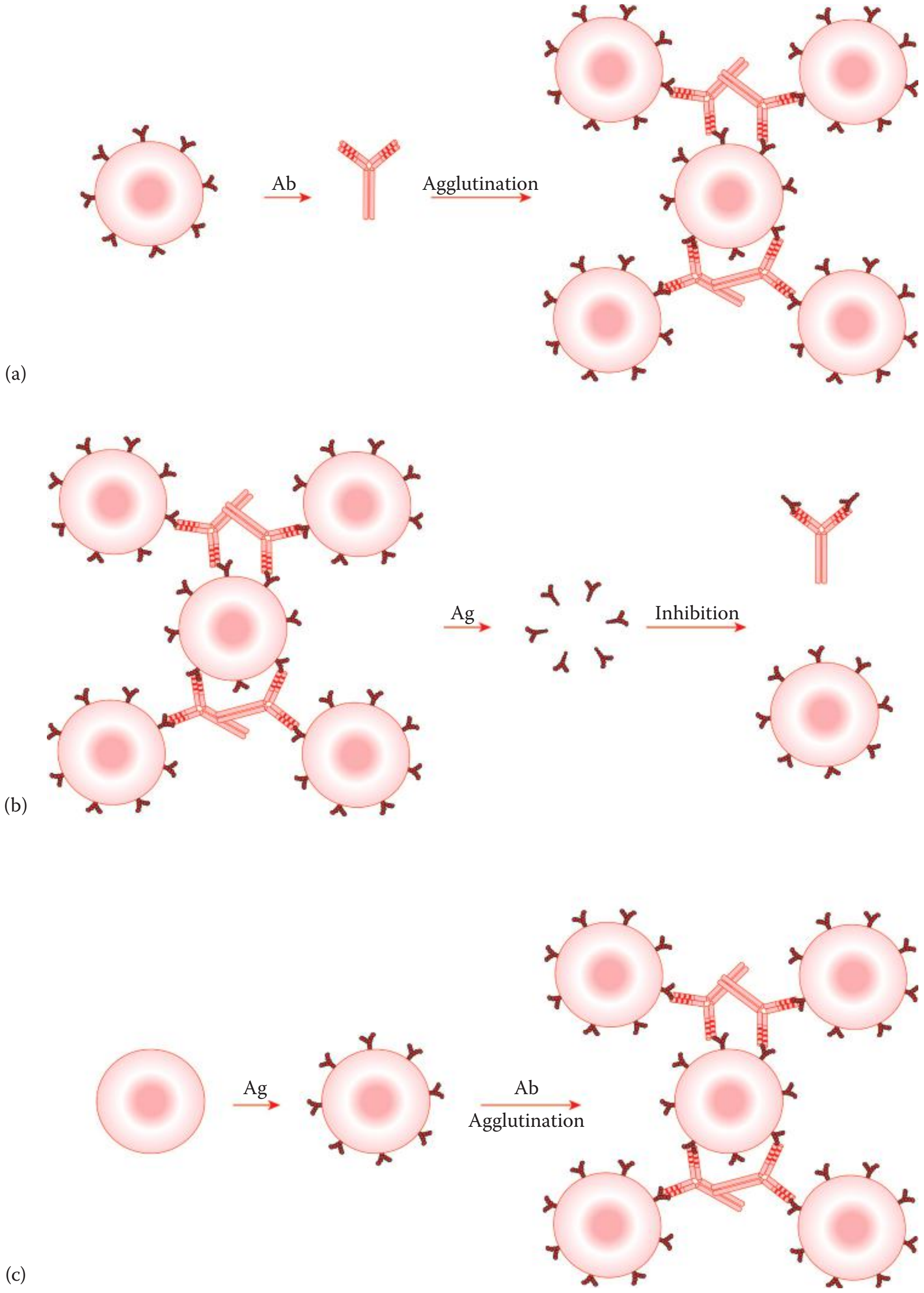
Ab
Agglutination
(a)
Ag
Inhibition
(b)
Ag
Ab
Agglutination
(c)

Figure 11.13 Agglutination-based assays. (a) Direct agglutination assay and (b) agglutination inhibition assay. Hemagglutination reactions are shown; antigens are located on erythrocytes. (c) Passive agglutination assay. (© Richard C. Li.)

for a subsequent coating of antigens. The carrier cells are then incubated with samples containing antigens. A coating of antigens can be formed on the surfaces of carriers. Such antigen-coated carrier cells can then be agglutinated using an antibody that is specific to the absorbed antigens (Figure 11.13c).

11.4 DNA Methylation Assays for Bodily Fluid Identification

In the eukaryotic genome, methylation occurs at the cytosine residues commonly in the CpG dinucleotide sequences of both DNA strands. The "p" in CpG refers to the phosphodiester bond between cytosine and guanine. Cytosine methylation is carried out *in vivo* by methyltransferase (DNMT). DNMT catalyzes the transfer of a methyl group (CH_3) from S-adenosylmethionine (SAM) to the C^5 position of cytosine (Figure 11.14). As a result, cytosine is converted to 5-methylcytosine. Cytosine methylation is observed throughout the eukaryotic genomes in both the coding and intergenic regions located between genes. However, cytosine methylation is rare at CpG islands, which are stretches of DNA containing a high frequency of CpG dinucleotides in the regulatory regions of genes (Figure 11.15). It is implicated that cytosine methylation alters the chromatin structure and causes chromatin condensation. As a result, gene expression is usually inhibited by cytosine methylation.

Genomic loci, known as *tissue-specific differentially methylated regions* (TDMRs), have been identified. TDMRs show differential DNA methylation patterns between different tissues. For example, semen-specific TDMRs are consistently hypomethylated in spermatozoa, which can be used to identify semen samples. Other TDMRs display varying degrees of methylation in different types of bodily fluids. This suggests that differential DNA methylation assays may be potentially useful for bodily fluid identification.

The detection of DNA methylation can be carried out by a number of methods. *Methylation-sensitive restriction enzyme digestion polymerase chain reaction* (MSRE-PCR) can be used for the

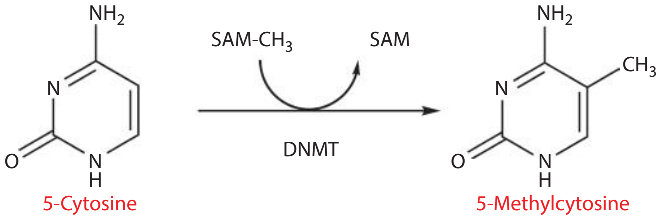

Figure 11.14 Eukaryotic cytosine methylation catalyzed by methyltransferase.

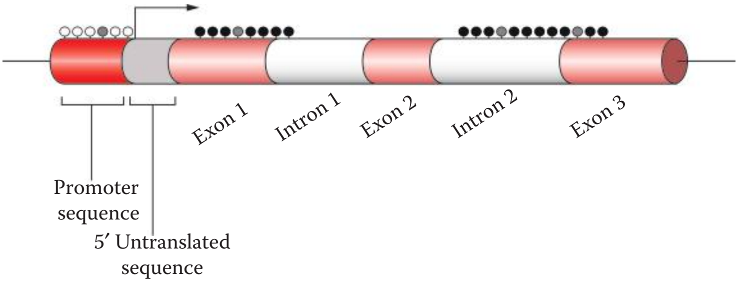

Figure 11.15 Methylation at the cytosine residues in CpG dinucleotide sequences. Note that the CpG dinucleotide sequences are usually unmethylated in the promoter regions. Black circle: methylated. Clear circle: unmethylated. Gray circle: partial methylated. (© Richard C. Li.)

rapid detection of DNA methylation. This method utilizes the *methylation-sensitive restriction enzyme* (MSRE). MSREs cleave DNA at unmethylated restriction sites, but they are not able to cleave once a cytosine residue is methylated. Thus, the methylated DNA remains intact. After PCR amplification, the methylated DNA is amplified and the amplicon is detected. In contrast, the unmethylated DNA is cleaved by the MSRE and cannot be amplified (Figure 11.16). *Bisulfite sequencing* is another widely used method. The genomic DNA is treated with sodium bisulfite, which catalyzes the hydrolytic deamination of unmethylated cytosines (Figure 11.17). As a result, unmethylated cytosines are converted to uracils, while methylated cytosines are resistant to conversion and remain unchanged. Next, uracils are replaced by thymines during PCR. After sequencing, the methylation sites can be deduced at a single-nucleotide resolution by comparing them with the reference sequence (Figure 11.18). *Methyl-DNA immunoprecipitation* (MeDIP) is a useful method for isolating methylated DNA. In this method, DNA is first sheared into fragments. The fragmented DNA is then treated with an antimethylcytosine antibody that binds to methylated cytosines. Methylated DNA fragments can then be isolated by immunoprecipitation for further analysis (Figure 11.19).

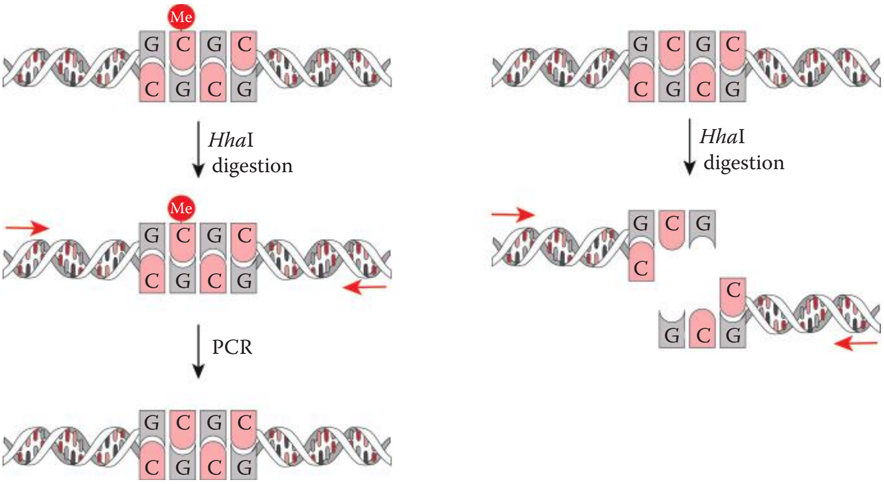

Figure 11.16 Methylation-sensitive restriction enzyme digestion PCR (MSRE-PCR) for the detection of DNA methylation. This method utilizes the methylation-sensitive restriction enzyme (MSRE) such as *Hha*I. *Hha*I cleaves DNA at the unmethylated sequence GCGC but is not able to cleave once a cytosine residue is methylated (GCmGC). The *Hha*I-treated DNA is then PCR amplified. The *Hha*I uncleaved DNA results in an amplicon, indicating the presence of a methylated cytosine in the sequence. The *Hha*I cleaved DNA cannot be amplified, indicating the absence of methylated cytosine in the sequence. Me, 5-methylcytosine site; red arrow, PCR primers. (Adapted from Frumkin, D. et al., *Forensic Sci Int Genet*, 5, 517–524, 2011.)

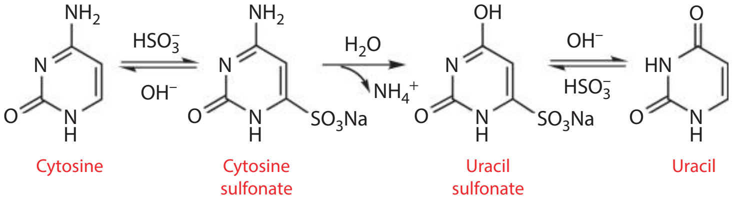

Figure 11.17 Bisulfite conversion of 5-methylcytosine.

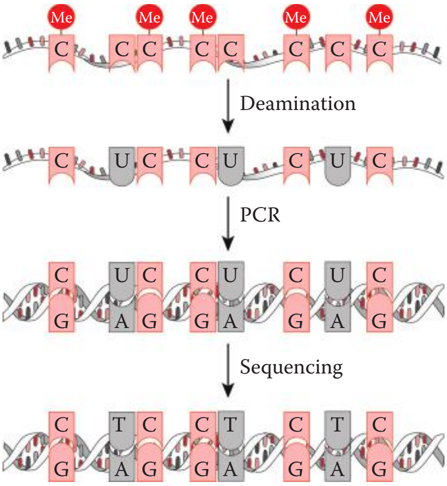

Figure 11.18 Schematic illustration of bisulfite sequencing of cytosine methylation. In a deamination reaction, unmethylated cytosines are converted to uracil. PCR and DNA sequencing are then carried out. The retention of C indicates that the site was methylated; the conversion of C to T indicates that the site was unmethylated in the DNA sample. Me, 5-methylcytosines site. (© Richard C. Li)

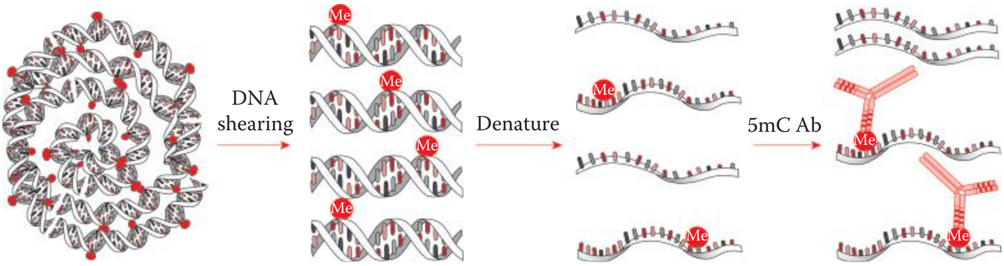

Figure 11.19 Methylated DNA immunoprecipitation (MeDIP) for the detection of methylated DNA. Genomic DNA is randomly and mechanically sheared into fragments. Fragments are then denatured to single-stranded DNA. The fragments containing the methylated region can be immunoprecipitated using an antibody that specifically recognizes 5-methylcytosine. The methylated DNA sequence in the immunoprecipitated fragments can then be determined by DNA sequencing and methylation analysis. Me, 5-methylcytosine site; 5mC Ab, 5-methylcytosine antibody. (© Richard C. Li.)

11.5 Forensic Applications of RNA-Based Assays and RNA Profiling

11.5.1 Messenger RNA-Based Assays

mRNA-based assays have been developed to identify bodily fluids for forensic investigation. In forensic pathological investigation, they can potentially be used for wound age estimation and the age of biological stains. The assays are based on the expression of certain genes in certain cell or tissue types. Candidate tissue-specific genes that may be useful for the identification of bodily fluids have been identified. Thus, the techniques that are used in the identification of bodily fluids are based on the detection of specific types of mRNA that are expressed exclusively in certain cells. The *tissue-specific genes* that are utilized for bodily fluid identification are summarized in Table 11.2. Additionally, *reference genes* that are constitutively expressed housekeeping genes are utilized as internal controls. The amount of mRNA can be assessed by normalizing the target gene to the expression level of the reference genes. Compared with conventional assays that are used for bodily fluid identification, the mRNA-based assay has higher specificity and is amenable to automation. However, one limitation is that the mRNA is unstable due to degradation by

Table 11.2 Representative Markers of mRNA-Based Assays for Bodily Fluid Identification

Bodily Fluid	Gene Symbol	Description
Blood	*ALAS2*	Aminolevulinatesynthase 2
	AMICA1	Adhesion molecule, interacts with CXADR antigen 1
	ANK1	Ankyrin1
	CD3G	CD3 gammamolecule
	CD93	CD93 molecule
	HBA1	Alpha 1 hemoglobin
	HBB	Beta hemoglobin
	PBGD	Porphobilinogen deaminase
	SPTB	Beta spectrin
Saliva	*HTN3*	Histatin 3
	MUC7	Mucin 7
	STATH	Statherin
Semen	*KLK3*	Kallikrein 3 (prostate-specific antigen)
	PRM1	Protamine 1
	PRM2	Protamine 2
	SEMG1	Semenogelin 1
	TGM4	Transglutaminase 4
Vaginal secretions	*CYP2B7P1*	Cytochrome P450, family 2, subfamily B, polypeptide 7 pseudogene 1
	DKK4	Dickkopf homolog 4
	FUT6	Fucosyltransferase 6
	HBD1	Beta defensin 1
	IL19	Interleukin 19
	MUC4	Mucin 4
	MYOZ1	Myozenin 1
	SFTA2	Surfactant associated 2
Menstrual blood	*MMP7*	Matrix metalloproteinase 7
	MMP11	Matrix metalloproteinase 11
Skin	*CDSN*	Corneodesmosin
	LOR	Loricrin

(*continued*)

Table 11.2 (Continued) Representative Markers of mRNA-Based Assays for Bodily Fluid Identification

Bodily Fluid	Gene Symbol	Description
Reference gene	*18S rRNA*	18S ribosomal RNA
	ACTB	Beta actin
	G6PDH	Hexose-6-phosphate dehydrogenase
	RPS15	Ribosomal protein S15

Sources: Adapted from Bauer, M. and Patzelt, D., *J Forensic Sci*, 47, 1278–1282, 2002; Hanson, E.K. and Ballantyne, J., *Sci Justice*, 53, 14–22, 2013; Lindenbergh, A., Maaskant, P., and Sijen, T., *Forensic Sci Int Genet*, 7, 159–166, 2013; Nussbaumer, C., Gharehbaghi-Schnell, E., and Korschineck, I., *Forensic Sci Int*, 157, 181–186, 2006.

endogenous ribonucleases. Additionally, bodily fluid stains collected from crime scenes are often exposed to ultraviolet (UV) light, moisture, and high temperature, which can promote mRNA degradation. Nevertheless, the successful detection of mRNA from aged samples is possible.

11.5.2 MicroRNA-Based Assays

The biological function of microRNAs (miRNAs) is to regulate gene expression. The mature miRNA strand associated with the RNA-induced silencing complex (RISC) binds to its target mRNA. In animal cells, the mature miRNA forms a base pairing with its complementary sequence of the *miRNA responsive element* (MRE) within the 3′ untranslated regions (3′UTRs) of the target mRNA (Figure 11.20). A single miRNA can bind different mRNA transcripts encoded by multiple genes. Animal miRNAs usually form a base pairing with their target mRNAs through partial complementary sequences, which lead to translation repression to inhibit protein synthesis. If the base pairing is exactly complementary to its target mRNA sequence, then the cleavage and the degradation of the target mRNA occurs. As a result, the synthesis of the protein encoded by the mRNA is reduced. Thus, miRNAs play important roles in cellular function.

miRNAs have potential applications in forensic identification. Recent studies have revealed that miRNAs can be detected from various bodily fluids such as blood, saliva, semen, vaginal secretions, and menstrual blood. The type of miRNA expressed is not exclusively tissue- or cell-type specific. However, the expression patterns of specific miRNAs are unique for various bodily fluids. Thus, a bodily fluid in question can potentially be identified using multiple differentially expressed miRNAs as markers (Table 11.3). miRNA markers for bodily fluid identification have their advantages compared with those of mRNA. Mature miRNAs are much

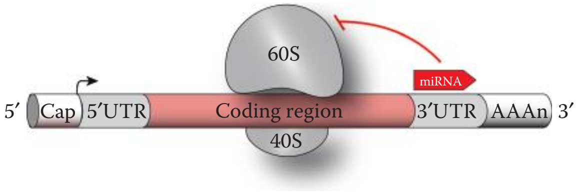

Figure 11.20 Schematic illustration of the roles of miRNA in translational inhibition. In animal cells, miRNAs bind to 3′UTR of their target mRNA with partially complementary Watson–Crick base pairing. As a result, the binding of miRNA to the target mRNA inhibits translation of the target mRNA. Eukaryotic 40S and 60S ribosomal subunits are shown. (© Richard C. Li.)

Table 11.3 Differentially Expressed miRNA Markers for Bodily Fluid Identification

Biological Fluid	miRNA Set
Blood	miR16; miR451
	miR16; miR486
	miR20a; miR106a; miR144; miR185
	miR126; miR150; miR451
Semen	miR10b; miR135b
	miR10a; miR135a; miR943; miR507; miR891a
Saliva	miR205; miR658
	miR200c; miR203; miR205
Vaginal secretions	miR124a; miR372
Menstrual blood	miR214
	miR412; miR451
Reference gene	*RNU6-2* (U6 small nuclear 2 RNA)

Sources: Adapted from Courts, C. and Madea, B., *J Forensic Sci*, 56, 1464–1470, 2011; Hanson, E.K., Lubenow, H., and Ballantyne, J., *Anal Biochem*, 387, 303–314, 2009; Wang, Z. et al., *Forensic Sci Int Genet*, 7, 116–123, 2013; Zubakov, D. et al., *Int J Legal Med*, 124, 217–226, 2010.

smaller, approximately 21–23 nucleotides in length, than mRNA. As a result, miRNAs are less susceptible to degradation and more stable than mRNAs. Additionally, the sensitivity of the miRNA-based method is much higher than that of the mRNA-based methods.

11.6 Proteomic Approaches Using Mass Spectrometry for Bodily Fluid Identification

The forensic application of proteomic approaches is to identify biomarker proteins derived from bodily fluids to determine the type of bodily fluid in question for forensic investigations. Mass spectrometry (MS) is a highly sensitive and rapid technique for protein identification from complex biological samples.

11.6.1 Mass Spectrometric Instrumentation for Protein Analysis

A mass spectrometer is an analytical technique to identify a molecule by measuring the ratio of the mass (m) to the charge (z) of a charged molecule (Figure 11.21). A typical mass spectrometer instrument analyzes ionized molecules while in its gas phase. A mass spectrometer consists of an *ion source* that converts analytes into gaseous phase ions, through a process known as *ionization*, by gaining a positive or a negative charge from a neutral species. The ions are then introduced into the *mass analyzer* of a mass spectrometer, where ions are accelerated under electric fields and separated based on their m/z ratio. The separated ions are detected by an *ion detector* that records the number of ions at each m/z value. The result of molecular ionization,

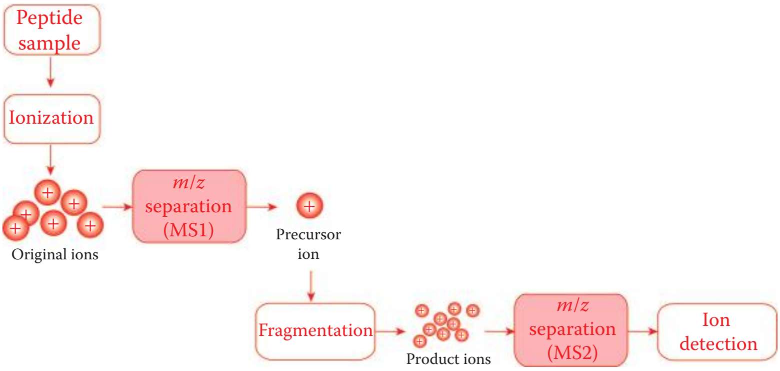

Figure 11.21 Diagram of tandem mass spectrometry. For the initial mass analysis of thermolabile analytes including peptides and proteins, soft ionization techniques such as matrix-assisted laser desorption ionization (MALDI) and electrospray ionization (ESI) can be used to produce original ions. MALDI utilizes a laser beam to trigger ionization and facilitate the vaporization of the analyte. In the ESI method, a fine mist of droplets is formed in the presence of a high electric field, producing charged ions. In the first round of mass analysis, ions are separated based on their *m/z* ratio. A particular ion, called a precursor ion, is then selected for fragmentation, generating product ions. The fragmentation can be carried out using collision techniques such as collision-induced dissociation (CID) by multiple collisions with rare gas atoms. Additionally, a new fragmentation technique, electron-capture dissociation (ECD), can be used in which the fragmentation is induced through the capture of a thermal electron by a protonated peptide cation. The product ions are analyzed by the second round of mass analysis and detected by an ion detector. MS, mass analyzer. (© Richard C. Li.)

ion separation, and ion detection is a spectrum that can be used to determine the mass (or molecular weight) and potentially the structure of the molecule.

Furthermore, biomarker proteins can be identified by *peptide sequencing* using the tandem mass spectrometry (MS/MS) mode of operation in which a mass spectrometer uses two or more mass analyzers. After an initial mass analysis, individual peptide ions in the mass spectrum can be selected. The selected ions are known as *precursor ions*. A precursor ion is then subjected to a second round of fragmentation through collision and is broken into smaller ions known as *product ions*. The resulting product ions are further analyzed by MS. Thus, the corresponding protein can be identified through searching a protein database, based on the mass of a specific peptide obtained.

11.6.2 Analysis Strategies for Protein Identification

To date, various MS-based protein identification strategies have been developed, which can be divided into two categories: “top-down” and “bottom-up” strategies (Figure 11.22). In the *top-down* strategy, intact proteins in a complex mixture are fractionated and separated into less complex protein mixtures or single proteins. Intact proteins are then analyzed using MS. A liquid chromatography–mass spectrometry (LC–MS) system can be used for such an application. The advantage of this approach is that an entire protein is analyzed for identification purposes. However, the throughput and efficiency of this approach is still a major challenge for large-scale sample analysis in forensic applications.

The *bottom-up* strategy is commonly used for high-throughput analysis of small peptides derived from highly complex samples. Current MS usually cannot resolve the mass measurement of large proteins; rather, MS is ideal for the analysis of small peptides. One approach is the *sort-then-break* approach in which proteins in a complex mixture are first isolated and then enzymatically cleaved. The target proteins are isolated from their complex biological source using 1-D or 2-D gel electrophoresis (Chapter 18). The isolated proteins are then enzymatically

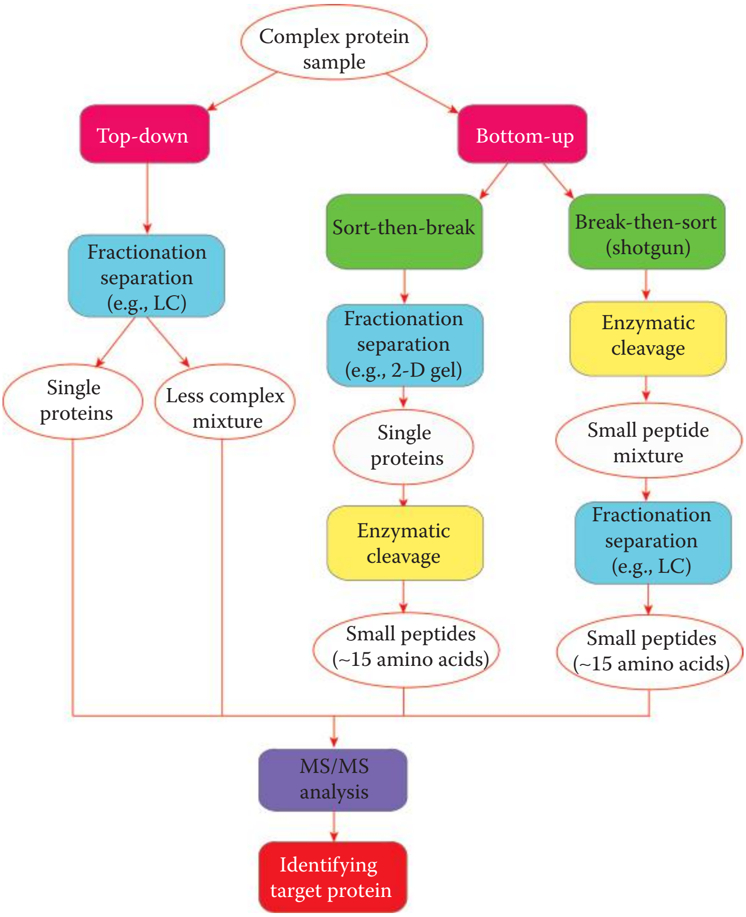
Complex protein sample
Top-down
Bottom-up
Fractionation separation (e.g., LC)
Sort-then-break
Break-then-sort (shotgun)
Single proteins
Less complex mixture
Fractionation separation (e.g., 2-D gel)
Enzymatic cleavage
Single proteins
Small peptide mixture
Enzymatic cleavage
Fractionation separation (e.g., LC)
Small peptides (~15 amino acids)
Small peptides (~15 amino acids)
MS/MS analysis
Identifying target protein

Figure 11.22 Top-down and bottom-up strategies for MS-based protein identification. LC, liquid chromatography; MS/MS, tandem mass spectrometry. (© Richard C. Li.)

cleaved into small peptides, approximately 15 amino acids in length, using proteases such as trypsin. These peptides are then analyzed by peptide sequencing using tandem MS to identify the target protein.

Break-then-sort, also known as the *shotgun* approach, is another approach of the bottom-up strategy. In this approach, proteins are cleaved first and the resulting peptide mixture is then separated by LC and analyzed by tandem MS (usually coupled to the LC). In a complex mixture, a peptide mass measurement alone is not sufficient for the identification of a target protein. Database searches are carried out utilizing software that compares the observed MS peptide spectra against all candidate spectra of the proteins that are present in a protein sequence (or translated from genomic DNA sequences) database for possible matches. Thus, a biomarker protein can be identified.

11.7 Microbial DNA Analysis for Bodily Fluid Identification

Human bodies harbor a large number of microbes. It is estimated that there are over 10 times more microbial cells than human cells in and on the human body, in the nose, mouth, throat, intestine, vagina, and skin. This microbial community is referred to as the human *microbiota*.

It is known that the microbiota has an important influence on human health. A decade ago, the concept of the *microbiome* was proposed by Nobel laureate Joshua Lederberg to identify and characterize the microbiota, their genomes, and their environmental interactions in a defined community. Traditionally, the studies of microbial genomes rely on cultivated individual species. The disadvantage of cultivation-based methods, however, is that large numbers of microbial species cannot be successfully isolated because many microbial species require specific growth conditions. Based on the advances in DNA sequencing technologies, a new approach, known as *metagenomics*, has been developed. Instead of studying the genome of an individual cultivated microbial species, metagenomics allows the study of the microbial genome of complete microbial communities harvested directly from natural environments. Metagenomics has been a powerful tool to analyze the human microbiome. Recently, human microbiota have been surveyed, revealing that microbial diversity is greatest in the teeth and the intestines, intermediate on the skin and the inside surface of the cheek, and lowest in the vagina (Table 11.4). More interestingly, each habitat is characterized by a small number of highly predominant bacterial taxa. The predominant taxa of each habitat can potentially be utilized for the forensic analysis of biological evidence. Bodily fluids identification is an important task in the forensic analysis of biological evidence. The detection of predominant taxa of bacteria can aid in the forensic identification of a particular type of bodily fluid (Table 11.4).

Table 11.4 Representative Microbiota that are Potentially Can Be Used for Forensic Identification

Body Habitats	Estimated Number of Microbial Species	Predominent Taxa	Potential Forensic Applications	DNA Marker	Further Reading
Cheek	800	*Streptococcus* spp.	Saliva identification	*gtf*	Nakanishi et al. (2011)
			Expirated blood	*gtf*	Donaldson et al. (2010)
				16S rRNA	Power et al. (2010)
Vagina	300	*Lactobacillus* spp.	Vaginal secretion identification	16S rRNA	Akutsu et al. (2012)
				16S–23S ISR	Fleming and Harbison (2010)
					Giampaoli et al. (2012)
Gastrointestinal tract	4000	*Bacteroides* spp.	Fecal matter identification	*rpoB*	Nakanishi et al. (2013)
Skin	1000	*Staphylococcus* spp.	Touched evidence identification	16S rRNA	Fierer et al. (2010)

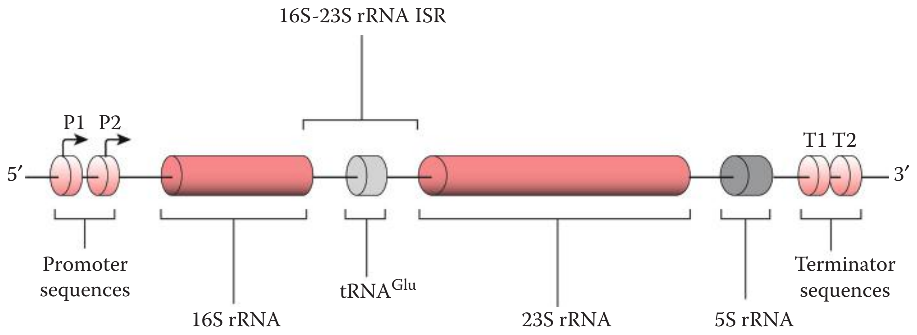

Figure 11.23 Schematic diagram of an *Escherichia coli* rRNA operon. *E. coli* has seven rRNA operons. A typical rRNA operon is shown. The rRNA operon encodes for three ribosomal RNA (rRNA) genes: the 5S and 23S genes code for the large ribosomal subunit, while the 16S gene encodes for the small ribosomal subunit. *E. coli* encodes one tRNA gene in the rRNA operon. The intergenic spacer regions (ISRs) and the promoter and terminator sequences are also shown. The rRNA operon is transcribed into a single precursor RNA transcript that is cleaved into separate rRNA and tRNA transcripts. The diagram is not to scale to the physical map of rRNA operons. (© Richard C. Li.)

The detection of bacteria can be achieved by utilizing DNA markers. The most commonly used DNA markers are the essential genes present in all bacterial species. These markers have highly variable regions that can be used to distinguish various bacterial species. The DNA sequences within these variable regions can also suggest taxonomic relationships between different taxa. Additionally, DNA markers contain conserved regions that are necessary for use as primer-binding sites for PCR-based detection.

For example, the rRNA genes (Figure 11.23), encoding for the ribosomal RNA, are conserved in all living organisms including bacteria. The bacterial rRNA operon contains three rRNA genes: the 5S and 23S rRNA genes encode the RNA components of the large subunit of the ribosome, while the 16S rRNA gene encodes the RNA component of the small subunit of the ribosome. The 16S rRNA gene is the most commonly used marker for the taxonomic identification of bacteria. The bacterial 16S rRNA genes are similar in length, approximately 1.5 kb. They contain highly conserved regions that can be used as primer-binding sites for the amplification of the adjacent DNA regions. Additionally, they contain variable regions that allow for taxonomic identification. In forensic applications, they are used as a marker for the identification of vaginal bacteria as an indicator of vaginal secretions (Chapter 16). However, the number of variable regions in the 16S rRNA genes of some bacteria species is limited. Furthermore, closely related species have high levels of sequence similarity to the 16S rRNA genes. Thus, the 16S rRNA gene marker is not adequate for distinguishing closely related species.

DNA markers of bacteria identification can also be located in noncoding regions of DNA. The *intergenic spacer region* (ISR) between the 16S rRNA and 23S rRNA genes in the rRNA operon is another commonly used marker. The 16S–23S rRNA ISR contains both length and sequence variations between species. These variations are partially caused by the number and type of tRNA genes that this region of operon contains. For example, most gram-negative bacteria contain both a copy of the tRNA^{ala} and the tRNA^{ile} genes, while some contain only a copy of the tRNA^{glu} gene. In contrast, most gram-positive bacteria have no tRNA gene; some contain either a copy of the tRNA^{ala} gene or the tRNA^{ile} gene or both. Thus, heterogeneity in the length and in the sequence of the 16S–23S rRNA ISR allows bacteria to be identified at the species level.

In addition to rRNA genes, many other genes are utilized as DNA markers for bacterial species identification. For example, the *rpoB* gene encodes the β subunit of bacterial RNA polymerase and is used as a marker for the forensic identification of fecal matter (Chapter 17). The sequence variation of the *rpoB* gene allows the distinguishing of species when they are not distinguishable, using 16S rRNA gene sequences. Several oral streptococcal species that produce extracellular polysaccharides contain the *gtf* gene, which encodes glucosyltransferase. Thus, the *gtf* gene is a useful marker for oral streptococcal species identification as a potential indicator of saliva in forensic investigations. However, this marker cannot be used to identify bacteria other than *streptococcus*. Nevertheless, combining several DNA markers can be used for the identification of bacteria species.

11.8 Nondestructive Assays for the Identification of Bodily Fluids

Most of the bodily fluid identification techniques mentioned previously consume a portion of the evidence. When the amount of sample evidence is very limited, such destructive assays may consume the evidence that is also needed for subsequent forensic DNA analysis. Moreover, most of these tests are used for a single type of bodily fluid. Tests for multiple bodily fluids in question will consume additional amounts of the evidence. Therefore, nondestructive identification techniques are highly desired. Additionally, it is important to develop an assay that can be utilized to test multiple types of bodily fluids. Furthermore, a portable device that can identify bodily fluids at a crime scene is very useful. It provides investigators with test results immediately to aid the crime scene investigations. Two techniques have been developed that can potentially be used for nondestructive bodily fluid identification: fluorescence spectroscopy and Raman spectroscopy.

Fluorescence spectroscopy is one example of a nondestructive technique. Fluorescence is the emission of light by a fluorophore. A fluorophore is a moiety in a molecule that fluoresces on absorbing the energy from an excitation light source or radiation. The emitted light usually has a longer wavelength and lower energy than the absorbed radiation. Constituents present in bodily fluids, such as nucleic acids, proteins, lipids, and metabolites, can exhibit fluorescence. The unique composition of a bodily fluid emits characteristic emission spectra, thus making it identifiable. Using multiple wavelengths of an excitation light source, fluorescent emissions at a wide range of wavelengths can be detected, which allows for the identification of various bodily fluids. This technique is sensitive and rapid. It does not utilize chemical reagents and the detection does not require physical contact with a sample. After identification, the same biological sample can be used for forensic DNA analysis. Additionally, portable fluorescence instruments can potentially be used at a crime scene for bodily fluid identification. However, it is not clear if exposure to an excitation light source can damage DNA evidence.

Raman spectroscopy is another example of a nondestructive technique. Raman spectroscopy utilizes a near-infrared excitation light source and measures the scattering of laser light caused by the vibrating molecules of a sample. A typical Raman spectrum provides information about the molecular structure and the “signature” based on the properties of the constituents of a sample. Thus, it is possible to obtain unique Raman spectra for a particular type of bodily fluid. Raman spectroscopy is highly sensitive. The measurements can be carried out on very small amounts of sample, ranging from a few picoliters to femtoliters. This technique does not require any chemical reagent. Additionally, it does not consume the sample, which can be used for subsequent DNA analysis. Raman spectroscopy has been utilized for various forensic purposes including the identification of drugs, trace evidence such as fibers, and questioned document evidence such as inks and paints. It can potentially be used for the nondestructive identification of various bodily fluids. A portable Raman spectrometer will allow bodily fluids to be identified at crime scenes.

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SECTION III

Identification of Biological Evidence

12

Identification of Blood

12.1 Biological Properties

Blood constitutes about 8% of the human body weight of a healthy individual. *Plasma* is the fluid portion of the blood. The cellular portion of the blood consists of *red blood cells*, *white blood cells*, and *platelets*, all of which are suspended in the plasma (Figures 12.1 and 12.2).

12.1.1 Red Blood Cells

These cells are also called *erythrocytes*. Their life span in humans is approximately 3–4 months. Additionally, mature human erythrocytes do not have nuclei, and therefore lack nuclear DNA. Erythrocytes consist of hemoglobin—proteins that are responsible for the transportation of oxygen. Most adult human hemoglobin consists of four polypeptide chains, two α chains and two β chains. Thus, adult hemoglobin is designated as $\alpha_2\beta_2$. Other forms of hemoglobin will be discussed in Chapter 18. Under normal physiological conditions, each hemoglobin subunit contains a heme moiety that binds to oxygen (Figure 12.3). A heme molecule consists of an organic component known as protoporphyrin IX and a *ferrous* (Fe^{2+}) iron ion (Figure 12.4). A heme molecule is also known as *ferroprotoporphyrin*. The ferrous ion of heme forms four bonds with the nitrogens of protoporphyrin IX, along with a fifth bond with a hemoglobin chain and a sixth bond with a molecule of O_2. Other chemicals such as carbon monoxide and cyanide also bind to the ferrous iron of the heme molecule and can cause chemical asphyxia. Heme groups are also present in the blood of various animals and in other proteins such as myoglobin in muscles and neuroglobin in the brain.

12.1.2 White Blood Cells

Also called leucocytes, white blood cells are subdivided into three types: granulocytes, lymphocytes, and monocytes. White blood cells are involved in defending the body against infection. They have nuclei and thus represent the main sources of nuclear DNA from the blood.

12.1.3 Platelets

These cells are also known as thrombocytes, and they play a role in blood clotting (Chapter 16). Platelets aggregate at sites of vascular and blood vessel injury. Like erythrocytes, they lack nuclei.

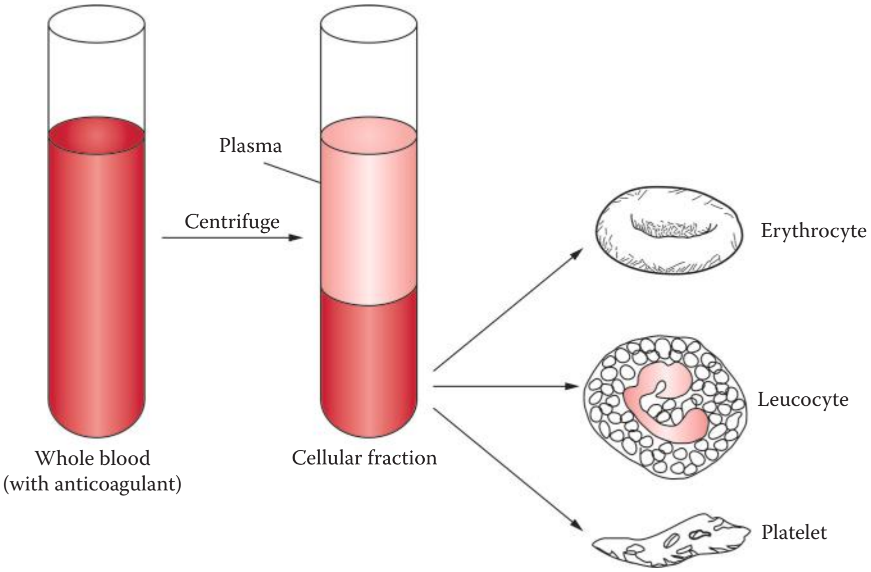

Figure 12.1 Basic composition of blood. Blood can be separated into two phases in the presence of an anticoagulant. The liquid portion called plasma accounts for approximately 55% of blood volume. The cellular elements include erythrocytes, leucocytes, and platelets. (© Richard C. Li.)

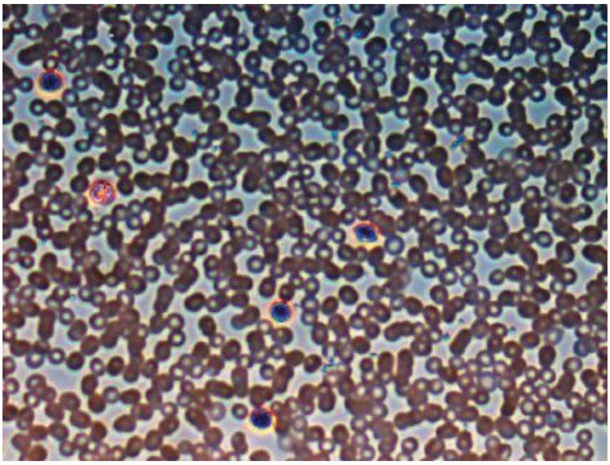

Figure 12.2 Blood cells. (© Richard C. Li.)

12.2 Presumptive Assays for Identification

12.2.1 Mechanisms of Presumptive Assays

Presumptive blood assays are designed to detect traces of blood. These assays are based on the basic principle of the oxidation–reduction reaction catalyzed by the heme moiety of the hemoglobin. As a result, colorless substrates catalyzed by heme undergo an oxidation reaction, causing either chemiluminescence, fluorescence, or a change of color. These assays are very sensitive and can detect blood in samples with 10^{-5}–10^{-6}-fold dilutions. A positive reaction indicates the possible presence of blood. Additionally, most of these assays do not interfere with forensic DNA analysis.

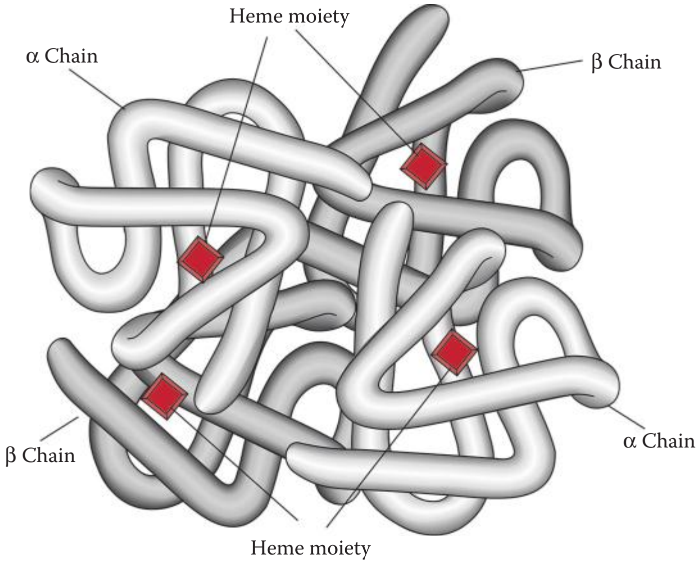
Heme moiety
α Chain
β Chain
β Chain
α Chain
Heme moiety

Figure 12.3 Human adult hemoglobin. Four subunits, two α and two β chains, of human adult hemoglobin are shown. Each hemoglobin subunit contains a heme moiety. (© Richard C. Li.)

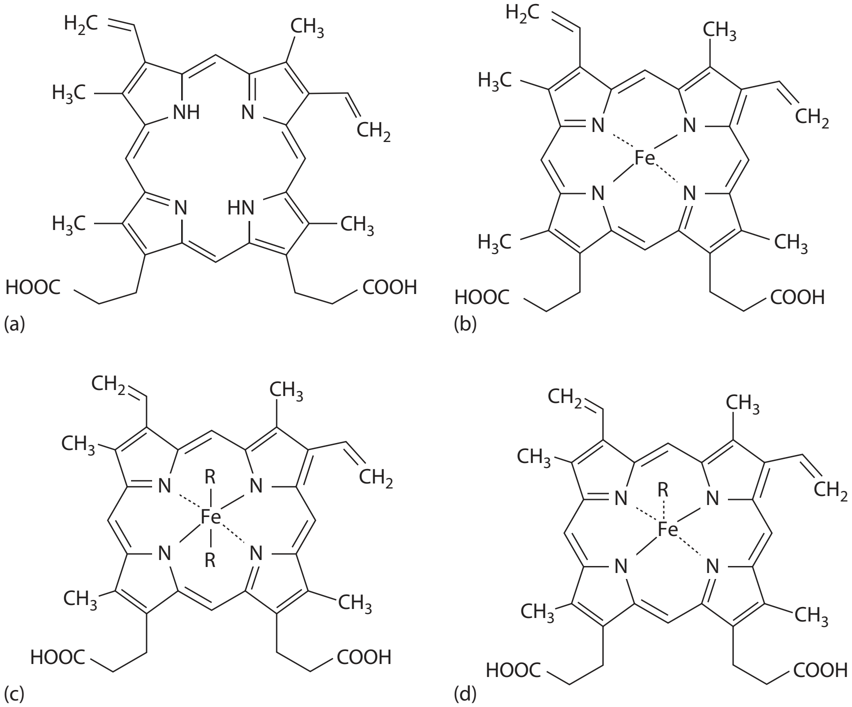
H2C
CH3
H3C
NH
N
CH2
N
HN
H3C
CH3
HOOC
COOH
(a)
H2C
CH3
H3C
N
N
Fe
N
N
CH2
H3C
CH3
HOOC
COOH
(b)
CH2
CH3
CH3
N
R
N
Fe
R
N
N
CH2
CH3
CH3
HOOC
COOH
(c)
CH2
CH3
CH3
N
R
N
Fe
N
N
CH2
CH3
CH3
HOOC
COOH
(d)

Figure 12.4 Chemical structures of heme and its precursor and derivatives. (a) Protoporphyrin IX. (b) Heme (ferroprotoporphyrin). (c) Hemochromagen, R = pyridine (pyridineferroprotoporphyrin). (d) Hematin hydroxide, R = OH (ferriprotoporphyrin hydroxide); hematin chloride, R = Cl (ferriprotoporphyrin chloride).

12.2.1.1 Oxidation–Reduction Reactions

An oxidation–reduction reaction involves a change in the oxidation state of a molecule. Specifically, the *oxidation* of a molecule means that the molecule has lost electrons, and the *reduction* of a molecule means that the molecule has gained electrons. Chemicals that can be reduced and therefore gain electrons from other molecules are called *oxidants*. In contrast, *reductants* are chemicals that can be oxidized and therefore lose electrons to other molecules. In biochemical reactions, oxidation often coincides with a loss of hydrogen. Figure 12.5 depicts an example of an oxidation–reduction reaction for blood identification. In presumptive assays, heme is utilized as the catalyst, and hydrogen peroxide is utilized as the oxidant for the reaction. In the presence of heme, a colorless substrate is oxidized, yielding a product with color, chemiluminescence, or fluorescence.

12.2.2 Colorimetric Assays

Many procedures are available for detecting heme in blood through color reactions. The most common agents are phenolphthalin, leucomalachite green, and benzidine derivatives. The color reactions produced by these assays can be observed immediately with the naked eye.

12.2.2.1 Phenolphthalin Assay

Phenolphthalein, a member of a class of indicators and dyes, is used in titrations of mineral and organic acids as well as most alkalis. The phenolphthalin assay for blood identification is also known as the Kastle–Meyer test. Kastle published a study in 1901, presenting the results of a reaction in which phenolphthalin, a colorless compound, is catalyzed by heme with hydrogen peroxide as the oxidant (Figures 12.6 and 12.7). The oxidized derivative is phenolphthalein, which appears pink under alkaline conditions.

12.2.2.2 Leucomalachite Green (LMG) Assay

Malachite green is a triphenylmethane dye. The leuco base form of malachite green is colorless and can be oxidized by the catalysis of heme to produce a green color. The reaction is carried out under acid conditions with hydrogen peroxide as the oxidant (Figures 12.8 and 12.9).

12.2.2.3 Benzidine and Derivatives

Historically, *benzidine* was used as an intermediate in dye manufacturing (Figure 12.10). Subsequently, it was used as a presumptive assay for the presence of blood after the discovery that the oxidation of benzidine can be catalyzed by heme to produce a blue to dark blue color (carried out in an acid solution). Since the blue color may eventually turn brown, the reaction must be read

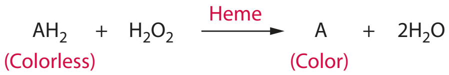

$$\underset{\text{(Colorless)}}{AH_2} + H_2O_2 \xrightarrow{\text{Heme}} \underset{\text{(Color)}}{A} + 2H_2O$$

Figure 12.5 Oxidation–reduction reaction as the basis for presumptive assays for blood identification. AH_2, substrate; A, oxidized substrate.

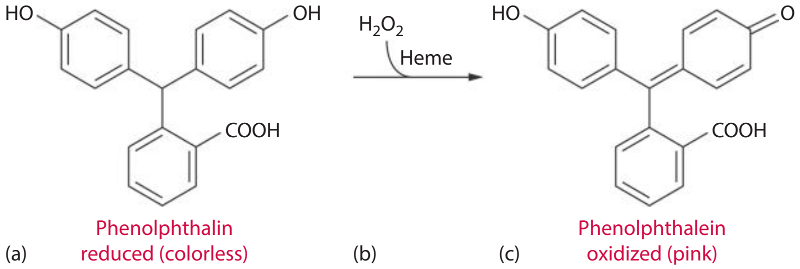

Figure 12.6 Chemical chemical reaction of phenolphthalin assay.

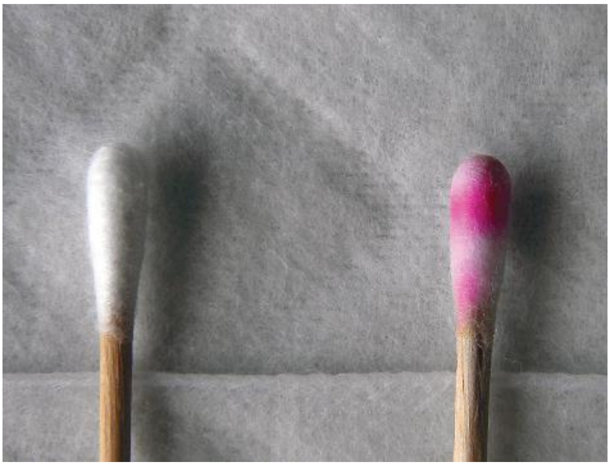

Figure 12.7 Photograph of phenolphthalin assay results. Negative (left) and positive (right) reaction. (© Richard C. Li.)

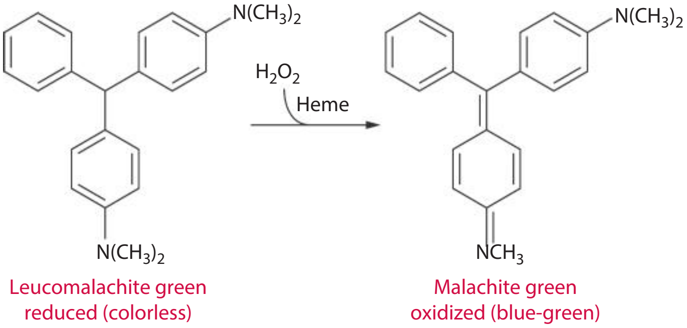

N(CH3)2
H2O2
Heme
N(CH3)2
Leucomalachite green
reduced (colorless)
N(CH3)2
NCH3
Malachite green
oxidized (blue-green)

Figure 12.8 Chemical reaction of leucomalachite green assay.

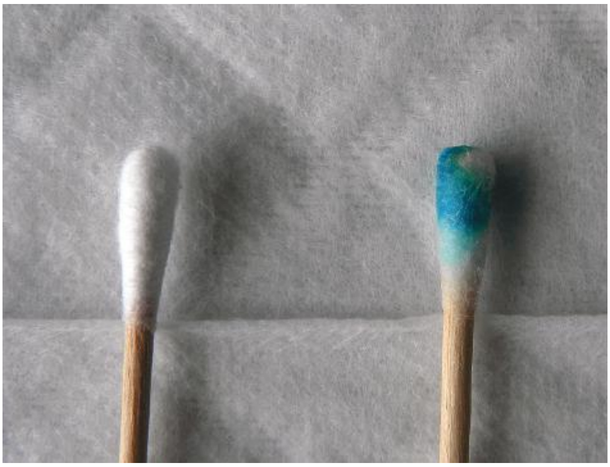

Figure 12.9 Photograph of leucomalachite green assay results. Negative (left) and positive (right) reaction. (© Richard C. Li.)

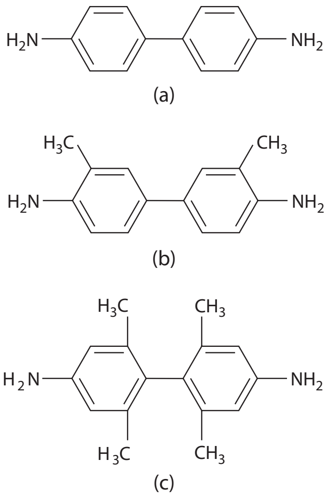

Figure 12.10 Chemical structures of benzidine and derivatives: (a) benzidine; (b) orthotolidine; (c) tetramethylbenzidine.

immediately. Benzidine was found to be a carcinogen and is therefore no longer used for forensic testing. *Orthotolidine* is a dimethyl derivative of benzidine. Its oxidation reaction can be catalyzed by heme to produce a blue color reaction under acidic conditions (Figure 12.11). Orthotolidine is also considered a potential carcinogen based on animal studies, and for this reason it has been replaced by tetramethylbenzidine. *Tetramethylbenzidine* (TMB) is a tetramethyl derivative of benzidine. The oxidation of TMB can be catalyzed by heme to produce a green to blue-green color under acidic conditions. TMB continues to be used. The Hemastix® assay kit (Miles Laboratories) is a TMB-based assay that utilizes a TMB-containing strip device. A test is carried out by applying a moistened sample to a Hemastix® strip. The appearance of a green or a blue-green color indicates the presence of blood.

12.2.3 Chemiluminescence and Fluorescence Assays

Other organic compounds whose oxidation products have chemiluminescent or fluorescent properties are utilized for testing. In the *chemiluminescence assay*, light is emitted as a product of a chemical reaction. In this category, luminol produces chemiluminescence when blood is present. In contrast, a *fluorescence assay* requires the exposure of an oxidized product, such as fluorescin, to a particular wavelength of an excitation light source. The fluorescence is then emitted at longer wavelengths than that of the excitation light source.

One advantage of chemiluminescent and fluorescent reagents is that they can be sprayed over large areas where latent bloodstains are potentially located. A positive reaction identifies blood and also reveals the patterns of bloody impressions such as footprints and fingerprints. These methods are very sensitive and can pinpoint the locations of even small traces of blood. Additionally, they are useful for detecting blood at crime scenes that have been cleaned and show no visible staining. One disadvantage of chemiluminescent and fluorescent reagents is that precautions must be taken if stains are very small or have been washed. The spraying of

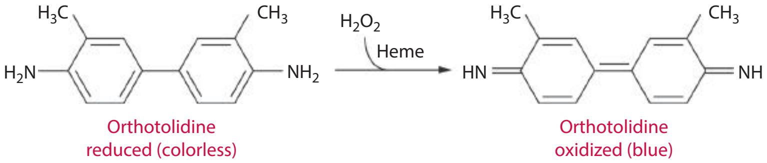

Figure 12.11 Chemical reaction of orthotolidine assay.

presumptive assay reagents may further dilute a sample and thus lead to difficulty in isolating sufficient amounts of DNA for forensic DNA analysis.

12.2.3.1 Luminol (3-Aminophthalhydrazide)

Luminol is usually utilized as a chemiluminescent reagent. The oxidation reaction of luminol catalyzed by heme produces light in the presence of an oxidant (Figures 12.12 through 12.14). The light emitted from a positive reaction can only be observed in the dark, which limits the

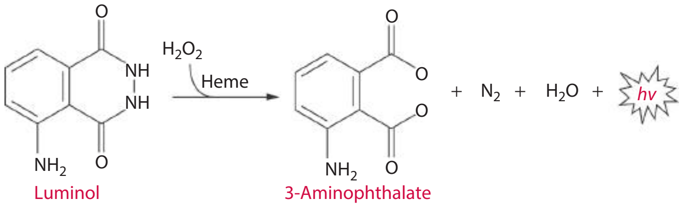

Figure 12.12 Chemical reaction of luminol assay.

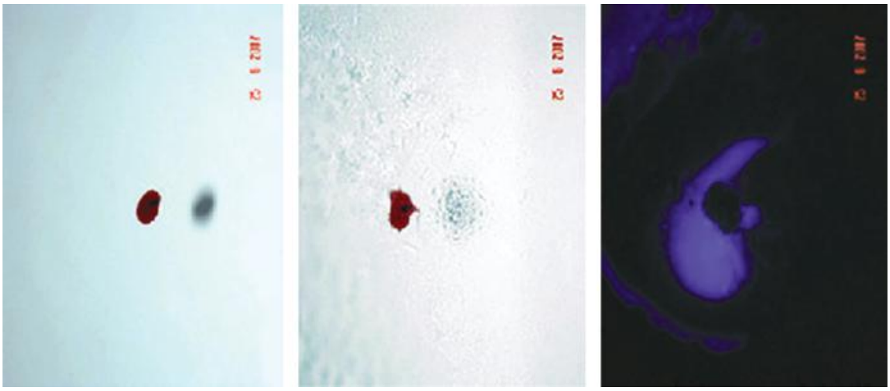

Figure 12.13 Results obtained from testing a drop of blood on a glass plate with luminol. From left to right: drop of blood; drop of blood after spraying with luminol; drop of blood after spraying with luminol and viewing in the dark. A blue chemiluminescence indicates the presence of blood. (From Bergervoet, P.W., et al., *J Hosp Infect*, 68, 329–333, 2008. With permission.)

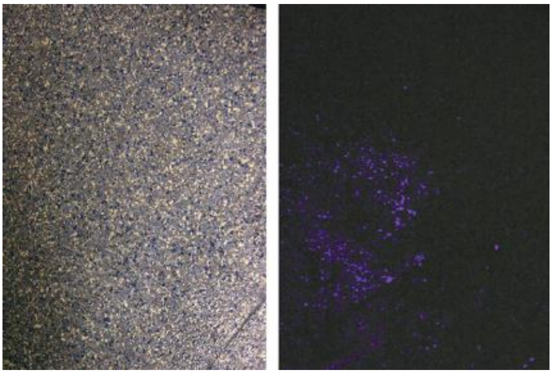

Figure 12.14 Detecting latent bloodstains on a floor with luminol. Left: with the light on; right: immediately after the light is switched off. A blue chemiluminescence indicates the presence of blood traces. (From Bergervoet, P.W., et al., *J Hosp Infect*, 68, 329–333, 2008. With permission.)

applications of luminol. The photodocumentation of a luminol-enhanced pattern should be done immediately before it fades away.

12.2.3.2 Fluorescin

Fluorescin is another reagent that is used to test for the presence of bloodstains at a crime scene (Figures 12.15 and 12.16). When oxidized and catalyzed by heme, fluorescin demonstrates fluorescent properties. Usually, fluorescin-sprayed stains are exposed to light in the range of 425–485 nm using an alternate light source device. In a positive reaction, the oxidized fluorescin emits an intense yellowish-green fluorescent light, which indicates the presence of a bloodstain. The light emitted from fluorescin-sprayed stains lasts longer than that of luminol.

12.2.4 Factors Affecting Presumptive Assay Results

The catalytic assays discussed in the previous sections are not specific to blood only, which can possibly lead to the observation of false-positive or false-negative results (Figure 12.17).

12.2.4.1 Oxidants

Chemicals that are strong oxidants may cause a false-positive reaction. Such chemicals can catalyze the oxidation reaction even in the absence of heme and result in a false-positive reaction. Certain metal salts, such as copper and nickel salts, household bleaches and cleaners that contain hypochlorite ions, and hair-coloring products that contain hydrogen peroxide, work as oxidants. To address this problem, a two-step catalytic assay should be performed. The substrate

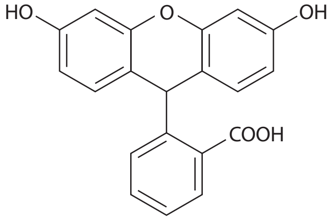

Figure 12.15 Chemical structure of fluorescein.

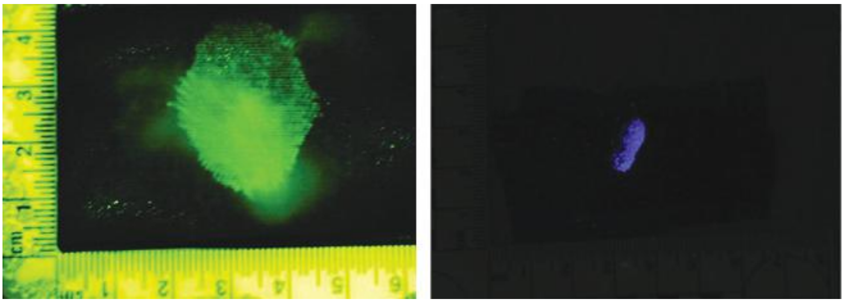

Figure 12.16 Detecting diluted bloodstains on black cotton fabric with fluorescin (left) and Bluestar (right). (From Finnis, J., Lewis, J., and Davidson, A., *Sci Justice*, 53, 178–186, 2013. With permission.)

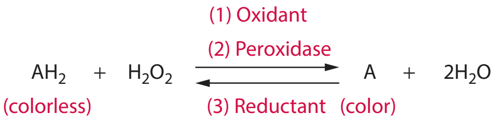

$$\underset{\text{(colorless)}}{AH_2} + H_2O_2 \underset{\text{(3) Reductant}}{\overset{\substack{\text{(1) Oxidant} \\ \text{(2) Peroxidase}}}{\rightleftharpoons}} \underset{\text{(color)}}{A} + 2H_2O$$

Figure 12.17 Factors affecting presumptive assay results. Strong oxidant and peroxidase may cause false-positive results; reductant may cause false-negative results.

is applied first to the sample in question. A color change occurring before the addition of hydrogen peroxide indicates a false-positive result due to a possible oxidant in the sample. If a color change is observed after the addition of hydrogen peroxide, the result is a true positive.

12.2.4.2 Plant Peroxidases

Many types of plants such as horseradish contain peroxidases. Plant peroxidases may also catalyze oxidation reactions and lead to false-positive results. However, plant peroxidases are usually heat sensitive and may be inactivated by high temperatures. Because the heme molecule is relatively stable at high temperatures, samples can be retested after heating. This will inactivate any plant peroxidases in a sample.

12.2.4.3 Reductants

Although not common, a false-negative result can occur when a strong reductant is present in a sample. Strong reductants such as certain metal ions including lithium and zinc may inhibit the oxidation reaction.

12.3 Confirmatory Assays for Identification

12.3.1 Microcrystal Assays

Microcrystal assays apply chemicals to treat bloodstains, forming crystals of heme molecules. The morphologies of the resulting crystals are distinctive for heme and can be compared with a known standard using a microscope. A positive microcrystal assay strongly indicates the presence of blood. However, confirmatory assays are usually not as sensitive as presumptive assays. Additionally, these assays cannot distinguish between human and animal blood.

12.3.1.1 Hemochromagen Crystal Assay

Hemochromagens are heme derivatives in which the ferrous iron of the heme forms two bonds with nitrogenous bases (Figure 12.4). The method for forming hemochromagen crystals was documented in 1864. Since then, various modifications have been reported. The *Takayama crystal assay*, published in 1912, has been the method preferred by many forensic laboratories. A bloodstain is treated with pyridine and glucose (a reducing sugar that is capable of reducing ferric ion) under alkaline conditions to form crystals of pyridine ferroprotoporphyrin (Figure 12.18).

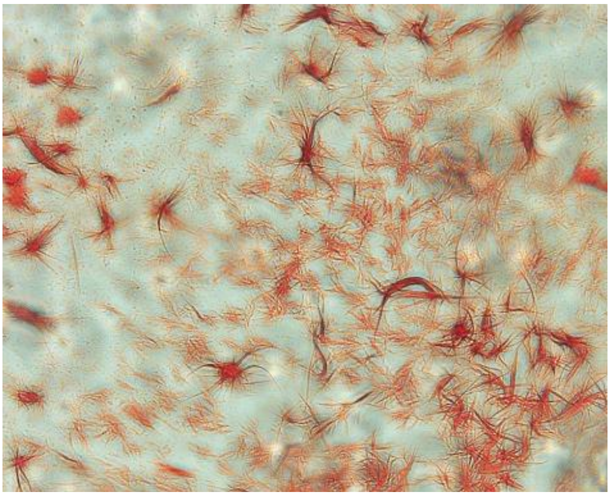

Figure 12.18 Microcrystal assays using the Takayama method. (© Richard C. Li.)

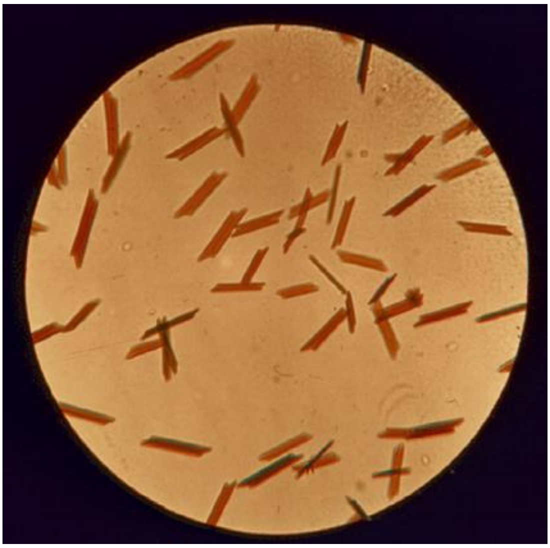

Figure 12.19 Microcrystal assays using the Teichmann method. (From James, S.H., Nordby, J.J., and Bell, S., *Forensic Science: An Introduction to Scientific and Investigative Techniques*, 4th edn., CRC Press, Boca Raton, 2014. With permission.)

12.3.1.2 Hematin Crystal Assay

This assay is also known as the *Teichmann crystal assay*. In 1853, Teichmann documented a method of forming crystals of blood specimens. When blood specimens are treated with glacial acetic acid and salts, and subsequently heated, hematin chloride (ferriprotoporphyrin chloride), a prismatic brown-colored crystal, is formed (Figure 12.19). Hematin (Figure 12.4) is a heme derivative; its iron is in the *ferric* (Fe^{+3}) state. This hematin assay has a similar sensitivity and specificity as hemochromagen assays. The hematin assay has the advantage of being more reliable than hemochromagen assays for aged blood samples.

12.3.2 Other Assays

Additional techniques may be used to confirm the presence of hemoglobin. For example, *chromatographic* and *electrophoretic methods* can identify hemoglobin by its mobility characteristics. *Spectrophotometric methods* for identifying hemoglobin are based on measurements of the

Table 12.1 Application of RT-PCR Assay for Blood Identification

Gene Symbol	Gene Product	Description	Further Reading
HBA1	Hemoglobin α1	Hemoglobin α1 chain (abundant in erythrocytes)	Waye and Chui (2001)
PBGD[a]	Porphobilinogen deaminase	Erythrocyte-specific isoenzyme of heme biosynthesis pathway	Gubin and Miller (2001)
SPTB	β-Spectrin	Subunit of major protein of erythrocyte membrane skeleton	Amin et al. (1993)

Source: Adapted from Juusola, J. and Ballantyne, J., *Forensic Sci Int*, 152, 1–12, 2005; Nussbaumer, C., Gharehbaghi-Schnell, E., and Korschineck, I., *Forensic Sci Int*, 157, 181–186, 2006.

[a] Also known as hydroxymethylbilane synthase (HMBS).

characteristic light spectra, with peak absorbance at 400–425 nm, absorbed by hemoglobin and its derivatives. Finally, *immunological methods* utilize antihuman hemoglobin antibodies. This antibody can be used to detect human hemoglobin and thus indicate the presence of human blood (see Chapter 13).

Recently, *RNA-based assays* have been developed to identify blood. These assays are based on the fact that certain genes are specifically expressed in certain cell types (Chapter 11). Thus, the techniques used in the identification of blood are based on the detection of specific types of messenger RNA (mRNA) that are expressed exclusively in erythrocytes. These assays utilize reverse transcriptase polymerase chain reaction (RT-PCR; see Chapter 7) methods to detect the gene expression levels of mRNAs for blood identification. Table 12.1 summarizes the tissue-specific genes utilized for blood identification. Compared with conventional assays that are used for blood identification, the RNA-based assays have higher specificity and are amenable to automation. However, one limitation is that RNA is unstable due to degradation by endogenous and environmentally born ribonucleases.

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13

Species Identification

Chapter 12 discussed the principles of the identification of blood. If a stain is identified as blood, the evidence can be tested to determine whether the blood is of human origin. If the bloodstain is nonhuman, further analysis is usually not necessary.

Before forensic DNA techniques were implemented, species identification was largely determined by serological methods. Currently, most forensic laboratories perform DNA quantitation prior to DNA profile analysis. The quantitation method specifically detects higher-primate DNA. The presence of DNA measured by the quantitation assays concurrently identifies a sample as being of human origin (since crimes involving primate blood are extremely rare). Thus, species identification is usually not performed in forensic laboratories.

Nevertheless, species identification assays can be useful for screening to exclude or eliminate nonhuman samples unrelated to an investigation. Thus, it is practical for small laboratories to eliminate unnecessary analyses due to time and budget constraints. Additionally, species identification kits such as immunochromatographic devices allow field testing by crime scene investigators.

In cases involving the killing, trading, and possession of products derived from species that are protected from illegal hunting, it may be necessary to identify the animal species prior to further analysis. Species identification using DNA analysis can be performed using commonly used loci at the mitochondrial cytochrome b gene (*Cytb*), the cytochrome c oxidase I gene (*COI*), and the D-loop region. This type of identification is usually within the scope of wildlife forensic science and is thus not discussed here.

13.1 General Considerations

Most assays for species identification are based on serological techniques, including primary and secondary binding assays. The most common primary binding assays are immunochromatographic assays. The most commonly used secondary binding assays are precipitation-based assays that rely on the binding of an antigen to an antibody, causing the formation of visible precipitation. These precipitation-based assays include ring assays, Ouchterlony assays, and crossed-over immunoelectrophoresis. These assays utilize antihuman and antianimal antibodies to identify human and animal species, respectively.

13.1.1 Types of Antibodies

An antihuman antibody that is used in the identification of human samples can be made by introducing human serum into a host animal, which then produces specific antibodies against the human serum proteins. Antibodies produced from different species of host animals may produce variations in the characteristics of reactions. Since albumin is the most abundant protein in human serum, the antihuman antibody that is produced reacts strongly with human albumin. Albumin is a protein that plays important roles in the maintenance of the vascular circulating fluid and the transportation of various substances such as nutrients, hormones, and metabolic products. Blood is drawn from the host animal and the serum portion is collected. The collected serum is a polyclonal antihuman antiserum containing a mixture of antibodies against various human serum proteins. Likewise, an antibody against animal serum proteins can also be made to identify animal species of interest.

Other antibodies such as antihuman hemoglobin (Hb) antibodies can also be used to identify the human origin of a sample. Hb is an oxygen-transport protein that is found in erythrocytes (Chapter 12). Purified Hb can be used to generate monoclonal and polyclonal antihuman Hb antibodies. Likewise, antibodies recognizing glycophorin A (GPA), a human erythrocyte membrane antigen (see Section 13.2.1.2), can also be produced in a similar manner.

13.1.2 Titration of Antibodies

Recall that the ratio of antigen to antibody is critical for the success of a secondary reaction (Chapter 10). An extreme excess of antigen or antibody concentrations can inhibit secondary reactions. The prozone and postzone phenomena must be considered, and the concentrations of antigen and antibody must be carefully determined for forensic serology assays. For instance, in the prozone situation, a false-negative reaction may occur due to the presence of a high concentration of antibody.

Quality-control procedures can be used to estimate the amount of a specific antibody that is present, often via titration (Figure 13.1). To titrate an antiserum, a series of dilutions are made and each dilution is then tested for activity using precipitation or agglutination methods. The reciprocal of the highest dilution giving a positive reaction is known as the *titer*. This reflects the amount of antibody in the antiserum. Additionally, the polyclonal antiserum is a mixture of antibodies; thus, the reaction of the antiserum may vary from animal to animal (of the same species). Each lot or batch of antiserum must be validated by titration.

13.1.3 Antibody Specificity

In addition to the titer, the specificity of the antihuman antibody must be tested. Most antihuman antibodies usually have cross-reactivity with higher primates. This is not a great

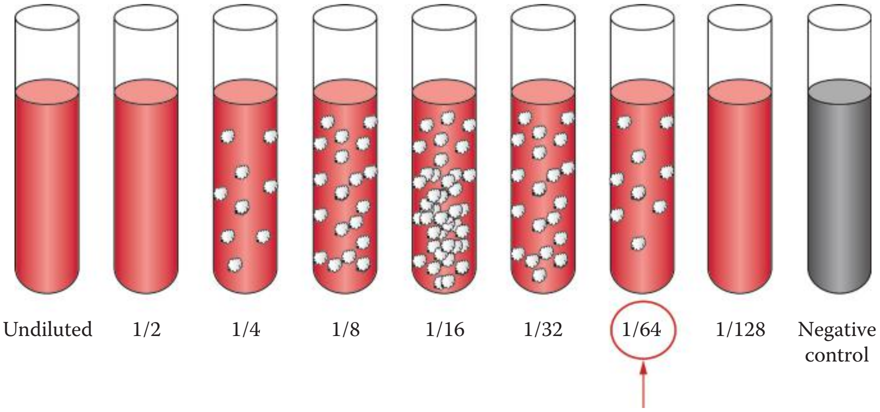

Figure 13.1 Titration of antibodies. Serum is serially diluted and a constant amount of antigen is applied to each tube. The mixture is incubated, allowing agglutination to occur. The reciprocal of the highest dilution giving a positive agglutination reaction is 64 (the titer). (© Richard C. Li.)

concern because crimes involving nonhuman primates are very rare. Nevertheless, the antihuman antibody must not cross-react with other commonly encountered animals. Antisera and positive control samples must be validated for cross-reactivity. Tissue specificity must also be validated. The antiserum against human serum is usually reactive with other human biological fluids such as semen and saliva.

13.1.4 Optimal Conditions for Antigen–Antibody Binding

A number of factors can affect antigen–antibody binding. For example, increasing ionic strength can inhibit the binding of an antigen and an antibody. Stronger inhibition is usually observed for ions with large ionic radii and small radii of hydration. It is believed that the lower degree of hydration permits interactions of ions and the antibody-binding site, leading to inhibition. A proper buffer system must be selected in serological assays to ensure reliable results. The introduction of polymers can facilitate precipitation in secondary binding reactions because the presence of a polymer in a solution decreases the solubility of proteins. Linear hydrophilic polymers with high molecular weights (e.g., polyethylene glycol) are preferred. Additional factors such as temperature and pH can also affect antigen–antibody binding.

13.2 Assays

Samples can be prepared by cutting out a portion of a stain or scraping stains from a surface. A sample is usually extracted with a small volume of saline or buffer. The extracted sample can be tested using the assays described in the following subsections. Controls should be included, for example, by using a known human serum as a positive control and an extraction blank as a negative control.

13.2.1 Immunochromatographic Assays

Immunochromatographic assays are rapid, specific, and sensitive and can be used in both laboratory and field tests for species identification. Two types of assays are discussed, including those based on the detection of human erythrocyte proteins. Chapter 11 discusses the principle of immunochromatographic assays in more detail.

13.2.1.1 Identification of Human Hemoglobin Protein

Commercially produced immunochromatographic kits such as the Hexagon OBTI (Human Gesellschaft für Biochemica und Diagnostica mbH, Wiesbaden) and the ABAcard HemaTrace® (Abacus Diagnostics, California) are available. They utilize the antibody–antigen–antibody sandwich method by using antibodies that recognize human Hb. The ABAcard HemaTrace assay utilizes a labeled monoclonal antihuman Hb antibody contained in a sample well, and a polyclonal antihuman Hb antibody immobilized at a test zone of a nitrocellulose membrane. Additionally, an antiglobulin that recognizes the antibody is immobilized onto a control zone (Figure 13.2).

A sample can be prepared by cutting a small portion (2 mm diameter) of a stain or a swab. Each sample is extracted for 5 min in 2 mL of extraction buffer. A longer extraction time may be used for older stains. The samples are loaded into the sample well, and the antigen in the sample binds to the labeled antibody in the well to form an antigen–antibody complex, which then diffuses across the nitrocellulose membrane. At the test zone, the solid-phase antihuman Hb antibody binds to the antigen–antibody complex to form a labeled antibody–antigen–antibody sandwich.

The ABAcard HemaTrace® uses a pink dye that is visualized in a positive result as a pink horizontal line at the test zone (Figure 13.3). In the control zone, unbound labeled antihuman

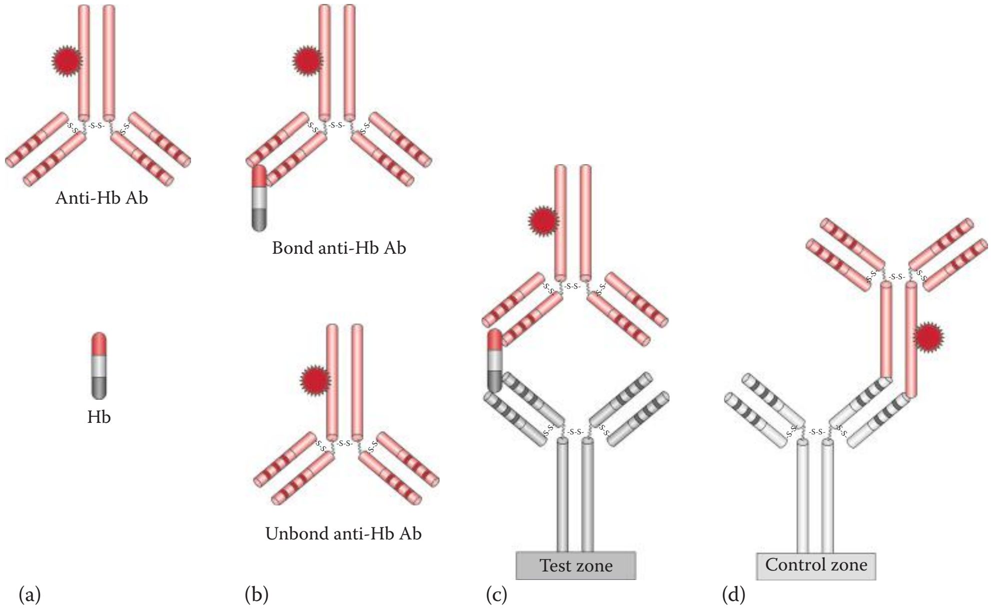

Figure 13.2 Immunochromatographic assays for the identification of Hb in human blood. (a) In a sample well, Hb in a blood sample is mixed with a labeled anti-Hb Ab. (b) The Hb binds to the labeled anti-Hb Ab to form a labeled Ab–Hb complex. The complex diffuses toward the test zone. (c) At the test zone, the labeled Ab–Hb complex binds to an immobilized anti-Hb Ab to form a labeled Ab–Hb–Ab sandwich. (d) At the control zone, the labeled anti-Hb Ab binds to an immobilized antiglobulin and is captured. Ab and Hb represent the antibody and hemoglobin, respectively. (© Richard C. Li.)

Hb antibody binds to the solid-phase antiglobulin. This antibody–antiglobulin complex at the control zone also produces a pink horizontal line. The test is considered valid only if the line in the control zone is observed. The presence of human Hb results in a pink line at both the test and control zones. The absence of human Hb results in a pink line in the control zone only. A positive result can appear in less than a minute.

Validation studies have revealed that the sensitivity of the ABAcard HemaTrace® can be as low as 0.07 μg/mL of Hb. The normal blood Hb concentration is 14–18 and 12–16 g/dL among males and females, respectively. This assay is more sensitive than the Kastle–Meyer assay (Chapter 12). Additionally, the assay is responsive to aged stains and degraded materials. Specificity studies have shown that it is specific for blood of higher primates, including humans. However, it is also responsive to seminal stains, and oral, vaginal, anal, and rectal swabs. It is believed that these biological fluids contain very low amounts of Hb, which can still be detected by highly sensitive assays. However, if the concentration of blood is too high, a false negative can result due to the high-dose hook effect described in Chapter 11.

13.2.1.2 Identification of Human Glycophorin A Protein

Commercially produced immunochromatographic kits such as RSID™-Blood (Independent Forensics, Hillside, IL) use antibodies that recognize human GPA (Figure 13.4). A labeled monoclonal antihuman GPA antibody is contained in a sample well, and a second monoclonal antihuman GPA antibody, to a different epitope of GPA, is immobilized onto a test zone of the membrane. An antiglobulin that recognizes the antibody is immobilized onto a control zone (Figure 13.5).

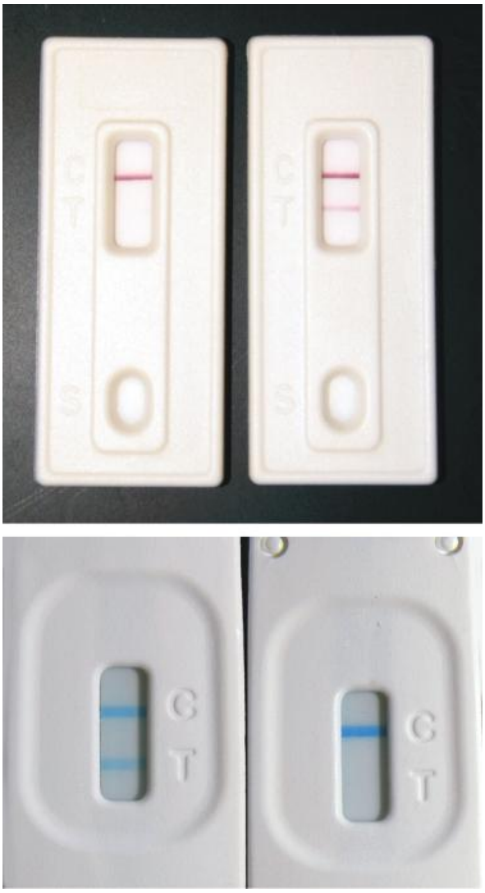

Figure 13.3 Human blood identification using immunochromatic devices. Top: In an assay using an ABAcard HemaTrace device, the negative (left) and positive (right) results are shown. The "C" band indicates that the test is valid. The "T" band indicates the presence of human blood. The sample well is labeled "S." (© Richard C. Li.) Bottom: The positive (left) and negative (right) results are shown using a Hexagon-OBTI device. The "C" band indicates that the test is valid. The "T" band indicates the presence of human blood. (From Ramsthaler, F., et al., Postmortem interval of skeletal remains through the detection of intraosseal hemin traces. A comparison of UV-fluorescence, luminol, Hexagon-OBTI(R), and Combur(R) tests. *Forensic Sci Int*, 209, 59–63, 2011. With permission.)

The sample can be collected by cutting out a small portion of a stain or a swab. The sample is then extracted overnight in an extraction buffer. The extract is removed and mixed with a running buffer. The assay is carried out by loading the extracted sample into the sample well. Again, the presence of GPA results in a pink line at both the test zone and the control zone, while the absence of GPA results in a pink line in the control zone only. The test is considered valid only if the line in the control zone is observed. A result can be read after 10 min.

Validation studies revealed that the sensitivity of the RSID kit can be as low as 100 nL of human blood. Species specificity studies showed no cross-reactivity with various animal species, including nonhuman primates. Biological fluid specificity studies revealed that the kit is not responsive to other human biological fluids such as semen, saliva, urine, milk, and amniotic and vaginal fluid. No high-dose hook effects were observed in samples containing up to 5 μL of blood.

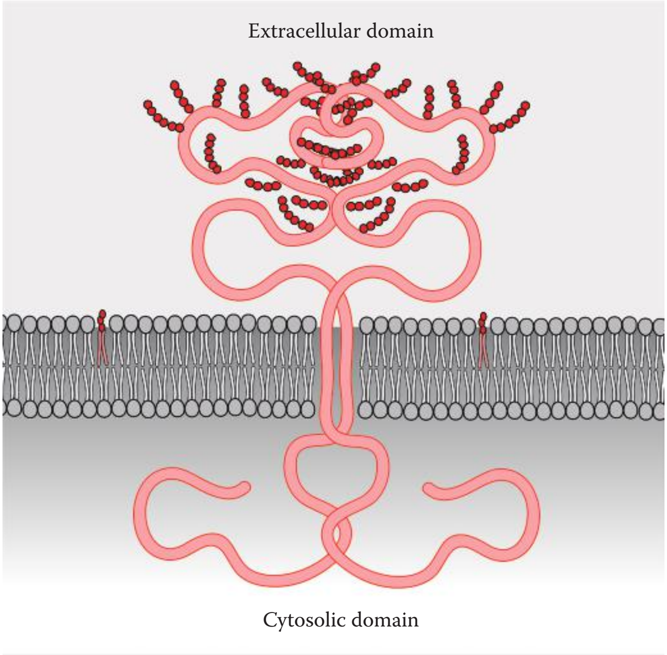
Extracellular domain
Cytosolic domain

Figure 13.4 Diagram of the structure of glycophorin (GPA) protein. GPA is a transmembrane protein on the human erythrocyte membrane. A GPA dimer is shown. The extracellular domain of the GPA is glycosylated with carbohydrate side chains (red). Various GPA epitopes are antigenic determinants of several blood group systems. (© Richard C. Li.)

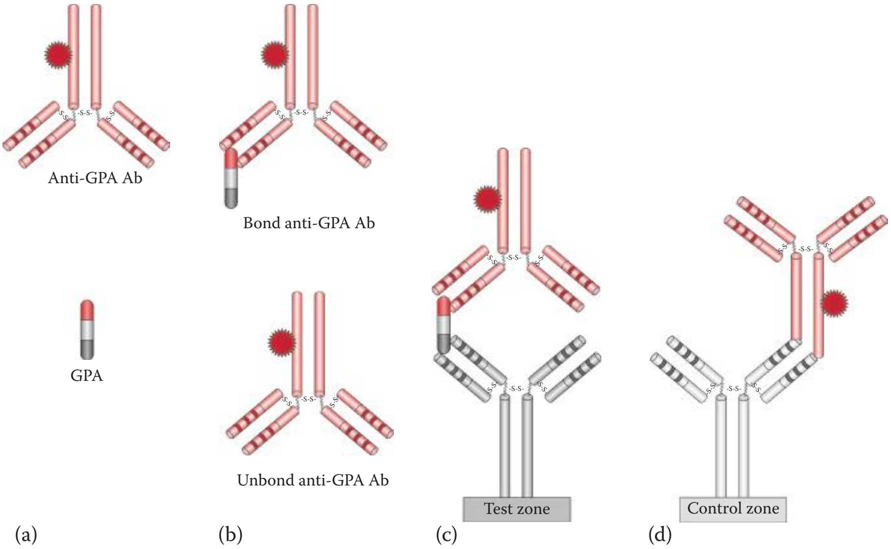
Anti-GPA Ab
GPA
Bond anti-GPA Ab
Unbond anti-GPA Ab
Test zone
Control zone
-S-S-
(a)
(b)
(c)
(d)

Figure 13.5 Immunochromatographic assays for the identification of GPA in human blood. (a) In a sample well, GPA in a blood sample is mixed with a labeled anti-GPA Ab. (b) The GPA binds to the labeled anti-GPA Ab to form a labeled Ab–GPA complex. (c) At the test zone, the labeled Ab–GPA complex binds to an immobilized anti-GPA Ab to form a labeled Ab–GPA–Ab sandwich. (d) At the control zone, the labeled anti-GPA Ab binds to an immobilized antiglobulin and is captured. Ab and GPA represent the antibody and GPA protein, respectively. (© Richard C. Li.)

13.2.2 Double Immunodiffusion Assays

13.2.2.1 Ring Assay

Chapter 11 discussed the basic principle of ring assay in detail. In this double immunodiffusion assay, an antihuman antibody reagent is placed at the bottom of a test tube and a bloodstain extract is placed on top of the bottom layer, as illustrated in Figure 13.6. The procedure is described in Box 13.1. In a positive reaction, a white precipitate between the two layers observed after several minutes indicates that a sample is of human origin. If the bloodstain extract is not human, no precipitation should appear.

13.2.2.2 Ouchterlony Assay

The basic principle of this double immunodiffusion assay has also been discussed in Chapter 11. The procedure of the Ouchterlony assay is described in Box 13.2. In a positive reaction, a line of precipitate will form between each antigen well and antibody well. This assay can also determine the similarity of the antigens (Figure 13.7). During the diffusion process, different antigen–antibody complexes migrate at different rates. Consequently, a separate line of precipitate will appear in the gel for each antigen–antibody complex. In an assay in which two antigens are loaded in adjacent wells and an antibody in the third well, the following results can be observed:

- If the two antigens are identical, the two lines will become fused. This phenomenon is referred to as *identity*.
- If the two antigens are totally unrelated, the lines will cross each other but not fuse; this is known as *nonidentity*.
- If the two antigens are related (share a common epitope) but are not identical, the lines will merge with spur formation. The spurs are continuations of the line formed by the antigen due to its unique epitope. This phenomenon is known as *partial identity*.

Thus, in a species test, a positive result is noted when the precipitate lines for the positive controls and the samples fuse. No spur formation should be observed.

13.2.3 Crossed-Over Electrophoresis

This method is a combination of immunodiffusion and electrophoresis (also see Chapter 11). The procedure for the assay is described in Box 13.3. With this technique, a sharp precipitate band is visualized in a positive reaction (Figure 13.8). However, false-negative results can occur due to the postzone phenomenon, in which excess antigen may inhibit precipitation. In this

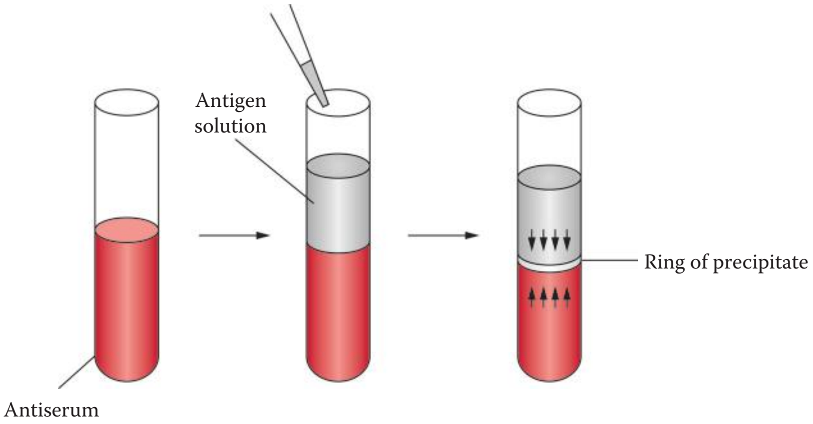

Figure 13.6 Ring assay. The antigen solution is carefully applied over the antiserum solution. Incubation may be necessary in order to form a ring of precipitate. (© Richard C. Li.)

BOX 13.1 RING ASSAY PROCEDURE

Sample preparation and extraction

- Extract a portion of a stain with saline at 4°C overnight.

Controls

- Include a positive control (known human serum sample) and a negative control (extraction blank).

Loading of antibody and samples

- Spin the antihuman antibody in a microfuge and transfer the supernatant into test tubes or capillary tubes (depending on the volume of the stain and the antiserum extracted).
- Place the sample carefully over the top of the antiserum solution, which is usually denser than the sample.

Immunodiffusion reaction

- Carry out the reaction at room temperature.
- In a positive reaction, white precipitate between the two layers can be observed after several minutes. This indicates that the sample is of human origin. No precipitate is formed if a bloodstain extract is from a nonhuman origin.

BOX 13.2 OUCHTERLONY ASSAY PROCEDURE

Sample preparation and extraction

- Cut out a small portion (approximately 5×5 mm) of a stain or a portion of a swab.
- Extract at room temperature in 100 μL of water for 30 min. The extract can be diluted if necessary. Alternatively, a very small piece of the stain or swab can be inserted directly into the well.

Controls

- Positive (known serum)
- Negative (extraction blank)
- Substrate controls (extraction of substrate from unstained area) if applicable

Agarose gel preparation

Heat a suspension of agarose (4%) until liquefied. Cool the solution in a water bath at 55°C. Pour the agarose onto a piece of glass slide and let the gel solidify to a thickness of about 2–3 mm. Alternatively, a polyester support film such as GelBond (Cambrex, New Zealand) can be used as a gel support. The agarose should be poured onto the hydrophilic side of a piece of GelBond film (6×9 cm). Punch wells consisting of a central well surrounded by four wells using a template.

Loading antibodies and samples

- Apply antihuman antibody to the central well. Apply the positive control to one of the surrounding wells.
- Apply the sample(s) in question next to a positive control.
- Apply negative and substrate controls to the remaining wells; only one negative control is needed per gel.

Immunodiffusion reaction

Incubate the plate overnight in a moisture chamber at 37°C.

Staining

Soak the gel overnight in saline solution and then soak it in deionized water for 10 min. Repeat once. Dry the gel between paper towels with a weight on top for 30 min. Dry in an oven for 30 min. Stain the gel with Coomassie blue. Stained precipitate bands appear blue.

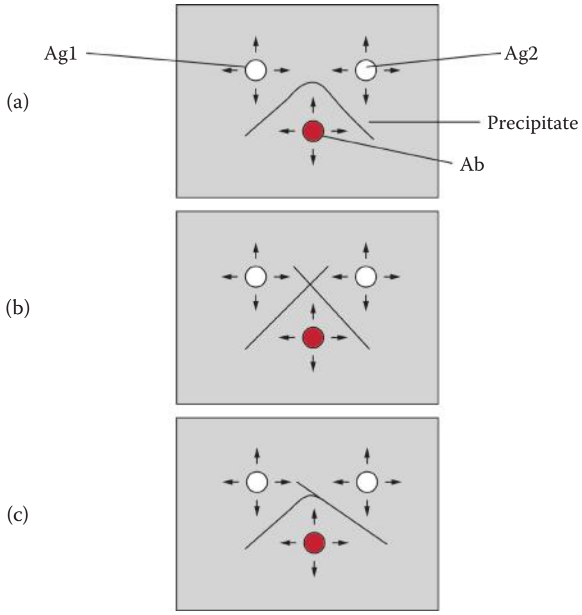

Figure 13.7 Results of Ouchterlony assay. Ab indicates an antibody. Ag1 and Ag2 are the antigen samples in question. (a) Identity. The two antigens are identical (fused line). (b) Nonidentity. The two antigens are unrelated (spur). (c) Partial identity. The two antigens are related but not identical (fused line with spur). (© Richard C. Li.)

situation, the sample can be diluted and the assay can be repeated. False-negative results can also occur due to simple mistakes made during electrophoresis:

- Electrophoresis is carried out in the opposite direction, which results in samples running off the gel.
- Electrophoresis is carried out using an incorrect buffer system, affecting antigen–antibody binding. The amount of current applied during the electrophoresis is too strong and generates heat and denatures proteins.

BOX 13.3 CROSSED-OVER ELECTROPHORESIS PROCEDURE

Sample preparation and extraction

- Cut out a small portion (~5 × 5 mm) of a stain or a portion of a swab.
- Extract at room temperature in 100 µL of water for 30 min. The extract can be diluted if necessary. Alternatively, a very small piece of the stain or swab can be inserted directly into the well.

Controls

- Positive (known serum)
- Negative (extraction blank)
- Substrate (extraction of substrate from unstained area) if applicable

Agarose gel preparation

Heat a suspension of agarose (4%) until liquefied. Cool the solution in a water bath at 55°C. Pour the agarose onto a piece of glass slide and let it solidify. Alternatively, a polyester support film such as GelBond can be used as a gel support. The agarose should be poured onto the hydrophilic side of a piece of GelBond (6 × 9 cm). Punch small wells (about 1–2 mm) in rows using a template.

Loading antibodies and samples

- Apply antihuman antibody in one row of wells.
- Apply samples in the other row of wells. Apply the positive, negative, and substrate controls.

Electrophoresis

Submerge the agarose gel in an electrophoresis tank in proper orientation. The wells containing antihuman antibody should be closest to the anode (positive electrode) and the wells containing samples should be closest to the cathode (negative electrode). During electrophoresis, the antibody in the antiserum should migrate toward the cathode while the antigen migrates toward the anode. Electrophoresis is carried out at 10 V/cm for 20 min.

Staining

Soak the gel overnight in a saline solution and then soak it in deionized water for 10 min. Repeat once. Dry the gel between paper towels with a weight on top for 30 min. Dry in an oven for 30 min. Stain the gel with Coomassie blue. Stained precipitate bands appear blue.

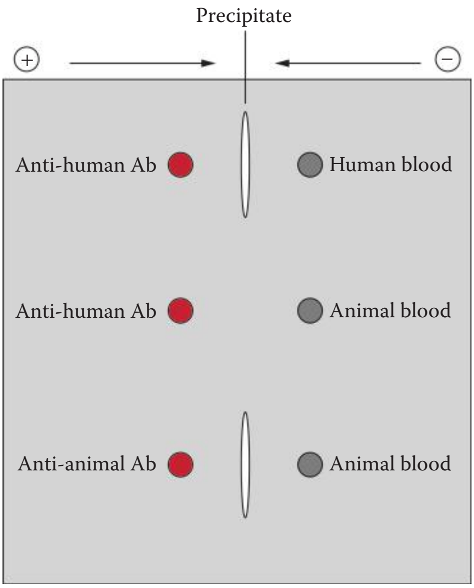

Figure 13.8 Results of crossed-over electrophoresis. A precipitate line is formed between a human blood sample and an antihuman antibody. No precipitate line is formed when the antihuman antibody is tested for an animal blood sample. A precipitate line is formed between the animal blood sample and the antianimal antibody. (© Richard C. Li.)

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14

Identification of Semen

14.1 Biological Characteristics

A typical ejaculation releases 2–5 mL of semen, which contains seminal fluid and sperm cells (*spermatozoa*). A normal sperm count ranges from 10^7 to 10^8 spermatozoa per milliliter of semen. The spermatozoa are formed from spermatogonia in the seminiferous tubules of the testes. This process of generating spermatozoa is referred to as spermatogenesis (Figure 14.1). The spermatozoa are then transported and stored in the tubular network of the epididymis where they undergo functional maturation (spermatogenesis and maturation take approximately 3 months). The epididymis joins the ductus deferens, which transports matured sperm from the epididymis to the ejaculatory duct. From there, spermatozoa follow the ejaculatory ducts into the prostatic urethra where they are joined with secretions from the prostate. Figure 14.2 illustrates the anatomy of the male reproductive system.

Seminal fluid is a complex mixture of glandular secretions. A typical sample of seminal fluid contains the combined secretions of several accessory glands. Seminal vesicle fluid accounts for approximately 60% of the ejaculate. Various proteins secreted by the seminal vesicles play a role in the coagulation of the ejaculate. Additionally, seminal vesicle fluid contains flavin, which causes semen to fluoresce under ultraviolet light, often utilized when searching for semen-stain evidence.

Prostatic fluid secretions account for approximately 30% of the ejaculate. The components of this fluid are complex as well. This portion of semen contains high concentrations of *acid phosphatase* (AP) and *prostate-specific antigen* (PSA). Both are useful markers for the identification of semen in forensic laboratories. The epididymis and the bulbourethral secretions each account for approximately 5% of the ejaculate.

A *vasectomy* is the surgical removal of a bilateral segment of the ductus deferens. The surgery prevents spermatozoa from reaching the distal portions of the male reproductive tract. However, a vasectomized male can still produce ejaculate that contains only seminal vesicle fluid, prostatic fluid, and bulbourethral fluid. The condition by which males have abnormally low sperm counts is known as *oligospermia*. *Azoospermia* is a condition that causes males to produce no spermatozoa. However, the secretion of seminal fluid is not affected in males who have these conditions. DNA derived from epithelial cells can be isolated from the seminal fluids of these individuals.

14.1.1 Spermatozoa

A human spermatozoon has three morphologically distinct structures: the head, the middle piece, and the tail (Figure 14.3). The head contains a nucleus with densely packed chromosomes. At the tip of the head is the *acrosomal cap*, which is a membranous compartment

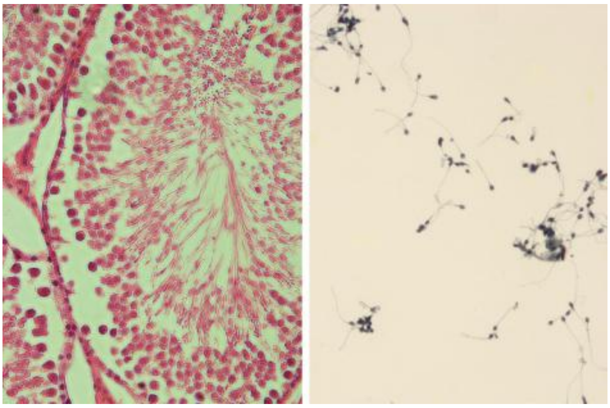

Figure 14.1 Spermatogenesis. In the seminiferous tubules (left) of the testes, spermatogonia (located at peripheral area of the seminiferous tubules) are differentiated to spermatids (located at the center of the seminiferous tubules). The spermatids are eventually differentiated to matured spermatozoa (right). (© Richard C. Li.)

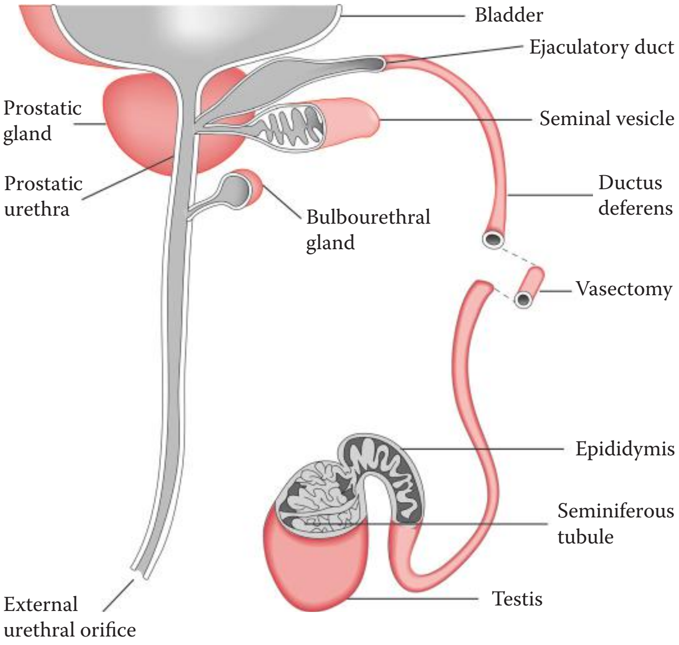
Bladder
Ejaculatory duct
Prostatic gland
Seminal vesicle
Prostatic urethra
Ductus deferens
Bulbourethral gland
Vasectomy
Epididymis
Seminiferous tubule
Testis
External urethral orifice

Figure 14.2 Male reproductive system and accessory glands (unilateral view). (© Richard C. Li.)

containing enzymes essential for fertilization. The head is attached to the middle piece through a short neck where the mitochondria that provide the energy for moving the tail are located. The tail or flagellum is responsible for spermatozoon motility. In contrast to other cell types, a mature spermatozoon lacks various intracellular organelles such as an endoplasmic reticulum, Golgi apparatus, lysosomes, and peroxisomes. In a normal male, at least 60% of spermatozoa have normal morphology, so morphological abnormalities can often be observed.

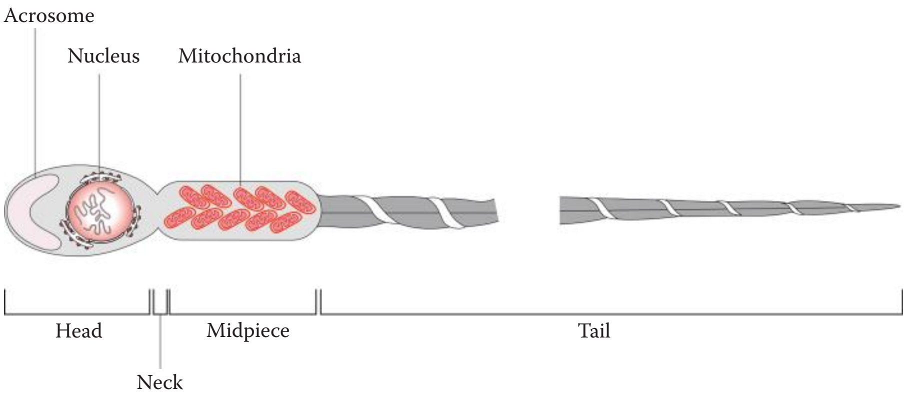

Figure 14.3 Structure of spermatozoon. (© Richard C. Li.)

14.1.2 Acid Phosphatase

Acid phosphatase (AP) consists of a group of phosphatases with optimal activity in an acidic pH environment. The greatest forensic importance of AP is that the prostate-derived AP contributes most of the AP activity present in semen. AP levels in semen are not affected by vasectomies. AP isoenzymes are also found in other tissues (Section 16.2).

The half-life of AP activity at 37°C is 6 months. However, the half-life is decreased if a sample is stored in a wet environment. AP activity can be detected from dry seminal stains stored at –20°C up to 1 year. Low levels of prostatic AP are present in the sera of healthy males. Elevated levels of prostatic AP found in serum are useful in diagnosing and monitoring prostate carcinoma. Many AP tests utilized in clinical testing may be used to identify semen for forensic applications.

14.1.3 Prostate-Specific Antigen

Prostate-specific antigen (PSA) is a major protein present in seminal fluid at concentrations of 0.5–2.0 mg/mL. PSA is produced in the prostate epithelium and secreted into the semen. PSA can also be found in the paraurethral glands, perianal glands, apocrine sweat glands, and mammary glands. Thus small quantities can be detected in urine, fecal material, sweat, and milk. PSA can also be found at much lower levels in the bloodstream. An elevated plasma PSA is present in prostate cancer patients, and it is widely used as a screening test for this disease. PSA is also elevated in cases of benign prostatic hyperplasia and prostatitis. The synthesis of PSA is stimulated by androgen, a steroid hormone.

PSA is a protein that has a molecular weight of 30 kDa and is thus also known as *P30*. It is responsible for hydrolyzing *semenogelin* (Sg), which mediates gel formation in semen (Section 14.1.4). PSA is a member of the tissue *kallikrein* (serine protease) family and is encoded by the *KLK3* locus located on chromosome 19. In addition to PSA, other tissue kallikreins encoded by *KLK2* and *KLK4* loci are expressed in the prostate. The half-life for PSA in a dried semen stain is about 3 years at room temperature. The half-life is greatly reduced when a sample is stored in wet conditions.

14.1.4 Seminal Vesicle–Specific Antigen

Human *seminal vesicle–specific antigen* (SVSA) includes two major types, semenogelin I (SgI) and semenogelin II (SgII), and constitutes the major seminal vesicle–secreted protein in semen. On ejaculation, SVSA forms a coagulum that is liquefied after a few minutes due to the degradation of SVSA by PSA. In humans, both SgI and SgII are present in a number of tissues of the male reproductive system, including the seminal vesicles, ductus deferens, prostate, and epididymis. They are also present in several other tissues such as skeletal muscle, kidney, colon, and trachea. They have also been found in the sera of lung cancer patients.

The use of Sg as a marker for semen identification instead of PSA presents certain advantages. The concentration of Sg in seminal fluid is much higher than that of PSA, and this is beneficial for the sensitivity of detection. Sg is present in seminal fluid and absent in urine, milk, and sweat, where PSA can be found. Although Sg compounds are present in skeletal muscle, kidney, and colon, this is not a great concern because these tissue samples are not routinely collected for semen detection in sexual assault cases.

14.2 Analytical Techniques for Identifying Semen

The location of semen stains is usually carried out through visual examination. Particularly, the application of alternate light sources (ALSs) can facilitate searches for semen stains. The presumptive identification of semen is largely based on the detection of the presence of prostatic AP activity in a sample. However, most presumptive assays cannot completely distinguish prostatic AP from nonprostatic AP. Confirmatory assays for the identification of semen are available, including the microscopic examination of spermatozoa, the identification of PSA and SVSA, and the RNA-based assay.

14.2.1 Presumptive Assays

14.2.1.1 Lighting Techniques for Visual Examination of Semen Stains

Lighting techniques can be used to aid in searching for semen stains. A dried semen stain fluoresces under certain light sources such as ALSs or argon lasers. ALSs are most commonly utilized for the visual examination of semen stains (Chapter 1; Figures 14.4 and 14.5). Excitation wavelengths between 450 and 495 nm can be used, allowing for the visualization of fluorescence with orange goggles. However, this approach is not specific for semen. Other bodily fluid stains, such as saliva and urine stains, can also fluoresce with less intensity. Additionally, the intensity of the fluorescence can be affected by different colors of substrates, and the material, such as clothing, where semen stains have been deposited.

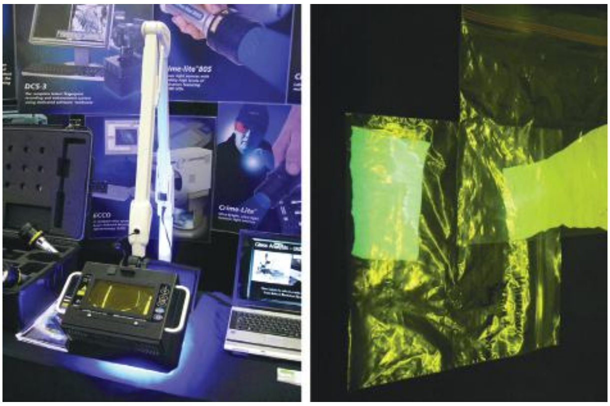

Figure 14.4 A tabletop ALS device (left) for the detection of semen stains (right). (© Richard C. Li.)

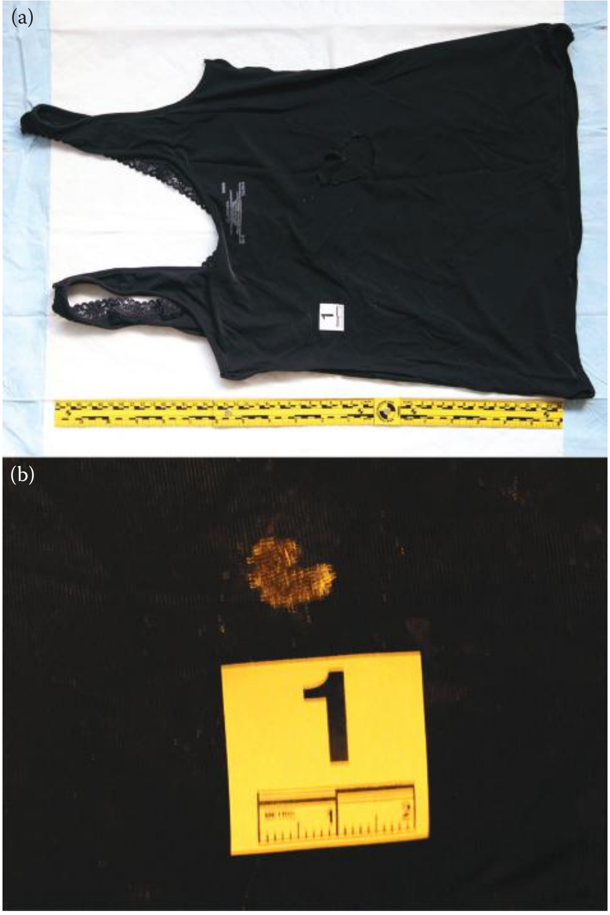

Figure 14.5 Examining a garment for semen stains. (a) A potential semen stain (labeled) is found on a garment, and (b) the stain fluoresces when irradiated with an ALS device. (© Richard C. Li.)

14.2.1.2 Acid Phosphatase Techniques

14.2.1.2.1 Colorimetric Assays

Colorimetric assays can be used for the presumptive identification of semen. The AP contained in semen can hydrolyze a variety of phosphate esters. It catalyzes the removal of the phosphate group from a substrate (Figure 14.6). Subsequently, an insoluble colored precipitate at sites of acid phosphatase activity is formed with a stabilized diazonium salt (usually in the form of zinc double salts).

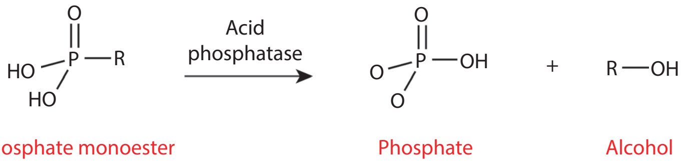

Figure 14.6 Reaction catalyzed by acid phosphatases (EC 3.1.3.2). The optimal pH of the reaction is usually under pH 7.

However, interference during a test by nonprostatic AP isoenzymes (multiple forms of AP), such as contamination by AP commonly present in vaginal secretions (Chapter 16), can create problems in specimens collected from victims. Thus, it is desirable to be able to increase the specificity of the assay for prostatic AP. One solution is the application of substrates that are hydrolyzed rapidly by the prostatic enzyme and at a slower rate by the other forms of AP isoenzymes. For example, α-naphthylphosphate and thymolphthalein monophosphate are more specific to prostatic AP than phenyl phosphate and 4-nitrophenyl phosphate (Figure 14.7). The most common method for forensic applications is the use of α-naphthyl phosphate as a substrate. In the presence of AP, α-naphthylphosphate is hydrolyzed to phosphate and α-naphthol. Subsequently, the Fast Blue B, a stabilized diazonium salt, is added to carry out an azo coupling reaction, producing a purple azo dye (Figures 14.8 through 14.10).

Prostatic AP is water soluble. Thus, a moistened cotton swab or piece of filter paper can be used to transfer a small amount of sample from a stain by briefly pressing onto the questioned stain area. The α-naphthylphosphate reagent is added to the swab or filter paper followed by the addition of Fast Blue B reagent. If a purple coloration develops within 1 min, the test is considered a positive indication for semen. Color that develops after more than 1 min may arise from the activity of nonprostatic AP.

Additionally, the prostatic enzyme is strongly inhibited by dextrorotatory tartrate ions. Thus, these inhibitors, particularly tartrate, allow a distinction to be made between prostatic AP and other AP isoenzymes. Prostate and vaginal acid phosphatase can also be distinguished by using gel electrophoresis (Chapter 16).

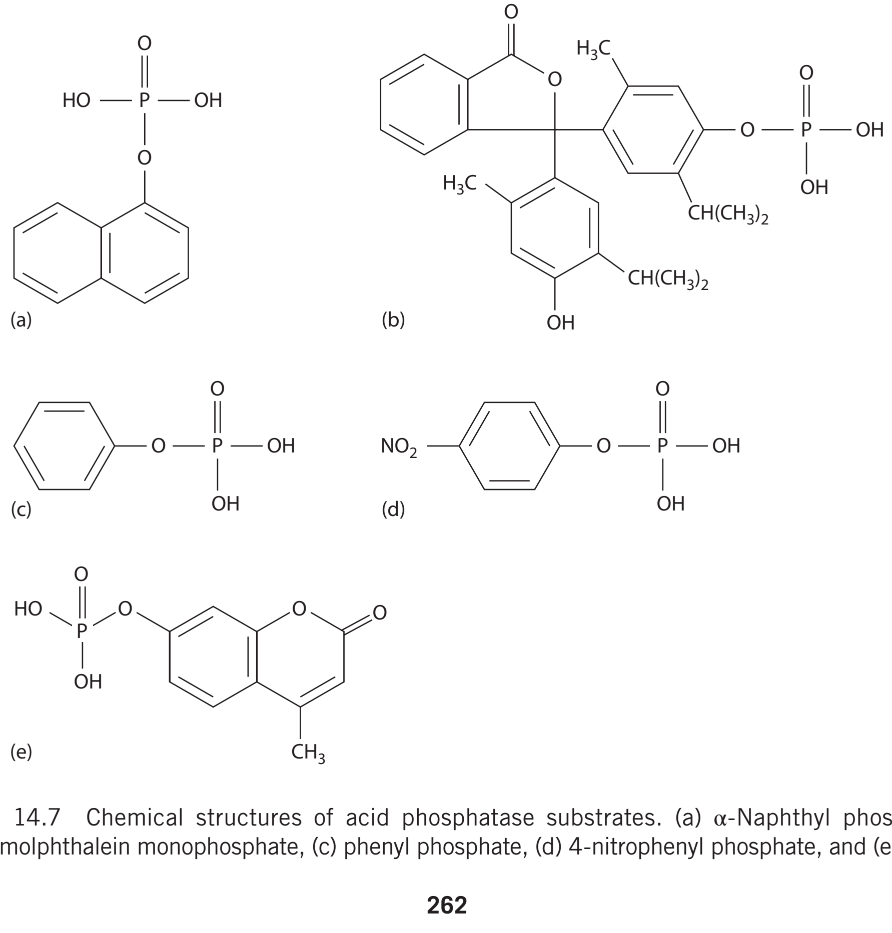

Figure 14.7 Chemical structures of acid phosphatase substrates. (a) α-Naphthyl phosphate, (b) thymolphthalein monophosphate, (c) phenyl phosphate, (d) 4-nitrophenyl phosphate, and (e) MUP.

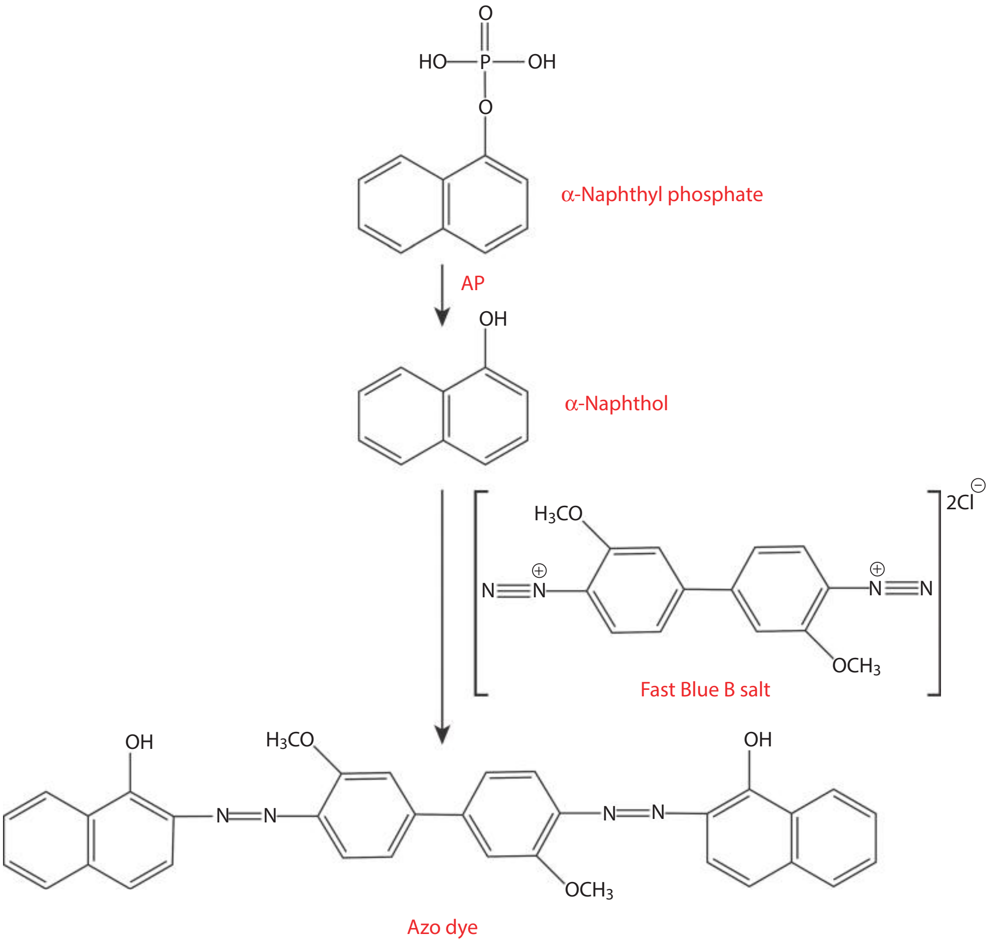

Figure 14.8 A colorimetric acid-phosphatase assay. In this assay, α-naphthylphosphate is hydrolyzed by acid phosphatase to phosphate and α-naphthol. The α-naphthol is subsequently converted into a purple azo dye with a diazonium salt such as Fast Blue B salt. AP, acid phosphatase.

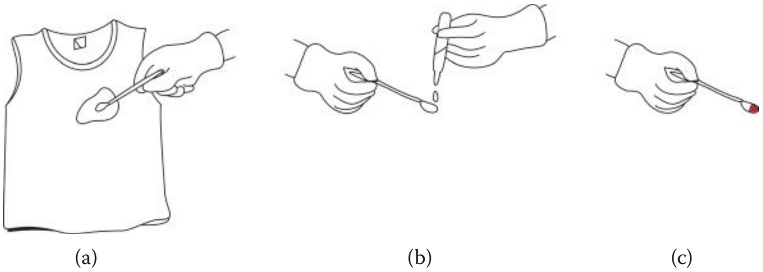

Figure 14.9 AP colorimetric assay. (a) A small amount of sample from the stain is transferred using a moistened cotton swab. (b) The substrate reagent is applied, followed by adding Fast Blue B reagent. (c) Purple coloration indicates a positive reaction. (© Richard C. Li.)

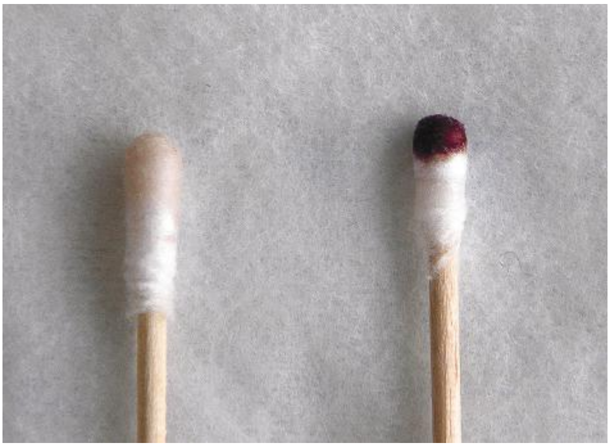

Figure 14.10 Photo of a colorimetric acid-phosphatase assay using α-naphthylphosphate as a substrate. (© Richard C. Li.)

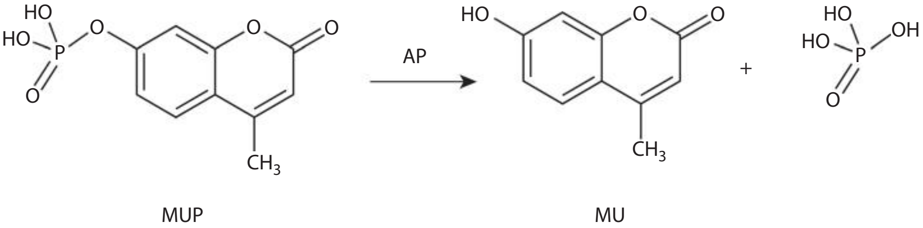

Figure 14.11 The principle of MUP assay for detecting acid phosphatase activity. In the presence of acid phosphatase, 4-methylumbelliferone phosphate (MUP) is hydrolyzed, forming phosphate and 4-methylumbelliferone (MU), which fluoresces. AP, acid phosphatase.

14.2.1.2.2 Fluorometric Assays

Fluorometric methods are more sensitive than the colorimetric detection of AP and are used for semen stain mapping. AP catalyzes the removal of the phosphate residue on a 4-methylumbelliferone phosphate (MUP) substrate (Figure 14.11), a reaction that generates fluorescence under ultraviolet light. A piece of moistened filter paper, marked for proper orientation and identification, is used for transferring the prostatic AP. The evidence to be tested, a garment for example, is covered by the filter paper. Gloved hands are used to press the filter paper onto the stained area, ensuring that the evidence is in close contact with the paper. The filter paper is lifted from the evidence and examined in a dark room using long-wave ultraviolet light to detect any background fluorescence, which is then marked on the paper. The paper can then be sprayed with MUP reagent in a fume hood. The AP reaction on the paper can be visualized immediately. Areas where semen is present can be visualized as fluorescent areas on the filter paper (Figure 14.12).

14.2.2 Confirmatory Assays

14.2.2.1 Microscopic Examination of Spermatozoa

The cells from a questioned stain on an absorbent material can be transferred to a microscope slide by extracting a small portion of a stain with water, followed by gentle vortexing. The suspension is then transferred to a slide and evaporated at room temperature or fixed with low heat. Alternatively, it can be transferred by dampening the stain with water and rubbing or rolling it onto a microscope slide.

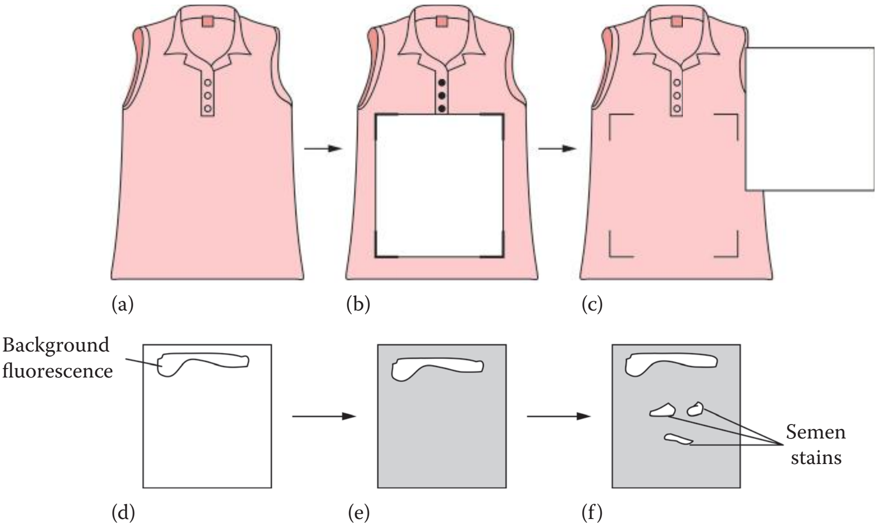

Figure 14.12 Fluorometric assay of acid phosphatase for locating semen stains. Evidence item (a) is closely covered by a piece of moistened filter paper (b) to allow transfer of a small amount of stain. The orientation of the paper is marked (c). The paper is lifted. The background fluorescence is marked under UV light (d). The filter paper is treated with MUP (e). The presence of fluorescence under ultraviolet light indicates semen stains (f). (© Richard C. Li.)

Microscopic identification of spermatozoa provides the proof of a seminal stain. Histological staining can facilitate microscopic examination. The most common staining technique is the *Christmas tree stain* (Figure 14.13). The red component known as Nuclear Fast Red (NFR) is a dye used for staining the nuclei of spermatozoa in the presence of aluminum ions. The green component, picroindigocarmine (PIC), stains the neck and tail portions of the sperm. The acrosomal cap and the nucleus stain pink-red, and the sperm tails and the midpiece stain blue-green. Epithelial cells, if present in the sample, appear blue-green and have red nuclei. Additionally, fluorescent detection utilizing SPERM HY-LITER Fluorescent Staining Kit can facilitate the identification of spermatozoa.

Laser capture microdissection (LCM) has been shown to be an effective technique for separating spermatozoa from nonsperm cells (i.e., epithelial cells from the victim) on a glass slide (Figure 14.14). This technique involves using a thin layer of a thermosensitive polymer that is placed on the surface of an LCM cap. Once spermatozoa are identified on the slide under a microscope, a polymer-containing LCM cap is placed over the spermatozoa on the slide. An infrared laser melts the polymer and causes it to adhere only to the targeted spermatozoa. The spermatozoa are then lifted off the slide. This allows spermatozoa to be separated and placed into snap-cap tubes for forensic DNA analysis.

14.2.2.2 Identification of Prostate-Specific Antigen

Over the years, a number of methods have been utilized to detect PSA: immunodiffusion, immunoelectrophoresis, enzyme-linked immunosorbent assay (ELISA), and immunochromatographic assays. ELISA and immunochromatographic assays have been found to be the most sensitive methods (Chapter 11).

14.2.2.2.1 Immunochromatographic Assays

Commercially produced immunochromatographic kits such as the PSA-check-1 (VED-LAB, Alencon), Seratec® PSA Semiquant (Seratec Diagnostica, Göttingen), and One Step ABAcard

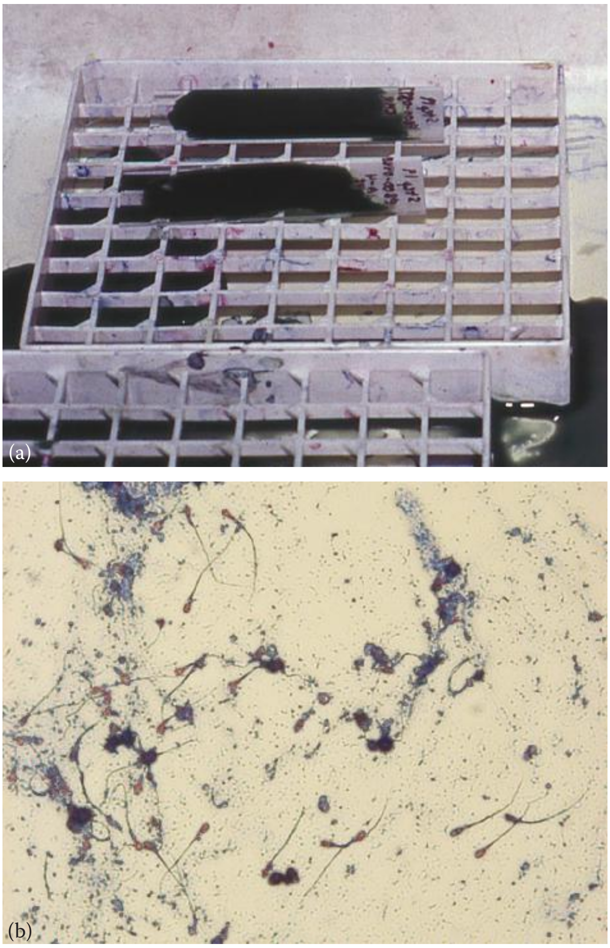

Figure 14.13 Human spermatozoa stained with Christmas tree stain. (a) Staining spermatozoa on a microscope slide and (b) stained spermatozoa. (© Richard C. Li.)

Figure 14.14 A microscopic device for fluorescent detection utilizing SPERM HY-LITER Fluorescent Staining Kit (left) and a laser-capture microdissection device for separating sperm cells from other types of cells (right). (© Richard C. Li.)

PSA® (Abacus Diagnostics, California) are available. These devices utilize antihuman PSA antibodies. In the ABAcard PSA® assay, a labeled monoclonal antihuman PSA antibody is contained in a sample well, a polyclonal antihuman PSA antibody is immobilized on a test zone of a nitrocellulose membrane, and an antiglobulin that recognizes the antibody is immobilized on a control zone (Figures 14.15 and 14.16).

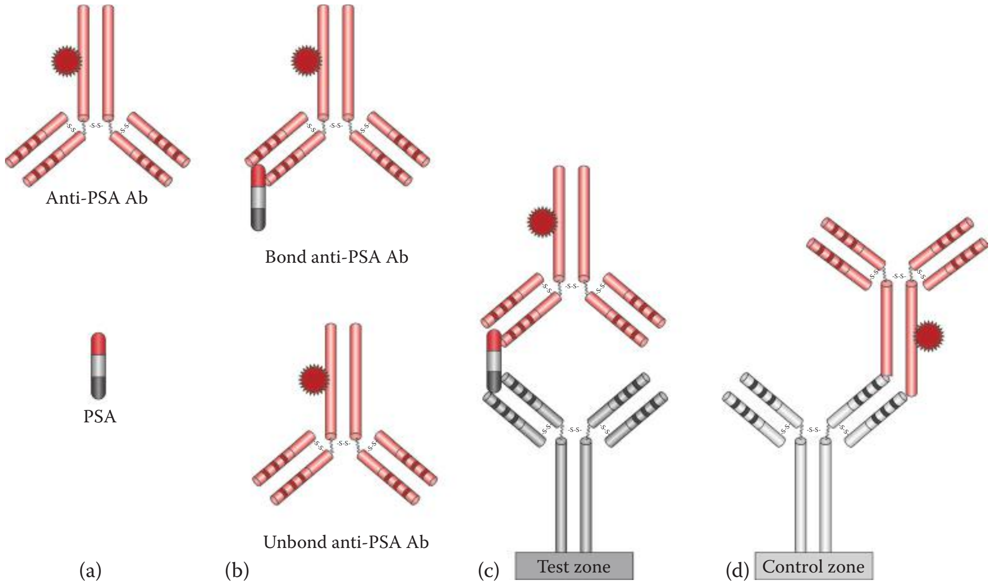

Figure 14.15 Immunochromatographic assays for identification of PSA in semen. (a) In a sample well, PSA in a semen sample is mixed with labeled anti-PSA Ab. (b) The PSA binds to the labeled anti-PSA Ab to form a labeled Ab–PSA complex. (c) At the test zone, the labeled complex binds to an immobilized anti-PSA Ab to form a labeled Ab–PSA–Ab sandwich. (d) At the control zone, the labeled anti-PSA Ab binds to an immobilized antiglobulin and is captured at the control zone. Ab and PSA represent antibody and prostate-specific antigen, respectively. (© Richard C. Li.)

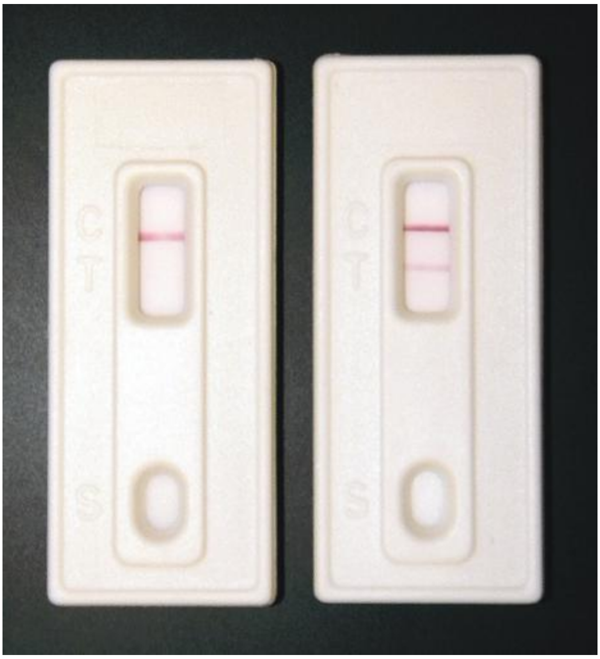

Figure 14.16 Semen identification using an immunochromatic device (ABAcard PSA). The negative (left) and positive (right) results are shown. The “C” band indicates that the test is valid. The “T” band indicates the presence of human blood. The sample well is labeled as “S”. (© Richard C. Li.)

The assay is carried out by loading an extracted sample into the sample well. The antigen in the sample binds to the labeled antibody in the sample well to form an antigen–antibody complex. The complex then diffuses across the nitrocellulose membrane. At the test zone, the immobilized antihuman PSA antibody binds with the antigen–antibody complex to form an antibody–antigen–antibody sandwich. The ABAcard PSA® uses a pink dye that allows for the visualization of a positive test with a pink line at the test zone. In the control zone, unbound labeled antihuman PSA antibody binds to the immobilized antiglobulin. This antibody–antiglobulin complex at the control zone also results in a pink line. The test is considered valid only if the line in the control zone is observed.

The presence of human PSA results in a pink line at both the test and control zones. The absence of human PSA produces a pink line in the control zone only. A positive result can appear within 1 min; a negative result is read after 10 min. However, the high-dose hook effect, an artifact that may cause false-negative results (Chapter 10), occurs when high quantities of seminal fluid are tested.

14.2.2.2.2 ELISA

The ELISA method can be used to detect PSA with anti-PSA antibodies. The most common method used in forensic serology is antibody sandwich ELISA, in which an antibody–antigen–antibody sandwich complex is formed (Figure 14.17). The intensity of the signal can be detected and is proportional to the amount of bound antigen. The amount of PSA can also be quantified by comparing a standard with known concentrations. Although this method is specific and highly sensitive, it is time-consuming. Chapter 11 discusses the principle of ELISA in further detail.

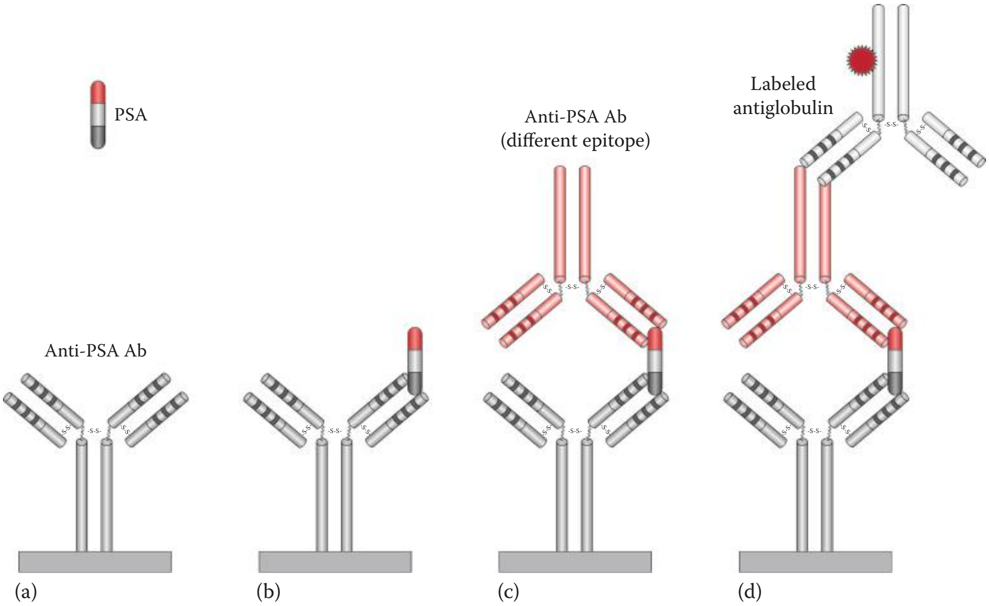

Figure 14.17 Use of ELISA for identification of PSA in semen. (a) Sample containing PSA is applied to polystyrene tubes in which anti-PSA Ab is immobilized. (b) The PSA binds to immobilized Ab to form a PSA–Ab complex. (c) A second anti-PSA Ab, specific for a different epitope of PSA, is added to form an Ab–PSA–Ab sandwich. (d) A labeled antiglobulin then binds to the Ab–PSA–Ab sandwich. The bound antiglobulin can be detected by various reporting schemes. Ab and PSA represent antibody- and prostate-specific antigen, respectively. (© Richard C. Li.)

14.2.2.3 Identification of Seminal Vesicle–Specific Antigen

14.2.2.3.1 Immunochromatographic Assays

Commercially produced immunochromatographic kits include the RSID®-Semen test (Independent Forensics, Hillside, IL) and the Nanotrap Sg. In the RSID®-Semen assay, a labeled monoclonal anti-Sg antibody is contained in a sample well, and a second monoclonal anti-Sg antibody, to a different epitope of Sg, is immobilized on the test zone of the membrane. An antiglobulin that recognizes the antibody is immobilized on a control zone (Figure 14.18).

The sample can be prepared by cutting a small portion of a stain or a swab and is extracted for 1–2 h in an extraction buffer (200–300 μL). Approximately 10% of the extract is removed and mixed with the running buffer. The assay is carried out by loading an extracted sample into the sample well. The antigen in the sample binds to the labeled anti-Sg antibody in the sample well to form a labeled antibody–antigen complex that then diffuses across the membrane. At the test zone, the solid-phase anti-Sg antibody binds with the labeled complex to form a labeled antibody–antigen–antibody sandwich. The antigen in the sample produces a pink line at the test zone. In the control zone, unbound labeled anti-Sg antibody binds to the solid-phase antiglobulin. This labeled antibody–antiglobulin complex at the control zone also results in a pink line. The presence of Sg generates a pink line at both the test and control zones. The absence of Sg results in a pink line in the control zone only. Results may be read after 10 min.

Validation studies have revealed that the sensitivity of the RSID-Semen kit for detecting seminal fluid can be as low as a 5×10^4-fold dilution. Species specificity studies have shown no cross-reactivity with various animal species including ruminants and small mammals. Bodily fluid specificity studies have also shown that the assay is not responsive to human blood, saliva,

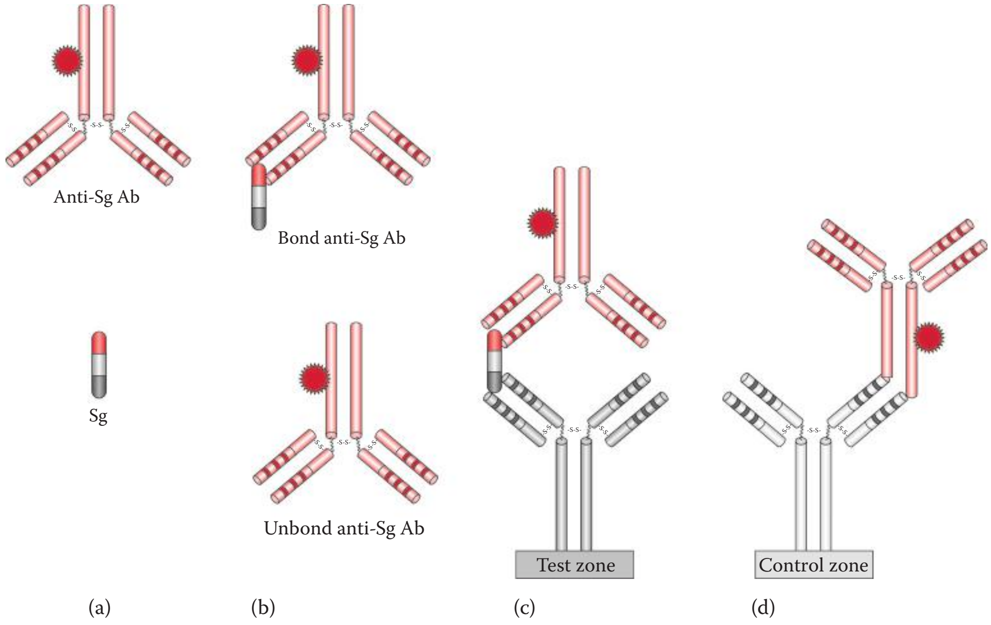

Figure 14.18 Immunochromatographic assays for identification of semenogelin (Sg) in semen. (a) In a sample well, Sg in a semen sample is mixed with labeled anti-Sg Ab. (b) Sg binds to the labeled anti-Sg Ab to form a labeled Ab–Sg complex. (c) At the test zone, the labeled complex binds to an immobilized anti-Sg Ab to form a labeled Ab–Sg–Ab sandwich. (d) At the control zone, the labeled anti-Sg Ab binds to an immobilized antiglobulin and is captured at the control zone. Ab represents antibody. (© Richard C. Li.)

urine, sweat, fecal matter, milk, or vaginal secretions. The assay results are not affected by condom lubricants or spermicides such as nonoxynol-9 and menfegol. However, the high-dose hook effect occurs when more than 3 μL of seminal fluid is tested.

14.2.2.3.2 ELISA

Identification of Sg for semen detection has also been carried out with ELISA. Anti-Sg antibodies are utilized. An antibody–antigen–antibody sandwich complex is formed (Figure 14.19). The intensity of the colorimetric or fluorometric signals can be detected spectrophotometrically and is proportional to the amount of bound antigen. The amount of Sg can be quantified by comparing a standard with known concentrations.

14.2.2.4 RNA-Based Assays

RNA-based assays (Chapter 11) have been developed to identify semen. The assays are based on the expression of certain genes in certain cell or tissue types. Thus, the techniques used in the identification of semen are based on the detection of specific types of mRNA expressed exclusively in spermatozoa and in certain cells of male accessory glands. These assays utilize reverse transcriptase polymerase chain reaction (RT-PCR; see Chapter 7) methods to detect gene expression levels of mRNAs for semen identification. Table 14.1 lists the tissue-specific genes utilized for semen identification. Compared to conventional assays used for semen identification, the RNA-based assay has higher specificity and is amenable to automation. However, one limitation is that the RNA is unstable due to degradation by endogenous ribonucleases.

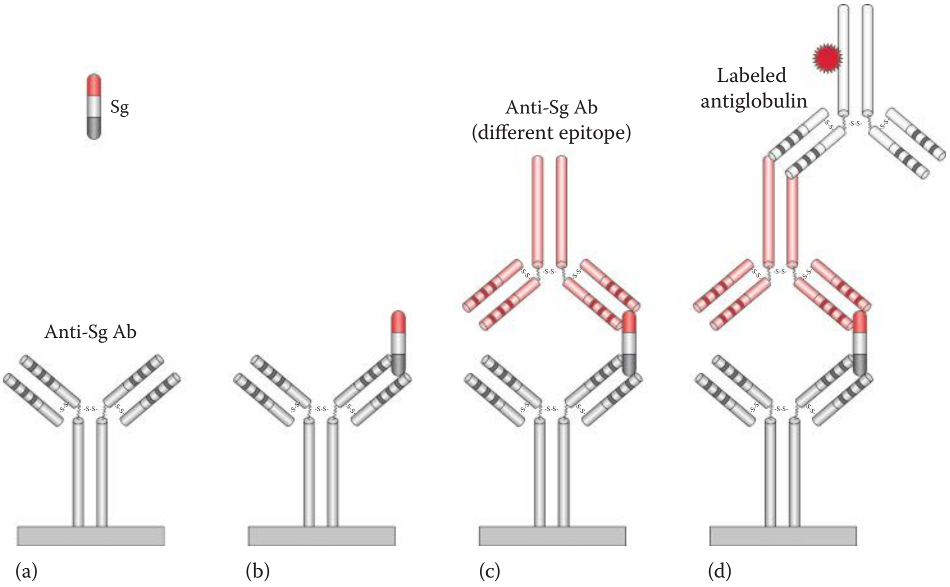

Figure 14.19 Use of ELISA for identification of semenogelin (Sg) in semen. (a) Sample containing Sg is applied to polystyrene tubes in which anti-Sg Ab is immobilized. (b) Sg binds to immobilized Ab to form a Sg–Ab complex. (c) A second anti-Sg Ab, specific for a different epitope of Sg, is added to form an Ab–Sg–Ab sandwich. (d) A labeled antiglobulin then binds to the Ab–Sg–Ab sandwich. The bound antiglobulin can be detected by various reporting schemes. Ab represents antibody. (© Richard C. Li.)

Table 14.1 Application of RT-PCR for Semen Identification

Gene Symbol	Gene Product	Description	Further Reading
KLK3	Kallikrein 3	Also called prostate-specific antigen (PSA)	Gelmini et al. (2001)
PRM1	Protamine 1	DNA-binding proteins involved in condensation of sperm chromatin	Steger et al. (2000)
PRM2	Protamine 2	DNA-binding proteins involved in condensation of sperm chromatin	Steger et al. (2000)

Source: Adapted from Juusola, J. and Ballantyne, J., *Forensic Sci Int*, 152, 1–12, 2005; Nussbaumer, C., Gharehbaghi-Schnell, E., and Korschineck, I., *Forensic Sci Int*, 157, 181–186, 2006.

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15

Identification of Saliva

15.1 Biological Characteristics of Saliva

The human salivary glands produce 1.0–1.5 L of saliva daily. About 70% of saliva is produced from the submandibular salivary glands, 25% from the parotids, and 5% from the sublingual salivary glands (Figure 15.1). Although a continuous basal level of saliva secretion is maintained, a large amount of saliva is produced during eating. Saliva is largely water containing small quantities of electrolytes, proteins, antibodies, and enzymes. The digestion of carbohydrates in the diet begins in the oral cavity, where amylase in the saliva breaks down carbohydrates such as starch. Thus, detecting amylase indicates the presence of saliva.

15.1.1 Amylases

Amylases are enzymes that cleave polysaccharides such as starches, which are composed of D-glucose units connected by α1→4 linkages. Starches contain two types of glucose polymers: *amylose* and *amylopectin* (Figure 15.2). Amylose consists of long, linear chains of glucose residues connected by α1→4 linkages. Amylopectin is highly branched and consists of linear chains of glucose residues connected by α1→4 linkages with the branch points connected by α1→6 linkages. Both linear amylose and amylopectin can be hydrolyzed by amylase by cleaving the chains at alternate α1→4 linkages. Amylase cleaves off one maltose (two glucose units) at a time. However, the α1→6 linkages at the branch points are not cleaved by the amylase.

Two types of amylases are characterized. β-*Amylases* found in plant and bacterial sources cleave only at the terminal reducing end of a polysaccharide chain. The end of a chain with a free anomeric carbon (not involved in a glycosidic bond) is called the reducing end. Human α-*amylases* cleave at α1→4 linkages randomly along the polysaccharide chain.

Human α-amylases have two major isoenzymes (multiple forms that differ in their amino acid sequences). Human *salivary* α-*amylase* (HSA) is encoded by the *Amy1* locus, synthesized at the salivary glands and secreted into the oral cavity. Human *pancreatic* α-amylase (HPA), encoded by the *Amy2* locus, is synthesized by the pancreas and secreted into the duodenum through the pancreatic duct. The amino acid sequences of the HSA and HPA are highly homologous. Therefore, monoclonal antibodies against HSA also cross-react with HPA. However, HSA is inactivated by acids in the stomach, while most HPA is inactivated in the lower portions of the intestine, and some amylase activity remains in the feces.

Amylase activity is found in various bodily fluids including semen, tears, milk, perspiration, and vaginal secretions. Most amylase present in normal serum consists of HPA and HSA. The amylases are small molecules and can pass through the glomeruli of the kidney (Chapter 17).

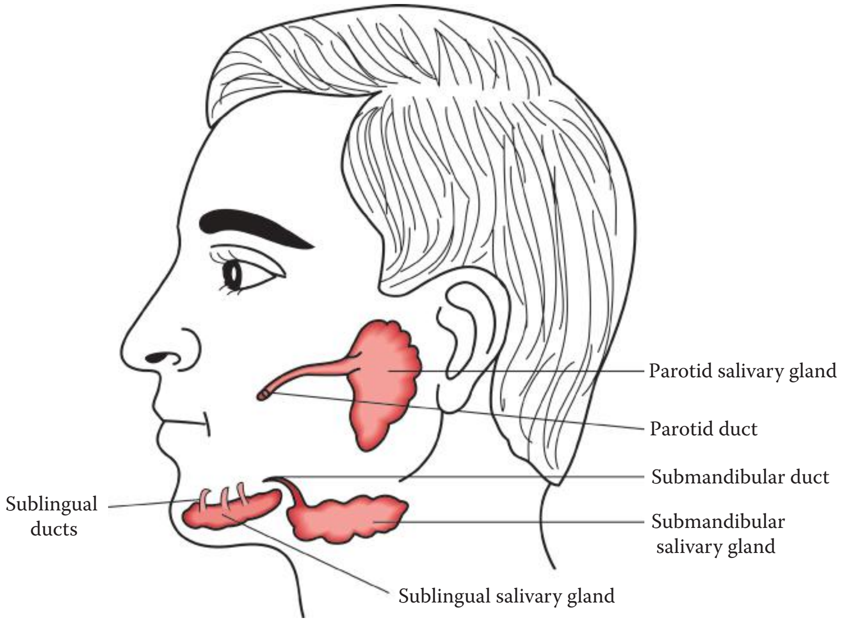
Parotid salivary gland
Parotid duct
Submandibular duct
Submandibular salivary gland
Sublingual ducts
Sublingual salivary gland

Figure 15.1 Human salivary glands. (© Richard C. Li.)

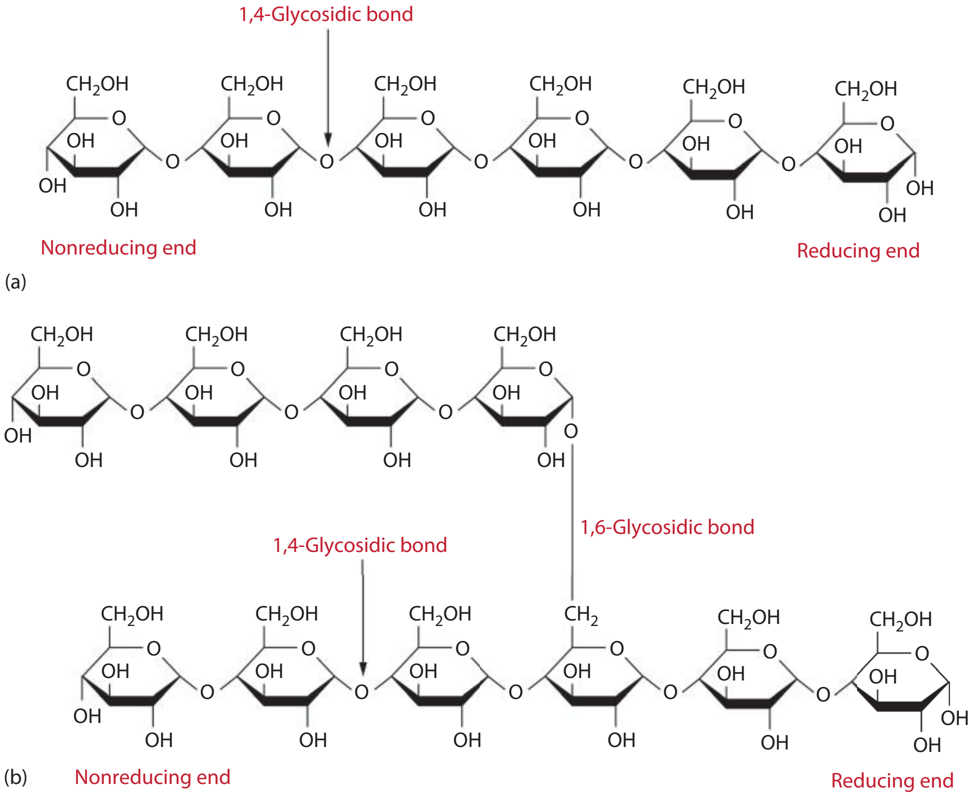
1,4-Glycosidic bond
CH_2OH
O
OH
Nonreducing end
Reducing end
(a)
1,6-Glycosidic bond
1,4-Glycosidic bond
CH_2
(b)
Nonreducing end
Reducing end

Figure 15.2 Chemical structures of polysaccharides found in starch: (a) amylose and (b) amylopectin.

Thus, the amylase present in urine is derived from plasma. Amylase can be inactivated under boiling temperatures and strong acidic and alkaline conditions. Based on various studies, its stability varies from a few weeks to several months.

15.2 Analytical Techniques for Identification of Saliva

The use of alternate light sources facilitates the search for and the visual examination of saliva stains. The identification of saliva is largely based on detecting the presence of amylase in a sample. Two types of amylase assays can be utilized. The first type measures the enzymatic activity of total amylase. This type of assay cannot distinguish HSA from other amylases including HPA and nonhuman amylases, such as those from plants, animals, and microorganisms. The second type of assay, which includes direct detection of HSA proteins and RNA-based assays, is more confirmatory than enzymatic assays.

15.2.1 Presumptive Assays

15.2.1.1 Visual Examination

The lighting techniques used to search for semen stains can be utilized in searching for saliva stains. For example, a 470 nm excitation wavelength can be used with orange goggles to allow visualization of fluorescence. However, the fluorescence of a saliva stain is usually less intense than that of a seminal stain (Figure 15.3). Microscopic examination with proper histological staining can also be performed to identify the buccal epithelial cells, indicating the presence of a saliva stain (Figure 15.4).

15.2.1.2 Determination of Amylase Activity

15.2.1.2.1 Starch–Iodine Assay

Iodine (I_2) is used to test for the presence of starch. The amylose in starch reacts strongly with iodine to form a dark blue complex, while amylopectin develops a reddish-purple color. In the presence of amylases, starch is broken down to mono- or disaccharides. Consequently, such colors do not develop when iodine is added.

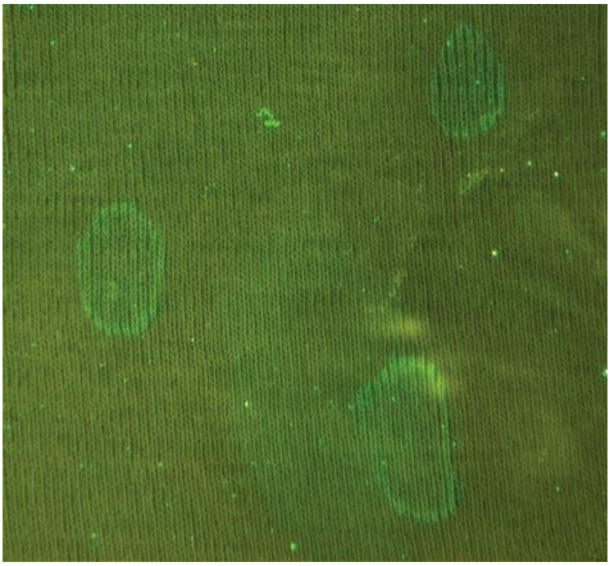

Figure 15.3 Examining saliva stains using an ALS technique. (© Richard C. Li.)

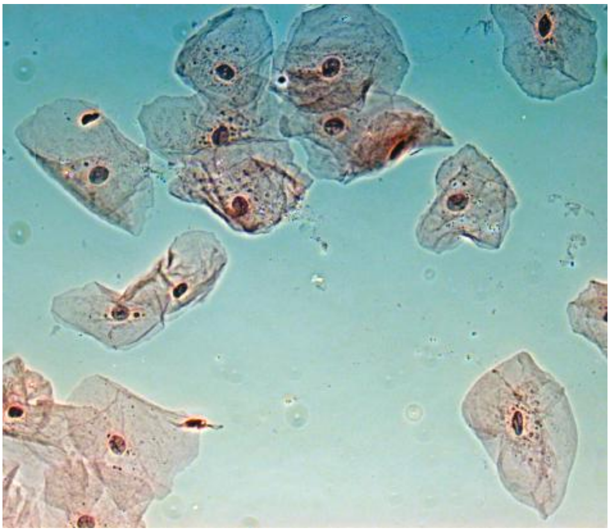

Figure 15.4 Buccal epithelial cells. (© Richard C. Li.)

A common configuration of the method is the radial diffusion assay (Figure 15.5). An agar gel containing starch is prepared. A sample well is created by punching a hole in the gel and an extract of the questioned sample is placed into the well. If amylase is present in the sample, it diffuses from the sample well and hydrolyzes the starch in the gel. The gel is then stained using an iodine solution. A clear area in the gel indicates amylase activity, and the size of the clear area is proportional to the amount of amylase in the sample. A linear standard curve

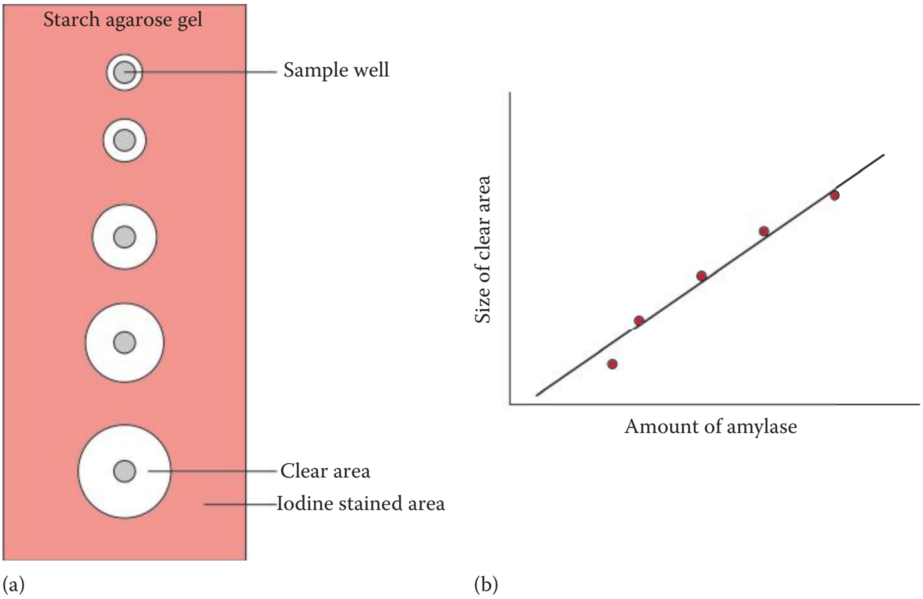

Figure 15.5 Radial diffusion assay for the identification of amylase. (a) Known amounts of amylase standards are applied to the well and allowed to diffuse. (b) The size of the clear area arising from amylase activity is plotted. The standard curve can be used to determine the amount of amylase in a questioned sample. (© Richard C. Li.)

(in log scale) can be prepared using a series of standard amylases with known concentrations. The amount of amylase can be quantified by comparing the results with the standard curve. However, this assay is not specific to HSA and can produce false-positive results. Moreover, the quantities of amylase can be used for determining the amount of sample needed for Y-STR analysis (Chapter 19), which now can be determined by using Y-chromosome-specific quantitative PCR assays (Chapter 6).

15.2.1.2.2 Colorimetric Assays

Dye-labeled amylase substrates such as dye-conjugated amylose or amylopectin are utilized. These substrates are not soluble in water. In the presence of amylase, the dye-containing moieties are cleaved and are soluble in water to produce a color. The degree of coloration, which can be measured colorimetrically by spectrophotometric methods, is proportional to the amount of amylase in the sample. Most of these assays are not HSA specific, although their specificity can be tested by using inhibitors that preferentially inhibit HSA, such as α-amylase inhibitors derived from the seeds of the wheat plant, *Triticum aestivum*. These amylase activity assays are considered presumptive, which means they are not conclusive for the presence of saliva in a sample.

While many substrates are available, Phadebas reagent (Pharmacia) is usually used in forensic laboratories. Produced in a tablet form, it is used to detect α-amylase in specimens for clinical diagnostic purposes. A small portion (approximately 3 mm^2) of a sample is cut and placed in a tube and incubated for 5 min at 37°C. One Phadebas tablet is added to each tube and mixed. Samples are then incubated for 15 min at 37°C, and the reaction is stopped at an alkaline pH by the addition of sodium hydroxide. The amylase substrate is an insoluble blue dye conjugated to starch. Amylase hydrolyzes the substrate to generate a blue color that can be measured at 620 nm using a spectrophotometer. The optical density of the supernatant is read and can be converted to amylase units by comparing to a standard curve.

The amylase assay can also be used for amylase mapping as a method of searching for possible saliva stains (Figures 15.6 and 15.7). These assays are based on the principle that amylase is water soluble and can be transferred from evidence to filter paper and then analyzed via colorimetric assay. This procedure is also referred to as a *press test*. The sensitivity of the method is similar to that of the test tube method.

The substrate can be prepared by evenly spraying the Phadebas reagent on a sheet of filter paper and allowing it to air-dry. The dried substrate-containing paper can be used immediately or stored until needed. To perform amylase mapping, a piece of paper is placed over the entire area to be tested (the item to be tested must be fairly flat to ensure good contact with the paper). The paper is dampened slightly by spraying with distilled water. An outline may be drawn on the paper to aid in locating stains. A piece of plastic wrap is placed on top to prevent the paper from drying during the assay, and a weight is applied to ensure close contact of substrate and evidence. The test is observed every minute for the first 10 min, and every 5 min thereafter up to 40 min, when a positive reaction should appear as a light blue area.

The SALIgAE® kit (Abacus Diagnostics), another commercially available colorimetric assay, has been validated for saliva identification (Figure 15.8). Its manufacturer also produces the SALIgAE spray kit, which can be used for amylase mapping.

15.2.2 Confirmatory Assays

15.2.2.1 Identification of Human Salivary α-Amylase

15.2.2.1.1 Immunochromatographic Assays

Commercially produced immunochromatographic kits include the RSID®-Saliva kit (Independent Forensics). A labeled monoclonal anti-HSA antibody is contained in a sample well. A second monoclonal anti-HSA antibody is immobilized onto a test zone of a membrane, and an antiglobulin that recognizes the antibody is immobilized onto a control zone (Figures 15.9 and 15.10).

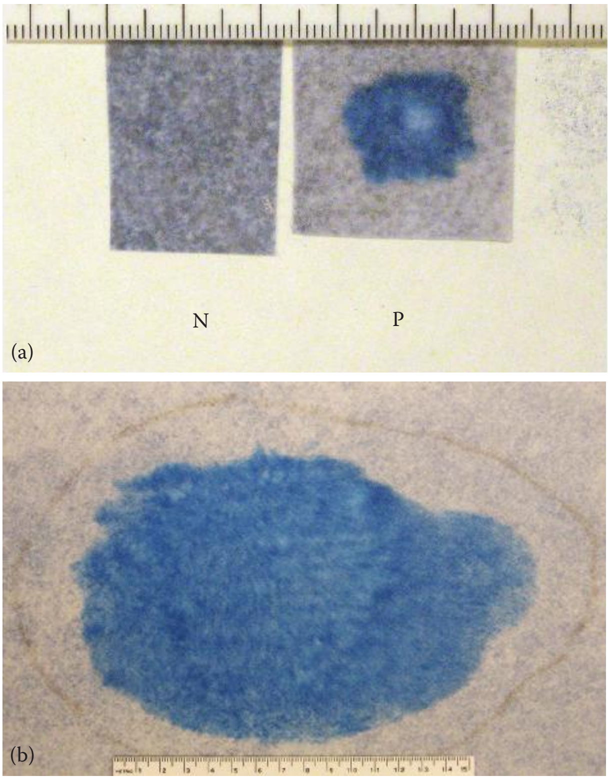

Figure 15.6 Amylase colorimetric assay using Phadebas reagent. (a) A spot test for saliva and (b) amylase mapping result showing a saliva-stained area. N, a negative result; P, a positive result. (© Richard C. Li.)

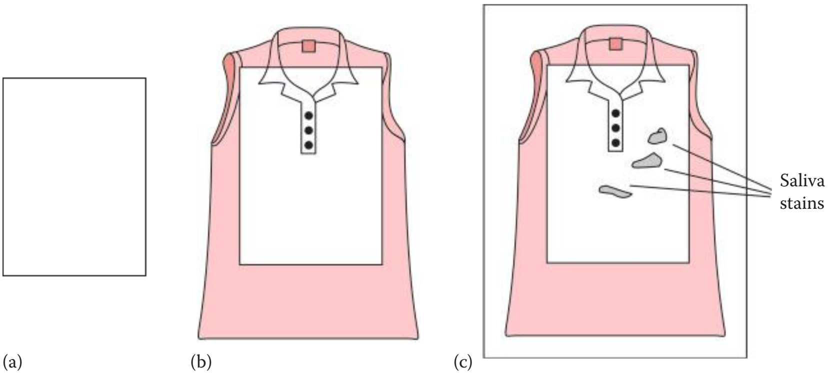

Figure 15.7 Amylase mapping for saliva stains. (a) Amylase substrate is sprayed on a sheet of filter paper. (b) Substrate-containing paper is placed over the area to be tested. The orientation of the filter paper is marked to aid in locating the stain. (c) The filter paper is dampened by spraying it with water, and plastic wrap is placed on top to prevent the paper from drying. Blue color indicates a positive reaction. (© Richard C. Li.)

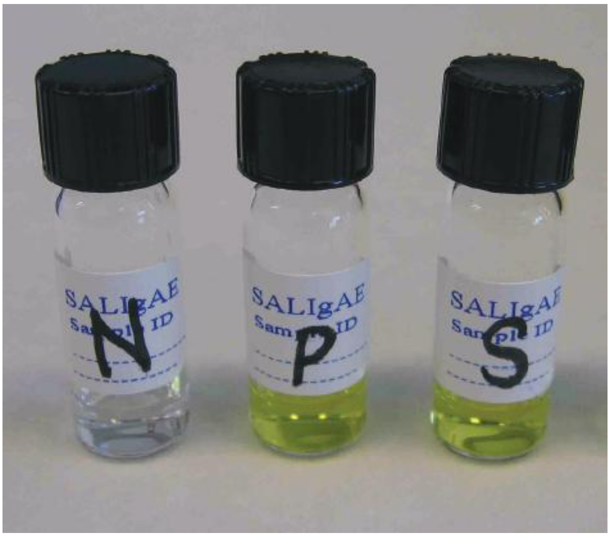

Figure 15.8 Saliva identification using SALIgAE reagent. P, a positive result; N, a negative result; S, a positive control. (© Richard C. Li.)

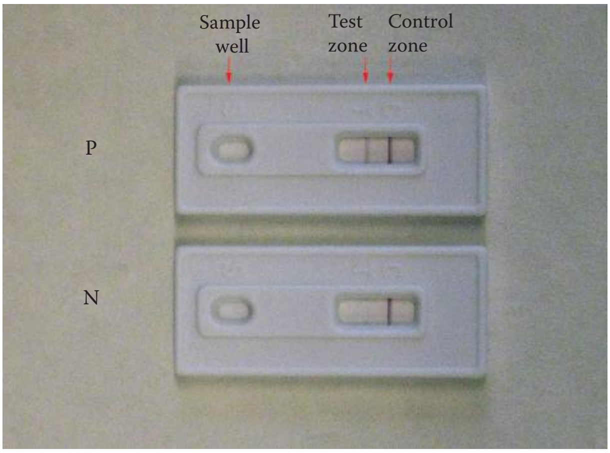

Figure 15.9 Identification of saliva using immunochromatographic assays. P, a positive result; N, a negative result. (© Richard C. Li.)

A sample can be prepared by cutting out a small portion of a stain or a swab. Each sample is extracted for 1–2 h in 200–300 μL of an extraction buffer. Approximately 10% of the extract is removed and mixed with a running buffer. The assay is carried out by loading an extracted sample into the sample well where the antigen in the sample binds to the labeled anti-HSA antibody in the well to form a labeled antibody–antigen complex. The complex then diffuses across the membrane to the test zone, where the solid-phase anti-HSA antibody binds with the labeled complex to form a labeled antibody–antigen–antibody sandwich.

The presence of antigen in the sample results in a pink line at the test zone. In the control zone, unbound labeled anti-HSA antibody binds to the solid-phase antiglobulin. The labeled antibody–antiglobulin complex at the control zone also results in a pink line. The test is

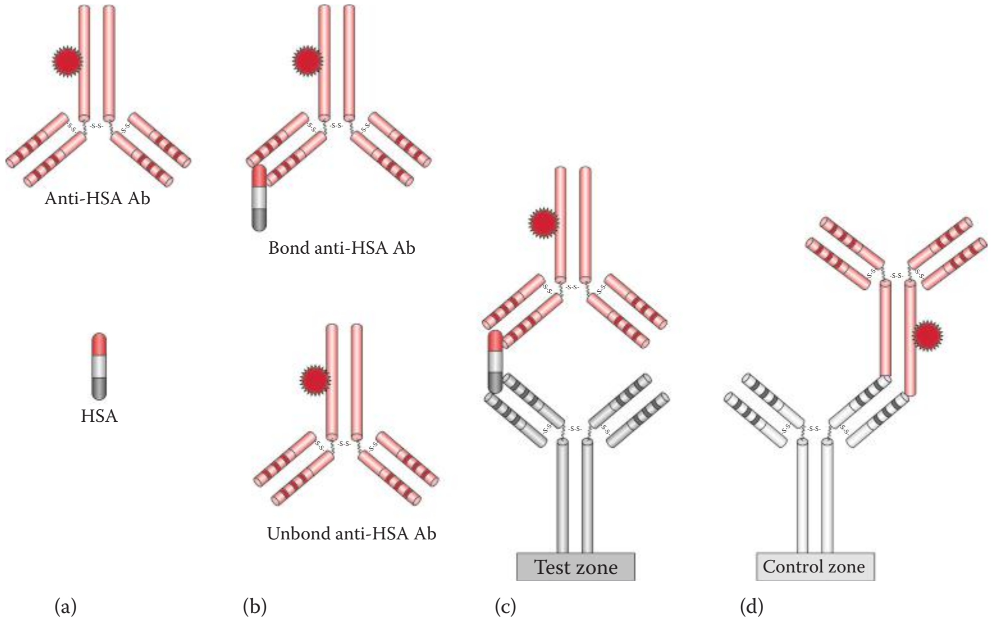

Figure 15.10 Immunochromatographic assay for the identification of HSA in saliva. (a) Sample containing amylases is loaded in a sample well. (b) Antigen binds to a labeled anti-HSA Ab to form a labeled Ab–HSA complex. (c) At the test zone, the labeled complex binds to an immobilized antihuman HSA Ab to form a labeled Ab–HSA–Ab sandwich. (d) At the control zone, the labeled anti-HSA Ab binds to an immobilized antiglobulin and is captured at the control zone. Ab, an antibody; HSA, human salivary α-amylase. (© Richard C. Li.)

considered valid only if the line in the control zone is observed. The presence of HSA results in a pink line at both the test zone and the control zone, while the absence of HSA results in a pink line in the control zone only. A result can be read after 10 min.

The sensitivity of the RSID®-Saliva kit can be as low as 1 μL of saliva. Additionally, the assay is responsive to samples extracted from saliva stains on both smooth and porous surfaces. In terms of species specificity, the kit has no cross-reactivity with various animal species, including monkeys (tamarin and callimico). As for bodily fluid specificity, it has also been shown that it is not responsive to human blood, semen, or urine. The high-dose hook effect, which creates an artifact that may cause false-negative results as described previously (Chapter 11), is not observed when up to 50 μL of saliva is tested. This method is rapid, specific, and sensitive and can be used in both laboratory and field analysis.

15.2.2.1.2 Enzyme-Linked Immunosorbent Assay (ELISA)

This method can be used to detect and to quantify a sample with the use of an anti-HSA antibody. The most common configuration in forensic serology is the antibody–antigen–antibody sandwich (Figure 15.11). ELISA utilizes reporting enzymes to produce colorimetric or fluorometric signals. The intensity of the signal can be detected spectrophotometrically and is proportional to the amount of bound antigen. The amount of HSA can be quantified by comparison with a standard of known concentration. This method is specific and highly sensitive in detecting HSA, but it is time-consuming. Chapter 11 discusses the ELISA principle in further detail.

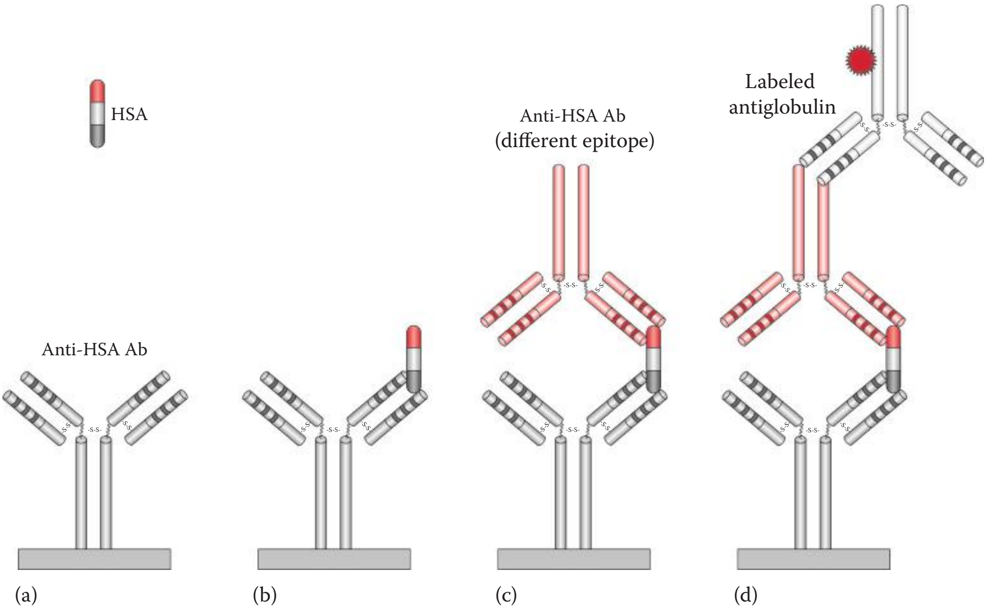

Figure 15.11 ELISA for identification of HSA in saliva. (a) Sample containing antigen is applied to polystyrene tubes where anti-HSA Ab is immobilized. (b) Antigen binds to immobilized Ab to form HSA–Ab complex. (c) Second anti-HSA Ab, specific for a different epitope of HSA, is added to form Ab–HSA–Ab sandwich. (d) Labeled antiglobulin then binds to the sandwich. The bound antiglobulin can be detected by various reporting schemes. Ab, an antibody; HSA, human salivary α-amylase. (© Richard C. Li.)

15.2.2.2 RNA-Based Assays

RNA-based assays (Chapter 11) have been developed recently for the identification of saliva. They are based on the expression of certain genes in certain cell or tissue types. Thus, the techniques used in the identification of saliva are based on the detection of specific types of mRNA expressed exclusively in certain cells in the oral cavity. These assays utilize reverse transcriptase polymerase chain reaction (RT-PCR; see Chapter 7) methods to detect gene expression levels of mRNAs for saliva identification. Table 15.1 summarizes the tissue-specific genes utilized for saliva identification. Compared to conventional assays used for saliva identification, RNA-based assays present higher specificity and are amenable to automation. However, one limitation is that the RNA is unstable because of degradation by endogenous ribonucleases.

Table 15.1 Application of RT-PCR Assay for Saliva Identification

Gene Symbol	Gene Product	Description	Further Reading
HTN3	Histatin 3	Histidine-rich protein involved in nonimmune host defense in oral cavity	Sabatini et al. (1993)
STATH	Statherin	Inhibitor of precipitation of calcium phosphate salts in oral cavity	Sabatini et al. (1990)

Source: Adapted from Juusola, J. and Ballantyne, J., *Forensic Sci Int*, 152, 1–12, 2005.

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16

Identification of Vaginal Secretions and Menstrual Blood

The identification of vaginal secretions and menstrual blood is important for the investigation of sexual assault cases. Such identification can help to corroborate allegations of sexual assault. For example, in a sexual assault investigation, a stain was observed after examining the suspect's clothing. Subsequently, forensic DNA analysis revealed that the DNA of the stain originated from the victim, establishing a link between the victim and the suspect. However, the defendant may assert that the victim's DNA originated from a sweat stain as a result of casual contact and deny any criminal act. If vaginal secretions were found in the stain, the evidence has probative value to corroborate an allegation of a sexual act. Additionally, postcoital drainage stains on clothing or bedding are often recovered at crime scenes. These stains usually consist of a mixture of semen and vaginal secretions. In such cases, the presence of vaginal secretions in these stains indicates the occurrence of sexual intercourse. Sometimes, vaginal secretions can be transferred onto a perpetrator during a sexual assault. For example, the presence of vaginal secretions on a suspect's genital area can indicate the occurrence of sexual intercourse. Furthermore, the presence of vaginal secretions on an object can corroborate an allegation of vaginal rape with a foreign object.

If a sexual assault victim is in menses when an assault occurred, blood evidence, such as the victim's bloodstains located on the suspect's clothing, may be recovered at the scene. The defense may argue that the bloodstains resulted from an injury and deny that any sexual act occurred. In this case, the identification of menstrual blood would corroborate an alleged rape. Therefore, it is necessary to distinguish between peripheral and menstrual blood in investigations of sexual assault where blood evidence is found at the scene.

16.1 Identification of Vaginal Stratified Squamous Epithelial Cells

A normal human vagina is covered by the *squamous mucosa*, which is composed of stratified squamous epithelial tissue (Figure 16.1a). Lying under the squamous mucosa is the *submucosa*, which contains an abundance of connective tissue and capillaries. Below the submucosa is the *muscularis*, which is made up of smooth muscle.

The squamous mucosa consists of multiple layers of cells (Figure 16.1b). At the *basal layer* of the squamous mucosa, basal cells are anchored to the basement membrane that separates the squamous mucosa from the submucosa. The basal cells are small in size with relatively large nuclei and are highly proliferative. As the cells migrate up from the basal layer to the *parabasal layer*, the cells undergo differentiation. At the *intermediate layer*, the cells are flattened and their nuclei are compressed. As the epithelial cells reach the apical layer, the *superficial layer*, the cells are fully differentiated with small and dense nuclei.

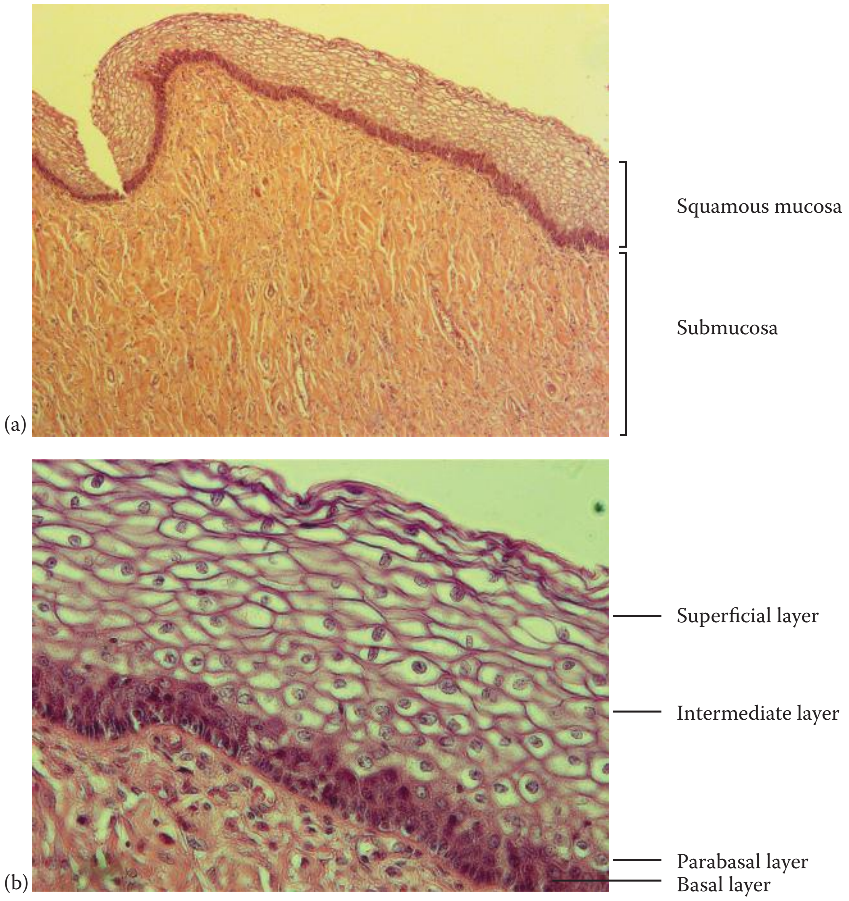

Figure 16.1 Histological structure of human vaginal tissues. (a) The squamous mucosa and the submucosa. (b) Multiple layers of cells in the squamous mucosa. (© Richard C. Li.)

Vaginal epithelial cells do not accumulate keratin, which is different from skin cells (Chapter 4). The intermediate and superficial layer cells contain abundant glycogen in their cytoplasm. The presence of glycogen in these cells is an indication of normal development and the differentiation of the vaginal epithelial cells. The apical surface of the vaginal squamous mucosa is usually covered by mucus that is secreted from glands that are located deep in the epithelium. The cells of the apical layers are eventually sloughed and are continuously replaced by the cells of deeper layers. When the lining of the vagina is swabbed during the collection of evidence, glycogenated cells with small numbers of parabasal cells are usually recovered (Figure 16.2). In addition to the vagina, glycogenated squamous epithelial cells are found in the linings of the oral cavity, pharynx, esophagus, anus, and the apex of the urethra. The differentiation of the vaginal epithelial cells requires estrogen. However, in premenarche and postmenopausal women, estrogen levels are very low; thus, the vaginal epithelial cells only differentiate to the parabasal cells. Primarily, parabasal cells are found in specimens from these individuals.

16.1.1 Lugol's Iodine Staining and Periodic Acid–Schiff Method

Lugol's iodine solution, named after the French physician Jean Lugol, is originally used as an antiseptic that is applied to skin or tissue to prevent infection. In forensic applications, it is utilized for the identification of glycogenated vaginal epithelial cells. The technique is based on the

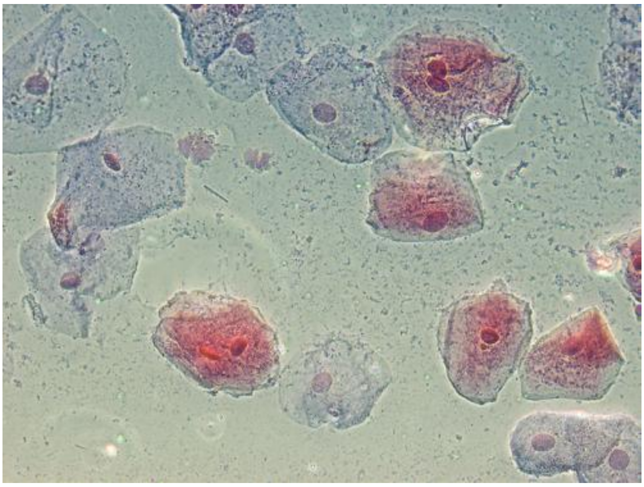

Figure 16.2 Vaginal stratified squamous epithelial cells. (© Richard C. Li.)

principle that iodine reacts with intracellular glycogen to exhibit a color. Glycogen is the principal storage form of glucose in animal and human cells and is found in the granules in the cytoplasm of the cells of many tissues. In addition to squamous epithelial cells, glycogen is also found in hepatocytes, which have the highest glycogen content, as well as muscle cells. Glycogen is a polysaccharide composed of D-glucose units. Similar to the amylopectin in plant cells (Chapter 15), glycogen is a branched polysaccharide consisting of linear and branched chains (Figure 16.3). The D-glucose residues of the linear chain are connected by α1→4 glycosidic bonds, while the branching points are connected by α1→6 glycosidic bonds. However, glycogen is more branched than

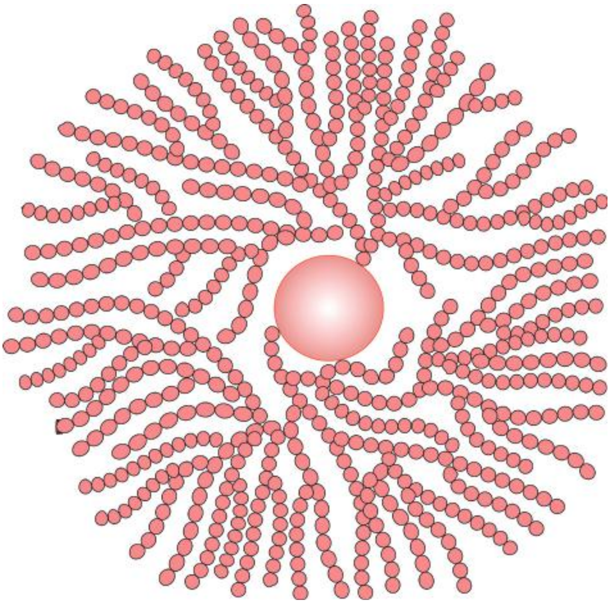

Figure 16.3 Structure of glycogen. Glycogen is a highly branched polysaccharide composed of glucose. Glycogen has a similar structure to amylopectin in starch (see Chapter 15). However, glycogen is more branched than starch. Additionally, glycogen contains a protein known as glycogenin at the center of its structure. (© Richard C. Li.)

amylopectin. Branch points occur approximately every 10 glucose residues in glycogen while they occur every 25 glucose residues in amylopectin. Lugol's stock solution is an aqueous solution of 5% iodine (I_2) and 10% potassium iodide (KI). Potassium iodide allows the iodine to be soluble in water through the formation of the triiodide ion. For staining the vaginal epithelial cells, 5% of the stock solution is usually used as the working solution. Iodine atoms fit into the helices of glycogen to form a dark brown glycogen–iodine complex (Figures 16.4 and 16.5). Vaginal epithelial cells can also be stained using the periodic acid–Schiff method. The cytoplasm of the vaginal epithelial cells is stained magenta, and the nucleus is stained purple.

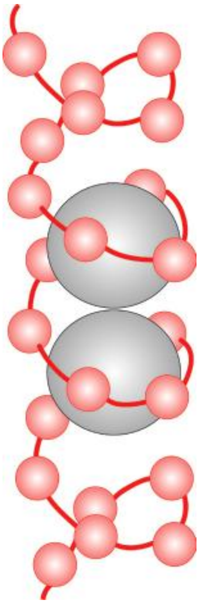

Figure 16.4 Diagram of a glycogen–iodine complex. In the complex, the glycogen chain forms a helix structure with six monosaccharide residues (red) per turn. Iodine molecules (gray) fit in the helix to form the glycogen–iodine complex, exhibiting a color. (© Richard C. Li.)

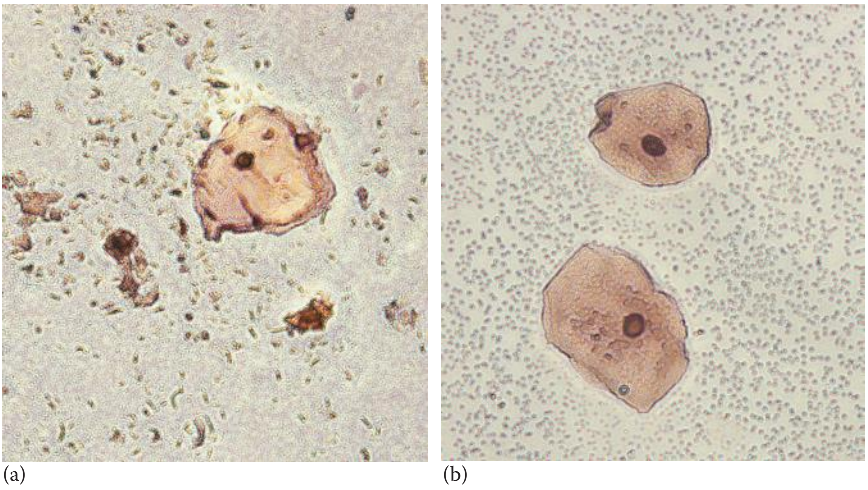

(a) (b)

Figure 16.5 Epithelial cells stained with Lugol's iodine solution. (a) Vaginal and (b) buccal epithelial cells. (© Richard C. Li.)

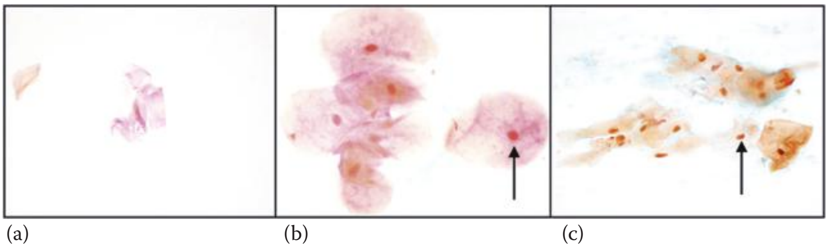

Figure 16.6 Staining of epithelial cells with Dane's method. The results obtained using methanol fixation followed by Dane's staining on skin (a), buccal (b), and vaginal epithelial (c) cells are shown. The arrows indicate red nuclei in buccal and orange nuclei in vaginal cells. (From French, C.E., et al., *Forensic Sci Int*, 178, 1–6, 2008. With permission.)

16.1.2 Dane's Staining Method

Evidence containing skin, buccal, and vaginal epithelial cells is often recovered in forensic investigations, particularly in sexual assault cases. Thus, it is necessary to distinguish between these cells. Skin, buccal, and vaginal epithelial cells belong to stratified squamous epithelium. Differentiated skin epithelial cells are keratinized and are classified as keratinizing squamous epithelial cells, while buccal and vaginal epithelial cells are nonkeratinizing squamous epithelial cells. Additionally, the skin epithelial cells lose nuclei and other cellular organelles during differentiation. In contrast, buccal and vaginal cells contain nuclei. Based on their morphology, it is possible to distinguish skin epithelial cells from buccal and vaginal epithelial cells. However, buccal and vaginal cells are morphologically indistinguishable from each other. Although Lugol's iodine solution and periodic acid–Schiff can stain vaginal epithelial cells, these stains cannot distinguish vaginal from other glycogenated epithelial cells in the oral mucosa and the urinary tract. Recently, Dane's staining method has been developed to distinguish all three types of cells. Skin cells are stained red and orange; buccal cells are stained predominantly orange-pink with red nuclei; and vaginal cells are stained bright orange with orange nuclei (Figure 16.6).

16.2 Identification of Vaginal Acid Phosphatase

Acid phosphatases are a group of enzymes that are capable of hydrolyzing a variety of small organic phosphomonoesters under acidic conditions. To date, at least five different acid phosphatase isoenzymes have been identified in human tissues: erythroid acid phosphatase (encoded by the *ACP1* gene), lysosomal acid phosphatase (encoded by the *ACP2* gene), prostate acid phosphatase (encoded by the *ACPP* gene, also known as *ACP3*), macrophage acid phosphatase (encoded by the *ACP5* gene), and testicular acid phosphatase (encoded by the *ACPT* gene). Human prostatic acid phosphatase is found in large quantities in seminal fluid and is used as a biomarker for semen identification (Chapter 14). The prostatic acid phosphatase is a homodimer containing two identical subunits with a molecular weight of 50 kDa. Small amounts of acid phosphatase can be detected in vaginal fluid, which is produced in normal cervical epithelial cells. However, the molecular characteristics of vaginal acid phosphatase are still not known. Historically, vaginal acid phosphatase has been used as a biomarker for the identification of vaginal secretions using acid phosphatase catalytic assays (Chapter 14). In sexual assault investigations, it is important to distinguish vaginal acid phosphatase from prostate acid phosphatase originating from semen exposure. These two enzymes have identical molecular weights, enzymatic specificities, and responses to the same inhibitors. Nevertheless, vaginal and prostate acid phosphatases can be distinguished using agarose electrophoresis. Based on their electrophoretic mobility, bands of vaginal and prostate acid phosphatases can be separated. The prostate acid phosphatase

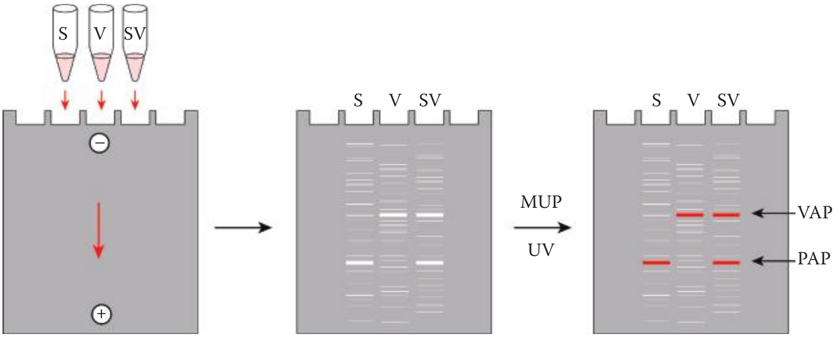

Figure 16.7 Distinguishing prostate and vaginal acid phosphatases using polyacrylamide gel electrophoresis. Bands of acid phosphatases are detected using 4-methylumbelliferyl phosphate (MUP). MUP is a substrate of acid phosphatases, resulting in a product that fluoresces in UV illumination (see Chapter 14). The prostate acid phosphatase has higher electrophoretic mobility toward an anode (a positively charged electrode) than vaginal acid phosphatase. S, semen; V, vaginal secretions; SV, mixture of semen and vaginal secretions; PAP, prostate acid phosphatase; VAP, vaginal acid phosphatase; MUP, 4-methylumbelliferyl phosphate; UV, ultraviolet illumination. (© Richard C. Li.)

has higher electrophoretic mobility toward an anode (a positively charged electrode) than the vaginal acid phosphatase (Figure 16.7). Thus, the presence of vaginal acid phosphatase can be determined.

16.3 Identification of Vaginal Bacteria

Lactobacillus can be found in the respiratory, the gastrointestinal, and the urogenital tract of healthy humans and animals. *Lactobacillus* taxa are the predominant bacteria in the vagina of women of reproductive age, and they play an important role in protecting the host against invasive pathogenic organisms. *Lactobacillus* consists of rod-shaped, nonmotile, and non-spore-forming gram-positive bacteria (Figure 16.8). Since these bacteria survive on carbohydrates, *Lactobacillus* bacteria produce lactic acid. As a result, a low pH environment is established in

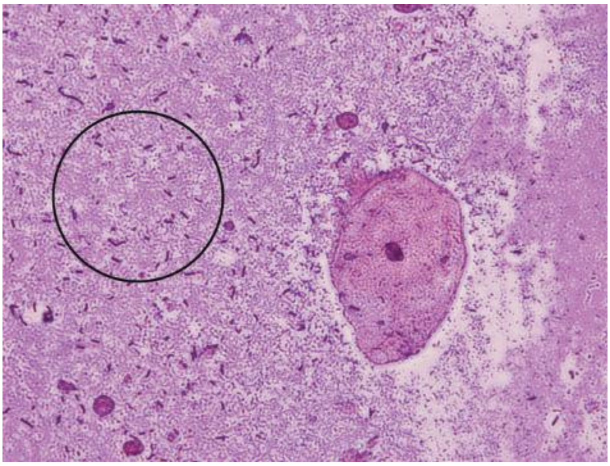

Figure 16.8 Vaginal *Lactobacillus* bacteria (circled). (© Richard C. Li.)

the lumen of the vagina, which restricts the growth of pathogenic organisms. Such vaginal lactic acid–producing bacteria were thought to be *Lactobacillus acidophilus*. In the 1980s, it was determined that *L. acidophilus* was not a single species, but actually a group of related species known as the *L. acidophilus* complex. The species of the complex can now be distinguished based on their DNA sequences. The most frequently occurring *Lactobacillus* species found in the vagina are *L. iners*, *L. crispatus*, *L. gasseri*, and *L. jensenii*. Among them, *L. iners* is the most common species of *Lactobacillus* in women. *Lactobacillus* can be identified based on the sequences of DNA markers such as the 16S rRNA gene and the intergenic spacer region between the 16S rRNA and 23S rRNA genes (Chapter 11). In forensic applications, *L. iners*, *L. crispatus*, *L. gasseri*, and *L. jensenii* can be detected in vaginal secretions. Thus, the identification of *Lactobacillus* taxa can potentially be utilized for the forensic identification of vaginal fluid. However, the presence of *Lactobacillus* taxa is not specific enough to vaginal fluid. Some studies show that *Lactobacillus* taxa are present in semen while others show that *Lactobacillus* can be found in female urine. The openings of the female urogenital system are in close proximity; thus, it is possible to have partially overlapping microbiota between the urine and vaginal secretions. Thus, the identification of multiple bacterial species, at least the four *Lactobacillus* species previously mentioned, should be carried out to distinguish these samples.

16.4 Outlook for Confirmatory Assays of Vaginal Secretions

The identification of the vaginal stratified squamous epithelial cells provides important probative evidence in forensic investigations. However, the existing methods described earlier can sometimes give false-negative or false-positive results. In some situations, these assays also cross-react with other types of bodily fluids. Thus, none of these assays is confirmatory. A useful identification method for vaginal secretions should be able to distinguish vaginal secretions from other bodily fluids and should be easy to perform. For example, nondestructive confirmatory identification methods such as fluorescence spectroscopy and Raman spectroscopy (Chapter 11) can potentially be useful for the identification of vaginal secretions. Recently, the analysis of tissue-specific gene expression has been utilized for the identification of vaginal secretions. Using the reverse transcription polymerase chain reaction (RT-PCR) technique (Chapter 7), the mRNAs of the tissue-specific genes of vaginal epithelial cells can be detected. For example, two commonly used markers for vaginal secretion identification are *MUC4* and *HBD1*. *MUC4* encodes a mucin protein that is a major component of vaginal mucus, and *HBD1*, the human β defensin 1, encodes a vaginal antimicrobial peptide. Both *MUC4* and *HBD1* are expressed in vaginal epithelial cells and are considered reliable markers of vaginal fluid. Additional mRNA and miRNA markers are described in Tables 16.1 and 16.2.

16.5 Menstruation

Menstruation is the periodic discharge of blood and the elimination of the degenerated lining of the endometrium from the uterus of nonpregnant women. From menarche to menopause, women may menstruate up to 400 times during their reproductive age. The uterus plays an important role in preparing the uterine endometrium for the possible implantation of a developing embryo. The linings of the uterus are composed of the myometrium and the endometrium. The *myometrium* consists of the muscle fibers of the uterus. The *endometrium* consists of the simple columnar epithelium and the stroma (Figure 16.9). The simple columnar epithelium is formed by single-layered elongated cells located at the apical surface of the endometrium. The stroma consists of connective tissues as well as spiral arteries. Spiral arteries are small arteries that ascend through the endometrium and form a coil-like structure, which supplies blood to the endometrium.

Table 16.1 Representative Markers of mRNA-Based Assays for Vaginal Secretions and Menstrual Blood Identification

Biological Fluid	Gene Symbol	Description
Vaginal secretions	*CYP2B7P1*	Cytochrome P450, family 2, subfamily B, polypeptide 7, pseudogene 1
	DKK4	Dickkopf homolog 4
	FUT6	Fucosyltransferase 6
	HBD1	β Defensin 1
	IL19	Interleukin 19
	MUC4	Mucin 4
	MYOZ1	Myozenin 1
	SFTA2	Surfactant associated 2
Menstrual blood	*MMP7*	Matrix metalloproteinase 7
	MMP11	Matrix metalloproteinase 11

Source: Adapted from Bauer, M. and Patzelt, D., *J Forensic Sci*, 47, 1278–1282, 2002; Hanson, E.K. and Ballantyne, J., *Sci Justice*, 53, 14–22, 2013; Juusola, J. and Ballantyne, J., *Forensic Sci Int*, 152, 1–12, 2005; Nussbaumer, C., Gharehbaghi-Schnell, E., and Korschineck, I., *Forensic Sci Int*, 157, 181–186, 2006.

Table 16.2 miRNA Markers for Vaginal Secretions and Menstrual Blood Identification

Bodily Fluid	miRNA Marker	Sequence
Vaginal secretions	miR124*a*	UAAGGCACGCGGUGAAUGCC
	miR372	AAAGUGCUGCGACAUUUGAGCGU
	miR617	AGACUUCCCAUUUGAAGGUGGC
	miR891a	UGCAACGAACCUGAGCCACUGA
Menstrual blood	miR214	UGCCUGUCUACACUUGCUGUGC
	miR412	ACUUCACCUGGUCCACUAGCCGU
	miR451	AAACCGUUACCAUUACUGAGUU

Source: Adapted from Hanson, E.K., Lubenow, H., and Ballantyne, J., *Anal Biochem*, 387, 303–314, 2009; Wang, Z., et al., *Forensic Sci Int Genet*, 7, 116–123, 2013.

16.5.1 Uterine Cycle

The endometrium can be divided into two zones: the functionalis and the basalis (Figure 16.10). The *functionalis* is the luminal part of the endometrium. It is the zone of cyclic changes in the endometrium and is shed during menstruation. The *basalis* is the basal part of the endometrium and is not shed during menstruation. This zone produces cells to regenerate the functionalis during the next cycle.

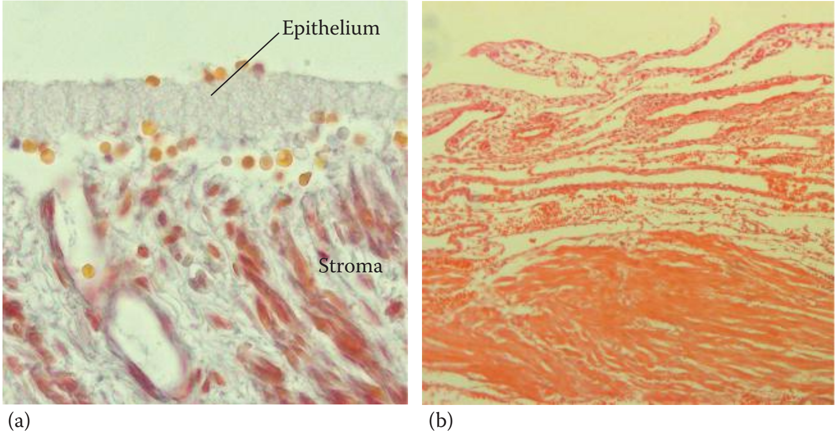
Epithelium
Stroma
(a)
(b)

Figure 16.9 Uterus endometrium. (a) The proliferative phase and (b) the menstrual phase. (© Richard C. Li.)

During the uterine cycle, repetitive physiological changes occur in the functionalis (Figure 16.10). The cycle is divided into three phases: the menstrual, proliferative, and secretory phases. The first day of menstrual bleeding is considered the onset of the menstrual phase. During the menstrual phase, the functionalis degenerates and is sloughed off from the uterine wall and bleeding occurs, known as menses. During the proliferative phase, the functionalis begins regeneration in which the spiral arteries are proliferated. During the secretory phase, the spiral arteries are further developed and coiled. In the absence of pregnancy, a decrease in the progesterone level leads to the constriction of the spiral arteries. As a result, the functionalis becomes ischemic (insufficient blood flow), leading to hypoxia (low levels of oxygen in tissue). In addition, the activation of an enzymatic degradation process causes the destruction and

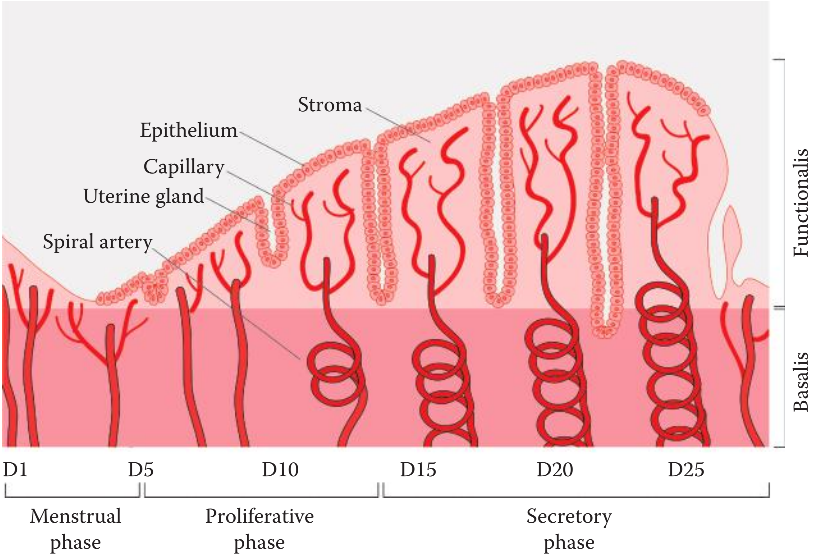
Stroma
Epithelium
Capillary
Uterine gland
Spiral artery
Functionalis
Basalis
D1
D5
D10
D15
D20
D25
Menstrual phase
Proliferative phase
Secretory phase

Figure 16.10 Changes in the functionalis of the uterine mucosa during a uterine cycle. D, day. (© Richard C. Li.)

shedding of the functionalis during menses. Menstrual fluid contains blood, the functionalis layer tissue, and mucus.

16.5.2 Uterine Endometrial Hemostasis

The cessation of menstrual bleeding is achieved by endometrial *hemostasis* that is initiated when injury occurs due to the shedding of the endometrium (Figure 16.11). Hemostasis begins with platelet activation and aggregation to form platelet plugs at the site of injury. Additionally, the blood coagulation cascade is activated to produce *thrombin*. Thrombin, a serine protease, converts soluble fibrinogen into fibrin. Fibrin, a protein involved in blood clotting, aggregates with the platelet plugs and leads to the cessation of bleeding by forming blood clots, known as *thrombi*. Under normal physiological conditions, uterine endometrial hemostasis is a balanced process between blood coagulation and clot dissolution to control blood loss and to prevent clot accumulation within the uterus. As a result, the balance of these two processes allows the removal of tissue fragments from the uterus cavity in order to reduce the risks of infection. Blood clots are prevented from accumulating during menstruation by forming low amounts of platelet plugs and synthesizing coagulation factor inhibitors that inhibit blood coagulation. Additionally, *fibrinolysis* is activated, during which thrombus is broken down by a protease known as *plasmin*. Plasmin cleaves fibrin, generating soluble degradation products. As a result, fibrinolysis can inhibit blood clot formation.

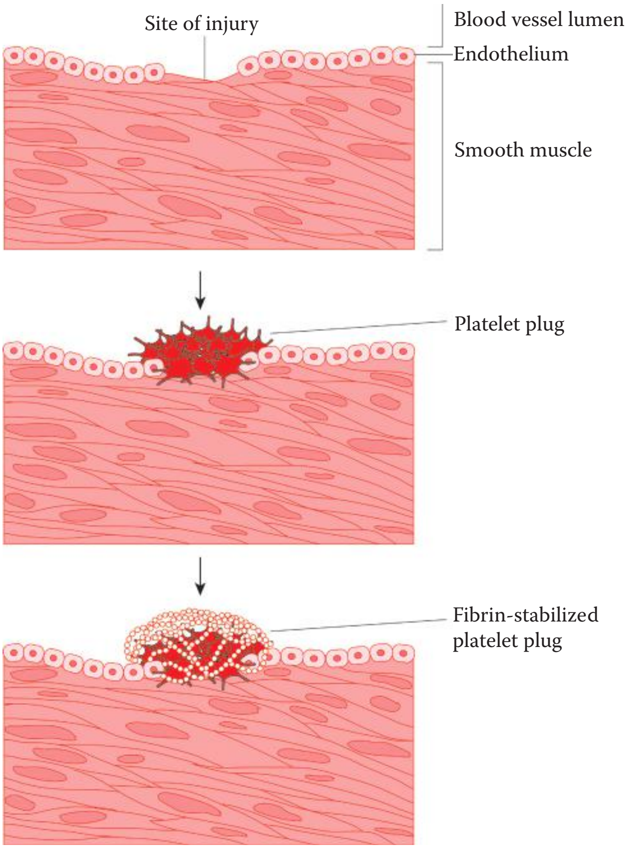

Figure 16.11 Diagram of hemostasis. Hemostasis occurs at the site of injury of a blood vessel. A platelet plug is formed as a result of the aggregation of platelets. The plug is further stabilized by the formation of a fibrin clot over the platelet plug. (© Richard C. Li.)

16.6 D-dimer Assay

During fibrinolysis, cross-linked fibrin is cleaved by plasmin, producing a degradation product known as *D-dimer* (Figure 16.12). Assays for D-dimer fragments have been utilized in the forensic identification of menstrual blood. A number of different formats of D-dimer assays can be used. In an enzyme-linked immunosorbent assay (ELISA; Chapter 11), antibodies bind to the D-dimer antigens on the solid phase. The D-dimer–antibody complex is subsequently analyzed using an antibody-based detection system. This method is highly sensitive, but is time-consuming. Latex agglutination assays are based on the interaction of antibodies and D-dimers that are located on carriers to form aggregates during the agglutination process (Chapter 11). However, the magnitude of the agglutination response is manually read and conclusions are based on subjective judgments. Immunochromatographic assays (Chapter 11) utilize monoclonal antibodies specific to D-dimers, which have been developed recently (Figures 16.13 and 16.14). This immunochromatographic assay is very specific, sensitive, and rapid, and can be completed within minutes. The immunochromatographic devices are portable, and thus can potentially be used at crime scenes. The D-dimer assays can positively identify menstrual blood samples. Although peripheral blood contains low levels of D-dimer, these assays do not show positive reactions with peripheral blood. Thus, menstrual blood can be distinguished from peripheral blood using D-dimer assays. However, postmortem blood also contains these D-dimers, which are detected by these assays. Although the detection of postmortem blood would complicate the interpretation of results, postmortem blood is not often encountered in sexual assault cases.

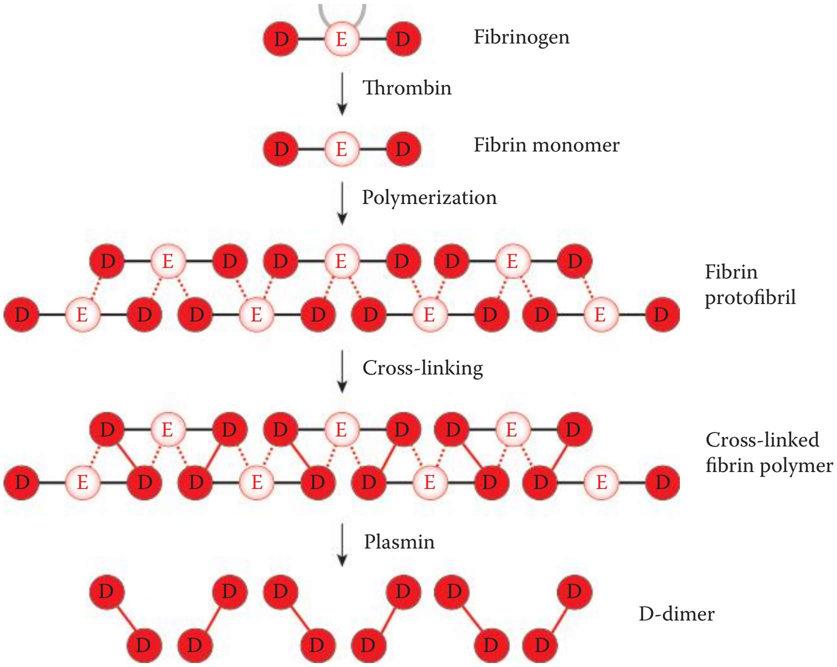

Figure 16.12 The formation and the degradation of a fibrin polymer. The activation of coagulation ultimately generates thrombin, which catalyzes the conversion of fibrinogen to fibrin by cleaving the fibrinopeptides (gray). A fibrin monomer contains an E domain and two D domains. The fibrin monomers are held together by noncovalent bonds (dotted red) between the D domains and E domain to form a fibrin polymer. Fibrin polymers are then covalently linked (solid red) to form a cross-linked fibrin polymer, which plays a role in forming clots. During fibrinolysis, plasmin cleaves the cross-linked fibrin at multiple sites giving rise to fibrin degradation products including D-dimer. (© Richard C. Li.)

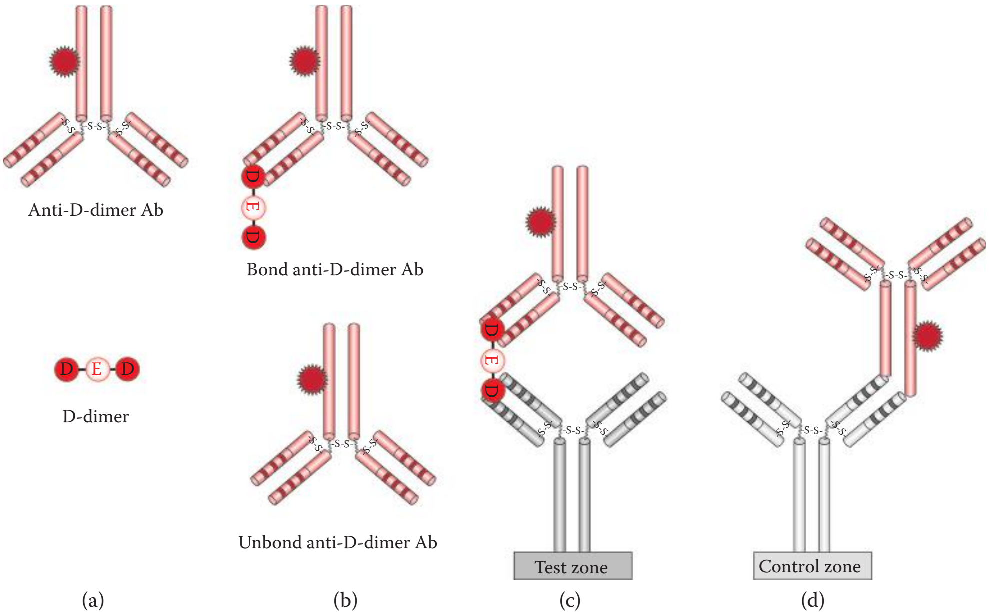
Anti-D-dimer Ab
Bond anti-D-dimer Ab
D-dimer
Unbond anti-D-dimer Ab
Test zone
Control zone
D
E
D
-S-S-
(a)
(b)
(c)
(d)

Figure 16.13 Immunochromatographic assays for the identification of D-dimer in menstrual blood. (a) In a sample well, D-dimer antigen in a menstrual blood sample is mixed with labeled anti-D-dimer Ab. (b) The D-dimer binds to the labeled anti-D-dimer Ab to form a labeled Ab–antigen complex. (c) At the test zone, the labeled complex binds to an immobilized anti-D-dimer Ab to form a labeled Ab–antigen–Ab sandwich. (d) At the control zone, the labeled anti-D-dimer Ab binds to an immobilized antiglobulin and is captured at the control zone. Ab, antibody. (© Richard C. Li.)

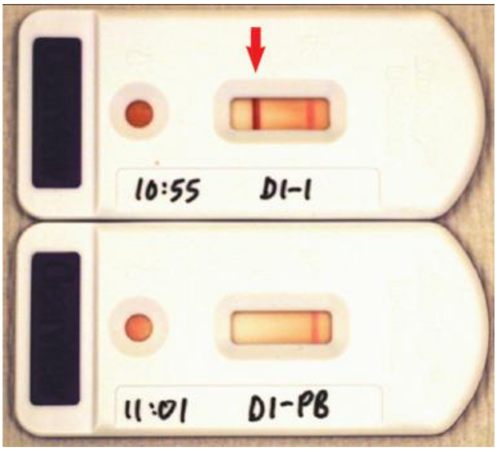
10:55
D1-1
11:01
D1-PB

Figure 16.14 Detecting D-dimer using immunochromatographic assays. The results obtained using the Clearview Simplify D-dimer devices (Alere, Cheshire, UK) on menstrual (top) and peripheral blood (bottom) are shown. A positive result (arrow) indicates the presence of D-dimer. (From Baker, D.J., Grimes, E.A., and Hopwood, A.J., *Forensic Sci Int*, 212, 210–214, 2011. With permission.)

16.7 Lactate Dehydrogenase Assay

Lactate dehydrogenase (LDH) is an enzyme that plays an important role in glycolysis. In humans, LDH catalyzes the reversible reduction of pyruvate into lactate when the amount of oxygen is limited. LDH is a tetrameric enzyme consisting of three different types of subunits. The A subunit, also known as the M subunit, is encoded by the *LDHA* gene and is primarily expressed in skeletal muscle. The B subunit, also known as the H subunit, is encoded by the *LDHB* gene and is primarily expressed in cardiac muscle. The C subunit, encoded by the *LDHC* gene, is expressed restrictively in the testes. LDHs are found in various human tissues. Five isoenzymes can be found in blood (Figure 16.15). LDH1 consists of four identical B subunits; LDH2 consists of one A and three B subunits; LDH3 consists of two A and two B subunits; LDH4 consists of three A and one B subunits; and LDH5 consists of four identical A subunits. The five isoenzymes can be separated using electrophoresis (Figure 16.16) and detected using a colorimetric assay (Figures 16.17 and 16.18). According to their electrophoretic mobility, five bands can be identified. LDH1 has the highest electrophoretic mobility (toward an anode that is a positively charged electrode) and LDH5 has the lowest electrophoretic mobility. In peripheral blood, LDH1, 2, and 3 are the predominant forms of the isoenzymes and LDH4 and 5 are the minor forms of the isoenzymes. In contrast, LDH4 and 5 are consistently the predominant isoenzymes in menstrual blood, while the amounts of LDH1, LDH2, and LDH3 vary. Thus, menstrual blood can be distinguished from peripheral blood. LDH was historically used as a marker for the forensic identification of menstrual blood.

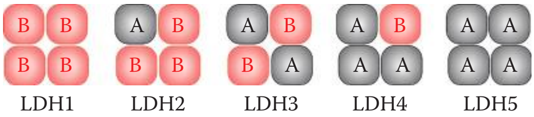

Figure 16.15 Isozymes of lactate dehydrogenase. Human lactate dehydrogenases are composed of four subunits. Five types of isozymes with their subunits are shown. A, LDH A subunit; B, LDH B subunit.

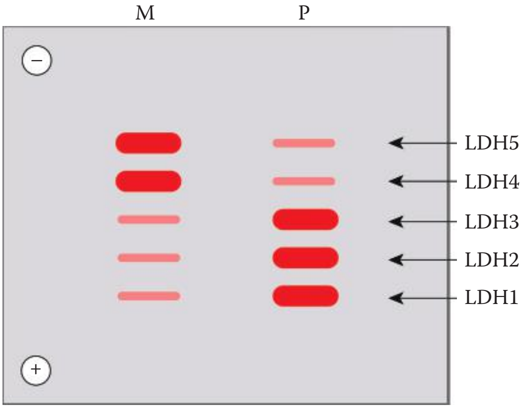

Figure 16.16 Electrophoretic separation of lactate dehydrogenase (LDH) isozymes. Extracted blood samples are loaded onto a cellulose acetate membrane. Electrophoresis is then carried out. Separated bands of LDH isozymes are detected using a colorimetric assay (see Figure 16.15). M, menstrual blood; P, peripheral blood. (© Richard C. Li.)

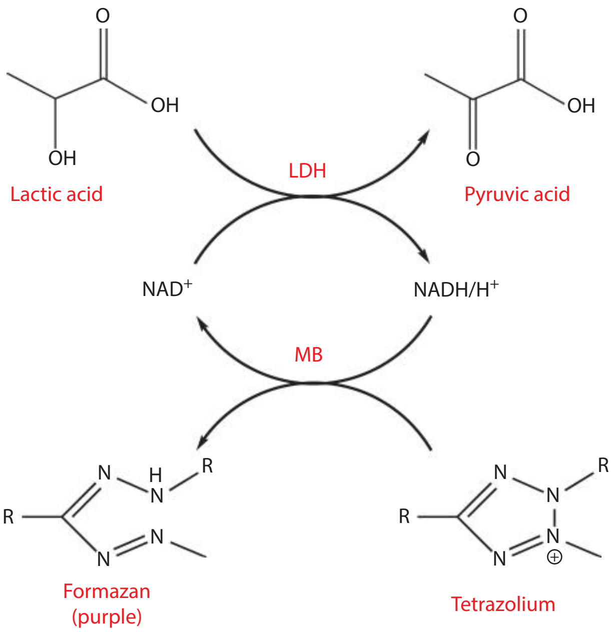

Figure 16.17 Detecting LDH activity using a colorimetric assay forming a colored dye. At the start of a cascade reaction, the LDH catalyzes the conversion of lactic acid to pyruvic acid. Nicotinamide adenine dinucleotide (NAD^+) is then reduced to $NADH/H^+$. Subsequently, Meldola's Blue (MB; 8-dimethylamino-2-benzophenoxazine), an electron carrier, transfers H/H^+ from $NADH/H^+$ to a tetrazolium salt. The pale yellow tetrazolium salt, nitroblue tetrazolium (NBT), is reduced to form a purple formazan dye.

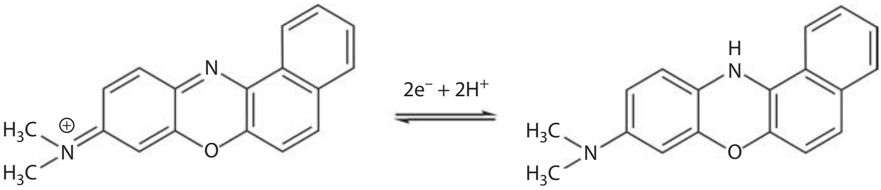

Figure 16.18 The reduction and oxidation of Meldola's Blue. Meldola's Blue is an electron carrier, which transfers hydrogen atoms (coupled to electron transfer).

16.8 RNA-Based Assays

Matrix metalloproteinase (MMP) genes are considered tissue-specific markers for human endometrium tissues. MMPs are zinc-dependent endopeptidases that degrade extracellular matrix components. Additionally, they cleave other proteins such as cytokines, chemokines, and growth factors. The *extracellular matrix* (ECM) is the extracellular space of tissue that is filled by macromolecules such as collagens, laminins, fibronectins, and proteoglycans. The ECM can be divided into two categories: the interstitial matrix and the basement membrane. The interstitial matrices are located in the intercellular spaces. The basement membranes are thin layers of macromolecule fibers that usually lie under the epithelium and the endothelium. Both the interstitial matrices and the basement membranes provide structural support to the cells. It is proposed that MMPs play an important role in the degradation of ECM, leading to the destruction of endometrium tissues during the uterine cycle. To date, a total of 23 MMPs, divided into five subgroups, have been found in humans. The most commonly used markers for the forensic identification of menstrual blood are *MMP7* and *MMP11* (Table 16.1).

Many MMPs are expressed in human endometrium throughout the uterine cycle. The patterns of the MMP gene expressions are correlated with their functions in endometrium tissue breakdown during menstruation. *MMP7* is predominantly expressed in epithelial cells, while *MMP11* is expressed in the stromal cells of the endometrium. Both *MMP7* and *MMP11* mRNA expressions are elevated at the menstrual phase and remain at high levels during the proliferative phase. It is also known that MMPs' mRNA may be elevated in postpartum, wound healing, and metastatic cancer conditions, which may potentially lead to a false-positive identification of menstrual blood.

In menstrual blood samples, among all of the MMP genes tested, *MMP11* is the most sensitive and specific marker for distinguishing menstrual blood from peripheral blood. Using the RT-PCR technique (Chapter 7), *MMP11* mRNA can be detected in menstrual blood from the first to the eighth day of menstruation but it is absent in peripheral blood and vaginal secretions. Therefore, *MMP11* can be used as a marker for the identification of menstrual blood. Likewise, *MMP7* is also a useful marker for menstrual blood identification. However, the *MMP7* mRNA level in menstrual blood is less than that of *MMP11*. Additional markers such as miRNA markers for menstrual blood identification are included in Table 16.2.

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17

Identification of Urine, Sweat, Fecal Matter, and Vomitus

17.1 Identification of Urine

The identification of the presence of urine is useful for the forensic investigation of an alleged sexual assault and harassment involving urination. More importantly, the identification of urine stains can aid in the investigation of homicides involving either ligature or manual strangulation. In these incidents, strangulation victims often involuntarily excrete urine prior to death. The locations of urine stains at the crime scene provide useful information to determine the site where the violence has occurred.

17.1.1 Urine Formation

In humans, the urinary excretory system eliminates soluble toxic wastes that are cellular metabolic by-products. The urinary system consists of the kidney, the ureter, the urinary bladder, and the urethra (Figure 17.1). The formation of urine takes place in the kidneys and, in particular, in the nephrons. The *nephron* is the basic structural and functional unit of the kidney (Figures 17.2 and 17.3). Each nephron is composed of a glomerulus, a Bowman's capsule, and a renal tubule. The glomerulus is formed by a network of capillaries and is surrounded by a Bowman's capsule. *Filtration* is the first step in urine formation. As blood flows through the glomeruli, much of its fluid, except cells and large molecules, is filtered through the capillaries into the Bowman's capsule. The glomerular filtrate, the preliminary form of urine, consists of water, salts (largely sodium and potassium ions), glucose, and waste products such as urea. The filtrate is then passed through the renal tubule where *reabsorption* occurs. During the reabsorption process, water, glucose, nutrients, and ions such as sodium are reabsorbed back into the blood. The last process of urine formation is *secretion*. Secretion occurs at the distal and the collecting tubules of the nephron where ions (such as hydrogen and potassium ions), ammonia, and certain metabolites are secreted from the blood into the lumen of the renal tubule to be eliminated in the urine. The urine is drained from the kidneys through the ureters and is stored in the bladder before it is finally excreted through the urethra.

Urine is an aqueous solution consisting largely of water. Urea is the most abundant waste product in urine, resulting from the elimination of ammonia that is produced from the metabolic process of amino acids. The average urea concentration in human urine is approximately 9 g/L. Other major components are creatinine, uric acid, and ions such as phosphate, sulfate,

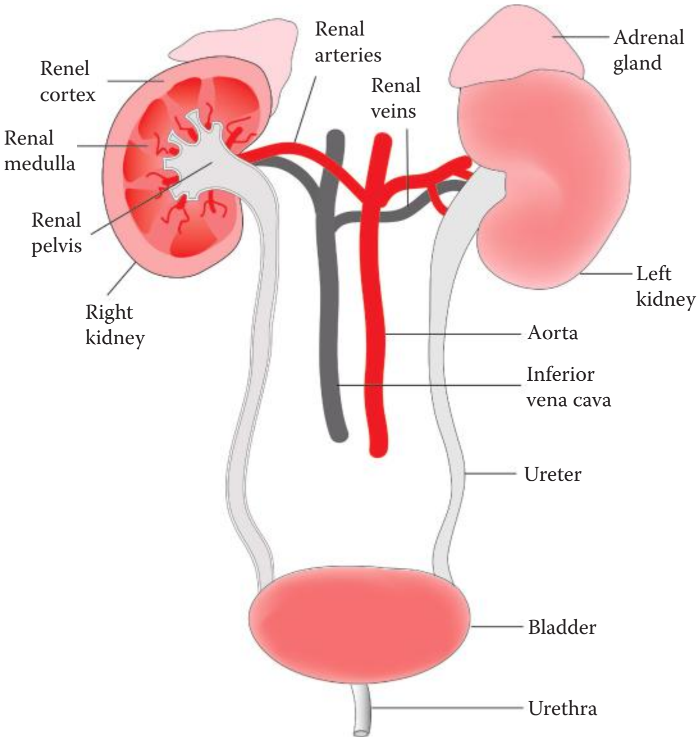

Figure 17.1 Human urinary system. A longitudinal view of the right kidney is shown. (© Richard C. Li.)

chloride, sodium, and potassium. Healthy individuals also excrete a small amount of protein. Urine has a characteristic yellow color. Subsequent to excretion from the body, urine acquires an odor that results from the ammonia that is released from the breakdown of urea by bacteria.

17.1.2 Presumptive Assays

In forensic identification, urine stains can be located by visual examination based on the characteristic yellow color of urine and the detection of the distinctive odor of urine stains. Under alternative light sources, urine stains emit a fluorescent light that facilitates the locating of urine stains in clothing and bedding. Chemical analysis can be carried out to detect the major inorganic anions in urine such as phosphate and sulfate as well as the major organic compounds in urine such as urea, creatinine, and uric acid. These assays are summarized in Table 17.1. However, these assays are not specific to urine. Other bodily fluids, such as sweat, also contain these chemical components.

17.1.2.1 The Identification of Urea

The *para-dimethylaminocinnamaldehyde* (DMAC) assay is simple and rapid and is the most commonly used presumptive assay for the forensic identification of urine stains (Figure 17.4). The DMAC assay can be performed using two different methods: the colorimetric and the fluorometric methods (Figure 17.5).

In the colorimetric method, a portion of a stain (~1 cm^2) is cut and is extracted with 1 mL of distilled water. The extraction is transferred onto a piece of filter paper and is allowed to dry. One drop of 0.1% DMAC solution is then added to the filter paper. DMAC reacts specifically with urea, if present, producing a pink-colored (or magenta-colored) product. DMAC does not react with creatinine, ammonia, or uric acid. The appearance of a pink color within 30 min after applying the DMAC reagent is considered a positive reaction. No color change within 30 min is

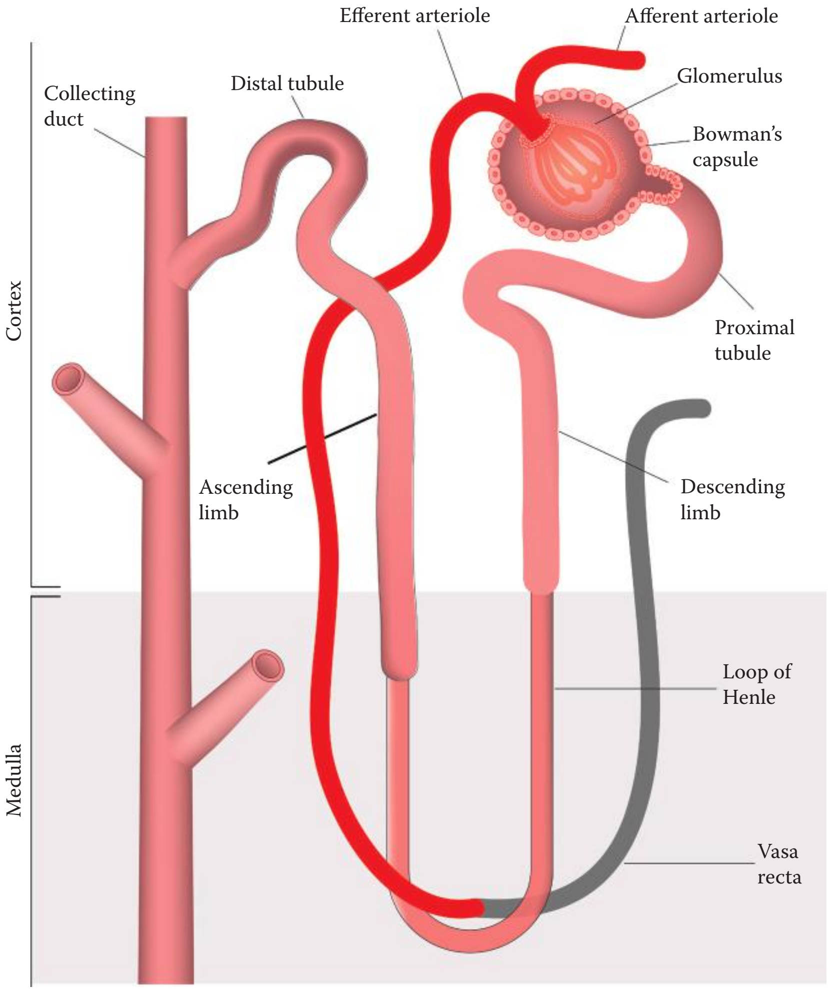
Efferent arteriole
Afferent arteriole
Glomerulus
Bowman's capsule
Collecting duct
Distal tubule
Proximal tubule
Cortex
Ascending limb
Descending limb
Loop of Henle
Medulla
Vasa recta

Figure 17.2 Diagram of the human nephron. (© Richard C. Li.)

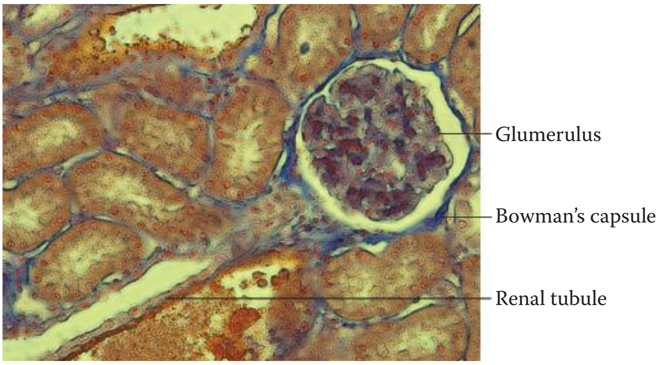
Glumerulus
Bowman's capsule
Renal tubule

Figure 17.3 Section view of the human nephron. (© Richard C. Li.)

Table 17.1 Assays for Identification of Urine and Sweat

Biological Fluid	Assays	Identification	Assay	Method	Further Reading
Urine	Presumptive assays	Locating stains	Visual examination	Alternate light source	Wawryk and Odell (2005)
		Urea	DMAC assay	Colorimetric method	Ong et al. (2012)
				Fluorometric method	Farrugia et al. (2012)
			Microscopic crystal assay	Microscopic examination of urea crystals and urea nitrate crystals converted from urea	Nickolls (1956)
				Microscopic examination of crystals using xanthydrol	Biles and Ziobro (1998)
			Urease assay	The enzyme catalyzes the breakdown of urea and releases ammonia and carbon dioxide. The ammonia is detected using an acid-base indicator, bromthymol blue, which exhibits a blue color	Bedrosian et al. (1984)
				The ammonia is detected using Mn and Ag nitrates, which exhibit a black color	Gaensslen (1983)
			Chromatography	Gas chromatograph–mass spectrometer, thin-layer chromatography	Lum (1991)
		Creatinine	Colorimetric assay	Jaffe’s test, using picric acid to convert creatinine to a red creatinine picrate compound	Greenwald (1930)
				Using potassium ferricyanide to produce a blue nitroprusside compound	O’Leary et al. (1992)
			Chromatography	Gas chromatograph–mass spectrometer	Lum (1991)

		Uric acid	Uricase assay	Measuring the disappearance of the absorption of uric acid at 293 nm after treatment with uricase that catalyzes the oxidation of uric acid to 5-hydroxyisourate	Kageyama (1971)
	Confirmatory assays	Tamm–Horsfall glycoprotein	Immunological assays	RIA, crossover electrophoresis, Ouchterlony, ELISA, and immunochromatographic methods	Tsutsumi et al. (1988)
		17-ketosteroids	Mass spectrometer	Liquid chromatograph–mass spectrometer	Nakazono et al. (2002)
Sweat	Presumptive assays	Lactate, lactic acid, urea, and single amino acids	Various	SEM coupled with EDX and Raman microspectroscopy	Sikirzhytski et al. (2011)
	Confirmatory assays	Dermcidin	Immunological assay	ELISA	Sagawa et al. (2003)
			RNA-based assay	RT-PCR	Sakurada et al. (2010)

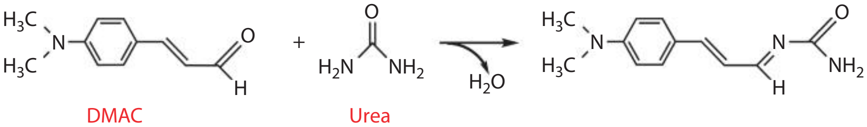

Figure 17.4 Chemical reaction of DMAC assay.

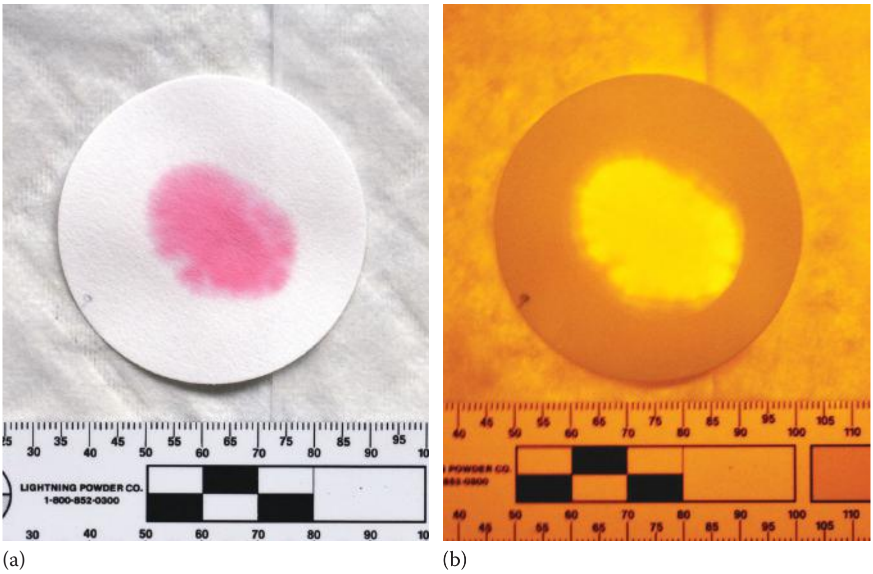

(a) (b)

Figure 17.5 Positive reaction of DMAC assay of a urine stain. (a) Colorimetric and (b) fluorometric method. (© Richard C. Li.)

considered a negative reaction. However, this method is not specific to urine, as other bodily fluids such as saliva, semen, sweat, and vaginal secretions can also give positive reactions. A diluted DMAC solution, from 0.1% to 0.05%, can maintain appropriate sensitivity to urine stains and minimize false-positive reactions caused by the detection of low levels of urea that are present in other bodily fluids.

The fluorometric method is useful for locating urine stains on large pieces of evidence such as clothing and bedding (Figure 17.6). Additionally, this method can detect patterns of urine stains (Figure 17.7), which can be useful in crime scene reconstructions. In the fluorometric method, the evidence to be examined, such as a garment, is covered by a sheet of filter paper that has been preabsorbed with the DMAC solution. The evidence and the filter are then wrapped together in a sheet of aluminum foil and are left overnight in a press, ensuring that the evidence is in close contact with the filter paper. Alternatively, the layers can be heated for 30 s using an iron. Using a light source at 473–548 nm, the DMAC-treated urine stain fluoresces. The fluoresced stain is best observed with a 549 nm filter. However, colored fabrics interfere with the assay since dyes and pigments can inhibit the fluorescence.

In addition to the DMAC test, the identification of urea that is present in urine stains can be carried out by urease assays. Ureases catalyze the breakdown of urea, thus releasing ammonia and carbon dioxide (Figure 17.8). The ammonia is detected using an acid-base indicator, bromthymol blue, which exhibits a blue color. Alternatively, the ammonia can be detected by manganese and silver nitrates, which exhibit a black color. Additional assays such as microscopic crystal and chromatographic assays are summarized in Table 17.1.

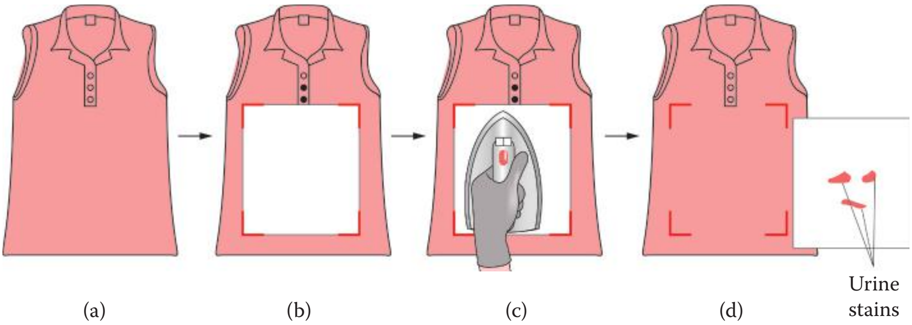

Figure 17.6 Fluorometric DMAC assay of urine stains. Evidence item (a) is closely covered by a piece of moistened filter paper containing DMAC. The orientation of the paper is marked (b). The layers are pressed to allow the transfer of a small amount of the stain onto the paper and are heated using an iron (c). The paper is then lifted. The DMAC-treated urine stain fluoresces under a light source at 473–548 nm (d). (© Richard C. Li.)

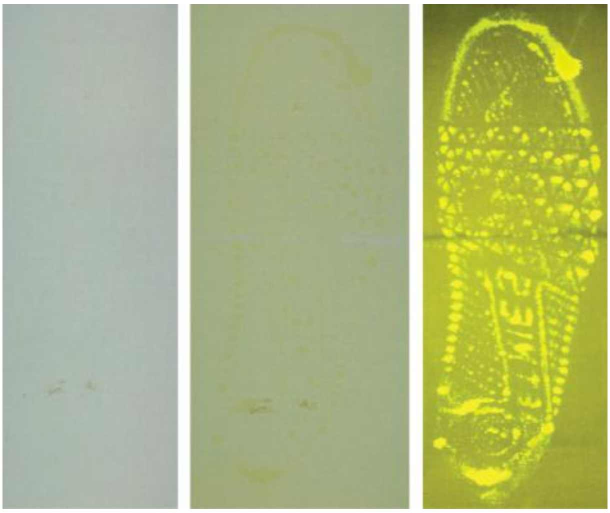

Figure 17.7 Fluorometric DMAC enhancement of a footwear impression in urine on white cotton fabric. From left to right: urine impression, DMAC-treated urine stains under white light, and DMAC-treated urine stains using an excitation light source. (From Farrugia, K.J., et al., *Forensic Sci Int*, 214, 67–81, 2012. With permission.)

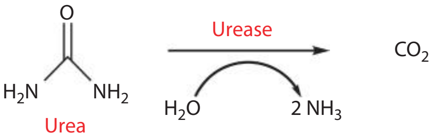

Figure 17.8 Biochemical reaction of urease.

17.1.2.2 Identification of Creatinine

Creatinine is produced during normal muscle cell metabolism (Figure 17.9). During this metabolism, phosphocreatine, an energy-storing molecule in muscle cells, breaks down to form creatine. Creatine is then metabolized to creatinine, which is released from the muscle cells into the blood. Serum creatinine is largely filtrated by the renal glomeruli. A small amount of creatinine is secreted by the renal distal tubules. The amount of creatinine excreted in urine is proportional to the muscle mass of an individual. However, creatinine is not only present in urine. It is also present in other bodily fluids such as blood and semen.

The creatinine present in urine can be detected using the Jaffe color test (Figure 17.10). In this test, picric acid is used to convert creatinine, under alkaline conditions, to form creatinine picrate, which is a bright red product. Additional tests for urine creatinine are summarized in Table 17.1. Recently, a Uritrace device (Abacus Diagnostics) has been made commercially available for the detection of creatinine.

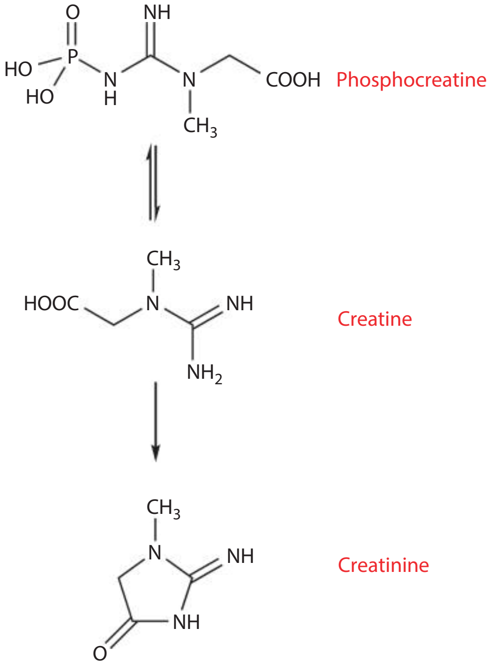

Figure 17.9 Schematic view of the formation of creatinine.

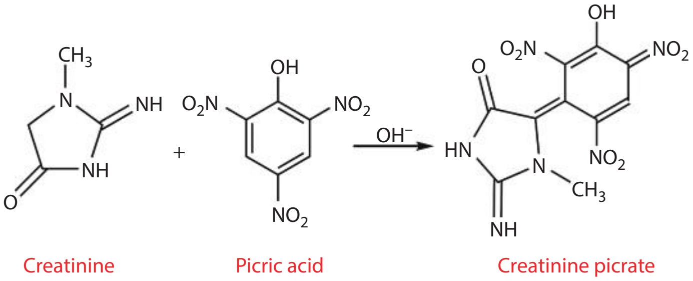

Figure 17.10 Chemical reaction of Jaffe's assay.

17.1.3 Confirmative Assays

17.1.3.1 Identification of Tamm–Horsfall Protein

Tamm–Horsfall protein (THP), also known as *uromodulin*, is the most abundant protein in urine, and accounts for 40% of the urine proteins. THP is exclusively synthesized in the epithelial cells of Henle's loop. THP is secreted from the apical plasma membrane of the epithelial cells into the lumen. Under physiological conditions, an adult excretes 20–100 mg of THP into urine daily. The biological function of THP is not fully understood. It is speculated that it prevents the body from contracting urinary tract infections and from forming renal stones.

THP is a urine-specific biomarker for forensic urine identification. It can be detected using an enzyme-linked immunosorbent assay (ELISA). More recently, it can be detected using an immunochromatographic assay, RSID-Urine, which utilizes a polyclonal rabbit antibody that is specific to THP (Figures 17.11 and 17.12). This test is rapid and simple and thus can be used as a screening test in laboratories and as a field test at crime scenes to identify urine. The detection limit of RSID-Urine for THP is 0.5 μL of urine. Although the sensitivity of RSID-Urine is lower than that of ELISA detection of THP, it is sufficient for forensic applications. These methods are specific to THP that is present only in urine while no detection is found in other bodily fluids such as plasma, saliva, semen, vaginal fluid, or sweat.

17.1.3.2 Identification of 17-Ketosteroids

In humans, urine contains derivatives of 17-ketosteroids such as androsterone, dehydroepiandrosterone (DHEA), and etiocholanolone. *Androsterone* is a steroid hormone with a weak potency of testosterone. *DHEA* is a metabolic intermediate in the biosynthesis of the gonadal steroids. DHEA also has a potential function as a steroid hormone. *Etiocholanolone* is a metabolite of testosterone. These compounds are present in urine as conjugates, in which 17-ketosteroids

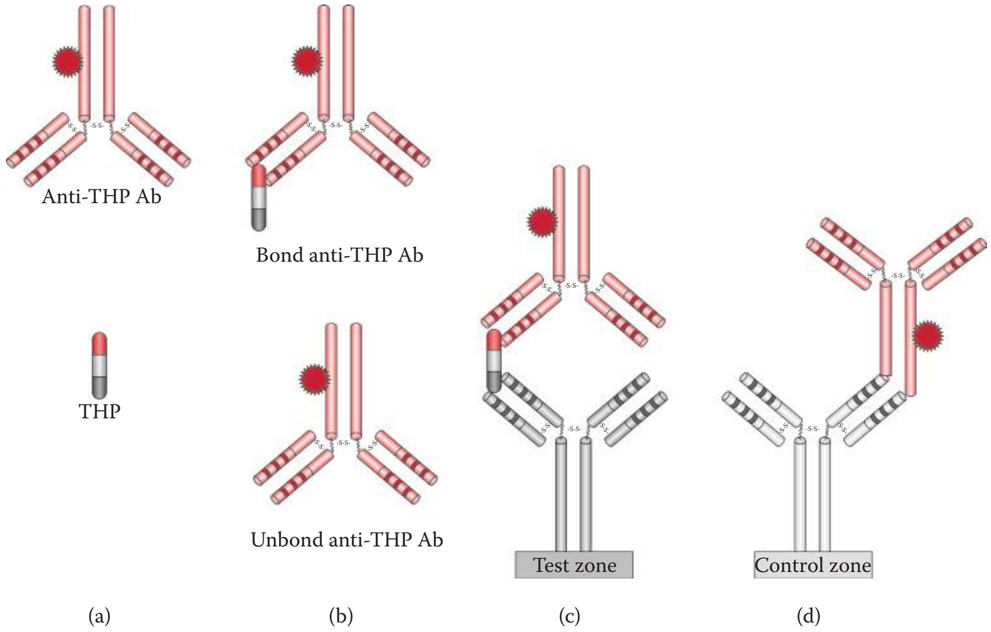

Figure 17.11 Immunochromatographic assays for the identification of THP in urine. (a) In a sample well, THP in a urine sample is mixed with labeled anti-THP Ab. (b) The THP binds to the labeled anti-THP Ab to form a labeled Ab–THP complex. (c) At the test zone, the labeled complex binds to an immobilized anti-THP Ab to form a labeled Ab–THP–Ab sandwich. (d) At the control zone, the labeled anti-THP Ab binds to an immobilized antiglobulin and is captured at the control zone. Ab, antibody; THP, Tamm–Horsfall protein antigen. (© Richard C. Li.)

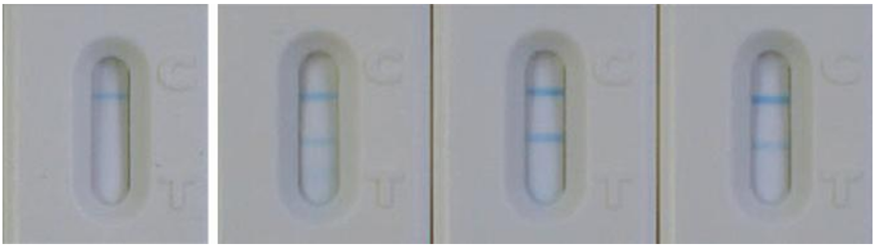

Figure 17.12 Results obtained using immunochromatographic assays (RSID™-Urine; Independent Forensics, Lombard, IL) for the identification of THP in urine. From left to right: negative control, undiluted, 1:10 diluted, and 1:100 diluted urine samples. A visible blue line at the test (T) zone and control (C) zone indicates a positive result. The blue line at the control zone only indicates a negative result. (From Akutsu, T., Watanabe, K., and Sakurada, K., *J Forensic Sci*, 57, 1570–1573, 2012. With permission.)

are modified in the liver through glucuronidation and sulfation. In glucuronidation, glucuronic acids are added to 17-ketosteroids while in sulfation, sulfates are transferred to 17-ketosteroids. As a result, these conjugates, containing charged moieties, are more water soluble than the nonconjugated 17-ketosteroids. Thus, they are excreted into urine to be eliminated from the body. The five major components of the 17-ketosteroid conjugates present in human urine are androsterone glucuronide, androsterone sulfate, DHEA sulfate, etiocholanolone glucuronide, and etiocholanolone sulfate (Figure 17.13). Thus, the analysis of 17-ketosteroid conjugates in urine stains is useful for the identification of human urine stains. These five 17-ketosteroid conjugates can be identified using liquid chromatography–mass spectrometry (LC-MS). However, some of these 17-ketosteroid conjugates are also detected in serum. Therefore, the presence of all five conjugated 17-ketosteroids in a sample is required to identify a urine stain. Additionally, the profiles of the 17-ketosteroid conjugates are human specific and are distinguishable between humans and animals.

17.2 Identification of Sweat

Sweat is the least common bodily fluid analyzed in forensic laboratories compared with others that have been mentioned in previous chapters. However, sweat identification is still useful for forensic investigations. For example, forensic DNA analysis allows the generation of DNA profiles from trace biological evidence such as fingerprints. Identifying sweat can be important for the analysis of these types of evidence.

17.2.1 Biology of Perspiration

Humans have two types of secretory sweat glands: the eccrine and the apocrine sweat glands (Figure 17.14). *Eccrine* sweat glands are distributed almost all over the body and are controlled by the sympathetic nervous system. Eccrine sweat glands play a role in regulating body temperature. When the body temperature rises, eccrine sweat glands secrete a watery sweat to the skin's surface where heat is carried away through the evaporation of the sweat to maintain normal body temperature. In humans, *apocrine* sweat glands, which are associated with hair follicles, are usually restricted to the underarm and genital areas and are controlled by emotional stress. Apocrine sweat glands are inactive until puberty. This type of sweat gland secretes an oily sweat that is odorous after being processed by skin bacteria. The majority of sweat evidence that is analyzed in forensic laboratories is sweat stains secreted from eccrine glands. Sweat contains water, minerals, lactate, and urea. Its biochemical composition varies

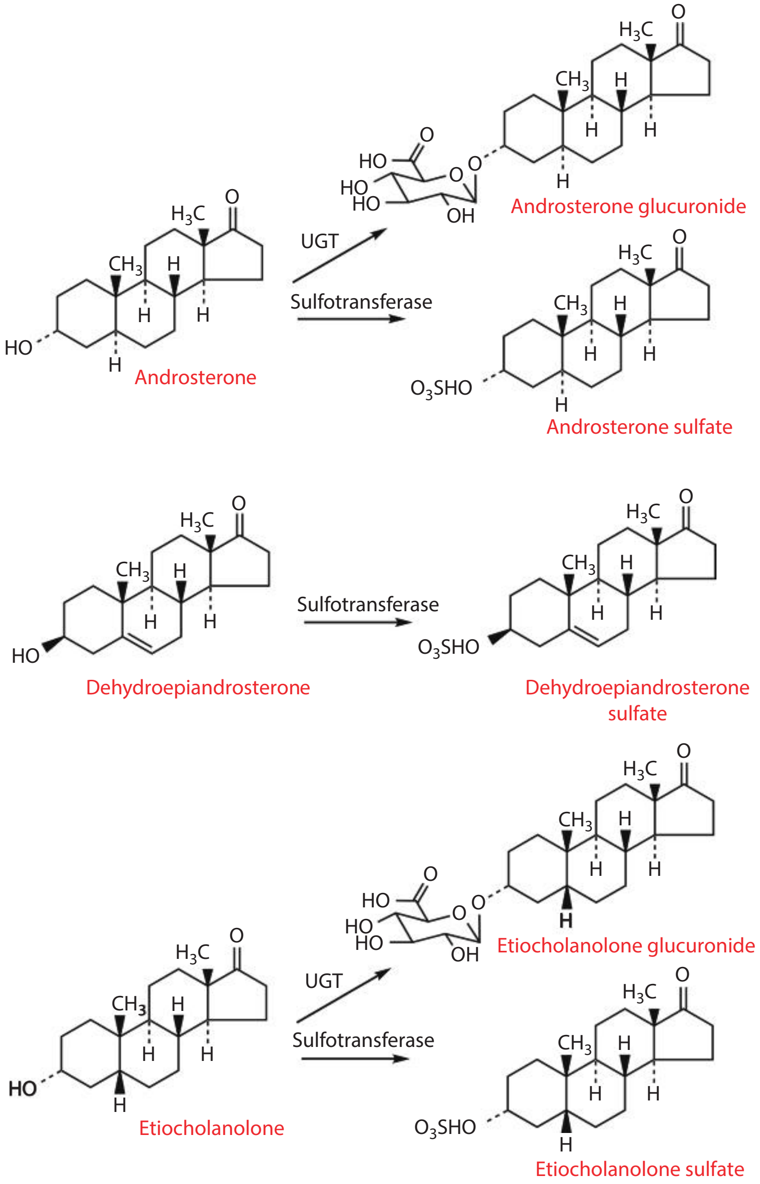
Androsterone
UGT
Sulfotransferase
Androsterone glucuronide
Androsterone sulfate
Dehydroepiandrosterone
Sulfotransferase
Dehydroepiandrosterone sulfate
Etiocholanolone
UGT
Sulfotransferase
Etiocholanolone glucuronide
Etiocholanolone sulfate

Figure 17.13 Structural formula of 17-ketosteroids and 17-ketosteroid conjugates present in human urine. UGT, UDP glucuronosyltransferase. (© Richard C. Li.)

among individuals and their physical activities. Sweat contains low levels of constituents that are also present in other bodily fluids such as urine. Thus, it has been considered a difficult bodily fluid to identify.

17.2.2 Sweat Identification Assays

Sweat evidence has been analyzed using presumptive assays (Table 17.1) such as elemental analysis using scanning electron microscopes coupled with energy dispersive x-ray spectroscopy in the detection of lactic acid. Since sweat contains many inorganic and organic compounds that are also present in other bodily fluids, these assays are not specific to sweat. Raman

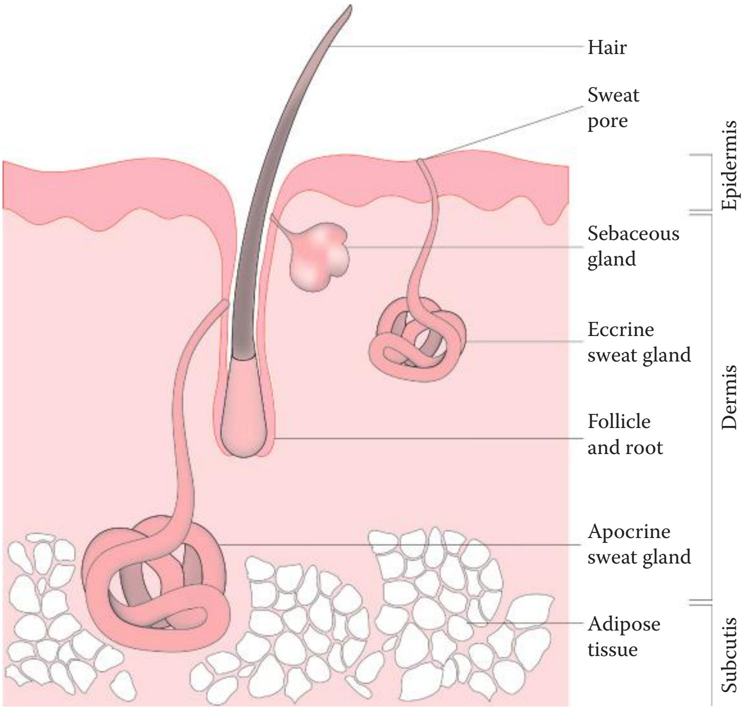

Figure 17.14 Diagram of the human eccrine and apocrine sweat glands. (© Richard C. Li.)

microspectroscopy is potentially useful for the identification of sweat for forensic purposes, which is based largely on the profiles of lactate, lactic acid, urea, and single amino acids in urine.

Recently, *dermcidin* has been identified as a potential biomarker of human sweat. Dermcidin belongs to a class of human antimicrobial peptides of the innate immune defense system and plays an important role in protecting epithelial barriers from infections. Dermcidin, specifically expressed in eccrine sweat glands (Figure 17.15), is secreted into the sweat and is transferred to the epidermal surface. In forensic applications, dermcidin can potentially be utilized as a biomarker for the confirmatory assay of sweat identification. The detection of dermcidin in sweat stains can be performed using ELISA assays utilizing antibodies specific to human dermcidin. This method is highly sensitive and is able to detect dermcidin in sweat samples that are diluted 10,000-fold. Dermcidin is encoded by the *DCD* gene. Its mRNA can be detected using reverse transcription polymerase chain reaction (RT-PCR) assays (Chapter 7) that can detect *DCD* mRNA in 10 μL of sweat sample. Dermcidin assays are also specific to sweat as dermcidin is not detected in other bodily fluids such as semen, saliva, and urine.

17.3 Identification of Fecal Matter

The examination of feces has been used in criminal investigations for over a century. Specifically in 1948, a burglary case was reported using fecal analysis to link the shoes of a suspect to a crime scene. One of the aspects of fecal analysis is to determine a common origin of the reference sample and the fecal evidence, thus potentially linking a suspect to a crime scene. Today, the individual characteristics of a fecal sample can be effectively determined using forensic DNA analysis of sloughed intestinal epithelial cells that are present in fecal matter. The identification of fecal matter is valuable in providing important information for a criminal investigation. For example, the presence of fecal matter may corroborate a sexual

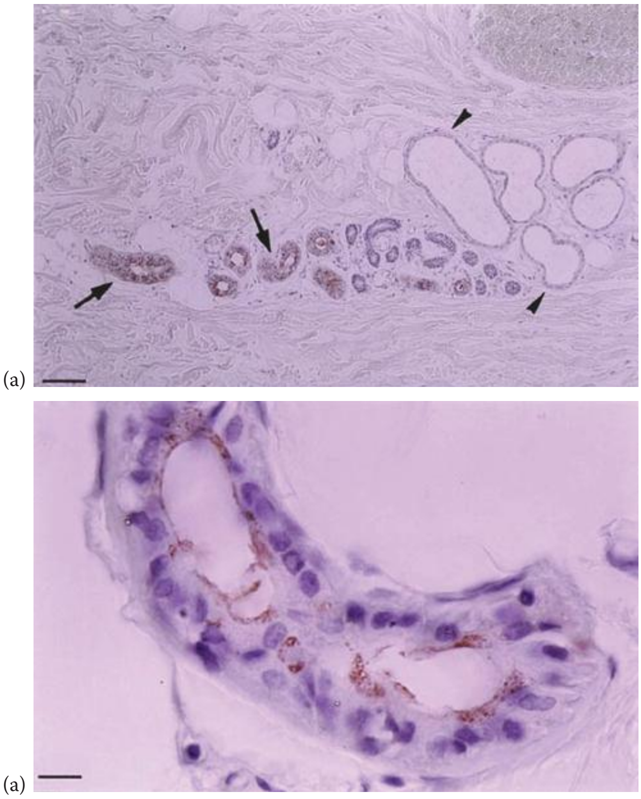

Figure 17.15 Localization of the dermcidin peptide in the sweat glands. Skin tissue sections are treated with a dermcidin antibody and stained. (a) Both the eccrine and apocrine sweat glands are shown. Only cells of the eccrine gland in the skin express dermcidin (brown stained). Arrows: eccrine sweat glands. Arrowheads: apocrine sweat glands. Scale bar: 100 μm. (b) Close-up view of the eccrine gland. The presence of the dermcidin peptide is observed (brown). Scale bar: 10 μm. (From Sagawa, K., et al., *Int J Legal Med*, 117, 90–95, 2003. With permission.)

assault involving sodomy, assault with fecal matter, vandalism, and burglary during which the perpetrator defecated at the scene.

17.3.1 Fecal Formation

Feces are a type of waste matter that is the direct result of food that has been processed by the digestive system (Figure 17.16). Human feces contain undigested foodstuffs, sloughed intestinal epithelial cells, intestinal bacteria, bile pigments, electrolytes, and water. Feces are formed in the intestines during the last phase of digestion. Feces first enter the colon in liquid form. Most of the nutrients are absorbed on the surface area of the small intestine. In the large intestine, water, sodium, and chloride are absorbed on the surface of the lumen. The remaining luminal contents are converted into feces. Food stays for approximately 2–6 h in the stomach. It takes an additional 3–5 h to travel through the small intestine and 12–24 h to travel through the large intestine.

17.3.2 Fecal Matter Identification Assays

A fecal analysis includes macroscopic and microscopic examination, chemical tests, and fecal bacterial identification.

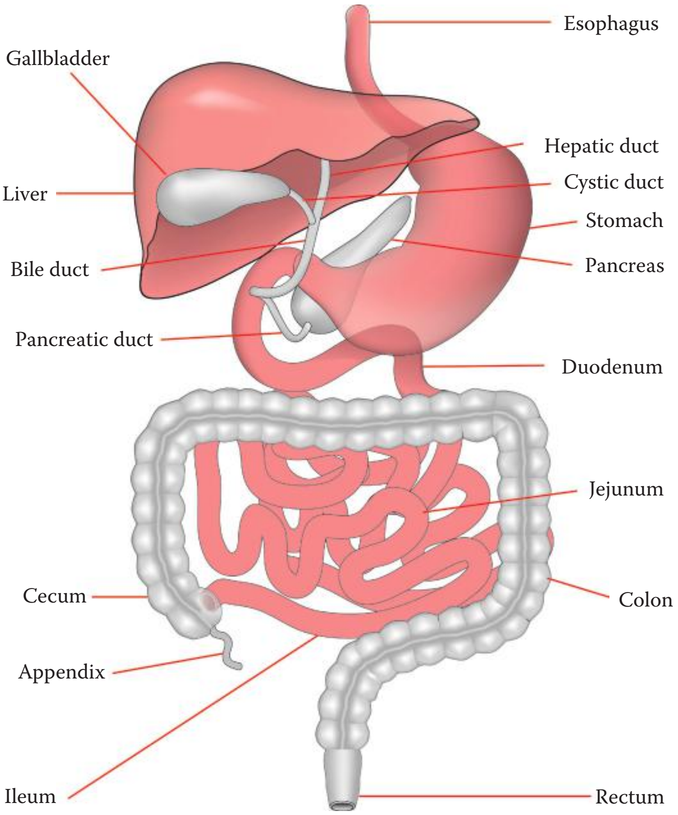

Figure 17.16 Diagram of the human digestive system. The esophagus, stomach, liver, gallbladder, pancreas, small intestine (duodenum, jejunum, and ileum), and large intestine (cecum, colon, appendix, and rectum) are shown. (© Richard C. Li.)

17.3.2.1 Macroscopic and Microscopic Examination

The color and odor of human feces are useful characteristics for fecal identification. The normal brown color of feces primarily results from the presence of urobilinoids, which are heme catabolic by-products. The characteristic odor of feces is caused by the metabolic by-products of the intestinal bacterial flora. Indole, skatole, and hydrogen sulfide are the compounds that are responsible for the odor of feces.

When fecal stains are analyzed, the microscopic examination of the feces can be performed on an aliquot of fecal suspension. The presence of characteristic undigested foodstuffs can indicate human feces. Fecal matter can be transferred from samples of clothing by scraping with a sterile stainless steel spatula. The fecal matter is then hydrated in 6% formalin solution for 24–48 h prior to microscopic examination. Undigested foodstuffs such as vegetable fragments and meat fibers are often present in human feces. Vegetable fragments (Figure 17.17) are often undigested vegetable dermal tissues that cover and protect the plant and fragments of vascular tissues that play roles in transporting water and nutrients throughout the plant. The types of vegetables can be identified by comparing the observed fragments with known plants. Meat fibers (Figure 17.18) are undigested animal skeletal muscle fibers. These fibers have characteristic striations, usually rectangular in shape, that are used for comparison with known animal tissues.

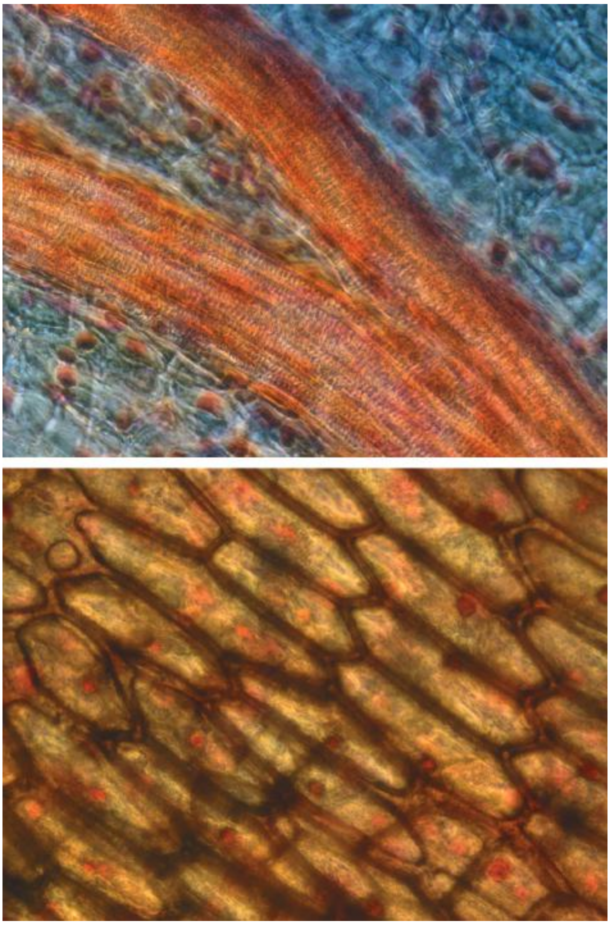

Figure 17.17 Scallion vascular tissue (top) and dermal tissue (bottom). (© Richard C. Li.)

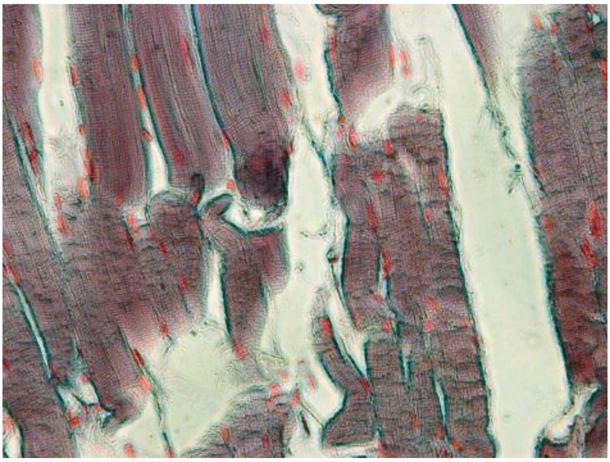

Figure 17.18 Cattle meat fibers. (© Richard C. Li.)

17.3.2.2 Urobilinoids Tests

The forensic analysis of fecal matter often involves the identification of fecal stains on swabs and clothing from which small amounts of sample may be available. Chemical tests can be useful for the analysis of fecal stains. By far the most common chemical test performed on feces is the detection of urobilinoids. *Urobilinoids*, including urobilin and stercobilin, are generated from the degradation of heme and are excreted into feces.

The average lifetime of erythrocytes is approximately 3–4 months. Erythrocytes are continuously undergoing hemolysis in which erythrocytes are naturally broken down and are usually processed in the reticuloendothelial system of the spleen. Hemoglobin is released daily during the hemolysis process and is degraded into heme, globin, and iron. Other sources of heme are derived from the degradation of erythrocyte precursors in bone marrow and other heme-containing proteins such as myoglobin and cytochromes. In the peripheral tissues, heme undergoes catabolism to form *bilirubin* (Figures 17.19 and 17.20). Bilirubin is further converted to *urobilinogen* in the intestine. A portion of urobilinogen is reduced to *stercobilinogen*. In the large intestine, the spontaneous oxidation of urobilinogen and stercobilinogen results in the formation of

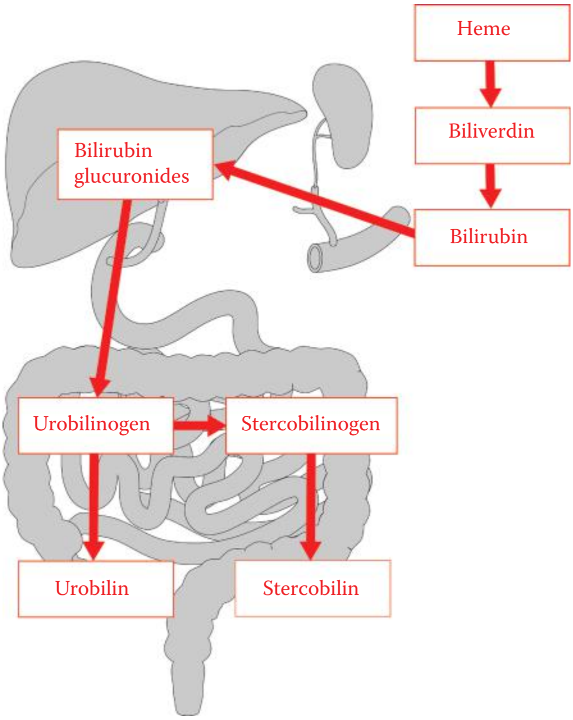

Figure 17.19 The formation of urobilinoids. Aged erythrocytes are disposed in the spleen, releasing hemoglobin that is broken down to heme. The heme is converted to biliverdin and is subsequently reduced to bilirubin. The bilirubin is then released into the bloodstream where it is bound to albumin, which cannot be filtrated at the glomeruli. The bilirubin is transported through the bloodstream to the liver where it is conjugated with glucuronic acid, forming water-soluble bilirubin monoglucuronide and diglucuronide. The bilirubin glucuronides are excreted into the bile and are subsequently excreted into the small intestine. In the intestines, the glucuronic acid of the conjugated bilirubin is removed. The unconjugated bilirubin is metabolized by intestinal bacteria, forming urobilinogen. A portion of the urobilinogen is further metabolized to stercobilinogen. The urobilinogen and the stercobilinogen are oxidized by intestinal bacteria, forming urobilin and stercobilin, respectively, which are excreted into the feces. (© Richard C. Li.)

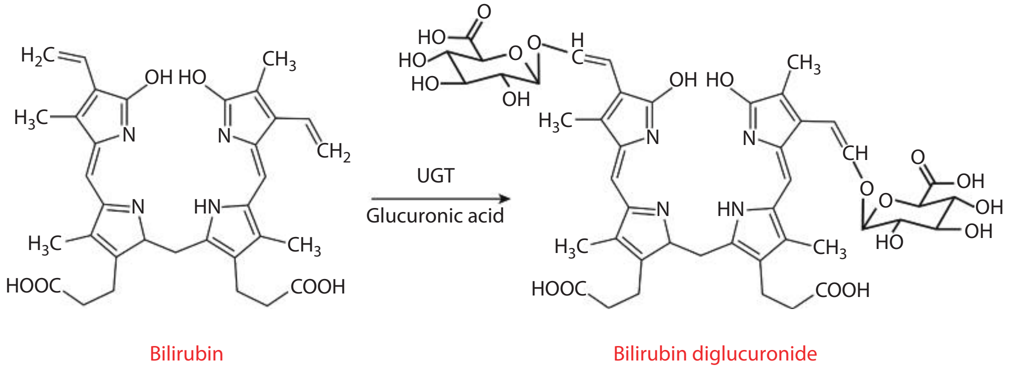

Figure 17.20 The formation of bilirubin glucuronides in the liver. UGT, UDP glucuronosyltransferases.

urobilin and stercobilin (Figure 17.21), respectively. These compounds are brown colored and are responsible for the characteristic color of feces.

The urobilinoids can be detected using the Schlesinger and Edelman tests. In the *Schlesinger* test, a sample is mixed with saturated zinc acetate in ethanol solution to form aurobilinoid–zinc chelation complex that emits a characteristic green fluorescence under ultraviolet light. The *Edelman* test is a variation of the Schlesinger test. A sample is treated with a mercuric salt solution to yield a pink-colored compound. Further treatment with a zinc salt produces fluorescence. However, less fluorescence is observed in the Edelman test than in the Schlesinger test. Inconclusive and inconsistent results are often obtained using these tests where fecal material sometimes gives no visible fluorescence. Additionally, the intensity of the fluorescence observed varies between samples. The reliability and selectivity of the tests can be increased using a spectrometric measurement of the fluorescence detection of fecal urobilinoids based on the principle of the Schlesinger test. A dry sample is treated with 1 mL of zinc acetate solution (1% zinc acetate methoxyethanol solution and 0.2% Tris). The suspension is then sonicated for 5 min, heated at 100°C for 10 min, cooled, and centrifuged. The presence of urobilinoids can be detected using excitation and emission maxima at 507 and 514 nm, respectively.

The disadvantages of the Schlesinger and the Edelman tests are their low species specificity as both tests cannot distinguish between human and other mammalian fecal materials. Moreover, under normal circumstances, up to 5% of urobilinogen is transported to the kidney and oxidized to urobilin in urine. Under some pathological conditions such as hepatic function disorders, the level of urobilin in the urine can be very high. Both the Schlesinger and Edelman tests respond to the urobilin of urine stains as well.

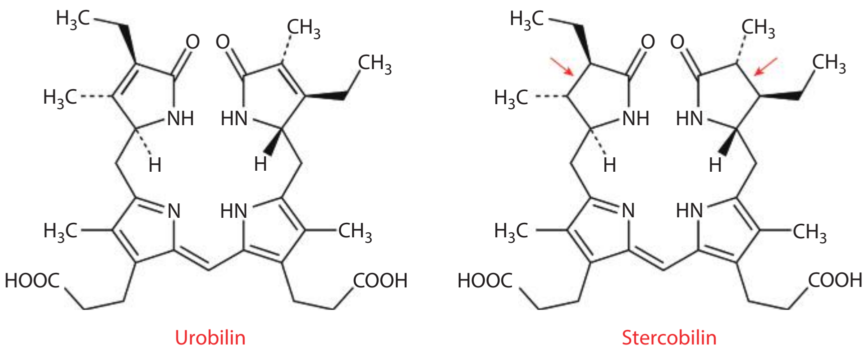

Figure 17.21 Urobilinoids: urobilin and stercobilin. Arrow, site of reduction.

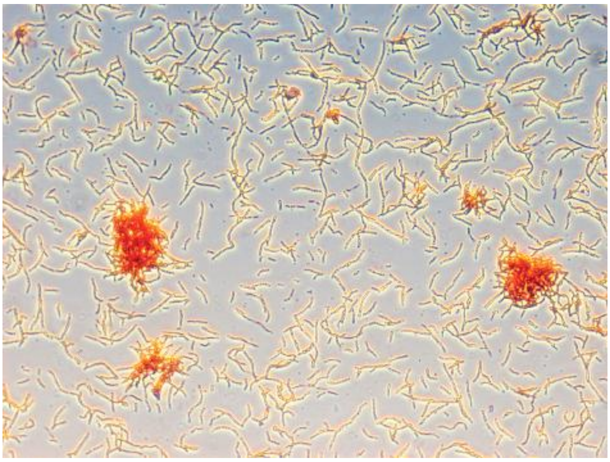

Figure 17.22 Intestinal bacteria. (© Richard C. Li.)

17.3.2.3 Fecal Bacterial Identification

The human intestinal microbiota contains more than 4000 bacterial species (Figure 17.22). Traditional methods for detecting fecal materials utilize the cultivation of fecal indicator bacteria such as *Escherichia coli* or *Enterococci* spp. However, these fecal indicator bacteria constitute only a small portion of the fecal microbiota, and thus may not be adequate for forensic identification purposes. *Bacteroides*, however, accounts for approximately 30% of fecal microbiota that are the predominant bacteria in human feces. *Bacteroides* can potentially be used for the forensic identification of feces. *Bacteroides* is a genus of rod-shaped, anaerobic gram-negative bacteria. These bacteria play a role in digesting complex carbohydrates and other substances that cannot be digested by human enzymes. The identification of *bacteroides* can be carried out by detecting specific DNA sequences of the *rpoB* gene, which encodes the β subunit of bacterial RNA polymerase (Chapter 11). The presence of the species-specific DNA sequence can be detected by RT-PCR utilizing primers that are specific to the target species but not to other species. Thus, only a targeted species can be amplified if it is present. Two fecal predominant bacteroides species, *B. uniformis* and *B. vulgatus*, can be detected in feces. *B. uniformis* is not detectable in blood, saliva, semen, urine, vaginal fluids, or on skin surfaces. Therefore, *B. uniformis* is considered as a specific indicator bacterium for forensic fecal identification. Sometimes, *B. vulgatus* can also be detected in vaginal fluid samples. Therefore, precaution should be taken in interpreting the results obtained using a *B. vulgatus* assay. Additionally, this method alone cannot discriminate between human and animal feces. Furthermore, fecal microbial populations can be affected by the host's diet. Individuals who consume saturated fats and proteins, which are abundant in Western diets, have predominantly *Bacteroides* species in their feces. However, individuals who consume a low-fat and carbohydrate-rich diet have predominantly *Prevotella* species, also a genus of gram-negative bacteria, in their feces.

17.4 Identification of Vomitus

17.4.1 Biology of Gastric Fluid

Gastric fluid can be found in stains derived from stomach wounds. Most often, gastric fluid is from vomitus found at a crime scene or as dried stains on clothing. Vomiting is the forceful expulsion of the contents of the stomach through the mouth (Figure 17.23). It is usually preceded by salivation, sweating, and the sensation of nausea. Vomiting usually begins with a deep

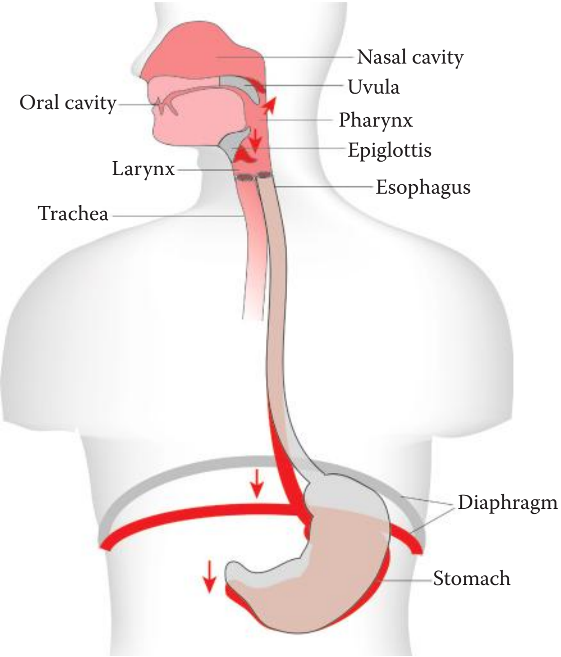

Figure 17.23 Act of vomiting. The contraction of the diaphragm and the stomach during the phase of vomiting is shown (in red). Additionally, the positions of the epiglottis and the uvula during vomiting are shown (in red). As a result, the stomach contents are expelled through the mouth. (© Richard C. Li.)

inhalation and the closure of the glottis. Subsequent contractions of the diaphragm and the abdominal muscles compress the stomach. The gastric contents are then forced upward through the relaxed sphincters and the esophagus, and are expelled through the mouth. Since the glottis is closed, vomitus usually does not enter the respiratory tract. Although the uvula is usually raised to close the nasal cavity, vomitus sometimes enters the nose. Vomiting can be caused by a wide variety of pathological conditions. Vomiting may be a specific response to acute intoxication in homicidal poisoning cases or it may be caused by trauma in a violent assault. Thus, the forensic identification of the gastric fluid can corroborate a criminal act.

The stomach stores ingested food until it can be emptied into the small intestines. When food enters the stomach, hydrochloric acid is secreted in large quantities, which facilitates the initial degradation of proteins. The stomach also secretes mucus that lubricates the gastric surface to protect the epithelium from acidic environments. Hormones such as gastrin, which are found in the gastric fluid, regulate acid secretion and gastric movement. A number of enzymes are secreted into the gastric fluid, including lipase, which plays a role in lipid hydrolysis, and gelatinase, which can hydrolyze gelatin. The stomach also secretes pepsinogens, which are enzyme precursors, into the gastric fluid. In the stomach, pepsinogens are activated by hydrochloric acid into pepsin, which is largely responsible for the digestion of proteins.

17.4.2 Vomitus Identification Assays

Vomitus is highly acidic and tends to be malodorous. The color of vomitus may be of forensic interest. Fresh blood in the vomit is usually bright red and suggests bleeding due to injuries, while dark red blood clots suggest bleeding in the stomach due to pathological conditions such as an ulcer. A microscopic examination (Section 17.3.2.1) can be performed to identify recently ingested food particles that are present in a sample. The presence of gastric fluid in vomitus can also be identified by the detection of pepsins secreted from the stomach. This identification test

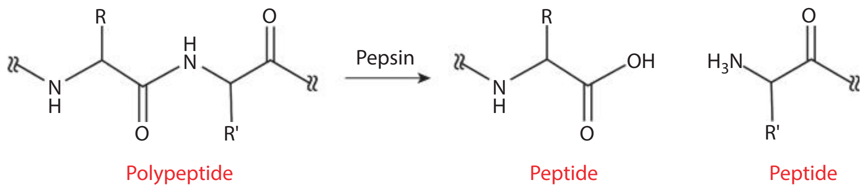

Figure 17.24 The cleavage of polypeptide by pepsin. Pepsin cleaves polypeptide at sites of aromatic amino acids. R and R′: tryptophan, phenylalanine, or tyrosine.

is based on the proteolytic activity of pepsins. Pepsins are endopeptidases that cleave primarily on peptide bonds in the middle of the protein. Aromatic amino acids such as tryptophan, phenylalanine, and tyrosine are the preferred targeted amino acids for the cleavage reaction by pepsins (Figure 17.24). In the pepsin-proteolytic assay, fibrin blue is used as a substrate for pepsin. Fibrin blue is an insoluble protein–dye complex that is colorless. In the presence of vomitus, pepsin cleaves fibrin blue and releases a chromophore that is soluble in water and exhibits a blue color. In the assay, a fibrin blue–containing agarose gel is utilized. The sample from vomitus is loaded onto the gel plate. After incubation, a blue ring around the sample can be observed as a result of the enzymatic reactivity of pepsin. The amounts of pepsin in a sample can be quantified. The results on the gel plate can be photographed and the dried gel plate can also be preserved as evidence. This method can determine the pepsin content of fresh and aged forensic samples. Bodily fluids other than vomitus do not show positive reactions with the use of this method. However, this method cannot distinguish the vomitus of humans from that of other vertebrates.

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SECTION IV

Individualization of Biological Evidence

18

Blood Group Typing and Protein Profiling

18.1 Blood Group Typing

18.1.1 Blood Groups

For the purposes of this text, blood groups are defined as antigen polymorphisms present on erythrocyte surfaces. Human erythrocyte surface membranes contain a variety of blood group antigens. Transfusion reactions occur when an incompatible type of blood is transfused into an individual, which can lead to severe symptoms or even death. Karl Landsteiner discovered the first blood group, known as the ABO system, in the early 1900s, while studying transfusion and transplantation. The discovery made blood transfusions feasible, and Landsteiner was awarded the Nobel Prize in 1930.

The International Society of Blood Transfusion currently recognizes 29 blood group systems, which include hundreds of antigen polymorphisms (Table 18.1). From the 1950s to the 1970s, the structures and biosynthesis pathways of many blood group antigens were determined. The genes for most of these blood group systems have been identified as well. The isolation of blood group genes has made it possible to understand the molecular mechanisms of the antigenic characteristics of the blood group systems.

The ABO system of antigens in human erythrocytes is the most commonly used blood group system for forensic applications. Forensic laboratories also use others, including the Rh, MNS, Kell, Duffy, and Kidd systems.

18.1.2 ABO Blood Group System

In the ABO blood group system, two types of antigens, designated A and B, give rise to four blood types:

- Type A individuals have the A antigen.
- Type B individuals have the B antigen.
- Type AB individuals have both A and B antigens.
- Type O individuals have neither A nor B antigens.

The antigens may be found in other bodily fluids as well as blood, such as amniotic fluid, saliva, and semen as well as many organs including the kidney, pancreas, liver, and lungs.

Table 18.1 Blood Group Systems

Number	Name	Symbol	Number of Antigens	Gene Names	Chromosomal Location
001	ABO	ABO	4	*ABO*	9q34.2
002	MNS	MNS	43	*GYPA, GYPB, GYPE*	4q31.21
003	P	P1	1		22q11.2-qter
004	Rh	RH	49	*RHD, RHCE*	1p36.11
005	Lutheran	LU	20	*LU*	19q13.32
006	Kell	KEL	25	*KEL*	7q34
007	Lewis	LE	6	*FUT3*	19p13.3
008	Duffy	FY	6	*FY*	1q23.2
009	Kidd	JK	3	*SLC41A1*	18q12.3
010	Diego	DI	21	*SLC4A1*	17q21.31
011	Yt	YT	2	*ACHE*	7q22.1
012	Xg	XG	2	*XG, MIC2*	Xp22.33, Yp11.3
013	Scianna	SC	5	*ERMAP*	1p34.2
014	Dombrock	DO	5	*DO*	12p12.3
015	Colton	CO	3	*AQP1*	7p14.3
016	Landsteiner-Wiener	LW	3	*ICAM4*	19p13.2
017	Chido/ Rodgers	CH/RG	9	*C4A, C4B*	6p21.3
018	H	H	1	*FUT1*	19q13.33
019	Kx	XK	1	*XK*	Xp21.1
020	Gerbich	GE	8	*GYPC*	2q14.3
021	Cromer	CROM	12	*DAF*	1q32.2
022	Knops	KN	8	*CR1*	1q32.2
023	Indian	IN	2	*CD44*	11p13
024	Ok	OK	1	*BSG*	19p13.3
025	Raph	RAPH	1	*CD151*	11p15.5
026	John Milton Hagen	JMH	1	*SEMA7A*	15q24.1
027	I	I	1	*GCNT2*	6p24.2
028	Globoside	GLOB	1	*B3GALT3*	3q26.1
029	Gill	GIL	1	*AQP3*	9p13.3

Source: Adapted from Daniels, G.L., et al., *Vox Sang*, 87, 304–316, 2004.

18.1.2.1 Biosynthesis of Antigens

All individuals generate the *O antigen*, also known as the *H antigen*. The O antigen is synthesized by *fucosyltransferase*, a fucose transferase encoded by the *FUT* genes, which adds a fucose on the end of a glycolipid (in erythrocytes) or glycoprotein (in tissues). An additional monosaccharide (Figure 18.1) is then transferred to the O antigen by a transferase encoded by the *ABO* locus. The specificity of this enzyme determines the ABO blood type (Figure 18.2):

- The *A* allele produces the A-transferase, which transfers N-acetylgalactosamine to the O antigen and thus synthesizes the A antigen.
- The *B* allele produces the B-transferase, which transfers galactose to the O antigen and thus synthesizes the B antigen.
- The *O* allele has a mutation (small deletion), which eliminates transferase activity, and no modification of the O antigen occurs.

As a result, the A and B antigens differ in their terminal sugar molecules. Subgroups of blood types A and B have been described. The most important are the A_1 and A_2 antigens. Both A_1 and A_2 (and A_1B and A_2B) cells react with anti-A antibodies. However, A_1 cells react more strongly than A_2 cells. The apparent difference between A_1 and A_2 is that each A_1 cell contains more copies of the A antigen than A_2 cells.

18.1.2.2 Molecular Basis of the ABO System

A- and B-transferases are encoded by a single gene, *ABO*, on chromosome 9. The *ABO* gene (approximately 20 kb) is organized into seven exons. Most of its coding regions are located in exons 6 and 7 of the *ABO* locus, including the domain responsible for catalytic activity (Figure 18.3). The gene products of the *A* and *B* alleles differ by four amino acid substitutions (Table 18.2). In particular, amino acid residues at positions 266 and 268 are more important in determining the enzymatic property of a transferase.

The A^1 allele and A^2 allele differ in a single nucleotide deletion upstream from the translation stop codon. The resulting reading-frame shift in the A^2 allele abolishes the stop codon, yielding a product with an extra 21–amino acid residue at the C-terminus.

Subgroups of blood types O have also been reported. The sequence of the O^1 allele has a deletion of a single nucleotide at exon 6. This nucleotide deletion leads to a reading-frame shift generating a truncated protein, which lacks the catalytic domain. While the O^{1y} allele also has a single nucleotide deletion, it differs from O^1 by nine nucleotides within the coding sequence. O^1 and O^{1y} have identical phenotypes. There is also an O^2 allele, which is inactivated by a substitution

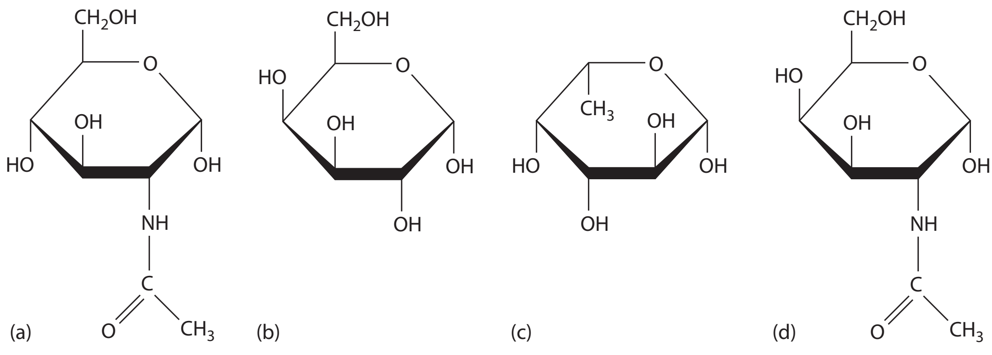

Figure 18.1 Chemical structures of (a) *N*-acetylglucosamine, (b) galactose, (c) fucose, and (d) *N*-acetylgalactosamine.

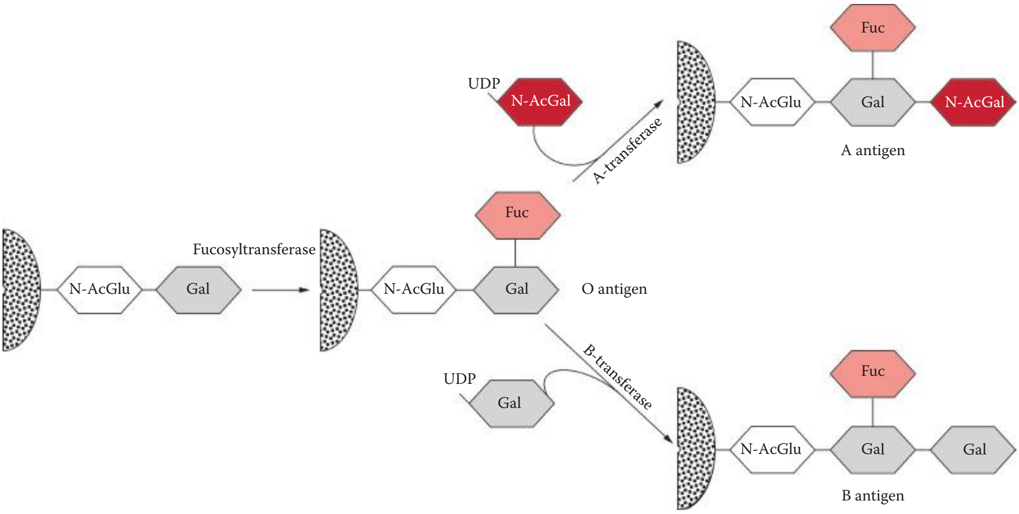
Fuc
UDP
N-AcGal
N-AcGlu
Gal
N-AcGal
A-transferase
A antigen
Fucosyltransferase
Fuc
N-AcGlu
Gal
N-AcGlu
Gal
O antigen
B-transferase
UDP
Gal
Fuc
N-AcGlu
Gal
Gal
B antigen

Figure 18.2 Biosynthesis of ABO antigens. O-antigen biosynthesis is catalyzed by fucosyltransferase. A-antigen biosynthesis is catalyzed by the A-transferase that transfers the N-acetylgalactosamine from the donor and uridine diphosphate (UDP)-*N*-acetylgalactosamine to the O antigen. B-antigen biosynthesis is catalyzed by the B-transferase that transfers the galactose from UDP-galactose to the O antigen. N-AcGlu, *N*-acetytglucosamine; Gal, galactose; Fuc, fucose; N-AcGal, *N*-acetylgalactosamine. (© Richard C. Li.)

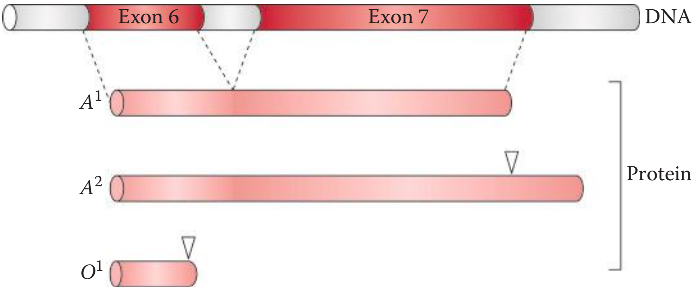
Exon 6
Exon 7
DNA
A1
A2
O1
Protein

Figure 18.3 Structure of ABO gene and variants. Exons 6 and 7 are shown. The deletion mutation in *A*^{2} and *O*^{1} variants is indicated by an inverted triangle and leads to their A_2 and O phenotypes, respectively. (© Richard C. Li.)

Table 18.2 Amino Acid Substitutions at Four Positions in Human ABO Variants *A*^{1}, *B*, and *O*^{2}

ABO Variant	Amino Acid Position			
	176	235	266	268
A^1	Arginine	Glycine	Leucine	Glycine
B	Glycine	Serine	Methionine	Alanine
O^2	Glycine	Glycine	Leucine	Arginine

mutation at glycine (position 268) by arginine. Additionally, a few dozen other rare *O* alleles, which yield inactive proteins, have also been documented.

18.1.2.3 Secretors

In addition to erythrocytes, individuals whose A, B, and O antigens can be found in other types of bodily fluids are referred to as *secretors*. Eighty percent of Caucasians are secretors. As described earlier, the O antigen is the substrate for the A- and B-transferase because the A- and B-transferase can only utilize a fucosylated substrate. The O antigen is synthesized by fucosylation of the terminal galactosyl residue catalyzed by the fucosyltransferase, which is encoded by *FUT* genes.

Chromosome 19 contains two homologous genes: *FUT1* and *FUT2*. *FUT1* is expressed in tissues of mesodermal origin (embryonic tissues that serve as precursors of hemopoietic tissues, muscle, the skeleton, and internal organs) and is responsible for the synthesis of the O antigen in erythrocytes. *FUT2* is expressed in tissues of endodermal origin (embryonic tissues that are precursors of the gut and other internal organs); it is responsible for the synthesis of the O antigen in secretions.

About 20% of Caucasian individuals (called *nonsecretors*) are homozygous for a nonsense mutation in *FUT2* at amino acid position 143, resulting in a truncated protein. Bodily fluids such as the semen of type A or B nonsecretors (who carry homozygous *FUT2* mutations) contain no A or B antigens despite containing active A- or B-transferases (Figure 18.4). This can be a problem in investigating sexual assault cases when the blood type of the seminal evidence needs to be determined. However, nonsecretors have O antigens on erythrocytes synthesized by *FUT1* and thus have A or B antigens in blood. Individuals carrying very rare homozygous *FUT1* mutations produce erythrocyte O-deficient phenotypes in which the erythrocytes express no O antigens and thus express neither A nor B antigens, regardless of *ABO* genotype. Individuals

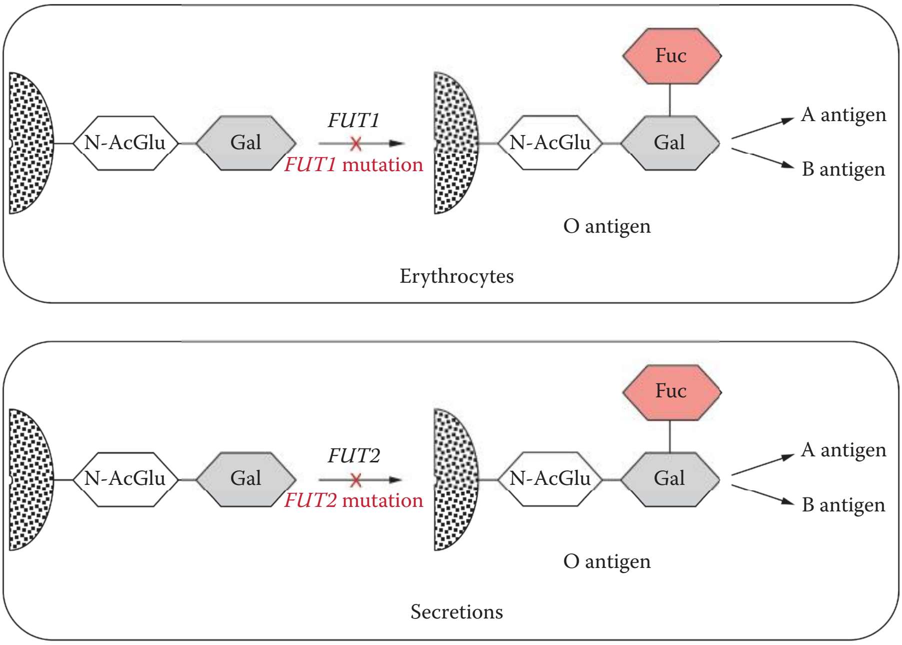

Figure 18.4 Tissue-specific O-antigen biosynthesis by *FUT1* and *FUT2* gene products. Tissue-specific O-antigen biosynthesis in erythrocytes is catalyzed by the *FUT1* gene product; in secretions, it is catalyzed by the *FUT2* gene product. The mutations abolishing the biosynthesis of O antigens are indicated. The *FUT2* mutation produces a nonsecretor phenotype. (© Richard C. Li.)

who carry both *FUT1* and *FUT2* mutations have no O antigens (nor A nor B antigens) in their erythrocytes and other bodily fluids and are known as Bombay (O_h) phenotypes.

18.1.2.4 Inheritance of A and B Antigens

A and *B* alleles are dominant. For *AO* and *BO* heterozygotes, the corresponding transferase synthesizes the A or B antigen. *A* and *B* alleles are codominant in *AB* heterozygotes because both transferase activities are expressed. The *OO* homozygote produces neither transferase activity and therefore lacks both antigens. The inheritance of *A* and *B* alleles obeys Mendelian principles (Chapter 25). For example, an individual with type B blood may have inherited a *B* allele from each parent or a *B* allele from one parent and an *O* allele from the other; thus, an individual whose phenotype is B may have the *BB* (homozygous) or *BO* (heterozygous) genotype. Conversely, if the blood types of the parents are known, the possible genotypes of their children can be determined. When both parents are type B (heterozygous), they may produce children with the genotype *BB* (B antigens from both parents), *BO* (B antigen from one parent, O from the other heterozygous parent), or *OO* (O antigens from parents who are both heterozygous). Thus, blood group typing can be used for paternity testing.

18.1.3 Forensic Applications of Blood Group Typing

The application and usefulness of blood typing in forensic identification are based on the ability to group individuals into four different types using the ABO blood system, allowing individuals to be identified. For example, if one crime scene blood sample is type B and a suspect has type A, the crime scene sample must have a different origin. However, if both the sample and the suspect are type A, the sample may have come from the same origin or from a different origin that happened to be type A.

Unfortunately, the probability that any two randomly chosen individuals have an identical blood type is very high. Approximately 42% of Caucasians have type A blood. The frequency of other blood types within the ABO system is shown in Figure 18.5. Multiple blood group systems were utilized to decrease the probability of a coincident match.

The A and B antigens are very stable and can be identified in dried blood even after many years. They can also be found in semen and other bodily fluids of secretors. Thus, in sexual assault cases, for example, the ABO type of a semen sample can be examined to identify a perpetrator.

18.1.4 Blood Group Typing Techniques

The most common assays used in forensic serology involve agglutination and include the Lattes crust and absorption–elution assays.

18.1.4.1 Lattes Crust Assay

In the early 1900s, Karl Landsteiner used his blood and blood obtained from his laboratory coworkers to test the effects of serum on erythrocytes. He discovered that naturally occurring

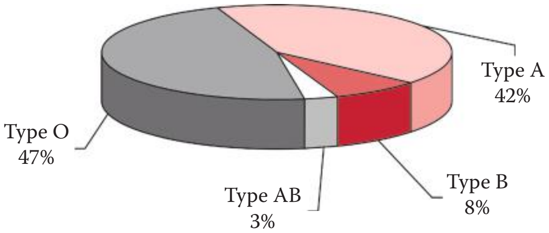

Figure 18.5 Frequency distributions of ABO types observed in American Caucasians. Different human populations may exhibit different frequencies of the four blood types. (© Richard C. Li.)

antibodies in serum caused agglutination of certain erythrocytes, and the agglutination patterns observed were designated A, B, and O. Each pattern indicated the presence or absence of a particular antigen on erythrocytes.

Shortly after birth, newborn infants develop antibodies against antigens that are not present in their own bodies. For example, type A individuals develop anti-B antibodies, type B individuals develop anti-A antibodies, type O individuals develop both types of antibodies, and type AB individuals do not develop anti-A or anti-B antibodies. When the plasma of a type A individual is mixed with type B cells, the anti-B antibodies from the type A individual cause the type B cells to agglutinate. This result forms the basis for blood group typing.

The Lattes crust assay relies on the principles of Landsteiner's experiments. It is an agglutination-based assay that utilizes the A, B, and O indicator cells to test the agglutination reaction with its corresponding naturally occurring serum antibodies in a questioned sample. The procedure for the Lattes crust assay is described in Box 18.1 and illustrated in Figure 18.6. Typical results are summarized in Table 18.3 and illustrated in Figure 18.7. Type A blood contains naturally occurring anti-B antibodies that agglutinate only with B cells. Likewise, type B blood agglutinates only with A cells, type O blood agglutinates with both A and B cells, and type AB blood does not agglutinate with any cells.

The Lattes crust assay is simple and rapid. However, one limitation is that the assay is not very sensitive and requires a large quantity of blood. Recall that successful agglutination reactions usually require intact cells. The agglutination assay of forensic samples is, therefore, difficult to carry out because blood cells lyse when they are dry. Therefore, this method is not reliable for testing old stains.

BOX 18.1 LATTES CRUST ASSAY PROCEDURE

1. Place small quantities of blood crust from a specimen on a microscopic slide and place a cover slide over the crusts. Prepare slides for A, B, and O cells separately.
2. Prepare cell suspensions with saline (0.85% NaCl in phosphate buffer, pH 7.4) for the A, B, and O cells separately.
3. Apply a few drops of the A-cell suspension and allow the cells to diffuse under the cover slip. Repeat this step for B cells and O cells.
4. Incubate the slides in a moisture chamber at room temperature for 2 h.
5. Examine results under a microscope.

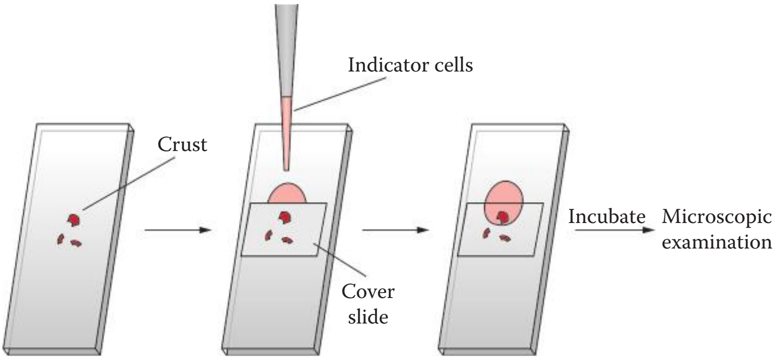

Figure 18.6 Lattes crust assay. (© Richard C. Li.)

Table 18.3 Representative Results of Lattes Crust Assay

Blood Type	Serum Antibody	Agglutination Reaction Observed
A	Anti-B	B cells
B	Anti-A	A cells
O	Anti-A, anti-B	A cells, B cells
AB	None	None

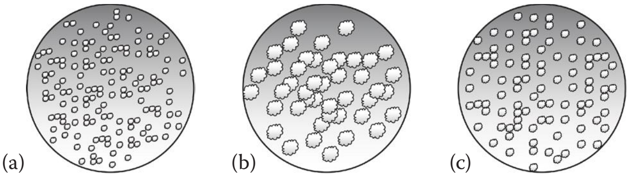

Figure 18.7 Diagram of Lattes crust assay results. (a) Indicator cells added before incubation. (b) Strong agglutination: large clumps are observed after incubation. (c) Negative agglutination: a cloudy background may be observed after incubation.

18.1.4.2 Absorption–Elution Assay

The absorption–elution assay is highly sensitive and can be used for testing dried bloodstains. This method indirectly detects the presence of antigens. The antigens are immobilized in a solid phase (Figure 18.8). At low temperatures, the antigens bind to their corresponding antibodies: anti-A antibodies, anti-B antibodies, or anti-O lectins. (The anti-O lectin is isolated from plants and reacts strongly with the O antigen present in type O blood, but has some cross-reaction with the A antigen). The excess unbound antibodies are removed by washing, and the bound antibodies are then eluted at higher temperatures (recall that antigen–antibody binding can be affected by temperature; Chapter 13). The eluted antibodies can then be identified by an agglutination assay using A, B, and O indicator cells.

Typical results of an absorption–elution assay are summarized in Table 18.4. The bloodstains containing the A antigen can bind to anti-A antibodies. The eluted anti-A antibody can form agglutination with A cells. Likewise, for type B blood, the eluted anti-B antibody can form agglutination with B cells; for type AB blood, the eluted antibodies can form agglutination with both A and B cells; and with type O blood, the eluted anti-O lectins can form agglutination with O cells.

18.2 Forensic Protein Profiling

Because of the limitations of blood group systems, inherited protein polymorphic markers have been utilized to decrease the chances of matches between two unrelated individuals. The amino acid sequences of many proteins vary in the human population. An estimated 20%–30% of the proteins in humans are polymorphic. Some of the variations in amino acid sequences affect the function of proteins, but many of them exert little or no effect on protein function. Thus, individuals can be divided into groups based on the types of protein polymorphisms. A combination of the blood group systems and protein polymorphic markers can be used for

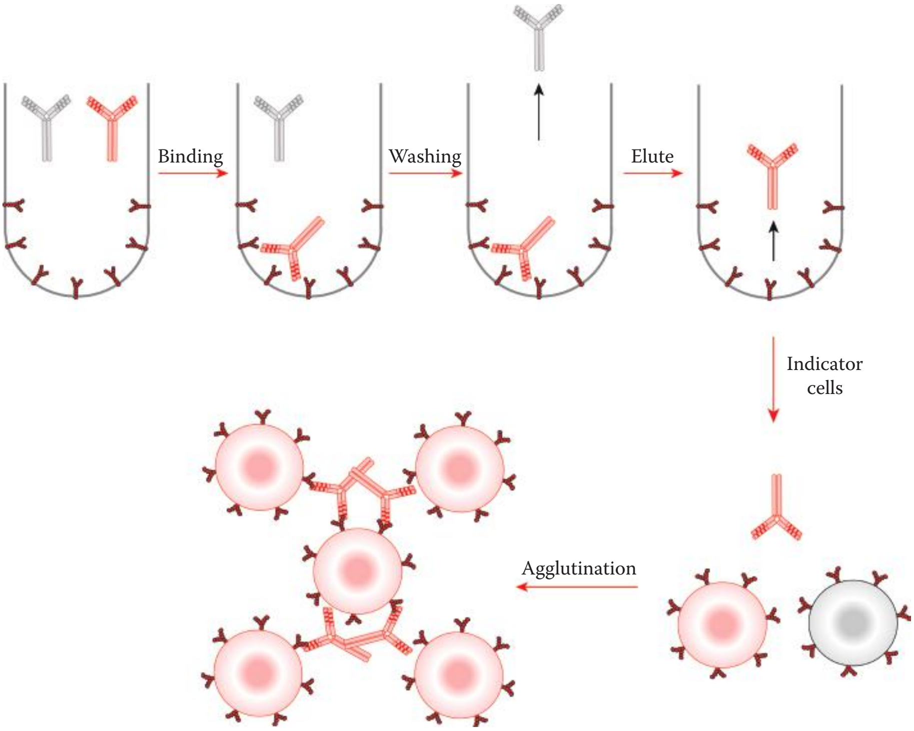

Figure 18.8 Absorption–elution assay. An antigen sample is immobilized on a solid-phase matrix. Antibodies (two different types are shown) are added. The antibody that is specific to the antigen binds. Unbound antibody is washed away. The bound antibody is then eluted. The eluted antibody is tested with indicator cells (two different types are shown). The indicator cell that is specific to the antibody eluted shows a positive agglutination reaction. (© Richard C. Li.)

Table 18.4 Representative Results of Absorption–Elution Assay

Blood Type (Stain)	Antibody Bound and Eluted	Agglutination Reaction Observed
A	Anti-A	A cells
B	Anti-B	B cells
O	Anti-O	O cells
AB	Anti-A, anti-B	A cells, B cells

criminal investigations and paternity testing. The probability that results for two unrelated persons would match is decreased to one in several hundred through use of the blood-typing and protein-profiling techniques.

18.2.1 Methods

Identification of protein polymorphisms is performed through electrophoretic separation based on the molecular weights (*Mr*) and charges of the protein variants.

18.2.1.1 Matrices Supporting Protein Electrophoresis

Electrophoresis of proteins is generally carried out in a support material, also called the matrix, to separate various macromolecules. The matrix also reduces the effects of diffusion and convection on the macromolecules. Historically, protein profiling for forensic application utilizes two types of matrices: papers such as cellulose acetate; and gels composed of starch, agar, agarose, or polyacrylamide. The first polymorphic protein marker, phosphoglucomutase, was characterized by starch-gel electrophoresis. However, agarose and polyacrylamide became more commonly used in electrophoresis due to good reproducibility and reliability (Table 18.5).

18.2.1.2 Separation by Molecular Weight

An electrophoretic method is frequently utilized to resolve various proteins based on their molecular weights. Native electrophoresis, also known as nondenaturing electrophoresis, can be used to isolate proteins for studying the functions of proteins. Biological activity of the protein can be retained for further analysis. However, some proteins are not well separated in electrophoresis in their native form. Thus, it may be necessary to denature the proteins in order for them to be resolved better during separation. This process is called *denaturing protein electrophoresis*. The following additives can be used:

18.2.1.2.1 Reducing Agents

It is common to include reducing agents such as mercaptoethanol (ME), dithiothreitol (DTT), or sodium mercaptoethane sulfonate (MESNA) to denature proteins. Reducing agents cleave the disulfide bonds of proteins. As a result, protein shape becomes unfolded and linear. These agents can be used during sample preparation and can also be added to the electrophoresis buffer.

18.2.1.2.2 Detergents

Detergents disrupt noncovalent interactions within the structures of native proteins. The procedure is generally performed with sodium dodecylsulfate (SDS), a strong anion detergent that binds to most proteins in amounts proportional to the molecular weight of the protein (approximately one molecule of SDS for two amino acids). The bound SDS contributes a large net negative charge on the protein, which masks any surface charges of the native protein. As a result, the charge-to-mass ratio of the protein becomes a constant. As with reducing agents, the various native conformations of proteins change to a more uniformly linear shape when SDS is bound.

Table 18.5 Properties of Matrices Supporting Protein Electrophoresis

Supporting Matrix	Pore Size	EEO	Reproducibility	Strength	Preparation	Toxicity
Cellulose acetate	Large	High	Poor	Good	Simple	Nontoxic
Starch	Large	High	Poor	Fragile	Simple	Nontoxic
Agar	Large	High	Poor	Fragile	Simple	Nontoxic
Agarose	Large	Low	Good	Fragile	Simple	Nontoxic
Polyacrylamide	Small	Very Low	Good	High; tolerates high electronic field	Complex	Toxic

Note: Electroendosmosis (EEO) occurs when fixed charges of the supporting matrix cause liquid flow toward the electrodes. A matrix with high EEO may affect the mobilities and separation performances of proteins during electrophoresis.

Electrophoretic mobility in the presence of SDS, therefore, becomes based on *M*r rather than both *M*r and the charge. Smaller proteins move through the pores of the gel matrix more rapidly than larger proteins. As a result, the larger the size of the protein, the smaller its electrophoretic mobility.

SDS gel electrophoresis can also be used to determine the *M*r of an unidentified protein based on its electrophoretic mobility on the gel. Standard marker proteins of known molecular weight are run on the same gel and allow the estimation of the *M*r of an unknown protein. A linear plot of log *M*r values of marker proteins versus relative migration during electrophoresis allows the molecular weight of the unknown protein to be determined from the graph.

18.2.1.3 Separation by Isoelectric Point

The *isoelectric focusing (IEF)* technique can be used to separate proteins according to their *isoelectric points (pI)*. The pI is the pH value at which the net electric charge of an amino acid is zero. All proteins are composed of amino acids, and each has its own characteristic pI at which its net electric charge is zero and does not migrate in an electric field.

In IEF electrophoresis, a pH gradient is created in a gel between the electrodes, and a protein sample is placed in a well on the gel. With an applied electric field, proteins enter the gel and migrate until they reach a pH equivalent to their pI values, at which they lose mobility (Figure 18.9). IEF, based on molecular charge, is capable of producing sharper bands than denaturing protein electrophoresis and thus has a higher resolving power. The technique can detect very low quantities of proteins in samples. A pH gradient in the gel is established by utilizing materials such as carrier ampholytes or immobilines that are dispersed in the gel. Carrier ampholytes are synthetic amphoteric compounds that contain multiple weak ionizable moieties acting as either acids or bases. To establish a pH gradient, a mixture of ampholytes with slightly different pIs is directly added to an IEF gel. The pH gradient is generated by applying an electric field on the ampholyte-containing gel. Under the electric field, the negatively charged ampholytes migrate toward the anode, and the positively charged ampholytes migrate to the cathode. As a result, a gradual pH gradient is created between the anodal end of the gel (acidic) and the cathodal side of the gel (basic). Immobilines are a series of modified acrylamide monomers that can be acidic or basic. The pH gradient of an IEF gel can also be established using a gradient-forming device that changes the proportion of the immobilines added to the gel matrix mixture as it is loaded into the gel-casting apparatus.

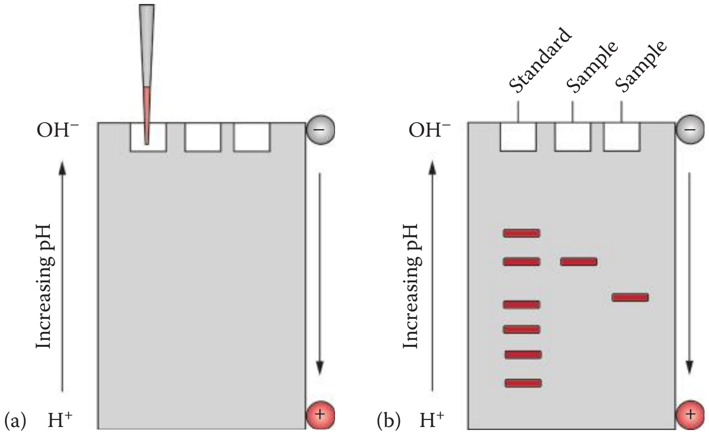

Figure 18.9 Isoelectric focusing. (a) A pH gradient is established by allowing low-molecular-weight organic acids and bases to distribute themselves in an electric field across a gel. A sample containing a protein mixture is loaded into a sample well. (b) During the electrophoresis, each protein migrates until it matches its pI. Proteins with different pIs are separated. (© Richard C. Li.)

18.2.2 Erythrocyte Protein Polymorphisms

18.2.2.1 Erythrocyte Isoenzymes

The human erythrocyte contains a number of *isoenzymes*, which are multiple forms of an enzyme that catalyze the same reaction but differ in their amino acid sequences. Individuals can be divided into groups on the basis of the different isoenzymes present in their erythrocytes. The isoenzyme type is also inherited according to Mendelian principles.

The polymorphism of erythrocyte phosphoglucomutase (PGM) was first described in the 1960s and was later successfully applied to the testing of bloodstains. PGM, an important metabolic enzyme, catalyzes the reversible conversion of glucose-1-phosphate and glucose-6-phosphate. The PGM found in erythrocytes is encoded at the *PGM1* locus at chromosome 1. The PGM encoded by *PGM1* can also be found in semen and thus can be utilized for the testing of semen samples in sexual assault cases. The protein polymorphisms of the PGM have two alleles, which result in three different phenotypes, depending on the combination of the two alleles. The success in the forensic application of PGM led to the similar use of many other erythrocyte isoenzyme polymorphisms. The most commonly used erythrocyte isoenzyme systems are listed in Table 18.6.

18.2.2.2 Hemoglobin

Recall that the use of hemoglobin (Hb) in screening and confirmatory blood tests was discussed in Chapter 12. Adult human Hb consists of two α chains and two β chains. Each polypeptide chain contains a heme group involved in oxygen binding. A very small portion of blood possesses a form of the human adult Hb consisting of two α chains and two δ chains.

More than 200 Hb variants have been identified and can be useful as markers for forensic applications. In particular, two types of human Hb variants are important in forensic testing: fetal Hb and sickle-cell Hb (Hb S). Hb S is the factor responsible for sickle-cell disease (Figure 18.10). Hb variants can be resolved using electrophoresis (Figure 18.11).

18.2.2.2.1 Fetal Hemoglobin

Humans have three forms of Hb during their development: embryonic, fetal, and adult Hb. In adults, the Hb tetramer consists of two identical α and two identical β chains. Embryonic erythrocytes contain Hb tetramers that are different from the adult form. Each embryonic Hb consists of two identical α-like chains and two identical β-like chains. The embryonic Hb is gradually replaced during pregnancy (approximately 3 months after conception) by fetal Hb, which comprises approximately 70% of the Hb in fetal blood. The fetal Hb has two identical α chains and two identical γ chains.

TABLE 18.6 Common Isoenzymes Used for Forensic Protein Profiling

Erythrocyte Isoenzyme	Protein Symbol	Number of Alleles
Phosphoglucomutase	PGM	2[a]
Erythrocyte acid phosphatase	ACP/EAP	3
Esterase D	ESD	2
Adenylate kinase	AK	2
Glyoxalase I	GLO	2
Adenosine deaminase	ADA	2

[a] Ten alleles can be observed using IEF electrophoresis.

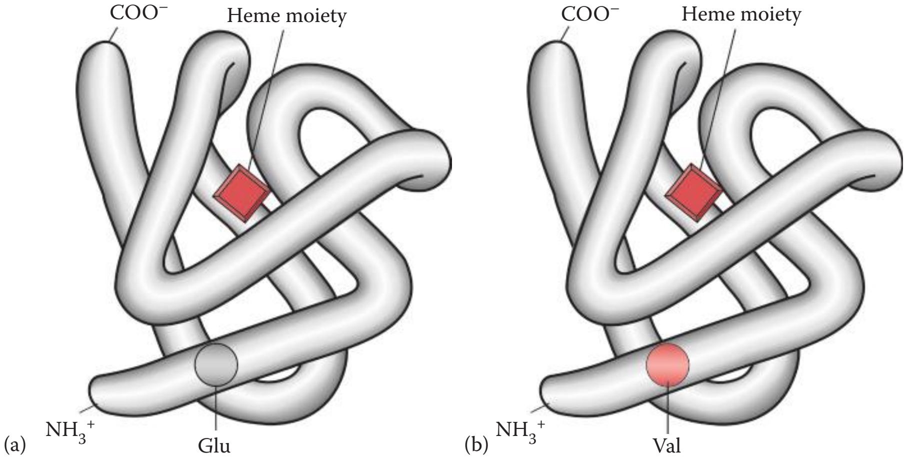

Figure 18.10 Normal and sickle-cell hemoglobin β chains. (a) Normal hemoglobin β chain contains a glutamic acid residue (Glu) at position 6 of the N-terminal of the protein. (b) At position 6 of the sickle-cell hemoglobin β chain, the glutamic acid residue is replaced by a valine (Val). (© Richard C. Li.)

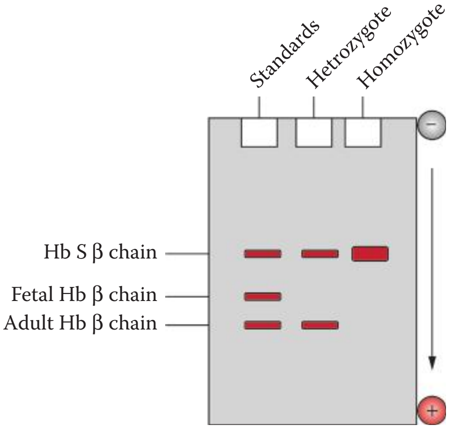

Figure 18.11 Hemoglobins resolved by isoelectric focusing electrophoresis. (© Richard C. Li.)

The embryonic and fetal Hbs have higher affinities to oxygen, required to provide the embryo and fetus with sufficient amounts of oxygen taken from maternal blood. Fetal Hb is replaced by adult Hb approximately 6 months after birth. These Hbs are encoded by their corresponding genes located at the globin gene clusters. The detection of fetal Hb in a bloodstain via electrophoresis can provide important evidence in cases of infanticide and concealed birth.

18.2.2.2.2 Hemoglobin S

Hb S polymorphism has forensic importance in identifying individuals. The Hb S polymorphism is observed in high frequencies among those of African heritage and some Hispanic populations. Such a protein polymorphic marker can provide investigational leads for the indication of the ethnic origin of a perpetrator. Hb S transports oxygen much less efficiently than normal Hb. Individuals who are homozygous for Hb S usually die early after suffering from sickle-cell anemia and related complications. However, a heterozygous individual (an individual with a copy of the wild-type Hb allele from one parent and a copy of the Hb S allele from the other) can survive. This condition is known as the sickle-cell trait.

In the 1950s, Vernon Ingram of Cambridge University discovered the molecular mechanism of the Hb S defect. His work revealed that the Hb S bears a mutation, which changes the glutamic acid in wild type to a valine at the sixth amino acid from the N-terminal end of the β chain. This substitution of amino acids causes a major change in the structure of the β chain, which in turn results in sickle-cell anemia.

18.2.3 Serum Protein Polymorphisms

The serum portion of blood consists of a large number of proteins. The work on serum proteins for forensic purposes started in the 1950s, when variations in serum proteins were found useful for distinguishing individuals. Over the years, a number of serum proteins were characterized and applied for forensic testing. Haptoglobin (Hp) was the most widely used of the polymorphic serum proteins in forensic biology (Figure 18.12). Haptoglobin is a protein that binds and transports Hb from the bloodstream to the liver for the recycling of the iron contained in the Hb.

Immunoglobulin (Chapter 10) accounts for approximately 15% of serum protein and has been found to be highly variable. Two immunoglobulin proteins are utilized for forensic application. The γ chain protein (G_m) is the heavy chain of immunoglobulin G and the κ chain protein (K_m) is one of two types of the light chain of all immunoglobulins. Table 18.7 lists common serum group systems. All exhibit genetic variations and can be detected in bloodstains. The variants of these proteins can be determined by electrophoresis or serological methods.

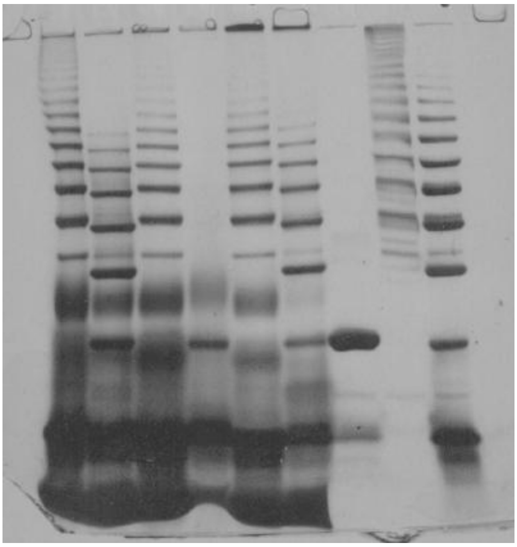

Figure 18.12 Polyacrylamide gel electrophoresis of haptoglobin proteins. From left to right: Hp2, Hp2-1, Hp2, Hp1, Hp2, Hp2-1, Hp1, Hp2, Hp2-1. An anode is at the bottom. (From James, S. and Nordby, J.J., *Forensic Science: An Introduction to Scientific and Investigative Techniques*, CRC Press, Boca Raton, FL, 2005. With permission.)

TABLE 18.7 Serum Proteins Used for Forensic Protein Profiling

Serum Protein	Protein Symbol	Gene Symbol	Chromosomal Location	Number of Amino Acids	Number of Alleles
Haptoglobin	Hp	*HP*	16q22.1	328/387	2
Group-specific component	Gc	*GC*	4q12–13	458	2
Transferrin	Tf	*TF*	3q22.1	679	3
Protease inhibitor (α1-antitrypsin)	Pi	*PI*	14q32.1	394	Many

Source: Adapted from Yuasa, I. and Umetsu, K., *Leg Med*, 7, 251–254, 2005.

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19

Variable Number Tandem Repeat Profiling

Tandem repeats are abundant in the human genome. *Minisatellites* were first defined as a class of tandem repeats in the 1980s. Some of these repeats share a GC-rich core sequence. Subsequently, tandem repeats with higher AT contents of core sequence have also been characterized. The minisatellites are also called *variable number tandem repeats* (*VNTRs*), as shown in Figure 19.1. The repeat unit length of a VNTR can range from several to hundreds of base pairs (bp). The tandem repeat arrays can be kilobases (kb, corresponding to 10^3 bp) long, and the numbers of tandem repeat units in some VNTR loci are highly variable, leading to variable lengths of DNA fragments. A genotype is defined by a particular number of tandem repeat units at a given locus.

Table 19.1 lists the common VNTR loci used for forensic testing. To achieve high discriminating power, the VNTR loci should not be linked, which means that they should be inherited independently of each other. For example, loci located on different chromosomes or far apart on the same chromosome can be used (Section 21.2). Many VNTR loci used for forensic applications are highly polymorphic, and as many as hundreds of different genotypes per locus can be observed among the population. The discriminating power of VNTR loci used for forensic testing can be measured by *population match probability* (P_m; Chapter 25). The lower the P_m, the less likely a match will occur between two randomly chosen individuals. A P_m of up to 10^{-12} can be achieved by testing several VNTR loci.

19.1 Restriction Fragment Length Polymorphism

VNTR profiling utilizes RFLP—the first historical method used in forensic DNA testing (Figure 19.2). It utilizes *restriction endonucleases* that recognize and cleave specific sites along the DNA sequence. Cleavage of a DNA sample with a particular restriction endonuclease results in a reproducible set of restriction fragments of various lengths. Appropriate restriction endonucleases should be selected so that the genomic DNA is cleaved at sites that flank the VNTR core repeat region. The resulting fragments are then separated according to their sizes by gel electrophoresis through a standard agarose gel (Chapter 9).

The DNA is then processed using the *Southern transfer and hybridization* technique. The DNA is denatured and transferred from the gel to a supporting matrix such as a nylon or nitrocellulose membrane. The DNA immobilized on the membrane is then hybridized with a labeled *probe*. Only bands of DNA that have complementary sequences to the probe are recognized by detection systems such as autoradiography (Section 19.1.4). Using the RFLP technique, the

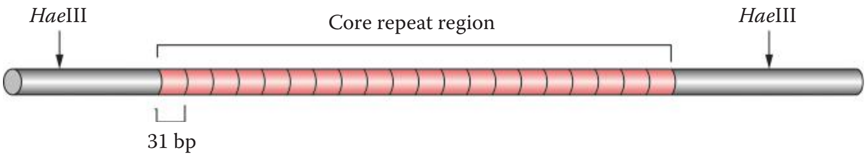

Figure 19.1 VNTR locus D2S44 (2q21.3–2q22). Each repeat unit consists of 31 bp. *Hae*III represents the *Hae*III restriction site.

Table 19.1 Common VNTR Loci

Locus	Chromosome Location	Repeat Unit Length (bp)	*Hae*III Fragment Size (kb)	Probe
D1S7	1	9	0.5–12	MS1
D2S44	2	31	0.7–8.5	yNH24
D4S139	4	31	2–12	pH30
D10S28	10	33	0.4–10	pTBQ7
D14S13	14	15	0.7–12	pCMM101
D16S85	16	17	0.2–5	3′HVR
D17S26	17	18	0.7–11	pEFD52
D17S79	17	38	0.5–3	V1

Source: Adapted from Budowle, B., et al., *DNA Typing Protocols: Molecular Biology and Forensic Analysis*, Eaton Publishing, Natick, MA, 2000; Office of Justice Programs, Future of forensic DNA testing: Predictions of the Research and Development Working Group. National Institute of Justice, US Department of Justice, 2000.

length variations among restriction sites can be detected. Most forensic applications focus on the length variations of VNTR regions located between two restriction sites.

In summary, the RFLP method includes several steps: (1) genomic DNA preparation, (2) restriction endonuclease digestion of the genomic DNA into fragments, (3) agarose gel electrophoretic separation of the DNA fragments according to size, (4) transfer of DNA fragments using Southern transfer, (5) hybridization with locus-specific probes, and (6) detection of locus-specific bands by autoradiography or chemiluminescence.

19.1.1 Restriction Endonuclease Digestion

Restriction endonucleases are enzymes that cleave the phosphodiester bond of DNA at or near specific recognition nucleotide sequences known as restriction sites. A restriction site usually is a short motif that is 4–8 bp in length. It often has a specific palindromic recognition sequence, that is, a segment of double-stranded DNA in which the nucleotide's sequence is identical with an inverted sequence in the complementary strand. Thus, double-stranded DNA is required to be cleaved by most restriction endonucleases. As a result, both sticky ends and blunt ends of restriction fragments can be generated after the cleavage (Figure 19.3).

To date, hundreds of restriction endonucleases have been described. They are traditionally classified into three types on the basis of subunit composition and enzymatic properties. Type II restriction endonucleases are most commonly used in molecular biology applications. Type II restriction endonucleases, requiring magnesium as a cofactor, usually cleave DNA at defined positions within their recognition sequences. The Enzyme Commission (EC) number of type II

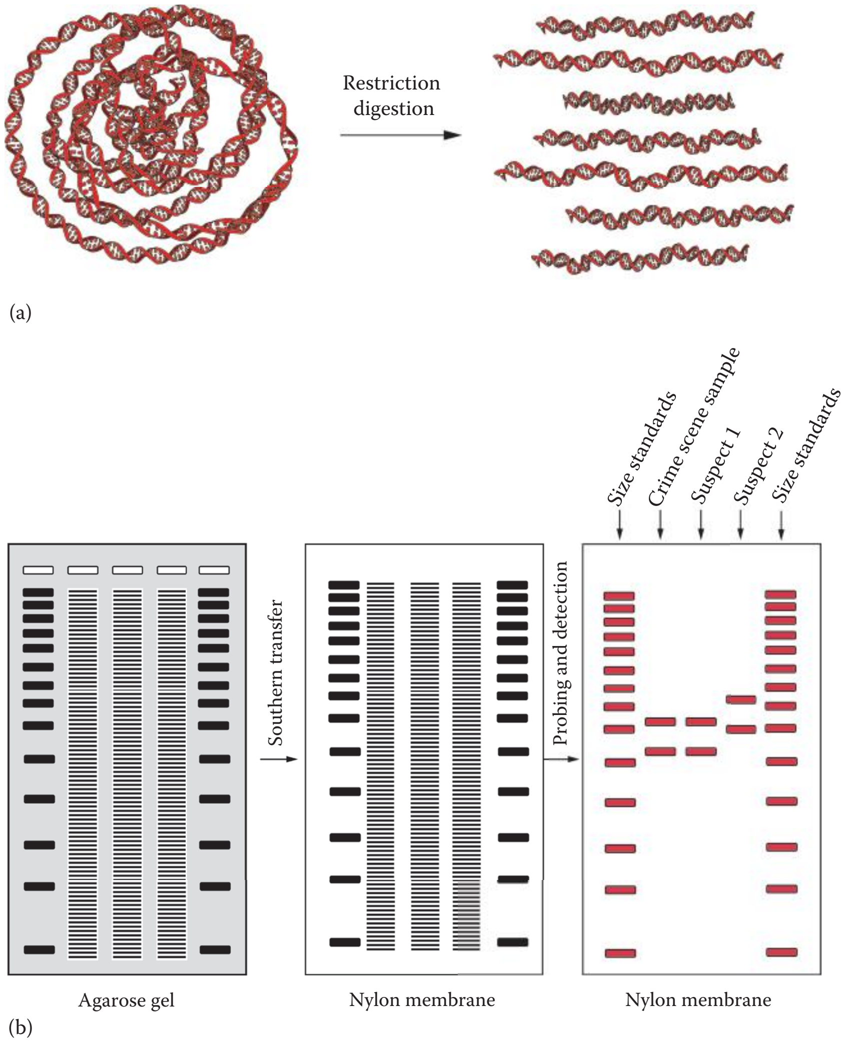
Restriction
digestion
(a)
Size standards
Crime scene sample
Suspect 1
Suspect 2
Size standards
Southern transfer
Probing and detection
Agarose gel
Nylon membrane
Nylon membrane
(b)

Figure 19.2 RFLP. (a) Restriction digestion generates restriction fragments with various lengths of genomic DNA. (b) Restriction fragments are separated by gel electrophoresis. DNA is transferred to a solid phase and probed. The signal is detected and the DNA fragment of interest can be observed. Band patterns of heterozygous loci of individuals are shown. (© Richard C. Li.)

restriction endonucleases is EC 3.1.21.4. The EC number is a numerical classification system of nomenclature based on the chemical reaction that is catalyzed by the enzyme. In contrast, type I (EC 3.1.21.3) and type III (EC 3.1.21.5) restriction endonucleases cleave at sites remote from their recognition site, which are not utilized for RFLP applications.

Restriction endonucleases are isolated from various bacteria. Each enzyme is named using a nomenclature system after the bacterium from which it was isolated. For example, in the restriction enzyme *Hae*III, H is from the genus name *Haemophilus*, ae is from the species name *aegypticus*, and III stands for the third endonuclease isolated from the *Haemophilus aegyptius* bacteria.

The restriction endonucleases play a role in protecting the bacteria from phage (bacterial virus) infections by using their endonucleases to destroy foreign DNA molecules. Bacterial DNA is usually methylated. In prokaryotes, the *Dam* methylase transfers a methyl group to the N6 position of the adenine in the sequence GmATC and the *Dcm* methylase transfers a methyl

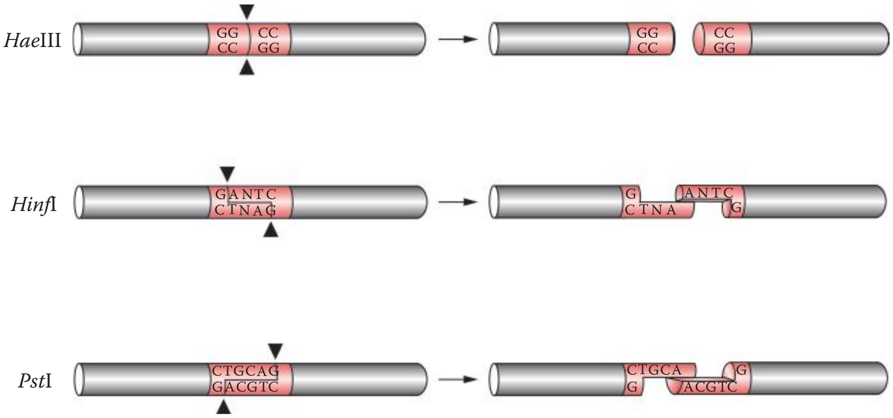

Figure 19.3 Restriction sites for *Hae*III, *Hinf*I, and *Pst*I. *Hae*III digestion produces a blunt end DNA fragment. *Hinf*I and *Pst*I digestions produce sticky ends. *N* represents any nucleotide. (© Richard C. Li.)

group to the C5 position of cytosine in the sequences CmCAGG and CmCTGG. The activities of restriction endonucleases can be influenced by DNA methylation. Many restriction endonucleases cannot cleave methylated DNA. Therefore, bacterial DNA is distinguishable from foreign DNA by the bacteria's restriction endonucleases. This phenomenon protects bacterial DNA from digestion by their own endonucleases. Note that because DNA methylation also occurs in the human genome (Chapter 11), it is important to choose the restriction endonucleases that are not affected by the methylation of human genomic DNA for RFLP analysis.

The type II restriction endonucleases were used in RFLP analysis for forensic DNA testing (Figure 19.3). In order to perform this analysis, the preferred restriction endonucleases for RFLP were those that cleave at the flanking regions of VNTR repeat units but not within the core repeat sequences of the VNTR. Most forensic laboratories used a single restriction endonuclease for a panel of VNTR loci because the DNA in evidence samples was often insufficient for performing multiple tests with different restriction endonucleases. For instance, *Hinf*I-based RFLP was commonly used in European forensic laboratories, and *Hae*III-based RFLP was used in North American and some European forensic laboratories. Other restriction endonuclease-based RFLPs such as *Pst*I were also used.

The use of these common restriction endonucleases allows the comparison of data of various laboratories. Several VNTR loci are suitable for RFLP analysis with these restriction endonucleases. For example, *Hae*III presents several advantages for forensic RFLP analysis. It recognizes a four-base sequence, 5′-GGCC-3′, and cleaves the DNA between the internal G and C residues of the recognition site (GG/CC). *Hinf*I recognizes a five-base restriction site, and *Pst*I recognizes a six-base restriction site. Hypothetically, four-base restriction sites are likely to occur more often than five- and six-base restriction sites in the human genome. Thus, *Hae*III restriction sites occur more frequently than *Hinf*I and *Pst*I sites. As a result, *Hae*III-cleaved DNA fragments are smaller than those of *Hinf*I and *Pst*I. The *Hae*III-generated VNTR allele sizes are easier to separate using conventional agarose gels, also called analytic gel electrophoresis. After electrophoresis, a smear of various sizes of DNA fragments can be observed. The analytic gel is then processed for Southern transfer. Moreover, the enzymatic activity of *Hae*III is not affected by the methylation of human genomic DNA. Its enzymatic activities also appear unaffected when a reaction proceeds under nonoptimal conditions. Additionally, low star activity is observed (Section 19.1.5.2.2).

19.1.2 Southern Transfer

Also known as *Southern blotting*, this technique was named after Sir Edwin Southern, who developed it in the United Kingdom in the mid-1970s. The method can be used to transfer

DNA from an agarose gel to a solid matrix so that it can be detected with a hybridization probe (Section 19.1.3). This method is still used today in many research laboratories. Prior to the transfer of DNA, the DNA in the gel must be denatured, under alkaline conditions such as treatment with sodium hydroxide, into single-stranded DNA. The single-stranded DNA in the gel is then transferred by capillary action to a solid matrix such as a piece of nylon membrane. The single-stranded DNA fragments transferred can be immobilized on a nylon membrane by an ultraviolet cross-linking process (Figure 19.4).

19.1.3 Hybridization with Probes

A hybridization probe of RFLP is a small segment of labeled DNA that is usually several hundred to a thousand bases in length containing the VNTR sequence. It is utilized to detect the presence of much longer target DNA sequences, in this case the VNTR sequences that are complementary to the nucleotide sequences of the probe. The probe is first denatured by heating or by exposure to alkaline conditions into single-stranded DNA. The hybridization process allows complementary pairing between the probe and the target sequence. Two types of probe techniques were developed for VNTR analysis: the multilocus probe and single-locus probe techniques.

19.1.3.1 Multilocus Probe Technique

The *multilocus probe* (*MLP*) technique can detect multiple VNTR loci simultaneously (Figure 19.5). Some VNTRs in the human genome share a short GC-rich core sequence of 10–15 bp. The MLP consists of this core sequence and hybridizes to multiple VNTRs that share these core sequences. As a result, the utilization of MLP produces a complex bar-code-like band pattern from alleles of multiple VNTR loci (Figure 19.6).

The MLP technique was pioneered by Sir Alec Jeffreys in 1984 at the University of Leicester in the United Kingdom and was called *DNA fingerprinting*. Because of its excellent discriminating power, the method was used for parentage testing in immigration disputes with great success.

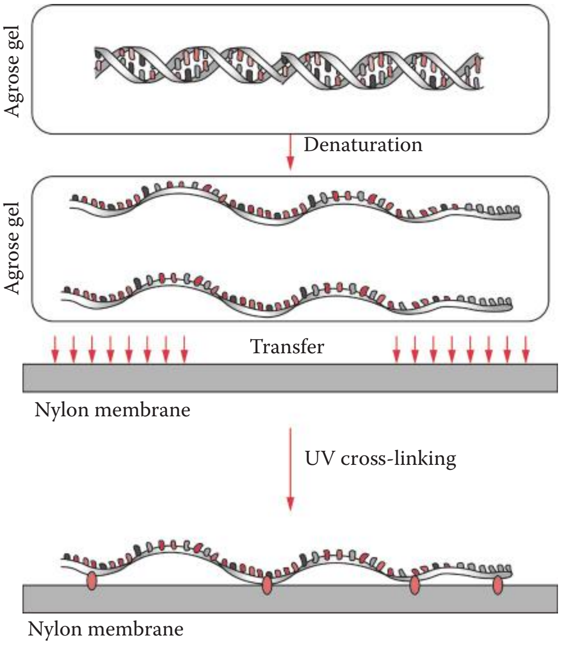

Figure 19.4 Southern blotting. DNA in agarose gel is denatured into single-stranded DNA and transferred to a solid-phase membrane where the single-stranded DNA is immobilized by ultraviolet cross-linking. (© Richard C. Li.)

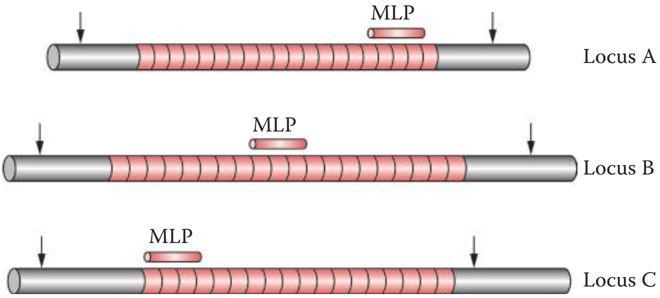

Figure 19.5 VNTR analysis using the MLP method. The technique can detect multiple VNTR loci simultaneously. Restriction sites are indicated by arrows. (© Richard C. Li.)

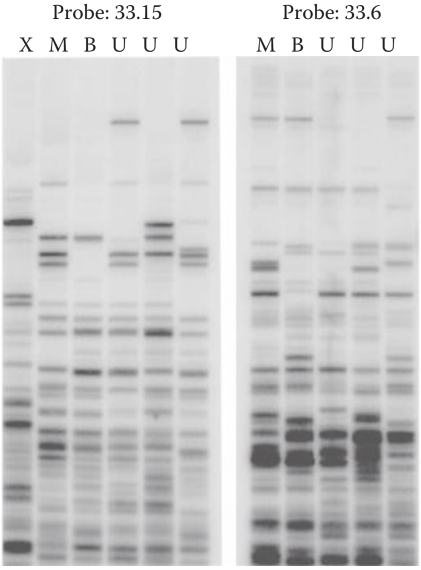

Figure 19.6 First application of DNA fingerprinting. The MLP method was used to analyze samples for an immigration case. M, mother; U, three undisputed children; B, male child in dispute; X, an unrelated individual. All bands in B can be traced back to M or U. (From Jeffreys, A.J., *Nat Med*, 11, 1035, 2005. With permission.)

However, one of the disadvantages of the MLP approach is that the interpretation of a mixed DNA sample from more than one individual is nearly impossible due to its complex DNA fingerprinting patterns. Therefore, MLP analysis was not widely utilized in forensic DNA laboratories.

19.1.3.2 Single-Locus Probe Technique

To resolve the disadvantages encountered in the MLP technique, probes that recognize the genomic DNA at the flanking regions of specific VNTR loci can be used. The probe only hybridizes to a single VNTR locus and the technique is called the *single-locus probe* (*SLP*), as depicted in Figure 19.7. SLP generates a simple pattern called a *DNA profile*, consisting of one band for a homozygote and two bands for a heterozygote per locus. In order to improve the discriminating power of the test, SLP analyses of different VNTR loci can be performed by using different probes sequentially with a single locus at one time. SLP can analyze mixed DNA samples from two or more contributors. The sizes of fragments can be estimated and converted into a numerical form suitable for databasing. Therefore, DNA profiles can be compared among different laboratories.

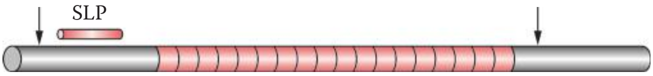

Figure 19.7 VNTR analysis using the SLP method. The technique can detect a single VNTR locus. Restriction sites are indicated by arrows. (© Richard C. Li.)

This technique led to the solving of a double murder case in Leicestershire in the 1980s. The case was the first to apply DNA evidence to a criminal investigation. DNA profiling identified the true perpetrator and also excluded an innocent suspect (Figure 19.8). In 1983 and 1986, two girls were raped and murdered. Crime scene evidence suggested that the two cases were committed by the same perpetrator. A young local man, Richard Buckland, was the suspect. However, the DNA evidence revealed that the semen samples from both crimes did not originate from Buckland. To solve the crimes, an investigation was carried out in which 5000 local men were asked to volunteer DNA samples for testing. Several months after the investigation, a witness tipped off police that a man named Pitchfork had paid someone for giving a blood sample as Pitchfork's. In 1987, Pitchfork was arrested. It was discovered that Pitchfork's DNA profile matched that of the crime scene evidence. He was sentenced to life imprisonment. This case demonstrated the great potential of DNA profiling in forensic investigations. Consequently, SLP became a common method in most forensic laboratories in the late 1980s–1990s.

19.1.4 Detection

To detect VNTR loci, a labeled SLP probe is hybridized to the target sequence of DNA, which has been immobilized on a solid matrix such as a piece of nylon membrane (see Southern

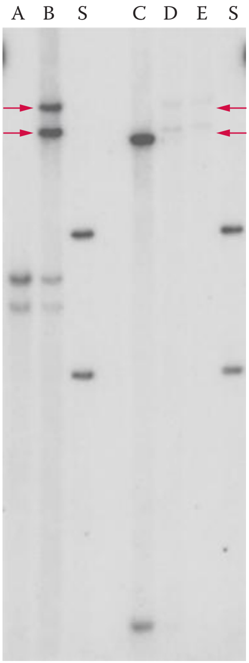

Figure 19.8 First application of DNA profiling in a criminal investigation using the SLP method. A, hair roots from the first victim; B, a mixture of semen and vaginal fluid from the first victim; C, blood from second victim; D, a vaginal swab from the second victim; E, a semen stain on clothing from the second victim; S, blood from the suspect. Alleles (arrows) are matched with the profiles of the two cases but not with the suspect profile. (From Jeffreys, A.J., *Nat Med*, 11, 1035, 2005. With permission.)

transfer, Section 19.1.2). Any unbound probes are washed away so that they do not interfere with the signal. Two types of detection systems are used for VNTR analysis. Radioisotope labeling, such as with a ^{32}P-labeled probe, can be used. The hybridized probe can be detected by exposing the membrane to a sheet of x-ray film to generate an autoradiograph. Alternatively, an enzyme-conjugated probe can also be used. Alkaline phosphatase (Section 9.2.2) is an example of an enzyme used in this type of probe. Its enzymatic activity can be detected with chemiluminescent substrates. A chemiluminescent signal can be detected by exposure to x-ray film as well.

In RFLP analysis, several loci are commonly analyzed sequentially using the same membrane. This approach has the advantage of not consuming additional DNA samples, which are often limited in forensic cases. When probing for multiple loci, multiple probes for each locus are sequentially hybridized and removed one at a time. Once the analysis of the first probe is completed, the probe is removed by a procedure called probe stripping, which is carried out under conditions such as high-temperature washing to denature the DNA strands (Chapter 17). The probe for the next locus to be analyzed is then hybridized to the same membrane, and the process is repeated for each probe to be tested.

Typically, a size standard is utilized on each gel. Band sizes can thus be estimated by comparison to these standards. However, the VNTR alleles that differ by only one or two repeat units are usually not distinguishable. For this reason, genotypes can be determined by bins but not discrete alleles. A *bin* is a range of DNA fragments that differ by only a few repeat units. A sample with a known VNTR genotype is also utilized on each gel as a positive control where historically a genomic DNA sample from cell line K562 (a human erythroleukemic cell line) was used for the positive control. DNA samples to be compared can be loaded side by side on the same gel. As a result, the patterns of VNTR fragments can be compared from sample to sample. The following possible conclusions can be made. If the VNTR fragments are at corresponding positions (profiles match), they are considered to be a match (inclusion). Chapter 25 evaluates and discusses the strengths of the results. If the profiles are different, the two DNA samples are considered to have come from different origins (exclusion).

19.1.5 Factors Affecting RFLP Results

The accuracy of VNTR profiling results can be affected by certain factors such as sample conditions, genetic mutations, and experimental artifacts appearing during the procedure. Consequently, these factors can impact data interpretation and are explained in the following sections.

19.1.5.1 DNA Degradation

RFLP analysis requires the genomic DNA to be intact. DNA degradation results in damage such as creating nicks and breaks in the strand. The more severe the degradation, the smaller the average size of the DNA fragments. When the average size of DNA fragments becomes too small, the allele may not be detected. Many VNTR tandem arrays can span several kilobases in length. In theory, large alleles are more likely to be affected by degradation than smaller alleles at a different locus.

A two-banded heterozygous profile can be observed as a one-banded homozygous profile if the larger band is not detected due to degradation. This artifact could lead to a false determination of exclusion. However, DNA degradation can be detected prior to conducting RFLP by the use of agarose gel electrophoresis, also known as a *yield gel*, used for evaluating the yield and integrity of the isolated genomic DNA. High-molecular-weight genomic DNA bands are usually observed for a typical genomic DNA sample. In contrast, a smear of low-molecular-weight DNA bands can be observed if DNA is degraded. The sizes of the DNA can be estimated by comparison to a size standard run on the same gel. Additionally, the yield of DNA can be estimated by comparing the intensity of the size standards with a known quantity of DNA.

19.1.5.2 Restriction Digestion–Related Artifacts

19.1.5.2.1 Partial Restriction Digestion

Complete restriction digestion should be achieved for RFLP analysis. If partial digestion occurs, the partially cleaved DNA strands are longer than the cleaved fragments (Figure 19.9). Thus, partial digestion results in a mixture of fragments with correct sizes and slightly larger fragments. Under these conditions, a larger uncleaved band, usually lower in intensity than the true bands, can be observed. The multibanded pattern due to the partial digestion can be observed at multiple loci analyzed in the same nylon membrane.

Detection of more than two bands in an RFLP profile may lead to a false interpretation and be incorrectly concluded to be a mixture. However, partial digestion can be detected after restriction digestion. DNA cleavage by restriction endonuclease digestion can be examined using agarose gel electrophoresis. A small portion of a sample can be analyzed. After separation using electrophoresis, a smear of various sizes of cleaved DNA fragments can usually be observed if restriction digestion is completed. Conversely, high-molecular-weight genomic DNA can still be observed from partially digested DNA samples. Additionally, comparisons can be made between the sample and uncleaved and completely cleaved standard samples of DNA. This quick assay is also called a *test gel*, used to determine if the DNA was cleaved to completion.

If partial digestion occurs, procedures such as additional purification of the DNA sample can be carried out. Additionally, optimal amounts of DNA, restriction enzymes, buffer, and proper incubation conditions should be used in achieving complete digestion.

19.1.5.2.2 Star Activity

Star activity refers to a deviation of the specificity of a cleavage site of a restriction endonuclease under certain conditions, such as a high concentration ratio of enzyme to DNA, the use of non-optimal buffers for restriction digestion, prolonged digestion time, the substitution of Mg^{2+} with other divalent cations, and the presence of organic solvents such as ethanol and concentrated glycerol. For instance, *Hae*III cleaves at the GGCC DNA sequence. When star activity occurs, the enzymatic specificity is reduced and cleaves at a sequence slightly different from GGCC. If the start site is presented at an internal location of a VNTR locus, the enzyme would cleave the GGCC sequences and additionally cleave at the internal star site (Figure 19.10). This would result in an additional band smaller than the true alleles, although the intensity of this band is usually not the same as other bands. Thus, a multiband pattern is observed. However, the star

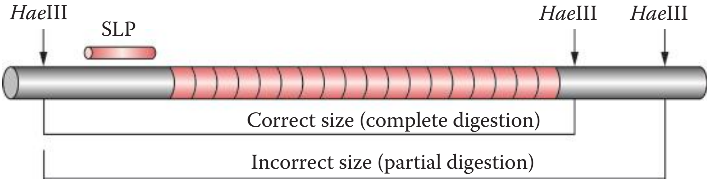
*Hae*III
SLP
*Hae*III
*Hae*III
Correct size (complete digestion)
Incorrect size (partial digestion)

Figure 19.9 Effects of partial restriction digestion on the RFLP profile. Only the restriction fragments detectable by the probe are shown. *Hae*III restriction sites are indicated by arrows. (© Richard C. Li.)

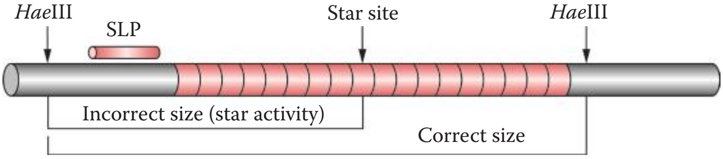

Figure 19.10 Star effects on RFLP profiles. Only the restriction fragments detectable by the probe are shown. *Hae*III restriction sites and star sites are indicated by arrows. (© Richard C. Li.)

site presented externally to a VNTR locus cannot be detected by the probe and does not affect the profiling results. Star activity can usually be avoided by carrying out restriction digestion reactions under conditions recommended by their manufacturers.

19.1.5.2.3 Point Mutations

A *point mutation* is caused by the substitution, deletion, or insertion of a single nucleotide. Point mutations at a restriction site within flanking regions may abolish the site, and the result is a band slightly larger than the true allele (Figure 19.11). The point mutation may also be present internally in a VNTR sequence. If such a point mutation creates a restriction enzyme site, the enzyme will cleave at the regular site and at the mutation site and yield two smaller bands. If the created restriction site is located internal to the probe binding region, both bands will be detected for that allele. These rare mutations obey Mendelian inheritance.

19.1.5.3 Electrophoresis and Blotting Artifacts

19.1.5.3.1 Partial Stripping

If more than one VNTR locus is analyzed sequentially using the same membrane, a probe must be removed by the stripping process before the application of the next probe. Any probe remaining on the membrane due to partial stripping may generate additional bands when the next probe is analyzed. However, bands due to partial stripping are usually faint and have the same electrophoretic mobility as the previous autoradiograph.

19.1.5.3.2 Separation Resolution Limits and Band Shifting

Agarose gel electrophoresis cannot resolve restriction fragments that differ by one or a few repeat units, especially for high-molecular-weight fragments. These bands may not be

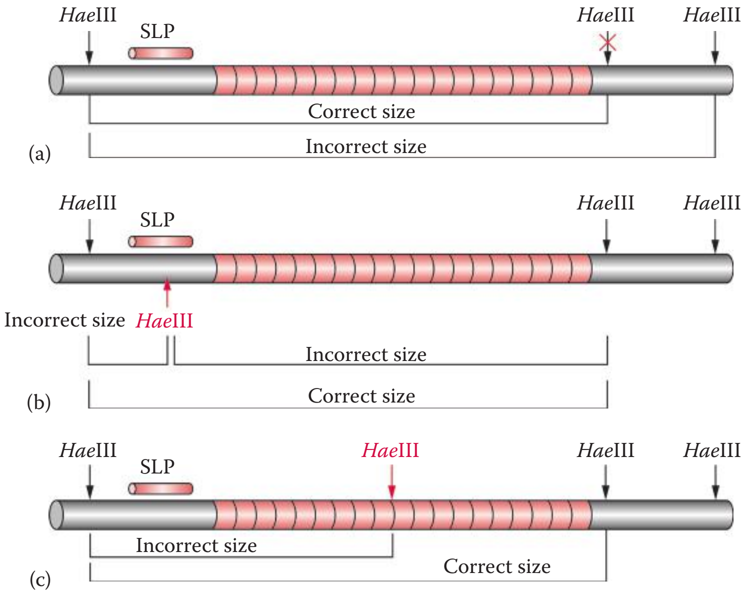

Figure 19.11 Effects of point mutations on the RFLP profile. Only the restriction fragments detectable by the probe are shown. *Hae*III restriction sites are indicated by arrows. (a) Point mutation (in red) abolishes the *Hae*III restriction site. (b) A point mutation (in red) creates an internal *Hae*III restriction site residing within the probe-binding region. (c) A point mutation (in red) creates an internal *Hae*III restriction site residing outside the probe-binding region. (© Richard C. Li.)

separated and will appear as a single band. This may lead to a false interpretation as a homozygous profile. Additionally, minor variations in the electrophoretic mobility of DNA fragments, known as band shifting, can cause two samples from the same individual to appear different.

19.1.5.3.3 Bands Running off Gel

The commonly used VNTR loci generate bands from hundreds of base pairs to 20 kb in length. The small bands have higher electrophoretic mobility and may run off the front edge of a gel during electrophoresis and fail to be detected. This phenomenon may also lead to a false interpretation as a homozygous profile. To prevent these DNA fragments from running off the gel into the buffer tank, a longer gel can be used. Alternatively, the electrophoresis can be stopped before the dye front, the furthest extent that dyes migrate, reaches the front edge of the gel.

19.2 Amplified Fragment Length Polymorphism

The RFLP analysis of VNTR profiling does not perform well for degraded or limited quantities of DNA from crime scene samples. For these reasons, an improved VNTR method was developed. Some VNTR loci have relatively short alleles (<1 kb). These loci are suitable for PCR amplification. This technique is called *amplified fragment length polymorphism* (*AFLP*). One locus, D1S80, was used by forensic DNA laboratories for AFLP analysis. Fragments in the range of 14–42 repeat units (16 bp per repeat) were amplified using the AFLP method (Figure 19.12). The amplified DNA fragments were commonly separated according to size using polyacrylamide gel electrophoresis and detected using a silver stain (Figure 19.13).

D1S80 loci are detected as discrete alleles and thus can be compared directly to an allelic ladder (a collection of common alleles used as a standard) on the same gel. This technique represented an improvement over the RFLP system. RFLP allele sizing cannot be performed with precision and the resolution limits of agarose gel electrophoresis are much lower than those of the polyacrylamide gels.

The AFLP technique requires less DNA than the RFLP method and performs better for degraded samples. The AFLP method at the D1S80 locus can be analyzed in a multiplex fashion with an amelogenin locus (Chapter 21). The amelogenin gene is used for forensic sex-typing applications. Typing the amelogenin gene enables the determination of the sex of the contributor of a biological sample.

Due to the wide variation in allele sizes at the D1S80 locus, preferential amplification may be observed. Under certain conditions, the larger alleles may not be as consistently amplified as the small alleles, which may cause lower signal intensity of the larger allele. Additionally, only one locus is analyzed in this system. Furthermore, the D1S80 locus contains two alleles that are very common in some populations. Thus, the discriminating power is reduced compared to RFLP. D1S80 was gradually replaced by multiplex STR systems in the late 1990s.

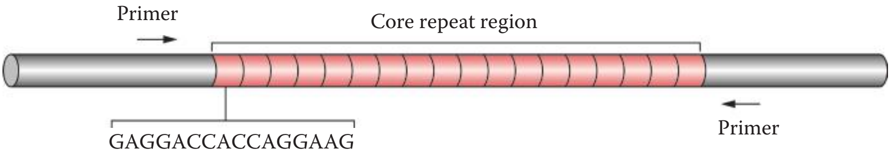

Figure 19.12 VNTR locus D1S80 (chromosome 1p). Each repeat unit is 16 bp long. PCR primers are indicated to amplify the core repeat region.

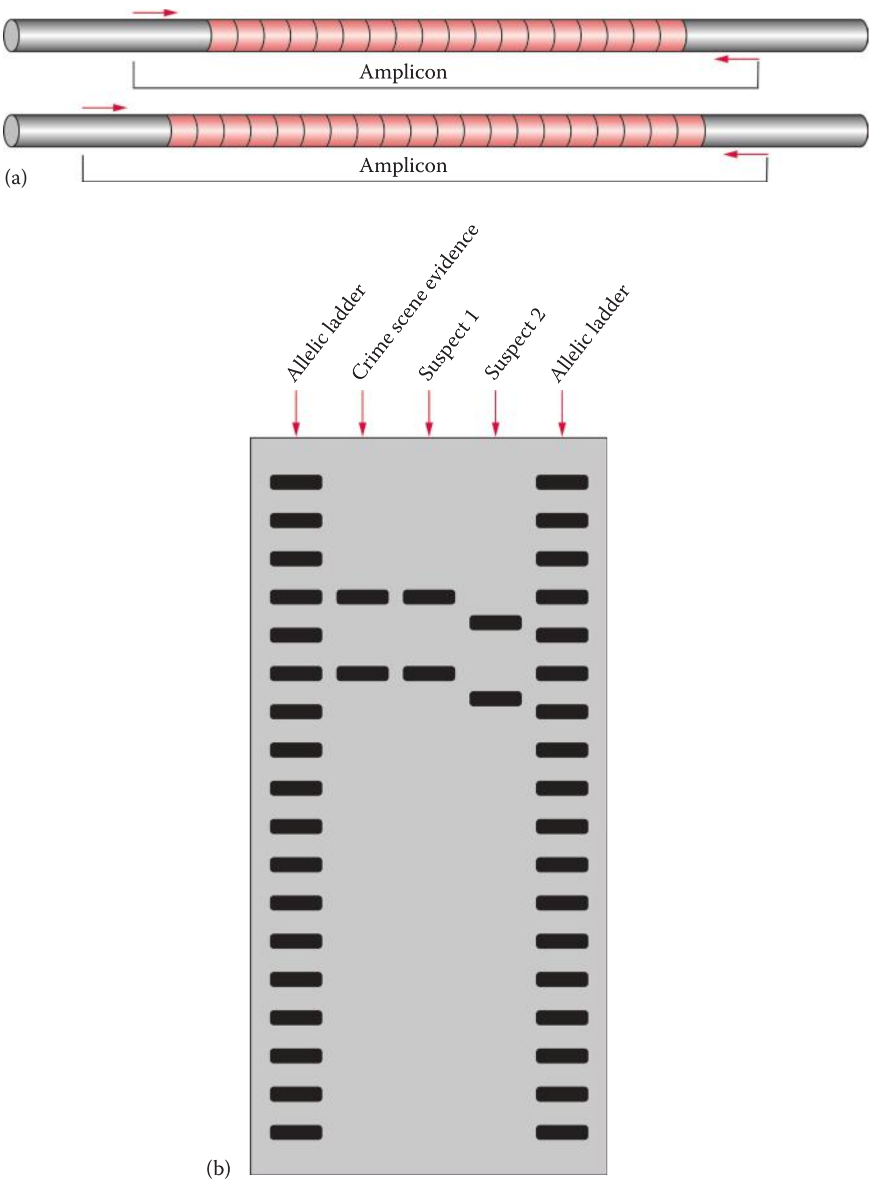
Amplicon
Amplicon
(a)
Allelic ladder
Crime scene evidence
Suspect 1
Suspect 2
Allelic ladder
(b)

Figure 19.13 AFLP analysis. (a) Heterozygous D1S80 loci amplified by PCR. PCR primers are indicated as *arrows*. (b) Silver-stained polyacrylamide gel showing D1S80 amplicons along with allelic ladders. (© Richard C. Li.)

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20

Autosomal Short Tandem Repeat Profiling

A *short tandem repeat* (STR) is a region of genomic DNA containing an array of short repeating sequences. STRs are also called *microsatellites* or *simple sequence repeats*. A STR repeat unit can be several base pairs (bp) in length. Arrays range from several to approximately a hundred *repeat units*, which are the component of repetition. The number of STR repeat units varies among individuals. The most commonly used STR loci are 100–500 bp in length, which are shorter than the smallest variable number tandem repeats (VNTRs) (approximately 1000 bp). Thus, STR loci have many advantages compared to VNTR loci:

- STR loci can be amplified by PCR.
- STR profiling can be carried out for degraded DNA samples.
- Preferential amplification is reduced at STR loci.
- The resolution of electrophoretic separation of STR fragments is superior.
- STR loci are suitable for multiplex amplification.

Additionally, STR profiling, as with VNTR profiling, is suitable for the interpretation of mixed DNA profiles from multiple individuals. Thus, STR loci are better candidates for forensic DNA testing than VNTR loci. This chapter will discuss autosomal STR profiling. Male-specific Y chromosomal STR will be discussed in Chapter 21.

20.1 Characteristics of STR Loci

More than 10^5 STRs exist in the human genome. Many STRs have been characterized and used in various types of studies such as genetic mapping and linkage analysis. Some STRs have been characterized specifically for forensic DNA profiling.

20.1.1 Core Repeat and Flanking Regions

The *core repeat region* of each STR locus contains tandemly repeated sequences. The designation of genotypes for human identification is based on the number of tandem repeat units at a STR locus, which varies among human individuals (Figure 20.1). The *flanking regions* surrounding the core repeat region are also needed for STR analysis. PCR primers complementary to these flanking regions are used, allowing the core repeat regions to be amplified.

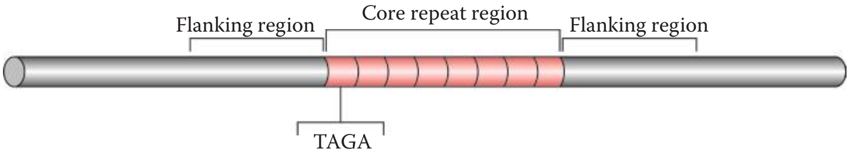

Figure 20.1 Core repeat and flanking regions of CSF1PO STR locus. It consists of eight repeating units of tetrameric nucleotides (TAGA); thus, it is designated as allele 8. (© Richard C. Li.)

20.1.2 Repeat Unit Length

Repeat unit length is the number of nucleotides in a single repeat unit. Dimeric, trimeric, tetrameric, pentameric, and hexameric repeat units appear in the human genome. For example, dimeric and trimeric repeats are very abundant, but they are not usually used for forensic applications. High frequencies of stutter peaks (Section 20.4.2.1) that interfere with genotype interpretation are observed when dimeric and trimeric repeats are amplified. On the contrary, only a few thousand pentameric repeats and a few hundred hexameric repeats exist in the human genome. The pentameric and hexameric repeats are very polymorphic. Only a few pentameric and hexameric repeats are used for forensic applications because they are less abundant in the human genome. The human genome has at least 10^4 tetrameric repeats representing approximately 9% of the total STRs. The STRs with tetrameric repeats are very polymorphic. When they are amplified by PCR, this category of STRs exhibits fewer frequencies of stutter peaks than STRs with dimeric and trimeric repeats. Therefore, the most commonly used STR loci for forensic DNA profiling are the STRs with tetrameric repeats.

20.1.3 Repeat Unit Sequences

STR loci compatible for forensic use can be divided into several classes based on their repeat unit sequences. Figure 20.2 shows representative examples of core repeat sequences. *Simple repeats* consist of tandem repeats with identical repeat unit sequences (Figure 20.2a). Allele designation is based on the number of repeat units in the core repeat region. For example, a D5S818 allele consisting of ten repeating units of the tetrameric nucleotide sequence AGAT is designated as allele 10. *Compound repeats* consist of more than one type of simple repeat (Figure 20.2b). *Complex repeats* contain several clusters of different tandem repeats with intervening sequences (Figure 20.2c).

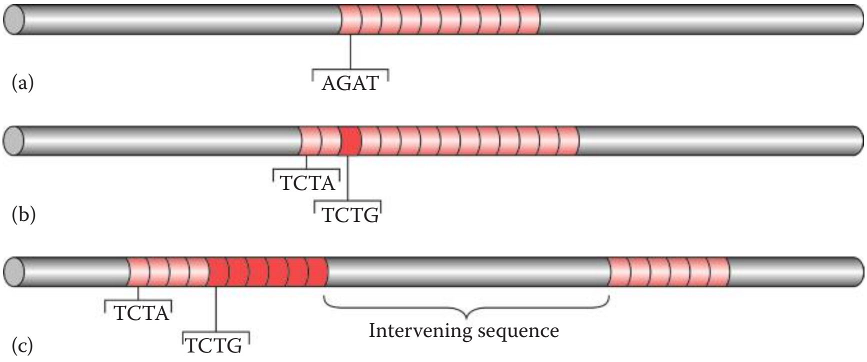

Figure 20.2 Examples of core repeat sequences. (a) A simple repeat in which D5S818 $[AGAT]_{10}$ is designated as allele 10, consisting of 10 repeating units of the tetrameric nucleotides, AGAT. (b) Compound repeats. Allele 14 of D8S1179 consists of two types of repeating units: $[TCTA]_2$, $[TCTG]_1$, and $[TCTA]_{11}$. (c) Complex repeats. Allele 24 of D21S11 contains several clusters of different tandem repeats, $[TCTA]_4$, $[TCTG]_6$, and $[TCTA]_6$, with a 43 bp intervening sequence: $[TCTA]_3$ TA $[TCTA]_3$ TCA $[TCTA]_2$ TCCATA. (© Richard C. Li.)

Nonconsensus alleles with partial repeat units also appear in the population. These nonconsensus alleles, also known as *microvariants*, differ from common alleles by one or more nucleotides. They are designated by the number of consensus repeats, followed by a decimal point and the number of nucleotides of the partial repeat, for example, the TH01 allele 9.3 is 1 nucleotide shorter than allele 10.

Another type of nonconsensus allele can result from a limitation of STR analysis. These alleles have the same number of tandem repeats as common alleles but contain different sequences. These microvariants cannot be distinguished by STR profiling because their length is identical to the lengths of common alleles.

20.2 STR Loci Commonly Used for Forensic DNA Profiling

In the early 1990s, STR loci were initially utilized for genetic studies and were later applied to forensic DNA profiling. The first STR multiplex system, known as the quadruplex, was developed by Forensic Science Services in the United Kingdom. It consisted of four STR loci (F13A1, FES, TH01, and VWA) with a *population match probability* (P_m) of 10^{-4} (Figure 20.3). P_m measures the discriminating power of an STR locus used for forensic DNA analysis. The lower the P_m (i.e., the higher the discriminating power), the less likely a match will occur between two randomly chosen profiles from different individuals (Chapter 25). In 1995, the first national DNA database was established in the United Kingdom. It contained six STR loci, also known as the *second-generation multiplex* (SGM), consisting of D8S1179, D18S51, D21S11, FGA, TH01, and VWA, with a P_m value of 10^{-7}. The SGM system also included the amelogenin locus (Section 21.3.1) for determining the sexes of DNA contributors. Subsequently, four additional loci were added to SGM with a P_m as low as 10^{-13} (SGM Plus).

To allow for international data exchange, the European DNA Profiling Group (EDNAP) recommended the use of TH01 and VWA loci for all participating European laboratories in 1996. In 1998, the *European Standard Set* (ESS) of loci was established and included TH01, VWA, FGA, and D21S11 for forensic use in Europe. Thereafter, D3S1358, D8S1179, and D18S51 loci were added to the ESS. Other loci are used as well, such as SE33, which is used in Germany's database. In 1998, the US Federal Bureau of Investigation established the *Combined DNA Index System* (CODIS). It contains 13 core STR loci plus the amelogenin sex-typing locus with a P_m

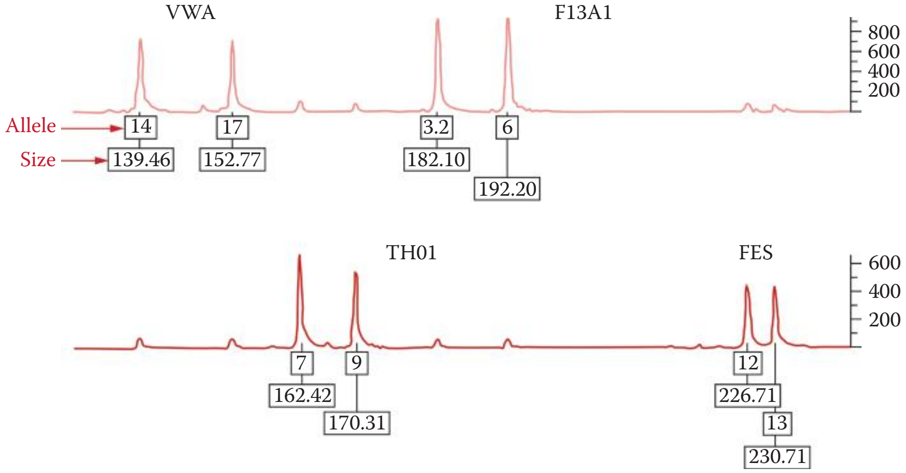

Figure 20.3 DNA profile obtained using the first STR multiplex system: the quadruplex. F13A1, FES, TH01, and VWA loci are shown. (© Richard C. Li.)

Table 20.1 Common STR Loci

Locus Symbol	Repeat Motif	Repeat Category	Cytogenetic Map Location on Chromosome	Distance from pter (Mb)	Structural Gene
CSFIPO	TAGA	Simple	5q33.1	149.4	Intron 6 of c-fms protooncogene
FGA	[CTTT] [CCTT]	Compound	4q31.3	155.5	Intron 3 of fibrinogen α chain gene
TH01	AATG	Simple	11p15.5	2.2	Intron 1 of tyrosine hydroxylase gene
TPOX	TGAA	Simple	2p25.3	1.5	Intron 10 of thyroid peroxidase gene
SE33/ ACTBP2	AAAG	Complex	6q14	89	5′ Flanking sequence of β-actin-related pseudogene 2 gene
VWA	[TCTG] [TCTA]	Compound	12p13.31	6.1	Intron 40 of von Willebrand factor gene
D1S1656	[TAGA] [TAGC]	Compound	1q42.2	230.9	Anonymous
D2S441	[TCTA] [TCAA]	Compound	2p14	68.2	Anonymous
D2S1338	[TGCC] [TTCC]	Compound	2q35	218.9	Anonymous
D3S1358	[TCTG] [TCTA]	Compound	3p21.31	45.6	Anonymous
D5S818	AGAT	Simple	5q23.2	123.1	Anonymous
D7S820	GATA	Simple	7q21.11	83.8	Anonymous
D8S1179	[TCTA] [TCTG]	Compound	8q24.13	125.9	Anonymous
D10S1248	GGAA	Simple	10q26	–[a]	Anonymous
D12S391	[AGAT] [AGAC]	Compound	12p13.2	12.5	Anonymous
D13S317	TATC	Simple	13q31.1	82.7	Anonymous
D16S539	GATA	Simple	16q24.1	86.4	Anonymous
D18S51	AGAA	Simple	18q21.33	60.9	Anonymous
D19S433	[AAGG] [TAGG]	Compound	19q12	30.4	Anonymous
D21S11	[TCTA] [TCTG]	Complex	21q21.1	20.6	Anonymous
D22S1045	ATT	Simple	22q12.3	37.5	Anonymous

Source: Ensembl Homo sapiens version 75.37 (GRCh37). Mb, megabase.

[a] Locus is not mapped to the assembly in the current Ensembl database.

of 10^{-15}. As the database grows rapidly, the chances of finding incidental matches among DNA profiles are increasing. Recently, additional loci have been added to CODIS and ESS core loci to reduce the likelihood of adventitious matches, as well as to facilitate international data sharing among law enforcement agencies and to improve the discrimination power of forensic STR analysis.

Commonly used STR loci characterized for forensic DNA profiling are summarized in Tables 20.1 and 20.2. To achieve low P_m in forensic STR profiling, desired STR loci should possess certain characteristics as described below. First, the alleles of STR loci selected should be highly variable among individuals. Second, if more than one locus is selected, the loci should not be linked to each other or inherited together (Section 21.2). The STR loci utilized are usually located at different chromosomes to ensure that they are not linked. However, loci that are far

TABLE 20.2 Core STR Loci

Locus	SGM	SGM Plus	ESS	ESS-Extended	CODIS	CODIS-Extended
Amel	☑	☑	☑	☑	☑	☑
CSFIPO					☑	☑
D1S1656				☑		☑
D2S441				☑		☑
D2S1338		☑				☑
D3S1358		☑	☑	☑	☑	☑
D5S818					☑	☑
D7S820					☑	☑
D8S1179	☑	☑	☑	☑	☑	☑
D10S1248				☑		☑
D12S391				☑		☑
D13S317					☑	☑
D16S539		☑			☑	☑
D18S51	☑	☑	☑	☑	☑	☑
D19S433		☑				☑
D21S11	☑	☑	☑	☑	☑	☑
D22S1045				☑		2
DYS391						☑
FGA	☑	☑	☑	☑	☑	☑
THO1	☑	☑	☑	☑	☑	☑
TPOX					☑	1
VWA	☑	☑	☑	☑	☑	☑
SE33						3

Source: Hares, D.R., *Forensic Sci Int Genet*, 6, e135, 2012; Gill, P., et al., *Forensic Sci Int*, 156, 242–244, 2006.

☑, minimum required loci; 1–3, recommended loci in ranked order of preference.

enough apart on the same chromosome can still be used (Figures 20.4 and 20.5), since they are not linked. Additionally, STR loci with fewer amplification artifacts such as stutter products are desired. Stutters can complicate the interpretation of profiles derived from a mixed DNA sample from more than one contributor. Moreover, STR loci with short amplicon (amplified product) lengths are preferred for multiplex STR analysis and the testing of degraded DNA samples.

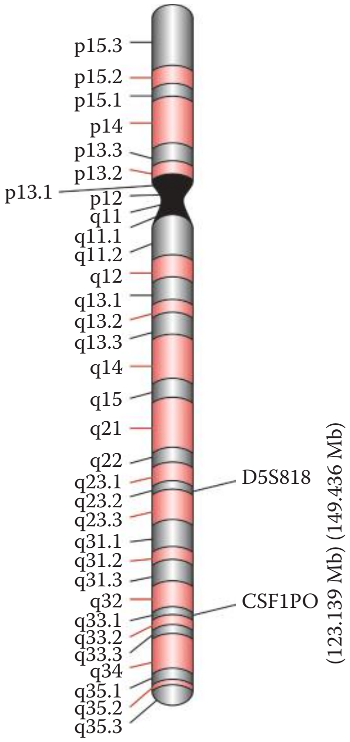
p15.3
p15.2
p15.1
p14
p13.3
p13.2
p13.1
p12
q11
q11.1
q11.2
q12
q13.1
q13.2
q13.3
q14
q15
q21
q22
q23.1
q23.2
q23.3
q31.1
q31.2
q31.3
q32
q33.1
q33.2
q33.3
q34
q35.1
q35.2
q35.3
D5S818
CSF1PO
(123.139 Mb) (149.436 Mb)

Figure 20.4 Cytogenetic map showing the locations of STR markers on chromosome 5. CSF1PO and D5S818 are separated by 26 Mb (megabases). (© Richard C. Li.)

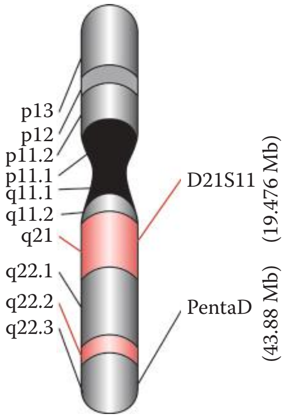
p13
p12
p11.2
p11.1
q11.1
q11.2
q21
q22.1
q22.2
q22.3
D21S11
PentaD
(43.88 Mb) (19.476 Mb)

Figure 20.5 Cytogenetic map showing the locations of STR markers on chromosome 21. D21S11 and PentaD are separated by 24 Mb (megabases). (© Richard C. Li.)

20.3 Forensic STR Analysis

STR loci are amplified using fluorescent dye-labeled primers. A multiplex STR system utilizes multiple fluorescent dyes to label each amplicon. The amplicons are separated via electrophoresis. The different fluorescent dye colors are resolved by the detector, and the signals corresponding to each DNA fragment are identified using specialized computer software. The data collection process generates an *electropherogram* that shows a profile of peaks corresponding to each DNA fragment. The positions of these peaks represent the electrophoretic mobility of the DNA fragments. A small fragment, migrating faster than a large one, peaks earlier in the electropherogram than a longer fragment. The DNA fragments are sized by comparison to an internal size standard (Figure 20.6; Chapter 8). Figure 20.7 summarizes the work flow of a forensic STR analysis.

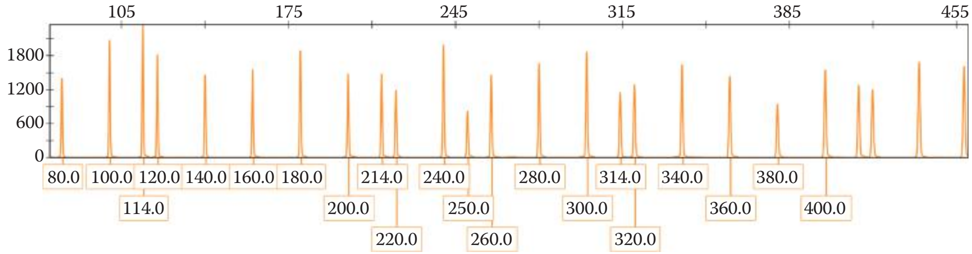

Figure 20.6 Electropherogram of GeneScan™ 500 size standard (Applied Biosystems). RFU represents relative fluorescence unit. (© Richard C. Li.)

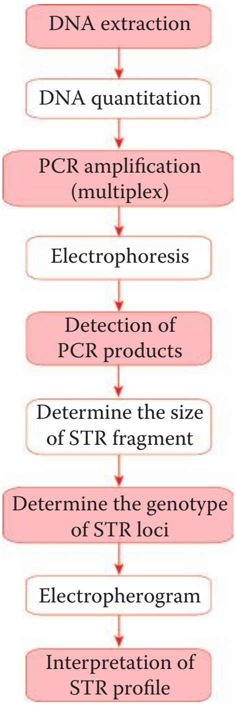
DNA extraction
DNA quantitation
PCR amplification (multiplex)
Electrophoresis
Detection of PCR products
Determine the size of STR fragment
Determine the genotype of STR loci
Electropherogram
Interpretation of STR profile

Figure 20.7 Capillary electrophoresis separation of amplified STR products. Fluorescent dye-labeled amplification products are separated and subsequently detected. Various fluorescent dye colors are resolved by the detector. The peaks corresponding to each DNA fragment are identified. (© Richard C. Li.)

The area or amplitude of the peak, expressed as relative fluorescence units (RFU) (Section 9.3.1.3), reflects the fluorescent signal intensity. The RFU value of peak height is proportional to the amount of DNA amplicons being analyzed. When the RFU value is very low, it is difficult to distinguish a signal from background noise. The manufacturer of commonly used instruments for forensic DNA analysis recommends 150 RFU as the threshold of detection. Peaks below 150 RFU should be interpreted with caution. Some forensic laboratories use lower thresholds, as low as 50 RFU, based on their own validation studies. In contrast, when the RFU value is too high, it saturates the sensitivity of an instrument as well as causing artifacts such as pull-up signals (Section 20.4.3.1). The maximum RFU allowed is usually 6000 RFU.

20.3.1 Determining the Genotypes of STR Fragments

As noted earlier, electropherograms are usually plotted as fluorescent signal intensity (in RFU) versus the sizes of the DNA fragments. The data in an electropherogram can then be converted into a genotype. The genotype for a specific STR locus is defined as the number of repeat units of the allele. STR genotype data generated from different laboratories can be compared easily and are suitable for databasing.

The genotype is determined by using an allelic ladder, which is important to achieve accurate genotype profiling. An allelic ladder is a collection of synthetic fragments corresponding to common alleles observed in the human population for a given set of STR loci (Figures 20.8 and 20.9). The ladders are compared to data obtained from an electropherogram of a questioned sample to determine the genotype. Thus, each allele in a ladder must be resolved properly in order to determine correct STR alleles for a sample. The sizes of DNA fragments of a sample are correlated to sizes of fragments for each allele in an allelic ladder in order to determine the allele designation (genotype) of a questioned sample (Figures 20.10 and 20.11). If a rare allele fails to match alleles within an allelic ladder, it is considered an *off-ladder allele*. If an off-ladder allele is present, the sample should be reanalyzed. The presence of a rare allele can be confirmed by repeating the electrophoresis process based on the characteristic electrophoretic mobility of the rare allele.

20.3.2 Interpretation of STR Profiling Results

General guidelines for the interpretation and the reporting of STR profile results were set by the Scientific Working Group on DNA Analysis Methods (SWGDAM) and the DNA Commission of the International Society of Forensic Genetics (ISFG). Typically, conclusions are categorized as inclusion, exclusion, or inconclusive result.

20.3.2.1 Inclusion (Match)

Peaks of compared STR loci, such as those between the profiles of suspect and crime scene evidence or victim and crime scene evidence, show identical genotypes. The strength of this conclusion can be evaluated via statistical analysis and is usually cited in the case report (Chapter 25).

20.3.2.2 Exclusion

The genotypes of two or more samples differ, and the profile of the sample is determined to be an exclusion, meaning that the profiles originated from different sources.

20.3.2.3 Inconclusive Result

The data do not support a conclusion of inclusion or exclusion. In other words, insufficient information is available to reach a conclusion.

20.4 Factors Affecting Genotyping Results

A number of genetics-, amplification-, and electrophoresis-related factors may affect the accuracy of genotypic profiles.

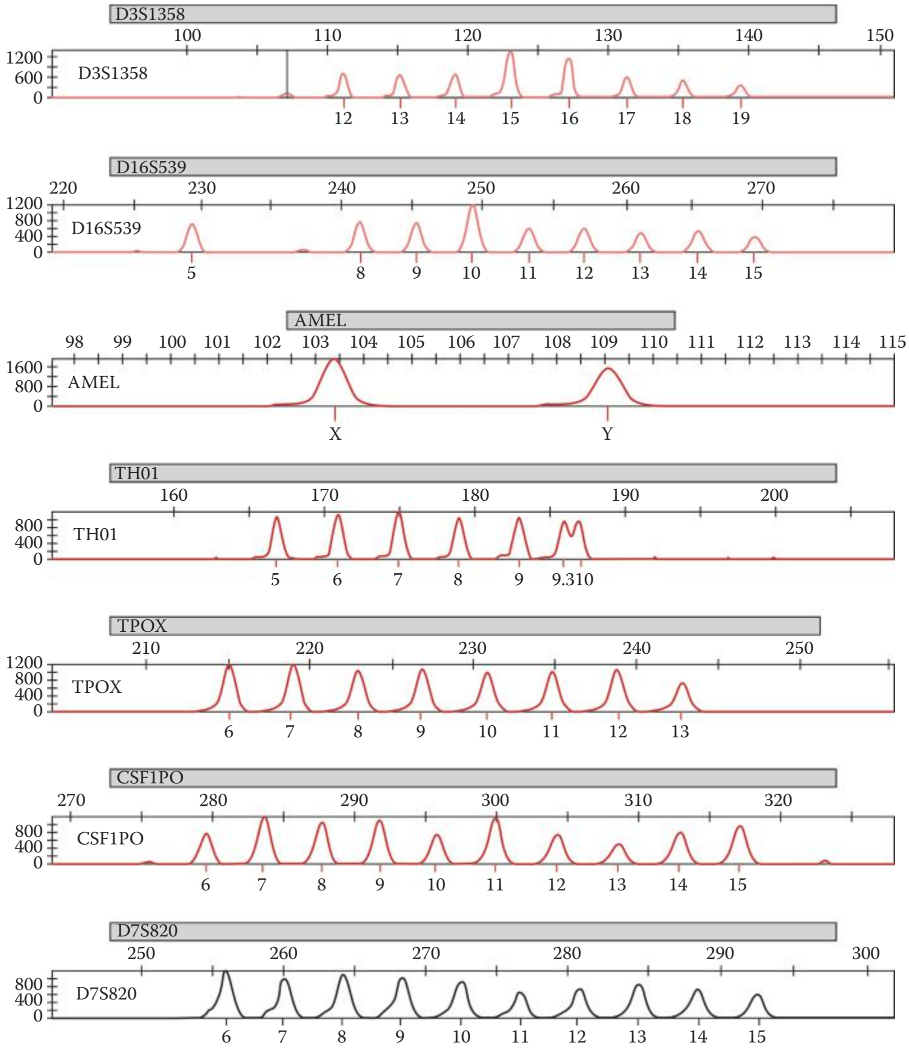

Figure 20.8 Electropherogram of the allelic ladder of the AmpFlSTR® COfiler® PCR Amplification Kit (Applied Biosystems). AMEL, CSF1PO, D3S1358, D7S820, D16S539, TH01, and TPOX loci are shown. (© Richard C. Li.)

20.4.1 Mutations

STR loci with low mutation frequencies are desired, in particular, for human identification in mass disasters and for missing person and paternity cases. However, STR mutations do occur, which can affect the profiling results.

20.4.1.1 Mutations at STR Core Repeat Regions

Mutations, usually resulting in a gain or a loss of a single repeat unit, are observed at STR loci. If a mutation occurs in the germ cells (cells that form gametes), the mutant allele will be transmitted to and be present in all cell types of the progeny. This type of inheritable mutation in germ cell lineage is called a *germ-line mutation*. The frequency of germ-line mutation can be measured by the *mutation rate*, expressed as the number of mutations per generation (germ-line transmission). The average mutation rate of commonly used STR loci is about 10^{-4} mutations per germ-line transmission. However, the mutation rate may vary among different STR loci.

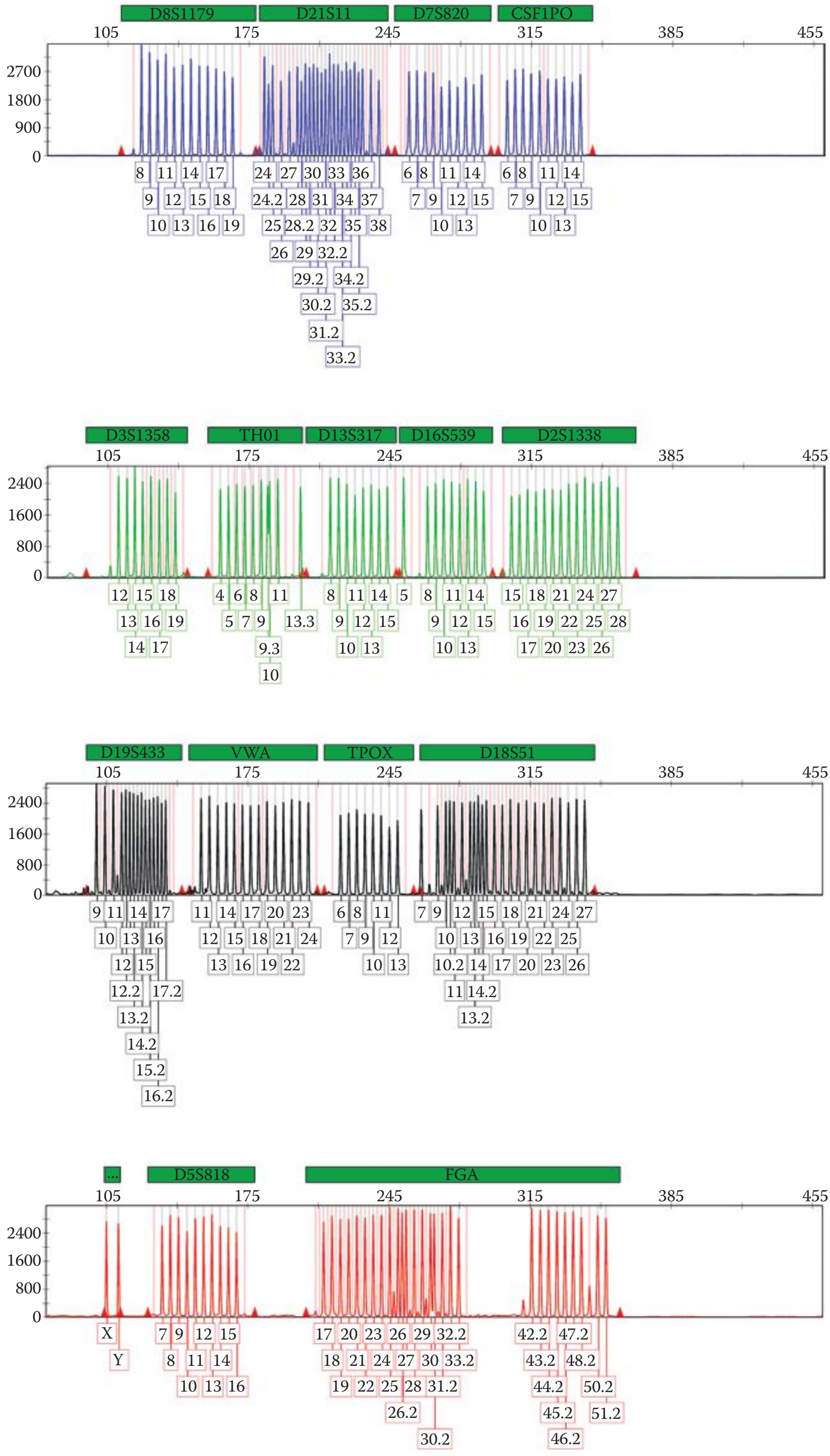

Figure 20.9 Electropherogram of the allelic ladder of the AmpFlSTR® Identifiler® Plus Kit (Applied Biosystems). AMEL, CSF1PO, D2S1338, D3S1358, D5S818, D7S820, D8S1179, D13S317, D16S539, D18S51, D19S433, D21S11, FGA, TH01, TPOX, and VWA loci are shown. (© Richard C. Li.)

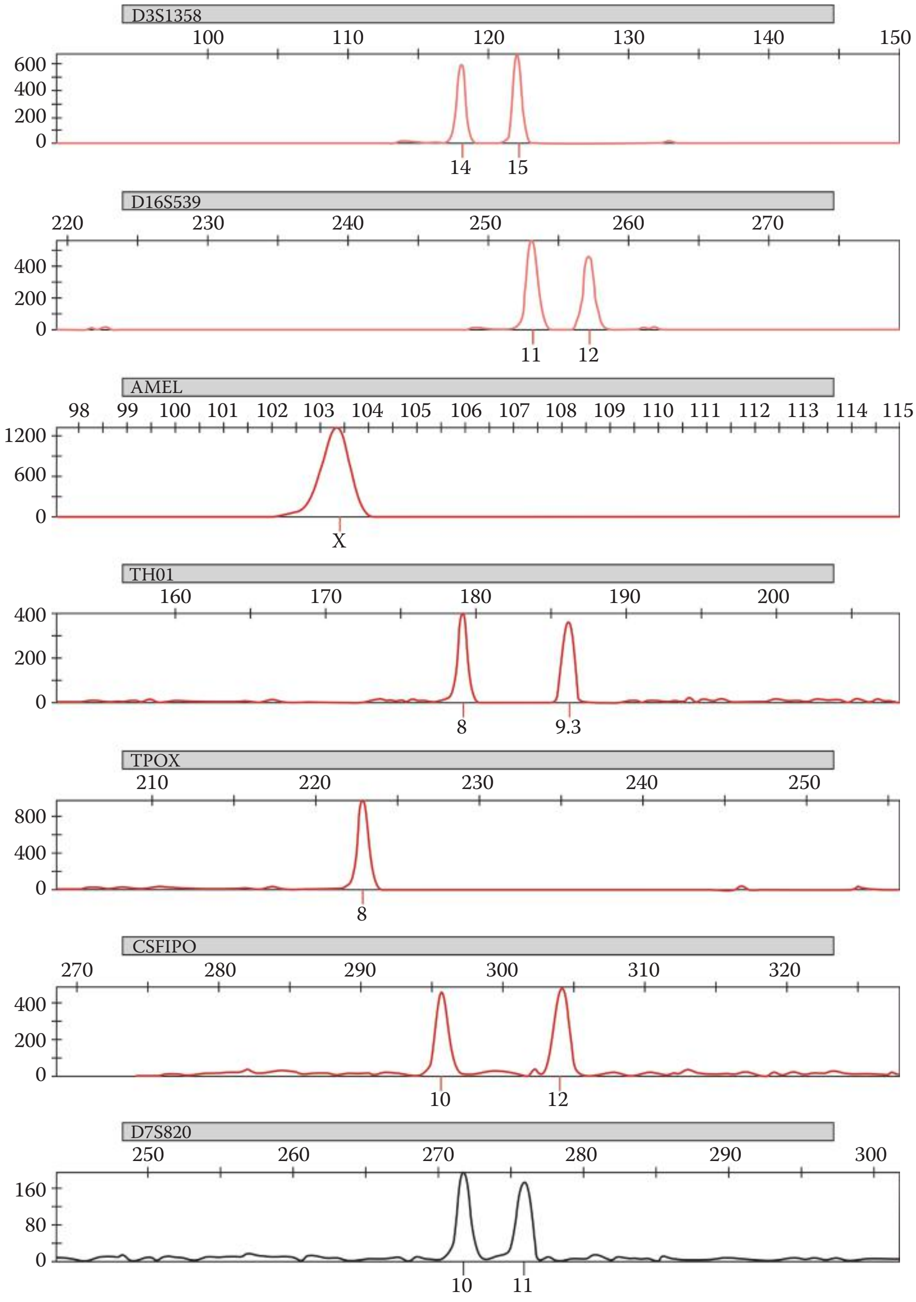

Figure 20.10 Individual DNA profile (Cofiler). The genotype of the DNA profile is shown. AMEL: X, X. CSF1PO: 10, 12. D3S1358: 14, 15. D16S539: 11, 12. D7S820:10, 11. TH01:8, 9.3. TPOX: 8, 8. (© Richard C. Li.)

In contrast, *somatic mutations* involve the mutation of only somatic cells. The germ cells are not affected, and thus a mutant allele is not transmitted to the progeny. A somatic mutation occurring at the core repeat region of an STR locus can be detected and compared to the wild-type allele. The ratio of the signal intensities of the wild-type and mutant alleles varies, depending on the number

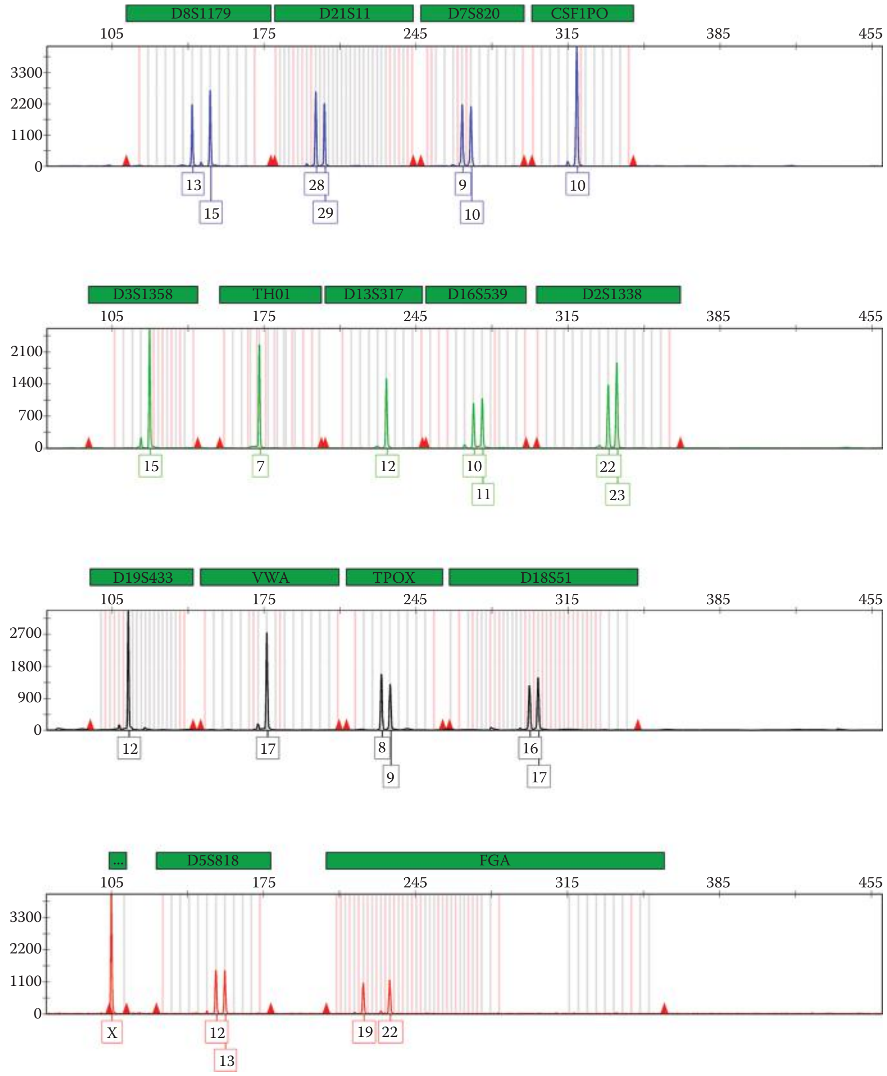

Figure 20.11 Individual DNA profile (Identifiler). The genotype of the DNA profile is shown. AMEL: X, X. CSF1PO: 10, 10. D2S1338: 22, 23. D3S1358: 15, 15. D5S818: 12, 13. D7S820: 9, 10. D8S1179: 13, 15. D13S317: 12, 12. D16S539: 10, 11. D18S51: 16, 17. D19S433: 12, 12. D21S11: 28, 29. FGA: 9, 22. TH01: 7, 7. TPOX: 8, 9. VWA: 17, 17. (© Richard C. Li.)

of mutation-carrying cells in the tissue. Somatic mutations are usually tissue specific. STR profiles from different tissues of the same individual can be compared if a somatic mutation is suspected.

20.4.1.2 Chromosomal and Gene Duplications

Duplicating one of the homologous chromosomes results in a total of three copies of a particular chromosome. This condition, called *trisomy*, is rare and often associated with genetic diseases such as Down's syndrome (chromosome 21 duplication). Duplications have also been observed in chromosomes 13, 18, and X. Other anomalies include duplication of a portion of a chromosome and a single or group of genes instead of an entire chromosome.

A duplication bearing a mutation within the STR core repeat region can affect the number of tandem repeat units. If the duplicated locus is mutated, a *triallelic* or three-peaks pattern can be detected at a single locus, but not at loci located at other chromosomes in a multiplex STR profile (Figure 20.12). The three alleles usually have equal signal intensity (peak amplitude or peak area). Triallelic patterns at STR loci commonly used for forensic DNA analysis have been documented. Many occur at the TPOX, FGA, and CSF1PO loci. If the duplicate locus is not mutated, only two alleles will be observed in a heterozygote. However, the ratio of the peak amplitude of the alleles will be 1:2 (one copy vs. two copies including the duplicate) at that particular locus. However, STR profiles at the loci located at other chromosomes are not affected.

20.4.1.3 Point Mutations

Point mutations involve the changing of a nucleotide sequence through nucleotide substitution, insertion, or deletion. Insertion or deletion mutations affect the lengths of the core repeat regions and the amplified flanking regions of STR loci and thus affect STR profiles. Nucleotide substitution mutations (except those residing within the primer-binding regions) do not affect the length of DNA and thus do not affect STR profiles.

However, mutations occurring at the primer-binding sequences of the flanking regions of STR loci may affect genotype results. If a mutation at a primer-binding sequence prevents the primer from annealing to the template, this leads to a complete failure of the amplification of the allele. This phenomenon is known as a *null allele* or silent allele (Figure 20.13). To overcome the consequences of a null allele, an alternative primer annealing to a flanking region away from the mutated sequence can be used. Additionally, a primer with the sequence that is complementary to the known mutation can also be used. If the mutation does not completely prevent the primer from annealing but reduces the efficiency of the amplification, the resulting signal intensity of the allele is usually decreased. This problem may be solved by modifying the condition of amplification for the mutant allele.

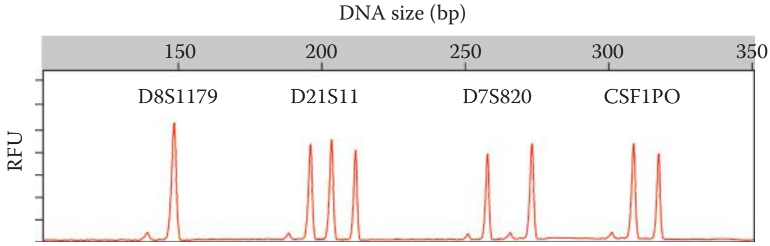

Figure 20.12 Triallele. In this example, the triallele is observed only at D21S11 and not at other STR loci. (© Richard C. Li.)

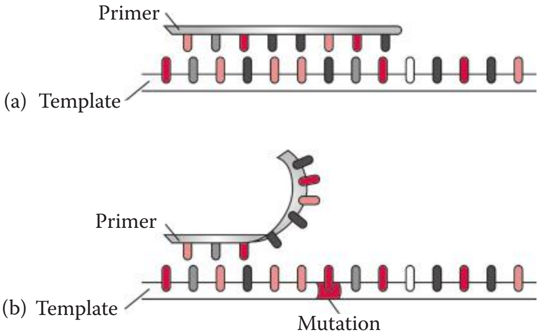

Figure 20.13 Null allele. An allele present in the sample failed to be amplified by one of the primer sets as a result of a rare mutation at the primer-binding sequence of the flanking region: (a) wild type and (b) mutation. (© Richard C. Li.)

20.4.2 Amplification Artifacts

20.4.2.1 Stuttering

A stutter is a minor allele peak, also known as a stutter peak, whose repeat units are shorter or longer than the parental allele peak (Figure 20.14). Less stuttering is observed with pentameric and hexameric repeat unit loci compared to shorter repeat unit loci. The loci that contain complex repeat sequences usually exhibit reduced stuttering. At a given STR locus, large alleles appear to yield more stutter than smaller alleles.

Commonly observed stutters are one repeat unit shorter than the parental allele. It is believed that stuttering is due to the slippage of polymerase, which may have occurred during amplification reactions (Figure 20.15). Stutters with repeat units longer than the parental allele peak can also be observed, but are very rare. The *stutter ratio* is defined as the area of the stutter peak divided by the area of the parental peak. The stutter ratio is usually less than 0.15. A ratio of greater than 0.15 should be interpreted with caution due to the potential presence of DNA from more than one contributor.

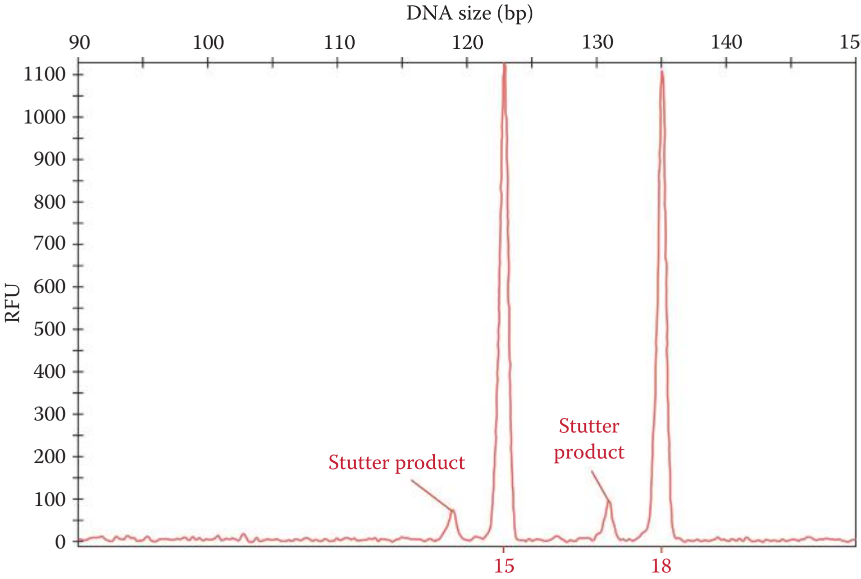

Figure 20.14 Stutter products. (© Richard C. Li.)

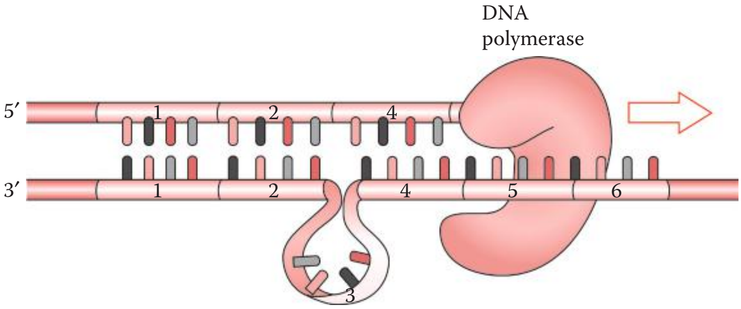

Figure 20.15 Proposed mechanism for stutter products. During the DNA synthesis step of PCR amplification, a DNA polymerase slips, and a region of the primer–template complex becomes unpaired, causing the template strand to form a loop. The consequence of this one-repeat loop is a shortened PCR product smaller than the template by a single repeat unit. (© Richard C. Li.)

20.4.2.2 Nontemplate Adenylation

During PCR amplification, DNA polymerase often adds an extra nucleotide, usually an adenosine, to the 3′-end of an amplicon. Such a phenomenon is referred to as a *nontemplate addition* resulting in an amplicon that is one base pair longer than the parental allele (designated the +A peak), as shown in Figure 20.16. As a result, an amplicon has both the –A amplicon, which corresponds to the size of the parental allele, and the +A amplicon, which represents the amplicon with the nontemplate addition. To simplify the analysis, the most commonly used multiplex STR kits utilize amplification conditions that favor the adenylation of amplicons. Thus, most amplicons in a sample contain an additional adenosine at the 3′ end (+A peak). However, partial nontemplate addition can occur when too much DNA template is utilized in PCR amplification. As a result, a mixture of –A and +A peaks is usually observed.

20.4.2.3 Heterozygote Imbalance

Heterozygote imbalance occurs when one of the alleles has greater peak area or amplitude than the other allele within the same locus in which the two alleles of a heterozygote are compared (Figure 20.17). It is believed that heterozygote imbalance may arise if the DNA sample contains unequal copies of DNA template of the two alleles for the heterozygote, or the two alleles of a heterozygote are unequally amplified, a condition known as *preferential amplification*. Preferential amplification usually refers to an event where a smaller allele is amplified more efficiently than larger ones. As a result, the presence of heterozygote imbalance interferes with the interpretation of samples with a DNA mixture derived from more than one contributor.

20.4.2.4 Allelic Dropout

Allelic dropout occurs when an allele, usually one of the heterozygote alleles, fails to be detected. To date, our understanding of what causes the dropout is very limited. The occurrence of allelic dropout can be the result of an extreme situation of preferential amplification or heterozygote imbalance. Additionally, certain mutations leading to amplification failure (Section 20.4.1.3) can cause allelic dropout.

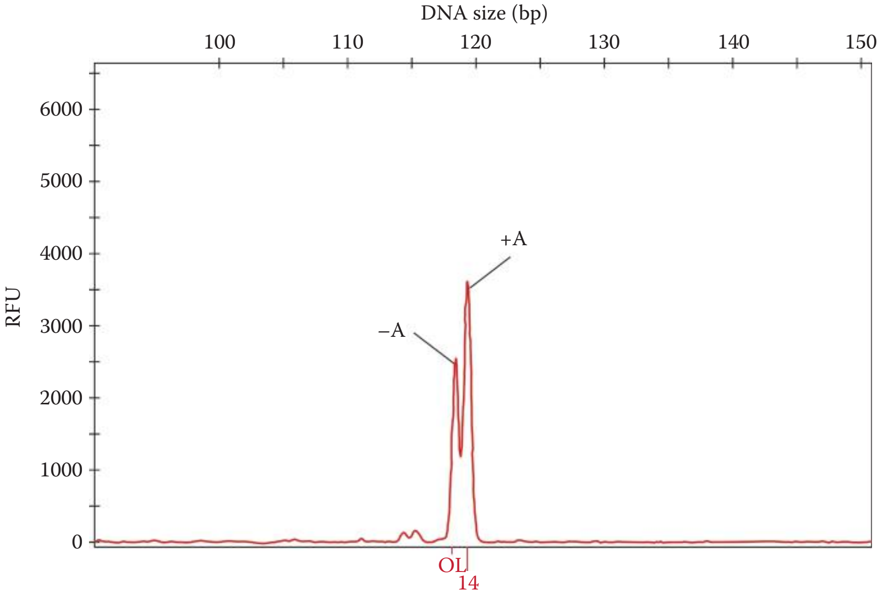

Figure 20.16 Nontemplate adenylation. OL represents the off-ladder allele. (© Richard C. Li.)

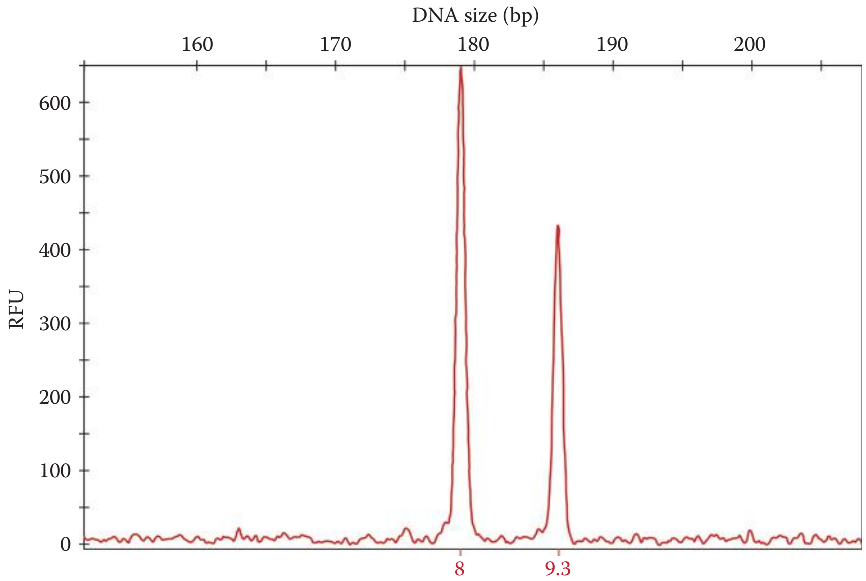

Figure 20.17 Heterozygote imbalance. The signal intensity of one allele is greater than that of the other allele within the same locus. (© Richard C. Li.)

20.4.3 Electrophoretic Artifacts

20.4.3.1 Pull-Up Peaks

A *pull-up peak* occurs when a minor peak of one color on an electropherogram is pulled up from a major allelic peak in another color (Figure 20.18) when the colors have overlapping spectra. For example, a green peak may pull up a yellow peak, or a blue peak may pull up a green peak. A pull-up peak may contribute to the inaccuracy of a profile if the position of a pull-up peak corresponds to the position of an allele. A pull-up peak often occurs when a sample is overloaded or a matrix file (a spectral calibration) is not updated. Thus, loading a proper amount of sample or installing an appropriate matrix file can prevent the occurrence of pull-up peaks.

20.4.3.2 Spikes

Spikes are sharp peaks, with similar signal intensities, that are present in all color panels of an electropherogram (Figure 20.19). Spikes are caused by air bubbles and urea crystals in the capillary of an electrophoretic platform. Voltage spikes can also contribute to spike peaks. The spikes are electrophoretic artifacts and are not reproducible. Thus, electrophoresis can be repeated to verify that the spikes occurred in a previous electrophoresis result.

20.5 Genotyping of Challenging Forensic Samples

20.5.1 Degraded DNA

Environmental exposure, such as high humidity and temperature, of biological evidence can lead to DNA degradation such as the breaking of DNA molecules into small fragments. The more severe the degradation, the more intensive the fragmentation. In forensic DNA analysis, the size range of STR amplicons is usually 100–500 bp in length. When a sample experiences some degradation, large alleles are less likely to be amplified than small alleles (Figures 20.20 and 20.21). As a result, the dropout of large alleles often occurs, leading to a partial DNA profile or even a failure in obtaining a DNA profile. To address this issue, the PCR primers can be

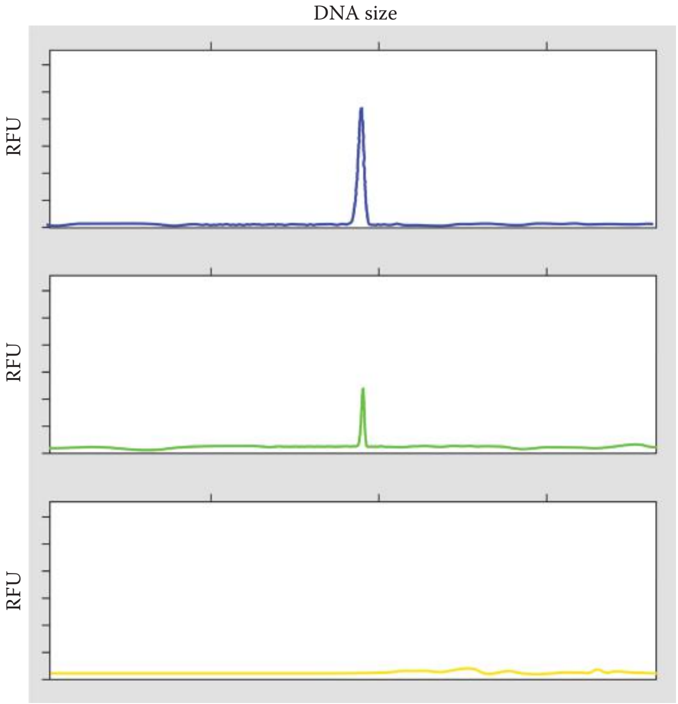

Figure 20.18 Pull-up peaks. The peaks with overlapping spectra observed in the top and middle panels are not observed in the bottom panel. (© Richard C. Li.)

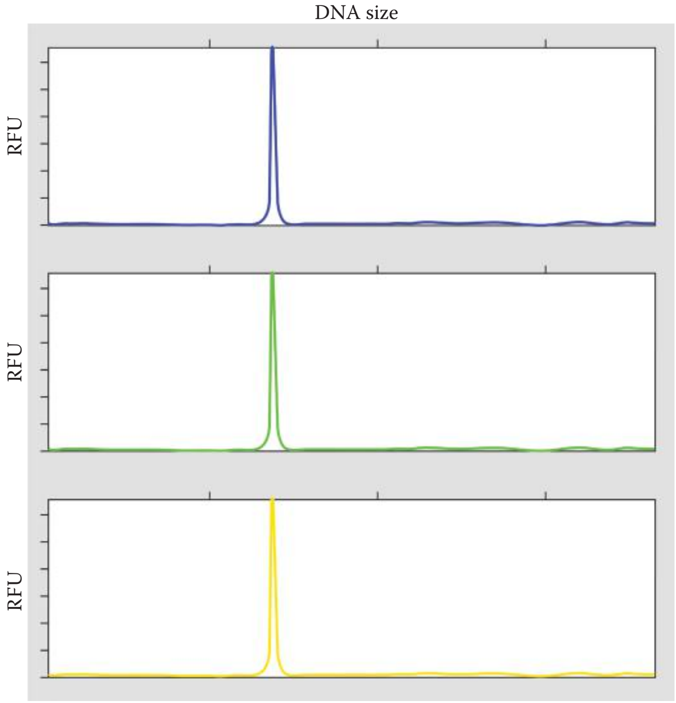

Figure 20.19 Spike peaks can be observed in various intensities. (© Richard C. Li.)

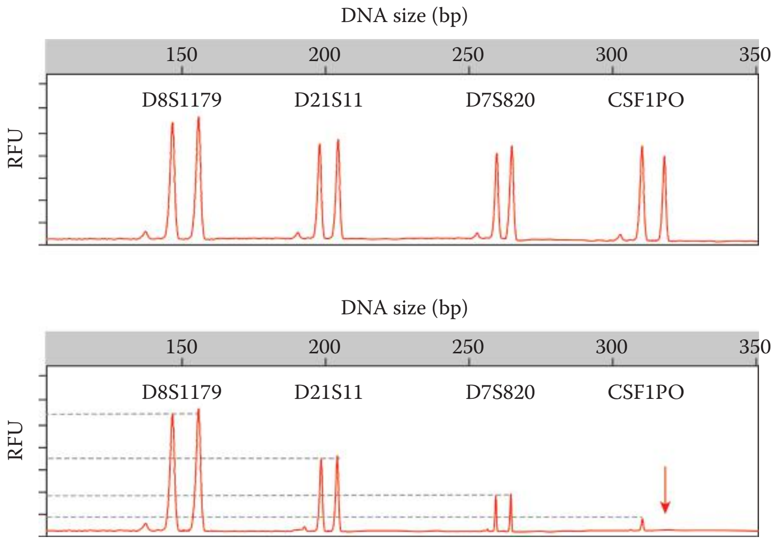

Figure 20.20 Diagram of STR profiles of samples: without DNA degradation (top) and with degradation (bottom). Arrow: allelic dropout. (© Richard C. Li.)

redesigned to anneal more proximally to the STR core repeat region than standard STR primers, yielding small amplicons also known as miniSTRs. Using the miniSTR strategy, more alleles can be detected in degraded DNA samples than using the standard STR primers.

20.5.2 Low Copy Number DNA Testing

Low copy number (LCN) DNA analysis involves the testing of very small amounts of DNA (<100 pg) in a sample. LCN DNA analysis is often needed for samples derived from evidence such as fingerprints and tools and weapons handled by perpetrators. STR analysis of extremely low levels of human DNA can be achieved by increasing the number of PCR cycles (e.g., increasing from 28 to 34 cycles) to improve the yield of amplicons, thus improving the sensitivity of the analysis.

However, this approach also increases the appearance of artifacts that can make interpretation difficult. For instance, the occurrence of allele dropout, heterozygote imbalance, and stuttering is frequently observed in LCN DNA analysis. Additionally, allele drop-in can arise from contamination. The phenomenon of allele drop-in is usually not reproducible. In an LCN DNA analysis, genotypes can be determined if identical alleles can be detected from two independent amplification reactions.

20.5.3 Mixtures

Samples of DNA from two or more contributors are commonly encountered in forensic cases such as sexual assaults in which the evidence recovered from a victim is mixed with a suspect's bodily fluids (Figure 20.22). The interpretation of DNA profiles of mixed stains is known as *mixture interpretation*, which is described below:

1. *To determine the presence of a mixture*: First, determine whether the source of the DNA in the sample came from one or more individuals by examining the number of alleles at multiple loci. The characteristics listed below usually indicate a mixture:
    a. Severe heterozygote imbalance.
    b. Stutter ratio above 0.15.
    c. Presence of three or more alleles per locus at multiple loci.

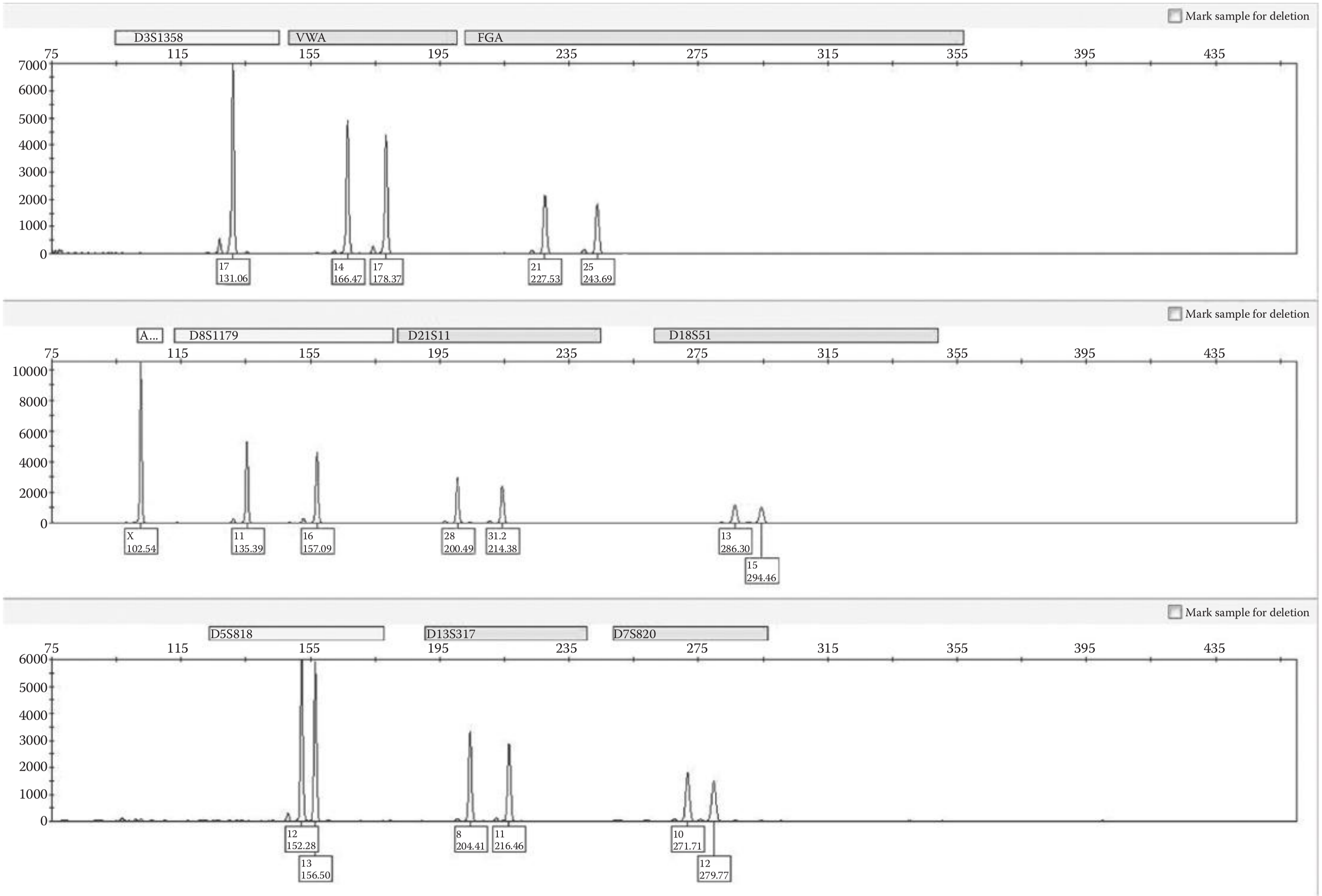

Figure 20.21 DNA profile (AmpFlSTR® Profiler Plus® PCR Amplification Kit; Applied Biosystems) of the degraded sample. (© Richard C. Li.)

Additionally, caution should be taken to distinguish the presence of a mixture and various artifacts such as stutters and nontemplate adenylation.

2. *To determine the genotypes of all alleles and to identify the number of contributors*: Note that the maximum number of alleles at any given locus is two per individual. In the case of homozygous or allele overlap, the number of alleles observed can be less than two per individual.
3. *To estimate the ratios of the contributions*: Determine the relative ratios of the contributions to the mixture made by each individual by comparing the peak areas or

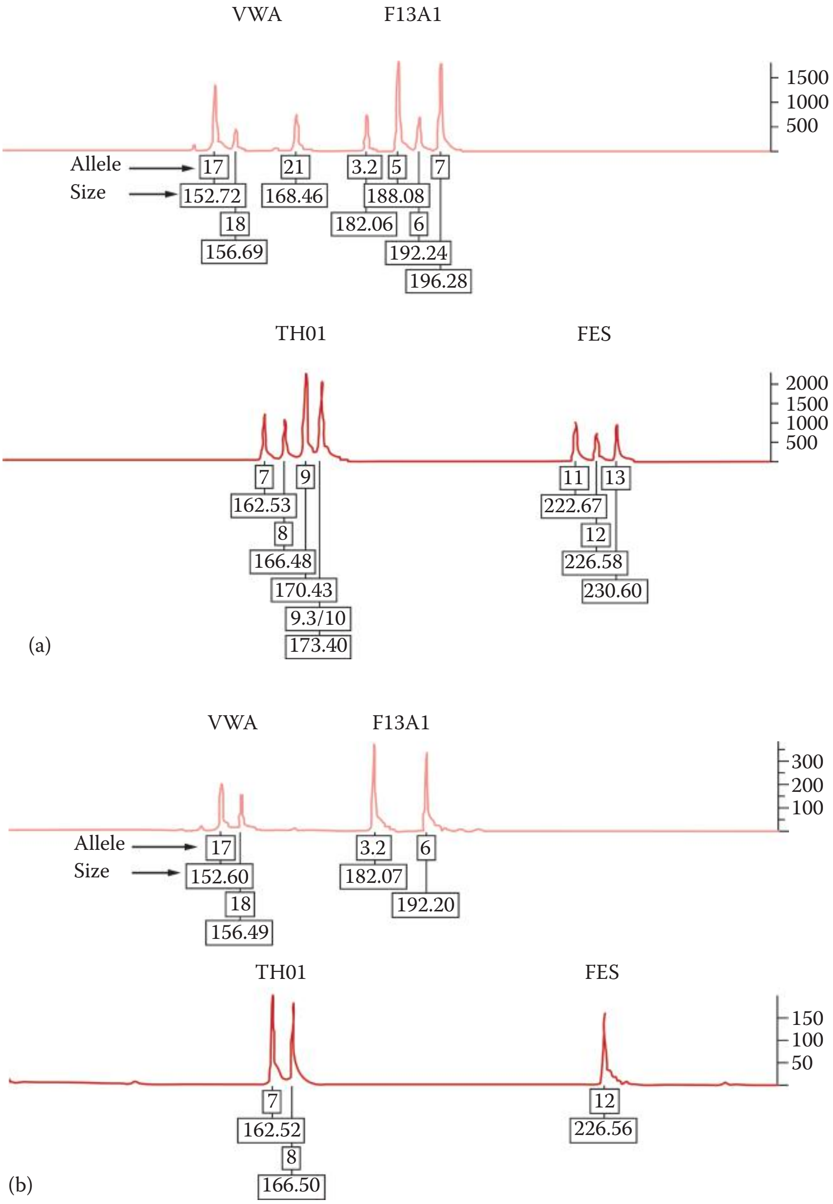

Figure 20.22 DNA profiles of mixed bodily fluids. (a) DNA profile of mixed stains from evidence, (b) DNA profile of the victim. (© Richard C. Li.)

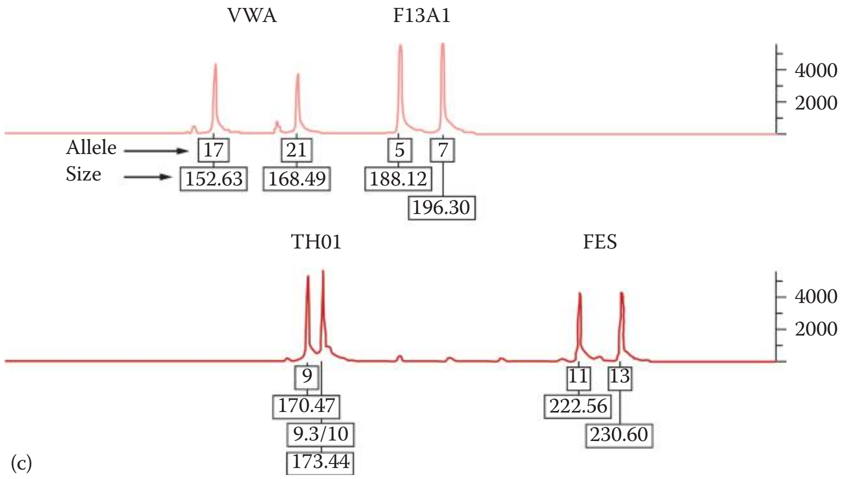

Figure 20.22 (Continued) (c) DNA profile of the suspect.

amplitudes. Amelogenin, a sex-typing marker, is useful in determining the genders of DNA contributors.

4. *To consider all possible genotype combinations*: This may be done by pair-wise comparisons to determine the allele combinations that belong to the minor contributor and those that belong to the major contributor.
5. *To compare reference samples*: The final step is to compare the genotype profiles with the genotypes of reference samples from a suspect and victim. If the DNA profile of the suspect's reference sample matches a major or minor component of the mixture, the suspect cannot be excluded as a contributor.

Detailed guidance for basic steps in mixture interpretation is provided in a number of published guidelines. For example, the Interpretation Guidelines for Autosomal STR Typing by Forensic DNA Testing Laboratories was recently established by the Scientific Working Group on DNA Analysis Methods (SWGDAM), which provides direction on DNA profiling and mixture interpretation. Additionally, guidance for the statistical evaluations of the mixture analysis results is also provided.

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Genetic Population Data

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21

Sex Chromosome Haplotyping and Gender Identification

21.1 Y Chromosome Haplotyping

21.1.1 Human Y Chromosome Genome

The Y chromosome is inherited from the father and is passed on to all male offspring; this is known as *patrilineage* (Figure 21.1). Thus, the Y chromosome is unique to males. The chromosome encodes dozens of genes required for male-specific functions, including sex determination and spermatogenesis. The human Y chromosome genome contains approximately 59 million base pairs (bp) and likely contains 50–60 genes. The Y chromosome can be divided into two regions: the pseudoautosomal region and the male-specific Y region (Figure 21.2).

21.1.1.1 Pseudoautosomal Region

The *pseudoautosomal regions (PARs)* are homologous nucleotide sequences that are present on the X and Y chromosomes. There are two PARs on each X and Y chromosome: PAR1 and PAR2. In the Y chromosome, PAR1 is located on the terminal region of the short arm. The PAR1 comprises 2.6 Mb. Twenty-four genes have been identified within the PAR1. The PAR2 of the Y chromosome is located at the tip of the long arm. The PAR2 comprises 320 kb, with only four genes identified so far.

The PARs play an important role in proper segregation of the X and Y chromosomes during meiosis. During meiosis in males, the PARs allow the Y chromosome to pair with the X chromosome. Crossing over and recombination (Chapter 25) within the PARs of the X and Y chromosomes can occur. As a result, males can inherit an allele originally present on the PARs of the X chromosome, and females can inherit an allele originally present on the PARs of the Y chromosome. In particular, PAR1 plays a major role in X–Y chromosome pairing. The deletion of PAR1 results in failure of pairing and leads to male infertility. PAR2 is much shorter than PAR1, and thus shows a lower frequency of pairing than PAR1. The deletion of PAR2 exhibits less severe phenotypes than that of PAR1.

21.1.1.2 Male-Specific Y Region

The remainder of the Y chromosome is known as the *male-specific Y (MSY)* region. It was previously called the *nonrecombining Y (NRY)* region. The bulk of this region does not participate in homologous recombination. However, certain sections involve intrachromosomal gene conversion, which is the nonreciprocal transfer of genomic DNA between a pair of repeated genes on a single chromosome; in this case, the Y chromosome. About 40 megabases (Mb) within the

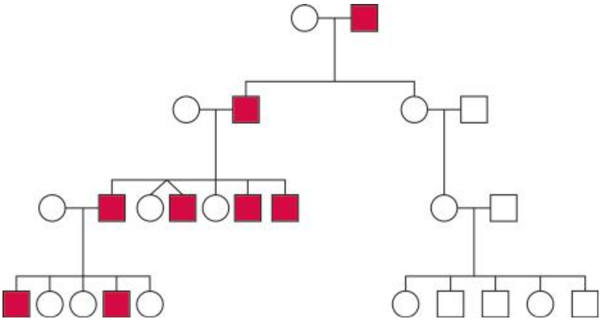

Figure 21.1 Human family pedigree showing inheritance of the Y chromosome. Females and males are denoted by circles and squares, respectively. Red symbols indicate individuals who inherited the same Y chromosome.

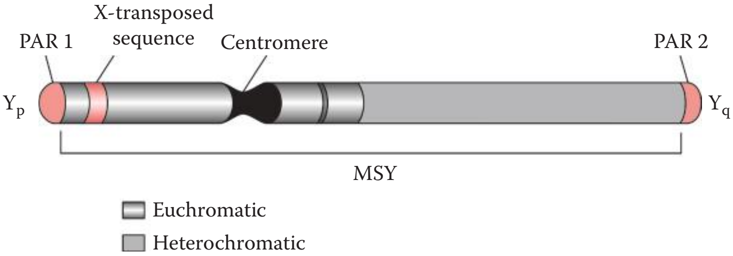

Figure 21.2 Human Y chromosome structure. PAR, the pseudoautosomal region; MSY, male-specific Y region; Y_p, the short arm of the Y chromosome; Y_q, the long arm of the Y chromosome. (© Richard C. Li.)

MSY region are heterochromatic (highly repetitive sequences) including the centromeric region and the bulk of the distal long arm. The euchromatic region, which comprises transcriptional active genes, is approximately 23 Mb. Certain sections of the euchromatic region share some homology with the X chromosome. For instance, X-transposed sequences of the Y chromosome are 99% identical to sequences within Xq21 (a band in the long arm of the X chromosome). The X-transposed sequences are the sequences, a total of approximately 3.4 Mb in length, that were transposed from the X chromosome to the Y chromosome several million years ago. Additionally, dozens of genes located in the euchromatic region share 60%–96% homology with their X chromosome counterparts. The regions sharing homology with the X chromosome should be avoided when selecting Y chromosome–specific markers for forensic DNA profiling.

21.1.1.3 Polymorphic Sequences

The Y chromosome contains an abundance of polymorphic markers. DYF155S1, also known as MSY1, is the first characterized variable number of tandem repeats (VNTR) or minisatellite at the human Y chromosome. It consists of an array of AT-rich repeats at 25 bp per unit repeat. The DYF155S1 locus is highly polymorphic. The unit repeat sequence varies through base substitution. At least five different variant types of unit repeat sequences exist. Additionally, the numbers of these units also vary, ranging from 50 to 115 repeats. Thus, the length of alleles range from approximately 1200 to 2800 bp. DYF155S1 is of considerable interest as a potential marker in forensic testing. However, the analysis method is labor intensive, making it difficult to implement in forensic casework, such as the investigation of sex crimes. Moreover, many single nucleotide polymorphisms (SNPs) and mobile elements exist at the Y chromosome. However, the discrimination power of SNPs and mobile elements is considerably less than that of Y chromosome short tandem repeats (Y-STRs). To date, Y-STRs are usually used for Y chromosome DNA testing due to the high-throughput analysis and good discrimination power (Section 21.1.2).

21.1.2 Y-STR

Y chromosome loci are very important for forensic DNA profiling, and this chapter will discuss such applications. For instance, the Y-STRs used in forensic DNA testing are male specific (for humans and certain higher primates) and are thus useful in the investigation of sexual assault cases involving male suspects. The evidence gathered in such cases usually consists of a mixture of high levels of female DNA and low levels of male DNA. The Y chromosome–specific loci can be examined without interference from large amounts of female DNA; differential extraction of sperm and nonsperm cells may not be needed. Furthermore, the Y-STR system is useful for determining the numbers of unrelated male perpetrators in sexual assault cases. The Y-STR loci used for forensic applications are located in the nonrecombining section of the Y chromosome so that patrilineage can be established. The technique can be used for paternity testing and the identification of missing persons. Finally, data interpretation can be simplified by the use of a single allele per Y-STR locus profile at most loci. Reference databases are available for estimating Y-STR haplotype frequencies among various human populations for statistical analysis of profiling results.

The major disadvantage of Y-STR loci is that their discriminating power is lowerthan that of autosomal loci. Because Y chromosome loci are linked, the product rule for statistical calculations for profile probability does not apply. Chapter 25 discusses the statistical evaluation of the strength of the matches. Also, the current Y-STR profiling cannot distinguish individuals with the same patrilineage.

More than 400 STR loci have been identified in the Y chromosome genome. The precise locations of these loci have been sequentially mapped using human genome sequencing data. Most Y-STR loci, approximately 60% of the 400 identified, are located on the long arm of the chromosome; about 22% are located on the short arm and a few are found in the centromeric region (Figure 21.3). Y-STRs in the telomeric region have yet to be identified. Only about 5% of Y-STRs are located within 5′ untranslated or intron regions of protein-coding genes. The

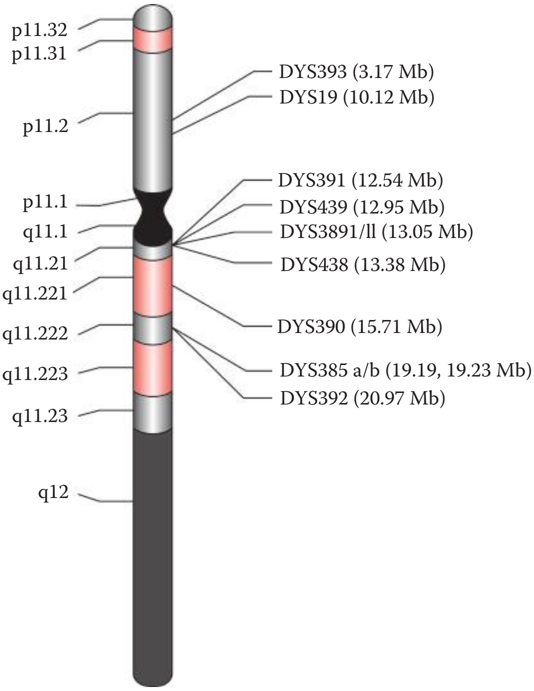

Figure 21.3 Human cytogenetic map of the Y chromosome. The Y-STRs and positions are shown (Mb = megabase). Cytogenetic patterns with alternating dark and light bands are shown. (© Richard C. Li.)

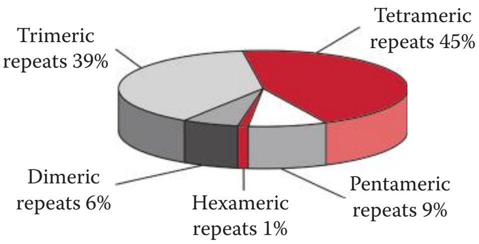

Figure 21.4 Human Y-STRs with different repeat unit length. About 400 Y-STRs have been identified and categorized according to repeat unit length. (Adapted from Hanson, E.K. and Ballantyne, J., *Leg Med (Tokyo)*, 8, 110, 2006.)

repeat unit lengths of identified Y-STRs have been analyzed. Among the 400 Y-STRs, 6% are dimeric repeats, 39% are trimeric, 45% are tetrameric, 9% are pentameric, and 1% are hexameric (Figure 21.4).

Fewer than half of the Y-STRs have been characterized. Some loci are polymorphic and are useful for forensic applications and developing new Y-STR multiplex systems. Since homologous recombination does not occur on the majority of the Y chromosome, alleles of Y-STR loci are linked (inherited together); they are referred to as *haplotypes*. As a result, the discrimination power of Y-STRs is much lower than that of autosomal STRs. The most commonly used Y-STR loci for forensic testing are described below.

21.1.2.1 Core Y-STR Loci

In 1997, the *European minimal haplotype* locus set, also known as the minimal haplotype loci, was recommended by the International Y-STR User Group for forensic applications (Table 21.1; Figure 21.5). This haplotype set includes a core set of nine Y-STR loci: DYS19, DYS385a and b, DYS389I, DYS389II, DYS390, DYS391, DYS392, and DYS393. In 2003, two additional loci were recommended by the Scientific Working Group for DNA Analysis Methods (SWGDAM) for forensic DNA analysis. The SWGDAM loci include the European minimal haplotype loci plus two additional loci: DYS438 and DYS439 (Table 21.1).

The application Y-STR for forensic casework has been expanded with additional Y-STR markers. The use of Y-STR loci has been facilitated by commercially available PCR amplification

Table 21.1 Common Y-STR Core Loci

Locus	EMH	US Haplotype Loci	Repeat Motif
DYS19	☑	☑	TAGA
DYS385a/b	☑	☑	GAAA
DYS389 I	☑	☑	TCTA
DYS389 II	☑	☑	[TCTG] [TCTA]
DYS390	☑	☑	[TCTG] [TCTA]
DYS391	☑	☑	TCTA
DYS392	☑	☑	TAT
DYS393	☑	☑	AGAT
DYS438		☑	TTTTC
DYS439		☑	GATA

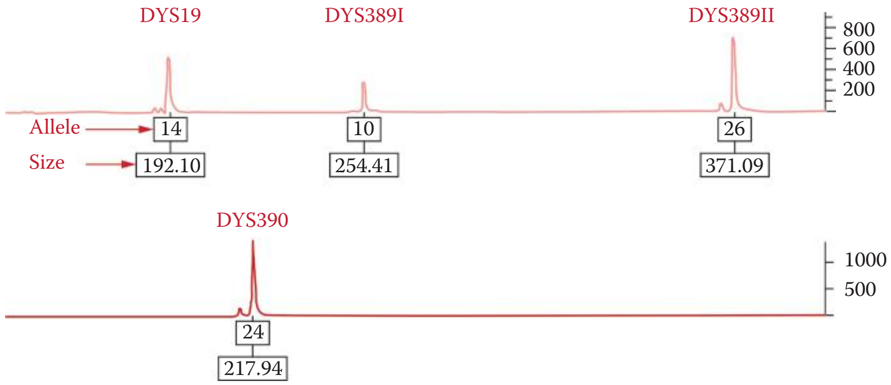

Figure 21.5 Electropherogram of Y-STR profile using an early generation of multiplex of four loci. The genotype of the DNA profile is shown (DYS19: 14. DYS389I: 10. DYS389II: 26. DYS390: 24). (© Richard C. Li.)

kits in multiplex Y-STR systems. To improve discriminating power, multiplex systems including new Y-STR loci are desired. Many new Y-STR loci are being characterized for developing new multiplex systems. Commercially available kits with more Y-STR loci are now available and have been validated for forensic use (Table 21.2; Figures 21.6 and 21.7). Some of the additional Y-STR loci are highly discriminating, allowing for further distinction between unrelated male individuals. Additionally, Y-STR loci, such as DYS570 and DYS576, with high mutation rates (see rapidly mutating Y-STR loci; Section 21.1.2.3) are included, which are useful for the discrimination of related individuals.

21.1.2.2 Multilocal Y-STR Loci

DYS385 and DYS389 are *multilocal Y-STR loci* (*MLL*). The MLL designation refers to the presence of a particular STR at more than one site on the Y chromosome due to duplication. To date, about 50 such MLL Y-STRs have been identified. Further MLL subdivisions are designated bilocal, trilocal, and so on. DYS385 and DYS389 are bilocal.

The DYS385 locus has two inverted duplicated clusters and is separated by a 4×10^4 bp interstitial region (Figure 21.8). It can be amplified by a single set of primers. One allele is observed if the duplicates are the same length. If the duplicated clusters have different lengths, they can generate two different alleles when amplified. The smaller allele is designated "a" and the larger allele is designated "b." Moreover, the DYS389 locus has two duplicated clusters with the same orientation (Figure 21.9). In a single set of PCR primers, there are two binding sites for the same forward primer at each 5′ flanking sequence of the core repeat region of DYS389. These binding sites between DYS389I and DYS389II are about 120 bp apart. Therefore, two amplicons are produced. DYS389I is designated for the smaller allele, and DYS389II is designated for the larger allele.

21.1.2.3 Rapidly Mutating Y-STR

Current Y-STR loci implemented in forensic casework have adequate resolution of males from different patrilineages. However, most Y-STR sets have limited abilities to differentiate related males who belong to the same patrilineage. Thus, current forensic Y-STR profiling is not able to exclude patrilineal relatives of the suspect. Recently, rapidly mutating Y-STR (RM Y-STR) loci have been identified and characterized. The mutation rates of RM Y-STR are above 10^{-2}, which is considerably higher than the average mutation rates of Y-STRs. The average mutation rate for the majority of the Y-STRs characterized, including the core Y-STR loci currently used in forensic casework, is approximately 10^{-4}–10^{-3} per generation. Due to the high mutation rates, RM Y-STRs can improve patrilineage resolution. For use in forensic casework, the RM Y-STR loci have potential abilities to differentiate both paternally related and unrelated males.

Table 21.2 Y-STR Loci Covered by Representative Commercial Kits

	Loci	Yfiler[a]	PowerPlexY23[b]
Core loci	DYS19	☑	☑
	DYS385a/b	☑	☑
	DYS389 I	☑	☑
	DYS389 II	☑	☑
	DYS390	☑	☑
	DYS391	☑	☑
	DYS392	☑	☑
	DYS393	☑	☑
	DYS438	☑	☑
	DYS439	☑	☑
Additional loci	DYS437	☑	☑
	DYS448	☑	☑
	DYS456	☑	☑
	DYS458	☑	☑
	DYS481		☑
	DYS533		☑
	DYS549		☑
	DYS570		☑
	DYS576		☑
	DYS635	☑	☑
	DYS643		☑
	Y-GATA-H4	☑	☑

[a] AmpFlSTR® Yfiler® PCR Amplification Kit (Applied Biosystems).

[b] PowerPlex® Y23 System (Promega).

21.2 X Chromosome Haplotyping

X-chromosomal STR (X-STR) profiling is a useful tool in kinship testing in forensic investigations. For example, males under usual circumstances have only one X chromosome; thus males are hemizygous for the X-STR loci on the X chromosome. Homologous recombination between the X and Y chromosomes is restricted to the homologous PARs (Figure 21.2). The paternal X chromosome is inherited by daughters as haplotypes. Thus, father–daughter kinship is easier to determine using X-STRs than autosomal STRs. In females, there are two copies of the X chromosomes. Homologous recombination can occur between two X chromosomes in the mother–child transmission. Although it is possible to determine mother–child kinship using X-STR analysis, the level of certainty is less than that of father–daughter kinship analysis. Nevertheless, sharing of rare X-STR haplotypes can strengthen an indication of kinship. The most useful

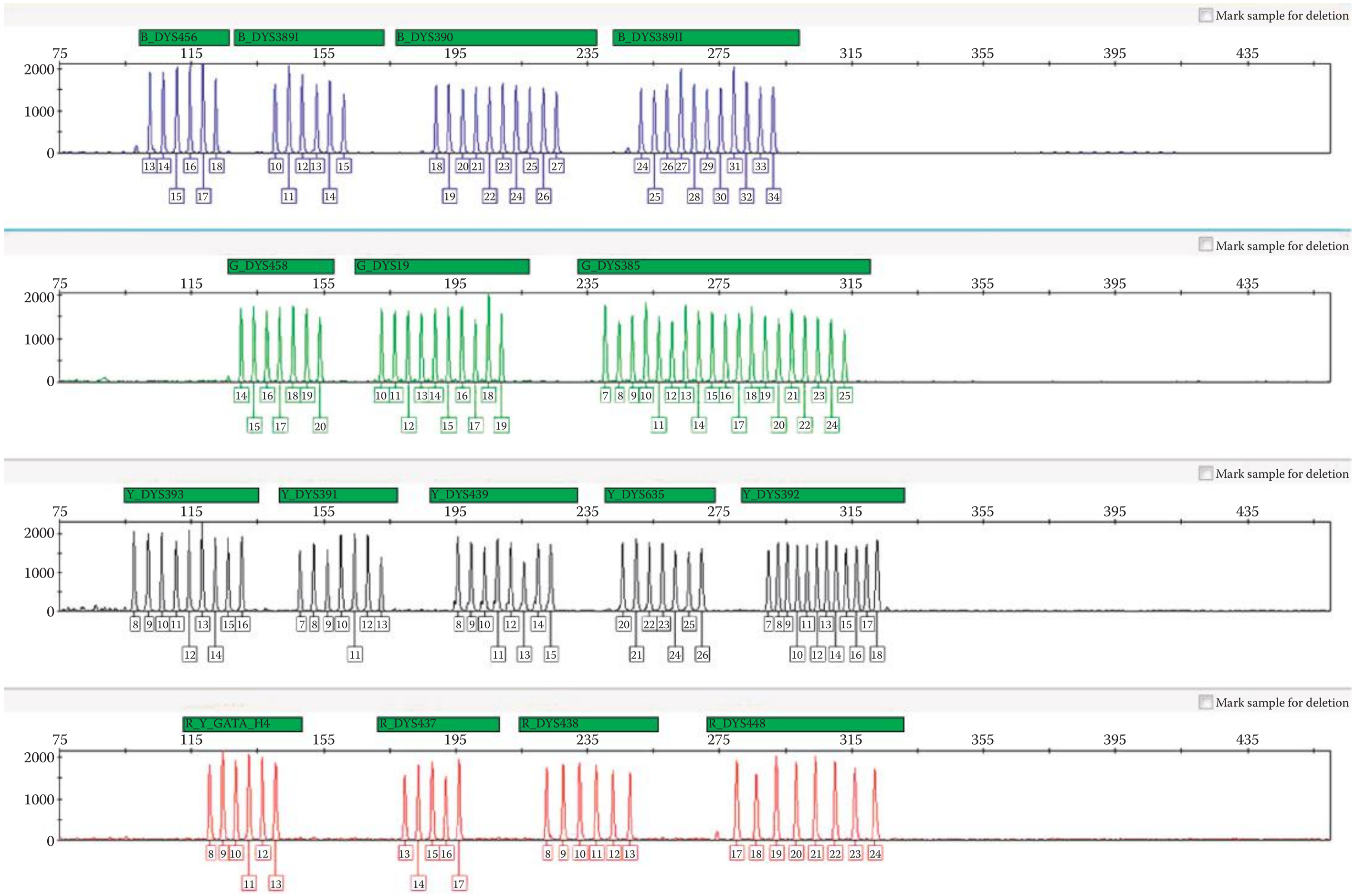

Figure 21.6 Electropherogram of the allelic ladder of AmpFISTR® Yfiler® PCR Amplification Kit (Applied Biosystems). DYS19, DYS385 a/b, DYS389 I, DYS389 II, DYS390, DYS391, DYS392, DYS393, DYS437, DYS438, DYS439, DYS448, DYS456, DYS458, DYS635, and Y-GATA-H4 loci are shown. (© Richard C. Li.)

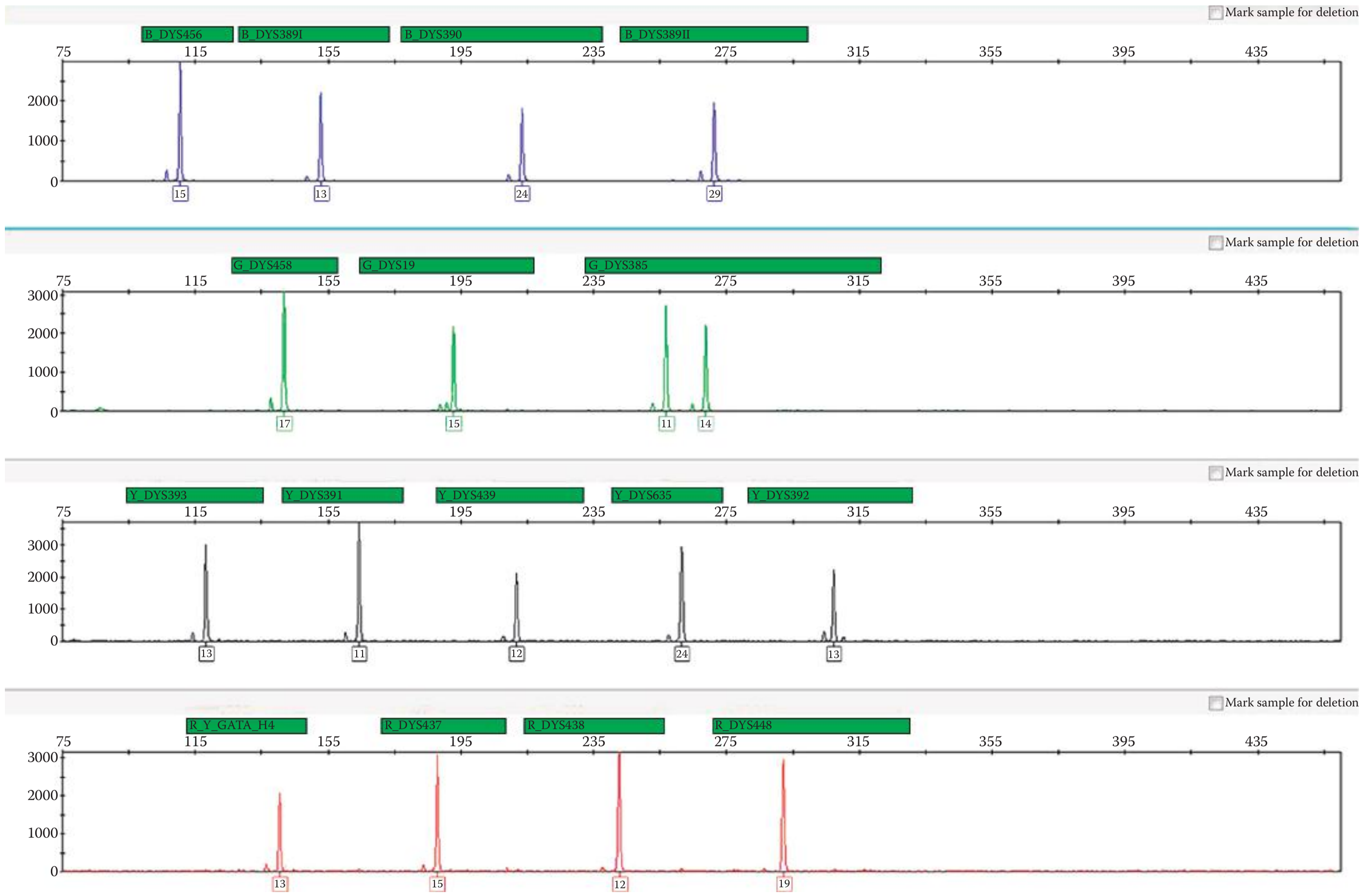

Figure 21.7 Individual Y-STR profile (AmpFlSTR® Yfiler® PCR Amplification Kit). The genotype of the DNA profile is shown. DYS19: 15. DYS385 a/b: 11, 14. DYS389 I: 13. DYS389 II: 29. DYS390: 24. DYS391: 11. DYS392: 13. DYS393: 13. DYS437: 15. DYS438: 12. DYS439: 12. DYS448: 19. DYS456: 15. DYS458: 17. DYS635: 24.Y-GATA-H4: 13. (© Richard C. Li.)

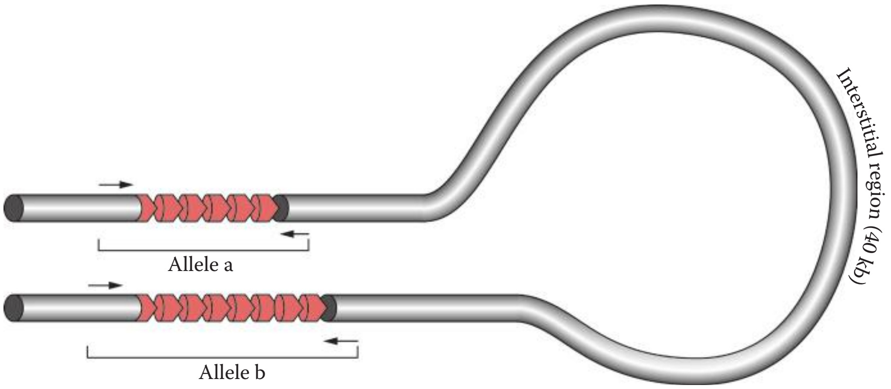

Figure 21.8 MLL Y-STR locus DYS385. At the DYS385 locus, note the two inverted duplicated regions of the Y chromosome with an interstitial region of 40 kilobases (kb). These inverted regions can be amplified with a single pair of primers (indicated by arrows) in one PCR reaction. The allele designations are described in the text. (© Richard C. Li.)

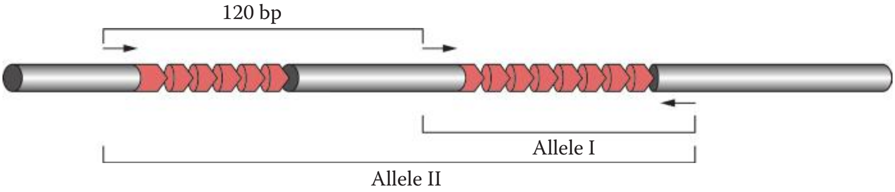

Figure 21.9 MLL Y-STR locus DYS389. At the DYS389 locus, note the two duplicated regions of the Y chromosome with the same orientation. These duplicated regions can be amplified with a single pair of primers (indicated by arrows) in one PCR reaction. The allele designations are described in the text. (© Richard C. Li.)

application of X-STR profiling, however, is in situations where autosomal STR profiling fails to determine kinship with high levels of certainty, and where Y-chromosomal or mitochondrial DNA profiling results are inconclusive.

Many X-STR loci have been identified spanning the entire human X chromosome. Increasing the number of X-STR loci to be analyzed in the inherited region would increase the degree of certainty in determining kinship. However, it is necessary to take into consideration the linkage between X-STR loci on the X chromosome. Based on Gregor Mendel's first law, the different alleles of two loci segregate independently. This is definitely true for loci localized on different chromosomes. The segregation can also be observed for loci located on the same chromosome, including the X chromosome, due to homologous recombination and meiotic crossing-over. Generally speaking, the farther apart the two loci are on the chromosome in physical distance, the more likely those loci are to segregate independently. When two loci are very close to each other, the alleles of the two loci are inherited together as a haplotype. Therefore, including additional closely linked STR loci does not necessarily improve the discrimination power in kinship analysis.

Homologous recombination events at different regions of the genome may occur with different probabilities. Thus, the tightness of linkage between two X-STR loci cannot be accurately measured based on the physical distance. In order to determine how closely two different loci are linked, the *recombination fraction* (or recombination frequency) can be used, which is the percentage of recombinants resulting from chromosomal crossover between two loci during meiosis among all the offspring. The recombination fraction reflects how often the loci are inherited together or how often they are separated. The recombination fraction ranges from 0% to 50%. The minimum recombination fraction is 0, indicating perfect linkage (no recombinants). The maximum is 50%, meaning complete independence of the two loci (they are actually located on different chromosomes or on the same chromosome with great distance between them).

Multiplex X-STR assays have also been developed. Commonly used X-STR loci can be grouped into linkage groups. Each linkage group is presumably transmitted independently from one another. These loosely linked loci can be treated as if they were located on different chromosomes. The distribution of alleles at these X-STR loci should be in accordance with the Hardy–Weinberg principle (Chapter 25). Within each linkage group, the occurrence of recombination is negligible. Thus, loci within groups are generally considered as closely linked and are thus treated as a haplotype.

21.3 Sex Typing for Gender Identification

Sex typing of a biological sample is useful in forensic investigation. For example, the application of sex typing facilitates the identification of the victim and the offender's DNA evidence in sexual assault cases and the remains of victims in mass disasters or missing persons investigations. One commonly used sex-typing marker is the amelogenin (*AMEL*) locus. The use of multiplex PCR systems with an additional amelogenin marker, a non-STR marker, leads to potential gender determination.

21.3.1 Amelogenin Locus

This region encodes extracellular matrix proteins involved in tooth enamel formation (Table 21.3). Mutations in the *AMEL* gene can lead to an enamel defect known as amelogenesis imperfecta. Amelogenesis imperfecta is a disorder that causes abnormal formation of tooth enamel in both primary and permanent teeth. The formed tooth enamel is soft and thin; therefore it is easily damaged. The *AMEL* locus has two homologous genes: *AMELX* (Xp22.2) is located on the human X chromosome (Figure 21.10) and *AMELY* (Yp11.2) is located on the human Y chromosome (Figure 21.11). Although the genes constitute a homologous pair, they differ in size and sequence. The coding sequence of the *AMELX* gene has a size of 2872 bp and the *AMELY* gene has a size of 3272 bp in length.

The most commonly used sex-typing method at the *AMEL* locus is the detection of a 6 bp deletion at intron 3 of *AMELX* (Figures 21.12 and 21.13). This deletion is not present in *AMELY*. Sex typing can be performed using primers specifically amplifying the region of the *AMEL* locus. Primer sets were developed to amplify both alleles in a single PCR. The two most commonly

Table 21.3 Sex-Typing Makers and Homologous Genes on the Human X and Y Chromosomes

Sex-Typing Markers					
X Chromosome			Y Chromosome		
Gene Symbol	Chromosomal Location	Distance from Xpter (Mb)	Gene Symbol	Chromosomal Location	Distance from Ypter (Mb)
AMELX	Xp22.2	11.3	*AMELY*	Yp11.2	6.7
DXYS156	Xq21.31	88.9	DXYS156	Yp11.2	3.2
SOX3	Xq27.1	139.6	*SRY*	Yp11.31	2.7
STS	Xp22.31	7.1–7.3	*STSP1*	Yq11.221	17.7
TSPYL2	Xp11.2	53.1	*TSPY1*	Yp11.2	9.2–9.3

Source: Ensembl Homo sapiens version 75.37 (GRCh37). Mb, megabase.

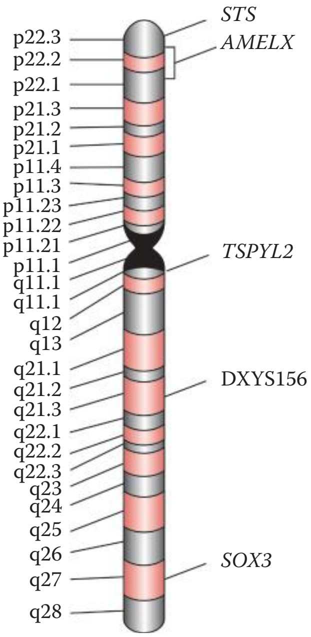
p22.3
p22.2
p22.1
p21.3
p21.2
p21.1
p11.4
p11.3
p11.23
p11.22
p11.21
p11.1
q11.1
q11.1
q12
q13
q21.1
q21.2
q21.3
q22.1
q22.2
q22.3
q23
q24
q25
q26
q27
q28
STS
AMELX
TSPYL2
DXYS156
SOX3

Figure 21.10 Cytogenetic map of the human X chromosome and sex-typing loci shown with physical positions (Mb = megabases). Cytogenetic patterns with alternating dark and light bands are shown. (© Richard C. Li.)

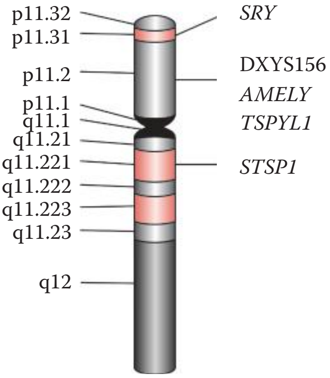
p11.32
p11.31
p11.2
p11.1
q11.1
q11.21
q11.221
q11.222
q11.223
q11.23
q12
SRY
DXYS156
AMELY
TSPYL1
STSP1

Figure 21.11 Cytogenetic map of the human Y chromosome and sex-typing loci shown with physical positions (Mb = megabases). Cytogenetic patterns with alternating dark and light bands are shown. (© Richard C. Li.)

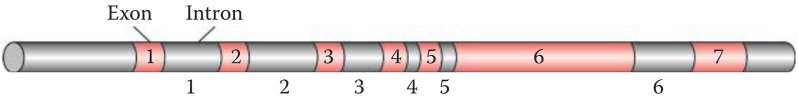
Exon
Intron
1
2
3
4
5
6
7
1
2
3
4
5
6

Figure 21.12 Structure of human *AMELY* gene. Exons 1 through 7 and introns 1 through 6 are numbered. (© Richard C. Li.)

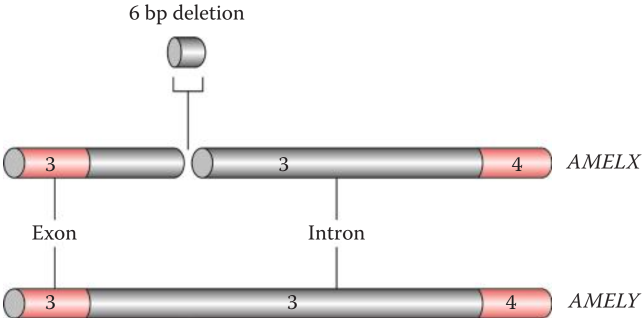

Figure 21.13 Sex typing using *AMEL* markers. A 6-bp deletion in intron 3 is present in *AMELX* but not in *AMELY* and can be resolved using electrophoresis as described in the text. (© Richard C. Li.)

used amelogenin primer sets generate amplicons of 106 and 112 bp or 212 and 218 bp for *AMELX* and *AMELY* loci, respectively. The amplicons generated from *AMELX* and *AMELY* are separated by electrophoresis. The observation of the *AMELX* fragment alone indicates a female, whereas the observation of both *AMELX* and *AMELY* fragments indicates a male (Figure 20.8). Nevertheless, DNA from primates and some rudiments can be amplified as well, but the amplicon sizes vary. The *AMEL* locus has been coamplified with other markers to provide a combined sex and identity test. Such combined tests have been used in historical D1S80 AFLP profiling (Chapter 19) and various current STR multiplex analyses.

Cases of *AMELY* null mutations have been reported where only the *AMELX* fragment is detected in *AMELY* null males. Many of them are phenotypically normal but present the *AMELX* sex types of females. Various interstitial deletions at the Y chromosome short arm and point mutations within the primer-binding sites have been identified as the possible cause of some *AMELY* null sex typing. The frequency of *AMELY* null males is rare, but is higher in Sri Lanka and India. However, the mutations may lead to incorrect identification of sex if the mutations occurred in the DNA evidence of criminal investigations such as sexual assaults or in the identification of human remains in mass disasters. In the case of a female individual, an *AMELX* mutation, which is rare, usually affects one copy of *AMELX*; however, the wild-type copy of the *AMELX* is detected. Thus, the *AMELX* mutation is less problematic in females than the *AMELY* mutation in sex typing in males.

21.3.2 Other Loci

To solve the incorrect identification problem with null *AMEL* mutations, additional candidate genetic markers are used in combination with *AMEL* analysis (Table 21.3). One useful marker is the sex-determining region Y (*SRY*) gene located on the Yp11.31 of the Y chromosome. *SRY* encodes a transcription factor that plays a role in the regulation of sex determination toward male development. The *SRY* protein contains a DNA-binding domain known as the HMG box. *SOX3*, an *SRY*-related HMG box-containing gene, has been identified at Xq27.1 of the X chromosome, which shares sequence homology with *SRY*. *SRY*-specific amplification is achieved using *SRY*-specific primers.

Another marker is the *TSPY* locus located on Yp11.2 of the Y chromosome. The *TSPY* locus encodes the testis-specific protein Y-encoded gene that is only expressed in the testis and may play a role in spermatogenesis. The *TSPY* structural gene is approximately 20 kb in length, consisting of 6 exons and 5 introns. The *TSPY* gene has multiple copies. A single Y chromosome contains several dozen copies of *TSPY* genes that are organized as a tandem array. The *TSPY* gene cluster shows copy number variation (CNV) between individuals in a population ranging from 23 to 64 copies. *DYS14* is a marker utilized for the characterization of the *TSPY* locus. The

DYS14 locus includes the partial sequence of the first exon and intron of the *TSPY* gene and shares approximately 98% sequence homology with other members of the *TSPY* gene cluster.

A *TSPY*-like (*TSPYL*) gene has been identified on the short arm of the X chromosome and is designated as *TSPYL2*. *TSPYL2* is a single-copy gene per X chromosome and is 6.3 kb in length, consisting of 7 exons and 6 introns. *TSPYL2* shares homology with *TSPY*. Additionally, several *TSPYL* genes have been identified on the autosomes. Primers are designed to amplify *TSPY* only and not amplify *TSPYL2* and other *TSPYL* gene sequences. The sensitivity of detecting *TSPY*, due to multiple copies, can be considerably higher than any single copy genetic maker such as *SRY*.

Furthermore, the DXYS156 locus, located at the pseudoautosomal region of both X and Y chromosomes, is another candidate marker used for sex typing. DXYS156 is a polymorphic pentanucleotide STR. The DXYS156 Y alleles have an additional adenine insertion in the repeat units of STR. Thus, the DXYS156 Y alleles can be distinguished from the DXYS156 X alleles because of the insertion. Additionally, the DXYS156 alleles are ethnically distributed. The DXYS156 profiling may potentially indicate the ethnic origin of an individual as an investigative lead.

Moreover, the steroid sulfatase (*STS*) gene encodes an enzyme that catalyzes the conversion of sulfated steroid precursors to biologically active steroids such as estrogens and androgens. The *STS* gene is located on the distal part of the short arm of the X chromosome within Xp22.31. The *STS* gene is 146 kb in length, consisting of 10 exons and 9 introns. The size of exons is between 120 and 160 bp long. However, the sizes of introns vary greatly, ranging from 102 bp to 35 kb. The entire coding sequence of the *STS* gene is 1542 bp in length. Deletions and point mutations of the *STS* gene have been associated with X-linked ichthyosis, a skin disease that affects males. There is an *STS* pseudogene, 100 kb in length, on the long arm of the Y chromosome known as *STSP1*. Although *STSP1* shares some sequence homologies with the *STS* gene, the pseudogene does not encode a functional gene. Primer sets are designed to amplify the target sequences within the first intron (35 kb in length) of the *STS* gene and its homologous *STSP1* pseudogene sequence. Although the homology of these target sequences of the *STS* gene and *STSP1* pseudogene is approximately 80%, amplicons with two different sizes are produced to identify *STS* and *STSP1* alleles for sex typing.

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22

Single Nucleotide Polymorphism Profiling

22.1 Basic Characteristics of SNPs

Human genomes contain sequence polymorphisms, which are the variations in nucleotide sequences among individuals. One type of sequence polymorphism is called *single-nucleotide polymorphism* (*SNP*). An SNP constitutes a single-base-pair change originating from a spontaneous mutation that can be a base substitution, insertion, or deletion at a single site. An estimated 10 million SNPs may exist in the human genome, and among them, over a million SNPs have been identified. Thus, SNPs are the most frequent form of DNA polymorphism observed in humans. Most SNPs appear in noncoding regions and some SNPs are found in coding regions of genes (Figure 22.1).

The vast majority of SNPs are biallelic, although very rare triallelic and tetraallelic SNPs also exist. If an SNP originating from a spontaneous mutation occurs in the germ line, it can be inherited by offspring and can spread in the human population. As a result, both the wild type (the typical form of an allele occurring in nature) and a mutant allele are produced. This type of SNP is referred to as a biallelic SNP. Subsequently, a third mutation, a very rare event, may occur at the same nucleotide site. This SNP has a wild type and two different mutant alleles, which results in a triallelic SNP. It is also possible that a triallelic SNP is created by introducing two of the mutations simultaneously at a single site, which is also a very rare event.

Generally speaking, there are a number of advantages to utilizing SNP loci as markers for forensic applications. First, SNPs are abundant within the human genome; therefore, a sufficient number of SNP loci that are suitable for human identification can be selected. Second, in SNP analysis, amplified fragments (amplicons) are usually 50–100 base pairs in length and are smaller than that in short tandem repeat (STR) analysis (Chapter 20). Therefore, SNP profiling can be more useful than STR for analyzing degraded DNA samples in which genomic DNA is fragmented (Section 20.5.1). Third, SNP loci have lower mutation rates than STRs and are, therefore, useful for specialized human identification such as paternity testing. Lastly, it is possible to achieve high-throughput SNP analysis by utilizing multiplex SNP assays, which are amendable for automation.

The application of SNPs for forensic DNA analysis also has some disadvantages, in that SNP loci are not as polymorphic as STR loci. It is estimated that the analysis of 50–60 SNP loci is needed to achieve a similar level of population match probability (P_m—the lower the P_m, the less likely a match occurs between two randomly chosen individuals; see Chapter 25) using 13

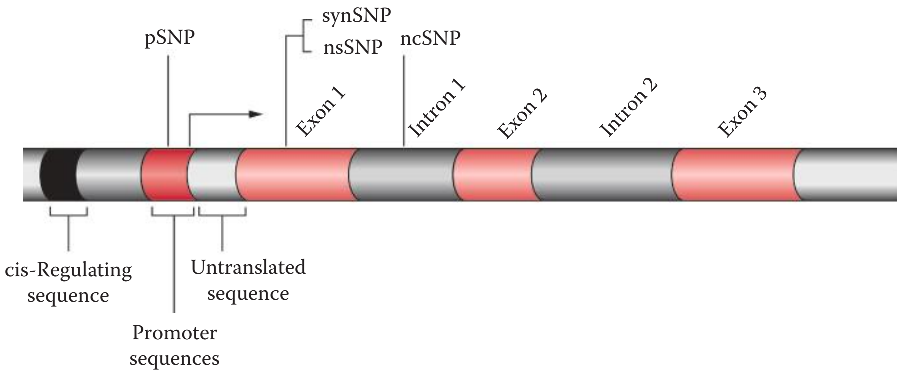

Figure 22.1 SNPs fall into several classes. Most reside in the noncoding regions of DNA and are designated as noncoding SNPs (ncSNPs). A subset of ncSNPs can also be found in introns. SNPs residing in exons are further divided into two types: The synonymous type (synSNP) is an exonic SNP that does not change the amino acid composition of the encoded polypeptide. Conversely, a nonsynonymous type (nsSNP) changes the encoded amino acid. SNPs in the promoter regions of the genome are known as promoter SNPs (pSNPs). Arrow: transcription start site. (© Richard C. Li.)

STR loci in CODIS. Moreover, most SNPs are biallelic; therefore, it is difficult to resolve mixed DNA profiles when a shared common allele exists in a mixture of more than one individual. Furthermore, most DNA databases contain STR profiles instead of SNP profiles, which means that it is not possible to carry out a database search for a matching SNP profile in cases where no suspect has yet been identified.

22.2 Forensic Applications of SNP Profiling

22.2.1 *HLA-DQA1* Locus

The first use of SNP-based profiling for forensic application involved sequence polymorphisms at the *HLA-DQA1* locus (formerly called the DQα locus). The *HLA-DQA1* gene is a member of the human leukocyte antigen (HLA) family, which contains a large number of genes involved in the immune response in humans. The *HLA-DQA1* locus is located within human HLA gene clusters on chromosome 6. The region tested for forensic use is highly polymorphic and is located at the second exon of the gene (Table 22.1).

22.2.1.1 DQα AmpliType and Polymarker Assays

The SNP profiling of the *HLA-DQA1* locus was carried out using the DQα AmpliType® kit. It was the first commercial kit, developed in the late 1980s by Cetus Corporation in Emeryville, CA. The *HLA-DQA1* panel can distinguish the following: alleles 1 (subtyped as 1.1, 1.2, or 1.3), 2, 3, and 4 (subtyped as 4.1 and 4.2/4.3, in which the 4.2 and 4.3 alleles are combined and cannot be distinguished). Therefore, a total of 28 possible genotypes from combinations of these alleles can be distinguished. Although the P_m of this SNP profiling is high (approximately 5×10^{-2}), it is useful as a preliminary test to quickly exclude suspects.

In addition to the *HLA-DQA1* locus, five additional loci—*LDLR, GYPA, HBGG,* D7S8, and *GC*—were utilized for forensic application in 1993 (Table 22.1). These loci were included in the second generation of the kit known as the AmpliType® PM PCR amplification and typing kit (also known as Polymarker), manufactured by Perkin-Elmer (Norwalk, CT). It consisted of one panel for the testing of *HLA-DQAl* and another panel for an additional five loci (Figure 22.2). Among these five additional loci, *LDLR, GYPA*, and D7S8 each have two alleles (designated

Table 22.1 Chromosomal Locations of SNP Loci Used in AmpliType® PM PCR Amplification and Typing Kit

Locus	Gene Product	Chromosome Location	Number of Alleles	Further Reading
HLA-DQA1	HLA-DQA1	6p21.3	7	Gyllensten and Erlich (1988)
LDLR	Low-density lipoprotein receptor	19p 13.1-13.3	2	Yamamoto et al. (1984)
GYPA	Glycophorin A	4q28-31	2	Siebert and Fukuda (1987)
HBGG	Hemoglobin G gammaglobin	11 p 15.5	3	Slightom et al. (1980)
D7S8	Anonymous	7q22-31.1	2	Horn et al. (1990)
GC	Group-specific component	4q11-13	3	Yang et al. (1985)

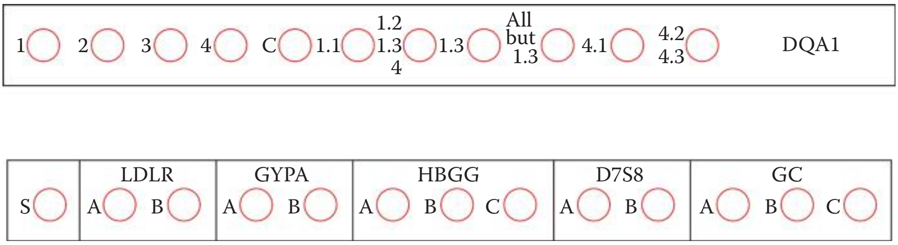

Figure 22.2 Panels of immobilized probes in the Polymarker kit. Top: *HLA-DQA1*. Bottom: additional five loci (*LDLR, GYPA, HBGG*, D7S8, and *GC*). C and S represent threshold control dots. (© Richard C. Li.)

A and B), while *HBGG* and *GC* each have three alleles (A, B, and C). As a result, the P_m of the Polymarker panels decreased to 10^{-4}.

The DNA profiles of the Polymarker system have been accepted in US courts. The Polymarker system has a number of advantages, particularly compared to variable number tandem repeat analysis (VNTR; see Chapter 19). First, the Polymarker system is a PCR-based method and is capable of analyzing a small amount of DNA sample (approximately 2 ng per analysis). Therefore, it is more sensitive than the method used in VNTR analysis. Second, the Polymarker system is an SNP assay with short amplicon sizes and, therefore, can analyze degraded DNA samples, which is not possible in VNTR analysis. Third, the Polymarker system is more rapid and less laborious than VNTR analysis. Lastly, the amplicon sizes of alleles at a given locus have identical lengths and, therefore, this assay does not exhibit preferential amplification as in amplified fragment length polymorphism (Chapter 19). However, the Polymarker system has its limitations compared to VNTR analysis. For example, compared to the VNTR analysis, the P_m of the Polymarker system is high, resulting in poor discrimination power in the comparison of two DNA profiles. Therefore, the Polymarker system is merely useful for excluding a suspect. Moreover, the SNP loci utilized in the Polymarker system are less polymorphic than VNTR loci. The limited number of alleles per SNP locus makes identifying the components of mixtures more difficult than with VNTR analysis in situations when contributors of a mixture sample share common alleles. For these reasons, the Polymarker system was replaced by STR profiling in the late 1990s.

22.2.1.2 Allele-Specific Oligonucleotide Hybridization

Both DQα AmpliType® and Polymarker kits utilize the *allele-specific oligonucleotide (ASO) hybridization* technique. This technique analyzes single-nucleotide variations, such as SNPs, at a given locus. It is based on the principle that ASO probes, usually 14–17 bases in length, hybridize to their complementary DNA sequences to distinguish known polymorphic alleles. ASO probes for multiple alleles at several loci can be arranged on the same panel to establish the presence or absence of specific alleles in PCR-amplified fragments of a DNA sample (Figure 22.3). Thus, the genotypes can be determined.

In the DQα AmpliType® and Polymarker kits, the oligonucleotides representing different alleles are immobilized to a solid matrix consisting of nylon membrane strips. Each immobilized probe at a particular site on the membrane is utilized to detect corresponding SNPs. Since the probe rather than the target DNA (as with regular blot format; see Chapter 9) is immobilized to the solid phase, the configuration used here is known as a *reverse blot* format.

The regions of the DNA in question are amplified by PCR. One of each pair of the primers is conjugated with biotin at the 5′ end (Figure 22.4). Thus, the amplicons are biotinylated for purposes of detection. This kit established multiplexing of a six-locus system, allowing simultaneous amplification of the *HLA-DQA1* locus along with *LDLR, GYPA, HBGG*, D7S8, and *GC* in

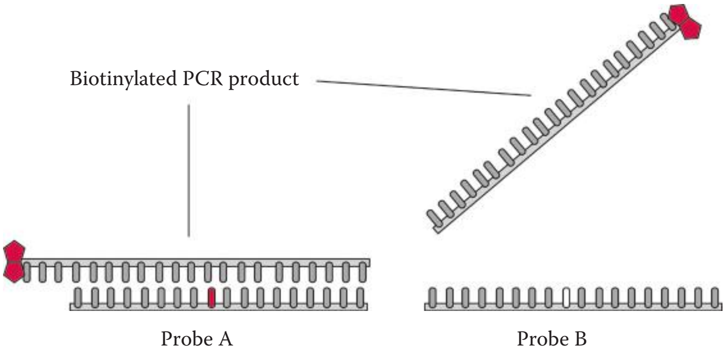

Figure 22.3 Hybridization with ASO. Two probes are incubated with the target DNA containing the SNP. Only the perfectly matched probe–target DNA can hybridize under optimal conditions.

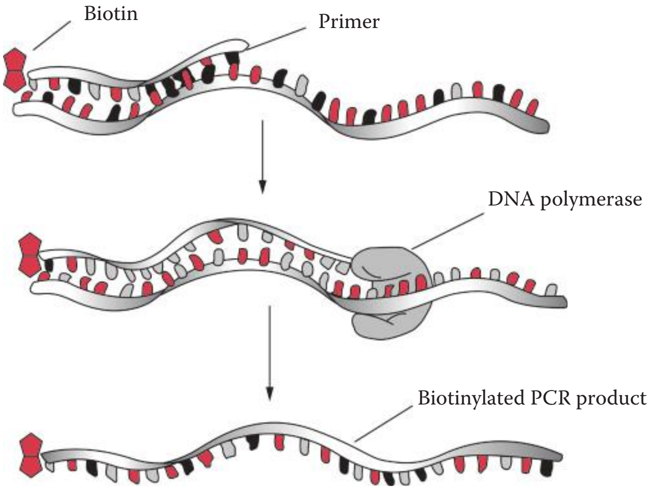

Figure 22.4 Amplification of DNA using biotinylated primers. The biotin is conjugated at the 5′ end of the primer. The amplified products are biotinylated. (© Richard C. Li.)

a single reaction for each sample. Following the denaturation of the PCR product to separate the two complementary DNA strands of the amplicons, the biotinylated strands are hybridized to the immobilized probes. Hybridization and washing conditions are established to ensure proper hybridization of the ASO probe and its target sequence. Unbound amplicons are washed away.

The presence of a PCR product bound to a specific probe can be detected by a colorimetric detection system (Figure 22.5). Since the amplicons are biotinylated, a horseradish peroxidase–conjugated streptavidin complex is utilized to bind to the biotinylated amplicons. The horseradish peroxidase then catalyzes the oxidation reaction of the colorless substrate, tetramethyl benzidine (TMB), into a blue precipitate at a designated location on the membrane strip, allowing the genotype of the sample to be determined (Figures 22.6 and 22.7).

The kit uses a threshold control (C dot in the *HLA-DQA1* panel and S dot in the panel of the other five loci) to distinguish between signal and background noise and to determine whether a

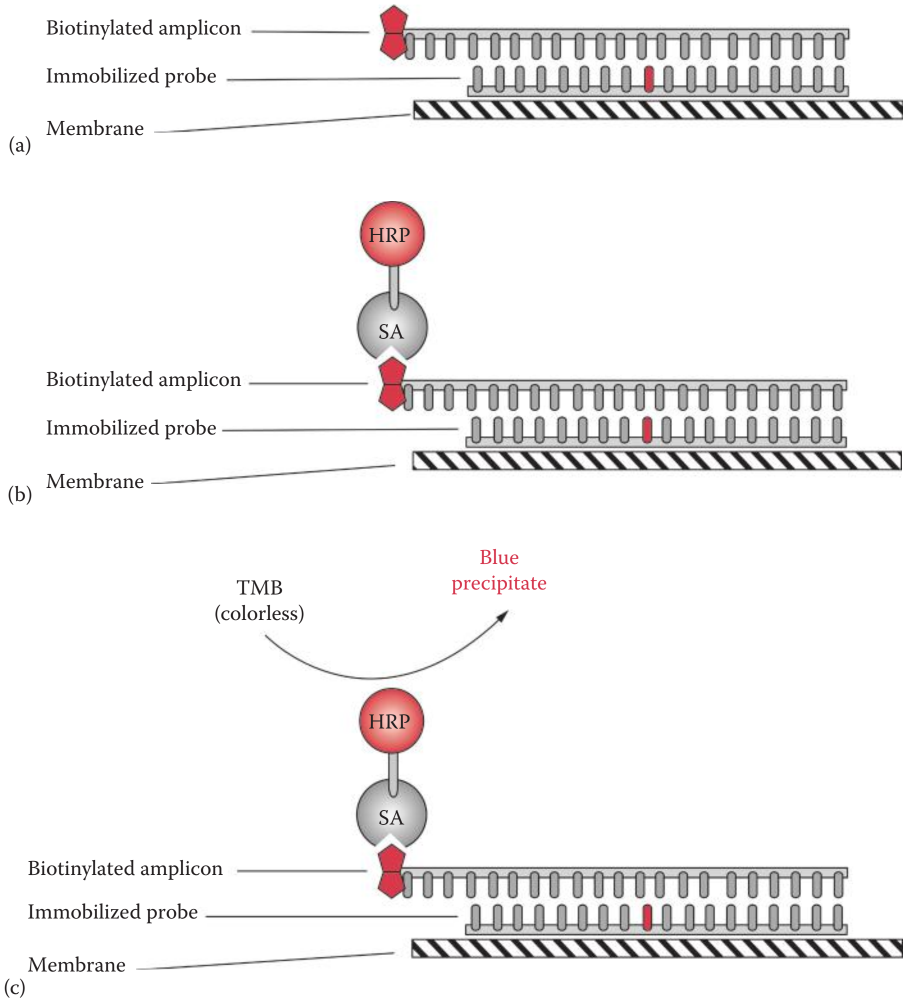
Biotinylated amplicon
Immobilized probe
Membrane
(a)
HRP
SA
Biotinylated amplicon
Immobilized probe
Membrane
(b)
TMB
(colorless)
Blue
precipitate
HRP
SA
Biotinylated amplicon
Immobilized probe
Membrane
(c)

Figure 22.5 Reverse blot assay. (a) The probe is immobilized onto a solid-phase membrane and hybridized with a biotinylated PCR product having the target sequence. (b) The detection of hybridization is carried out by streptavidin (SA) and horseradish peroxidase (HRP) conjugate. (c) Colorimetric reaction is catalyzed by HRP using TMB as a substrate. (© Richard C. Li.)

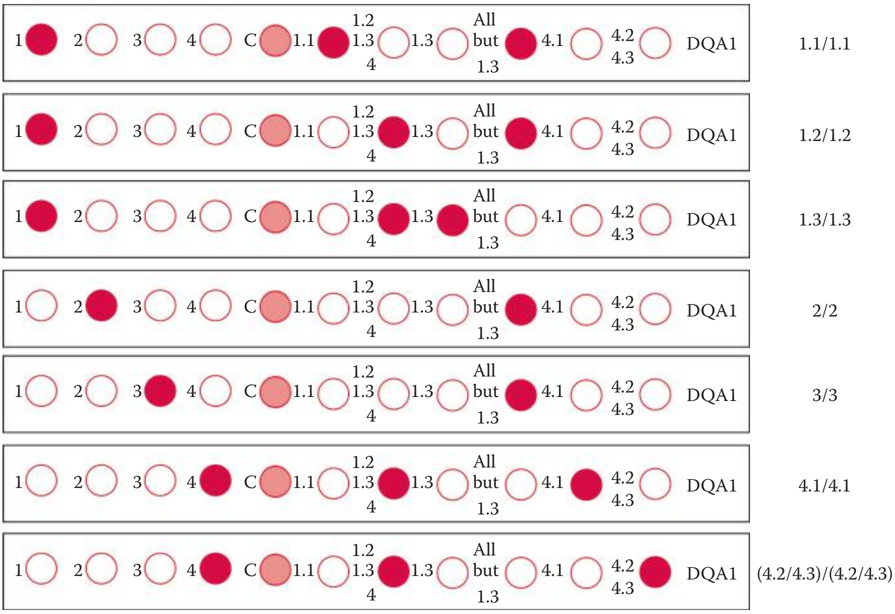
1 2 3 4 C 1.1 1.2 1.3 4 1.3 All but 1.3 4.1 4.2 4.3 DQA1
1.1/1.1
1.2/1.2
1.3/1.3
2/2
3/3
4.1/4.1
(4.2/4.3)/(4.2/4.3)

Figure 22.6 DNA typing of homozygous alleles at the *HLA-DQA1* locus using the reverse blot assay (Polymarker kit). The genotype of each sample is noted on the right. (© Richard C. Li.)

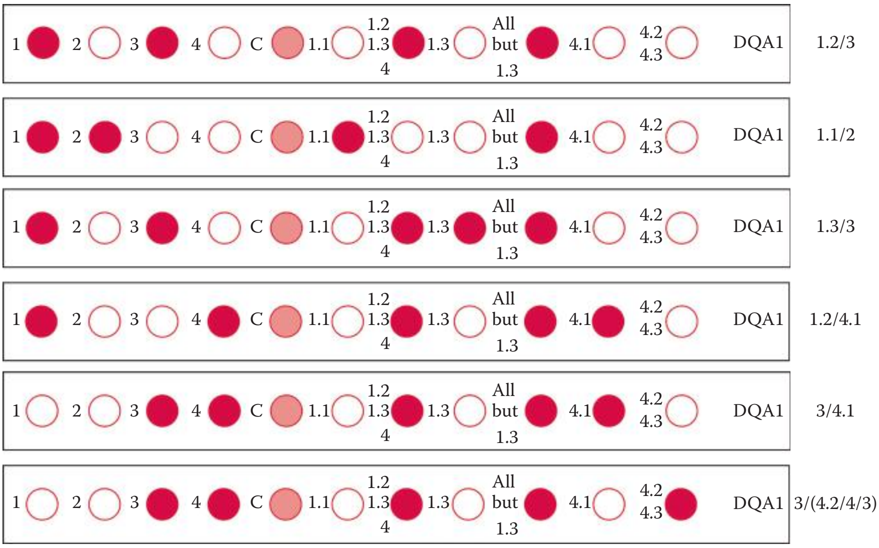
1 2 3 4 C 1.1 1.2 1.3 4 1.3 All but 1.3 4.1 4.2 4.3 DQA1
1.2/3
1.1/2
1.3/3
1.2/4.1
3/4.1
3/(4.2/4/3)

Figure 22.7 DNA typing of heterozygous alleles at the *HLA-DQA1* locus using the reverse blot assay (Polymarker kit). The representative genotypes of the samples are noted on the right. (© Richard C. Li.)

sufficient amount of DNA has been amplified to detect all the alleles present in a sample. If the signal intensities of allele dots are greater than or equal to the threshold control, the alleles are considered true. If the allele dots are less intense than the threshold control, they are considered inconclusive for the determination of full genotypes because an allele may not have been detected due to a low level of DNA template.

22.2.2 Current and Potential Applications of SNP Analysis

22.2.2.1 Application of SNP Analysis for Forensic Identification

The applications of SNP analysis for forensic human identification are summarized in Table 22.2. Autosomal SNP panels can be used for the most common types of forensic testing, including analysis of degraded DNA samples. The SNP panels for mitochondrial DNA (mtDNA) profiling are useful for identifying human remains by comparing the DNA profiles in question to those of potential relatives. This approach may serve as an alternative method to the DNA sequencing method of mtDNA analysis, which is time-consuming and laborious. SNP loci on the Y chromosome are also potentially useful markers for paternity testing because of low mutation rates. SNP loci such as ancestry informative markers (AIM) can be used to determine the ethnic origins of questioned samples to generate leads for investigations.

Table 22.2 Examples of Forensic Applications of SNP Profiling

Testing	Candidate SNP Loci	Application	Further Reading
Identity	Autosomal SNPs	Human identification	Kidd et al. (2006); Sanchez et al. (2006)
		Human identification via degraded DNA	Budowle (2004)
	mtDNA SNPs	Human identification	Grignani et al. (2006)
	Y chromosome SNPs	Paternity testing	Hammer et al. (2006)
Biogeographical origin	Ancestry informative markers (AIMs)	Ethnic group identification	Frudakis et al. (2003); Shriver and Kittles (2004)
Physical characteristics	*MC1R* (melanocortin 1 receptor gene)	Hair color identification (investigative lead)	Grimes et al. (2001)
	P (gene has role in pigmentation)	Eye color identification (investigative lead)	Rebbeck et al. (2002)
Pathology	*KCNH2* (cardiac potassium channel gene)	Determining cause of sudden death from cardiac arrhythmia long QT syndrome	Lunetta et al. (2002)
	SCN5A (encodes cardiac sodium channel gene)	Determining cause of sudden death from cardiac arrhythmia long QT syndrome	Burke et al. (2005)
Toxicology	*CYP2C19*, *CYP2D6*, *CYP3A4*, *CYP2E1* (drug metabolizing enzyme genes)	Investigation of drug overdose (including death)	Kupiec et al. (2006)

22.2.2.2 Potential Applications of SNPs for Phenotyping

One potential application of SNP analysis is in determining phenotypic information, also known as *phenotyping* (Table 22.2). The relevant SNP loci are usually *nonsynonymous SNPs* (*nsSNPs*); they reside in the exon and change the encoded amino acid, which leads to an altered phenotype. Phenotyping of a questioned sample can reveal physical characteristics of an individual, such as hair and eye color, to provide leads for investigations. A number of SNPs residing within the melanocortin 1 receptor gene (*MC1R*) are associated with red hair, fair skin, and freckles, while SNPs residing within the *P* gene, which play a role in pigmentation, are associated with eye color variations.

Phenotyping can also be employed in the area of forensic pathology. Cardiac arrhythmia long QT syndrome (LQTS) can cause sudden death. A number of LQTS-associated SNPs—for example, SNPs in *KCNH2* and *SCN5A* genes—have been shown to correlate to such deaths. Thus, these SNPs are potentially useful for investigating the causes of death. Finally, phenotyping also has applications in forensic toxicology. A number of SNPs in genes, such as *CYP2D6*, that are responsible for metabolizing drugs can serve as potential markers for postmortem investigations of drug-overdose cases.

22.3 SNP Techniques

Over the years, various techniques of SNP analysis have been developed and can be divided into several groups based on the mechanisms used: allele-specific hybridization, primer extension, oligonucleotide ligation, and invasive cleavage. In *allele-specific hybridization*, allele discrimination is based on an optimal condition allowing only the perfectly matched probe–target hybridization to form. *Primer extension* methods are based on the ability of DNA polymerase to incorporate specific deoxynucleotides (dNTPs) complementary to the sequence of the template DNA. *Allele-specific oligonucleotide ligation* is based on the condition that only the allelic probe perfectly matched to the target is ligated. In the *invasive cleavage* method, allelic discrimination is based on DNA sequence-specific cleavage by endonucleases. A number of detection methods can be utilized in SNP analysis, such as the measurements of fluorescence, luminescence, and molecular mass. Most assays are carried out in solutions or on solid matrices such as glass slides, chips, or beads. Table 22.3 summarizes the representative assays for SNP typing.

For decades, Sanger sequencing, using chain-termination chemistry, has been the standard method for DNA sequencing (Chapter 23). In recent years, *next-generation sequencing* (NGS), a rapidly developing technology, has had a profound impact on biology. Compared to Sanger sequencing, NGS is advantageous in that it can achieve substantially higher throughput, and at lower cost, than the Sanger method. For example, a human genome can now be sequenced in several days using NGS technologies. Although NGS is not yet widely utilized for forensic applications, it has great potential for forensic DNA analysis, particularly in SNP analysis.

22.3.1 Next-Generation Sequencing Technologies

NGS technologies have two categories of application: *de novo* sequencing and resequencing. In *de novo* genome sequencing, uncharacterized genomes or characterized genomes with substantial structural variations are sequenced. Sequence reads are assembled without any reference sequence. In *resequencing* applications, characterized genomes are sequenced. Sequence reads are assembled against an existing reference sequence to identify sequence polymorphisms. Thus, resequencing can potentially be used for forensic applications to detect polymorphisms associated with human identification. *Target resequencing* is a useful method of resequencing that can be utilized for forensic applications. Prior to sequencing, the genomic regions of interest from a DNA sample are selectively isolated through a method known as *enrichment*. Several target-enrichment strategies have been developed. PCR is the most widely used enrichment method.

Table 22.3 Techniques for SNP Assay

Basis of Technique	Representative Assay	Detection	Format	Notes	Further Reading
Allele-specific hybridization	Reverse Blot	Colorimetry	Membrane based	Useful for screen assay	Saiki et al. (1989)
	LightCycler® (Roche)	Fluorescence	Solution based	Applicable for automation; limited multiplexing capability	Lareu et al. (2001)
	TaqMan® (Applied Biosystems)	Fluorescence	Solution based	Applicable for automation; limited multiplexing capability	De la Vega et al. (2005)
	Molecular beacons	Fluorescence	Solution based	Applicable for automation; limited multiplexing capability	Tyagi et al. (1998)
	GeneChip® (Affymetrix)	Fluorescence	Chip based	Designed for genotyping large number of SNPs; exceeds forensic needs	Mei et al. (2000)
Primer extension	SNaPshot™ (Applied Biosystems)	Fluorescence	Solution based	Applicable for capillary electrophoresis and multiplexing	Sanchez et al. (2006)
	PinPoint (Applied Biosystems)	Mass spectrometry	Solution based	Multiplex capability lower than SNaPshot™	Haff and Smirnov (1997)
	Arrayed primer extension (APEX)	Fluorescence	Chip based	Low reproducibility	Pastinen et al. (1997)
	Pyrosequencing	Fluorescence	Solution based	May be applicable for analysis of mixed profiles; not applicable for automation; limited multiplexing capability	Ronaghi et al. (1998)
Allele-specific oligonucleotide ligation	SNPstream® UHT (Orchid-Gene Screen)	Fluorescence	Chip based	Developed for mass disaster cases	Bell et al. (2002)
	SNPlex™ (Applied Biosystems)	Fluorescence	Solution based	Applicable for multiplexing; requires higher amount of target DNA template than other PCR-based methods	De la Vega et al. (2005)
Invasive cleavage	Invader® (Third Wave Technology)	Fluorescence	Solution based	PCR not required; large amount of target DNA required	Lyamichev et al. (1999)

Source: Adapted from Sobrino, B., M. Brion, and A. Carracedo, SNPs in forensic genetics: a review on SNP typing methodologies. Forensic Sci Int, 2005. 154(2-3): p. 181–94.; Budowle, B., SNP typing strategies. Forensic Sci Int, 2004. 146 Suppl: p. S139–42.

The PCR-based approach is highly effective in targeting genomic regions that are small in size. Nevertheless, a typical NGS involves several major steps, including sample, library, and template DNA preparation; template amplification; sequencing and detection; and base calling; as well as data analysis (Figure 22.8).

22.3.2 DNA Samples, Sequencing Library, and Template Preparation

For most sequencing applications, micrograms of purified DNA are needed. This requirement is still a challenge for forensic casework applications where nanograms of DNA are often obtained. Human autosomal genome sequencing usually requires converting a DNA sample into a sequencing library. Two types of sequencing libraries are usually used: mate-pair libraries and fragment libraries. A mate-pair library is often used in *de novo* sequencing applications, while the fragment libraries can be used for resequencing and forensic applications. To construct a fragment library, a DNA sample is fragmented using mechanical methods such as sonication, nebulization, or shearing; endonuclease digestion; or a transposon-based method. Subsequently, sequencing adapters containing primer-binding sites for universal PCR primers are ligated to both ends of the DNA fragments. In resequencing applications, multiplex sequencing of pooled samples is often carried out, which can improve the efficiency and reduce the costs of sequencing. For multiplex sequencing, an index tag containing a bar code can be ligated to each DNA fragment to allow it to be identified after sequencing. Indexing can minimize the risk of sample mix-ups and contaminations during the sample preparation.

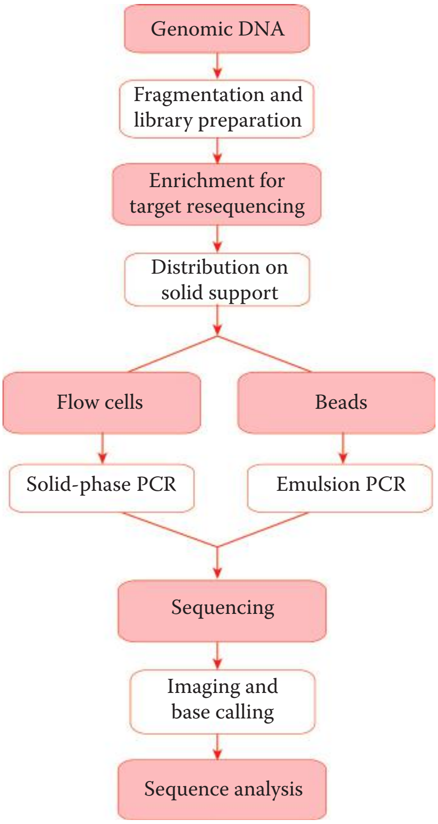
Genomic DNA
Fragmentation and library preparation
Enrichment for target resequencing
Distribution on solid support
Flow cells
Beads
Solid-phase PCR
Emulsion PCR
Sequencing
Imaging and base calling
Sequence analysis

Figure 22.8 NGS work flow for potential forensic applications. (© Richard C. Li.)

Most imaging systems of sequencing platforms are not equipped to detect single-molecule fluorescence. Thus, DNA templates are amplified using either emulsion or solid-phase PCR. In the *emulsion PCR*, single-stranded DNA templates are bound to beads. DNA-bound beads are suspended in a water-in-oil emulsion, where each bead is placed in a single aqueous droplet. DNA fragments are amplified using PCR. As a result, each bead is coated with thousands of copies of the same template sequence. Subsequently, beads carrying amplified DNA are deposited on a glass slide or into individual fiber-optic wells for sequencing. In *solid-phase PCR*, both forward and reverse primers are attached to a slide (Figure 22.9). DNA templates are hybridized to immobilized PCR primers. The extended primer bends and hybridizes to a second immobilized primer, forming a bridge. During the "bridge amplification," the single-stranded template is amplified to form clusters. Solid-phase amplification can produce millions of spatially separated template clusters with free ends, allowing universal sequencing primers to hybridize for sequencing.

22.3.3 NGS Chemistry

The amplified template fragments are then sequenced. At present, there are two major categories of NGS chemistry that are routinely used: *sequencing by synthesis* and *sequencing by ligation*. The *pyrosequencing* technology is one example of NGS using the sequencing-by-synthesis chemistry. During the pyrosequencing, each nucleotide substrate is introduced one at a time. Only the correct nucleotide corresponding to the template is incorporated, and a pyrophosphate is released (Figure 22.10a). Pyrophosphate is then converted to ATP, catalyzed by sulfurylase (Figure 22.10b). ATP is then utilized by luciferase to convert luciferin to oxyluciferin, and the reaction emits light that is detected by a charge-coupled device camera (Figure 22.10c). This technology allows the generation of sequences with long read lengths. *Cyclic reversible termination* is another example of NGS using sequencing-by-synthesis chemistry. In this method, chain terminators (fluorescent-labeled dideoxynucleotides) are used to extend a primer sequence complementary to the template DNA. Each of four nucleotides is labeled with a different fluorophore. After incorporation and fluorescence detection, the terminating and fluorescent moieties are cleaved and removed (Figure 22.11). As a result, the next sequencing cycle is carried out. This process is repeated until the sequence is completed. This is the most commonly used method throughout the field of NGS.

In the sequencing-by-ligation chemistry, probes (eight nucleotides in length) are utilized for ligation reactions. Each probe contains five specific nucleotides that are complementary to the template and three nucleotides that are universal. Probes containing all possible combinations of the first five nucleotides are utilized. Each probe is fluorescently labeled according to the first two bases of the probe so that it can be identified. During the first round of sequencing reaction, only the probe that is complementary to the template sequence can hybridize. The probe is then ligated to the 3′ end of the primer. After detection, three universal nucleotides, including fluorophore, are cleaved. The ligation process is repeated several times using a new set of probes each time. The newly made complementary DNA strand is then stripped off. In the next round of sequencing, new primers that are one nucleotide shorter than the previous primer are utilized, and the ligation reaction is repeated. In this round of sequencing, different nucleotide positions are read. This process is repeated for several rounds with different primers, until all nucleotides in the template have been sequenced twice. As a result, this sequencing method has a low error rate.

22.3.4 NGS Coverage

In NGS, sequencing reads are usually not distributed evenly over the genomic regions of interest. As a result, some nucleotides will be covered by fewer or more reads than the average. Therefore, multiple reads for each nucleotide are necessary to obtain a reliable sequence. The average number of times that each nucleotide in the genomic regions of interest is sequenced is known as the

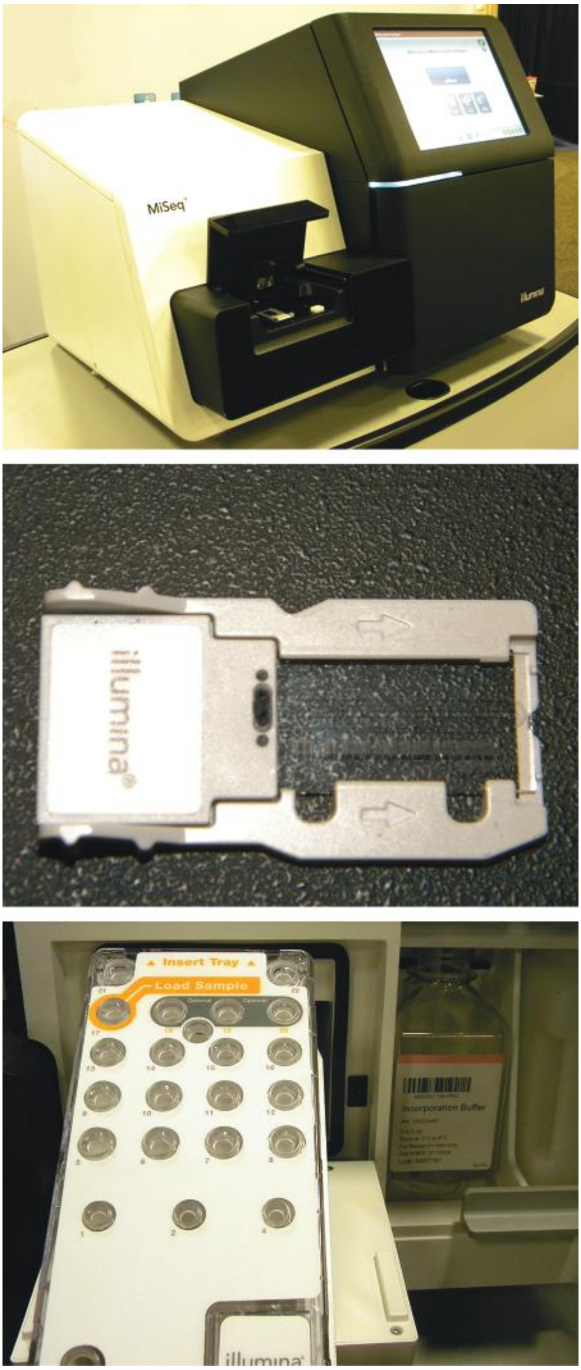
MiSeq
illumina
illumina®
Insert Tray
Load Sample
Incorporation Buffer
illumina

Figure 22.9 A photo of an NGS platform. A MiSeq (Illumna) desktop sequencer (top), a flow-cell device (middle) where DNA templates are distributed for PCR, and a reagent cartridge (bottom) are shown. (© Richard C. Li.)

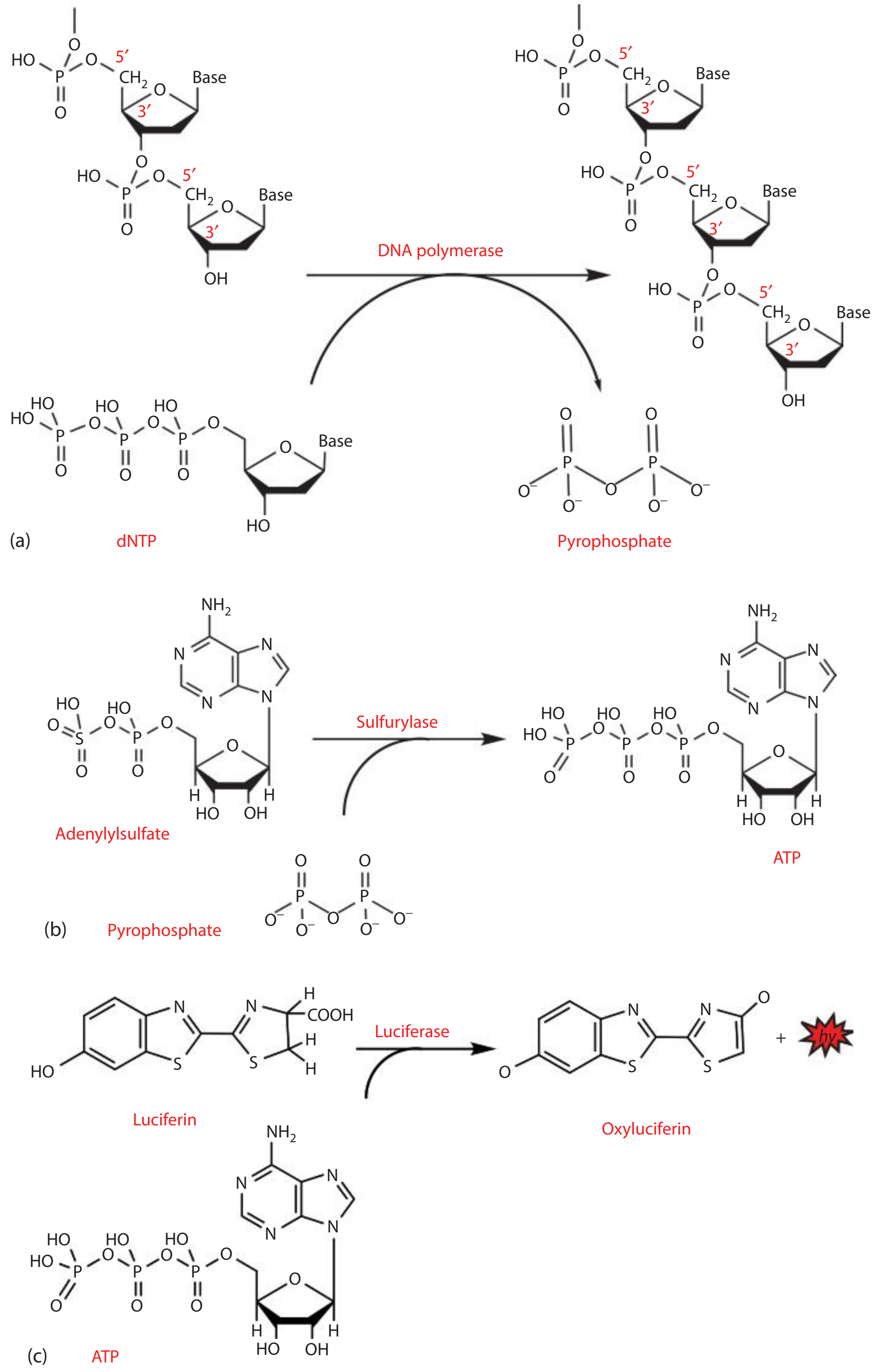
(a)
dNTP
DNA polymerase
Pyrophosphate
Base
5′
3′
OH
(b)
Adenylylsulfate
Sulfurylase
ATP
Pyrophosphate
(c)
Luciferin
Luciferase
Oxyluciferin
ATP
hν

Figure 22.10 Pyrosequencing chemistry. (a) During the pyrosequencing, a nucleotide substrate is incorporated, releasing a pyrophosphate. (b) Pyrophosphate is then converted to ATP. (c) ATP is utilized by luciferase, converting luciferin to oxyluciferin, which emits light.

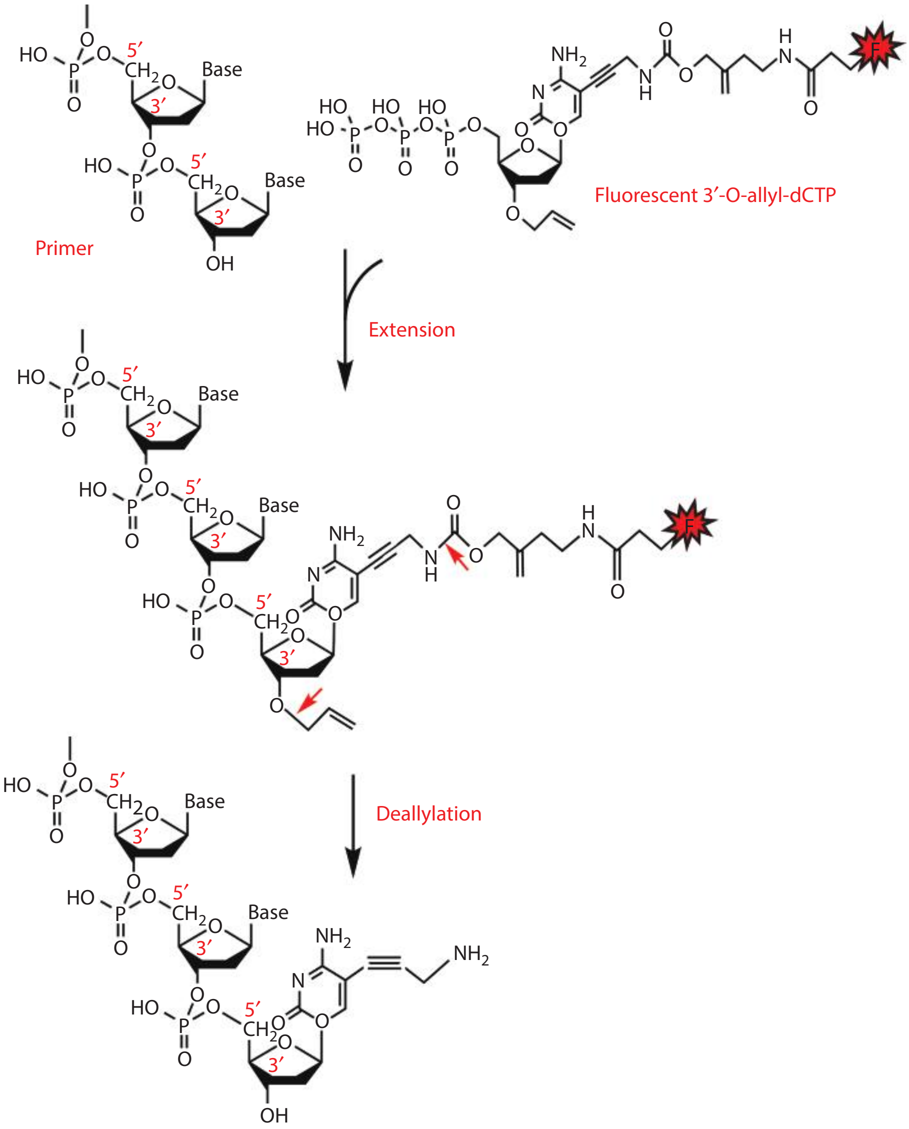
Primer
Fluorescent 3′-O-allyl-dCTP
Extension
Deallylation
Base
5′
3′
CH2
HO
P
O
OH
NH2
N
H
F

Figure 22.11 Cyclic reversible termination. A single sequencing cycle is shown. The incorporation of a C is illustrated as an example.

coverage or the *sequencing depth*. The level of coverage depends on the types of applications. For example, for human genome SNP analysis, the level of coverage is from 10 to 30. The coverage can be calculated using the following equation:

$$C = \frac{LN}{G}$$

where:

C = coverage
G = haploid genome length
L = read length
N = number of reads

Currently, NGS has not been widely used in forensic applications. One disadvantage of NGS is that the error rate of NGS is higher than that of Sanger sequencing. Although the error rate of NGS is not yet acceptable for forensic casework analysis, it can potentially be overcome by increasing the sequencing coverage.

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23

Mitochondrial DNA Profiling

Forensic mitochondrial DNA (mtDNA) analysis is an important tool for human identification and is especially useful for identifying victims such as missing persons and individuals in mass fatality cases. Because mtDNA is maternally inherited, the mtDNA profiles of these individuals can be compared to those of their maternal relatives, and thus these individuals can be identified. Additionally, cells contain a much higher copy number of the mtDNA genome than that of the nuclear genome. Therefore, mtDNA testing is frequently used to analyze evidence samples, such as hair shafts, that contain low amounts of nuclear DNA. Furthermore, buried bones and decomposed tissues, in which nuclear DNA may be degraded, can be tested with mtDNA analysis.

23.1 Human Mitochondrial Genome

Mitochondria are cellular organelles that serve as the energy-generating components of cells (Figure 23.1). Each cell contains hundreds of mitochondria, which have their own extrachromosomal genomes separated from the nuclear genomes. Although each human mitochondrion contains multiple copies of the mtDNA genome, the exact copy number varies for each cell. However, it is estimated that hundreds of copies of the mtDNA genome exist in most cells.

23.1.1 Genetic Contents of Mitochondrial Organelle Genomes

The human mitochondrial genome was first sequenced by Fred Sanger's laboratory at Cambridge University and was published in 1981; it is known as the *Cambridge reference sequence* (CRS). The sequence was largely derived from a placental sample from an individual of European descent and also partially from HeLa cells (a cell line derived from cervical cancer cells), as well as from bovine cells. It was later discovered, by resequencing the original mtDNA sample, that the CRS contains substitution errors at 10 nucleotide positions. The *revised Cambridge reference sequence* (rCRS) was published in 1999 and presented corrections to these substitution errors. Additionally, CRS contains a cytosine dimer at nucleotide positions 3106 and 3107, which is in fact a single cytosine nucleotide. This error is not corrected in the rCRS in order to retain the original nucleotide numbering system of CRS and thus to avoid inconsistency with the previous literature. The human mitochondrial DNA genome is circular with no beginning and end, which can make sequence comparison a potential problem. Therefore, the rCRS, with its nucleotide numbering system, is used as a reference when aligning with other mitochondrial sequences for comparison purposes.

Organelle genomes are usually much smaller than their nuclear counterparts. The human mtDNA genome consists of 16,569 base pairs (bp) containing 37 genes (Figure 23.2). Thirteen of

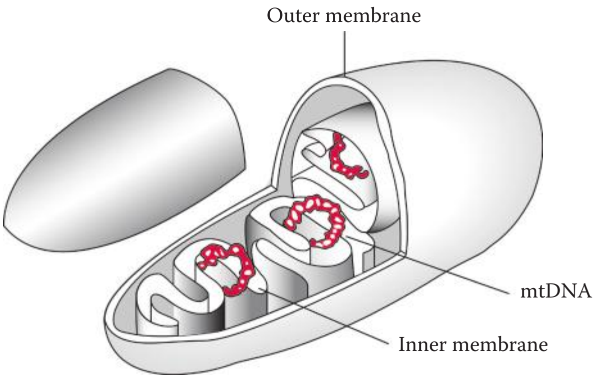
Outer membrane
mtDNA
Inner membrane

Figure 23.1 Mitochondrion. mtDNA, mitochondrial DNA. (© Richard C. Li.)

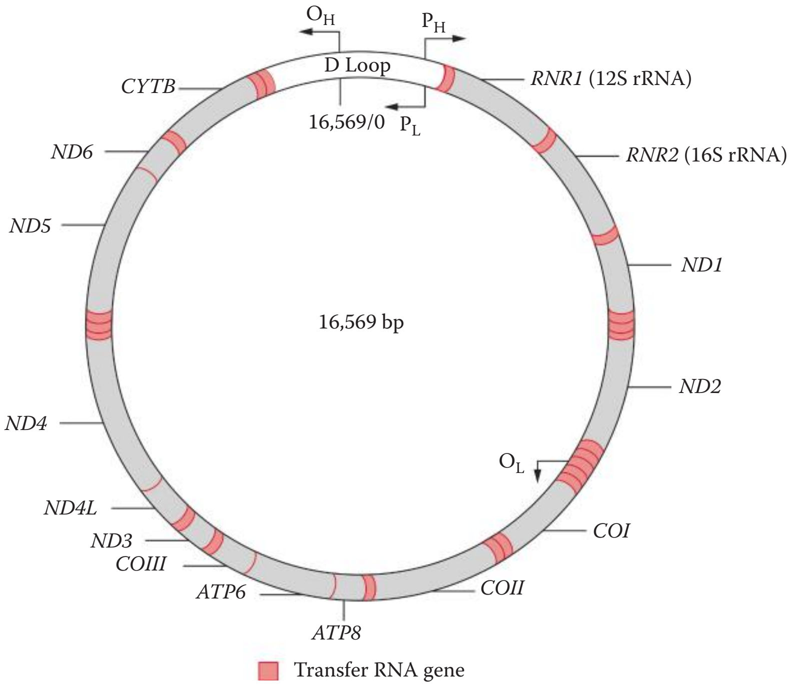
O_H
P_H
D Loop
16,569/0
P_L
CYTB
RNR1 (12S rRNA)
ND6
RNR2 (16S rRNA)
ND5
ND1
16,569 bp
ND2
ND4
O_L
ND4L
ND3
COIII
COI
ATP6
COII
ATP8
Transfer RNA gene

Figure 23.2 Human circular mitochondrial genome. The transcription direction for the H (heavy) and L (light) strands are indicated by arrows (P_H, P_L, respectively). The origins of replication are labeled O_H for the heavy strand and O_L for the light strand. The mitochondrial DNA genome encodes genes. ND, NADH coenzyme Q oxidoreductase complex; CO, cytochrome c oxidase complex; CYTB, cytochrome b; ATP, ATP synthase; rRNA, ribosomal RNA. Transfer RNA genes are shown as indicated. (© Richard C. Li.)

these genes code for proteins involved in the respiratory complex, a main energy-generating component in mitochondria. The other 24 specify noncoding RNA molecules required for the expression of the mitochondrial genome. The genes in the human mitochondrial genome are much more closely packed than in the nuclear genome and contain no introns. A *control region*, also known as a *displacement loop* (*D loop*), contains the origin of replication for one of the mtDNA strands but does not code for any gene products (Figure 23.2). An asymmetric distribution of

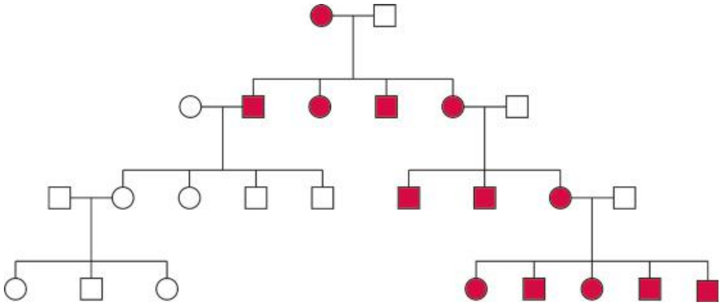

Figure 23.3 Pedigree of a human family showing inheritance of mtDNA. Females and males are denoted by circles and squares, respectively. Red symbols indicate individuals who inherited the same mtDNA.

nucleotides gives rise to light (L) and heavy (H) strands. The H strand contains a greater number of guanine nucleotides and a higher molecular weight in comparison to the L strand.

23.1.2 Maternal Inheritance of mtDNA

Maternal inheritance is typically observed for the mtDNA genome (Figure 23.3), which is inherited differently from nuclear genes. The inheritance of the mtDNA genome does not obey the rules of Mendelian inheritance and is thus called non-Mendelian inheritance.

The mitochondria of a spermatozoon are located in the midpiece (Chapter 14). At conception, only the head portion of a spermatozoon (containing a nucleus but no mitochondria) enters the egg. The fertilized egg contains the maternal mitochondria, which are transmitted to the progeny. Occasionally, the paternal mitochondria can enter the cell. However, paternal mitochondria in the spermatozoon that enter the egg are usually destroyed by the egg cell after fertilization (Figure 23.4). Therefore, the coinheritance of maternal and paternal mtDNA in a single individual is extremely rare in humans. The mtDNA sequence is identical for relatives within the same maternal lineage, a property that is useful when identifying individuals by comparing their mtDNA with that of maternal relatives.

Homologous DNA recombination (Chapter 25) has not been observed in the mtDNA genome. Thus, an mtDNA profile, also referred to as the *mitotype*, is considered a haplotype treated as a single locus. The mitochondrial genome has a higher mutation rate (up to 10 times higher) than its nuclear counterpart. The presence of mutations can be problematic in victim identification when comparing the mtDNA profiles of a victim with the relatives of the victim.

23.2 mtDNA Polymorphic Regions

23.2.1 Hypervariable Regions

The most polymorphic region of mtDNA is located within the D-loop (Figure 23.5). The three *hypervariable regions* in the D-loop are designated hypervariable region I (HV1: 16,024–16,365; 342 bp), hypervariable region II (HV2: 73–340; 268 bp), and hypervariable region III (HV3: 438–574; 137 bp). The most common polymorphic regions of the human mtDNA genome analyzed for forensic purposes are HV1 and HV2.

23.2.2 Heteroplasmy

Heteroplasmy occurs when an individual carries more than one mtDNA haplotype. Heteroplasmy may be observed with one kind of tissue and may be absent in other kinds of tissues; for example,

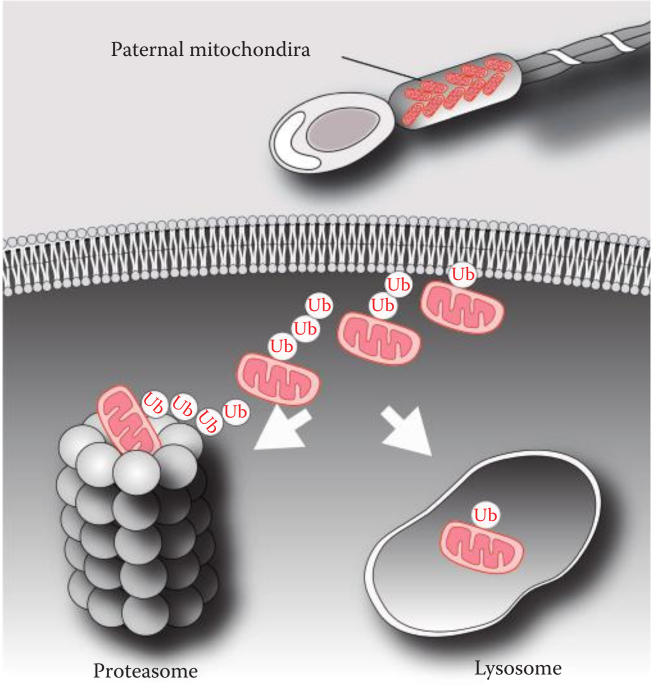

Figure 23.4 A model of uniparental mtDNA inheritance in humans. Paternal mitochondria occasionally enter the egg cell. Paternal mitochondria inside fertilized eggs are tagged by ubiquitin protein (Ub). It is proposed that the ubiquitination of sperm mitochondria leads to the degradation of paternal mitochondria in fertilized eggs. Tagged Ub can be recognized by proteasomes and lysosomes, which are cellular degradation machineries. A polyubiquitin chain with at least four ubiquitin units is needed to be recognized by the proteasomes. Ubiquitin with less than four ubiquitin units can be processed by the lysosomes. (© Richard C. Li.)

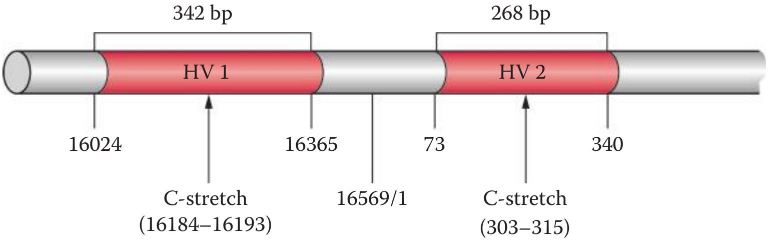

Figure 23.5 Hypervariable regions of the D-loop in mtDNA (with nucleotide positions). (© Richard C. Li.)

mtDNA heteroplasmy is commonly observed in hair samples (Chapter 4). Additionally, an individual may exhibit one mitotype in one tissue and a different mitotype in another. Thus, it is necessary to obtain and process additional samples to confirm the heteroplasmy when it is observed in a questioned sample but not in a known sample or vice versa. The two types of heteroplasmies are sequence and length heteroplasmy.

Sequence heteroplasmy is defined as the presence of two different nucleotides at a single position shown as overlapping peaks in a sequence electropherogram (Figure 23.6). Heteroplasmy usually occurs at one position, but on rare occasions it can be observed at more than one position. Hot spots for heteroplasmy have been documented at both HV1 and HV2 regions. Heteroplasmy may complicate the interpretation of mtDNA results, but its presence can also

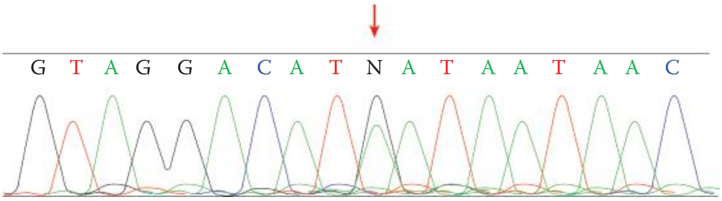

Figure 23.6 Electropherogram showing mtDNA sequence heteroplasmy at position 234R (A/G) as indicated by an arrow. N, unresolved sequence. (© Richard C. Li.)

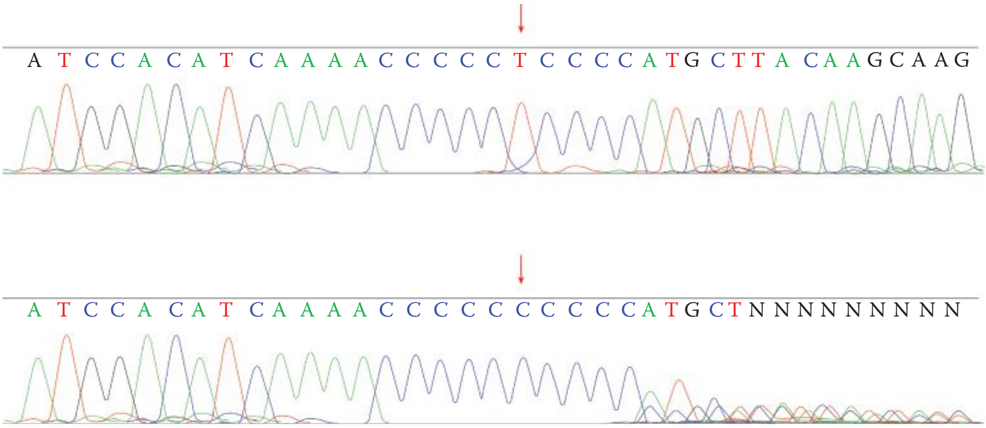

Figure 23.7 Length heteroplasmy. Electropherogram showing mtDNA length heteroplasmy at the C stretch of the HV1 region where position 16,189 is a T (top) and a C (bottom) as indicated by an arrow. N, unresolved sequence. (© Richard C. Li.)

improve the strength of a match. Both HV1 and HV2 of the human mtDNA D-loop region contain homopolymeric cytosine sequences known as *C stretches*. The HVI region contains a C stretch between nucleotide positions 16,184 and 16,193, interrupted by a thymine at position 16,189. If a base transition from T to C occurs at position 16,189 (a variant present in approximately 20% of the population), it results in an uninterrupted C stretch. A similar C stretch resides between positions 303 and 315 of the HV2 region.

Length heteroplasmies are often observed at the uninterrupted C stretches in sequencing, in which sequencing products with various lengths of polymeric cytosine residues are present. As a result, sequences downstream from the C stretch cannot be resolved (Figure 23.7). It is not clear whether the length heteroplasmy is due to replication slippage at the C stretches or results from the presence of a mixture of length variants in the cells. If length heteroplasmy occurs, alternative sequencing primers that anneal at the downstream of C stretches can be used to obtain the downstream sequences of the C stretches.

23.3 Forensic mtDNA Testing

23.3.1 General Considerations

mtDNA analysis is often used on samples derived from skeletal or decomposed remains. The surface of the sample should be cleaned to remove any adhering debris or contaminants. Bones and teeth are pulverized to facilitate extraction of the mtDNA (Chapter 5). Duplicate extractions (e.g., two sections of a single hair) are recommended if sufficient sample material is available.

mtDNA is extracted using a similar method to nuclear DNA (nuclear DNA is coextracted with mtDNA). The amount of mtDNA can therefore be estimated from the quantity of nuclear DNA obtained. Alternatively, mtDNA-specific quantization methods using real-time PCR (Chapter 6) can also be used to directly obtain measurements of mtDNA extracted.

For mtDNA sequencing, the analysis of both strands of the mtDNA in a given region must be performed to ensure accuracy. Due to the high sensitivity of mtDNA analysis, it is essential to minimize risks of contamination during the procedure. Contamination must be strictly monitored using proper controls such as extraction reagent blanks (Section 7.5.3) and amplification negative controls (samples containing all reagents except DNA template).

Finally, a positive control must also be used to monitor the success of the analysis. It should be introduced at the amplification step and remain through the sequencing process. A positive control consists of a DNA template of known sequence, such as DNA purified from the HL60 cell line.

23.3.2 mtDNA Screen Assay

One example of the assay for screening mtDNA variations is the allele-specific oligonucleotide (ASO) assay. It allows initial screening of mtDNA sequence polymorphisms and has the potential to reduce the number of samples required for mtDNA sequencing. This method is also useful for excluding or eliminating suspects from a case. However, HV1 and HV2 sequencing should be performed to obtain complete sequence information for the targeted HV regions to confirm a match.

The commercial Linear Array™ mtDNA HV1/HV2 region sequence typing kit (Roche Applied Sciences, Indianapolis) utilizes reverse ASO configuration with a panel of immobilized ASO probes that detect common polymorphic sites (Figures 23.8 and 23.9). The mtDNA is amplified at both HV1 (444 bp amplicon) and HV2 (415 bp amplicon) regions and the forward primers are biotin labeled at the 5′ ends of the oligonucleotides. Thus, the amplified PCR product (amplicon) is biotinylated. A horseradish peroxidase–conjugated streptavidin complex then binds to the biotinylated amplicon (see Chapter 9). Finally, colorimetric detection is carried out with tetramethylbenzidine (TMB) as the substrate to produce a colored precipitate at the designated location. The typing kit detects sequence variations in 19 positions within the HV1 and HV2 regions.

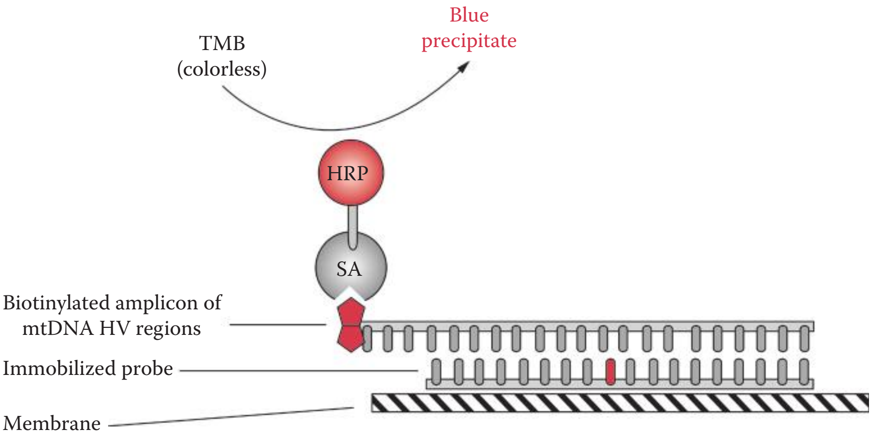

Figure 23.8 Reverse blot assay employed in mtDNA screen. A probe is immobilized onto a solid-phase membrane, and then hybridized with a biotinylated amplicon of the mtDNA HV sequences. Hybridization is detected by a streptavidin (SA) and horseradish peroxidase (HRP) conjugate. A colorimetric reaction is catalyzed by HRP using tetramethylbenzidine (TMB) as a substrate. (© Richard C. Li.)

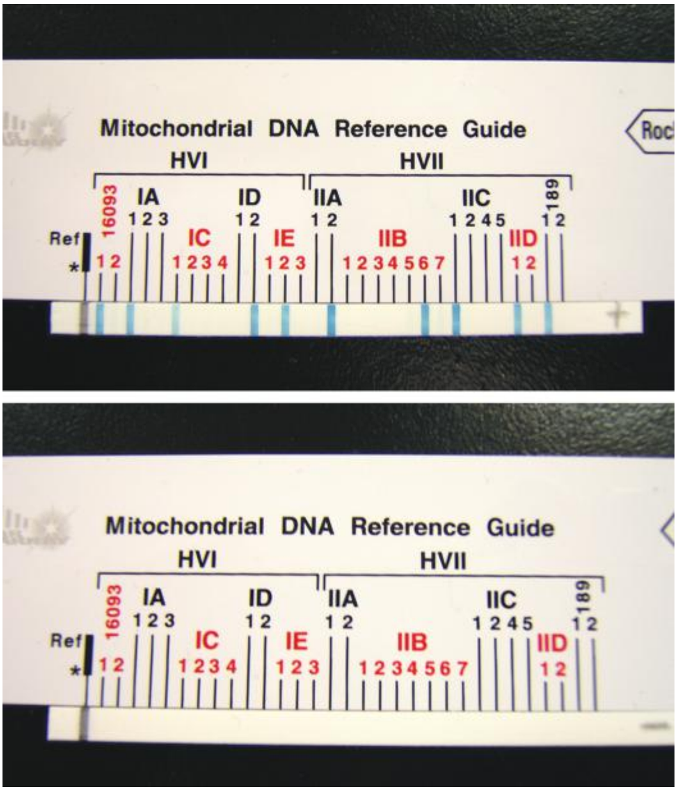

Figure 23.9 Linear array mtDNA assay results (top) and negative control (bottom). (© Richard C. Li.)

23.3.3 mtDNA Sequencing

To sequence a specific region of mtDNA, a combination of PCR amplification and DNA sequencing techniques is utilized to reduce the time and labor needed to obtain DNA sequences from genomic DNA templates. mtDNA sequencing usually consists of (1) PCR amplification, (2) DNA sequencing reactions, (3) separation using electrophoresis, and (4) data collection and sequence analysis (Figure 23.10). Chapter 25 describes the evaluation of the strength of the results via statistical analysis.

23.3.3.1 PCR Amplification

The extracted DNA samples must be amplified to yield sufficient quantities of template for sequencing reactions. PCR amplification of all or a part of the D-loop region can be carried out with various primer sets. If a sample contains intact mtDNA, the HV1 and HV2 regions can be amplified as two amplicons, each of about 350–400 bp in length. If an mtDNA sample is fragmented due to degradation, the hypervariable regions can be amplified as smaller amplicons. PCR amplification of mtDNA is usually done in 34–38 cycles. Protocols for highly degraded DNA specimens sometimes require 42 cycles. The use of higher PCR cycle numbers can improve the yield of the amplicons.

Following mtDNA amplification, a purification step is necessary to remove excess primers and deoxynucleotide triphosphates (dNTPs). This step can be performed using filtration devices such as a Microcon® to remove small molecules from the sample or using nuclease digestion with shrimp alkaline phosphatase or exonuclease I to degrade remaining primers and dNTPs. The concentration of the amplicons is important for an optimal sequencing reaction in the next phase of mtDNA sequencing. The quality and quantity of the mtDNA amplicon must be evaluated to confirm the presence or absence of amplicons and their concentrations. This can be done

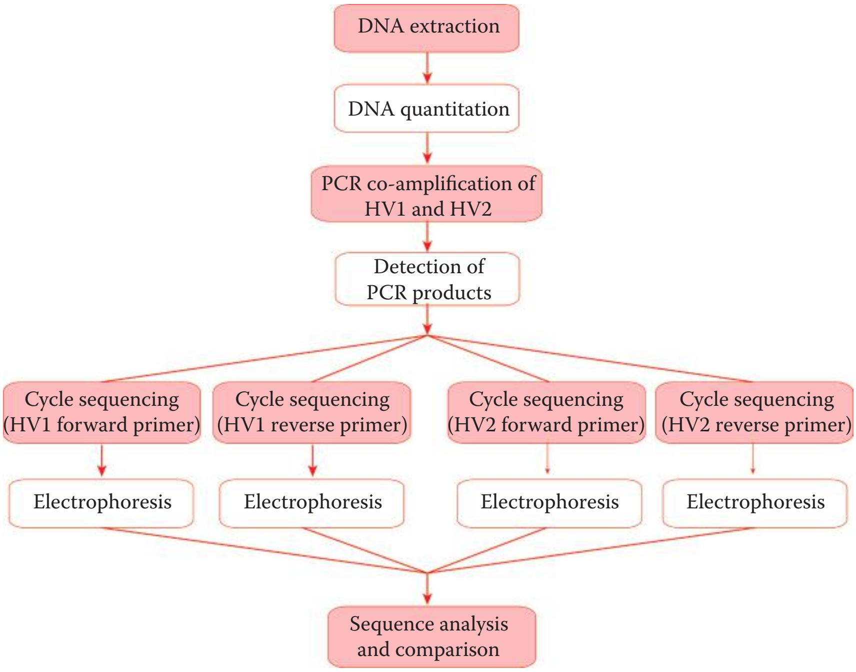
DNA extraction
DNA quantitation
PCR co-amplification of HV1 and HV2
Detection of PCR products
Cycle sequencing (HV1 forward primer)
Cycle sequencing (HV1 reverse primer)
Cycle sequencing (HV2 forward primer)
Cycle sequencing (HV2 reverse primer)
Electrophoresis
Electrophoresis
Electrophoresis
Electrophoresis
Sequence analysis and comparison

Figure 23.10 Sanger sequencing work flow for the mtDNA HV regions. (© Richard C. Li.)

using an agarose yield gel to visualize the amplicons of the sample or via capillary electrophoresis using a modular microfluidic chip device (Figure 8.12), a more informative method, for quantifying amplicons.

23.3.3.2 DNA Sequencing Reactions

The best-known DNA sequencing techniques are the *chain-termination* method and the *chemical degradation* method developed by Sanger and Gilbert (who shared the Nobel Prize for their work), respectively, in 1977. Over the years, the chain-termination method has become more common because it is suitable for automation and does not require the toxic chemicals necessary for the chemical degradation method.

23.3.3.2.1 Chain-Termination or Sanger Method

Using the chain-termination method, an oligonucleotide primer that can anneal to a single-stranded DNA template is utilized. A sequencing reaction contains DNA polymerase and the four dNTPs in order to carry out extension. The reaction also contains small quantities of dideoxynucleotide triphosphates (ddNTPs, Figure 23.11). Thus, a sequencing reaction involves a combination of extension and termination of the chain (Figure 23.12). If a ddNTP molecule is incorporated into a growing DNA chain, the absence of a 3′ OH group in the ddNTP molecule prevents the formation of a phosphodiester bond and thus disrupts the extension of the oligonucleotide chain.

The ratio of ddNTPs to dNTPs has been optimized to result in a collection of DNA fragments varying in length by one nucleotide from the primer length to the full length of the sequencing reaction product. As a result, the products of the sequencing reaction consist of a pool of various lengths of oligonucleotide chains terminated by ddNTPs. By using the four different ddNTPs, populations of DNA fragments are generated that terminate at positions occupied by every A, C, G, or T in the template strand.

The sequencing product of chain termination can be labeled with the *dye-terminator* system, in which the terminator is labeled, or with the *dye-primer* system, in which the primer is labeled.

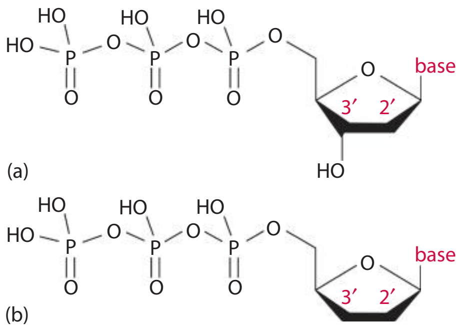
(a)
HO
P
O
base
3′
2′
(b)

Figure 23.11 Chemical structures of dNTP and ddNTP: (a) dNTP; (b) ddNTP. Both hydroxyl groups attached to the 2′ and 3′ carbons of ribose are replaced by hydrogens.

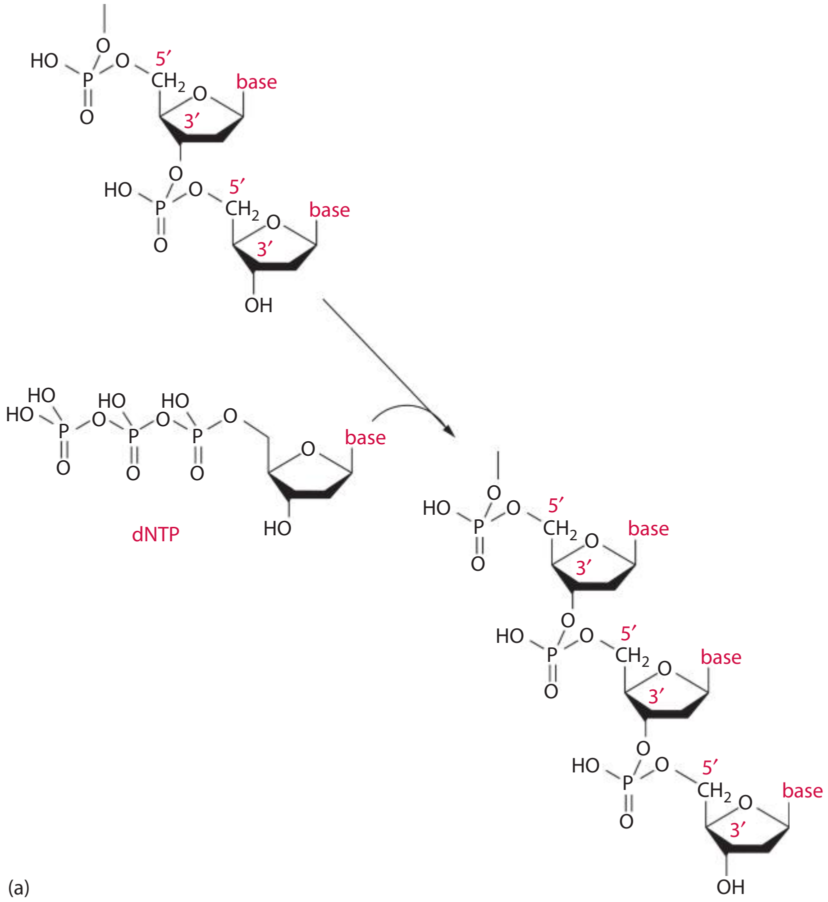
HO
P
O
5′
CH_2
base
3′
OH
dNTP
(a)

Figure 23.12 Competition between extension and termination. (a) Growing chain in extension.

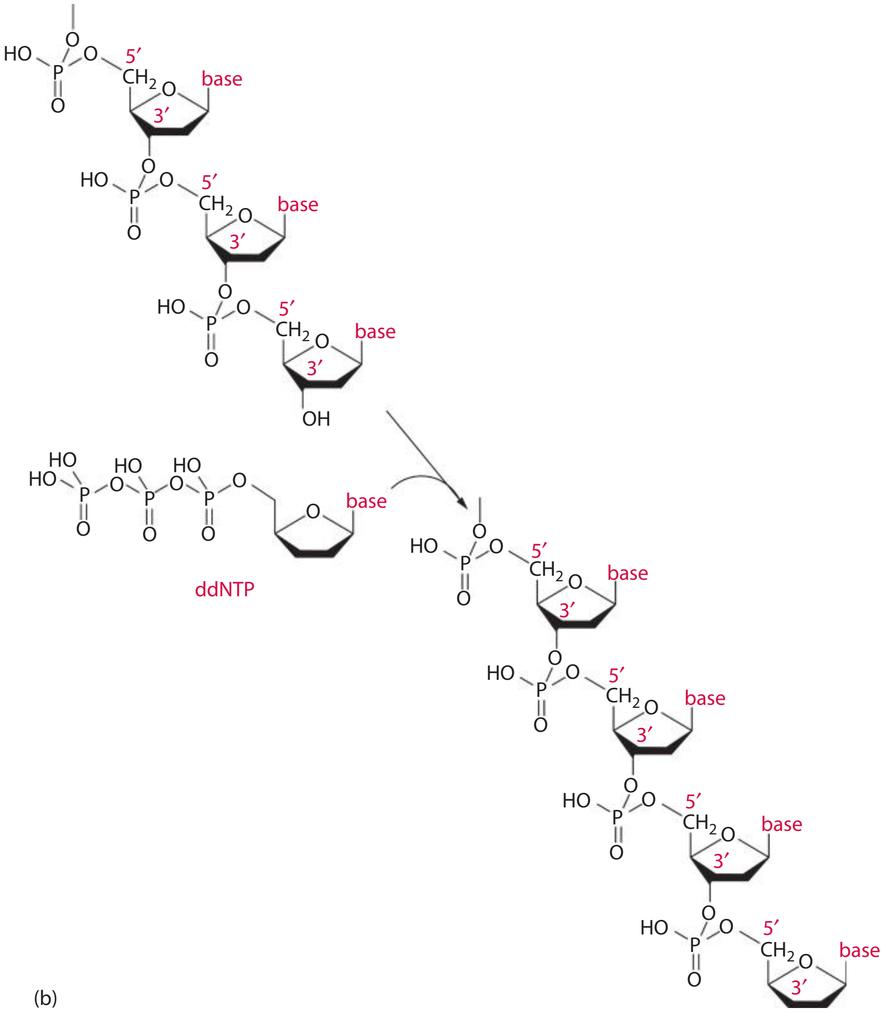

Figure 23.12 (Continued) (b) DNA strand with labeled ddNTP incorporated into a growing DNA chain that interrupts the incorporation of new nucleotides. The ddNTP usually is labeled with a fluorescent dye used for detection.

The dye-terminator system is commonly used for mtDNA sequencing in forensic laboratories. With the dye-terminator system, the ddNTPs are labeled with four different fluorescent dyes, each with a distinct spectrum. Thus, the sequencing with all four ddNTPs can be carried out in a single reaction. The labeled products of sequencing reactions are then resolved during electrophoresis and the sequencing data can be collected (Section 23.3.3.).

23.3.3.2.2 Cycle Sequencing

The chain-termination reaction is carried out using a *cycle sequencing* technique commonly used in forensic laboratories for mtDNA sequencing. Cycle sequencing, developed in the late 1980s, utilizes thermal cycling to generate a single-stranded template for chain-termination sequencing reactions. The application of thermal cycling in a sequencing reaction greatly increases the signal intensity and thus the sensitivity of the sequencing.

The sequencing reactions are carried out with multiple rounds of thermal cycling. Each cycle consists of three steps: denaturation of the double-stranded DNA template, annealing of a sequencing primer to its target sequence, and the extension of the annealed primer by DNA polymerase. Cycle sequencing utilizes only a single primer per reaction. During the extension of cycle sequencing, the extension of the strand is terminated with the incorporation of a ddNTP (Figure 23.13). The resulting partially double-stranded hybrid, consisting of the full-length template strand and its complementary chain-terminated product, is denatured during the first step of the next cycle, thereby liberating the template strand for another round of annealing, extension, and termination.

23.3.3.3 Electrophoresis, Sequence Analysis, and Mitotype Designations

The cycle sequencing products can be separated using electrophoresis in a 4% polyacrylamide denatured gel or a POP-6 polymer (Applied Biosystems) as the matrix for capillary electrophoresis (Figure 23.14). Following data collection, sequence data analysis can be performed with the Sequencher™ software (Gene Codes Corporation, Ann Arbor). Figure 23.15 shows sequence data.

Sequencing of a region of the mtDNA genome should be performed twice. Additionally, both strands of a region of the mtDNA genome should be sequenced to reduce ambiguities in sequence determination. The sequences of evidence samples and reference samples such as that of the victim or suspect can be compared. The nomenclature used in reporting should be compatible with International Union of Pure and Applied Chemistry (IUPAC) codes.

23.3.3.3.1 Reporting Format

The rCRS is used as a reference standard to facilitate the designation of mitotypes. For reporting purposes, sequence differences relative to the rCRS are listed in data format. When a difference between an individual's sequence and that of the rCRS sequence is observed, only the position (designated by a number) and the nucleotide differing from the reference standard are recorded. In this format, nucleotides identical to the rCRS are not listed. For example, at position 228 (HV2), the rCRS has a G. If a mitotype carries an A at position 228, the individual's mtDNA sequence is described as 228A. If an unresolved sequence ambiguity is observed at a position,

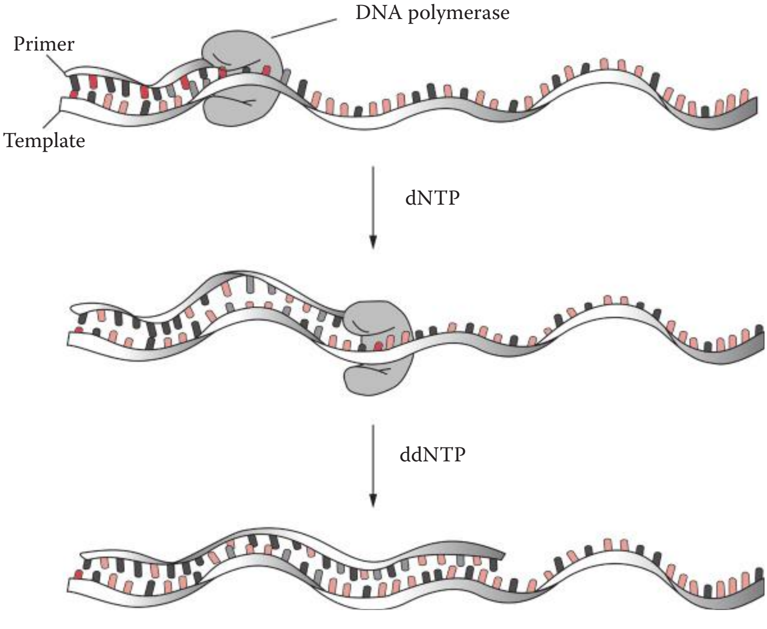

Figure 23.13 Cycle sequencing reaction. The reaction requires DNA polymerase, a template, and a primer. During DNA synthesis, the dNTP is incorporated by a new phosphodiester bond with the primer. The incorporation of ddNTP blocks further DNA synthesis of the growing chain. (© Richard C. Li.)

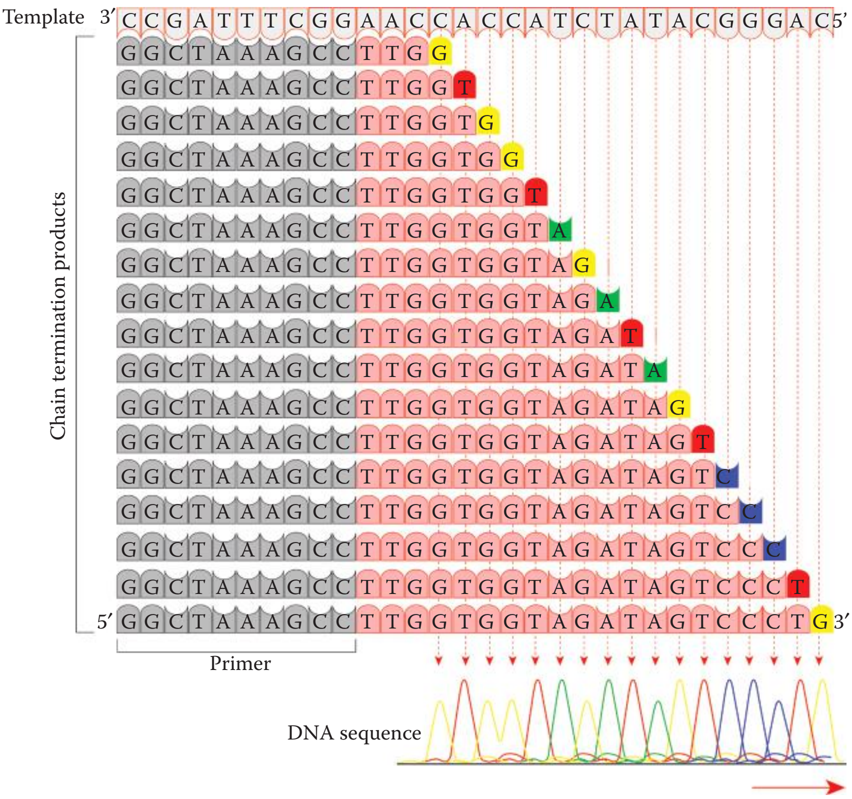
Template
3′ CCGATTTCGGAACCACCATCTATACGGGAC 5′
Chain termination products
5′ GGCTAAAGCCTTGGTGGTAGATAGTCCCTG 3′
Primer
DNA sequence

Figure 23.14 Diagram of the Sanger sequencing products. The DNA chain lengths are determined by the addition of ddNTP at different positions. The fluorescent dye-labeled cycle-sequencing products are separated using capillary electrophoresis. The fluorescent dyes are resolved by a detector, and the peaks corresponding to each DNA fragment are identified. (© Richard C. Li.)

the base number for the position is listed followed by an N. For example, 228N means an unresolved sequence ambiguity was observed at position 228.

23.3.3.3.2 Insertions

The insertion site is described by noting the position (at 5′ to the insertion) followed by a decimal point and a number. The number indicates the order of the insertions (e.g., 1 indicates the first insertion, 2 indicates the second, etc.). The base calling following the number indicates the inserted nucleotide (e.g., 524.1A, 524.2C).

23.3.3.3.3 Deletions

The deletion site designation is followed by the letter *d*. For example, a deletion at position 16,296 is recorded as 16,296d.

23.3.3.3.4 Heteroplasmic Sites

The IUPAC codes for base calling can be applied to heteroplasmic sites. For example, an A/G heteroplasmy can be designated as R, and a C/T heteroplasmy can be designated as Y.

23.3.4 Interpretation of mtDNA Profiling Results

Interpretation guidelines are used when comparing sequencing results between evidence and reference samples. General guidelines were set forth by the Scientific Working Group on DNA

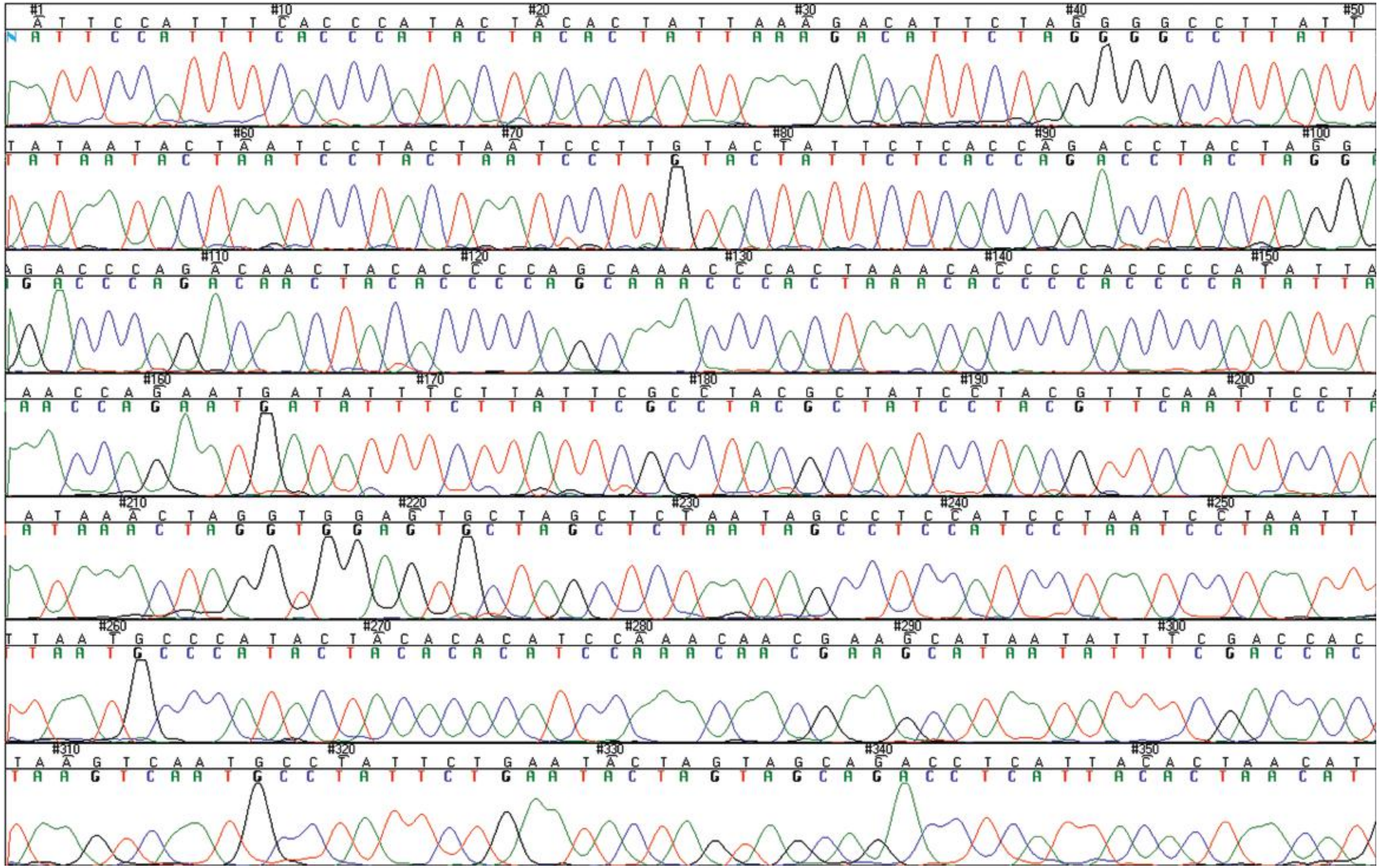

Figure 23.15 Electropherogram representing a DNA sequence presented as peaks with corresponding colors for each of the four bases. The bases associated with each peak are noted. The sequence is read from left to right (5′ to 3′). (© Richard C. Li.)

Analysis Methods (SWGDAM) and the DNA Commission of the International Society of Forensic Genetics (ISFG). In reporting mtDNA profiling results, the most common categories of conclusions are the following: cannot exclude, exclusion, and inconclusive result.

23.3.4.1 Exclusion

If the sequences of questioned and known samples are different, then the samples can be excluded as originating from the same source. It should be taken into account that higher mutation rates are found with the mtDNA genome than are found with the nuclear genome. The SWGDAM's guidelines define that the conclusion of exclusion can be made if there are two or more nucleotide differences between the questioned and known samples. Additionally, mutations seem to be more common in certain tissues. For this reason, the sources of the tissues analyzed should be taken into consideration.

23.3.4.2 Cannot Exclude

If the sequences are the same, the reference sample and evidence cannot be excluded as arising from the same source. When an mtDNA profile cannot be excluded, it is desirable to evaluate the weight of the evidence. In cases where the same heteroplasmy is observed in both questioned and known samples, its presence increases the strength of the evidence. However, if heteroplasmy is observed in a questioned sample but not in a known sample or vice versa, a maternal lineage still cannot be excluded.

23.3.4.3 Inconclusive Result

If the questioned and known samples differ by a single nucleotide, and no heteroplasmy is present, the results are considered to be inconclusive.

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SECTION V

Forensic Issues

24

Forensic DNA Databases

Tools for Crime Investigations

24.1 Brief History of Forensic DNA Databases

Forensic DNA databases are networks for exchanging information among law enforcement agencies to assist in solving crimes. For example, forensic DNA databases allow forensic laboratories to search DNA profiles against the databases to identify criminals. In 1995, the United Kingdom established the world's first national DNA database, NDNAD, in England and Wales. Scotland and Northern Ireland have their own databases but also submit their profiles to NDNAD. NDNAD demonstrated initial success in solving crimes. Three years later, the United States introduced its national *Combined DNA Index System* or CODIS. By the end of 1998, other countries (such as Austria, Germany, the Netherlands, New Zealand, and Slovenia) had also introduced national DNA databases. Table 24.1 describes some of these national DNA databases. This chapter will focus on CODIS.

24.2 Infrastructure of CODIS

In the United States, a pilot project of DNA databasing was initiated by the Federal Bureau of Investigation (FBI) and 14 participating state and local laboratories. Subsequently in 1994, the Congressional DNA Identification Act authorized the FBI to establish a national DNA database including "DNA identification profiles of persons convicted of crimes, and analyses of DNA samples recovered from crime scenes and from unidentified human remains." By 1997, 13 STR loci were selected and in 1998 were implemented as the core loci for the national database, known today as CODIS. All 50 states, the District of Columbia, the federal laboratories, the US Army Criminal Investigation Laboratory, and Puerto Rico contribute to CODIS.

CODIS has three hierarchical levels: the Local DNA Index System (LDIS), the State DNA Index System (SDIS), and the National DNA Index System (NDIS) (Figure 24.1). The LDIS is maintained at crime laboratories operated by police departments, sheriff's offices, and local agencies. All forensic DNA profiles originating at the local level are stored in the LDIS and are transmitted to the SDIS and NDIS. Each state maintains a SDIS, which is typically operated by a designated state laboratory. An SDIS also stores the DNA profiles generated from state laboratories. The quality assurance standards for a qualified laboratory were set up by the DNA Advisory Board in 1998. The periodic revision of the standards is now carried out by the

Table 24.1 Characteristics of National DNA Databases

Country	Year Established	Suspect Entry Criteria	Convicted Offender Entry Criteria	Removal Criteria
United Kingdom	1995	Any recordable offense that leads to imprisonment	Entered as suspect	Never removed
New Zealand	1996	No suspects entered	Relevant offense (≥7 years in prison)	Never removed unless conviction quashed
Austria	1997	Any recordable offense that leads to imprisonment	Entered as suspect	Only after acquittal
The Netherlands	1997	No suspects entered except when suspect's DNA is tested for case	Offense leading to >4 years in prison	20–30 years after conviction
Germany	1998	Offense leading to >1 year in prison	After court decision	After acquittal or 5–10 years after conviction if prognosis good
Slovenia	1998	Any recordable offense that leads to imprisonment	Entered as suspect	Depends on severity of crime
United States	1998	No suspects entered; under revision	Depends on state law	Depends on state law
Finland	1999	Offense leading to >1 year in prison	Entered as suspect	Only after acquittal
Sweden	2000	No suspects entered	Offense leading to >2 years in prison	10 years after release from prison
Switzerland	2000	Any recordable offense that leads to imprisonment	Entered as suspect	After acquittal or 5–30 years after conviction
France	2001	No suspects entered	Sexual assaults and serious crimes	40 years after conviction

Source: Adapted from Jobling, M.A. and Gill, P., *Nat Rev Genet*, 5, 739–751, 2004.

Scientific Working Group of DNA Analysis and Methods (SWGDAM). The SDIS enables local laboratories within that state to compare DNA profiles. SDIS also serves as the communication path through which the LDIS and NDIS are able to exchange messages. Communication is mediated using a secured network with encryption. Only authorized personnel, approved by the FBI, have access to CODIS network terminals and servers. NDIS is the highest level of the CODIS infrastructure, which contains DNA profiles contributed by participating local and state

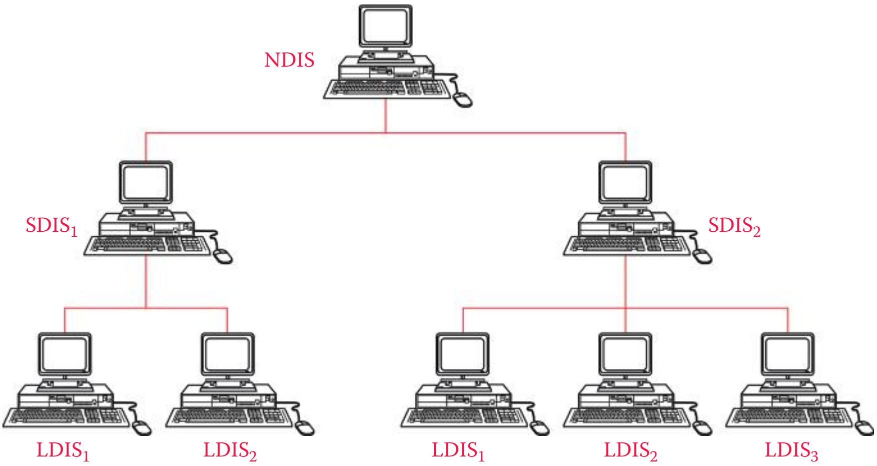

Figure 24.1 CODIS infrastructure. All DNA profiles originate at LDIS, and then enter SDIS and NDIS. SDIS allows laboratories within states to exchange DNA profiles. NDIS is the highest level of the infrastructure. It allows the participating laboratories to exchange DNA profiles on a national level.

laboratories. Additionally, NDIS stores DNA profiles generated by federal laboratories, such as those generated by the FBI and the US Army Criminal Investigation Laboratory. NDIS enables qualified state laboratories to compare DNA profiles. Searches of DNA profiles can be conducted at the national level. All DNA profiles submitted to NDIS are automatically searched weekly against the DNA profiles from other states. NDIS is administered by the FBI, which provides software, training, and support for all participating laboratories. Many law enforcement laboratories from other countries utilize the CODIS software for their own databases. However, laboratories in foreign countries do not have any access to the CODIS system. Nevertheless, a search through the CODIS database may be requested either from the FBI or International Criminal Police Organization (Interpol). Conversely, a search of an international DNA database can be arranged through Interpol.

24.3 Indexes of CODIS

The DNA profiles entered in CODIS are organized into categories known as indexes (Figure 24.2). The Convicted Offender Index contains DNA profiles of individuals convicted of crimes. The Arrestee Index contains DNA profiles of arrested individuals. It varies in SDIS databases based on each state's law permitting the collection of DNA samples from arrestees. The Forensic Index contains DNA profiles, also known as forensic profiles, derived from crime scene evidence, potentially originating from perpetrators but not including suspects.

Additionally, the FBI also established the National Missing Person DNA Database (NMPDD) Program for the identification of missing and unidentified persons at the national level. The DNA profiles entered into the NMPDD are categorized into three indexes that can be searched against each other. The Missing Person Index and the Unidentified Human Remains Index contain DNA profiles from missing persons and unidentified human remains, respectively. The Biological Relatives of the Missing Person Index contains DNA profiles voluntarily contributed from relatives. This index may also store patrilineal or matrilineal DNA profiles from the relative such as a biological father, mother, or child of the missing person to assist investigations. Additionally, a pedigree chart (a diagram showing the relationship between the missing person and relatives) can be created.

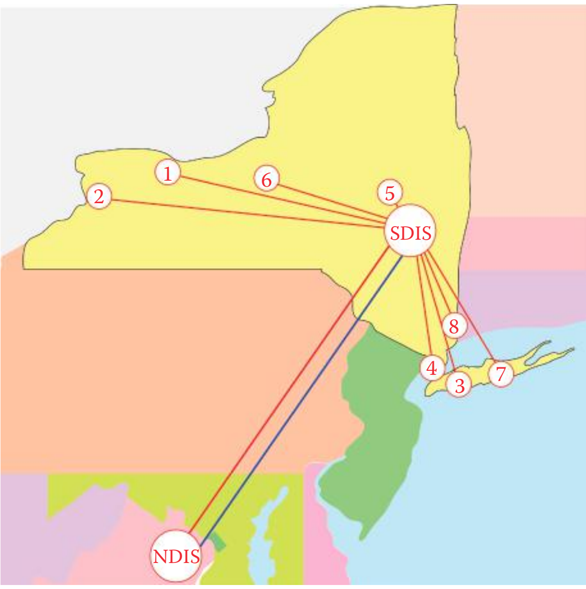

Figure 24.2 Example of an SDIS maintaining the Forensic Index (red) and Convicted Offender Index (blue). In this example, the New York State Police Forensic Investigation Center serves as the SDIS laboratory for New York State. LDIS sites: 1. Erie County Department of Central Police Services Forensic Laboratory, 2. Monroe County Public Safety Laboratory, 3. Nassau County Office of the Medical Examiner Division of Forensic Services, 4. New York City Office of the Chief Medical Examiner Department of Forensic Biology, 5. New York State Police Forensic Investigation Center, 6. Onondaga County Center for Forensic Sciences, 7. Suffolk County Crime Laboratory, and 8. Westchester County Department of Laboratories & Research Division of Forensic Sciences. (© Richard C. Li.)

In 2010, the FBI established a Rapid DNA Program Office for the purpose of developing rapid DNA technology. Rapid DNA technology is a fully automated process of performing STR analysis within 1–2 h to generate a CODIS core STR profile from a reference sample such as a buccal swab (Figure 24.3). The Rapid DNA Index System (RDIS) is the proposed index of NDIS. It shall be an integrated system capable of applying rapid DNA technology and carrying out database searches from police custody or booking units by trained police officers. The entire process, including obtaining any match from a database search, shall take less than 2 h.

The forensic DNA analysis of a reference sample, taken from an individual, takes 2–3 days if processed immediately in a forensic laboratory. The entire process includes the extraction of DNA from a sample, DNA quantification, PCR amplification, electrophoresis, and data collection and analysis. After being transported to a laboratory for processing, samples are usually stored and batched in laboratories prior to analysis. A typical turnaround time for analysis of such a sample is 1–3 months. While the sample is processed, the suspect is often released from custody. Perpetrators released on police bail may commit another crime. Thus, it is desirable to develop new technology that is capable of completing the forensic DNA analysis and database search while the suspect remains in custody. This technology would also facilitate rapid exclusion of a suspect, thus redirecting the investigation.

Rapid DNA instruments are portable, compact instruments designed to be deployed into field testing. These instruments are fully automated for processing reference samples in order to generate a DNA profile in less than 2 h. Several versions of the instruments have recently been developed by manufacturers and some of them are currently commercially available. In addition to rapid DNA instruments, rapid DNA profiling may be achieved through alternative processes. First, it can be achieved through rapid services that offer a quick turnaround time (<2 h). Second,

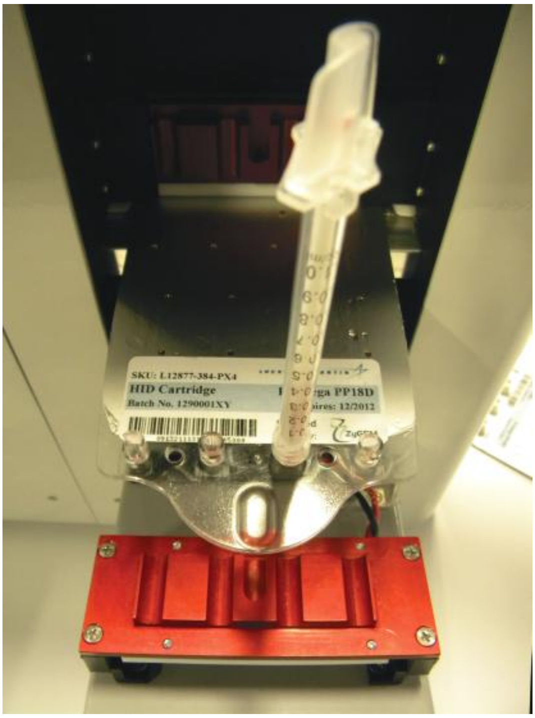

Figure 24.3 A rapid DNA instrument. A compact instrument that is designed to process swab samples and to produce DNA profiles within 2 h in the field. (© Richard C. Li.)

rapid DNA techniques can be applied using standard laboratory equipment but implementing specialized protocols to generate CODIS-compatible profiles in less than 2 h.

The primary goal of the rapid DNA initiative is to produce a CODIS-compatible DNA profile of a sample taken from an arrestee in police custody and to search DNA databases during the booking process in less than 2 h. This technology could be used, for example, to quickly identify other unsolved crimes or eliminate suspects, which can aid in investigative decision making. It can also potentially be useful for other investigations, such as identifying human remains in mass disasters; identifying detainees in counterterrorism applications; and, for immigration and border agents, confirming and verifying individual identifications or family relationships.

24.4 Database Entries

Currently, over 190 public law enforcement laboratories participate in CODIS across the United States. As of April 2013, CODIS contains the DNA profiles of more than 10 million convicted felons, over 1 million arrestees, and half a million crime scene samples. The proportion of the population represented in the database is approximately 3%. The NDIS is one of the largest DNA databases containing DNA profiles in terms of absolute numbers. Each CODIS entry consists of the DNA profile of the sample and the specimen identification number, as well as the information of the laboratory submitting the DNA profile and the laboratory analyst that performed the DNA analysis. The entry does not include case information or the personal information of the offenders or arrestees. Access to CODIS profiles is restricted to criminal justice agencies for law enforcement identification purposes.

The SDIS database retains samples collected from convicted offenders after DNA profiles are obtained. State policies vary in the retention of samples and DNA profiles in situations of dismissed charges, acquittal, or no charges for arrestees. Some states, such as Virginia, destroy the DNA sample and expunge the DNA profile from the database. Other states, such as California, require a petition to destroy the sample and expunge the DNA profile from the database. There are two major reasons for sample retention. First, the sample is needed for confirmatory processes for the purpose of quality assurance and control. In confirmatory processes, the DNA analysis of the original sample is repeated and compared against the prior analysis. Second, the retention of samples allows for possible retesting if new technology becomes available. It also allows retesting of a sample for purposes of updating with expanded loci. Considerable debate has surrounded the retention of samples. It can be argued from the opposite perspective that the database could reveal private genetic information that could then be misused. The objection is based on concern for the protection of privacy rights. If a sample were made available to an unauthorized person, confidential information could be disclosed.

24.5 Database Expansion

Currently, all 50 states have authorized the collection of samples from convicted felons for DNA databasing. Over the years, the demand for the utilization of databases has increased sharply (Figure 24.4). More jurisdictions are incorporating more felonies into the lists of crimes that require DNA profiles, and some jurisdictions plan to include all felonies in such databases. Additionally, the database system is projected to include the profiles of minor criminals, because statistics show that most offenders found guilty of serious crimes were previously convicted for minor crimes. Broadening the size of the database and including samples from more types of crimes could lead to the assumption that the number of crimes solved would also increase. Although state laws vary, each state has its own statute governing the entry criteria of the database samples. More and more states are authorizing the collection of additional types of DNA samples, including individuals convicted of misdemeanor crimes and adult felony arrestees who have not yet been convicted for the offense. It is known that offenders tend to commit multiple

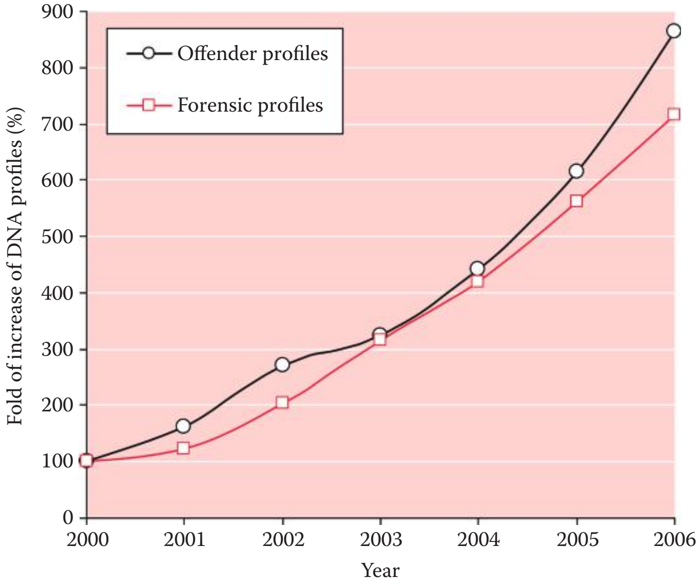

Figure 24.4 Growth of the CODIS database. In 2000, 460,365 offender profiles and 22,484 forensic profiles were entered.

crimes. Thus, including DNA profiles of arrestees in the database is beneficial in catching serial offenders and potentially preventing future crimes. Virginia is the first state to collect DNA from violent-felony arrestees, among other crimes. Over the years, more than half of states in the United States have amended their law to include all felony arrestees or a subset of arrestees for felonies that involve violence or sexual assault.

In 2009, Alonzo King was arrested in Wicomico County, Maryland, on violent assault charges. Maryland's DNA Collection Act authorizes law enforcement agencies to collect DNA samples from an individual who is arrested for violent crimes. During the booking process, under state law, King's buccal swabs were collected for forensic DNA identification. When King's DNA profile was entered into Maryland's SDIS, it matched to a crime scene DNA profile from an unsolved rape case in 2003. Based on the DNA evidence, King was indicted for first-degree rape by a grand jury. The defendant filed a motion to suppress the DNA evidence. King argued that using his DNA to investigate his connection to the 2003 rape was an unreasonable search and seizure under the Fourth Amendment, since the police had no reason to suspect his involvement in the 2003 rape. During the trial at Wicomico County Circuit Court, King's motion was denied. He was convicted of rape and sentenced to life in prison. The Court of Appeals of Maryland, the state's highest court, upheld that the DNA Collection Act was constitutional. The police had probable cause to arrest King on the assault charge, and thus collecting King's DNA sample was a reasonable search. However, the court overturned the low court and reversed King's conviction. It stated that the DNA Collection Act was inappropriately applied to King in this case. Thus, investigating King without probable cause for the unrelated rape was unconstitutional. To determine whether the Fourth Amendment permits states to collect and analyze the DNA of arrestees, a divided Supreme Court ruled 5–4 and reversed the Court of Appeals. The Supreme Court's judgment ruled that Maryland has the right to collect DNA evidence from individuals arrested for serious crimes. The ruling reflects the Supreme Court's view on the balance between the interest of criminal justice systems in solving violent crimes and an individual's interest in the Fourth Amendment, which protects them from unreasonable searches.

Some jurisdictions, such as the United Kingdom, allow DNA samples to be taken from individuals suspected of committing recordable offenses that may lead to prison sentences. In contrast, DNA profiles from suspects are not eligible for entry into CODIS. In some jurisdictions, it has been suggested that databases include many more offenders and suspects, as well as the general public. One advantage of including an entire population in a database is the ability to identify missing, kidnapped, and abducted individuals in addition to victims of major accidents and mass fatalities. Nevertheless, debates concerning the need to balance the benefits and dangers of developing a broader database will inevitably continue.

24.6 DNA Profiles

Currently, the CODIS software supports the storage and search of DNA profiles of short tandem repeat (STR), Y chromosome STR (Y-STR), and mitochondrial DNA (mtDNA). Y-STR and mtDNA profiles may only be searched within NMPDD-related indexes. The CODIS software no longer supports searches of DNA profiles generated by restriction fragment length polymorphism (RFLP) analysis. The 13 core CODIS STR loci are CSF1PO, FGA, THO1, TPOX, VWA, D3S1358, D5S818, D7S820, D8S1179, D13S317, D16S539, D18S51, and D21S11. DNA profiles are entered into one of the indexes, such as convicted offender, arrestee, forensic, unidentified human remains, missing person, or a relative of a missing person. There is a minimum loci requirement for each DNA profile entering CODIS: 13 core CODIS loci are required for a DNA profile entering the Convicted Offender Index and the Arrestee Index; 13 core CODIS loci and amelogenin, a sex-typing marker, are required for a DNA profile entering the Relatives of Missing Person Index; at least 10 CODIS loci are required (all 13 core loci must be tested) for the Forensic Index; and at least 8 loci and amelogenin are required (all 13 core loci must be tested) for the Missing Person and Unidentified Human Remains Index. The DNA profiles must be generated by an accredited and audited laboratory in accordance with the FBI's Quality Assurance Standards using approved commercially available kits. As the database is growing rapidly, the chances of finding incidental matches among DNA profiles is increasing. To increase discrimination power, it has recently been proposed that CODIS core loci be expanded to include 20 or more markers (Chapter 20). Additionally, the expanded core loci share additional loci compatible with international standards for forensic DNA analysis, which facilitates the exchange of information with international law enforcement agencies.

24.7 Routine Database Searches for Forensic Investigations

The ultimate goal of the database utilization is to provide investigative leads for law enforcement in solving crimes, particularly in cases where no suspect has yet been identified. Currently, DNA profiles uploaded to NDIS are automatically searched once a week (Figure 24.5). A hit is a match made from the information provided by comparing a target DNA profile against the DNA profiles contained in the database. There are two types of CODIS hits: an *offender hit* provides the identity of a potential suspect of a crime, while a *forensic hit* reveals the linkage between two or more crime scenes. Once a hit is identified, the match is verified by the laboratories that originally processed the evidence. A verified CODIS hit can be utilized as probable cause to allow law enforcement to obtain a court order to collect a DNA sample from a suspect. Collecting DNA with a warrant ensures admissibility in court. *Investigation-aided* cases are those assisted by CODIS hits, including case-to-case matches as well as case-to-offender matches. The number of investigations aided is a useful measure of the successful application of the database (Figure 24.6). As of April 2013, over 207,800 hits had been made with CODIS assistance in more than 199,200 investigations.

24.7.1 Case-to-Offender Searches

Matches of profiles from the Forensic Index and the Offender Index reveal the identities of perpetrators of crimes. For example, in 1998, a Florida man, Leon Dundas, became a suspect in a rape case but refused to provide his DNA reference sample for testing. Dundas was killed a year later in an illegal drug deal. Thus, a postmortem sample of Dundas was obtained and his DNA profile was compared with the Forensic Index of CODIS. It was discovered that Dundas's profile

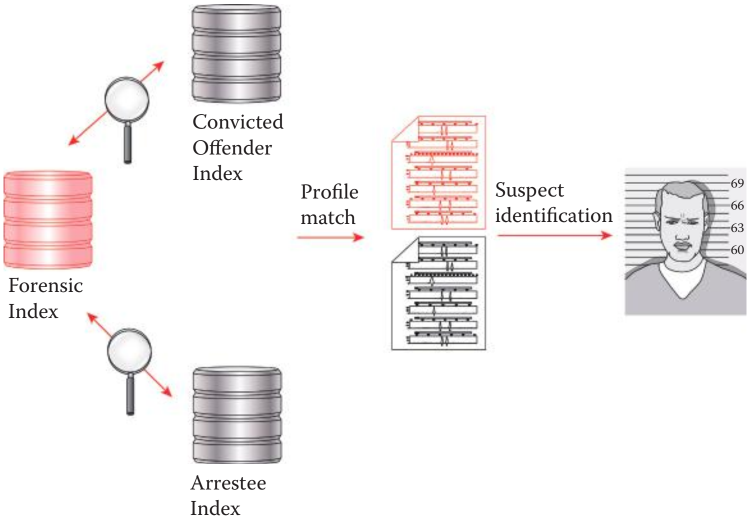

Figure 24.5 Example of a weekly routine CODIS search. (© Richard C. Li.)

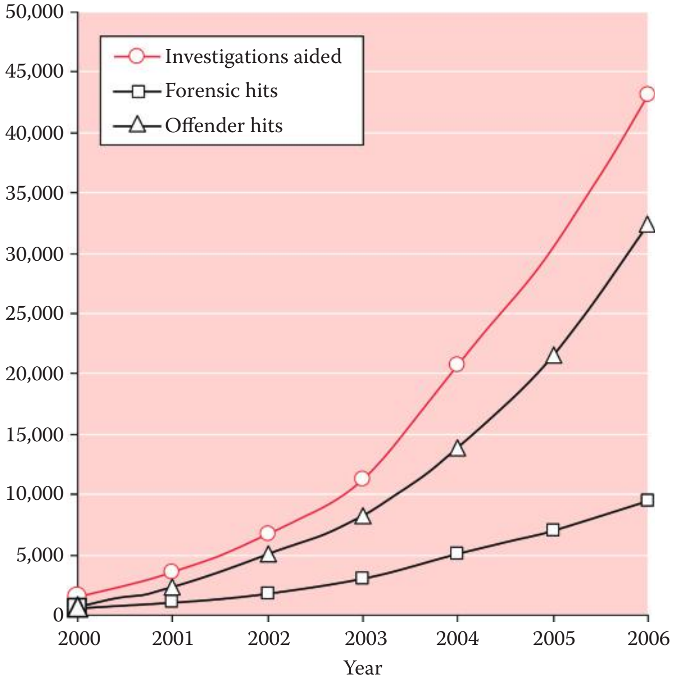

Figure 24.6 Number of hits and investigations aided by the CODIS database.

matched the DNA sample found in the rape case. Additionally, his DNA profile was linked to several other unsolved rapes in Jacksonville and Washington, DC. Such cases can now be solved by utilizing DNA databases.

24.7.2 Case-to-Case Searches

A target DNA profile from a crime scene is also searched against the profiles stored in the Forensic Index of the database. Matches of profiles among the target profile and the profile in the Forensic Index can link separate crime scenes and aid in identifying serial offenders. This helps law enforcement agencies in multiple jurisdictions to coordinate their investigations and share leads. For example, in 1996, two young girls were abducted from bus stops in St. Louis. Both girls were raped and DNA samples were collected. Both DNA profiles pointed to the same perpetrator. In 1999, the St. Louis police decided to reanalyze the samples using new STR technology through the CODIS database. The database found a match to a different rape case, to which the perpetrator, Dominic Moore, had already confessed, thus identifying him as the perpetrator of the 1996 rapes.

24.7.3 Search Stringency and Partial Matches

Database searches are carried out using the CODIS software with three stringency levels, which allow the search of complex forensic profiles against offender profiles (Figure 24.7). A high-stringency match requires an exact match in which all alleles are matched at each locus between the target and candidate profiles. A moderate-stringency match, as defined by the FBI, is a candidate match "between two single source profiles having at each locus all of the alleles of one sample represented in the other sample." In a moderate-stringency match, allelic drop-outs in a target or candidate profile are allowed, possibly resulting in a partial match at some loci. As a result, high-stringency matches are automatically included in a moderate-stringency

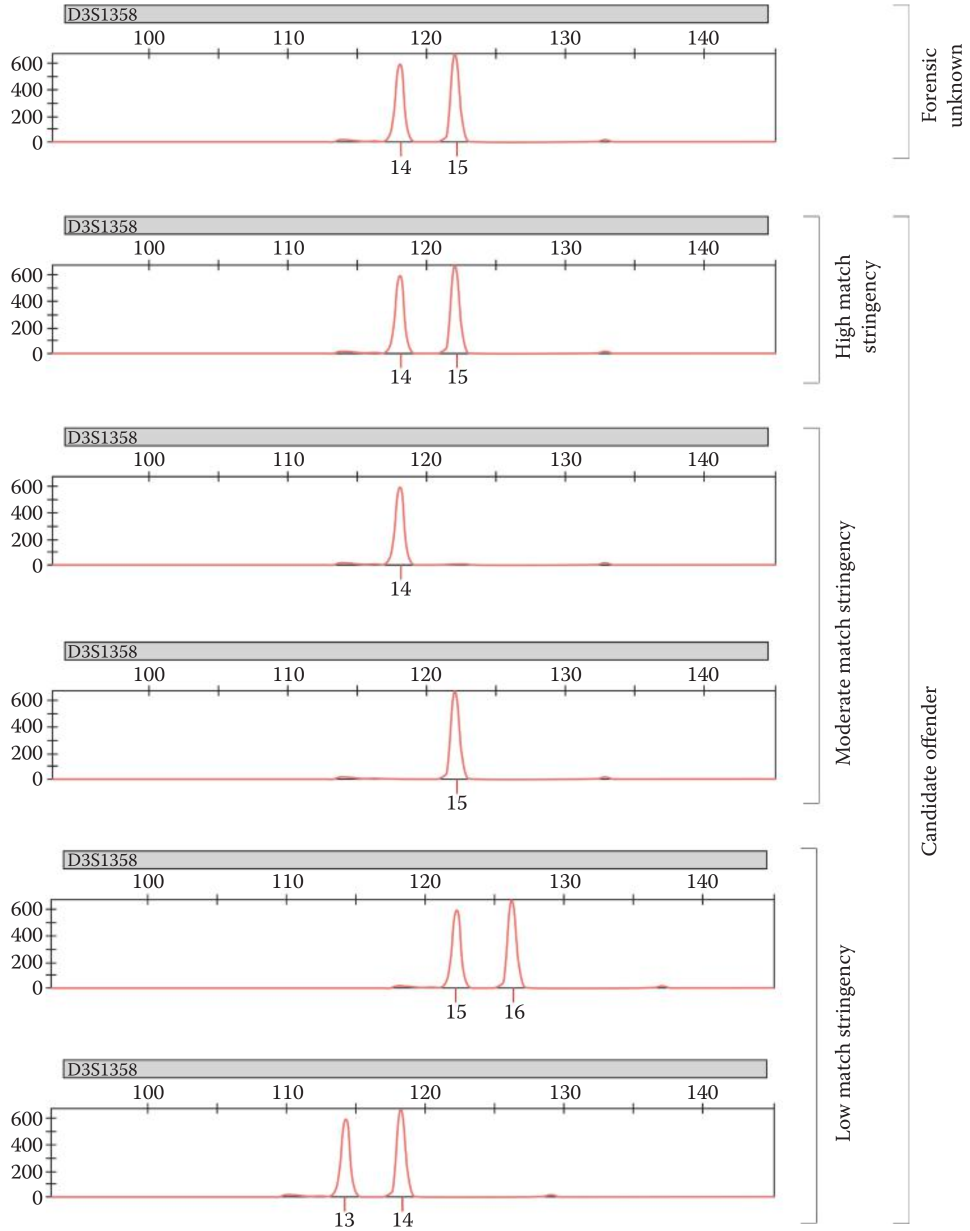

Figure 24.7 Diagram of match stringencies. A heterozygote (allele 14 and 15) at locus D3S1358 is utilized as the genotype for the forensic unknown profile. (© Richard C. Li.)

search. In a low-stringency search, both mismatches and allelic dropouts are allowed. Presently, NDIS searches are only carried out at moderate stringency. During forensic DNA analysis, DNA degradation may prevent full DNA profiles from being processed, producing only partial profiles. Additionally, mixture profiles derived from forensic samples containing DNA contributed by more than one individual may be encountered. Furthermore, due to mutations, null alleles may occur in the profiles produced with some primer sets but not other primers. Therefore, searching at moderate stringency allows the detection of matches under the situations described above.

Such moderate-stringency searches between the Forensic Index and Offender Index may occasionally generate partial match profiles. Since a partial match is not an exact match of the two profiles, further investigation is needed. For instance, additional Y-STR and mtDNA analysis is needed to eliminate unrelated individuals.

24.8 Familial Searches

Familial search, initiated in the United Kingdom, is a new method of applying databases in criminal investigations. It is known that, in the United States, nearly half of prison inmates have close relatives who have also been incarcerated. Familial search is based on the assumption that close relatives share more alleles of DNA profiles than unrelated individuals. Thus, databases may be utilized to identify perpetrators by finding a close relative, if the close relative has been convicted of a crime and is listed in the database. Familial search is an intentional search of a target crime scene profile against an offender database to obtain a list of candidate profiles that are similar to the target profile. This list may include the profile of a close relative of the perpetrator, who is the source of crime scene evidence. These matches most frequently involve siblings, parents, or children. The investigative leads produced by familial searches allow law enforcement to conduct further investigations to identify the perpetrator.

The first familial search leading to a successful prosecution was conducted in Surrey, England. In 2003, a truck driver was killed after a brick was thrown through his windshield from a bridge. The perpetrator's DNA profile was obtained from the brick. A search of the UK's national DNA database revealed no match for the perpetrator. Next, a familial search of the database was conducted. The system identified a close relative that led police to identify the perpetrator, Craig Harman, who was then convicted of manslaughter.

24.8.1 Legal and Ethical Issues of Familial Search

The use of forensic databases involves a balance of individual civil rights and the interests of the criminal justice systems. Many concerns have been raised, including the potential for these searches to violate the privacy of unrelated people whose genetic profiles happen to resemble those of individuals included in the databases. In the United States, the Fourth Amendment protects against unreasonable searches and seizures. The permissibility of familial searching under the Fourth Amendment is yet to be addressed by courts. The collection of biological material for the initial creation of a profile for law enforcement purposes is subject to the Fourth Amendment implications. In terms of familial searches, some legal experts argue that the biological materials are not collected directly from the individuals for a familial search, and that these individuals may thus be protected under the Fourth Amendment. Others argue, however, that the Fourth Amendment protects the initial creation of the profile, including the sample collection, forensic DNA analysis, and the databasing. They argue that the Fourth Amendment may not protect subsequent investigations of DNA profiles during familial searches. In addition, the CODIS database consists of a high percentage of profiles from individuals of racial minority groups, including African Americans. Familial searches can disproportionately focus on a specific racial group.

Familial searches are rare in the United States. Two jurisdictions, Maryland and the District of Columbia, have laws prohibiting the use of familial searches. Familial searches are not conducted at the NDIS. While familial searches are now being performed in several jurisdictions in the United States, policies on familial searches vary among jurisdictions. The major issues relate to criteria for privacy, information release, search approval, and the types of crimes eligible for familial searches. Currently, California, Colorado, Texas, and Virginia have state legislation permitting familial searches. Familial searches are initiated when a specific suspect is not known, and the cause for the search needs to be justified. Familial searches are usually conducted for crimes that pose a substantial threat to public safety, typically those cases involving the most serious offenses. Additionally, familial searches are only conducted after a routine search of a DNA profile has yielded no match in the database.

In 2003, for example, a crime scene DNA sample of a closed rape and murder case, committed decades previously, was reanalyzed using forensic DNA techniques. The crime scene DNA profile was compared to the profile of a man, Darryl Hunt, who was then imprisoned for the crime. Surprisingly, the crime scene DNA profile did not match either that of Hunt or those of convicted felons in the database. However, the database search revealed a close relative of the true perpetrator and thus led law enforcement to identify Willard Brown as the perpetrator. Brown was sentenced to life imprisonment. Additionally, Hunt was exonerated after 18 years in prison.

24.8.2 Familial Search Strategies

The familial search is usually carried out using specially designed software. Although the CODIS software is not designed for familial search, it can be used for familial search through a low-stringency search, which may result in a list of candidate profiles including close relatives of individuals, such as parent–offspring or full-sibling relatives. In a large offender DNA database, similar DNA profiles from unrelated people are often observed due to shared alleles. Therefore, the candidate profile list may also include unrelated individuals whose DNA profiles are similar to the target profile. As a result, a familial search can provide a list of potential candidates consisting of hundreds of profiles, which would be too labor intensive to pursue through further investigations. Several methods can be used to determine a cutoff analytical threshold in order to limit a pool of candidate profiles and exclude unrelated individuals from familial searches (Figure 24.8).

24.8.2.1 Identity-by-State and Kinship Index Method

The *identity-by-state* (IBS) method compares the number of shared alleles and loci between a target forensic profile and the offender profiles in a database but does not take into account allele frequencies. The analytical threshold for a familial search is determined by a preset number of shared alleles or loci in order to prompt further investigation. For example, some states use 15 shared alleles as the analytical threshold to be considered as a candidate, while other states require at least one shared allele for each locus. Additionally, this method can prioritize a pool of candidates based on the highest to the lowest number of shared alleles for investigation.

The *Kinship Index* (KI) method is a likelihood ratio–based method that evaluates the familial match by comparing the probability that two DNA profiles are from related individuals to the probability that they are unrelated. The KI method analyzes the allele frequency data, including all CODIS core loci, to calculate the Combined Kinship Index. The KI may vary based on the allele frequency data across the population. Thus, the accuracy of the KI method relies on the relevance of the population data set analyzed. False inclusions or exclusions may occur if nonrelevant population data are utilized. The KI method also allows the generation of a ranked candidate list according to the probability that the individuals are related. Generally speaking, the accuracy of the KI method is higher than that of the IBS method. However, using both IBS and KI methods is better than using a single method alone for familial search.

24.8.2.2 Focusing on Rare Alleles

During a familial search, target DNA profiles may contain rare alleles with low allelic frequencies. The chance of sharing rare alleles for two close relatives is higher than for two unrelated individuals. If a target profile carries a rare allele, it can be used to narrow the pool of candidates.

For example, Jeffrey Gafoor, then 23, had been living in a suburban neighborhood in Cardiff, Wales. He had a reputation for being a loner. Besides working in his family-owned shop, he spent most of his time at home. On February 13, 1988, Gafoor entered 7 James Street in the Butetown area of Cardiff. The first-floor unit was temporarily occupied by Lynette White, a 20-year-old

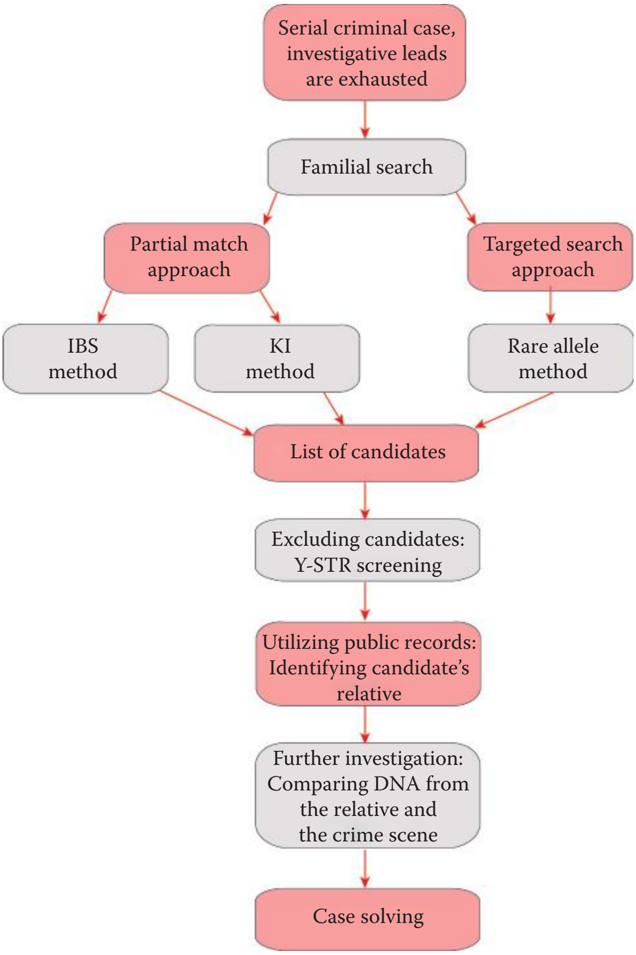
Serial criminal case, investigative leads are exhausted
Familial search
Partial match approach
Targeted search approach
IBS method
KI method
Rare allele method
List of candidates
Excluding candidates: Y-STR screening
Utilizing public records: Identifying candidate's relative
Further investigation: Comparing DNA from the relative and the crime scene
Case solving

Figure 24.8 Example of a familial search workflow. (© Richard C. Li.)

woman who was working as a prostitute in the area. Gafoor went there for the purpose of receiving sexual services. He left the scene in the early hours of Valentine's Day. On Valentine's night, White's body was discovered. She suffered from more than 50 stab, cut, and slash wounds as well as defensive wounds on her hands. The body was dragged to the corner of the room adjacent to the bed, the only piece of furniture in the room.

Gafoor left blood and semen evidence at the scene. He bled during the murder and deposited bloodstains at the scene. Additionally, he left seminal stains at the scene; the semen had no measurable level of sperm and most likely came from an individual who had a medical condition known as azoospermia (Chapter 14). After the murder, Gafoor lived at the same place as he did beforehand and kept the same job for many years.

Two years later, three local men, known as the "Cardiff Three," were convicted of White's murder and sentenced to life in prison. In 1992, however, their convictions were reversed by the court of appeal. Subsequently, the crime scene evidence was tested using new techniques in forensic DNA analysis that were not available in 1988. A DNA profile was obtained from the crime scene. A familial search revealed a similar profile from a 14-year-old boy in the UK National DNA Database. In particular, there was a rare allele match between the crime scene and the candidate DNA profiles. This search led to the further investigation of Gafoor, who was the uncle of the boy. Gafoor was charged with murder.

24.8.2.3 Excluding Candidates through Y-STR Screening

The vast majority of DNA profiles in CODIS come from males. Patrilineal markers, such as Y-STR loci, are successfully utilized to screen the candidates to verify the relationship between two individuals. This analysis helps to identify first-order relatives as well as paternal half-siblings. STR loci beyond the CODIS core loci and maternal lineage makers, such as mitochondrial DNA typing systems, can be used to narrow the pool of candidates and eliminate coincidental partial matches. One or more of these methods can be incorporated to evaluate highly ranked candidates.

For example, Lonnie Franklin lived in a southern Los Angeles neighborhood. Throughout the 1980s, Franklin worked for the city as a maintenance worker and a sanitation truck operator. His neighbors recalled that he often brought prostitutes to a camper parked in the backyard of his house. He also took photos of nude women, which he kept in his garage. Nevertheless, to many of his neighbors, Franklin seemed to be a friendly person who often chatted with them.

Since 1985, the bodies of many women, most of which were prostitutes, had been dumped in an alley running along Western Avenue in a southern Los Angeles neighborhood. The victims had been shot and some had been strangled after sexual contact. DNA and ballistics analysis revealed that at least 10 of the murders had been committed by the same perpetrator. The perpetrator was known to the general public as the “Grim Sleeper” because he had taken a 14-year break during the period in which these 10 murders had taken place. The crime scene DNA profile did not match any profile in the database.

In 2008, the first familial search of the “Grim Sleeper” case was conducted by the California Department of Justice. California state law allows familial searches for high-profile cases if all other leads have been exhausted. However, all candidate DNA profiles were excluded through Y-STR screening. As a result, no candidate was identified as a possible relative of the “Grim Sleeper.” In 2010, a second search targeted partial matches that shared at least 15 alleles. It produced a list of 100 candidate profiles ranked by the likelihood that they were related. Y-STR was used as a screen tool to identify possible patrilineal relatives. This time, the search generated a match to a new DNA profile of a felon, which had recently been entered into California’s SDIS, in 2009. The search suggested that the candidate was a relative of the source of the DNA from the crime scenes. This search led to the identification of Franklin as a suspect in the “Grim Sleeper” murders. Police detectives conducted surveillance and collected a discarded slice of pizza and a cup used by Franklin at a local restaurant for DNA identification. The DNA profile was identical to the crime scene DNA profiles. Franklin was arrested and was charged with ten counts of murder and one of attempted murder.

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25

Evaluation of the Strength of Forensic DNA Profiling Results

25.1 A Review of Basic Principles of Genetics

25.1.1 Mendelian Genetics

Mendel's first law is the principle of segregation of alleles. Each pair of alleles segregates from others in the formation of gametes (mature reproductive cells such as spermatozoa and oocytes). One-half of the gamete carries one allele, and the other half carries the other allele.

Mendel's second law is the principle of independent assortment of alleles. The segregation of each pair of alleles is independent of the segregation of other pairs during the formation of gametes.

Gametes are formed during a process known as *meiosis*, in which cells with haploid chromosome numbers (23 in humans) are produced by the division of cells with diploid chromosome numbers (46 in humans). A fertilized human egg thus contains a diploid number of chromosomes. A diploid is composed of 22 pairs of autosomes and 2 sex chromosomes (XX in females and XY in males).

Based on Mendelian principles, genes on different chromosomes assort independently of one another in gamete production. Genes residing very closely together on the same chromosome are usually inherited together. Thus, they do not assort independently and are called *linked genes*. Genes distant from each other on the same chromosome are usually inherited separately. This results from an exchange of segments between a pair of *homologous* chromosomes when the chromosomes are paired during the early phases of meiotic division. These types of gene-exchange events on homologous chromosomes are collectively called *crossing over*, which results in the *recombination* of genes in a pair of chromosomes (Figure 25.1).

The Mendelian inheritances of genes can often be measured using *probabilities*. A probability is the ratio of the number of actual occurrences of an event to the number of possible occurrences. Additionally, the probability of two independent events occurring simultaneously is the product of each of their individual probabilities; this is known as the *product rule of probability*.

Mendelian principles apply to the inheritance of loci of the autosomal nuclear DNA genome commonly used for forensic testing. The Y-chromosomal genome is inherited paternally, which does not obey the rules for Mendelian principles. Mitochondria contain their own mitochondrial genomes and are inherited maternally. This maternal inheritance

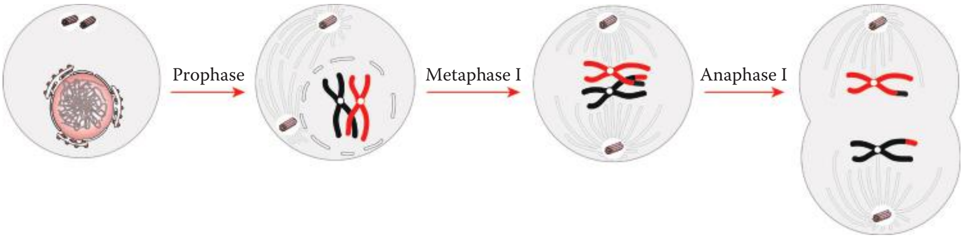

Figure 25.1 Crossing over hypothesis. Chromosomes are replicated prior to the first meiotic division. Each duplicate is called a chromatid, which forms into tetrads in the prophase. A crossover event occurs between the maternal and the paternal chromatids. Each chromatid breaks at the point of the cross and fuses with a portion of its counterpart. Chromosomes are associated with the microtubules during metaphase I and are pulled toward the spindle poles during anaphase I. The maternal and paternal homologs of one chromosome are shown. (© Richard C. Li.)

of mitochondrial genes also does not obey the rules for Mendelian principles. The inheritance of Y-chromosomal and mitochondrial genomes is referred to as non-Mendelian inheritance.

25.1.2 Population Genetics

Population genetics studies the causes of patterns of genetic variations within and among populations.

25.1.2.1 Allele Frequency

Allele frequency (p) can be calculated directly by counting the number of alleles of one type at a given locus and dividing it by the total number of alleles at that locus in a sampled population. This is called the *gene counting* method.

25.1.2.2 Genotype Frequency

Genotype frequency (P) observed at a given locus can be calculated by dividing the number of individuals with one genotype by the total number of individuals in a sampled population. Each genotype at the locus can be calculated separately. The summation of all genotype frequencies at that locus should equal 1.

25.1.2.3 Heterozygosity

Heterozygosity is the proportion of alleles, at a given locus, that are heterozygous and is calculated as

$$h = 1 - \sum_i p^2 \qquad (25.1)$$

where:

h = heterozygosity
p = allelic frequency of the locus for homozygotes

The amount of heterozygosity at a locus in a sampled population is a measure of genetic variation. The higher the heterozygosity, the more variation there is at a given locus.

25.1.2.4 Hardy–Weinberg Principle

The Hardy–Weinberg (HW) principle, independently discovered by two scholars in the early 1900s, allows predictions of genotype frequencies to be made based on allelic frequencies. However, certain conditions must be met. The population must be large; mate randomly; and lack mutation, migration, and natural selection. If these conditions of the HW principle are met, the population will be in *equilibrium*, and the following results are expected:

1. The frequencies of the alleles will not change from one generation to the next.
2. Genotype frequencies can be predicted by the allelic frequencies (p^2 and q^2 for genotype frequencies of homozygotes and $2pq$ for genotype frequencies of heterozygotes). The sum of the genotype frequencies should equal 1.

$$p^2 + 2pq + q^2 = 1 \tag{25.2}$$

If the observed genotype proportions are different from those expected, one or more of the HW assumptions have been violated.

25.1.2.5 Testing for HW Proportions of Population Databases

To determine whether the genotypes of a population in question obey the HW principle, a population database can be constructed. Samples (usually 100–200 samples for STR loci) are collected and analyzed at the loci of interest. Allelic frequencies are obtained by using the gene counting method. Table 25.1 shows the allelic frequencies of CODIS loci from a population database. The *observed genotype frequencies* at a given locus, as described earlier in Section 25.1.2.2, are calculated by dividing the number of individuals with one genotype by the total number of individuals in the population sampled. The *expected genotype frequencies* are calculated using p^2, $2pq$, and q^2.

The observed and expected genotype frequencies are then compared using a chi-square test. The significance of the differences between observed and expected genotype frequencies can then be determined. The chi-square is calculated using the following formula:

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \tag{25.3}$$

where:
O_i = ith observed genotype frequency
E_i = ith expected genotype frequency
n = total number of genotypes

Chi-square (χ^2) is calculated as the sum of all genotypes of a given locus.

The chi-square value and the degrees of freedom (the number of genotypes minus the numbers of alleles) are then used to obtain a p value (not to be confused with the allelic frequency designated p) from a table of p values, and such tables can be found at the backs of most statistics textbooks. If the p value exceeds 0.05 (5% significance level), the deviation of the expected genotype frequencies from the observed genotype frequencies is not considered statistically significant. Thus, the null hypothesis that the observed genotype frequencies fit the expected genotype frequencies predicted by the HW principle is not rejected if the p value is greater than 0.05.

Table 25.1 Allelic Frequencies of 13 CODIS STR Loci

Allele	Allelic Frequency (%)		
	African American	Caucasian	Hispanic
D3S1358	(*N*=210)	(*N*=203)	(*N*=209)
<12	0.476	0.000	0.000
12	0.238	0.000	0.000
13	1.190	0.246	0.239
14	12.143	14.039	7.895
15	29.048	24.631	42.584
15.2	0.000	0.000	0.000
16	30.714	23.153	26.555
17	20.000	21.182	12.679
18	5.476	16.256	8.373
19	0.476	0.493	1.435
>19	0.238	0.000	0.239
VWA	(*N*=180)	(*N*=196)	(*N*=203)
11	0.278	0.000	0.246
13	0.556	0.510	0.000
14	6.667	10.204	6.158
15	23.611	11.224	7.635
16	26.944	20.153	35.961
17	18.333	26.276	22.167
18	13.611	22.194	19.458
19	7.222	8.418	7.143
20	2.778	1.020	1.232
21	0.000	0.000	0.000
FGA	(*N* = 180)	(*N* = 196)	(*N* = 203)
<18	0.278	0.000	0.000
18	0.833	3.061	0.246
18.2	0.833	0.000	0.000
19	5.278	5.612	7.882
19.2	0.278	0.000	0.000
20	7.222	14.541	7.143
20.2	0.000	0.255	0.246
21	12.500	17.347	13.054

Table 25.1 (Continued) Allelic Frequencies of 13 CODIS STR Loci

Allele	Allelic Frequency (%)		
	African American	Caucasian	Hispanic
21.2	0.000	0.000	0.246
22	22.500	18.878	17.734
22.2	0.556	1.020	0.493
22.3	0.000	0.000	0.000
23	12.500	15.816	14.039
23.2	0.000	0.000	0.739
24	18.611	13.776	12.562
24.2	0.000	0.000	0.000
24.3	0.000	0.000	0.000
25	10.000	6.888	13.793
26	3.611	1.786	8.374
27	2.222	1.020	3.202
28	1.667	0.000	0.246
29	0.556	0.000	0.000
30	0.278	0.000	0.000
>30	0.278	0.000	0.000
D8S1179	($N = 180$)	($N = 196$)	($N = 203$)
<9	0.278	1.786	0.246
9	0.556	1.020	0.246
10	2.500	10.204	9.360
11	3.611	5.867	6.158
12	10.833	14.541	12.069
13	22.222	33.929	32.512
14	33.333	20.153	24.631
15	21.389	10.969	11.576
16	4.444	1.276	2.463
17	0.833	0.255	0.739
18	0.000	0.000	0.000
D21S11	($N = 179$)	($N = 196$)	($N = 203$)
24.2	0.279	0.510	0.246
24.3	0.000	0.000	0.000

(*continued*)

Table 25.1 (Continued) Allelic Frequencies of 13 CODIS STR Loci

Allele	Allelic Frequency (%)		
	African American	Caucasian	Hispanic
26	0.279	0.000	0.000
27	6.145	4.592	0.985
28	21.508	16.582	6.897
29	18.994	18.112	20.443
29.2	0.279	0.000	0.246
30	17.877	23.214	33.005
30.2	0.838	3.827	3.202
30.3	0.000	0.000	0.000
31	9.218	7.143	6.897
31.2	7.542	9.949	8.621
32	0.838	1.531	1.232
32.1	0.000	0.000	0.000
32.2	6.983	11.224	13.547
33	0.838	0.000	0.000
33.2	3.352	3.061	4.187
34	0.838	0.000	0.000
34.2	0.279	0.000	0.493
35	2.793	0.000	0.000
35.2	0.000	0.255	0.000
36	0.559	0.000	0.000
>36	0.559	0.000	0.000
D18S51	($N = 180$)	($N = 196$)	($N = 203$)
<11	0.556	1.276	0.493
11	0.556	1.276	1.232
12	5.833	12.755	10.591
13	5.556	12.245	16.995
13.2	0.556	0.000	0.000
14	6.389	17.347	16.995
14.2	0.000	0.000	0.000
15	16.667	12.755	13.793
15.2	0.000	0.000	0.000
16	18.889	10.714	11.576

Table 25.1 (Continued) Allelic Frequencies of 13 CODIS STR Loci

Allele	Allelic Frequency (%)		
	African American	Caucasian	Hispanic
17	16.389	15.561	13.793
18	13.056	9.184	5.172
19	7.778	3.571	3.695
20	5.556	2.551	1.724
21	1.111	0.510	1.970
21.2	0.000	0.000	0.000
22	0.556	0.255	0.739
>22	0.556	0.000	1.232
D5S818	(*N* = 180)	(*N* = 195)	(*N* = 203)
7	0.278	0.000	6.158
8	5.000	0.000	0.246
9	1.389	3.077	5.419
10	6.389	4.872	6.650
11	26.111	41.026	42.118
12	35.556	35.385	29.064
13	24.444	14.615	9.606
14	0.556	0.769	0.493
15	0.000	0.256	0.246
>15	0.278	0.000	0.000
D13S317	(*N* = 179)	(*N* = 196)	(*N* = 203)
7	0.000	0.000	0.000
8	3.631	9.949	6.650
9	2.793	7.653	21.921
10	5.028	5.102	10.099
11	23.743	31.888	20.197
12	48.324	30.867	21.675
13	12.570	10.969	13.793
14	3.631	3.571	5.665
15	0.279	0.000	0.000
D7S820	(*N* = 210)	(*N* = 203)	(*N* = 209)
6	0.000	0.246	0.239

(*continued*)

Table 25.1 (Continued) Allelic Frequencies of 13 CODIS STR Loci

Allele	Allelic Frequency (%)		
	African American	Caucasian	Hispanic
7	0.714	1.724	2.153
8	17.381	16.256	9.809
9	15.714	14.778	4.785
10	32.381	29.064	30.622
10.1	0.000	0.000	0.000
11	22.381	20.197	28.947
11.3	0.000	0.000	0.000
12	9.048	14.039	19.139
13	1.905	2.956	3.828
14	0.476	0.739	0.478
CSF1PO	($N = 210$)	($N = 203$)	($N = 209$)
6	0.000	0.000	0.000
7	4.286	0.246	0.239
8	8.571	0.493	0.000
9	3.333	1.970	0.718
10	27.143	25.369	25.359
10.3	0.000	0.246	0.000
11	20.476	30.049	26.555
12	30.000	32.512	39.234
13	5.476	7.143	6.459
14	0.714	1.478	0.957
15	0.000	0.493	0.478
TPOX	($N = 209$)	($N = 203$)	($N = 209$)
6	8.612	0.000	0.478
7	2.153	0.246	0.478
8	36.842	54.433	55.502
9	18.182	12.315	3.349
10	9.330	3.695	3.349
11	22.488	25.369	27.273
12	2.392	3.941	9.330
13	0.000	0.000	0.239
TH01	($N = 210$)	($N = 203$)	($N = 209$)

Table 25.1 (Continued) Allelic Frequencies of 13 CODIS STR Loci

Allele	Allelic Frequency (%)		
	African American	Caucasian	Hispanic
5	0.000	0.000	0.239
6	10.952	22.660	23.206
7	44.048	17.241	33.732
8	18.571	12.562	8.134
8.3	0.000	0.246	0.000
9	14.524	16.502	10.287
9.3	10.476	30.542	24.163
10	1.429	0.246	0.239
D16S539	($N = 209$)	($N = 202$)	($N = 208$)
8	3.589	1.980	1.683
9	19.856	10.396	7.933
10	11.005	6.683	17.308
11	29.426	27.228	31.490
12	18.660	33.911	28.606
13	16.507	16.337	10.337
14	0.957	3.218	2.404
15	0.000	0.248	0.240

Source: Budowle, B., et al., *J Forensic Sci*, 44, 1277–1286, 1999. With permission.

25.1.2.6 Probability of Match

The discriminating power of genetic loci used above can be measured by *population match probability* (P_m). P_m is defined as the probability of having a matching genotype between two randomly chosen individuals. The lower the P_m, the less likely a match between two randomly chosen individuals will occur. This is calculated as follows:

$$P_m = \sum_i \left(p^2\right)^2 + \sum_j \left(2pq\right)^2 \tag{25.4}$$

where:

p and q = the frequencies of two different alleles

P_m can also be used to compare the discriminating powers of different loci

Tables 25.2 through 25.4 show P_m values of loci commonly used for forensic applications, including SNP, VNTR, and STR.

Table 25.2 Heterozygosity and P_m Values of Six SNP Loci

Locus	Allele	Heterozygosity	P_m
DQA1	7	0.828	0.053
LDLR	2	0.493	0.379
GYPA	2	0.498	0.376
HBGG	3	0.508	0.360
D7S8	2	0.476	0.388
GC	3	0.592	0.235
Average		0.566	
Product			2.5×10^{-4} (1 in 4000)

Source: Office of Justice Programs, National Institute of Justice, US Department of Justice, *The Future of Forensic DNA Testing: Predictions of the Research and Development Working Group*, 2000.

Table 25.3 Heterozygosity and P_m Values of Six VNTR Loci

Locus	Bins	Heterozygosity	P_m
D1S7	28	0.945	0.0058
D2S44	26	0.926	0.0103
D4S139	19	0.899	0.0184
D10S28	24	0.943	0.0063
D14S13	30	0.899	0.0172
D17S79	19	0.799	0.0700
Average		0.902	
Product			8.26×10^{-12} (1 in 1.2×10^{11})

Source: Office of Justice Programs, National Institute of Justice, US Department of Justice, *The Future of Forensic DNA Testing: Predictions of the Research and Development Working Group,* 2000.

25.2 Statistical Analysis of DNA Profiling Results

It is desirable to evaluate the strength of DNA profiling results, particularly if two DNA profiles match. A DNA profile from crime scene evidence and a profile from a suspect may be the same for two reasons: (1) the crime scene sample may have come from the suspect or (2) the suspect happens to have the same profile as the individual who left the evidence found at the crime scene. The significance of a match between DNA profiles can be evaluated by using statistical calculations that determine the rarity of a specific DNA profile in a relevant population. The statistical evaluation of the significance can be included in a case report

Table 25.4 Heterozygosity and P_m Values for CODIS Loci

Locus	Allele	Caucasian American		African American	
		Heterozygosity	P_m	Heterozygosity	P_m
CSF1PO	11	0.734	0.112	0.781	0.081
TPOX	7	0.621	0.195	0.763	0.090
TH01	7	0.783	0.081	0.727	0.109
VWA	10	0.811	0.062	0.809	0.063
D16S539	8	0.767	0.089	0.798	0.070
D7S820	11	0.806	0.065	0.782	0.080
D13S317	8	0.771	0.085	0.688	0.136
D5S818	10	0.682	0.158	0.739	0.112
FGA	19	0.860	0.036	0.863	0.033
D3S1358	10	0.795	0.075	0.763	0.094
D8S1179	10	0.780	0.067	0.778	0.082
D18S51	15	0.876	0.028	0.873	0.029
D2S11	20	0.853	0.039	0.861	0.034
Average		0.7812		0.7866	
Product			1.738×10^{-15} (1 in 5.753×10^{14})		1.092×10^{-15} (1 in 9.161×10^{14})

Source: Office of Justice Programs, National Institute of Justice, US Department of Justice, *The Future of Forensic DNA Testing: Predictions of the Research and Development Working Group*, 2000.

(Figure 25.2). Guidelines for DNA profile interpretation such as those issued by the National Research Council, the DNA Advisory Board, and the European DNA Profiling Group can be consulted.

25.2.1 Genotypes

The approaches to performing statistical analysis are (1) calculation of profile probability and (2) use of the likelihood ratio method. Although profile probability is the most commonly used method because of its simplicity, both approaches lead to the same conclusion.

25.2.1.1 Profile Probability

Profile probability can be calculated based on the following steps:

1. The locus genotype frequency can be calculated as follows; p and q are the allelic frequencies observed in the database for a given allele:

   Locus genotype frequency for homozygotes:

$$P_i = p^2 \tag{25.5}$$

Locus genotype frequency for heterozygotes:

$$P_j = 2pq \tag{25.6}$$

2. Profile probability can then be calculated based on the product rule by multiplying all the locus genotype frequencies calculated as above.

The lower the profile probability is, the less likely that an individual chosen at random will have a coincident match with the DNA profile of the evidence sample. Table 25.5 shows calculations of profile probability from a DNA profile.

25.2.1.1.1 Structured Populations

The above calculation of profile probability is based on the assumption that a randomly selected individual is unrelated to a perpetrator. However, it is likely that the individual and the perpetrator are from the same subpopulation (groups within a population) and are thus not completely independent. Mating is more likely to occur within subpopulations than between subpopulations. As a result, the proportion of homozygotes increases and the proportion of heterozygotes decreases in a subpopulation because individuals in a subpopulation appear to be related.

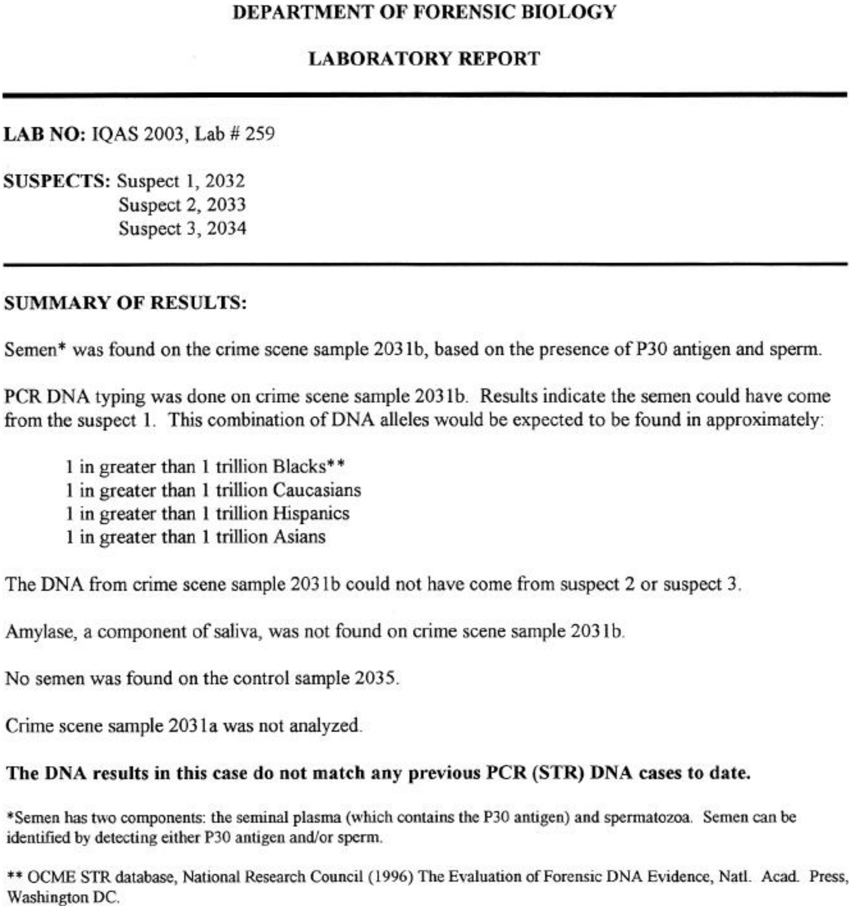

DEPARTMENT OF FORENSIC BIOLOGY

LABORATORY REPORT

LAB NO: IQAS 2003, Lab # 259

SUSPECTS: Suspect 1, 2032
Suspect 2, 2033
Suspect 3, 2034

SUMMARY OF RESULTS:

Semen* was found on the crime scene sample 2031b, based on the presence of P30 antigen and sperm.

PCR DNA typing was done on crime scene sample 2031b. Results indicate the semen could have come from the suspect 1. This combination of DNA alleles would be expected to be found in approximately:

1 in greater than 1 trillion Blacks**
1 in greater than 1 trillion Caucasians
1 in greater than 1 trillion Hispanics
1 in greater than 1 trillion Asians

The DNA from crime scene sample 2031b could not have come from suspect 2 or suspect 3.

Amylase, a component of saliva, was not found on crime scene sample 2031b.

No semen was found on the control sample 2035.

Crime scene sample 2031a was not analyzed.

The DNA results in this case do not match any previous PCR (STR) DNA cases to date.

*Semen has two components: the seminal plasma (which contains the P30 antigen) and spermatozoa. Semen can be identified by detecting either P30 antigen and/or sperm.

** OCME STR database, National Research Council (1996) The Evaluation of Forensic DNA Evidence, Natl. Acad. Press, Washington DC.

Figure 25.2 An example of a laboratory report. (© Richard C. Li.)

Table 25.5 Calculation of Profile Probability of STR Profile with 13 CODIS Loci

Locus	Profile	Allelic Frequency[a]	Formula	Locus Genotype Frequency
CSF1PO	10	0.25369	$2pq$	0.165
	12	0.32512		
D3S1358	14	0.14039	$2pq$	0.0691
	15	0.24631		
D5S818	11	0.41026	p^2	0.168
	11	0.41026		
D7S820	10	0.29064	$2pq$	0.117
	11	0.20197		
D8S1179	13	0.33929	p^2	0.115
	13	0.33929		
D13S317	11	0.31888	p^2	0.102
	11	0.31888		
D16S539	11	0.27228	$2pq$	0.185
	12	0.33911		
D18S51	15	0.12755	$2pq$	0.00911
	19	0.035710		
D21S11	30	0.23214	p^2	0.0539
	30	0.23214		
FGA	23	0.15816	$2pq$	0.0436
	24	0.13776		
TH01	8	0.12562	$2pq$	0.0767
	9.3	0.30542		
TPOX	8	0.54433	p^2	0.296
	8	0.54433		
VWA	17	0.26276	$2pq$	0.117
	18	0.22194		
				Profile probability $= 2.76 \times 10^{-14}$

[a] See Table 25.1.

The effect of population structure should be considered and an appropriate correction should be made to estimate profile probabilities. The correction can be made by using the factor θ. Thus, the locus genotype frequency can be calculated as follows:

Locus genotype frequency for homozygotes:

$$P_i = \frac{\left[2\theta + (1-\theta)p\right]\left[3\theta + (1-\theta)p\right]}{(1+\theta)(1+2\theta)} \tag{25.7}$$

Locus genotype frequency for heterozygotes:

$$P_j = \frac{2\left[\theta + (1-\theta)p\right]\left[\theta + (1-\theta)q\right]}{(1+\theta)(1+2\theta)} \tag{25.8}$$

The θ value is 0.01 for the majority US population and 0.03 for the Native American population. Table 25.6 shows the calculation of profile probability with subpopulation correction using $\theta = 0.01$. The profile probability is approximately three times higher than the value without the correction (Table 25.5). Additional corrections can be calculated for relatives, mixed stains, or database searches using formulas provided by the National Research Council's guidelines.

25.2.1.2 Likelihood Ratio

The *likelihood ratio* (LR) method is an alternative for evaluating the strength of a match. The method allows the calculation of the probability of the DNA profile under two hypothesis:

Hypothesis 1 (H_1) —The evidence and suspect profiles originated from the same source.

Hypothesis 2 (H_2) —The evidence and suspect profiles did not originate from the same source (i.e., the suspect happens to have the same profile as that of the individual who left the evidence).

The LR is the probability of hypothesis H_1 divided by the probability of hypothesis H_2. Where Pr_1 is the probability under hypothesis H_1, and Pr_2 is the probability under hypothesis H_2, this can be expressed as:

$$\mathrm{LR} = \frac{\mathrm{Pr}_1}{\mathrm{Pr}_2} \tag{25.9}$$

The greater the numerator (Pr_1), the greater the likelihood ratio becomes. The result favors hypothesis H_1 (the evidence and suspect profile originated from the same source). Pr_1 is equal to 1 (100%) when a match occurs, and Pr_2 is equal to the profile probability. A LR of 1000 indicates that the evidence is 1000 times as probable if the evidence and suspect profiles originated from the same source.

25.2.2 Haplotypes

The term *haplotype* was first used to describe very closely linked polymorphic loci. During meiosis, alleles at neighboring loci cosegregate (both alleles segregate as a single allele) because of the close linkage of loci. The term also applies to genetic regions within which recombination events are very rare, that is, within mitochondrial and Y-chromosomal DNA. The entire mitochondrial DNA (mtDNA) sequence can be considered to be a single locus or haplotype because of the absence of recombination. Likewise, Y chromosome loci can also be considered haplotypes.

Where recombination is very rare, certain allelic combinations occur in populations much more frequently than would be expected. This phenomenon is called *linkage disequilibrium*. As a result, the HW principle cannot be applied. The two methods for evaluating the strength of

Table 25.6 Calculation of Profile Probability of STR with 13 CODIS Loci and Correction Factor ($\theta = 0.01$)

Locus	Profile	Allelic Frequency[a]	Formula	Locus Genotype Frequency
CSF1PO	10	0.25369	$\frac{2[\theta+(1-\theta)p][\theta+(1-\theta)q]}{(1+\theta)(1+2\theta)}$	0.168
	12	0.32512		
D3S1358	14	0.14039	$\frac{2[\theta+(1-\theta)p][\theta+(1-\theta)q]}{(1+\theta)(1+2\theta)}$	0.0734
	15	0.24631		
D5S818	11	0.41026	$\frac{[2\theta+(1-\theta)p][3\theta+(1-\theta)p]}{(1+\theta)(1+2\theta)}$	0.180
	11	0.41026		
D7S820	10	0.29064	$\frac{2[\theta+(1-\theta)p][\theta+(1-\theta)q]}{(1+\theta)(1+2\theta)}$	0.121
	11	0.20197		
D8S1179	13	0.33929	$\frac{[2\theta+(1-\theta)p][3\theta+(1-\theta)p]}{(1+\theta)(1+2\theta)}$	0.126
	13	0.33929		
D13S317	11	0.31888	$\frac{[2\theta+(1-\theta)p][3\theta+(1-\theta)p]}{(1+\theta)(1+2\theta)}$	0.113
	11	0.31888		
D16S539	11	0.27228	$\frac{2[\theta+(1-\theta)p][\theta+(1-\theta)q]}{(1+\theta)(1+2\theta)}$	0.187
	12	0.33911		
D18S51	15	0.12755	$\frac{2[\theta+(1-\theta)p][\theta+(1-\theta)q]}{(1+\theta)(1+2\theta)}$	0.012
	19	0.03571		
D21S11	30	0.23214	$\frac{[2\theta+(1-\theta)p][3\theta+(1-\theta)p]}{(1+\theta)(1+2\theta)}$	0.0630
	30	0.23214		
FGA	23	0.15816	$\frac{2[\theta+(1-\theta)p][\theta+(1-\theta)q]}{(1+\theta)(1+2\theta)}$	0.0473
	24	0.13776		
TH01	8	0.12562	$\frac{2[\theta+(1-\theta)p][\theta+(1-\theta)q]}{(1+\theta)(1+2\theta)}$	0.0815
	9.3	0.30542		
TPOX	8	0.54433	$\frac{[2\theta+(1-\theta)p][3\theta+(1-\theta)p]}{(1+\theta)(1+2\theta)}$	0.309
	8	0.54433		
VWA	17	0.26276	$\frac{2[\theta+(1-\theta)p][\theta+(1-\theta)q]}{(1+\theta)(1+2\theta)}$	0.120
	18	0.22194		
				Profile probability $= 7.8 \times 10^{-14}$

[a] See Table 23.1.

a match between haplotypes are (1) mitotype frequency and (2) likelihood ratios. The current most common approach for interpreting mtDNA profiles is mitotype frequency carried out with the gene counting method, that is, the calculation of the number of occurrences of a particular sequence or haplotype. The interpretation of Y chromosome profiles is similar to the interpretation of mtDNA profiles. The estimation of the frequency of a mitotype can be calculated as shown below.

25.2.2.1 Mitotypes Observed in Database

If a mitotype is observed at least once in a database, Equation 25.10 can be used. P_{mt} is the mitotype frequency, x is the number of observations of the haplotype, and n is the size of the database (the number of mitotype entries):

$$P_{\mathrm{mt}} = \frac{x+2}{n+2} \tag{25.10}$$

Any sampling error may be addressed by a confidence interval:

$$P_{\mathrm{mt}} \pm 1.96\sqrt{\frac{P_{\mathrm{mt}}\left(1-P_{\mathrm{mt}}\right)}{n}} \tag{25.11}$$

In this case, P_{mt} is the mitotype frequency, and n is the size of the database. The conservative upper bound of the frequency is usually quoted.

25.2.2.2 Mitotype Not Observed in Database

If a mitotype has not been observed in a database, Equation 25.12 can be used to calculate the mitotype frequency; α is 0.05 for a 95% confidence interval and n is the size of the database.

$$P_{\mathrm{mt}} = 1-\alpha^{1/n} \tag{25.12}$$

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26

Quality Assurance and Quality Control

Quality assurance (*QA*) for forensic services requires certain processes to ensure that a service will meet laboratory requirements for the integrity of testing. A QA program must include components that address:

- Continuing education, training, and certification of personnel
- Specification and calibration of equipment and reagents
- Documentation and validation of analytic methods
- Use of appropriate standards and controls
- Sample handling procedures
- Proficiency testing
- Data interpretation and reporting
- Audits (internal and external) and laboratory accreditation
- Corrective actions to address deficiencies and assessments for laboratory competence

Over the years, many guidelines for quality assurance in forensic DNA laboratories have been established. These guidelines will be introduced in this chapter.

Quality control (*QC*) for forensic services refers to the operational procedures necessary to meet quality requirements. QC procedures may include maintenance of calibration records for equipment and instruments as well as the testing of chemical reagents and supplies used in analysis to ensure reliable results.

26.1 US Quality Standards

DNA profiling methods were first used in criminal investigations in the 1980s. By the early 1990s, emerging forensic DNA techniques had undergone detailed reviews by the *National Research Council* (*NRC*) of the National Academy of Sciences. In 1992, the first published NRC report included recommendations in the areas of (1) technical considerations, (2) statistical interpretation, (3) laboratory standards, (4) data banks and privacy, (5) legal considerations, and (6) societal and ethical issues related to forensic DNA testing. The NRC report attempted to explain the basic scientific principles of forensic DNA technology and made suggestions for applications and improvements. However, the report received negative criticism from both the forensic and the legal communities.

In 1996, a second NRC committee was formed "to update and clarify discussion of the principles of population genetics and statistics as they apply to DNA evidence." Its report stated:

> The central question that the report addresses is this: What information can a forensic scientist, population geneticist, or statistician provide to assist a judge or jury in drawing inferences from the finding of a match? To answer this question, the committee reviewed the scientific literature and the legal cases and commentaries on DNA profiling, and it investigated the criticisms that have been voiced about population data, statistics, and laboratory error. Much has been learned since the last report. The technology for DNA profiling as well as the methods for estimating frequencies and related statistics have progressed to the point where the reliability and validity of properly collected and analyzed DNA data should not be in doubt. The new recommendations presented here should pave the way to more effective use of DNA evidence. (*The Evaluation of Forensic DNA Evidence* also known as the NRC II report)

The NRC II report consisted of (1) an introduction describing the 1992 report, changes made subsequent to that report, and the validity and application of DNA typing techniques; (2) assurance of high standards of laboratory performance; (3) population genetics issues; (4) statistical issues; and (5) DNA evidence in the legal system.

In 1995, The *DNA Advisory Board* (*DAB*) was formed as a result of the DNA Identification Act (1994) passed by Congress. The DAB served from 1995 to 2000 to develop guidelines for quality assurance in forensic laboratories. During that time, the DAB provided two sets of guidelines: Quality Assurance Standards for Forensic DNA Testing Laboratories (1998) and Quality Assurance Standards for Convicted Offender DNA Databasing Laboratories (1999). These standards describe the requirements to ensure quality and integrity of the data as well as competency of laboratories.

These standards were built on the previous standards set by the *Scientific Working Group on DNA Analysis Methods* (*SWGDAM*). After the DAB's assignment ended in 2000, the SWGDAM became responsible for providing guidelines to the US forensic community. The SWGDAM was established in 1988 by the FBI Laboratory. It was initially called the Technical Working Group on DNA Analysis Methods; the name changed in 1998. The SWGDAM comprises forensic scientists from DNA laboratories in the United States and Canada. Its purpose is to facilitate forensic DNA community discussions regarding necessary laboratory methods and to share protocols for forensic DNA testing. The FBI sponsors and hosts its meetings and plays an important role in its activities.

The SWGDAM established and revised several guidelines including the Guidelines for a Quality Assurance Program for DNA Analysis, published in 1989, 1991, and 1995 (the validation section was revised in 2003); Quality Assurance Standards for Forensic DNA Testing Laboratories (2011); Quality Assurance Standards for DNA Databasing Laboratories (2011); Validation Guidelines for DNA Analysis Methods (2012); and SWGDAM Training Guidelines, published in 2001 and revised in 2013.

The SWGDAM also formed subcommittees to provide guidelines in more specific areas of forensic DNA testing, for example, SWGDAM's Interpretation Guidelines for Autosomal STR Typing by Forensic DNA Testing Laboratories (2010), Y-chromosome Short Tandem Repeat (Y-STR) Interpretation Guidelines (2009), and Interpretation Guidelines for Mitochondrial DNA Analysis by Forensic DNA Testing Laboratories (2013). The SWGDAM also organized a number of interlaboratory and validation studies for new techniques.

26.2 International Quality Standards

In the early stages of forensic DNA testing, the *International Society for Forensic Genetics* (*ISFG*) recognized the potential of DNA testing for criminal investigations and made a number of recommendations related to the forensic application of DNA polymorphisms.

The ISFG provided various recommendations for forensic DNA testing of STR, mtDNA, and Y chromosome markers for the international community. It formed a working group called the *European DNA Profiling Group* (*EDNAP*) in 1991. The EDNAP has investigated systems for DNA profiling, has organized a number of collaborative exercises for the evaluation of new methods, and has published reports of its studies.

The *European Network of Forensic Science Institutes* (*ENFSI*) formed its DNA working group about a decade ago to address issues of quality and standards for forensic DNA testing. The *Interpol European Working Party on DNA Profiling* (*IEWPDP*) also makes recommendations for applying DNA evidence to criminal investigations in Europe. Based on the EDNAP exercises and recommendations by the ENFSI and IEWPDP, the *European Standard Set* (*ESS*) for autosomal STR core loci was established. The Standardization of DNA Profiling Techniques in the European Union (STADNAP) group has been working on the selection of forensic DNA profiling systems, methods for use among European countries, and the maintenance of European population databases.

26.3 Laboratory Accreditation

Accreditation is the process used to assess the qualification of a laboratory to meet established standards. During an accreditation process, the services and performance of a laboratory are evaluated, particularly in the areas of management, operations, personnel, procedures, equipment, physical plants, security, and personnel safety procedures. The accreditation process generally involves several components such as self-evaluation, the preparation of supporting documents, on-site inspection and reports, and accreditation review reports.

Accreditation in the United States is offered by the *Laboratory Accreditation Board* of the *American Society of Crime Laboratory Directors* (*ASCLD/LAB*) for forensic laboratories performing casework. The *American Association of Blood Banks* (*AABB*) provides accreditation for laboratories performing DNA parentage testing according to the AABB's standards.

The accreditation of a forensic laboratory is granted for 5 years. To remain in compliance, a laboratory must undergo audits to evaluate its operation according to established guidelines. The FBI has published the Quality Assurance Standards Audit for Forensic DNA Testing Laboratories (2011) and the Quality Assurance Standards Audit for DNA Databasing Laboratories (2011). The areas of operating protocols, instruments and equipment, and personnel training are evaluated based on guidelines. Problems identified during an audit must be documented and actions to resolve the problems must be addressed. Annual internal audits and external audits during alternate years are required under the guidelines.

26.4 Laboratory Validation

Validation is the process of confirming that a laboratory procedure is sufficiently robust, reliable, and reproducible. A robust method maintains successful performance and can cope with errors. A reliable method produces accurate results. A reproducible method achieves the same or very similar results each time a sample is tested.

Two types of laboratory validations, developmental and internal validations, are used for modifying methods for forensic DNA analysis. An *internal validation* is required when adopting a procedure for forensic applications. Based on the SWGDAM's Validation Guidelines for DNA Analysis Methods, the internal validation is "an accumulation of test data within the laboratory to demonstrate that established methods and procedures perform as expected in the laboratory." The *developmental validation* "is the acquisition of test data and determination of conditions and limitations of a new or novel DNA methodology for use on forensic, database, known or casework reference samples." For example, the characterization of a new genetic marker requires studies in the inheritance, the genomic location, the detection method, and the polymorphism of the genetic marker. However, developmental validation studies in the same subject but from fields other than forensic DNA analysis may be acceptable for forensic applications.

Additionally, the precision and the accuracy of the test are important criteria for developmental validation. Based on the SWGDAM, *precision* "characterizes the degree of mutual agreement among a series of individual measurements, values and/or results. Precision depends only on the distribution of random errors and does not relate to the true value or specified value." The measure of precision can be expressed as a standard deviation of test results. *Accuracy* is referred to as "the ability of a measuring instrument to give responses close to a true value," which can be assessed by a *performance check*, a quality assurance procedure monitoring the performance of instruments and equipment affecting the accuracy of forensic DNA testing.

26.5 Proficiency Testing

Proficiency testing is an important component of quality control and quality assurance. It evaluates a laboratory's performance of DNA analyses according to the laboratory's standard protocols. Proficiency testing also evaluates the quality of performance by individual analysts following laboratory protocols.

Proficiency tests of DNA analysts must be conducted every 6 months based on DNA Advisory Board Standards. The testing usually involves mock forensic case samples including questioned bodily fluid stains and reference samples. The test is assigned to an analyst for processing according to the laboratory procedures. A report must be prepared and is then reviewed. The proficiency test can be administered as either an open or a blind test. In the blind test, the analyst is not aware that he or she is being tested. Blind testing is considered a more effective means of evaluating performance.

The tests may be administered internally or by any of a number of external testing organizations. For example, Orchid Cellmark provides the *International Quality Assessment Scheme* (*IQAS*) DNA proficiency test, and the Collaborative Testing Services (CTS) Forensics Testing Program offers similar proficiency tests. These proficiency tests may include a selection of sample types (neat or mixture) for serological tests and/or DNA analysis (autosomal STR, Y-STR, and mitochondrial DNA). The College of American Pathologists (CAP) has a paternity testing proficiency program offering external proficiency tests. In Europe, the *German DNA Profiling Group* (*GEDNAP*) provides proficiency testing for participating European laboratories.

26.6 Certification

Certification is a voluntary process that recognizes the attainment of professional qualifications needed for practice in forensic services. Certification is not required, but is desired by some laboratories. In 2009, a report entitled Strengthening Forensic Science in the United States: A Path Forward was published by the Committee on Identifying the Needs of the Forensic Science Community at the National Academy of Sciences. The report recommends that certification should be mandatory for forensic science professionals, which includes written examinations, supervised practice, proficiency testing, and compliance to a code of ethics (Section 26.8). In the United States, the *American Board of Criminalistics* (*ABC*) offers three types of certification for forensic scientists. A diplomate must pass a general knowledge examination. ABC also requires a bachelor's degree in a natural science and 2 years of experience in a forensic laboratory. To obtain fellow status (higher than diplomate status), an applicant must have 2 years of experience in his or her specialty and must have met the diplomate requirements in addition to passing a written specialty examination and a proficiency test.

ABC has added a third certification that is completely separate from the other certification programs. The technical specialist certification for molecular biology was created to recognize the qualifications required for the analysis of biological materials through DNA profiling. An applicant must take a specialist examination containing questions from the general knowledge examination and a subset of questions from the forensic biology fellow examination. This certification also requires a bachelor's degree in a natural science and 2 years of experience along with successful completion of a proficiency examination within 12 months of taking the technical specialist certification examination.

26.7 Forensic DNA Analyst Qualifications

DAB's Quality Assurance Standards for Forensic DNA Testing Laboratories require that an examiner or analyst have "at a minimum a BA/BS degree or its equivalent degree in a biology, chemistry or forensic science-related area and must have successfully completed college course work (graduate or undergraduate level) covering the subject areas of biochemistry, genetics and molecular biology," as well as "course work and/or training in statistics and population genetics as it applies to forensic DNA analysis."

Additionally, SWGDAM Training Guidelines discuss the course work requirements in detail. At least nine cumulative semester hours are required for the course work covering the required subject areas. Particularly, the section in Fundamental Scientific Knowledge of the SWGDAM Training Guidelines defines required key elements to be covered in course work. The key elements also aid in evaluating the contents of the course work.

Biochemistry "refers to the nature of biologically important molecules in living systems, DNA replication and protein synthesis, and the quantitative and qualitative aspects of cellular metabolism," and may include but is not limited to:

- Structure and function of cellular components such as proteins, carbohydrates, lipids, nucleic acids, and other biomolecules
- Chemistry of enzyme-catalyzed reactions
- Metabolism
- DNA and RNA
- Protein synthesis
- Cell membrane transport
- Signal transduction

Genetics "refers to the study of inherited traits, genotype/phenotype relationships, and population/species differences in allele and genotype frequencies," and may include but is not limited to:

- Heredity
- Function of genes
- Gene expression
- Recombinant DNA
- Mitosis/meiosis

Molecular biology "covers theories, methods, and techniques used in the study and analysis of gene structure, organization, and function," and may include, but is not limited to:

- Interrelationship of DNA, RNA, and protein synthesis
- Central dogma

- Transcription, translation, replication
- Recombinant DNA techniques
- PCR
- Cloning

Course work that is similar in content and scope to those described above may be qualified as required course work. Compliance with the required course contents can be evaluated through transcripts, syllabi, and letters from the instructors.

DAB's Quality Assurance Standards for Forensic DNA Testing Laboratories also describes requirements for an analyst to meet prior to initiating independent casework analysis using DNA technology. First, an analyst must have at least 6 months of forensic DNA laboratory experience "including the successful analysis of a range of samples typically encountered in forensic casework." Second, an analyst must have "successfully completed a qualifying test before beginning independent casework responsibilities."

26.8 Code of Ethics of Forensic Scientists

Ethical codes for forensic scientists are used as guides for individuals making their decisions in distinguishing the difference between correctness and incorrectness. These codes are usually adopted by forensic organizations to regulate the profession. Failure to comply with a code of forensic practice can raise doubt in an individual's fitness for providing forensic services. Additionally, it may result in the expulsion of an individual from a forensic organization. A typical document of ethical codes for forensic scientists generally contains five sections: (1) ethics relating to the scientific method, (2) ethics relating to opinions and conclusions, (3) ethical aspects of court presentation, (4) ethics relating to the general practice of forensics, and (5) ethical responsibilities to the profession.

For the first section, the ethical application of scientific methods is discussed in detail. True scientific methods should be utilized to adequately analyse all the evidence. Such analyses should not be conducted by secret processes. Conclusions should be drawn from the analyses of evidence that appears representative, typical, or reliable.

Moreover, ethical standards relating to opinions and conclusions are very important to the forensic profession. Conclusions should always be drawn from the application of proven scientific methods. The purpose of experimental design and the interpretation of results is to reveal facts. During an analysis, experimental controls should always be utilized. If necessary, the results of analyses should be verified by repeating the analysis or using additional techniques. Explanations should be provided where inconclusive results are obtained. The opinion provided by a forensic scientist should be unbiased and should not be influenced by matters unrelated to the specific evidence in question. A forensic scientist should not choose the interpretation that is in favor of the side of his or her employer.

Pertaining to the courtroom, ethical standards relating to expert witness testimonies is a crucial component for a forensic scientist. An expert opinion is defined as a formal consideration of a subject within an individual's knowledge, skill, education, training, and experience. A forensic scientist should not extend an opinion beyond his or her competence. Appropriate terms should be used to represent the degrees of certainty of an expert opinion. A forensic scientist should not only present the evidence that supports the view of the side of his or her employer. When testifying as an expert witness, language that can be understood by lay jurors should be used to avoid misinterpretation.

Furthermore, in terms of the general practice of forensic science, a few things should be mentioned here. A forensic scientist in private practice should set a reasonable fee for the services provided, which should not be rendered on a contingency fee basis. When a different opinion is presented by another analyst in the reexamination of evidence, both analysts should resolve their contradiction before the trial. A forensic scientist may serve, in an advisory capacity, either the prosecutor or defense in the cross-examination of another expert.

Lastly, ethical responsibilities to the profession are an important component of ethical codes. Information regarding new developments or techniques of forensic analysis should be made available to other forensic scientists. Likewise, any information regarding methods in use that may appear unreliable should be brought to the attention of others. Individual forensic scientists should not seek publicity for the association of their name with specific cases, developments, publications, or organizations solely for the purpose of gaining personal prestige.

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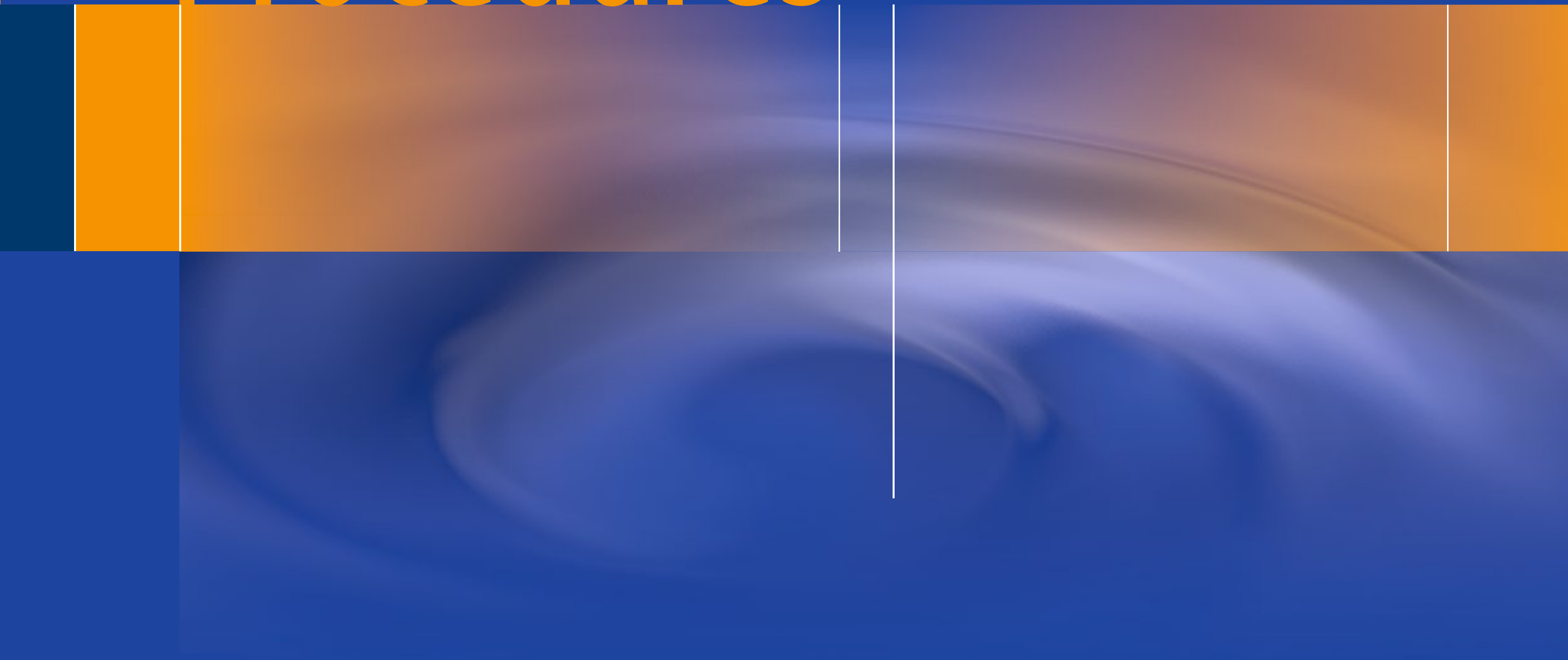

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Atlas of Emergency Medicine Procedures

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To my father, my role model and career coach –
Dr. Ganti L. Rao
Dad, I wouldn't have had the career I do were it
not for you. Your unconditional belief in me, your confidence in
my success, your never ending patience and generosity – you
lead a life of great achievements with utmost humility.
It is my privilege to be your daughter.

Preface

The *Atlas of Emergency Medicine Procedures* is presented in the spirit of "see one, do one, teach one" and "a picture is worth a thousand words." It can be used at the bedside, both by novice practitioners and seasoned clinicians as a teaching aid. For ease of reference, the most common procedures are grouped by organ systems. Each procedure follows a standardized format, beginning with keywords, a definition if appropriate, indications, and contraindications. These are followed by materials and medications, often accompanied by a photograph of the specific equipment or setup. The procedure itself is numbered rather than bulleted, highlighting the sequence of steps. Photographs are placed where the relevant information is encountered in the text rather than at the end. Every procedure also lists complications. Finally, there is a section on pearls and pitfalls, gleaned from the collective experience of the contributors in addition to traditional teachings.

Emergency medicine, by nature, is a field best suited to a visually appealing, concise text able to deliver the information required. Much effort therefore has been dedicated to images. These are either actual photographs taken of the procedure steps or specially commissioned drawings by Springer's professional illustration team. A work of this magnitude could not have been accomplished without the expertise of my dedicated Springer team. A huge thank you to Shelly Reinhardt, Megan Ruzomberka, and Lee Klein. It is hoped that readers will find this atlas useful and practical. Feedback and suggestions for future editions are welcomed and can be sent to AtlasEMprocedures@gmail.com.

Orlando, FL, USA
Latha Ganti

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Part I

Vascular Procedures

Arterial Cannulation (Radial and Femoral)

1

Jeffrey Kile, Katrina John, and Amish Aghera

Arterial cannulation is frequently performed in the care of critically ill patients for purposes of both serial arterial blood gas sampling and continuous intra-arterial blood pressure monitoring. It also provides arterial access for less common procedures, including thrombolysis, embolization, angiography, and infusion of vasoactive drugs. This chapter discusses cannulation of the radial and femoral arteries—the two most common sites for indwelling arterial catheter placement.

1.1 Indications

- Continuous monitoring of blood pressure in acute illness or major surgery
- Serial sampling of arterial blood during resuscitation
- Inability to use noninvasive blood pressure monitoring (*e.g.*, burns, morbid obesity)
- Continuous infusion of vasoactive inotropes (*e.g.*, phentolamine for reversal of local anesthesia)
- Angiography
- Embolization

1.2 Contraindications

- Absolute
  - Circulatory compromise in the extremity
  - Third-degree burns of the extremity
  - Raynaud’s syndrome
  - Thromboangiitis obliterans (Buerger’s disease)
- Relative
  - Recent surgery in the extremity
  - Local skin infection
  - Abnormal coagulation
  - Insufficient collateral circulation
  - First- or second-degree burns of the extremity
  - Arteriosclerosis

1.3 Materials and Medications

- Radial artery cannulation: standard over-the-needle catheter assembly (Fig. 1.1)
  - Antimicrobial solution and swabs
  - Sterile gloves
  - Local anesthetic (1–2 % lidocaine without epinephrine)
  - Blunt needle
  - 25- or 27-gauge needle
  - Two 5 mL syringes
  - 4″×4″ gauze sponges
  - Standard over-the-needle catheter assembly
- Additional materials required for radial artery cannulation: over-the-needle catheter assembly with integrated guide wire
  - Over-the-needle catheter assembly with integrated guide wire
- Additional materials required for femoral artery cannulation: The Seldinger Technique
  - Introducer needle
  - Guide wire
  - Scalpel
  - Dilator
  - Arterial catheter

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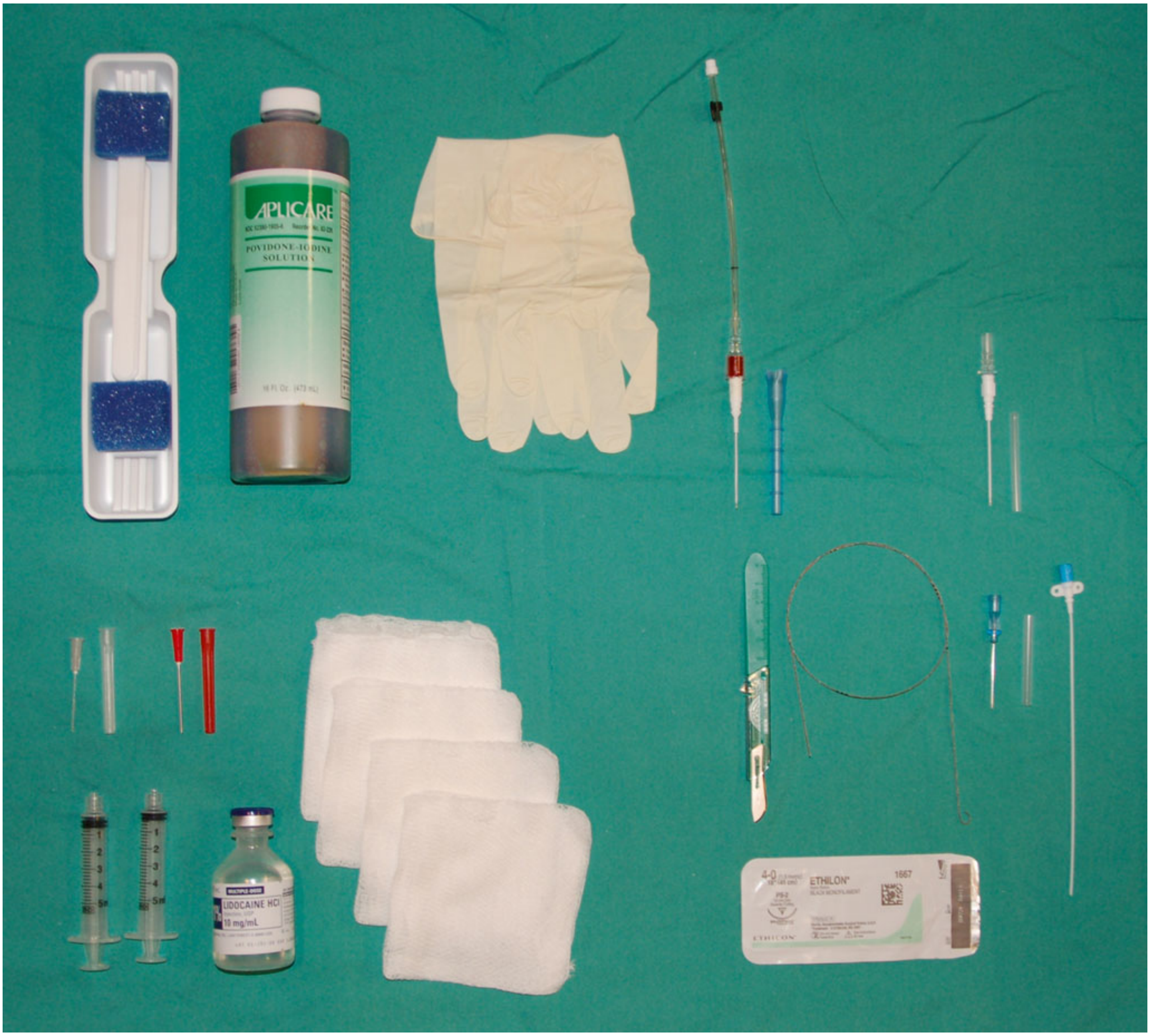
APLICARE
POVIDONE-IODINE SOLUTION
LIDOCAINE HCl
10 mg/mL
4-0
ETHILON
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ETHICON

Fig. 1.1 Materials and medications

1.3.1 Procedure: Radial Artery Cannulation—Standard Over-the-Needle Catheter Assembly

1. Ensure adequate collateral flow in the selected extremity using the Allen test (see details below).
2. Immobilize the extremity by dorsiflexing the wrist to approximately 60° over a small towel roll and taping the base of the fingers to an arm board or other flat, fixed surface (Fig. 1.2).
    - Rotation of the wrist may shift the artery from its normal anatomical position, complicating cannulation.
3. Locate vessel by palpation of arterial pulse using the second and third fingers of the gloved nondominant hand.
4. Sterilize overlying skin with antimicrobial solution.
5. Inject local anesthetic to raise a small (0.5 cm) wheal using 25- or 27-gauge needle, and direct needle through wheal to infiltrate skin superficial to the artery with additional local anesthetic.
    - Infiltration of the subcutaneous tissue with local anesthetic may also reduce vessel spasm during arterial puncture.
    - Injection of local anesthetic into the vessel may precipitate arrhythmia, so draw back on the plunger prior to infiltration to ensure the tip of the needle is not inside the vessel.
    - Injection of excessive anesthetic when raising a wheal may obscure palpation of the pulse.
6. Ensure proper function of needle-cannula assembly by checking that cannula advances smoothly over needle.
7. Connect a 5 mL syringe with the plunger removed to the over-the-needle catheter assembly.
    - Attachment of syringe improves control during cannulation.
8. Hold syringe connected to needle-cannula assembly like a pen with needle bevel facing upward.
9. Directing the needle at a 30° angle to the skin, puncture the skin through the anesthetic wheal immediately overlying the palpated artery, and advance needle slowly until tip enters arterial lumen, which is confirmed by visible arterial blood flow (“flashback”) into the needle hub and syringe.
    - Avoid self-puncture by maintaining adequate distance between needle tip and index finger (Fig. 1.3).
10. Reduce the angle between needle and skin (by lowering the needle) and advance an additional 2 mm to ensure catheter tip (which sits approximately 2 mm behind the needle tip) has entered the lumen.
    - Advancing the needle too far (or failing to reduce angle between needle and skin) once initial flashback is visualized may result in piercing the back side (or “double puncture”) of the artery wall, in which case visible blood flow will cease; if this occurs, slowly withdraw needle several millimeters until pulsatile blood flow reappears.
11. Stabilize position of introducer needle and advance catheter alone into artery over needle until hub of catheter is in contact with the skin; blood flow from catheter hub at this point indicates successful cannulation of the artery.
    - If difficulty is encountered at this step, catheter hub may be rotated slightly to facilitate advancement.
12. Remove the needle without dislodging catheter from artery.
13. Manually apply pressure to proximal aspect of artery to occlude blood flow from the catheter.
14. Attach desired extension tubing, injection cap, and stopcock to the catheter hub.
15. Secure the catheter hub to the skin using silk (2.0) or nylon (4.0) sutures as follows. Take a 0.5 cm bite of skin under the catheter hub with the suture needle, tie several knots in the suture without pinching the skin, then tie a second set of knots around the hub of the catheter firmly. If the catheter assembly contains an integrated suture wing for fixation, take a 0.5 cm bite of skin under suture wing with the suture needle, thread suture through wing perforation, and secure wing against the skin with several knots. If suture wing has two perforations, repeat this process to secure other half of wing to skin (Fig. 1.4).
16. Cover the catheter with an appropriate self-adhesive sterile dressing.
    - A small bead of antibiotic ointment applied to the puncture site prior to dressing reduces the likelihood of cutaneous wound infection.
17. Secure the tubing connected to the catheter with gauze and adhesive tape or other sterile dressing.
18. Ensure all connections extending from catheter are tight and well secured, as accidental disconnection may result in rapid exsanguination.

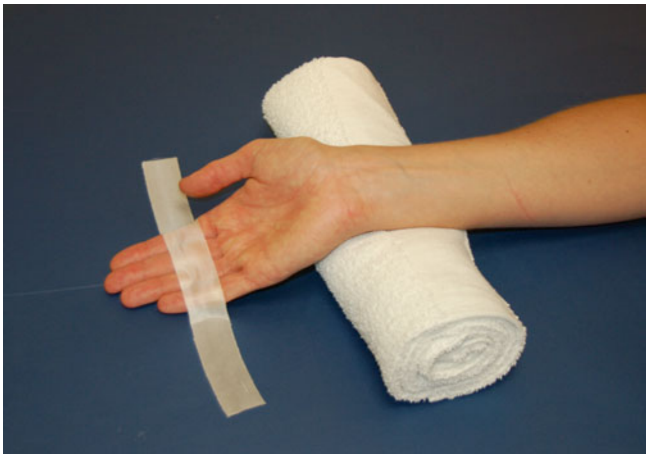

Fig. 1.2 Correct position of wrist prior to cannulation

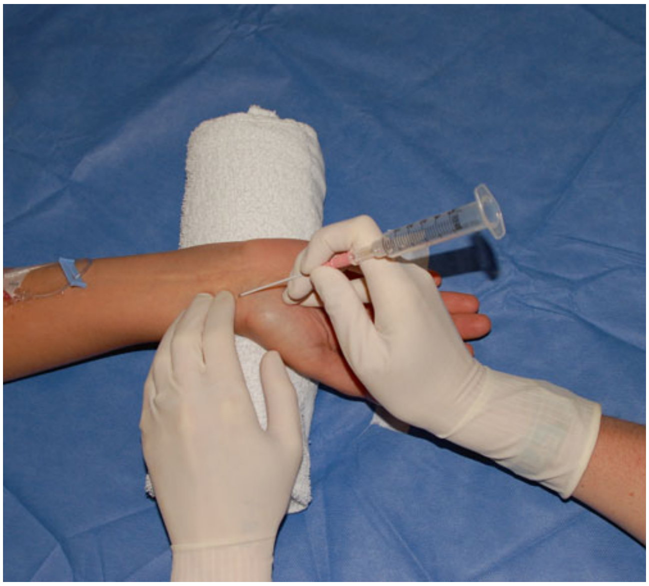

Fig. 1.3 Puncture of radial artery with standard over-the-needle catheter assembly

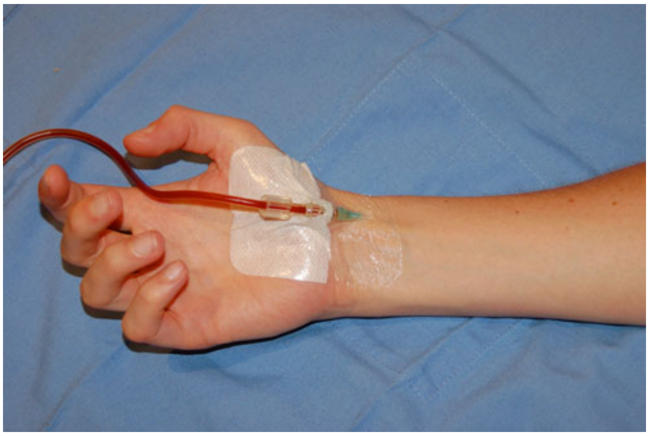

Fig. 1.4 Radial arterial catheter secured to wrist

1.3.2 Procedure: Radial Artery Cannulation—Over-the-Needle Catheter Assembly with Integrated Guide Wire (Arrow and Other Brands)

Perform steps 1–6 from the "Radial Artery Cannulation: Standard Over-the-Needle Catheter Assembly," above, and then proceed with the steps below:

1. Remove protective cap from needle-cannula assembly and ensure proper function by sliding actuation lever along extension tubing to advance and retract guide wire through needle.
2. Retract guide wire as far back as possible using actuation lever to maximize visibility arterial blood flow ("flashback") within introducer hub.

Perform steps 8–10 from the "Radial Artery Cannulation: Standard Over-the-Needle Catheter Assembly," above, and then proceed with the steps below (Fig. 1.5):

1. Hold needle stationery and slowly slide actuating lever forward to feed guide wire as far as possible into artery.
    - If resistance is met while feeding the guide wire, discontinue sliding actuating lever and withdraw entire unit from artery to prevent damage to guide wire or vessel wall
2. Advance entire assembly 1–2 mm further into vessel to ensure catheter tip (which sits approximately 2 mm behind the needle tip) has entered the lumen.
3. Stabilize clear introducer hub in position and advance catheter forward into artery over guide wire until hub of catheter is in contact with the skin.
    - If difficulty is encountered at this step, catheter hub may be rotated slightly to facilitate advancement.
4. Stabilize catheter in position and withdraw introducer needle, guide wire, and feed tube as a single unit; blood flow from catheter hub at this point indicates successful cannulation of the artery.

Perform steps 13–18 from the "Radial Artery Cannulation: Standard Over-the-Needle Catheter Assembly," above.

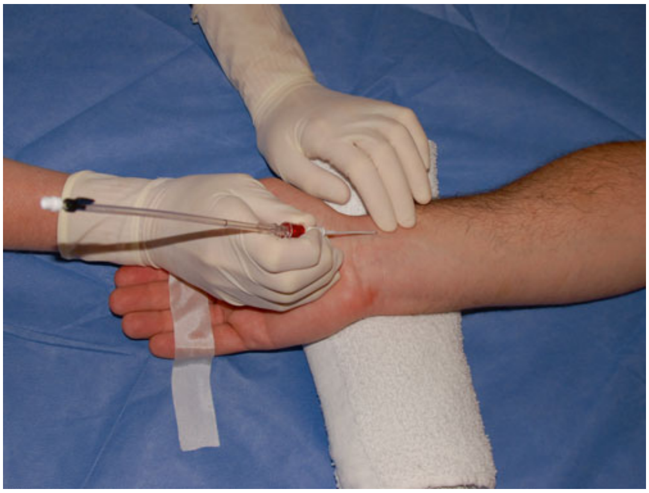

Fig. 1.5 Puncture of radial artery using over-the-needle catheter assembly with integrated guide wire

1.3.3 Procedure: Radial Artery Cannulation—The Allen Test

1. Occlude both radial and ulnar arteries of one extremity with digital pressure at wrist.
2. Instruct patient to repeatedly clench the fist tightly to exsanguinate the hand while occlusion of the arteries is maintained.
3. Without releasing digital pressure on arteries, instruct patient to extend fingers and observe palmar surface to confirm blanching of skin.
4. Release pressure on ulnar artery only and observe palmar surface for reperfusion (Fig. 1.6).
   - If reperfusion of the hand does not occur within 5–10 s, ulnar arterial blood flow may be compromised and radial artery cannulation should not be attempted. If reperfusion is brisk, repeat the test releasing pressure on radial artery only and observing palmar surface for reperfusion. If the return of rubor takes longer than 5–10 s, radial artery puncture should not be performed.

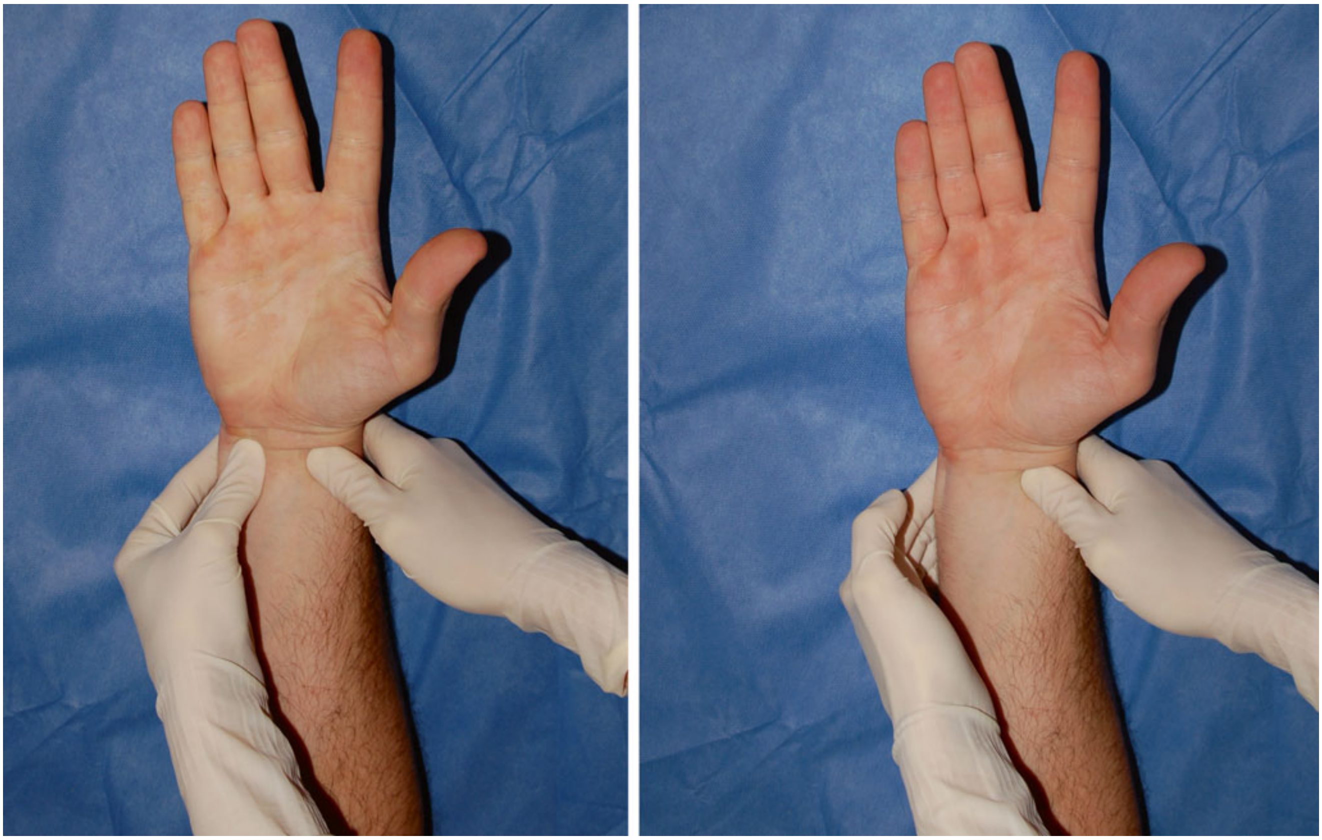

Fig. 1.6 The Allen Test

1.3.4 Procedure: Femoral Artery Cannulation—The Seldinger Technique

1. Place the patient in the supine position with the inguinal region adequately exposed.
2. Palpate the femoral pulse, located at midpoint between pubic symphysis and anterior superior iliac spine, using the second and third fingers of the gloved nondominant hand.

Perform steps 4 and 5 from the "Radial Artery Cannulation: Standard Over-the-Needle Catheter Assembly," above, and then proceed with the steps below (Fig. 1.7):

1. Attach 5 mL syringe to an introducing needle of bore sufficient to accommodate guide wire.
2. Hold syringe connected to introducing needle like a pen with needle bevel facing upward.
3. Directing the needle at a 45° angle to the skin in a cephalic direction, puncture the skin through the anesthetic wheal immediately overlying the palpated artery just distal to the inguinal ligament and advance needle slowly toward palpated artery until tip enters arterial lumen, which is confirmed by visible arterial blood flow ("flashback") into the needle hub and syringe.
   - Avoid self-puncture by maintaining adequate distance between needle tip and index finger.
   - Care must be taken to avoid trauma to the femoral nerve and vein bordering the femoral artery.
4. Hold needle stationery and remove syringe, taking care not to displace the intraluminal position of the needle tip.
   - Advancing the needle too far once initial flashback is visualized may result in piercing the back side (or "double puncture") of the artery wall, in which case visible blood flow will cease; if this occurs, slowly withdraw needle several millimeters until pulsatile blood flow reappears.
5. Occlude needle hub temporarily with gloved finger to prevent unnecessary blood loss and air embolism.
6. Thread blunt end of flexible guide wire smoothly into needle and gently into artery until at least one-quarter of guide wire is intravascular (Fig. 1.8).
   - If resistance is met while threading guide wire, remove wire from needle, reattach syringe, and aspirate blood to confirm continued intraluminal needle tip placement; if resistance is met while *removing* guide wire from needle, remove guide wire and needle from artery *as a single unit* to prevent shearing the guide wire off inside the vessel.
7. Holding the wire securely in place, remove the introducing needle.
8. Using a scalpel, make a small incision (approximately the width of the catheter to be used) through the dermis at the insertion site of the guide wire.
   - Avoid severing the guide wire by facing the sharp edge of the scalpel *away* from the guide wire.
9. While stabilizing the guide wire at its insertion site, thread the dilator over the free end of the guide wire until it is approximately one inch from the skin.
10. Grasp the free end of the guide wire protruding from the tail end of the dilator.
    - If it does not protrude from the tail end of the dilator, the guide wire must be removed sufficiently from the artery to be securely grasped; it must protrude visibly from the tail end of the dilator throughout the subsequent process of threading the dilator into the artery.
11. Holding the dilator firmly near its tip, thread the dilator over the wire into the skin with a back-and-forth twisting motion until it reaches the artery.
    - Only the skin tract should be dilated; dilation of the artery may result in excessive arterial injury and/or hemorrhage.
12. Holding the wire securely in place, remove the dilator.
13. While stabilizing the guide wire at its insertion site, thread the catheter over the free end of the guide wire until it nears the skin.
14. Grasping the guide wire where it protrudes from the tail end of the catheter, thread the catheter into the skin to its appropriate insertion length.
15. While stabilizing the catheter at its insertion site, slowly remove the guide wire.
    - If resistance is met while removing guide wire, remove guide wire and catheter from artery as a single unit to prevent shearing the guide wire off inside the vessel.
16. Secure the catheter to the skin using silk (2.0) or nylon (4.0) sutures. Take a 0.5 cm bite of skin with the suture needle. If the catheter assembly contains integrated "wings" for fixation, thread suture through the perforated wings and secure catheter against the skin with several knots. If no fixation device is included, tie several knots in the suture without pinching the skin, leaving both ends of the suture long. Using the loose ends of the suture, tie a second set of knots around the hub of the catheter, firmly, but without constricting its lumen.

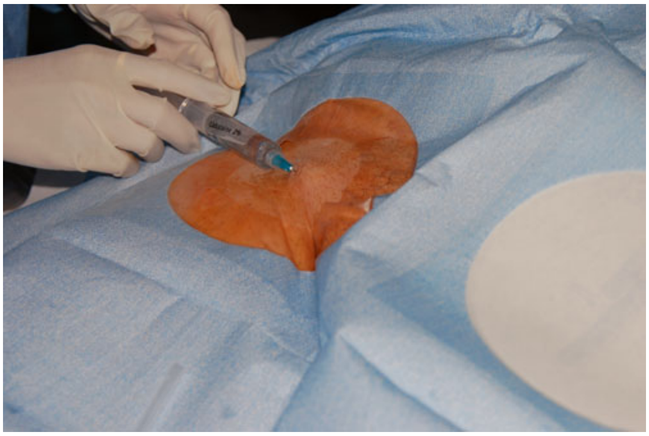

Fig. 1.7 Anesthetic injection over the femoral artery

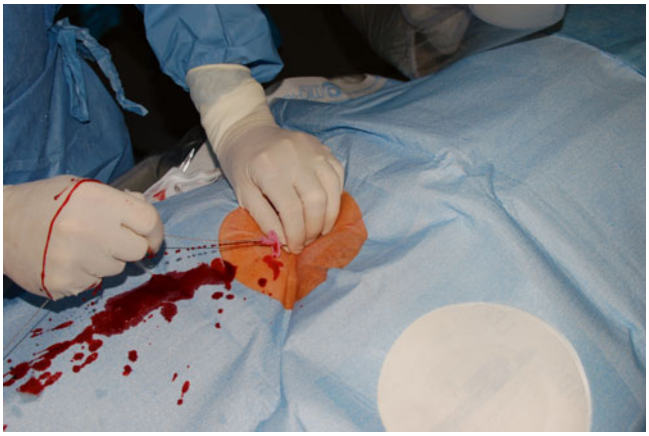

Fig. 1.8 Insertion of guide wire into femoral artery

1.4 Complications

- Hemorrhage
- Hematoma (at puncture site)
- Infection (at insertion site or systemic)
- Thrombosis
- Arteriovenous fistula
- Pseudoaneurysm formation
- Exsanguination (secondary to dislodgement of catheter)
- Cerebrovascular accident (CVA; secondary to air embolism)

1.5 Pearls and Pitfalls

- The shorter and stiffer the plastic tubing connected to the arterial cannula for blood pressure monitoring, the higher its frequency response and the accuracy of measurements.
- Use of an ultrasound probe can facilitate artery location and vessel cannulation.
- Puncture of the femoral artery proximal to the inguinal ligament, or distal to its bifurcation into superficial femoral and deep femoral arteries, may cause massive hemorrhage due to poor vessel compressibility in these regions; the artery should therefore be cannulated just distal to the inguinal ligament, where it is easily compressible against the femoral head if necessary.
- If difficulty is encountered when advancing an over-the-needle catheter into the artery, attach a 10 mL syringe containing 5 mL of sterile normal saline to the catheter hub, aspirate 1 or 2 mL of blood to confirm catheter tip placement within the vessel lumen, and then advance the catheter while gently injecting the saline-blood mixture; the jet of fluid momentarily dilates the lumen, aiding advancement of the catheter.
- An alternative approach to the over-the-needle catheter that will not fully advance is the use of a guide wire. After intraluminal placement of the cannula tip is confirmed by blood return, a guide wire is gently inserted through the catheter into the artery. The cannula is then passed along the guide wire until fully advanced. The guide wire employed must have a blunt, flexible tip to minimize the possibility of vessel wall trauma.
- Two potential consequences of arterial cannulation are vessel obstruction secondary to intravascular thrombosis and hemorrhage (the latter being the most common complication). Choice of puncture site is therefore essential. Due in part to their generous collateral blood flow, as well as ease of compressibility, the radial and femoral are the two most commonly cannulated arteries.
- Repeated puncture following unsuccessful cannulation increases the risk of arterial obstruction secondary to vessel wall damage and thrombosis.

- Double puncture of the cannulated artery by inadvertent over-insertion of the needle has not been shown to increase complications despite the additional trauma to the vessel walls.

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Ultrasound-Guided Peripheral Intravenous Access

2

Coben Thorn and L. Connor Nickels

2.1 Indications

- Difficulty placing peripheral intravenous (PIV) using traditional methods of direct visualization and palpation
- To reduce needle sticks in a hypercoagulable patient

2.2 Contraindications

- Patient needs emergent central venous access

2.3 Materials and Medications

- Ultrasound machine
- High-frequency (5–8 MHZ) linear probe (Fig. 2.1)
- Ultrasound gel
- Minimum 1.5-in. needle length
- IV setup
- Skilled operator

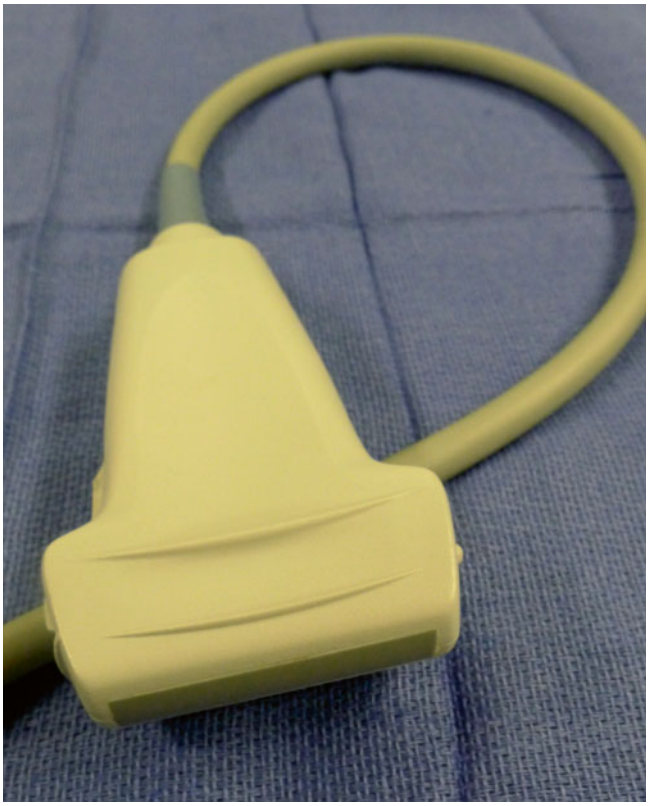

Fig. 2.1 High-frequency (5–8 MHZ) linear probe

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2.4 Procedure

1. Scan the selected area to identify a target vessel for PIV cannulation.
    - Basilic (runs on the medial side of upper arm) (Fig. 2.2) and cephalic (runs on the lateral side of the upper arm) veins are good superficial veins that are generally not seen without ultrasound. The deep brachial vein is also an option; however, this is a deep vein that runs with the brachial artery, and there is higher chance for complications (Fig. 2.3).
2. Now the site should be prepared for IV insertion. It should be cleaned. An appropriate gauge long needle should be selected, and IV setup should be conveniently located for when access is obtained.
3. The ultrasound probe should be placed in the transverse plane (Fig. 2.4) to best visualize surrounding structures and vein. Alternatively, the probe can be placed longitudinally (Fig. 2.5) for better visualization of needle depth and slope.
    - Most practitioners seem to prefer the transverse approach.
4. The concept of the Pythagorean Theorem is used for accuracy. The needle should be inserted at a 45° angle to the skin and at an equal distance back from the probe as the approximate depth of the vessel vertically. The depth is given on the screen, usually at the bottom in centimeters. As soon as the needle has penetrated the skin the needle tip should be located by fanning the probe toward the needle until it is identified. The needle should then be advanced slowly always keeping the needle tip in view. Once directly on top of the vein, it should tent with pressure and then the needle should be inserted into the vein. Follow the needle in the vein as far as possible while keeping the tip of the needle in the center of the vein to make sure the catheter is securely in the vein and does not infiltrate.

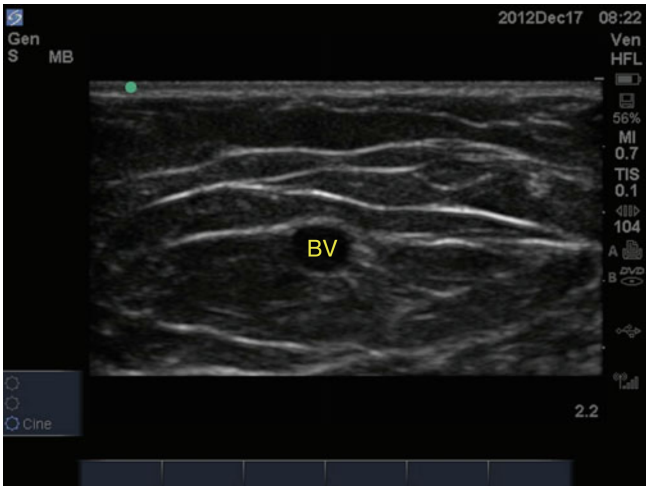

Fig. 2.2 Basilic vein (BV) located medially when scanning proximally from the antecubital fossa

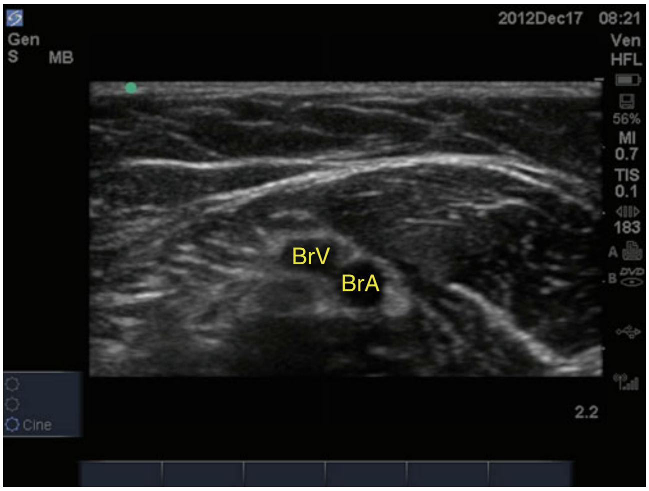

Fig. 2.3 Brachial artery (BrA) and vein (BrV). The less round, slightly compressed, anechoic structure on the left is the vein. The very circular, not compressed, anechoic structure to the right is the artery

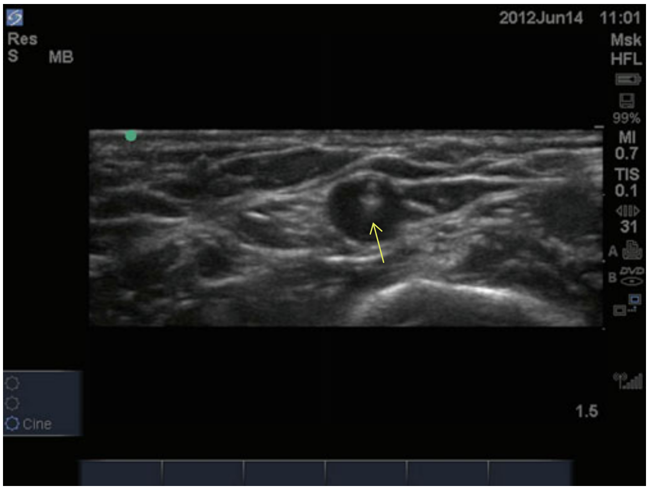

Fig. 2.4 Needle tip in vein seen in a transverse orientation

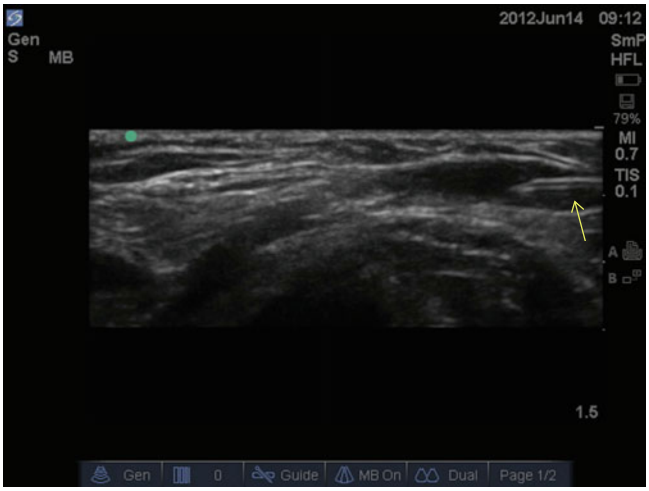

Fig. 2.5 Needle tip in vein seen in a longitudinal orientation

2.5 Complications

Inadvertent puncture of artery. Veins should be thin walled, compressible, and have no pulsations.

2.6 Pearls and Pitfalls

- Mistaking the midshaft of the needle for the needle tip. If this occurs, the needle tip is actually deeper than expected. The ultrasound machine will plot a hyperechoic "dot" on the screen for the needle tip, as long as it crosses the ultrasound beam at any point. This same "dot" will appear whether the tip is directly centered under the beam or *any* segment of the needle shaft is intersecting the beam. This can be visually deceiving and makes this procedure difficult to grasp.
- Very slow movements of the needle and the probe are important for keeping the needle tip in view. Once the needle tip is identified, the probe should be fanned forward (away from operator) just slightly and then the needle advanced until the needle tip comes into view again. This is repeated until the needle is securely moved further into the vein.

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Central Venous Line Placement: Internal Jugular Vein, Subclavian Vein, and Femoral Vein

3

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3.1 Indications

- Volume replacement
- Emergent venous access
- Administration of caustic medications: vasopressors, calcium chloride, hypertonic saline, high dose of potassium
- Dialysis catheter placement (hemodialysis)
- Nutritional support (total parenteral nutrition)
- Long-term antibiotics
- Chemotherapy
- Plasmapheresis
- Frequent or persistent blood draws or intravenous therapy when unable to establish peripheral access due to edema or other causes
- Jugular and subclavian: Central venous pressure monitoring, transvenous pacing wire introduction, pulmonary artery catheterization

3.2 Contraindications

- Absolute
  - Infection at site of insertion
  - Distorted anatomy/landmarks (prior surgery, radiation, or history of thrombus in the specified vein)
  - Subclavian only: Trauma to the ipsilateral clavicle, anterior proximal rib, subclavian or superior vena cava vessels
- Relative
  - Morbid obesity
  - COPD
  - Children less than 2 years (higher complication rates)
    - Coagulopathy (although ultrasound-guided internal jugular can be done in this situation)
  - Agitated or moving patient
  - Jugular only: Trauma to the ipsilateral clavicle, anterior proximal rib, subclavian or superior vena cava vessels
  - Jugular and subclavian: Inability to tolerate potential pneumothorax of the ipsilateral thoracic cage
    - Pneumothorax or hemothorax of the contralateral thorax
    - Patients receiving ventilatory support with high-end expiratory pressures (temporarily reduce the pressures)
  - Femoral only: Intra-abdominal (or retroperitoneal) hemorrhage

3.3 Materials and Medications

- Central venous catheter tray or bundle: single/double/triple/quadruple lumen, dialysis catheter, large-bore introducer (for transvenous pacing or pulmonary artery catheter kit)
- Sterile gloves
- Sterile drapes or towels
- Sterile gown
- Hat/hair cap and mask with eye protection
- Antiseptic solution with skin swabs (e.g., chlorhexidine)
- Sterile saline flushes (one 30 mL syringe or three 10 mL syringes)
- Lidocaine 1 %

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- Sterile gauze
- No. 11 blade scalpel
- Dressing (sterile waterproof transparent dressing or sterile 4×4 gauze with tape)
- Sterile biopatch
- Suture material with needle driver if needed
- Transducing line (optional)
- Sterile probe cover (if using ultrasound guidance)

3.4 Procedures

3.4.1 Internal Jugular Vein Access Procedure

1. Obtain informed consent if not emergently indicated procedure.
2. Obtain supplies and prepare the room, ensuring that all supplies are within operator reach prior to placing gown and commencing the procedure. Include a sterile ultrasound sheath on the sterile field if ultrasound is being used.
3. Raise bed to a comfortable height for the operator.
4. Place patient with head facing away from side of central line site (if using ultrasound, other positions may be preferred). Place patient in 15–20° Trendelenburg position to help fill the upper central veins and reduce the risk of air embolism.
5. Identify the anatomy. Palpate triangle made by the clavicle and sternal and clavicular heads of the sternocleidomastoid (SCM) muscle to identify the location of the internal jugular vein (Fig. 3.1). If using ultrasound guidance, identify optimal anatomical arrangement.
6. Wash your hands and wear sterile attire using aseptic technique, including cap, mask, gown, and sterile gloves.
7. Prepare the site from the clavicle to the ear and across the trachea with antiseptic solution. Allow the antiseptic (chlorhexidine or iodine) to fully dry.
8. Drape the site and patient with sterile towels and drapes included in most CVL bundles. Make sure to cover the whole area and bed.
9. Cover the ultrasound probe with a sterile sheath. This can be done solo or by holding the sterile ultrasound sheath and having an unsterile assistant hold the probe so that the probe can be covered by the sheath.
10. Prepare the kit by checking the guide wire and flushing the tubing and lines with saline included in the kit.
11. With a 25-gauge needle, use 1 % lidocaine to anesthetize the skin at the apex of the triangle made by the SCM and clavicle. Aspirate to make sure the operator is not in a vessel and make a superficial wheel for the insertion site.
12. Preferred method is with ultrasound guidance (see steps 13–17 and Sect. 3.6 for description of ultrasound guidance). If performing without ultrasound, palpate the carotid artery and insert needle lateral to the artery at the apex of the triangle formed by the SCM, aiming toward the ipsilateral nipple at an angle 30–45° above the horizontal plane (Fig. 3.1). Once blood returned, go to step 18.
13. Place sterile ultrasound gel over the insertion site. Use the ultrasound to identify vessel anatomy including internal jugular vein and carotid artery. Use the ultrasound probe to compress the vein, which is compressible as opposed to the carotid artery, which is not compressible (Fig. 3.2).
14. Prepare the insertion needle and syringe (if long and short needles are available, a short needle may be used to reduce posterior vein perforation) and prime the syringe by pulling back on the plunger prior to making the puncture.
15. Use the ultrasound probe to re-identify the patient's anatomy.
16. Ultrasound can be used in short axis or long axis (Fig. 3.3). Short axis is easier for novice operators due to increased ability to see the artery and vein but has a higher risk of posterior perforation if the needle tip is not visualized well. Once short axis of the vein is found, turning the probe 90° clockwise allows the operator to see the vein in long axis. The needle is better visualized in this view but technically more difficult and has less chance to penetrate the posterior wall. In patients with short necks, it may be difficult to obtain long-axis view and needle insertion in the limited space.
17. Insert the needle using the ultrasound guidance with dynamic approach preferred (see Sect. 3.6 for specifics). Make sure to aspirate while inserting the needle to identify when the venous access is obtained. The needle tip should be visualized through the whole process.
    - If using the static approach (see Sect. 3.6), insert needle lateral to carotid pulsation as this is where the vein anatomically is located. Standard method is to insert the needle as far back as the depth the vessel is visualized (e.g., if the vein is visualized 2 cm below skin surface, the needle should be inserted 2 cm behind the probe at a 45° angle).
    - If inserting the needle ~3 cm does not achieve access, gently withdraw the needle toward the surface of the skin while aspirating. Avoid withdrawing the needle completely from the skin. If needed, redirect the needle and advance until blood is aspirated. Cannulation of the vein often takes place while withdrawing the needle.
18. Hold the needle steady with your nondominant hand and remove the syringe, careful not to advance or withdraw the needle. You can place the base of your hand on the patient's chest to make your hand more stable during

this part of the procedure. Occlude the hub of the needle to prevent air embolus.

19. You may verify that you are in the vein by transducing pressure with a fluid column. The fluid should flow easily into the vein.
    - If the aspirated blood is pulsatile and moves up the column, withdraw the needle completely and apply pressure for 10–20 min while taking the patient out of Trendelenburg position (if nonemergent procedure).
20. Once it is verified that you are in the vein, insert the J-tip of the guide wire into the needle hub and advance into the vein. The J-tip can be straightened with a pinching motion (Fig. 3.4). Always keep one hand on the guide wire until it is removed from the patient. Monitor for arrhythmias as the guide wire is advanced toward the right atrium.
    - If the guide wire does not flow easily, remove the guide wire and reattach the syringe, checking for blood flow.
    - If arrhythmia occurs, slowly withdraw the guide wire until the patient's native rhythm returns.
    - Alternatively, the catheter/syringe found in most kits can be used as a bridge to guide wire placement. For the author, this has improved success when there is difficulty in wire placement. Use the same steps above with the catheter (Fig. 3.5) and when you have return of blood, advance the angiocath into the vein followed by insertion of the guide wire through the angiocath. This is especially useful in moving/agitated patients, patients who have collapsible veins due to hypovolemia, and patients who have abnormal anatomy and may have veins that take an abnormal angle shortly past the needle tip.
21. Remove the needle over the guide wire, making sure to always keep control of the guide wire.
22. Make an incision contiguous with the guide wire using a straight (No. 11) blade with the scalpel blade facing upward (away from the wire).
23. Advance the dilator over the guide wire in a twisting motion, keeping control of the guide wire.
    - The dilator only needs to go slightly beyond the anticipated depth of the patient's jugular vein. Do not advance the entire length of the dilator.
24. Withdraw the dilator and hold pressure over the wound site.
25. Advance the catheter over the guide wire while keeping control of the guide wire.
26. With the catheter inserted 10–12 in. from the skin insertion site, retract the guide wire until it comes out of the distal port. Maintain control of the guide wire and advance the catheter to the appropriate length. Usually catheters are inserted 15–16 cm from the right side and 18–20 cm from the left side (Fig. 3.6).
27. Flush each port of the catheter and check aspiration. If difficulty with aspiration or flushing, concern is raised for catheter malposition. The operator can change the depth slightly or twist the catheter and recheck.
28. At this time, an antibiotic ointment or biopatch may be applied to skin around the intersection with the lumen of the catheter. This step is based on local institutional guidelines.
29. Suture the line in place.
30. Enclose CVL site with sterile waterproof transparent dressing.
31. Confirm placement using chest X-ray (CXR). The tip of the catheter should be in the lower third of the superior vena cava (SVC) at the insertion of the SVC into the right atrium.

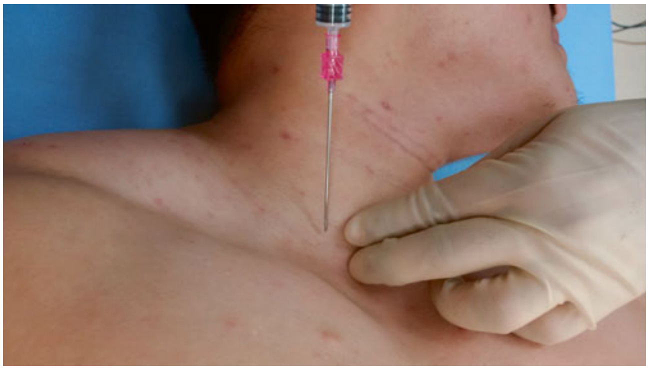

Fig. 3.1 Internal jugular blind approach; this would be the same location for probe placement if doing ultrasound guided

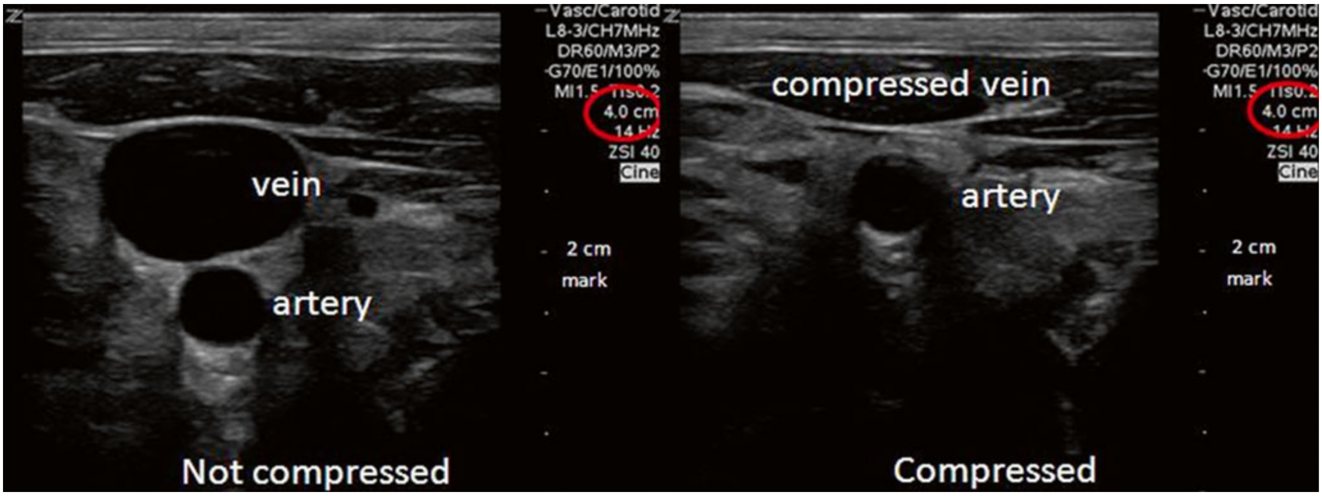
Vasc/Carotid
L8-3/CH7MHz
DR60/M3/P2
G70/E1/100%
4.0 cm
ZSI 40
Cine
vein
artery
2 cm
mark
Not compressed
compressed vein
artery
Compressed

Fig. 3.2 Ultrasound showing internal jugular vein and artery with and without compression

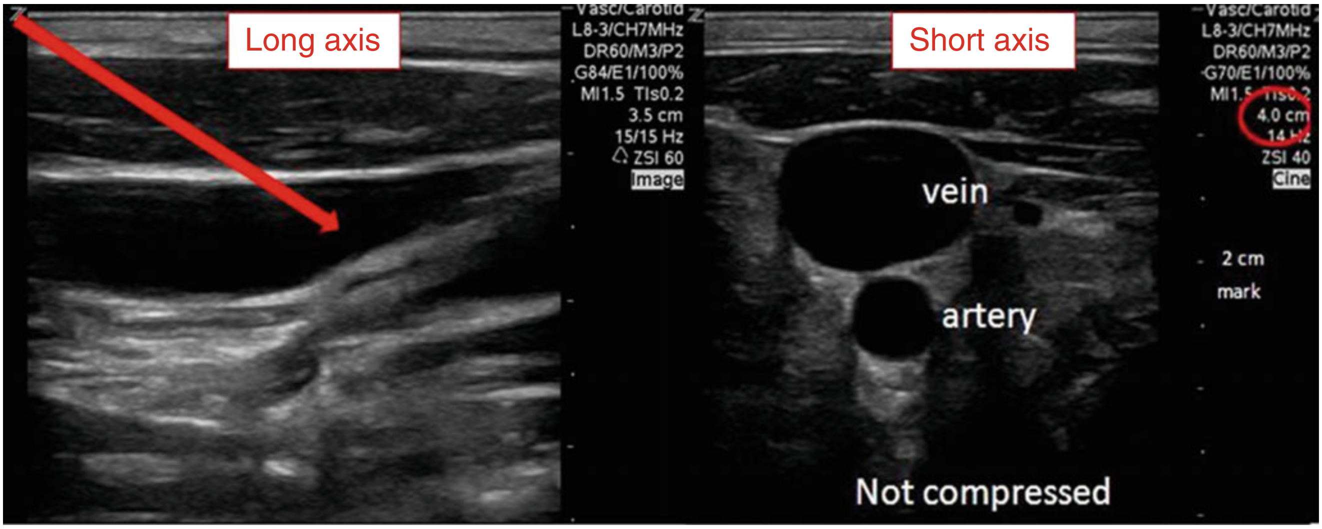
Long axis
Vasc/Carotid
L8-3/CH7MHz
DR60/M3/P2
G84/E1/100%
MI1.5 TIs0.2
3.5 cm
15/15 Hz
ZSI 60
Image
Short axis
G70/E1/100%
4.0 cm
ZSI 40
Cine
vein
artery
2 cm
mark
Not compressed

Fig. 3.3 Long- and short-axis views of the internal jugular vein

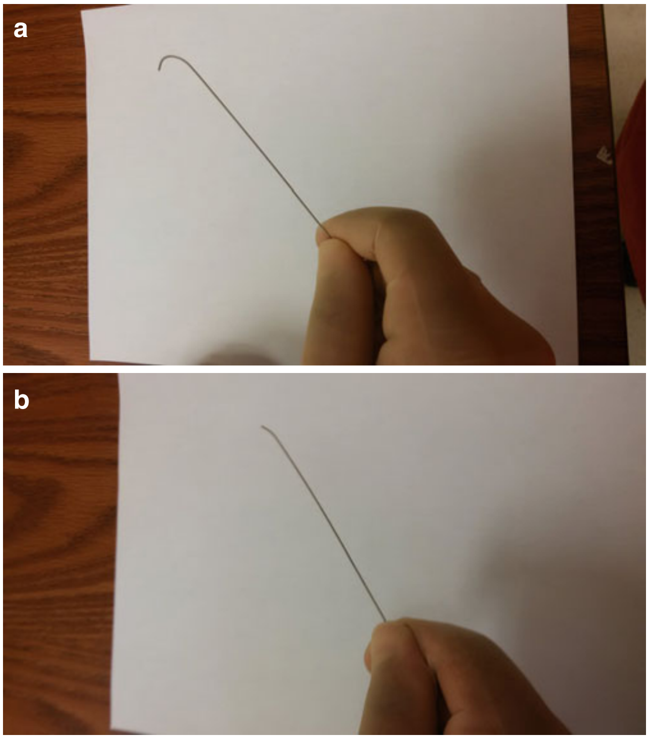

Fig. 3.4 (**a**, **b**) J-tip straightening using pinch/stretch method

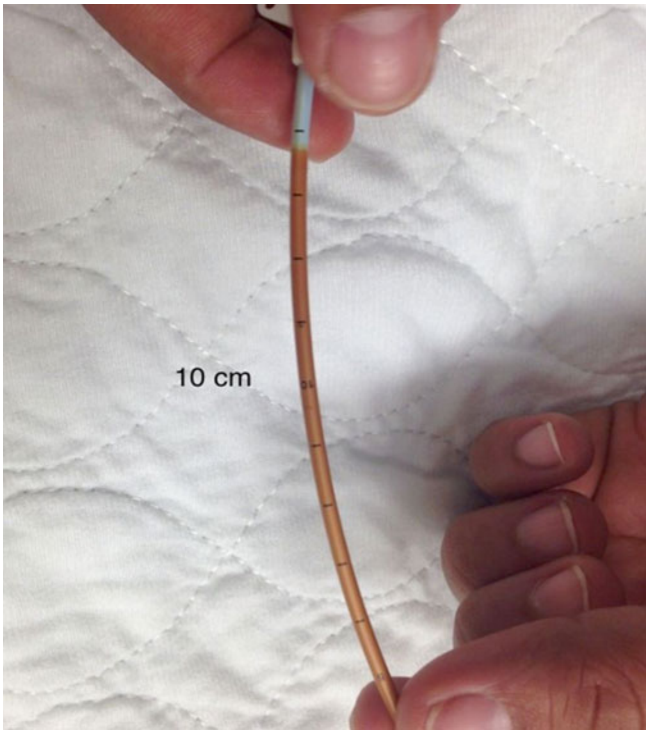

Fig. 3.6 Length: marking seen on typical central venous catheters; number indicates distance in centimeters from distal tip

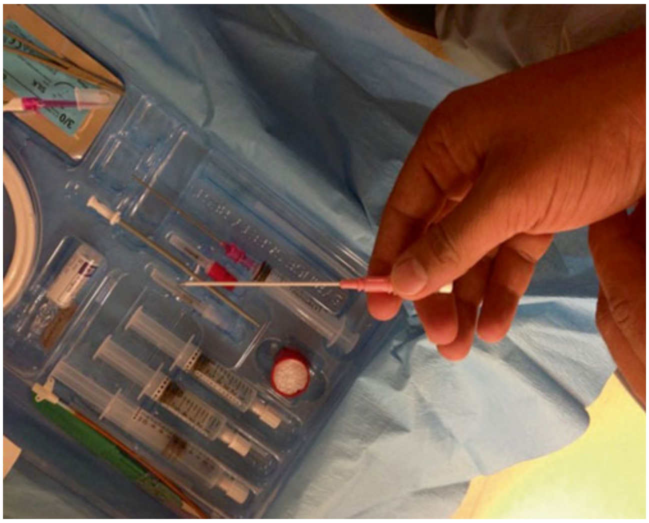

Fig. 3.5 Angiocath that can be used in difficult to cannulate/wire patients

3.4.2 Subclavian Vein Access Procedure

1. Obtain informed consent if not emergently indicated.
2. Raise bed to comfortable height for the operator.
3. Place patient in supine position and position so patient's head is at the top of the bed.
4. Place patient in 15–20° Trendelenburg position (if tolerated) to reduce risk of air embolism. Studies show this will also increase the size of the subclavian vein. Do NOT place towel between shoulder blades (arch shoulder back) as this has been shown to decrease vein diameter and affect reliability of accessibility. Keep shoulders at anatomical location (forward).
5. Prep area chosen from the anterior neck, clavicle, and upper chest (above nipple line) with chlorhexidine prep or iodine.
6. Open kit and place close to operator's dominant hand to allow for easy access. Diameter of catheter/kit used based on clinical situation:
    - Introducer or large bore if requiring large volumes of resuscitation
    - Triple lumen catheters for vasopressors
    - Introducers if anticipating pulmonary artery catheter or venous pacer
7. Operator should prepare with all aseptic techniques (e.g., hand washing) and maximal barrier precautions (e.g., sterile gowns, sterile gloves, caps, masks covering both mouth and nose, eye protection, and full-body patient drapes).
8. Once sterile and able to touch the inside of the CVL kit, the operator may want to retract the curved J-tip wire into the plastic loop sheath for easy directing into the introducer needle. The operator should also uncap all distal lumens and flush all ports with 3–5 cc of the sterile NS syringes to ensure no defects in the lumen of the catheter. Close all ports except the distal tip port (usually marked with words "distal tip") with the slide clamp.
9. Prep area chosen (right or left side) from the anterior neck, clavicle, and upper chest (above nipple line) with sterile chlorhexidine prep (this is the second cleaning).
10. Place full-body drape over patient with opening over selected side where needle will be inserted.
11. Needle insertion site options (Fig. 3.7):
    - One centimeter inferior to the junction of the middle and medial third of the clavicle
    - Just lateral to the midclavicular line, with the needle perpendicular along the inferior lateral clavicle
    - One fingerbreadth lateral to the angle of the clavicle
12. Anesthetize needle insertion site with 5–10 mL of 1 % lidocaine superficially (make sure to pull back on needle syringe to ensure operator is not in the vein or artery).
    - Never place equipment on a patient.
13. Prepare the needle and syringe by placing the long needle on the syringe. Make sure to break seal of syringe by pulling back on the plunger of the syringe prior to making incision with needle.
14. Turn patient's head to opposite of CVL placement and retract ipsilateral shoulder down to improve clavicle-vein relationship. The retraction of the arm can be done a few steps earlier and can be held in position using a person or tape/restraints.
15. Direct the insertion needle toward sternal notch in the coronal plane at an angle no greater than 10–15° while gently withdrawing the plunger of the syringe. Keep bevel of the needle facing up and in line with the numbers on the syringe until operator enters skin, then face bevel caudally to facilitate smooth progression of the guide wire down the vein toward the right atrium.
16. It helps to place nondominant hand (not holding the needle) on the sternal notch so operator can feel where sternal notch is and direct needle in that direction (Fig. 3.7).
17. NEVER increase the angle of the needle greater than 15° as pneumothorax may ensue.
18. Advance the needle under and along the inferior border of the clavicle, making sure the needle is virtually horizontal to the chest wall. Aim medially in the direction of the suprasternal notch, attempting to first aim for the clavicle then "walk" the needle below the clavicle.
19. Once under the clavicle, continue to advance the needle in a plane almost parallel to the skin approximately 2–3 cm until venous blood is freely aspirated into the syringe.
20. When venous blood is freely aspirated, disconnect the syringe from the needle, and immediately occlude the lumen to prevent air embolism and insert the guide wire. If the vein is difficult to locate, remove the introducer needle, flush it clean of clots, and try again. Change insertion sites after three unsuccessful passes with the introducer needle.
21. At this point, the hand holding the needle should be "set in stone." Use the patient's chest wall as a base to keep needle completely still as to not inadvertently advance or retract needle out of the vein.
22. Insert the guide wire through the needle into the vein with the J-tip directed caudally to improve successful placement into the subclavian vein.
    - Beware a return of red pulsatile blood. If this occurs, the wire is in an artery.
    - Beware aspirating air bubbles through the probing introducer needle. This indicates a pneumothorax.
23. Advance the wire until it is mostly in the vein or until arrythmia is seen on the cardiac monitor. Then, retract the wire 3–4 cm.
24. If the wire does not pass easily, remove the wire, reattach the syringe, and confirm that the needle is still in the

lumen of the vein before reattempting. The J-tip can be straightened with a pinching motion (Fig. 3.4).

- Alternatively, the catheter/syringe found in most kits can be used as a bridge to guide wire placement. For the author, this has improved success when there is difficulty in wire placement. Use the same steps above with the catheter (Fig. 3.5) and when you have return of blood, advance the angiocath into the vein followed by insertion of the guide wire through the angiocath. This is especially useful in moving/agitated patients, patients who have collapsible veins due to hypovolemia, and patients who have abnormal anatomy and may have veins that take an abnormal angle shortly past the needle tip.

25. Use the tip of the scalpel to make a small incision just against the needle to enlarge the catheter entry site for the dilator and catheter.
26. Holding the wire in place, withdraw the introducer needle and place in needle holder.
27. Thread the dilator over the wire and into the vein with a firm and gentle twisting motion while maintaining constant control of the wire. If a large-bore introducer is placed, the dilator/introducer goes in one step, after the introducer is inserted, hold the wire in place and remove the dilator.
28. If operator is having difficulty threading the dilator, the skin incision with the scalpel may have been too superficial or small. It may help to enlarge this incision to avoid having the dilator get caught on superficial skin or connective tissue.
29. It is helpful to have sterile gauze handy to apply pressure with the hand not holding the wire as the vein will now bleed profusely from around the wire secondary to dilation.
30. Thread the catheter until it is close to the skin insertion site. Then pull back on the guide wire until it shows outside of the distal port. Grasp the wire outside of the distal port and thread the catheter while holding onto the guide wire. Usually catheters are inserted 15–16 cm from the right side and 18–20 cm from the left side (Fig. 3.6)
31. Hold the catheter in place and remove the wire. After the wire is removed, occlude the open lumen.
32. Attach sterile saline syringe to the hub and aspirate blood. Take needed samples and then flush the line with saline and recap. Repeat this step with all lumens.
33. Place biopatch on skin around the intersection with the lumen of the catheter.
34. Suture the line in place.
35. Enclose CVL site with sterile waterproof transparent dressing.
36. Confirm placement using CXR. Tip of catheter should be in the lower third of the SVC at the insertion of SVC into right atrium (tip at right bronchiotracheal angle or up to 2.5 cm below bronchiotracheal angle).
    - Alternatively, ultrasound can be used for subclavian line access but only a few limited studies have confirmed this as to date so will not describe in detail (see below for typical ultrasound technique used). See references for more information.

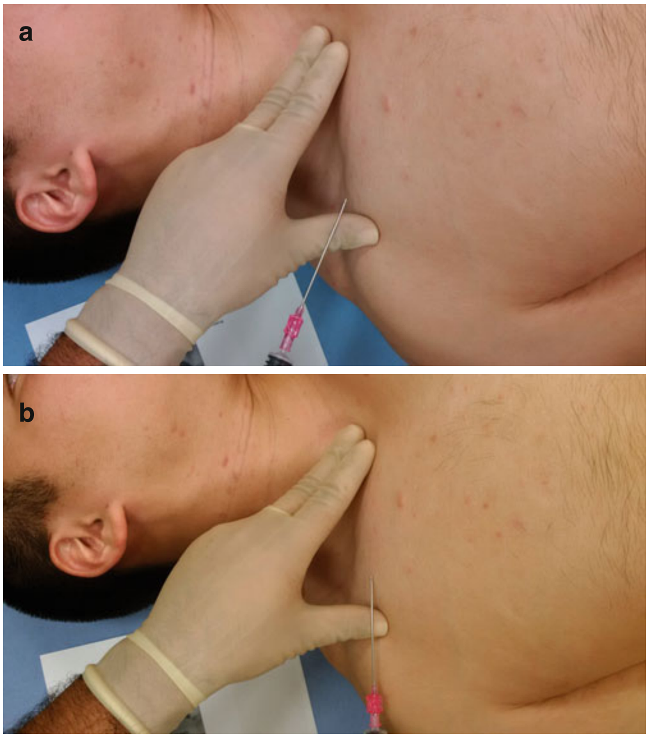

Fig. 3.7 Subclavian vein approach: wrong (**a**) and correct (**b**) angles to take when making skin puncture

3.4.2.1 Subclavian Vein Pearls and Pitfalls

- Inadequate landmark identification: operator should always palpate for landmarks and check anatomy prior to starting the procedure.
- Improper insertion position.
- Insertion of needle through periosteum.
  – Operator should NOT increase angle of needle to avoid the clavicle bone (this can cause a pneumothorax).
  – Operator should press on needle with downward pressure on chest wall to allow needle to maneuver under the clavicle without changing the angle of insertions of the needle.
- Taking too shallow a trajectory with needle.
- Aiming the needle too cephalad (aim for sternoclavicular junction).
- Failure to keep needle in place for wire passage: hand holding the needle should be planted on patient's chest for stabilization.

3.4.3 Femoral Vein Access Procedure

1. Palpate the patient's femoral artery below the inguinal ligament. This is usually found halfway between the anterior superior iliac spine (ASIS) and the midline of the symphysis pubis.
2. Trim overlying hair as necessary.
3. If ultrasound-guided approach is desired, use the linear probe (same as internal jugular) to detect the femoral vein at this location. The femoral vein will be easily compressible, while the femoral artery will be less compressible and pulsatile (Fig. 3.2).
4. Wash hands and use sterile technique to apply iodine or chlorhexidine solution (various forms available).
5. Open your femoral CVL kit and don cap, mask, sterile gown, and sterile gloves. Nonsterile assistants should wear a cap, mask, sterile gown, and sterile gloves. Flush all ports of your CVL kit with saline flushes and check for leaks or malfunction of catheter.
6. Under sterile technique, apply the drape over the area of insertion, and have an assistant extend the drape the length of the bed. Reapply sterile iodine or chlorhexidine at the site.
7. Anesthetize the skin overlying the femoral vein with lidocaine.
8. If ultrasound-guided approach is desired, have an assistant hold up the vascular ultrasound probe. Place your gloved hand through a sterile ultrasound sleeve and grasp the top of the ultrasound probe. Without breaking sterile technique, pull and invert the sterile ultrasound sleeve over the probe and cable. See Sect. 3.6 for detailed ultrasound-guided cannulation technique.
9. Insert the needle at a 45° angle, bevel down, directed superiorly, 1 cm medial to the palpable femoral artery pulse. Once the needle has broken the skin, aspirate by applying a small amount of continuous traction on the plunger of the attached syringe.
10. Advance smoothly and slowly until blood appears in the syringe. Stop once blood is aspirated. If femoral vein is not cannulated, withdraw your needle until just beneath the skin and redirect.
11. Hold the hub of the needle with thumb and forefinger to immobilize in place. Remove the syringe carefully. If blood appears arterial or pulsatile, remove the needle and hold pressure for 5–10 min.
    - Use the palm of your hand on the thigh to stabilize your hand. Not having your hand stable is a common mistake leading to needle movement out of the vein.
12. If blood appears venous (dark color, emerges as a continuous trickle, or transduced), cannulate the needle with the guide wire. Maintain a two-finger grip on the guide wire at all times. Advance the guide wire until approximately 15 cm remains.
    - Must keep handle of guide wire at ALL times and can be done through proper technique.
13. If guide wire does not advance easily, remove guide wire and reposition needle until blood aspirates easily. The J-tip can be straightened using a pinching motion if needed (Fig. 3.4)
    - Alternatively, the catheter/syringe found in most kits can be used as a bridge to guide wire placement. For the author, this has improved success when there is difficulty in wire placement. Use the same steps above with the catheter (Fig. 3.5) and when you have return of blood, advance the angiocath into the vein followed by insertion of the guide wire through the angiocath. This is especially useful in moving/agitated patients, patients who have collapsible veins due to hypovolemia, and patients who have abnormal anatomy and may have veins that take an abnormal angle shortly past the needle tip.
14. Using your scalpel, make a single 1/2 cm stab incision at the site of needle insertion to assist with dilator placement.
    - You can do the stab incision with or without the needle in place, but from experience, most novices have difficulty locating the correct stab location due to small amount of blood accumulation when the needle is taken out.
15. Remove your needle, carefully leaving guide wire in place. Apply dilator over guide wire and advance into the body with gentle pressure and a twisting motion in the same plane that you used to direct the needle.
16. Holding pressure at the insertion site with sterile gauze 4×4 pads, remove the dilator from the guide wire,

leaving the guide wire in place. Insert the central venous catheter over the guide wire until it fits snugly against the skin. Use the markings on the catheter to determine proper length placed (usually with femoral site you can "hub" the catheter) (Fig. 3.6).

17. Using a sterile saline flush, ensure that each lumen of the CVL draws blood easily and flushes easily. Carefully note any that do not and consider repositioning as needed. You can attempt moving catheter in or out a few centimeters or rotating the catheter and recheck. Apply caps to each open lumen of the CVL.
    - Remember to cover the introducer port if not using immediately. If you do not, it poses an infection and air embolism risk to the patient.
18. Suture the line in place.
19. Place an antibiotic biopatch or similar antimicrobial dressing.
20. Enclose CVL site with sterile waterproof transparent dressing.

3.4.3.1 Femoral Vein Pearls and Pitfalls

- Femoral central venous lines cannot accurately transduce central venous pressures.
- Asking the patient to perform a Valsalva maneuver has been shown to increase the width of the femoral vein by 1/3.
- The mnemonic NAVEL (Nerve Artery Vein Empty space Lymphatics) assists in remembering the order of femoral structures from lateral to medial.
- Traditionally, femoral venous lines were thought to have higher rates of infection than subclavian or internal jugular lines, but more recent analyses are challenging this belief.
  - Obesity is a more important risk factor for infection in femoral sites.

3.5 Complications

3.5.1 Jugular and Subclavian Complications

- Pneumothroax/Hemothorax
  - Prevention: Remove patient from ventilator before advancing the needle, choose the right side rather than left, and avoid multiple attempts when possible.
  - Management: Check postprocedure x-ray; if pneumothorax, arrange for thoracostomy depending on the size of the hemo-/pneumothorax.
- Catheter embolization
  - Prevention: Never withdraw a catheter past a needle bevel as this might shear off the catheter.
  - Management: X-ray the patient and contact specialist who can remove the embolized catheter.
- Arterial puncture: Hold compression if this occurs.
- Hematoma: Usually requires monitoring only.
- Thrombosis: This complication may lead to pulmonary embolism.
- Local site or systemic infection: Using maximal sterile precautions has been shown to greatly decrease rate of infection.
- Air embolism
  - May be caused by negative intrathoracic pressure when inspiration by the patient drawing air into an open line hub
  - Prevention: Be sure the line hubs are always occluded; placing the patient in the Trendelenburg position lowers the risk.
  - Management: The patient should be placed in Trendelenburg position with a left lateral decubitus tilt, which may prevent the movement of air into the right ventricle and onward into the left side of the heart. One hundred percent oxygen should be administered to speed the resorption of the air. If a catheter is located in the heart, aspiration of the air should be attempted.
- Dysrhythmias: Due to cardiac irritation by the wire or catheter tip. This can usually be terminated by simply withdrawing the line into the superior vena cava. One should always place a central venous catheter with cardiac monitoring.
- Lost guide wire: If the operator is not careful about maintaining control of the guide wire, it may be lost into the vein. This requires retrieval by interventional radiology or surgery and is an emergency.
- Catheter tip too deep: Check the postprocedure chest radiograph and pull the line back if the tip disappears into the cardiac silhouette.
- Catheter in the wrong vessel: Check the postprocedure chest radiograph for this complication; remove catheter and try again.
- Arterial puncture (subclavian only): The subclavian artery cannot be compressed; so, the subclavian approach should be avoided in anticoagulated patients.

3.5.2 Femoral Complications

- Arterial puncture: The femoral artery site can be compressed, so if punctured hold pressure.
- Hematoma: Usually requires monitoring only.
- Thrombosis: This complication may lead to pulmonary embolism.
- Catheter embolization.
  - Prevention: Never withdraw a catheter past a needle bevel which might shear off the catheter.
  - Management: X-ray the patient and contact specialist who can remove the embolized catheter.

- Lost guide wire: If the operator is not careful about maintaining control of the guide wire, it may be lost into the vein. This requires retrieval by interventional radiology or surgery and is an emergency.
- Local site or systemic infection: Using maximal sterile precautions has been shown to greatly decrease rate of infection.

3.6 Ultrasound Guided Cannulation: Tips for Each Approach

- Venous anatomy is best visualized using high-frequency (5–10 MHz) linear probe. Higher frequencies generate less penetration but better resolution.
- You can use the ultrasound to identify the location of the vessel prior to the procedure and utilize external landmarks during the procedure itself (static technique), or you can use the ultrasound to visualize cannulation of the vessel during the procedure (dynamic technique).
- Static view is advantageous in that the ultrasound transducer is not needed during the sterile portion of the procedure, but it does not allow for direct visualization of cannulation and guidance during the procedure.
- Dynamic view (preferred) allows for direct visualization during the procedure but requires more technique and requires use of transducer during the sterile portion of the procedure.
- The dynamic technique can be used in either a short-axis view, where a cross-sectional view of the vessel and needle is used, or a long-axis view, where a longitudinal view of vessel and needle is used (Fig. 3.3).
- The long-axis view allows for full visualization of the needle throughout the procedure and allows for better visualization and adjustment of needle depth. It is more difficult for lateral changes in positioning and tends to be more difficult technically.
  - Key in this view is that once a good section of vein is obtained, do not move probe to visualize the needle; move the needle into the ultrasound view by slightly adjusting trajectory.
- The short-axis view allows for lateral changes in position but is not as good at visualizing depth throughout the procedure, as visualization of the needle is in cross-sectional imaging. Perforation of the posterior wall is more common in this view.
- When using the short-axis view, remember to position the ultrasound probe such that the field of the ultrasound intersects the vessel (internal jugular, subclavian, femoral) at the anticipated site of insertion of the needle into the vein. Remember that the needle is only visualized as it intersects the plane of the ultrasound.
- When using the long-axis view, make sure to visualize the vessel with the ultrasound such that you can see the greatest diameter of the vessel along the entire length of the ultrasound probe. Keep the ultrasound steady during the procedure, and insert the needle at an angle at the lateral edge of the ultrasound probe. Using this technique, one can visualize the entire length of the needle.

3.7 Removing a Central Line

1. Place patient in supine or Trendelenburg position (for femoral removal can help decrease bleeding).
2. Remove suturing and dressing.
3. Jugular and subclavian: Have patient exhale and pull the line during the exhalation.
   - Exhalation increases intrathoracic pressure as compared to atmospheric pressure, thereby reducing the risk of air thromboembolism.
4. Hold pressure for approximately 1 min to stop bleeding.
5. Dress with a sterile dressing.
6. If central line-related infection is suspected, cut off the tip with sterile scissors and send for culture.

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Pulmonary Artery Catheter

4

Rohit Pravin Patel and Marie-Carmelle Elie

4.1 Indications

- Prevention or treatment of multiorgan failure in high-risk patients
- Preoperative and postoperative management in high-risk patients with cardiac, pulmonary, or renal dysfunction
- Patients with anticipated large fluid shifts (sepsis, bleeding, burns, cirrhosis)
- Oliguria or hypotension not relieved by fluids
- Suspected cardiac event leading to shock
- For continuous SVO2 (central venous oxygenation) monitoring in shock
- To differentiate shock states
- For monitoring cardiac output in patients requiring high-positive end-expiratory pressure (>14 cm H20)
- Monitoring and management of complicated myocardial dysfunction or cardiogenic shock
- Congestive heart failure with poor response to afterload reduction and diuretic therapy
- Suspected tamponade or contusion from blunt chest injury
- Pulmonary hypertension with myocardial dysfunction
- Diagnosis of primary pulmonary hypertension
- Aspiration of air emboli
- Direct pulmonary artery administration of thrombolytic therapy

4.2 Contraindications

- Tricuspid or pulmonary valve mechanical prosthesis
- Right heart mass (thrombus or tumor)
- Tricuspid or pulmonary valve endocarditis
- Recurrent sepsis (catheter could serve as nidus for infection)
- Hypercoagulopathy (catheter could serve as site for thrombus formation)
- Patient known sensitivity to heparin (catheters with heparin coating)
- Electrocardiographic (ECG) monitoring encouraged in conditions of complete left bundle branch block (risk of complete heart block increased), Wolfe–Parkinson–White syndrome, and Ebstein's malformation (risk of tachyarrhythmias)

4.3 Materials

- Pulmonary artery or Swan–Ganz catheter
- Percutaneous sheath introducer and contamination shield
- Compatible cardiac output computer for measuring cardiac output by the bolus thermodilution method
- Injectate temperature sensing probe (bolus thermodilution method)
- Connecting cables
- Sterile flush system and pressure transducers
- Bedside ECG and pressure monitor system
- Appropriate ECG "slave" cables

4.3.1 Catheter Preparation

- Avoid forceful wiping or stretching of catheter to avoid injury to the thermistor wire circuitry; wiping the heparin coat may cause removal of the coating.
- In vivo calibration is required if in vitro calibration is not done; refer to the monitor operator's manual for detailed calibration instructions.
- Connect catheter's injectate and pressure-monitoring lumens to the flush system and pressure transducers; ensure all lines are free of air.
- Connect the thermistor to the monitor and confirm no fault messages appear.

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4.4 Procedure

1. Maintain sterile precautions including sterile cap, mask, gown, gloves.
2. Place a central venous line introducer and verify placement of introducer with chest radiograph; it is also acceptable to obtain the chest radiograph after the insertion of the pulmonary artery catheter if no complication was suspected with the central venous line introducer.
3. Cleanse the skin and introducer thoroughly with chlorhexidine.
4. Have assistant open pulmonary artery catheter kit in sterile fashion.
5. Remove pulmonary artery catheter from kit and have assistant hook up all the ports to the transducers and make sure readings are accurate as the catheter is being manipulated.
6. Gently lift the distal portion of the catheter up from the silicone gripper; do not pull the balloon through the gripper to avoid damage.
7. Have assistant check the proximal and distal ports for patency by flushing with sterile saline. Also have the assistant check the patency of the balloon with the syringe provided in the kit (Fig. 4.1). Check for major asymmetry and for leaks (optional) by submerging in sterile saline or water. Deflate balloon prior to insertion. Carefully wave the distal catheter segment up and down to confirm electrical continuity by observing a pressure tracing on monitor. Ensure proper readings, no information is sometimes better than wrong information. Make sure each port transduces appropriately *prior to* insertion.
8. Familiarize yourself with the catheter line markings. Each thin line indicates 10 cm from the tip and thick line indicates 50 cm from the tip. These are used in combination to indicate length from tip (Fig. 4.2).
9. Place the sterile plastic sleeve (lock side toward patient, Fig. 4.3) over the catheter after flushing all ports to further protect the catheter during manipulation.
10. The distal end of the catheter is inserted into the introducer hub of the central venous line and threaded to the superior vena cava. The catheter must be placed at least 30 cm into the introducer for the balloon to clear the distal end of the introducer prior to inflation. At *no point* should the catheter be withdrawn with the balloon inflated; ensure the assistant has deflated the balloon prior to withdrawal. The balloon assists in directing the catheter through the vascular system using the directional blood flow.
11. At 20 cm, the balloon should be inflated and catheter advanced through right atrium, past the tricuspid valve into the right ventricle, then past the pulmonary valve to the pulmonary artery. The waveform and pressure readings can guide you through the various locations (Fig. 4.4).
12. Once in the pulmonary artery, the catheter should be carefully and slowly advanced to wedge position. The balloon can be deflated and pulmonary artery tracings should reappear. If a wedge is obtained with less than the maximum recommended volume, the catheter should be withdrawn to a position where full inflation volume produces a wedge tracing. Avoid prolonged times when obtaining wedge pressure (2 respiratory cycles or 10–15 s), especially in patients with pulmonary hypertension.
13. General guidelines for distance necessary at various points include: right atrium 20–25 cm, right ventricle 30–35 cm, and pulmonary artery 40–45 cm; catheter usually wedges at 50–55 cm. These are dependent on the starting location you are using to advance the catheter (subclavian, internal jugular, femoral).
14. Once the catheter is in correct position, it should be locked into place with the plastic sleeve tip onto the hub of the introducer.
15. Correct placement is confirmed with chest radiograph (Fig. 4.5).

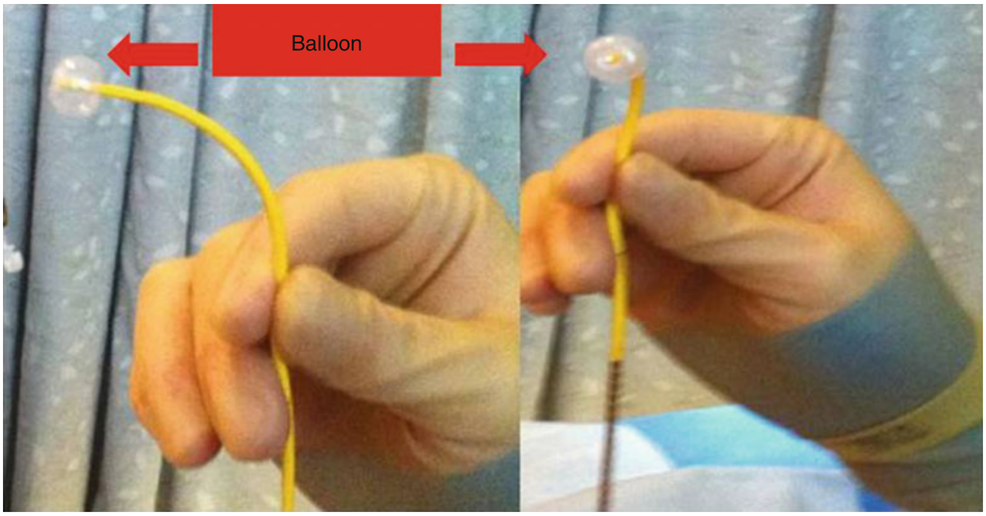

Fig. 4.1 Balloon inflation prior to insertion for evaluation of patency or leaks

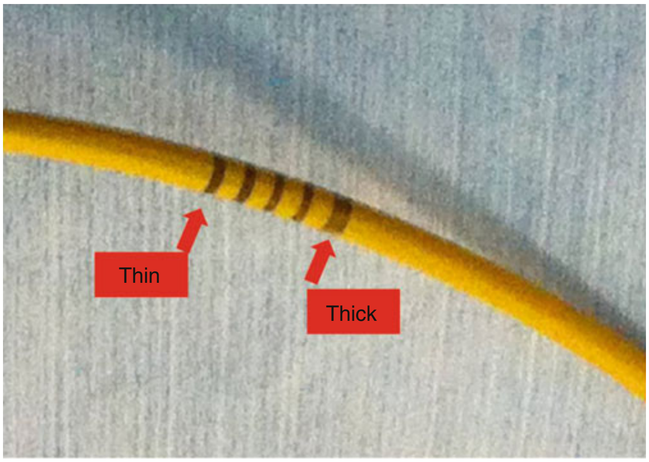

Fig. 4.2 Thick and thin markings found on the catheter representing length from distal tip

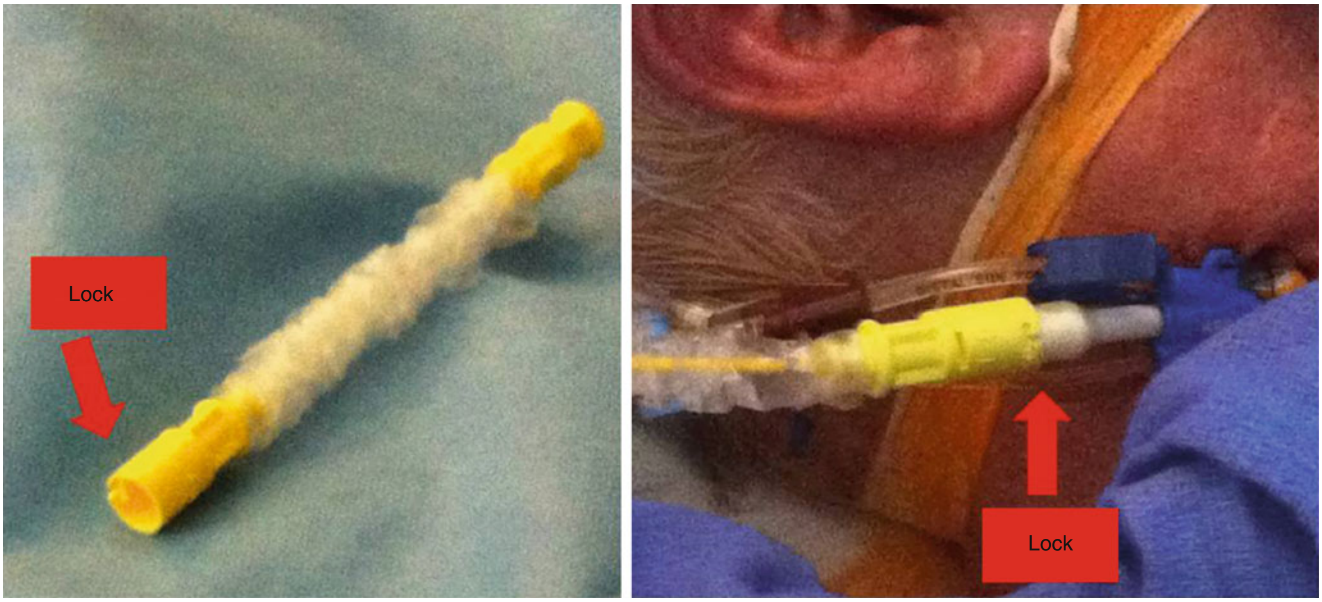

Fig. 4.3 Lock position on catheter for stabilization of catheter

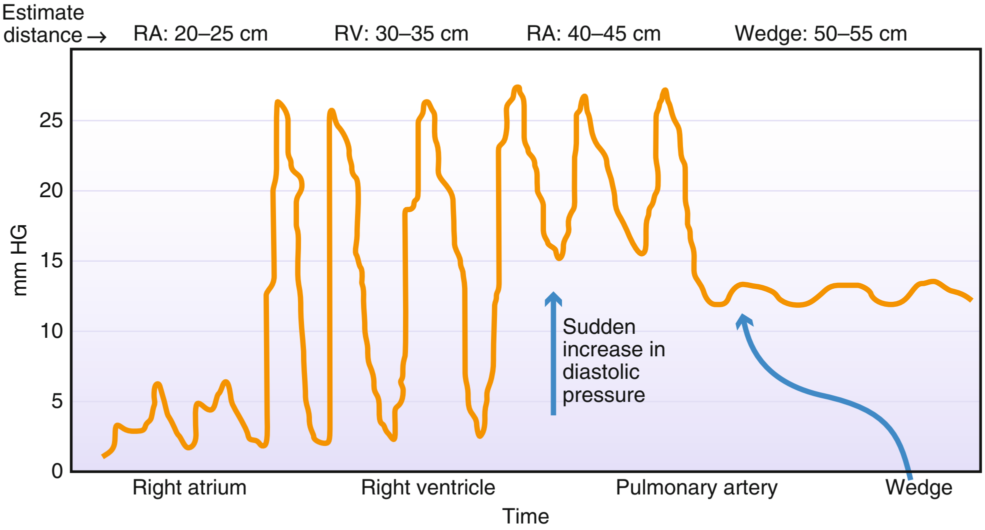

Fig. 4.4 Typical waveform seen at specific locations in the heart with associated estimated distances from catheter tip

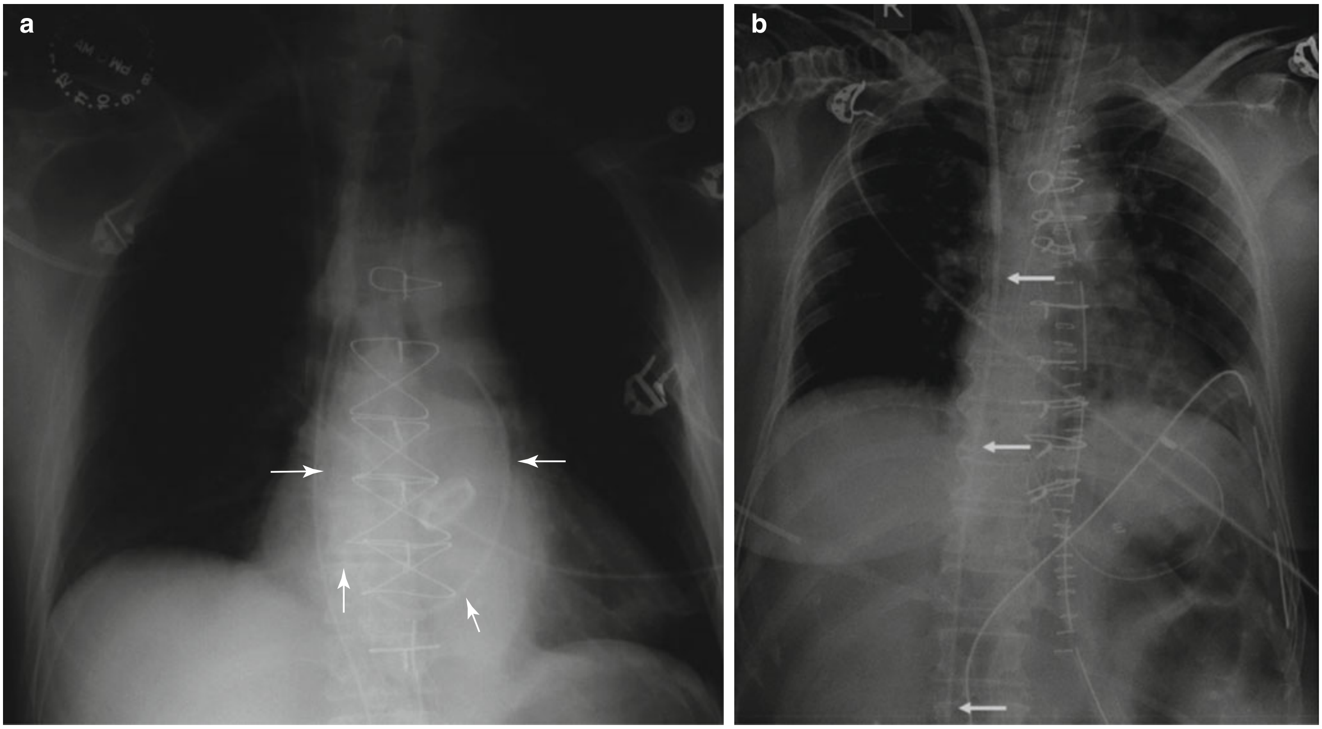

Fig. 4.5 Chest radiograph demonstrating correct (**a**) and incorrect (**b**) positioning of pulmonary artery catheter (*arrows*) (**a** Reproduced with permission from McGraw-Hill: Stead LG, et al. *First Aid for the Radiology Clerkship*. New York: McGraw-Hill; 2009; **b** Reproduced with permission from Wolters Kluwer: Jain SN. A pictorial essay: radiology of lines and tubes in the intensive care unit. *Indian J Radiol Imaging*. 2011;21(3):182–190)

4.5 Complications

- Arrhythmias: most are premature ventricular contractions that are self-limiting and resolve with advancement into pulmonary artery or withdrawal into atrium.
- Right bundle branch block: usually transient after positioning catheter into the pulmonary artery; if has already left bundle branch block may lead to complete heart block; should have temporary pacing equipment on standby.
- Knotting in the right ventricle (RV): risk increased in those with dilated cardiac chambers; a persistent RV tracing (15 cm beyond the point where initial RV tracing was observed) should alert you to this possibility.
- Pulmonary artery rupture: age >60 year, anticoagulation therapy, and presence of pulmonary hypertension increase risk of rupture; hemoptysis shortly after placement is indicative and management includes lateral decubitus positioning (bleeding side down), intubation with double lumen tube, and increasing positive end-expiratory pressure (PEEP).
- Infection.
- Pulmonary infarction: due to unintentional migration of distal tip.

4.6 Pearls and Pitfalls

- If the catheter requires stiffening during insertion, slowly perfuse the catheter with 5–10 mL of cold sterile solution as the catheter is advanced through a peripheral vessel.
- The incidence of complications increases significantly with periods of use longer than 72 h, so assess the need for the catheter on daily basis.
- Anticipate spontaneous catheter tip migration toward periphery of pulmonary bed; if a wedge tracing is observed when balloon is deflated, pull the catheter back.

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Noninvasive Cardiac Monitoring: The Edwards Vigileo System

5

Dawood G. Dalaly and Rohit Pravin Patel

5.1 Indications

Cardiac output monitoring is indicated when trying to determine fluid responsiveness in patients. It assists in directing and assessing results of resuscitative efforts to ensure appropriate tissue perfusion. Although most catheters are systemically invasive, tools like the Vigileo (Edwards Lifesciences; Irvine, CA) are excellent noninvasive devices for determining values such as the stroke volume, stroke volume variation, stroke volume index, cardiac output, and cardiac index (Fig. 5.1).

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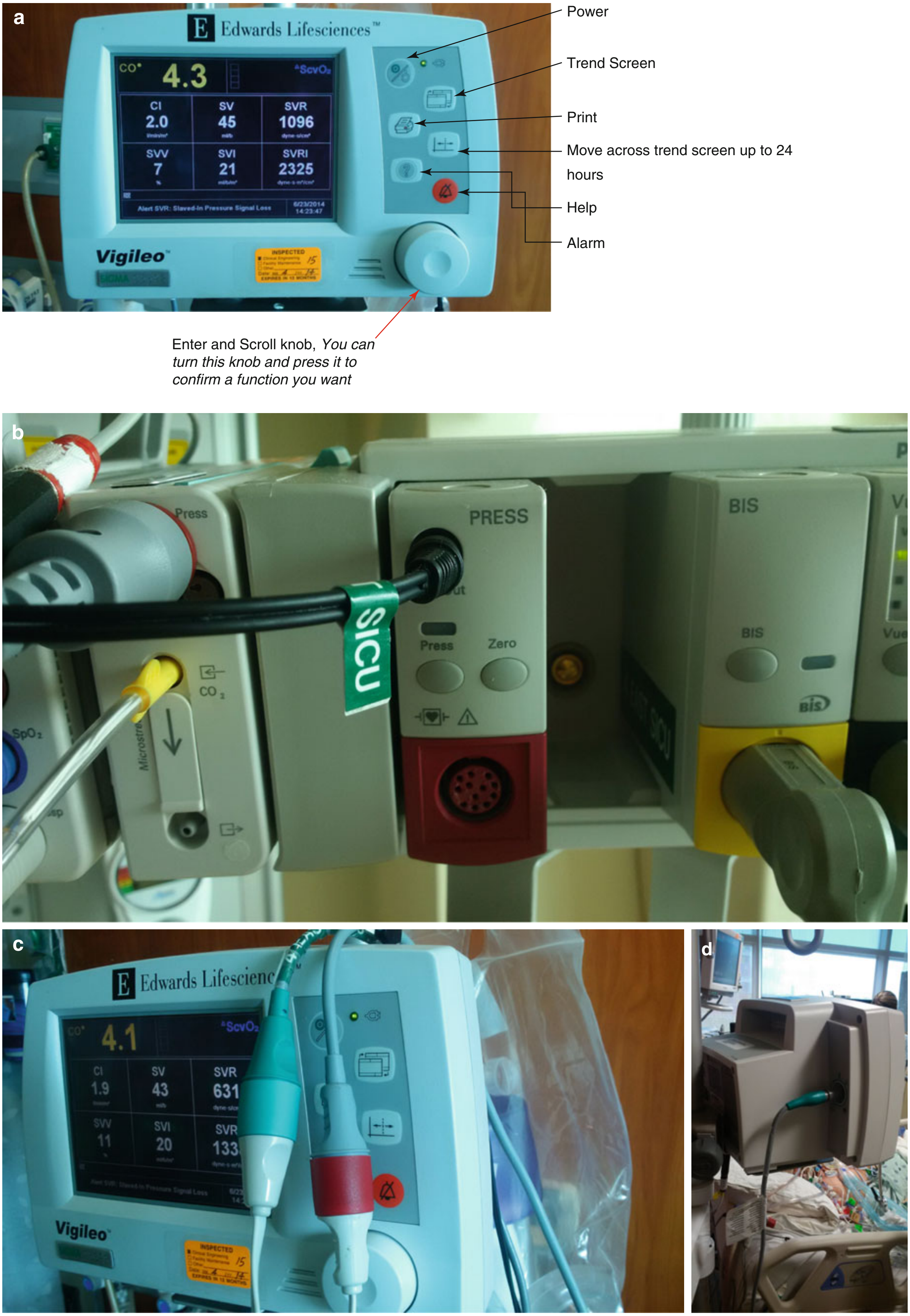
a
Power
Trend Screen
Print
Move across trend screen up to 24 hours
Help
Alarm
Enter and Scroll knob, *You can turn this knob and press it to confirm a function you want*
Edwards Lifesciences
Vigileo
CO
4.3
ScvO2
CI 2.0
SV 45
SVR 1096
SVV 7
SVI 21
SVRI 2325
Alert SVR: Slaved-In Pressure Signal Loss
b
Press
PRESS
Press
Zero
SICU
CO2
BIS
BIS
SpO2
c
Edwards Lifescienc
Vigileo
4.1
CI 1.9
SV 43
SVR 631
SVV 11
SVI 20
d

Fig. 5.1 Typical monitoring devices and connecting devices from monitor to patient: (**a**) FloTrac monitor, (**b**) FloTrac red port connects to the heart monitor, (**c**) the FloTrac system connects to the arterial line on one end and the pressure bag/monitors on the other; monitor connections are color coded, (**d**) the green port connects to the green port from the FloTrac

5.2 Contraindications

There are no contraindications to noninvasive monitoring of the heart, although most systems will need to be connected to an arterial line catheter, therefore contraindications to arterial line placement must be determined. Current literature supports the use of noninvasive monitoring to those who are 100 % supported ventilation with tidal volumes ≥8 mL/kg. There is no support for use in those with spontaneous breaths or arrhythmia. Patients with significant variation in respiratory pattern may have results that are unreliable.

5.3 Definitions and Values (Table 5.1)

Table 5.1 Cardiac output monitoring definitions

Term	Reference range	Definition
Cardiac output	4–8 L/min	Volume of blood being pumped by the heart in 1 min
Cardiac index	2.5–4 L/min/m^2	Compares the amount of fluid being pumped by the heart with an individual's body surface area
Stroke volume	40–80 mL/beat	Volume of blood being pumped by the ventricle per beat
Stroke volume variation	10–15 %	Represents percentage of change between minimum and maximum stroke volumes and predictor of fluid responsiveness
Stroke volume index	33–47 mL/m^2/beat	Quantity of blood ejected from the heart per beat
Mixed venous saturation (SvO_2)	60–80 %	Percentage of oxygen bound to hemoglobin in blood returning to the right side of the heart; represents oxygen delivery and consumption at the tissue level. Usually obtained from pulmonary artery catheter
Central venous oxygen saturation ($ScvO_2$)	70 %	Surrogate marker for $SvO_{2,}$ usually obtained from internal jugular or subclavian catheters

5.4 Materials

- FloTrac (Edwards Lifesciences, Irvine, CA, USA)
- Vigileo monitor
- Pressure bag

5.5 Procedure

1. Connect FloTrac to arterial line and distal FloTrac port to pressure bag. Inflate bag to 300 mmHg.
2. Connect green FloTrac cord to green Vigileo cord and red FloTrac cord to arterial line port on heart monitor.
3. Turn the port on the FloTrac off to the patient and zero on your heart monitor as you would with an arterial line. At the same time, you should have pressed the “Enter” knob on the Vigileo system, scrolled it to “zero arterial pressure,” and pressed the knob again for that function.
4. You should now have an arterial waveform on your heart monitor and your cardiac values on the Vigileo system.

5.6 Pearls and Pitfalls

- Some components of the values obtained are not reliable on spontaneously breathing patients and it is critical to check the ventilator waveforms for these breaths.
- Patients without adequate tidal volumes (at least 8 mL/kg) will also have unreliable values.
- Stroke volume variation usually is more reliable when greater than 13 % and indicates fluid responsiveness rather than when it is less than 13 % (similar to a low central venous pressure (CVP) being more informative than normal or high CVP levels).

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Peripheral Venous Cutdown

Jeffrey Kile, Katrina John, and Amish Aghera

6.1 Indications

- Distorted anatomy of peripheral venous access sites
- Unavailability of cannulable veins (e.g., in hypovolemia, burn victim, traumatic anatomy, sclerosed veins, etc.)
- Emergency venous access for infusion/transfusion
- Unavailability of central venous access or less invasive means peripherally

6.2 Contraindications

- Absolute
  - Availability of less invasive or less time-consuming means of vascular access
  - Overlying infection, traumatic tissue, burn, etc., at cutdown site
  - Traumatic injury proximal to cutdown site
- Relative
  - Coagulation disorders

6.3 Materials and Medications (Fig. 6.1)

- Sterile gloves
- Antimicrobial solution and swabs
- 4″×4″ gauze sponges
- Local anesthetic (1 % lidocaine 5 mL)
- 5-mL syringe
- Blunt needle
- 25- or 27-gauge needle
- Scalpel
- Vein dilator/lifter
- Peripheral intravenous catheter
- Curved hemostat
- 0-0 silk sutures or 4.0 nylon sutures
- Iris scissors
- Intravenous infusion tubing
- Adhesive tape

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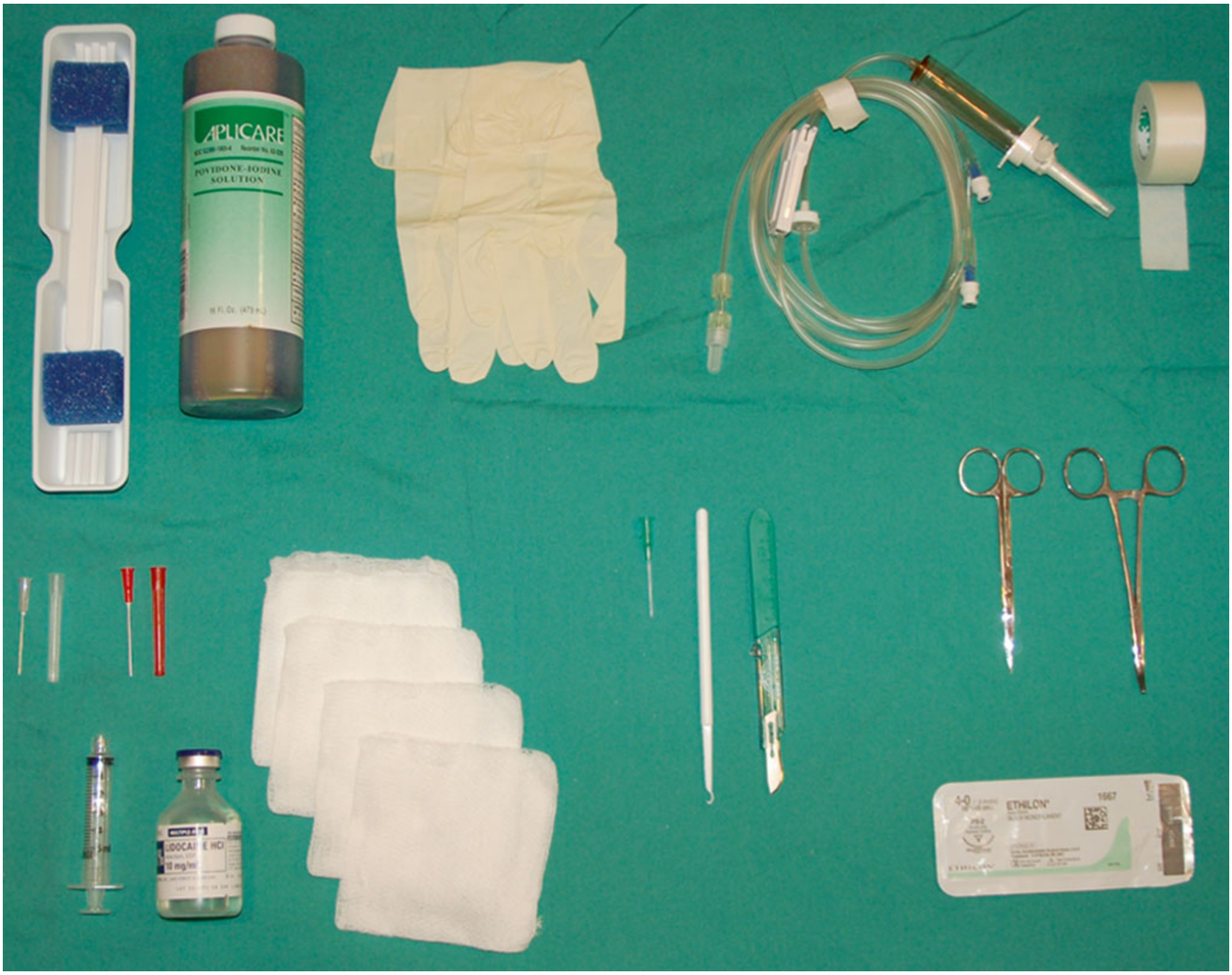
APLICARE
POVIDONE-IODINE SOLUTION
LIDOCAINE HCl
10 mg/ml
ETHILON
4-0

Fig. 6.1 Materials and medications

6.4 Choice of Vessel for Cutdown

- Greater saphenous vein: this vessel is the longest vein in the body, is predominantly subcutaneous, and is exposed with minimal blunt dissection just anterior to the medial malleolus at the ankle.
- Basilic vein: this vessel is reliably located 1–2 cm lateral to the medial epicondyle on the anterior aspect of the humeral region, typically catheterized just superior to the antecubital fossa approximately, and its diameter permits its localization relatively easily even in the hypotensive patient.
- Cephalic vein: this vessel runs anteromedially from the radial aspect of the wrist to the antecubital fossa, is superficial and large in diameter, and is most easily cannulated at the distal flexor crease in the antecubital fossa.

6.5 Procedure

6.5.1 Standard Venous Cutdown Technique

1. Apply antimicrobial solution liberally to the skin surrounding the incisional area.
2. Establish a sterile field by placing drapes around the incisional area.
3. Apply a tourniquet proximal to the planned cutdown site to maximize visualization of vein to be cannulated.
4. Inject local anesthetic to raise a small (0.5 cm) wheal using 25- or 27-gauge needle and then insert the tip of the needle through wheal to infiltrate skin superficial to the artery with approximately 4 mL of anesthetic.
    - Injection of local anesthetic into the vessel may precipitate arrhythmia, so draw back on the plunger prior to infiltration to ensure the tip of the needle is not inside the vessel.
5. Incise the skin with scalpel perpendicular to the course of the vein through all cutaneous layers until subcutaneous fat is visualized (Fig. 6.2).
    - Some practitioners prefer using a longitudinal incision to reduce the risk of transecting neurovascular structures, but this may not produce sufficient exposure of vein.
6. Using a curved hemostat or gloved finger, bluntly dissect the subcutaneous tissue to isolate and mobilize approximately 2–3 cm of the vein (Fig. 6.3).
    - A small self-retaining retractor or tissue spreader can be used in this step to improve visualization of vein if desired
7. Pass suture under the vein distal to the planned venous puncture site using hemostat to stabilize the vein and tie the suture over the vein (Fig. 6.4).
8. Pass a second suture under the vein proximal to the planned venous puncture site using hemostat (Fig. 6.5).
    - This step enables increased visualization, vessel control, and hemostasis during incision.
    - Leave the ends of both sutures long to facilitate maneuvering the vein.
9. Incise one-half to one-third of the diameter of the vein using a scalpel or iris scissors held at a 45° angle to the vessel (Fig. 6.6).
10. Grasping the proximal edge of the incision with a hemostat to apply counter traction (in a distal direction), insert the tip of the catheter into the venous incision (Fig. 6.7).
    - Do not force the catheter if it does not easily advance.
    - Catheter can be introduced directly through the skin incision or via skin puncture adjacent to the skin incision.
    - If the catheter lacks a tapered tip, cut the distal end of the cannula at a 45° angle to fashion a beveled tip.
11. Thread catheter into vein (Fig. 6.8).
12. Aspirate any air which may have entered the cannula during insertion.
13. Connect hub of catheter to intravenous tubing.
14. Tie the proximal suture around the vein just proximal to the venous incision, encircling both the vein and the intraluminal cannula with the suture.
15. Remove tourniquet.
16. Secure the catheter hub to the skin using nylon (4.0) sutures as follows. Take a 0.5 cm bite of skin under the catheter hub with the suture needle, tie several knots in the suture without pinching the skin, then tie a second set of knots around the hub of the catheter firmly.
17. Close the incision using nylon (4.0) sutures.
18. Dress the wound with appropriate self-adhesive sterile dressing or sterile gauze pads and adhesive tape.

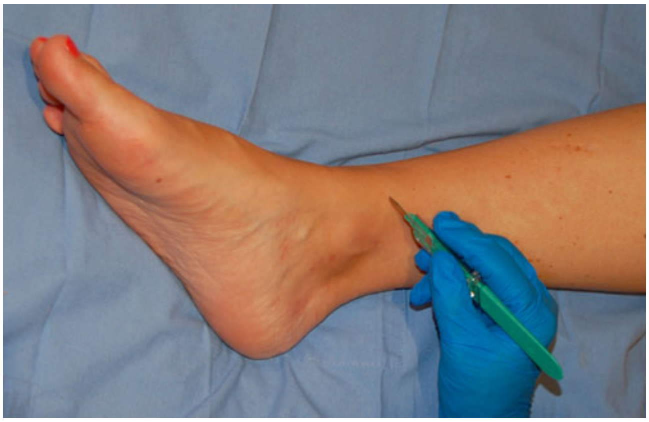

Fig. 6.2 Incision of skin

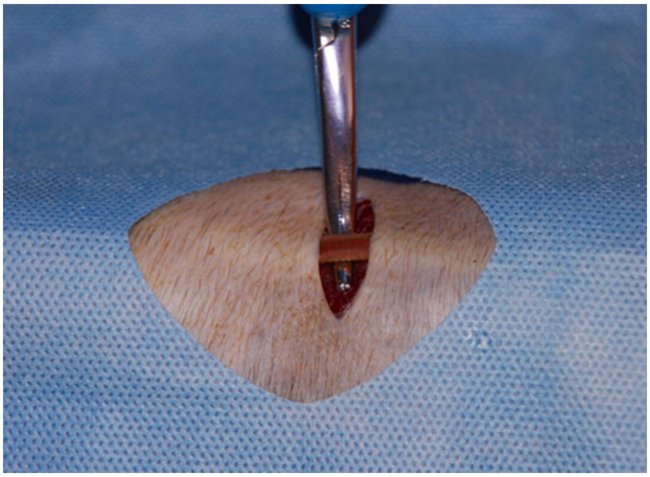

Fig. 6.3 Mobilization of vein

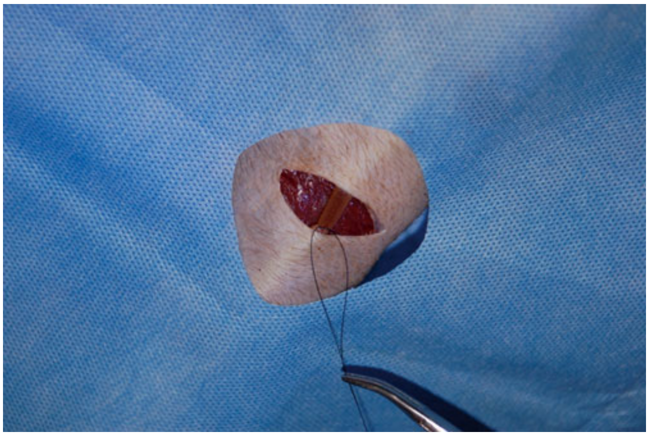

Fig. 6.4 Distal ligature tied around vein

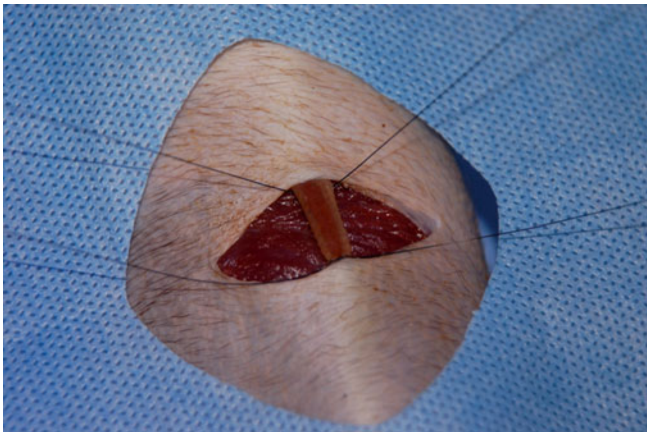

Fig. 6.5 Distal and proximal ligatures in place

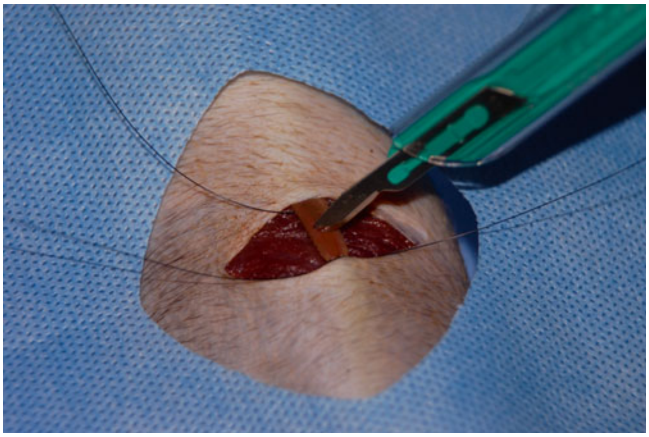

Fig. 6.6 Incision of vein

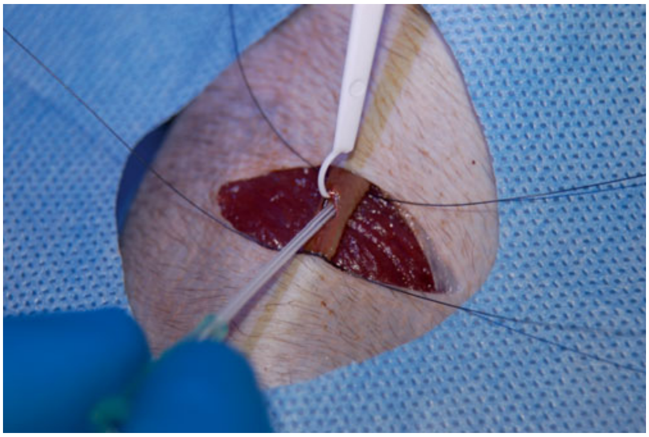

Fig. 6.7 Catheterization of vein

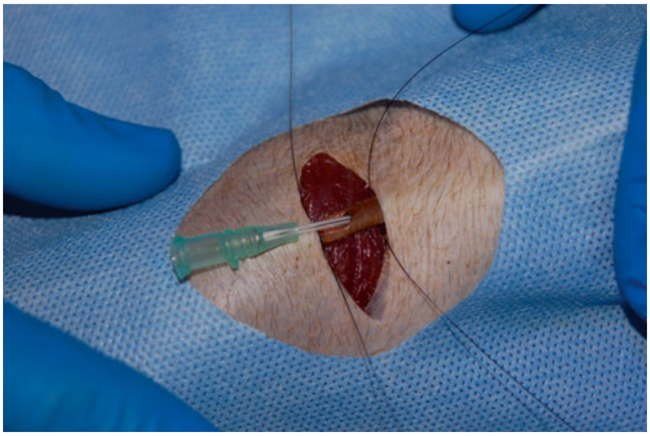

Fig. 6.8 Catheter threaded into vein

6.5.2 "Mini-Cutdown" Technique

(Perform steps 1–6 from the "Standard Venous Cutdown Technique," above, and then proceed with the steps below.)

1. Puncture the vein using a standard over-the-needle venous catheter.
    - Catheter can be introduced directly through the skin incision or via skin puncture adjacent to the skin incision.
2. Thread catheter into the vein over the needle.
3. Remove and discard the needle.
4. Aspirate any air which may have entered the catheter during insertion.
5. Connect catheter to intravenous tubing.

(Continue with steps 15–18 from the "Standard Venous Cutdown Technique," above.)

6.5.3 Modified/Guide Wire Technique

(Perform steps 1–6 from the "Standard Venous Cutdown Technique," above, and then proceed with the steps below.)

1. Insert the blunt end of the guide wire into the incised vein.
2. While stabilizing the guide wire at its insertion site, thread the dilator and sheath assembly over the free end of the guide wire until it is approximately one inch from the skin.
3. Grasp the free end of the guide wire protruding from the tail end of the assembly.
    - If it does not protrude from the tail end of the assembly, the guide wire must be removed sufficiently from the artery to be securely grasped. It must protrude visibly from the tail end of the dilator throughout the subsequent process of threading the dilator into the vein.
    - Never let go of the guide wire during this step, as insertion of the dilator and sheath assembly can otherwise push the guide wire completely into the vein.
4. Holding it firmly near its tip, thread the assembly over the wire into vessel with a gentle back-and-forth twisting motion.
5. Holding the sheath securely in the vein, remove and discard the dilator and guide wire.
6. Aspirate any air which may have entered the sheath during insertion.
7. Connect sheath to intravenous tubing.
8. Remove tourniquet.
9. Secure the sheath to the skin.
10. Close the incision using nylon (4.0) sutures.
11. Dress the wound with appropriate self-adhesive sterile dressing or sterile gauze pads and adhesive tape.

6.6 Complications

- Hematoma
- Infection
- Sepsis
- Phlebitis
- Embolization
- Wound dehiscence

6.7 Pearls and Pitfalls

- Fluids are infused most quickly via short, large-bore catheters.
- If the line is inserted for slow infusion of intravenous drugs, catheter lumen size is relatively insignificant.
- In larger children and adults, intravenous plastic tubing, small-bore pediatric feeding tubes, and Silastic catheters may be used as infusion catheters.
- Threading a 10-gauge intravenous catheter or intravenous tubing directly into the incised vein achieves excellent flow rates.
- If difficulty is encountered while threading the catheter into the incised vein, ensure an appropriately sized catheter has been used and that the vessel lumen has been correctly identified and that no false passage has been created in the adventitia.
- As compared to the standard venous cutdown technique, the mini-cutdown technique is easier and also preserves the vein, permitting repeated catheterization if necessary.
- As compared to the standard venous cutdown technique, the modified/guide wire technique reduces procedure time and increases the likelihood of vein salvage in the event of vessel transection.

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Part II

Airway and Vascular Procedures

Bag-Valve-Mask Ventilation

7

Braden Hexom and Tatiana Havryliuk

7.1 Indications

- Hypoxia
- Hypoventilation/apnea
- Rescue maneuver if failed intubation

7.2 Contraindications

- Absolute
  - Inability to ventilate due to lack of seal (thick beard, deforming facial trauma)
  - Inability to ventilate secondary to complete upper airway obstruction
  - Active, adequate spontaneous ventilation
- Relative
  - Full stomach (aspiration risk)
  - After induction and paralysis during rapid sequence intubation (aspiration risk)

7.3 **Materials** (Fig. 7.1)

- Bag valve mask (BVM) with reservoir
- Oxygen connector tubing
- Nasal pharyngeal airway/oral pharyngeal airway
- Lubricant jelly

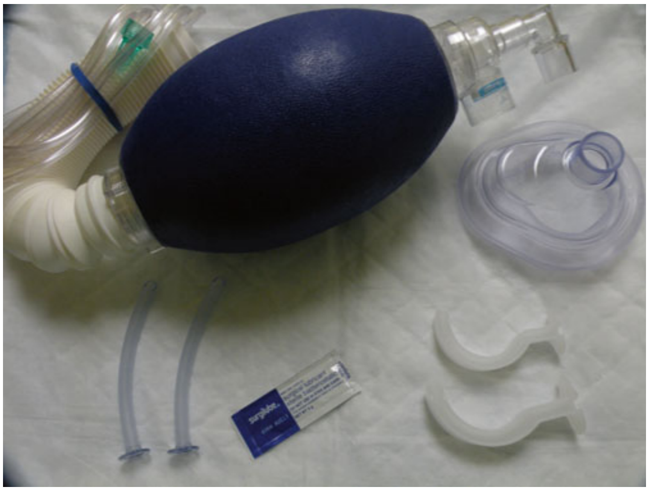

Fig. 7.1 BVM supplies: bag, mask, oral airways, nasopharyngeal airways, lubricant

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7.4 Procedure

1. Position patient in “sniffing” position.
2. Open the airway with chin-lift/head-tilt or jaw thrust maneuvers.
3. Place airway adjuncts to maintain airway patency. Use oral airway (Fig. 7.2) in unconscious patients. Use nasal airway (Fig. 7.3) in semiresponsive patients.
4. Attach oxygen tubing to high-flow oxygen (15 L/min).
5. Place appropriately sized mask on patient’s face covering the nose and mouth.
   - For one-handed technique (Fig. 7.4), use nondominant hand to make a “C” with index finger and thumb on top of the mask and form an “E” with the rest of the fingers using them to pull up on the mandible (E–C technique). Use the dominant hand to provide bag ventilations.
   - For two-handed (Fig. 7.5), two-person technique (preferred), make two semicircles with index fingers and thumbs of both hands on top of the mask and use the rest of the fingers to pull up on the mandible.
6. Consider the Sellick maneuver (cricoid pressure) to compress the esophagus against the cervical vertebrae, preventing gastric insufflation.
7. Ventilate patient providing reduced tidal volume breaths (500 mL) at a rate of 10–12 breaths per minute.
8. Give each breath gently over 1–1.5 s to avoid high peak pressures, avoiding gastric insufflation.
9. Prepare for definitive airway as dictated by the clinical scenario.

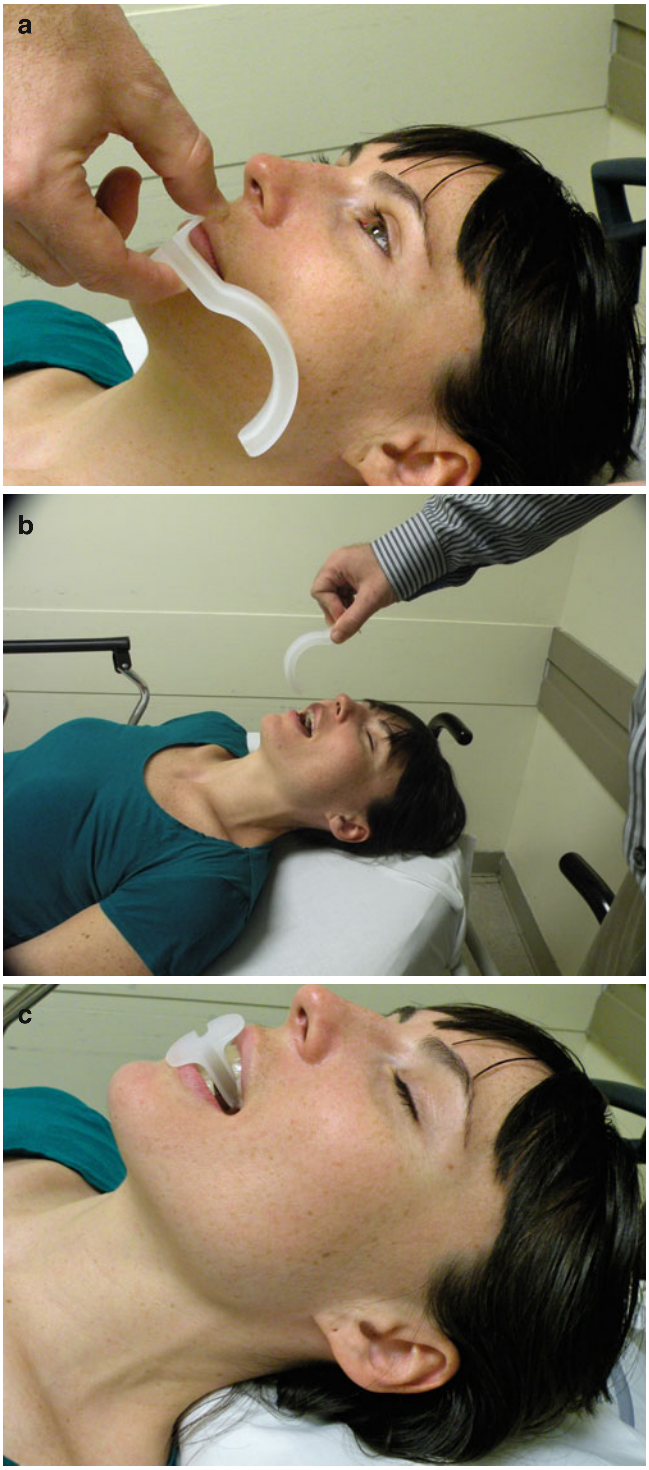

Fig. 7.2 (**a**–**c**) Oral airway insertion

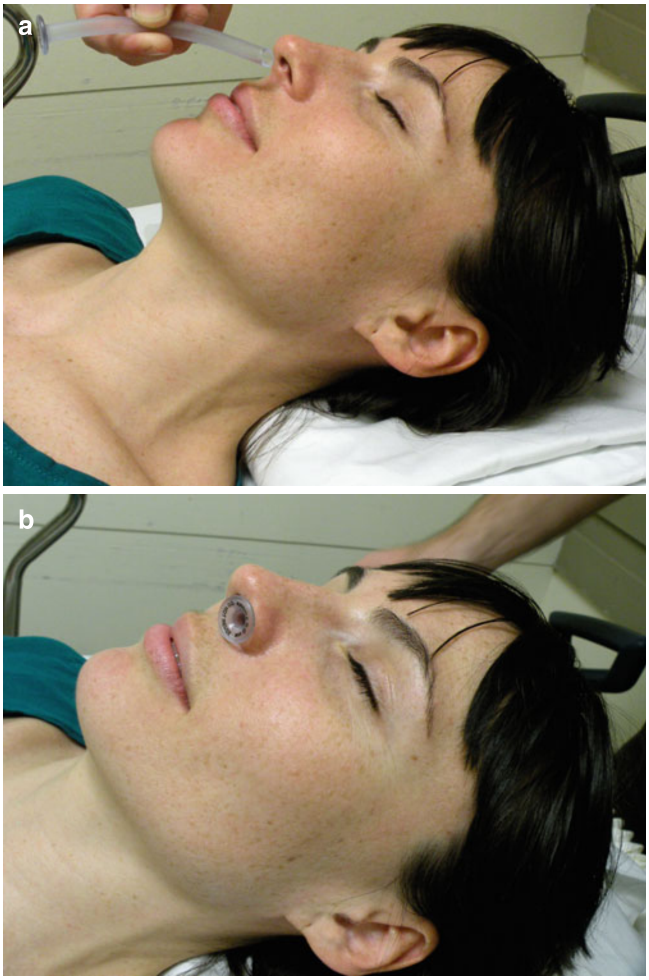

Fig. 7.3 (**a**, **b**) Nasal airway insertion

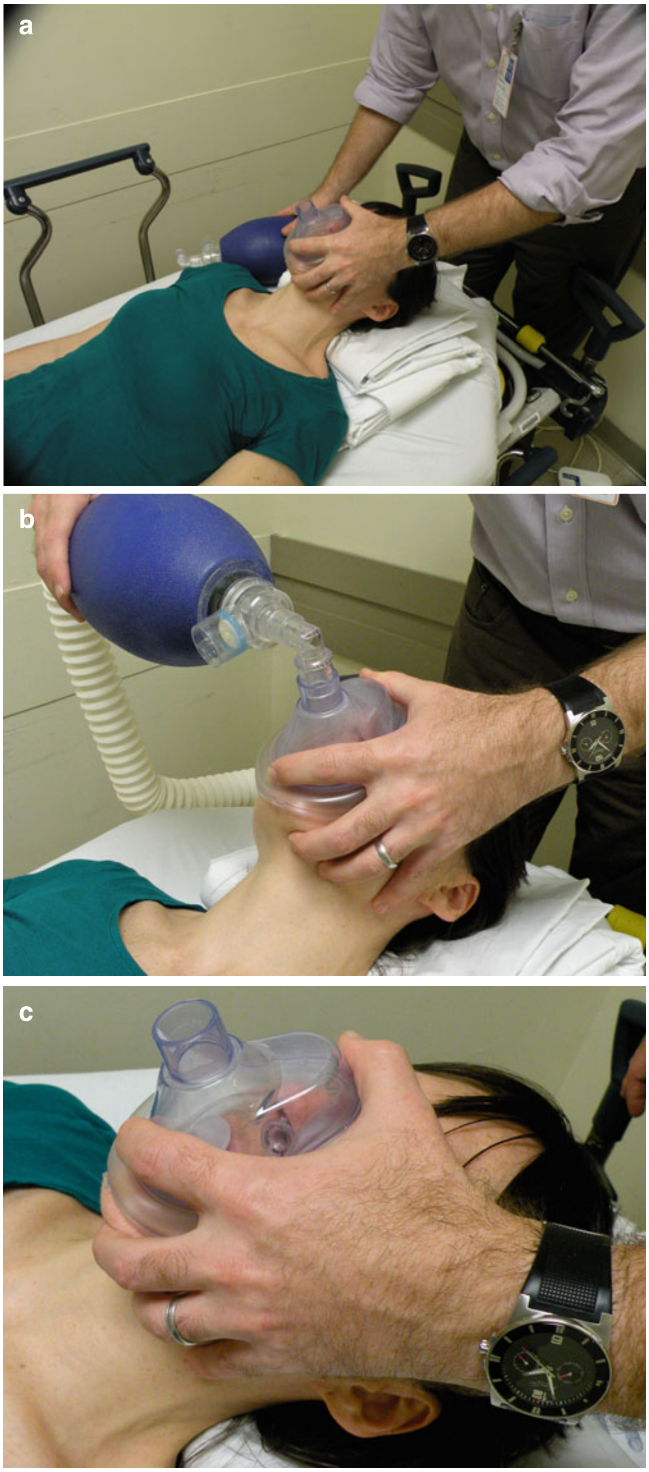

Fig. 7.4 (**a**–**c**) One-handed seal technique

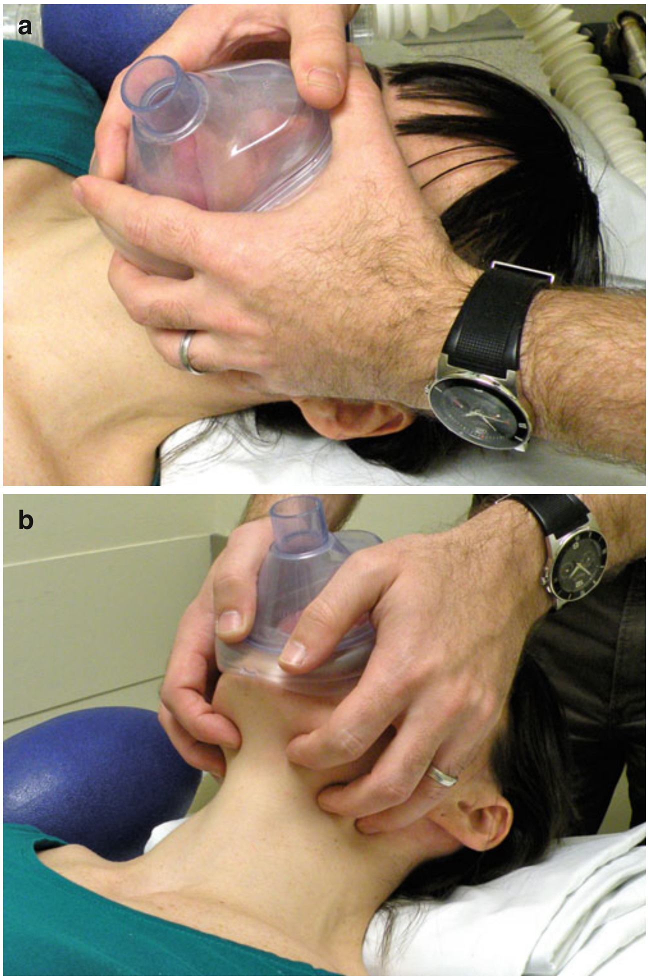

Fig. 7.5 Two-handed seal technique: (**a**) two semicircles, (**b**) alternative thumbs method

7.5 Complications

- Stomach inflation may lead to vomiting and aspiration.
- Increased positive thoracic pressure may cause decreased preload, worsening cardiac output, and/or hypotension.
- Hypoventilation (inadequate O_2 tidal volume, airway patency, or mask seal).

7.6 Pearls and Pitfalls

- Pearls
  - Use jaw thrust to open mouth for patients with possible cervical spine injury.
  - Use airway adjuncts whenever available, especially if prolonged BVM ventilation is anticipated.
  - Use lubricant jelly to insert nasal airway; do not insert in patients with severe facial trauma.
  - Mask should be placed on patient's face prior to attaching to bag.
  - Apply pressure to the bony part of the mandible only to avoid soft-tissue injury.
  - Provide just enough tidal volume to see a chest rise and deliver each breath gently over 1–1.5 s to prevent gastric insufflation.
  - Ensure good seal:
    - Select appropriate mask size.
    - Choose two-handed technique over one-handed, if possible.
    - Keep well-fitting dentures in place if present (and remove before intubation).
    - Lift the mandible toward the mask (as opposed to pushing the mask onto the face).
    - Rock the mask on face until no leak is present.
    - Apply K–Y jelly to beard to improve the seal.
- Pitfalls
  - Overcompression during the Sellick maneuver can compress the cricoid ring, preventing ventilation.
  - Cricoid pressure (Sellick maneuver) is not recommended during cardiac arrest resuscitation.
  - Difficult BVM ventilation: MOANS
    - *M*ask seal
    - *O*besity/obstruction
    - *A*ge
    - *N*o teeth
    - *S*tiff

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8

Awake Orotracheal Intubation

Benjamin M. Mahon, Justin Bennett, and Lars K. Beattie

8.1 Indications

- Urgent but not emergent endotracheal intubation is required in a patient who:
  - Is awake
  - Is currently protecting his airway
  - Is not a candidate for a supraglottic airway (LMA)
  - The patient
    - Is predicted to have a difficult airway
    - Has structural abnormalities of the airway
    - Will not tolerate a period of apnea
    - May lose his airway (anaphylaxis, angioedema, traumatic airway)
- Patients requiring urgent but not emergent intubation in whom paralytics are contraindicated (i.e., allergies, myasthenic crisis)

8.2 Contraindications

- Absolute
  - Surgical airway indicated
  - Emergent crash airway needed
  - Obtunded patient
  - Allergies to medications needed (lidocaine, glycopyrrolate)
- Relative
  - Inability to maintain airway or tolerate secretions

8.3 Materials and Medications

- Suctioning equipment
- Intravenous access equipment, cardiac monitor, pulse oximetry, blood pressure cuff
- 4 % lidocaine solution
- 2 % viscous lidocaine jelly
- Nebulizer
- Mucosal atomization device
- 4×4 gauze
- Tongue depressor
- Glycopyrrolate/atropine
- Sedation: ketamine, propofol, Versed, and/or fentanyl
- Intubation equipment
- Backup emergency airway adjuncts
- Bag valve mask
- Laryngoscope, fiber optics, oral airway, etc.

8.4 Procedure

1. Preparation
   (a) Establish IV access.
   (b) Place the patient on a cardiac monitor with continuous pulse oximetry.
   (c) Keep backup RSI emergency airway medication and equipment at the bedside.
2. Administer 0.2–0.4 mg of intravenous glycopyrrolate (or a small dose (0.5–1 mg) of atropine to decrease secretions) 15 min prior to procedure.
3. Nebulize 2 mL of 4 % lidocaine with oxygen at 5 l O2 per minute to anesthetize the pharynx (Fig. 8.1).

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4. Use Yankauer suction (with the patient's assistance) to dry out the mouth as much as possible. Dabbing the tongue with gauze can assist in this step.
5. Continue preoxygenation.
6. Immediately after the nebulized solution is applied, give the patient a "lidocaine lollipop" (Fig. 8.2).
   (a) A 2 ml dollop of 2 % viscous lidocaine is to be placed on the end of a tongue depressor and is given to the patient to place in his mouth (like a lollipop).
   (b) Have the patient copiously gargle, then swallow the viscous lidocaine.
7. Using a mucosal atomizer, spray 2 ml of 4 % lidocaine in the posterior oropharynx and as far down toward the glottis as possible (Figs. 8.3, 8.4, and 8.5).
8. Sedation
   (a) It is feasible to proceed with the awake intubation in an un-sedated, wide awake but cooperative patient.
   (b) Sedation can be initiated using institutional preferences, but some options include:
      (i) Midazolam 2 mg IV
      (ii) Ketamine 1 mg/kg IV
      (iii) Propofol 1 mg/kg IV
      (iv) Ketofol (ketamine and propofol both at concentrations of 10 mg/ml, 5 ml of each mixed in a 10 cc syringe) titrated at 1–3 ml aliquots
   (c) More atomized lidocaine can be provided prior to endotracheal tube (ETT) passage, but one must be aware of the upper lidocaine dose for your patient.
   (d) Adequate anesthesia is confirmed by the absence of a gag reflex upon direct palpation (Fig. 8.6).
9. Intubation, induction, and gentle direct laryngoscopy can be performed at this point to place the ETT (Fig. 8.7).
   (a) Induction (if no prior sedation) and paralytic agents should be available to immediately administer after ETT placement.
   (b) Thorough discussions on intubation techniques can be found in other chapters in the atlas.

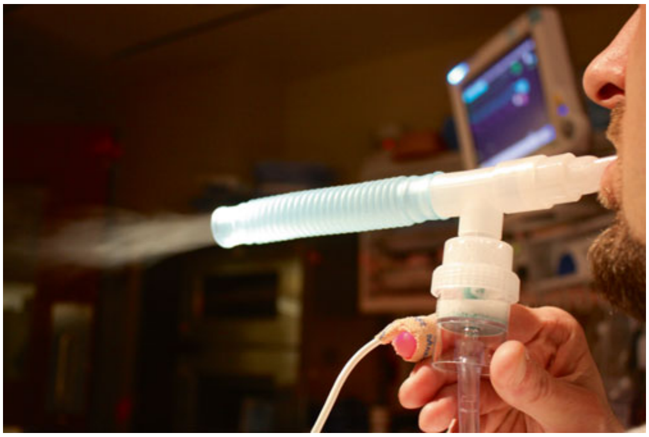

Fig. 8.1 Nebulization of 4 % lidocaine

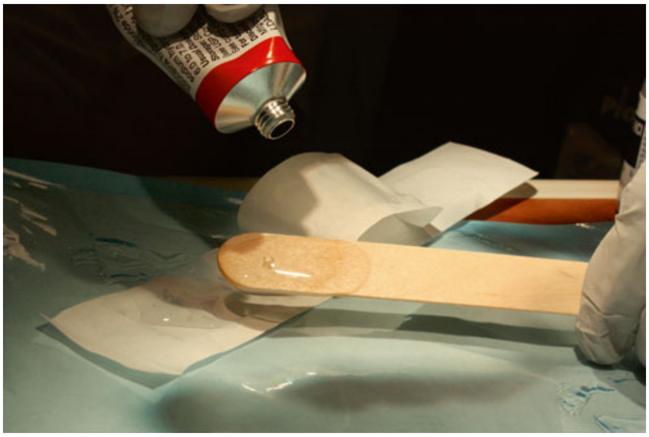

Fig. 8.2 Lidocaine lollipop

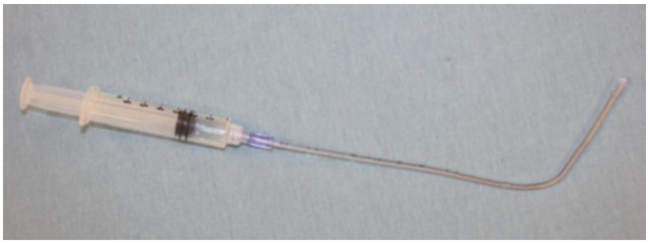

Fig. 8.3 Mucosal atomizer attached to syringe

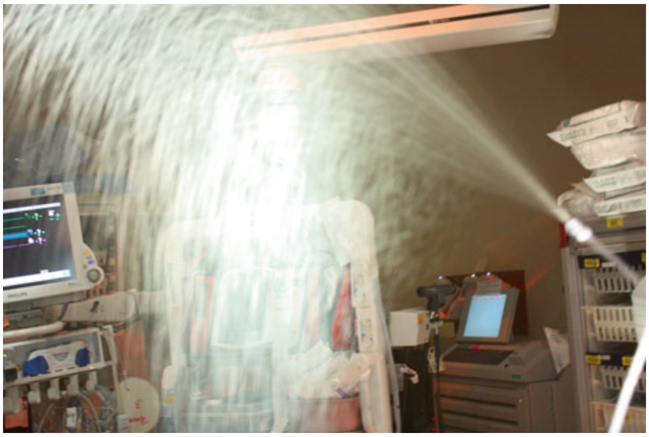

Fig. 8.4 Pushing syringe plunger atomizes lidocaine

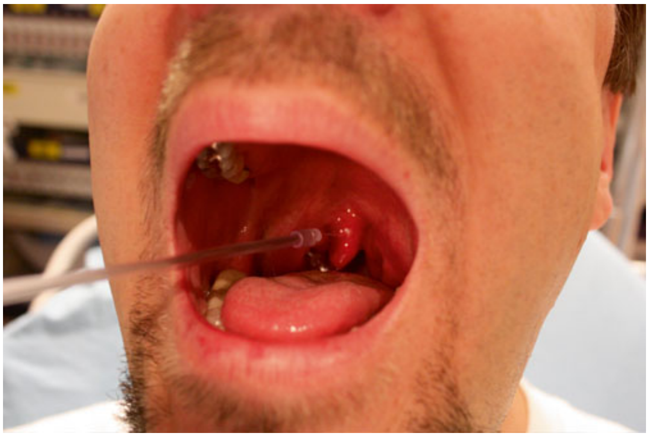

Fig. 8.5 Atomized lidocaine being administered to the posterior pharynx

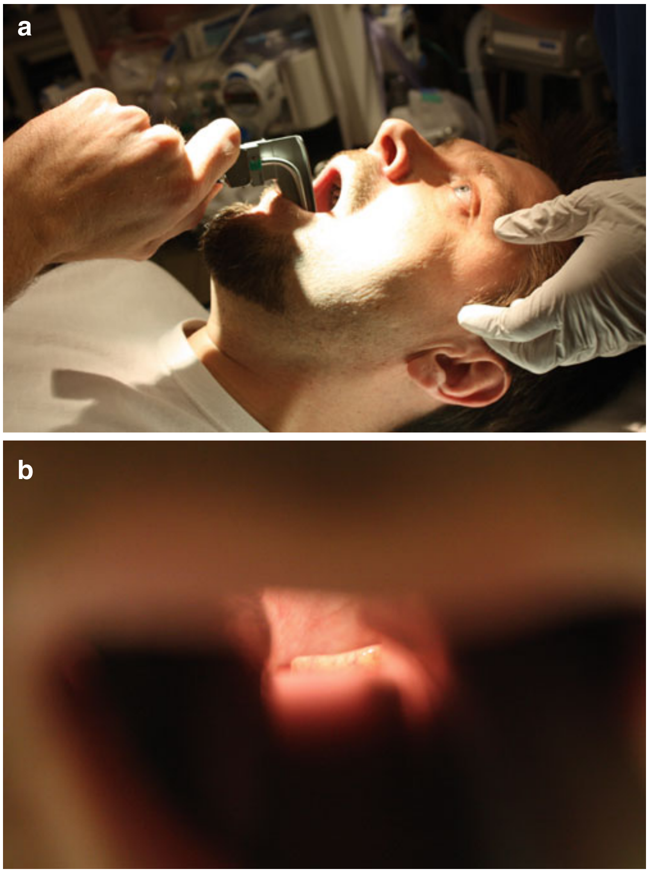

Fig. 8.6 (**a**, **b**) Adequately anesthetized awake patient with laryngoscopic view of epiglottis

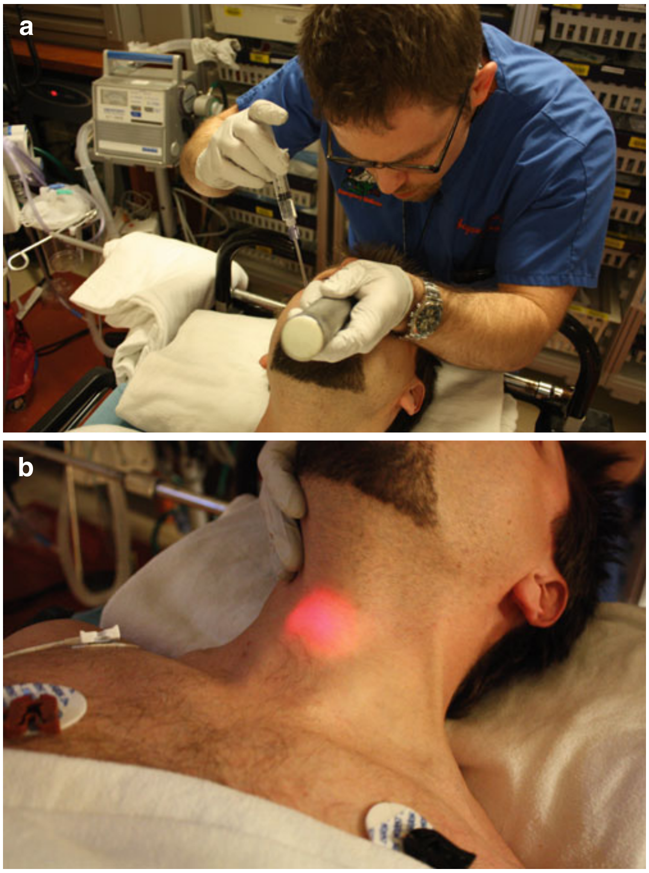

Fig. 8.7 (**a**) Final lidocaine atomization of deep structures and trachea, (**b**) intubation using a lighted stylet

8.5 Pearls and Pitfalls

- Pearls
  - Steps 3–7 should be done successively and as quickly as possible, to capitalize on the short half-life of lidocaine.
  - Simultaneous preoxygenation and anesthetization can be achieved by nebulizing the 4 % lidocaine through a face mask.
  - If the patient has been sedated, soft restraints may help prevent the patient from inadvertently grabbing the tube or your intubating equipment.
  - A nasotracheal intubation can be performed by simply anesthetizing the nares through which the ETT will be placed using lidocaine jelly and/or atomized lidocaine.
- Pitfalls
  - Failure to prepare all equipment beforehand may extend the procedure beyond the lidocaine half-life.
  - The toxic dose of lidocaine is 300 mg or 3–5 mg/kg. The dosages listed are intended for a 70 kg patient and yields a total dose of 280 mg (4 mg/kg). This dose may need to be decreased in smaller individuals.

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Rapid-Sequence Intubation

9

Ram A. Parekh

9.1 Indications

- Failure to oxygenate
- Failure to ventilate
- Unable to protect airway patency or reflexes
- Projected clinical course deterioration

9.2 Contraindications

- Absolute
  - Complete upper airway obstruction
  - Significant facial and airway trauma with loss of landmarks for orotracheal intubation
- Relative
  - Anticipated difficult intubation
    - Not an absolute contraindication.
    - Patient scenario requires a careful preintubation assessment and plan.
    - Consider an "awake" intubation.
    - Consider alternative airway adjuncts (e.g., extraglottic devices, video laryngoscopy, laryngeal mask airway [LMA]).
  - Induction or paralytic agent-specific contraindications given clinical circumstances
    - Caution: induction agents that lower blood pressure in hypotensive patients
    - Caution: succinylcholine in potentially hyperkalemic patients
  - Crash airway
    - Apneic, arrest, and periarrest situation

9.3 Materials and Medications

- Laryngoscope with appropriate blade (choice based on proceduralist's preference and patient anatomy) (Fig. 9.1)
- Intubating stylet
- Endotracheal tubes (ETTs)
- Syringe, 10 mL (to inflate ETT cuff)
- Surgilube
- Suction catheter
- Oral and nasal airways (Fig. 9.2)
- Ambu bag and mask attached to oxygen source
- Induction, pretreatment, and paralytic agents
- ETT confirmation device—EZ capnometry, quantitative end-tidal carbon dioxide concentration ($EtCO_2$) detection

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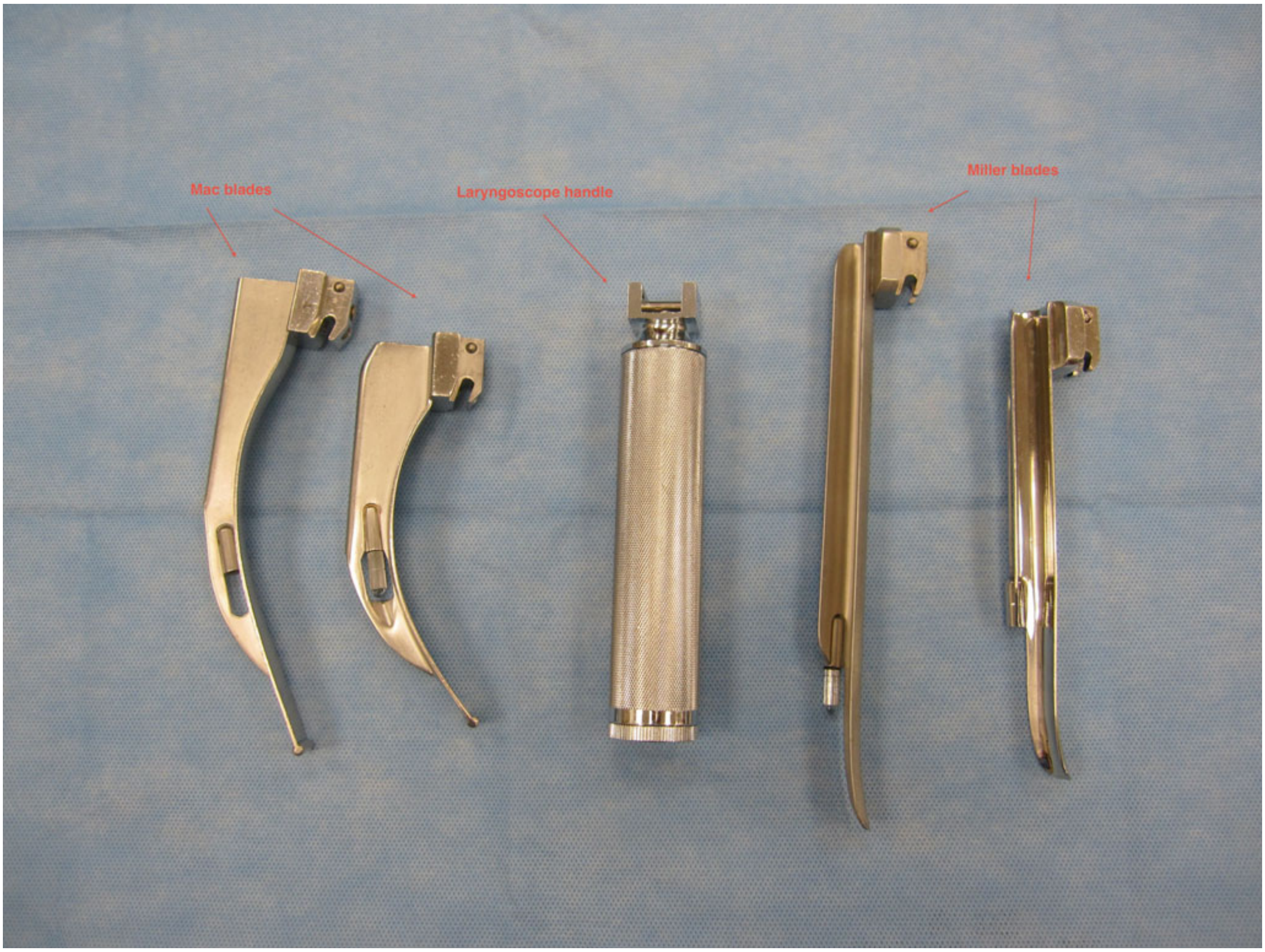
Mac blades
Laryngoscope handle
Miller blades

Fig. 9.1 Laryngoscope and blades

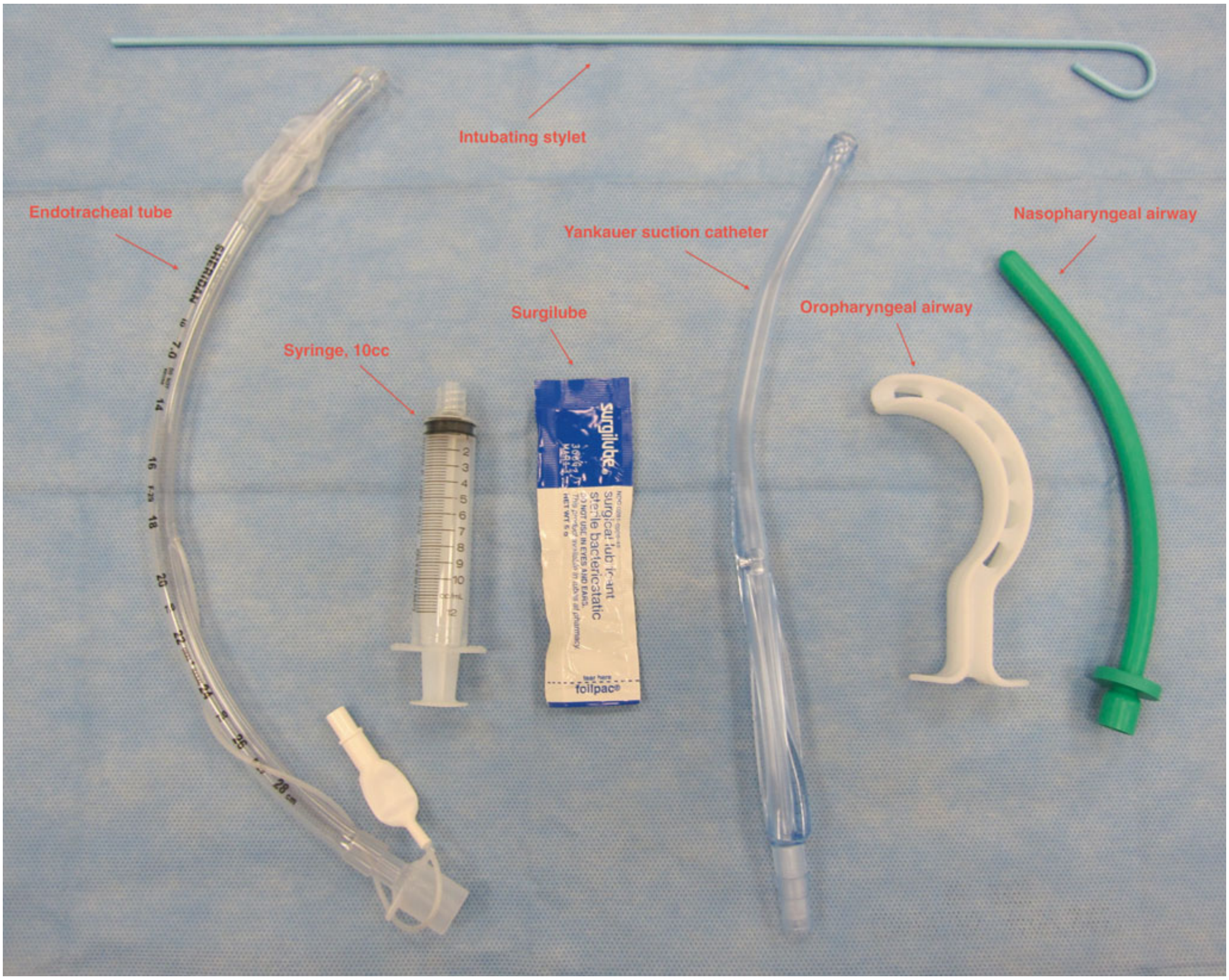
Intubating stylet
Endotracheal tube
Yankauer suction catheter
Nasopharyngeal airway
Surgilube
Oropharyngeal airway
Syringe, 10cc

Fig. 9.2 Oral and nasal airways

9.4 Procedure

1. Preparation
   - Thoroughly assess patient for difficulty of intubation (Fig. 9.3).
   - Develop fallback plans for failed intubation attempt.
   - Establish at least one, but preferably two, secure intravenous (IV) lines.
   - Place on cardiac monitor with pulse oximetry, blood pressure monitoring, and continuous capnography.
   - Yankauer suction device attached to suction, suction on.
   - Pharmacological agents, drawn and labeled.
   - Laryngoscope and blades tested to ensure proper functioning of light source.
   - Desired ETT size, prepared for intubation:
     - Intubating stylet in position (tip at eye of ETT)
     - 10-mL syringe attached to ETT
     - ETT configured per proceduralist's preference (e.g., hockey stick, curved)
     - Cuff tested for air leak
2. Preoxygenation
   - Administer high-flow oxygen for 3–5 min (Fig. 9.4).
     - Nitrogen is exchanged for O_2 in the functional residual capacity of the lungs.
     - Establishes oxygen reservoir within lungs (primarily), blood, and body tissue.
     - Also known as nitrogen "washout."
   - This can be done using:
     - Non-rebreather masks—delivers 65–70 %
       - Difficult intubation not anticipated
     - Well-fitting bag-valve-masks (without positive-pressure ventilation)—delivers greater than 90 % oxygen (Fig. 9.5)
     - Noninvasive positive-pressure ventilation (NIPPV)—delivers 100 % oxygen
       - Consider NIPPV in high-risk patients with moderate to severe shunt physiology.
3. Pretreatment
   - Administer pharmacological agents to mitigate adverse physiological effects of intubation, induction, and paralysis, which may be undesirable in certain clinical circumstances (Table 9.1).
4. Induction and paralysis
   - Administer a rapidly acting induction agent to produce rapid loss of consciousness via IV push (Table 9.2).
   - Immediately follow induction agent with a neuromuscular-blocking agent via IV push (Table 9.3).
5. Positioning
   - If no cervical spine injury suspected, place the patient in the "sniff" position (Fig. 9.6):
     - Flex neck
     - Extend head
   - Ideally, the patient's pinna will be at the level of the sternum.
6. Direct laryngoscopy (see Chap. 10)
7. Proof of placement
   - Visualize ETT passing vocal cords
   - Confirm tube placement via $EtCO_2$:
     - Qualitative detection device—EZ Cap
     - Quantitative continuous $EtCO_2$ waveform on monitor (preferred) (Fig. 9.7)
   - Auscultation of breath sounds:
     - Lung fields bilaterally
     - Epigastric region (ensuring no breath sounds in the stomach)
8. Postintubation management
   - Secure ETT (Fig. 9.8)
   - Initiate mechanical ventilation.
   - Postintubation sedation and analgesia.
   - Postintubation chest x-ray.

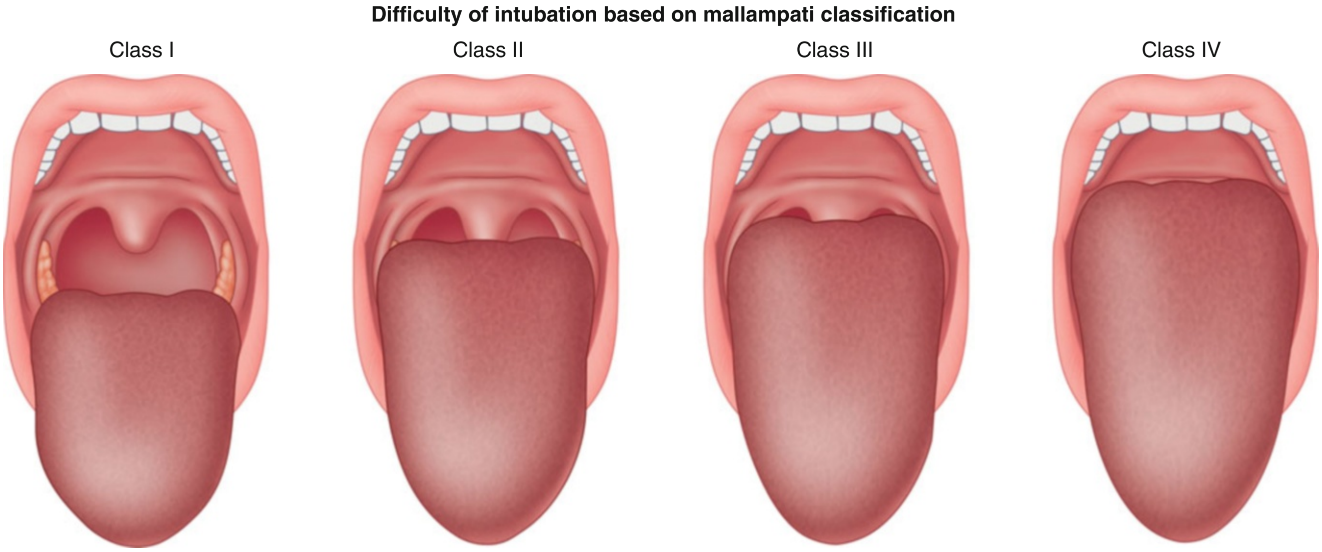
Difficulty of intubation based on mallampati classification
Class I
Class II
Class III
Class IV

Fig. 9.3 Assess patient for difficulty of intubation

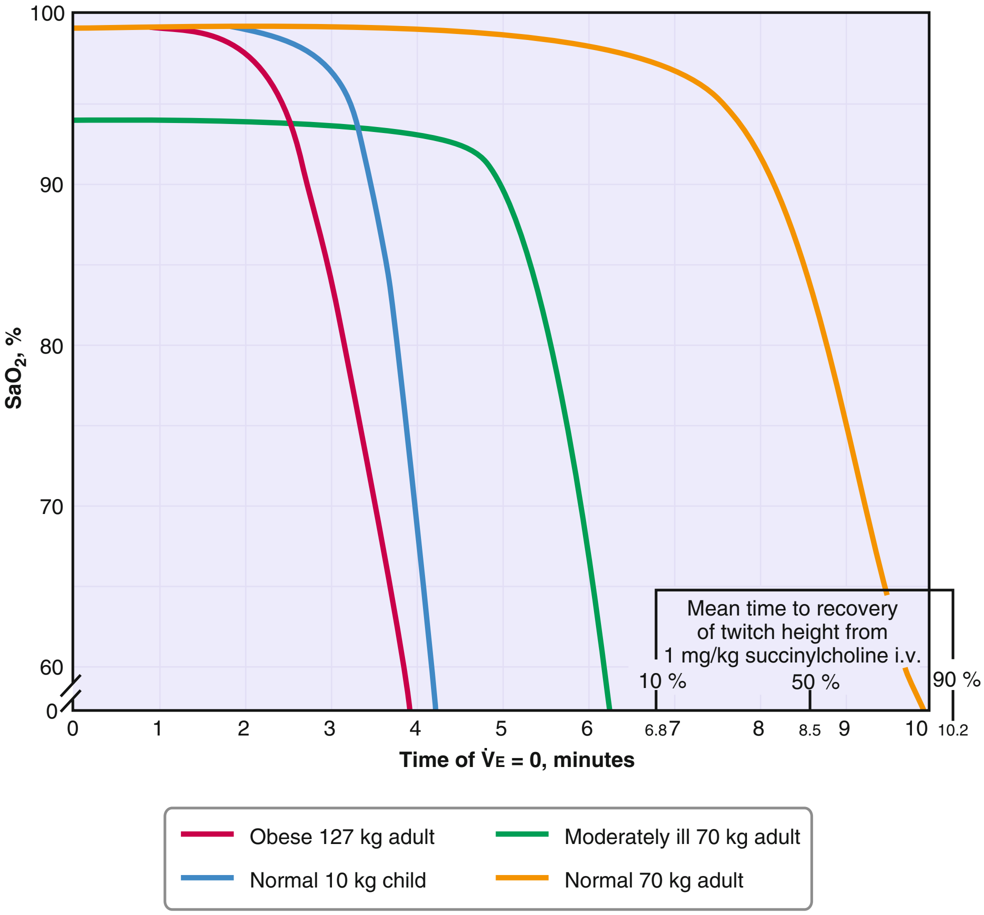

Fig. 9.4 *FaO2* fractional concentration of alveolar oxygen, *SaO2* arterial oxygen saturation, *Ve* expired volume per minute

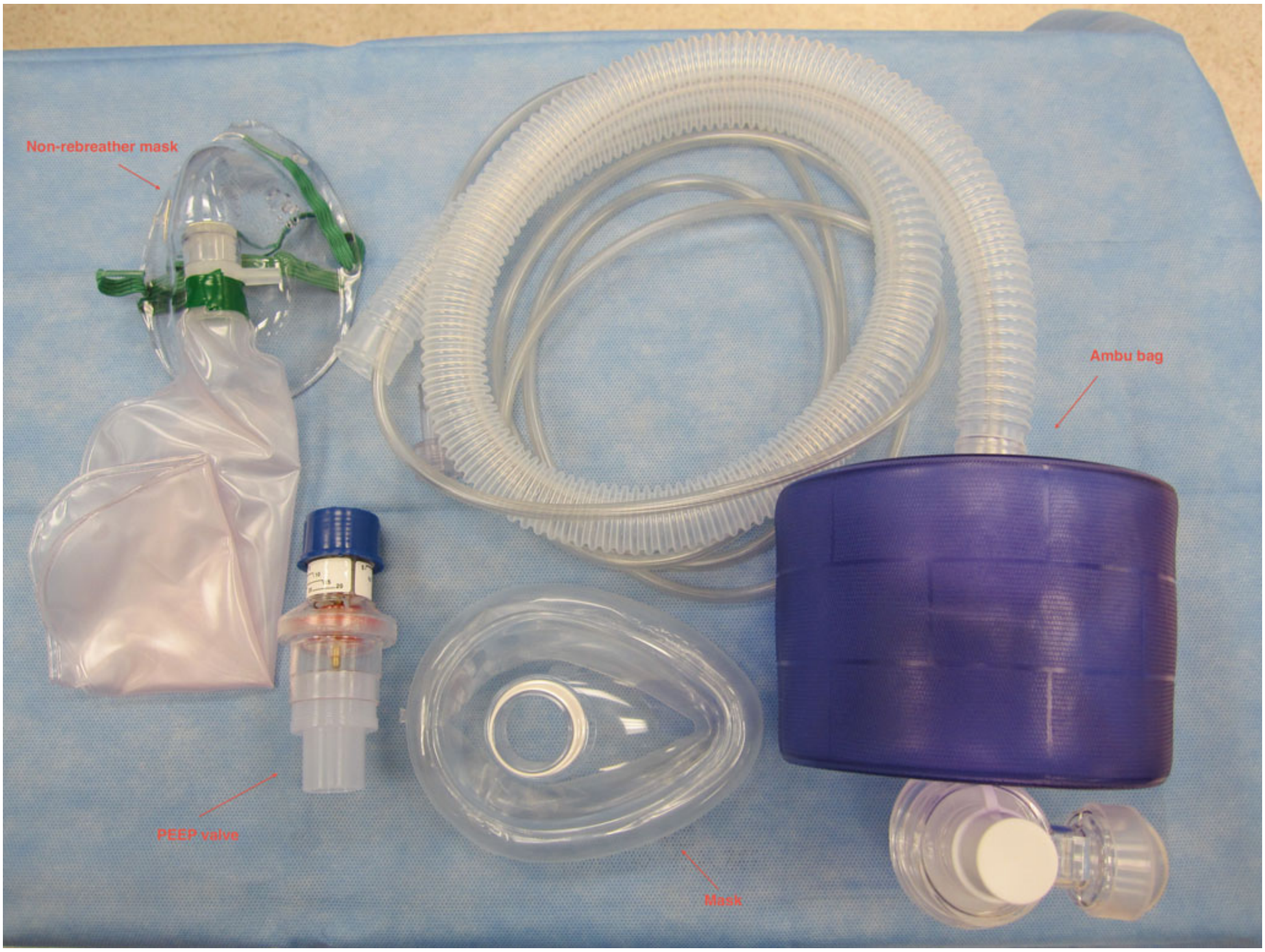

Fig. 9.5 Preoxygenation materials

Table 9.1 Pretreatment: pharmacological agents used to mitigate adverse physiological effects of intubation, induction, and paralysis

Agent	Dose (IV)	Indication
Lidocaine	1.5 mg/kg Rapid push	Use in tight brain to attenuate ICP increase from laryngoscopy/intubation; use in tight lungs to blunt bronchospastic response
Fentanyl	1–3 mcg/kg Slow push	Use in tight brain, tight heart, and tight vessels to blunt reflex sympathetic response to laryngoscopy

ICP intracranial pressure

Table 9.2 Induction: rapidly acting induction agents used to produce rapid loss of consciousness

Agent	Dose (IV) (mg/kg)	Onset (sec)	Duration (min)
Midazolam	0.2–0.3	60–90	15–30
Etomidate	0.3	15–45	3–12
Thiopental	3	<30	5–10
Ketamine	1.5–2.0	45–60	10–20
Propofol	1.5	15–45	5–10

Table 9.3 Paralysis: neuromuscular-blocking agents administered immediately after induction agent

Agent	Dose (IV)	Onset (sec)	Duration (min)
Succinylcholine	1.5 mg/kg	45	6–10
Rocuronium	1.0 mg/kg	60–75	40–60
Vecuronium	0.01 to prime, then 0.15 mg/kg	75–90	60–75

Fig. 9.6 Patient in the “sniff” position. *OA* oral axis, *LA* laryngeal axis, *PA* pharyngeal axis

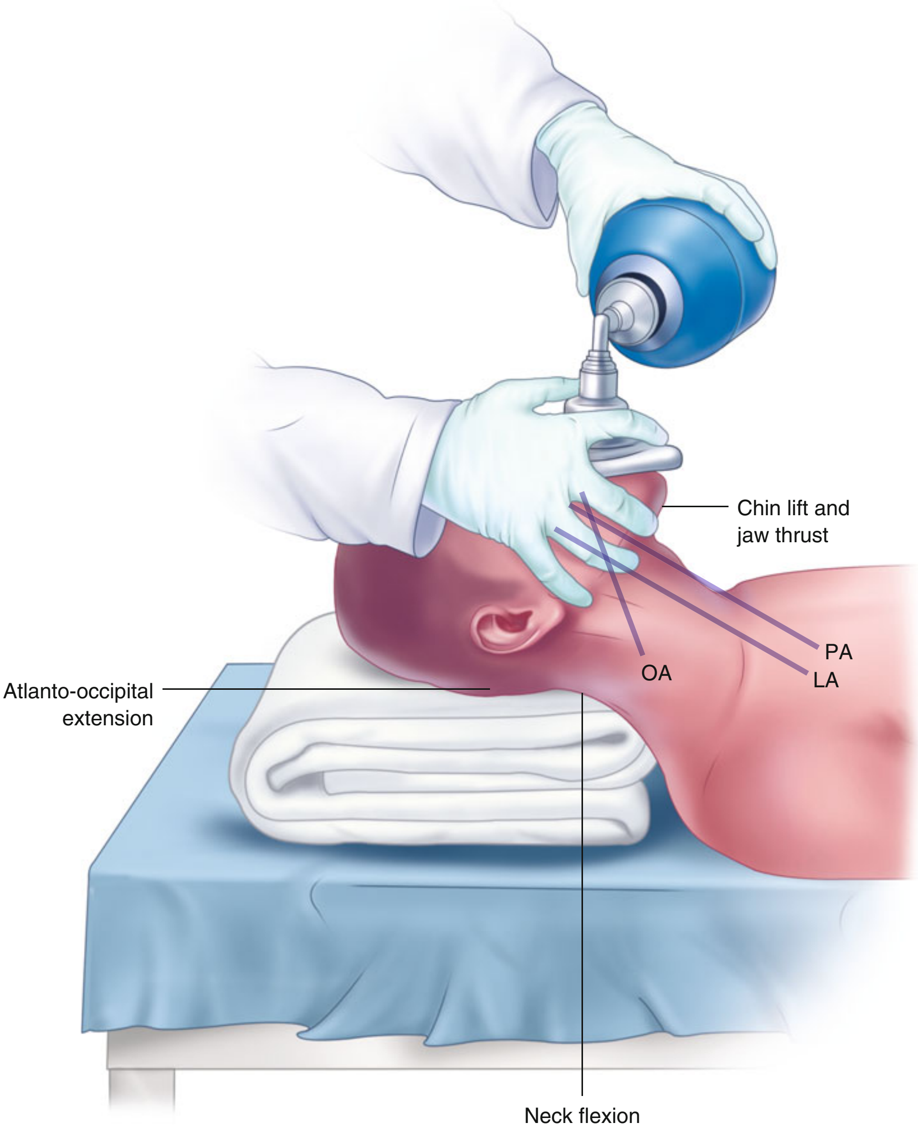
Chin lift and jaw thrust
PA
OA
LA
Atlanto-occipital extension
Neck flexion

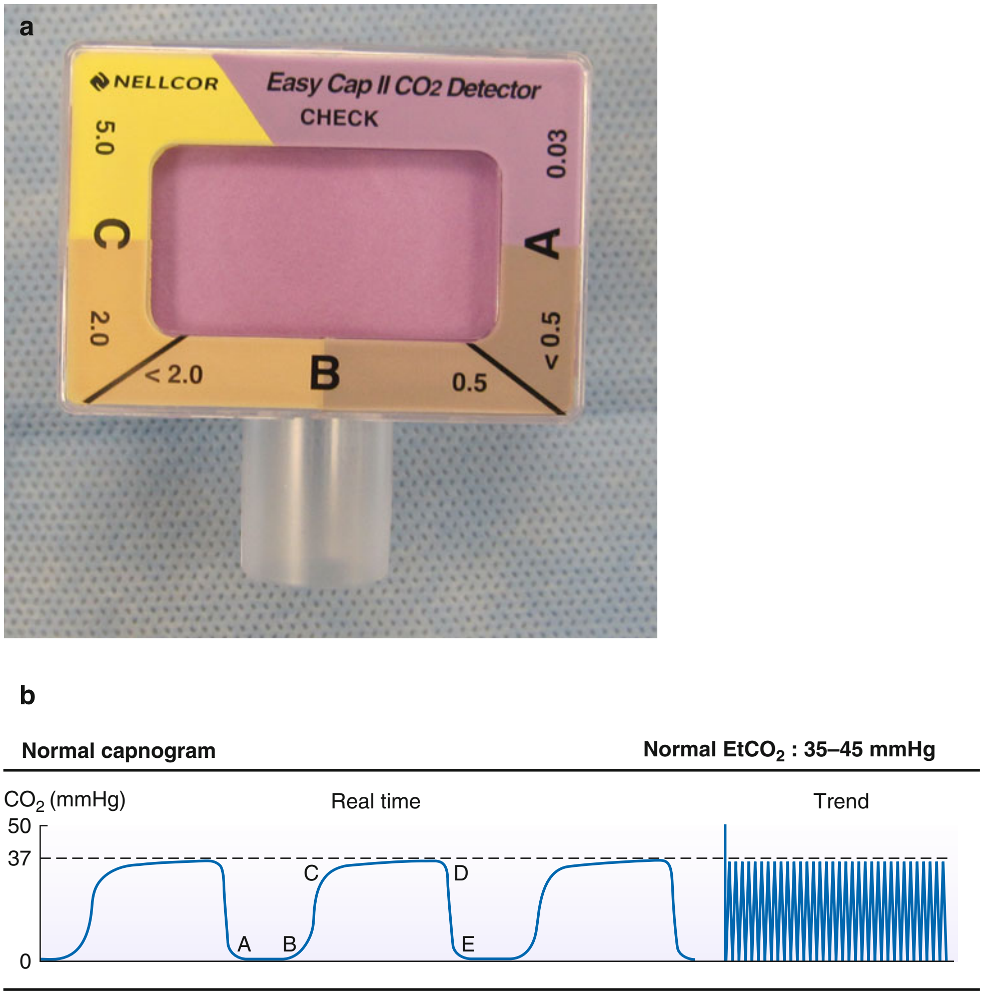

Fig. 9.7 EtCO$_2$, end-tidal carbon dioxide concentration: *a* Qualitative detection device—EZ Cap, *b* quantitative continuous EtCO$_2$ waveform on monitor

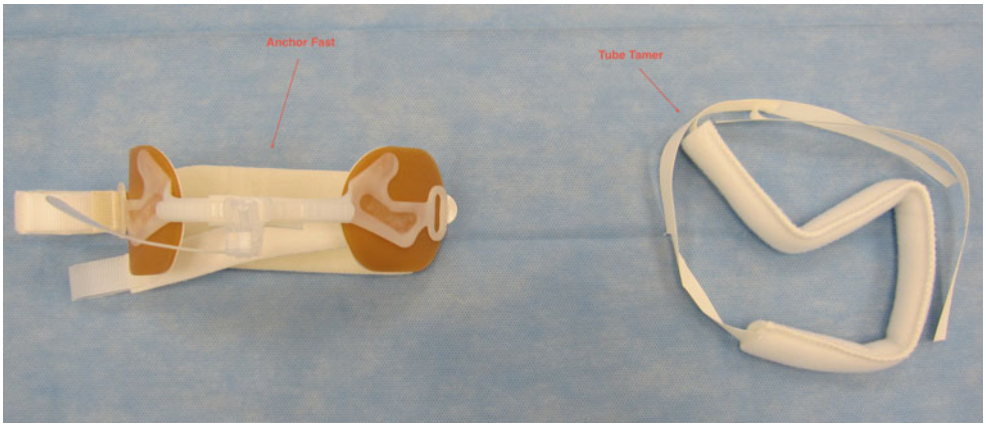
Anchor Fast
Tube Tamer

Fig. 9.8 Equipment used to secure ETT

9.5 Complications

- Esophageal intubation
- Right mainstem intubation
- Pneumothorax from laryngeal trauma
- Aspiration
- Dental trauma
- Vocal cord injury
- Hypotension
  - Induction agent
  - Decreased venous return from positive pressure
  - Pneumothorax
- Hyperkalemia (succinylcholine used in mildly hyperkalemic patient)
- Iatrogenically obstructed airway
- Failure to intubate

9.6 Pearls and Pitfalls

- Utilization of oral and nasal airways will greatly increase the ease of preoxygenation and reoxygenation.
- Inadequate preoxygenation will cause premature desaturation, decreasing time for intubation.
- Suboptimal patient positioning can prevent vocal cord visualization during direct laryngoscopy.
- Consider alternative airway devices before intubation to have a plan in place if a difficult airway is encountered.
- Underdosing induction or paralytic agent will prevent adequate time to perform procedure or create patient discomfort.
- Inappropriately sized McIntosh laryngoscopic blades.
  - Too small—more difficulty in moving tongue and epiglottis out of way for vocal cord visualization
  - Too large—easier to overshoot and go past vocal cords into the esophagus
- Excessive cricoid pressure (Sellick maneuver) may lead to disrupted laryngoscopic view and difficulty passing the ETT.
  - Disrupted view: readjust larynx using dominant hand to allow cord visualization.
  - Difficulty passing ETT: ask for release of some cricoid pressure to allow for ETT passage.
- Inadequate postintubation sedation and analgesia, especially when long-acting paralytics are used.
- Acidic gastric contents can cause CO_2 qualitative capnometry to change to yellow, falsely indicating tracheal placement of the ETT.

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Direct Laryngoscopy

10

Bharath Chakravarthy and Weston Seipp

10.1 Indications

- Orotracheal intubation
  - Maintenance of oxygenation/ventilation
  - Airway protection
- Visualization of laryngeal anatomy
- Foreign body retrieval

10.2 Contraindications

- Absolute
  - None
- Relative
  - Presumed difficult airway
    - Anatomical limitations
      - Small oral opening (less than three of the patient's fingers)
      - Small mandible (hyomental distance less than three fingers)
      - Hyoid-thyroid distance (less than two fingers)
    - Clinical limitations
      - Patient with unstable cervical spine
      - Patient with multiple facial or neck trauma
      - Patient with history of tracheal stenosis, irradiation, or history of tracheal mass or surgery

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10.3 Materials and Medications (Fig. 10.1)

- Laryngoscope handle
- Laryngoscope blade with light
  - Macintosh blade (“Mac” or “curved blade”)
  - Miller blade (“straight blade”)
- Bag valve mask attached to 100 % O_2 source
- Endotracheal tube (ETT)
- 10-mL syringe
- Yankauer suction
- End-tidal CO_2 ($EtCO_2$) monitor (colorimetric or quantitative)
- McGill forceps (for foreign body retrieval)
- Postintubation chest radiograph

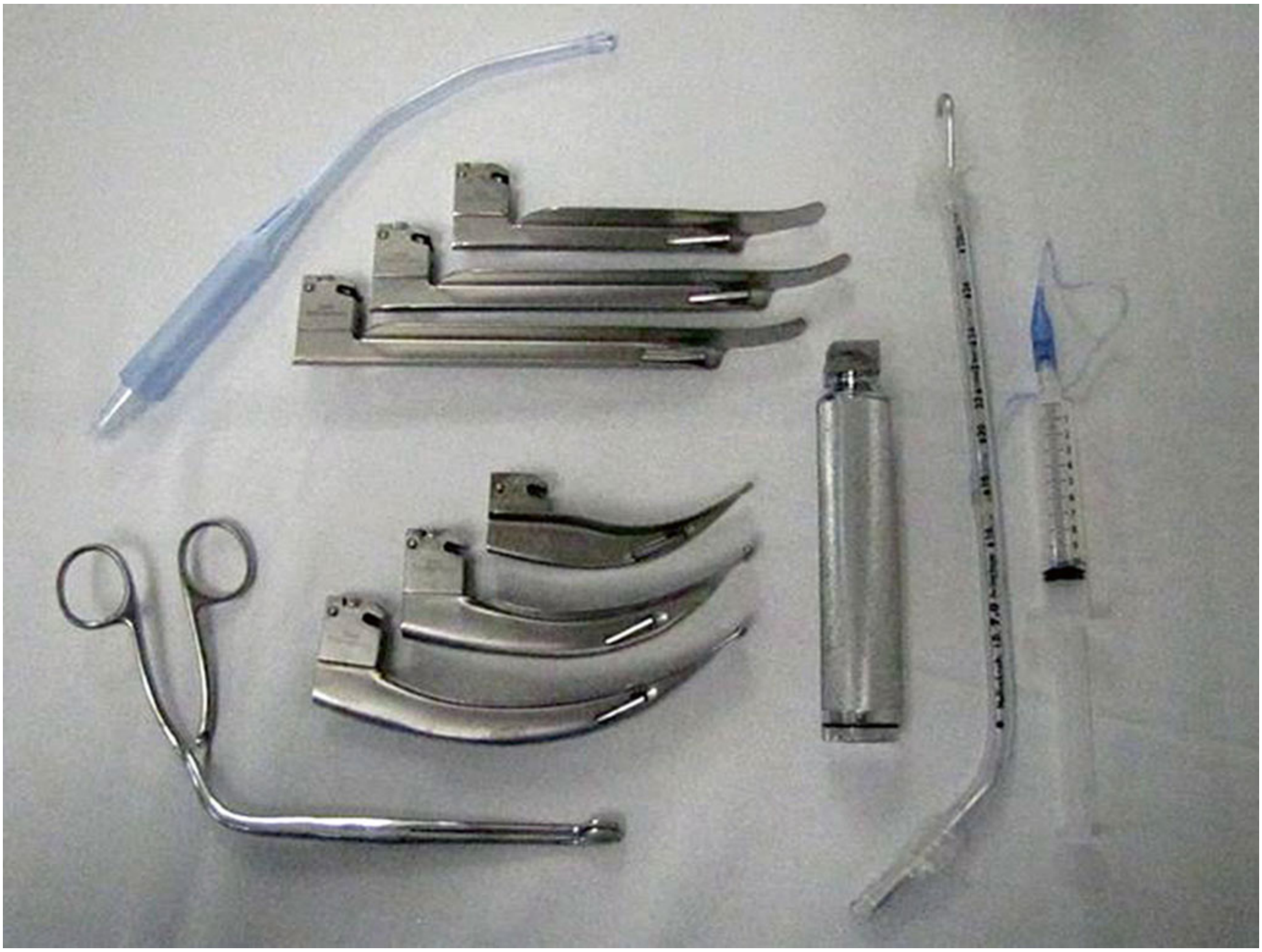

Fig. 10.1 Basic laryngoscopy supplies. *Clockwise from top left*: Yankauer suction, Miller Blades, endotracheal tube, 10-mL syringe, laryngoscope handle, Macintosh blades, and McGill forceps

10.4 Procedure

1. Check the laryngoscope handle and blades to ensure that the light is functioning.
2. Choose the appropriate blade based on patient size.
    - (a) The Macintosh or Miller 3 size is appropriate for the majority of adults, and a 4 can be used for a larger body habitus.
    - (b) The Macintosh blade is generally preferred in adults owing to increased space for ETT passage [1].
    - (c) The Miller blade may be preferable in cases in which the patient has limited mouth opening (owing to its smaller vertical height), or in which the airway is particularly floppy (such as in infants and children) [1].
3. Position the patient (Fig. 10.2).
    - (a) Raise the bed so that the patient's oral opening is at the level of the xiphoid process of the laryngoscopist.
    - (b) The optimal laryngeal view is obtained in the neck flexion/head extension or "sniffing" position. To achieve this, place towels under the patient's occiput to raise it approximately 6–9 cm [2].
    - (c) If patient is in cervical spine precautions, then an assistant must hold the cervical spine in midline immobilization throughout the laryngoscopy; elevation of the occiput is therefore contraindicated.
4. Provide 100 % O_2 via face mask to preoxygenate the patient before laryngoscopy.
5. After ensuring adequate anesthesia and neuromuscular blockade (if performing laryngoscopy for intubation), perform the scissor technique to open the patient's mouth and to lift the tongue base from the glottic opening.
6. Macintosh blade insertion (Fig. 10.3).
    - (a) Insert the laryngoscope into the patient's mouth, starting from the right side, and slowly advance into the oropharynx, using the blade's vertical flange to "sweep" the tongue to the left and away from the glottic opening.
    - (b) Advance the blade along the tongue toward the tongue base, until the epiglottis and posterior arytenoids are viewed.
    - (c) In order to expose the cords, insert the Macintosh blade into the vallecula, which is the potential space anterior to the epiglottis and posterior to the tongue base. This will act as a fulcrum and raise the epiglottis, exposing the vocal cords.
    - (d) To further expose the cords and/or expose the vallecula, exert force outward at a 45° angle to the patient. Do not "rock" the laryngoscope because this may cause injury to the teeth.
7. Miller blade insertion (Fig. 10.4).
    - (a) Insert the blade into the right side of the mouth and slowly advance along tongue toward the tongue base. The Miller blade does not have a flange for isolating the tongue, and thus the Macintosh may be preferable in patients with large tongues.
    - (b) Advance the blade along the right side of the tongue until the epiglottis and posterior arytenoids are visible.
    - (c) In contrast to the Macintosh blade, the Miller blade is used to directly isolate the epiglottis and expose the vocal cords. Using the tip of the Miller, move the epiglottis anteriorly to expose the vocal cords.
    - (d) As with the Macintosh, exert force outward at a 45° angle to the patient to increase the view of vocal cords. Do not "rock" the laryngoscope because this may cause injury to the teeth.
8. Assessing the glottic view (Fig. 10.5).
    - (a) With the epiglottis either directly or indirectly lifted from the glottic opening, assess the Cormack-Lehane laryngeal view grade.
        - (i) Grade I—view of entire laryngeal opening, including cords
        - (ii) Grade II—view of posterior laryngeal cartilages
        - (iii) Grade III—visualization of epiglottis only
        - (iv) Grade IV—no structures visualized
    - (b) A lower grade (higher quality, better) view is predictive of intubation success [3].
    - (c) In the event of a higher grade view, the operator may request airway adjuncts, such as a bougie.
9. Improving the glottic view [4].
    - (a) With the laryngoscope in the desired position, it is possible to improve the glottic view by exerting backward pressure on the thyroid cartilage either with the operator's right hand (bimanual laryngoscopy) or with an assistant applying BURP (backward-upward-rightward pressure) (Fig. 10.5a).
    - (b) Backward pressure increases the vertical distance between the epiglottis and the posterior cartilages, thereby increasing the likelihood of vocal cord visualization.
10. Passing the ETT (Fig. 10.6).
    - (a) With the optimal view of the cords obtained, pass the ETT from the right corner of the mouth through the vocal cords, to a depth of 21 cm at the incisors in females and 23 cm in males.
    - (b) Inflate the ETT cuff with approximately 5 cc of air until the pilot balloon is firm to touch.
11. After completing intubation or after completion of laryngoscopy, slowly remove the blade from the mouth, taking care to avoid dental or lip trauma.
12. Attach the capnography device to the ETT tube to ensure $EtCO_2$ return.
    - (a) Colorimetric devices will turn from purple to yellow in the presence of $EtCO_2$.
    - (b) Quantitative devices will return a CO_2 waveform.
13. Attach the ETT to ventilator or bag-valve-mask connected to an oxygen source.

14. Auscultate breath sounds in both lung fields and ensure absence of breath sounds over the epigastrium (which could signify esophageal intubation).
15. Obtain a postintubation chest x-ray to ensure no right mainstem intubation or pneumothorax.

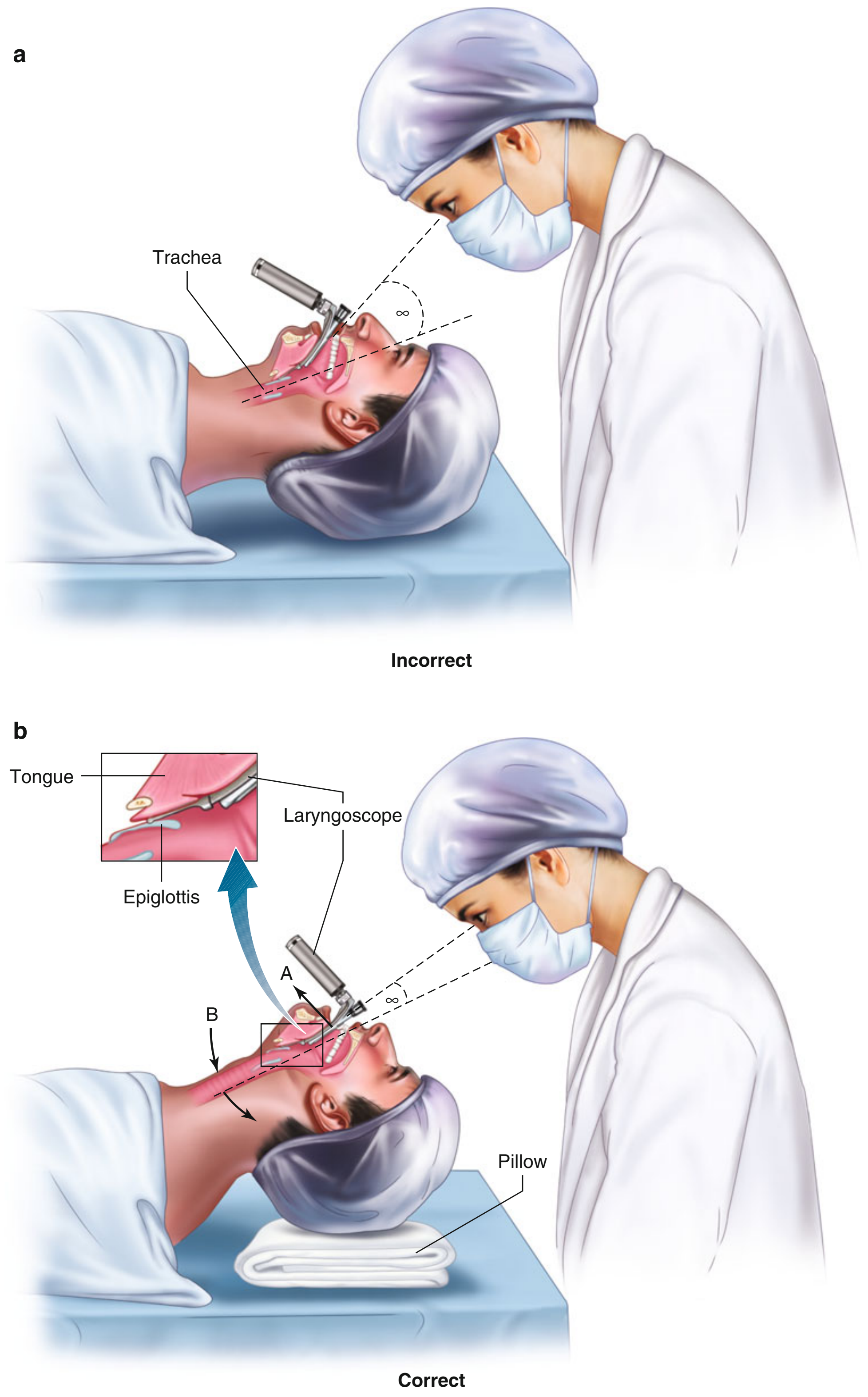
a
Trachea
∞
Incorrect
b
Tongue
Laryngoscope
Epiglottis
A
B
∞
Pillow
Correct

Fig. 10.2 Visualization axis and sniffing position: (**a**) The patient's occiput is not elevated and the neck is not in flexion, thereby creating a steep visual axis, (**b**) the occiput is correctly elevated 6–9 cm, placing the patient in sniffing position and allowing the visual axis to align with the airway axis

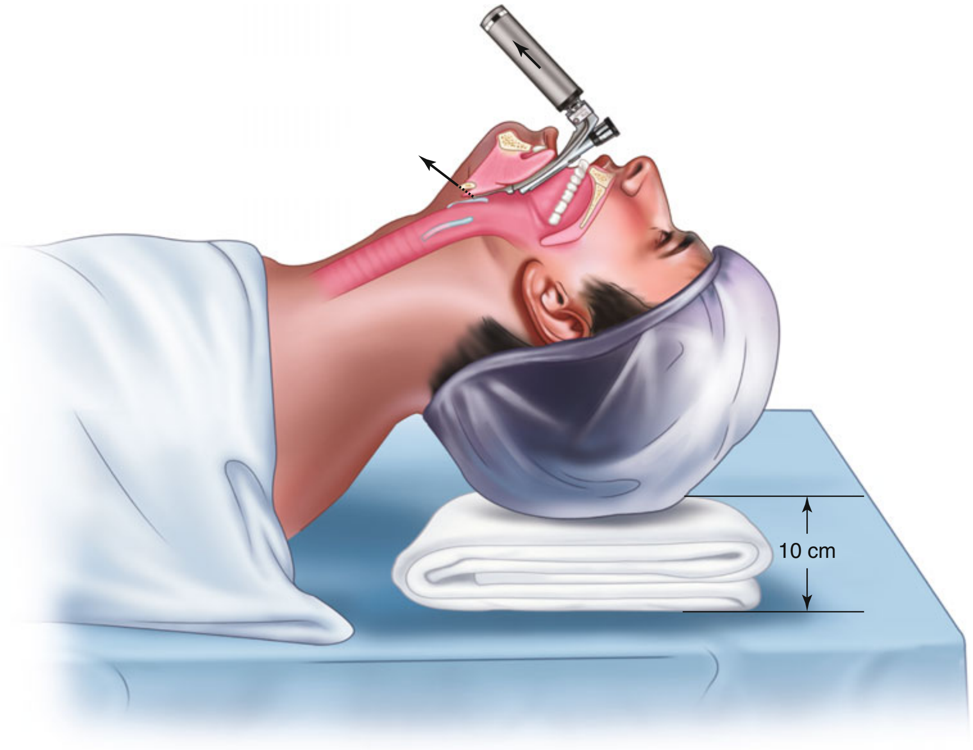

Fig. 10.3 Macintosh blade insertion. The blade is inserted into the vallecula, which raises the epiglottis and exposes the glottic opening

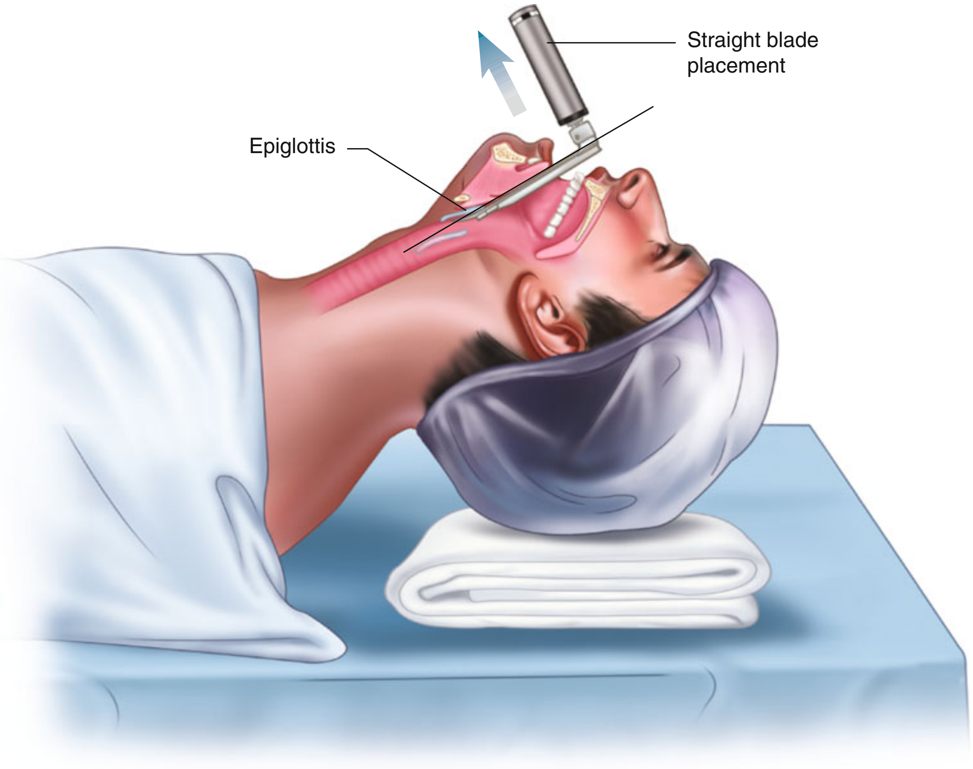
Straight blade placement
Epiglottis

Fig. 10.4 Miller blade insertion. The blade is used to elevate the epiglottis directly, exposing the glottic opening

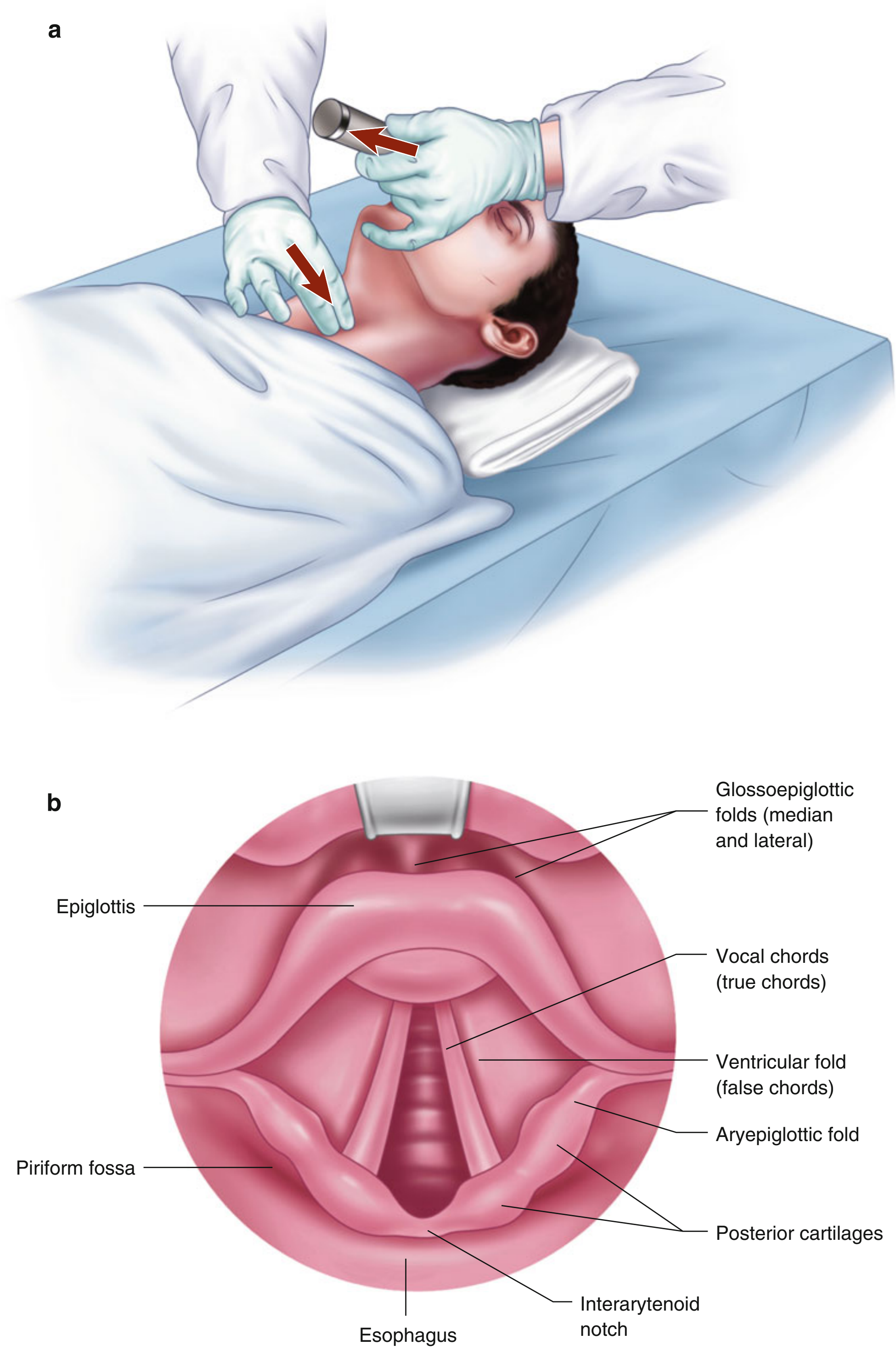
a
b
Glossoepiglottic folds (median and lateral)
Epiglottis
Vocal chords (true chords)
Ventricular fold (false chords)
Aryepiglottic fold
Piriform fossa
Posterior cartilages
Interarytenoid notch
Esophagus

Fig. 10.5 (**a**) Bimanual laryngoscopy. The force on the neck is opposite the direction of lift by the laryngoscope, (**b**) laryngoscopy view, (**c**) Cormack and Lehane

Fig. 10.5 (continued)

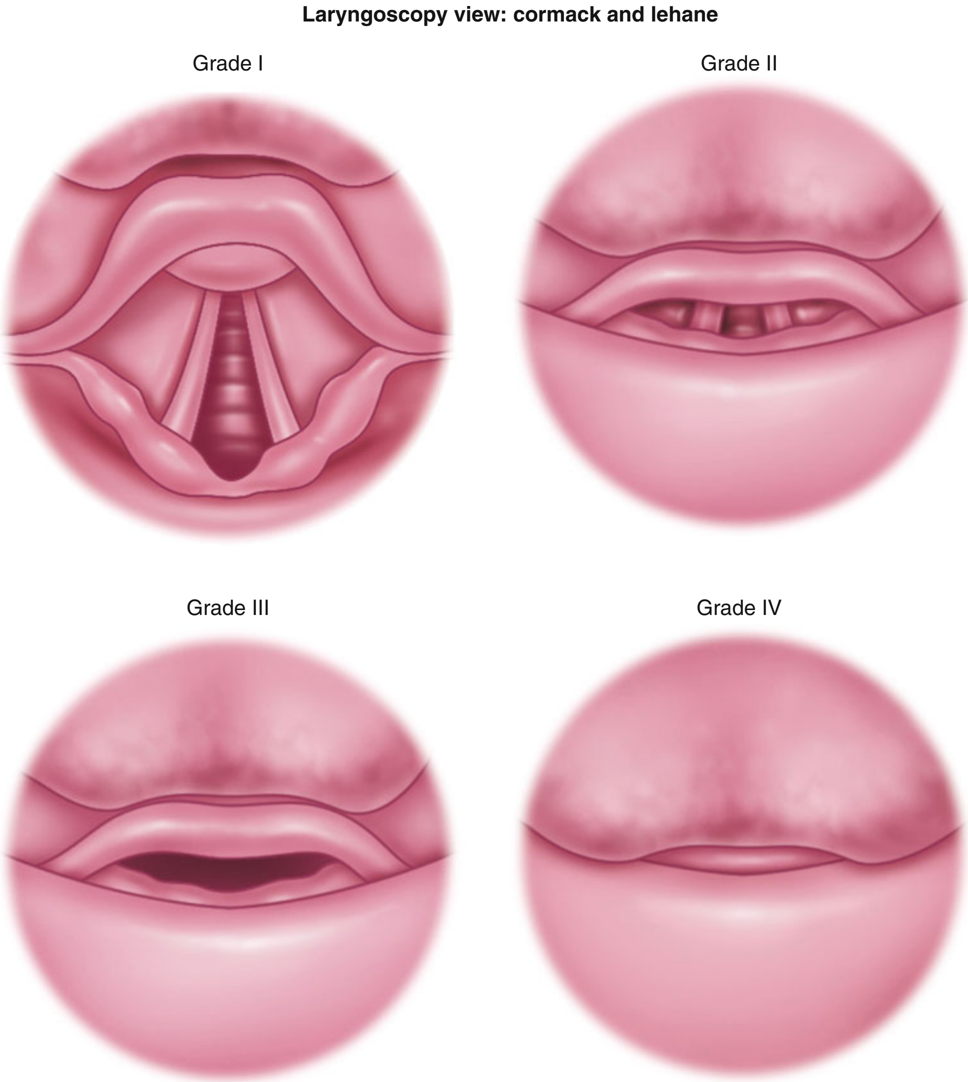
Laryngoscopy view: cormack and lehane
Grade I
Grade II
Grade III
Grade IV

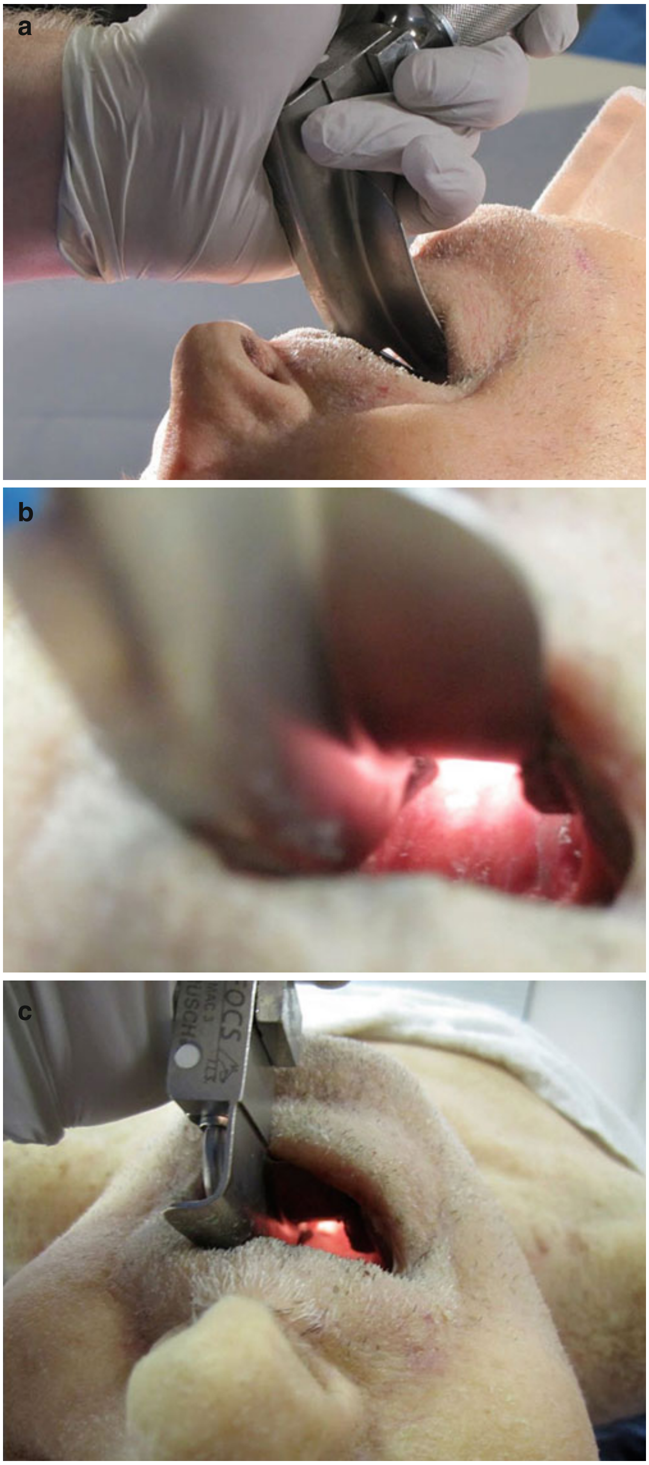

Fig. 10.6 (**a**) Insert the laryngoscope into the mouth, (**b**) sweep the tongue to the left, (**c**) advance the laryngoscope until the epiglottis is visible, and insert the blade into vallecula to expose the cords. When using the Miller blade, insert the blade until the epiglottis is seen. Slide the blade under the epiglottis and lift to expose the cords

10.5 Complications [3, 5]

- Common (1–4 %)
  - Esophageal intubation—*can be fatal if unrecognized*
  - Mainstem bronchus intubation
  - Tachycardia
  - Aspiration
  - Hypotension
- Uncommon (<1 %)
  - Dental/oral trauma
  - Oropharyngeal edema or bleeding
  - Laryngospasm
  - Dysrhythmia
  - Pneumothorax
  - Cardiac arrest

10.6 Pearls and Pitfalls

- Pearls
  - Positioning is of key importance—all patients with a stable cervical spine should be placed in the "sniffing" position to maximize view.
  - Consider the "ramping" position in obese patients with stable cervical spines—elevation of the head and shoulders allows redundant tissue to fall and gives an improved glottic view.
  - Always have suction readily available to remove blood, vomitus, or edema.
  - If structures are not readily visible, withdraw the blade gradually because it is common to insert the blade too deep.
- Pitfalls
  - "Rocking" the laryngoscope instead of lifting outward
  - Failure to recognize esophageal intubation
  - Failure to evaluate postintubation chest x-ray

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Laryngeal Mask Airway

11

Sohan Parekh

11.1 Indications

- Rescue device in a failed intubation
- Initial device in a predictably difficult airway
- Temporizing airway prior to definitive endotracheal intubation or surgical airway

11.2 Contraindications

- Absolute
  - Inadequate mouth opening
- Relative
  - Neck trauma/injury/radiation
  - High risk of aspiration

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11.3 Types (Fig. 11.1)

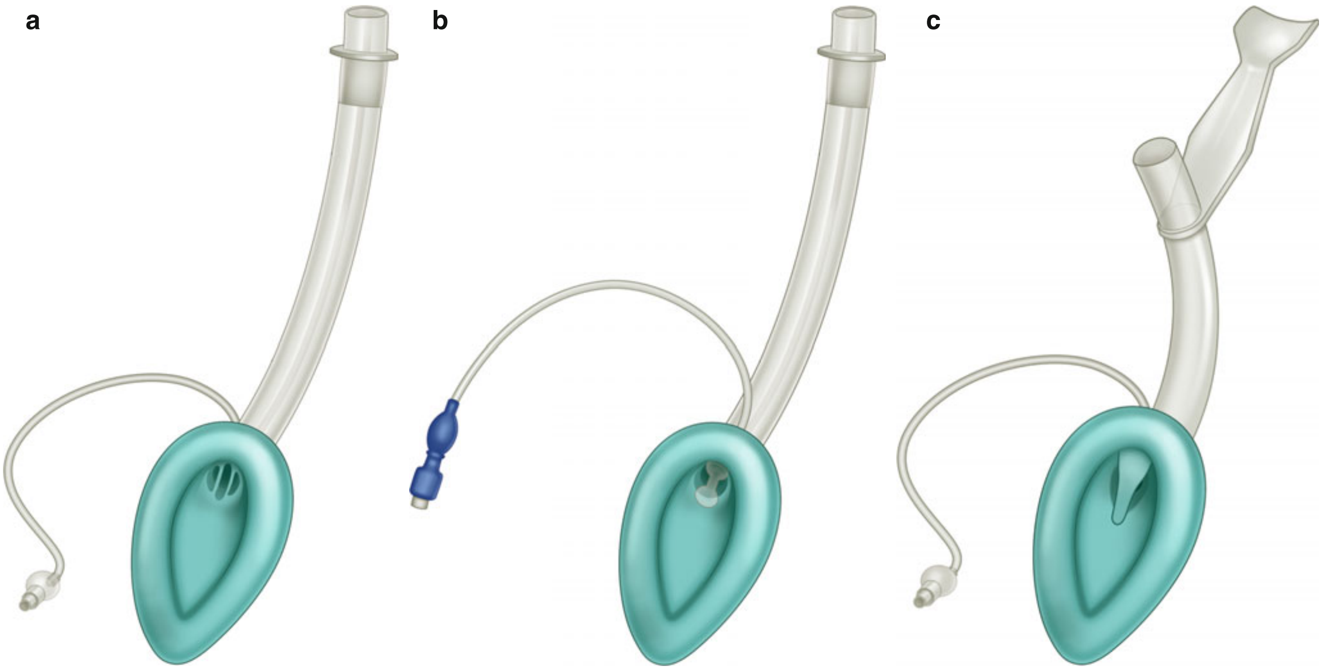

Fig. 11.1 Types of laryngeal mask airway: (**a**) LMA Unique, (**b**) LMA Classic Excel, (**c**) LMA Fastrach

11.4 Materials and Medications

- Appropriately sized laryngeal mask airway (LMA; LMA Unique/LMA Classic Excel/LMA Fastrach) and corresponding syringe (Table 11.1)
- Surgilube
- Bag valve mask
- Continuous end-tidal CO_2 ($EtCO_2$) or colorimetric $EtCO_2$ detector
- 8-mm or smaller endotracheal tube (ETT) (for Fastrach intubating LMA only)

Table 11.1 Laryngeal mask airway sizing

Size	Patient weight (kg)	Maximum cuff inflation volume (mL)	LMA product availability
1	<5	4	Unique
1½	5–10	7	Unique
2	10–20	10	Unique
2½	20–30	14	Unique
3	30–50	20	Unique, Classic Excel, Fastrach
4	50–70	30	Unique, Classic Excel, Fastrach
5	70–100	40	Unique, Classic Excel, Fastrach
6	>100	50	Unique

LMA laryngeal mask airway

11.5 Procedure

11.5.1 LMA Unique or Classic Excel

1. If using a reusable LMA Classic Excel, ensure that it is sterile and inspect it for any damage or wear.
2. Tightly deflate the cuff using a syringe such that it forms a spoon shape (Fig. 11.2).
3. Lubricate the posterior surface of the LMA with sterile lubricating jelly.
4. Stand behind the patient at the head of the bed as in direct laryngoscopy.
5. Place the patient's head in the sniffing position and ensure proper induction and paralysis.
6. Hold the LMA with the index finger of the dominant hand positioned at the juncture of the tube and cuff (Fig. 11.3).
7. Widely open the mouth with the nondominant hand and insert the LMA with the flattened tip flush with the palate.
   - Ensure that the tip of the device does not fold over during insertion.
8. Using the index finger, push the LMA along the curvature of the hard and soft palate (Fig. 11.4).
9. Continue to insert the LMA into the hypopharynx until resistance is felt. (At this point the tip of the LMA is in the esophagus.)
10. Stabilize the tube with the nondominant hand and remove index finger of the dominant hand from the LMA.
11. Inflate the cuff of the LMA to at least half of the maximum value using a syringe.
    - The LMA might move slightly outward during cuff inflation as the LMA positions itself in the hypopharynx.
12. Confirm placement and adequate gas exchange with continuous $EtCO_2$ capnography or colorimetry.

Fig. 11.2 Deflate the laryngeal mask airway (LMA) cuff using a syringe

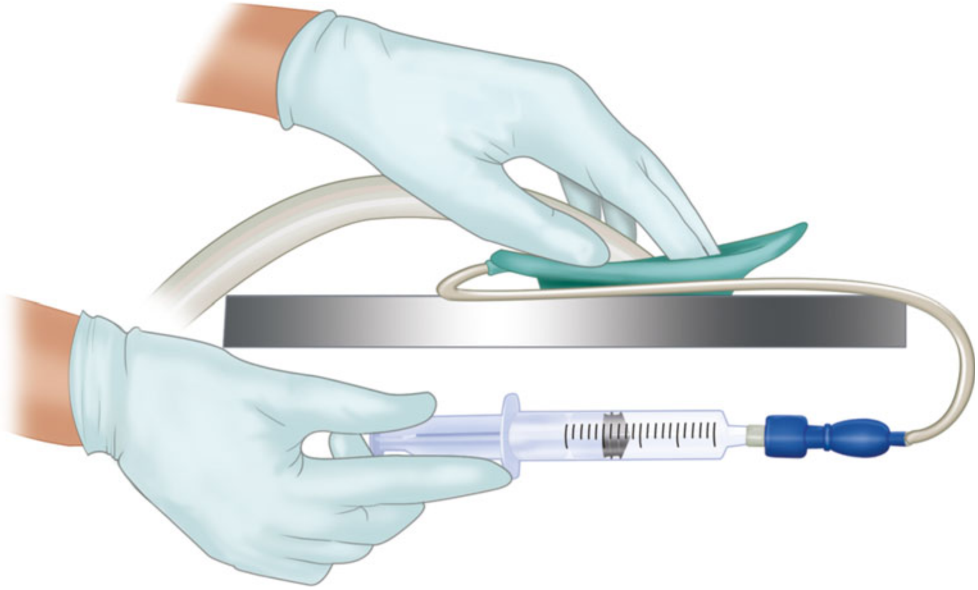

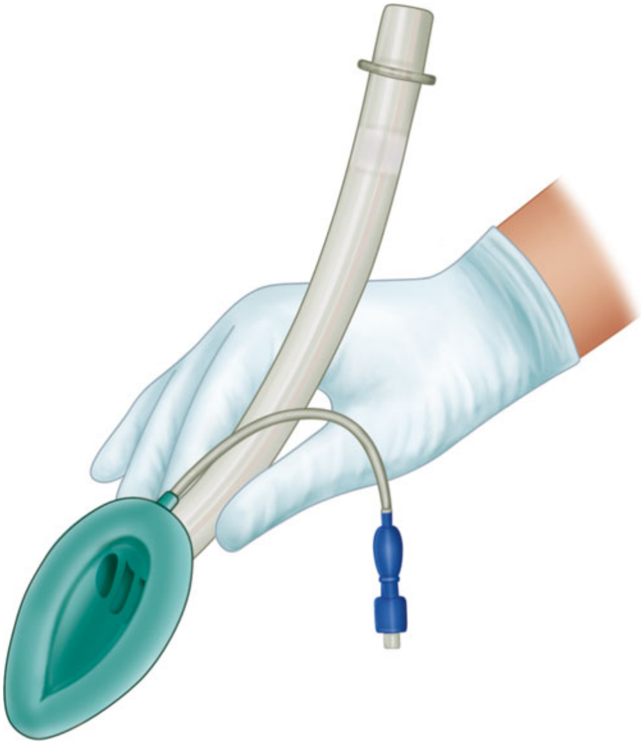

Fig. 11.3 Hold the LMA with the index finger positioned at the juncture of the tube and the cuff

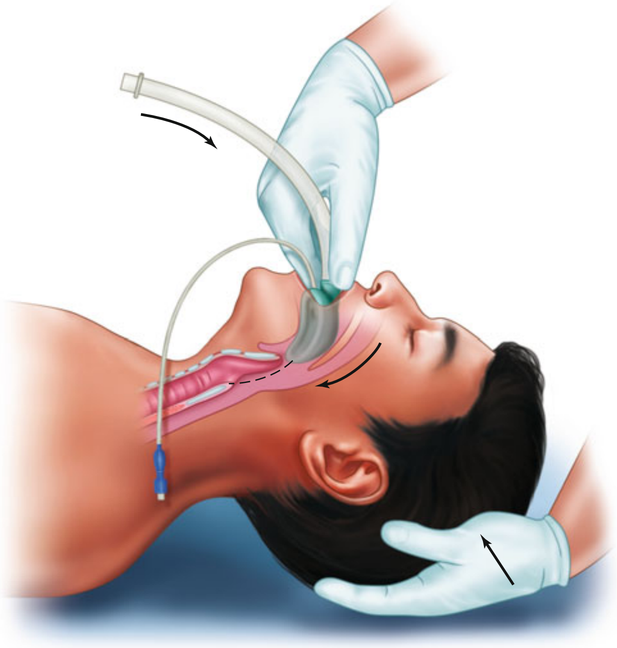

Fig. 11.4 Use the index finger to guide the LMA along the hard and soft palate

11.5.2 LMA Fastrach

1. If using a reusable LMA Fastrach, ensure that it is sterile and inspect it for any damage or wear.
2. Tightly deflate the cuff using a syringe such that it forms a spoon shape.
3. Lubricate the posterior surface of the LMA with sterile lubricating jelly.
4. The LMA Fastrach may be inserted from any position with respect to the patient's head.
5. Position the patient's head in the neutral position. Do not extend the head.
6. Widely open the mouth with the nondominant hand.
7. Holding the handle of the LMA Fastrach, insert the device into the mouth, placing the deflated cuff flush with the superior palate.
    - Distribute the lubricant over the superior palate using a side-to-side motion to allow for easier insertion.
    - Ensure that the tip of the device does not fold over during insertion.
8. Using the handle, gently advance the LMA Fastrach directly into the oropharynx until the curved portion of tube comes into the contact with the patient's chin (Fig. 11.5).
9. At this point use the handle to rotationally advance the device further into the oropharynx following the natural curvature of the palate and posterior pharynx (Fig. 11.6).
    - Do not initiate any rotation until the tube is in contact with the patient's chin.
10. Once resistance is felt, inflate the cuff of the device to at least half of the maximum value using a syringe.
    - Note that the tube is directed slightly caudally when properly inserted.
    - Confirm placement and adequate gas exchange with $EtCO_2$ capnography or colorimetry.

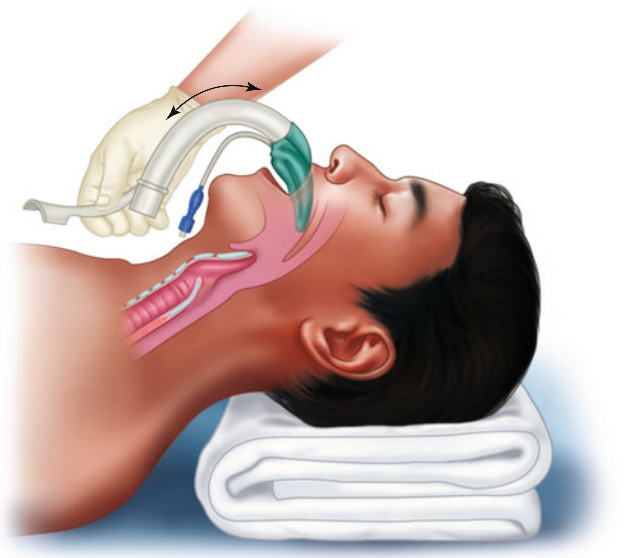

Fig. 11.5 Using the handle, insert the LMA Fastrach such that the posterior surface is in contact with the superior palate

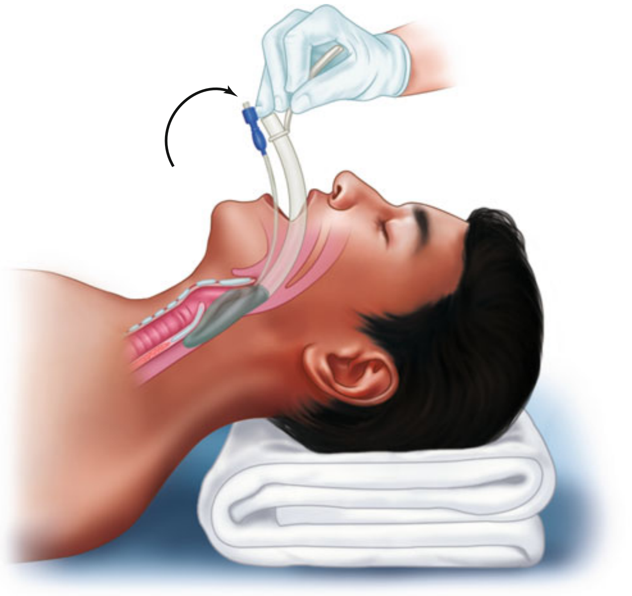

Fig. 11.6 Once the tube is in contact with the chin, use the handle to rotationally advance the device further into the oropharynx

11.5.3 Endotracheal Intubation through the LMA Fastrach

1. Ensure that the ETT will pass freely in the LMA.
2. Lubricate the cuff of the ETT.
3. Firmly hold the handle of the LMA Fastrach with the nondominant hand and insert the ETT to a depth of 15 cm (Fig. 11.7), which places the ETT tip at the point of emergency from LMA Fastrach.
    - Ensure that the tube does not pass beyond 15 cm at this point.
4. Using the handle of the LMA Fastrach, draw the device outward in order to displace the larynx slightly to accommodate insertion of the ETT (Fig. 11.8).
    - Use a lifting rather than a levering motion.
5. Carefully advance the ETT slightly further. If no resistance is felt, continue with insertion of the ETT (Fig. 11.9).
6. Confirm placement and adequate gas exchange with $EtCO_2$ capnography or colorimetry.
7. Once successful confirmation of intubation is established, deflate the cuff pressure on the LMA Fastrach.

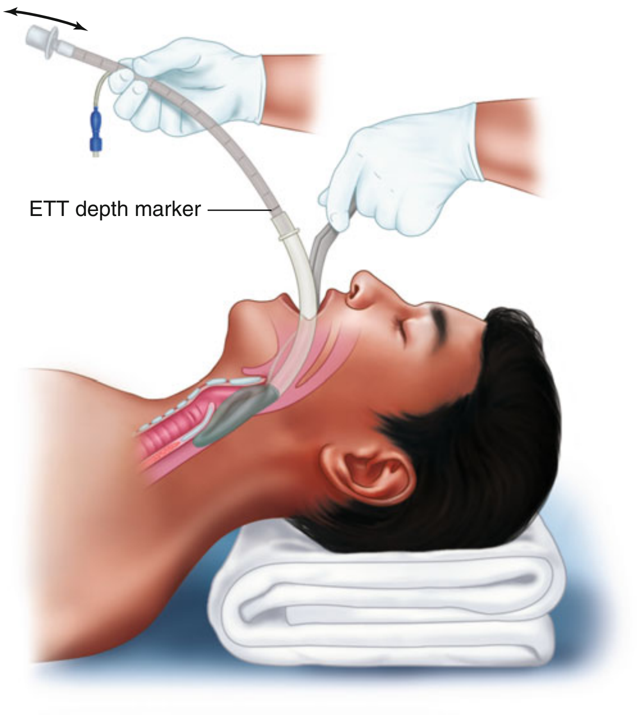

Fig. 11.7 While holding the handle of the LMA, insert the endotracheal tube (*ETT*) to the 15-cm mark

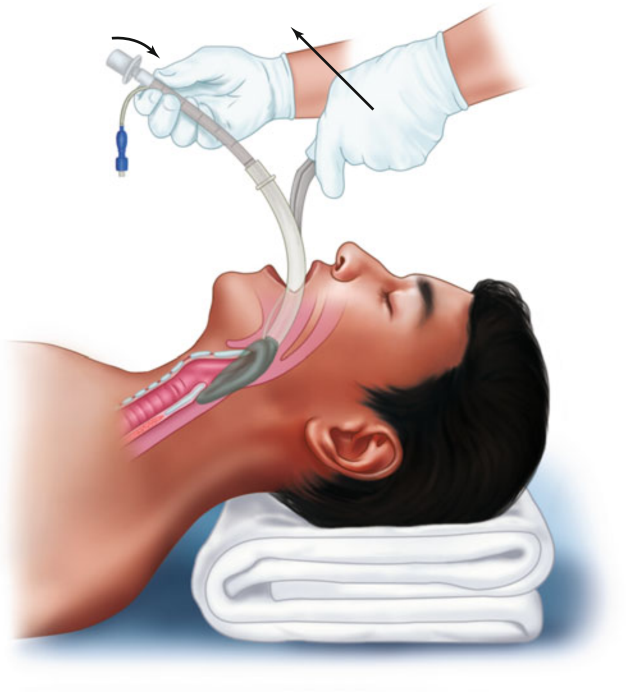

Fig. 11.8 Lift the handle outward to open the glottis for the ETT

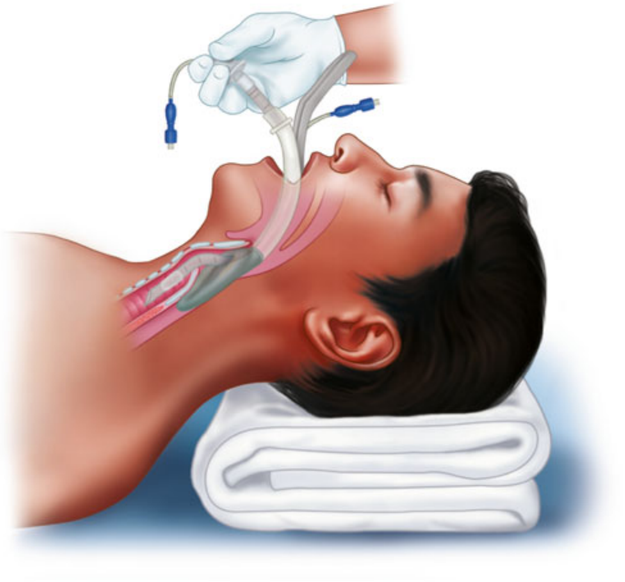

Fig. 11.9 If no resistance is felt during further insertion of the ETT, the ETT may be fully advanced

11.5.4 Removing the LMA Fastrach after Successful Intubation

1. The LMA Fastrach need not be removed immediately, but if this is desired, first adequately oxygenate the patient and then disconnect the patient from the circuit.
2. Remove the airway connector from the proximal end of the ETT.
3. Ensure that the cuff of the LMA Fastrach is entirely deflated.
4. Stabilize the ETT with the nondominant hand, and using the dominant hand, gently ease the LMA Fastrach out by rotating the handle caudally (Fig. 11.10).
5. Once the tube of the LMA Fastrach reaches the proximal end of the ETT, use the stabilizer rod to maintain the position of the ETT while continuing to remove the LMA Fastrach using the handle (Fig. 11.11).
6. After the cuff of the LMA Fastrach has been fully removed from the oral cavity, release the stabilizer rod and ensure stability of the ETT by grasping it distally at the mouth with the nondominant hand (Fig. 11.12).
7. Continue to ease the LMA Fastrach out from around the ETT, ensuring that the pilot balloon and inflation line of the ETT cuff pass through the device (Fig. 11.13).
   - Take care not to rupture the pilot balloon or tear the inflation line of the ETT.
8. Replace the airway connector on the proximal end of the ETT and reconnect the patient to the circuit.

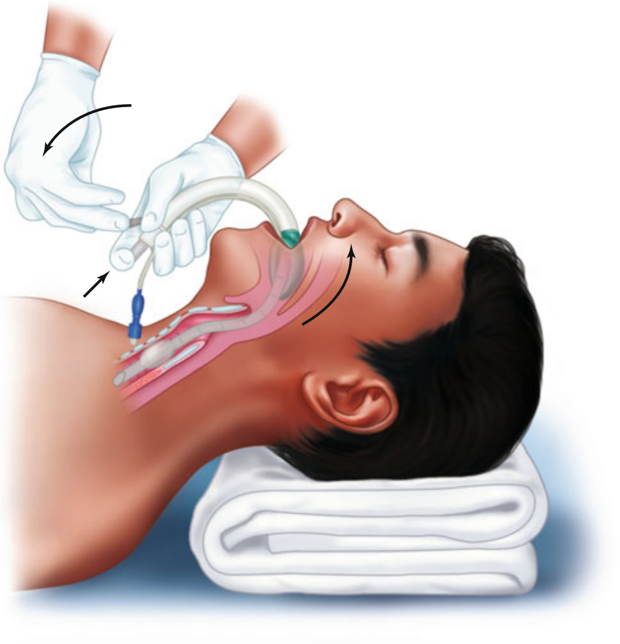

Fig. 11.10 Rotate the handle caudally to gently ease the LMA Fastrach out of the pharynx

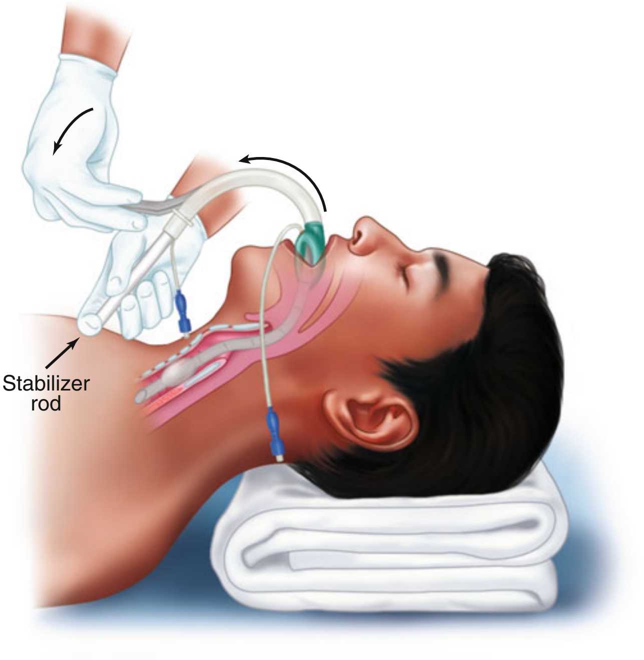

Fig. 11.11 Use the stabilizer rod to allow for further removal of the LMA Fastrach

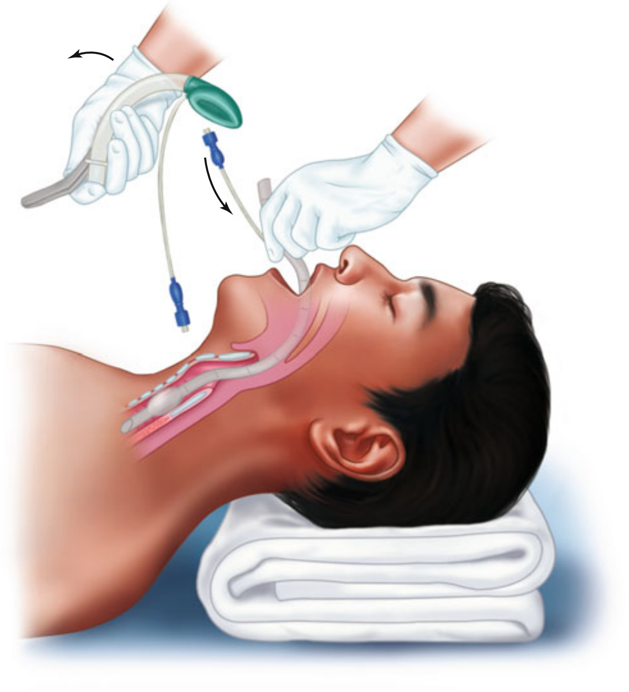

Fig. 11.13 Carefully pass the pilot balloon and inflation line of the ETT cuff through the tube of LMA Fastrach as it is removed

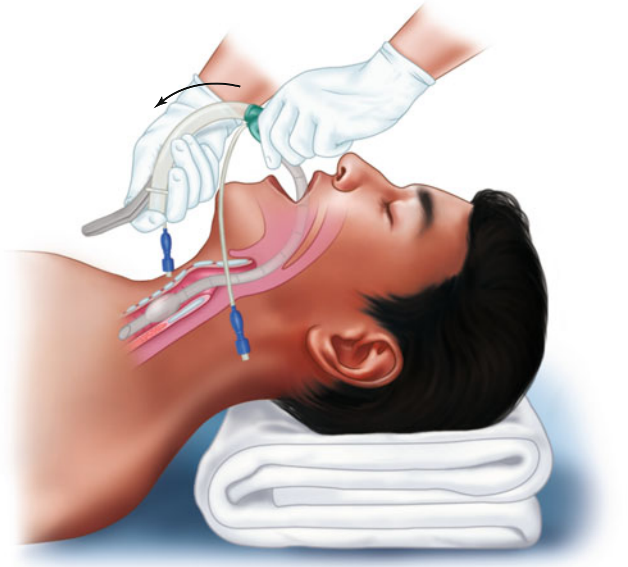

Fig. 11.12 Once the cuff of the LMA Fastrach is out of the mouth, grasp the ETT distally and remove the LMA entirely

11.6 Complications

- Aspiration with resulting pneumonitis
- Ineffective seal resulting in insufficient ventilation
- Coughing, bucking, or breath holding
  - Ensure that the patient is adequately sedated.

11.7 Pearls and Pitfalls

- Cricoid pressure can push the tip of the LMA out of the esophagus and prevent optimal placement.

Selected Reading

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Combitube

12

Clint Masterson

12.1 Indications

- Need for ventilation and oxygenation in an unconscious, unresponsive, or paralyzed patient
- Rescue airway needed after failed intubation

12.2 Contraindications

- Absolute
  - Awake, responsive patient
  - Intact gag reflex
  - Known esophageal disease
  - Ingestion of caustic substances
  - Child (no Combitubes are made for children)
- Relative
  - D50 or naloxone about to be given
  - Facial trauma

12.3 Materials

- Combitube sized based upon height (Fig. 12.1)
  - >5 ft—size 41 French (cuff inflation 15 and 100 mL)
  - >4 ft to<5.5 ft—size 37 French (cuff inflation 12 and 85 mL)

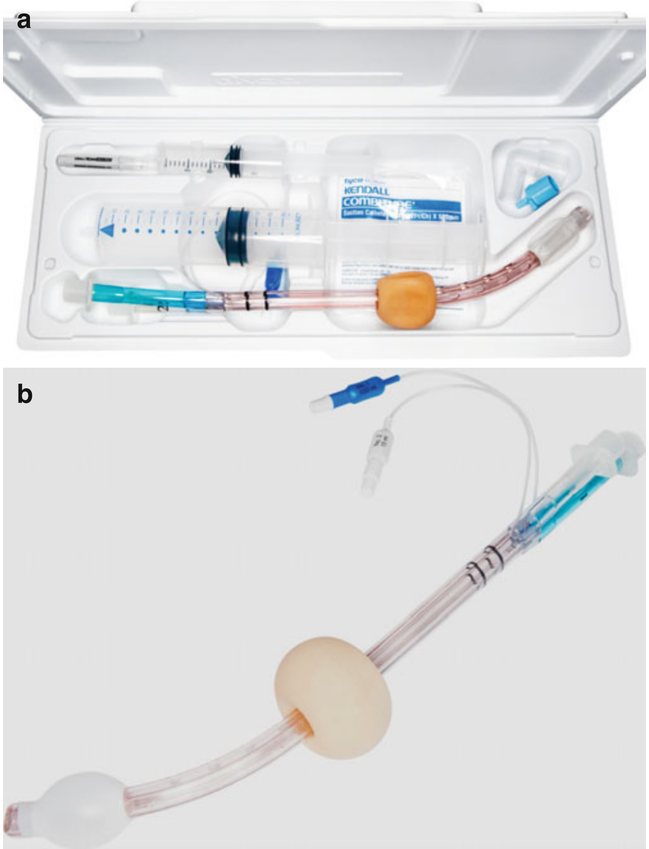

Fig. 12.1 (**a**, **b**) Combitube equipment

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12.4 Procedure

1. Test both balloons and cuffs for leaks as one would an endotracheal tube (ETT).
2. Open up the airway.
   - (a) Use a laryngoscope to move the tongue and open the oropharynx.
     OR
   - (b) Use the left hand to elevate the chin, elevating the tongue and pharyngeal tissue.
3. Insert Combitube blindly into the oropharynx until the teeth lie between the two black bands on the proximal Combitube (Fig. 12.2).
4. Inflate the proximal blue cuff until air pressure is produced or the manufacturer-recommended pressure is reached.
   - (a) 85 mL for 37 French Combitube
   - (b) 100 mL for 41 French Combitube
5. Identify placement and attach to oxygen.
   - (a) Ventilate through tube #1 (blue).
   - (b) Auscultate the stomach and lungs.
     - (i) If breath sounds are heard, the Combitube is in its more common esophageal location.
     - (ii) Attach tube #1 to bag valve mask and O_2.
   - (c) ONLY IF gurgling is present over the stomach when tube #1 is ventilated:
     - (i) Ventilate through tube #2.
     - (ii) If breath sounds are heard, the Combitube is in the less common tracheal location.
     - (iii) Attach tube #2 to bag valve mask and O_2.
6. If no breath sounds are heard in either location:
   - (a) Consider obstruction—Combitube may be obstructing the glottis or collapsing the trachea owing to deep proximal cuff inflation.
     - (i) Deflate the cuffs.
     - (ii) Withdraw 3 cm.
     - (iii) Reinflate and start from step 4.
   - (b) Consider equipment failure.
     - (i) Check that balloons are maintaining pressure and intact.
   - (c) Consider reinsertion.
7. Confirm placement with capnogram and pulse oximetry.
8. Secure the Combitube in position (Fig. 12.3).

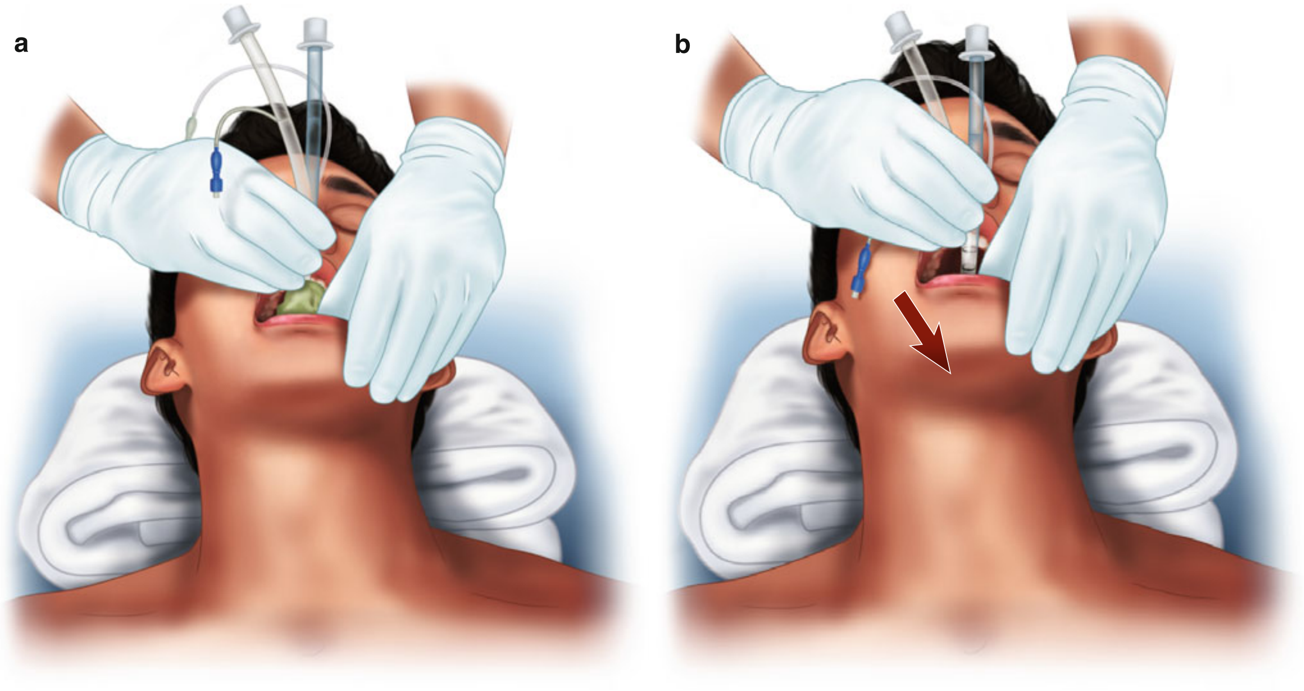

Fig. 12.2 (**a**) Insertion of Combitube. (**b**) Teeth should lie between the two black bands on the proximal Combitube

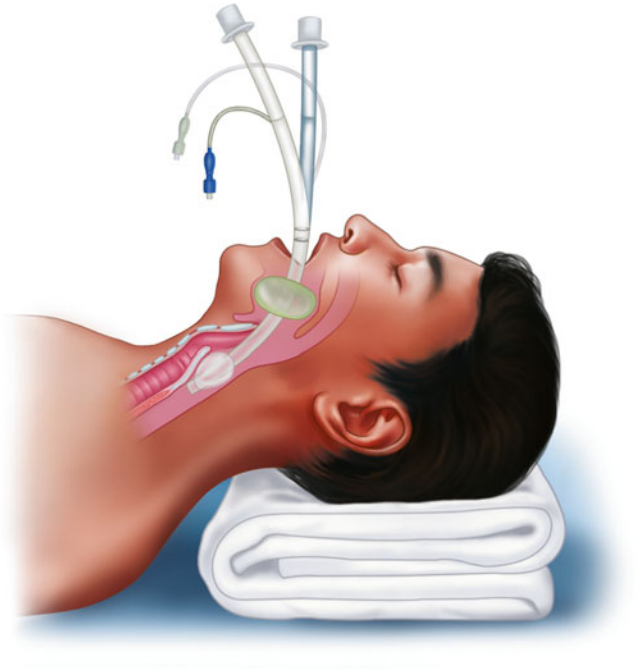

Fig. 12.3 Secure the Combitube in position

12.5 Pearls and Pitfalls

- Pearls
  - In an esophageal intubation situation, a suction tube may be threaded down using tube #2 to decompress the stomach.
  - The Combitube comes with an L-shaped piece that may also be attached to the end of tube #2 to deflect gastric contents away from practitioners.
- Pitfalls
  - After Combitube placement, a definitive airway should be placed when possible.
    - Gastric contents may aspirate despite placement of the Combitube.
    - Combitube should be considered a bridging airway device.
  - Combitubes are associated with a more pronounced hemodynamic stress response than ETTs or laryngeal mask airways (LMAs).
  - Balloon overinflation can lead to esophageal rupture (albeit rare).
  - Combitubes are associated with an increased incidence of sore throat, dysphagia, and upper airway hematomas than ETTs and LMAs.
  - Piriform sinus perforation.

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Assessment of the Difficult Airway

13

Melinda W. Fernandez and Lars K. Beattie

13.1 Indications

- Should be performed on all patients that require airway management, conditions permitting
- Respiratory distress
- Airway protection

13.2 Materials and Medications

- None required

13.3 Procedure

1. Anticipating a difficult airway in emergency department patients is the first step to avoiding an unexpected surgical airway.
2. Two mnemonics can be applied quickly and easily to aid in an airway assessment: MOANS and LEMON.

13.3.1 Predicting Bag-Valve-Mask Difficulty

1. Use the mnemonic *MOANS* to assess for possible bag-valve-mask (BVM) difficulty.
   M—mask seal. Will you be able to get a good seal on the face? Predictors of difficulty include facial hair such as a beard, elderly, or emaciated owing to loss of muscle tone in the face.
   O—obesity. Body mass index (BMI) >30.
   A—age (>55 years). Loss of facial muscle tone can make bagging difficult.
   N—no teeth. Although being edentulous makes for an easier intubation, it makes bagging more difficult.
   S—stiff lungs. Acute or chronic lung disease can make a person difficult to bag. In the setting of Trauma, pulmonary contusion(s) and/or other direct lung injuries may increase BVM difficulty.

13.3.2 Predicting Difficult Laryngoscopy

1. Attempts should be made, if at all possible, to assess for a potentially difficult airway. This does not mean you cannot perform direct laryngoscopy if you are anticipating a difficult airway. It does, however, force you to consider all options and to have a solid backup plan in place with backup equipment readily available in the room.
2. Use the mnemonic *LEMON* to predict difficult direct laryngoscopy.
   L—look. A quick look at the patient will tell you a lot. Are there facial injuries; facial anomalies; obesity; short, thick neck; and small mouth or mandible?
   E—evaluate. Use the 3-3-2 rule to quickly assess for the strongest predictors of difficult laryngoscopy.
   - *3:* Open the patient's mouth and three vertically aligned fingers should fit between the incisors.
   - *3:* Three finger widths should fit along the length of the mandible from the mentum to the hyoid bone. Shorter or longer distances may make for a difficult intubation.
   - *2:* Thyromental distance should ideally be two fingers. Measure this from the hyoid to the thyroid.

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M—Mallampati classification (Fig. 13.1). If patient's condition and situation allow, have the patient open the mouth wide, stick out the tongue, and say "Ahh." Evaluate for visible structures.

- *Class I:* Tonsillar pillars and the entire uvula are visible.
- *Class II:* More than the base of the uvula is visible but no pillars are visible.
- *Class III:* Only the base of the uvula is visible.
- *Class IV:* No uvula or soft palate is visible. Only the hard palate is visible.
- These classifications correlate with the Cormack-Lehane grading system for laryngoscopic views. A Mallampati class I will correlate with a grade 1 view about 99 % of the time, whereas a Mallampati IV will be a grade 3 or 4 view all of the time and a rescue plan with backup equipment immediately available should always be in place [1, 2].

O—obstruction. Observe for anything that can get in the way (e.g., the tongue, dentures, blood, vomit, foreign body, edema, redundant tissue).

N—neck mobility. If patient's condition and situation allow, have the patient flex and extend the neck to evaluate mobility. Many patients in the emergency department have limited neck mobility. Examples include the trauma patient who arrives in cervical collar immobilization or a patient with degenerative or rheumatoid arthritis.

3. The *"6-D"* method is another assessment tool that can be used to predict difficult laryngoscopy and intubation. This method can be remembered by the fact that the word "difficult" begins with the letter "D":

Disproportion

- Increased tongue size in relation to pharyngeal size
- Airway swelling or trauma

Distortion

- Neck mass, hematoma, abscess, previous surgical airway, arthritic neck changes

Decreased thyromental distance

- Anterior larynx and decreased mandibular space.
- Look for a receding chin or greater than three fingerbreadths from the mentum to the hyoid bone.

Decreased inter-incisor gap

- Reduced mouth opening.
- Look for less than two to three fingerbreadths placed vertically in the patient's open mouth.

Decreased range of motion in any joints of the airway

- Limited head extension
- Previous neck radiation and/or surgery
- Neck contractures

Dental overbite

- Oversized, angled teeth disrupt the alignment of airway axes.
- Can decrease the interincisor gap.

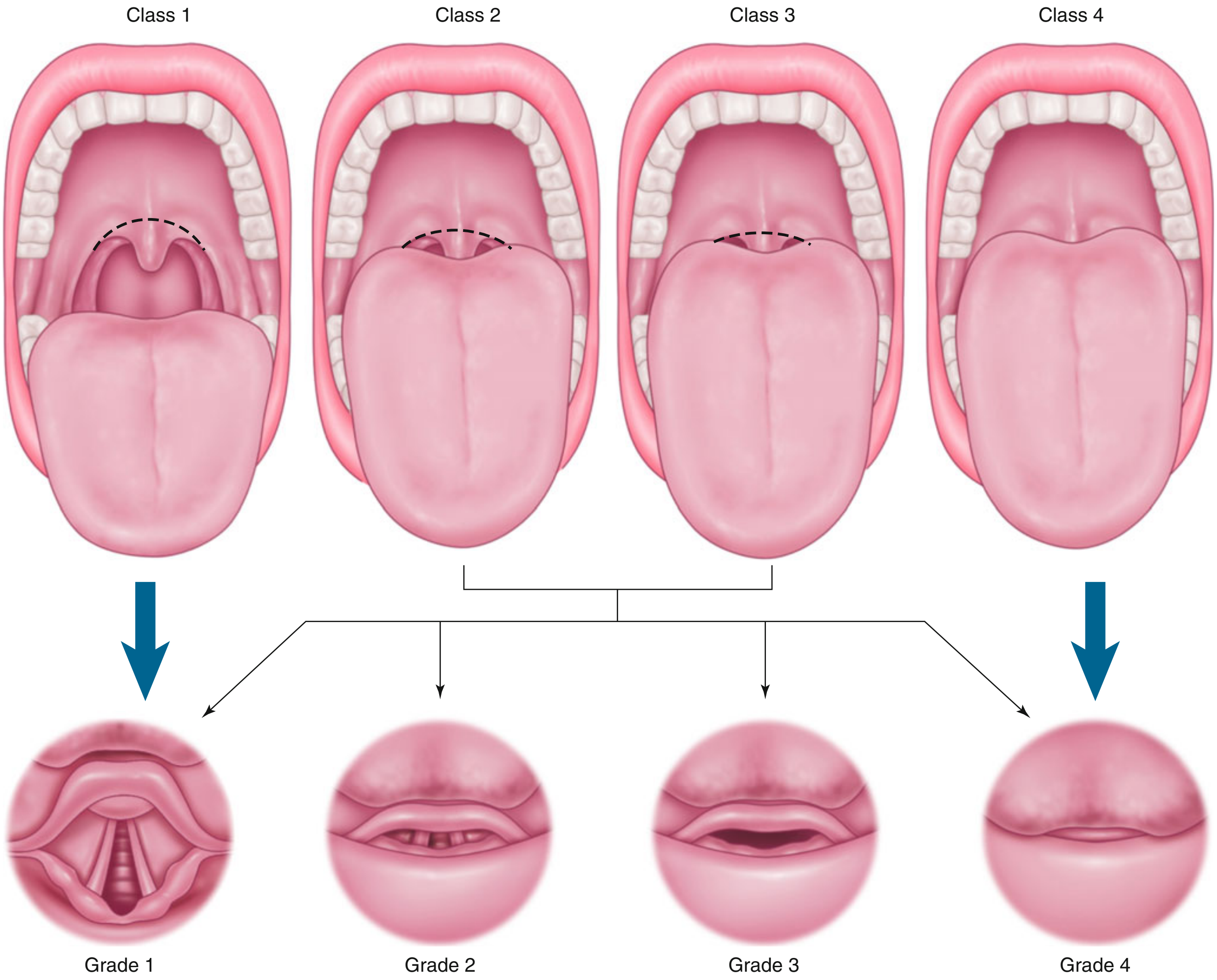
Class 1
Class 2
Class 3
Class 4
Grade 1
Grade 2
Grade 3
Grade 4

Fig. 13.1 Mallampati classification

13.3.3 Optimizing Laryngoscopy in the Obese Patient

- It is essential that emergency medicine physicians are able to successfully intubate the obese patient.
- Proper assessment and positioning will increase the success rate:
  - The goal is to ensure alignment of the oropharyngeal-pharyngeal-laryngeal (OA-PA-LA) airways by placing the patient in the head-elevated laryngoscopy position (Fig. 13.2a).
  - Align the external auditory meatus with the sternal notch along a horizontal line by positioning the patient on a "ramp."
  - The ramp can be created by stacking blankets/towels under the lower back ramping up to the neck and head (Fig. 13.2b).
- While the patient is in position on the ramp, the support is adjusted to minimize head flexion and allow for positioning in the sniffing position.
  - Because of the increased height, a step stool may be required to adequately visualize the airway from the head of the bed.

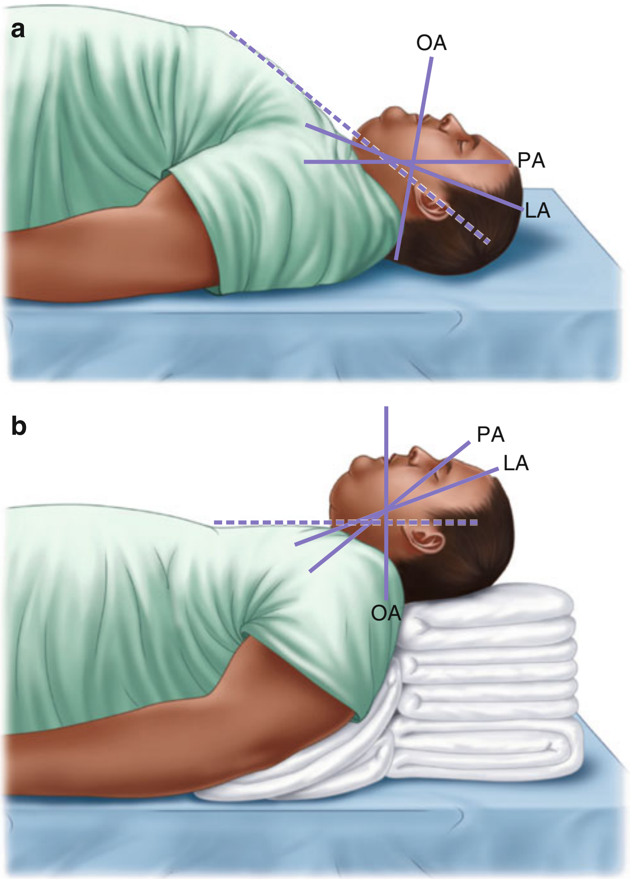

Fig. 13.2 (**a**, **b**) Ramping the obese patient will align the axes of the airway and allow easier direct laryngoscopy when viewed from the head of bed. (*LA* laryngeal airway, *OA* oropharyngeal airway, *PA* pharyngeal airway)

13.4 Pearls and Pitfalls

- Owing to time-sensitive patient care situations, emergency physicians are often not able to perform a thorough airway evaluation on every patient.
- With every airway that you manage and before pushing any drugs, always ask yourself:
  - Will I be able to ventilate this patient?
  - Will I be able to intubate this patient?
  - What is my difficult airway plan if I encounter trouble?
  - Will I be able to perform a surgical airway, if necessary?
- Be sure you have a solid backup plan A, B, and C before pushing any drugs.

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GlideScope

14

Sohan Parekh

14.1 Indications

- Initial device in a predictably difficult airway
- Rescue device in a failed intubation

14.2 Contraindications

- Absolute
  - Inadequate mouth opening
- Relative
  - Blood, vomit, or other secretions that can coat and obstruct the camera lens

14.3 Materials and Medications

- GlideScope video monitor with video cable (GlideScope Video Laryngoscope [GVL] system) (Fig. 14.1) or appropriate-size video baton (Cobalt System) (Fig. 14.2)
- Appropriate-size reusable video laryngoscope (GVL) or single-use laryngoscope blade (GVL Stat) (Table 14.1).
- Endotracheal tube (ETT)
- Malleable stylet or GlideRite rigid stylet
- 10 mL syringe
- End-tidal CO_2 ($EtCO_2$) capnography or colorimetry

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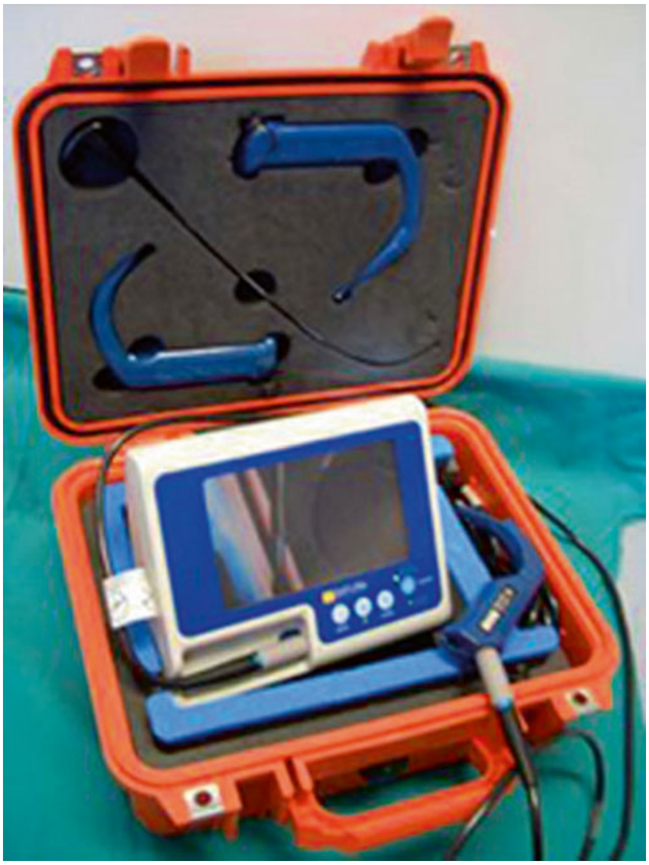

Fig. 14.1 GlideScope GVL system (With kind permission from Springer Science+Business Media: Noppens RR, Werner C, Piepho T. Indirekte Laryngoskopie. *Der Anaesthesist*. 2010;59(2):149–61)

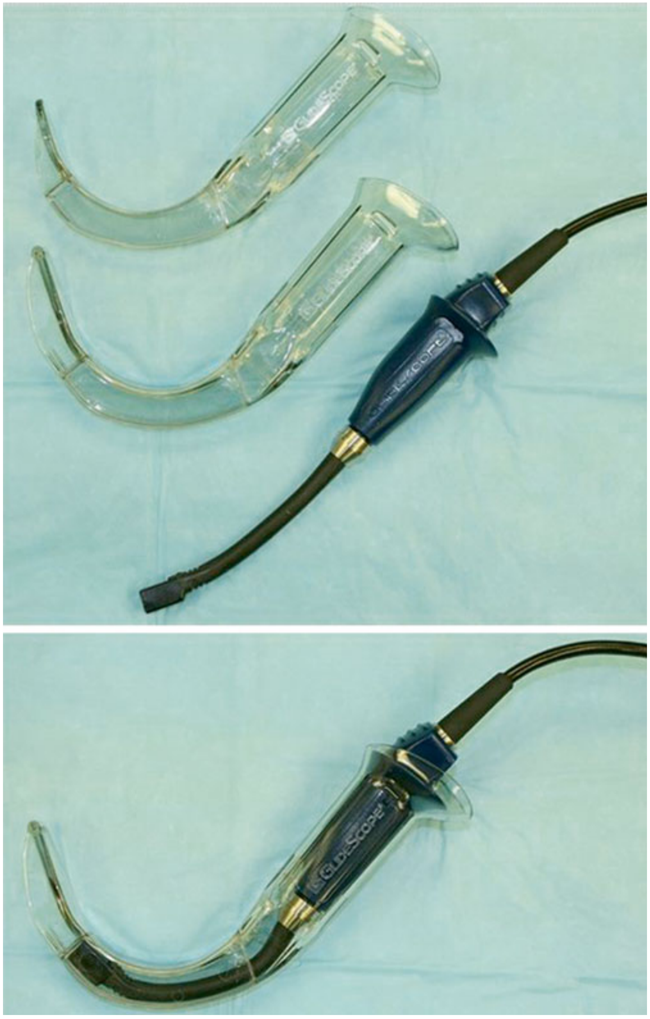

Fig. 14.2 GlideScope Cobalt system (With kind permission from Springer Science+Business Media: Jones PM, Turkstra TP, Armstrong KP, et al. Comparison of a single-use GlideScope® Cobalt videolaryngoscope with a conventional GlideScope® for orotracheal intubation. *Can J Anesthe/Journal canadien d'anesthésie*. 2010;57(1))

Table 14.1 GlideScope sizing

				Video Baton 1–2			Video Baton 3–4	
GVL 1	GVL 2	GVL 3	GVL 4	Stat 0	Stat 1	Stat 2	Stat 3	Stat 4
1.8–10 kg	10 kg—adult	40 kg—morbidly obese	40 kg—morbidly obese	<1.5 kg	1.5–3.6 kg	1.8–10 kg	10 kg—adult	40 kg—morbidly obese

14.4 Procedure

1. Insert the video cable (GVL system) or the video baton (Cobalt system) into the GlideScope video monitor (Fig. 14.3).
2. If using the GVL system, insert the distal end of the video cable into the port on the handle of the reusable video laryngoscope (GVL) (Fig. 14.4).
3. If using the Cobalt system, insert the video baton into the GVL Stat (Fig. 14.5).
   (a) Align the logo on the side of the video baton with the logo on the side of the single-use laryngoscope blade (GVL stat).
   (b) The video baton should slide smoothly and click into the place.
4. Turn on the GlideScope at for at least 30–120 s before use to fully activate the antifog mechanism.
5. Insert a stylet into the ETT. If using a malleable stylet, shape the curvature of the distal end of the tube to conform to the 60° curvature of the laryngoscope blade.
6. Firmly hold the laryngoscope handle in the left hand and ensure that an image can be clearly seen on the video monitor.
7. After ensuring adequate sedation and paralysis, open the mouth wide and insert the laryngoscope blade in the midline underneath the tongue (Fig. 14.6).

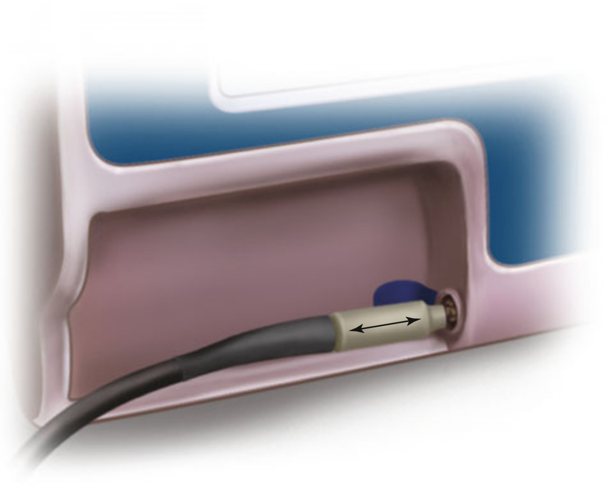

Fig. 14.3 Cable insertion into the video monitor

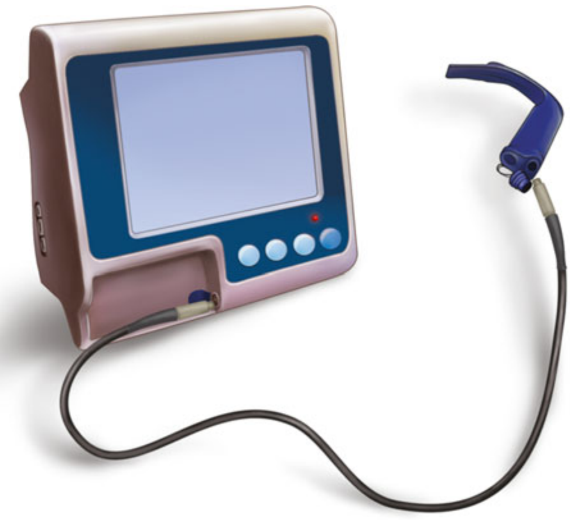

Fig. 14.4 Connect the distal end of the video cable the port on the handle of the GVL (GVL System)

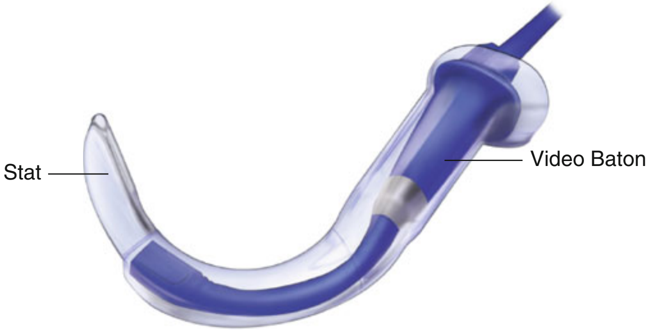

Fig. 14.5 Slide the video baton into the GVL Stat, Cobalt System

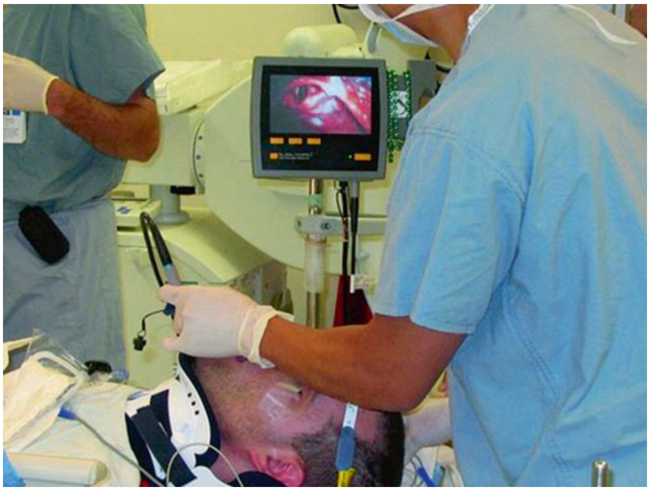

Fig. 14.6 Insert the laryngoscope blade in the midline beneath the tongue (with kind permission from Springer Science+Business Media: Osborn IP, Kleinberger AJ, Gurudutt VV. Chapter 8: Airway emergencies and the difficult airway. In: Levine AI, Govindaraj S, DeMaria S, editors. *Anesthesiology and otolaryngology*. 2013)

8. Looking at the video monitor, advance the laryngoscope blade further into the oropharynx in order to obtain a view of the epiglottis.
    (a) Do not look directly into the oropharynx.
    (b) Movements and adjustments should be guided by the image on the video monitor.
9. Place the laryngoscope blade in the vallecula (analogous to a Macintosh blade) and apply a gentle backward tilt to expose the glottis.
10. In the event that a satisfactory glottic view cannot be obtained, the laryngoscope blade may be advanced and used like a Miller blade to lift the epiglottis out of the way.
11. Directing attention back toward the patient, insert the ETT into the mouth adjacent to the laryngoscope blade.
12. Guide the ETT toward the tip of the laryngoscope such that the end of the ETT emerges on the video monitor.
13. Looking at the video monitor, advance the ETT toward the glottis, and maneuver the tip of the tube between the vocal cords by rotating and altering the angle of the ETT.
    (a) If the ETT tip is posterior to the arytenoids:
        (i) Pull the ETT superiorly, rotate it over the left arytenoid, and gently twist the tube over the epiglottic aperture.
        (ii) Apply external laryngeal manipulation.
        (iii) Withdraw the blade to reduce tilting of the laryngeal axis and lessen the angle of introduction.
    (b) If the ETT abuts the false vocal cords, turn the ETT in the clockwise direction while withdrawing the stylet (Fig. 14.7).
14. Using the thumb, partially withdraw the stylet a few centimeters from the ETT.
    (a) The distal end of the tube should be free of the stylet.
    (b) An assistant can perform this task to allow for greater control and stability of the ETT.
15. Insert the ETT to the desired depth.
16. Fully remove the stylet, inflate the cuff of the ETT using a syringe, and confirm placement with $EtCO_2$, capnography, or colorimetry.

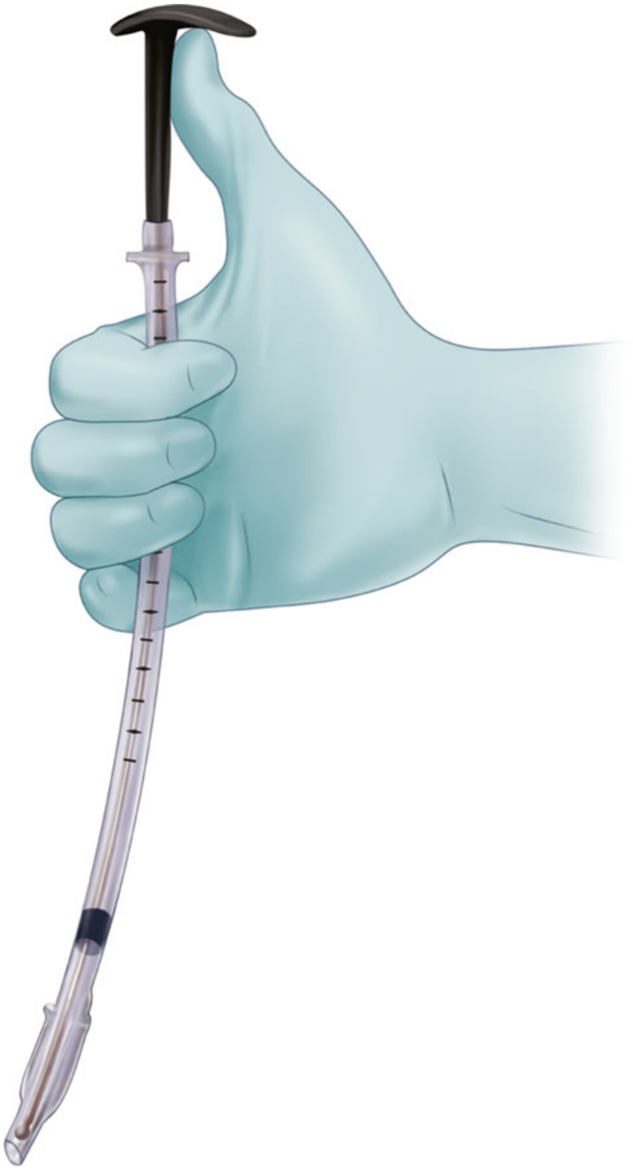

Fig. 14.7 Partially withdraw the stylet from the ETT to allow for passage through the vocal cords

14.5 Complications

- Dental injury
- Airway trauma

14.6 Pearls and Pitfalls

- Unlike conventional laryngoscopy, there is no need to displace the tongue.
- The greatest challenge when intubating with the GlideScope is maneuvering the ETT into the glottis aperture. Alternatives to the conventional technique are:
    – Make a 90° bend in the ETT just proximal to the cuff and insert it in the horizontal direction with the tip toward the right cheek. Once the tube is advanced past the flange of the laryngoscope, rotate it counterclockwise, at which point it should be pointed at the glottis. The tube can then be gently rotated into the glottis.
    – Consider inserting the laryngoscope slightly to the left of the midline upon initial insertion to allow greater space for advancement and maneuvering of the ETT.
- Do not overly lever the laryngoscope or use excessive lifting force after insertion into the vallecula. An adequate view of the glottis is generally easily obtained with minimal effort.
- Display settings can be adjusted using the menu button on the video monitor.

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Endotracheal Tube Introducer (Bougie)

15

Joseph Rabinovich

15.1 Indications

- During orotracheal intubation, when only epiglottic visualization or partial glottic view is obtained during laryngoscopy.
- Particularly useful when neck mobility is limited, leading to inadequate visualization of the glottis (as in the case with cervical spine immobilization).
- When the glottic opening is narrowed either from pathological causes (burns, trauma, tumor, or other anatomical variation).
- When the direct view of the airway is very narrow, as with limited mouth opening or large tongue. In these scenarios, the endotracheal tube (ETT) can obstruct one's view of the cords during placement.

15.2 Contraindications

- When a failed airway occurs (three unsuccessful attempts at endotracheal intubation and inability to adequately oxygenate)
- When surgical airway is indicated (i.e., upper airway obstruction that prevents passage of the ETT via the orotracheal route)

15.3 Materials and Medications

- ETT introducer (bougie) (Fig. 15.1)
- Water-based lubricant
- Lubricated ETT 6 mm or larger *without* stylet (pediatric bougies are available that accommodate smaller ETTs)
- Standard orotracheal direct laryngoscopy (Miller or Macintosh blade) or video laryngoscopy setup
- Assistant

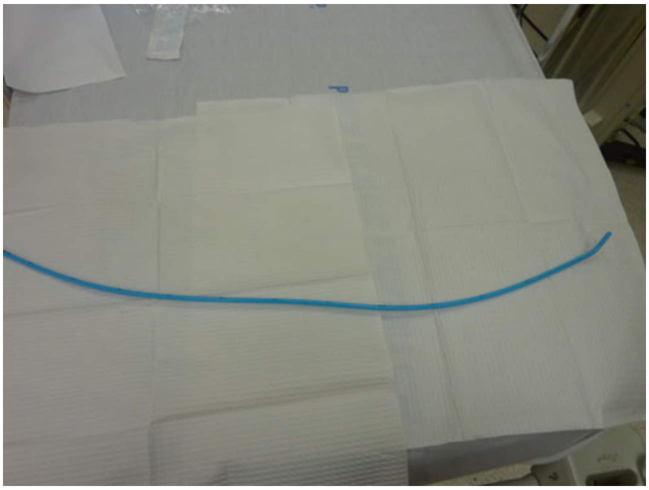

Fig. 15.1 Endotracheal tube introducer (bougie)

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15.4 Procedure

1. The operator first optimizes airway visualization (Fig. 15.2). (Bougie use should not be a substitute for poor technique.)
2. Without losing sight of the airway, the operator asks the assistant to hand him or her the bougie with the coudé tip facing up.
3. The operator directs the bougie tip underneath the epiglottis (Fig. 15.3).
4. Confirmation of placement can be done visually or by tactile sensation:
   (a) A ratchet-like sensation may be felt as the bougie tip is advanced into the airway and slides over the tracheal rings.
   (b) As the bougie is further advanced, the operator may feel the bougie rotate as it enters the bronchus and/or will get a "hold up," the most reliable sign that the bougie is in the trachea [1]. (The "hold-up" sign occurs when the Bougie encounters a terminal bronchus [typically at around 35 cm] and stops advancing.) [2]
5. Once placement is confirmed, the bougie needs to be partially withdrawn to about 25 cm at the lip line.
   (a) Some brands will have a thick black indicator line.
   (b) A sufficient amount of the bougie needs to extend out beyond the proximal end of the ETT.
6. While the operator holds the bougie in place, the assistant threads the ETT over the bougie (Fig. 15.4).
7. The operator now grasps the ETT in her or his right hand and advances it over the bougie.
8. Simultaneously, the assistant holds and stabilizes the proximal end of the bougie.
9. The ETT should be advanced to approximately 23 cm in males and 21 cm in females. The assistant removes the bougie as the operator holds the ETT in place (Fig. 15.5).
10. As the operator holds the ETT firmly in position, the assistant inflates the ETT balloon and withdraws the bougie.
11. Confirmation of proper ETT placement is achieved through traditional means (end-tidal CO_2 detection, auscultation of breath sounds).

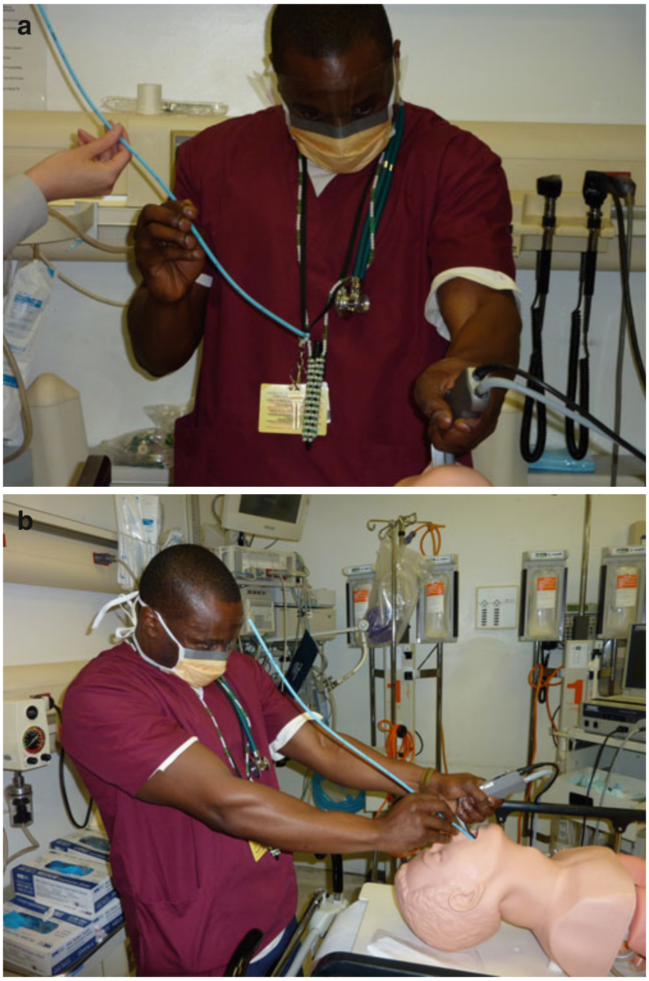

Fig. 15.2 (**a**) Assistant hands operator bougie with coudé tip directed upward, while operator maintains his focus on the target. (**b**) Bougie being placed, parallel with line of sight, underneath epiglottis

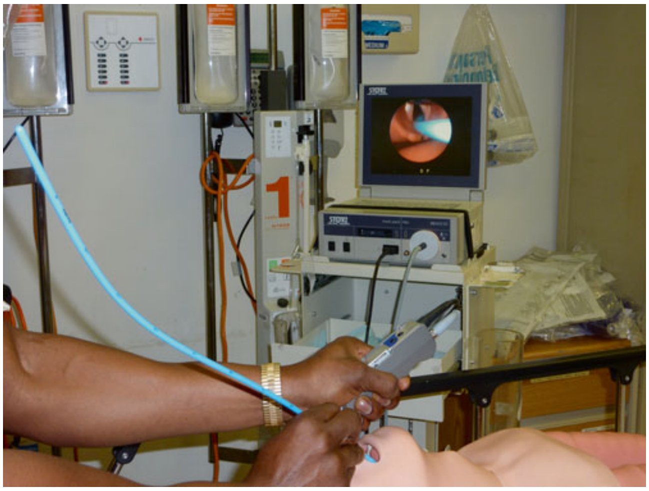

Fig. 15.3 Bougie can be placed into the glottis using direct laryngoscopy or video assistance

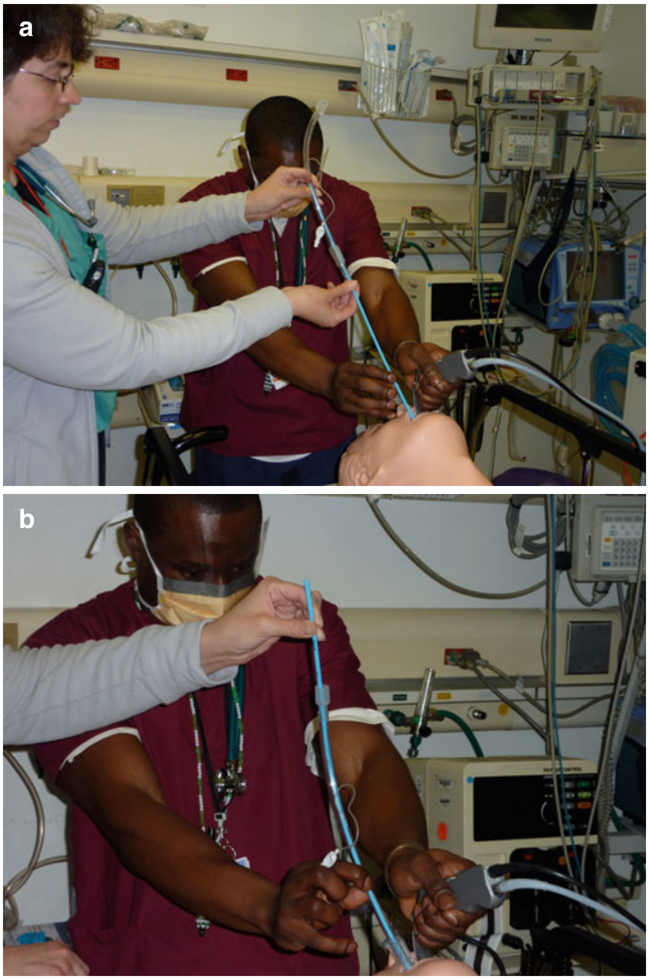

Fig. 15.4 (**a**) Assistant places ETT over bougie and operator withdraws bougie until it protrudes out the top of the ETT, (**b**) while assistant stabilizes the protruding portion of the bougie, the operator railroads the ETT into the airway. The operator continues to support the soft tissues with the laryngoscope blade to facilitate placement

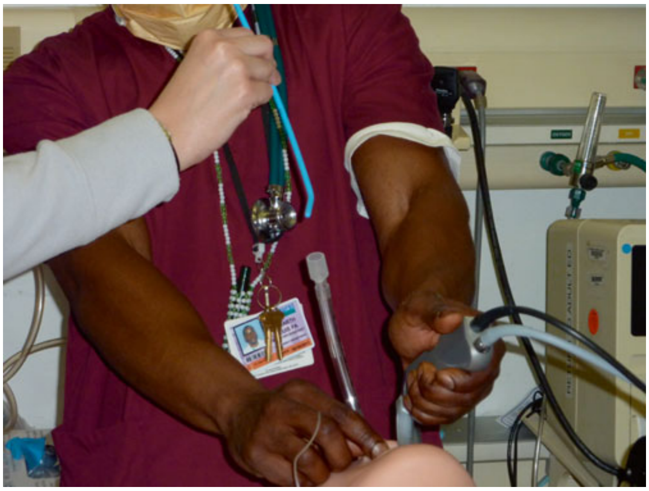

Fig. 15.5 The assistant removes the bougie while the operator stabilizes the endotracheal tube

15.5 Complications

- Trauma to the esophagus, larynx, trachea, or bronchus, including perforation [3, 4].
- In general, complications are rare.

15.6 Pearls and Pitfalls

- The line of sight should be as parallel as possible to the axis of the bougie as it is being passed, allowing better eye-hand coordination. This augments more accurate placement of the bougie tip.
- Maintain the view of the airway as the assistant hands the operator the bougie.
- Keep the laryngoscope in place to support the soft tissues, as the endotracheal tube is slid over the bougie, to facilitate placement.
- If resistance is met during passage, withdraw the ETT slightly (~2 cm) and rotate the ETT counterclockwise one-quarter turn (90°) and reattempt passage.
  - This changes the position of the leading edge of the ETT, which may catch on the posterior laryngeal inlet [2].
  - By rotating the ETT, the leading edge now is anterior facing and is less likely to catch on the arytenoid cartilage along with other laryngeal inlet structures.
- If encountering resistance to ETT placement, consider releasing cricoid pressure (if used).
- Measurement markings on the bougie are aligned with the coudé tip. If not sure of orientation and the loose site of the tip, use the markings to properly orient the tip.

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Lighted Stylet Intubation

16

Benjamin M. Mahon and Lars K. Beattie

When lighted stylet intubation is done correctly, the procedure can be very safe, with very little difference in outcome from that of primary laryngoscopy. (*Note*: *several lighted stylet devices*, *such as the TrachlightTM and Light WandTM*, *are no longer being manufactured*, *but these devices are still in use*.)

16.1 Indications

- Difficult/impossible direct laryngoscopy [1, 2]
  - Congenital abnormalities of airway
  - High Mallampati grade [3]
  - Dental appliances
- Failed direct laryngoscopy

16.2 Contraindications

- Absolute
  - Morbid obesity
  - Airway foreign body
  - Expanding neck mass
- Relative
  - Abnormal airway anatomy
  - Airway lesions (e.g., abscess, mass, epiglottitis) that change oropharyngeal anatomy
  - Acute care where concomitant resuscitation requires a well-lit room
  - Lack of familiarity or experience with procedure
  - “Can’t oxygenate, can’t ventilate” situation

16.3 Materials and Medications

- Intravenous (IV) access, O_2, and monitor
- Ambu bag with supplemental oxygen
- Suction (Yankauer and tubing)
- Lighted stylet (LS)
- Endotracheal tube (ETT) 2.5-mm larger than LS with 10-cc syringe
- Surgilube
- Intubation medications (this procedure may be performed as an awake or a rapid-sequence intubation)

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16.4 Procedure

1. Preoxygenate.
2. Positioning.
    (a) Sniffing position, pinna at the level of the sternal notch (Fig. 16.1).
    (b) Skip sniffing position if cervical spine injury is suspected.
3. LS-ETT unit preparation.
    (a) Insert the wire stylet into the device.
    (b) Check the LS light.
    (c) Lubricate the LS with K-Y Jelly.
    (d) Position the LS just distal to the Murphy eye.
    (e) Curve the LS to user preference at the line labeled "Bend Here."
4. Administer intubation medications.
5. Have an assistant to apply cricoid pressure.
6. Grasp and elevate the patient's jaw near the corner of the mouth with the operator's thumb, index, and middle fingers, elevating the tongue and epiglottis along with it.
7. Using the free hand, insert the LS-ETT unit into the oropharynx and advance (Fig. 16.2).
8. Use the midline glow in the neck to guide insertion of the LS-ETT (Fig. 16.3).
9. Bright light *below* the thyroid prominence indicates correct placement of the ETT tip.
10. Dim or blurred light or light at the thyroid prominence suggests incorrect positioning (Fig. 16.4).
11. If the transilluminated light is dim, off center, or not seen, esophageal positioning must be considered.
    (a) Withdraw the LS-ETT unit approximately 2–5 cm.
    (b) Reposition the patient's head and neck.
    (c) Reattempt according to steps 5–8.
12. Placement of the ETT (Fig. 16.5).
    (a) Hold the LS-ETT unit steady with one hand.
    (b) Check the depth of the ETT and adjust accordingly.
    (c) Release the LS latch that holds the ETT to the LS.
    (d) While holding the ETT in position, gently slide the LS out from the ETT.
    (e) Inflate the ETT balloon.
13. Confirm ETT placement (continuous end-tidal CO_2 [$EtCO_2$], colorimetric capnometry).
14. Secure the ETT.

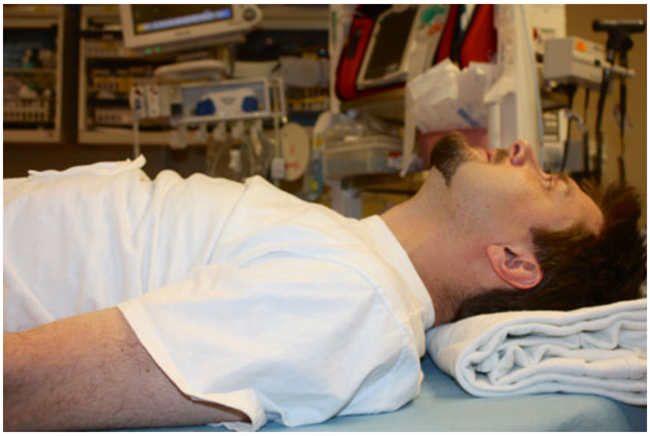

Fig. 16.1 Sniffing position, pinna at the level of the sternal notch

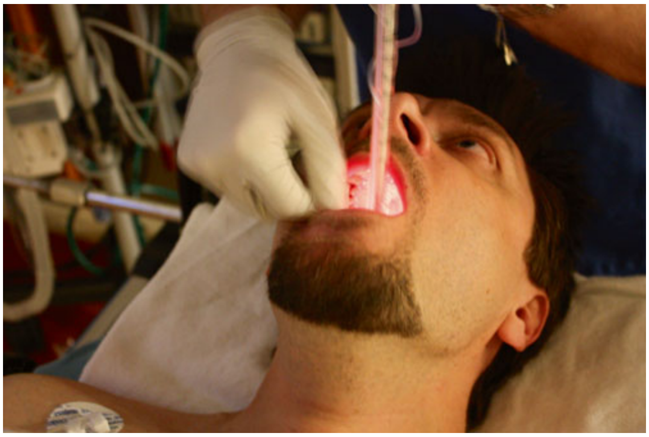

Fig. 16.2 Grasp and elevate the patient's jaw near the corner of the mouth with the operator's thumb, index, and middle fingers, elevating the tongue and epiglottis along with it. Using the free hand, insert the LS-ETT unit into the oropharynx and advance

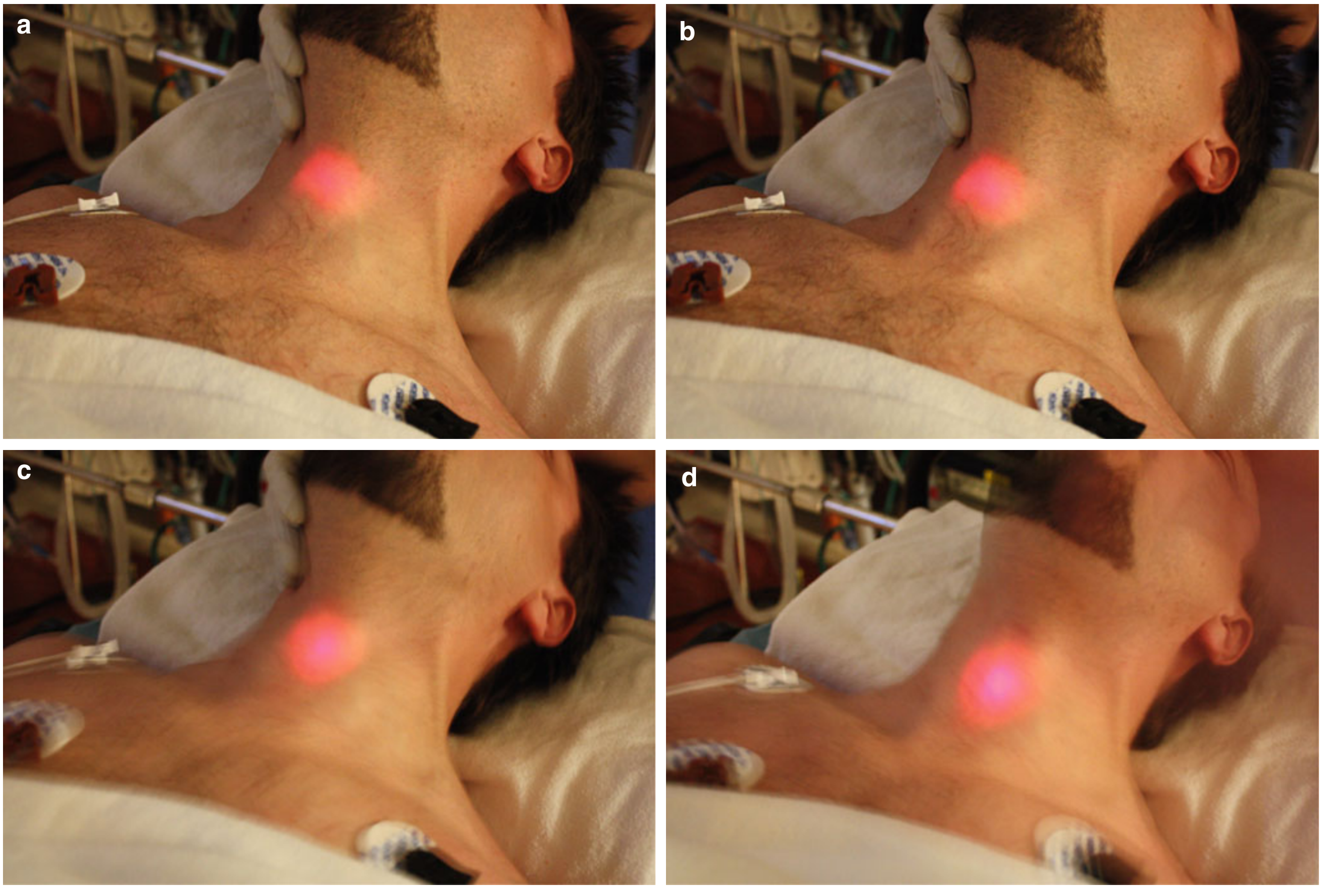

Fig. 16.3 (**a**–**c**) Use the midline glow in the neck to guide insertion of the LS-ETT. (**d**) Bright light *below* the thyroid prominence indicates correct placement of the ETT tip

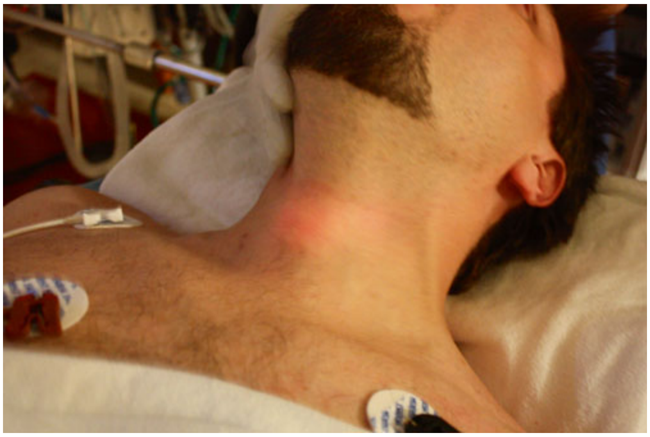

Fig. 16.4 Dim or blurred light or light at the thyroid prominence suggests incorrect positioning

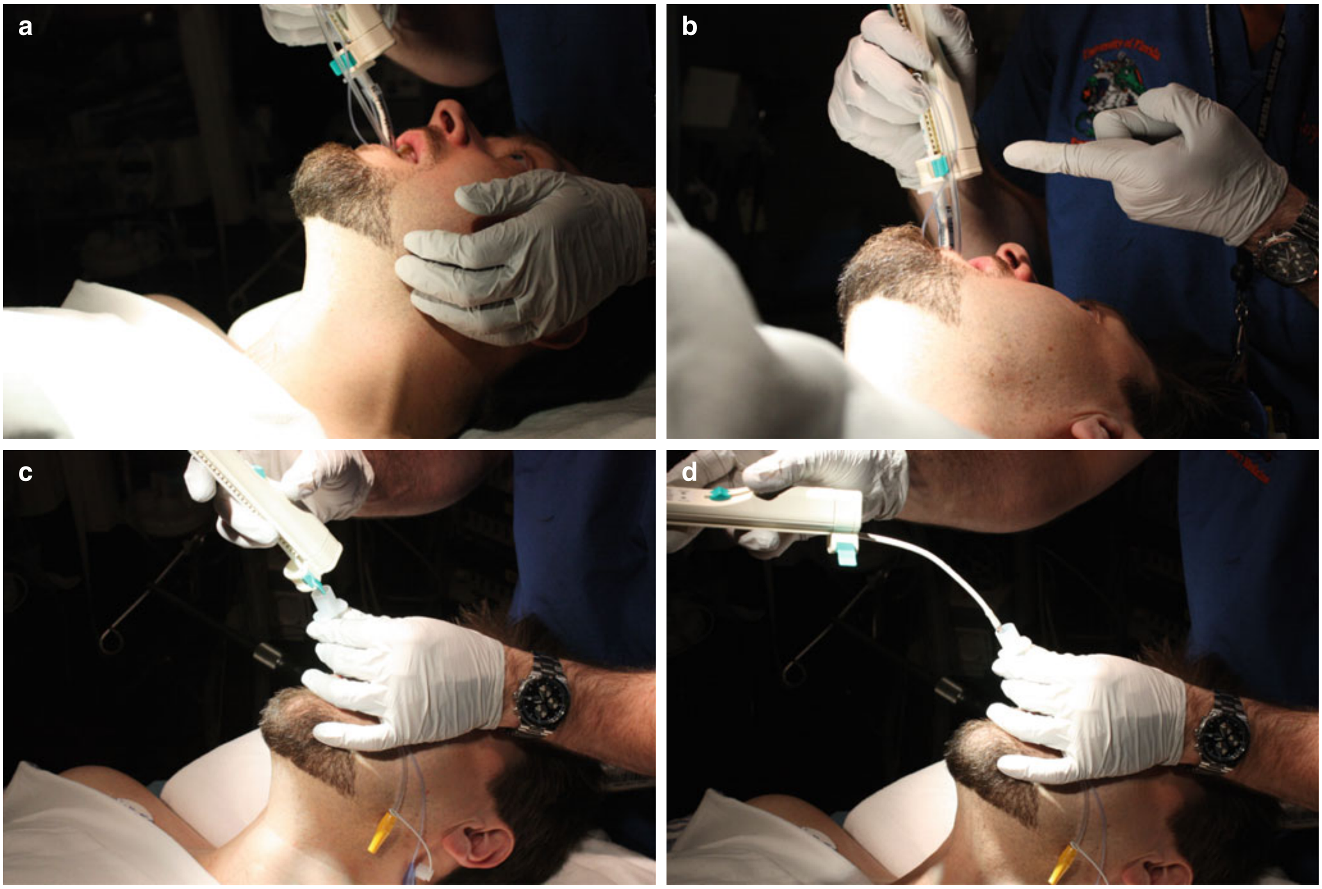

Fig. 16.5 (**a**) Hold the LS-ETT unit steady with one hand. (**b**) Check the depth of the ETT and adjust accordingly. (**c**) Release the LS latch that holds the ETT to the LS. (**d**) While holding the ETT in position, gently slide the LS out from the ETT

16.5 Pearls and Pitfalls

- Pearls
  - LS-ETT complex—Typically the classic “hockey-stick” shape with the 90° curve just proximal to the cuff is recommended [2].
  - Dimming the room lights will enhance transillumination.
  - Pulling the wire stylet out from the LS-ETT unit will make it more pliable and may facilitate its placement in the trachea and removal of the LS.
  - Some LS devices start to blink after 30 s to prevent bulb overheating.
  - The LS may be used with nasotracheal intubation, intubation through a laryngeal mask airway (LMA), or conventional laryngoscopy to enhance success.
- Pitfalls
  - LS intubation should not be used as an emergency airway alternative by a proceduralist unfamiliar with the technique:
    - It is technically complicated and more challenging than many other airway adjuncts in the standard difficult airway algorithm.
    - One study compared the use of four rescue airway devices in the difficult airway algorithm. A success rate of only 20 % was achieved with the Trachlight™ on the first attempt when in the hands of the novice physician when used as a rescue device in their difficult airway algorithm [4].
  - In very thin patients, transillumination may be visualized quite well even when the LS-ETT unit is in the esophagus:
    - When the unit is in the esophagus, typically the light it will be more diffuse.
    - When the unit is in the trachea, the transilluminated area will be well circumscribed.
  - In obese patients or patients with significant neck tissue, the transilluminated light from the LS-ETT unit may be dim despite correct positioning in the trachea.

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Fiber-Optic Stylet Intubation (Rigid and Semirigid)

17

Joseph Rabinovich

17.1 Indications

- For use in routine and predicted difficult oral intubations.
- Similar to a flexible fiber-optic scope with the specific advantages of:
  - Less setup time
  - Less time to perform the procedure
  - Appropriate for routine intubations (and easier to accumulate experience)
  - Rigid enough to lift up the epiglottis
  - Easier to navigate through tissue
  - Less susceptible to being obscured by blood and secretions
  - More durable, more portable, easier to clean, and less expensive
- Particularly useful when neck mobility or mouth opening is restricted.
- Advantageous in awake intubations because it can minimize tissue contact, resulting in less stimulation to the patient's airway and better tolerance.
- Certain stylets can be used to intubate through supraglottic airways such as laryngeal mask airways (LMAs).

17.2 Contraindications

- Complete upper airway obstruction where surgical airway is indicated
- Oral pharyngeal swelling requiring a nasotracheal or surgical approach
- Failed airway and unable to adequately maintain oxygenation

17.3 Relative Contraindications

- Large amounts of blood and secretions may obscure visualization of the airway and cords.
- Very distorted airways. Compared with flexible endoscopy, this device is less maneuverable.

17.4 Materials and Medications

- Endotracheal tube (ETT) 5.5 mm or greater (Fig. 17.1) (Pediatric stylets are also available.)
- Water-soluble lubricant
- Defogging agent
- Optional: Swivel adaptor and meconium aspirator

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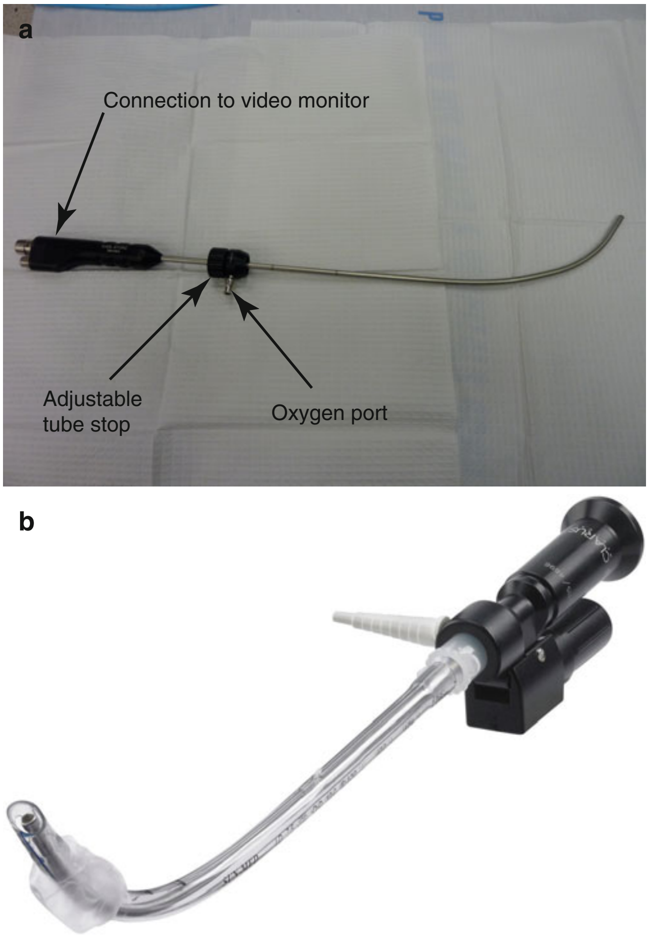

Fig. 17.1 (**a**) Bonfils rigid fiber-optic stylet, Karl Storz endoscopy, (**b**) Levitan FPS malleable fiber-optic stylet

17.5 Procedure

1. Use standard preparation for rapid sequence intubation (RSI) or for awake intubation.
2. Place the ETT over the stylet.
    (a) The ETT should extend slightly beyond the stylet tip.
    (b) If using the malleable stylet:
        (i) Without a laryngoscope: Bend tip to about 70° [1].
        (ii) With a laryngoscope: Bend tip to 35° [1].
    (c) Lubricate the tip of the ETT.
3. Depending on specific scope capability, connect oxygen tubing to the port on the scope.
    (a) This keeps secretions away from the tip while providing an oxygen source.
    (b) Keep flow less than 6 L/min [2].
4. Lens fogging prevention.
    (a) Warm the tip of the scope with the hand or immerse the tip in warm saline.
    (b) Apply the defogging agent.
    (c) Alternatively, chlorhexidine is an effective defogger.
5. Scope insertion.
    (a) Use the nondominant hand to pull the jaw forward while holding the tongue.
        (i) In an awake patient, have the patient protrude the tongue and the operator grasps it with 4×4 gauze. (Alternatively, a Macintosh laryngoscope blade can be used.)
        (ii) The goal is to move the base of the tongue off the posterior pharyngeal wall.
    (b) Initially position the scope horizontally and to the right of the patient's mouth.
    (c) Once the tip is in the oropharynx, reposition the scope vertically (Fig. 17.2a).
    (d) The scope tip should be in the midline or in the retromolar position (per scope design).
    (e) Position the scope and the tip of the ETT in front of the uvula.
    (f) Refer to the eyepiece or video screen to see if there is a clear image of the uvula (Fig. 17.2b).
    (g) Advance the scope very slowly to maintain a view of landmarks, avoiding tissue contact (Fig. 17.3).
6. Once the epiglottis is visualized:
    (a) Continue to advance slowly.
    (b) To get underneath the epiglottis, the tip of the scope may need to be moved posteriorly (by tilting the operator's hand slightly forward) (Fig. 17.4).

7. Once underneath the epiglottis, tilt the scope back, to advance into the more anterior directed airway.
   (a) Make sure the glottic opening is well centered on the screen to facilitate placement (Fig. 17.5).
   (b) If resistance is felt, operator may need to rotate the scope clockwise, or tip scope slightly forward, to prevent the ETT from abutting the anterior aspect of the trachea.
   (c) The ETT may need to be advanced off the rigid stylet to allow further advancement.
8. To remove scope:
   (a) Twist the proximal end of the ETT clockwise.
   (b) Stabilize the tube with the nondominant hand.
   (c) Use the dominant hand to pull the scope forward, following the curvature of the stylet (Fig. 17.6).
   (d) An assistant may be of use during this step.

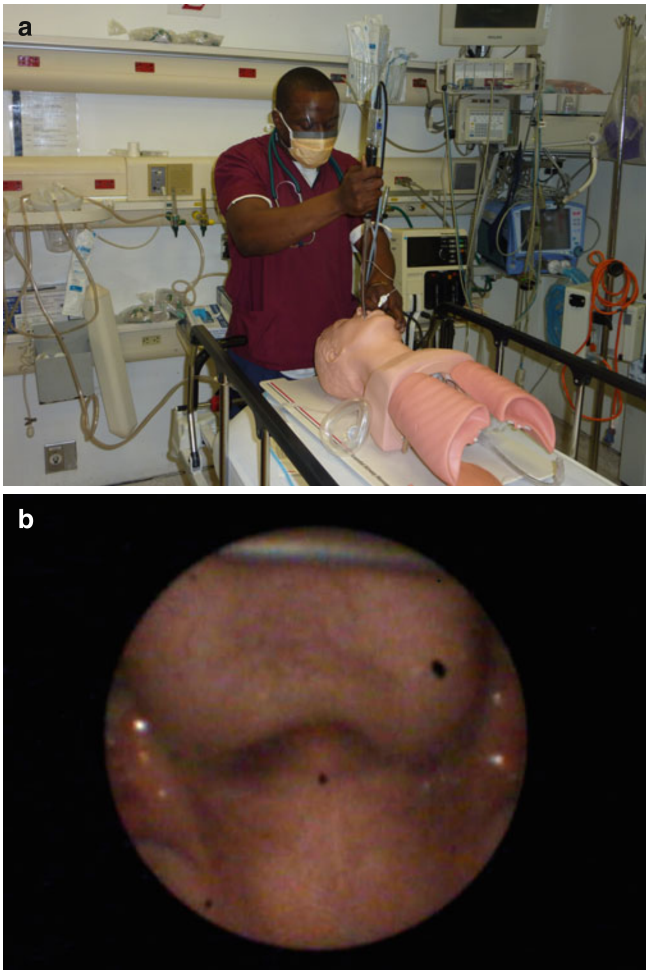

Fig. 17.2 (**a**) Initial placement of scope, under direct visualization; (**b**) tip is positioned in from the uvula

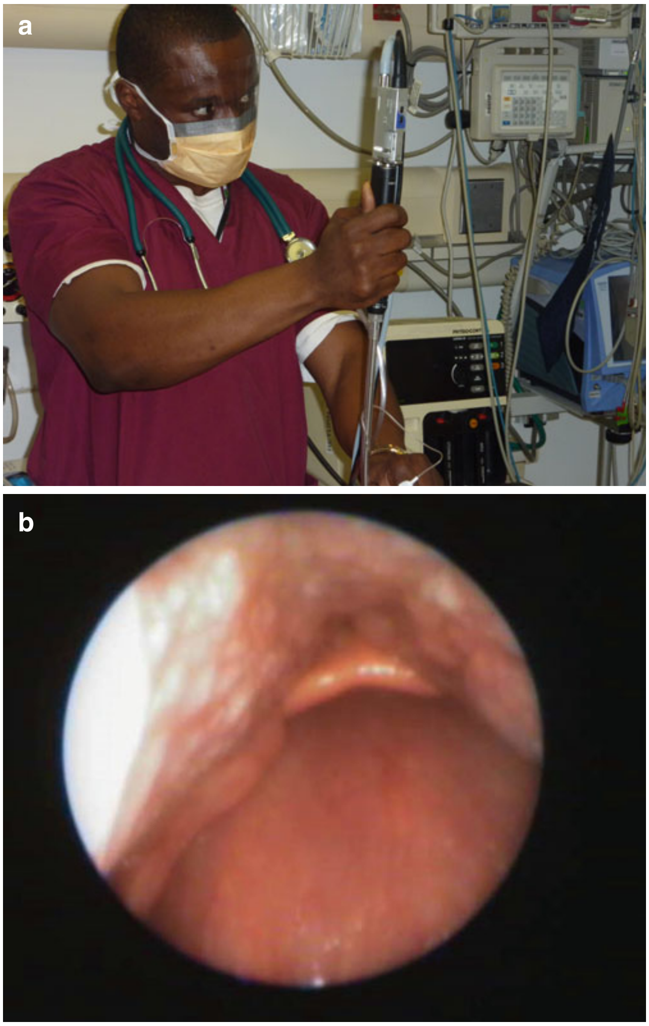

Fig. 17.3 (**a**) Using the video monitor, or through an eyepiece, the operator advances to the next landmark, (**b**) the epiglottis

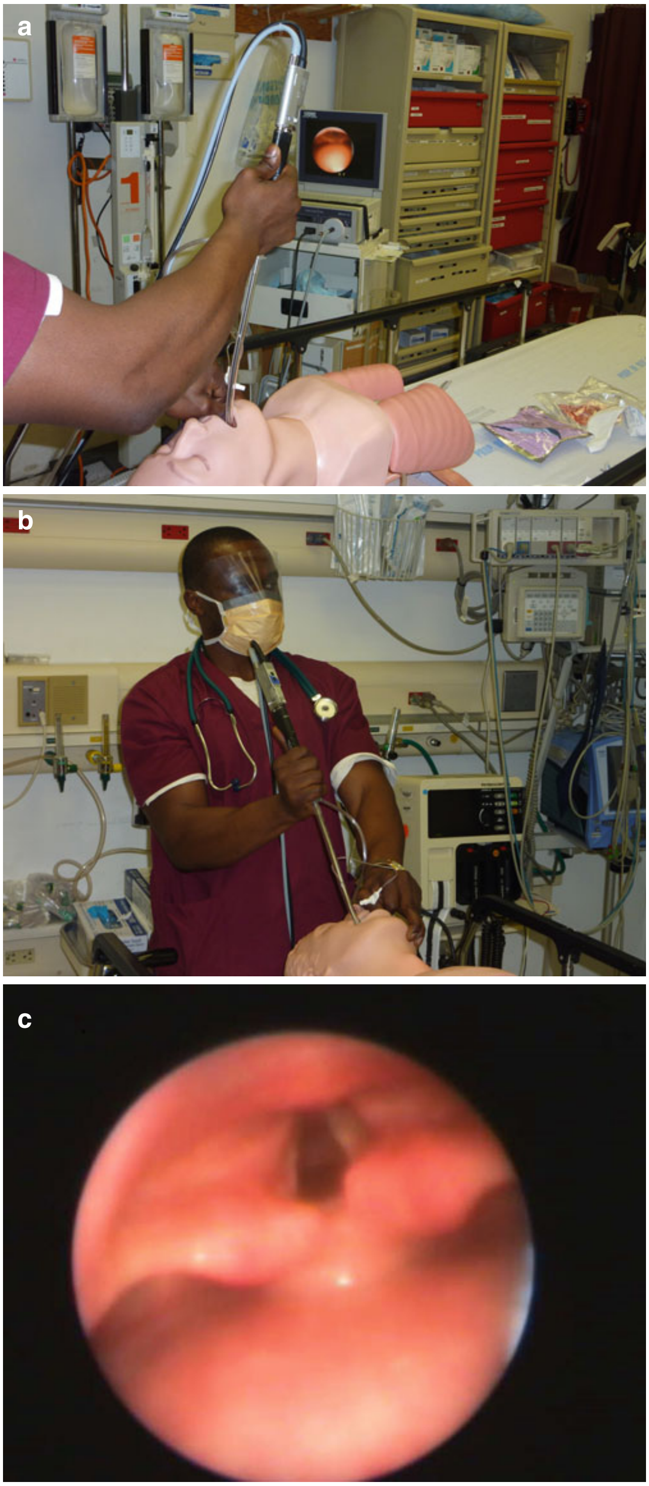

Fig. 17.4 (**a**) Operator tips scope forward to get underneath the epiglottis while advancing; (**b**) once under the epiglottis, the scope may need to be tipped back to advance to the glottic opening; (**c**) operator should try to keep the glottic opening in the center of the screen

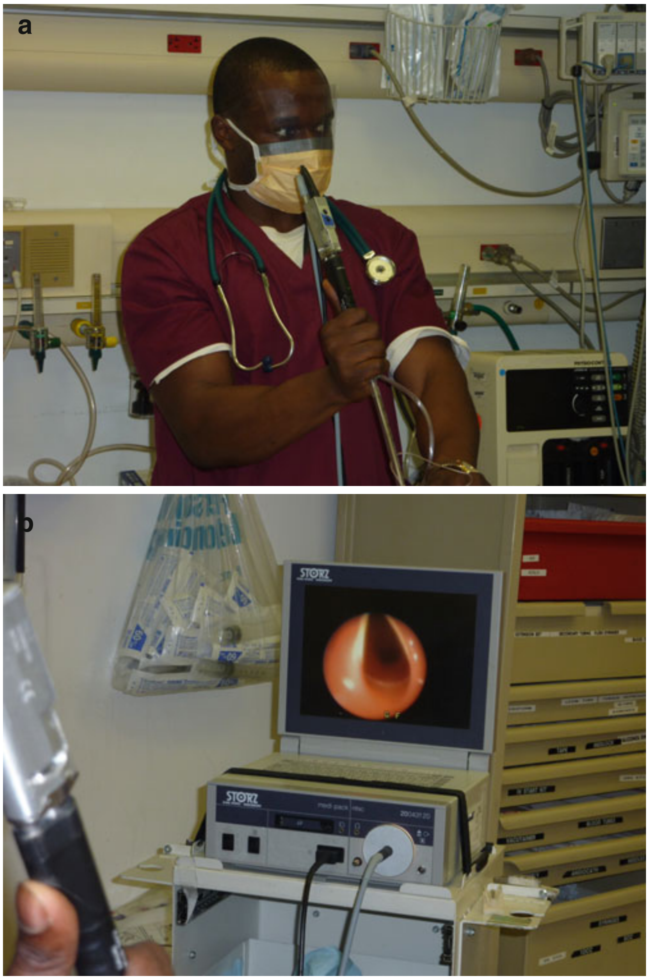

Fig. 17.5 (**a**) Operator is advancing the scope, (**b**) through the glottic opening keeping the image centered

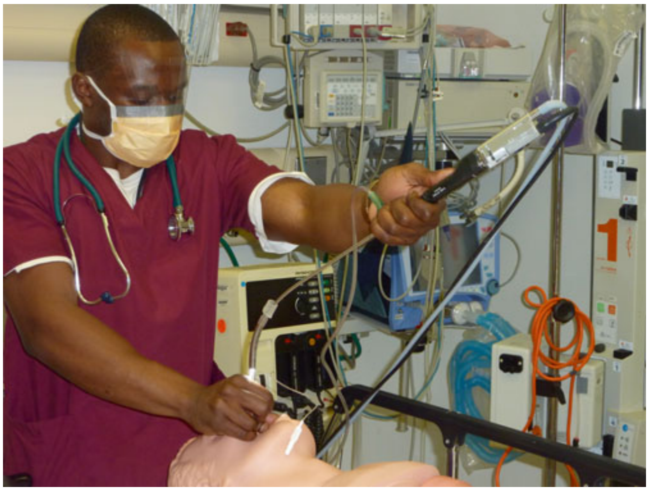

Fig. 17.6 To remove scope, operator must pull it forward while stabilizing the endotracheal tube

17.6 Pearls and Pitfalls

- Pearls
  - When the operator loses perspective or a clear view, withdraw the scope back to the point where identifiable structures are visualized and proceed.
  - The operator can suction through the scope by attaching a swivel adaptor and a meconium aspirator (Fig. 17.7) [3].
- Pitfalls
  - If the scope is advanced too quickly, orientation can be lost.
  - Structures that are too close to the scope will become blurred and unidentifiable.
  - If the scope tip abuts pharyngeal tissue, visualization can become blurred.
  - Flow greater than 6 L/min connected to the oxygen port may result in subcutaneous emphysema (single case report) [2].

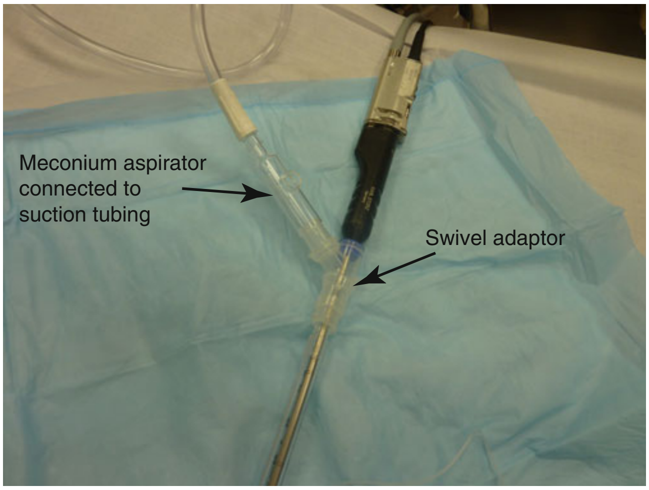

Fig. 17.7 By placing the stylet through the rubber valve of a swivel adaptor, which is then connected to suction via a neonatal meconium aspirator, the operator can now suction through the endotracheal tube

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18 Storz Video Laryngoscope

Joseph Rabinovich

18.1 Indications

- Orotracheal intubation for both routine and predicted difficult airways.
- Teaching traditional direct laryngoscopy to novice intubators.
- Ideal for unanticipated difficult airway with the option of intubating indirectly if an adequate direct view is unobtainable.
- An excellent tool when cervical spine precautions need to be taken: Because the video view of the airway is generated by a camera at the tip of laryngoscope blade, less manipulation is required for optimal glottic views.

18.2 Contraindications

- Absolute
  - When orotracheal intubation is contraindicated, e.g., for massive facial trauma, complete upper airway obstruction precluding orotracheal access to the airway
  - In a failed airway (three unsuccessful attempts with inability to maintain adequate oxygenation)
- Relative
  - Blood or copious secretions may prevent indirect viewing of the airway but does not always preclude the use of this device.

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18.3 Materials and Medications (Fig. 18.1)

- Standard materials and medications for endotracheal intubation. Operator should have a backup laryngoscope in case of equipment failure.
- Endotracheal tube (ETT) with or without stylet.
- Water-based lubricant.
- Antifogging agent (not required for C-Mac).

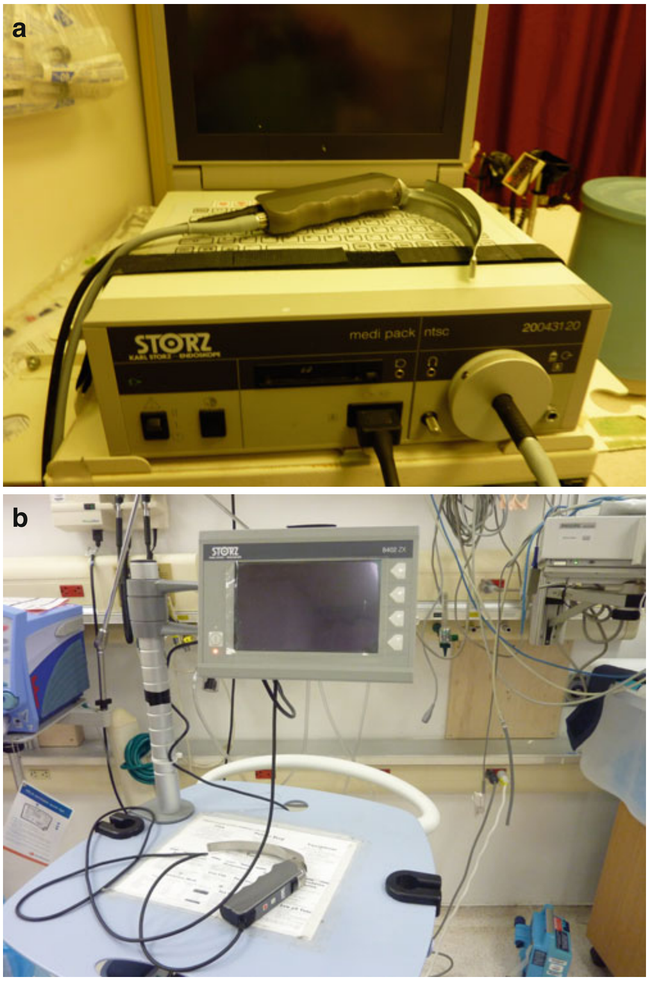

Fig. 18.1 (**a**) Storz video laryngoscope (older version), (**b**) Storz C-Mac (newer version)

18.4 Procedure

1. Standard preparation for orotracheal intubation. If there are no cervical spine precautions, then align the external auditory meatus with the sternal notch [1].
2. Apply antifogging drops to lens at tip of the blade, and/or hold the hand over the blade tip to warm it up to body temperature (older V-Mac model) (Fig. 18.2a).
3. Because blade geometry is the same as in standard laryngoscopes, the insertion technique is identical to that of standard laryngoscopy with a Macintosh blade (Fig. 18.2b).
4. Obtain the best direct view possible.
5. Consider the addition of the backward-upward-rightward pressure (BURP) maneuver [2].
6. Airway maneuvers may be performed by the operator or by the assistant using the video screen as a guide along with operator feedback (Fig. 18.3).
7. The operator has the option of intubating directly with adequate view or indirectly if visualization is improved.
8. Consider using an ETT introducer (bougie—see Chap. 15) if the view is inadequate.
9. Place the ETT, with or without a stylet, into the airway under direct or indirect visualization. If using a stylet, bend the distal end of the tube to approximately 35° as for a standard intubation (Fig. 18.4) [3].
10. Remove the stylet, inflate the cuff of the ETT using a syringe, and confirm placement with end-tidal CO_2, capnography, or colorimetry.

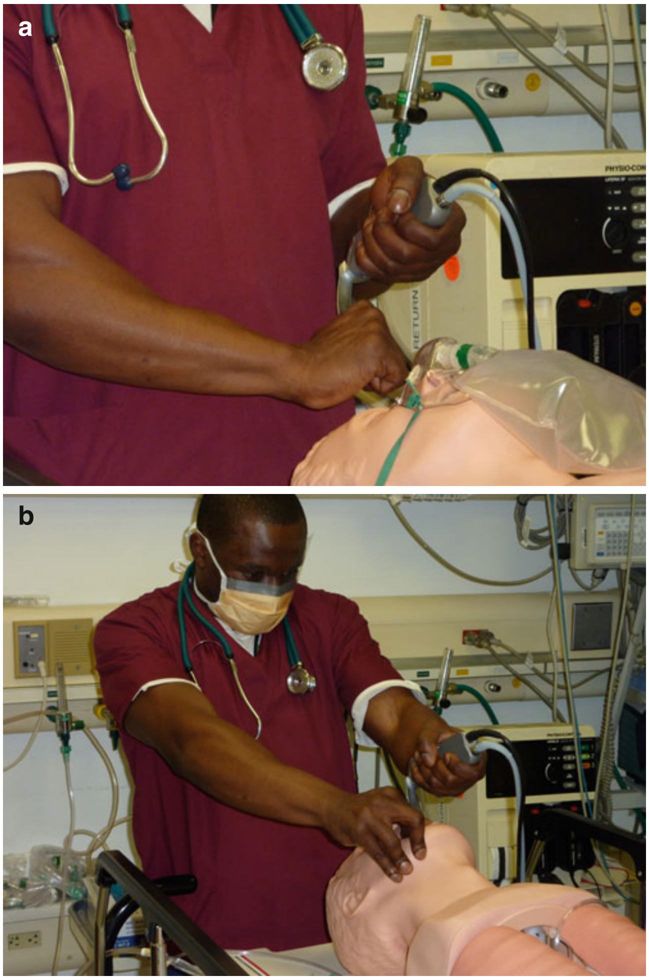

Fig. 18.2 (**a**) Operator warming the blade to prevent fogging, (**b**) laryngoscope blade insertion using the standard direct technique. Operator visually places the blade and optimizes the glottic view

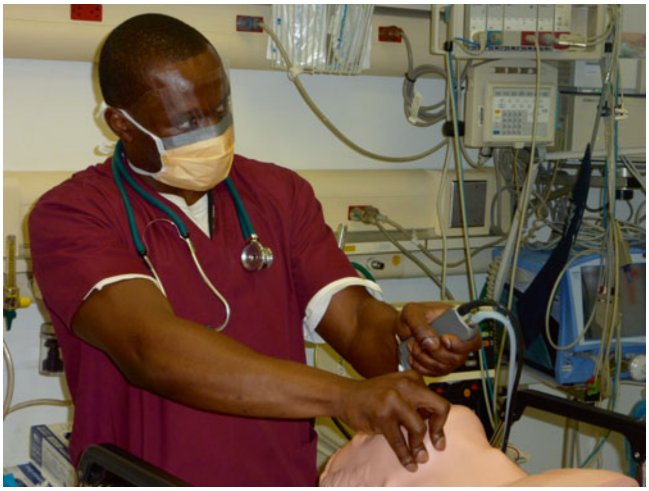

Fig. 18.3 Operator has the choice of using direct visualization (preferred when a novice intubator is learning laryngoscopy) or the indirect video view of the glottis

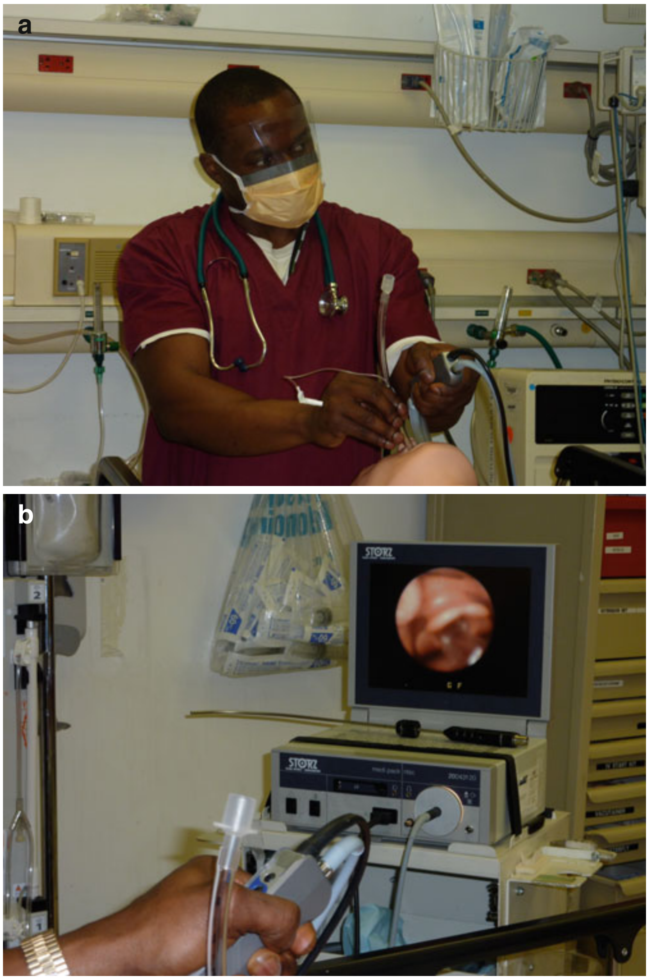

Fig. 18.4 (**a**) Operator initially places the endotracheal tube (ETT) into the oropharynx using direct visualization to avoid injury; (**b**) the tip of the ETT passing through the cords can be confirmed by direct visualization or by watching the video image

18.5 Complications (As with any Direct Laryngoscopy)

- Dental trauma
- Oropharyngeal trauma
- Vocal cord injury

18.6 Pearls and Pitfalls

- The initial placement of the laryngoscope blade and ETT should be done under direct visualization to avoid trauma to the oropharyngeal structures.
- As with direct laryngoscopy, the ETT should not be placed blindly, and the ETT must be seen to pass through the vocal cords to avoid placement in the esophagus.
- View can be obscured by secretions or fogging. If this occurs, the operator may need to remove the blade, wipe it down, and reinsert. The newer model, the C-Mac, is less likely to fog owing to design improvements.
- Observing the ETT pass through the vocal cords can sometimes be easier using the video image because the camera is angled to provide the most optimal view.
- Placement of the blade into the oropharynx can be awkward because the handle of laryngoscope is bulkier than a standard laryngoscope. Its handle is larger and has cables attached to its base. In patients with large anteroposterior diameter chests, the operator may need to rotate the laryngoscope handle toward the right corner of the mouth in order to introduce the blade into the oral cavity and then rotate it back to the proper position.
- These devices are ideal for teaching laryngoscopy. With same blade geometry, the technique is the same as with standard laryngoscopy. As the operator attempts intubation directly, the instructor can observe on the video screen and guide the student. The instructor will also be able to visually confirm that the ETT is entering the trachea.

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Cricothyroidotomy

19

Henry Young II, Shannon Toohey, Bharath Chakravarthy,
and Lars K. Beattie

Up to seven intubation attempts in 1000 end up in a "can't intubate/can't ventilate" situation in the emergency department. These are considered failed airways that may require a surgical airway to maintain ventilation and oxygenation.

19.1 Indications

- Endotracheal tube (ETT) placement attempts unsuccessful
- Failed bag valve mask, laryngeal mask airway, or Combitube ventilation
- Severe facial trauma affecting the upper airway
- Severe oropharyngeal hemorrhage or profound emesis
- Obstruction (foreign body, mass, mass effect)

19.2 Contraindications

- Airway protection achievable using a less invasive strategy
- Tracheal transaction
- Pediatric patients younger than 8 years

19.3 Techniques

- Scalpel-bougie – minimalist
- Scalpel-Trousseau – standard

19.3.1 Scalpel-Bougie

19.3.1.1 Materials and Medications (Fig. 19.1)

- Betadine or chlorhexidine
- Scalpel #11 blade
- ETT (≥6 cm)
- Bougie
- Surgilube
- Bag valve mask

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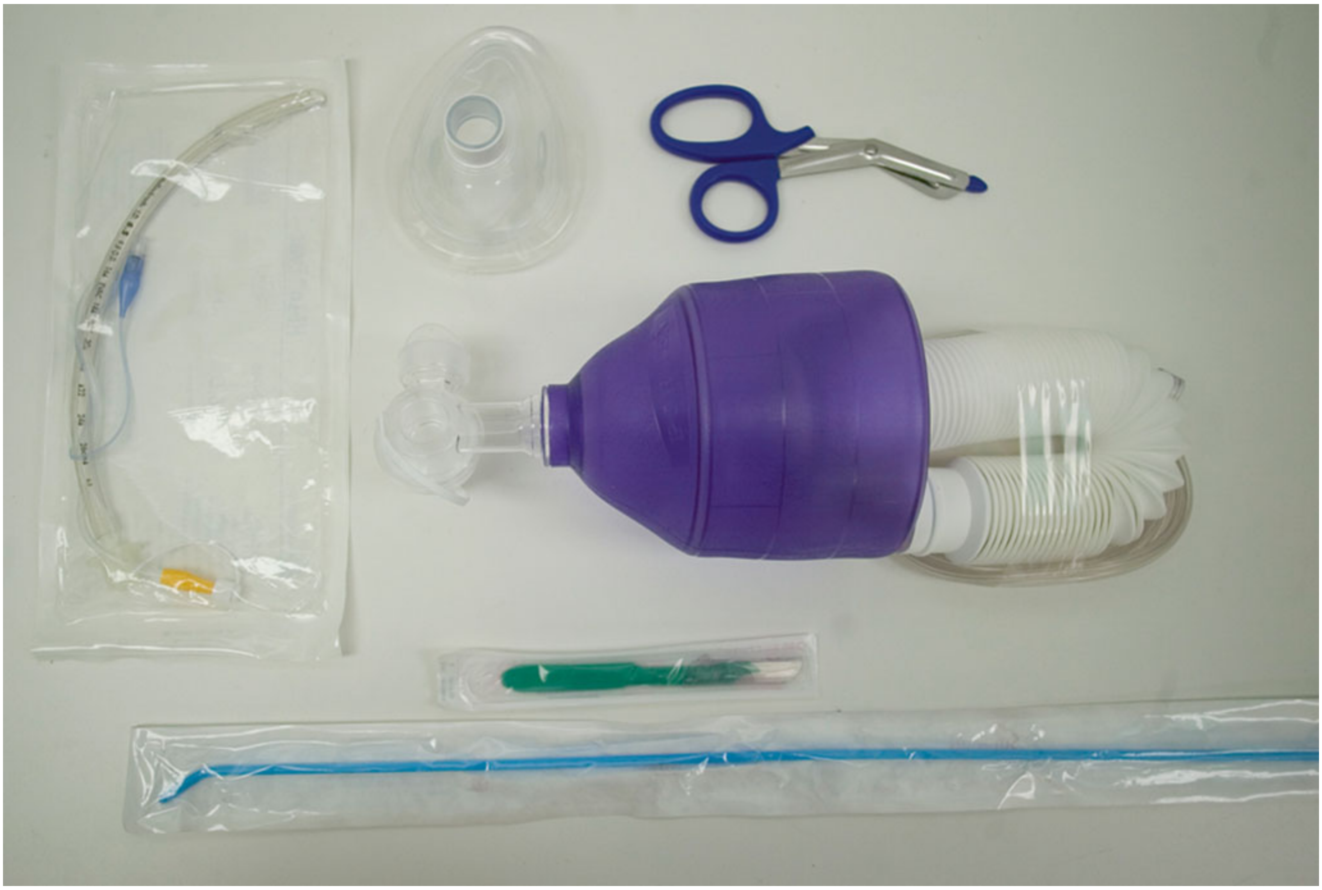

Fig. 19.1 *Right to left*, *top to bottom*: ETT (≥6 cm); bag valve mask; trauma shears; scalpel #11 blade; bougie

19.3.1.2 Procedure

1. Apply topical antiseptic.
2. Remove the 15-mm ETT ventilator connector from the ETT end.
3. Place copious Surgilube on the bougie and railroad over the end of the bougie.
4. Palpate the thyroid notch, cricothyroid membrane, and hyoid bone for orientation (Fig. 19.2a).
5. Stabilize the thyroid cartilage between the thumb and the middle finger of the nondominant hand.
6. Make a vertical skin incision (2–3 cm) over the cricothyroid membrane (Fig. 19.2b).
7. Use the index finger to palpate the cricothyroid membrane.
8. Turn the scalpel 90° and make a 1.5-cm horizontal incision through the lower half of the cricothyroid membrane (Fig. 19.3a).
9. With the scalpel still in the incision, turn it 90°, and insert the bougie into the incision, using the blade as a guide (Fig. 19.3b).
10. Advance the bougie caudally 5–6 cm. Stop if resistance is encountered.
11. Slide the ETT over the bougie into the incision (Fig. 19.4a).
12. Inflate the ETT cuff and ventilate the patient (Fig. 19.4b).
13. Verify the position of the ETT via auscultation, end-tidal CO_2 ($EtCO_2$), and chest radiograph.
14. Secure the ETT.

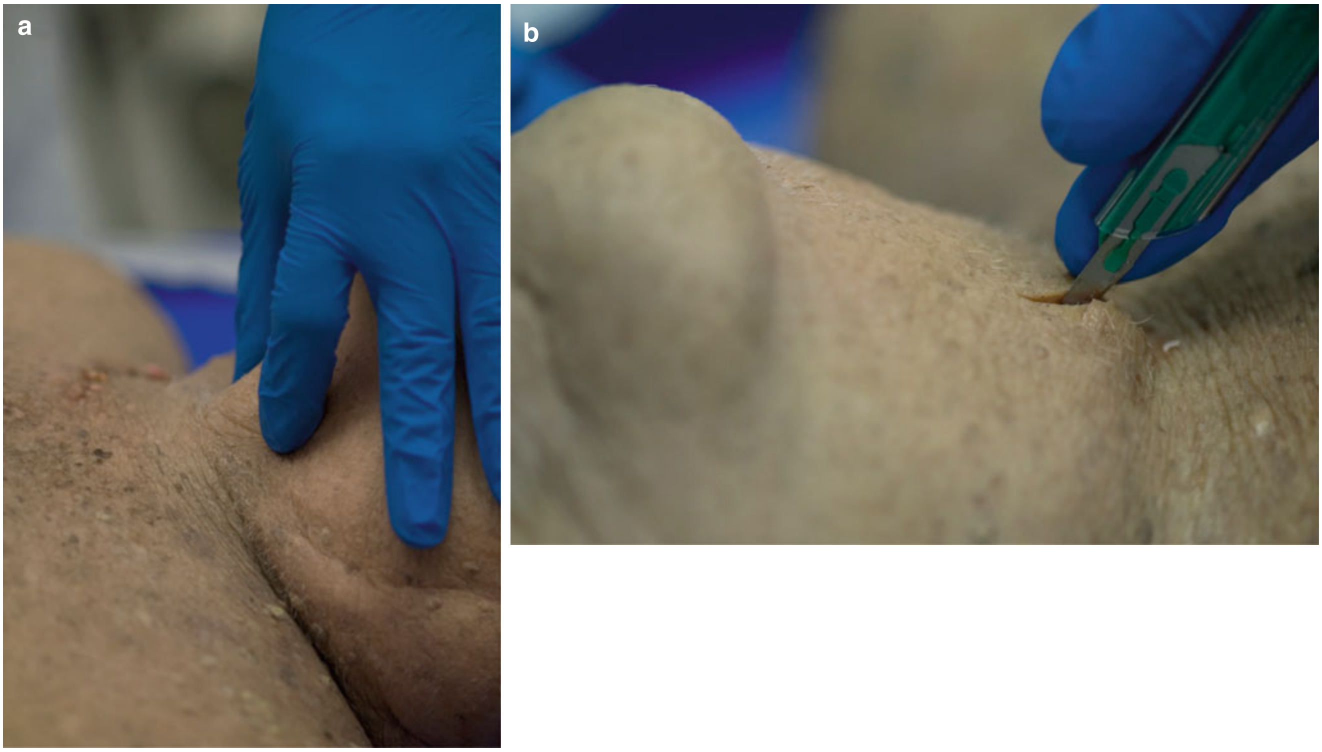

Fig. 19.2 (**a**) Palpate and stabilize the thyroid cartilage, (**b**) make a vertical 2–3 cm incision over the cricothyroid membrane

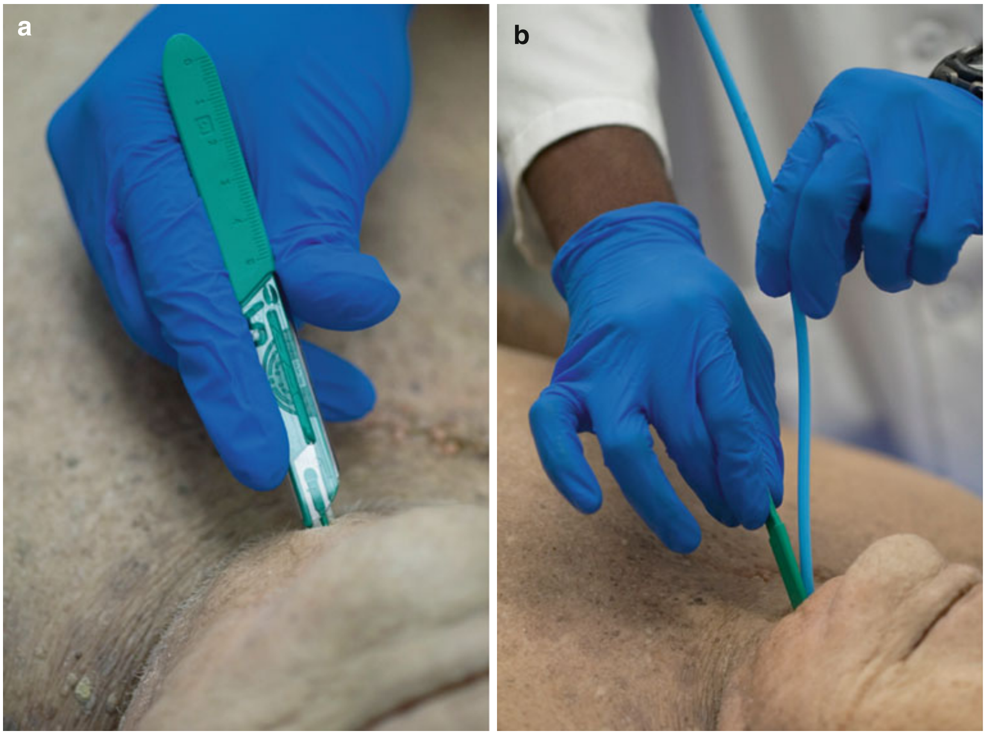

Fig. 19.3 (**a**) Make a horizontal incision into the cricothyroid membrane, (**b**) insert the bougie into the incision made in the cricothyroid membrane

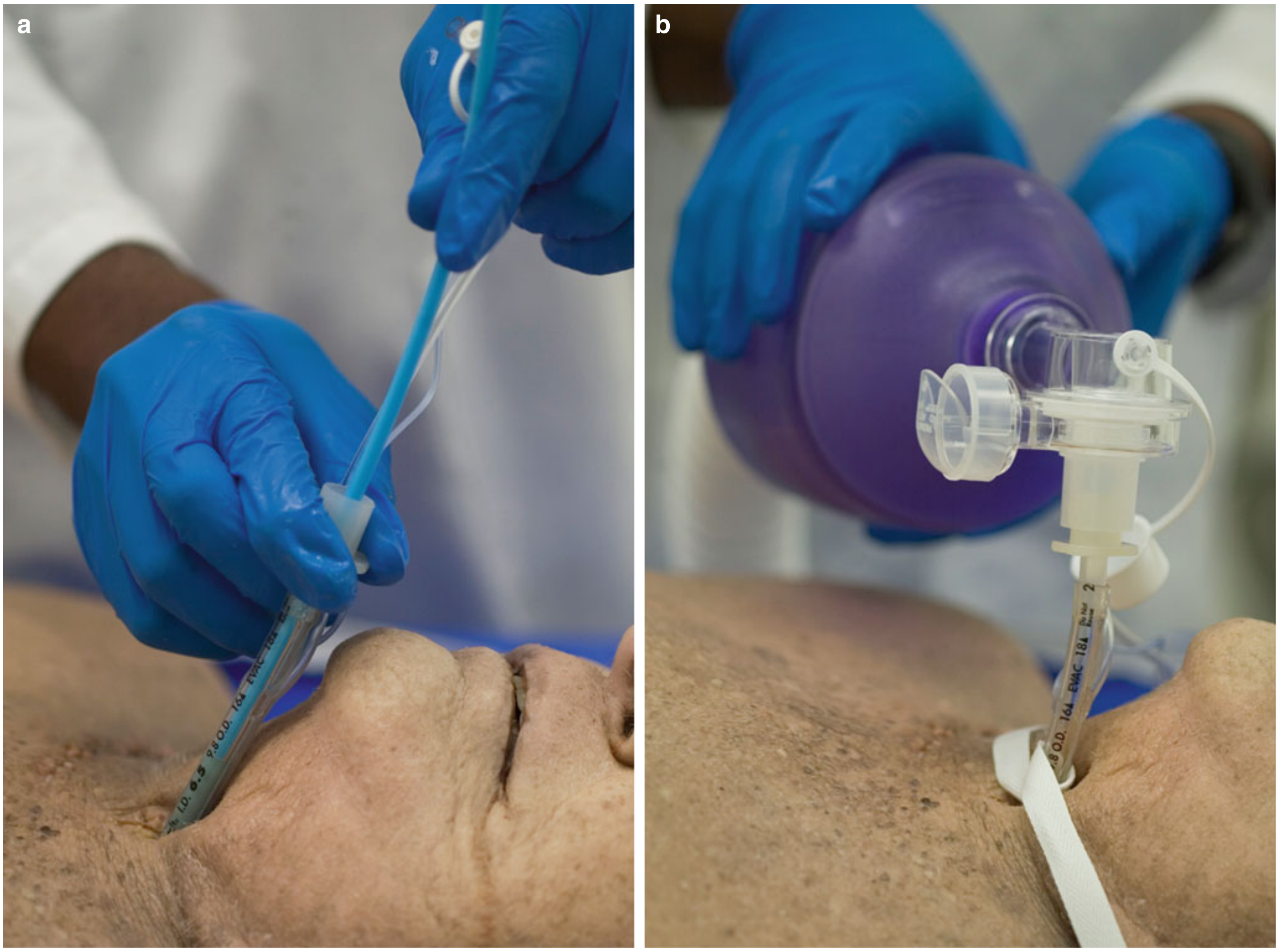

Fig. 19.4 (**a**) Slide the endotracheal tube (ETT) over the bougie into the trachea, (**b**) ventilate the patient

19.3.2 Scalpel-Trousseau

19.3.2.1 Materials and Medications (Fig. 19.5)

- Scalpel with #11 blade
- Tracheal hook
- Trousseau dilator
- Cuffed tracheostomy tube (TT) (6.5 or 7.0) or ETT (5.0, 5.5, or 6.0)
- Antiseptic preparation

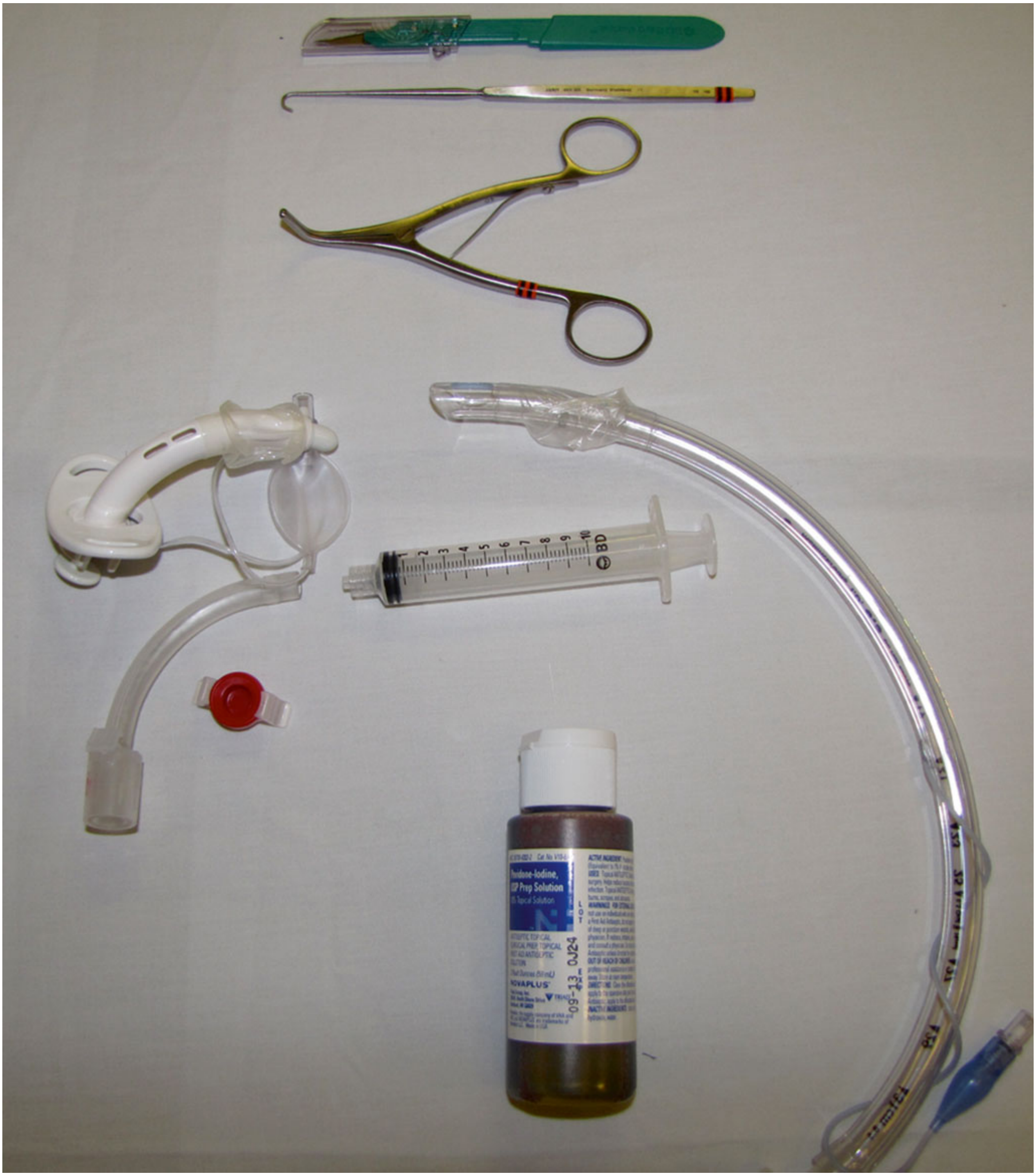

Fig. 19.5 *Top to bottom*, *right to left*: Scalpel with #11 blade; tracheal hook; Trousseau dilator; cuffed tracheostomy tube (TT) (6.5 or 7.0) or ETT (5.0, 5.5, or 6.0); antiseptic preparation

19.3.2.2 Procedure

1. Apply topical antiseptic.
2. Palpate the thyroid notch, cricothyroid membrane, and hyoid bone for orientation.
3. Stabilize the thyroid between the thumb and the middle finger of the nondominant hand (Fig. 19.6a).
4. Make a vertical skin incision (2–3 cm) over the cricothyroid membrane (Fig. 19.6b).
5. Palpate with the index finger to verify the cricothyroid membrane location.
6. Use stabilization of the thyroid and palpation to maintain orientation of the anatomy.
7. Make a 1.5-cm horizontal incision through the lower half of the membrane (Fig. 19.7a).
8. Insert a tracheal hook into the incision, then rotate such that hook faces superiorly (Fig. 19.7b).
9. Withdraw at a 45° angle in a cephalad direction, applying gentle traction to the thyroid cartilage.
10. Place the Trousseau dilator into the incision transversely and open the membrane incision vertically (Fig. 19.8a).
11. Insert a cuffed ETT (5.0–6.0) or TT (6.5–7.0) into the incision between the prongs of the dilator in the horizontal access (Fig. 19.8b).
12. Rotate both the dilator and the ETT toward the head of the patient and then direct the tube downward into the trachea while removing the dilator.
13. Inflate the ETT cuff and ventilate the patient.
14. Verify the position of the ETT via auscultation, $EtCO_2$, and chest x-ray.
15. Once placement of the tube has been verified, the tracheal hook can be removed.
16. Secure the ETT.

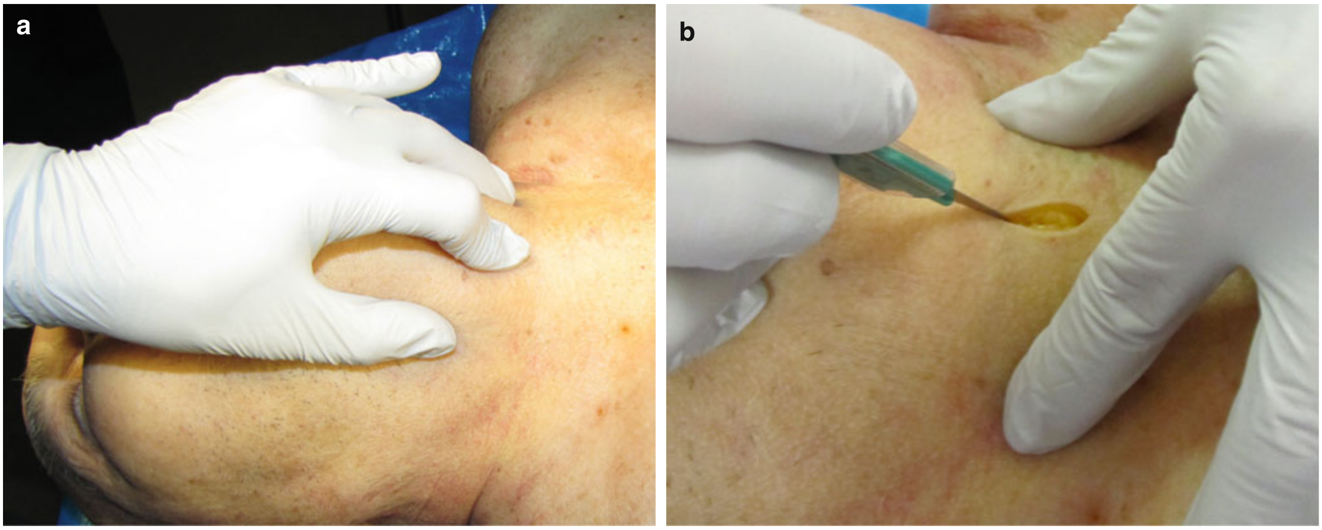

Fig. 19.6 (**a**) Stabilize the thyroid cartilage between the thumb and the middle finger of the nondominant hand; (**b**) make a vertical incision over the cricothyroid membrane

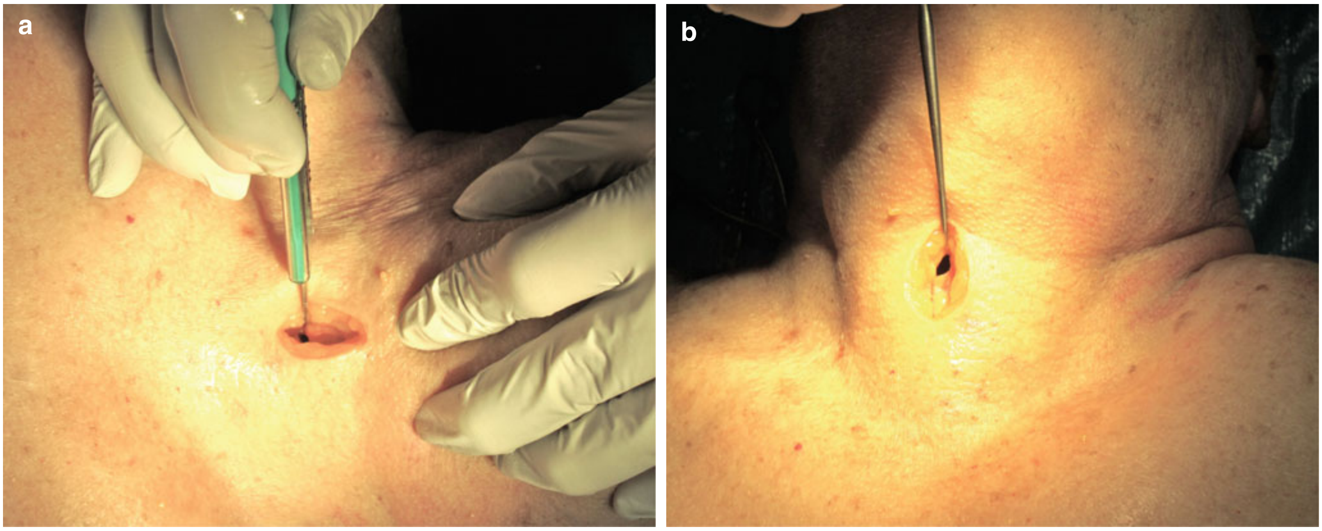

Fig. 19.7 (**a**) Make a horizontal incision in the lower half of the cricothyroid membrane. (**b**) Insert a tracheal hook and apply gentle traction superiorly at a 45° angle

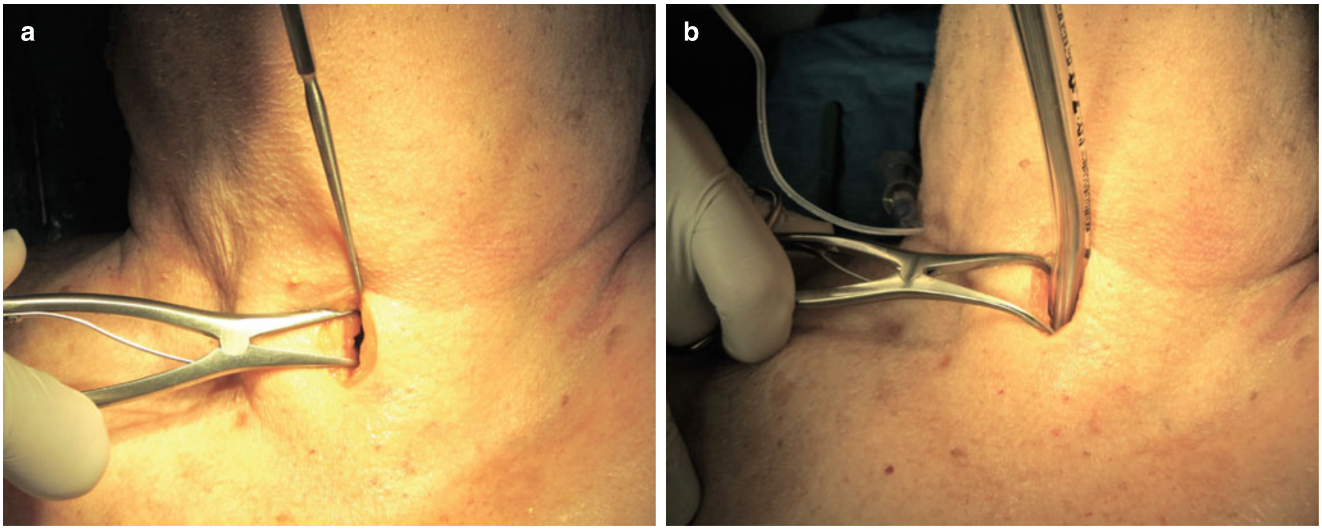

Fig. 19.8 (**a**) Insert the Trousseau dilator into the incision, and open the path for placement of the tracheostomy tube (TT) or the ETT. (**b**) Insert the TT or the ETT into the expanded incision between the Trousseau dilator prongs

19.4 Complications

- Bleeding
- ETT misplacement (false passage, through the thyrohyoid membrane, unintentional tracheostomy)
- Hoarseness, dysphonia, or vocal cord paralysis
- Subglottic or laryngeal stenosis
- Damage to thyroid cartilage, cricoid cartilage, or tracheal rings
- Perforated esophagus
- Infection
- Aspiration

19.5 Pearls

- Predictors of difficult cricothyrotomy: "SHORT" [1]
  - Prior *S*urgery or *S*car tissue
  - *H*ematoma
  - *O*bese
  - Prior *R*adiation
  - *T*umor/abscess
- The incision should cut through the skin and subcutaneous tissue down to the cricothyroid membrane and cartilages.
- Vertical incisions allow for extension in either direction if the cricothyroid membrane is above or below initial incision.
- Blood in the field may hinder visualization of the membrane, but the airway should be established before attempts to control any bleeding.
- Cricothyroid arteries are located cephalad to the cricothyroid membrane.
- Either a TT or an ETT can be used for the procedure.
  - ETTs are more ubiquitous.
  - TTs are easier to secure.
- If an ETT is used, a stylet can help direct placement.
- Cricothyroidotomy is preferred in the emergency setting over tracheostomy owing to the increased risks of bleeding, the mobility of the trachea, and the risk of lacerating the underlying thyroid gland [2].
- Ultrasound can be used to visualize landmarks in patients in whom landmarks are difficult to identify.

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Tracheostomy Tube Malfunction

20

Deena Bengiamin and Bharath Chakravarthy

Tracheostomy tube (TT) malfunction is the source of airway compromise in patients requiring these airway devices. TT malfunction may create an airway emergency, and the timely replacement of TTs is a challenging procedure in the most experienced hands.

20.1 Indications

- Cuff rupture
  - Can lead to dislodgment
- Dislodgment
  - Most common emergency department TT complication
  - Can lead to air passage obstruction
- Obstruction
  - Caused by blood or thick, dry secretions (formed in the absence of nasopharyngeal air humidification).
  - Dried secretions or blood can act as a one-way valve, allowing air in but restricting outward flow.

20.2 Materials and Medications

- Airway suction catheter
- Oxygen humidifier
- Bougie/nasogastric (NG) tube (12 French)
- Saline
- N-Acetyl-cysteine (NAC)
- Appropriately sized endotracheal tube (ETT) or TT

20.3 Procedure

1. Supply high-flow humidified oxygen through a bag valve mask (BVM), or a non-rebreather face mask.
2. Assess clinical indicators to determine TT problem.
   (a) Indicators of cuff rupture: Air leak with BVM and loose TT.
   (b) Indicators of dislodged TT (if TT is still in the stomal opening): Subcutaneous emphysema, crepitus, and diminished or absent breath sounds.
   (c) Indicators of an obstructed TT: ±stridor and diminished or absent breath sounds.
   (d) If time allows, chest radiograph, continuous capnography, and oxygen saturation can be helpful.
3. Obstruction
   (a) Remove the inner cannula and inspect for obstruction—clean if necessary.
   (b) If this fails, 5–10 mL of saline or NAC can be squirted directly down the TT to loosen secretions.
   (c) Suction thoroughly with a suction catheter (Fig. 20.1).
   (d) In refractory cases, the TT will need replacement.
4. Replacement
   (a) Ideally, the replacement tube should be of the same type and size as the original TT.
   (b) A smaller size TT or ETT can be helpful in settings of airway compromise.
   (c) A 6–7.5-cm ETT tube may be used if a TT is unavailable.
   (d) Remove the existing TT.
   (e) Hyperextend the patient's head and neck to maximize visualization of the stoma.

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- (f) Note: Careful inspection of the area is paramount because the thyroid isthmus may obscure visualization of the tracheal stoma.
- (g) Techniques
    - (i) Direct insertion
        1. As soon as possible, insert the new TT or ETT into the stoma to prevent stomal narrowing (Fig. 20.2).
        2. Inflate the new TT/ETT cuff.
    - (ii) Bougie or NG tube
        1. Lubricate the TT or ETT tube.
        2. Lubricate a bougie or 12-French NG tube.
        3. Insert the lubricated bougie or NG tube into the TT or ETT.
        4. Insert the bougie or NG tube into stoma and advance into the trachea (Fig. 20.3a).
        5. Direct the NG tube or bougie caudad toward the lower tracheobronchial tree.
        6. Do not advance more than 7 cm.
        7. If resistance is noted:
            - (a) Either the operator has reached a terminal bronchiole or is in a false passage.
            - (b) Do not force bougie/NG tube farther at this point.
            - (c) Use clinical judgment (bougie/ETT depth, palpation) to determine likely placement.
        8. Advance TT or NG tube over bougie or NG tube is in trachea (Fig. 20.3b).
        9. After the TT is in place, remove the bougie/NG tube.
    - (iii) The fingertip technique
        1. Insert a gloved forefinger into tracheal stoma (Fig. 20.4a).
        2. Formulate a mental plan as to the direction and path of the stoma.
        3. Then place a TT or an ETT into the stoma as the finger is withdrawn (Fig. 20.4b).

5. If placement of a TT or ETT is not possible through the stoma, consider endotracheal intubation.

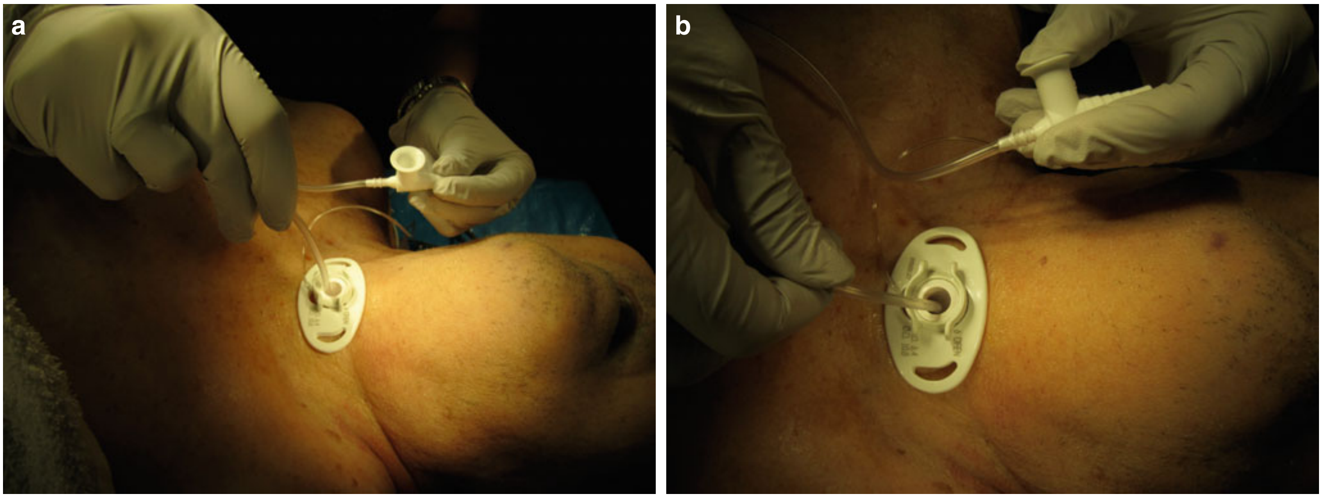

Fig. 20.1 (**a**) Insert the suction catheter to the appropriate depth, keeping the suction port open. (**b**) Slowly withdraw the catheter in a circular motion, keeping the suction port closed

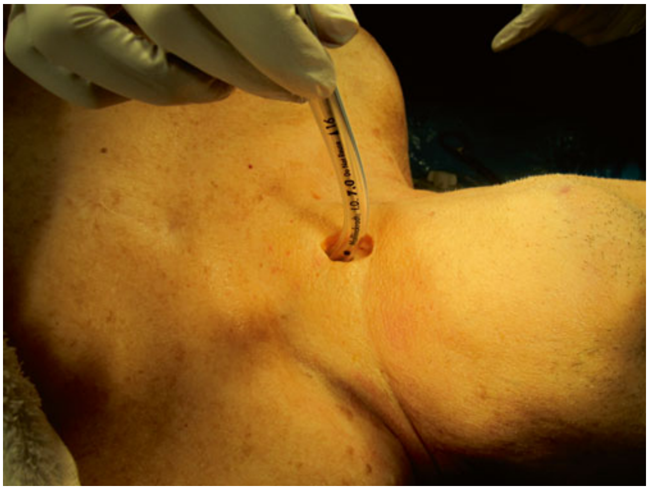

Fig. 20.2 Insertion of the endotracheal tube (ETT) directly into the stoma

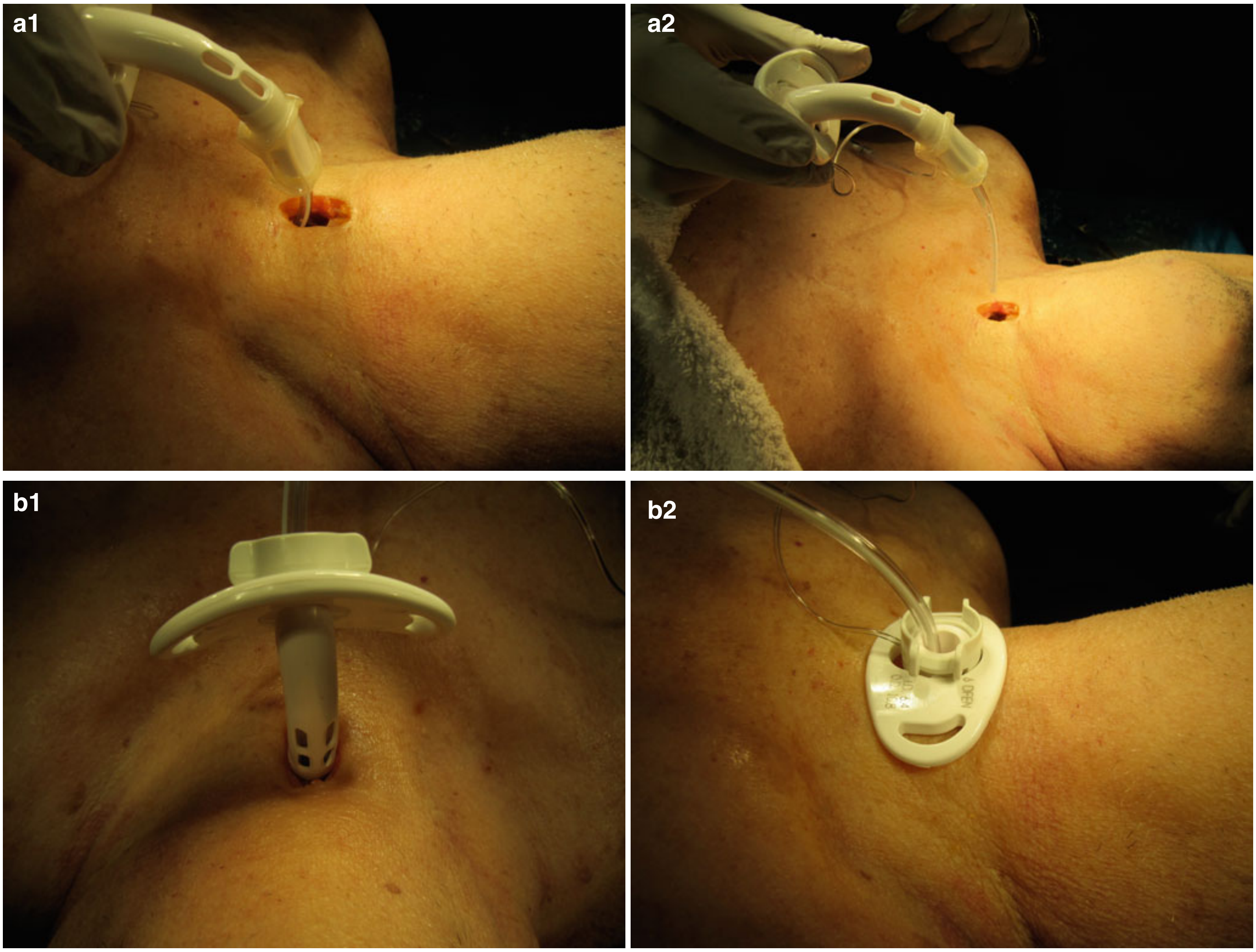

Fig. 20.3 (**a1, a2**) Insert the tracheostomy tube (TT) over the nasogastric (NG) tube or bougie, which is first inserted into the trachea. (**b1, b2**) Advance the TT over the NG tube or bougie, which serves as a guidewire

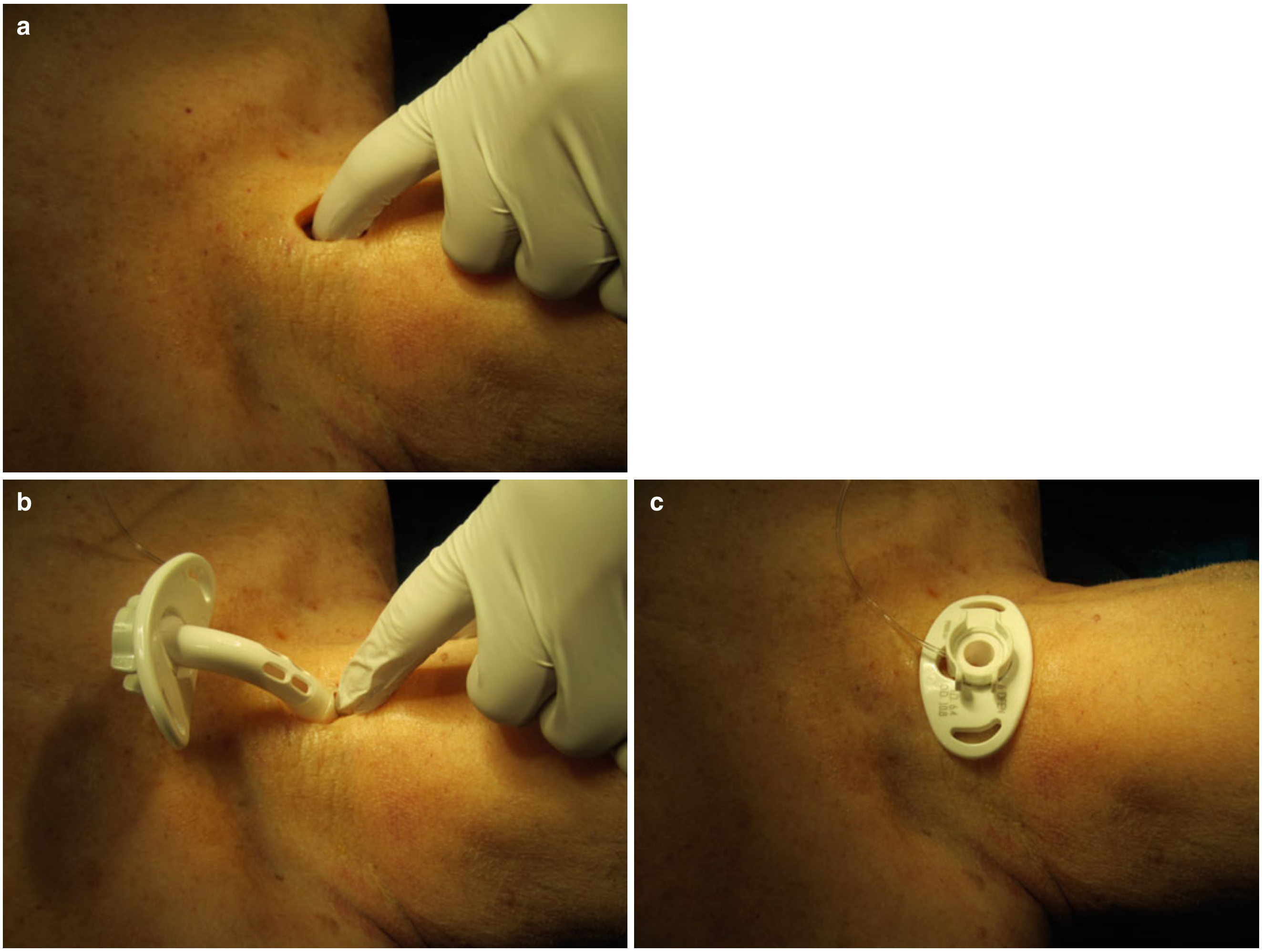

Fig. 20.4 (**a**) Insert a gloved finger into the stoma. (**b**) Insert the TT along the path while withdrawing the gloved finger. (**c**) TT in place

20.4 Pearls and Pitfalls

- Stomal closing
  - Stomal constriction begins as soon as the TT is removed or displaced.
  - Forceful attempts to replace a large TT may result in false passages and trauma.
- Tracheal stenosis
  - Constant TT cuff pressure may cause necrosis, ulceration, and granulation tissue formation, leading to tracheal narrowing.
  - Complicates TT replacement in the setting of dislodgment or obstruction.
  - Bougie use can be helpful to place a small(er) ETT until surgical dilation and/or resection can be achieved.
- Creation of a false lumen during recannulation
  - Subcutaneous emphysema will be an early indicator of this.
  - Early confirmation of correct placement of TT by confirming:
    - Continuous end-tidal CO_2 monitoring
    - Equal chest rise
    - Bilateral breath sounds
- Unrecognized trachea–innominate artery fistula (Fig. 20.5)
  - Usually occurs within 3–4 weeks of placement
  - Presentation: Bleeding around the tracheostomy tube (>10 mL) or massive hemoptysis
  - Requires
    - ETT cuff overinflation to compress the fistula.
    - Digital pressure on stoma may be helpful to tamponade the bleeding.
    - Place stomal ETT deep to bleeding fistula to protect airway.
    - Definitive surgical intervention in operating room.
  - Associated with high mortality
- Unrecognized tracheoesophageal fistula
  - Usually iatrogenic injury from TT placement or NG tube erosion
  - Presentation: Dyspnea, copious TT secretions, recurrent food aspiration, and gastric distention
  - Requires
    - Bronchoscopy or swallowing studies to confirm diagnosis
    - Surgical repair or stenting

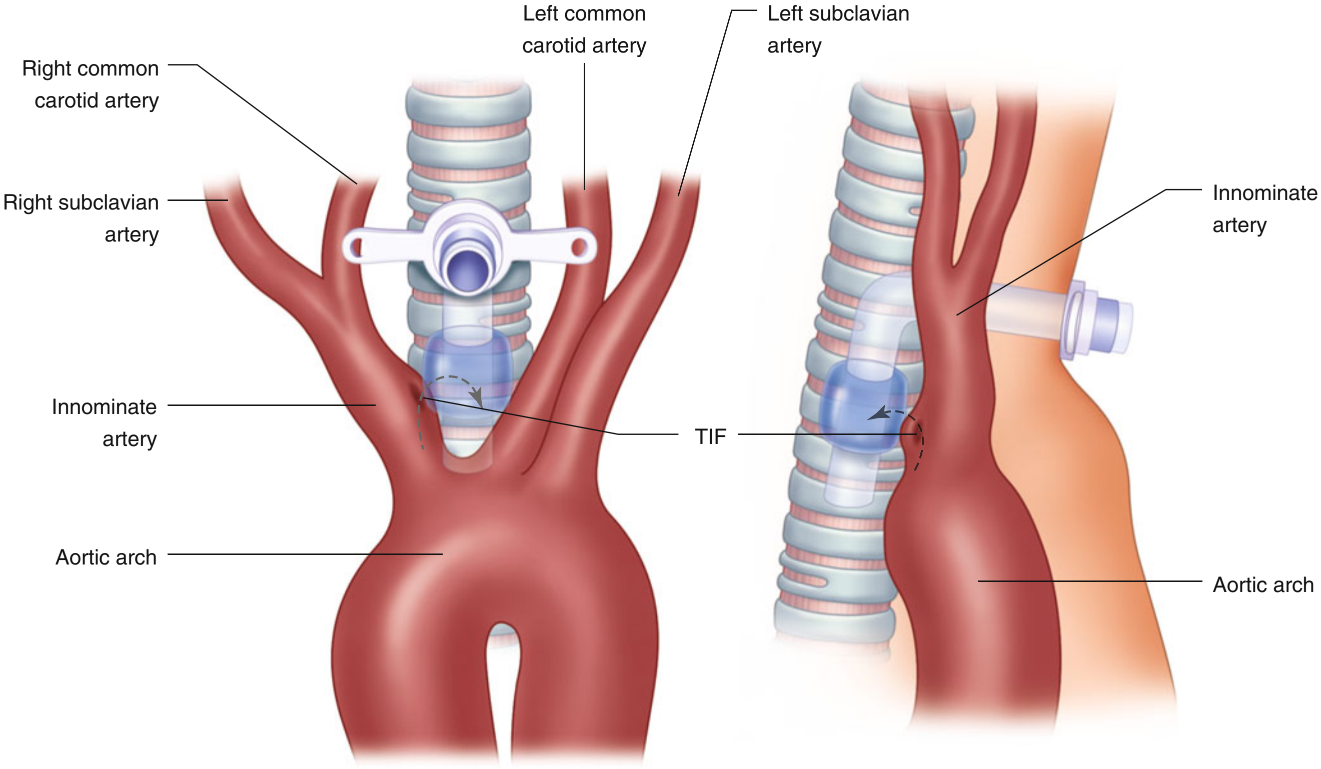

Fig. 20.5 Anatomical relationship between the trachea and the innominate artery. *TIF* trachea–innominate artery fistula

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Percutaneous Transtracheal Jet Ventilation

21

Clint Masterson

21.1 Indications

- Failure to control the airway by other means
- As a temporary measure while preparing for definitive airway control
- Securing the airway in crash airways in infants and small children

21.2 Contraindications

- Absolute
  - – Transection of the trachea below the cricothyroid membrane
- Relative
  - – Inability to identify the cricothyroid landmarks
  - – Anatomical distortion to the cricothyroid membrane
  - – Supraglottic obstruction (preventing gas exhalation)

21.3 Materials and Medications (Fig. 21.1)

- Betadine, chlorhexidine, or similar skin sterilization solution
- 12- to 16-gauge angiocatheter or transtracheal jet ventilation (TTJV) purpose-specific catheter
- 10-mL syringe filled with 4 mL of normal saline, 2 % lidocaine, or viscous lidocaine
- Hand-operated regulator valve
- Attach oxygen supply.
  - – Connect kit tubing to wall oxygen OR.
  - – Connect 7–0 endotracheal connector to bag valve mask (BVM) attached to oxygen.

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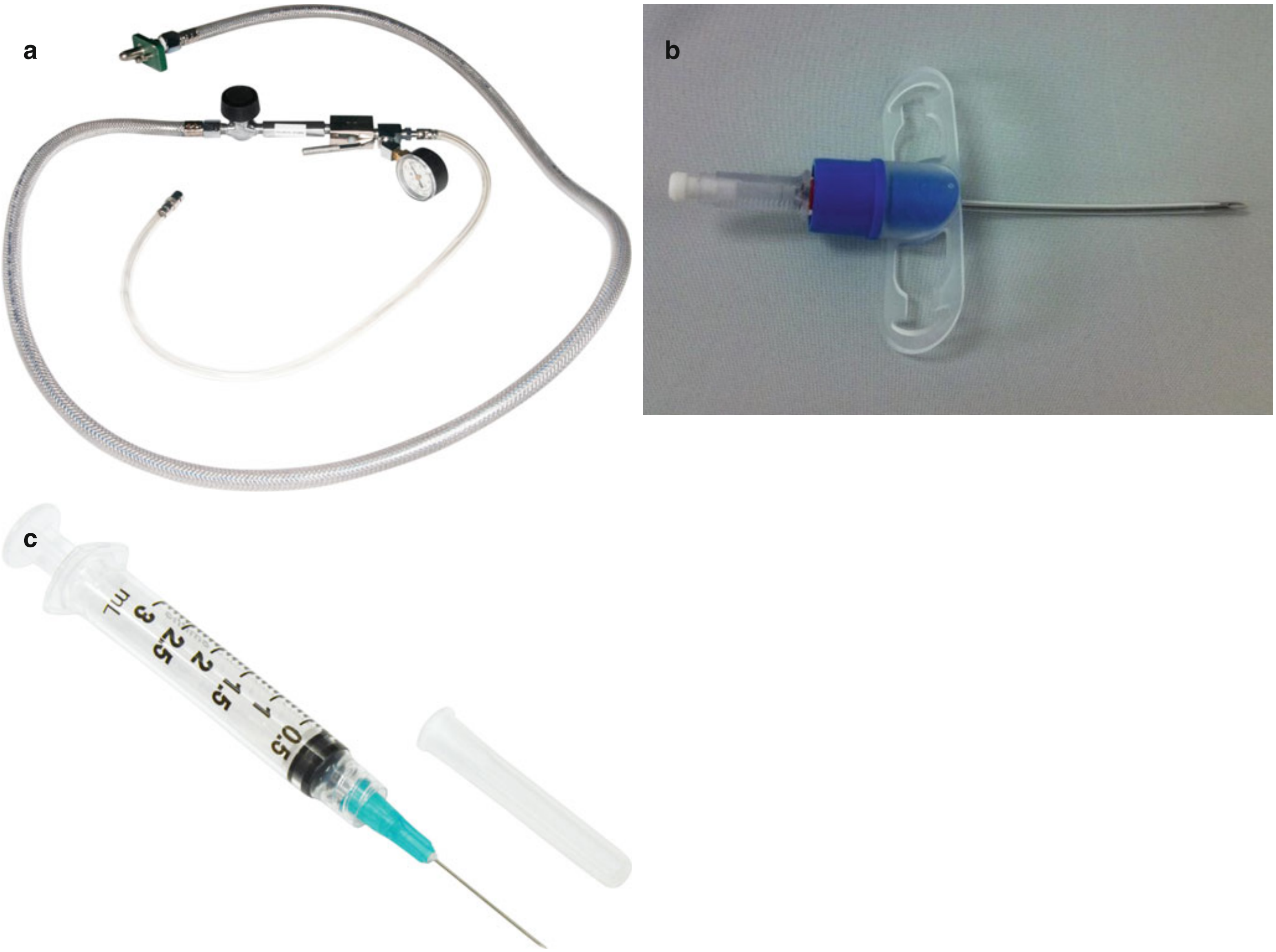
a
b
c
mL
3
2.5
2
1.5
1
0.5

Fig. 21.1 (**a**) Tubing and regulator valve, (**b**) commercially available catheter, (**c**) 3-mL or 10-mL syringe

21.4 Procedure

1. Attach the tubing and the hand-operated regulator valve to wall oxygen (Fig. 21.2a), and place the distal end of the tubing near the patient in preparation for ventilation.
2. Adjust regulator to maximum pressure, 50 psi if possible (Fig. 21.2b).
3. Palpate the cricothyroid membrane just distal to the thyroid prominence (Fig. 21.3).
    (a) Sterilize the area with a suitable cleansing agent.
    (b) Use the thumb and index finger of the nondominant hand to stabilize the trachea for the procedure.
4. Attach the TTJV catheter (or angiocatheter) to the syringe (Fig. 21.4).
5. Advance the catheter through the cricothyroid membrane at a 30–45° caudal direction while aspirating with the syringe (Fig. 21.5).
6. Return of air confirms entry into the trachea.
7. If lidocaine is utilized, it can then be injected to prevent spasm during the procedure.
8. Fully advance the angiocatheter and secure it while the needle and syringe are withdrawn.
9. Remove the needle, secure it to the skin, and connect it to the regulator hose.
10. Secure the distal end of the oxygen tubing (distal to the hand-operated valve) to the catheter (Fig. 21.6).
11. If a BVM is used as the oxygen source:
    (a) Attach a 3-mL syringe to the angiocatheter.
    (b) Attach the BVM with the 7–0 endotracheal tube (ETT) connector to the end of the plungerless 3-mL syringe (Fig. 21.7).
12. Operate the valve 12–20 times a minute with long periods to allow gas exhalation and exchange (Fig. 21.8).
13. Preparations should be made for a definitive airway as soon as possible—preferably within 15 min.

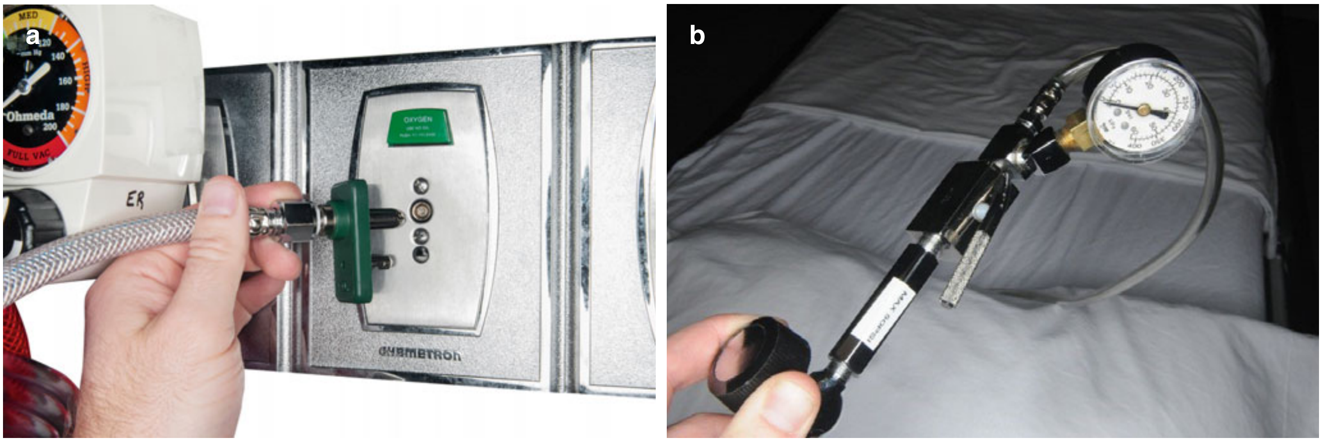

Fig. 21.2 (**a**) Attach tubing and the hand-operated regulator valve to wall oxygen, and (**b**) adjust regulator to maximum pressure (50 psi if possible)

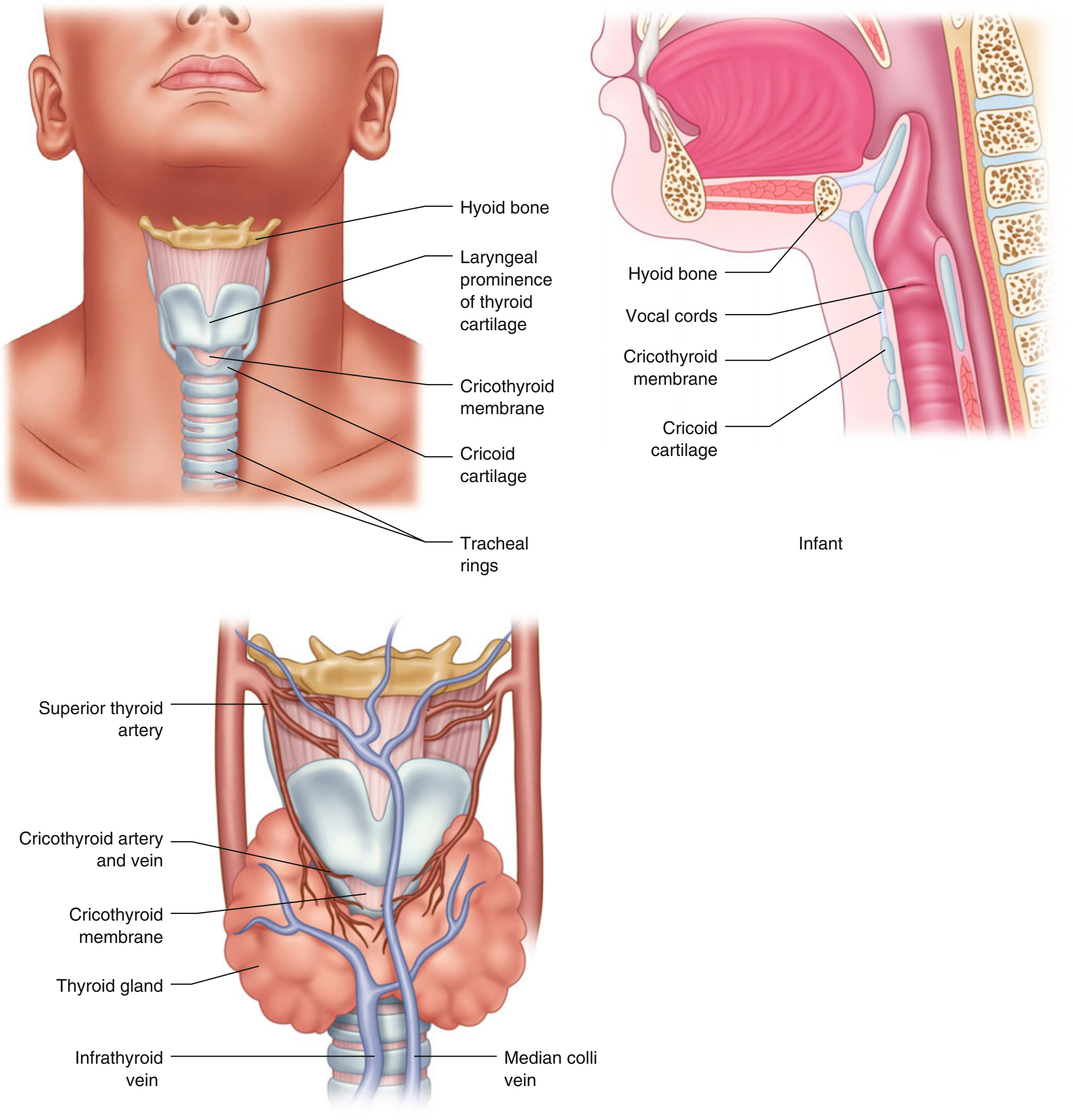
Hyoid bone
Laryngeal prominence of thyroid cartilage
Cricothyroid membrane
Cricoid cartilage
Tracheal rings
Hyoid bone
Vocal cords
Cricothyroid membrane
Cricoid cartilage
Infant
Superior thyroid artery
Cricothyroid artery and vein
Cricothyroid membrane
Thyroid gland
Infrathyroid vein
Median colli vein

Fig. 21.3 Airway anatomy

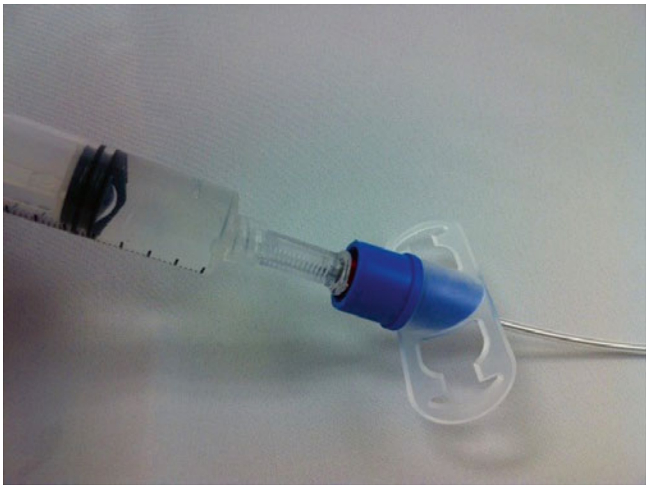

Fig. 21.4 Attach the TTJV catheter to the syringe

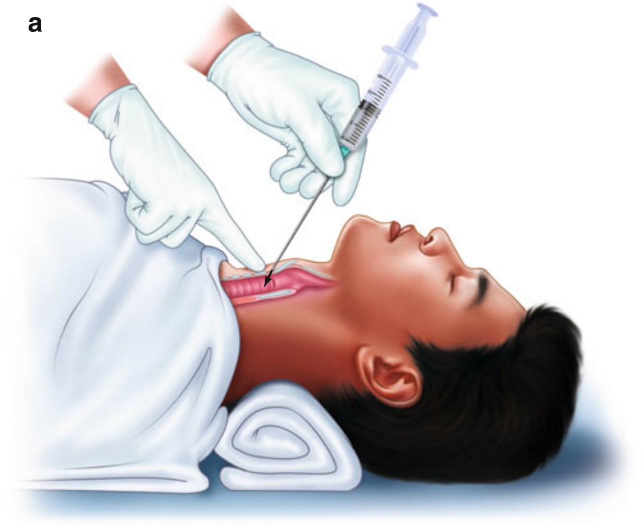

Fig. 21.5 (**a**) Advance the catheter through the cricothyroid membrane at a 30–45° caudal direction (**b**) while aspirating with the syringe

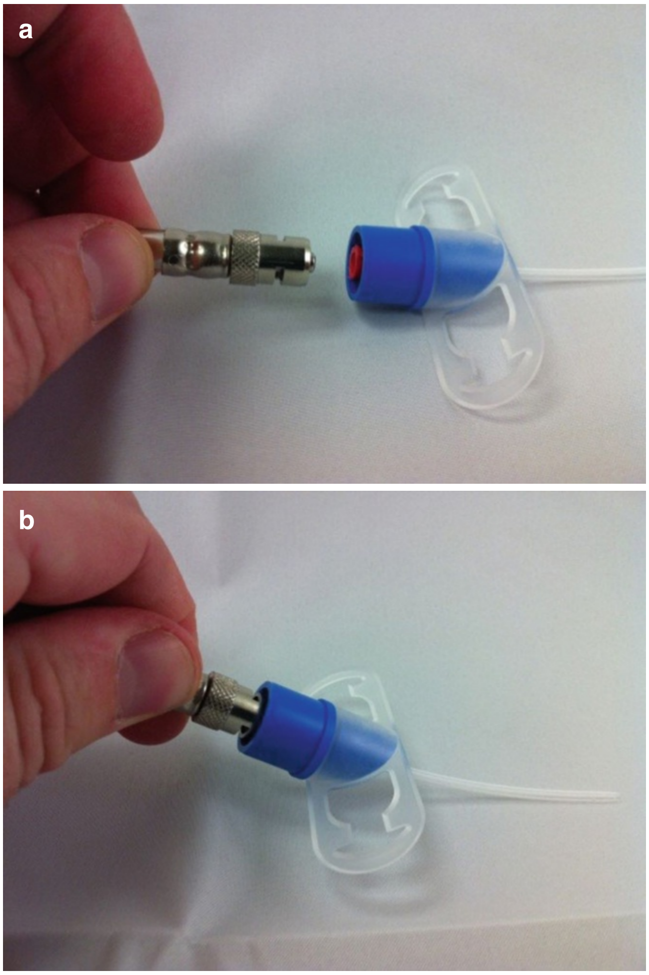

Fig. 21.6 Secure the distal end of the oxygen tubing to the catheter

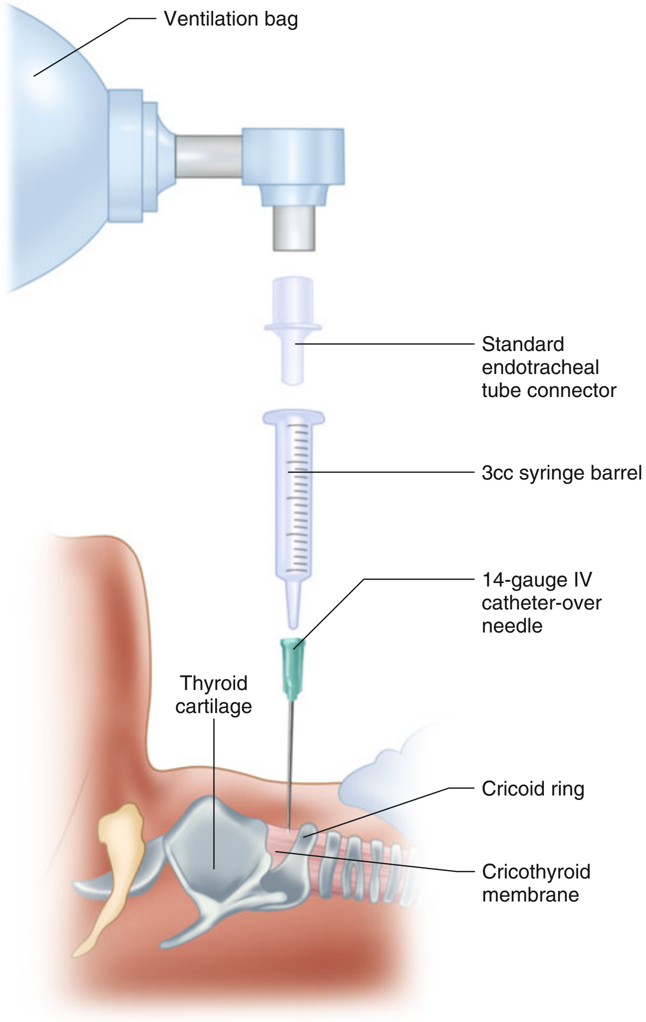
Ventilation bag
Standard endotracheal tube connector
3cc syringe barrel
14-gauge IV catheter-over needle
Thyroid cartilage
Cricoid ring
Cricothyroid membrane

Fig. 21.7 Attach the BVM with the 7–0 endotracheal tube (ETT) connector to the end of the plungerless 3-mL syringe

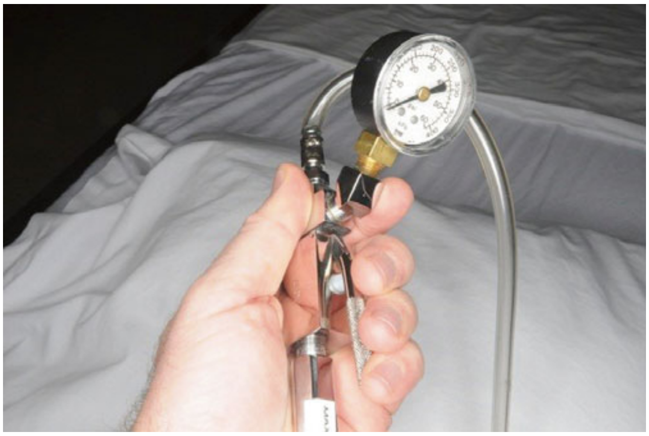

Fig. 21.8 Operate the valve 12–20 times a minute with long periods to allow gas exhalation and exchange

21.5 Complications

- Pneumothorax
- Pneumomediastinum
- Subcutaneous emphysema
- Catheter kink or misplacement
- Hypercarbia and respiratory acidosis
  - Use of TTJV for prolonged periods of time without adequate ventilation will elevate CO_2.
- Barotrauma
- Coughing in conscious patients
- Aspiration
- Persistent stoma

21.6 Pearls and Pitfalls

- If the wall connector does not have a pressure regulator, it can still be used although the risk of barotrauma is greater. Use the endpoint of chest rise to determine the end of each ventilation burst in this case.
- Higher pressures and lack of supraglottic air exchange are risk factors for pneumothorax. If the supraglottic area is obstructed, a Y catheter can be attached to allow gas to escape before the next insufflation.
- TTJV may or may not allow sufficient gas exchange to prevent hypercarbia. Preparations should be made to obtain a definitive airway as soon as possible.
- Endotracheal intubation may be facilitated by the high pressures insufflated in the trachea, and a repeat attempt may be performed after the transtracheal ventilation is achieved.

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Part III

Thoracic Procedures

Needle Thoracostomy

22

Lucas McArthur and Christian Fromm

22.1 Indications

Needle decompression thoracostomy is a procedure used in the emergent treatment of a tension pneumothorax. Tension pneumothorax is a clinical diagnosis. Decompression treatment should not be delayed in order to obtain radiographic confirmation. The following scenarios illustrate some of the clinical signs that *may* be present in such patients:

- *Awake patient* with suspected or confirmed tension pneumothorax
  - Chest pain
  - Respiratory distress
  - Decreased breath sounds with hyperresonance and/or subcutaneous emphysema
  - Trachea deviated away from the side of the pneumothorax
  - Tachycardia
  - Falling pulse oximetry (SpO_2)
  - Shock
- *Ventilated patient* with suspected or confirmed pneumothorax (often insidious)
  - Increased resistance to ventilation
  - Hypotension
  - Elevated central venous pressure
  - Tachycardia
  - Decreased breath sounds with hyperresonance and/or subcutaneous emphysema
  - Trachea deviated away from the side of the pneumothorax
  - Falling SpO_2
  - Shock
- *Injured patient* (especially with penetrating chest trauma) with suspected or confirmed tension pneumothorax
  - In arrest
  - Unexplained hypotension
  - Apnea
  - Decreased breath sounds with hyperresonance and/or subcutaneous emphysema

22.1.1 Absolute Indications

- Patient in acute respiratory distress with rapid decompensation secondary to suspected or confirmed tension pneumothorax
- Injured patient in extremis with apnea, unexplained hypotension, or arrest

22.2 Contraindications

- No absolute contraindications.

22.3 Materials

- Large-bore needle/angiocatheter (minimum of 16 gauge)
- 10-mL syringe (optional)
- One-way valve (optional)
- Betadine (povidone-iodine) swab/chlorhexidine scrub
- Tape

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22.4 Procedure

1. Expose the anterior chest at the level of the second intercostal space on the affected side (Fig. 22.1). Alternatively, expose the chest wall at the level of the anterior axillary line in the fourth or fifth intercostal space on the affected side.
2. Cleanse the area with a Betadine swab or chlorhexidine scrub (Fig. 22.2).
3. Using a gloved hand, locate the second intercostal space at the midclavicular line.
   (a) The first rib is normally not felt.
   (b) The second rib is felt just below the clavicle.
   (c) The second intercostal space is the area between the second and the third ribs.

   Note: Alternatively, this procedure may also be performed on the midaxillary line in the fourth intercostal space of the affected side. The same general steps listed later are employed in this approach and care is taken to avoid the neurovascular bundles inferior to the fourth rib.
4. Insert the needle/angiocatheter perpendicular to the chest wall into the second intercostal space just above the superior edge of the third rib to avoid the intercostal neurovascular bundle (Fig. 22.3).
   (a) This step may be done with or without a syringe attached.
   (b) Local anesthesia is usually unnecessary but may be used if the patient is not in extremis.
5. Carefully walk the needle over the third rib and advance until the pleural space is entered.
   (a) Entry into the pleural space is accompanied by a "popping" sound or a sensation of "giving way."
6. If you are able to withdraw air with the syringe or hear a "hiss" of air escaping through the angiocatheter during expiration and inspiration, then placement is considered successful.
7. After removing the needle, secure the angiocatheter in place with tape (Fig. 22.4).

   Caution: Do not reinsert needle into the angiocatheter owing to the danger of sheering the angiocatheter.
8. Assess the patient and evaluate the effectiveness of the procedure.
   (a) The patient should exhibit immediate and obvious improvement in respiratory status including improved lung sounds and vital signs.
   (b) The procedure may be repeated if the patient is not improving.
   (c) Excess pleural air may be aspirated through the angiocatheter with a syringe.
9. Obtain a chest radiograph to confirm success.
   (a) Repeat in 6 h.
10. Because needle decompression is only a temporizing measure, tube thoracostomy (see Chap. 23) must be performed for definitive management of the pneumothorax.

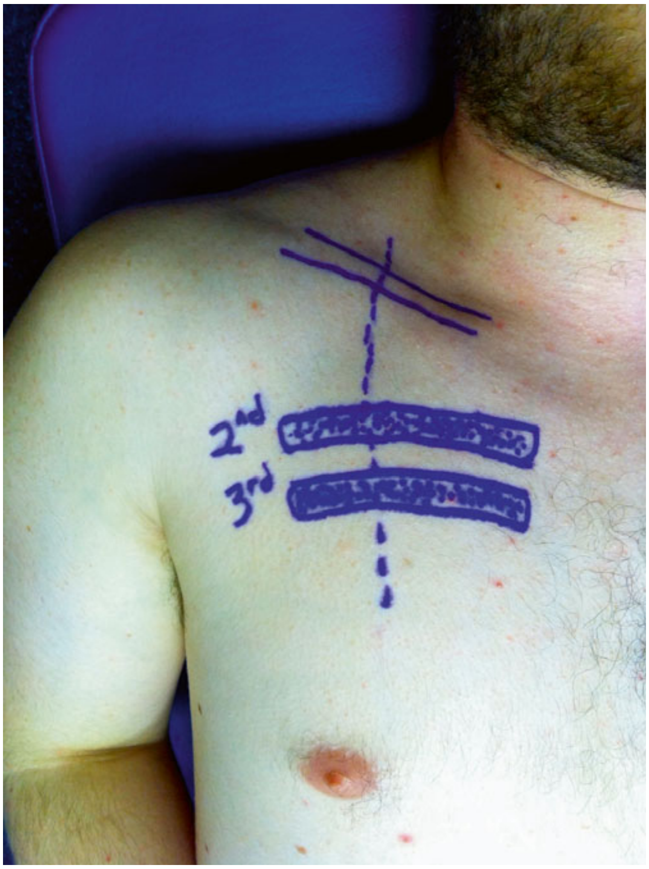

Fig. 22.1 The preferred site for needle thoracostomy is the second intercostal space in the midclavicular line

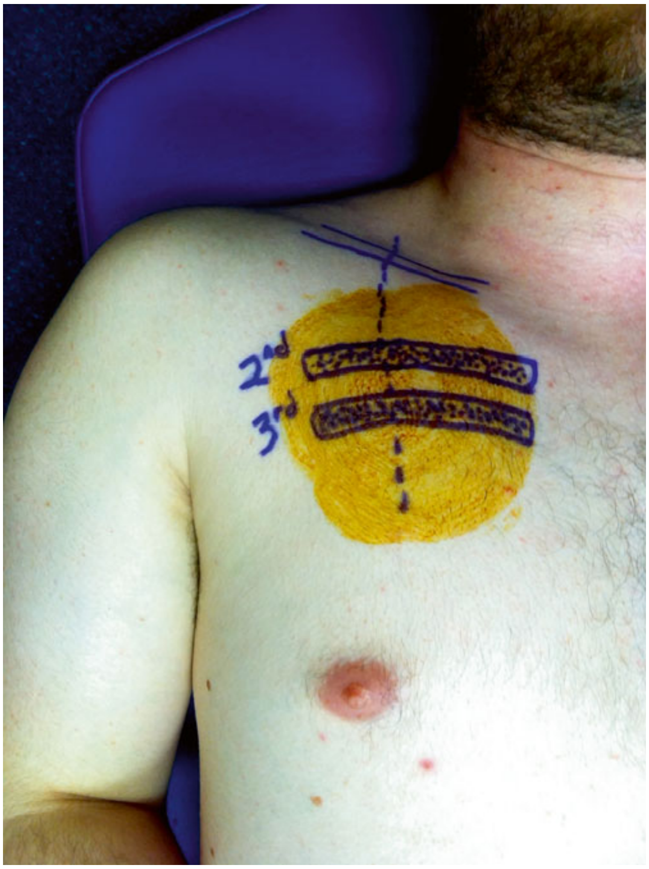

Fig. 22.2 Prepare the skin with povidone-iodine or chlorhexidine

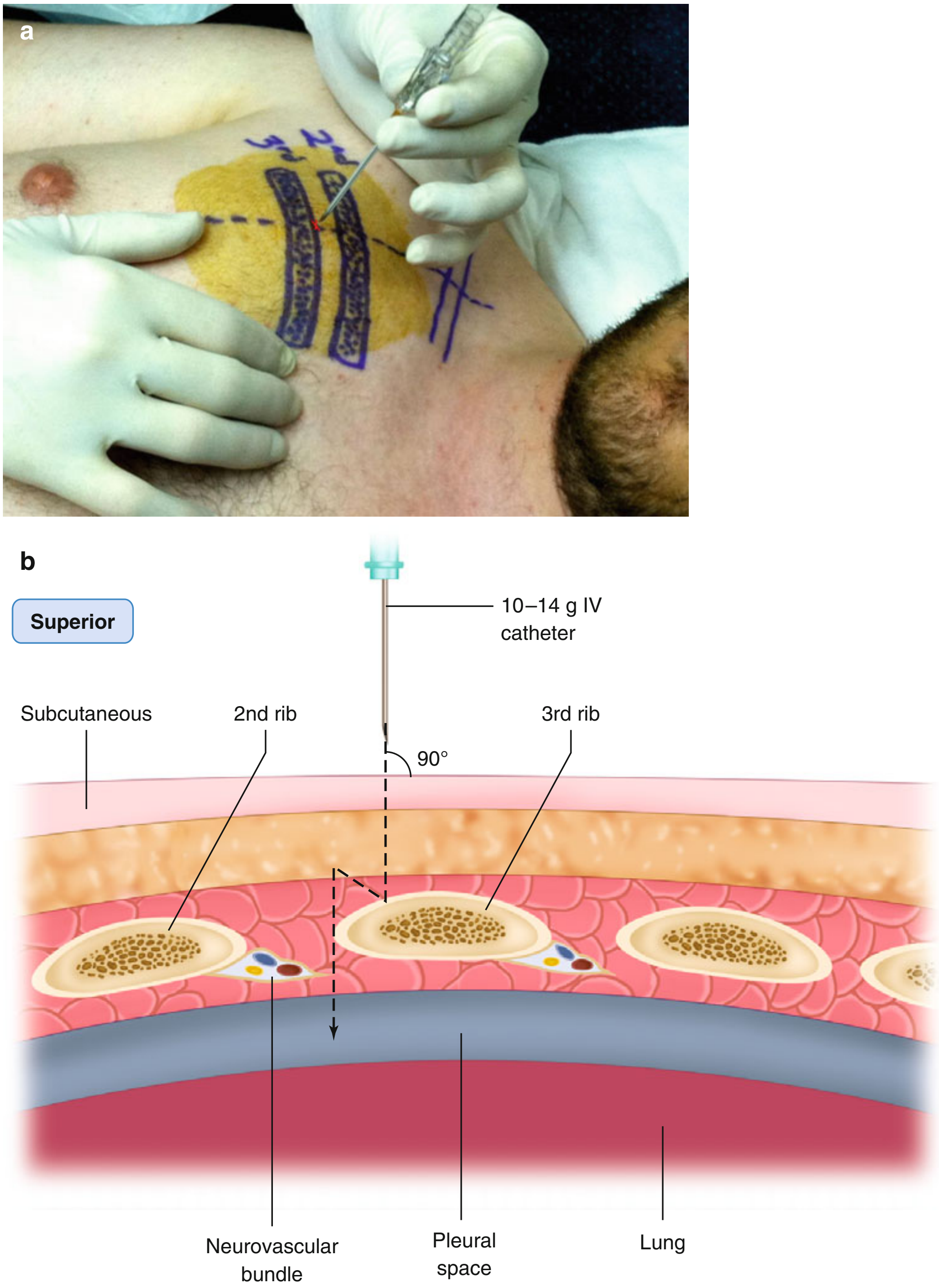
a
3rd
2nd
b
Superior
10–14 g IV catheter
Subcutaneous
2nd rib
3rd rib
90°
Neurovascular bundle
Pleural space
Lung

Fig. 22.3 (**a**) Insert the needle into the second intercostal space just above the superior edge of the third rib and (**b**) avoid the neurovascular bundle by approaching the skin with the needle perpendicular to the chest wall just above the superior edge of the third rib

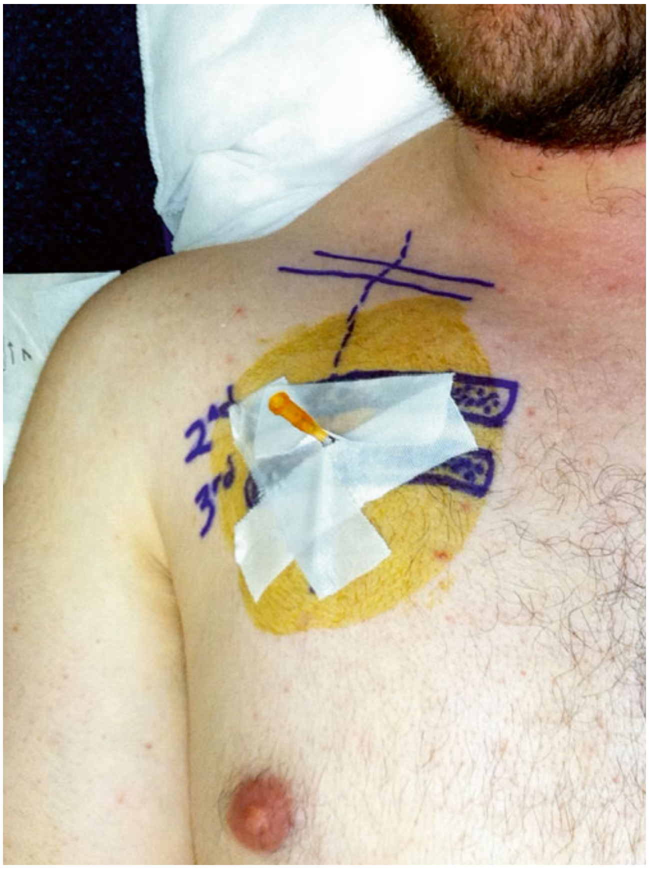

Fig. 22.4 After removing the needle, secure the angiocatheter in place with tape

22.5 Complications

- Failure to resolve the tension pneumothorax.
  - Obese or muscular patients may require a longer needle and catheter to reach the pleural space or, alternatively, may require proceeding immediately to tube thoracostomy.
- Iatrogenic pneumothorax.
- Laceration of intercostal artery or nerve.
- Rapid re-expansion may result in the development of pulmonary edema.
- Infection.

22.6 Pearls and Pitfalls

- Use the sternum as a landmark to more easily locate the second and third ribs.
- The same procedure may also be done on the midaxillary line in the fourth intercostal space, which is usually landmarked with the nipple.
- Primary pneumothorax is unusual in those older than 40 years. Consider the presence of underlying disease in this population.

Acknowledgments We would like to thank Antonios Likourezos, MA, MPH, and Abraham Lederman for assisting with the photographs.

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Chest Tube Thoracostomy

23

Brandon R. Allen and Latha Ganti

23.1 Indications

- Spontaneous pneumothorax (large and/or symptomatic)
- Tension pneumothorax (or suspected)
- Iatrogenic pneumothorax
- Penetrating chest injuries
- Hemopneumothorax in acute trauma
- Patient in extremis with evidence of thoracic trauma
- Complicated parapneumonic effusions (empyema)
- Chylothorax/hemothorax
- Post-thoracic surgery
- Bronchopleural fistula

23.2 Contraindications

- Absolute
  - Emergent thoracotomy
- Relative
  - Coagulopathy
  - Pulmonary bullae
  - Pulmonary, pleural, or thoracic adhesions
  - Loculated pleural effusion or empyema
  - Skin infection over the chest tube insertion site

23.3 Materials and Medications

- Tube thoracostomy tray
  - #10 scalpel; 18-, 22-, and 25-gauge needles; 10-mL syringes; forceps; clamps; scissors; drape; abdominal pads; 0 or 1–0 silk suture; needle driver; curved clamp (Fig. 23.1a)
- Betadine (povidone-iodine) or other skin antiseptic preparation solution
- Lidocaine (1 % or 2 % with epinephrine)
- Appropriate chest tube size (approximate)
  - Adult male: 28–36 French
  - Adult female: 28 French
  - Child: 12–24 French
  - Infant: 12–16 French
  - Neonate: 10–12 French

Vaseline gauze
Chest drainage system (Fig. 23.1b)

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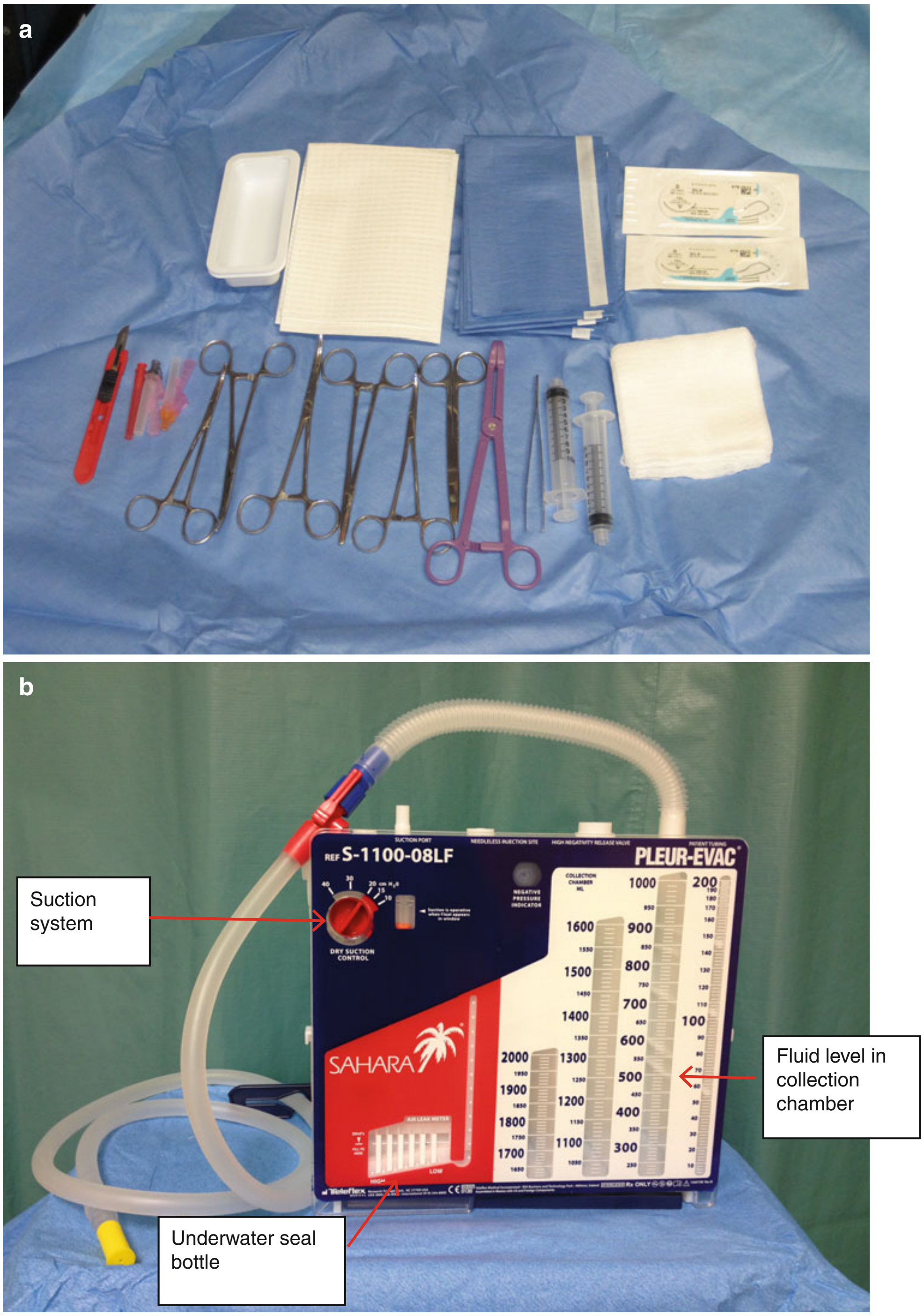
a
b
REF S-1100-08LF
PLEUR-EVAC
SAHARA
DRY SUCTION CONTROL
Suction system
Fluid level in collection chamber
Underwater seal bottle

Fig. 23.1 (**a**) Tube thoracostomy tray, (**b**) chest drainage system

23.4 **Procedure** (Fig. 23.2)

1. Sterile skin preparation with sterile drape.
2. Anesthetize the appropriate area subcutaneously up to and including the rib periosteum with 5 mL of 1 % lidocaine with epinephrine (Fig. 23.2a).
3. Using a #10 or #11 blade, make an approximately 4-cm skin incision over the desired intercostal level of entry (most often the fourth or fifth intercostal space in the midaxillary line) (Fig. 23.2b, c).

   If the incision is placed *below* the fifth intercostal space, the risk of subdiaphragmatic placement into the abdominal space is increased.
4. Bluntly dissect with a hemostat or Kelly clamp through the subcutaneous tissue to the level of the intercostal muscles with intermittent opening of the dissection instrument during advancement (Fig. 23.2d, e).
5. Digitally palpate the selected intercostal space and the superior margin of the inferior rib (pay careful attention to avoid the neurovascular bundle lying inferiorly) (Fig. 23.2f).
   - If time permits, additional analgesia is recommended at this point of the procedure.
6. Guiding the closed Kelly clamp over the upper margin of the rib, enter the chest wall into the pleural cavity. (This will require some controlled force and a twisting motion.) Once the pleural space is entered, a rush of air or fluid should occur (Fig. 23.2g).

   Uncontrolled force and a lunging motion can result in penetration to the lung, heart, liver, or spleen.
7. Open the Kelly clamp while still inside the pleural space and then withdraw while the clamp is still open to enlarge the dissected tract of entry and allow easier passage of the thoracostomy tube (TT).
8. Explore the dissected tract with a sterile finger to appreciate lung tissue and possible adhesions.
9. To estimate the length the TT is to be inserted, measure the distance between the skin incision and the apex of the lung. If preferred, place a clamp over the tube at the estimated length (Fig. 23.2h).
10. Grasp the proximal end of the TT with the large Kelly clamp and pass the tube through the thoracic cavity along the previously dissected tract.
11. Release the Kelly clamp and continue to advance the tube posteriorly and superiorly.

    Make sure all of the fenestrated holes of the TT are within the thoracic cavity to prevent unnecessary manipulation and/or replacement of the TT.
12. Once the TT is in the desired position, connect the tube to the drainage device (Fig. 42.1b). Once connected, release the cross clamp on the distal end of the TT.
13. Secure the TT to the skin with 0 or 1–0 silk or nylon suture. A simple, interrupted suture above and below the TT with each stitch wrapped tightly around the TT is recommended.

    Incomplete security of the TT leads to dislodging of the tube with routine patient movements.
14. Apply petrolatum gauze over the skin closure surrounding the TT and then apply a support dressing with 4×4 gauze and adhesive tape (4 in.).
15. Obtain a chest radiograph to confirm placement of the TT.

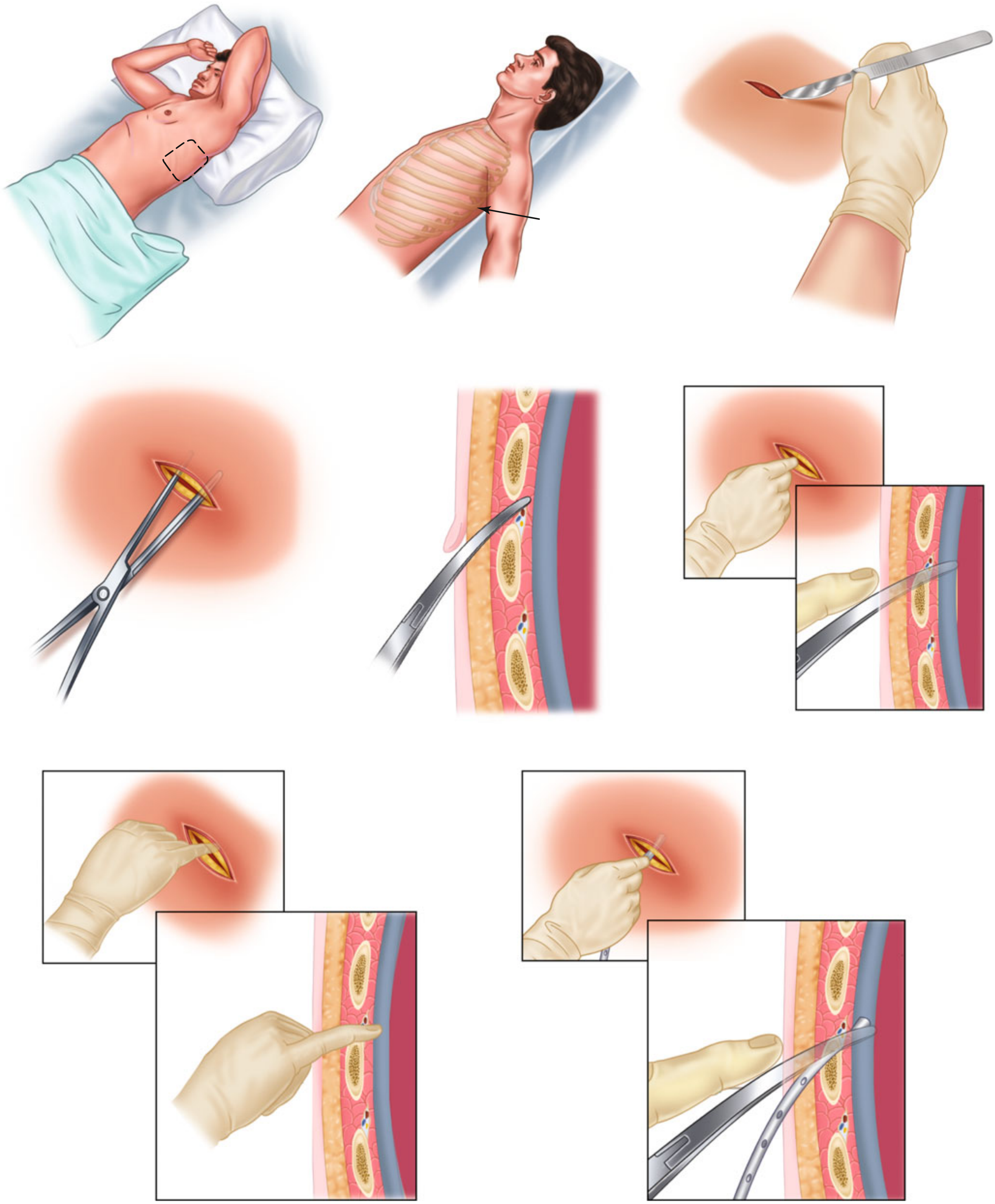

Fig. 23.2 Chest tube thoracostomy procedure

23.5 Complications

- Improper placement for pneumothorax
  - Reposition if:
    - Horizontal (over diaphragm)
    - Subcutaneous
    - Placed too far into the chest (against apical pleura)
  - Remove if:
    - Placed into the abdominal space
- Bleeding (local vs. hemothorax)
- Hemoperitoneum (liver or spleen injury)
- Tube dislodgment
- Empyema (TT introduces bacteria into the pleural space)
- Retained pneumothorax (may require second TT)
- Re-expansion pulmonary edema
- Subcutaneous emphysema

23.6 Pearls and Pitfalls

- Water seal acts as a one-way valve; if the system bubbles, there is an air leak.
- In the Pleur-evac® systems, there is an orange floater which, when static, means the desired suction pressure (usually 20 cmH_2O) has been reached.
- The negative pressure in the chest cavity equals the amount of water in water seal plus amount of suction.
- A chest tube can be removed when there is no air loss or blood for 24 h.
- When removing the tube, have the patient exhale and remove as quickly as possible.
- Leave petrolatum gauze in place for 48 h before changing it (allows wound to heal better).

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Thoracentesis

24

Lee Richard Donner and Michael Anana

24.1 Indications

- *Therapeutic thoracentesis* is performed to relieve dyspnea, hypoxia, or otherwise compromised respiratory function due to a large pleural effusion.
- *Diagnostic thoracentesis* is performed to aid in the diagnosis and workup of:
  - Pleural effusions of unknown cause
  - Unilateral pleural effusions
  - Pleural effusions originally determined to be due to heart failure but persisting after 3 days of diuresis

24.2 Contraindications

- Absolute
  - None
- Relative:
  - Coagulopathy, thrombocytopenia.
  - Small or loculated pleural effusion. These will increase the risk of missing the effusion and causing lung injury.
  - Positive-pressure ventilation.
  - Skin infection over the needle insertion site.

24.3 Materials and Medications

- Thoracentesis tray (commercially available kits generally include the items in the following list) (Fig. 24.1)
  - (1) Fenestrated drape
  - (1) 25-gauge × 1-in. needle
  - (1) 21-gauge × 1.5-in. needle
  - (1) 8-French catheter over 18-gauge needle
  - (1) Small plastic syringe, 5 mL
  - (1) Small plastic syringe, 10 mL
  - (1) Large plastic syringe, 50–60 mL
  - (1) Three-way stopcock
  - Specimen vials and caps
  - (1) Collection bag, 1500 mL, or vacuum container
  - (1) Tubing set
  - (1) Hemostat
  - Betadine (povidone-iodine) or other skin antiseptic preparing solution
  - 10-mL lidocaine 1 % without epinephrine

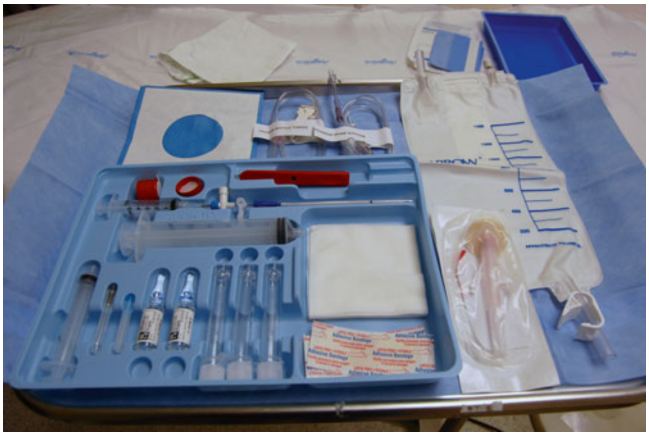

Fig. 24.1 Typical commercial thoracentesis tray

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24.4 Procedure

1. Place patient in seated position with arms at rest on a bedside table (Fig. 24.2).
2. The location and height of the pleural effusion are confirmed by physical examination. Auscultation of decreased or absent breath sounds, dullness to percussion, and decreased tactile fremitus are physical findings to confirm the location and height of the effusion (Fig. 24.3).
3. Determine and mark the site of needle insertion. This will be at the midscapular line one or two intercostal spaces below the maximum height of the effusion as determined by a combination of imaging and physical examination (Fig. 24.4).
   - *Do not* attempt thoracentesis inferior to the eighth intercostal space because respiratory cycle and anatomical variation place the diaphragm and intra-abdominal organs at risk.
4. Prepare the skin with the sterile skin preparation and sterile drape.
5. Anesthetize the appropriate area subcutaneously using a 25-gauge needle on a 10-mL syringe. Create a wheal in the skin and then infiltrate up to and including the periosteum of the rib inferior to the landmarked space with 5 mL of 1 % lidocaine.
   - Remember that the neurovascular bundle is found at the inferior border of each rib. Keep this in mind as you approach the rib and throughout the rest of the procedure to avoid injury to these structures (Fig. 24.5).
6. Using a 22-gauge needle, slowly walk the needle up and over the superior border of the rib. Continue to advance the needle along the superior border of the rib with the syringe withdrawn and infiltrating lidocaine intermittently along the way.
7. Pleural fluid will be aspirated once the pleural space is reached. Do not advance the needle further. Deposit 1–2 mL more lidocaine. A hemostat can be placed on the needle at the level of the skin to mark the depth of the pleural space and the needle can be removed.
8. Some commercial kits may come with an adjustable depth guard to be positioned at the determined depth. On an 18-gauge catheter-over-needle device, position the depth guard to the appropriate depth determined from the prior step. If a depth guard is not available, use the index finger and thumb on the catheter at the appropriate depth. With the 5-mL syringe attached, advance the device over the superior border of the rib while aspirating, expecting pleural fluid to return again at the determined depth (Fig. 24.6).
9. When the pleural space is reached, do not advance the needle further. Advance the catheter over the needle until the hub reaches the skin. Remove the needle during expiration and immediately cover the open hub with a gloved finger to prevent development of pneumothorax. Some kits provide catheters with one-way valves to prevent air entry.
10. Attach the 50–60-mL syringe to the catheter via the three-way stopcock. Pleural fluid can be drained and transferred to appropriate collection vials for diagnostic thoracentesis. A collection bag may be attached with tubing to the third port of a three-way stopcock for larger volume evacuation in the case of a therapeutic thoracentesis. Employ a syringe pump method to drain 50–60 mL of fluid at a time to the collection bag. Fill the syringe by withdrawing the plunger while the stopcock is closed to the bag. Then, close the stopcock to the patient and pump the contents of the syringe to the bag. Next, close the syringe closed to the bag, and repeat the cycle until the desired volume is drained. A vacuum container is an alternative that simply attaches via tubing to the stopcock (Fig. 24.7).
    - If using a three-way stopcock and a device that does not have a one-way valve on the catheter, be sure to always keep the stopcock closed to the patient unless withdrawing fluid in order to decrease the risk of pneumothorax.
11. When the desired amount of pleural fluid is obtained, remove the catheter during expiration and apply an occlusive dressing.

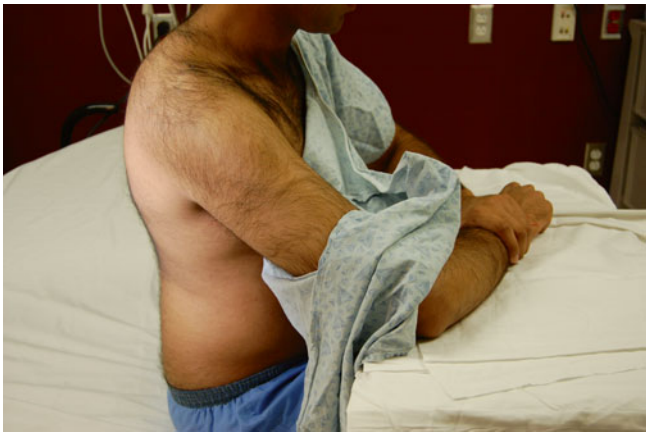

Fig. 24.2 Patient in upright, seated position

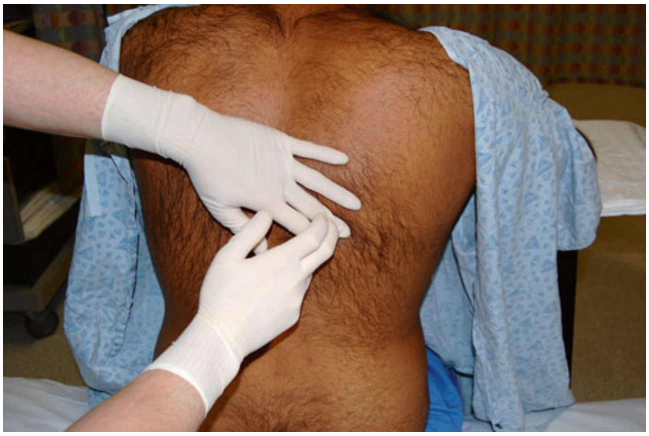

Fig. 24.3 Determining the location and height of the pleural effusion

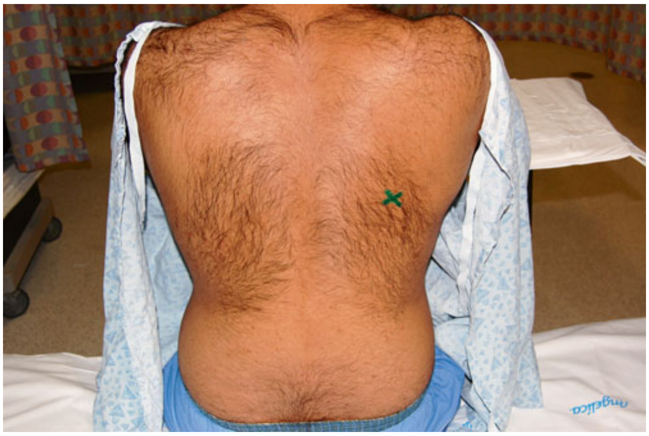

Fig. 24.4 Marked site for needle insertion

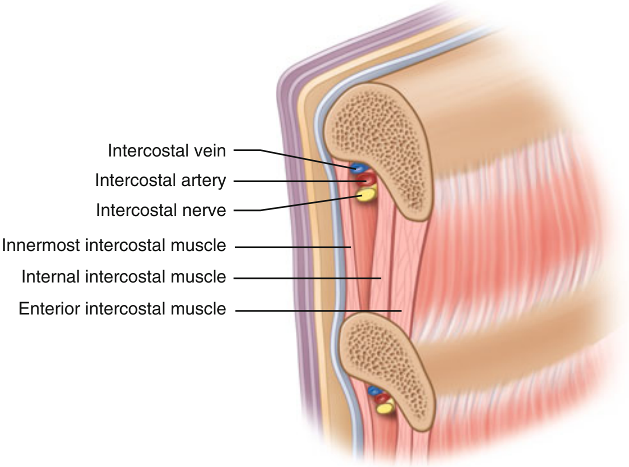

Intercostal vein
Intercostal artery
Intercostal nerve
Innermost intercostal muscle
Internal intercostal muscle
Enterior intercostal muscle

Fig. 24.5 The intercostal neurovascular bundle

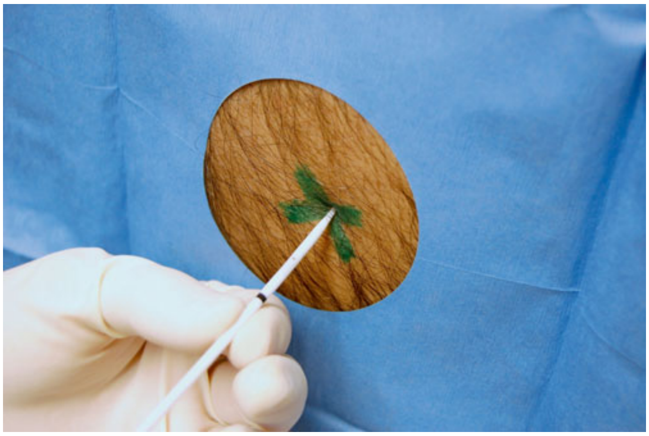

Fig. 24.6 Needle and catheter insertion, thumb and index finger at desired depth

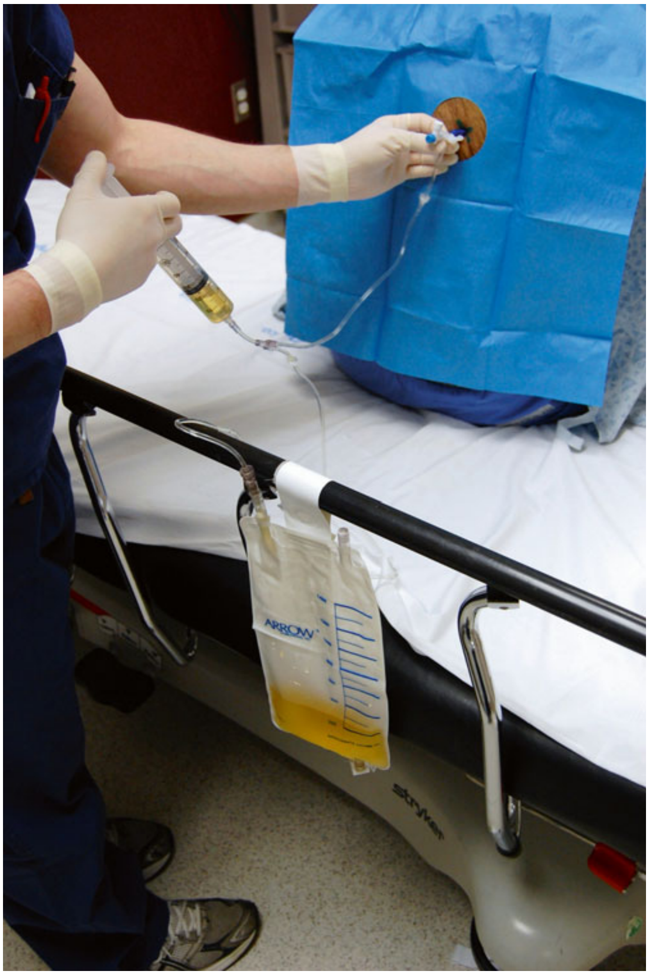

Fig. 24.7 Pleural fluid collection via syringe pump method

24.5 Complications

- Pneumothorax
- Re-expansion pulmonary edema
- Hemothorax, hematoma
- Intra-abdominal organ injury
- Air embolism
- Empyema

24.6 Considerations

- If available, the use of bedside ultrasound is highly recommended because ultrasound guidance has been shown to substantially reduce the risk of pneumothorax. Before the procedure, the height, width, and depth of the effusion can be appreciated by scanning the chest and viewing the effusion through the intercostal spaces. The use of ultrasound aids in selecting the needle insertion site by:
  - Visualizing the distance the needle must pass to reach the parietal pleura
  - Confirming the thickness of the effusion in the site selected is at least a minimum of 1.5 cm
  - Providing the clinician with a view of the effusion and surrounding structures through the complete respiratory cycle

  With these items in mind, the needle insertion site can be selected with confidence and marked before beginning the procedure.
- In addition, the use of bedside ultrasound in real time will allow the clinician to visualize the needle as it passes toward and enters the pleural space. This use requires sterile probe covers.
- Re-expansion pulmonary edema is a rare but feared complication of thoracentesis. The cause is not fully understood. Historically it was thought that re-expansion pulmonary edema was caused by removing too large a volume of fluid from the pleural space (>1–1.5 L). Another theory is that re-expansion pulmonary edema is caused when great negative intrapleural pressures (<20 cmH_2O) are generated during the procedure. The low incidence of this complication has yielded inconclusive evidence.
  - In light of this, it is prudent to continue to limit the volume of pleural fluid removed to no more than 1–1.5 L. Pleural manometry is not widely available for use in the emergency department, but should also be considered if available to maintain intrapleural pressures from reaching more negative values.

24.7 Pearls and Pitfalls

- Bedside ultrasound reduces the risk of complications.
- Never attempt thoracentesis below the eighth intercostal space.
- Thoracentesis should not be performed on pleural effusions demonstrated to be less than 1–1.5 cm thick by ultrasound or on a lateral decubitus film.
- Positive-pressure ventilation mandates extreme care while performing thoracentesis because the lungs can be punctured during inflation. In addition, ventilated patients will not be able to sit upright and will need to have the procedure performed in lateral decubitus position with the effusion side down and the posterior axillary line as the needle insertion site. Alternatively, the patient can be placed supine with the head of the bed elevated to 45° and the midaxillary line as the needle insertion site.
  - Routine post-procedure radiographs are not necessary to exclude pneumothorax. Indications for post-procedure imaging include onset of chest pain during the procedure, persisting cough or chest discomfort after the procedure, air aspiration along any step of the procedure, or positive-pressure ventilation.
  - Pneumothorax rates are higher for inexperienced providers. Although an effusion compromising respiratory function is considered a clear indication for therapeutic thoracentesis, the performance of nonurgent diagnostic thoracentesis might best be delayed for those more practiced in the procedure.

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Open Chest Wounds and Flail Chest

25

Jacob J. Glaser and Carlos J. Rodriguez

25.1 Background

Thoracic injuries are commonly associated with penetrating and blunt abdominal trauma and are implicated in 50–70 % of trauma deaths [1]. Cardiac tamponade, tension pneumothorax, massive hemothorax, airway obstruction, flail chest, and open pneumothorax represent the six immediately life-threatening injuries attributed to chest trauma [2]. Accordingly, they must be accurately identified and dealt with urgently.

Open pneumothorax ("sucking" chest wound) is seen in penetrating chest injuries. If the associated chest wound is greater than 2/3 the diameter of the trachea (generally anything greater than 1.5–2 cm), air can preferentially enter the intrapleural space, via the trachea, with each inspiration [3] (Fig. 25.1). This allows equilibration of pressure between the pleural space and the atmosphere, causing the lung to collapse and leading to profound hypoventilation and hypoxia.

Flail chest results from high-energy blunt, crushing chest trauma causing two or more fractures in two or more contiguous ribs. Classically, the fractures are lateral or sternal. Posterior rib fractures rarely cause flail physiology (Fig. 25.2). Flail chest has been reported to have mortality as high as 16 % [4]. This injury pattern is associated with a high incidence of underlying pneumothorax, hemothorax, pulmonary contusion, and chest wall instability. Mortality from flail chest is thought to be correlated with the degree of underlying pulmonary contusion and attendant hypoxia [2].

Both open pneumothorax and flail chest are immediately life threatening and require early appropriate management.

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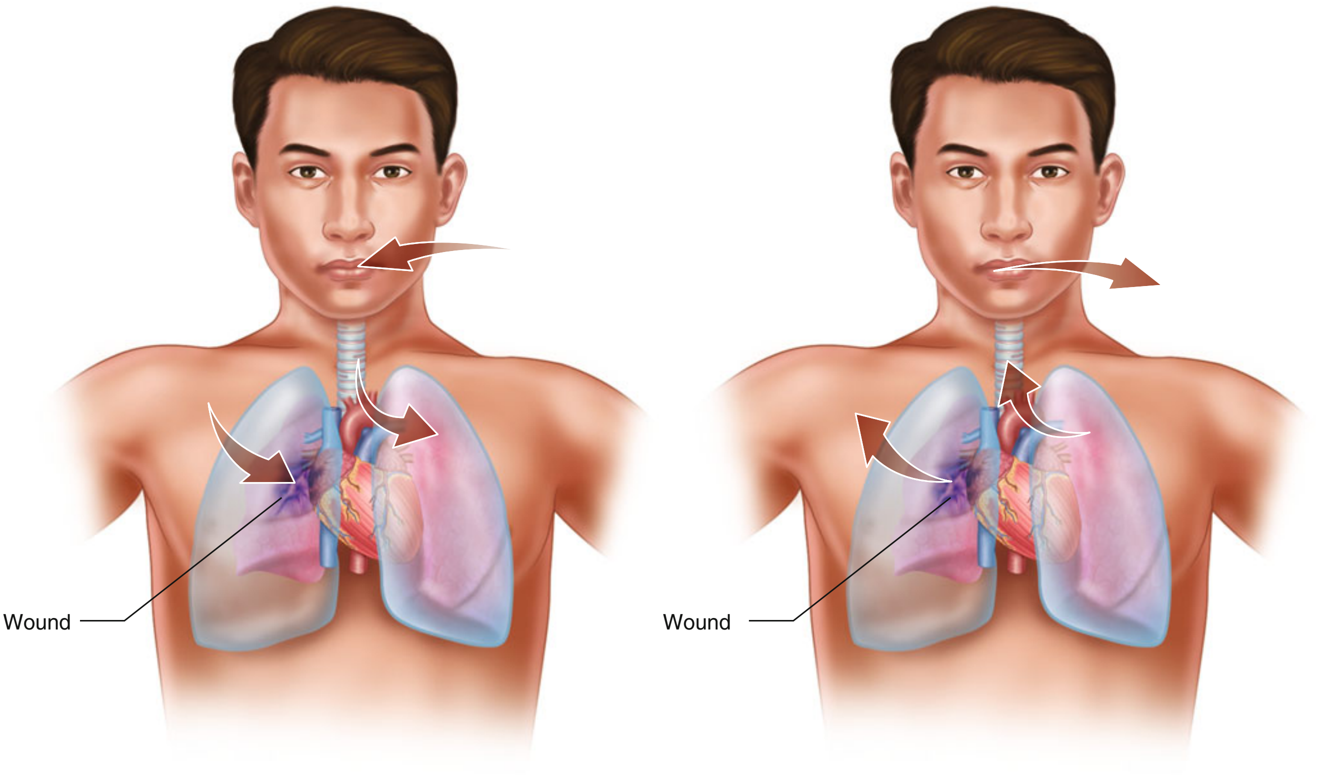
Wound
Wound

Fig. 25.1 Air preferentially will enter the chest via the wound, collapsing the lung on the affected side

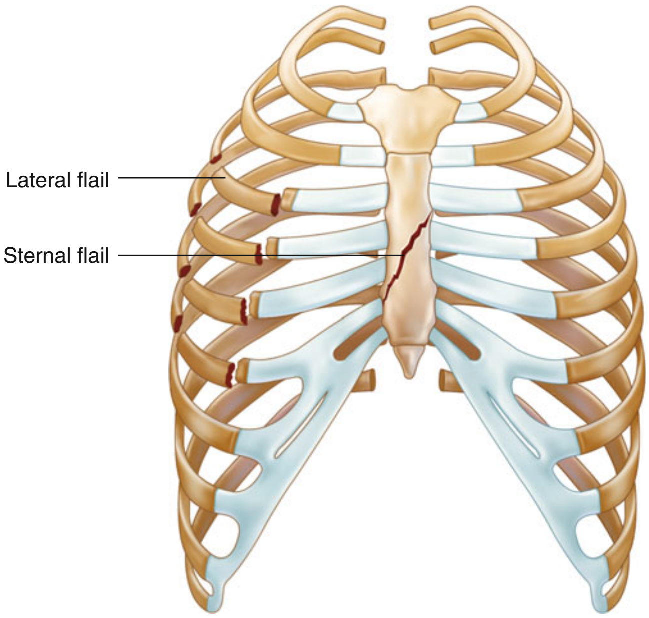
Lateral flail
Sternal flail

Fig. 25.2 Flail chest: two or more rib fractures in two or more segments. Lateral flail (most common) and sternal flail segments represented below

25.2 Initial Evaluation of Thoracic Trauma

- To the best extent possible, obtain good patient handover from the prehospital caregivers.
- Initial physical evaluation.
  - Appropriate attention should be given to the ABCs (airway, breathing, circulation) of ATLS (Advanced Trauma Life Support) management.
  - Evaluation and resuscitation are to be *concurrent* with diagnostic procedures and immediate interventions.
  - Maintain a high degree of suspicion for open chest wound in impalement injury and destructive penetrating trauma (blast injury or shotgun).
  - Maintain a high degree of suspicion for flail chest in high-energy direct impact trauma (motor vehicle crash, fall, crush injury).
- Administer high-flow O_2 with a non-rebreather mask.
  - If patient is in respiratory distress, is unstable, or has an obvious chest wall defect, consider early intubation to secure the airway.
  - Inspect the chest wall for occlusive dressings.
- Decompress the chest if tension physiology is present or suspected.
  - Immediate decompression of a suspected tension pneumothorax can be readily accomplished by removing any existing occlusive dressings *or*
  - Place a large-bore cannula over the rib, second intercostal space, or midclavicular line.
- Specific immediate management appropriate to open chest wound and flail chest (see later).
- Monitor continuous pulse oximetry and electrocardiogram.
- Initiate crystalloid resuscitation via large-bore intravenous (IV) access.
  - Early mobilization of blood products if ongoing hemorrhage or expectation of excessive blood loss.
  - Placement of resuscitative lines concurrent with management of respiratory parameters.
- Early surgical consultation for management of intrathoracic injuries and management of chest wall defect.

25.3 Open Pneumothorax ("Sucking Chest Wound")

- Immediate management requires attention to airway and respirations.
  - If in respiratory distress, *intubate*.
- Close the chest wall defect with an occlusive three-sided dressing.
  - This includes a valve mechanism that allows trapped air to escape, preventing tension (Fig. 25.3).
  - An IV bag cut to fit the wound and then taped on three sides can be useful in an emergent situation.
  - Commercial products are available and appropriate for smaller wounds, including the Asherman Chest Seal and HyFin Vent.
- A completely occlusive dressing may quickly convert an open chest wound into a tension pneumothorax [2, 3, 5] and therefore should *never* be done.
  - The patient and dressing must be serially checked to ensure that trapped air is allowed to escape.
  - If there is any doubt, immediately remove the dressing and replace it with an appropriate dressing.
- These maneuvers are a bridge to definitive care.
- When the timing is appropriate (i.e., time and resources are available), perform a formal tube thoracostomy and convert to a completely occlusive dressing over the wound.
  - Avoid placing the tube through the open wound.
- Once tube thoracostomy, placement of occlusive dressing, and the airway are secured, the pathophysiology of the open pneumothorax becomes inconsequential.
- Immediate consultation with surgery for definitive care of associated intrathoracic injuries is required.
  - The patient may need urgent thoracotomy to treat associated injuries.
  - Irrigation and debridement should take place in the operating room.
  - Depending on injury severity, the patient may need chest wall reconstruction.

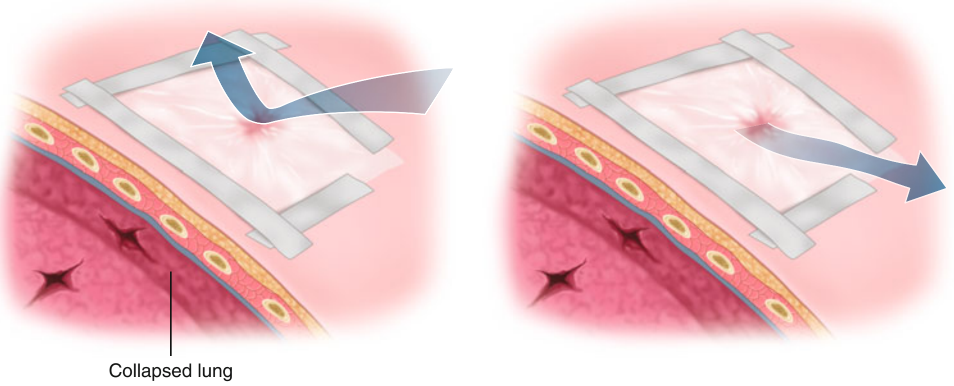

Fig. 25.3 Three-sided dressing, allowing a valve to decompress tension in the chest

25.4 Flail Chest

- Diagnosis is made from mechanism and examination, not radiographically.
  - With inspiration, the affected chest will move inward with negative pressure.
  - With expiration, the affected chest will move outward.
  - Patients who are intubated on positive pressure (and not spontaneously breathing) will often not show this paradoxical chest movement.
- Attention *must* be paid to presumed underlying blunt lung injury and contusion.
  - The degree of underlying contusion (not the flail segment itself) is directly related to the degree of hypoxia and associated morbidity and mortality [2, 3].
  - There should be a low threshold for intubation to manage respiratory distress, hypoxemia, or hemodynamic instability.
  - The patient is at high risk for hemothorax and pneumothorax requiring tube thoracostomy.
- Abdominal injuries may be present in up to 15 % of patients [2].
- After initial stabilization, treatment is supportive.
  - Intensive care unit admission for management of underlying pulmonary contusion.
  - Pain control in the form of epidural or regional block for excellent pain control.
  - Close attention to pulmonary toilet and lung re-expansion.
  - Patients require observation and treatment in a monitored setting until ensured that respiratory parameters and oxygenation are improving.
- Surgical stabilization of the chest wall is rarely performed.
  - Early surgical consultation for chest wall fixation in questionable cases is warranted.

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Emergent Resuscitative Thoracotomy, Open Cardiac Massage, and Aortic Occlusion

26

Kevin M. Jones and Jay Menaker

26.1 Indications

- Penetrating chest trauma with recent or immanent loss of vital signs
- Consider in blunt trauma with pericardial tamponade or exsanguination where aortic occlusion may provide proximal control

26.2 Contraindications

Absolute
  - Prolonged cessation of vital signs
  - Injury profile obviously incompatible with life
  - Absence of surgical services to whom care can be transferred

Relative
  - None

26.3 Materials and Medications (Fig. 26.1)

- Betadine (povidone-iodine) for rapid skin preparation
- #10 Scalpel
- Mayo or long Metzenbaum scissors
- Finochietto retractor (rib spreader)
- Long DeBakey or other tissue forceps (2)
- Satinsky vascular clamp and/or straight vascular clamp
- Long needle holders (2)
- Lebsche knife or sternal osteotome with hammer
- Lap sponges or gauze pads

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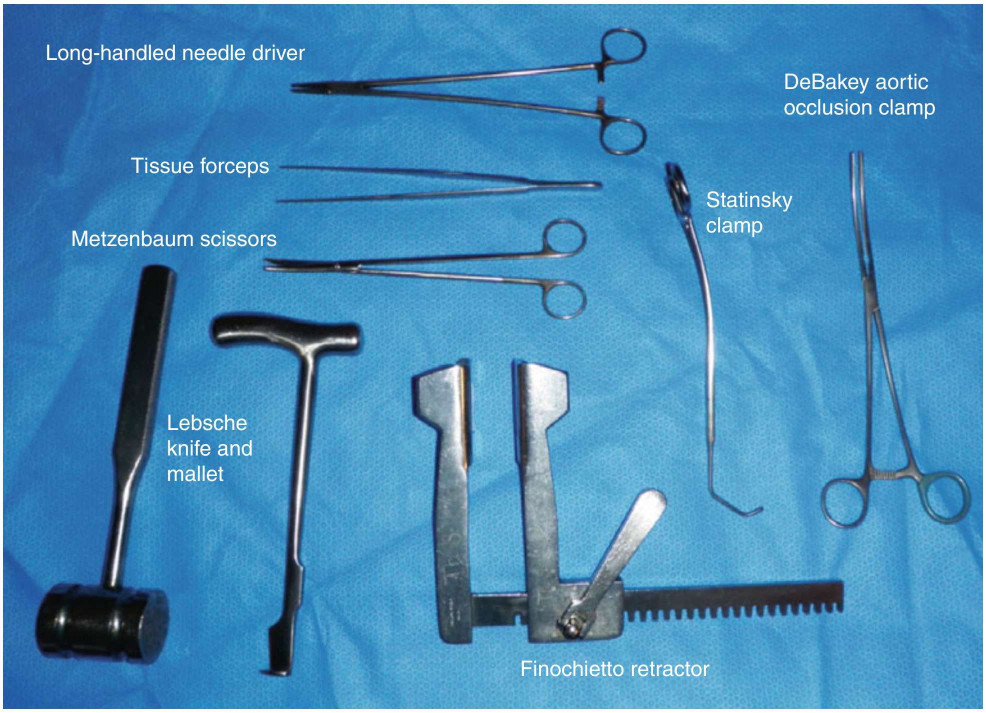
Long-handled needle driver
DeBakey aortic occlusion clamp
Tissue forceps
Statinsky clamp
Metzenbaum scissors
Lebsche knife and mallet
Finochietto retractor

Fig. 26.1 Basic components of an emergency thoracotomy tray: Lebsche knife and mallet for crossing sternum (bone-cutting forceps or sternal osteotome would also suffice), Finochietto retractor, atraumatic vascular clamps (a Satinsky clamp and a DeBakey aortic occlusion clamp), long-handled needle driver, tissue forceps, and Metzenbaum scissors. *Not illustrated* Scalpel with #10 or #20 blade, Mayo scissors

26.4 Procedure

26.4.1 Resuscitative Thoracotomy and Open Cardiac Massage

1. Rapidly prepare the entire anterior and bilateral chest with Betadine.
2. Using a scalpel, incise the skin and subcutaneous tissue from just right of the sternum to the anterior margin of the left latissimus dorsi, following the curvature of the inframammary crease or the fourth or fifth intercostal space (Fig. 26.2).
   - This incision is often made too low on the patient's chest. It should extend across the sternum, not at the level of the xiphoid. Upward retraction of the breast may help provide access to the fourth or fifth intercostal space, where the incision should be located.
3. Bluntly enter the right pleural space through the fourth or fifth intercostal space.
4. Using scissors, cut the intercostal muscles, dividing between the fourth and the fifth ribs from the sternum to the posterior axillary line.
5. If better exposure to the heart is desired, some practitioners advocate extending the incision across the sternum using a Lebsche knife, sternal osteotome, or bone-cutting forceps at this time (Fig. 26.3).
   - If the thoracotomy incision extends to or through the sternum, tie off the internal mammary arteries before closing the chest should the patient be successfully resuscitated, because these will have been divided with the incision.
6. Insert a Finochietto retractor and retract the ribs in order to gain access to the left chest and expose the pericardium (Figs. 26.4 and 26.5).
   - Insert a Finochietto retractor with the rack and pinion bar down and lateral, as in Fig. 26.4, so as not to interfere with extension of the thoracotomy across the sternum into a clamshell maneuver if needed.
7. If massive left pleural hemorrhage is encountered, investigate and control the source at this time.
8. Using tissue forceps, raise a portion of the pericardium anterior to the phrenic nerve, and enter the pericardium using scissors (Fig. 26.6).
9. Widely open the pericardium with scissors, cutting in a cranial-caudal direction anterior to the phrenic nerve and deliver the heart (Fig. 26.7).
10. If hemopericardium is encountered, investigate for and initiate appropriate repair of identified cardiac injuries.
11. Initiate open cardiac massage by cupping the heart between the flattened palmar aspect of the fingers of both hands and rhythmically compressing the heart from apex to base, relaxing completely between compressions to allow filling (Fig. 26.8).

26.4.2 Aortic Occlusion

1. Expose the posterior aspect of the left mediastinum by having an assistant retract the left lung superomedially, dividing the inferior pulmonary ligament if necessary (Fig. 26.9).
2. Bluntly dissect the pleura separating the pleural and mediastinal space just anterior to the vertebral bodies, exposing the aorta (Fig. 26.9).
3. Completely encircle the aorta with the finger of the non-dominant hand (Fig. 26.10).
   - Differentiating the aorta from the esophagus when the patient is in a state of profound shock is very difficult. Having an assistant pass an orogastric tube may help distinguish the two. The aorta should be the most posterior structure, lying immediately on the anterior aspect of the vertebral bodies.
4. With the aorta completely encircled, place a vascular clamp across the aorta and verify by sight and feel that the complete vessel is occluded within the clamp (Fig. 26.11).

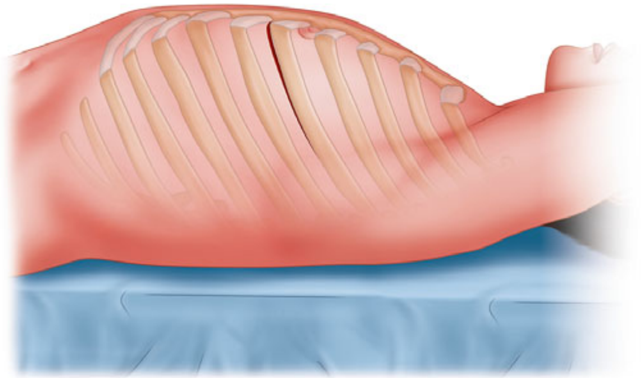

Fig. 26.2 Raise the left arm above the head. Make an incision along the left fourth intercostal space, just below the nipple in a male or at the inframamillary crease in a female

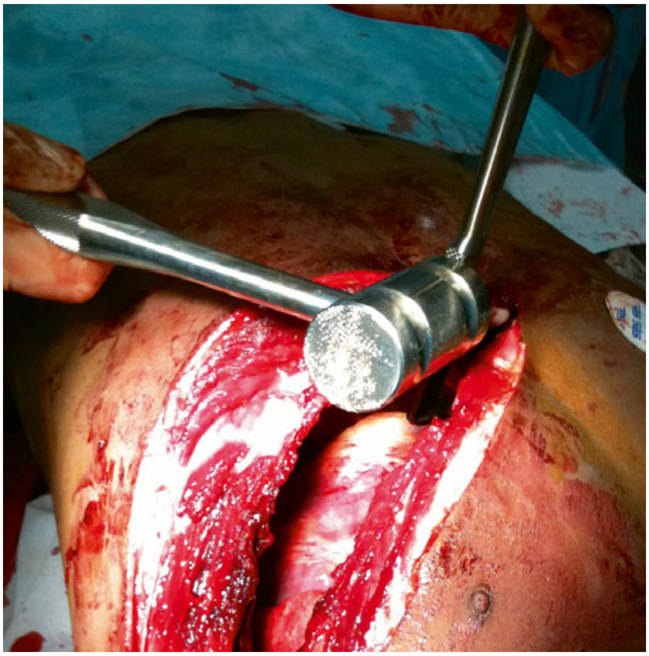

Fig. 26.3 Use a Lebsche knife to extend the incision across the sternum to improve exposure to the heart

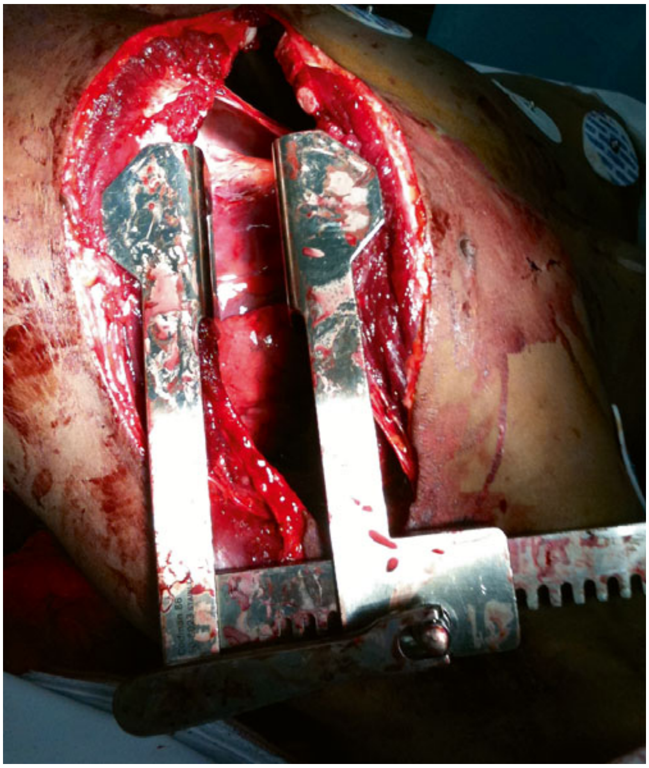

Fig. 26.4 Finochietto retractor placed through the fourth intercostal anterolateral incision. Note the rack and pinion bar placed posterolaterally, where it will not impede access to the midline

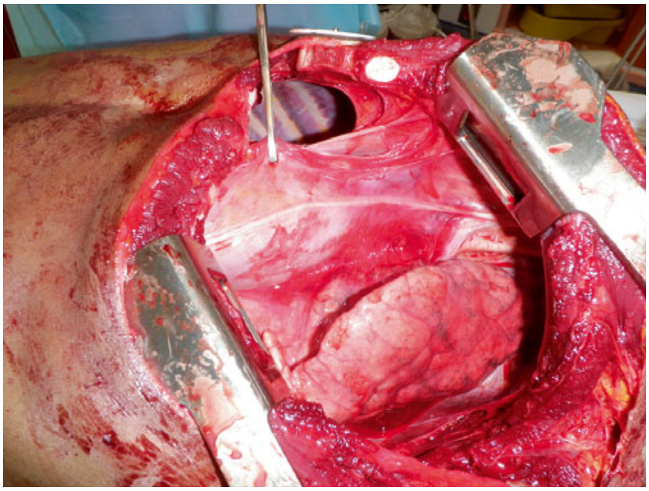

Fig. 26.5 Finochietto retractor extended, exposing the left pleural space and the pericardium. In this case the sternum has been divided as above, and the resultant window into the right pleural space is seen anterior to the pericardium. The lung is deflated in this postmortem picture but would be far more an obstacle in the actively ventilated patient. The clamp seen in the upper portion of the picture is reapproximating the pericardium, which has previously been divided, for the sake of illustration

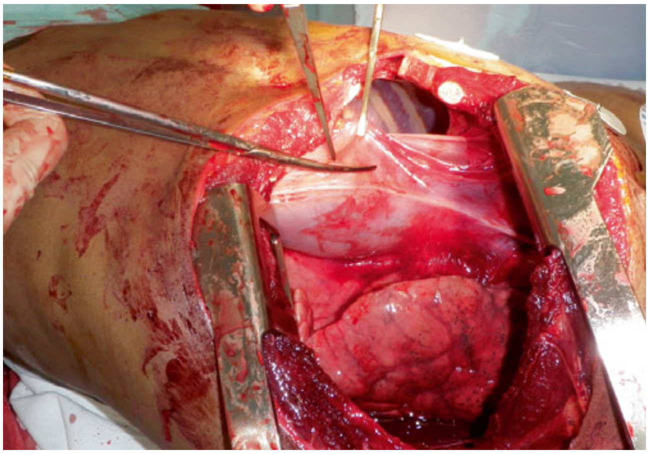

Fig. 26.6 The pericardium is lifted with tissue forceps and opened with a nick using scissors. The phrenic nerve is easily visualized running cranial-caudal just below the scissors in this picture

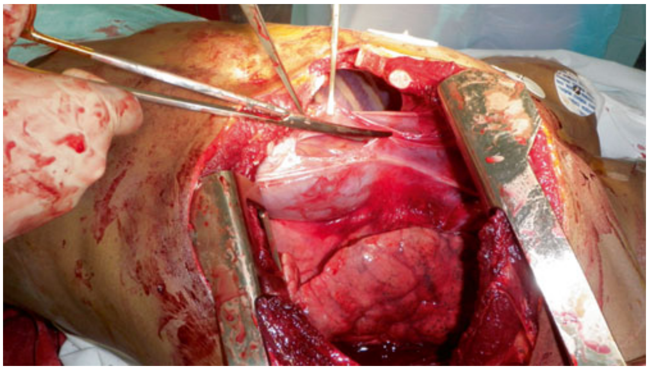

Fig. 26.7 Open the pericardium widely in the cephalad-caudad plane anterior to the phrenic nerve, taking care not to damage the phrenic nerve

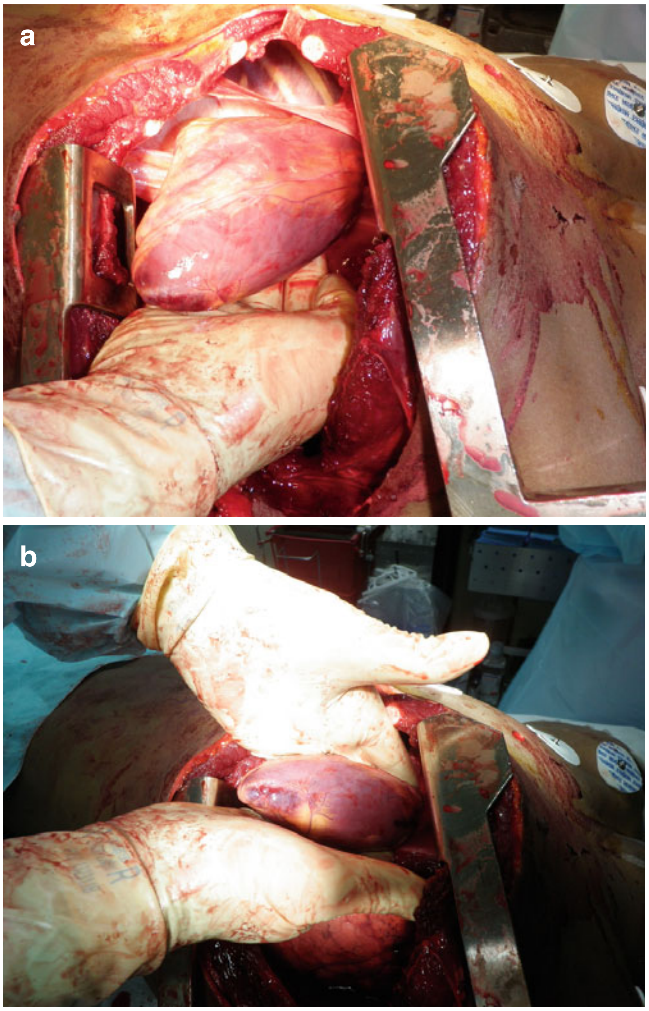

Fig. 26.8 (**a**) Deliver the heart from the pericardium, rapidly assess for cardiac injury requiring damage-control repair; (**b**) initiate open cardiac massage

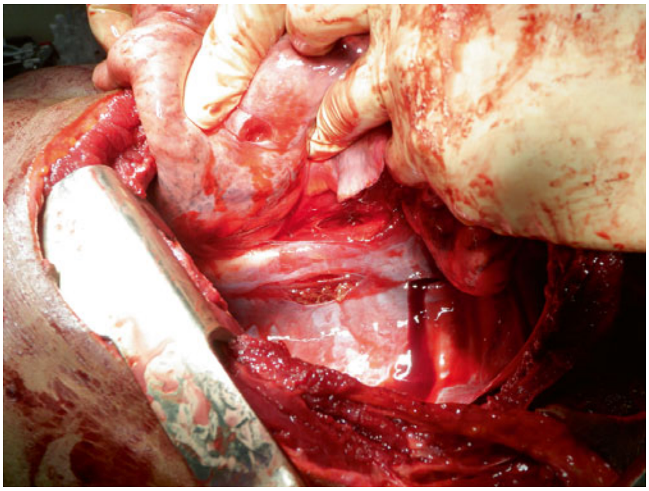

Fig. 26.9 The heart and lung are retracted superomedially, allowing visualization of the left posterior mediastinal pleura; the aorta lies just anterior to the vertebral bodies and has been previously isolated through the pleural interruptions seen here. The heart and lung are assertively retracted here for the benefit of illustration of the posterior mediastinum. Such retraction would completely occlude venous return

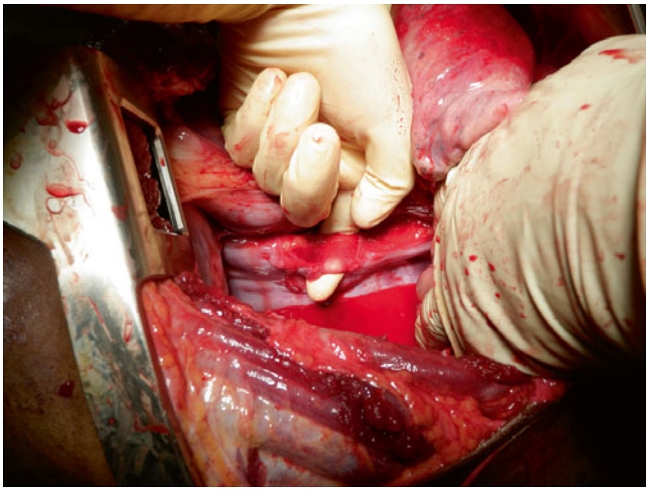

Fig. 26.10 After bluntly dissecting the mediastinal pleura, the aorta is looped using a finger of the nondominant hand

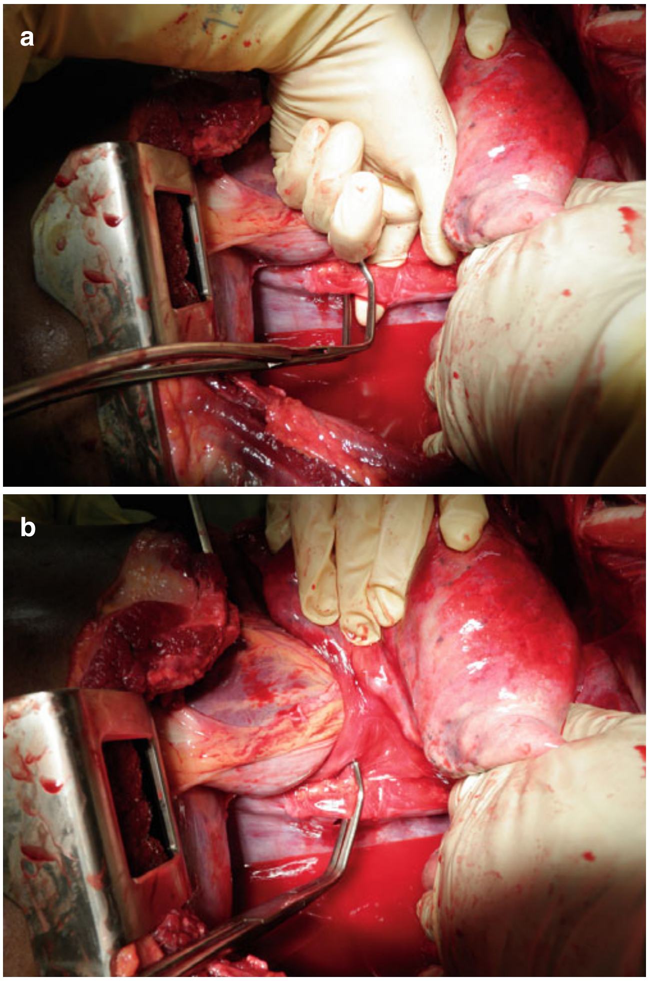

Fig. 26.11 (**a**) A vascular clamp (a Satinsky clamp is used here, although any large atraumatic vascular clamp can be used) is applied across the descending aorta, (**b**) followed by visual and tactile confirmation that the aorta is completely occluded

26.5 Complications

- Injury to care providers, by means of scalpel, needlestick, or sharp foreign body, is the principal concern.
- Post-emergency department thoracotomy infections are rare, even given the less than optimal sterile conditions.
- Damage to lung parenchyma during the initial incision is common and often leads to air leak in survivors.
- Neglect of the mammary arteries, often divided during emergent thoracotomy and not briskly bleeding in the shock state, will result in intrathoracic hemorrhage if not tied off.

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27 Lung Ultrasonography

Ali H. Dabaja, L. Connor Nickels, and Rohit Pravin Patel

27.1 Indications

- Evaluation of respiratory failure and insufficiency due to pneumothorax, pleural effusion, pulmonary edema, acute respiratory distress syndrome (ARDS), and alveolar consolidation (atelectasis, pneumonia, aspiration)
- Monitoring progress of diseases such as pulmonary edema and pneumothorax
- Procedural guidance during pleural fluid removal or pneumothorax treatment
- Procedural guidance for chest tube placement for complex pleural effusions, hemothorax, pneumothorax, and other pleural diseases

27.2 Contraindications

- None

27.3 Materials

- Ultrasound equipment/machine, ultrasonography gel
- Microconvex or phased-array cardiac probe for sufficient evaluation of lung artifact (use abdominal preset). Linear-array probes, or vascular probes, can be used for more detailed evaluation of the pleura, although this is insufficient for penetration to deeper structures.
- Sterile materials and equipment where appropriate

27.4 Preparations

- Clean ultrasound equipment and use sterile operating procedures and ultrasound conductive gel whenever adequate.
- Ultrasound positioning. Place ultrasound device where it is easily accessible and in adequate view.
- Proper environment. Minimize light interference. Close shades and lights where appropriate.
- Position the patient. This helps optimize and expedite the examination. Supine position should be adequate for critically ill patients. Upright positioning is best for all others, with arms abducted above the head or spaced away from the chest to allow space for the probe. Patients should be moved to the edge of the bed. Uncover appropriate areas, including anterior and lateral chest walls.
- Equipment use. Turn on equipment, enter patient data, and select proper probe (cardiac probe or abdominal probe with abdomen presets). Depth and gain should be adjusted accordingly, where depths in the range of 4–10 cm give proper evaluation of more superficial and deeper structures, respectively.

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27.5 Procedure

1. Probe position (Fig. 27.1). Start examination at the midclavicular level at the space between the second and the third ribs. Probe positioning should be perpendicular to the ribs (longitudinal positioning) with the ultrasound marker pointed cephalad. This should place the most superficial structures at the top, with deeper structures at the bottom of the monitor. Upon completion, probe positioning can be mapped to evaluate three or four additional areas, typically between the anterior and the posterior axillary lines. Lateral views with the probe should be most posterior, typically along the posterior axillary line, tracking caudad toward the diaphragm. PLAPS (posterolateral alveolar and/or pleural syndrome) pointed posteriorly should also be evaluated, specifically in supine patients. PLAPS is lateral to the scapula and typically requires that the patient be lifted off the bed from one side.
2. Identify the “bat sign” (Fig. 27.2). The initial view observed should be a window of lung flanked by two rib shadows. This view, termed the “bat sign,” should now allow evaluation of the parietal and visceral pleura, seen most superficial as echogenic line (approximately 0.5 cm below start of rib shadows), subsequent lung sliding, and other findings such as “A” and “B” lines, as well as abnormal lung tissue.
3. Identify “A lines” (Fig. 27.3). A lines indicate air. These are multiple echogenic lines appearing horizontally in sequence deep to the pleural line. This artifact represents reverberations of the pleura and can be found in aerated lungs, which can be normal or abnormal (e.g., pulmonary embolism, chronic obstructive pulmonary disease [COPD]). The first true A line, denoted “A1,” is found equidistant from the chest wall to the pleural line. Many other A lines might be seen and are denoted “A′” lines. Subsequent equidistant A lines are “A2,” “A3,” and so on.
4. Identify “B lines” (Fig. 27.4). These artifacts appear in well-aerated lung and are vertical echogenic lines (ray, flashlight, lung rockets) transmitted from the pleura to the deeper parts of the lung on the ultrasound monitor field. They are due to thickened interlobular septa and represent alveolar fluid surrounded by air. True B lines arise from the pleural line and shoot all the way down to the far lung fields, whereas “comet tails” are seen only close to the pleural and are sometimes referred to as “shimmering” or “glimmering” during movement of the pleural line. When multiple B lines are seen in a patient, it is sometimes referred to as “lung rockets” or “flashlights” because many rays are shooting from the pleura. Even though most of the time B lines represent pulmonary edema, they can be seen in other conditions such as aspiration, pulmonary fibrosis, acute respiratory distress syndrome (ARDS), and pneumonia.
5. Identify lung sliding (Fig. 27.5). Lung sliding identifies movement of a normal parietal-visceral interface. Patient breathing causes a rhythmic movement of parietal against the visceral pleura appearing as movement of the hyperechoic line. M-mode can be used to show a timed clip of this through a still image and should only be used as a method of reporting or saving for documentation purposes. A “lung point” is an area adjacent to lung sliding (parietal pleura) that is devoid of movement. This is highly specific for pneumothorax. If one suspects a pneumothorax, quantification of the size can be made by evaluation at the anterior lung points and movement toward the lateral wall of the chest. The more rib spaces found to have absent lung sliding, the larger the pneumothorax. Lung sliding (Fig. 27.5) can be evaluated with M-mode, which can help identify a normal parietal-visceral interface at that level. Obtain an adequate two-dimensional view (“bat sign”) and press the “M-mode” option on the equipment. A normal interface appears as multiple hyperechoic lines, the pleura (termed “seashore”; Fig. 27.5a), followed by a sandlike pattern, the lung tissue. This pattern together is termed a “seashore sign.” Air that disrupts the parietal-visceral interface, as found within a pneumothorax, is identified as horizontal repeating echogenic lines, similar to a barcode (Fig. 27.5b), and is termed “stratosphere sign.” M-mode can be discontinued.
    - Lung sliding can be absent in conditions other than pneumothorax: apnea, right or left bronchial intubation, lung collapse (blebs), pneumonia, and pulmonary fibrosis.
6. Identify lung pulse. This appears as a shimmering of the pleural line due to cardiac activity. This is most apparent on the left side of the chest, closest to the heart. This helps to exclude pneumothorax as well.
7. Move posteriorly. Move the ultrasound probe laterally and posteriorly to the PLAPS point. The transducer can be directed toward the center of the patient’s body in supine patients. Pleural effusions and consolidations are found in the dependent areas of the lung.
8. Move caudally. With the marker still pointing cephalad, move along the posterior axillary line in two or three additional rib spaces. Identification of pleural disease and other pathology requires multiple views and will aid in evaluating the extent of the disease. This will also allow for identification of boundaries of the lung, such as the diaphragm. Identification of the diaphragm is most critical to determine location of fluid.

9. Identify the diaphragm and liver and/or spleen (Fig. 27.6). Along the posterior axillary line, or the posterior chest wall, move the probe caudad to identify the diaphragm. This appears as an echogenic curvilinear structure, with the liver or spleen being subdiaphragmatic and typically of different echogenicity than the lung. Many times the diaphragm is very high in the supine critically ill patient. Massive edema and obesity may also degrade image quality in this location.
   - Always identify the diaphragm. Hypoechoic fluid surrounding the liver or spleen can appear as a pleural effusion and must not be mistaken as such. In addition, lung tissue may mimic hepatic tissue in certain diseases such as dense consolidations termed "hepatization" of the lung. Proper probe positioning, clear identification of the diaphragm, subdiaphragmatic structures, and lung are crucial. This is a common error in novice operators owing to the confusion of the hepatorenal or splenorenal recess for the diaphragm.
   - Identifying the diaphragm can be technically difficult depending on patient position, size, and clinical condition. It maybe useful to start below the diaphragm, first identifying the hepatorenal recess (liver and kidney view interface) and then moving cephalad until the lung and diaphragm are visualized. In addition as ribs change their orientation anatomically, the probe may need to be adjusted while still in the longitudinal axis. Moving the probe clockwise and counterclockwise may be of benefit to bring into view the lung, the diaphragm, and the subdiaphragmatic structures.
10. Identify pleural effusions (Fig. 27.6). Confirming the presence of pleural effusions requires identifying anechoic material between the pleura and the lung. This can be seen as lung movement in an undulating pattern, which typically is facilitated by cardiac activity and respirations. This is termed "jellyfish sign," where the lung flaps as it freely floats in the effusion. Floating debris can also confirm effusion, termed "plankton sign." It is also important to identify the depth of the chest wall to the pleural fluid in order to determine the best location/depth of needle insertion when attempting thoracentesis or chest tube insertion. The challenge is to find a safe path for needle insertion. The key when using ultrasound as guidance is that the angle of the needle/syringe assembly must duplicate the angle of the probe. The time between scan and needle insertion must also be minimized. Real-time guidance is not required. In patients who are obese or edematous, skin indentation during probe placement can result in underestimation of depth of needle insertion required and must be taken into account. Safety margin of thoracentesis is thought to be 10 mm of visceral-parietal distance. Dry taps may be due to loculations the blocking needle, needle plugs, patient movement from scan to tap, and poor angle selection.
    - Exudates, empyemas, and hemothoraces may appear more echogenic, unlike, for example, a transudative effusion that could be anechoic. Complex effusions can also appear as heterogeneous and echogenic. The consistency of the effusion can make identification technically difficult because this can limit lung motion. Sometimes the operator may think there is no effusion when there is an echo-dense effusion.
11. Identify consolidations (Fig. 27.7). Compressed lung appears with alveolar consolidation pattern (tissue-like sign). Alveolar consolidations are devoid typically of air and appear as tissue density; these can be atelectasis, pneumonia, aspiration, or other diseased lung. "Hepatization" of the lung is typical, where the images mimic liver tissue. Images may also have hyperechoic foci representing air bronchograms, which would indicate pneumonia. Probe location should be correlated with an anatomical lobular or segmental area.
    - Lung may slide into the effusion during the respiratory cycle and can be problematic during needle insertion, causing pneumothorax or abnormal wire placement during the performance of pigtail chest tube catheters. This is called a "curtain sign."
12. Sinusoid sign (Fig. 27.8). M-mode is placed in the center of the visible lung when a large amount of pleural fluid is seen. A sinusoid sign strengthens the operator's determination that pleural fluid is present and that the pleural fluid is not necessarily compromising lung dynamics. If the sinusoid sign is absent, it may indicate a "trapped" lung dynamic.
13. Assessment and clinical decision making. Upon completion of ultrasonography of bilateral lung fields, clinical decision-making tools may be of benefit, especially in undifferentiated respiratory failure. A protocol has been developed to organize the exam of a respiratory failure patient (on noninvasive or invasive ventilation only). The BLUE protocol assesses patients based on findings (e.g., A lines, B lines, lung sliding) of both lungs and incorporates them into an algorithm. With acceptable sensitivities and specificities, practitioners can diagnose pulmonary edema, pneumonia, pneumothorax, and COPD/asthma with the BLUE protocol.

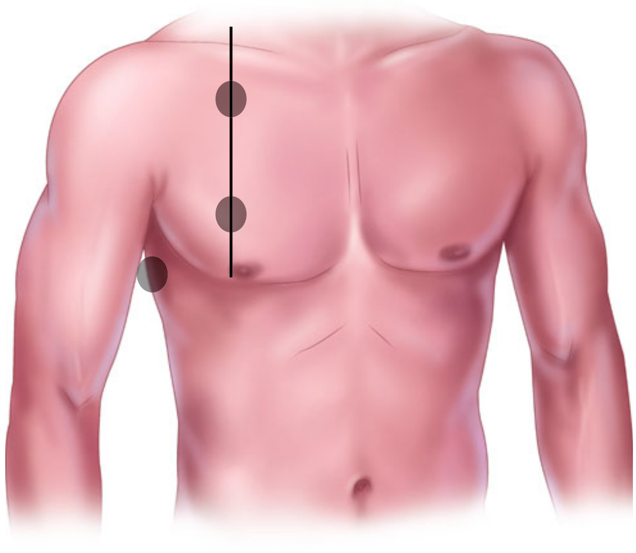

Fig. 27.1 *Black circles* indicate possible ultrasound view points. These are just guides, and one may view a few interspaces left/right and cephalad/caudad from each point to obtain better views

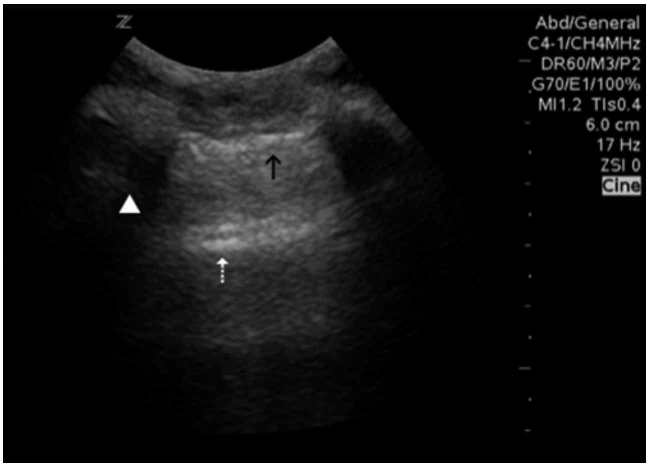
Abd/General
C4-1/CH4MHz
DR60/M3/P2
G70/E1/100%
MI1.2 TIs0.4
6.0 cm
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Fig. 27.2 Typical bat sign with rib shadows (*arrowhead*) that surround the pleura (*black arrow*) and lung tissue. Incidentally, A lines (*white arrow*) are seen

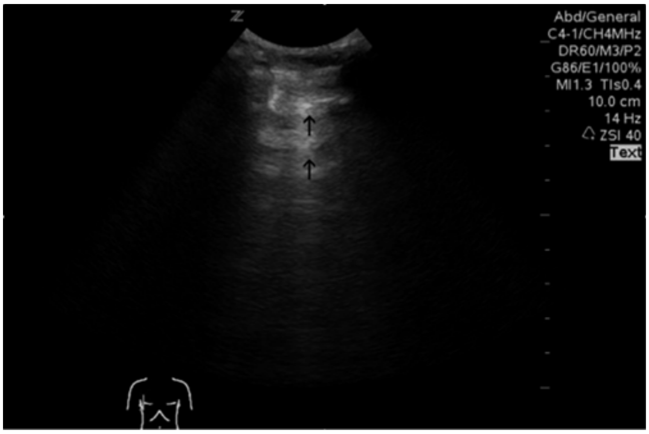
Abd/General
C4-1/CH4MHz
DR60/M3/P2
G86/E1/100%
MI1.3 TIs0.4
10.0 cm
14 Hz
ZSI 40
Text

Fig. 27.3 Rib shadows can be seen, with multiple A lines (*arrows*)

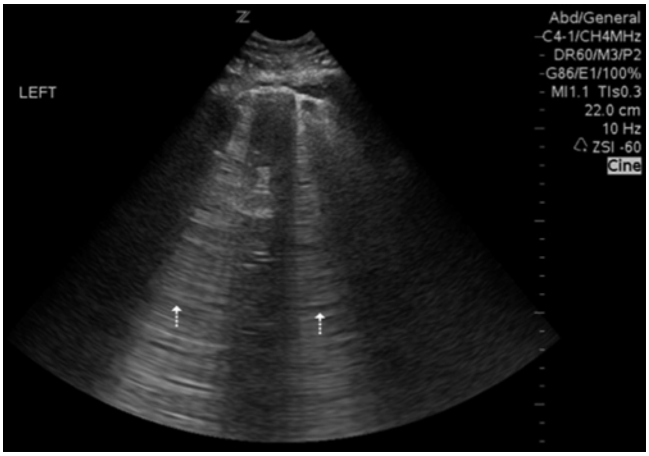
LEFT
Abd/General
C4-1/CH4MHz
DR60/M3/P2
G86/E1/100%
MI1.1 TIs0.3
22.0 cm
10 Hz
ZSI -60
Cine

Fig. 27.4 Two B lines can be appreciated (*arrows*)

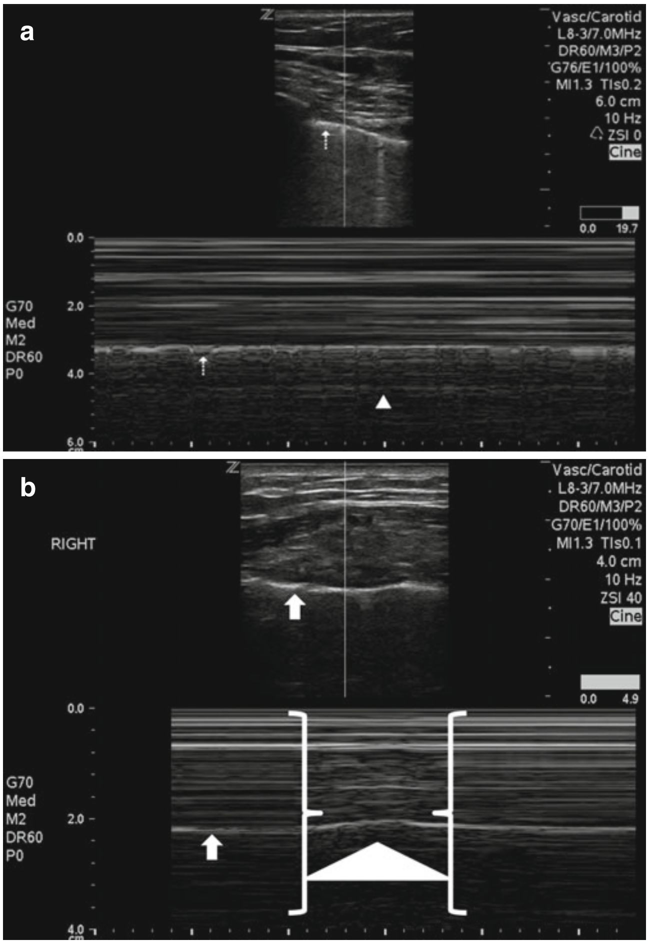
a
Vasc/Carotid
L8-3/7.0MHz
DR60/M3/P2
G76/E1/100%
MI1.3 TIs0.2
6.0 cm
10 Hz
ZSI 0
Cine
0.0
19.7
0.0
2.0
4.0
6.0
G70
Med
M2
DR60
P0
b
RIGHT
Vasc/Carotid
L8-3/7.0MHz
DR60/M3/P2
G70/E1/100%
MI1.3 TIs0.1
4.0 cm
10 Hz
ZSI 40
Cine
0.0
4.9
0.0
2.0
4.0
G70
Med
M2
DR60
P0

Fig. 27.5 (**a**) M-mode identifies the seashore sign, with the pleura (*arrows*) and the lung parenchyma (*arrowhead*) together producing an image similar to a seashore. (**b**) M-mode shows the stratosphere or barcode sign. *White arrows* indicate the pleura, and the *large triangle* shows an area of artifact from movement. Artifact from movement can be distinguished by a similar pattern change above and below the pleural line. On either side of the bracket is a continued horizontal line pattern typical of absent lung sliding

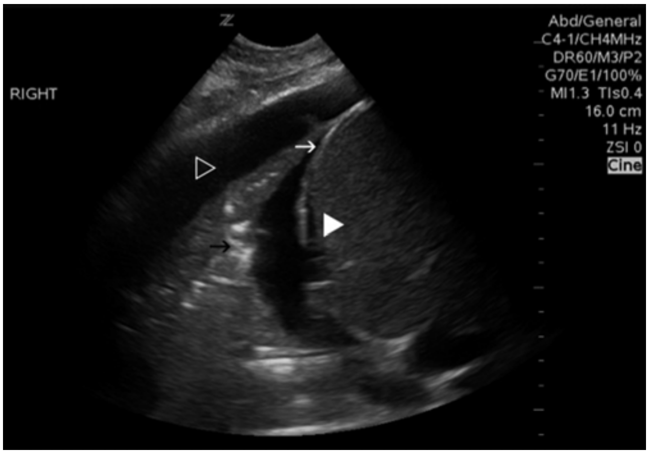
RIGHT
Abd/General
C4-1/CH4MHz
DR60/M3/P2
G70/E1/100%
MI1.3 TIs0.4
16.0 cm
11 Hz
ZSI 0
Cine

Fig. 27.6 Diaphragm (*white arrow*), liver (*white arrowhead*), lung (*black arrow*), and anechoic fluid, likely an effusion (*open arrowhead*). Incidentally, hyperechoic foci in the lung tissue, likely representing air bronchograms, can be seen

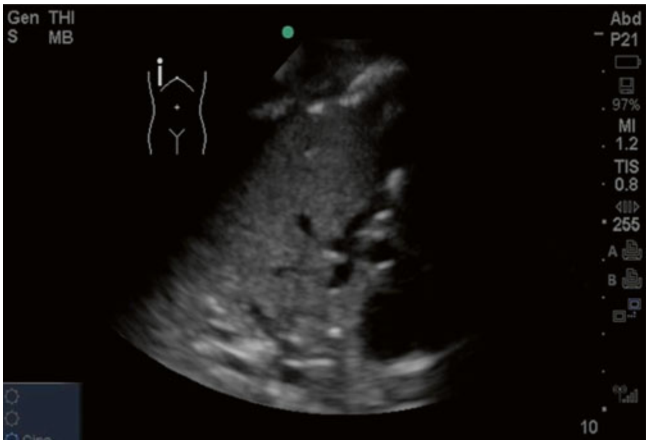
Gen THI
S MB
Abd
P21
97%
MI
1.2
TIS
0.8
255
A
B
10

Fig. 27.7 Lung here appears as tissue density, likely representing the alveolar consolidation pattern seen in pneumonia, and is termed "hepatization" and "tissue-like sign"

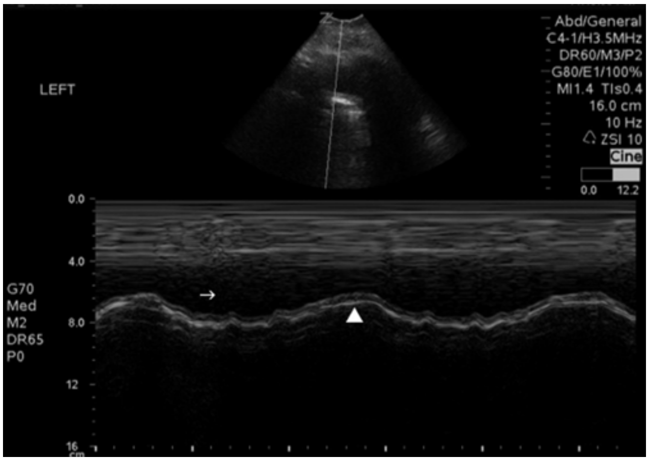
LEFT
Abd/General
C4-1/H3.5MHz
DR60/M3/P2
G80/E1/100%
MI1.4 TIs0.4
16.0 cm
10 Hz
ZSI 10
Cine
0.0 12.2
0.0
4.0
8.0
12
16 cm
G70
Med
M2
DR65
P0

Fig. 27.8 In M-mode, identification of pleural effusion becomes evident with the sinusoidal sign (*arrowhead*) and identification of pleural fluid (*arrow*)

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Part IV

Cardiac Procedures

Repair of Cardiac Injuries

28

Ronald Tesoriero

Whether performed by an emergency physician or a surgeon, the majority of cardiac repairs performed at emergency department thoracotomy will be temporary in nature and require further revision in the operating room. This chapter's main focus is the temporary control of cardiac injuries.

28.1 Indications

- Wounds to the heart in patients presenting with pulseless electrical activity (PEA) or asystole with evidence of cardiac tamponade
  - Penetrating wounds: <15 min of prehospital cardiopulmonary resuscitation (CPR)
  - Blunt wounds: <10 min of prehospital cardiopulmonary resuscitation (CPR)

28.2 Contraindications

- Absolute
  - Presenting rhythm of asystole and no evidence of pericardial tamponade on Focused Assessment with Sonography for Trauma (FAST)
- Relative
  - None

28.3 Materials and Medications

- Diagnostic ultrasound
- Emergency department thoracotomy tray (Fig. 28.1)
  - Sterile drapes, #10 scalpel, curved Mayo scissors, Finochietto retractor, Lebsche sternal knife and mallet, forceps, curved Metzenbaum scissors, surgical skin stapler, Foley catheter, clamps, needle driver, 2–0 and 3–0 polypropylene suture on MH or SH (noncutting) needle, Satinsky vascular clamps
- Betadine (povidone-iodine) or other skin antiseptic preparing solution
- Defibrillator and internal cardiac panels
- Epinephrine

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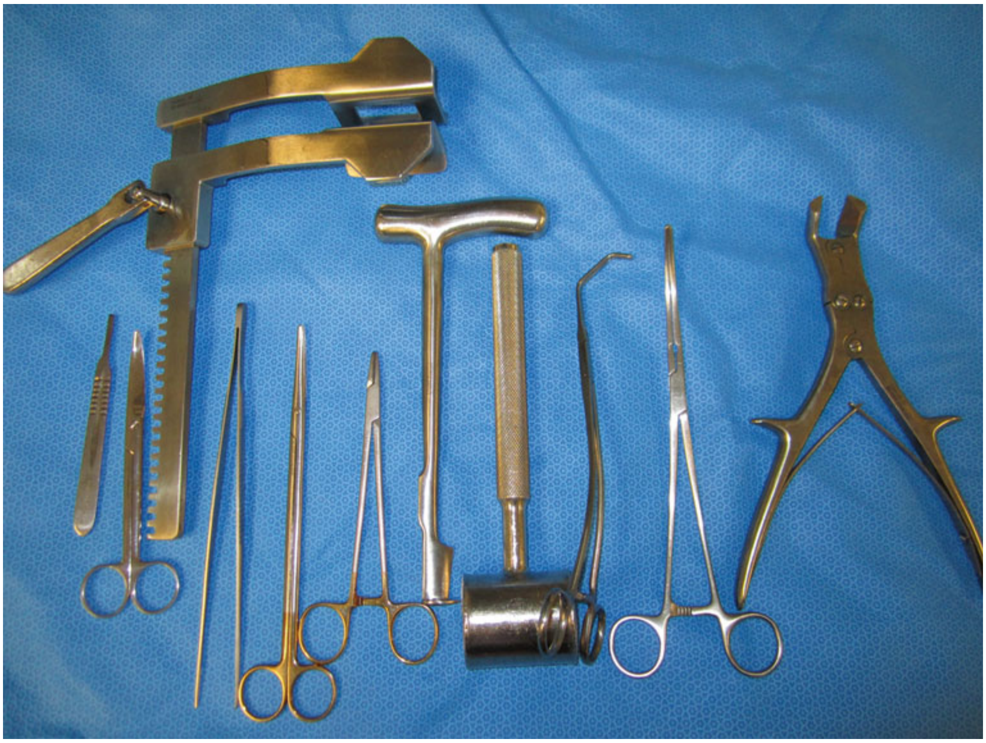

Fig. 28.1 Emergency department thoracotomy tray. *Left to right*: Scalpel, curved Mayo scissors, Finochietto rib spreader, DeBakey forceps, Metzenbaum scissors, needle driver, Lebsche knife and mallet, Satinsky vascular clamp, aortic clamp, bone cutter

28.4 Procedure

1. Identify the pericardium anterior to the phrenic nerve, pinch it between the fingers, and enter it by making a nick with the Metzenbaum scissors. Then open the pericardium longitudinally anterior to the phrenic nerve.
2. If the heart is not contracting effectively (PEA, asystole, fibrillation), immediately begin internal cardiac massage.
    - Unless the injury is so large that it cannot be controlled, taking time out at this point to repair the injury may lead to significant acidosis and inability to reestablish a perfusing rhythm.
3. While continuing internal cardiac massage, identify the area of injury and attempt to control it with manual pressure; if a larger wound, use a Foley catheter to prevent continued bleeding.
4. If necessary owing to the location of injury, extend the incision to a bilateral anterolateral thoracotomy and transect the sternum with a Lebsche knife and mallet or heavy shears.
5. If, after several minutes of internal massage and appropriate red blood cell and plasma transfusion, the patient remains in PEA or asystole, irrigate the heart with warmed saline and administer intravenous (IV) or intracardiac epinephrine.
6. If the heart enters ventricular fibrillation or ventricular tachycardia, cardiovert with internal paddles applied directly to the heart with an energy between 10 and 30 J.
7. Once a perfusing rhythm is reestablished, or if on initial evaluation the wound is so large that it cannot be controlled and will require immediate repair before internal massage can be effective, proceed to cardiac repair.
8. Choose the simplest method that will allow control of the injury until definitive repair can be performed in the operating room.
    (a) Injuries to the atrium: The pliable nature of the atria will often allow placement of a Satinsky clamp for control followed by repair with a running 3–0 polypropylene suture (Fig. 28.2).
    (b) Small injuries to the ventricles: Control the injury with direct manual pressure and close with either interrupted 3–0 polypropylene suture or a surgical skin stapler (Figs. 28.3 and 28.4).
    (c) Medium to large injuries to the ventricle: Attempt to control the wound by placing a Foley catheter through it, then blow up the balloon and apply gentle traction. Either staple or suture the wound closed before deflating the balloon and removing the catheter (Fig. 28.5).
        - Place an occluding clamp on the open end of the catheter or blood loss will continue through the catheter
        - Avoid excessive traction on the Foley because it will pull through the ventricle and make the hole larger
    (d) Extensive or inaccessible injury: Perform temporary inflow occlusion to the heart by manually compressing the right atrium against the heart so that it cannot fill. The heart will likely immediately enter PEA, fibrillation, or asystole giving the physician a couple of minutes to gain control of the injury before the patient becomes unrecoverable.
    (e) Injuries in proximity to coronary vessels: To avoid compression of the vessel, perform a horizontal mattress suture that passes beneath the artery. Teflon pledgets may assist in the repair (Fig. 28.6).

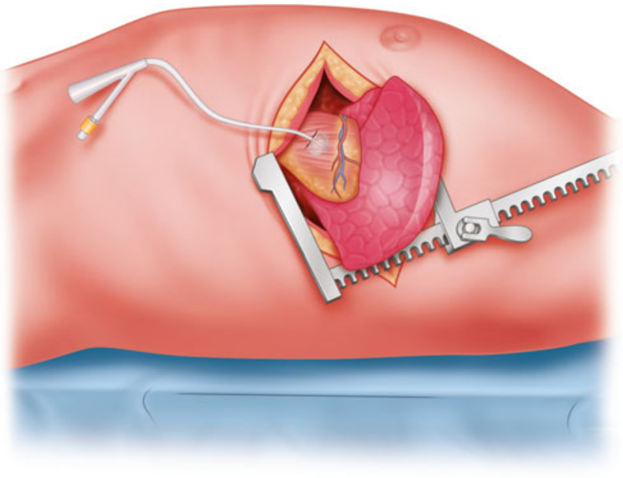

Fig. 28.2 Position the Finochietto retractor with the closed end toward the axilla. A Foley catheter may be used for initial control of large cardiac lacerations

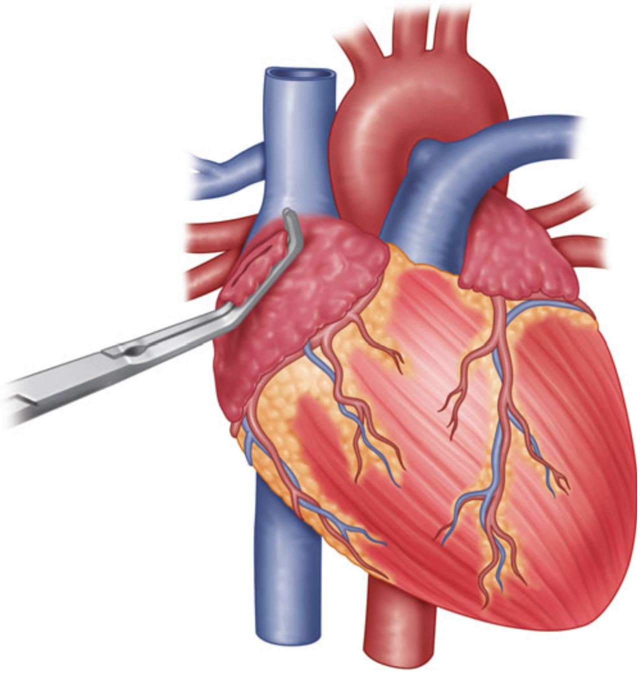

Fig. 28.3 Atrial injuries may be quickly controlled with a Satinsky clamp followed by repair with a 3–0 polypropylene suture

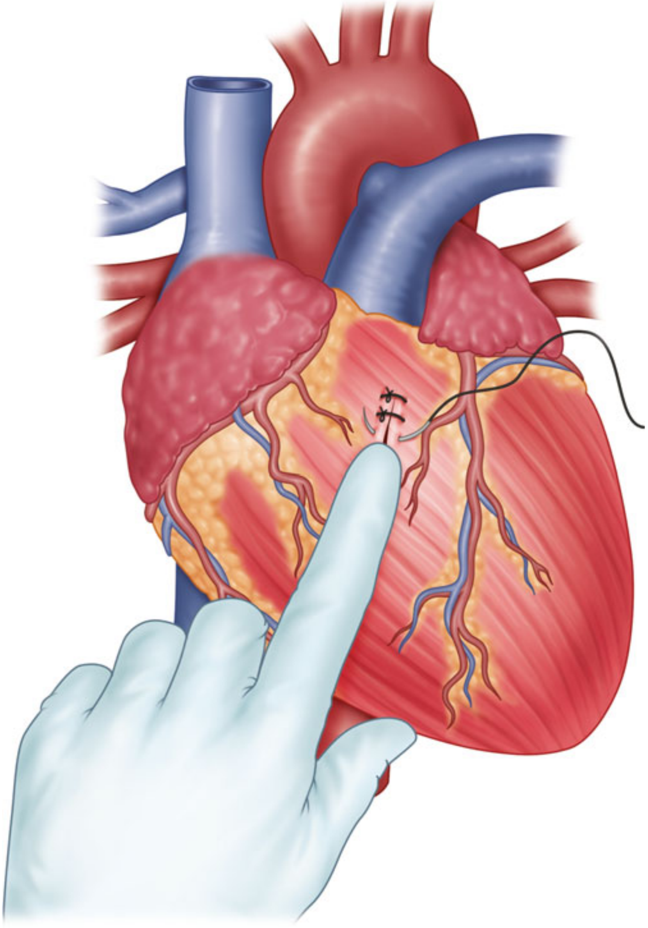

Fig. 28.4 Injuries may be controlled with direct manual pressure and closed with interrupted 3–0 polypropylene suture

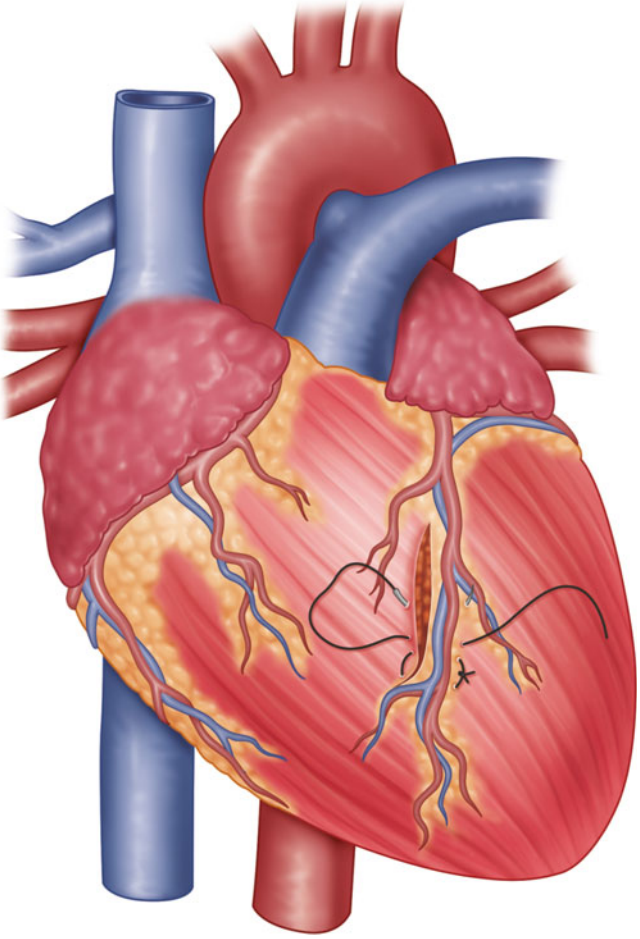

Fig. 28.6 Lacerations in close proximity to coronary vessels can be controlled with horizontal mattress sutures passed beneath the artery to avoid coronary arterial compression

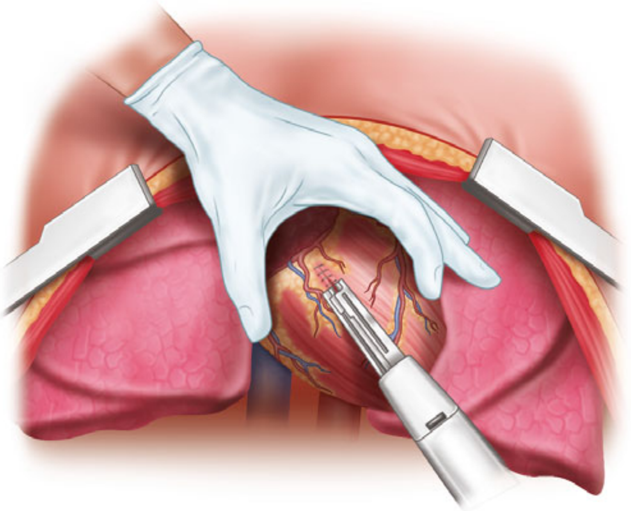

Fig. 28.5 A surgical skin stapler is a quick way to gain initial control of simple cardiac lacerations with minimal risk to the provider

28.5 Complications

- Cardiac and/or pulmonary laceration during entry into the chest
- Bleeding
- Delayed hemorrhage (failure to control internal mammary artery, disruption of sutures or staples)
- Infections: empyema and sternal infection
- Missed intracardiac valvular or septal injury (echocardiography should be performed after repair is complete)
- Air embolus

28.6 Pearls and Pitfalls

- Pearls
  - There may be more than one wound to the heart (especially with gunshot wounds). Look for them. However, if the wound is posterior and not bleeding with the heart in its natural position, it will be more prudent to leave the injury alone until the patient can be transported to the operating room. Elevating the heart can cause both inflow and outflow obstruction, leading to dysrhythmia that may be difficult to recover from.
  - To avoid sutures pulling through in patients with thin, edematous, or friable myocardium, consider horizontal mattress rather than simple sutures. These may be buttressed with Teflon pledgets for added security.
- Pitfalls
  - The myocardium tears easily. When tying sutures, take care to not tighten them too forcefully.

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Synchronized Electrical Cardioversion

29

Jason Jones, Ann Tsung, and Marie-Carmelle Elie

Tachycardia is defined as >100 beats per minute

29.1 Indications

- Non-sinus-rhythm tachycardias with a pulse including:
  - Atrial fibrillation
  - Atrial flutter
  - Monomorphic ventricular tachycardia (VT)
  - Refractory or unstable supraventricular tachycardia (SVT)
- Unstable signs and symptoms including acute coronary syndrome, decreased level of consciousness, chest pain, dyspnea, pulmonary edema, and hypotension

29.2 Contraindications

- Absolute
  - Ventricular fibrillation and pulseless or polymorphic (irregular) VT require unsynchronized electrical cardioversion (defibrillation), not synchronized cardioversion.
  - Known atrial thrombus.
  - Sinus tachycardia.
- Relative
  - Digitalis toxicity-related tachycardia
  - Atrial fibrillation of greater than 48 h duration without anticoagulation
  - Multifocal atrial tachycardia
  - Electrolyte abnormalities
  - Left atrial diameter greater than 4.5 cm
  - Patients with low probability of maintaining sinus rhythm and readily return to atrial fibrillation
  - Patients with sick sinus syndrome or sinoatrial blockage who will require a pacemaker for maintenance of stable rhythm

29.3 Materials and Medications

- Airway management equipment (laryngoscopes, endotracheal tubes)
- Cardiac monitoring, pulse oximetry, end-tidal CO_2 monitoring
- Cardioverter/defibrillator
- Sedation and analgesic medications

29.4 Procedure

1. Obtain a 12-lead electrocardiogram (ECG) and intravenous (IV) access.
2. If possible, correct underlying electrolyte abnormalities that may cause or contribute to the patient's arrhythmia.
3. Discuss risks, benefits, and alternatives (including pharmacological cardioversion) with the patient and obtain consent.
4. Prepare airway equipment and Advanced Cardiac Life Support (ACLS) code drugs.
5. Consider IV sedation (e.g., propofol, midazolam).
6. Provide IV analgesia (e.g., fentanyl, morphine).
7. Place defibrillator adhesive pads (8- to 12-cm diameter in adults) or paddles on the patient. Pediatric-sized pads/paddles should be used if the patient is less than 10 kg.

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8. The first paddle/pad is placed to the right of the sternum at the second/third intercostal space. The second paddle/pad can be placed in one of two equally efficacious positions:
    (a) Anterolateral position—left fourth/fifth intercostal space in the midaxillary line (Fig. 29.1)
    (b) Anteroposterior position—between the spine and the edge of the left scapula (Fig. 29.2)
9. Turn the defibrillator/cardioverter into synchronized mode—marker above R-waves will be present (Fig. 29.3).
10. Select the energy level to be delivered based on the underlying rhythm
    (a) Regular VT (with pulses)—Adults: 100 J (monophasic or biphasic), 200 J for subsequent shocks
    (b) Atrial fibrillation—120–200 J (biphasic), 200 J (monophasic), 360 J for subsequent shocks
    (c) Atrial flutter and paroxysmal SVT—50–100 J (biphasic), 100 J for subsequent shocks
    (d) Pediatric dosage (regular and pulsed VT or SVT)—0.5–1 J/kg, up to 2 J/kg for subsequent shocks (Fig. 29.4)
11. Announce that you are going to deliver the shock on the count of three, and ensure that everyone is clear of the patient.
12. Deliver the shock by pressing button marked "SHOCK."
    - If using paddles, apply firm pressure and keep paddles in place until shock is delivered.
13. Reassess the patient's pulse and cardiac rhythm.
14. Repeat with escalating energy in a stepwise fashion if cardioversion is unsuccessful.

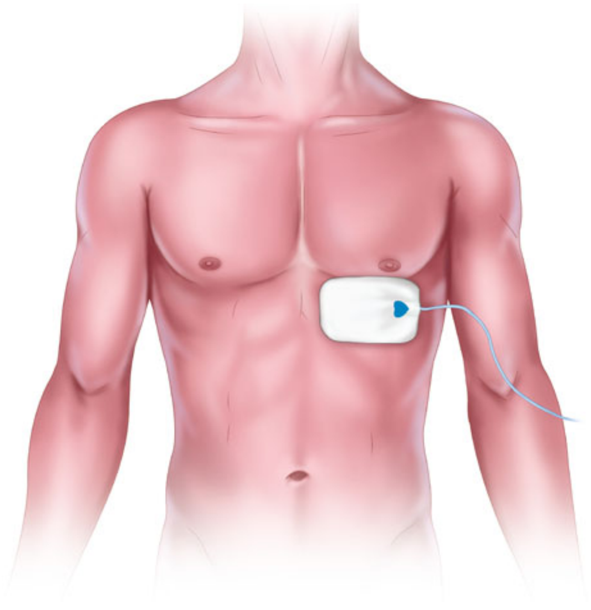

Fig. 29.1 Anterolateral pad placement

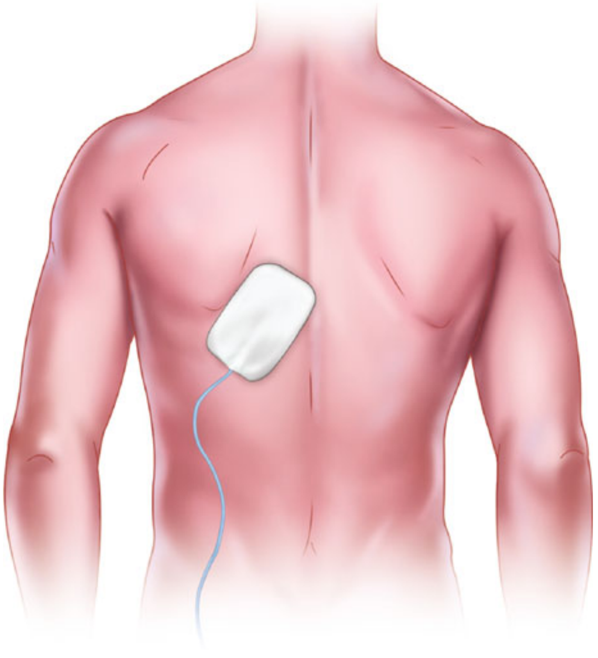

Fig. 29.2 Anteroposterior pad placement

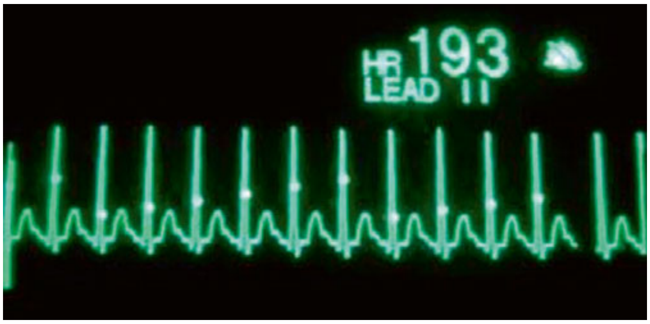

Fig. 29.3 Synchronized cardioversion—mark on R wave

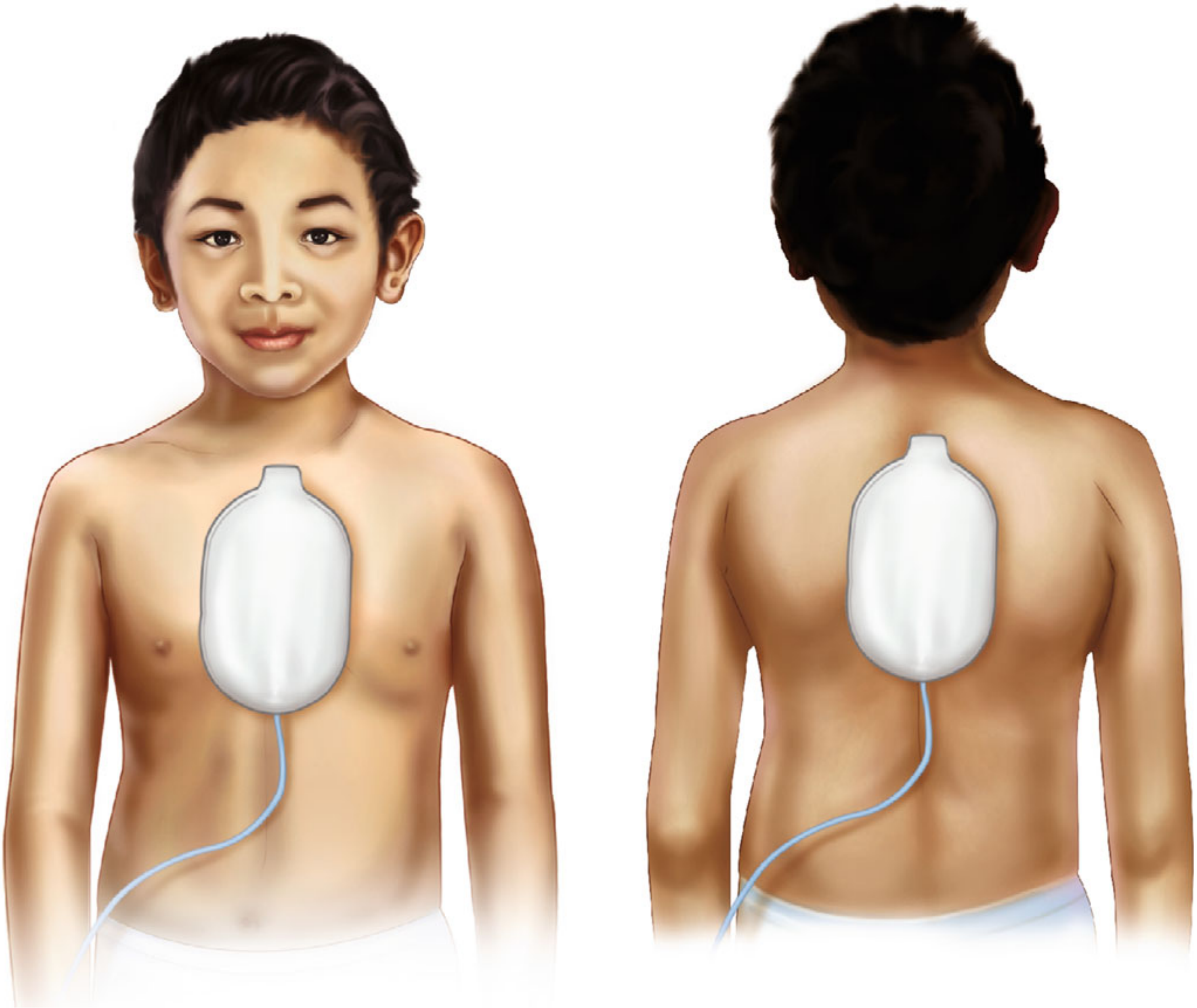

Fig. 29.4 Pediatric pad placement

29.5 Complications

- Superficial burns if there is inadequate gel.
- Induced arrhythmias (bradycardia in patients with previous inferior myocardial infarction, atrioventricular block, VT, ventricular fibrillation, asystole).
- Improperly synched cardioversion may rarely induce ventricular fibrillation.
  - Ectopy of the atria or ventricle in first 30 min after cardioversion
  - Atrial clot embolization in patients without adequate anticoagulation
- Apnea, hypoxia, hypercarbia, or hypotension may occur from sedation/analgesia.
- Medical professionals who incidentally touch the patient during shock delivery may be shocked or burned.
- Rarely, fire has occurred as a consequence of poor pad placement and a hyperoxygenated environment.

29.6 Pearls and Pitfalls

- Hirsute males should be shaved at the pad/paddle placement sites.
- Placing the cardioverter in "synchronized" mode avoids delivering a shock during the relative refractory segment, which could induce ventricular fibrillation.
- Cardioversion of pregnant patients is performed as in the general adult population.
- Keep pacemakers and implantable cardioverter-defibrillators at least 10 cm away from contact with paddles.
- If patient has implanted pacemaker, position pads so that they are not directly over the device.

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Unsynchronized Cardioversion (Defibrillation)

30

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Unsynchronized cardioversion or defibrillation is the delivery of a *high-energy* shock as soon as the button is pushed on defibrillator. This means it can be delivered anywhere in the cardiac cycle. By contrast, synchronized cardioversion (see Chap. 29) delivers a low-energy shock at the peak of the R wave in the cardiac (QRS) cycle.

30.1 Indications

- Ventricular fibrillation (VF)
- Pulseless ventricular tachycardia (VT)
- Cardiac arrest due to or resulting from VF

30.2 Contraindications

- Absolute
  - Conscious patient
  - Presence of a pulse
  - Pulseless electrical activity (PEA)
  - Asystole
  - Multifocal atrial tachycardia
  - Defibrillation without knowing the rhythm
  - A second defibrillation before 2 min (or five cycles) of CPR
  - Advanced Directive, Physician Order for Life-Sustaining Treatment (POLST) indicating no cardiopulmonary resuscitation (CPR) or do not resuscitate (DNR)
- Relative
  - Potential electrical catastrophe (explosive environment [i.e., operating rooms])
  - Dysrhythmias due to enhanced automaticity such as in digitalis toxicity and catecholamine-induced arrhythmia (because mechanism of tachycardia remains after the shock)
- Factors that are not contraindications
  - Pregnancy.
  - Chest trauma.
  - Automatic implantable cardiac defibrillators (AICDs).
  - The patient is on a wet or moist surface.
  - Piercings on the chest.

30.3 Materials and Medications

- Electrocardiogram (ECG) monitor/defibrillator.
- Self-adhesive defibrillation pads or defibrillation paddles (paddles may be more successful than self-adhesive pads, but they have more complications and pose more danger to operators).
- Conductive gel for defibrillation paddles (not ultra sound gel).
- ECG electrodes.
- Supplemental oxygen.
- Intubation equipment as needed.

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30.4 Procedure

Defibrillation is an emergent maneuver and, when necessary, should be promptly performed in conjunction with or before administration of induction or sedative agents to facilitate intubation.

1. Assess the ABCs (airway, breathing, circulation).
   - Open the airway with a head tilt/chin lift (or jaw thrust in a suspected traumatic patient). If the patient is apneic, provide breaths with a bag-valve-mask (BVM) and observe chest rise.
   - Check for pulses. If absent, start CPR.
   - CPR should be initiated before any shock while getting all equipment ready for at least 2 min to provide adequate circulation to the brain and heart.
2. Wipe off the patient's chest if moist or wet.
3. Remove transdermal patches, jewelry, and piercings if possible.
4. Attach ECG electrodes to the patient.
   - The self-adhesive defibrillation pads or defibrillation paddles can be used as ECG electrodes to access the rhythm.
5. Paddles: With conductive gel applied to the metal surface, place one paddle on the patient's right chest, just below the clavicle, near the sternal border. The other should be on the left chest, midaxillary line above the fifth or sixth intercostal space (Fig. 30.1).
   - The long axis of the paddles should be perpendicular to the ribs to allow for better transduction of current through the chest.
   - Pads: Same placement as paddles except that pads can be placed in any orientation as long as they are in full contact with the chest.
   - If a lot of breast tissue is present, push the tissue to one side or lift it away and place the paddles or pads underneath.
   - An error in pad or paddle placement can distort the rhythm into looking like a rhythm that does not require defibrillation.
6. Place the ECG monitor/defibrillator into a mode to acquire a rhythm from the pads or paddles.
   - Steps 1–3 can be done simultaneously.
7. Stop CPR and assess the rhythm and pulse for no longer than 10 s.
8. If VF or pulseless VT is observed, then switch the defibrillator to charge mode.
9. Charge to 200 J.
   - Continue CPR while the defibrillator is being charged.
10. When the defibrillator indicates that it is charged, clearly order that everyone stop touching the patient and observe that there is no physical contact before defibrillating the patient.
    - If using the paddles, apply extra force to the chest through the paddles to deflate the lungs to allow for better defibrillation.
    - The operator should observe a muscle twitch during defibrillation.
11. Restart CPR for 2 min or five cycles.
    - Another operator may charge (but not fire) the defibrillator while CPR is being performed to expedite the time between pulse/rhythm check and the initiation of a shock.
12. After 2 min or five cycles of CPR, assess the rhythm and pulse and repeat steps 6–8 and give appropriate Advanced Cardiac Life Support (ACLS) medications.
13. If successful return of spontaneous circulation (ROSC) occurs, initiate the hypothermia protocol per hospital guidelines.

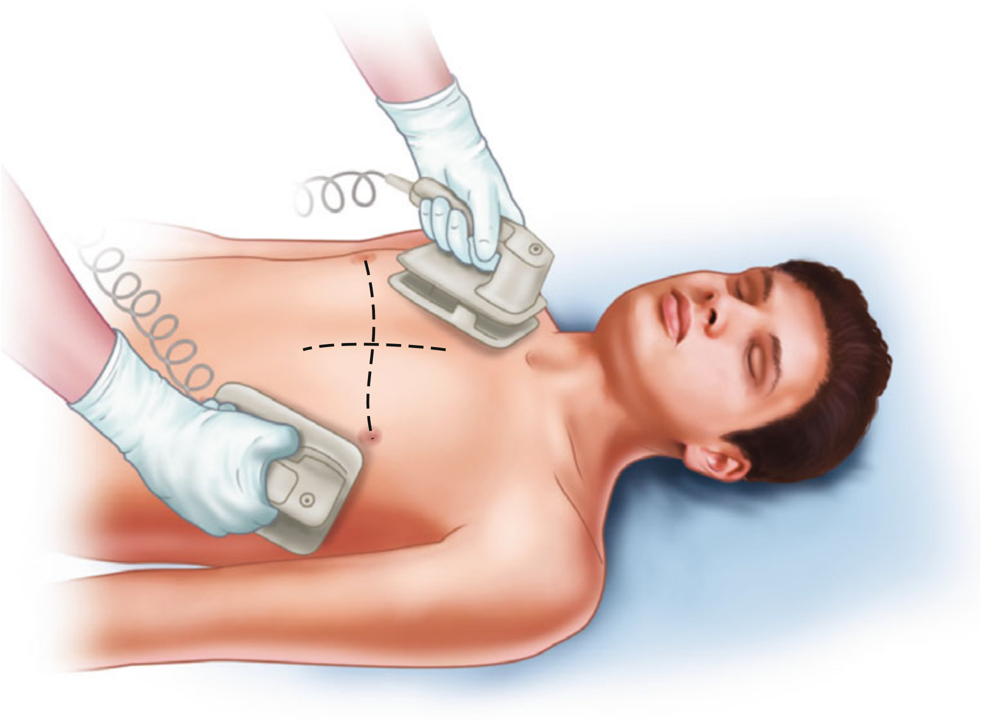

Fig. 30.1 Proper placement of defibrillation paddles

30.5 Complications

- Skin burns (most common and likely due to improper technique).
- Injury to cardiac tissue (myocardial necrosis secondary to burn).
  - ST segment elevation that lasts longer than 2 min usually indicates myocardial injury unrelated to the shock.
- Abnormal heart rhythms (usually benign like atrial, ventricular, and junctional premature beats).

30.6 Pearls and Pitfalls

- Pearls
  - Post-defibrillation cardiac dysrhythmias are more common following prolonged VF and higher-energy-level countershocks. Early defibrillation at the recommended energy levels minimizes this complication. Follow ACLS protocols to manage the resulting dysrhythmias.
  - The presence of liquid (body fluids, medications, or intravenous fluids) may cause electrical arcing thermal burns to the skin and soft tissue and produce ineffective defibrillation by allowing the current to pass across the trunk rather than transthoracically. To minimize this potential complication, ensure that any body fluids or liquids are wiped away from the skin before defibrillation attempts.
- Pitfalls
  - Myocardial and epicardial injury (not direct thermal injury) may result from the electrical current applied in defibrillation. Use the minimal recommended energy levels to minimize injury.
  - Electrical injuries to health-care providers can result if participants remain in contact with the patient during delivery of a countershock because they can serve as a ground for the current discharged.
    - This can be minimized by wearing gloves and using biphasic machines and electrode pads.
  - Fires that can result from sparks in the presence of nitroglycerin patches or ointment, flammable gases, or an oxygen-rich environment can also be a source of injury to the patient or health-care providers. Ensure “all clear” from the patient before delivery of shock to avoid these complications.

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31 Transcutaneous Pacing

Nour Rifai and Christian Coletti

31.1 Indications

- Hemodynamically unstable (i.e., hypotension, pulmonary edema, chest pain, shortness of breath, or evidence of decreased cerebral perfusion) bradyarrhythmias refractory to medical therapies
- As a bridge to a transvenous or permanent pacemaker
- As an overdrive pacer in tachyarrhythmias
- Controversially, within the first 10 min of a witnessed asystolic cardiac arrest
- In children only with bradycardia associated with a known congenital cardiac defect or after cardiac surgery

31.2 Contraindications

- Absolute
  - None
- Relative
  - Bradyarrhythmia associated with hypothermia (ventricles are more prone to defibrillation-resistant fibrillation)
  - Prolonged cardiac arrest (>20 min)
  - Bradyarrhythmia in children (usually secondary to hypoxia or a respiratory issue)
  - Patient is unable to tolerate the procedure despite sedation and analgesia

31.3 Materials and Medications

- Pacemaker device (modern units offer combined pacer and defibrillator functions) (Fig. 31.1)
- One set of standard electrocardiogram (ECG) electrodes
- One set of pacer pads
- Code cart and airway equipment (prophylactically)
- Sedation and analgesia (typically a short-acting benzodiazepine and an opioid)
  - Midazolam: 0.2–0.10 mg/kg intravenous (IV) push and may repeat with 25 % of initial dose after 3–5 min. Do not exceed 2.5 mg/dose or a cumulative dose of 5 mg.
  - Fentanyl: 1–2 mcg/kg IV slow push over 1–2 min, may repeat dose in 30 min. (Fentanyl is the opioid of choice because it is less likely to exacerbate any hypotension.)

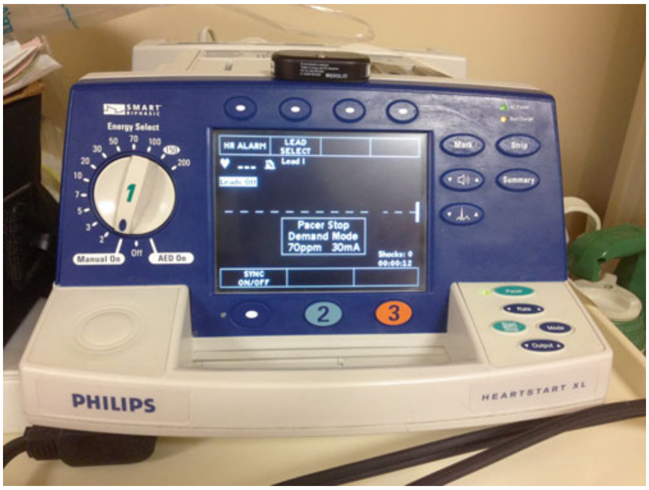

Fig. 31.1 Pacemaker device

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31.4 Procedure

1. Time permitting, clean and dry the skin, and shave any excess hair off the chest.
2. Administer any appropriate sedation and analgesia.
3. Attach the ECG electrodes to both the input port of the pacemaker unit and the patient. On the patient, the white lead is placed just above the right clavicle, the black lead is just above the left clavicle, and the red lead is around the left midaxillary line.
4. Attach the pacer pads either in the anteroposterior or anterolateral positions as pictured (avoid placement over an implanted pacemaker or defibrillator; Fig. 31.2).
5. Turn the machine on and switch it to synchronous (or on-demand) mode.
    - Asynchronous (or fixed) mode fires impulses with no regard to the intrinsic cardiac cycle, increasing the likelihood of an R on T phenomenon, which could result in ventricular tachycardia or fibrillation.
    - Synchronous (or on-demand) mode will not fire an electrical impulse when a QRS complex is sensed; this is the preferred mode for transcutaneous pacing.
6. Set the desired heart rate: typically 60–80 beats/min to achieve adequate perfusion.
7. Select a lead on the pacemaker unit and then press Start.
8. Slowly increase the output current until electrical capture is denoted by a visible pacemaker spike, which will precede every QRS complex on the ECG monitor (Fig. 31.3).
    - Electrical capture is usually achieved between 50 and 100 mA.
    - If a patient is unconscious or truly deteriorating quickly or in cardiac arrest, it may be prudent to set the initial currents at maximum to ensure rapid capture and then decrease the current to just above that at which electrical capture was achieved.
9. After electrical capture is appreciated on the monitor, assess for mechanical capture by palpation of a pulse at a rate that corresponds to that which the machine is set at. An improved blood pressure or resolution of chest pain, shortness of breath, or altered mental status also suggests that the heart rate has improved and perfusion has been restored.
10. When pacing in overdrive for tachyarrhythmias, the pacer rate is set 20–60 beats/min faster than the detected tachycardic rate.
    - Bear in mind that rhythm acceleration or the induction of ventricular fibrillation is a possibility with pacing, hence the recommendation of having a code cart and airway equipment in the room at all times.

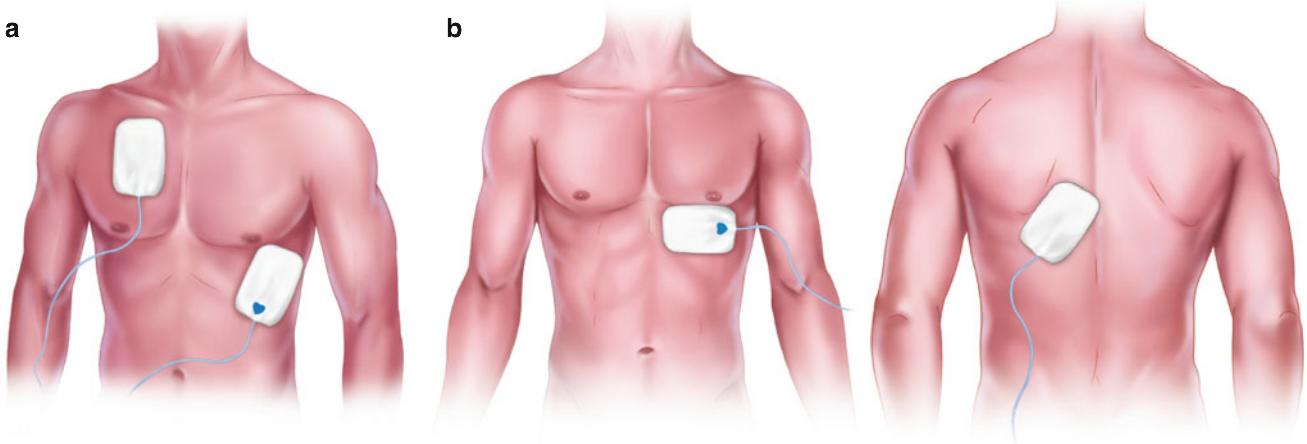

Fig. 31.2 Pacer pads attached in the anterolateral (**a**) or anteroposterior positions (**b**)

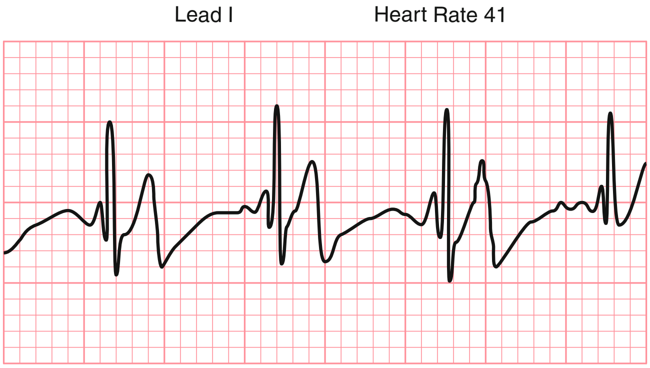
Lead I
Heart Rate 41

Bradycardia prepacing attempt

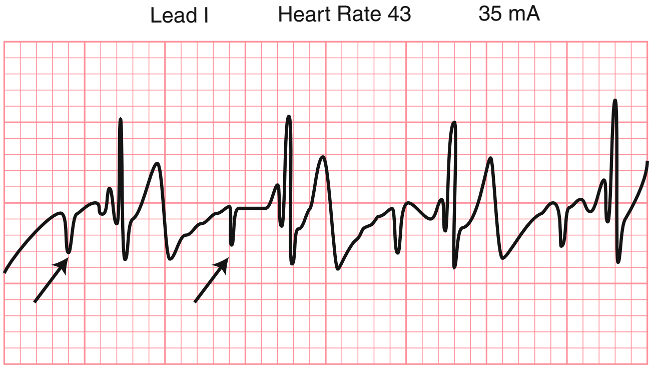
Lead I
Heart Rate 43
35 mA

Pacing attempted, note pacing stimulus indicator (arrow) which is below threshold, no capture

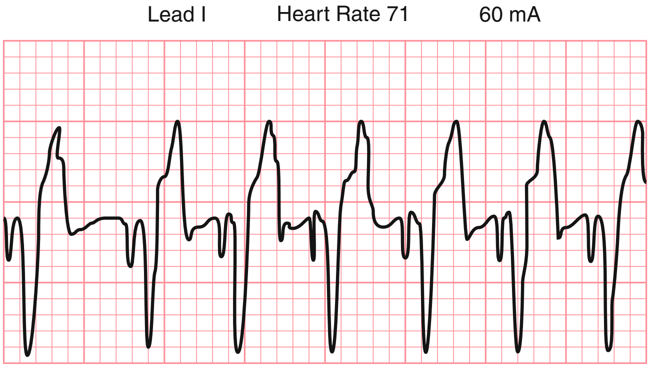
Lead I
Heart Rate 71
60 mA

Pacing above threshold (60mA), with capture (QRS complex broad and ventricular, T wave opposite QRS)

Fig. 31.3 A visible pacemaker spike will precede every QRS complex on the ECG monitor

31.5 Pearls and Pitfalls

- Pearls
  - Pacer pads can be prophylactically placed on bradycardic but stable patients in preparation for potential decompensation.
  - It may be prudent to discuss with a stable but bradycardic patient the option of trying the pacemaker not only to ensure that the machine and pads are working but also to gauge an idea of the output current that will be needed to electrically capture for quicker, more efficient, and potentially lifesaving pacing that may prove necessary.
  - When palpating for mechanical capture, the femoral pulse may be easier because carotid palpation may prove difficult with muscular contractions induced by the pacer impulses.
  - If impulses are not capturing, try slightly readjusting the pacer pads, making sure the leads are still on, the settings were not changed, the machine's battery did not die, or that the machine is plugged in.
  - If electrical capture is achieved but mechanical is not, increase the rate until adequate pulses are palpated.
  - Be careful to not miss an underlying ventricular fibrillation if the monitor is not blanked or dampened by an ECG screen.
  - Cardiopulmonary resuscitation (CPR) can be continued even while transcutaneous pacing is taking place because the pacer pads are insulated and the power delivered in each impulse is minimal, making the risk of injury to health-care workers very low.
- Pitfalls
  - Certain factors including a large body habitus, the presence of large pericardial effusions, scarring secondary to intrathoracic surgeries, or large amounts of intrathoracic air associated with obstructive pulmonary diseases may not only increase the threshold for capture but also may even cause a failure to capture, in which case transvenous pacing should immediately be considered.
  - Be aware that long-term pacing and pacing in children increases the likelihood for cutaneous and soft tissue damage.

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Transvenous Cardiac Pacing

32

Katrina John, Jeffrey Kile, and Amish Aghera

32.1 Indications

Hemodynamic compromise in the presence of:

- Sinus node dysfunction
- Second- and third-degree heart block
- Atrial fibrillation with slow ventricular response
- New left bundle branch block (LBBB)
- Right bundle branch block (RBBB)
- Bifascicular block
- Alternating bundle branch block (BBB)
- Implanted pacemaker malfunction

32.2 Contraindications

- Absolute
  - Prosthetic tricuspid valve
- Relative
  - Bradycardia in the presence of severe hypothermia

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32.3 Materials and Medications (Fig. 32.1)

- Sterile gloves
- Sterile gown and drapes
- Face mask and surgical cap
- Two 10-mL syringes
- One 3-mL syringe
- Local anesthetic (1 or 2 % lidocaine without epinephrine)
- 22-gauge needle
- Povidone-iodine or chlorhexidine/isopropyl alcohol
- Several 4×4-in. gauze sponges
- Sterile dressing pack
- 4-0 nylon or silk sutures
- Scalpel (#11 blade)
- Needle holder
- Scissors
- Introducer needle
- Guidewire
- Dilator
- Introducer sheath
- Collapsed sterile extension sheath
- Balloon-tipped pacing catheter
- Pacing generator with working battery
- Insulated cable with alligator clamps or other suitable connectors
- Electrocardiogram (ECG)/cardiac monitor

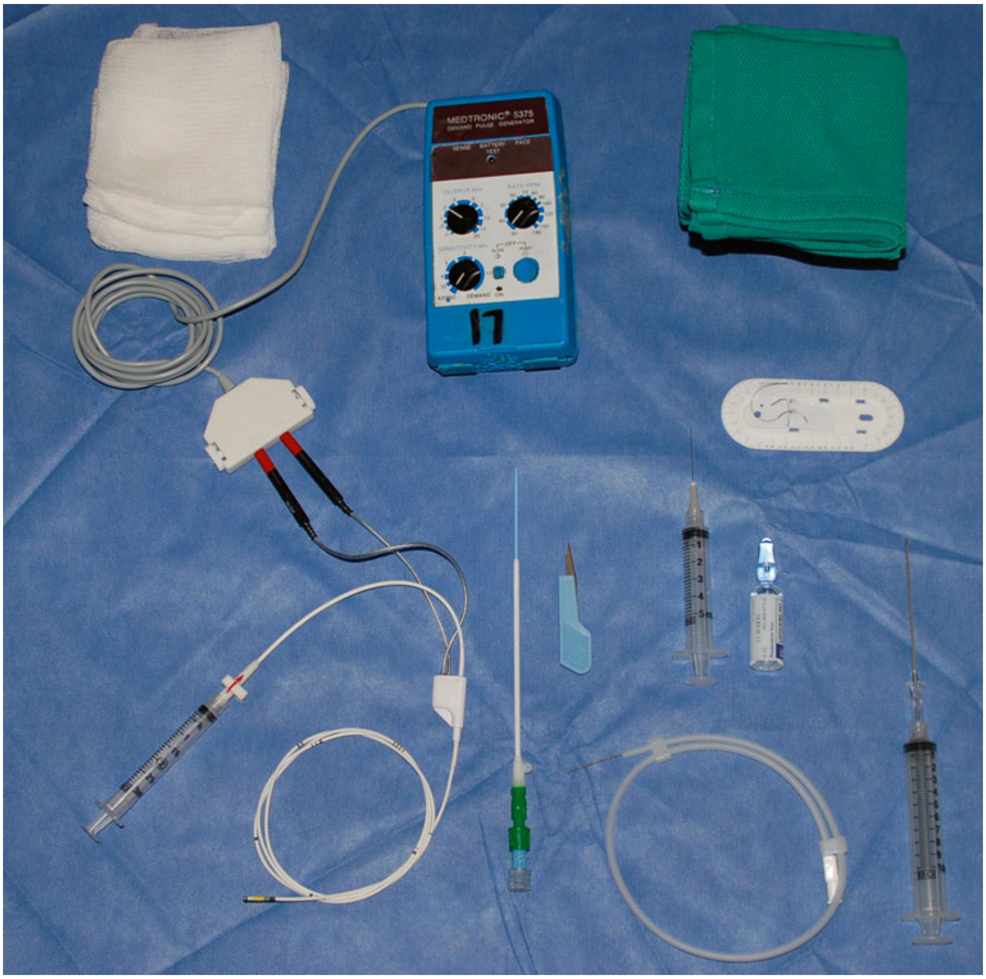

Fig. 32.1 Materials and medications

32.4 Procedure

1. Select appropriate catheterization site.
   - Four sites provide superior access to right atrium: brachial, femoral, internal jugular, and subclavian veins. The right internal jugular and left subclavian veins, respectively, are the most direct routes and, thus, the most commonly used in the emergency department setting.
2. If clinical situation permits, explain the procedure fully to the patient and obtain consent.
3. Sterilize the skin and apply sterile drapes.
4. Anesthetize the intended insertion site with lidocaine.
5. Prepare the pacing wire by inflating and deflating the balloon with 1–1.5 mL of air using a 3-mL syringe, and confirm that locking lever functions correctly to maintain balloon inflation (Fig. 32.2).
6. Using ultrasound guidance by means of a probe covered in a sterile sheath, insert the introducer needle into the vein while applying negative pressure to the attached 10-mL syringe (as with standard central line placement) (Fig. 32.3).
7. When flashback of blood is visualized in the syringe, remove the syringe, stabilizing the introducer needle firmly in place.
8. Pass the guidewire through the needle to a depth of 10–15 cm.
9. Holding the guidewire securely in place, remove the introducing needle.
10. Using a scalpel, make a small incision (approximately the width of the catheter to be used) through the dermis at the insertion site of the guidewire.
    - Avoid severing the guidewire by facing the sharp edge of the scalpel *away* from the guidewire.
11. Pass a dilator over the guidewire to make a tract in the skin and then remove the dilator.
12. Pass the introducer catheter over the guidewire until the hub is in contact with the skin and then remove the guidewire (Fig. 32.4).
13. Attach the collapsible sterile sheath to the hub of the introducer catheter.
14. Attach the positive and negative connectors of the pacing wire to their respective terminals on the cable(s) connected to the generator.
15. Set generator rate at 80 beats/min, output to 5 mA, and sensitivity to 3 mV.
16. Insert the free end of the pacing wire into introducer catheter with the balloon deflated and slowly advance the wire.
17. When the tip of the wire is within the superior vena cava, inflate the balloon, lock the valve to ensure that the balloon remains inflated, and continue to advance the pacing wire.
18. Closely watch the cardiac monitor for signs of capture (i.e., a wide QRS preceded by a pacing spike).
    - Markings on the pacing wire indicate its depth of insertion. At 20 cm, the wire should be in the right ventricle. If there is no capture observed by 25 cm, then the wire should be slowly withdrawn and advanced again.
19. Once capture is achieved, deflate the balloon.
20. Advance the wire a further 1–2 cm.
21. Coil the wire that remains outside the extended sterile sheath and suture it loosely but securely to the skin.
22. Suture the introducer hub to the skin.
23. Reduce generator output to zero and then increase it slowly to determine the minimum pacing threshold (i.e., the minimum voltage at which capture is achieved) and then set the output to twice this value.
24. Set the generator rate.
25. Stabilize the generator near the catheterization site.
    - For example, the generator can be attached to an intravenous (IV) fluid stand to the right of the patient's head if the pacing wire has been placed via the patient's right internal jugular vein.
26. Obtain a chest x-ray to confirm pacing wire position and absence of potential complications (e.g., pneumothorax) (Fig. 32.5).
27. Obtain a 12-lead ECG (Fig. 32.6).

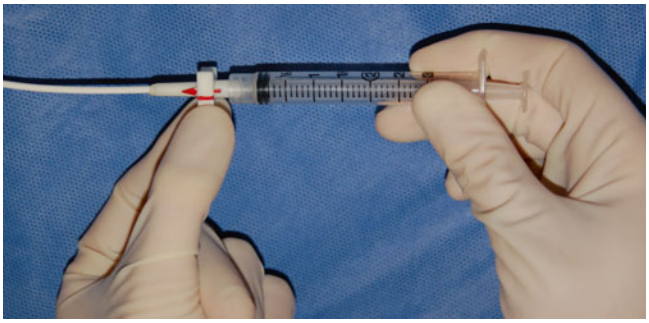

Fig. 32.2 Pacing wire balloon locking lever

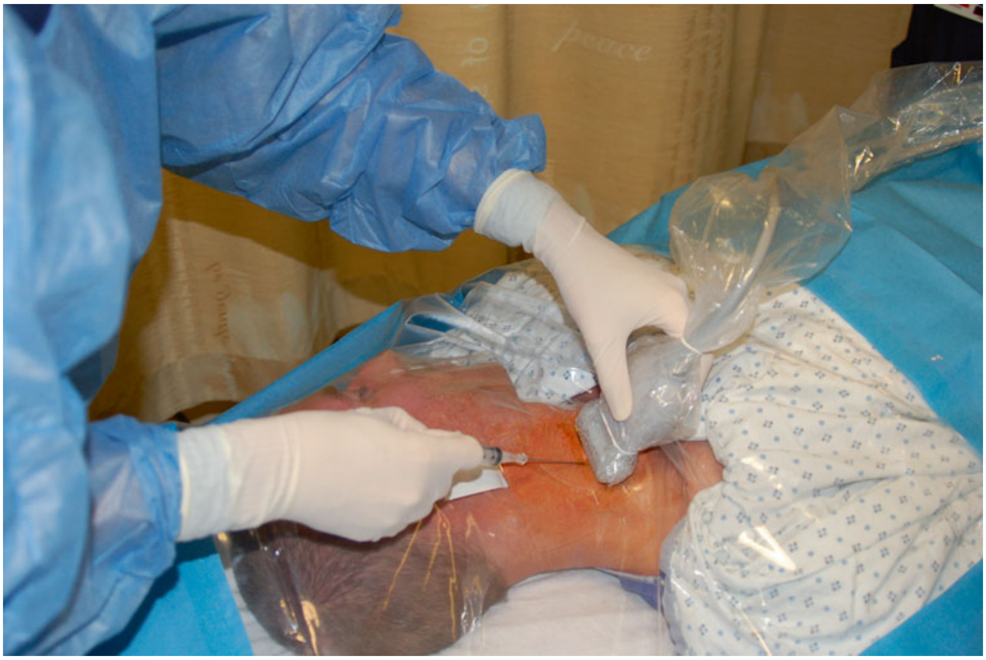

Fig. 32.3 Insertion of introducer needle into internal jugular vein with ultrasound guidance

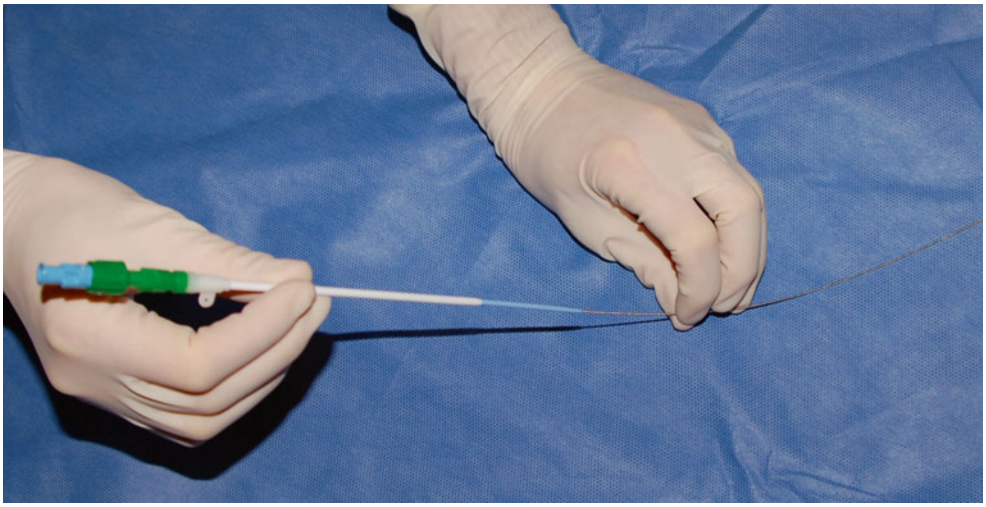

Fig. 32.4 Placement of introducer catheter over guidewire

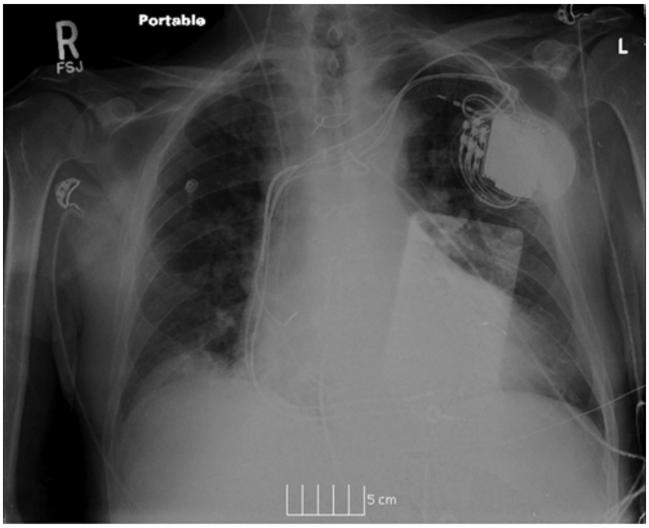

Fig. 32.5 X-ray displaying correct position of pacing wire in the right ventricle

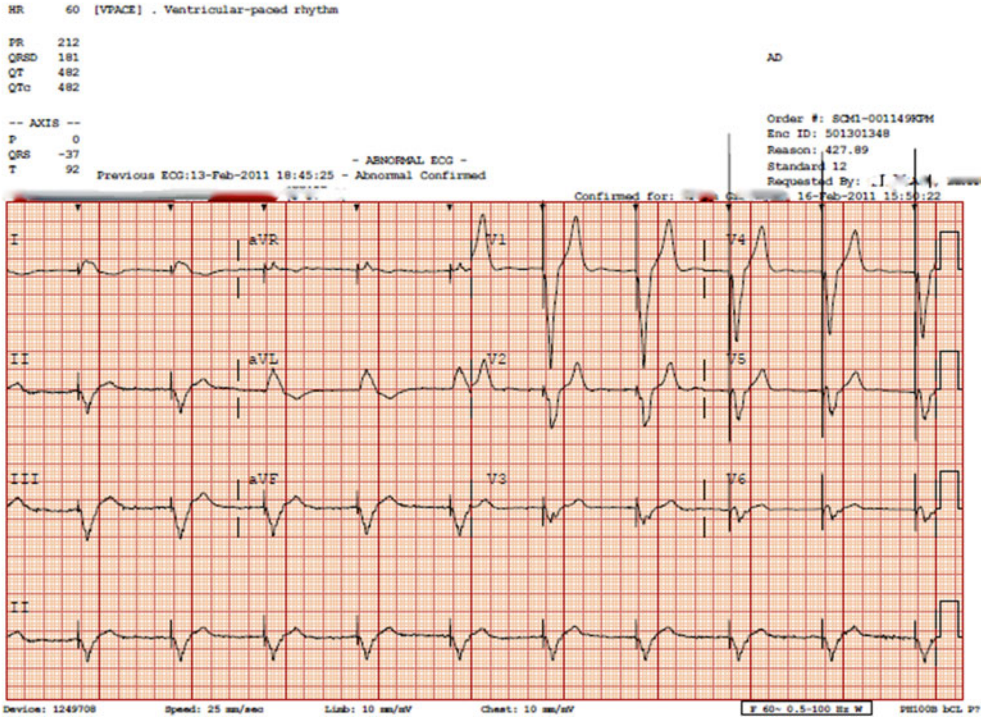

HR 60 [VPACE] . Ventricular-paced rhythm

PR 212
QRSD 181
QT 482
QTc 482

-- AXIS --
P 0
QRS -37
T 92

- ABNORMAL ECG -
Previous ECG:13-Feb-2011 18:45:25 - Abnormal Confirmed

[redacted]

AD

Order #: SCM1-001149KPM
Enc ID: 501301348
Reason: 427.89
Standard 12
Requested By: [redacted]
Confirmed for: [redacted] 16-Feb-2011 15:50:22

Device: 1249708 Speed: 25 mm/sec Limb: 10 mm/mV Chest: 10 mm/mV F 60~ 0.5-100 Hz W PH100B bCL P?

Fig. 32.6 Cardiac monitor displaying wide-complex QRS and pacing spike

32.5 Complications

- Arterial puncture
- Venous thrombosis
- Thrombophlebitis
- Pulmonary embolus
- Pneumothorax
- Fracture of guidewire with embolization
- Hemothorax
- Thoracic duct laceration
- Indwelling line infection (local or systemic)
- Dysrhythmias/premature ventricular contractions (PVCs)
- Insertion of pacing wire into coronary sinus/pulmonary artery
- Left (rather than right) ventricular pacing through atrial septal defect/ventricular septal defect (ASD/VSD)
- Septal perforation
- Ventricular perforation
- Entrapment/twisting of preexisting permanent pacing wires by the temporary pacing wire
- Balloon rupture
- Chordae tendineae rupture
- Pacing wire fractures
- Loss of capture owing to wire displacement or fracture
- Generator failure

32.6 Pearls and Pitfalls

- Confirm all necessary equipment is present and functional before beginning the procedure. If a dedicated transvenous pacing set is unavailable, individual components required (e.g., pacing catheter, connector cables, introducer catheter, guidewire) may need to be "cannibalized" from several different procedure kits in an emergency department.
- Become familiar with the locking valve for the pacing wire balloon before beginning the procedure. This small part is essential for inflating and deflating the balloon but is frequently difficult to adjust owing to stiffness (and all the more so if covered in blood).
- The ideal position for the pacing wire tip is against the diaphragmatic aspect of the right ventricle between its midpoint and its apex. This position is confirmed by development of an LBBB pattern with left axis deviation on the cardiac monitor. If difficulty is encountered achieving this position, the tip of the pacing wire can be moved to the right ventricular outflow tract, where the wire is less stable, but adequate pacing can still be achieved. In this latter position, the threshold will need to be kept relatively high and the monitor should display an LBBB pattern with an inferior axis.
- The use of balloon-tipped catheters enables the catheter tip to be directed with blood flow and its position (and successful capture) to be confirmed with a cardiac monitor. Nonballoon-tipped catheters, however, have typically required insertion with guidance of either constant ECG monitoring or fluoroscopy.

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Pericardiocentesis (Optional: Ultrasound Guidance)

33

Katrina Skoog Nguyen, L. Connor Nickels,
and Rohit Pravin Patel

33.1 Indications

- Treatment of hemodynamic compromise from cardiac tamponade
- To diagnose the cause or presence of a pericardial effusion

33.2 Contraindications

- Absolute
  - Aortic dissection
  - Need for immediate surgery for trauma patients
- Relative
  - Coagulopathy
  - Anticoagulant therapy
  - Thrombocytopenia

33.3 Materials and Medications

- Antiseptic (e.g., Chloraprep)
- 1 % lidocaine
- 25-gauge needle, 5/8-in. long
- 18-gauge catheter-type needle, 1½-nch long
- Syringes (10, 20, and 60 mL)
- Ultrasound (US) machine and cardiac/phased array probe
- Sterile US probe cover
- Cardiac monitor

33.4 Procedure

1. Identify the point of maximal effusion with US. Evaluate for hypoechoic or anechoic (dark) effusion around the heart, between the pericardial sac and the myocardium. A patient with hemodynamic compromise from a pericardial effusion or tamponade will have right ventricular collapse, septal bulging, and dilation of the inferior vena cava. Diastolic collapse of the right ventricular free wall can be absent in elevated right ventricular pressure and right ventricular hypertrophy or in right ventricular infarction.
2. Measure the distance from the skin surface to the effusion border to assess the expected needle depth.
3. Choose the needle trajectory based on the point of maximal effusion in the path with the fewest intervening structures. The most commonly used approaches are left parasternal, apical, and subxiphoid. For complex loculated posterior pericardial effusions, optional techniques such as transatrial and transbronchial may be performed by specialists. These types of loculated effusions can occur in autoimmune diseases, infective pericarditis, after cardiac surgery, and after radiotherapy.
4. Sterile preparation: prepare the skin of the entire lower xiphoid and epigastric area with antiseptic. Prepare the US transducer with a sterile sleeve.
5. Local anesthetic: if the patient is awake, anesthetize the skin and planned route of the needle.
6. Pericardial needle insertion: depends on approach used.

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33.4.1 Subxiphoid Approach (Fig. 33.1)

- The US transducer is placed just inferior to the xiphoid process and left costal margin.
- Insert the needle between the xiphoid process and the left costal margin at a 30–45° angle to the skin.
- Aim for the left shoulder.

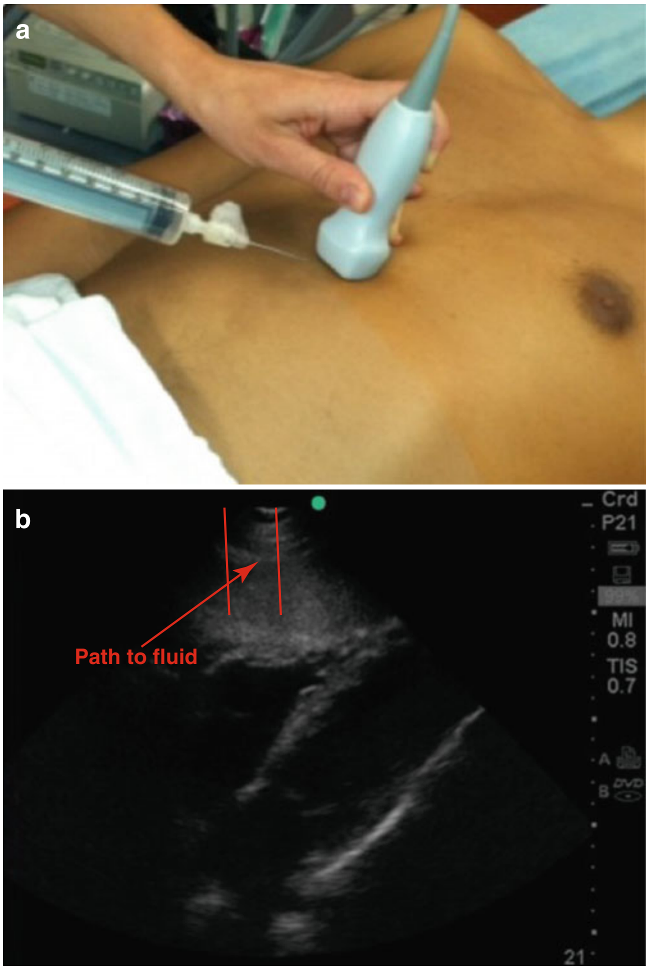
a
b
Path to fluid
Crd
P21
MI
0.8
TIS
0.7
A
B
21

Fig. 33.1 Subcostal approach (**a**) and corresponding ultrasound image (**b**). *Red line* through liver to obtain fluid (no fluid present on ultrasound image)

33.4.2 Apical Approach (Fig. 33.2)

- The US transducer is placed at the patient's point of maximal impulse and aimed at the patient's right shoulder for a four-chamber view of the heart.
- Insert the needle in the fifth intercostal space 1 cm lateral to and below the apical beat, within the area of cardiac dullness.
- Aim for the right shoulder.
- A Mayo Clinic review showed, in 80 % of total effusions, that the distance to the effusion was least and the size was maximal in the apical approach [1].

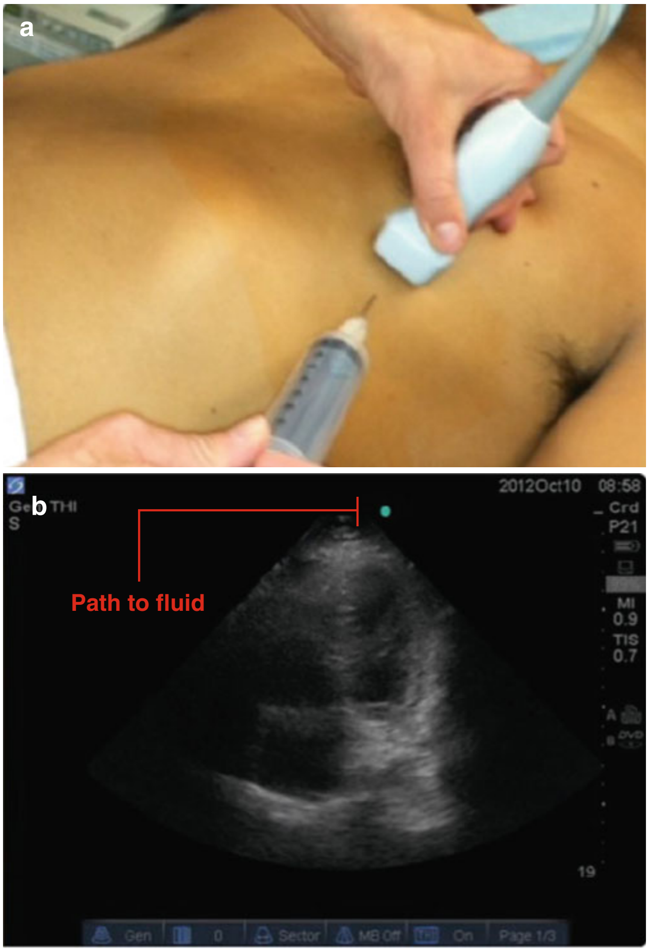
a
b
2012Oct10 08:58
THI
Path to fluid
Crd
P21
MI
0.9
TIS
0.7
A
B
19
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MB Off
On
Page 1/3

Fig. 33.2 Apical approach (**a**) and corresponding ultrasound image (**b**). *Red line* with minimal distance to fluid if present (no fluid present on ultrasound image)

33.4.3 Parasternal Long-Axis Approach

- The US transducer is placed obliquely on the left sternal border between the fourth and fifth ribs with the transducer indicator aimed at the right shoulder.
- Insert the needle perpendicular to the skin in the fifth intercostal space medial to the border of cardiac dullness.
  - Visualize and feel a giving way as the needle penetrates the pericardium. Removal of fluid confirms successful entry. Remove fluid with the goal of restoring hemodynamic stability. Aspiration of fluid should result in improvement in blood pressure and cardiac output.
  - Remove the catheter and apply a dressing. Optional: Place a pigtail catheter using the Seldinger technique for continued drainage.

33.5 Complications

- Blind techniques are associated with 20 % morbidity and 6 % mortality. The complication rate with US-guided approaches is less than 5 % [2].
- Any vital structure within reach of the pericardial needle has the potential for injury: pneumothorax; hemothorax; coronary vessel laceration; hemopericardium; heart chamber lacerations; intercostal vessel injury; dysrhythmias; ventricular tachycardia; puncture of the liver, diaphragm, or gastrointestinal tract; bacteremia; purulent pericarditis; air embolisms; and pleuropericardial fistulas.

33.6 Pearls and Pitfalls

- Pearls
  - A scoring index is available that can be obtained at initial presentation in patients without hemodynamic compromise that identifies those who require pericardial effusion drainage later in the course of treatment. The scoring index uses echocardiographic findings, etiological information, and the size of the effusion at end-diastole [3].
  - Take care to avoid the left internal mammary artery, which travels in a cephalad-to-caudad direction 3–5 cm lateral to the left sternal border [4].
- Pitfalls
  - Tamponade should always be considered in the differential diagnosis of shock or cardiac arrest owing to pulseless electrical activity (PEA). Complications of acute coronary syndrome, aortic dissection, and decompensations in chronic advanced constriction may also need treatment [5].
  - When cardiac compensation mechanisms are exhausted, small increases in pericardial volume can lead to an increase in ventricular diastolic pressure, systemic and pulmonary congestion, and decrease preload and cardiac output.
  - Use US-guidance rather than a blind or an electrocardiogram (ECG)-alone-guided approach for pericardiocentesis to significantly decrease the risk of injury to vital structures [4].
  - Do not delay patient transport to the operating room to perform pericardiocentesis on a traumatically induced effusion unless the patient is hemodynamically unstable and on the verge of cardiac arrest.

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34

Ultrasound Evaluation of Pulmonary Embolism and Heart Strain

Giuliano De Portu, L. Connor Nickels,
and Marie-Carmelle Elie

34.1 Indications

- Undifferentiated respiratory distress
- Unexplained hypotension
- Evaluation for cardiac tamponade, pericardial effusion

34.2 Contraindications

- Relative
  - Morbidly obese patients
  - Patients with chest wall deformities
  - Patient with subcutaneous emphysema, pneumopericardium
  - Combative or altered patients

34.3 Materials and Medications

- Portable ultrasound machine with appropriate probes (phased array)
- Ultrasonic gel for the probe
- Drapes for the patient (if the condition allows)

34.4 Procedure

1. Begin with the parasternal long-axis view. If possible have the patient turn to the left decubitus side (that helps "move" the heart closer the chest wall).
2. Find the phased array probe, select the "cardiac examination" on the machine, and make sure the orientation marker is pointed toward the right shoulder of the patient.
3. Place the probe along the left side of the sternum over the fourth to sixth intercostal space. This should produce the image shown in Fig. 34.1.
4. Measure the diameter of the ventricle during the end of diastole (normal values, 21 mm ± 1 mm; any measurement >25–30 mm is abnormal).
5. Using the aorta as a landmark, evaluate the structures starting with the pericardium (bright white line around the heart), making sure there is no fluid around it. (Fluid above the aorta indicates a pericardial effusion. Fluid below the aorta indicates a pleural effusion.) If a hypoechoic or anechoic stripe appears in the anterior side of the heart, it is most likely a fat pad. Fluid seen "all around" categorizes it as an effusion.
6. While keeping the probe in the same place, rotate the probe marker 90° clockwise toward the left shoulder to obtain the parasternal short-axis view (Fig. 34.2).

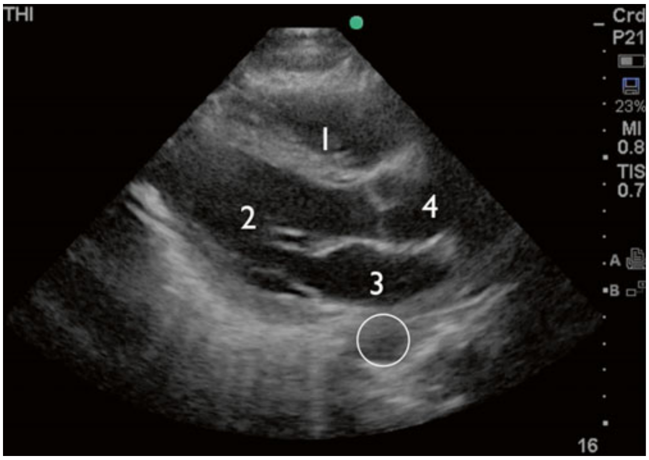

Fig. 34.1 Parasternal long-axis view (PSLA). *1* right ventricle, *2* left ventricle, *3* left atrium, *4* aortic outflow track; *circle* descending aorta (right atrium is not visualized in the PSLA)

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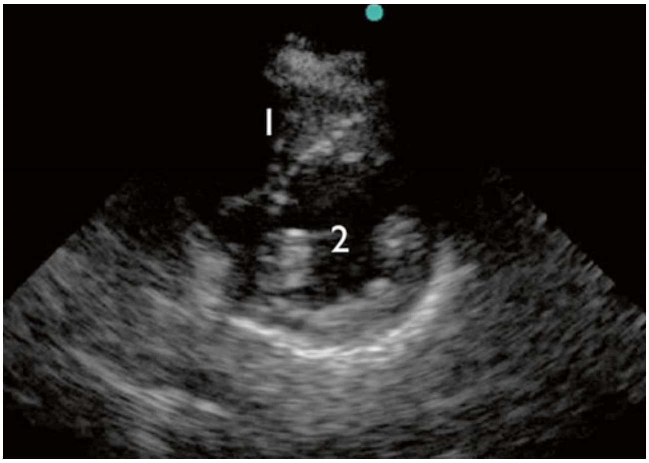

Fig. 34.2 Parasternal short-axis view (PSSA). *1* right ventricle, *2* left ventricle

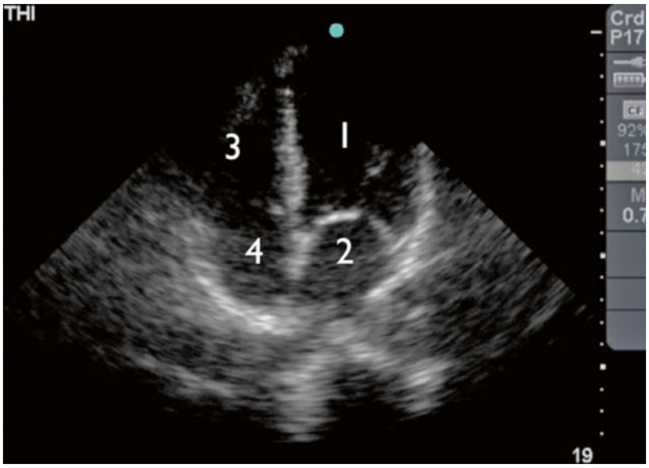

Fig. 34.3 Four-chamber view (4C). *1* left ventricle, *2* left atrium, *3* right ventricle, *4* right atrium

7. The parasternal short-axis view will give information on the contractility of the heart. The right ventricle should be anterior and to the left and the left ventricle to the right. The normal position of the septum bows slightly toward the right ventricle.
8. Obtain a four-chamber view. Place the orientation marker to the patient's left.
9. Palpate for the point of maximum impulse (PMI) and place the transducer. All four chambers should appear in one view (Fig. 34.3).
10. Compare the sizes of the ventricles and note any difference. Notice also the interventricular septum. The normal right-to-left ventricular ratio is less than 0.5. (In an unstable patient, this is probably the most useful because both ventricles can be quickly visualized and the ratio compared.)
11. A subxiphoid approach is also possible. Make sure the orientation marker is toward the right side of the patient (Fig. 34.4).

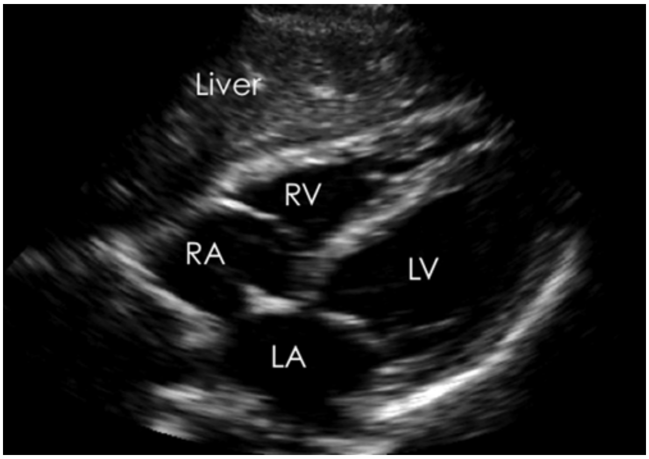

Fig. 34.4 Subcostal/subxiphoid view. *RV* right ventricle, *RA* right atrium, *LV* left ventricle, *LA* left atrium

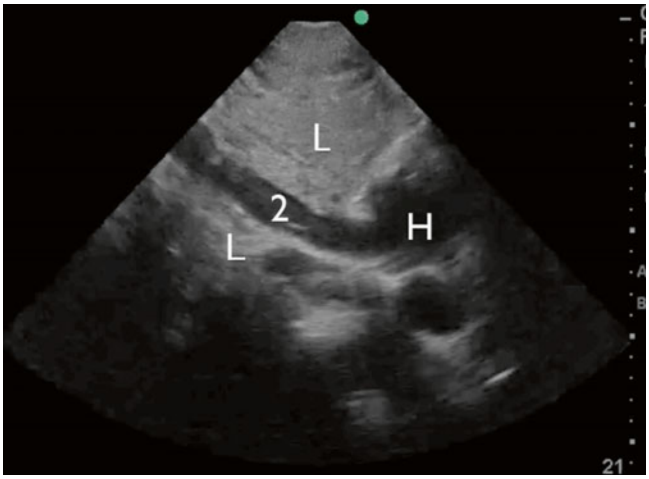

Fig. 34.5 Inferior vena cava. *L* liver, *2* inferior vena cava, *H* heart

12. Use the liver for orientation. The right side of the heart will be nearest to the liver (think that the liver is on the right of the body); again note for any differences in the size ratio.
13. Next take a look at the inferior vena cava (IVC) by placing the curved array transducer just inferior to the xiphoid in a longitudinal fashion. (Switch from the subxiphoid view to the IVC by rotating the probe counterclockwise until the IVC is seen.) Evaluate the IVC. During normal physiological inspiration, the drop in intrathoracic pressure "pulls" blood into the heart, thus decreasing the relative IVC size. If something is preventing venous return, such as a massive PE, collapse will not be as evident and the suspicion for PE increases (fluid overload and increased central venous pressure [CVP] will also account for this finding). Normal IVC diameter is 1.2–2.3 cm, and total collapse and greater than 50 % collapse are normally visualized. An increase in IVC size and less than 50 % or no change has been correlated with increased right atrial pressures (11 to >20 cm Hg) (Fig. 34.5).

34.5 Findings

A right heart that is "strained" or pumping against a higher resistance owing to a PE will show some or all of these changes:

1. Right ventricular dilation (Fig. 34.6).
2. Right ventricular hypokinesis (especially of the middle segment), McConnell's sign but normal motion of the apex.
3. Tricuspid regurgitation.
4. Abnormal septal motion: deviated toward the left ventricle (normally it relaxes during diastole toward the right ventricle); as pressure increases, the right ventricle will not empty properly and septal flattening can be seen.
5. Dilated IVC with little or complete loss of changes in diameter with respiration (variability); the IVC collapses less than 50 % during inspiration.

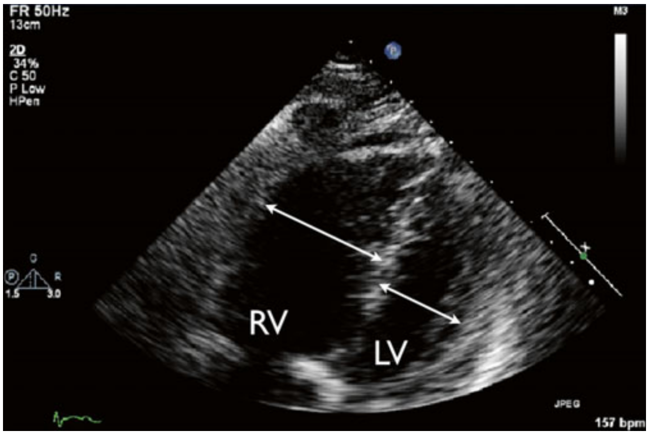

Fig. 34.6 Four-chamber view that shows right ventricular dilatation due to pulmonary embolism. Normally, the LV is greater than the RV during diastole, but in the case of increased pressure, the RV will be enlarged. *RV* right ventricle, *LV* left ventricle

34.6 Complications

- Ultrasound per se has been shown to cause no direct complications with proper use unless it is interfering with advanced airway or life-saving procedures.

34.7 Pearls and Pitfalls

- Pearls
  - Proper interpretation of the images is necessary because some normal anatomy could be confused with a positive finding. Make sure to properly identify the structures because a common mistake is to identify the aorta thinking it is the IVC.
  - Depth: increase to be sure to visualize all structures.
- Pitfalls
  - Ultrasound is user dependent, and the acquisition of images will vary with each user, creating the possibility of false-negatives if images not properly acquired.
  - Reversal of the orientation owing to transducer misplacement could "reverse" the anatomy and allow mistakenly identification of structures.
  - An enlarged right ventricular wall (>5 mm) is considered hypertrophied and would indicate a more chronic etiology of a right ventricular dilation.
  - Gain problems: adjust so the heart chambers are anechoic and the walls are echogenic.

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Pacemaker Evaluation in the Emergency Department

35

Joseph D. Romano and Christian Coletti

35.1 Pacemaker Function

There are approximately 500,000 implanted cardiac pacemakers in the USA and another 100,000 are implanted each year [1]. In the emergency department, a physician may be faced with a pacemaker that is not functioning appropriately. To understand the ways in which a pacemaker can malfunction or lead to medical complications, first it is important to understand how pacemakers work when they do so appropriately.

A common pacemaker system is composed of a pulse generator and insulated wire leads that originate in the pulse generator and end within the myocardium. The pulse generator is implanted in the pectoral region. It contains circuitry and the battery and creates the electrical impulses that depolarize the myocardium. The leads leave the pulse generator and are directed to the heart by following the venous system. Leads may terminate in the right atrium, the interventricular septum of the right ventricle, or biventricular pacing; a third lead navigates the coronary sinus to the left ventricular wall (Figs. 35.1 and 35.2).

Early pacemakers produced impulses only at a set rate. Today, however, virtually all pacemakers have sensing leads that detect intrinsic activity and react with electrical impulses when the intrinsic intervals fall outside of a set time threshold. Some pacemakers are programmed to allow for rate changes based on physical activity. To simplify the classification of different pacemaker types, the North American Society of Pacing and Electrophysiology and British Pacing and Electrophysiology Group (NASPE/BPEG) developed a five-letter code to describe each pacemaker (Table 35.1) [2].

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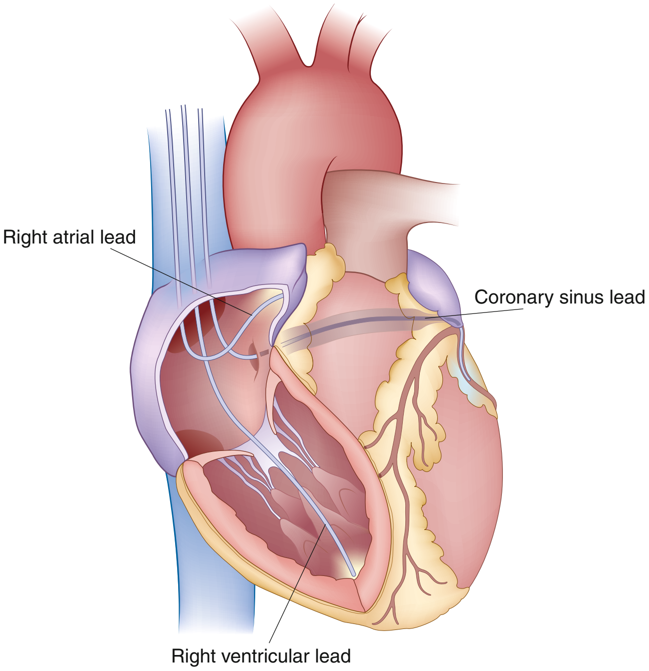
Right atrial lead
Coronary sinus lead
Right ventricular lead

Fig. 35.1 Common pacemaker lead insertion sites

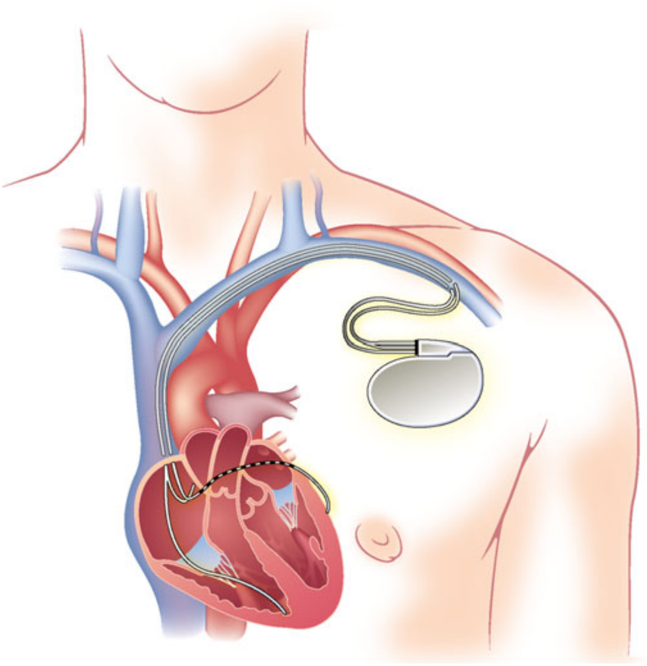

Fig. 35.2 Common generator location and path of pacemaker leads

Table 35.1 NASPE/BPEG five-letter pacemaker code

Paced chamber	Sensed chamber	Response to sensing	Rate modulation	Multisite pacing
A = atrium	A = atrium	T = triggered	R = rate modulation	A = atrium
V = ventricle	V = ventricle	I = inhibited	O = none	V = ventricle
D = dual	D = dual	D = dual		D = dual
O = none	O = none	O = none		O = none

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35.2 Common Pacemaker Codes [3]

- VVI: ventricular paced and sensed, inhibited by normal intrinsic pacing; used for patients with a need for pacing if bradycardia occurs
- VVIR: ventricular paced and sensed, inhibited by normal intrinsic pacing; adaptive to changes in intrinsic rate for physically active patients
- DDD: dual-chamber paced and sensed, inhibited by normal intrinsic atrial and ventricular electrical activity; used in third-degree atrioventricular (AV) block to allow for more physiological conduction
- DDDR: dual-chamber paced and sensed, inhibited by normal intrinsic atrial and ventricular electrical activity; adaptive to changes in intrinsic rate; used primarily in sinoatrial (SA) node dysfunction to closely mimic normal, adaptable heart conduction

35.3 Pacemaker Malfunction

Malfunctioning pacemakers can have complicated programming that is best altered after thorough "interrogation" by a trained electrophysiologist. This type of evaluation is beyond the scope of this chapter and, in many clinical settings, subspecialty support is not readily available. In the emergency department, it is vital to stabilize the patient and identify common pacemaker system issues. Pacemaker system malfunctions can be identified as a failure to sense, failure to pace, failure to capture, or pacing at an inappropriate rate [4]. Another common abnormality associated with pacing is the "pacemaker syndrome" [3].

- Failure to sense:
  - Oversensing: The sensor interprets external stimuli as a normal ventricular rate leading to inappropriate inhibition. This may be due to lead fracture, fibrosis of the lead tip, or lead dislodgment. Cross talk is present when the atrial stimulus is sensed on the ventricular lead causing inappropriate inhibition. Oversensing is rarely due to failure of the generator.
  - Undersensing: Present when there is constant pacing despite cardiac activity that has not exceeded threshold. This can be due to low-amplitude intrinsic cardiac activity, lead dislodgment, battery depletion, or metabolic abnormalities.
- Failure to pace:
  - Lack of pacing despite appropriate sensing of the intrinsic electrical activity or activity below the threshold rate.
  - Typically caused by lead fracture, battery depletion, or fibrosis of the lead tip.
  - It is rare for any specific part of the device to fail, but suspicion should be high if the patient had recent radiation therapy, electrocautery, defibrillation, electroshock therapy, magnetic resonance imaging (MRI), lithotripsy, or transcutaneous electrical nerve stimulation (TENS) treatments.
  - Rarely due to battery depletion.
- Failure to capture:
  - A lack of cardiac response despite appropriate sensing and subsequent pacer stimuli.
  - Commonly due to lead dislodgement, but can be due to myocardial perforation, lead fracture, fibrosis of the lead tip, poor lead placement, battery depletion, and antiarrhythmic medications.
  - Functional failure to capture occurs when pacer stimuli fall within the refractory period of previous depolarization.
- Pacing at an inappropriate rate:
  - Likely due to an endless-loop reentry tachycardia known as pacemaker-mediated tachycardia.
    - More common in DDD pacemakers.
    - Initiated by a premature ventricular stimulus, which is carried retrograde through the intrinsic conduction system to the atrioventricular node (AVN) and then the atria. This conduction is sensed by the atrial lead and causes triggering of pacing back in the ventricle. The ventricular depolarization is then sensed again in the atria, forming a loop. The intrinsic conduction system acts as a retrograde limb and the pacer circuit acts as the anterograde limb of a reentry tachycardia.
- The "pacemaker syndrome":
  - Constellation of symptoms found in 20 % of patients with pacemakers.
  - Symptoms include syncope, near-syncope, dizziness, fatigue, weakness, pain, shortness of breath, and cough.
  - Ventricular rates are poorly timed with atrial activity such that atrial contraction occurs against closed mitral and tricuspid valves.
  - Ventricles lose the benefit of the atrial kick, the atria enlarge, and signs and symptoms similar to congestive heart failure ensue.

35.4 Initial Evaluation of the Patient with a Pacemaker [4]

- History:
  - Symptoms of syncope, near-syncope, chest pain, palpitations, and irritation at the generator pocket
  - Brand and NASPE/BPEG code
  - Date of implantation
  - Location of generator pocket and any previous locations
  - Most recent electrophysiological interrogation
  - Medications that interfere with function, such as flecainide or lidocaine
  - Recent procedures, such as MRI, lithotripsy, or defibrillation
- Physical examination:
  - Check vital signs, listen for heart sounds (paradoxically split S2 is normal).
  - Inspect generator pocket; turning of the leads is associated with Twiddler's syndrome, in which a patient compulsively touches the skin around the device.
  - Look for jugular venous distension.
- Laboratory studies and electrocardiogram (ECG):
  - Obtain a chest x-ray to determine effusions, infiltrates, generator placement, and lead placement or fracture.
  - Electrolyte imbalances must be detected and corrected.
  - ECG: The following are examples of appropriate ECG patterns in patients based on type of pacing [3]:
    - VOO (asynchronous pacing): Regular pacer spikes lead to immediate QRS waveforms. Left bundle branch block (LBBB) is a normal finding in a right ventricular lead location.
    - VVI: Pacer spikes and an LBBB waveform should be seen if the intrinsic rate is below the threshold rate.
    - DDD: Various patterns are possible. If the intrinsic rhythm and intervals are normal, then no pacer spikes will be seen. If the atrial rate is slow and AV delay is normal, then an atrial spike will cause a P wave and a normal QRS. If AV delay is prolonged, then two spikes may be observed: a P wave and a QRS with an LBBB waveform.
- If malfunction is suspected:
  - Obtain intravenous (IV) access, place the patient on a heart monitor, and, if possible, consult cardiology for interrogation and reprogramming.
  - Obtain a ring magnet:
    - Positioning over the generator causes the pacing stimuli to revert to an asynchronous ventricular pacing mode at a set rate [5].

35.5 Interpreting the Type of Malfunction Based on ECG

The first step in evaluating the ECG of a malfunctioning pacemaker is to determine the presence of pacing spikes [6]:

- If pacing spikes are noted on the ECG, determine whether capture is present by ensuring that an appropriate waveform follows each pacer spike and that there is an associated pulse.
  - If capture is present, check the rate:
    - If the rate is appropriate, the pacer is functioning normally.
      - If the rate is slow, suspect oversensing.
      - If the rate is rapid, suspect undersensing or pacemaker-mediated tachycardia.
  - If capture is not present, consider metabolic effects or component failure.
- If pacing spikes are not noted on the ECG, determine whether the patient is in an intrinsic rhythm:
  - If the patient is in an intrinsic rhythm and the rate is appropriate, application of a ring magnet will cause pacer spikes to show up at a set rate. This is normal functioning.
    - If application of the magnet does not cause pacing, suspect mechanical failure.
  - If the patient is not in an intrinsic rhythm, place a magnet over the generator.
    - If magnet application causes pacing, consider oversensing.
    - If it does not, consider mechanical failure.
- If a patient is hemodynamically unstable and application of a magnet leads to stability, keep the magnet in place until the patient is able to have the pacemaker interrogated.

35.6 Management of Pacemaker-Mediated Tachycardia

- After ensuring adequate IV access, placing a heart monitor, and interpreting a baseline ECG, put a ring magnet over the generator [5].
  - If a normal rhythm results, keep the magnet on the chest.
  - If it does not change the rate, attempt isometric pectoral exercises by having the patient press the left hand against the right shoulder.
    - This is an attempt to overstimulate the pacemaker sensor and precipitate inhibition of pacer output.
    - If this is unsuccessful, consider transcutaneous pacing.
    - If transcutaneous pacing is unsuccessful, then the leads may require surgical adjustment or removal.

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Part V

Spine Evaluation

36 Cervical Collar Placement

Justin Bennett and Lars K. Beattie

The cervical spine (C-spine) accounts for the majority of all spinal injuries. In the US prehospital setting, patients are often transported using cervical collars (C-collars) and rigid backboards in trauma and when spinal cord injuries are suspected. After airway, breathing, and circulation, every effort must be made to secure the C-spine.

There are two main subcategories of C-collars: the one-piece and the two-piece. One-piece C-collars include the Stifneck and the Ambu Perfit. Two-piece C-collars have posterior and anterior pieces, with the anterior piece usually the larger of the two. Examples of two-piece collars include the Aspen collar, the Philadelphia collar, and the Miami J collar. The basic features of a C-collar include:

- Adjustable circumference with fasteners (usually Velcro straps)
- Adjustable height with a locking device of different sizes
- Hooks for a nasal cannula
- Exposure of the anterior neck for pulse checks and advanced airway procedures
- Posterior access for cervical palpation
- Padding to protect the soft tissues of the neck

36.1 Indications

- Prehospital suspicion for spine trauma:
  - Emergency department patients or trauma patients who fail clinical rule-out criteria such as NEXUS (National Emergency X-Radiography Utilization Study) and Canadian C-spine rules (see Chap. 37)

36.2 Contraindications

- Absolute:
  - Cervical dislocation with fixed angulation
  - Impaled foreign object in the neck
  - Massive soft tissue swelling in the neck
- Relative:
  - Unsecured airway
  - Surgical airway
  - Vomiting
  - Mandible or soft tissue injuries with potential for airway compromise
  - Preexisting anatomical abnormalities

36.3 Materials and Medications

- Properly fitting C-collar
- Consider:
  - Head blocks, if needed for lateral stabilization
  - Towels or backboard pads for custom support
    - Under shoulders – pediatric patients
    - Under occiput – adults with poor C-spine mobility

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36.4 Procedure (Aspen Collar)

1. Address airway, breathing, and circulation while maintaining in-line immobilization, before placing a C-collar.
2. Gather personnel:
   - (a) One person is needed to apply the collar to an awake patient.
   - (b) Two or more people may be required when a patient has an altered level of consciousness:
     - (i) One to maintain in-line immobilization in the neutral position
     - (ii) One to place the C-collar
3. While the C-spine is being held in neutral position, assess the airway before placing the C-collar:
   - (a) Anticipate and prepare for airway compromise early to avoid a crash intubation.
   - (b) Place airway if necessary.
4. Palpate and inspect the C-spine, head, and shoulders for evidence of trauma *before* placing the C-collar.
5. While maintaining the neutral position of the C-spine, place the C-collar:
   - (a) Remove loose clothing, jewelry, and earrings that may cause soft tissue pressure wounds.
   - (b) Begin with the piece of C-collar that fits under the occiput (Fig. 36.1).
   - (c) Fold the Velcro straps behind the C-collar.
   - (d) Gently hold back the hair (Fig. 36.2).
   - (e) Slide the occipital section or piece of the C-collar behind the occiput (Fig. 36.3). (Use in-line C-spine stabilization in patients with an altered level of consciousness.)
   - (f) Wrap (one-piece) or place (two-piece) the anterior section of the C-collar around the circumference of the patient's neck and snugly under the chin (Fig. 36.4).
   - (g) Once the Velcro fasteners are in place, ensure that the height is properly adjusted on the C-collar to minimize C-spine mobility.
     - (i) Most C-collars have height adjustments that utilize a locking device that requires releasing a locking mechanism by pulling out.

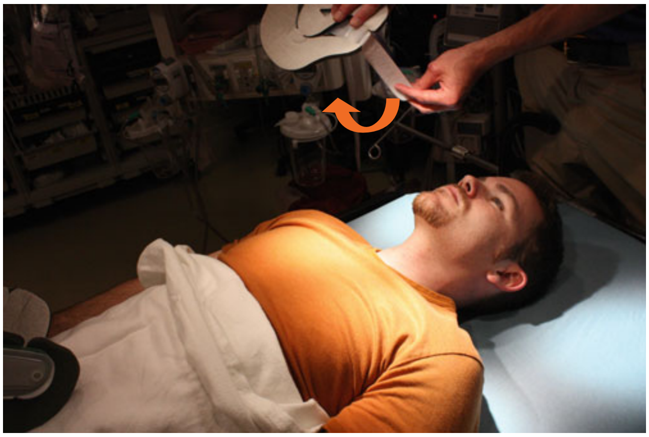

Fig. 36.1 Fold Velcro strap of C-collar posteriorly

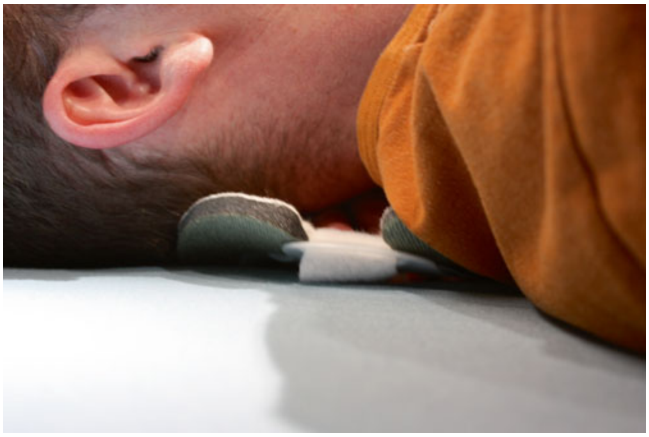

Fig. 36.2 Slide occipital section of collar behind occiput flat against stretcher

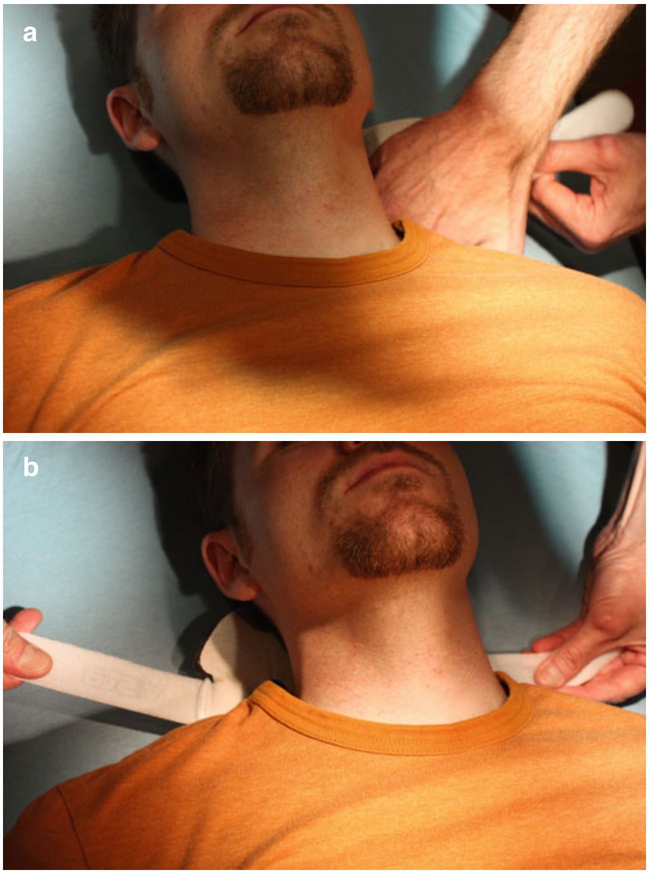

Fig. 36.3 (**a**) Use of hand to guide C-collar behind occiput; (**b**) unfold Velcro strap and position collar behind cervical spine

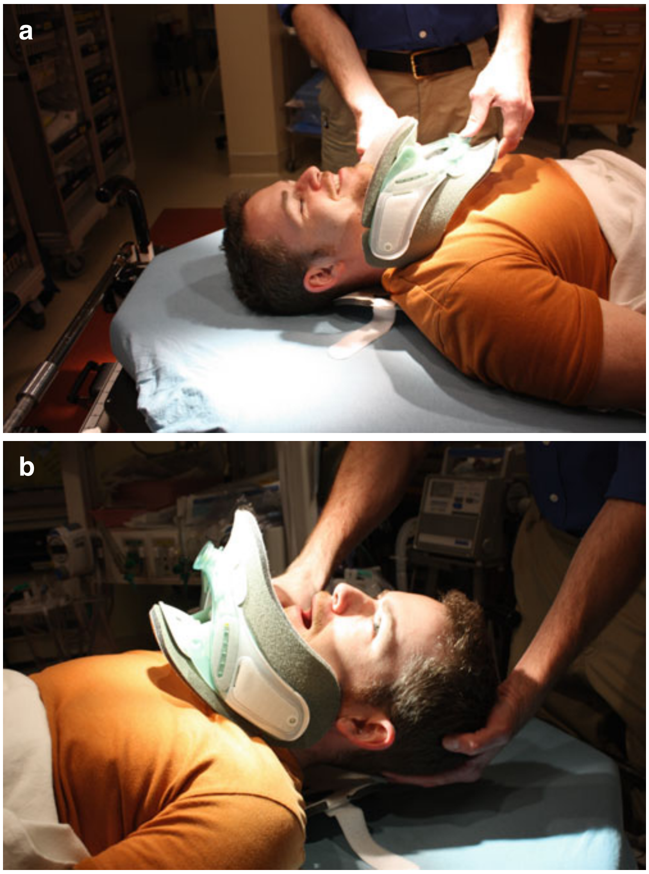

Fig. 36.4 (**a**) Correct orientation of anterior portion of C-collar; (**b**) incorrect orientation of anterior portion of C-collar may cause injury

    (ii) The Aspen collar is adjusted with a combination of pulling out while twisting a round knob at the sternal notch (Fig. 36.5).
    (iii) Pull out (away from patient) and twist for height adjustment of the Aspen two-piece collar.
    (iv) Adjust the height of the Ambu Perfit one-piece collar by simultaneously pulling (away from the patient) the two locking pins out and adjusting the height of the collar before pushing the pins back in (toward the patient) to lock the collar at the desired height (Fig. 36.6).

6. Special cases:
   (a) Depending on the age of the patient, it may be necessary to place towels under the shoulder blades to keep the neck in a neutral position.
   (b) Children:
      (i) Head-to-body ratios are relatively larger than that of adults.
      (ii) Placement on a backboard may cause significant neck flexion because the occiput rests on a flat board.
      (iii) Towels can be placed under a child's shoulders to minimize flexion.

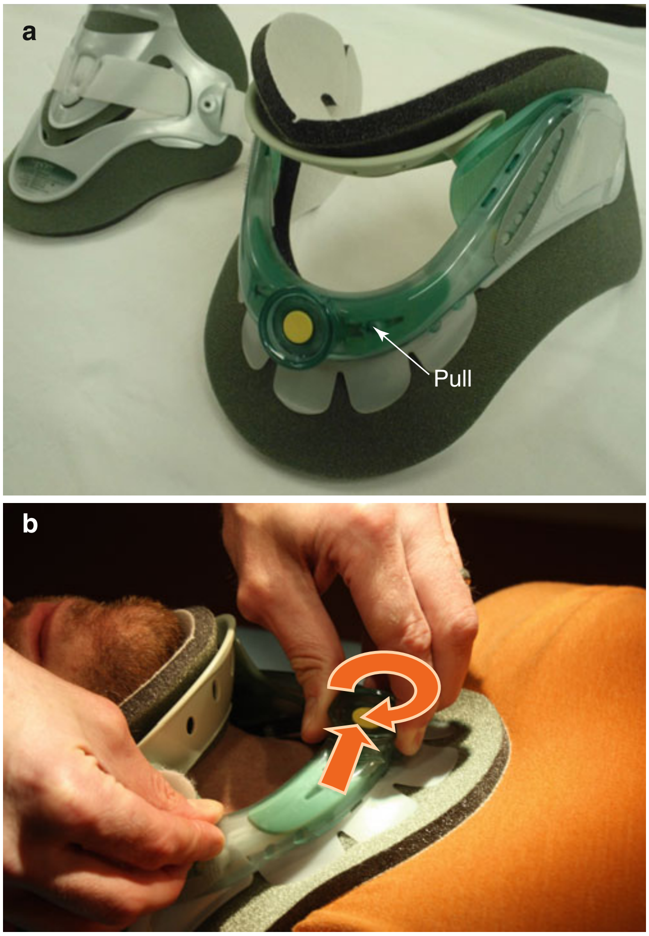

Fig. 36.5 Aspen collar is adjusted with a combination of (**a**) pulling out while (**b**) twisting a round knob at the sternal notch

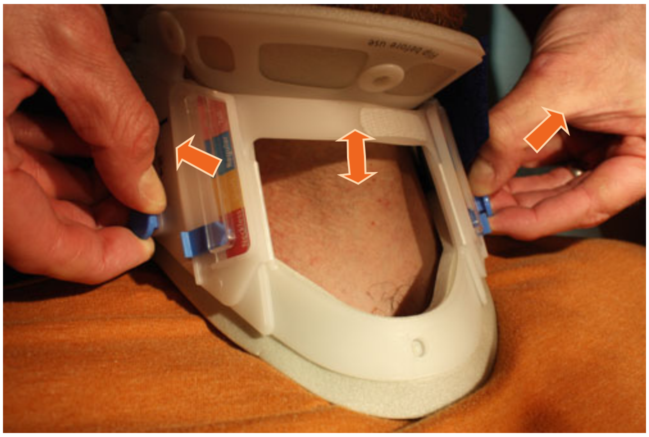

Fig. 36.6 Adjustment the height of the Ambu Perfit one-piece collar by simultaneously pulling (away from the patient) the two locking pins out and adjusting the height of the collar before pushing the pins back in (toward the patient) to lock the collar at the desired height

(c) Adults with excess soft tissue or degenerative changes that prevent C-spine straightening:
    (i) A towel or pad is placed behind the occiput to prevent hyperextension.

36.5 Pearls and Pitfalls

- Pearls
  - Airway, breathing, and circulation should be assessed before placement of the C-collar.
  - A high index of suspicion of C-spine injury is needed in intoxicated or comatose patients and the elderly.
  - Always remember to adjust the height and circumference of a C-collar for a snug fit.
- Pitfalls
  - Spinal immobilization increases the risk of aspiration in vomiting patients.
  - Failure to palpate and inspect the C-spine, head, and shoulders before C-collar placement may delay recognition of an impending airway emergency and conceal signs of critical injury needing rapid assessment and care.
  - Lateral C-spine motion is unsecured unless tape, rubber blocks, or towels are used for support.
  - Overlooking C-spine stabilization during C-collar placement leaves the C-spine at risk of further injury in patients with an altered level of consciousness.
  - C-collars that are too tight may decrease venous return from the head and may increase intracranial pressure.

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Cervical Spine Clearance

37

Braden Hexom and Tatiana Havryliuk

37.1 Indications

- Assessment of the need for radiological imaging in trauma

37.2 Contraindications

- Known unstable cervical spine (C-spine) fracture
- Known unstable ligamentous injury
- Intoxication/altered mental status
- Presence of distracting injury

37.3 National Emergency X-Radiography Utilization Study (NEXUS) and Canadian C-Spine Rules (CCR) to Assess the Need for Imaging

- *The NEXUS clinical criteria*
  1. Tenderness at the posterior midline of the C-spine
  2. Focal neurological deficit
  3. Decreased level of alertness
  4. Evidence of intoxication
  5. Clinically apparent pain that might distract the patient from the pain of a C-spine injury
- The presence of any one of the above findings is considered to be clinical evidence that a patient is at increased risk for C-spine injury and requires radiographic evaluation.
- *CCR*

  For alert (Glasgow Coma Scale [GCS] 15) and stable trauma patients
  1. Any high-risk factor that mandates radiography? *YES → Radiography*
     - Age older than 65 years
     - Dangerous mechanism (Table 37.1)
     - Paresthesias in extremities

     ↓ *NO*
  2. Any low-risk factor that allows safe assessment of range of motion? *NO → Radiography*
     - Simple rear-end motor vehicle crash (MVC)
     - Sitting position in emergency department
     - Ambulatory at any time
     - Delayed onset of neck pain
     - Absence of midline C-spine tenderness

     ↓*YES*
  3. Able to actively rotate neck? *NO → Radiography*
     - 45° left and right

     ↓*ABLE*

     No radiography
- CCR found to have higher sensitivity (99.4 % vs. 90.7 %) and specificity (45.1 % vs. 36.8 %) and a lower rate of imaging (55.9 % vs. 66.6 %) than NEXUS criteria for C-spine clearance of low-risk alert trauma patients.

Table 37.1 Dangerous Mechanism

Fall from elevation ≥3 ft/5 stairs
Axial load to head (e.g., diving)
Motor vehicle crash at high speed (>100 km/h), rollover, ejection
Motorized recreational vehicles
Bicycle crash

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37.4 Type of Imaging

- Bones
  - C-spine computed tomography (CT)—the new gold standard.
  - Plain X-rays—less sensitive than CT; in one study X-rays missed 45 % of injuries that were picked up by CT [1].
- Ligaments
  - C-spine magnetic resonance imaging (MRI)—consider for possible ligamentous injuries and for further evaluation of obtunded patients.
  - Flexion-extension X-rays—less sensitive than MRI for detection of ligamentous injuries in the acute phase. Delayed flexion-extension films are more sensitive for ligamentous injury than those done the day of injury, but less sensitive than MRI.

37.5 Materials

- Cervical collar (C-collar) (Fig. 37.1)

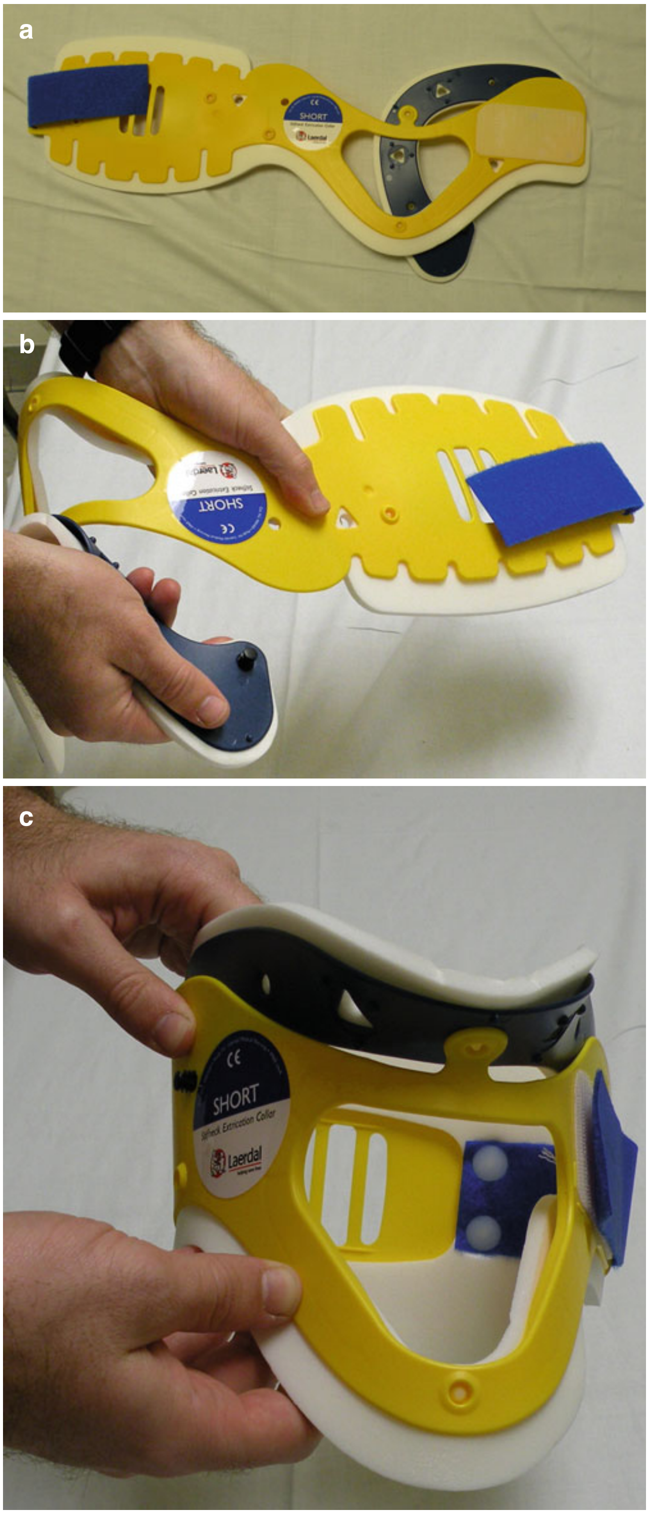

Fig. 37.1 Assembly of C-collar: Select appropriate size (**a**). Invert chinstrap and snap into place (**b**). Assembled C-collar (**c**)

37.6 Procedure (Fig. 37.2)

1. Apply C-collar to stabilize spine. Select appropriate size.
2. Perform a brief neurological examination and assess the patient's mental status; proceed only if both are normal.
3. Loosen the collar to palpate the midline while the patient holds his or her head still. If spinal tenderness exists replace the C-collar and proceed to imaging (Fig. 37.3).
4. Instruct the patient to rotate the neck 45° to each side and flex the neck. If the patient is pain free and with no neurological comprise, the C-collar may be removed and no imaging of the C-spine is required (Fig. 37.4).

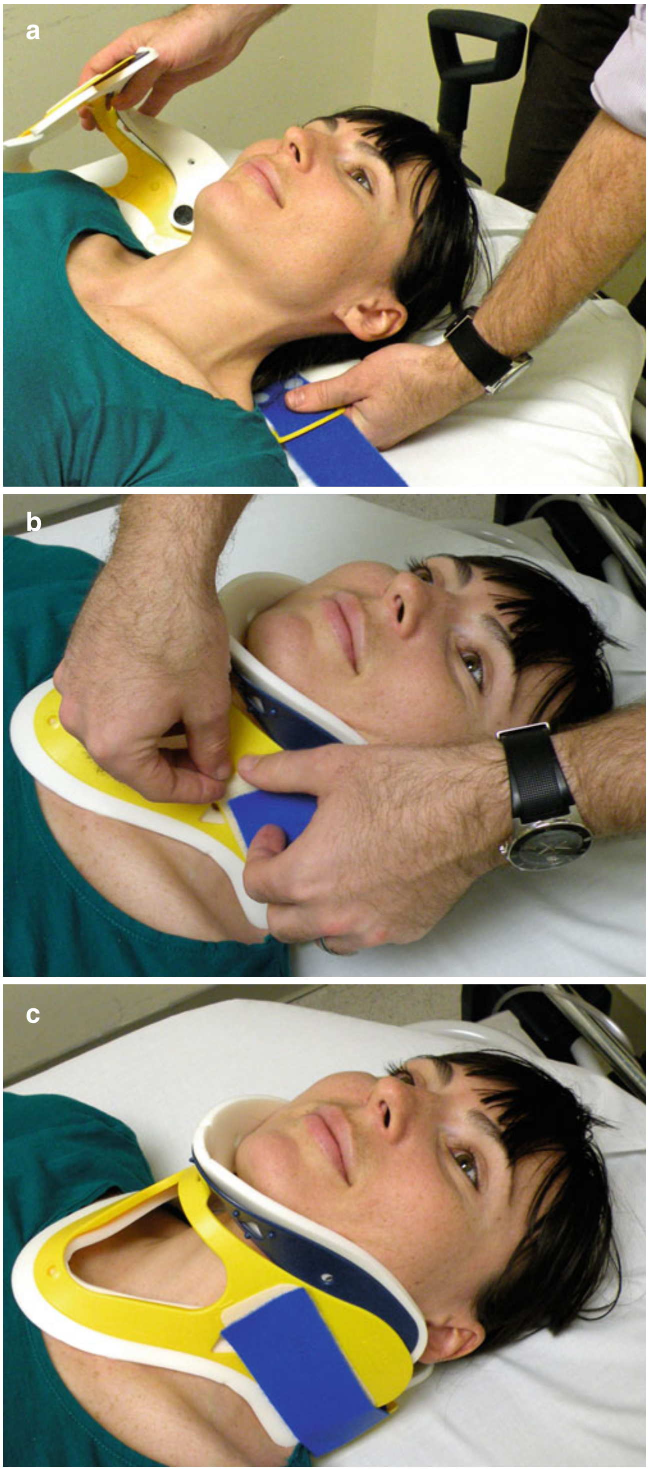

Fig. 37.2 Proper placement of C-collar: Slide C-collar under the neck while keeping neck immobilized (**a**). Secure the collar (**b**). Correct C-collar placement (**c**)

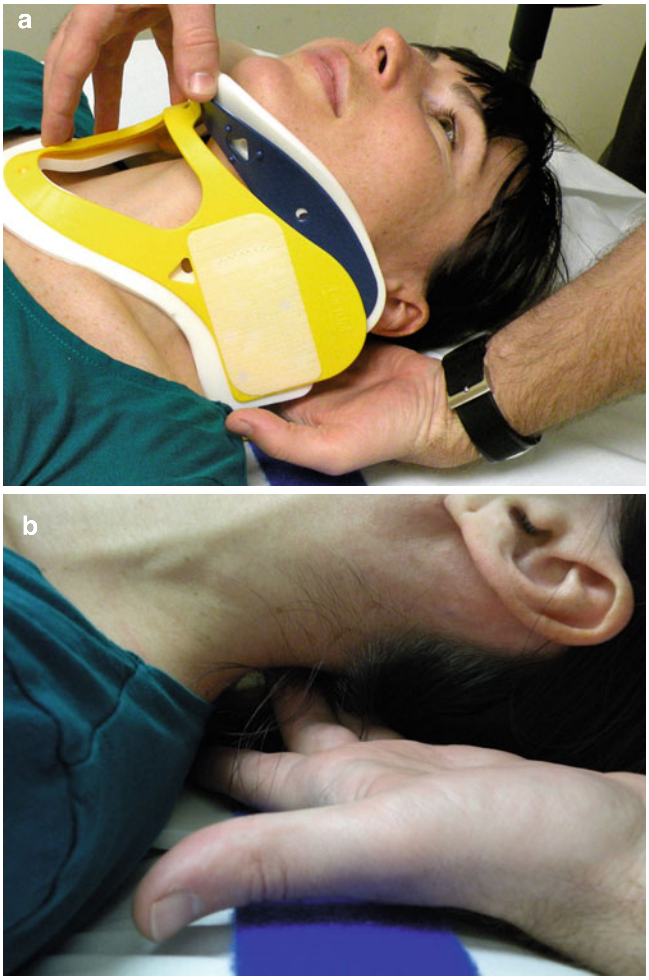

Fig. 37.3 Assessment of C spine tenderness: Loosen C-collar while keeping neck immobilized (**a**). Palpate midline of C spine (**b**)

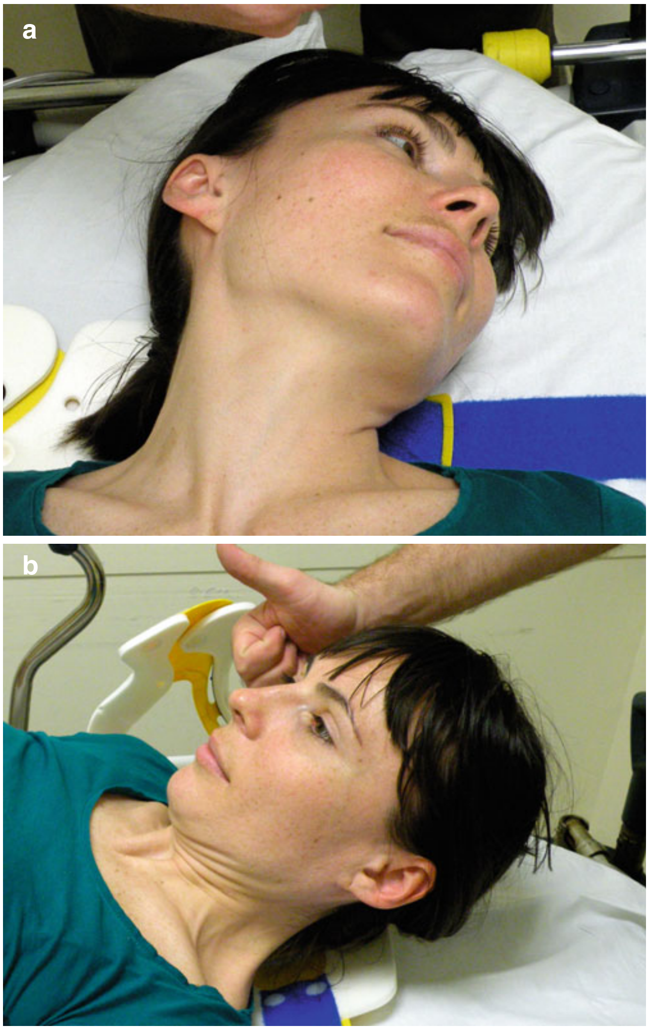

Fig. 37.4 C-spine clearance: Instruct patient to rotate neck 45° each way (**a**). Instruct patient to flex neck (**b**)

37.7 Complications

- Missing clinically important C-spine injury
- Pressure ulcer from prolonged use of C-collar

37.8 Pearls and Pitfalls

- *Pearls*
  - Select appropriate size of C-collar.
  - Ensure adequate mental status because further imaging might be required in obtunded/intoxicated patients.
- *Pitfalls*
  - Avoid prolonged use of C-collar because this can lead to a pressure ulcer.

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Log Roll

38

Justin Bennett and Lars K. Beattie

38.1 Indications

- Any patient arriving on a rigid backboard in the emergency department
- Assessment of posterior traumatic injuries
- Performed as early as possible after arrival to prevent skin breakdown from pressure ulcers

38.2 Contraindications

- Improperly fitted cervical collar (C-collar) or unsecured cervical spine (C-spine) before log roll
- Unsecured endotracheal tube before log-rolling intubated patients

38.3 Materials and Medications

- Personnel: three or four people
  - One to stabilize the C-spine
  - One or two to roll the patient
  - One to palpate the length of the spine
- Properly fitting hard C-collar
- Trauma shears for removing transport straps

38.4 Procedure

1. Ensure that the airway, breathing, and circulation (ABCs) are established before attempting to remove the patient from the backboard.
2. Gather personnel, at least three, but preferably four people. Larger patients will often require additional assistance.
3. For intubated patients an additional person will be needed to secure the endotracheal tube during the log roll.
4. Ensure the height is properly adjusted on the C-collar to minimize C-spine mobility (Fig. 38.1).
5. Position the stretcher at an ergonomic lifting position for the person responsible for stabilizing the C-spine.
6. Clothing and transport straps should be removed before the log roll to improve visualization of injuries.
7. The patient is asked to cross his or her hands over the chest.
8. C-spine stabilization (at head of bed)
   - Grasp the patient's trapezoids at the midclavicular line.
   - Secure the sides of the patient's head between the operator's forearms.
   - Stabilize the patient's head in neutral anatomical position relative to the body using the operator's forearms (Fig. 38.2).

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9. Thoracic and lumbar spine stabilization
   - One or two (preferably two) people should stand next to the patient on the side to which the patient will be rolled.
     - One person: Place hands over the patient's shoulder and hip.
     - Two people
       - First person places hands on the patient's shoulder and hip.
       - Second person places hands on the patient's hip and knees.
   - The decision to roll to the left or right side is determined by injury sites, to minimize injury exacerbation and pain, and to minimize risk of endotracheal tube dislodgment.

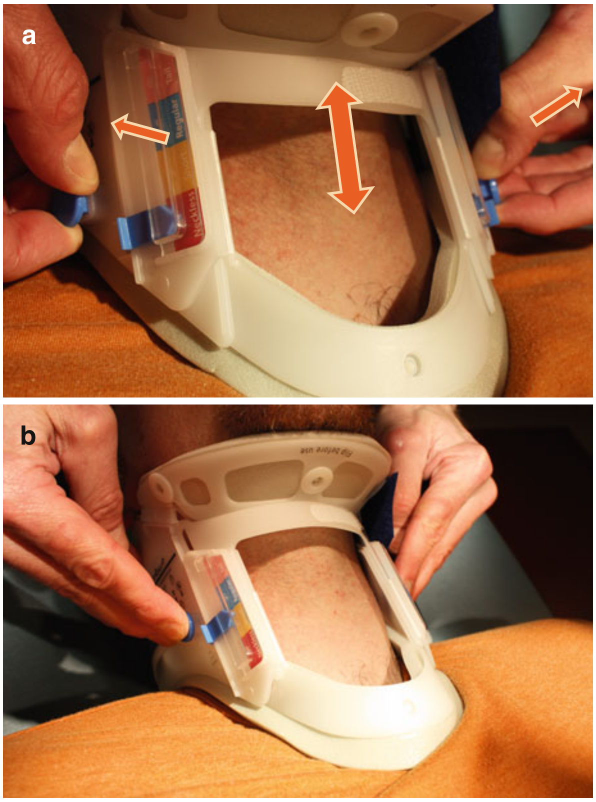

Fig. 38.1 (**a**) The height of the Ambu Perfit one-piece collar is adjusted by simultaneously pulling the two locking pins out (away from the patient) and adjusting the height of the collar, (**b**) then pushing the pins back in (toward the patient) to lock the collar at the desired height

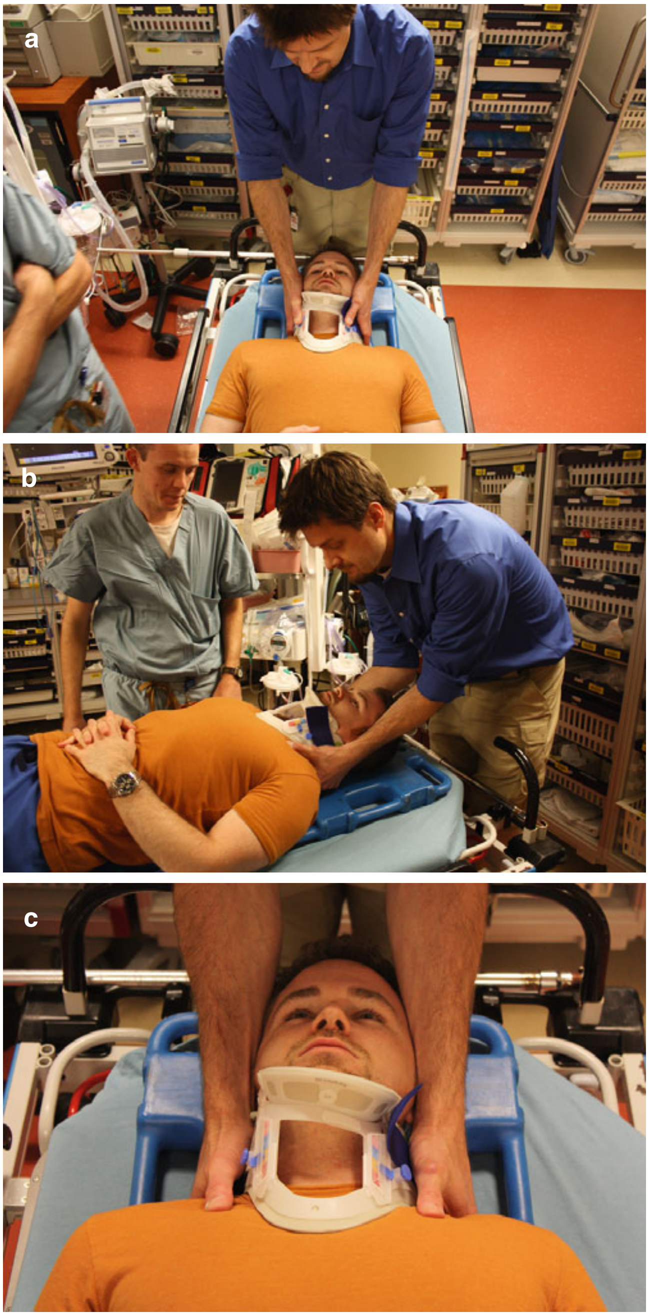

Fig. 38.2 (**a**) Incorrect: Single-point stabilization does not keep head and C-spine in line with torso (**b**, **c**). Correct: The two-point stabilization technique keeps the head and C-spine in line with the torso during the log roll

10. The person at the head of the bed signals the initiation of a synchronized log roll when everyone is in position.
11. Attention should be directed at maintaining a neutral axis along the anatomical line of symmetry during the roll (Fig. 38.3).
12. While the patient is on her or his side, the rigid backboard should be removed and secured to prevent injury of caretakers.
13. The patient's entire posterior should be exposed and examined, taking care to note lacerations and obvious deformities.
14. The entire length of the spine is examined by inspection and then by palpation to assessed for tenderness, step-offs, and deformities (Fig. 38.4).
15. Before returning the patient back onto the stretcher, ensure that any debris, glass, lumps of clothing, or blankets are removed.

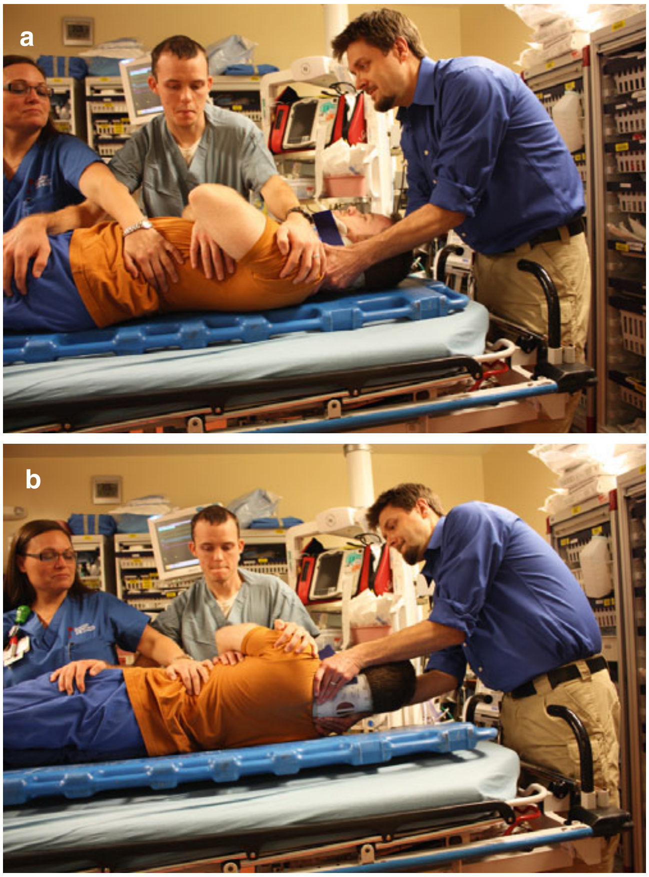

Fig. 38.3 (**a**) The interlocking hands of operators performing lateral log roll help maintain spine immobilization and minimize twisting. (**b**) Two-point cervical spine stabilization is maintained in neutral axis relative to the anatomical line of symmetry during the roll. Appropriate bed height adjustment will increase the ease of the procedure

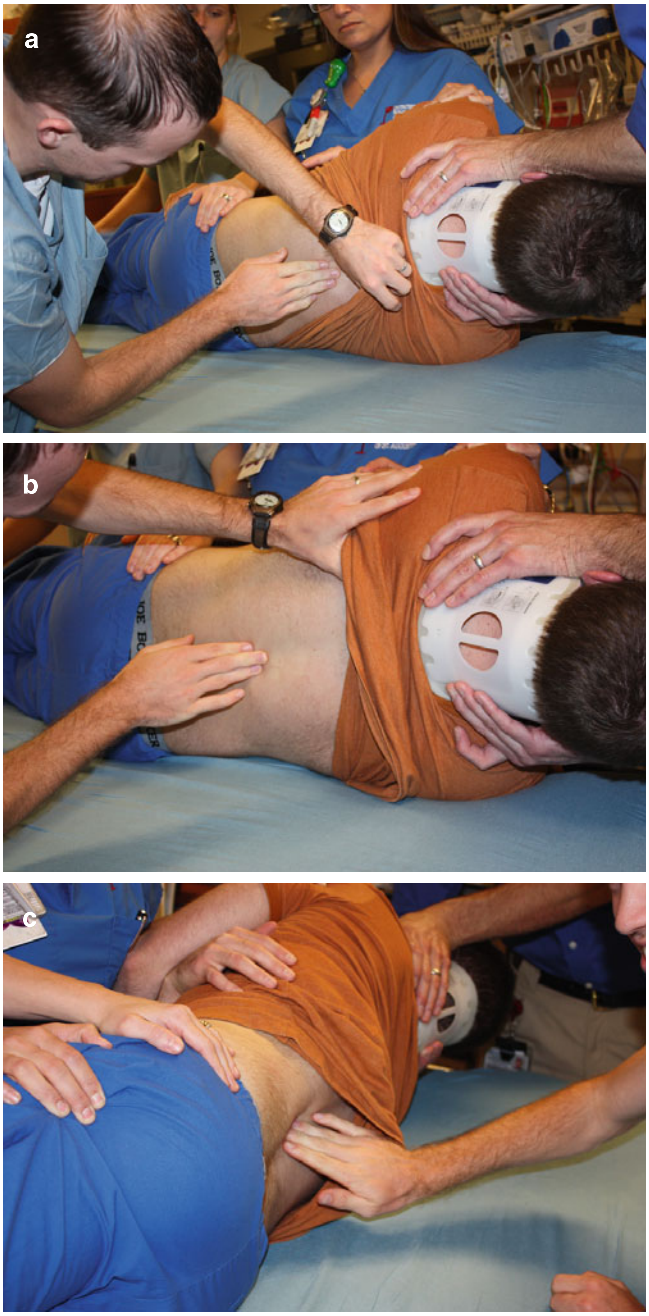

Fig. 38.4 (**a**–**c**) After backboard has been removed, the entire length of the of the spine can be appropriately palpated and assessed for injury to the thoracic and lumbar spine

38.5 Pearls and Pitfalls

- Pearls
  - The log roll should be performed in unison to avoid segmental rotation.
  - The ABCs should be established before initiating the log roll, which is part of the secondary survey in the trauma evaluation.
  - A proper log roll begins with stabilization of the C-spine because it is the most freely mobile part of the spine and, therefore, most frequently injured.
  - Take the patient off the backboard as soon as possible to prevent formation of pressure sores.
- Pitfalls
  - Failure to establish a two-point stabilization between the patient's body and the head leaves the C-spine at risk of further injury during the log roll.
  - Patients should not be left on the backboard for spinal precautions.
  - Failure to ensure that the ABCs are established before attempting a log roll.

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Part VI

Neurologic and Neurosurgical Procedures

Burr Hole Craniotomy

39

Latha Ganti

39.1 Indications

- Extradural hematoma (EDH) or subdural hematoma (SDH) with Glasgow Coma Scale (GCS) <8 and unavailability of timely neurosurgical intervention in the face of increased intracranial pressure
- Signs of increased intracranial pressure [1]
  - Deteriorating level of consciousness
  - Slowing of the pulse
  - Dilating pupils
  - Focal seizures
  - Hemiparesis
  - Extensor posturing of the limbs

39.2 Contraindications

- Absolute
  - GCS >8
  - Immediate availability of neurosurgeon
- Relative
  - Lack of imaging (in this case, decision is guided by neurologic findings and signs of increased intracranial pressure or impending herniation)

39.3 Materials and Medications

- Razor to shave area
- 2 % lidocaine with epinephrine to numb scalp
- 10 % povidone-iodine or chlorhexidine prep
- Light, suction, cautery, dressing tray
- Gelfoam
- Penrose drain
- 3-0 silk
- #10 scalpel blade and #3 handle
- Small self-retractors or rakes
- Drill and drill bits: can be manual (Fig. 39.1) or automatic stopping variety (Fig. 39.2)
- Bone wax or electric cautery apparatus
- Suction apparatus
- Saline irrigation (IV tubing connected to a saline bag with clamp set so flow is low, or a saline syringe flush)

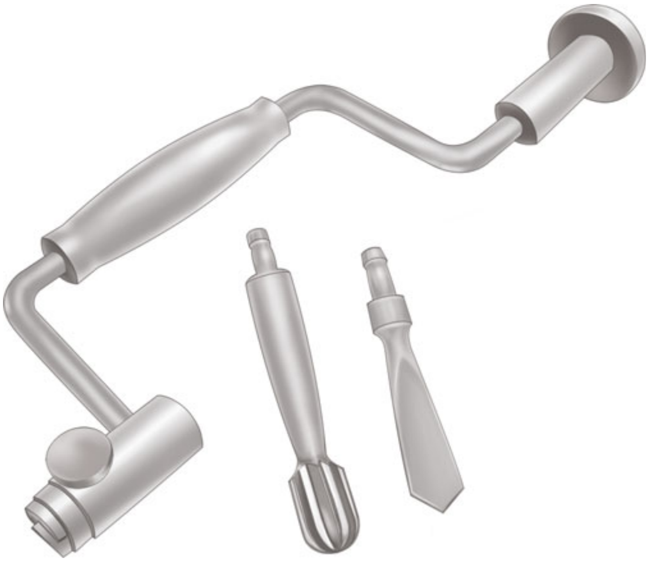

Fig. 39.1 Hudson brace, burr, and perforator

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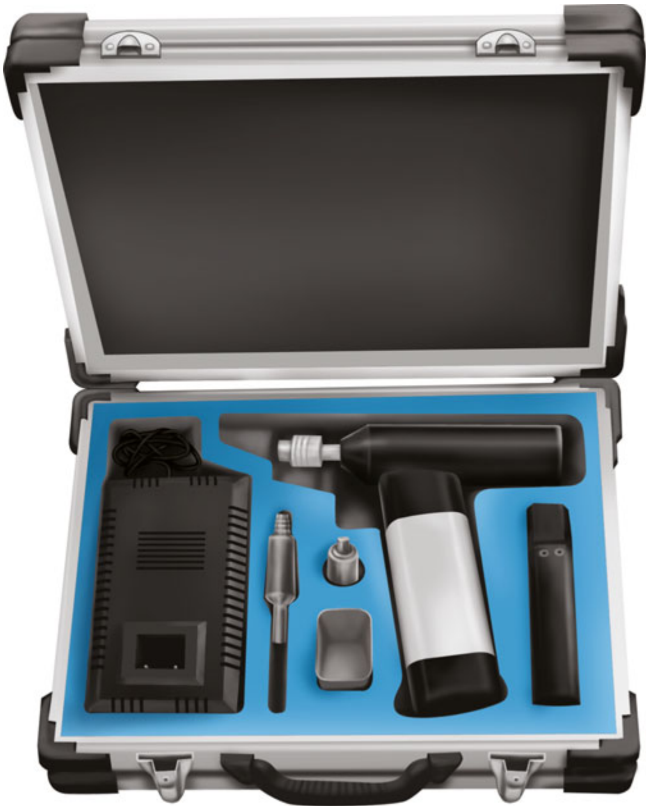

Fig. 39.2 Automatic stopping craniotomy drill set

39.4 Procedure

Preparation

1. Patient should be supine, intubated, with appropriate C-spine precautions
    - Hypertonic saline and/or mannitol can be considered for medical management of increased ICP if/as directed by neurosurgery
2. Determine location and depth for burr hole placement (Figs. 39.3 and 39.4):
    - Have CT images immediately available for viewing
    - Most common location for EDH or SDH is temporal
        - Temporal burr hole placement: 2 fingerbreadths above the ear, 2 fingerbreadths forward (Fig. 39.5)
        - Parietal burr hole placement: 2 fingerbreadths above the ear, 3 fingerbreadths backward (behind the ear)
        - Frontal burr hole placement: 3 fingerbreadths from midline, 3 fingerbreadths above hairline
    - Estimate depth of hematoma by counting the number of slices the hematoma is as seen on CT scan and multiplying by the slice thickness [2]
3. Shave hair around area of hematoma.
4. Prep skin with betadine and chlorhexidine.
5. Anesthetize scalp skin with lidocaine and epinephrine.

    Accessing hematoma
6. Make a vertical incision approximately 4 cm long down to bone.s
7. Use periosteal elevator or end of scalpel blade to scrape muscle and periosteum away from bone.
8. Place self-retaining retractors (or rakes) to keep field open (Fig. 39.6).
9. Using a drill with a clutch mechanism [2], drill through outer table (resistance), diploic space (no resistance), then inner table.
    - Burr hole needs to be placed over the *center* of the hematoma (Fig. 39.7).
10. Control bone bleeding with bone wax; control bleeding from veins and/or muscle with gelfoam sponge or cautery (diathermy).
    - Wound edges may also be cauterized or tamponaded with manual pressure +/– epinephrine gauze.
11. Once in the inner table, separate dura from bone
12. Enlarge opening by switching to a conical or cylindrical burr or use a rongeur

    Evacuating hematoma
13. EDH blood will be visible at this point and should be gently suctioned out.
14. SDH blood will be seen as a tenting of the dura and may be clotted: lift the dura with a hook or make an incision with a fresh scalpel through it to expose the clot and drain.

15. Irrigate with saline (this can be via a hand syringe or via IV tubing connected to a saline bag at low sped flow).
16. Repeat gentle suction.

Closure

17. For temporal burr holes, ligate middle meningeal artery (if visible) or cauterize.
18. Place Penrose drain (Fig. 39.8) and close the dura first with a 3-0 absorbable suture, ensuring there is no dural leak (will lead to infection if present).
    - A watertight seal of the duraplasty is essential to minimize cerebrospinal fluid leakage.
19. Loosely suture scalp using 3-0 silk.

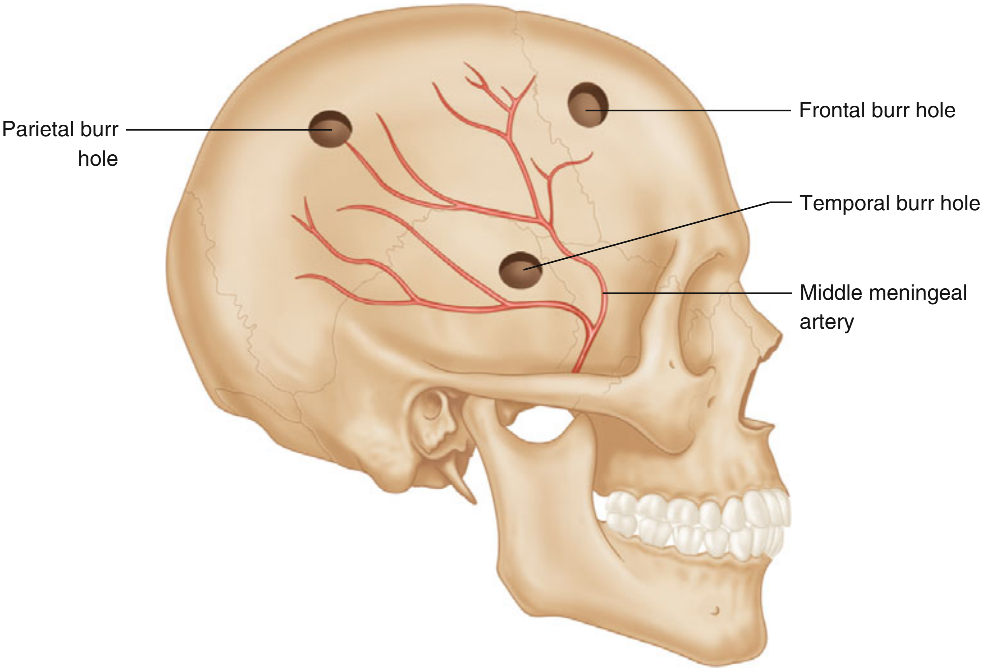
Parietal burr hole
Frontal burr hole
Temporal burr hole
Middle meningeal artery

Fig. 39.3 Positions of burr hole placement

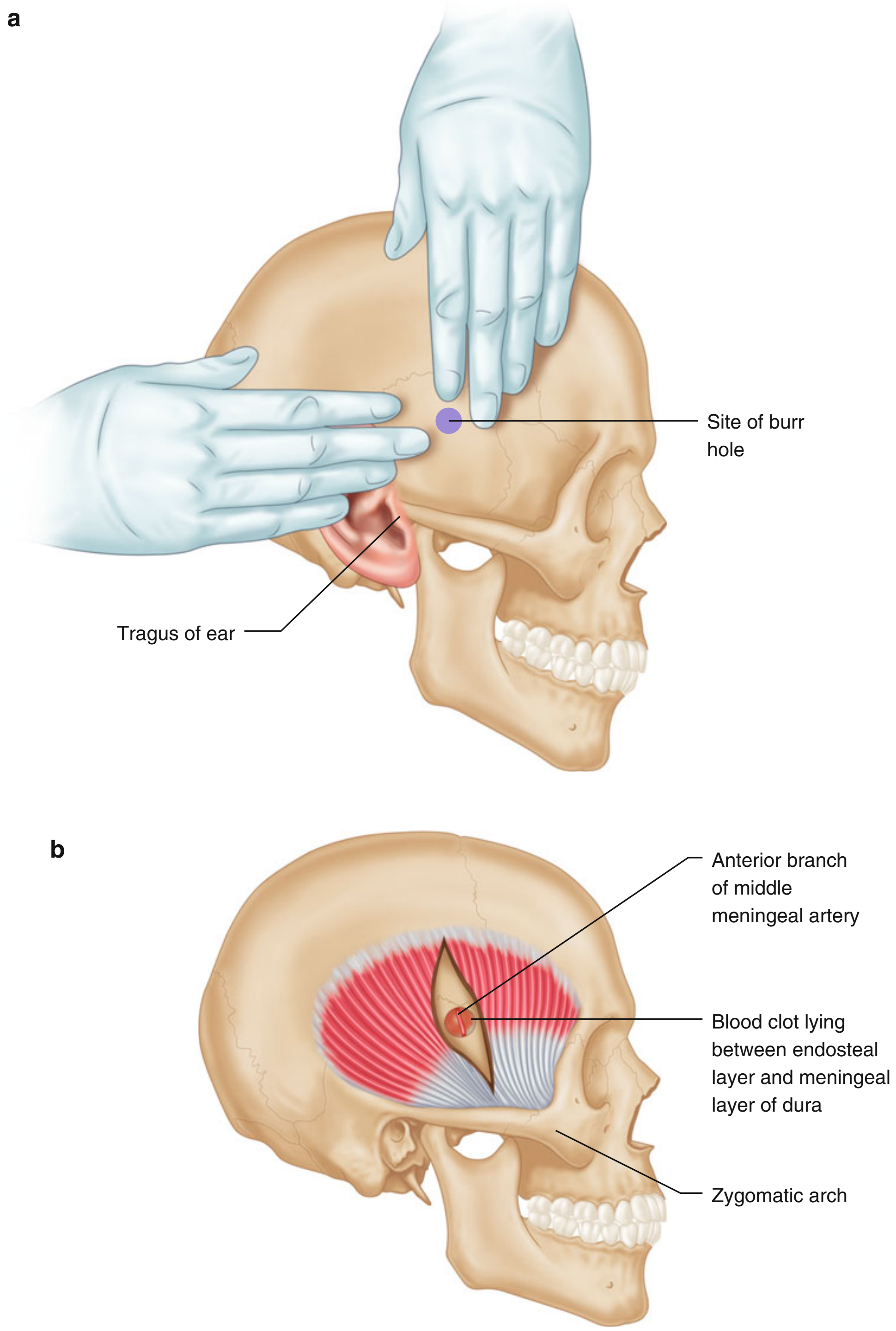
a
Site of burr hole
Tragus of ear
b
Anterior branch of middle meningeal artery
Blood clot lying between endosteal layer and meningeal layer of dura
Zygomatic arch

Fig. 39.4 (**a**, **b**) Anatomy for temporal burr hole placement (most common location)

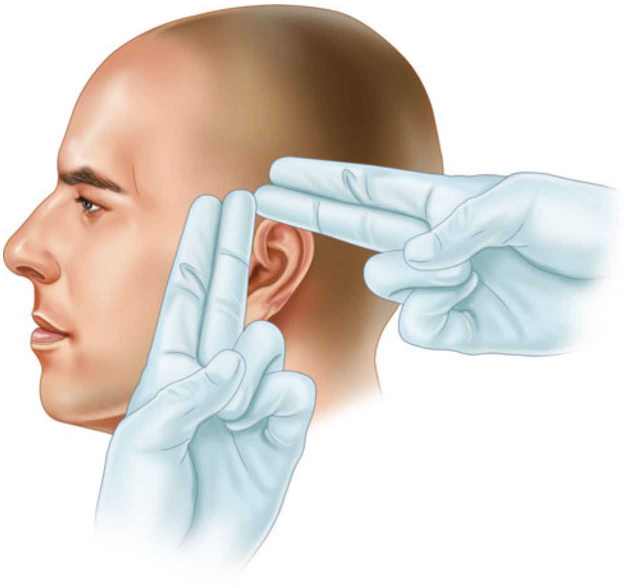

Fig. 39.5 Landmark for temporal burr hole above zygoma, make 5 cm incision over site

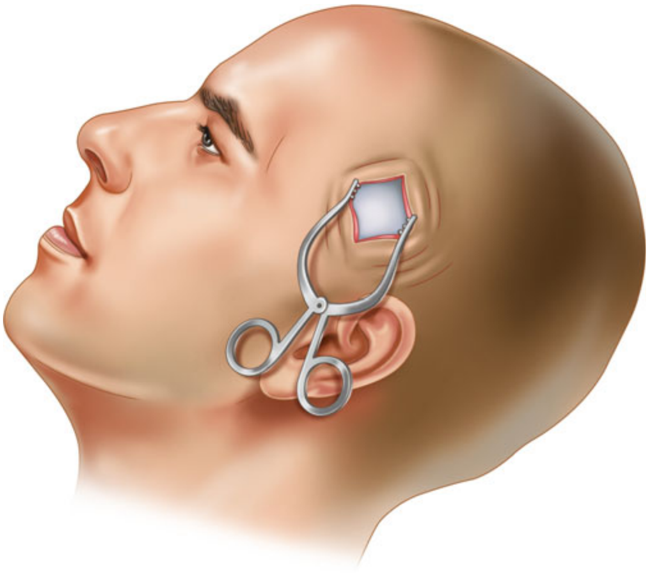

Fig. 39.6 After incision is made, use retractors (preferably self-retaining) to visualize field

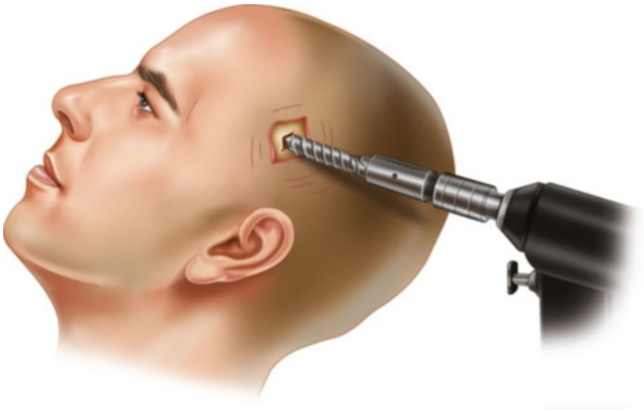

Fig. 39.7 Use penetrator drill to get through outer table. Follow up with a burr to get through the rest of the layers. Can also use an automatic stop craniotomy drill

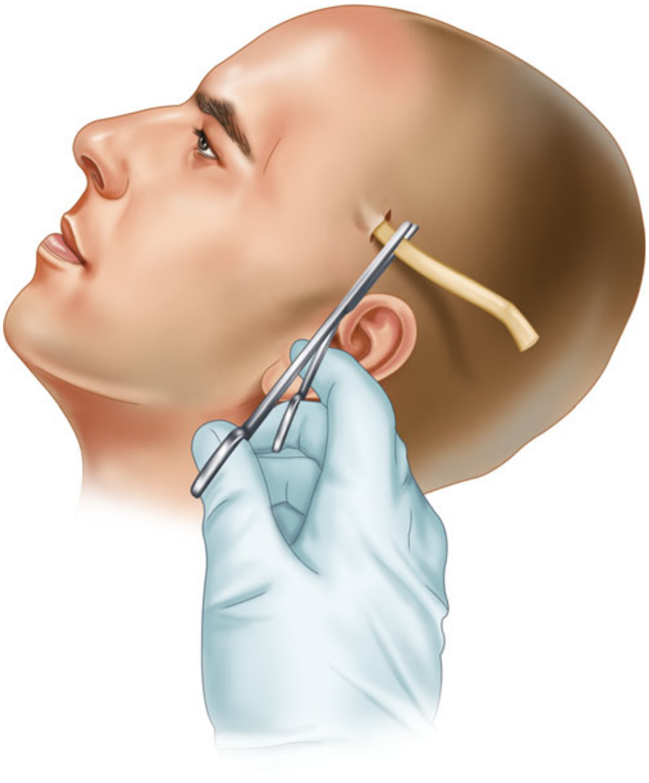

Fig. 39.8 Suture in Penrose drain and close the wound

39.5 Complications

- Brain laceration/perforation
- Temporal artery laceration
- Wrong location (minimized when viewing images during procedure)
- Facial artery laceration
- Meningitis
- Brain abscess

39.6 Pearls and Pitfalls

- Pearls
  - If brain herniates through the burr hole, there is likely a hematoma at another location.
  - Remember this is only a lifesaving procedure that is to be done when timely neurosurgical intervention is not possible. *Do not delay transfer* of the patient
- Pitfalls
  - Bone in temporal area is quite thin; if not using an automatic stop drill, be very careful not to go too far and perforate the brain.

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External Ventricular Drain Placement

40

Latha Ganti

An external ventricular drain (EVD; also known as a ventriculostomy tube) is placed via a burr hole in one of the ventricles of the brain (Fig. 40.1) to drain excess cerebrospinal fluid (CSF) that causes elevated intracranial pressure.

40.1 Indications

- Emergent need for intracranial pressure (ICP) monitoring and or management
- Enlarged ventricles on neuroimaging with Glasgow coma scale <12
- Subarachnoid hemorrhage with Hunt-Hess grade ≥3 (Table 40.1)
- Coma
- Obstructive hydrocephalus
- Intraventricular hemorrhage
- Signs of increased intracranial pressure

40.2 Contraindications

- Absolute
  - Immediate availability of a neurosurgeon who can do the procedure
- Relative
  - Coagulopathy
  - Scalp infection

40.3 Materials and Medications

- Intubation equipment and medications for sedation as needed
- Sterile gloves, gown, mask
- Ruler
- Surgical marking pen
- 1–2 % lidocaine with epinephrine to numb scalp
- 5 cc syringe and needles to give anesthetic
- 10 % povidone-iodine solution and swabs
- Razor to shave area
- Fenestrated clear drape
- Scalpel #11 blade (for scalp) and #15 blade (for periosteum) with #3 handle (Fig. 40.2a)
- 4×4 sterile gauze
- Adson forceps
- Mosquito forceps
- Self-retaining eyebrow retractor (Fig. 40.2b)
- 3-0 nylon suture and needle holder and/or skin stapler
- Scissors
- A hand drill with variable chuck
- One or more drill bits with depth guards in 5/32″ (3.97 mm), 13/64″ (5.31 mm), and 1/4″ (6.35 mm) sizes
- A hex wrench for depth guard adjustment
- Ventricular catheter
- Primed ventricular drainage collection system

40.4 Procedure

Patient preparation

1. Patient is intubated and placed supine in neutral position with head of the bed elevated 30–45°.
2. Administer one dose of intravenous antibiotics that covers skin flora.
3. Make precise measurement of where the hole and incision will be made. Most commonly, EVDs are placed in

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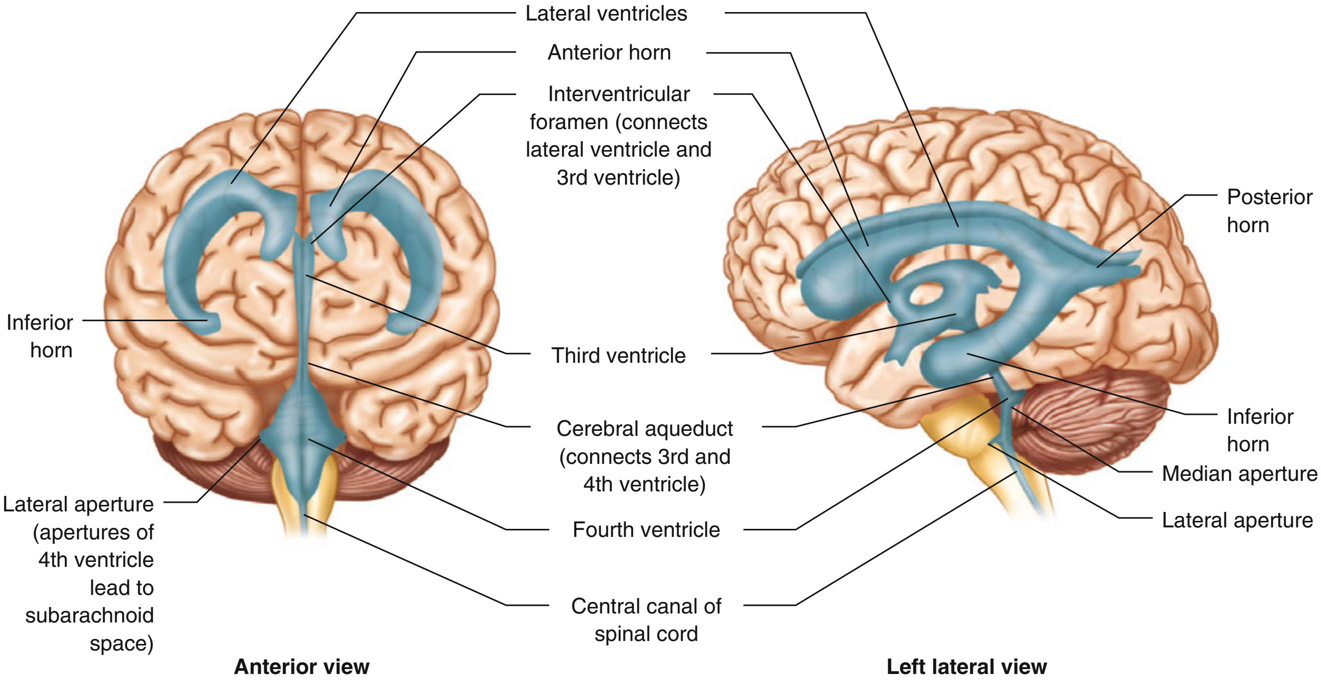
Lateral ventricles
Anterior horn
Interventricular foramen (connects lateral ventricle and 3rd ventricle)
Inferior horn
Third ventricle
Cerebral aqueduct (connects 3rd and 4th ventricle)
Lateral aperture (apertures of 4th ventricle lead to subarachnoid space)
Fourth ventricle
Central canal of spinal cord
Posterior horn
Inferior horn
Median aperture
Lateral aperture
Anterior view
Left lateral view

Fig. 40.1 Ventricles of the brain that contain CSF

Table 40.1 Hunt and Hess scale for subarachnoid hemorrhage [1]

Grade	Signs and symptoms
1	Alert and oriented, mild headache, slight or no nuchal rigidity
2	Alert and oriented, moderate to severe headache, nuchal rigidity, no neurologic deficit
3	Drowsiness, confusion, mild focal neurologic deficit
4	Stupor, moderate-severe hemiparesis
5	Coma, decerebrate posturing

the right frontal scalp, as this is the nondominant hemisphere in >95 % of the population.

4. Using a sterile skin/surgical marker, draw a line 11 cm back from nasion and then a point 3 cm to the right of that, which corresponds to the mid-pupillary line. This is called Kocher's point (Fig. 40.3).
5. Once Kocher's point is marked, shave skin and remove loose hairs so field is wide enough for subcutaneous catheter placement and tunneling.
6. Prep area with povidone-iodine.
7. Place sterile clear drape over field.
8. Prep area of incision once more.
9. Infiltrate scalp with 1–2 % lidocaine with epinephrine (the epinephrine acts as a hemostatic agent, keeping surgical field clean) (Fig. 40.4).
10. Make a 2 cm linear stab incision and extend incision to skull (Fig. 40.5).
11. Use eyebrow self-retaining retractors to hold skin edges back.
12. Drill burr hole with hand drill (Fig. 40.6).
13. Irrigate burr hole with sterile saline.
14. Put on a new pair of sterile gloves (prior to handling ventriculostomy catheter).
15. Remove ventricular tubing from sterile package. It has markings on it that are 1 cm apart.
16. Insert ventriculostomy catheter perpendicular to the skull at the point of insertion. Catheter is aimed at the ipsilateral medial canthus of the eye (anteroposterior plane) and tragus of ear (lateral plane).
17. Advance ventriculostomy tube 5–6 cm with stylet from outer skull table so it sits in the anterior horn of the lateral ventricle (Fig. 40.7).
18. Ensure ventriculostomy catheter is draining CSF.
19. Attach metal trocar to tip of ventriculostomy catheter and tunnel the trocar and catheter under the galea approximately 3–5 cm to the right of the original incision. Bring trocar out through separate stab incision in scalp.
20. Remove trocar, make sure ventriculostomy catheter is still draining CSF.
21. Place temporary cap on ventriculostomy catheter to prevent overdrainage of CSF.

22. Close the original incision with either sutures or staples.
23. Secure catheter to the scalp using staples.

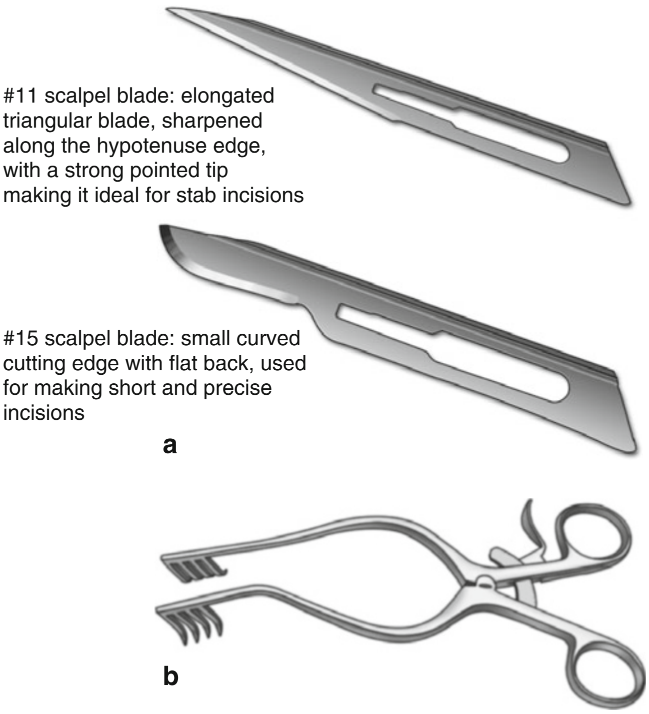
#11 scalpel blade: elongated triangular blade, sharpened along the hypotenuse edge, with a strong pointed tip making it ideal for stab incisions
#15 scalpel blade: small curved cutting edge with flat back, used for making short and precise incisions
a
b

Fig. 40.2 (**a**) Surgical scalpel blades. (**b**) Self-retaining eyebrow retractors

24. Cover incision with sterile transparent dressing.
25. Suture stopcock to ventricular catheter to ensure it does not come off (take care not to make suture too tight or it will occlude ventriculostomy catheter).
26. Remove blind end of stopcock, attach ventricular catheter to ventricular drain system once it is primed.

    Priming, setup, and maintenance of ventricular drainage system
27. Prepare drainage system by priming system with sterile, preservative-free saline.
28. Place zero point of drainage system at midbrain (level of patient's ear tragus) or above midbrain at 15–20 cm of $H_2$0 (target ICP set by neurointensivist and will change depending on patient's situation) (Fig. 40.8).
29. Attach drainage tubing.
30. Patients who require an EVD should be closely monitored by nurses trained and competent in assessment and management of the drain and in recognizing signs of increased ICP in the patient.
31. Assessment of the drainage system should be done a minimum of every 4 h, which includes inspecting the EVD from the insertion site along the entire drainage system, checking for cracks in the system or fluid leaking from the insertion site [2].

    Post-procedure
32. Obtain CT scan of brain to verify placement (Fig. 40.9).

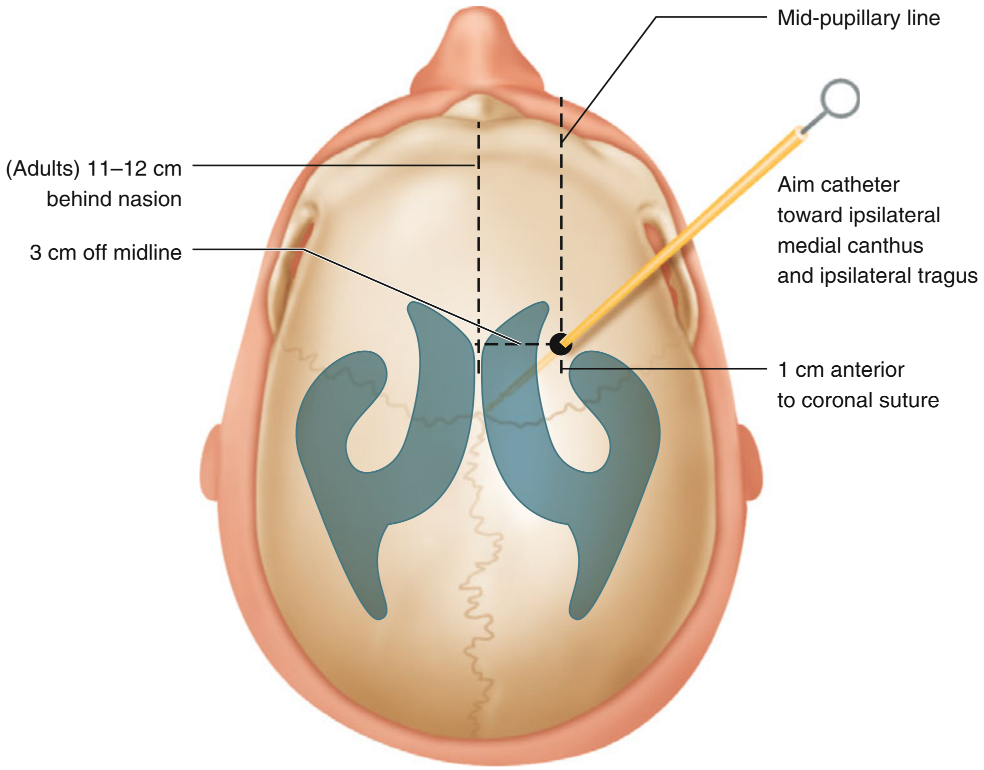
Mid-pupillary line
(Adults) 11–12 cm behind nasion
3 cm off midline
Aim catheter toward ipsilateral medial canthus and ipsilateral tragus
1 cm anterior to coronal suture

Fig. 40.3 Kocher's point for frontal EVD placement

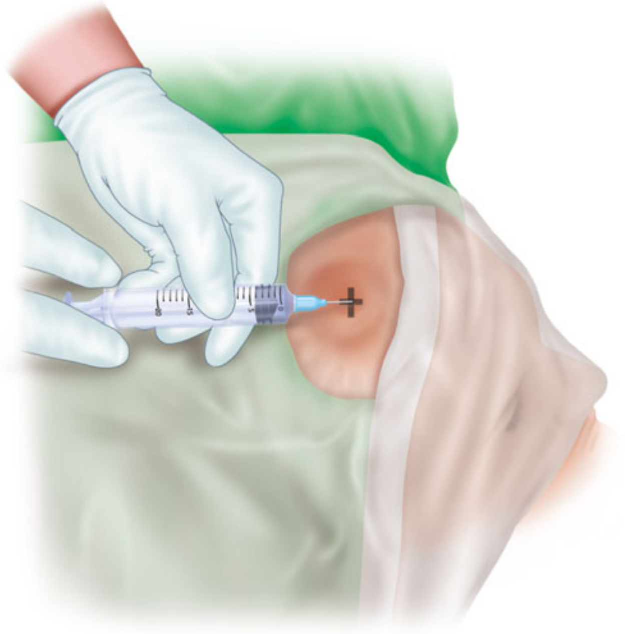

Fig. 40.4 Anesthetize skin

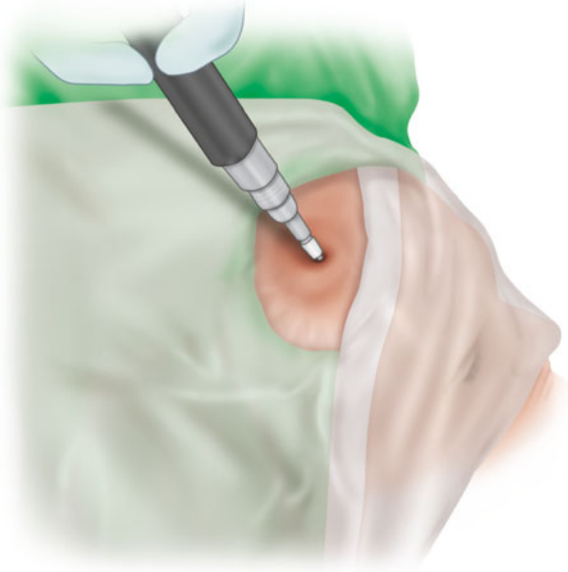

Fig. 40.6 Make burr hole

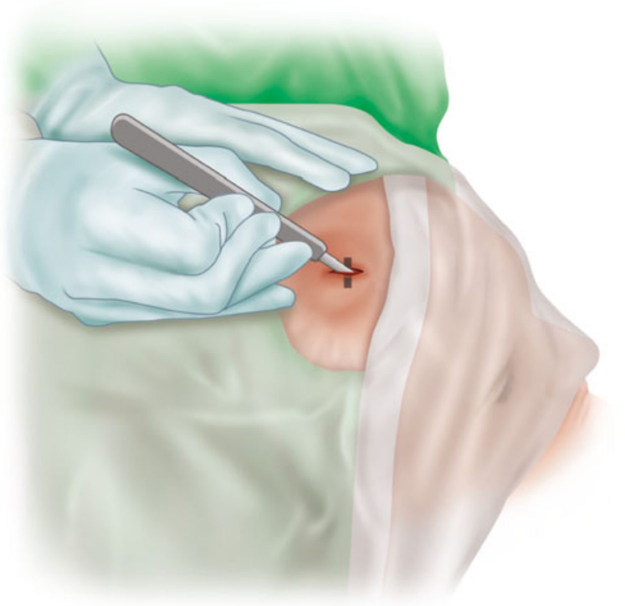

Fig. 40.5 Make stab incision

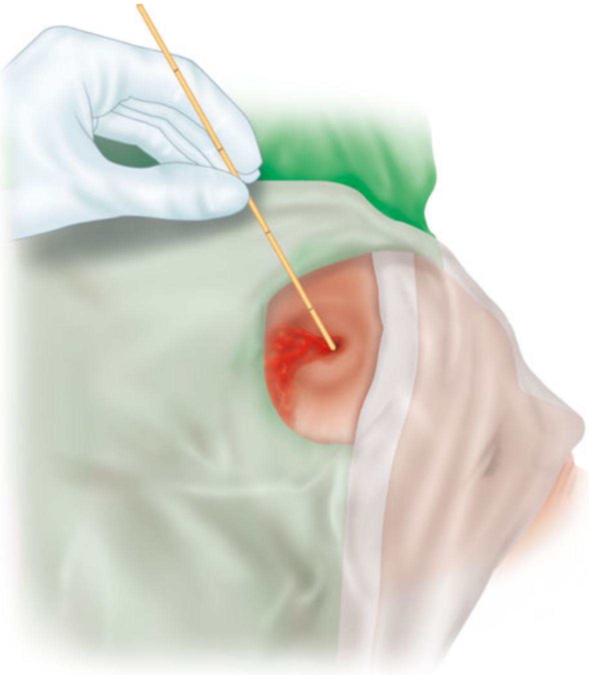

Fig. 40.7 Advance ventriculostomy catheter with stylet

40.5 Complications

- Hemorrhage
- Infection: meningitis, ventriculitis
- Tract hematoma
- Migration/dislodgement

40.6 Pearls and Pitfalls

- Pearls
  - EVD needs to be re-leveled every time the patient moves. Family and all visitors must be informed that any patient movement or change in elevation of head

Fig. 40.8 Zero point of drainage system placed at midbrain (level of patient's ear tragus)

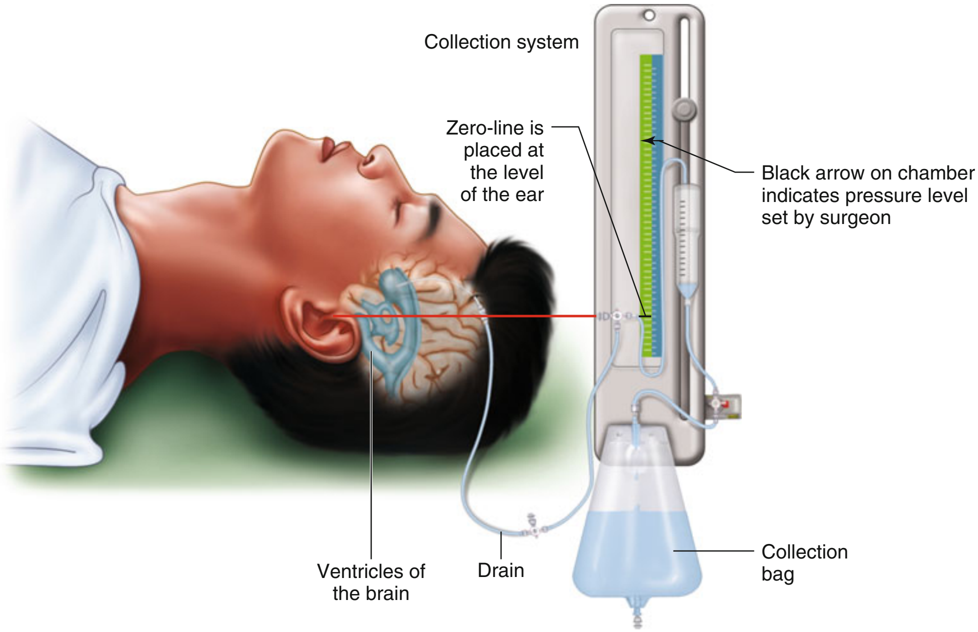
Collection system
Zero-line is placed at the level of the ear
Black arrow on chamber indicates pressure level set by surgeon
Ventricles of the brain
Drain
Collection bag

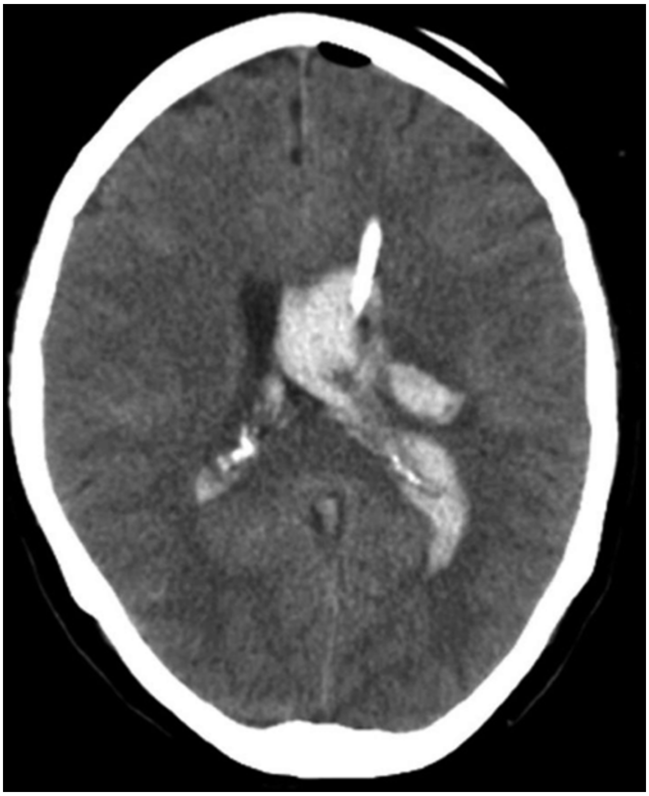

Fig. 40.9 CT scan demonstrating typical placement of ventriculostomy catheter in ipsilateral anterior horn of lateral ventricle [3] (Reproduced with permission from National Institutes of Health: Jaffe et al. [3])

of bed will require re-leveling of EVD in order to ensure it is a the appropriate level for CSF drainage.
  - CSF collection chamber should remain upright to prevent reflux/leakage.
  - EVD placement in the parieto-occipital scalp or frontotemporal or trans-sylvian locations is generally not done at the bedside due to higher rate of complications. This is performed in the operating room.
- Pitfalls
  - If the drain is leveled too low: CSF will drain too easily, which can lead to re-rupture of an unrepaired ruptured cerebral aneurysm or cause a subdural hematoma due to shearing of bridging veins.
  - If the drain is leveled too high, CSF will not drain or will not drain at desired rate, leading to hydrocephalus. The ICP will need to be higher in order for the CSF to drain.

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Lumbar Puncture in Adults

41

Kevin Tench, L. Connor Nickels, and Rohit Pravin Patel

41.1 Indications

- Diagnostic
  - Evaluation for the possibility of a central nervous system (CNS) infection: viral, bacterial, and fungal meningitis and encephalitis
  - Evaluation for inflammatory processes: multiple sclerosis, Guillain-Barré syndrome
  - Evaluation for spontaneous subarachnoid hemorrhage (SAH)
  - Suspicion of CNS diseases: oncological and metabolic processes
- Therapeutic
  - Therapeutic reduction of cerebrospinal fluid (CSF) pressure
  - Procedures requiring lower body analgesia or anesthesia
  - Intrathecal antibiotic administration for some types of meningitis
  - Chemotherapy and methotrexate for some forms of leukemia and lymphomas

41.2 Contraindications

- Presence of infection in tissues at or around puncture site.
- Increased intracranial pressure (ICP) from a space-occupying lesion; patients with signs of cerebral herniation or with potential of increased ICP and focal neurological signs.
- Bleeding diathesis (thrombocytopenia, anticoagulant therapy, hemophilia); may increase risk of spinal hematoma, but level of coagulopathy that increases risk is unclear.
- Patients with cardiorespiratory compromise may worsen owing to position.

Patients with prior history of lumbar surgery, osteoarthritis, ankylosing spondylitis, kyphoscoliosis, or degenerative disk disease might have more success if lumbar puncture is performed by an interventional radiologist using imaging techniques and should be considered.

41.3 Materials and Medications (See Fig. 123.1)

- Spinal needle(s) with stylet
  - Adults: 3.5-in. 20-gauge needle; obese may require 5.0-in. 22- to 24-gauge needle
  - Children: 2.5-in. 22-gauge needle
  - Infants: 1.5-in. 22-gauge needle
- Three-way stopcock (optional: drainage catheter)
- Manometer (optional: extension tube for higher opening pressures)
- Specimen tubes (# may vary, but in general labeled 1–4, important to obtain from 1, 2, 3, 4 owing to cell count obtained from tubes 1 and 3)
- Local anesthetic (lidocaine 1 or 2 %), 5- to 10-mL syringe and needle (25-gauge) for local anesthesia
- Sterile drapes and gauze
- Mask, sterile gown, sterile gloves
- Antiseptic solution for skin preparation (Chloroprep or iodine)

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41.4 Procedure

1. Positioning
   - Determined by practitioner preference or patient capability.
   - Options: lateral recumbent position, upright sitting position (Fig. 41.1).
   - Lateral recumbent position is preferred to obtain accurate opening pressure and to reduce the risk of post-puncture headache.
   - Both positions require the patient to arch the lower back toward the practitioner in order to open up the intervertebral spaces (obtain the “fetal position” or arch “like a cat”).
   - Shoulders and hips should remain aligned during process.
2. Landmarks
   - Determined by palpation.
   - Draw a visual line between the superior aspects of the iliac crests that intersects the midline at the L4 interspace. The L3–4 and L4–5 spaces are preferred because these points are below the termination of the spinal cord.
   - Palpate the posterosuperior iliac crests with the midpoint of a visual line that connects the two crests representing the L4 spinous process.
   - Palpate the space between the L3–4 or the L4–5 spinous processes and mark where the needle will be placed.
3. Ultrasound guidance (optional)
   - Helpful in obese patients, patients with previous surgical scarring, or anyone in whom palpation of the spinous processes is not easily done.
   - Sonographic measurement of the dura mater strongly correlates with needle depth needed to obtain CSF.
   - Identify the spinal process in the short and long axis to determine the midline and the interspinous space.
   - Identify the interspinous ligament for estimation of the depth of needle insertion.

     Commonly only the spinous processes are well visualized, and the interspinous ligament, ligamentum flavum, and subarachnoid space are less clearly seen.
   - High-frequency (5–10 MHz) linear probe to best evaluate anatomy.
   - A marking pen can be used to create a cross-hair-type figure (Fig. 41.1).
   - After placing the patient as described, locate the midline at the lumbar spine in transverse and longitudinal orientations.
   - Bright echogenic structures with shadowing posteriorly identify the spinous processes.
   - Transverse probe positioning to identify midline (Fig. 41.2), and then longitudinal probe positioning to identify interspinous space (Fig. 41.3).
4. Sterile preparation
   - After positioning and palpating the appropriate landmarks, the practitioner should then dress in the appropriate protective gear: mask, gown, and sterile gloves.
   - After dressing, the practitioner can then sterilely prepare the patient.
   - – Make sure the patient’s back is completely exposed.
   - – Clean the patient’s back with an antiseptic solution (Chloroprep should be scrubbed in an up/down and side/side fashion; iodine in a circular motion starting from the center of the anticipated insertion point).
   - – Apply sterile drapes with the puncture site exposed.

     This is an optimal time to make sure all equipment in a standard lumbar puncture tray connects properly and that the stopcock for opening pressure measurement is assembled. Make sure the stopcock is closed away from the patient so that CSF can flow from the patient to the manometer. If the assembly is done, it will decrease the amount of CSF lost after the puncture.

- Local anesthesia
  - 1 % Lidocaine or anesthetic cream topically before preparing skin
  - For injection, form a skin wheal over the insertion site.
  - Inject into the deep tissues below the wheal in all directions while only breaking the skin once.
  - Systemic sedatives and analgesics may also be used.

5. Needle insertion
   - Needle should be inserted in the midline between the L3–4 or the L4–5 spinous process, and the stylet should be firmly in place.
   - Initially parallel to the bed, but once into the subcutaneous tissue, the needle should be angled toward the umbilicus (slightly cephalad, 15°) with the bevel facing upward (Fig. 41.4). This sagittal plane orientation spreads rather than cuts the fibers of the dural sac, which run parallel to the spinal axis.
   - If properly positioned, the needle passes through the skin; subcutaneous tissue; supraspinous ligament; interspinous ligament between the spinous processes; ligamentum flavum; epidural space including the internal vertebral venous plexus, dura, and arachnoid; into the subarachnoid space and between the nerve roots of the cauda equina.
   - In most cases, a “pop” will be felt when the needle penetrates the ligamentum flavum, entering into the subarachnoid space; then intermittent withdrawal should be done in 2-mm intervals to assess for CSF flow.
   - If bone is encountered during insertion, the needle should be withdrawn partially without exiting the skin and readjusted to a different angle more cephalad.

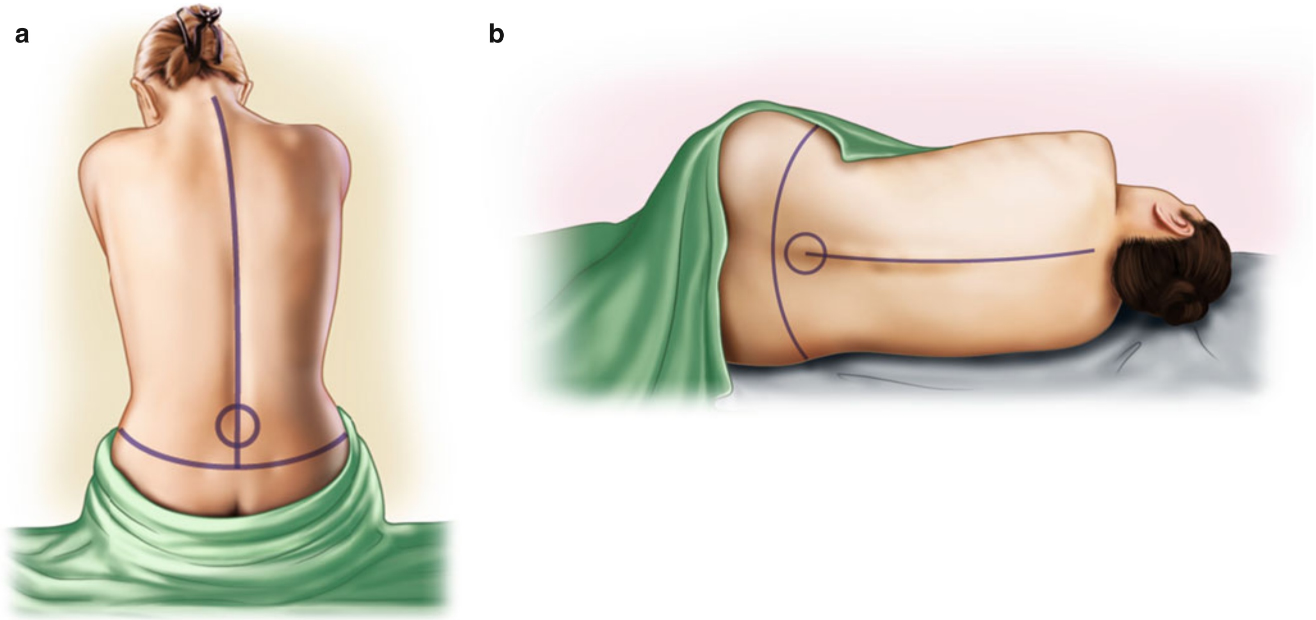

Fig. 41.1 Sitting position (**a**) left lateral decubitus position, (**b**) with general areas of insertion of needle

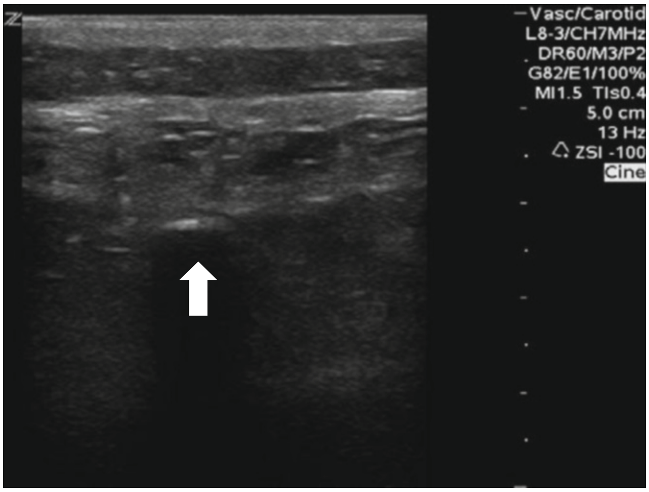

Fig. 41.2 Transverse view, *white arrow* indicates spinous process. Place in middle of ultrasound view to locate appropriate midline access point

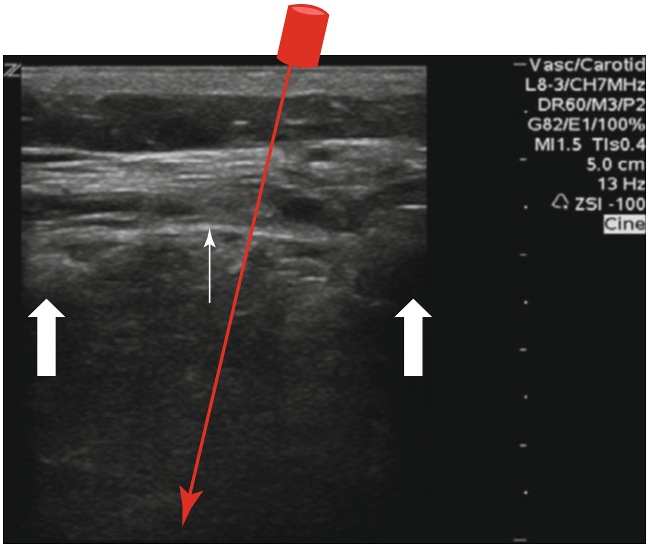

Fig. 41.3 Longitudinal view of lumbar spine. *Thick white arrows* indicate vertebral shadows; *thin white arrow* indicates supraspinous ligament. *Red arrow* indicates trajectory of needle

- If the tap is traumatic, CSF may be blood tinged but should clear as more is collected. If it does not clear, it may indicate intracranial hemorrhage or subarachnoid blood. Also in traumatic patients, clotting will be seen in the tubes; clotting does not occur in SAH owing to defibrinated blood being present in the CSF. Blood-tinged CSF can also be seen in herpes simplex virus (HSV) encephalitis.
- A dry tap is usually due to incorrect positioning and misdirection of needle, often due to a superior direction of the needle with obstruction by the lamina or spinous process of the superior or inferior vertebra. If the needle is too lateral, an inferior or superior articular process may be hit.

  If flow slows down, rotate the needle 90° because a nerve root may be obstructing the opening.

6. Opening pressure measurement
   - Must be performed in the lateral recumbent position. Although there are some conversion formulas from the sitting position, these are not standard of care.

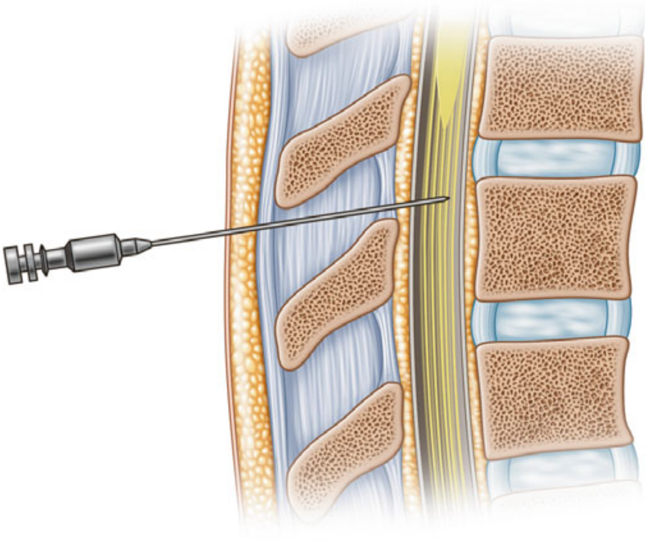

Fig. 41.4 Angle of insertion of needle, cephalad with bevel up

  - Once the needle is in the subarachnoid space and CSF is flowing from the needle, the three-way stopcock should be attached to the needle and the manometer should be attached to the stopcock to take a measurement. Use the flexible tube to connect the manometer to the hub of the needle.
  - Note the height of fluid in the manometer after it stops rising (normal opening pressure, <20 cm Hg); it may be possible to see pulsations from cardiac or respiratory motion.
    - Elevated CSF pressure is seen with meningeal inflammation, hydrocephalus, pseudotumor cerebri, SAH, and CHF.
    - Decreased CSF pressure is seen in leakage of CSF and severe dehydration.

7. Collecting CSF fluid
  - Collect at least 1–2 mL of CSF fluid in each tube, going from 1 to 4 and never aspirate because this can cause hemorrhage.
  - After collecting the fluid, replace the stylet and remove the needle, clean the skin, and place a bandage over the puncture site.
  - General recommendations
    - Tube 1: glucose, protein, protein electrophoresis
    - Tube 2: Gram stain, bacterial and viral cultures
    - Tube 3: cell count and differential
  - When ruling out SAH, cell count should be performed in tubes 1 and 3 or 1 and 4 to differentiate between SAH and traumatic tap.
    - Tube 4: Any special tests: myelin basic proteins, lactate, pyruvate, and smear on cell concentrates all depend on suspicion.

41.5 Complications

- Implantation of epidermoid tumors: from introducing skin plug into the subarachnoid space and can be avoided by using stylet when advancing.
- Postlumbar puncture headache: most common, occurring in 36.5 % of patients within 48 h
- CSF leak: causes headache when CSF leak through puncture site exceeds rate of production
- Bleeding: most common in patients with bleeding diathesis; may result in spinal cord compression
- Epidural hematoma
- Infection: local cellulitis, abscess (local or epidural), or meningitis
- Herniation syndromes: high risk can be identified by computed tomography but may not completely identify all patients with increased ICP
- Backache: local or referred pain
- Cardiorespiratory compromise

41.6 Pearls and Pitfalls

- Pearls
  - Positioning the patient is key to a successful procedure.
  - In adults the spinal cord may terminate higher than previously thought and it may be okay to go one interspace higher than recommended; but in infants owing to the differential in longitudinal growth of the spinal canal and cord, the spinal cord usually ends in L3. So in children the tap must go L4–5 or L5–S1.
  - Always keep the stylet in place until after the skin barrier is penetrated because this will avoid introduction of epidermoid tissue.
- Pitfalls
  - Postspinal headaches can be avoided with smaller needles and intravenous (IV) fluids.
    - Having the patient lie on the back for 1 h after the procedure has no change in incidence of headache.
    - Treatment consists of IV fluids initially, then caffeine, and, ultimately, if the headache persists, a blood patch.

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Reflex Eye Movements (Doll's Eyes and Caloric Testing)

42

Thomas T. Nguyen, Tina Dulani, and Saadia Akhtar

42.1 Doll's Eyes (Oculocephalic Reflex Testing)

42.1.1 Indications: Doll's Eyes

- To assess brain stem function of a comatose patient
- To assess cerebral function in a comatose patient if brainstem function is intact

42.1.2 Contraindications: Doll's Eyes

- Absolute
  - Occult cervical spine injury; rule out radiographically and clinically
  - Basilar skull fracture
- Relative
  - Rheumatoid arthritis; increased risk of atlantoaxial subluxation resulting in spinal cord compression
  - Osteoporosis; increased risk of cervical spine injury
  - Cervical spine ankylosis; increased risk of cervical spine injury

42.1.3 Procedure: Doll's Eyes (Fig. 42.1)

1. Stand at the head of bed and grasp the patient's head with both hands.
2. Use the thumbs of both of hands to open the patient's eyelids.
3. Rapidly move the patient's head to one side and hold.
4. Simultaneously observe for the presence or absence of horizontal movements.
   (a) Head movement to one side should result in conjugate eye movement to the opposite side and then in spontaneous return of the eyes to the midline (normal test).
   (b) Normal oculocephalic reflex is the observation of conjugate eye movements to the opposite side of head turning. This indicates a functionally intact brainstem in a comatose patient.
   (c) Abnormal oculocephalic reflex: incomplete or absent horizontal eye movements. The eyes remain in the midline. This indicates impairment of the brainstem; caloric testing should be done if not contraindicated.
   (d) A partially abnormal oculocephalic reflex: conjugate eye movement opposite to head turning but does not return to the midline means the brainstem is intact but cerebrum function is not.
5. Repeat by rotating the head to the opposite side.
6. Vertical oculocephalic response can be tested by moving the patient's head up and down. A compensatory vertical eye movement should be observed.
   (a) This test is useful only if the horizontal oculocephalic reflex is negative. An intact vertical oculocephalic reflex with a negative horizontal oculocephalic reflex suggests a pontine lesion.
7. Document the observations.

42.1.4 Pearls and Pitfalls: Doll's Eyes

- Oculocephalic reflex may not be present in the first 10 days of life and is unreliable until 2 years of age.
- Do not attempt the doll's eye maneuver in patients with cervical spinal injuries.

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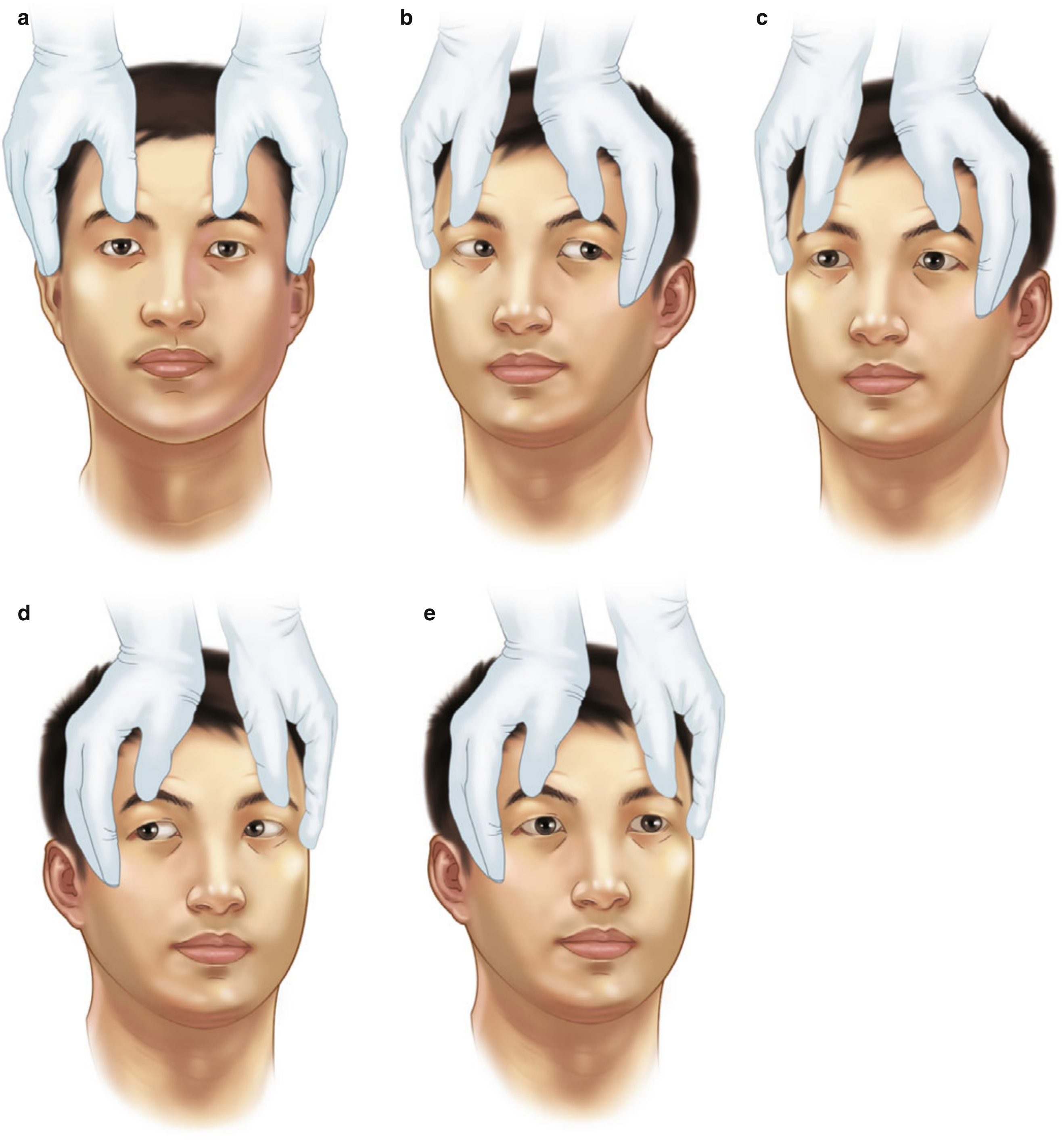

Fig. 42.1 The oculocephalic (doll's eyes) reflex in a patient with an intact brainstem. (**a**) Start with the head facing upright and grasp as depicted using both thumbs to keep the eyes open. (**b**) Rotate the head 90° to the right and the eyes deviate to the left (opposite side). (**c**) The eyes will spontaneously return to the midline. (**d**) Then rotate the head 180° to the left and the eyes should deviate to the right (opposite side). (**e**) The eyes will spontaneously return to the midline

- The doll's eye reflex can be absent or partial in patients with ocular muscle nerve palsy (e.g., cranial nerve [CN] 6).
- Make sure the patient does not have a neuromuscular blockade agent or other toxins present.
- A conscious person can suppress the doll's eye or oculocephalic reflex.

42.2 Caloric Reflex Testing (Vestibuloocular Reflex)

42.2.1 Indications: Caloric Reflex Testing

- In any comatose patient with abnormal doll's eye or if it cannot be performed
- To assess brainstem function of a comatose patient
- To assess asymmetrical function in the peripheral vestibular system

42.2.2 Contraindications: Caloric Reflex Testing

- Absolute
  - Perforated tympanic membrane
  - Presence of tympanostomy tubes
  - Basilar skull fracture, petrous bone fracture
  - Suspicion of cerebrospinal fluid (CSF) otorrhea

42.2.3 Materials and Medications: Caloric Reflex Testing

- Otoscope
- 60-mL syringe
- 16- to 18-gauge angiocatheter
- Thermometer
- Ice-cold water (30–33 °C)
- Warm water (44 °C)
- Emesis basin (to collect water)
- Towels or Chux

42.2.4 Procedure: Caloric Reflex Testing (Fig. 42.2)

1. Place the patient supine and elevate the head to 30° to bring the lateral semicircular canal into the upright position.
   (a) Careful otoscopic examination should be done before caloric testing to make sure there are no contraindications.
   (b) Remove any cerumen from the external auditory canal (EAC); the irrigation fluid should be able to reach the tympanic membrane.
2. Get a 60-mL syringe with an 18-gauge angiocatheter. Remove the plastic angiocatheter from the needle and discard the needle.
3. Place the angiocatheter on the 60-mL syringe and fill it with ice water (30 °C).
4. Place the angiocatheter in the EAC and squirt the water in over a period of 30–40 s. The water should freely enter and exit the auditory canal.
   (a) The stimulus depends upon the temperature of the water and not on water pressure.
   (b) Reflex horizontal movements may be delayed for up to 1 min after irrigation of the EAC.
5. Observe: Have an assistant hold the eyelids open with the head still and facing forward.
   (a) Normal test: Cold water induces slight deviation of the eyes to the side being irrigated followed by a latent period of approximately 20 s and then nystagmus to the opposite side (direction of the fast phase).
   (b) Abnormal test: Eyes do not deviate; this implies brainstem problems.
   (c) The quick phase may return in patients in a persistent vegetative state. Search for the slow, full eye deviation in response to caloric stimulation and not nystagmus when assessing a comatose patient.
6. Pause at least 5 min so the auditory canal can warm up.
   (a) The same EAC can be irrigated with warm water if the contralateral side cannot be tested for any reason.
7. Repeat steps 3–5 in the opposite ear.
   (a) Warm water testing can be used if there is no response to cold water testing. Use warm water (44 °C) and repeat testing, starting with one ear and then, after 5 min, with the other ear.
   (b) Warm water induces nystagmus to the same side (direction of the fast phase).
   (c) COWS: Cold opposite, warm same (referring to the compensatory fast phase of eye movement, the nystagmus).
8. Dry the patient off and reexamine the tympanic membranes to assess for testing-related injury.

42.2.5 Complications: Caloric Reflex Testing

- If contraindications are excluded, no significant complications are expected.
- Tympanic membrane injury or EAC injury can occur from the angiocatheter, forceful irrigation, or injury during cerumen removal.
- Potential complications from caloric testing include meningitis, otitis media, and vomiting.

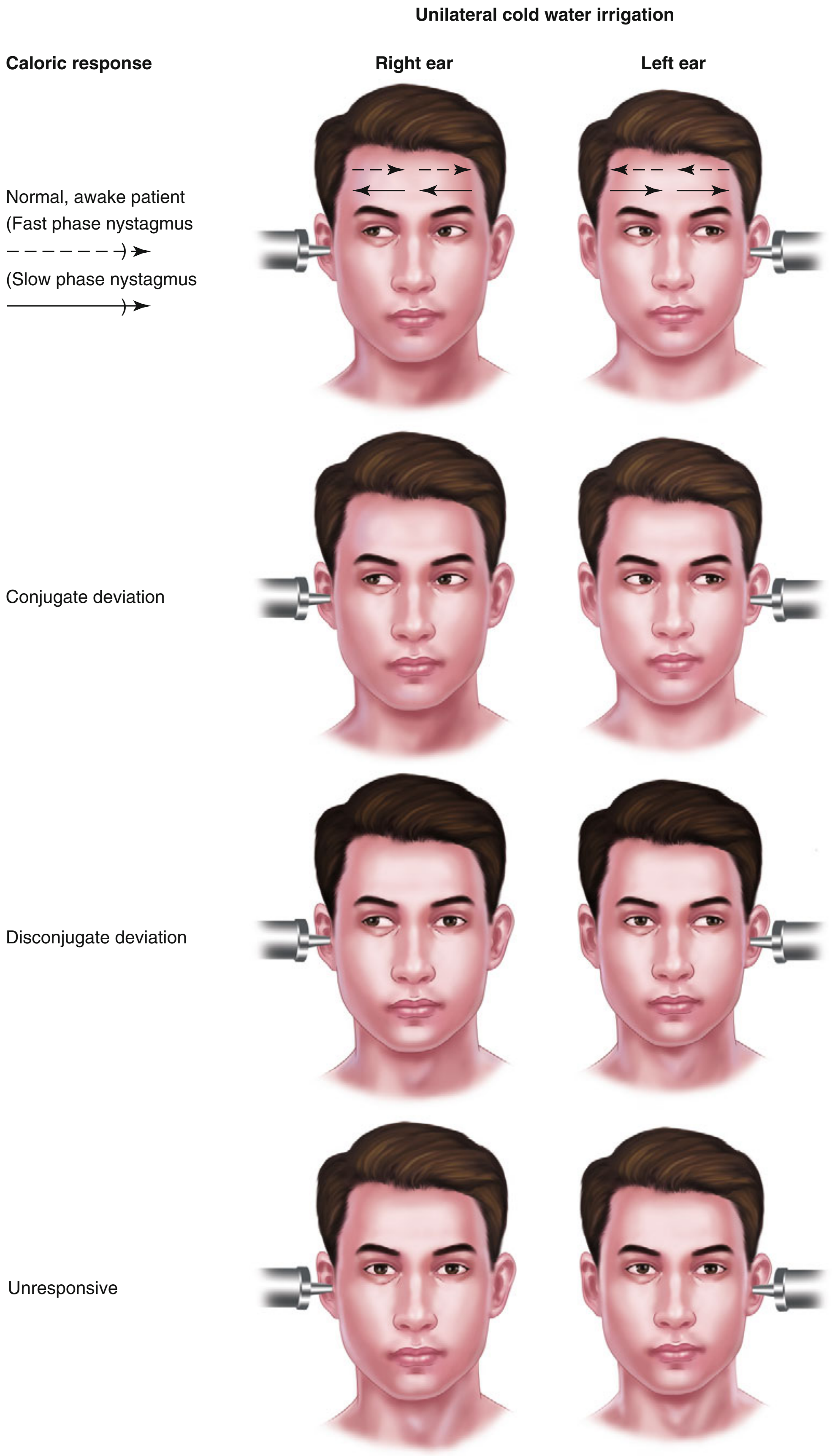
Unilateral cold water irrigation
Caloric response
Right ear
Left ear
Normal, awake patient
(Fast phase nystagmus
(Slow phase nystagmus
Conjugate deviation
Disconjugate deviation
Unresponsive

Fig. 42.2 Depiction of the vestibuloocular reflexes with unilateral cold-water irrigation

42.2.6 Pearls and Pitfalls: Caloric Reflex Testing

- A positive response to caloric testing indicates intact brainstem function.
- In an awake patient, excessive reflex vagal activity may occur (i.e., nausea, vomiting, dizziness).
- Absence of horizontal eye movement means comatose brainstem injury.
- Disconjugate or impaired reflex horizontal eye movements indicate impaired brainstem function at or below the level of the oculomotor nucleus.
- A comatose patient with intact full-reflex horizontal eye movements indicates that the lesion causing coma is in the cerebral hemisphere.

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Dix-Hallpike Maneuver

43

Rui Domingues and Muhammad Waseem

The Dix-Hallpike maneuver, also termed the "head-hanging positioning maneuver," is helpful in confirming the clinical suspicion of benign paroxysmal positional vertigo (BPPV). This maneuver provokes abnormal nystagmus, which is a characteristic feature of BPPV.

43.1 Indications

- BPPV is one of the most common types of vertigo.
  - The pathophysiology of BPPV, in brief, is believed to be due to free-moving densities (canaliths/otoliths) in the posterior semicircular canal; with head movement, the particles would alter the flow of the endolymph and cause the stimulation of the ampulla. The particles in the canal cause slow or even reversal of the movement of the cupula and create signals that do not correlate with the actual head movements, therefore causing the sensation of nystagmus.
  - This maneuver locates the cause of vertigo as either the inner ear or the brain; if the problem is in the ear, this maneuver helps localize which ear is affected.
- This maneuver is indicated for patients presenting with vertigo, which is evoked by a change in position and has no symptoms at rest.
- This maneuver is inexpensive, easily done, and part of the physical examination when a patient presents with the complaint of dizziness or vertigo.

43.2 Contraindications

- Severe cervical spine disease.
- Unstable spinal injury.
- High-grade carotid stenosis.
- Unstable heart disease.
- Elderly patients may not tolerate this maneuver.
- There is no need to perform this test in the presence of nystagmus at rest.

43.3 Materials

- Examination table
- Flat cushion
- Frenzel goggles: These high-powered (+20 diopters) magnifying glasses can be placed on a patient during the performance of the maneuver and have shown to increase the sensitivity of the Dix-Hallpike maneuver by preventing the patient from visually fixating on an object, thereby preventing suppression of nystagmus. They are not required to perform the maneuver; they usually are used by specialists.

43.4 Procedure (Fig. 43.1)

1. Have the patient sit at the edge of a bed. The patient is instructed to maintain eye contact with the physician throughout the maneuver.
2. With the patient seated, the examiner will extend the neck, approximately 20°, and turn the head to one side, approximately 30–45°.
3. The examiner then assists the patient by lowering the patient quickly into a supine position, so that the head hangs over the edge of the bed or table, with the neck in a hyperextended position. A flat cushion can be placed

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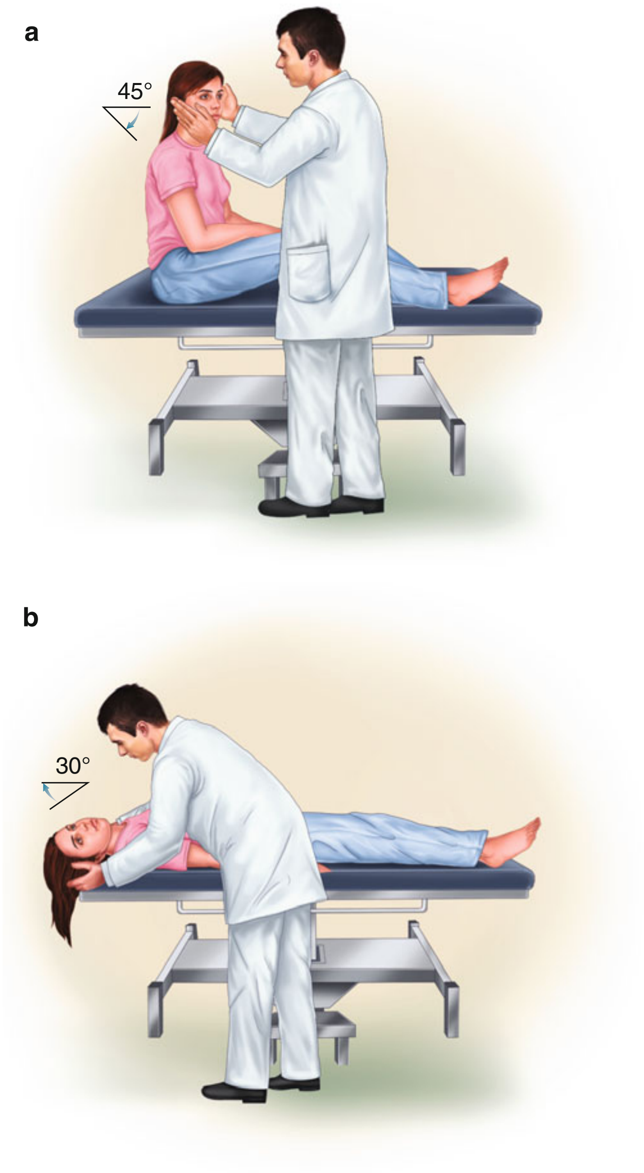

Fig. 43.1 (**a**) With the patient seated, the doctor will extend the neck, approximately 20°, and turn the head to one side, approximately 30–45°. (**b**) The physician then assists the patient by lowering the patient quickly into a supine position, so that the head hangs over the edge of the bed or table, with the neck in a hyperextended position

beneath the person's back in the shoulder blade area to assist with obtaining head extension.

4. This position is held, and the examiner observes for nystagmus for up to 60 s.
    (a) Nystagmus is a rapid, rhythmic movement of the eyes and usually appears after a brief period and lasts less than 30 s.
    (b) The direction of the nystagmus is usually up and twisted; therefore, the eyes will beat toward the ground.
    (c) If the patient becomes dizzy or the doctor sees nystagmus, the test is positive for the ear that is pointed to the floor.
5. The patient is then returned to the upright position and is again observed for nystagmus for 30 s.
6. If nystagmus is not provoked, the maneuver is repeated with the head turned to the opposite direction.
7. If nystagmus is provoked, the patient should have the maneuver repeated to the same side.
    (a) With each repetition, the intensity and duration of nystagmus should decrease.

43.5 Complications

- Vertigo
- Nausea

43.6 Pearls and Pitfalls

- The maneuver can be uncomfortable to the patient because it can cause vertigo and nausea.

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Epley Maneuver for Vertigo (Particle Repositioning or Canalith Repositioning Procedure)

44

Rui Domingues and Muhammad Waseem

During the Dix-Hallpike test (see Chap. 43), the particles move in the canal and trigger a burst of upbeat-torsional nystagmus. The Epley maneuver causes resolution of positional nystagmus. This maneuver is effective in about 80 % of patients with benign paroxysmal positional vertigo (BPPV).

44.1 Indications

- Performed to alleviate the symptoms of posterior canal BPPV

44.2 Contraindications

- Back or spine injuries or other problems
- Presence of detached retina

44.3 Materials

- Pillow or pad
- Padded table or bed

44.4 Procedure (Fig. 44.1)

1. The patient is positioned on the bed with the head slightly extended and turned 45° to the affected side; hold this position for 60 s.
   - The patient may hold the physician's arm for support.
2. The patient is then assisted by the physician to a supine position, with the head in extension, with a pillow or pad placed at the shoulder level allowing for extension; this position is held for a 60 s. This position will likely provoke transient dizziness and vertigo.
3. The head is then turned 90° to the opposite side; this position is held for 60 s. This position will likely provoke transient dizziness and vertigo.
4. The head is then turned through a further 90° while the patient rolls onto the unaffected side; this position is held for 60 s.
5. The patient then sits up slowly, by rolling up from lying on the unaffected side; this position is held for 60 s.
6. The patient should wait for 10–15 min before discharge.
7. Discharge instructions are then provided. Home instructions:
   - Instruct the patient to sleep in a semi-recumbent position for the next two nights; the patient should sleep at a 45° angle, which is most easily done by sleeping in a recliner or with several pillows arranged on a couch.
   - Sleep on the nonaffected side.
   - During the day, try to keep the head in a vertical position; no sudden head movements to the right, left, up, or down.
   - When men shave under their chins, they should bend their bodies forward in order to keep their heads vertical.
   - Do not go to the hairdresser or dentist because these require head movements.
   - Care should be taken when putting in eye drops because it requires head extension.
   - No vacuuming or mopping the floor.
   - Try not to wear clothing that needs to be pulled over the head. Try to avoid bending down to tie shoes.

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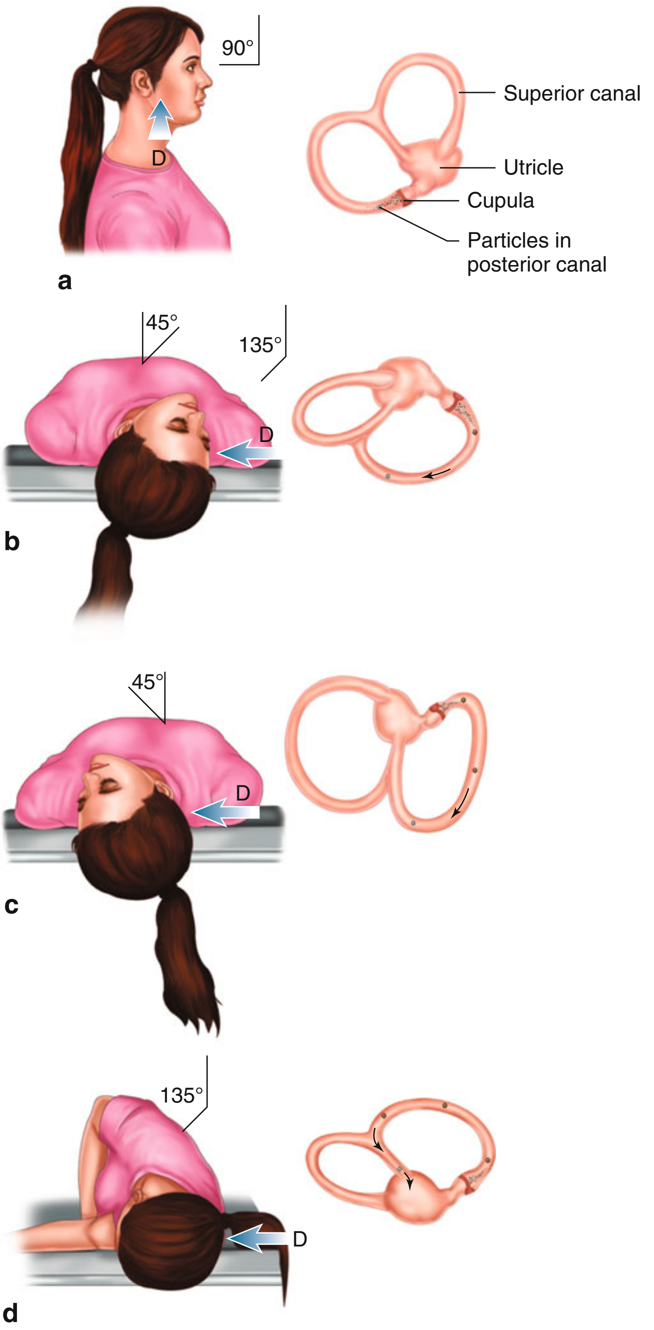

Fig. 44.1 (**a**) Patient seated on the table. (**b**) Patient in supine position, with the head turned 45° to the affected side. (**c**) Head then turned to the unaffected side (45°). (**d**) Head turned additional 90° on the unaffected side. *D* direction of view of labyrinth

44.5 Complications

When performing the previous maneuver, caution is advised should neurological symptoms occur. Occasionally such symptoms are caused by compression of the vertebral arteries; if it persists for a long period of time, a stroke can occur.

44.6 Pearls and Pitfalls

- Pearls
  - This maneuver should initially be performed by a trained therapist or medical physician.
  - It is best to perform the Epley maneuver before going to bed at night.
- Pitfalls
  - The patient should not drive herself or himself home after the procedure.
  - Avoid rapid changes in head position that might provoke BPPV.

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Clinical Brain Death Examination in Adults

45

Eric S. Papierniak, Hassan M. Alnuaimat, Tracy Timmons, and Deborah M. Stein

45.1 Indications

- Deep coma without any identifiable reversible causes
- Suspected brain death in a mechanically ventilated patient

45.2 Contraindications

- Metabolic derangements
- Acid-base disorders
- Electrolyte abnormalities sufficient to cause the coma
- Profound hypotension
- Hypothermia (core body temperature <36°C)
- Drug overdose or toxic exposure
- Locked-in syndrome

45.3 Materials and Medications

- A bright light
- Intravenous (IV) catheter
- 30-mL syringe
- 50-mL of ice water
- Endotracheal suction catheter
- Long swab or tongue depressor
- Gauze 4×4 or saline eye drops

45.4 Procedure

1. Evaluate the motor response to pain.
    - Apply pressure to the supraorbital nerve and nail beds. No motor response is consistent with brain death (Figs. 45.1 and 45.2).
2. Test for the absence of brainstem function.
    - Check pupillary response to bright light.
    - Check the oculocephalic reflex. With the eyelids held open, quickly turn the head to the side. The normal response is for the eyes to move in the opposite direction, maintaining the focus forward. Failure of the eyes to deviate during head rotation is consistent with brain death (Fig. 45.3).
    - Check the oculovestibular reflex with cold caloric testing. Elevate the head of the bed to 30°. Attach an IV catheter to the tip of a 30-mL syringe. Inject 50 mL of cold water into the external ear canal. Observe the pupils for 1 min for deviation toward the ear with the cold stimulus. Wait 5 min before testing the other side. No deviation of the pupils is consistent with brain death (Figs. 45.4 and 45.5).
    - Check for bulbar paralysis.
        - Check for a cough response to bronchial suctioning.

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  - Stimulate the posterior pharynx with a long swab or tongue depressor and observe for a gag.
  - Check the corneal reflex by lightly touching the cornea with a cotton swab, corner of gauze, or drops of sterile saline and observe for blinking of the eyelids (Fig. 45.6).

3. Check for respiratory effort by performing an apnea test. Before starting the apnea test, the following conditions must be met:
   (a) The patient must not be hypothermic. The core temperature must be greater than 36°C.
   (b) The patient must be hemodynamically stable with a systolic blood pressure greater than 90 mmHg.
   (c) The arterial blood gas (ABG) must demonstrate a normal arterial partial pressure of carbon dioxide ($PaCO_2$). The arterial partial pressure of oxygen (PaO_2) may be elevated with preoxygenation to minimize the risk of hypoxemia prematurely ending the examination.
   - Monitor the patient with a pulse oximeter.
   - Disconnect the ventilator and deliver oxygen at 6 L/min by cannula into the endotracheal tube.
   - Alternately the patient can remain connected to the ventilator with no applied support, which allows for an in-line negative pressure monitor to be attached to the circuit. Note: Most ventilators are too sensitive to be used as the sole method of sensing respiratory effort as they can produce false-negative results.
   - Watch the chest and abdomen for respiratory motion, or monitor for negative inspiratory force on the pressure gauge. Check an ABG every 10 min and when the test ends.
   - If the $PaCO_2$ increases by 20 mmHg or the $PaCO_2$ is greater than 60 mmHg and there was no respiratory effort, the test is consistent with brain death.
   - The test must be aborted and the patient reconnected to mechanical ventilation if the patient becomes hypotensive, desaturates, or develops cardiac arrhythmias.
   - If there is respiratory effort, the patient must be reconnected to mechanical ventilation (Figs. 45.7 and 45.8).

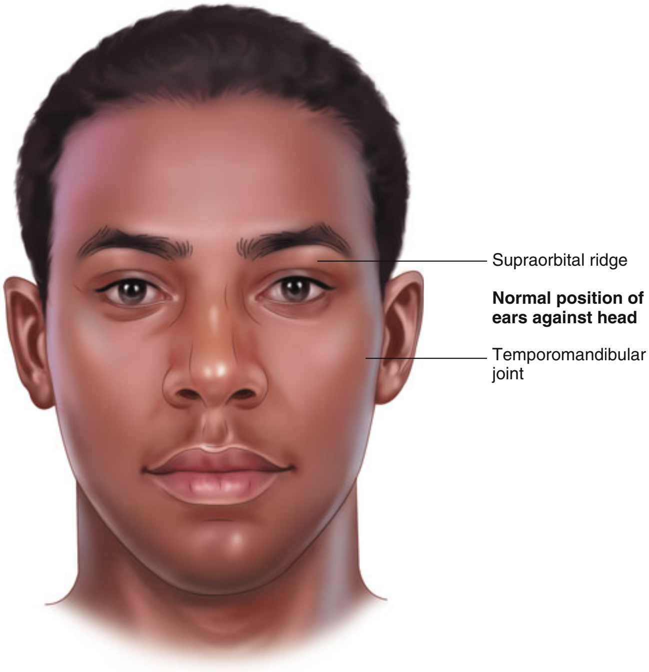

Fig. 45.1 Motor response to pain 1. Temporomandibular joint and supraorbital ridge test supraorbital nerve function

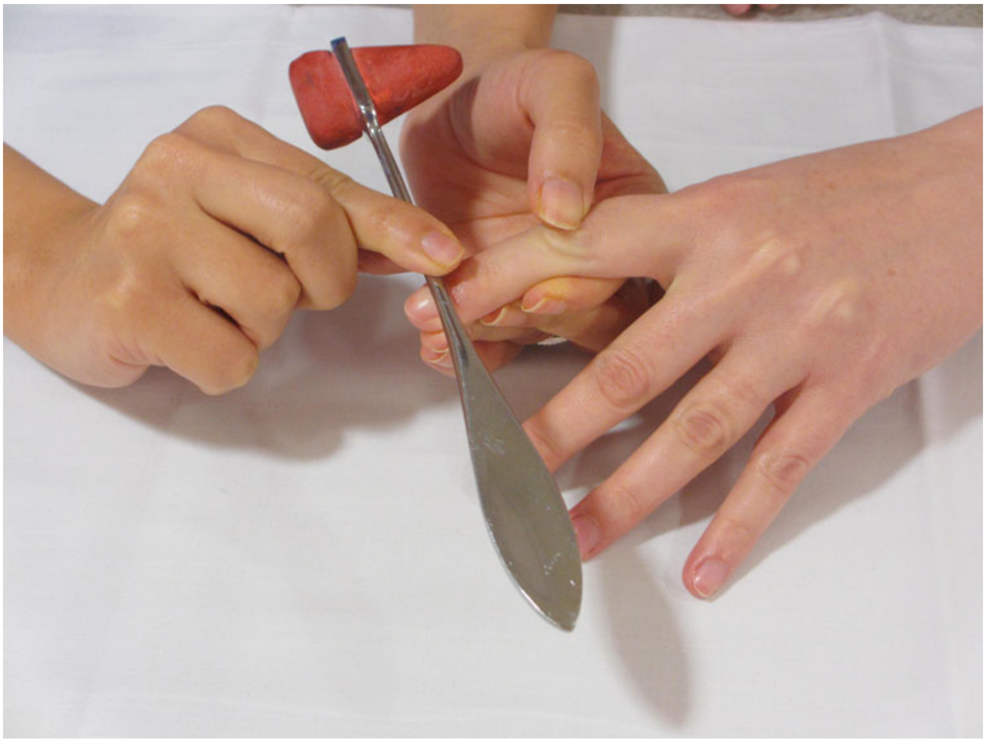

Fig. 45.2 Motor response to pain 2: Firm pressure can be applied to the nail beds with a penlight or similar instrument

a Normal reaction: Eyes move side to side when head is turned

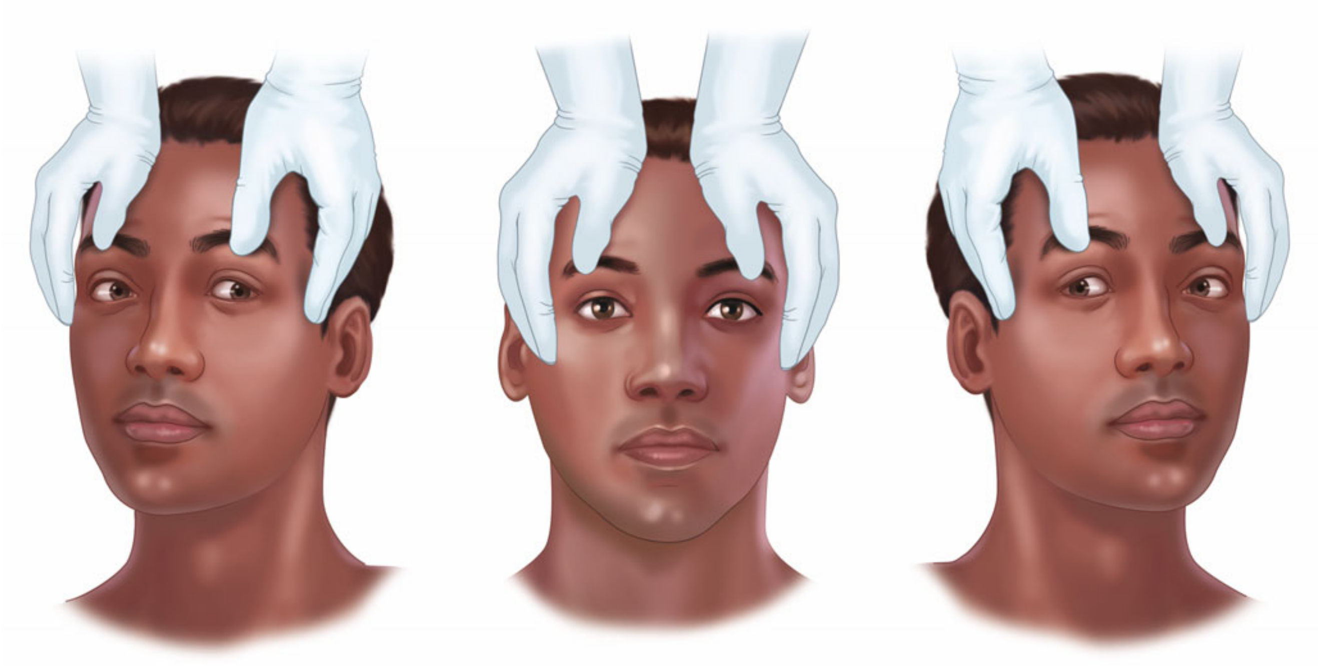

b Abnormal reaction: Eyes remain in fixed position in skull when head is turned

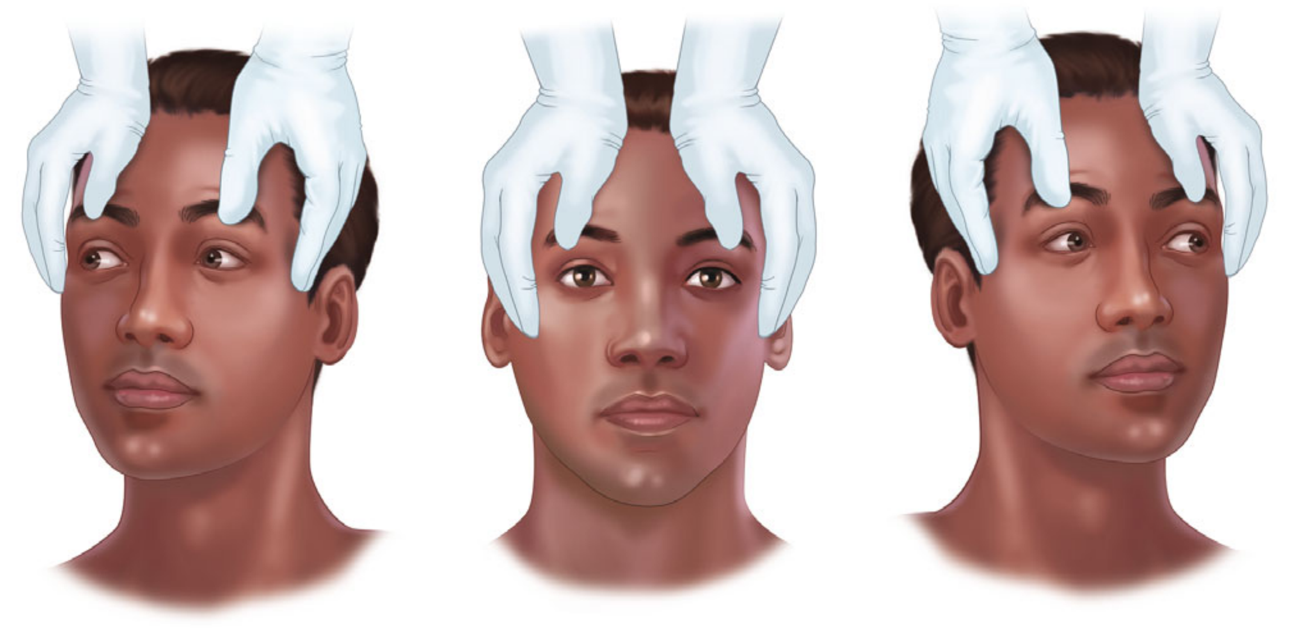

Fig. 45.3 (**a**, **b**) Oculocephalic reflex or "Doll's eyes." Movement of the eyes away from the direction of head turning (i.e., to keep the gaze forward) indicates intact functioning

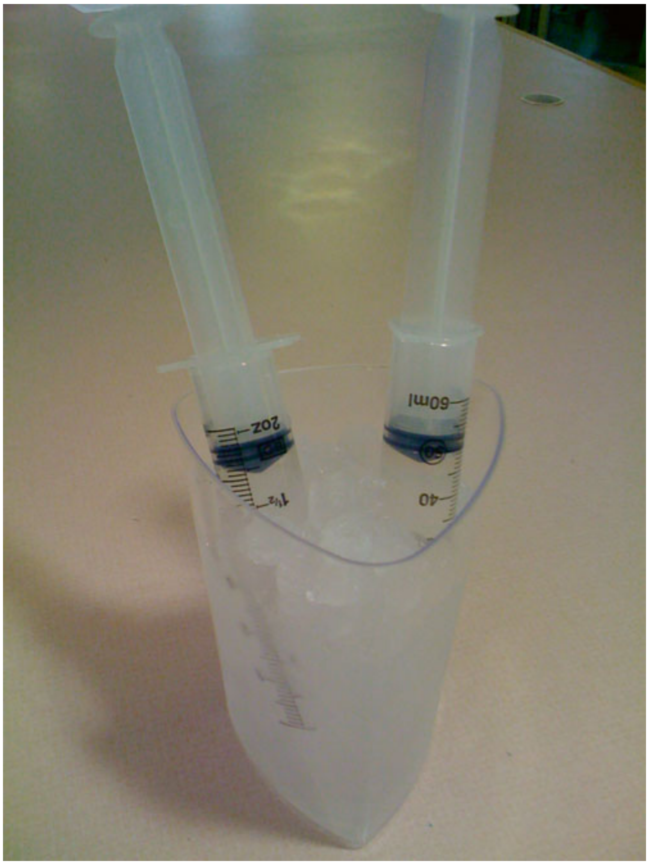
2oz
1½
60ml
40

Fig. 45.4 Preparation of cold saline for testing of the oculovestibular reflex or "cold calorics"

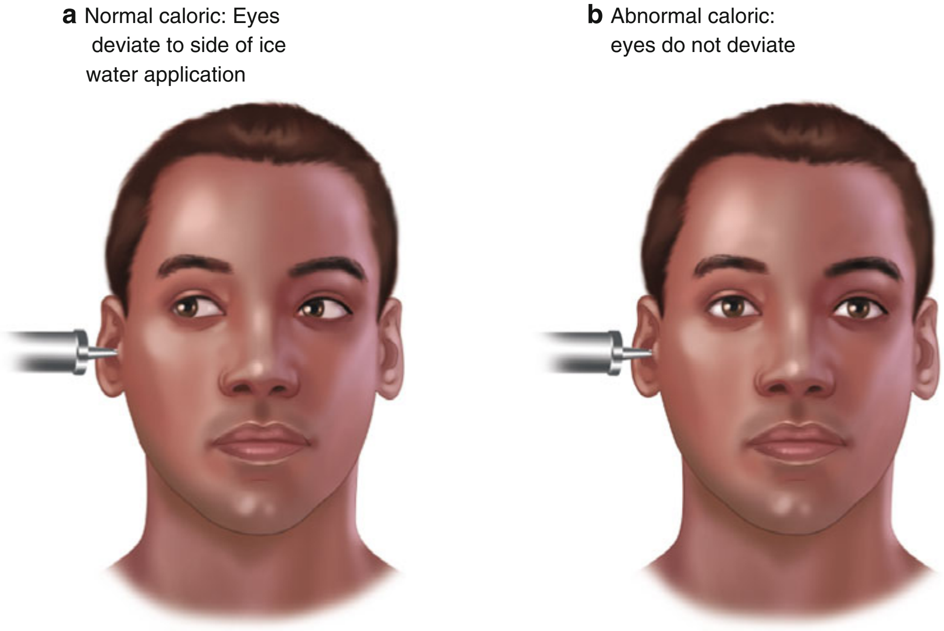
a Normal caloric: Eyes deviate to side of ice water application
b Abnormal caloric: eyes do not deviate

Fig. 45.5 (**a**, **b**) Oculovestibular reflex. Intact functioning is demonstrated by deviation of the gaze toward the side being tested

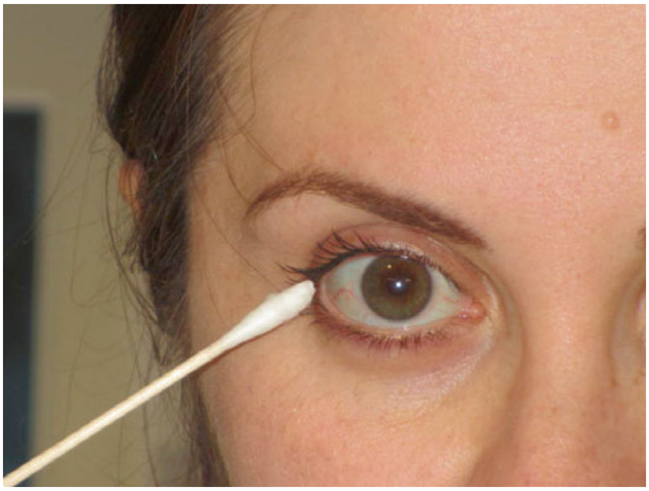

Fig. 45.6 Use of a cotton ball or unwound tip of a cotton swab for testing of the corneal reflex. A piece of sterile gauze (“4×4”) is also commonly used

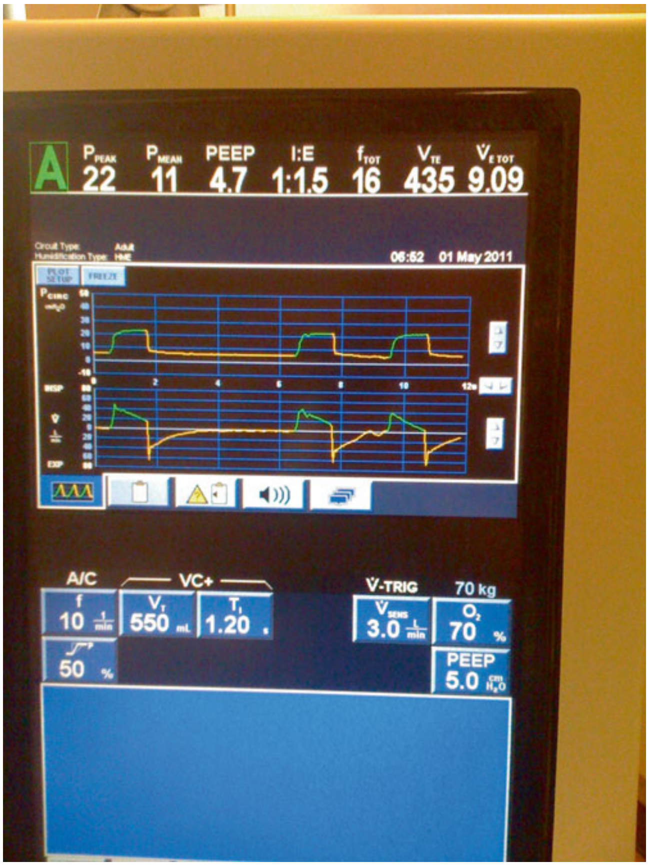
A
PPEAK 22
PMEAN 11
PEEP 4.7
I:E 1:1.5
fTOT 16
VTE 435
VE TOT 9.09
06:52 01 May 2011
PLOT SETUP
FREEZE
A/C
VC+
V-TRIG
70 kg
f 10
VT 550 mL
TI 1.20
VSENS 3.0
O2 70 %
PEEP 5.0 cmH2O
50 %

Fig. 45.7 Ventilator waveform before apnea test

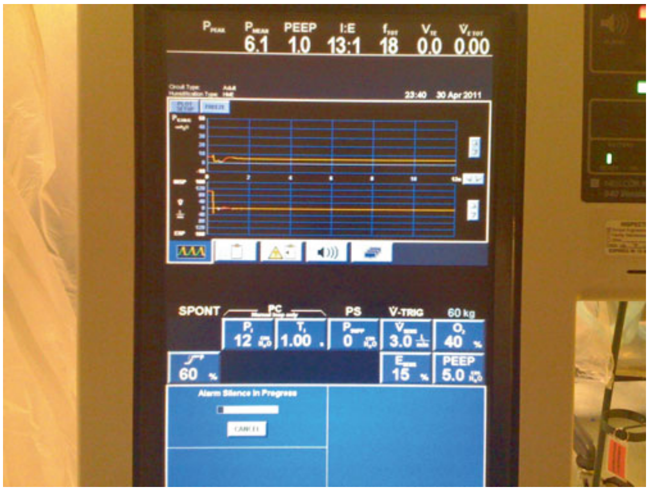
PPEAK
PMEAN 6.1
PEEP 1.0
I:E 13:1
fTOT 18
VTE 0.0
VE TOT 0.00
23:40 30 Apr 2011
SPONT
PC
PS
V-TRIG
60 kg
PI 12
TI 1.00
PSUPP 0
VSENS 3.0
O2 40 %
60 %
ESENS 15 %
PEEP 5.0
Alarm Silence in Progress
CANCEL

Fig. 45.8 Ventilator waveform in a patient without spontaneous respirations during the apnea test

45.5 Pearls and Pitfalls

- Pearls
  - The clinical examination should be performed by someone with experience or training in brain death examinations. Local regulations as well as hospital policies should be reviewed in order to determine the requirements for brain death. Some locales require a repeat examination by a different practitioner.
  - A patient with a cervical spine injury causing quadriplegia may not feel nail bed pressure and may be unable to respond to pain with more than facial movements.
- Pitfalls
  - Pupillary constriction less than 3 mm is not consistent with brain death.
  - Do not test oculocephalic reflex (doll's eyes) on patients who may have a cervical spinal cord injury from trauma.
  - Do not test the oculovestibular reflex with cold caloric testing in patients with a ruptured tympanic membrane.
  - A large number of patients may demonstrate spinal reflex movements during brain death. These reflexes may be triggered by touch, noxious stimuli, or removal of the ventilator. These movements can include plantar flexion, upper extremity posturing, eye opening, and the "Lazarus sign" (the arms raise off the bed and cross). Although these movements can be disconcerting to the health care team and family, they do not preclude a diagnosis of brain death.

45.6 Controversies

- Repeat examinations
  - The American Academy of Neurology guidelines recommend repeating the brain death examination at 6 h. The guidelines acknowledge that this is an arbitrary interval. Recent evidence suggests that the second examination may be unnecessary.
- Confirmatory Testing
  - Confirmatory testing is an option if specific elements of the clinical examination cannot be performed. For example, a trauma patient with suspected cervical spinal cord injuries precluding the oculocephalic reflex test would be a candidate for confirmatory testing.
  - Conventional cerebral angiography will demonstrate no filling beyond the carotid bifurcation or within the circle of Willis. Electroencephalography demonstrates no electrical activity. Transcranial Doppler ultrasonography will demonstrate vascular resistance associated with elevated intracranial pressure. Technetium-99m hexamethylpropylene-amine oxime brain scans demonstrate the "hollow skull" sign or no uptake of isotope in the brain (Fig. 45.9).
  - Newer modalities of confirmatory testing include computed tomography (CT) angiography and magnetic resonance imaging/magnetic resonance angiography (MRI/MRA). These tests are being used in some hospitals; however, the recent review by the American Academy of Neurology finds evidence insufficient to recommend using these newer modalities to confirm brain death.

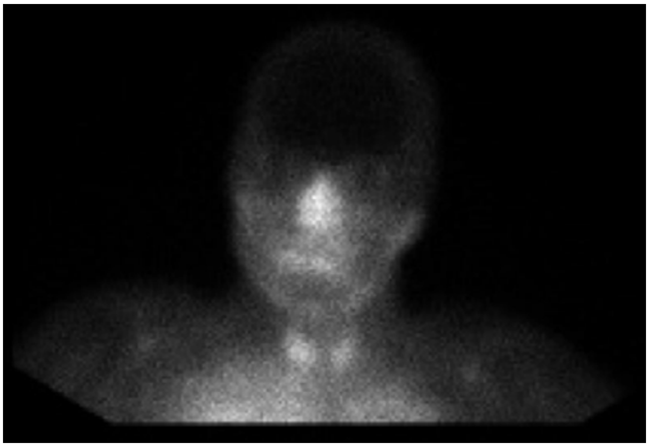

Fig. 45.9 "Empty skull sign" on nuclear medicine flow study confirms brain death

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Part VII

Ophthalmic Procedures

Slit Lamp Examination

46

Bobby K. Desai

46.1 Indications

- A slit lamp magnifies structures of the eye (Fig. 46.1).
- Gives the operator a three-dimensional view of the area visualized.
- Used to delineate abnormalities that cannot be visualized by other means.
- Helpful in foreign body removal.

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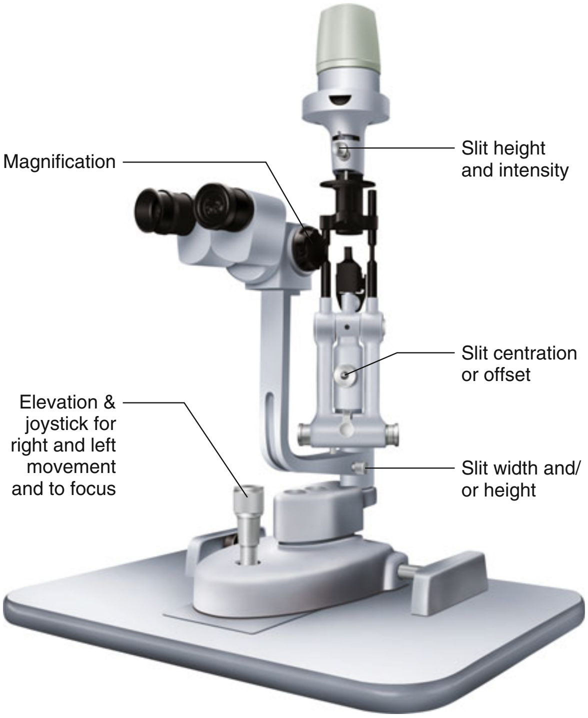
Magnification
Slit height and intensity
Slit centration or offset
Elevation & joystick for right and left movement and to focus
Slit width and/ or height

Fig. 46.1 A basic slit lamp

46.2 Contraindications

- Not to be used in patients who cannot tolerate an upright posture (e.g., trauma patients).
  - In these cases if a slit lamp examination is required, a portable slit lamp may be beneficial (Fig. 46.2).

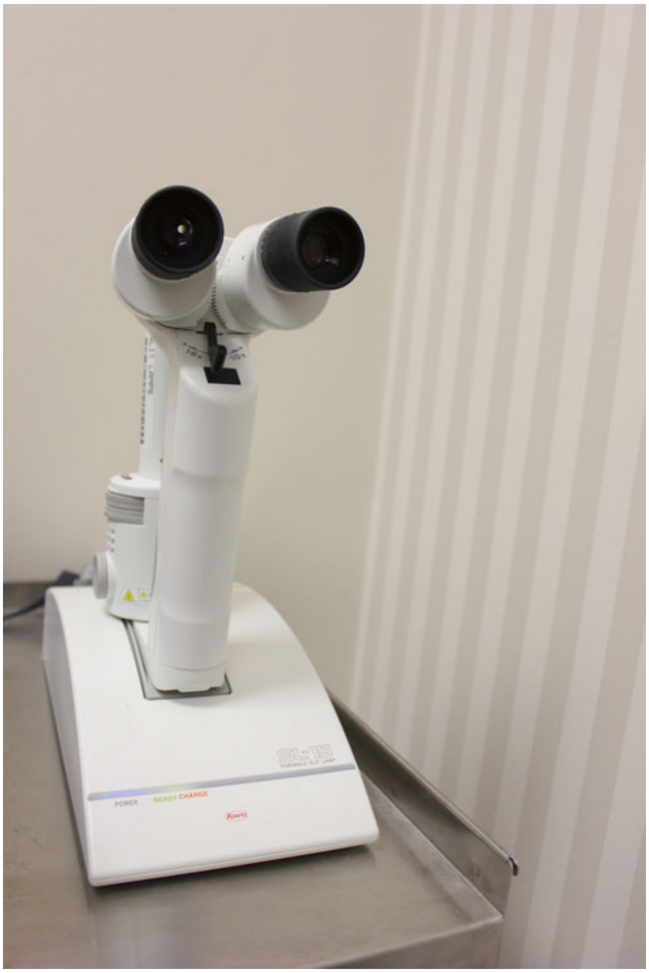
SL-15
POWER
READY
CHARGE

Fig. 46.2 A portable slit lamp

46.3 Materials

- The slit lamp is an eye-specific binocular stereoscope specifically designed to examine the eye and its structures and gives the practitioner a three-dimensional assessment of the eye.
- The operator has full movement of the microscope in all directions and the apparatus can be locked in place if required.
- Its light source can be manipulated to change the characteristics of the beam from its intensity to the angle at which it projects (Fig. 46.3).
  - A low-power setting is typically used for normal examination.
  - A higher-intensity beam is used when evaluating the anterior chamber with a narrow slit beam.
- It has colored filters typically built within the slit lamp.
  - Cobalt blue: Used with fluorescein dye to evaluate for corneal abrasions (Fig. 46.4) and avulsions; the dye will collect where the corneal epithelium is absent. It results in a yellow glow or hue visible through the microscope.
  - Green filter: Used to increase contrast of blood vessels. They appear black and the filter is useful for the assessment of hemorrhage.
- The operator is able to adjust the magnification of the microscopic typically through dial controls.
  - Low magnifications are most helpful for general examination.
  - Higher magnifications are used for examination of a particular area in fine detail.

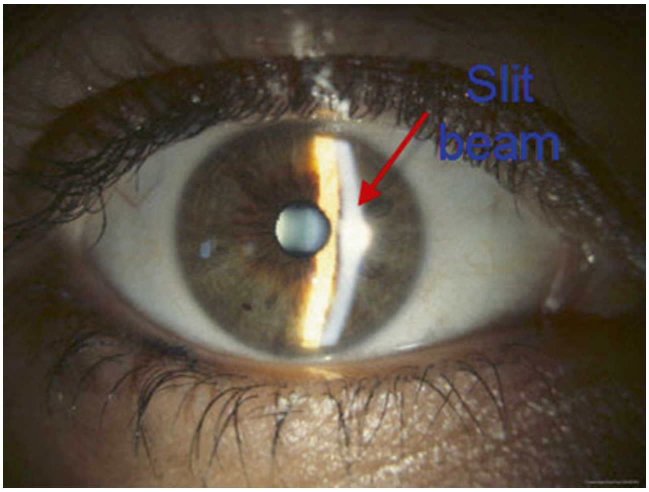

Fig. 46.3 The slit lamp beam and the reflection of the beam

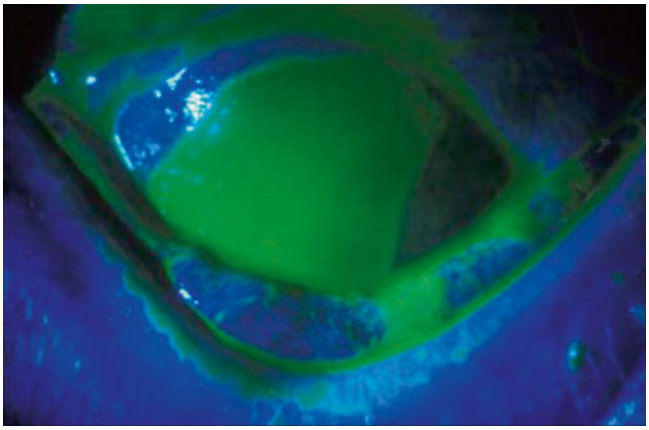

Fig. 46.4 Example of a corneal abrasion seen with a cobalt blue filter (With kind permission from Springer Science + Business Media: Das S, Chohan A, Snibson GR, Taylor HR. Capsicum spray injury of the eye. *International Ophthalmology*. 2005;26(4–5):171–3)

46.4 Procedure

1. As part of a complete eye examination, informed consent is not generally required.
2. An explanation of the procedure and reassurance are helpful.
3. Lock the slit lamp before positioning the patient because unintended movement may inadvertently damage the equipment or cause injury to the operator or patient.
4. The apparatus has a chin and a head rest. Ask the patient to place the chin and forehead in the respective areas (Fig. 46.5).
5. Adjust the height of the apparatus and the patient's chair for optimum comfort (Figs. 46.6 and 46.7). It may be necessary for children to stand during the examination.
6. The patient may place his or her hands on the sides of the table that the lamp is mounted on; this ensures stability of both the lamp and the patient.
7. Adjust the eyepieces of the microscope to fit the operator.
8. Turn on the slit lamp at its lowest setting to avoid a sudden power surge that could potentially damage the bulb.
9. Move the stage forward and narrow the beam and angle it at 45° to the patient. Aim the beam laterally so as not to cause the patient discomfort.
10. Focus the beam by manipulating the joystick to move the apparatus forward and backward so that the beam is clearly visible and its lines are sharp.
11. For each area of the eye to be examined, inspect the area thoroughly using the joystick to slowly manipulate the slit lamp across the eye in all directions, using the height adjustment of the joystick to slightly raise and lower the slit lamp as needed.
    - The operator may find that the slit lamp may move too freely; in that case she or he may find slightly tightening the locking nut of the C-arm may provide better and more precise control.

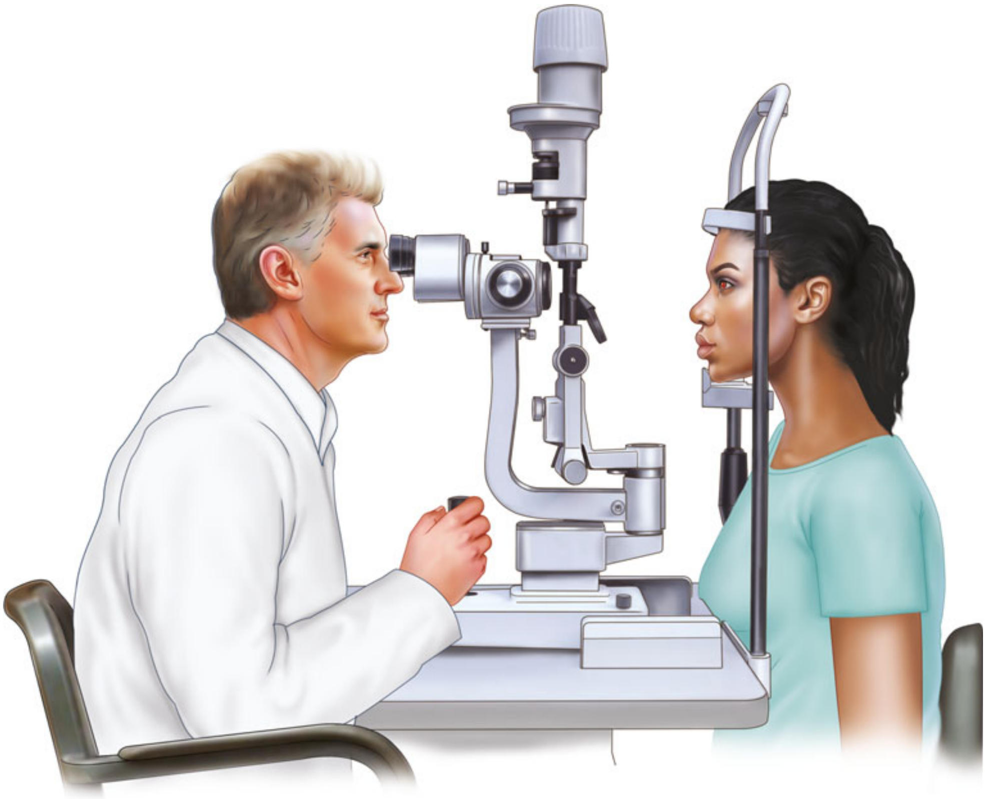

Fig. 46.5 Appropriate positioning for a slit lamp examination

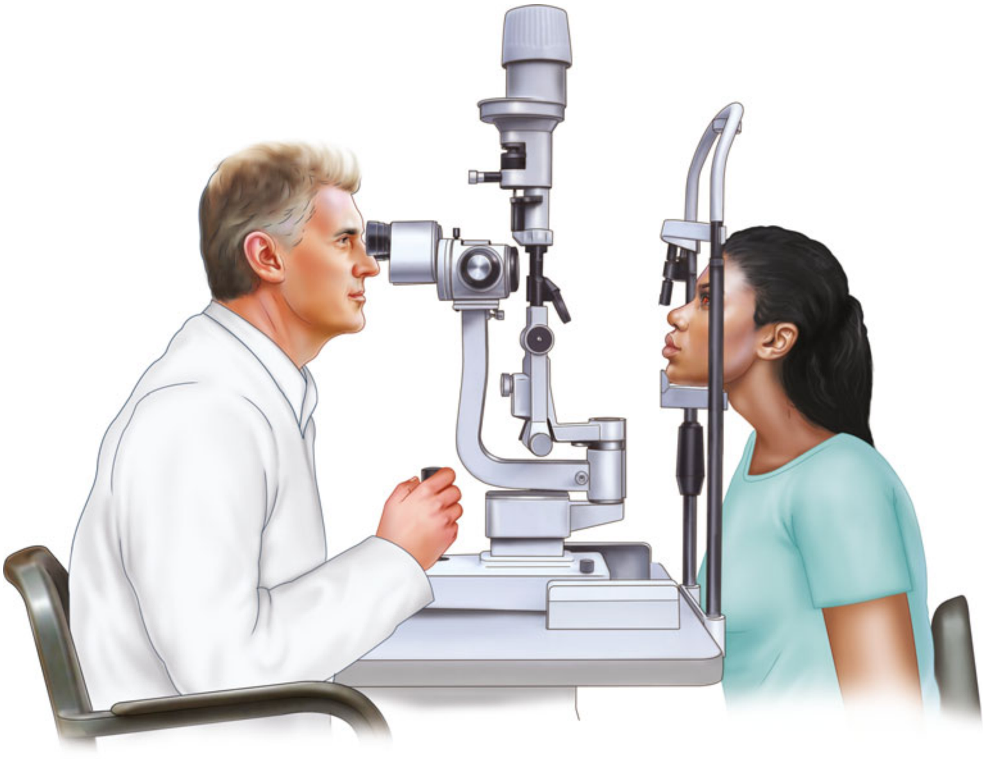

Fig. 46.6 The slit lamp is too high

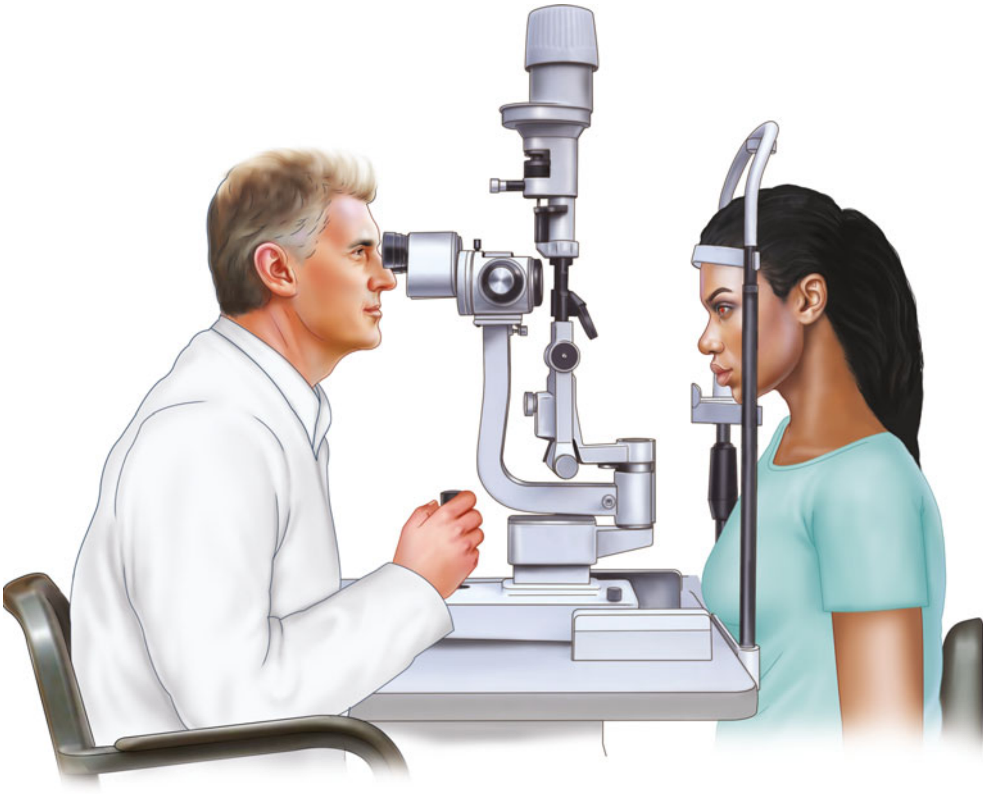

Fig. 46.7 The slit lamp is too low

46.5 Complications

There are no complications following routine slit lamp examination.

46.6 Pitfalls

- Ensure a working bulb.
- Appropriately set the microscope's oculars for the operator's pupillary distance.
- Ensure all dials and knobs are firmly set.
- Inadequate focusing
- Patient noncompliance

46.7 Fluorescein Testing

46.7.1 Indications and Uses

- Examination of the cornea under a cobalt blue filter on a slit lamp or Wood's lamp: The chemical fluoresces under blue light and appears green under these circumstances.
- Useful for detecting corneal abrasions, corneal foreign bodies, and infections of the eye.

46.7.2 Procedure

- Fluorescein is typically used after installation of a topical anesthetic, which provides patient comfort especially for those with significant pathology.
- The fluorescein strip comes packaged in single-use wrappers (Fig. 46.8).
- Hold the strip by the white end and wet the orange end *lightly* because heavily moistening the strip may cause a significant amount of dye to be present, obscuring the examination.
  - A dry strip may be used, but it may irritate the patient's eye especially if already sensitive.
- If this occurs, the clinician may use tissue paper to gently blot the excess solution away.
  - The exception to this is the performance of the *Seidel test*, which is used to assess the eye for potential perforation (Fig. 46.9).
  - The clinician will instill a large amount of dye into the eye by wetting the orange strip copiously.
  - The clinician will next examine the eye for a stream of fluid leaking from the ruptured globe.
  - This stream will fluoresce green or blue in distinction to the rest of the globe, which appears orange.
- The choice of solution to wet fluorescein strip is up to the clinician because saline, tap water, or the recently used anesthetic solution may be used safely.
- Place the now-wet orange end on the lower lid of the patient's eye.
- Ask the patient to blink several times to allow the solution to spread evenly.
- The clinician may use a Wood's lamp, penlight, or the cobalt blue filter on the slit lamp to examine the now-stained eye.
  - The slit lamp is preferable owing to the potential for missing small abrasions.

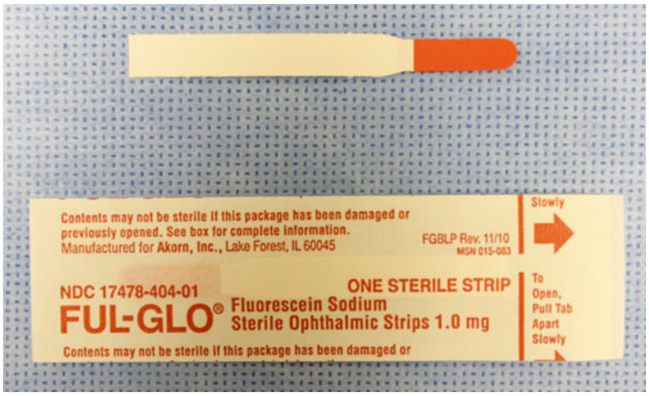
Contents may not be sterile if this package has been damaged or previously opened. See box for complete information.
Manufactured for Akorn, Inc., Lake Forest, IL 60045
FGBLP Rev. 11/10
MSN 015-083
Slowly
NDC 17478-404-01
ONE STERILE STRIP
FUL-GLO®
Fluorescein Sodium
Sterile Ophthalmic Strips 1.0 mg
To Open, Pull Tab Apart Slowly
Contents may not be sterile if this package has been damaged or

Fig. 46.8 A typical fluorescein strip package

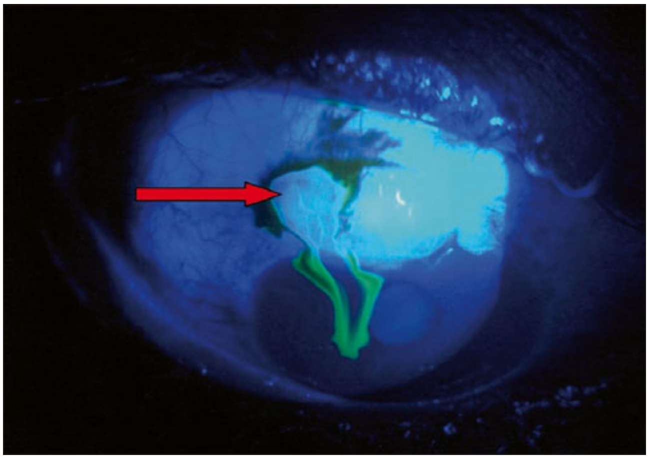

Fig. 46.9 A positive Seidel test (Reproduced with permission from: Lingam V, Panday M, George R, Shantha B. Management of complications in glaucoma surgery. *Indian J Ophthalmol*. 2011;59(Suppl1): S131–40)

46.7.3 Complications

- There is a theoretical risk of the development of superficial punctate keratitis from instillation of topical anesthetic before fluorescein testing.
- Discoloration of soft contact lenses.
- Potential for infection using premixed fluorescein solution.

46.7.4 Pitfalls

- Contact lens wearers should remove their lenses because the fluorescein will permanently stain the lens.
  - The wearer should not put the contacts back in for several hours.

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Eye Irrigation

47

Bobby K. Desai

47.1 Indications

- Chemical burns to the eye
- Removal of superficial foreign bodies

47.2 Contraindications

- For suspected globe perforation, extreme care must be taken to not exacerbate the injury.

47.3 Materials and Medications

- Irrigating device—the Morgan lens (Fig. 47.1)
- Saline solution or lactated Ringer's (preferably warmed)
- Topical anesthetic drops (Fig. 47.2)
- Basin to secure the extruded solution
- Intravenous (IV) tubing to attach the IV bag to the Morgan lens
- pH paper (Fig. 47.3)

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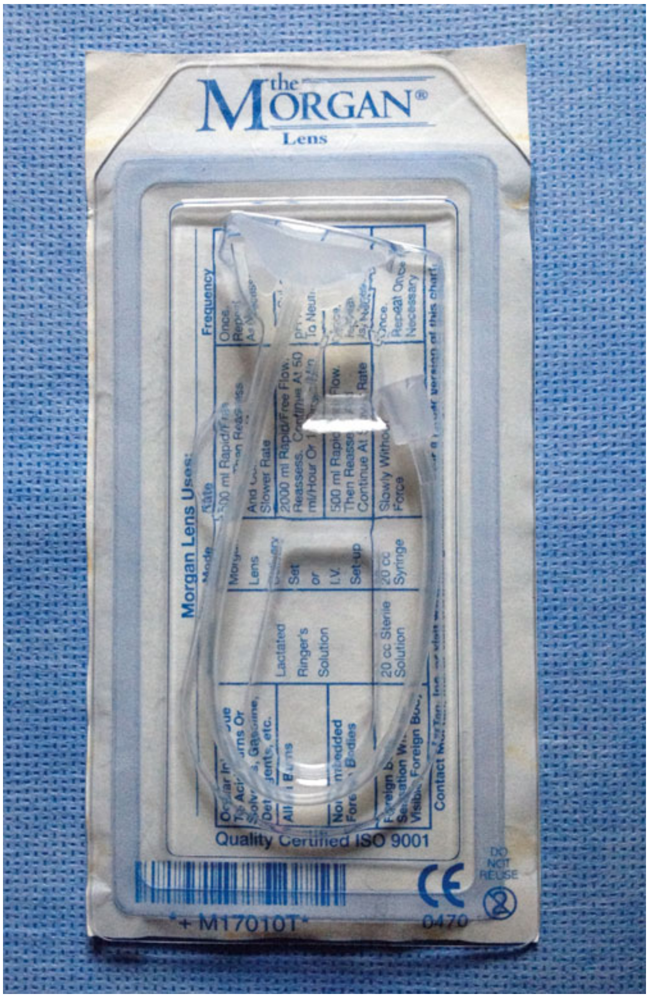

Fig. 47.1 The Morgan lens and packaging

Fig. 47.2 Examples of topical anesthetics

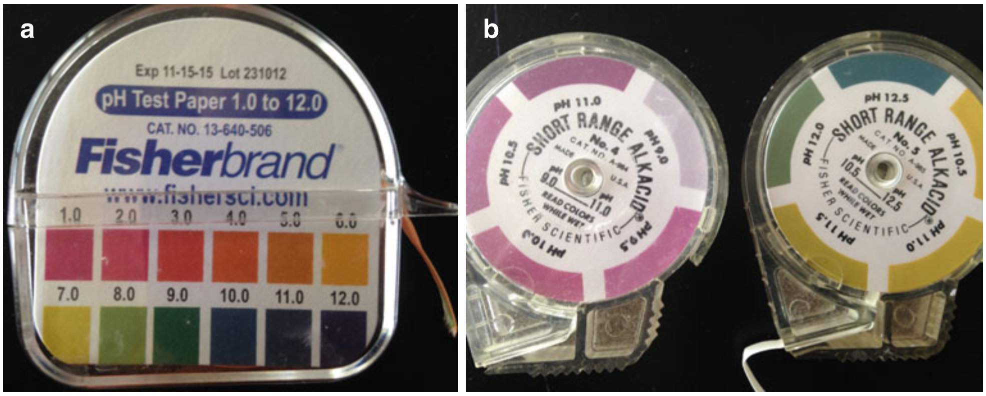

Fig. 47.3 (**a**, **b**) Examples of pH paper

47.4 Procedure

1. Informed consent is generally not required, although a thorough explanation to the patient is warranted.
2. Obtain pH of the eye *before* instilling anesthetic drops.
3. Anesthetize the eye(s) with topical anesthetic of choice by instilling drops within the lower lid and then asking the patient to blink several times in order to evenly distribute the solution.
4. Ensure there are no foreign bodies on the inside of the upper lids by inverting the upper lid.
    - Particulate foreign bodies may be removed with moistened cotton tip applicators.
5. After adequate anesthesia is ensured, place one end of the Morgan lens within the fornix of the upper lid (Fig. 47.4).
6. Next, gently retracting the lower lid will ensure smooth placement of the remaining portion of the Morgan lens (Fig. 47.5).
7. Using the end of the Morgan lens, screw in the prepared IV tubing (Fig. 47.6).
8. Attach the end of the IV tubing to the saline bag and place at height to allow for gravity to ensure a smooth flow of solution.
    - Continue to irrigate the eye until desired pH is obtained.
9. To remove the Morgan lens, use the opposite technique for insertion.

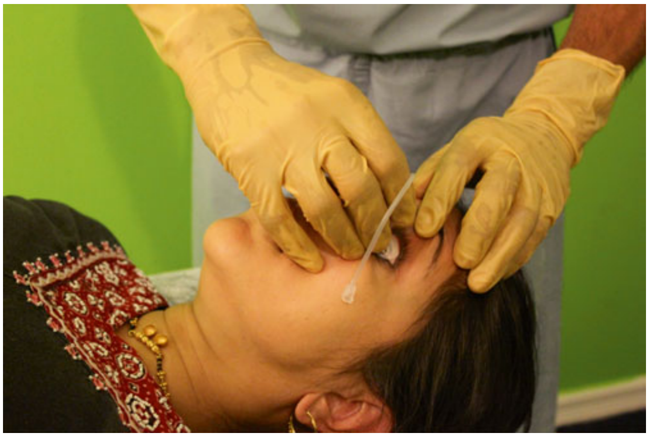

Fig. 47.4 Inserting the Morgan lens under the upper lid

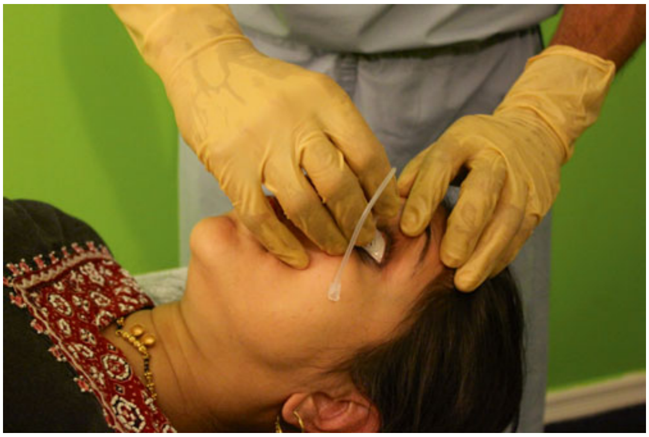

Fig. 47.5 Inserting the Morgan lens under lower lid

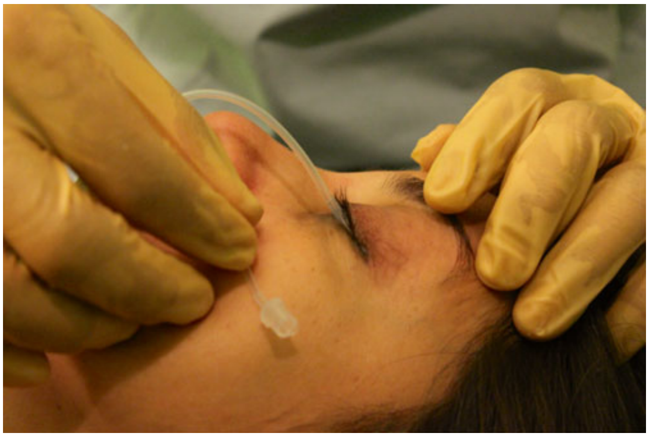

Fig. 47.6 The Morgan lens in place, ready to be attached to IV tubing for saline irrigation

47.5 Complications

- Corneal abrasions may be caused by the Morgan lens and are treated in the usual fashion.
- Deep corneal injury may occur with inadequate irrigation.

47.6 Pearls and Pitfalls

- Note that alkali burns will require significant irrigation and more topical anesthesia may be required.
- Ophthalmological consultation may be required, especially for alkaline and hydrofluoric acid burns.

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Corneal Foreign Body Removal

48

Bobby K. Desai

48.1 Indications

- Presence of a corneal foreign body (Fig. 48.1)

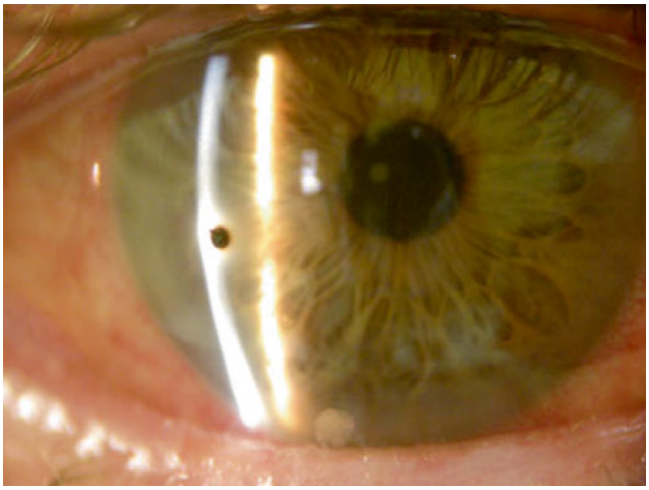

Fig. 48.1 Corneal foreign body (With kind permission from Springer Science+Business Media: Zuberbuhler B, Tuft S, Gartry D, Spokes D. Ocular Surface and Reconstructive Surgery. In: *Corneal Surgery*. 2013. 29–48)

48.2 Contraindications

- An uncooperative patient may require ophthalmological consultation as well as sedation.
- Suspected foreign bodies from high-velocity injuries must be referred to an ophthalmologist subsequent to initial evaluation.
- Any signs of globe penetration (e.g., hyphema) require emergent ophthalmological consultation.
- Overt globe rupture.
- Evidence of an inflammatory process such as iritis requires emergent ophthalmological consultation.
- Foreign bodies associated with corneal burns secondary to chemical exposure such as alkaline corneal burns will require emergent ophthalmological consultation.

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48.3 Materials and Medications

- Eye chart for visual assessment
- Cotton tip applicator
- Slit lamp or other source of magnification
- 27-Gauge needle or ophthalmic foreign body needle (Fig. 48.2)
- Topical ophthalmic anesthetic
- Ophthalmic burr (Fig. 48.3)

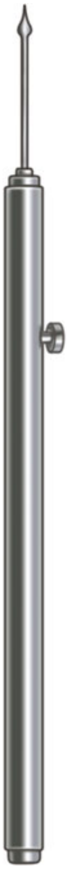

Fig. 48.2 Foreign body needle

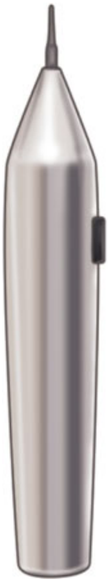

Fig. 48.3 Ophthalmic burr drill

48.4 Procedure

1. Informed consent may be required.
2. Visual acuity and a formal assessment of the eye should be done and documented.
3. Consider intraocular foreign body.
    - Computed tomography (CT) scan may be used to assess for the presence of an intraocular foreign body.
4. Eversion of the upper lid should be performed to evaluate for retained foreign body under the lid.
    - These usually can be removed by:
        - A moistened cotton tip applicator
        - Irrigation
5. Magnification is preferable, but some foreign bodies may be large enough to see with the naked eye.
6. Anesthetize the eye with topical anesthetic.
7. For multiple loose foreign bodies, removal may be attempted with irrigation after appropriate anesthesia.
8. Removal of the foreign body may be attempted with a moistened cotton swab.
    - Metallic foreign bodies recently embedded within the cornea may be difficult to remove in this fashion.
    - However, during the healing process, some metallic foreign bodies may be pushed closer to the surface during reepithelialization of the cornea. These potentially can be removed with this technique.
        - Care must be taken to avoid leaving a rust ring that could permanently stain the cornea.
9. A 27-gauge needle bent at a 90° angle may be used to remove foreign bodies by gently prying it out.
    - An advantage of using a needle is that any rust ring as well as any metallic foreign body can potentially be removed.
10. Technique: A slit lamp may be used to magnify the area.
    - See slit lamp chapter (Chap. 46) for details.
    - The patient should be informed about the procedure; formal informed consent may not be required.
    - Proper positioning is critical for success.
    - The patient's head should be fully forward and firmly placed against the head rest.
    - The patient's hands may be placed on the sides of the slit lamp stage for stabilization.
    - Apply topical anesthesia to the cornea.
11. Using the patient's cheek as a bolster potentially avoids significant movement of the needle if the patient unexpectedly moves.
    - Other modalities for stabilization include supporting the elbow by placing on a box or using towels.
12. Have the patient gaze at one point in the far distance.
    - Using the needle or burr as a scoop, gently manipulate the foreign body out.
        - Using a burr can allow for the total removal of any rust ring.
13. Once the foreign body is removed, patching is not required.
14. Consider application of topical antibiotics.
15. Tetanus prophylaxis should be given as for open other wounds.
16. Arrange follow-up with a primary care physician or preferably an ophthalmologist.

48.5 Complications

- Forceful attempts to dislodge a foreign body may result in corneal perforation.
- Incomplete removal of a foreign body.

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Ultrasound Evaluation of Retinal Detachment

49

Shalu S. Patel, L. Connor Nickels, and Rohit Pravin Patel

49.1 Indications

- To aid in the evaluation of vision loss or change in vision

49.2 Contraindications

- Relative: Suspicion of increased intraocular pressure
- Relative: Suspicion of globe rupture (see Chap. 50)

49.3 Materials and Medications

- Bedside ultrasound machine with high-frequency (7.5- to 10-MHz) linear transducer
- Transparent adhesive such as Tegaderm (optional)
- Sterile ultrasound gel
- Sterile gauze

49.4 Procedure

1. Position the patient supine with his or her eyes closed. The eyelid may be taped closed with a transparent adhesive if desired (Fig. 49.1).
2. Place a liberal amount of ultrasound gel over the eyelid.
3. Place the ultrasound probe over the eye in a transverse position.
4. Adjust the depth of the ultrasound so that the whole eye fills the screen.
5. Scan through the eye fully in the transverse and sagittal planes.
6. When viewing the ultrasound image, the normal eye is a circular hypoechoic structure (Fig. 49.2). The structures should be evaluated from anterior to posterior.
7. Identify the cornea. This is the first thin hypoechoic line in the anterior eye.
8. Continuing posteriorly, identify the anterior chamber, which is an anechoic area bordered by the cornea, iris, and lens. The iris is an echogenic linear structure, and the normal lens is anechoic.
9. Identify the vitreous chamber, the large anechoic region posterior to the lens.
10. Carefully evaluate the posterior globe. The normal retina cannot be distinguished from the other choroidal layers on ultrasound.
11. A detached retina will appear as a hyperechoic linear floating membrane in the posterior vitreous chamber (Fig. 49.3).
12. In the retrobulbar region, the optic nerve can be identified as a hypoechoic linear structure perpendicular to the globe (Fig. 49.3).

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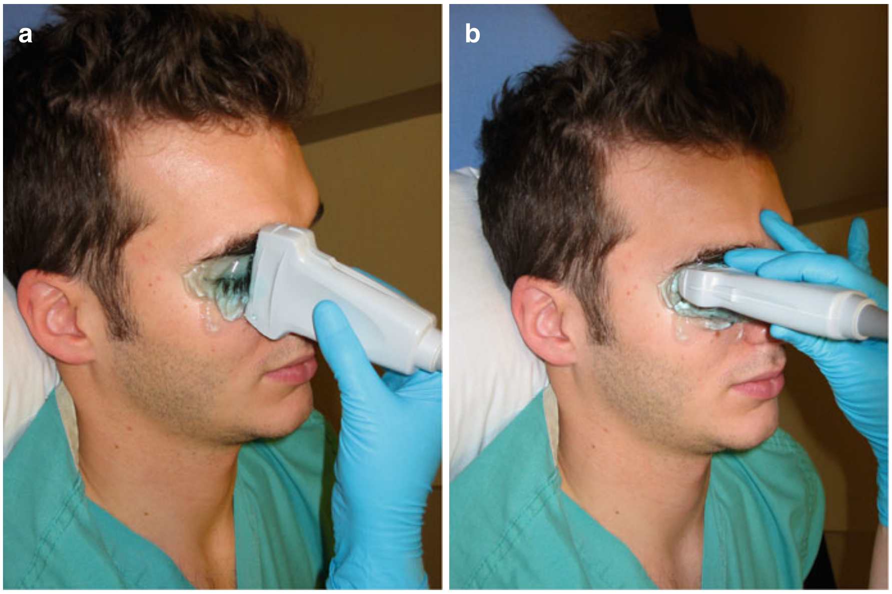

Fig. 49.1 Probe positioning with Tegaderm applied to orbit: (**a**) sagittal view, (**b**) axial view

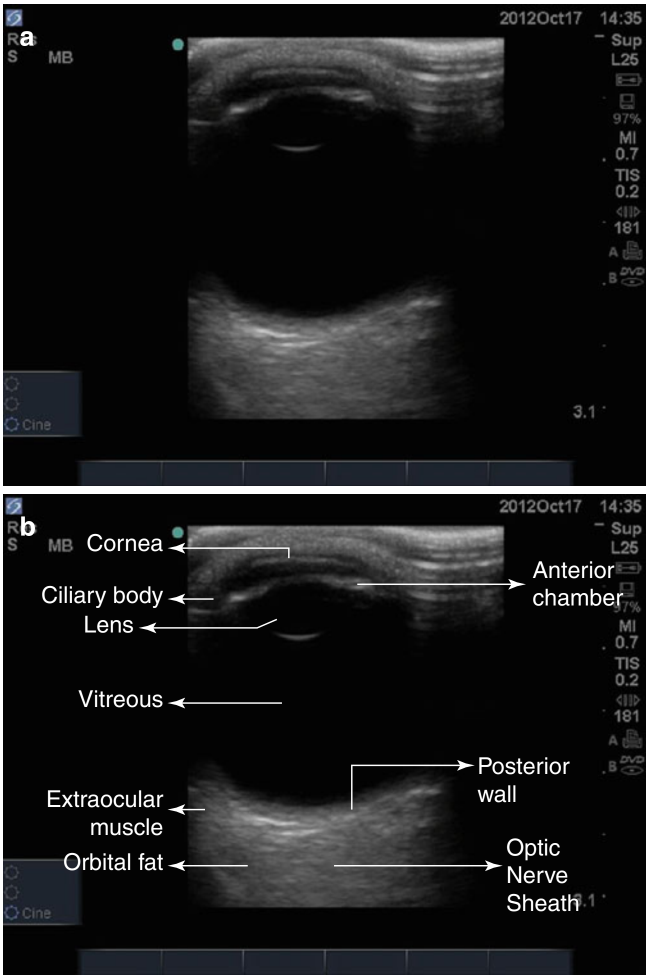
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181
MB
3.1
Cine
Cornea
Ciliary body
Lens
Vitreous
Extraocular muscle
Orbital fat
Anterior chamber
Posterior wall
Optic Nerve Sheath

Fig. 49.2 Ocular ultrasound with normal anatomy findings ((**a**) without labels, (**b**) with anatomy labeled)

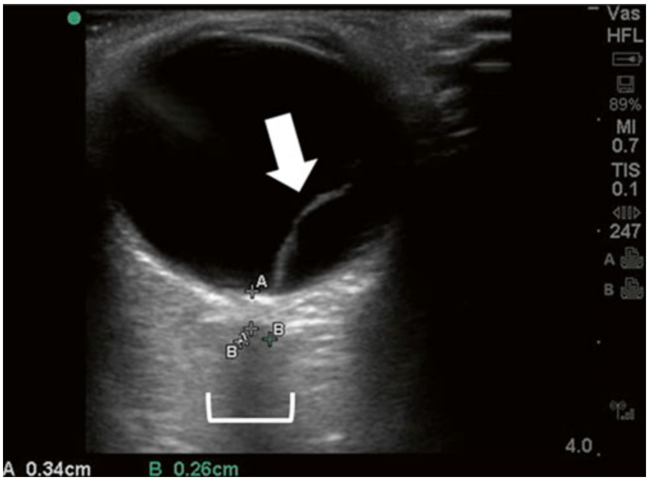
Vas
HFL
89%
MI
0.7
TIS
0.1
247
A
B
4.0
A 0.34cm
B 0.26cm

Fig. 49.3 Retinal detachment appears as a hyperechoic linear structure (*white arrow*). *White* bracket shows the optic nerve sheath shadow (see Chap. 50 for more information)

49.5 Complications

- Conjunctival infection
- Increased intraocular pressure (if too much pressure is applied)

49.6 Pearls and Pitfalls

- Pearls
  - Use a transparent adhesive such as Tegaderm to decrease the risk of conjunctival infection.
  - Use a liberal amount of gel to obtain the best images.
  - Use minimal pressure to obtain the best images.
  - False positives on ocular ultrasound may occur with disk edema or vitreous hemorrhage.
- Pitfalls
  - Subacute retinal detachments may be missed on ocular ultrasound.

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Ultrasonography in the Evaluation of Intraocular Pathology

50

Benjamin M. Mahon, Marie-Carmelle Elie,
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50.1 Indications

- Eye trauma
- Loss of vision or decreased vision
- Head injury
- Ocular pain
- Suspected foreign body

50.2 Contraindications

- None

50.3 Materials

- Linear probe (7.5–10 MHz)
- Tegaderm or other protective eye covering
- Copious amounts of water-soluble transmission gel

50.4 Procedure

1. Begin by asking the patient to close her or his eye, and then apply the Tegaderm or other suitable eye cover over both eyes.
2. Apply a copious amount of transmission jelly over both eyes.
3. Gently apply the ultrasound probe to the outer eyelid. If the operator has used a sufficient enough amount of jelly, the probe itself should not need to be in actual contact with the eyelid. This becomes of critical importance in suspected globe trauma or intraocular foreign body, when excess manipulation of the intraocular contents could precipitate further damage or worsening of present damage. Ensure the pressure is gentle enough to prevent this, but sufficient to obtain good imaging (see Chap. 49).
4. Image the normal eye first, to become familiar with the patient's anatomy (see Chap. 49), before proceeding to the suspected abnormal eye.
5. Start with low gain.
6. Ask the patient to move the eye slowly from the left to the right. This is called kinetic echography and will provide information elaborated upon later. Have the patient keep her or his eye straight ahead, as the operator phases up and down and side to side, between the transverse and the sagittal planes.
7. Increase gain slowly while the patient is moving the eye. Shifting from low gain to higher gain during the examination will help to prevent overlooking certain disease processes. As a fluid-filled structure, the eye provides its own acoustic window, and imaging is generally easy.

50.5 Complications

- Through excessive pressure applied to the eye, as described previously, further disruption of the intraocular contents and worsening of preexisting injury can occur.

50.6 Pearls and Pitfalls

- Pitfalls
  - Applying too much pressure to the globe and disrupting already damaged intraocular contents
  - Failing to image with full spectrum of gain
  - Using an insufficient amount of gel

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50.7 Specific Disease Processes/Pathology [1]

50.7.1 Vitreous Hemorrhage (Fig. 50.1)

- Best seen in high gain.
- Clinical: Very common pathology. Seen as “floaters” on the visual field. Can cause blindness if large.
- Ultrasound: Appearance may vary. Early on in the evolution of a hemorrhage, these can be seen as small dots or mobile linear opacities that float freely in the back of the posterior chamber with eye movement. Has been described as a “snow-storm appearance.” As hemorrhage ages, the blood organizes and membranes form, sometimes layering inferiorly owing to gravity.

50.7.2 Vitreous Detachment

- Best seen with higher gain.
- Clinical: Common in older patients. Presents as “flashers.” Vitreous gel loses its attachment from the internal membrane lining.
- Ultrasound: Seen as “swaying seaweed.” There are layering opacifications. Also seen as “snow-globe appearance.” Concurrent vitreous hemorrhage is also common.
- Note: A small percentage of patients also have a retinal tear, so ophthalmology follow-up is necessary.

50.7.3 Retinal Detachment (Figs. 50.2 and 50.3)

- Best seen with lower gain.
- Clinical: Acute loss of vision, usually painless, often preceded by “flashers” and/or “floaters” as the neurosensory component of the retina pulls away from the retinal pigment epithelium. *An ophthalmological emergency.* Can be caused by ocular trauma or no known precipitant at all.
- Ultrasound: Seen as a taut, hyperechoic, linear opacity that moves with the eye, attached to the optic disc, in the posterior region of the globe.

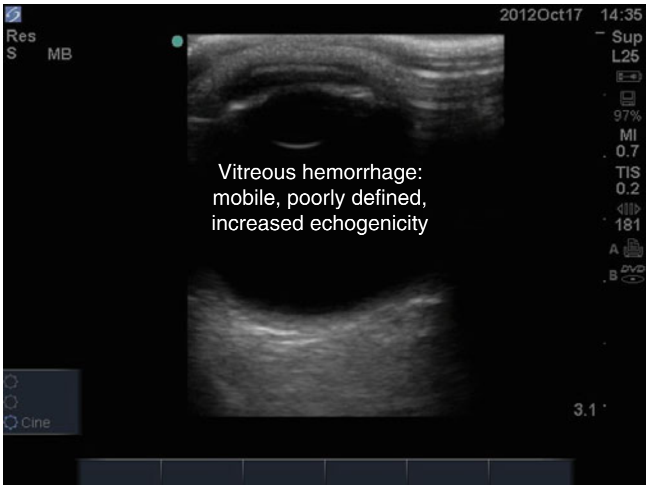

Vitreous hemorrhage: mobile, poorly defined, increased echogenicity

Fig. 50.1 Vitreous hemorrhage

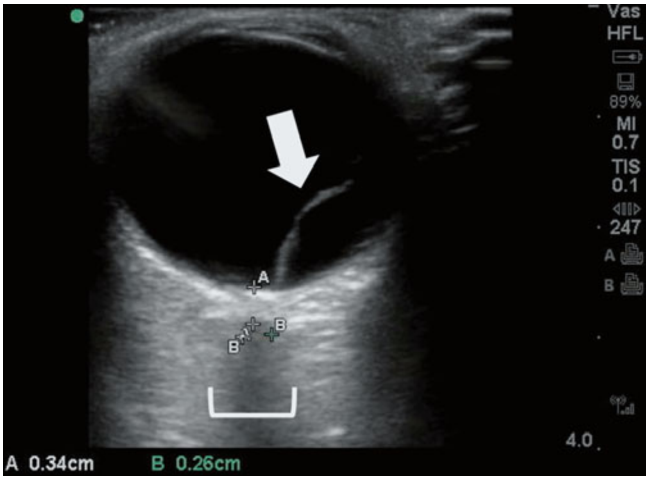

Fig. 50.2 Retinal detachment ultrasound image

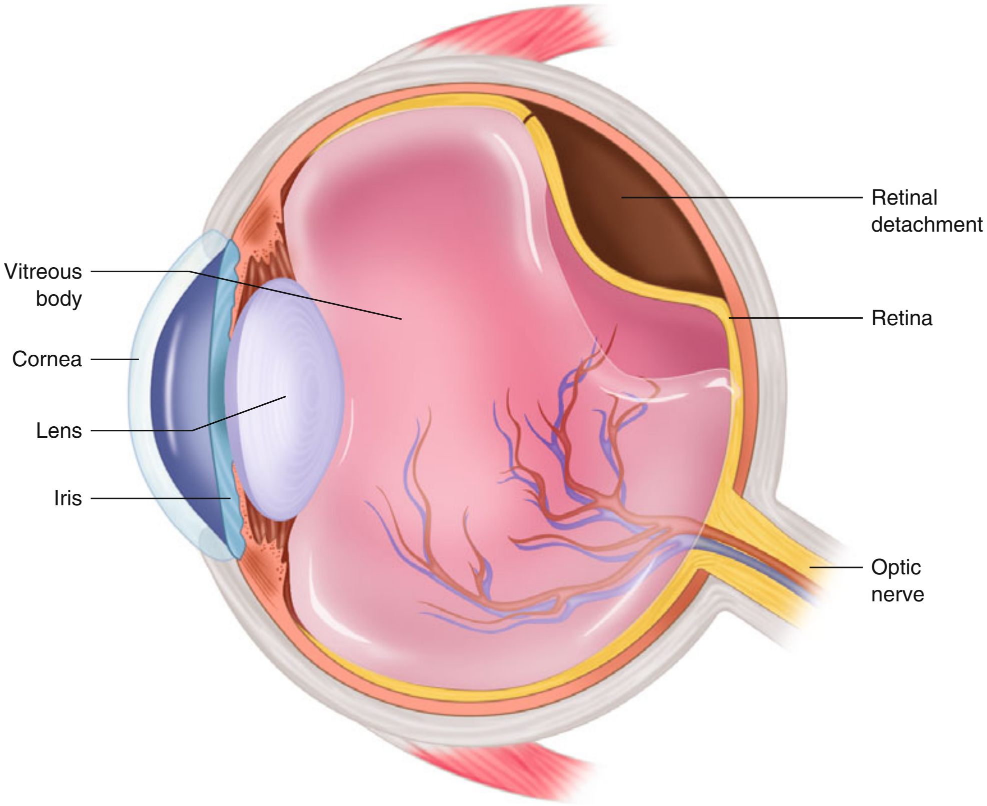
Retinal detachment
Vitreous body
Cornea
Lens
Iris
Retina
Optic nerve

Fig. 50.3 Retinal detachment graphical representation

50.7.4 Intraocular Foreign Body (Fig. 50.4)

- Clinical: Usually a preceding episode of trauma, often from metalworking or landscaping.
- Ultrasound: Foreign bodies are seen as hyperechoic substances in the eye often with distal shadowing. Certain shadow patterns distal to the foreign body, as well as comet tails, can help to differentiate the type of foreign body material.

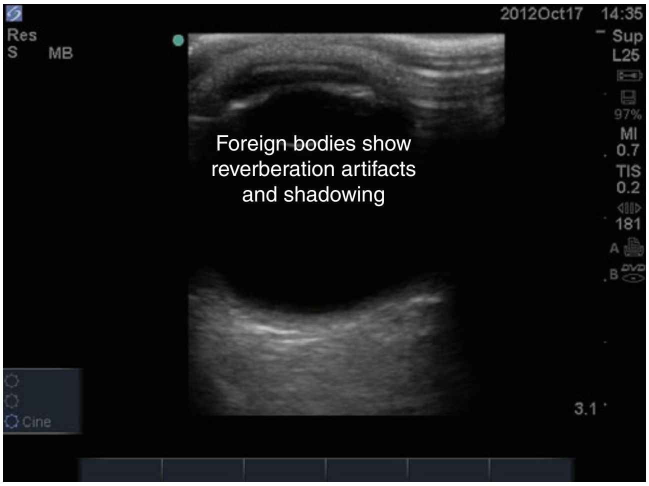
2012Oct17 14:35
Res
S MB
Sup
L25
97%
MI
0.7
TIS
0.2
181
A
B
Foreign bodies show reverberation artifacts and shadowing
Cine
3.1

Fig. 50.4 Foreign bodies

50.7.5 Globe Rupture (Fig. 50.5)

- Clinical: Usually the result of trauma. Frequently, the mechanism causing the injury has subsequently made the eye examination itself impossible, if edema, blepharospasm, hyphema, or distorted anatomy makes visualization of the posterior chamber too difficult. In these circumstances ultrasound can be immeasurably helpful.
- Ultrasound: Findings include decreased size of the anterior chamber, posterior chamber, or both, often with buckled sclera. Globe rupture should be suspected when the injury mechanism is present and any major distortion of the ocular anatomy is appreciated.

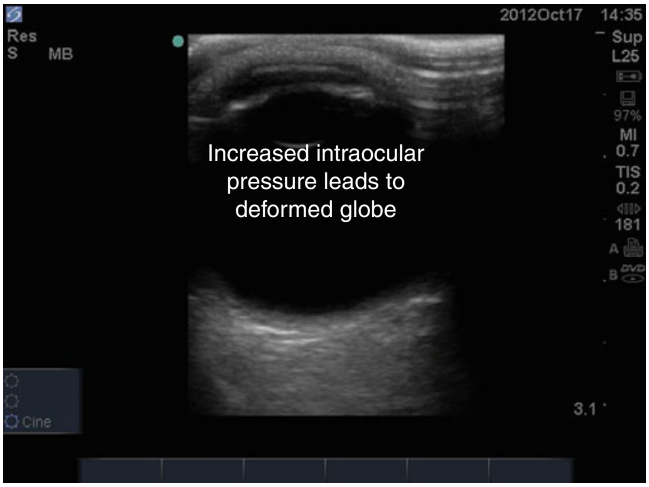
2012Oct17 14:35
Res
S MB
Sup
L25
97%
MI
0.7
TIS
0.2
181
A
B
Increased intraocular pressure leads to deformed globe
Cine
3.1

Fig. 50.5 Globe rupture

50.7.6 Increased ICP

- Clinical: Increased ICP is encountered in a number of pathological processes, such as closed head injury from trauma, altered mental status, pseudotumor cerebri, space-occupying lesion, or any other process causing intracranial injury. Physical examination may be suggestive of an intracranial process, but often key examination findings such as papilledema are not appreciated, owing to both limitations from the patient and their mental status, as well as limitations in the skill of the ED doctor, or the ability to dilate the eyes sufficiently, to appreciate the finding.
- Ultrasound: The size of the *optic nerve sheath diameter* is an indirect measurement of ICP. It is visualized as a hypoechoic linear strip radiating posteriorly from the edge of the back of the globe. A normal diameter is 5.0 mm or less. This measurement is taken at 3 mm back from the posterior edge of the globe (Fig. 50.6). Take measurements bilaterally to compare. Two or more measurements should be taken and then averaged on each side.
- A diameter greater than 5.0 mm, at 3.0 mm distal from the posterior globe border, is strongly suggestive of increased ICP and warrants further evaluation and imaging [2].

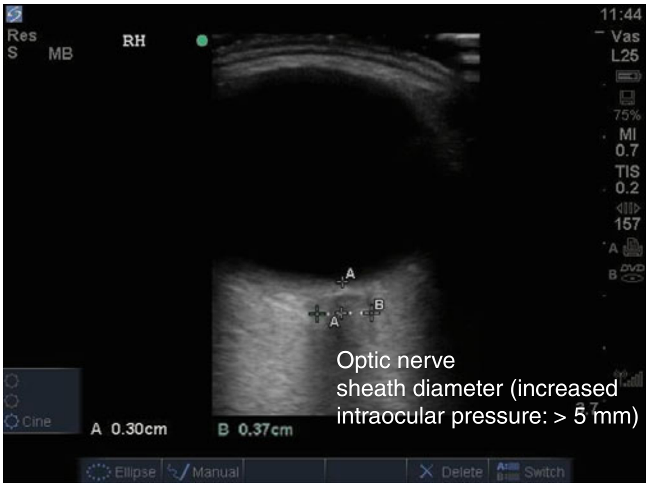

Optic nerve sheath diameter (increased intraocular pressure: > 5 mm)

Fig. 50.6 Optic nerve sheath measurement

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Tonometry

51

Bobby K. Desai

51.1 Indications

- To measure intraocular pressure (IOP)

51.2 Contraindications

- A relative contraindication is the presence of an active or indolent infection about the cornea or conjunctiva, unless a one-time-use device is used (e.g., a Tono-Pen XL).
- Recent trauma to the eye.
- Uncooperative patients because improper technique may cause damage to the eye.

51.3 Overview

- Tonometry is the measurement of IOP obtained by evaluating the resistance of the eye to indentation by a force applied to it.
- Can be obtained by several methods.
- Two methods are routinely used in an emergency department setting:
  - *Impression tonometry*: measures the indentation made by a plunger carrying a known amount of weight.
  - More weight can be added to the apparatus.
  - The more weight needed to indent the cornea results in a higher IOP reading.
    - The Schiøtz tonometer is the most commonly used apparatus to utilize this method (Fig. 51.1).
- *Electronic indentation tonometry*: does not exert pressure on the eye (Fig. 51.2).

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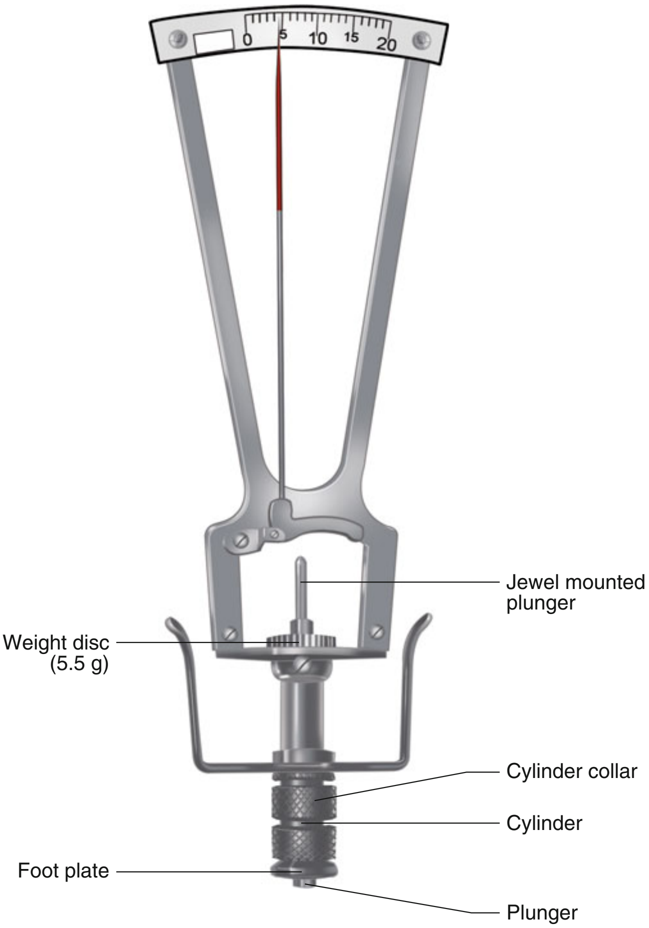
0
5
10
15
20
Jewel mounted plunger
Weight disc (5.5 g)
Cylinder collar
Cylinder
Foot plate
Plunger

Fig. 51.1 Schiøtz tonometer

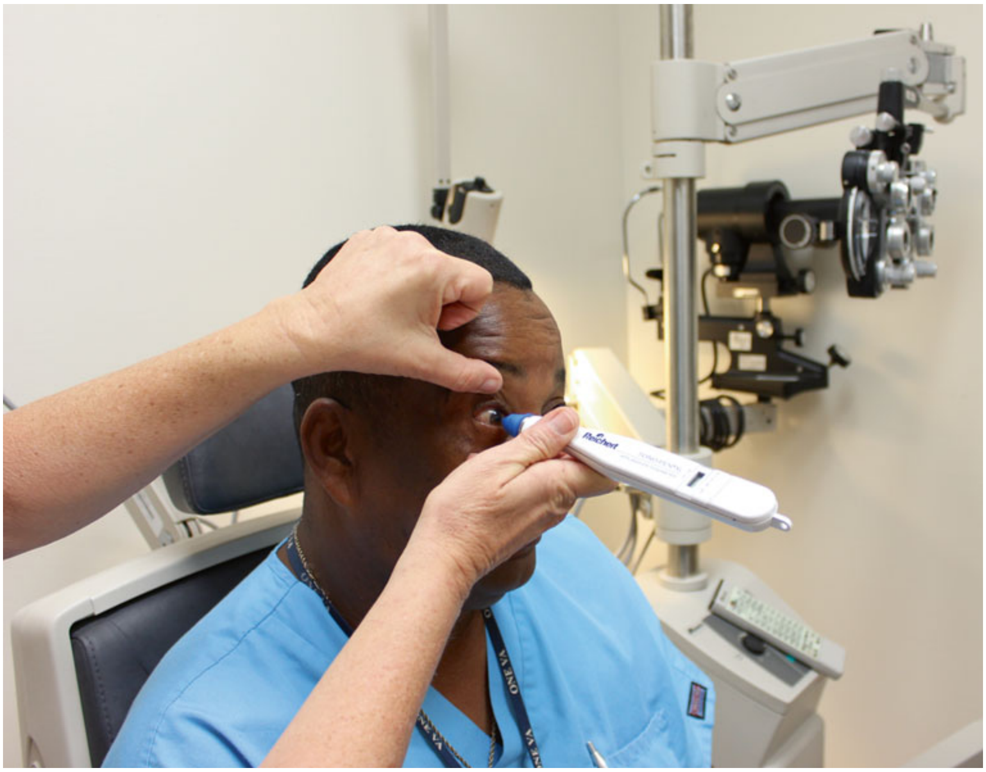

Fig. 51.2 Tono-Pen

51.4 Schiøtz Tonometry

51.4.1 Procedure: Schiøtz Tonometry (Fig. 51.3)

1. Carefully clean the apparatus between each patient.
    - Rubbing alcohol may be used.
    - Because it is metal, it can be autoclaved.
2. Calibrate the Schiøtz tonometer with the metal test block provided.
    - Test by placing the apparatus directly on the metal block.
    - The needle should be at "0" at the far end of the scale.
        - If not, loosen the screw at the base of the needle to rezero it.
        - Ensure that the needle is completely straight because any bend will produce an erroneous reading.
3. An explanation of the procedure is helpful because patient cooperation is critical for accurate results.
4. Anesthetize the eye with topical ophthalmic anesthetic of choice.
5. The patient should be in a recumbent position.
    - Have the patient focus on an area of the ceiling.
6. Hold the instrument with the aid of the curved arms at the side of the tonometer.
    - The operator can rest her or his hand on the patient's cheek or forehead to maintain stability.
7. Gently rest the tonometer on the patient's eye such that the instrument is centered on the eye and the instrument is completely vertical; no pressure should be exerted on the eye.
8. Note the scale reading.
9. Lift the Schiøtz directly off the cornea to avoid injury.
10. Using the table provided with the Schiøtz, the operator may convert the scale reading into the IOP.
    - The scale is inversely proportional to the actual IOP.
    - If the scale is low (i.e., high IOP), the additional weights provided with the instrument may be used and the patient retested.

51.4.2 Pitfalls

- Ensure the plunger is clean because it can transmit infection.
- False readings may be obtained without proper calibration.
- Placing pressure on the instrument will cause false readings.

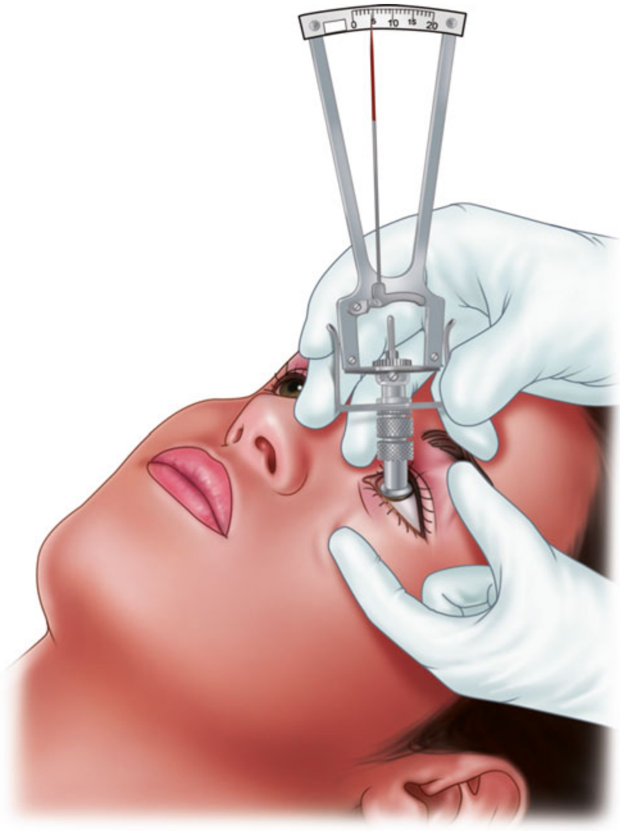

Fig. 51.3 Correct use of Schiøtz tonometer

51.5 Tono-Pen Tonometry

51.5.1 Overview

- Electronically measures IOP
  - Combines applanation and indentation tonometry
- Uses pressure-sensitive electronics to average four successive readings and displays the reading and a reliability factor digitally

51.5.2 Calibration of the Tono-Pen

- Should be performed once daily
- Hold the instrument with the tip down (Fig. 51.4).
- Press the black button twice.
  - The letters “CAL” will appear in the display.
- Press the black button again.
  - After a few seconds the word “UP” will appear.
- Rotate the instrument so that the tip points upward.
  - If “GOOD” appears, the Tono-Pen is ready for use.
  - If “BAD” appears, repeat the process until “GOOD” appears.
    - If “GOOD” does not appear, the device cannot be used.

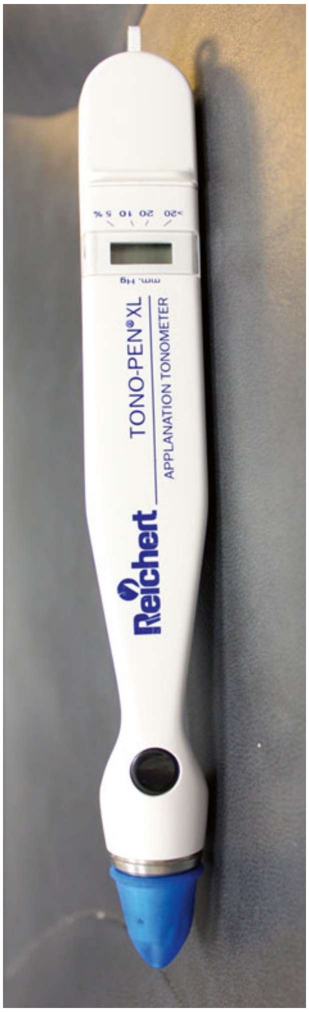

Fig. 51.4 Tono-Pen calibration position

51.5.3 Procedure: Tono-Pen Tonometry

1. An explanation of the procedure is helpful because patient cooperation is critical for accurate results.
2. Anesthetize the eye with the topical ophthalmic anesthetic of choice.
3. Place a probe cover on the unit.
4. The patient should be in a comfortable position because the unit can be used in any position.
   - Have the patient focus on a specific area.
5. The best way to hold the instrument is similar to that of a pen.
   - Ensure that the digital readout is visible.
6. The operator can rest his or her hand on the patient's cheek or forehead to maintain stability.
7. Hold the unit perpendicular to the patient's cornea.
8. Press the black button only once.
   - If "ICALI" is seen, followed immediately by a single row of dashes [– – – –], it indicates that the Tono-Pen requires calibration before it will measure.
   - If "====" is seen and a "beep" is heard, the unit is ready.
   - Proceed with measurement.
9. Gently touch the Tono-Pen to the cornea and withdraw (Fig. 51.5). Repeat several times.
   - Indentation is not required.
10. The unit will "chirp" and a digital reading will be displayed if a valid reading is obtained.
11. After four valid readings are obtained, the average of these measurements as well as a single bar that signifies statistical reliability will appear on the readout.
    - After the final beep if the liquid crystal display (LCD) readout shows "----,“ not enough valid readings were obtained.
    - In this case, the measurement must be repeated.

51.5.4 Pitfalls

- Unsuccessful calibration mandates a repeat attempt at calibration.
- Loosen the Ocu-Film tip cover and repeat for multiple failed attempts.
- Press the reset button and reattempt calibration.
- Replace the battery if necessary.
- If all else fails, use another device or Schiøtz tonometer.

Fig. 51.5 Proper use of Tono-Pen

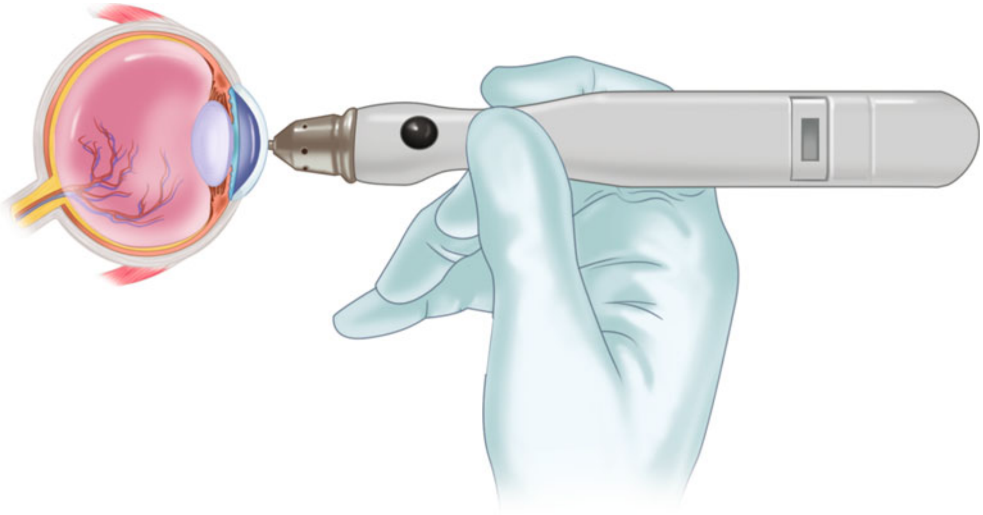

Correct

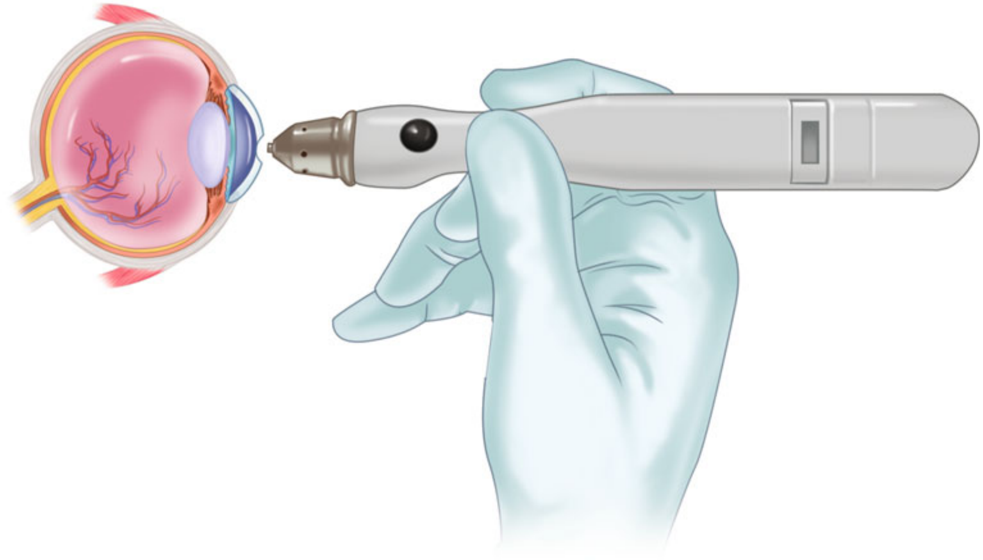

Incorrect

51.6 Complications

- Unusual if proper technique is used.
- If too much force is applied, a corneal abrasion may result.
- Infection when using an improperly sterilized Schiøtz tonometer.

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Lateral Canthotomy

52

Benjamin M. Mahon and Bobby K. Desai

52.1 Indications

- Absolute indications: In the presence of presumed or confirmed retrobulbar hemorrhage
  - Acute visual loss
  - Intraocular pressure (IOP) greater than 40 mmHg (normal IOP is 10–20 mmHg)
  - Proptosis not amenable to retropulsion
- Relative indications: In the context of presumed or confirmed retrobulbar hemorrhage (Fig. 52.1)
  - Ophthalmoplegia
  - Cherry red macula
  - Profound eye pain
  - Afferent pupillary defect (Marcus Gunn pupil)
    - This defect is seen with the *swinging flashlight test.*
      - Shine a light into both eyes; a normal response is equal constriction of both pupils.
      - In those patients with an afferent papillary defect, when light is swung from an unaffected pupil to an affected pupil, the pupil will seem to paradoxically dilate, rather than constrict. The pupil on the nonaffected side will similarly dilate as light is shown into the affected eye. This results from injury to the afferent fibers of cranial nerve (CN) II on the affected side, while the efferent fibers, innervated by CN III, remain intact.
  - This procedure is most effective if performed as soon as possible because irreversible vision loss can occur secondary to ischemia in as little as 90 min.

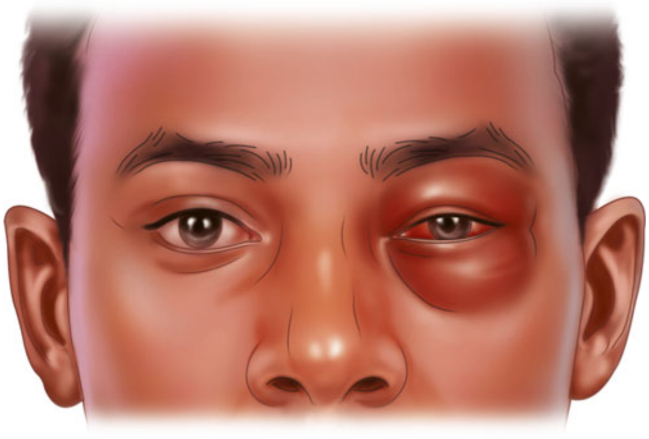

Fig. 52.1 Retrobulbar hemorrhage

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52.2 Contraindications

- Absolute
  - – Globe rupture
- Relative
  - – Suspected globe rupture: Heralded by a number of signs including hyphema, irregularly shaped pupil, exposed uveal tissue, or profound restriction of extraocular movement

52.3 Materials and Medications

- Straight hemostat
- Suture or iris scissors
- Forceps
- 1–2 % lidocaine with epinephrine
- Sterile gloves
- Sterile towels/drapes
- 4×4 gauze
- Face shield/mask
- Large-bore needle to withdraw anesthetic, 25-gauge needle to infiltrate
- 10-cc syringe
- Normal saline

52.4 Procedure

1. Position the patient
   - While waiting for the procedure to begin, the patient should initially be upright to produce any decrease in IOP that can be provided.
   - At the start of the procedure, lay the patient supine.
   - A cooperative patient is absolutely necessary because even slight movements can cause devastating iatrogenic injury.
   - If the patient is anxious or conscious, sedation may be required.
   - In extreme cases of altered mental status or combative trauma patients, endotracheal intubation and mechanical ventilation may be required.
2. Gently irrigate the affected eye to remove any debris.
3. Inject approximately 1–2 mL of 1–2 % lidocaine with epinephrine into the lateral canthus of the affected eye (Fig. 52.2).
4. Using a curved hemostat, gently crimp the skin over the lateral corner of the patient’s eye down to the orbital rim for 3 min to establish hemostasis and set the boundaries for the incision.
   - Using forceps, use the hemostats to pick up the skin just crushed.
   - Raise the skin with forceps and then use scissors to make a 1- to 2-cm incision from the lateral corner of the eye extending laterally outward (Fig. 52.3).
     - – This incision can often sufficiently decrease IOP.
     - – It is feasible to remeasure the IOP at this point, and if it is still greater than 40 mmHg, proceed to the next step.
   - Visualize the lateral canthal tendon by retracting the inferior orbital lid inferiorly.
   - Direct the scissors along the lateral side of the orbital rim away from the globe, and cut the lateral canthal tendon inferiorly (Fig. 52.4).
   - At this point, again measure IOP, and if greater than 40 mmHg, proceed to the next step.
   - Direct the scissors along the lateral side of the orbital rim away from the globe, this time directed superiorly, and cut the superior crux of the lateral canthal tendon.

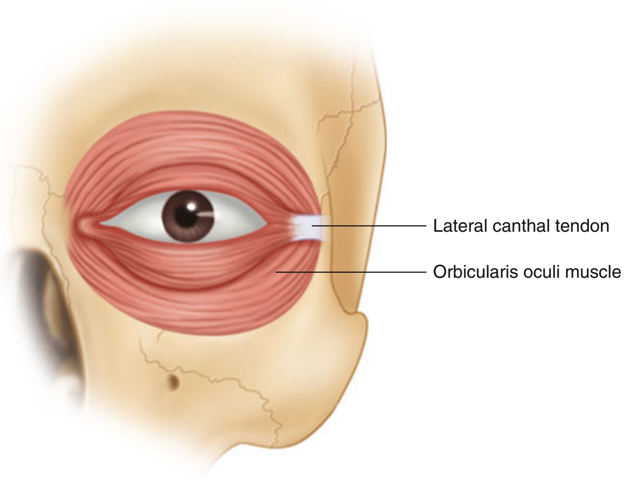
Lateral canthal tendon
Orbicularis oculi muscle

Fig. 52.2 Lateral canthal tendon

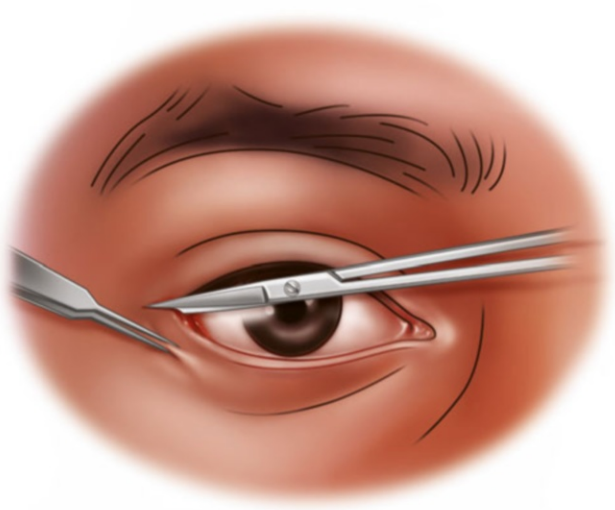

Fig. 52.4 Further cut to reduce intraocular pressure

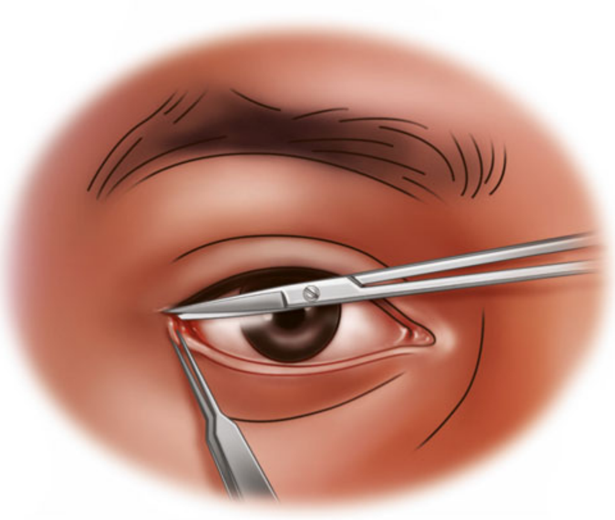

Fig. 52.3 Initial cut

52.5 Complications

- If one is making a superior incision, caution must be taken during this procedure to avoid injury to the lacrimal gland or artery.
- An additional complication of the procedure is ptosis due to iatrogenic injury to the levator aponeurosis, either partially or completely.
- The most obvious complication involves direct injury to the globe itself due to either operator error or poor patient control and immobility.
- Hemorrhage from inadequate hemostasis.
- Infection.

52.6 Pearls and Pitfalls

- Abrupt decrease in pain, decrease in IOP, and resolution of afferent pupillary defect will herald a successful procedure, assuming it was performed within an early enough time frame.
- Having an assistant present is beneficial.
  - In this case, the role of the assistant is to provide lateral retraction of the tissues to decrease likelihood of globe rupture.
- After cantholysis of the inferior component of the lateral canthal tendon, the lower lid will become lax as its attachment to the lateral wall is separated. This signifies a successful incision.
- Incisions made during this procedure generally heal without the need for suturing.
- Emergent ophthalmological consultation should ideally be sought before beginning this procedure.
- Emergent ophthalmological consultation is mandatory subsequent to the procedure.

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Part VIII

Otorhinolaryngologic Procedures

Epistaxis Control

53

Benjamin M. Mahon and Bobby K. Desai

53.1 Etiology

- Anterior source: approximately 90 % of nosebleeds, usually Kiesselbach's plexus (Fig. 53.1)
  - Nose picking ("epistaxis digitorum")
  - Trauma
  - Infection
  - Nasal foreign body
  - Dry air
  - Atmospheric pressure alterations (e.g., increased altitude, lower arterial partial pressure of oxygen [PaO_2])
  - Allergies
  - Blood dyscrasias
  - Malignancy (e.g., leukemia, lymphoma)
- Posterior source: approximately 10 % of nosebleeds, usually sphenopalatine artery (Fig. 53.2)
  - Iatrogenic coagulopathy (e.g., warfarin, heparin, high-dose aspirin)
  - Blood dyscrasia
  - Liver failure
  - Renal failure
  - Malignancy
  - Older age

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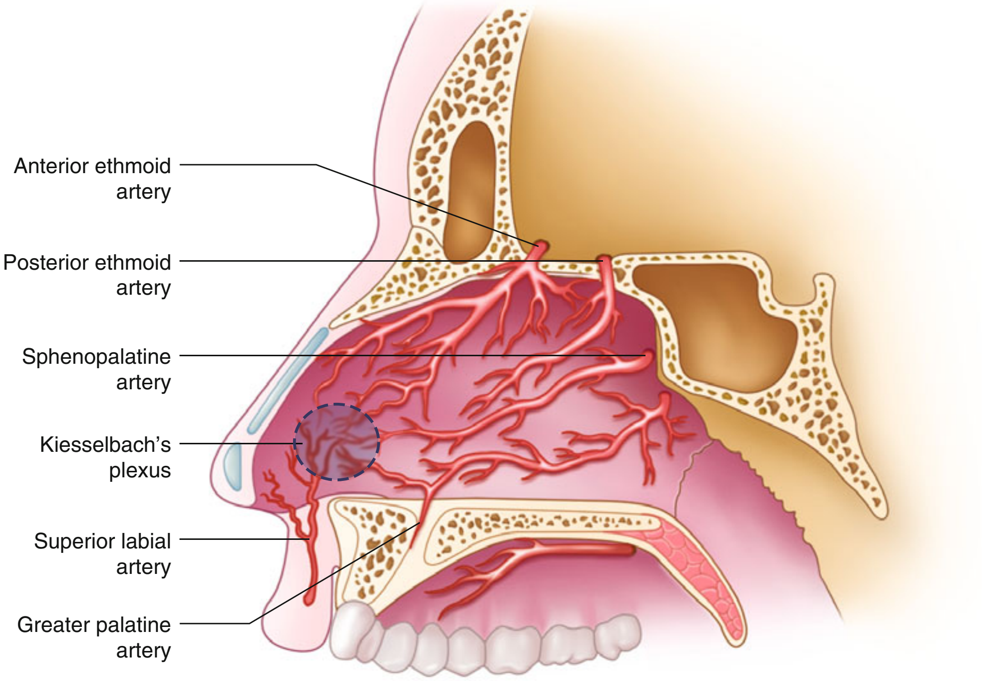
Anterior ethmoid artery
Posterior ethmoid artery
Sphenopalatine artery
Kiesselbach's plexus
Superior labial artery
Greater palatine artery

Fig. 53.1 Vascular supply to the nasal septum

Fig. 53.2 Vascular supply of the lateral wall of the nose

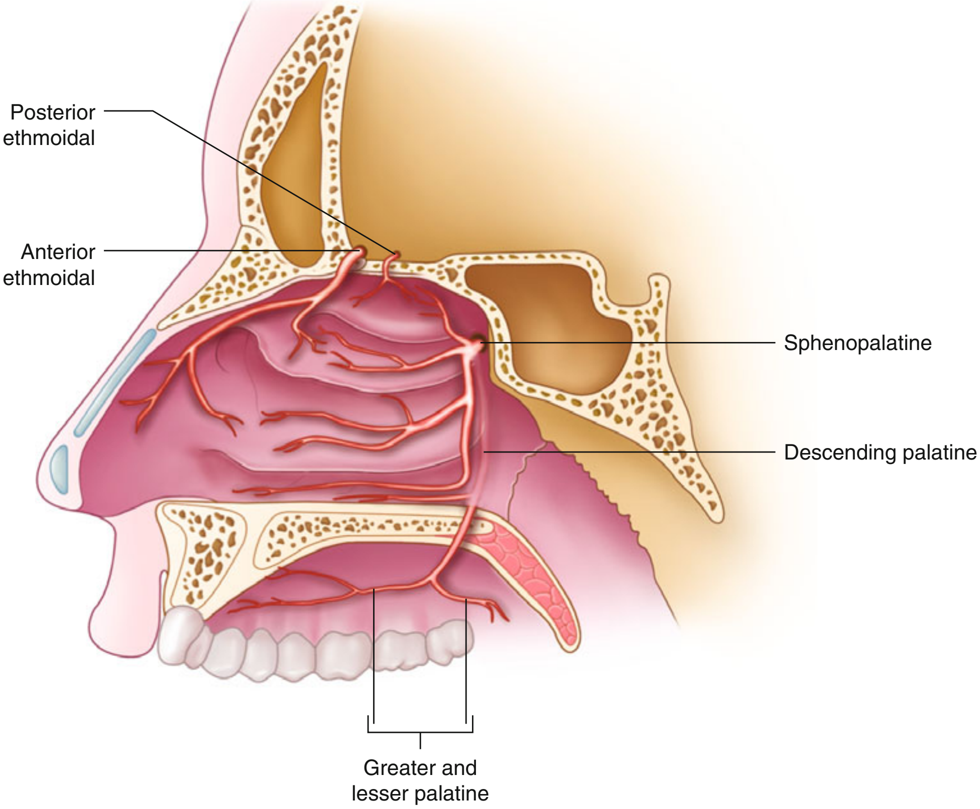
Posterior ethmoidal
Anterior ethmoidal
Sphenopalatine
Descending palatine
Greater and lesser palatine

53.2 Indications

- Acute/recurrent epistaxis

53.3 Contraindications

- Resolution of epistaxis episode before arrival
- Massive facial trauma

53.4 Materials and Medications

- Headlight with focused beam
- Gown
- Gloves
- Mask with visor
- Full-body drape or sterile towels
- Nasal packing material (any or all of the following, as needed [see later]): several cotton pledgets, 3–5 feet of ½-inch ribbon gauze (preferably enriched with petroleum jelly and bacitracin), anterior epistaxis balloon nasal pack
- Topical vasoconstrictor (e.g., 1 % pseudoephedrine or 1:1000 epinephrine)
- Topical anesthetic (e.g., 4 % lidocaine solution or 2 % tetracaine)
- Nasal speculum
- Bayonet forceps
- Anterior epistaxis balloon (e.g., Rhino Rocket)
- Any of the following commercial products, as needed (see later): Gelfoam, Surgicel, Crosseal, and FloSeal
- Foley catheter

53.5 Procedure: Anterior Epistaxis

- Initial preparation
  1. Assemble necessary equipment at the bedside.
  2. Have the patient seated upright, with head and neck in the sniffing position.
  3. Universal precautions are mandatory: gown, glove, and mask.
  4. Drape the patient with towels or a large body drape.
  5. If initial evaluation using the headlamp and nasal speculum with gentle spreading in a vertical fashion or a simple visual examination reveals the source (anterior vs posterior), proceed with the appropriate management pathway as determined later.
     – If clot obstructs visualization, it is recommended for the patient to gently blow her or his nose once to remove any easily friable clots, and then proceed with immediate inspection. If anterior nose bleeds, go to the next step.
- Management of anterior epistaxis:
  1. Initial step in the management of anterior nosebleeds involves pinching the patient's nostrils firmly for at least 10–15 min.
     – This can be done by the patient.
     – Simple pressure is very often enough to provide appropriate hemostasis in anterior nosebleeds. If it fails, proceed to the next step.
  2. A topical vasoconstrictor of choice (e.g., cocaine, oxymetazoline, 1 % pseudoephedrine) can be applied to the septum and lateral walls of the nose either topically with cotton-tipped applicators or by using soaked pledgets.
  3. Continue to apply firm pressure to the nares for 10–15 min, and recheck the nose for evidence of bleeding.
  4. If the bleeding site can be easily visualized, chemical cautery may be attempted with silver nitrate (Fig. 53.3).
     – This can be accomplished with the help of a nasal speculum and a headlight.
     – It is advised to cauterize both the site itself and 0.5 cm around the site, by holding the silver nitrate stick to the site for at least 20 s until the bleeding stops.
     – If bleeding then stops, cover the site with an absorbable gelatin foam or an oxidized cellulose such as Gelfoam or Surgicel or simply apply topical antibiotic to the site.
  5. If there is continued bleeding, the clinician may apply either two elongated cotton pledgets or a commercially available substitute (e.g., a Rhino Rocket or similar device [Fig. 53.4]) presoaked in a few milliliters or a 1:1 mixture of a topical vasoconstrictor and an anesthetic. Combinations can include the previously cited two agents, plus 2 % tetracaine or 4 % lidocaine.
  6. Universal instructions for the insertion of a commercially available anterior nasal pack include (Fig. 53.5):
     - Soak the fabric via the manufacturer's recommended solution if required.
     - Insert antibiotic ointment in the nares to facilitate insertion.
     - Insert the entire length of the balloon along the inferior surface of the nasal cavity.
     - The fluid within the nasal cavity should cause it to expand spontaneously while in the nares, after which the remaining exposed string can be taped to the cheek.
     - For those devices that require air instillation, read the manufacturer's instructions on how much air to instill within the device.

7. Another option is to provide an anterior nasal packing using a few feet of ½-inch ribbon gauze (Fig. 53.6).
8. It is preferable if this gauze is impregnated with petroleum jelly and is enriched with bacitracin ointment.
   - If it is not, bacitracin can be applied to the strip before its insertion into the nasal cavity.
9. To facilitate the insertion, bayonet forceps can be used to gently lay each successive strip on top of the one before it.
10. Begin inferiorly, laying each strip on top of the other, about three or four layers at a time, with the end points protruding from the opening of the nasal cavity.
11. Pack the strands firmly.
12. It may take several feet to pack the entire nasal cavity.
13. This may be both uncomfortable for the patient and time consuming for the provider, so ensure adequate time and copious topical anesthetic.
14. Parenteral analgesic or anxiolytics may be required for any of these techniques.
15. If none of these resources is available, another technique requires the use of two cotton pledgets gently inserted into the nostrils after vasoconstrictor/anesthetic topical solution has been sprayed into the nose either manually or with the addition of bayonet forceps, where they will remain for 20 min, supplemented by firm pressure to the nares as described previously.
   - If the bleeding has then stopped, they can be removed at this time. If it does not, it is advised to repeat the previous step a second time, this time with a longer period of pressure, before proceeding to the next step.
16. If all of these techniques fail to control bleeding, the clinician may apply a sealant spray or foam enriched with thrombin to enhance clotting.
   - Commercially available options include Crosseal or FloSeal.
17. Finally, if none of these techniques manage to halt what one is sure is only an anterior, albeit persistent, nosebleed, consult the otolaryngologist for further guidance.
   - Another consideration at this point may be that the uncontrollable anterior nosebleed is really a posterior nosebleed from an undetermined location.
   - It may be prudent to proceed to the algorithm for treatment of posterior epistaxis, even if a posterior bleed is not specifically confirmed.

53.5.1 Complications

- Using an inadequate amount of packing when inserting the ribbon gauze, the entire product may serve as a plug with potential aspiration risk, rather than as a tool for hemostasis.
- Otitis, sinusitis, and toxic shock syndrome.

53.5.2 Pearls and Pitfalls

- Pearls
  - Be sure to perform a reevaluation of both the posterior oropharynx and the posterior nasopharynx after insertion of any of the previously discussed devices, and inspect for continued bleeding/oozing to ensure hemostasis has been accomplished.
  - For those patients with nasal packs in place, consider the use of oral antibiotics to avoid subsequent sinusitis, otitis, or toxic shock syndrome.
    - Appropriate antibiotic choices include cephalexin, clindamycin, or amoxicillin–clavulanic acid.
    - The use of antibiotics for short-term packing has not been proven.
  - Consider admission for elderly patients or for those patients with potential airway complications such as those patients with chronic obstructive pulmonary disease (COPD) and for those at risk for aspiration.
  - Have the patient follow up with otolaryngology within 2–3 days for reevaluation and packing removal.
  - Provide adequate discharge instructions warning the patient against nose blowing, sneezing with the mouth closed, or any movements or actions that cause a Valsalva maneuver.
  - The patient should try to keep his or her head elevated for the next 24–48 h even while sleeping to prevent potential aspiration.
- Pitfalls
  - Discharging a patient without an adequate period of observation.
  - Failing to ensure appropriate follow-up.
  - Providing inadequate discharge instructions.
  - Mistaking an anterior nosebleed for a posterior nosebleed.
  - Leaving silver nitrite on exposed nasal mucosa can lead to iatrogenic nasal septal perforation.
  - Not informing the patient that minimal oozing of blood from the nose can be expected.

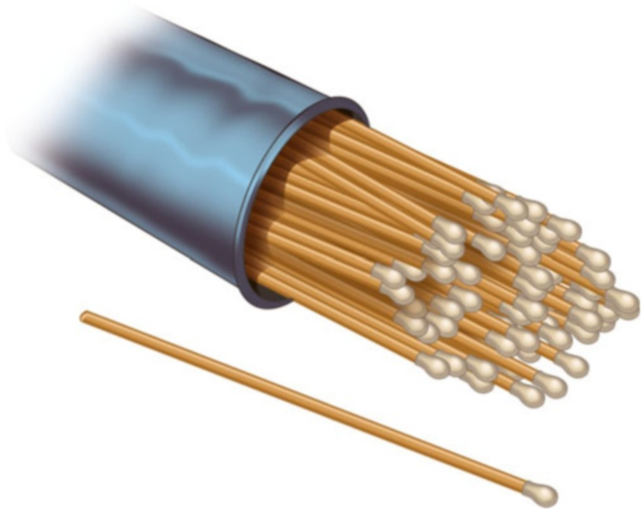

Fig. 53.3 Example of silver nitrate stick and packaging

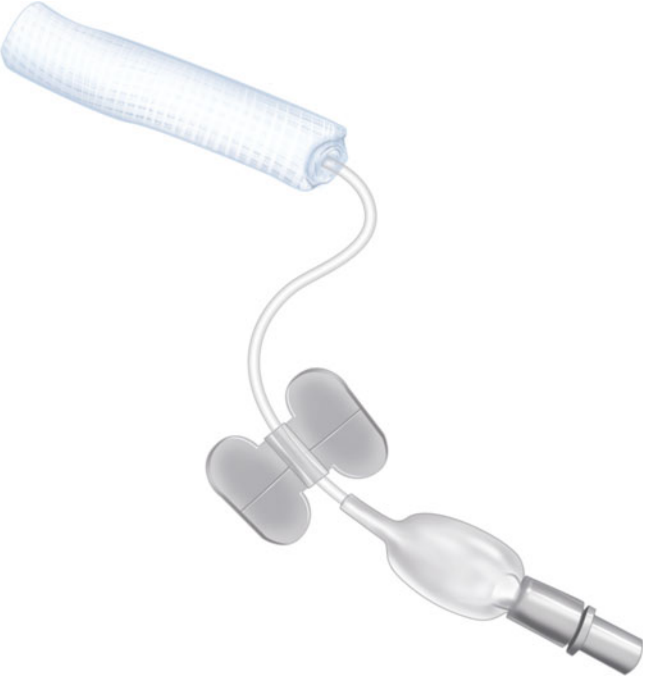

Fig. 53.4 Example of commercial nasal pack

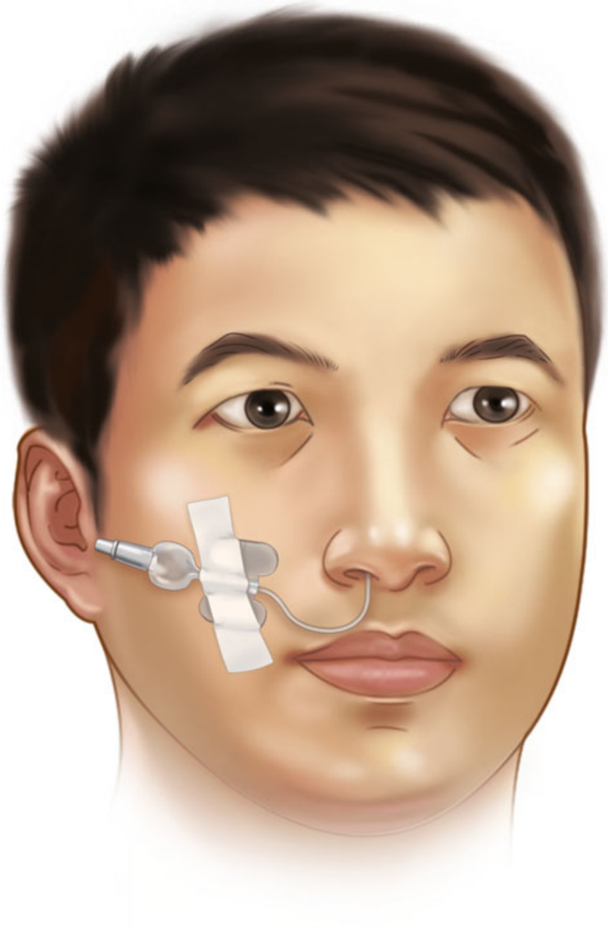

Fig. 53.5 Proper taping of a commercial anterior nasal pack

Fig. 53.6 Gauze method

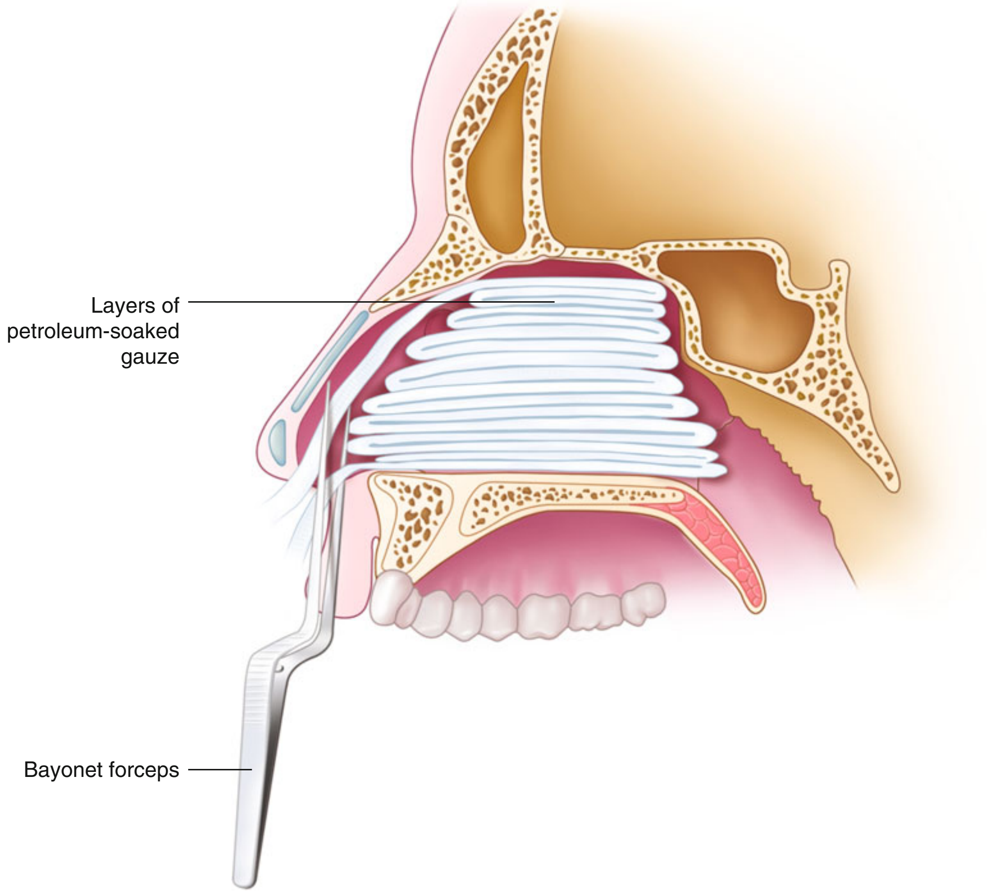
Layers of petroleum-soaked gauze
Bayonet forceps

53.6 Procedure: Posterior Epistaxis

- Preliminary Steps
  1. Owing to the possibility of extreme exsanguination from a posterior source of epistaxis or airway obstruction from a large clot dislodgment or large volume of blood aspiration, the stability of the patient's airway, breathing, and circulation must be ensured first.
     - Appropriate interventions entirely depend on the presentation of the patient and therefore are not described in this chapter.
     - Patients with posterior epistaxis can lose a large volume of blood quickly, so this needs to be an initial consideration.
  2. Consider establishing intravenous access and placing the patient on a cardiac monitor.
  3. Because patients with posterior epistaxis tend to be either older, on various blood thinners, or to potentially have some type of coagulopathy, consider obtaining a complete blood count, prothrombin time, and partial thromboplastin time as part of the preliminary workup.
  4. Consider a blood type and screen.
- Management of posterior epistaxis:
  1. Inspect the nares as described in the previous section on anterior nosebleeds.
  2. Several of the techniques discussed may be attempted but may not be successful.
  3. Assemble necessary equipment at the bedside.
  4. Have the patient seated upright, with the head and neck in the sniffing position.
  5. Universal precautions including a gown, glove, and mask should be employed.
  6. Drape the patient with towels or a large body drape.
  7. Apply a combination of a topical vasoconstrictor and anesthetic to the nose.
     - An appropriate choice (e.g., 1 % pseudoephedrine or 1:1000 epinephrine in a 1:1 ratio with 4 % lidocaine or 2 % tetracaine)
     - Be aware, however, that there are situations in which the bleeding may be too brisk, and this step may need to be avoided owing to time constraints and the volume of bleeding. So it is not unheard of to be required to intervene in posterior epistaxis without this initial step.
  8. Otolaryngology should be consulted as early as possible in the workup of this condition, both for admission and in case the following techniques fail.
  9. An advised initial step for the treatment of posterior epistaxis is to proceed directly to insertion of a unilateral or, preferably, bilateral posterior nasal pack or balloon.
     - An example of these is the elongated version of the Rhino Rocket as described previously.
     - Insertion and securing of the product proceed essentially the same way, except that it is inserted deeper into the posterior oropharynx.
  10. Consider the use of a dedicated posterior balloon, such as a Nasostat or Epistat (Fig. 53.7).
     - These devices are double-balloon systems that are lubricated preferably with bacitracin (sterile jelly is also appropriate) and inserted into the posterior nasopharynx.
     - The posterior balloon is then inflated with the product-specific quantity of air.
     - The product is then withdrawn slightly to ensure that the posterior balloon is situated firmly in its desired location of the posterior nasal cavity.
     - The anterior balloon is then inflated with the device-specific quantity of normal saline, and the device is secured.
- If the previously discussed resources are not available, a clinician can insert an adult-caliber Foley catheter into the posterior nasopharynx, with inflation of the balloon, and gentle traction anteriorly to ensure the bulb is situated similarly to the Nasostat or Epistat, firmly in the posterior nasal cavity to tamponade off the bleeding (Fig. 53.8).
- If all of these techniques still fail to control bleeding, an otolaryngologist will likely need to intervene, performing techniques outside the scope of practice of the emergency physician, including electrocautery, submucosal lidocaine/epinephrine injections, or other surgical interventions.
- The final step in the management of this patient includes admission to a monitored bed.

53.6.1 Pearls and Pitfalls

- Pearls
  - Consult otolaryngology early in the workup as soon as a posterior bleed is identified.
  - Patients receiving packing will still need to be placed on antibiotics, such as a first-generation cephalosporin, clindamycin, or amoxicillin–clavulanic acid.
  - Perform a good physical examination concomitantly with the management of the bleed specifically geared toward assessing the patient's volume status (orthostatics, capillary refill, heart rate), because the patient may have significant volume loss depending on the duration and quantity of the bleed.
  - Take a good history including prior bleed, prior admission requirements owing to epistaxis, any anticoagulant use, blood dyscrasias, and so on.

- Pitfalls
  - Misidentifying a posterior bleed as an anterior bleed. This can be catastrophic if the patient is discharged. Reference the "Etiology" section earlier.
  - Discharging the patient.
  - Consulting otolaryngology too late.
  - Underestimating the volume of blood loss. It may be helpful to think of these patients as trauma patients in their initial management and to proceed down the standard primary survey/intervention/secondary survey/intervention approach, ensuring that the volume needs are identified early.
  - Infection.
  - Pressure necrosis of the septum.
  - Hypoxia.
  - Aspiration.
  - Arrhythmias.
  - Dysphagia.
  - Dislodgment of the pack.

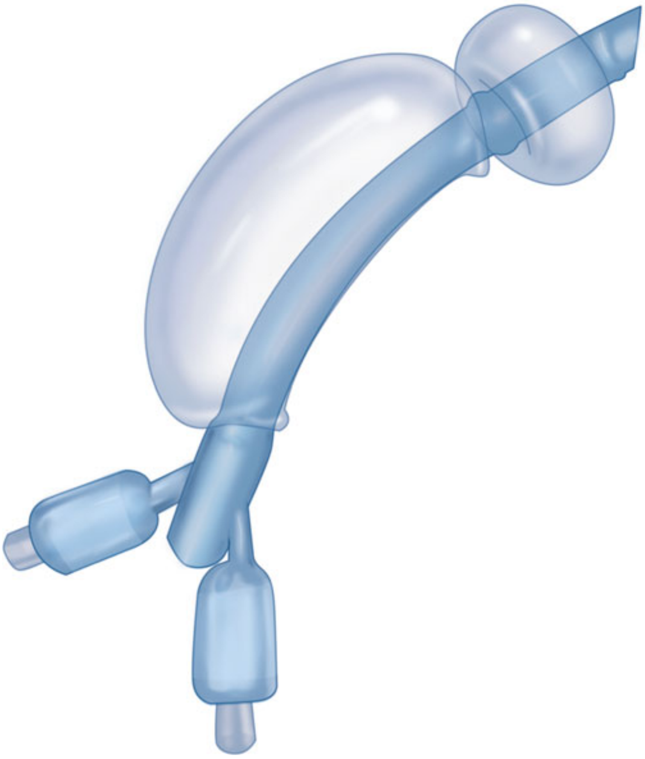

Fig. 53.7 Example of posterior balloon

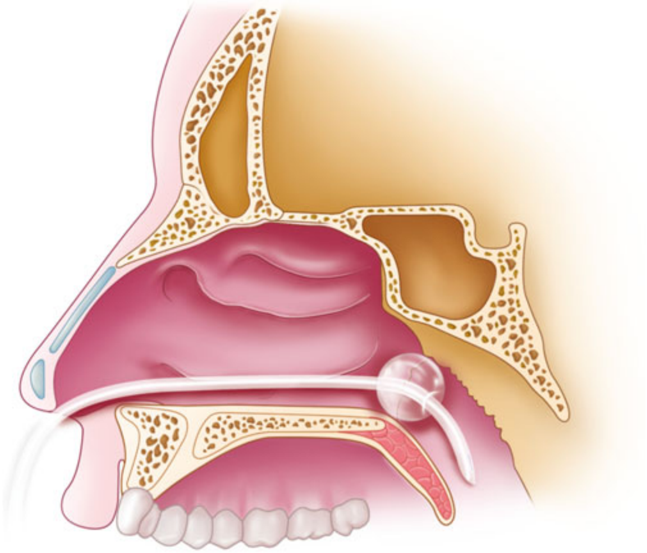

Fig. 53.8 Foley catheter in the posterior nasopharynx

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Treatment of Septal Hematoma

54

Bobby K. Desai

54.1 Indications

- Septal hematomas occur after force applied to the nasal cartilage results in leakage of blood from the perichondrium (Figs. 54.1 and 54.2). They may be unilateral or bilateral.
- Untreated, this hematoma can expand and mechanically obstruct the blood vessels that supply the nasal cartilage.

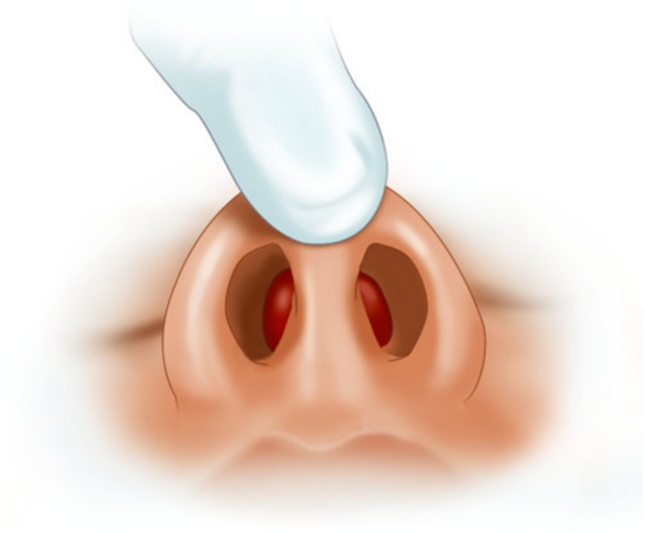

Fig. 54.1 Example of a septal hematoma

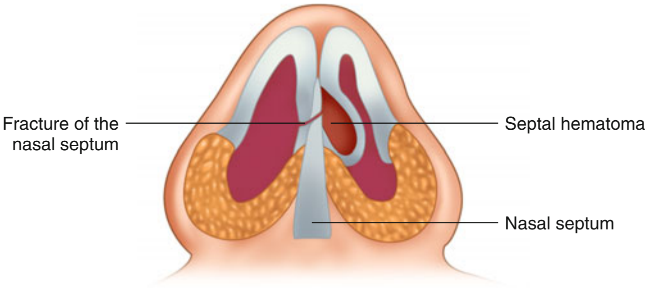

Fig. 54.2 Diagram of a septal hematoma

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54.2 Contraindications

- In the setting of massive facial trauma, airway protection and consultation with otolaryngology or oral surgery may be required.

54.3 Materials and Medications

- 5-cc syringe
- 20-gauge needle (may use larger-gauge needle, but smaller ones may not allow for adequate suctioning).
- Topical antiseptic
- Sterile drapes, gown, eye protection, and gloves
- Light source—preferably a head lamp
- If using procedural sedation, specific medications of choice are needed as well as monitoring and resuscitation equipment
- Nasal speculum
- 4 % liquid cocaine or 4 % liquid lidocaine for anesthesia
- Topical vasoconstrictor of choice (oxymetazoline or phenylephrine)
- Scalpel (#15 blade)
- Suction setup
- Saline for irrigation
- Sterile gauze
- Iodoform packing or sterile rubber band
- Anterior nasal pack (Rhino Rocket)
- Intravenous antibiotics to cover *Staphylococcus aureus*, group A β-hemolytic streptococci, *Streptococcus pneumonia,* and *Haemophilus influenzae*

54.4 Procedure

- Preprocedure
  - Explain the procedure to the patient.
  - Informed consent may be required.
- Procedure—unilateral (Fig. 54.3):

1. Place the patient in a seated position if the procedure is to be done without procedural sedation.
    - If performing the procedure under procedural sedation, the patient may be placed in the supine position with appropriate monitoring and resuscitation equipment on standby.
2. Provide local anesthesia by applying the topical anesthetic of choice to cotton pledgets, wringing out the excess before insertion.
    - Remove after 10 min.
    - If using lidocaine, a topical vasoconstrictor may be required that may be mixed with the lidocaine or applied directly on the nasal mucosa before the procedure.
3. Using a nasal speculum, open the affected nares vertically as wide as possible. Horizontal use may obscure the hematoma.
4. Using a #15 blade, make a vertical incision at the hematoma extending the incision posteriorly at its base.
    - Take care not to make too deep an incision because septal perforation may occur.
5. Suction and gauze should be at the ready to remove as much blood as possible.
6. Pack the incision site with iodoform gauze or a sterile rubber band in order to keep the incision open to prevent accumulation of blood.
7. This packing can be held in place with an anterior nasal pack.
    - The pack should be placed in both nares to prevent deformity of the nasal septum.
8. Consider administration of a dose of intravenous antibiotics.
9. Send the patient home with a prescription for oral antibiotics.
10. Arrange follow-up for 24 h.

- Procedure—bilateral (Fig. 54.4):

1. If bilateral hematomas are present, otolaryngology consultation should be sought.
2. One method involves the incision of one side only through the nasal septum so that both may drain through one side.
    - Care must be taken NOT to penetrate the overlying mucosa of the other side.
3. The second option is to repeat the unilateral drainage procedure on the contralateral side.
4. Care must be taken to not have the incision exactly in the same location as the contralateral side owing to the risk of permanent septal perforation.

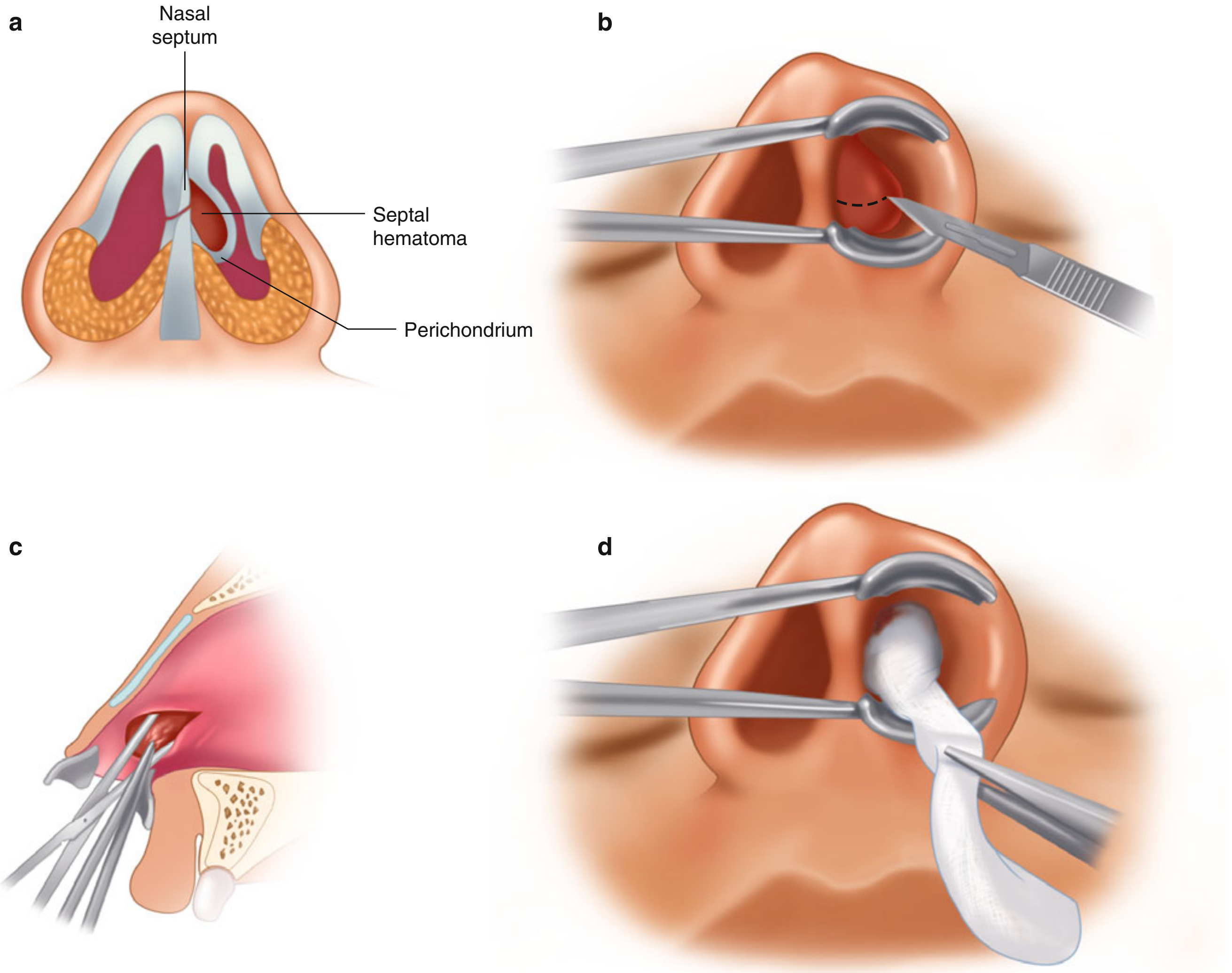
a
Nasal septum
Septal hematoma
Perichondrium
b
c
d

Fig. 54.3 (**a**–**d**) Technique for drainage of a unilateral septal hematoma

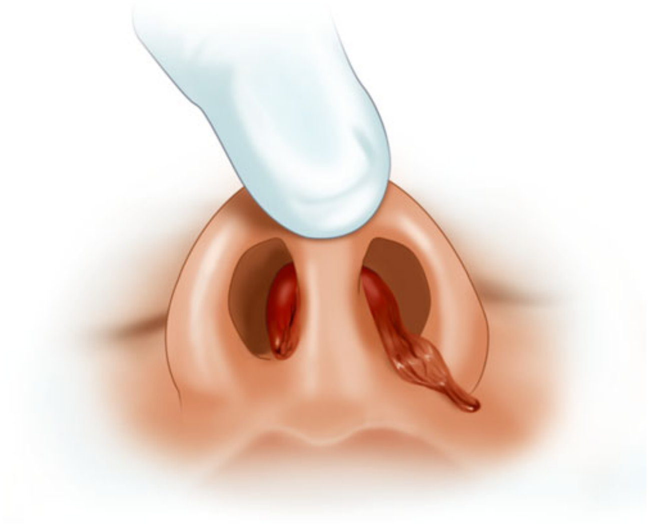

Fig. 54.4 Technique for drainage of a bilateral septal hematoma

54.5 Pitfalls and Complications

- Bleeding
- Infection: toxic shock syndrome
- Deformity of the nose
- Permanent septal perforation
- Inadequate drainage
- Reaccumulation of blood
- Development of septal abscess

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Nasal Foreign Body Removal

55

Bobby K. Desai

55.1 Indications

- Visualized foreign body (FB) on inspection
- Continued unilateral nasal discharge of unknown etiology
- Recurrent epistaxis

55.2 Contraindications: Need Urgent Referral

- Those cases in which the emergency physician is not confident of success.
- Combative patients who are not candidates for conscious sedation.
- Embedded FBs.
- Penetrating injuries with an FB.
- Button batteries that cannot be removed.
- Patients with bleeding diathesis.
- Respiratory distress.
- FBs superior and medial to the middle turbinate owing to risk of puncture to the cribriform plate.
- Chronic FBs may be difficult to visualize and these should be referred.

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55.3 Materials and Medications

- 1 % lidocaine without epinephrine (solution) for anesthesia
- 2 % lidocaine jelly
- 0.5 % phenylephrine to vasoconstrict vessels
- Nasal speculum (Fig. 55.1)
- Headlamp or other direct lighting instrument
- Ambu bag (Fig. 55.2)
- Alligator forceps (Fig. 55.3)
- Curved hook (Fig. 55.4)
- Foley catheter
- Suction: schuknecht catheter (Fig. 55.5)
- Eye and biohazard protection for the clinician

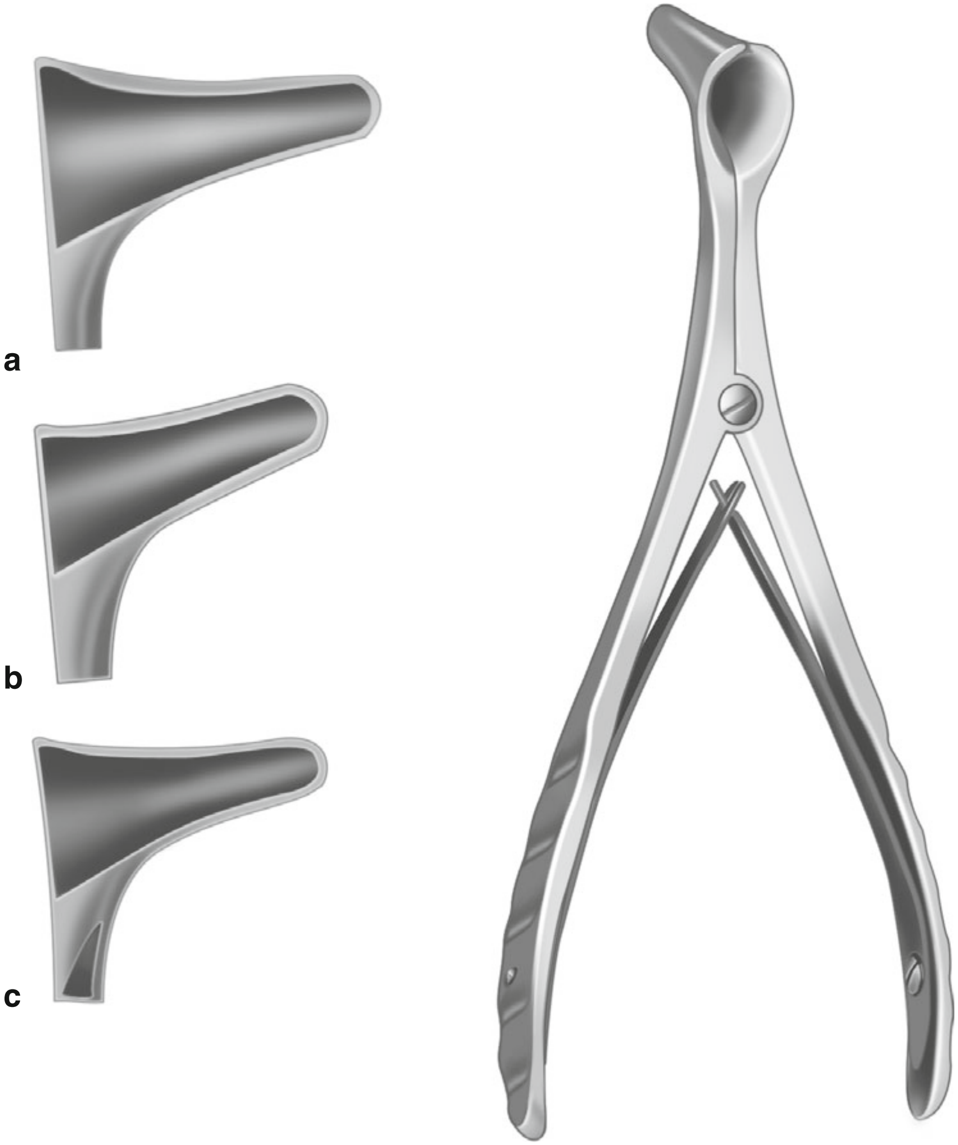

Fig. 55.1 (**a**–**c**) Example of nasal speculum

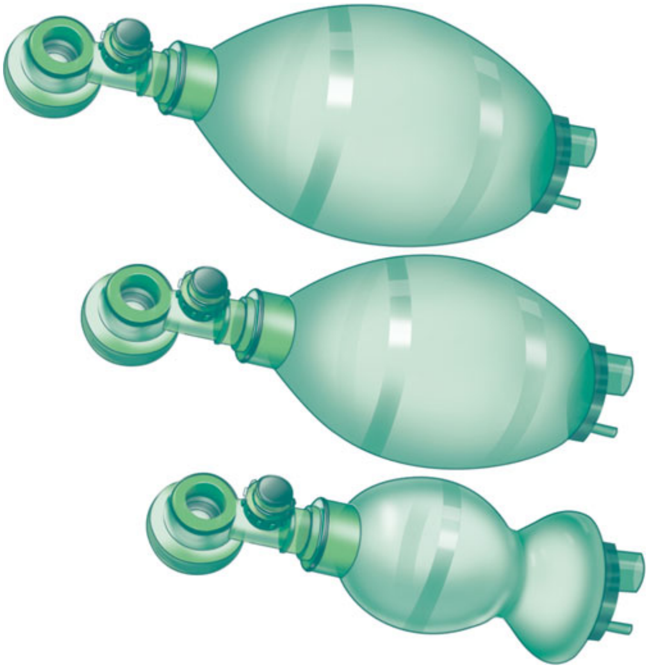

Fig. 55.2 Example of Ambu bags

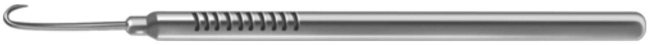

Fig. 55.4 Example of a curved hook

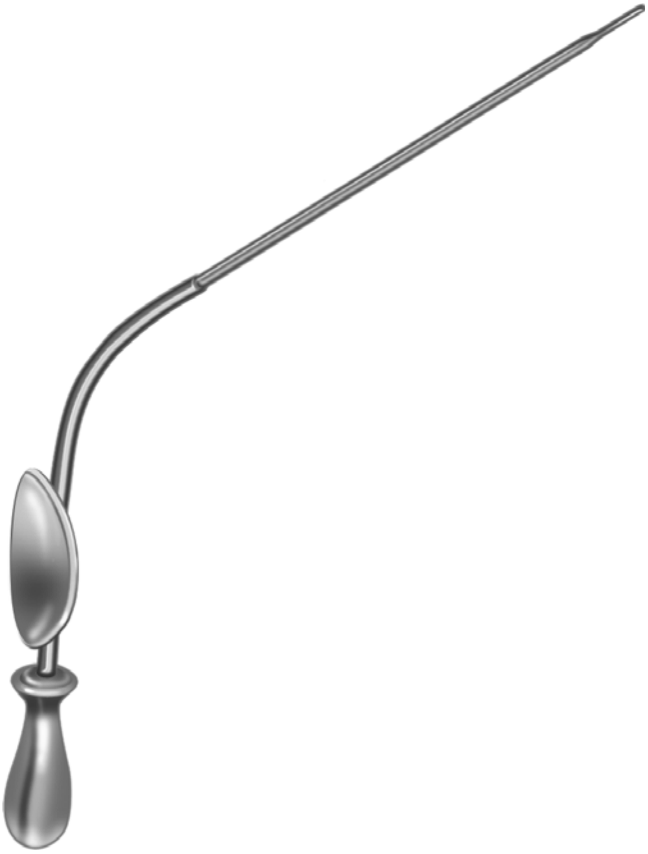

Fig. 55.5 Example of a schuknecht suction tube

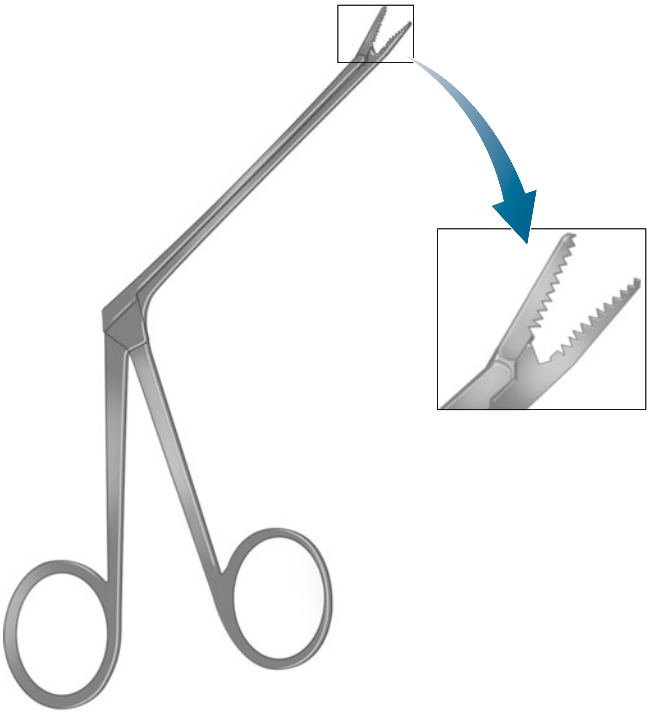

Fig. 55.3 Example of alligator forceps

55.4 Procedures (Based on the Method Chosen)

55.4.1 Alligator Forceps

- Perhaps the easiest method to use for easily visualized FBs.
- Care must be taken for those FBs that are easily broken apart (e.g., peas) to ensure that all of the matter has been removed.
- Using a nasal speculum, spread the nares as much as possible to maximize visualization.
- Stabilize the head with the nondominant hand, or for children, consider a papoose board to secure the patient.
- Attempt to grasp the FB with the forceps.
- After removal, ensure the complete removal of the object and ensure that no other FBs are present.

55.4.1.1 Pitfalls and Complications

- Pushing the object deeper into the nares.
- Inability to totally remove the FB.
- Attempted removal of an embedded FB may cause significant bleeding.

55.4.2 Curved Hook

- Used for nongraspable objects especially in the anterior nares.
- Using a nasal speculum, spread the nares as much as possible to maximize visualization.
- Stabilize the head with the nondominant hand, or for children, consider a papoose board to secure the patient.
- Pass the hook behind the object, or if the object has holes, the hook may be placed inside the hole to facilitate removal.
- Slowly withdraw the hook, thereby removing the FB.
- After removal, ensure the complete removal of the object and ensure that no other FBs are present.

55.4.2.1 Pitfalls and Complications

- This technique cannot be used if the object cannot be directly visualized because significant trauma may arise owing to the misplacement of the hook.
- Attempted removal of an embedded FB may cause significant bleeding.

55.4.3 Foley Catheter Removal

- Use a 5 or 6 French catheter.
- Anesthetize the nares with lidocaine with or without epinephrine and vasoconstrict the nasal vessels with phenylephrine.
- Ensure that the Foley balloon has no leaks.
- Place the patient in a supine position.
  - Consider procedural sedation for children and/or a papoose board.
- Lubricate the Foley tip and balloon with lidocaine jelly.
- Advance the tip past the object.
- Blow up the balloon with 2–3 mL of air and gently withdraw the catheter.
  - The amount of air may need to be adjusted depending on the size of the object to be withdrawn.
  - Pulling too quickly may cause a soft FB to break apart.

55.4.3.1 Pitfalls and Complications

- This technique may be used if the FB is not visible.
- In order for this technique to work, the catheter must be able to slide posterior to the object in order for the balloon to pull out the object.

55.4.4 Suction

- A small metal suction catheter—the schuknecht catheter—may be used.
- The suction is placed against the FB and slowly withdrawn.
- This technique works best for round smooth objects visualized in the anterior nares.

55.4.4.1 Pitfalls and Complications

- May not work for posteriorly displaced FBs.
- May not work for objects too tightly entrenched in the nares.

55.4.5 Nasal Positive Pressure

- This technique works best for round FBs occluding the nares.
- Place the patient in a supine position.
  - Consider a papoose board to secure the patient.
- Apply pressure to the contralateral nares to occlude it.
- Connect an Ambu bag to high-flow oxygen.
  - Use a facemask that covers only the mouth.
- Place the mask on the patient's mouth and allow it to expand by covering the thumbhole.
- If this pressure is insufficient to expel the object, the Ambu bag may be compressed to add pressure to the attempt.
- This may allow the object to be seen and grasped in the anterior nares.

55.4.5.1 Pitfalls and Complications

- Too much pressure could theoretically rupture the tympanic membranes.

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Cerumen Removal

56

Bobby K. Desai

56.1 Indications

- Hearing loss
- Profound dizziness
- Pain

56.2 Contraindications

- Uncooperative patient
- Potential for foreign bodies
- Prior surgery to ear or mastoid
- History of middle or outer ear disease

56.3 Materials and Medications

- Ear speculum (Fig. 56.1).
- Eye and biohazard protection for the clinician
- Headlamp or other direct lighting instrument
- Cerumen-softening solutions
  - Carbamide peroxide
  - Mineral oil or other oil-based agents including almond or olive oil
  - Liquid docusate sodium
  - Acetic acid
  - Sodium bicarbonate
- Alligator forceps (Fig. 56.2)
- Curved hook or cerumen spoon (Figs. 56.3 and 56.4)
- Suction—Schuknecht catheter
- Irrigation setup
  - Ear syringe (Figs. 56.5 and 56.6)
- – 20- to 60-mL syringe with an 18-gauge angiocath attached
  - Commercial ear irrigation setup
  - Water (tap water may be used)
  - Basin or other collection device
  - Towels

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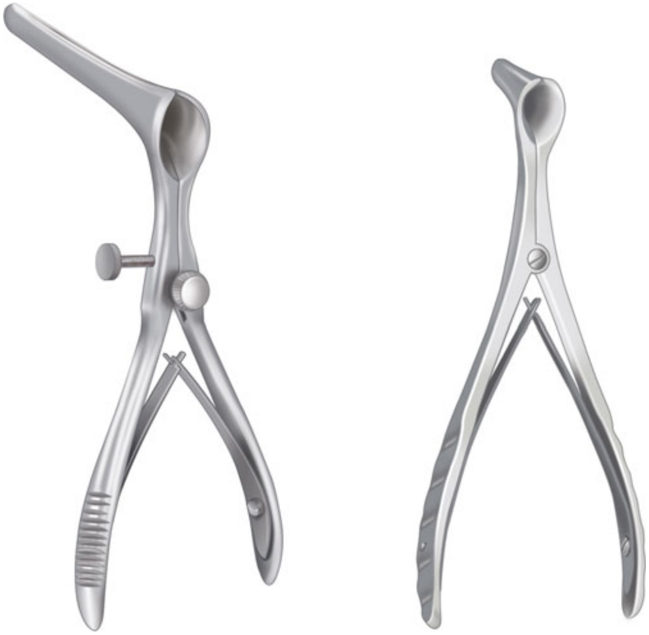

Fig. 56.1 Example of an ear speculum

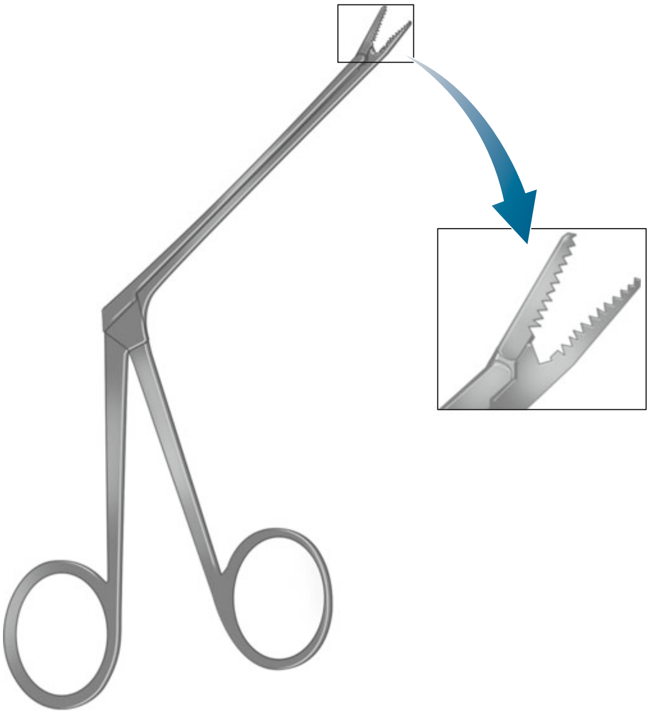

Fig. 56.2 Example of alligator forceps

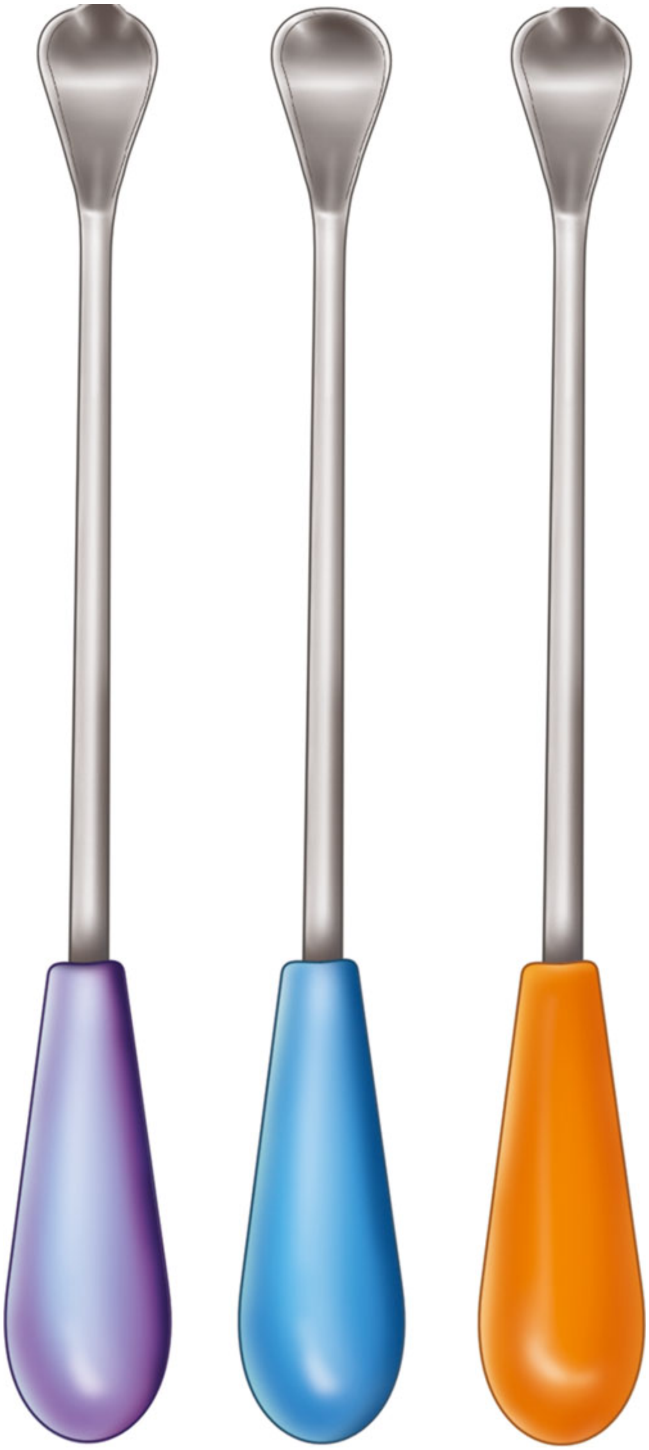

Fig. 56.3 Examples of cerumen spoons

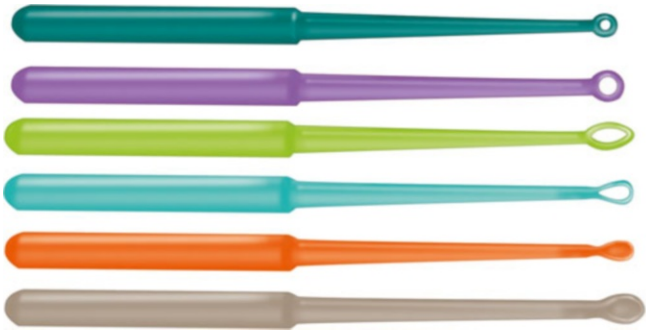

Fig. 56.4 Examples of ear curettes

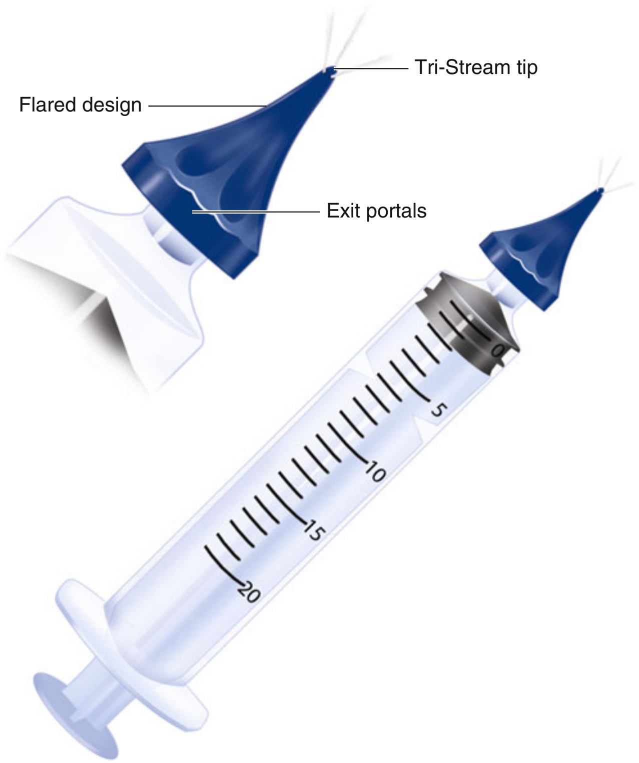
Tri-Stream tip
Flared design
Exit portals
0
5
10
15
20

Fig. 56.6 Example of a specialized ear syringe

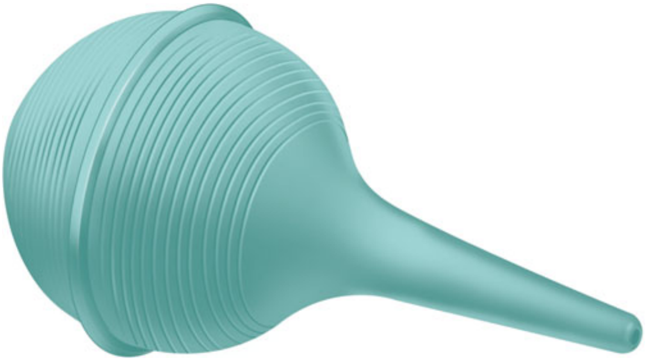

Fig. 56.5 Example of a typical bulb syringe used in irrigation

56.4 Procedure

1. Explain the procedure to the patient to facilitate cooperation.
    - Some discomfort may be involved, including a sensation of pressure and the cold, wet feeling from the water used.
    - Nausea, vomiting, or a sensation of vertigo may also be experienced.
        - Consider pretreatment of vertigo with agent of choice.
2. The patient may be seated or supine with the head slightly turned to the affected side to facilitate the collection of fluid.
3. Stabilize the head with the nondominant hand, or for children, consider a papoose board to secure the patient.
4. Pull the ear up and out to straighten the ear canal.
5. Before irrigation, if the cerumen is hard, alligator forceps or a cerumen spoon may be used under direct visualization to remove as much cerumen as possible.
6. Use a cerumen-softening agent before irrigation by instilling and leaving in for 30 min to maximize softening.
7. Place a collection device next to the patient's ear, or alternatively, have the patient hold a basin near the ear to collect any liquid.
8. Attach an angiocath to a 20- or 60-mL syringe, place the tip of the catheter within the ear canal, and aim toward the tympanic membrane.
9. Slowly inject the solution into the ear canal.
    - Care must be taken to limit the force used owing to the potential for tympanic membrane rupture.
    - The fluid can be injected in short bursts or all at once.
10. Direct the stream as much as possible toward the rear of the cerumen to be removed.
11. Continually reassess the ear canal to ensure that all cerumen has been removed.
    - If one large piece remains, use a cerumen hook to facilitate removal.
12. If the patient complains of severe sharp pain, stop the procedure and assess the tympanic membrane for rupture.
    - Consider referral or otolaryngological consultation at this point.
13. After successful removal, dry the ear canal with cotton-tipped applicators to prevent otitis externa.

56.5 Pitfalls and Complications

- Owing to instillation of room temperature water, a caloric response may occur including vertigo, nausea, and vomiting.
- Rupture of the tympanic membrane.
- Unsuccessful irrigation secondary to inadequate time given to softening agents before attempting removal.
- Bleeding of the external auditory canal.
- Otitis externa.
- Hearing loss.

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Ear Foreign Body Removal

57

Bobby K. Desai

57.1 Indications

- Visualized foreign body (FB) on inspection.
- Continued unilateral otorrhea of unknown etiology mandates a search.
- Recurrent bleeding.
- History of FB placement by patient.

57.2 Contraindications: Need Urgent Referral

- Those cases in which the emergency physician is not confident of success.
- Combative patients are not candidates for conscious sedation.
- Embedded FBs.
- Penetrating injuries with an FB.
- FBs close to the tympanic membrane.
- Consider referral of spherical FBs because these may be difficult to grasp.
- Chronic FBs may be difficult to visualize; these should be referred.
- Consider referral for those patients who have attempts made at other institutions.

57.3 Materials and Medications

- Ear speculum (Fig. 56.1)
- Eye and biohazard protection for the clinician
- Headlamp or other direct lighting instrument
- Alligator forceps (Fig. 56.2)
- Curved hook (Fig. 57.1) or cerumen spoon (Fig. 56.3)
- Suction—Schuknecht catheter (Fig. 57.2)
- Irrigation setup
  - Ear syringe (Fig. 57.3)
  - 20- to 60-mL syringe with an 18-gauge angiocath attached
  - Water (tap water may be used)
  - Basin or other collection device
  - Towels
- Cyanoacrylate (Fig. 57.4)

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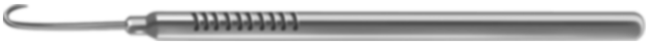

Fig. 57.1 Example of a curved hook

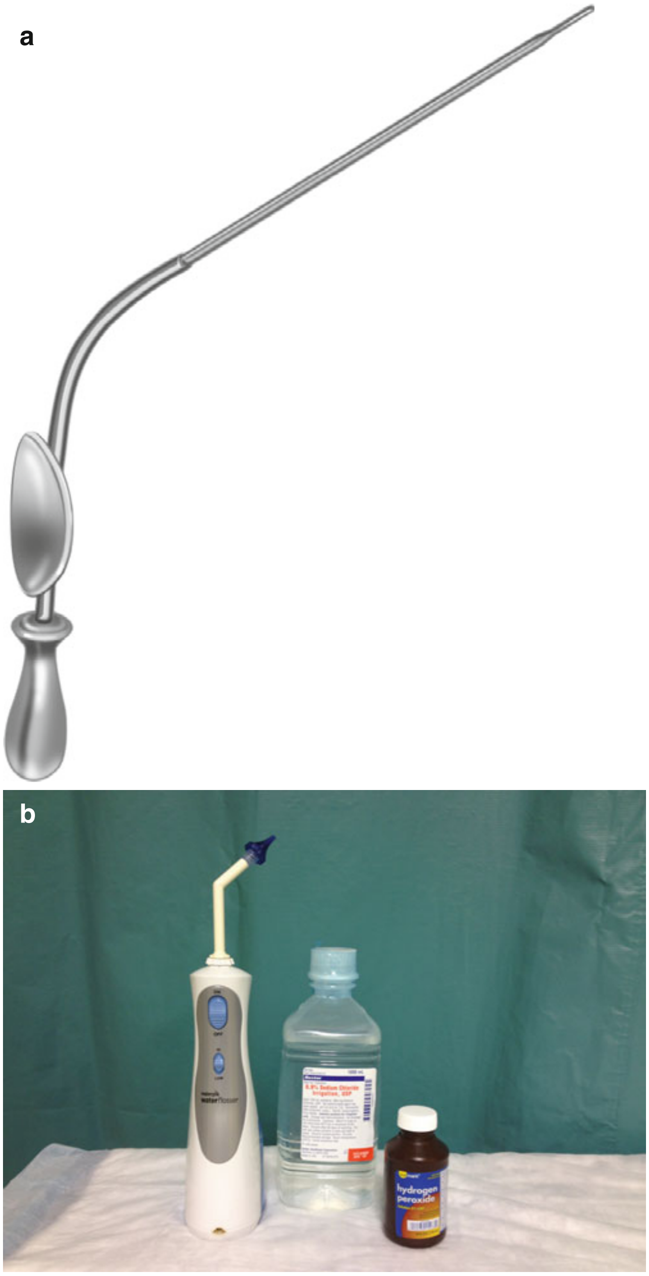
a
b
hydrogen peroxide

Fig. 57.2 (**a**) Example of a Schuknecht suction tube, (**b**) example of ear irrigation setup using a Waterpik system

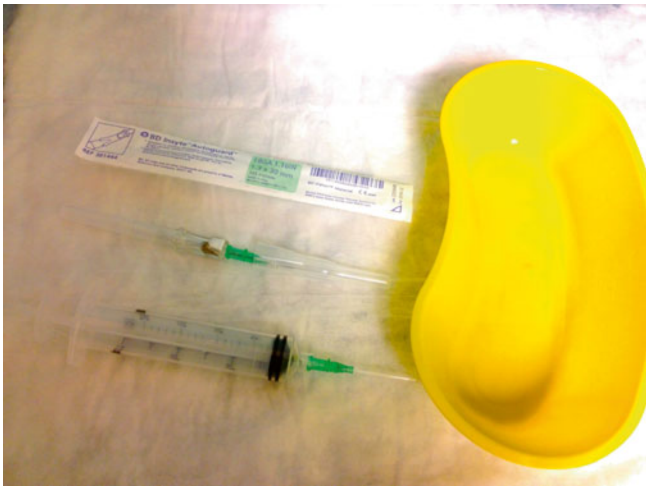

Fig. 57.3 Example of a typical syringe used in irrigation

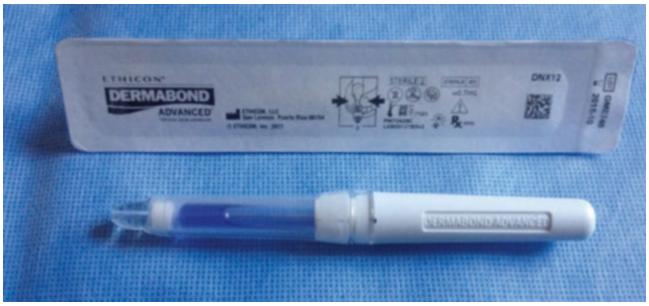
ETHICON
DERMABOND
ADVANCED
DNX12
DERMABOND ADVANCED

Fig. 57.4 Example of cyanoacrylate

57.4 Procedures (Based on the Method Chosen)

57.4.1 Alligator Forceps

- Ideal for easily visualized FBs, especially graspable FBs in the lateral third of the ear canal.
  – May have limited success with rounded objects.
- Care must be taken for those FBs that are easily broken apart (e.g., peas) to ensure that all of the matter has been removed.
  – May need irrigation subsequent to the attempt.
- Explain the procedure to the patient to facilitate cooperation.
- Pull the ear up and out to straighten the ear canal.
- Consider using a specialized otoscope with magnification (an operating otoscope) to maximize visualization.
- The patient may be seated or supine with the unaffected side turned to the gurney or examining chair.
- Stabilize the head with the nondominant hand, or for children, consider a papoose board to secure the patient.
- Attempt to grasp the FB with the forceps.
  – If using an ear speculum, attempt to bring the object as close as possible to the speculum in order to stabilize it and slowly remove both.
- After removal, ensure the complete removal of the object and ensure that no other FBs are present.

57.4.1.1 Pitfalls and Complications

- Pushing the object deeper into the auditory canal.
- Inability to totally remove the FB.
- Attempted removal of an embedded FB may cause significant bleeding.

57.4.2 Curved Hook

- Ideal for spherical objects in the lateral third of the auditory canal.
- Can be used for non-graspable objects especially in the lateral third of the auditory canal.
- Direct visualization is necessary to avoid trauma to the ear canal.
- Consider using a specialized otoscope with magnification (an operating otoscope) to maximize visualization.
- Explain the procedure to the patient to facilitate cooperation.
- The patient may be seated or supine with the unaffected side turned to the gurney or examining chair.
- Stabilize the head with the nondominant hand, or for children, consider a papoose board to secure the patient.
- Pull the ear up and out to straighten the ear canal.
- Pass the hook behind the object, or if the object has holes, place the hook inside the hole to facilitate removal.
  – In order for this technique to succeed, there must be sufficient area near the object to facilitate the hook going behind it.
- Slowly withdraw the hook, thereby removing the FB.
- After removal, ensure the complete removal of the object and ensure that no other FBs are present.

57.4.2.1 Pitfalls and Complications

- Pushing the object deeper into the auditory canal.
- This technique cannot be used if the object cannot be directly visualized because significant trauma may arise owing to the misplacement of the hook.
- Attempted removal of an embedded FB may cause significant bleeding.
- Do not use this technique if the object is close to the tympanic membrane owing to risk of rupture.

57.4.3 Suction

- A small metal suction catheter—the Schuknecht catheter—may be used.
- Ideal for hard rounded objects in the lateral third of the ear canal.
  – Does not work as well for those objects closer to the tympanic membrane owing to lack of suction and the narrow ear canal
- Direct visualization of the object is mandatory.
  – The catheter must be placed directly on the object for this technique to succeed.
- Explain the procedure to the patient to facilitate cooperation.
- The patient may be seated or supine with the unaffected side turned to the gurney or examining chair.
- Stabilize the head with the nondominant hand, or for children, consider a papoose board to secure the patient.
- Pull the ear up and out to straighten the ear canal.
- Place the suction against the FB and slowly withdraw.

57.4.3.1 Pitfalls and Complications

- Pushing the object deeper into the auditory canal
- May not work for objects too tightly entrenched in the ear canal

57.4.4 Irrigation

- Useful for small particulate matter unable to be grasped by forceps or too small for a hook to pull out.
  - Cannot be used for button batteries or vegetable matter.
    - Irrigation may cause an alkaline necrosis with the button battery.
    - Vegetable matter may expand, increasing the difficulty of removal.
- Explain the procedure to the patient to facilitate cooperation.
  - Some discomfort may be involved, including a sensation of pressure and a feeling cold wetness from the water used.
- The patient may be seated or supine with the head slightly turned to the affected side to facilitate collection of fluid.
- Stabilize the head with the nondominant hand, or for children, consider a papoose board to secure the patient.
- Pull the ear up and out to straighten the ear canal.
- Place a collection device next to the patient's ear, or alternatively, have the patient hold a basin.
- Attach an angiocath to a 20- or 60-mL syringe and place the tip of the catheter within the ear canal, or use a Waterpik system.
- Slowly inject the solution into the ear canal.
  - Care must be taken to limit the force used owing to the potential for tympanic membrane rupture.
- Direct the stream as much as possible toward the rear of the object(s) to be removed.
- Continually assess the ear canal to ensure that all foreign matter has been removed.
- If the patient complains of severe sharp pain, stop the procedure and assess the tympanic membrane for rupture.
  - Consider referral or otolaryngological consultation at this point.

57.4.4.1 Pitfalls and Complications

- Owing to instillation of room temperature water, a caloric response may occur including vertigo, nausea, and vomiting.
- Rupture of the tympanic membrane.

57.4.5 Cyanoacrylate

- Useful for objects that can be directly visualized.
- Ideal for hard rounded objects in the lateral third of the ear canal.
  - Does not work as well for those objects closer to the tympanic membrane owing to lack of visualization
- Direct visualization of the object is mandatory.
  - The stick with the cyanoacrylate must be placed directly on the object for this technique to succeed.
- Consider using a specialized otoscope with magnification (an operating otoscope) to maximize visualization.
- Explain the procedure to the patient to facilitate cooperation.
- The patient may be seated or supine with the unaffected side turned to the gurney or examining chair.
- Stabilize the head with the nondominant hand, or for children, consider a papoose board to secure the patient.
- Pull the ear up and out to straighten the ear canal.
- Place a small amount of cyanoacrylate on the end of a cerumen spoon or wooden end of a cotton-tipped swab.
- Using direct visualization, place the stick in the ear canal and touch the FB.
- Leave the stick on the object for approximately 30–60 s to facilitate drying of the glue.
- Remove the stick and the FB.

57.4.5.1 Pitfalls and Complications

- This technique cannot be used if the object cannot be seen.
- The object must be relatively smooth to facilitate placement of the glue.

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Treatment of Auricular Hematoma

58

Bobby K. Desai

58.1 Indications

- Presence of auricular hematoma
  - These occur after significant force is applied to the ear.
  - This type of hematoma will separate the perichondrium from the cartilage.
    - Untreated, this hematoma prevents the development of new cartilage, subsequently deforming the auricle, causing *cauliflower ear* (Figs. 58.1 and 58.2).

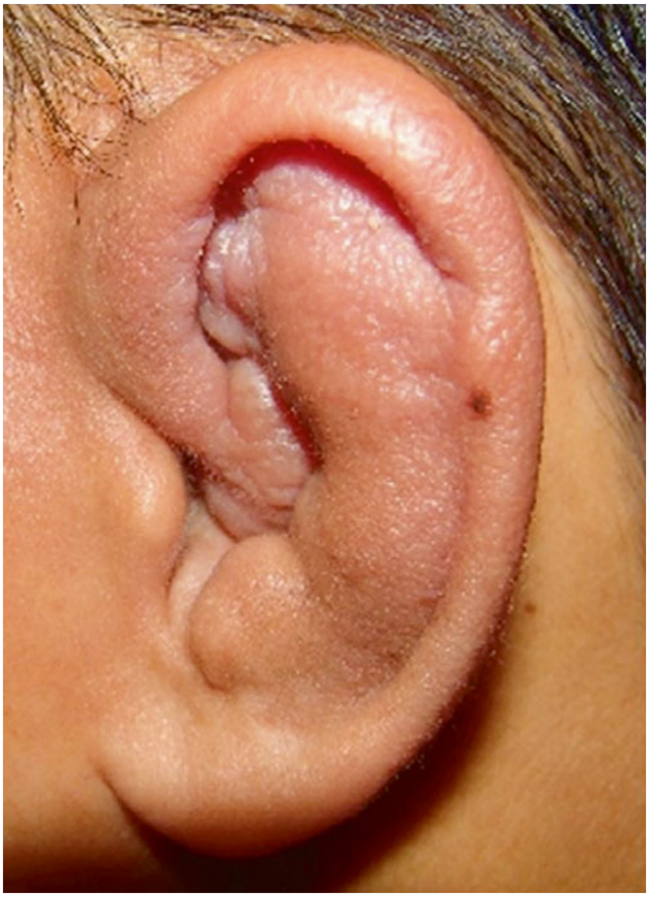

Fig. 58.1 Example of a cauliflower ear

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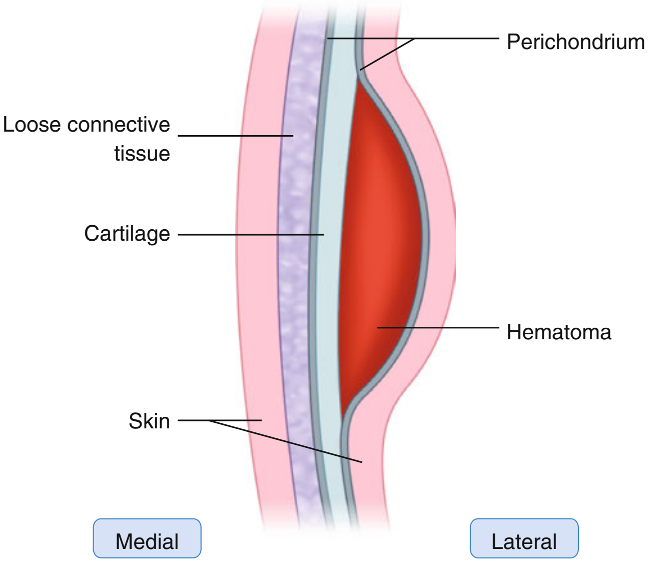

Fig. 58.2 Schematic of auricular hematoma

58.2 Contraindications

- Uncooperative patient.
- Evidence of infection mandates plastic surgery or otolaryngology consultation.
- Significant trauma to area around the ear.

58.3 Materials and Medications

- 5-cc syringe
- 20-gauge needle (may use larger-gauge needle, but smaller ones may not allow for adequate suctioning)
- Topical antiseptic
- Sterile drapes, gown, eye protection, and gloves
- 1 % lidocaine for anesthesia
- Scalpel (#11 or #15 blade)
- Suction setup
- Saline for irrigation
- Hemostat and forceps
- Penrose drain or plain gauze packing
- Xeroform gauze
- Laceration tray setup
  - Needle driver
  - 4–0 Nonabsorbable suture
- Antibiotic ointment
- Gauze bandages

58.4 Procedure (Needle Aspiration)

1. Explain the procedure to the patient.
2. Informed consent may be required.
3. The patient may be seated or supine with the unaffected side turned to the gurney or examining chair.
4. Stabilize the head with the nondominant hand, or for children, consider a papoose board to secure the patient.
   - Consider procedural sedation for children.
5. Carefully clean the area with an antiseptic solution of choice (povidone-iodine [Betadine] or chlorhexidine solution) and allow to dry.
6. Anesthetize the area where the hematoma is of greatest diameter with 1 % lidocaine.
7. Inject the hematoma itself to promote increased anesthesia.
8. The clinician should prepare for the procedure by practicing universal precautions.
9. Drape the patient's ear.
10. Attach a 20-gauge needle to a syringe.
    - A 5-cc syringe should be sufficient.
11. Attempt to aspirate the hematoma contents with the prepared syringe (Fig. 58.3).

12. "Milking" the hematoma may be required to fully remove the clot.
    - If the hematoma has been present for sufficient time for the blood to completely clot, needle aspiration will fail, and an alternative technique, described later, may be necessary to completely evacuate the hematoma.
13. Place antibiotic ointment around the injection site.
14. Loosely dress the area.
15. Refer to an otolaryngologist or a plastic surgeon for follow-up care.

If needle aspiration fails, a larger incision may be required using the following procedure:

1. Perform the previously discussed steps.
2. Consider a local field block of the greater auricular nerve.
3. Make an incision over the hematoma, following the anatomy of the helix (Fig. 58.4).
    - The incision should be 5–6 mm in length and curvilinear, following the concavity of the helix.
    - More than one incision may be required.
4. Remove the hematoma with hemostats or forceps.
    - Suctioning may be used as well.
5. Copiously irrigate the cavity with saline to make certain of complete removal of the hematoma.
6. Insert the Penrose drain or plain packing into the incision.
7. Antibiotic ointment may be applied to the incision site.
8. Place the Xeroform gauze over the incision site.
9. Apply a compression dressing to the ear (Fig. 58.5).
    - Place dry cotton into the ear canal to protect from possible drainage and subsequent infection (Fig. 58.6).
    - Mold Xeroform gauze in and around the contours of the helix (Fig. 58.7).
    - With the aid of an assistant, place gauze behind the pinna and over the Xeroform gauze already molded to the anterior portion of the ear (Fig. 58.8).
    - Place more fluffed gauze over the ear (Fig. 58.9).
    - While the assistant holds the anterior and posterior gauze in place, use a web roll (Kerlix) around the head to keep the gauze in place. Then wrap the head with an ACE wrap or stretchy bandage (Figs. 58.10 and 58.11).
    - These steps are critical to maintain equal compression of the ear, which will help prevent future deformity.
    - Alternatively, dental rolls can be secured with suture to the anterior and posterior site of the drained hematoma (Fig. 58.12).
10. Place the patient on prophylactic antibiotics.
11. Refer to an otolaryngologist or a plastic surgeon for follow-up care.

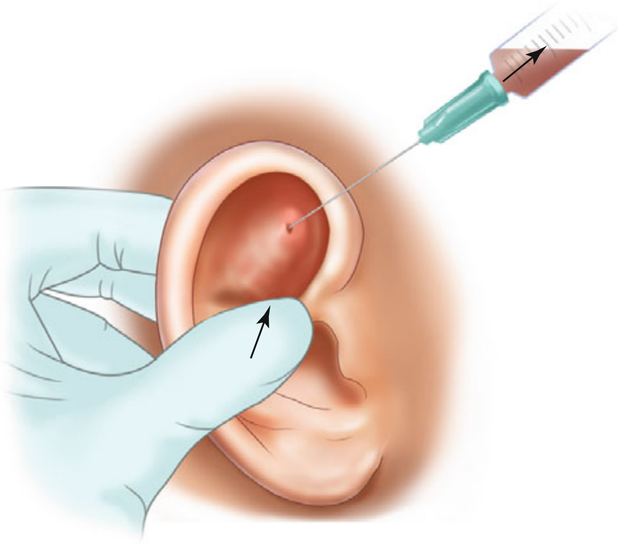

Fig. 58.3 Aspiration of a hematoma

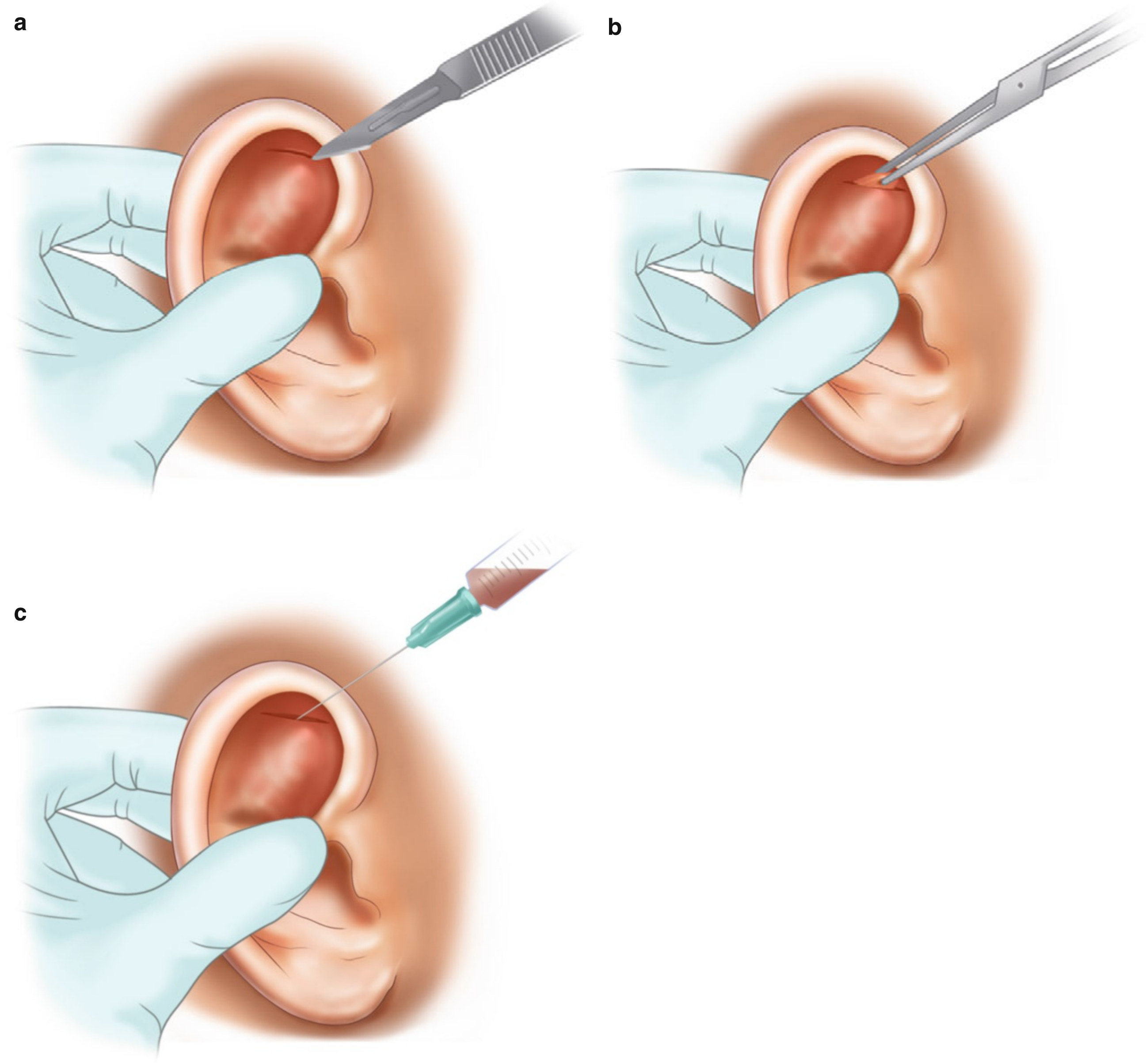

Fig. 58.4 Incision of an auricular hematoma. (**a**) Incision; (**b**) removal of clot with forceps; (**c**) aspiration of blood with syringe

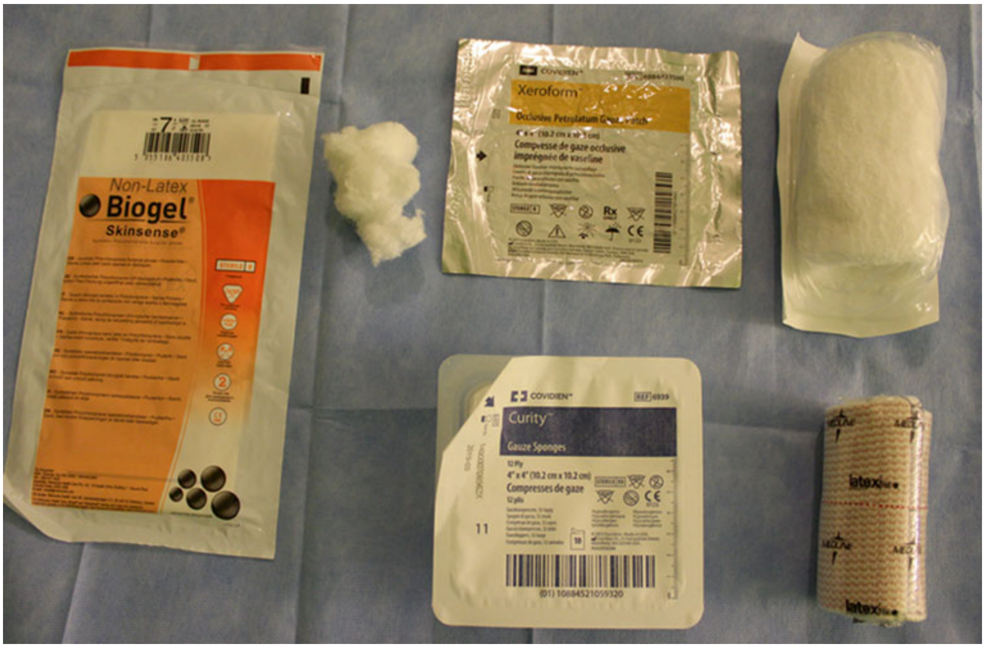

Fig. 58.5 Materials needed for compression dressing

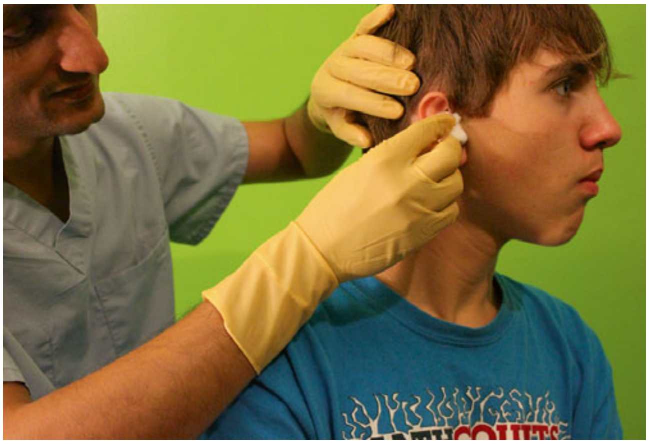

Fig. 58.6 Place cotton in the ear to prevent drainage into ear

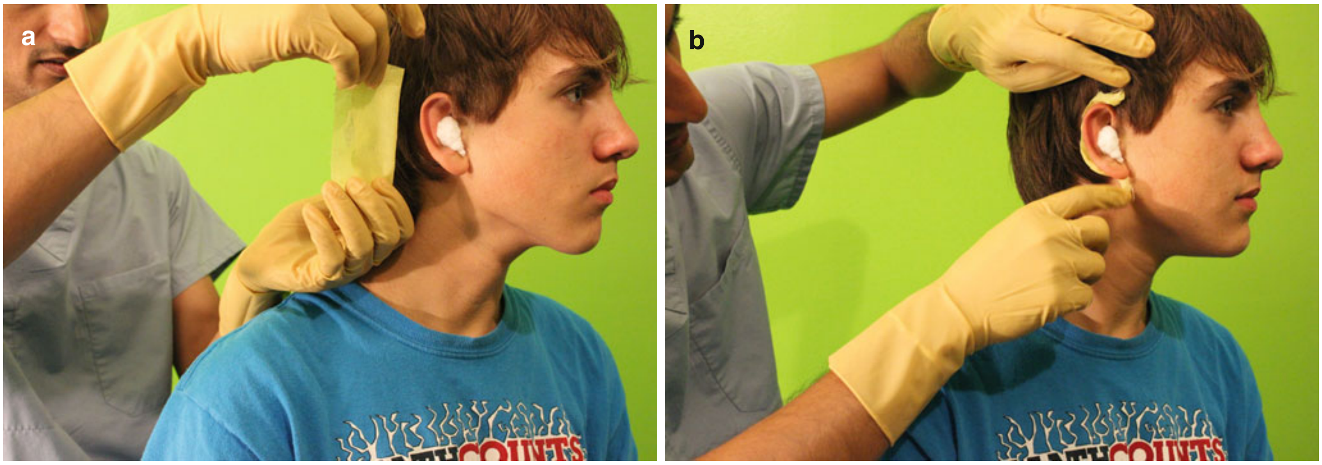

Fig. 58.7 (**a**, **b**) Mold Xeroform gauze around ear helix

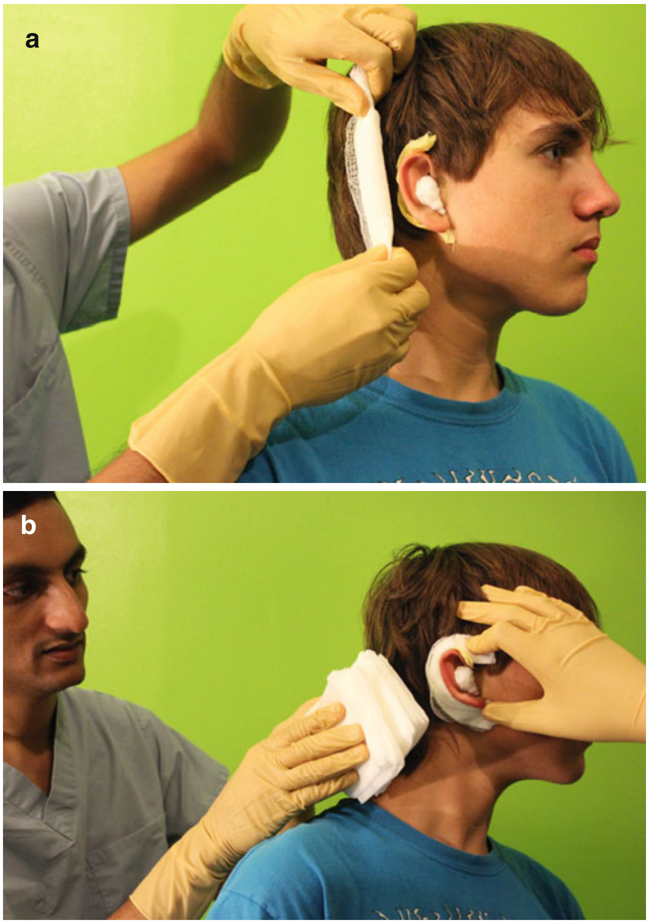

Fig. 58.8 (**a**, **b**) Mold sterile gauze on top of Xeroform gauze around ear helix

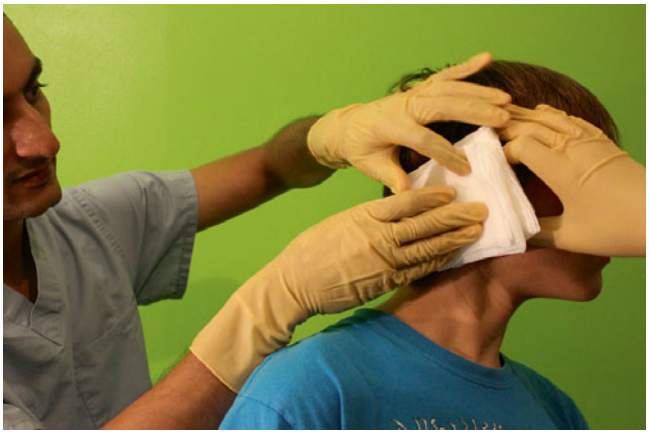

Fig. 58.9 Pad outside of ear with 4 × 4 gauze pads

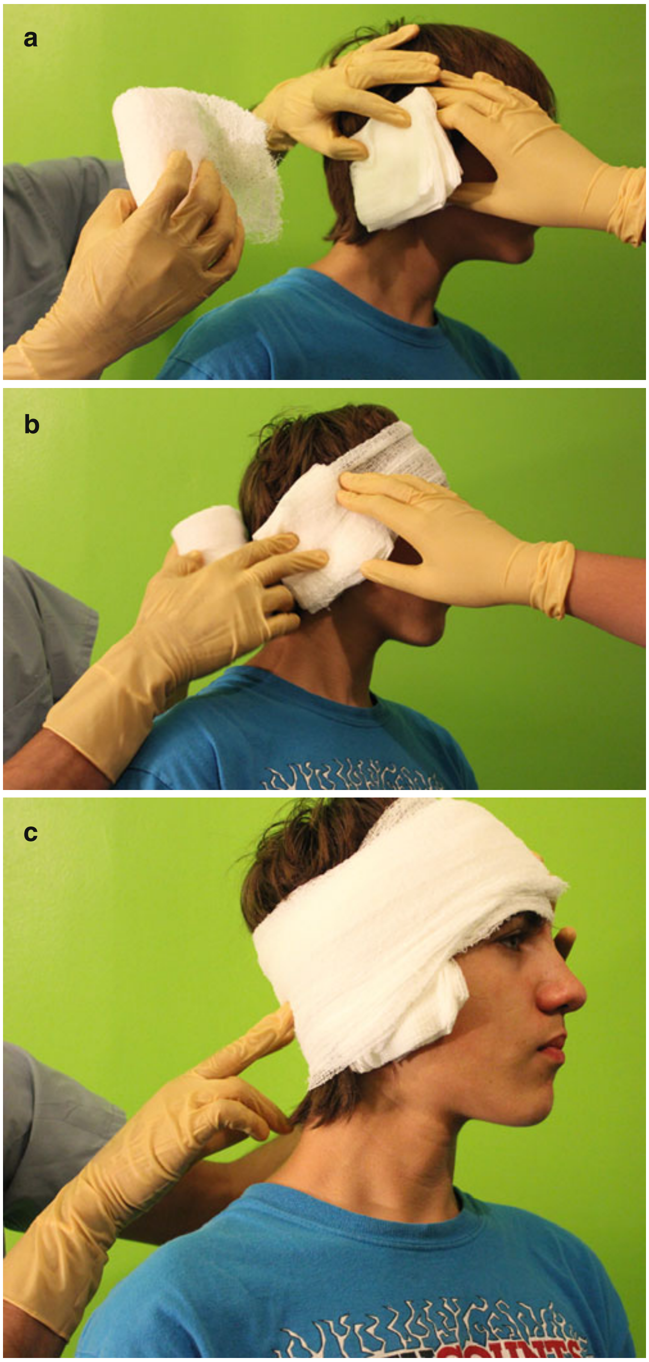

Fig. 58.10 (**a**–**c**) Wrap head with Kerlix (sterile gauze roll)

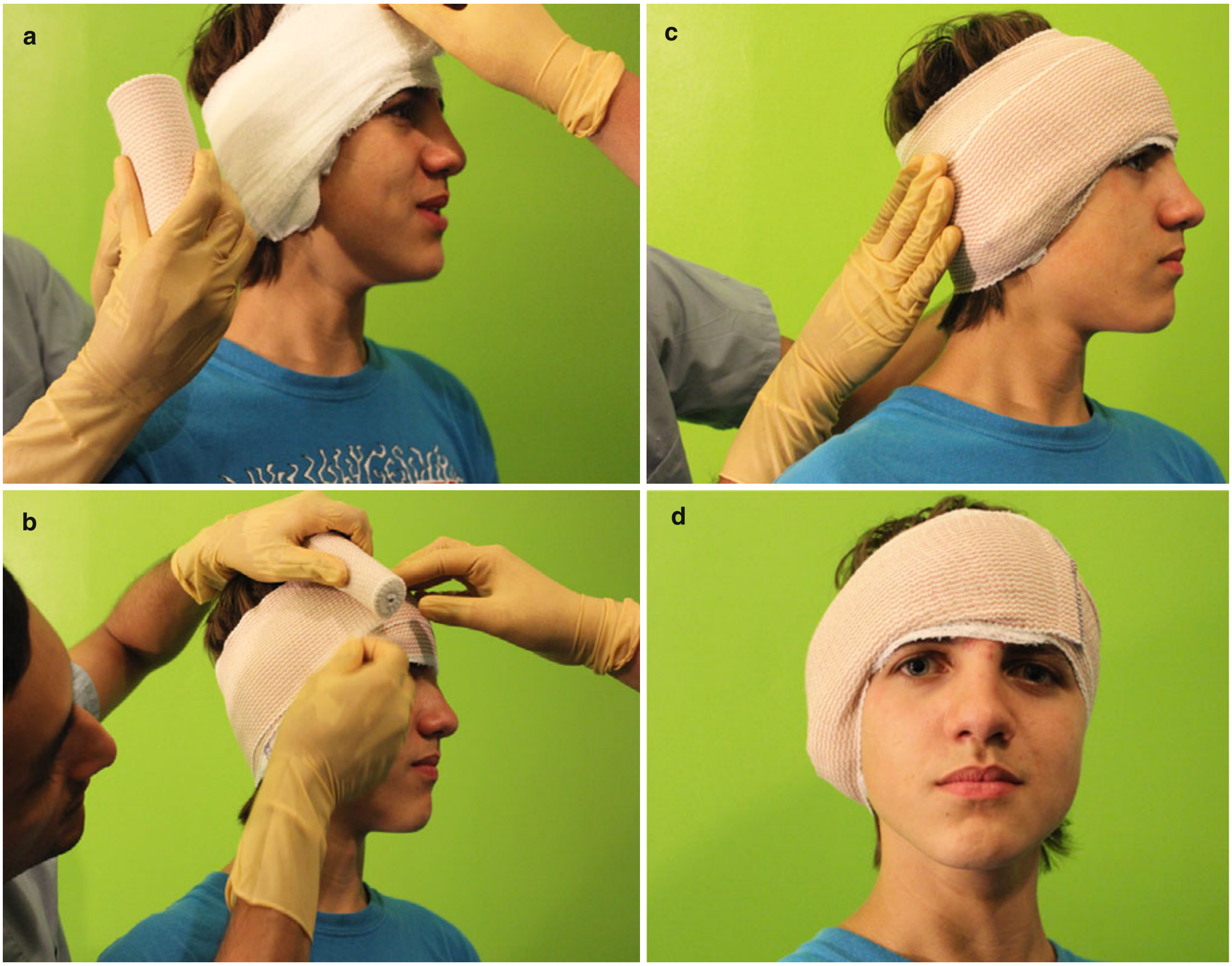

Fig. 58.11 (**a**–**d**) Wrap head with elastic bandage

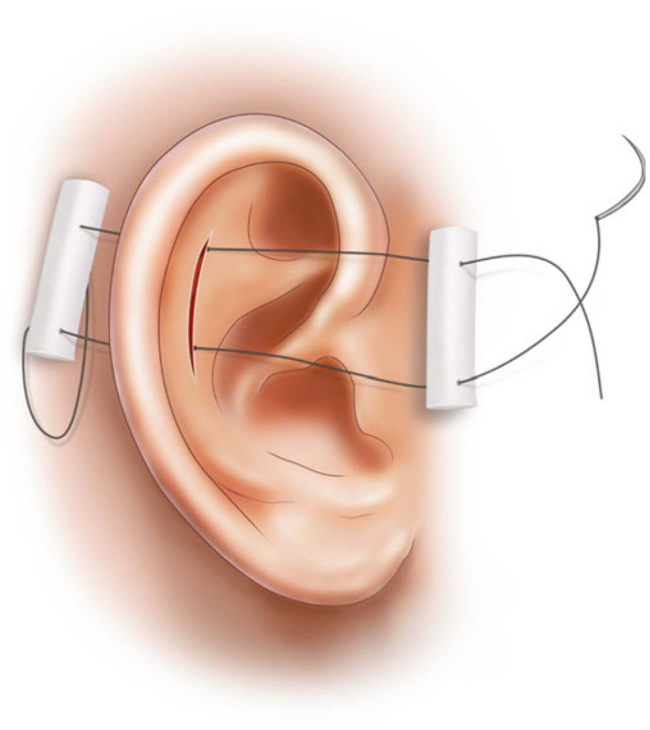

Fig. 58.12 Dental rolls secured to the ear

58.5 Pitfalls and Complications

- Bleeding
- Infection—perichondritis
- Deformity of the auricle
- Inadequate clot removal
- Hematomas present for several days warrant a plastic surgery or an otolaryngology consultation

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Incision and Drainage of Peritonsillar Abscess

59

Melinda W. Fernandez and Bobby K. Desai

59.1 Indications

- Peritonsillar abscess

59.2 Contraindications

- Absolute
  - – Malignancy
  - – Vascular malformations
- Relative
  - – Pediatric patient
  - – Severe trismus
  - – Uncooperative patient

59.3 Materials and Medications

- #11 or #15 scalpel
- 27-gauge 1.5-inch needle, 18- to 20-gauge 1.5-inch or longer needle
- 5-mL syringe, 10- to 20-mL syringe
- Tape
- Trauma shears
- Viscous lidocaine
- Lidocaine 1 % with epinephrine
- Laryngoscope with MAC 3 or 4 *or* tongue blade(s) and headlamp or other light source
- Suction setup with Frazier or tonsil suction tip

59.4 Procedure: Aspiration

1. Informed consent may be required.
2. Raise head of bed to at least 60° and place a pillow or other support behind the patient's head.
3. Prepare an 18- to 20-gauge 1.5-inch needle on a 10- to 20-mL syringe with a needle guard.
   - This can be accomplished by using trauma shears to cut 1–1.5 cm off the distal plastic needle cover and replacing the cover over the needle.
   - This now creates a guard to prevent deep penetration into vascular structures (Fig. 59.1).
4. Topically anesthetize area with viscous lidocaine (alternatively, can use Cetacaine [benzocaine, tetracaine hydrochloride, and butamben] spray)
5. Using lidocaine 1 % with epinephrine and a 27-gauge 1.5-inch needle on a 5-mL syringe, infiltrate 1–2 mL into the area. Blanching should be apparent.
6. Palpate the oropharynx with the gloved finger to evaluate for fluctuance.
7. Assemble a MAC 3 or 4 intubation blade on a laryngoscope handle and open into the light-on position. Insert the blade into the patient's mouth, and advance the blade as far posteriorly as possible without inducing gagging. Have the patient hold the laryngoscope handle. Alternatively, use a tongue blade and head lamp or other light source, but the laryngoscope technique allows for an unobstructed view of the area and the weight of the handle helps hold the patient's mouth open.
8. Using the previously prepared needle guard on the long 18- to 20-gauge needle on a 12-mL syringe, insert the needle into the most fluctuant area (as determined from the previous examination), aspirating as the needle advances (Fig. 59.2). The most fluctuant area will usually be located in the superior pole of the tonsil.

- It is very important to be careful not to angle the needle laterally toward the carotid artery. Also remember, this is a peritonsillar abscess so do not aspirate the tonsil itself.

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9. After aspiration, if there is a pus return, remove as much purulent drainage as possible. Typical drainage is between 2 and 6 mL. If a large amount of pus is obtained (>6 mL), incision and drainage (I&D) may be indicated. (See later for details on I&D.)
10. If the aspirate did not return pus, attempt aspiration again by moving the insertion site 1 cm inferiorly to the middle pole of the peritonsillar space. If there is still no pus aspirated, make a final attempt by moving again 1 cm inferiorly to the lower pole of the peritonsillar space.
11. Suction should be set up, readily available, and turned on. Use suction to prevent the patient from aspirating or swallowing any purulent drainage.
12. Expect a small amount of bleeding when the procedure is complete and the needle is removed.

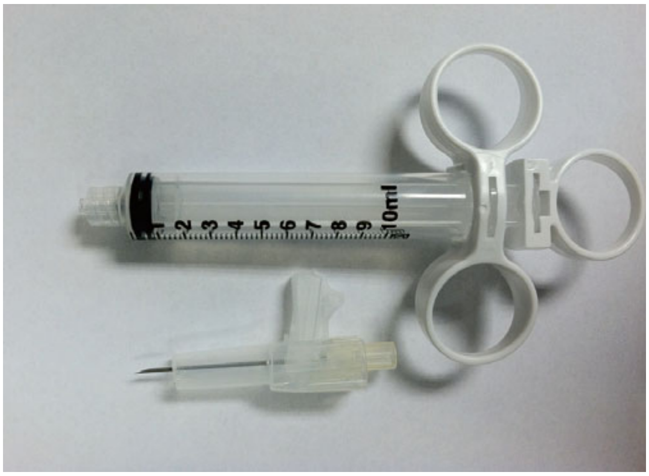

Fig. 59.1 Guard to prevent deep penetration of vascular structures

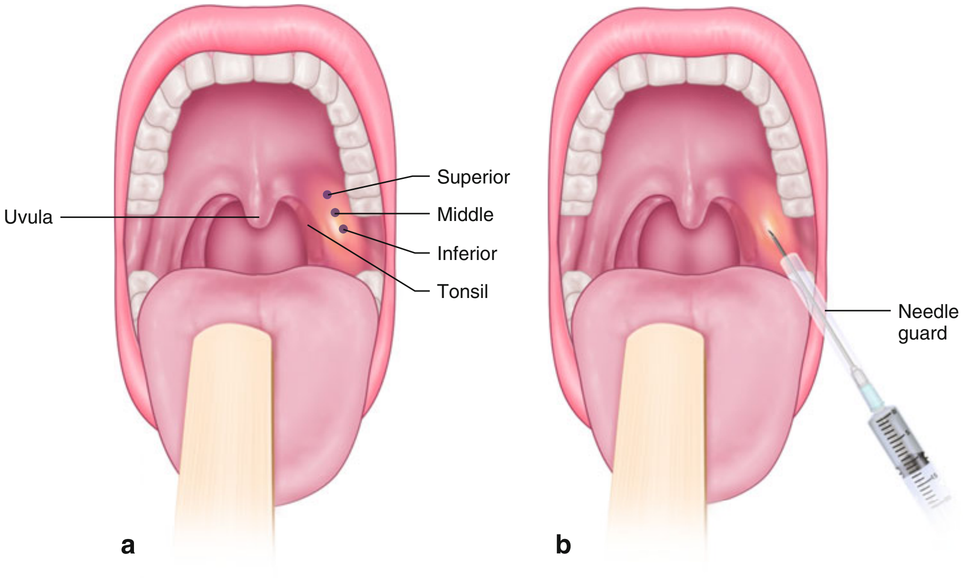

Fig. 59.2 Aspiration of a peritonsillar abscess: (**a**) Aspirate superior pole first. If no pus aspirated, move 1 cm inferior to the middle pole. If still no pus, make final attempt by moving 1 more cm inferiorly to the inferior pole. (**b**) Demonstrates use of needle guard

59.5 Procedure: Incision and Drainage

1. Raise the head of the bed and anesthetize the area as described previously.
2. Have suction set up with a Fraser or tonsil tip, available, and turned on.
3. Have the patient hold the laryngoscope handle after the blade has been inserted orally as described previously.
4. Fashion a blade guard on a #11 or #15 blade scalpel by taping over the blade with only 0.5 cm of the blade exposed at the tip. Incise the area that was previously aspirated with a small stab incision. Suction the area.
5. Insert a curved Kelly clamp into the incision and open gently to enter the abscess cavity and break up loculations (Fig. 59.3). Suction as necessary.
6. Have the patient gargle with a saline solution and expectorate.
7. Do not pack the abscess cavity.
8. Observe for 2–4 h for bleeding.

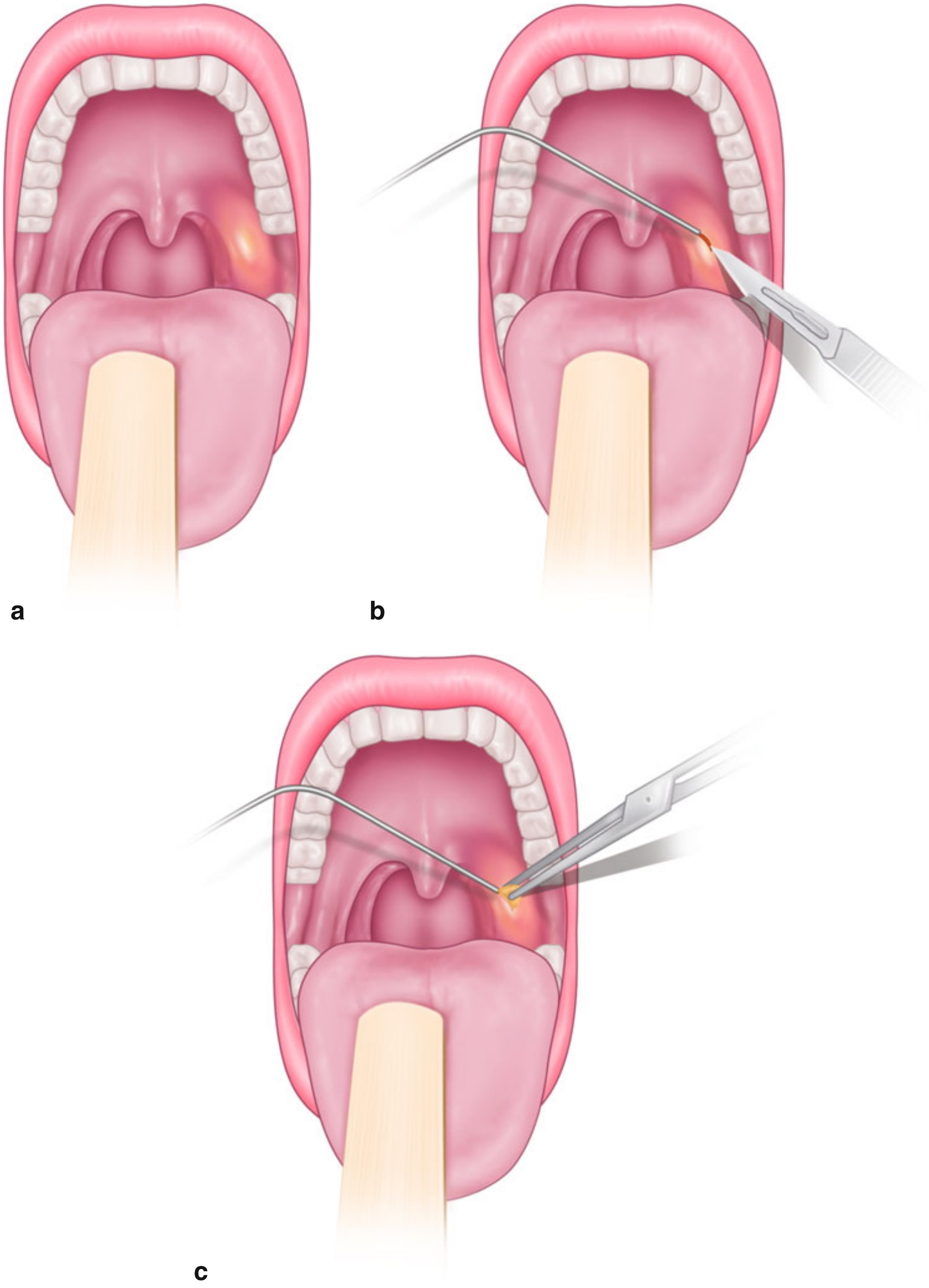

Fig. 59.3 Incision and drainage of peritonsillar abscess: (**a**) Gain access with appropriate lighting. (**b**) Fashion a blade guard on a #11 or #15 blade scalpel by taping over the blade with only 0.5 cm of the blade exposed at the tip. Incise the area that was previously aspirated with a small stab incision. (**c**) Insert a curved Kelly clamp into the incision and open gently to enter the abscess cavity and break up loculations. Do not pack!

59.6 Complications

- Aspiration or incision of the carotid artery
- Excessive bleeding
- Aspiration of purulent material
- Pain

59.7 Pearls and Pitfalls

- Pearls
  - Airway protection should always be considered. Intubation may be necessary for very large abscesses with airway compromise.
  - Bedsides ultrasound is a valuable tool in confirming the diagnosis of peritonsillar abscess. Perform using the intracavitary probe covered with a sterile glove or other appropriate probe cover and insert into the oropharynx. The abscess will appear as any other abscess: an encapsulated, hypoechoic structure. Doppler flow can also be used to locate the carotid artery relative to the abscess.
  - Empirical oral antibiotics after aspiration or I&D are considered usual care and should cover for group A streptococcus and oral anaerobes.
    - Amoxicillin/clavulanate or clindamycin is the most commonly used.
  - A single dose of high-dose steroids may be helpful in relieving symptoms.
  - Patients who cannot tolerate oral fluids, cannot take oral antibiotics, or who appear to have a toxic response should be admitted. Others may be discharged with 24-h follow-up.
- Pitfalls
  - The carotid artery is located approximately 2.5 cm posterolaterally to the tonsils. Take care that the needle is not inserted too far laterally or the risk of aspirating the carotid artery is increased.
  - Incision into the tonsil itself may cause excessive bleeding. Aspiration or incision into the tonsil will likely miss the abscess altogether and may result in misdiagnosis.
  - There is a 1–15 % failure and recurrence rate.

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Incision and Drainage of Sublingual Abscess

60

Melinda W. Fernandez and Bobby K. Desai

60.1 Indications

- Sublingual abscess (Fig. 60.1)

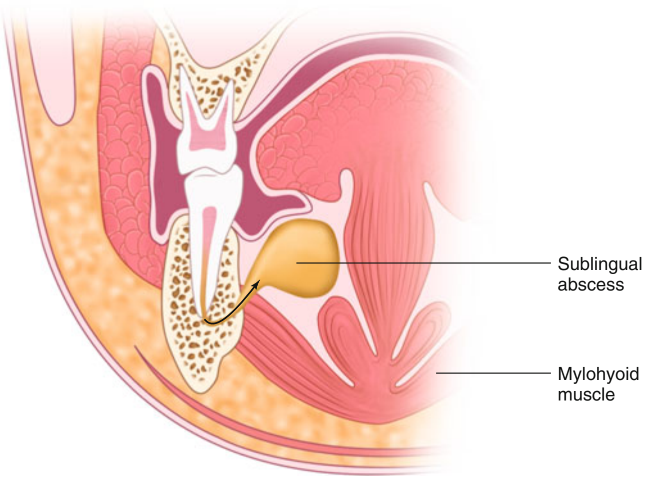

Fig. 60.1 Sublingual abscess

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60.2 Contraindications

- Relative
  - Pediatric patient
  - Severe trismus—may need sedation or drainage in the operating room
  - Uncooperative patient—may need sedation or drainage in the operating room
  - Coagulopathy, patients taking anticoagulants, or patients with a known bleeding disorder

60.3 Materials and Medications (Fig. 60.2)

- #11 scalpel
- Hemostats
- Penrose drain
- 4-0 silk suture
- 25- to 27-gauge 1.5-inch needle for injecting anesthetic
- 18- to 20-gauge needle for drawing up anesthetic
- 5- to 10-mL syringe or control syringe
- Viscous lidocaine (or other topical anesthetic)
- Lidocaine 1 % with epinephrine
- Light source
- Suction setup with tonsil suction tip
- Culture swab

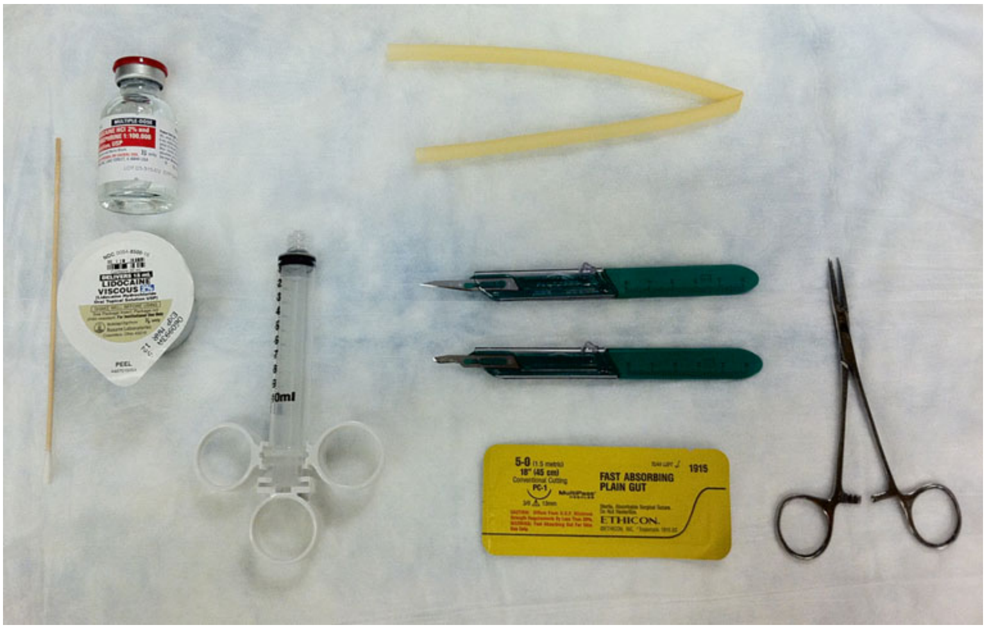

Fig. 60.2 Materials needed: #11 scalpel, hemostats, Penrose drain, 4-0 silk suture, 25–27-gauge 1.5-inch needle for injecting anesthetic, 18- to 20-gauge needle for drawing up anesthetic, 5- to 10-mL syringe or control syringe, viscous lidocaine (or other topical anesthetic), lidocaine 1 % with epinephrine, light source, suction setup with tonsil suction tip, culture swab (optional)

60.4 Procedure: Incision and Drainage

1. After explaining the procedure, risks, and benefits to the patient, put the head of the bed in the most comfortable working position for the clinician and the patient. Alternatively, the clinician may also elect to position the patient in an upright procedure chair that has multiple positions.
2. Apply viscous lidocaine topically with a cotton-tipped swab to the area to be injected with anesthetic. Leave in place for a minute or 2. Alternatively, spray the area with a topical anesthetic spray.
3. Have suction set up with a tonsil tip, available, and turned on.
4. Draw up the appropriate amount of lidocaine with epinephrine into a 5-mL syringe (control syringe if available).
5. Direct light source to area to be worked on. *Adequate lighting is essential.* Options include a headlamp or an overhead adjustable light.
6. Change needle to the 27-gauge needle and inject 1–2 mL of lidocaine with epinephrine using an inferior alveolar block. Alternatively, anesthetize the floor of the mouth around the most fluctuant area. Avoid injecting through infected tissue to avoid possible spread into deeper spaces.
7. Using the scalpel, make an intraoral stab incision superficially at the lowest point of the pus accumulation (Fig. 60.3). This will facilitate evacuation of pus under gravity. Have the suction catheter in the mouth and allow the purulent material to drain into the suction.
8. Obtain a specimen of the purulent fluid for culture and sensitivity.
9. Insert a hemostat into the incision to facilitate drainage, but do not open it up to avoid injury to neurovascular structures. Gently massage the soft tissue surrounding the abscess to assist drainage. Suction as necessary to avoid swallowing or aspirating the pus.
10. Once adequate drainage has been achieved, place a small Penrose drain (or other rubber-type drain) into the cavity, and stabilize on one side with a silk suture that goes through the drain and the mucosa (Fig. 60.4).
11. Have the patient rinse and spit with a half-strength peroxide solution followed by either water or saline.
12. Watch for signs of bleeding or upper airway symptoms.
13. Ensure that the patient can tolerate oral fluids before discharge.

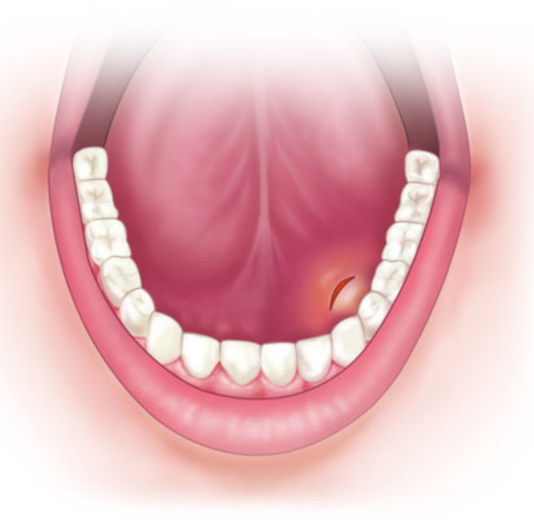

Fig. 60.3 Incise lowest portion of abscess

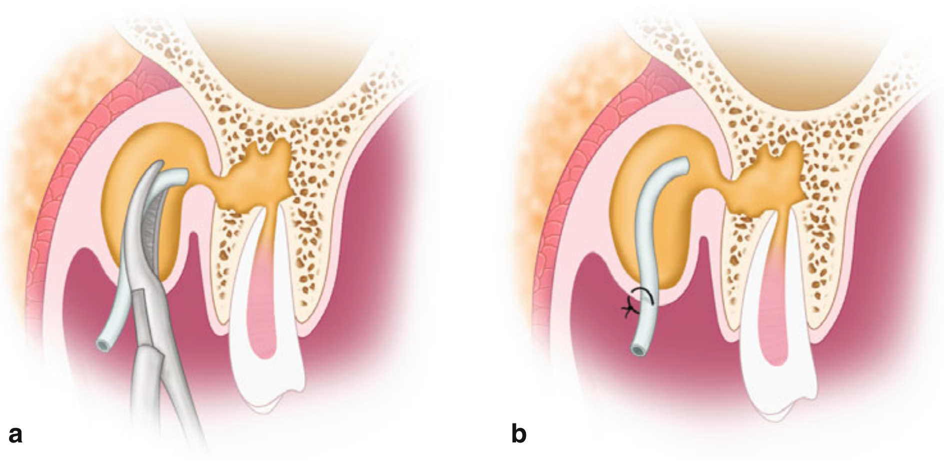

Fig. 60.4 (**a**) Using hemostats, place small Penrose drain into the abscess cavity. (**b**) Suture Penrose in place with a silk suture that goes through the drain and the mucosa

60.5 Complications (Generally Minimal)

- Excessive bleeding (apply pressure—to avoid potential nerve injury, do not cauterize or ligate unless absolutely necessary)
- Aspiration of purulent material (have the patient sit upright and use suction as the abscess is incised)
- Pain

60.6 Pearls and Pitfalls

- Pearls
  - Airway protection is paramount. Infections in this space can quickly spread to the submandibular region and can compromise the airway owing to swelling (Ludwig's angina).
    - Assess for elevation of the floor of the mouth and tongue, ability to lie supine, drooling, stridor, and restlessness.
    - If these signs are present, emergent surgical airway will be necessary before incision and drainage (I&D).
  - The sublingual space is bounded superiorly by the oral mucosa and inferiorly by the mylohyoid muscle.
  - Infected premolars and first molars drain into this space because the apices of their roots are located superior to the mylohyoid muscle.
  - The source molar should be extracted as soon as possible after I&D.
  - Empirical oral antibiotics after I&D should cover for group A streptococcus and oral anaerobes. Penicillin remains the drug of choice, but clindamycin or amoxicillin–clavulanic acid can be substituted.
- Pitfalls
  - The lingual artery, vein, and nerve are contained in the posterolateral area of the floor of the mouth, and the hypoglossal nerve is nearby. These must be avoided when performing I&D for sublingual abscesses.

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Incision and Drainage of Parotid Duct Abscess

61

Melinda W. Fernandez and Bobby K. Desai

61.1 Indications

- Parotid duct abscess

61.2 Contraindications

- Absolute
  - None
- Relative
  - Pediatric patient
  - Severe trismus—may need sedation or drainage in the operating room
  - Uncooperative patient—may need sedation or drainage in the operating room
  - Coagulopathy, patients taking anticoagulants, or patients with a known bleeding disorder

61.3 Materials and Medications (Fig. 61.1)

- #11 scalpel
- 4×4 gauze
- Hemostat
- Penrose drain or ¼-inch packing gauze
- Light source (headlamp or overhead light)
- Culture swab
- 4-0 silk suture
- 25- to 27-gauge needle, 1.5–2 inches long
- 18-gauge needle to withdraw anesthetic from vial
- 5-mL syringe
- Viscous lidocaine or other topical anesthetic
- Lidocaine with epinephrine
- Suction setup with Frazier or tonsil suction tip

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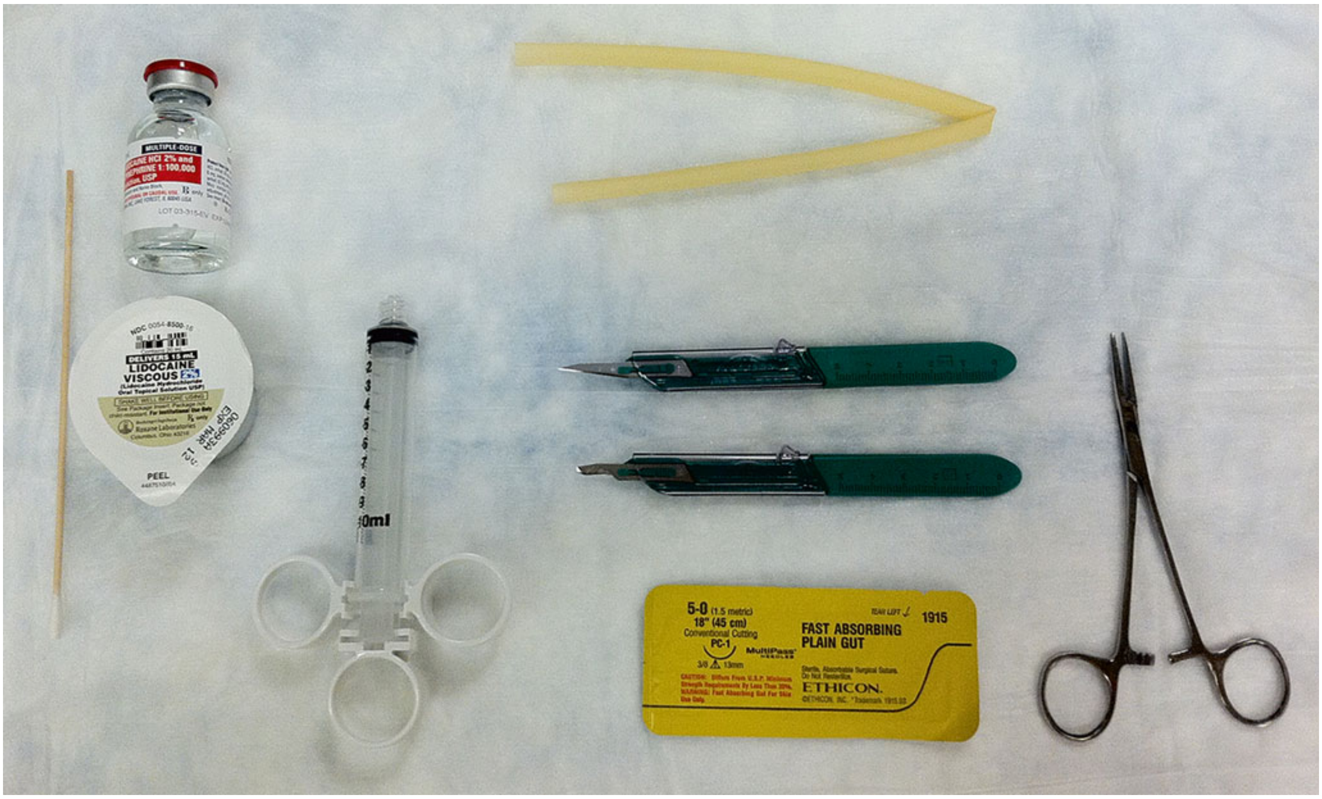

Fig. 61.1 Materials needed: #11 scalpel, hemostats, Penrose drain, 4-0 silk suture, 25- to 27-gauge 1.5-inch needle for injecting anesthetic, 18- to 20-gauge needle for drawing up anesthetic, 5- to 10-mL syringe or control syringe, viscous lidocaine (or other topical anesthetic), lidocaine 1 % with epinephrine, light source, suction setup with tonsil suction tip, culture swab (optional)

61.4 **Procedure** (Figs. 61.2 and 61.3)

1. After explaining the procedure, risks, and benefits to the patient, put the head of the bed in the most comfortable working position for the operator and the patient. Alternatively, position the patient in an upright procedure chair that has multiple positions.
2. Find the most fluctuant area. Apply viscous lidocaine topically with a cotton-tipped swab to the area to be injected with anesthetic. Leave in place for a minute or 2. Alternatively, spray the area with a topical anesthetic spray.
3. Have suction setup with a tonsil tip, available, and turned on.
4. Draw up the appropriate amount of lidocaine with epinephrine into a 5-mL syringe (control syringe if available).
5. Direct light source to area to be worked on. *Adequate lighting is essential.* Options include a headlamp or an overhead adjustable light.
6. Change needle to a 25- or 27-gauge needle. Inject 1–2 mL of lidocaine with epinephrine just beneath the mucosal surface. Avoid injecting through infected tissue to avoid possible spread into deeper spaces.
7. Using the scalpel, make an intraoral stab incision superficially into the area of greatest fluctuance (Fig. 61.4). Have the suction catheter in the patient's mouth and allow the purulent material to drain into the suction.
8. Obtain a specimen of the purulent fluid for culture and sensitivity.
9. Insert a hemostat into the incision to facilitate drainage, but do not open it up in order to avoid injury to neurovascular structures. Gently massage the soft tissue surrounding the abscess to assist drainage. Suction as necessary to avoid swallowing or aspirating the pus.
10. Have the patient rinse and spit with a half-strength peroxide solution.
11. Place a small Penrose drain (or other rubber-type drain) into the cavity, and stabilize on one side with a silk suture that goes through the drain and the mucosa. Alternatively, cut a strip of ¼- inch packing gauze and insert into the abscess cavity.
12. Have the patient rinse and spit with a half-strength peroxide solution followed by either water or saline.
13. Watch for signs of bleeding or upper airway symptoms.
14. Ensure that the patient can tolerate oral fluids before discharge.

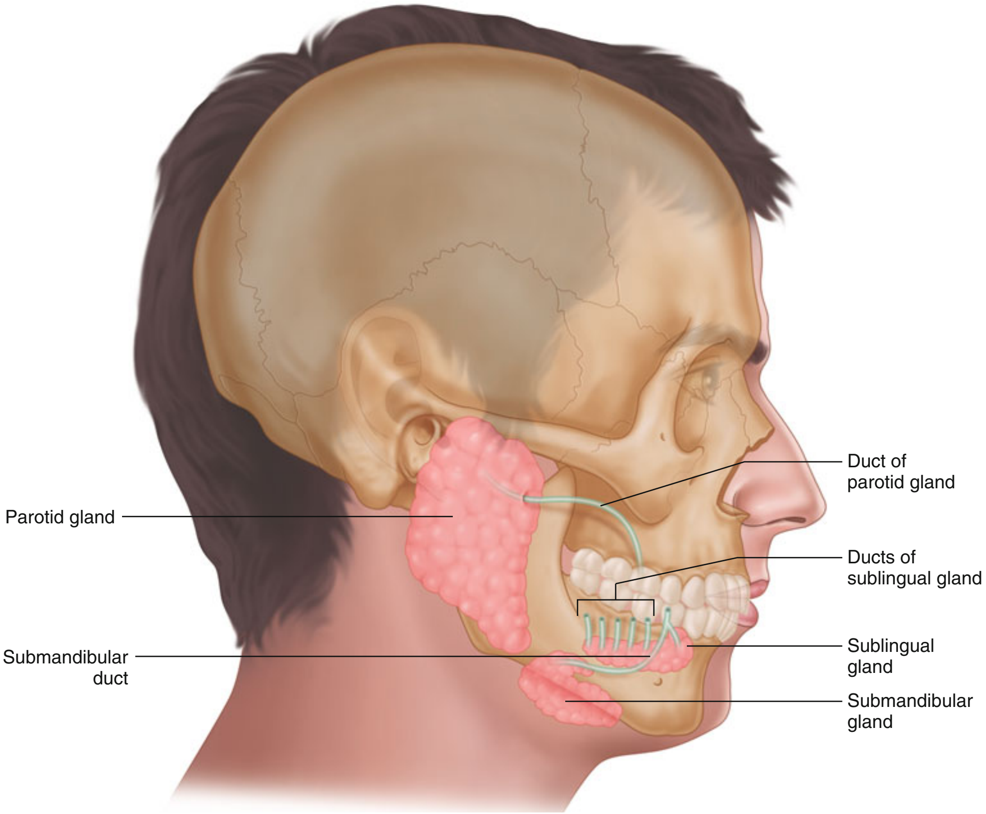

Fig. 61.2 Anatomy of the salivary glands

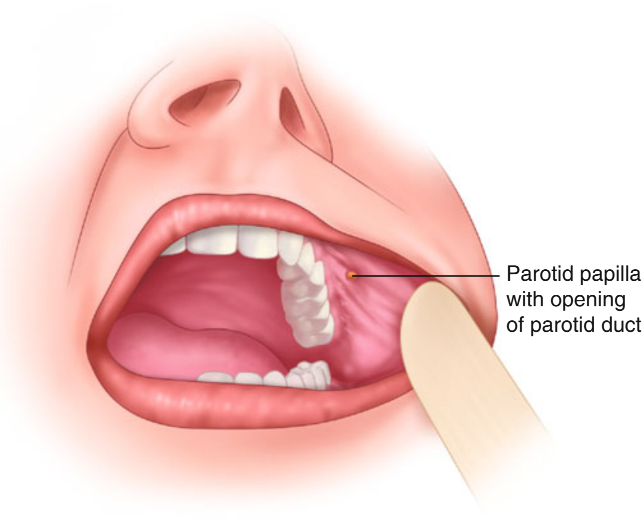

Fig. 61.3 Parotid papilla: opening of the parotid gland located adjacent to third upper molar

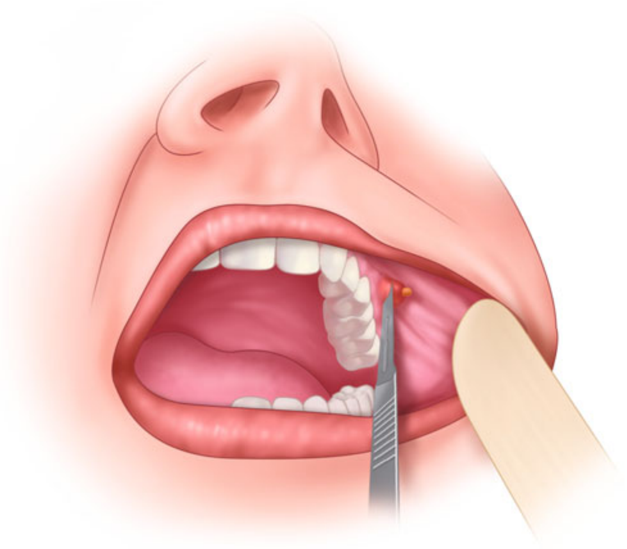

Fig. 61.4 Parotid abscess; make a superficial stab into most fluctuant area

61.5 Complications

- Complications are generally minimal but may include:
  - Excessive bleeding (apply pressure; to avoid potential nerve injury, do not cauterize or ligate unless absolutely necessary)
  - Aspiration of purulent material (have the patient sit upright and use suction as the abscess is incised)
  - Pain

61.6 Pearls and Pitfalls

- Airway protection should always be considered.
- Empirical oral antibiotics after incision and drainage are considered usual care and should cover for group A streptococcal and oral anaerobes. Penicillin remains the drug of choice, but clindamycin or amoxicillin–clavulanic acid can be substituted.
- Patients who cannot tolerate oral medications, cannot take oral antibiotics, or who appear to have a toxic response should be admitted. Pediatric patients should be admitted. Others may be discharged with 24-h follow-up.

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Part IX

Dental Procedures

Techniques of Mandibular Anesthesia

62

Susana Perry, Joshua Perry, and Rosalia Rey

62.1 Inferior Alveolar Nerve Block

62.1.1 Nerves Anesthetized

- Inferior alveolar, branch of the posterior division of the mandibular nerve (V3, branch of the trigeminal nerve)
- Incisive
- Mental
- Lingual (usually)

62.1.2 Areas Anesthetized (Fig. 62.1)

- Mandibular teeth to midline
- Body of the mandible
- Buccal mucoperiosteum, mucous membrane anterior to the mandibular first molar
- Anterior two thirds of the tongue and floor of the mouth (via the lingual nerve)
- Lingual soft tissues and periosteum (via the lingual nerve)

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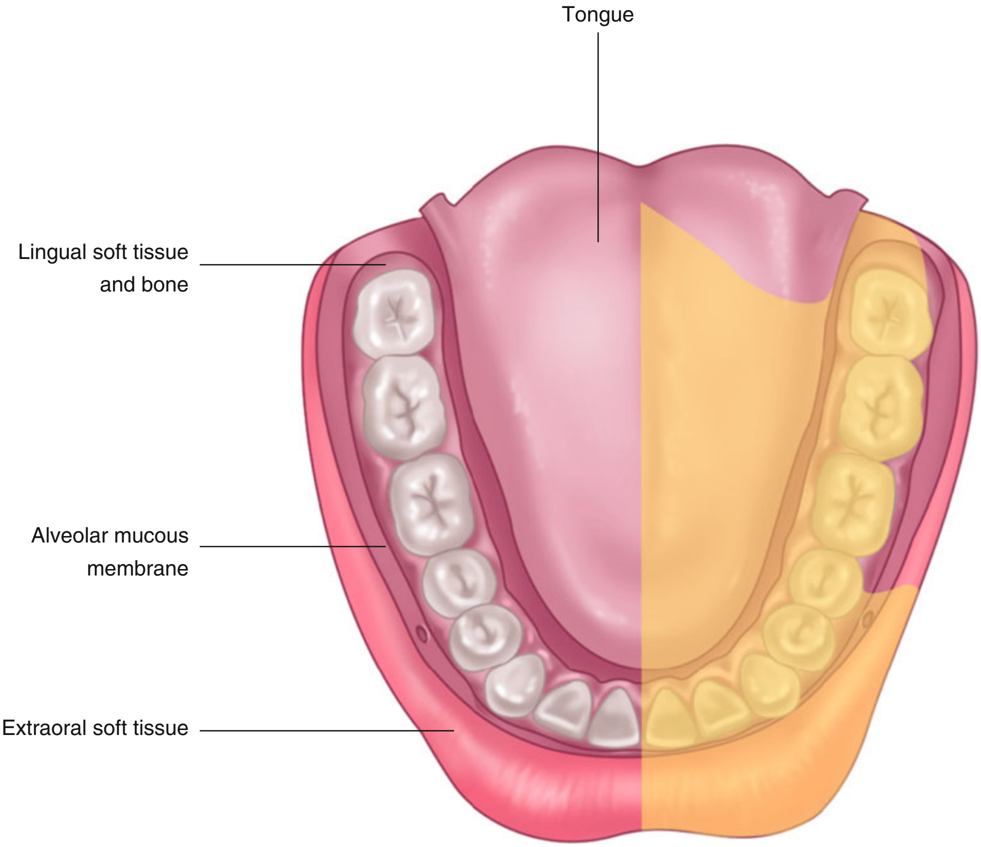

Fig. 62.1 Areas anesthetized with inferior mandibular nerve block

62.1.3 Indications

- When buccal soft tissue anesthesia is necessary
- When lingual soft tissue anesthesia is needed
- When performing procedures on multiple mandibular teeth in one quadrant

62.1.4 Contraindications

- Infection or acute inflammation in the area of injection
- Patients who might bite their lip or tongue (e.g., very young child or physically or mentally handicapped adult or child)
- In relation to local anesthetic use

Absolute

- Local anesthetic allergy
  - Avoid all local anesthetics in the same chemical class (e.g., esters).
- Bisulfite allergy
  - Avoid vasoconstrictor-containing local anesthetics.

Relative

- Atypical plasma cholinesterase
- Methemoglobinemia (idiopathic or congenital)
- Significant liver dysfunction (American Society of Anesthesiologists [ASA] III–IV)
- Significant kidney dysfunction (ASA III–IV)
- Significant cardiovascular disease (ASA III–IV)
  - Avoid high concentrations of vasoconstrictors.
  - Use local anesthetics with epinephrine concentrations of 1:200,000 or 1:100,000 or 3 % mepivacaine or 4 % prilocaine.
- Clinical hyperthyroidism (ASA III–IV)
  - Avoid high concentrations of vasoconstrictors.
  - Use local anesthetics with epinephrine concentrations of 1:200,000 or 1:100,000 or 3 % mepivacaine or 4 % prilocaine.

62.1.5 Materials and Medications

- Local anesthetic carpule (1.7–1.8 mL)
  - Mepivacaine 3 % (+epinephrine 1:100,000)
  - Articaine HCI 4 % (+epinephrine 1:100,000 or 1:200,000)
  - Lidocaine HCI 2 % (+ epinephrine 1:50,000 or 1:100,000) (Fig. 62.2)
  - Bupivacaine HCI 0.5 % + epinephrine 1:200,000
- Aspirating syringe (Fig. 62.3)
- Needle (Fig. 62.4)
  - Gauge refers to the lumen of the needle: The smaller the number, the greater the diameter of the lumen.
  - Needles are color coded by gauge: red = 25 gauge, yellow = 27 gauge, and blue = 30 gauge.
  - *Recommendations: For inferior alveolar nerve (IAN) block, it is best to use a 25-gauge long needle.*
- Mouth props
- Retractors

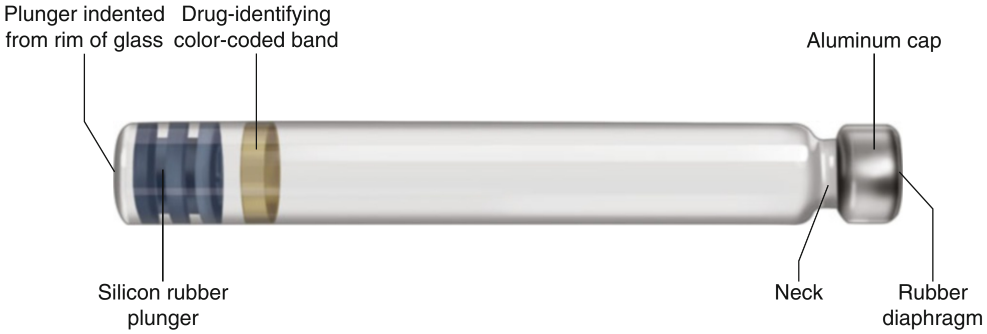
Plunger indented from rim of glass
Drug-identifying color-coded band
Aluminum cap
Silicon rubber plunger
Neck
Rubber diaphragm

Fig. 62.2 Local anesthetic carpule (1.7–1.8 mL)

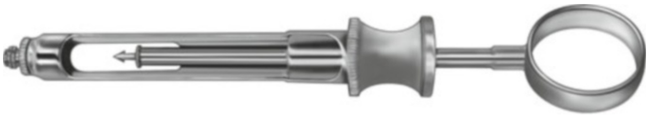

Fig. 62.3 Aspirating syringe

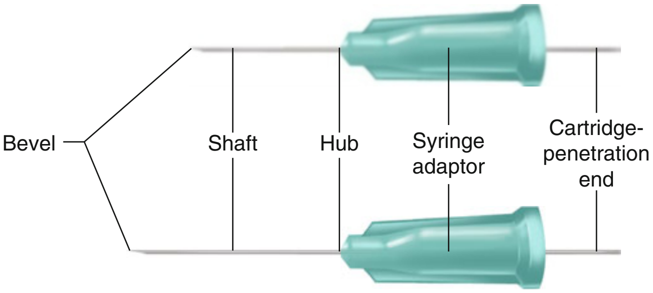
Bevel
Shaft
Hub
Syringe adaptor
Cartridge-penetration end

Fig. 62.4 Needle

62.1.6 Procedure

1. Target area: IAN as it passes downward toward the mandibular foramen.
2. Landmarks.
    - (a) Coronoid notch
    - (b) Pterygomandibular raphe
    - (c) Occlusal plane of mandibular posterior teeth
3. Procedure.
    - (a) Correct position for operator.
        - (i) For a right IAN block, a right-handed administrator should sit at the 8 o'clock position facing the patient.
        - (ii) For a left IAN block, a right-handed administrator should sit at the 10 o'clock position facing in the same direction as the patient.
    - (b) Recommended to position the patient supine and with the mouth wide open.
    - (c) Place thumb on the coronoid notch and index finger extraorally on the posterior border of the ramus in order to estimate the distance between these two points (Fig. 62.5).
        - (i) The needle insertion should be three fourths of the anteroposterior distance from the coronoid notch to the deepest part of the pterygomandibular raphe.
    - (d) Place the barrel of the syringe in the corner of the mouth on the contralateral side, usually corresponding to the premolars.
    - (e) Slowly advance the needle until bony resistance is met.
        - (i) For anxious or sensitive patients, a small volume of anesthetic may be deposited as the soft tissue is penetrated.
        - (ii) Average depth of penetration to bony contact will be 20–25 mm, approximately two thirds to three fourths the length of a long needle.
        - (iii) If the bone is contacted too soon (less than half the length of a long needle), the needle tip is usually located too far anteriorly (laterally) on the ramus. To correct:
            - Withdraw it slightly from the tissues and bring the syringe barrel anteriorly toward the lateral incisor or canine; reinsert to the proper depth.
        - (iv) If the bone is not contacted, the needle tip is usually located too far posterior (medial). To correct:
            - Withdraw it slightly in tissue (leaving approximately one fourth its length in tissue), and reposition the syringe barrel more posteriorly (over the mandibular molars).
            - Continue the insertion until contact with the bone is made at an appropriate depth (20–25 mm).
    - (f) Aspirate. If negative, slowly deposit 1.5 mL of anesthesia over 60 s.
    - (g) Wait 3–5 min before commencing the dental procedure.
4. Precaution: *Do not deposit anesthesia if the bone is not contacted*. The needle tip may be resting within the parotid gland near the facial nerve (cranial nerve VII), and a transient paralysis of the facial never may occur if solution is deposited.

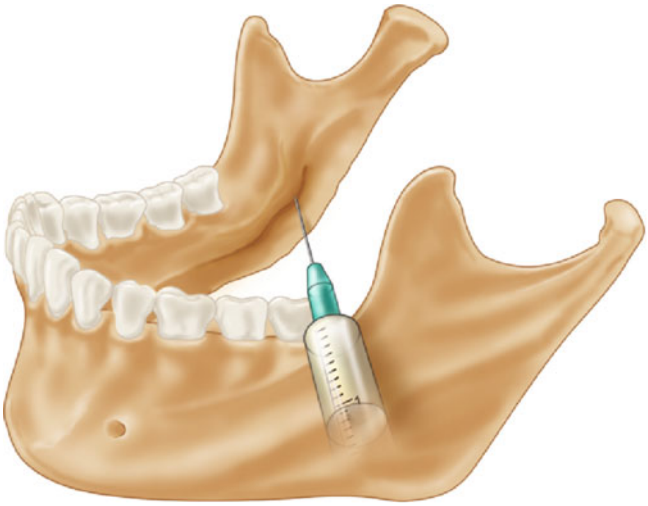

Fig. 62.5 Needle orientation for inferior alveolar nerve block

62.2 Buccal Nerve Block

62.2.1 Nerve Anesthetized

- Buccal nerve, a branch of the anterior division of the mandibular nerve

62.2.2 Area Anesthetized (Fig. 62.6)

- Soft tissues and periosteum buccal to the mandibular molars

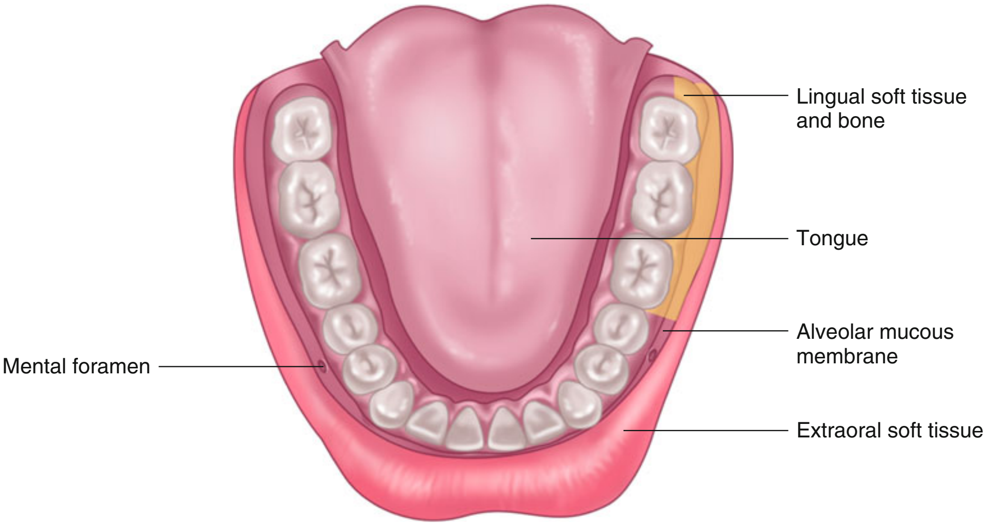
Lingual soft tissue
and bone
Tongue
Alveolar mucous
membrane
Mental foramen
Extraoral soft tissue

Fig. 62.6 Areas anesthetized with buccal nerve block

62.2.3 Procedure

1. A 25-gauge long needle is recommended.
2. Landmarks: mandibular molars and mucobuccal fold.
3. Orient the bevel of the needle *toward* the bone during injection.
4. Correct positioning.
   (a) For a right buccal nerve block, a right-handed administrator should sit at the 8 o'clock position directly facing the patient.
   (b) For a left buccal nerve block, a right-handed administrator should sit at the 10 o'clock facing in the same direction as the patient.
5. Procedure.
   (a) With the index finger, pull the buccal soft tissues in the area of injection laterally to allow for better visualization.
   (b) Align the syringe parallel to the occlusal plane of the teeth.
   (c) Penetrate the mucous membrane at the injection site, distal and buccal to the last molar (Fig. 62.7).
6. If tissue at the injection site becomes swollen, stop depositing solution.

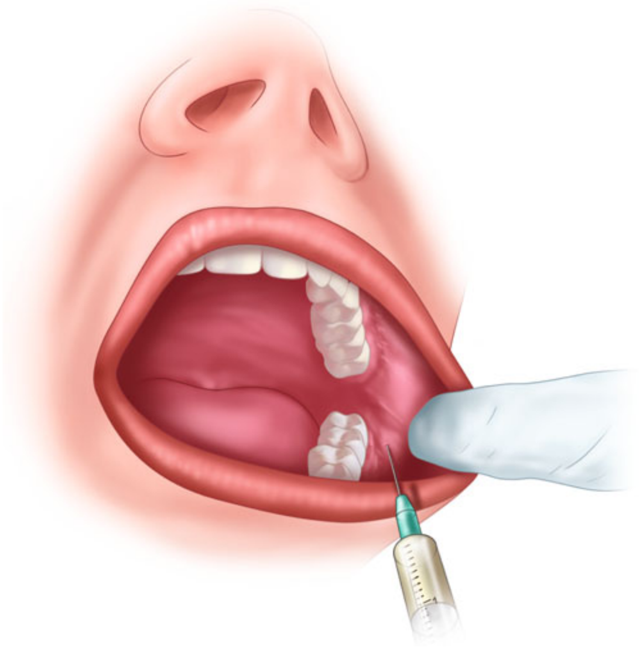

Fig. 62.7 Needle orientation for buccal nerve block

62.3 Mental Nerve Block

62.3.1 Nerve Anesthetized

- Mental nerve, a terminal branch of the inferior alveolar nerve

62.3.2 Area Anesthetized (Fig. 62.8)

- Buccal mucous membranes anterior to the foramen (around the second premolar) to the midline and skin of the lower lip

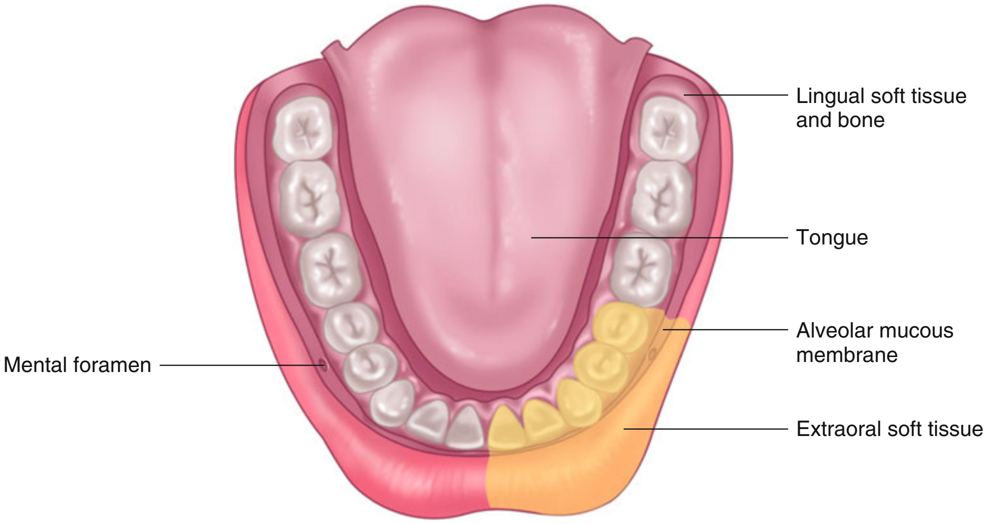
Lingual soft tissue and bone
Tongue
Alveolar mucous membrane
Mental foramen
Extraoral soft tissue

Fig. 62.8 Areas anesthetized with mental nerve block

62.3.3 Indications

- For buccal soft tissue anesthesia in procedures such as:
  - Soft tissue biopsies
  - Suturing of soft tissues

62.3.4 Procedure

1. Area of insertion: mucobuccal fold at or just anterior to the mental foramen.
2. Orientation of bevel should be *toward* the bone during injection.
3. Operator should sit in front of the patient so that the syringe is below the patient's line of sight.
4. Locate the mental foramen.
   (a) Place the index finger in the mucobuccal fold and press against the body of the mandible in the area of the first molar.
   (b) Move the finger anteriorly until the bone beneath the finger feels somewhat concave.
   (c) Mental foramen is usually found around the apex of the second premolar.
   (d) Orient the needle with the bevel directed toward the bone.
   (e) Penetrate the mucous membrane and advance needle slowly; penetration depth is usually 5–6 mm.
   (f) If aspiration is negative, deposit approximately one third of the cartridge over 20 s.
      (i) If the site balloons, stop the deposition of anesthetic and remove the syringe.

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Reduction of Dislocated Temporomandibular Joint

63

Christopher J. Spencer and Geraldine Weinstein

63.1 Indications

- Open lock: associated with yawning, vomiting, or opening the mouth wide
- Open lock: associated with a dental procedure
- Open lock: associated with endoscopy
- Open lock: associated with oral intubation
- Time duration: acute to 3 weeks or less duration

63.2 Contraindications for Closed Reduction

- Absolute
  - Head trauma with fracture of the skull, maxilla, mandible, or mandibular
    Condyles
- Relative
  - Dislocation of 30 days or longer (will likely be unable to accomplish reduction without general anesthesia and/or open surgical approach)

63.3 Materials and Medications

- Local anesthetic syringe.
- Lidocaine 2 % 1–2 mL.
- 25- to 27-gauge needle (long or approximately 2 inches long).
- Betadine (povidone-iodine) or other skin antiseptic preparation.
- Gauze padding for thumbs.
- Consider a muscle relaxant.
- Consider conscious sedation.

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63.4 Procedure

63.4.1 Manual Closed Reduction *without* Local Anesthesia (Figs. 63.1)

1. Position the patient in an upright posture with the mandible at the physician's flexed elbow height (physician's comfortable position).
2. Place the thumbs on the mandibular molars with wrapping around the thumbs to protect from possible biting force once the mandible reduces.
3. Apply bilateral firm force in an inferior direction.
4. The mandible will move rapidly in an inferior and then a posterior direction as the condyles slide back over the height of their respective articular eminences.

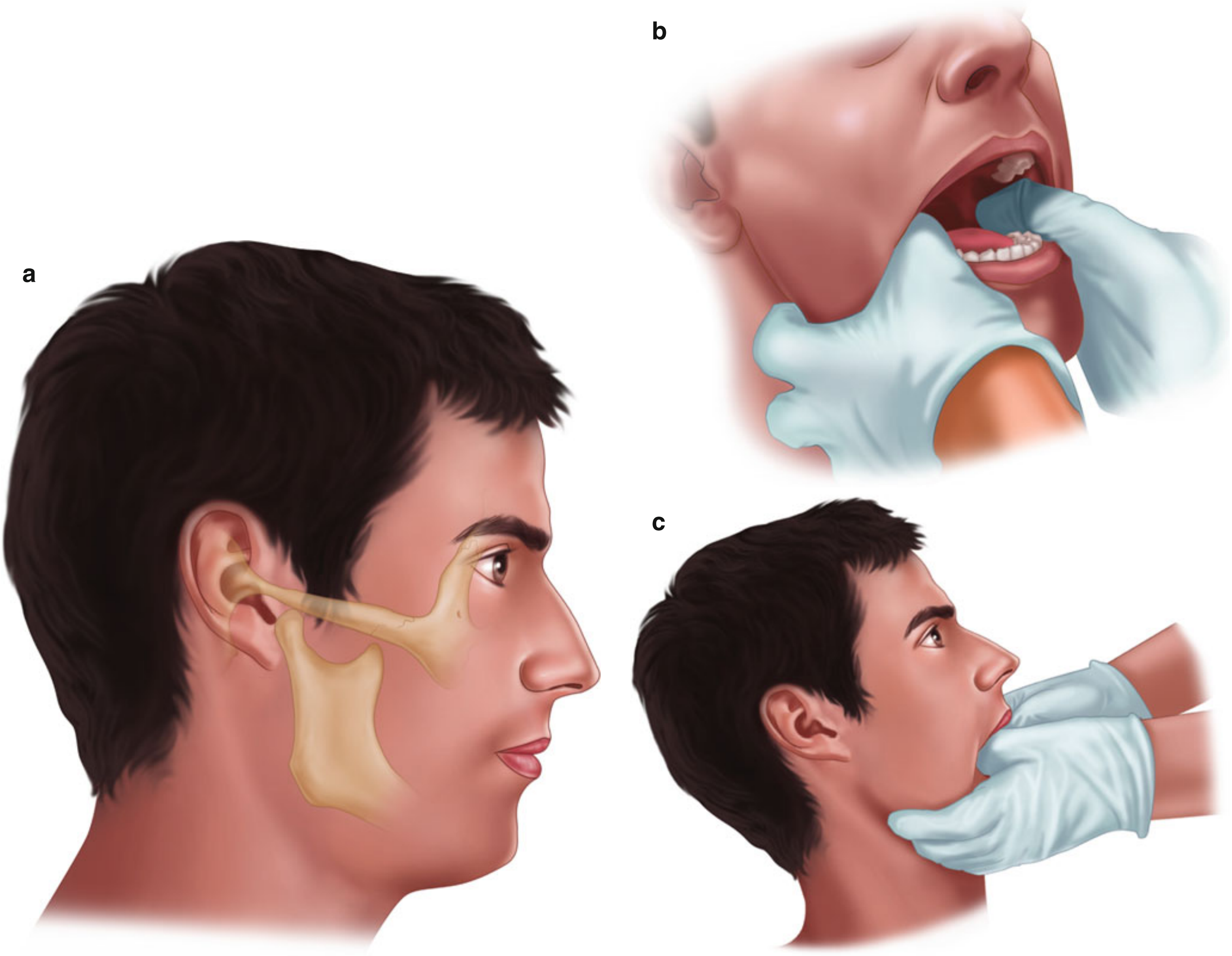

Fig. 63.1 Reduction in progress: (**a**) In a mandibular dislocation, the condyle will be anterior and superior to the articular eminence. (**b**) Position the thumbs on mandibular molars, and apply firm pressure in an inferior direction to distract the TM joint condyles so that they can reposition themselves into the glenoid fossa so that the TM joint can be reduced. (**c**) Lateral view of the distraction force with direction in an inferior direction to distract the condyle of the TM joint

63.4.2 Manual Closed Reduction *with* Local Anesthesia

- If the mandible will not respond to closed reduction with just thumb pressure, likely the masticatory muscles are contracting with sufficient force to prohibit the condyles from being sufficiently distracted owing to pain.
  1. Reduction of pain in the temporomandibular joint (TMJ) with local anesthesia.
  2. *Auriculotemporal block of V3:*
     - The auriculotemporal nerve that innervates the TMJ may be anesthetized inferior to the TMJ capsule. It can be accessed through the skin just anterior to the tragus.
     - With the patient's mouth wide open (it already is in this case), a triangular-shaped hollow will be evident inferior and posterior to the mandibular condyle. Insert the needle at a 20-degree anterior inclination, in the horizontal plane, at the level of the inferior border of the tragus of the ear (Fig. 63.2). The bevel of the needle should be anterior.
     - The needle should be inserted behind the (posterior) ramus and approximately 2 cm deep (aiming for the medial aspect of the posterior border of the ramus). If the posterior border of the ramus is contacted, the needle will need to be directed in a more posterior direction. Then deposit 1–2 mL of lidocaine 2 %.
  3. Then, as before, place the thumbs in a bilateral position on the patient's mandibular molars, and depress the mandible to distract the condyles in an inferior direction.
  4. Conscious sedation may be utilized if the reduction procedure has been arduous and stressful for the patient.

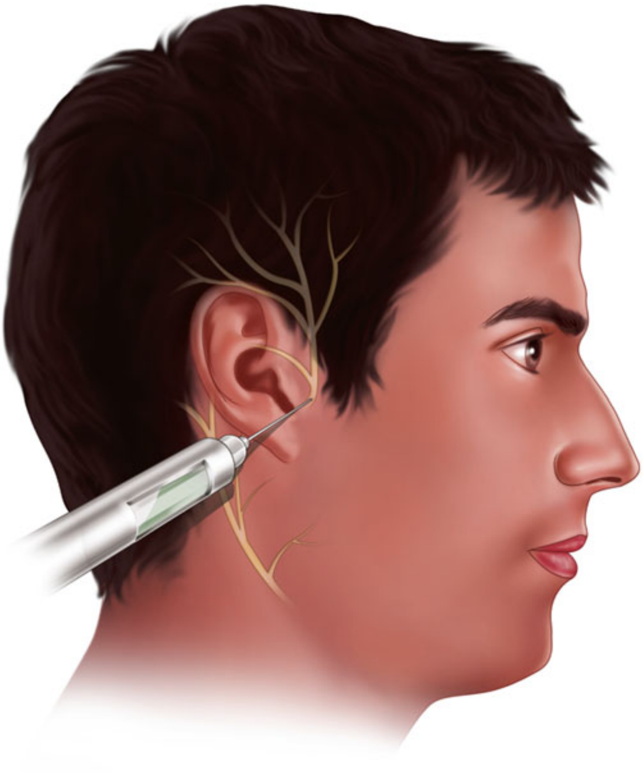

Fig. 63.2 Infiltration of cranial nerve V, the auriculotemporal branch (V3)

63.5 Complications

- Inability to reduce the condyles manually which may lead to more invasive procedures.
- If the condition is acute (≤24 h) and not associated with trauma, there are few if any significant complications or risks for this procedure.

63.6 Pearls

- The manual pressure required on the mandibular molars needs to be sustained and very firm.
- If both condyles are dislocated, it is likely beneficial to attempt one side at a time.
- The clinician needs to protect the thumbs from the impact of the patient's molars during the sudden successful reduction because the biting forces are significant in the molar region.

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Dry Socket (Alveolar Osteitis, Fibrinolytic Osteitis)

64

Michael A. Abraham, Amir Azari, Jennifer Westcott,
and Franci Stavropoulos

64.1 Indications (Fig. 64.1)

- Definition: severe pain occurring 2–3 days after tooth extraction
- Recent tooth extraction, especially of a mandibular tooth or an impacted third molar
- Partially or completely visible bone socket
- Intense radiating pain (often to the ear)
- Fetid odor without suppuration
- Absence of swelling, lymphadenitis, or bacteremia
- Foreign bodies present in the extraction socket

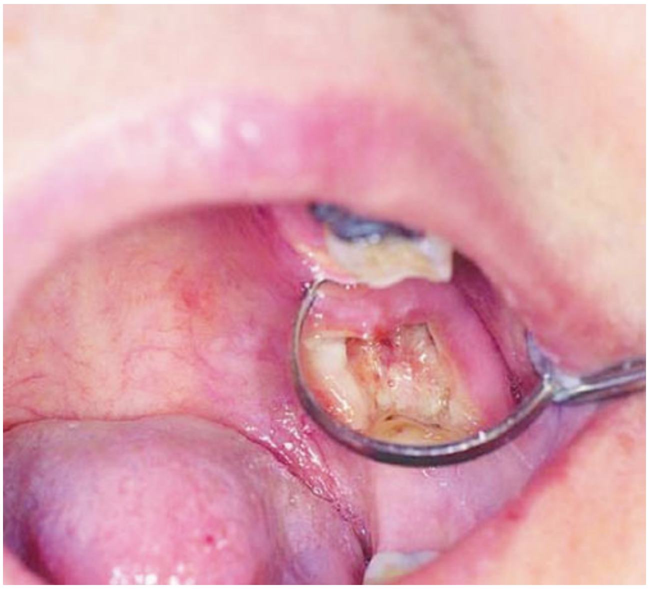

Fig. 64.1 Clinical photograph suggestive of a dry socket. Clinical correlation is necessary

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64.2 Contraindications

- Absolute
  - Osteomyelitis
  - Jaw fracture
- Relative
  - Retained roots
  - Infection

64.3 Materials and Medications

- Warm saline or 0.12 % aqueous chlorhexidine solution
- 12-mL syringe with curved tip (Monoject® syringe)
- 25-gauge needle, syringe
- Local anesthetic, 2 % lidocaine 1:100,000 epinephrine
- Suction with small tip or gauze
- Socket dressing
  - Gelfoam or small gauze strips
- Socket medicament
  - Sultan dry socket paste® (guaiacol, balsam of Peru, eugenol, 1.6 % chlorobutanol), iodoform, or eugenol® (zinc oxide eugenol dental cement)
- Curved forceps

64.4 Procedure

1. Administer local anesthesia as necessary.
2. Remove any sutures closing the extraction site.
3. Irrigate the wound gently with warm saline or 0.12 % aqueous chlorhexidine.
4. Carefully suction or gently dry any excess saline; the socket area should be isolated from saliva by using gauze or cotton rolls.
5. Gently place iodoform-soaked gauze, Gelfoam soaked in eugenol, or Sultan dry socket paste in the extraction socket with forceps/Monoject syringe.
6. Rinse with saline and replace the dressing as needed for the first 2–3 days and every 2–3 days thereafter.
7. Remove the dressing, if it does not dissolve, without replacement once the pain has resolved.
8. Pain medication (nonsteroidal anti-inflammatory drugs [NSAIDS] or narcotics) should be prescribed if necessary.
9. Follow-up with dentist.

64.5 Complications

- Delayed healing
- Wound dehiscence

64.6 Pearls and Pitfalls

- *Pearls*
  - Wound irrigation may be so painful at the first visit that administration of a local anesthetic without a vasoconstrictor should be considered.
  - The patient should experience profound pain relief within minutes of placement of the soaked medicated dressing.
  - If a medicated dressing is necessary for more than 2 weeks, reevaluate for development of osteomyelitis.
  - “Dry socket” is not a progressive disease but may persist for 10–14 days whether treated or not; therapy is palliative.
  - Instruct the patient to avoid the following, which can cause changes of pressure in the mouth:
    - Smoking
    - Using a straw
    - Spitting
    - Drinking carbonated beverages (e.g., soda, seltzer water, beer)
- *Pitfalls*
  - Avoid over manipulating the socket because this will increase the amount of exposed bone and pain.

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Postextraction Hemorrhage

65

Michael A. Abraham, Amir Azari, Jennifer Westcott, and Franci Stavropoulos

65.1 Indications

- Recent tooth extraction site, presenting with more than a slight oozing of blood
- Full evaluation indicating amount of blood loss, present physical condition, and reason for hemorrhage including coagulopathy or medication use

65.2 Contraindications

- Absolute
  - None
- Relative
  - None

65.3 Materials and Medications

- 2×2 gauze pad
- Saline
- 25-gauge needle, syringe
- Local anesthetic without vasoconstrictor—2 % lidocaine plain
- Gelfoam® (absorbable gelatin-compressed sponge) or oxidized cellulose
- Topical thrombin
- Suture kit with 3-0 chromic gut suture or 3-0 Vicryl® suture (synthetic absorbable sterile surgical suture composed of a copolymer made from 90 % glycolide and 10 % L-lactide)
- Hemostat

65.4 Procedure

1. Use suction and saline irrigation to gently rinse the affected area. If a "liver" clot is present, irrigate and remove it with suction.
2. Determine the source of hemorrhage without local anesthesia, if possible, because the use of local anesthetic with an added vasoconstrictor may obscure bleeding sites.
3. Moisten a folded 2×2 gauze pad with saline and place it directly onto the extraction site.
4. Instruct the patient to apply firm biting pressure, and observe for 1 h, changing gauze as necessary.
5. If bleeding persists, an intraoral nerve block should be performed.
   - Blocks are preferred to infiltrations; anesthetic with epinephrine infiltrated near the bleeding site will produce only temporary local hemostasis from vasoconstriction.
6. Gently curette the tooth extraction socket and remove areas of old blood clot or granulation tissue.
7. Check soft tissue for associated arterial bleeding.
   - If hemorrhage is localized to soft tissue, use pressure or tie off vessels.
8. Fold Gelfoam® into a small cylinder to fit into the extraction socket.
9. Place Gelfoam® with topical thrombin or Surgicel® (absorbable hemostat) into the socket and hold in

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position with a figure-of-eight stitch using 3-0 chromic gut suture or 3-0 Vicryl suture (Figs. 65.1 and 65.2).

10. Fold 2×2 gauze, moisten it with saline, and place it over the suture.
11. Instruct the patient to bite down with firm pressure for 30 min; repeat as necessary.
12. Follow-up with dentist.

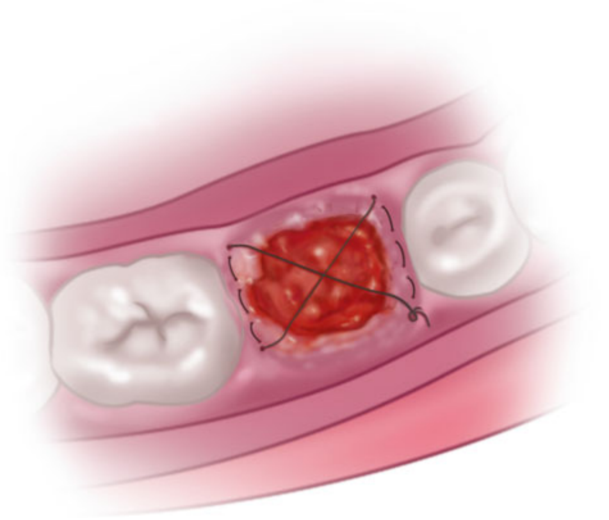

Fig. 65.1 A resorbable figure-of-eight suture placed over an extraction socket

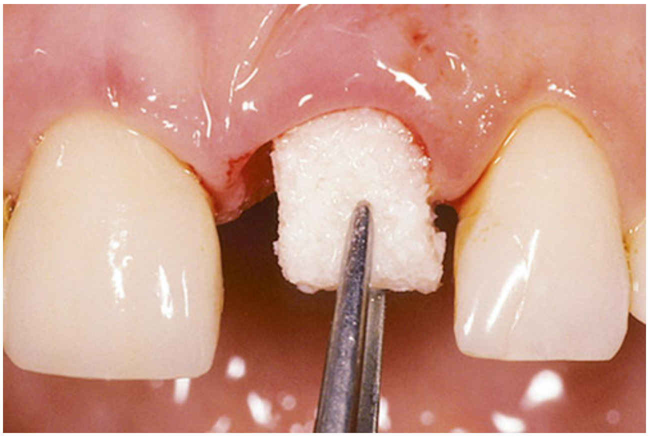

Fig. 65.2 Gelfoam® (absorbable gelatin-compressed sponge) being placed into the extraction socket (Photograph courtesy of Dr. Michael Abraham)

65.5 Complications

- Continued bleeding due to lack of patient compliance.
- Continued bleeding due to coagulopathy or medication use.
- If bleeding persists and coagulopathy is identified, the administration of intravenous blood replacement products may be necessary.

65.6 Pearls and Pitfalls

- Pearls
  - Minor bleeding concerns may be addressed at home by instructing the patient to bite on the affected area with a tea bag for 30 min (tannic acid in tea is a vasoconstrictor).
  - It is normal for an extraction socket to ooze slight amounts of blood for 12–24 h; it is normal for patients to see some blood on their pillow after waking.
  - The patient should be instructed to avoid the following, which can cause changes of pressure in the mouth:
    - Smoking
    - Using a straw
    - Spitting
    - Drinking carbonated beverages (e.g., soda, seltzer water, beer)
- Pitfalls
  - Small amounts of blood mixed with saliva may deceptively appear as large amounts of blood.

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Fractured Tooth

66

Geraldine Weinstein

66.1 Indications (Fig. 66.1)

- Temporary repair of an acute dental fracture until follow-up by a dentist can be secured.

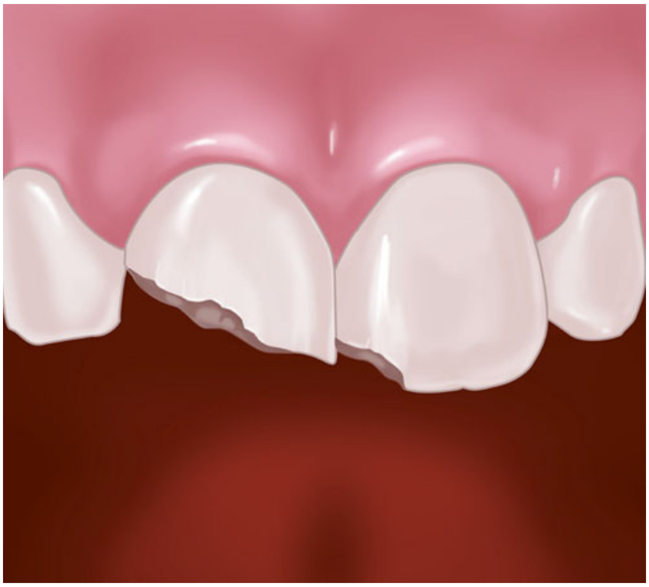

Fig. 66.1 Examples of fractured teeth

66.2 Methods of Sustaining Dental Fracture

- Traumatic injury to the head/facial area
- Falling down
- Extensive tooth decay that has undermined the integrity of the tooth structure
- Biting down on something hard

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66.3 Four Types of Fractured Tooth (Fig. 66.2)

- *Type 1*: contained to the enamel of the tooth, asymptomatic, and can be treated easily with a composite filling by a dentist.
- *Type 2*: involves a fracture through the dentin layer of the tooth. The patient may experience some sensitivity to temperature changes and chewing. Depending on the severity, treatment may include a root canal and a restoration by a dentist.
- *Type 3*: involves the pulp of the tooth and will require endodontic treatment by a dentist.
- *Type 4*: a root fracture in the tooth that makes it nonrestorable and requiring extraction. It is diagnosed by means of a periapical radiograph taken in a dental office.

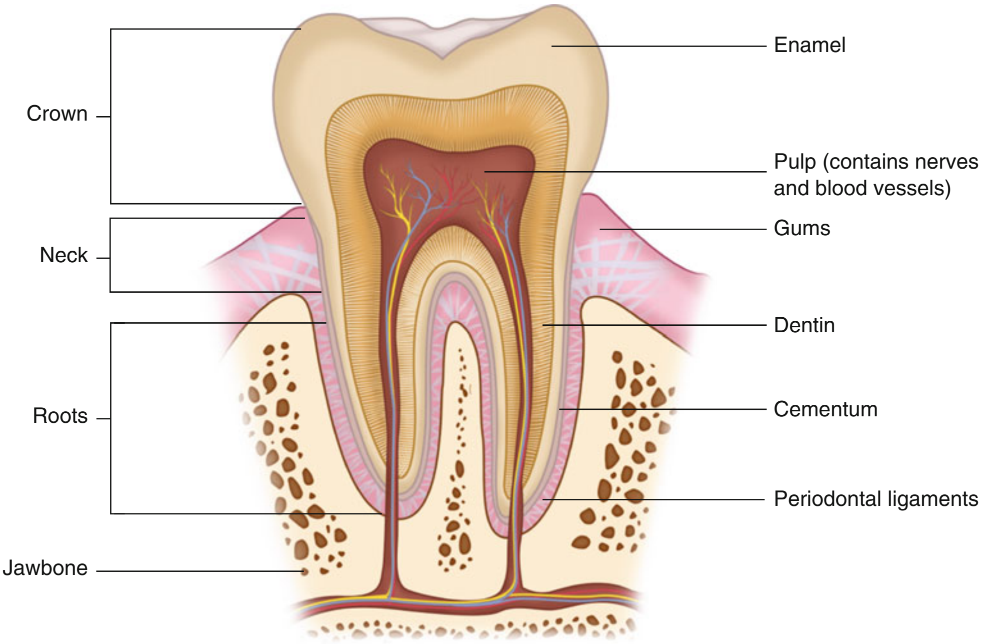
Crown
Neck
Roots
Jawbone
Enamel
Pulp (contains nerves and blood vessels)
Gums
Dentin
Cementum
Periodontal ligaments

Fig. 66.2 Anatomy of a tooth

66.4 Contraindications

- *Relative*
  - Patients at high risk of aspiration owing to intoxication and altered mental status

66.5 Materials and Medications

- Warm saline or 0.12 % aqueous chlorhexidine solution for irrigation of tissues and tooth
- Irrigating syringe
- Suction with a small tip
- Gauze to control hemorrhage
- Resorbable sutures and local anesthetic as needed for soft tissue lacerations
- Temporary tooth restoration material like intermediate restorative material (IRM) and glass ionomer (like Fuji)

66.6 Procedure

1. Have the patient rinse the mouth out with warm water to clean out any debris. Apply an ice pack to the affected cheek to reduce swelling.
2. Anesthetize the area, either locally at the tooth apex or with a nerve block (mental or inferior alveolar).
3. Irrigate the area; assess the fracture intraorally and check for soft tissue lacerations. Use the gauze with finger pressure to control bleeding in the soft tissue or the tooth.
4. Check if the tooth or bony segment is mobile. If so, a referral to a dentist or oral surgeon is necessary as soon as possible for proper assessment.
5. Type II fractures (fracture limited to dentin layer): cover the exposed surface with a temporary dental cement. In a pinch, 2-octyl cyanoacrylate (Dermabond) is an acceptable secondary alternative (Fig. 66.3).
6. Type III (pulp involved)
   - Provide immediate dental follow-up and analgesics.
   - Initiate antibiotic coverage with penicillin or clindamycin.

50% MORE
Than Other Brands
12+
REPAIRS
net wt. 2.64 g (0.09 oz)
Repair
Lost Fillings & Loose Caps
DenTek
Temparin Max
One Step
Formula
MAXIMUM
STRENGTH
Dentist
Recommended
Instant Pain Relief
Easy To Apply
NEW!
Applicator
Tip
Spade Tool
DenTek

Fig. 66.3 Example of temporary dental cement (Reproduced with permission from DenTek Oral Care, Inc.)

66.7 Complications

- Loss of a tooth
- Infection or abscess
- Aspiration of a segment or a whole tooth
- Cosmetic deformity

66.8 Pearls

- Be certain to perform a thorough intraoral examination, looking for tooth fragments or lacerations that may be hiding fragments.
- Dental blocks are very useful for pain control.
- If a tooth is not mobile and the *pulp is exposed*, immediate referral (within a few hours) to a dentist is necessary for extraction or endodontic (root canal) treatment of the tooth. Placement of a temporary-type restoration on this tooth is *not* recommended at this time because it may exacerbate symptoms. Prescribe pain medication and possibly antibiotics when the tooth's pulp is exposed and the patient is unable to see the dentist within 24 h.
- If the tooth is not mobile and *the pulp is not exposed*, a temporary restoration can be placed on the tooth and the patient referred to a dentist for treatment. The fractured part of the tooth should be saved in the event that it can be used. If temporary tooth restoration is unavailable in the emergency department, advise the patient that it is readily available at local pharmacies.
- ALL DENTAL FRACTURES, EXCEPT TYPE I, REQUIRE DENTAL FOLLOW-UP WITHIN 24 h.

Dental Avulsion Management

67

Laura Tucker and Abimbola O. Adewumi

67.1 Indications

- The tooth is completely displaced *out* of its socket, leading to severance of the neurovascular pulp supply and separation of the periodontal ligament (Fig. 67.1).
- Diagnosis
  - Clinically, the socket is found empty or filled with coagulum.
  - Imaging (occlusal, periapical, and lateral views of the affected tooth and surrounding area) (Fig. 67.2):
- Confirm vacuous socket.
- Ensure that the missing tooth is not intruded.
- Diagnose root fracture or alveolar fracture.

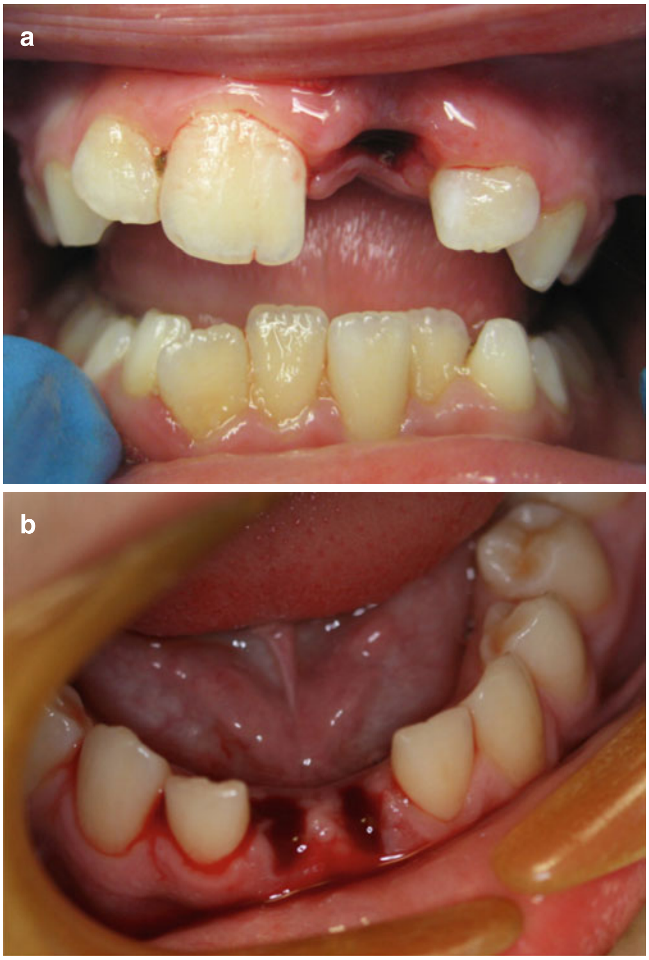

Fig. 67.1 (**a**, **b**) Empty socket following traumatic dental avulsion

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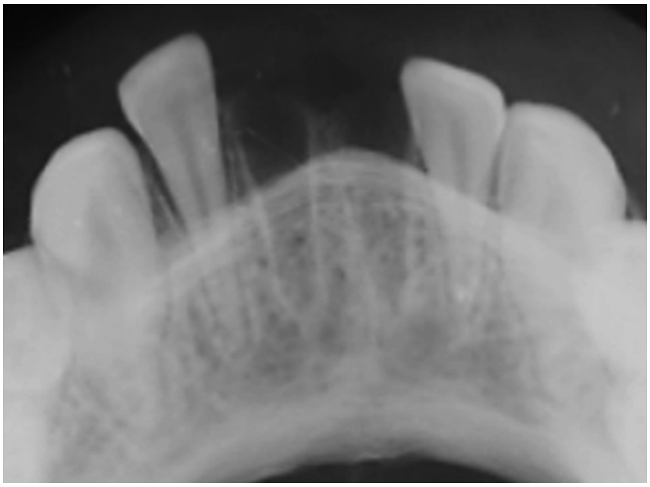

Fig. 67.2 Lower occlusal radiograph shows a complete avulsion of the mandibular right and left central incisors

67.2 Contraindications

- Absolute
  - Avulsed tooth is a primary tooth.
    - DO NOT REPLANT OR REPOSITION AVULSED PRIMARY TEETH.
    - Replantation of primary teeth increases the potential for damage to the developing permanent tooth owing to the increased frequency of pulpal necrosis.
- Relative
  - Fractured root (further intervention required before replantation)
  - Alveolar fracture (further intervention required before replantation)
  - Prolonged extraoral dry time and out of compatible solution (>1 h)
  - Immunocompromised host or congenital heart disease
  - Severe seizure disorder that may put tooth at risk for coming out while the airway is compromised
  - Patient with potential to lose airway reflexes

67.3 Materials and Medications

- Hank's Balanced Salt (Save-A-Tooth) solution or milk in which to preserve tooth until it can be replanted
  - Normal saline if neither of those is available
- Normal saline rinse
- 20- or 18-gauge cannula for gentle irrigation of the socket
- Absorbable suture for gingival lacerations, if present
- Flexible splint materials
  - Round dental wire
  - A flat pliable metal long enough to cover the affected tooth and the two teeth on other side (e.g., the metal nasal bridge from a respirator mask)
- Fixative
  - Dental adhesive
  - Dermabond or some other brand of cyanoacrylate for adhesive skin closures

67.4 Procedure

1. Be certain the tooth is a permanent one and not a primary tooth.
2. If not done by the patient, gently wash the tooth under water for approximately 10 s.
    - Be certain to hold the tooth by the crown, not the root (Fig. 67.3)
3. If the tooth cannot be replanted immediately, place the tooth in Hank's solution or milk.
4. If no such media is available, instruct the patient to hold the tooth inside his or her mouth between the cheek and the gums.
5. Gently replant the tooth, using digital pressure only into as anatomical a position as possible (Fig. 67.4).
    - Assess clinically for alignment.
    - Radiograph for confirmation.
6. Suture any gingival lacerations if present.
7. Apply a flexible splint, securing the affected tooth to the teeth on either side.
    - Consider using skin adhesive both to secure the tooth to its neighbors and, perhaps, to apply a makeshift splint until the patient can be seen by her or his dentist.
        - Towel dry the teeth as best as possible.
        - Apply skin adhesive (using the standard applicator) to the lateral edges of the avulsed tooth where it will make contact with its adjacent teeth.
        - If dental wire is available, apply adhesive to the buccal surfaces of the three teeth (the avulsed tooth central to the other two) and apply length of metal to the Fixodent (Fig. 67.5).
8. Systemic antibiotics with anaerobic coverage is empirical.
9. Ascertain tetanus status for the patient; update if uncertain.

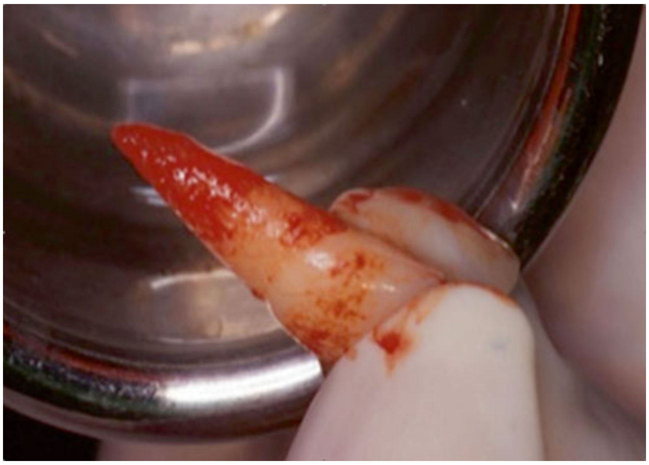

Fig. 67.3 Proper way to hold an avulsed tooth

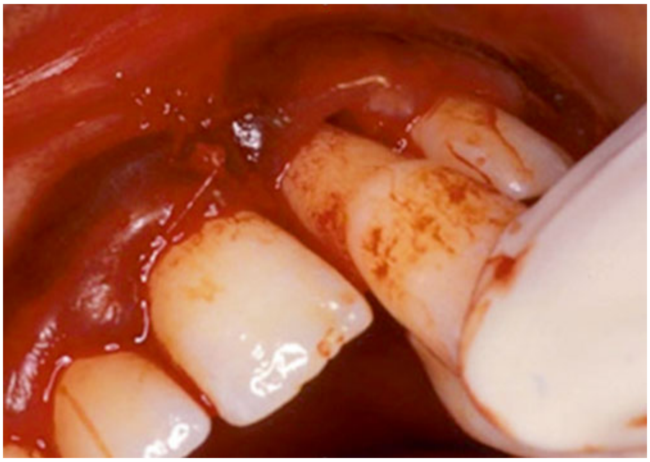

Fig. 67.4 Gentle replantation using digital pressure

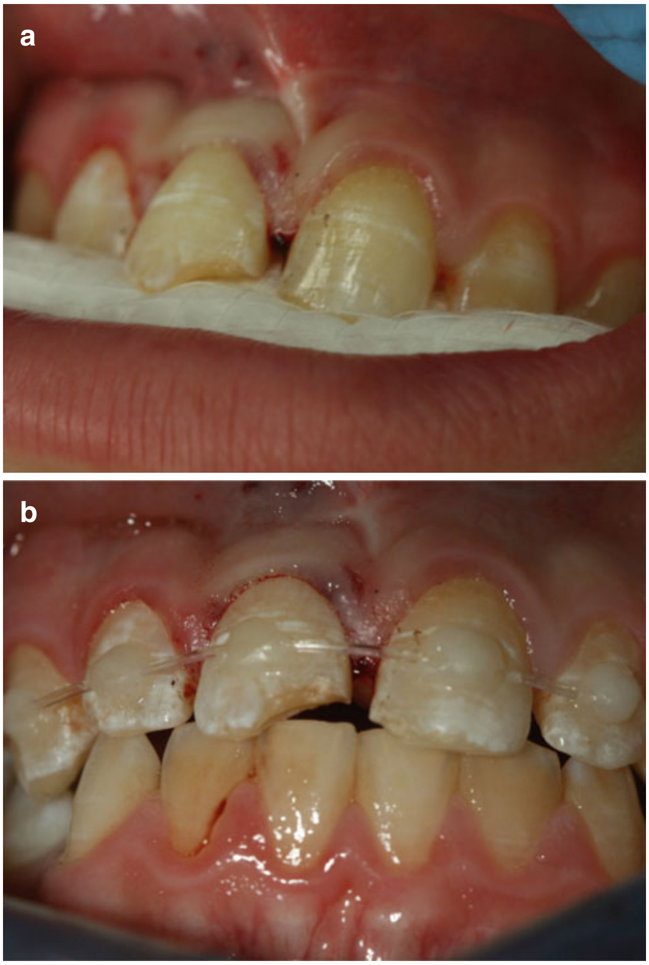

Fig. 67.5 (**a**, **b**) Splint stabilization

67.5 Complications

- Primary teeth
  - Dilaceration (bend) in the permanent tooth crown
  - Enamel defect of the lower permanent incisors as a result of avulsion of the preceding primary tooth
- Permanent teeth
  - Discoloration as a result of loss of vitality of the avulsed tooth.
  - Ankylosis of the alveolar ridge, leading to functional and aesthetic changes.
  - Replacement resorption occurs when the replanted tooth is slowly replaced with bone.
  - External inflammatory resorption is a progressive loss of tooth associated with destruction of adjacent alveolar bone.
  - Infection
  - Aspiration of an inadequately secured replanted tooth.

67.6 Pearls and Pitfalls

- Pearls
  - At the initial examination, make sure that all avulsed teeth are accounted for.
    - If not, a radiographic examination is necessary to ensure that the missing tooth is not completely intruded (pushed into the gum) or has sustained a root fracture with loss of the coronal fragment.
  - In children, always consider the likelihood of nonaccidental trauma (abuse).
  - Short-term and long-term dental follow-up cannot be emphasized enough.
- Pitfalls
  - If the avulsed tooth cannot be accounted for, aspiration is a possibility.
- Prognosis
  - Depends on extraoral dry time (length of time the tooth has been out of the mouth and not stored in an appropriate medium):
    - Ideally, tooth should be implanted within 5 min.
    - Extraoral dry time greater than 60 min has a poor prognosis for periodontal healing.
  - Depends on stage of root development of the avulsed tooth (Fig. 67.6)
- The more advanced the root development, the lower the probability of pulp healing and survival.

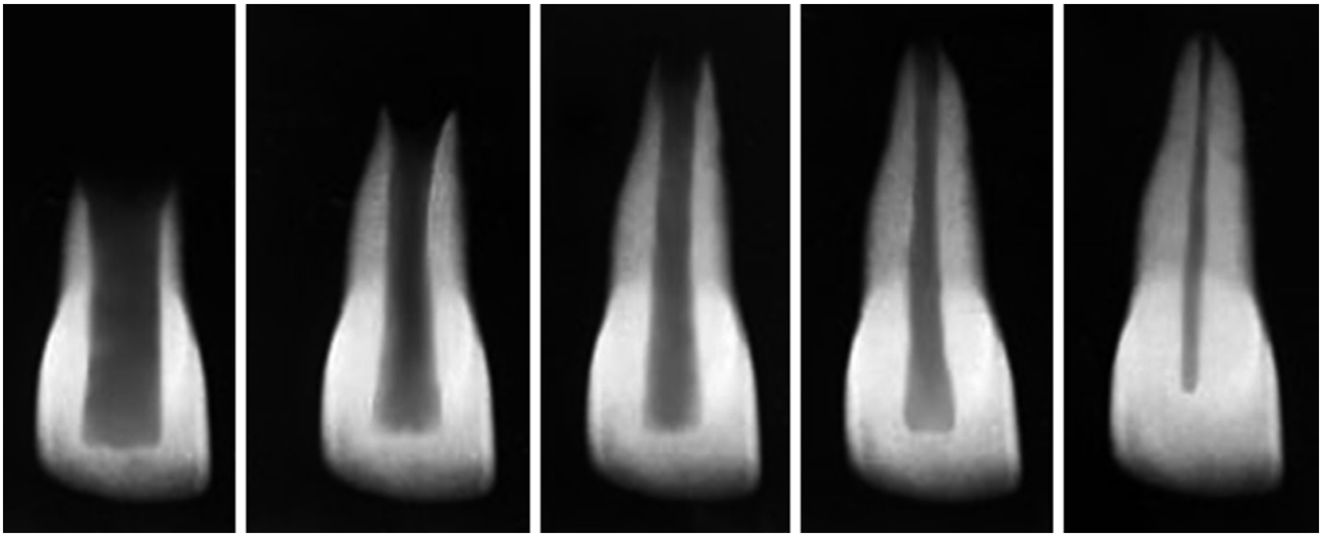

Fig. 67.6 The various stages of root development, from the less advanced (*open apex, left*) to the more advanced (*closed apex, right*)

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Part X

Gastrointestinal Procedures

Excision of Thrombosed External Hemorrhoid

68

Latha Ganti

68.1 Indications

- Acute pain within 72 h of thrombosis onset
- The thrombosis will be visible as a bluish-purplish painful mass in perianal area (Fig. 68.1).

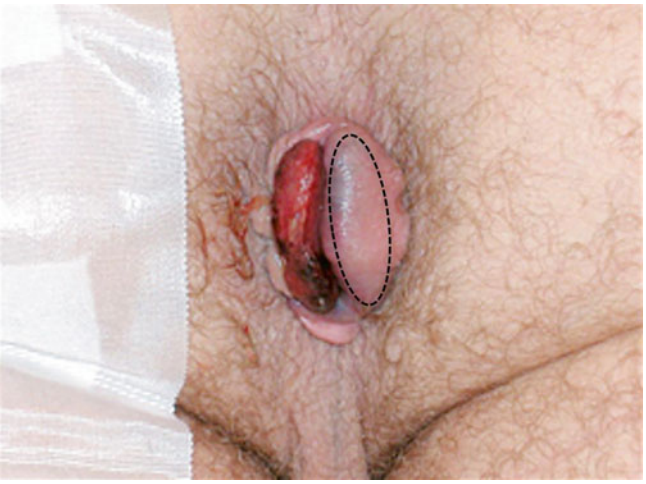

Fig. 68.1 Bluish-purplish appearance of an external thrombosed hemorrhoid. The *ellipse* denotes the area of the elliptical incision to be made (Reproduced with permission from: Fargo and Latimer [3])

68.2 Contraindications

- Absolute
  - Severe coagulopathy
  - Hemodynamic instability
  - Concurrent internal hemorrhoid with rectal prolapse
  - Painless rectal mass (external hemorrhoids are almost always painful, so a painless mass is not a thrombosed external hemorrhoid; also, the whole point of doing this procedure is to provide pain relief).
- Relative
  - Allergy to local anesthetics
  - Perianal infection
  - Inflammatory bowel disease
  - Serious systemic illness or comorbidity that could increase risk of procedure

68.3 Materials and Medications

- Sterile gloves and drape
- Alcohol swabs or pads
- 10 % povidone-iodine or chlorhexidine prep
- 2 % lidocaine with epinephrine
- 5 ml syringe with 25 or 27 gauge and 18 gauge needles
- #11 or #15 scalpel blade and handle
- Direct light source
- Forceps
- Iris scissors
- 4×4 gauze pads
- Adhesive tape
- 3-0 absorbable suture
- 1/4 inch iodoform packing
- Silver nitrate sticks
- Sterile dressing

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68.4 Procedure

1. Patient should be in either prone, left lateral decubitus, or jackknife position (Fig. 68.2).
2. Place 2 vertically oriented pieces of tape down each buttock from lower back to upper thigh. Next, place a perpendicular (horizontal) strip spreading buttocks to either side, securing gurney (Fig. 68.3).
3. Place sterile drape over field and center direct lighting over field (Fig. 68.4).
4. Wipe area with alcohol.
5. Inject 1–2 cc of anesthetic into base of hemorrhoid.
6. Clean area with povidone-iodine or chlorhexidine prep.
7. Make an elliptical incision in the roof of the hemorrhoid, being careful to avoid anal sphincter muscle.
8. Remove blood clot(s); multiple clots are often present.
9. If profuse bleeding is a problem, consider cauterization with silver nitrate sticks.
10. Wound can be closed with figure-of-8 absorbable suture OR can be loosely packed with1/4 inch iodoform gauze if not suturing (do not suture wound closed with packing inside).
11. Cover wound with 4×4 gauze folded in half and taped into place (Fig. 68.5).

- Discharge medicines:
  - Antibiotics generally not necessary.
  - Prescribe ibuprofen and/or acetaminophen for analgesia. Avoid opiates, which are constipating.
  - Prescribe stool softeners, to be taken two to three times daily.
- Discharge instructions to patient:
  - Sitz baths 3–4 times daily, for 20 min, warm not hot water.
  - Packing should fall out spontaneously in 2 days.
  - Keep well hydrated.
  - Use gauze to protect underclothing from soilage/blood stains.
  - Return to ED if pain persists beyond 48 h.

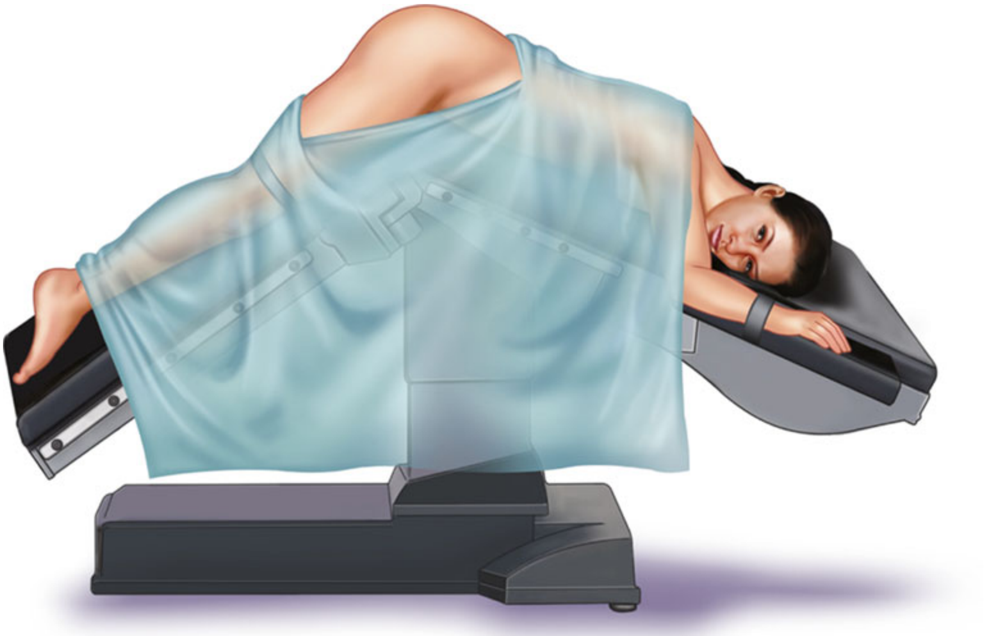

Fig. 68.2 Jackknife position

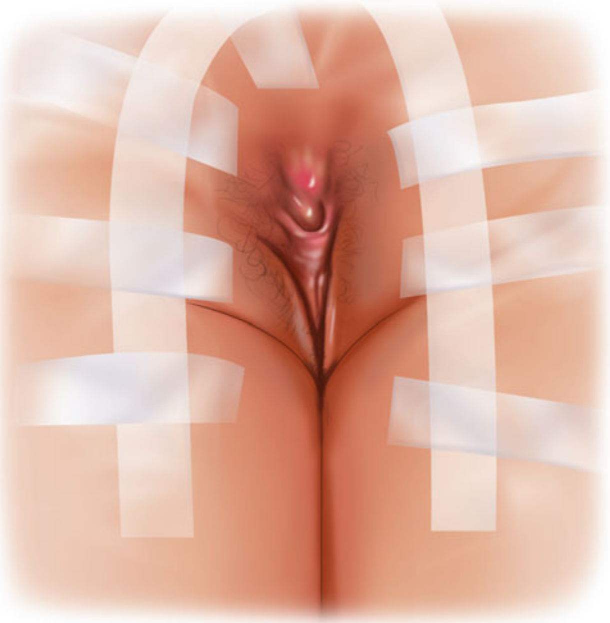

Fig. 68.3 Taping of buttocks to maximize visualization of hemorrhoid

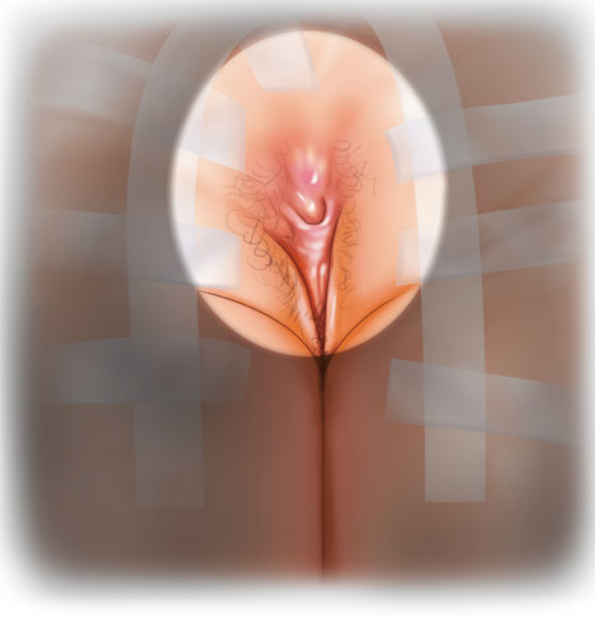

Fig. 68.4 Direct lighting over field

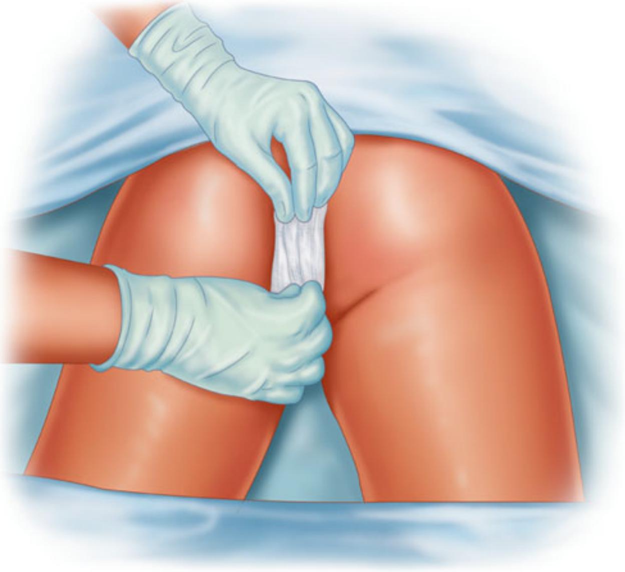

Fig. 68.5 Dress wound with sterile gauze

68.5 Complications

- Common
  - Bleeding: usually self-limited. Can apply cautery or figure-of-8 suture if not previously done
  - Pain: usually controlled with ibuprofen or acetaminophen
  - Perianal skin tag: benign
- Rare
  - Infection rate is 5 % [1].
  - Recurrence rate is 5–19 %, vs. 30 % for simple lancing [2].
  - Stricture and/or incontinence: prevented by avoiding underlying external anal sphincter muscle

68.6 Pearls and Pitfalls

- Pearls
  - Elliptical excision of the hemorrhoid results in much lower recurrence rate than simple lancing.
  - Risk factors for thrombosed external hemorrhoids include constipation, 2nd or 3rd trimester pregnancy, and traumatic vaginal delivery.
- Pitfalls
  - Excision of multiple hemorrhoids in circumferential fashion on all sides of the anal canal can cause anal stenosis.
  - Excision of a painless mass: if it is *painless*, it is *not* a thrombosed external hemorrhoid.

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Diagnostic Peritoneal Lavage

69

Latha Ganti

69.1 Indications (Table 69.1)

- Inability to perform FAST exam due to lack of equipment or operator
- Hemodynamically unstable patient in whom FAST exam is negative or equivocal

Table 69.1 Comparison parameters for DPL, FAST, and CT [1]

	DPL	FAST	CT
Speed	10–15 min	Fastest: <5 min	Variable
Repeatable	Yes, but rarely done	Yes, and frequently done	Yes, but not done often
Cost	$	$$	$$$
Invasive	Yes	No	No
Mobile	Yes	Yes	No
Advantages	Most sensitive for mesenteric and hollow viscus injuries	Highest specificity	Highly accurate but can be hampered by patient movement
Disadvantages	Misses retroperitoneal and diaphragm injuries	Hampered by subcutaneous or intra-abdominal air, obesity, and pelvic fractures Significant false-negative rate	Misses diaphragm, small bowel, and pancreatic injuries Small but significant risk of radiation-associated malignancy Cannot be done at bedside

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69.2 Contraindications

- Absolute
  - Indication for laparotomy already exists.
- Relative
  - 2nd or 3rd trimester pregnancy
  - Previous lower abdominal surgery
  - Inexperienced operator
  - Abdominal wall infection
  - Coagulopathy
  - Cirrhosis
  - Morbid obesity

69.3 Materials and Medications

- 10 % povidone iodine prep
- 1 % lidocaine with epinephrine
- Fenestrated drape
- #10 scalpel blade and scalpel holder
- Skin retractors
- Hemostats
- Diagnostic peritoneal lavage (DPL) catheter (standard peritoneal dialysis catheter)
- 10 cc syringe
- Warmed lactated Ringer's or normal saline solution
- Skin stapler
- Simple suture tray with suture material

69.4 Procedure

69.4.1 Patient Preparation

- Place patient in supine position.
- Ensure nasogastric and urethral catheter (Foley) are in place.
- Prep and drape the area from the umbilicus to the symphysis pubis.
- Anesthetize the skin using 1 % lidocaine with epinephrine in the midline where incision will be made (Fig. 69.1).

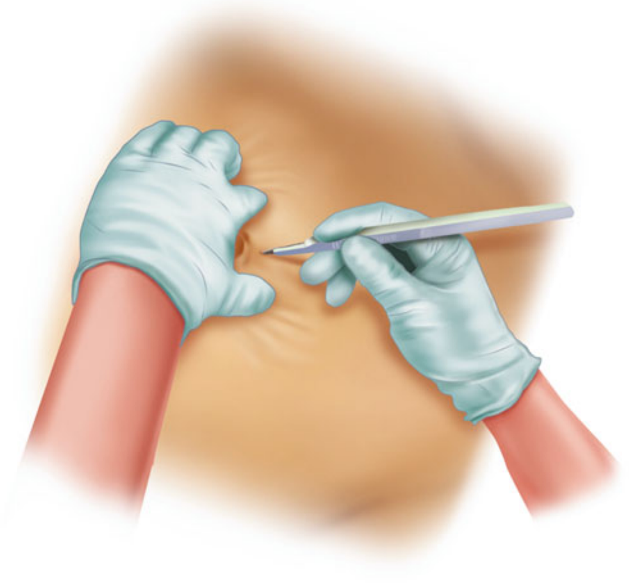

Fig. 69.1 Anesthetize skin where incision will be made (supraumbilical incision shown here, can also make infraumbilical incision)

69.4.2 Three DPL Techniques

- Semiopen (Seldinger) technique
  1. Using a #10 scalpel blade, make a 2 cm incision either superior or inferior to the umbilicus.
  2. Dissect subcutaneous fat until linea alba is exposed.
  3. Hold incision open with skin retractors (Fig. 69.2).
  4. Grasp fascia with hemostats on either side of midline.
  5. Insert 18 gauge needle at 45° angle toward pelvis (Fig. 69.3).
  6. First "pop" will be heard once fascia is penetrated.
  7. Second "pop" will be heard once peritoneum is traversed.
  8. Pass guidewire through needle into pelvis (should pass easily without resistance).
  9. Remove needle while keeping wire stable.
  10. Pass dilator over the wire through fascia, and remove (Fig. 69.4).
  11. Slip DPL catheter over guidewire aiming toward pelvis.
  12. Aspirate peritoneal contents with syringe; aspiration of blood is a positive DPL and means immediate laparotomy (can stop DPL procedure here).
  13. If no blood is immediately obvious, then connect the DPL catheter to a liter of warmed lactated Ringer's (LR) or normal saline (NS) solution for lavage (ensure setup has no one-way valves as solution and peritoneal fluid need to be able to freely mix).
  14. Place LR or NS bag on floor once it is almost empty (minimum 300–350 ml for adults or 10–15 ml/kg for children) and allow intra-abdominal fluid to return (Fig. 69.5).
  15. Send fluid for analysis (Table 69.2).
  16. Irrigate wound, and close skin only with staples or sutures.
- Open technique
  1. Make a 5 cm incision inferior to the umbilicus over linea alba and directly visualize peritoneal cavity.
  2. Both fascia (absorbable suture) and skin (nonabsorbable suture) need to be closed.
- Closed technique
  1. Access peritoneal cavity via percutaneous needle access.
  2. No surgical closure required.

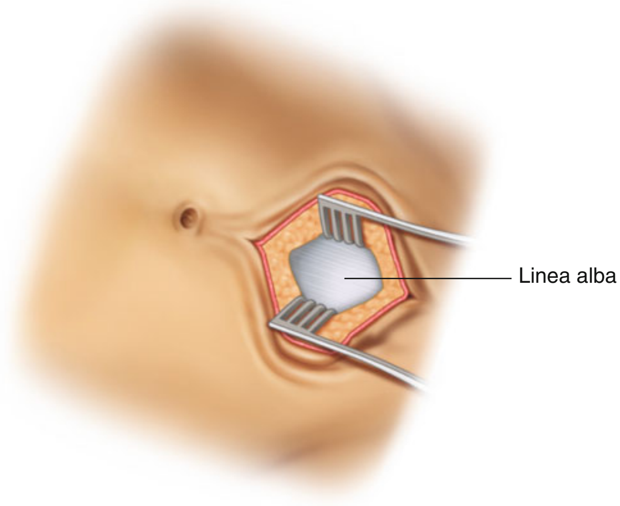

Fig. 69.2 Hold incision open with skin retractors

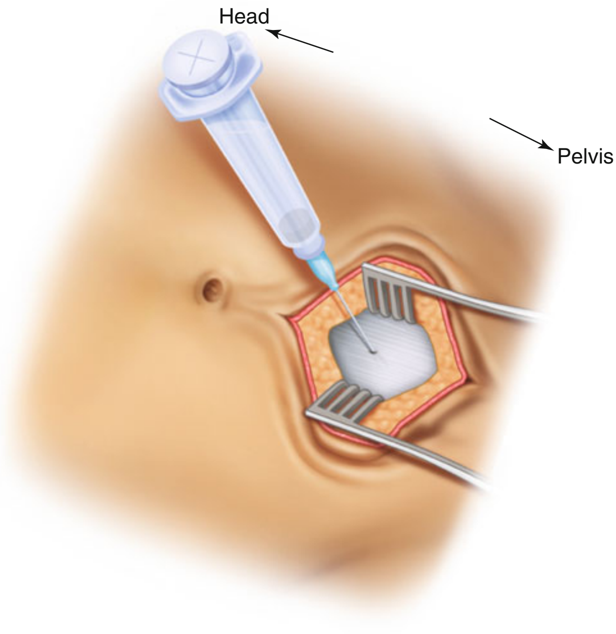

Fig. 69.3 Insert 18 gauge needle at 45° angle toward the pelvis

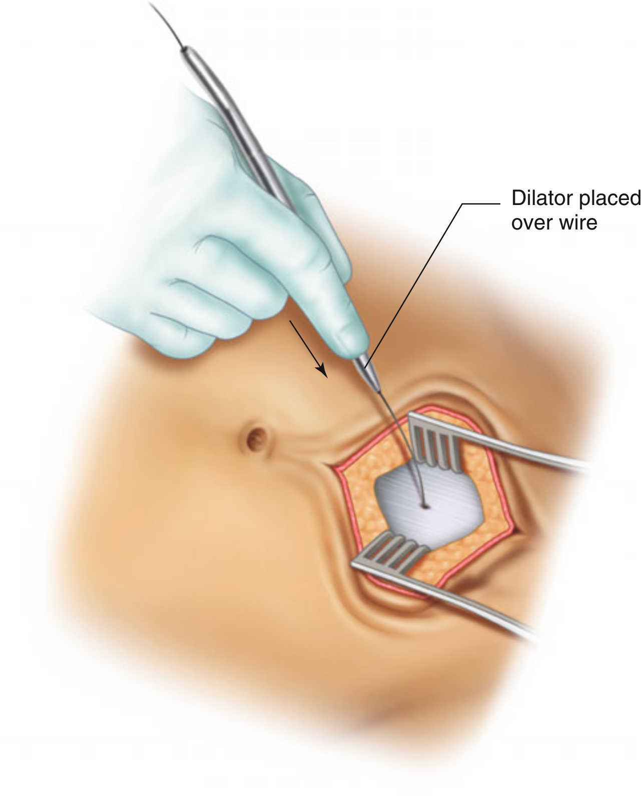

Fig. 69.4 Pass dilator over the wire through fascia and remove

Table 69.2 Diagnostic peritoneal lavage red blood cell criteria (per mm^3) [2]

	Positive	Indeterminate
Immediate gross return of blood via catheter	Any amount	
Immediate return of food particles/intestinal contents	Any amount	
Aspiration of blood	10 cc	
RBC in blunt trauma	100,000	20,000–100,000
RBC in penetrating trauma	10,000	5000–10,000
RBC in gunshot wound	5000	1000–5000
Amylase level (IU/L)	≥175	
Alkaline phosphatase level (IU/L)	≥3	
WBCs (per mm^3)	>500	250–500

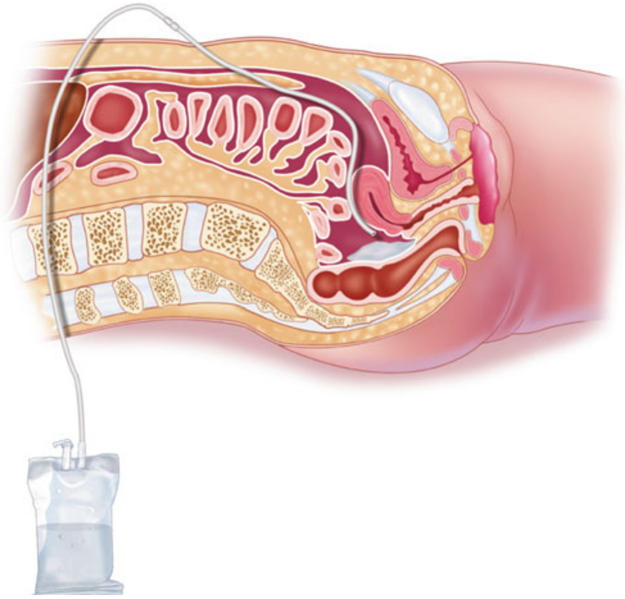

Fig. 69.5 Lavage

69.5 Complications

- Wound infection or dehiscence
- Intraperitoneal injury to organs or vessels (iatrogenic hemoperitoneum)
- Unnecessary laparotomy due to false-positive result from bleeding within rectus sheath or from site of incision
- Potential failure to recover lavage fluid due to:
  - Inadvertent placement of the catheter into the preperitoneal space
  - Compartmentalization of fluid by adhesions
  - Obstruction of fluid outflow (e.g., by omentum)
  - Fluid pooling in the intrathoracic cavity due to diaphragmatic injury
- Incisional hernia

69.6 Pearls and Pitfalls

- Pearls
  - When properly done, complication rate for DPL is low.
  - Prophylactic antibiotics are generally not indicated.
- Pitfalls
  - Inadequate decompression of stomach and urinary bladder increases the chance of injury to these organs; thus, nasogastric and Foley decompression is an important step in patient preparation.

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70

Manual Reduction of Abdominal Hernia

Latha Ganti

An abdominal wall hernia is a protrusion of the intestine through an opening or area of weakness in the abdominal wall. See Table 70.1 for types of abdominal hernias and Fig. 70.1 for locations along the abdominal anatomy.

Table 70.1 Types of abdominal hernias

Type	Defect	Most commonly seen in	Notes
Inguinal	Intestine or bladder protrudes through abdominal wall or into inguinal canal in the groin	Men because of a natural weakness in this area	96 % of all groin hernias are inguinal; 4 % are femoral
Femoral	Intestine enters canal carrying femoral artery into the upper thigh	Women, especially those who are pregnant or obese	
Incisional	Intestine pushes through abdominal wall at the site of previous abdominal surgery	Elderly or overweight people who are inactive after abdominal surgery	
Umbilical	Part of the small intestine passes through abdominal wall near the navel	Newborns and obese women or those who have had many children	In children, not repaired until age five because often resolve on their own
Hiatal	Upper stomach squeezes through hiatus, an opening in the diaphragm through which the esophagus passes		

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Fig. 70.1 Types of abdominal wall hernias

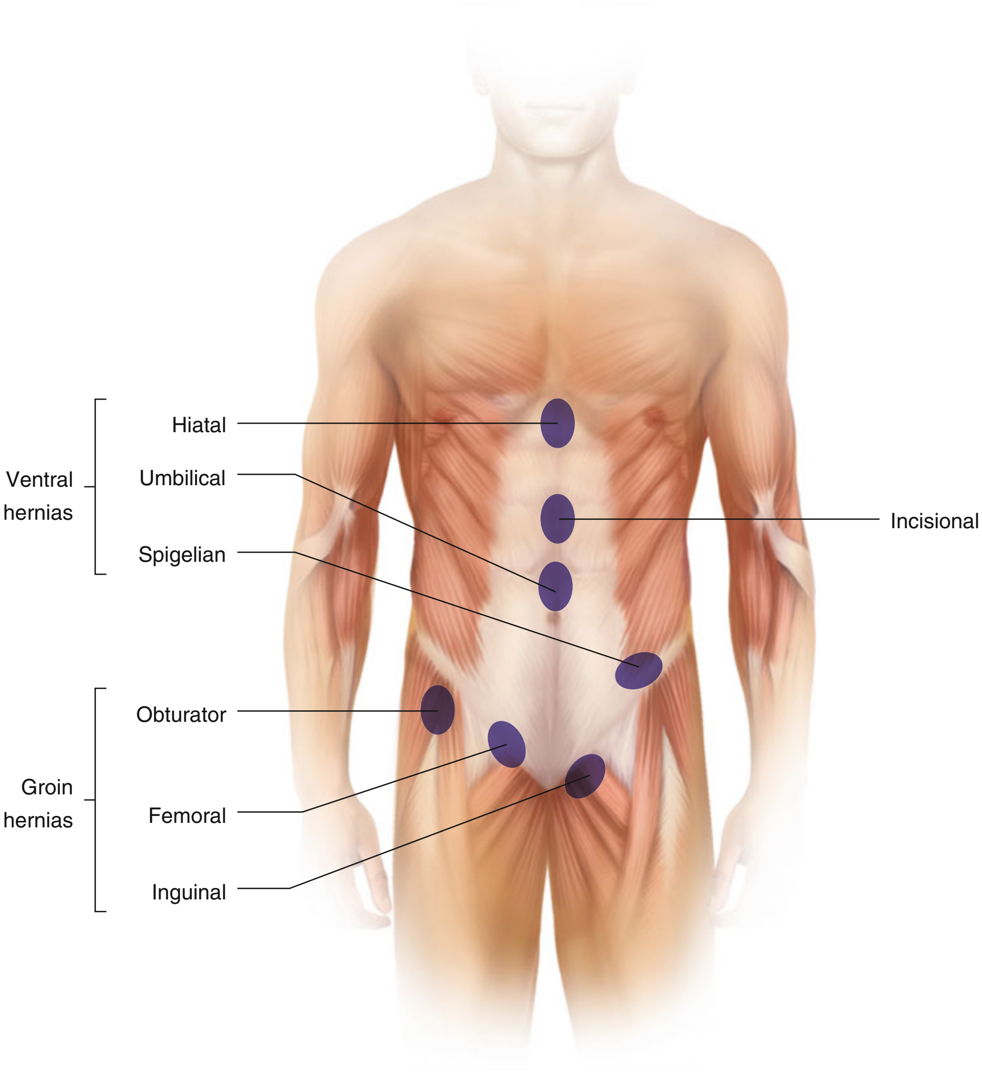
Hiatal
Ventral hernias
Umbilical
Spigelian
Incisional
Obturator
Groin hernias
Femoral
Inguinal

70.1 Indications

- Incarcerated hernia

70.2 Contraindications

- Absolute
  - Strangulated hernia (could result in placing dead bowel into abdominal cavity)
- Relative
  - Inability to get patient relaxed enough
  - Previous unsuccessful attempts

70.3 Materials and Medications

- Ice or cold compress
- Stretcher or gurney that can tilt to provide Trendelenburg position
- Moderate sedation drugs if providing moderate sedation
- Truss for post-procedure

70.4 Procedure

1. Patient positioning:
   - For abdominal hernia: place patient supine.
   - For groin hernia in adult: place in 20 ° of Trendelenburg.
   - For groin hernias in children: place in unilateral frog leg position (Fig. 70.2).
2. Apply ice or cold compress directly over hernia site to reduce swelling.
3. Administer opiate analgesia or moderate/procedural sedation.
4. Wait up to 30 min as hernia may reduce spontaneously after swelling has gone down and patient is relaxed.
5. Gently apply steady pressure distally on the tissue at the neck of the hernia with one hand and with other hand, guide hernia proximally through fascial defect. Too much pressure distally can cause hernia to balloon further, making manual reduction difficult. Takes up to 15–20 min. Do not rush procedure.
6. Once hernia is reduced, pain will improve.
7. An external support garment or truss (Fig. 70.3) can be helpful to hold reduced hernia in place and serve as a temporizing measure until surgical repair can be done.
8. Advise patient to schedule elective surgical repair.
9. If unable to reduce the hernia, obtain surgical consultation. Do not force repeated attempts.

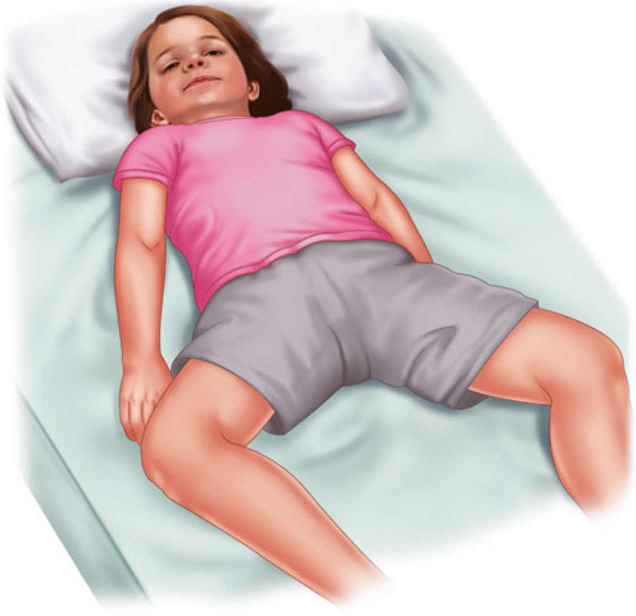

Fig. 70.2 Frog leg position in child

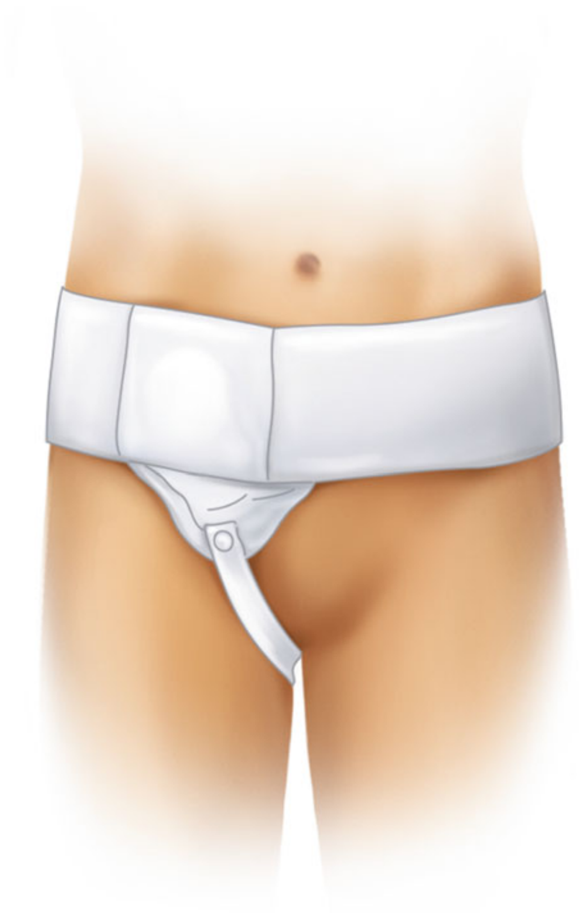

Fig. 70.3 An example of a truss, or external support, that can be useful as a temporizing measure until definitive hernia repair can be done

70.5 Complications

- Pain.
- Inability to achieve manual reduction, leading to strangulation of the hernia.
- Strangulation can result in peritonitis and sepsis.
- Recurrence.
- Hydrocele.

70.6 Pearls and Pitfalls

- Pearls
  - Definitive treatment for a hernia is surgery (herniorrhaphy). Without surgery, hernias grow larger over time; they do not disappear. Small hernias are easier to fix and result in fewer complications.
  - The only hernia that can resolve on its own is an umbilical hernia in a child.
  - Trusses, bandages, and tape may provide some comfort but do not reduce risk of incarceration or strangulation.
  - Note that if a truss is worn, it should be in place after reduction of the hernia. Also, it can be impractical in hot climates.
- Pitfalls
  - When the constricting neck and the protrusion are both reduced into the abdomen together (known as a reduction *en masse*), without actually reducing the hernia itself, strangulation ensues even though it appears one has reduced the hernia.
  - If there is still considerable pain after the reduction, it is likely the reduction was not successful or that dead bowel has been reduced into the abdominal cavity.
  - Not recognizing strangulation leads to gangrenous bowel, peritonitis, and sepsis.

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Extended Focused Assessment with Sonography for Trauma

71

Coben Thorn and L. Connor Nickels

71.1 Indications

- Blunt abdominal or chest trauma
- Penetrating abdominal or chest trauma
- Undifferentiated hypotension
- The "E" in EFAST refers to the "extended" ability to detect lung pathology such as a pneumothorax or hemothorax during the otherwise standard trauma FAST exam using the same equipment with or without an additional transducer probe.
- Specific findings that can be detected on extended focused assessment with sonography for trauma (EFAST):
  - Pericardial fluid
  - Pleural fluid
  - Free intraperitoneal fluid
  - Pneumothorax
- Free fluid appears as anechoic or black.

71.2 Contraindications

- Need for immediate operative intervention

71.3 Materials and Medications

- Ultrasound machine
- Probe(s): phased array probe (5 to 1 MHz) or curved array probe (5 to 2 MHz)
  - Phased array has a smaller footprint, allowing easier access between intercostal spaces (Fig. 71.1); however, curved array provides better resolution of images

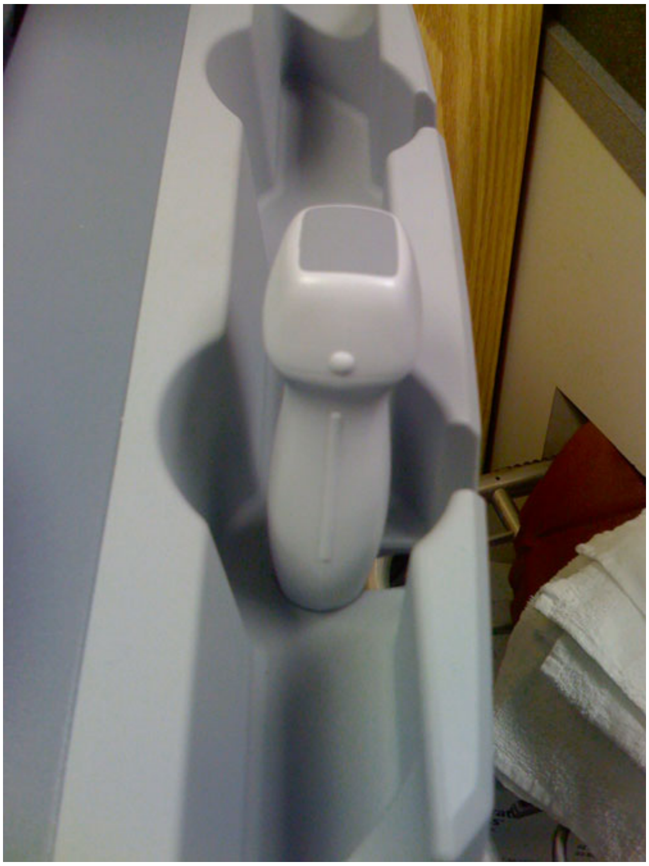

Fig. 71.1 Phased array transducer (P17) with a small footprint that is helpful to fit between the ribs and can be used for focused assessment with sonography for trauma (FAST) examination

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(Fig. 71.2). The linear array transducer (L38, 10–5 MHz) is good for lung images.

- Gel
- Skilled ultrasound operator
- ± Laboratory work, cardiac monitor, and two large-bore intravenous (IV) needles
  - All trauma alerts and unstable patients must have all of these.

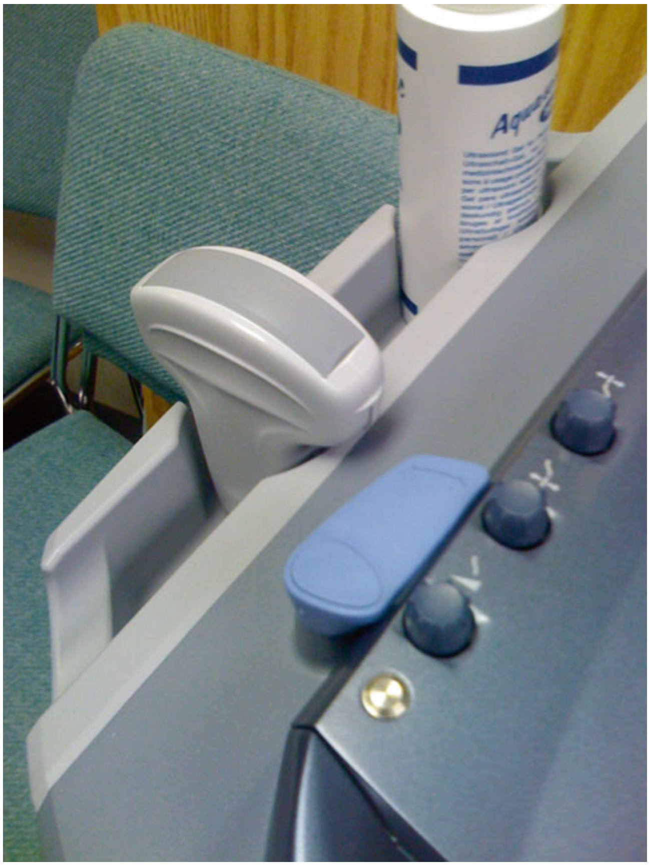

Fig. 71.2 Curved array transducer (C60) with a larger footprint and better resolution for deeper imaging that can be used for FAST examination as well as lung examination

71.4 Procedure

1. Ultrasound machine in the abdominal preset.
2. Patient in the supine position.
3. Phased array or curved array probe for focused assessment with sonography for trauma (FAST) and linear array for lung.
4. Begin scanning the patient in a systematic fashion.
   - All the views should be scanned by thoroughly sweeping through the area in question in order to maximize the information obtained.
   - All views should be obtained in the same order every time.
   - Obtain all four views, five views if pneumothorax is included.

71.4.1 Subxiphoid Four-Chamber View (Fig. 71.3)

1. Examine for free pericardial fluid.
    - Anechoic (black) stripe seen between the myocardium and the pericardium
2. Probe is placed in the subxiphoid area.
3. Indicator is to the patient's right.
4. Probe is directed toward the patient's left shoulder.
5. Use a shallow angle in the head to feet direction.
6. Should adequately visualize the following:
    - Liver edge superficially
    - Right ventricle
    - Left ventricle
    - Right atrium
    - Left atrium
7. If unable to obtain this view, proceed to *parasternal long-axis view*:
    - Probe is placed perpendicular at the left parasternal border.
    - Third to fourth intercostal space.
    - Indicator is to the patient's right shoulder.
    - Coronal section through the heart's long axis should adequately visualize the following:
        - Right ventricle most superficially
        - Left ventricle
        - Mitral valve
        - Left atrium
        - Aortic valve
        - Aortic outflow tract

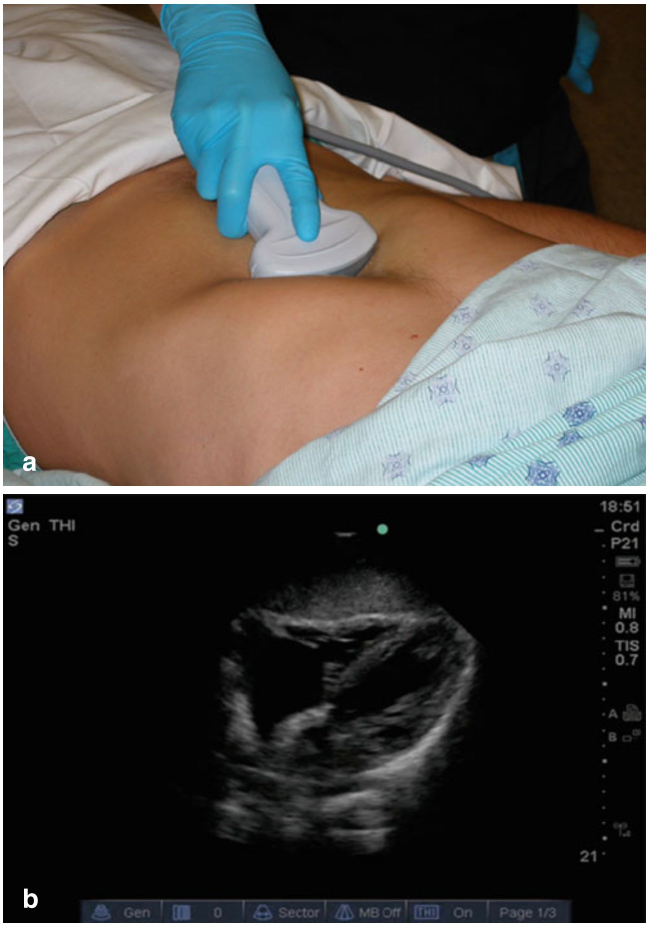

Fig. 71.3 (**a**) Image shows how to obtain the subxiphoid four-chamber view of the heart using the curved array transducer (C60) (Photograph courtesy of F. Eike Flach, MD).(**b**) Ultrasound image of four-chamber view of the heart (Used with permission from First aid for the emergency medicine clerkship 3rd Ed, McGraw Hill, 2011.) *RV* right ventricle, *LV* left ventricle, *RA* right atrium, *LA* left atrium

71.4.2 Right Upper Quadrant View (Fig. 71.4)

1. Examine for free fluid in all of the following areas:
   - Right intrathoracic space
     – Anechoic area above the diaphragm
   - Morison's pouch: hepatorenal space
     – Anechoic stripe between the liver and the kidney
   - Right paracolic gutter
     – Anechoic collection surrounding the inferior tip of the kidney
2. Probe is placed in the midaxillary line on the right.
3. Indicator is directed toward the patient's head.
4. Probe is in the coronal plane, angle can be aimed obliquely while scanning anterior to posterior.

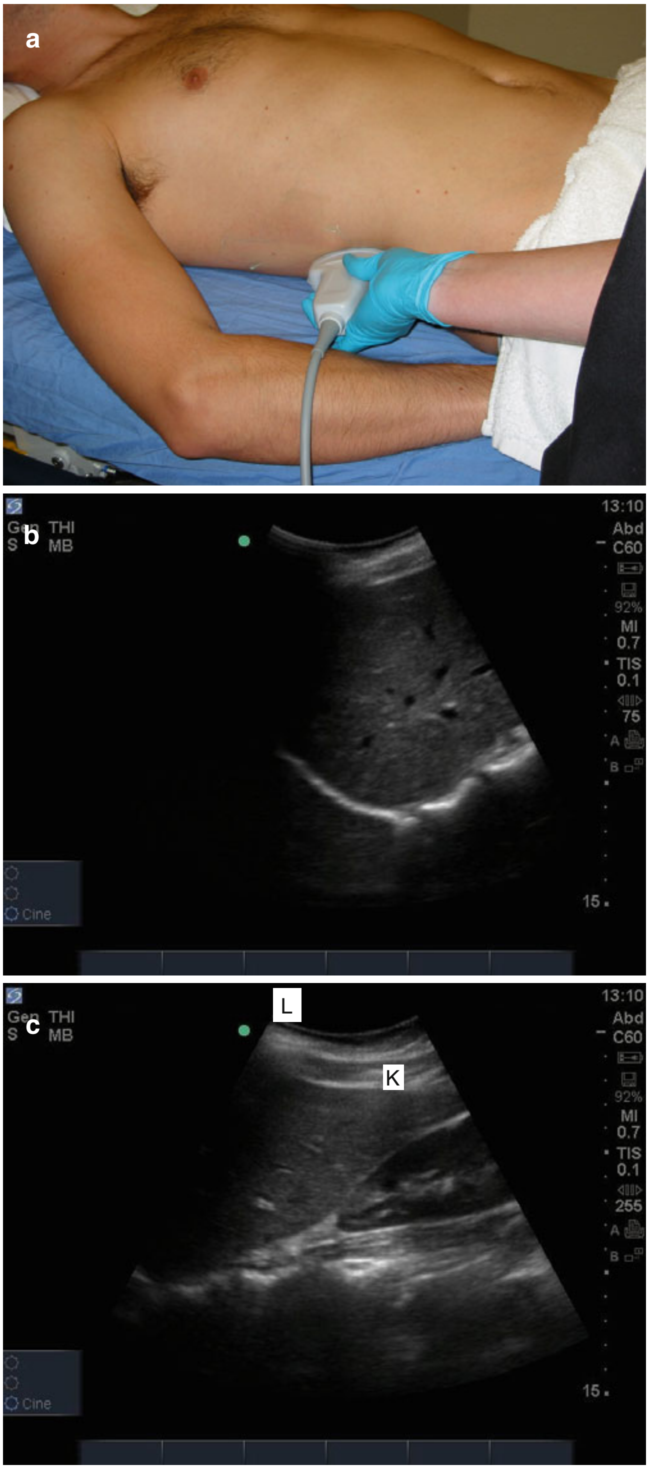

Fig. 71.4 (**a**) Image shows how to obtain the right upper quadrant view of the FAST exam using the curved array transducer (C60). The probe is aimed slightly obliquely in the coronal plane to get a better view between the ribs (Photograph courtesy of F. Eike Flach, MD). (**b**) Ultrasonographic view of the liver. (**c**) Ultrasonographic view of the liver–kidney interface (Morrison's pouch). *L* liver, *K* kidney

71.4.3 Left Upper Quadrant View (Fig. 71.5)

1. Examine for free fluid in all of the following areas:
    - Left intrathoracic space
        - Anechoic area above the diaphragm
    - Subphrenic space
        - Anechoic stripe below the diaphragm and above the spleen
    - Splenorenal space
        - Anechoic stripe between the spleen and kidney
    - Left paracolic gutter
        - Anechoic collection surrounding the inferior tip of the kidney
2. Probe is placed in the midaxillary line on the left.
3. Indicator is directed toward the patient's head.
4. Probe in the coronal plane, angle can be aimed obliquely while scanning anterior to posterior.

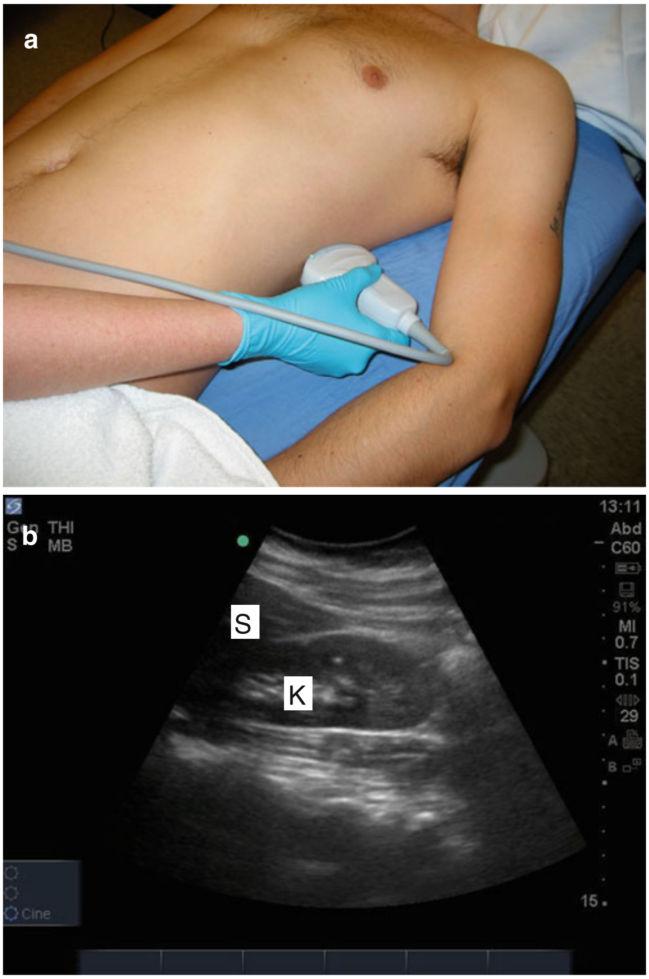

Fig. 71.5 (**a**) Image shows how to obtain the left upper quadrant view of the FAST examination using the curved array transducer (C60). Again, the probe is aimed slightly obliquely and is placed more superiorly in the midaxillary line (Photograph courtesy of F. Eike Flach, MD). (**b**) Ultrasonographic view of spleen–kidney interface. *S* spleen, *K* kidney

71.4.4 Pelvic View (Figs. 71.6 and 71.7)

1. Examine for intraperitoneal free fluid in the pelvis:
    - Anterior pelvis, above the bladder
        - Anechoic fluid above the bladder
    - Posterior cul-de-sac (pouch of Douglas)
        - Anechoic fluid posterior to the bladder or uterus
2. Probe is placed above the pubic symphysis over the bladder.
3. Scan through in both planes:
    - Transverse plane (Fig. 71.6)
        - Indicator is to the patient's right.
        - Scan through the bladder in the head to feet direction.
    - Sagittal plane (Fig. 71.7)
        - Indicator is aimed to the patient's head.
        - Scan through the bladder in a right to left direction.

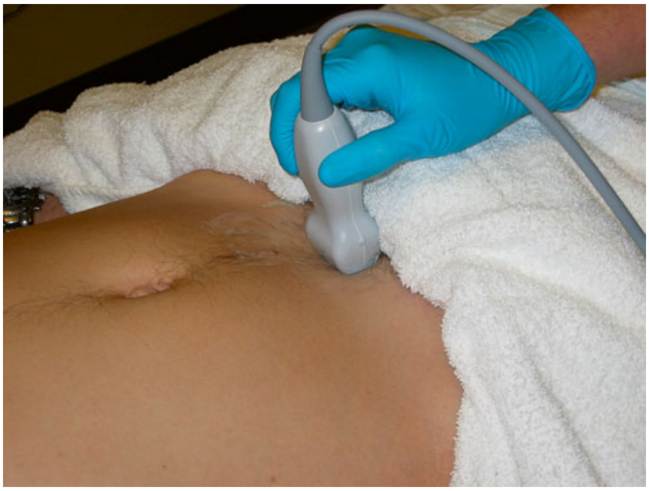

Fig. 71.6 Transverse pelvic view of the FAST examination using the phased array transducer (P17). With gentle force, the probe is pressed downward in order to look back behind the pubic symphysis and view the bladder (Photograph courtesy of F. Eike Flach, MD)

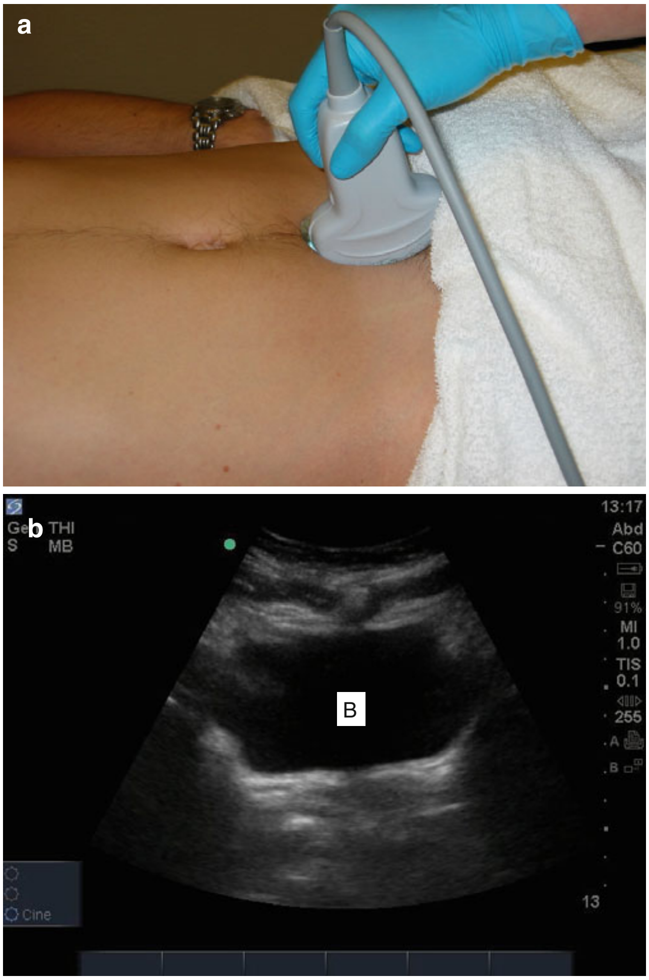

Fig. 71.7 (**a**) Sagittal pelvic view of the FAST exam using the curved array transducer (C60). With gentle force, the probe is pressed downward in order to look back behind the pubic symphysis and view the bladder (Photograph courtesy of F. Eike Flach, MD). (**b**) Ultrasonographic view of the bladder. *B* bladder

71.4.5 EFAST with Lung Views (Figs. 71.8 and 71.9)

1. Examine for pneumothorax:
    - Lung sliding
        - Absence: pneumothorax
        - Presence: normal lung
    - M mode tracing
        - Stratosphere sign: pneumothorax
        - Seashore sign: normal lung
2. Probe is placed on the anterior chest in the midaxillary line.
3. Level of the second to fourth intercostal spaces.
4. Sagittal position.
5. Center the probe over the pleural line between the ribs.
    - Find the rib and then slide the probe toward the head or feet to center the pleural line.
6. Observe for lung sliding.
7. Press M mode and move the line over the pleural line and press M mode again to get the tracing.
8. Examine multiple other areas anteriorly, moving distally, and in midaxillary line laterally, moving from superior to inferior.

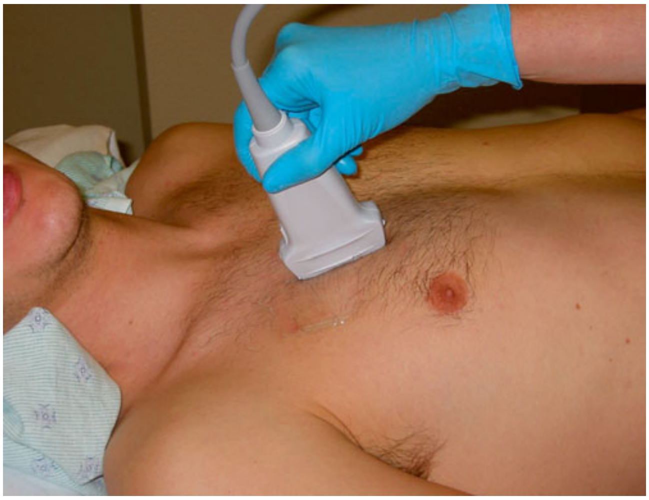

Fig. 71.8 Right lung view of the extended focused assessment with sonography for trauma (EFAST) examination using the linear array transducer (L38). The probe is placed in the sagittal plane on the anterior chest in the midaxillary line approximately at the second intercostal space and centered over the pleural line (Photograph courtesy of F. Eike Flach, MD)

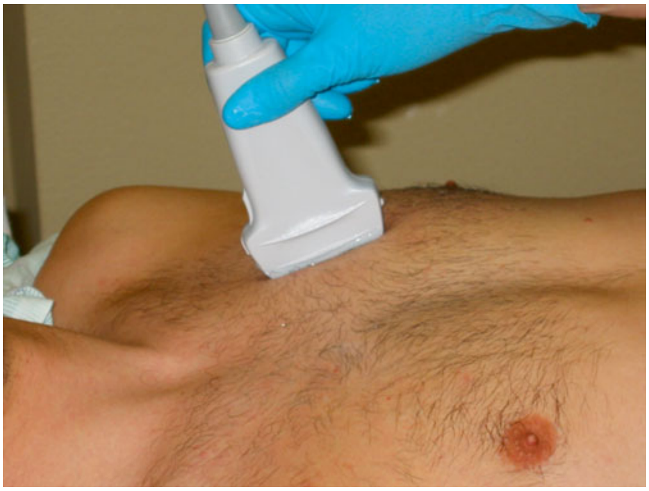

Fig. 71.9 Left lung view of the EFAST examination using the linear array transducer (L38) (Photograph courtesy of F. Eike Flach, MD)

71.5 Complications

- Overreliance on ultrasound to rule out abdominal injury:
  - FAST examinations do not detect retroperitoneal bleeding, solid organ injury, contained subcapsular hematomas, and bowel injuries.
- Not scanning through the object in question could lead to false-negative results.

71.6 Pearls and Pitfalls

- Always follow the ABCs (airway, breathing, circulation) first in any unstable patient.
- Always make sure the depth is set adequately.
  - Recommend starting deeper to make sure positive findings are not missed and then adjustments can be made from there.
- The curved array probe may be used throughout the entire EFAST for convenience if necessary.

71.6.1 Subxiphoid Four-Chamber View

- For larger body habitus, need to parallel the probe with the body in the subxiphoid area and use firm pressure to press the entire probe downward so as to look up under the xiphoid process at the heart.
- Moving the entire probe more to the patient's right in the subxiphoid area while still looking toward the left shoulder may improve visualization by using the liver as a window.
- Fat pad:
  - May be mistaken for pericardial fluid
  - Contains echoes and, therefore, is hypoechoic rather than anechoic
  - Should only be present anteriorly
    - Fluid should be gravity dependent, completely encircling the heart, and seen in multiple views.

71.6.2 Right Upper Quadrant View

- Normal artifacts of mirroring and loss of the spine are obscured when pleural fluid is present and, instead, the anechoic fluid is seen and there is loss of mirroring and continuation of the spine.

71.6.3 Left Upper Quadrant View

- Same as right upper quadrant view
- May be more difficult view to find than in right upper quadrant view for all of the following:
  - Spleen and kidney are more posterior and superior than in right upper quadrant view.
  - Spleen is smaller and less of a window for viewing.

71.6.4 Pelvic View

- Bowel can be mista0ken for free fluid or vice versa, but holding the probe still and observing can sometimes help distinguish the two.
  - Peristalsis will occur with bowel.
  - Internal echoes may be present in bowel.

71.6.5 Lung Views

- Ultrasound is more sensitive than a supine portable chest x-ray.
  - Apex anteriorly in midaxillary line.
- Rib
  - Hyperechoic horizontal line with a dense shadow posteriorly
  - Evenly spaced along the chest
- Pleural line
  - First hyperechoic line deep to the rib.
  - Actually includes the visceral and parietal pleura, but appears as one line.
  - Lung sliding is present in normal lung.
  - Comet tail artifact.
  - M mode tracing will be the same in normal lung and pneumothorax above the pleural line and different below the pleural line.
    - Seashore sign (Fig. 27.5a):
      - Appears as waves washing up on the shore.
      - Granular appearance represents movement.
    - Stratosphere sign (Fig. 27.5b):
      - Appears as straight lines
      - Bar code appearance

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Nasogastric Tube Placement

72

David P. Nguyen, L. Connor Nickels,
and Giuliano De Portu

72.1 Indications

- Evaluation of upper gastrointestinal (GI) bleeding (history of melena, bright red blood per rectum, or coffee-ground emesis)
  - Only in the cases in which frank blood is obtained, the sensitivity/specificity in detecting upper GI bleeding is poor.
  - It should not be used for diagnostic purposes. It is used to remove blood that is irritating the stomach and to determine whether bleeding is still occurring (lavage does not clear).
- Commonly used in decompression of the GI tract (partial/complete small bowel obstruction)
- Prevents aspiration and gastric dilation in intubated patients
- Used during gastric lavage and/or removal of toxins (activated charcoal) for acute overdose or poisonings

72.2 Contraindications

- Absolute
  - Facial trauma with possible cribriform plate fracture
- Relative
  - Severe coagulopathy (consider orogastric tube placement)
  - Esophageal strictures and alkali ingestions (possible esophageal perforation)
  - Esophageal varices (studies show that it is actually safe)

72.3 Materials and Medications

- For awake patients, consider pretreatment: lidocaine gel (2 % viscous)/nebulized lidocaine (4 or 10 %), vasoconstrictors (e.g., phenylephrine 0.5 %), and antiemetic (e.g., ondansetron 4 mg).
- 16- or 18-French sump tube lubricating jelly
- 50- or 60-mL syringe stethoscope

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72.4 Procedure

- Preparation
  1. Awake patients, should receive antiemetics 15 min before procedure.
  2. Anesthetize both nares at least 5 min before placement.
     - Spray vasoconstrictor into both nares.
     - Inject about 5 mL of lidocaine gel along the floor of the nose.
     - Nebulized lidocaine via facemask also reduces both nasal and pharyngeal discomfort.
  3. Elevate the head of the bed to an upright position (when possible).
  4. Estimate tube insertion distance by measuring the tube from the xiphoid to the earlobe and then to the tip of the nose. Add 6 in. to this estimate and note the total distance. This helps with placement in the stomach and prevents esophageal placement or coiling in stomach. Mark the tube with markers or tape at the desired length.
  5. Lubricate the nasogastric (NG) tube.
- Insertion (Fig. 72.1)
  1. Always insert the tube gently into the nares along the floor of the nose under direct visualization. Always point inferiorly (do not point upward).
  2. If resistance is encountered, try to apply a small amount of pressure. STOP if unable to advance. Try the other side. It is necessary to prevent bleeding or dissecting the tissues.
  3. Have the patient flex his or her head forward when the tube is in the nasopharynx. This helps direct the tube toward the correct placement in the esophagus and not the trachea. Have the awake and cooperative patient sip water from a straw and swallow as the tube enters the oropharynx.
  4. Making the tube more rigid by placing it in cold water will help advance it because the "warmer" tube will tend to coil.
  5. Once the tube is in the esophagus, rapidly advance the tube into the stomach, taking into consideration the previously marked depth.
- Confirmation of tube placement
  1. Insufflate air into the end of the NG tube, via a 50- or 60-mL syringe, while auscultating for a rush of air (borborygmi) over the stomach.
  2. Aspiration of gastric contents (pH <4, there is $>90\ \%$ gastric placement).
  3. The awake and cooperative patient should be able to talk, and if coughing or severe discomfort occurs, consider that esophageal or bronchial placement might have occurred.
  4. Radiographic evaluation:
     - "Gold standard" is to evaluate simple radiograph for position.
     - Consider in comatose patients.
- Secure the tube
  1. Tape the NG tube in place by taping both the tube and the nose. A butterfly bandage is typically used. Some companies produce a specific fixation for the tube.
  2. Secure the tube to where it does not press on the medial or lateral nostril (can lead to bleeding/necrosis).

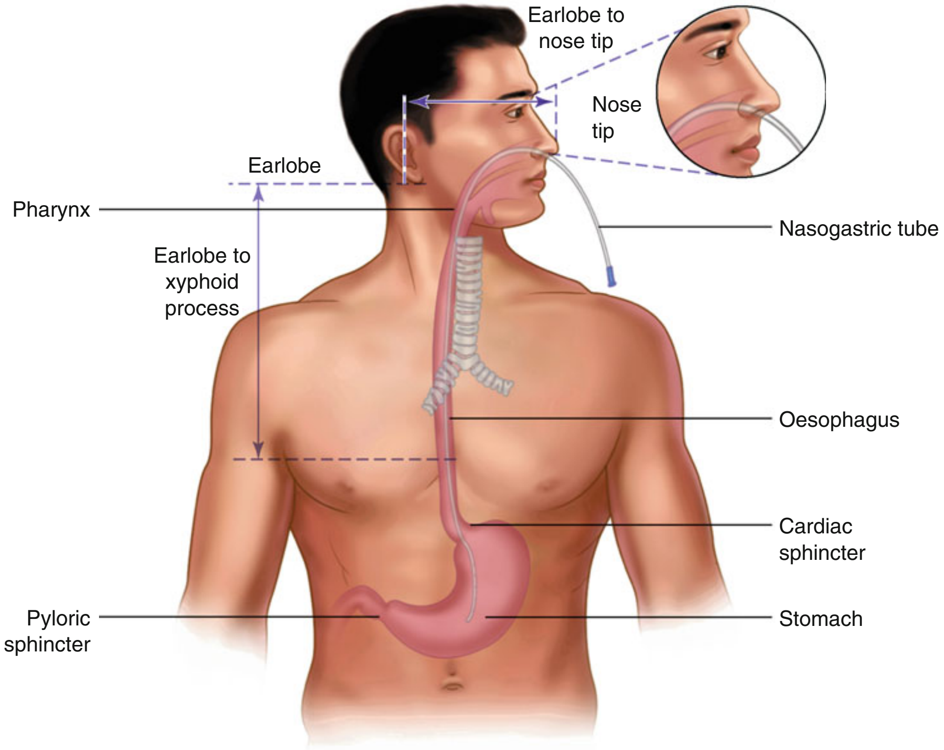

Fig. 72.1 NG tube placement

72.5 Complications

- Inability to pass the tube
- Bleeding
- Curling of the NG tube in the patient's mouth
- Pulmonary placement
- Nasal necrosis

72.6 Pearls

- Pearls
  - NG tube placement was ranked #1 as the most painful procedure in the emergency department so it is imperative to maintain patient's comfort by using anesthetics and even maybe intravenous anxiolytics.
  - Estimate the proper length of the tube before passage to avoid placing the tip of the tube in the esophagus or excessively coiling it in the stomach.
  - If leaving the tube for a prolonged period of time, make sure that the suction is set "intermittent" or "off" to prevent irritation to the gastric mucosa owing to direct pressure.

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73

Esophageal Foreign Body Removal

David P. Nguyen, L. Connor Nickels,
and Rohit Pravin Patel

73.1 Indications

- Patient presenting with any one or combination of the following:
  - Foreign body sensation in throat, neck, substernal chest, or epigastric area
  - Clear history of ingestion
  - Dysphagia
  - Airway compromise
  - Drooling
  - Inability to tolerate fluids
  - Inability to tolerate solids
  - Evidence of perforation
  - Active bleeding
- All unstable patients should have immediate airway management and urgent endoscopy.
- FBs lodged superior to the epiglottis may be retrieved by emergency physicians in an emergent situation, but generally, a consultant should be present, whether ear, nose, and throat, gastroenterology, or general surgery.

73.2 Contraindications

- Absolute
  - None
- Relative
  - Performing rapid sequence intubation (RSI) in a patient with an FB that could compromise the airway.
  - Generally, if the patient is breathing on their own, collaborate with a consultant on the best method to secure the airway (emergency department, intensive care unit, operating room).
  - Treating with glucagon repeatedly if it is inducing vomiting and/or not working.
  - Conservatively managing a patient who should otherwise undergo a procedure for removal.

73.3 Materials

- Esophagoscopy/endoscopy is the definitive diagnostic and therapeutic procedure for impacted esophageal FBs.
  - Generally, should not be performed by an emergency physician.
  - Devices used include forceps, baskets, polypectomy snares, and nets.
  - Endoscopic techniques include push into stomach, push plus fragmentation, pull with retrieval forceps, and pull with various items (basket, snare, nets).
- Foley catheter removal
  - Widely used technique for recently ingested single, smooth, blunt, and radiopaque objects
  - #12 to #16 French Foley catheter
  - Forceps (bayonet and Magill) of various sizes
  - Often done under fluoroscopic guidance
- Bougienage
  - A single, smooth object, such as a coin, lodged less than 24 h in a patient with no respiratory distress or esophageal disease can be advanced successfully into the stomach by using bougienage.
  - Dilator size is selected based on age:
    - 1–2 years: 28 French
    - 2–3 years: 32 French
    - 3–4 years: 36 French
    - 4–5 years: 38 French
    - Longer than 5 years: 40 French
- Relaxation of the lower esophageal sphincter (LES)
  - Some FBs lodged at the LES can be medically managed by relaxation of the LES.

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  - Most ingested FBs and impacted food boluses eventually pass spontaneously.
    - 1–2 mg of glucagon intravenously
    - 0.4–0.8 mg of nitroglycerin sublingually
    - 5–10 mg of nifedipine sublingually
    - Carbonated beverage

73.4 Procedure

- Push technique and push with fragmentation technique (generally performed by specialists)
  1. First accepted endoscopic method.
  2. Gentle pressure is applied with the tip of the endoscope on the esophageal food bolus after air insufflation.
  3. If pressure does not disimpact the bolus, fragmentation can be attempted but is generally avoided owing to unknown pathology behind the food bolus.
- Foley catheter removal
  1. Moderate sedation and nasopharyngeal topical anesthesia may be used.
  2. Place the patient in a head-down Trendelenburg position.
  3. Check for symmetrical balloon inflation of the Foley catheter.
  4. Under fluoroscopy, visually pass the catheter distal to the FB.
  5. Fill the balloon slowly with 3–5 mL of saline or contrast agent.
  6. Using steady, gentle traction, withdraw the catheter with the balloon inflated distal to the FB.
  7. Grasp the object with fingers, forceps, or clamp once it is visualized in the oropharynx.
- Bougienage
  1. Topical anesthesia is recommended.
  2. Blind esophageal bougienage resembles placement of an orogastric tube.
  3. Place the patient in a sitting position.
  4. Pass a well-lubricated, appropriately sized bougie posteriorly along the roof of the mouth, following the natural curve of the soft palate caudally to the hypopharynx.
  5. Encourage the patient to swallow (to help pass the dilator through the cricopharyngeus muscle).
  6. Ask the patient to phonate to help exclude accidental laryngeal intubation.
  7. Once past the cricopharyngeus muscle, extend the head to aid the bougie in passing distally to the stomach.
  8. Post-procedure radiograph is used to confirm passage into the stomach.
- Relaxation of the LES
  1. Premedicate with an antiemetic, such as ondansetron.
  2. Administer 1–2 mg of glucagon intravenously (0.02–0.03 mg/kg in children, not to exceed 0.5 mg) with the patient in a sitting position over 1–2 min.
  3. Carbonated beverages given after glucagon ingestion have shown to have higher success rates.
  4. An alternative is to use either sublingual nitroglycerin (1–2 0.4 mg tabs) or 5–10 mg of nifedipine to relieve LES tone.
  5. This procedure does not work in patients with structural abnormalities.

73.5 Complications

- Esophageal FBs may cause esophageal pressure leading to edema, necrosis, infection, laceration, and/or perforation.
- Be cognizant of time (risk of complications is higher the longer the FB is left in place) and treatment side effects (i.e., do not continue to give patient water or glucagon if these induce vomiting).
- Aspiration and perforation during procedures listed previously.
- Late complications: esophageal stricture, abscess, mediastinitis, tracheoesophageal fistula, vascular injuries, pneumothorax, pericarditis, aspiration pneumonia, and vocal cord paralysis.

73.6 Pearls

- Esophageal foreign bodies can be lodged in the upper (proximal), middle, or lower (distal) one third:
  - Proximal: cervical web, Zenker's diverticulum
  - Middle: eosinophilic esophagitis, cancer, radiation structure, spastic dysmotility
  - Distal: peptic stricture, eosinophilic esophagitis, cancer, achalasia, esophageal diverticula, spastic dysmotility
- Because food bolus impactions are generally associated with pathology, follow-up evaluation for these abnormalities should be considered.
- Esophagus foreign bodies should not be allowed to remain in the esophagus beyond 24 h from presentation.
- Button/disc batteries in esophagus (emergent removal)
  - Considered an emergency, because liquefaction necrosis and perforation can occur rapidly.
  - Most common ingestions are hearing aid batteries.
  - If in stomach, and patient is a symptomatic, can wait up to 24 h.
- Sharp objects (emergent removal)

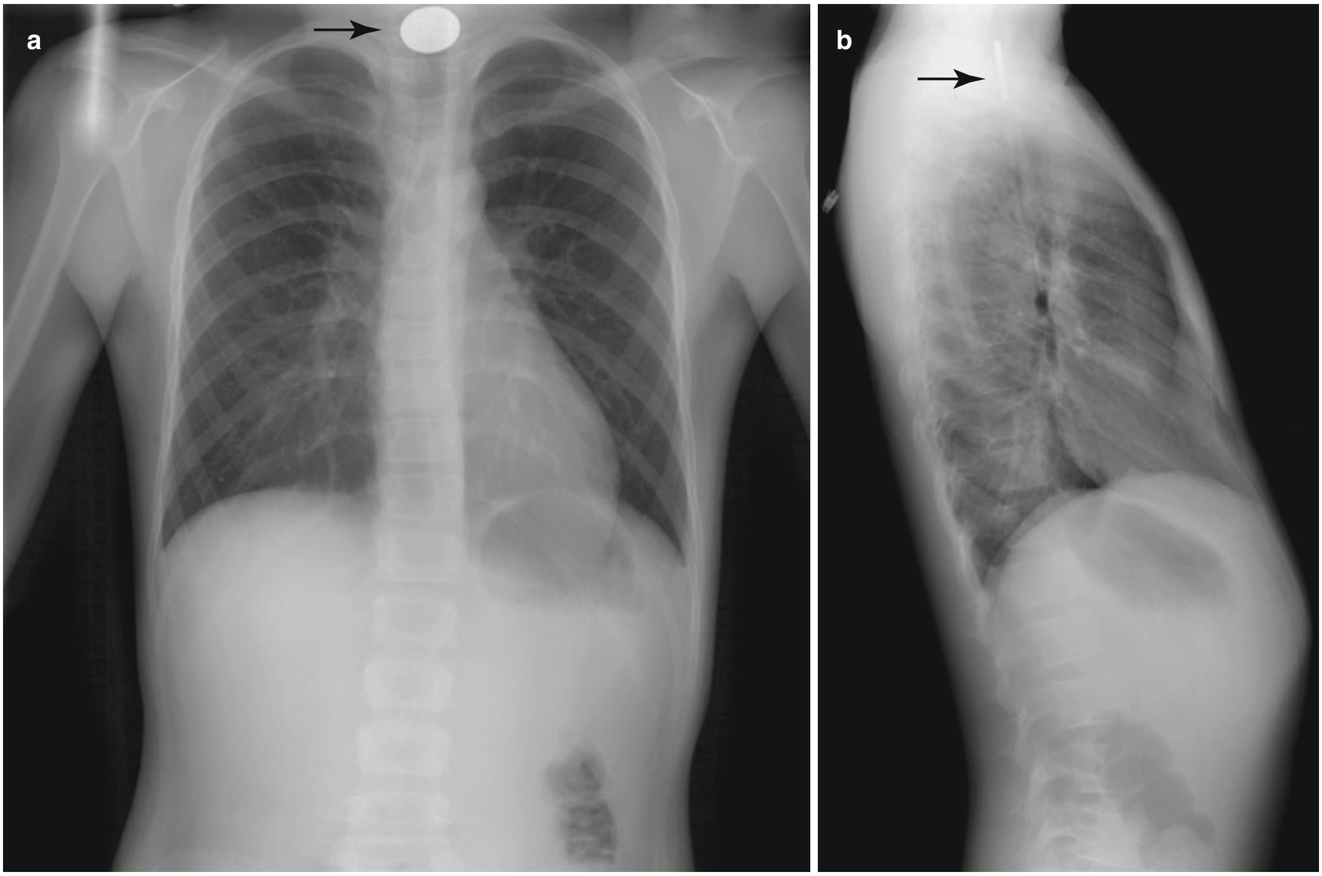

Fig. 73.1 (**a**) Anteroposterior (AP) and (**b**) lateral views demonstrating a coin in the esophagus. A coin in the trachea would present in the opposite manner—the coin would be seen on edge in the AP view and flat on the lateral view (Reproduced with permission from McGraw-Hill: Stead LG, et al. *First Aid for the Pediatrics Clerkship*. New York: McGraw-Hill, 2010)

  - Cause the majority of complications (~35 %) with esophageal FBs.
  - Direct visualization with endoscopy is the only appropriate removal technique.
- Magnets (urgent removal)
  - Can cause necrosis and fistula formation due to the way they adhere to the mucosa
- Esophageal coins (remove within 24 h) (Fig. 73.1)
  - Up to 80 % of coins at the LES will pass spontaneously within 24 h without interventions. The watchful waiting approach is used only in patients with single coins and who are asymptomatic.
  - Common complications of these procedures include mild bleeding, lip laceration, bradycardia with Foley catheter insertion, and teeth injuries.
  - Some protocols include RSI as part of the management process and should be considered if lifesaving.

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Activated Charcoal

74

Deylin I. Negron Smida and Judith K. Lucas

74.1 Indications

- Single-dose activated charcoal (AC) (Fig. 74.1)
  - Does not meet criteria for gastric emptying.
  - Gastric emptying may be too harmful.
  - Ingestion of toxic xenobiotic is known to be adsorbed by AC.
  - Ingestion occurred with a time frame amenable to adsorption by AC, or clinical factors are present that suggest that not all of the xenobiotic had already been systemically absorbed.
  - Ingestion of extended- or sustained-release formulations.
- Multiple-dose activated charcoal therapy (MDAC)
  - Life-threatening ingestion of:
    - Carbamazepine
    - Phenobarbital
    - Quinine
    - Theophylline
    - Dapsone
  - Life-threatening ingestion of another xenobiotic that undergoes enterohepatic recirculation and is adsorbed to AC
  - Ingestion of a significant amount of a slowly released xenobiotic
  - Ingestion of a xenobiotic known to form concretions or bezoars, such as aspirin

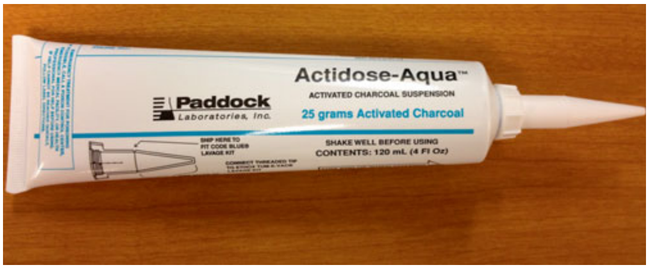
Actidose-Aqua™
ACTIVATED CHARCOAL SUSPENSION
25 grams Activated Charcoal
Paddock Laboratories, Inc.
SHAKE WELL BEFORE USING
CONTENTS: 120 mL (4 Fl Oz)

Fig. 74.1 Activated charcoal (AC)

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74.2 Contraindications

- Absolute
  - Gastric perforation
  - Gastrointestinal ileus, obstruction, or diminished peristalsis
  - Nonintubated patients with the potential of losing protective airway reflexes
  - Intestinal obstruction
  - Ingestion of:
    - Corrosives
    - Petroleum distillates
- Relative
  - Altered or decreased level of consciousness unless intubated.
  - Vomiting.
  - Xenobiotic has limited toxicity at almost any dose.
  - Dose ingested is less than the dose expected to produce significant illness.
  - Presentation many hours after ingestion.
  - Minimal signs or symptoms of poisoning.
  - Ingested xenobiotic has a highly efficient antidote.
  - Administration of charcoal may increase the risk of aspiration (i.e., hydrocarbons).

74.3 Materials and Medications

- Nasogastric (NG) tube/orogastric (OG) tube (Fig. 74.2)
- Baby bottle with split nipple (designed for drinking of slurry solutions, such as thickened formulas) or sippy cup without the valve
- Absorbent pad
- Basin
- Water-soluble lubricant
- Tubing connected to suction device
- Flavored syrup

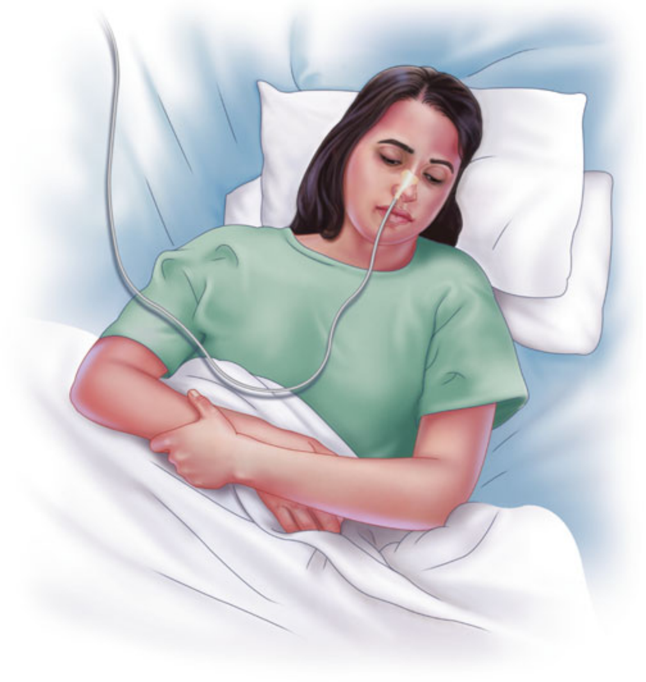

Fig. 74.2 Drinking AC (by cup, sippy cup, or bottle) is effective, but it may also be infused via nasogastric or orogastric tube

74.4 Procedure

- Single-dose administration
  - Adult
    - Can be taken via a cup and straw (drunk) if the patient is cooperative.
    - The optimal dose of AC is unknown.
    - 50–100 g/dose (1 g/kg), administered at a rate no less than 12.5 g/h or its equivalent.
    - If vomiting is anticipated, an intravenous antiemetic is recommended.
  - Children
    - 1 g/kg or 10:1 ratio of AC to drug ingested.
    - After massive ingestion, give 2 g/kg.
    - Many children will drink the suspension from a bottle or sippy cup, especially if it is mixed with juice or flavored syrup (e.g., chocolate or strawberry).
- MDAC
  - Adults: 0.5–1 g/kg every 2–4 h for 24–48 h
  - Children (<12 y old): 0.25–0.5 g/kg every 2–4 h or rate of 0.2 g/kg/h for 24–48 h
- Mixtures
  - Ready to drink
  - Powder form
    - Add eight parts water to the selected powdered form.
    - Gatorade or juices can also be used to help hide the flavor and texture.
    - In children, the AC can be mixed with cold chocolate or some other flavored syrup, which also hides the flavor.
  - Shake liquid suspension well for 1 min.
  - If the patient vomits, the dose should be repeated. Smaller, more frequent, dosing may be better tolerated, and an antiemetic may be needed.

74.5 Complications

- Aspiration pneumonitis
- Transient constipation
- Intestinal bezoars
- Bowel obstruction
- Diarrhea, dehydration, hypermagnesemia, and hypernatremia with coadministered cathartics or MDAC
- Vomiting
- Corneal abrasion if spilled in the eyes

74.6 Pearls and Pitfalls

- Pearls
  - If an OG or NG tube is used, time should be allowed for the last dose to pass through the stomach before the tube is removed. Suctioning the tube before removal may prevent subsequent AC aspiration.
  - With children, the colder and sweeter the solution and if the color is camouflaged (cup with a lid or a sippy cup), there will be increased success at oral administration (vs NG/OG).
- Pitfalls
  - No evidence-based literature supports the assertion that AC changes clinical outcome.
  - Xenobiotics and AC adsorption (Table 74.1).
  - Incorrect application (e.g., into the lungs) results in pulmonary aspiration, which can be fatal if unrecognized.
    - Incorrect placement of NG/OG tube into trachea.
    - Administration of AC to a patient with an ileus (e.g., in anticholinergic overdoses).
  - No specific contraindication for AC in pregnant women; however, diarrhea or hypernatremia in the mother may adversely affect the fetus.

Table 74.1 Absorption of xenobiotics by AC

Good absorption	Poor absorption
Acetaminophen	Alkali
Bupropion	Chlorpropamide
Caffeine	Doxepin
Carbamazepine	Ethanol or other alcohols
Chlordecone	Ethylene glycol
Dapsone	Fluoride
Digitoxin	Heavy metals
Nadolol	Imipramine
Phenobarbital	Inorganic salts
Phenylbutazone	Iron
Phenytoin	Lithium
Salicylate	Methotrexate
Theophylline	Mineral acids
	Potassium
	Tobramycin
	Valproate sodium
	Vancomycin

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Gastric Lavage

75

Deylin I. Negron Smida and Judith K. Lucas

75.1 Indications

- Recent ingestion (<30–60 min).
- Life-threatening exposure where there is a high suspicion that a xenobiotic is still present in the stomach and evacuation is expected to contribute to an improved outcome (e.g., iron, tricyclic antidepressants).
- Ingested agent is not absorbed with activated charcoal (e.g., pesticides, hydrocarbons, iron, alcohols, lithium, and solvents).
- Activated charcoal is unavailable.
- Ingestion exceeds adsorptive capacity of initial activated charcoal dosing (e.g., >100 mg/kg of pills).
- Ingestion of an agent likely to form a durable mass or bezoars after overdose.

75.2 Contraindications

- Vomiting
- Unintubated patients with potential to lose airway protective reflexes
- Ingestion of a xenobiotic with aspiration potential (e.g., hydrocarbon) without intubation
- Ingestion of caustic substances (alkali or acidic)
- Ingestion of sharp metals
- Ingestion of a foreign body (e.g., drug packet)
- Risk for hemorrhagic gastrointestinal perforation
- Ingestion of xenobiotic in a form known to be too large to fit into the lumen of the orogastric tube
- Nontoxic ingestions

75.3 Materials and Medications

- Orogastric tube (Ewald tube or the Tum-E-Vac) (Fig. 75.1)
  - Adults and adolescents: 36–40 French
  - Children: 22–28 French
- Pen or tape to mark the length of the tube
- Water-soluble lubricant
- Suction
- Emesis basin
- Absorbent pad
- Catheter-tip syringe with 2 mL water/saline to check position of the tube
- Room temperature irrigation fluid
- Bite block or oral airway to prevent patients from biting down on the tube

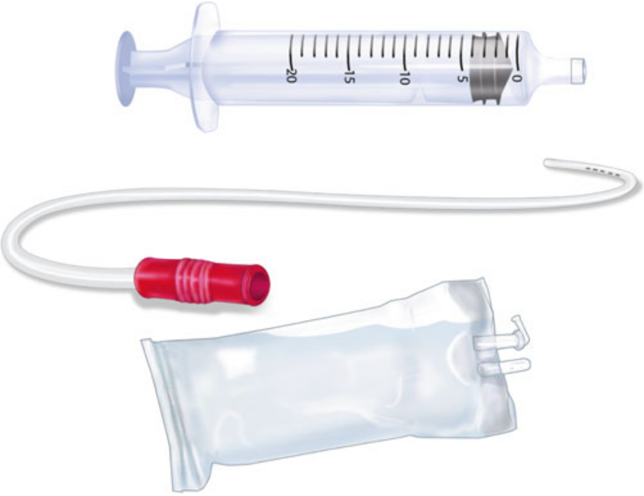

Fig. 75.1 Materials needed for gastric lavage include a large-bore nasogastric tube, a 60-cc non-Luer-Lok syringe, and a solution, typically normal saline, for lavage

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75.4 Procedure

1. If there is potential airway compromise, endotracheal or nasotracheal intubation should precede orogastric lavage.
2. Place an oral airway or a bite block to prevent biting of the endotracheal tube if the patient recovers consciousness or has convulsions during the procedure.
3. Ensure suction apparatus is available and functioning.
4. Place the patient in an upright-seated position if awake and alert.
5. Place patient in the left lateral decubitus position if obtunded.
6. Before insertion, the proper length of tubing to be passed should be measured from the mouth, back to the ear, and down anterior to the chest and abdomen, beyond the point where any side ports on the tube would be beyond the level of the estimated lower esophageal sphincter (Figs. 75.2 and 75.3).
7. If the patient is still awake, insert the gastric tube to the level of the glottis, and encourage the patient to swallow.
8. Pass the tube to the stomach.
    (a) Coughing, airflow, or fog from the tube raises the concern for inadvertent tracheal positioning.
9. After the tube is inserted, it is essential to confirm that the distal end of the tube is in the stomach, by "popping" 5–10 mL of air into the tube while someone is listening with a stethoscope over the stomach.

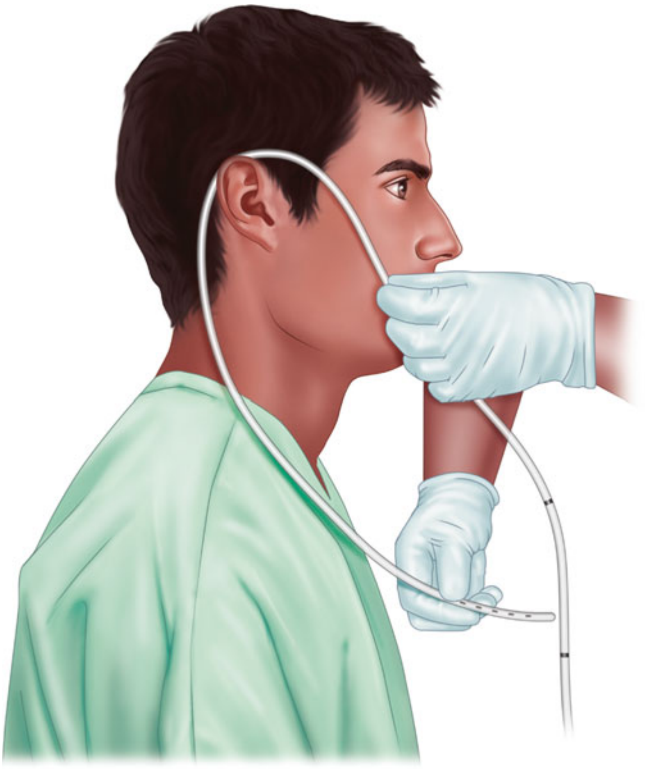

Fig. 75.3 Measuring correct placement of the tube. Place the distal tip over the stomach and wrap the tube up behind the ear (usually the right ear because the tubes generally pass easier through the right nares) and around the nares. The black line or centimeter mark at the level of the nares is the point of insertion when passage stops

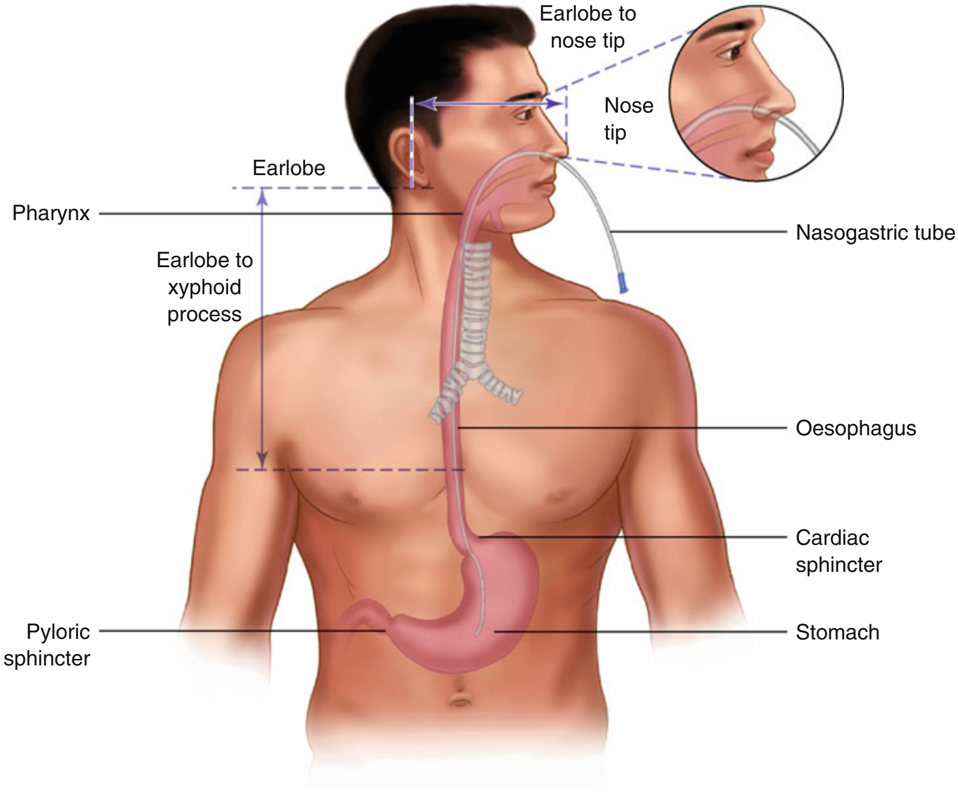

Fig. 75.2 Diagram illustrates appropriate placement of the lavage tube

10. In adults, 250-mL aliquots of a room temperature saline lavage solution are instilled via a funnel or lavage syringe. In children, aliquots should be 10–15 mL/kg to a maximum of 250 mL and suctioned back out of the tube attached to low to moderate continuous wall suction. Instillation of lavage solution and suction is repeated (Fig. 75.4).
11. Orogastric lavage should continue for at least several liters in an adult and/or at least 0.5–1 L in a child if the return is free of debris or until no particulate matter returns and the effluent lavage solution is clear.
12. Those caring for the patient must remain protected at all times, using goggles, mask, gown, and gloves. If the ingested poison is toxic via pulmonary or skin absorption, isolate the ingestant immediately in a self-contained wall suction unit.
13. Any material still in the stomach should be withdrawn, and immediate instillation of the activated charcoal should be considered for large ingestions of xenobiotics known to be adsorbed by activated charcoal.

75.5 Complications

- Vomiting
- Esophageal tears or perforation after orogastric tube insertion
- Inadvertent tracheal intubation and/or airway trauma
- Aspiration pneumonitis

75.6 Pearls and Pitfalls

- Pearls
  - You must use a large-bore orogastric tube for maximal efficacy.
  - The left lateral decubitus position is recommended because the pylorus points upward in this orientation. This position theoretically helps prevent the xenobiotic from passing through the pylorus during the procedure.
- Pitfalls
  - Large drug packets, adherent masses of pills, and plant and mushroom fragments will not pass through a 40-French lavage tube.

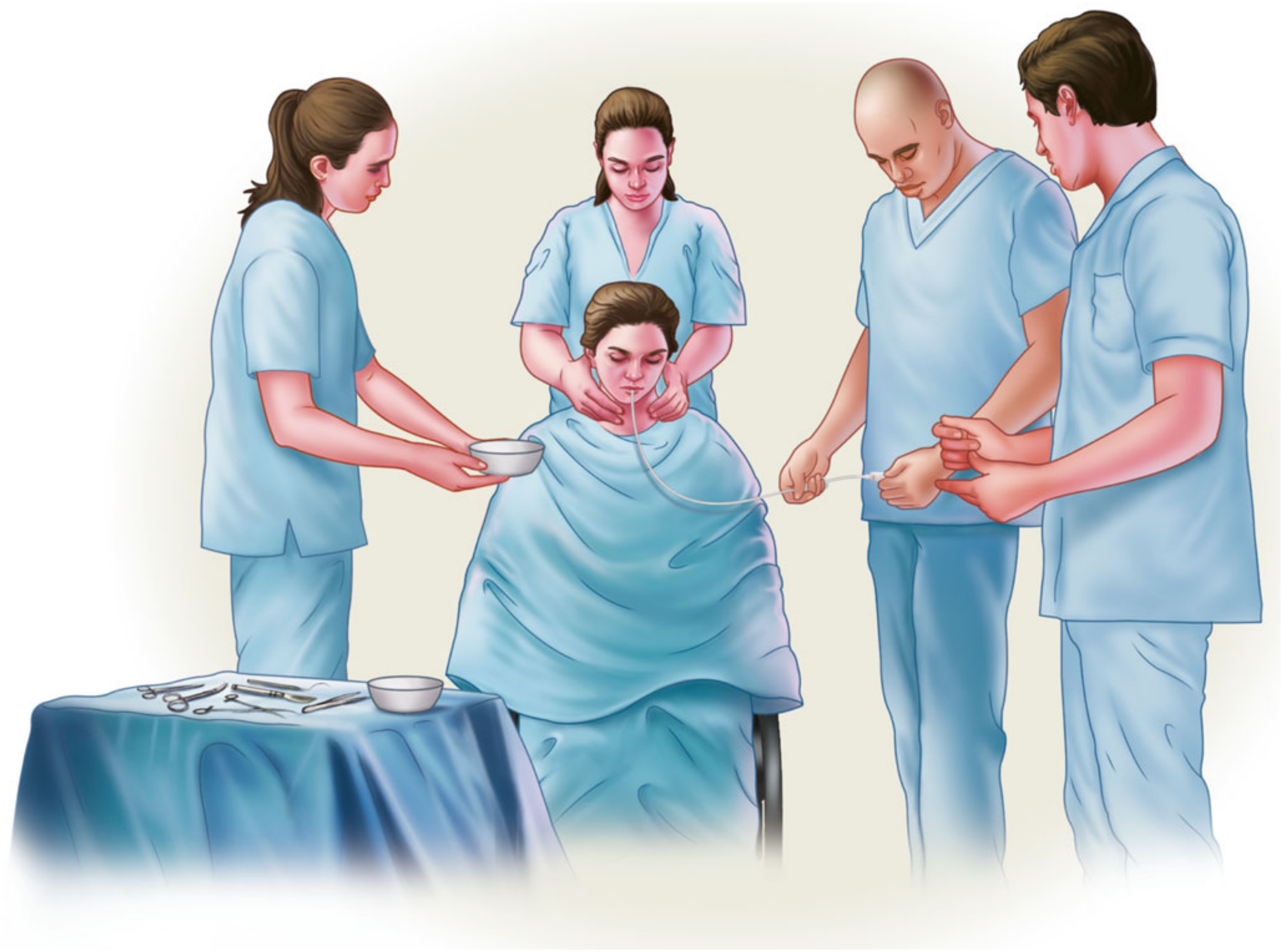

Fig. 75.4 Lavage in progress

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Whole-Bowel Irrigation

76

Judith K. Lucas

76.1 Indications

- Whole-bowel irrigation (WBI) should not be used routinely in the management of the poisoned patient (because there is no clinical proof it will change clinical outcome).
- Ingestion of significant amount of medications.
  - Not adsorbed by activated charcoal
    - Lead, lithium, arsenic, and zinc
    - Substantial amounts of iron (high morbidity and no other effective method to gastrointestinal decontamination)
  - Sustained-release medications or enteric-coated drugs
  - Disk batteries distal to the pylorus
  - Whole transdermal patches (fentanyl, clonidine, nicotine)
  - Drug concretions
  - Ingested packets of illicit drugs

76.2 Contraindications

- Absolute
  - Bowel obstruction
  - Bowel perforation
  - Ileus
  - Hemodynamic instability
  - Compromised or unprotected airway
  - Intractable vomiting
- Relative
  - Concurrent or recent administration of activated charcoal (may decrease the effectiveness of activated charcoal)

76.3 Materials and Medications

- Topical anesthesia, although not mandatory, will reduce the pain of nasogastric (NG) tube placement.
  - 10 % lidocaine spray
  - Lidocaine gel
- Small-bore (12-French) NG tube (Fig. 76.1).
- Tape for securing the NG tube.
- Reservoir or feeding bag used for NG tube feedings (Fig. 76.2).
- Intravenous pole.
- Bedside commode or toilet (Fig. 76.3).
- Polyethylene glycol-electrolyte solution (PEG-ES) (Fig. 76.4).
- Antiemetic.
  - No absolute indication for prophylactic use
  - May be helpful if vomiting ensues during infusion
    - Metoclopramide
      - Antiemetic
      - *Increases gastric motility*

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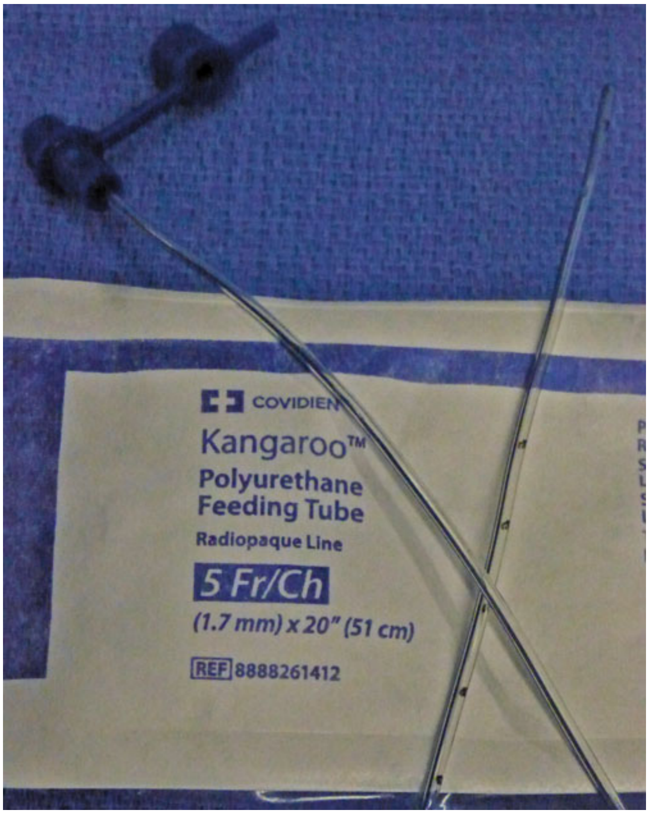
COVIDIEN
Kangaroo™
Polyurethane
Feeding Tube
Radiopaque Line
5 Fr/Ch
(1.7 mm) x 20" (51 cm)
REF 8888261412

Fig. 76.1 Nasogastric (NG) tube. Typically, the infusion of the lavage solution is too rapid to be taken orally, so an NG tube can be placed. Since the irrigation solution is of low viscosity, a small-bore NG tube should be used for comfort

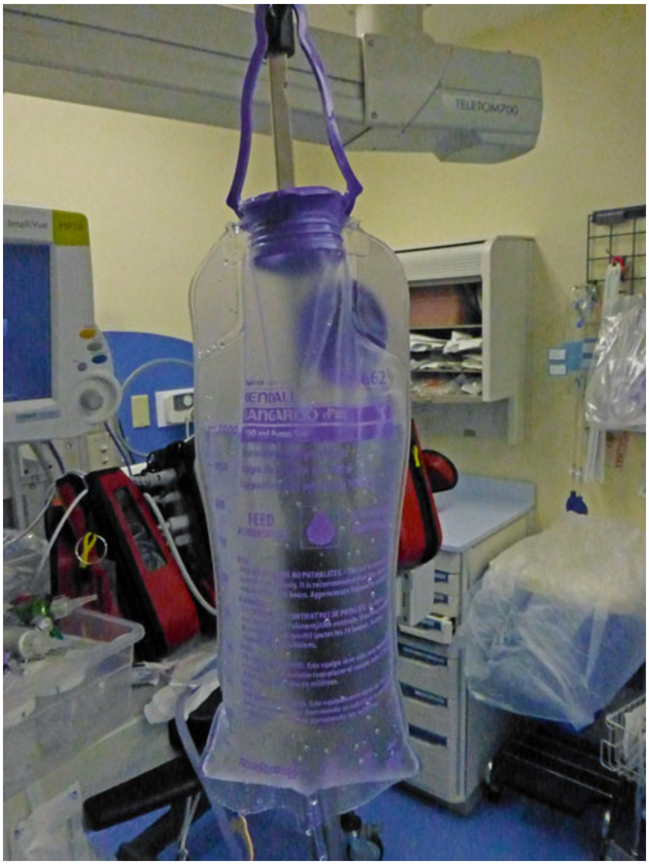

Fig. 76.2 Bag from which the lavage solution will drain; it is similar to the bags used for gastrostomy tube feeding

Fig. 76.3 Almost always, the patient will need to be seated on or very near a portable commode, as once the irrigation solution starts to move through the bowels, defecation will occur rapidly

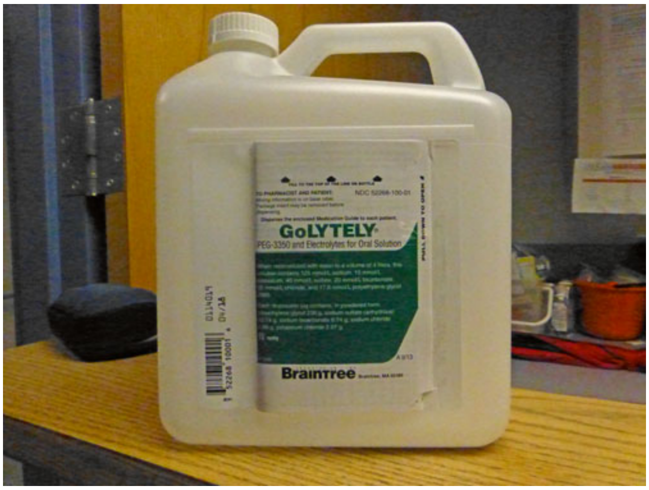

Fig. 76.4 Example brands of intestinal irrigation electrolyte solutions

76.4 Procedure

1. An NG tube is required because most patients will not drink the PEG-ES at the necessary rate.
2. Place a small-bore (12-French) NG tube to a sufficient distance that the tip lies in the central portion of the stomach.
3. Confirm NG placement with a radiograph.
4. Attach the tube to the reservoir bag of PEG-ES and hang from an elevated site (an extended intravenous pole).
5. The patient should be seated in an upright position.
    - Promotes settling of the intoxicant in the distal portion of the stomach
    - Decreases the likelihood of vomiting
6. Dosing:
    - Children 9 months to 6 years: 500 mL/h
    - Children 6–12 years: 1,000 mL/h
    - Adolescents/adults: 1,500–2,000 mL/h
7. Collect effluent.
8. Continue infusion.
    - Until the rectal effluent is the same color as the influent (i.e., clear), usually between 4 and 6 h.
    - You may continue beyond clear effluent if clinical evidence indicates ongoing effectiveness:
        – Continued pill fragments or drug packets are present in the effluent.
        – Radiographic evidence that pills, pharmacobezoars, or packets are still present.

76.5 Complications

- Nausea, vomiting, and bloating
- Misplacement of the NG tube
- Esophageal perforation owing to NG tube placement
- Aspiration pneumonitis in the unprotected airway

76.6 Pearls

- Overall, WBI is probably more effective than gastric lavage, but probably less effective than activated charcoal in preventing poison absorption (when the intoxicant can be adsorbed to charcoal).
- Vomiting.
    – Usually secondary to the ingestant (i.e., emetogenic toxins, such as iron)
    – May be due to rate of infusion
        - Slow rate by 50 % for 30–60 min.
        - Then return to original rate.
- If resistance is encountered during NG tube placement, do not force passage. Remove and redirect.

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77 Sengstaken-Blakemore Tube

Thomas T. Nguyen, Etan Eitches,
and Stephanie Wetmore-Nguyen

77.1 Indications

- Life-threatening esophageal variceal bleed refractory to endoscopy and medical therapy
- Life-threatening esophageal variceal bleed refractory to medical therapy in the absence of possible endoscopy

77.2 Contraindications

- Absolute
  - Known esophageal rupture
  - Unable to intubate or maintain airway
- Relative
  - History of prior esophageal trauma or strictures
  - Recent surgery of the gastroesophageal junction
  - Resolved or resolving variceal bleeding

77.3 Materials and Medications

- Sengstaken-Blakemore (SB) tube (Fig. 77.1)
- 60-mL syringe with catheter tip (Fig. 77.2)
- Sphygmomanometer (Fig. 77.3) or cuffalator (Fig. 77.4)
- Y-Tube connector (Fig. 77.5) or 3-way stop-valve connector (Fig. 77.6)
- Vacuum suction device and tubing (Fig. 77.7)
- Tube clamps (4) (Fig. 77.8)
- Lubricant (water soluble)
- Lidocaine (Xylocaine) spray or gel
- Anchoring device such as a football helmet or catcher's mask (Fig. 77.9)
- Cup of water and straw if the patient is awake
- Scissors (Fig. 77.10)
- Intubation equipment
- Sterile water

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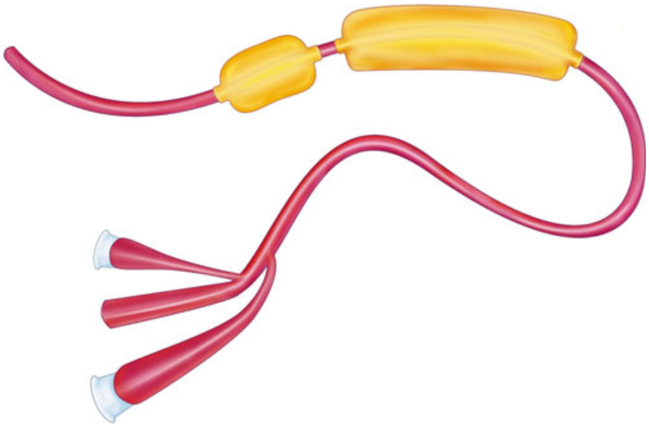

Fig. 77.1 Sengstaken-Blakemore (SB) tube

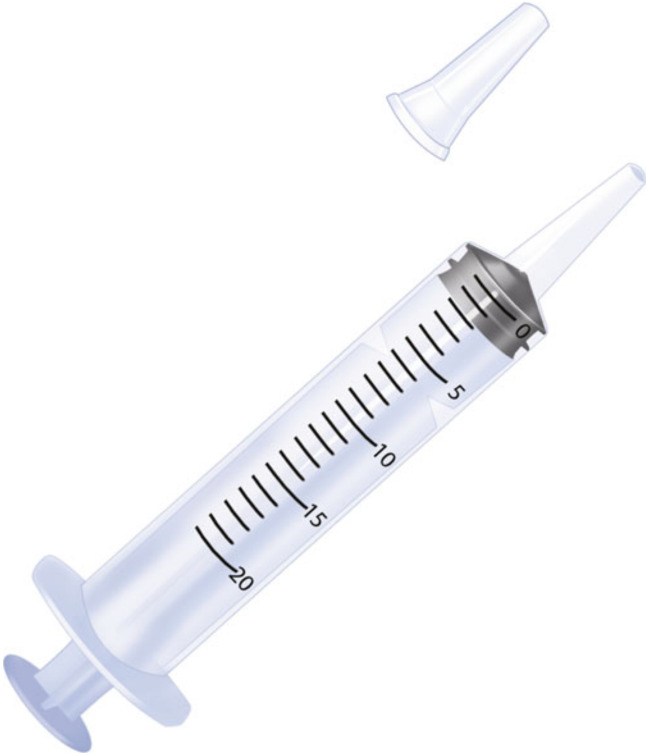

Fig. 77.2 Syringe

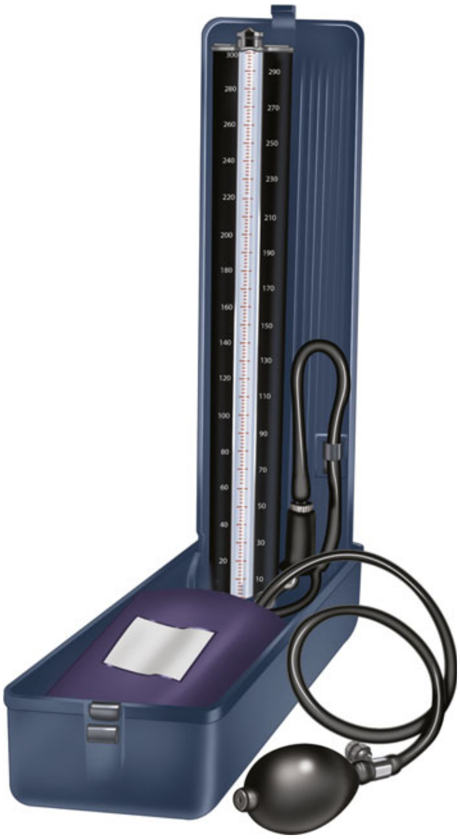

Fig. 77.3 Sphygmomanometer

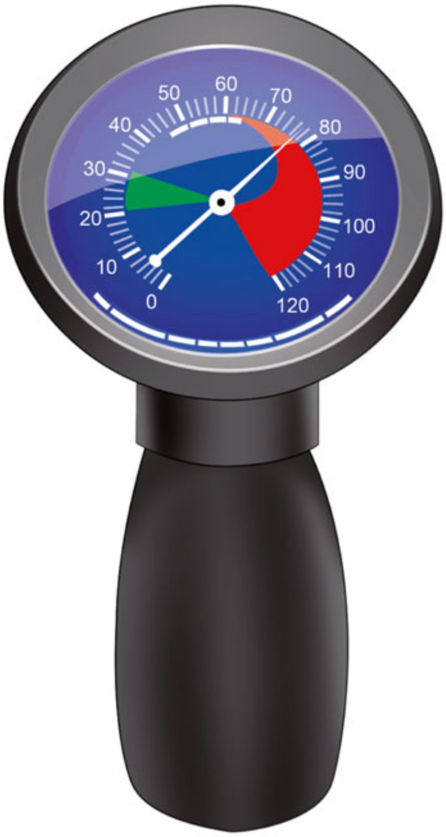
0
10
20
30
40
50
60
70
80
90
100
110
120

Fig. 77.4 Cuffalator

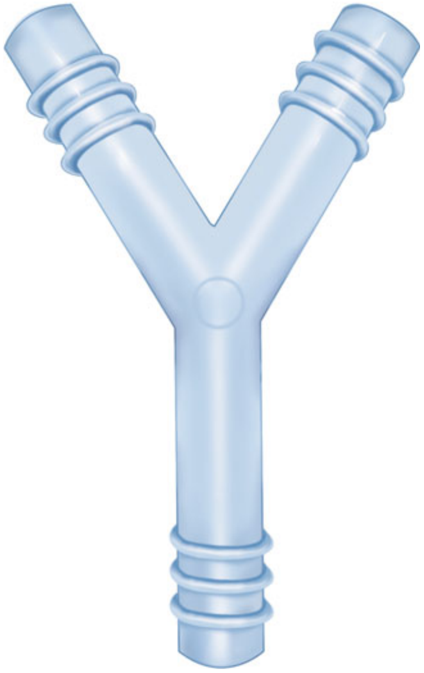

Fig. 77.5 Y-Tube connector

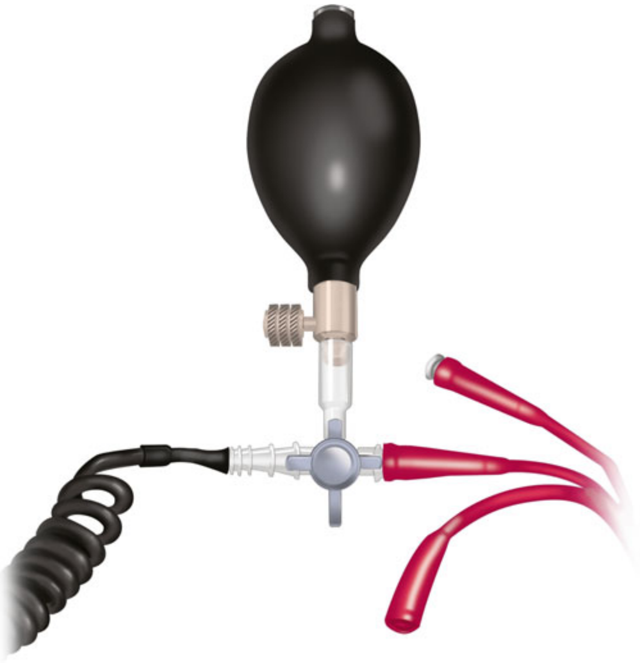

Fig. 77.6 3-way stop-valve tube connector

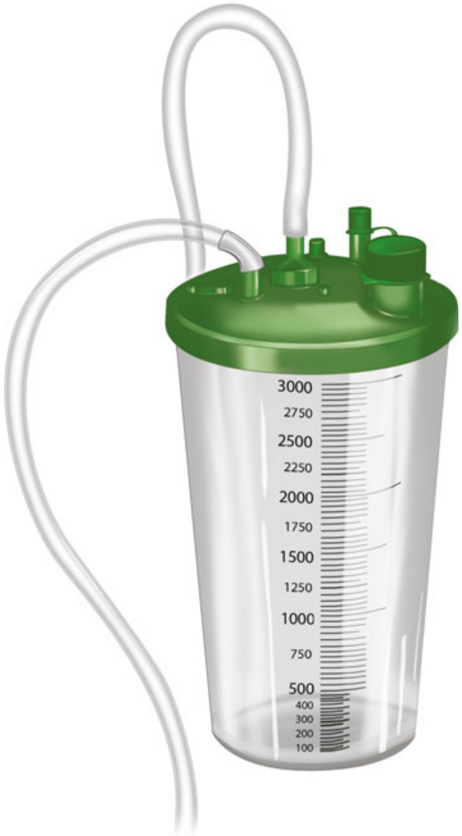
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
400
300
200
100

Fig. 77.7 Suction device and tubing

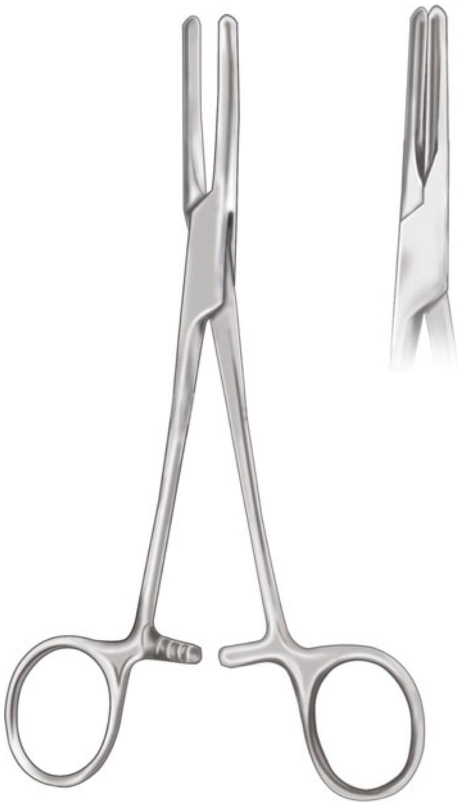

Fig. 77.8 Tube clamps

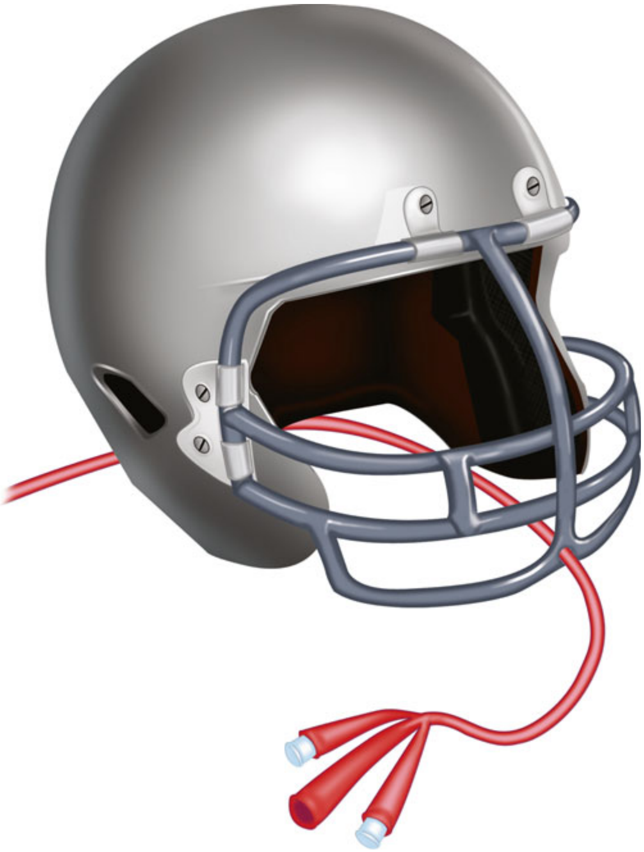

Fig. 77.9 Helmet traction setup

Fig. 77.10 Scissors

77.4 Procedure

1. Sedate and/or intubate the patient for adequate control of the patient during the procedure.
2. Ensure that the SB tube balloons are functional by inflating and deflating the balloons to ensure the absence of leaks.
3. Perform gastric lavage and irrigate the stomach with copious amount of sterile water.
4. Coat the distal and proximal portions of the SB tube with a thin layer of lubricating jelly or lidocaine gel. Spray the nasal passage with lidocaine spray.
5. Pass the SB tube via the nasogastric (NG) or the orogastric route (in intubated patients) to the 50-cm line. You may confirm placement with x-ray.
6. Inflate the gastric balloon to 200 mL of air and clamp the tube.
7. Apply gentle traction of 1–2 lb (0.4–2 kg) of force until it is felt that the gastric balloon has lodged at the gastroesophageal junction (Fig. 77.11).
8. Secure the tube to an anchor (e.g., football helmet or catcher's mask) placed on the patient's head.
9. Aspirate and lavage the gastric aspiration port. If it is clear of blood, do not inflate the esophageal balloon.
10. If it is not clear of blood, connect the esophageal tube of the SB tube to the sphygmomanometer/cuffalator using the 3-way stop-valve device (Fig. 77.12). You may use the Y-Tube connector instead.
11. Inflate the esophageal balloon to the lowest pressure determined to stop bleeding, typically 20–45 mmHg. Clamp the balloon.
12. Place an NG tube until it is felt overlying the top of the esophageal balloon of the SB tube. Check for further proximal esophageal bleed through aspiration and gentle lavage. Attach this NG tube to intermittent section to aid in the clearance of secretions.
13. Obtain a portable radiograph to confirm the position of the SB tube.
14. The esophageal tube should be at the lowest pressure that prevents bleeding and kept inflated for 24 h or until other definitive treatment is obtained.

Fig. 77.11 Proper placement of the balloons

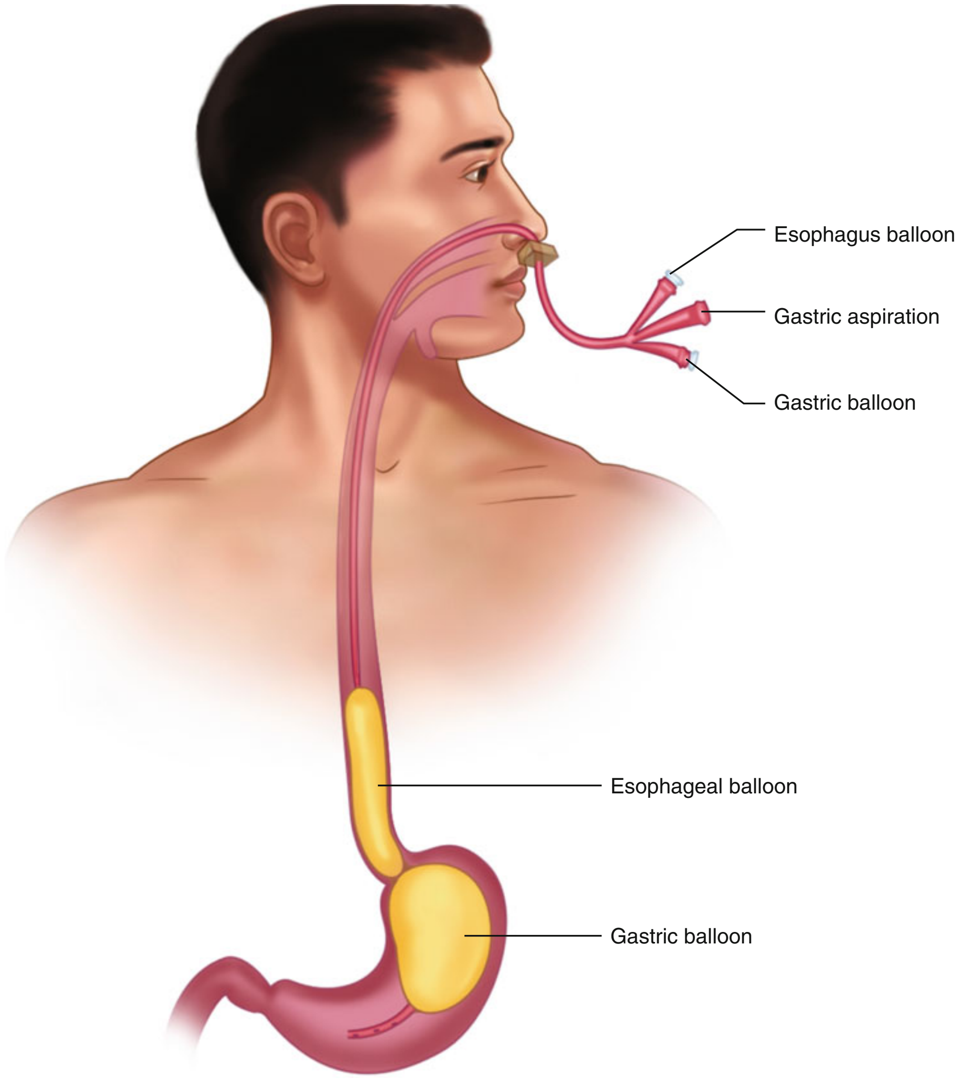
Esophagus balloon
Gastric aspiration
Gastric balloon
Esophageal balloon
Gastric balloon

Fig. 77.12 Connection of the sphygmomanometer to the esophagus balloon port

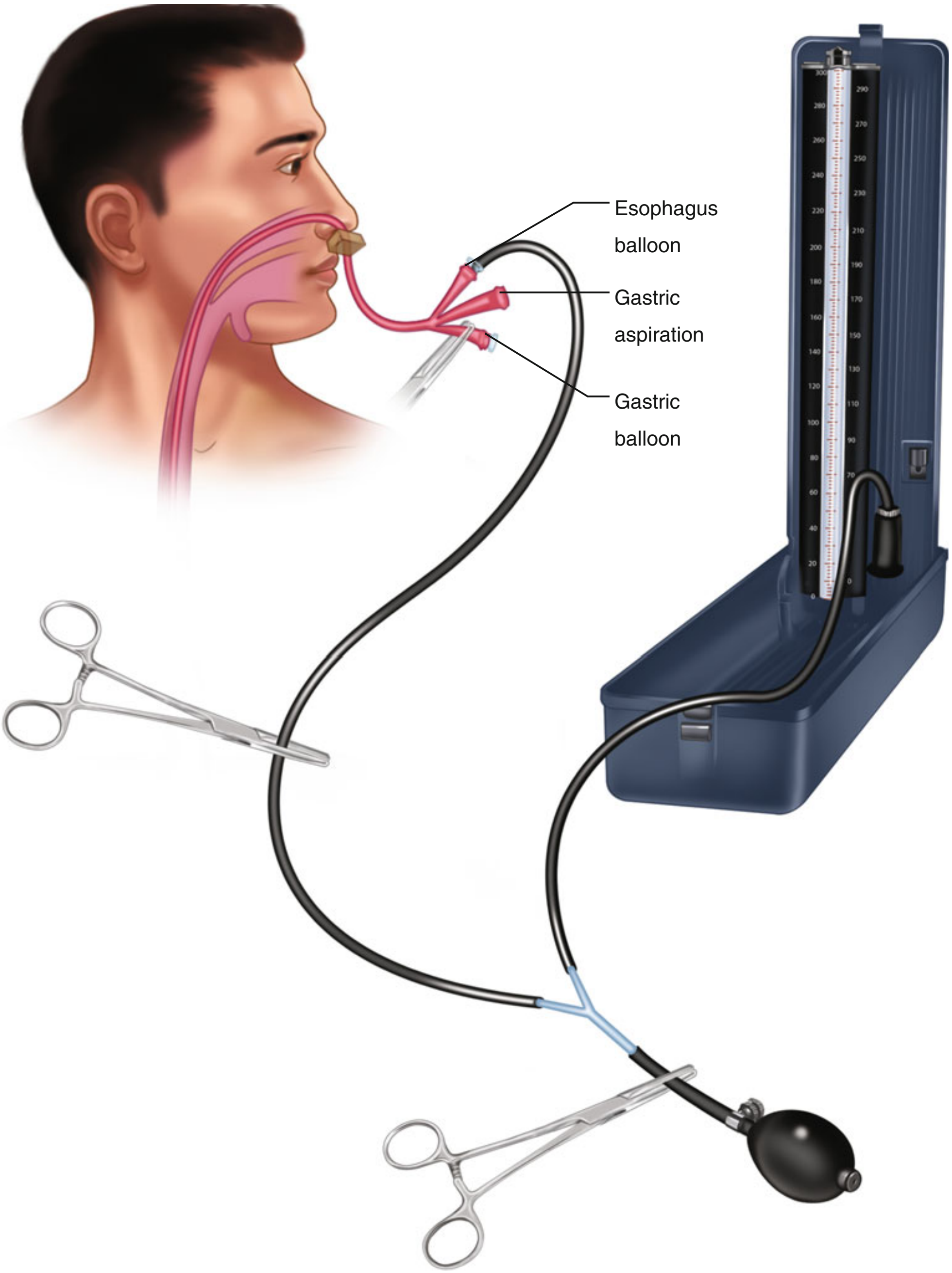
Esophagus balloon
Gastric aspiration
Gastric balloon

77.5 Complications

- Esophageal rupture occurs owing to esophageal erosion and necrosis owing to a balloon tamponade effect on tissue perfusion or overzealous balloon inflation.
- Airway obstruction owing to gastric tube deflation or failure, allowing esophageal tube to move up and occlude airway. Keep scissors near the patient to cut the SB tube lumens and remove the tube as necessary.
- Regurgitation and aspiration pneumonia from failure to adequately suction oropharyngeal secretions.

77.6 Pearls and Pitfalls

- Pearls
  - The esophageal balloon should not be inflated if the gastric balloon alone stops the bleeding.
  - Never inflate the esophageal balloon without the inflating the gastric balloon first. This will prevent it from slipping proximally into the oropharynx and obstructing the airway.
  - Nausea, vomiting, or aspiration is highly likely to occur. Use antiemetics and lavage the stomach before the procedure.
  - Intubate if there is airway compromise or risk of aspiration into the lungs.
  - Inflate the esophageal balloon only to the minimum pressure necessary to stop the variceal bleeding.
  - Using a catcher's mask may be more practical and comfortable for the recumbent patient.
- Pitfalls
  - The SB tube may induce hiccups.

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Gastrostomy Tube Placement

78

Nathaniel Lisenbee and Latha Ganti

There are several types of gastrostomy tubes and related procedure variations:

- Procedure variations:
  - Open gastrostomy tube (G tube)
  - Percutaneous endoscopic gastrostomy (PEG) tube
  - Laparoscopic G tube
- Tube types:
  - PEG tube (Fig. 78.1)
  - Malecot tube (Fig. 78.2)
  - Balloon G tube (Fig. 78.3)
  - Low-profile G tube (nonobturated, button) (Fig. 78.4)
  - Low-profile G tube (obturated, button) (Fig. 78.5)

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Fig. 78.1 Percutaneous endoscopic gastrostomy (PEG) tube

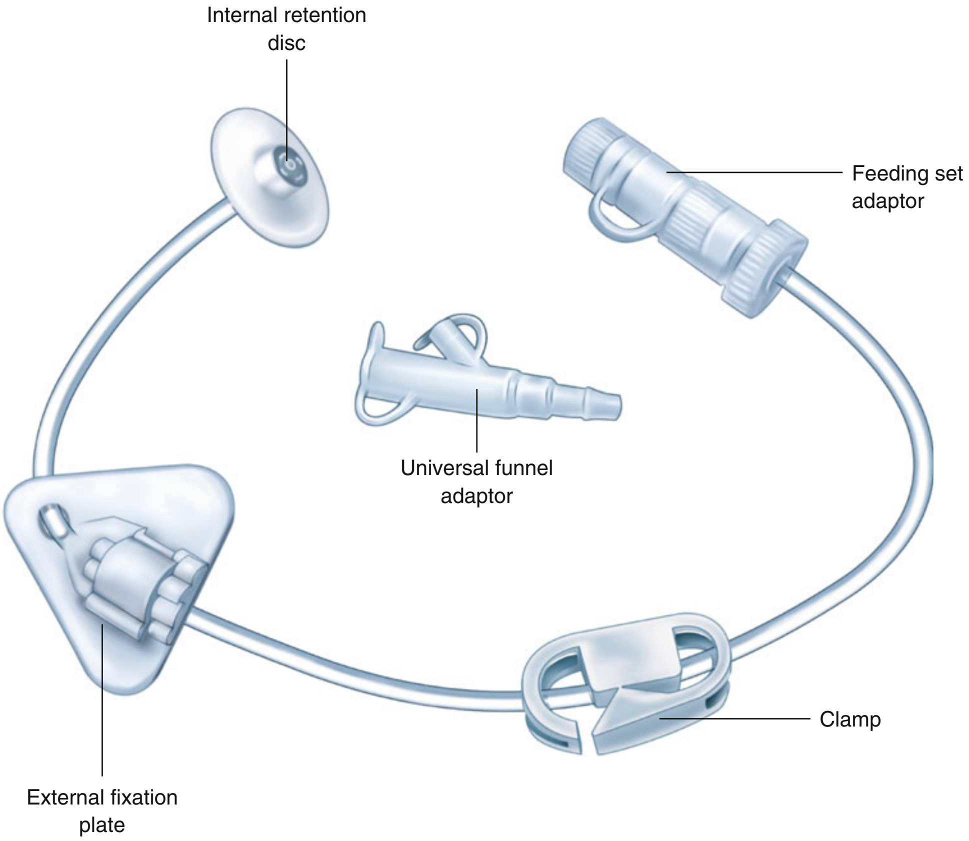
Internal retention disc
Feeding set adaptor
Universal funnel adaptor
Clamp
External fixation plate

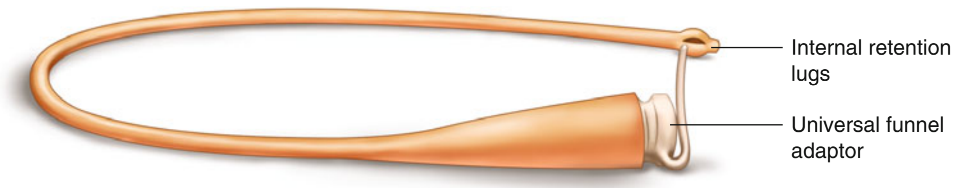
Internal retention lugs
Universal funnel adaptor

Fig. 78.2 Malecot tube

Fig. 78.3 Balloon gastrostomy tube

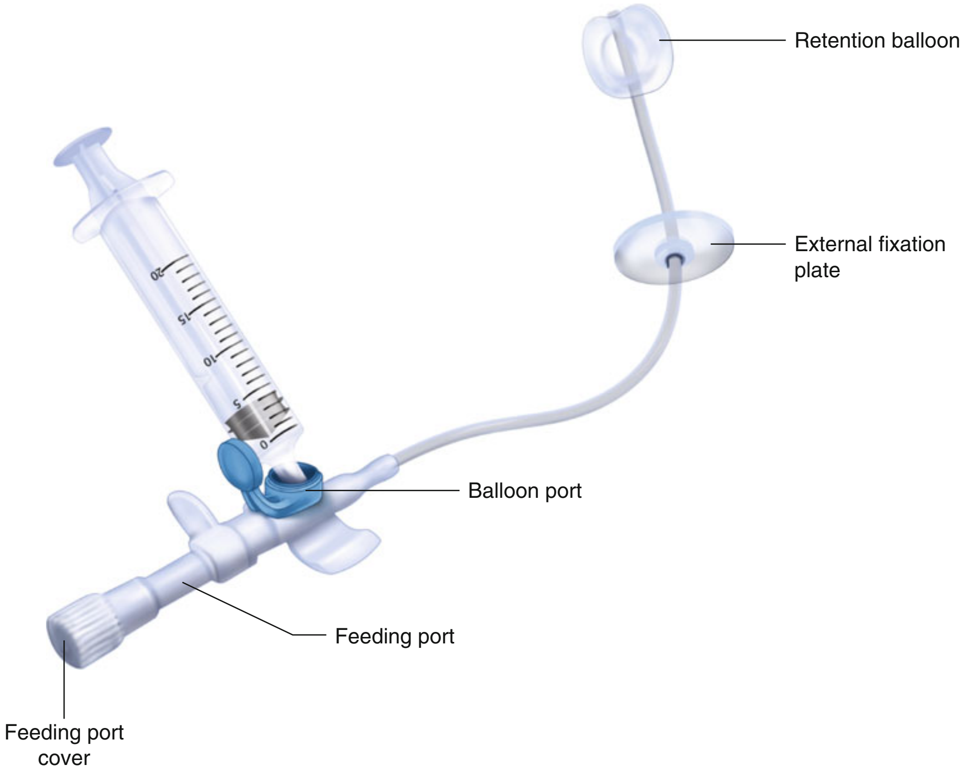
Retention balloon
External fixation plate
Balloon port
Feeding port
Feeding port cover
20
15
10
5
0

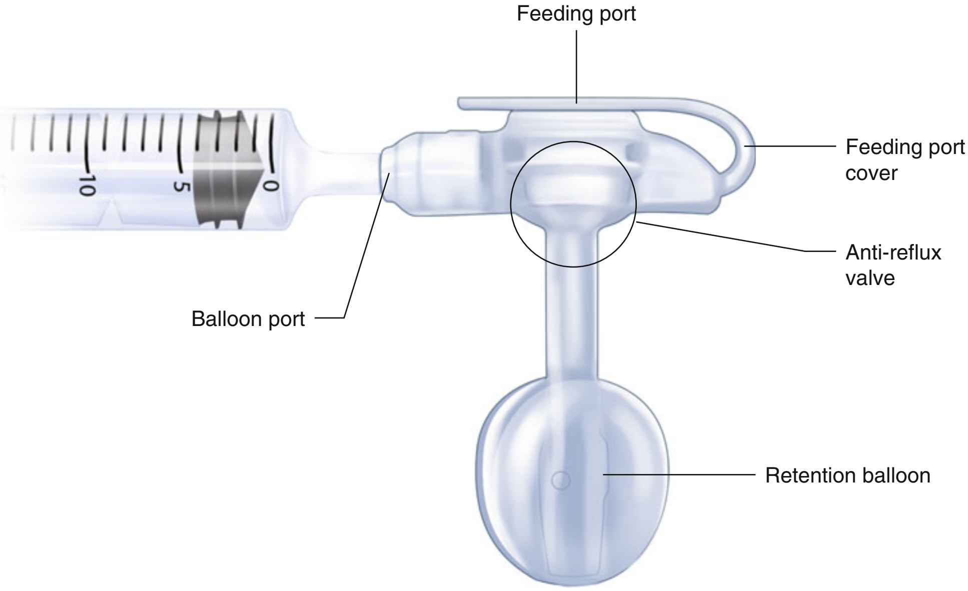
Feeding port
Feeding port cover
Anti-reflux valve
Balloon port
Retention balloon
10
5
0

Fig. 78.4 Low-profile gastrostomy tube (nonobturated, button)

Fig. 78.5 Low-profile gastrostomy tube (obturated, button)

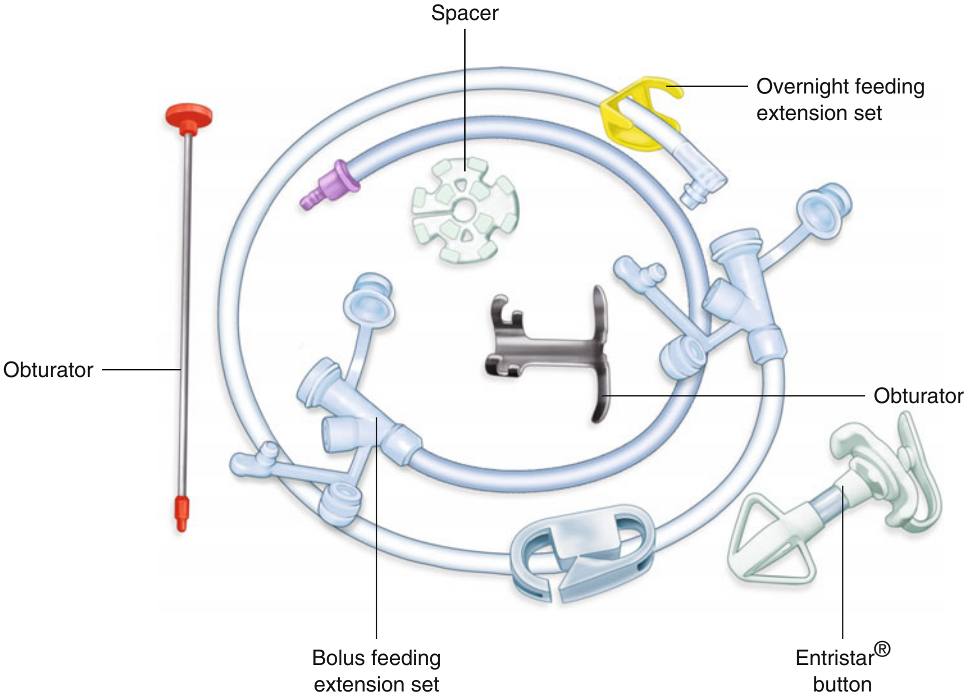
Spacer
Overnight feeding extension set
Obturator
Obturator
Bolus feeding extension set
Entristar® button

78.1 Indications

- Inability to swallow
  - Neurological deficit
  - Head trauma
  - Facial burns
  - Decreased mental status
- Need for gastric decompression
  - Gastric outflow obstruction
  - Small bowel obstruction (SBO), ileus, or volvulus
  - Intra-abdominal malignancy

78.2 Contraindications

- Absolute
  - Peritonitis
  - Ascites
- Relative
  - Hemodynamic instability
  - Coagulopathy
  - Abdominal wall infection at surgical site
  - History of gastric resection
  - Portal hypertension
  - Gastric varices

78.3 Materials and Medications

- Materials
  - Gloves
  - Lubricant
  - G tube (commercial kit) or Foley catheter
  - Sterile saline
  - External bolster
  - Multiple syringes
  - Suture material
  - Needle driver
  - Scissors
  - Stethoscope
- Medications
  - PEG tube placement
    - Moderate sedation (e.g., propofol, midazolam, fentanyl)
    - Local anesthesia (e.g., lidocaine, bupivacaine)
  - Open or laparoscopic G tube placement (not an emergency department procedure)
    - General anesthesia

78.4 Procedure (PEG Tube Replacement)

1. If the G tube is only partially removed upon patient presentation, the tube must first be removed.
2. Remove the G tube by deflating the balloon and pull gently on the tube while applying pressure to the abdominal wall at the surgical site.
3. The G tube should slide out easily with gentle traction, and the procedure should be discontinued if it does not.
4. Initially, it is important to assess the tract to determine the size and potential need for dilation.
5. If necessary for tube passage, the tract can be dilated with a cotton-tipped applicator or hemostat; however, be sure to dilate gently because it is possible to create a false tract.
6. Once the tract has been assessed, obtain the appropriate tube for replacement.
7. Initially, attempt replacement of the patient's G tube with an identical tube.
8. If an identical tube is not available, attempt placing a small Foley catheter in the tract to ensure that it stays open.
9. To initiate placement, place lubricant on the tube and carefully advance the tube into the tract.
10. Once the tube is in place, secure an air-filled syringe to the tip of the tube and insufflate a small amount of air into the stomach while auscultating to confirm passage of air into the stomach.
11. Secondary procedural confirmation can be performed by aspirating gastric contents from the tube.
12. Once placement is verified, do not forget to inflate the balloon with saline and then pull the tube backward until it abuts the inside of the stomach wall (Fig. 78.6).
13. Finally, it is very important to secure the external portion of the tube to prevent the tube from being lost into the stomach.
14. Commercial G tubes are accompanied by a bolster made specifically for the specific type of G tube in order to provide security of tube placement.

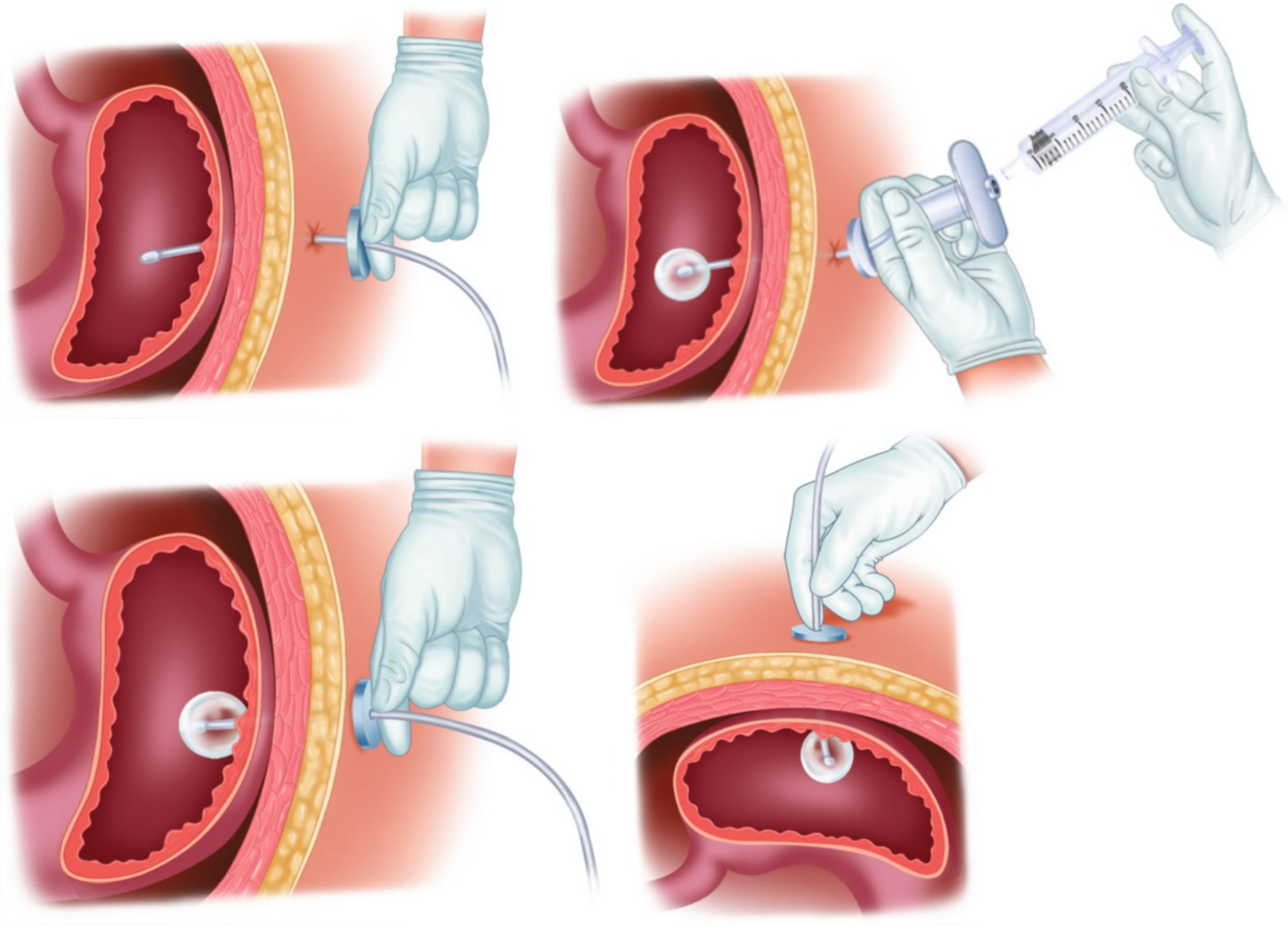

Fig. 78.6 Placement of low-profile gastrostomy tube

15. If a Foley catheter is used to maintain tract patency, an external bolster must be created using the following steps:
    - Trim a 2- to 3-in. portion from the tip of the catheter.
    - Cut two small holes just above each other on the 2- to 3-in. trimmed catheter portion.
    - Slide the external portion of the Foley catheter through both holes of the bolster.
    - Slide the bolster down the Foley catheter to the abdominal wall.
    - Secure the two ends of the bolster to the skin in order to maintain patency of the Foley catheter.
    - An interventional radiologist may also be contacted to advance the tube over a wire under fluoroscopic guidance.
16. Radiographic confirmation.
    - Typically, G tube placement is confirmed by injecting approximately 20 mL of Gastrografin® (diatrizoate meglumine, diatrizoate sodium) water-soluble contrast into the G tube, followed shortly by an abdominal x-ray.
    - Proper placement will result in an abdominal radiograph showing contrast outlining the stomach (Fig. 78.7).

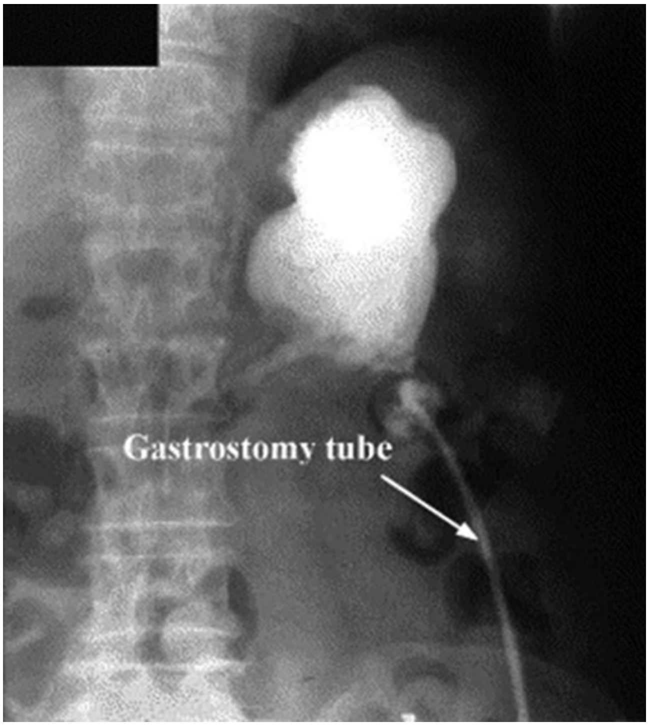

Fig. 78.7 An anteroposterior abdominal radiograph after PEG tube placement and injection of 25 mL of gastrografin. The tube can be seen projecting up the left side of the abdomen, and contrast medium appears to enter the stomach lumen. The balloon is not visualized in the stomach (Reproduced with permission from: Burke DT, El Shami A, Heinle E, and Pina BD. Comparison of gastrostomy tube replacement verification using air insufflation versus gastrografin. Archives of physical medicine and rehabilitation. 2006;87(11): 1530–3.)

78.5 Pearls and Pitfalls

- Pearls
  - Even if a patient's G tube is only partially removed upon presentation to the emergency department, the tube likely needs complete removal and replacement.
  - Most G tubes are easily removed at the bedside; however, some are not able to be safely removed in the emergency department setting. Thus, if the tube does not withdraw easily, attempt to contact the proceduralist who placed the tube in order to inquire about the best method for removal.
- Pitfalls
  - Never use barium contrast when confirming G tube placement radiographically because barium can cause significant intra-abdominal damage if accidentally injected in the intraperitoneal cavity.

78.6 Complications

- Aspiration
- Surgical site infection
- Bleeding
- Pneumoperitoneum
- Accidental perforation of the colon or small bowel
- Tube dislodgment
- Peritonitis

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Paracentesis

79

Shalu S. Patel and Bobby K. Desai

79.1 Indications

- Diagnosis of infection in ascites
- Diagnosis of malignant ascites
- Diagnosis of hemoperitoneum in traumas
- Relief of abdominal pressure/pain or respiratory compromise secondary to ascites

79.2 Contraindications

- Severe coagulopathy
  - Prothrombin time (PT) > 21 s
  - International normalized ratio (INR) > 1.6
  - Platelets < 50,000/mm^3
- Skin infection over the needle insertion site
- Acute abdomen that requires surgery
- Pregnancy
- Distended bowel
- Intra-abdominal adhesions

79.3 Materials and Medications

- 18- to 22-gauge 1.5- to 3.5-in. needle or angiocatheter, 25-gauge needle
- Lidocaine 1 or 2 % (10 mL)
- Syringes
  - 10 mL (1), 50 mL (2)
- 1-L vacuum bottle (4) (if therapeutic tap)
- Thoracentesis kit tubing or any high-pressure connection tubing (if therapeutic tap)
- Sterile gloves
- Surgical pen (recommended)
- Povidone-iodine (Betadine) or other skin antiseptic
- Sterile drape
- Sterile gauze (4 × 4)
- Band-Aid
- Bedside ultrasound (recommended)

79.4 Procedure (Fig. 79.1)

1. Position the patient supine. If possible, adjust the head of the bed to make a 45° angle to help the fluid accumulate in the pocket. Sometimes, it may also be beneficial to have the patient lie recumbent toward the site of drainage.
2. Scan the abdomen with an ultrasound to determine whether there is a pocket of fluid that can be drained. This also allows the physician to see how far the needle needs to be inserted and how deep it can be placed without risking injury to the bowel (Fig. 79.2).
3. Mark the optimal needle insertion site with a surgical pen.
4. Prepare the skin and drape in a sterile fashion.
5. Using lidocaine, anesthetize the appropriate area subcutaneously and then continue to insert the needle, and inject anesthetic through the deeper tissues until ascitic fluid can be drawn back.
6. Withdraw the needle.
7. When ready for the paracentesis, stretch the skin caudad and insert the needle or angiocatheter (connected to a syringe) while aspirating. Then, release the skin and continue to insert the needle or angiocatheter through the peritoneal wall until fluid is retrieved. This will create a "Z-track" that will decrease leakage of peritoneal fluid through the skin.

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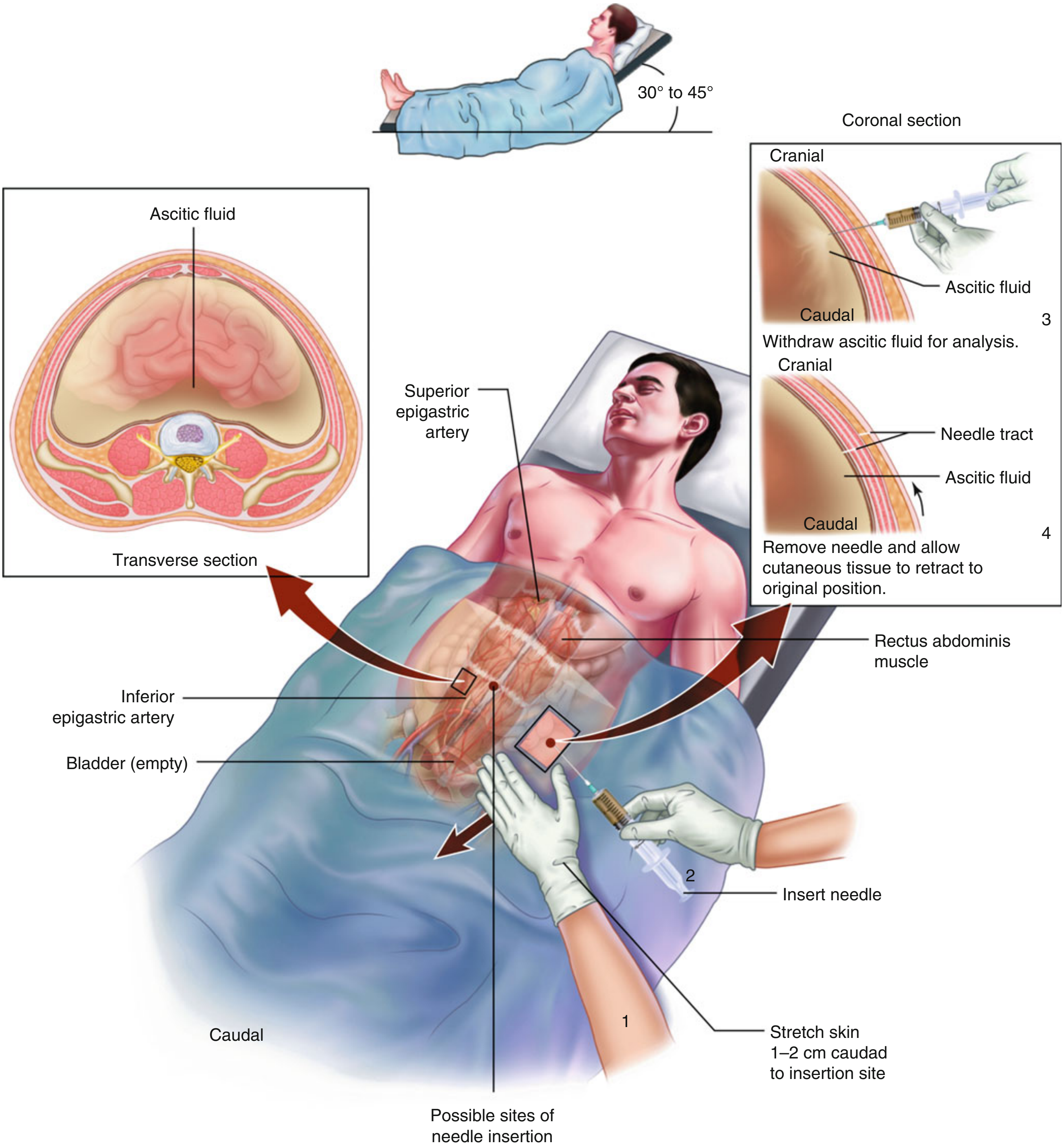
30° to 45°
Coronal section
Cranial
Ascitic fluid
Caudal
3
Withdraw ascitic fluid for analysis.
Cranial
Needle tract
Ascitic fluid
Caudal
4
Remove needle and allow cutaneous tissue to retract to original position.
Ascitic fluid
Transverse section
Superior epigastric artery
Rectus abdominis muscle
Inferior epigastric artery
Bladder (empty)
2
Insert needle
1
Caudal
Stretch skin 1–2 cm caudad to insertion site
Possible sites of needle insertion

Fig. 79.1 Paracentesis procedure

8. Once fluid is retrieved, push in the catheter and remove the needle portion (if used) or hold the needle steady.
9. Aspirate from the catheter to ensure that it is in the appropriate location.
10. If fluid easily is aspirated, unscrew the syringe and connect a 50-mL syringe to the needle or catheter and fill it with fluid. This may be done twice. Alternatively, if the procedure is done for therapeutic purposes, attach the tubing that is already connected to the vacuum bottle to the catheter and allow the vacuum to withdraw fluid into the collection bottles.
11. If fluid cannot be aspirated easily, the catheter can be repositioned further in the pocket or turned by 45° sequentially as needed.

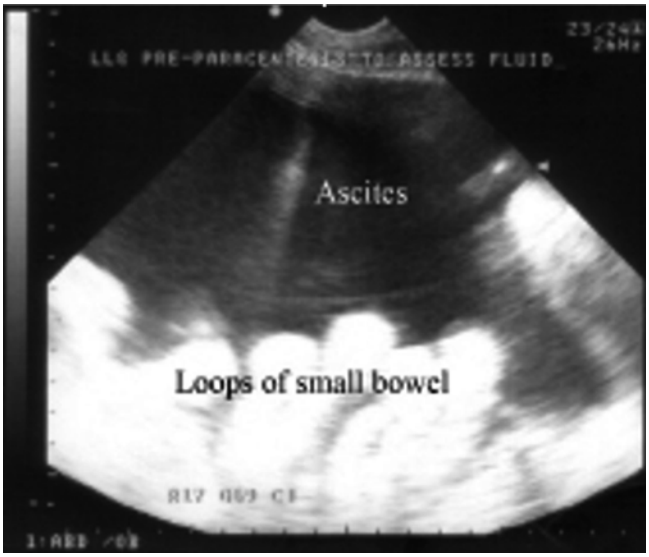

Fig. 79.2 Ultrasound to determine whether there is a pocket of fluid that can be drained

12. Once the fluid is aspirated, pull out the needle or angiocatheter and hold pressure with gauze. Bleeding should be minimal.
13. Place a Band-Aid or other dressing over the site.
14. Send the fluid to the laboratory. Generally, laboratory analyses include protein, albumin, specific gravity, glucose, bilirubin, amylase, lipase, triglyceride, lactate dehydrogenase (LDH), cell count and differential, culture and sensitivity (C&S), Gram stain, acid-fast bacillus (AFB), fungal culture, cytology, and pH.

79.5 Complications

- Persistent leakage from the needle insertion site
- Abdominal wall hematoma
- Bowel perforation
- Introduction of infection
- Hypotension (after a large-volume paracentesis)
- Dilutional hyponatremia
- Hepatorenal syndrome
- Bleeding
- Postparacentesis circulatory dysfunction

79.6 Pearls and Pitfalls

- Pearls
  - The preferred site of entry is in the midline of the abdomen, below the umbilicus.
  - The serum-ascites albumin gradient (SAAG) can be used to identify the cause of the ascites. It is calculated by subtracting the albumin concentration in the ascites from the albumin concentration in the serum. A high gradient (>1.1 g/dL) suggests portal hypertension, whereas a low gradient (<1.1 g/dL) suggests other causes.
  - Postparacentesis circulatory dysfunction (PPCD) occurs secondary to hypovolemia after large-volume paracentesis (>4 L) in cirrhotic patients. It is associated with worsening hyponatremia, renal dysfunction, shorter time to ascites recurrence, and increased mortality. Prevention of PPCD has been demonstrated with the administration of 6–8 g of albumin per liter of ascites removed.
- Pitfalls
  - Polymorphonuclear lymphocyte (PMN) count greater than 250/mm^3 is diagnostic of spontaneous bacterial peritonitis.

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80

Anal Fissure Management

David P. Nguyen, L. Connor Nickels, and
Giuliano De Portu

80.1 Indications

- An anal fissure is a small ulcer of the mucosa at the anal verge (Fig. 80.1).
- It is the most common cause of intense sudden rectal bleeding.
- Posterior midline anal fissures are the most common type (90 %).
  - Mostly found in young adults (30–50 y) but can occur at any age.
  - Usually associated with constipation (firm, large-caliber, painful bowel movements) or chronic diarrhea.
  - Most uncomplicated fissures resolve in 3–4 weeks.
- Can be extremely painful, during and after defecation.
- Classified as acute or chronic.
- Now believed to be caused by reduced anal blood flow in the posterior midline, anal sphincter hypertonia, and thus mucosal ischemia.

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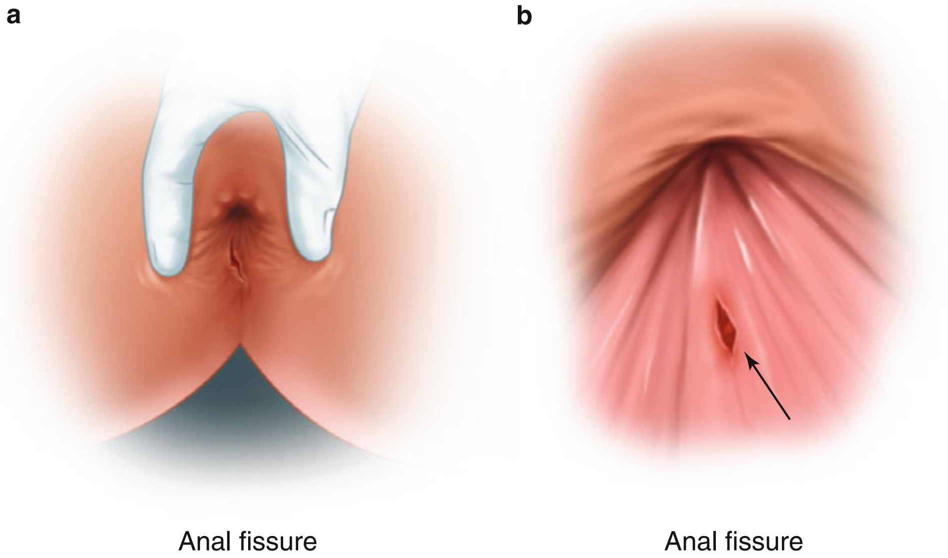
a
b
Anal fissure
Anal fissure

Fig. 80.1 (**a**, **b**) Anal fissures

80.2 Contraindications

- Digital rectal examination should be avoided unless the diagnosis is in doubt.
- Surgical procedures are generally reserved for when medical management has failed after 1–3 months of treatment.

80.3 Materials and Medications

- Standard precautions barrier protection for the provider.
- Good light source.
- Optional emergency department treatments:
  - Topical anesthetic/preparation (Anusol [pramoxine hydrochloride; zinc oxide] with cortisone).
  - Nitroglycerin (0.2 %) or nifedipine gel (2 %) is second-line therapy (relaxes muscles and promotes blood flow).

80.4 Procedure

1. In a private, calm environment, gently spread the buttocks for complete visual inspection.
   - This may cause an increase in the patient's pain and spasming.
   - If a fissure is clearly identified, stop here.
2. Apply topical anesthetic/preparation for symptomatic relief (optional, as the physician may want to just start with the treatments that follow).
3. Discharge the patient with conservative therapy management.
4. In acute anal fissures (onset of 3–6 weeks), medical management is indicated along with dietary modifications (WASH regimen [warm baths, analgesia, stool softeners, high-fiber diet]):
   - Warm sitz baths.
     - Usually 20 min soaking each time
     - Recommended after every bowel movement
     - At least twice per day if not having regular bowel movements
   - High-fiber diet with fiber supplements.
   - Increase fluid intake.
   - May add stool softeners, if needed.
   - If chronic or the previous regimen has been exhausted, one of the following may be considered:
     - 0.2–0.4 % nitroglycerin cream applied to anal area
       - May cause headache
       - Recommend wearing a glove to prevent absorption through digital skin
     - Calcium channel blockers:
       - Topical nifedipine
       - 2 % diltiazem cream
     - Botulinum toxin A injection:
       - Controversial; may have poorer success rates than surgery
5. Provide surgical referral for nonhealing wounds.
   - Lateral internal sphincterotomy is the surgical procedure of choice.

80.5 Complications

- Infection
- Abscess
- Bleeding
- Chronic fissure formation
- Postsurgical fecal incontinence

80.6 Pearls and Pitfalls

- Pearls
  - Multiple or recurrent fissures are associated with Crohn's disease, tuberculosis, syphilis, human immunodeficiency virus (HIV), and malignancy.
- Pitfalls
  - Suspect child abuse if an anal fissure is found in a child.

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Part XI

Genitourinary Procedures

Bladder Catheterization

81

Maritza A. Plaza-Verduin and Judith K. Lucas

81.1 Indications

- Obtaining a sterile urine specimen
- Preventing or relieving urinary retention
- Close monitoring of urine output for fluid balance with an indwelling urinary catheter
- Urgent cystourethrography
- Child with contusion or burns to the perineum and at risk for meatal swelling and obstruction to urine outflow
- Temporary measure to relieve lower urinary tract obstruction
- Neurogenic bladder
- Anesthesia-induced and/or surgery-induced urinary retention has occurred.

81.2 Contraindications

- Absolute
  - Potential urethral injury from trauma
    - Pelvic fractures
    - Known trauma to the urethra
    - Blood at the meatus
- Relative
  - Recent genitourinary surgery (consult with a urologist before placing a catheter)

81.3 Materials and Medications

- Bladder catheterization kit:
  - Sterile gloves
  - Sterile drapes
  - Povidone-iodine (Betadine) solution
  - Cotton sponges or applicators for sterilizing solution
  - Lubricant
  - Specimen collection cup
  - Catheter
    - 5-French feeding tube for neonates
    - 8-French catheters for Infants
    - 10- to 12-French catheters in older children
- Local anesthetic (if desired—2 % lidocaine hydrochloride jelly)
- Absorbent pad

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81.4 Procedure

1. Inspect the urinary catheterization tray for all the appropriate materials.
2. Place the patient supine with an absorbent pad under the buttocks.
   (a) Girls should be placed in the frog-leg position (Fig. 81.1).
3. Before sterilizing the field, locate the urethral opening.
4. Remove any powder, ointments, or medicated creams the child might have on the perineum.
5. If needed, apply anesthetic to the area.
   (a) Soak a cotton ball with anesthetic (2 % lidocaine hydrochloride jelly) and hold over the urethra opening for 2 min.
   (b) 0.5–2.0 mL of anesthetic can also be injected into the urethra.
6. Sterilize the area and place drapes appropriately, exposing the genitalia.
7. Catheterization of males
   (a) If uncircumcised, gently retract foreskin, *if possible*, for cleaning and visualization of the meatus.
   (b) Hold the penis using the nondominant hand at a 90° angle from the body (Fig. 81.2).
   (c) Lubricate the catheter tip.
   (d) Insert the lubricated catheter into the meatal opening and advance it while applying gentle traction to the penis from the base of the penis.
   (e) If resistance is met, maintain gentle pressure with the catheter.
      - *Do not attempt to force the catheter that could create a false tract or traumatic fistula.*
   (f) Advance the catheter until urine is obtained, approximately inserting the catheter to just beyond the penile length.
   (g) Once completed, gently withdraw the catheter.
   (h) Clean the area, wiping away the Betadine solution.
   (i) If uncircumcised, pull the foreskin over the glans to avoid paraphimosis.
8. Catheterization of females
   (a) Sterilization of the area should occur from anterior to posterior.
   (b) Have an assistant hold the labia majora apart.
      (i) If no assistant is available, use the nondominant hand to hold the labia apart.
         - Holding the labia majora with a gentle outward, lateral, and upward traction will help visualize the meatus (Fig. 81.3).

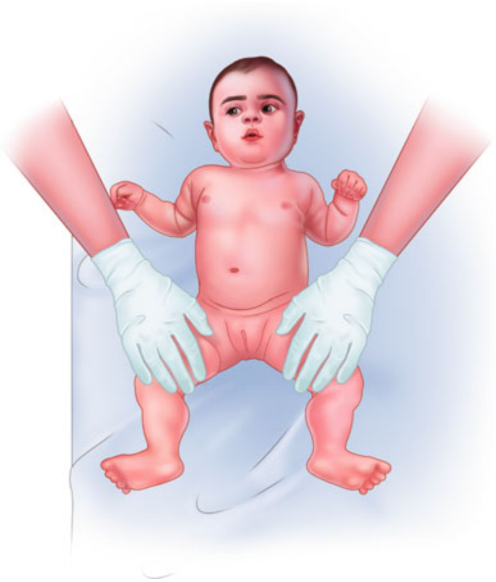

Fig. 81.1 Infant held in the frog-leg position for catheterization

Fig. 81.2 Bladder catheterization of a male; penis should be held perpendicular to the body

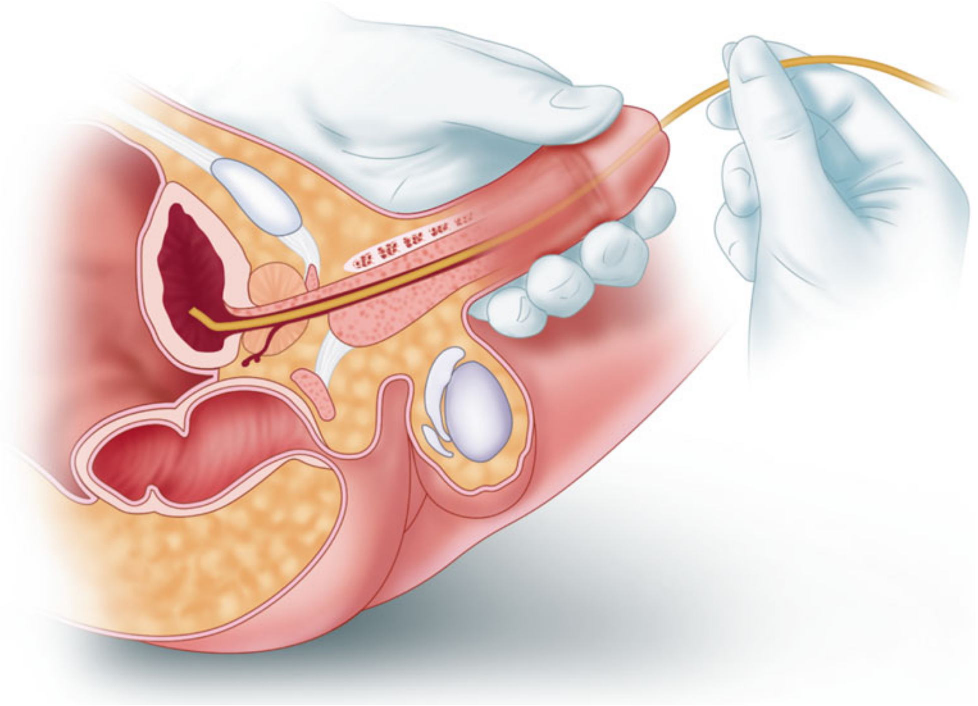

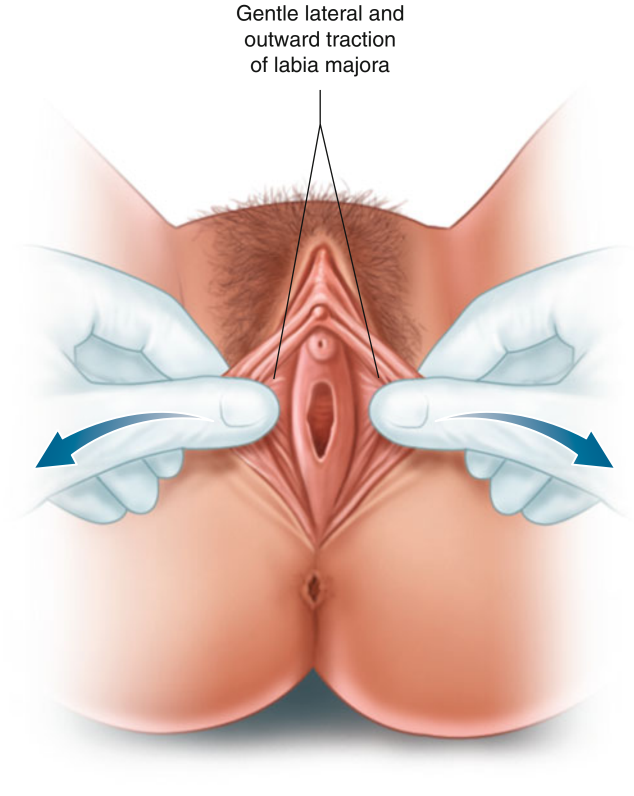
Gentle lateral and
outward traction
of labia majora

Fig. 81.3 Positioning of labia for better visualization of the meatus

- Downward displacement of the cephalad aspect of the vaginal introital fold with a cotton-tipped applicator can help visualize the urethral meatus (Fig. 81.4).

(c) Lubricate the catheter tip.

(d) Insert the lubricated catheter into the meatal opening. Advance slowly until urine is obtained (Fig. 81.5).

(e) Once completed, gently withdraw the catheter.

(f) Clean area, wiping away the Betadine solution.

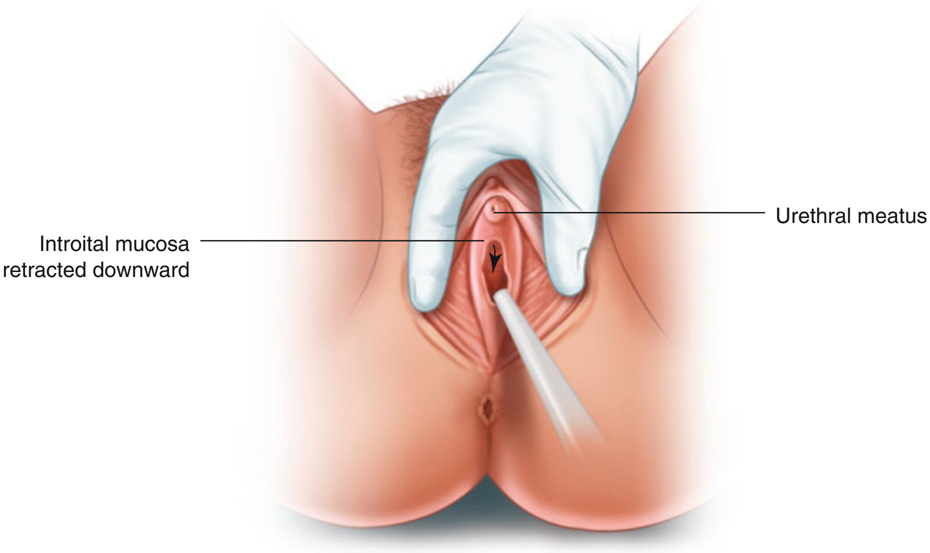

Fig. 81.4 Better visualization of the meatus is achieved with downward displacement of the introital mucosa

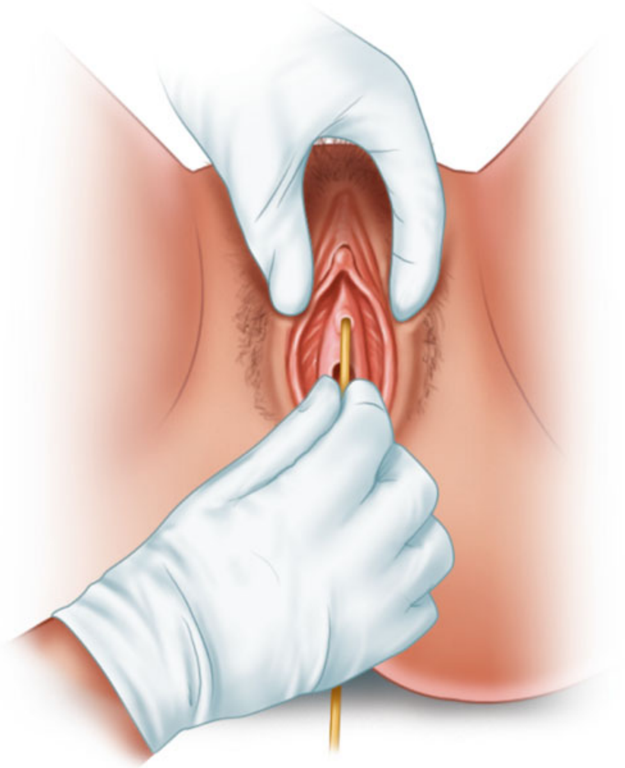

Fig. 81.5 Bladder catheterization of a female

81.5 Complications

- Urethral or bladder injury
- Infection if sterile field not maintained
- Paraphimosis owing to failure to restore a retracted foreskin to its normal position

81.6 Pearls and Pitfalls

- Pearls
  - It is not necessary to fully retract a foreskin. This only causes trauma and increases the likelihood of paraphimosis. As the infant/boy ages, the foreskin will loosen and the naturally occurring adhesions will spontaneously release.
  - The urethral meatus in an infant female is usually tucked just above the redundant hymen (as opposed to the more anteriorly located meatus in the adult woman) and often looks like a dimple or small blind pouch.
  - Using viscous lidocaine in lieu of, or blended with, lubricant anesthetizes the meatus and urethra as the catheter passes.
  - Have the specimen cup at the ready because, at times, once the (usually cold) Betadine or antiseptic solution is applied, the infant often releases the urine and it can be caught, literally, midstream.
  - In the uncircumcised male, be certain to return the foreskin over the glans to avoid paraphimoses.
- Pitfalls
  - If catheterizing a child in search of infection, send a urine culture regardless of the urinalysis results because the younger infants can have false-negative urinalysis and still have positive cultures.

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Pelvic Examination and Wet Preparation

82

Nauman W. Rashid, Elaine B. Josephson,
and Muhammad Waseem

82.1 Indications

- Lower abdominal or pelvic pain
- Vaginal bleeding or discharge
- Cancer screening
- Pregnancy
- Exposure to sexually transmitted disease
- Sexual assault

82.2 Contraindications

- Physical or mental disability
- Recent gynecological surgery
- Third-trimester pregnancy with bleeding
- Premenstrual females (may not be indicated in adolescents, who are not sexually active, unless there is discharge, bleeding, suspicion for abuse, or a foreign body)
- If a speculum examination is necessary, examination under general anesthesia should be considered.

82.3 Materials and Medications

- Examination table with stirrups (Fig. 82.1)
- Reliable light source
- Appropriately sized speculum (Fig. 82.2)
- Endocervical brush or spatula
- Culture swab for gonorrhea and chlamydia
- Large cotton swabs for vaginal discharge or bleeding (Fig. 82.2)
- pH paper
- Saline and potassium hydroxide dropper bottles for wet preparations
- Lubricating gel
- Disposable gloves (Fig. 82.2)
- Small stool or chair for examiner

82.4 Procedure

1. Obtain permission from patient before beginning examination.
2. Chaperone should be present (medical staff member).
3. Make sure the examination table is clean and appropriately draped.
4. Have the patient in a loose-fitting gown.
5. Place the patient on the examination table in the lithotomy position with both feet in the stirrups and have the patient's pelvis as close to the edge of the table as possible.
6. Turn on the light source and adjust for optimum illumination. Put on the disposable gloves.
7. Communicate the procedure well to the patient.
8. Begin the examination with inspection and palpation of the abdomen.
9. Examine the external genitalia. Evaluate the skin, labia minora and majora, clitoris, urethral meatus, vaginal

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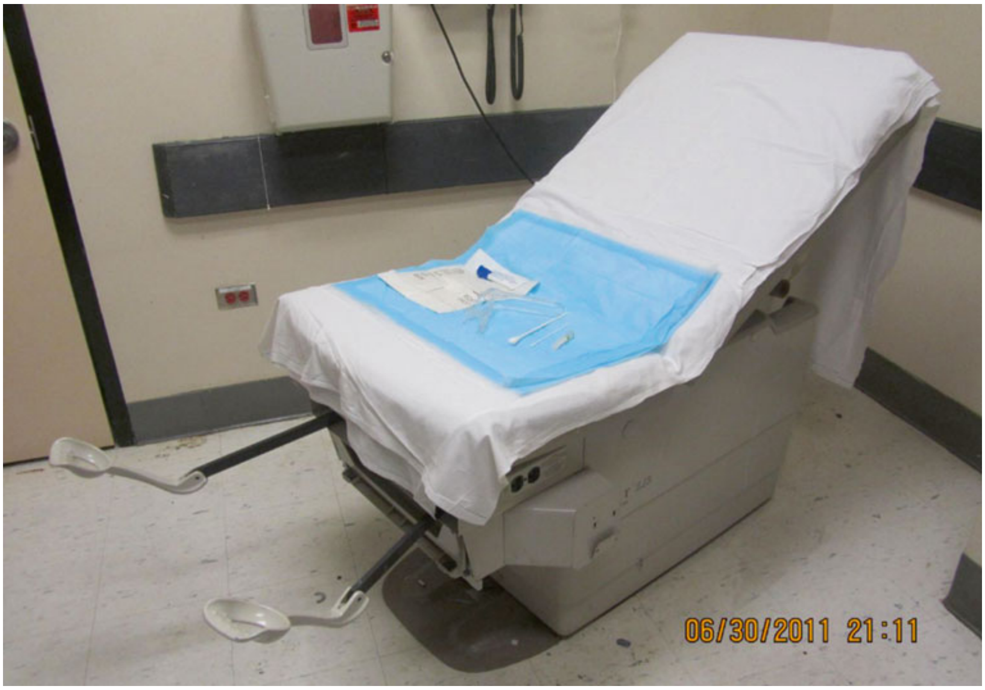

Fig. 82.1 Examination table with stirrups

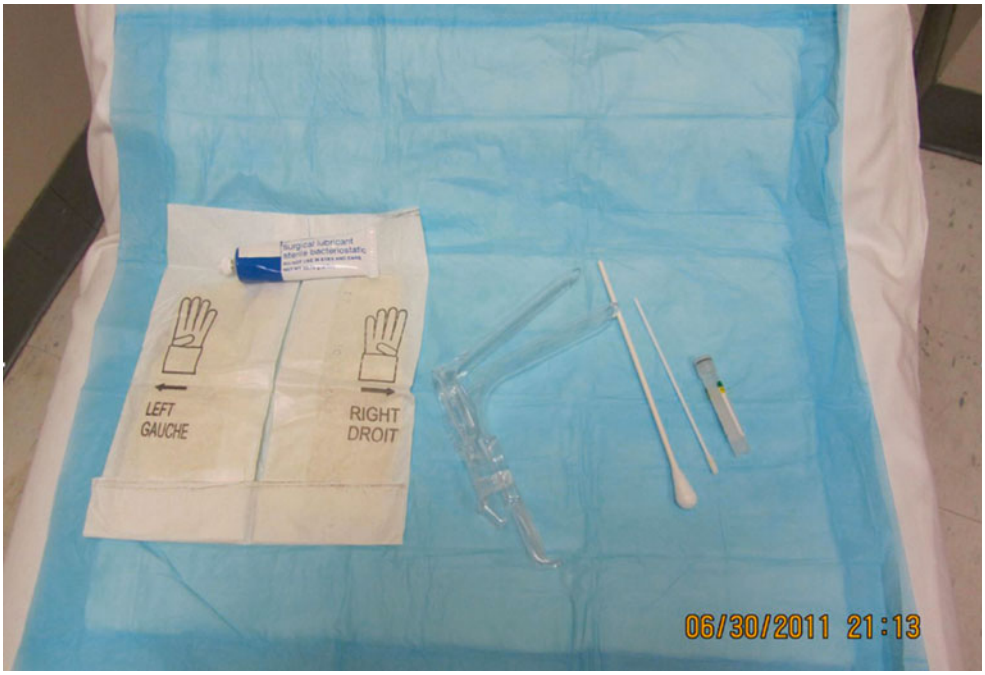

Fig. 82.2 Gloves, speculum, and swabs

canal, and Bartholin glands (Fig. 82.3). Look for skin abnormalities, lesions, masses, rashes, excoriation, abscesses, discharge, bleeding, or trauma. Palpate for tenderness.

10. Lubricate the appropriate-size speculum (mostly medium size). Insert the speculum through the vaginal opening with gentle downward pressure. The speculum should advance without any resistance until the cervical os is visualized.
11. Inspect the vaginal walls for any lesions or masses (Fig. 82.4). The cervical os is inspected to see if it is open or closed. Cervical cultures for gonorrhea and chlamydia are obtained with a cotton swab and sent for microbiology.
12. A sample of the discharge or bleeding is taken with a large cotton swab. The color, odor, and amount should be noted. The pH of the vaginal discharge can be evaluated. Normal pH is less than 4.5. An elevated pH indicates an infection (Table 82.1).

Fig. 82.3 Female external genitalia

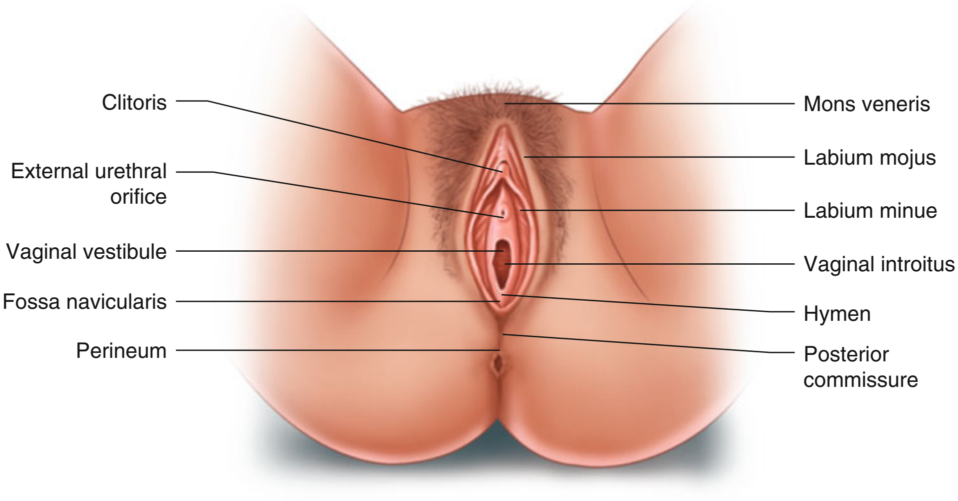
Clitoris
External urethral orifice
Vaginal vestibule
Fossa navicularis
Perineum
Mons veneris
Labium mojus
Labium minue
Vaginal introitus
Hymen
Posterior commissure

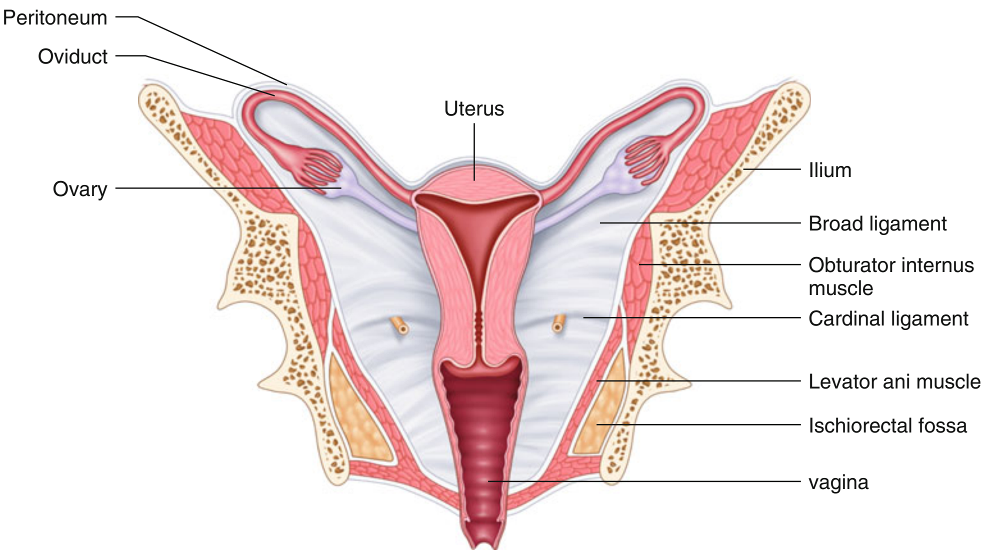
Peritoneum
Oviduct
Ovary
Uterus
Ilium
Broad ligament
Obturator internus muscle
Cardinal ligament
Levator ani muscle
Ischiorectal fossa
vagina

Fig. 82.4 Female internal genitalia

Table 82.1 Wet preparation interpretation

Organism	Preparation	pH	Microscope	Cervix	Appearance of discharge
Bacterial vaginosis	Saline	>4.5	Clue cells	Redness	Thin, milky, fishy odor
Trichomoniasis	Saline	>4.5	Motile flagella	Strawberry red	Yellow-green, foamy
Yeast	Potassium hydroxide	3.8–4.5	Budding yeast pseudohyphae	Normal	White, cottage cheese

13. Next, a bimanual examination should be performed (Fig. 82.5). Lubricating gel is applied to the nondominant gloved hand and the index and middle finger are inserted into the vagina until the cervix is felt. The other hand is placed on the abdomen to palpate the uterus and ovaries. Pressure is applied to the abdomen while the vaginal hand is elevated upward.
14. The cervix is palpated to elicit any cervical motion tenderness. The uterus is palpated and the size, position, and mobility are noted. The adnexa are examined for masses and tenderness. If a mass is palpated, the size, mobility, consistency, and tenderness are noted.
15. The final part of the pelvic examination is the rectovaginal examination. Lubricate the index and middle fingers

of the left hand. Place the index finger in the vagina and the middle finger in the rectum. Palpate for any fistulas or masses. With the finger, also palpate the uterosacral ligaments, the broad ligaments, and the pelvic side walls. The finger is then gently removed and any feces are inspected for mucous or occult blood.

16. A wet preparation is made by obtaining a sample of the vaginal discharge and placing it in a vial mixed with saline solution. A drop of the solution is placed on a microscopic slide and examined under high magnification for the presence of clue cells (Fig. 82.6) diagnostic for bacterial vaginosis and trichomonads (Fig. 82.7) diagnostic for trichomoniasis. For yeast, two drops of the solution is mixed with two drops of potassium hydroxide. Presence of hyphae is diagnostic of candida (yeast) species (Fig. 82.8)

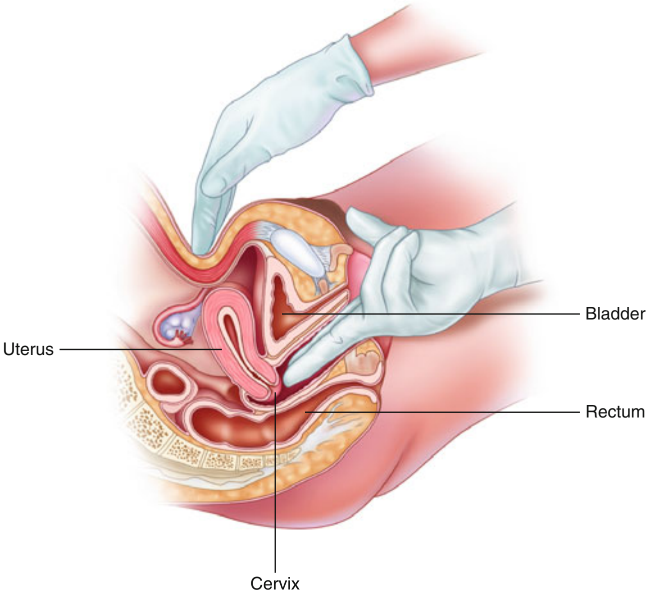

Fig. 82.5 Bimanual pelvic examination

82.5 Complications

- Urinary tract infection
- Vaginal bleeding
- Cramping

82.6 Pearls and Pitfalls

- Pearls
  - Good communication is essential to ensure the patient is comfortable and not anxious.
  - The chaperone should be a medical staff member.
  - Do not skip the pelvic examination if the patient is menstruating.
- Pitfalls
  - Do not forget to perform a complete abdominal exam along with the pelvic exam to rule out any GI etiology.
  - In older females (>50), perform the DRE for a stool occult sample as a possible source of bleeding.

Fig. 82.6 Photomicrograph of a vaginal smear specimen depicting two epithelial cells, a normal cell, and an epithelial cell with its exterior covered by bacteria giving the cell a roughened, stippled appearance known as a "clue cell" (From the CDC Public Health Image library)

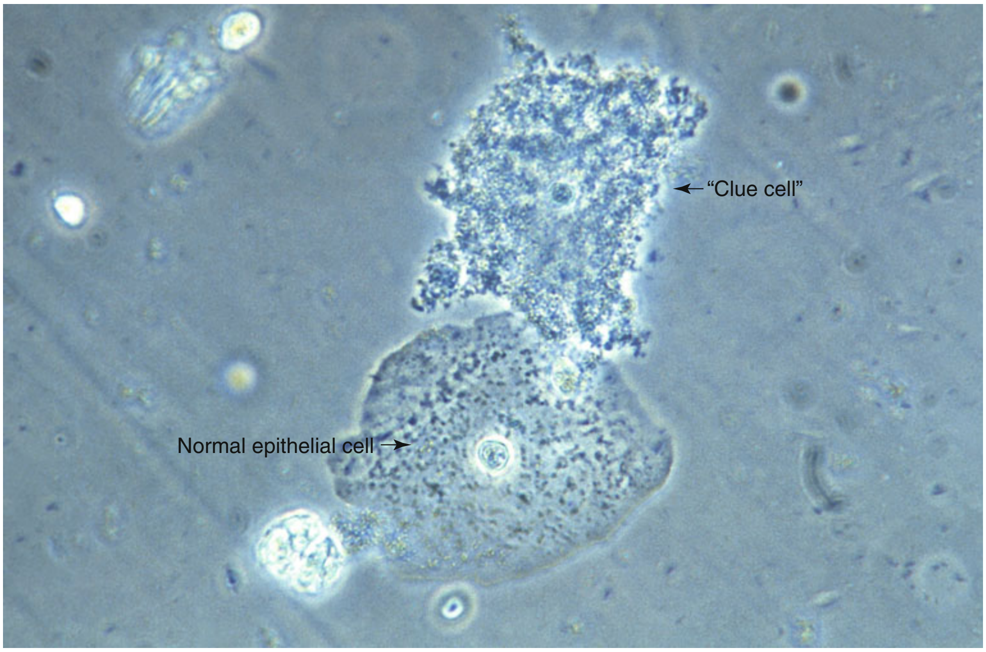

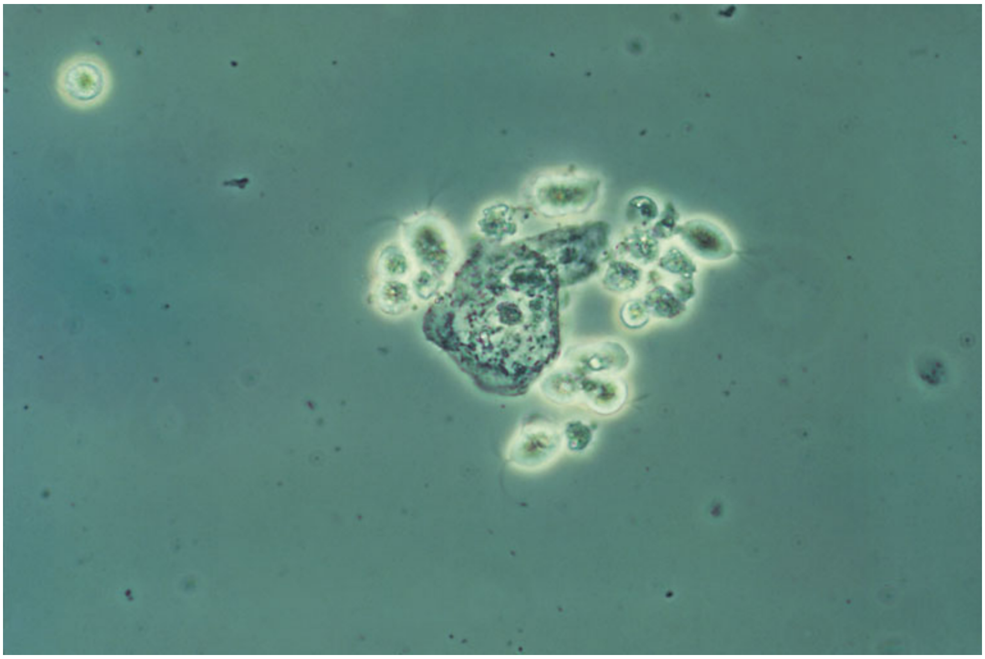

Fig. 82.7 Photomicrograph of trichomonads in wet mount prepared witvh physiological saline (From the CDC Public Health Image library)

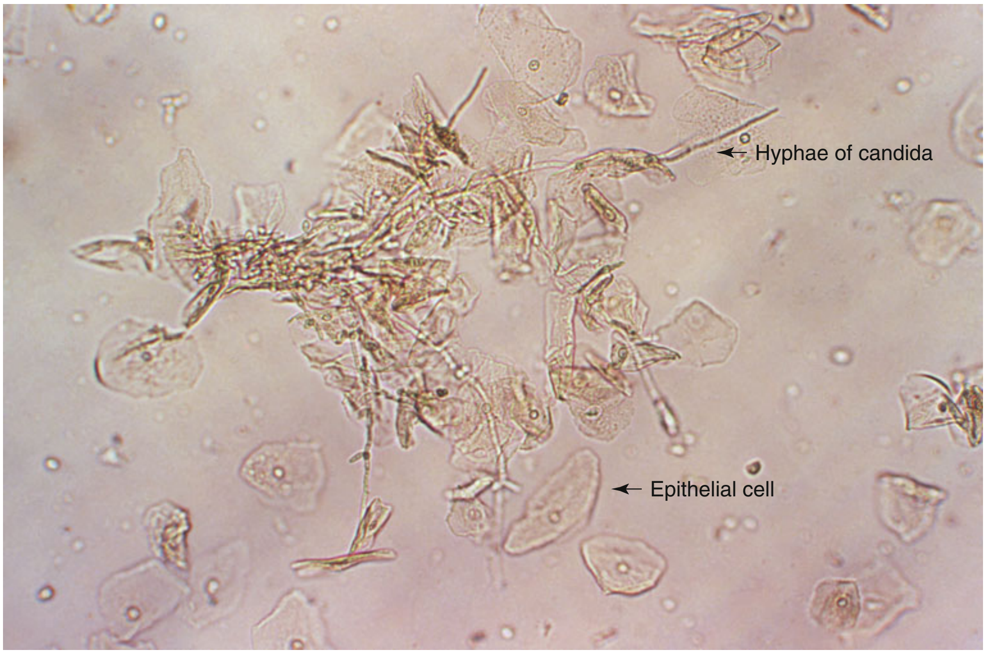

Fig. 82.8 *Candida albicans* from vaginal wet prep (From the CDC Public Health Image library)

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Bartholin Gland Abscess/Cysts Drainage

83

Holly H. Charleton, Marylin Otero, Diane F. Giorgi,
and Joseph A. Tyndall

83.1 Indications

- Bartholin gland cysts larger than 1 cm or painful
- Bartholin gland abscess

83.2 Contraindications

- Absolute
  - None
- Relative
  - Recurrent/complex abscess requiring general anesthesia in operating room
  - Coagulopathy

83.3 Procedure Types

- Incision and drainage (I&D)
- Iodoform packing
- Word catheter
- Jacobi ring catheter
- Silver nitrate stick ablation (after I&D)

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83.4 Materials

- Sterile gloves
- Sterile skin preparatory solution/swabs and drapes
- Lidocaine 1 % (local anesthesia); may give oral or intravenous sedatives or analgesics
- Needles 25 or 27 gauge with 3-mL syringe for lidocaine injection
- Scalpel #11 for incision
- Culture swab
- Hemostat or suture kit
- Word catheter (if choosing that method) (Fig. 83.1)
- Jacobi ring catheter (if choosing that method) (Fig. 83.2)
- 3-mL syringe with saline for inflation of Word catheter balloon
- Silver nitrate stick (if choosing that method)
- Gauze pads for bleeding and effluents
- Iodoform packing

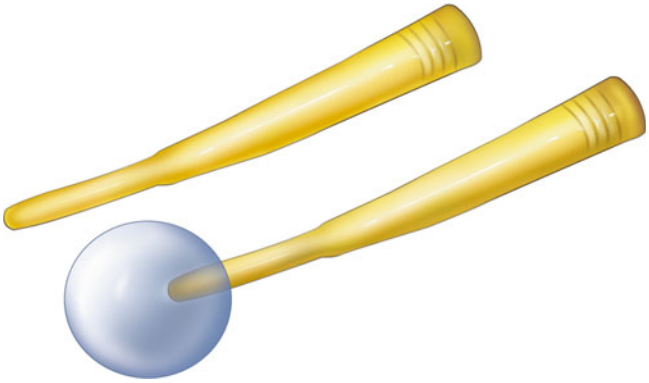

Fig. 83.1 Word catheter (inflated/deflated)

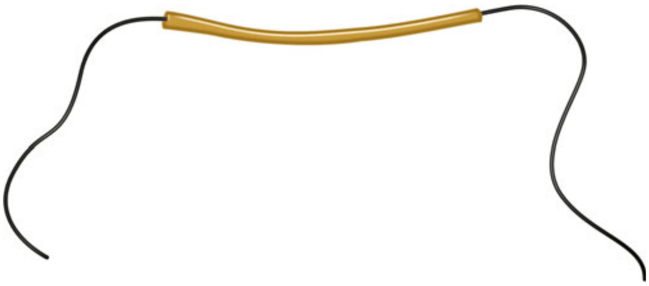

Fig. 83.2 Jacobi ring catheter

83.5 Procedures

83.5.1 Incision and Drainage

1. Obtain informed consent from the patient.
2. Place the patient in the lithotomy position.
3. Prepare the cyst/abscess and the surrounding area with sterilizing fluid/swabs and drape the area, leaving the cyst/abscess accessible for the procedure (Fig. 83.3)
4. May need to hold traction to the labia to fully expose the cyst/abscess (Fig. 83.4).
5. Inject 1–4 mL of lidocaine at the planned site of incision (Fig. 83.5).
6. Hold one side of the cyst/abscess with a forceps or hemostat to maintain traction while incising.
7. With a #11 scalpel, make an incision approximately 0.5–1 cm and 1.5 cm deep in the introitus or behind the hymnal ring to prevent vulvar scarring. The incision should be made through the fluctuant area of the abscess on the mucosal surface. The incision should be linear and large enough to fit the Word catheter (if using that method).
8. Drain the cyst/abscess completely, using the hemostat to break up the loculations.
9. Culture the abscess with a swab and send to microbiology.
10. All previous steps should be done regardless of the procedure type to follow.

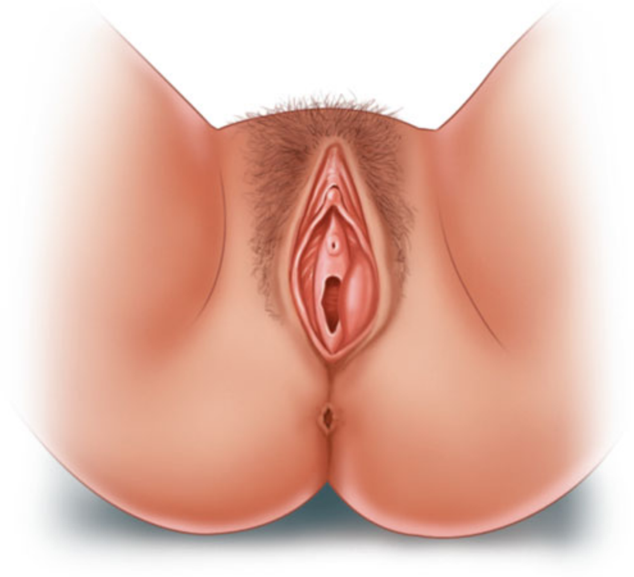

Fig. 83.3 Cyst/abscess accessible for the procedure

Fig. 83.4 May need to hold traction to the labia to fully expose the cyst/abscess

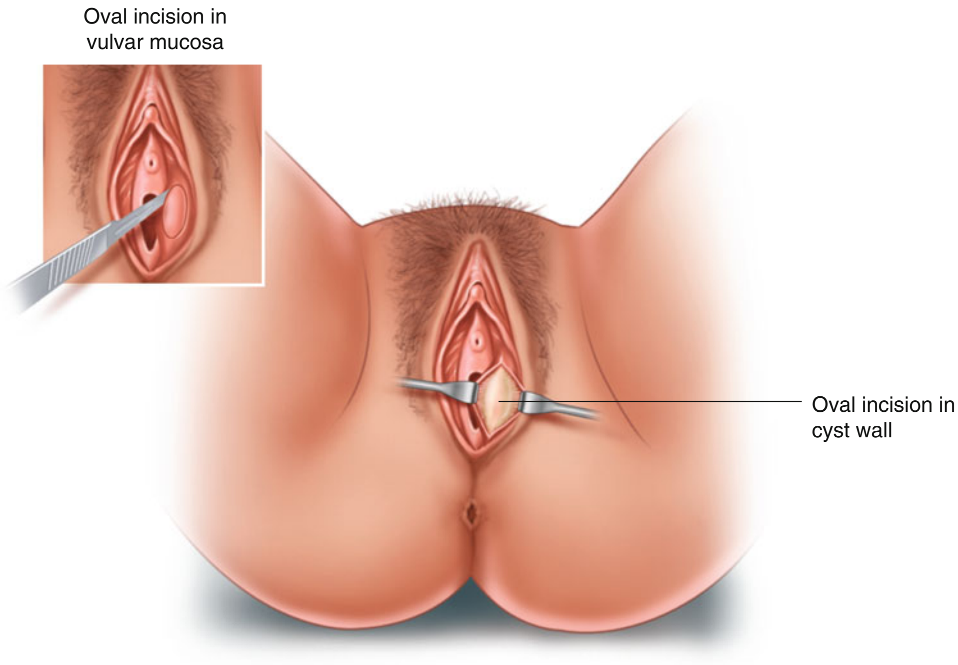
Oval incision in vulvar mucosa
Oval incision in cyst wall

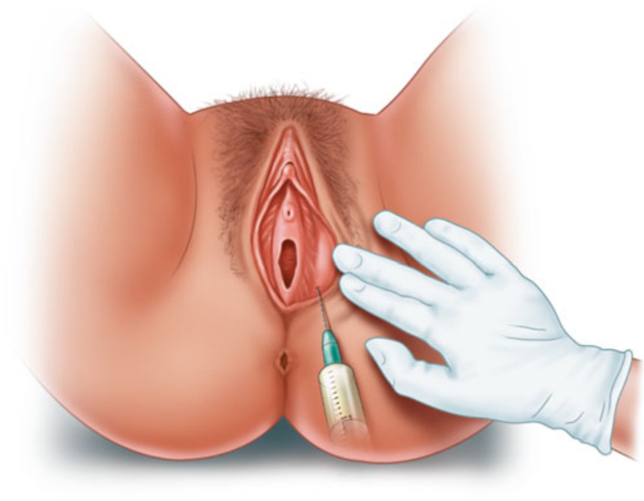

Fig. 83.5 Inject 1–4 mL of lidocaine at the planned site of incision

83.6 Iodoform Packing

1. Pack with iodoform packing, grasping the end of the packing material with a hemostat and inserting deeply within the cavity.
2. The cavity should be filled with the packing material and a small piece left exposed (for ease of retrieval during follow-up).
3. Clean the site and cover with gauze.

83.6.1 Word Catheter

- After culturing the abscess
    1. Place the Word catheter into the incision site as deep as possible (if the incision is too large, the catheter will slip out) (Fig. 83.6).
    2. Inflate the balloon of the Word catheter with 2–3 mL of saline or water injected into the hub with a needle and syringe (Fig. 83.7).
    3. Tuck the end of the Word catheter into the vagina for comfort purposes.
    4. The catheter should remain in place for 4 weeks to allow for epithelialization of the tract.

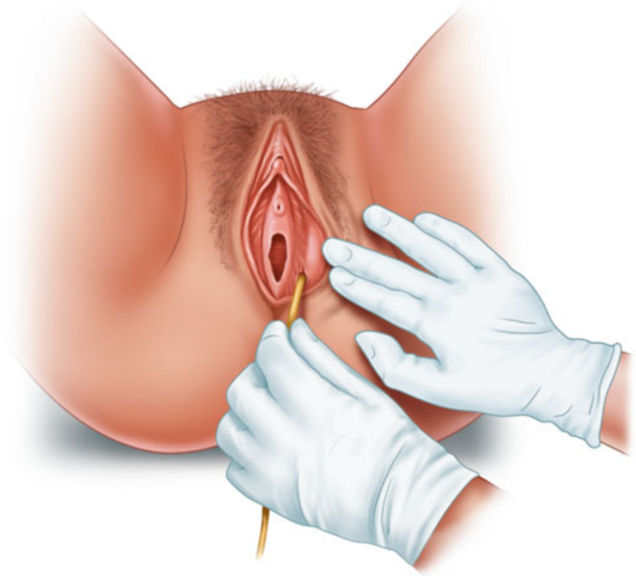

Fig. 83.6 Place the Word catheter into the incision site as deep as possible

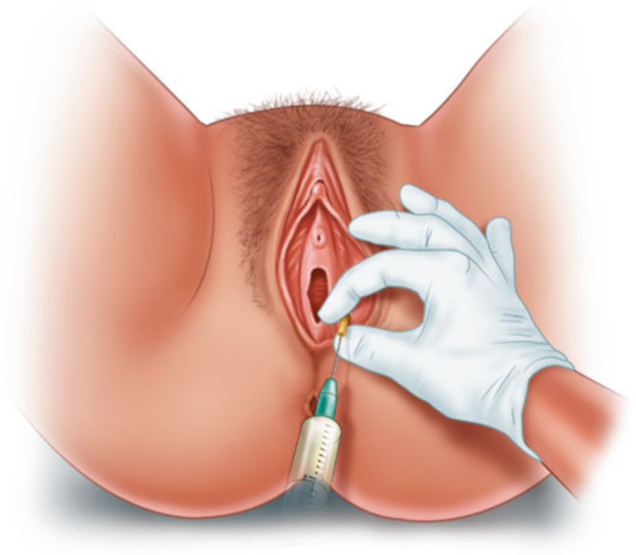

Fig. 83.7 Inflate the balloon of the Word catheter with 2–3 mL of saline or water injected into the hub with a needle and syringe

83.6.2 Jacobi Ring Catheter

1. Grasp one end of the Jacobi ring with a hemostat and pass it through the initial incision site.
2. At this time, use a hemostat to break loculations and culture the material for microbiology.
3. Pull the Jacobi ring through the abscess cavity (be careful not to pull the suture out of the catheter) and make a second incision to pull the catheter out through it.
4. The two ends of the catheter are then tied, forming a ring.

83.6.3 Nitrate Stick

- After sending the culture
    1. Take the silver nitrate stick and place it deep within the cyst/abscess cavity (Fig. 83.8).
    2. The patient is instructed to return in 48 h for removal of the remaining nitrate material and necrotic tissue and wound cleaning.
    3. The patient should be warned of side effects including pain, chemical burns of nearby tissue, edema, discharge, and scarring.

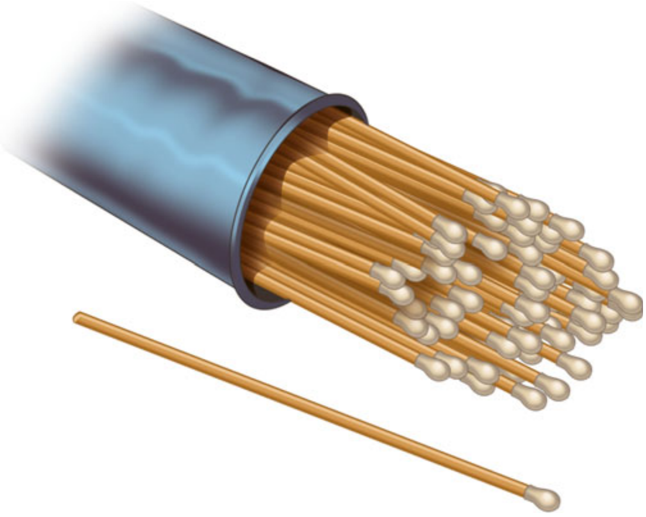

Fig. 83.8 Silver nitrate sticks

83.7 Aftercare

- Follow-up care is required after each of these procedures.
- A high-risk patient (e.g., diabetic) may need to be covered with broad-spectrum antibiotics.
- Pregnant women are also considered high risk and should be given antibiotics and followed closely.
- The patient should be instructed to remain on pelvic rest (nothing in vagina) while the catheter is in place, wear a pad owing to discharge, use sitz baths and analgesics for pain control, and follow up 1–2 days after the procedure.

Although a few other methods are available for draining Bartholin cyst/abscess including marsupialization, carbon dioxide laser vaporization, and excision, these methods are typically done by gynecologists and rarely, if ever, performed by an emergency department physician.

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84

Sexual Assault Forensic Examination

Rajnish Jaiswal, Mary T. Ryan, and Muhammad Waseem

When the survivor of a sexual assault seeks medical care, in addition to addressing their medical needs, their forensic needs must also be addressed. This is best achieved by a specialist examiner, who is trained to conduct a Sexual Assault Forensic Examination (SAFE). When the examiner is a nurse, she or he is referred to as a Sexual Assault Nurse Examiner (SANE). In designated centers, the forensic examiner and the nurse, physician, law enforcement officials, social workers, and patient advocates work together as a Sexual Assault Response Team (SART).

The process of caring for survivors of sexual assault continues to evolve and reflects the advances in forensic science, judicial reform and our understanding of assault survivor psychology.

However, when an emergency medical condition exists, it should be addressed by the designated medical team. The role of the SAFE examiner becomes secondary in these situations. Life- or limb-threatening injuries always take priority over forensic evidence collection, although emergency medical care can often be rendered without compromising existing evidence.

84.1 Indications

- Survivors of sexual assault who seek and consent to forensic examination.
- The upper limit of time for evidence collection varies from state to state (e.g., 96 h in New York State [1]).

84.2 Contraindications

- Absolute
  - If the survivor does not consent to evidence collection
- Relative
  - If the upper time limit has been exceeded

84.3 Materials and Medications

- Ideally, a designated SAFE room should be available.
- Standardized sexual assault evidence collection kits.
- Gloves.
- Camera.
- Portable light source.
- Swab dryer.
- Wood's lamp.
- Anoscope.
- Colposcope, ideally with a camera.
- Support material for survivors: information pamphlets, clothing.
- Prophylactic medications: antibiotics, antiretrovirals, contraceptives.

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84.4 Procedure: "Prepare the Patient, Prepare the Room"

1. Informed Consent
    - A separate consent is required for the SAFE. Obtaining consent has important psychosocial implications for the survivor and returns "control" and "choice" to him or her at this critical time [2]. If the survivor chooses not to undergo a SAFE, the examiner must respect his or her decision. Consent is not an "all-or-none" phenomenon and survivors can chose to consent to some steps and decline others. The examiner should be respectful of their decision.
    - Consent for the SAFE should include consent for evidence collection, forensic photography, release of evidence to law enforcement, and permission to discuss the findings of the SAFE with investigators.
2. Law Enforcement Involvement
    - State laws vary in terms of reporting requirements for sexual assault. The examiner should be familiar with the requirements in the state in which she or he practices. All survivors should be offered law enforcement involvement and the benefits of doing so should be outlined to them.
3. Evidence Collection
    - Sexual assault evidence collection kits are specialized preassembled kits containing essential materials for collecting and preserving evidence (Fig. 84.1). The kit contains written instructions, swabs, envelopes, body diagrams, and an integrity seal for the examiner's use.
4. Forensic Interview and History Taking
    - The forensic interview is the first step in the SAFE process. It is a therapeutic as well as a forensic exercise, designed to establish rapport with the survivor, offer support, and gather information to help guide the medical care and direct evidence collection. Acquiring information is a continuous process that ends only when the survivor-SAFE interaction ends.
    - The survivor's exact words with quotation marks should be recorded. A simple factual account of events should be documented. Avoid biased or prejudicial language, such as "allegedly" or "claims." Relevant information includes the time of the assault, the type of contact involved (offender-survivor and survivor-offender), the number of people involved, and the survivor's activities since the assault. A basic medical and obstetrical-gynecological history is also relevant. The SAFE interview is not an investigative interview. Investigation of the sexual assault is the role of law enforcement.
5. General Physical Examination
    - The patient should be asked to undress over a paper sheet to allow any trace evidence to fall and be collected. She or he should be given a gown to wear. A systematic head-to-toe examination should be undertaken. Identify any injuries, no matter how minor. Document them in writing, on a body diagram (Fig. 84.2), and, when possible, with photography. Pay attention to areas that can be easily overlooked: in the mouth, behind the ears, under the chin, and the soles of the feet, for example. Take time to palpate the scalp for areas of tenderness.
6. Injury Documentation
    - Always take time during documentation. Describe the type of injury—abrasion, contusion, laceration, or bite mark. Document the size and site of the injury, ideally include a measuring device in the photograph. A commonly used scale is the one provided by the American Board of Forensic Odontology (ABFO) (Fig. 84.3). If an injury appears to have a shape or pattern (e.g., linear, circular, curvilinear, petechial), describe it without drawing specific conclusions.
7. Bite Marks
    - Bite marks require additional evaluation because they may have salivary trace evidence associated with them. In addition to being described and photographed, they should be swabbed and the dried swabs included in the evidence collection kit.
8. Forensic Pelvic Examination
    - The purpose of the genital examination (external and speculum) is to identify injury and collect forensic evidence.
9. Inspection
    - Visually examine the external genitalia. Separate the labia and look in skin folds and at the posterior fourchette for injury. The TEARS mnemonic (T = tear, E = ecchymosis, A = abrasions, R = redness, S = swelling) is a useful tool while inspecting and documenting. External genital injury findings can be photographed using a standard camera (digital or conventional 35 mm) or a colposcope camera for additional magnification.
10. Speculum Examination
    - Insert a moistened speculum under a good light source and inspect the vault and cervix for any injuries or possible trace evidence for collection (pooled secretions, hair, retained condom, debris). A colposcope (Fig. 84.4) is a useful adjunct and allows for magnification and assists in injury identification and photodocumentation.
    - Bimanual pelvic examination may be a part of some protocols but is not mandatory.
11. Rectal Examination
    - Inspect the area looking for fissures, bleeding, or secretions. Anoscopy, if indicated by this history and permitted by the survivor, should be performed and the findings documented and photographed.

12. Evidence Collection
    - The evidence collection kit should be opened and the contents laid out in a systematic way. Once the evidence collection kit has been opened, it cannot be left unattended at any time. Each envelope should be labeled with the survivor's name and the time and date of collection. The required swabs and slides are included in the kit.
13. Collection of Biological Material
    - Evidence collection will include oral, anal, and vaginal swabs. Swabs should be allowed to air dry before being placed back in the envelopes. Trace evidence should be collected and may include nail scrapings, dried secretions, loose hair collection, and possible foreign bodies (e.g., soil, condom). A Wood's lamp may help the examiner to identify dried secretions on skin or clothing. When each step is completed, the envelope will be closed, sealed, and signed by the examiner and returned to the box.
    - When completed, the Sexual Assault Evidence Collection Kit (SAECK) is closed, the provided evidence seal placed on the box, and the seal signed and dated by the examiner. The evidence is then given to law enforcement (if the patient consents) or maintained in a predesignated, secure locked area if law enforcement is not yet involved in the case. Each time evidence is passed from person to person, the transfer must be documented in writing to ensure it is not compromised or tampered with in any way. This is the underlying principle of maintaining a "Chain of Custody." This chain must be maintained for evidence to be admissible in court.
14. Collection of Clothing
    - Clothing may be considered "evidence" and collected in some cases. Depending on the case, this may include underwear and any feminine hygiene products. These may fit in the evidence collection kit itself. Larger items of clothing and/or shoes will need to be collected separately. They should be placed in an appropriately sized paper bag and labeled with the patient's name. The bag should be sealed, signed, and dated by the examiner in the same way as all other evidence. Any additional evidence should remain with the SAECK. The survivor should be provided with replacement clothes and underwear.
15. Forensic Photography
    - Although the examiner is not expected to be a specialized forensic photographer, photodocumentation of injuries is an important part of the SAFE. A separate consent is required. Either a conventional 35-mm camera or a high-resolution digital camera is acceptable.
    - At least one image should include the survivor's face or some form of identifying marks. Near and far images should be taken. The camera should be held at 90° to the surface to avoid distortion of the image. A tape measure should be included when an injury is being photographed. An identifier, like medical record number or case number, should be visible in the image if possible. The examiner should document in the records that photographs were taken.
16. Investigations
    - Baseline complete blood count (CBC), chemistry panel, and liver function tests are generally drawn before initiation of human immunodeficiency virus (HIV) prophylaxis. Serologic tests for syphilis, hepatitis B virus (HBV), hepatitis C virus, and HIV should be obtained. Urine should be sent for analysis and pregnancy testing. Urine for toxicology may be useful in selected cases. Testing for gonorrhea and chlamydia before starting prophylactic antibiotics may be undertaken, but this remains controversial.
17. Prophylaxis
    - Survivors should be offered prophylaxis against pregnancy, common sexually transmitted infections, HBV, and HIV. The current Centers for Disease Control and Prevention (CDC) guidelines recommend the following:
      (a) HBV vaccination should be offered to sexual assault victims at the time of the initial examination if they have not been previously vaccinated. Postexposure HBV vaccination, without hepatitis B immunoglobulin (HBIG), should adequately protect against HBV infection. Follow-up doses of vaccine should be administered 1–2 and 4–6 months after the first dose.
      (b) An empirical antimicrobial regimen for chlamydia, gonorrhea, and trichomonas should be offered.
        - Recommended regimens:
          - *Ceftriaxone* 125 mg intramuscularly in a single dose
          - *PLUS*
          - *Metronidazole* 2 g orally in a single dose
          - *PLUS*
          - *Azithromycin* 1 g orally in a single dose
          - *OR*
          - *Doxycycline* 100 mg orally twice a day for 7 days
      (c) Emergency contraception protocols are state and institution specific. A negative pregnancy test should be documented before evidence collection. Commonly prescribed regimens are "Plan B," "Ovral," and the recently approved "Ella."
      (d) Update tetanus profile if indicated.
      (e) HIV postexposure prophylaxis.
        - All patients with significant exposure should receive pretest counseling and postexposure prophylaxis as per CDC guidelines [3]. The regimens are complex (Table 84.1).

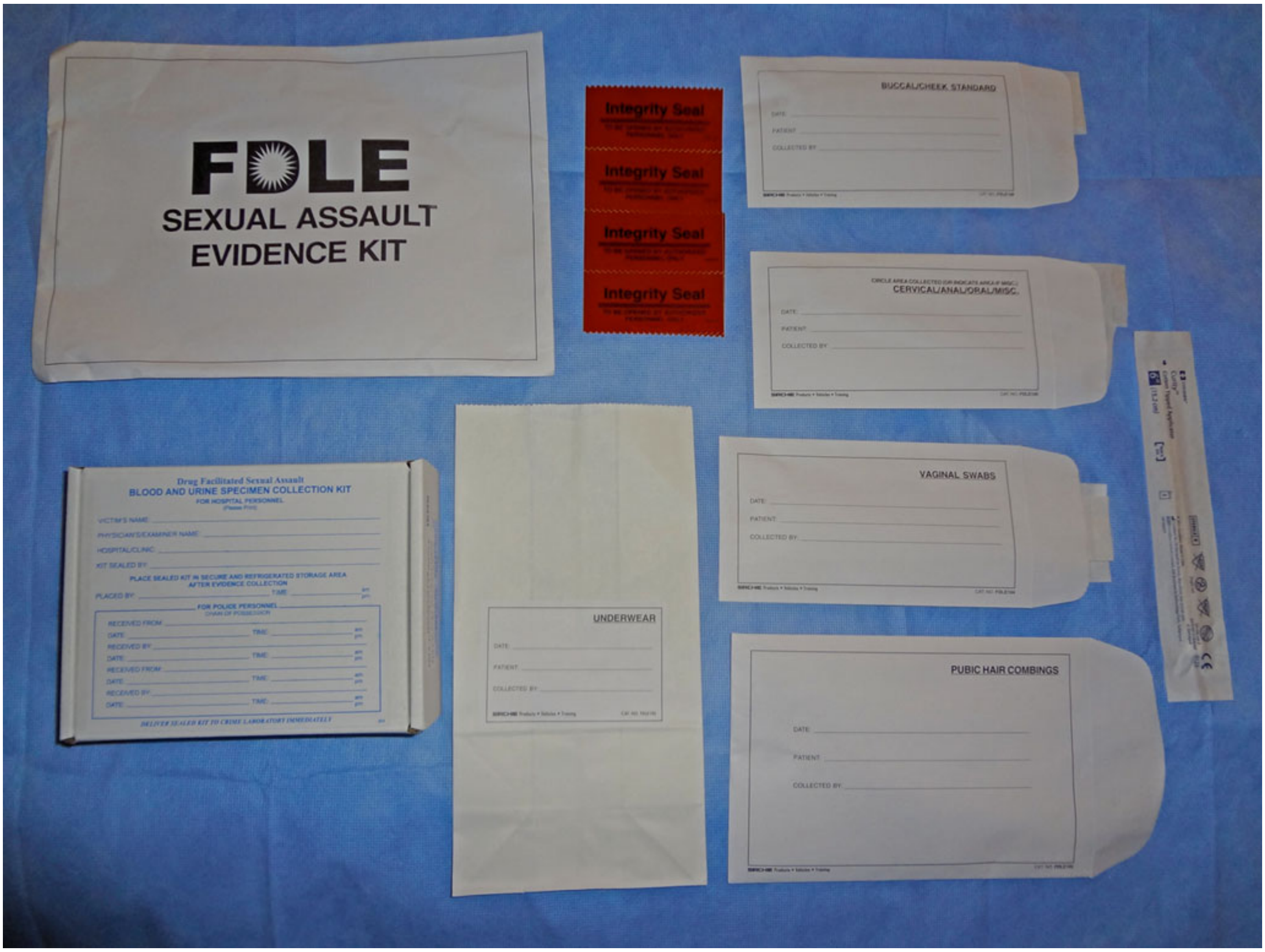
FDLE
SEXUAL ASSAULT EVIDENCE KIT
Integrity Seal
Integrity Seal
Integrity Seal
Integrity Seal
BUCCAL/CHEEK STANDARD
CERVICAL/ANAL/ORAL/MISC.
Drug Facilitated Sexual Assault
BLOOD AND URINE SPECIMEN COLLECTION KIT
UNDERWEAR
VAGINAL SWABS
PUBIC HAIR COMBINGS

Fig. 84.1 Sexual assault evidence collection kit

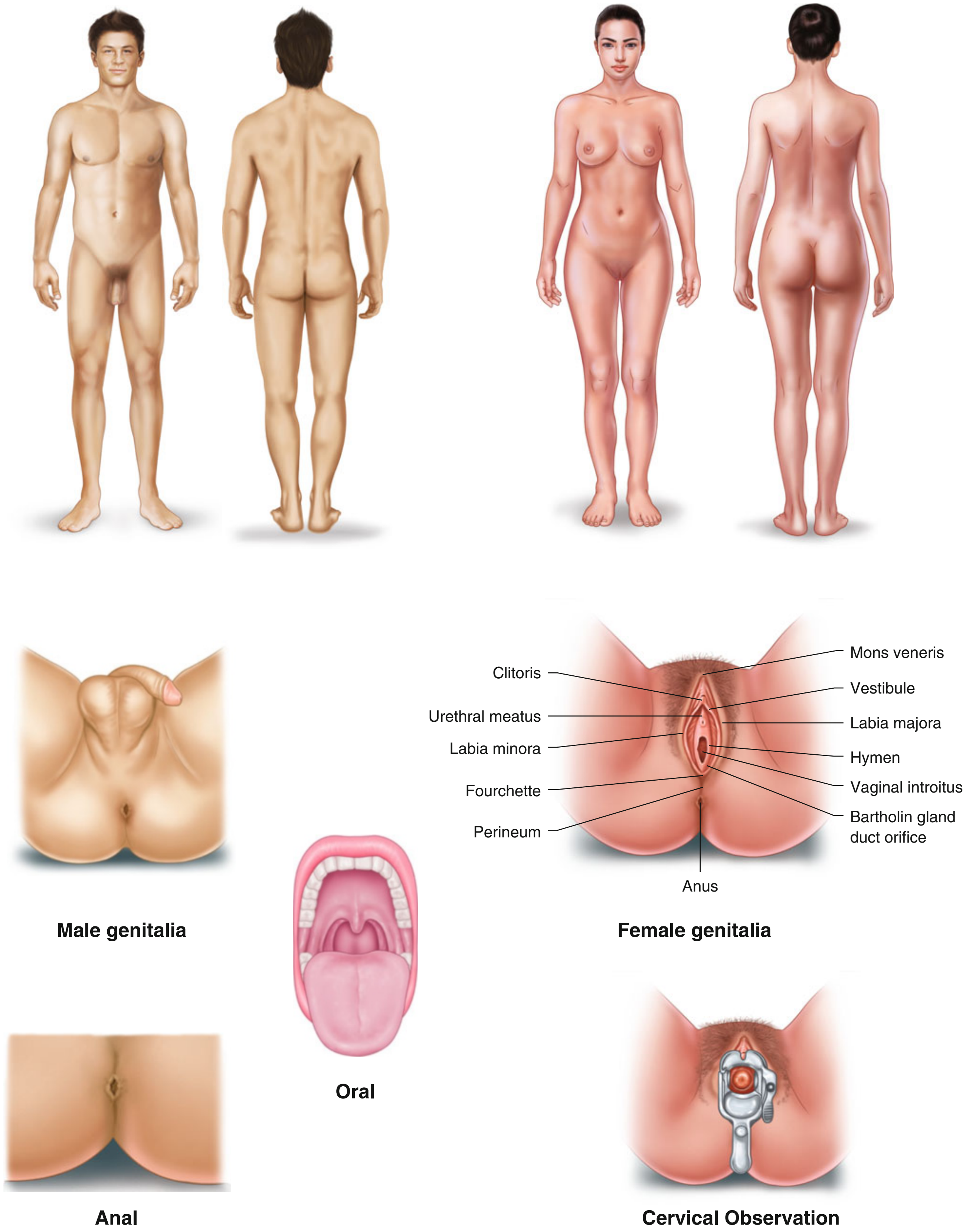
Clitoris
Urethral meatus
Labia minora
Fourchette
Perineum
Mons veneris
Vestibule
Labia majora
Hymen
Vaginal introitus
Bartholin gland duct orifice
Anus
Male genitalia
Oral
Female genitalia
Anal
Cervical Observation

Fig. 84.2 Traumagram

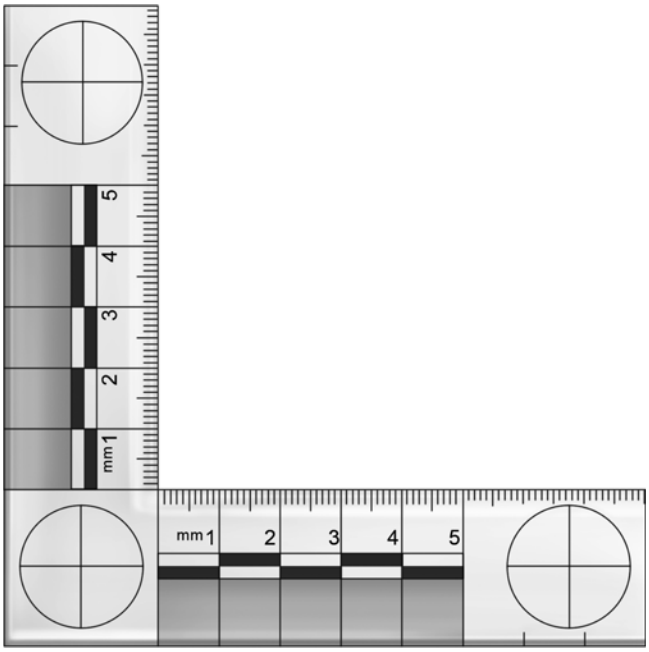

Fig. 84.3 American Board of Forensic Odontology (ABFO) scale (Courtesy Bronx SART Program)

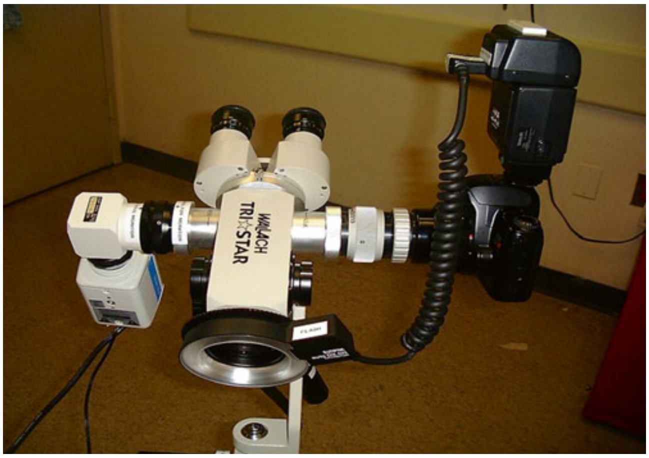

Fig. 84.4 Colposcope (Courtesy Bronx SART Program)

Table 84.1 Postexposure prophylaxis as per Centers for Disease Control and Prevention (CDC) guidelines [3]

Regimen	Dosage
Zidovudine (Retrovir, ZDV, AZT) + lamivudine (Epivir®, 3TC); *available as Combivir™*	ZDV: 300 mg twice daily or 200 mg three times daily, with food; total: 600 mg daily 3TC: 300 mg once daily or 150 mg twice daily Combivir: one tablet twice daily
Zidovudine (Retrovir, ZDV, AZT) + emtricitabine (Emtriva, FTC)	300 mg twice daily or 200 mg three times daily, with food; total: 600 mg/day, in 2 or 3 divided doses; FTC: 200 mg (one capsule) once daily
Tenofovir DF (Viread, TDF) + lamivudine (Epivir, 3TC)	300 mg once daily; 3TC: 300 mg once daily or 150 mg twice daily
Tenofovir DF (Viread, TDF) + emtricitabine (Emtriva, FTC)	TDF: 300 mg once daily; FTC: 200 mg once daily Truvada: one tablet daily

AZT azidothymidine, *FTC* emtricitabine, *3TC* lamivudine, *TDF* tenofovir disoproxil fumarate, *ZDV* zidovudine

84.5 Pearls and Pitfalls

- Pearls
  - Survivors will need to have both medical and psychosocial follow-up. Medical referrals should include gynecology and primary care for follow-up of their baseline serology, testing and completion of HBV vaccination regimen, and so on.
  - Referrals for counseling and information with 24-h hotlines should be provided**.** Recovery from a sexual assault is a process and is best achieved by a long-term support network [4].
- Pitfalls
  - It is estimated that survivors are men in fewer than 10 % of cases, although sexual assault in males appears to be greatly underreported. The same principles for evidence and prophylaxis apply for the SAFE.

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Treatment of Priapism

85

Jeffrey Kile, Katrina John, and Amish Aghera

85.1 Indications

- Ischemic ("low-flow") priapism

85.2 Contraindications

- To cavernosal aspiration/irrigation
  - Nonischemic ("high-flow") priapism
  - Overlying cellulitis
  - Uncontrolled bleeding disorder
  - Skin infection at the site of injection
- To intracavernosal injection of vasoactive agents (α-adrenergic sympathomimetics)
  - Severe hypertension
  - Dysrhythmias
  - Monoamine oxidase inhibitor use

85.3 Materials and Medications (Fig. 85.1)

- Sterile gloves
- Antimicrobial solution and swabs
- 4×4 gauze sponges
- Local anesthetic (1 % lidocaine 5 mL and 0.5 % bupivacaine 5 mL, without epinephrine)
- 10-mL syringe
- 20-mL syringe
- 19- or 21-gauge butterfly or straight needles (2)
- Blunt needle
- 27-gauge needle
- Normal saline, 1000 mL
- Phenylephrine 1 % solution (10 mg/mL), 1 mL

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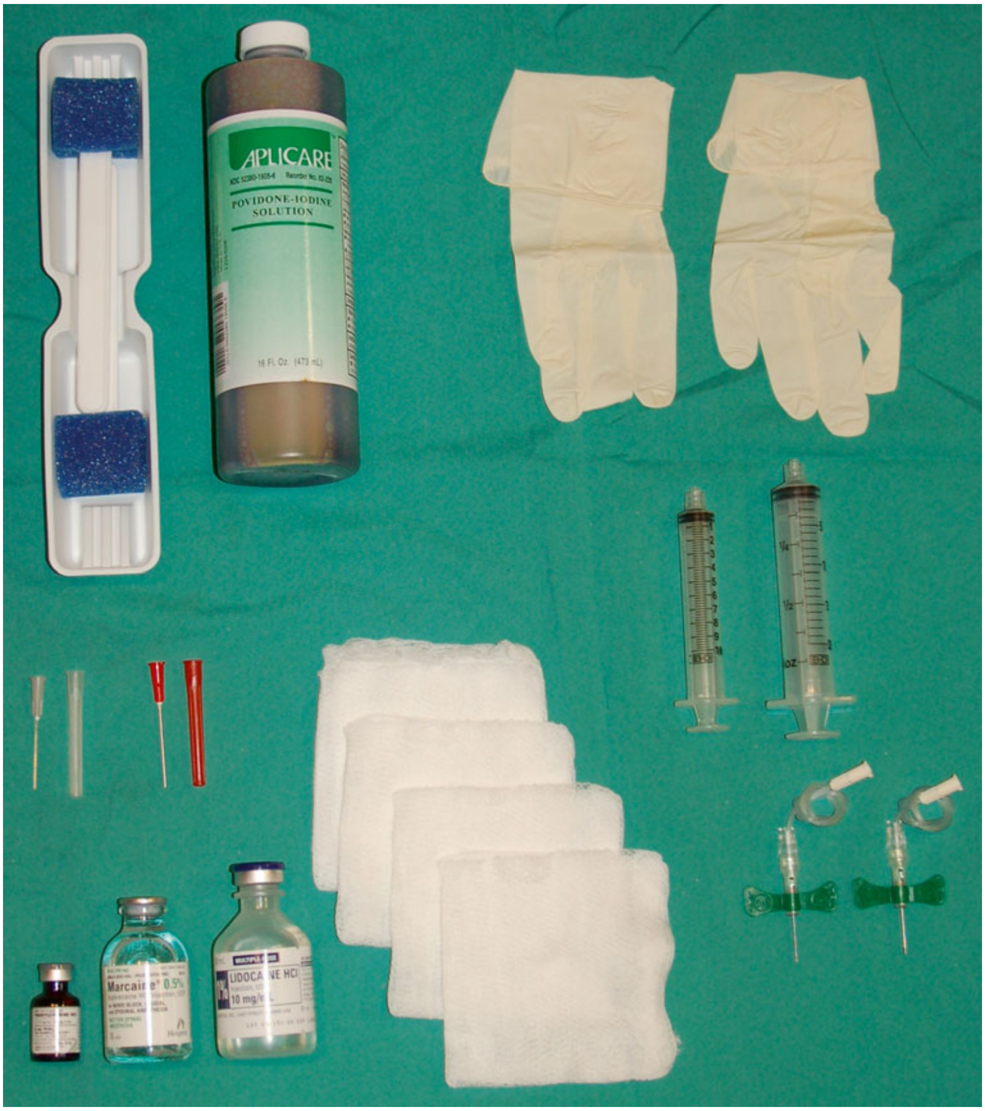

APLICARE
POVIDONE-IODINE SOLUTION
16 FL OZ (473 mL)
Marcaine 0.5%
LIDOCAINE HCl
10 mg/mL

Fig. 85.1 Materials and medications

85.4 Noninvasive Therapy Preprocedure

1. Administer analgesia (e.g., parenteral opiates, benzodiazepines).
2. Administer subcutaneous terbutaline as soon as the diagnosis is suspected (0.25–0.5 mg subcutaneous in quadriceps, deltoid, or gluteus maximus) and repeat after 20 min if necessary.
   - If resolution of priapism does not occur with subcutaneous terbutaline, proceed to cavernosal aspiration.

85.5 Procedures

85.5.1 Dorsal Penile Nerve Block Procedure

1. Position the patient in the supine position.
2. Apply povidone-iodine solution liberally to the penis and scrotum using a 4×4 gauze pad.
3. Clean the glans and shaft of the penis in a circular motion.
4. Establish a sterile field by placing drapes between the scrotum and the shaft, above the shaft, and on either side (Fig. 85.2).
5. Draw up 5 mL 0.5 % bupivacaine and 5 mL 1 % lignocaine (both without epinephrine) into a single syringe.
6. Using a 27-gauge needle, inject local anesthetic superficially to raise skin wheals at the (dorsal) 2 and 10 o'clock positions as proximal to the base of the penis as possible.
7. Insert the needle through the wheal at the 2 o'clock position at the base of the penis until it contacts the pubic symphysis.
8. Withdraw the needle slightly and walk the needle in a caudal fashion down the pubis until the needle passes immediately below the symphysis and advance to a depth of 5 mm deeper than the depth of the pubic symphysis (Fig. 85.3).
   - A transmitted "pop" may be felt as the needle penetrates the superficial penile fascia beneath the symphysis.
9. Aspirate to confirm the tip of the needle is not within the lumen of a vessel.
10. Inject 4 mL of solution.
11. Repeat the injection of local anesthetic as outlined at the 10 o'clock position of the penile base to anesthetize the right dorsal penile nerve (Fig. 85.4).

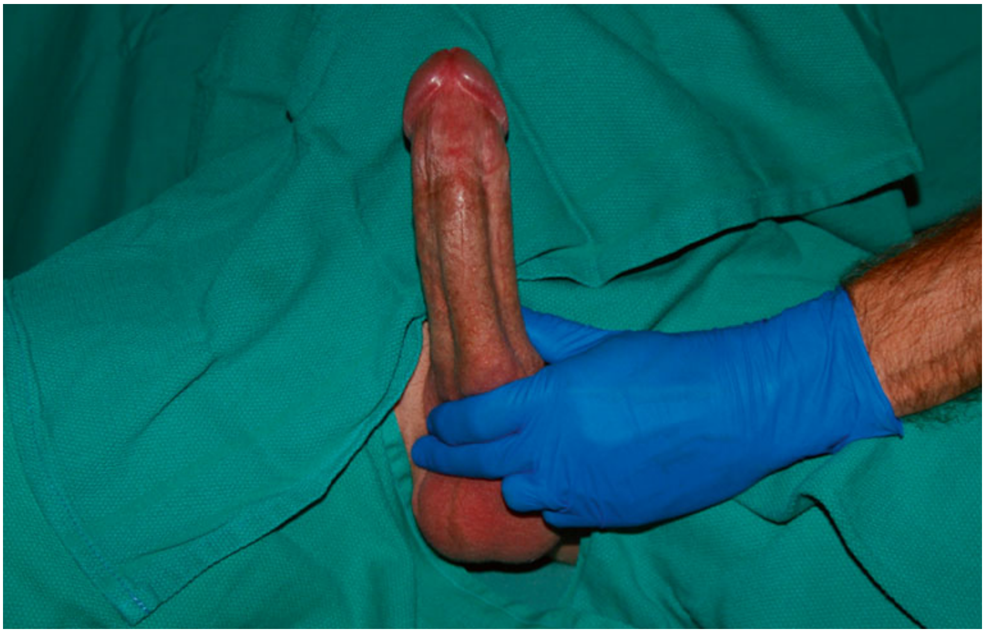

Fig. 85.2 Priapism in sterile field

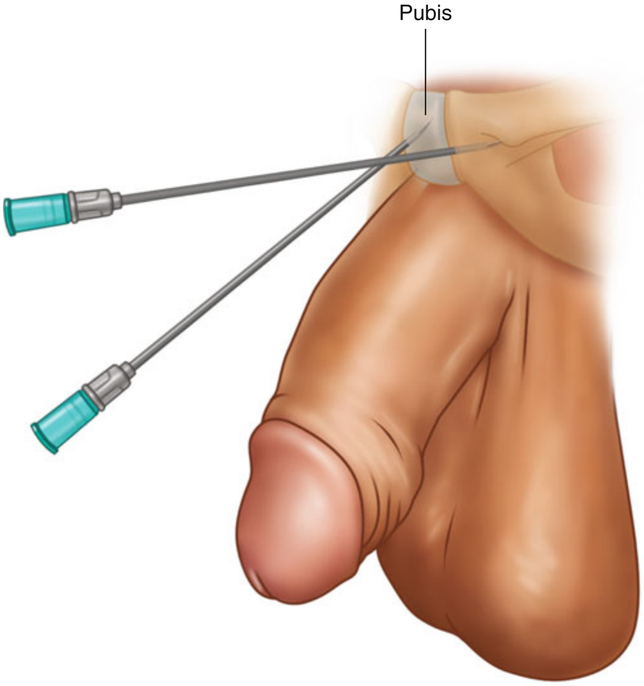

Fig. 85.3 Schematic anatomy of dorsal penile nerve block

Fig. 85.4 Injection of local anesthetic

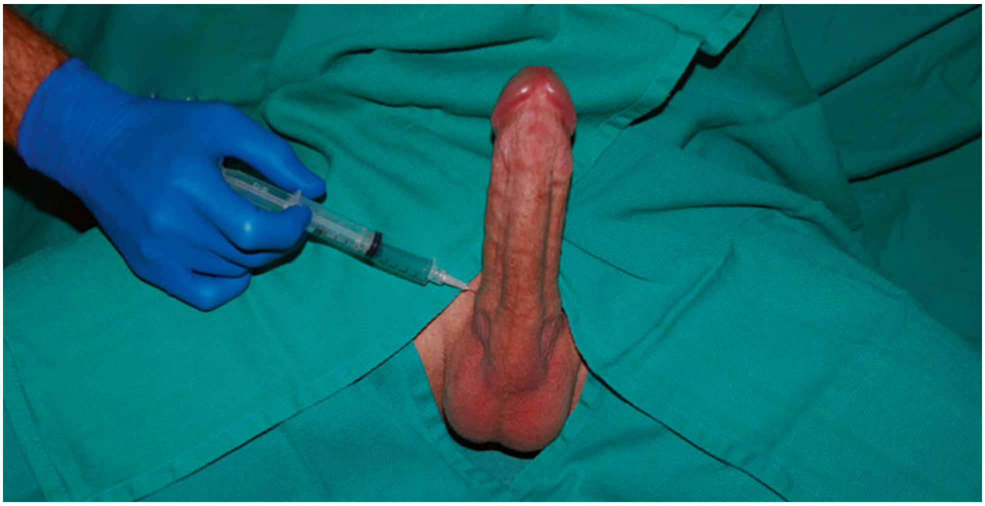

85.5.2 Cavernosal Aspiration Procedure

1. Attach a 19- or 21-gauge needle to a syringe.
2. Puncture the corpus cavernosa at the 2 o'clock or 10 o'clock position (~+60° or −60° from the midline) on the suprapubic aspect of the penis approximately 3 cm from the penile base, directing the needle straight toward the center of the ipsilateral cavernosum.
    - Never use the glans as a puncture site during this procedure.
3. Advance the needle slowly while drawing back on the plunger until blood is visible in the syringe (blood is usually easily aspirated).
4. Once blood is obtained, do not advance further, stabilize the needle, and use one hand to aspirate 20–30 mL of blood while milking the corpus with the free hand (Fig. 85.5).
    - The needle should not be advanced further once blood is visible in the syringe to minimize the risk of injury to the cavernosal artery.
    - Avoid excessive negative pressure on the plunger because this often halts aspiration.
    - If detumescence is not achieved using the above steps, proceed with the following steps.
5. Insert an irrigation needle by puncturing the corpus cavernosum on the same side of the penis punctured with the aspiration needle, approximately 1 cm from the penile base.
6. Irrigate the oxygen-depleted blood in the cavernosa by injecting 20–30 mL of 0.9 % normal saline via the proximal needle in exchange for the blood aspirated (Fig. 85.6).
7. Repeat the cycle of aspiration of 20- to 30-mL volumes of blood from the distal needle followed by irrigation with an equal volume of 0.9 % normal saline via the proximal needle until flow into the syringe of dark red (oxygen-depleted) blood ceases and bright red (oxygen-rich) blood is aspirated or until detumescence is achieved (Fig. 85.7).
    - When removing the needle after cavernosal aspiration, compress the puncture site for approximately 1 min to prevent hematoma formation.
8. Wrap the detumescent penis in gauze or an elastic bandage to prevent return of priapism and to compress the puncture site(s) (Fig. 85.8).

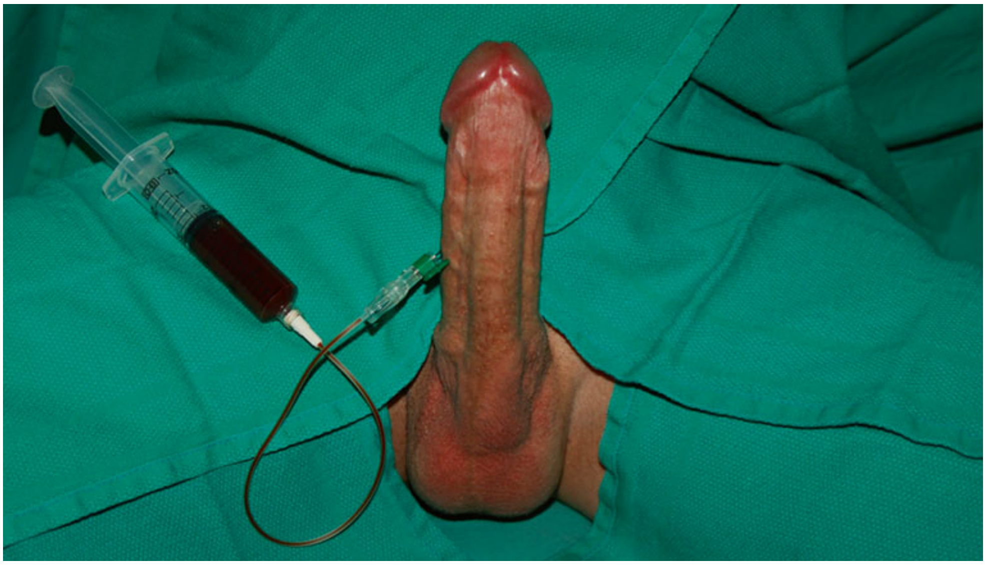

Fig. 85.5 Aspiration of cavernosal blood

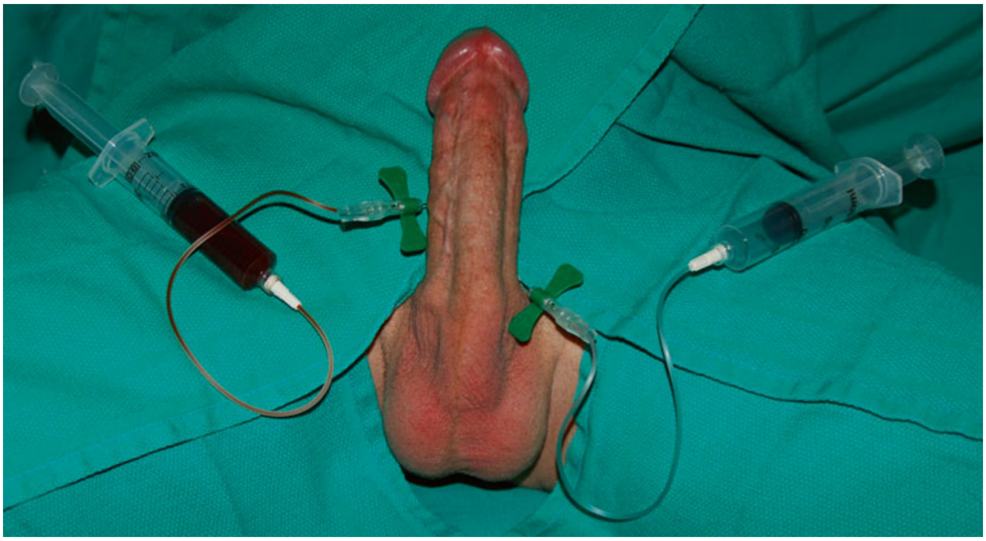

Fig. 85.6 Aspiration and irrigation of cavernosal blood

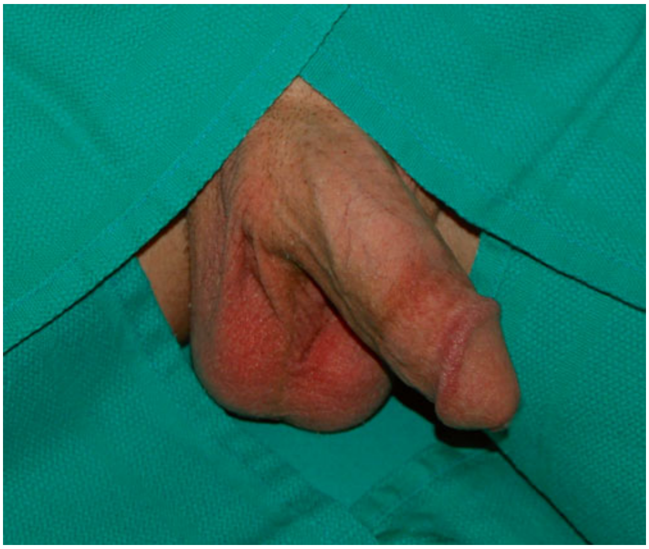

Fig. 85.7 Detumescence

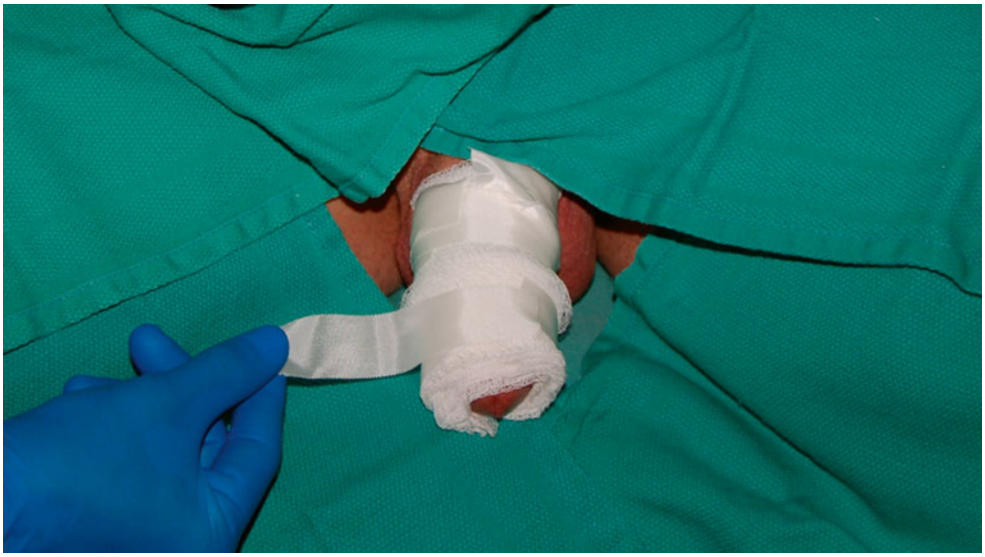

Fig. 85.8 Detumescent penis wrapped in compression dressing

85.5.3 Intracorporeal Injection Procedure

1. Prepare a diluted concentration of 100 μg/mL (1 mg/10 mL) phenylephrine solution by aspirating 0.1 mL of standard 1 % (10 mg/mL) phenylephrine solution into a 10-mL syringe and then adding normal saline to a total volume of 10 mL
2. Attach a 25- or 27-gauge needle to the syringe.
3. Puncture the corpus cavernosum at the 2 o'clock *or* 10 o'clock position (~+60° or −60° from the midline) on the suprapubic aspect of the penis approximately 1 cm from the penile base.
   - Puncture only one side of the penis.
4. Confirm the position of the needle by drawing back on the plunger to aspirate blood from the corpus cavernosa.
5. Inject 1 mL of phenylephrine solution every 3–5 min.
   - Repeat injections of phenylephrine (up to the maximum dose of 1000 μg) should be continued until the erection resolves; only thereafter should this procedure be abandoned in favor of the more invasive approach of surgical shunt.
6. Wrap the detumescent penis in gauze or an elastic bandage to prevent the return of priapism and to compress the puncture site(s).

85.6 Complications

- Of cavernosal aspiration/irrigation
  - Hematoma (at puncture site)
  - Infection (at insertion site or systemic)
  - Thrombosis
  - Arteriovenous fistula
  - Pseudoaneurysm formation
  - Traumatic puncture of dorsal penile or urethra
  - Exsanguination (secondary to dislodgement of catheter)
  - Cerebrovascular accident (secondary to air embolism)
- Of intracavernosal injection of vasoactive agents (α-adrenergic sympathomimetics)
  - Fibrosis of the corpora, pain, penile necrosis, urinary retention
  - Phenylephrine toxicity
  - Acute hypertension, headache, reflex bradycardia, tachycardia, palpitations, cardiac arrhythmia

85.7 Pearls and Pitfalls

- Pearls
  - In ischemic priapism, the penis and corpora cavernosa are rigid and tender to palpation.
  - Ischemic priapism commonly results from an underlying hypercoagulable state, tumor, infection, neurological impairment ("spinal shock"), or vasoactive drug use.
  - During intracorporeal injection, the patient should be monitored for known side effects of sympathomimetics, including hypertension, headache, reflex bradycardia, tachycardia, palpitations, and cardiac arrhythmia. In addition, in patients with elevated cardiovascular risk profiles, blood pressure and electrocardiographic monitoring should be performed.
  - Seek a urological consult as soon as possible for any patient presenting with priapism.
  - Resolution of priapism can be verified by measurement of cavernous blood gases or measurement of blood flow by color duplex ultrasonography.
  - Phenylephrine is the sympathomimetic agent of choice for intracavernosal injection because it is has a lower likelihood of causing adverse cardiovascular side effects than other agents. If this is unavailable, alternatives include epinephrine, norepinephrine, ephedrine, metaraminol, and etilephrine.
  - Intracavernous aspiration/irrigation/injection therapy is unlikely to resolve ischemic priapism lasting for 48 h or longer. In such cases, immediate surgical shunting is first-line treatment.
  - Once detumescence is achieved, any unmetabolized drugs in the corpus cavernosa enter the venous circulation, and thus, dosages of any vasoactive drugs injected must be monitored carefully.
- Pitfalls
  - The most common complication of ischemic priapism is complete erectile dysfunction.

85.8 Considerations

85.8.1 Blood Gas Analysis

This investigation provides a rapid distinction between ischemic and nonischemic priapism. Blood aspirated from the corpus cavernosum in ischemic priapism is dark in color with partial pressure of oxygen (PO_2) less than 30 mmHg, partial pressure of carbon dioxide (PCO_2) greater than 60 mmHg, and pH less than 7.25. In nonischemic priapism, respective values will be PO_2 greater than 90 mmHg, PCO_2 less than 40 mmHg, and pH of 7.4 (Table 85.1).

Table 85.1 Summary of cavernosal blood gas findings

	pH	PO_2 (mm Hg)	PCO_2 (mm Hg)
Ischemic priapism	<7.25	<30	>60
Arterial blood	7.40	>90	<40
Mixed venous blood	7.35	40	50

PCO_2 partial pressure of carbon dioxide, *PO2* partial pressure of oxygen

85.8.2 Sickle Cell Testing

The sickle-solubility test detects any sickle hemoglobin (therefore, it is positive in patients with either sickle cell train or sickle disease). Hemoglobin electrophoresis with 10 % or greater HbS suggests sickle cell disease. Anemia and increased reticulocyte count may also be present in sickle cell disease.

85.8.3 Hemoglobin Electrophoresis

Confirmatory test for sickle status after a positive sickle-solubility test.

85.8.4 Complete Blood Count

White blood cell (WBC) count may suggest infection or blood dyscrasia. Hemoglobin (Hb) and reticulocyte counts may suggest sickle cell disease.

85.8.5 Color Duplex Ultrasonography

Blood flow in cavernosal arteries is absent or minimal in ischemic priapism, whereas flow velocity is normal to high in nonischemic priapism.

85.8.6 Urine Toxicology and Psychoactive Drug Screen

The following drugs have been associated with priapism: antihypertensives, anticoagulants, antidepressants, alcohol, marijuana, cocaine, and other illegal substances. Intracavernous injection therapy using drugs such as alprostadil, papaverine, prostaglandin E1, phentolamine, and others may precipitate priapism.

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Reduction of Phimosis/Paraphimosis

86

Justin Chen and Muhammad Waseem

Phimosis occurs when the distal aspect of the prepuce cannot be retracted over the glans.

Paraphimosis is a true urological emergency; it occurs when retracted paraphimotic foreskin cannot be replaced to its normal position past the coronal sulcus, resulting in venous and lymphatic congestion leading to arterial occlusion, ischemia, and necrosis of the glans.

Both conditions commonly result from chronic infection from poor local hygiene in uncircumcised males; it can also be due to redundant skin.

86.1 Indications

- Phimosis: signs of acute urinary retention
- Paraphimosis: signs of present or impending *arterial* occlusion

86.2 Contraindications

- Absolute
  - Failure to rule out penile swelling and pain due alternative conditions (e.g., posthitis/balanoposthitis, angioedema, insect bite, constricting band)

86.3 Materials and Medications

- Latex-free gloves (sterile)
- Local anesthetic
  - 2 % lidocaine without epinephrine (preferred)
  - 2 % lidocaine gel or eutectic mixture of local anesthetics (EMLA) cream (2.5 % prilocaine and 2.5 % lidocaine)
- 25- to 27-gauge 1.5-in. needles (2)
- Small plastic syringe, 10 mL (1)
- Bag of ice (1)
- 2-inch elastic pressure dressing (1)
- Sterile gauze (1)

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86.4 Procedure: Manual Reduction for Paraphimosis

1. Grasp the swollen foreskin of the penis and apply gentle compression for a few minutes.
2. Grasp the swollen foreskin and elevate upward.
3. Push the glans into the foreskin.
4. Place the patient in the supine position and carefully inspect the penis for constricting bands or foreign bodies (e.g., piercings).
5. Usage of penile block to provide analgesia to the shaft and glans penis depends on urgency, patient age, and cooperativeness (Fig. 86.1).
   (a) Use a 25- to 27-gauge needle to inject lidocaine into the base of the penis, at the junction between the penis and the suprapubic skin, away from the midline to avoid the superficial dorsal vein.
   (b) Inject lidocaine just deep to Buck's fascia (3–5 mm beneath the skin) to form wheals, where a slight "pop" is felt as the needle penetrates the fascial layer.
   (c) Between 1 and 5 mL of local anesthetic should be used, depending on the age of the patient, which can be delivered as follows:
      - Half the volume should be injected at the 10 o'clock position and the remainder at the 2 o'clock position *or*
      - Full volume of local anesthetic is injected midline through Buck's fascia, directed toward each direction, ensuring negative aspiration of blood.
6. Alternatively, use gauze soaked in topical local anesthetic to cover the penis (2 % lidocaine gel or EMLA cream [2.5 % prilocaine and 2.5 % lidocaine]), which has slower onset.
7. For phimosis
   (a) If acute urinary retention occurs, dilate the foreskin under procedural sedation or penile block to allow Foley catheterization.
8. For paraphimosis
   (a) Once penile analgesia is achieved (typically in 5 min with penile block), relieve tissue edema before attempting reduction by using:
      - Bag of ice (3 min at a time), *or*
      - Granulated sugar (*contraindicated* in emergent situations owing to time required), *or*
      - Manual compression (squeezing the glans for 5 min), *or*
      - Pressure dressing (2-in. elastic bandage over the gland for 5 min)
   (b) Place both thumbs over the glans, with both index fingers and long fingers surrounding the trapped foreskin proximal from the paraphimotic tissue.
   (c) Use the thumbs to push the glans back into the foreskin while pulling the trapped foreskin distally, which may require a few minutes of constant pressure (Fig. 86.2).
   (d) Can also attempt using Babcock (once in each quadrant) or Adson (3 and 9 o'clock positions) forceps to grasp the paraphimotic tissue (Fig. 86.3).
   (e) If ineffective owing to extreme tissue edema, seek emergent urological consultation.
   (f) Follow-up with urologist is always recommended; circumcision may be performed once infection and/or edema have resolved to prevent recurrence (Fig. 86.4).

Fig. 86.1 Penile block to provide analgesia to the shaft and glans penis

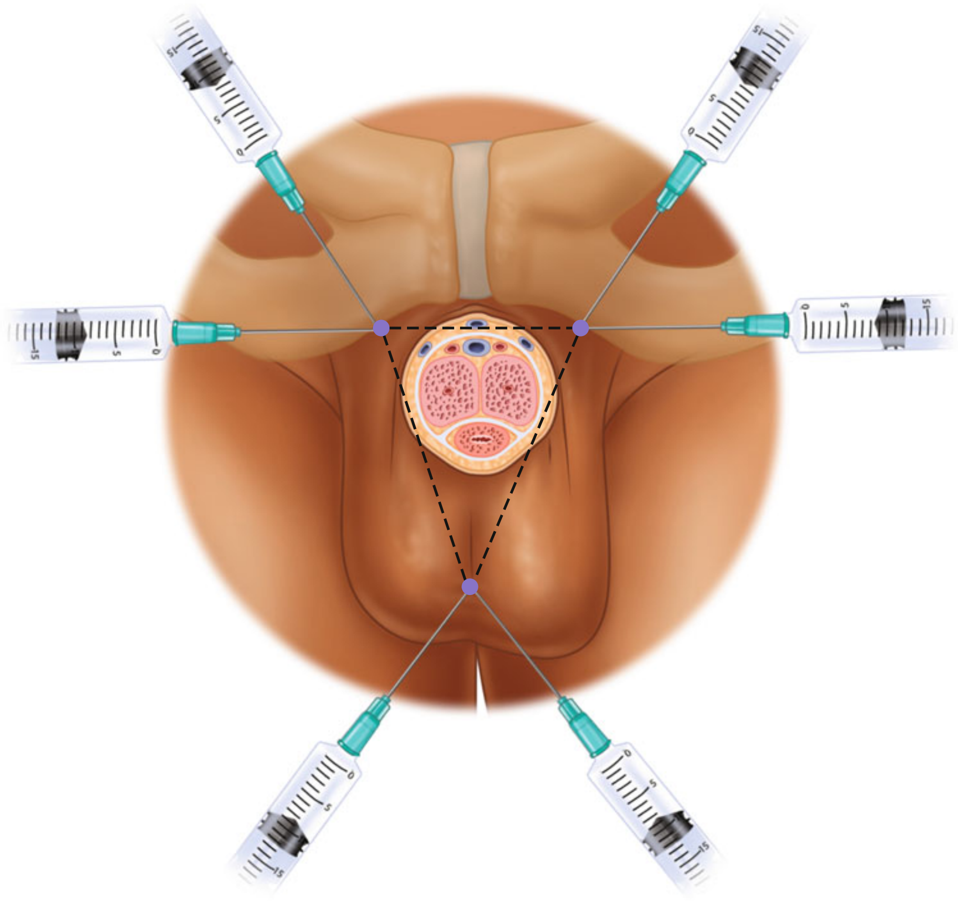

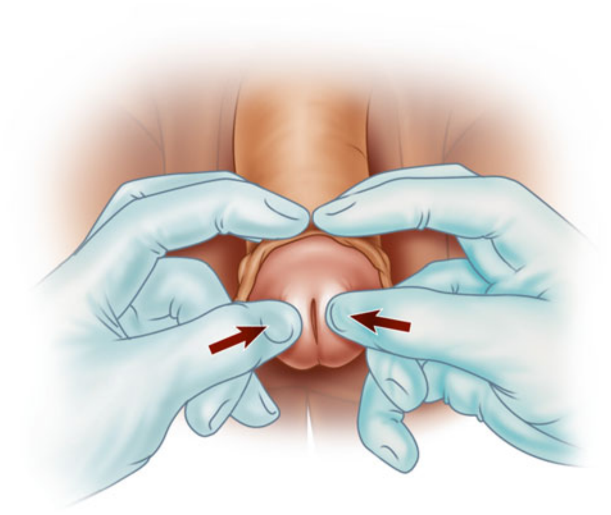

Fig. 86.2 Use the thumbs to push the glans back into the foreskin while pulling the trapped foreskin distally

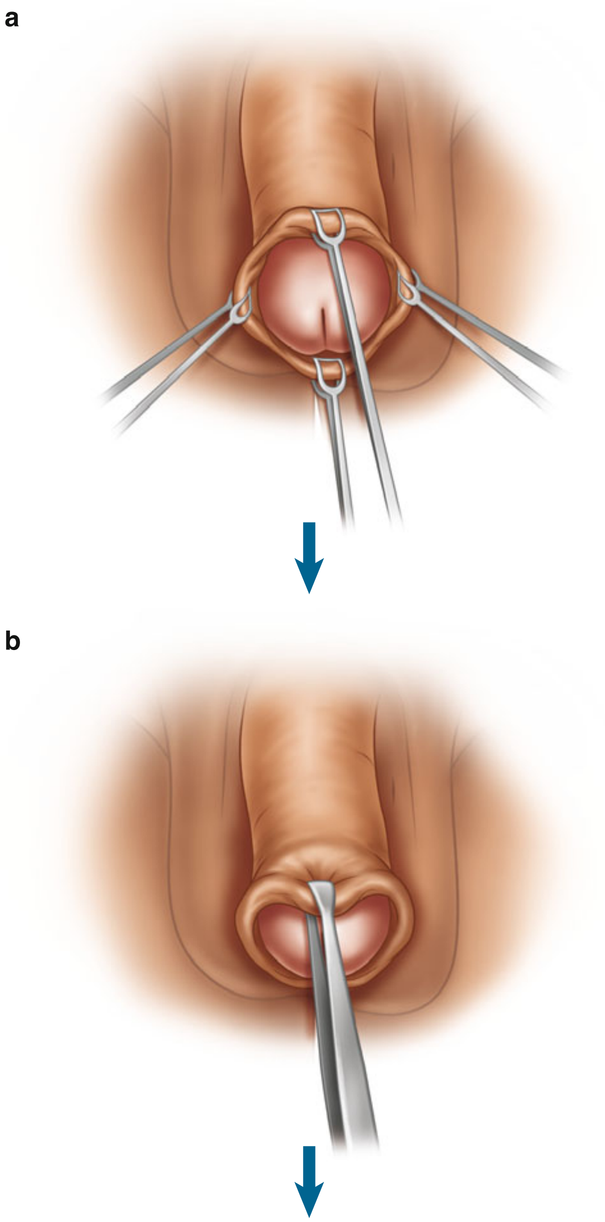

Fig. 86.3 (**a**) Babcock forceps. (**b**) Adson forceps

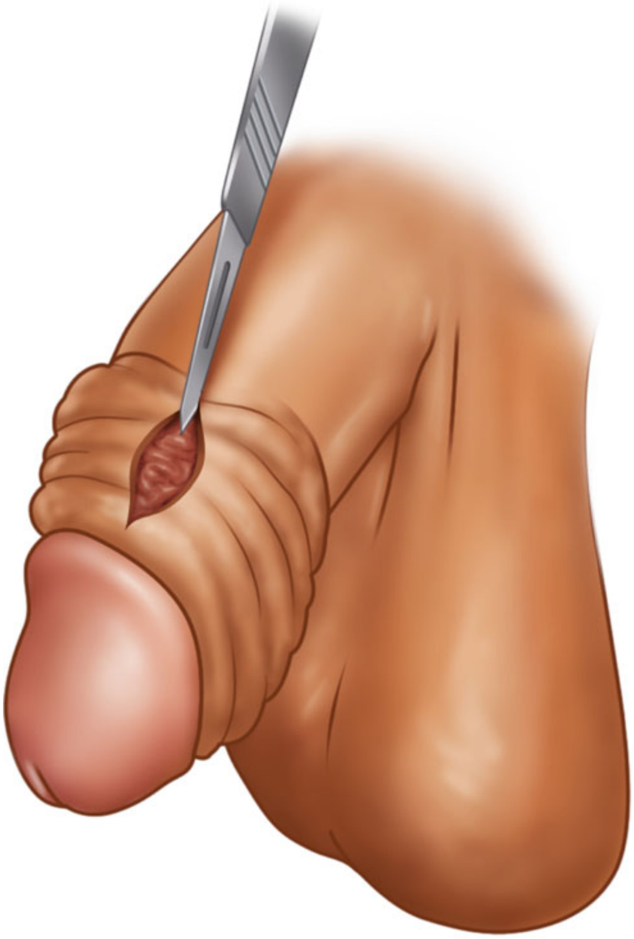

Fig. 86.4 Circumcision may be performed once infection and/or edema have resolved to prevent recurrence

86.5 Complications

- Bleeding/infection of injection site(s).
- Phimosis and scarring due to foreskin manipulation.
- Usage of Adson or Babcock forceps may result in minor bruising and abrasion to the foreskin and glans penis.

86.6 Pearls and Pitfalls

- Pearls
  - Phimosis is a normal occurrence in young males (<5–6 years) and should be treated only in the presence of acute urinary retention.
  - If arterial compromise is imminent in paraphimosis, the emergency physician should attempt reduction if urological consult is unavailable.
- Pitfalls
  - Reduction of phimotic tissue over the coronal sulcus may lead to emergent paraphimosis.

Selected Reading

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Manual Testicular Detorsion

87

Brandon R. Allen and L. Connor Nickels

87.1 Indications

- Testicular torsion is a clinical diagnosis (Fig. 87.1).
  - Although no single clinical finding has 100 % sensitivity for the presence of testicular torsion, patients will have one or more of these signs and symptoms: nausea or vomiting, pain for less than 24 h, high position of the testis, and/or abnormal cremasteric reflex [1].
  - If the diagnosis is in question, radionuclide scan or ultrasonography of the testicles may be helpful to assess blood flow and to differentiate torsion from other conditions (Fig. 87.2).

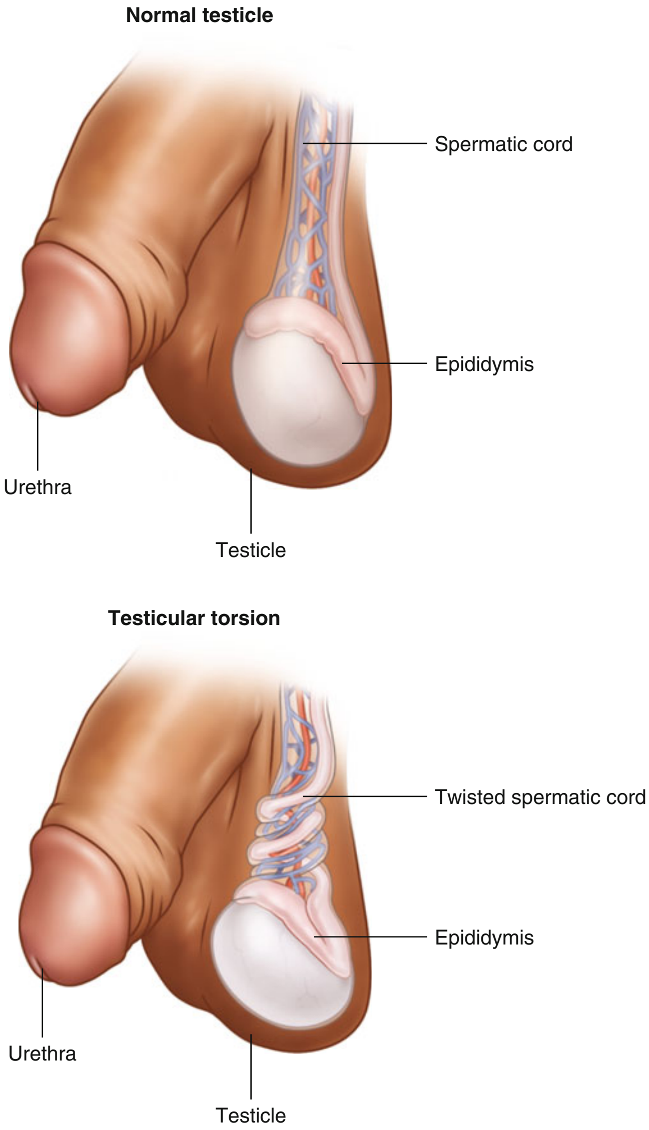
Normal testicle
Spermatic cord
Epididymis
Urethra
Testicle
Testicular torsion
Twisted spermatic cord
Epididymis
Urethra
Testicle

Fig. 87.1 Schematic of normal testicle and testicular torsion

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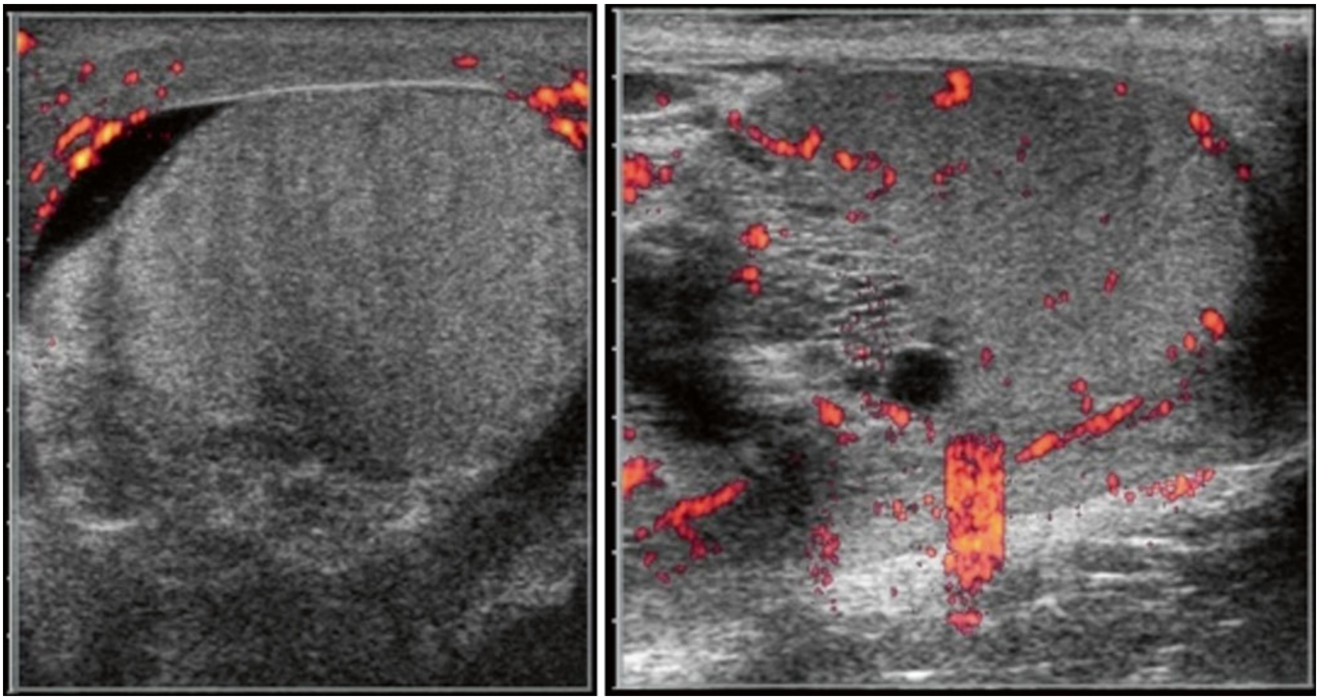

Fig. 87.2 Doppler ultrasound of bilateral testes shows swollen right testis with hypoechoic areas within and reduced arterial signal suggesting testicular torsion with necrosis (*left panel*). This is compared to the left testis which has normal flow (*right panel*) (Reproduced with permission from: Bhagra et al. [4])

87.2 Contraindications

- Do not attempt if the length of symptoms is greater than 24 h.
- Manual detorsion should not delay scrotal exploration and bilateral orchiopexy in the operating room [2].

87.3 Materials and Medications

- Standard precautions barrier protection for the provider
- Local anesthetic (optional to anesthetize the spermatic cord near the external ring)
- Intravenous sedation (optional)

87.4 Procedure

- The physician stands at the patient's feet and rotates the affected testicle away from the midline (as if opening a book) (Fig. 87.3).
  - For detorsion of the left testicle: the physician will place his or her right thumb and index finger on the affected testicle and rotate the testicle 180° from medial to lateral [2].
  - For detorsion of the right testicle: the physician will place his or her left thumb and index finger on the affected testicle and rotate the testicle 180° from medial to lateral.

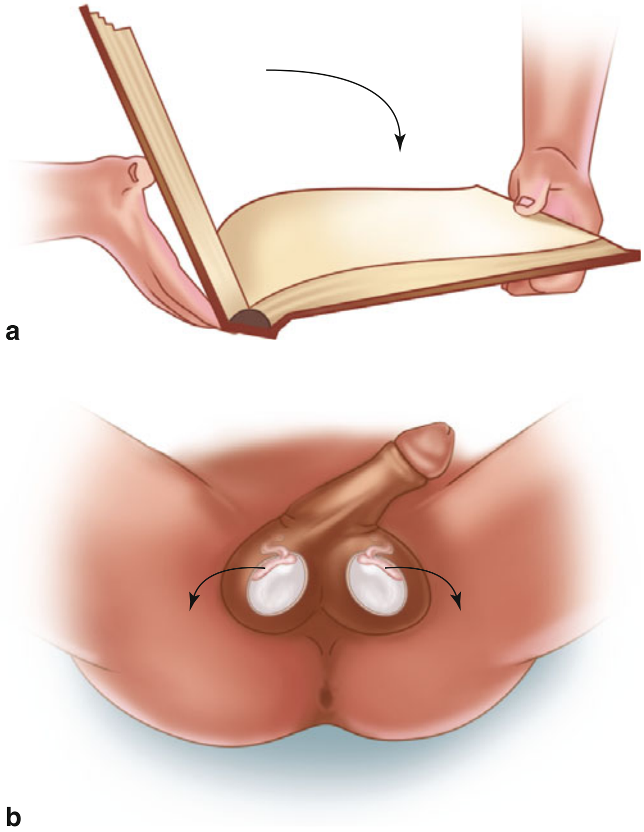

Fig. 87.3 (**a**) As if opening a book, rotate the testicle away from the midline. (**b**) Affected testicle should be rotated 180° from medial to lateral

87.5 Pearls and Pitfalls

- Pearls
  - The most common misdiagnosis is epididymitis.
  - Because torsion of greater than 360° degrees is possible, more than one rotation may be needed to fully detorse the affected testis (Fig. 87.4).
  - Only surgical exploration can provide a definitive resolution if testicular torsion is present [2].
- Pitfalls
  - The most common causes of testicular loss after torsion are delay in seeking medical attention (58 %), incorrect initial diagnosis (29 %), and delay in treatment at the referral hospital (13 %) [3]

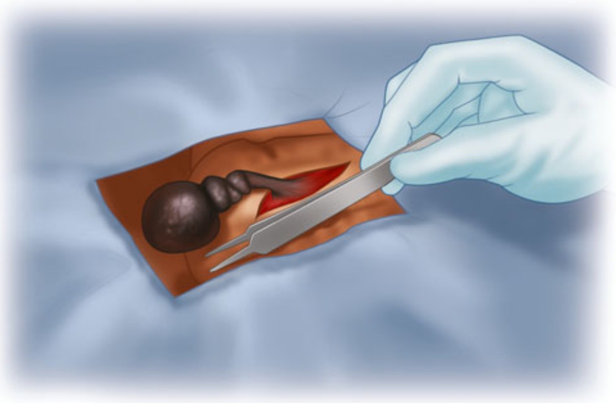

Fig. 87.4 Because torsion of greater than 360° degrees is possible, more than one rotation may be needed to fully detorse the affected testis

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Part XII

Skin and Soft Tissue Procedures

Local Anesthesia

88

Derek Ailes and Muhammad Waseem

88.1 Indications

- Laceration repair
- Abscess incision and drainage
- Wound exploration
- Vascular access procedures
- Foreign body removal
- Lumbar puncture

88.2 Contraindications

- History of allergy (usually to the ester class [e.g., procaine, tetracaine]), amide class (e.g., lidocaine [Xylocaine], bupivacaine, mepivacaine) may be safely substituted if true allergy to esters and vice versa. One percent diphenhydramine (4 mL normal saline: 1 mL 5 % intravenous [IV] diphenhydramine [Benadryl] mixture) can be used in patients with true allergy.
- Topical preparations on mucous membranes, burns, abraded/denuded skin, or eyes owing to potential toxicity from increased absorption and corneal injury.
- Common teaching is to avoid epinephrine-containing anesthetic solutions in nose, penis, and digits for concern of ischemia owing to end-artery constriction. Recent studies including prospective trials and comprehensive literature reviews, however, do not validate this concern [1, 2].

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88.3 Materials and Medications (Fig. 88.1)

- 1 % Xylocaine with or without 1:200,000 epinephrine, 0.25 % bupivacaine solution. 8.4 % (1 mL/mL) sodium bicarbonate (optional)
- 18-, 25-, or 27-gauge needles, syringes up to 10 mL
- Sterile and nonsterile gloves, face shield
- Alcohol pads and povidone-iodine swabs

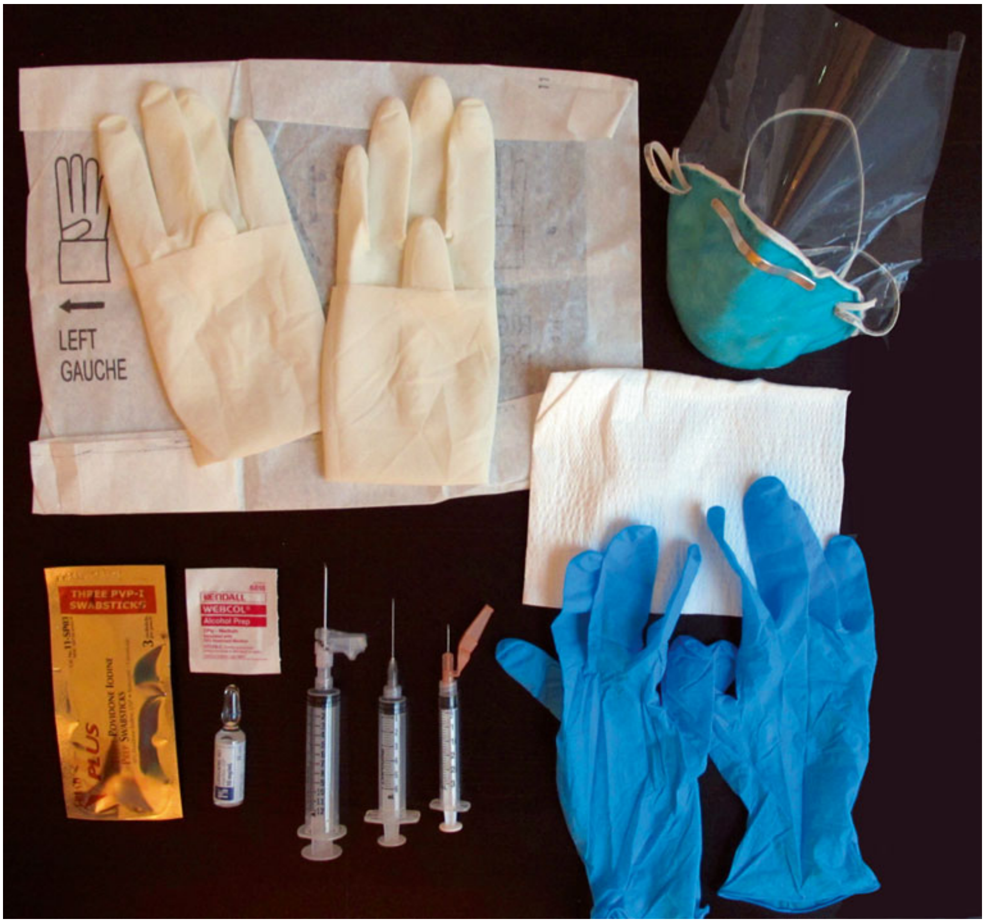
LEFT
GAUCHE
THREE PVP-I SWABSTICKS
POVIDONE IODINE
PLUS
KENDALL
WEBCOL
Alcohol Prep

Fig. 88.1 Local anesthesia materials

88.4 Procedure

1. Position the patient in a comfortable position (supine, sitting, anticipating vasovagal response).
2. Draw the anesthetic with an 18-gauge needle into a syringe. Be aware of the maximum dose for the particular local anesthetic to avoid systemic toxicity.
3. Take steps to minimize the pain of infiltration (Table 88.1).
4. Prepare the area with povidone-iodine solution; cover surrounding areas with sterile drapes.
5. Inject subcutaneously by direct infiltration with a 25- to 27-gauge needle noting wheal and blanching. If a clean wound, may inject into wound edges. Usually no aspiration is needed because the infiltration is superficial to major blood vessels.
6. For contaminated wounds or abscess incision and drainage, perform field block by inserting the needle into clean intact skin adjacent to the wound and continuing in a circular manner around the wound, injecting into the previously anesthetized area (Fig. 88.2).
7. Wait several minutes for the local anesthetic to provide the maximum effect.
8. Test the area for sharp sensation with a needle tip or other sharp object.

Table 88.1 Common anesthetics and their characteristics

Medication	Time to onset (min)	Length of action	Maximum dose (mg/kg)	Maximum dose with epinephrine (mg/kg)
Marcaine (bupivacaine)	5–10	>3 h, up to 9 h with epinephrine	2.5	2.5–3.5
Xylocaine (lidocaine)	<2	30–75 min (longer with epinephrine)	3	5–7

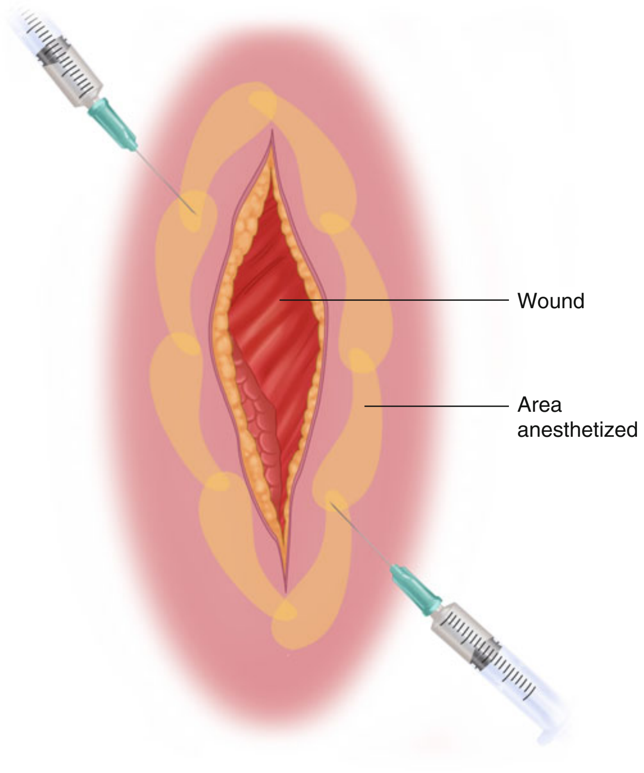

Fig. 88.2 Local infiltration should be performed in a circular fashion with each injection performed over the prior anesthetized area

88.5 Complications

- Systemic toxicity
- Allergic reaction
- Infection
- Digital artery vasospasm from accidental injection of epinephrine (can be reversed with topical nitroglycerine or subcutaneous phentolamine)
- Vasovagal response

88.6 Pearls

- Minimize or reduce the pain of infiltration by use of the following:
  - Warm Xylocaine before infiltration (blanket warmer or water bath) [3].
  - Buffer Xylocaine with 1 mL 8.4 % sodium bicarbonate for every 10 mL of Xylocaine. Buffer bupivacaine with 0.05–0.10 mL sodium bicarbonate for every 10 mL of bupivacaine (greater chance of precipitation).
  - Use a small-gauge needle (e.g., 27 gauge) and inject slowly.
  - Use a small syringe (1–3 mL) to reduce the pressure of injection.
  - Withdraw the needle and, just before exiting the skin, redirect and inject.
  - Inject in a circular manner around the wound with each subsequent injection entering a previously anesthetized area, such that the patient feels only one needle stick (Fig. 88.2).
  - Inject into the subcutaneous plane as opposed to the intradermal plane.
  - Consider using a topical anesthetic before infiltration, especially in pediatrics (lidocaine, epinephrine, tetracaine [LET]).
- Beware of toxicity by not exceeding the maximum dose, especially in large or multiple lacerations. Even at standard doses, toxicity can occur with inadvertent vascular injection, injection into highly vascular areas, or onto mucous membranes [4, 5].
  - Convert % mg/mL into mg/kg by moving the decimal one place to the right (e.g., 1 % Xylocaine becomes 10 mg/mL and 0.25 % bupivacaine becomes 2.5 mg/mL).
  - Xylocaine can be safely injected up to 3.5 mg/kg every 30 min, up to 300 mg/dose. If the mixture contains epinephrine, 5–7 mg/kg is safe.
  - Bupivacaine can be injected at 2.5 mg/kg and 3.5 mg/kg with epinephrine and can be injected every 3 h with daily maximum of 400 mg [5].
- When treating a wound, it is important to first anesthetize so debridement, cleansing, and irrigation can adequately be performed.
- Choose appropriate anesthetics. Xylocaine lasts approximately 75 min, and bupivacaine lasts several hours. Adding epinephrine to either increases vascular constriction, thereby decreasing systemic absorption and significantly increasing the duration of effect.
- Topical anesthetics have a role in pediatric populations and in conjunction with or as an alternate to local infiltrative anesthesia. TAC is a mixture of 0.5 % tetracaine, 0.05 % epinephrine, and 11.8 % cocaine. LET is 4 % lidocaine, 0.1 % epinephrine, and 0.5 % tetracaine. LET has been found to be safer and more cost-effective [6].

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89 Regional Anesthesia (Nerve Blocks)

Derek Ailes and Muhammad Waseem

89.1 Indications

- Repair of wounds where preserving anatomical landmarks or having precise anatomical alignment is important (e.g., vermillion border of lip)
- Pain control in dislocation or fracture reductions
- Incision and drainage of abscesses
- Burn and wound care
- Extensive or multiple lacerations (reduces total amount of local anesthetic needed)
- Foreign body removal

89.2 Contraindications

- Allergic to local anesthetic (see Chap. 88)
- History of coagulopathy or bleeding disorder
- Injection through infected tissue

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89.3 Materials and Medications (Fig. 89.1)

- Povidone-iodine, alcohol swabs
- Sterile gloves and drapes
- Local anesthetic solution (e.g., lidocaine, Marcaine with or without epinephrine)
- 18-gauge, 20- to 30-gauge needles 2 in. in length
- 22- to 24-gauge spinal needles
- Syringes up to 60 mL

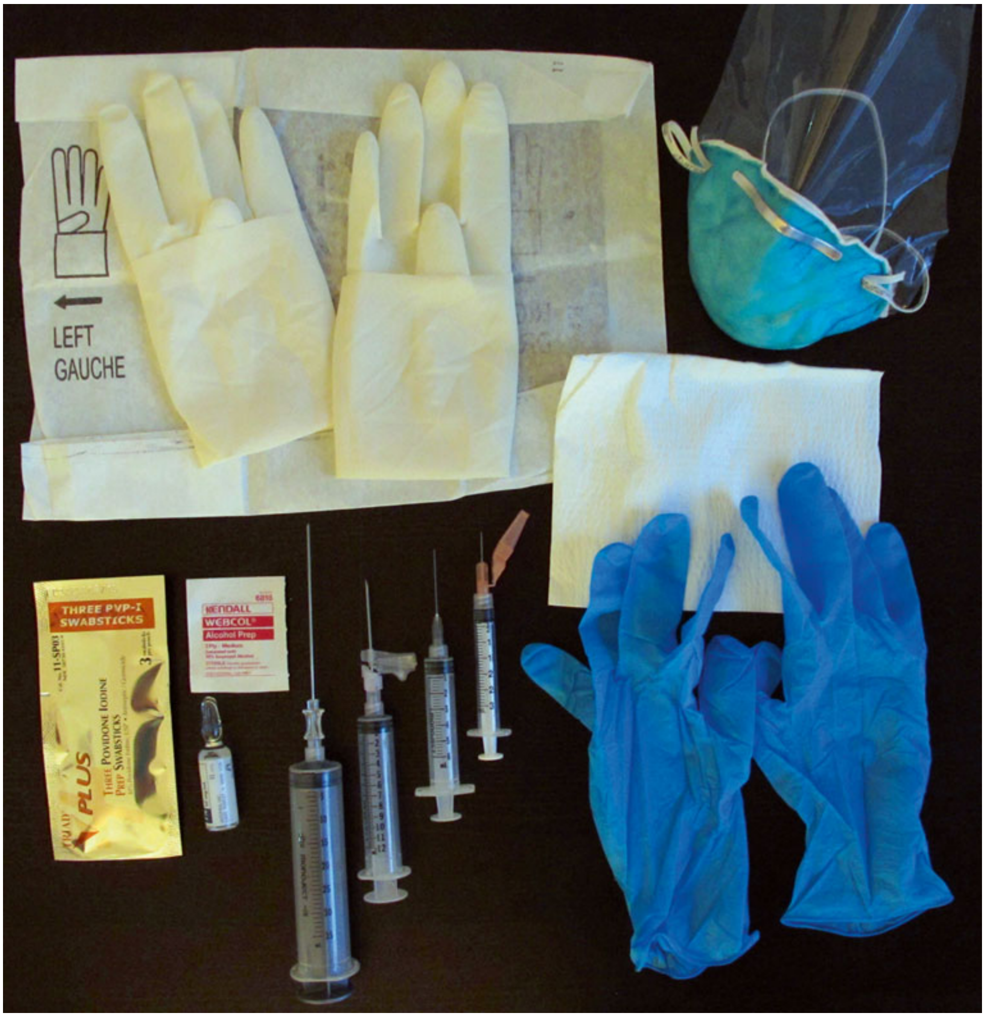
LEFT
GAUCHE
THREE PVP-I SWABSTICKS
PLUS
THREE POVIDONE IODINE PREP SWABSTICKS
KENDALL
WEBCOL
Alcohol Prep

Fig. 89.1 Materials

89.4 Procedure: General Block

1. Obtain consent after explaining the risks of procedure including temporary paresthesias and expected duration of block. Perform neurological examination before procedure, documenting any preexisting deficits.
2. Position the patient comfortably, preferably supine, anticipating vasovagal response.
3. Identify landmarks for the block. Clean area, prepare with povidone-iodine, and surround with sterile drapes.
4. A small skin wheal of local anesthetic may be placed at the site of needle entry before block.
5. Insert the needle into the site while aspirating to ensure it is not in a vessel.
6. If paresthesia is elicited, withdraw the needle slightly allowing paresthesia to improve and inject.
7. Wait 5–15 min for the block to reach full effect.
8. Test for sharp sensation in the anesthetized area and document.

89.5 Complications

- Infection
- Hemorrhage
- Hematoma
- Allergic reaction
- Systemic toxicity (exceeded maximum dose or inadvertent injection into vasculature)
- Paresthesias, pain
- Intraneural injection causing ischemia
- Intra-arterial injection of epinephrine causing vasospasm and tissue ischemia

89.6 Pearls and Pitfalls

- Pearls
  - It is important to aspirate before injecting anesthesia when performing regional anesthesia because, unlike local techniques, the needle is deeper and in proximity to larger vessels.
  - Shooting pain and/or paresthesias occurs when the needle contacts the nerve. When this happens, withdraw the needle 1 mm and wait for the paresthesia to resolve before injecting.
  - Injury can occur to a limb or digit if the patient manipulates it before the anesthesia wears off. The patient should be cautioned not to use the affected area until motor and sensation return. If an extensive block was done, monitor the patient in the emergency department until return of baseline neurological function.
- Pitfalls
  - It is traditionally taught to avoid epinephrine-containing solutions in blocks in end-artery blocks (e.g., digital blocks). However, evidence for any vascular insufficiency and necrosis as a result is lacking in standard commercially available lidocaine with epinephrine preparations. They should, however, be avoided in patients with peripheral artery disease [1, 2].

89.7 Selected Specific Blocks

- Contraindications and materials are the same as general block.

89.7.1 Facial Blocks: Trigeminal Nerve (Fig. 89.2) [2, 3]

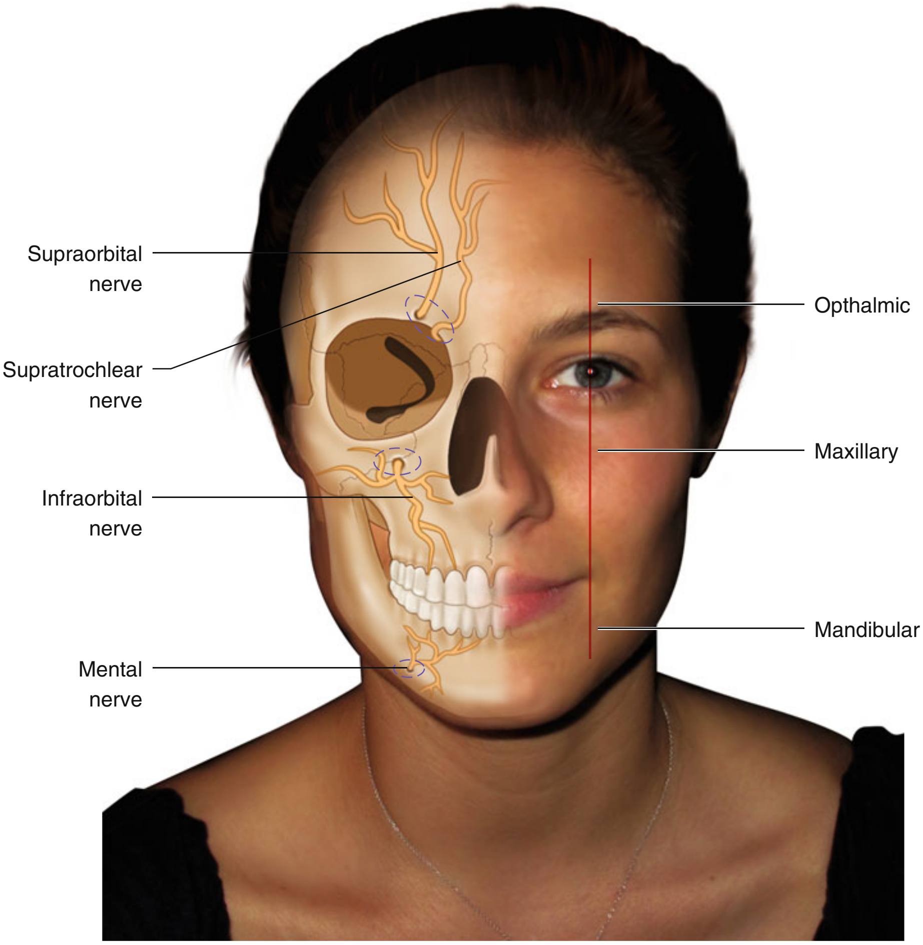
Supraorbital nerve
Supratrochlear nerve
Infraorbital nerve
Mental nerve
Opthalmic
Maxillary
Mandibular

Fig. 89.2 Vertical plane through the midposition of the pupil shows the position of the supraorbital foramen, infraorbital foremen, and mental foramen

89.7.1.1 Supraorbital (Fig. 89.3) and Supratrochlear Nerve Block

- Indications
  – To anesthetize the forehead from the orbital ridge to the vertex of the scalp. The supraorbital nerve emerges from the supraorbital foramen/notch and is a branch of the ophthalmic division of the trigeminal nerve. The supratrochlear nerve also is a branch of the ophthalmic division of the trigeminal nerve and exits through the superior medial aspect of the orbit.
- Procedure
  1. Inject local anesthetic solution over the midline of the forehead at eyebrow level.
  2. Inject a 25- or 27-gauge needle through skin wheal aimed laterally while injecting 3–5 mL local anesthetic subcutaneously. Stop infiltrating when the needle reaches the midline of the orbit.

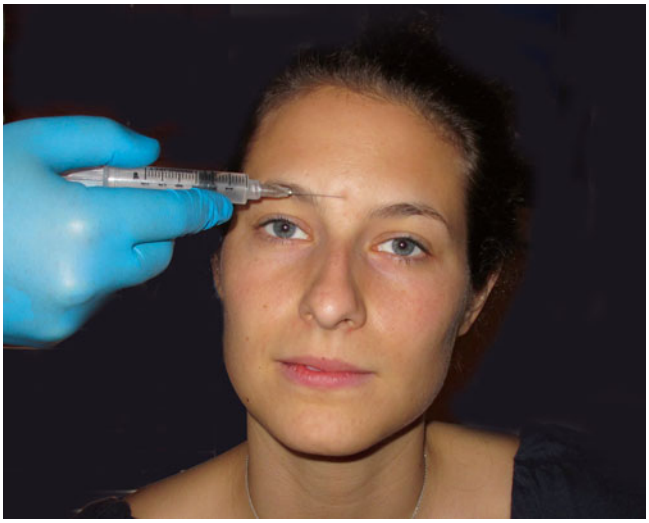

Fig. 89.3 Supraorbital nerve block

89.7.1.2 Infraorbital Nerve Block

- Indications
  – To anesthetize the medial cheek, upper lip, philtrum, skin between the lips and the nose, and nasal ala. The infraorbital nerve emerges from the infraorbital foramen and is a branch of the maxillary division of the trigeminal nerve. Anesthesia to the infraorbital nerve will also provide anesthesia to its terminus, the superior alveolar nerves.
- Procedure: Extraoral Approach (Fig. 89.4)
  1. Palpate the inferior orbital foramen in its midline position. The infraorbital nerve is often tender on palpation as it exits the foramen.
  2. Inject a 25- or 27-gauge needle just above the infraorbital foramen injecting 1–2 mL of local anesthetic.
  3. Take care not to inject into the foramen because there is an increased risk of intraneural injection.
  4. Hold a finger on the inferior orbital rim to avoid ballooning of the lower eyelid with injection.
  5. Intraoral approach is possible and preferred because it is less painful.

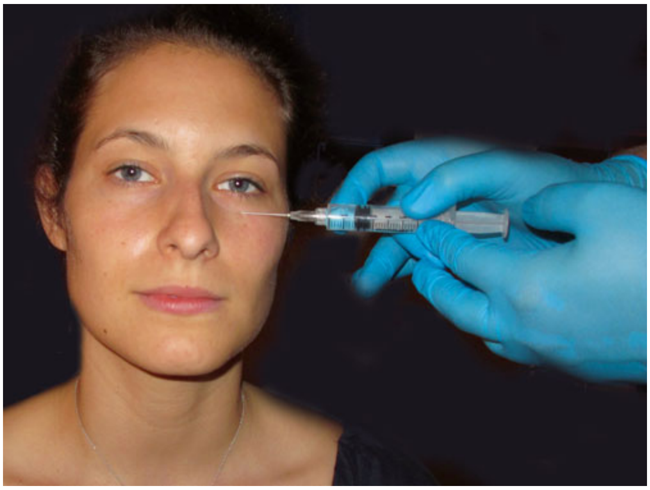

Fig. 89.4 Extraoral approach to the infraorbital nerve block

- Procedure: Intraoral Approach (Fig. 89.5) [3]
  1. Apply topical benzocaine or lidocaine gel to the point of insertion, which is the height of the mucobuccal fold over the first premolar, which is the site of insertion. Wipe off after 1–3 min.
  2. Palpate with the finger of the noninjecting hand over the inferior border of the inferior orbital rim. Retract the lip with the noninjecting hand.
  3. Using a long 25- to 27-gauge needle, with the bevel toward the bone, advance the needle at the insertion site toward the infraorbital foramen. Once the target is reached, aspirate and inject 1 mL of local anesthetic.
  4. Exert pressure on the foramen for 1 min after injection to force the anesthetic through the infraorbital foramen.
  5. If the needle is difficult to advance and the patient experiences pain on insertion, redirect the needle laterally and advance.
  6. If analgesia is attained for the lip but not the eyelid, the analgesia was placed inferior to foramen, and if analgesia is attained for the eyelid but not the lip, placement was superior to the foramen.

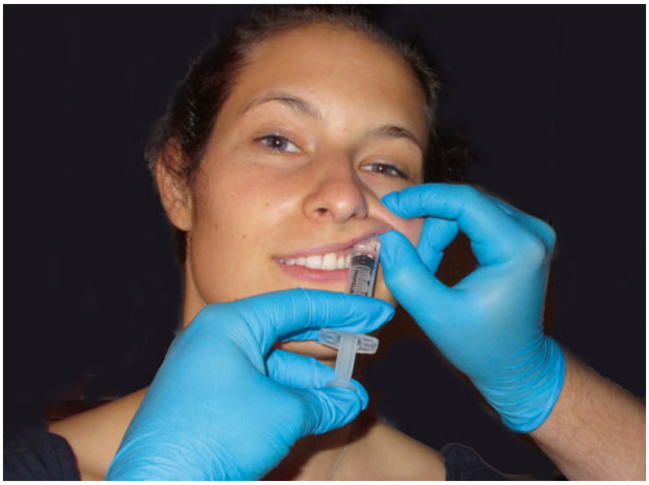

Fig. 89.5 Intraoral approach to the infraorbital nerve block

89.7.1.3 Mental Nerve Block

- Indications
  - To anesthetize the lower lip and chin and is especially useful in laceration repair at those sites. The mental nerve emerges from the mental foramen and is a branch of the mandibular division of the trigeminal nerve. Mental foramen lies in the vertical plane with the midpoint of the pupil and sits in the middle of the body of the mandible.
- Procedure: Extraoral Approach (Fig. 89.6)
  1. Inject local anesthetic solution over the identified location of the mental foramen, creating a skin wheal.
  2. Advance a 25- or 27-gauge needle through the skin wheel until the mandible is contacted, injecting 1–2 mL of local anesthetic.
  3. Intraoral approach is possible and preferred because it is less painful.
- Procedure: Intraoral Approach (Fig. 89.7) [3]
  1. Apply topical benzocaine or lidocaine gel to the point of insertion, which is the mucobuccal fold between the apices of the first and the second premolars. Wipe off after 1–3 min.
  2. Insert a 25- to 27-gauge needle, with the bevel toward the mandible, aimed toward the mental foramen.
  3. After advancing one-third the depth of the mandible and contacting the mandible, inject 1–2 mL of local anesthetic.
  4. By pressing firmly on the mental foramen for 2–3 min after the mental foramen has been blocked, an incisive nerve block is also created. This is useful if anesthesia to the lower anterior teeth is also desired.

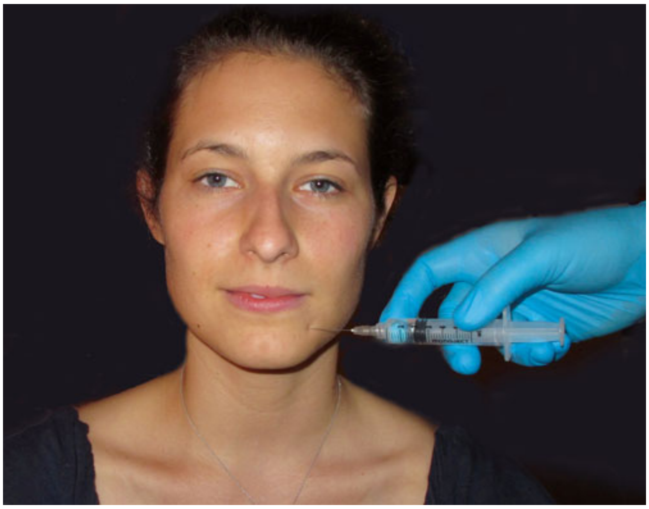

Fig. 89.6 Extraoral approach to the mental nerve block

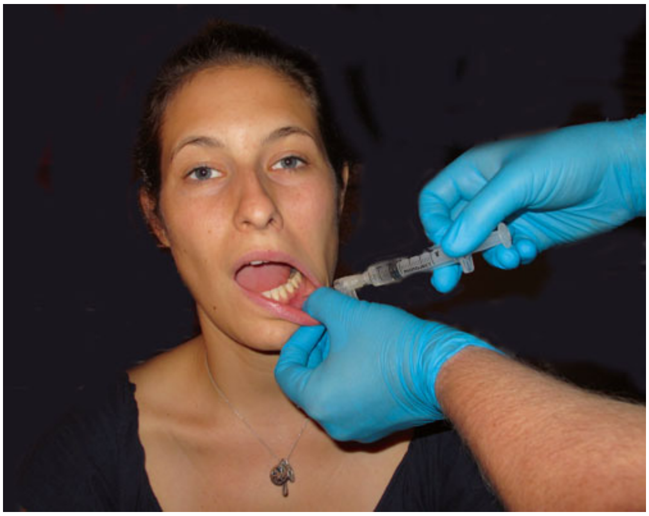

Fig. 89.7 Intraoral approach to the mental nerve block

89.7.2 External Ear Block (Fig. 89.8) [4]

- Indications
  - To anesthetize the entire external ear, excluding the external auditory canal and the concha
  - Especially useful in large lacerations of the ear and surrounding skin, hematoma evacuations, or incision and drainage of abscess.
- Procedure: Auricular Ring Block (Fig. 89.9) [4]
  1. Using a 25- to 27-gauge needle, insert the needle just inferior to the earlobe directing it toward the tragus.
  2. Aspirate and advance the needle superiorly subcutaneously injecting 3–4 mL of local anesthetic (Fig. 89.9, #1).
  3. Withdraw the needle without fully removing it and redirect it posterosuperiorly along the inferior posterior auricular sulcus, aspirating and injecting as before (Fig. 89.9, #2).
  4. Remove the needle and insert it just superior to the point of helix insertion into the scalp.
  5. Advance the needle and aspirate and inject in the direction of the tragus. Inject into the subcutaneous tissue while avoiding the ear cartilage (Fig. 89.9, #3).
  6. Withdraw and redirect the needle posteriorly and inferiorly toward the skin behind the ear, injecting as before (Fig. 89.9,#4).
  7. Beware of inadvertent cannulation of the superficial temporal artery, which crosses the zygomatic arch and crosses medial to the ear. If the artery is violated, it requires 20–30 min application of firm pressure.

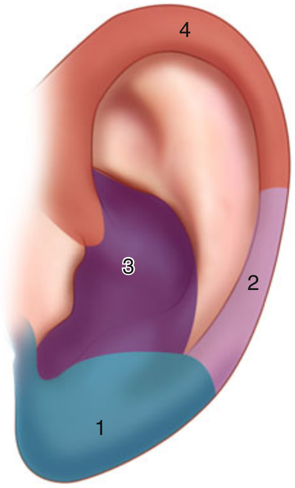

Fig. 89.8 Auricular block anesthetizes four nerves that innervate the auricle. *1* Great auricular nerve, *2* lesser occipital nerve, *3* auricular branch of vagus nerve, *4* auriculotemporal nerve

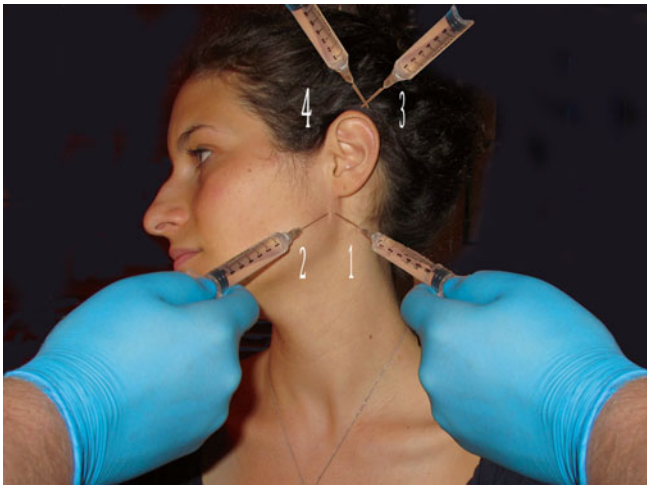

Fig. 89.9 Auricular ring block technique

89.7.3 **Wrist Block** (Fig. 89.10) [3, 5, 6]

- Indications
  - To anesthetize the hand in preparation for laceration repair, fracture or dislocation reduction, or pain relief

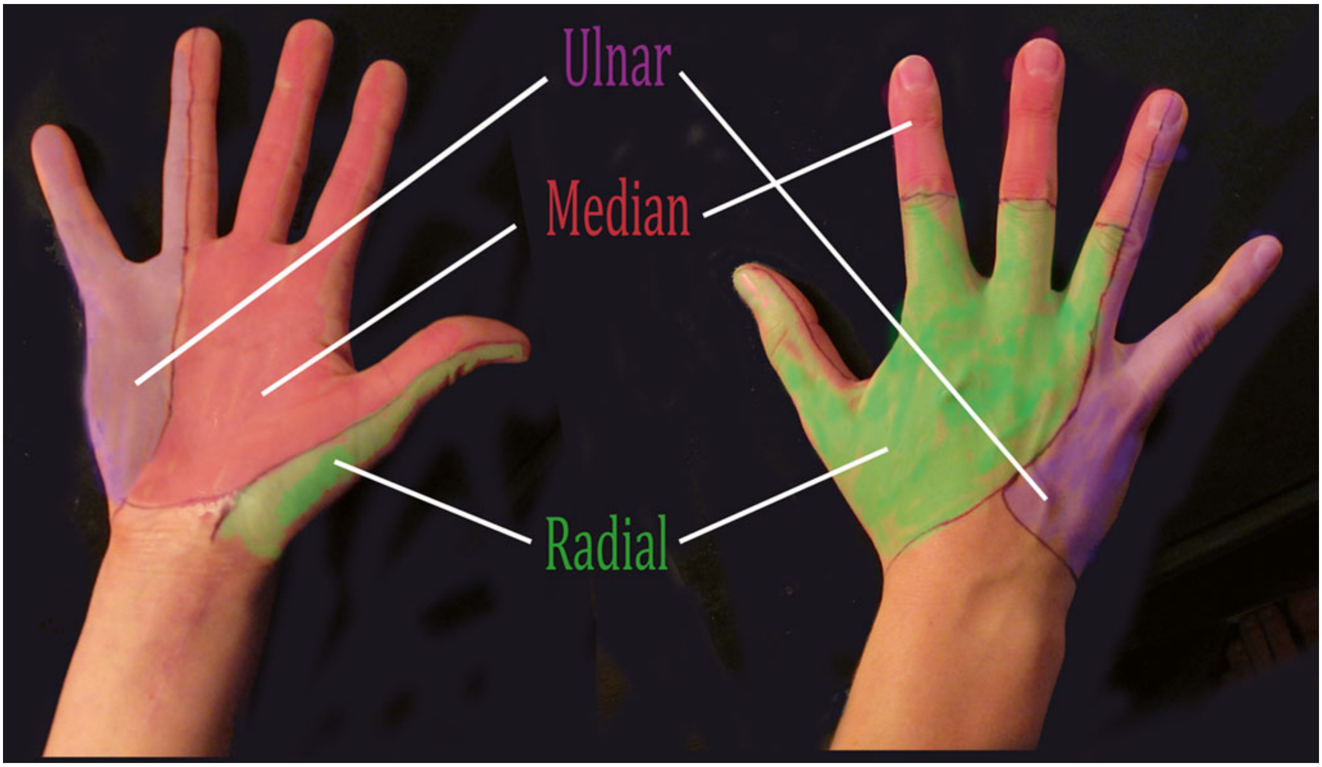

Fig. 89.10 Nerve distribution in the hand

89.7.3.1 **Wrist Block: Median Nerve** (Fig. 89.11)

- Procedure
  1. Position the patient supine with the palmar surface of the hand face up.
  2. Have the patient make a fist and slightly flex the wrist so that the palmaris longus and flexor carpi radialis tendons become prominent.
  3. Create a skin wheal of local anesthetic between the two tendons between the proximal skin crease and the distal skin crease at the wrist. Alternatively, anesthetic can be injected in line with the ulnar styloid process at the proximal skin crease.
  4. The palmaris longus tendon is absent normally in 10–20 % of the population. In this case, inject over the midpoint of the proximal skin crease at the level of the styloid process.

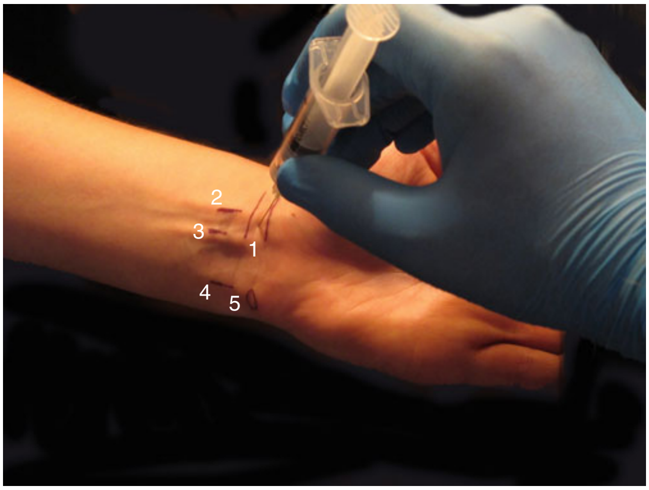

Fig. 89.11 Median nerve block at the wrist: *1* proximal and distal wrist creases radial artery, *2* flexor carpi radialis tendon, *3* palmaris longus tendon, *4* ulnar artery, *5* styloid process

89.7.3.2 **Wrist Block: Radial Nerve** (Figs. 89.12 and 89.13) **[3, 7]**

- Procedure
  1. To block the radial nerve, block multiple peripheral branches on the dorsal and the radial aspects of the lateral wrist.
  2. A field block in and around the anatomical snuffbox may be performed, requiring roughly 5–6 mL of local anesthetic. This anesthetizes the terminal branches of the radius arising from the forearm.
  3. Position the patient's palm face up and inject a skin wheal to the area 1 mm lateral to the radial pulse and in line with the proximal wrist crease. Inject 2 mL of local anesthesia with a 25- to 27-gauge needle. This anesthetizes the terminal trunk of the radial nerve.

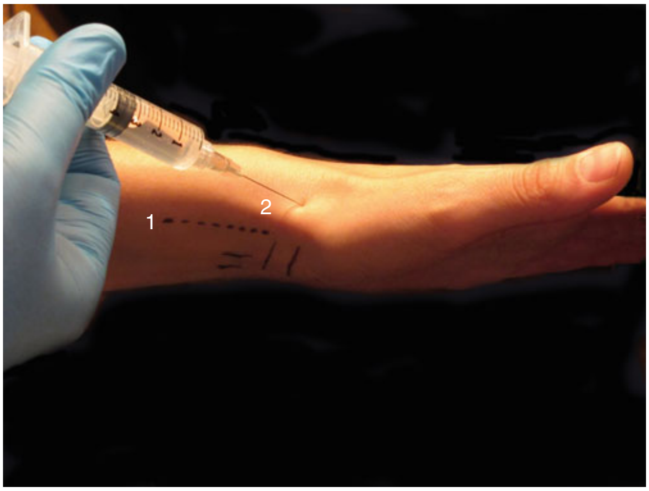

Fig. 89.12 Radial nerve block at the wrist: *1* radial artery, *2* anatomical snuffbox

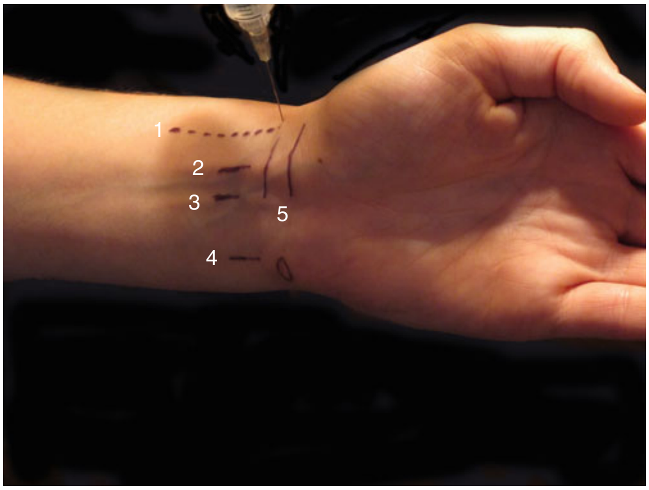

Fig. 89.13 Radial nerve block at the wrist: *1* radial artery, *2* flexor carpi radialis tendon, *3* palmaris longus tendon, *4* ulnar artery, *5* proximal and distal wrist creases

89.7.3.3 Wrist Block: Ulnar Nerve (Fig. 89.14)

- Procedure
  1. Position the patient with the hand face up.
  2. Palpate the styloid process of the ulna and pisiform and find the ulnar artery pulse.
  3. Create a skin wheal of local anesthetic between lateral to the ulnar artery and medial to the flexor carpi ulnaris tendon just proximal to the styloid process. This is at the level of the proximal wrist crease.

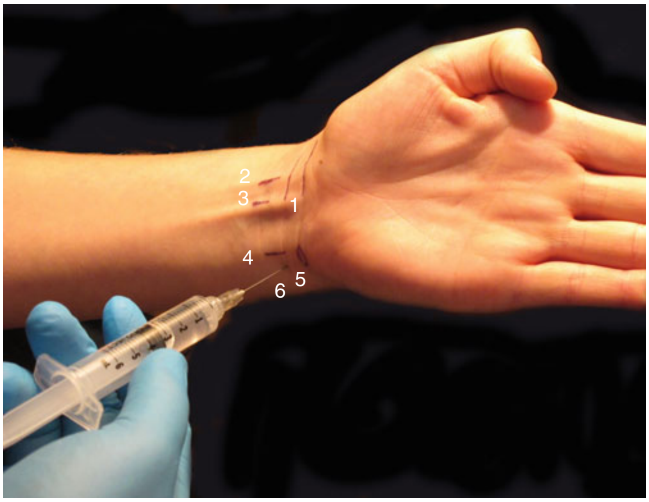

Fig. 89.14 Ulnar nerve block at the wrist: *1* proximal and distal wrist creases, *2* flexor carpi radialis tendon, *3* palmaris longus tendon, *4* ulnar artery, *5* styloid process, *6* flexor carpi ulnaris

89.7.4 Digital Nerve Blocks: Ring, Web Space, and Tendon Sheath (Fig. 89.15) [3, 8, 9]

- Indications
  - To anesthetize the digits in preparation for laceration repair, nail bed repair, joint reduction, or pain relief

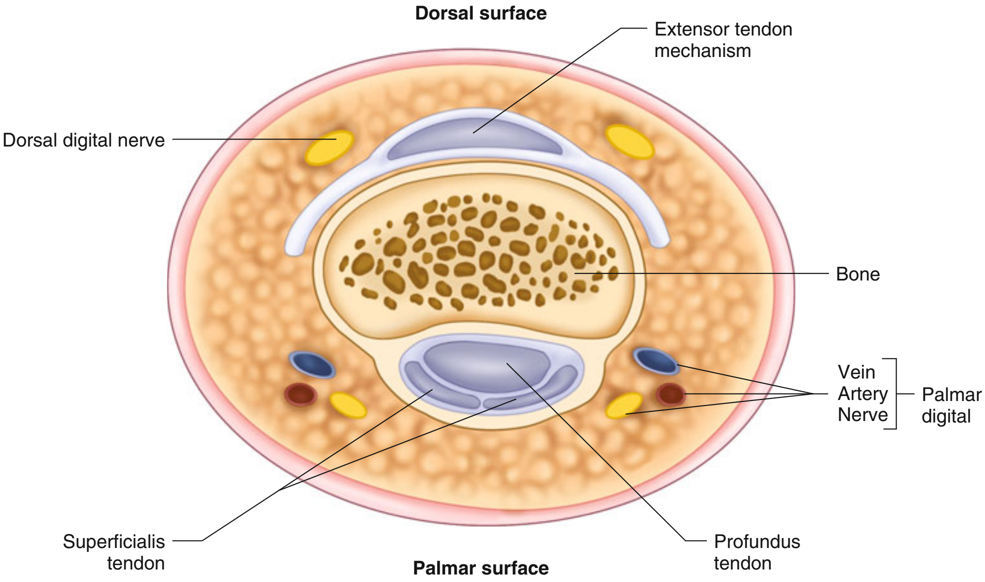
Dorsal surface
Extensor tendon mechanism
Dorsal digital nerve
Bone
Vein
Artery
Nerve
Palmar digital
Superficialis tendon
Profundus tendon
Palmar surface

Fig. 89.15 Cross section of finger

89.7.4.1 Ring Block (Fig. 89.16) [3]

- Procedure
  1. Insert a 25-gauge needle on the dorsal surface of the proximal phalanx of the digit to be anesthetized. Inject 1 mL along the dorsal surface and withdraw the needle.
  2. Reinsert the needle again perpendicular to the last injection and running on the lateral surface of the phalanx. Inject 1–1.5 mL of local anesthetic to just past the phalanx base.
  3. Repeat the injection in the same fashion on the medial aspect of the phalanx.
  4. Do not inject more than 5 mL into a digit.
  5. Toe blocks are similar to finger ring blocks, except that the great toe requires plantar surface injection as well, owing to its unique nerve supply.

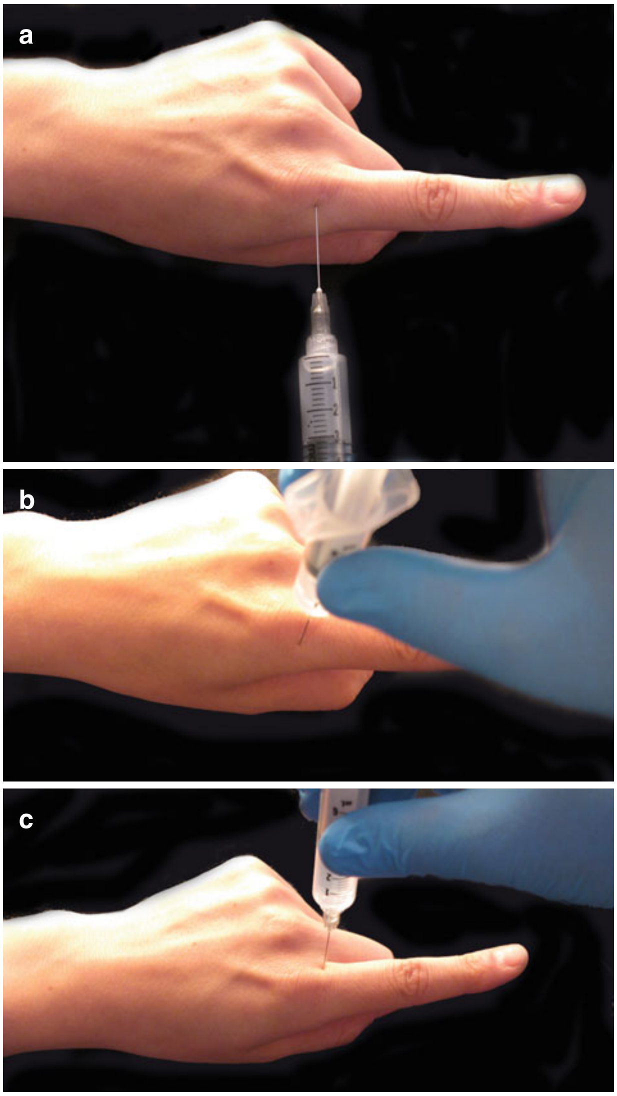

Fig. 89.16 Dorsal surface injection of digital nerve ring block. Digital nerve block is performed by injecting onto the (**a**) dorsal, (**b**) lateral, and (**c**) medial surfaces of the proximal phalanx

89.7.4.2 Web Space Digital Block (Fig. 89.17) [9]

- Procedure
  1. Have the patient abduct the fingers.
  2. Palpate the metacarpophalangeal joint and then insert a 25- to 27-gauge needle into the lateral web space subcutaneously, directing it dorsally. Aspirate then inject 1 mL of local anesthetic.
  3. Withdraw the needle but before the exiting skin, redirect toward the palmar aspect until the tip is next to the metacarpophalangeal joint, and inject 1 mL of local anesthetic.
  4. Repeat the procedure on the medial web space of the digit. Each digit blocked requires injection on both the lateral and the medial web spaces.

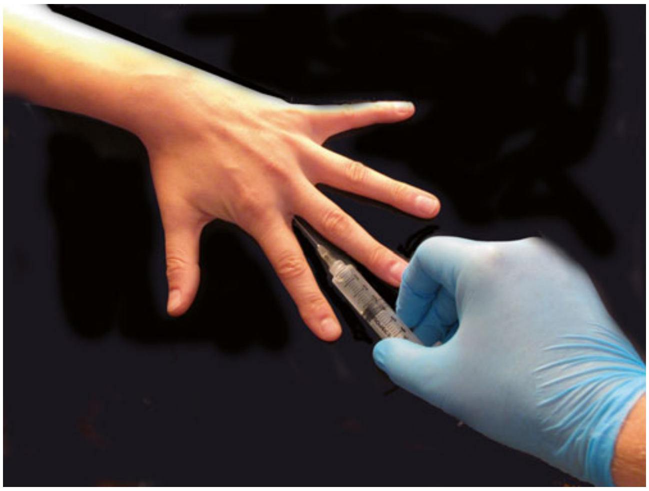

Fig. 89.17 Web space approach to the digital block, requiring injection on the medial and lateral web spaces for a blocked digit

89.7.4.3 Intrathecal Digital Block: Flexor Tendon Sheath (Fig. 89.18) [8]

- Procedure
  1. Inject anesthetic directly into the flexor tendon sheath. Palpate on the palmar surface over and proximal to the metacarpophalangeal joint. Gentle flexion of digit may better reveal the sheath. Have the patient abduct the fingers.
  2. Insert a 25-gauge needle at a 45° angle to the skin and along the long axis of the digit directly into the flexor tendon sheath at the level of the distal skin crease.
  3. Inject 2 mL of local anesthetic. The anesthetic should flow freely if it is in the sheath. If it does not, it is likely in the tendon and should be withdrawn slightly.
  4. Contraindications to intrathecal block are local infection and preexisting flexor tendon injury.
  5. Risk of tenosynovitis; sterilize the skin before introducing the needle.
  6. If laceration has involved the tendon, anesthetic may leak from the wound.

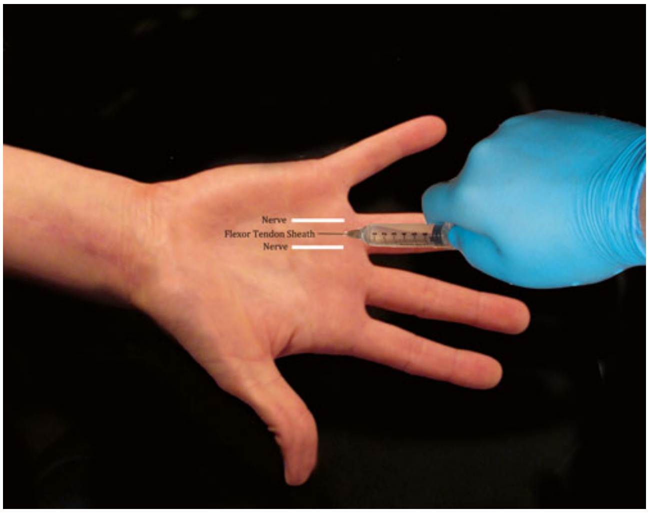

Fig. 89.18 Intrathecal/tendon sheath approach to the digital block

Acknowledgment The authors would like to thank Katy Howard for serving as the subject in many of the photographs in this chapter.

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Wound Management and Hemostasis

90

Rich Teitell and Muhammad Waseem

90.1 Indications for Primary Wound Repair

- Wounds that have been sustained less than 8 h before presentation may be closed primarily.
- If there is suspicion of broken glass or the presence of a foreign body, the patient should receive an x-ray before primary wound repair. Of note, x-ray has poor sensitivity for radiolucent foreign bodies such as wood and plastic.
- Wounds that are free of foreign bodies or show no gross evidence of infection or dead tissue may be closed primarily.

90.2 Contraindications for Primary Wound Repair

- History must address the factors that predispose a wound to greater risks of infection and not implement primary wound closure in such wounds that have had a duration greater than 8–12 h or contamination with saliva, stool, or foreign matter and a wound that has been sustained by blunt or crush mechanism.
- When wounds are highly contaminated with debris or if devitalized tissue is present, the wound should be left open for 3–4 days and then reevaluated.
- After a proper physical examination has been performed that assesses distal pulse and sensory and motor function of the surrounding region and distal extremity, if any of these are compromised, appropriate orthopedic and/or vascular consultation should be sought before wound closure, especially in the setting of a suspicion for open fracture.
- Consider delayed closure in wounds over joints.
- Wounds that have a significant loss of skin should be left to heal by secondary intention.

90.3 Procedure for Wound Closure and Hemostasis

1. Wound should be thoroughly prepared with Betadine (10 % povidone with 1 % iodine), which has a rapid onset with greatest antimicrobial effect.
2. Skin surrounding the wound should be covered with sterile drapes (Fig. 90.1) so as to reduce additional contamination within the open wound.
3. The most important determinant for preventing wound infection is adequate high-pressure irrigation.
4. Normal saline is the best solution for irrigation. Use pressures above 7 psi and an 18-gauge needle with a syringe of 30 mL or more; this gauge needle will achieve pressure greater than 7 psi.
5. It has been suggested that tap water irrigation may be just as effective. Because this approach will reduce costs, it can be considered.
6. Sharp debridement should be performed when foreign matter is found in an open wound that does not easily rinse out with saline. In this circumstance, consider wound closure by secondary intention or delayed primary closure.
7. At this point, wounds that do not meet criteria for primary closure must be left open, covered with a sterile dressing, and reevaluated in 3–4 days for consideration of delayed primary closure versus healing by secondary intention.
8. Wounds that do meet criteria as previously discussed for primary closure should be closed with either sutures or staples.
9. Staples are the preferred method of closure of scalp wounds and can be used under low wound tension.

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10. The angle of the stapler is critical and must be positioned perpendicular to the intended area of delivery. A two-person approach can be utilized for optimal placement of the staple, using forceps to approximate the edges of the tissue.
11. Synthetic or monofilament sutures have a lower rate of infection than braided sutures (for closure techniques with sutures, see Chap. 92).
12. Dermabond should be utilized only for the most superficial linear lacerations and confers the benefit of efficiency of time and less discomfort to the patient. However, it should be mentioned that Dermabond does not offer any statistically significant difference in cosmesis when compared with suturing or other adhesives (see Chap. 93).
13. When a wound presents with deep underlying tissue involvement and direct bleeding is evident, direct pressure may be used to achieve hemostasis within a wound. Surgicel may also be applied with pressure to achieve control of small capillary and venous oozing (Fig. 90.2).
14. When a persistent bleed is visible within a wound that does not respond to direct pressure, a figure-of-eight suture (Fig. 90.3) may be used.
15. If a bleeding vessel is visible within a wound, an alternate method of hemostasis may be achieved by utilizing a hemostat to clamp the vessel and then tying an absorbable suture (Fig. 90.4).

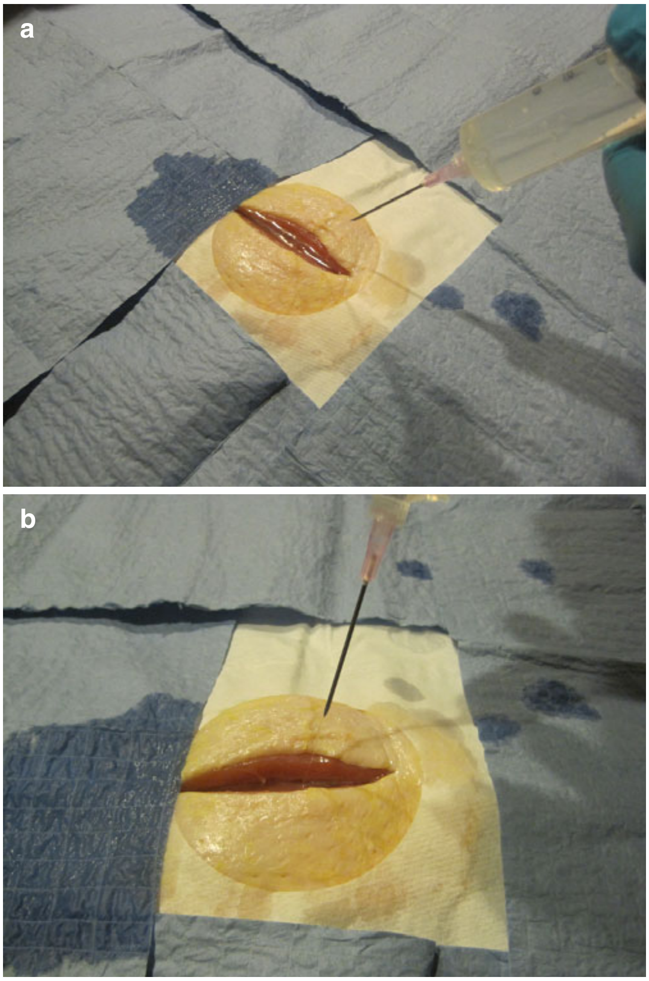

Fig. 90.1 (**a**) High-pressure irrigation using an 18-gauge needle (**b**)

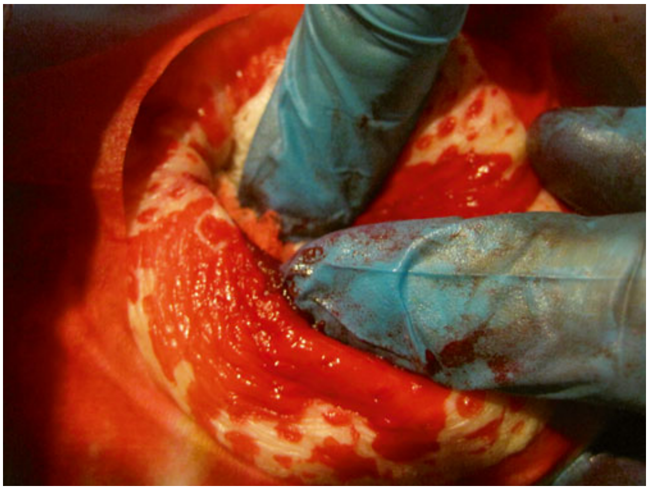

Fig. 90.2 Direct pressure with or without Surgicel may be used to achieve hemostasis within a wound and also to achieve control of small capillary and venous oozing

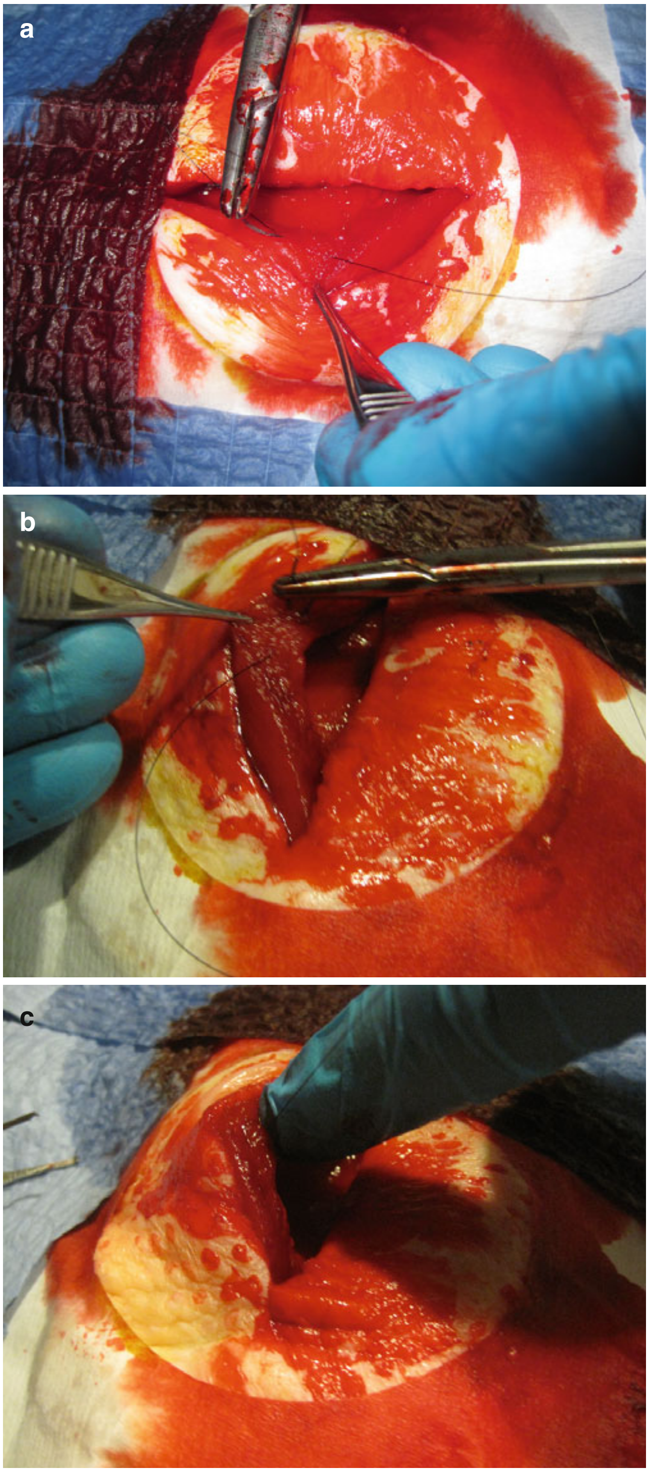

Fig. 90.3 (**a**) The location of the bleeding vessel in the subcutaneous tissue is identified and an absorbable suture is threaded through the region. (**b**) In a diagonal direction, a second suture is placed, which when tied will form the shape of an eight. (**c**) Once tied, the suture forms a figure eight in the tissue and hemostasis is achieved

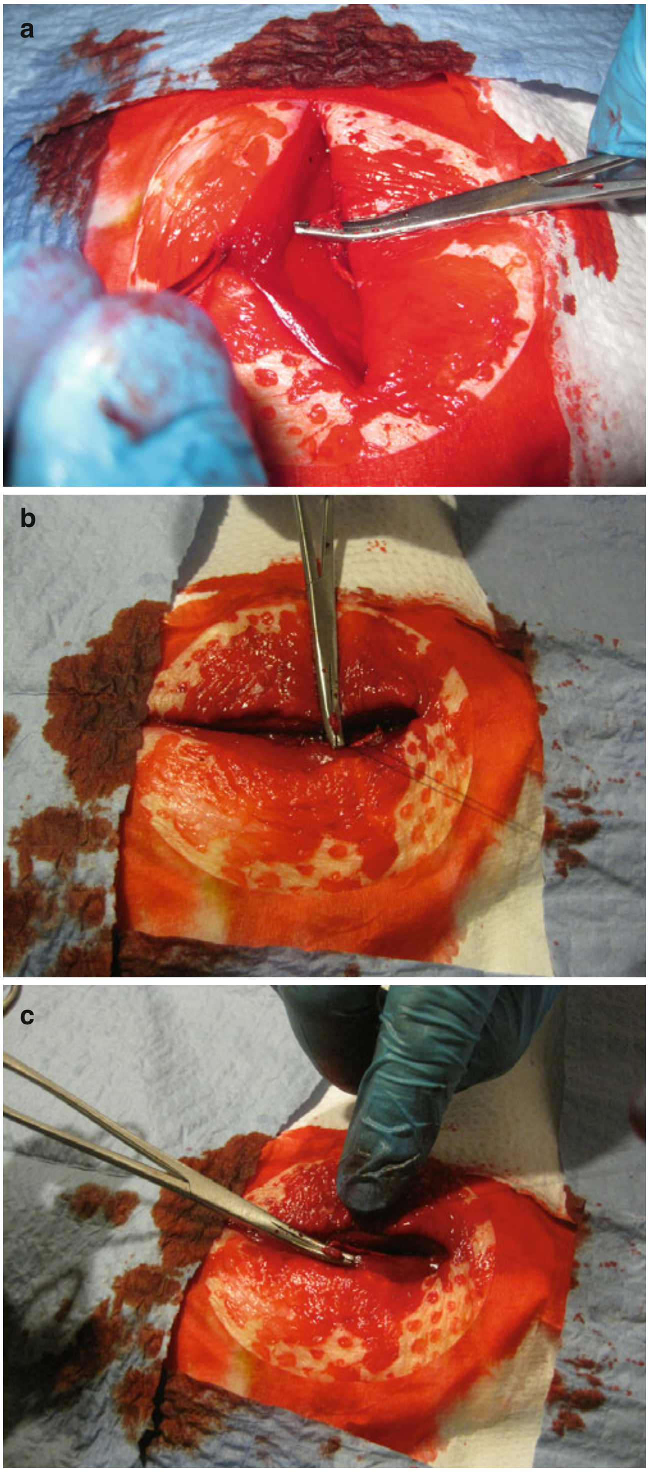

Fig. 90.4 (**a**) The culprit vessel is identified and clamped with a hemostat. (**b**) An absorbable suture is wrapped around the vessel inferior to the hemostat. (**c**) Once the first tie is placed being driven down with index finger, the hemostat may be removed and the knot can be completed for a total of three or four passes

90.4 Complications

- Hematoma formation
- Infection
- Scar formation

90.5 Pearls and Pitfalls

- Pearls
  - Antibiotic coverage should be employed judiciously depending on the wound and location.
  - Wounds to the face that are not heavily contaminated generally do not require antibiotics because the face and scalp have a significant vascular supply.
  - Patients with diabetes have higher incidences of wound infection, and the physician should consider prophylactic antibiotics in such individuals.
  - Wounds that are clean-contaminated and sutured in the emergency department should have a nonadherent dressing applied for 48 h until epithelialization has occurred. After that, the dressing may be removed, and soap and water gentle washing should commence to keep area clean. Only small amounts of bacitracin should be applied to wound in the interim period before sutures are removed.
- Pitfalls
  - Wounds located on the extremities have greater incidences of infection than those on the trunk or head/face.

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Burn Care

91

Thomas Parry and Jeffrey Pepin

Burns result from exposure to heat, caustic chemicals, electricity, or radiation. Damage to the natural barrier provided by skin results in rapid fluid losses and risk of infection. Permanent scarring is a common long-term complication. They may also be complicated by sensory deficits due to loss of nerve connections and limb loss due to circulatory compromise.

91.1 Burn Description (Fig. 91.1)

- First degree or superficial: burn that remains confined to the epidermis (e.g., sunburn)
- Second degree or partial thickness: burn that extends into the dermis (e.g., blistering scald burns)
- Third degree or full thickness: burn involving the entire depth of the dermis and epidermal appendages

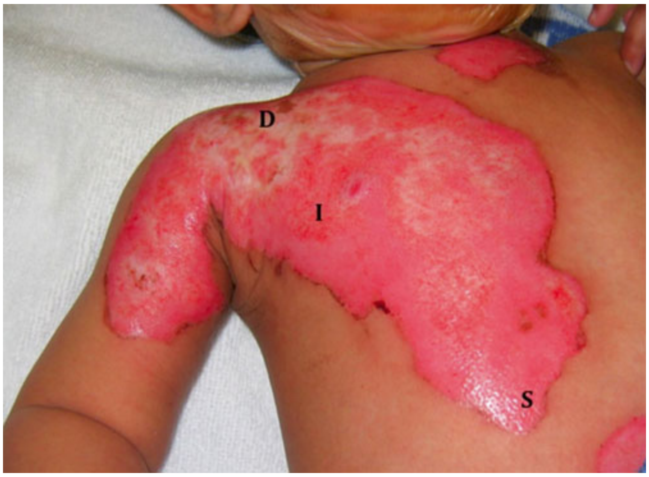

Fig. 91.1 Tea scald over the chest and shoulder of a child showing heterogeneity of burn depth. *D* deep (second or third degree), *I* intermediate (second degree), *S* superficial (first degree) (Reproduced from: Enoch S, Roshan A, Shah M. Emergency and early management of burns and scalds. *BMJ*. 2009;338:b1037, with permission from BMJ Publishing Group Ltd.)

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91.2 Indications

- Superficial, deep second degree, and third degree.
- First-degree burns generally need only supportive care.

91.3 Materials and Medications

- Appropriate analgesia
- Antibiotic ointment
- Silver sulfadiazine (avoid on face)
- Sulfamylon for ears
- Alternative agents include bacitracin or polymyxin B ointments
- Cleansing solution such as chlorhexidine prep and water
- Basin
- Petroleum gauze
- Several 4×4 gauze pads
- Rolled gauze
- Tape
- Gloves

Airway, breathing, and circulation and cervical spine should be immediately assessed before any burn wound management. It is important to remember that any patient suspected of an inhalation injury or carbon monoxide poisoning should receive 100 % humidified oxygen until carboxyhemoglobin returns to normal. Inhalation injuries may not present themselves until after fluid resuscitation has already been started, so early intubation is recommended in these cases.

91.4 Sizing

Total body surface area (TBSA) of body parts is estimated by multiples of 9 (Rule of Nines)

- Adults
  - Head and neck: 9
  - Arms: 9 each
  - Legs: 18 each
  - Trunk: 18 front and 18 back
  - Perineum and palms: 1
- Infants/children
  - Head and neck: 18
  - Arms: 9 each
  - Legs: 14 each
  - Trunk: 18 front and 18 back

A second way to estimate TBSA in smaller burns is by using the palm surface area: using the patient's palm as a guide, each palmar surface equals 1 %.

A third way to estimate TBSA is via the use of the Lund and Browder chart (Fig. 91.2).

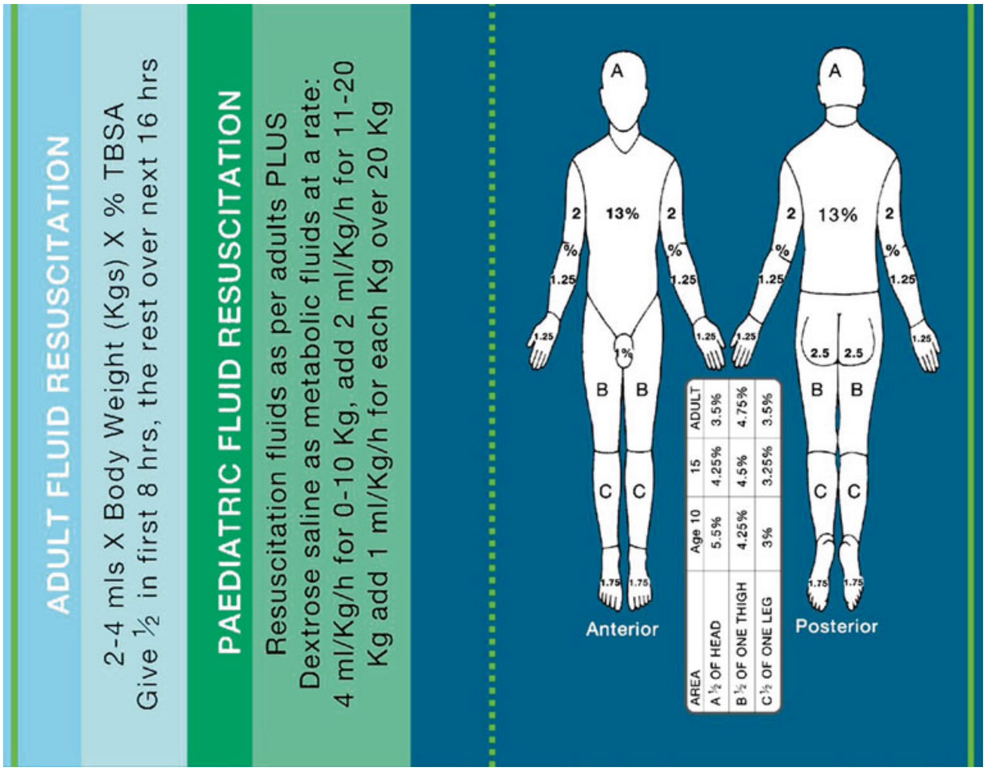

ADULT FLUID RESUSCITATION

2-4 mls X Body Weight (Kgs) X % TBSA
Give ½ in first 8 hrs, the rest over next 16 hrs

PAEDIATRIC FLUID RESUSCITATION

Resuscitation fluids as per adults PLUS
Dextrose saline as metabolic fluids at a rate:
4 ml/Kg/h for 0-10 Kg, add 2 ml/Kg/h for 11-20 Kg add 1 ml/Kg/h for each Kg over 20 Kg

AREA	Age 10	15	ADULT
A ½ OF HEAD	5.5%	4.25%	3.5%
B ½ OF ONE THIGH	4.25%	4.5%	4.75%
C ½ OF ONE LEG	3%	3.25%	3.5%

A
13%
2
%
1.25
1.25
1.25
1.25
1.25
2
%
1%
B
B
C
C
1.75
1.75
Anterior
A
13%
2
%
1.25
1.25
2
%
1.25
1.25
2.5
2.5
B
B
C
C
1.75
1.75
Posterior

Fig. 91.2 Lund Browder chart for estimating total body surface area of burns, with suggested fluid resuscitation guidelines (Reprinted from Malic CC, Karoo RO, Austin O, Phipps A. Resuscitation burn card–a useful tool for burn injury assessment. *Burns*. 2007;33(2)195–9, with permission from Elsevier)

91.5 Fluid Resuscitation

Because fluid resuscitation is absolutely essential in the early aspects of burn care, the Parkland formula has been used to estimate fluid requirements in burn patients. The patient's weight in kilograms is multiplied by the percent body surface area (BSA) involved; this number is multiplied by 4 mL of lactated Ringer's solution. Half of this amount is given during the first 8 h and the remaining amount is given over the next 16 h of resuscitation. The goal is to keep urine output approximately 0.5–1.0 mL/kg/h.

In pediatric cases, the Galveston formula may be used instead: 5000 mL/m^2 BSA burned plus 2000 mL/m^2. TBSA of 5 % dextrose in lactated Ringer's solution intravenously over the first 24 h, half in the first 8 h, and the other half over the next 16 h.

91.6 Procedure

1. Provide appropriate analgesia.
2. Clean the wound with antiseptic solution and water (if it is a dry chemical burn, make sure to brush off as much chemical before using copious amounts of water to clean the wound).
3. Debride any loose skin or foreign debris using a dry 4×4 or rolled gauze.
4. Apply antibiotic ointment or cream to the burn.
5. Apply petroleum gauze in a single layer just over the affected skin.
6. Use loose 4×4 gauzes and "fluff" them to make a thick layer of padding to place over the petroleum gauze.
7. Either wrap the entire area with a rolled gauze or tape a small layer of 4×4 gauze over the "fluffed" layer of 4×4 gauze.

91.7 Complications

- Wound infection
- Nonhealing wound requiring skin graft (deep second-degree and third-degree burns)
- Compartment syndrome (circumferential burns may require escharotomy)
- Rhabdomyolysis

91.8 Pearls and Pitfalls

- Pearls
  - Determination of the depth of burns on initial presentation is difficult (especially when covered with petroleum). A good rule of thumb is if it blanches and/or hurts, it is a partial thickness burn.
  - First-degree burns are not included in burn size estimations for fluid resuscitation calculation.
  - Burn size determines fluid requirements and transfer decision.
  - Burn of greater than 20 % TBSA should receive intravenous fluids.
  - Patients who have inhalation injury, greater than 10 % TBSA, high-voltage electrical injury, or chemical burns should be referred to burn unit.
  - Fluid resuscitation should be adjusted according to physiological response such as urine output (30–50 mL/h in adults and 1 mL/kg/h in children).
  - Assure tetanus is up to date.
- Pitfalls
  - Keep the patient warm in the first few hours. There is no need to apply ice.
  - All jewelry and rings should be removed.
  - Prophylactic antibiotics are not recommended.
  - Silver sulfadiazine should be avoided in facial burns because of the risk of staining of the skin.

Blister care is a very controversial topic. Current research suggests that it may be beneficial to keep the blister intact unless it appears to be tense or over a joint. Most blisters will rupture in 2–4 days. Ruptured blisters should be debrided with all the extra skin removed. Most burn units will scrub everything off once they receive a patient.

Wounds should be kept clean to prevent an environment that will increase the chances of infection. Wrap in saline-soaked sterile gauze prior to transfer.

Dressing changes should be done daily with all previously applied antibiotic ointment removed before a reapplication of new ointment. It is important to provide analgesic 30 min before a dressing change.

91.9 Admission Criteria

- Partial-thickness burns of noncritical areas not including the eyes, ears, face, hands, feet, or perineum that total a BSA of 10–20 % in adults
- Partial-thickness burns of noncritical areas involving 5–10 % of BSA in children younger than 10 years
- Suspicious of non-accidental trauma
- Patients unable to care for wounds in outpatient settings
- Prompt referral to a burn specialist is required in the following cases:
  - Partial-thickness and full-thickness burns greater than 10 % of the TBSA in patients younger than 10 years or older than 50 years of age.
  - Partial-thickness and full-thickness burns greater than 20 % of the TBSA in other age groups.

- Partial-thickness and full-thickness burns involving the face, eyes, ears, hands, feet, genitalia, or perineum or the skin overlying major joints.
- Full-thickness burns greater than 5 % TBSA in any age group.
- Electrical burns, including lightning injury: significant volumes of tissue beneath the surface may be injured and result in acute renal failure and other complications.
- Significant chemical burns.
- Inhalation injury.
- Burn injury in patients with preexisting illness that could complicate management, prolong recovery, or affect mortality.
- Any burn patient in whom concomitant trauma poses an increased risk of morbidity or mortality may be treated initially in a trauma center until stable before transfer to a burn center.
- Children with burns seen in hospitals without qualified personnel or equipment for their care should be transferred to a burn center with these capabilities.
- Burn injury in patients who will require special social and emotional or long-term rehabilitative support, including cases involving suspected child abuse and neglect.

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Wound Closure

92

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Karlene Hosford, and Muhammad Waseem

92.1 Indications

- Open wound of skin or mucosal tissues
- Purpose
  - Preserve function
  - Control bleeding
  - Promote healing
  - Cosmesis

92.2 Contraindications

- Wounds caused by animal or human bites
- Contaminated, infected, or puncture wounds
- Complex wounds (may require operating room)

92.3 Methods

- Suture placement
- Tissue adhesives
- Adhesive tapes
- Staples

92.4 Preparation

- Obtain a complete history of injury
  - Mechanism
  - Time since injury
  - Tetanus status
  - Comorbidities
- Examine the extent of the wound, remove any contaminants, debride devitalized tissue, inspect for foreign bodies. Obtain a radiograph if foreign body is suspected.
- Copious irrigation with normal saline.
- Clean around the wound with a povidone-iodine solution.
- Drape the area in sterile manner.
- Inject the anesthetic agent into the wound edges using a 25- or 27-gauge needle. The most common agent is lidocaine 2 % with or without epinephrine 1 % (maximum dose is 3 mg/kg without epinephrine and 5 mg/kg with epinephrine).
- Close the wound using the appropriate technique (see later).
- Dress the wound.
- Update tetanus and diphtheria vaccination if needed.

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92.5 Suture Repair

92.5.1 Materials and Medications

- Commercial kits commonly contain all the following except the suture material (Fig. 92.1)
  - Povidone-iodine solution
  - Normal saline for irrigation
  - 5- to 12-mL syringe with a 25-gauge needle
  - Anesthetic agent
  - Needle holder
  - Pickups
  - Suture scissors
  - Suturing material
  - Sterile drape or sheet, gloves, gauze

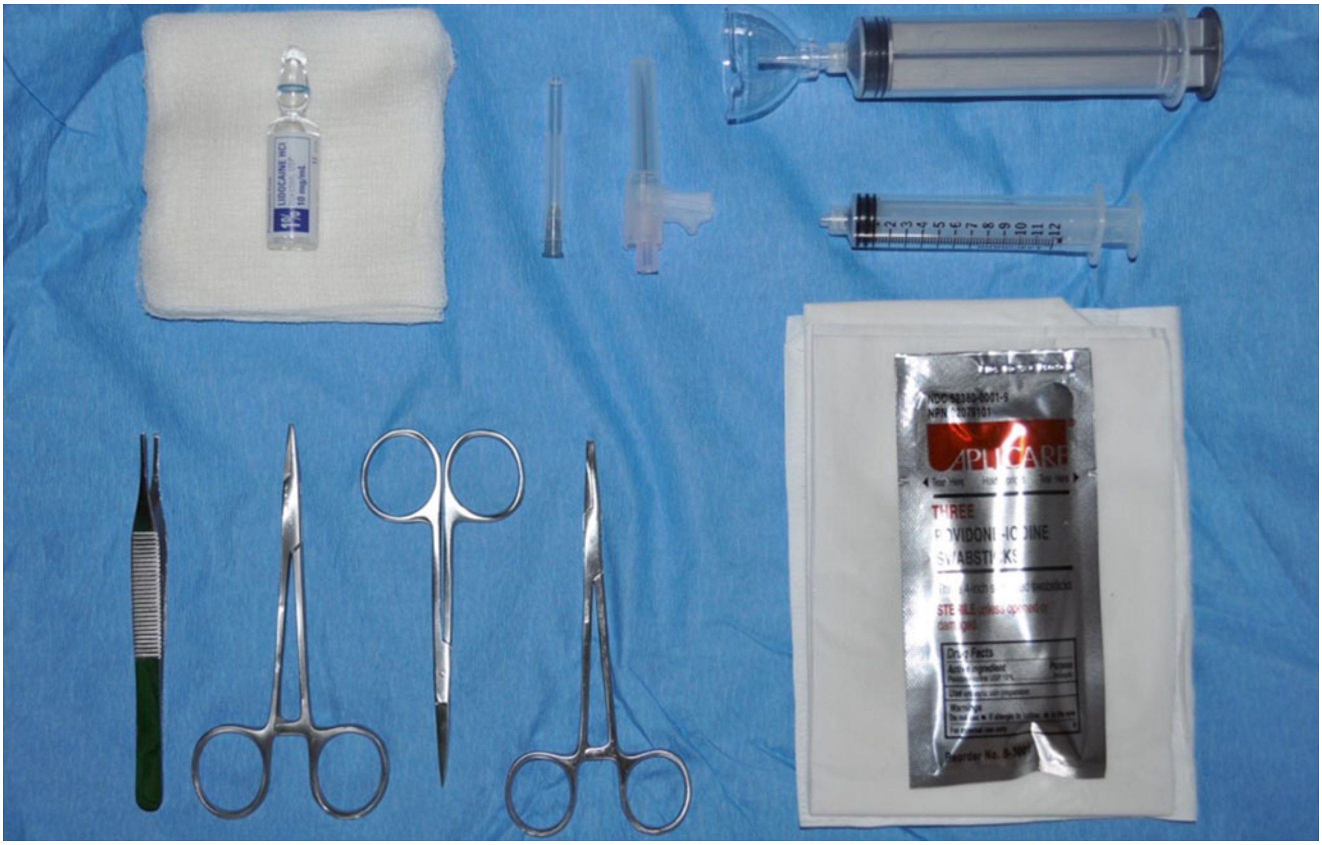
LIDOCAINE HCl
10 mg/mL
APLICARE
THREE
POVIDONE-IODINE
SWABSTICKS
Drug Facts

Fig. 92.1 Suture kit

92.5.2 General Guidelines

- Local anesthetic lidocaine 1 % or lidocaine 1 % with epinephrine.
- Minimize direct use of instruments on the tissues.
- Wound edges should be everted to maximize healing and cosmetic effect. This is achieved by inserting the needle at 90° to the skin.
- Sutures should be evenly spaced, placed 1–3 mm apart and 2 mm from the wound edge.
- Optimal tension is achieved by tying the sutures so the edges lightly approximate.

92.5.3 Suture Material

- Nonabsorbable
  - Silk: for specialty use, reactive and weak
  - Nylon (Ethilon), polypropylene (Prolene): good strength, good overall material for cutaneous wounds
  - Polypropylene: good strength, difficult to use
  - Require removal at a specified time
- Absorbable
  - Undergo rapid degradation in tissues, losing their tensile strength within 60 days
  - Indication: buried suture to reduce wound edge tension
  - Vicryl: subcutaneous placement, mucous membranes
  - Chromic: use for intraoral lacerations
  - Removal not required

92.5.4 Suture Size

- 0.0–2.0: thick material for large wounds, trunk
- 0.3–0.4: used on medium-sized wounds, extremities, scalp
- 0.5–0.6: fine sutures, used on facial wounds

92.5.5 Suture Techniques

- Simple interrupted sutures (Fig. 92.2)
  - Most common method
  - Position needle 2 mm from the wound edge at a 90° angle. Enter the needle into the skin and arc through the wound edge and into the opposing edge at the same level, exiting the skin on the opposing side 2 mm from wound edge, tie.
- Deep dermal suture (Fig. 92.3)
  - Also known as buried sutures, used to minimize tension in a wound.
  - Use absorbable suture material.
  - The needle is placed at the base of the wound wall and arched upward, exiting the ipsilateral wall more superficially. The needle is then directed across to the opposing wound wall at the same level and directed downward, exiting deep, tie. Note: The knot will be deep in the wound.
- Simple running suture (Fig. 92.4)
  - This method provides rapid closure of long and relatively linear lacerations.
  - Place the initial suture in the same manner as a simple suture, tie, cut the free strand, and leave the needle attached. Reintroduce the needle into the skin on the opposite side so the suture crosses the wound superficially at a 65° angle. The needle is then inserted perpendicular to the skin, emerging on the opposite side about 3 mm from the wound edge. Repeat without tying until closure is complete, maintaining appropriate tension. When the last stitch is placed, leave a loose loop of suture on one side so that both ends can be tied together.
- Vertical mattress suture (Fig. 92.5)
  - Provides the benefits of both simple and deep techniques. For use on deeper, gaping wounds and wounds over high-tension areas such as joints.
  - Position the needle 1 cm from skin edge, at a 90° angle, drive a deep arc perpendicular through the wound, exiting the skin on the opposing side the same distance from the wound edge. Next, reinsert the needle on the ipsilateral side 2 mm from the edge, emerging on the opposing side and approximate, tie.
- Horizontal mattress suture (Fig. 92.6)
  - For large wounds with tension.
  - Place the initial suture in the same manner as a simple suture, only do not tie. Reposition the needle on the ipsilateral side, horizontally 5 mm to the side of the exit at the same distance from the wound edge and drive through to the other side, tie. Note: The tie lies parallel to the wound.
- Half-buried horizontal mattress suture (Fig. 92.7)
  - Used on wounds with skin flap.
  - On one side, drive the needle percutaneously, and then pass horizontally through the dermal tissue of the tip of flap, finally passing into the dermis of the opposing edge and exiting the skin, tie.

92.5.6 Recommendations

- Face
  - 5.0–6.0 nylon.
  - Remove after 3–5 days.
- Scalp
  - 2.0–3.0 nylon or staple.
  - Remove at 8–10 days.

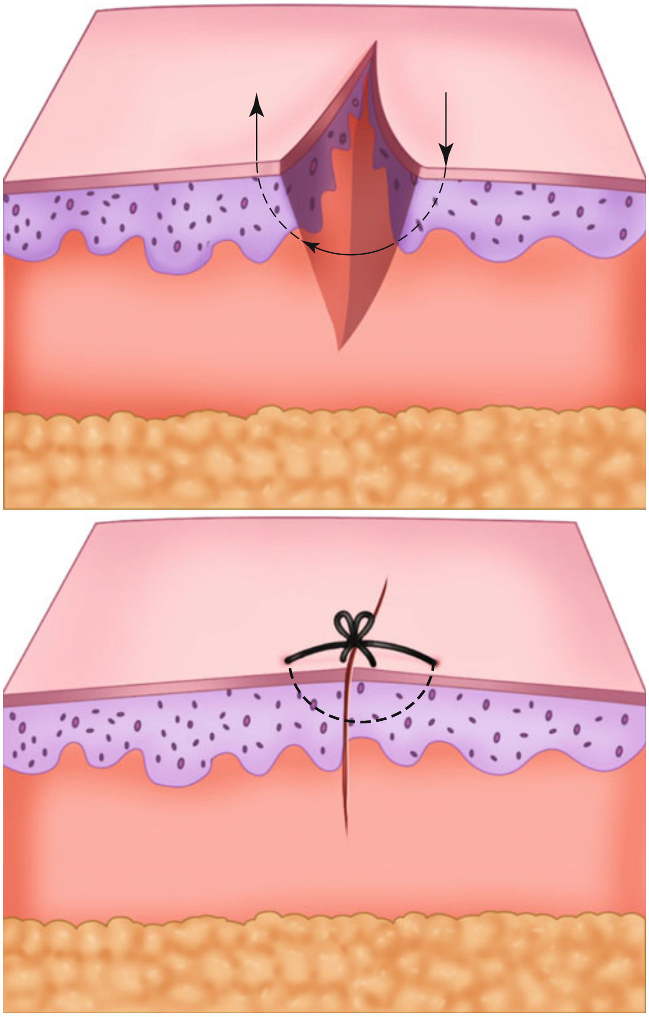

Fig. 92.2 Simple suture

- Hand
  - 4.0–5.0 nylon, consider vertical or horizontal mattress.
  - 5.0–6.0 Monocryl for nail bed.
  - Remove at 10–14 days, use for a longer time if directly over the joint.
- Extremity
  - Nonmobile skin: 3.0–4.0 nylon, remove at 8–10 days
  - Over joint: 3.0–4.0 nylon, remove at 10–14 days
- Trunk
  - Anterior trunk: 3.0–4.0 nylon, remove at 8–10 days.
  - Posterior trunk: 2.0–3.0 nylon, remove at 10–14 days.
  - Consider staples.
- Oral mucosa
  - Thin mucosa: 4.0 Vicryl will absorb; duration, 5–7 days
  - Tongue: 3.0 Vicryl will absorb; duration, 5–7 days

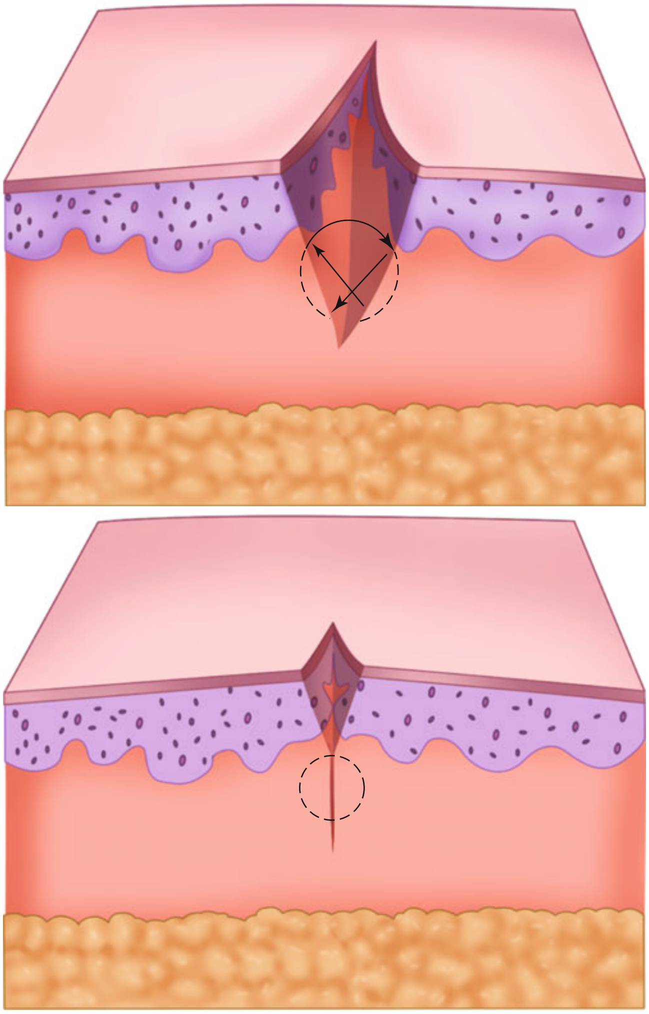

Fig. 92.3 Deep suture

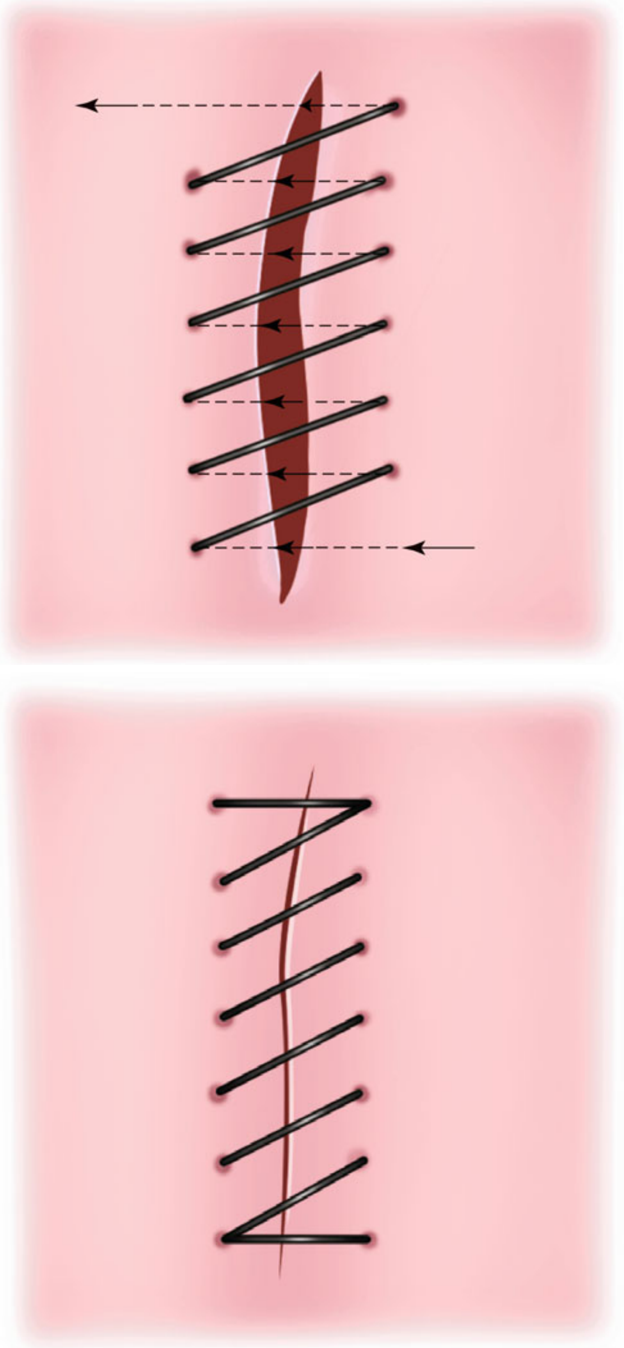

Fig. 92.4 Running suture

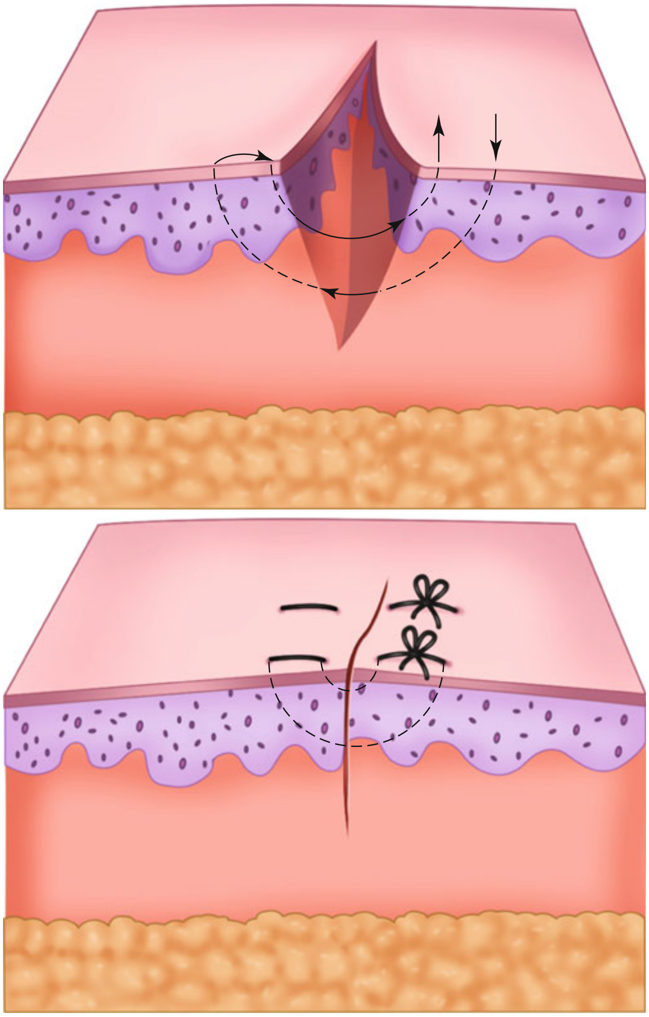

Fig. 92.5 Vertical mattress suture

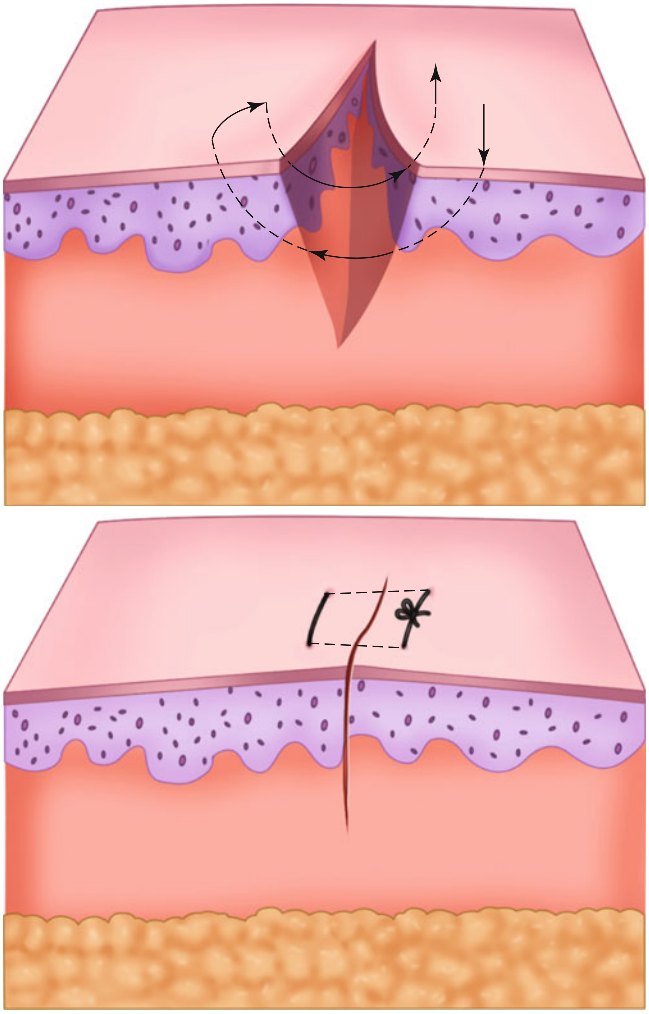

Fig. 92.6 Horizontal mattress suture

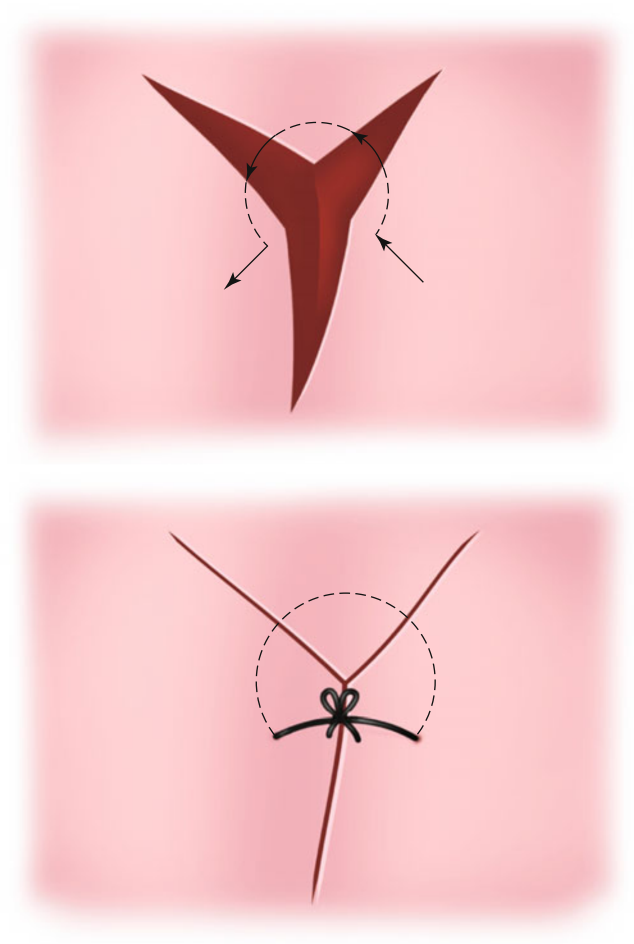

Fig. 92.7 Half-buried horizontal mattress suture

92.6 Alternative Methods of Wound Closure

92.6.1 Cyanoacrylate Tissue Adhesives

See Chap. 93.

92.6.2 Adhesive Tape

- Advantages
  - Rapid and painless application
  - Inexpensive
  - Good cosmetic result
- Disadvantages
  - Minimal strength
- Contraindications
  - Allergy to product
- Precautions
  - For use with wounds under little tension
- Procedure
  - Thoroughly clean the wound as described previously.
  - Approximate the wound edges.
  - Apply adhesive tape directly over the wound with 2–3 mm of space between strips.
  - An adjunct adhesive, such as benzoin, may be used to improve durability.

92.6.3 Staple Closure (Fig. 92.8)

- Advantages
  - Rapid
  - Inexpensive
- Disadvantages
  - Minimal strength
- Contraindications
  - Wounds on face, hands, or feet
- Procedure
  - Thoroughly clean the wound as described previously.
  - Anesthetize the wound edges.
  - Approximate the wound edges (may require an additional set of hands).
  - Apply staples.

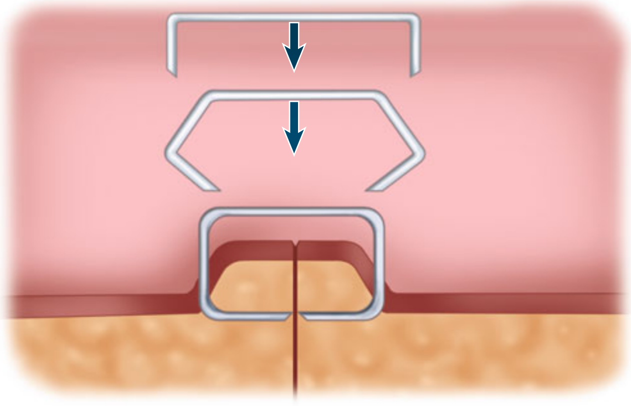

Fig. 92.8 Staple

92.7 Pearls and Pitfalls

- Pearls
  - Sutures should not remain in place longer than the recommended period. If the wound is not completely healed, sutures should be removed and an adhesive tape may be used for edge approximation.
  - Remember to verify tetanus status.
  - Antibiotics should be used judiciously.
- Pitfalls
  - Wound infection.
  - Incomplete healing may lead to wound separation.
  - Tissue reaction to suture or adhesive materials.
  - Allergy to anesthetic agent.

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Wound Closure with Tissue Adhesive

93

Pratik S. Patel and Latha Ganti

93.1 Indications

- Small superficial skin incisions or laceration repairs which require 5.0 or smaller-diameter sutures.

93.2 Contraindications

- Absolute
  - Large irregular/stellate lacerations
  - Infected/contaminated wounds
  - Animal/human bites
  - Puncture wounds
  - Crush wounds
  - Skin ulcers
  - Mucous membranes and mucocutaneous junctions
  - Axillae and perineum (owing to high moisture)
- Relative
  - Wounds on extremities (unless kept dry)
  - Joints (unless kept immobilized with a splint)

93.3 Materials and Medications

- Dermabond (2-octyl cyanoacrylate)
- Betadine (povidone-iodine) solution
- 0.9 % normal saline solution
- 20-mL sterile syringe
- Sterile gloves
- Dry 4×4 gauze

93.4 Optional Materials

- Topical anesthesia
- 1:1000 epinephrine solution
- Forceps
- Bacitracin ointment or sterile petroleum jelly ointment
- Gown and protective eyeglasses
- Splint

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93.5 Procedure

1. Have the patient rest comfortably on a chair or bed.
2. Use universal precaution measures: sterile gloves (gown and eye-screen, if necessary for wound irrigation).
3. Wash the wound with 0.9 % normal saline irrigation.
4. Use a topical anesthetic such as LET (lidocaine, epinephrine, tetracaine) or EMLA (eutectic mixture of local anesthetics) cream (lidocaine and prilocaine), or a 1:1000 epinephrine solution soaked into gauze can be used to achieve hemostasis in a bleeding wound.
5. Approximate the edges of the wound with fingers. Toothed forceps or other skin approximation devices may be used as an adjunct. Apply bacitracin ointment or Vaseline to the tips of the forceps and wipe off the excess to prevent sticking of Dermabond glue to the forceps.
6. Crush Dermabond vial between the thumb and the finger while in the inverted position until the adhesive is seen at the applicator tip (Fig. 93.1).
7. Squeeze gently until a drop of adhesive forms at the applicator tip.
8. Gently brush the adhesive at the applicator tip over the approximated wound edges (Fig. 93.2). (Do not force or press the applicator tip over the wound.)
9. Cover the entire wound with single coat of adhesive.
10. Hold the wound edges for 30 s to 1 min until it dries.
11. Apply two or three more coats of adhesive over and around the wound in a circular or oval movement to provide extra strength.
12. Wipe off extra adhesive in the surrounding skin with gauze if needed.
13. Apply a splint (optional) to provide wound stability over the joints.
14. Recommend the patient to keep the wound dry for 4–5 days. Patients may shower but should be instructed to pat dry instead of rubbing a towel over the skin.
15. No topical antibiotic ointment is required before or after application of Dermabond.

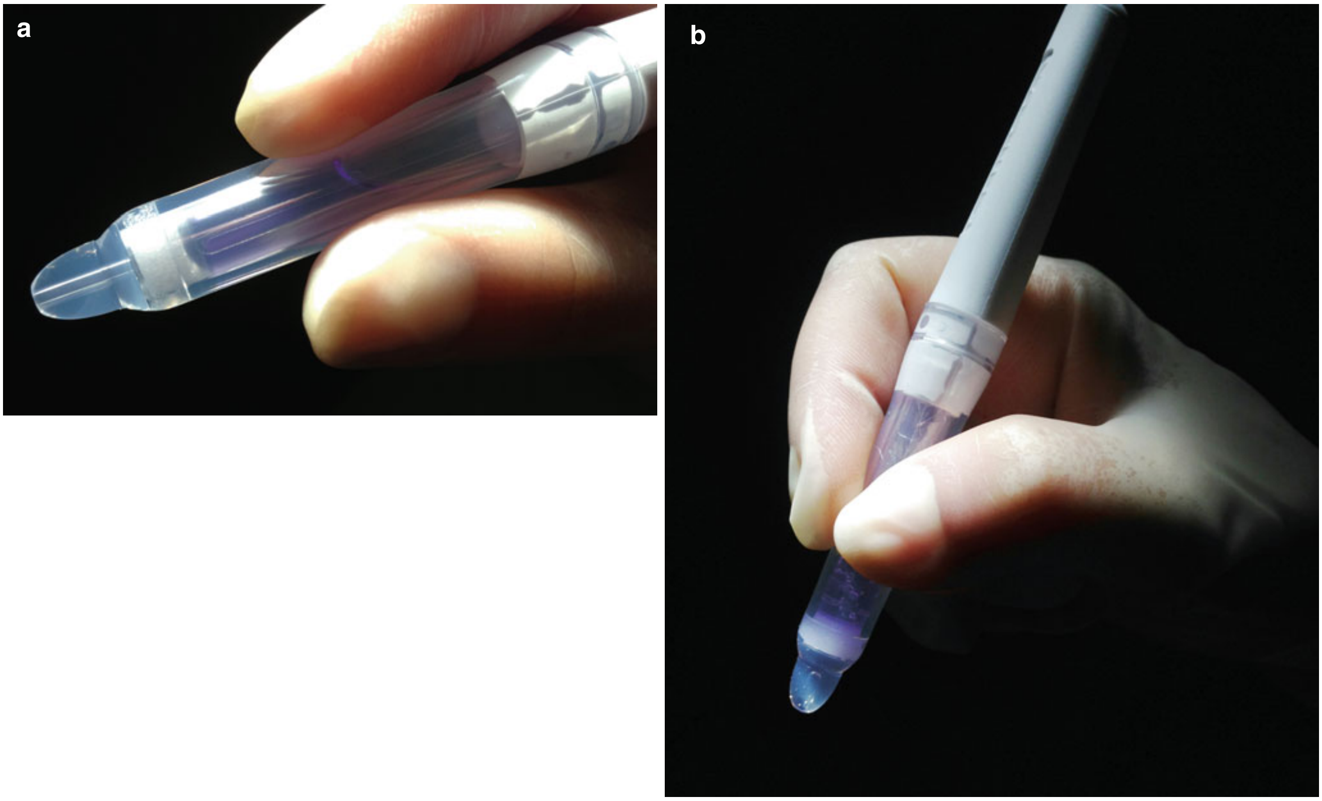

Fig. 93.1 (**a**) Before the tip has been crushed. (**b**) The purple Dermabond is in the tip

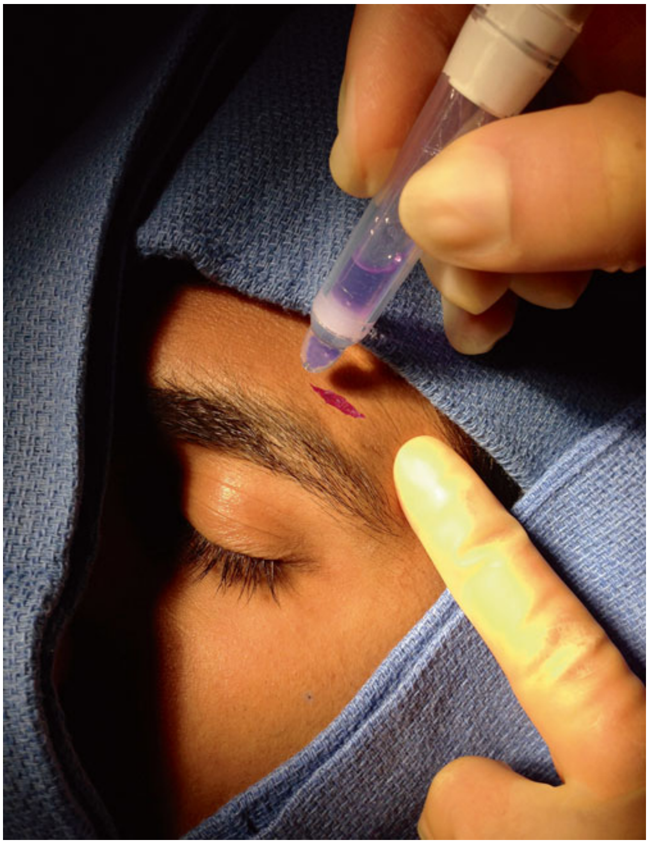

Fig. 93.2 Closing the wound: use tip of Dermabond pen to "paint" over the laceration

93.6 Complications

- Wound dehiscence
- Wound infection

93.7 Pearls and Pitfalls

- Pearls
  - Advantages of tissue adhesives for wound repair compared with sutures include faster repair time, better acceptance by patients (especially children), water-resistant covering, and no need for a second visit to remove sutures (sloughs off in 5–10 days).
- Pitfalls
  - Dermabond is a super adhesive. Take care not to have the glove, finger, drape, gauze, or instrument inadvertently stuck to the wound or the patient by having a bacitracin or petroleum jelly coating around the wound, on gloved fingers, and on forceps as needed.

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Fishhook Removal

94

Judith K. Lucas

94.1 Indications

- Removal of a fishhook from nonvital structures (Fig. 94.1)

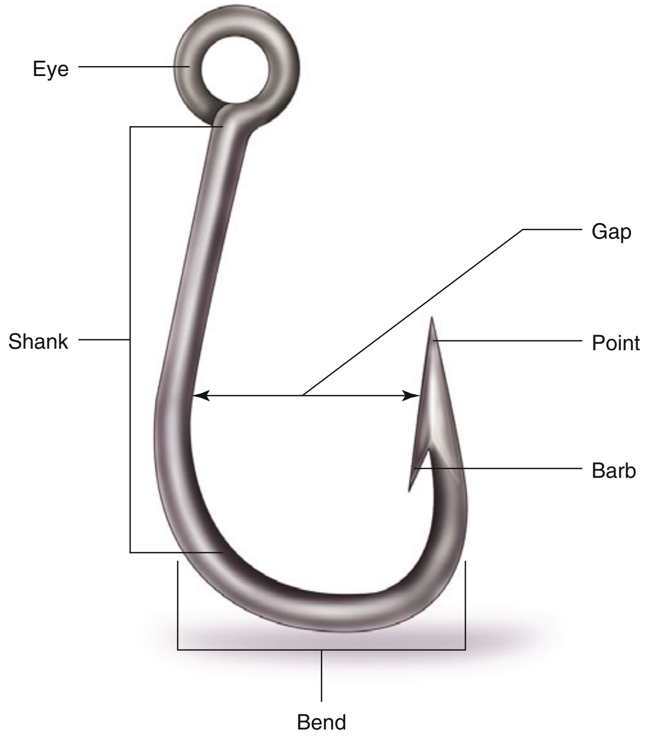

Fig. 94.1 Anatomy of a fishhook

94.2 Contraindications

- Removal of hooks located near/in eyes or eyelids, embedded near or within neurovascular structures, or embedded within vital structures such as peritoneum, testicle, or urethra.
  - Fishhooks in these areas require specialist consultation.

94.3 Materials and Medications

- Antiseptic cleansing solutions
  - Betadine (povidone-iodine)
  - Chloraprep
- Local anesthetic
  - 1 % lidocaine, with or without epinephrine
- Needle drivers or pliers
- 18- or 20-gauge needle
- 3-0 silk suture or umbilical tape
- Wire cutters
- Protective eyewear

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94.4 Procedures

- Retrograde technique (Fig. 94.2): simplest, least traumatic, but least successful; good for small to medium hooks, superficially embedded hooks, and hooks with no barbs or a single barb.
    1. Detach extra hooks, line, or foreign materials (e.g., worms, fish, debris).
    2. Cleanse the puncture site and surrounding tissue with antiseptic solution.
    3. Infiltrate the entry site and surrounding area with local anesthetic.
    4. Apply downward pressure on the shank or shaft of the hook, near the eye, thus disengaging the barb from the tissue.
    5. Back the hook out of the skin along the path of entry.
- String and yank technique (Fig. 94.3): Good for small to medium hooks. Often requires no anesthesia. Good for areas of deep soft tissue penetration. Cannot be used on parts of the body that are not fixed, such as earlobes.
    1. Detach extra hooks, line, or foreign materials (e.g., worms, fish, debris).
    2. Cleanse the penetration site and surrounding area with antiseptic wash.
    3. Consider infiltrating the entry site with local anesthetic.
    4. Wrap 3-0 silk suture, fishing line, or umbilical tape several times around the bend of the hook (at the point of greatest curvature).
    5. The loose ends of the string need be held tightly. Sometimes the loose ends can be more firmly held if wrapped around a pencil or tongue depressor.
    6. The skin around the entry site should be well stabilized, while simultaneously depressing the shank, close to the eye of the hook.
    7. While stabilizing the skin and applying downward pressure on the shaft, quickly and firmly yank the string, in a parallel line to the shaft. Be certain downward pressure is applied along the shank.
    8. The hook will “fly” out quickly. Be certain to wear eye protection.
- Needle cover technique (Fig. 94.4): good method to remove large hooks with a single barb, especially if superficially embedded
    1. Detach extra hooks, line, or foreign materials (e.g., worms, fish, debris).
    2. Cleanse the penetration site and surrounding area with antiseptic wash.
    3. Infiltrate the entry site and surrounding area with local anesthetic.
    4. Advance an 18-gauge needle along the entrance wound of the hook. Pass the needle parallel to the shank. The bevel should be pointed downward, toward the barb and point.
    5. The needle is advanced until it disengages the barb, entrapping it within the needle lumen.
    6. The hook and needle are advanced just enough to disengage the barb.
    7. The hook and needle are withdrawn along the track of the wound.
- Advance and cut technique (Fig. 94.5). Almost always successful but does cause additional tissue trauma.
    1. Detach extra hooks, line, or foreign materials (e.g., worms, fish, debris).
    2. Cleanse the penetration site and surrounding area with antiseptic wash.
    3. Infiltrate the entry site and surrounding area with local anesthetic.
    4. If the hook has a single barb:
        - Grip the hook on the shank, near the bend, with either a needle driver or pliers.
        - Push the hook through along its natural trajectory, until the point and barb pass completely through the skin.
        - Clip the point proximal to the barb. Be certain to wear eye protection because the point can fly off in an unpredictable direction.
        - Withdraw the hook out back along its entry path.
    5. If the hook has multiple barbs (Fig. 94.6):
        - Grip the hook on the shank, near the hook’s bend with either a needle driver or pliers.
        - Push the hook through along its natural trajectory, until the point and barb pass completely through the skin.
        - Clip the eye of the hook with wire cutters.
        - Grasp the point and withdraw the hook through the skin forward along its natural course.

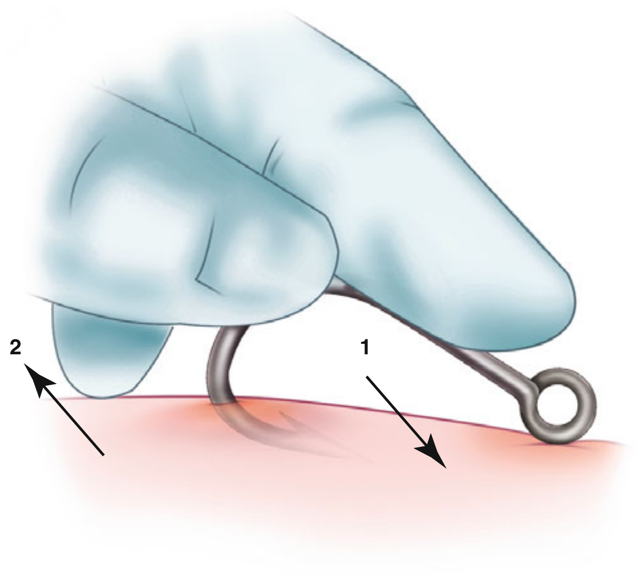

Fig. 94.2 Retrograde technique. *1* Push down along whole shank and slightly forward to release the barb. *2* Pull back and out along hook's entry path, applying steady downward pressure

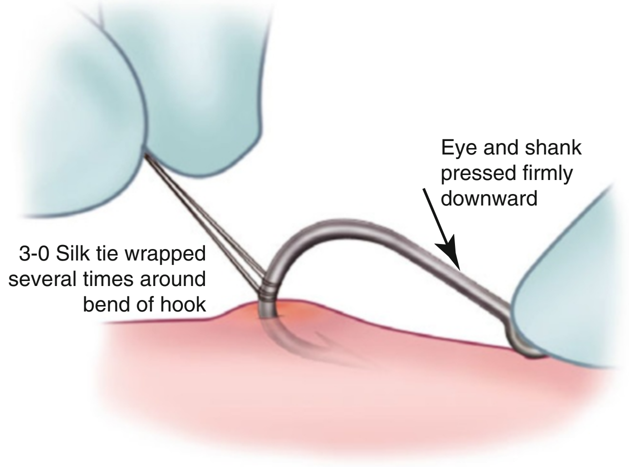
Eye and shank pressed firmly downward
3-0 Silk tie wrapped several times around bend of hook

Fig. 94.3 String and yank technique

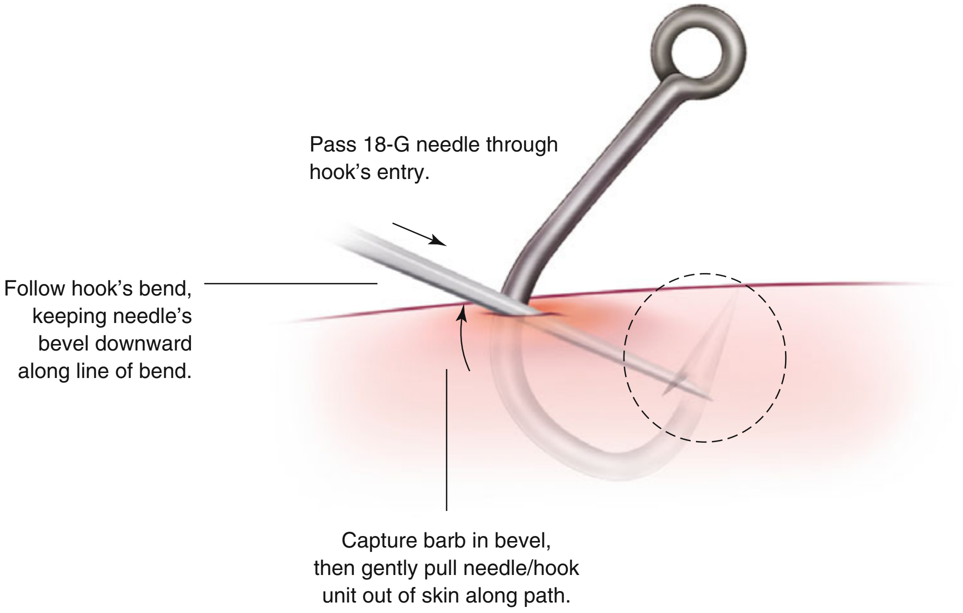
Pass 18-G needle through hook's entry.
Follow hook's bend, keeping needle's bevel downward along line of bend.
Capture barb in bevel, then gently pull needle/hook unit out of skin along path.

Fig. 94.4 Needle technique

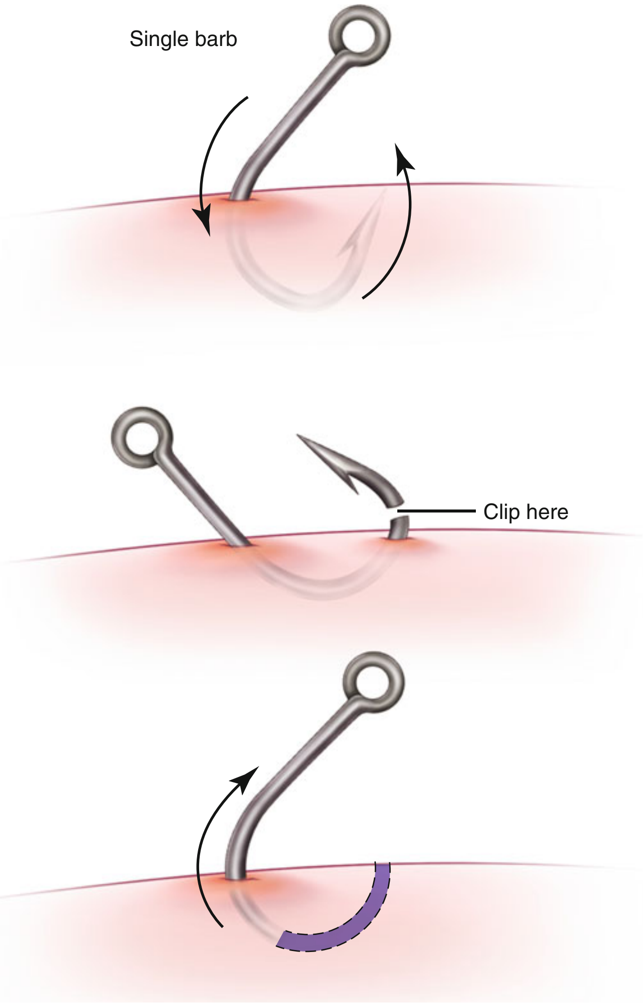
Single barb
Clip here

Fig. 94.5 Advance and cut technique

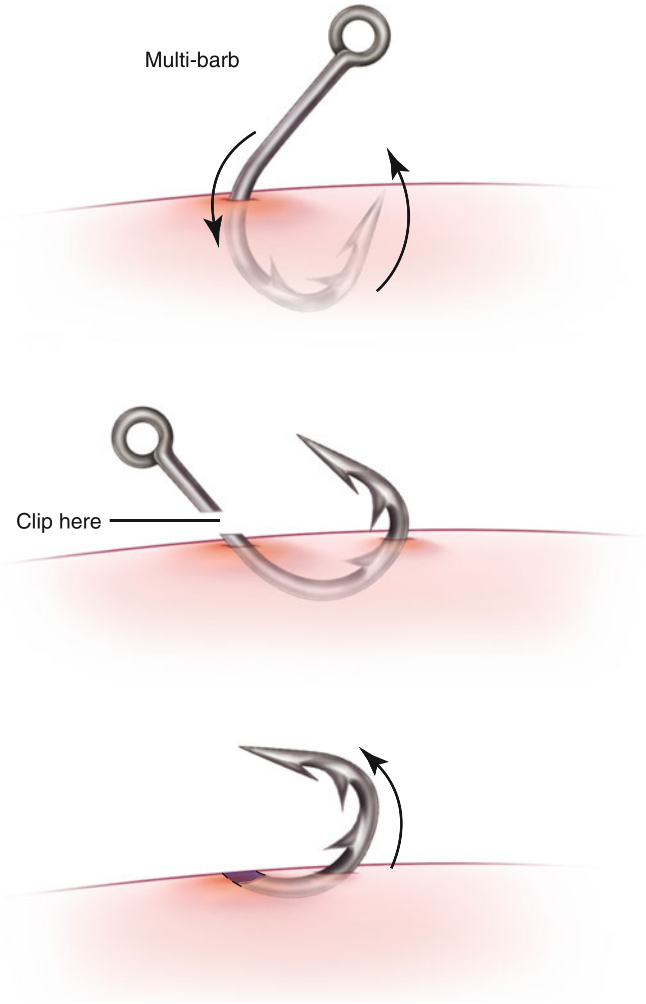
Multi-barb
Clip here

Fig. 94.6 Advance and cut a hook with multiple barbs present

94.5 Postremoval Wound Care

- Immune competent, without peripheral vascular disease:
  1. Explore the wound for possible foreign bodies.
  2. Irrigate or scrub the wound copiously with soapy solution.
  3. Apply antibiotic ointment and sterile dressing.
  4. Tdap (or Dtap) should be given to anyone in whom the last tetanus booster has been longer than 5 years.
  5. Wound check in 24–48 h with care provider.
- Immunocompromised or a patient with peripheral vascular disease:
  1. As previously.
  2. Give strong consideration to treating prophylactically with antibiotics, choosing a fluoroquinolone, third-generation cephalosporin, or aminoglycoside.

94.6 Complications

- Infection
- Retained foreign body
- Injury to neurovascular structures, if method of removal is not carefully selected
- Injury to provider if adequate (eye) protection not used

94.7 Pearls and Pitfalls

- Pearls
  - Begin with either the retrograde method or the string-yank method, because these result in less tissue damage and are the easiest to perform, although they have the lowest rate of success.
  - Eye protection is imperative, especially if utilizing the string-yank method or clipping any portion of the hook (eye or point) because the retraction of the hook, or its parts, is generally at a high velocity and travels an unpredictable path.
  - When trying the advance and cut technique, stop immediately if, when advancing the hook, impasse, or resistance is met because this may indicate bone or neurovascular structures are blocking the natural path of the hook.
  - Fishhooks that embed into or near the eye or lids should be covered with a metal patch or cup and the patient should be sent (immediately) for ophthalmologic consultation.
  - Close follow-up is imperative to watch for signs of infection.
- Pitfalls
  - When utilizing the advance and cut technique, do not cut anything until certain there is another portion of the hook on which to grasp.

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Tick Removal

95

David N. Smith and Judith K. Lucas

95.1 Indications

- Tick attachment to the skin

95.2 Contraindications

- None

95.3 Materials and Medications

- Gloves
- Skin disinfectant (commercially available product, such as Chloraprep, isopropyl alcohol, or Betadine [povidone-iodine])
- Fine-toothed forceps

95.4 Procedure

1. Comfortably position the patient with the tick site exposed.
2. Grasp the tick as close to the skin surface as possible (e.g., grasp the mouth parts).
3. Gently pull upward with steady, nontwisting, even traction (Figs. 95.1 and 95.2).
4. After removal, clean the bite area and apply antibiotic ointment.

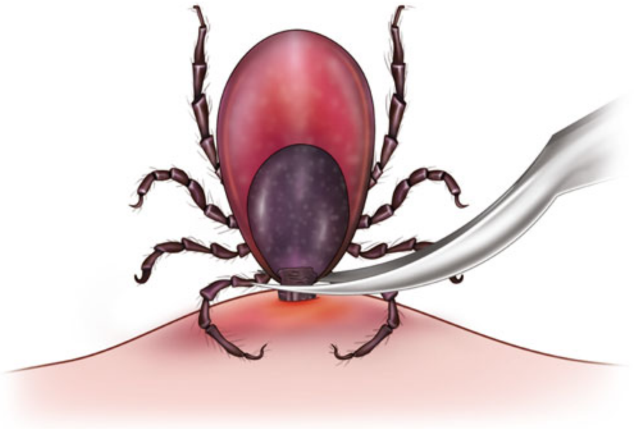

Fig. 95.1 Place the forceps as close to the mouth of the tick as possible, hold firmly, and pull straight up with steady gentle traction

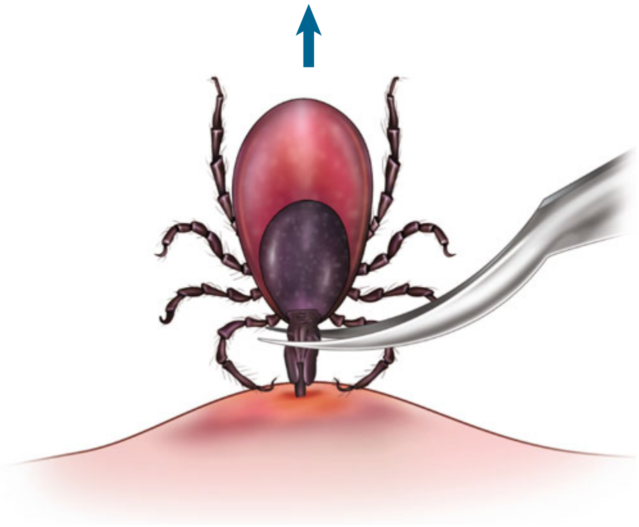

Fig. 95.2 Steady upward traction

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95.5 Complications

- Multiple diseases including:
  - Lyme disease
  - Human granulocytic and monocytic ehrlichiosis
  - Babesiosis
  - Relapsing fever
  - Rocky Mountain spotted fever
  - Colorado tick fever
  - Tularemia
  - Q fever
  - Tick paralysis
- Secondary infection (methicillin-resistant *Staphylococcus aureus* [MRSA] and group A streptococcus).
- Scratching can lead to lichenification.
- Rare cases of alopecia when tick located in the scalp.

95.6 Pearls and Pitfalls

- Pearls
  - Do not twist or jerk the tick out (may cause breakage of mouth parts; they may remain in the skin).
  - Do not squeeze the body of the tick.
  - Do not use a hot match, gasoline, or other noxious stimulus for removal (causes irritation of tick and release of internal contents).
  - Lyme disease transmission increases significantly after 24–48 h of attachment, so early removal is the key.
  - Patients should be monitored for up to 30 days for signs of tick-borne diseases, including erythema migrans (bull's-eye rash) indicating Lyme disease (Fig. 95.3).
- Prophylactic antibiotic treatment, a single dose of doxycycline, is used only in patients with an identified *Ixodes scapularis* tick that has been attached for longer than 36 h and if treatment can start within 72 h of tick removal.
  - Serological testing for Lyme disease is not indicated for a reported tick bite.
- Pitfalls
  - Use of lidocaine subcutaneously can irritate the tick and cause it to regurgitate its stomach contents, increasing the risk of disease transfer.

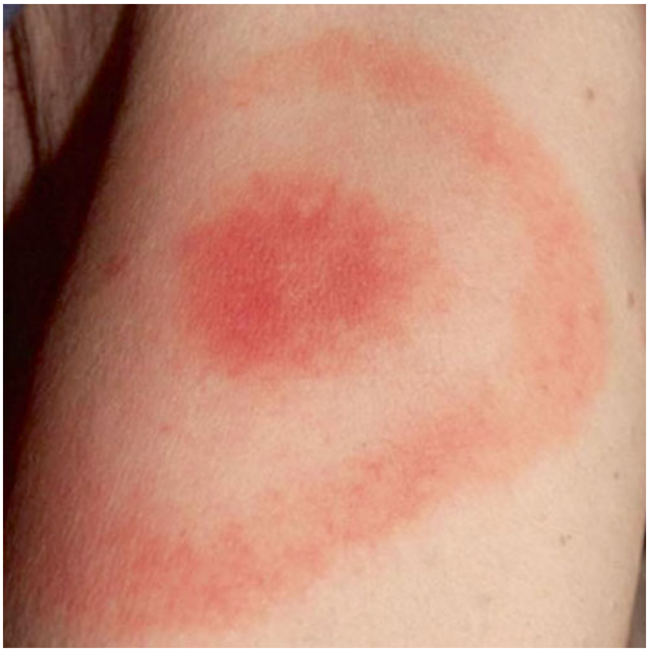

Fig. 95.3 Erythema migrans (the bull's-eye rash), the rash typically associated with Lyme disease. Often the rash is so pale as to go unnoticed

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Subungal Hematoma Drainage

96

Pratik S. Patel and Latha Ganti

96.1 Causes

- Crushing injury to the finger or toe
- Ill-fitted shoes/inadequate space for toes

96.2 Indications

- Pain that is not tolerable with nail edges intact

96.3 Contraindications

- Relative
  - Disrupted nail edges
  - Tolerable pain that can be managed conservatively
  - Skin infections around toe/finger
  - Bleeding disorder

96.4 Materials and Medications

- 18-gauge needle
- Betadine (povidone-iodine) solution
- Gloves
- Topical antibiotic

96.4.1 Optional materials

- Electrocautery tool
- Paper clip or sewing needle and sterilizing flame
- Finger splint
- Lidocaine (1 or 2 % with epinephrine)

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96.5 Procedure

1. Have the patient rest the affected finger comfortably on a flat surface.
2. Use universal precaution measures: gloves, gown, and eye screen.
3. Sterile skin preparation with Betadine.
4. Optional (for complicated subungal hematoma): use 1 or 2 % lidocaine with epinephrine for providing local digital block.
5. Using the thumb and index finger gently twist the 18-gauge needle with light pressure over the base of the nailbed or in the center of the hematoma until no resistance is felt. Do not apply any further pressure in order to avoid nailbed damage. Nail penetration is confirmed by return of dark blood from the hole. This procedure is known as trephination (Figs. 96.1 and 96.2).
6. Apply light pressure around the tip of the finger and hematoma to facilitate drainage. In case of continuous bleeding elevate the digit and apply firm and continuous pressure over the nail with a gauze piece.
7. Apply topical antibiotic ointment (e.g., bacitracin) over the puncture hole.
8. Apply a gauze dressing or a bandage over the wound site/fingernail.
9. Apply a finger splint (optional) to provide additional comfort.
10. Recommend the patient to keep the finger or toe dry (avoid soaking) and elevated for 1–2 days.

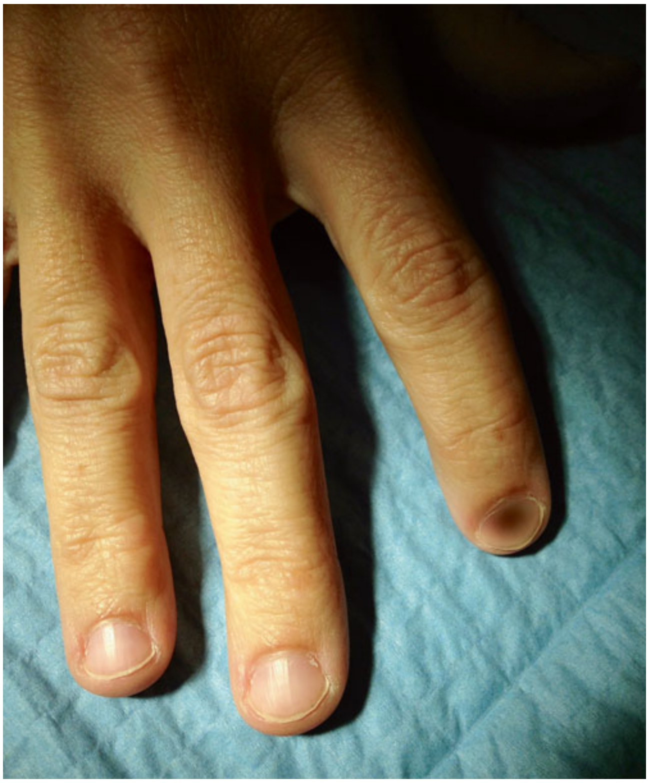

Fig. 96.1 Subungal hematoma of right index finger

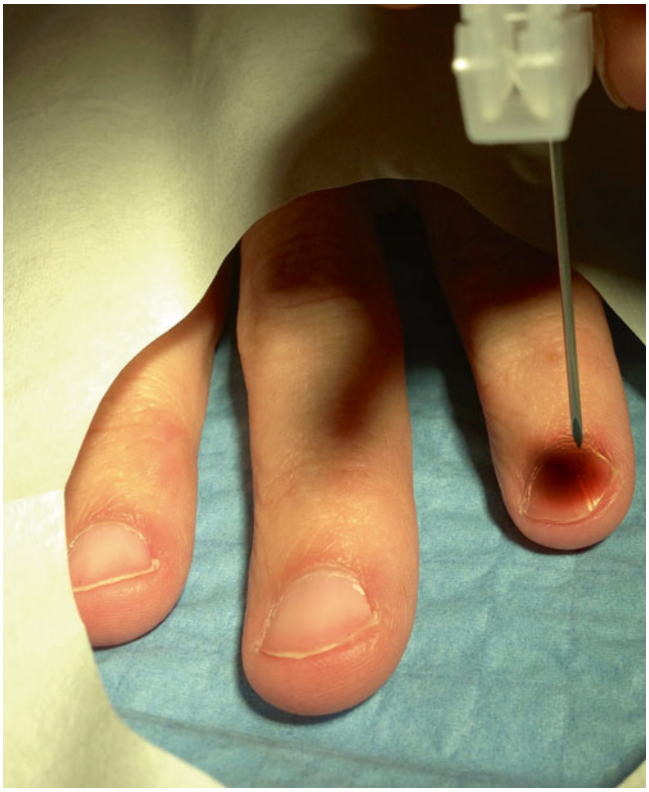

Fig. 96.2 Positioning of needle to perform subungal hematoma drainage

96.6 Complications (Rare)

- Infection
- Injury to nail bed or underlying bone if too much pressure is applied with puncture
- Onycholysis when there is incomplete drainage in rare cases

96.7 Pearls and Pitfalls

- Pearls
  - Multiple holes may be necessary for appropriate drainage of the hematoma.
  - When using electrocautery for hole puncture, execute high caution with acrylic nails because they are flammable.
  - When using a paper clip or regular needle, make sure to sterilize the tip over a flame.
  - Take a radiograph of the finger whenever necessary to rule out phalangeal fracture.
  - Check for avulsion of the extensor tendon.
  - Inform the patient that the existing nail may fall off and will regenerate in few months if the nailbed is intact.
  - Systemic or oral antibiotics are not recommended.
- Pitfalls
  - Development of a dark color change over the nailbed without any history of trauma should raise suspicion of a tumor and should be evaluated accordingly.
  - Do not remove the nail to evaluate injury to nailbed.

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97 Incision and Drainage of Abscess

Nicholas D. Caputo, Karlene Hosford,
and Muhammad Waseem

97.1 Indications

- Abscess greater than 5 mm in diameter and in accessible areas (e.g., axilla, extremities, trunk)

97.2 Contraindications

- Absolute
  - Absence of fluctuation
  - Large, deep, and complicated (multiloculated) abscesses
  - Location
    - Perianal
    - Mastoid
- Relative
  - Location
    - Face (e.g., nose, nasolabial fold)
    - Palms
  - Coagulopathy
  - Recurrent pilonidal cysts (may mandate operative excision)
  - Area of cosmetic importance where aspiration may be preferred

97.3 Materials and Medications

- Incision and drainage tray (Fig. 97.1)
  - Drape
  - Betadine (povidone-iodine) swabs
  - 1 % lidocaine
  - 18- and 27-gauge needles
  - 12-mL syringes, gauze pads
  - #11 scalpel, mosquito clamps (hemostat)
  - Iodoform packing of appropriate size
- Ultrasound machine (Fig. 97.2)

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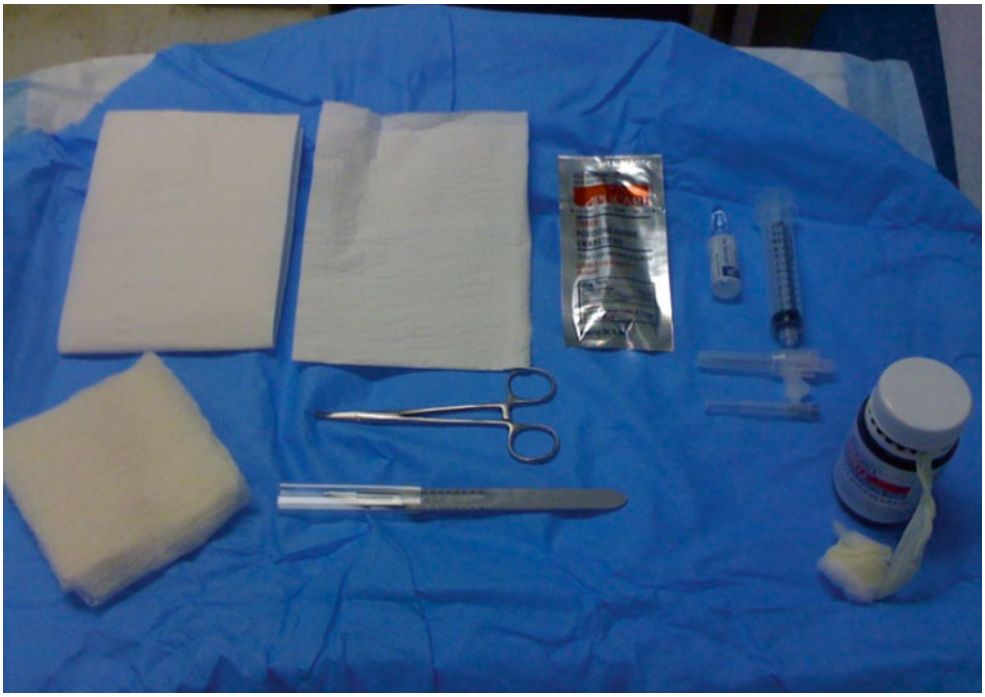

Fig. 97.1 Supplies necessary for incision and drainage

Fig. 97.2 Bedside SonoSite ultrasound

97.4 Procedure

1. Ultrasound (optional) may be helpful when abscess is suspected in the absence of fluctuation. Using the vascular probe (7 mHz), confirm the clinical suspicion of abscess and check the depth and width of the abscess (Fig. 97.3).
2. Sterile skin preparation with Betadine swab and sterile drape.
3. Anesthetize the appropriate area subcutaneously with 5 mL of 1 % lidocaine by inserting the 27-gauge needle at an acute angle into the intradermal space (Fig. 97.4a, b).
4. Using a #11 blade, make an approximately 1- to 2-cm skin incision over the desired area parallel to the Langer lines. The incision must approach into the abscess cavity (Fig. 97.4c).
    - Some physicians still advocate the technique of making a cruciate incision. This may leave a larger scar and should be discussed with patient before doing so because of cosmetic consequences.
5. Allow for spontaneous drainage. After resolution of drainage, you may express more pus with gentle downward pressure.
6. Using the hemostat, enter the incision to break any suspected loculations. This should be done with the clamps closed and curved part down. The clamps should then be opened and removed slowly (Fig. 97.4d).
7. After clearing the remaining loculations, the wound should be packed.
    - Evidence suggests that packing the abscesses does not prevent recurrence; however, this is still practiced. If packing the wound, follow the next step.
8. Take the iodoform packing with the hemostat, and place the packing into the incision site until no further packing will fit.
9. Cut the packing leaving a tail out of the incision site (Fig. 97.4e).
10. Apply dressing with 4×4 gauze and adhesive tape (2 in.).

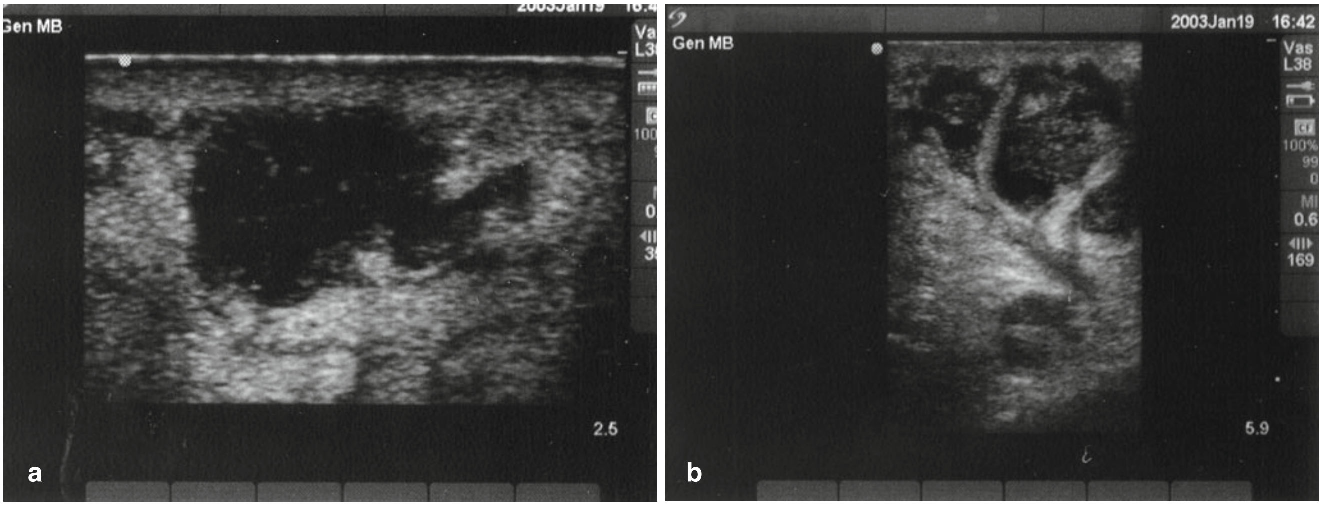

Fig. 97.3 (**a**) Example of an abscess as viewed on bedside ultrasound. (**b**) A multiloculated abscess

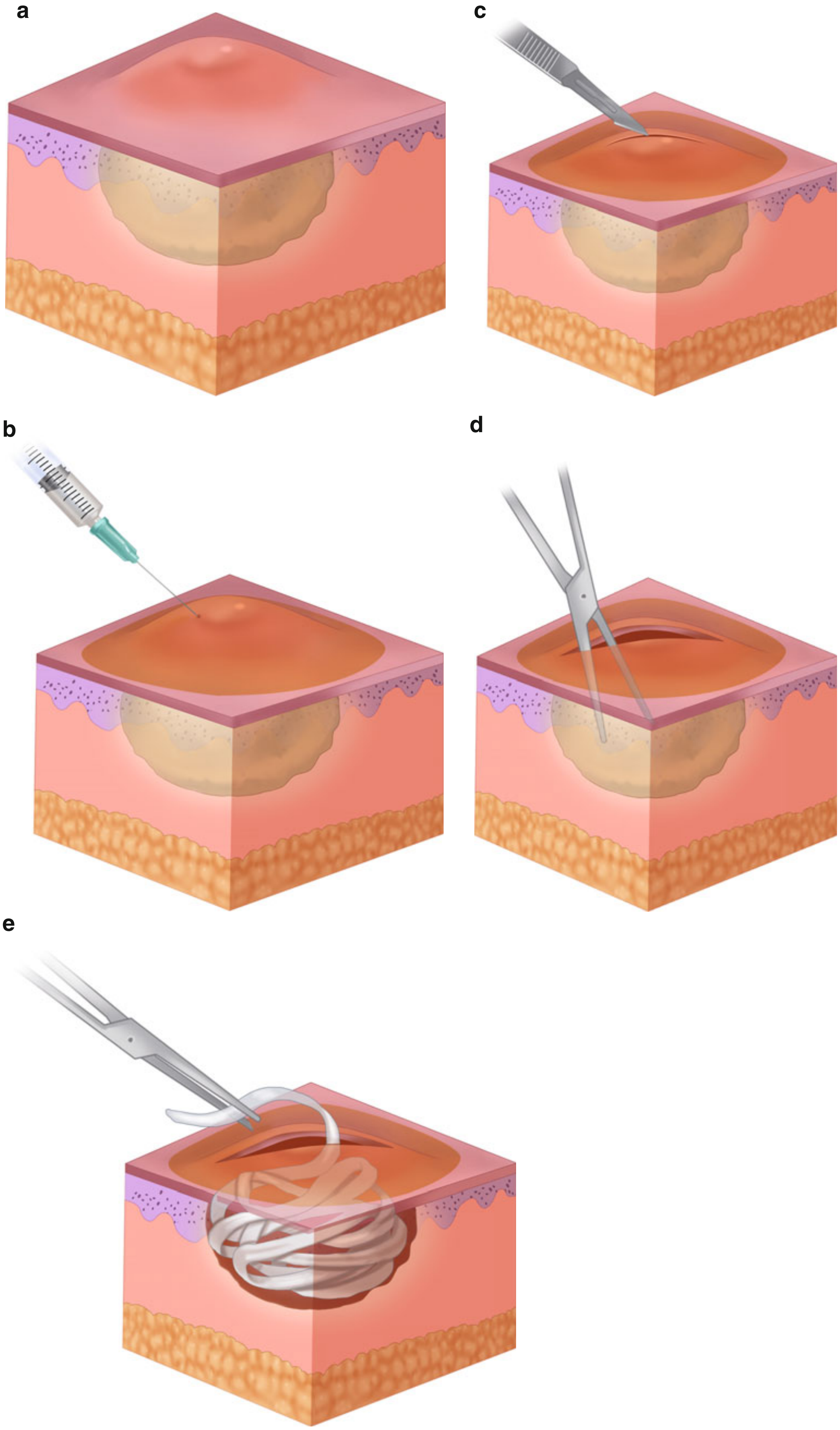

Fig. 97.4 (**a**) Abscess with overlying erythema. (**b**) Lidocaine injection in the superficial layer. (**c**) Linear incision with #11 blade. (**d**) Expression of purulent material and breaking of loculations with clamps. (**e**) Optional placement of packing

97.5 Complications

- Recurrence of abscess
- Progression of cellulitis
- Neurovascular injury to adjacent structures

97.6 Pearls

Antibiotic coverage is a controversial topic. Methicillin-resistant *Staphylococcus aureus* (MRSA) is a concern not only in the immunocompromised and diabetic patients. *S. aureus* has been detected in up to 51 % of patients with abscesses. Of these isolates, approximately 75 % were MRSA. Bactrim (trimethoprim/sulfamethoxazole) should be utilized for all prophylactic measures.

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Part XIII

Orthopedic Procedures

Splinting

98

Christopher H. Stahmer and Muhammad Waseem

98.1 Indications

- Need for immobilization for fracture, dislocation, or soft tissue injury
- Suspicion for occult injury of an extremity
- Immobilization for pain management

98.2 Contraindications

- Absolute
  - Open fracture (requires operative intervention)
- Relative
  - Infection
  - Compartment syndrome

98.3 Materials and Medications (Fig. 98.1)

- Plaster of Paris
- Fast drying: 5–8 min to set
- Extra fast drying: 2–4 min to set
  - Variety of widths depending upon splint of choice:
  - Splints may take up to 2 days to dry and achieve maximum strength.
- Prefabricated splinting materials
  - Plaster OCL® (Orthopedic Casting Laboratories)
    - 10–20 sheets of plaster with padding and cover
    - Faster setup time but less customizable
  - Fiberglass splints
    - Cure rapidly
    - Less messy
    - Less moldable
    - Stronger and lighter
- Stockinette.
  - Protects the skin.
  - Variety of sizes available.
- Soft wrap (Webril™).
  - Provides padding.
  - Five to six layers depending on anticipated swelling.
    - Too much padding reduces the stability of the splint.
  - Use extra padding over bony prominences.
  - Pad between digits for splinting of digits.
  - Avoid wrinkles, which generate pressure points.
  - Do not wrap circumferentially.
    - Increased risk of ischemia.
- Ace wraps.
  - Variety of sizes depending.
    - Larger widths over legs.
    - Narrow widths around fingers and joints.
      - Avoid bunching by using narrow widths at joints.
- Water
  - Warm water and splint sets more quickly but increases the risk of burns.
    - Splint drying is an exothermic or heat-releasing reaction.
  - Hot water leaves less time to mold the splint.

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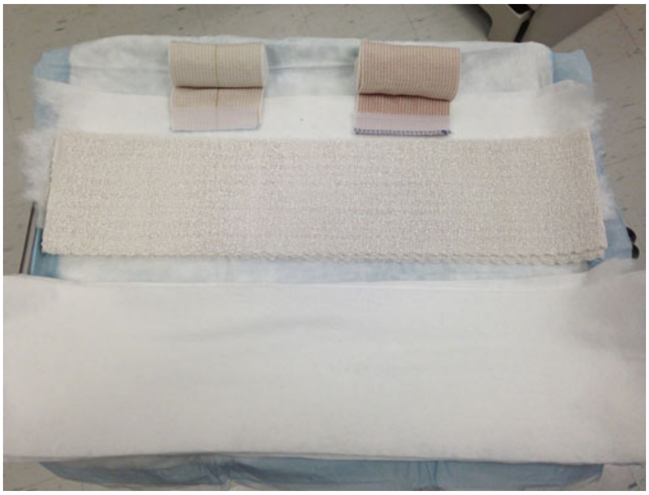

Fig. 98.1 Posterior splint materials: plaster of Paris, Ace wraps, soft roll. Note there are two layers of soft wrap: the inner layer to face the patient (eight layers) and the outer layer to pad the exterior (two layers)

98.4 Procedure

1. Completely expose and examine the afflicted body part for tissue, vascular, or neurological injury.
    - Address respective injuries before proceeding.
2. Lay out all splinting materials before initiating procedure.
    - Layer plaster of Paris.
        - Upper extremity: 8–10 layers.
        - Lower extremity: 12–15 layers.
        - Up to 20 for a large person.
        - More layers of plaster of Paris increase the risk of burn and the weight of the splint.
3. Administer appropriate anesthesia.
    - Conscious sedation
    - Hematoma block
    - Intra-articular injection
    - Intravenous pain medication
    - Oral pain medication
4. Hang fractures as indicated for improved success of reduction to relax muscles before reduction attempt.
5. Reduce afflicted extremity.
6. While maintaining reduction, apply respective splint.
7. Apply in the following order for plaster of Paris splint.
    - Stockinette (not necessary).
    - Soft wrap.
    - Select appropriate layers of plaster of Paris.
    - Prepare plaster of Paris to create splint:
        - Layer plaster with no overlap.
        - Submerge completely into water.
        - Crumple into ball without letting go of the ends of the splint.
        - Release the lower end of the splint while holding the top tightly together.
        - Run fingers in a "squeegee" manner from top to bottom to smooth the splint (Fig. 98.2).
            - This also removes excess water.
            - Repeat until the splint is smooth and free of dripping water.
        - Apply soft wrap layers to the splint.
            - Apply thicker layer to the patient's body.
            - Apply two or three layers of soft wrap to the exterior of plaster of Paris for padding and to facilitate drying.
        - Apply Ace wrap to hold the splint and assist in contouring the splint to the patient's extremity (Fig. 98.3).
            - Applying the Ace wrap too tightly may cause ischemia. Observe the patient after splinting for 30 min for tingling, burning, pain, or discomfort.
        - Mold the splint without making indentations with the fingertips (Fig. 98.4).
            - An indentation may cause a pressure point, which may result in an ulcer.

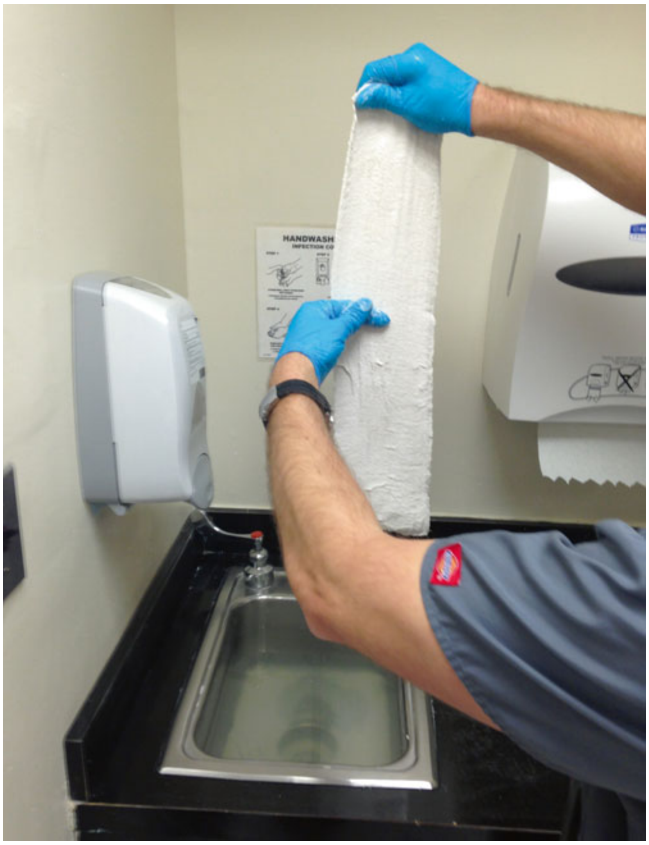

Fig. 98.2 Hold the top of the saturated plaster securely with one hand while removing excess water with the other hand

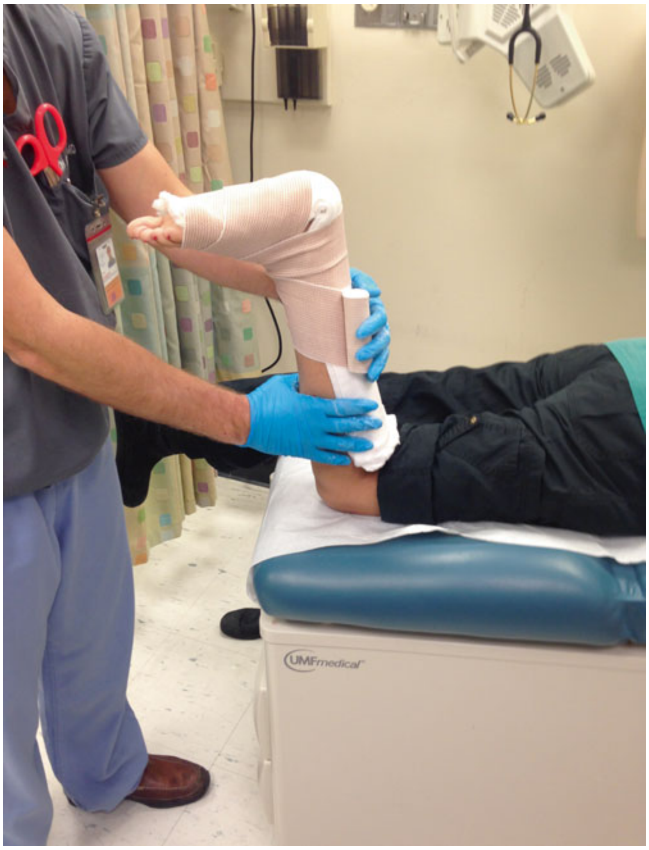

Fig. 98.3 Apply Ace wrap to hold the splint and assist in contouring the splint to the patient's extremity

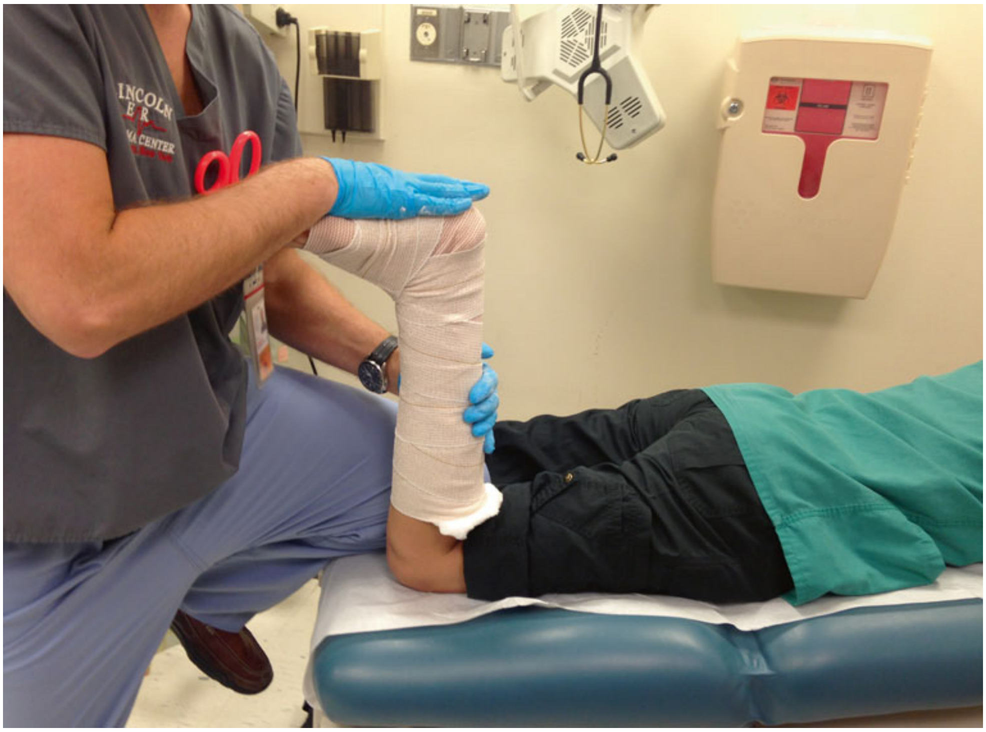

Fig. 98.4 Hold the splint in a neutral anatomical position while taking care not to make indentations with the fingertips

  - Allow the splint to cure while the practitioner maintains the appropriate position. This will take approximately 5 min depending upon water temperature and splint thickness.

98.5 Complications

- Ischemia may result in compartment syndrome.
  - Advise the patient to unwrap the splint for the following indications.
    - Increasing pain.
    - Discoloration of fingers, toes, or the splinted extremity.
    - Loss of sensation of splinted extremity.
- Burns
  - Plaster drying releases heat.
  - Increased risk with limited layers of padding.
  - If pain is troubling the patient, remove the splint and add more padding.
- Pressure sores
  - Apply ample padding.
  - Smooth all wrinkles.
  - Instruct the patient to return for increased discomfort.
- Infection
  - Clean and débride all devitalized tissue before application.
  - Requires close follow-up to reevaluate wounds.

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Ulnar Gutter Splint

99

Jeffrey Kile, Katrina John, and Amish Aghera

99.1 Indications

- Fractures and soft tissue injuries of the ring or little finger
- Fractures of the neck, shaft, or base of the fourth or fifth metacarpal

99.2 Contraindications

- Relative
  - Evidence of compartment syndrome or any neurovascular compromise

99.3 Materials (Fig. 99.1)

- Splint roll (plaster of Paris, prefabricated foamcore, or fiberglass)
- Stockinette
- Cotton padding, such as simple cotton sheet wadding or a newer alternative such as Webril (Curity), Specialist (Johnson & Johnson), and so on
- Elastic bandages, such as Ace (3M) or similar
- Shears
- Adhesive tape
- Gloves

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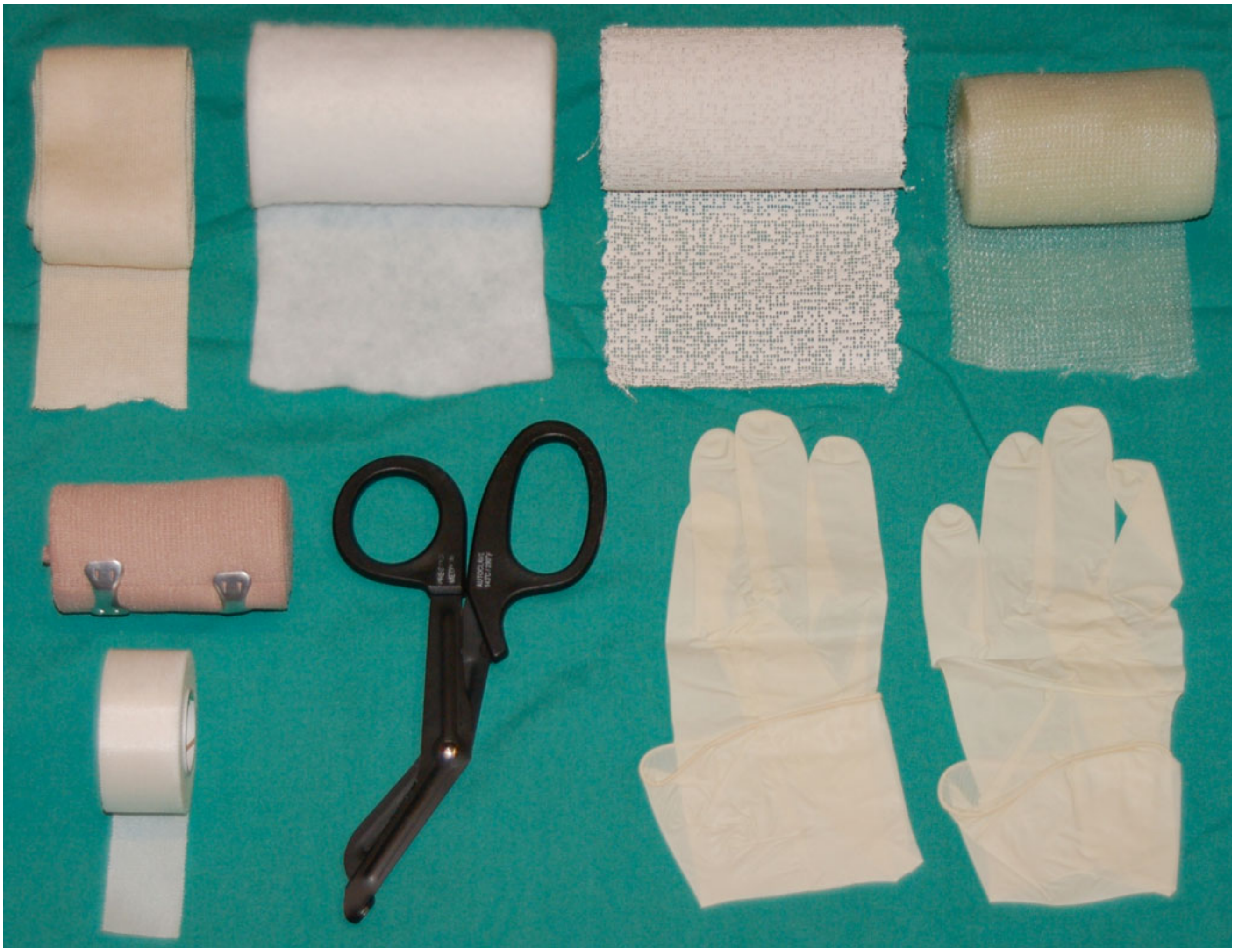

Fig. 99.1 Materials and medications

99.4 Procedure

1. Select the appropriate diameter stockinette according to the size of the forearm.
    - Generally, 3-in. diameter stockinette is used for the ulnar gutter splint.
2. Cut the stockinette to a length approximately 20 cm longer than the total length of the desired splint.
3. Apply the stockinette to the injured limb so that the stockinette extends approximately 10 cm beyond the region to be splinted proximally and distally.
4. Cut the distal aspect of the stockinette to free the thumb and also the index and middle finger (Fig. 99.2).
5. Insert cotton padding cut to the appropriate size between the ring and the little fingers to prevent skin degradation (Fig. 99.3).
6. Wrap cotton padding circumferentially around the entire region to be splinted, with each turn overlapping the previous turn by approximately 25 % of its width.
    - Generally, 3-in.-wide padding is used for the ulnar gutter splint.
    - Apply padding to an approximate thickness of 1 cm, with extra padding placed over the bony prominences of the wrist and carpometacarpal joints.
    - Extend the padding at least an inch beyond the desired splint length so that it may later be folded back over the jagged ends of the plaster or fiberglass splint roll (Fig. 99.4).
7. Unwrap and prepare an appropriate length splint.
    - The width of splinting material used should be approximately one-half the circumference of the extremity measured at the wrist, such that it is wide enough to extend approximately halfway around the distal forearm once applied.
    - Layer the splint eight sheets thick if using plaster roll and six sheets thick if using fiberglass roll.
    - It is best to begin with a generous length of splinting material because both plaster and fiberglass splint rolls shrink slightly once moistened. If the wet splint turns out too long, the ends can be either folded back or cut with shears before hardening.
8. Apply the dry splinting material to the ulnar aspect of the extremity from the midforearm to just beyond the distal interphalangeal joint of the little finger and cut the splint to approximately 20 cm longer than the desired length.
9. Submerge the dry splint in water until bubbling stops.
10. Remove the splint from water, place on a hard flat surface, and smooth out the excess water to ensure no wrinkles are present.
11. Apply to the splint to the limb over the cotton padding.
    - If the splint is too long at this stage, the ends may be folded back or cut with shears to the proper length.

12 Once positioned properly, fold the side of the splint up around the ulnar aspect of the forearm and hand to form a gutter (Fig. 99.5).

13. Fold the underlying cotton padding and stockinette back over the ends of the splint, which both protects the skin and holds the splint in place.
14. Secure the loose end(s) of the elastic bandage with adhesive tape.
    - Avoid using the metal clips often packaged with elastic bandages because these can become displaced and embed in the skin.
15. Manipulate the forearm and hand into the “neutral” position: (1) the wrist in slight extension (10–20°), (2) the metacarpophalangeal joints in 50° of flexion, and (3) the proximal and distal interphalangeal joints of the ring and little finger in slight flexion (10–15°) (Fig. 99.6).
    - When splinting a boxer’s (i.e., metacarpal neck) fracture, the metacarpophalangeal joint should be flexed to 90°.
16. Mold the splint to the contour of the extremity (Fig. 99.7).
    - Use only the palms of the hands when molding because the fingertips may cause indentations, resulting in excessive skin pressure.
17. Wrap the extremity with an elastic bandage in a distal-to-proximal direction to secure the splint in place (Fig. 99.8).
18. Ensure the extremity is neurovascularly intact.
19. Instruct the patient to loosen the elastic bandage if it feels too tight.

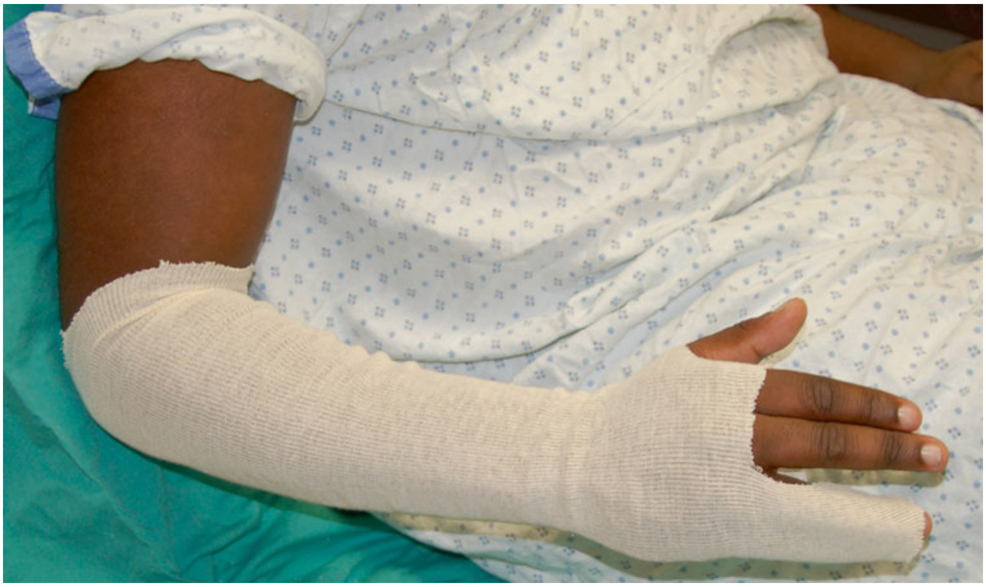

Fig. 99.2 Stockinette applied to the forearm and hand

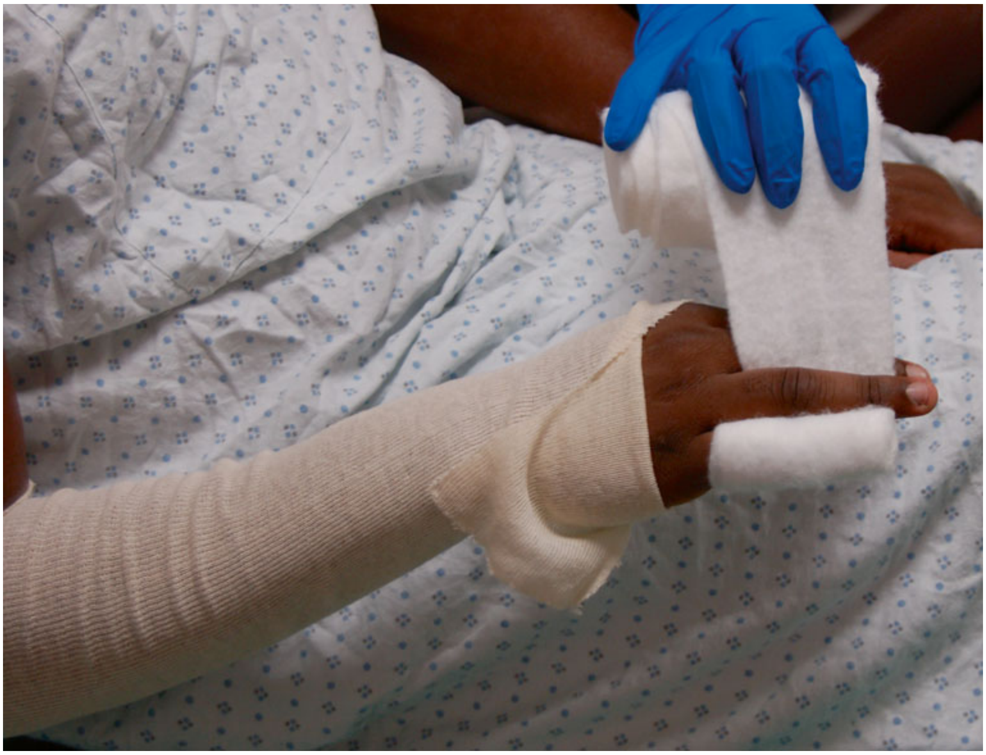

Fig. 99.3 Cotton padding applied to the ring and little fingers

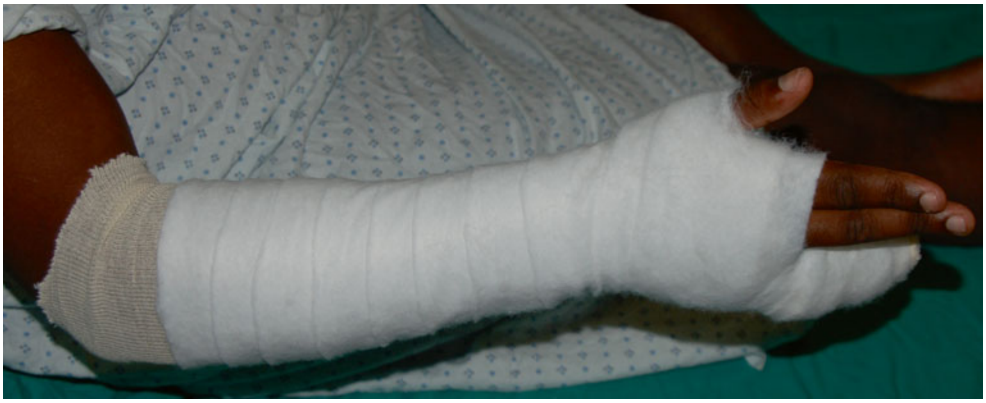

Fig. 99.4 Cotton padding applied to the forearm and hand

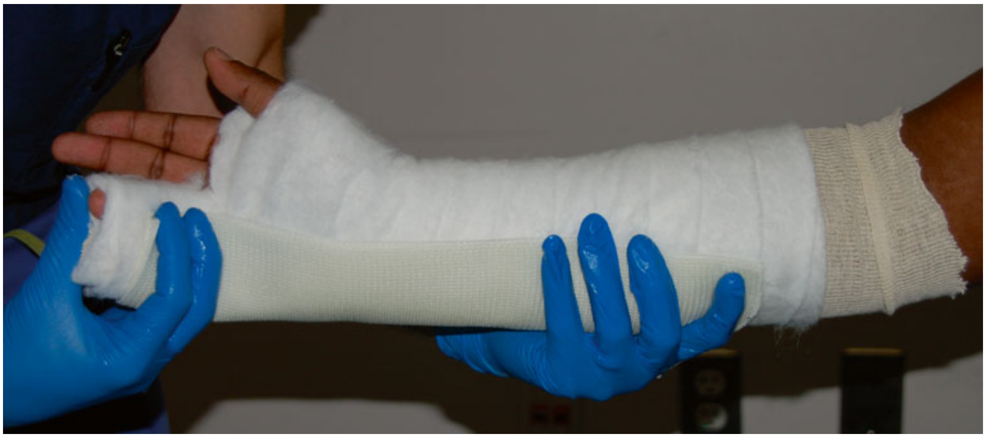

Fig. 99.5 Splint folded around the ulnar aspect of the forearm and hand

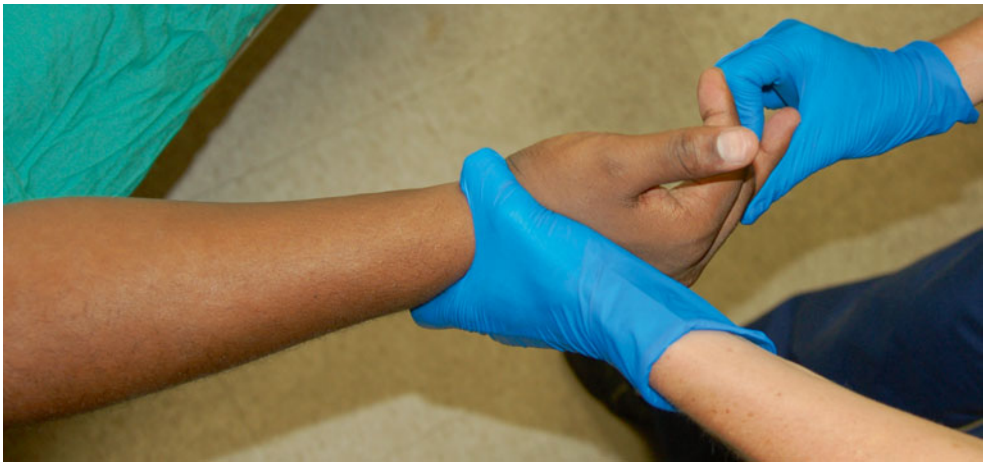

Fig. 99.6 Forearm and hand in the neutral position (without splint)

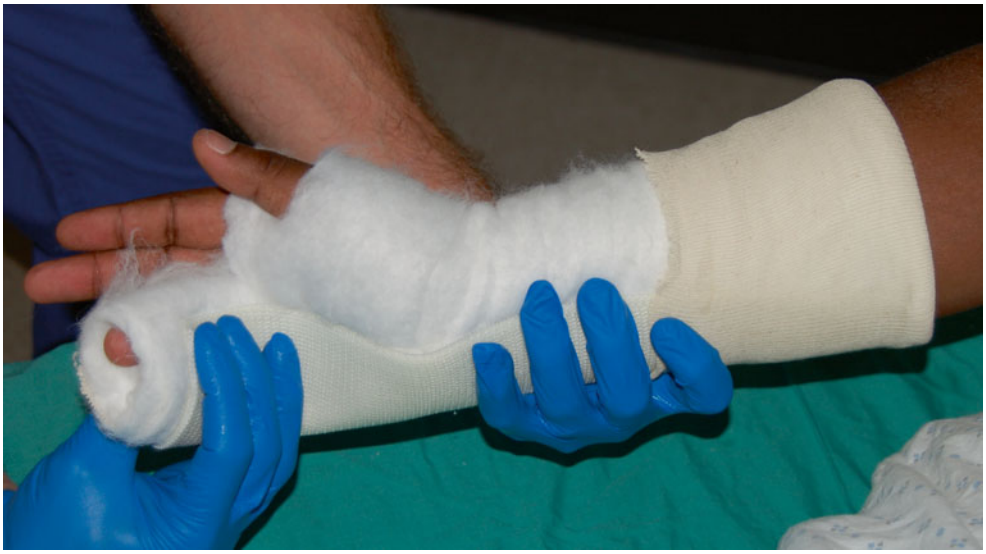

Fig. 99.7 Splint molded to maintain the forearm and hand in the neutral position

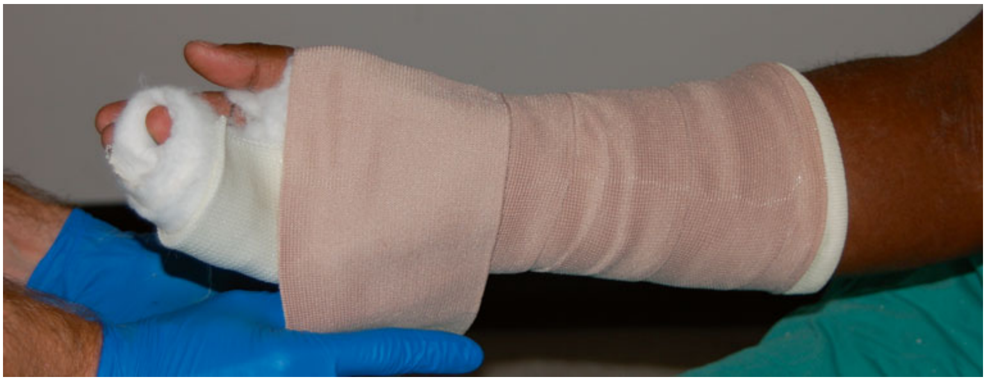

Fig. 99.8 Splint secured in place with an elastic bandage

99.5 Complications

- Neurovascular or other soft tissue compromise (if the splint/bandage is too tight)
- Soft tissue degradation (if the splint is left in place too long)

99.6 Pearls and Pitfalls

- Pearls
  - Simple plaster of Paris splints are inexpensive and allow a thoroughly customizable fit but can be damaged by water and require more time to set and more clean up than prefabricated foamcore or fiberglass splint rolls.
  - Simple fiberglass splints set quickly, are not damaged by water, are stronger and lighter than simple plaster and prefabricated splints, and offer a fully customized fit, but are not applied as quickly as prefabricated splints.
  - Prefabricated fiberglass splints are quickly applied, require virtually no clean up, and are not damaged by water, but are relatively expensive and provide a somewhat less customizable fit than simple splint rolls.
  - Stockinette protects the skin and, when folded back over the ends of the plaster or fiberglass splint roll, holds the wet splint in place before the elastic bandage is placed, and provides a padded rim with a professional appearance.
- Pitfalls
  - Avoid wrinkling the cotton padding applied between the stockinette and the splinting material because, once under the pressure of the elastic bandage, wrinkles can cause unnecessary skin pressure.
  - Avoid using more or fewer layers of splinting material than recommended. Additional layers can result in excessive heat during the setting process and a splint that is too heavy, whereas insufficient layers can result in a splint that is too weak.

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Shoulder Dislocation Reduction Techniques

100

Katrina Skoog Nguyen, L. Connor Nickels, and Rohit Pravin Patel

100.1 Indications

- Subjective history of new-onset dislocation or recurrent dislocations combined with clinical assessment consistent with shoulder dislocation
  - Anterior dislocations (96 %)
    - Typical mechanism of injury being indirect, with combination of abduction, extension, and external rotation. Rarely, the etiology is a direct blow to the posterior shoulder.
    - Prominent acromion with a palpable drop off below the acromion and subclavicular region fullness is consistent with anterior shoulder dislocation.
  - Posterior dislocations (4 %)
    - Mechanism of injury is indirect with a combination of internal rotation, adduction, and flexion. Precipitating events include seizure, electrical shock, and falls.
    - More subtle presentation. Patient will maintain arm locked in internal rotation and adduction; he or she cannot externally rotate. Shoulder is flattened anteriorly and rounded posteriorly.
    - Ultrasound can be used to prevent missed or delayed diagnosis (Figs. 100.1 and 100.2 show probe positioning and a diagram of abnormal ultrasound anatomy).
  - Inferior dislocations (luxation erecta)
    - Arm will be held fixed in overhead position.
- Radiographs reveal shoulder dislocation.
- Ultrasound can be used to identify the nature of the dislocation (anterior or posterior) and can be determined by the position of the humeral head relative to the transducer and glenoid. Although at this point, it should not replace radiographs owing to missed fractures. Advantages may include less radiation (decreased need for postreduction x-rays) and re-sedation if reduction is not complete.

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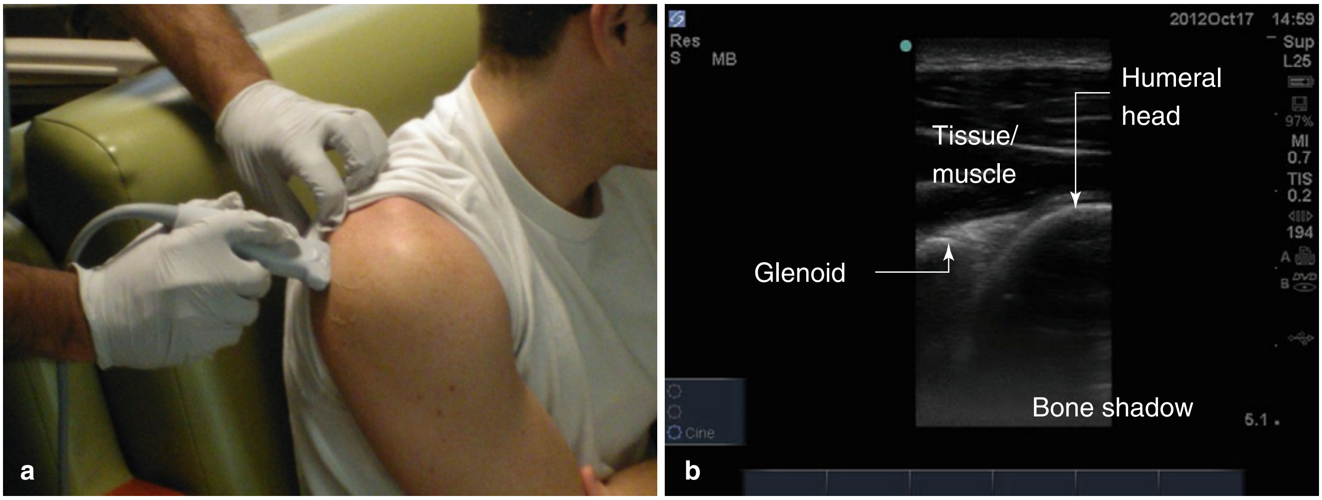
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Humeral head
Tissue/ muscle
Glenoid
Bone shadow

Fig. 100.1 (**a**, **b**) Ultrasound image of normal shoulder anatomy. “Dot fits the Dot” means when looking at the ultrasound machine from the sonographer’s standpoint, the side of the probe marker corresponds to the side the marker is on the screen. This ensures when doing procedures, the direction of needle correction is the same as the orientation of the probe (Images courtesy of Dr. Rohit Patel)

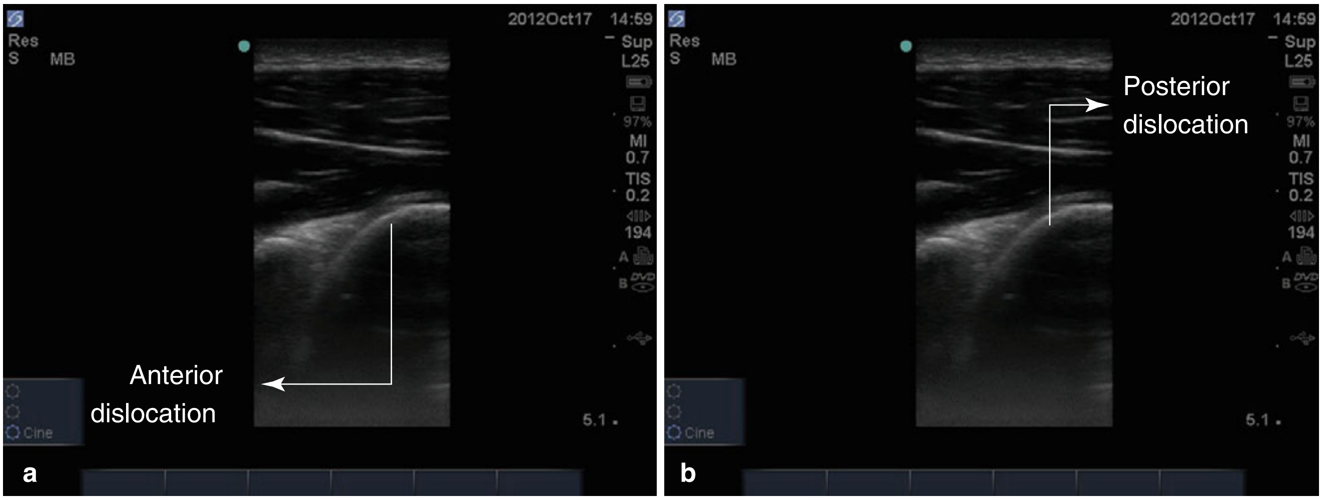
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Anterior dislocation
a
Posterior dislocation
b

Fig. 100.2 Anterior (**a**) and posterior (**b**) dislocations (Images courtesy of Dr. Rohit Patel)

100.2 Contraindications

- Associated fracture
  - This warrants orthopedic evaluation.
- Associated neurovascular deficit
  - May attempt reduction once but avoid multiple attempts.

100.3 Materials and Medications

- 1 % lidocaine, with syringe and needle and povidone-iodine prep if administering local anesthesia
- Moderate sedation medications if administering moderate sedation
- Bed sheet for traction-countertraction method
- Dangling weight for Stimson maneuver

100.4 Procedure

- Physical examination
  - Compare affected with unaffected shoulder.
  - Perform a complete neurovascular examination: test axillary, radial, ulnar, and median nerves for sensory deficit and motor function.
- Radiographs
  - Always obtain before attempting reduction for assessment of possible fracture and type and position of dislocation.
  - Obtain three views: anteroposterior, scapular Y, and axillary lateral views.
  - Anterior dislocations: humeral head appears anterior to the glenoid fossa on lateral or Y views.
  - Posterior dislocations: on anteroposterior view (vacant glenoid sign, 6-mm sign, lightbulb sign; on lateral or Y view: humeral head appears posterior to glenoid fossa).
- Pain management and sedation
  - Decide whether to use intra-articular lidocaine versus procedural sedation and analgesia.
  - For intra-articular lidocaine
    - Use 10–20 mL of 1 % lidocaine.
    - Attach a 1.5-in., 20-gauge needle.
    - Prepare the shoulder with povidone-iodine.
    - Insert the needle lateral to the acromion process and 2 cm inferiorly into the sulcus.
    - After withdrawing to ensure that the needle is not in a vessel, inject 10–20 mL lidocaine into the joint.
- Reduction techniques: it is important for the emergency department physician to be familiar with several different techniques. The following techniques are presented:

100.4.1 Stimson Maneuver (Fig. 100.3)

1. Patient is placed prone with 2.5–5 kg of weight hanging from the wrist.
2. Reduction may be facilitated by traction and external rotation of the arm.
3. A success rate of 96 % has been reported using the combined prone position, hanging weights, intravenous drug therapy, and scapular manipulation.

- Advantage: can be performed by one person only.
- Disadvantages: requires time to gather materials; the danger involved in the patient falling off the stretcher, requiring staff to monitor the patient.

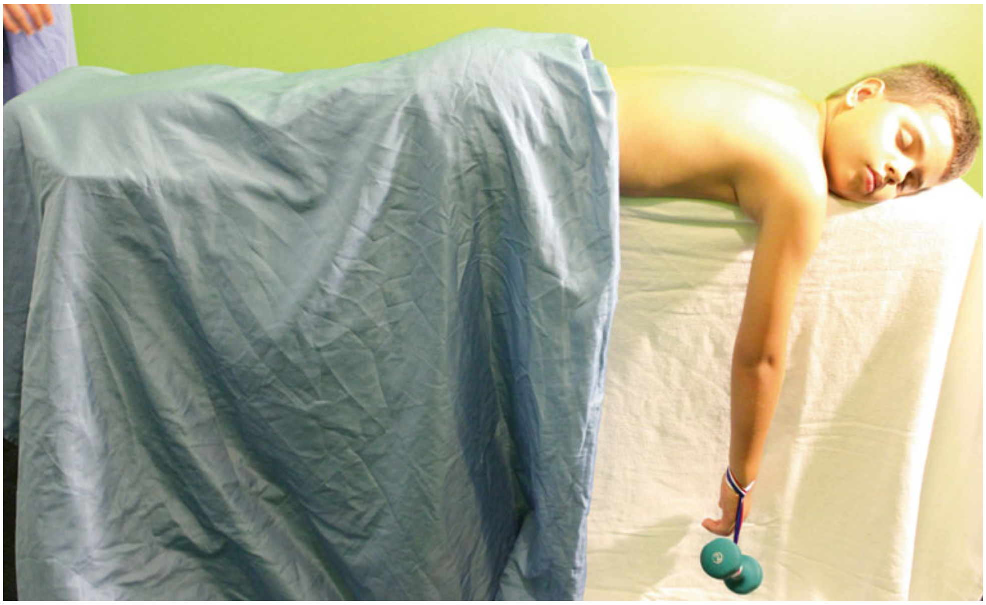

Fig. 100.3 Stimson maneuver

100.4.2 Scapular Manipulation Technique (Fig. 100.4)

1. Place the patient in the prone position with the affected arm hanging downward.
2. Apply traction down on the arm.
3. Locate the inferior tip of the scapula. Simultaneously push the inferior tip of the scapula medially toward the spine and use the other hand push the superior scapula laterally.

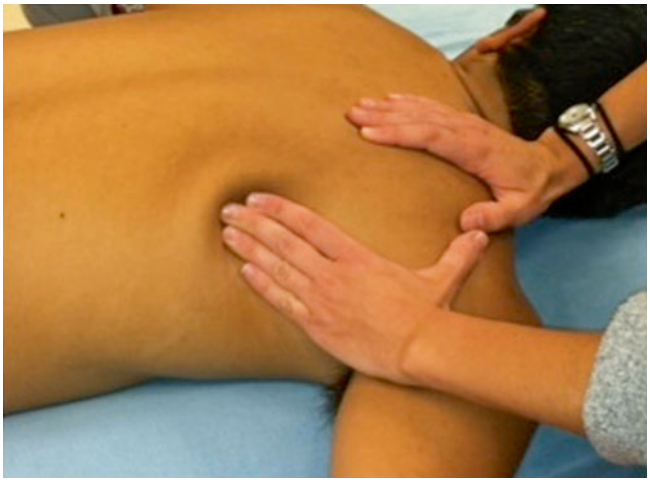

Fig. 100.4 Scapular manipulation method

- Advantages: high success rate, greater than 90 %; very safe to perform.
- Disadvantages: it requires the patient to assume the prone position; may require another person to perform traction.

100.4.3 External Rotation Method (Fig. 100.5)

1. Place the patient in the supine position with the affected arm adducted directly next to the patient's side with the elbow flexed to 90°.
2. The operator uses one hand to direct downward traction on the affected arm while maintaining it next to the patient's side.
3. The operator uses the other hand to hold the patient's wrist and guide the arm into slow external rotation.
4. Reduction usually takes place between 70° and 110° of external rotation.

- Advantages: requires no strength by operator; well tolerated by patients.
- Disadvantage: patient may have persistent dislocation during procedure, requiring operator to make adjustments.

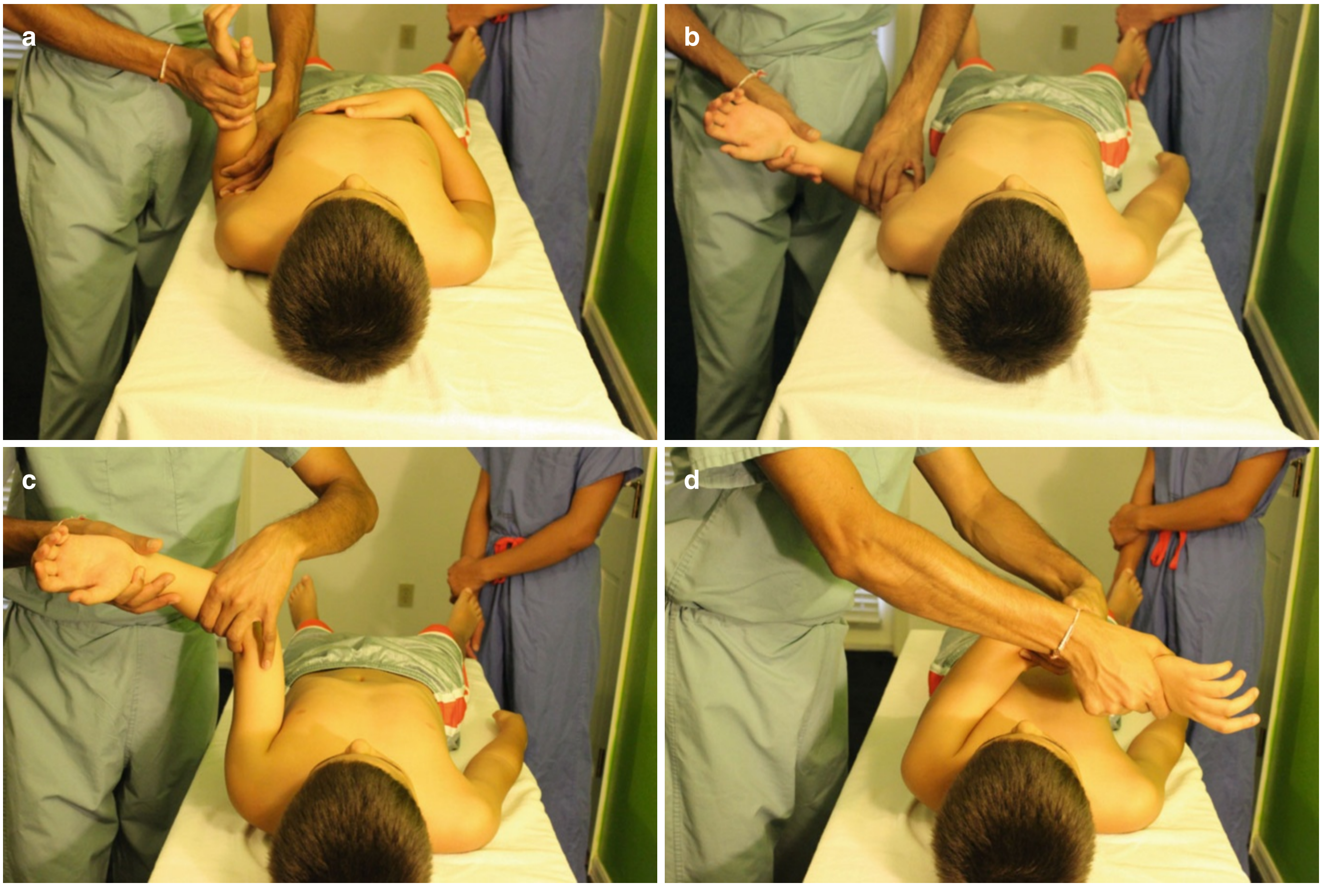

Fig. 100.5 (**a**–**d**) Kocher technique: external rotation method

100.4.4 Milch Technique (Fig. 100.6)

1. Technique looks as though one is reaching up to grab an apple from a tree.
2. Abduct the injured arm up to the overhead position.
3. Once in the overhead position, apply gentle vertical traction with external rotation.
4. An adjustment may need to be made if the reduction does not occur easily; push the humeral head upward into the glenoid fossa.

- Advantages: lack of complications; patient tolerance
- Disadvantage: variable success rate reported: 70–90 %

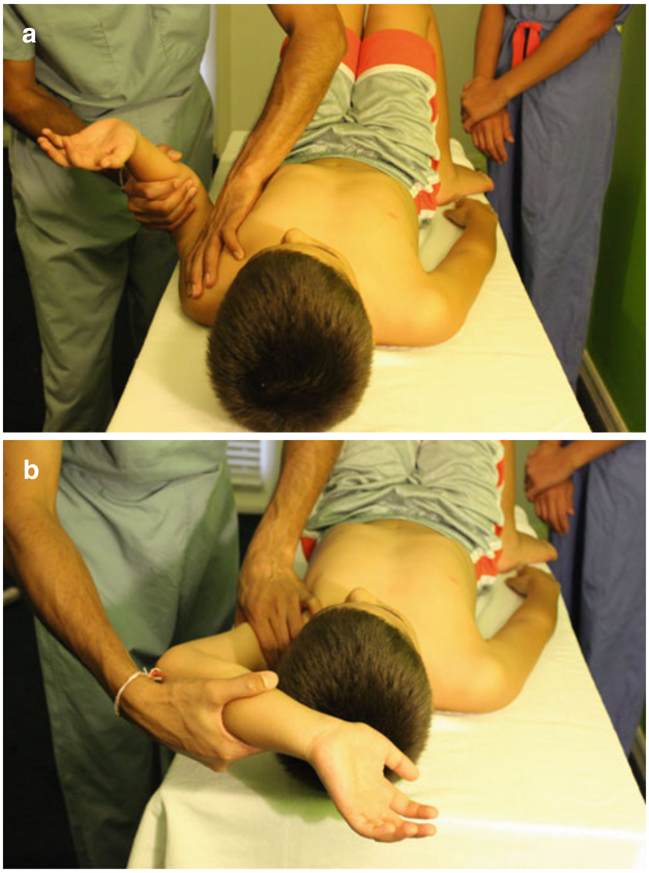

Fig. 100.6 (**a**, **b**) Milch technique

100.4.5 Spaso Technique (Fig. 100.7)

1. Place the patient in the supine position.
2. Operator grasps the affected arm at the wrist and lifts the straight arm directly upward while applying longitudinal traction.
3. Apply external rotation.

- Advantages: single operator, high level of success
- Disadvantage: may require more time to allow the shoulder muscles to relax

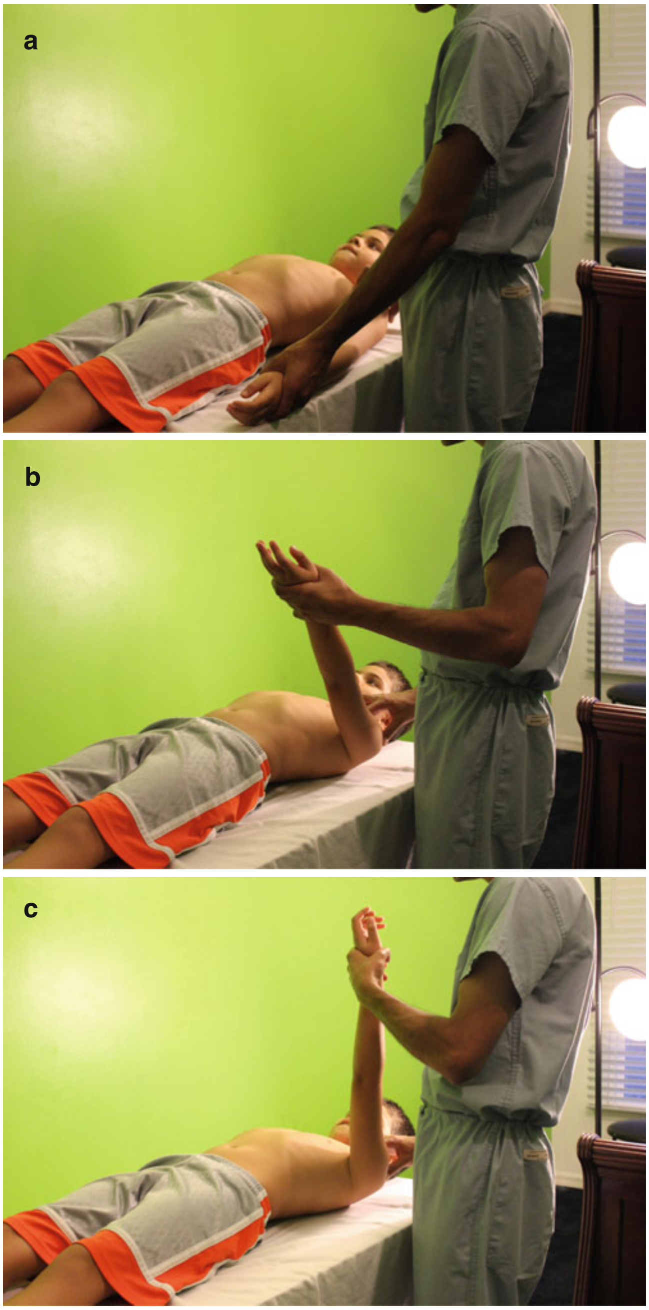

Fig. 100.7 (**a**–**c**) Spaso technique (Photographs courtesy of Dr. Pratik S. Patel)

100.4.6 Traction-Countertraction Technique (Fig. 100.8)

1. With the patient is sitting up, have an assistant wrap a sheet around the upper chest and under the axilla of the affected shoulder. Have the assistant wrap the sheet behind her or his back. Now have the patient lay supine.
2. Wrap another sheet around the flexed elbow of the affected arm and behind the operator's back.
3. Both the operator and the assistant lean back, applying gentle traction.

- Advantage: many older physicians are familiar with this method and, therefore, have a high degree of success.
- Disadvantages: requires two people; may cause skin tears on elderly patients.

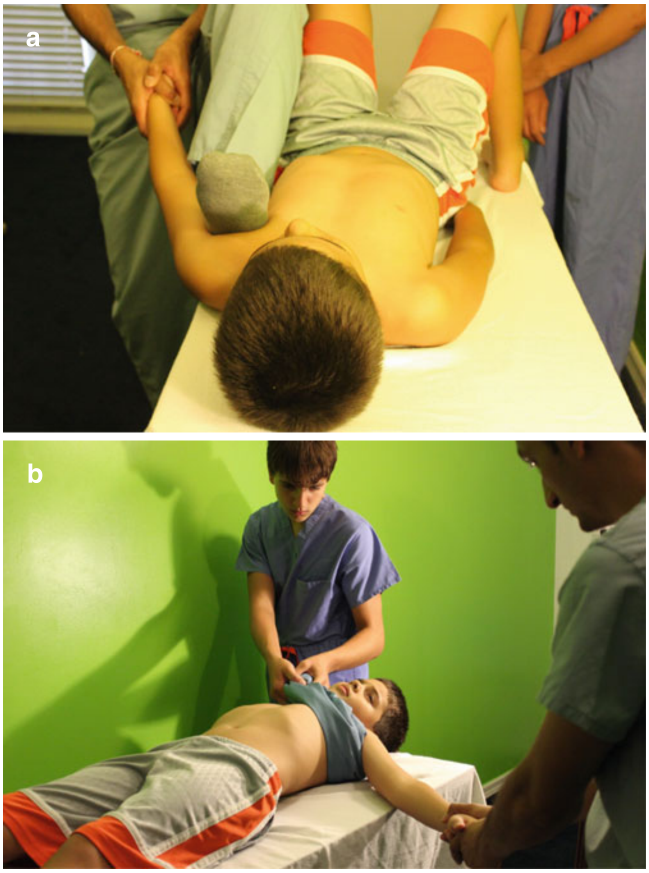

Fig. 100.8 (**a**, **b**) Hippocrates method/traction-countertraction method

100.4.7 Posterior Shoulder Dislocation Reduction

1. Give adequate premedication.
2. Place the patient supine and apply lateral traction on the proximal humerus.
3. Have an assistant apply anterior pressure to the posteriorly located humeral head.

- Advantage: logical methods for reduction
- Disadvantages: require sufficient premedication because often posterior dislocations present late; may require open reduction

100.4.8 Postreduction

- Obtain postreduction x-rays. There is some literature on using ultrasound to confirm adequate reduction, which allows repetitive assessments throughout procedure, as well as reduce radiation (see Fig. 100.2 for ultrasound of anterior and posterior dislocations).
- Do a postreduction neurovascular examination.
- Sling and swath or shoulder immobilizer for 2–3 weeks.
- Orthopedic follow-up in 1 week.

100.5 Complications

- Fractures
- Adhesive capsulitis, or frozen shoulder; especially a concern in the elderly with prolonged immobilization in sling
- Brachial plexus injury, especially of the axillary nerve
- Vascular laceration, most commonly of the axillary artery
- Rotator cuff tears

100.6 Pearls

- It is imperative to document the pre- and postreduction neurovascular status in the medical record.
- If unsure whether the reduction was successful, attempt to place the palm of the injured extremity on the contralateral shoulder. This is a good sign the reduction was successful.

Acknowledgment The authors would like to thank Karthik Stead for serving as the subject in many of the photographs in this chapter.

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Elbow Dislocation Reduction

101

Katrina John, Jeffrey Kile, and Amish Aghera

101.1 Indications

- Any dislocation of the elbow joint. Direction of the dislocation (i.e., anterior, posterior, lateral and divergent radius, and ulnar dislocations) is determined by the position of the ulna relative to the joint space (Fig. 101.1).

101.2 Contraindications

- Relative
  - Compound fracture dislocation

Fig. 101.1 Anatomical depiction

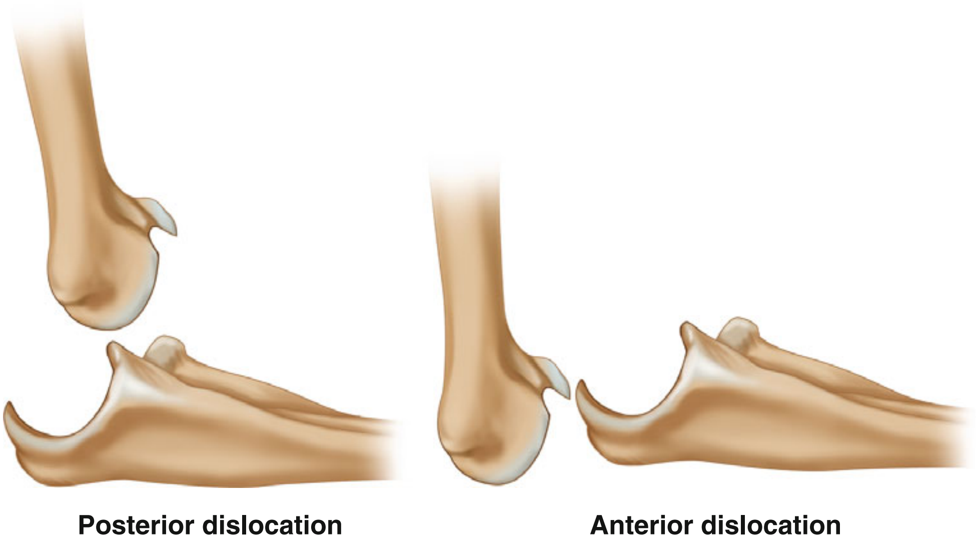

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101.3 Materials and Medications

- Parenteral sedation and analgesia medications
- Local anesthetic for local and intra-articular anesthesia
- Splinting material
- Stockinette
- Padding
- Elastic bandage
- Tape
- Sling

101.4 Procedure for Posterior Dislocations

1. Obtain a true lateral and anteroposterior radiographs of the affected elbow.
2. Ensure adequate sedation and analgesia.
3. Consider intra-articular analgesia.
4. Check the neurovascular status of affected extremity.
5. Follow a selected method for reduction as detailed later.
6. Following successful reduction gently flex the elbow to ensure full range of motion.
7. Place a long-arm posterior splint with the elbow in at least 90° flexion and secure the arm in a regular sling.
8. Check neurovascular status.
9. Obtain a postreduction radiograph of the elbow.

101.4.1 **Method A** (Fig. 101.2)

1. Position the patient on a stretcher in the supine position.
2. Apply steady traction at the supinated distal forearm keeping the elbow slightly flexed, while an assistant applies countertraction to the midhumerus with both hands.

101.4.2 **Method B** (Fig. 101.3)

1. Position the patient on a stretcher in the supine position.
2. Extend the affected extremity over the edge of the stretcher.
3. Apply traction to the supinated forearm slightly flexed at the elbow, while an assistant holds the distal humerus with both hands and uses thumbs to apply pressure to the olecranon as if pushing it away from the humerus.

101.4.3 **Method C** (Fig. 101.4)

1. Position the patient on a stretcher in the prone position.
2. Hang the affected extremity over the side of the stretcher toward the floor.
3. Apply downward traction to the pronated distal forearm and with the other hand just above the patient's antecubital fossa lift the humerus toward you.

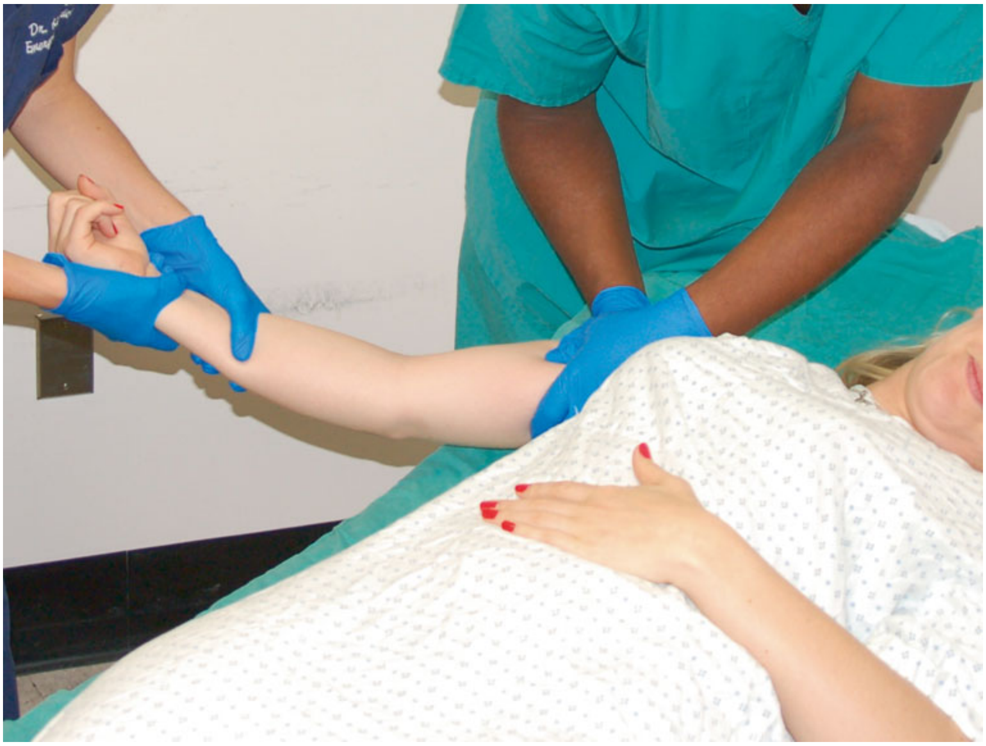

Fig. 101.2 Posterior method A

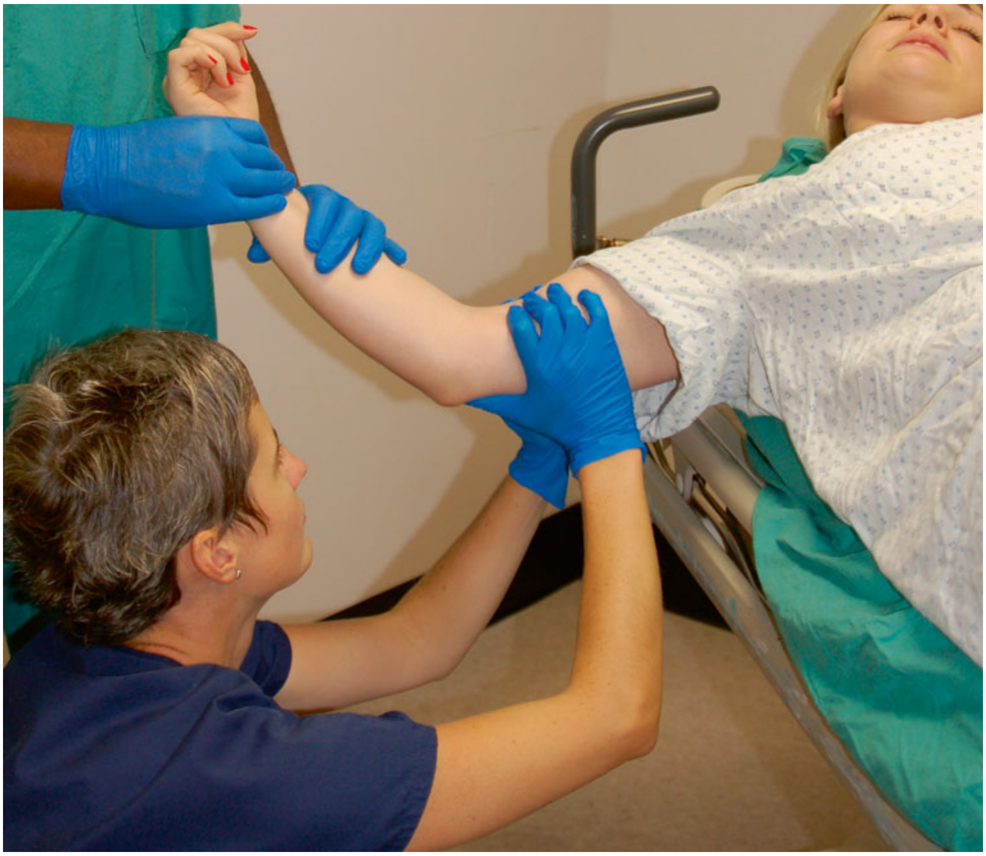

Fig. 101.3 Posterior method B

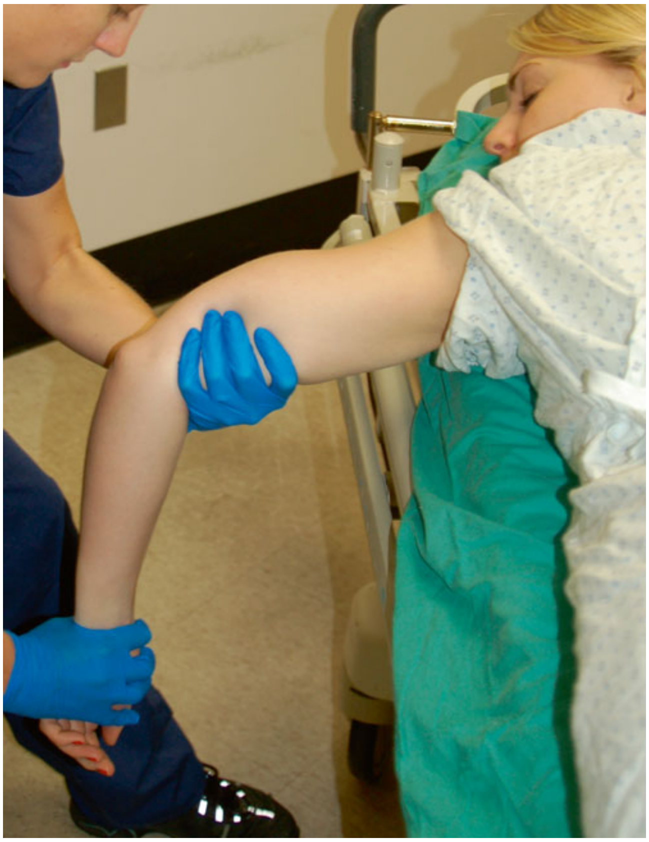

Fig. 101.4 Posterior method C

101.5 Procedure for Anterior Dislocations (Fig. 101.5)

1. Follow pre- and postprocedure steps as documented for the posterior dislocation.
2. Position the patient on a stretcher in the supine position.
3. With one hand, apply traction to the supinated distal forearm with the elbow extended, while an assistant applies countertraction with both hands around the distal humerus.
4. With the other hand apply downward and backward pressure over the proximal forearm just below the antecubital fossa.

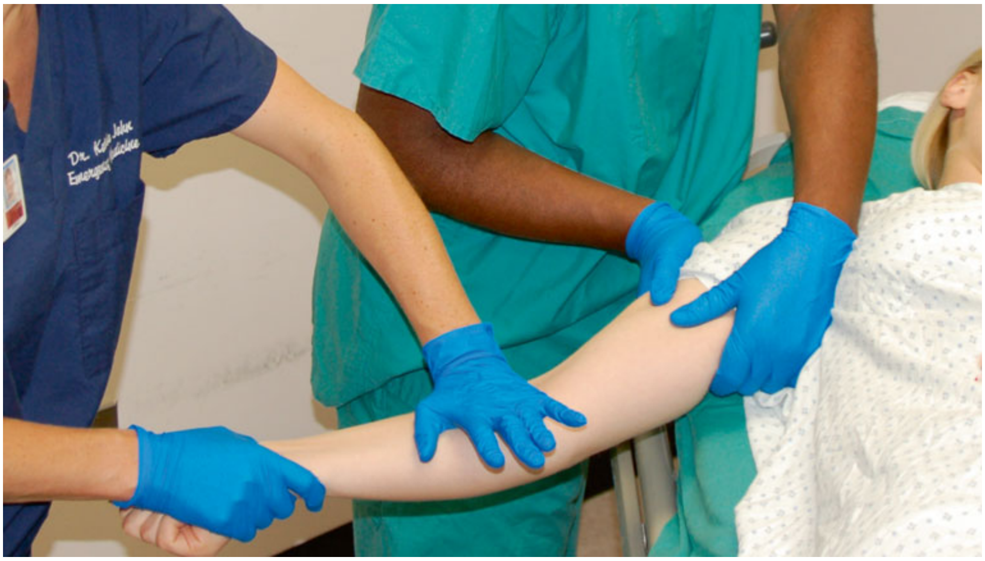

Fig. 101.5 Anterior elbow

101.6 Procedure for Radial Head Subluxations (See Also Chap. 127)

1. This procedure can normally be performed without any sedation or parenteral analgesia.
2. Position the patient, most commonly a child aged 1–3 years, facing forward on the caretaker's lap.
3. Hold the flexed elbow of the affected extremity placing your thumb firmly over the radial head.
4. With the other hand, take the child's hand and wrist, and in one continuous movement, hyperpronate and flex the forearm (Figs. 101.6 and 101.7).
5. Another method is to supinate and flex the forearm instead of hyperpronating it (Fig. 101.8).
6. Leave the room, encourage the caretaker to engage the child with distracting activities and reexamine the child in 10–20 min, at which stage, if reduction was successful, the child should be using the extremity normally again.
7. No postreduction radiograph or immobilization is required.

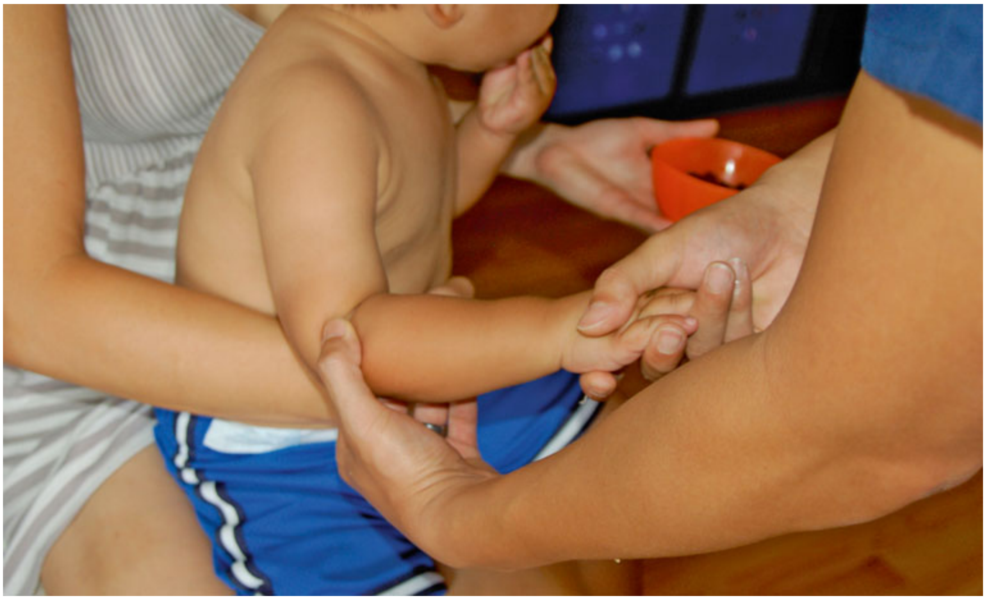

Fig. 101.6 Subluxation hyperpronated

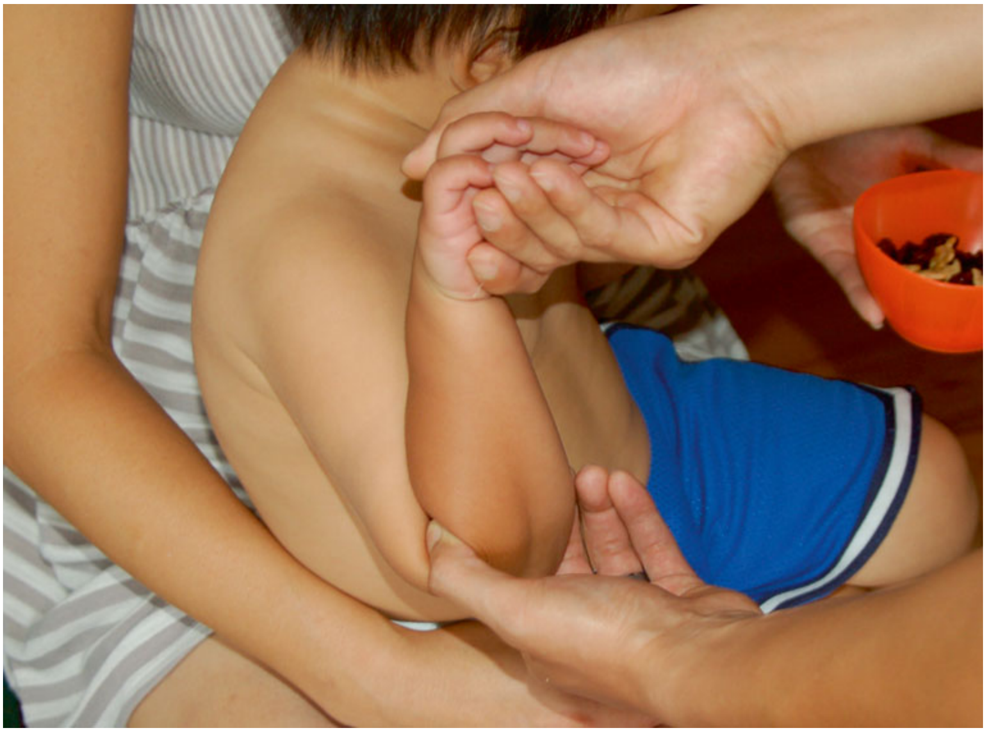

Fig. 101.7 Subluxation hyperpronated and flexed

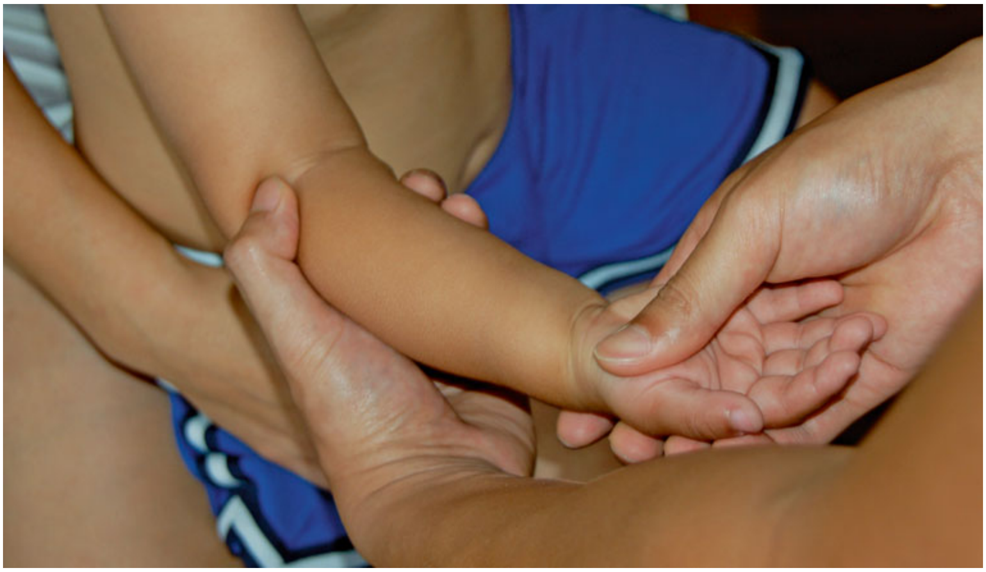

Fig. 101.8 Subluxation supinated

101.7 Complications

- Concomitant fractures
- Vascular injury, most commonly to the brachial artery
- Median nerve injury/entrapment
- Recurrent dislocation—rare

101.8 Pearls and Pitfalls

- Pearls
  - A true lateral radiograph is necessary to accurately detect and identify elbow fractures, dislocations, and soft tissue abnormalities (i.e., the fat pad sign). It is obtained with the patient's elbow in 90° flexion, in neutral rotation with the thumb pointing up and the arm and forearm resting on the radiograph cassette and the beam nearly perpendicular to the cassette. On a true lateral, the "hourglass" or "figure-of-eight" formation at the distal humerus should be clearly visible, and the rings of the capitellum and trochlea should be concentric.
  - During nursemaid elbow reduction, provide age appropriate distractions to divert the child's attention and minimize resistance.
- Pitfalls
  - On the pre- and postreduction radiographs, search for commonly associated fractures of the distal humerus, radial head, and coronoid process.
  - Inability to range the elbow after apparent reduction indicates possible trapped fracture fragments and the need for operative intervention.
  - Vascular or open injuries are common with anterior dislocations, and early orthopedic consultation is advised.
  - Ninety percent of simple elbow dislocations are posterior, and this injury is rarely associated with vascular injury. However, it does occur, and vascular evaluation after every reduction is good clinical practice.

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Distal Interphalangeal Joint Reduction

102

Justin Chen and Muhammad Waseem

Distal interphalangeal (DIP) joint dislocation is rare. It occurs when an axial force is applied to the distal phalanx (Fig. 102.1).

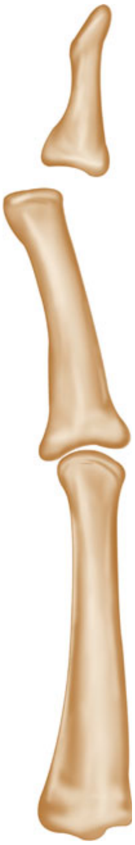

Fig. 102.1 Distal interphalangeal joint dislocation

102.1 Indications

- DIP joint reduction is performed to alleviate functional and anatomical derangements resulting from DIP joint dislocation, commonly dorsal, from axial compression.

102.2 Contraindications

- Absolute
  - Absence of radiographic confirmation (anteroposterior, true lateral, and oblique) of simple DIP joint dislocation, especially in pediatric cases
- Relative
  - Open joint dislocation, associated fracture, or entrapped volar plate
  - Digital neurovascular compromise

102.3 Materials and Medications

- Latex-free gloves
- Local anesthetic: 2 % lidocaine without epinephrine, 1.5 % mepivacaine, 0.5 % ropivacaine, or 0.5 % bupivacaine
- 25-gauge × 1.5-in. needle (can substitute with 27 or 30 gauge)
- Small plastic syringe, 10 mL
- Padded, malleable, aluminum digital splint

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102.4 Procedure

1. Place the patient in the seated position with the arms at rest on a bedside table or supported by an assistant.
2. Pronate the patient's hand, remove rings if present, and rest on a flat surface.
3. Insert a 25-gauge needle at the dorsolateral aspect of the base of the finger to form a wheal to reduce patient discomfort.
4. Advance the needle and direct anteriorly toward the phalangeal base.
5. Inject 0.5–1 mL of local anesthetic as the needle is withdrawn 1–2 mm from the point of bone contact.
6. Inject an additional 1 mL of local anesthetic continuously as the needle is withdrawn.
7. The injection should never render the tissue tense nor be circumferential.
8. Hyperextend the DIP joint while applying longitudinal traction, followed by immediate joint flexion at the base of the distal phalanx.
9. Place finger(s) in an aluminum digital dorsal splint in slight flexion for 2 weeks (Fig. 102.2).
10. Postreduction radiograph is recommended for confirmation.

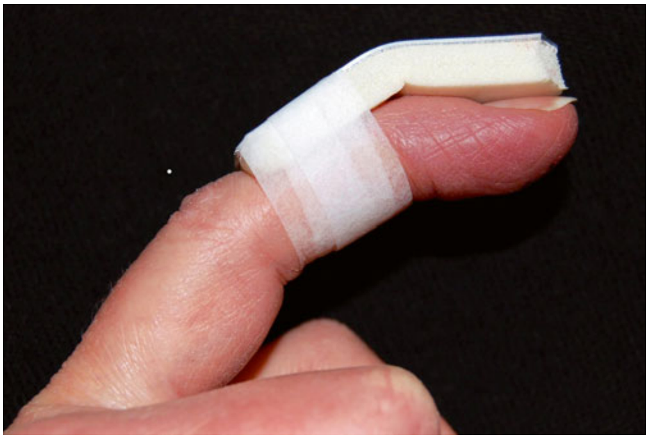

Fig. 102.2 Padded aluminum splint applied to block the DIP joint in flexion but allow further flexion, which encourages active flexion of that joint when the PIP joint flexes (Reproduced with permission from: HandLab Clinical Pearls Feb 2011, No 12. www.handlab.com)

102.5 Complications

- Irreducible dislocations
- Stiffness
- Recurrent dislocation
- Extensor lag in joints with residual subluxation
- Associated with dorsal joint prominences, swan-neck/boutonnière deformity, and degenerative arthritis

102.6 Pearls and Pitfalls

- Pearls
  - Lidocaine without epinephrine is preferred owing to the risk of vasoconstriction of the digital vessels with epinephrine.
  - Regardless of the mechanism of trauma, all joints (DIP, proximal interphalangeal, metacarpophalangeal) should be assessed for instability.
  - Joint dislocations involving volar plate entrapment may require surgical repair (open reduction internal fixation) for successful reduction.
- Pitfalls
  - Irreducible DIP joint dislocations may be due to entrapment of an avulsion fracture, the profundus tendon, or the volar plate.

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Hip Dislocation Reduction

103

Katrina John, Jeffrey Kile, and Amish Aghera

103.1 Indications

Displacement of the femoral head in relation to the acetabulum without concomitant femoral neck, head, or acetabulum fractures:

- Posterior hip dislocations make up 80–90 % of cases.
- Anterior hip dislocations make up 10–15 % of cases. These are classified into obturator, pubic, iliac, central, or inferior types. Central dislocations are associated with comminuted acetabulum fractures, and inferior dislocations are a rare occurrence normally occurring in children younger than 7 years of age.
- Prosthetic hip dislocations

103.2 Contraindications

- Absolute
  - Femoral neck fracture: attempted reduction may increase the displacement of the fracture and increase the probability of avascular necrosis.
- Relative
  - Fractures in other parts of the affected lower extremity: these may limit the pressure that can be applied necessary for traction during reduction.

103.3 Materials and Medications

- Parenteral sedation and analgesia medications
- Sheet or belt to fix the pelvis to the stretcher
- Knee immobilizer
- Abduction pillow

103.4 Procedure

1. Check the neurovascular status of the affected extremity.
2. Obtain anteroposterior (AP) views of the pelvis and lateral views of the hip.
3. Ensure adequate parenteral sedation and analgesia.
4. Decide upon a technique, as detailed later, and position the patient accordingly.
5. Once the hip has been successfully reduced, test the joint for stability by moving it gently thought its range of motion.
6. Place a knee immobilizer and an abduction pillow between the knees.
7. Check the neurovascular status.
8. Obtain repeat AP films of the pelvis.

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103.4.1 Stimson Maneuver

1. Place the patient prone on the stretcher with the affected extremity hanging over the edge and the hip flexed to 90°.
2. Flex the knee and the foot to 90°.
3. Apply downward pressure to the area just distal to the popliteal fossa with a hand (Fig. 103.1) or knee (Fig. 103.2) while using the opposite hand to internally and externally rotate the hip at the ankle.
4. Have an assistant simultaneously manipulate the displaced femoral head into position with both hands, applying downward pressure over the affected buttock (Fig. 103.3).

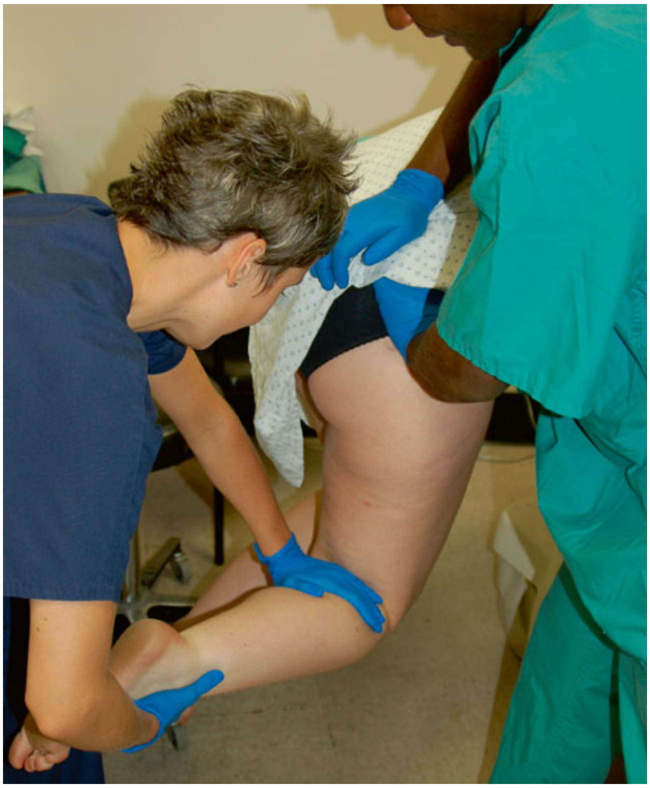

Fig. 103.1 Stimson maneuver with hand

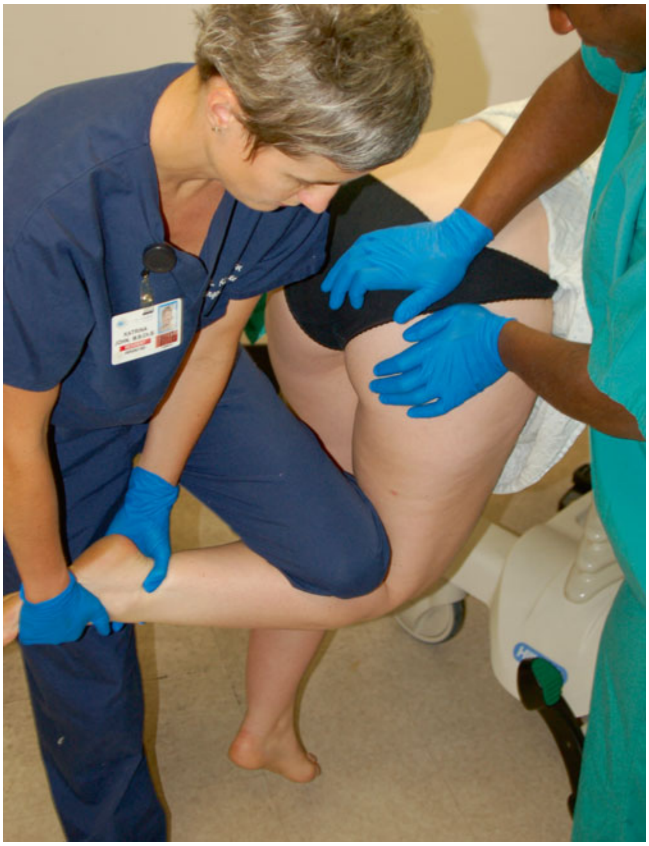

Fig. 103.2 Stimson maneuver with knee

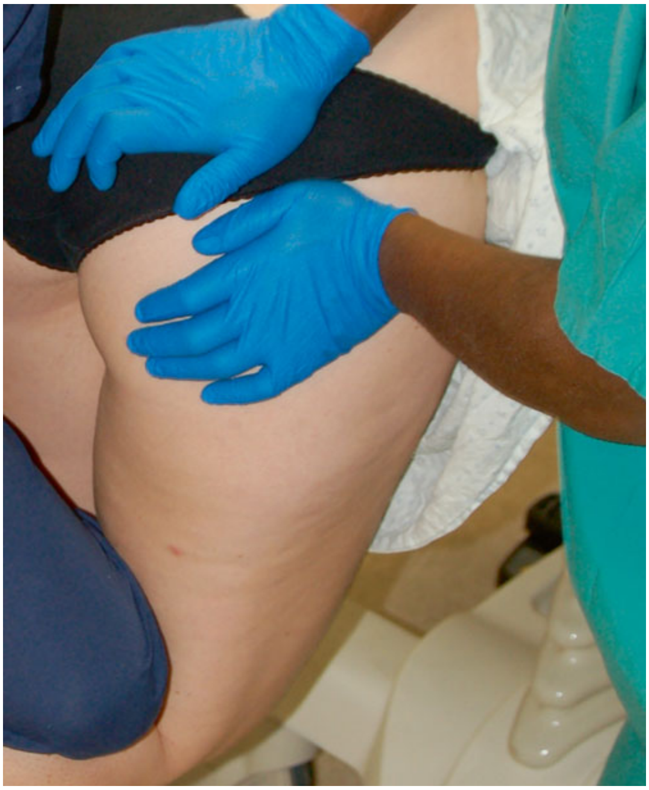

Fig. 103.3 Manipulation of the femoral head

103.4.2 Allis Maneuver

1. Position the patient supine on the stretcher.
2. The operator should stand on the stretcher to achieve maximum leverage or have the patient on a backboard on the ground.
3. Have an assistant apply downward pressure to both iliac crests.
4. Apply constant, gentle upward traction in line with the deformity while maneuvering the hip to 90° flexion and through internal and external rotation (Fig. 103.4).
5. Have a second assistant provide lateral traction to the midthigh.
6. Once the femoral head has cleared the outer lip of the acetabulum, continue traction while keeping the hip in external rotation and gently abducting and extending the hip (Fig. 103.5).

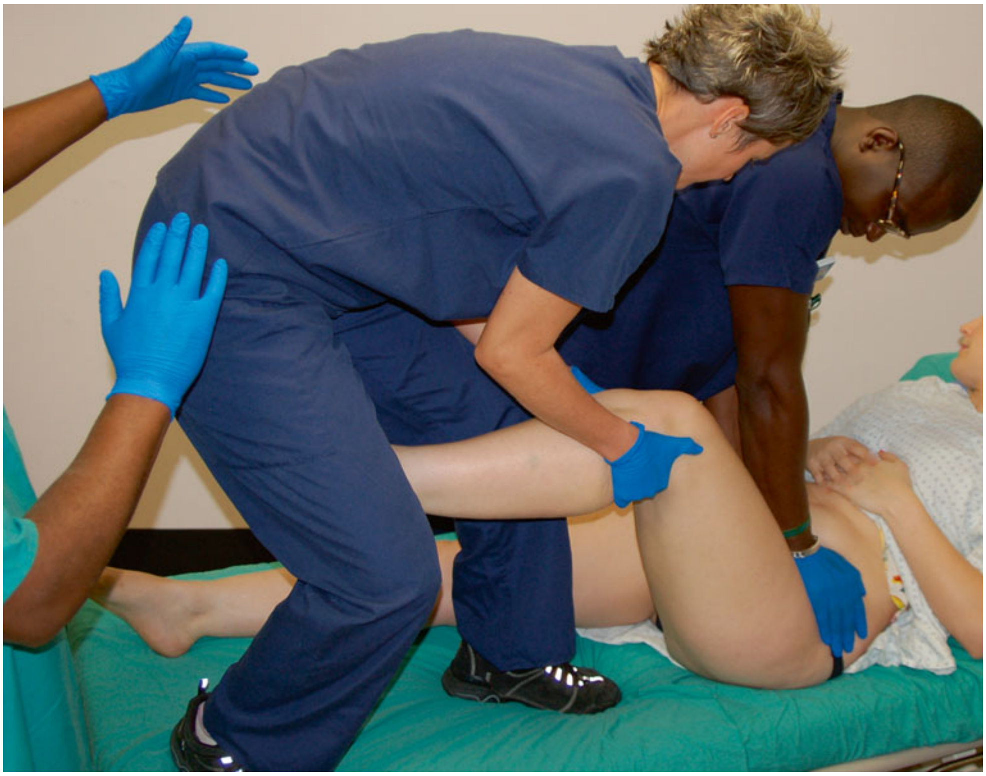

Fig. 103.4 Allis flexion

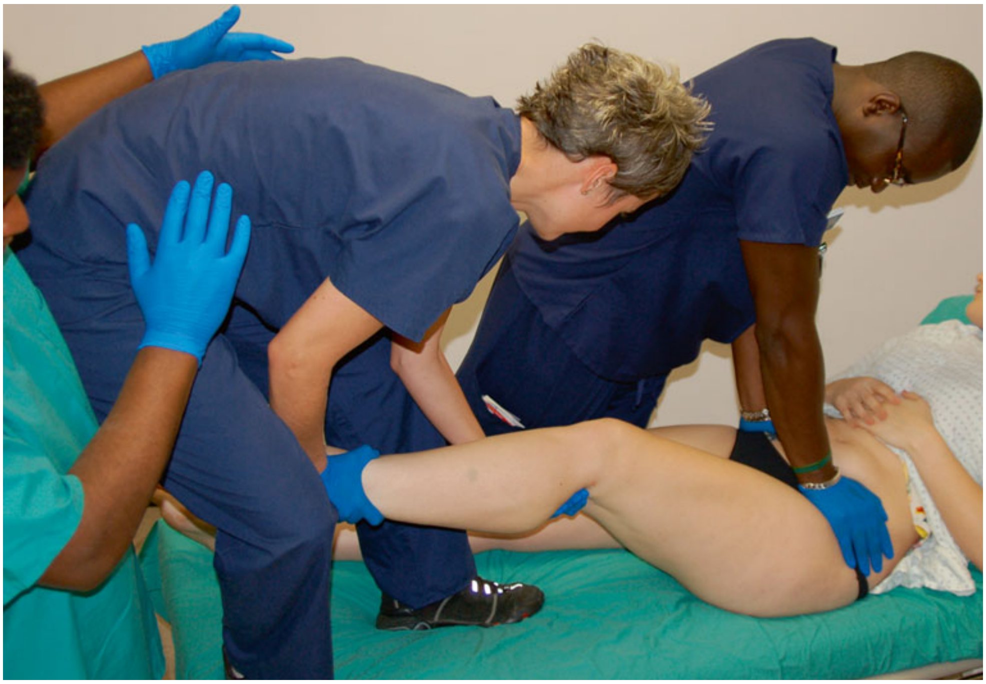

Fig. 103.5 Allis extension

103.4.3 Whistler Technique

1. Position the patient supine on the stretcher with the knee and hip flexed to 45°.
2. Have an assistant stabilize the pelvis with downward pressure on both iliac crests.
3. Stand on the side of the affected extremity and place one arm under the knee, resting the hand on the flexed knee of the unaffected extremity.
4. Secure the ankle of the affected extremity with the other hand and elevate the shoulder of the opposite arm, providing upward traction at the distal thigh and a strong fulcrum to reduce the dislocation (Fig. 103.6).
5. Internal and external rotation can be achieved with the opposite hand at the ipsilateral ankle.

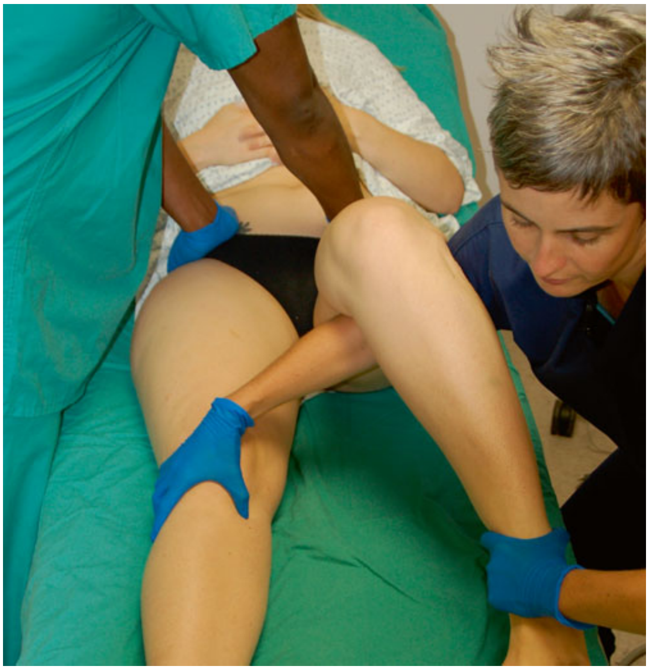

Fig. 103.6 Whistler technique

103.4.4 Captain Morgan Technique

1. Position the patient supine on the stretcher with the knee and hip flexed to 90°.
2. Stabilize and fix the pelvis with a sheet tied securely over the pelvis and under the stretcher.
3. Standing on the side of the affected extremity, the operator's foot should be resting perpendicular on the stretcher with the knee placed under the patient's knee.
4. With the opposite hand, apply downward pressure to the ankle and provide a sustained upward force to the patient's thigh by elevation of the knee through plantar flexion of the toes and upward pressure of the other hand placed behind the patient's knee.
5. Internal and external rotation can be applied simultaneously if necessary by gently twisting the ankle (Fig. 103.7).

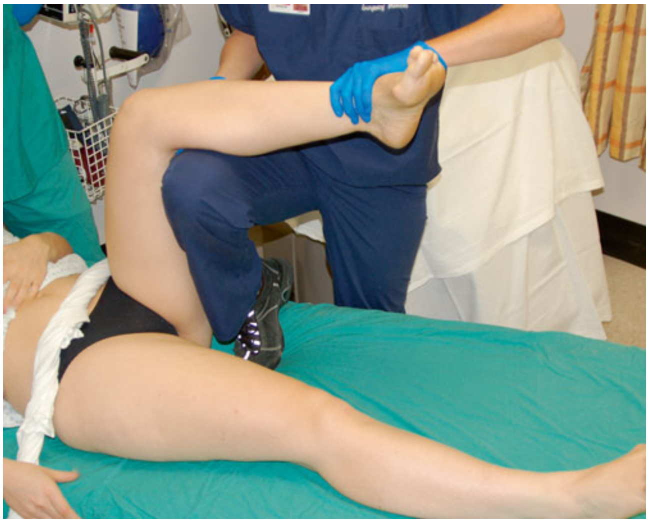

Fig. 103.7 Captain Morgan technique

103.5 Complications

- Sciatic nerve injury
- Avascular necrosis of the femoral head due to delay in adequate reduction
- Inability to perform reduction due to occult fractures and fracture fragments, incarceration of the joint capsule, or associated tendons
- Unstable or irreducible dislocations
- Traumatic arthritis and joint instability

103.6 Pearls and Pitfalls

- Pearls
  - On AP radiograph, posterior dislocations can be more easily detected by the presence of a smaller femoral head compared with the unaffected side and poor visualization of the lesser trochanter.
  - On AP radiographs, anterior dislocations can be detected by a larger femoral head and a clear lesser trochanter seen in profile alongside the femoral shaft.
  - Pay close attention to the femoral vessels and the sciatic nerve. Injury to the sciatic nerve most commonly affects the common peroneal branch, therefore causing weakness in great toe extension and foot dorsiflexion. Sensation may also be reduced over the dorsum of the foot.
  - Check the femoral head is intact and clearly in the acetabulum and for intact Shenton lines, symmetrical intra-articular spaces, and clear outlines of the lesser trochanters.
  - For any of the techniques requiring stabilization of the pelvis, an alternative is to fix it to the stretcher using a sheet or belt.
  - To overcome the powerful muscles that oppose successful reduction, it is important to provide adequate muscle relaxation and steady, prolonged traction.
  - An assistant should stand on the floor behind to support the operator if standing on a stretcher.
- Pitfalls
  - Owing to the force necessary to dislocate a native hip, this injury should serve as a red flag to the physician to consider other potentially life- or limb-threatening occult injuries.
  - Hip dislocation is a true orthopedic emergency and must be treated without delay. Delay in reduction, especially greater than 6 h, results in increased incidence of avascular necrosis of the femoral head and sciatic nerve injury.
  - Review imaging carefully because associated fractures of the femoral head, neck, and acetabulum are often present.
  - It is recommended that anterior dislocations be reduced by orthopedic surgeons under general anesthetic in the operating room. These are often more complicated and difficult to reduce, and failure at closed reduction in the operating room can be followed by an open procedure.
  - Multiple attempts at reduction should not be performed in the emergency department because these are unlikely to be successful and will only delay definitive management and lead to an increased risk of complications.

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Knee Dislocation Reduction

104

Katrina John, Jeffrey Kile, and Amish Aghera

104.1 Indications

- Dislocation of the knee/fibular head/patella

104.2 Contraindications

- Absolute
  - None
- Relative
  - Immediate availability of orthopedic consultation

104.3 Materials and Medications

- Parenteral sedation and analgesia medications
- Knee immobilizer or splinting materials

104.4 Procedure

104.4.1 Knee (Femur/Tibia) Dislocation Reduction

1. Assess neurovascular function.
2. Pretreat the patient with sedation or analgesia as appropriate.
3. Position the patient supine with the affected leg fully extended.
4. Instruct an assistant to stand near the patient's hip and, facing the patient's affected knee, grasp the distal femur firmly with both hands to fix it in place.
5. Stand near the patient's foot and, facing the patient's affected knee, grasp the distal tibia and apply straight traction in a distal direction.
   - Longitudinal traction-countertraction alone, as described previously, will usually reduce the dislocation. If reduction does not occur, proceed with the following steps.
6. While applying straight traction in a distal direction to the tibia with the dominant hand, with the nondominant hand:
   (a) Anterior dislocation: push the proximal tibia in a posterior direction (Fig. 104.1)
   (b) Posterior dislocation: lift the proximal tibia in an anterior direction (Fig. 104.2)
   (c) Lateral dislocation: push the proximal tibia in a medial direction (Fig. 104.3)
   (d) Medial dislocation: push the proximal tibia in a lateral direction (Fig. 104.4)
   (e) Rotary dislocation: rotate the proximal tibia into proper linear alignment with the femoral condyles (Fig. 104.5)
      - Reduction may be facilitated by the use of two assistants rather than just one. The second assistant grasps the distal tibia and applies straight traction in a distal direction, freeing the operator to manipulate the proximal tibia as described previously using both hands.
7. After reduction, reassess neurovascular function and, if available, obtain angiography.
8. Immobilize the knee in 15° of flexion in a knee immobilizer or long-leg posterior splint.

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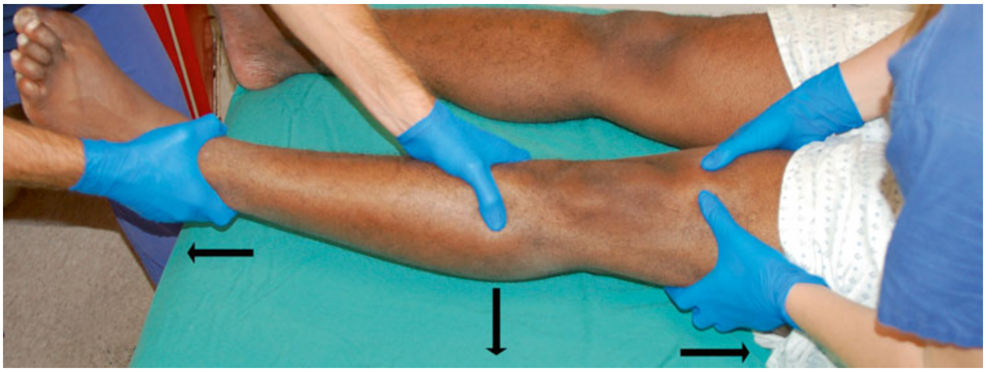

Fig. 104.1 Anterior dislocation of the knee: the proximal tibia is pushed in a posterior direction. The *arrows* indicate the direction in which force should be applied by the operator during reduction of dislocation

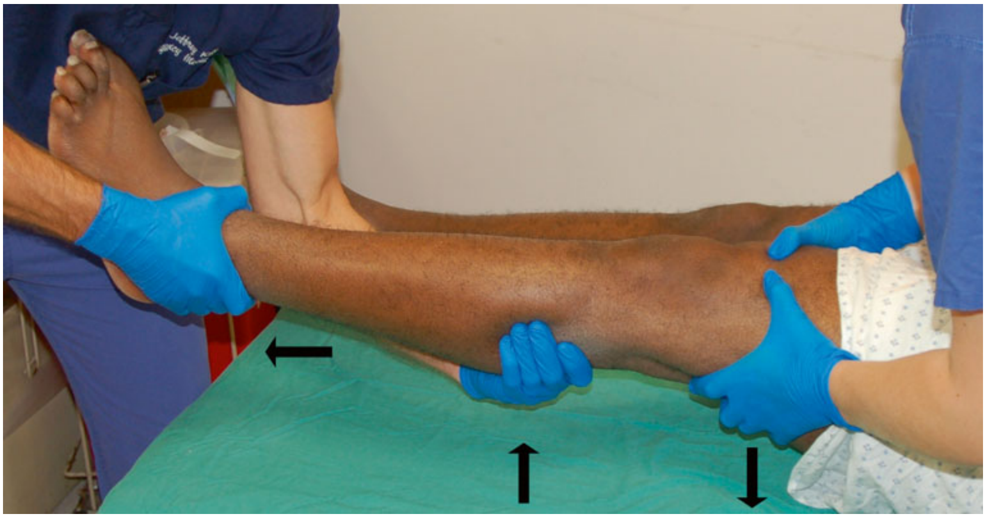

Fig. 104.2 Posterior dislocation of the knee: the proximal tibia is pushed in an anterior direction. The *arrows* indicate the direction in which force should be applied by the operator during reduction of dislocation

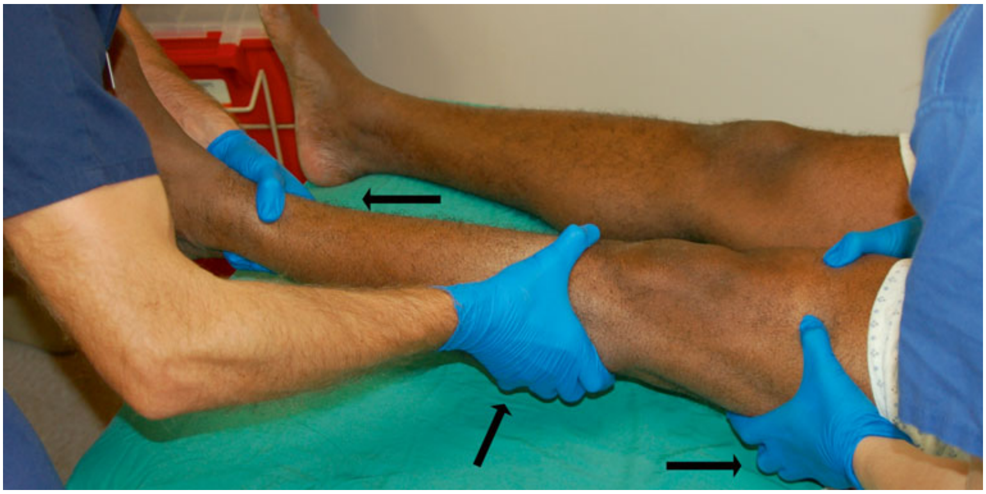

Fig. 104.3 Lateral dislocation of the knee: the proximal tibia is pushed in a medial direction. The *arrows* indicate the direction in which force should be applied by the operator during reduction of dislocation

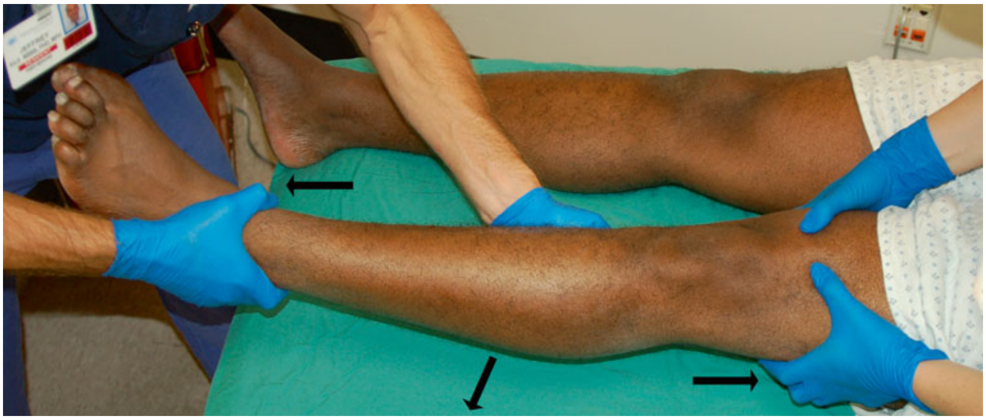

Fig. 104.4 Medial dislocation of the knee: the proximal tibia is pushed in a lateral direction. The *arrows* indicate the direction in which force should be applied by the operator during reduvction of dislocation

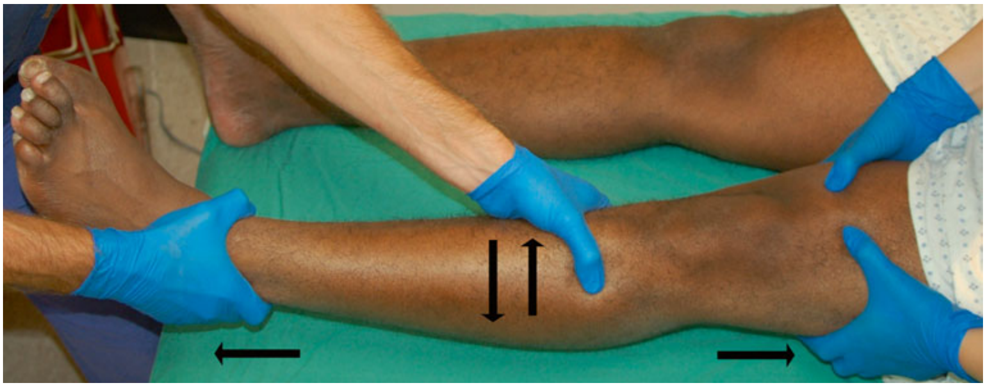

Fig. 104.5 Rotary dislocation of the knee: the proximal tibia is rotated into proper alignment with the femoral condyles. The *arrows* indicate the direction in which force should be applied by the operator during reduction of dislocation

104.4.2 Fibular Head Dislocation Reduction

1. Assess neurovascular function.
2. Pretreat the patient with sedation or analgesia as appropriate.
3. Position the patient supine.
4. Flex the knee to 90° to relax the biceps femoris tendon.
5. Instruct an assistant to stand near the patient's hip and, facing the patient's affected knee, grasp the distal femur firmly with both hands to fix it in place.
6. Stand near the patient's foot and, facing the patient's affected knee, grasp the distal tibia and apply straight traction in a distal direction with the dominant hand and with the nondominant hand.
   (a) Anterior dislocation: push the fibular head in a posterior direction (Fig. 104.6)
   (b) Posterior dislocation: push the fibular head in an anterior direction (Fig. 104.7)
      - Reduction may be facilitated by the use of two assistants rather than just one. If a second assistant is available, instruct the second assistant to stand near the patient's foot and, facing the patient's affected knee, grasp the distal tibia and apply straight traction in a distal direction. This enables the operator to grasp and move the proximal fibula as described previously using both hands.
      - Reduction is often signified by a palpable and audible click as the fibula snaps back into position.
7. After reduction, reassess neurovascular function and, if available, obtain angiography.
   - After reduction, patients should receive orthopedic referral, avoid weight-bearing for the first 2 weeks, and then gradually increase weight-bearing over the next 6 weeks.
   - Typically, immobilization is not required following reduction of an i.solated fibular head dislocation.

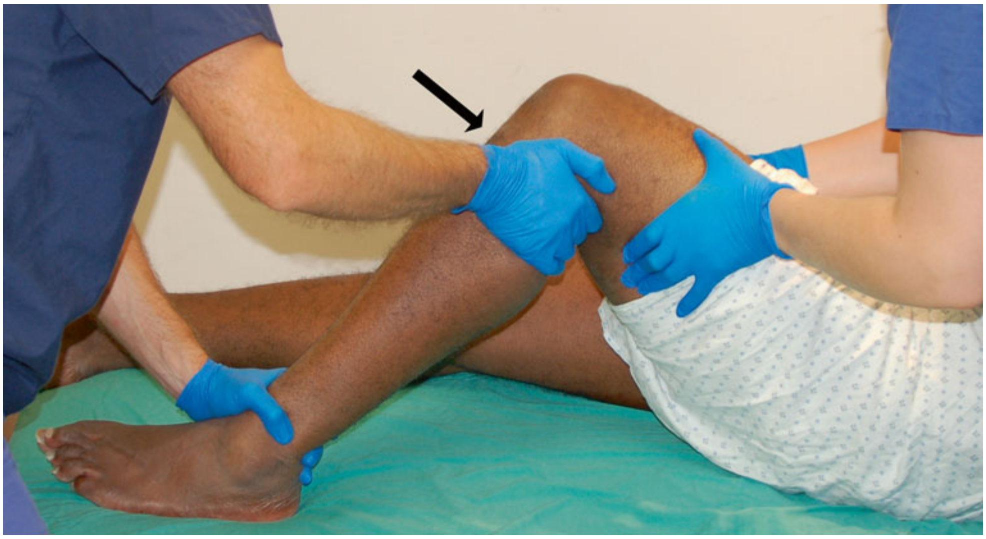

Fig. 104.6 Anterior dislocation of the fibular head: the fibular head is pushed in a posterior direction. The *arrow* indicate the direction in which force should be applied by the operator during reduction of dislocation

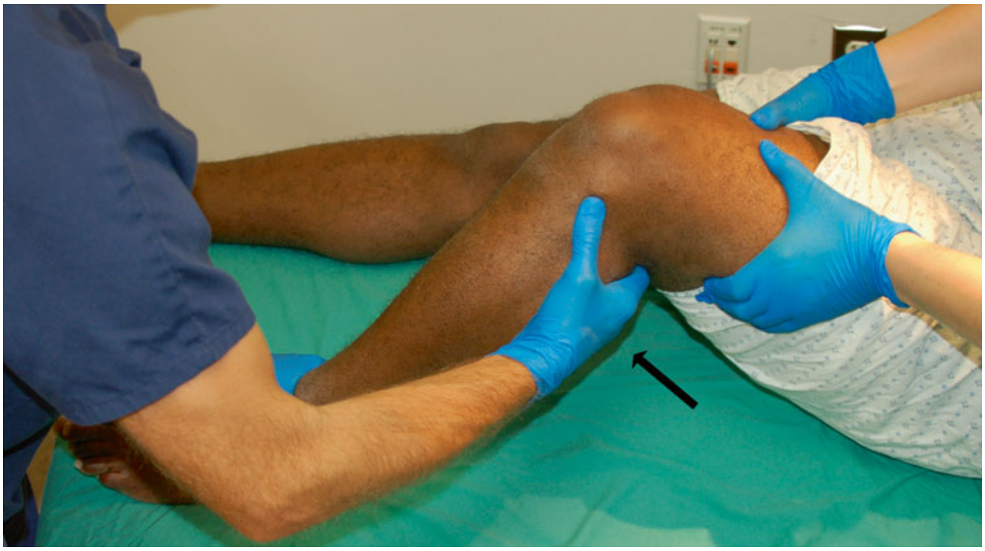

Fig. 104.7 Posterior dislocation of the fibular head: the fibular head is pushed in an anterior direction. The *arrow* indicate the direction in which force should be applied by the operator during reduction of dislocation

104.4.3 Lateral Patellar Dislocation Reduction

1. Pretreat the patient with sedation or analgesia as appropriate.
2. Stand at the side of the affected knee and, facing the knee, grasp the distal tibia and slowly extend the knee with one hand, and with the other hand simultaneously apply gentle pressure to the patella in a medial direction.

- The lateral edge of the patella may be lifted slightly to facilitate its travel over the femoral condyle during reduction (Fig. 104.8).
- After reduction, the knee should be immobilized in full extension in a knee immobilizer or long-leg posterior splint, and the patient should receive orthopedic referral, avoid weight-bearing for the first 2 weeks, and then gradually increase weight-bearing over the next 6 weeks.

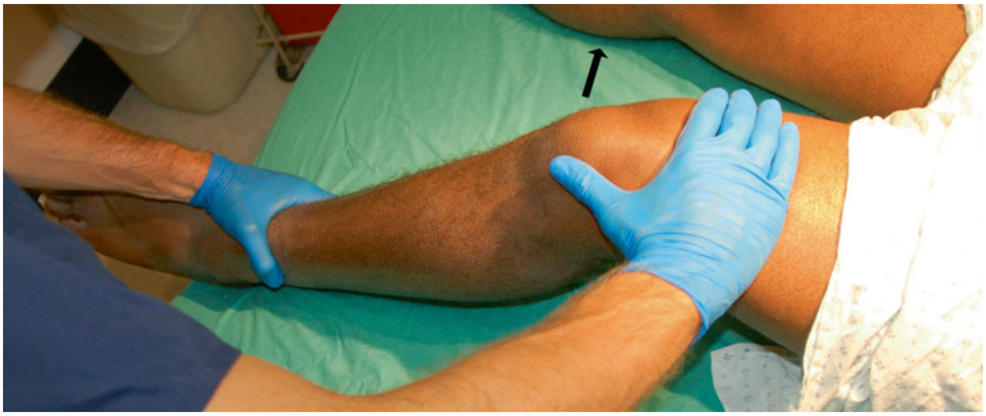

Fig. 104.8 Lateral dislocation of the patella: the patella is pushed in a medial direction. The *arrow* indicate the direction in which force should be applied by the operator during reduction of dislocation

104.5 Complications

104.5.1 Knee (Femur/Tibia) Dislocations

- Distal ischemia (even requiring amputation)
- Degenerative arthritis
- Joint instability due to ligamentous injury

104.5.2 Fibular Head Dislocations

- Peroneal nerve injury
- Fibular head instability/subluxation
- Degenerative arthritis

104.5.3 Patellar Dislocations

- Failure of reduction
- Degenerative arthritis
- Recurrent dislocation/subluxation

104.6 Pearls and Pitfalls

104.6.1 Knee (Femur/Tibia) Dislocations

- Pearls
  - Dislocations of the knee are described in terms of the tibia's position in relation to the femur.
  - All knee dislocations require orthopedic evaluation at the earliest possible opportunity.
  - Owing to the frequency of associated popliteal artery and peroneal nerve injury, a neurovascular examination should be performed before and after any attempts at reduction or manipulation of the knee.
  - Dislocations of the knee should be reduced as soon as possible, particularly if distal neurovascular compromise exists.
  - Operative ligamentous repair is often required approximately 2 weeks postreduction (once acute swelling has resolved) to achieve the maximum functional recovery.
- Pitfalls
  - If the knee hyperextends more than 30° when the horizontal leg is lifted by the foot, the knee is considered severely unstable. This is likely due to a previous dislocation, and thus, the knee should be evaluated for the neurovascular complications of dislocation.
  - Because the joint capsule is commonly disrupted during knee dislocation, synovial fluid may diffuse into the surrounding tissue, such that an effusion is not always present.
  - A posterolateral dislocation may be irreducible because the medial femoral condyle traps the medial capsule within the joint.

104.6.2 Fibular Head Dislocations

- Pearls
  - Fibular head dislocations are usually anterolateral, but these do not result in neurovascular compromise.
  - A knee joint effusion is usually not seen in a fibular head dislocation because the tibiofibular ligaments are contained within a separate synovium.
  - Anterior dislocations typically result from a fall on the flexed, adducted leg, often combined with ankle inversion.
  - Flexion of the knee relaxes the fibular collateral ligament, reducing the stability of the tibiofibular joint.
  - Superior dislocation is accompanied by interosseus membrane damage and proximal displacement of the lateral malleolus.
- Pitfalls
  - Posterior fibular head dislocations usually result from direct trauma to the flexed knee and may be accompanied by peroneal nerve injury.

104.6.3 Patellar Dislocations

- Pearls
  - Patellar dislocation occurs most frequently among adolescents.
  - Patellar dislocation typically occurs in the setting of external rotation combined with a strong valgus force and quadriceps contraction.
  - Patellar dislocations are described in terms of the patellar relationship to the normal knee joint.
  - The most common patellar dislocations are lateral.
  - If a spontaneous reduction has occurred, a knee effusion and tenderness along the medial aspect of the patella are likely to be present on examination, and the patellar apprehension test will be positive.
  - To perform the patellar apprehension test, flex the knee to 30° and push the patella laterally. If the patient senses an impending redislocation, the test is considered positive.

  - Isolated lateral patellar dislocations do not usually require hospitalization, but orthopedic follow-up is recommended owing to the likelihood of persistent instability.
  - Intracondylar and superior dislocations require surgical reduction.
  - Patients with an isolated patellar dislocation typically present with the knee in 20–30° of flexion and the patella displaced laterally.
- Pitfalls
  - Dislocations tend to be recurrent, particularly in patients with patellofemoral anatomical abnormalities.

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Ankle Dislocation Reduction

105

Katrina John, Jeffrey Kile, and Amish Aghera

105.1 Indications

- Dislocation of the ankle joint. This is defined by the articulation of the talus with the mortise that is formed by the distal tibia and fibula. Dislocations can be posterior, anterior, superior, or lateral and are classified by the position of the talus in relation to the tibial mortise.

105.2 Contraindications

- Relative
  - Open dislocations where there is no evidence of acute neurovascular compromise are better managed definitively in the operating room to avoid further contamination.

105.3 Materials and Medications

- Parenteral sedation and analgesia medications
- Local anesthetic for local and intra-articular anesthesia
- Splinting material
- Stockinette
- Padding
- Elastic bandage
- Tape
- Sheet

105.4 Procedure

1. Check the neurovascular status of the affected foot and ankle.
2. If there is no evidence of critical neurovascular compromise, obtain a lateral and an anteroposterior radiograph of the affected ankle.
3. Ensure adequate parenteral sedation and analgesia to maximize success and limit pain and suffering.
4. Position the patient on a stretcher with the knee flexed at 90° over a folded pillow or rolled-up sheet or with the lower leg and knee hanging over the edge of the stretcher.

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105.4.1 Posterior Dislocations

1. Hold the heel in one hand and pull with longitudinal traction.
2. With the other hand, hold the top of the foot and gently plantarflex it downward, while an assistant provides countertraction at the back of the midcalf (Fig. 105.1).
3. Continue longitudinal traction at the heel and countertraction at the calf.
4. Dorsiflex the foot while another assistant applies downward pressure to the distal anterior leg (Fig. 105.2).
5. Examine foot for restoration of normal anatomy and for any new lacerations or defects to the skin.
6. Recheck neurovascular integrity.
7. Place the leg in a sugar-tong splint with the foot at 90°.
8. Recheck neurovascular integrity.

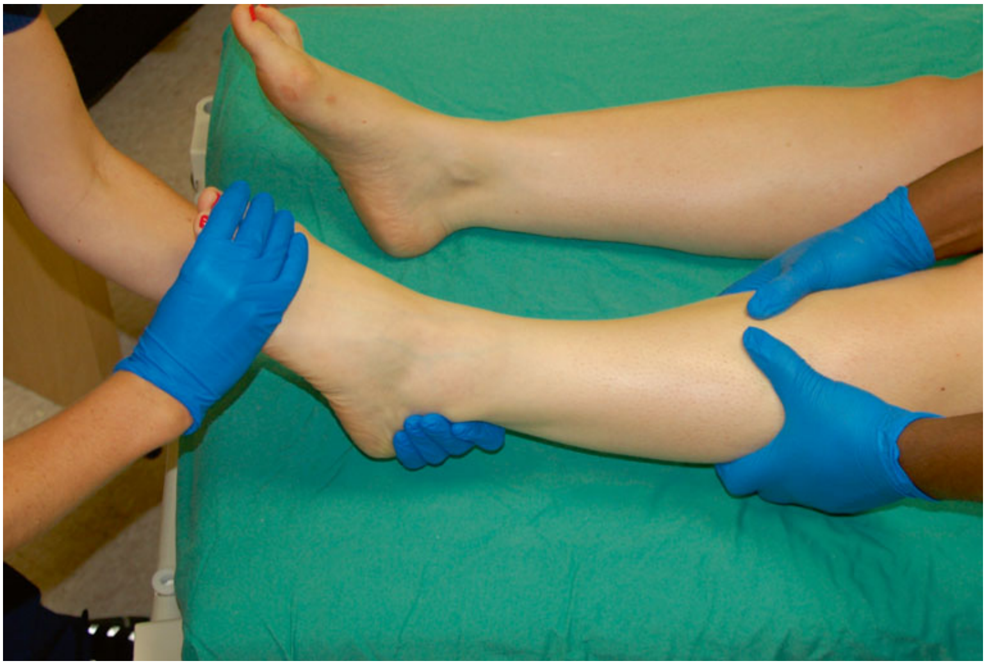

Fig. 105.1 Plantarflexion with longitudinal heel traction

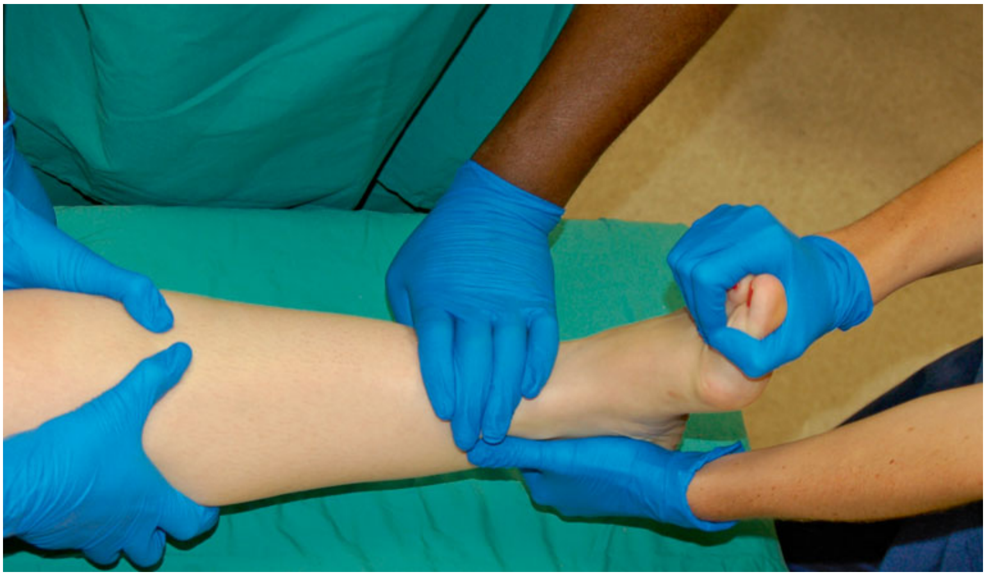

Fig. 105.2 Dorsiflexion with longitudinal heel traction

105.4.2 Anterior Dislocations

1. Hold the heel in one hand and pull with longitudinal traction.
2. With the other hand, hold the top of the foot and dorsiflex, while an assistant provides countertraction at the back of the midcalf (Fig. 105.3).
3. Continue longitudinal traction at the heel and countertraction at the calf.
4. Keeping the foot at 90° to the leg, hold the foot firmly and push the foot downward toward the floor while another assistant applies upward pressure to the distal posterior leg (Fig. 105.4).
5. Examine the foot for restoration of normal anatomy and for any new lacerations or defects to the skin.
6. Recheck neurovascular integrity.
7. Place the leg in a sugar-tong splint with the foot at 90°.
8. Recheck neurovascular integrity.

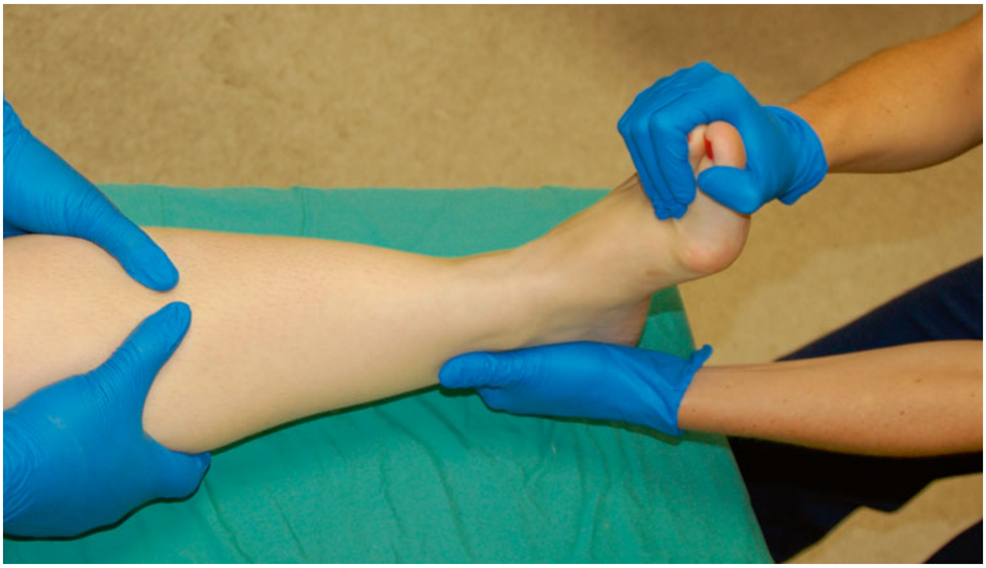

Fig. 105.3 Dorsiflexion with longitudinal heel traction

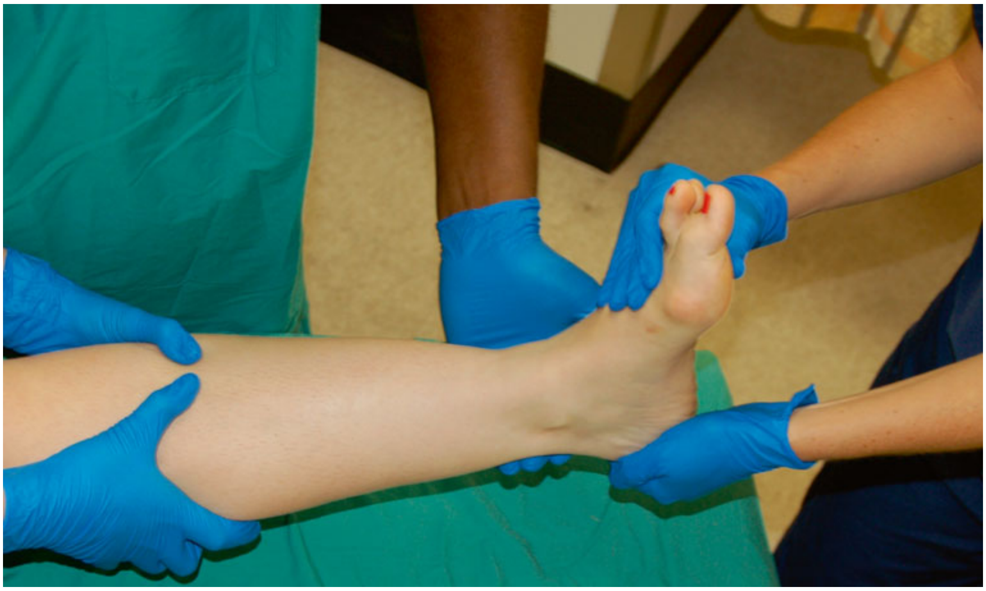

Fig. 105.4 Downward movement of foot (toward the floor) with longitudinal heel traction

105.5 Complications

- Compound fractures
- Neurovascular injury
- Skin and soft tissue damage
- Compartment syndrome

105.6 Pearls and Pitfalls

- Pearls
  - The ankle rarely dislocates without associated fractures.
- Pitfalls
  - Ankle dislocation is an orthopedic emergency, and reduction should not be delayed by imaging if there is evidence of neurovascular impairment. Complications that are exacerbated by delay in management include concomitant fractures, gross deformity of the ankle, severe stretching and tenting of the skin with resultant skin blisters, skin necrosis, and possible conversion to a compound fracture.
  - Be sure to check the radiograph carefully for commonly associated fractures notably of the malleoli.

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106

Arthrocentesis

Shalu S. Patel and Bobby K. Desai

106.1 Indications

- Diagnosis of septic joint
- Diagnosis of traumatic effusion
- Diagnosis of inflammatory effusion
- Diagnosis of crystal-induced arthritis
- Therapeutic relief of pain from effusion

106.2 Contraindications

- Severe coagulopathy
- Skin infection over the needle insertion site
- Joint prosthesis
- Patients with bacteremia or sepsis (except to diagnose a septic joint)

106.3 Materials and Medications

- Betadine (povidone-iodine) or other skin antiseptic
- Sterile gloves
- Sterile towels
- Lidocaine 1 % or 2 % (5 mL) or other anesthetic of choice
- 18- to 22-gauge needle, 25-gauge needle
- Syringes (5 mL, 5–50 mL)
- Sterile gauze (4×4)
- Band-aid

106.4 Procedure

1. Informed consent may be required.
2. Position the patient appropriately. The joint should be placed in slight flexion.
3. Palpate the joint and identify anatomical landmarks.
    (a) For knee arthrocentesis, the needle should be inserted at the midpoint of either the medial or the lateral side of the patella (Fig. 106.1).
    (b) For acromioclavicular (AC) joint arthrocentesis, the needle should be inserted at the superior surface of the AC joint (Fig. 106.2).
    (c) For glenohumeral joint arthrocentesis, there are two approaches.
        (i) In the anterior approach, the needle is inserted into the groove lateral to the coracoid process (Fig. 106.3).
        (ii) In the posterior approach (preferred), the needle is inserted below the posterior border of the acromion process and lateral to the border of the scapula (Fig. 106.4).
4. Prepare the skin and drape in a sterile fashion.
5. Using lidocaine (drawn up in 5-mL syringe), anesthetize the skin with the 25-gauge needle.
6. Secure the 18- to 22-gauge needle on the 5- to 50-mL syringe (depending on the size of the joint) and insert it into the skin.
7. Advance the needle slowly into the joint space while aspirating until joint fluid can easily be withdrawn. While inserting the needle into the joint space, avoid scraping the needle against the bone.

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8. If fluid cannot be aspirated easily, the catheter can be repositioned further in the joint space or turned by 45° sequentially as needed.
9. Once the joint fluid is aspirated, pull out the needle and hold pressure with gauze. Bleeding should be minimal.
10. Place a band-aid or other dressing over the site.
11. Send the synovial fluid to the laboratory. Generally, laboratory analyses may include crystals, protein, glucose, cell count and differential, culture and sensitivity, and Gram stain.

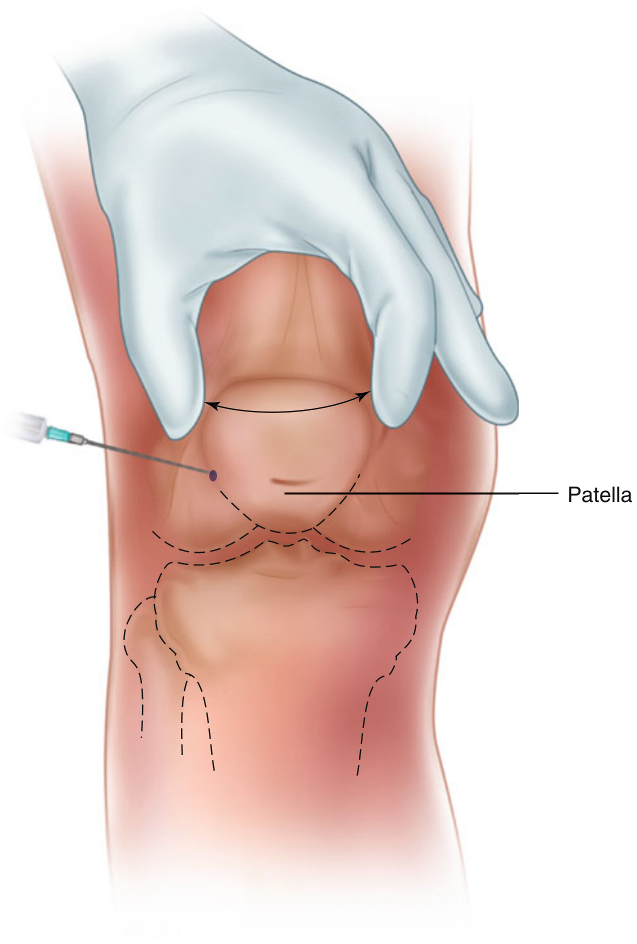

Fig. 106.1 Knee arthrocentesis

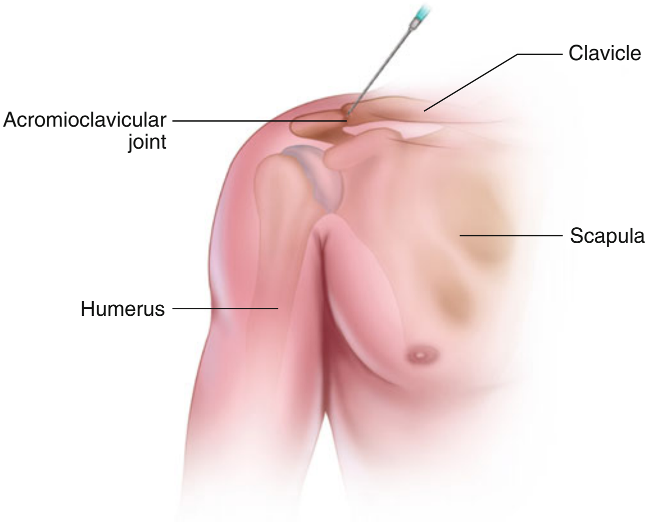

Fig. 106.2 Acromioclavicular joint arthrocentesis

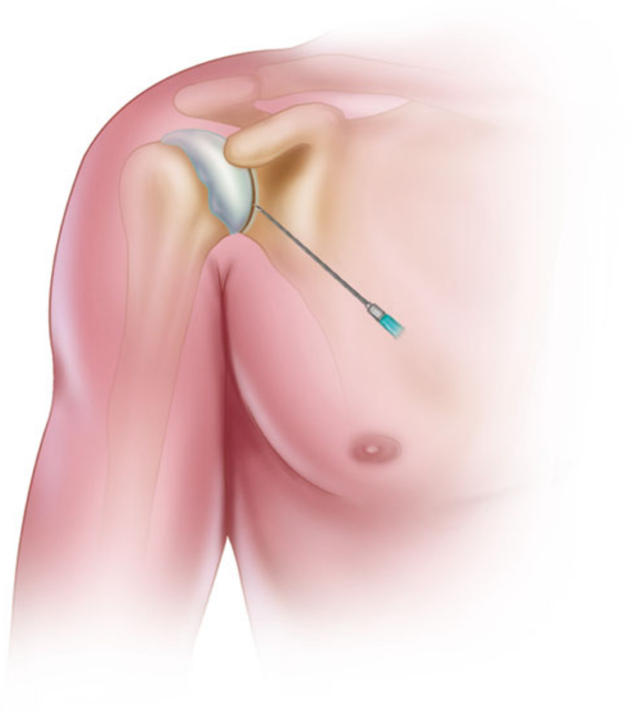

Fig. 106.3 Glenohumeral joint arthrocentesis: anterior approach

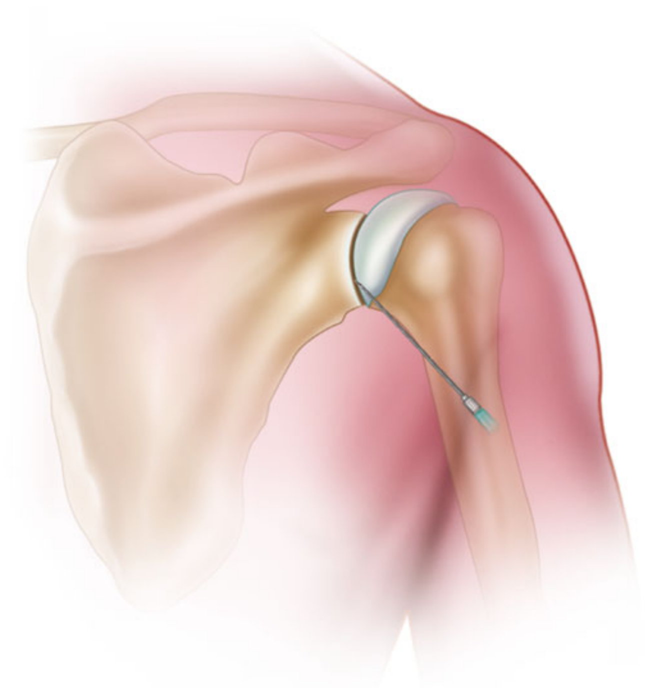

Fig. 106.4 Glenohumeral joint arthrocentesis: posterior approach

106.5 Complications

- Introduction of infection
- Bleeding

106.6 Pearls and Pitfalls

- The preferred site of entry is over the extensor surface of the joint. This will reduce the risk of damage to tendons, ligaments, and blood vessels.
- When assessing synovial fluid, the Rule of Twos may be used to differentiate among normal, inflammatory, and septic fluid. Normal synovial fluid has less than 200 white blood cells (WBCs)/mm^3. Noninflammatory synovial fluid has 200–2000 WBCs/mm^3. Inflammatory synovial fluid has greater than 2000 WBCs/mm^3 (but <50,000 WBCs/mm^3). Septic synovial fluid has greater than 75,000 WBCs/mm^3.
- Only septic synovial fluid will have a positive Gram stain and culture.

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Intra-articular Injection

107

Bharat Kothakota and Muhammad Waseem

107.1 Indications

- Aspiration of fluid (arthrocentesis)
  - For diagnosis: to rule out infection
  - To relieve pressure from large, painful joint effusion
- Injection of joints with inflammatory arthritis
  - Tendinitis
  - Bursitis
  - Rheumatoid arthritis (RA)
- Injection of joints with osteoarthritis (OA)
  - Injection of large weight-bearing joints
  - Injection of small joints of hands
- Intra-articular anesthetic
  - Shoulder reduction
  - Ankle impingement syndrome

107.2 Contraindications

- Cellulitis
- Bacteremia
- Fracture

107.3 Materials and Medications

- Glucocorticoid
  - Duration of effect inversely proportional to solubility
    - Less soluble → longer acting
  - Choice of steroid is the personal preference of the physician
  - Methylprednisone (Depo-Medrol) and triamcinolone acetonide (Kenalog)
    - Less likely to induce postinjection flare
  - Kenalog and triamcinolone hexacetonide (Aristospan)
    - Longest-acting agents
- Local anesthetic
  - 1 % Lidocaine
- Needle
  - 18- to 22-gauge used for knee, ankle, hip, elbow, and shoulder
  - 25-gauge or smaller used for smaller joints (interphalangeal)
- Syringe

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107.4 Procedure

1. Selecting an injection approach.
   - Knee
     - Lateral approach: 1 cm inferior to the patella laterally (Fig. 107.1)
     - Medial approach: 1 cm inferior to the patella medially (Fig. 107.2)
   - Ankle
     - Lateral approach: just inferior to the lateral malleolus (Fig. 107.3)
     - Medial approach
       - Plantar flex the foot.
       - Angle the needle cephalad to pass between the medial malleolus and the tibialis anterior tendon (Fig. 107.4).
   - Shoulder
     - Posterior approach
       - Insert the needle 1 cm inferior and 1 cm medial to the posterolateral corner of the acromion.
       - Direct the needle anterior and medial toward the coracoid process (Fig. 107.5).
2. Skin preparation.
   - Make three separate concentric outward spirals with iodine disinfectant
   - Scrub with cyclohexidine preparation
3. Mark the injection site by impressing the skin with a hard object.
   - Sterile end of needle sheath
   - Ball point pen with tip retracted
4. Local anesthesia.
   - 1 % Lidocaine injected into the skin and subcutaneous tissue
   - Short burst of ethyl chloride spray before iodine preparation
   - Mixing lidocaine with glucocorticoid preparation
5. Always aspirate joint fluid before injecting the corticosteroids.
   - Use a 1.5-inch 18-gauge needle for aspiration.
   - Confirm that the needle is in the joint space.
   - Reduced effusion size before injection can improve outcomes.
   - Compress the opposite side of the joint to aid in aspiration (Fig. 107.6).
6. After aspirating, change the syringe.
   - Use a sterile hemostat or hand to stabilize the needle within the joint space (Fig. 107.7).
   - Avoid injecting corticosteroids if the aspirate appears purulent.
7. Injection of medication.
   - Can use the same needle used for aspiration.
   - Insert needle 0.75–1.25 inch in depth for injection.
8. Remove the needle, wipe the iodine solution clean, and apply the bandage.
9. Postinjection care.
   - First 48 h: bedrest versus minimize walking
   - Next 2–3 weeks: crutches or cane

Fig. 107.1 Knee arthrocentesis, lateral approach

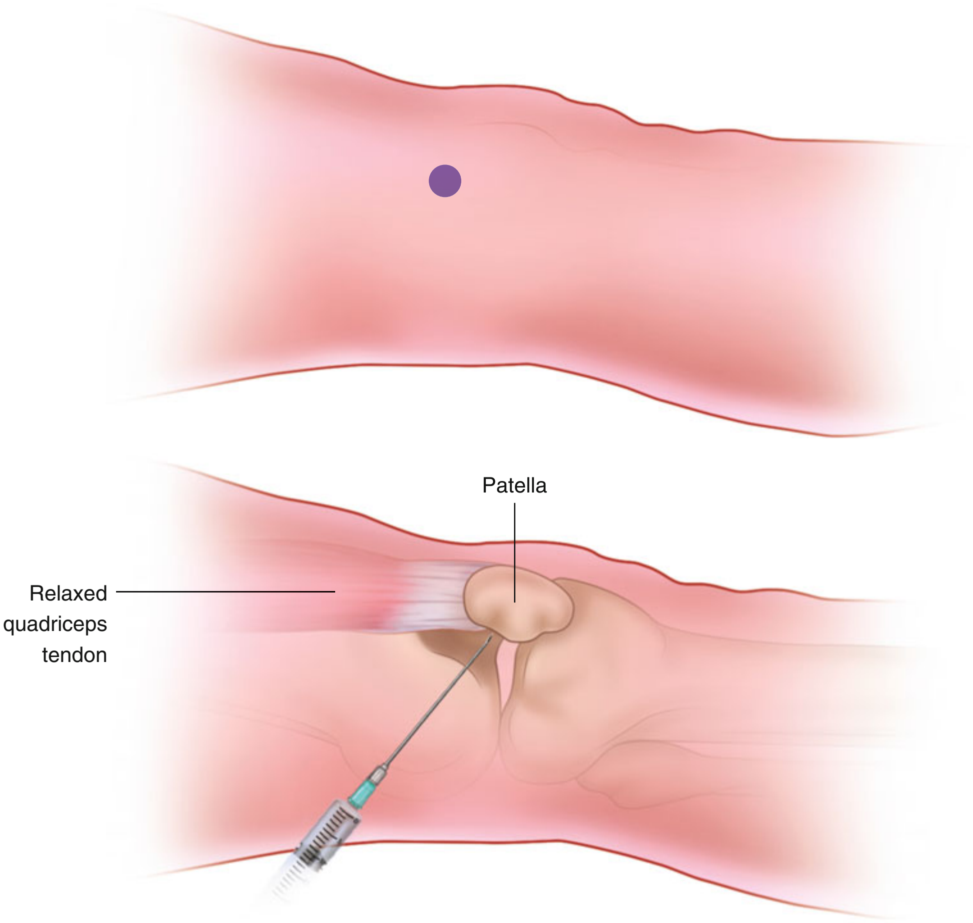
Patella
Relaxed quadriceps tendon

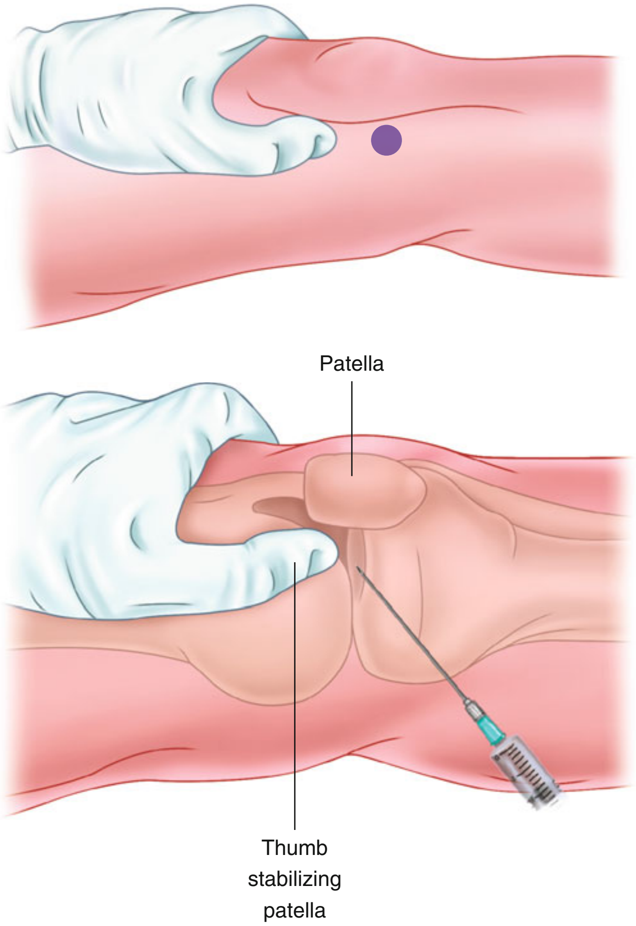
Patella
Thumb stabilizing patella

Fig. 107.2 Knee arthrocentesis, medial approach

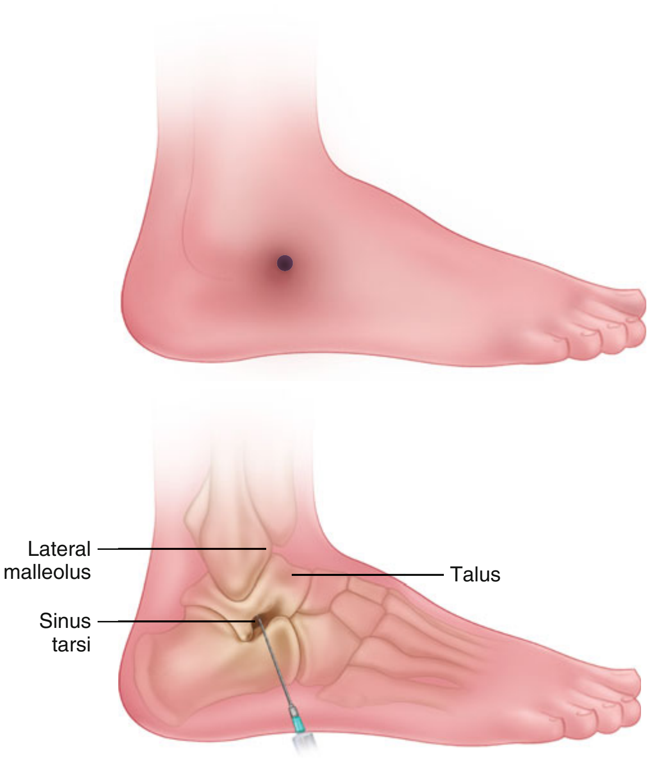
Lateral malleolus
Talus
Sinus tarsi

Fig. 107.3 Ankle arthrocentesis, lateral approach

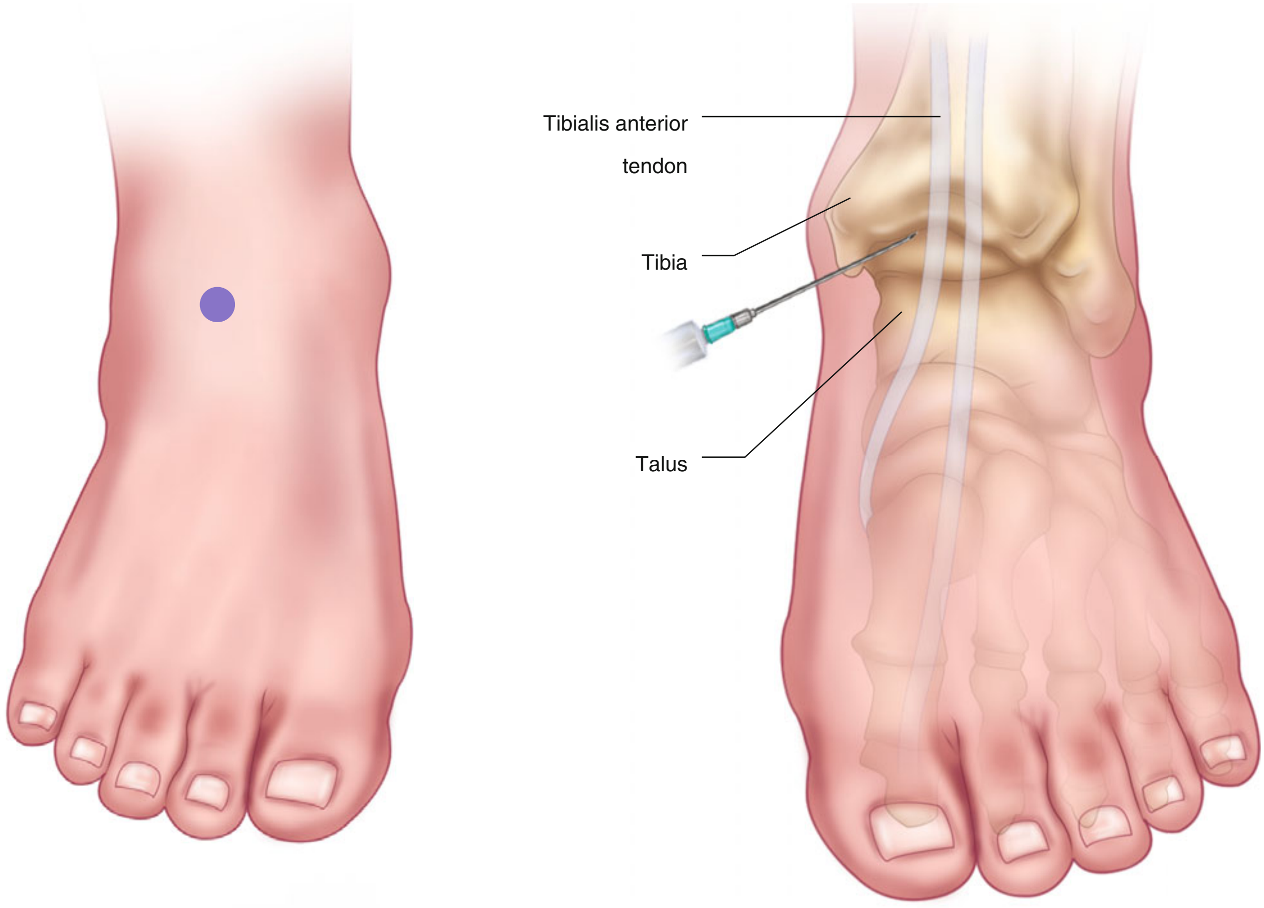
Tibialis anterior tendon
Tibia
Talus

Fig. 107.4 Ankle arthrocentesis, medial approach

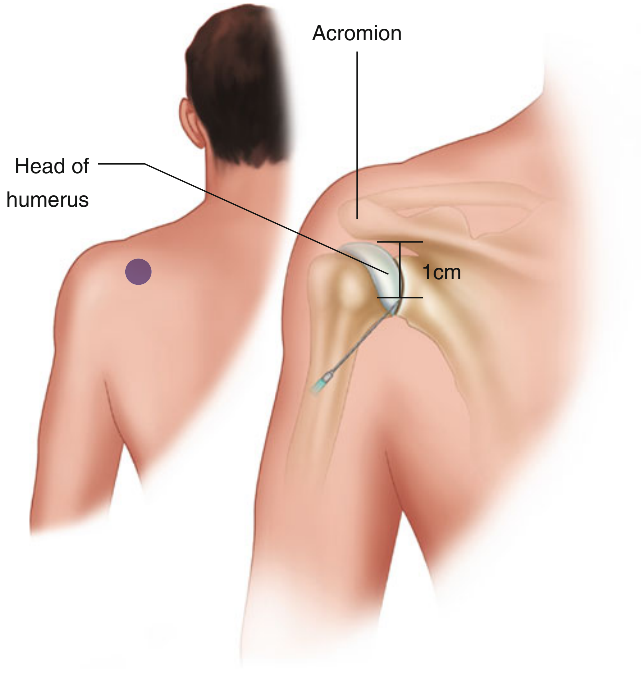
Acromion
Head of humerus
1cm

Fig. 107.5 Shoulder arthrocentesis, posterior approach

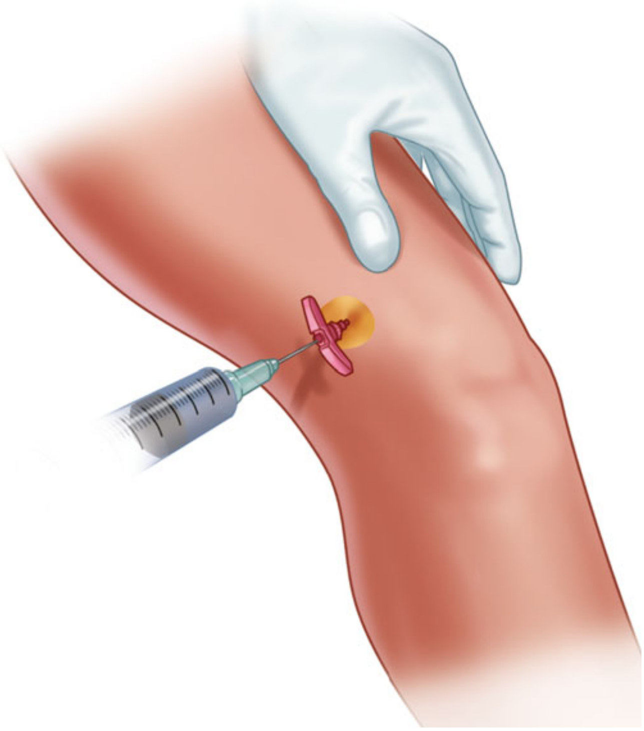

Fig. 107.6 Compress opposite side of joint to aid in aspiration

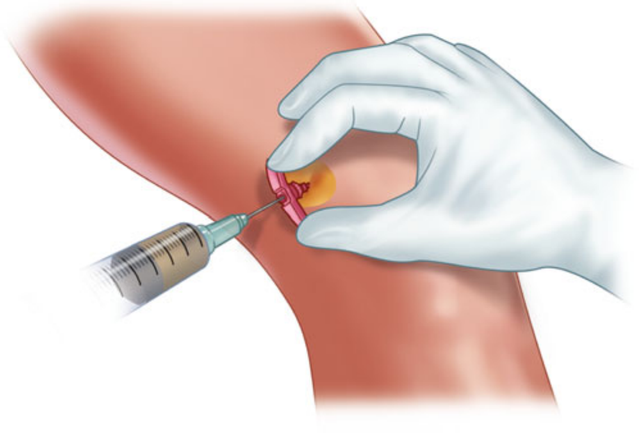

Fig. 107.7 Use hemostat or hand to stabilize needle within joint space

107.5 Complications

- Local postinjection flare
  - Irritation of the synovium by steroid microcrystals
  - Can be confused for infection
  - Occurs and resolves within 48 h after injection
  - Treat with ice and appropriate analgesics.
- Iatrogenic joint infection
  - Suspect if it begins later than, or lasts longer than, flare
  - Increasing pattern of pain
  - Fever, malaise, redness, or drainage around injection site
  - *Staphylococcus aureus* most common
- Subcutaneous atrophy and depigmentation
  - Leakage of corticosteroids into soft tissues
- Aspiration of blood
  - Indicative of trauma or bleeding disorder (hemophilia)
- Systemic absorption
  - Water-soluble preparations
  - Dose dependent
  - Injection into multiple joints
  - Transient hyperglycemia in diabetic patients
  - Avascular necrosis of the femoral head

107.6 Pearls

- Mixing lidocaine with glucocorticoids
  - Reduces pain caused by injection of steroids into joint space
  - Less likely to cause soft tissue atrophy and tendon rupture
  - Immediate relief from anesthetic indicates proper injection
- Limiting intra-articular glucocorticoid injections per joint
  - OA
    - Four injections per lifetime of the joint
    - Injections reduce the rate of accelerated degeneration in joints
  - RA
    - Limit of one injection per month
    - No evidence of glucocorticoid-induced cartilage loss

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Sugar-Tong Splint

108

Katrina John, Jeffrey Kile, and Amish Aghera

108.1 Indications

- Fractures to the wrist or forearm
- To prevent motion at the wrist and elbow
- To prevent supination and pronation

108.2 Contraindications

- Relative
  - Evidence of compartment syndrome or any neurovascular compromise

108.3 Materials (Fig. 108.1)

- Stockinette
- Padding
- Splint material: fiberglass/plaster of Paris or prefabricated splint rolls, 2, 3, 4 inches depending on age and body habitus
- Trauma shears/scissors
- Elastic bandage
- Tape
- Container with water
- Gloves, eyemask, sheet
- Sling

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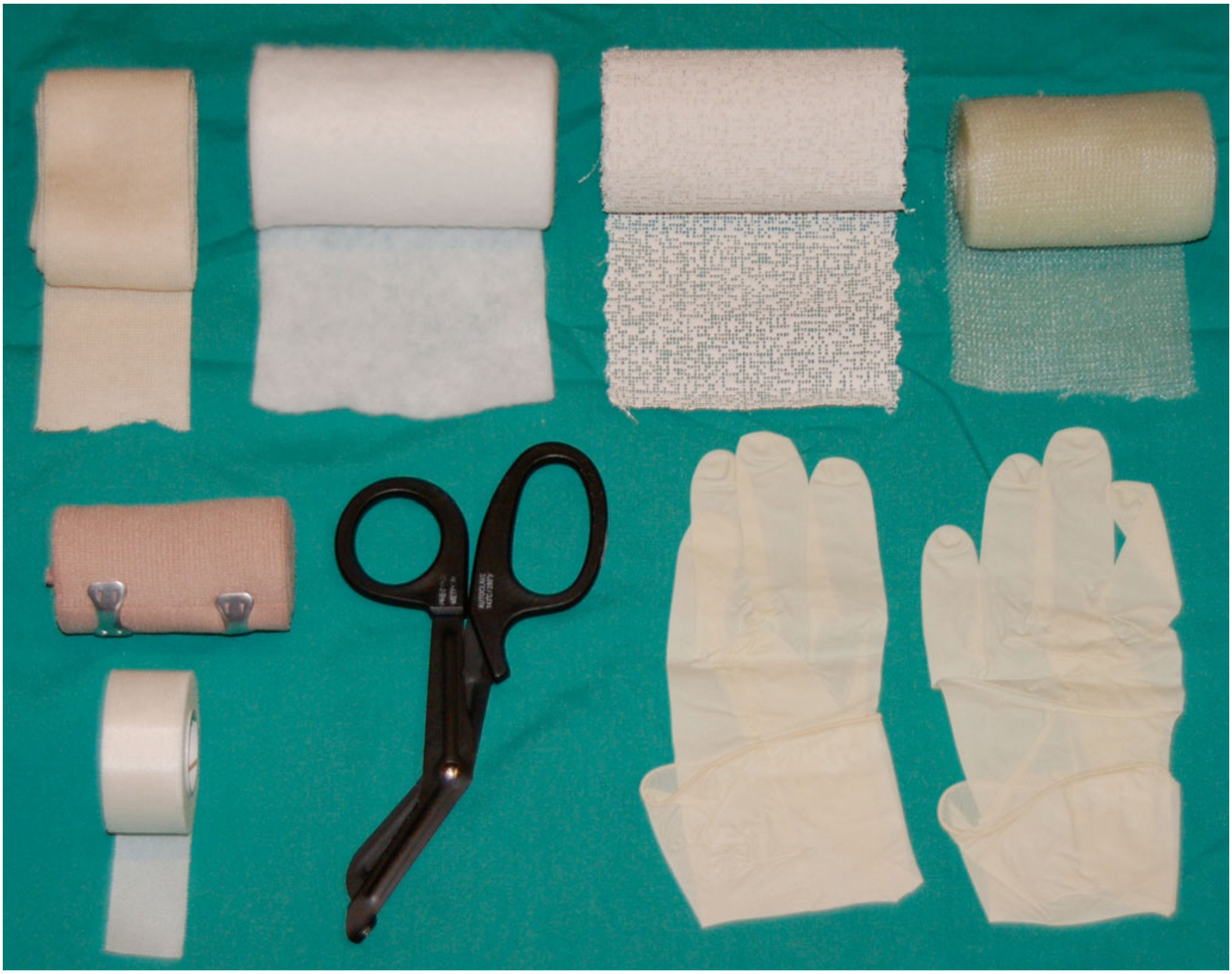

Fig. 108.1 Equipment

108.4 Procedure

1. Ensure the skin of the affected extremity is clean, dry, and intact.
2. Cover the patient with a sheet or gown to protect the patient's clothing and the surrounding area.
3. Position the patient's arm abducted at 90° at the shoulder and internally rotated with the elbow flexed at 90° (Fig. 108.2).
4. Measure the splinting material by running a single layer from the metacarpal heads of the dorsum of the hand along the extensor surface of the forearm over the elbow and humeral condyles and back down the flexor surface of the forearm to the palmar aspect of the hand to the metacarpal heads.
5. If using non-prefabricated splint rolls, lay the measured piece of splinting material out on a flat surface and multiply the layers to the same length, 6–8 layers for fiberglass and 10–12 layers for plaster.
6. Measure the stockinette from the finger tips to the midhumerus and cut a hole for the thumb.
7. Place the stockinette on the arm (Fig. 108.3).
8. Use a 3- to 4-inch padding roll to apply several layers of circumferential padding extending from the metacarpal heads to the midhumerus below the level of the stockinette (Fig. 108.4).
9. Wet the already prepared and measured splinting material and remove the excess water.
10. Ensure the forearm is in the aforementioned position, and apply the splinting material from the metacarpal heads of the dorsum of the hand along the extensor surface of the forearm over the elbow and humeral condyles and back down the flexor surface of the forearm to the palmar aspect of the hand to the metacarpal heads (Fig. 108.5).
11. Fold each end of the stockinette down over the padding and splinting material.
12. An extra layer of padding can be added at this stage.
13. Secure the entire splint with two elastic bandages/ace wrap and apply tape to ensure the bandages stay in place (Fig. 108.6).
14. Place the arm in a sling.

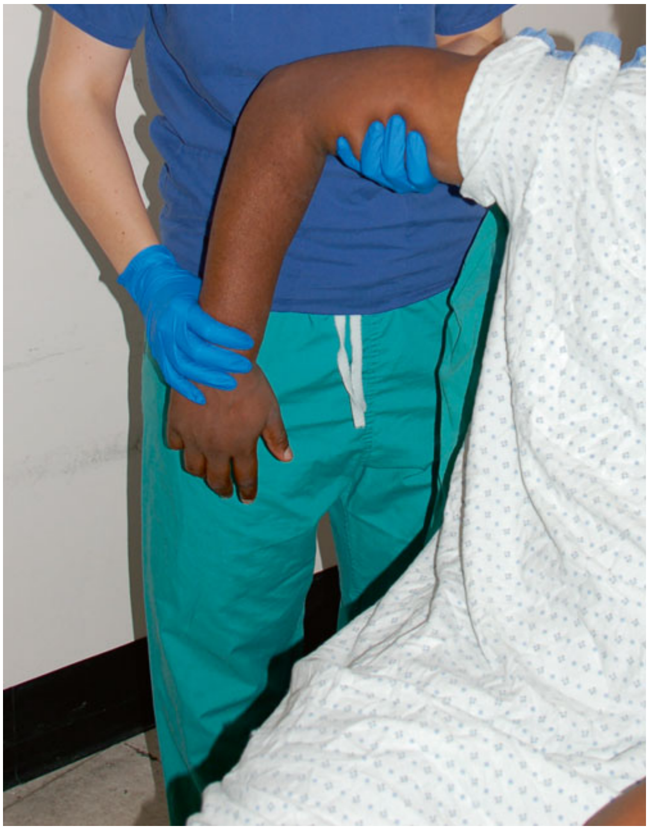

Fig. 108.2 Arm positioning

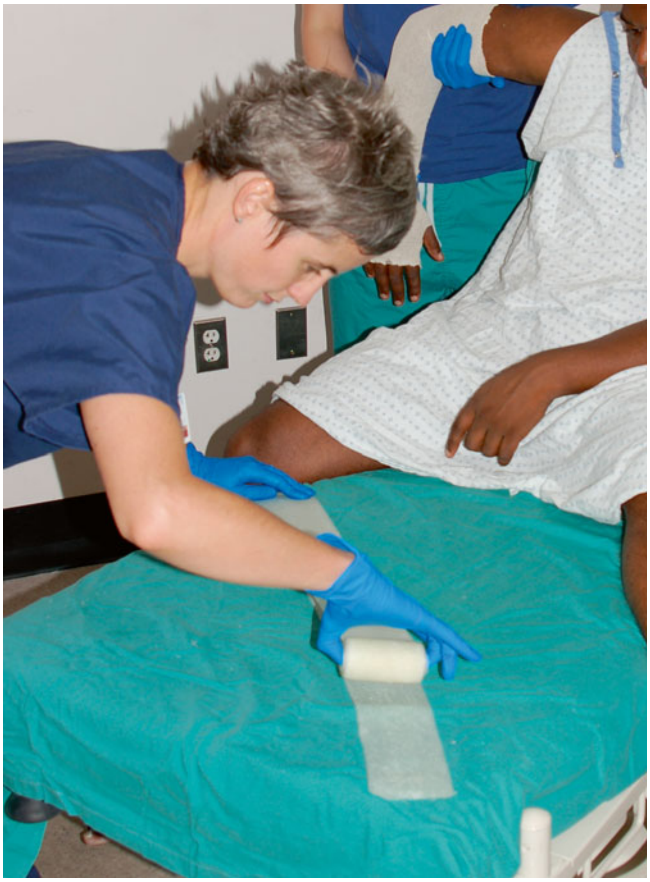

Fig. 108.3 Fiberglass being measured and stockinette on patient

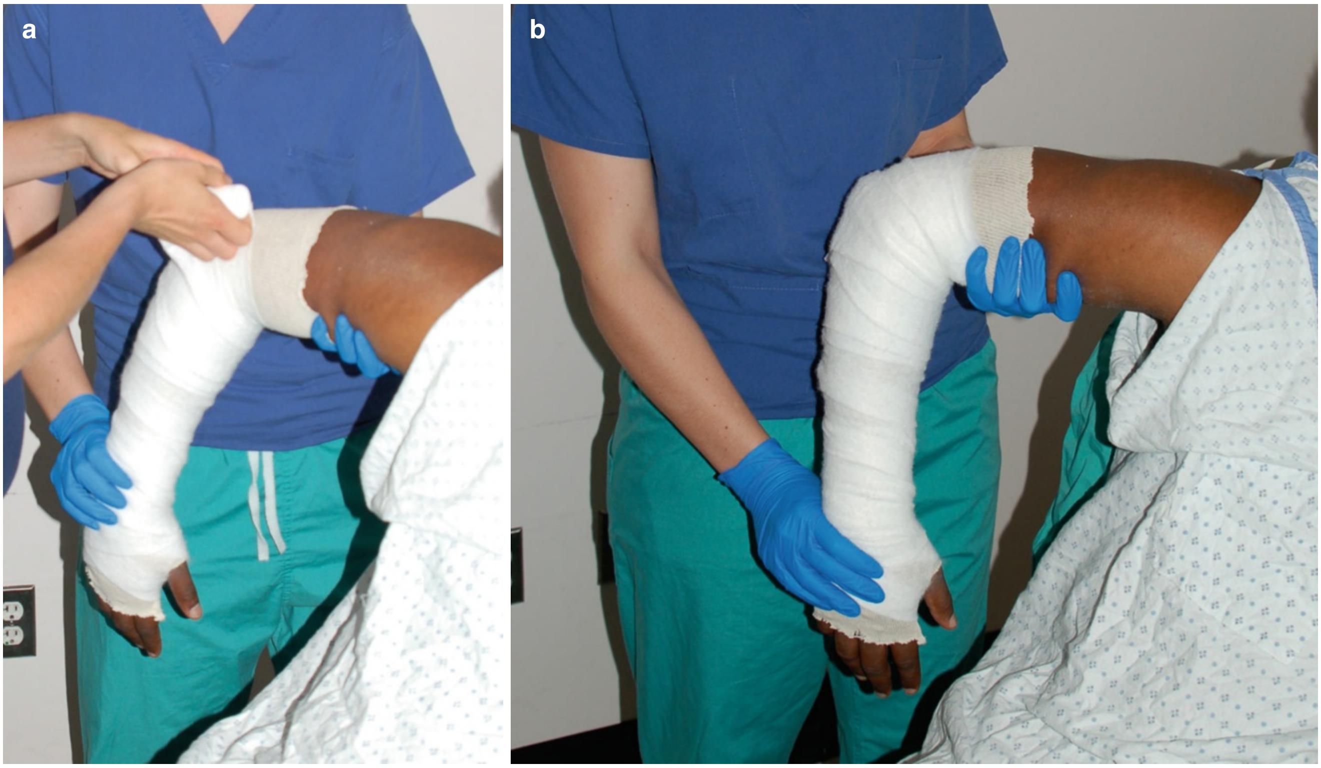

Fig. 108.4 (**a**) Application of padding over the stockinette (partial), (**b**) Application of padding over the stockinette (complete)

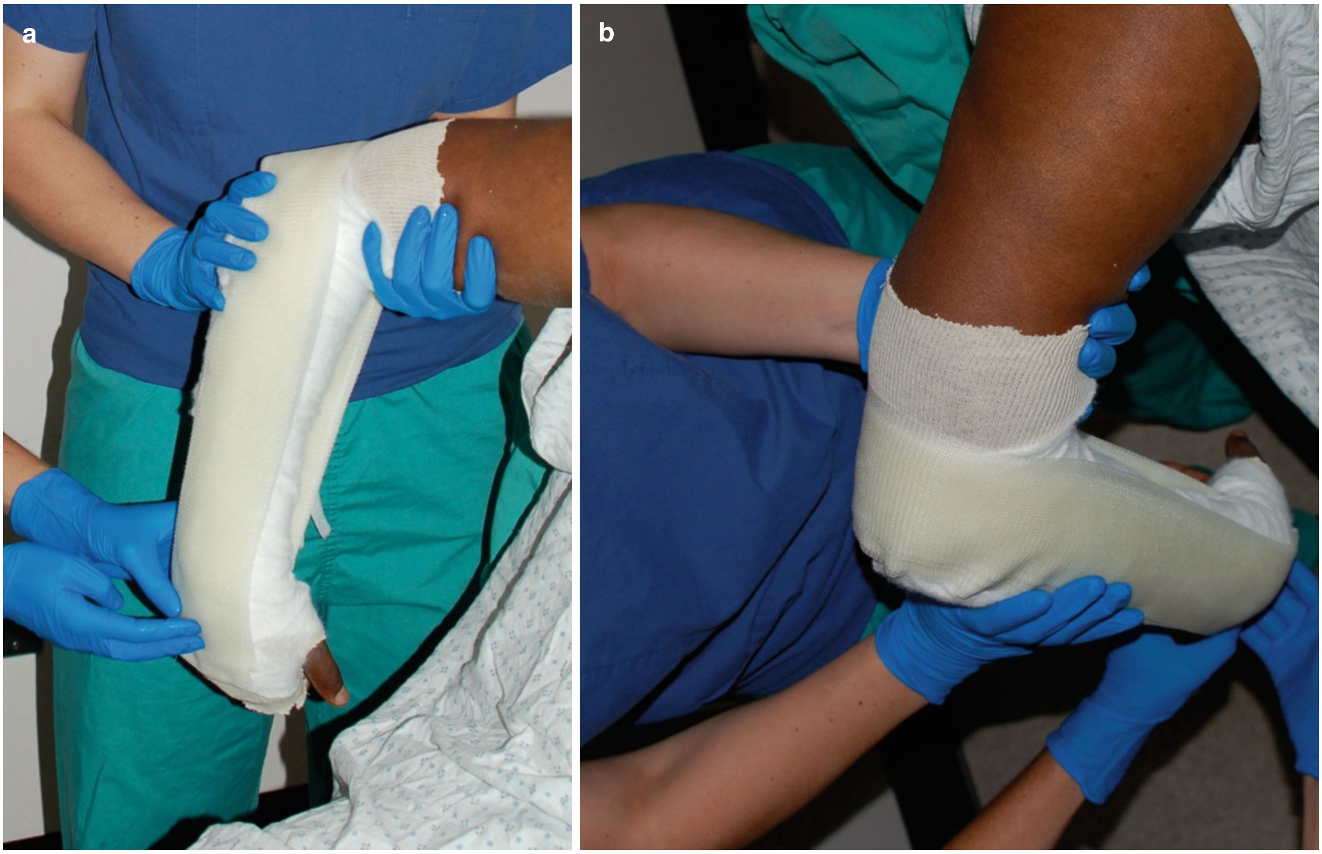

Fig. 108.5 (**a**) Application of splinting material over padding (anteromedial view), (**b**) Application of splinting material over padding (anterolateral view)

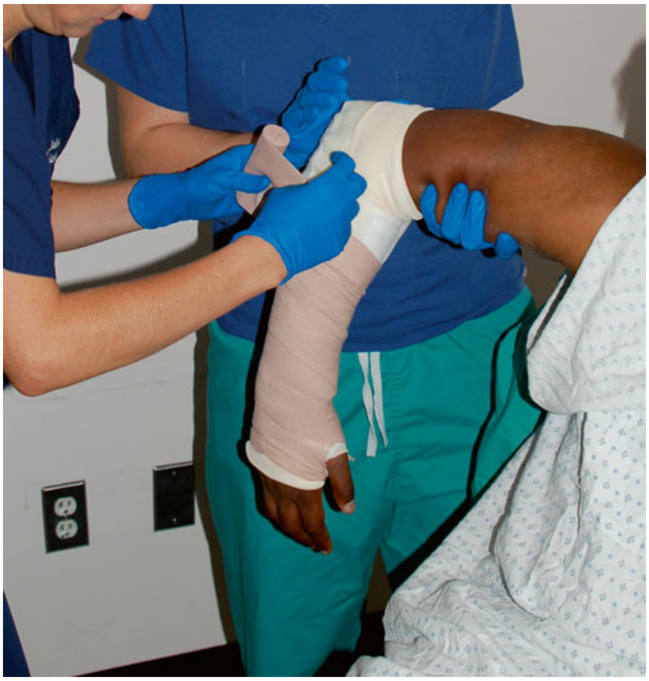

Fig. 108.6 Application of elastic bandage over splinting material

108.5 Complications

- Compartment syndrome

108.6 Pearls and Pitfalls

- Pearls
  - This procedure is best done with an assistant to hold the extremity in the desired position and to prevent the splint slipping as it is secured.
  - Having the patient in the illustrated position enables the practitioner to use gravity to hold the splint in the correct position while securing it; especially helpful if an assistant is not available.
- Pitfalls
  - If the splint is too short, it fails to immobilize the wrist.
  - If the splint is too long, it will cause reduced motion and stiffness at the metacarpophalangeal joints and swelling of the fingers due to immobility.

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Part XIV

Obstetric Procedures

Fetal Heart Rate Monitoring

109

Nathaniel Lisenbee and Joseph A. Tyndall

109.1 Indications

- Fetal heart rate (FHR) monitoring is important because it provides basic patterns that can be correlated to the acid–base status, circulatory volume, and oxygenation status of the fetus through brainstem detection and subsequent cardiac response. It has numerous indications during the antepartum and intrapartum stages [1].
- Antepartum indications include:
  - Nonstress test (consists of monitoring FHR in conjunction with fetal movements)
  - Contraction stress test (consists of monitoring FHR during contractions, which are induced pharmacologically)
  - Biophysical profile (BPP; consists of a nonstress test with an additional ultrasound)
- Intrapartum indications include monitoring FHR during:
  - Uterine contractions
  - Pain medications/anesthetic administration to the mother during labor
  - Procedures performed during labor
  - Second stage of labor
  - High-risk pregnancies, which can be defined by a number of conditions including [2, 3]:
    - Maternal diabetes, asthma, preeclampsia/eclampsia
    - Multiple gestations
    - Intrauterine growth restriction
    - Premature rupture of membranes
    - Lack of prenatal care

109.2 Contraindications

- Contraindications for internal FHR monitoring
  - Presence of placenta previa
  - Lack of ability to identify the portion of the fetal body where device application is being considered
  - Active herpes, active hepatitis, or human immunodeficiency virus (HIV) in the mother
- Contraindications for external FHR monitoring
  - None

109.3 Methods

- Two methods for FHR monitoring:
  - Auscultation monitoring
    - Defined as auscultating FHR every 15 min in the first stage of labor and auscultating every 5 min in the second stage
    - Does not provide strips with information on FHR variability or the shape of FHR accelerations and decelerations
- Electronic FHR monitoring
  - Allows for real-time continuous monitoring of FHR activity
  - Provides strips with information on FHR variability or the shape of FHR accelerations and decelerations
  - Can be performed by Doppler ultrasound or internal fetal electrocardiography (ECG)

When comparing the two methods for electronic FHR monitoring, both are equally as reliable in most settings. Thus, external monitoring is the preferred method because it is noninvasive. However, in instances in which external monitoring becomes difficult owing to poor quality or technical difficulties, invasive monitoring is indicated.

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109.4 Equipment and Procedures

Multiple methods exist for electronic FHR monitoring [4]. The most commonly used are external monitoring by Doppler ultrasound and internal monitoring by fetal ECG.

109.4.1 Doppler Ultrasound is a Noninvasive Method to Monitor FHR (Fig. 109.1)

- Equipment
  - Electronic FHR monitor
  - Contraction monitor sensor with belt
  - FHR sensor with belt (consists of ultrasound transducer and ultrasound sensor)
  - Ultrasound coupling gel
- Procedure
  1. Place the patient in a supine position.
  2. Palpate the fetal anatomy through the maternal abdomen to find the approximate location of the fetal heart.
  3. Place ultrasound coupling gel on the maternal abdomen at the sight of suspected fetal cardiac activity.
  4. Place the transducer probe on gel and locate the fetal heart tones.
  5. Once the fetal heart tones are located, secure the FHR sensor to the maternal abdomen with the attached belt.
  6. Place the contraction monitor sensor near the fundus in order to monitor uterine contractions.
  7. Attach the FHR sensor and contraction monitor to the electronic FHR monitor to obtain printouts of FHR and uterine contractions.

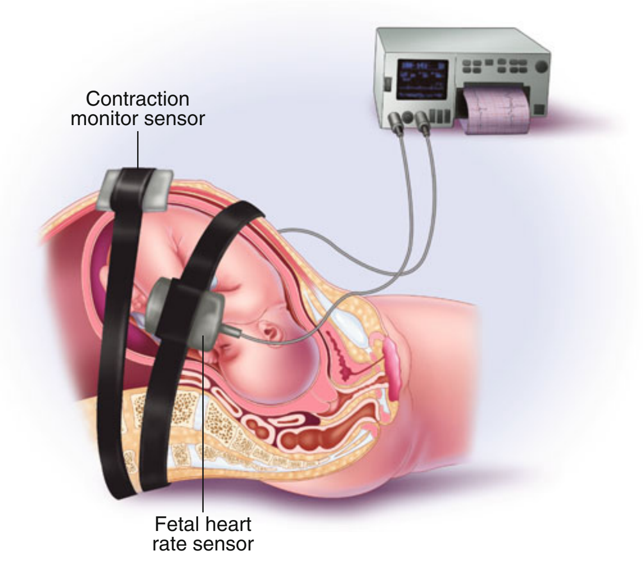

Fig. 109.1 External fetal heart rate monitoring

109.4.2 Internal Fetal ECG is an Invasive Method to Monitor FHR and is Used Only in the Intrapartum Period (Fig. 109.2)

- Equipment
  - Fetal scalp monitoring electrode
  - Leg plate electrode
  - Sterile vaginal lubricant
  - Electronic FHR monitor
- Procedure (Fig. 109.3)
  1. Place the patient in a dorsal lithotomy position.
  2. Sterilize the perineal area.
  3. Perform a bimanual vaginal examination to identify the presenting fetal head. (Note: rupture of membranes must occur before scalp electrode placement.)
  4. Place the spiral electrode guide tube on the fetal scalp and advance the electrode until it contacts the scalp.
  5. Rotate the drive tube clockwise approximately one rotation while maintaining pressure on the guide tube and drive tube.
  6. Release the electrode locking device by pressing together the arms on the drive tube grip.
  7. Carefully slide the drive and guide tubes off the electrode wires while holding the locking device open.
  8. Attach the leg plate to the inner thigh of the mother as a means to eliminate electrical interference.
  9. Attach the spiral electrode wires to the color-coded leg plate, which is then connected to the electronic fetal monitor.
  10. Do not forget to sterilize the area of electrode placement after delivery is completed and the scalp electrode is removed.

When comparing the two methods, both are equally reliable in most settings. Thus, external monitoring is the preferred method because it is noninvasive. However, in instances in which external monitoring becomes difficult owing to poor quality or technical difficulties, invasive monitoring is indicated.

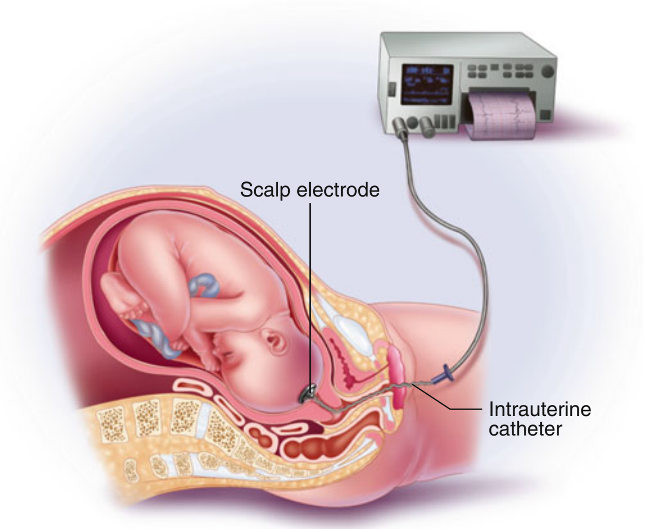

Fig. 109.2 Internal fetal heart rate monitoring

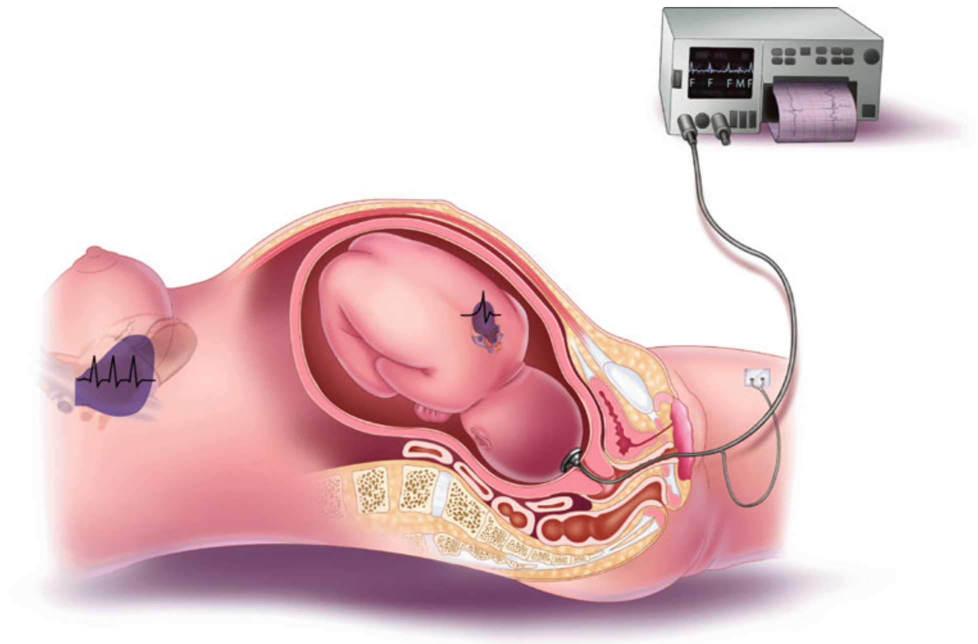

Fig. 109.3 Internal fetal heart rate monitoring

109.5 Complications

- Complications of external FHR monitoring
  - Confusing maternal aortic pulsations with FHR
  - Inability to locate FHR
- Complications of internal FHR monitoring
  - Fetal or maternal hemorrhage, fetal infection (usually scalp abscess at the site of insertion)
  - Uterine perforation
  - Subsequent fetal infection due to the invasive nature of the procedure

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Ultrasonography for Ectopic Pregnancy

110

L. Connor Nickels

An ectopic pregnancy is a pregnancy occurring outside of the uterine cavity (fundus) (Fig. 110.1).

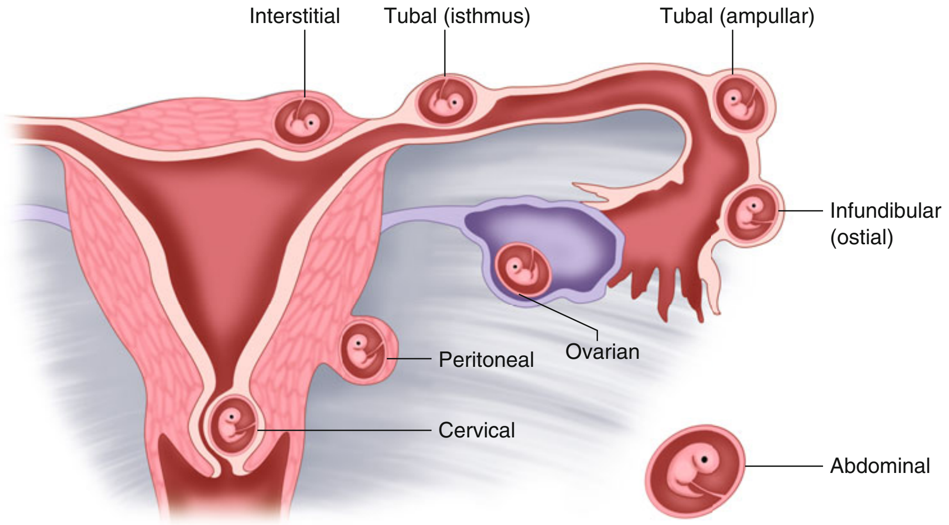
Interstitial
Tubal (isthmus)
Tubal (ampullar)
Infundibular
(ostial)
Peritoneal
Ovarian
Cervical
Abdominal

Fig. 110.1 Ectopic pregnancy diagram: pregnancy occurring outside of the uterine cavity

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110.1 Indications

- Patient in the first trimester of pregnancy with any combination of the following:
  - Vaginal bleeding.
  - Acute pelvic pain.
  - Hypotension or shock.
  - Dizziness or syncope.
  - Positive pregnancy test.
  - Adnexal mass.
  - Cervical tenderness.
  - Abnormal rise in the serum human chorionic gonadotropin (hCG).
  - No specific sign or symptom is absolute; therefore, the index of suspicion must be high.
- Risk factors for ectopic pregnancy
  - Pelvic inflammatory disease (PID)
  - Previous or current intrauterine device
  - Infertility treatment
  - Previous tubal surgery
  - Tubal ligation
  - Advanced maternal age
  - Previous ectopic pregnancy
- Usually a sonographic diagnosis
- Sonographic signs of an ectopic can include any of the following:
  - Gestational sac seen in one of the following:
    - Adnexa with any of the following:
      - Yolk sac (Figs. 110.2 and 110.3)
      - Fetal pole with or without cardiac activity
      - Both of these
    - Low position in the cervix (cervical ectopic)
    - Seemingly in the uterus, but off to one side and with minimal surrounding myometrium (interstitial ectopic)
    - Within the peritoneal cavity, outside of the tubes (abdominal ectopic)
  - Pseudogestational sac seen in the uterus
    - Uterine enlargement or decidual reaction (single outline only) in the endometrium without a gestational sac
  - Other unidentifiable adnexa mass
  - Free fluid in the pelvis or other gravity-dependent area (i.e., Morison's pouch in the right upper quadrant in a supine or reverse Trendelenburg patient) (Fig. 110.4)
    - Small free fluid: tracks less than one third of the posterior cul-de-sac
    - Moderate free fluid: tracks less than two third of the posterior cul-de-sac
    - Large free fluid: tracks greater than two third of the posterior cul-de-sac
    - Right upper quadrant free fluid: 100 % predictability for ectopic
  - Empty uterus with serum hCG >1000 mIU/mL
- Patient in the first trimester of pregnancy with a serum hCG at or above the discriminatory zone (i.e., 1000 mIU/mL) without a sonographically normal gestational sac visualized within the uterus has an ectopic pregnancy until proven otherwise and should have an obstetrics consult in the emergency department.
  - Discriminatory zone may differ depending on the reference, but typically serum hCG between 1000 and 2000 mIU/mL.
  - For this chapter, we have used serum hCG greater than 1000 mIU/mL [1].
- Yolk sac should be first sign of definitive intrauterine pregnancy for emergency physicians because the decidual reaction and gestational sac are not 100 % accurate.
- May be treated surgically or medically depending on findings.
  - Decision to be made by obstetrics consultant

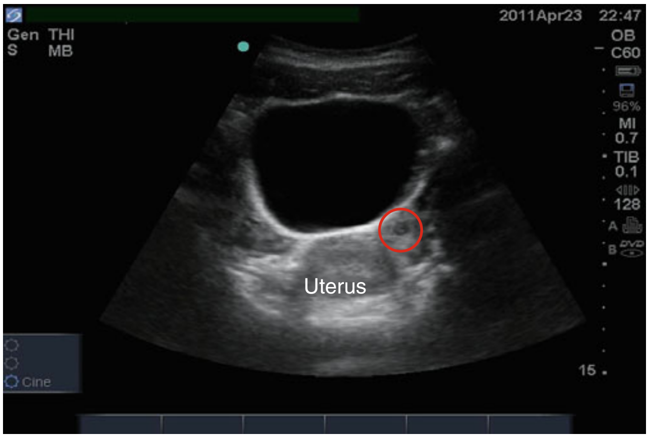
2011Apr23 22:47
Gen THI
S MB
OB
C60
96%
MI
0.7
TIB
0.1
128
Uterus
15
Cine

Fig. 110.2 Transabdominal transverse image of the uterus shows an ectopic pregnancy in the left adnexa (red circle) with the yolk sac present (Photo courtesy of L. Connor Nickels, MD, RDMS)

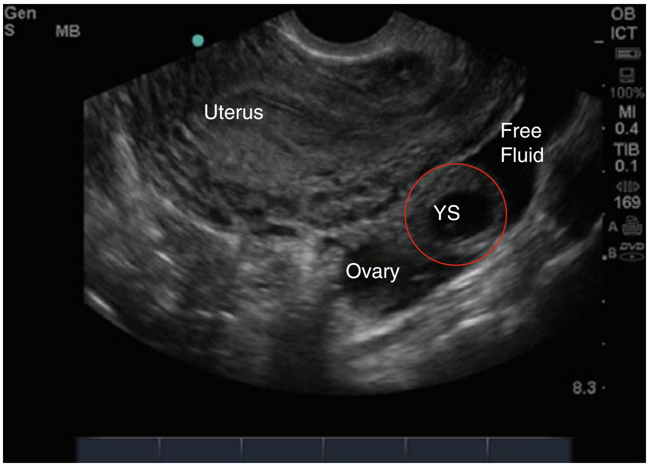
Gen
S MB
OB
ICT
100%
MI
0.4
TIB
0.1
169
Uterus
Free
Fluid
YS
Ovary
8.3

Fig. 110.3 Transvaginal sagittal image of an empty uterus with an ectopic pregnancy (in red circle) noted just posterior in the adnexa, adjacent to the ovary. The gestational sac contains a yolk sac and there is free fluid surrounding the ectopic, concerning for rupture (Photo courtesy of L. Connor Nickels, MD, RDMS). YS–yolk sac

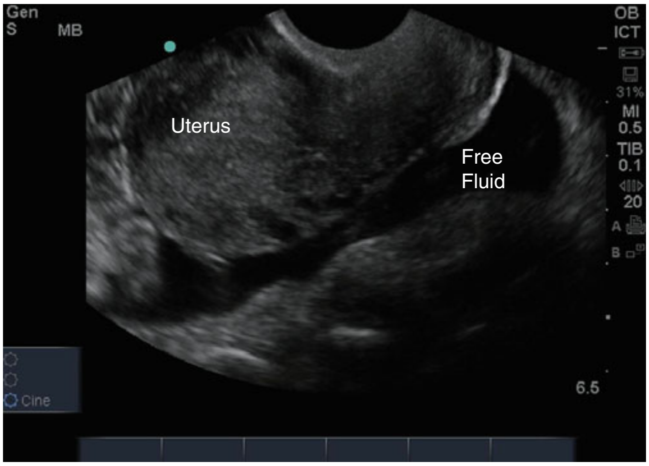
Gen
S MB
OB
ICT
31%
MI
0.5
TIB
0.1
20
Uterus
Free
Fluid
6.5
Cine

Fig. 110.4 Transvaginal sagittal image of an empty uterus and large free fluid in the posterior cul-de-sac in a patient with a presumed ectopic pregnancy (Photo courtesy of L. Connor Nickels, MD, RDMS)

110.2 Contraindications

- Treating ectopic pregnancy medically when there is a fetal pole with fetal cardiac activity present
- Failing to consult obstetrics/gynecology when the patient has a serum hCG above the discriminatory zone and no sonographic findings to diagnose intrauterine pregnancy

110.3 Materials and Medications

- Ultrasound machine
- Probes: transabdominal and transvaginal
- Gel
- Skilled ultrasound operator
- Endocavitary probe covers
- Pelvic setup (speculum and cultures)
- Cardiac monitor, two large-bore intravenous needles
- Laboratory work: serum quantitative hCG, hemoglobin, group and Rh, type and screen
  - May add additional laboratory tests depending on the stability and symptoms of the patient

110.4 Procedure

- Ultrasound machine in obstetrics preset
- Transabdominal
  1. Place the patient in the supine position.
  2. Ideally, the bladder will be full for a good acoustic window.
  3. Using a curvilinear probe, 3.5–5.0 MHz.
  4. Begin scanning the patient in a sagittal position to identify the uterus as it lies in position with the bladder. Scan through the uterus completely in this plane, looking for signs of intrauterine pregnancy.
  5. Imaging in the transverse plane should be done in the same fashion.
  6. Any signs of an intrauterine pregnancy should be clearly identified and measured.
     - Gestational sac diameter
     - Yolk sac diameter
     - Fetal pole with crown rump diameter
       - If present, fetal cardiac activity should be recorded by using M mode to obtain a tracing and measure the fetal heart rate.
  7. Although sometimes limited transabdominally, an attempt to identify the adnexa should be performed in both planes bilaterally.
  8. Any abnormalities identified should be noted.
     - Free fluid surrounding the uterus (anterior or posterior cul-de-sac) or ovaries
     - On pelvic imaging or FAST examination
     - Intrauterine contents not consistent with an intrauterine pregnancy and/or not clearly, centrally visualized within the fundus of the uterus
     - Masses or contained fluid collections outside the uterus
     - Yolk sac or fetal pole with or without fetal cardiac activity seen outside the uterus
  9. Transvaginal scanning should be performed if a definitive intrauterine pregnancy is not identified on transabdominal imaging.
- Transvaginal
  1. Place the patient in the lithotomy position.
  2. Bladder is preferably empty.
  3. Use a transvaginal probe, 5–7.5 MHz.
  4. Repeat same steps as transabdominal imaging previously.
- The procedure is the same for all pelvic ultrasounds including transabdominal and transvaginal imaging because this should be performed in a systematic fashion so as to not miss pertinent findings. Therefore, the findings may change, but the examination remains the same.
- Yolk sac should be first sign of definitive intrauterine pregnancy for emergency physicians because the decidual reaction and gestational sac are not 100 % accurate.

110.5 Complications

- Bleeding: internal and/or external
- Maternal death if ectopic ruptures
  - Nine percent of pregnancy-related deaths
  - Leading cause of maternal death in the first trimester
- Sterility if tube(s) are damaged or surgically removed

110.6 Pearls and Pitfalls

- Pearls
  - Following the algorithm despite the patient being asymptomatic can help avoid missed ectopic pregnancies.
  - Cervical ectopic pregnancy can be difficult to distinguish from a spontaneous abortion. If the patient is aborting, the ultrasound findings should change quickly and the patient should have vaginal bleeding.
  - Double decidual reaction versus pseudogestational sac can be a very subtle distinction and should not be made by emergency physicians; hence, the statement made earlier, requiring a yolk sac as the earliest definitive sign of an intrauterine pregnancy.

  - Fibroids, bicornuate uterus, and eccentrically located normal pregnancy can all appear similar to a cornual pregnancy.
  - The majority of times when the patient is pregnant, has an empty uterus on sonographic imaging, and has vaginal bleeding, the final diagnosis is still unknown because it could still be an early normal pregnancy or an ectopic pregnancy.
- Pitfalls
  - Failing to obtain a pregnancy test in all reproductive-age women who have not undergone a hysterectomy
  - Failing to identify subtle signs of ectopic pregnancies

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Ultrasonography for Hydatidiform Mole

111

L. Connor Nickels

Definition: molar pregnancy = hydatidiform mole = anomalous growth of trophoblastic tissue

- Complete: 46,XX or 46,XY
  - Completely paternal in origin
  - Contains no fetal tissue
  - Most recognizable by clinical symptoms
- Incomplete (partial mole): 69,XXX or 69,XXY
  - Maternal and paternal in origin
  - Contains fetal tissue
  - More subtle clinical presentation

111.1 Indications

- Clinical presentation of any combination of the following:
  - Vaginal bleeding
  - With or without vomiting, persistent hyperemesis gravidarum
  - High blood pressure
  - Uterine size large for dates
- Serum human chorionic gonadotropin (hCG) very elevated (more than would be consistent for dates)
  - Usually greater than 100,000 mIU/mL

111.2 Contraindications

- Conservative management

111.3 Materials and Medications

- Ultrasound machine
- Probes: curvilinear (abdominal) and endocavitary (transvaginal)
- Gel
- Skilled ultrasound operator
- Endocavitary probe covers
- Pelvic setup (speculum and cultures)
- Lab work: serum quantitative hCG, hemoglobin, group and Rh
  - May add additional laboratory tests depending on the stability and symptoms of the patient

111.4 Procedure

- Ultrasound machine in obstetrics preset
- Transabdominal imaging
  1. Place the patient in the supine position.
  2. Ideally the bladder will be full for a good acoustic window.
  3. Using a curvilinear probe, 3.5–5.0 MHz, begin scanning the patient in a sagittal position to identify the uterus as it lies in position with the bladder. Scan through the uterus completely in this plane, looking for signs of intrauterine pregnancy.
  4. Rotate the probe to a transverse position (counterclockwise), with the probe indicator toward the patient's right. Scan through the uterus completely in this plane, looking for signs of intrauterine pregnancy.
  5. Any signs of an intrauterine pregnancy should be clearly identified and measured.
  6. Sonographic findings of a molar pregnancy include:
     - Uterus filled with heterogeneous material.
       - Echogenic material interspersed with anechoic areas known as the "snowstorm" is the most common appearance of a mole (Fig. 111.1).

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    - Can be confused with missed abortion or fibroid, underscoring the importance of the serum hCG because this will be markedly elevated, which would make the alternative diagnoses less likely.
  - Theca lutein cysts are present in the adnexa.
    - Multiple cysts that occur with trophoblastic disease, multiple pregnancies (e.g., twins, triplets, quadruplets), and induced ovulation.
  7. Although sometimes limited transabdominally, an attempt to identify the adnexa should be performed in both planes bilaterally.
  8. Any abnormalities should be noted.
  9. Transvaginal scanning should be performed if a definitive intrauterine pregnancy is not identified on transabdominal imaging.
- Transvaginal imaging
  1. Place the patient in the lithotomy position.
  2. Bladder is preferably empty.
  3. Use an endocavitary probe, 5–7.5 MHz.
  4. Repeat the same steps as for transabdominal imaging previously discussed (#2).
  5. After scanning through the uterus in sagittal and transverse planes, the adnexa should be scanned in the same format bilaterally, looking for any abnormalities, as mentioned previously.
  6. Again, any abnormalities should be noted:
     - Free fluid surrounding the uterus (anterior or posterior cul-de-sac) and/or ovaries
     - Masses or contained fluid collections outside the uterus
     - Yolk sac or fetal pole with or without fetal cardiac activity seen outside the uterus
- The procedure is the same for all pelvic ultrasounds, transabdominal and transvaginal imaging, because this should be performed in a systematic fashion so as to not miss pertinent findings. Therefore, the findings may change, but the examination remains the same.
- Yolk sac should be the first sign of definitive intrauterine pregnancy for emergency physicians because the decidual reaction and gestational sac are not 100 % accurate.

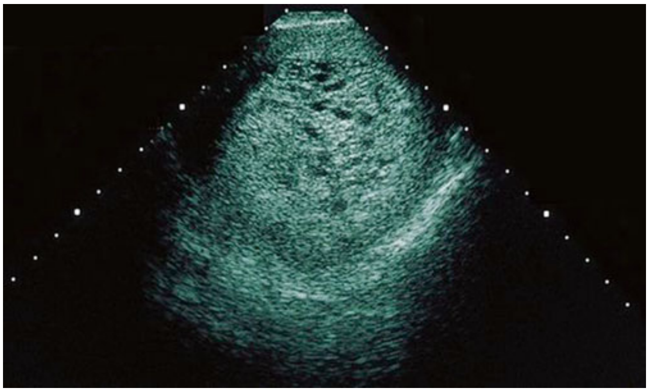

Fig. 111.1 Uterus with “cluster of grapes” represents a molar pregnancy (With kind permission from Springer Science+Business Media: Swisher E, Greer B, Montz FJ, Stenchever M. Chapter 14. In: *Atlas of Clinical Gynecology*. Vol. 4. 2002)

111.5 Complications

- Multiple complications can occur and include the following:
  - – Invasive mole: when a hydatidiform mole recurs after a dilation and curettage and, subsequently, invades the muscle of the uterus.
    - Molar tissue is extremely vascular and necessitates an ultrasound with color flow to visualize any residual invasive tissue.
  - – Choriocarcinoma: molar tissue develops into an aggressive malignancy, metastasizing early throughout the body.
    - – In this scenario, the tumor takes on a very cystic appearance with an echogenic rim. When this is seen, one should attempt to view the liver as well for heterogeneous appearance consistent with metastasis or consider other imaging tests (more comprehensive ultrasound, computed tomography, or magnetic resonance imaging) as indicated to further assess concerns for malignancy.
    - – Extremely sensitive to chemotherapy, but most favorable results are seen when diagnosed and treated early.

111.6 Pearls and Pitfalls

- Pearls
  - – An obstetrics consult must be obtained in the emergency department when this diagnosis is made.
    - Patient must have a dilation and curettage to evacuate the mole.
    - Serum hCG must be followed to less than detectable levels because they have a high rate of recurrence (invasive mole) and potential for malignancy (choriocarcinoma).
  - – May occur with intrauterine or ectopic pregnancies or after spontaneous abortions or full-term pregnancies
  - – Qualitative and quantitative β-hCG results may be falsely negative in the setting of a molar pregnancy secondary to the “high-dose hook effect” found in sandwich immunoassays in which there is an overabundance of antigen. This error can be corrected by diluting the urine or serum sample and repeating the test.
- Pitfalls
  - – Many pitfalls with potentially life-threatening consequences surround this diagnosis. Meticulous observation of the entire picture, including clinical presentation, laboratory results, and ultrasound findings, will help to avoid these outcomes.

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Ultrasonography for Blighted Ovum (Anembryonic Gestation)

112

Katrina Skoog Nguyen and L. Connor Nickels

112.1 Indications

- A blighted ovum or anembryonic gestation is a pregnancy in which the embryo never develops in the gestational sac (Fig. 112.1).
- Presents as first-trimester vaginal bleeding and/or pelvic pain or cramping
- Criteria for defining an anembryonic pregnancy:
  - Based, in part, on mean gestational diameter (MGD), which is an average of three orthogonal measurements of the gestational sac
    - MGD greater than or equal to 25mm with no embryo
    - 5 MHz or less
      - MGD greater than or equal to 20 mm without a yolk sac
  - May have abnormally low sac position
- References differ in their measurements depending on the approach, transabdominal versus transvaginal, and the frequency of the probe (e.g., 5 MHz vs. 6.5 MHz or greater).

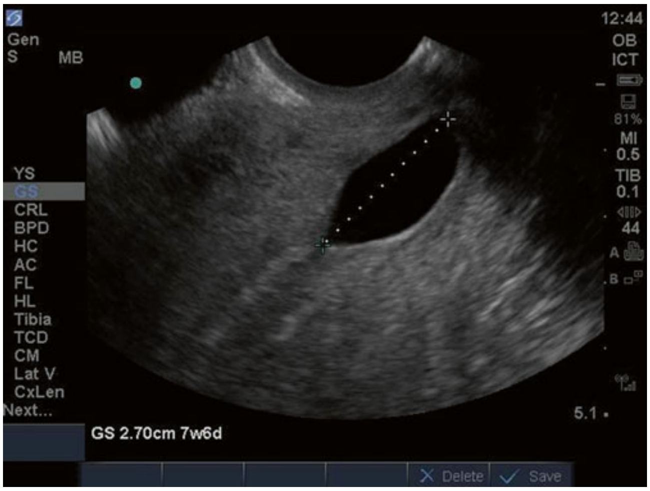

Fig. 112.1 Low-lying empty gestational sac consistent with blighted ovum (Photo courtesy of L. Connor Nickels, MD, RDMS)

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112.2 Contraindications

- Misinterpreting images as blighted ovum when any of the following could potentially be present:
  - Early intrauterine pregnancy
  - Pseudogestational sac
  - Molar pregnancy
- Discussions with the patient should always involve an obstetrics consult or referral for definitive decisions and treatment.

112.3 Materials and Medications

- Ultrasound machine
- Probes: transabdominal and transvaginal
- Ultrasound gel
- Endocavitary probe covers
- Skilled ultrasound operator
- Laboratory tests: serum quantitative human chorionic gonadotropin (hCG), hemoglobin, group, and Rh
  - May add additional laboratory tests depending on the stability and symptoms of the patient

112.4 Procedure

- Ultrasound machine in obstetrics preset
- Transabdominal
  1. Place the patient in the supine position.
  2. Ideally the bladder will be full for a good acoustic window.
  3. Use a curvilinear probe, 3.5–5.0 MHz.
  4. Begin scanning the patient in a sagittal position to identify the uterus as it lies in position with the bladder. Scan through the uterus completely in this plane, looking for signs of intrauterine pregnancy.
  5. Imaging in the transverse plane should be done in the same fashion.
  6. Any signs of an intrauterine pregnancy should be clearly identified and measured.
     - In this case, gestational sac and any other intrauterine contents
  7. Although sometimes limited transabdominally, an attempt to identify the adnexa should be performed in both planes bilaterally.
  8. Any abnormalities should be noted.
     - Free fluid surrounding the uterus (anterior or posterior cul-de-sac) or ovaries
     - Masses or contained fluid collections outside the uterus
     - Yolk sac or fetal pole with or without fetal cardiac activity seen outside the uterus
  9. Transvaginal scanning should be performed if a definitive intrauterine pregnancy is not identified on transabdominal imaging.
- Transvaginal
  1. Place the patient in the lithotomy position.
  2. Bladder is preferably empty.
  3. Use a transvaginal probe, 5–7.5 MHz.
  4. Repeat the same steps as for transabdominal imaging previously discussed (#2).
- The procedure is the same for all pelvic ultrasounds including transabdominal and transvaginal imaging because this should be performed in a systematic fashion so as to not miss pertinent findings. Therefore, the findings may change, but the examination remains the same.
- Yolk sac should be first sign of definitive intrauterine pregnancy for emergency physicians because the decidual reaction and gestational sac are not 100 % accurate.

112.5 Complications

- Bleeding
- Retained products of conception

112.6 Pearls and Pitfalls

- Pearls
  - See "Contraindications." If following an algorithm, a blighted ovum would fall into indeterminate category and obstetrics consult is recommended in the emergency department.
- Pitfalls
  - It is imperative to inform all pregnant patients that obstetrical ultrasonography performed by emergency physicians is limited and not used to detect fetal health and/or anatomy.

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Ultrasonography for Threatened, Incomplete, or Compete Abortion

113

L. Connor Nickels and Giuliano De Portu

Key Points

Threatened abortion: closed os, no passage of products of conception (POC).

Inevitable abortion: open os, no POC.

Incomplete abortion: open os, passage of POC.

Complete abortion: closed os, empty uterus (all POC passed).

Missed abortion: fetus has died and the uterus has failed to enlarge any further.

113.1 Indications

- Vaginal bleeding in the setting of early intrauterine pregnancy

113.2 Contraindications

- There are no contraindications to ultrasonography.

113.3 Materials and Medications

- Ultrasound machine
- Probes: curvilinear (transabdominal) and endocavitary (transvaginal)
- Gel
- Endocavitary probe covers
- Towels
- Skilled ultrasound operator
- Pelvic setup (speculum and cultures)
- Cardiac monitor and intravenous access if bleeding is significant
- Laboratory tests: serum human chorionic gonadotropin (hCG), hemoglobin, group and Rh, type, and screen

113.4 Procedure

The procedure is the same for all pelvic ultrasounds including transabdominal and transvaginal imaging because this should be performed in a systematic fashion so as to not miss pertinent findings. Therefore, the findings may change, but the examination remains the same.

1. Place the patient in the supine position.
2. Ultrasound machine in obstetrics preset with abdominal probe and gel.
3. Begin scanning the patient in a transabdominal sagittal plane to identify the uterus as it lies in position with the bladder. Scan through the uterus completely in this plane looking for signs of intrauterine pregnancy (gestational sac, yolk sac, fetal pole, fetal cardiac activity).
   - For our purposes as emergency physicians, a yolk sac (at the least) must be seen within the uterus to definitively report an intrauterine pregnancy (Fig. 113.1). The decidual reaction and/or presence of gestational sac is not 100 % accurate.
4. Transabdominal imaging in the transverse plane should be done in the same fashion.
5. If an intrauterine pregnancy is clearly identified on transabdominal scanning, appropriate measurements can be taken to estimate dates:
   - Gestational sac diameter.
   - Yolk sac diameter or crown rump length (CRL).
   - If present, fetal cardiac activity should be recorded by using M mode to obtain a tracing and measure the fetal heart rate (Fig. 113.2).
6. For a complete examination, the adnexa should be scanned in an attempt to identify the ovaries bilaterally.
7. Any abnormalities identified should be noted:
   - Free fluid surrounding the uterus (anterior or posterior cul-de-sac) or ovaries
     - On pelvic imaging or focused assessment with sonography in trauma (FAST) examination

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- Intrauterine contents not consistent with an intrauterine pregnancy and/or not clearly, centrally visualized within the fundus of the uterus
- Any masses or contained fluid collections noted outside the uterus
- Yolk sac or fetal pole with or without fetal cardiac activity seen outside the uterus

8. Transvaginal scanning with the endocavitary probe should be performed if a definitive intrauterine pregnancy is not identified on transabdominal imaging.
9. Transvaginal imaging is performed in the sagittal and transverse planes to identify an intrauterine pregnancy, with bladder preferably empty.
10. Measurements should be taken of any intrauterine findings.
    - Same as #5.
    - CRL >7 mm on transvaginal ultrasound should have fetal cardiac activity.
11. Each adnexa should be scanned in the sagittal and transverse planes.
12. Any abnormalities identified should be noted.
    - Same as #7.
13. The uterus will be empty in the case of a complete abortion (Figs. 113.3 and 113.4).

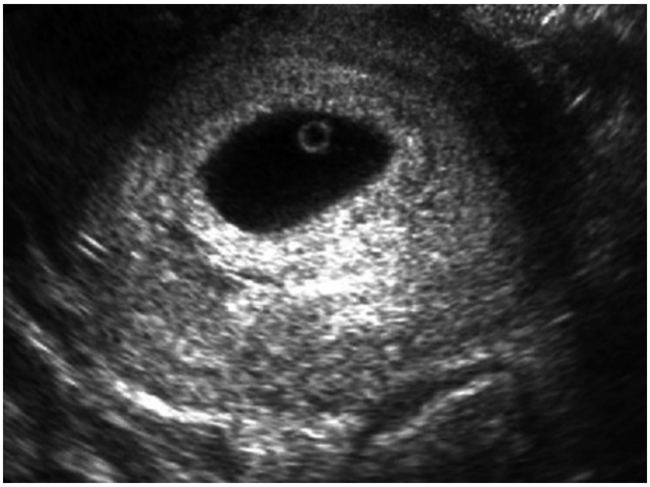

Fig. 113.1 Yolk sac present within the gestational sac with double decidual reaction (With kind permission from Springer Science+Business Media: Buja LM, Chandrasekhar C. Chapter 7: pathology of the breast and female genital tract. In: Krueger GRF, Buja LM, eds. *Atlas of Anatomic Pathology with Imaging*. 2013)

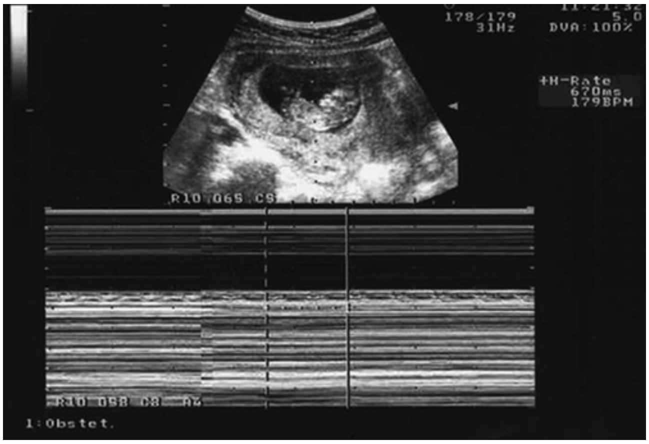

Fig. 113.2 Fetal cardiac activity recorded using M mode to obtain a tracing and measure the fetal heart rate (With kind permission from Springer Science+Business Media: Hanprasertpong T, Phupong V. First trimester embryonic/fetal heart rate in normal pregnant women. *Archives of Gynecology and Obstetrics*. 2006;274(5))

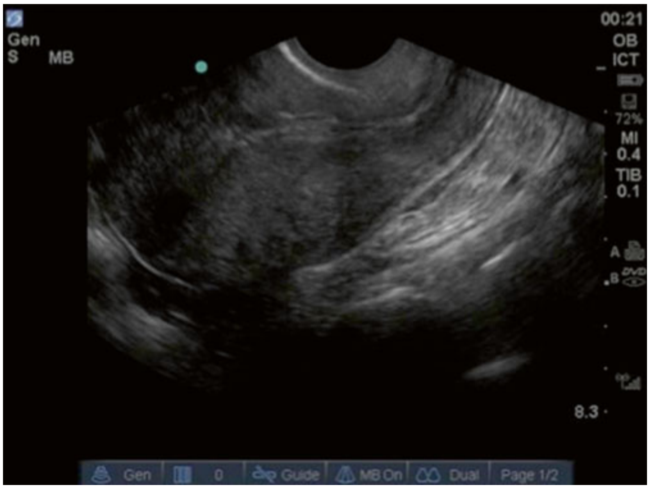

Fig. 113.3 Transvaginal sagittal image of an empty uterus (Photo courtesy of L. Connor Nickels, MD, RDMS)

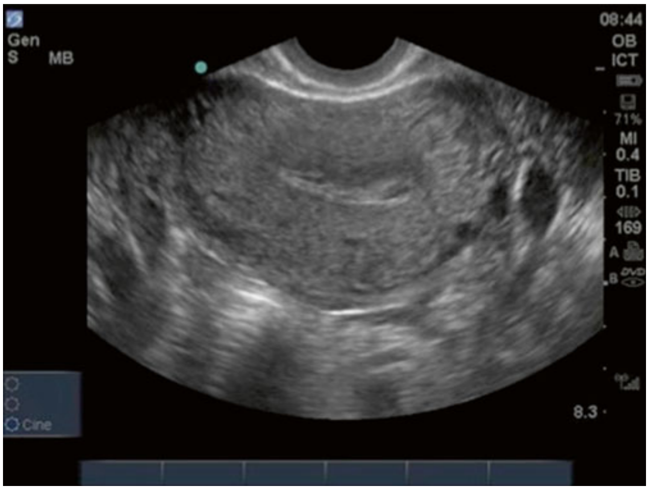

Fig. 113.4 Transvaginal transverse image of an empty uterus (Photo courtesy of L. Connor Nickels, MD, RDMS)

113.5 Complications

- Vaginal bleeding
- Miscarriage
- Rh isoimmunization

113.6 Pearls and Pitfalls

- Pearls
  - Threatened abortion:
    - Threatened abortion is not visible sonographically. It is the presumed diagnosis when a patient presents with vaginal bleeding in the first 20 weeks of pregnancy, an intrauterine pregnancy is found with dates corresponding to the patient's dates, and the cervix is closed.
    - Fetal cardiac activity suggests a better prognosis than those without.
    - Fetal heart rate less than 120 bpm suggests impending fetal death (only 6 % survival).
  - Completed abortion:
    - There are only three scenarios in which this diagnosis can confidently be made in the emergency department:
      1. Intact gestation is passed and identified in the emergency room.
      2. Ultrasound shows an empty uterus in the setting of a prior known intrauterine pregnancy.
         - Small internal echoes within the uterus may represent blood rather than retained products of conception, but this determination should be made in consultation with obstetrics.
      3. Negative pregnancy test result in the setting of a prior known intrauterine pregnancy.
    - In all other cases, the quantitative β-hCG must be followed until it is less than 2 mIU/mL.
- Pitfalls
  - Treating threatened abortion as fetal demise or abortion – many of these pregnancies actually go on to completion with a normal fetus.
  - If there is any concern for alternative diagnoses in any of the abortion types (i.e., ectopic gestation), obstetrics consult should be obtained.
  - Failing to order a quantitative serum hCG to rule out other possibilities (e.g., molar pregnancy) and to ensure that it is trending downward (if others to compare).
  - Failing to establish follow-up for an incomplete abortion to ensure appropriate management. The patient may eventually require a dilation and curettage if products do not pass naturally.

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Ultrasonography for Placenta Previa

114

L. Connor Nickels and Giuliano De Portu

Placenta previa is a condition in which the placenta covers the internal cervical os. It is the leading cause of antepartum hemorrhage. There are four grades of the condition:

- Complete: Placenta completely covers the internal os.
- Partial: Placenta partially covers the internal os.
- Marginal : Lower margin of placenta reaches the internal os but does not cover it (within 3 cm).
- Low lying: Lower margin of placenta is located in the lower uterine segment but does not reach the internal os (Fig. 114.1).

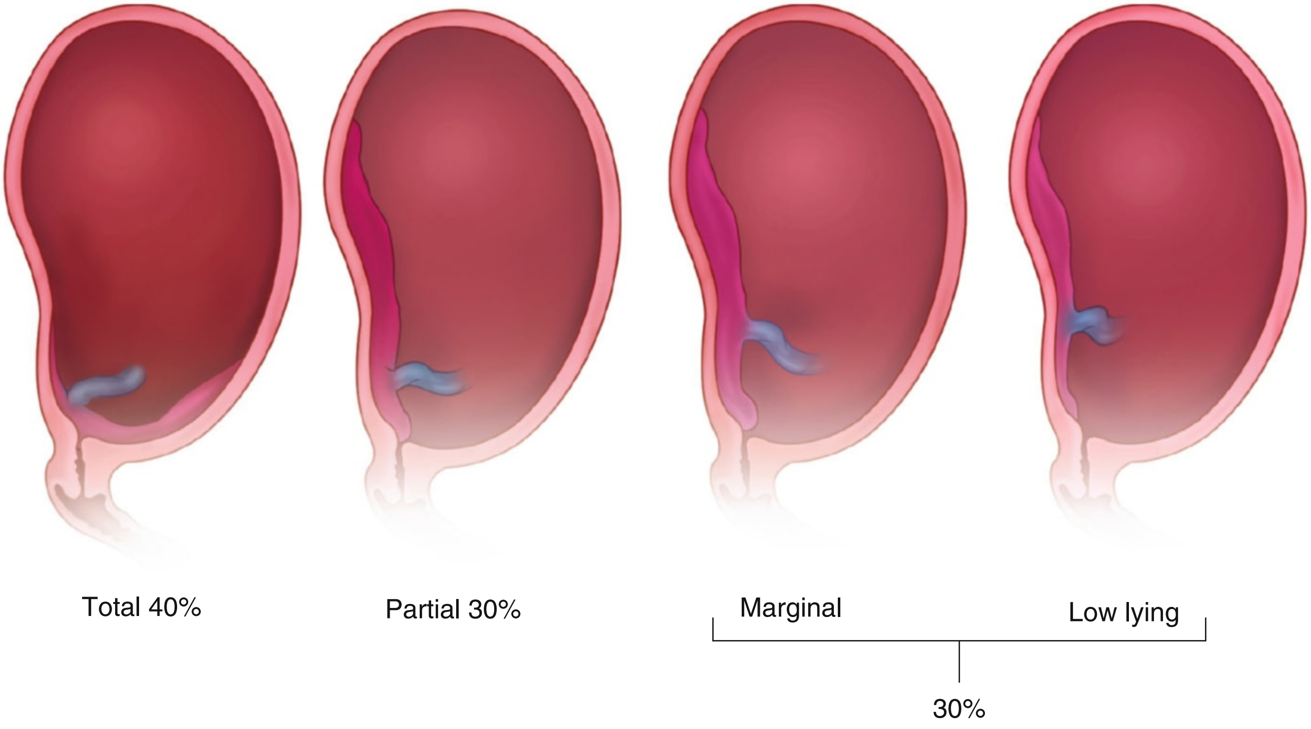

Fig. 114.1 Varying degrees of placenta previa

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114.1 Indications

- A patient in the second half of pregnancy who presents to the emergency room with bright red, painless vaginal bleeding OR premature labor should be evaluated for this condition.

114.2 Contraindications

- Absolute:
  - There are no absolute contraindications to transabdominal ultrasonography.
- Relative:
  - Transvaginal ultrasound should be carried out with caution, so as to avoid hemorrhage.

114.3 Materials and Medications

- Ultrasound machine
- Probes: curvilinear or phased array, endocavitary
- Sterile gel
- Endocavitary probe covers
- Towels
- Sterile speculum (see previously)
- Cardiac monitor, two large-bore intravenous needles, laboratory tests

114.4 Procedure

1. Place the patient in the supine position.
2. Ultrasound machine with abdominal probe and gel.
3. Begin scanning the patient in a transabdominal sagittal position (Fig. 114.2) to determine the placental position and whether it is lying in the lower uterine segment.
4. The patient should then be scanned in a transverse fashion to further evaluate the exact position of the placenta.
5. If the placenta appears to lie in the lower uterine segment, the patient should be scanned in the oblique plane as well.
6. The bladder should initially be full for best visualization. However, if the placenta appears to reside low or lie over the internal os, the scanning should be repeated after the patient has voided.
   - An overdistended bladder may create the appearance of a placenta previa. The anterior wall of the uterus is compressed against the posterior wall by the distended bladder, shortening the distance between the placenta and the internal os (Fig. 114.3).
7. The following ultrasonographic findings exclude placenta previa [1]:
   - Direct apposition of the presenting part of the fetus and the cervix without space for interposed tissue
   - Presence of amniotic fluid between the presenting part of the fetus and the cervix, without the presence of placental tissue
   - Distance of greater than 2 cm between the inferior aspect of the placenta
   - Indirect visualization of the internal cervical os
8. If placenta previa cannot be ruled out with transabdominal ultrasound, the patient should then be scanned transvaginally with the endocavitary probe because this is more sensitive for diagnosing placenta previa.
9. A sterile speculum examination should be performed before transvaginal scanning to assess the cervix and ensure there are no presenting parts or bulging membranes. Transvaginal imaging is contraindicated if the patient has ruptured or bulging membranes.
10. The probes should be swapped out and a sterile cover placed on the endocavitary probe with gel inside the cover and sterile gel on the outside of the cover.
11. The endocavitary probe should be inserted into the vaginal canal, ensuring that caution is taken to stay off the cervix and distal to it, keeping the cervix in view on the screen.
12. The patient should be scanned in both the sagittal and the transverse planes to assess the inferior margin of the placenta.

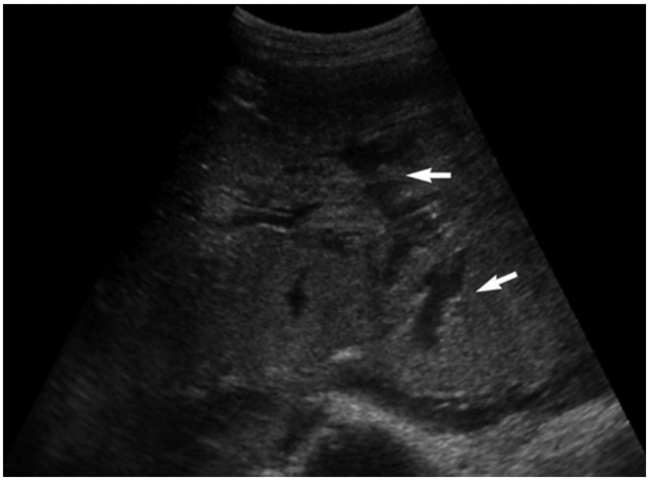

Fig. 114.2 Transabdominal ultrasound of placenta previa. Note loss of the decidual interface between the placenta and the myometrium on the lower part of the uterus and multiple intraplacental lacunae (*arrows*) (Reproduced with permission from *J Korean Med Sci*. 2010; 25(4):651–5)

13. If the inferior margin appears to be located near the internal os, then the distance should be measured.
    - Steps 8 through 13 should only be performed by the emergency physician if he or she feels confident in this ultrasound skill and there is no obstetrics available. If obstetrics is available, these steps should be performed in conjunction with them or by them to ensure the best outcome for the patient.

Fig. 114.3 (**a**) Overdistended bladder creating the appearance of placenta previa, (**b**) empty bladder showing the more accurate position of the placenta

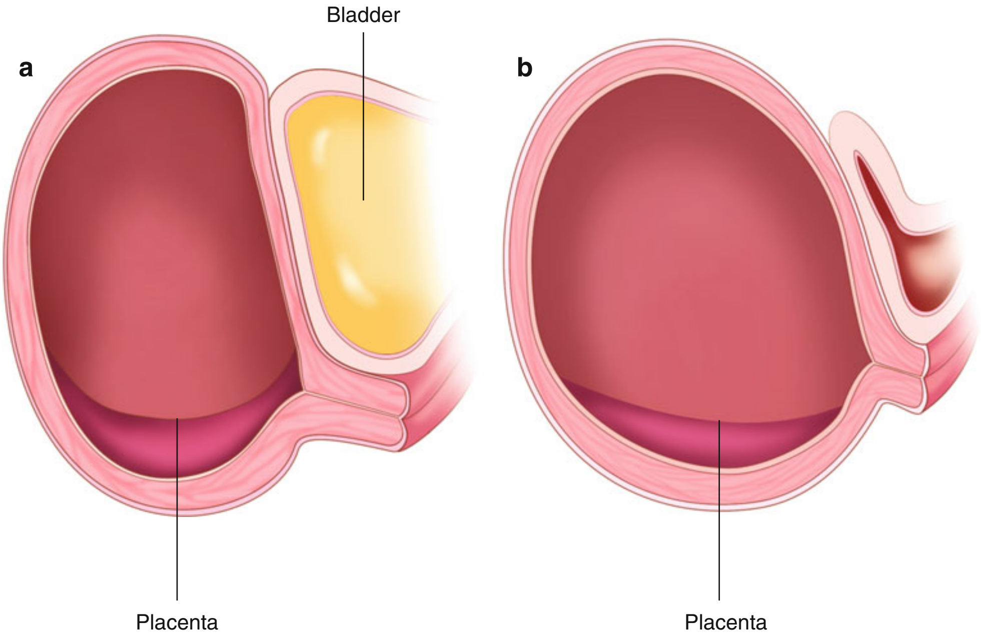

114.5 Complications

- Bleeding:
  - May range from self-limited to life-threatening hemorrhage
- Maternal and/or fetal distress or death

114.6 Pearls and Pitfalls

- Pearls
  - Risk factors include:
    - Multiparity
    - Multiple pregnancy
    - Advanced maternal age
    - Previous placenta previa
    - Cigarette smoking
    - Cocaine abuse
    - Hypertension
    - Previous cesarean delivery/uterine surgeries
  - Myometrium contraction: can mimic placenta previa by temporarily displacing the placenta in the lower uterine segment.
  - If ultrasound capabilities are not available, but the patient is in the second half of pregnancy and having vaginal bleeding, do not perform a digital cervical examination.
- Pitfalls
  - Digital examination should be avoided because this may precipitate life-threatening hemorrhage and/or death.
  - Always consult obstetrics as soon as possible if this is suspected or known and the patient is symptomatic. Not consulting obstetrics could be detrimental to the mother and fetus.
  - Gentle sterile speculum examination should be done only if an obstetrician is not available. This is to ensure the bleeding is coming from the cervix. If placenta previa is suspected or known and obstetrics are available, then abdominal ultrasound evaluation alone should be sufficient for the examination of the patient.

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Vaginal Delivery

115

Umarfarook Javed Mirza, Christopher Shields,
and Muhammad Waseem

115.1 Indications

- Inevitable delivery of the fetus (cervix fully dilated at 10 cm and fully effaced 1 mm with crowning of the head)

115.2 Contraindications

- Absolute:
  - Indications for emergent cesarean section (C-section)
  - Prolapsed cord
  - Prior C-section with classic vertical incision
  - Placenta previa – complete/partial
  - Breech presentation – footling
- Relative:
  - Placenta previa – marginal/low lying
  - Breech presentation – complete/incomplete/frank

115.3 Materials and Medications (Fig. 115.1)

- 4 Crile clamps or Kelly clamps
- 1 Mayo scissor curved and 1 Mayo scissor straight
- 2 sponge forceps
- 2 towel clamps
- 1 Mayo-Hegar needle holder
- 1 mouse-tooth forceps
- Suction bulb
- Betadine (povidone-iodine)
- Umbilical cord clamp (Fig. 115.2)
- Incubator warmer (Fig. 115.3)
- Most importantly, help.

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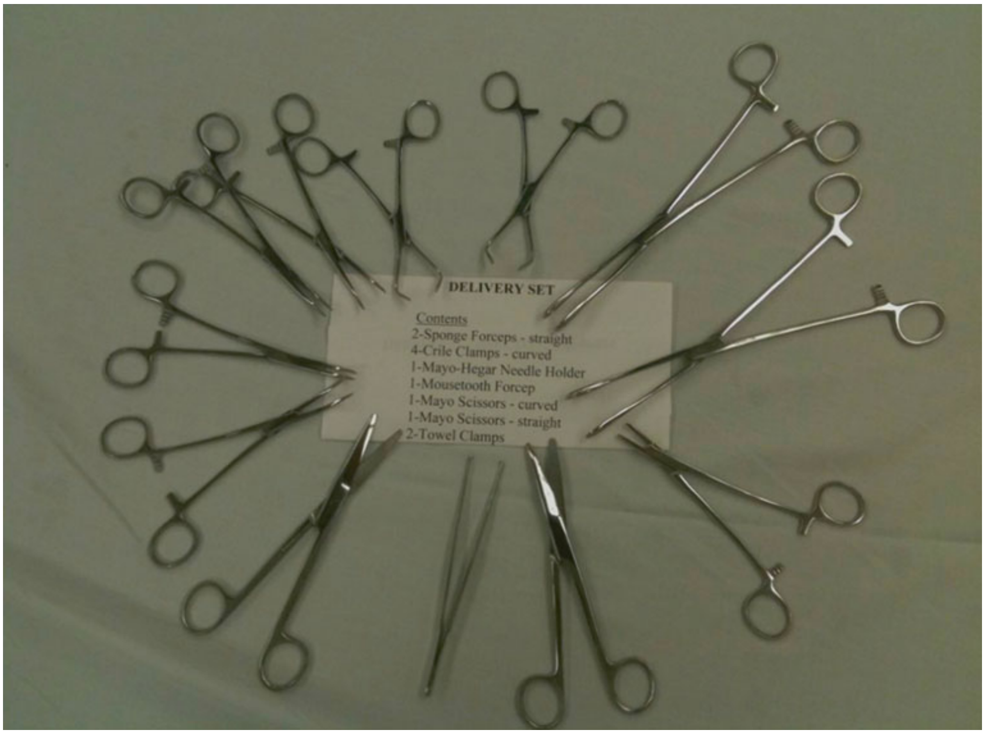
DELIVERY SET
Contents
2-Sponge Forceps - straight
4-Crile Clamps - curved
1-Mayo-Hegar Needle Holder
1-Mousetooth Forcep
1-Mayo Scissors - curved
1-Mayo Scissors - straight
2-Towel Clamps

Fig. 115.1 Equipment: delivery set

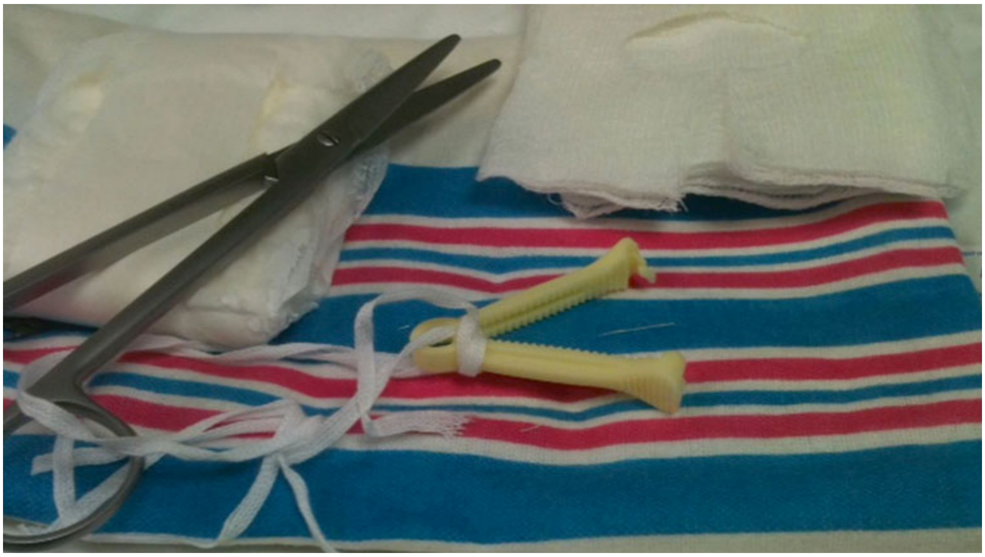

Fig. 115.2 Equipment: umbilical clamp

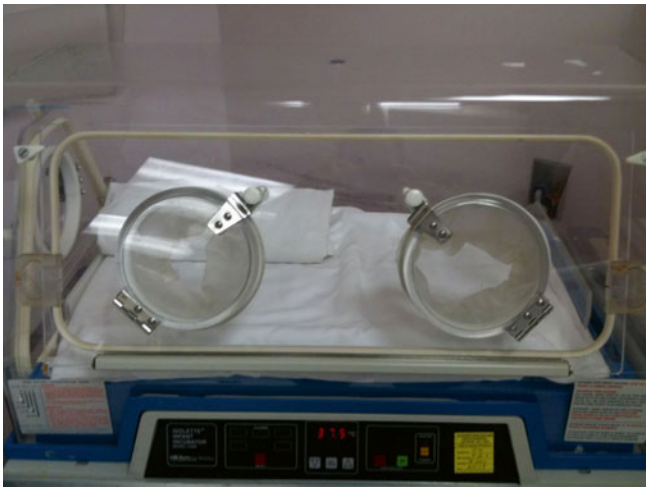

Fig. 115.3 Equipment: incubator warmer

115.4 Procedure

1. Determine the fetal presentation (breech or cephalic) with Leopold's maneuvers or bedside ultrasound.
2. If breech, follow the breech pathway.
3. Perform a vaginal examination.
4. Check for cord prolapse.
5. Check effacement.
6. Check dilation.
7. Prepare the site.
8. Position the mother in the extreme lithotomy position.
9. Deliver the head in a controlled manner.
10. Check to see if the cord is wrapped around the neck. If present, follow cord presentation pathway.
11. Deliver the anterior shoulder with downward traction of the head.
12. Check for shoulder dystocia. If present, follow the McRobert-Rubin maneuvers (see Chap. 116).
13. Deliver the posterior shoulder by gently pulling the trunk upward.
14. Suction the airway.
15. Clamp the cord 5 cm from the umbilicus in two places and cut.
16. Obtain Apgar score of the baby. Initiate resuscitation if required.
17. Keep the baby warm in the incubator.
18. Clamp the cord again closer to the vaginal opening.
19. Use this clamp to help deliver the placenta. Use gentle controlled traction on the clamp with one hand while placing the other hand suprapubically to push the uterus upward.
20. If the placenta does not deliver easily, stop and wait a few minutes to allow it to come away from the uterine wall naturally and then try again.
21. Placenta must be fully intact. If not, check for retained intrauterine placental products, and manually remove them; retained placenta may cause postpartum hemorrhage.
    - Massage the fundus externally to prevent uterine atony, but only after all products have been removed.
22. Repair any vaginal or cervical lacerations.

115.5 Complications

- Postpartum hemorrhage due to uterine atony or retained products
- Uterine inversion
- Rectal or urethral injuries
- Shoulder dystocia
- Meconium aspiration

115.6 Pearls and Pitfalls

- Pearls
  - Postpartum hemorrhage has a high incidence during the first hour postpartum.
  - Be aware of possible second delivery.
  - Oxytocin or Methergine (methylergonovine maleate) may be used after delivery of the placenta; both help increase uterine contractions and decrease postpartum hemorrhage.
- Pitfalls
  - Rushing delivery of the head/shoulders can lead to trauma to the mother/baby.
  - Rushing delivery of the placenta, when the placenta is not ready to detach, may cause placental or cord tearing or uterine inversion. Remember: it may take up to 20 min for the placenta to detach from the uterus.

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Shoulder Dystocia Management

116

Irina Fox Brennan and Joseph A. Tyndall

116.1 Indications

- Retracting fetal head (“turtle sign”)
- Failure of anterior shoulder delivery following gentle downward traction
- Difficult face-chin delivery
- Failure of shoulders to descend

116.2 Contraindications

- Mother with diabetes and fetus larger than 4500 g
- Mother without diabetes and fetus larger than 5000 g
- History of shoulder dystocia with prior birth
- Factors that signal the need for cesarean section:
  - Complete/partial placenta previa
  - Cord prolapse
  - Brow/face presentation
  - Non-reassuring fetal heart rate
  - Extensive uterine surgery and previous classic uterine incision

116.3 Materials and Medications

- No specialized materials/equipment required.
- Team coordination is of utmost importance.

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116.4 Procedure

1. *Accurate documentation*: Designate a team member to document the progress of labor, the position and rotation of the infant's head, the time of delivery for the head and body, the presence of episiotomy, anesthesia requirements, the duration of shoulder dystocia, whether the shoulder is anterior or posterior at the time of delivery, the onset/duration/results of maneuver(s) performed, and Apgar scores.

   The HELPERR mnemonic is commonly employed:

2. *Help recruitment*: Involve anesthesiology, pediatric resuscitation, and obstetric/gynecology colleagues either as part of advance preparations or via activation of protocol during labor.
3. *Episiotomy consideration*: Not required but might be of benefit if more space is needed for rotation maneuvers.
   - Episiotomy alone will not release the impacted shoulder.
4. *Legs positioned for the McRoberts maneuver*: Position the woman's thighs onto her abdomen by abducting and flexing her hips. Have two assistants help her, one on either side. This increases the functional size of the bony pelvis by rotating the pubic symphysis toward the mother's head, hence aiding delivery (Fig. 116.1).

Fig. 116.1 McRoberts maneuver: hyperflexion of the maternal thighs against the abdomen

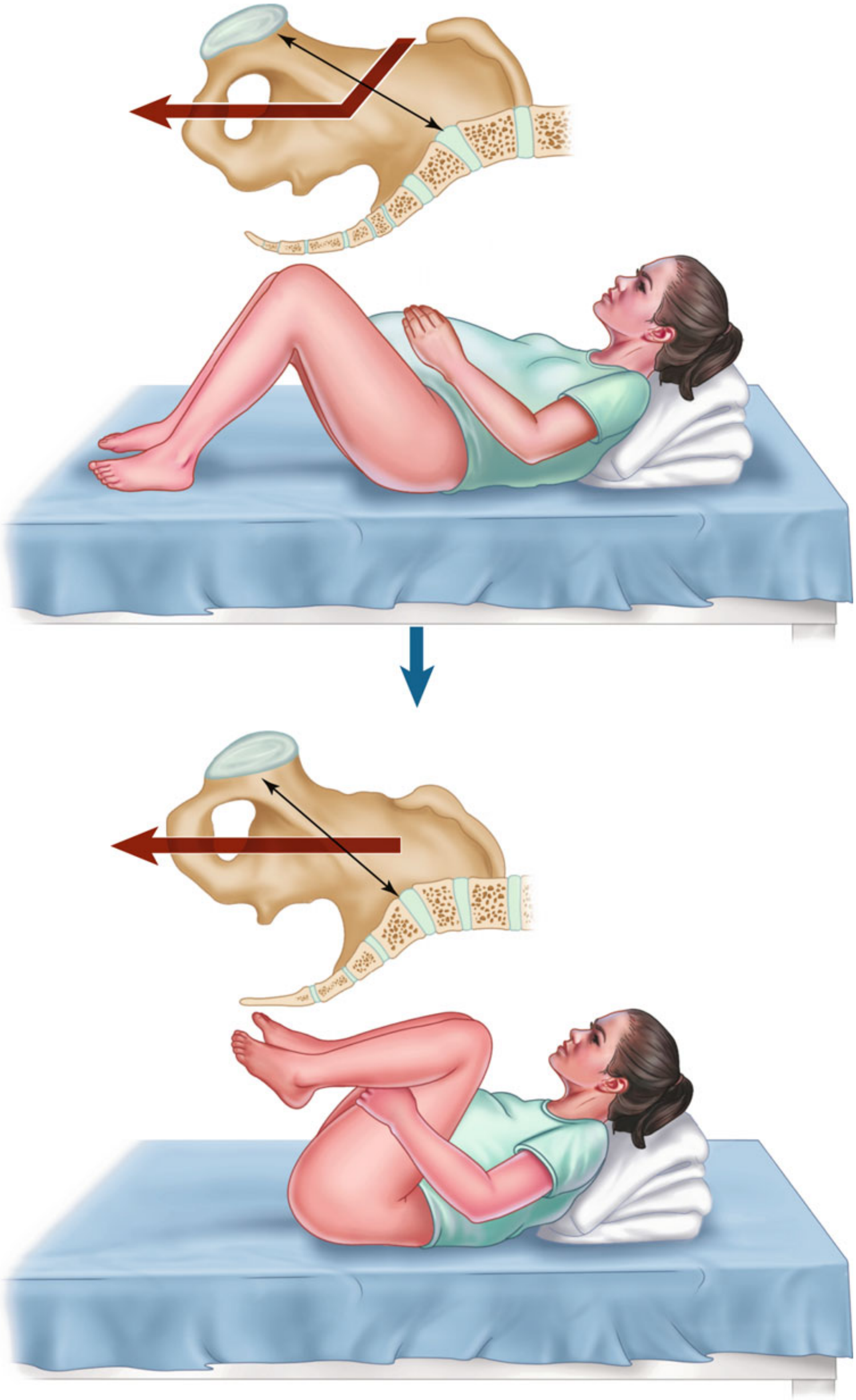

5. *Pressure suprapubically* (*Rubin I maneuver*): While continuing downward traction, have a colleague place his or her hand suprapubically on the fetal anterior shoulder and apply pressure down and laterally on its posterior aspect in 30-second increments. This allows the fetal shoulders to enter the pelvis in an oblique fashion (pelvic inlet is widest in the transverse plane) (Fig. 116.2).
6. *Enter maneuver* (*internal rotation*): Rotate the anterior shoulder into the oblique plane and under the maternal symphysis.
    - It may be necessary to push the fetus slightly up into the pelvis in order to successfully perform this maneuver.
        (a) *Rubin II maneuver*: Insert one hand vaginally behind the fetal anterior shoulder and rotate the shoulder toward the chest. This will reduce the diameter of the fetal shoulder girdle and facilitate delivery (Fig. 116.3).
        (b) *The Woods corkscrew maneuver*: Place one hand at the front of posterior shoulder and push upward gently. This can be combined with the Rubin II maneuver (Fig. 116.4).
        (c) *The reverse Woods corkscrew maneuver*: Place one hand behind the fetal posterior shoulder and rotate in the direction opposite to that of the Woods corkscrew maneuver to adduct the shoulder.
7. *Remove the posterior arm*: Flex the fetal elbow and deliver the forearm in a sweeping motion over the fetal anterior chest wall. This allows the fetus to drop into the sacral hollow, freeing the anterior shoulder impaction.
    - Avoid grasping and pulling on the fetal arm directly because it may fracture the fetal humerus.
8. *Roll the patient* (*Gaskin maneuver*): Position the patient on all fours (this acts as an upside-down McRoberts maneuver). Continue gentle traction. The turning itself, as well as gravity, will often dislodge the impacted shoulder.

    Last-resort maneuvers:
9. *Deliberate fracture of the fetal clavicle*: Apply direct pressure upward in the middle of the clavicle to reduce the shoulder-to-shoulder distance.

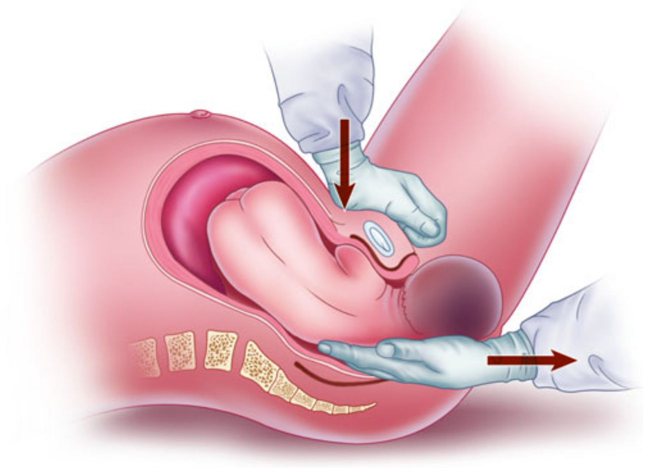

Fig. 116.2 Ruben I maneuver: suprapubic pressure is directed at the anterior shoulder

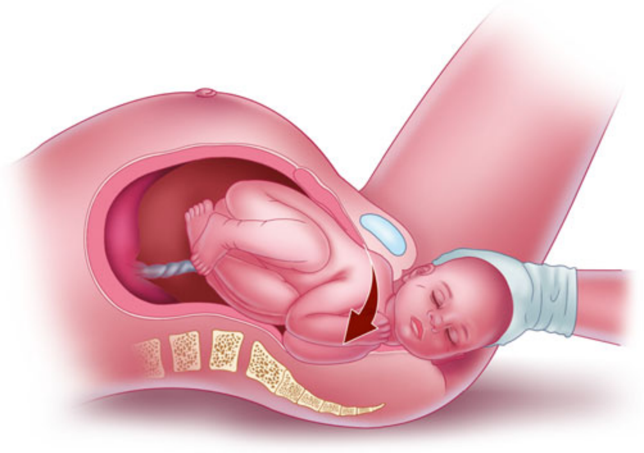

Fig. 116.3 Ruben II maneuver: pressure is applied to the most accessible part of the fetal shoulder and rotated toward the chest

Fig. 116.4 The Woods corkscrew maneuver: pressure is applied to the clavicle of the posterior arm, enabling rotation and dislodgement of the anterior shoulder

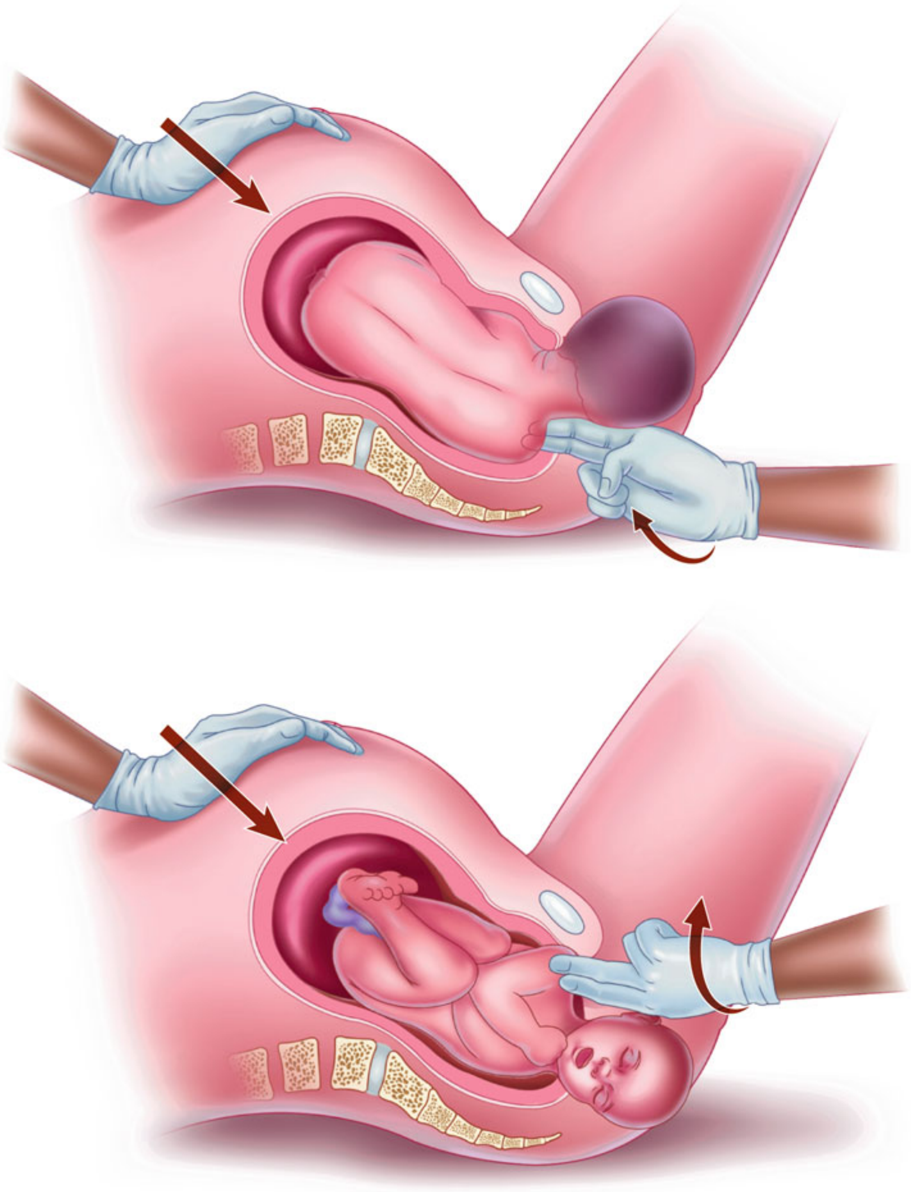

10. *Zavanelli maneuver*: Rotate the fetal head into the direct occiput anterior position, flex, and push back into the birth canal. Continue holding upward pressure until cesarean delivery. Ensure the operating and anesthesiology teams are present (Fig. 116.5).
    - Do not perform this maneuver if the nuchal cord has been clamped or cut.
11. *Symphysiotomy*: Place the patient in the exaggerated lithotomy position, insert a transurethral catheter, displace the urethra laterally, and separate the cephalad portion of fibrous cartilage of the symphysis pubis under local anesthesia with either a scalpel blade or Kelly clamp.
    - This technique is associated with significant maternal morbidity, including bladder neck injury and infection. It is truly the last resort and should be used only when all other methods have failed and cesarean delivery is unavailable.

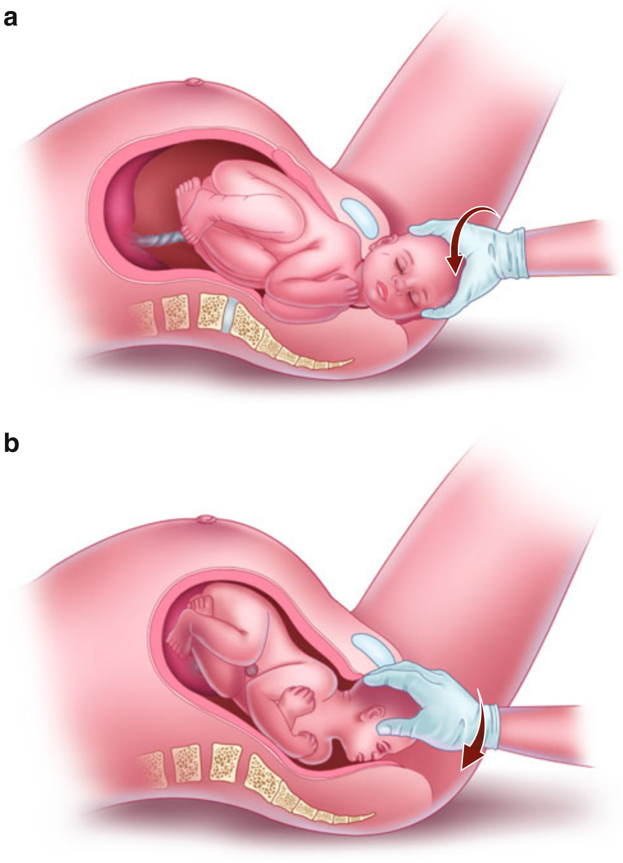

Fig. 116.5 Zavanelli maneuver: the fetal head is rotated into the direct occiput anterior position, flexed, and pushed back into the birth canal. (**a**) Rotation of the head to the occiput anterior position. (**b**) Replace head with constant firm pressure on occiput with palm of hand flexing head

116.5 Complications

- Maternal:
  - Postpartum hemorrhage
  - Fourth-degree laceration/soft tissue damage to cervix and vagina
  - Uterine rupture
  - Bladder atony
  - Symphyseal separation with or without femoral neuropathy (transient)
  - Sacroiliac dislocation
- Fetal:
  - Brachial plexus palsies (Erb, Klumpke): most resolve within 6–12 months; permanent injury occurs in less than 10 % of patients
  - Clavicular and/or humeral fractures
  - Ischemia/hypoxia/asphyxia due to umbilical cord compression with or without neurological damage
  - Significant fetal acidosis, with pH drop of 0.04 U/min between delivery of the head and trunk
  - Death

116.6 Pearls and Pitfalls

- Pearls
  - Many cases of shoulder dystocia and birth trauma are encountered in the absence of risk factors and in non-macrosomic infants. Shoulder dystocia is largely neither predictable nor preventable.
  - Presence of risk factors for shoulder dystocia should prompt advance preparation in anticipation of a difficult delivery. Risk factors include maternal diabetes, obesity, multiparity, advanced maternal age, prolonged pregnancy, macrosomia (fetal weight >4,500–5,000 g), male fetal gender, and prior birth complicated by shoulder dystocia.
- Pitfalls
  - Do not cut and clamp the nuchal cord if at all possible in order to avoid fetal hypoxia and hypotension should shoulder dystocia arise.
  - Labor induction or prophylactic cesarean delivery of macrosomic fetuses has not decreased rates of shoulder dystocia.
  - Avoid fundal pressure in shoulder dystocia because it has been shown to increase the risk of permanent neurological damage and uterine rupture.

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Breech Delivery in the Emergency Department

117

Kristin Stegeman, Sapnalaxmi Amin, Anton A. Wray, and Joseph A. Tyndall

Breech presentation: the buttocks enter the pelvis before the head (Fig. 117.1)

- Frank (extended):
  - Hips flexed and knees extended, buttocks presenting
  - Most common
- Incomplete/complete (flexed):
  - One or both hips and knees flexed, buttocks presenting
- Footling:
  - One or both hips and knees extended, foot presenting

The emergent delivery of a breech baby is one of the most challenging situations for an emergency physician.

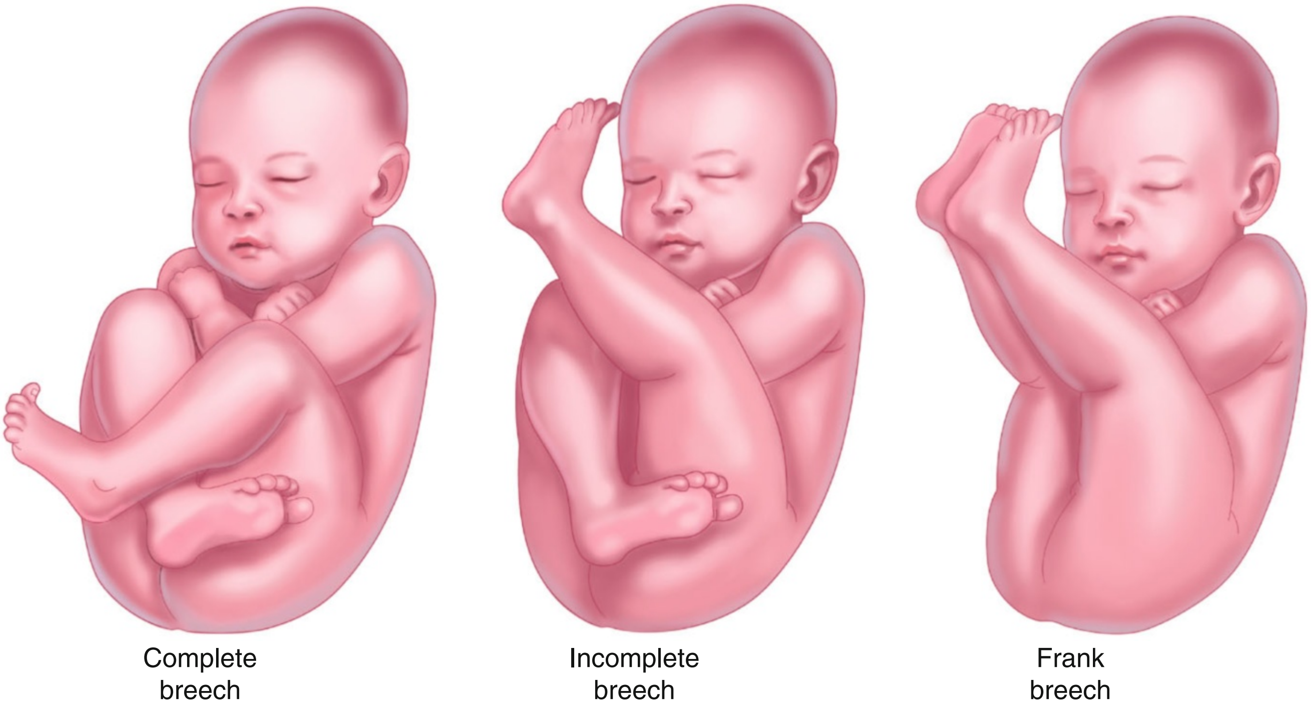

Fig. 117.1 Variations of the breech presentation

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117.1 Indications

- Inevitable delivery of fetus with complete or frank breech presentation
- Absence of vertex presentation

117.2 Contraindications

- Footling presentation (increased risk of cord prolapse and entrapment of the after-coming head).
- There is adequate time to transfer the mother safely to labor and delivery in the knee/chest position (administer subcutaneous terbutaline before transfer).

117.3 Materials and Medications

- Supplemental oxygen for mother
- Ultrasound machine
- Piper forceps
- Sterile towels/gloves
- Betadine (povidone-iodine) or another antiseptic preparing solution
- Sterile lubricant (Surgilube)
- Instruments to cut the umbilical cord/perform episiotomy/resuscitate baby (Kelly clamps/scissors/#10 scalpel/bulb suction)
- Available emergency department staff
- Pediatric, obstetrics, and anesthesia practitioners

117.4 Procedure

1. Assess the health of the mother and the baby (vitals/physical examination/history).
2. Listen to the fetal heart with stethoscope or Doppler ultrasound.
   - Should be 120–160 beats/min.
3. Identify the type of presentation by bedside ultrasound or by digital exam.
4. Perform a sterile digital examination to confirm the position of the baby and the stage of labor.
   - Membranes should not be artificially ruptured. The amniotic sac will help to dilate the cervix, lubricate the canal, and protect the umbilical cord from compression.
5. If footling presentation: await OB/general surgery for emergency C-section.
6. If frank/complete/incomplete: instruct the patient to push when the cervix is completely dilated.
7. When the breech has descended to the perineum, consider performing an episiotomy if more space is needed. Cleanse the perineum with antiseptic and sterile lubricant beforehand.
8. Allow the baby to extrude to the umbilicus with maternal efforts alone. Do not exert traction before this time.
9. If frank: deliver the posterior leg by gently guiding the sacrum anteriorly, grasping the thigh and flexing the leg at the knee.
10. Deliver the anterior leg in a similar manner while guiding the sacrum posteriorly.
11. If incomplete: deliver the extended leg as #8 or #9 as appropriate.
12. Delivery continues as it would for a complete presentation.
13. Wrap the legs/buttocks in a clean towel to decrease trauma (create grip).
14. Grasp the upper legs with the index fingers holding the anterior iliac crests. Place the thumbs on the sacrum (Fig. 117.2).
15. Apply gentle traction as the mother pushes until the scapulae and axillae are visible.
16. If there is difficulty delivering the shoulders, deliver the posterior shoulder by rotating the trunk 90° and applying gentle downward traction to rotate the shoulder anteriorly.
17. Rotate the baby 180° so as to deliver the anterior arm in a similar manner.
18. If the arms do not spontaneously deliver, a finger can be hooked over the shoulders to bring the arm down while rotating the trunk as above (Fig. 117.3).
19. Use the McRoberts position to increase the diameter of the pelvis (Fig. 117.4).

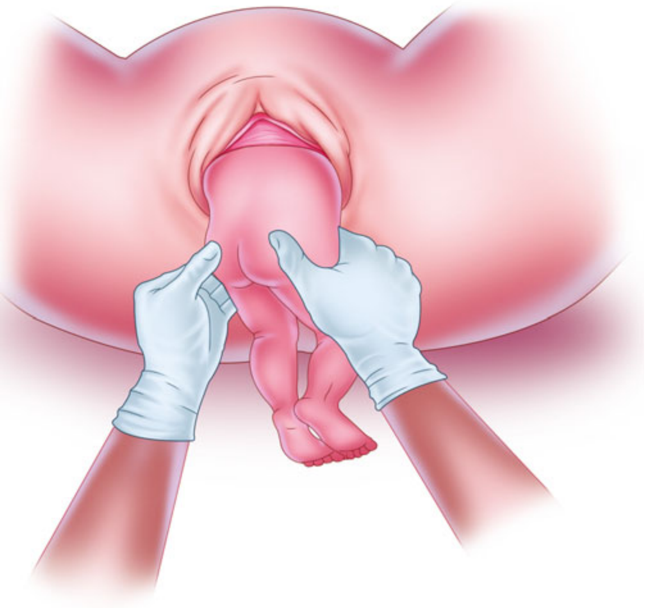

Fig. 117.2 Correct placement of hands on sacrum

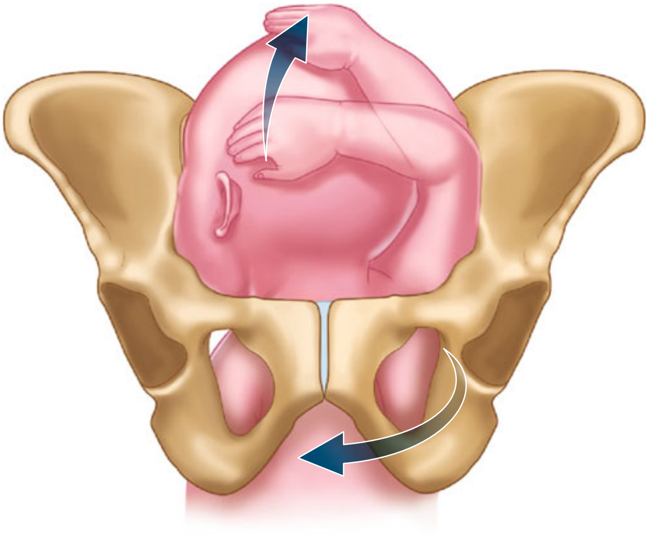

Fig. 117.3 Rotation toward maternal symphysis pubis to avoid nuchal arm

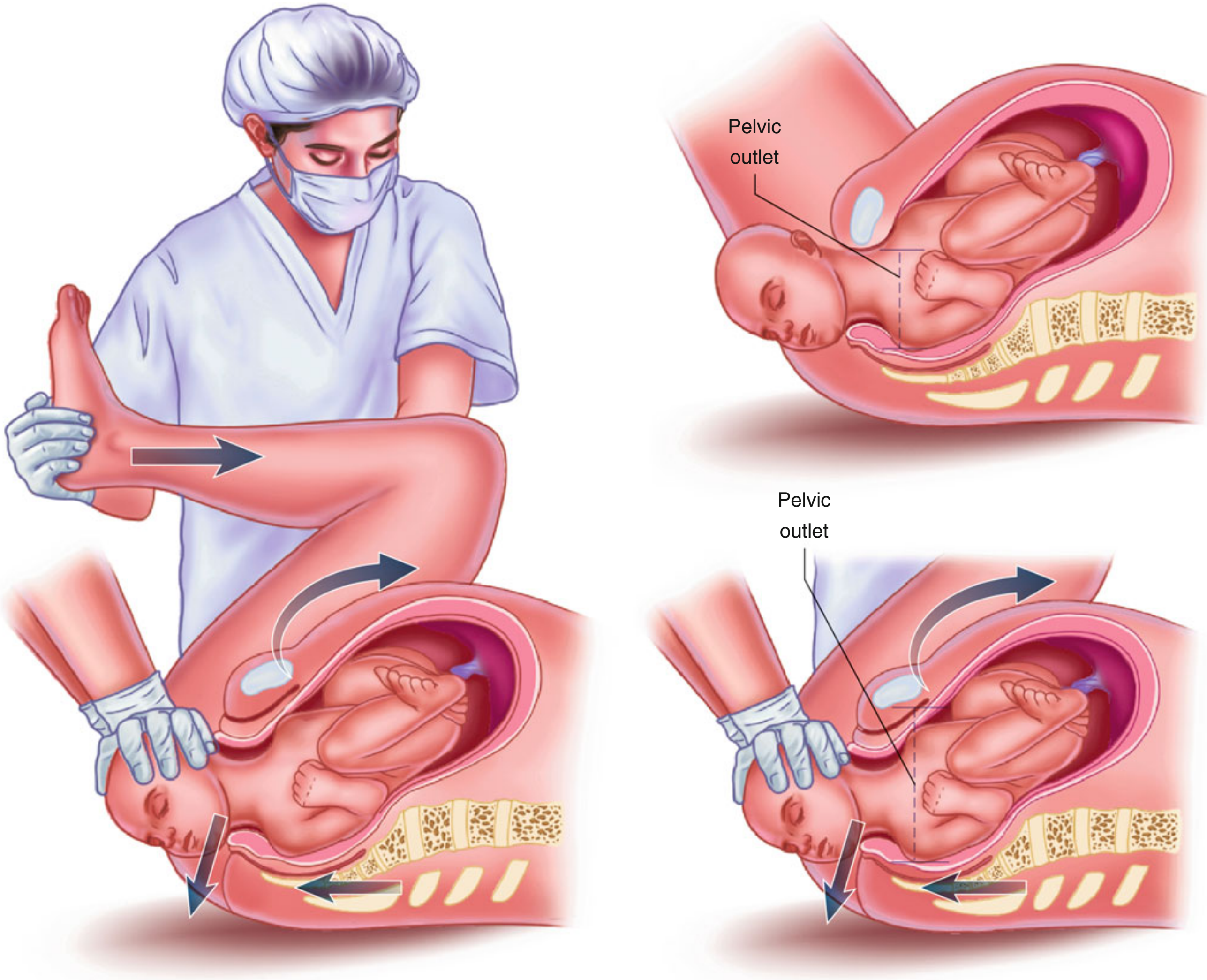
Pelvic outlet
Pelvic outlet

Fig. 117.4 The McRoberts maneuver in vertex (head-first) presentation

20. Maintain the baby in the same plane as the vagina (support the body with the forearm) and place the second and fourth fingers over the maxilla of the baby. Place the middle finger in the mouth or on the chin and the other hand on the upper back/occiput (Fig. 117.5).
    - Avoid extreme elevation of the fetus to prevent hyperextension and cervical spine injury. Piper forceps may also be used to promote flexion.
21. Deliver the head in the flexed position.
    - If the baby descends with the neck and abdomen facing anteriorly: Grasp the shoulders posteriorly with two fingers of one hand while the other hand flexes the abdomen and the baby's feet are brought upward (Fig. 117.6).
    - If the baby's neck remains extended: Leave the baby hanging (weight = traction). When the hairline appears under the symphysis, grab the baby by the feet and elevate upward (Fig. 117.7).
22. Clamp and cut the umbilical cord (collect arterial and venous samples for pH).
23. Suction the baby's mouth and nose, and resuscitate as indicated.
24. Deliver the maternal placenta.
25. Repair tears or episiotomy made during delivery.

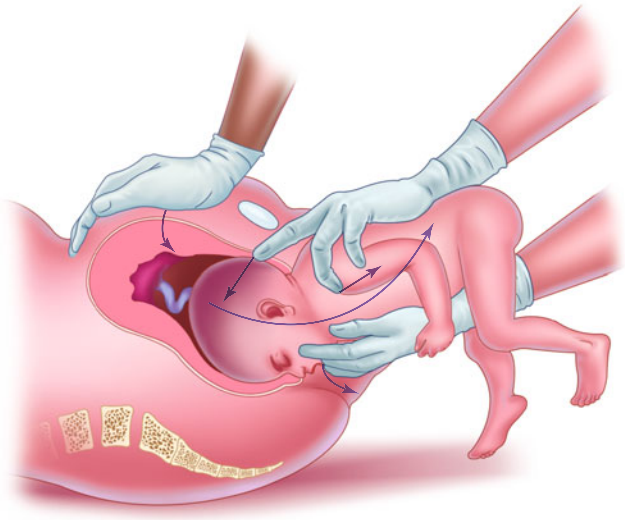

Fig. 117.5 Delivery of head in flexed position

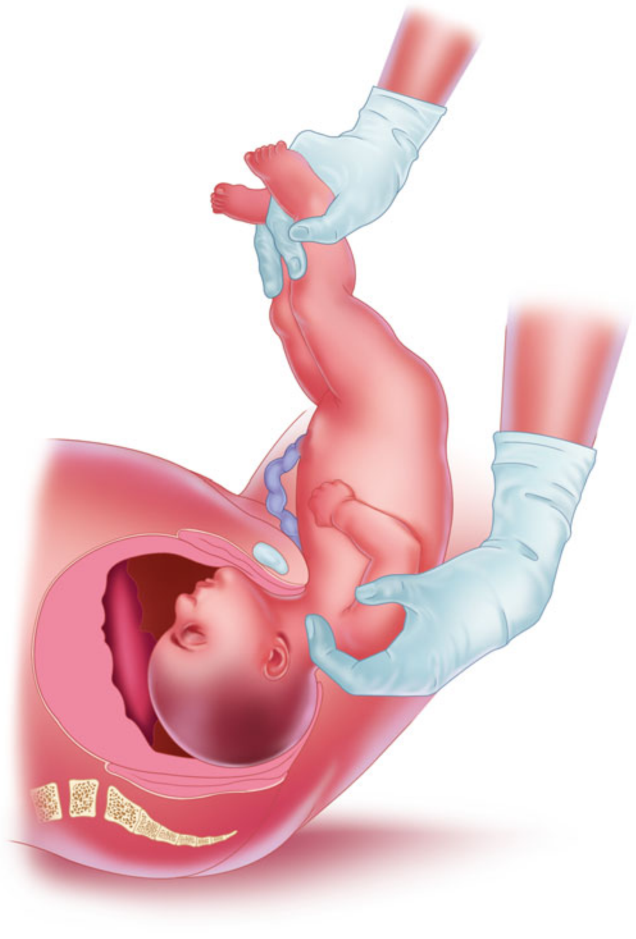

Fig. 117.6 Correct hand placement if abdomen facing anterior

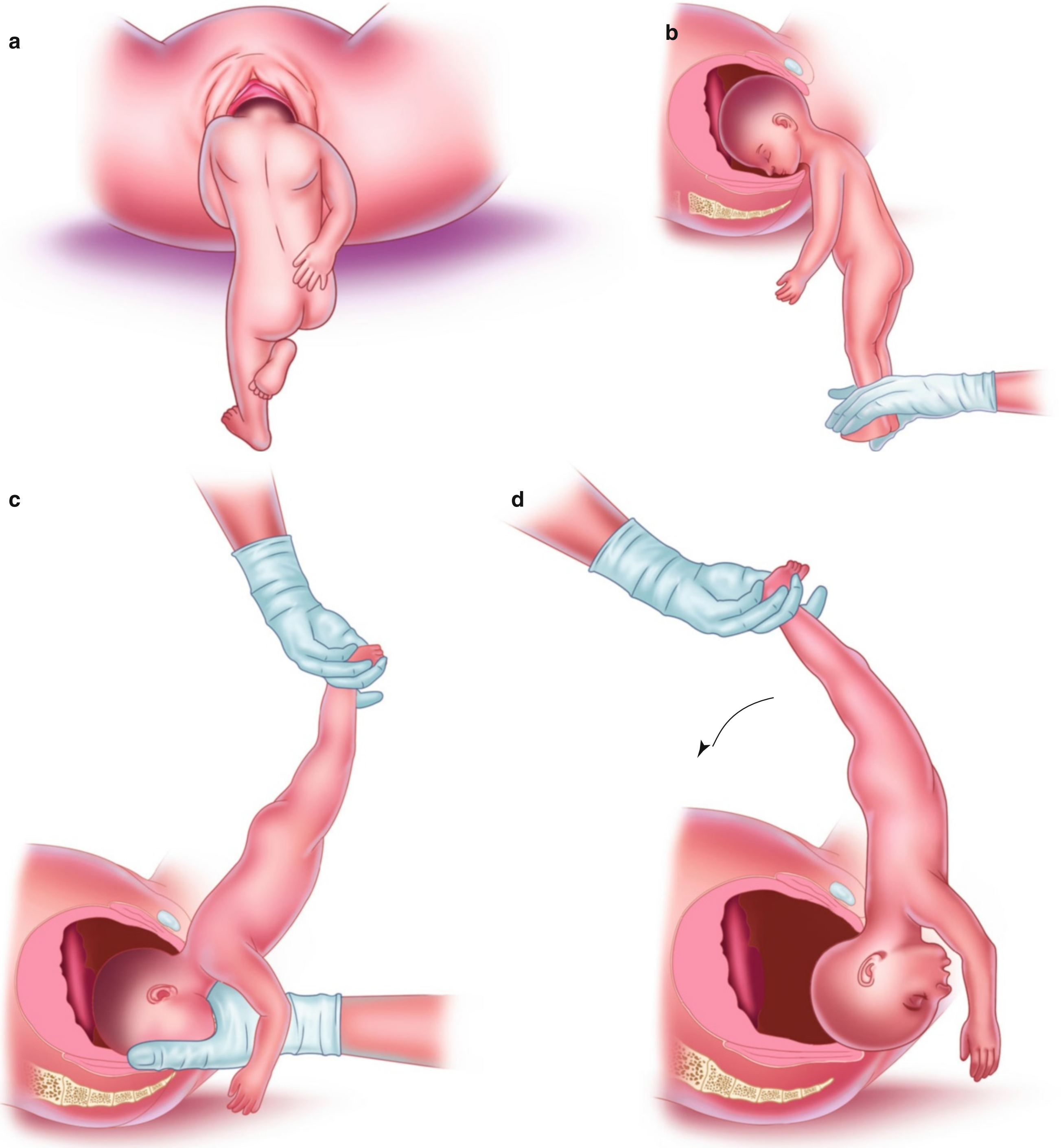

Fig. 117.7 The Burns-Marshall maneuver. (**a**) Allow baby to hang until you can see the hair at the nape of his neck; (**b**) swing the baby's head clear of the birth canal; (**c**) left hand guards and slips the perineum over fetal mouth; suction baby's air passage to clear mucus; (**d**) hold baby's feet

117.5 Complications

- Umbilical cord prolapse
- Brachial plexus injury (from the nuchal arm)
- Fetal head entrapment
- Cervical spine injury (from hyperextension of the neck)
- Birth asphyxia

117.6 Pearls and Pitfalls

- Pearls
  - Allow the uterine contractions to help deliver the baby.
- Pitfalls
  - Do not rush the delivery or use too much force. This can increase the risk of trauma to the baby and mother.
  - Beware of nuchal arm. To avoid brachial plexus injury: Rotate the face of baby toward the maternal symphysis pubis. This will reduce the tension keeping the arm around the back of the fetal head (Fig. 117.3).

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Management of Primary Postpartum Hemorrhage

118

Megan Kwasniak, Anton A. Wray, and Joseph A. Tyndall

Postpartum hemorrhage (PPH) is defined as ≥500 ml blood loss within 24 h of vaginal delivery or 1000 ml loss within 24 h of cesarean section. It is the leading cause of maternal mortality worldwide.

118.1 Indications

- Excessive vaginal bleeding with or without pain and/or hemodynamic instability within 24 h of delivery

118.2 Contraindications

- There are no absolute contraindications to the management of PPH.

118.3 Materials and Medications

- Sterile technique
- Good lighting
- Sponge forceps
- Gauze
- Towels
- IV fluids
- Type and screen/crossmatch of blood
- Absorbable suture with curved needle
- Needle holder
- Tooth forceps

118.4 Procedure

- Standard resuscitation measures: Place IV, O_2, monitor.
- Assessment and treatment should occur simultaneously.
- All techniques should be performed under strict sterile conditions.

118.4.1 Uterine Exam

1. Assess by placing the hand on the uterine fundus and checking its size and firmness.
2. High, soft, or boggy uterus implicates retained placenta or uterine atony. Start external fundal massage.
3. Non-palpable uterus implicates uterine inversion.

118.4.2 Vaginal Exam

1. Keeping one hand on the abdomen, gently examine the vaginal canal using the other sterilely gloved hand.
2. Gently scoop out any clots/retained placenta that are easily removable.
3. Look for traumatic sources of bleeding from the perineum, vaginal walls, and cervical lacerations.
4. Gauze-wrapped ring forceps can be used to assist direct visualization and clearing of clots.

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118.4.3 If Uterine Atony Suspected

1. Continue external fundal massage with the abdominal hand. Make a fist with the vaginal hand and start bimanual massage. Raise the uterus from the pelvis and pivot it anteriorly, compressing it between the external hand and the internal fist. This maneuver will result in expression of any clots present and decrease uterine bleeding via direct compression (Fig. 118.1).
2. Administer oxytocin (20–40 units in 1 L of normal saline or lactated Ringer's solution intravenously [IV]; alternatively give 10 units intramyometrially with a spinal needle).
3. Methylergonovine may also be used at this time if oxytocin fails to reduce uterine bleeding (100 or 125 mcg IV or intramyometrially; alternatively 200 or 250 mcg may be given intramuscularly).
4. Continue massage until bleeding slows and the uterus becomes more firm. This can take 15–30 mins.

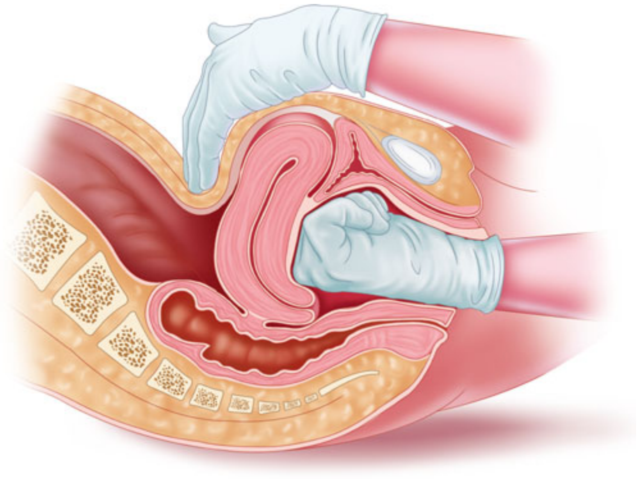

Fig. 118.1 Intrauterine massage for uterine atony

118.4.4 If Retained Placenta Suspected

1. Manual removal of the placenta or any of its retained tissue should be facilitated with sedation or additional analgesia.
2. Keeping the thumb and fingers together in a teardrop shape and using sterile technique as described previously, insert the hand through the vaginal canal and the cervix into the lower uterine segment.
3. Keep the other hand on the lower abdomen to continue gentle yet firm upward pressure and massage.
4. Find the placental edge within the uterus, grasp it gently, detach it from the uterine wall, and withdraw the hand from the patient.
5. Repeat the maneuver as necessary; remove any additional clots from the uterus and continue bimanual massage until it becomes firm and bleeding decreases.
6. If the entire placenta has been removed this way, an assistant should be available to inspect it for completeness and any torn vessels.
7. If the bleeding is particularly severe and placenta accreta is strongly suspected, pack the uterus with gauze and prepare the patient for urgent surgical intervention.

118.4.5 If Uterine Inversion Suspected

1. Using sterile technique, insert a fist through the vaginal canal and push the inverted fundus back through the cervical canal with pressure directed toward the umbilicus.
2. If the uterus has contracted, tocolytics such as IV magnesium sulfate or terbutaline can be used to aid myometrial relaxation. Alternatively, provided the patient is not overly hypotensive, nitroglycerin 50–100 mcg IV may be administered to relax the myometrium and facilitate return to normal uterine position.
3. If manual replacement is ineffective, hydrostatic reduction may be attempted. Warm fluids are run into the upper vagina under high pressure while occluding the introitus.

118.4.6 Trauma: Genital and Perineal Lacerations

1. For significant cervical lacerations: use absorbable sutures with a continuous interlocking stitch technique to close (Fig. 118.2).
2. For vaginal wound repair: place the initial and final stitch above the apices of the lacerations and grab a good amount of tissue with the needle. Small bites can lead to ongoing bleeding and hematoma formation.
3. Observe the repaired lacerations for any additional bleeding after the torn edges have been sutured.
    - Apply additional pressure to any site that continues to ooze blood; gauze-wrapped ring forceps may be used for this purpose if necessary.

If none of the above causes are apparent, consider underlying coagulopathies and treat appropriately. This may require administration of fresh-frozen plasma, platelets, or clotting factors as indicated.

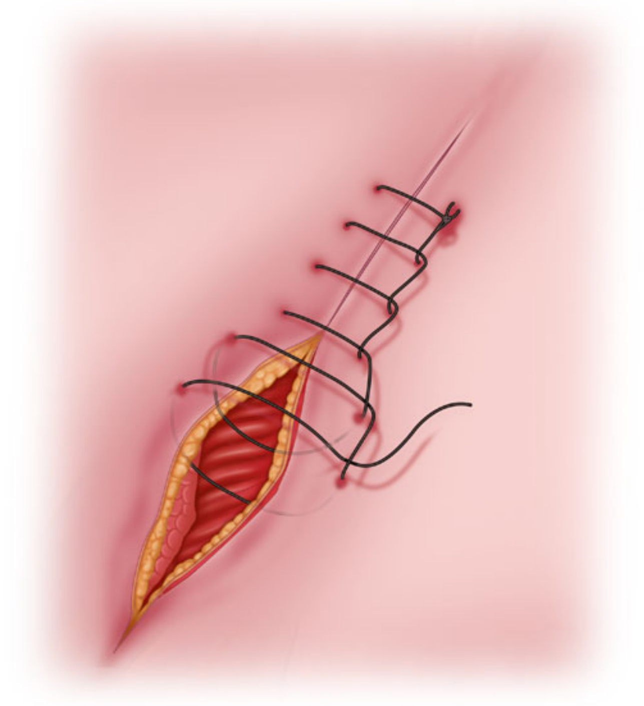

Fig. 118.2 Continuous interlocking stitch: perineal lacerations repair

118.5 Complications

- Uterine perforation and scarring
- Urinary and genital tract trauma and injury
- Genitourinary and genitointestinal fistula
- Pelvic hematoma
- Genital vascular injury
- Infection and sepsis
- Disseminated intravascular coagulation (DIC)
- Maternal death

118.6 Pearls and Pitfalls

- Pearls
    - Causes of PPH can be divided into the “5 Ts”:
        - Tone: uterine atony, occurring within the first 4 h after delivery.
        - *T*issue: retention of the placenta, especially placenta accreta and its fragments, more common at extreme preterm deliveries.
        - *T*rauma: injury to the uterus, cervix, and perineal structures after delivery of a large fetus, use of forceps and/or vacuum, frequent vaginal manipulation during delivery, and episiotomy procedures.
        - *T*hrombosis: intrinsic or acquired coagulation disorders, including idiopathic thrombocytic purpura (ITP); hemolysis, elevated liver enzymes, and low platelets (HELLP) syndrome; and disseminated intravascular coagulation (DIC), as well as preexisting conditions such as von Willebrand disease.
        - *T*raction: inversion of the uterus during placental delivery secondary to excessive traction on the umbilical cord. The uterine fundus can be within the endometrial cavity, in the cervical canal, or outside the external os and within the vaginal canal.
    - The administration of broad-spectrum antibiotics should be strongly considered following any manual removal, exploration, or instrumentation of the uterus and the genital tract.
    - Bedside ultrasonography can be very helpful for identifying uterine abnormalities, retained placental tissue, free fluid in the pelvis, and/or intrauterine hematoma.
    - Risk factors for PPH include prolonged active phase of labor, previous PPH, multiple pregnancy, and history of a bleeding disorder.
- Pitfalls
    - Failure to recognize and treat PPH early increases morbidity and mortality.
    - Underestimating the potential blood loss of PPH. The gravid uterus at term has a blood flow of 600 ml/min (non-gravid: 60 ml/h).

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119

Perimortem Cesarean Section

Jordana J. Haber, Elaine B. Josephson,
and Muhammad Waseem

119.1 Indications

- Maternal arrest with a viable fetus (gestation >24 weeks)

119.2 Contraindications

- Stable mother
- Fetus less than 24 weeks' gestation
- Extreme fetal prematurity
- Maternal hypoxia longer than 15 min

119.3 Materials and Medications

- Cesarean section instrument tray if available
  - #10 or #11 scalpel blade, scissors, bladder retractor, 2 large retractors, gauze sponges, hemostats, suction, forceps, and straight and curved clamps
- Skin antiseptic preparing solution, such as Betadine (povidone-iodine)
- Silk suture with needle driver or skin stapler
- Sterile drapes
- Sterile gloves
- Obstetrical pack (See Chap. 115)
  - Bulb syringe and umbilical cord clamp
- Clean blanket or towels for delivery
- Neonatal resuscitation equipment

Owing to the rarity of this procedure in the emergency department, it is unlikely to have a prepared cesarean section tray available. In this case, a thorocotomy or thorocostomy tray combined with an obstetrical pack would contain all the supplies needed. At a minimum, a scalpel and an obstetrical pack are necessary.

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119.4 Procedure

1. Prepare skin with antiseptic solution and a sterile drape.
2. Insert a Foley catheter to empty the bladder.
3. Continue cardiopulmonary resuscitation until delivery.
4. Obtain emergent obstetrician and neonatologist consult if available, but do not delay procedure.
5. Using a #10 or #11 blade, make a vertical midline incision beginning 4–5 cm below the xiphoid process and extend the incision to the pubic symphysis (Fig. 119.1).
6. Incise through the subcutaneous fat no further than the rectus sheath.
7. Lift the rectus sheath with a toothed forceps and make an incision with scissors to expose the uterus (Fig. 119.2).
8. With forceps and scissors, lift and incise the peritoneal membrane in the midline.
9. Identify and lift the bowel and cover it with saline-soaked gauze.
10. Retract the rectus sheath and bladder with a bladder retractor or, if not available, use saline-soaked gauze or a towel.
11. Create a 2- to 4-cm midline vertical opening in the uterus.
12. Place a finger in the opening directed caudally to protect the fetus while making a superior incision through the uterine wall. Once complete, repeat this step in the inferior direction.
13. Use a clamp to rupture the amniotic membranes. Immediately deliver the fetus and clamp the umbilical cord.
14. Expulse the head by placing a hand between the pubic symphysis landmark and the fetal occiput. Then, gently flex the fetus while simultaneously moving the head superiorly and anteriorly until delivery (Fig. 119.3).
15. Suction the mouth and nose with a bulb syringe immediately.
16. Deliver the shoulders, followed by the torso and extremities. Secure the umbilical cord with a hemostat or umbilical cord clamp 10 cm distal to the fetus and a second clamp 2 cm distal to this clamp. With scissors, incise the umbilical cord between the two clamps.
17. Immediately begin resuscitation of the infant (Fig. 119.4).
18. If the patient is still alive or regains vital signs, prepare to deliver the placenta. Begin with an oxytocin infusion at 20 U in 1 L at 10 mL/h. Apply cautious traction to the umbilical cord until the placenta separates from the uterus (Fig. 119.5).
19. Following delivery, the uterus should be closed using two layers with either 2-0 or 1-0 suture. In the case of maternal death, skin staples or a running stitch is an acceptable method of skin closure.

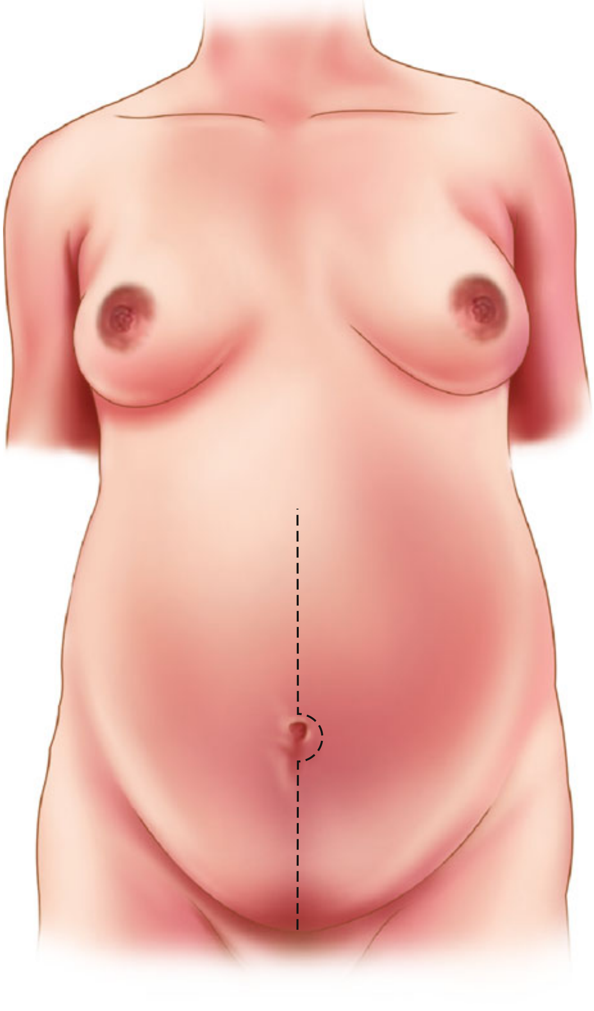

Fig. 119.1 Vertical incision

Fig. 119.2 Exposing rectus sheath

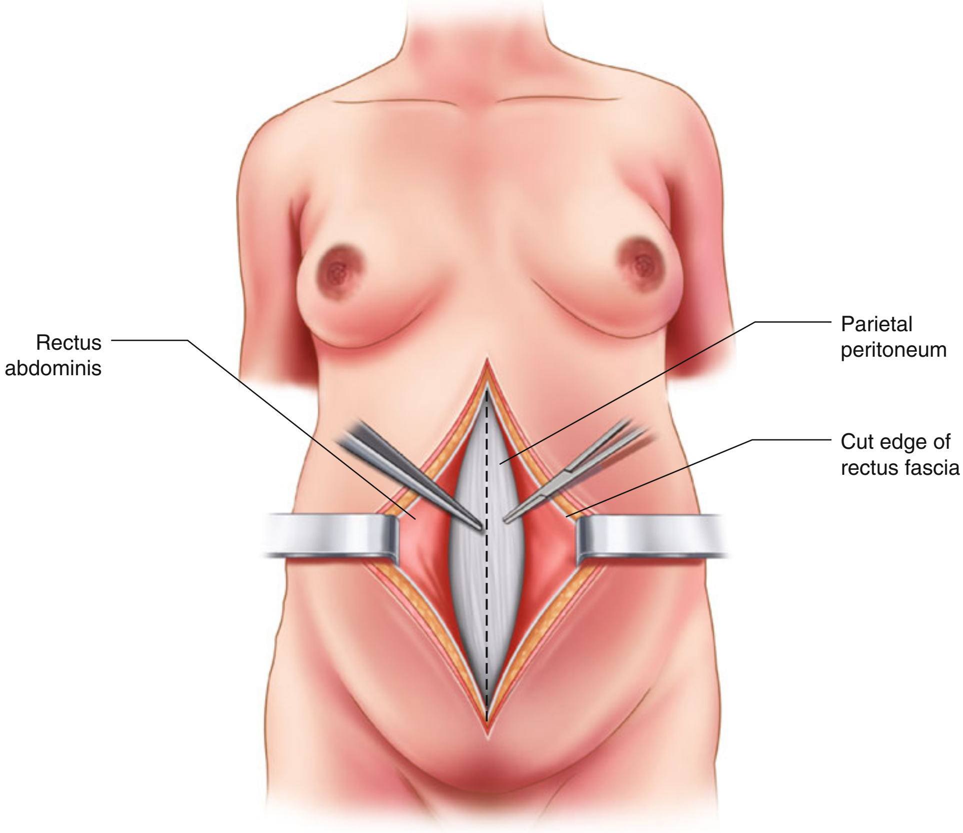
Rectus abdominis
Parietal peritoneum
Cut edge of rectus fascia

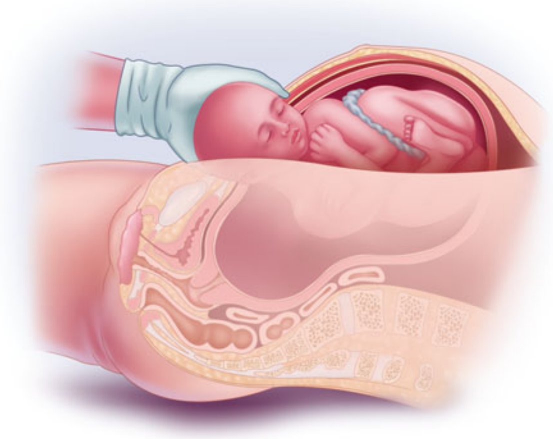

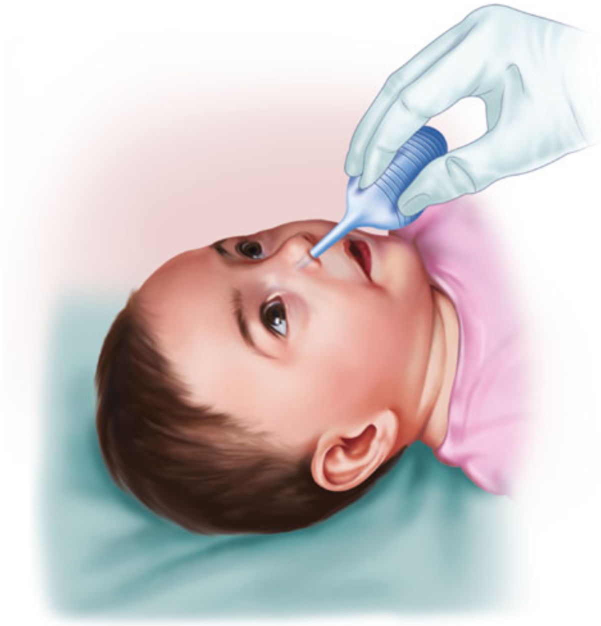

Fig. 119.3 Delivery of the fetus

Fig. 119.4 Suctioning newborn as part of resuscitation

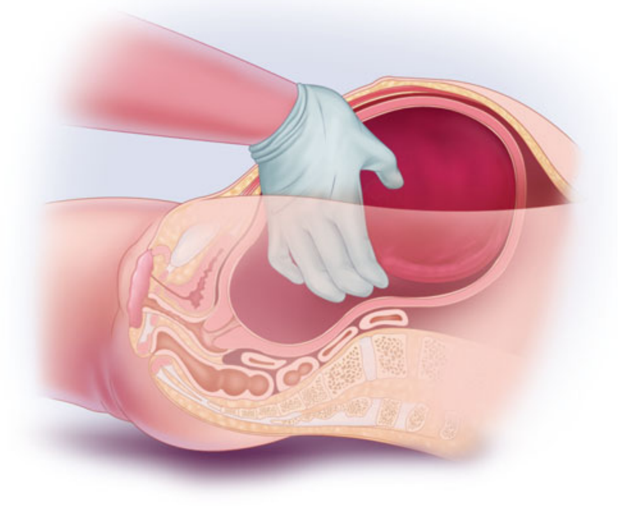

Fig. 119.5 Delivery of the placenta

119.5 Complications

- Maternal sepsis
- Maternal visceral injury
- Maternal hemorrhage
- Maternal death
- Fetal injuries and laceration
- Fetal sepsis

119.6 Pearls and Pitfalls

- Pearls
  - Perimortem cesarean section, although rarely performed, should be considered in any maternal arrest when the fetus is greater than 24 weeks' gestation.
  - In addition to saving the life of the fetus, this procedure may aid in resuscitation of the mother. Emptying of the uterus may improve thoracic compliance and, therefore, improve maternal ventilation.
- Pitfalls
  - The decision to perform an emergency cesarean section must be made early. There is a higher chance of survival if performed no more than 5 min after the onset of maternal cardiac arrest.

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Part XV

Common Pediatric Procedures

Peripheral Venous Catheterization

120

David N. Smith and Judith K. Lucas

120.1 Indications (See Also Chap. 2)

- Fluid resuscitation
- Medication administration
- Blood draws

120.2 Contraindications

- Relative
  - Avoid catheterizing areas of trauma in which extravasation of fluid is possible (e.g., burns, open wounds, or severe edema in tissue).
  - Avoid catheterizing in an area of local infection for risk of inoculating the circulation with bacteria (e.g., cellulitis).
- Absolute
  - None

120.3 Materials and Medications

- Gloves
- Skin disinfectant (isopropyl alcohol, chlorhexidine, or Betadine [povidone-iodine])
- Appropriate-sized catheter (18- to 24-gauge [IV]) (Fig. 120.1)
  - Large child: 18 to 20 gauge
  - Infant or small child: 22 to 24 gauge
- Tourniquet
- Sterile 2 × 2 gauze
- Appropriate-sized Tegaderm transparent dressing
- Adhesive tape
- IV bag with solution set (tubing flushed and ready) or saline lock
- Sharps container

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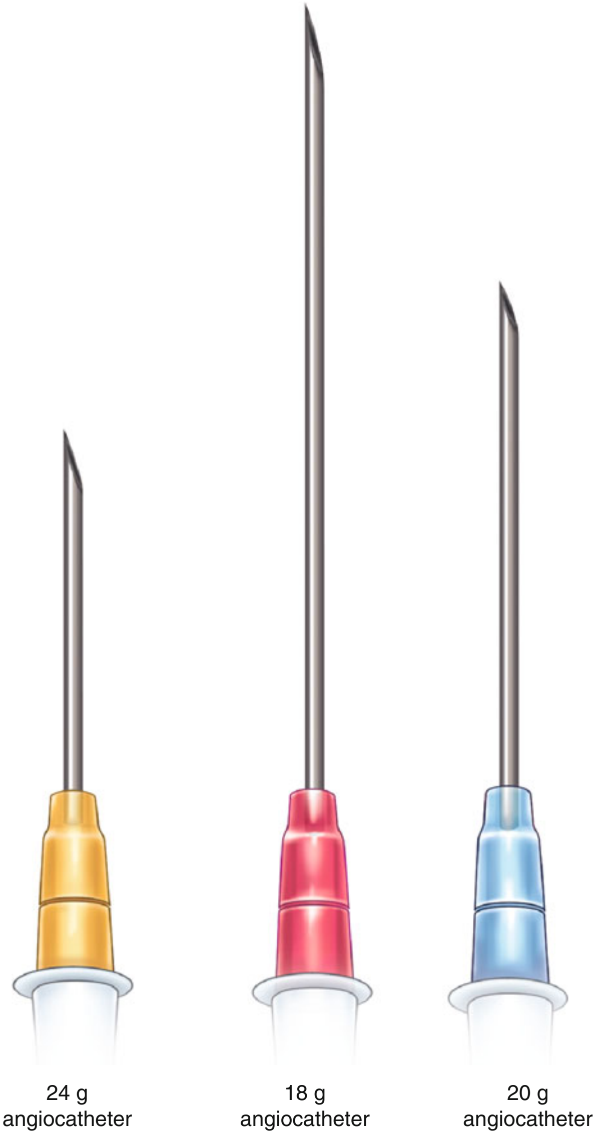

Fig. 120.1 24-Gauge angiocatheter (*yellow*), 18-gauge angiocatheter (*red*), 20-gauge angiocatheter (*blue*)

120.4 Procedure

1. Comfortably position the patient with the site exposed.
2. Assemble the equipment and don a pair of (nonlatex) examination gloves.
3. Apply the tourniquet to the extremity above the site to be catheterized (Fig. 120.2).
4. Visualize and palpate the vein.
5. Cleanse the site with a disinfectant swab using an expanding circular motion.
6. Prepare and inspect the catheter and flush the tubing; be certain that the stylet and catheter separate easily, then fit again into the notch, aligning the bevel with the hub.
7. Stabilize the vein and apply countertension to the skin, being careful not to touch the cleansed area.
8. Insert the stylet through the skin and then reduce the angle while advancing through the vein (Fig. 120.3).
9. Observe for "flashback" as blood slowly fills the flashback chamber.
10. Advance the needle approximately 1–2 mm further into the vein, depending on the gauge and age of the patient, to ensure that the catheter is within the vein.
11. Slowly advance the catheter into the vein while keeping tension on the vein and skin (Fig. 120.4).
12. While advancing the catheter, be certain to hold the stylet portion with the thumb and forefinger, so as to avoid advancing the needle portion into and through the opposite side of the vessel, thus "blowing" the vein.
13. When the catheter is advanced about halfway, slowly withdraw and remove the stylet while simultaneously continuing to advance the catheter to its hub.
14. Attach a 3-mL non-Luer-Lok syringe to the hub.
15. Remove the tourniquet.
16. Gently attempt to aspirate blood. The blood should be free flowing.
17. Secure the catheter by either placing a transparent occlusive dressing (e.g., Tegaderm) over the lower half of the catheter hub or taping over the catheter hub in a cruciate

fashion, taking care not to cover the IV tubing connection (Fig. 120.5).

18. Remove the cover from the end of the IV tubing and insert the IV tubing into the hub of the catheter (the tubing must have been flushed with IV solution before connecting with the catheter hub: the unit from the solution bag/bottle through the catheter must be air free).
19. Open up the IV roller clamp and observe for drips forming in the drip chamber.

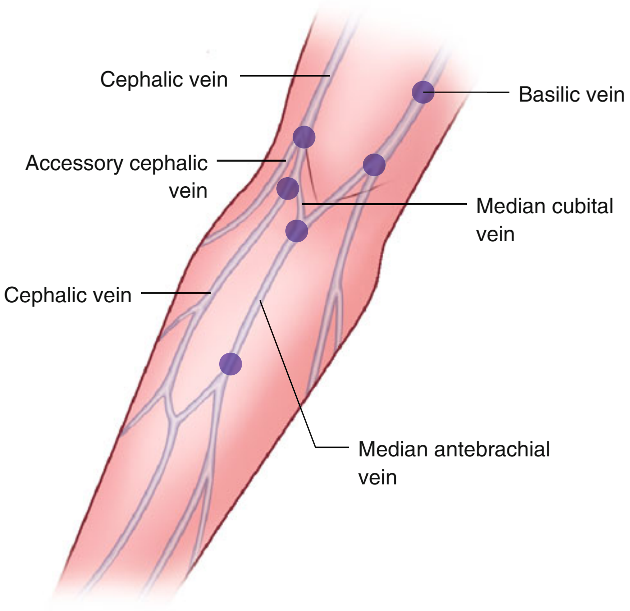
Cephalic vein
Basilic vein
Accessory cephalic vein
Median cubital vein
Cephalic vein
Median antebrachial vein

Fig. 120.2 Anatomy of the volar surface antecubital fossa and forearm

20. Place a piece of tape over the catheter hub then make a small (kink-free) loop in the IV tubing and place a second piece of tape over the first piece to secure the loop (Fig. 120.6).
21. Place a third piece of tape over the IV tubing above the site.
22. Ensure that the IV is properly secured and infusing properly.
23. Ensure that all "sharps" are placed in the sharps container.

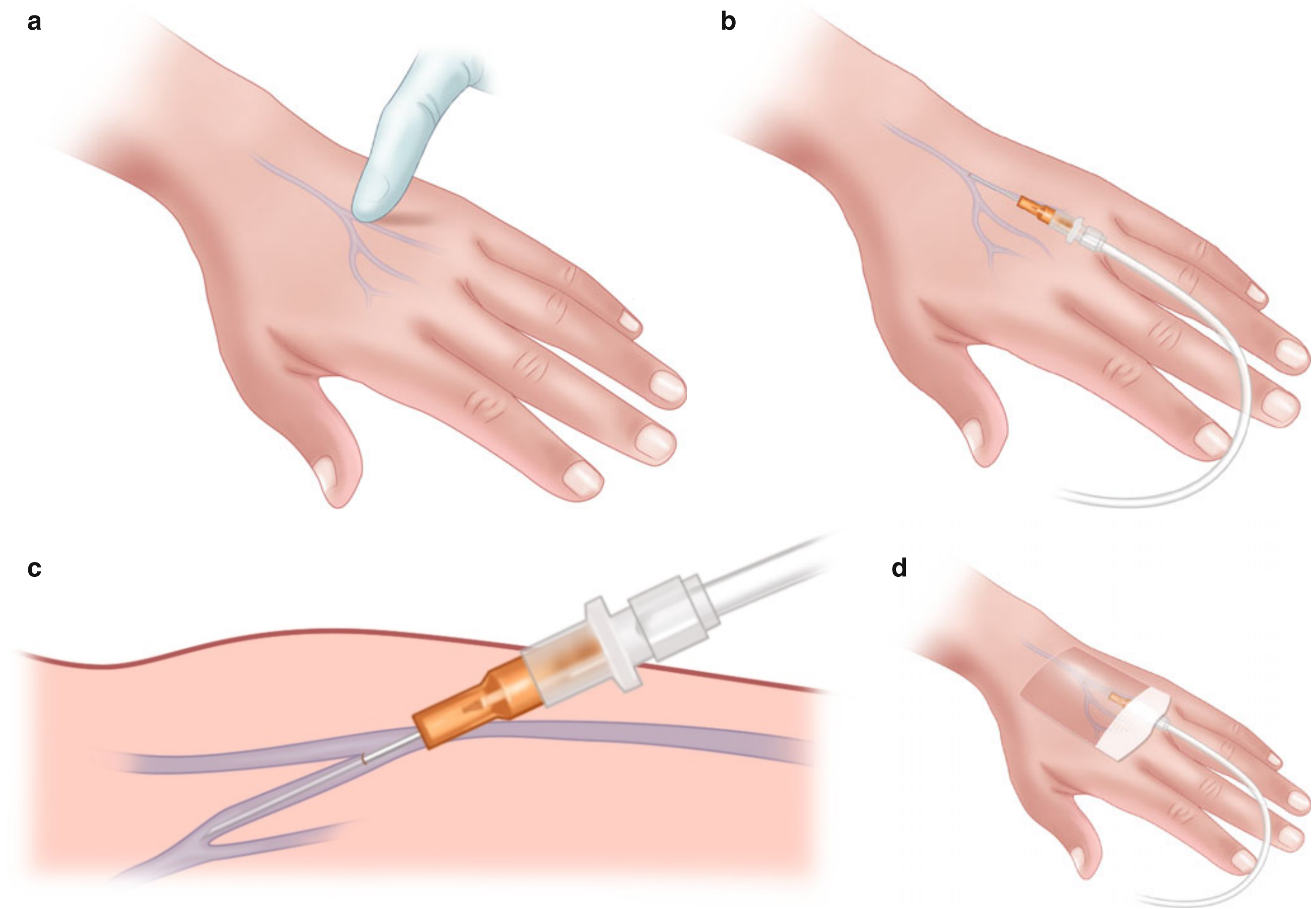

Fig. 120.3 (**a**–**d**) After applying the tourniquet, palpate a vein, as straight as possible, and ideally without many "knots" (i.e., valves)

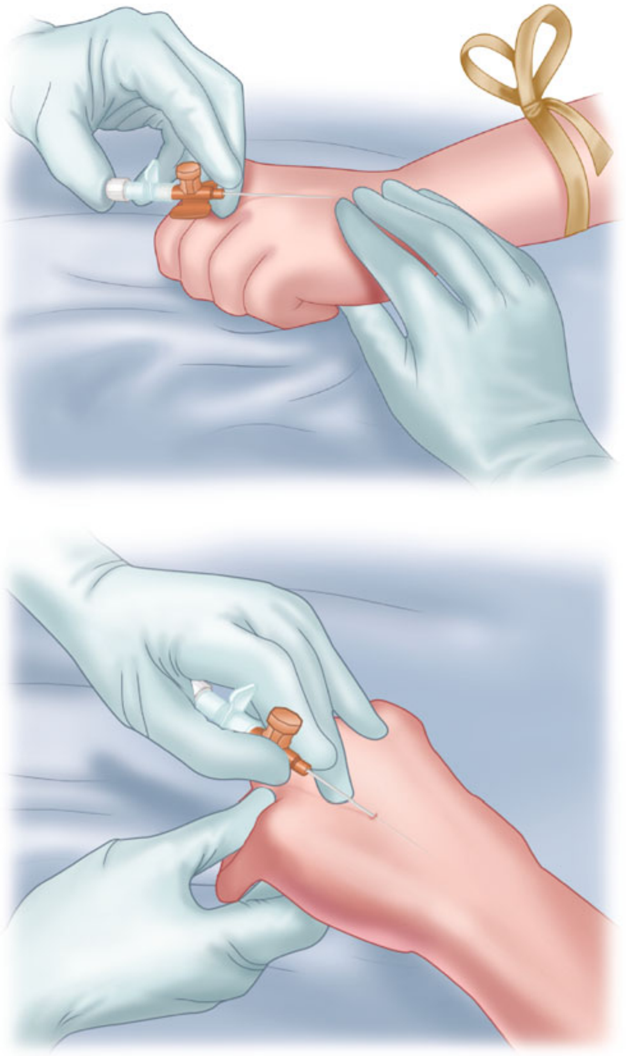

Fig. 120.4 With the tourniquet “up,” and the vein distended, apply traction to the skin, pierce the skin, and pass the catheter tip (into the vein) until blood return is noted in the catheter hub

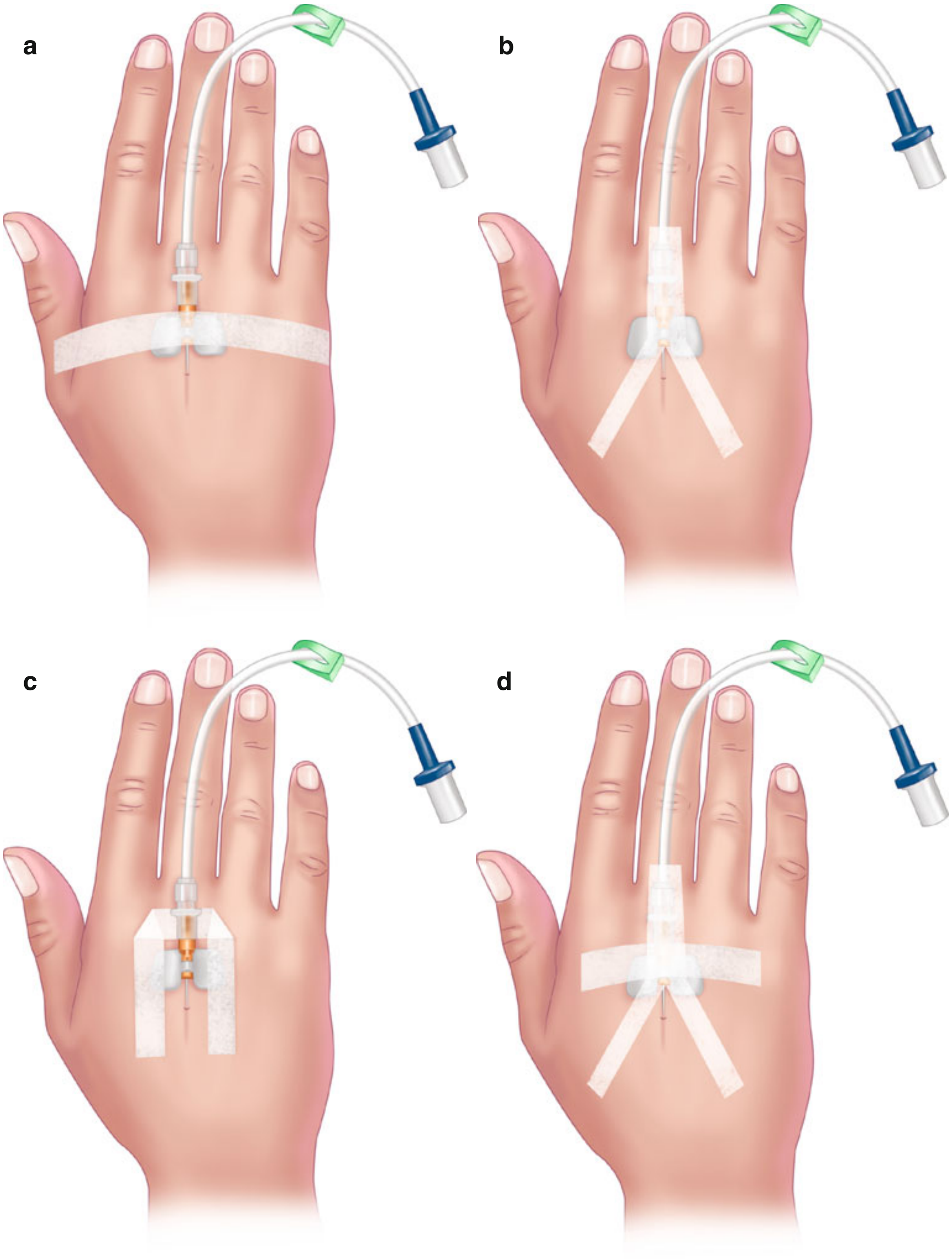

Fig. 120.5 (**a**–**d**) Securing the intravenous line utilizing the cruciate taping style

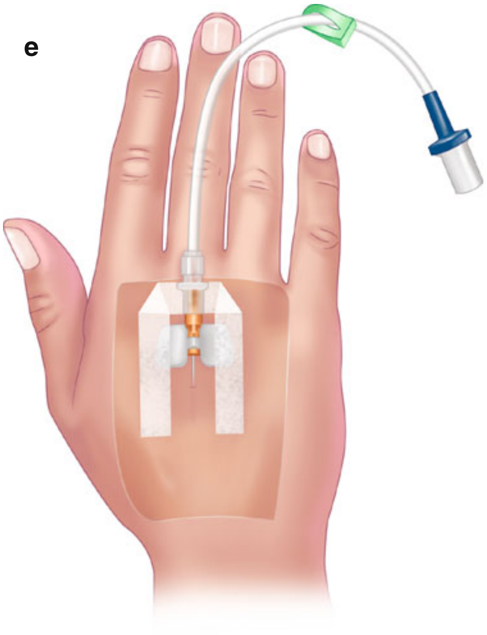

Fig. 120.5 (continued)

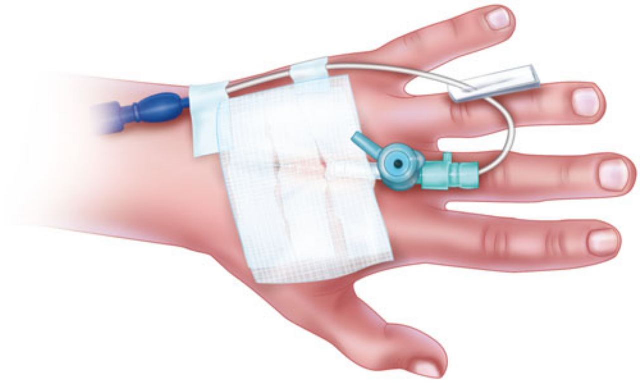

Fig. 120.6 Commercially available hub stabilizer, minimizing the need for excessive tape

120.5 Pearls and Pitfalls

- Pearls
  - Start catheter attempts distal in the extremities and move proximally with each subsequent attempt.
  - The use of ultrasound or a light source in infants can aid in location of the vessel and placement of the line.
  - In an emergent situation, in which fluids or medications are needed quickly, intraosseous access (see Chap. 122) can be obtained if venous catheterization fails.
- Pitfalls
  - The use of lidocaine subcutaneously can improve patient comfort, but it does disrupt anatomical landmarks.

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Umbilical Venous Catheters (Insertion and Removal)

121

Judith K. Lucas

121.1 Indications

- Temporary vascular access for infants up to roughly 10 days of life (between 7 and 14 days) with shock or cardiopulmonary failure
- Emergency vascular access in this age group, when peripheral intravenous (IV) access cannot be rapidly obtained
- Preferred vascular access in infants less than 1000 g

121.2 Contraindications

- Omphalitis
- Omphalocele
- Necrotizing enterocolitis
- Peritonitis

121.3 Materials and Medications

- Anesthetic: not necessary; procedure is painless
- Soft ties to restrain infant's extremities
- Sterile gloves/gowns
- Antiseptic solution
- Sterile towels/drapes
- 3.5- (infants <1500 g) or 5-French (>1500 g) umbilical venous catheter
- 5-French feeding tube
- Three-way stopcock
- 10-mL syringe with heparinized saline flush (1 U/mL)
- Umbilical tape or 3-0 silk on a cutting needle
- Non-toothed forceps
- Small hemostats (2)
- #11 scalpel and blade
- Scissors
- Graph depicting length of catheter insertion, if placing umbilical venous catheter (UVC) above the diaphragm in either very small infants or infants for whom measurement of central venous pressure (CVP) is indicated (Fig. 121.1)

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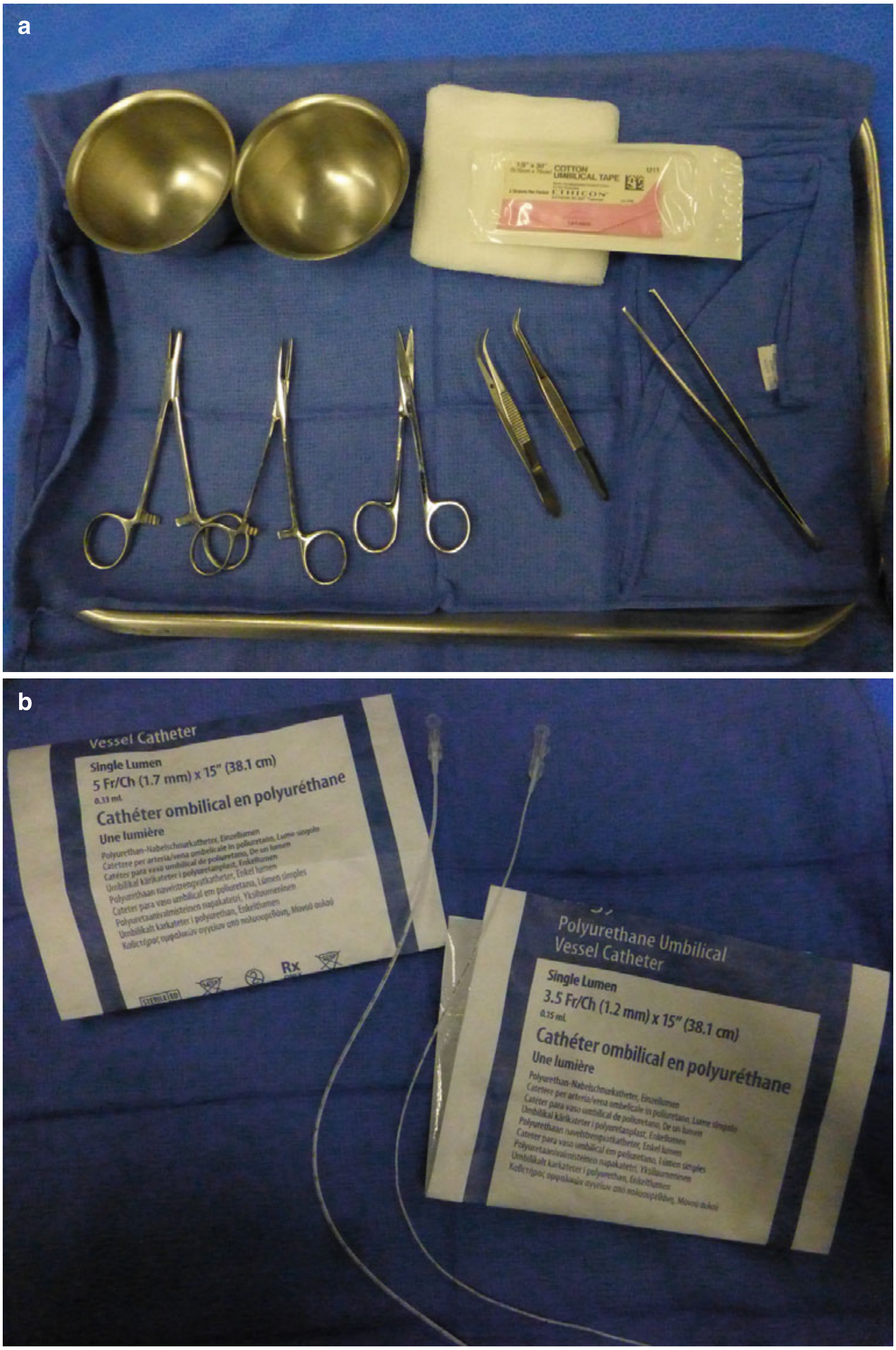
a
COTTON UMBILICAL TAPE
ETHICON
b
Vessel Catheter
Single Lumen
5 Fr/Ch (1.7 mm) x 15" (38.1 cm)
Cathéter ombilical en polyuréthane
Une lumière
Rx
Polyurethane Umbilical Vessel Catheter
Single Lumen
3.5 Fr/Ch (1.2 mm) x 15" (38.1 cm)
Cathéter ombilical en polyuréthane
Une lumière

Fig. 121.1 (**a**) Instrumentation suggested for umbilical venous catheter placement. (**b**) Umbilical venous catheters (in an emergency, 5 F feeding tube is an acceptable alternative)

121.4 Procedure (Insertion)

1. Place the infant under a radiant warmer.
2. Using soft ties, restrain the infant's extremities.
3. Scrub the umbilicus and surrounding abdomen with antiseptic solution.
4. Drape the umbilicus and area in sterile manner (leave the infant's head exposed).
5. Tie a loose loop with the umbilical tape around the base of the cord OR run the 3-0 silk through the skin *of the cord* in a purse-string fashion.
   - This will be used later to anchor the line after placement and to provide hemostasis should the line accidentally be pulled out and bleeding ensue.
6. Using the scalpel blade, cut the umbilical cord horizontally approximately 2 cm above the junction between the cord and the skin.
7. Identify the umbilical vessels
   - The vein is thinner walled, larger in diameter, and somewhat floppy appearing, relative to the umbilical arteries, and typically located at the 12 o'clock position.
   - The arteries are smaller, thick walled, and paired (a single umbilical artery often signifies the presence of a congenital malformation/syndrome) and located at the 4 and 8 o'clock positions (Fig. 121.2).
8. Place the stopcock on the receiving end of the umbilical catheter or the 5-French feeding tube and flush with heparinized saline solution, and then close the stopcock.
   - It is imperative that there is no air in the catheter.
9. Introduce a closed smooth-surfaced forceps into the lumen of the umbilical vein and allow the forceps to separate, allowing the vein to dilate (Fig. 121.3).
10. Insert the catheter (or feeding tube) into the lumen and gently advance, directing the catheter toward the right shoulder (Fig. 121.4).
11. Advance the catheter only until good blood flow is noted and then another 1 to 2 cm (this should be a total of only 4–5 cm in a term infant).
    - *Do not force the advancement.*
    - At this level the tip of the catheter should still be inferior to the liver (Fig. 121.5).
12. Tighten the umbilical tie or the purse-string suture.
13. Secure the catheter with a tape bridge (Figs. 121.6, 121.7, and 121.8).
14. Although if placed only up to point of blood return, the catheter tip should be below the liver; it is best to get an abdominal x-ray to confirm; many solutions are caustic to the liver and can result in complications.

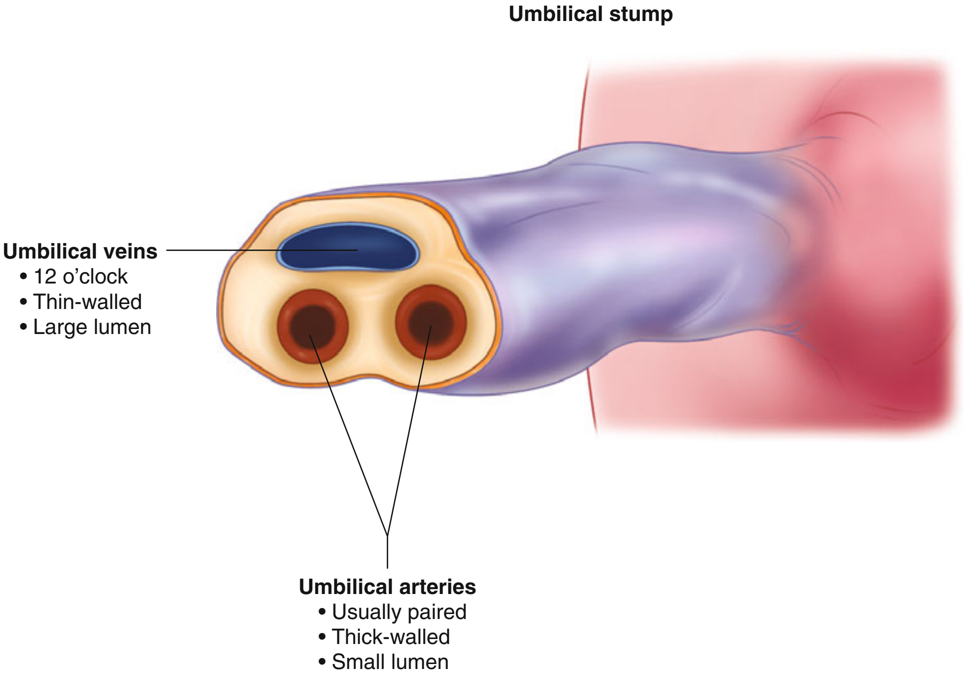

Fig. 121.2 Anatomy of the umbilical cord when cut transversely approximately 2 cm from abdominal wall

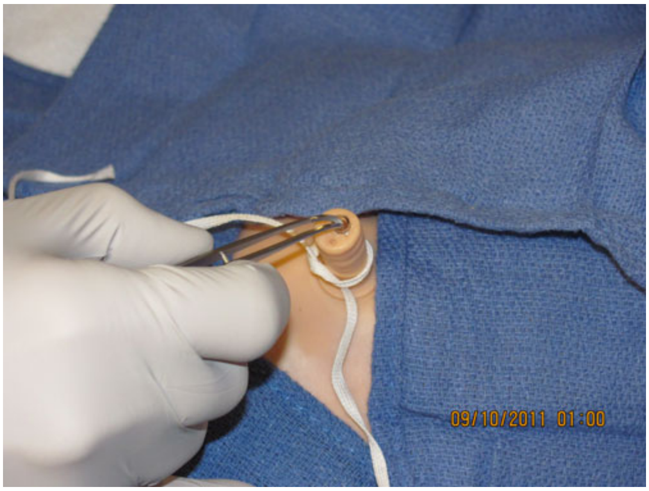

Fig. 121.3 Sterilely draped umbilicus, with umbilical tape loosely tied at base of umbilical cord. This tie will be cinched and secured once the catheter is placed, but meanwhile, can assist with homeostasis should the catheter be inadvertently dislodged during placement. Gently dilate the umbilical vein with a smooth toothed forceps. Insert the distal most couple of mm of a closed forceps into umbilical vein and relax, so the forceps tips smoothly separate

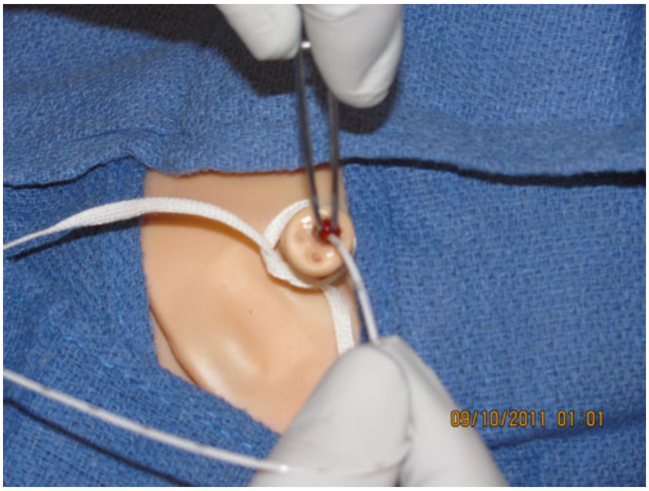

Fig. 121.4 Gently pass the umbilical venous catheter (or 5 F feeding tube) until there is easy blood return

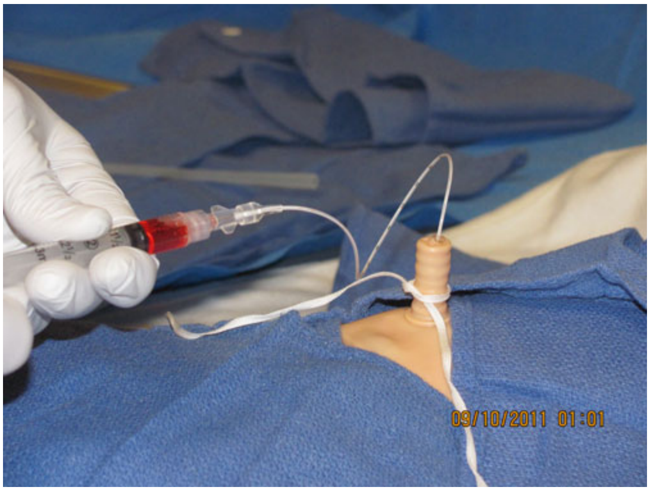

Fig. 121.5 Once there is easy blood return, pass the catheter an additional 1–2 cm. The catheter should still be inferior to the liver at this point

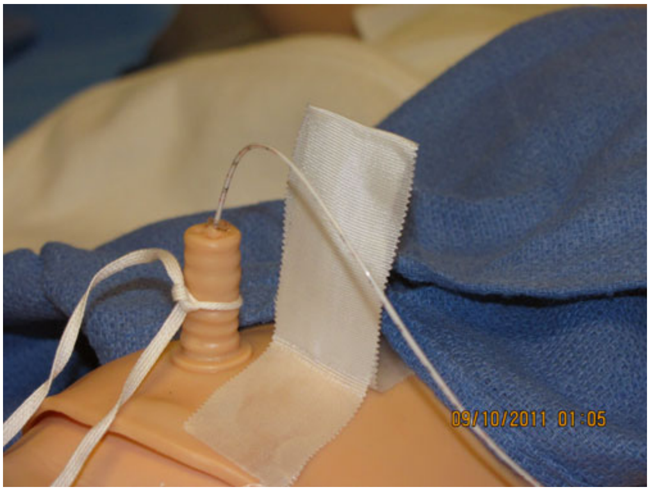

Fig. 121.6 Creating an umbilical catheter tape bridge: the uprights

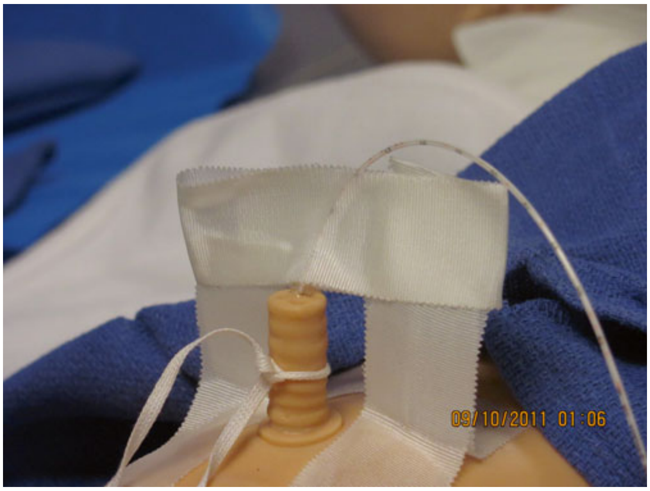

Fig. 121.7 Umbilical tape catheter bridge: the "cross bar" secures the catheter without applying tape to the umbilical stump

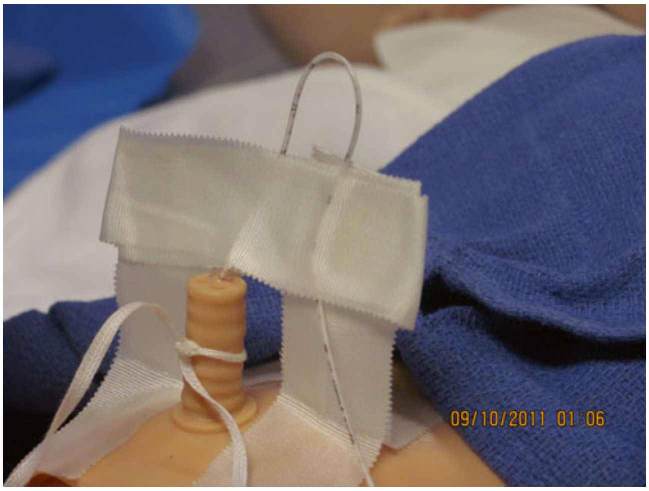

Fig. 121.8 Fold the catheter over to create a "U." Be careful not to kink the catheter, and secure with a second taped cross bar to lend additional security to the catheter and prevent displacement

121.5 Procedure (Removal)

1. The UVC should be removed as soon as adequate peripheral venous access is obtained (unless in an infant estimated to weigh <1000 g).
2. Turn infusions off.
3. Be certain the stopcock is closed to the infant.
4. It is imperative that there be no air in the catheter before withdrawal (if air is present and infant takes inspiration, the negative pressure generated can pull significant amount of air into the central vasculature).
5. Remove the securing tape from the infant.
6. Withdraw the catheter gradually as a single maneuver.

121.6 Complications

- Infection
- Bleeding due to disconnection of tubing (*always use Luer-Lok connections*) or perforation of vessels
- Arterial injury by accidental perforation
- Hepatic injury and necrosis if the catheter sits within a portal vein
- Thrombosis
- Air embolus
- Dysrhythmia or pericardial tamponade or perforation if catheter is advanced too far

121.7 Pearls and Pitfalls

- Pearls
  - The umbilical vein is 2–3 cm long before it widens into the umbilical recess, just before intersecting with the left portal vein and the ductus venosus.
  - Be certain to include the length of the umbilical stump in any calculations for placement.
  - If using the calculating graph, measure from the right shoulder to the umbilicus (Fig. 121.9).
- If choosing the above-diaphragm site for placement, corkscrewing the catheter clockwise while passing the catheter will encourage it to pass through the ductus venosus.
  - A kidney, ureter, and bladder study is mandatory in high UVC placement.
- Pitfalls
  - When preparing with Betadine (povidone-iodine), be certain to wipe away and remove any pooled Betadine along the infant's side because this will cool the infant initially; as the Betadine is warmed, it becomes highly irritating to newborn skin.

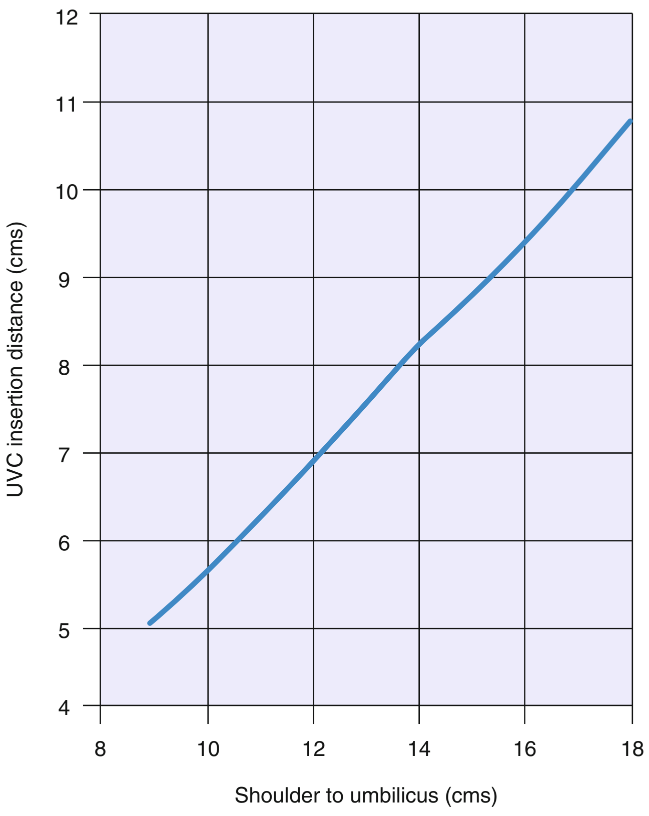

Fig. 121.9 Graph for estimation of insertion distance of the catheter; be certain to add the length (cm) of the umbilical stump to the insertion distance

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122

Intraosseous Access

Judith K. Lucas

122.1 Indications

- During cardiac arrest: Failure to attain vascular access after three peripheral intravenous attempts or 90 s, whichever comes first
- Inability to gain vascular access in pediatric patients presenting in shock due to hemorrhage (trauma), sepsis, profound dehydration, or cardiac failure

122.2 Contraindications

- Absolute
  - Fracture of the long bone considered for intraosseous (IO) access
- Relative
  - Previous IO access attempt in the same long bone
  - Cellulitis over the insertion site
  - Inferior vena cava injury (circulatory access proximal to the injury site is preferred).
  - Osteogenesis imperfecta

122.3 Materials and Medications

- Preparation materials, such as an antiseptic solution and sterile drapes, IF the patient's stability offers the time.
- Lidocaine without epinephrine: If it becomes necessary to place an IO in a conscious patient, use lidocaine to anesthetize the skin to the bony cortex; then once accessed, infiltrate 2–3 mL into the marrow to alleviate some of the pain of medications infusing through the marrow.
- IO needle (a few examples shown) (Figs. 122.1, 122.2, and 122.3).

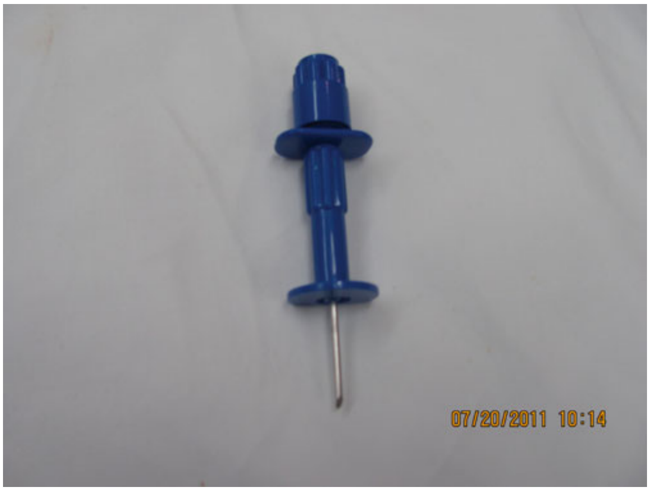

Fig. 122.1 Jamshidi disposable sternal/iliac aspiration needle (Jamshidi, Cardinal Health Dublin, OH)

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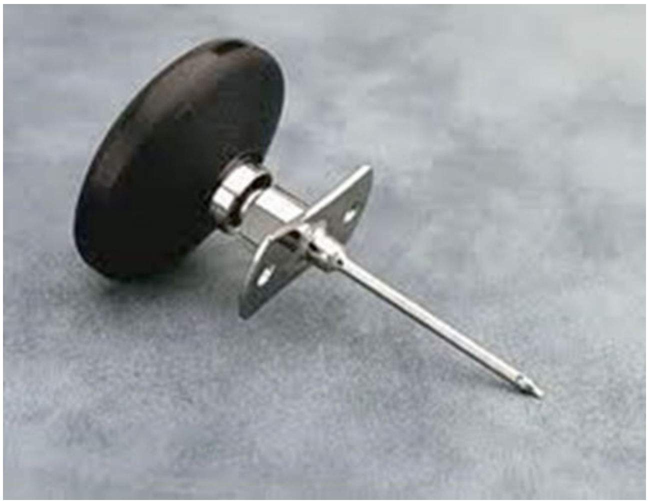

Fig. 122.2 Cook intraosseous needle (Cook Critical Care, Bloomington, IN)

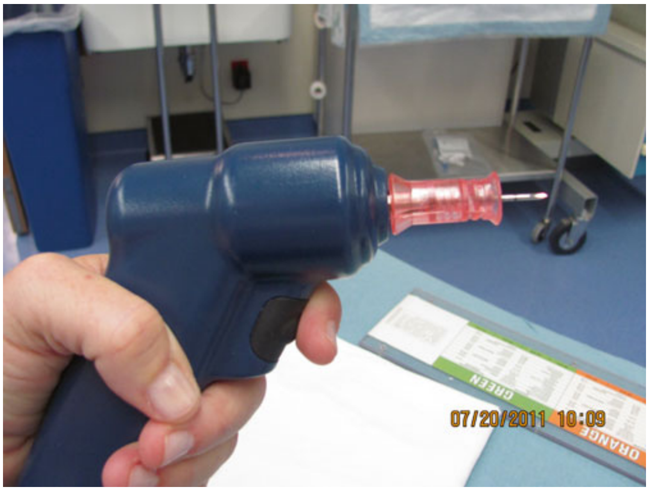

Fig. 122.3 EZ-IO (Vida-Care, San Antonio, TX)

122.4 Procedure

- Most common site: proximal tibia
  1. Patient should be supine, with the intended leg slightly externally rotated and flexed at the hip. Flex the knee about 90°.
  2. Place a towel underneath the knee and the proximal lower leg.
  3. Palpate the tibial tuberosity. Then move fingers 2 cm distal to the tuberosity (1–2 fingerbreadths) and 2 cm medial. This area is consistently flat and is distal to the growth plate (Figs. 122.4 and 122.5).
  4. If the patient is stable, create a sterile field focused on the insertion site.
  5. Insertion site should be cleaned with an antiseptic solution.
  6. Pass the needle through the skin and subcutaneous tissue to the cortex.
  7. Once bone is reached, stabilize the IO with the thumb and first fingers adjacent to where the needle penetrates the skin.
  8. Apply steady and firm pressure downward and with a twisting motion (back and forth) with the palm on the end of the device. Although inserting the needle perpendicularly to the bone is totally acceptable, ideally angling the needle caudally slightly (~15°) will avoid the growth plate (Fig. 122.6).
  9. As the cortex is fully penetrated indicating entrance into the marrow space, one *may* feel an ease in resistance. Do not advance the needle further. The needle should be able to stand up without support.
  10. Remove the inner trocar (Fig. 122.7).
  11. Attempt to aspirate marrow/blood. Not being able to do so DOES NOT mean inadequate or inaccurate placement. Instead, if marrow cannot be aspirated, affix a 10-mL syringe with normal saline and attempt to infiltrate. Resistance to flow should be minimal, and one should not appreciate either extravasation around the insertion site, coolness, or tissue expansion posterior to the site (indicating the fluid is passing through the IO).

12. Once placement is confirmed, connect an intravenous line, using a three-way stop-cock.
13. Secure the needle with tape and gauze (Fig. 122.8).

- Alternative sites
  - – Distal tibia
    - The landmarks are the medial aspect of the tibia (the flat portion), 2 fingerbreadths proximal to the medial malleolus.
    - Again, externally rotate and abduct the hips, with the knee flexed about 60° (as with the proximal tibia).
    - Angle the needle toward the knee (cephalad) about 10–15° to avoid the distal tibia growth plate.
    - The remainder of the IO insertion is identical to the procedure for proximal tibia placement.
  - – Distal femur
    - Slightly flex and externally rotate the hip.
    - Flex the knee enough that the quadriceps muscle group is relaxed.
    - The landmarks for the distal femur are the anterior thigh, midline, about 3 fingerbreadths proximal to the medial and lateral condyles.
    - The IO is inserted perpendicular to the bone (because there is no growth plate in the distal femur other than the condyles).
    - The remainder of the procedure is identical to the procedure for placement in the proximal tibia.
  - – Proximal humerus (Fig. 122.9)
    - The patient should be supine, with the shoulder, upper arm, and elbow as close to the body as possible, yet still on the bed. The elbow should be flexed at 90°, with the forearm and palm resting on the patient's abdomen.
    - The provider slides his or her thumb up the anterior shaft of the humerus toward the shoulder until the greater humerus tubercle is palpated, which identifies the surgical neck of the humerus.
    - The insertion site is perpendicular to the humerus, approximately 1–2 fingerbreadths proximal to the tubercle.
    - The remainder of the insertion is identical to that for the proximal tibia.
  - – Sternum (not usually recommended for small children).
    - Requires a special IO needle and system.
    - Method of placement is specific to the insertion system chosen.
    - Manubrium is the desired site (as opposed to the body of the sternum, which would interfere with cardiopulmonary resuscitation).
    - Risks specific to sternal placement include pneumothorax, mediastinitis, and great vessel injury.

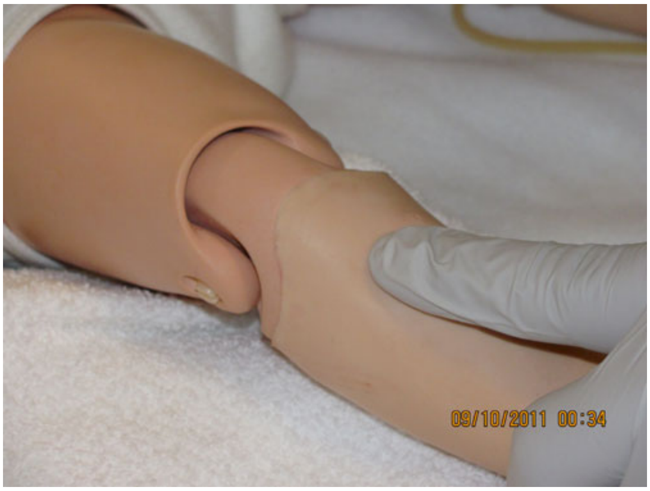

Fig. 122.4 Step 1. Identify the tibial tuberosity

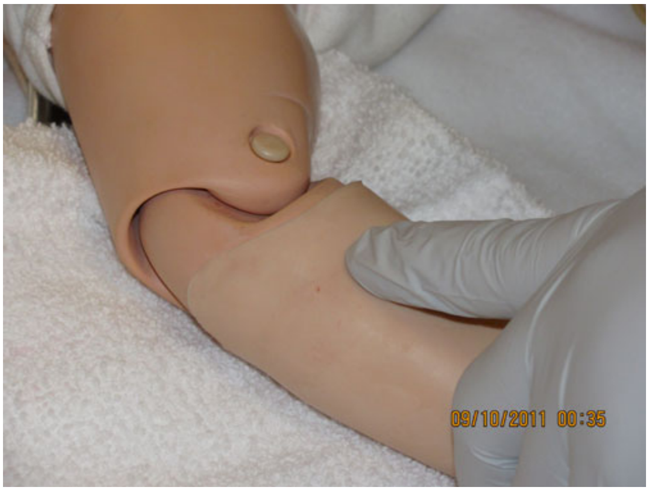

Fig. 122.5 Step 2. One to 2 fingerbreadths below the tuberosity and medially, to the flat aspect of the proximal tibia

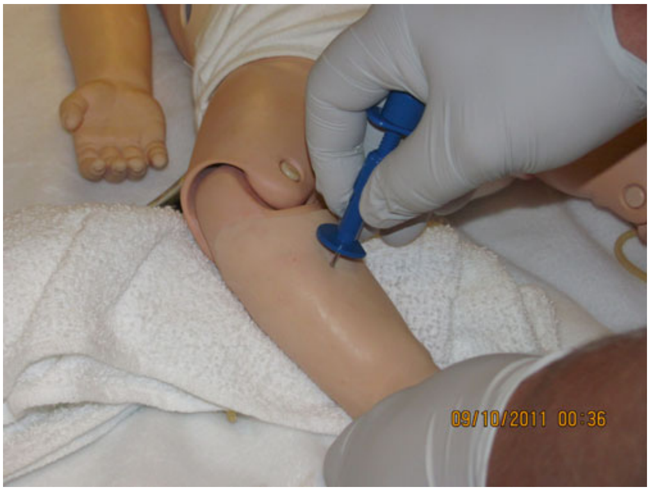
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Fig. 122.6 Step 3. Angle the device slightly caudal to avoid growth plate

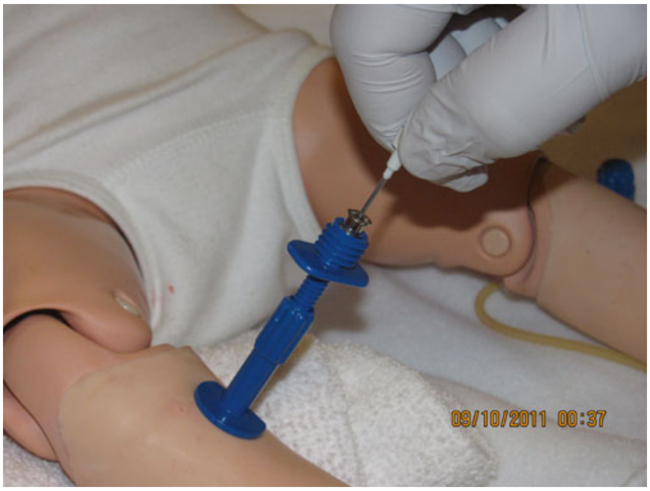
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Fig. 122.7 Step 4. Uncap the top of the device and remove the trocar

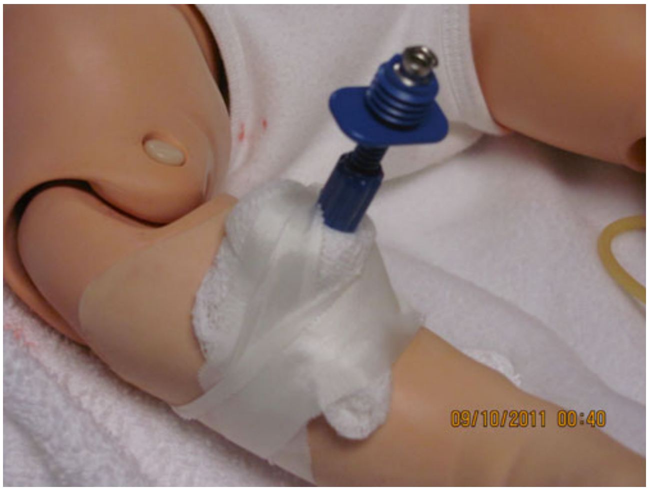
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Fig. 122.8 Step 5. Stabilize the intraosseous cannula

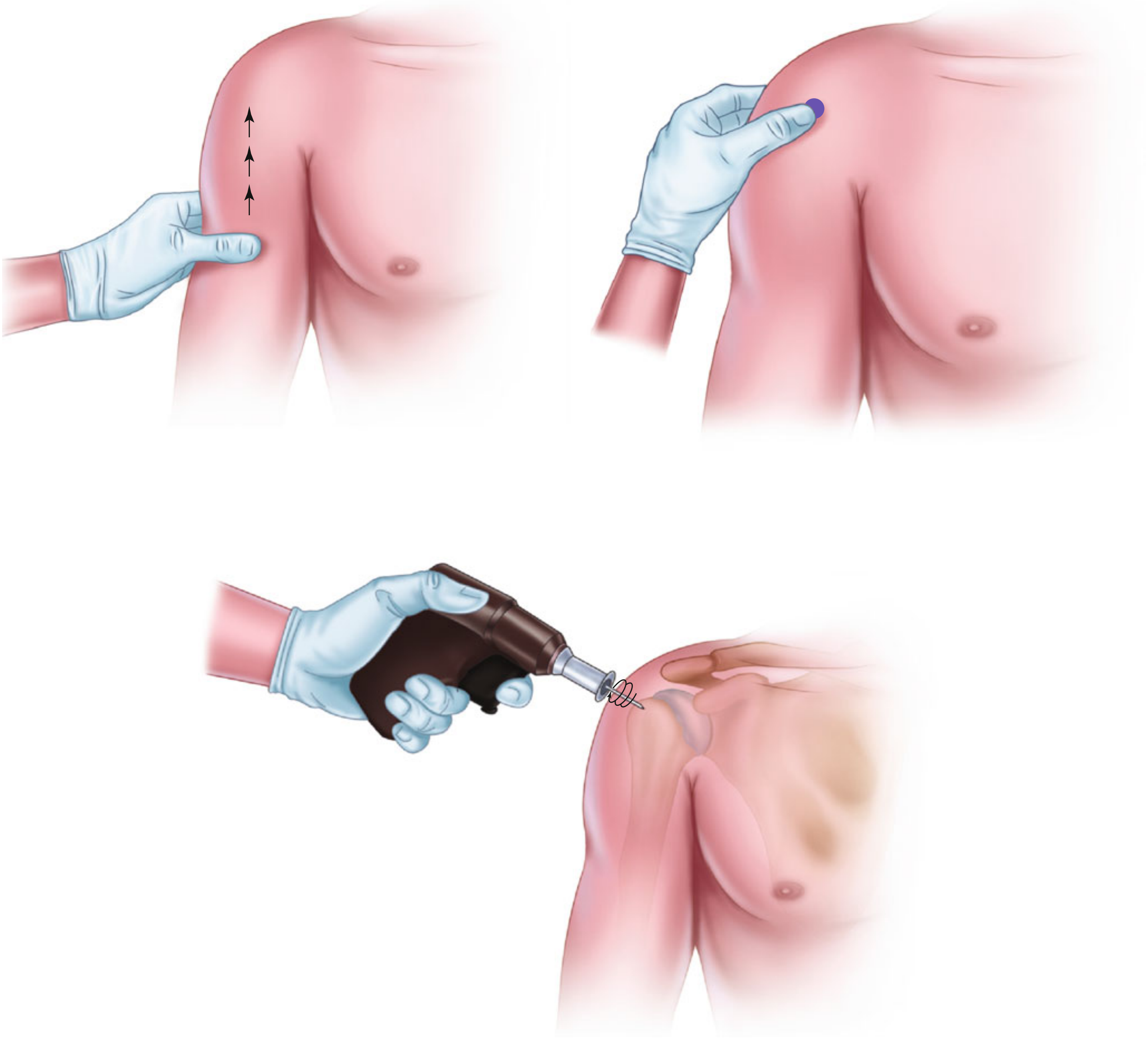

Fig. 122.9 IO insertion into proximal humerus site

122.5 Complications

- Extravasation of fluid.
  - Occurs as a result of a misplaced IO, either not completely in the marrow space anteriorly or through the cortex posteriorly.
  - Tissue necrosis.
- Compartment syndrome if extravasation is not recognized.
- Fracture and growth plate injury.
- Infection and osteomyelitis are rare complications if sterile technique is used.
- Fat embolism, considered rare and only in adult patients.

122.6 Pearls and Pitfalls

- Be certain to avoid placing a hand beneath the IO site during placement in order to prevent possible IO penetration into the provider's tissue.
- Do not rely on the sensation of a "pop" to determine appropriate penetration into the cortex, especially in infants.
- Likewise, one may not be able to aspirate bone marrow or blood, even with an appropriately placed IO. DO NOT pull out the IO if marrow cannot be aspirated. Rather, gently but firmly infiltrate 10 mL normal saline.
- Blood gases, body chemistries, and blood typing can be obtained from IO samples, but the sample CANNOT be used for hematocrit determination.

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Lumbar Puncture in Pediatrics

123

Maritza A. Plaza-Verduin and Judith K. Lucas

123.1 Indications

- Evaluation of cerebrospinal fluid (CSF) for infection or malignancy
- Measurement of opening pressure
- Treatment of pseudotumor cerebri
- Diagnosis of central nervous system (CNS) metastases
- Instillation of intrathecal chemotherapy
- Injection of radiopaque dye for spinal cord imaging

123.2 Contraindications

- Increased intracranial pressure
- Bleeding diathesis (platelet count <50,000)
- Overlying skin infection near the area of puncture site
- Spinal cord trauma or spinal cord compression
- Signs of progressive cerebral herniation
- Condition of the patient (e.g., unstable airway, potentially dangerous breathing problem, severe circulatory instability) that could cause an abrupt decompensation
- Known spinal cord deformity

123.3 Materials and Medications

- Lumbar puncture (LP) tray (Fig. 123.1)
  - Sterile drapes
  - Betadine (povidone-iodine) swabs or tray to pour Betadine
  - Sterile sponges for preparing the puncture site
  - Sterile 3-mL syringe with needle for lidocaine injection
  - Sterile collecting tubes (4)
  - Sterile spinal needle with stylet (size depending on age of patient)
    - Premature infant: 22 gauge or smaller, 1.5 inch
    - Neonate to 2 years: 22 gauge, 1.5 inch
    - 2–12 years: 22 gauge, 2.5 inch
    - Older than 12 years: 20 or 22 gauge, 3.5 inch
  - Pressure manometer column with a three-way stopcock
- Betadine solution
- Sterile gloves
- Mask
- Lidocaine (1–2 % without epinephrine)
- 4 % Lidocaine cream (LMX-4) or lidocaine and prilocaine mixture (EMLA [eutectic mixture of local anesthetics])

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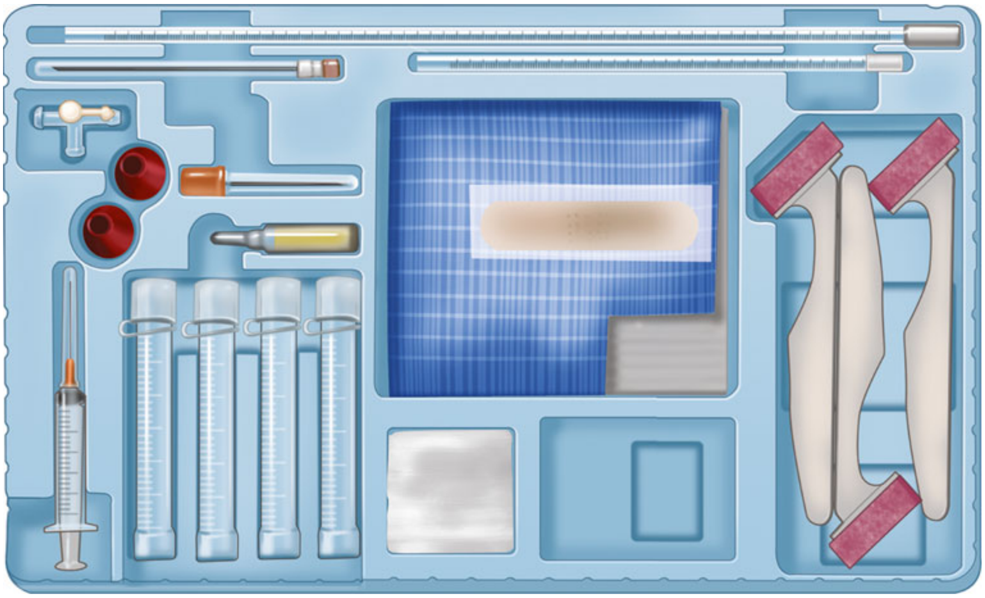

Fig. 123.1 Lumbar puncture (LP) tray

123.4 Procedure

1. Position the child (Figs. 123.2 and 123.3).
    (a) Can be positioned in either the sitting or the lateral recumbent position with the hips, knees, and neck flexed.
    (b) For small infants or any patient with any degree of cardiorespiratory compromise, keep close monitoring of heart rate, respirations, and oxygen saturation while in the flexed position.
2. Palpate the top of the iliac crest and draw an imaginary line connecting the two across the back, which should cross the midline just above the fourth lumbar spine (Fig. 123.4).
3. Palpate L3–4 or L4–5 space along this line.
4. Place EMLA or LMX-4 on the area at this time and allow some time for anesthesia to occur (can take up to 30 min to be effective).
5. Prepare the skin in sterile fashion with Betadine solution using enlarging circles that begin at the puncture site.
6. Drape the patient with sterile towels, exposing the puncture site.
    (a) If an infant, do so conservatively to be able to monitor the infant during the procedure.
7. Locate the intervertebral space (L3–4 or L4–5) once again.
    (a) Make a small mark on the chosen intervertebral space with a fingernail depression or the plastic cap of the spinal needle.
8. If desired, or if anesthetic cream was not previously used or more is needed, apply a small wheal of lidocaine at the desired puncture site using a 25-gauge needle.
9. Insert the spinal needle in the intervertebral space.
    (a) Puncture the skin in the midline just caudal to the palpated spinous process.
    (b) Bevel should be positioned so that the dura mater is pierced parallel to its fibers (which will reduce the likelihood of CSF leakage).
        (i) If in the lateral recumbent position, the bevel of the needle should be positioned horizontally.
        (ii) If in the sitting position, the bevel of the needle should be positioned vertically.
        (iii) Angle the needle slightly cephalad toward the umbilicus and parallel to the bed if the patient is in the lateral recumbent position or slightly caudal (perpendicular to the skin) if the patient is in the sitting position.
10. Advance the needle several millimeters at a time and withdraw the stylet frequently to check for CSF flow.
    (a) Advance the needle until a loss of resistance is felt or approximately 1–2 cm.
        (i) In the infants, whose dura are not so thick and a "pop" or give may be unnoticeable, after passing between the spiny processes and approximately 2 cm through the skin, remove the stylet frequently to check for CSF return. This will allow you to avoid passing through the subarachnoid space.
        (ii) After the change in resistance occurs, if resistance is met again, pull back gently on the needle to reposition in the subarachnoid space and remove the stylet to check for CSF fluid.
11. Once CSF is free flowing, attach a pressure manometer to the needle hub via the three-way stopcock (Fig. 123.5).
    (a) Make sure to hold the spinal needle with one hand in place while attaching the manometer to prevent movement of the needle.
    (b) Measure the CSF pressure once the CSF reaches the highest level in the manometer column.
    (c) CSF pressures will be best obtained in the lateral recumbent position with the neck and legs extended.
    (d) Normal CSF pressure is 5–20-cm H_2O with the neck and legs extended, 10–28-cm H_2O with the neck and legs flexed.
    (e) Have an assistant hold the top of the pressure manometer while the spinal needle is supported at the connection of the manometer and stopcock.
12. Remove the manometer and collect the CSF into sterile tubes.
    (a) Make sure to keep the needle in place when removing the manometer.
    (b) Continue to drain fluid into the collecting tubes, approximately 1 mL per tube.
    (c) The tubes should be labeled for specific studies, depending on the order of collection.
        (i) First tube for gram stain and culture.
        (ii) Second tube for quantitative glucose and protein.
        (iii) Third or fourth tube for cell count and differential.
        (iv) Leftover tube for any additional studies that may be needed.
        (v) When the LP is to assess for possible subarachnoid blood, the first and fourth tubes are sent for cell count.
13. Replace the stylet and remove the spinal needle.
14. Cleanse the puncture area to avoid staining with the Betadine solution.
15. Apply a sterile dressing to the puncture site.
16. Patients 4 years and older should remain in the supine position, with the head elevated no more than the height of a pillow (for comfort), for at least an hour to avoid spinal tap headaches.
17. Likewise, after the LP, giving a fluid bolus of normal saline (10–20 mL/kg in children; 1 L in non-volume-sensitive adults) will also assist with avoidance of spinal tap headaches.

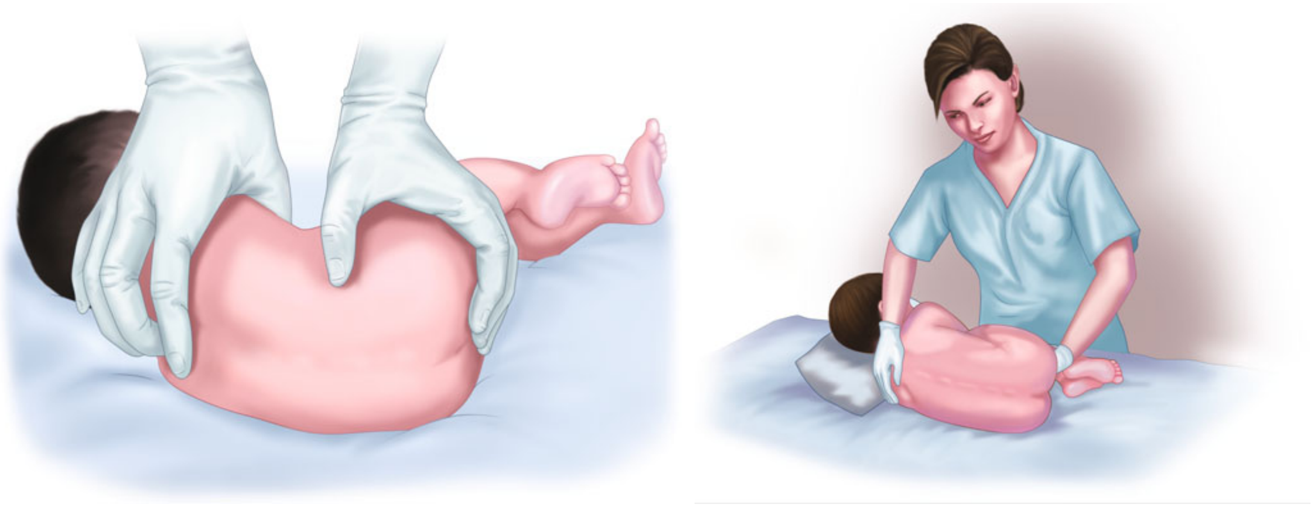

Fig. 123.2 Curling up for an LP

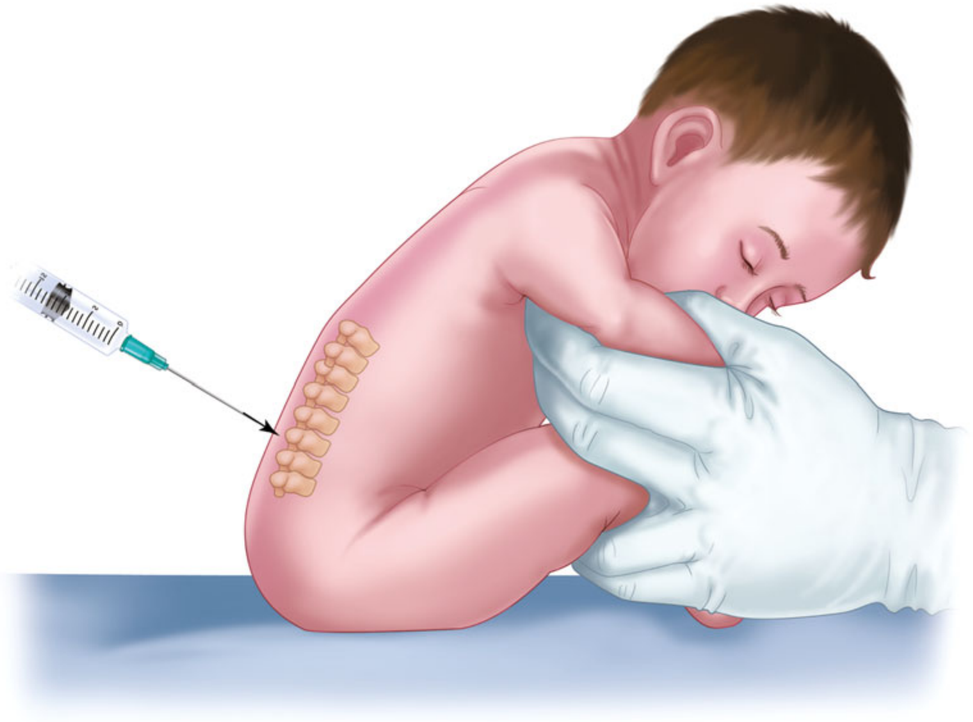

Fig. 123.3 Having the LP

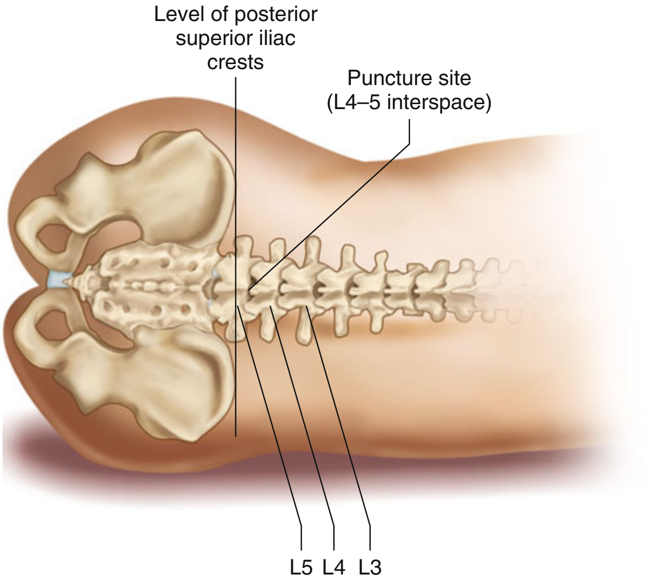
Level of posterior superior iliac crests
Puncture site (L4–5 interspace)
L5
L4
L3

Fig. 123.4 Anatomy of the lumbar spine showing the sites for dural puncture

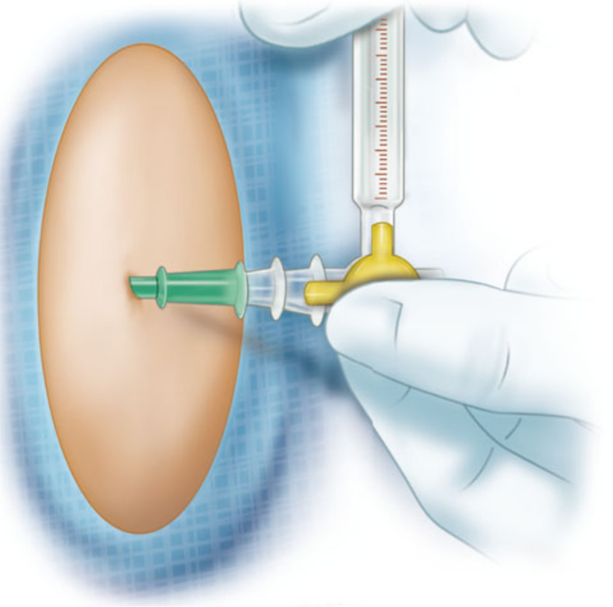

Fig. 123.5 Pressure manometer attached to the needle hub via the three-way stopcock

123.5 Complications

- Minor
  - Localized back pain
  - Transient paresthesia during procedure
  - Post-LP headache
- Major
  - Severe back pain associated with neurological signs (may be subdural or epidural spinal hematoma)
  - LP-induced meningitis
  - Cerebral herniation
  - Acquired epidermoid tumor
  - Damage to adjacent structures (disk herniation, retroperitoneal abscess, spinal cord hematoma)

123.6 Pearls and Pitfalls

- Pearls
  - Success of the LP depends on the positioning of the patient.
    - Goal of positioning is to stretch the ligamentum flavum and increase the interlaminar spaces.
    - In the recumbent position, the shoulder and hips should be perpendicular to the bed, keeping the spinal cord straight, with no rotation.
    - Sitting position is useful with older, cooperative patients or with very young infants who are unlikely to struggle and may have increased respiratory distress in the lateral recumbent position.
  - Administration of an anxiolytic (e.g., midazolam) can be used to facilitate the procedure in an older child. In some cases, procedural sedation may be required.
  - Placing the tip of the thumb on the spinous process just above the space being entered can ensure good alignment of the needle.
  - In older patients a “pop” may often be felt as a change in resistance occurs once the dura is penetrated; however, in infants and neonates, that “pop” may be exceedingly subtle or not palpable.
  - If no CSF returns, attempt the following options:
    - Ensure the needle is in the appropriate position, withdrawing the needle slowly if necessary.
    - Rotate the needle 90°.
    - If an infant, have the assistant massage the anterior fontanel to help facilitate CSF flow.
    - If the procedure continues without CSF, withdraw the needle to just under the skin and redirect it.
    - If the procedure continues without CSF, withdraw the needle and insert a new needle with stylet at an alternate site.

  - If these steps do not yield CSF, the infant may be dehydrated, not allowing for adequate CSF flow.
    - Give the patient a bolus and reattempt later.
    - Attempt putting the infant in a sitting position to increase flow.
- Pitfalls
  - Traumatic LP
    - Bloody CSF fluid, which usually clears as the CSF drains if the needle is in the correct space.
    - Occurs with improper technique (inserting the needle too far to one side into an epidural venous plexus or through the subarachnoid space into or adjacent to the vertebral body).
    - Can occur with proper technique as well.
    - If fluid does not clear and clots form in the tubes, LP should be reattempted at a different site.
  - Failed LP attempts despite proper procedure and positioning
    - Ultrasound can be used to visualize the area and determine the reason for failure or the likelihood of success with future attempts.

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Suprapubic Bladder Aspiration

124

Maritza A. Plaza-Verduin and Judith K. Lucas

124.1 Indications

- Collection of sterile urine for urinalysis and culture (avoiding urethral contamination)
- Collection of sterile urine in a child with gastroenteritis and frequent diarrheal stools
- Female child with labial adhesions or male child with minimally retractable foreskin
- Urinary retention

124.2 Contraindications

- Empty or nonpalpable bladder
- Urination within 1 h before the procedure
- Anatomical abnormalities of the gut or genitourinary tract
- Bleeding diathesis
- Intestinal obstruction
- Overlying cellulitis on abdominal wall
- Lower abdominal scars or wounds

124.3 Materials and Medications

- Sterile gloves
- Lidocaine (1–2 %) with syringe and needle
- EMLA (eutectic mixture of local anesthetics) cream
- Betadine (povidone-iodine) solution
- Sterile syringe, 5–20 mL
- Sterile needle 22 or 23 gauge, 1.5 inch
- Sterile specimen container
- Sterile towels
- Sterile gauze
- Sterile dressing
- Adhesive bandage

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124.4 Procedure

1. Place the infant in the supine, frog-leg position (Fig. 124.1).
2. Localize the bladder.
3. Palpate the midline between the umbilicus and the pubis symphysis to feel for bladder fullness.
    - Use a portable ultrasound device to localize the bladder and allow for approximation of bladder size (see later).
4. Localize the symphysis pubis and the imaginary line midline from the umbilicus to the pubic symphysis (Fig. 124.2).
5. Sterilize the area from the umbilicus to the urethra.
6. Drape the area with sterile towels, keeping the puncture site area exposed.
7. Area of insertion should be midline 1–2 cm above the symphysis pubis on the abdominal wall.
    - The suprapubic crease can usually be used as a guideline to the puncture site.
8. Place a small wheal of anesthetic at the intended puncture site or can apply EMLA cream.
    - For use of EMLA cream, place before sterilization and allow some time for anesthesia to occur.
9. Occlude the urethral opening to avoid spontaneous loss of urine specimen.
    - In males, apply gentle pressure to the base of the penis against the pubic symphysis.
    - In females, directly apply pressure to the urethral meatus.
10. Puncture the skin with the needle (attached to the syringe).
    - Puncture at a 10–20° angle to the perpendicular, aiming slightly cephalad (Fig. 124.3).
11. Apply negative pressure to the syringe as the needle is advanced until urine enters the syringe; do not advance more than 1 inch.
    - If unsuccessful, draw back the needle until it rests in the subcutaneous fat and redirect 10° in either direction.
    - Do not attempt more than three times.
12. Cleanse the area of antiseptic solution and apply an adhesive dressing.

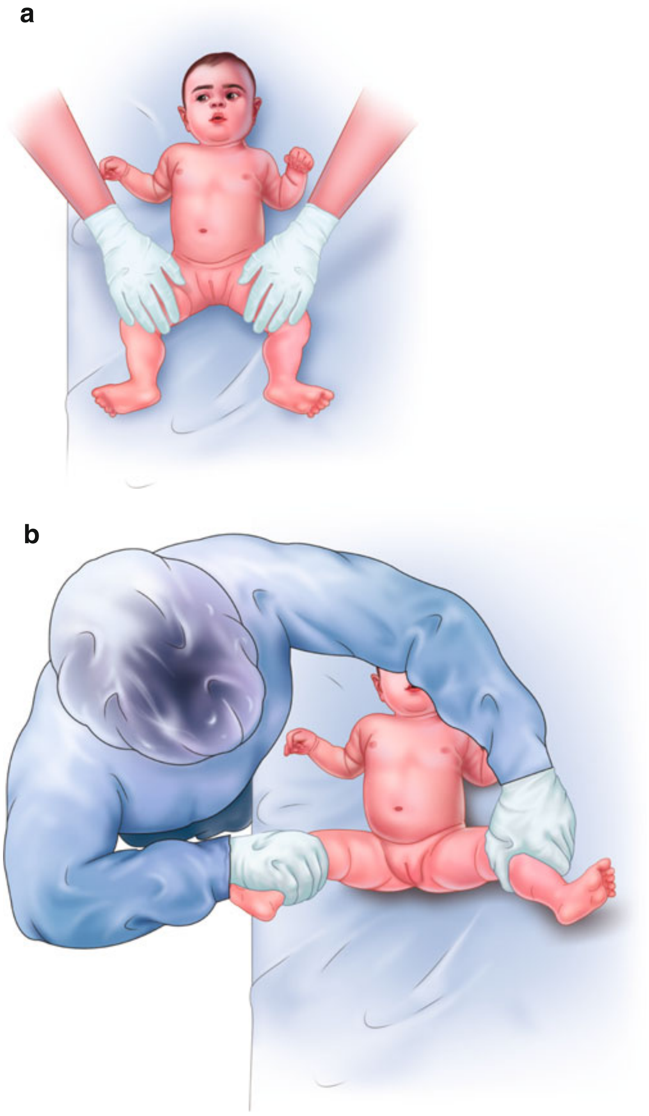

Fig. 124.1 Frog-leg position

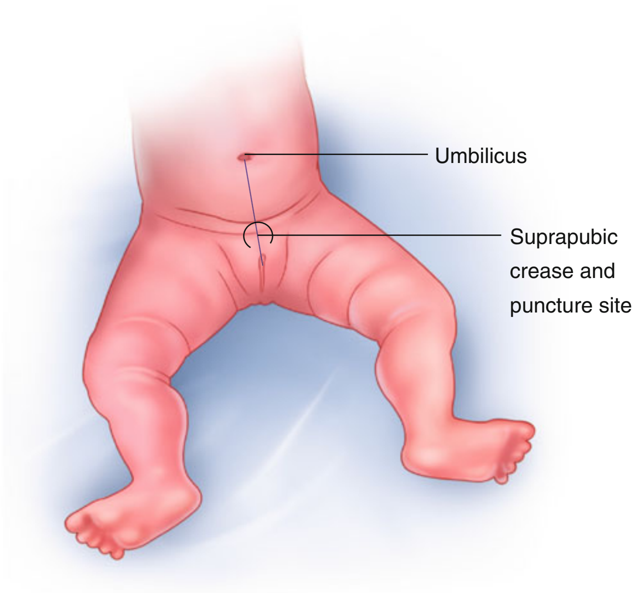
Umbilicus
Suprapubic crease and puncture site

Fig. 124.2 Landmarks

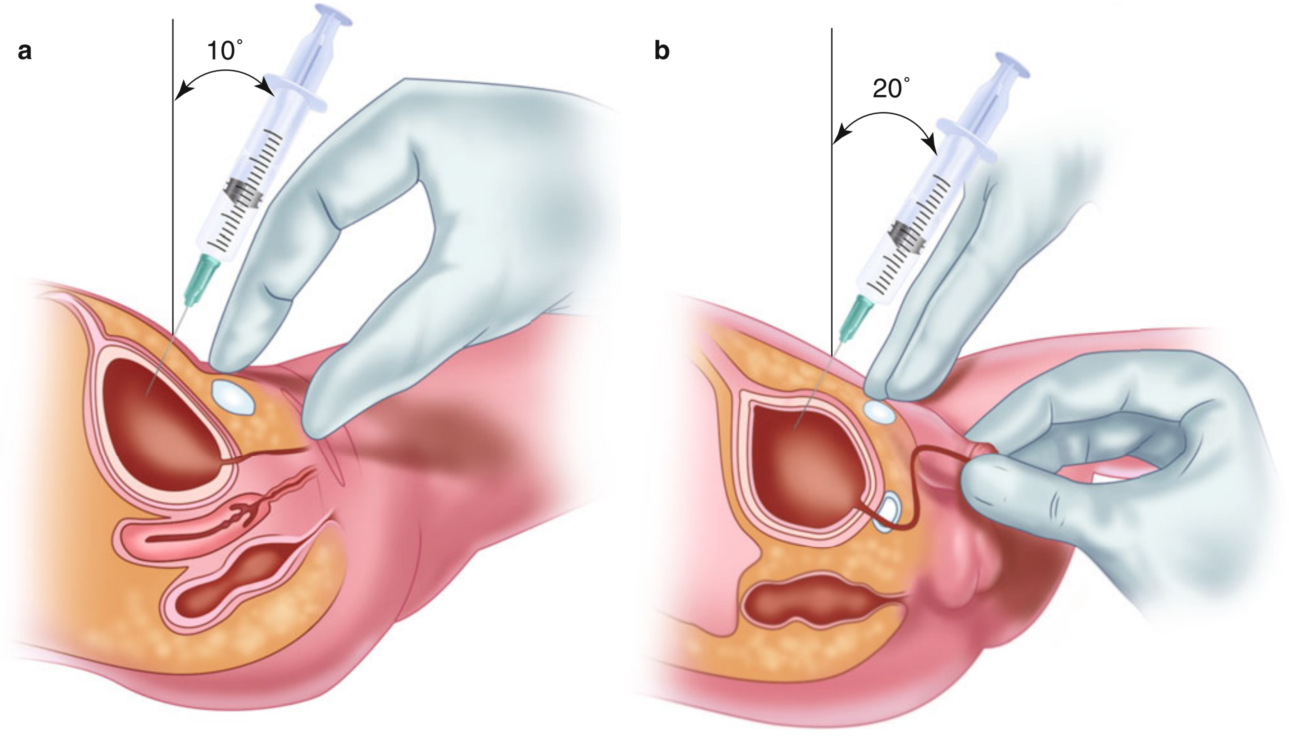

Fig. 124.3 Insert the needle 10–20° perpendicular to the skin

124.5 Complications

- Peritoneal perforation with or without bowel perforation
- Infection
- Hematuria
- Inability to aspirate urine

124.6 Pearls and Pitfalls

- If no fluid is obtained:
  - Hydrate the child and reattempt in 1 h.
- Ultrasound can be used to identify bladder size or for ultrasound-guided aspiration:
  - Use a portable ultrasound device with a standoff 7.5-MHz sector probe to allow for superficial scanning and measurement of the diameter of the bladder.
  - Bladder diameter measurement:
    1. Apply approximately 5 mL of ultrasound transmission gel to the infant's suprapubic region.
    2. Apply pressure to the ureteral meatus as previously described.
    3. Gently apply the probe to the suprapubic region in the midline and scan the area in transverse plane, with the probe directed caudad or cephalad as needed to maximize bladder image.
       - Bladder will appear anechoic below the brighter reflections of the rectus muscle and bladder wall.
    4. When maximum bladder size obtained, freeze the image.
       - Measure the anteroposterior and transverse internal bladder diameters.
       - Goal measurement is 2 cm or more of each diameter. If either diameter is less than 2 cm, the bladder is considered to be empty.
  - Ultrasound-guided bladder aspiration:
    1. After preparing the sterile field, place a sterile sheath over the ultrasound probe and proximal cable.
       (a) Gel should be placed within the sheath to eliminate the air interface between the probe and the sheath.
    2. Apply gel to the abdomen above the symphysis pubis.
    3. Locate the bladder and measure the maximum diameter as described previously.
    4. Insert the needle midline at the location where the bladder wall is closest to the probe.
    5. Continue steps for aspiration as described previously.

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Removal of Hair/Thread Tourniquet

125

Judith K. Lucas

125.1 Indications

- Consider the diagnosis when presented with an appendage that has a well-demarcated, circumferential, painful, edematous distal segment, adjacent to a nonedematous, nonerythematous proximal portion (Fig. 125.1).
- Removal is imperative in all cases of tourniquet syndrome and should be undertaken without delay.
- Method of removal is determined by degree of constriction.
  - Unwrapping: in situations with minimal or no edema and the ability to visualize the offending hair or thread
  - Blunt probe, cutting: mild to moderate edema
  - Incision: severe swelling or inability to visualize the constricting band; epithelialization
  - Depilatory: for areas with mild to moderate edema, but without epithelialization

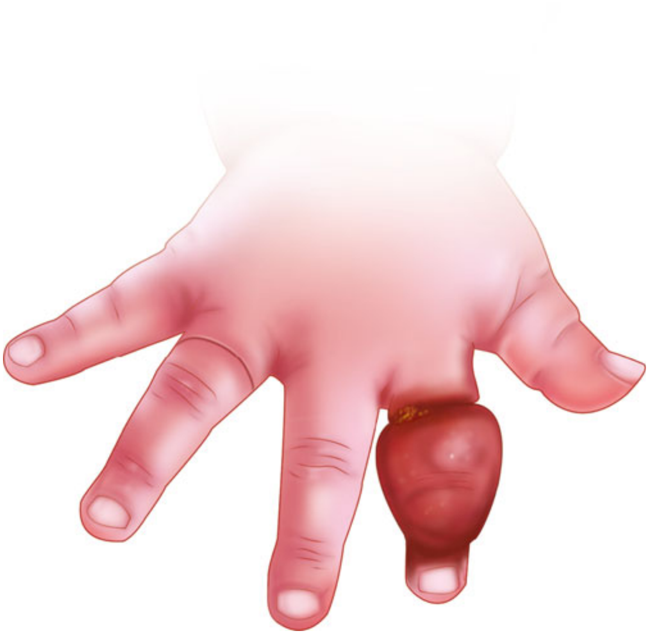

Fig. 125.1 Hair tourniquet

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125.2 Contraindications

- Absolute
  - There are no absolute contraindications; the tourniquet must be removed.
- Relative
  - Based more on the specific approach (e.g., avoid incising the skin of a patient with hemophilia; avoid depilatory creams in a patient with known allergies to such)

125.3 Materials and Medications

- Unraveling technique
  - Fine-tipped, non-rat-tooth forceps or small fine hemostats
- Blunt probe and tourniquet cutting
  - Antiseptic solution of choice
  - Lidocaine 1 % without epinephrine for local or regional anesthesia
  - Scalpel blade #11 or Iris scissors
  - Blunt probe or metal earwax curette
- Incision technique
  - Antiseptic solution of choice
  - Lidocaine 1 % without epinephrine for local or regional anesthesia
  - Scalpel blade #11
  - Fine-tipped, non-rat-tooth forceps or small, fine hemostats
- Depilatory technique
  - Commercial depilatory cream

125.4 Procedures

- Unraveling method (Fig. 125.2)
  1. Place the appendage in an orientation that maximizes exposure.
  2. Apply skin traction such that as much of the tourniquet and base of the constriction can be seen.
  3. Look closely to identify a free end of the hair or thread. If no free end is visible, identify an area of bunching or a knot. Break the knot from the strand and grasp the end with the forceps or hemostat.
  4. Slowly and gently pull and unwind the hair.
  5. This may take several attempts because the hair strand or thread may break repeatedly during removal. Sometimes more than one hair strand may be involved.
- Blunt probe and cutting method (Figs. 125.3 and 125.4)
  1. Apply gentle traction to the skin to maximally expose the involved area and to make the base of the wedge caused by the tourniquet as shallow as possible.
  2. Gently impose a blunt probe or a metal ear curette between the skin and the tourniquet, starting proximally to the band and sliding distally beneath the constriction.
  3. Cut the tourniquet by sliding the scalpel blade along the edge of the probe, placing the blunt edge of the scalpel against the skin and slicing the constricting material in a movement away from the skin, in order to avoid inadvertently cutting the skin.
  4. Once an end of the tourniquet has been created, the remainder of the offending strap can be removed via unraveling.

- Incision technique for digits (Fig. 125.5)
  1. Perform a digital nerve block to anesthetize the extremity proximal to the constriction.
  2. Sterilize the involved area with antiseptic solution of choice and drape in typical protocol to allow as sterile a procedure as is possible outside a surgical suite.
  3. Incise the skin across the demarcation indicating the presence of the tourniquet at the 3 o'clock or 9 o'clock position or the midline dorsal area (12 o'clock), passing the scalpel blade proximally to distally and down to the bone (Fig. 125.6). Incision at these locations will avoid the laterally located neurovascular bundles of the digits.
- Incision technique for severe penile tourniquet
  1. Begin with a dorsal nerve block (Fig. 125.7).
  2. Sterilize the involved area with antiseptic solution of choice and drape in typical protocol to allow as sterile a procedure as is possible outside a surgical suite.
  3. A longitudinal incision is made at either the 4 o'clock or the 8 o'clock position, in order to avoid the penile neurovascular structures located dorsally.
  4. The incision should be made perpendicular to the tourniquet, but shallowly, in order to avoid penetration through the deep fascia. It will be necessary to repeat the incision, staying within the original incision, gently but repeatedly in order to cut through the whole tourniquet. In this way the constriction is relieved, but the integrity of the corpus cavernosum and the corpus spongiosum is maintained (Fig. 125.8).
  5. Once the layers of the tourniquet have been interrupted, grasp an end of the hair/thread and remove the remainder of the tourniquet utilizing the unraveling method.
- Depilatory method
  1. Depilatories work only on hair and will not work on threads.
  2. Apply the depilatory cream directly to the hair tourniquet with a saturated cotton swab, so as to avoid applying this potential irritant to surrounding tissue.
  3. Wait the recommended amount of time, as dictated by whatever brand of depilatory is used.
  4. After the appropriate time has elapsed, wash off the cream thoroughly with soap and water.

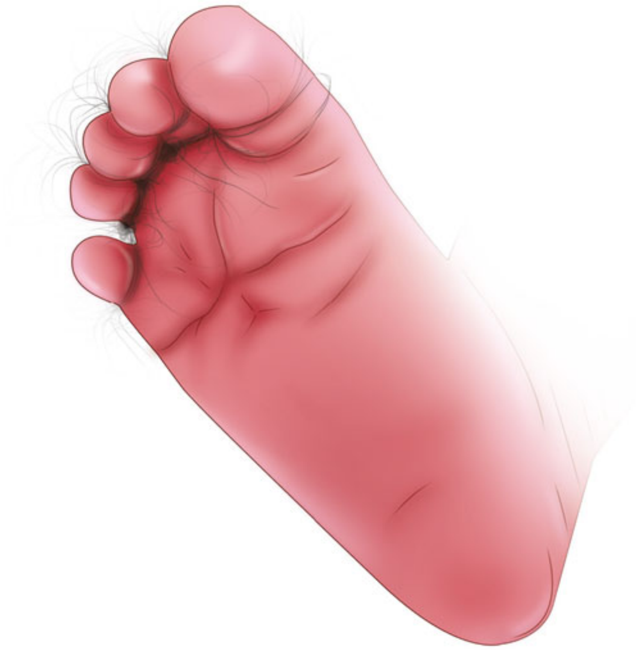

Fig. 125.2 A good example for use of the unraveling technique. The edema is minimal and the hair is easily identifiable

Fig. 125.3 Blunt and cut method. Notice the cutting edge of the scalpel blade is away from the skin as it is placed adjacent to the probe and slips beneath the tourniquet

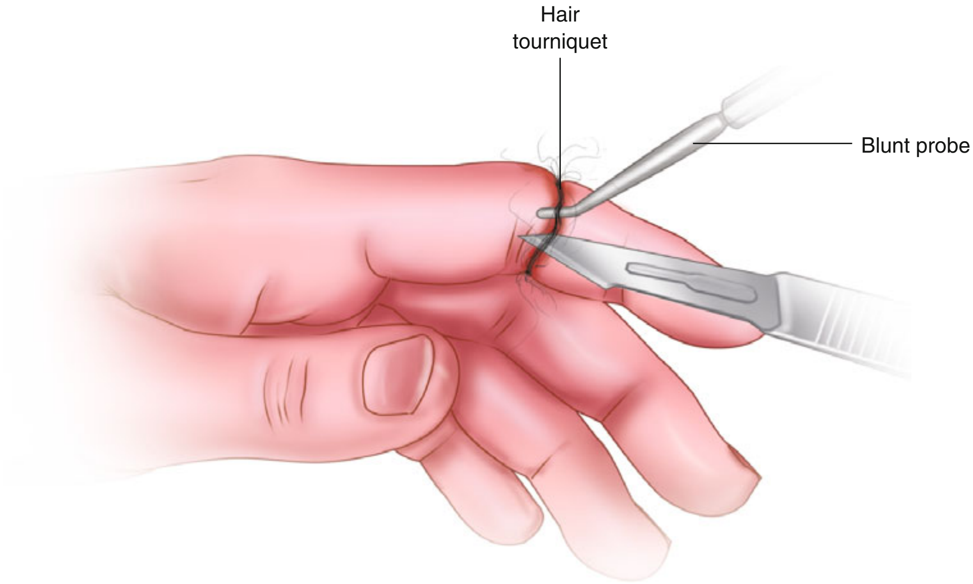
Hair tourniquet
Blunt probe

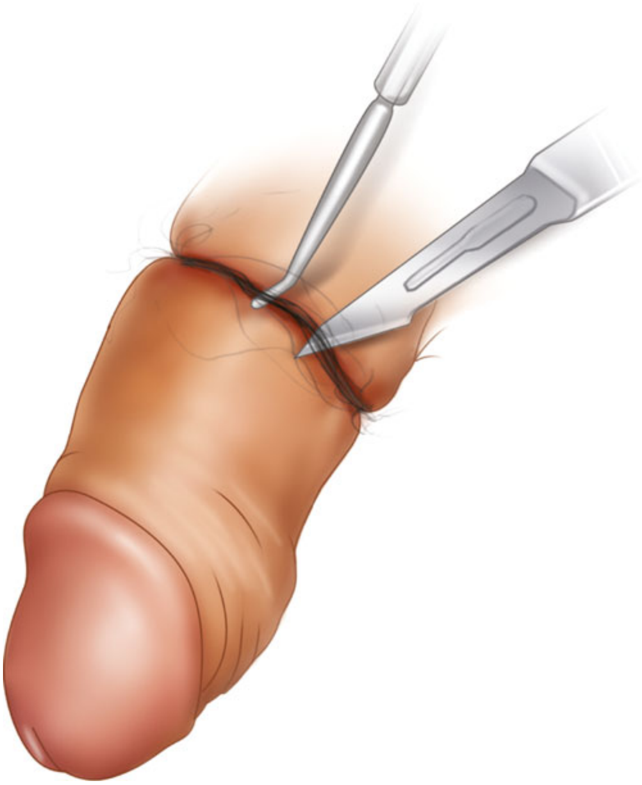

Fig. 125.4 Blunt and cut method

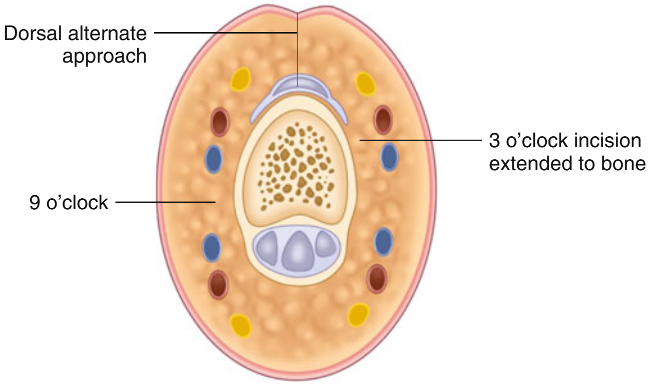
Dorsal alternate approach
3 o'clock incision extended to bone
9 o'clock

Fig. 125.5 Incision technique for digits

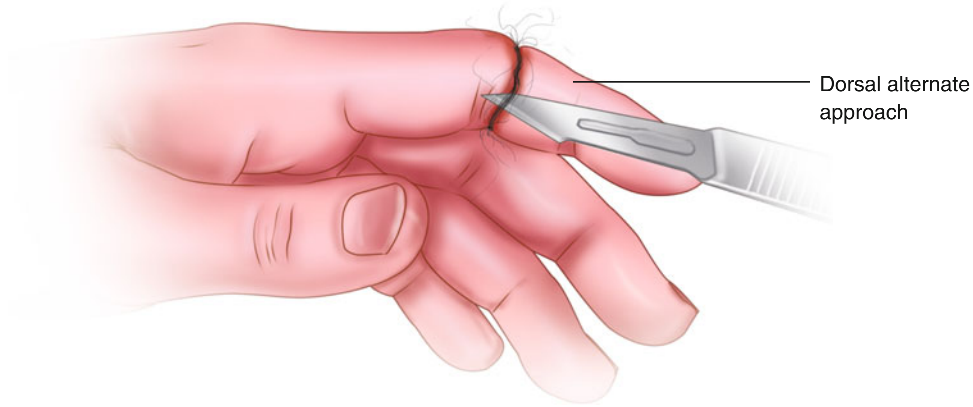
Dorsal alternate approach

Fig. 125.6 Incision at 12 o'clock preferred

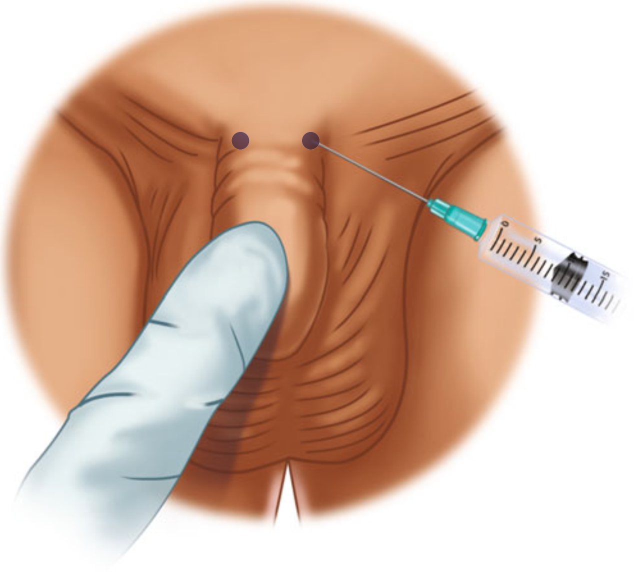

Fig. 125.7 Dorsal nerve block

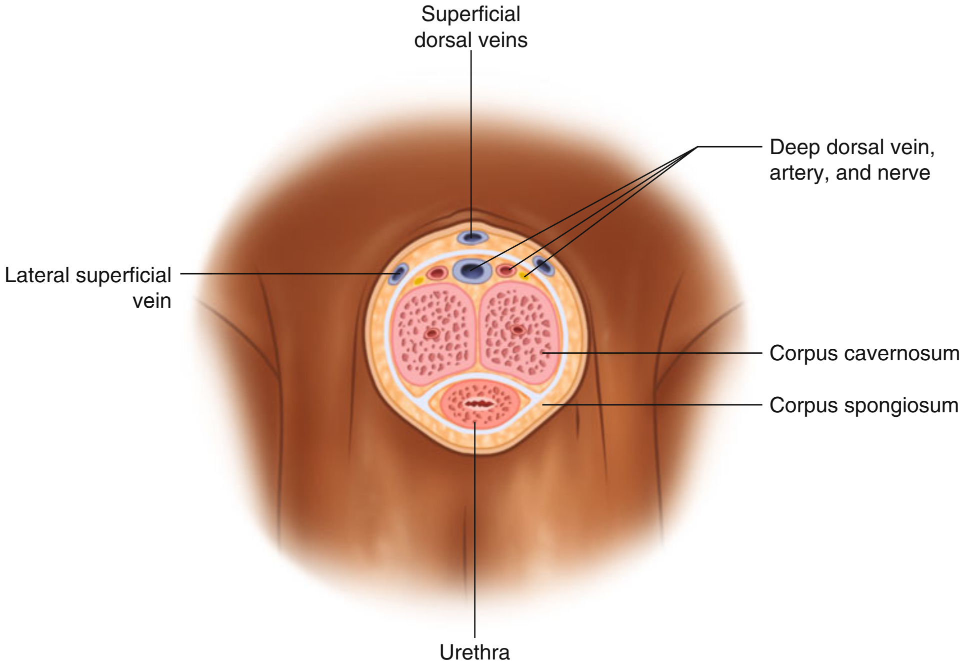
Superficial dorsal veins
Deep dorsal vein, artery, and nerve
Lateral superficial vein
Corpus cavernosum
Corpus spongiosum
Urethra

Fig. 125.8 Penile tourniquet schematic

125.5 Complications

- Necrosis of tissue distal to the tourniquet
- Neurovascular damage secondary to prolonged ischemia
- The incision technique can cut into the tendon insertions or neurovascular bundles of the digits or into the corpus callosum of the penis. Be certain to ascertain function after incision.
- Infection, especially after incision.

125.6 Pearls and Pitfalls

- Pearls
  - All tourniquets must come off.
  - The easiest way to get to the bottom of the tourniquet, regardless of method used, is to identify the knot or bunched area if possible.
  - When using the incision technique, keep the incision in the longitudinal plane of the appendage and perpendicular to the tourniquet.
  - Do not use depilatories on open wounds.
  - 24-h follow-up is mandatory, although if the tourniquet has been present for an extended period of time, it may actually take several days for return of color and blood flow.
  - Be certain to document neurovascular status before and after tourniquet removal.
  - Consider surgical consult in cases of severe tissue edema or distorted anatomy.
  - Tourniquets have been described in the child abuse literature. Consider that possibility in the preverbal child.
- Pitfalls
  - The depilatories will not work on nonorganic tourniquets.

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Use of the Broselow Tape

126

Judith K. Lucas

126.1 Indications

- To determine the equipment size and the medication doses during a pediatric resuscitation, without having to take the time to perform calculations

126.2 Contraindications

- Premature infant or newborn whose heel, while the infant is fully extended, does not fall at least into the white area (corresponding to 3, 4, and 5 kg).
- The length of the child exceeds the distal end of the green area (36 kg).

126.3 Materials

- Broselow Pediatric Emergency Tape (Armstrong Medical Industries, Wilshire, IL) (Figs. 126.1 and 126.2)

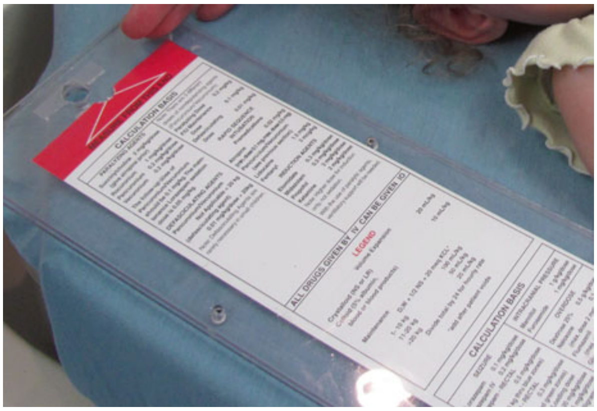

Fig. 126.1 Broselow tape, proximal end (at patient's head)

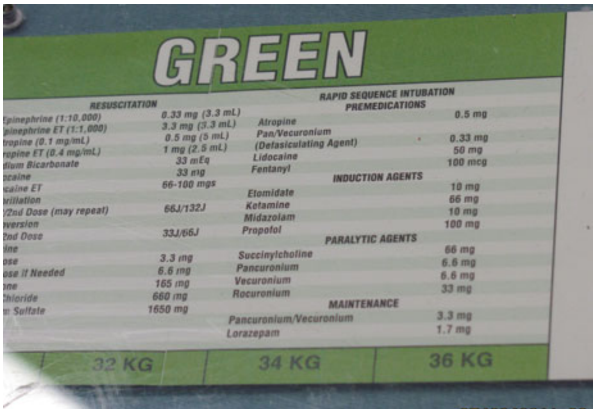

GREEN

RESUSCITATION	
pinephrine (1:10,000)	0.33 mg (3.3 mL)
pinephrine ET (1:1,000)	3.3 mg (3.3 mL)
tropine (0.1 mg/mL)	0.5 mg (5 mL)
ropine ET (0.4 mg/mL)	1 mg (2.5 mL)
dium Bicarbonate	33 mEq
caine	33 mg
caine ET	66-100 mgs
rillation	
/2nd Dose (may repeat)	66J/132J
version	
2nd Dose	33J/66J
ine	
ose	3.3 mg
ose If Needed	6.6 mg
ne	165 mg
Chloride	660 mg
Sulfate	1650 mg

RAPID SEQUENCE INTUBATION	
PREMEDICATIONS	
Atropine	0.5 mg
Pan/Vecuronium (Defasiculating Agent)	0.33 mg
Lidocaine	50 mg
Fentanyl	100 mcg
INDUCTION AGENTS	
Etomidate	10 mg
Ketamine	66 mg
Midazolam	10 mg
Propofol	100 mg
PARALYTIC AGENTS	
Succinylcholine	66 mg
Pancuronium	6.6 mg
Vecuronium	6.6 mg
Rocuronium	33 mg
MAINTENANCE	
Pancuronium/Vecuronium	3.3 mg
Lorazepam	1.7 mg

32 KG | 34 KG | 36 KG

Fig. 126.2 Broselow tape, distal end (the tape will accommodate a 36-kg child, at most)

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126.4 Procedure (Figs. 126.3, 126.4, and 126.5)

- Place the infant or child on the bed in the supine position.
- Extend the Broselow Pediatric Emergency Tape next to the patient, placing the red line at the top of the patient's head.
- With the patient fully extended, especially through the hips and knees, align the bottom of the heel, while the ankle is flexed and toes upward, with the color on the tape adjacent to the heel.
- The color on the tape corresponds to the patient's weight.
- The side of the tape with weights noted along the bottom has medication doses for resuscitation, rapid-sequence intubation (RSI), and paralytics (Fig. 126.6).
- The top half of the other side of the tape has the appropriate dosing for managing seizures, overdoses, elevating intracranial pressure, and fluids. The bottom half of this side has the appropriate equipment sizes, such as endotracheal tubes, nasogastric tubes, chest tubes, and other equipment, that correspond to the patient's weight (Fig. 126.7).

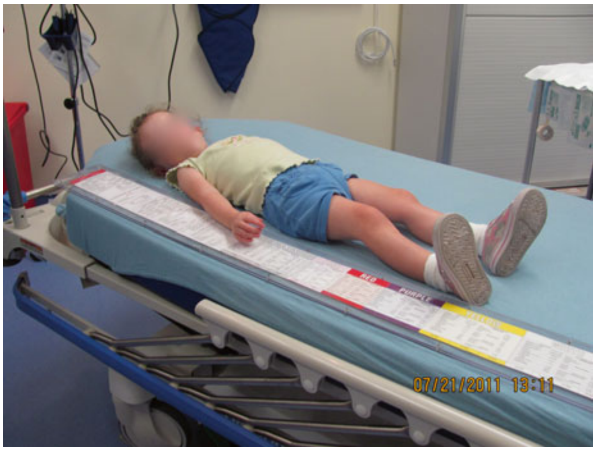

Fig. 126.3 Placement of the child on the tape

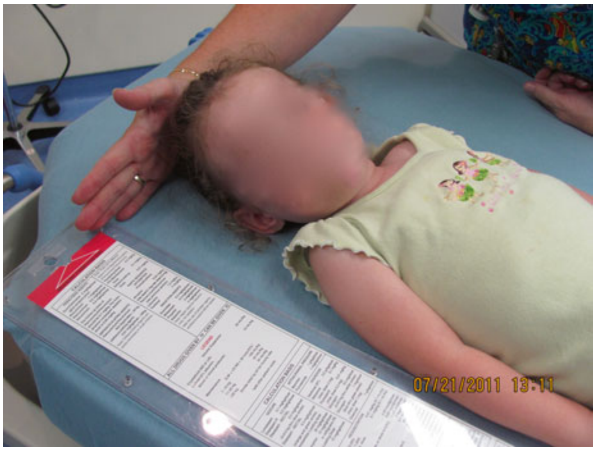

Fig. 126.4 Placement of the child on the tape

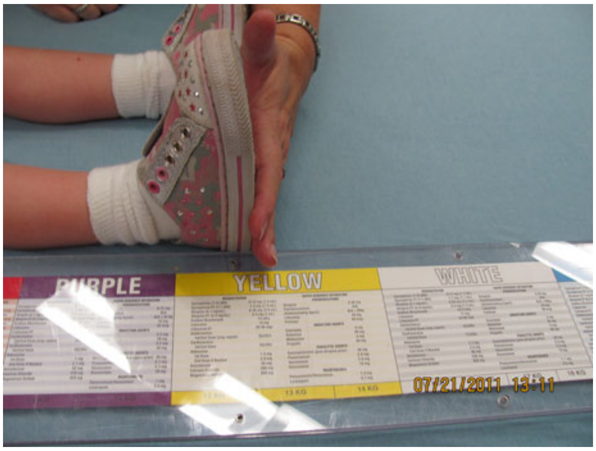

Fig. 126.5 Placement of the child on the tape

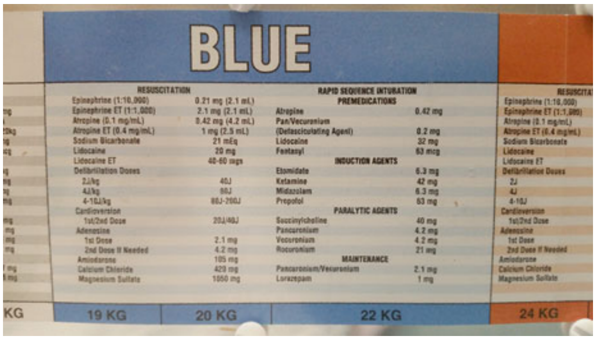

BLUE

RESUSCITATION	
Epinephrine (1:10,000)	0.21 mg (2.1 mL)
Epinephrine ET (1:1,000)	2.1 mg (2.1 mL)
Atropine (0.1 mg/mL)	0.42 mg (4.2 mL)
Atropine ET (0.4 mg/mL)	1 mg (2.5 mL)
Sodium Bicarbonate	21 mEq
Lidocaine	20 mg
Lidocaine ET	40-60 mgs
Defibrillation Doses	
2J/kg	40J
4J/kg	80J
4-10J/kg	80J-200J
Cardioversion	
1st/2nd Dose	20J/40J
Adenosine	
1st Dose	2.1 mg
2nd Dose If Needed	4.2 mg
Amiodarone	105 mg
Calcium Chloride	420 mg
Magnesium Sulfate	1050 mg

RAPID SEQUENCE INTUBATION	
PREMEDICATIONS	
Atropine	0.42 mg
Pan/Vecuronium	
(Defasciculating Agent)	0.2 mg
Lidocaine	32 mg
Fentanyl	63 mcg
INDUCTION AGENTS	
Etomidate	6.3 mg
Ketamine	42 mg
Midazolam	6.3 mg
Propofol	63 mg
PARALYTIC AGENTS	
Succinylcholine	40 mg
Pancuronium	4.2 mg
Vecuronium	4.2 mg
Rocuronium	21 mg
MAINTENANCE	
Pancuronium/Vecuronium	2.1 mg
Lorazepam	1 mg

19 KG 20 KG 22 KG 24 KG

Fig. 126.6 Front of tape. Weight groupings are noted at the bottom. This is the side with resuscitation and RSI medications

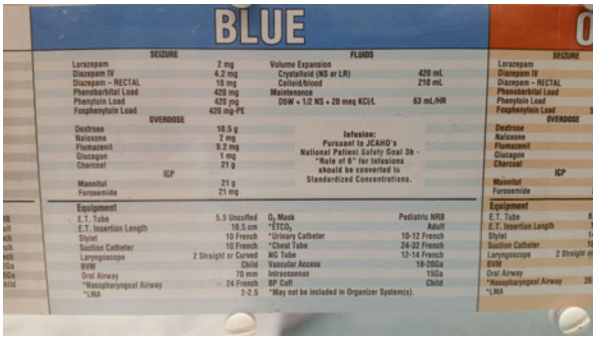

BLUE

SEIZURE	
Lorazepam	2 mg
Diazepam IV	4.2 mg
Diazepam – RECTAL	10 mg
Phenobarbital Load	420 mg
Phenytoin Load	420 mg
Fosphenytoin Load	420 mg-PE
OVERDOSE	
Dextrose	10.5 g
Naloxone	2 mg
Flumazenil	0.2 mg
Glucagon	1 mg
Charcoal	21 g
ICP	
Mannitol	21 g
Furosemide	21 mg

FLUIDS	
Volume Expansion	
Crystalloid (NS or LR)	420 mL
Colloid/blood	210 mL
Maintenance	
D5W + 1/2 NS + 20 meq KCl/L	63 mL/HR

Infusion:
Pursuant to JCAHO's
National Patient Safety Goal 3b -
"Rule of 6" for Infusions
should be converted to
Standardized Concentrations.

Equipment			
E.T. Tube	5.5 Uncuffed	O_2 Mask	Pediatric NRB
E.T. Insertion Length	16.5 cm	*$ETCO_2$	Adult
Stylet	10 French	*Urinary Catheter	10-12 French
Suction Catheter	10 French	*Chest Tube	24-32 French
Laryngoscope	2 Straight or Curved	NG Tube	12-14 French
BVM	Child	Vascular Access	18-20Ga
Oral Airway	70 mm	Intraosseous	15Ga
*Nasopharyngeal Airway	24 French	BP Cuff	Child
*LMA	2-2.5	*May not be included in Organizer System(s).	

Fig. 126.7 Reverse side of tape. This side has medications for critical interventions aside from the primary survey, as well as equipment sizes

126.5 Pearls and Pitfalls

- Pearls
  - Be certain that the top of the head is at the red line and that the patient's body is fully extended. Infants tend to lay flexed at the hips and knees.
  - Determining the appropriate color code depends on noting the bottom of the heel while the ankle is flexed and the toes are pointing upward.
- Pitfalls
  - Beware of the child who is unusually heavy compared with other children of the same height.

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Nursemaid's Elbow

127

Judith K. Lucas

127.1 Definition

- An injury commonly seen in children between 6 months and late preteens, although generally seen between 1 and 3 years
- A subluxation of the radial head, usually resulting from sudden, longitudinal traction on an extended arm with the wrist pronated
- Often occurs when a parent/caregiver is holding the child by the hand while walking and suddenly pulls the child away from a dangerous situation (Fig. 127.1)

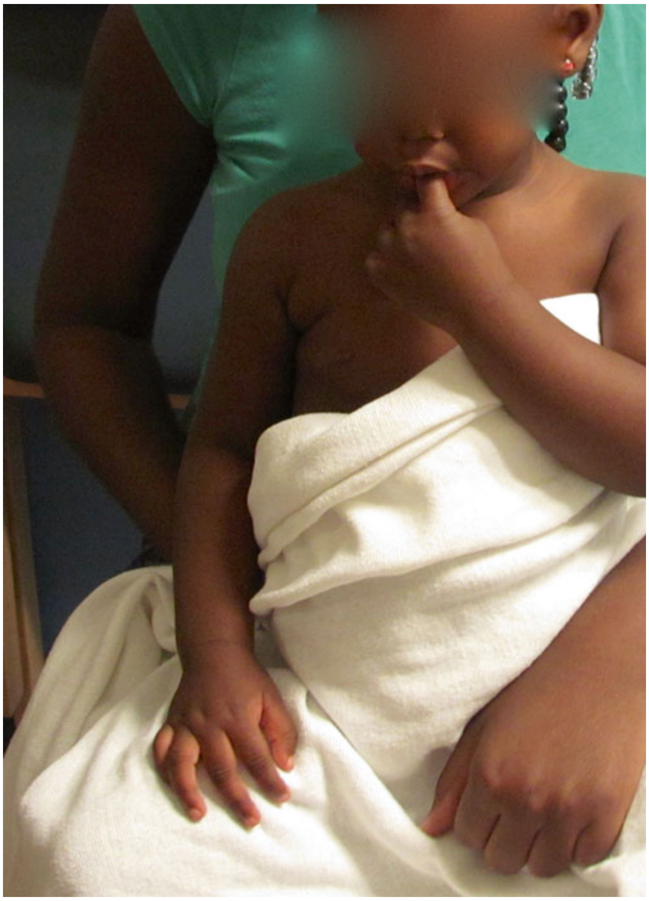

Fig. 127.1 Note that the toddler prefers to hold her right arm pronated and somewhat flexed at the elbow. When asked where it hurts, she may as often point to her wrist as to her elbow. There will be no soft tissue swelling anywhere along the upper extremity

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127.2 Clinical Diagnosis

- History of pulling-type injury.
- Child presents with arm held slightly flexed at elbow and pronated.
- Patient may point to elbow or wrist as source of pain, but both areas are without any swelling and are nontender on palpation.
- Elbow can be flexed and extended, but the forearm cannot be supinated.
- Radiography is not helpful.

127.3 Indications

- Clinical presence of subluxed radial head

127.4 Contraindications

- Absolute
  - Radiographic evidence of elbow or forearm fracture
  - Swelling or pain about the elbow, forearm, or wrist
- Relative
  - Unknown history or witnessing of pulling-type injury

127.5 Materials and Medications

- None

127.6 Procedure

127.6.1 Method A: Superpronation (preferred method) (Fig. 127.2)

1. Explain to the caretaker that the reduction will cause the child *very brief* discomfort.
2. Seat the child on the lap of a parent/caregiver or an assistant, facing the operator and holding the child in such a way as to hold the child's humerus against her or his side.
3. The person performing the procedure holds the elbow at approximately 90° and grasps the elbow, with the physician's thumb over the region of the radial head (this is done in order to be able to palpate the reduction "clunk" or "click").
4. The physician then holds the patient's wrist firmly and rapidly hyperpronates the forearm. A palpable or audible "click" signifies successful reduction but may not be appreciable.
5. The child may cry for a few minutes after reduction; however, the provider should leave the bedside for 5–10 min and instruct the parents to allow the child to simply play, without focusing on the affected arm.
6. After approximately 10 min, return to the bedside and reevaluate the child, who should have full use of her or his arm by then.

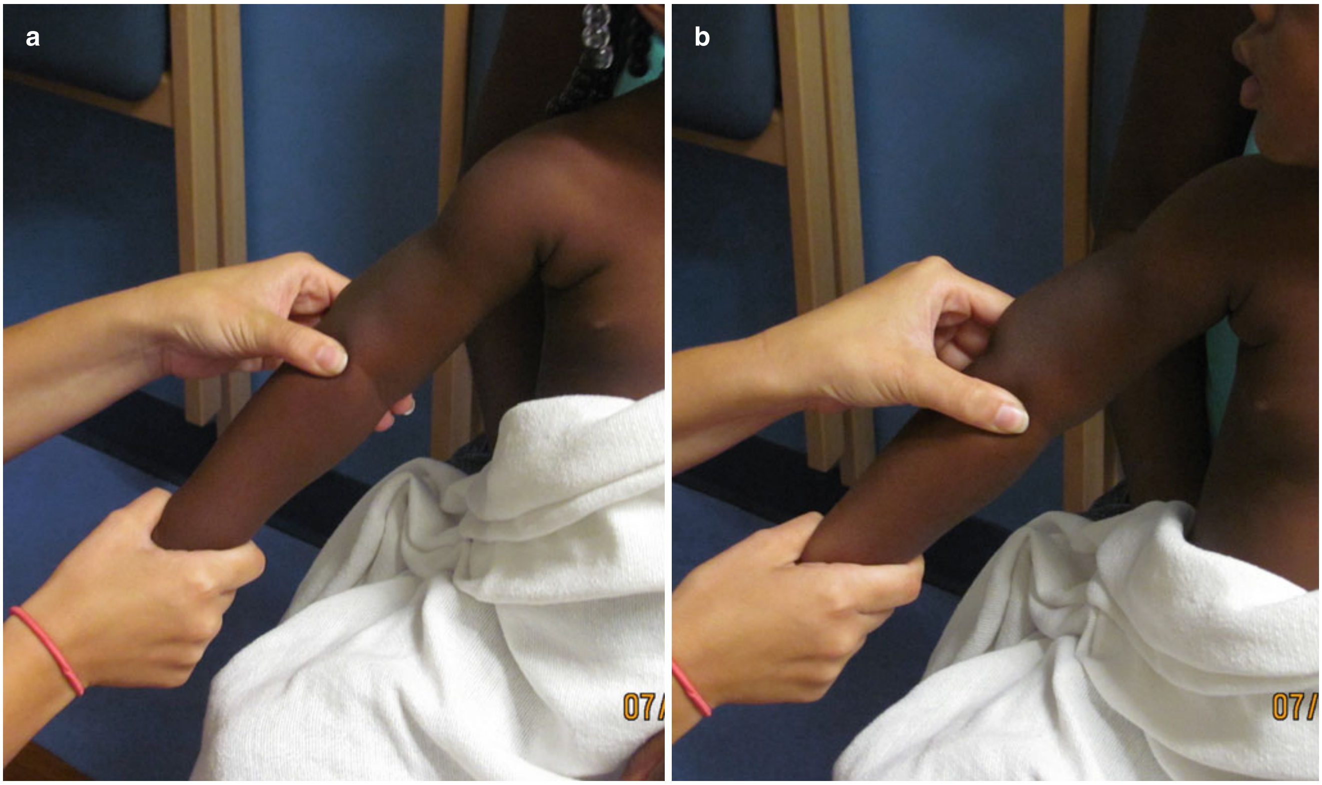

Fig. 127.2 Pronation: (**a**) The examiner's left hand holds the patient's radial head and medial condyle to better appreciate palpable reduction of the subluxation, (**b**) The examiner's right hand gently, but firmly, hyperpronates the patient's forearm from the level of the wrist. Within this maneuver, the examiner should feel or sense a "pop"

127.6.2 Method B: Supination (Fig. 127.3)

1. Follow the first three steps in Method A.
2. While holding the patient's wrist firmly, the operator steadily supinates the patient's forearm completely, followed by flexing the elbow, bringing the patient's wrist up to the shoulder.
3. Return to the fifth and sixth steps in Method A.

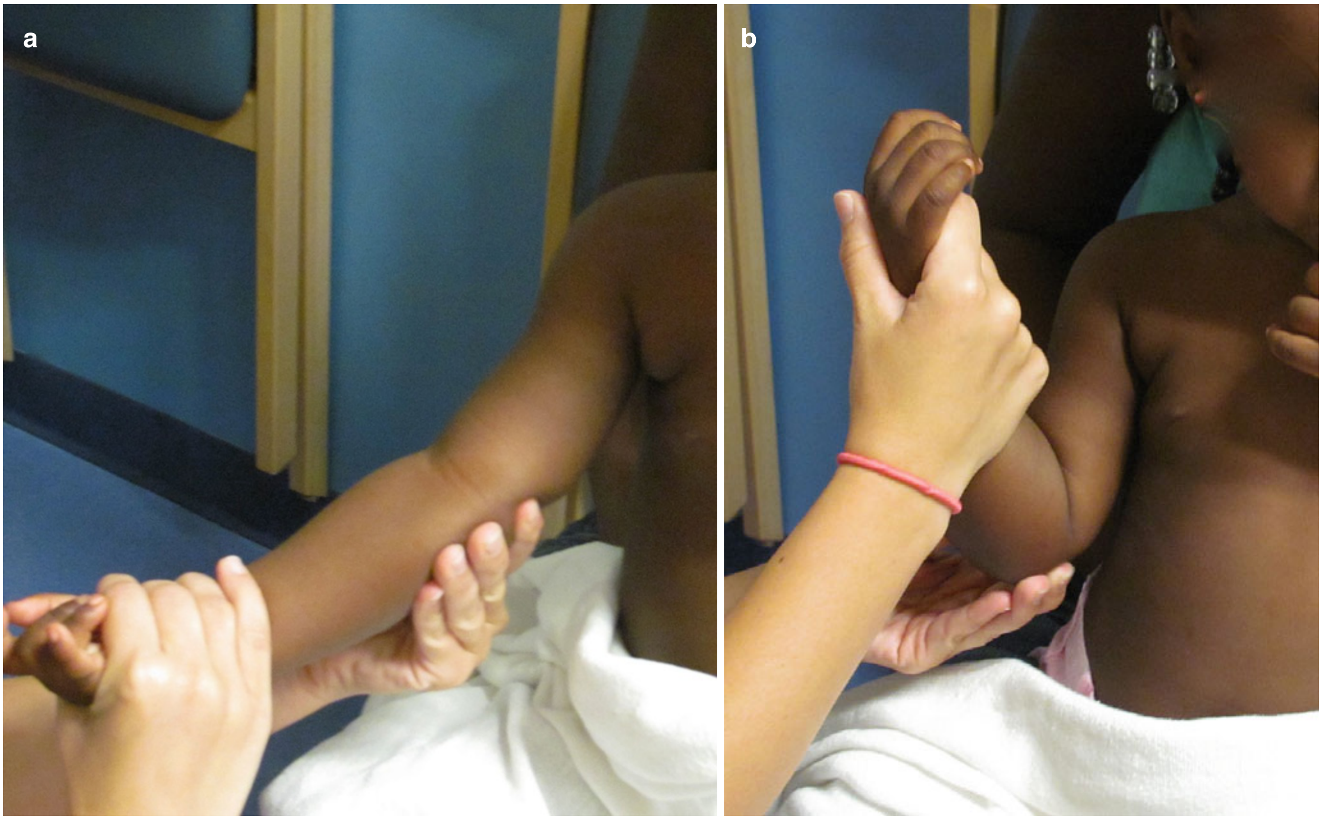

Fig. 127.3 Supination: (**a**) With the examiner's left hand in the same position as for the pronation technique, (**b**) the examiner supinates the forearm, from the level of the wrist, and fully flexes at the elbow. In either of these two maneuvers, the examiner should feel or sense a "pop"

127.7 Evaluation After Procedure

- If the child has complete use of the arm, no further intervention is required.
- If the child is still unable to supinate the forearm after 20–30 min, consider a repeat attempt at reduction.
- If there is still no return to full function after 30 min and/or repeated attempts at reduction, X-rays should be considered.
- In a child who still refuses to use the arm and X-rays are negative, the child should be reevaluated in 24 h.

127.8 Pearls and Pitfalls

- Pearls
  - Once reduced, there is rarely the need for analgesic medications. However, should the need arise, stay with ibuprofen because it is a proven anti-inflammatory.
  - If not seeing improvement within 15 min of reduction, consider this to be a fracture and obtain appropriate views of the elbow and forearm.
- Pitfalls
  - The longer the radial head has been subluxed, the longer it will take the child to return to full use.

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Johannes W. Rohen
Chihiro Yokochi
Elke Lütjen-Drecoll

Color Atlas of Anatomy

FOURTH EDITION

A Photographic Study
of the Human Body

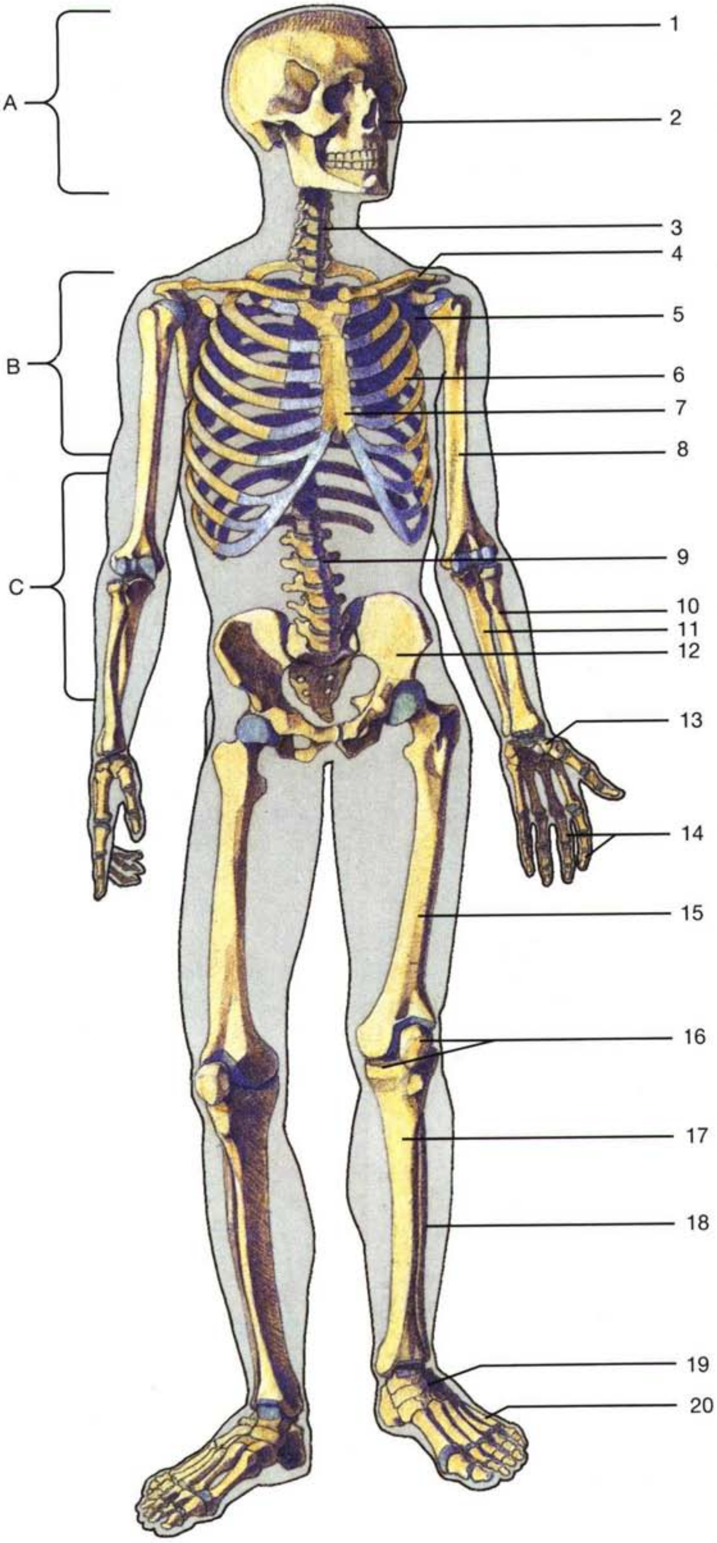

Structure of the human body and the skeleton. Blue = joints.
A Head (caput) B Thorax (thoracic cavity) C Abdominal and pelvic cavities

In contrast to most other mammals the human body is adapted for bipedal locomotion. Three general principles in the architecture of the human organism are recognizable:

1. The principle of **segmentation,** which dominates in the trunk. The vertebral column and the thorax consist of relatively equal, segmentally arranged elements.
2. The principle of **bilateral symmetry.** Both sides of the body are separated by a midsagittal plane and resemble each other like image and mirror-image.
3. The principle of **polarity** between the head at one end of the body and the lower extremities at the other. As the center of the information system the head contains the main sensory organs and the brain. The head has a predominantly spherical form while the extremities consist of radially formed skeletal elements, the number of which increases distally.

A. The **skull** consists of two parts: 1. a **cranial part** containing mainly the brain and the sensory organs and 2. a **facial part** which contains the nasal and oral cavity and the chewing apparatus. The cranial cavity is continuous with the vertebral canal which contains the spinal cord.

B. The **thorax** contains the respiratory and circulatory organs (lung, heart, etc.) but also some of the abdominal organs which are located underneath the diaphragm.

C. The **abdominal cavity** contains the organs of metabolism such as the liver, the stomach and the intestinal tract as well as the excretory and genital organs (kidney, uterus, urinary bladder, etc.). The latter are located primarily in the **pelvic cavity** with the exception of the testes.

1 Cranial part } of the skull
2 Facial part
3 Vertebral column (cervical part)
4 Clavicle
5 Scapula
6 Ribs
7 Sternum
8 Arm (humerus)
9 Vertebral column (lumbar part)
10 Radius } forearm
11 Ulna
12 Pelvis
13 Wrist (carpals) } hand
14 Fingers (phalanges)
15 Thigh (femur)
16 Patella and knee joint
17 Tibia } leg
18 Fibula
19 Tarsals } foot
20 Metatarsals

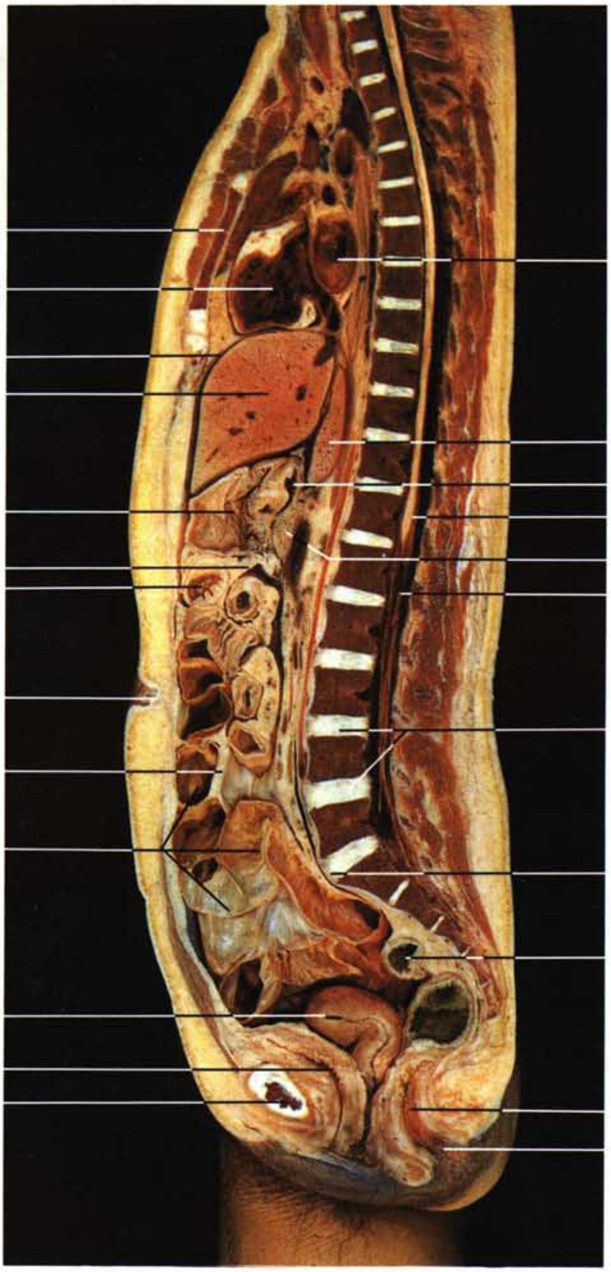
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Median section through the trunk (female).

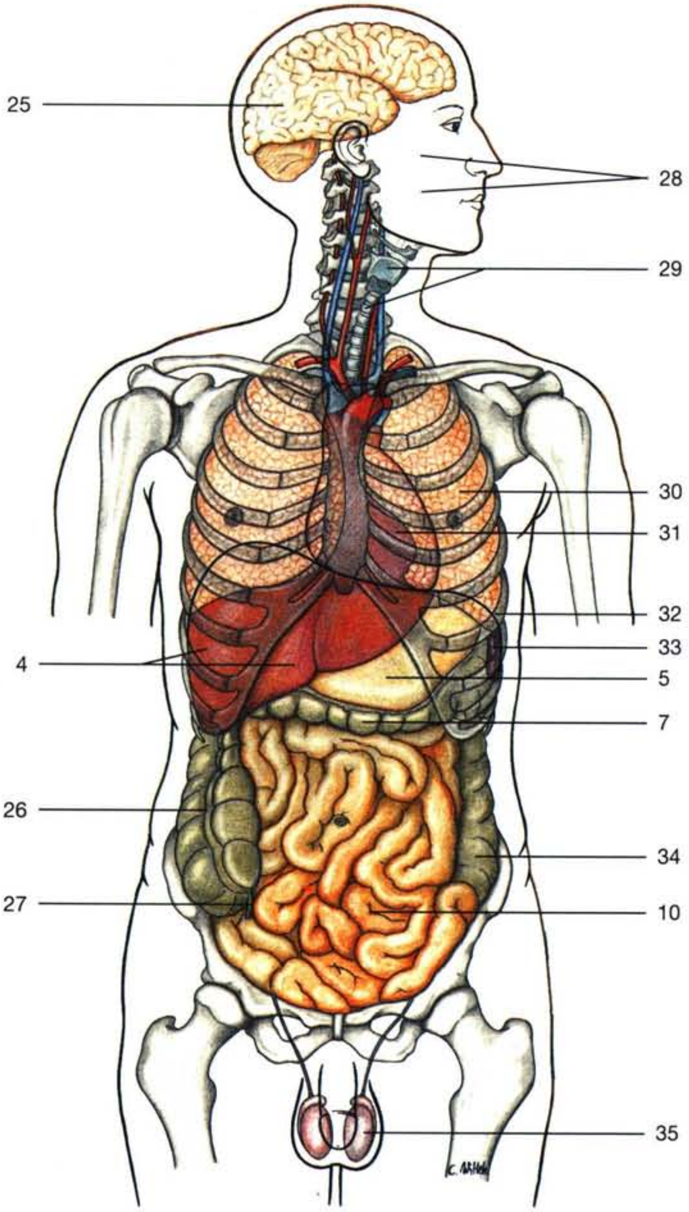
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C. MAHLKE

Positon of the inner organs of the human body (anterior aspect) The main cavities of the body and their contents.

1 Sternum
2 Right ventricle of heart
3 Diaphragma
4 **Liver**
5 **Stomach**
6 Transverse mesocolon
7 Transverse colon
8 Umbilicus
9 Mesentery
10 **Small intestine**
11 Uterus
12 Urinary bladder
13 Pubic symphysis
14 Left atrium of heart
15 Caudate lobe of liver
16 Omental bursa or lesser sac
17 Conus medullaris
18 **Pancreas**
19 Cauda equina
20 Intervertebral discs (lumbar vertebral column)
21 Sacral promontory
22 Sigmoid colon
23 Anal canal
24 Anus
25 Head (neurocranium) with brain
26 Ascending colon
27 Appendix
28 Facial region (viscerocranium) with oral and nasal cavities
29 Trachea and larynx
30 Thorax with the lungs
31 **Heart**
32 Surface projection of the diaphragm
33 **Spleen**
34 Descending colon
35 Testis

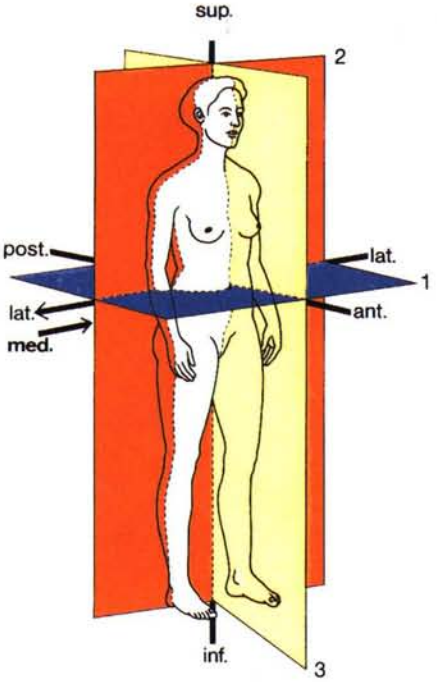
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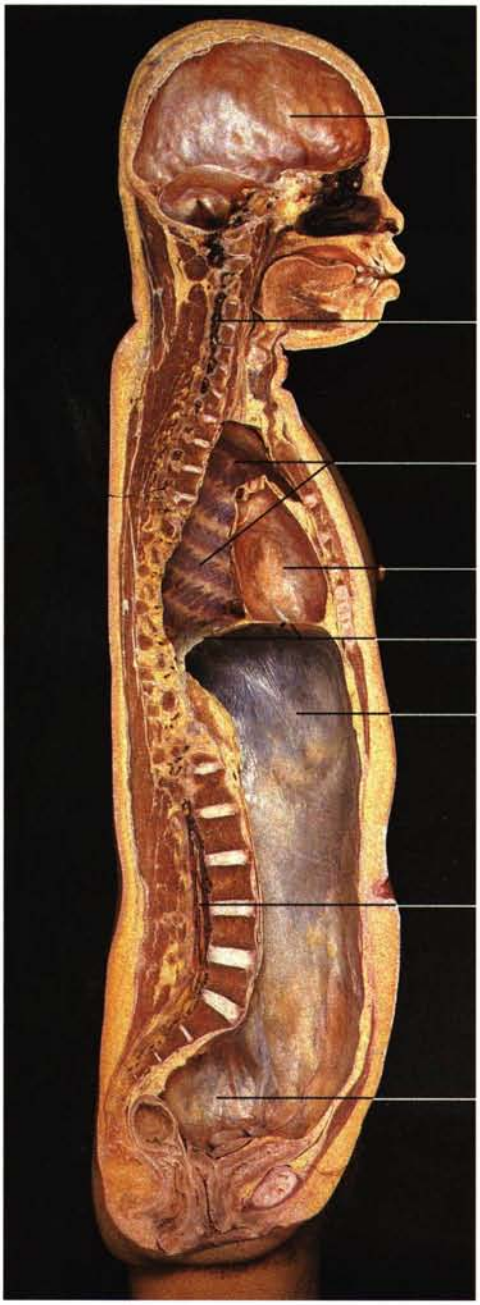

Sagittal section through the human body (female).
Demonstration of the main cavities of the body.
Internal organs are removed.

A_1 Cranial cavity
A_2 Vertebral canal
B_1 Thoracic cavity
B_2 Pericardial cavity
C_1 Abdominal cavity
C_2 Pelvic cavity
D Diaphragm

◁

Planes of the body

1 Transverse plane
2 Frontal plane
3 Sagittal plane (midsagittal)

Lines of direction

ant. = anterior
inf. = inferior
lat. = lateral
med. = medial
post. = posterior
sup. = superior

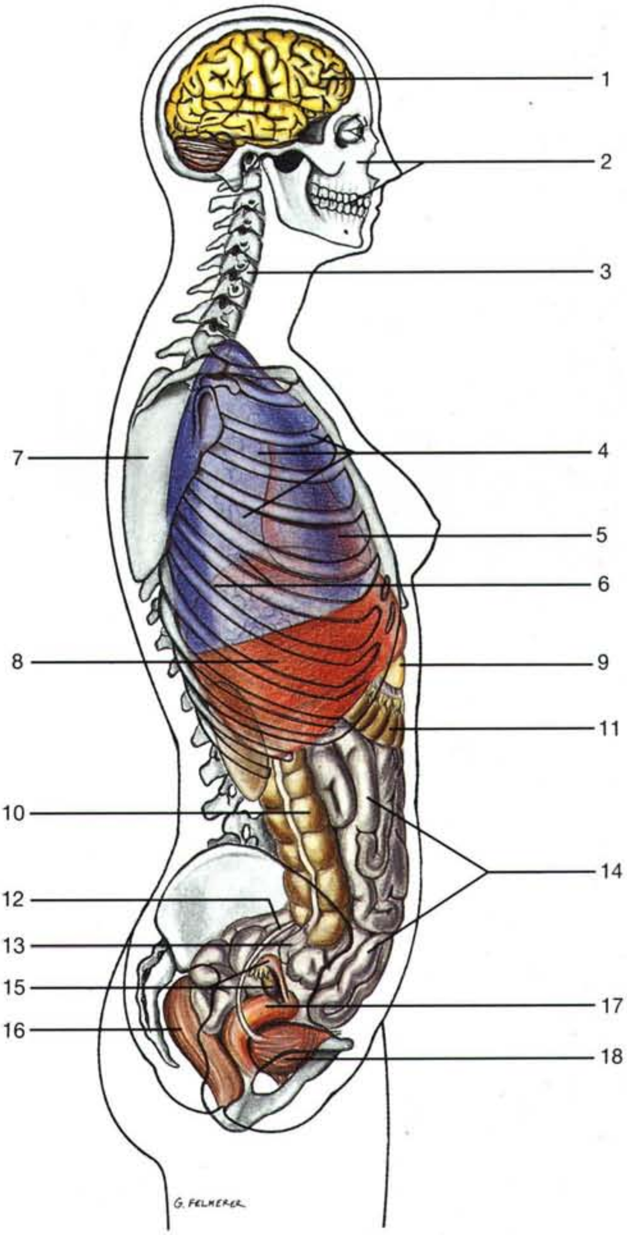

Position of the inner organs of the human body (lateral aspect).
The three main cavities of the body and their contents.

1 Head (neurocranium) with the brain
2 Facial bones with oral and nasal cavities
3 Vertebral column (cervical part)
4 Thorax with the lungs
5 Heart
6 Surface projection of the diaphragm
7 Scapula
8 Liver
9 Stomach
10 Ascending colon
11 Transverse colon
12 Ureter
13 Appendix
14 Small intestine
15 Ovary, uterine tube
16 Rectum
17 Uterus
18 Urinary bladder

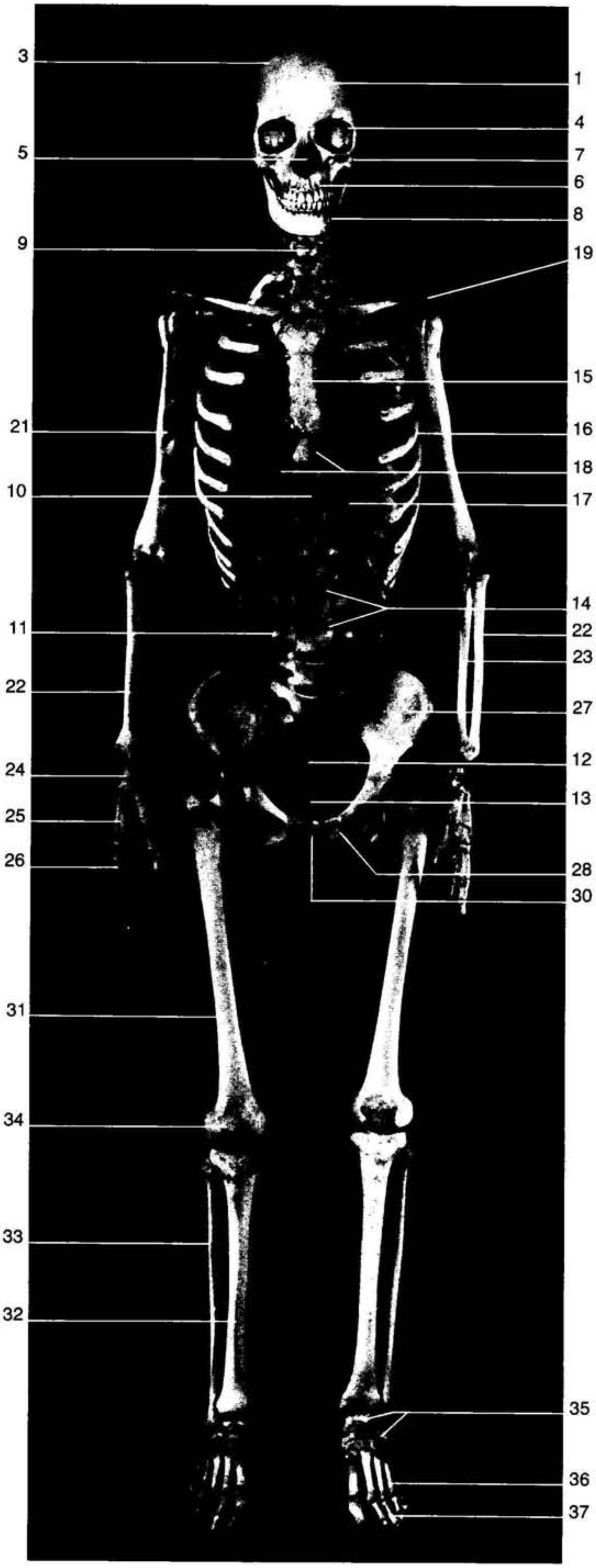
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Skeleton of a female adult (anterior aspect).

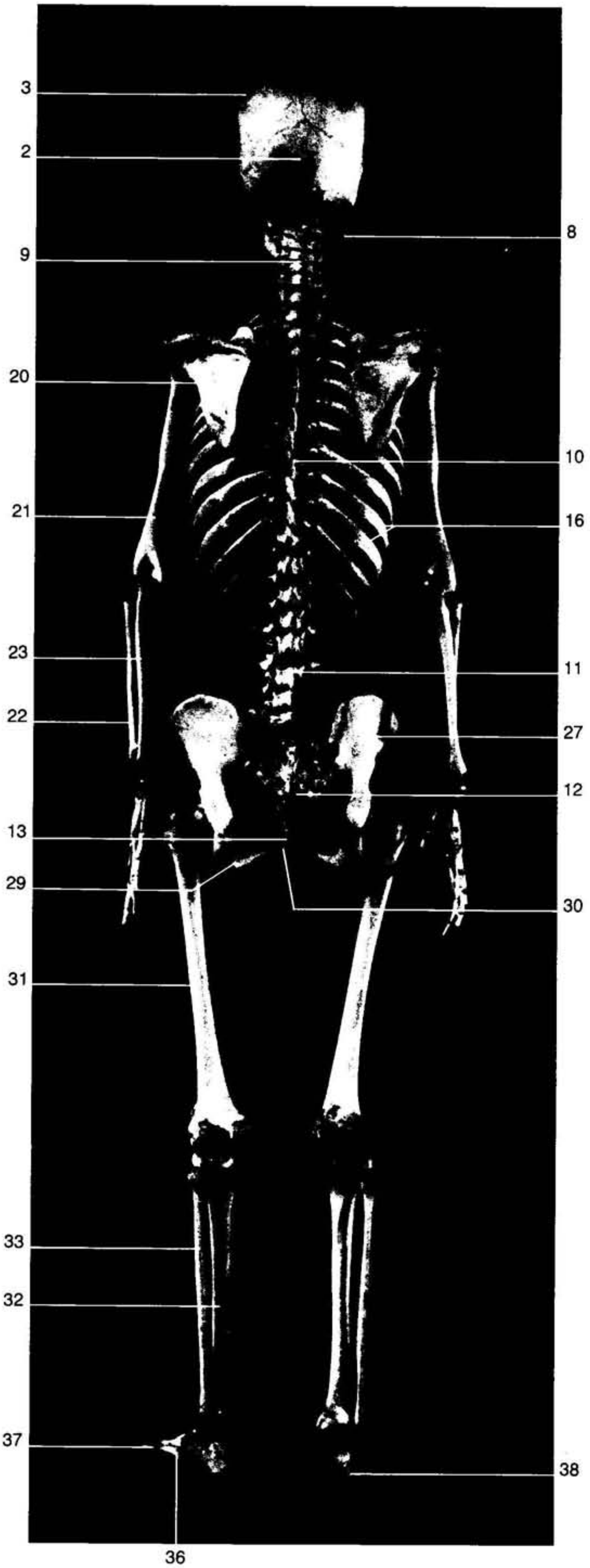
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Skeleton of a female adult (posterior aspect).

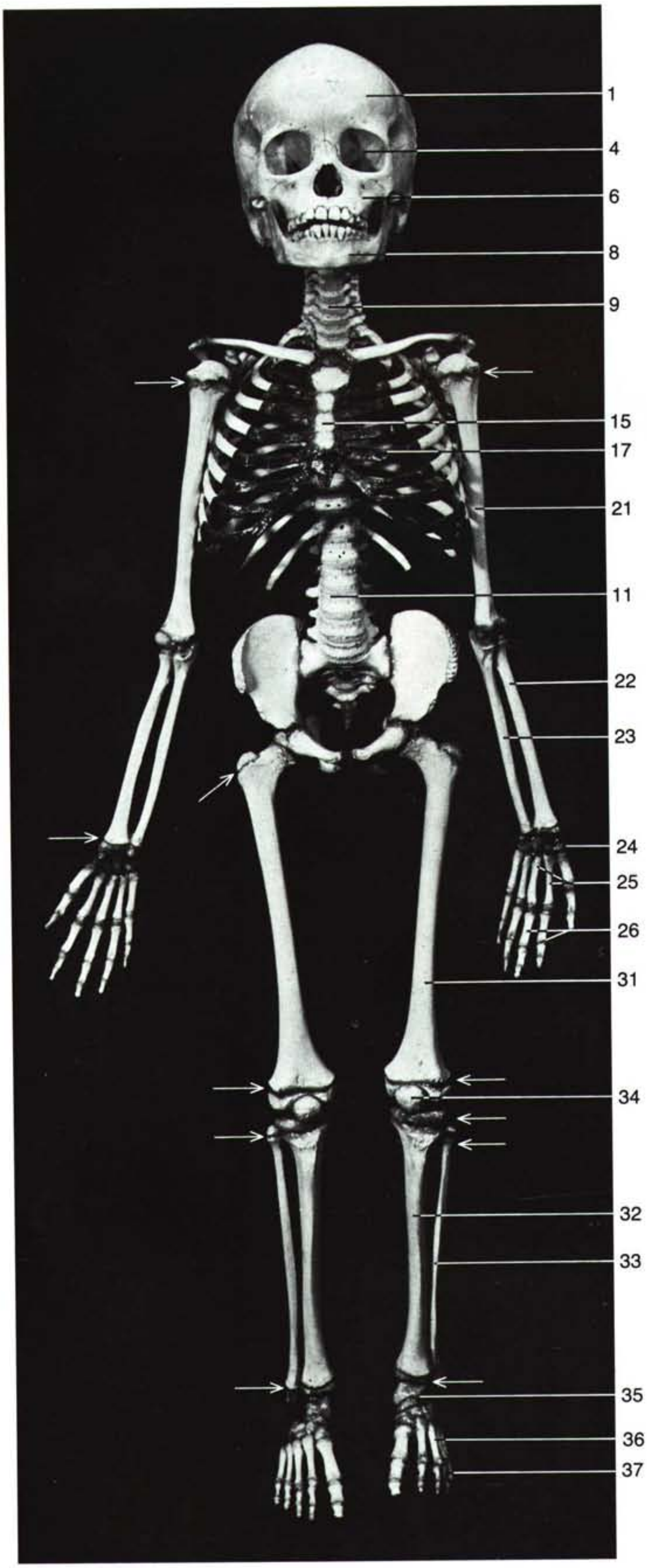

Skeleton of a 5-year-old child (anterior aspect).
The zones of the cartilaginous growth plates are seen (arrows).
In contrast to the adult, the ribs show a predominantly horizontal position.

Axial skeleton

Head

1 Frontal bone
2 Occipital bone
3 Parietal bone
4 Orbit
5 Nasal cavity
6 Maxilla
7 Zygomatic bone
8 Mandible

Trunk and thorax

Vertebral column

9 Cervical vertebrae
10 Thoracic vertebrae
11 Lumbar vertebrae
12 Sacrum
13 Coccyx
14 Intervertebral discs

Thorax

15 Sternum
16 Ribs
17 Costal cartilage
18 Infrasternal angle

Appendicular skeleton

Upper limb and shoulder girdle

19 Clavicle
20 Scapula
21 Humerus
22 Radius
23 Ulna
24 Carpal bones
25 Metacarpal bones
26 Phalanges of the hand

Lower limb and pelvis

27 Ilium
28 Pubis
29 Ischium
30 Symphysis pubis
31 Femur
32 Tibia
33 Fibula
34 Patella
35 Tarsal bones
36 Metatarsal bones
37 Phalanges of the foot
38 Calcaneus

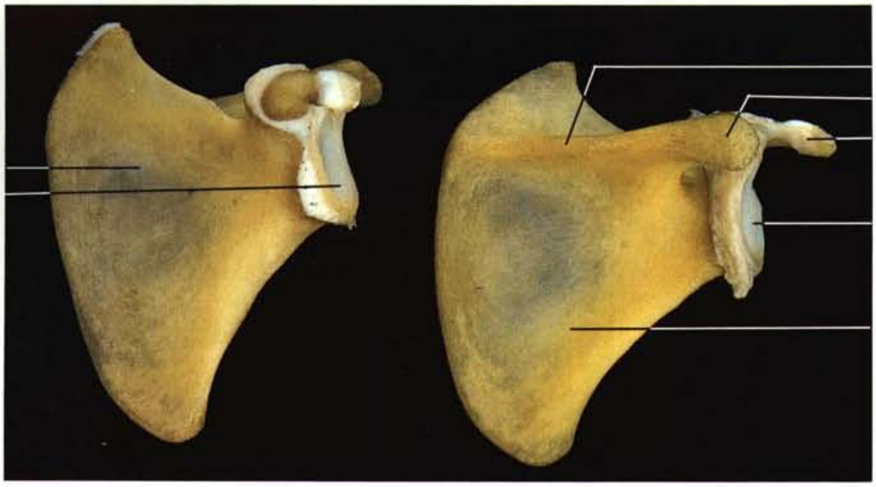

1 Subscapular fossa
2 Coracoid process
3 Glenoid fossa
4 Acromion
5 Spine of scapula
6 Infraspinous fossa

Ossification of the scapula
(left: anterior aspect, right: posterior aspect).

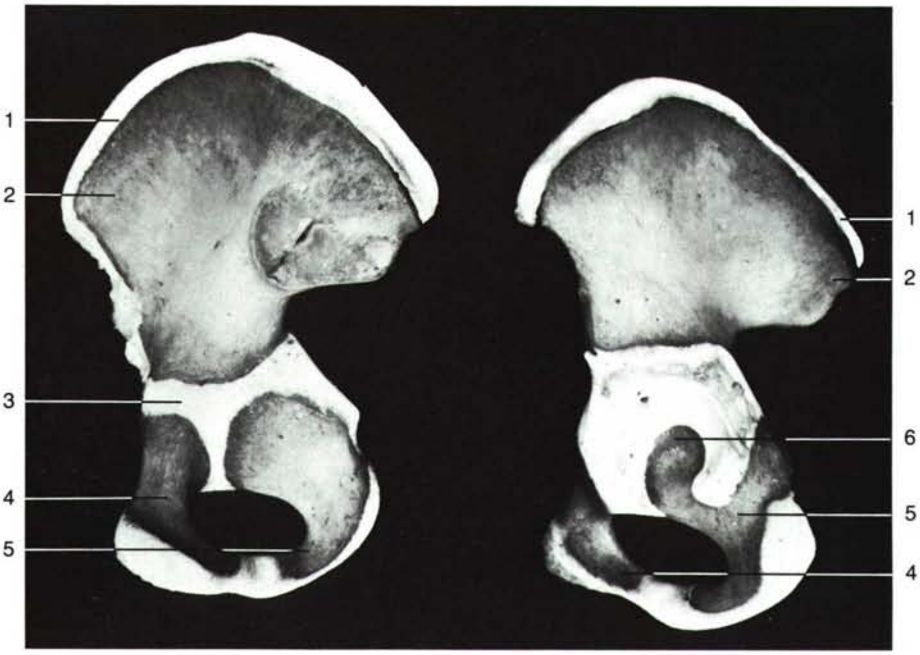

1 Cartilage of the iliac crest
2 Ilium
3 Cartilage
4 Pubis
5 Ischium
6 Acetabulum

Ossification of the hip bone
(left: medial aspect, right: lateral aspect).

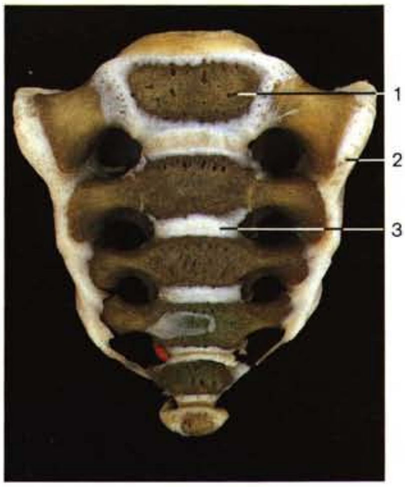

1 Bone tissue (vertebral body)
2 Cartilaginous tissue (lateral epiphysis)
3 Intervertebral discs

Ossification of the sacrum (anterior aspect).
Note the five vertebral bones, which are still separated from each other.

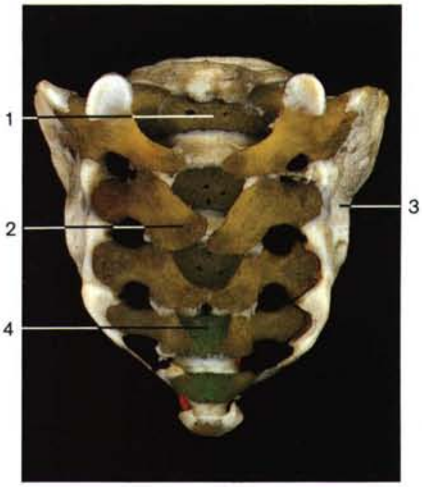

1 Bony tissue (center of ossification)
2 Vertebral arch (not completely united)
3 Cartilaginous tissue (lateral epiphysis)
4 Sacral canal

Ossification of the sacrum
(posterior aspect).

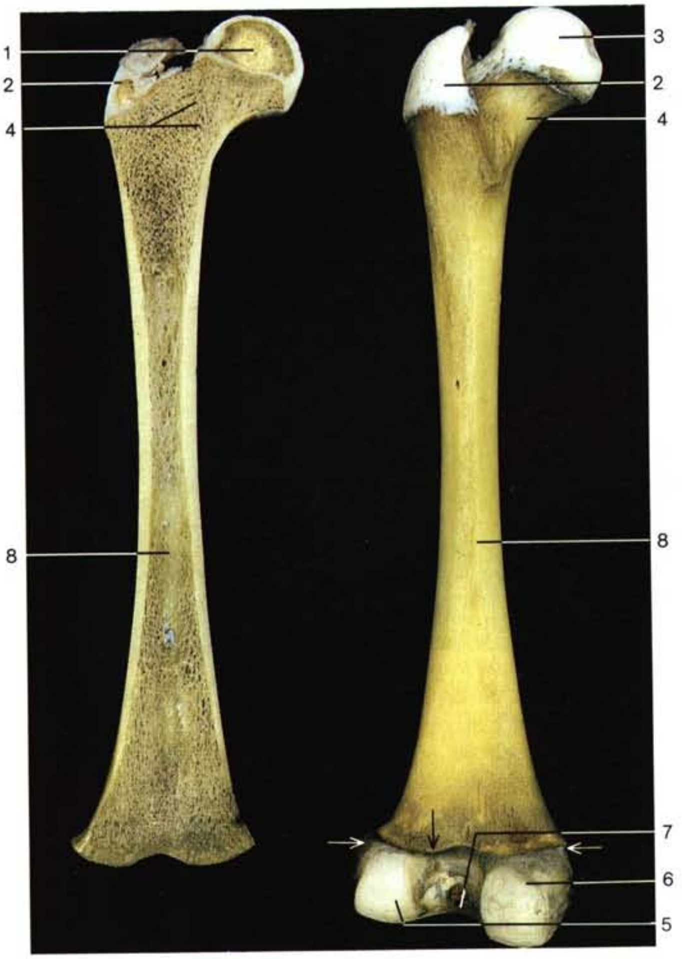

1 Ossification center in the head of the femur
2 Greater trochanter
3 Head of the femur
4 Neck of the femur
5 Lateral condyle
6 Medial condyle
7 Intercondylar notch
8 Diaphysis

Ossification of the femur (left: coronal section, right: posterior view of the femur). Arrows: distal epiphysis.

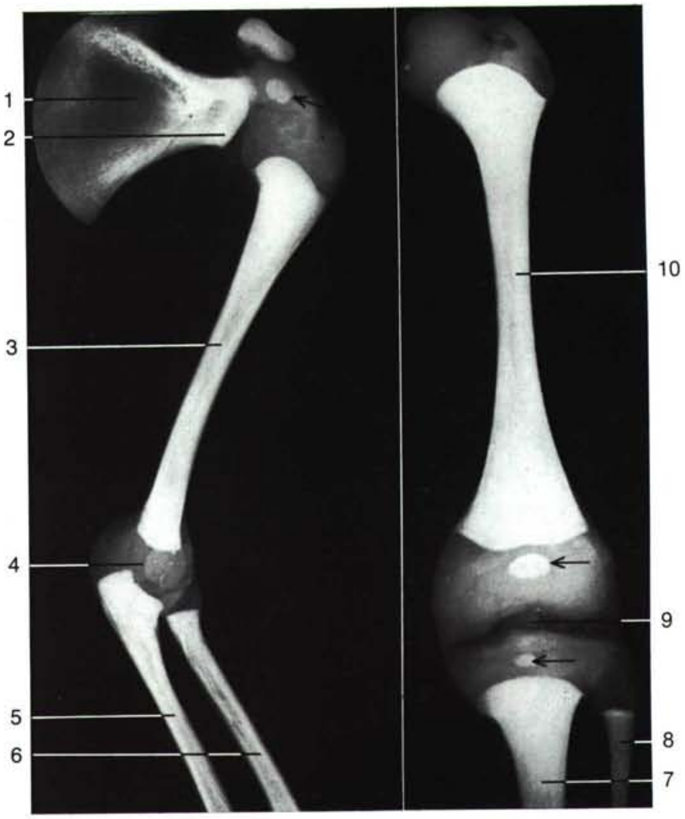

X-ray of the upper and lower limb of a newborn child.
Left: upper limb. Right: lower limb.
Arrows: ossification centers.

1 Scapula
2 Shoulder joint
3 Humerus
4 Elbow joint
5 Ulna
6 Radius
7 Tibia
8 Fibula
9 Knee joint
10 Femur

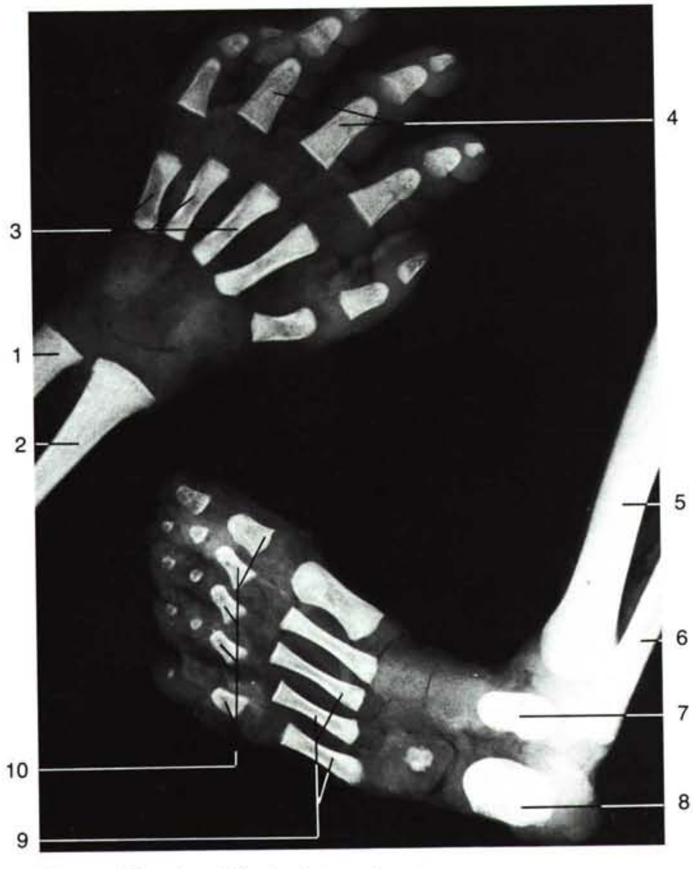

X-ray of hand and foot of a newborn.

1 Ulna
2 Radius
3 Metacarpals
4 Phalanges
5 Tibia
6 Fibula
7 Talus
8 Calcaneus
9 Metatarsals
10 Phalanges

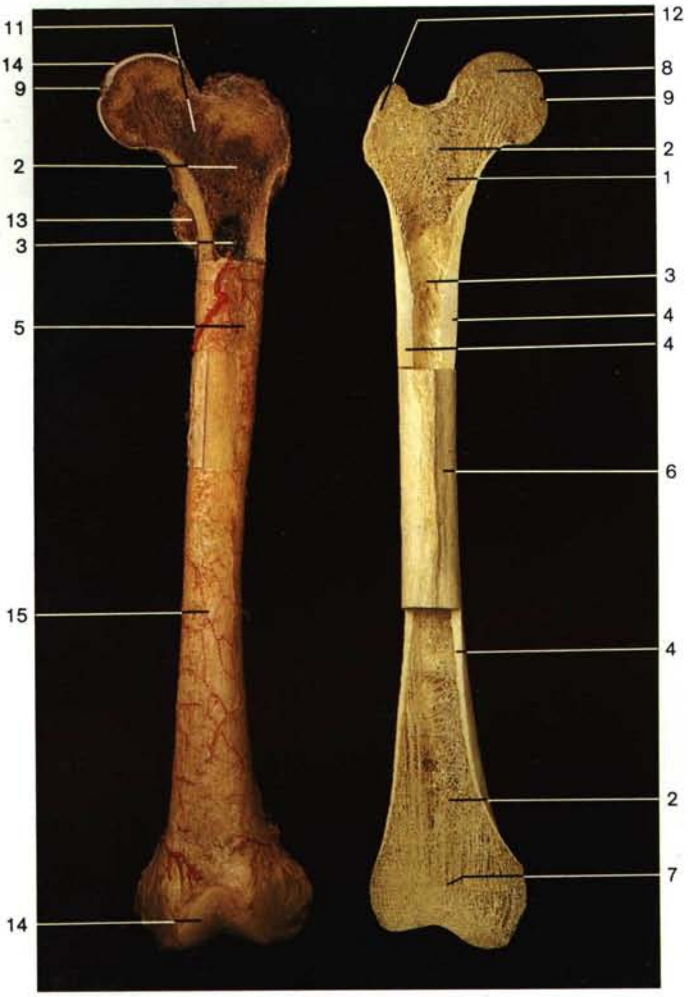

Femur of the adult. Left: the periosteum and the nutrient vessels are preserved. Right: coronal section of the proximal and distal epiphyses to display the spongy bone and the medullary cavity.

1 Metaphysis
2 Spongy bone
3 Medullary cavity in the diaphysis
4 Compact bone
5 Nutrient canal
6 Diaphysis
7 Epiphyseal line (remnants of the epiphyseal plate)
8 Epiphysis (head of the femur)
9 Fovea of head
10 Trabeculae of spongy bone
11 Neck of the femur
12 Greater trochanter
13 Lesser trochanter
14 Articular surface
15 Periosteum
16 Skin
17 Vastus medialis muscle
18 Sartorius muscle
19 Femoral artery and vein
20 Great saphenous vein
21 Gracilis muscle
22 Adductor longus muscle
23 Adductor magnus muscle
24 Semimembranosus muscle
25 Semitendinosus muscle
26 Rectus femoris muscle
27 Vastus lateralis muscle
28 Femur and medullary cavity
29 Vastus intermedius muscle
30 Sciatic nerve
31 Biceps femoris muscle
32 Spongy bone trabeculae containing bone marrow
33 Compact bone
34 Osteon with Haversian lamellae
35 Periosteum
36 Blood vessels and nerves for periosteum and bone

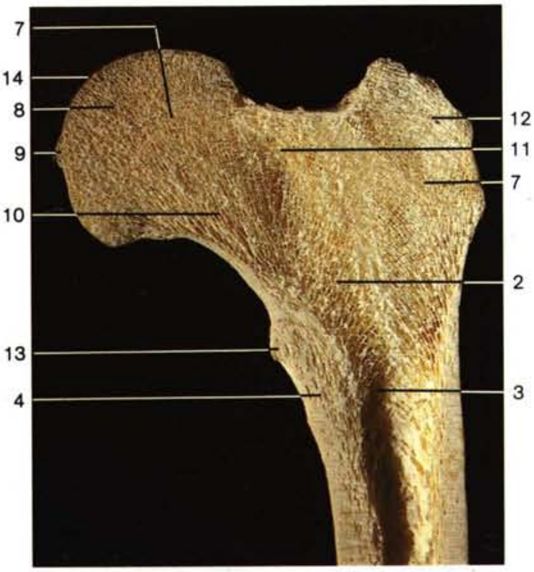

Coronal section through the proximal end of the adult femur, revealing the characteristic trajectorial structure of the spongy bone.

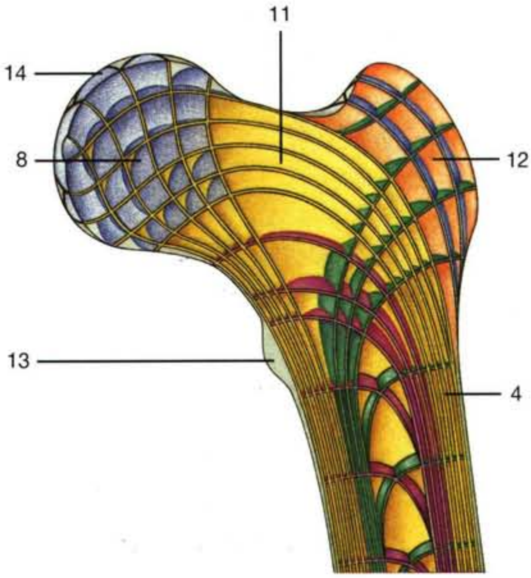

Three dimensional representation on the trajectorial lines of the femoral head (according to B. Kummer).

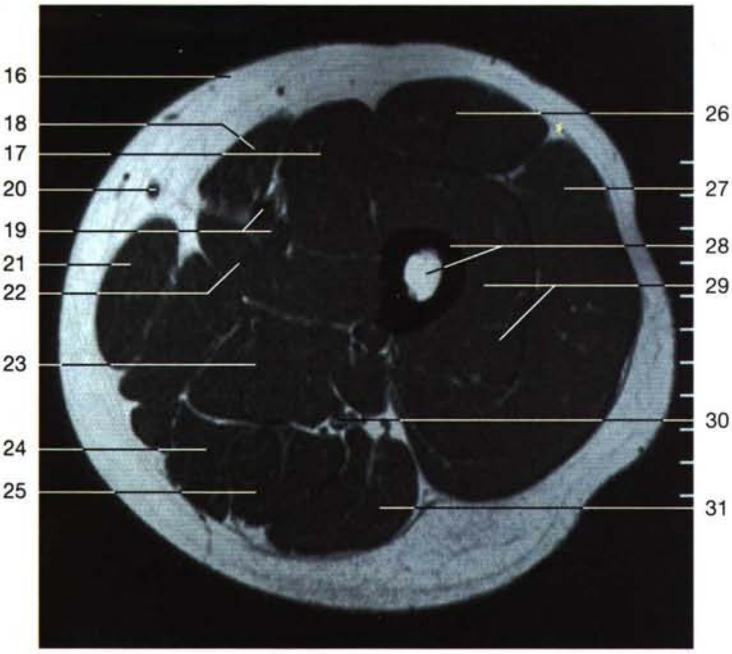

MR-Image of the thigh (axial section through the middle of the left thigh, the same level as the CT-Image).

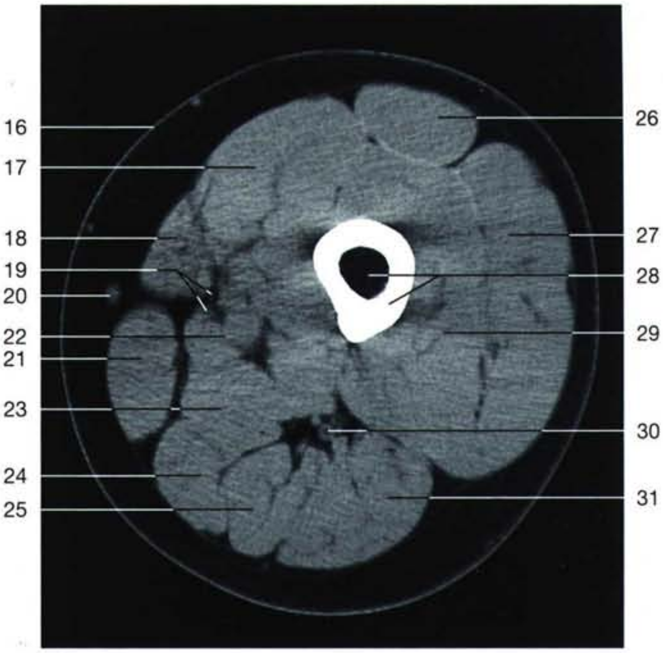

CT-Image of the section through the middle of the left thigh (axial section). Note the differences between the CT- and MR-Image (see text below).

The **bones** of the skeletal system consist of two different parts, the spongy and the compact bone. The spongy bone trabeculae are highly adapted to mechanical forces revealing a trajectorial structure. The intertrabecular spaces are filled with bone marrow, the site of blood formation. The appearance of bones, muscles and soft tisssues is quite different in **CT-** and **MR-Images**. The CT-images relate well to radiographs in that areas of great absorption such as bones are white, and those with little absorption such as fat appear black. In contrast, the intensity of signals in MR-Images, obtained without X-rays but by magnetic forces, is different so that dense areas of bones appear black and soft tissues such as bone marrow and fat appear white (for comparison see above figures).

A highly innervated **periosteum** is an essential structure for bone nutrition, blood supply, growth and bone repair.

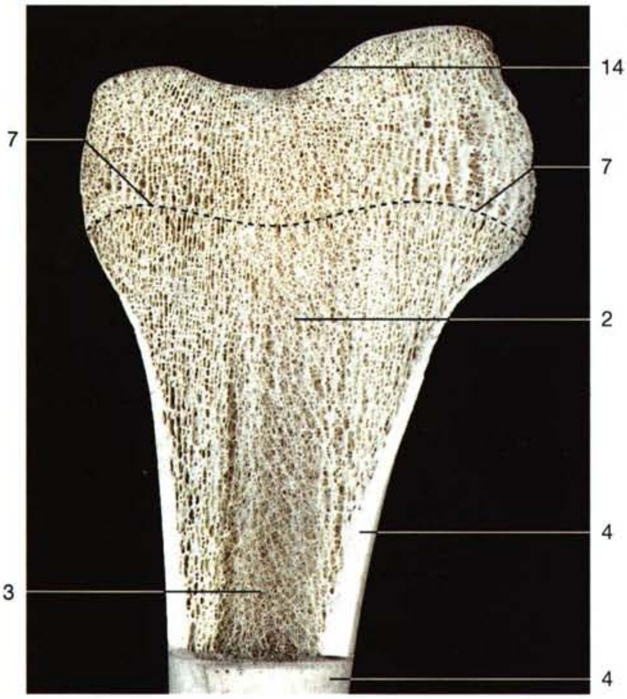

Coronal section through the proximal epiphysis of the adult tibia. Note the zone of dense bone at the site of the former epiphyseal plate (dotted line).

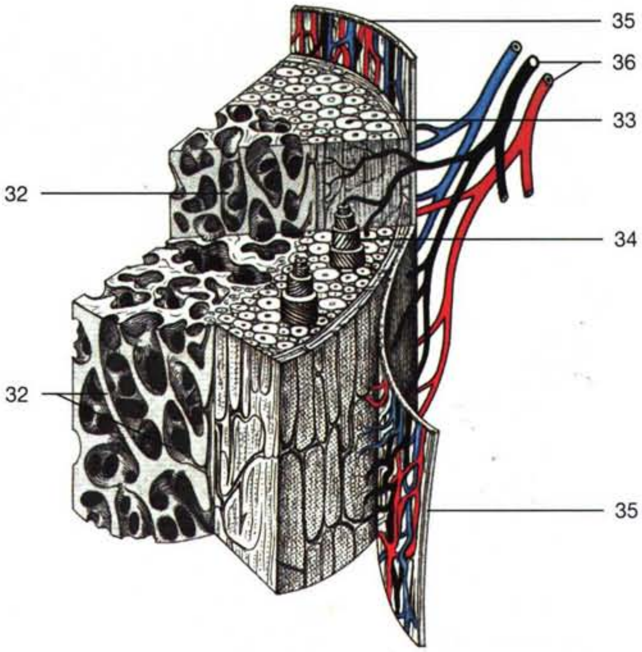

Structure of bones of the skeletal system (after Benninghoff). Note that the compact bone reveals a lamellar structure with Haversian lamellae and canals.

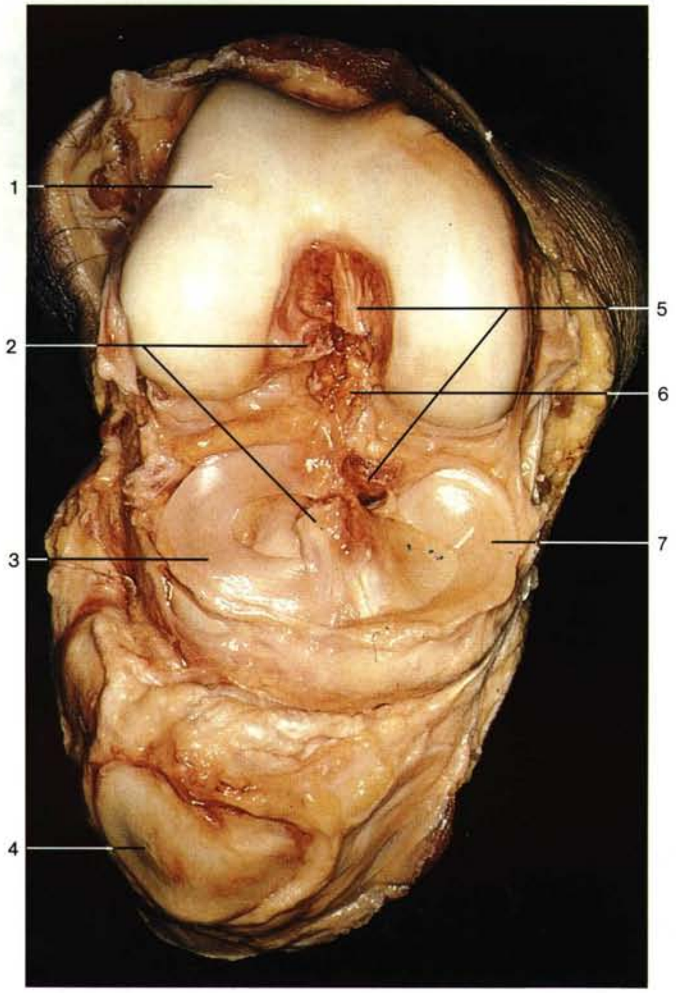

Knee joint. Anterior aspect, showing menisci and cruciate ligaments (cut). Quadriceps tendon cut and patella reflected distally.

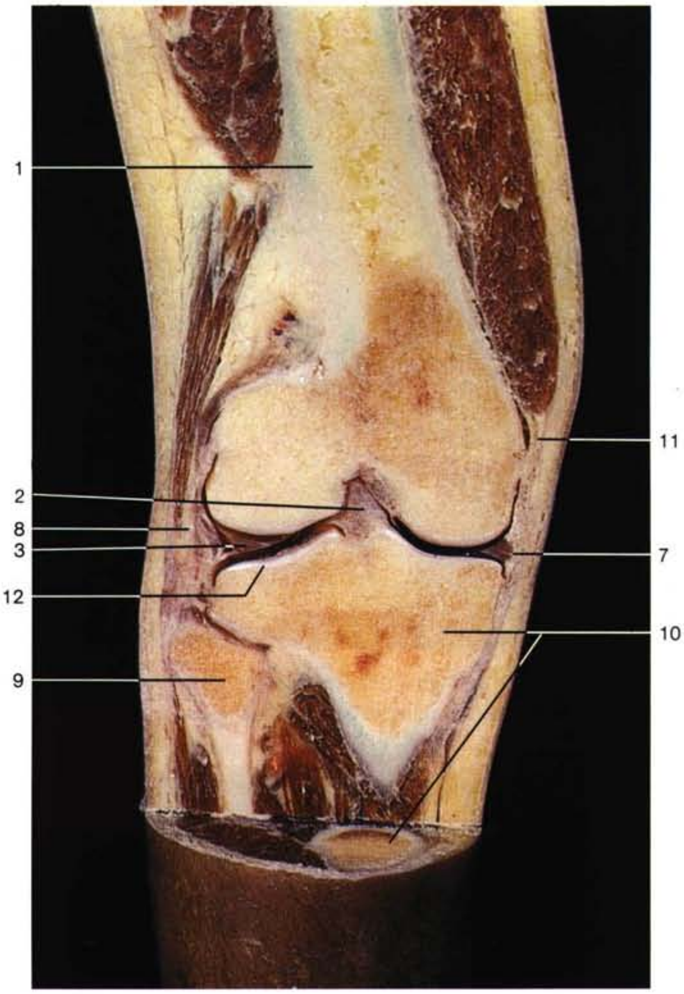

Coronal section through the knee joint. Anterior aspect of the right joint in extension.

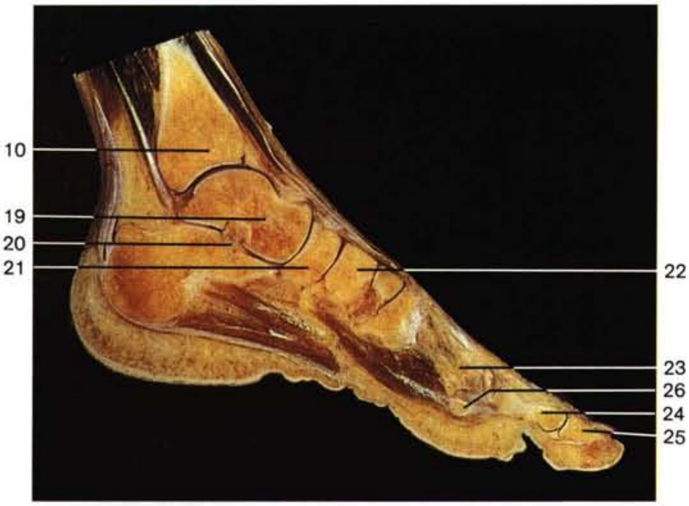

Sagittal section through the lower limb and the foot.

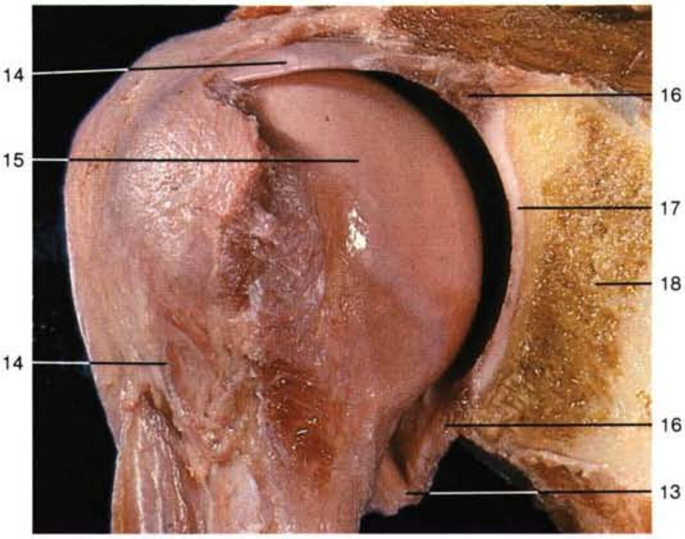

Shoulder joint (anterior view). The anterior part of the articular capsule has been removed.

1 Femur
2 Anterior cruciate ligament
3 Lateral meniscus
4 Patella
5 Posterior cruciate ligament
6 Posterior meniscofemoral ligament
7 Medial meniscus
8 Fibular collateral ligament
9 Fibula
10 Tibia
11 Tibial collateral ligament
12 Articular cartilage
13 Articular capsule
14 Tendon of long head of biceps brachii muscle
15 Head of humerus
16 Glenoid labrum
17 Articular cartilage of glenoid fossa
18 Scapula
19 Talus
20 Interosseous talocalcaneal ligament
21 Navicular bone
22 Medial cuneiform bone
23 First metatarsal bone
24 Proximal phalanx of the hallux (great toe)
25 Distal phalanx of the hallux
26 Sesamoid bone

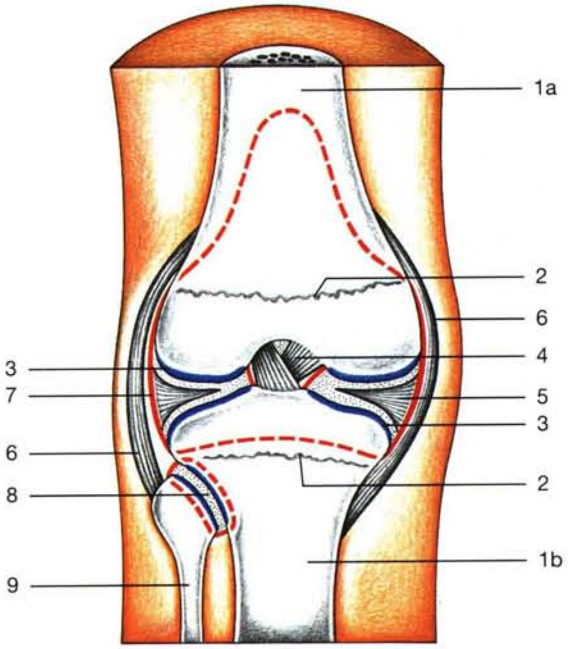

General architecture of a synovial joint with 2 articulating bones and a synovial cavity (right side, anterior view).
Coronal section throught the knee joint.
Red line = Articular capsule with synovial membrane.
Dotted red line = extension of articular capsule (suprapatellar bursa).

1 Articulating bones: a) Femur, b) Tibia
2 Epiphysial line
3 **Articular cartilage**
4 Intraarticular ligaments (e.g. cruciate ligaments)
5 Fibrocartilaginous disk (e.g. meniscus)
6 Collateral ligaments
7 Articular capsule with synovial membrane
8 **Tibiofibular articulation** (example of gliding synovial joint)
9 Fibula

	Movement	Examples
A Fibrous joints		
1 Sutures	No movements	Sutures of the skull
2 Syndesmoses	No movements	Distal tibiofibular joint
3 Gomphosis	No movements	Roots of teeth in alveolar process
B Cartilaginous joints		
1 Synchondroses	No movements	Epiphyseal plates
2 Symphyses	Slight movement	Symphysis pubis intervertebral discs
C Synovial joints		
1 Gliding	Monaxial	Intercarpal joint Intertarsal joint Sacroiliacal joint
2 Hinge	Monaxial	Interphalangeal joint Humeroulnar joint Talocrural joint
3 Pivot	Monaxial	Atlantoaxial joint Radioulnar joint
4 Ellipsoidal	Biaxial	Radiocarpal joint
5 Saddle	Biaxial	Carpometacarpal joint of the thumb
6 Ball-and-socket	Multiaxial	Shoulder and hip joint

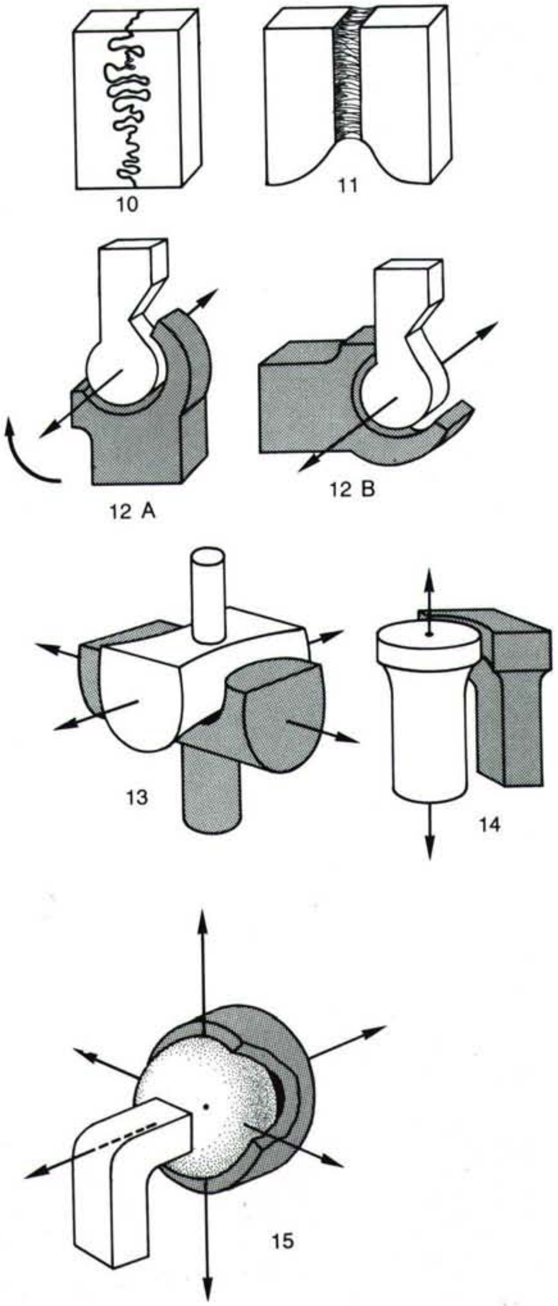

Main types of joints. Arrows: axes of movement.

Fibrous joints (synarthroses)
10 Serrate suture
11 Syndesmosis

Synovial joints (diarthroses)
12 Hinge joints (monaxial) ginglymus
A Extension
B Flexion
13 Saddle joint (biaxial)
14 Pivot joint (monaxial, rotation)
15 Ball-and-socket joint (multiaxial)

An articulation or joint is the functional connection between two or more bones. Joints can be divided into two categories depending upon whether the articulating surfaces of the bones are separated by a real cavity (joint cavity) so that they are movable against each other **(synovial joints)** or whether the bones are firmly connected by fibrous or cartilaginous tissue and practically immovable (**fibrous joints, cartilaginous joints,** symphysis, etc.). Synovial joints always possess a joint capsule (with a vascularized synovial membrane), articular cartilages, and a joint cavity. They are grouped according to the degree of movement they permit. A hinge joint (ginglymus) permits movement in only one plane about a single axis **(uniaxial** or **monaxial),** an ellipsoidal joint permits movements in two planes **(biaxial),** and ball-and-socket joints permit a range of movements around several axes **(multiaxial).** The following survey gives a few examples of these types of articulation.

1. Fibrous joints

A Sutures

a) Serrate or dentate suture

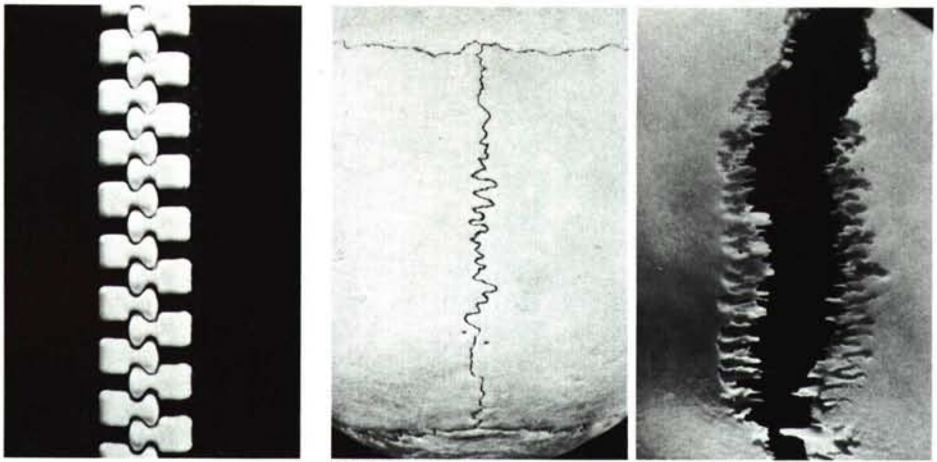
Sagittal suture

Separated

b) Squamous suture (arrows)

1 Parietal bone
2 Sphenoid bone
3 Squama of temporal bone

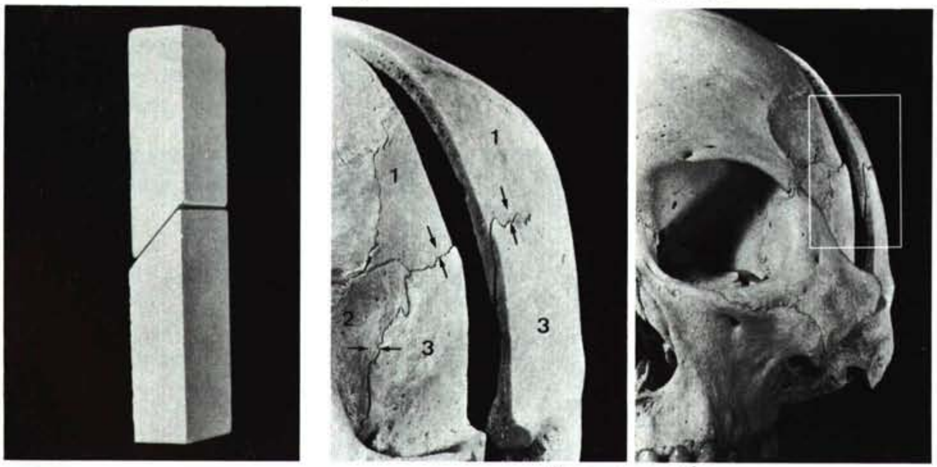

Squamous suture

c) Plane suture (arrow)

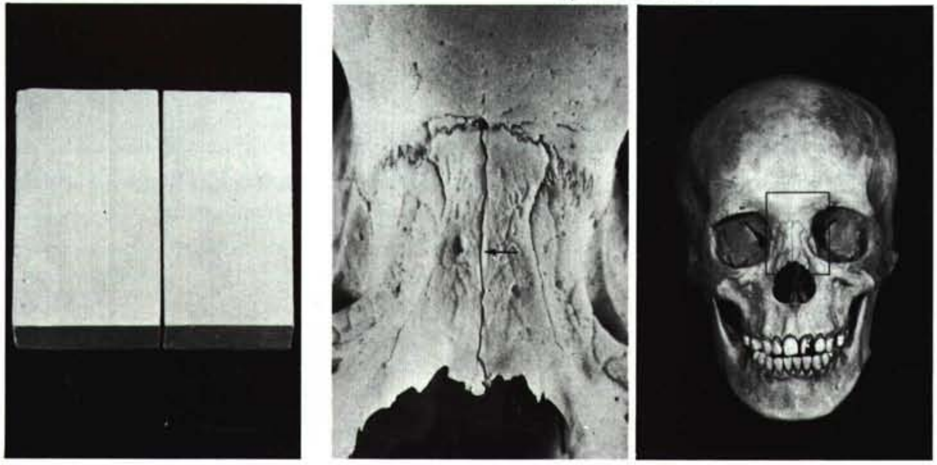
Nasal bones

B Peg suture
(Gomphosis)

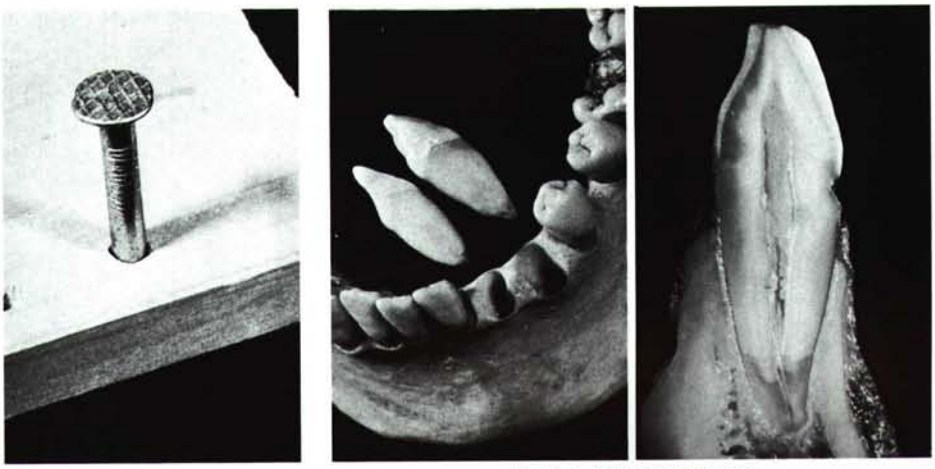

Teeth and alveolar process

2. Cartilaginous joints

a) Symphysis
(fibrocartilage)

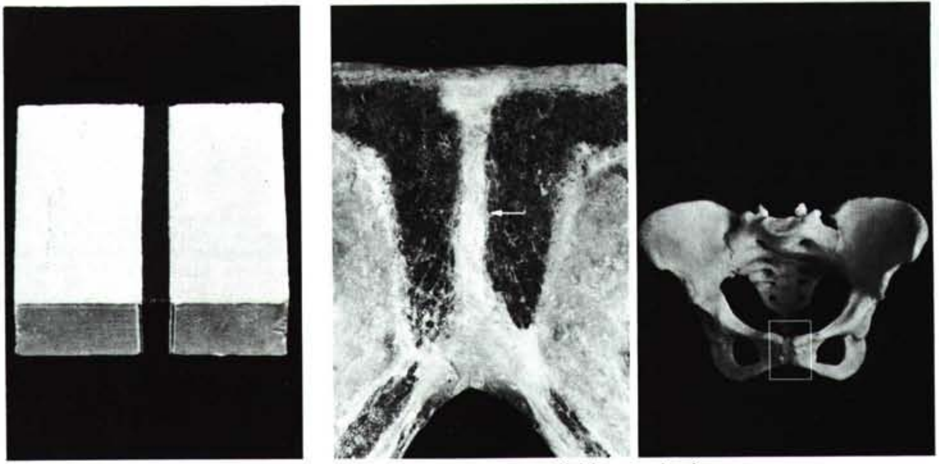

Pubic symphysis

b) Synchondrosis
(hyaline cartilage)

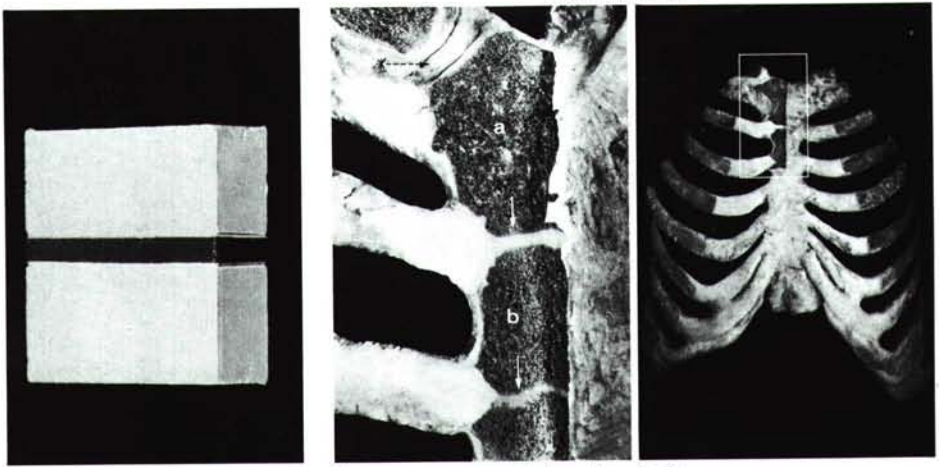

Sternum a = manubrium; b = body

* Articular disc
(sternoclavicular joint)

3. Osseous joints
(synostosis)

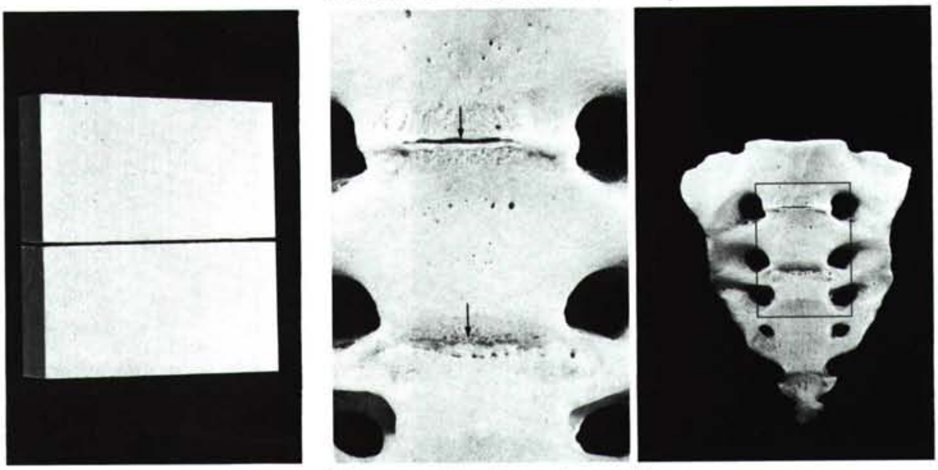

Transverse ridge (arrows) Sacrum

1. Ball-and-socket joint

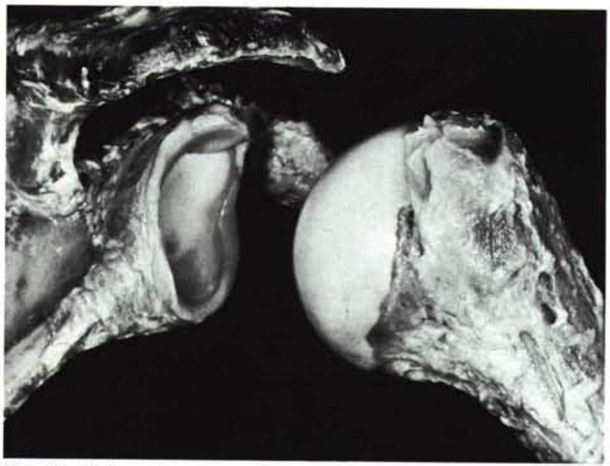

Shoulder joint

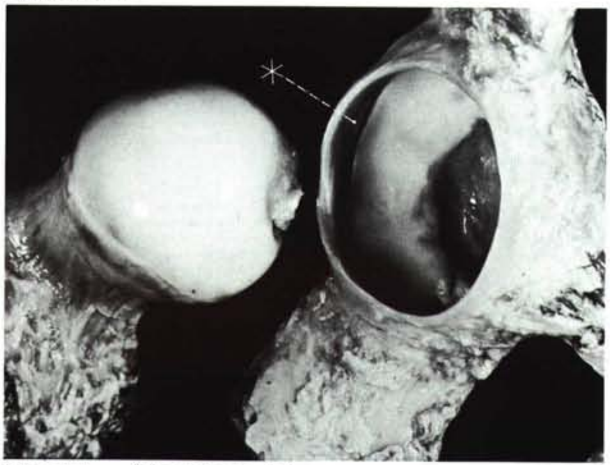

Hip joint *Acetabular labrum

2. Ellipsoid joint

OFFICIAL
Rugby Football
OFFICIAL
SIZE-WEIGHT

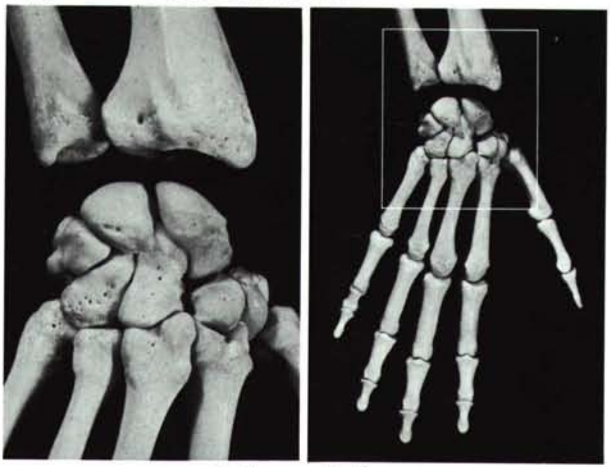

Radiocarpal joint

3. Hinge joint

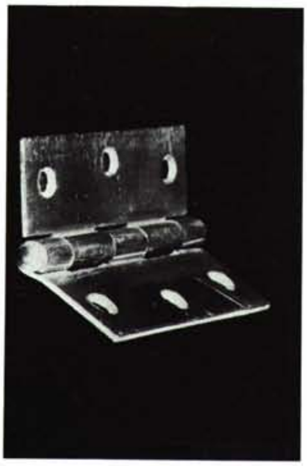

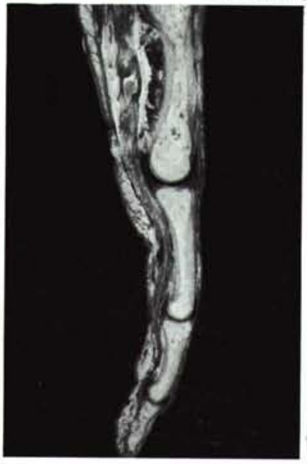

Interphalangeal joint

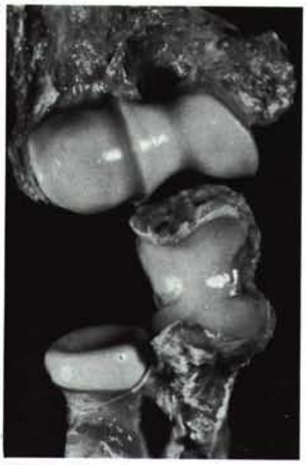

Elbow joint (humeroulnar joint)

4. Pivot joint

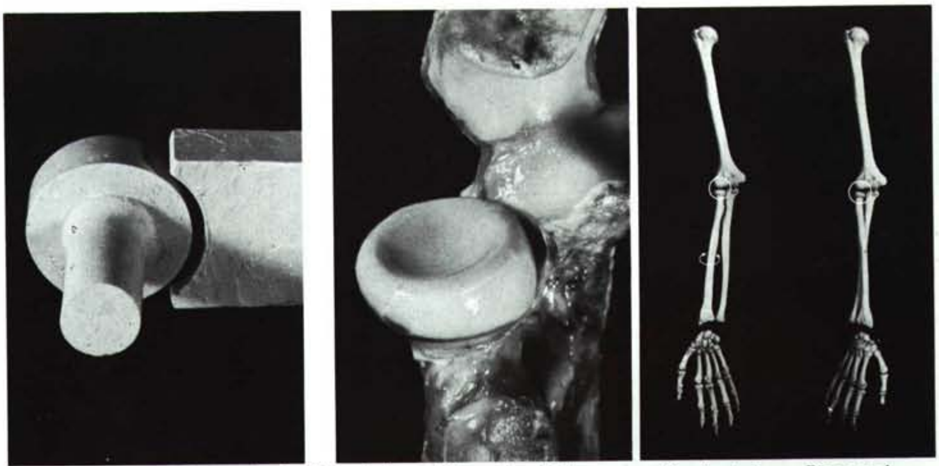

Radioulnar joint; left: head of radius, right: radial notch of ulna

Supinated Pronated

5. Hinge joint

(but a gradually tilting axis produces a slight spiral motion)

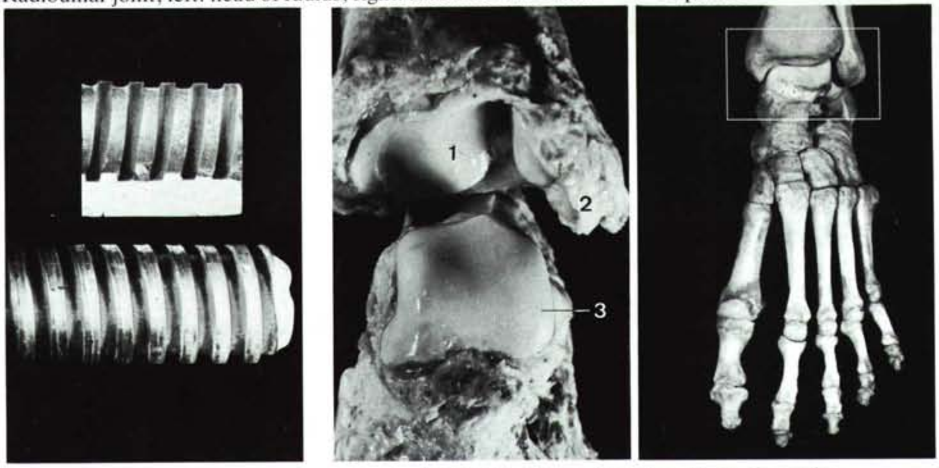

Ankle joint: 1 = tibia; 2 = fibula; 3 = talus

6. Saddle joint

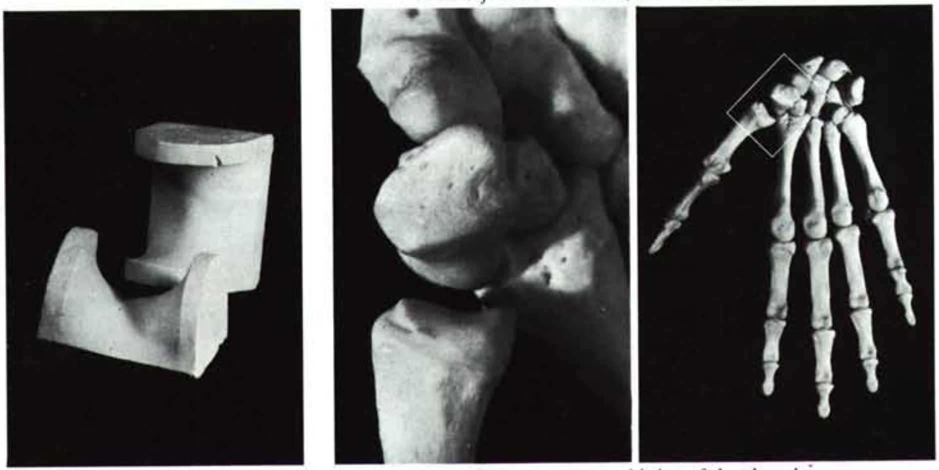

Carpometacarpal joint of the thumb

7. Plane joint

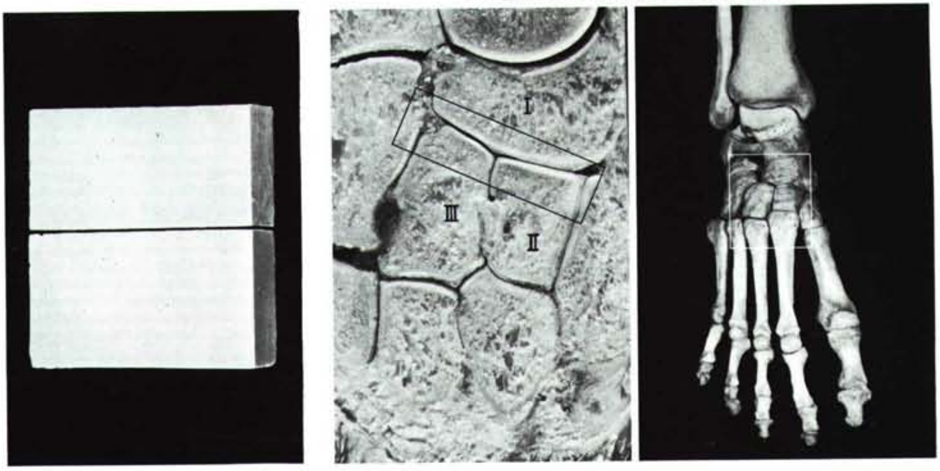

I = navicular; **II** = intermediate cuneiform; **III** = lateral cuneiform

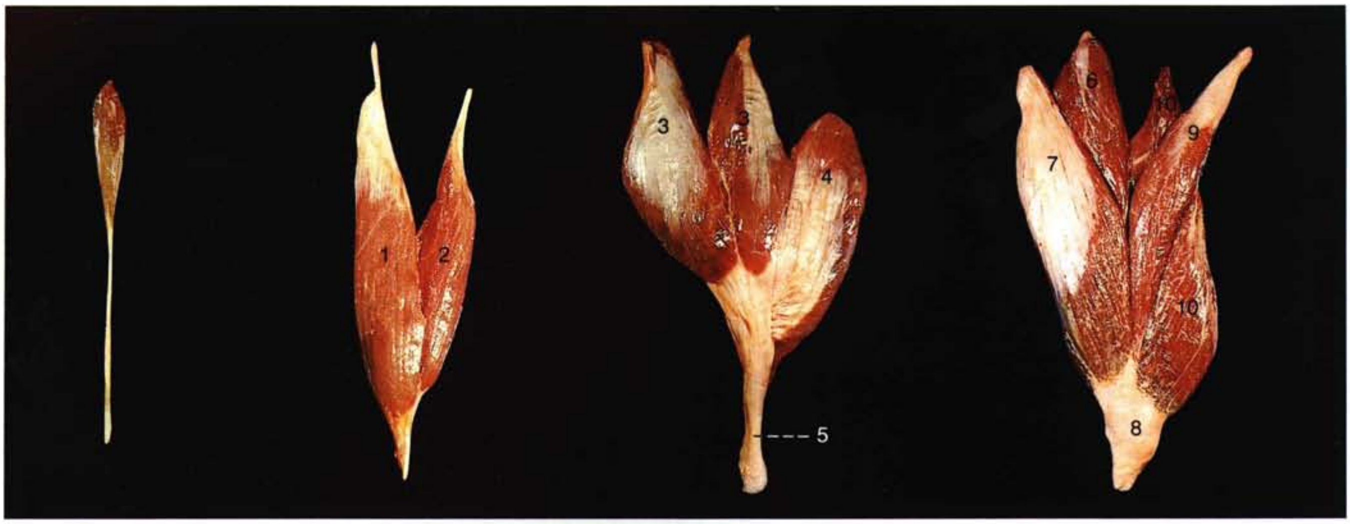

Fusiform
(palmaris longus muscle)

Bicipital
(biceps brachii muscle)

Tricipital
(triceps surae muscle)

Quadricipital
(quadriceps femoris muscle)

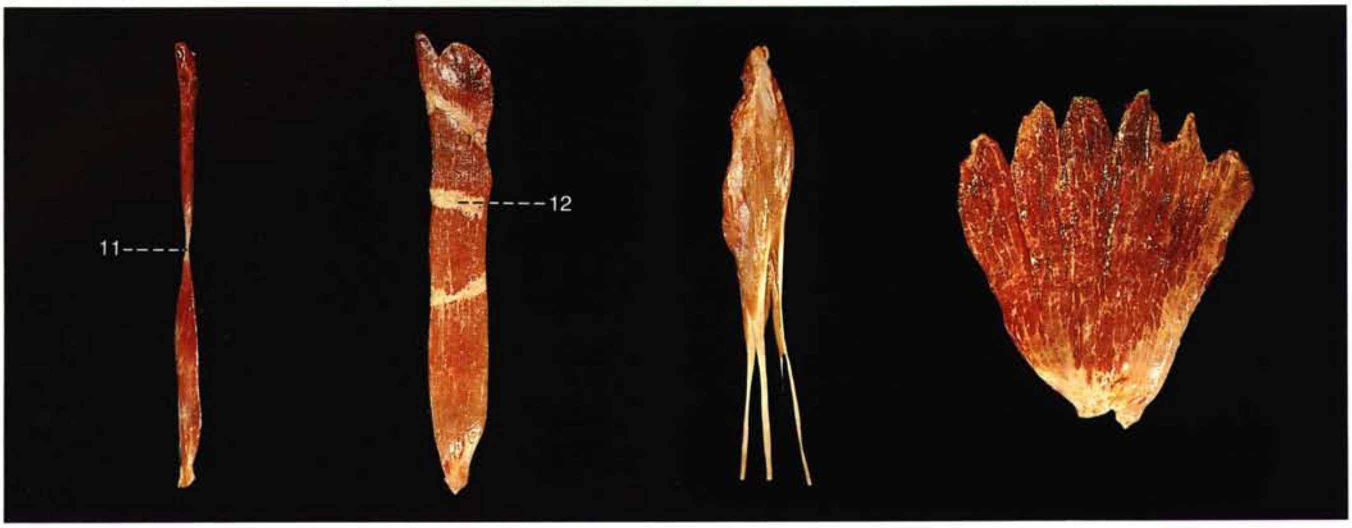

Digastric
(omohyoid muscle)

Multiventral
(rectus abdominis muscle)

Multicaudal
(flexor prof. muscle)

Serrated
(serratus anterior muscle)

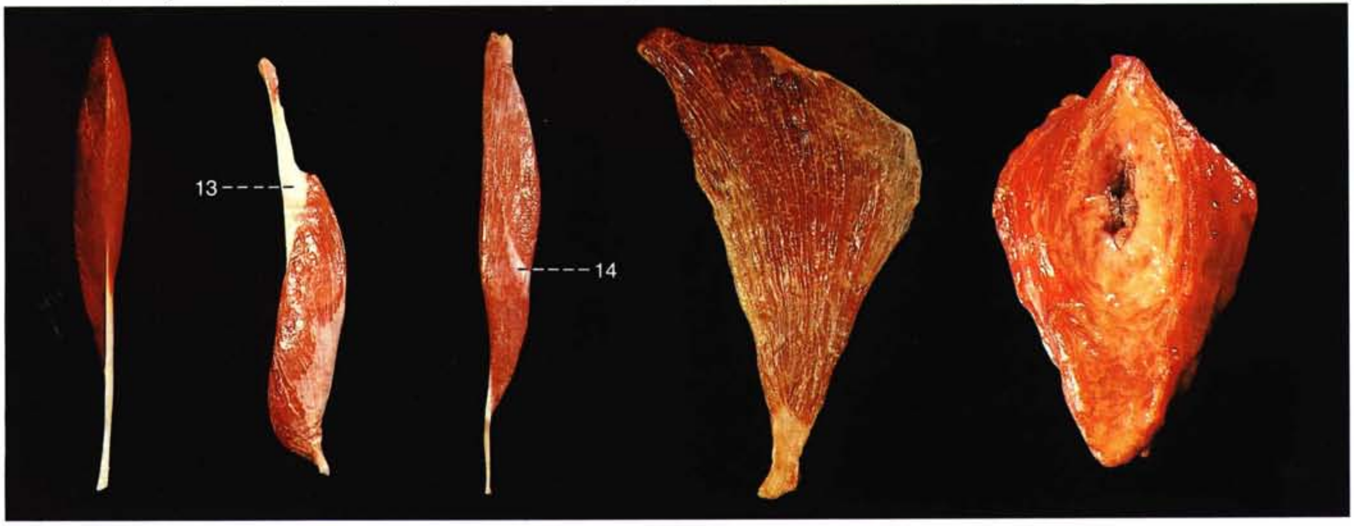

Bipennate
(tibialis anterior muscle)

Unipennate
(semimembranous muscle)

Semitendinous
(semitendinous muscle)

Broad, flat muscle
(latissimus dorsi muscle)

Ring-like
(external anal sphincter muscle)

1 Long head
2 Short head
3 Gastrocnemius muscle (medial head, lateral head)
4 Soleus muscle
5 Achilles tendon
6 Vastus intermedius muscle
7 Vastus lateralis muscle
8 Patella
9 Rectus femoris muscle
10 Vastus medialis muscle
11 Intermediate tendon
12 Tendinous intersection
13 Aponeurosis
14 Tendinous intersection

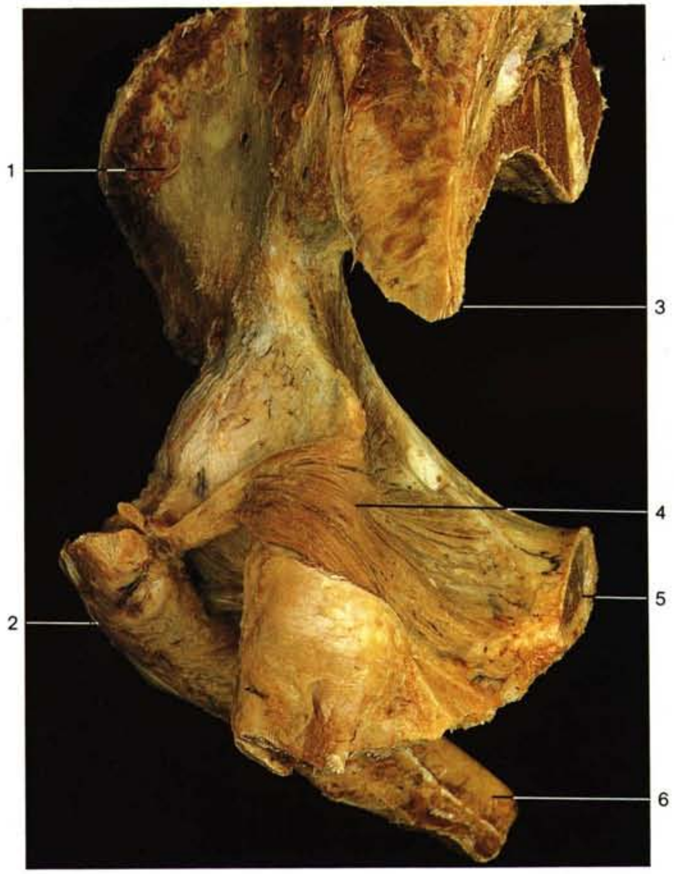

Left half of the pelvis (posterior aspect).
Obturator internus muscle as an example of a muscle, the tendon of which does not act in the direction of the main muscle fibers. Its fibers originate at the internal aspect of the obturator foramen, turn around the posterior rim of the ischium and insert at the greater trochanter of the femur. The ischium thereby serves as a pulley.

1 Ilium
2 Greater trochanter
3 Coccyx
4 Obturator internus muscle
5 Pubis
6 Femur

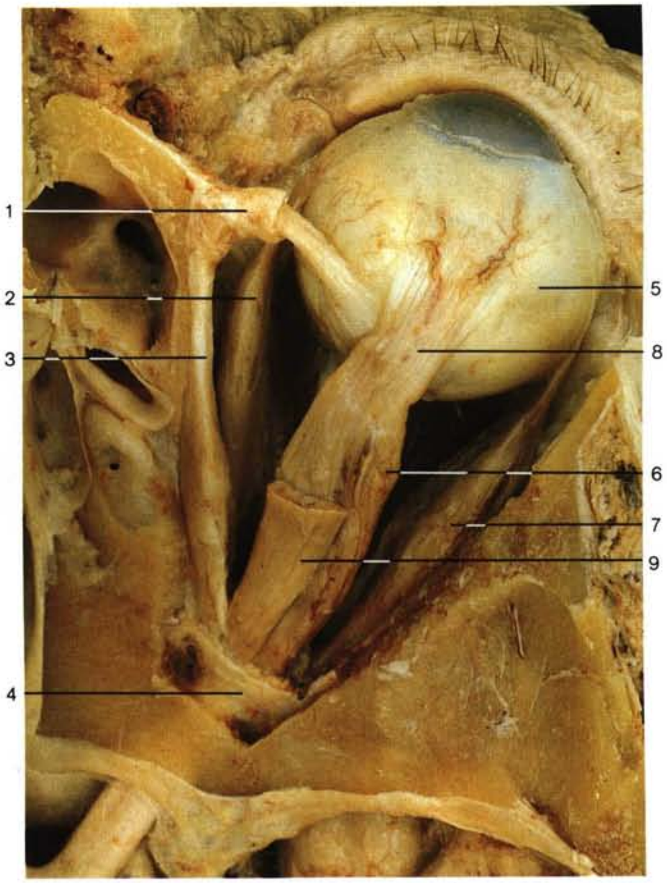

Superior oblique muscle of the eyeball, right eye (superior aspect). The tendon of this muscle bends over the trochlea changing its direction so that it becomes attached to the posterior lateral quadrant of the eyeball.

1 Trochlea
2 Medial rectus muscle
3 Superior oblique muscle
4 Common annular tendon
5 Eyeball
6 Superior rectus muscle
7 Lateral rectus muscle
8 Superior rectus muscle (tendon)
9 Levator palpebrae superioris muscle (divided)

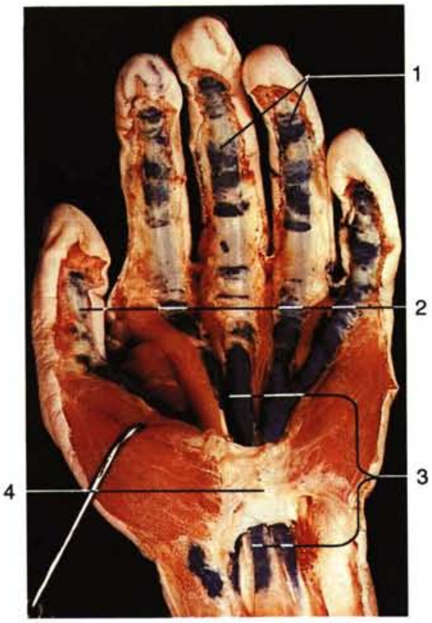

1 Digital synovial sheaths of the tendons of flexor digitorum superficialis and profundus muscles
2 Digital synovial sheaths of the tendon of long flexor pollicis longus muscle
3 Common flexor synovial sheaths of flexor digitorum superficialis and profundus muscles
4 Flexor retinaculum

The synovial sheaths of the tendons on the palmar aspect of the left wrist (colored fluid has been injected).

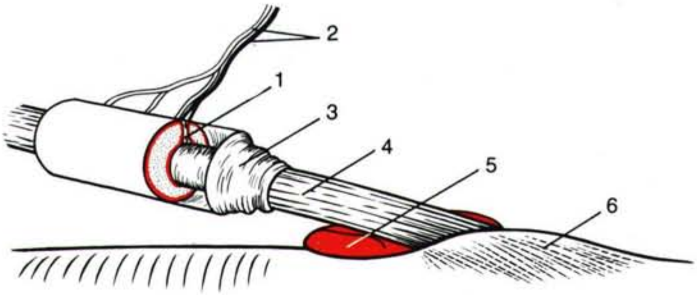

1 Mesotendon
2 Blood vessels
3 Synovial sheath
4 Tendon
5 Synovial bursa
6 Bone (tuberosity)

Structure of a tendon sheath. The synovial membrane which also forms the mesotendon is indicated in red. (Schematic drawing.)

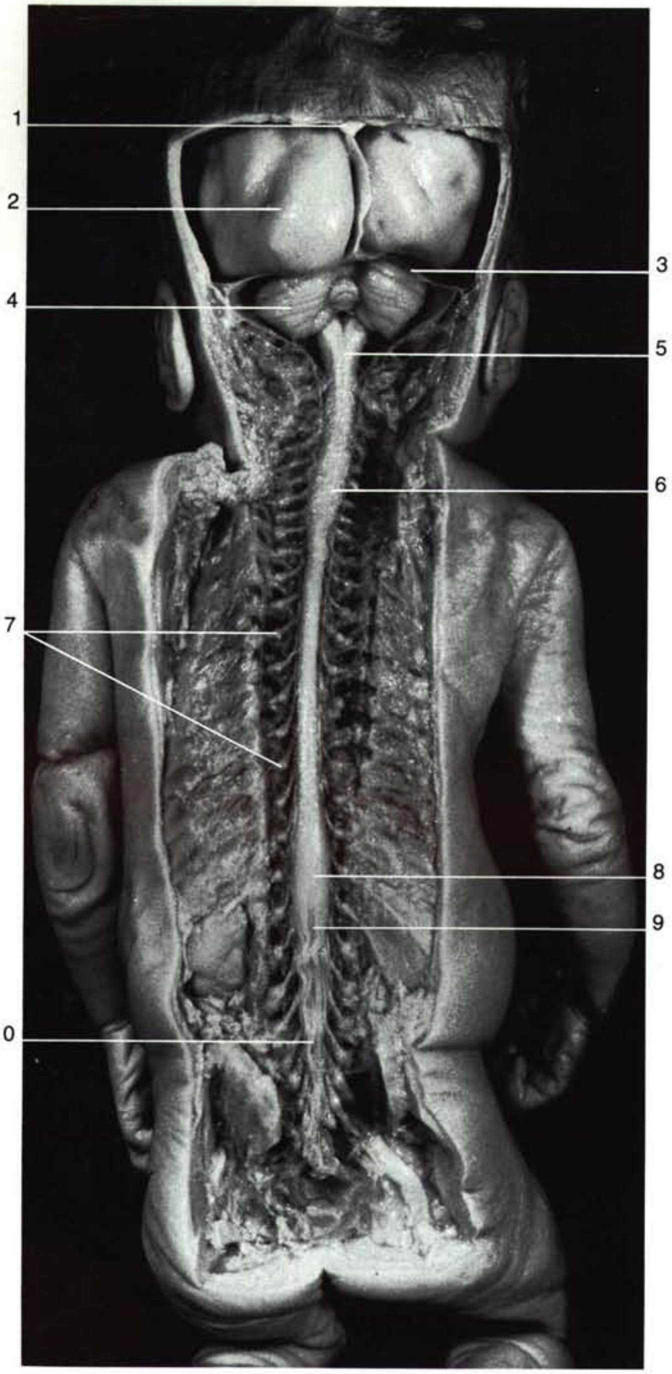

1 Falx cerebri
2 Cerebral hemispheres
3 Tentorium cerebelli
4 Cerebellum
5 Medulla oblongata
6 Spinal cord, cervical enlargement
7 Spinal ganglia
8 Spinal cord, lumbar enlargement
9 Conus medullaris
10 Cauda equina
11 Cervical plexus (formed from ventral rami of C_1–C_4)
12 Brachial plexus (formed from ventral rami of C_5–T_1)
13 Lumbosacral plexus (formed from ventral rami of L_1–S_4)
14 Sympathetic trunk

Brain, the **spinal cord** and the **spinal nerves** in the fetus (posterior aspect).

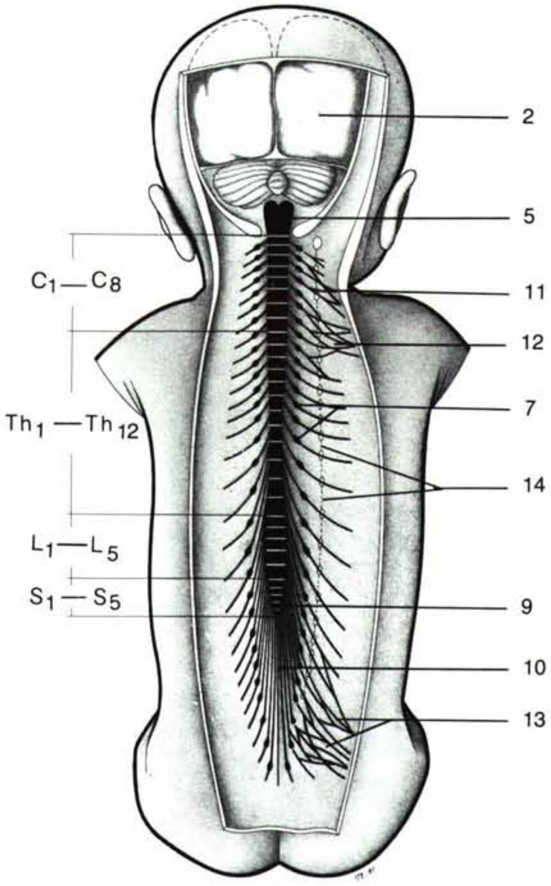

Schematic drawing to illustrate the three main parts of the nervous system in general.

The **nervous system** can be divided into three, functionally distinct parts: 1. the cranial part which comprises the great sensory organs and the brain, 2. the spinal cord which shows a segmental structure and serves predominantly as a reflex-organ, and 3. the autonomic nervous system which controls the unvoluntary functions (subconscious control) of organs and tissues. The autonomic part of the nervous system forms many delicate plexus within the organs. At certain places these plexus contain aggregations of nerve cells (prevertebral and intramural ganglia). The spinal nerves leave the spinal cord at regular intervals, forming the 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and a varying number of coccygeal segments. The ventral rami of the first four cervical spinal nerves (C_1–C_4) form the cervical plexus (for innervation of the anterior neck), the ventral rami of the lower cervical spinal nerves (C_5–T_1) form the brachial plexus which innervates the upper leg, and the ventral rami of the lumbar and sacral spinal nerves form the lumbosacral plexus (L_1–S_4) which innervates the pelvic and genital organs and the lower extremity.

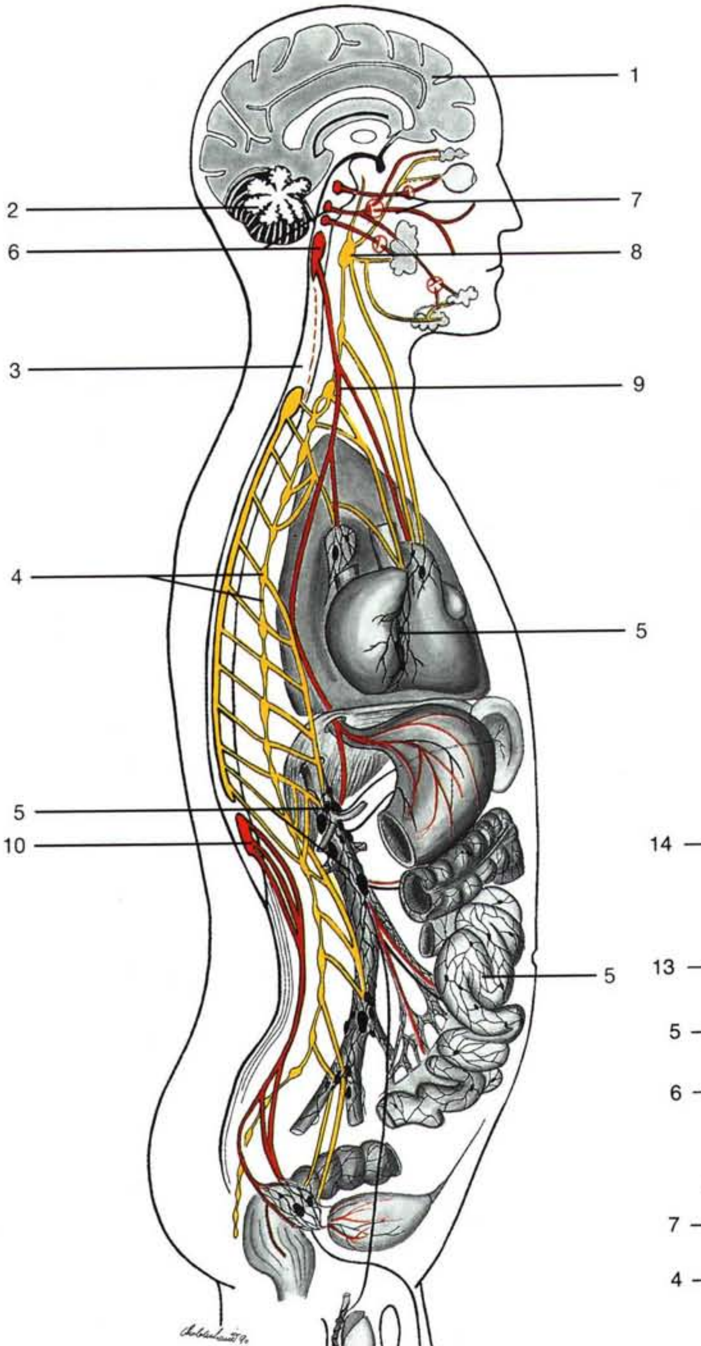

Diagram illustrating the localization of the **three functional portions** of the **nervous system** (brain, spinal cord and autonomic nervous system). Yellow = sympathetic system; red = parasympathetic system.

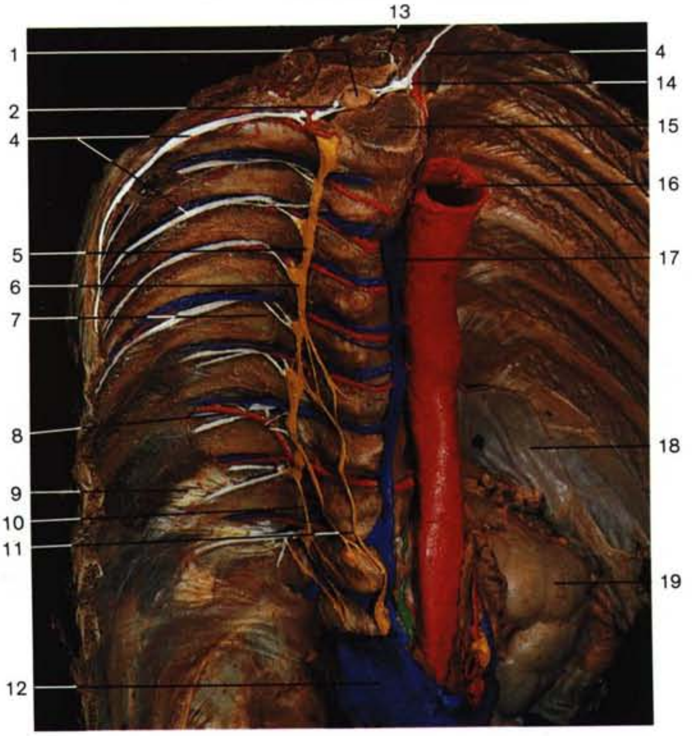

Posterior part of the thorax. Cross-section at the level of the 5th thoracic segment. Spinal nerves and their connections to the sympathetic trunk.

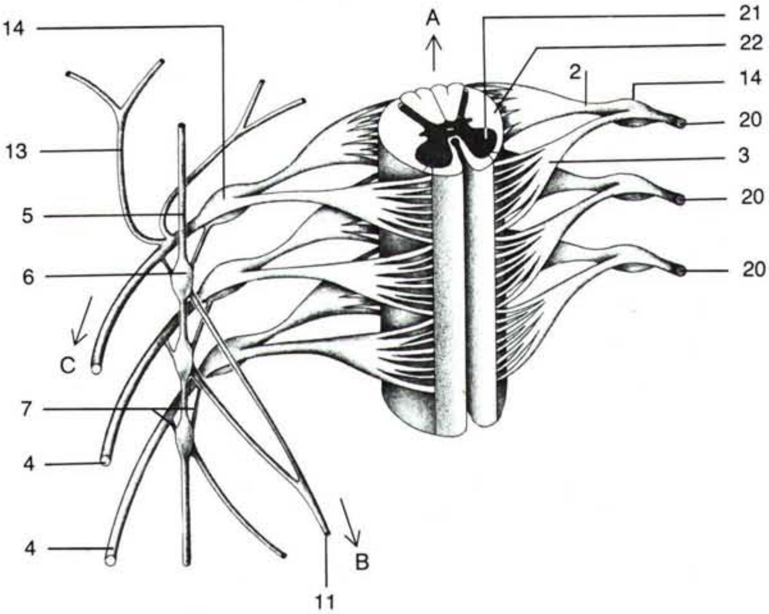

Organization of the spinal cord in structurally equal segments which form the paired spinal nerves. A = connections to the brain; B = connections to the autonomic nervous system; C = connections to the trunk and extremities (intercostal nerves and plexus). (Schematic drawing.)

1 Cerebrum
2 Cerebellum
3 Spinal cord
4 Sympathetic trunk and ganglion
5 Plexus and ganglia of the autonomic nervous system
6 Cranial autonomic system
7 Cranial nerves (n. III and n. VII)
8 Superior cervical ganglion
9 Vagus nerve (n. X)
10 Sacral autonomic system

1 Spinal cord
2 **Dorsal root**
3 **Ventral root**
4 Intercostal nerves
5 Sympathetic trunk
6 Ganglia of the sympathetic trunk
7 Rami communicantes
8 Intercostal artery and vein
9 Subcostalis muscle
10 Lesser splanchnic nerve
11 Greater splanchnic nerve
12 Inferior vena cava
13 Dorsal ramus of spinal nerve
14 **Spinal (dorsal root) ganglion**
15 Body of the vertebra
16 Aorta
17 Azygos vein
18 Diaphragm
19 Left kidney
20 **Spinal nerve**
21 Gray matter of the spinal cord
22 White matter of the spinal cord

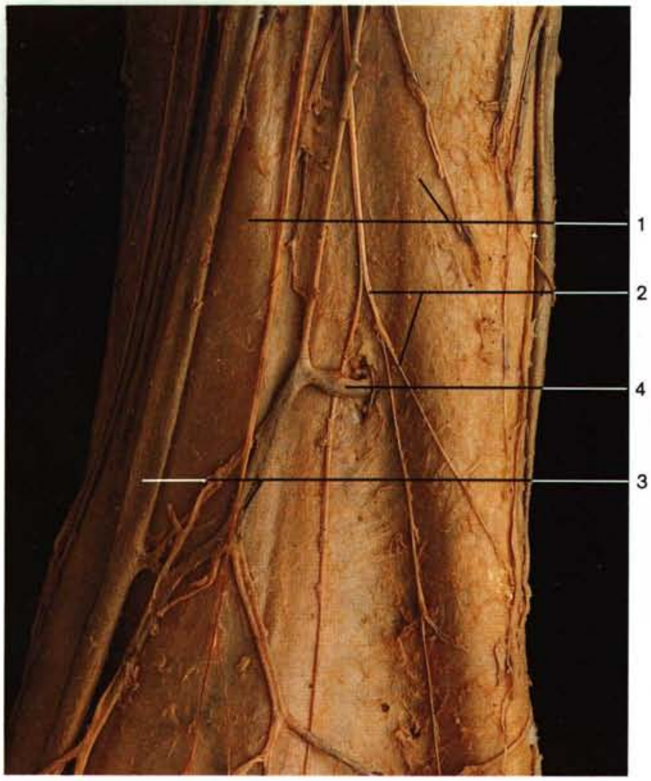

Superficial nerves and vessels of the lower leg, illustrating the structural differences between veins and nerves.

1 Crural fascia (fascia cruris)
2 Cutaneous nerves
3 Superficial cutaneous veins
4 Perforating vein

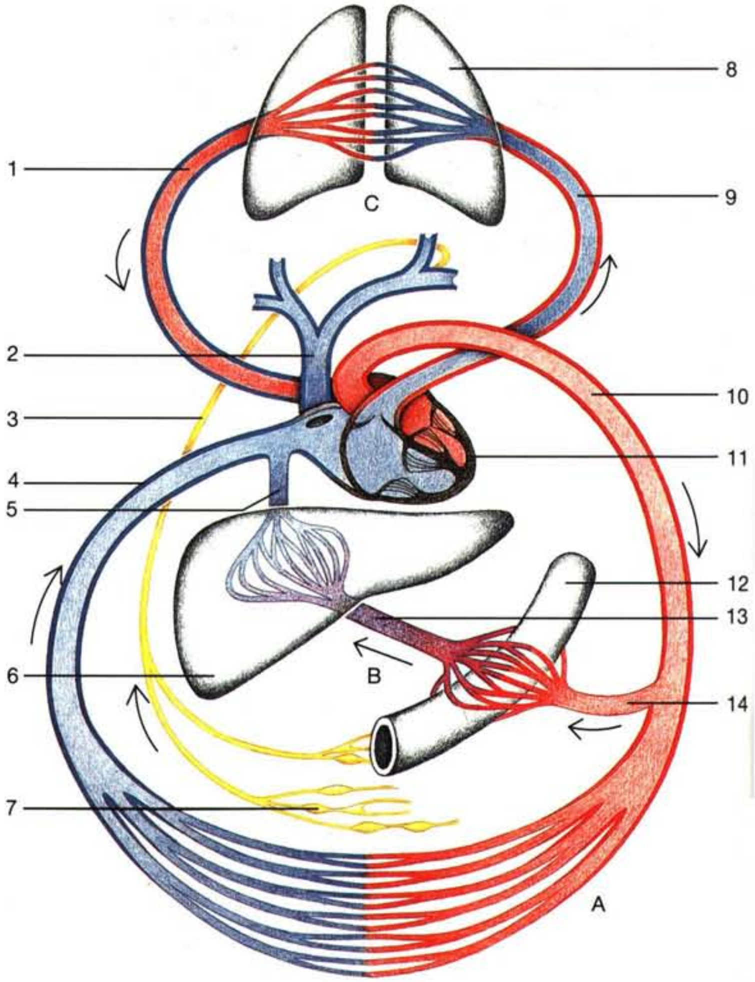

Organization of the circulatory system. Arrows: direction of the blood flow.

Vessel wall in red = Arteries
Vessel wall in blue = Veins
Yellow = Lymphatic vessels

A Systemic circulation
B Hepatic portal circulation
C Pulmonary circulation

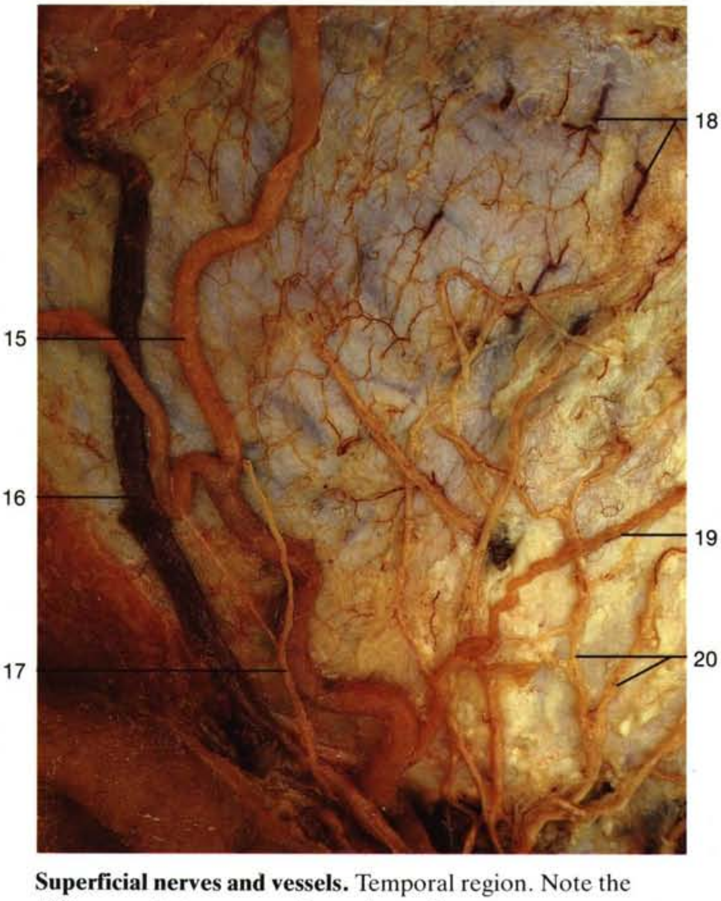

Superficial nerves and vessels. Temporal region. Note the differences between arteries, veins and nerves.

1 Pulmonary vein
2 Superior vena cava
3 Thoracic duct
4 Inferior vena cava
5 Hepatic vein
6 Liver
7 Lymph nodes and lymphatic vessels
8 Lung
9 Pulmonary artery
10 Aorta
11 Heart
12 Small intestine with capillary network
13 Portal vein
14 Mesenteric artery
15 Superficial temporal artery
16 Superficial temporal vein
17 Auriculotemporal nerve
18 Perforating veins for subcutaneous fatty tissue
19 Small artery
20 Small nerves (branches of facial nerve)

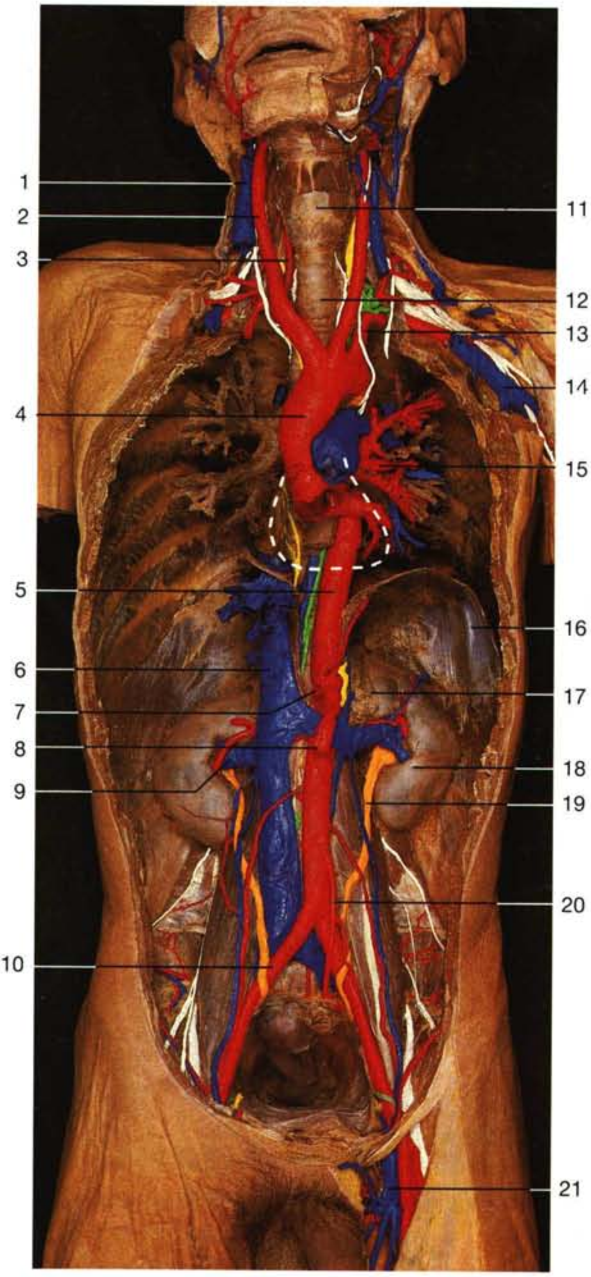

Major vessels of the trunk. The position of the heart is indicated by the dotted line.

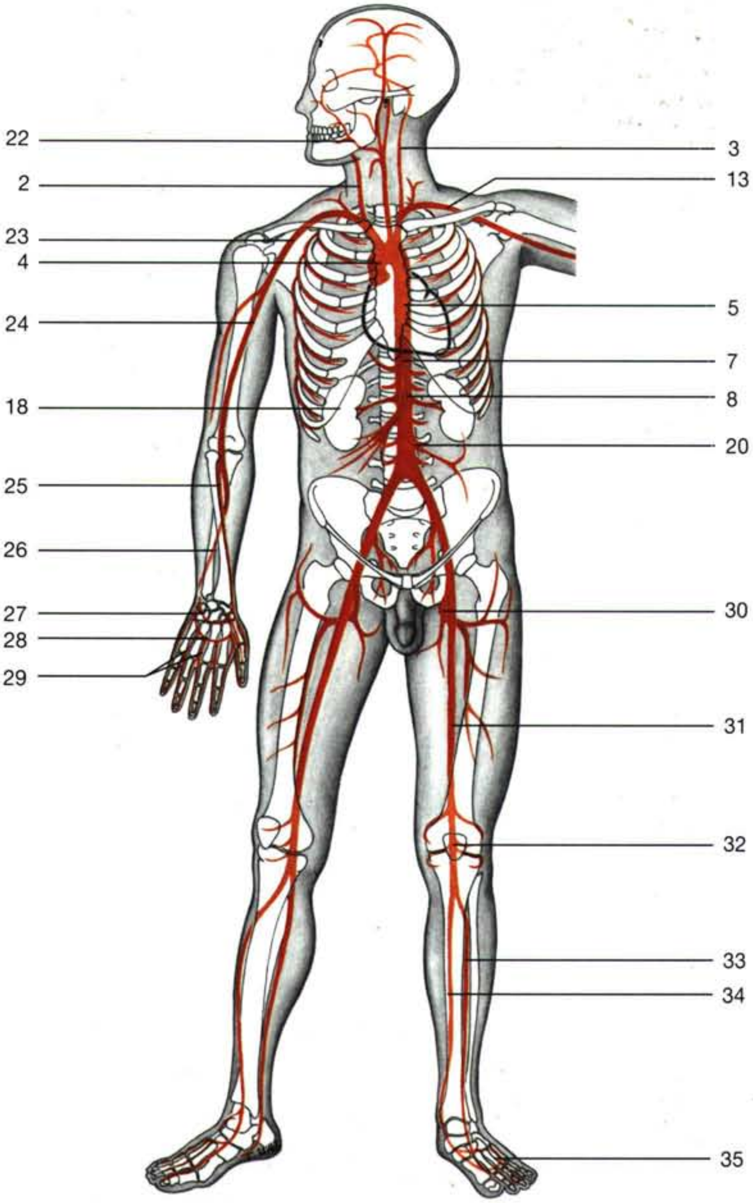

Major arteries of the human body. (Schematic drawing.)

1 Internal jugular vein
2 **Common carotid artery**
3 Vertebral artery
4 **Ascending aorta**
5 **Descending aorta**
6 **Inferior vena cava**
7 Celiac trunk
8 Superior mesenteric artery
9 Renal vein
10 **Common iliac artery**
11 Larynx
12 Trachea
13 Left subclavian artery
14 Left axillary vein
15 **Pulmonary veins**
16 Diaphragm
17 Suprarenal gland
18 Kidney
19 Ureter
20 Inferior mesenteric artery
21 **Femoral vein**
22 Facial artery
23 Axillary artery
24 Brachial artery
25 Radial artery
26 Ulnar artery
27 Deep palmar arch
28 Superficial palmar arch
29 Common palmar digital arteries
30 Profunda femoris artery
31 **Femoral artery**
32 Popliteal artery
33 Anterior tibial artery
34 Posterior tibial artery
35 Plantar arch

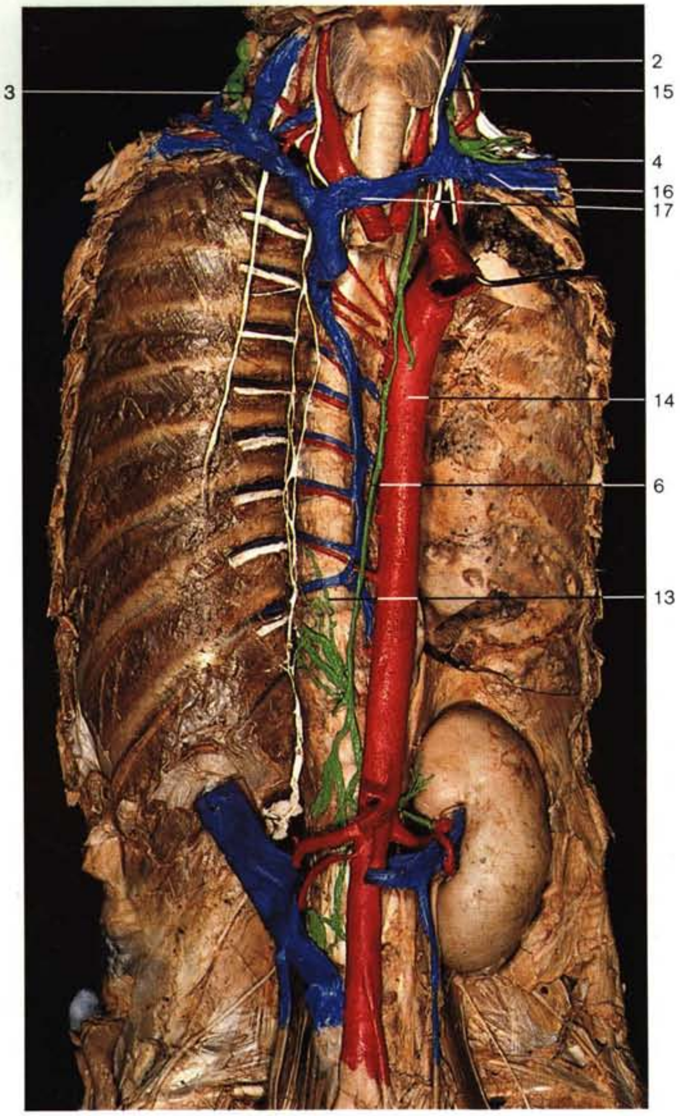

Major lymph vessels of the trunk.

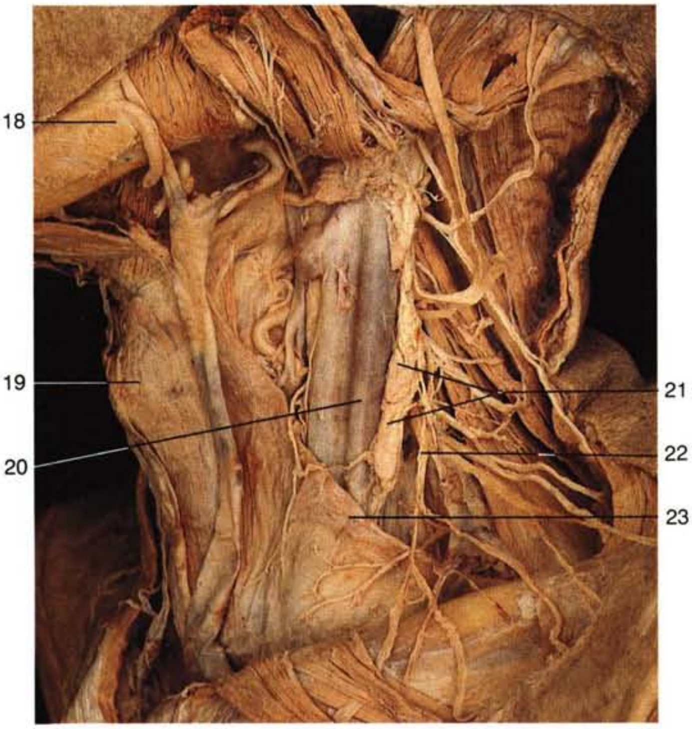

Deep cervical nodes, adjacent to the internal jugular vein.

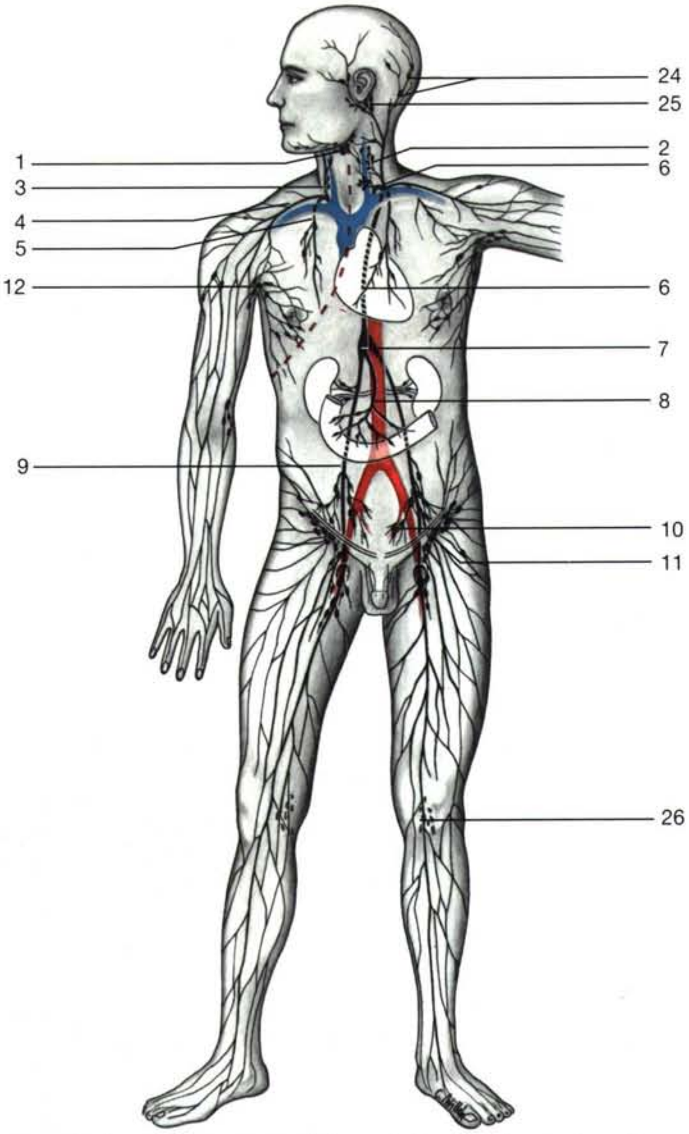

Lymphatic system. Course of the main lymphatic vessels and lymph nodes in the body. Dotted line = border between lymphatic vessels draining towards the right venous angle and towards the left.

1 Submandibular nodes
2 Deep cervical nodes
3 Right jugular trunk
4 Subclavian trunk
5 Right bronchomediastinal trunk
6 Thoracic duct
7 **Cisterna chyli**
8 **Intestinal trunk**
9 Right **lumbar trunk**
10 Internal iliac nodes
11 **Inguinal nodes**
12 **Axillary nodes**
13 Descending trunk
14 Descending aorta
15 Internal jugular vein
16 Subclavian vein
17 Left brachiocephalic vein
18 Mandible
19 Larynx
20 Internal jugular vein
21 **Deep cervical nodes**
22 Cervical nerve plexus
23 Superficial layer of deep fascia
24 Occipital nodes
25 Parotid nodes
26 Popliteal nodes

Lymphatic vessels originate as blind-ending tubes in the tissue spaces (lymph capillaries) and unite to form larger vessels (lymphatics). These resemble veins but have a much thinner wall, more valves and are interrupted by lymph nodes at various intervals. Large groups of lymph nodes are located in the inguinal and axillary regions, deep to the mandible and sternocleidomastoid muscle and within the root of the mesentery of the intestine.

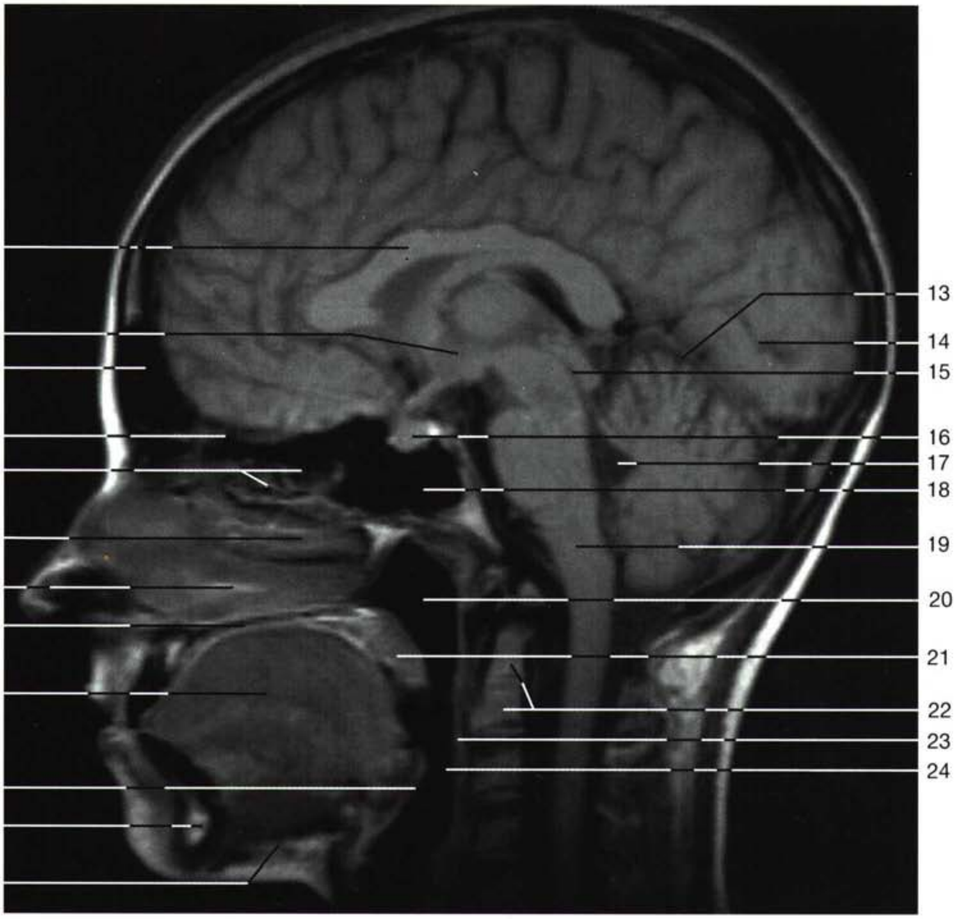

Sagittal section through head and neck (MR-Scan. 23-year-old female, courtesy of PD Dr. A. Heuck, Munich).

1	Corpus callosum
2	**Hypothalamus**
3	Frontal sinus
4	Cribriform plate
5	Ethmoidal air cells
6	Middle nasal concha
7	Inferior nasal concha
8	Hard palate
9	**Tongue**
10	Epiglottis
11	Mandible
12	Mylohyoid muscle
13	Tentorium of cerebellum
14	Calcarine fissure
15	Cerebral aqueduct
16	**Pituitary gland**
17	Fourth ventricle
18	**Sphenoidal sinus**
19	Medulla oblongata
20	Nasopharynx
21	Uvula
22	Dens of axis
23	Constrictor muscle of pharynx
24	Oral part of pharynx
25	**Cerebrum** (right hemisphere)
26	Calvaria
27	**Cerebellum**

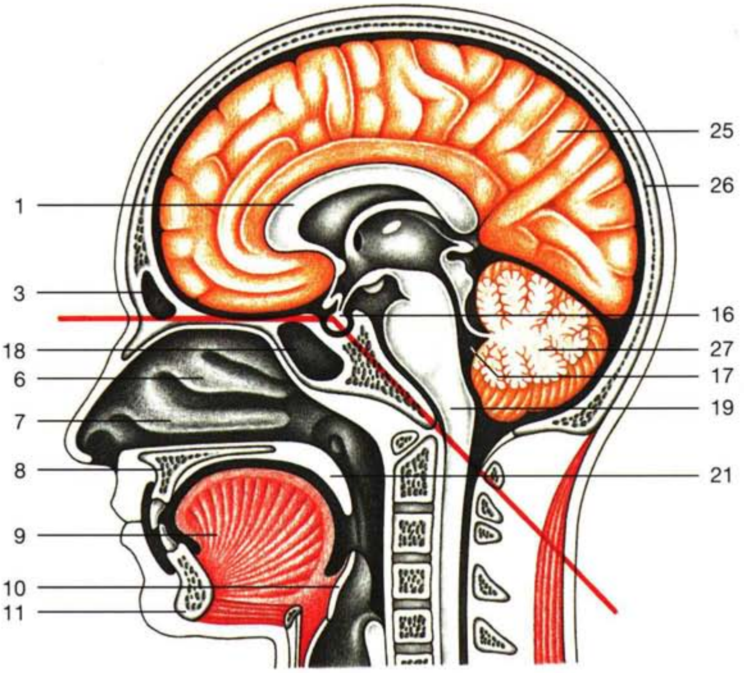

Sagittal section through the head
(schematic drawing). The red line represents the border between the neurocranium and viscerocranium forming the clivus angle. The neural cavity contains the brain; the viscerocranium comprises the orbit, the nasal cavity and the oral cavity arranged one beneath the other.

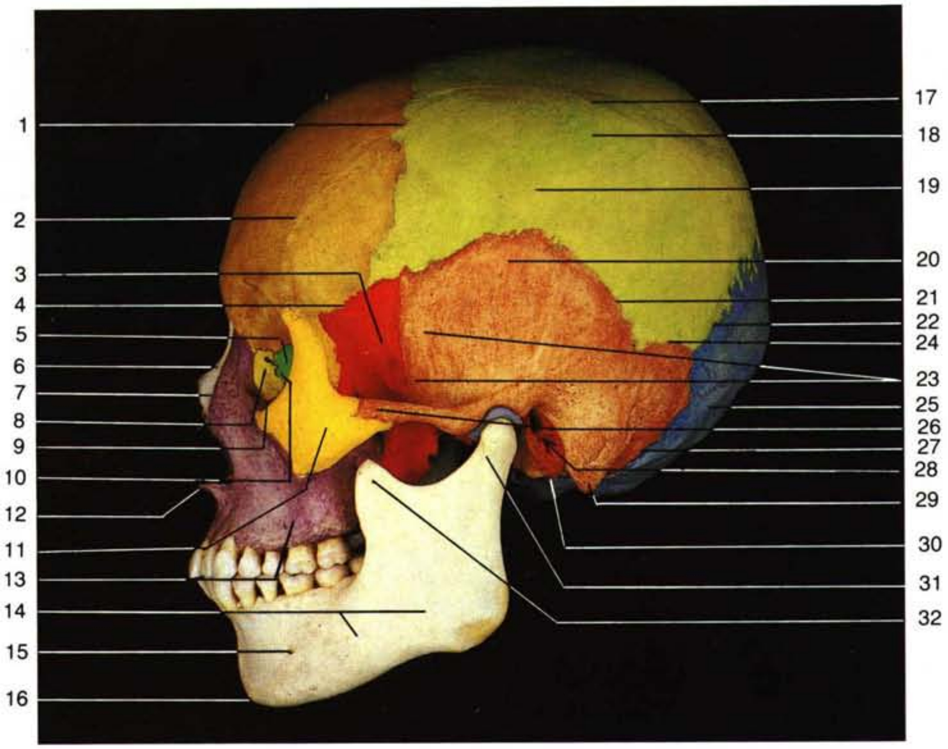

General architecture of the skull (lateral aspect). The different bones are indicated in color (numbers cf. table).

1 Coronal suture
2 **Frontal bone**
3 **Sphenoid bone**
4 Sphenofrontal suture
5 **Ethmoid bone**
6 **Nasal bone**
7 Nasomaxillary suture
8 **Lacrimal bone**
9 Lacrimomaxillary suture
10 Lacrimoethmoid suture
11 **Zygomatic bone**
12 Anterior nasal spine
13 **Maxilla**
14 **Mandible**
15 Mental foramen
16 Mental protuberance
17 Superior temporal line
18 Inferior temporal line
19 **Parietal bone**
20 **Temporal bone**
21 Squamous suture
22 Lambdoid suture
23 Temporal fossa
24 Parietomastoid suture
25 **Occipital bone**
26 Zygomatic arch
27 Occipitomastoid suture
28 External acoustic meatus
29 Mastoid process
30 Tympanic portion of temporal bone
31 Condylar process of mandible
32 Coronoid process of mandible

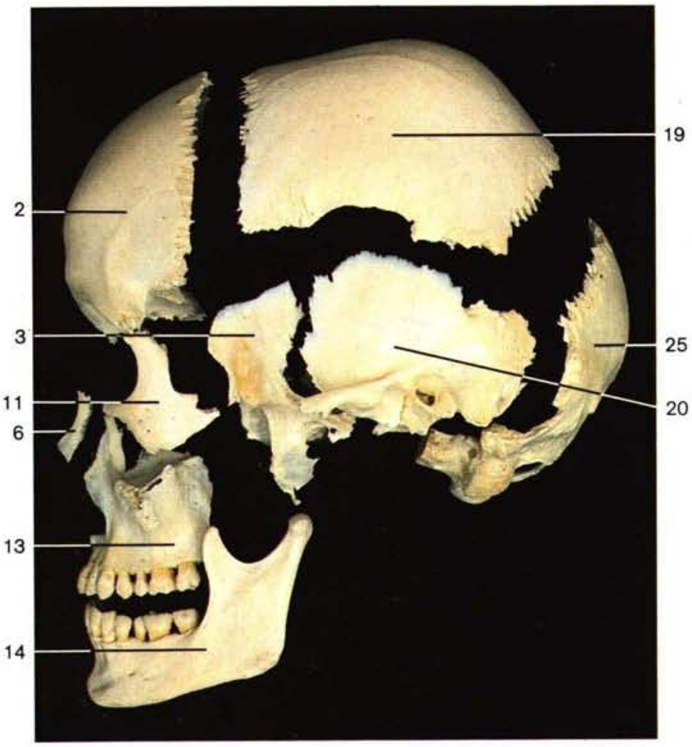

Lateral aspect of the disarticulated skull (palatine bone, lacrimal bone, ethmoid bone and vomer are not depicted).

2 Frontal bone (orange) 19 Parietal bone (light green) 3 Greater wing of sphenoid bone (red) 25 Squama of occipital bone (blue) 20 Squama of temporal bone (brown)		Cranial bones
5 Ethmoid bone (dark green) 3 Sphenoid bone (red) Temporal bone excluding squama (brown) 30 Tympanic portion of temporal bone (dark brown) Occipital bone excluding squama (blue)		Base of skull
6 Nasal bone (white) 8 Lacrimal bone (yellow) Inferior nasal concha Vomer 11 Zygomatic bone (light yellow) Palatine bone 13 Maxilla (violet) 14 Mandible (white)		Facial bones
Malleus Incus Stapes	} within petrous portion of temporal bone	Auditory ossicles
Hyoid		

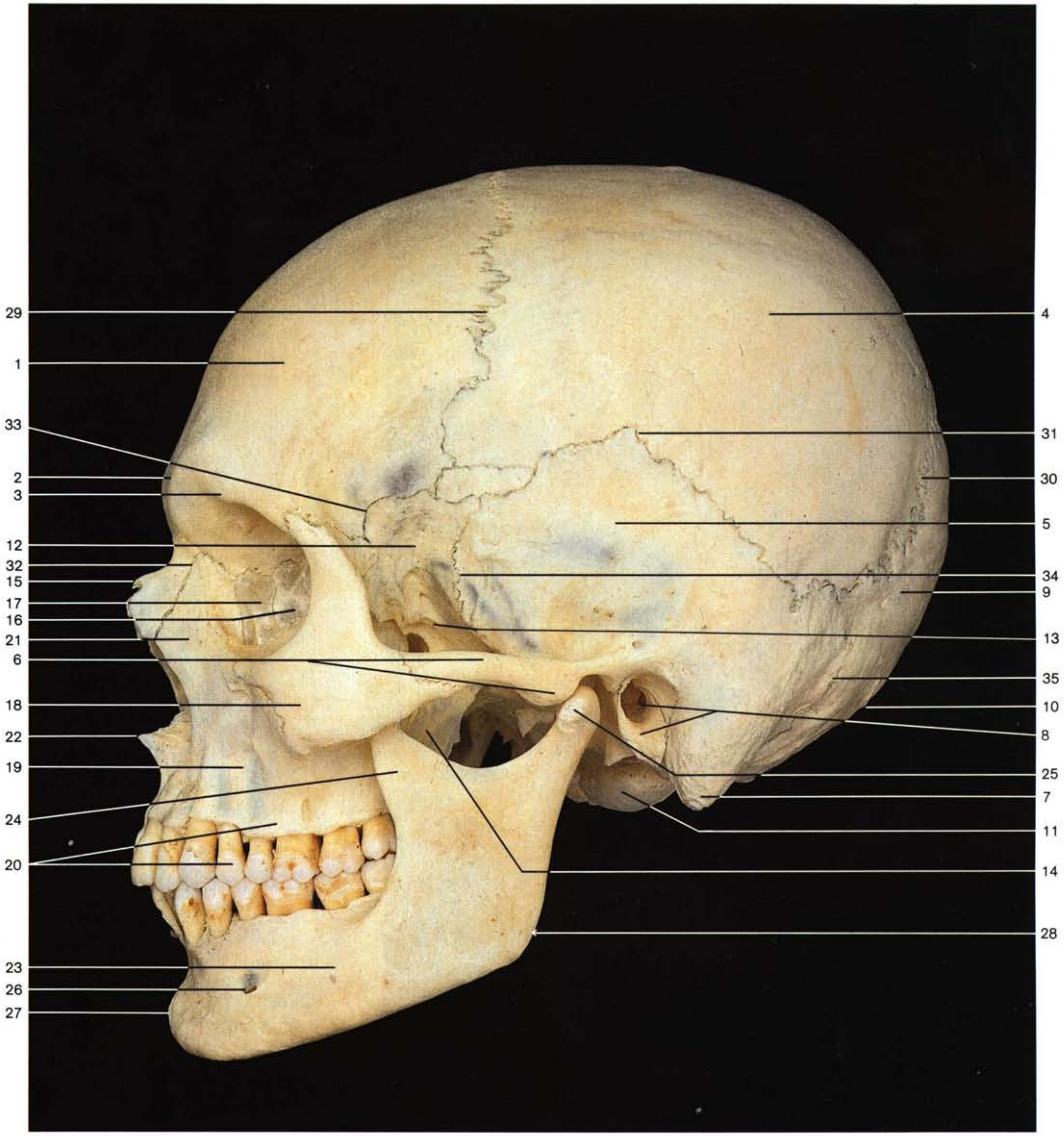

Lateral aspect of the skull.

1 **Frontal bone**
2 Glabella
3 Supraorbital margin
4 **Parietal bone**
5 **Temporal bone** (squamous part)
6 Zygomatic process (articular tubercle)
7 Mastoid process
8 Tympanic part (tympanic plate) and external acoustic meatus
9 **Occipital bone** (squamous part)
10 External occipital protuberance
11 Occipital condyle
12 **Sphenoid bone** (greater wing)
13 Infratemporal crest of sphenoid
14 Pterygoid process (lateral pterygoid plate)
15 **Nasal bone**
16 **Ethmoid bone** (orbital part)
17 **Lacrimal bone**
18 **Zygomatic bone**
19 **Maxilla** (body)
20 Alveolar process and teeth
21 Frontal process
22 Anterior nasal spine
23 **Mandible** (body)
24 Coronoid process
25 Condylar process
26 Mental foramen
27 Mental protuberance
28 Angle of the mandible

Sutures

29 Coronal suture
30 Lambdoid suture
31 Squamous suture
32 Nasomaxillary suture
33 Frontosphenoid suture
34 Sphenosquamosal suture
35 Occipitomastoid suture

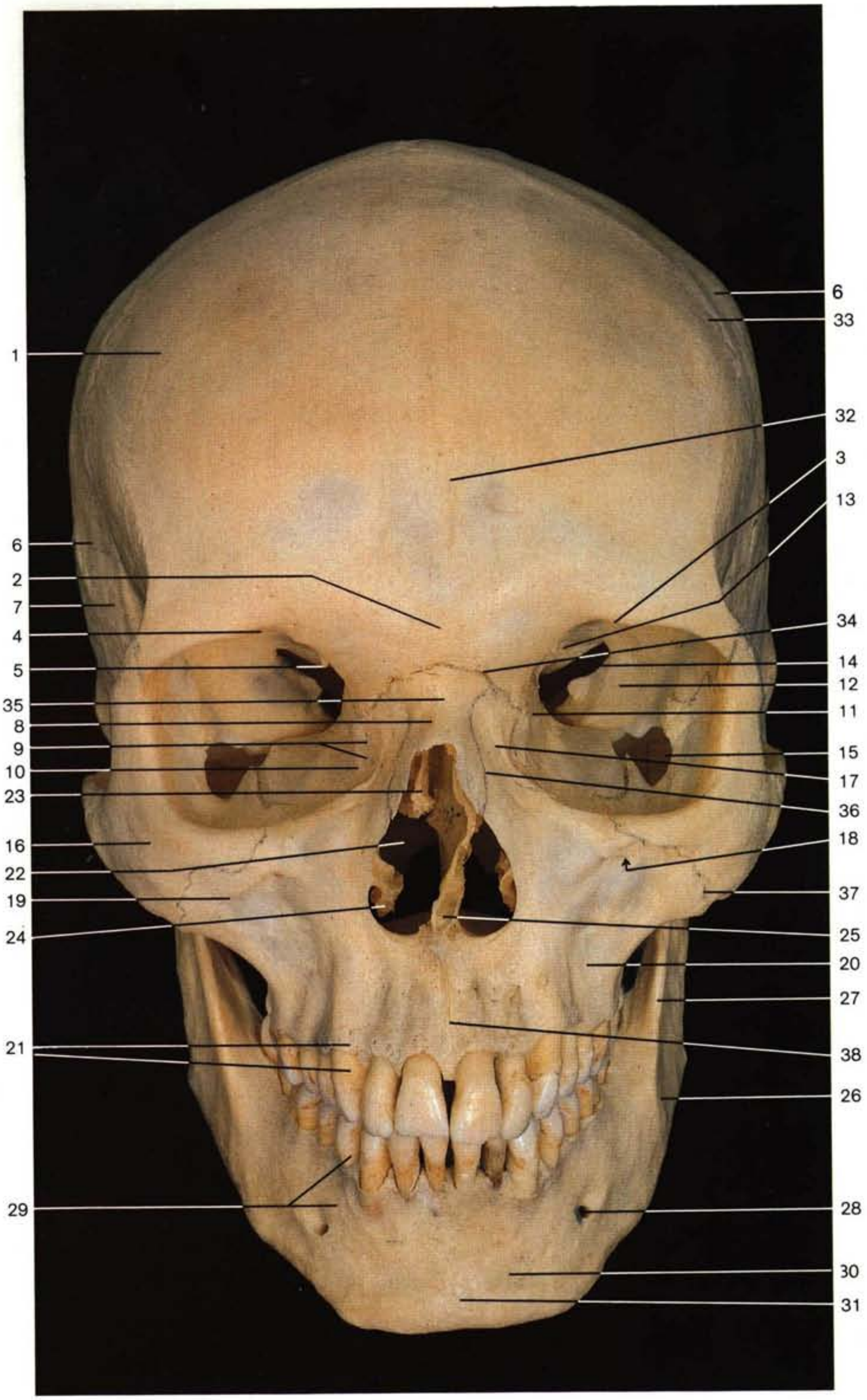

1 **Frontal bone**
2 Glabella
3 Supraorbital margin
4 Supraorbital notch
5 Trochlear spine
6 **Parietal bone**
7 **Temporal bone**
8 **Nasal bone**

Orbit
9 Lacrimal bone
10 Posterior lacrimal crest
11 Ethmoid bone

Sphenoid bone
12 Greater wing of sphenoid bone
13 Lesser wing of sphenoid bone
14 Superior orbital fissure
15 Inferior orbital fissure
16 **Zygomatic bone**

Maxilla
17 Frontal process
18 Infraorbital foramen
19 Zygomatic process
20 Body of maxilla
21 Alveolar process with teeth

Nasal cavity
22 Anterior nasal aperture
23 Middle nasal concha
24 Inferior nasal concha
25 Nasal septum, vomer

Mandible
26 Body of mandible
27 Ramus of mandible
28 Mental foramen
29 Alveolar part with teeth
30 Base of mandible
31 Mental protuberance

Sutures
32 Frontal suture
33 Coronal suture
34 Frontonasal suture
35 Internasal suture
36 Nasomaxillary suture
37 Zygomaticomaxillary suture
38 Intermaxillary suture

Anterior aspect of the skull.

The skull comprises a mosaic of numerous complicated bones which form the cranial cavity protecting the brain **(neurocranium)** and several cavities such as nasal and oral cavities in the facial region. The neurocranium consists of large bony plates which develop directly from the surrounding sheets of connective tissue **(desmocranium).** The bones of the skull base are formed out of cartilaginous tissue **(chondrocranium)** which ossifies secondarily. The **visceral skeleton** which, in fish, gives rise to the gills, has in higher vertebrates been transformed into the bones of the masticatory and auditory apparatus (maxilla, mandible, auditory ossicles and hyoid bone).

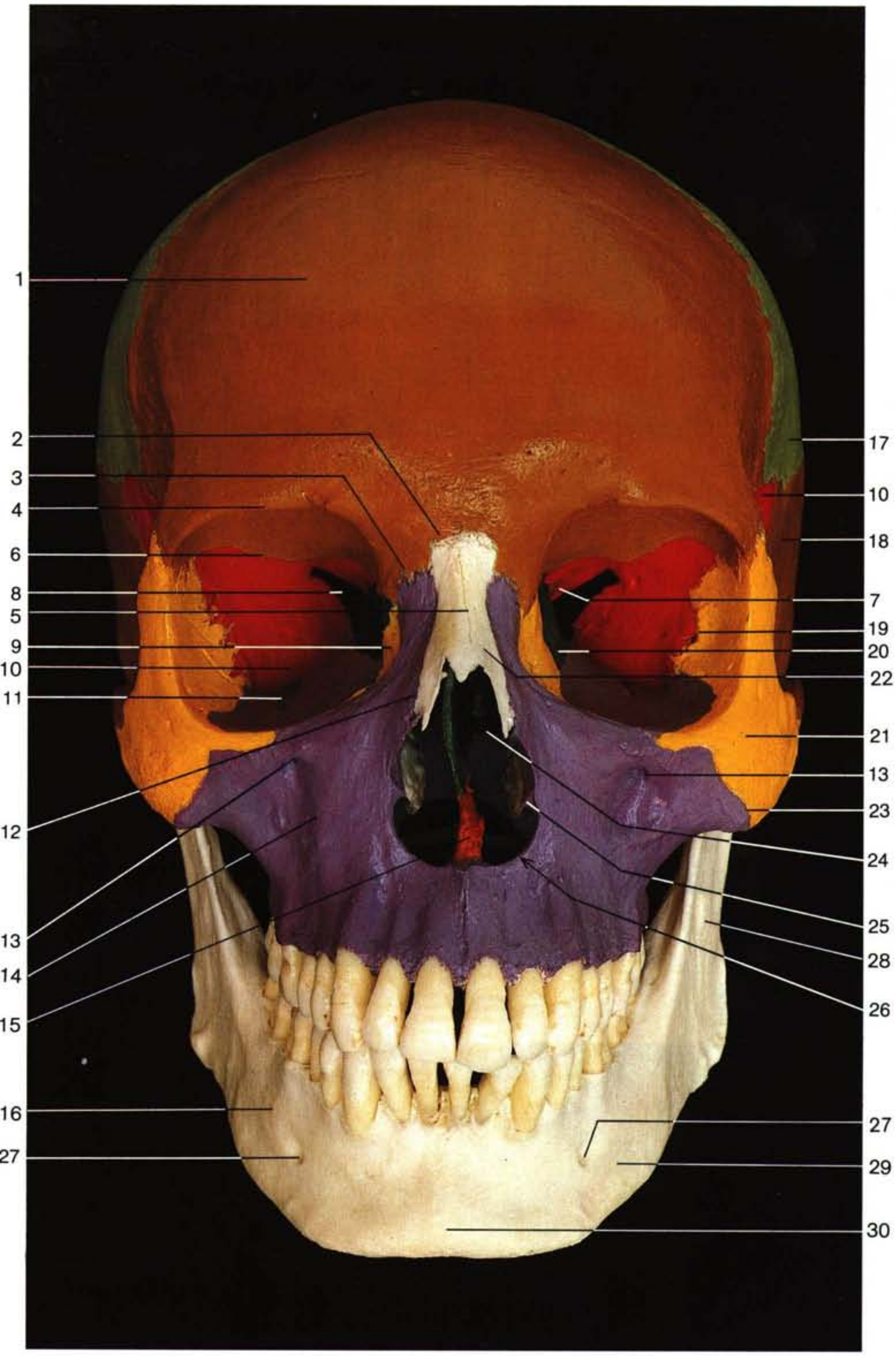

1 **Frontal bone**
2 Frontonasal suture
3 Frontomaxillary suture
4 Supraorbital margin
5 Internasal suture
6 Sphenofrontal suture
7 Optic canal in lesser wing of sphenoid bone
8 Superior orbital fissure
9 **Lacrimal bone**
10 **Sphenoid bone** (greater wing)
11 Inferior orbital fissure
12 Nasomaxillary suture
13 Infraorbital foramen
14 **Maxilla**
15 **Vomer**
16 Body of mandible
17 **Parietal bone**
18 **Temporal bone**
19 Sphenozygomatic suture
20 **Ethmoid bone**
21 **Zygomatic bone**
22 **Nasal bone**
23 Zygomaticomaxillary suture
24 Middle nasal concha
25 Inferior nasal concha
26 Anterior nasal aperture
27 Mental foramen
28 Ramus of mandible
29 Base of mandible
30 Mental protuberance

Bones
Frontal bone (brown)
Parietal bone (light green)
Temporal bone (dark brown)
Sphenoidal bone (red)
Zygomatic bone (yellow)
Ethmoid bone (dark green)
Lacrimal bone (yellow)
Vomer (orange)
Maxilla (violet)
Nasal bone (white)
Mandible (white)

Anterior aspect of the skull (individual bones indicated by color).

The following series of figures are arranged so that the mosaic-like pattern of the skull becomes understandable. It starts with the bones of the **skull base** (sphenoid and occipital) to which the other bones are added step by step. The facial skeleton is built up by the ethmoid bone to which the palatine bone and maxilla are attached laterally; the small nasal and lacrimal bones fill the remaining spaces. Cartilages remain only in the external part of the nose.

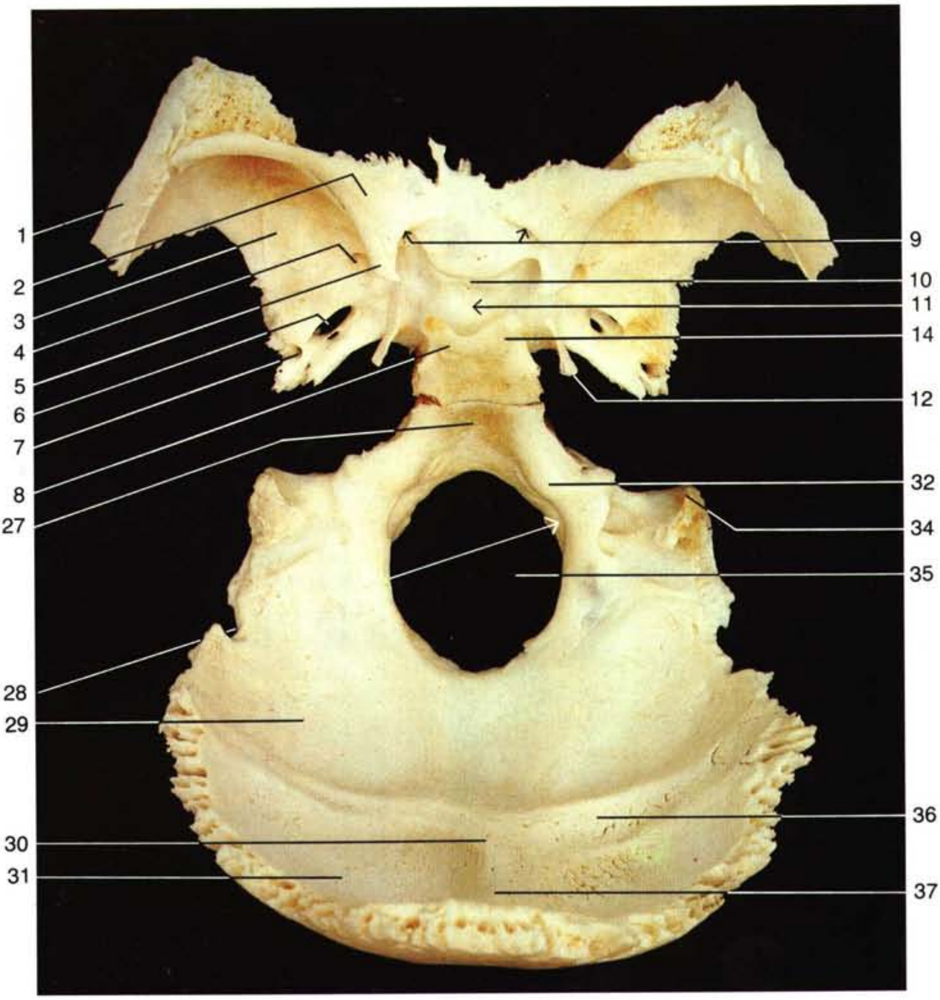
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Sphenoid and occipital bone (from above).

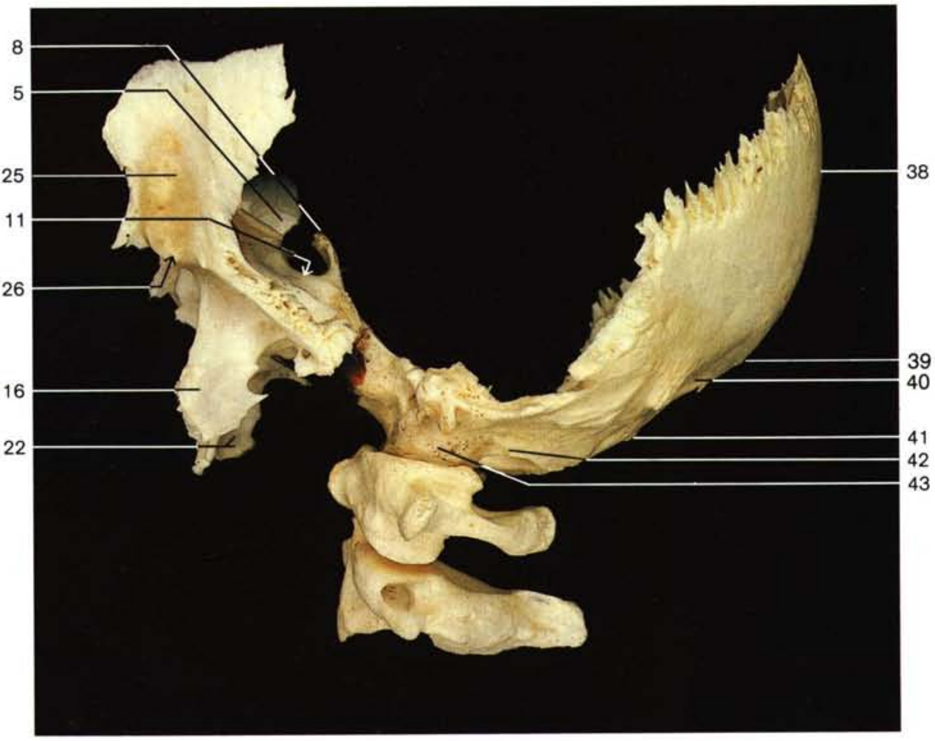
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Sphenoid and occipital bone in connection with the atlas and axis (1st and 2nd cervical vertebrae) (left lateral view).

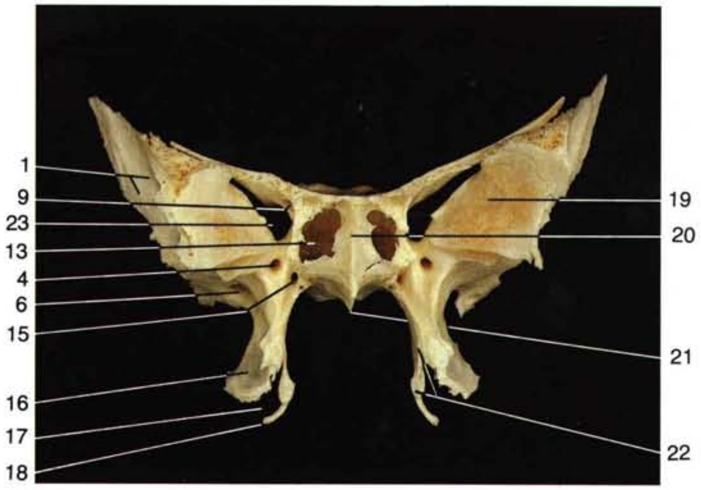

Sphenoid bone (anterior aspect).

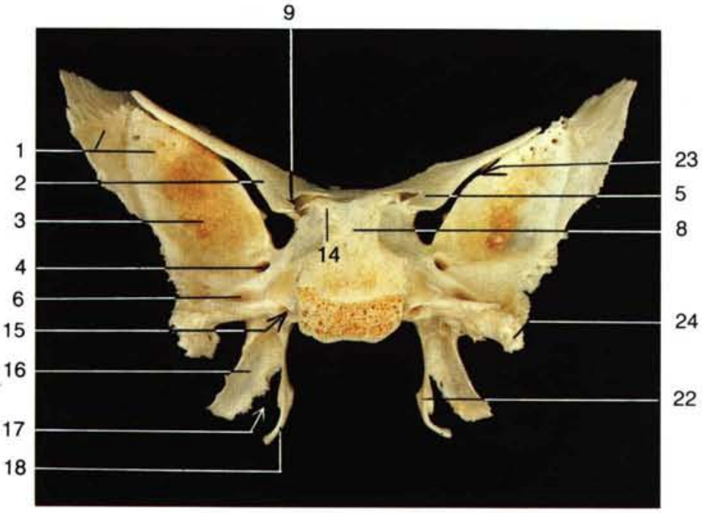

Sphenoid bone (posterior aspect).

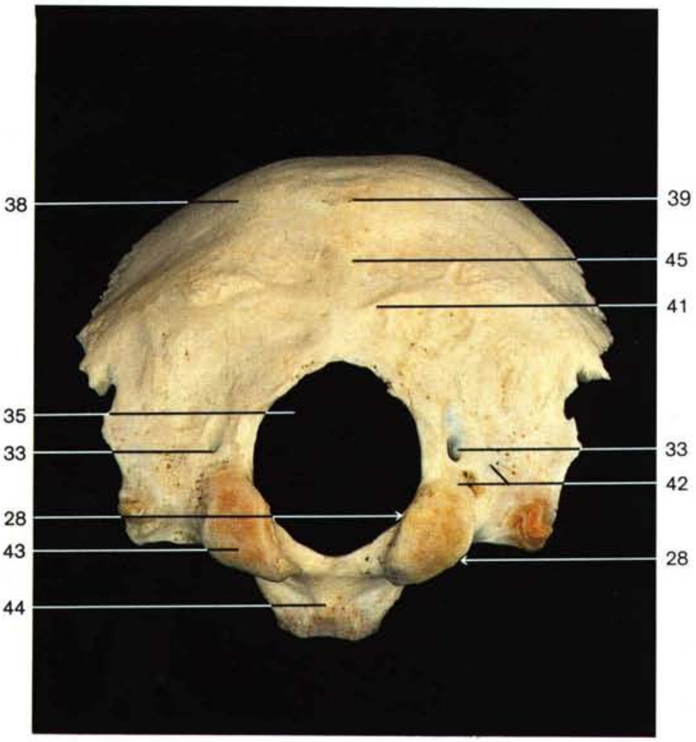

Occipital bone (from below).

Sphenoid bone

1 **Greater wing**
2 **Lesser wing**
3 Cerebral or superior surface of greater wing
4 **Foramen rotundum**
5 Anterior clinoid process
6 Foramen ovale
7 Foramen spinosum
8 Dorsum sellae
9 Optic canal
10 Chiasmatic groove (sulcus chiasmatis)
11 **Hypophysial fossa (sella turcica)**
12 Lingula
13 Opening of sphenoidal sinus
14 Posterior clinoid process
15 **Pterygoid canal**
16 Lateral pterygoid plate of **pterygoid process**
17 Pterygoid notch
18 Pterygoid hamulus
19 Orbital surface of greater wing
20 Sphenoid crest
21 Sphenoid rostrum
22 Medial pterygoid plate
23 Superior orbital fissure
24 Spine of sphenoid
25 Temporal surface of greater wing
26 Infratemporal crest

Occipital bone

27 **Clivus** with basilar part of occipital bone
28 **Hypoglossal canal**
29 Fossa for cerebellar hemisphere
30 Internal occipital protuberance
31 Fossa for cerebral hemisphere
32 Jugular tubercle
33 Condylar canal
34 Jugular process
35 **Foramen magnum**
36 Groove for transverse sinus
37 Groove for superior sagittal sinus
38 **Squamous part** of the occipital bone
39 External occipital protuberance
40 Superior nuchal line
41 Inferior nuchal line
42 Condylar fossa
43 **Condyle**
44 Pharyngeal tubercle
45 External occipital crest

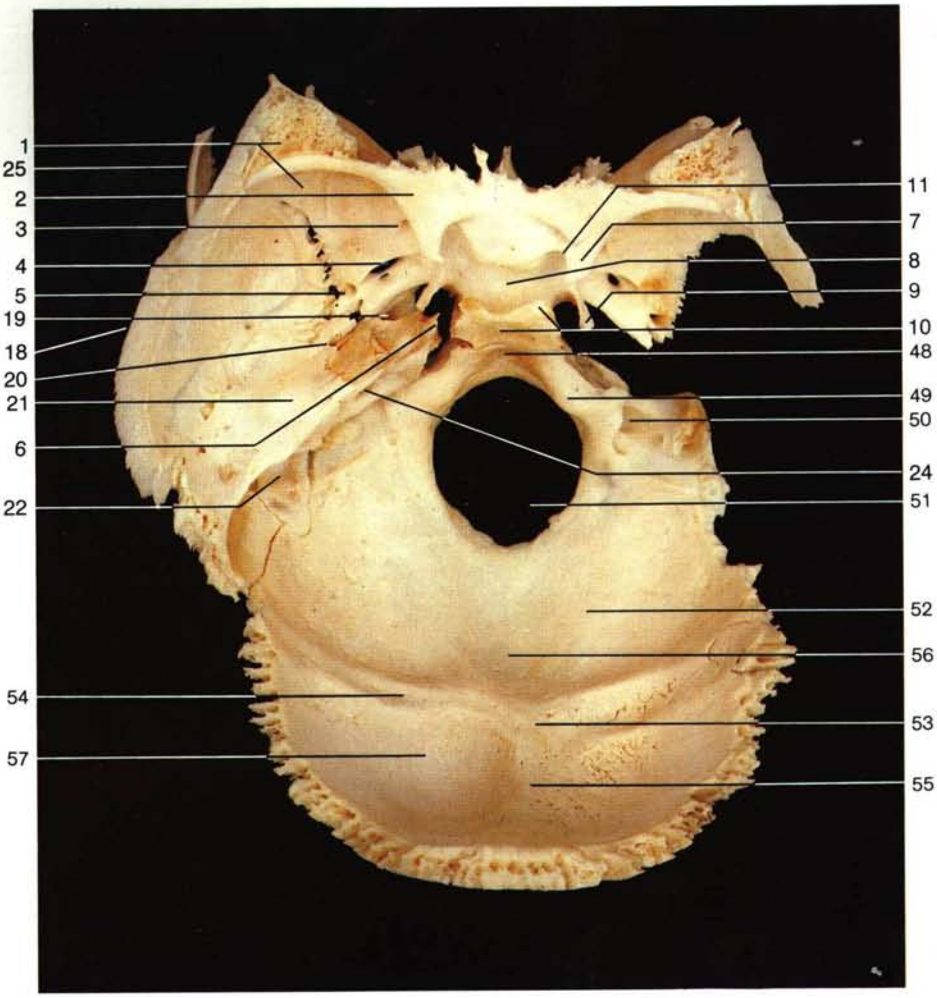

Sphenoid, occipital and left temporal bone (from above). Internal aspect of the base of the skull. The left temporal bone has been added to the preceeding figure.

Sphenoid bone

1 **Greater wing**
2 **Lesser wing**
3 Foramen rotundum
4 **Foramen ovale**
5 Foramen spinosum
6 Foramen lacerum
7 Anterior clinoid process
8 Hypophysial fossa (**sella turcica**)
9 Lingula
10 Dorsum sellae and posterior clinoid process
11 **Optic canal**
12 Sphenoid rostrum
13 Medial pterygoid plate
14 Lateral pterygoid plate
15 Pterygoid hamulus
16 Infratemporal crest
17 Body of the sphenoid

Temporal bone

18 **Squamous part**
19 **Carotid canal**
20 Hiatus of facial canal (for the greater petrosal nerve)
21 Arcuate eminence
22 Groove for the sigmoid sinus
23 Mastoid foramen
24 **Internal acoustic meatus**
25 Zygomatic process
26 Mandibular fossa
27 Petrotympanic fissure
28 Canalis musculotubarius (bony part of auditory tube)
29 **External acoustic meatus**
30 Styloid process (remnant only)
31 Stylomastoid foramen
32 Mastoid canaliculus
33 Jugular fossa
34 **Mastoid process**
35 Mastoid notch

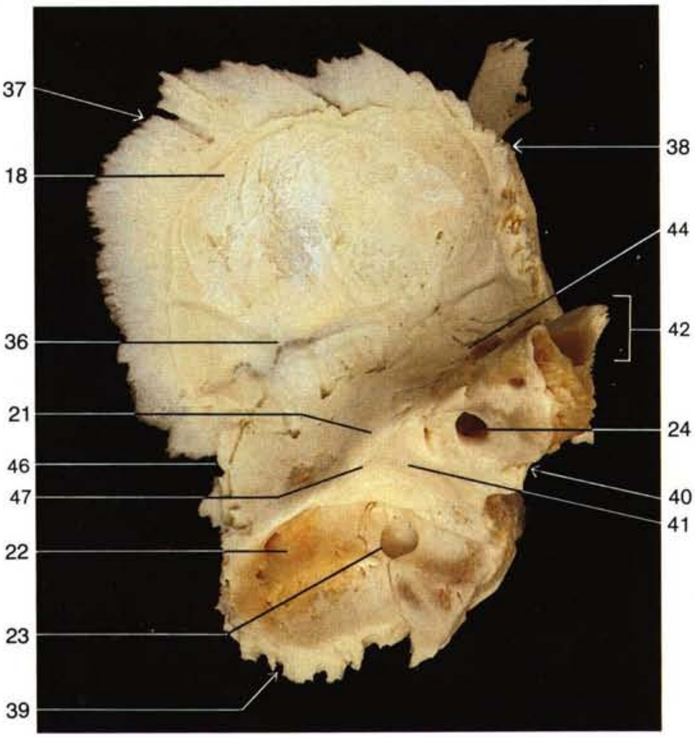

Left temporal bone (medial aspect).

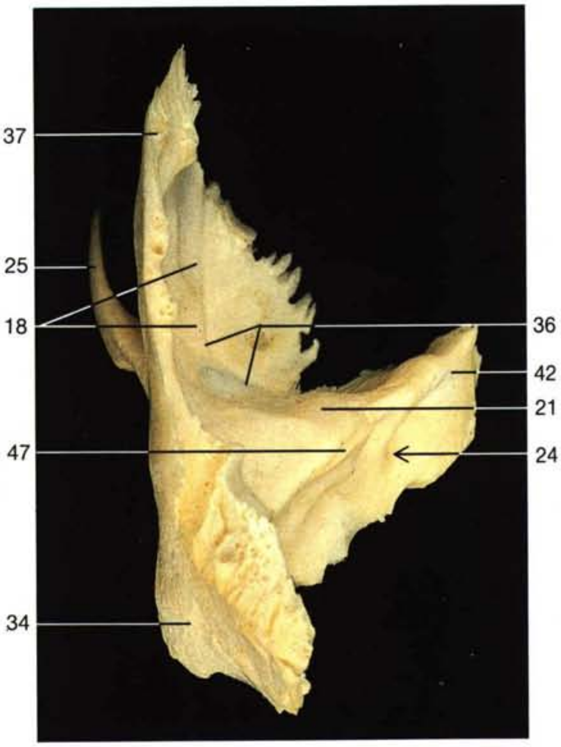

Left temporal bone (from above).

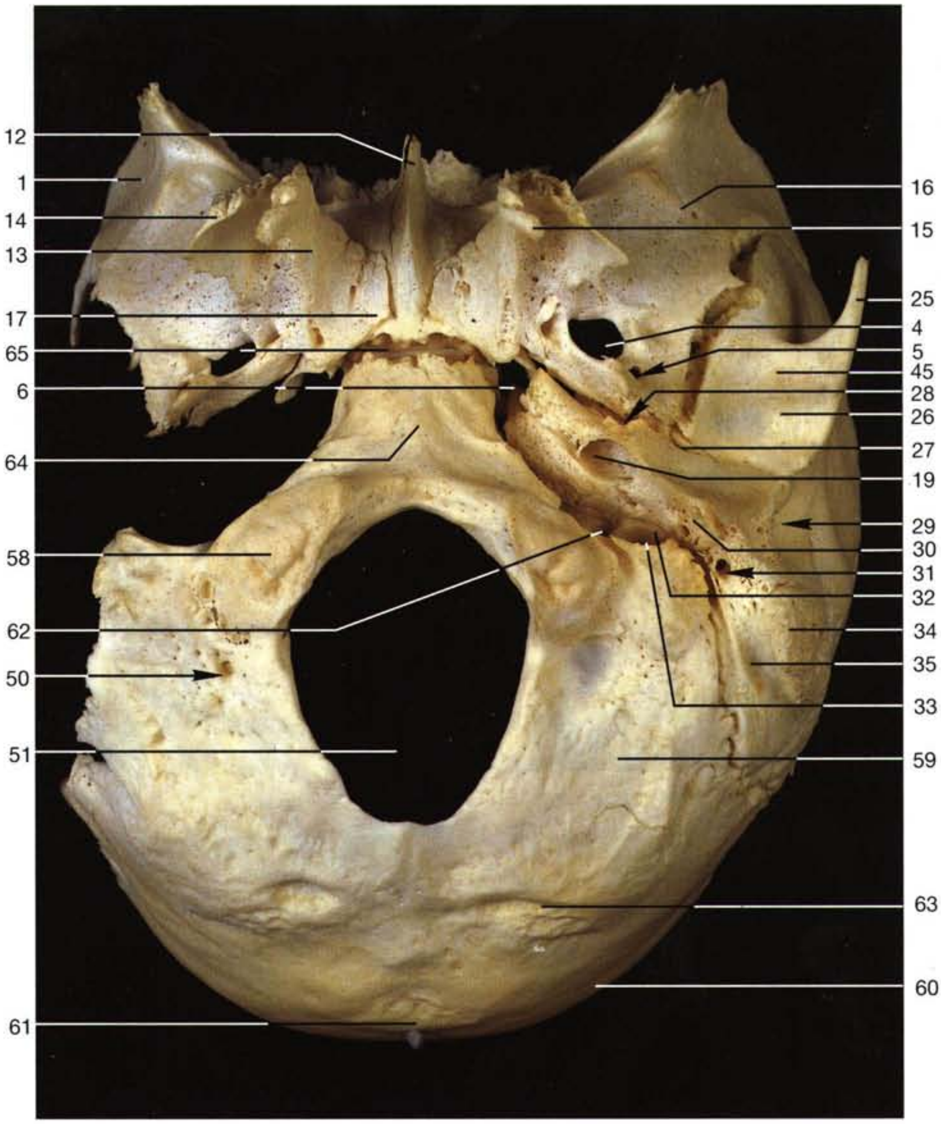
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Sphenoid, occipital and left temporal bone.
Base of the skull (external aspect).

36 Groove for middle meningeal vessels
37 Parietal margin
38 Sphenoid margin
39 Occipital margin
40 Cochlear canaliculus
41 Aqueduct of the vestibule
42 Apex of the petrous part
43 **Tympanic part**
44 Trigeminal impression
45 **Articular tubercle**
46 Parietal notch
47 Groove for the superior petrosal sinus

Occipital bone

48 **Clivus**
49 Jugular tubercle
50 Condylar canal
51 **Foramen magnum**
52 Lower part of squamous occipital bone (cerebellar fossa)
53 Internal occipital protuberance
54 Groove for the transverse sinus
55 Groove for the superior sagittal sinus
56 Internal occipital crest
57 Upper part of squamous occipital bone (cerebral fossa)
58 **Condyle**
59 Nuchal plane
60 Superior nuchal line
61 **External occipital protuberance**
62 **Jugular foramen**
63 Inferior nuchal line
64 Pharyngeal tubercle
65 **Sphenooccipital synchondrosis**

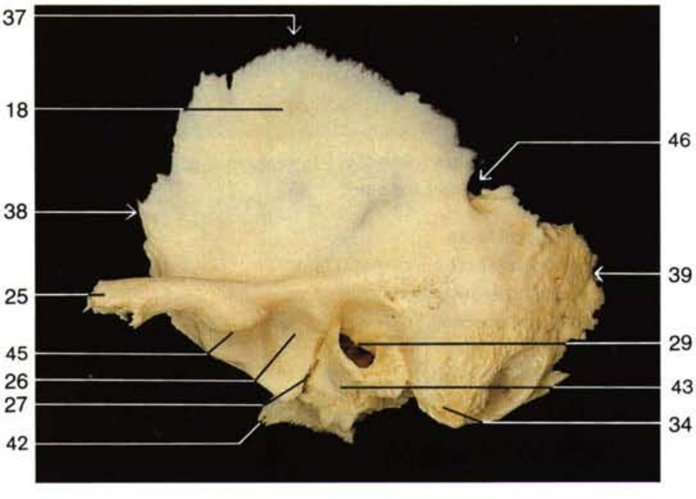
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Left temporal bone (lateral aspect).

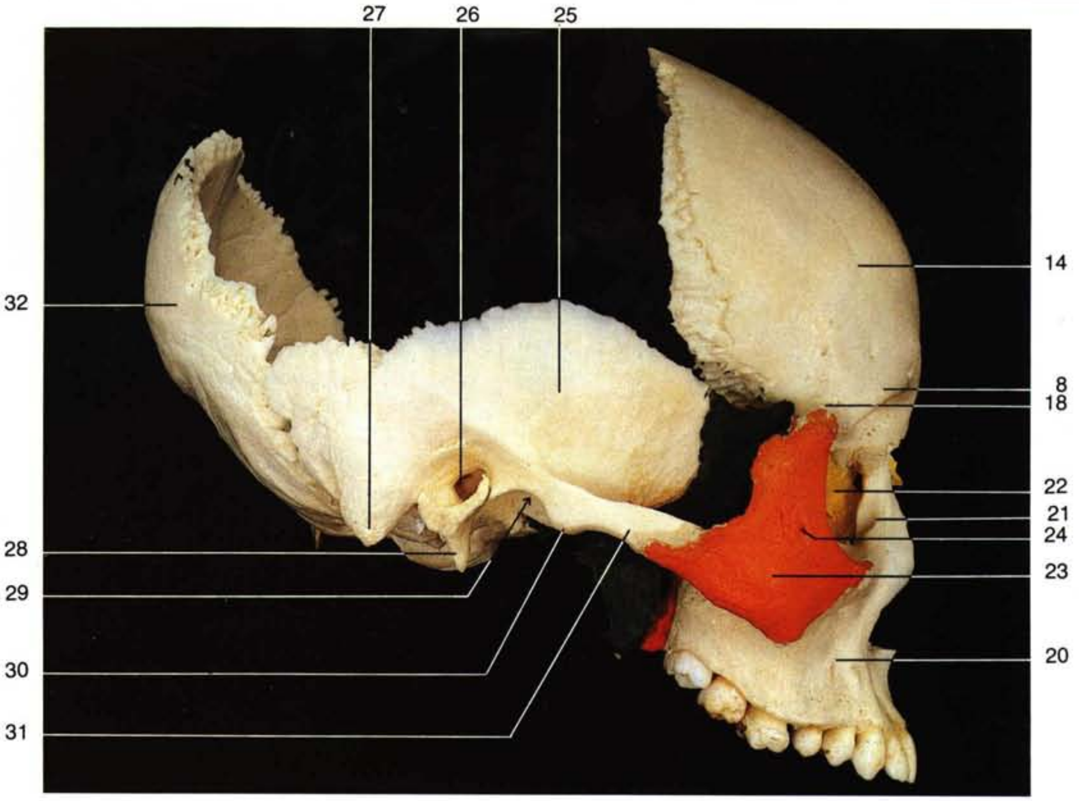

Part of a disarticulated skull (right lateral aspect). The **frontal bone** and the maxilla are connected with the temporal bone by the zygomatic bone (orange). Sphenoid bone (green), palatine bone (red), lacrimal bone (yellow).

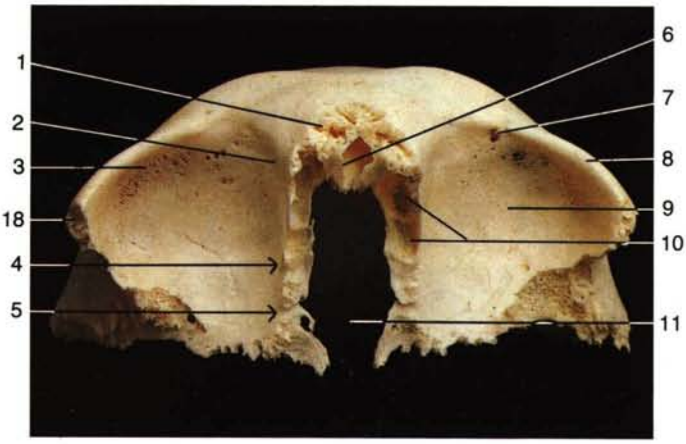

Frontal bone (inferior aspect). The ethmoidal foveolae cover the ethmoidal cavities of the ethmoid bone.

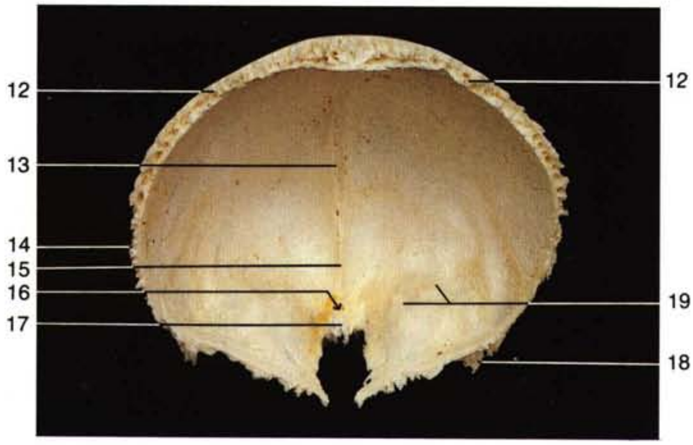

Frontal bone (posterior aspect).

Frontal bone

1 Nasal margin
2 Trochlear fossa
3 Fossa for lacrimal gland
4 Anterior ethmoidal foramen
5 Posterior ethmoidal foramen
6 Nasal spine
7 Supraorbital notch
8 Supraorbital margin
9 **Orbital plate**
10 Roofs of the ethmoidal air cells
11 Ethmoidal notch
12 Parietal margin
13 Groove for superior sagittal sinus
14 **Squamous part** of frontal bone
15 Frontal crest
16 Foramen cecum
17 Nasal spine
18 **Zygomatic process** of frontal bone
19 Juga cerebralia

20 **Maxilla**
21 Frontal process of maxilla
22 **Lacrimal bone** (yellow)
23 **Zygomatic bone** (orange)
24 Zygomaticofacial foramen

Temporal bone

25 Squamous part of temporal bone
26 External acoustic meatus
27 **Mastoid process**
28 **Styloid process**
29 **Mandibular fossa**
30 Articular tubercle
31 Zygomatic process

Occipital bone

32 Squamous part of occipital bone

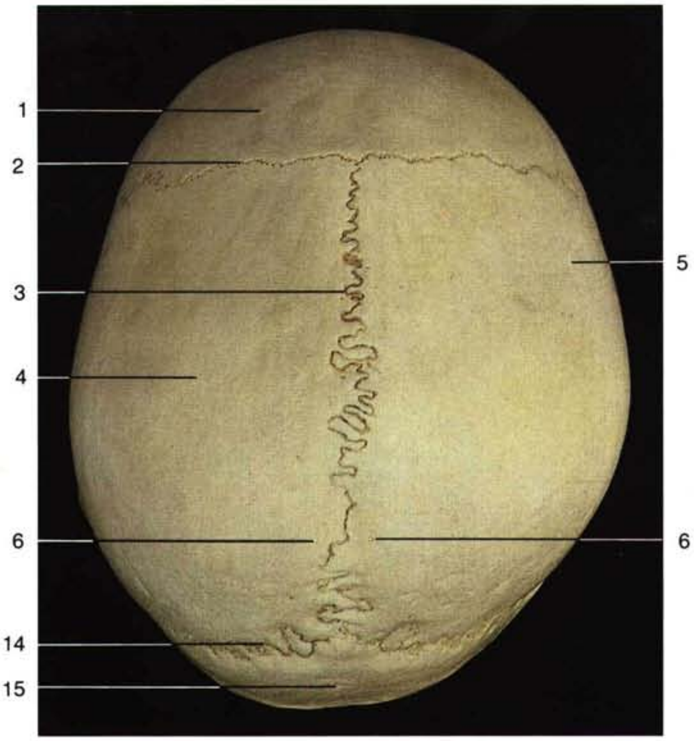

Calvaria (superior aspect).

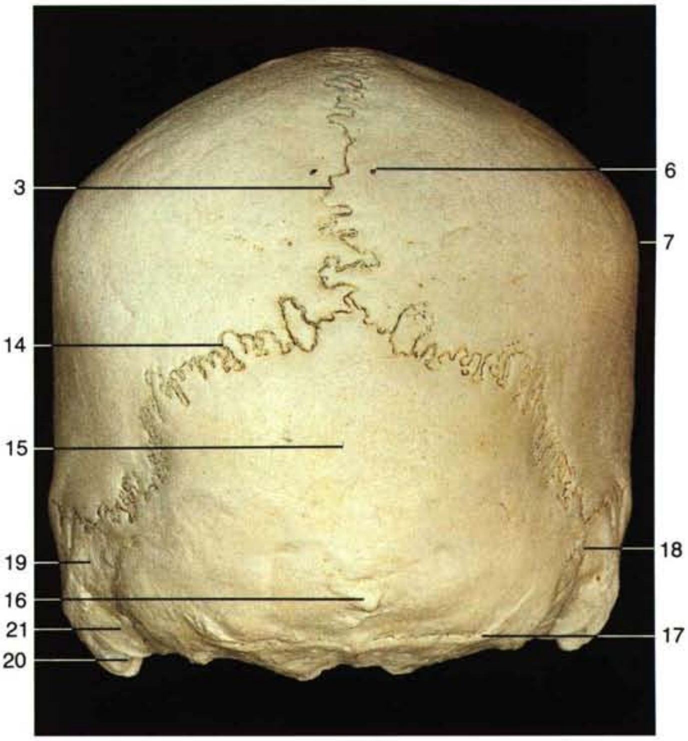

Calvaria (posterior aspect).

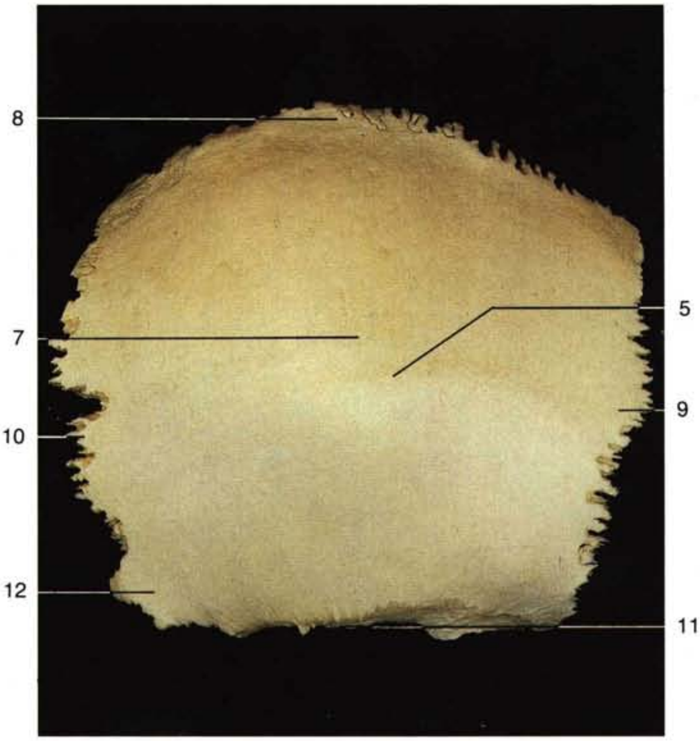

Left parietal bone (external aspect).

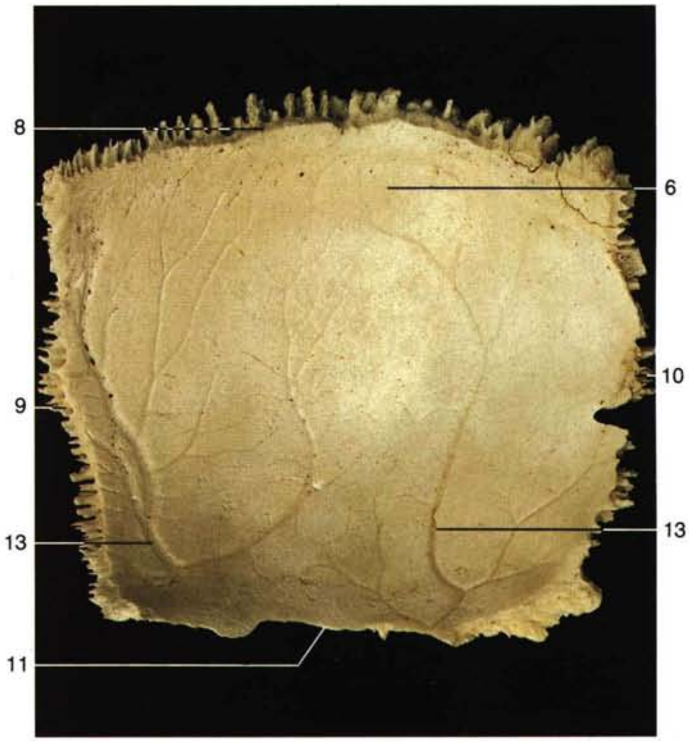

Left parietal bone (internal aspect).

1 **Frontal bone**
2 Coronal suture
3 Sagittal suture
4 **Parietal bone**
5 Superior temporal line
6 Parietal foramen
7 Parietal tuber or eminence
8 Sagittal margin
9 Occipital margin
10 Frontal margin
11 Squamous margin
12 Sphenoidal angle
13 Groove for middle meningeal artery
14 Lambdoid suture
15 **Occipital bone**
16 External occipital protuberance
17 Inferior nuchal line
18 Occipitomastoid suture
19 **Temporal bone**
20 Mastoid process
21 Mastoid notch

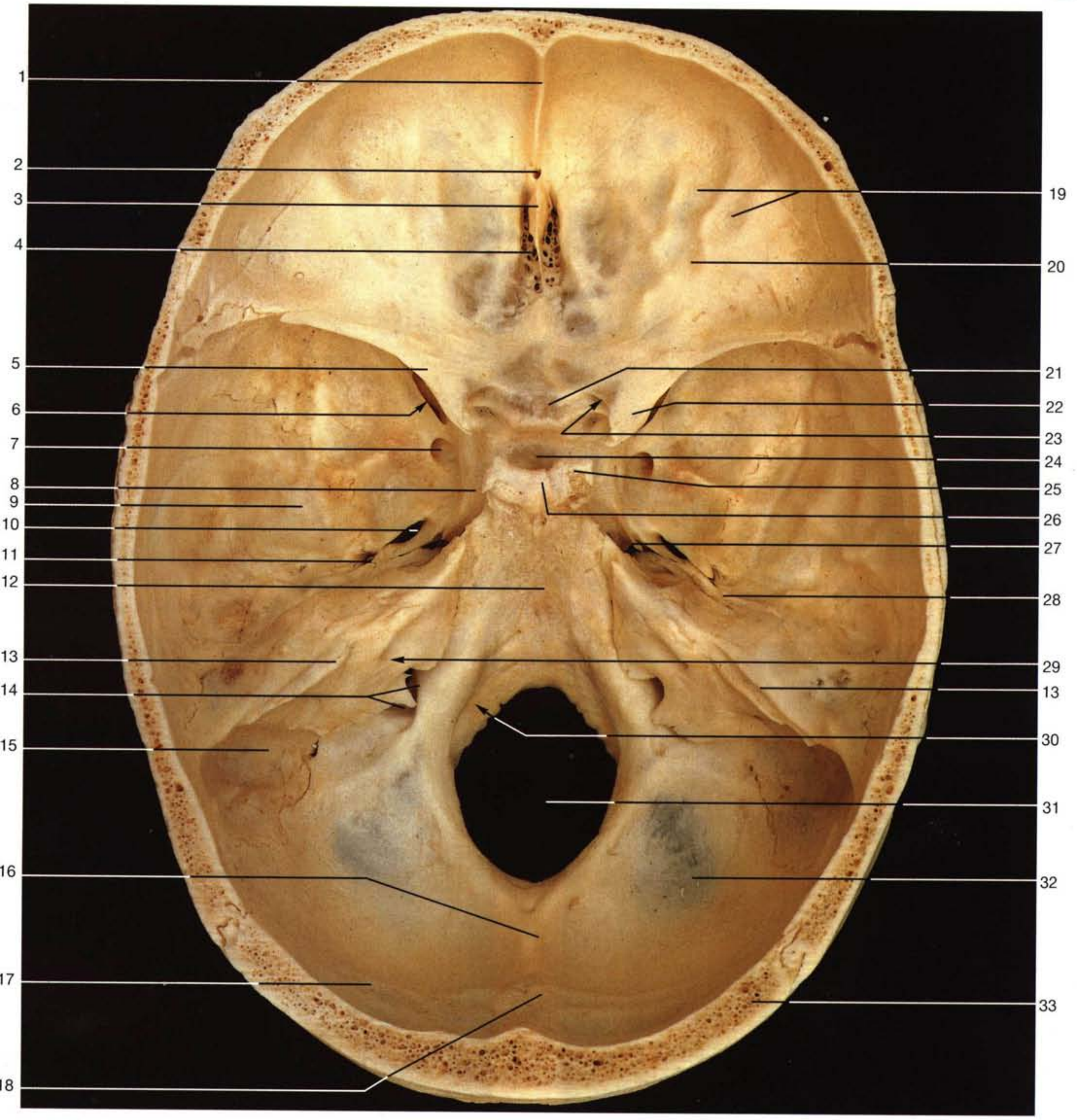

Base of the skull, calvaria removed (internal aspect).

1 Frontal crest
2 Foramen cecum
3 **Crista galli**
4 **Cribriform plate** of ethmoid bone
5 Lesser wing of sphenoid bone
6 Superior orbital fissure
7 **Foramen rotundum**
8 **Carotid sulcus**
9 Middle cranial fossa
10 **Foramen ovale**
11 Foramen spinosum
12 **Clivus**
13 Groove for superior petrosal sinus
14 **Jugular foramen**
15 Groove for sigmoid sinus
16 Internal occipital crest
17 Groove for transverse sinus
18 Internal occipital protuberance
19 Marking of brain convolutions
20 Anterior cranial fossa
21 Chiasmatic sulcus
22 Anterior clinoid process
23 **Optic canal**
24 **Sella turcica** (hypophysial fossa)
25 Posterior clinoid process
26 Dorsum sellae
27 **Foramen lacerum**
28 Groove for greater petrosal nerve
29 Internal acoustic meatus
30 **Hypoglossal canal**
31 **Foramen magnum**
32 Posterior cranial fossa
33 Diploe

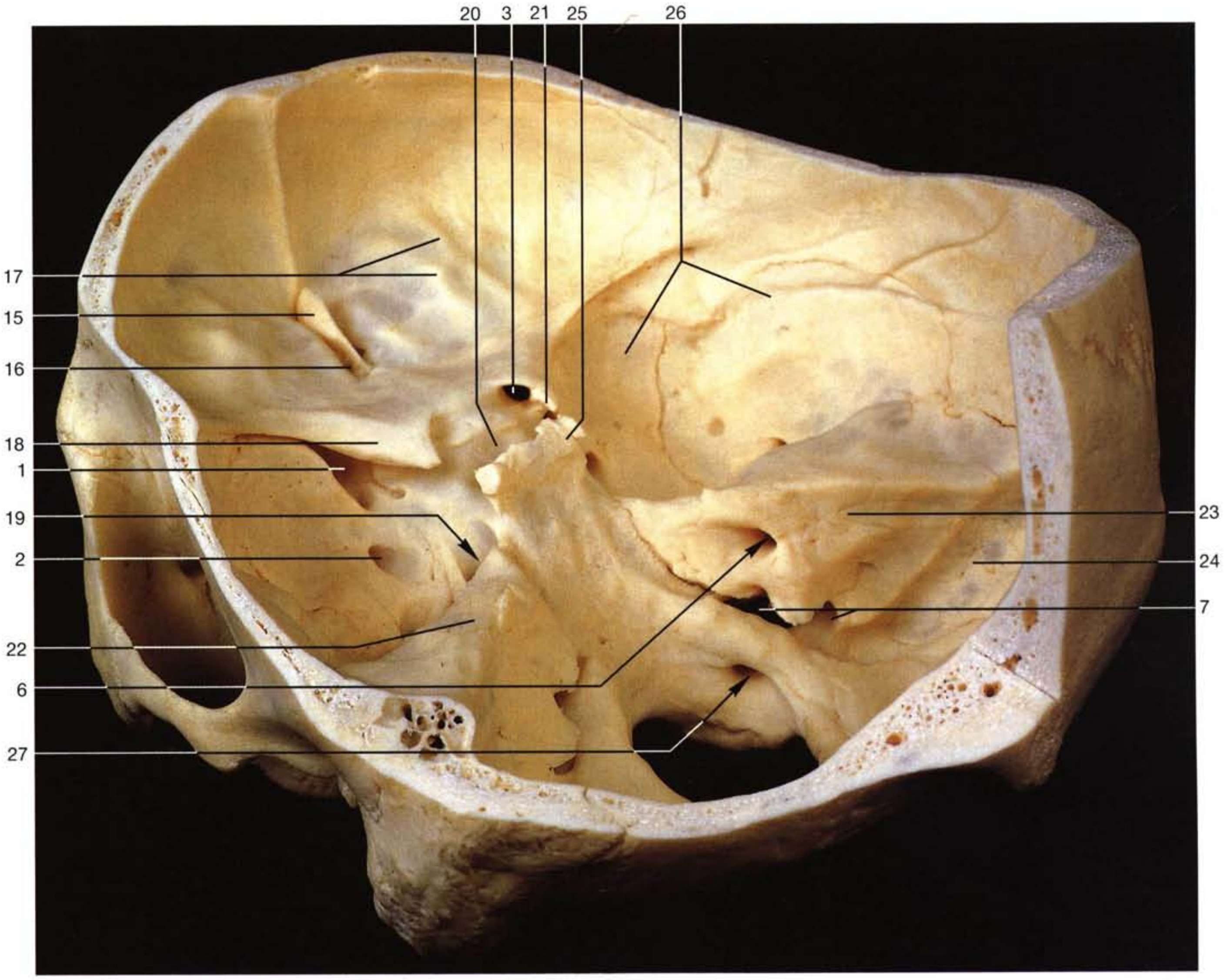

Base of the skull (internal aspect, oblique lateral view from left side).

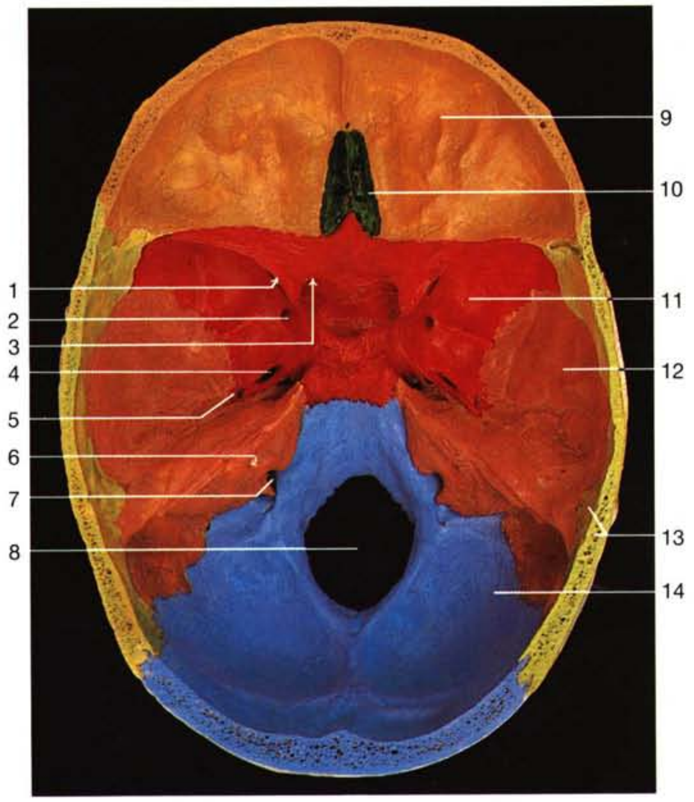

Base of the skull (internal aspect, superior view). Individual bones indicated by color.

Canals, fissures and foramina of the base of the skull

1 Superior orbital fissure
2 Foramen rotundum
3 Optic canal
4 Foramen ovale
5 Foramen spinosum
6 Internal acoustic meatus
7 Jugular foramen
8 Foramen magnum

Bones

9 Frontal bone (orange)
10 Ethmoid bone (dark green)
11 Sphenoid bone (red)
12 Temporal bone (brown)
13 Parietal bone (yellow-green)
14 Occipital bone (blue)

Details of bones

15 Crista galli
16 Cribriform plate
17 Marking of brain convolutions (frontal bone)
18 Lesser wing of sphenoid bone
19 Foramen lacerum
20 Hypophysial fossa (sella turcica)
21 Anterior clinoid process
22 Depression for trigeminal ganglion
23 Petrous part of temporal bone
24 Groove for sigmoid sinus
25 Dorsum sellae (posterior clinoid process)
26 Greater wing of sphenoid bone, groove for middle meningeal artery
27 Hypoglossal canal

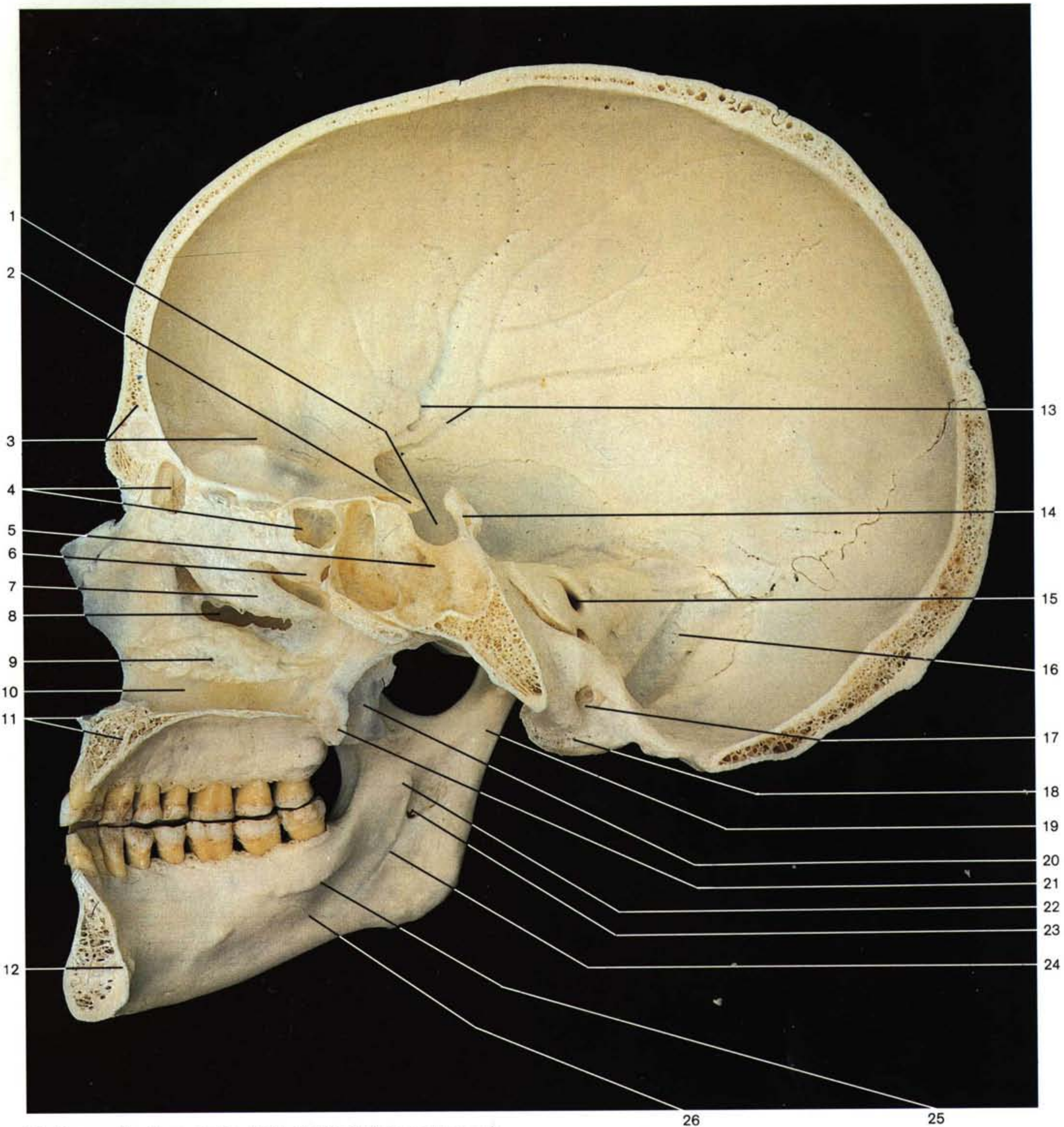

Median section through the skull, right half (internal aspect).

1 **Hypophysial fossa (sella turcica)**
2 Anterior clinoid process
3 **Frontal bone**
4 **Ethmoidal air cells**
5 **Sphenoidal sinus**
6 Superior concha
7 Middle concha
8 **Maxillary hiatus**
9 **Inferior concha**
10 Inferior meatus
11 Anterior nasal spine and maxilla
12 Mental spine or genial tubercle
13 Groove for middle meningeal artery

14 Dorsum sellae
15 Internal acoustic meatus
16 Groove for sigmoid sinus
17 **Hypoglossal canal**
18 **Occipital condyle**
19 Condylar process
20 Lateral pterygoid plate }
21 Medial pterygoid plate } of **pterygoid process**
22 Lingula of mandible
23 **Mandibular foramen**
24 Mylohyoid groove
25 Mylohyoid line
26 Submandibular fovea

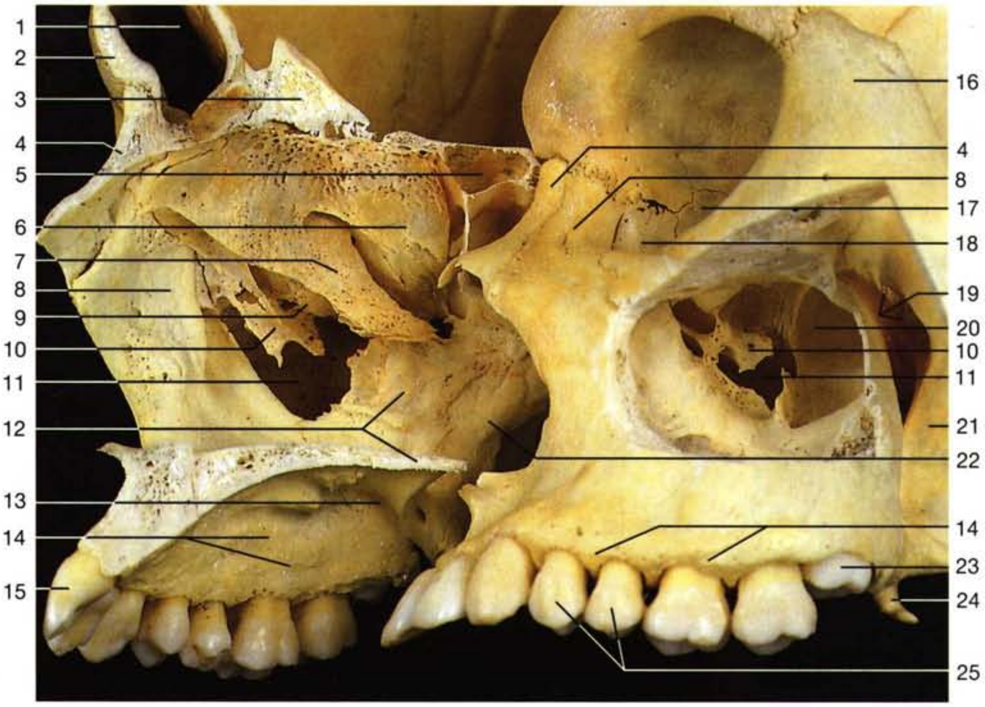

Facial part of the skull (viscerocranium), divided in two halves (lateral and medial aspect). Right inferior concha has been removed to show the maxillary hiatus. Left maxillary sinus opened.

1 Frontal sinus
2 **Frontal bone**
3 Crista galli
4 **Nasal bone**
5 Sphenoidal sinus
6 **Superior concha** ⎫ of **ethmoid**
7 **Middle concha** ⎭ **bone**
8 Frontal process of maxilla
9 Ethmoidal bulla
10 **Uncinate process**
11 Maxillary hiatus
12 **Palatine bone**
13 Greater palatine foramen
14 **Alveolar process of maxilla**
15 Central incisor
16 Zygomatic bone
17 Ethmoid bone
18 **Lacrimal bone**
19 Pterygopalatine fossa
20 **Maxillary sinus**
21 Lateral pterygoid plate
22 Medial pterygoid plate
23 Third molar tooth
24 Pterygoid hamulus
25 Two premolar teeth

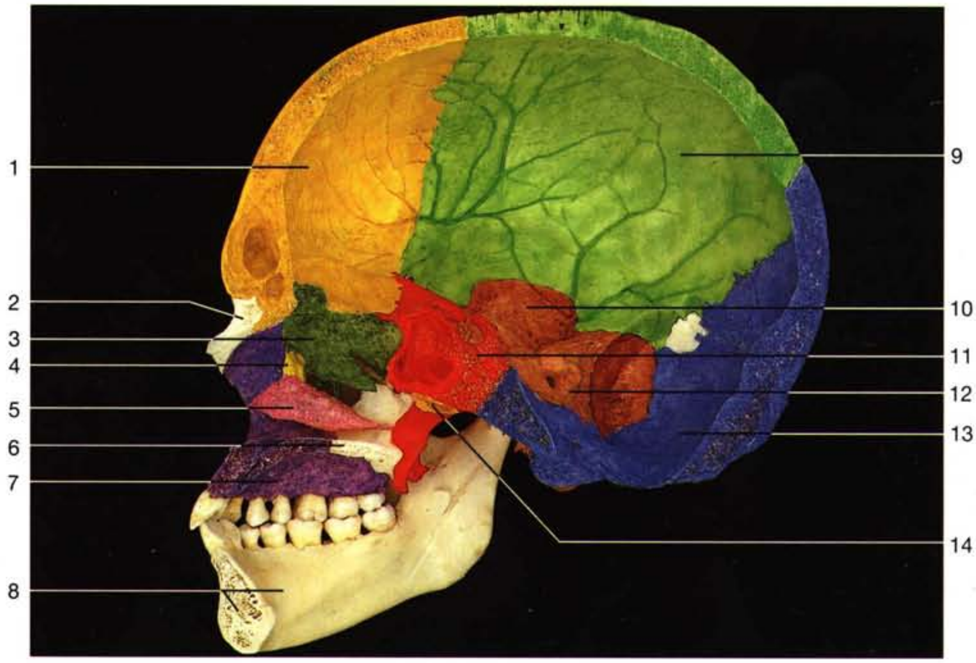

Median section through the skull. The nasal septum has been removed. Bones indicated by colors.

Bones (indicated by colors)
1 Frontal bone (yellow)
2 Nasal bone (white)
3 Ethmoid bone (dark green)
4 Lacrimal bone (yellow)
5 Inferior nasal concha (pink)
6 Palatine bone (white)
7 Maxilla (violet)
8 Mandible (white)
9 Parietal bone (light green)
10 Temporal bone (brown)
11 Sphenoid bone (red)
12 Petrous part of temporal bone (brown)
13 Occipital bone (blue)
14 Ala of vomer (light brown)

Because of the upright posture which the man developed in the course of evolution, the cranial cavity greatly increased in size whereas the facial skeleton decreased. As a result, the base of the skull developed an angulation of about 120° between the clivus and the cribriform plate. The hypophysial fossa containing the pituitary gland lies at the angle formed between these two planes.

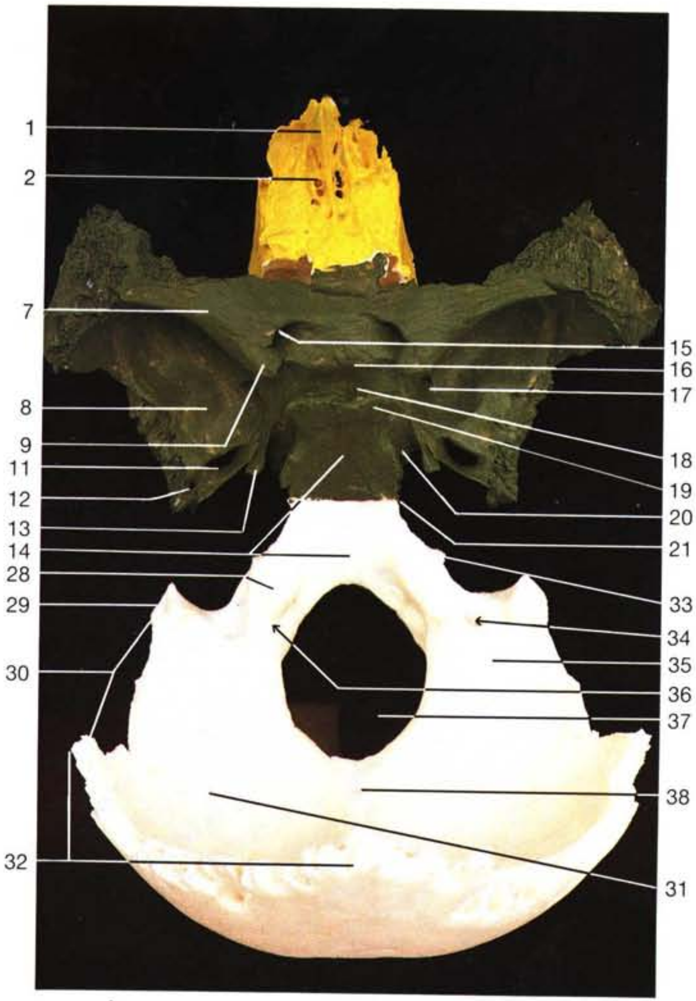

Part of the disarticulated base of the skull.
Ethmoid, sphenoid and occipital bones (from above).
Green = sphenoid bone; yellow = ethmoid bone.

Ethmoid bone

1 Crista galli
2 Cribriform plate
3 Ethmoidal air cells
4 Middle concha
5 Perpendicular plate (part of nasal septum)
6 Orbital plate

Sphenoid bone

7 Lesser wing
8 Greater wing
9 Anterior clinoid process
10 Posterior clinoid process
11 Foramen ovale
12 Foramen spinosum
13 Lingula of the sphenoid
14 Clivus
15 Optic canal
16 Tuberculum sellae
17 Foramen rotundum (right side)
18 Hypophysial fossa (sella turcica)
19 Dorsum sellae
20 Carotid sulcus
21 Sphenooccipital synchondrosis
22 Lateral pterygoid plate
23 Greater wing of sphenoid bone (orbital surface)
24 Greater wing of sphenoid bone (maxillary surface)
25 Foramen rotundum (left side)
26 Superior orbital fissure
27 Infratemporal crest of the greater wing

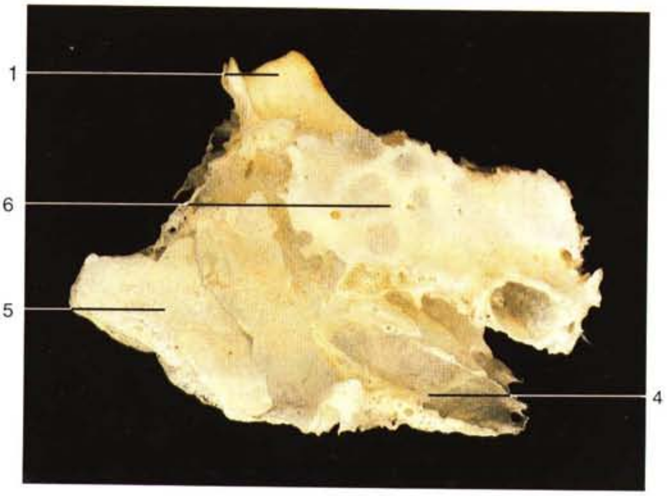

Ethmoid bone (lateral aspect), posterior portion to the right.

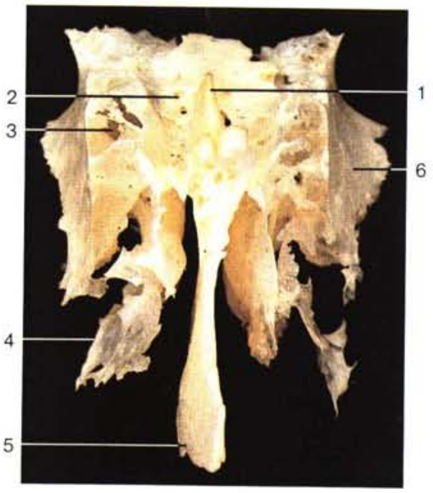

Ethmoid bone (anterior aspect).

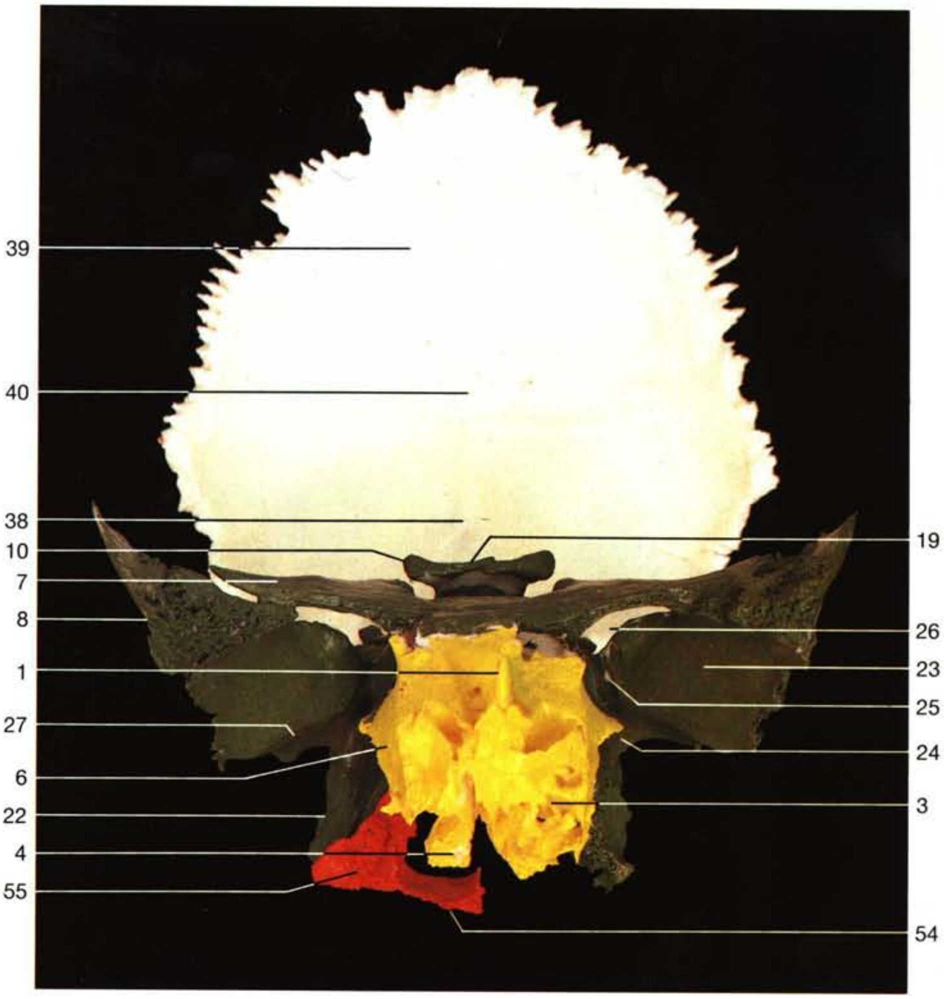

Disarticulated base of the skull (anterior aspect).
Green = sphenoid bone; yellow = ethmoid bone; red = palatine bone.

Occipital bone

28	Jugular tubercle
29	Jugular process
30	Mastoid margin
31	Posterior cranial fossa
32	Lambdoid margin
33	Intrajugular process
34	Condylar canal
35	Lateral part of occipital bone
36	Hypoglossal canal
37	Foramen magnum
38	Internal occipital crest
39	Squamous part of occipital bone
40	Internal occipital protuberance

Maxilla

41	Orbital surface
42	Infraorbital groove
43	Maxillary tuberosity with foramina
44	Frontal process
45	Nasolacrimal groove
46	Infraorbital margin
47	Anterior nasal spine
48	Zygomatic process
49	Alveolar process

Palatine bone

50	Orbital process
51	Sphenopalatine notch
52	Sphenoidal process
53	Perpendicular plate
54	Horizontal plate
55	Pyramidal process

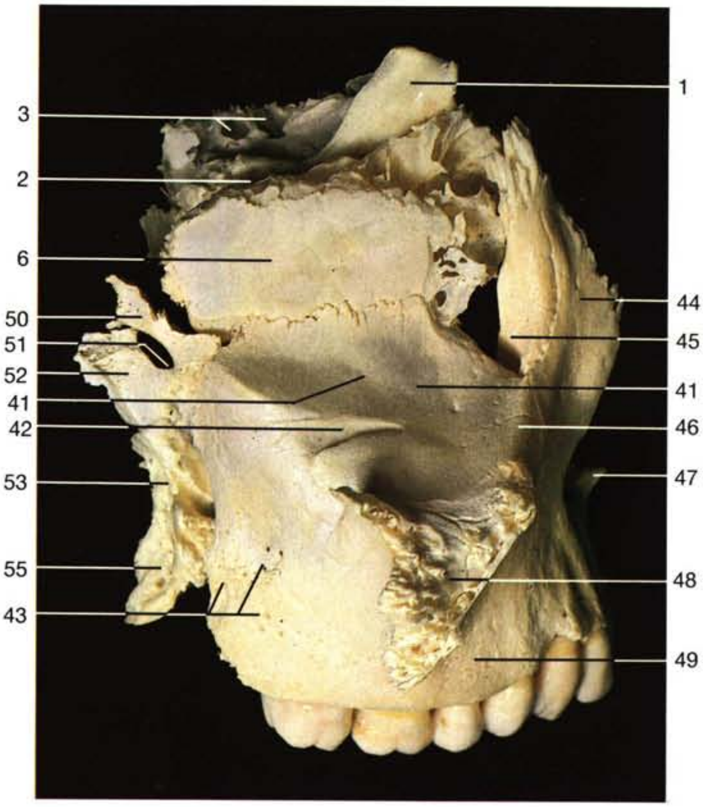

Right maxilla, ethmoid and palatine bone (lateral aspect).

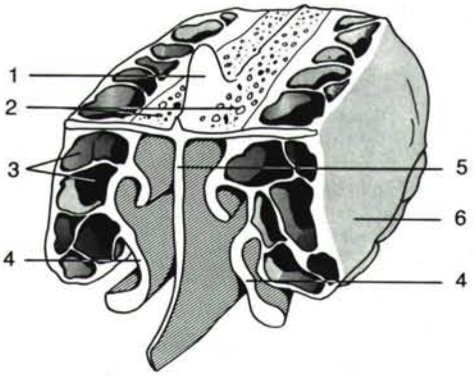

Ethmoid bone (oblique anterior aspect).
(Schematic drawing.)

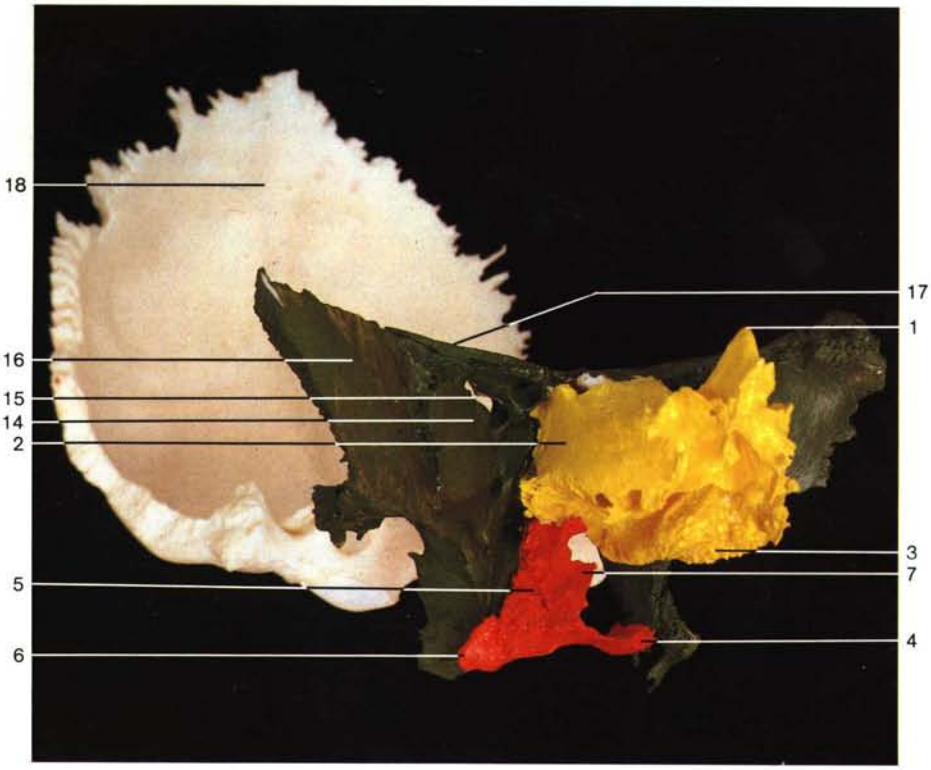

Part of a disarticulated skull base, similar to the foregoing figures, but with palatine bone. Green = sphenoid bone; yellow = ethmoid bone; red = palatine bone.

Ethmoid bone

1 Crista galli
2 Orbital plate
3 Middle concha

Palatine bone

4 Horizontal plate of palatine bone
5 Greater palatine canal
6 Pyramidal process
7 Maxillary process
8 Orbital process
9 Sphenopalatine notch
10 Perpendicular plate of palatine bone
11 Conchal crest
12 Nasal crest
13 Sphenoidal process

Sphenoid bone

14 Greater wing
15 Superior orbital fissure
16 Greater wing (orbital surface)
17 Lesser wing

Occipital bone

18 Squamous part of occipital bone

Maxilla

19 Maxillary tuberosity
20 Frontal process
21 Orbital surface
22 Infraorbital margin
23 Infraorbital groove
24 Zygomatic process
25 Alveolar process

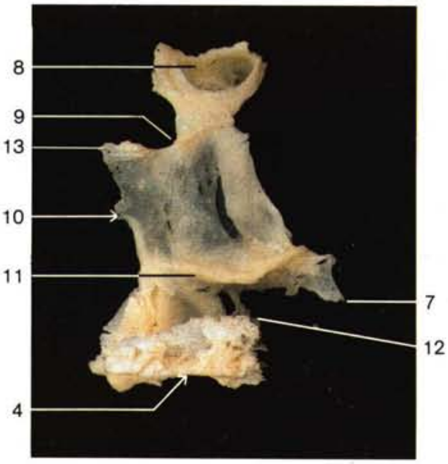

Left palatine bone (medial aspect, posterior aspect to the left).

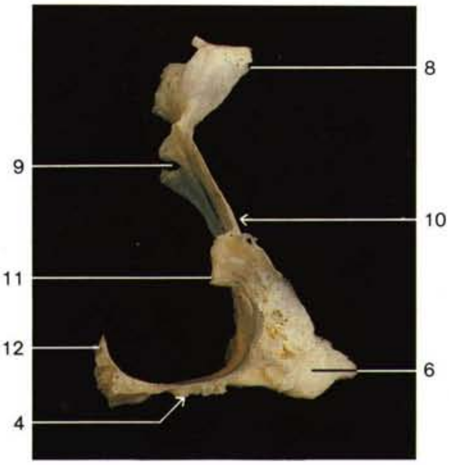

Left palatine bone (anterior aspect).

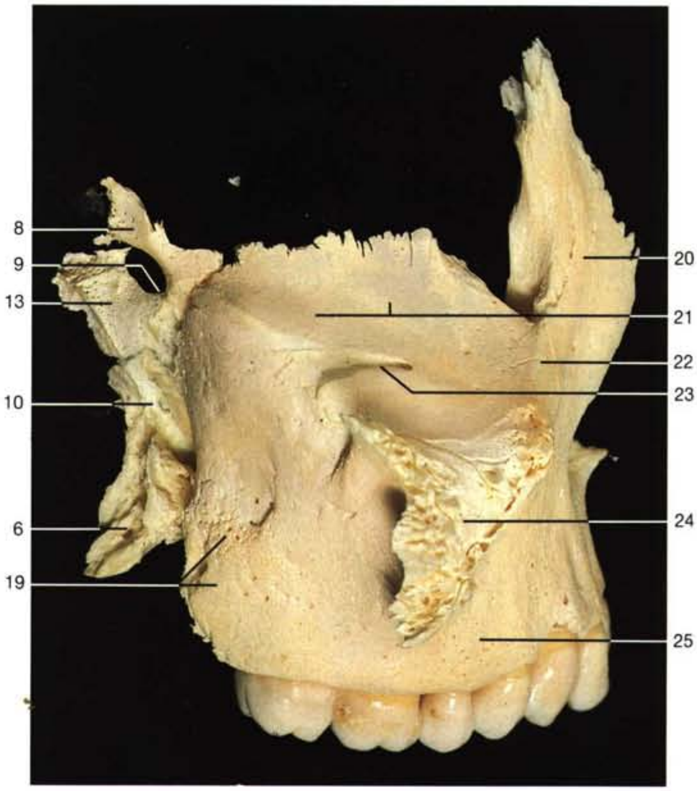

Right maxilla and right palatine bone (lateral aspect).

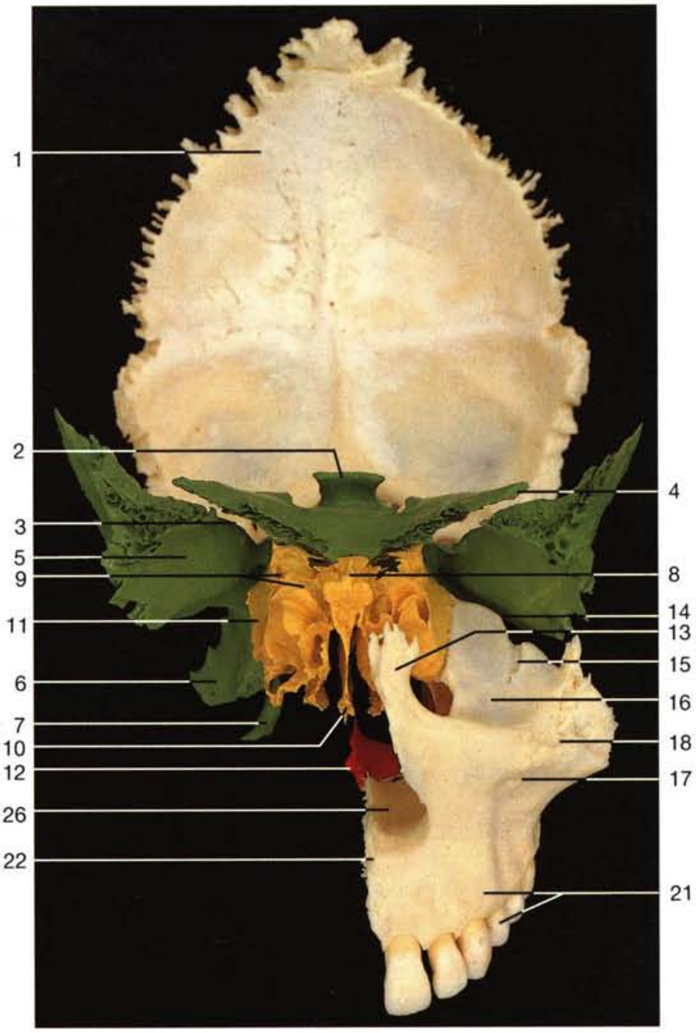

Part of a disarticulated skull.
The left **maxilla** is added to the preceding specimen.

Occipital bone

1 Squamous part

Sphenoid bone

2 Dorsum sellae
3 Superior orbital fissure
4 Lesser wing
5 Greater wing (orbital surface)
6 Lateral pterygoid plate
7 Medial pterygoid plate

Ethmoid bone

8 Crista galli
9 Ethmoidal air cells
10 Perpendicular plate
11 Orbital plate

Palatine bone

12 Horizontal plate (nasal crest)

Maxilla

13 Frontal process
14 Inferior orbital fissure
15 Infraorbital groove
16 Orbital surface
17 Infraorbital foramen
18 Zygomatic process
19 Anterior lacrimal crest
20 Canine fossa
21 Alveolar process with teeth
22 Anterior nasal spine
23 Juga alveolaria (elevations formed by roots of teeth)
24 Lacrimal groove
25 Maxillary tuberosity with alveolar foramina
26 Palatine process of maxilla

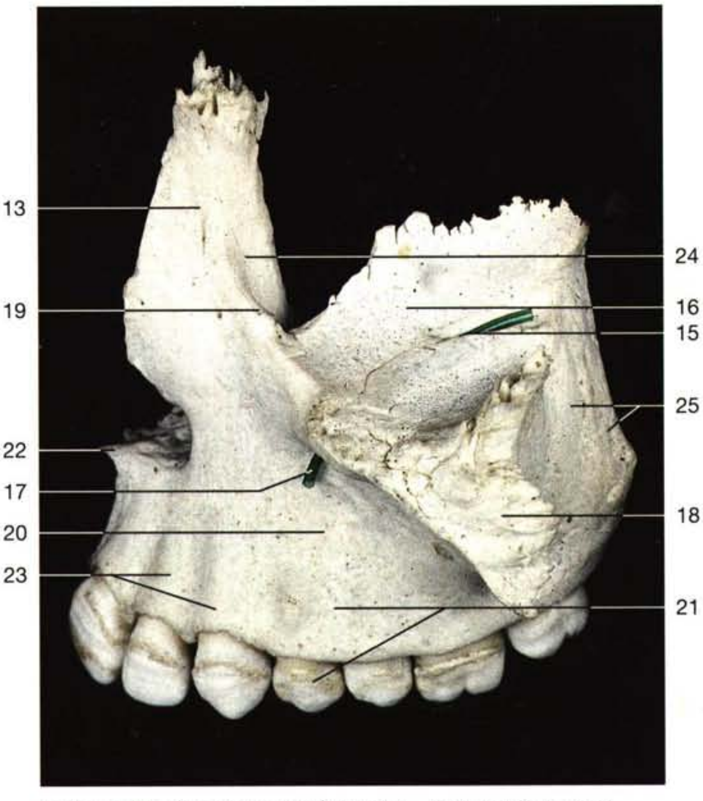

Left maxilla (lateral aspect). Probe = infraorbital canal.

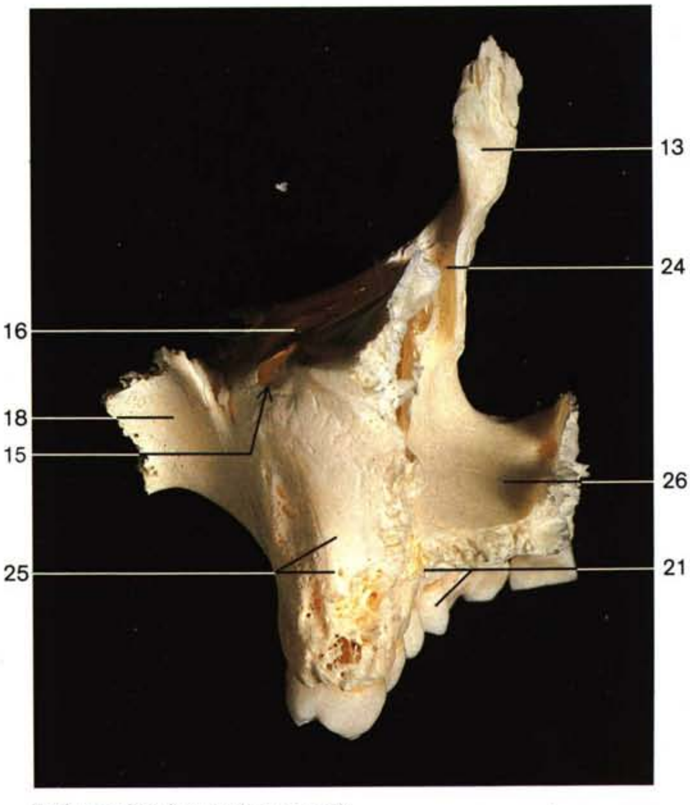

Left maxilla (posterior aspect).

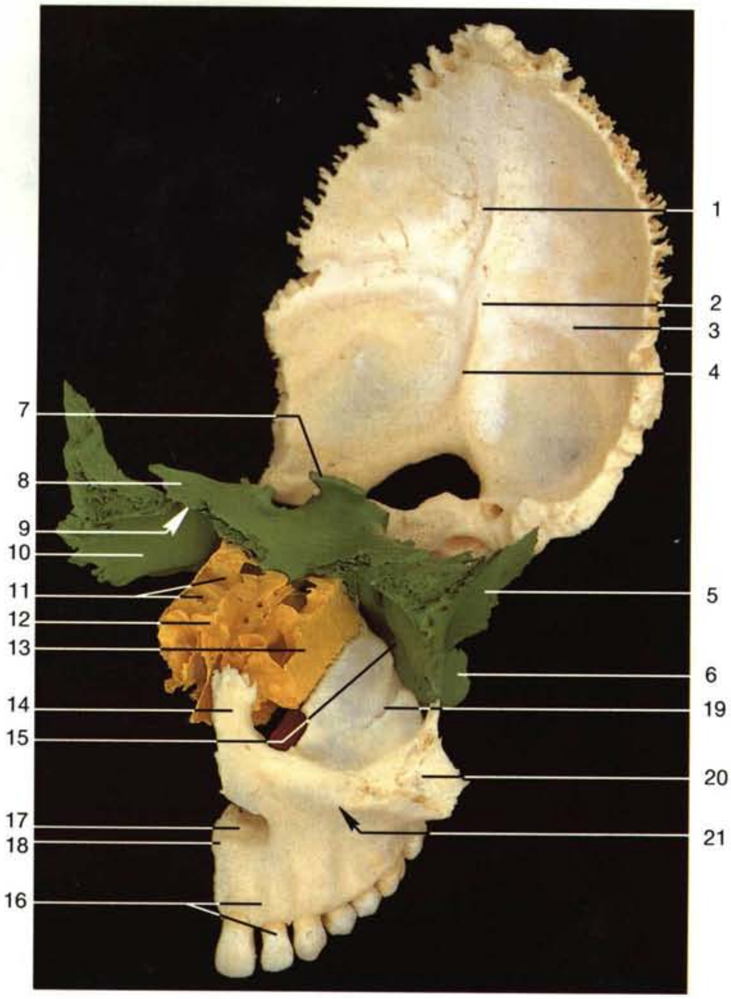

Part of a disarticulated base of skull. The mosaic of the facial bones [sphenoid bone (green), ethmoid bone (yellow), and palatine bone (red)] is seen from the anterior-lateral aspect.

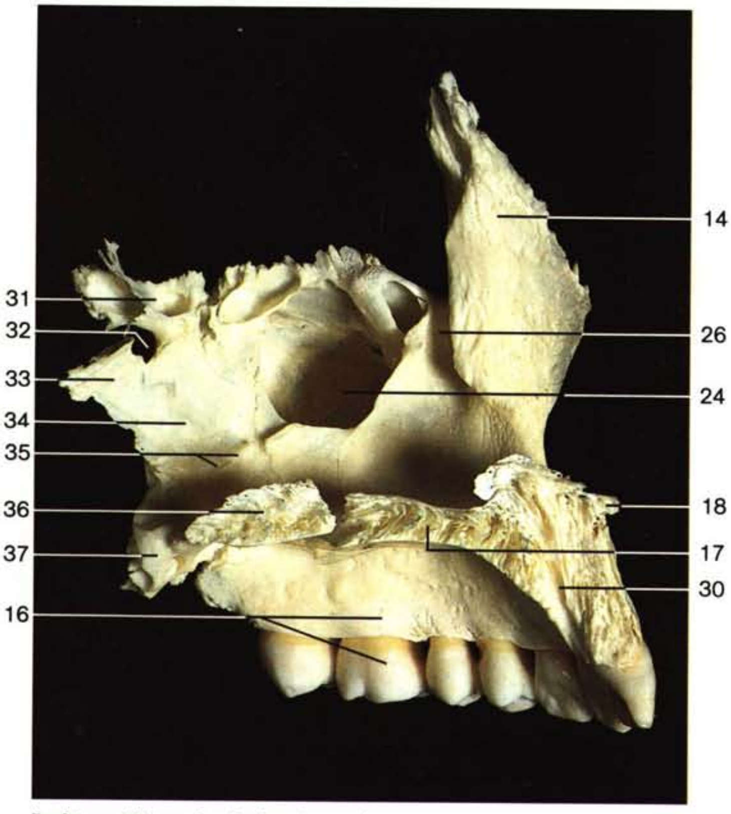

Left maxilla and palatine bone (medial aspect).

Occipital bone

1 Groove for superior sagittal sinus
2 Internal occipital protuberance
3 Groove for transverse sinus
4 Internal occipital crest

Sphenoid bone

5 Greater wing (temporal surface)
6 Lateral pterygoid plate
7 Dorsum sellae
8 Lesser wing
9 Superior orbital fissure
10 Greater wing (orbital surface)

Ethmoid bone

11 Ethmoidal air cells
12 Crista galli
13 Orbital plate

Maxilla

14 Frontal process
15 Inferior orbital fissure
16 Alveolar process with teeth
17 Palatine process
18 Anterior nasal spine
19 Infraorbital groove
20 Zygomatic process
21 Location of infraorbital foramen
22 Middle nasal meatus
23 Inferior nasal meatus
24 Maxillary hiatus
(leading to maxillary sinus)
25 Third molar
26 Lacrimal groove
27 Conchal crest
28 Body of maxilla (nasal surface)
29 Nasal crest
30 Incisive canal

Palatine bone

31 Orbital process
32 Sphenopalatine notch
33 Sphenoidal process
34 Perpendicular plate
35 Conchal crest
36 Horizontal plate
37 Pyramidal process

Frontal bone

38 Squamous part
39 Supraorbital foramen
40 Frontal notch
41 Frontal spine

Inferior nasal concha

42 Inferior nasal concha
with maxillary process

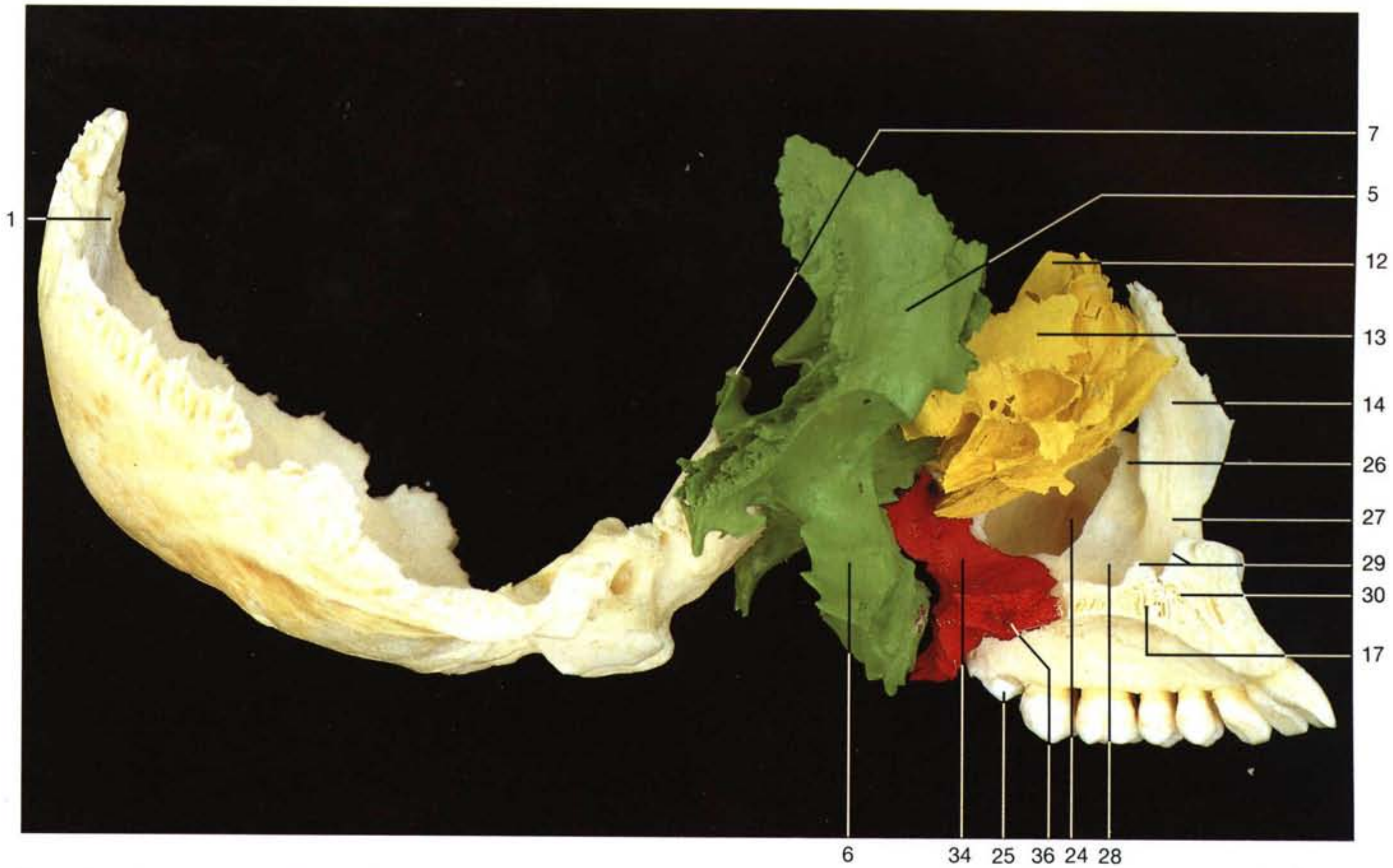
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Part of a disarticulated base of skull (medial aspect). Green = sphenoid bone; yellow = ethmoid bone; red = palatine bone; natural colored = left maxilla.

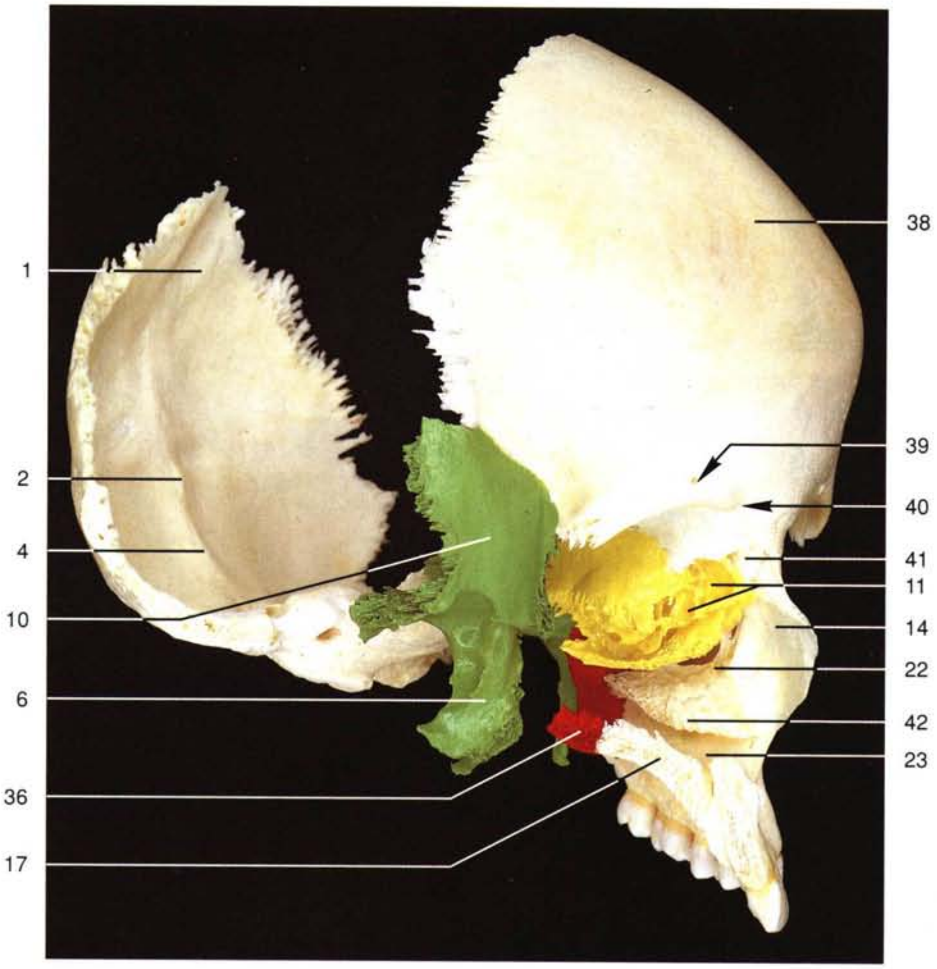
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Part of a disarticulated base of skull. The same specimen as shown above but with frontal bone (oblique-lateral aspect).

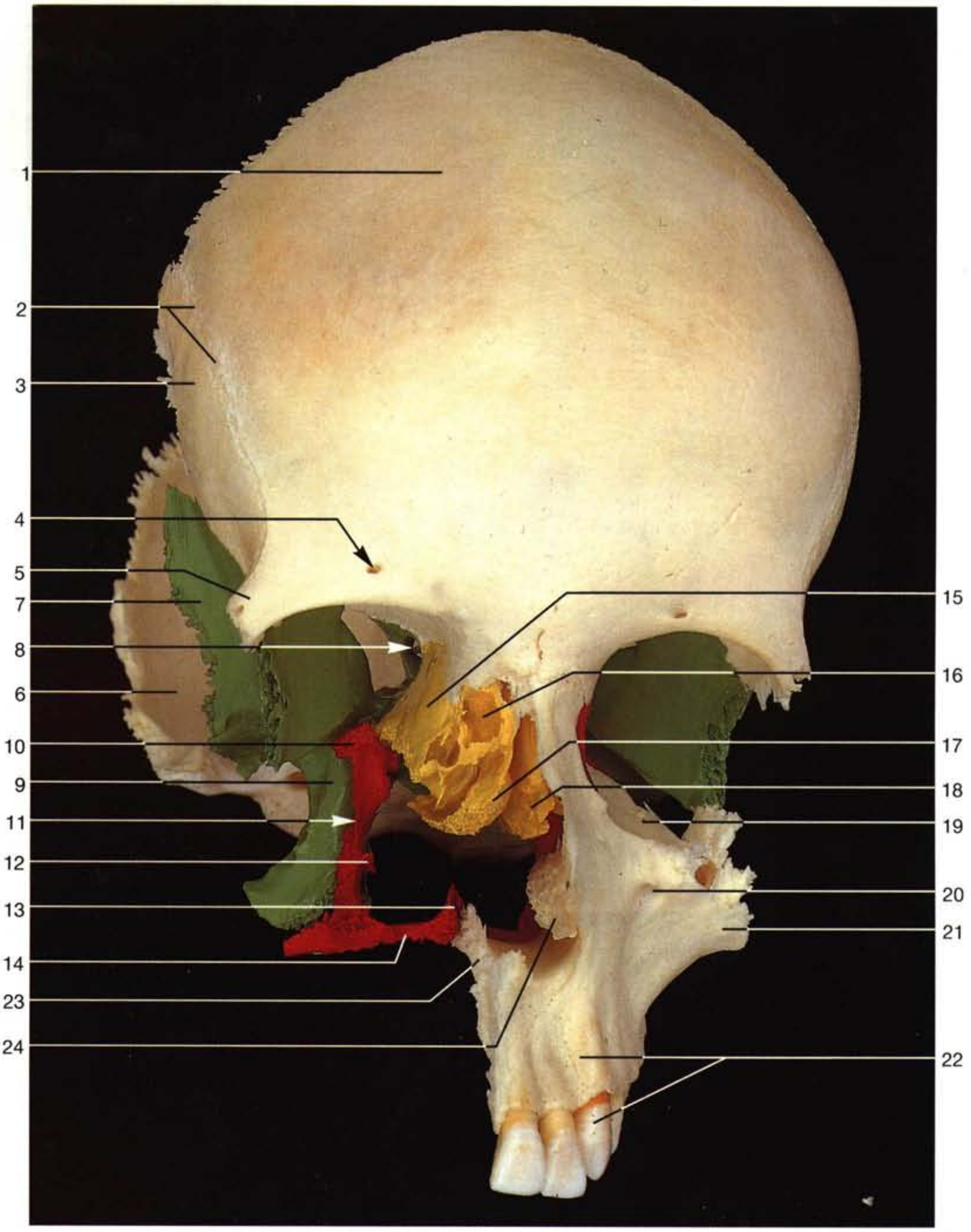

Part of a disarticulated skull, showing the connection of the palatine bone (red) and the maxilla with ethmoid bone (yellow) and sphenoid bone (light green) (anterior aspect).

Frontal bone
1 Squamous part
2 Inferior temporal line
3 Temporal surface
4 Supraorbital foramen
5 Zygomatic process

Occipital bone
6 Squamous part

Sphenoid bone
7 Greater wing (temporal surface)
8 Optic canal within the lesser wing
9 Lateral pterygoid plate

Palatine bone
10 Orbital process
11 Perpendicular plate
12 Conchal crest
13 Nasal crest
14 Horizontal plate

Ethmoid bone
15 Orbital plate
16 Ethmoidal air cell
17 Middle concha
18 Perpendicular plate (part of bony nasal septum)

Maxilla
19 Infraorbital groove
20 Infraorbital foramen
21 Zygomatic process
22 Alveolar process with teeth
23 Palatine process

Left inferior nasal concha
24 Anterior part of inferior concha

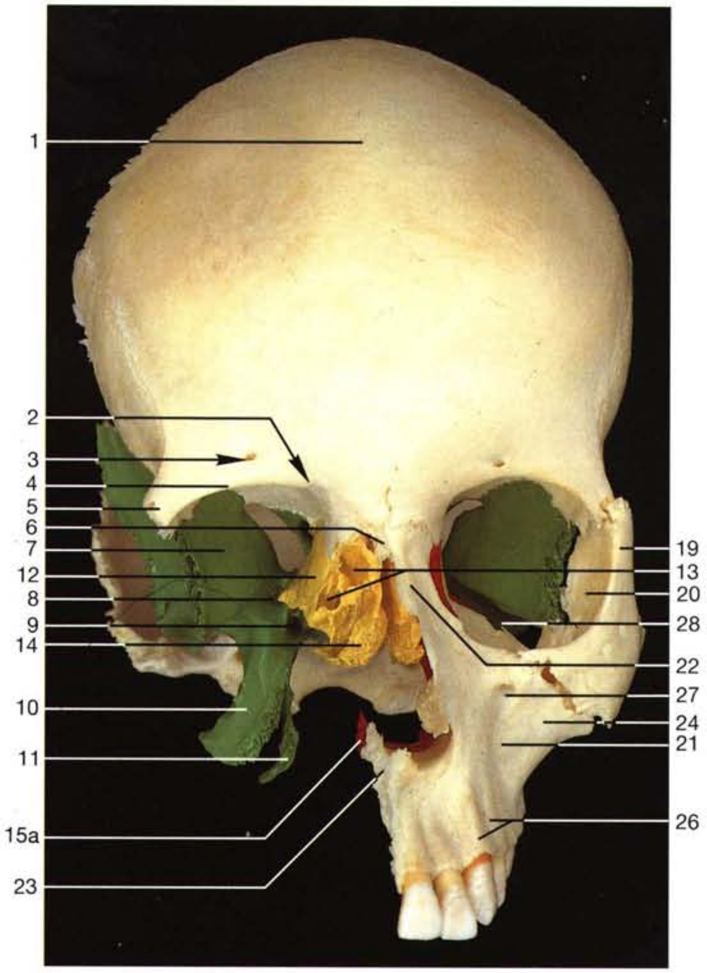

Anterior view of a disarticulated skull, showing the connection of the maxilla with the frontal and zygomatic bones. Yellow = ethmoid bone; red = palatine bone; green = sphenoid bone.

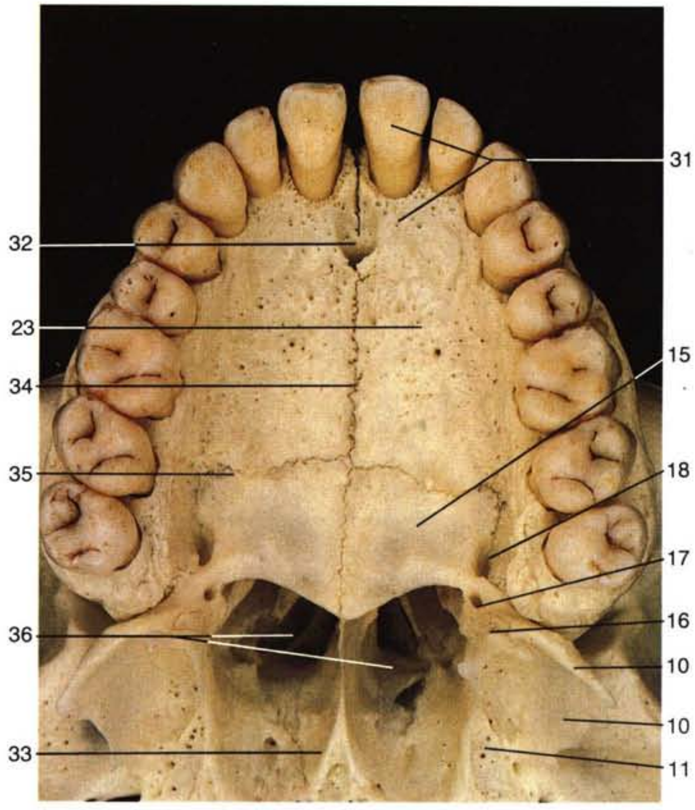

Bony palate and teeth of the maxillae (from below).

Frontal bone

1 Squamous part
2 Frontal notch
3 Supraorbital foramen
4 Supraorbital margin
5 Zygomatic process
6 Frontal spine

Sphenoid bone

7 Greater wing (orbital surface)
8 Foramen rotundum
9 Pterygoid or Vidian canal
10 Lateral pterygoid plate
11 Medial pterygoid plate

Ethmoid bone

12 Orbital plate
13 Ethmoidal air cells
14 Middle concha

Palatine bone

15 Horizontal plate
15a Nasal crest
16 Pyramidal process
17 Lesser palatine foramen
18 Greater palatine foramen

Zygomatic bone

19 Frontal process
20 Orbital surface

Maxilla

21 Canine fossa
22 Frontal process
23 Palatine process
24 Zygomatic process
25 Alveolar process and teeth
26 Juga alveolaria
27 Infraorbital foramen
28 Infraorbital groove
29 Anterior nasal aperture
30 Anterior nasal spine

Incisive bone

31 Central incisor and incisive bone or premaxilla
32 Incisive fossa

Vomer

33 Ala of the vomer

Sutures and choanae

34 Median palatine suture
35 Transverse palatine suture
36 Choanae

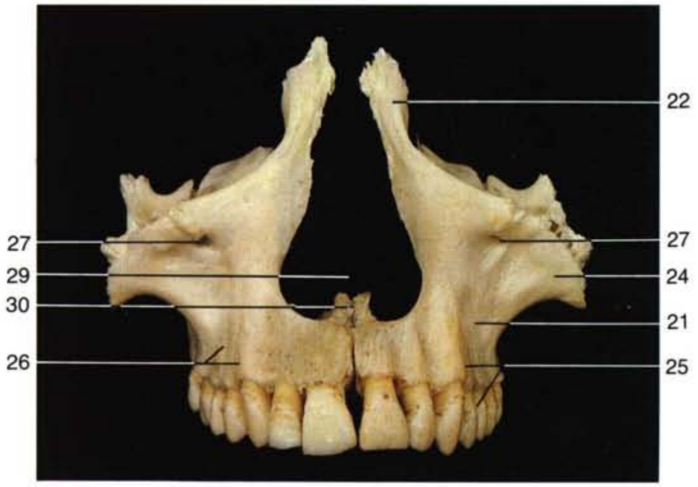

Anterior view of both maxillae, forming the anterior bony aperture of the nose.

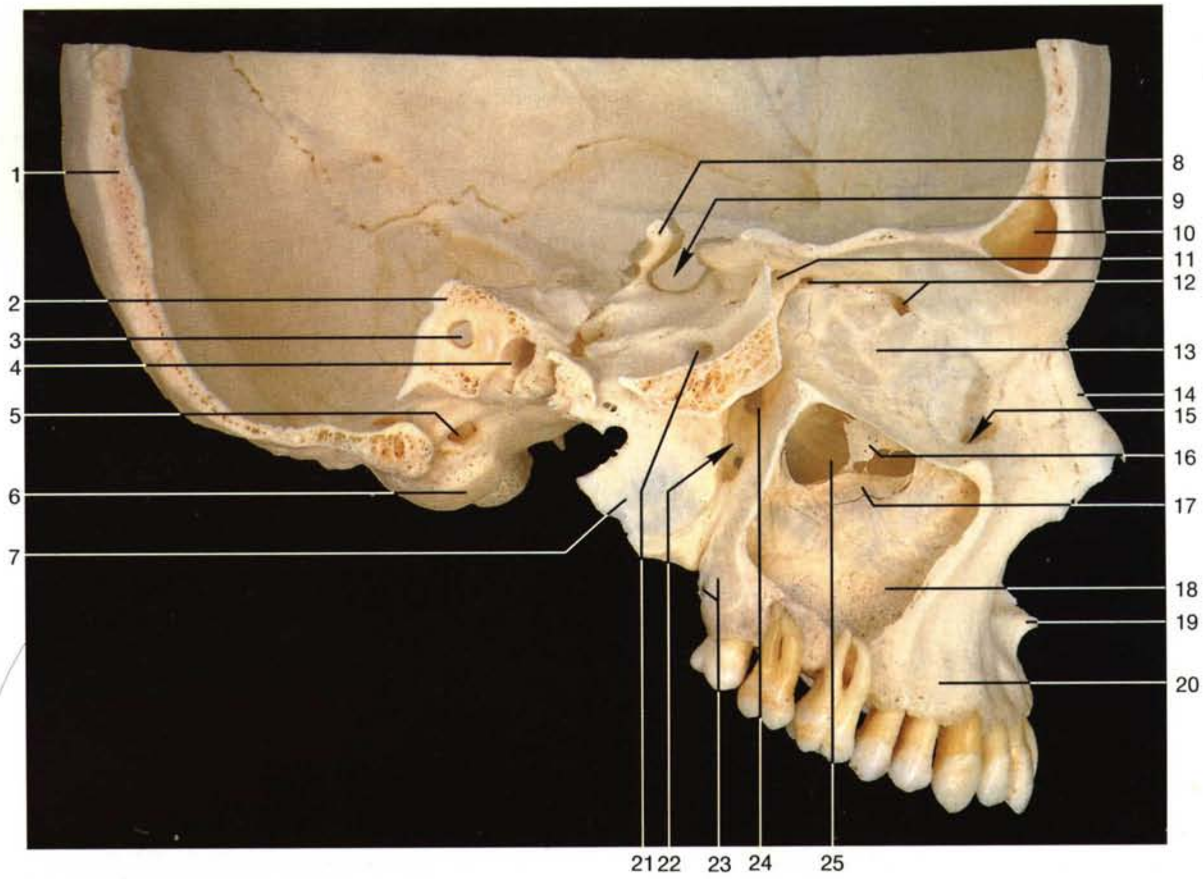

Paramedian section through the skull, right side (lateral aspect). Frontal and maxillary sinus are opened.

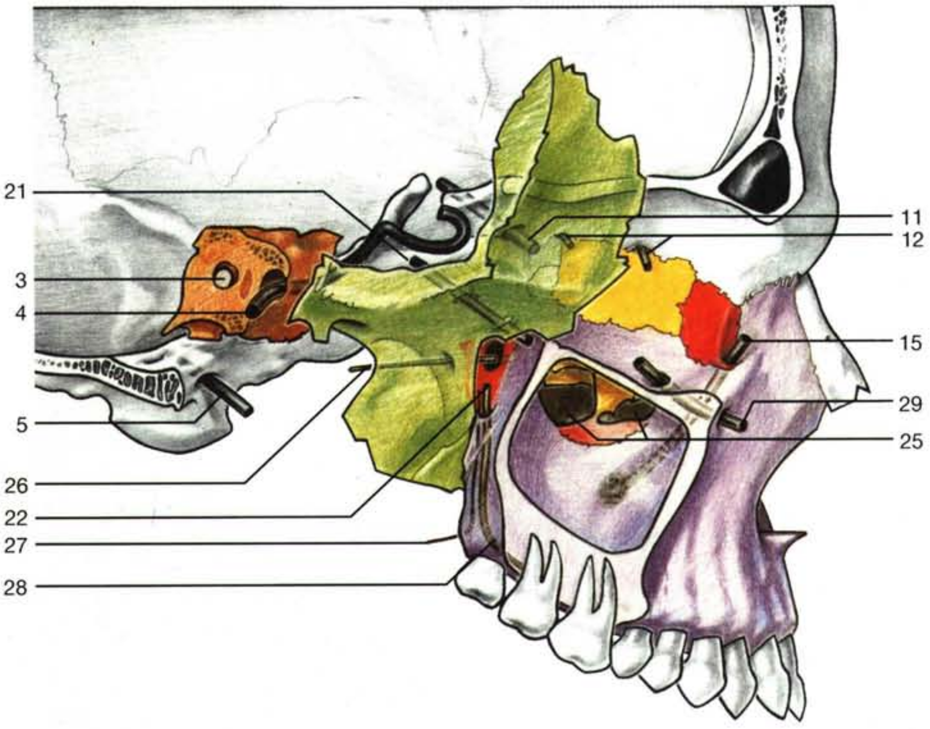

Illustration of canals and foramina connected with the right orbit and pterygopalatine fossa (compare the above figure). The greater wing of sphenoid bone (green) is shown as being transparent. Brown = temporal bone; yellow = ethmoid bone; red = lacrimal bone; light red = inferior nasal concha; violet = maxilla; orange = palatine bone.

1 Occipital bone
2 Temporal bone (petrous part)
3 **Internal acoustic meatus**
4 **Carotid canal**
5 **Hypoglossal canal**
6 Occipital condyle
7 Lateral plate of pterygoid process
8 Dorsum of sella turcica
9 Sella turcica
10 Frontal sinus
11 **Optic canal**
12 **Posterior** and **anterior ethmoidal foramen**
13 Orbital plate of ethmoidal bone
14 Nasal bone
15 **Nasolacrimal canal**
16 Uncinate process
17 Inferior nasal concha (maxillary process)
18 Maxillary sinus
19 Anterior nasal spine
20 Alveolar process of maxilla
21 **Foramen rotundum**
22 **Pterygopalatine fossa**
23 Tuberosity of maxilla with **alveolar foramina**
24 **Sphenopalatine foramen**
25 Maxillary hiatus
26 **Pterygoid** or Vidian **canal**
27 **Lesser palatine canal**
28 **Greater palatine canal**
29 **Infraorbital canal**

1 **Occipital bone**
2 **Temporal bone**
3 **Frontal bone**
4 Nasal spine of frontal bone
5 **Zygomatic bone**
6 **Maxilla**
7 Frontal process of maxilla
8 **Ethmoid bone**
9 Orbital plate of ethmoid bone
10 Perpendicular plate of ethmoid bone
11 Site of **lacrimal bone**
12 Lacrimal groove of lacrimal bone
13 Posterior lacrimal crest
14 Fossa for lacrimal sac
15 Lacrimal hamulus
16 Nasolacrimal canal
17 Site of **nasal bone**
18 Nasal foramina of nasal bone
19 Anterior nasal spine of maxilla
20 **Vomer**
21 Greater wing of sphenoid bone
22 Anterior and posterior ethmoidal foramina
23 Optic canal
24 Superior orbital fissure
25 Inferior orbital fissure
26 Infraorbital groove
27 Infraorbital foramen

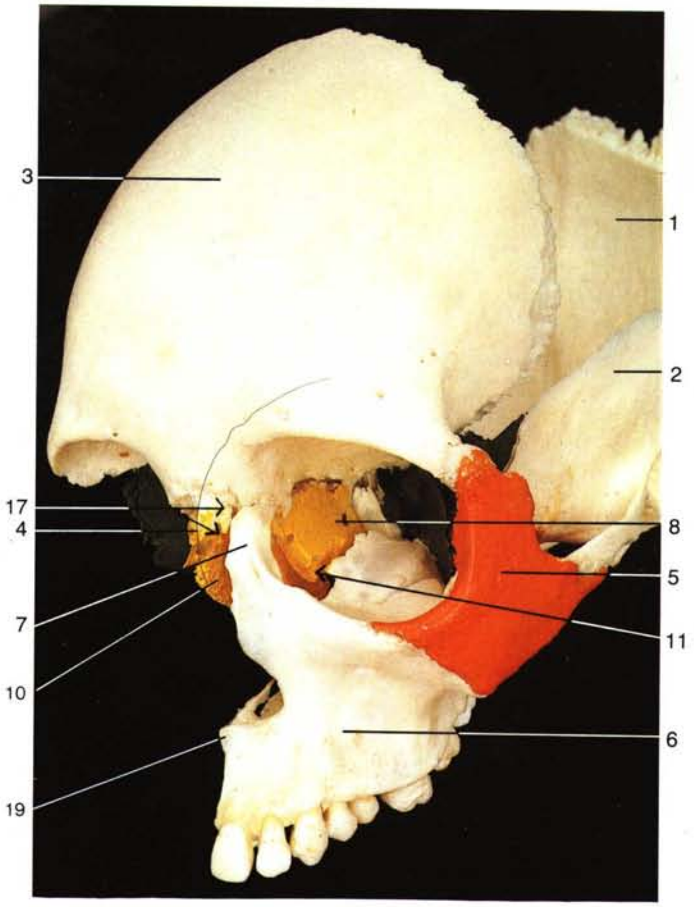

Anterior part of a disarticulated skull. Orange = zygomatic bone; yellow = ethmoid bone; green = sphenoidal bone. The arrows indicate the locations of the lacrimal bone (11) and the nasal bone (17).

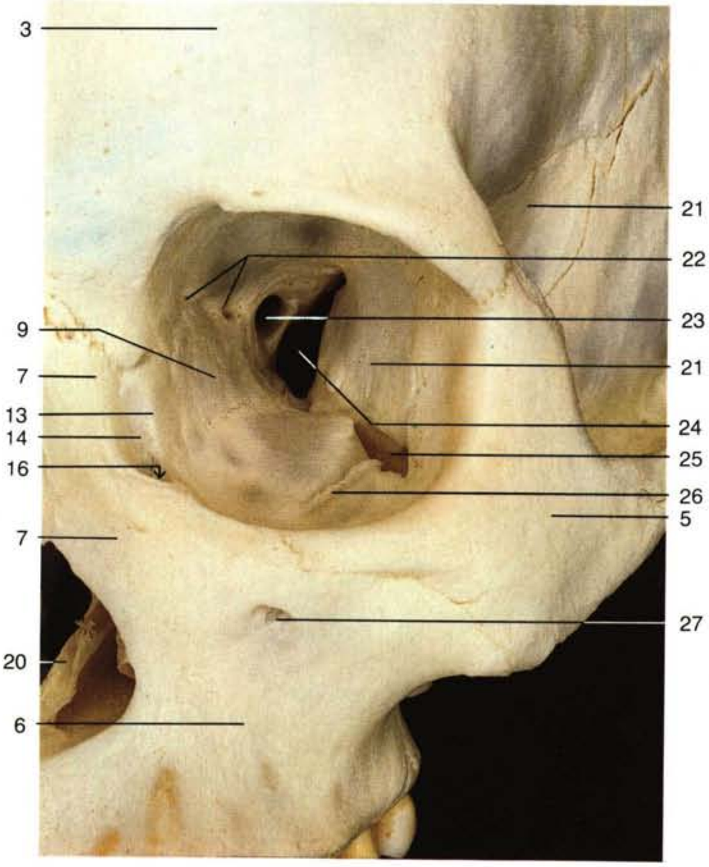

Left orbit (anterior aspect).

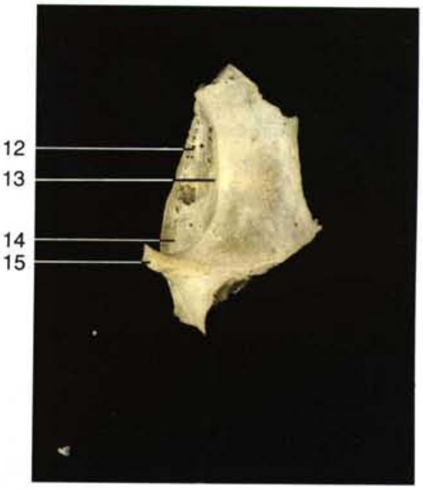

Left lacrimal bone (anterior aspect).

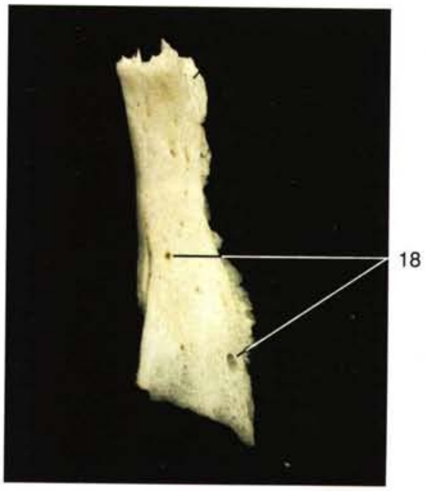

Left nasal bone (anterior aspect).

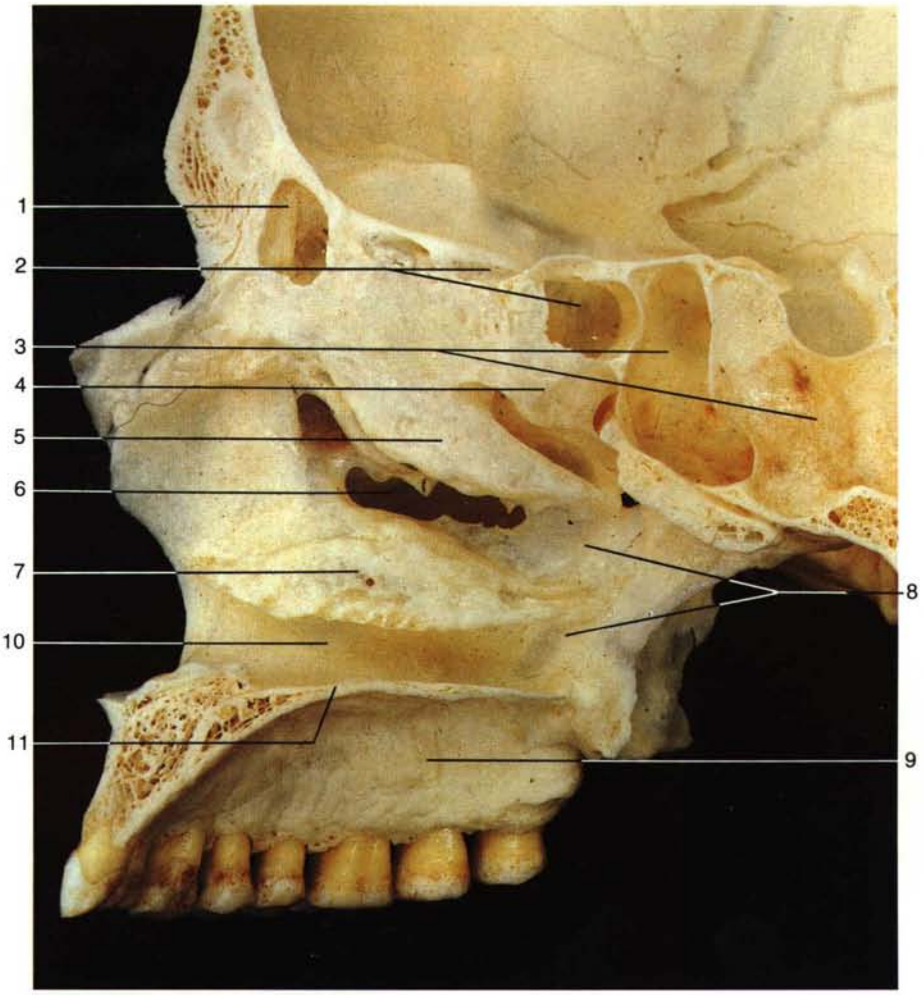

Lateral wall of the nasal cavity. Median section through the skull.

1 Frontal sinus
2 Ethmoidal air cells
3 Sphenoid sinus
4 Superior nasal concha
5 Middle nasal concha
6 Maxillary hiatus
7 Inferior nasal concha
8 Palatine bone
9 Maxilla
10 Inferior meatus
11 Palatine process of the maxilla

▷
To page 49:
Blue = Occipital bone
Light green = Parietal bone
Light brown = Frontal bone
Dark brown = Temporal bone
Red = Sphenoid bone
Dark green = Ethmoid bone
Light blue = Nasal bone
Pink = Inferior concha
Orange = Vomer
Violet = Maxilla
White = Palatine bone
White = Mandible

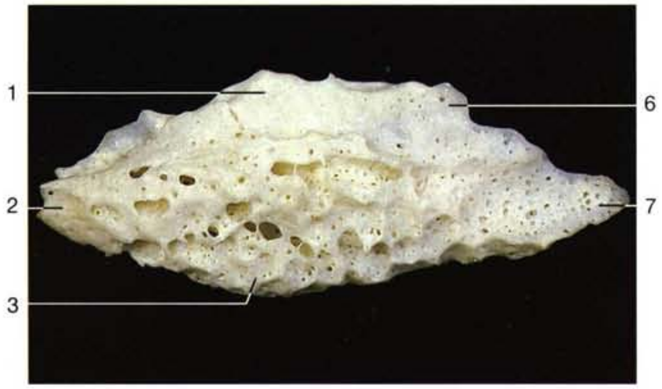

Right inferior nasal concha (medial aspect). Anterior part to the left.

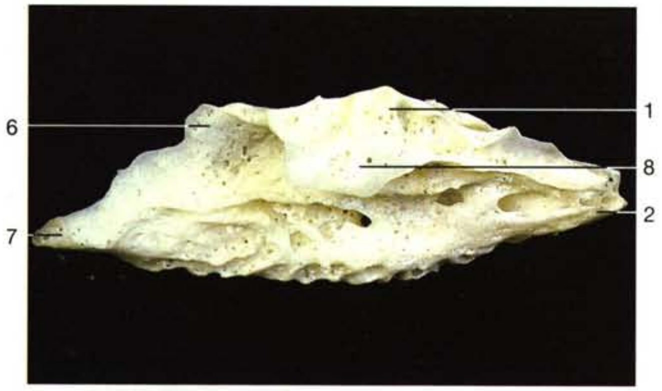

Right inferior nasal concha (lateral aspect). Anterior part to the right.

Inferior Concha and Vomer

1 Ethmoidal process
2 Anterior part of concha
3 Inferior border
4 Ala of vomer
5 Posterior border of nasal septum
6 Lacrimal process
7 Posterior part of concha
8 Maxillary process

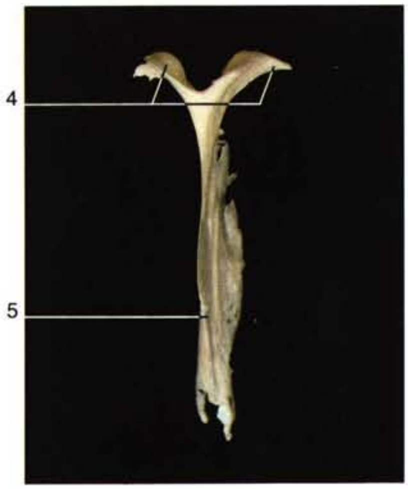

Vomer (posterior aspect).

1 Crista galli
2 Cribriform plate of ethmoid bone
3 Perpendicular plate of ethmoid bone
4 Vomer
5 Ala of the vomer
6 Palatine bone (perpendicular process)
7 Palatine bone (horizontal plate)
8 Mandible
9 Nasal bone
10 Sphenoidal sinus
11 Hypophysial fossa (sella turcica)
12 Grooves for the middle meningeal artery

Cartilages of the nose

13 Lateral nasal cartilages
14 Greater alar cartilage
15 Lesser alar cartilages
16 Septal cartilage

17 Location of nasal bone

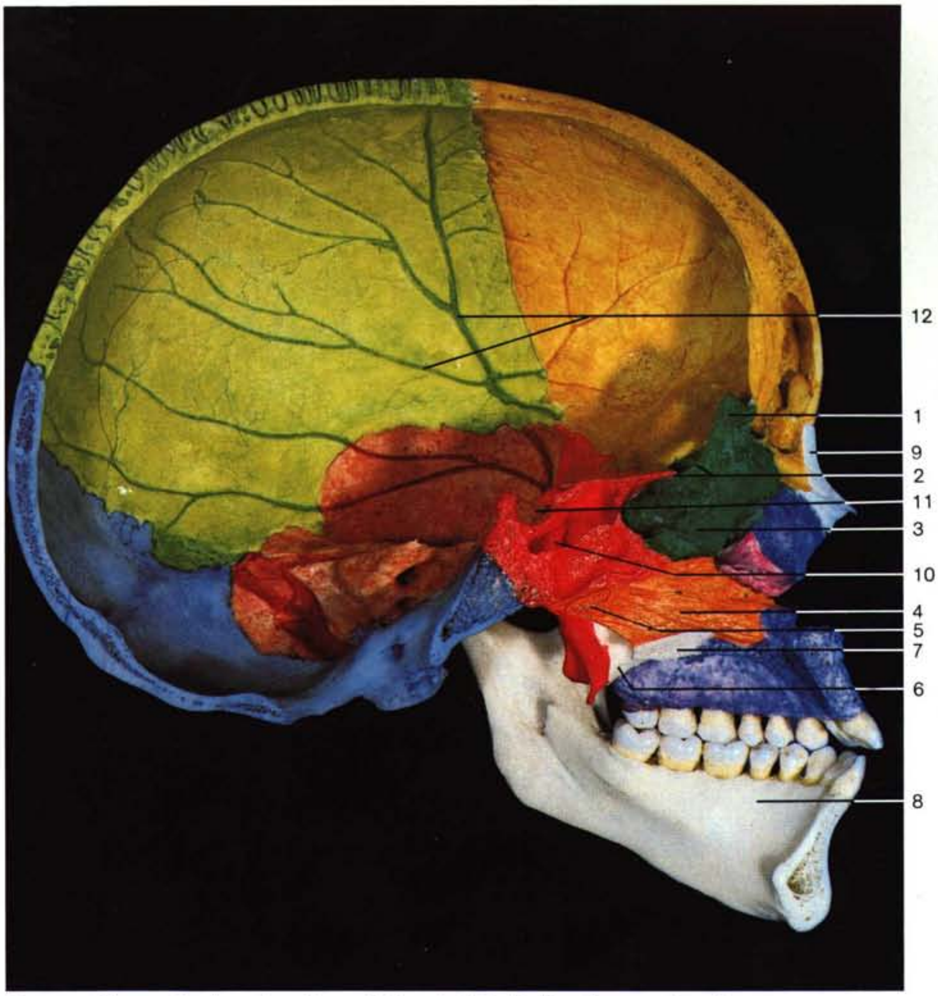

Paramedian sagittal section through the skull including the nasal septum.

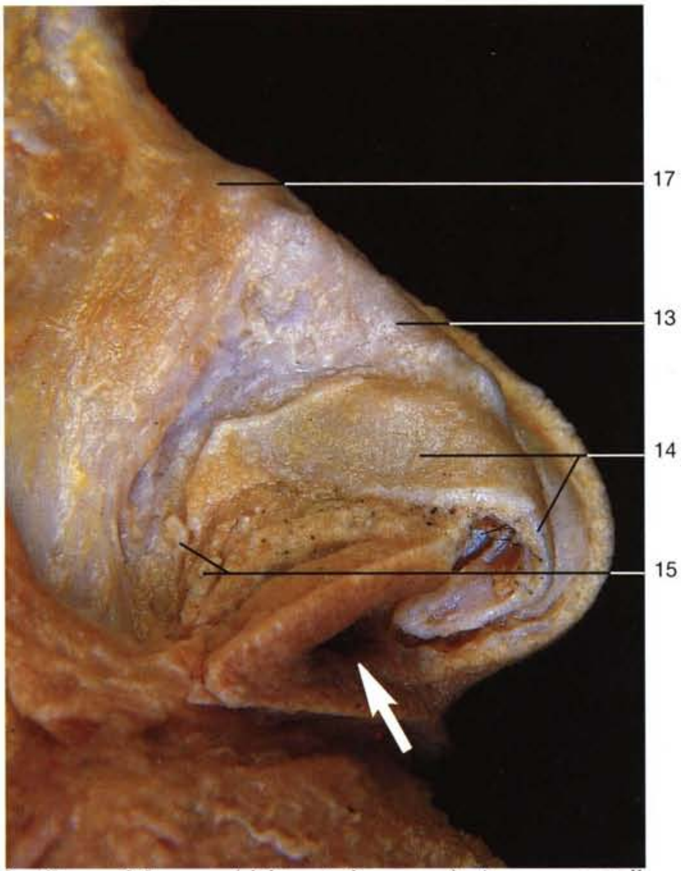

Cartilages of the nose (right anterior aspect). Arrow = nostril, framed by nasal wing.

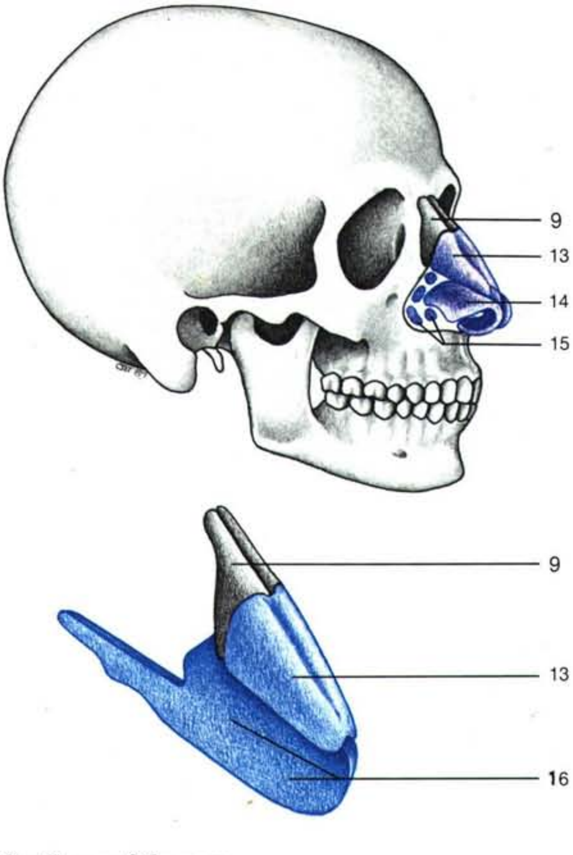

Cartilages of the nose.
Schematic diagram of the external nose.

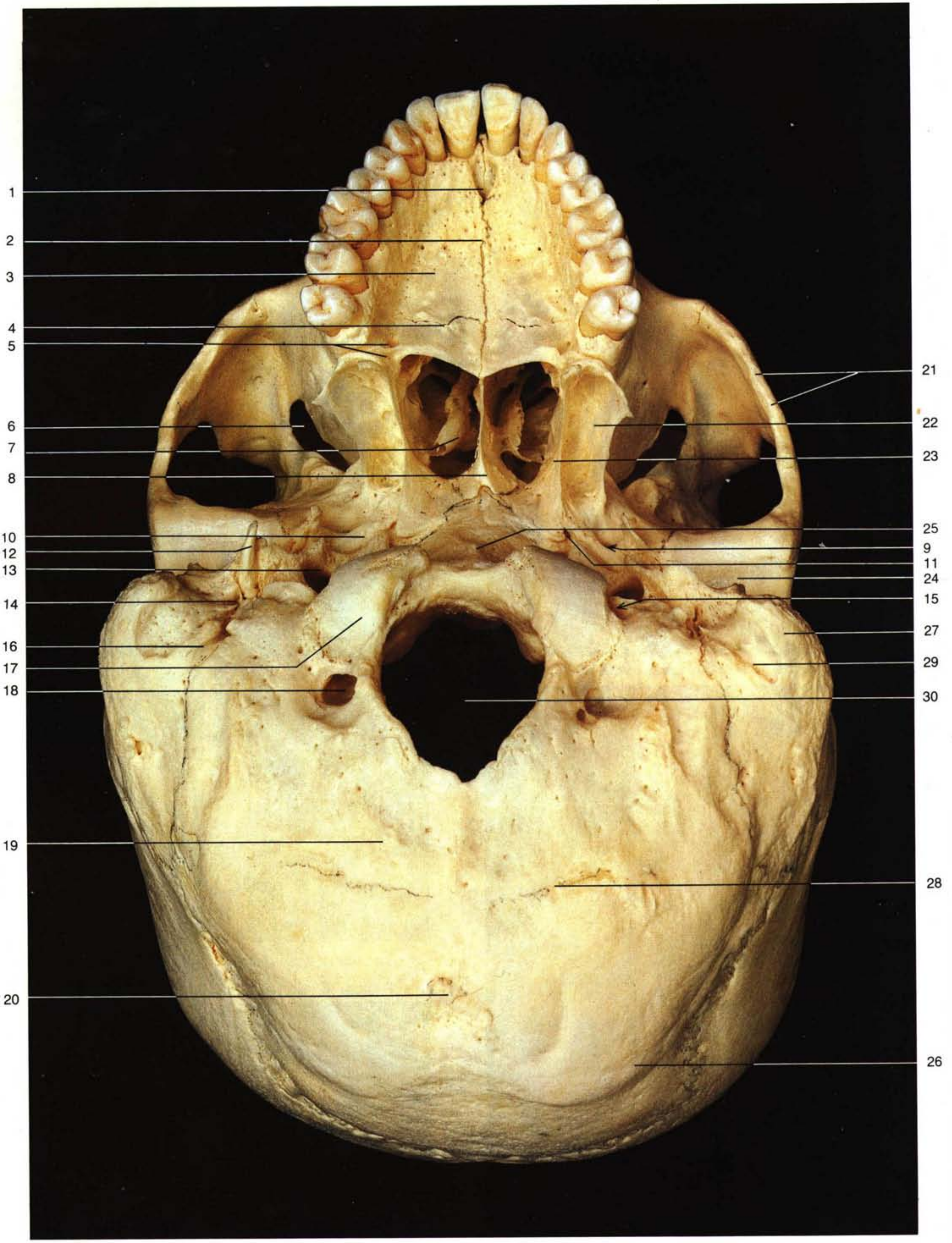
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Base of the skull (inferior aspect).

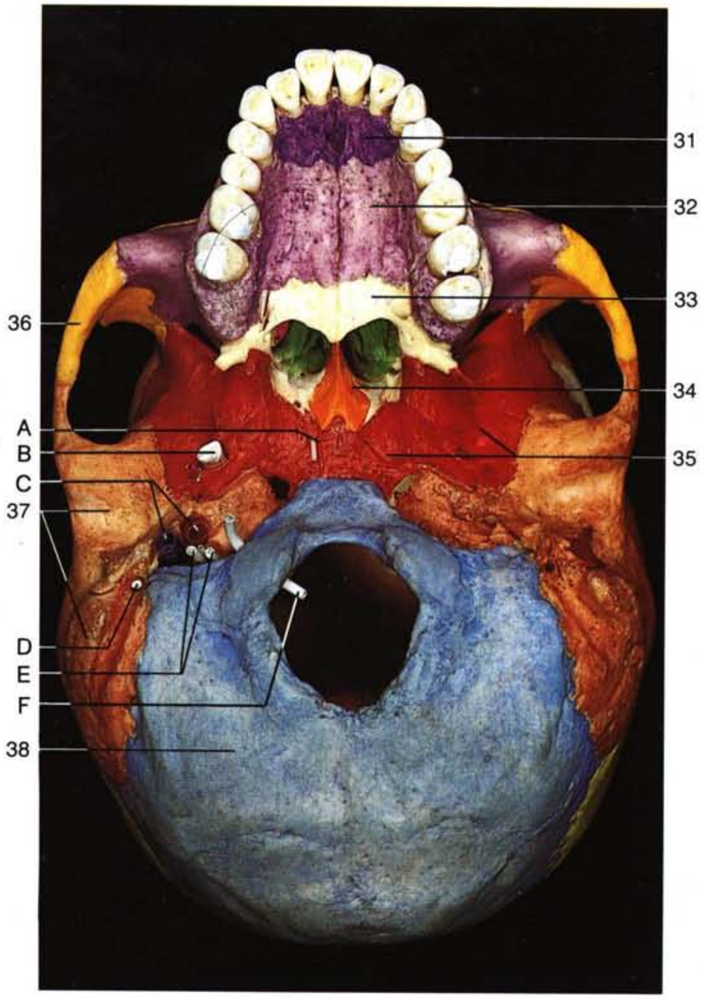

Base of the skull (from below). The individual bones are indicated by different colours.

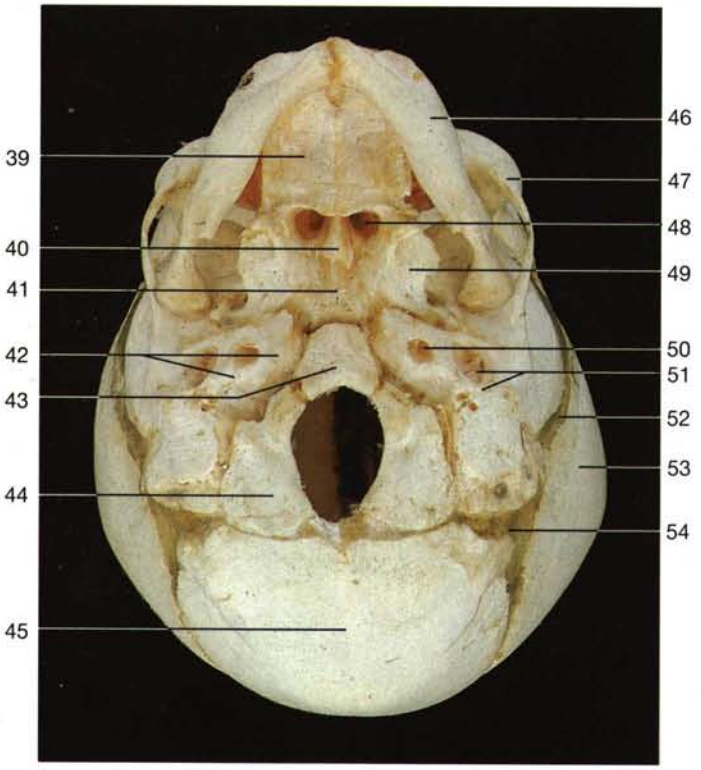

Skull of the newborn (inferior aspect).

A **Pterygoid canal**
B **Foramen ovale**
C Internal carotid artery within **carotid canal** and internal jugular vein within the venous part of jugular foramen
D **Stylomastoid foramen** (facial nerve)
E **Jugular foramen** (glossopharyngeal, vagus and accessory nerves)
F **Hypoglossal canal** (hypoglossal nerve)

1 Incisive canal
2 Median palatine suture
3 Palatine process of maxilla
4 Palatomaxillary suture
5 Greater and lesser palatine foramina
6 Inferior orbital fissure
7 Middle concha (process of ethmoid bone)
8 Vomer
9 Foramen ovale
10 Groove for auditory tube
11 Pterygoid canal
12 Styloid process
13 Carotid canal
14 Stylomastoid foramen
15 Jugular foramen
16 Groove for occipital artery
17 Occipital condyle
18 Condylar canal
19 Nuchal plane
20 External occipital protuberance
21 Zygomatic arch
22 Lateral pterygoid plate
23 Medial pterygoid plate
24 Mandibular fossa
25 Pharyngeal tubercle
26 Superior nuchal line
27 Mastoid process
28 Inferior nuchal line
29 Mastoid notch
30 Foramen magnum
31 **Incisive bone** or **premaxilla** (dark violet)
32 **Maxilla** (violet)
33 **Palatine bone** (white)
34 **Vomer** (orange)
35 **Sphenoid bone** (red)
36 **Zygomatic bone** (yellow)
37 **Temporal bone** (brown)
38 **Occipital bone** (blue)
39 Palatine process of maxilla
40 Vomer
41 Sphenoid bone
42 Petrous part of temporal bone
43 Basilar part }
44 Lateral part } of occipital bone
45 Squamous part }
46 Mandible
47 Zygomatic arch
48 Choana
49 Pterygoid process of sphenoid bone
50 Carotid canal
51 External acoustic meatus (tympanic annulus)
52 Sphenoidal fontanelle
53 Parietal bone
54 Mastoid fontanelle

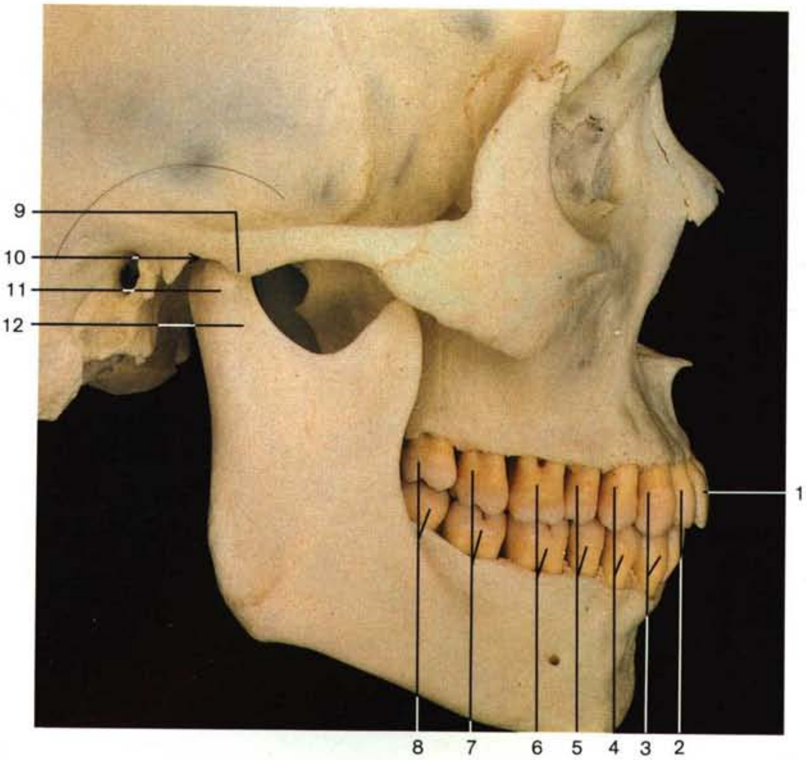

Normal position of teeth. Dentition in centric occlusion (lateral view).

1 Central incisor
2 Lateral incisor
3 Canines
4 First premolars or bicuspids
5 Second premolars or bicuspids
6 First molars
7 Second molars
8 Third molars
9 Articular tubercle
10 Mandibular fossa
11 Head of mandible
12 Condylar process

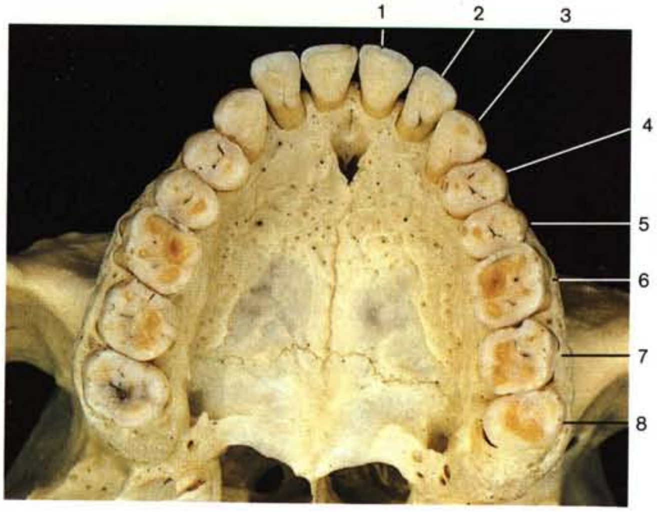

Upper teeth of the adult (inferior aspect).

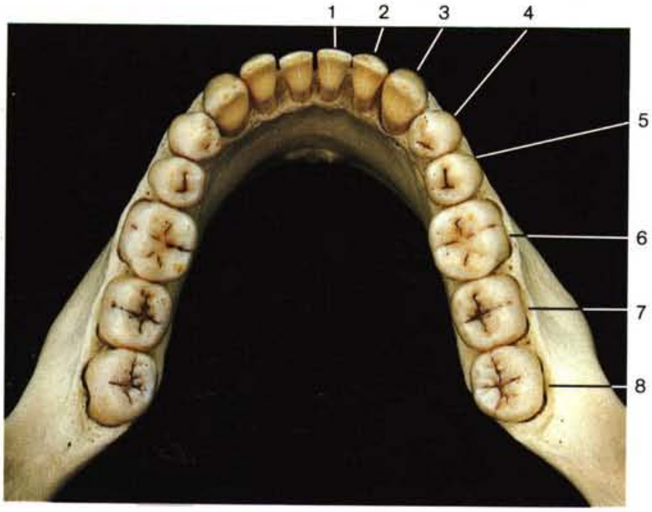

Lower teeth of the adult (superior aspect).

Table of dentition. Eruption of deciduous and permanent teeth (after C. Röse according to A. Kröncke).

Primary dentition (Deciduous teeth)	Maxilla months post partum	Mandible months
1. Central incisor	10.3	8.6
2. Lateral incisor	12.2	14.4
3. Cuspid incisor	19.5	20.1
4. First molar	15.5	16.5
5. Second molar	24.8	24.5

Secondary dentition (Permanent teeth)	years and months ♂	♀	years and months ♂	♀
1. Central incisor	7/8	7/5	6/10	6/7
2. Lateral incisor	8/11	8/6	7/11	7/7
3. Cuspid incisor	12/2	11/7	11/12	10/3
4. First premolar	10/5	10/1	11/3	10/8
5. Second premolar	11/4	11/1	12/0	11/7
6. First molar	6/7	6/6	6/5	6/3
7. Second molar	12/9	12/5	12/3	11/9

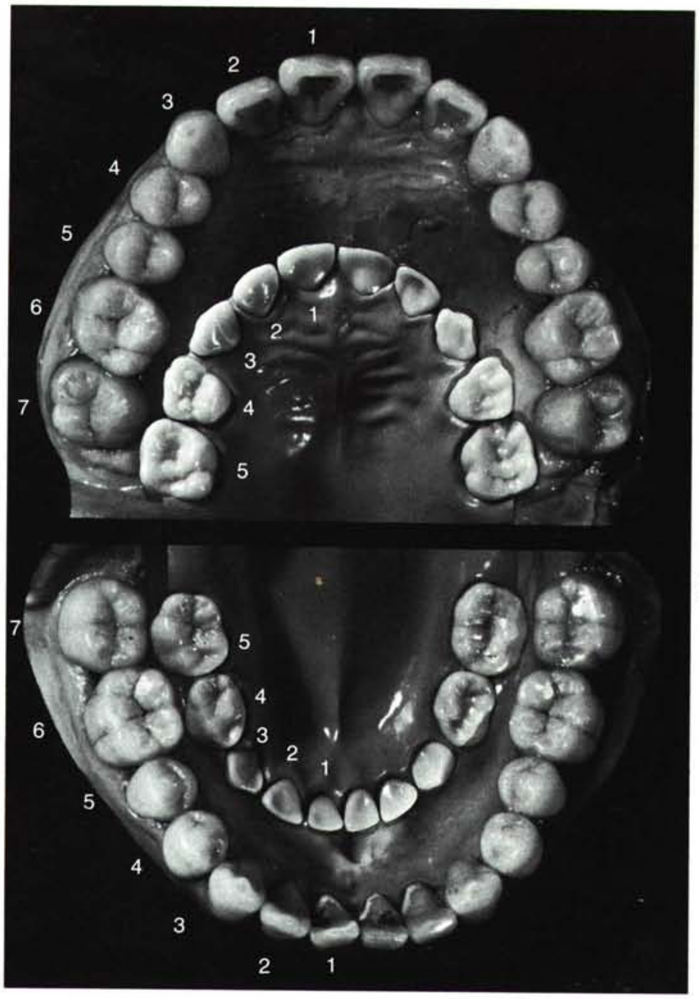

Comparison of the deciduous and permanent teeth. Notice that the breadth of the alveolar arch of the child's mandible and maxilla holding the deciduous teeth is nearly the same as the comparable portion in the jaws of the adult. Note the unerupted third molars.

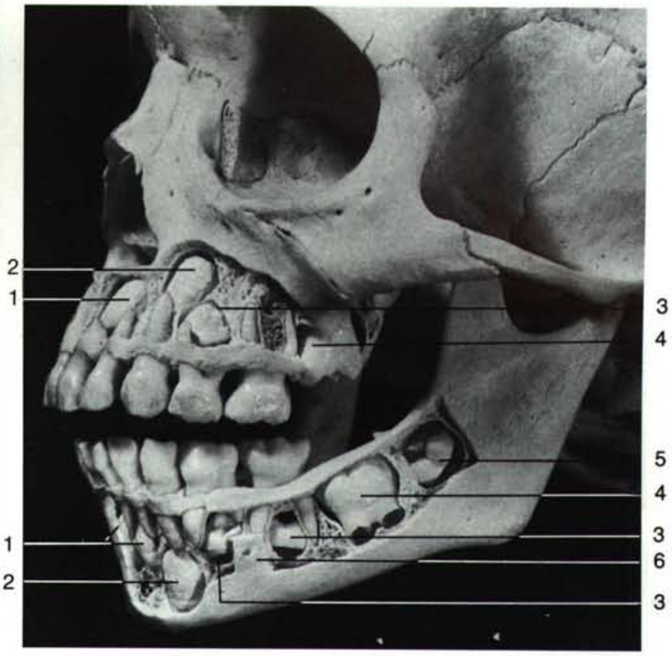

Deciduous teeth in child's skull. The developing crowns of the permanent teeth are displayed in their sockets in the maxilla and mandible.

△

1 Permanent incisors
2 Permanent cuspid (canine)
3 Premolars
4 First permanent molar
5 Second permanent molar
6 Mental foramen

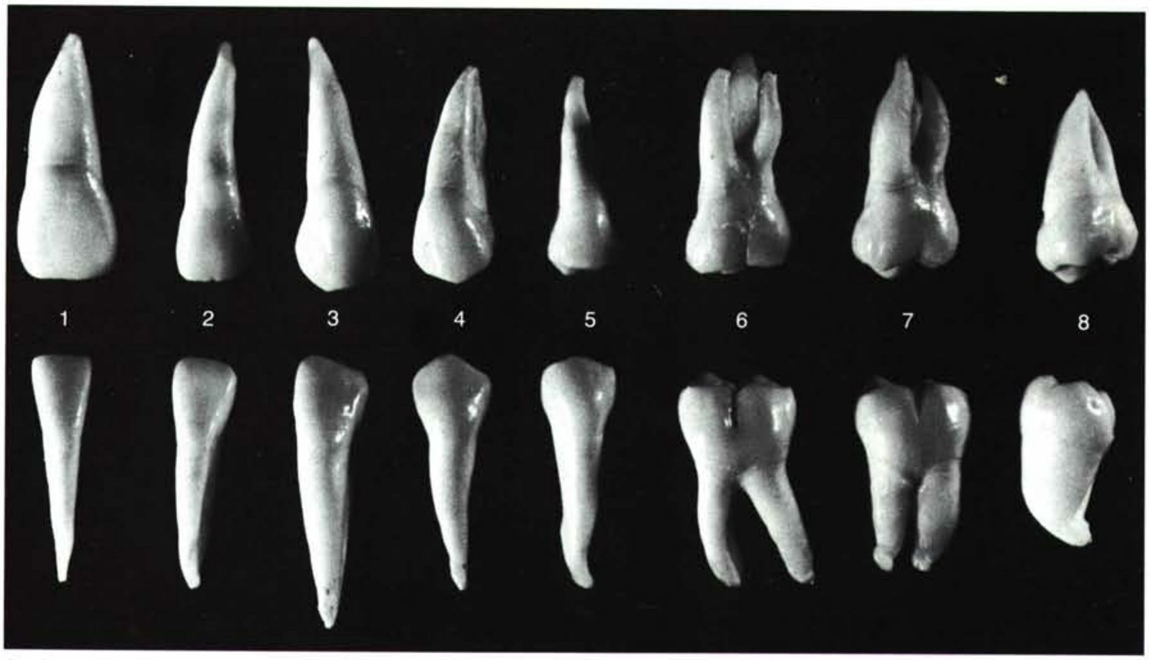

Isolated teeth of the alveolar part of the maxilla (top row) and the mandible (lower row), labial surface of the teeth.

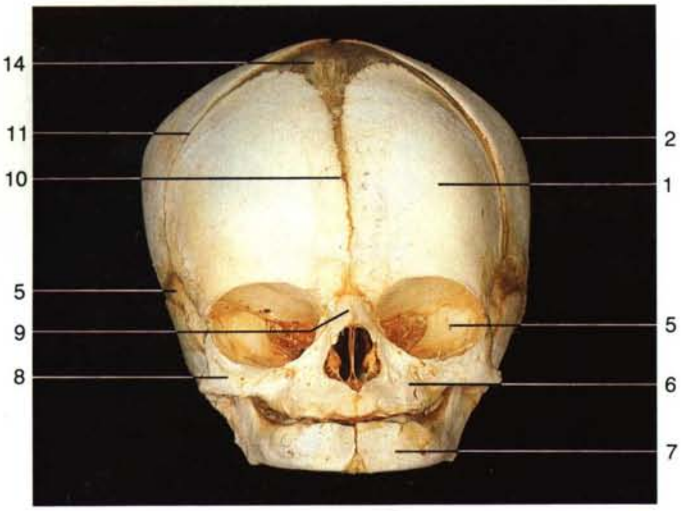

Skull of the newborn (anterior aspect).

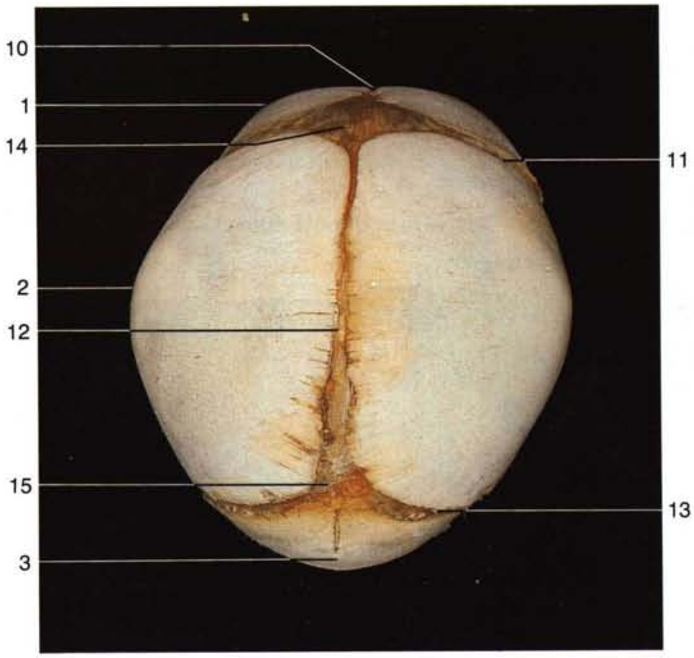

Skull of the newborn (superior aspect). Calvaria.

Cranial skeleton

1 Frontal tuber or eminence
2 Parietal tuber or eminence
3 Occipital tuber or eminence
4 Squamous part of temporal bone
5 Greater wing of sphenoid bone

Facial skeleton

6 Maxilla
7 Mandible
8 Zygomatic bone
9 Nasal bone

Sutures and fontanelles

10 Frontal suture
11 Coronal suture
12 Sagittal suture
13 Lambdoid suture
14 Anterior fontanelle
15 Posterior fontanelle
16 Sphenoidal fontanelle
17 Mastoid fontanelle

Base of the skull

18 Frontal bone
19 Ethmoid bone
20 Sphenoid bone
21 Hypophysial fossa (sella turcica)
22 Dorsum sellae
23 Temporal bone
24 Mastoid fontanelle
25 Occipital bone

In the newborn the facial skeleton, in contrast to the cranial skeleton, appears relatively small. There are no teeth presenting. The bones of the cranium are separated by wide fontanelles.

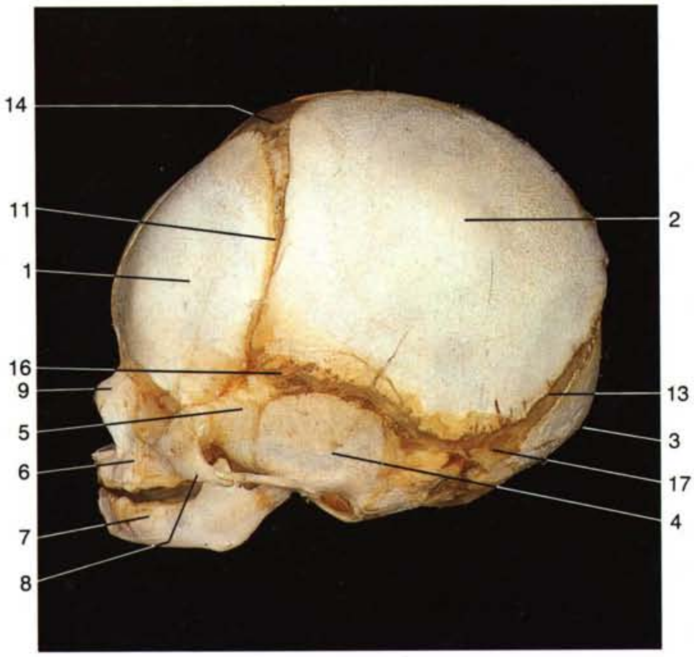

Skull of the newborn (lateral aspect).

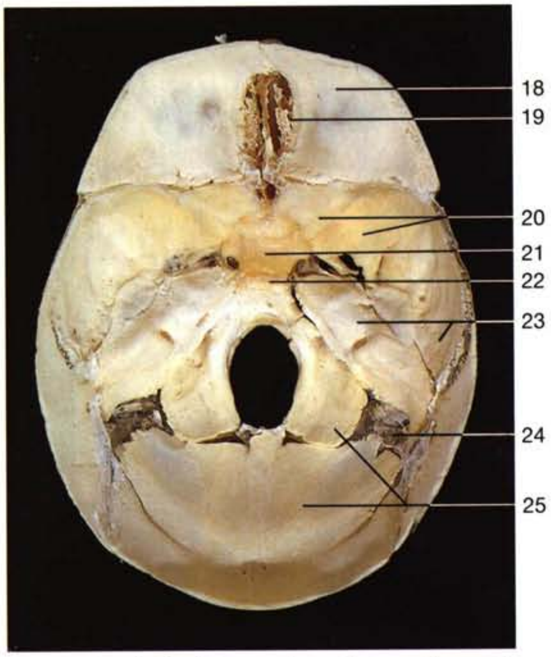

Base of the skull of the newborn (internal aspect).

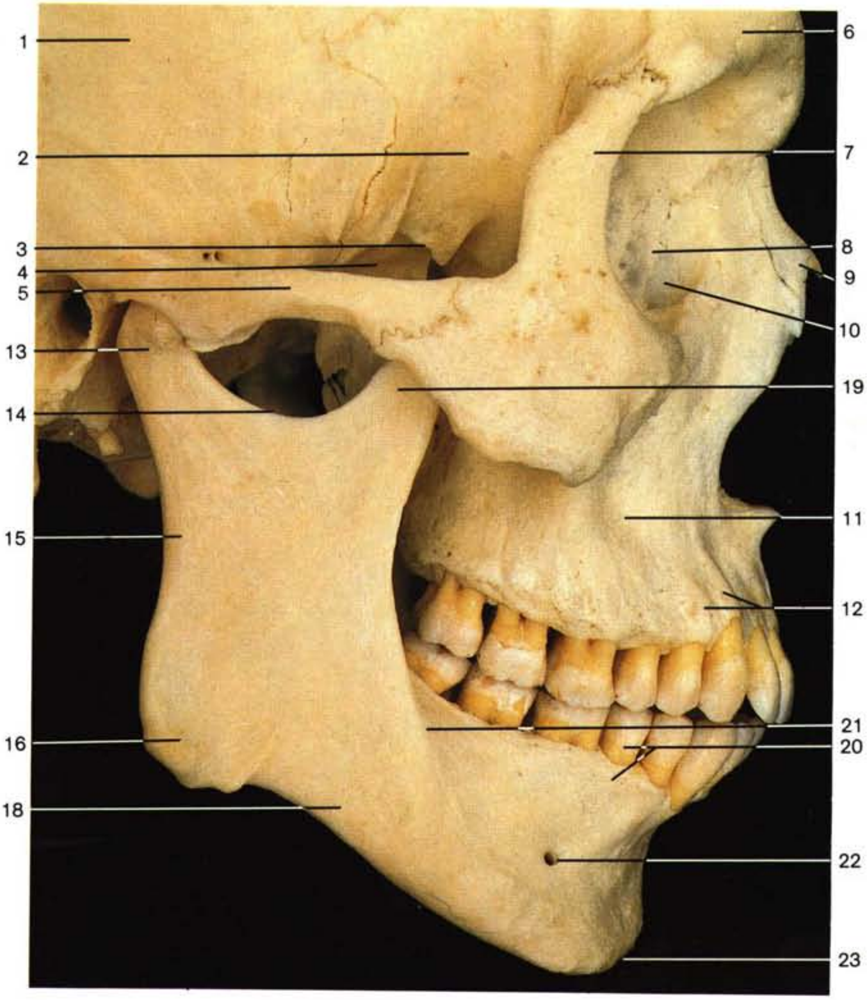

Lateral aspect of the facial bones. Mandible and teeth in the position of occlusion. Upper and lower jaw occluded.

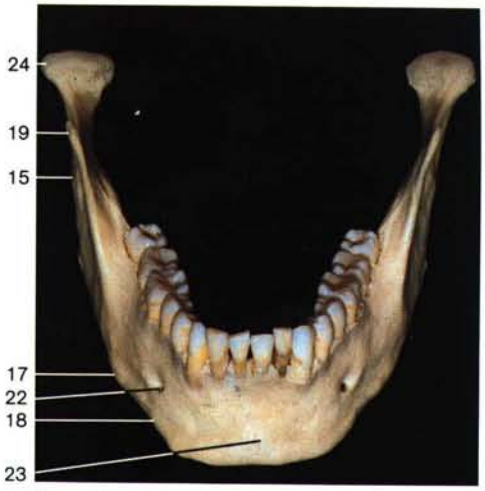

Mandible of the adult (anterior aspect).

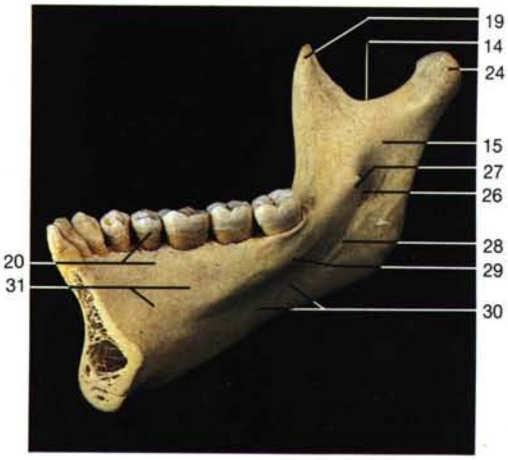

Right half of mandible (medial aspect).

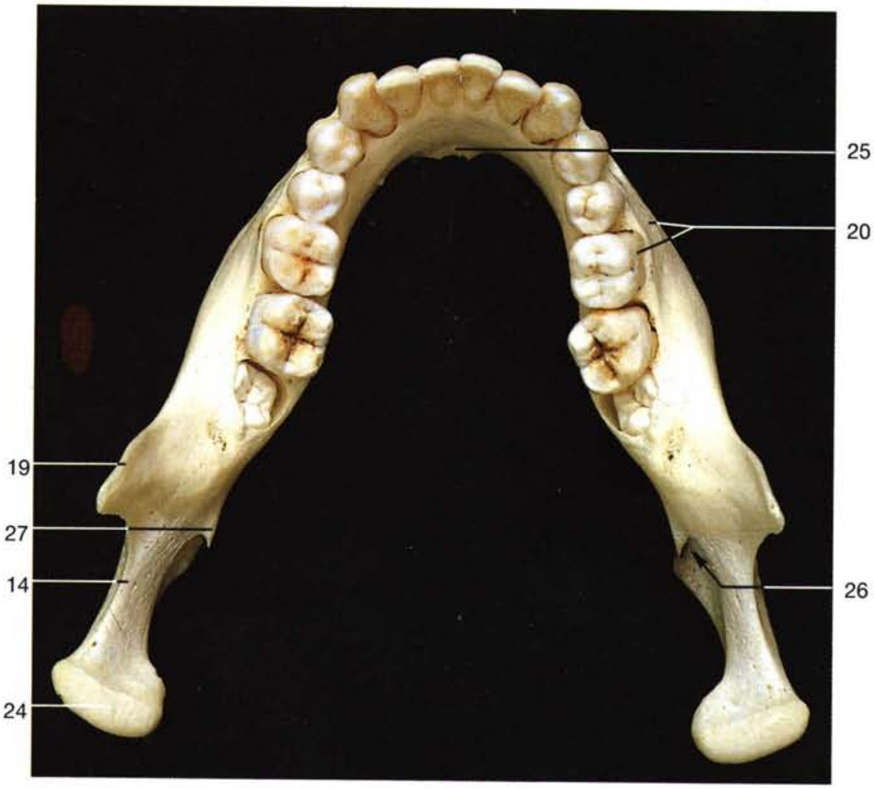

Mandible of the adult (superior aspect).

1 **Temporal bone**
2 Temporal fossa (greater wing of sphenoid bone)
3 Infratemporal crest
4 Infratemporal fossa
5 Zygomatic arch
6 **Frontal bone**
7 **Zygomatic bone** (frontal process)
8 **Lacrimal bone**
9 **Nasal bone**
10 Lacrimal groove
11 **Maxilla** (canine fossa)
12 Alveolar process of maxilla

Mandible

13 Condylar process
14 Mandibular notch
15 Ramus of the mandible
16 Masseteric tuberosity
17 Angle of the mandible
18 Body of the mandible
19 Coronoid process
20 Alveolar process including teeth
21 Oblique line
22 Mental foramen
23 Mental protuberance
24 Head of the mandible
25 Genial tubercle or mental spine
26 Mandibular foramen (entrance to mandibular canal)
27 Lingula
28 Mylohyoid sulcus
29 Mylohyoid line
30 Submandibular fossa
31 Sublingual fossa

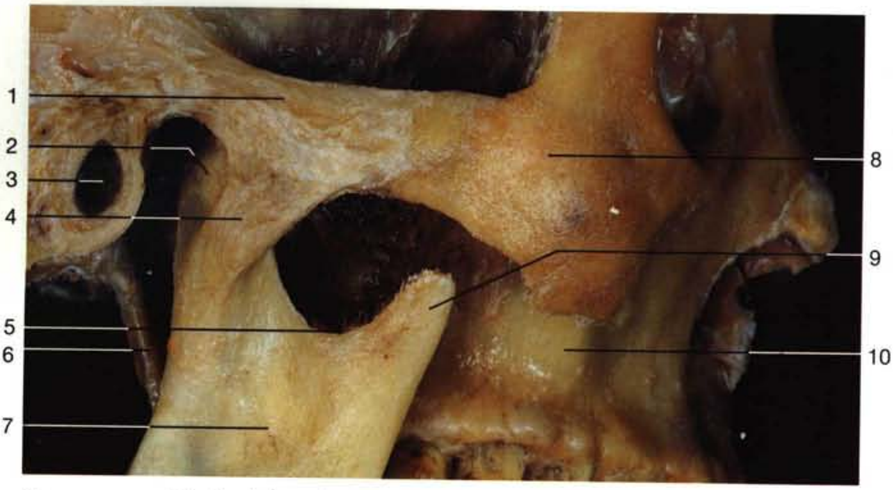

Temporomandibular joint with ligaments.

1 Zygomatic arch
2 Articular capsule
3 External acoustic meatus
4 **Lateral ligament**
5 Mandibular notch
6 **Stylomandibular ligament**
7 Ramus of the mandible
8 Zygomatic bone
9 Coronoid process
10 Maxilla
11 Articular cartilage of condylar process
12 Styloid process
13 Mandibular fossa
14 **Articular disc**
15 Articular tubercle
16 Lateral pterygoid muscle
17 Condylar process of mandible

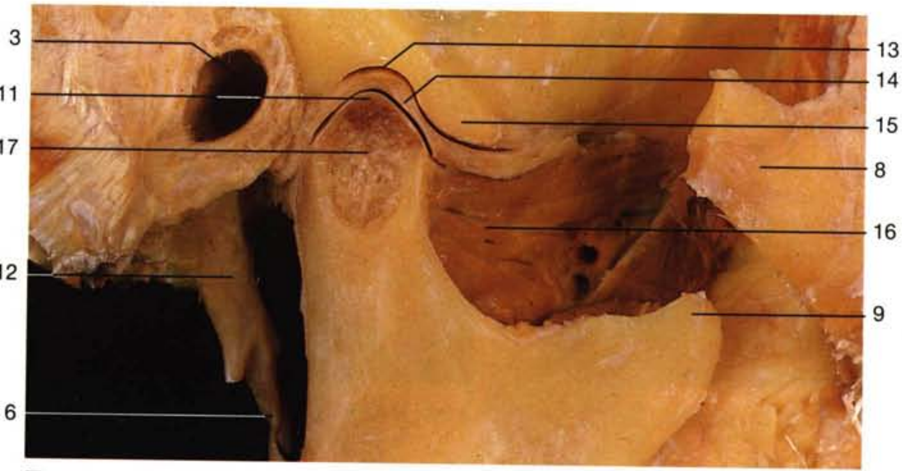

Temporomandibular joint, sagittal section.

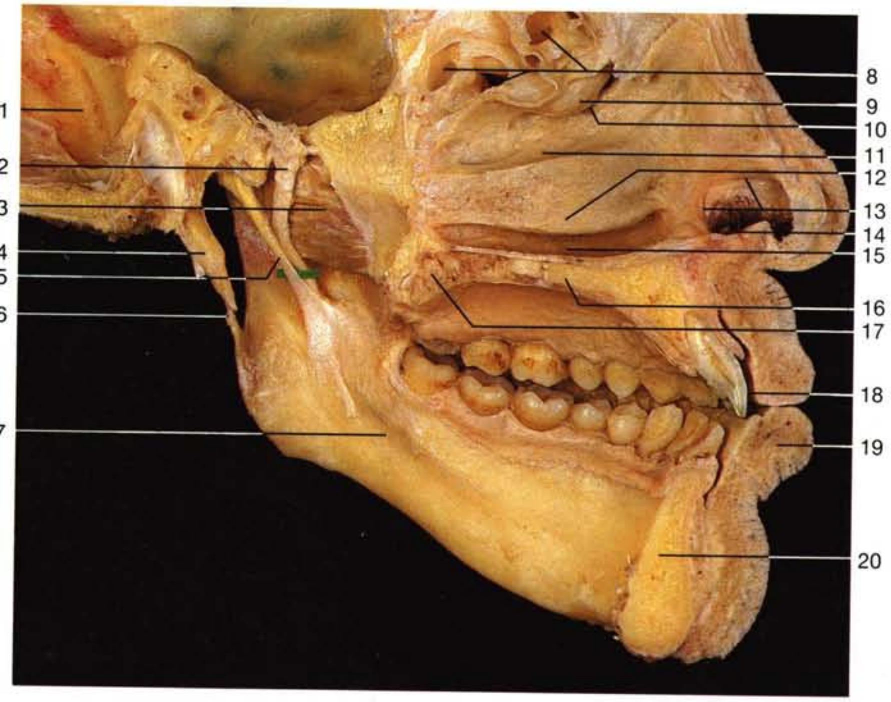

Ligaments of temporomandibular joint. Left half of the head (medial aspect).

1 Groove for sigmoid sinus
2 Mandibular nerve
3 Lateral pterygoid muscle
4 Styloid process
5 **Sphenomandibular ligament**
6 **Stylomandibular ligament**
7 Mylohyoid groove
8 **Ethmoidal air cells**
9 Ethmoidal bulla
10 **Hiatus semilunaris**
11 Middle meatus
12 **Inferior nasal concha**
13 Limen nasi
14 Vestibule with hairs
15 Inferior meatus
16 Hard palate
17 Soft palate
18 Vestibule of oral cavity
19 Lower lip
20 Mandible

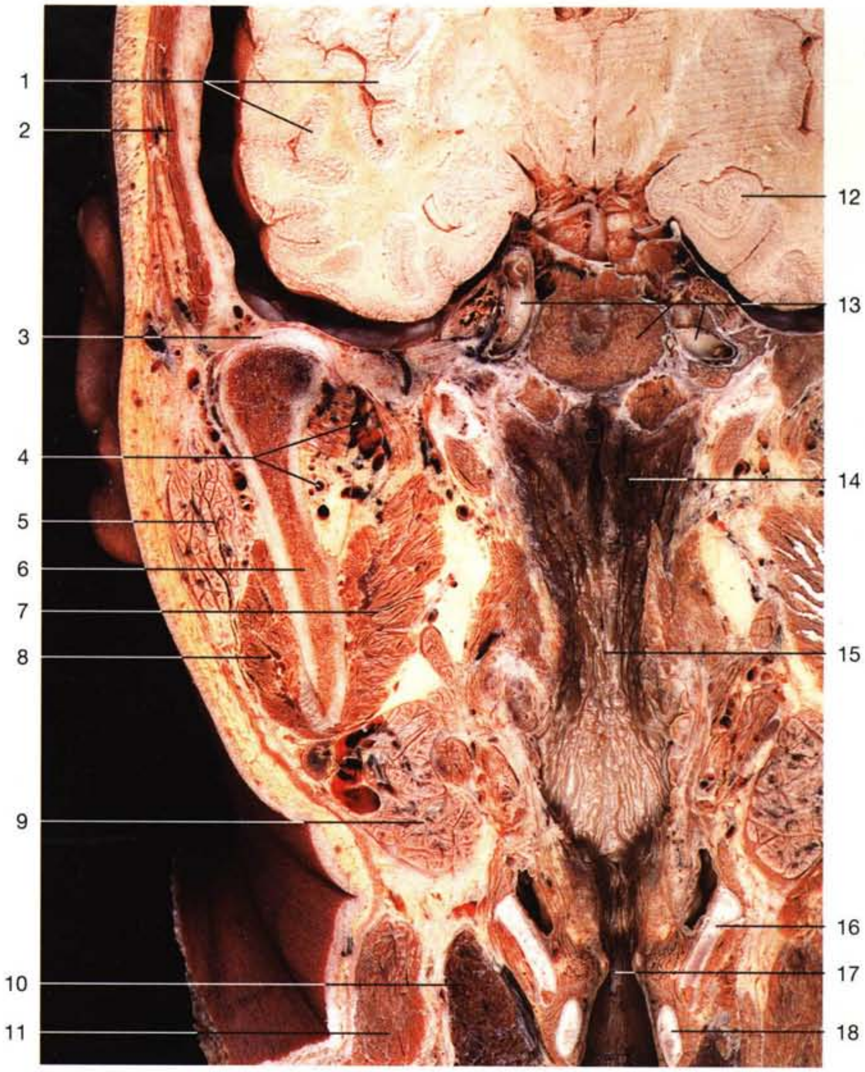

Coronal section through the head at the level of the temporomandibular joint (right side, anterior aspect).

1 Insular lobe and temporal lobe
2 Temporalis muscle
3 **Articular disc of temporomandibular joint**
4 Maxillary artery and pterygoid venous plexus
5 Parotid gland
6 **Mandible**
7 **Medial pterygoid muscle**
8 **Masseter muscle**
9 Submandibular gland
10 Thyroid gland
11 Sternocleidomastoid muscle
12 Hippocampus
13 Internal carotid artery and sphenoid bone
14 Pharyngeal tonsil
15 Pharynx
16 Thyroid cartilage
17 Rima glottidis
18 Cricoid cartilage
19 **Hard palate** and palatine glands
20 **Oral cavity**
21 Upper molar
22 **Oral vestibule**
23 Lower molar
24 Platysma muscle
25 Maxillary sinus
26 Superior longitudinal muscle of tongue
27 **Transverse muscle of tongue**
28 Buccinator muscle
29 Inferior longitudinal muscle of tongue
30 Sublingual gland
31 **Genioglossus muscle**
32 Mastoid process
33 Styloid process
34 **Stylomandibular ligament**
35 Articular capsule
36 **Lateral ligament**
37 Zygomatic arch
38 **Sphenomandibular ligament**
39 Mandibular foramen

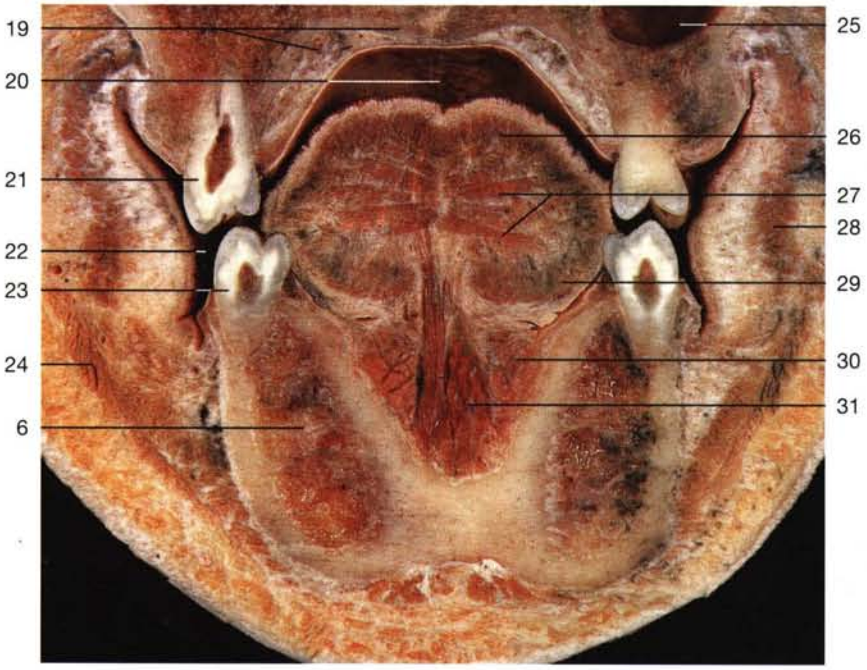

Coronal section through the oral cavity

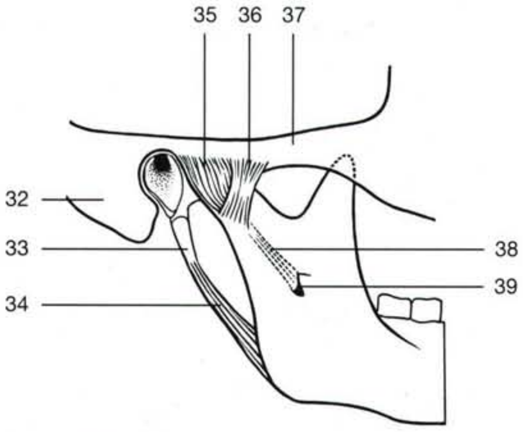

Ligaments related to the **temporomandibular joint**

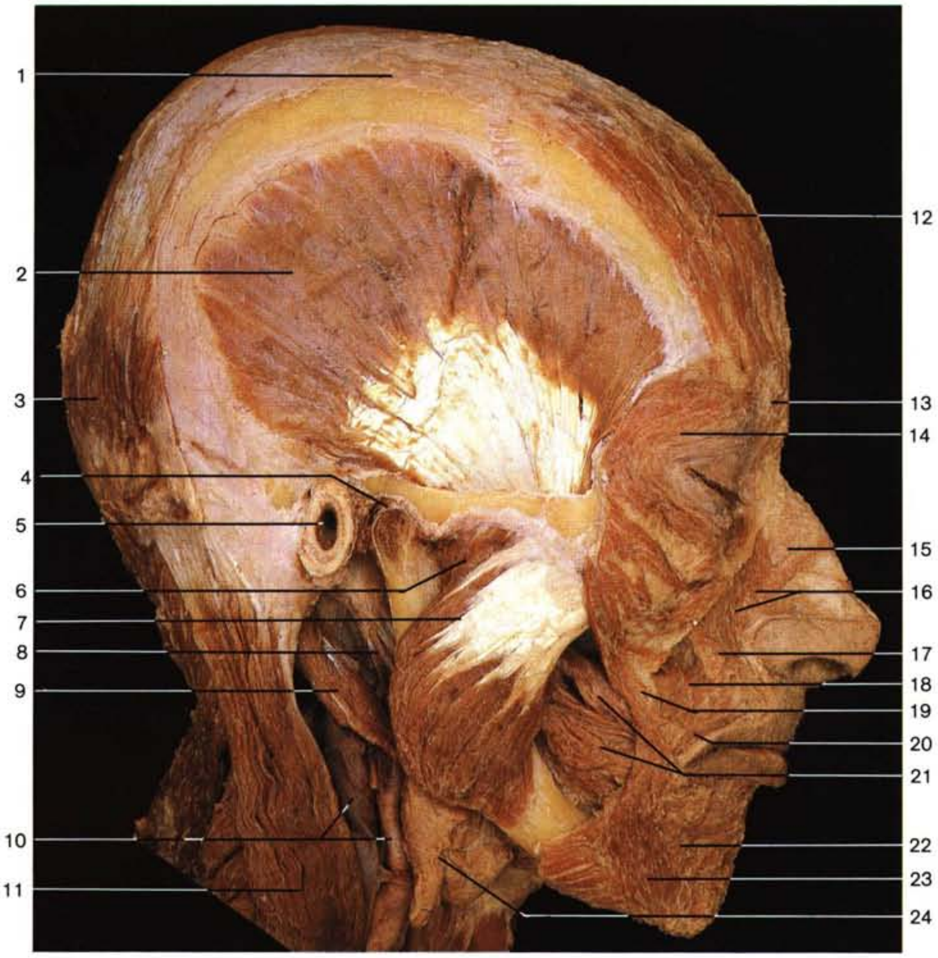

Temporalis and masseter muscles. The temporal fascia has been removed, the temporomandibular joint severed and the zygomatic arch displayed.

1 Galea aponeurotica
2 **Temporalis muscle**
3 Occipital belly of occipitofrontalis muscle
4 **Temporomandibular joint**
5 External acoustic meatus
6 Deep layer of **masseter muscle**
7 Superficial layer of masseter muscle
8 Stylohyoid muscle
9 Posterior belly of **digastric muscle**
10 Internal jugular vein and external carotid artery
11 **Sternocleidomastoid muscle**
12 Frontal belly of occipitofrontalis muscle
13 Depressor supercilii muscle
14 **Orbicularis oculi muscle**
15 Transverse part of nasalis muscle
16 Levator labii superioris alaeque nasi muscle
17 Levator labii superioris muscle
18 Levator anguli oris muscle
19 **Zygomaticus major muscle**
20 **Orbicularis oris muscle**
21 **Buccinator muscle**
22 Depressor labii inferioris muscle
23 Depressor anguli oris muscle
24 **Submandibular gland**
25 Lateral nasal cartilage
26 Greater alar cartilage (lateral part)
27 Lesser alar cartilages
28 Greater alar cartilage (medial part)
29 Infraorbital nerve
30 Anterior belly of digastric muscle
31 Hypoglossal nerve and hyoglossus muscle
32 Superior thyroid artery
33 **Zygomatic arch**
34 Internal carotid artery
35 Common carotid artery

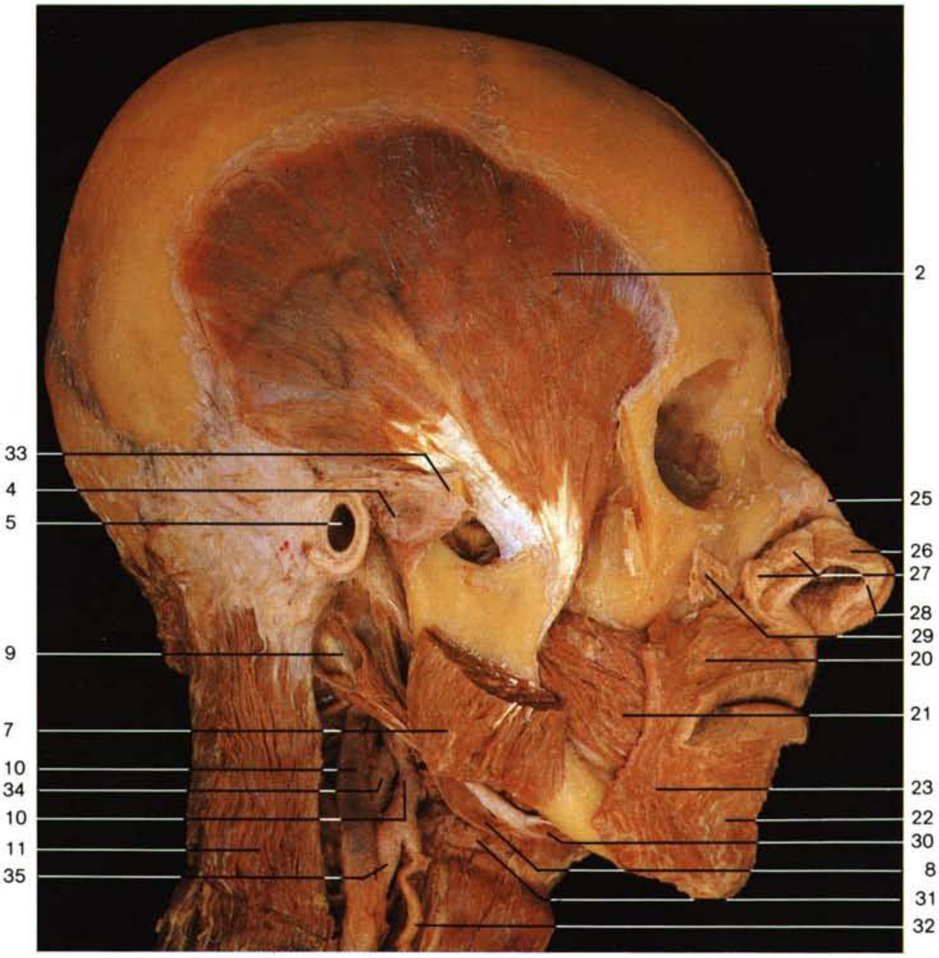

Temporalis muscle and temporomandibular joint. The zygomatic arch and the masseter muscle have been partially severed to display the insertion of the temporalis muscle.

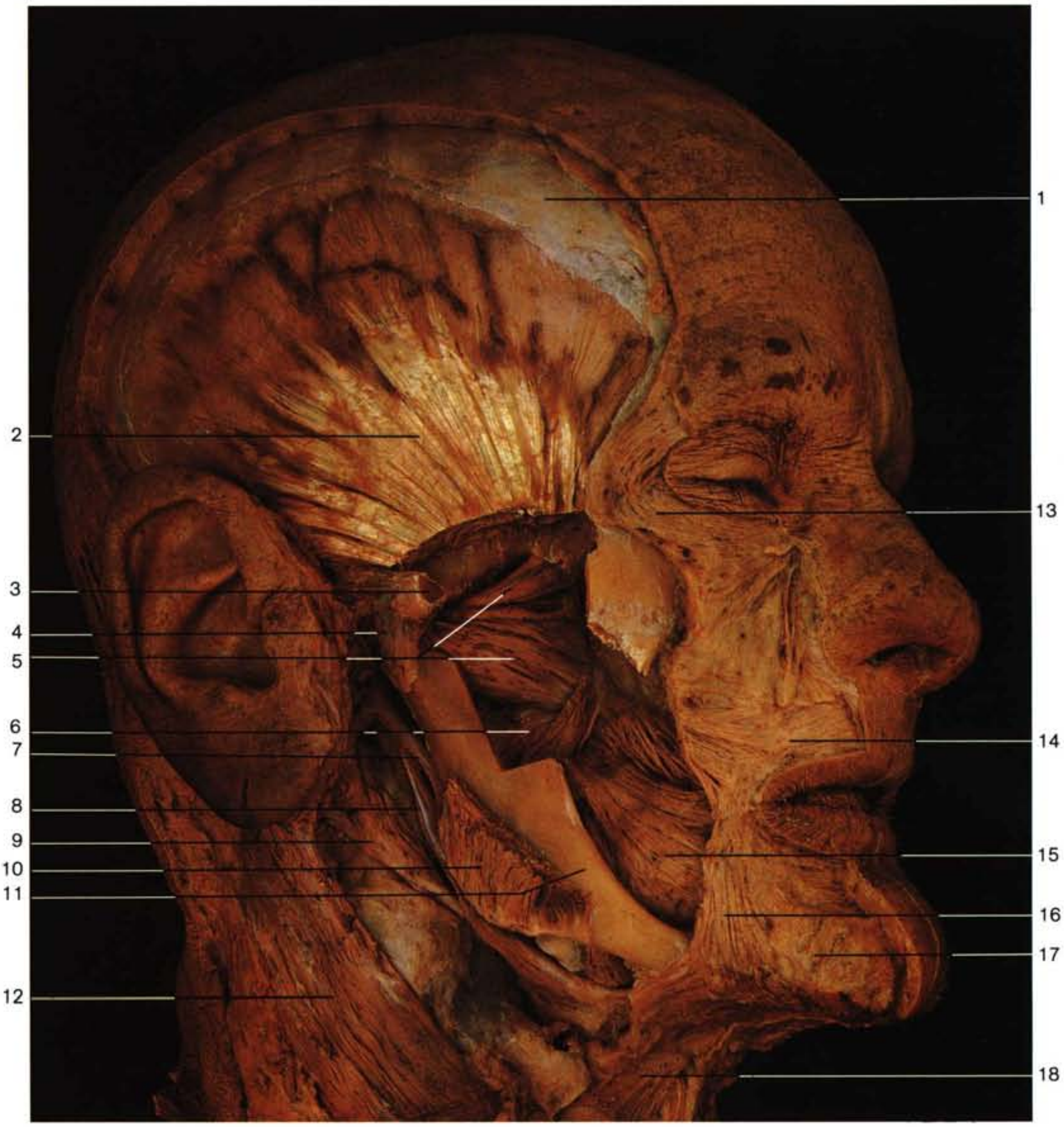

1 Periosteum
2 **Temporalis muscle**
3 Zygomatic arch
4 Articular capsule of temporomandibular joint
5 **Lateral pterygoid muscle** (upper and lower head)
6 **Medial pterygoid muscle**
7 Styloglossus muscle
8 Stylohyoid muscle
9 Posterior belly of digastric muscle
10 **Masseter muscle** (severed)
11 Mandible
12 Sternocleidomastoid muscle
13 Orbicularis oculi muscle
14 Orbicularis oris muscle
15 Buccinator muscle
16 Depressor anguli oris muscle
17 Depressor labii inferioris muscle
18 Platysma muscle
19 **Articular disc of temporomandibular joint**
20 Head of mandible
21 Anterior belly of digastric muscle
22 Mylohyoid muscle
23 Hyoid bone

Medial and lateral pterygoid muscles. A portion of the mandible and the zygomatic arch has been removed revealing the pterygoid region or infratemporal fossa.

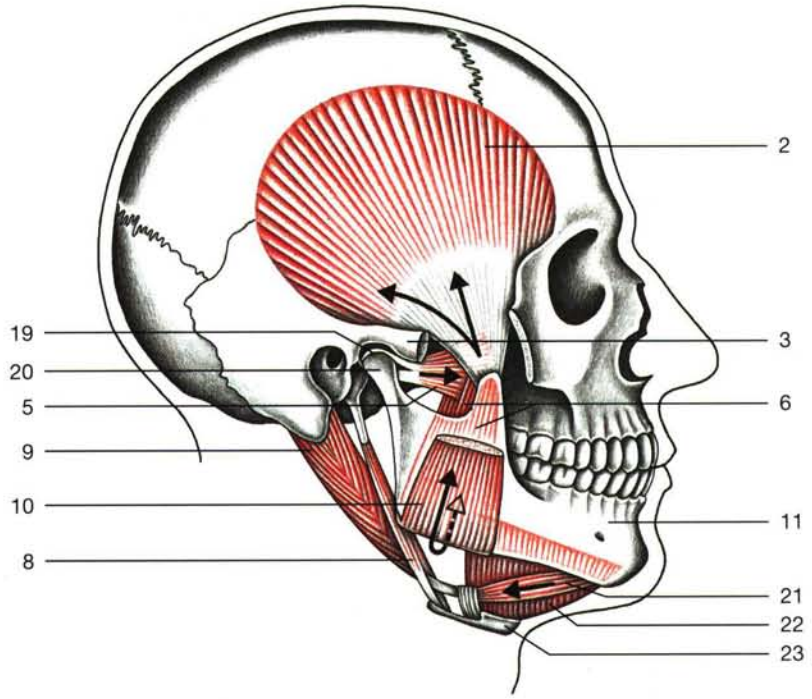

Effect of the muscles of mastication on the temporomandibular joint (arrows).

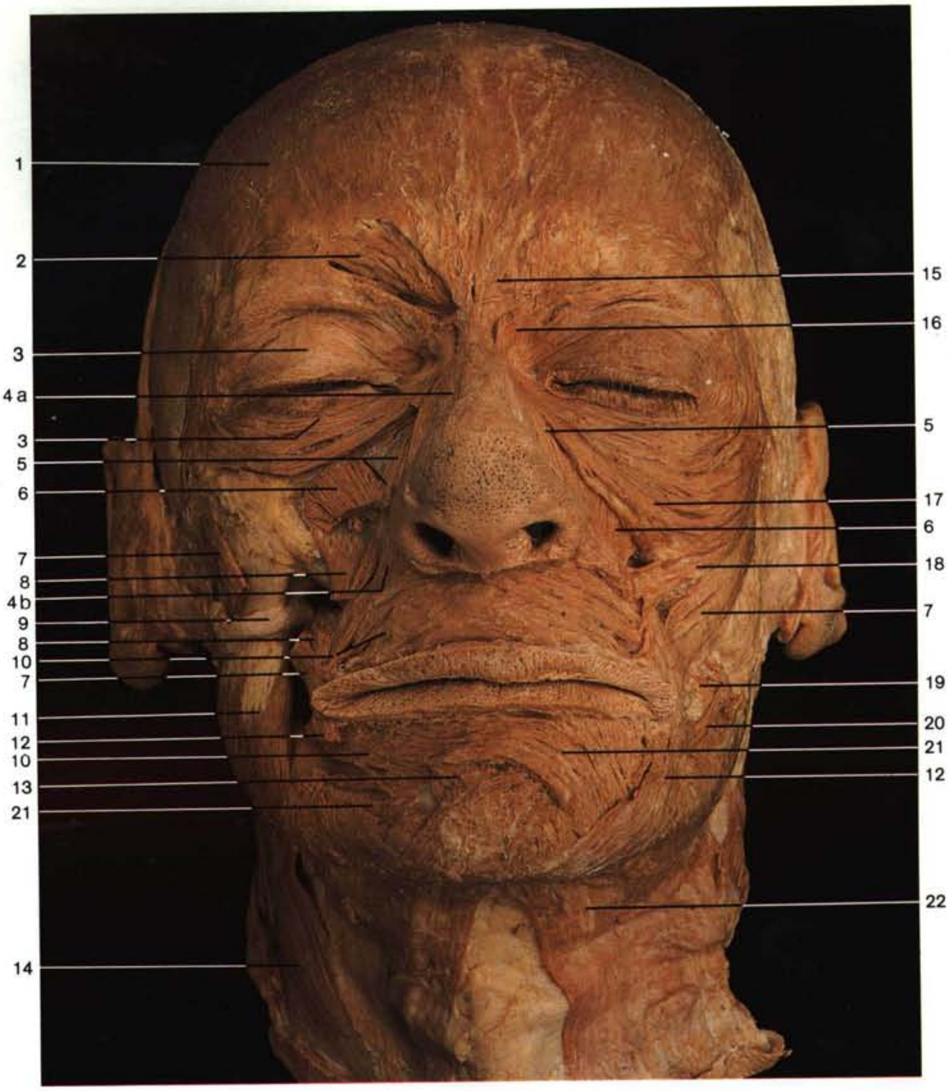

Facial muscles (anterior aspect). Left side: superficial layer; right side: deeper layer.

1 Frontal belly of **occipitofrontalis muscle**
2 **Corrugator supercilii muscle**
3 Palpebral part of orbicularis oculi muscle
4a Transverse part of nasalis muscle
4b Alar part of **nasalis muscle**
5 Levator labii superioris alaeque nasi muscle
6 **Levator labii superioris muscle**
7 **Zygomaticus major muscle**
8 Levator anguli oris muscle
9 Parotid duct
10 **Orbicularis oris muscle**
11 Masseter muscle
12 **Depressor anguli oris muscle**
13 **Mentalis muscle**
14 Sternocleidomastoid muscle
15 **Procerus muscle**
16 **Depressor supercilii muscle**
17 Orbital part of **orbicularis oculi muscle**
18 Zygomaticus minor muscle
19 **Buccinator muscle**
20 Risorius muscle
21 **Depressor labii inferioris muscle**
22 **Platysma muscle**
23 Galea aponeurotica
24 **Temporoparietalis muscle**
25 Occipital belly of occipitofrontalis muscle
26 Parotid gland with fascia
27 Temporal fascia
28 **Orbicularis oculi muscle**
29 Parotid duct, masseter muscle

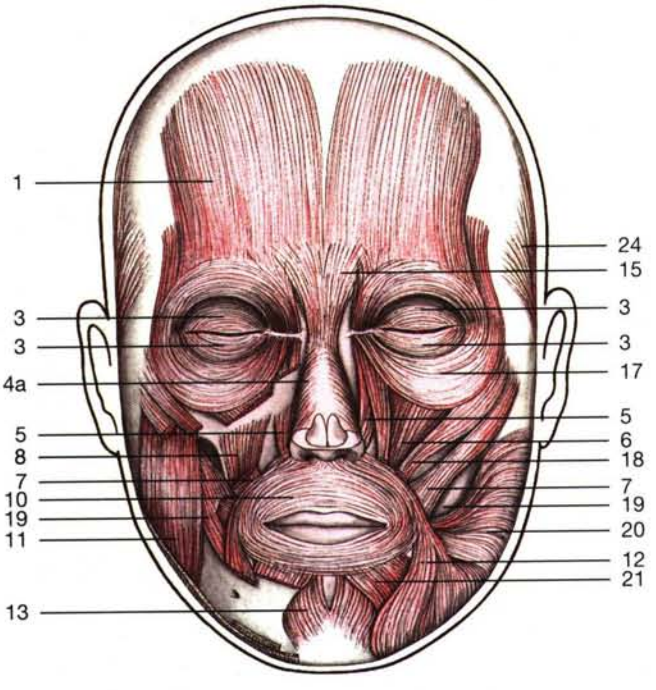

Facial muscles (schematic drawing). Left side: superficial layer; right side: deeper layer.

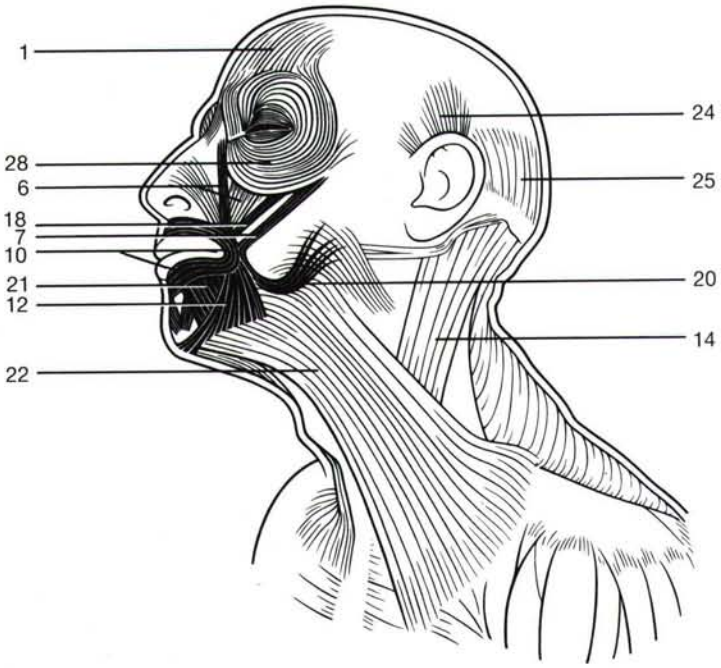

Facial muscles. Sphincter-like muscles surround the orifices of the head. Radially arranged muscles work as their antagonists.

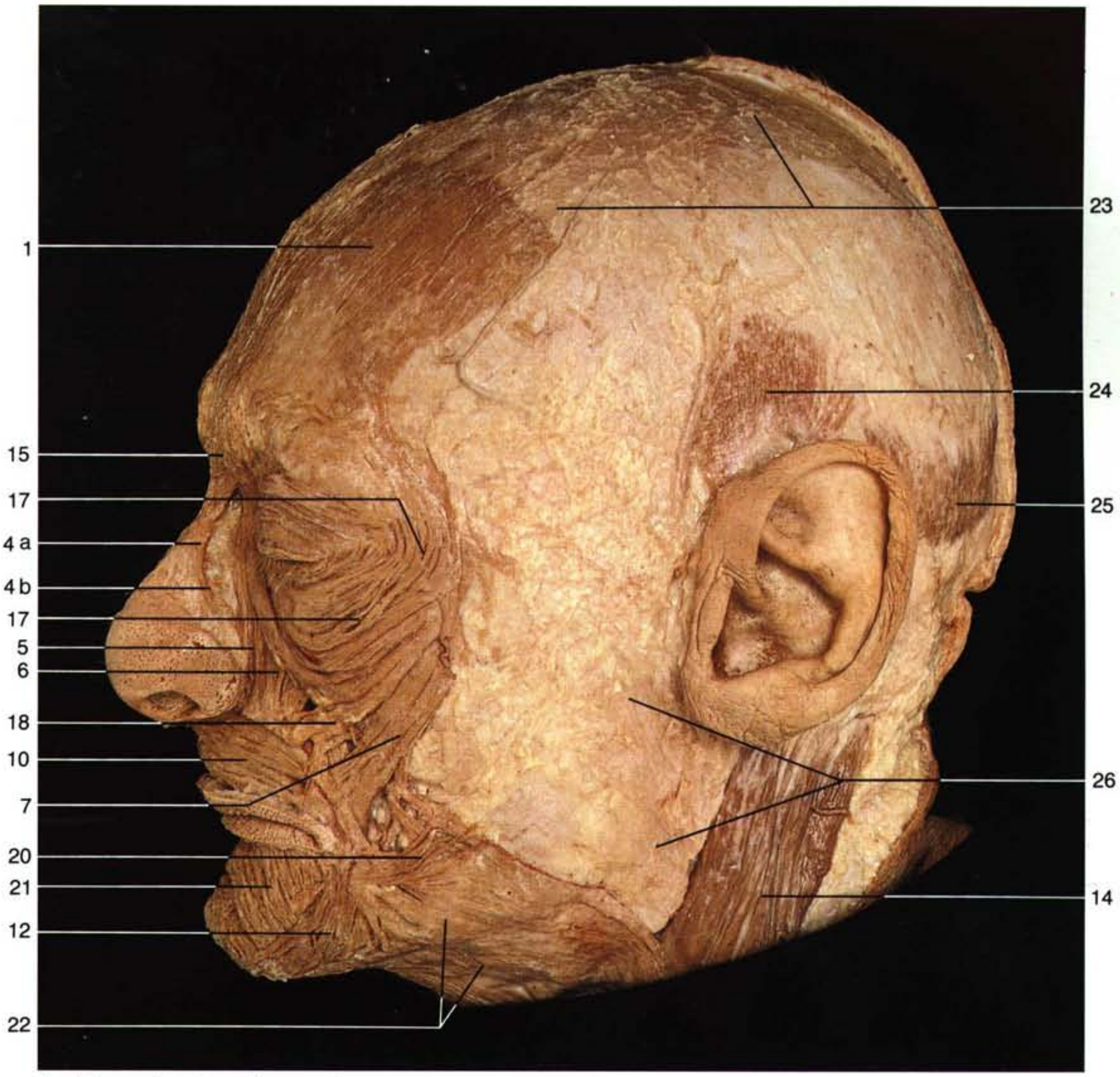
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Facial muscles (lateral aspect).

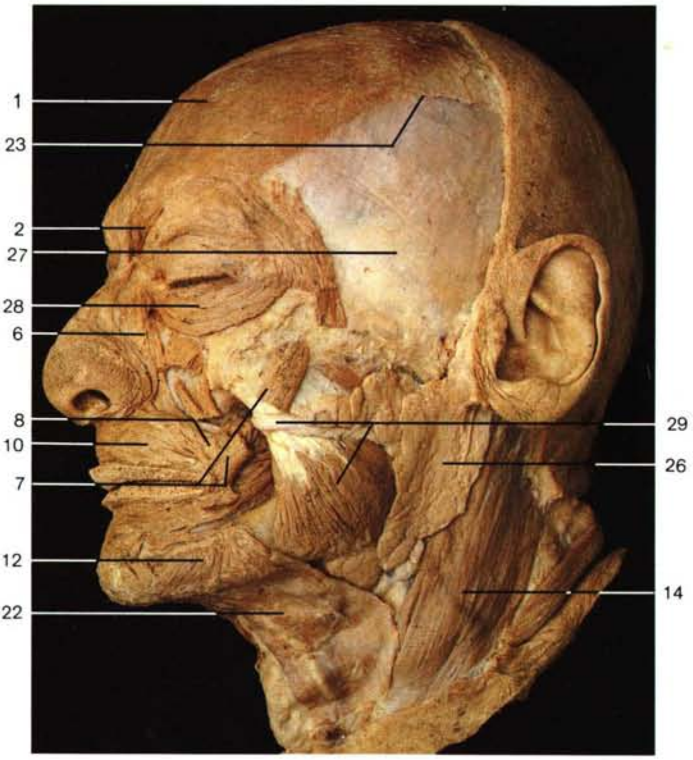
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Facial muscles and parotid gland (lateral aspect).

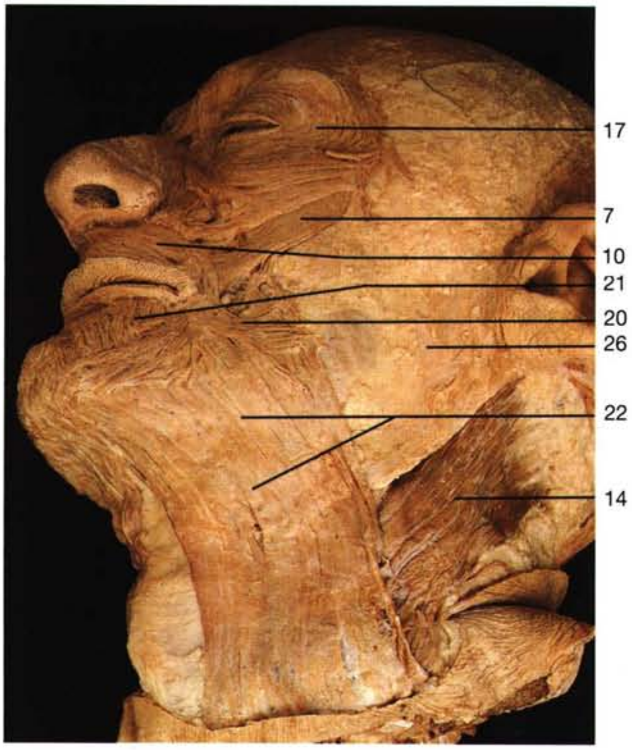
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Platysma muscle (oblique lateral aspect). Superficial lamina of cervical fascia partly removed.

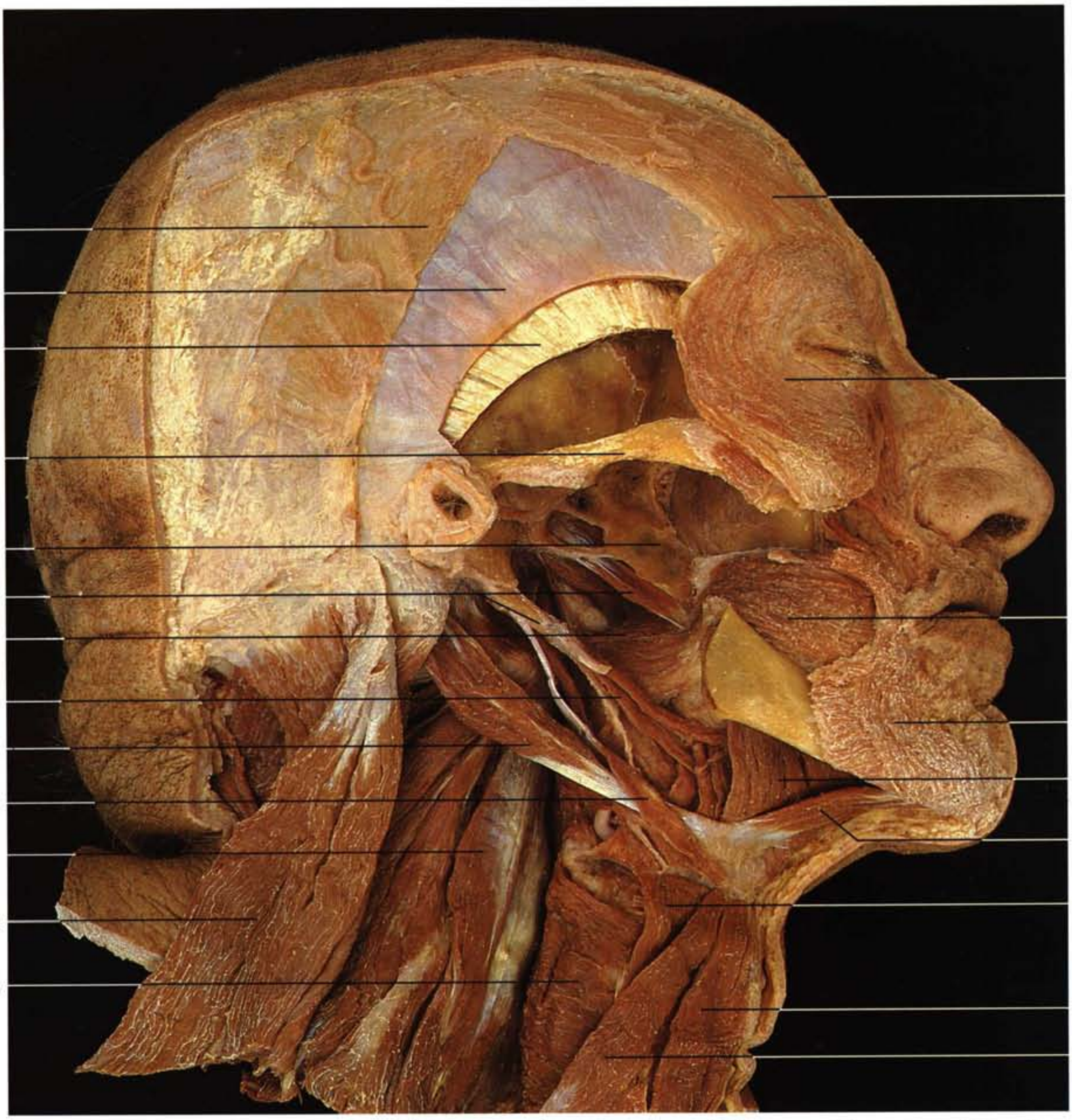

Supra- and infrahyoid muscles, pharynx I (lateral aspect). Ramus of mandible, pterygoid muscles and insertion of temporalis muscle removed.

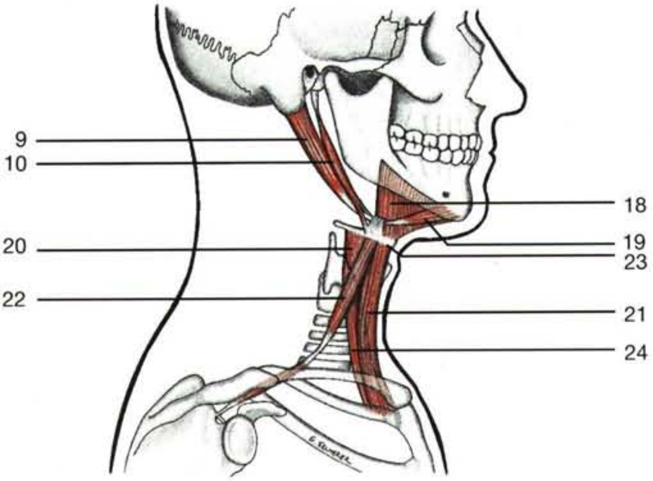

Supra- and infrahyoid muscles. (Schematic diagram.)

1 Galea aponeurotica
2 **Temporal fascia**
3 Tendon of temporalis muscle
4 Zygomatic arch
5 Lateral pterygoid plate
6 Tensor veli palatini muscle (styloid process)
7 Superior constrictor muscle of pharynx
8 **Styloglossus muscle**
9 Posterior belly of digastric muscle
10 **Stylohyoid muscle**
11 Longus capitis muscle
12 Sternocleidomastoid muscle (reflected)
13 Inferior constrictor of pharynx
14 Frontal belly of occipitofrontalis muscle
15 Orbital part of orbicularis oculi muscle
16 **Buccinator muscle**
17 Depressor anguli oris muscle
18 **Mylohyoid muscle**
19 Anterior belly of digastric muscle
20 **Thyrohyoid muscle**
21 **Sternohyoid muscle**
22 **Omohyoid muscle**
23 Hyoid bone
24 Sternothyroid muscle

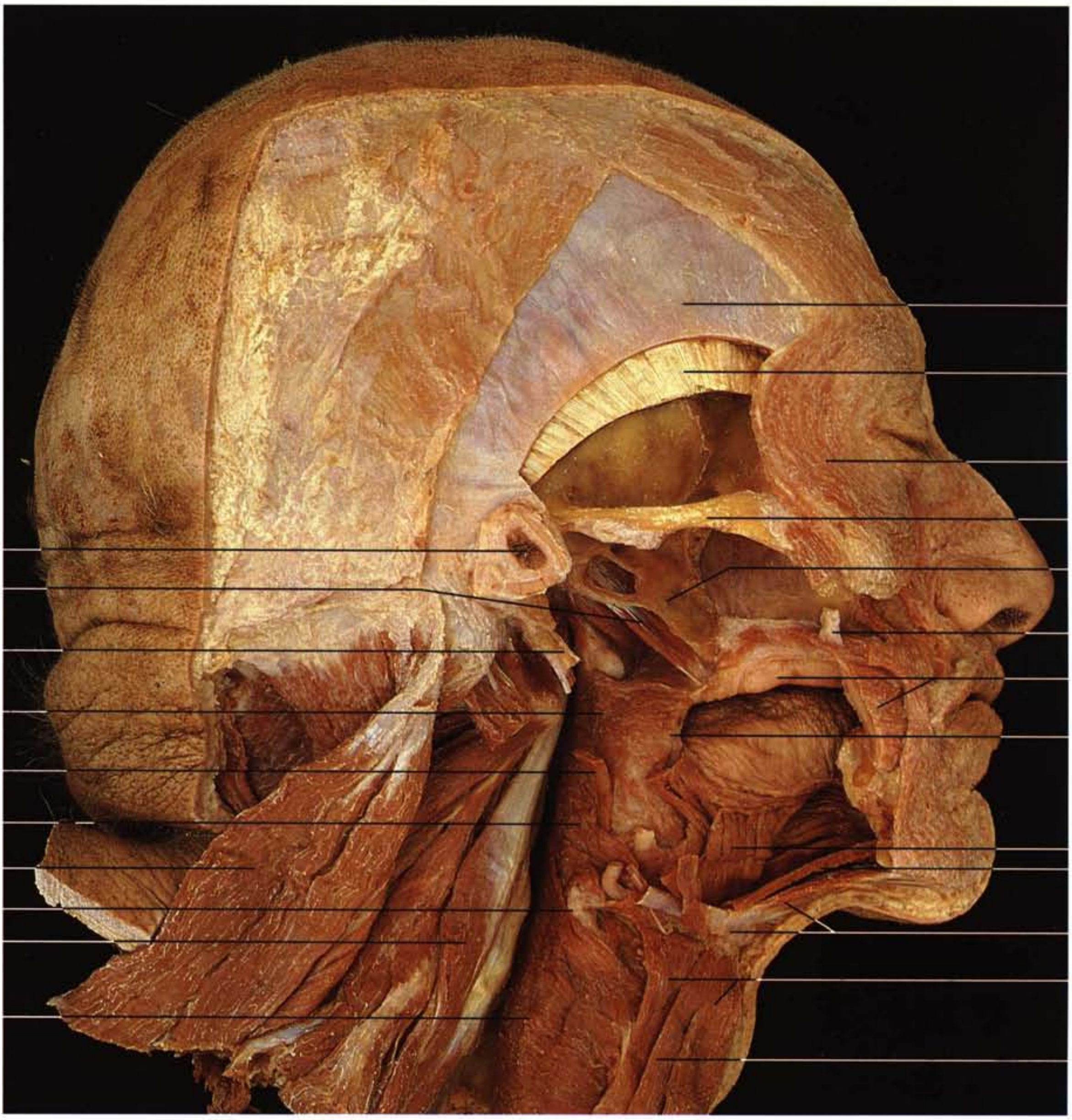

Supra- and infrahyoid muscles, pharynx II. Buccinator muscle removed; oral cavity opened.

1	External acoustic meatus	13	Orbicularis oculi muscle
2	Tensor veli palatini muscle	14	Zygomatic arch
3	Styloid process	15	Lateral pterygoid plate
4	**Superior constrictor muscle of pharynx**	16	Parotid duct
5	Stylopharyngeus muscle (divided)	17	Gingiva of upper jaw (without teeth), buccinator muscle (divided)
6	**Middle constrictor muscle of pharynx**	18	Pterygomandibular raphe
7	Sternocleidomastoid muscle	19	Hyoglossus muscle
8	Greater horn of hyoid bone	20	Mylohyoid muscle
9	Longus capitis	21	Anterior belly of digastric muscle (hyoid bone)
10	**Inferior constrictor muscle of pharynx**	22	Sternohyoid and thyrohyoid muscles
11	Temporal fascia	23	Omohyoid muscle
12	Tendon of temporalis muscle		

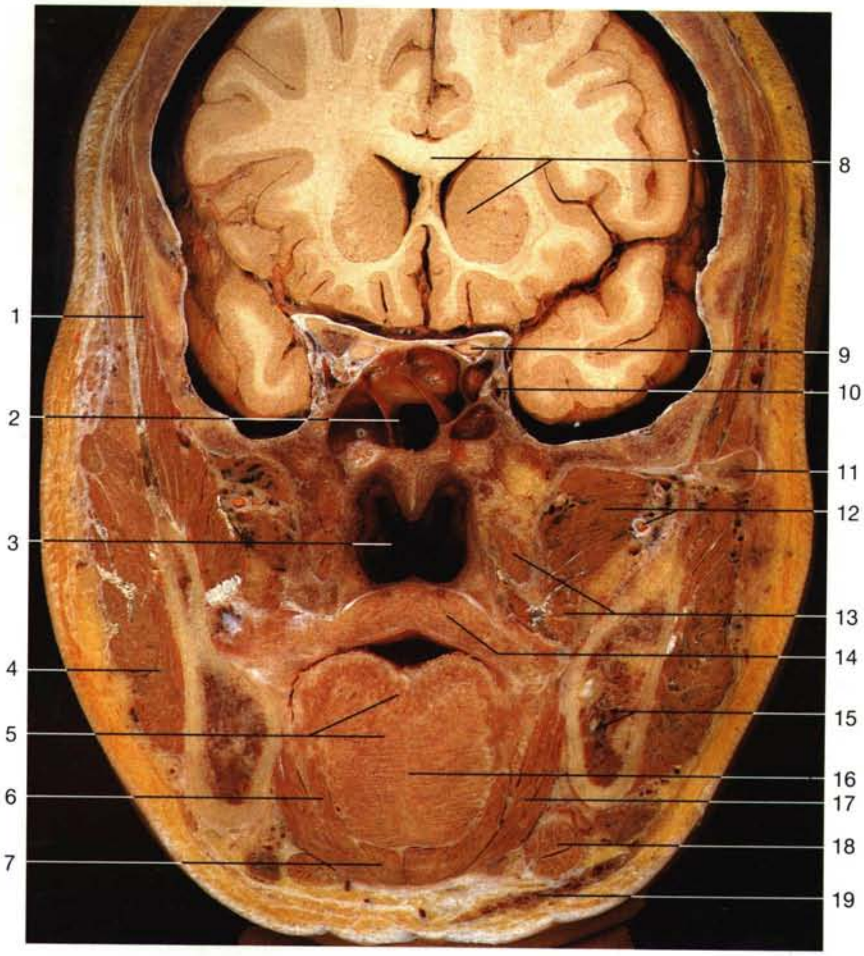

Coronal section through cranial, nasal and oral cavity at the level of sphenoidal sinus.

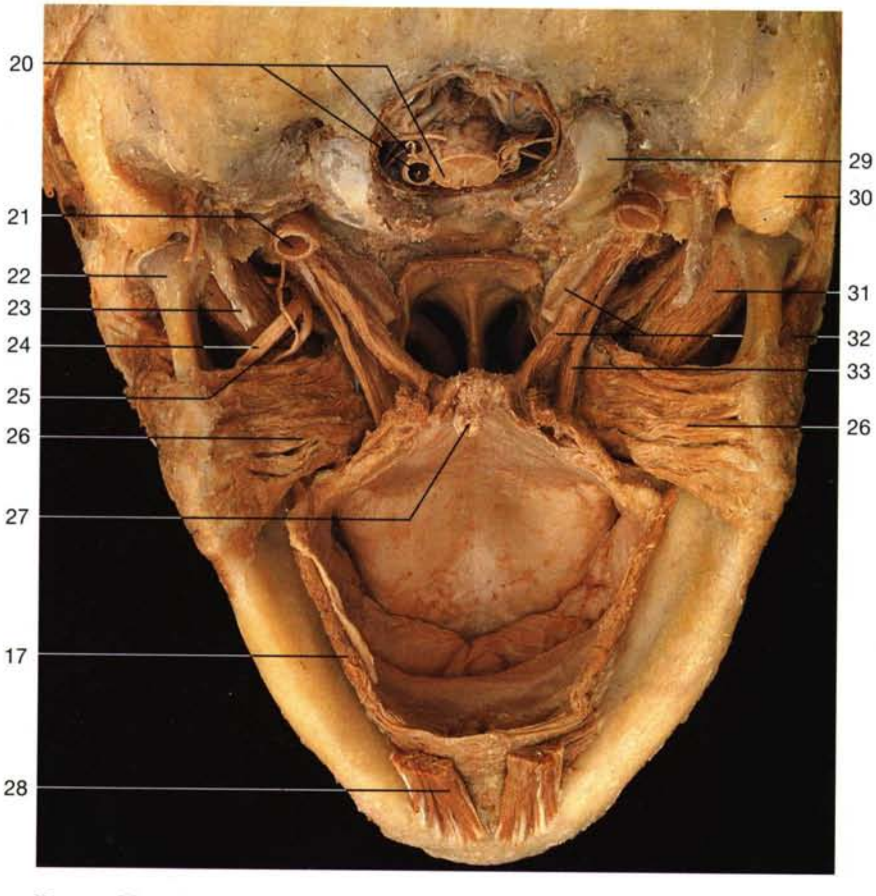

Pterygoid and palatine muscles (posterior aspect).

1 Temporalis muscle
2 **Sphenoidal sinus**
3 **Nasopharynx**
4 Masseter muscle
5 Superior longitudinal, transverse and vertical muscles of tongue
6 Hyoglossus muscle
7 Geniohyoid muscle
8 Corpus callosum (caudate nucleus)
9 Optic nerve
10 Cavernous sinus
11 Zygomatic arch
12 Cross section of lateral pterygoid muscle and maxillary artery
13 Section of medial pterygoid muscle
14 **Soft palate**
15 Mandible and inferior alveolar nerve
16 Septum of the tongue
17 **Mylohyoid muscle**
18 Submandibular gland
19 Platysma muscle
20 Foramen magnum, vertebral artery and spinal cord
21 Internal carotid artery
22 **Head of mandible**
23 Styloid process
24 Inferior alveolar nerve
25 Lingual nerve and chorda tympani nerve
26 **Medial pterygoid muscle**
27 Uvula
28 Anterior belly of digastric muscle (cut)
29 Condyle of occipital bone
30 Mastoid process
31 **Lateral pterygoid muscle**
32 Auditory tube and **levator veli palatini muscle**
33 **Tensor veli palatini muscle**

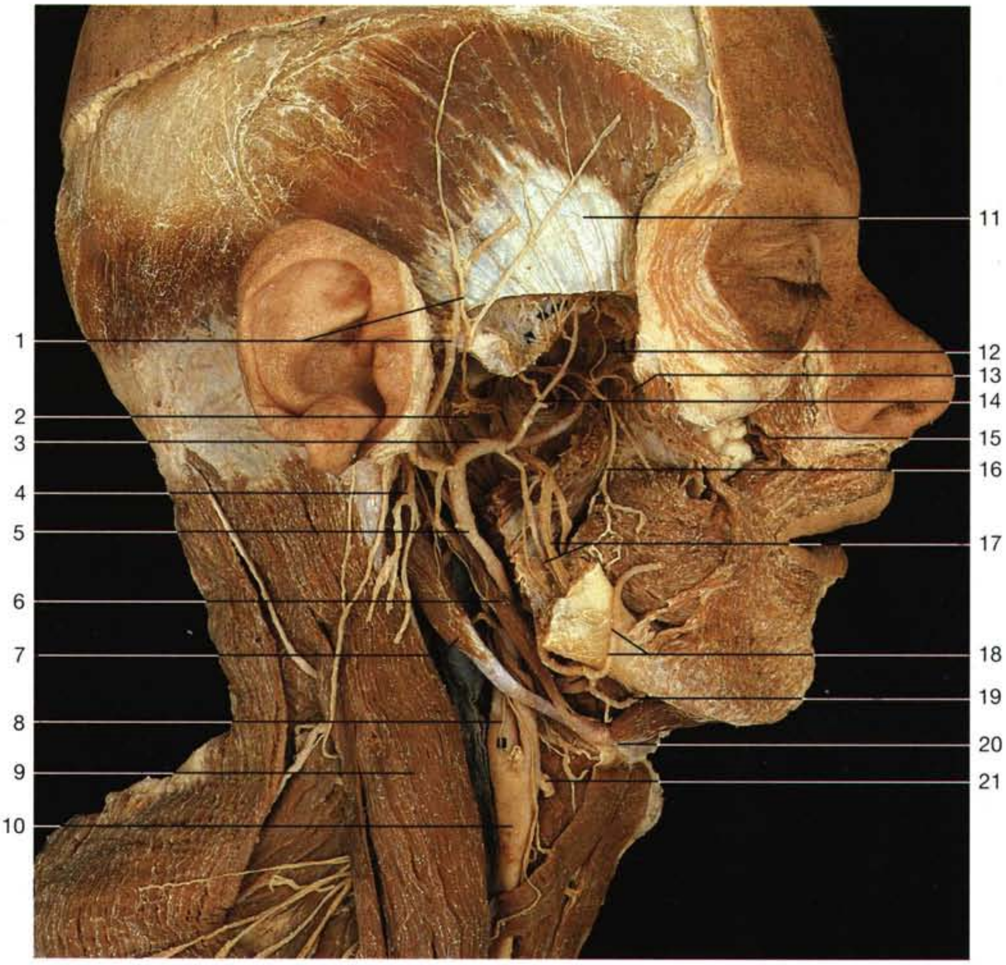

1 Superficial temporal artery and auriculotemporal nerve
2 Middle meningeal artery
3 **Maxillary artery**
4 Facial nerve (divided and reflected)
5 **External carotid artery**
6 Stylohyoid muscle
7 Digastric muscle (posterior belly)
8 Internal carotid artery and carotid sinus branch of glossopharyngeal nerve
9 Sternocleidomastoid muscle
10 Common carotid artery
11 Temporalis muscle
12 Pterygopalatine fossa
13 Posterior superior alveolar artery
14 Deep temporal artery
15 Infraorbital artery
16 Buccal nerve
17 Inferior alveolar artery and nerve
18 **Facial artery**
19 Submental artery
20 Hyoid bone
21 Superior thyroid artery (divided)

Dissection of maxillary artery. Mandible and lateral pterygoid muscle partly removed.

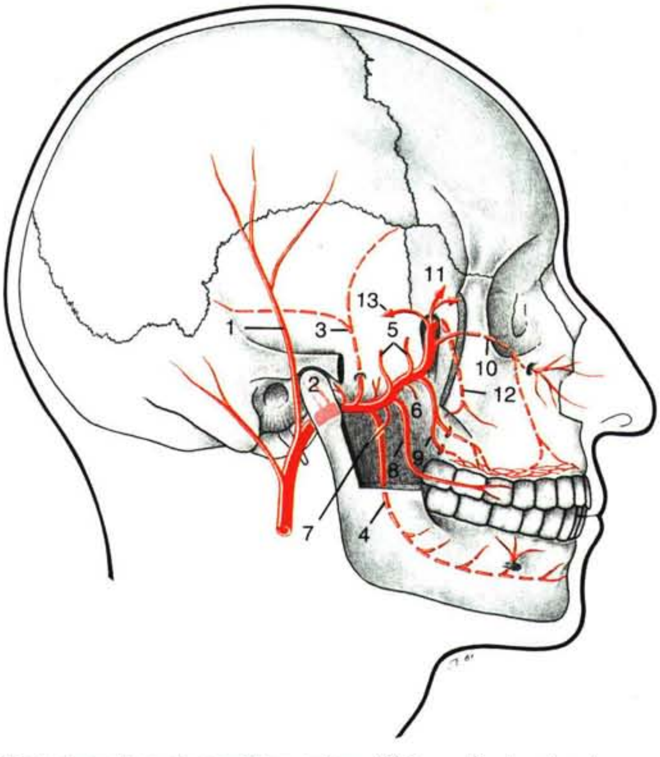

1 Superficial temporal artery

Branches of the first part
2 Deep auricular artery and anterior tympanic artery
3 Middle meningeal artery
4 Inferior alveolar artery

Branches of the second part
5 Deep temporal branches
6 Pterygoid branches
7 Masseteric artery
8 Buccal artery

Branches of the third part
9 Posterior superior alveolar artery
10 Infraorbital artery
11 Sphenopalatine artery and branches to the nasal cavity
12 Descending palatine artery
13 Artery of the pterygoid canal

Main branches of maxillary artery. (Schematic drawing.)

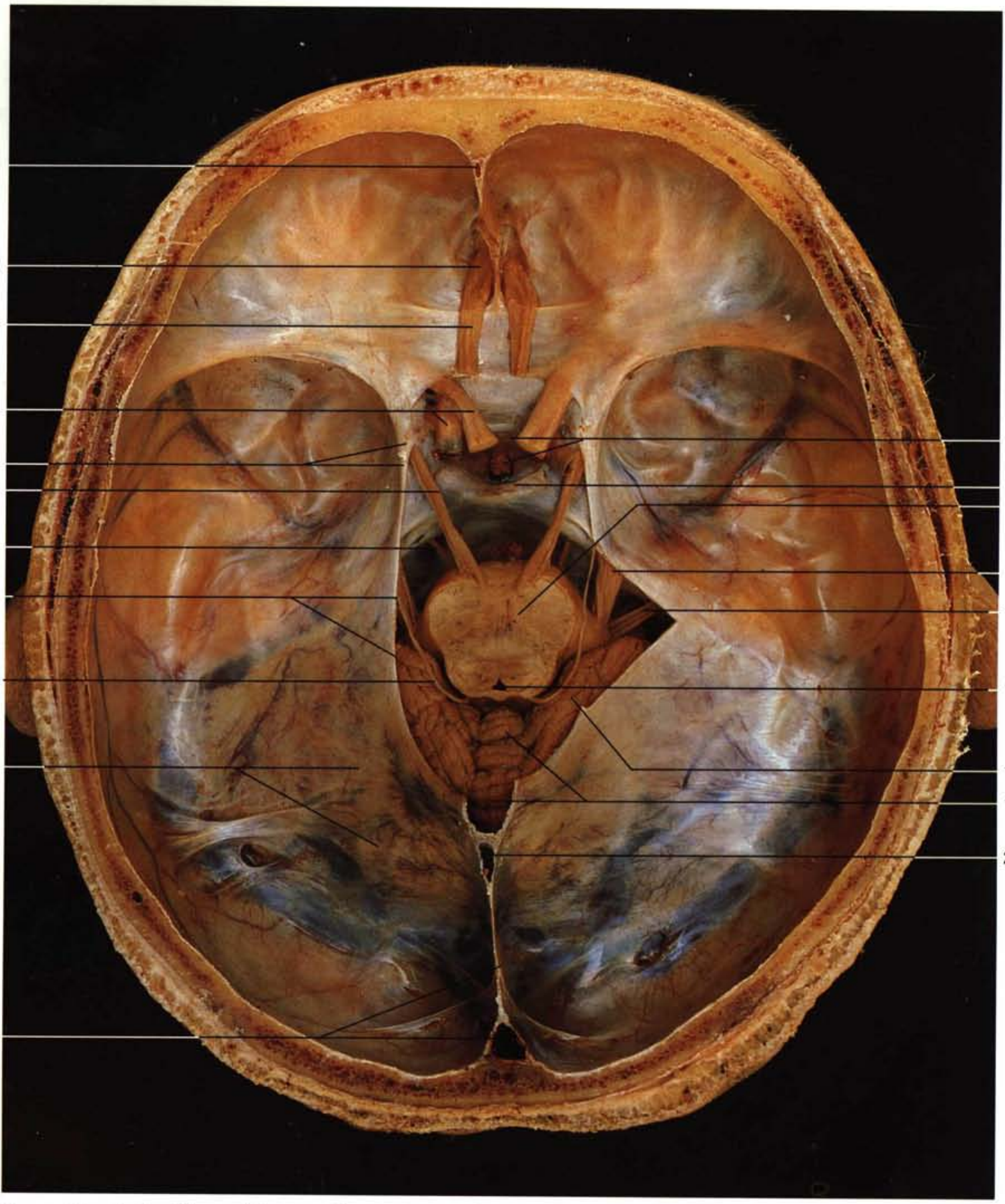

Base of the skull with cranial nerves (internal aspect). Both cerebral hemispheres and upper part of the brain stem removed. Incision on the right tentorium cerebelli to display the cranial nerves of the infratentorial space.

1	Superior sagittal sinus with falx cerebri	12	Hypophysial fossa, infundibulum, and diaphragma sellae
2	Olfactory bulb	13	Dorsum sellae
3	**Olfactory tract**	14	Midbrain (divided)
4	**Optic nerve** and internal carotid artery	15	**Trigeminal nerve** (n. V)
5	Anterior clinoid process and anterior attachment of tentorium cerebelli	16	**Facial nerve** (n. VII), nervus intermedius, and **vestibulocochlear nerve** (n. VIII)
6	**Oculomotor nerve** (n. III)	17	Cerebral aqueduct
7	**Abducens nerve** (n. VI)	18	Right hemisphere of cerebellum
8	Tentorial notch (incisura tentorii)	19	Vermis of cerebellum
9	**Trochlear nerve** (n. IV)	20	Straight sinus
10	Tentorium cerebelli		
11	Falx cerebri and confluence of sinuses		

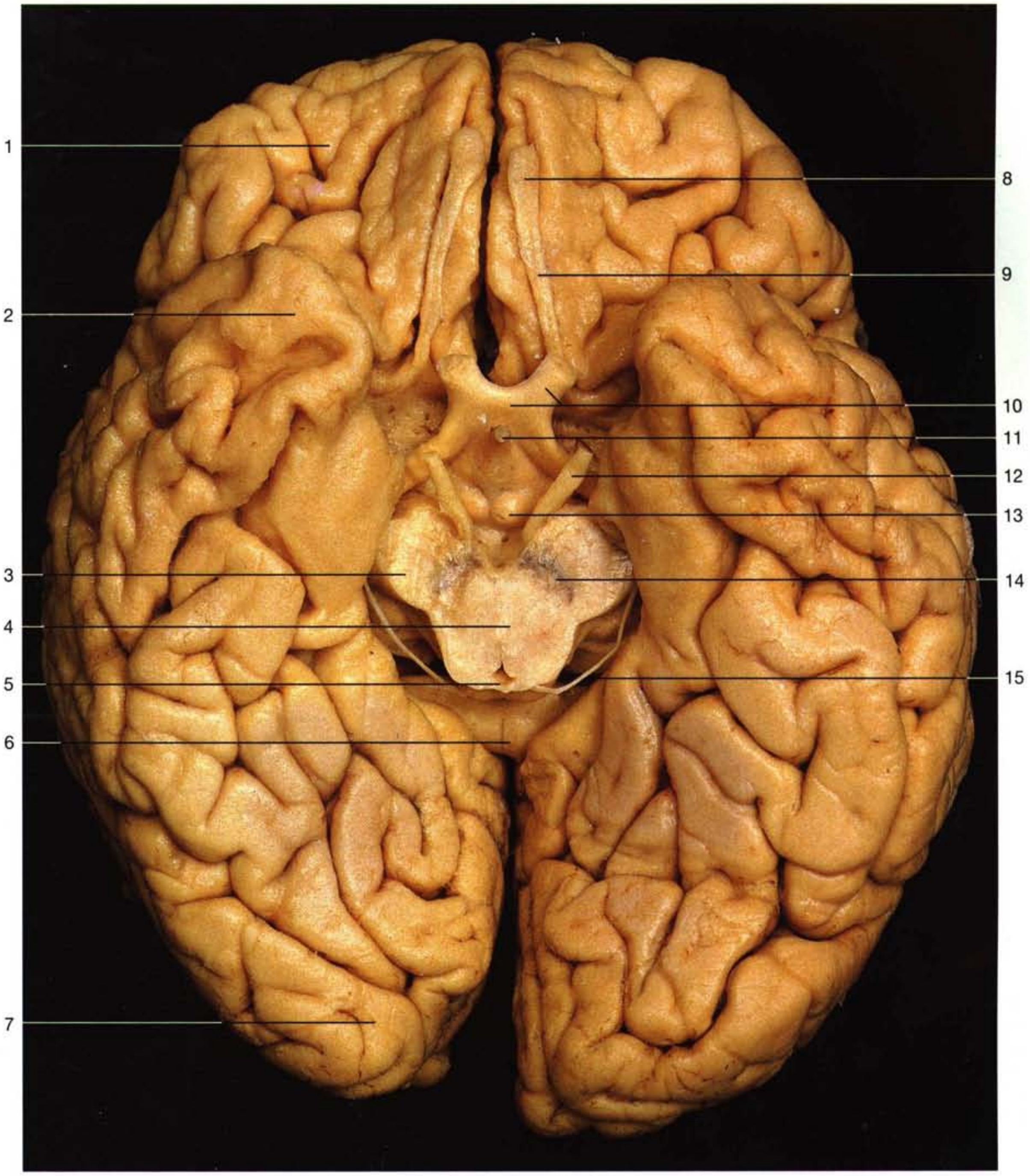

Inferior aspect of the brain with cranial nerves. Midbrain divided.

1 **Frontal lobe**
2 **Temporal lobe**
3 Pedunculus cerebri
4 **Midbrain** (divided)
5 Cerebral aqueduct
6 Splenium of corpus callosum
7 **Occipital lobe**
8 Olfactory bulb
9 Olfactory tract
10 **Optic nerve and optic chiasma**
11 Infundibulum
12 **Oculomotor nerve** (n. III)
13 Mamillary body
14 Substantia nigra
15 **Trochlear nerve** (n. IV)

Cranial nerves	
I = Olfactory nerves	VII = Facial nerve
II = Optic nerve	VIII = Vestibulocochlear nerve
III = Oculomotor nerve	IX = Glossopharyngeal nerve
IV = Trochlear nerve	X = Vagus nerve
V = Trigeminal nerve	XI = Accessory nerve
VI = Abducens nerve	XII = Hypoglossal nerve

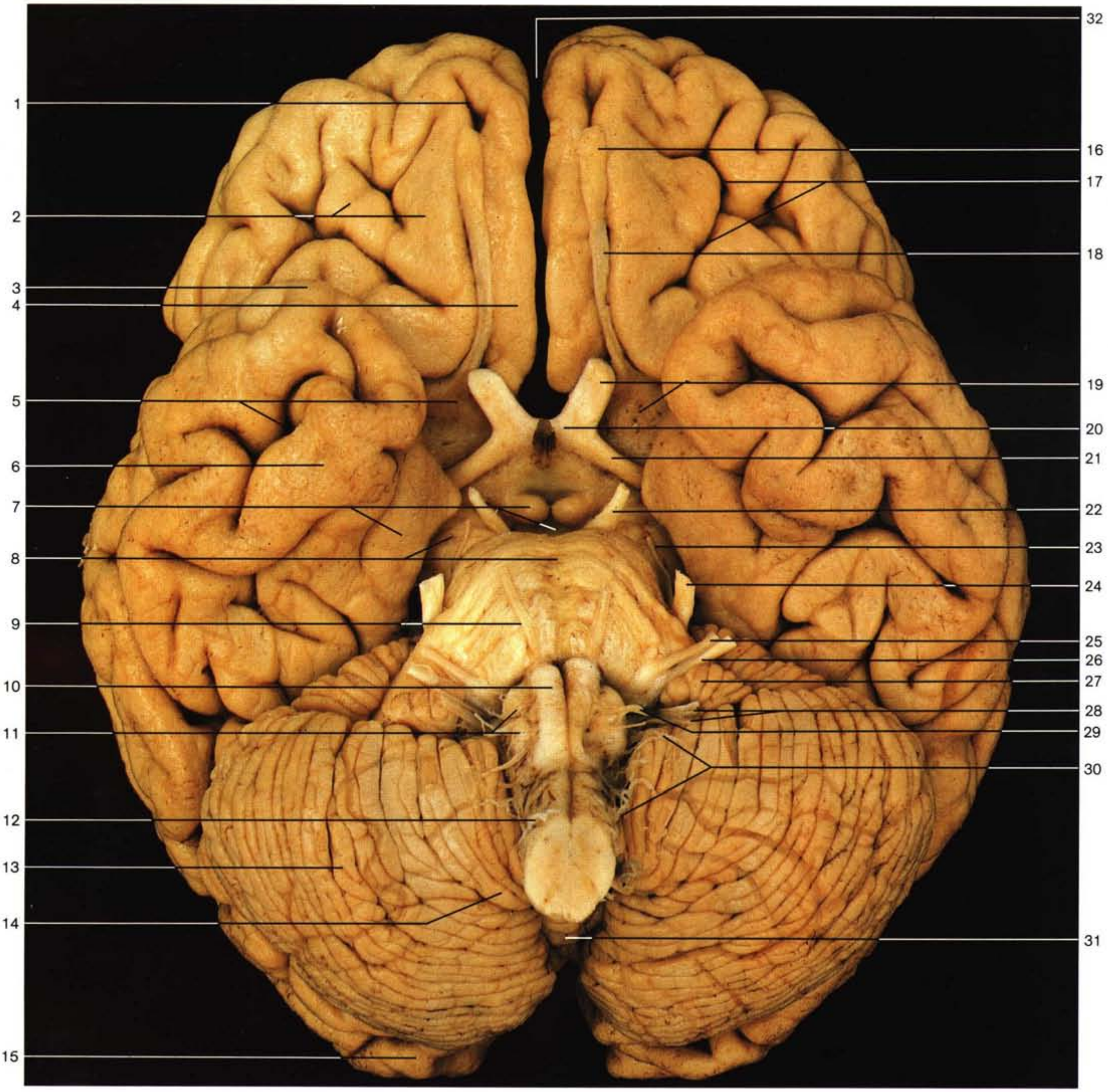

Cranial nerves. Brain (inferior aspect).

1 Olfactory sulcus (termination)
2 Orbital gyri
3 Temporal lobe
4 Straight gyrus
5 Olfactory trigone and inferior temporal sulcus
6 Medial occipitotemporal gyrus
7 Parahippocampal gyrus, mamillary body, and interpeduncular fossa
8 Pons and cerebral peduncle
9 **Abducens nerve** (n. VI)
10 Pyramid
11 Lower part of olive
12 Cervical spinal nerves
13 Cerebellum
14 Tonsil of cerebellum
15 Occipital lobe (posterior pole)
16 Olfactory bulb
17 Orbital sulci of frontal lobe
18 **Olfactory tract**
19 **Optic nerve** (n. II) and anterior perforated substance
20 Optic chiasma
21 Optic tract
22 **Oculomotor nerve** (n. III)
23 **Trochlear nerve** (n. IV)
24 **Trigeminal nerve** (n. V)
25 **Facial nerve** (n. VII)
26 **Vestibulocochlear nerve** (n. VIII)
27 Flocculus of cerebellum
28 **Glossopharyngeal** (n. IX) and **vagus nerve** (n. X)
29 **Hypoglossal nerve** (n. XII)
30 **Accessory nerve** (n. XI)
31 Vermis of cerebellum
32 Longitudinal fissure

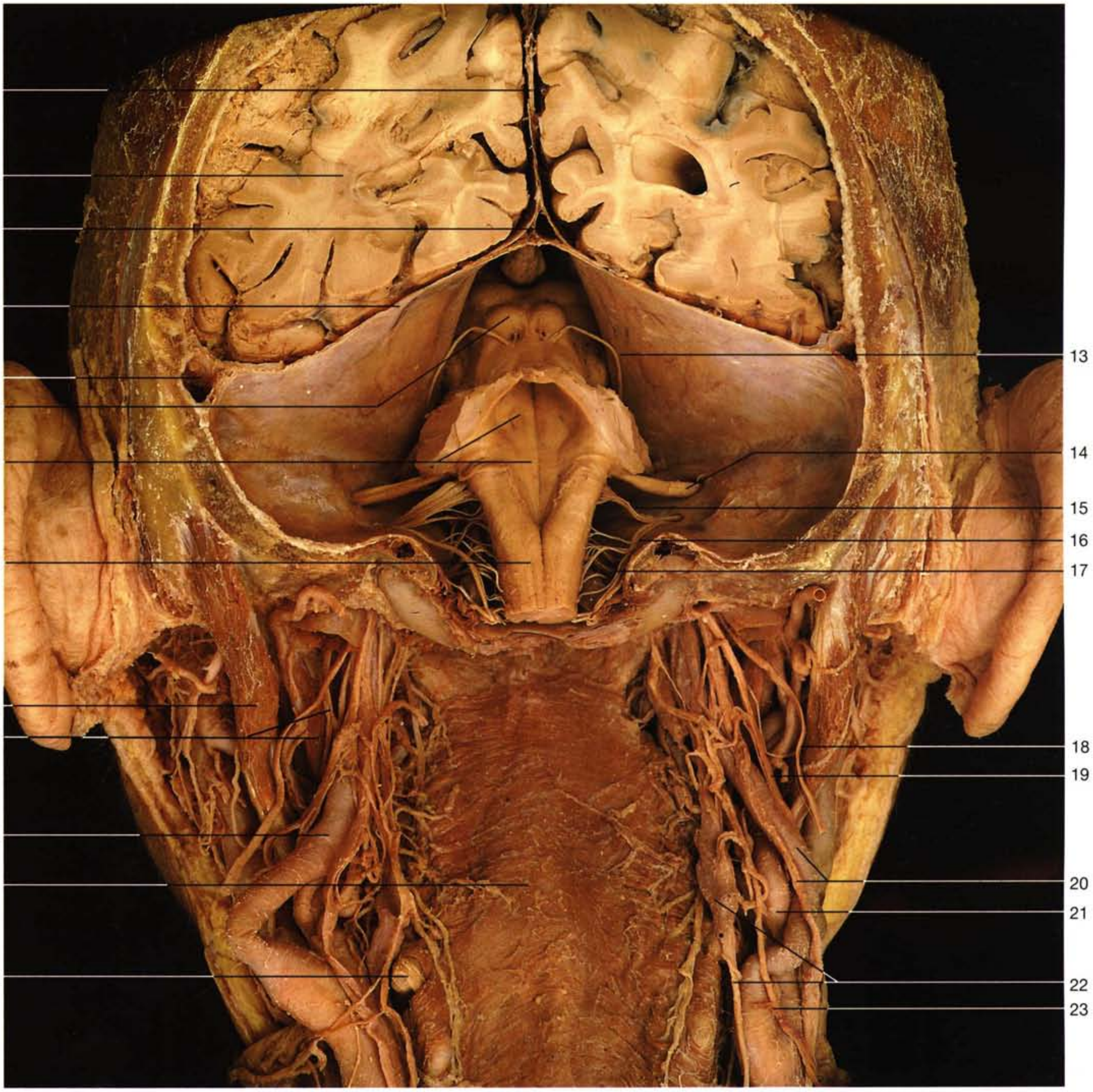

Brain stem and pharynx with cranial nerves (posterior aspect). Cranial cavity opened and cerebellum removed.

1 Falx cerebri
2 Occipital lobe
3 Straight sinus
4 Tentorium cerebelli
5 Transverse sinus
6 Inferior colliculus of midbrain
7 **Rhomboid fossa**
8 Medulla oblongata
9 Posterior belly of digastric muscle
10 Internal carotid artery
11 Pharynx (middle constrictor muscle)
12 Hyoid bone (greater horn)
13 **Trochlear nerve** (n. IV)
14 **Facial nerve** (n. VII), **vestibulocochlear nerve** (n. VIII)
15 **Glossopharyngeal nerve** (n. IX) and vagus nerve (n. X)
16 **Accessory nerve** (intracranial portion) (n. XI)
17 **Hypoglossal nerve** (intracranial portion) (n. XII)
18 **Accessory nerve** (n. XI)
19 **Hypoglossal nerve** (n. XII)
20 **Vagus nerve** (n. X) and internal carotid artery
21 External carotid artery
22 **Sympathetic trunk** and superior cervical ganglion
23 Ansa cervicalis (superior root of hypoglossal nerve)
24 **Glossopharyngeal nerve** (n. IX) and stylopharyngeus muscle

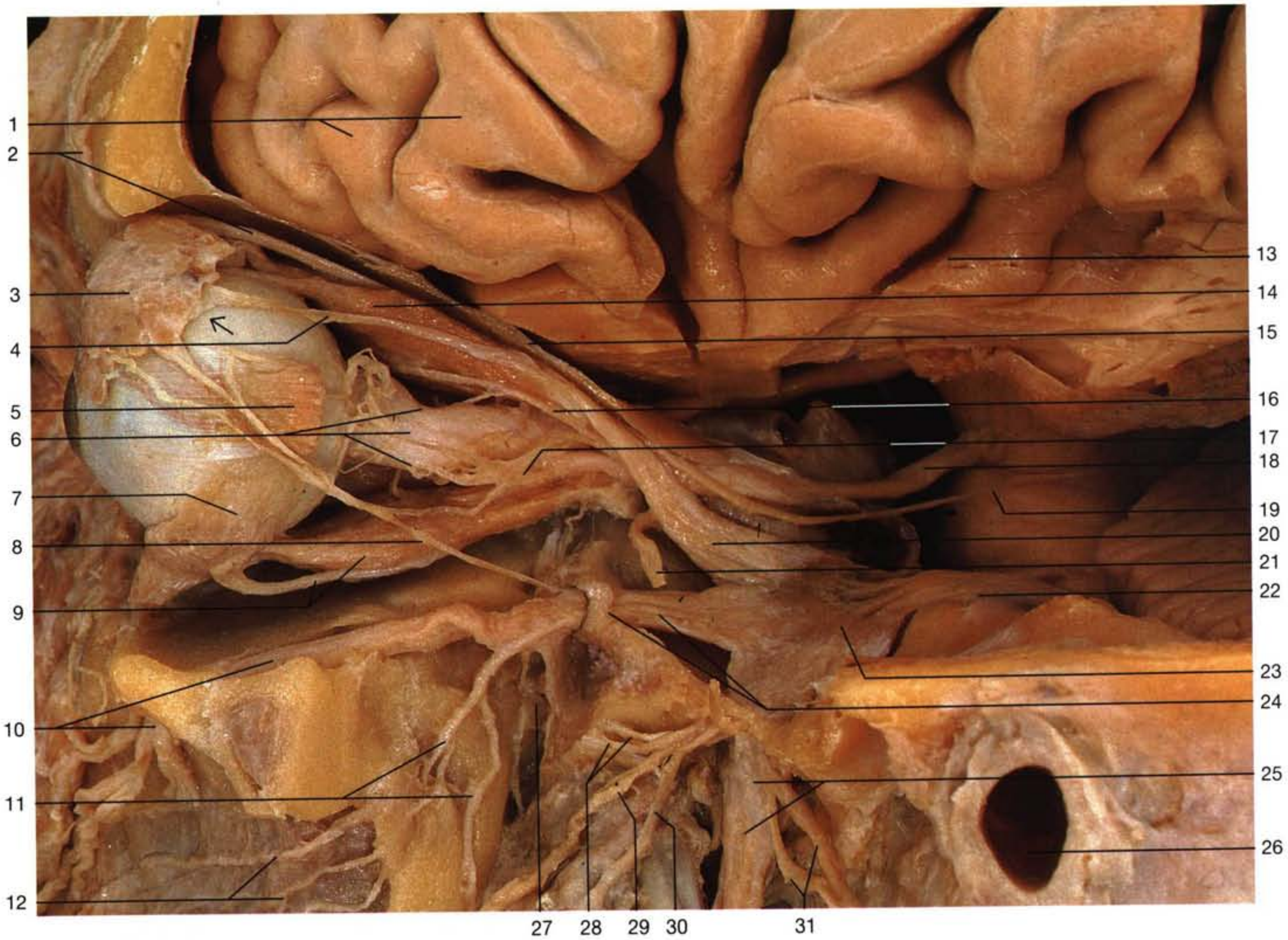

Cranial nerves of the orbit and pterygopalatine fossa. Left orbit (lateral aspect). Note the zygomaticolacrimal anastomosis (arrow).

1 Frontal lobe
2 Supraorbital nerve
3 Lacrimal gland
4 Lacrimal nerve
5 Lateral rectus muscle (divided)
6 **Optic nerve** and short ciliary nerves
7 Inferior oblique muscle
8 Zygomatic nerve
9 Inferior branch of oculomotor nerve and inferior rectus muscle
10 Infraorbital nerve
11 Posterior superior alveolar nerves
12 Branches of superior alveolar plexus adjacent to mucous membrane of maxillary sinus
13 Central sulcus of insula
14 Superior rectus muscle
15 Periorbita (roof of orbit)
16 Nasociliary nerve
17 Ciliary ganglion
18 **Oculomotor nerve** (n. III)
19 **Trochlear nerve** (n. IV)
20 **Ophthalmic nerve** (n. V_1)
21 **Abducens nerve** (n. VI) (divided)
22 **Trigeminal nerve** (n. V)
23 Trigeminal ganglion
24 **Maxillary nerve** (n. V_2) and foramen rotundum
25 **Mandibular nerve** (n. V_3)
26 External acoustic meatus
27 Pterygopalatine nerves
28 Deep temporal nerves
29 Buccal nerve
30 Masseteric nerve
31 Auriculotemporal nerve
32 Trochlea and superior oblique muscle

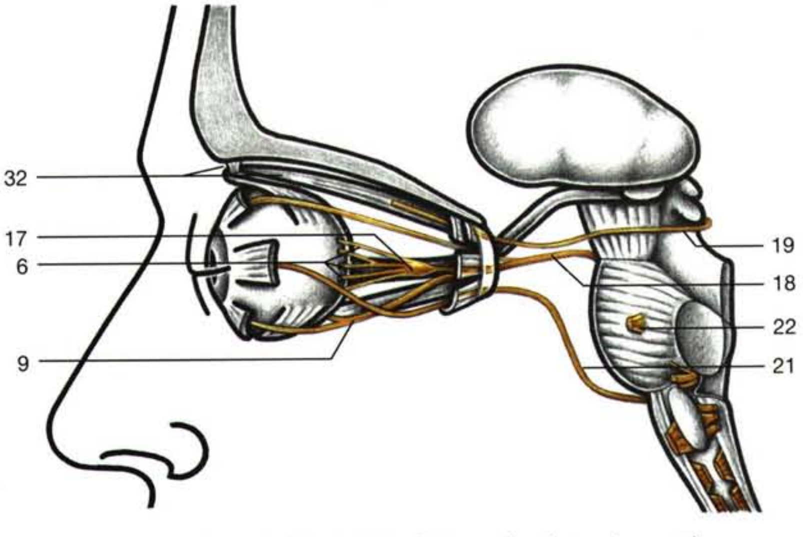

Cranial nerves innervating extraocular muscles (lateral aspect). (Schematic drawing.)

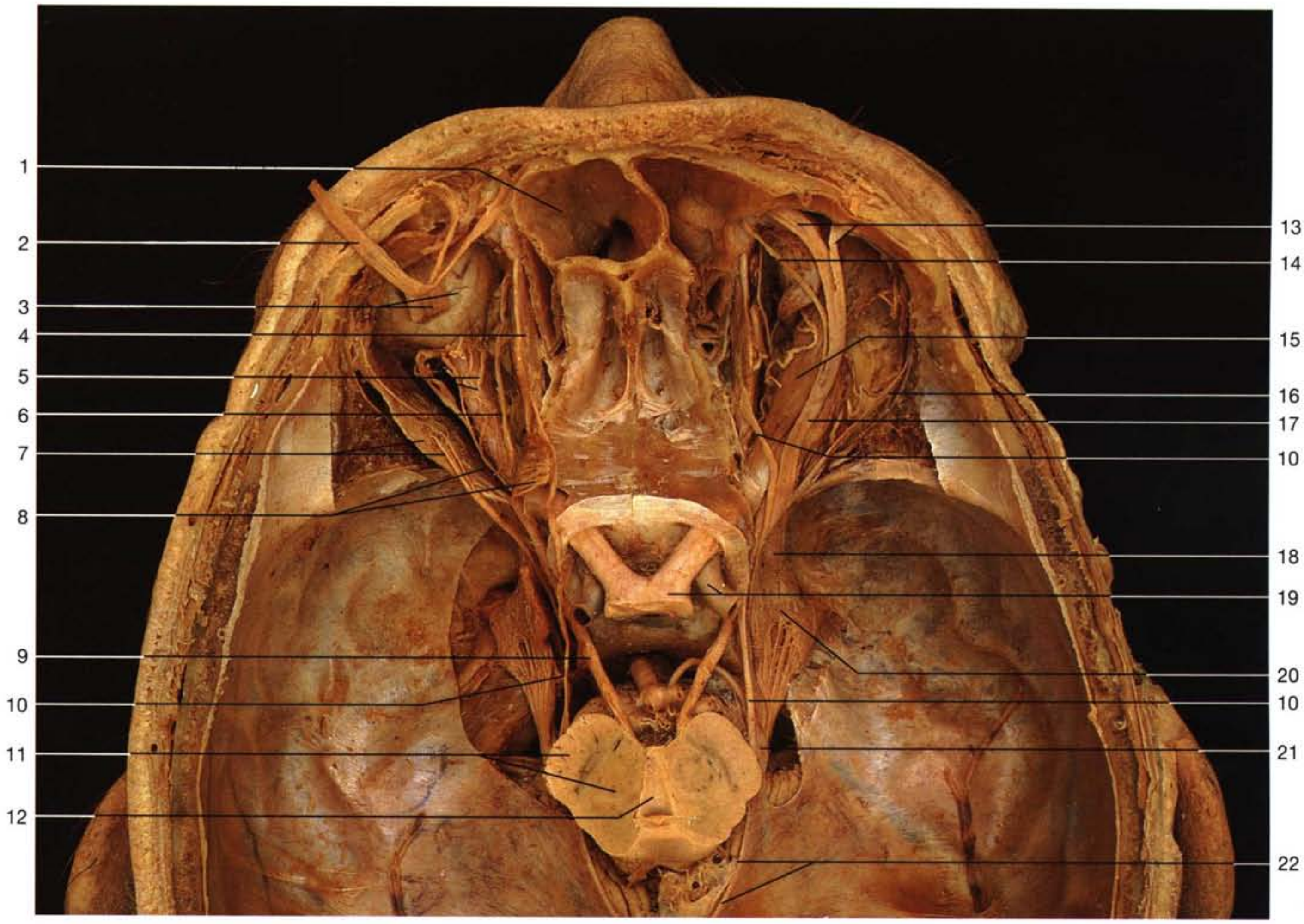

Cranial nerves of the orbit (superior aspect). Right side: superficial layer; left side: middle layer of the orbit (superior rectus muscle and frontal nerve divided and reflected). Tentorium and dura mater partly removed.

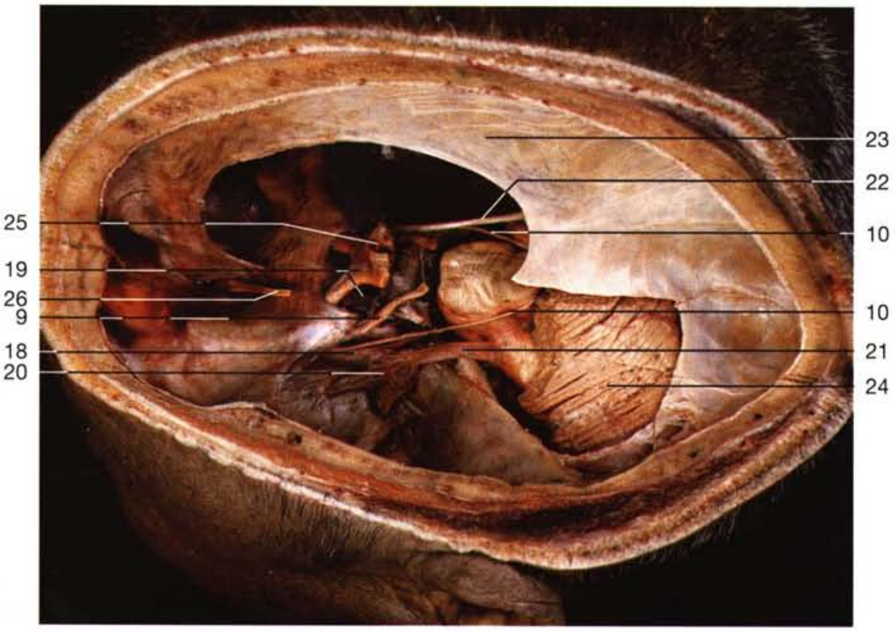

Cranial nerves at the skull base. The brain stem was divided and the tentorium fenestrated. Both hemispheres were removed.

1 Frontal sinus (enlarged)
2 Frontal nerve (divided and reflected)
3 Superior rectus muscle (divided) and eyeball
4 Superior oblique muscle
5 Short ciliary nerves and optic nerve (n. II)
6 Nasociliary nerve
7 **Abducens nerve** (n. VI) and lateral rectus muscle
8 Ciliary ganglion and superior rectus muscle (reflected)
9 **Oculomotor nerve** (n. III)
10 **Trochlear nerve** (n. IV)
11 Crus cerebri and midbrain
12 Inferior wall of the third ventricle connected with cerebral aqueduct
13 Lateral and medial branch of supraorbital nerve
14 Supratrochlear nerve
15 Superior rectus muscle
16 Lacrimal nerve
17 Frontal nerve
18 **Ophthalmic nerve** (n. V1)
19 Optic chiasma and internal carotid artery
20 Trigeminal ganglion
21 **Trigeminal nerve** (n. V)
22 Tentorial notch
23 Falx cerebri
24 Cerebellum
25 Infundibulum
26 Olfactory tract

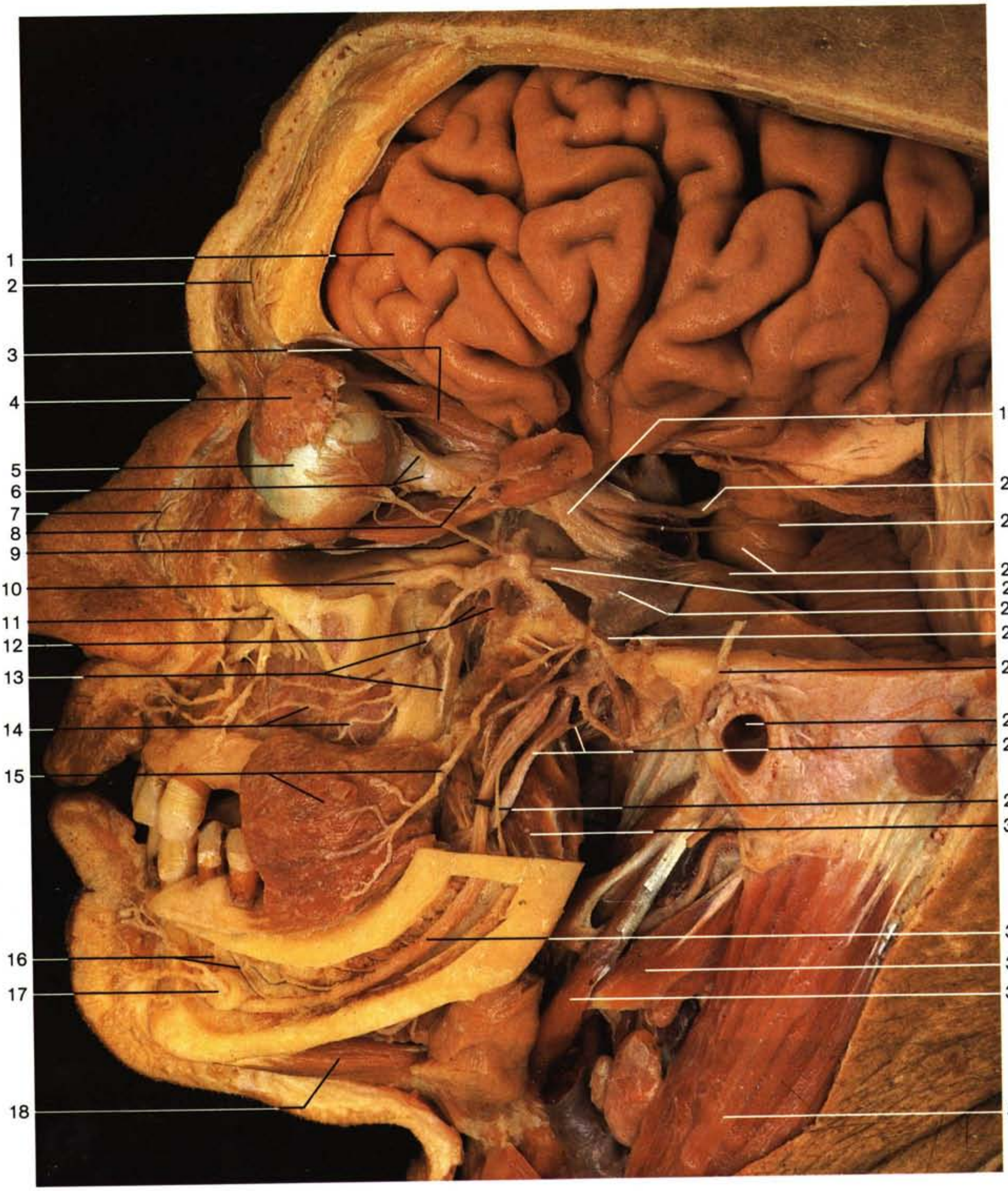

Dissection of the trigeminal nerve in its entirety. Lateral wall of cranial cavity, lateral wall of orbit, zygomatic arch and ramus of the mandible have been removed and the mandibular canal opened.

1 Frontal lobe of cerebrum
2 Supraorbital nerve
3 Lacrimal nerve
4 Lacrimal gland
5 Eyeball
6 **Optic nerve** and short ciliary nerves
7 External nasal branch of anterior ethmoidal nerve
8 Ciliary ganglion
9 Zygomatic nerve
10 Infraorbital nerve
11 Infraorbital foramen and terminal branches of infraorbital nerve
12 Pterygopalatine ganglion and pterygopalatine nerves
13 Posterior superior alveolar nerves
14 Superior dental plexus
15 Buccinator muscle and buccal nerve
16 Inferior dental plexus
17 Mental foramen and mental nerve
18 Anterior belly of digastric muscle
19 **Ophthalmic nerve** (n. V_1)
20 **Oculomotor nerve** (n. III)
21 **Trochlear nerve** (n. IV)
22 Trigeminal nerve and pons
23 **Maxillary nerve** (n. V_2)
24 Trigeminal ganglion
25 **Mandibular nerve** (n. V_3)
26 Auriculotemporal nerve
27 External acoustic meatus (divided)
28 Lingual nerve and chorda tympani
29 Mylohyoid nerve
30 Medial pterygoid muscle
31 Inferior alveolar nerve
32 Posterior belly of digastric muscle
33 Stylohyoid muscle
34 Sternocleidomastoid muscle

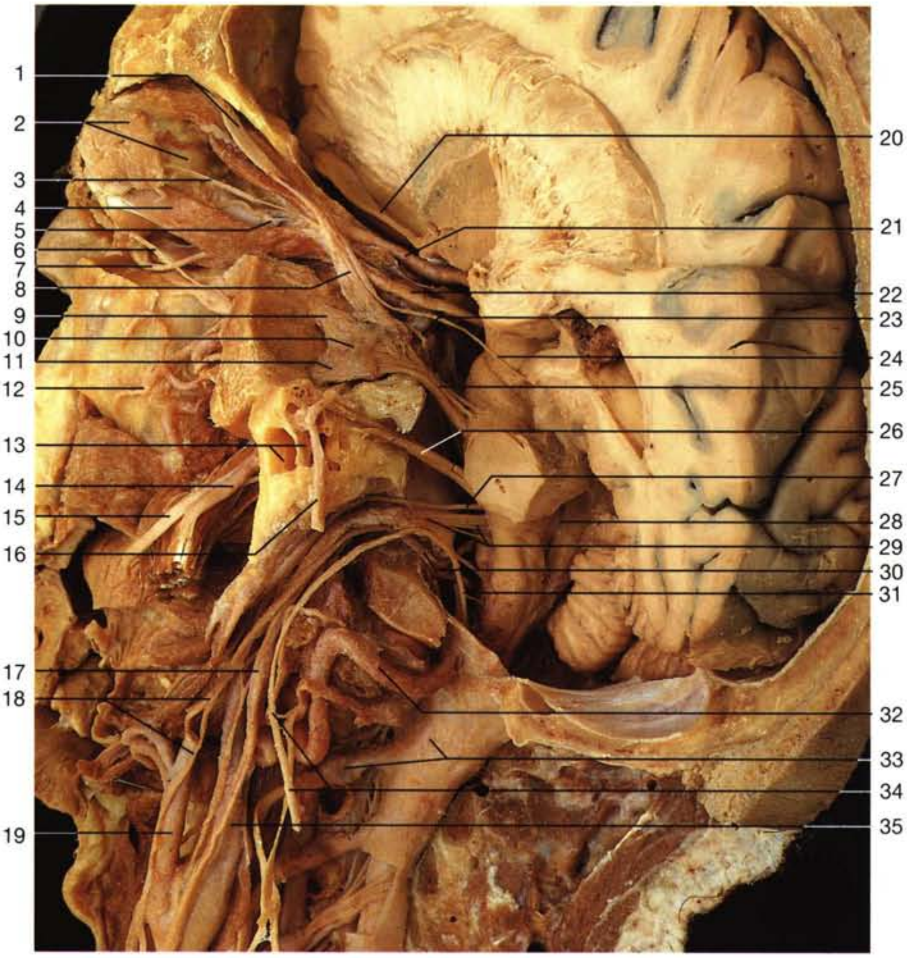

Cranial nerves in connection with the brain stem. Left side (lateral superior aspect). Left half of brain and head partly removed. Notice the location of trigeminal ganglion.

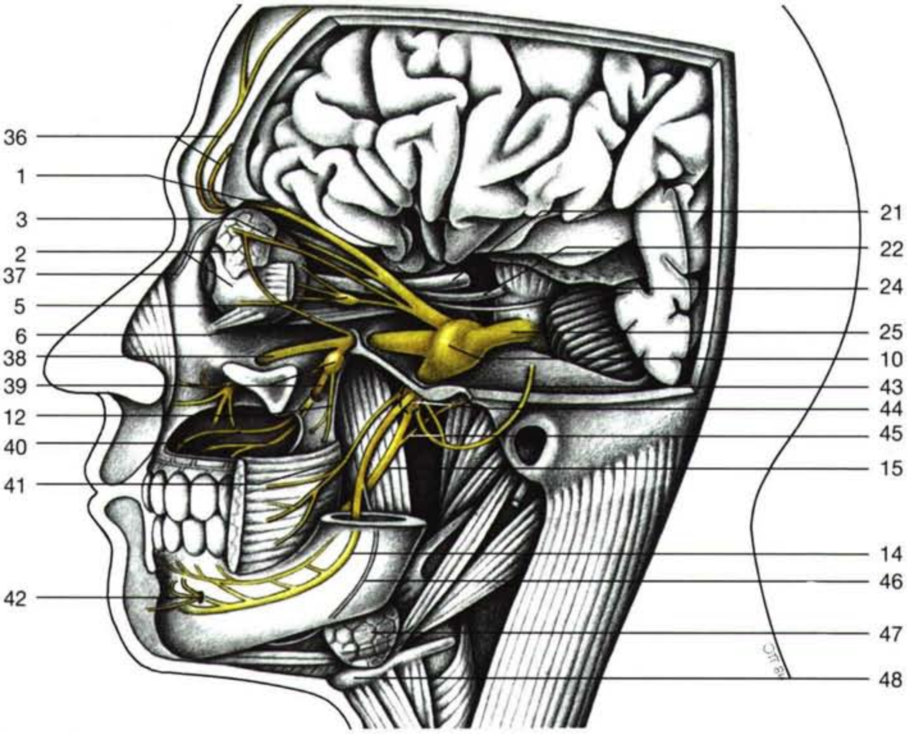

Main branches of trigeminal nerve. (Schematic drawing of figure on opposite page.)

1 Frontal nerve
2 Lacrimal gland and eyeball
3 Lacrimal nerve
4 Lateral rectus muscle
5 **Ciliary ganglion** lateral to optic nerve
6 Zygomatic nerve
7 Inferior branch of oculomotor nerve
8 **Ophthalmic nerve** (n. V_1)
9 **Maxillary nerve** (n. V_2)
10 **Trigeminal ganglion**
11 **Mandibular nerve** (n. V_3)
12 Posterior superior alveolar nerves
13 Tympanic cavity, external acoustic meatus, and tympanic membrane
14 Inferior alveolar nerve
15 Lingual nerve
16 **Facial nerve** (n. VII)
17 **Vagus nerve** (n. X)
18 **Hypoglossal nerve** (n. XII) and superior root of ansa cervicalis
19 External carotid artery
20 **Olfactory tract** (n. I)
21 **Optic nerve** (n. II) (intracranial part)
22 **Oculomotor nerve** (n. III)
23 **Abducens nerve** (n. VI)
24 **Trochlear nerve** (n. IV)
25 **Trigeminal nerve** (n. V)
26 **Vestibulocochlear nerve** (n. VIII) and **facial nerve** (VII)
27 **Glossopharyngeal nerve** (n. IX) (leaving brain stem)
28 Rhomboid fossa
29 **Vagus nerve** (n. X) (leaving brain stem)
30 **Hypoglossal nerve** (n. XII) (leaving medulla oblongata)
31 **Accessory nerve** (n. XI) (ascending from foramen magnum)
32 Vertebral artery
33 Spinal ganglion and dura mater of spinal cord
34 Accessory nerve (n. XI)
35 Internal carotid artery
36 Lateral and medial branch of supraorbital nerve
37 Infratrochlear nerve
38 Infraorbital nerve
39 **Pterygopalatine ganglion** and middle superior alveolar nerve
40 Middle superior alveolar nerves (entering superior dental plexus)
41 Buccal nerve
42 Mental nerve and mental foramen
43 Auriculotemporal nerve
44 Otic ganglion (dotted line)
45 Chorda tympani
46 Mylohyoid nerve
47 Submandibular gland
48 Hyoid bone

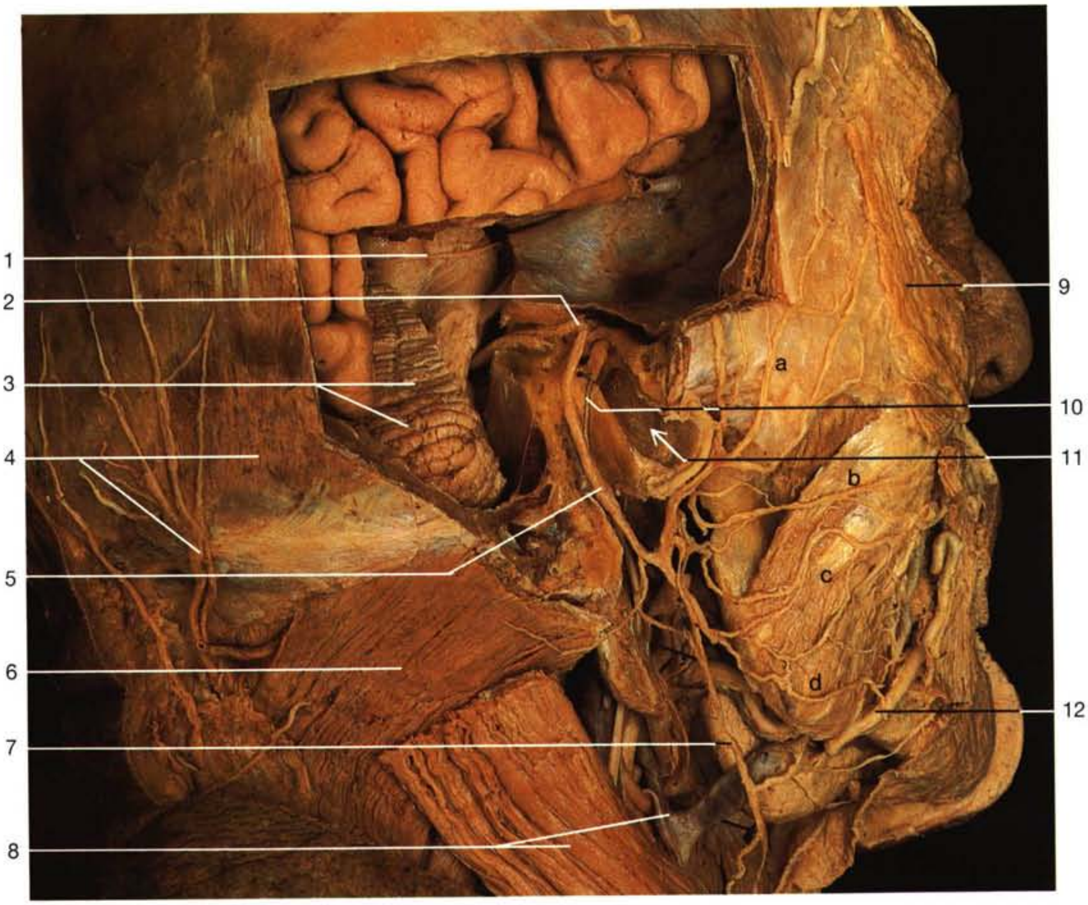

Dissection of facial nerve in its entirety. Cranial cavity fenestrated; temporal lobe partly removed. Facial canal and tympanic cavity opened, posterior wall of external acoustic meatus removed. **Branches of facial nerve:** a = temporal branch; b = zygomatic branches; c = buccal branches; d = marginal mandibular branch.

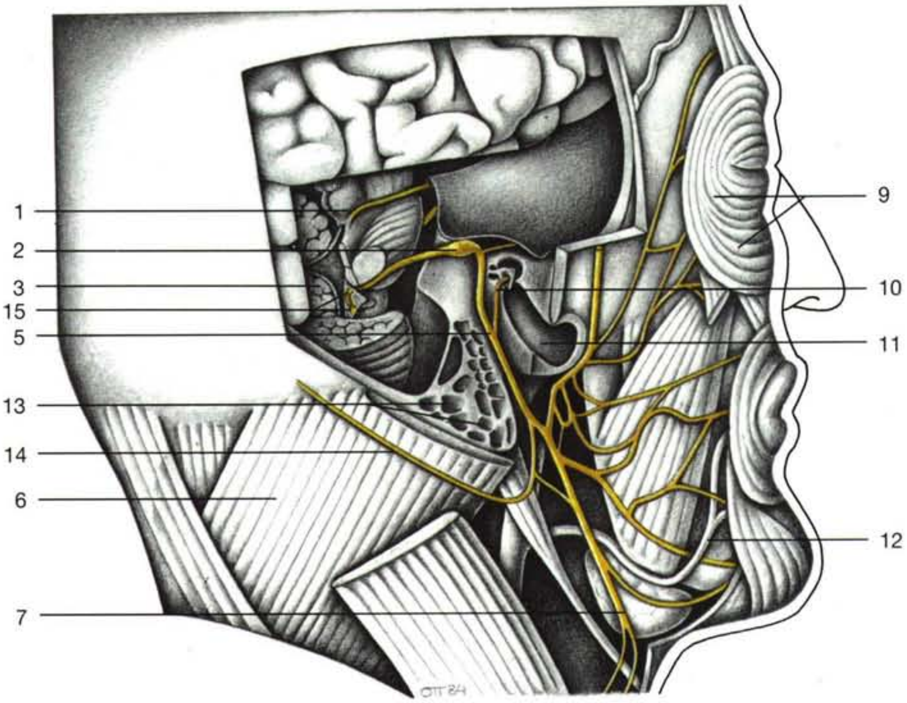

Facial nerve. (Schematic drawing of the dissection above.)

1 Trochlear nerve
2 Facial nerve with geniculate ganglion
3 Cerebellum (right hemisphere)
4 Occipital belly of occipitofrontalis and greater occipital nerve
5 Facial nerve at stylomastoid foramen
6 Splenius capitis muscle
7 Cervical branch of facial nerve
8 Sternocleidomastoid muscle and retromandibular vein
9 Orbicularis oculi muscle
10 Chorda tympani
11 External acoustic meatus
12 Facial artery
13 Mastoid air cells
14 Posterior auricular nerve
15 Nucleus and genu of facial nerve

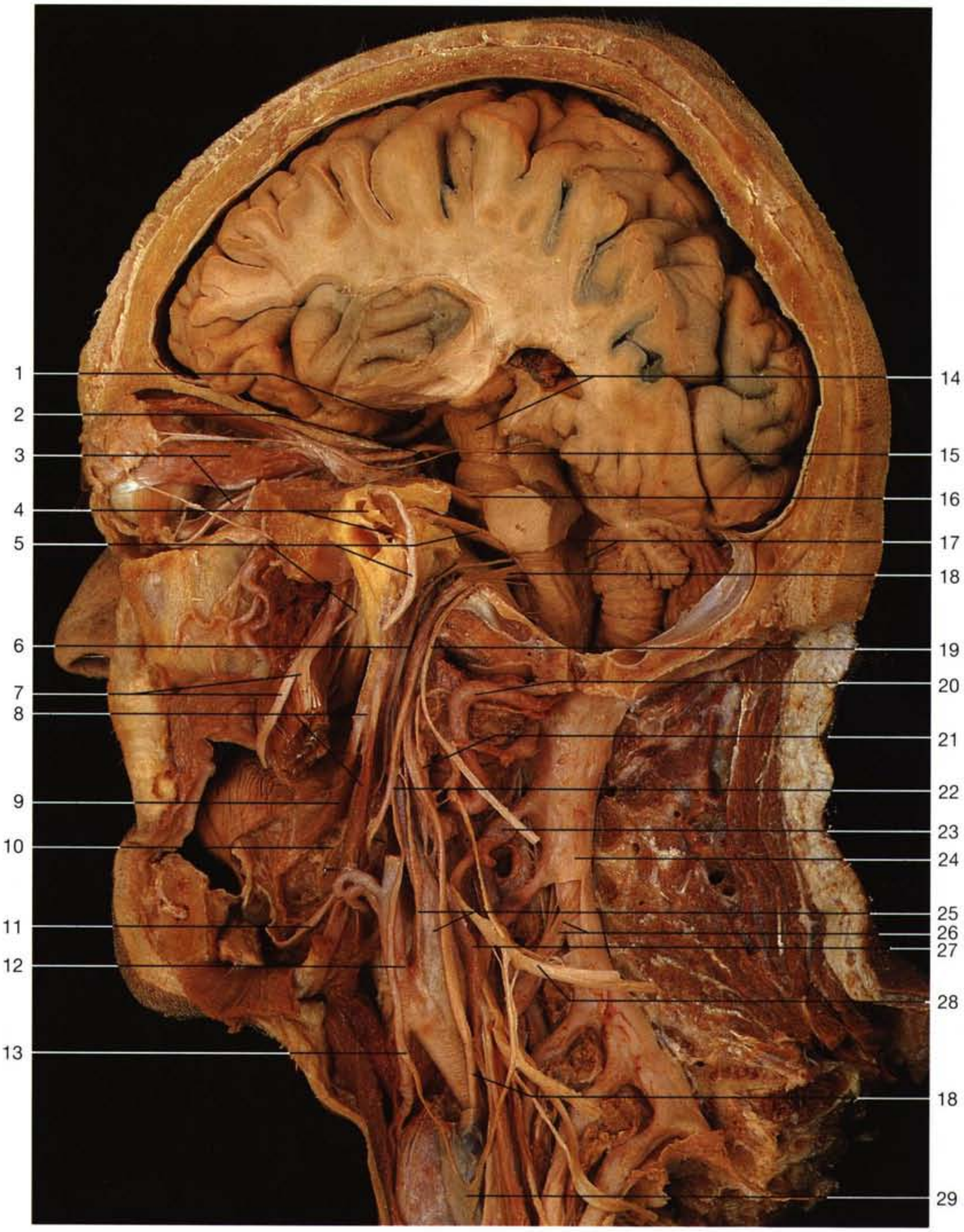

Cranial nerves in connection with the brain stem (oblique-lateral aspect). Lateral portion of the skull, brain, neck and facial structures, lateral wall of orbit and oral cavity have been removed. The tympanic cavity has been opened. The mandible has been divided and the muscles of mastication have been removed.

1 Optic tract
2 **Oculomotor nerve** (n. III)
3 Lateral rectus muscle and inferior branch of oculomotor nerve
4 Malleus and chorda tympani
5 Chorda tympani, **facial nerve** (n. VII), and **vestibulocochlear nerve** (n. VIII)
6 **Glossopharyngeal nerve** (n. XI)
7 Lingual nerve and inferior alveolar nerve
8 Styloid process and stylohyoid muscle
9 Styloglossus muscle
10 Lingual branches of glossopharyngeal nerve
11 Lingual branch of hypoglossal nerve
12 External carotid artery
13 Superior root of ansa cervicalis (branch of hypoglossal nerve)
14 Lateral ventricle with choroid plexus and cerebral peduncle
15 **Trochlear nerve** (n. IV)
16 **Trigeminal nerve** (n. V)
17 Fourth ventricle and rhomboid fossa
18 **Vagus nerve** (n. X)
19 **Accessory nerve** (n. XI)
20 Vertebral artery
21 Superior cervical ganglion
22 **Hypoglossal nerve** (n. XII)
23 Spinal ganglion with dural sheath
24 Dura mater of spinal cord
25 Internal carotid artery and carotid sinus branch of glossopharyngeal nerve
26 Dorsal roots of spinal nerve
27 Sympathetic trunk
28 Branch of cervical plexus (ventral primary ramus of third cervical spinal nerve)
29 Ansa cervicalis

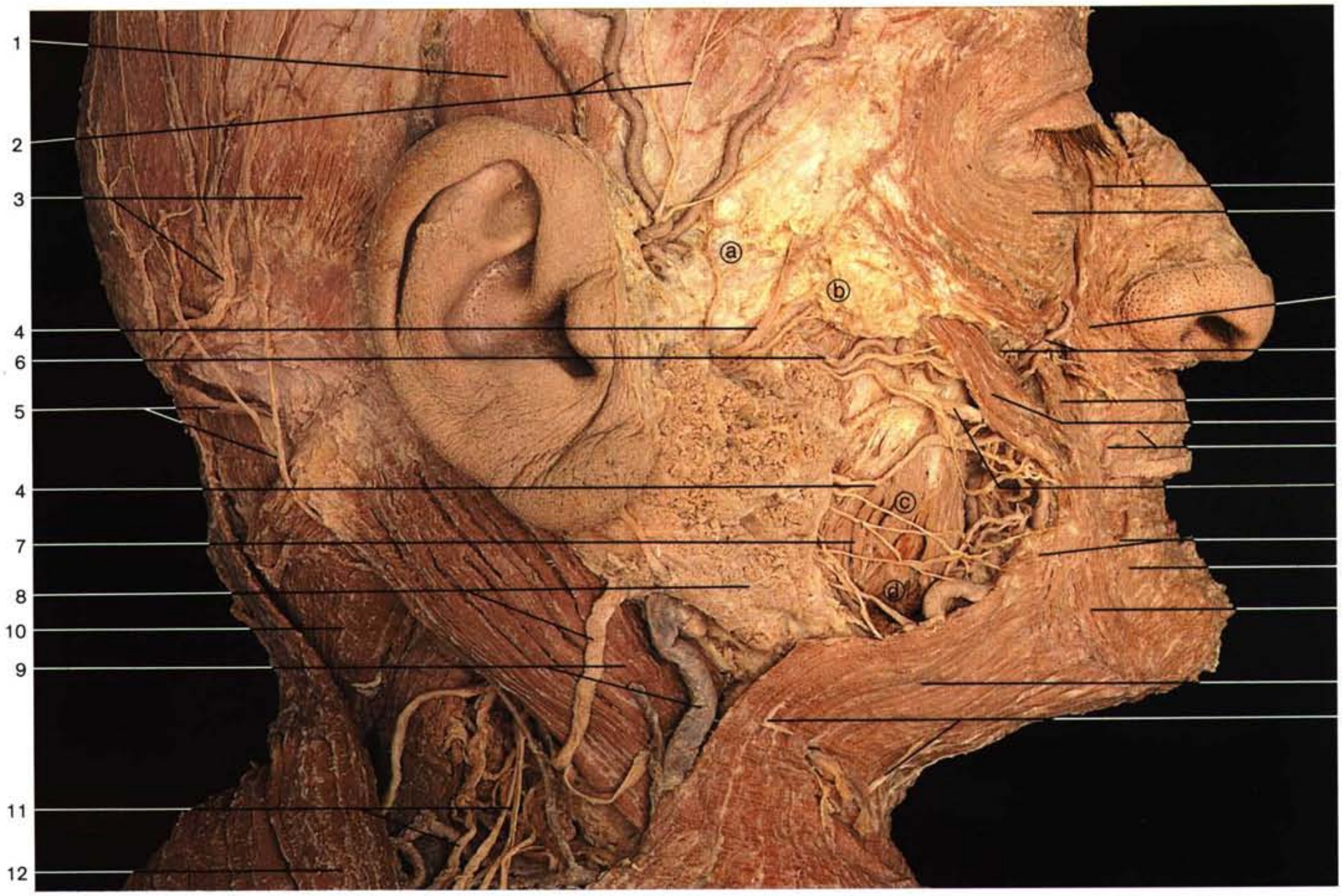

Lateral superficial aspect of the face. Peripheral distribution of facial nerve. a–d = branches of facial nerve: a = temporal branch; b = zygomatic branches; c = buccal branches; d = marginal mandibular branch.

1 Temporoparietalis muscle
2 Parietal branch of **superficial temporal artery** and **vein** and **auriculotemporal nerve**
3 Occipital belly of occipitofrontalis muscle and greater occipital nerve
4 **Facial nerve**
5 Lesser occipital nerve and **occipital artery**
6 Transverse facial artery
7 Masseter muscle
8 **Parotid gland** and great auricular nerve
9 Sternocleidomastoid muscle and external jugular vein
10 Splenius capitis muscle
11 Branches of cervical plexus
12 Trapezius muscle
13 Angular artery (terminal portion of facial artery)
14 Orbicularis oculi muscle
15 Levator labii superioris alaeque nasi muscle
16 **Facial artery** and zygomaticus minor muscle
17 Levator anguli oris muscle
18 Zygomaticus major muscle
19 Orbicularis oris muscle and superior labial artery
20 Parotid duct
21 Risorius muscle and inferior labial artery

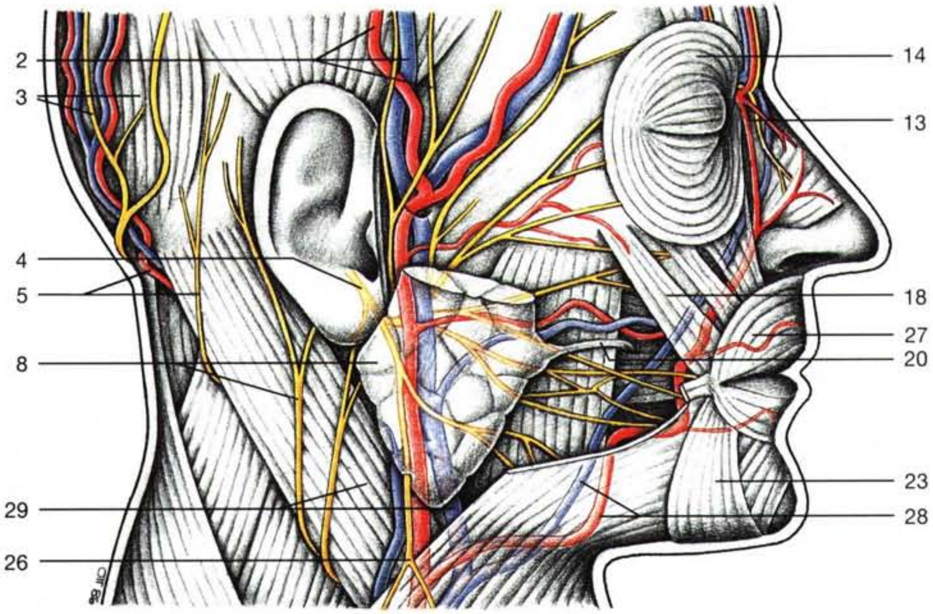

Superficial region of the face. Note the facial plexus within the parotid gland. (Semischematic drawing.)

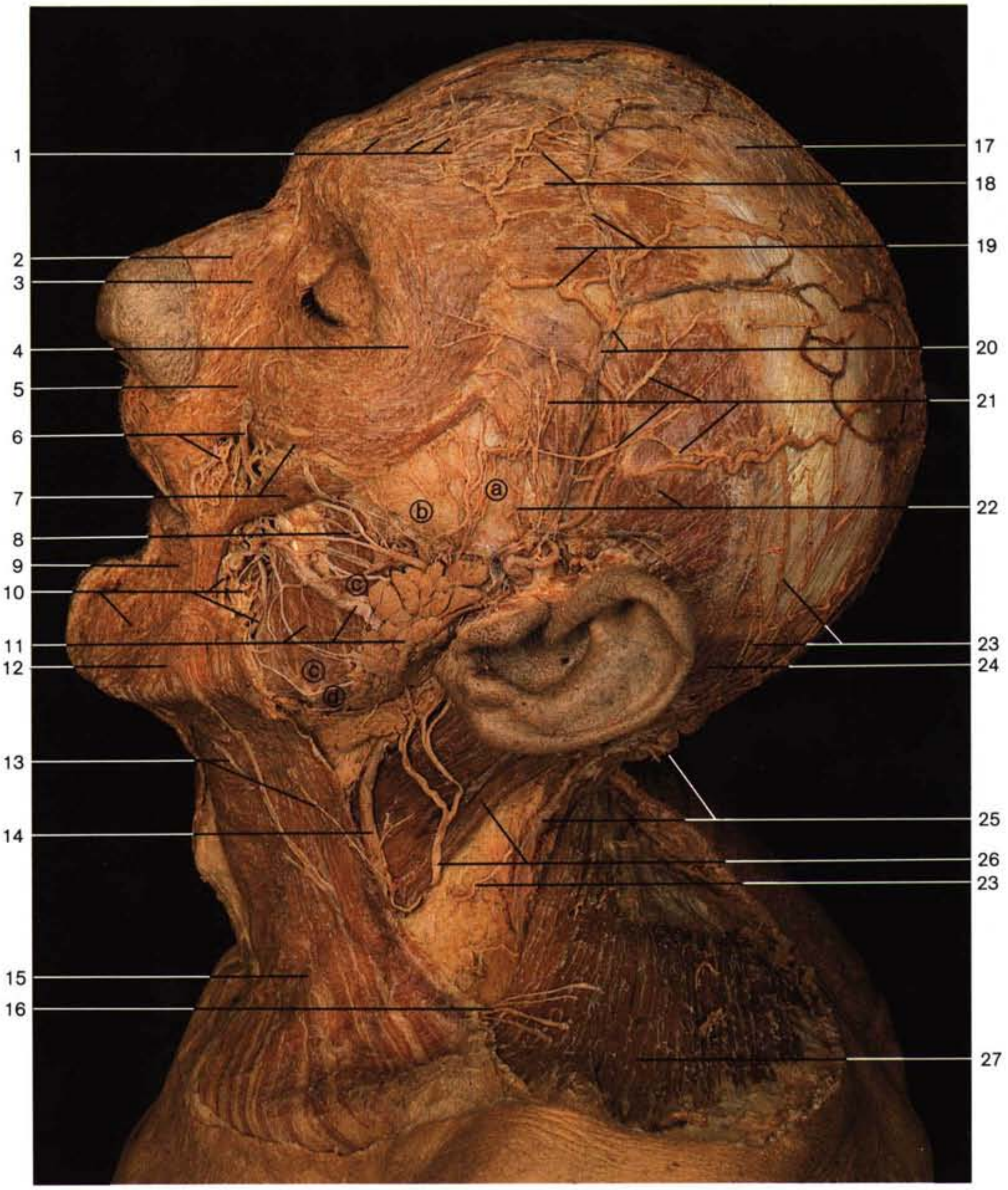

Superficial layer of the head and neck. Parotid fascia removed. Branches of **facial nerve:** a = temporal branch; b = zygomatic branches; c = buccal branches; d = marginal mandibular branch.

1 Medial branch of supraorbital nerve
2 Nasalis muscle
3 Levator labii superioris alaeque nasi muscle
4 **Orbicularis oculi muscle**
5 Levator labii superioris muscle
6 **Facial artery and vein**
7 Zygomaticus minor and major muscle
8 Transverse facial artery
9 **Orbicularis oris muscle**
10 Buccal nerves, depressor labii inferioris muscle, **facial artery** and **vein**
11 **Parotid gland** and duct and masseter muscle
12 Depressor anguli oris muscle
13 Transverse cervical nerve
14 External jugular vein
15 **Platysma muscle**
16 Supraclavicular nerve
17 Galea aponeurotica
18 Lateral branches of the supraorbital nerve
19 Frontal belly of occipitofrontalis muscle and branches of superficial temporal vein and artery
20 Superficial temporal artery and vein
21 **Auriculotemporal nerve**
22 Zygomatico-orbital artery and temporoparietalis muscle
23 Lesser occipital nerve
24 Occipital belly of occipitofrontalis muscle
25 Occipital vein and occipital artery
26 **Great auricular nerve** and sternocleidomastoid muscle
27 Trapezius muscle
28 Greater petrosal nerve
29 Geniculate ganglion
30 Chorda tympani
31 Posterior auricular nerve
32 Stylomastoid foramen

◁ **to page 76**
22 Depressor labii inferioris muscle
23 Depressor anguli oris muscle
24 Platysma muscle
25 Terminal branches of transverse cervical nerve
26 Cervical branch of facial nerve
27 Orbicularis oris muscle
28 **Facial artery** and **vein**
29 Sternocleidomastoid muscle and retromandibular vein

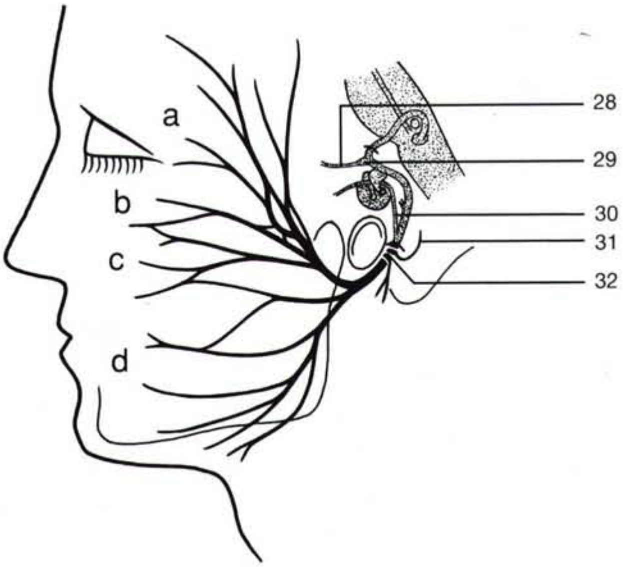

Facial nerve. Main branches. (Schematic diagram.)

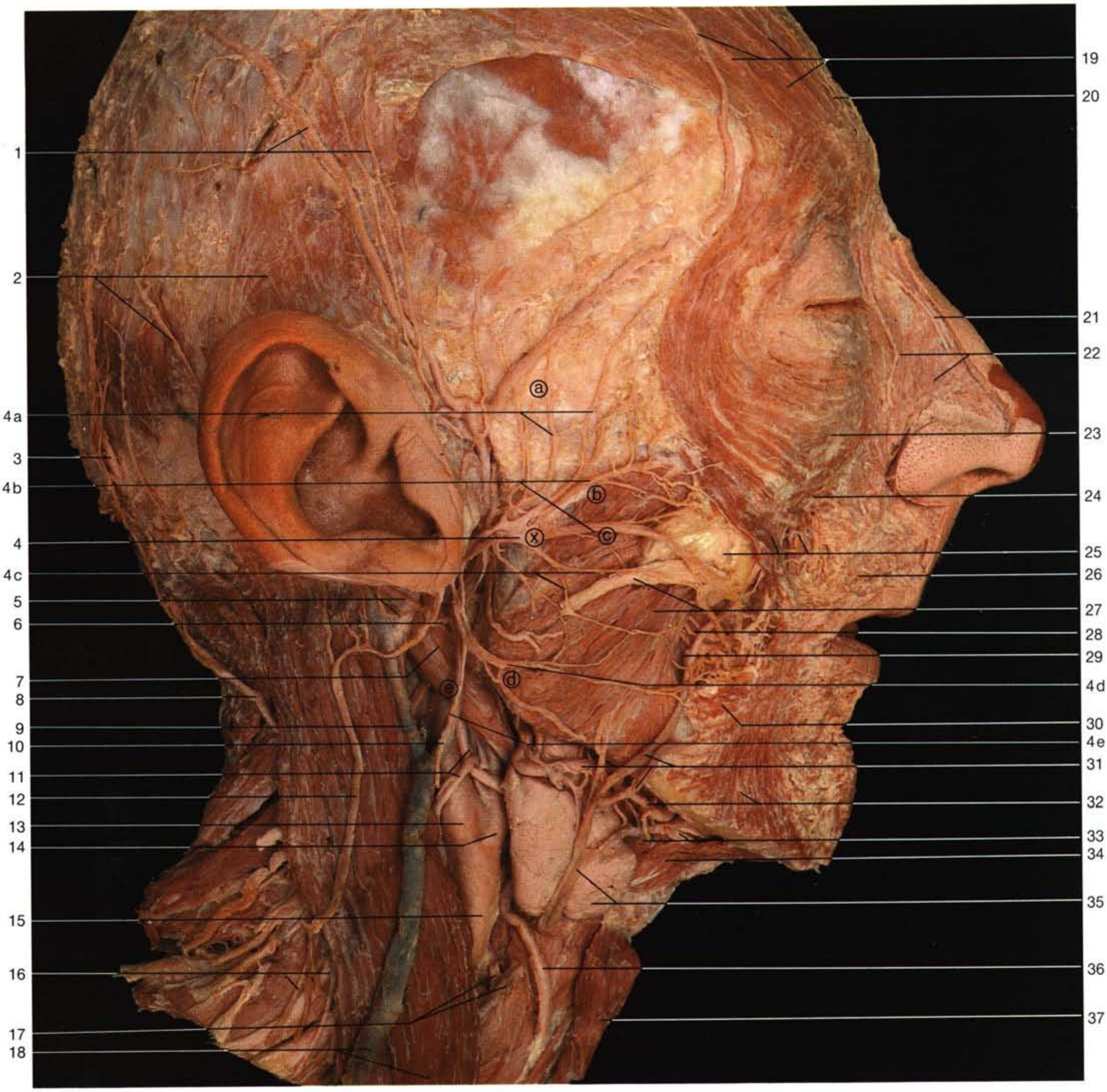

Lateral superficial aspect of the face. The parotid gland has been removed to display the parotid plexus of the facial nerve. a–e = branches of facial nerve: a = temporal branch; b = zygomatic branches; c = buccal branches; d = marginal mandibular branch; e = cervical branch.

1 Superficial temporal artery and auriculotemporal nerve
2 Posterior auricular artery and nerve and temporoparietalis muscle
3 Occipital artery
4 **Facial nerve** (n. VII) (**parotid plexus** [×])
  a Temporal branches
  b Zygomatic branches
  c Buccal branches
  d Marginal mandibular branch
  e Cervical branch
5 Posterior auricular nerve
6 Posterior auricular artery
7 Digastric muscle (posterior belly)
8 **Lesser occipital nerve**
9 Posterior auricular vein
10 Retromandibular vein
11 **Hypoglossal nerve** and sternocleidomastoid artery
12 **Great auricular nerve**
13 Internal carotid artery
14 External carotid artery
15 Common carotid artery
16 Branches of cervical plexus
17 Superior laryngeal artery and vein
18 External jugular vein and sternocleidomastoid muscle
19 Frontal branch of superficial temporal artery, lateral branch of supraorbital nerve, and frontal belly of occipitofrontalis muscle
20 Medial branch of supraorbital nerve
21 Dorsal nasal artery
22 Angular artery and nasalis muscle
23 **Orbicularis oculi muscle**
24 Zygomaticus minor muscle
25 Buccal fat pad, zygomaticus major muscle, and infraorbital nerve
26 **Orbicularis oris muscle**
27 **Parotid duct** and **masseter muscle**
28 Buccal artery and nerve
29 Buccinator muscle
30 Risorius muscle
31 **Facial artery** and **vein**
32 Submental artery and depressor anguli oris muscle
33 Mylohyoid nerve and mylohyoid muscle
34 Digastric muscle (anterior belly)
35 Facial vein and submandibular gland
36 **Superior thyroid artery**
37 Sternohyoid muscle

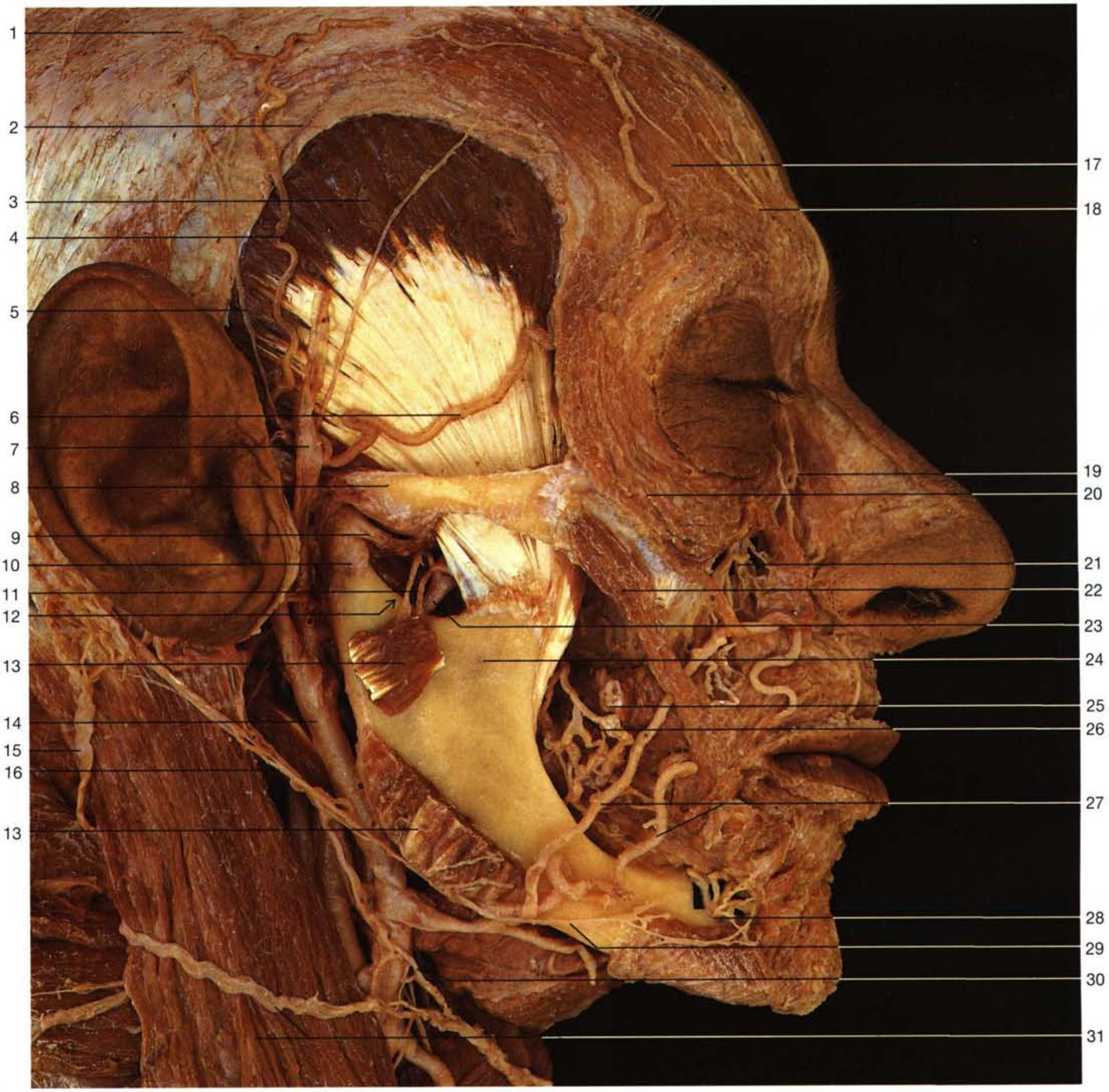

Lateral superficial aspect of the face. Masseter muscle and temporal fascia have been partly removed to display the masseteric artery and nerve.

1 Galea aponeurotica
2 Temporal fascia
3 **Temporalis muscle**
4 Parietal branch of **superficial temporal artery**
5 **Auriculotemporal nerve**
6 Frontal branch of superficial temporal artery
7 Superficial temporal vein
8 **Zygomatic arch**
9 **Articular disc of temporomandibular joint**
10 **Head of mandible**
11 Masseteric artery and nerve
12 Mandibular notch
13 Masseter muscle (divided)
14 **External carotid artery**
15 Great auricular nerve
16 Facial nerve (reflected)
17 Frontal belly of occipitofrontalis muscle
18 Medial branch of supraorbital nerve
19 **Angular artery**
20 Orbicularis oculi muscle
21 **Infraorbital nerve**
22 Zygomaticus major muscle
23 **Maxillar artery**
24 **Coronoid process**
25 Parotid duct (divided)
26 Buccal nerve
27 **Facial artery** and **vein**
28 **Mental nerve**
29 Mandibular branch of facial nerve
30 Cervical branch of facial nerve
31 Transverse cervical nerve (communicating branch with facial nerve) and sternocleidomastoid muscle

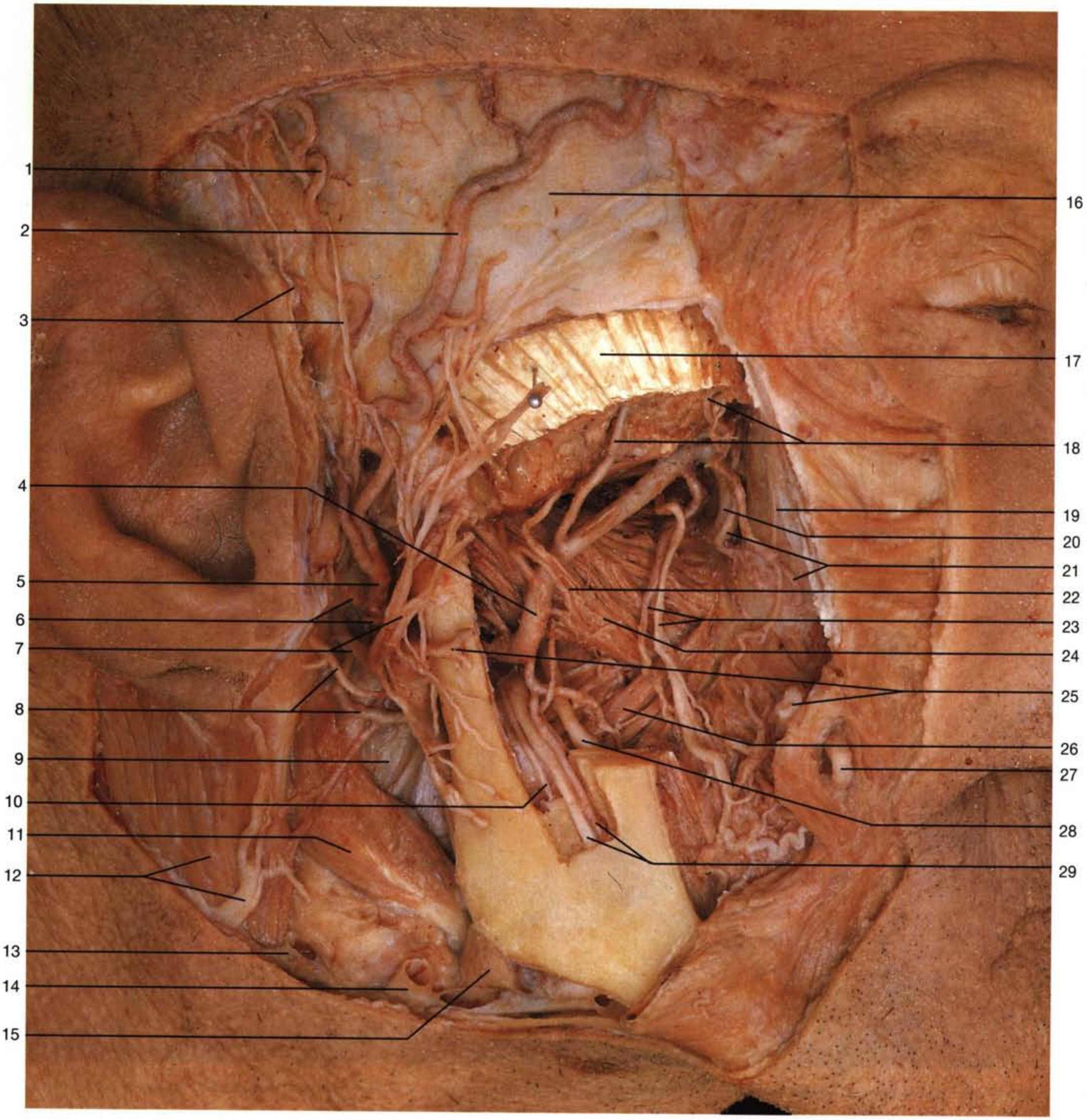

Deep dissection of facial and retromandibular regions. The coronoid process together with the insertions of temporalis muscle have been removed to display the maxillary artery. The upper part of the mandibular canal has been opened.

1 Parietal branch of the superficial temporal artery
2 Frontal branch of the superficial temporal artery
3 Auriculotemporal nerve
4 **Maxillary artery**
5 **Superficial temporal artery**
6 Communicating branches between facial and auriculotemporal nerves
7 **Facial nerve**
8 Posterior auricular artery and anterior auricular branch of superficial temporal artery
9 Internal jugular vein
10 Mylohyoid nerve
11 Posterior belly of digastric muscle
12 Great auricular nerve and sternocleidomastoid
13 External jugular vein
14 Retromandibular vein
15 Submandibular gland
16 Temporal fascia
17 **Temporalis tendon**
18 Deep temporal arteries
19 Posterior superior alveolar nerve
20 Sphenopalatine artery
21 Posterior superior alveolar arteries
22 Masseteric artery and nerve
23 **Buccal nerve and artery**
24 **Lateral pterygoid**
25 Transverse facial artery and parotid duct (divided)
26 Medial pterygoid
27 **Facial artery**
28 **Lingual nerve**
29 **Inferior alveolar artery and nerve** (mandibular canal opened)

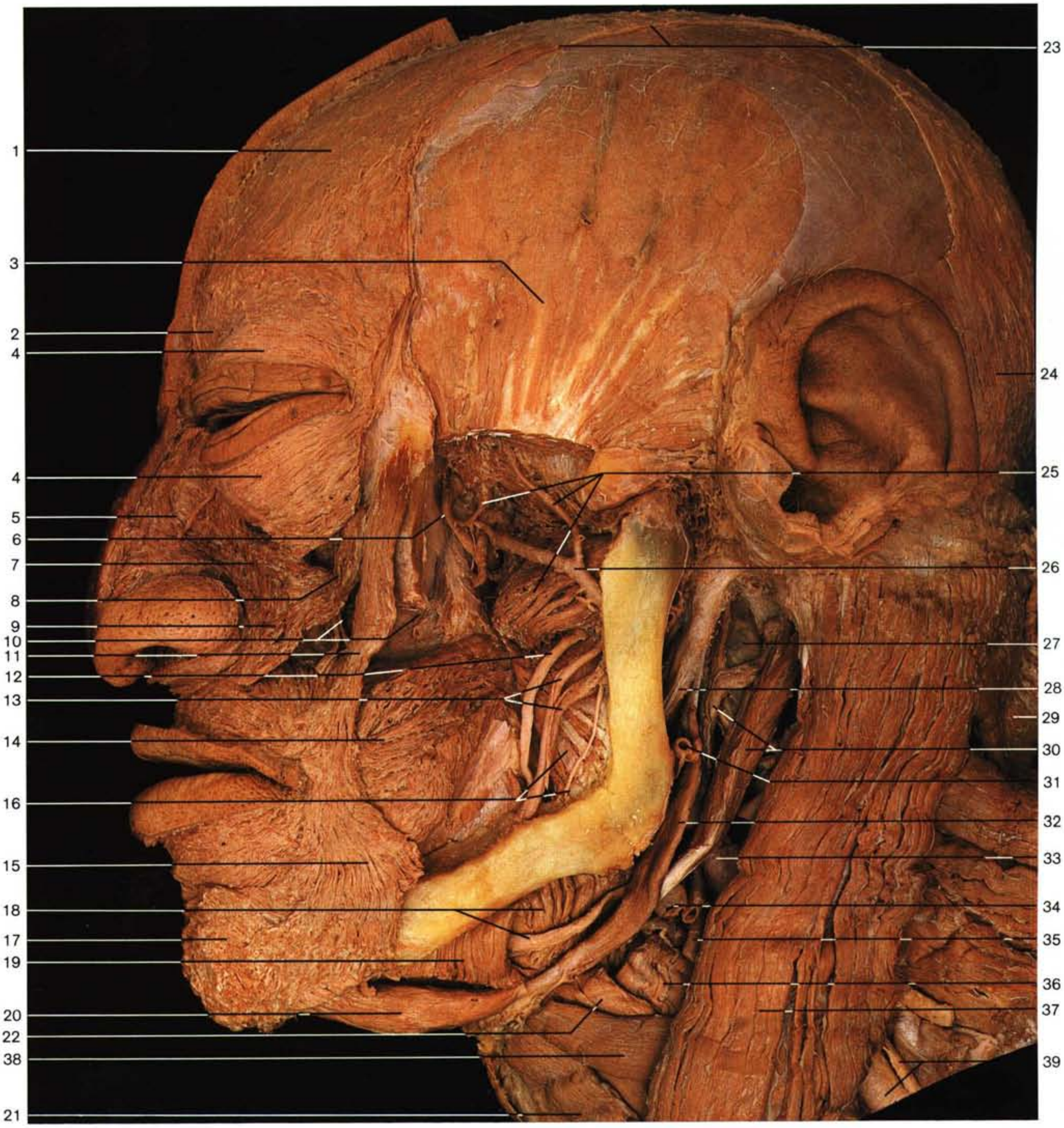

Retromandibular region with maxillary artery and branches of trigeminal nerve (n. V).

1	Frontal belly of occipitofrontalis muscle
2	Depressor supercilii muscle
3	Temporalis muscle
4	**Orbicularis oculi muscle**
5	Nasalis muscle
6	Infraorbital artery
7	Levator labii superioris alaeque nasi muscle
8	Zygomaticus minor muscle
9	Levator labii superioris muscle
10	Infraorbital artery and nerve and posterior superior alveolar artery
11	**Zygomaticus major muscle**
12	**Lingual nerve**
13	**Inferior alveolar artery and nerve**
14	Buccinator muscle
15	Depressor anguli oris muscle
16	**Medial pterygoid muscle** and **mylohyoid nerve**
17	Depressor labii inferioris muscle
18	**Hypoglossal nerve** and **hyoglossus muscle**
19	Mylohyoid muscle
20	Anterior belly of diagastric muscle
21	Sternohyoid muscle
22	Thyrohyoid muscle
23	Galea aponeurotica
24	Occipital belly of occipitofrontalis muscle
25	**Lateral pterygoid muscle** and deep temporal artery
26	**Maxillary artery**
27	Internal jugular vein
28	Styloglossus muscle
29	Splenius capitis muscle
30	Posterior belly of diagastric muscle and occipital artery
31	Superficial temporal artery
32	**Stylohyoid muscle**
33	External carotid artery
34	Retromandibular vein
35	Superior thyroid artery
36	Inferior constrictor muscle of the pharynx
37	Sternocleidomastoid muscle
38	Omohyoid muscle
39	Common carotid artery and vagus nerve

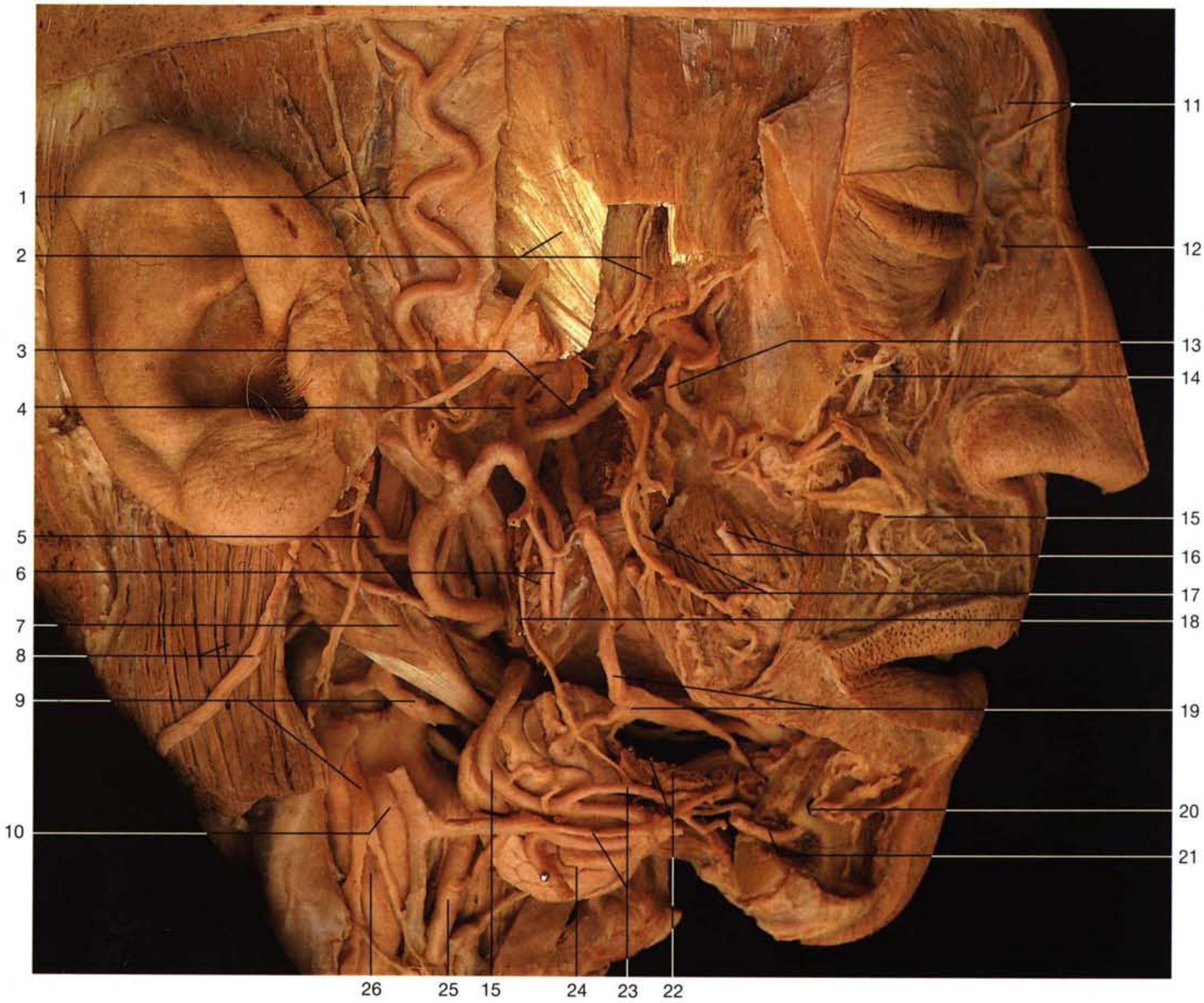

Dissection of deep facial and retromandibular regions after removal of mandible. Pterygoid muscles removed, temporalis muscle fenestrated.

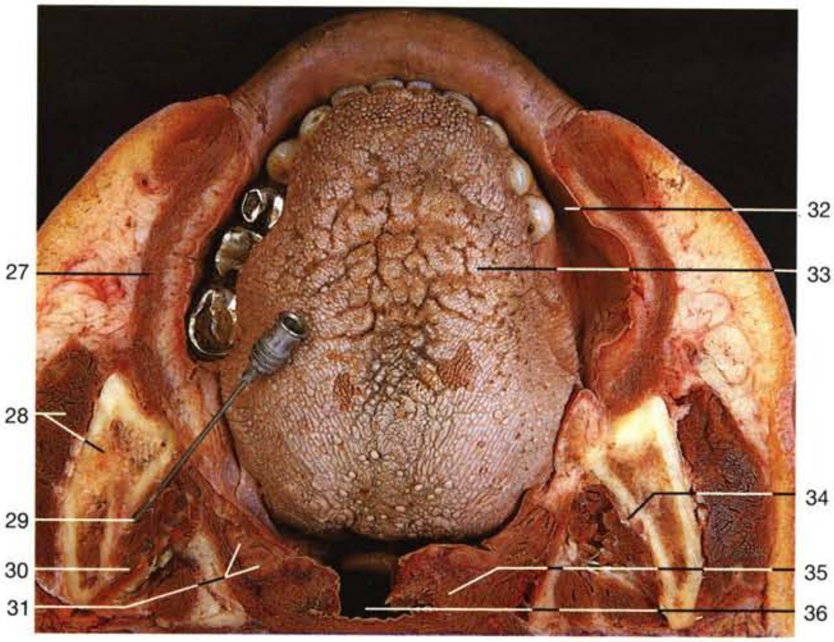

Transverse section through oral cavity and pharynx. The location of inferior alveolar nerve and artery is indicated by a needle.

1 Superficial temporal artery and vein and auriculotemporal nerve
2 Temporalis tendon, deep temporal nerves and artery
3 **Maxillary artery**
4 Middle meningeal artery
5 Occipital artery
6 Inferior alveolar artery and nerve
7 Posterior belly of digastric muscle
8 Great auricular nerve and sternocleidomastoid muscle
9 Hypoglossal nerve and superior root of ansa cervicalis
10 **External carotid artery**
11 Supratrochlear nerve and medial branch of supraorbital artery
12 Angular artery
13 Posterior superior alveolar artery
14 Infraorbital nerve
15 **Facial artery**
16 Parotid duct (divided) and buccinator muscle
17 Buccal artery and nerve

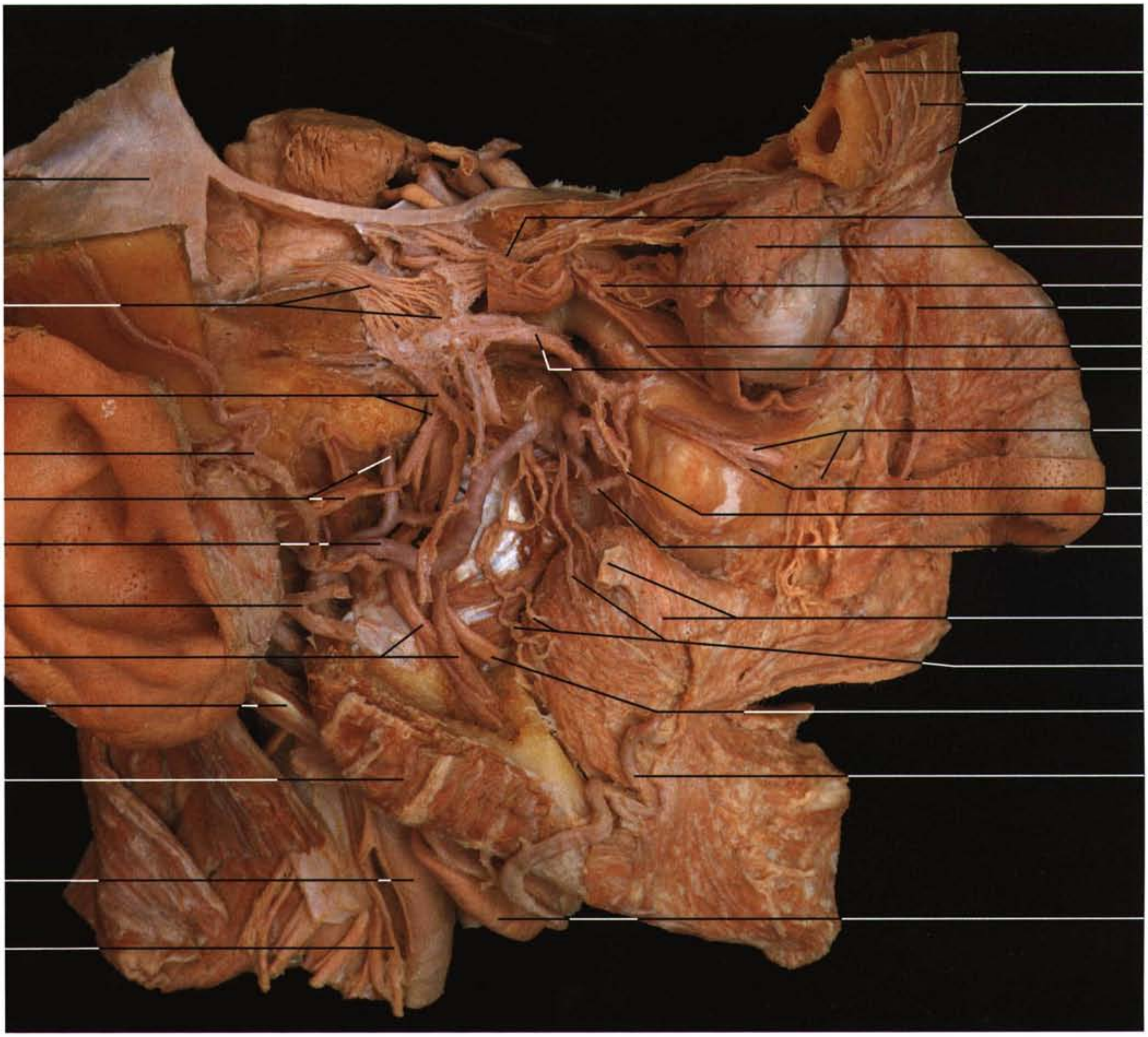

Para- and retropharyngeal regions. The mandible and the lateral wall of the orbit have been removed. The main branches of the trigeminal nerve and its ganglion are displayed.

18 Mylohyoid nerve
19 **Lingual nerve** and **submandibular ganglion**
20 Mental nerve and mental foramen
21 Inferior alveolar nerve
22 Mylohyoid muscle (divided) and hypoglossal nerve
23 Submental artery and vein
24 Submandibular gland
25 Superior thyroid artery
26 Common carotid artery
27 Buccinator muscle
28 Masseter muscle and mandible
29 Entrance of mandibular canal
30 Medial pterygoid muscle
31 Palatine tonsil
32 Oral vestibule
33 Tongue
34 Inferior alveolar nerve, artery and vein
35 Paryngeal constrictor muscle

36 Pharynx
37 Tentorium of cerebellum
38 **Trigeminal nerve** and **ganglion**
39 **Mandibular nerve**
40 Superficial temporal artery
41 Auriculotemporal nerve and middle meningeal artery
42 Facial nerve (divided)
43 Masseter muscle
44 Superior root of ansa cervicalis
45 Lateral branch of supraorbital nerve
46 **Ophthalmic nerve**
47 Lacrimal gland
48 Ciliary ganglion and short ciliary nerves
49 Angular artery
50 Inferior branch of oculomotor nerve
51 **Maxillary nerve**
52 Infraorbital nerve
53 Anterior superior alveolar nerve
54 Posterior superior alveolar nerve

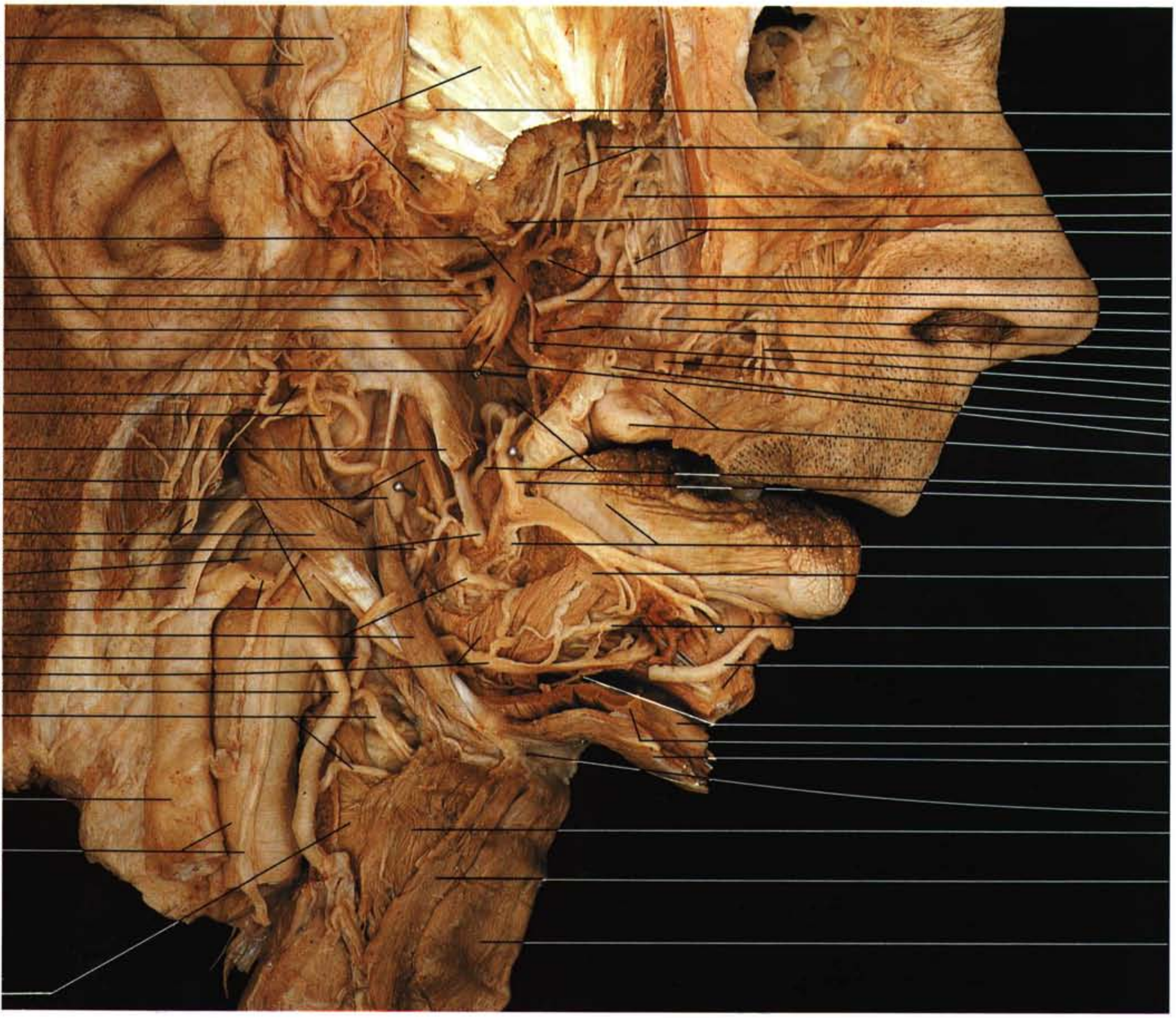

Retropharyngeal and sublingual regions. The mandible has been completely removed.

1 Parietal branch of superficial temporal artery
2 Auriculotemporal nerve
3 Temporalis muscle tendon and zygomatic arch (cut)
4 Mandibular nerve (n. V_3)
5 Middle meningeal artery
6 Chorda tympani
7 Mylohyoid nerve
8 Inferior alveolar nerve
9 **Lingual nerve**
10 Posterior auricular artery
11 Facial nerve
12 Styloglossus muscle (cut)
13 Great auricular nerve
14 Maxillary artery, external carotid artery, and stylopharyngeus muscle
15 Posterior belly of digastric muscle
16 Styloid process and facial artery
17 Vagus nerve (n. X)
18 **Accessory nerve** (n. XI)
19 Hypoglossal nerve (n. XII) and retromandibular vein (cut)
20 Stylohyoid muscle and glossopharyngeal nerve (n. IX)
21 Facial vein
22 Hypoglossal nerve (n. XII) and hyoglossus muscle
23 Superior thyroid artery
24 Superior laryngeal artery and internal laryngeal nerve
25 Internal jugular vein
26 Common carotid artery and superior root of ansa cervicalis
27 Inferior pharyngeal constrictor muscle
28 Middle temporal artery
29 Deep temporal nerves and posterior deep temporal artery
30 Anterior deep temporal artery
31 Masseteric nerve
32 Posterior superior alveolar branches of maxillary artery and nerve
33 Pterygoid branches of mandibular nerve
34 Posterior superior alveolar artery
35 Lateral pterygoid plate and medial pterygoid muscle
36 Infraorbital nerve and artery
37 Buccal nerve
38 Facial artery
39 Parotid duct

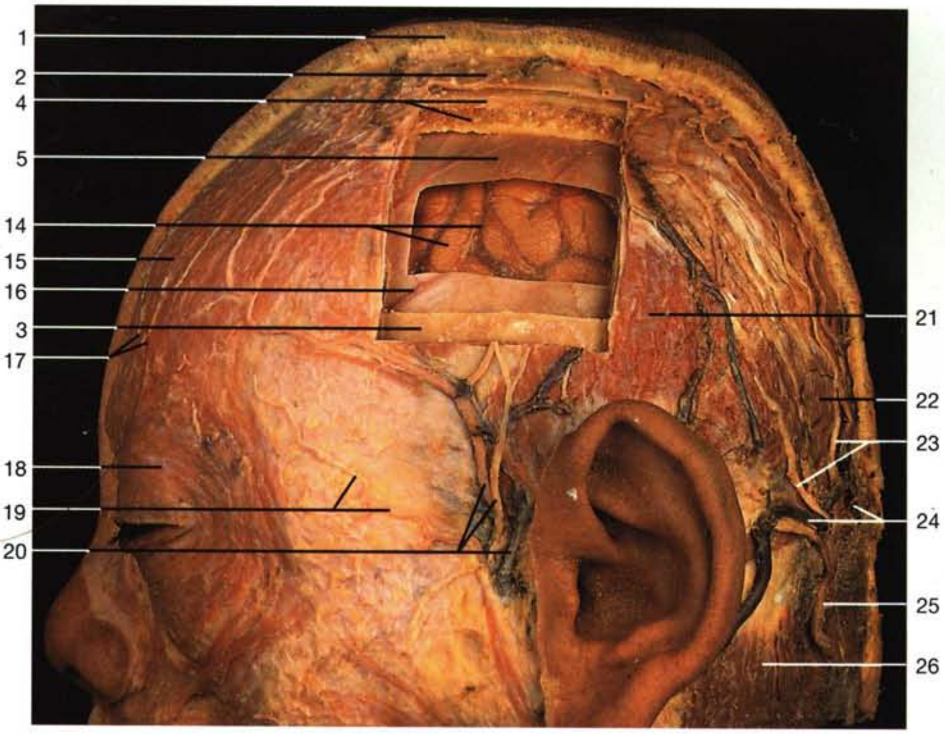

Nerves and blood vessels of the scalp. Scalp and meninges are demonstrated by a series of window-like openings.

1 Skin
2 **Galea aponeurotica**
3 Pericranium (periosteum)
4 Skull with diploe
5 **Dura mater**
6 Subdural space
7 **Arachnoid mater**
8 **Subarachnoid space**
9 Arachnoid granulations
10 Superior sagittal sinus
11 **Pia mater** with cerebral vessels
12 Falx cerebri
13 Cerebral cortex
14 Arachnoid and pia mater with cortical vessels
15 Frontal belly of occipitofrontal muscle
16 Branch of middle meningeal artery
17 Lateral and medial branch of supraorbital nerve
18 Orbicularis oculi muscle
19 Zygomatico-orbital artery
20 **Auriculotemporal nerve, superficial temporal artery** and **vein**
21 Superior auricular muscle
22 Occipital belly of occipitofrontalis muscle
23 Branches of **greater occipital nerve**
24 **Occipital artery** and **vein**
25 Greater occipital nerve
26 Sternocleidomastoid muscle

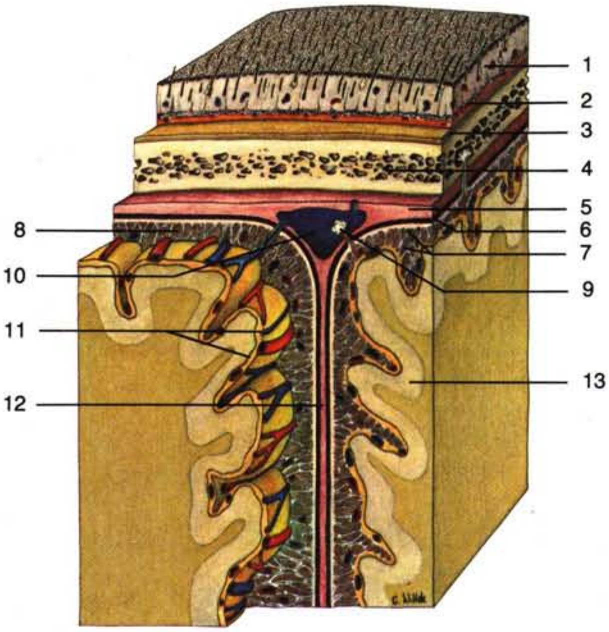

A coronal **section through the vertex of the skull** showing the arrangement of the meninges and vessels of the brain. Together the arachnoid mater and the pia mater form the leptomeninx.

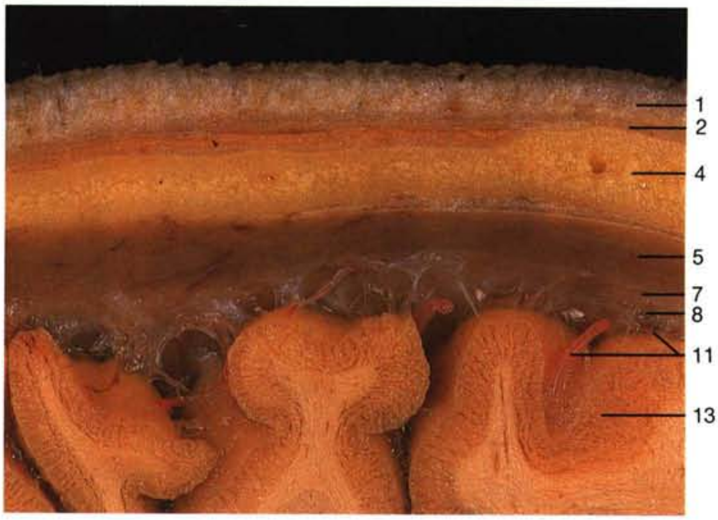

Cross-section of the scalp and the meninges. The subarachnoid space is shown.

40 Levator veli palatini muscle
41 Gingiva and buccinator muscle
42 Ascending pharyngeal artery and superior pharyngeal constrictor muscle (pterygopharyngeal part)
43 Lingual nerve
44 **Submandibular ganglion** and tongue
45 Palatoglossus muscle
46 Deep lingual artery
47 Submandibular duct and genioglossus muscle
48 Geniohyoid nerve and muscle
49 Mylohyoid muscle
50 Anterior belly of digastric muscle
51 Hyoid bone
52 Thyrohyoid muscle
53 Omohyoid muscle (superior belly)
54 Sternohyoid muscle
55 **Maxillary artery**

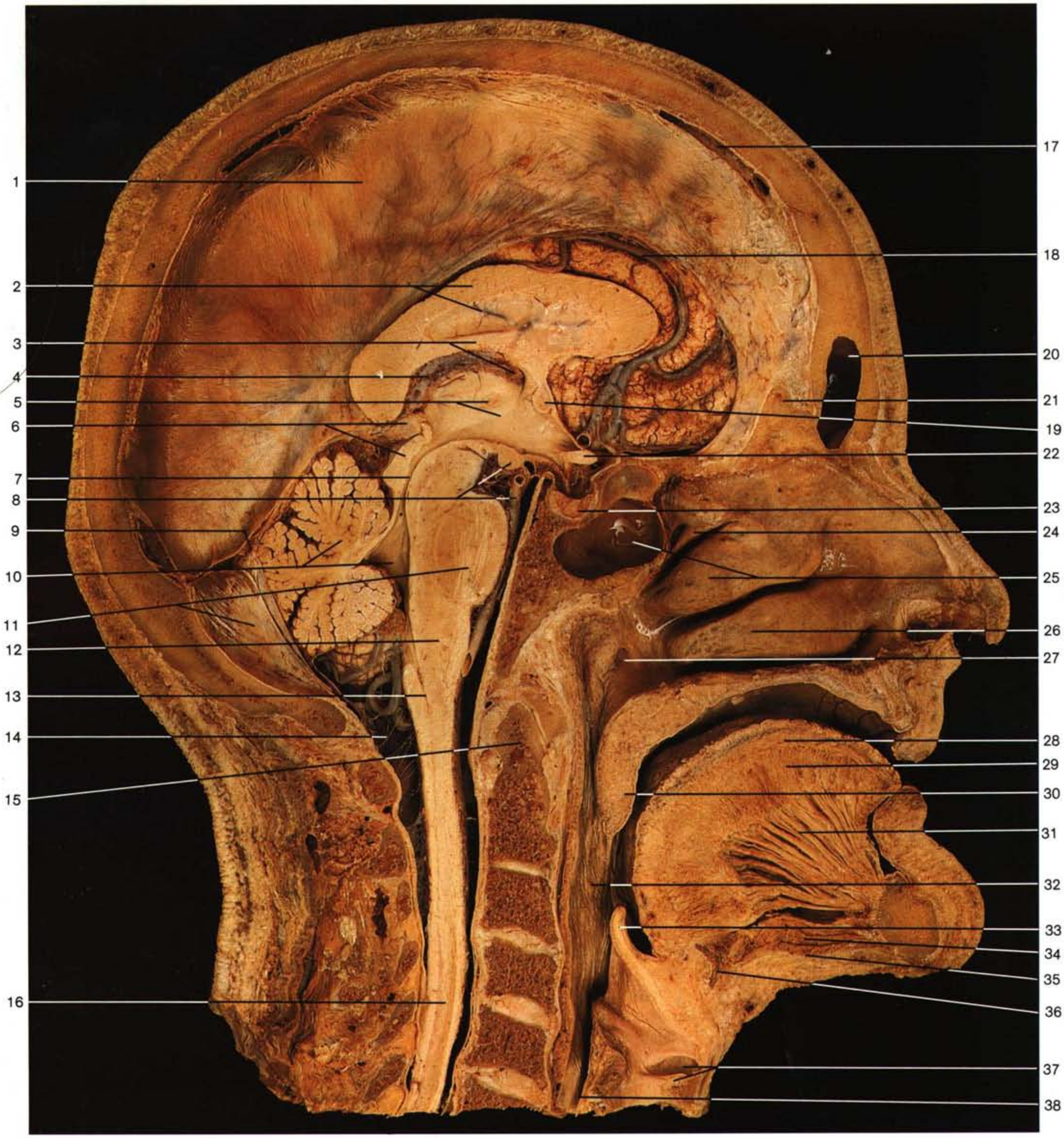

Median sagittal section through the head and neck.

1 Falx cerebri
2 **Corpus callosum** and **septum pellucidum**
3 Interventricular foramen and fornix
4 Choroid plexus of third ventricle and internal cerebral vein
5 **Third ventricle** and interthalamic adhesion
6 **Pineal body** and **colliculi of the midbrain**
7 Cerebral aqueduct
8 Mamillary body and basilar artery
9 Straight sinus
10 **Fourth ventricle** and **cerebellum**
11 Pons and falx cerebelli
12 **Medulla oblongata**
13 Central canal
14 **Cerebellomedullary cistern**
15 Dens of the axis (odontoid process)
16 Spinal cord
17 **Superior sagittal sinus**
18 **Anterior cerebral artery**
19 Anterior commissure
20 **Frontal sinus**
21 Crista galli
22 Optic chiasma
23 Pituitary gland (hypophysis)
24 Superior nasal concha
25 **Middle nasal concha** and **sphenoid sinus**
26 **Inferior nasal concha**
27 **Pharyngeal opening of auditory tube**
28 Superior longitudinal muscle of tongue
29 Vertical muscle of the tongue
30 **Uvula**
31 Genioglossus muscle
32 Pharynx
33 **Epiglottis**
34 Geniohyoid muscle
35 Mylohyoid muscle
36 Hyoid bone
37 Vocal fold and sinus of larynx
38 Esophagus

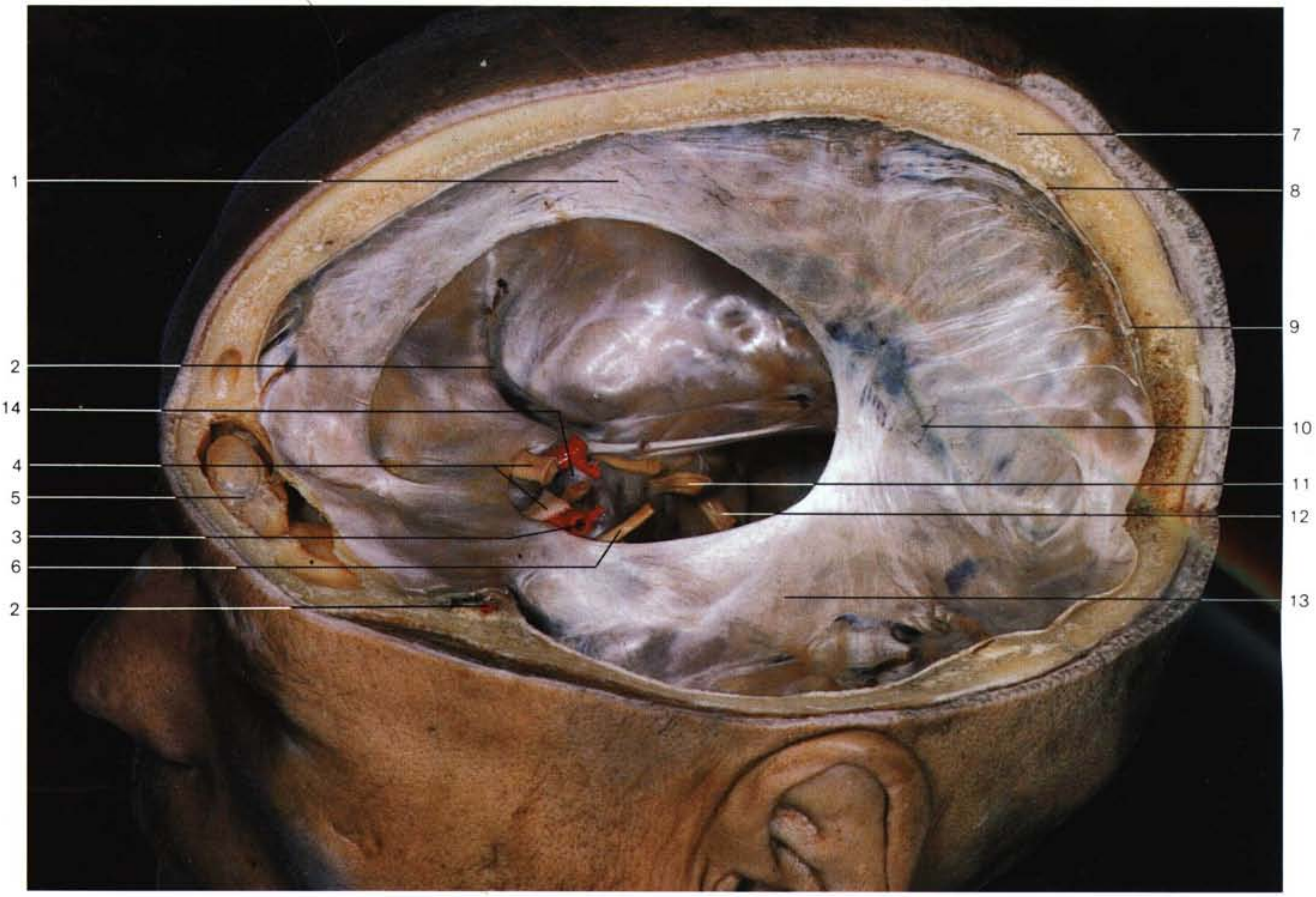

Dura mater and venous sinuses of the dura mater. The brain has been removed (oblique lateral aspect).

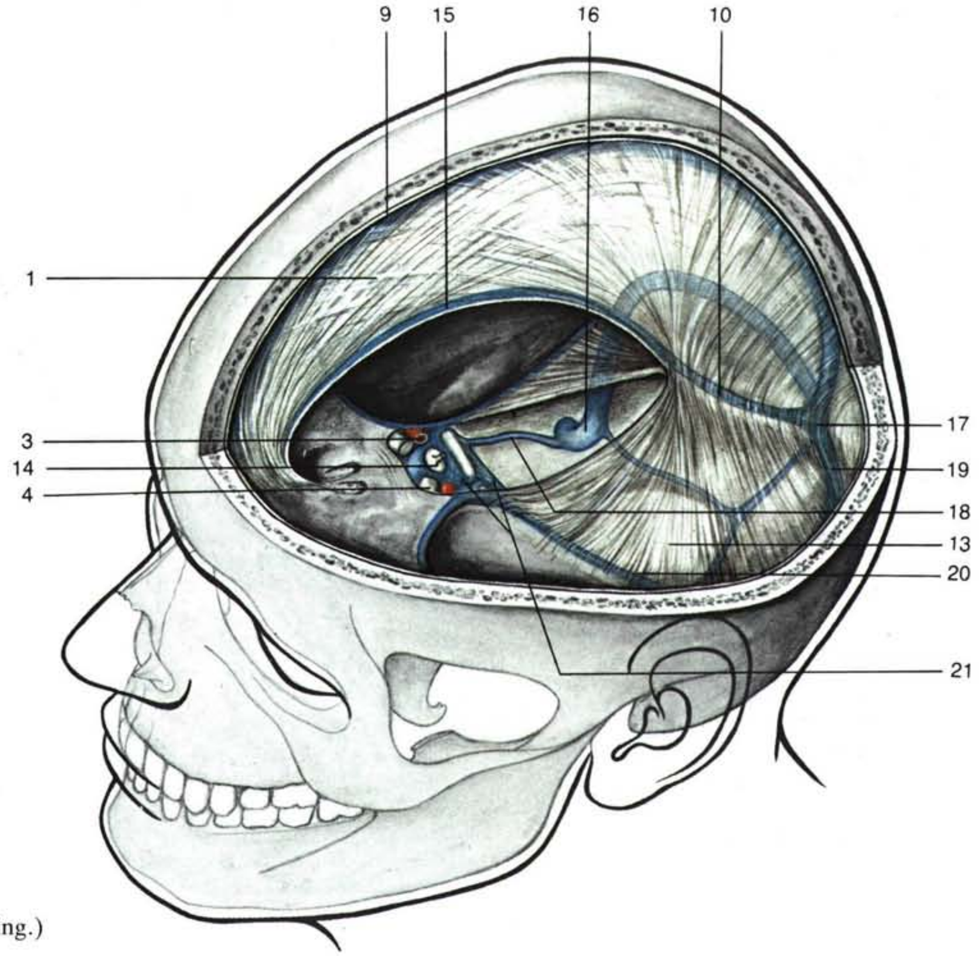

1 Falx cerebri
2 Position of middle meningeal artery and vein
3 Internal carotid artery
4 **Optic nerves** (n. II)
5 Frontal sinus
6 **Oculomotor nerve** (n. III)
7 Diploe
8 **Dura mater**
9 Superior sagittal sinus
10 Straight sinus
11 **Trigeminal nerve** (n. V)
12 Facial and vestibulocochlear nerve (n. VII and n. VIII)
13 **Tentorium cerebelli**
14 **Pituitary gland (hypophysis)**
15 Inferior sagittal sinus
16 Sigmoid sinus
17 Confluence of sinuses
18 Inferior petrosal sinus
19 Transverse sinus
20 Superior petrosal sinus
21 **Cavernous** and **intercavernous sinuses**

Dura mater and **venous sinuses** (left lateral aspect). (Schematic drawing.)

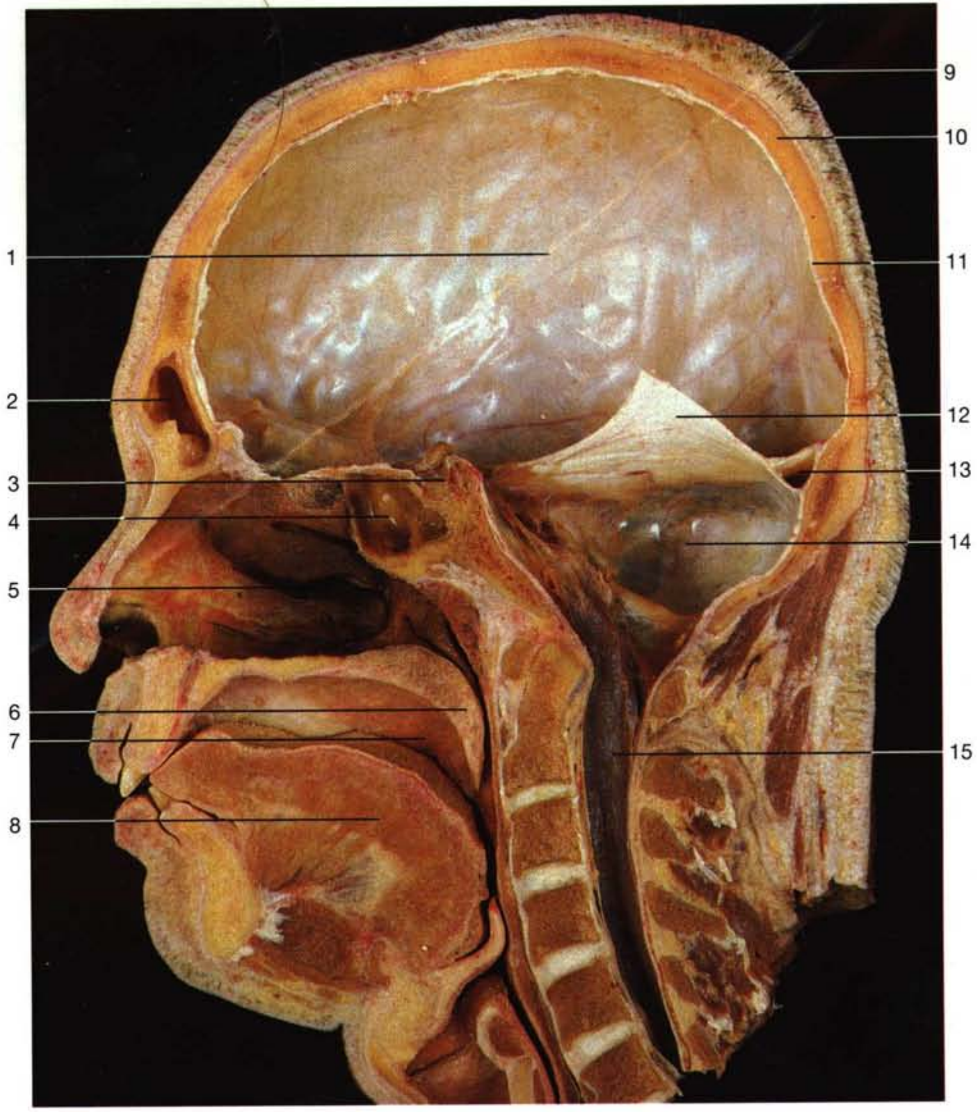

Median section through the head. Demonstration of dura mater covering the cranial cavity. Brain and spinal cord are removed (right half of the head, as seen from medial).

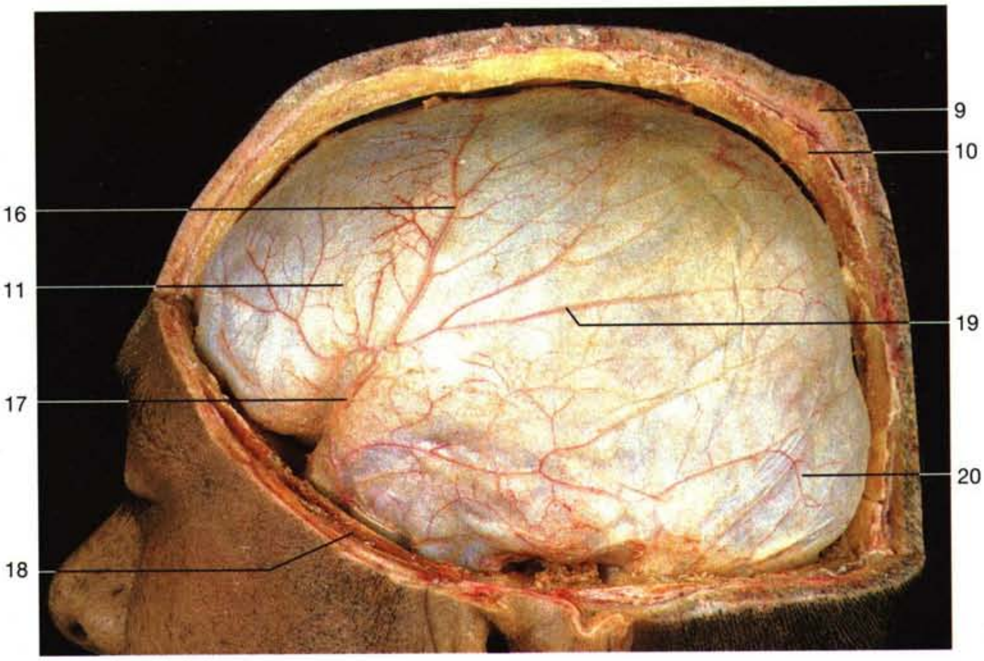

Dissection of dura mater and meningeal vessels. Left half of calvaria removed.

1 **Cranial cavity** with dura mater (the right cerebral hemisphere has been removed)
2 Frontal sinus
3 Hypophysial fossa with pituitary gland
4 Sphenoidal sinus
5 **Nasal cavity**
6 Soft palate (uvula)
7 **Oral cavity**
8 Tongue
9 Skin
10 Calvaria
11 Dura mater
12 Tentorium cerebelli
13 Confluence of sinuses
14 **Infratentorial space** (cerebellum and part of the brain stem have been removed)
15 Vertebral canal
16 Frontal branch of middle meningeal artery and veins
17 Middle meningeal artery
18 **Diploe**
19 Parietal branch of middle meningeal artery and vein
20 Occipital pole of left hemisphere covered with dura mater

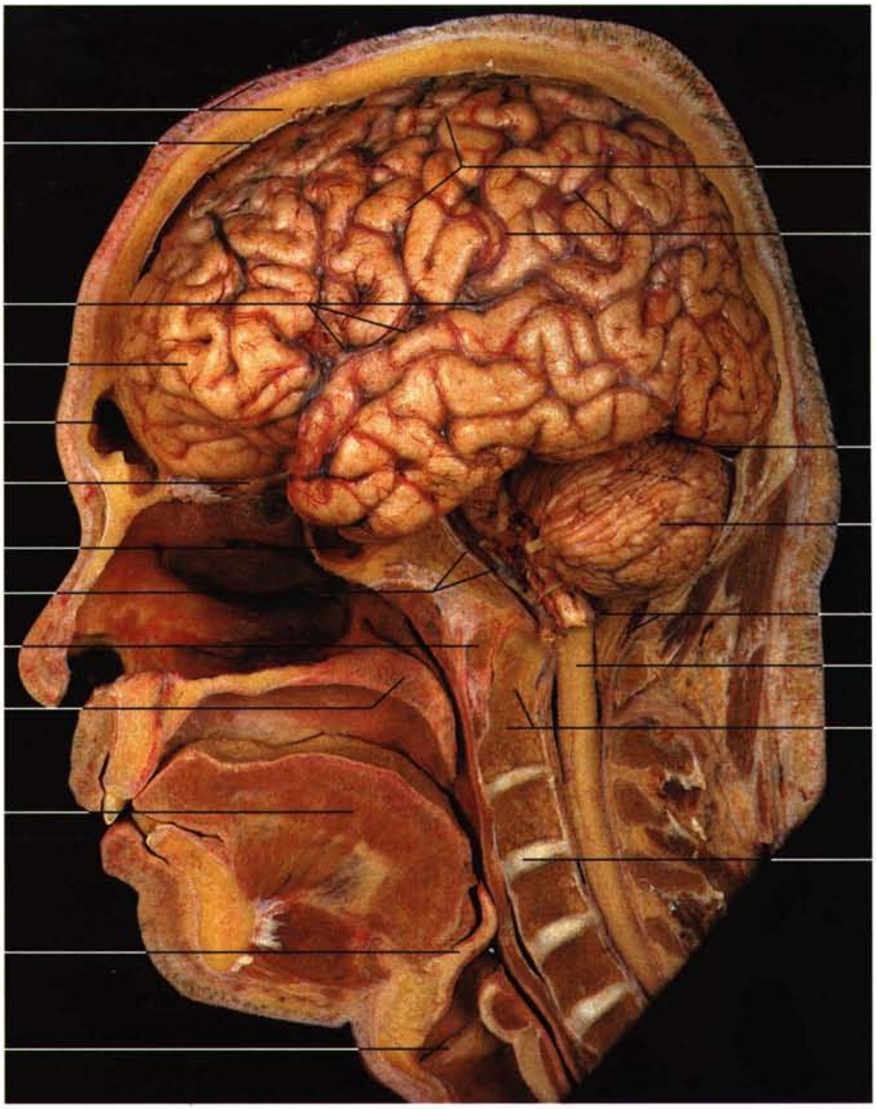

1 Calvaria and skin of the scalp
2 Dura mater (divided)
3 Position of lateral sulcus
4 **Frontal lobe** covered by **arachnoid** and **pia mater**
5 Frontal sinus
6 Olfactory bulb
7 **Sphenoidal sinus**
8 Dura mater on clivus and basilar artery
9 Atlas (anterior arch, divided)
10 **Soft palate**
11 Tongue
12 Epiglottis
13 Vocal fold
14 Position of central sulcus
15 Superior cerebral veins
16 Tentorium (divided)
17 **Cerebellum**
18 Cerebellomedullary cistern
19 Position of foramen magnum and **spinal cord**
20 Dens of axis
21 Intervertebral disc

Dissection of the brain with pia mater and arachnoid in situ. The head is cut in half except for the brain, which is shown in its entirety.

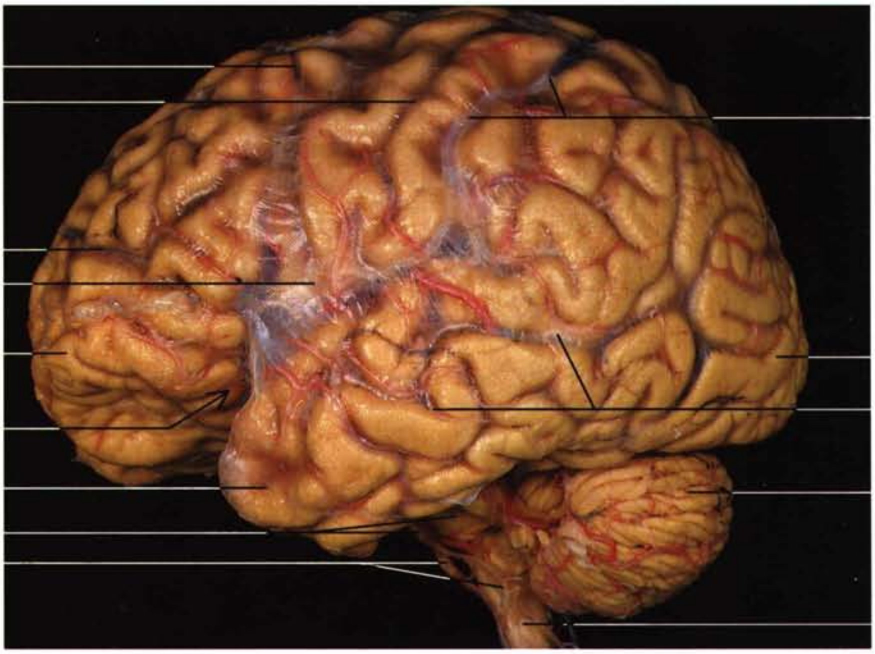

1 Superior cerebral veins
2 Position of central sulcus
3 Position of lateral sulcus and **cistern of lateral cerebral fossa**
4 **Frontal pole**
5 Lateral sulcus (arrow)
6 **Temporal pole**
7 Pons and basilar artery
8 Vertebral arteries
9 Superior anastomotic vein
10 Occipital pole
11 Inferior cerebral veins
12 Hemisphere of **cerebellum**
13 Medulla oblongata

Brain with pia mater and arachnoid. Frontal pole to the left (lateral aspect).

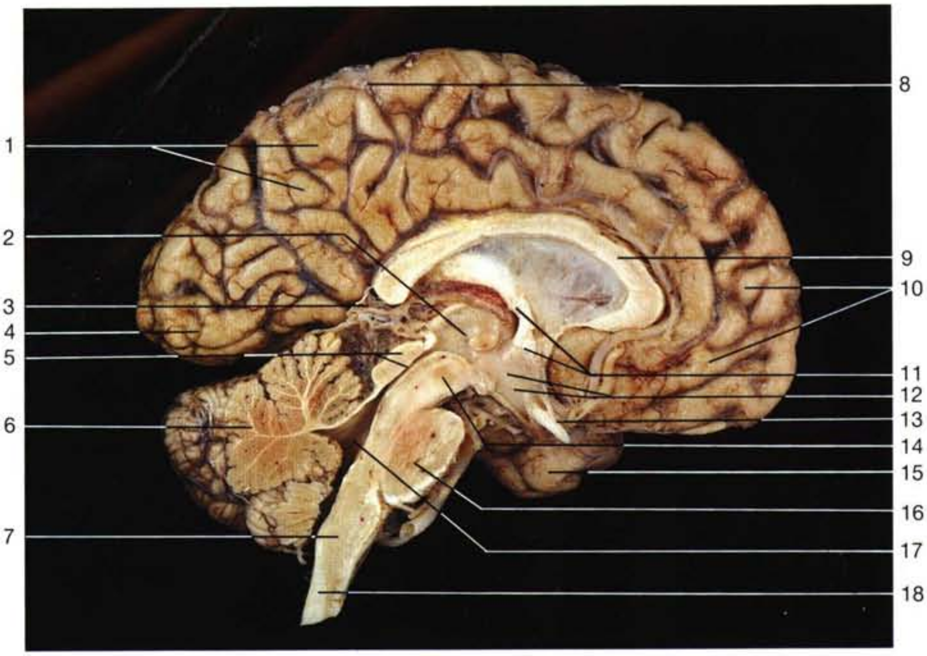
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Brain and brain stem, median section. Frontal pole to the right.

1 Parietal lobe
2 Thalamus, **third ventricle** and intermediate mass
3 Great cerebral vein
4 **Occipital lobe**
5 Colliculi of the **midbrain** and **cerebral aqueduct**
6 Cerebellum
7 **Medulla oblongata**
8 Central sulcus
9 **Corpus callosum**
10 **Frontal lobe**
11 Fornix and anterior commissure
12 **Hypothalamus**
13 Optic chiasma
14 Midbrain
15 Temporal lobe
16 **Pons**
17 **Fourth ventricle**
18 Spinal cord
19 Inferior concha and nasal cavity
20 Alveolar process of maxilla
21 Tongue
22 Dens of axis
23 Oral part of pharynx
24 Alveolar process of mandible
25 Epiglottis

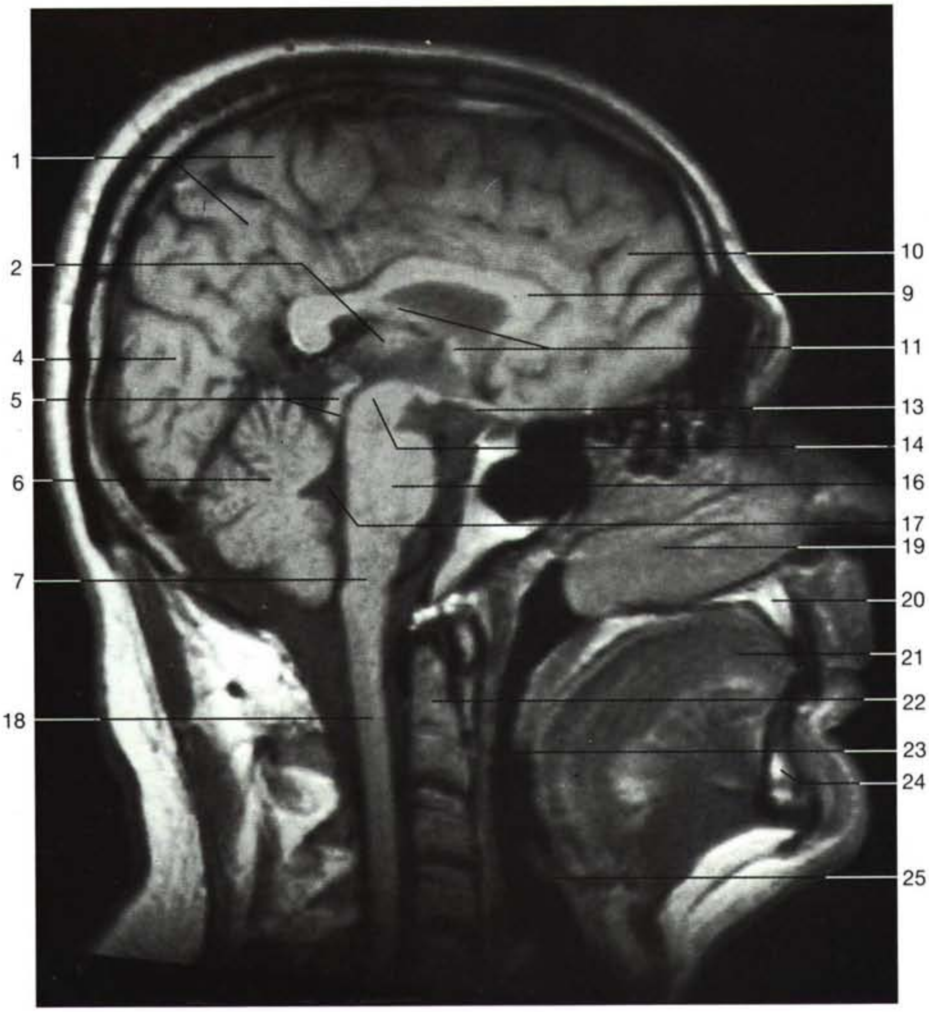
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Median section through the head. (MR-Scan, cf. section on opposite page.)

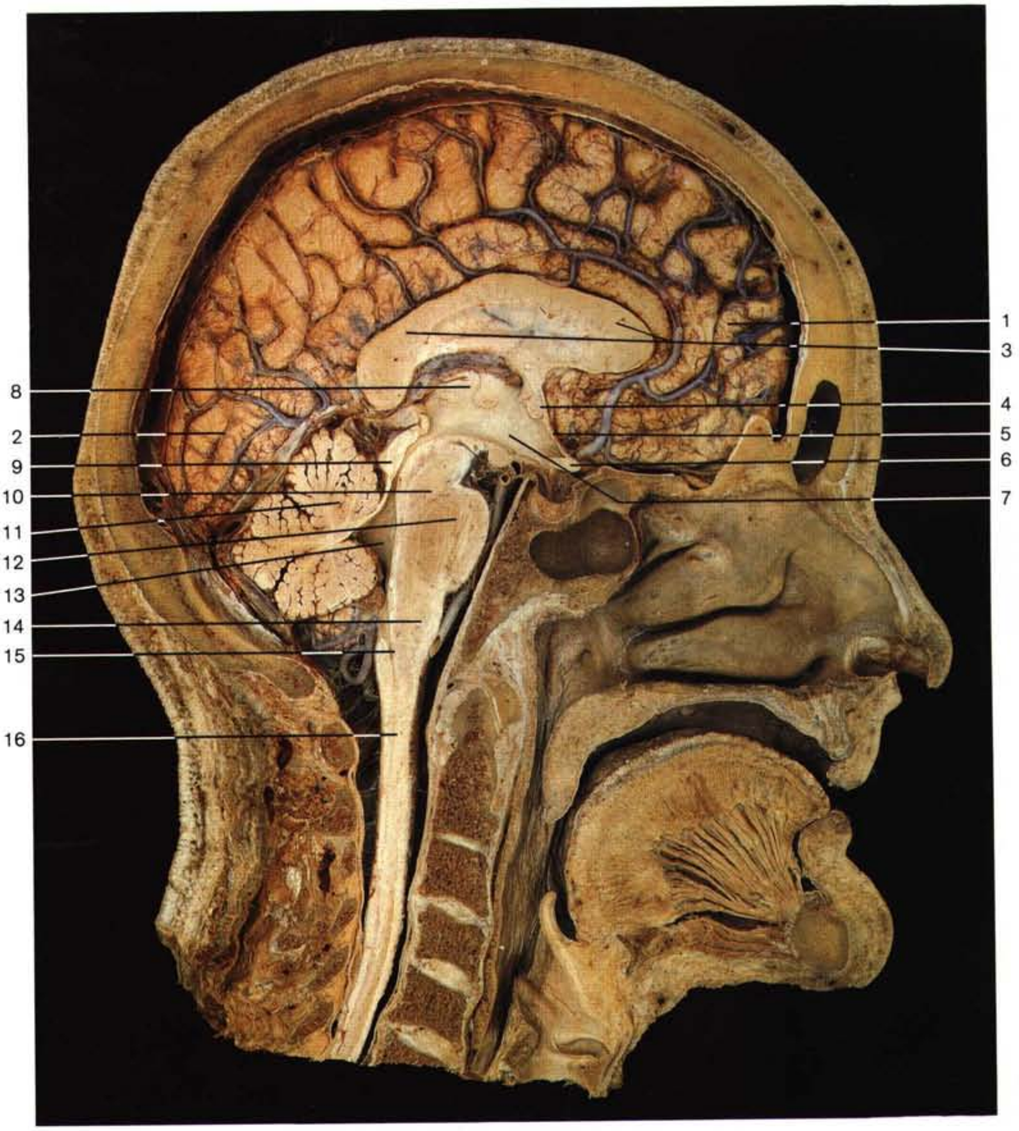

Median section through the head. Regions of the brain. Falx cerebri removed.

1 Frontal lobe of cerebrum
2 Occipital lobe of cerebrum
3 **Corpus callosum**
4 Anterior commissure
5 **Lamina terminalis**
6 Optic chiasma
7 **Hypothalamus**
8 Thalamus and third ventricle
9 **Colliculi of the midbrain**
10 Midbrain (inferior portion)
11 **Cerebellum**
12 Pons
13 **Fourth ventricle**
14 Medulla oblongata
15 Central canal
16 **Spinal cord**

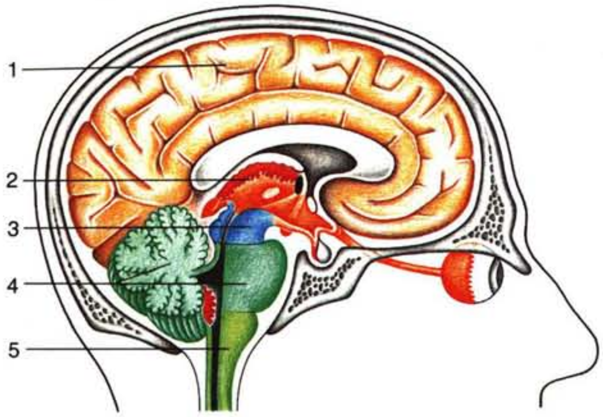

Scheme of brain divisions (cf. table).
Red = choroidal plexus. (Schematic drawing.)
1 Telencephalon (yellow) with lateral ventricles
2 Diencephalon (orange) with III ventricle, optic nerve and retina
3 Mesencephalon (blue) with cerebral aqueduct
4 Metencephalon (green) with IV ventricle
5 Myelencephalon (yellow-green)

I. Prosencephalon (forebrain)	1. Telencephalon (cerebral hemispheres, striatum, etc.)
	2. Diencephalon (thalamus, metathalamus, hypothalamus, etc.)
II. Mesencephalon (midbrain)	3. Mesencephalon (colliculi, cerebral peduncles, tegmentum)
III. Rhombencephalon (hindbrain)	4. Metencephalon (pons, cerebellum)
	5. Myelencephalon (medulla oblongata)

Main divisions of the brain
I-III = primary brain vesicles; 1-5 = secondary brain vesicles

Midbrain, pons and medulla oblongata are collectively termed the **brain stem.**

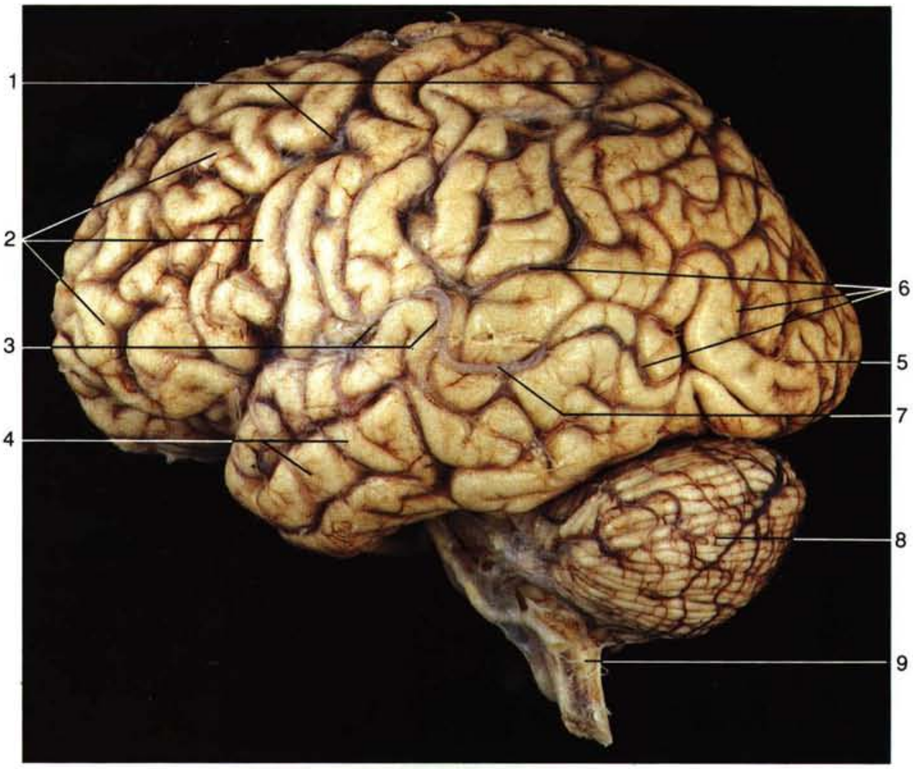

1 Superior cerebral veins and parietal lobe
2 Frontal lobe
3 Superficial middle cerebral vein and **cistern of lateral cerebral fossa**
4 Temporal lobe
5 Occipital lobe
6 Inferior cerebral veins and transverse occipital sulcus
7 Inferior anastomotic vein
8 Cerebellum
9 Medulla oblongata

Brain with pia mater. Cerebral veins (bluish). In the lateral sulcus the cistern of the lateral fossa is recognizable. Frontal lobe to the left.

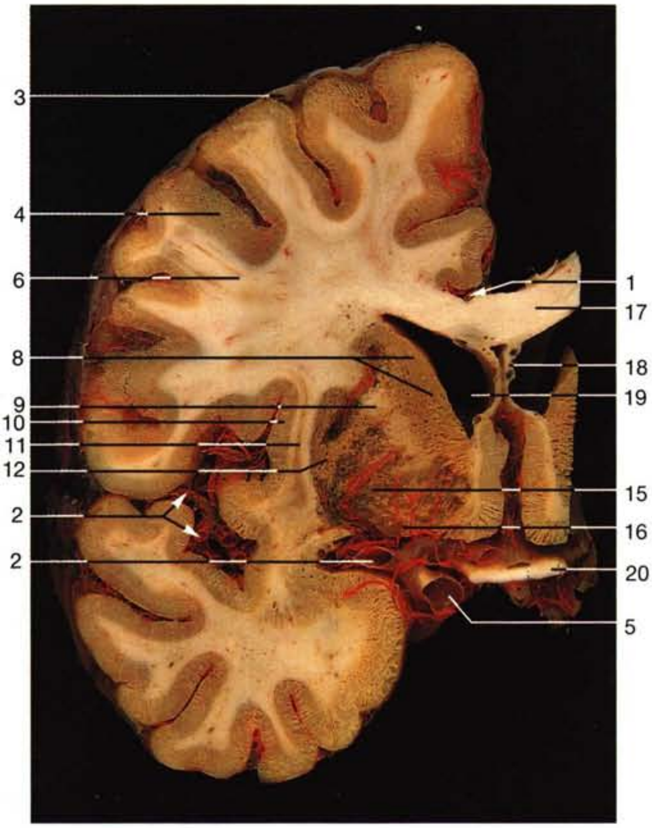

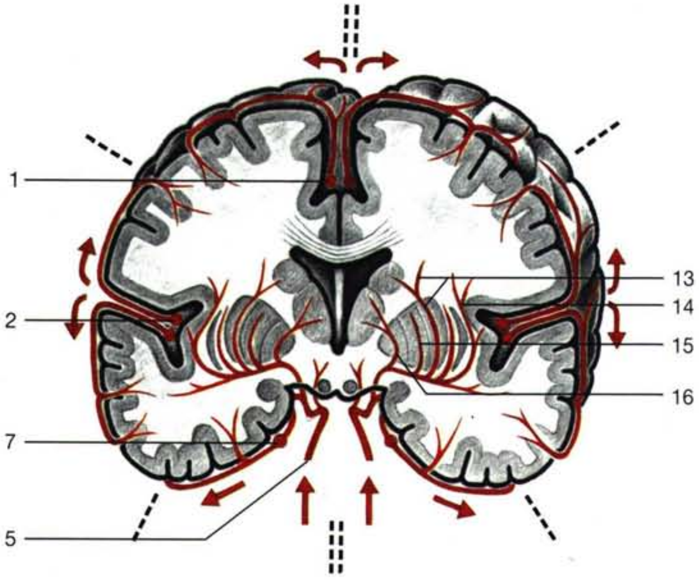

Arteries of the brain. Coronal section. Areas supplied by cortical and central arteries. Dotted lines indicate boundaries of arterial supply areas; arrows: direction of blood flow.

◁

Coronal section through the right hemisphere showing arachnoid, pia mater, and the arterial blood supply (anterior aspect).

1 **Anterior cerebral artery**
2 **Middle cerebral arteries**
3 Arachnoid
4 Cortex
5 **Internal carotid artery**
6 Frontal lobe (white matter)
7 **Posterior cerebral artery**
8 Caudate nucleus
9 Internal capsule
10 Insular lobe
11 Claustrum
12 Putamen
13 Posterior striate branch
14 Insular artery
15 Pallidostriate artery
16 Thalamic artery
17 Corpus callosum
18 Pellucid septum
19 Lateral ventricle
20 Optic chiasm

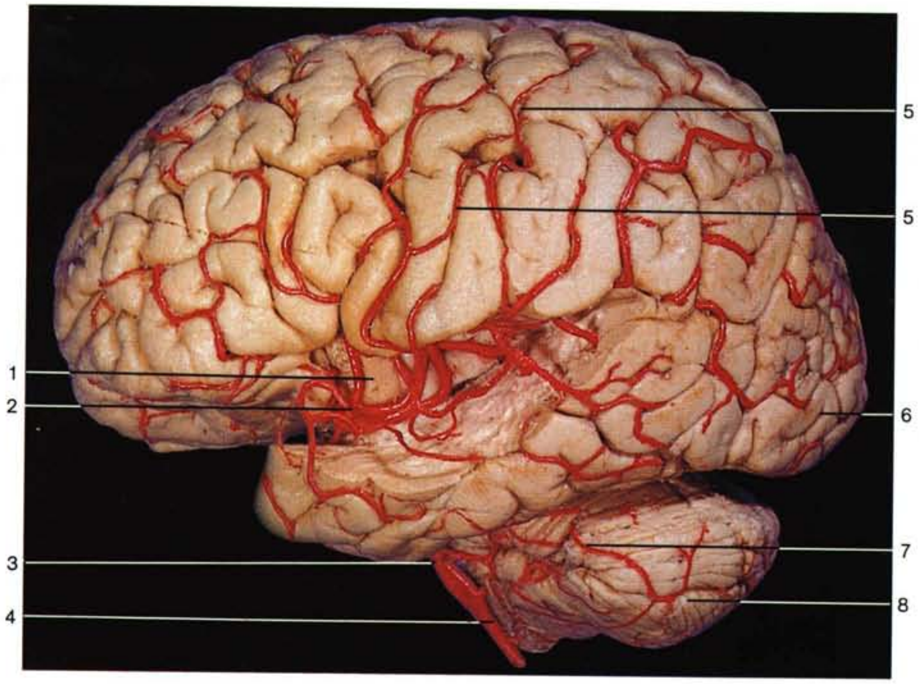

1 Insula
2 **Middle cerebral artery** [2 branches:
a) Parietal branches,
b) Temporal branches]
3 Basilar artery
4 **Vertebral artery**
5 Central sulcus
6 Occipital lobe
7 Superior cerebellar artery
8 Cerebellum
9 **Anterior cerebral artery**
10 Ethmoidal arteries
11 Ophthalmic artery
12 **Internal carotid artery**
13 Posterior communicating artery
14 **Posterior cerebral artery**
15 Anterior inferior cerebellar artery
16 Posterior inferior cerebellar artery

Cerebral arteries. Lateral aspect of the left hemisphere. The upper part of the temporal lobe has been removed to display the insula and cerebral arteries.

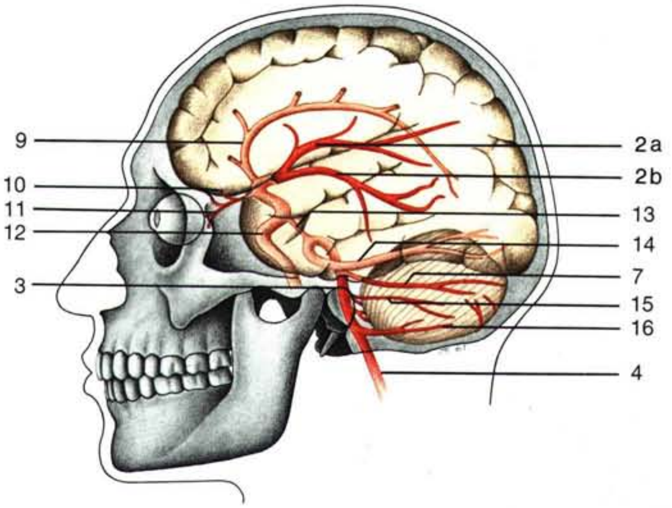

Arteries of the brain.

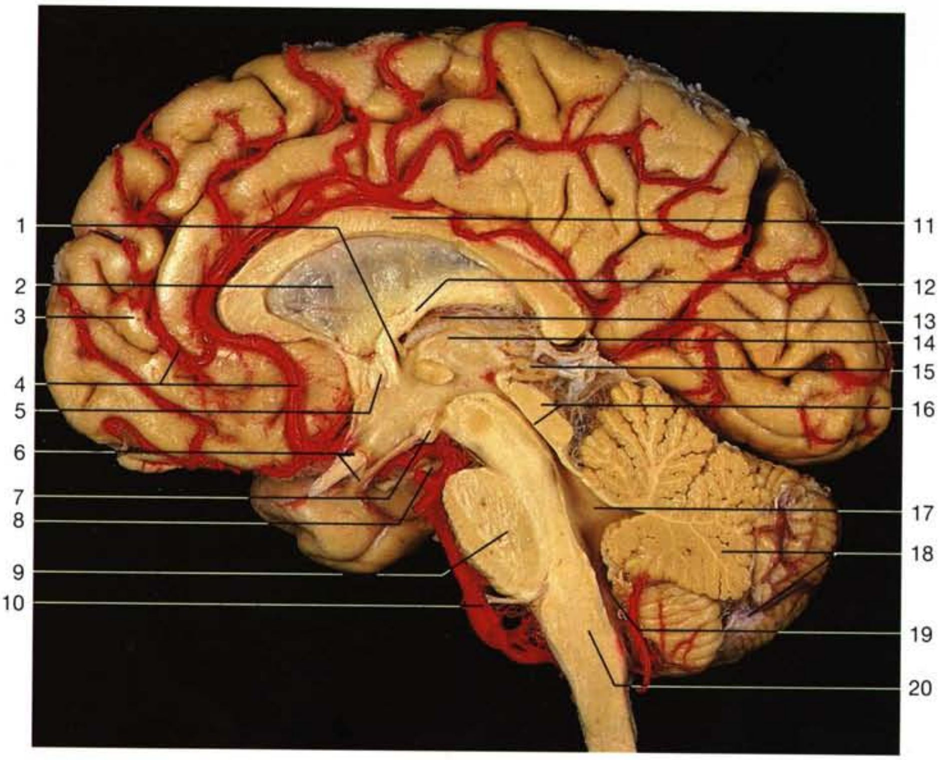

1 Interventricular foramen
2 Septum pellucidum
3 Frontal lobe
4 **Anterior cerebral artery**
5 Anterior commissure
6 Optic chiasma and infundibulum
7 Mamillary body
8 Oculomotor nerve (n. III)
9 Pons
10 **Basilar artery**
11 Corpus callosum
12 **Fornix**
13 **Choroid plexus**
14 **Third ventricle**
15 Pineal body
16 **Tectum** and **cerebral aqueduct**
17 **Fourth ventricle**
18 Cerebellum (arbor vitae, vermis)
19 Median aperture of Magendie
20 Medulla oblongata

Median section through the brain and brain stem. Cerebral arteries injected with red resin.

1 Anterior communicating artery
2 Left **anterior cerebral artery**
3 **Internal carotid artery**
4 Pons and left **superior cerebellar artery**
5 **Anterior inferior cerebellar artery**
6 **Posterior inferior cerebellar artery**
7 Medulla oblongata
8 **Right anterior cerebral artery**
9 Olfactory tract
10 Optic nerve
11 **Middle cerebral artery**
12 Infundibulum
13 Oculomotor nerve and **posterior communicating artery**
14 **Posterior cerebral artery**
15 **Basilar artery** and abducens nerve (n. VI)
16 Anterior spinal artery
17 **Vertebral artery**
18 Cerebellum
19 Labyrinthine arteries
20 Posterior spinal artery
21 Right **superior cerebellar artery**
22 Olfactory bulb

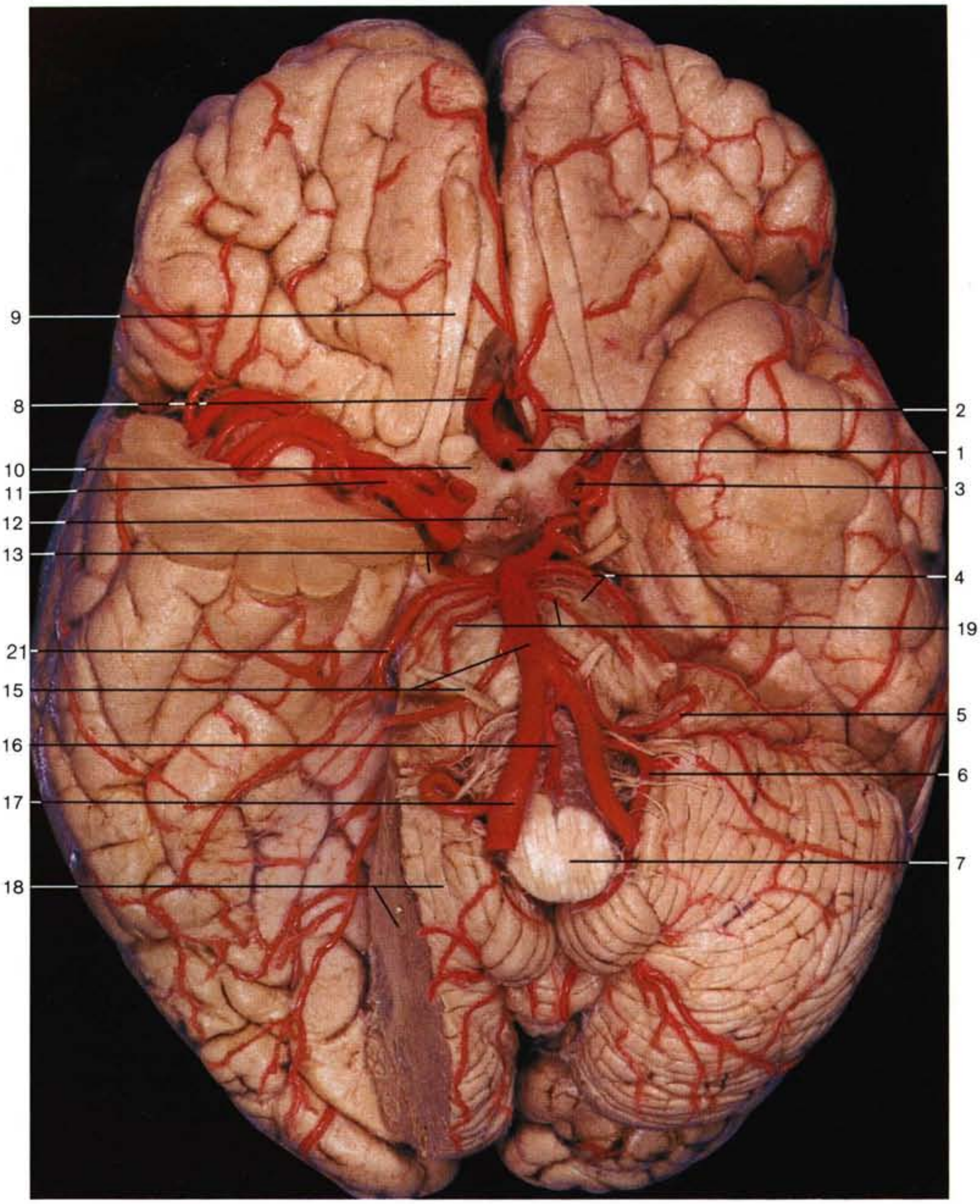

Arteries of the brain (inferior aspect). Frontal pole above; right temporal lobe and cerebellum partly removed.

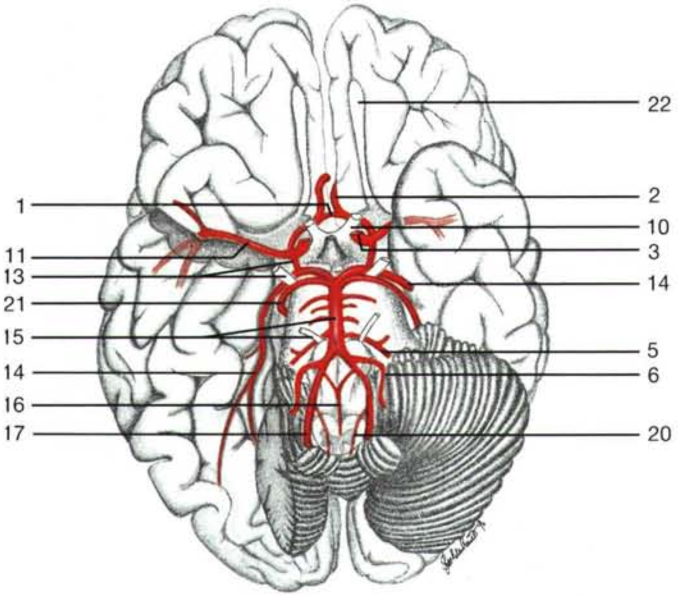

Arteries of the base of the brain, arterial circle of Willis. (Schematic drawing.)

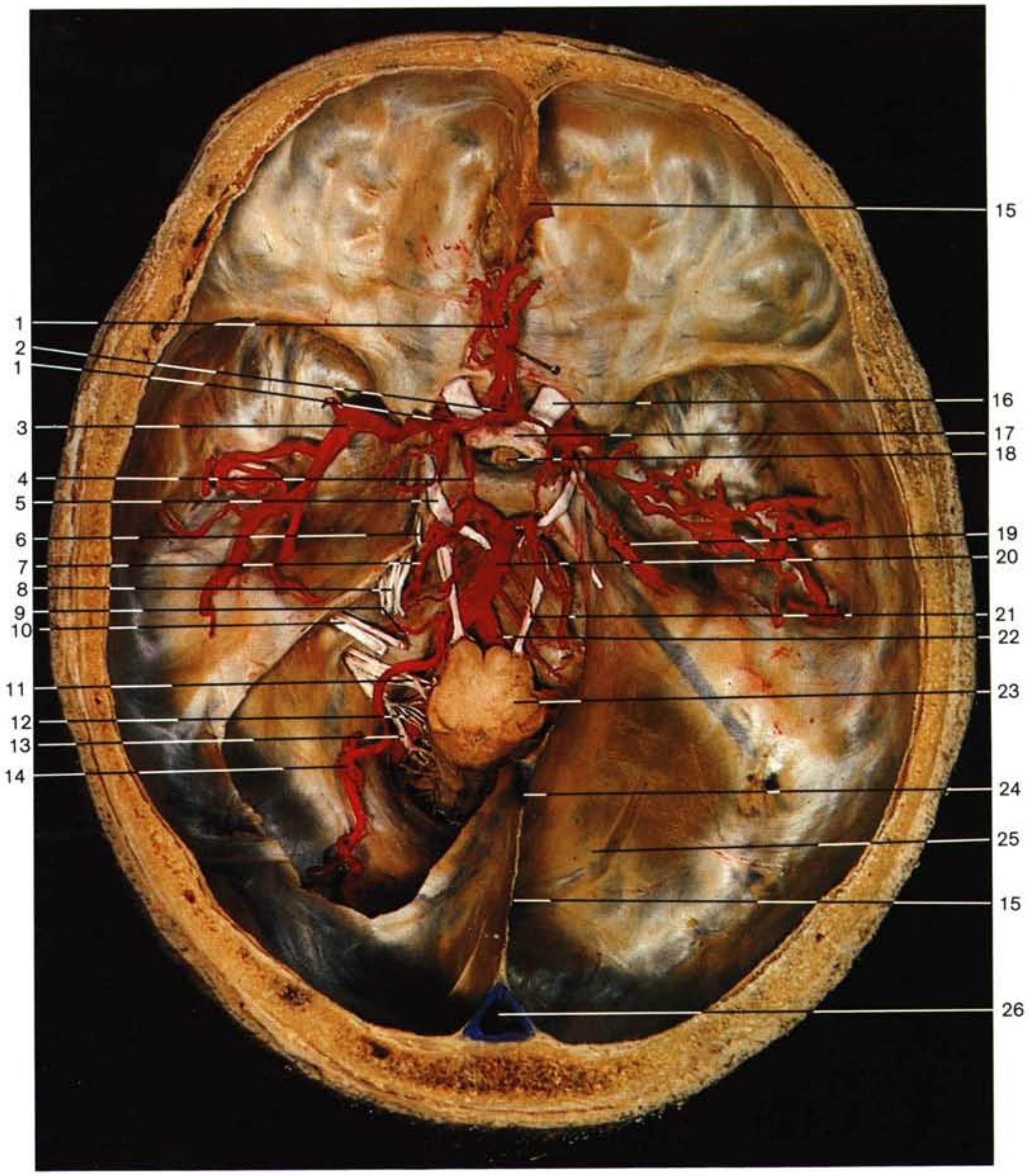

Base of the cranial cavity (internal aspect). Left tentorium has been cut.

1 Anterior cerebral artery
2 Anterior communicating artery
3 **Middle cerebral artery**
4 Posterior communicating artery
5 **Oculomotor nerve**
6 **Trochlear nerve**
7 Posterior cerebral artery
8 **Trigeminal nerve**
9 Internal auditory artery
10 **Facial nerve** and **vestibulocochlear nerve**
11 **Glossopharyngeal nerve** and **vagus nerve**
12 **Hypoglossal nerve**
13 **Accessory nerve**
14 Anterior inferior cerebellar artery
15 Falx cerebri
16 **Optic nerve**
17 Optic chiasma
18 Infundibulum and pituitary gland
19 Anterior choroidal artery and choroid plexus
20 **Basilar artery**
21 **Abducens nerve**
22 Vertebral arteries
23 Medulla oblongata
24 Inferior sagittal sinus
25 Tentorium cerebelli
26 Superior sagittal sinus and confluence of sinuses
27 Anterior spinal artery
28 Internal carotid artery
29 Superior cerebellar artery
30 Anterior inferior cerebellar artery
31 Posterior inferior cerebellar artery
32 Posterior spinal artery
33 Ophthalmic artery

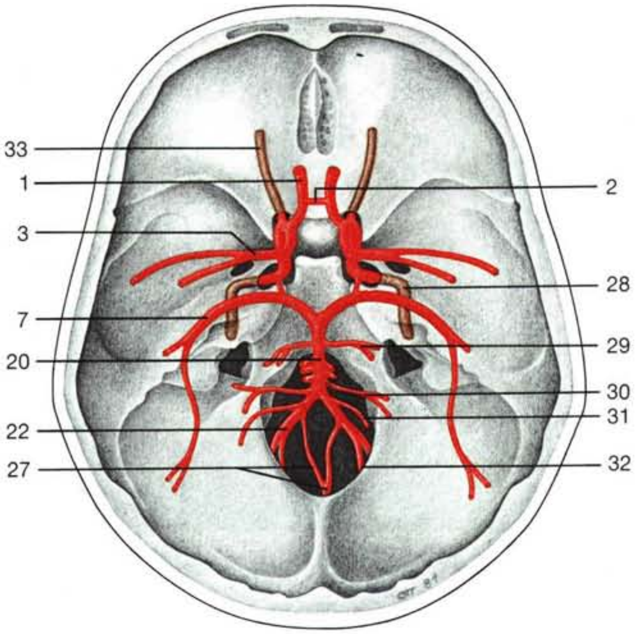

Arterial circle of Willis (superior aspect). (Schematic drawing.)

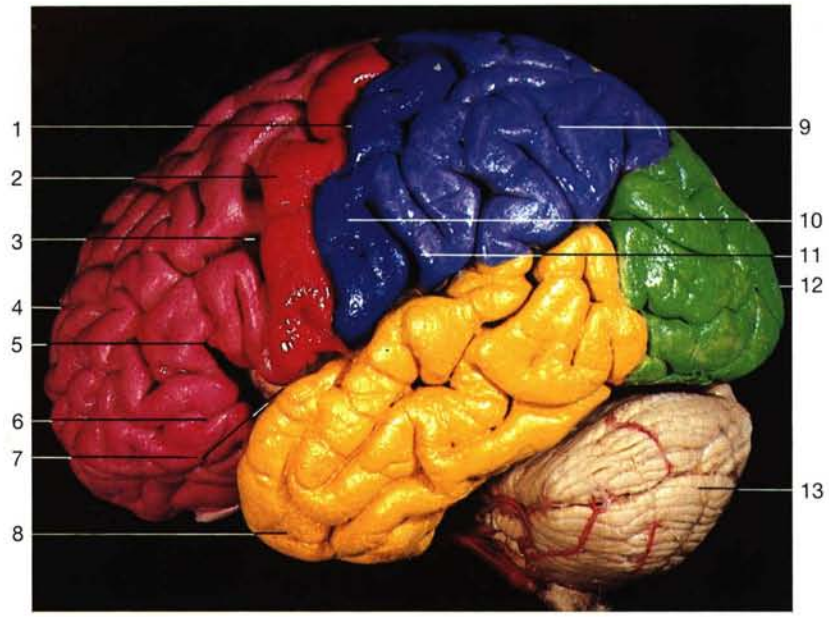

1 Central sulcus
2 Precentral gyrus
3 Precentral sulcus
4 **Frontal lobe**
5 Anterior ascending ramus of lateral sulcus
6 Anterior horizontal ramus of lateral sulcus
7 Lateral sulcus
8 **Temporal lobe**
9 **Parietal lobe**
10 Postcentral gyrus
11 Postcentral sulcus
12 **Occipital lobe**
13 Cerebellum
14 Superior frontal sulcus
15 Middle frontal gyrus
16 Lunate sulcus
17 Longitudinal fissure
18 Arachnoid granulations

Brain, left hemisphere (lateral aspect). Frontal pole to the left.

Pink = Frontal lobe
Blue = Parietal lobe
Green = Occipital lobe
Yellow = Temporal lobe
Dark red = Precentral gyrus
Dark blue = Postcentral gyrus

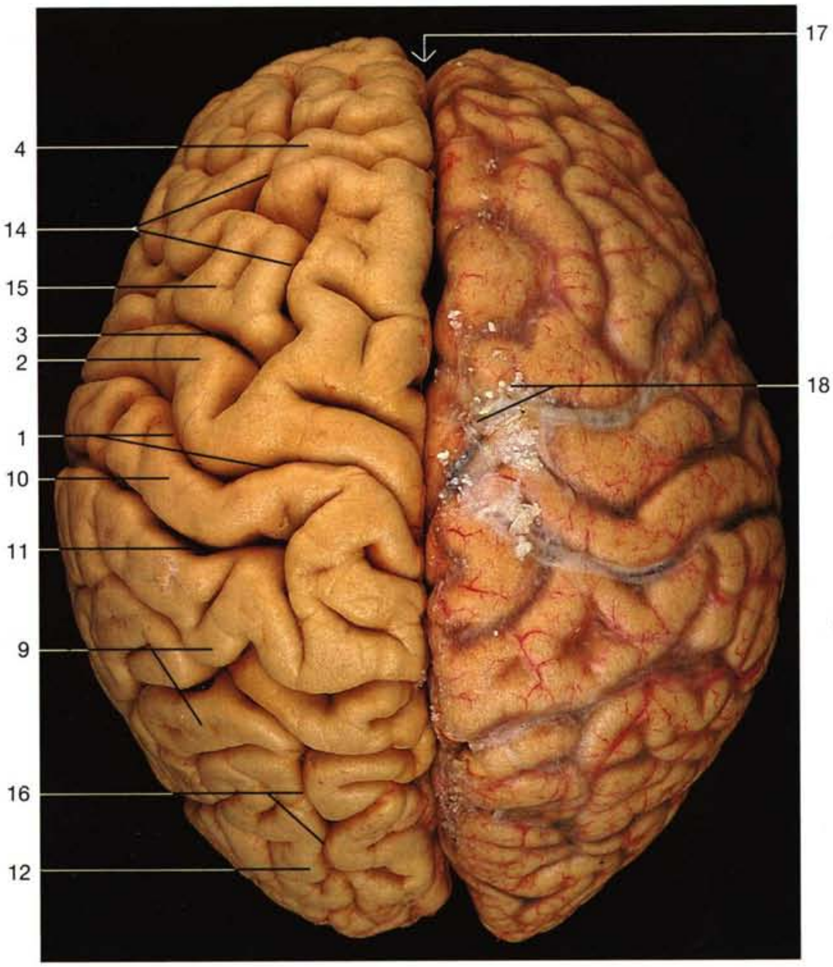

Brain (superior aspect). Right hemisphere with arachnoid and pia mater.

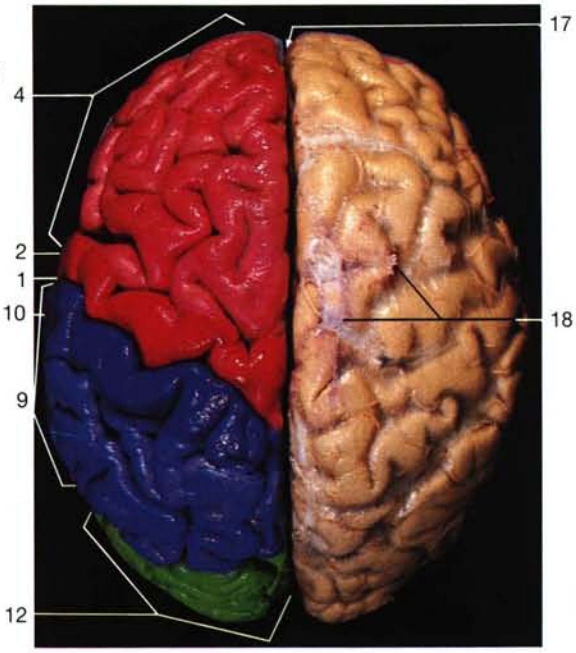

Brain (superior aspect). Lobes of the left hemisphere indicated by color; right hemisphere is covered with arachnoid and pia mater.

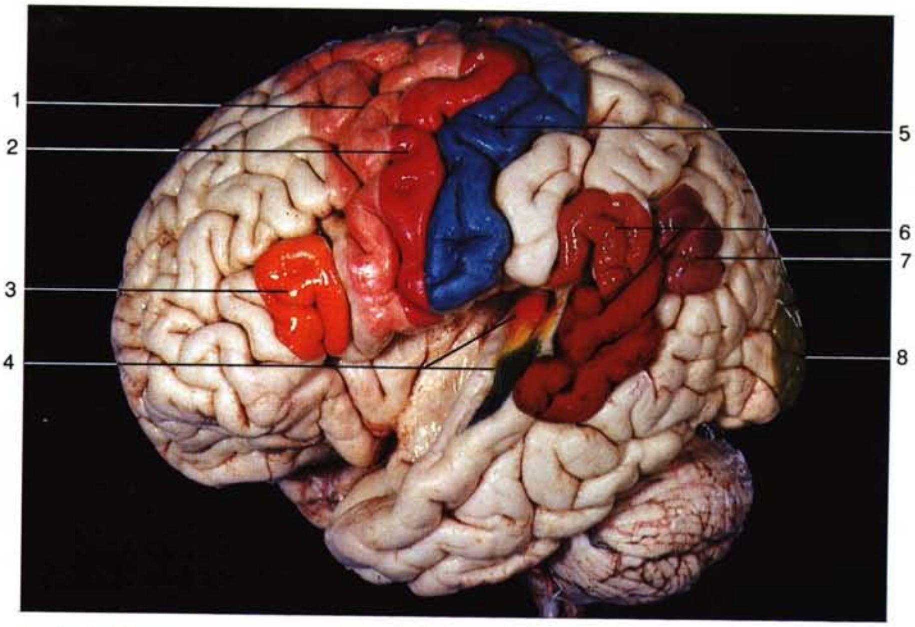

1 Premotor area
2 Somatomotor area
3 Motor speech area of Broca
4 Acoustic area
(red: high tone; blue: low tone)
5 Somatosensory area
6 Sensory speech area of Wernicke
7 Reading comprehension area
8 Visuosensory area

Brain, left hemisphere (lateral aspect). **Main cortical areas** are colored. The lateral sulcus has been opened to display the insula and the inner surface of the temporal lobe.

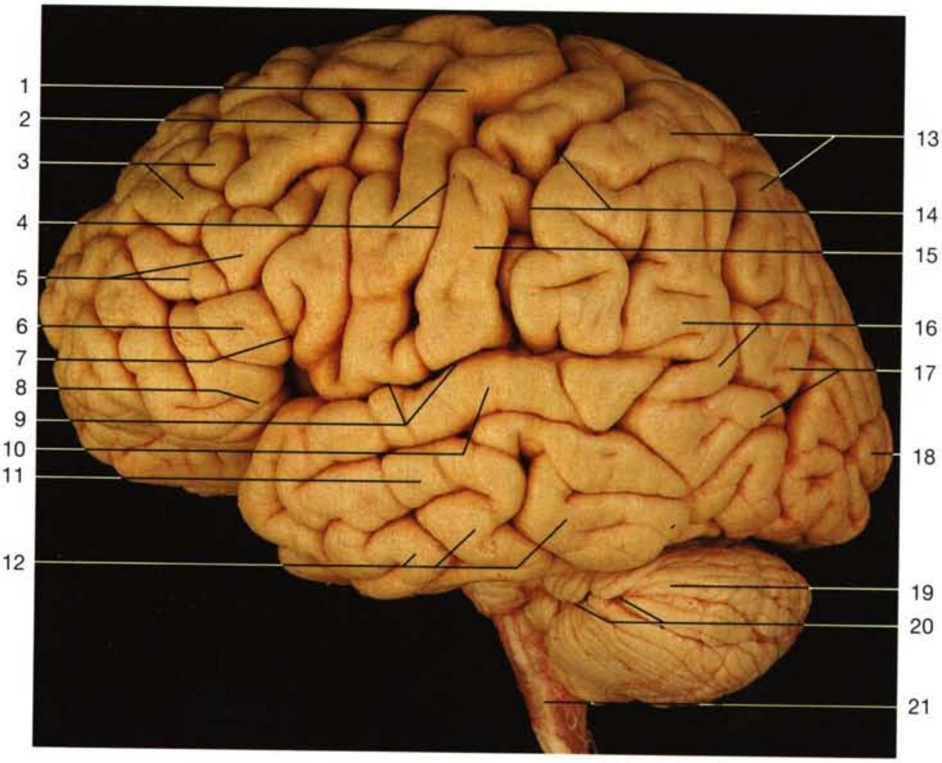

1 Precentral gyrus
2 Precentral sulcus
3 Superior frontal gyrus
4 **Central sulcus**
5 Middle frontal gyrus
6 Inferior frontal gyrus
7 Ascending ramus
8 Horizontal ramus } of lateral sulcus
9 Posterior ramus
10 Superior temporal gyrus
11 Middle temporal gyrus
12 Inferior temporal gyrus
13 Parietal lobule
14 Postcentral sulcus
15 Postcentral gyrus
16 Supramarginal gyrus
17 Angular gyrus
18 **Occipital lobe**
19 **Cerebellum**
20 Horizontal fissure of cerebellum
21 Medulla oblongata

Brain, left hemisphere (lateral aspect). Frontal pole to the left.

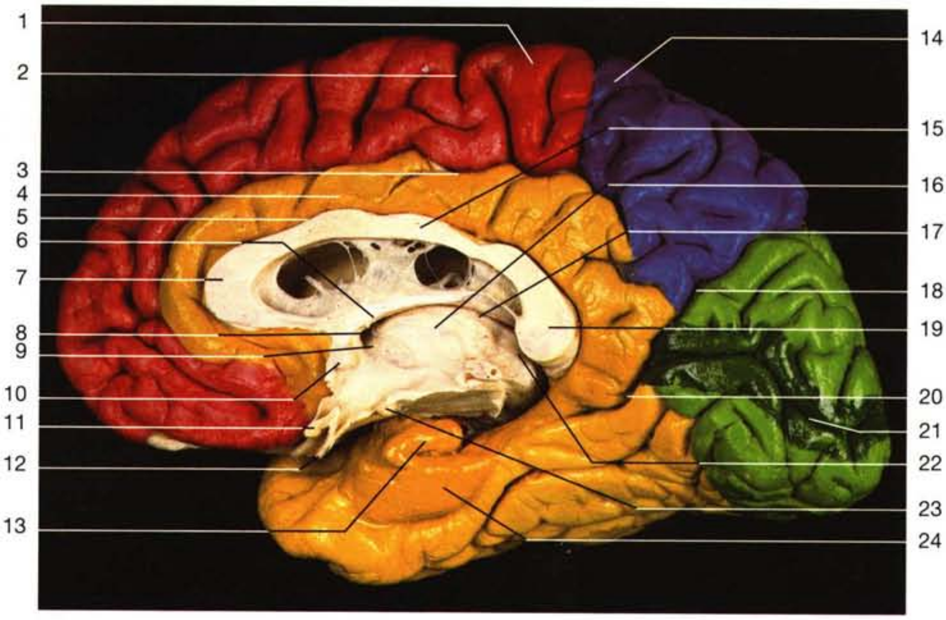

Brain, right hemisphere (medial aspect). Frontal pole to the left (midbrain divided, cerebellum and inferior part of brainstem removed).

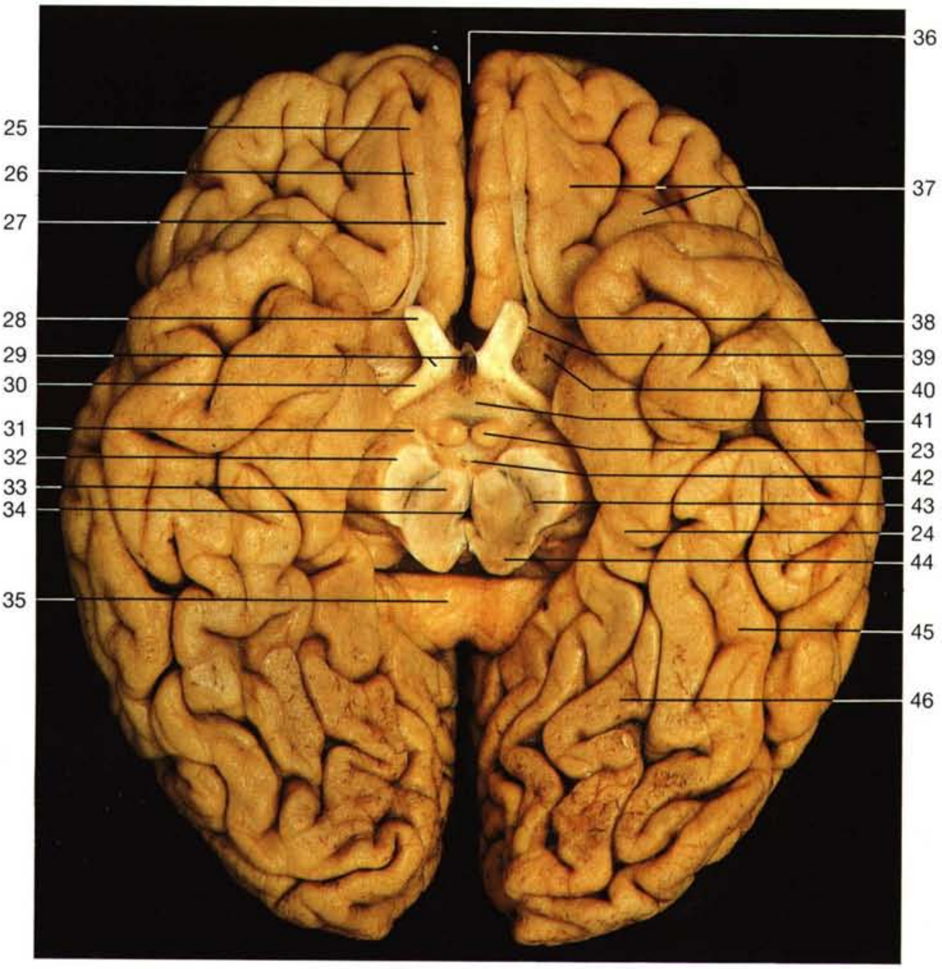

Brain (inferior aspect). Midbrain divided. Cerebellum and inferior part of brain stem removed. Frontal pole at the top.

1 **Precentral gyrus**
2 Precentral sulcus
3 Cingulate sulcus
4 **Cingulate gyrus**
5 Sulcus of corpus callosum
6 **Fornix**
7 Genu of **corpus callosum**
8 Interventricular foramen
9 Intermediate mass
10 Anterior commissure
11 **Optic chiasma**
12 **Infundibulum**
13 Uncus hippocampi
14 **Postcentral gyrus**
15 Body of corpus callosum
16 Third ventricle and thalamus
17 Stria medullaris
18 **Parietooccipital sulcus**
19 Splenium of corpus callosum
20 Communication of calcarine and parietooccipital sulcus
21 Calcarine sulcus
22 **Pineal body**
23 **Mamillary body**
24 **Parahippocampal gyrus**
25 **Olfactory bulb**
26 Olfactory tract
27 Gyrus rectus
28 **Optic nerve**
29 Infundibulum and optic chiasma
30 **Optic tract**
31 Oculomotor nerve
32 Pedunculus cerebri
33 **Red nucleus**
34 **Cerebral aqueduct**
35 Corpus callosum
36 Longitudinal fissure
37 Orbital gyri
38 Lateral root of olfactory tract
39 Medial root of olfactory tract
40 Olfactory tubercle and anterior perforated substance
41 Tuber cinereum
42 Interpeduncular fossa
43 **Substantia nigra**
44 Colliculi of the **midbrain**
45 Lateral occipitotemporal gyrus
46 Medial occipitotemporal gyrus

Pink = Frontal lobe
Blue = Parietal lobe
Green = Occipital lobe
Yellow = Temporal lobe
Dark red = Precentral lobe
Dark blue = Postcentral lobe
Orange = Limbic cortex (cingulate and parahippocampal gyri)

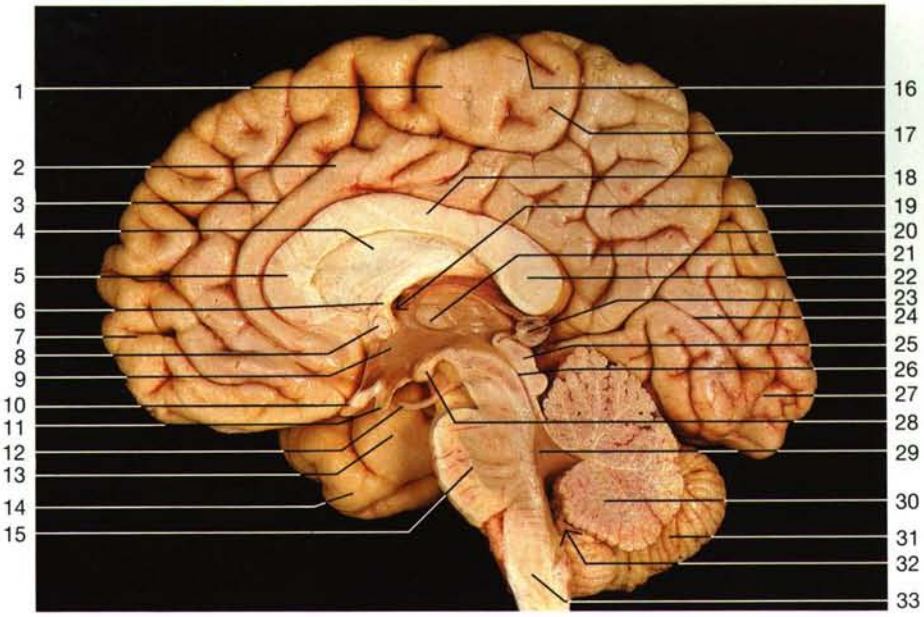

Brain (sagittal section). Frontal pole to the left.

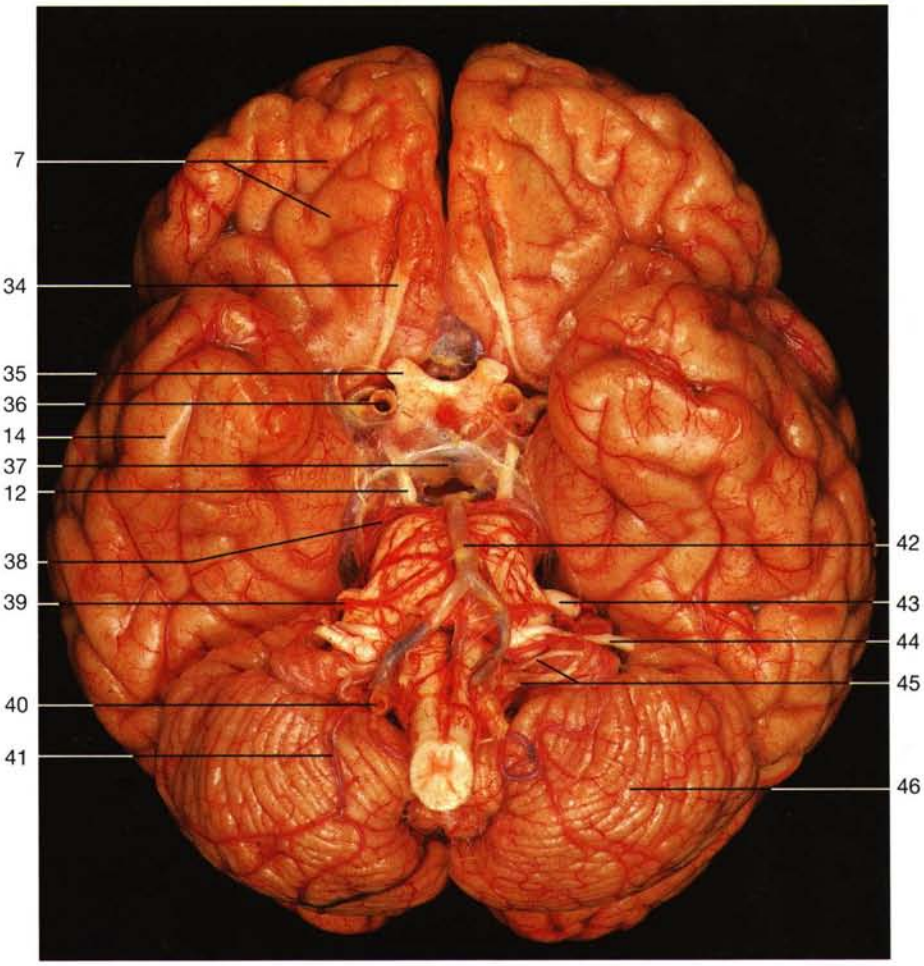

Brain, with pia mater and blood vessels (inferior aspect).

1 Precentral gyrus
2 Cingulate gyrus
3 Cingulate sulcus
4 Septum pellucidum
5 Genu of corpus callosum
6 Fornix
7 **Frontal lobe**
8 Anterior commissure
9 **Hypothalamus**
10 Optic chiasma
11 Infundibulum
12 Oculomotor nerve
13 Uncus
14 **Temporal lobe**
15 Pons
16 Central sulcus
17 Postcentral gyrus
18 Body of corpus callosum
19 Interventricular foramen (arrow)
20 Parietooccipital sulcus
21 Intermediate mass
22 Splenium of corpus callosum
23 Pineal body
24 Calcarine sulcus
25 Colliculi of midbrain
26 Cerebral aqueduct
27 **Occipital lobe**
28 Mamillary body
29 Fourth ventricle
30 Vermis of cerebellum
31 Right hemisphere of cerebellum
32 Median aperture of Magendie (arrow)
33 Medulla oblongata
34 Olfactory tract
35 Optic nerve
36 **Internal carotid artery**
37 Interpeduncular cistern
38 Superior cerebellar artery
39 Anterior inferior cerebellar artery
40 **Vertebral artery**
41 Posterior inferior cerebellar artery
42 **Basilar artery**
43 Trigeminal nerve (n. V)
44 Facial nerve (n. VII)
45 Accessory nerve (n. XI),
hypoglossal nerve (n. XII)
46 Cerebellum

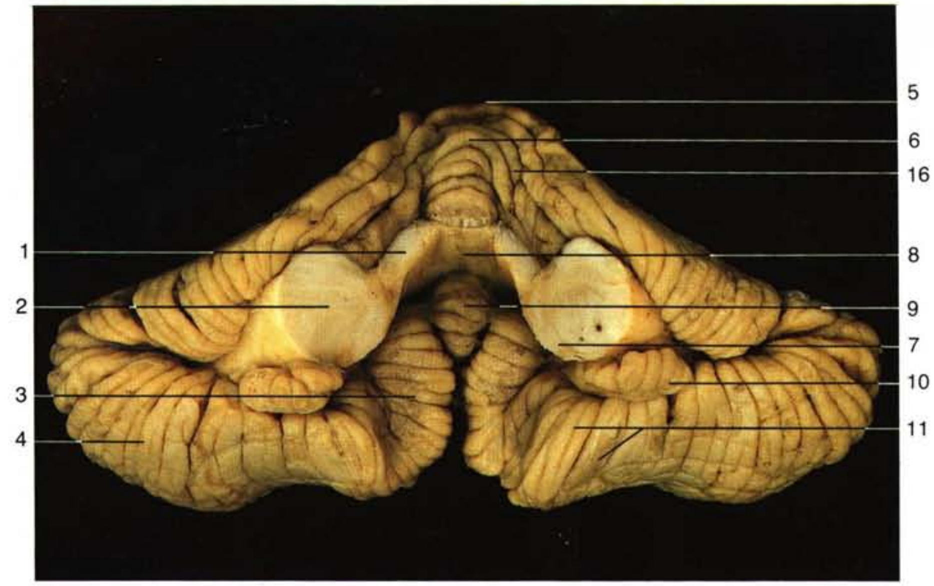

Cerebellum (inferior anterior aspect). The cerebellar peduncles have been severed.

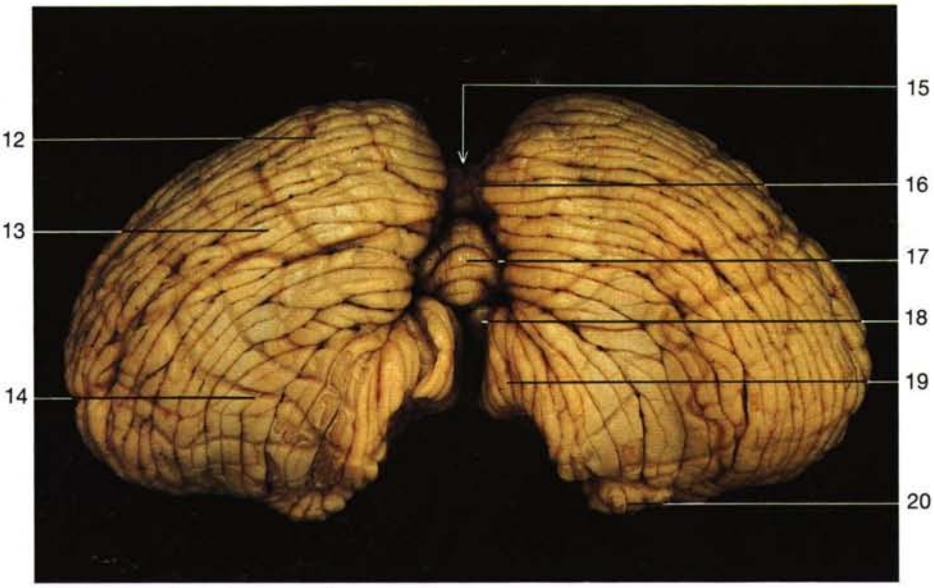

Cerebellum (inferior posterior aspect).

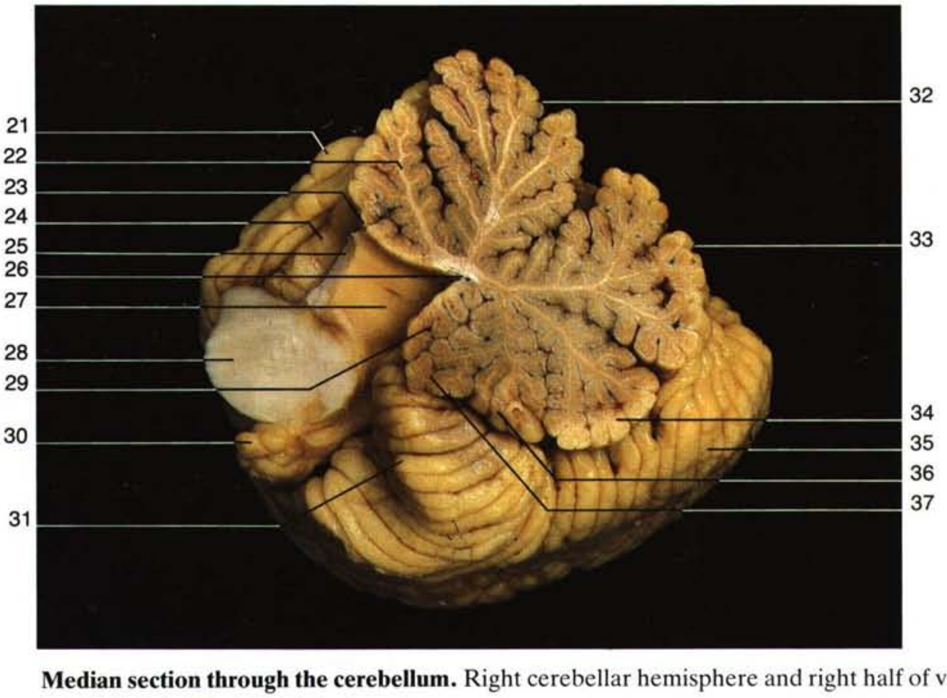

Median section through the cerebellum. Right cerebellar hemisphere and right half of vermis.

1	Superior cerebellar peduncle
2	Middle cerebellar peduncle
3	Cerebellar tonsil
4	Inferior semilunar lobule
5	**Vermis**
6	Central lobule of vermis
7	Inferior cerebellar peduncle
8	Superior medullary velum
9	**Nodule of vermis**
10	**Flocculus**
11	Biventral lobule
12	Left cerebellar hemisphere
13	Inferior semilunar lobule
14	Biventral lobule
15	Vermis of cerebellum
16	Tuber of vermis
17	Pyramid of vermis
18	Uvula of vermis
19	Tonsil of cerebellum
20	Floccule of cerebellum
21	Right cerebellar hemisphere
22	Vermis (central lobule)
23	Cerebellar lingula
24	Ala of central lobule
25	**Superior cerebellar peduncle**
26	Fastigium
27	**Fourth ventricle**
28	**Middle cerebellar peduncle**
29	Nodule of vermis
30	Flocculus of cerebellum
31	Cerebellar tonsil
32	Culmen of vermis
33	Declive of vermis
34	Tuber of vermis
35	Inferior semilunar lobule
36	Pyramis of vermis
37	Uvula of vermis

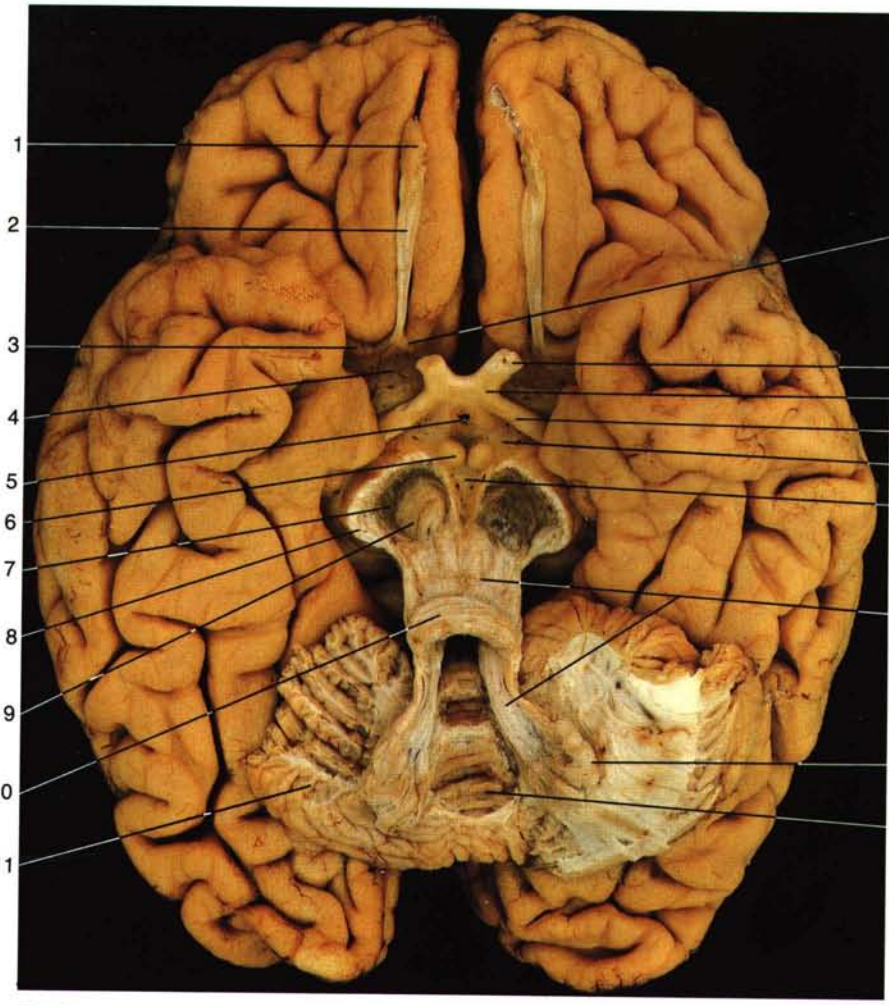

Brain and cerebellum (inferior aspect). Parts of the cerebellum have been removed to display the dentate nucleus and the main pathway to the midbrain (cerebellorubral tract).

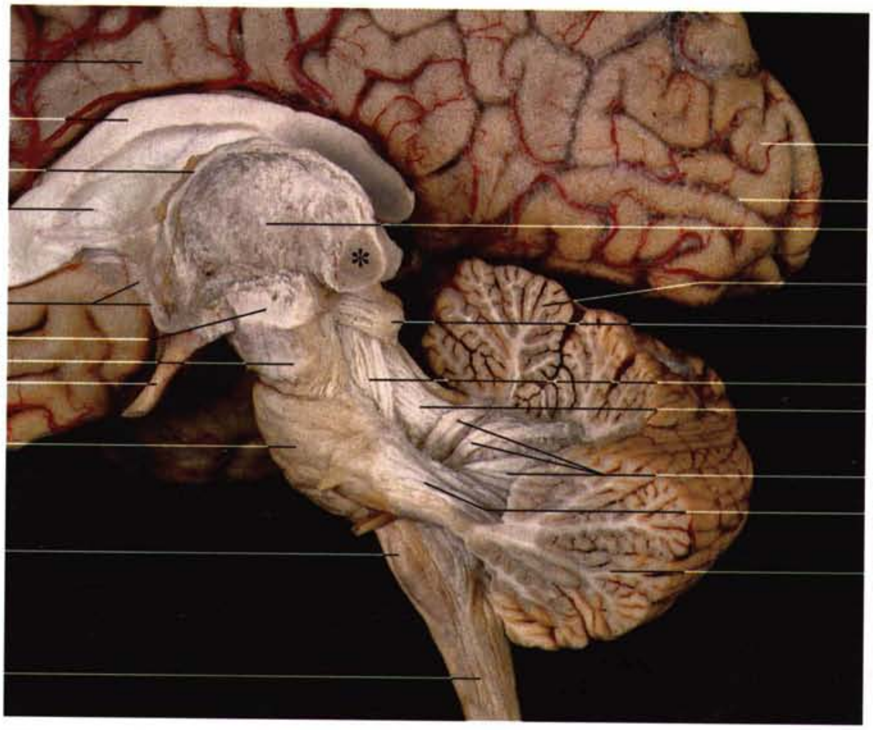

Dissection of the cerebellar peduncles and their connection with midbrain and diencephalon. A small part of pulvinar thalami (*) has been cut to show inferior brachium.

1 Olfactory bulb
2 **Olfactory tract**
3 Lateral olfactory stria
4 Anterior perforated substance
5 Infundibulum (divided)
6 **Mamillary body**
7 Substantia nigra
8 Pedunculus cerebri
9 **Red nucleus**
10 Decussation of superior cerebellar peduncle
11 **Cerebellar hemisphere**
12 Medial olfactory stria
13 **Optic nerve**
14 Optic chiasma
15 Optic tract
16 Posterior perforated substance
17 Interpeduncular fossa
18 **Superior cerebellar peduncle** and cerebellorubral tract
19 **Dentate nucleus**
20 **Vermis of cerebellum**
21 Cingulate gyrus
22 **Corpus callosum**
23 Stria terminalis
24 Septum pellucidum
25 **Columna fornicis**
26 Cerebral peduncle at midbrain level
27 Pons
28 Inferior olive
29 Medulla oblongata with lateral pyramidal tract
30 Occipital lobe
31 Calcarine sulcus
32 **Thalamus**
33 Inferior colliculus with brachium
34 **Medial lemniscus**
35 **Superior cerebellar peduncle**
36 **Inferior cerebellar peduncle**
37 **Middle cerebellar peduncle**
38 Cerebellar hemisphere

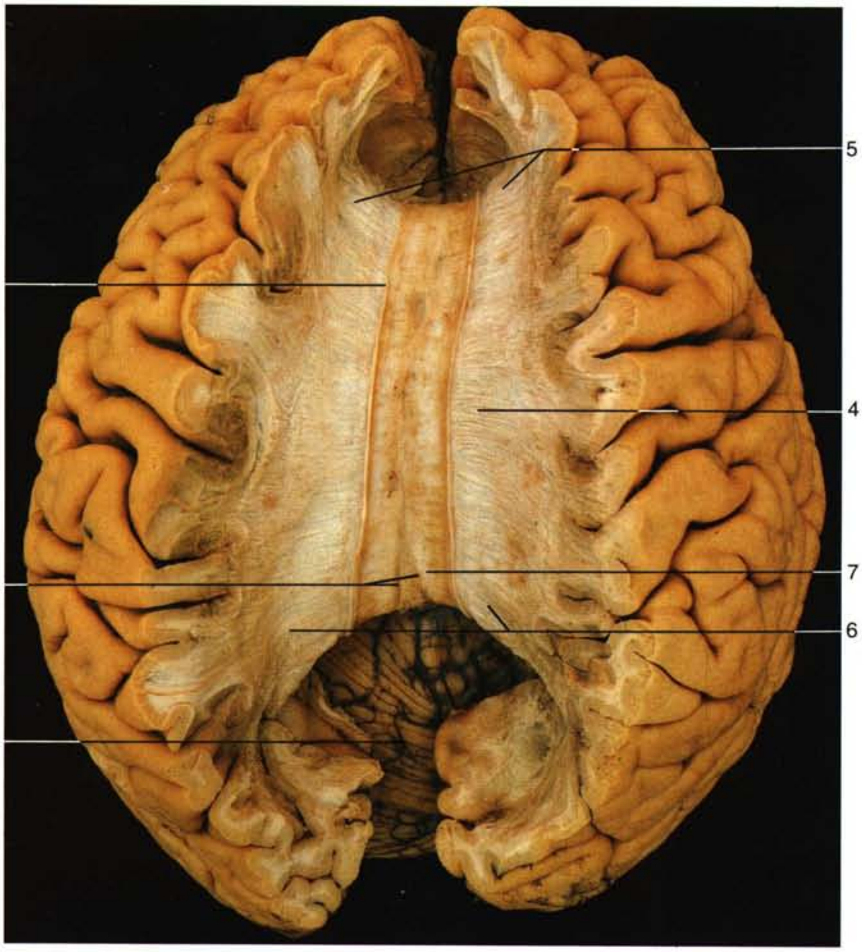

1 Lateral longitudinal stria of indusium griseum
2 Medial longitudinal stria of indusium griseum
3 Cerebellum
4 Radiating fibers of the corpus callosum
5 Forceps minor of corpus callosum
6 Forceps major of corpus callosum
7 Splenium of corpus callosum

Dissection of the brain I. The fiber system of the corpus callosum has been displayed by removing the cortex lying above it. Frontal pole at top.

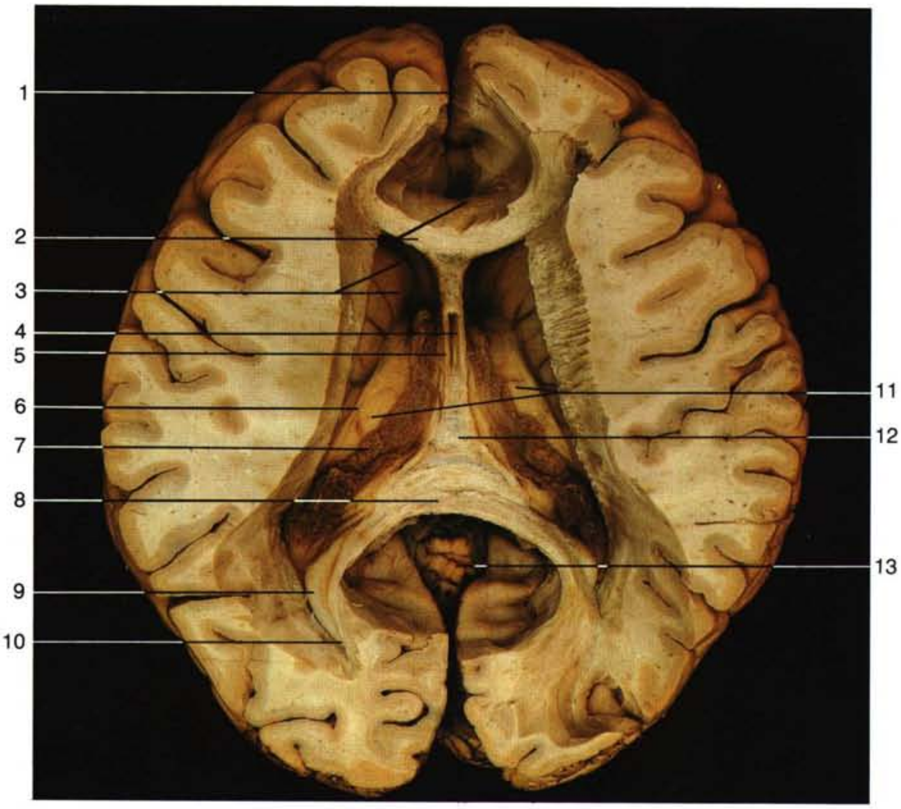

1 Longitudinal cerebral fissure
2 Genu of corpus callosum
3 Head of **caudate nucleus** and anterior horn of lateral ventricle
4 Cavum of septum pellucidum
5 **Septum pellucidum**
6 Stria terminalis
7 **Choroid plexus** of **lateral ventricle**
8 Splenium of **corpus callosum**
9 Calcar avis
10 Posterior horn of lateral ventricle
11 **Thalamus** (lamina affixa)
12 Commissure of fornix
13 Vermis of cerebellum

Dissection of the brain II. The lateral ventricles and subcortical nuclei of the brain are dissected. The corpus callosum has been partly removed. Frontal pole at the top.

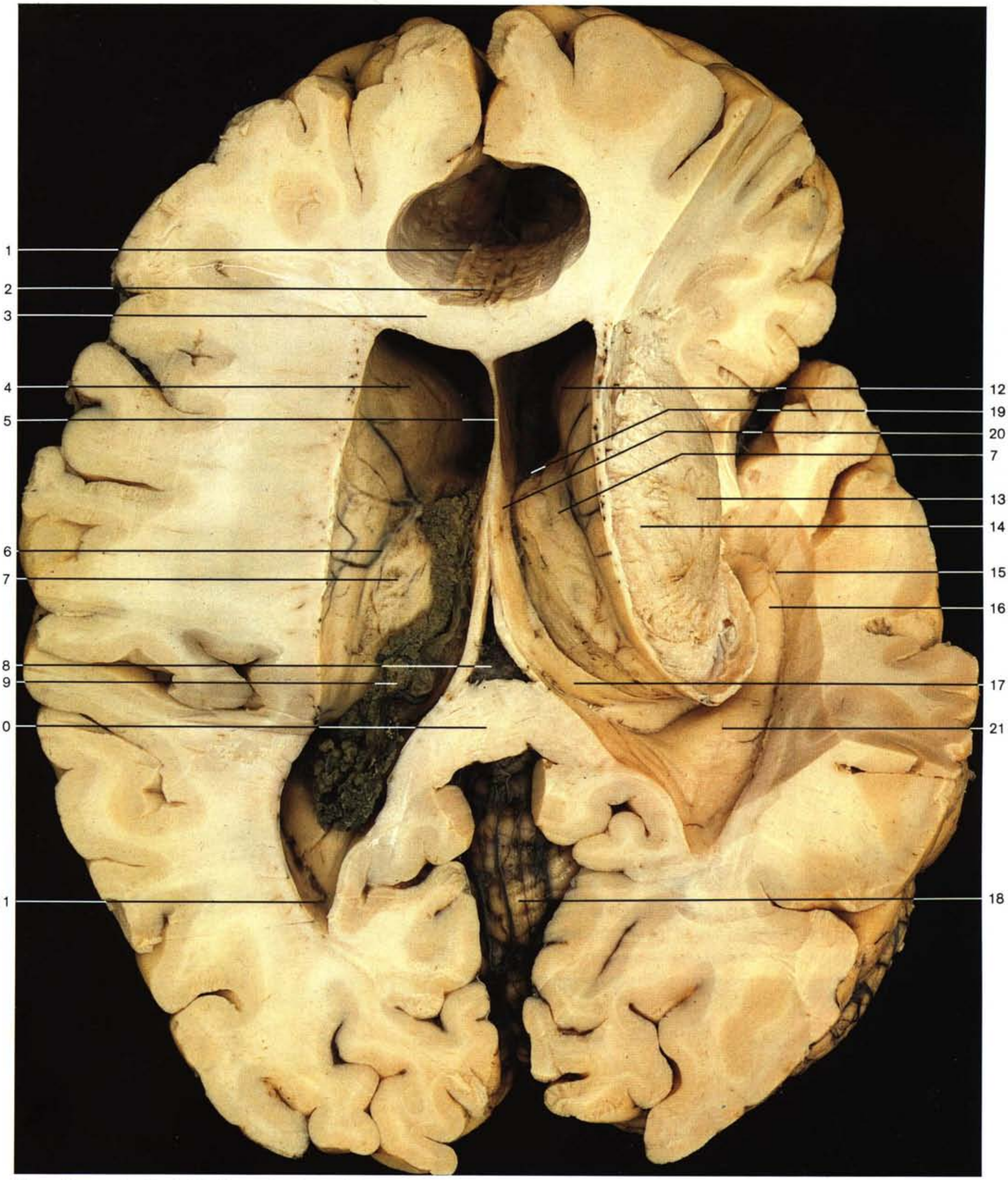

Dissection of the brain III (superior view of lateral ventricle and subcortical nuclei of the brain). Corpus callosum partly removed. At right, the entire lateral ventricle has been opened, the insula with claustrum, extreme and external capsules have been removed, exposing the lentiform nucleus and the internal capsule.

1 Lateral longitudinal stria
2 Medial longitudinal stria
3 Genu of corpus callosum
4 Head of **caudate nucleus**
5 **Septum pellucidum**
6 Stria terminalis
7 **Thalamus** (lamina affixa)
8 Choroid plexus of third ventricle
9 **Choroid plexus** of **lateral ventricle**
10 Splenium of corpus callosum
11 Posterior horn of lateral ventricle
12 Anterior horn of lateral ventricle (head of caudate nucleus)
13 **Putamen** of **lentiform nucleus**
14 **Internal capsule**
15 Inferior horn of lateral ventricle
16 **Pes hippocampi**
17 **Crus of fornix**
18 Vermis of cerebellum with arachnoid and pia mater
19 Interventricular foramen
20 Right column of fornix
21 Collateral eminence

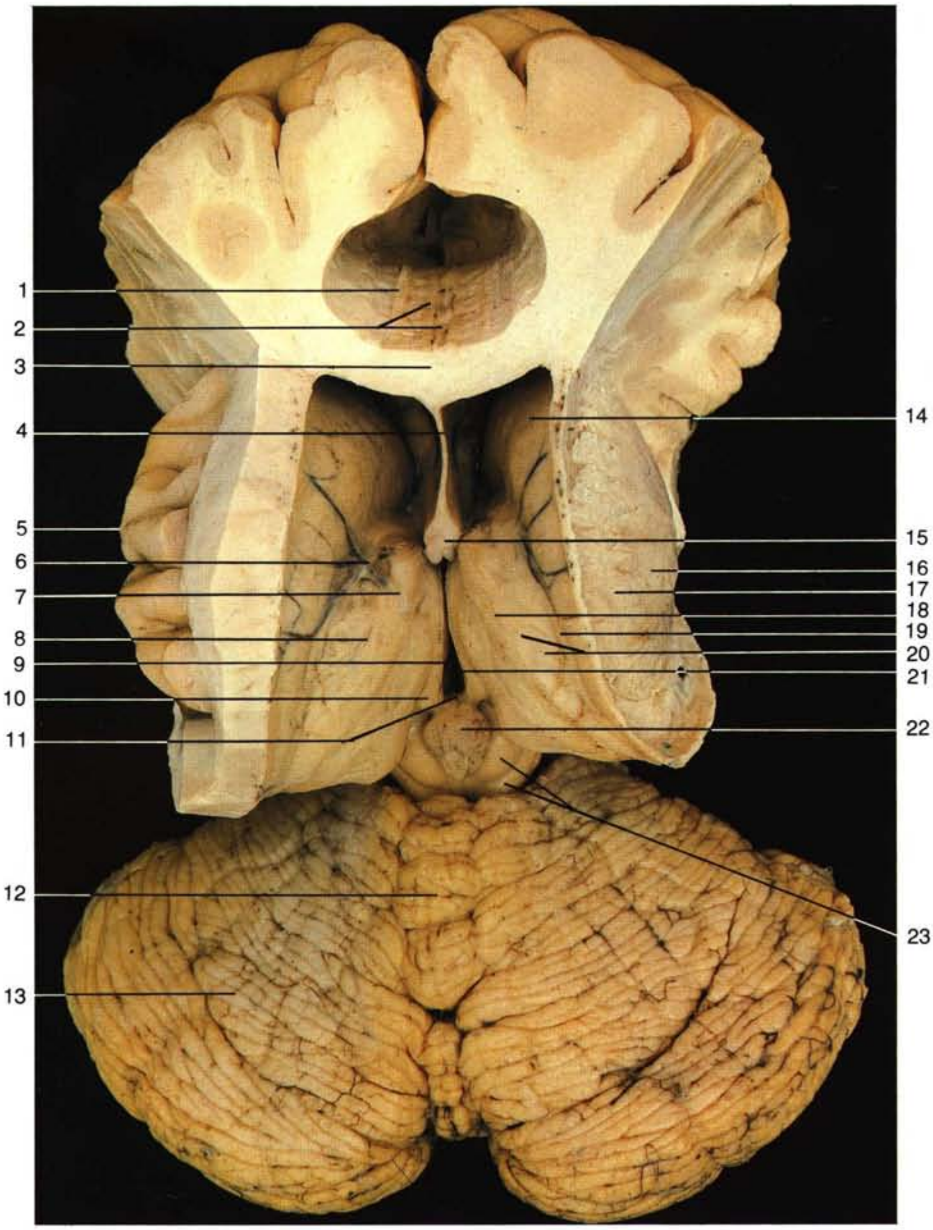

1 Lateral longitudinal stria
2 Medial longitudinal stria
3 **Corpus callosum**
4 Septum pellucidum
5 Insular gyri
6 Thalamostriate vein
7 Anterior tubercle of thalamus
8 **Thalamus**
9 Medullary stria of thalamus
10 Habenular trigone
11 Habenular commissure
12 **Vermis of the cerebellum**
13 Left **hemisphere of cerebellum**
14 **Head of caudate nucleus**
15 **Columns of fornix**
16 Putamen of lentiform nucleus
17 **Internal capsule**
18 Taenia of choroid plexus
19 Stria terminalis and thalamostriate vein
20 Lamina affixa
21 **Third ventricle**
22 **Pineal body**
23 Superior and inferior colliculus of midbrain

Dissection of the brain IVa. Temporal lobe, fornix and the posterior corpus callosum have been removed (this part of the specimen is depicted below). Frontal pole at top (superior aspect).

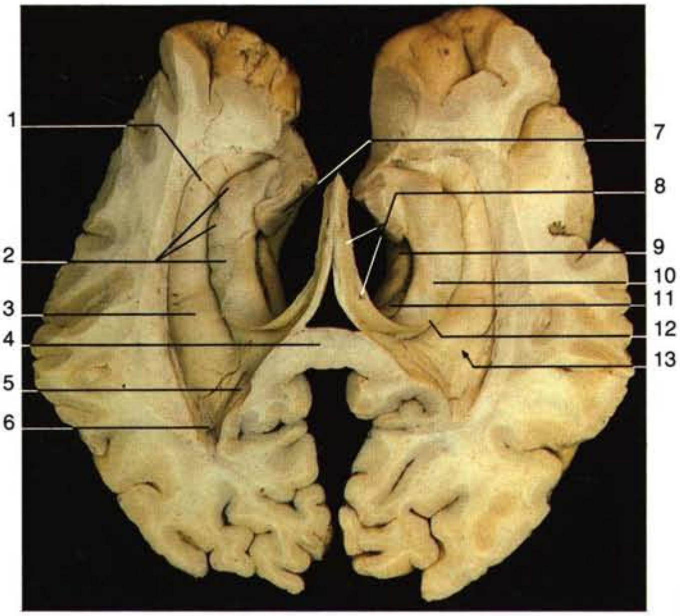

1 Inferior horn of lateral ventricle
2 **Hippocampal digitations**
3 Collateral eminence
4 Splenium of corpus callosum
5 Calcar avis
6 Posterior horn of lateral ventricle
7 **Uncus** of parahippocampal gyrus
8 Body and crus of **fornix**
9 **Parahippocampal gyrus**
10 **Pes hippocampi**
11 Dentate gyrus
12 Hippocampal fimbria
13 Lateral ventricle

Dissection of the brain IVb. Depicted is the portion of the brain removed from the specimen above. **Temporal lobe and limbic system** (superior aspect). Columns of fornix are served.

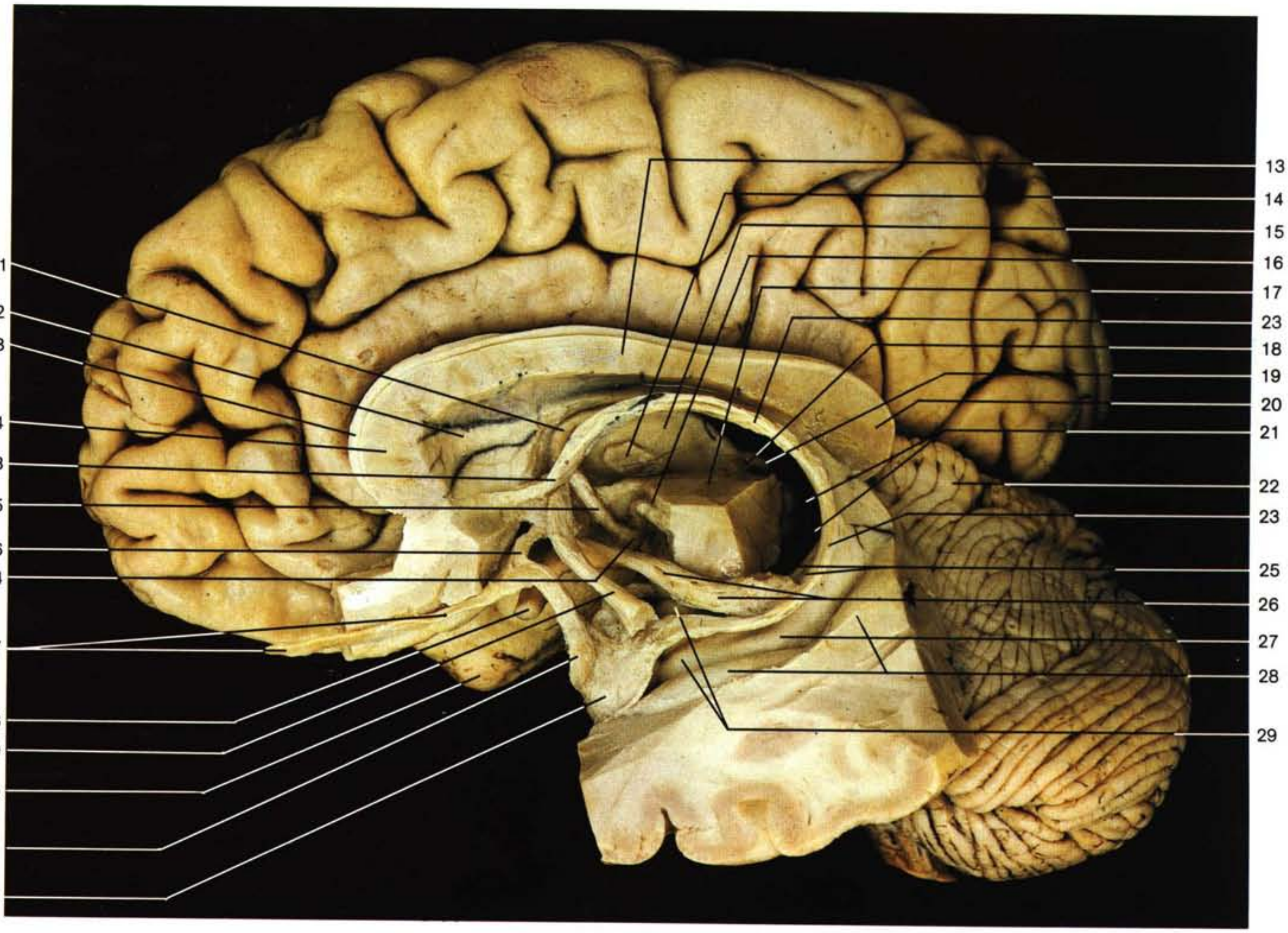

Dissection of the limbic system. Left side, lateral aspect. Corpus callosum has been cut in the median plane. The left thalamus and the left hemisphere have been partly removed.

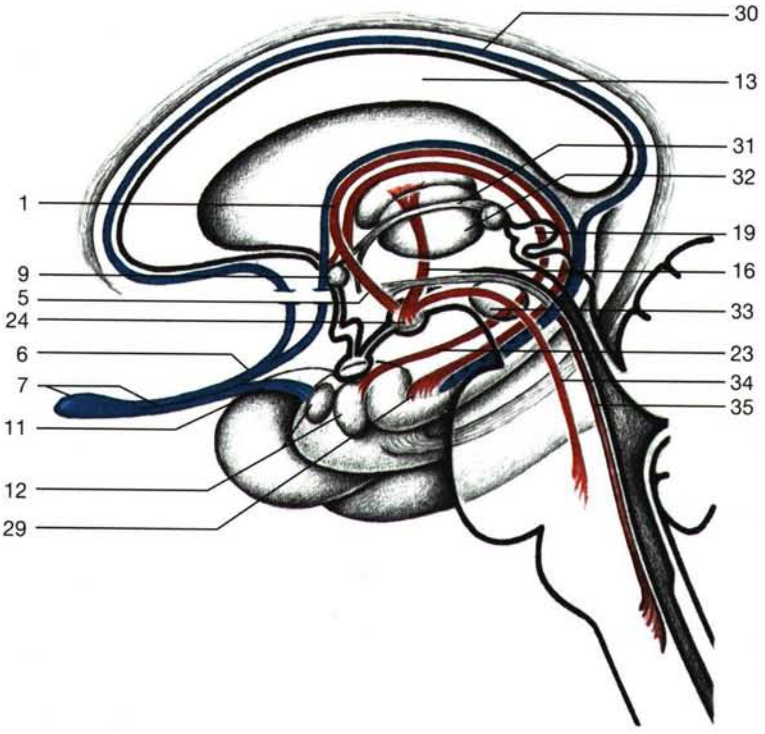

Main pathways of **limbic and olfactory system.** (Schematic drawing.) Blue = afferent pathways; red = efferent pathways.

1 **Body of fornix**
2 Septum pellucidum
3 **Lateral longitudinal stria**
4 Genu of corpus callosum
5 **Column of fornix**
6 Medial olfactory stria
7 **Olfactory bulb** and **olfactory tract**
8 Optic nerve
9 Anterior commissure (left half)
10 Right temporal lobe
11 **Lateral olfactory stria**
12 **Amygdala**
13 Body of **corpus callosum**
14 Interthalamic adhesion
15 Third ventricle and right thalamus
16 **Mamillothalamic tract**
17 Part of the thalamus
18 Habenular commissure
19 Pineal body
20 Splenium of corpus callosum
21 Colliculi of midbrain
22 Vermis of cerebellum
23 **Stria terminalis**
24 **Mamillary body**
25 Fimbria of hippocampus and pes hippocampi
26 Left optic tract and lateral geniculate body
27 Lateral ventricle and **parahippocampal gyrus**
28 Collateral eminence
29 Hippocampal digitations
30 **Supracallosal gyrus** (longitudinal stria)
31 Stria medullaris thalami
32 Thalamus
33 Red nucleus
34 Mamillotegmental tract
35 Dorsal longitudinal fasciculus (Schütz)

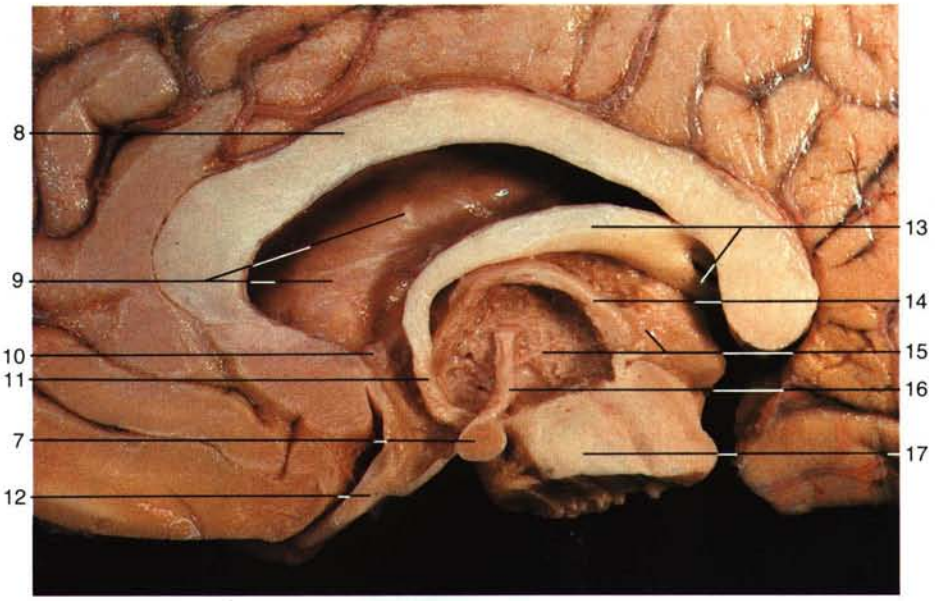

Median section through the diencephalon. Medial part of the thalamus and septum pellucidum have been removed to show the fornix and mamillothalamic tract.

1 Paraventricular nucleus
2 Preoptic nucleus
3 Ventromedial nucleus
4 Supraoptic nucleus
5 Posterior nucleus
6 Dorsomedial nucleus
Hypothalamic nuclei
7 **Mamillary body**
8 **Corpus callosum**
9 Lateral ventricle (showing caudate nucleus)
10 Anterior commissure
11 **Column of fornix**
12 Optic chiasma
13 **Crus of fornix**
14 Medullary stria of thalamus
15 Thalamus and interthalamic adhesion
16 **Mamillothalamic tract** of Vicq d'Azyr
17 Cerebral peduncle
18 **Pineal body**
19 Tectum of midbrain
20 Lamina terminalis

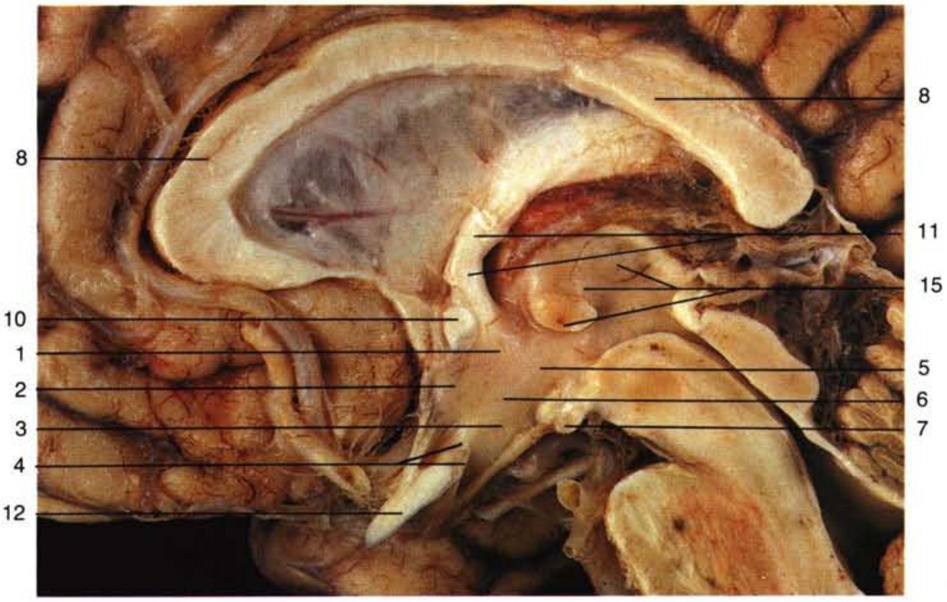

Median section through the diencephalon and midbrain; location of hypothalamic nuclei.

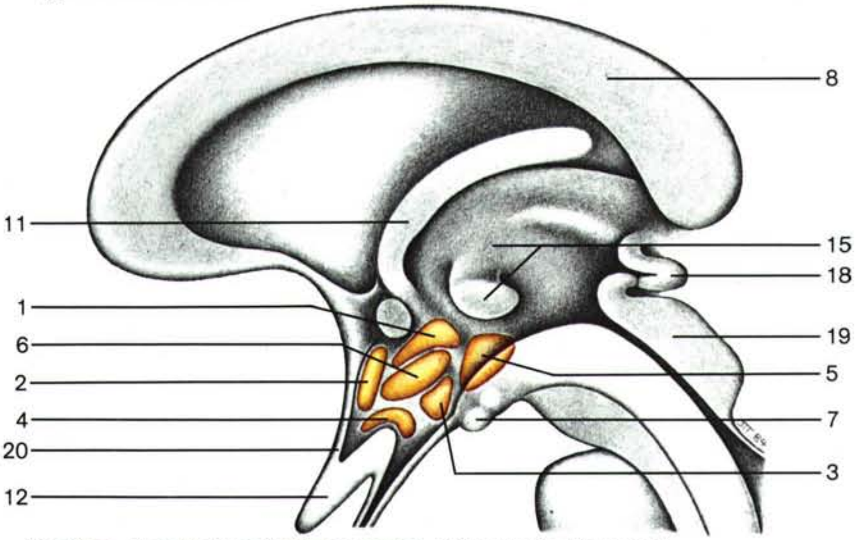

Position of main hypothalamic nuclei. (Schematic diagram.)

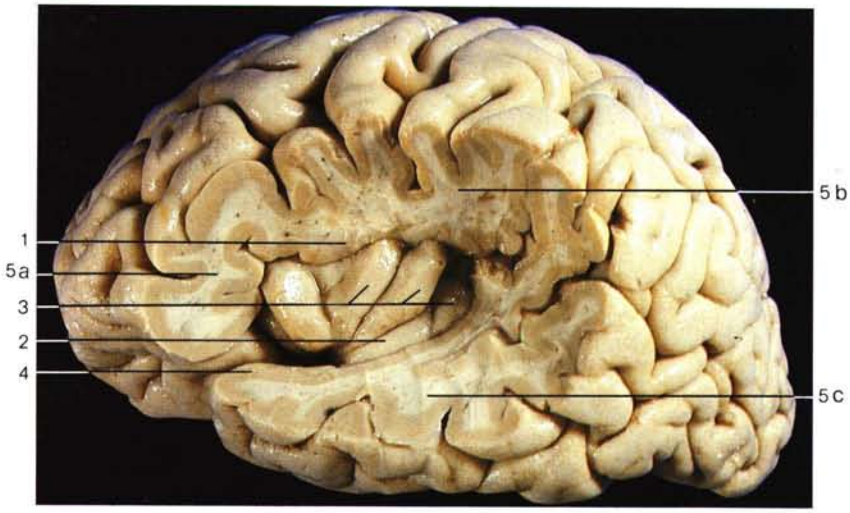

Insula (Reili). The opercula of the frontal, parietal and temporal lobes have been removed to display the insular gyri. Left hemisphere.

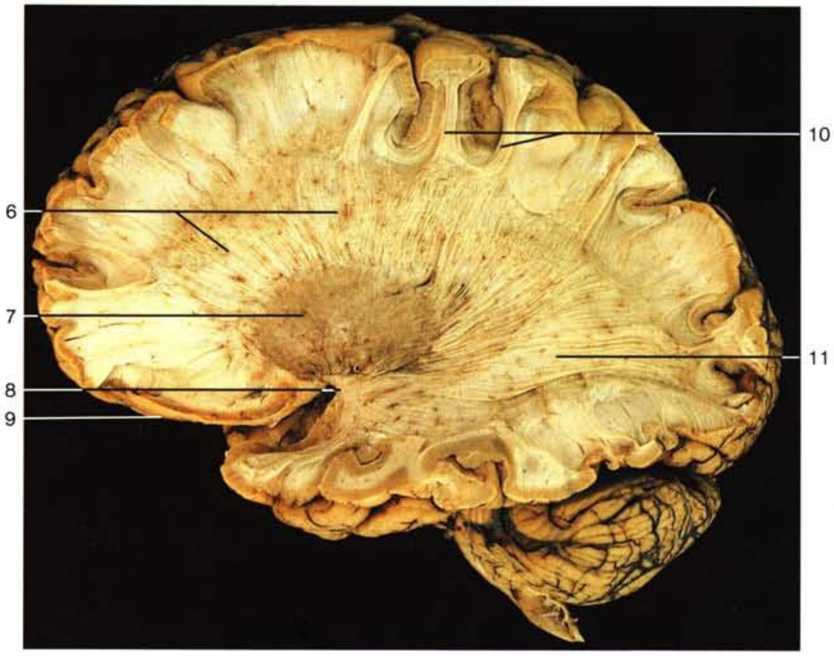

Dissection of the corona radiata, left hemisphere. Frontal pole on the left.

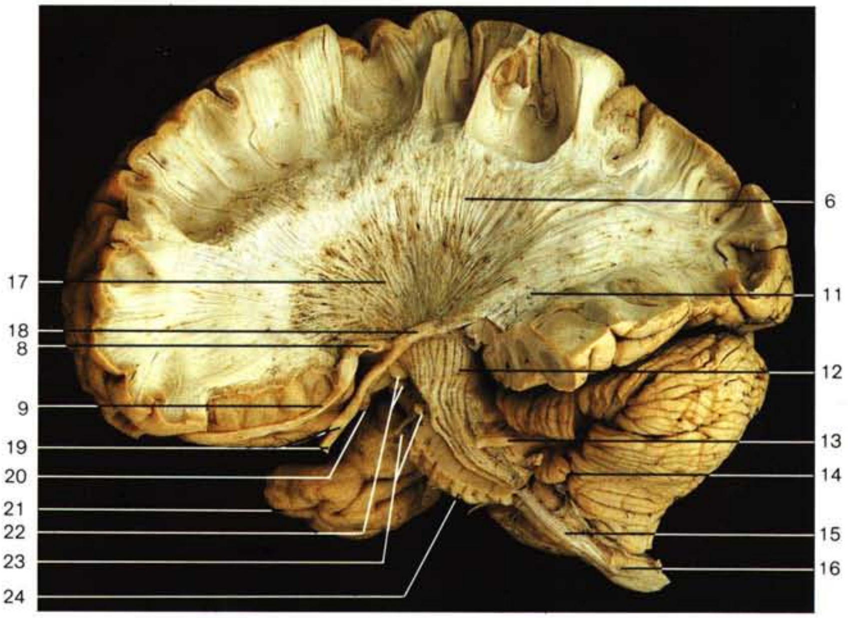

1 Circular sulcus of insula
2 Long gyrus of insula
3 Short gyri of insula
4 Limen insulae
5 Opercula (cut)
  a Frontal operculum
  b Frontoparietal operculum
  c Temporal operculum
6 **Corona radiata**
7 **Lentiform nucleus**
8 **Anterior commissure**
9 Olfactory tract
10 Cerebral arcuate fibers
11 Optic radiation
12 Cerebral peduncle
13 Trigeminal nerve (n. V)
14 Flocculus of cerebellum
15 **Pyramidal tract**
16 Decussation of pyramidal tract
17 Internal capsule
18 Optic tract
19 Optic nerve (n. II)
20 Infundibulum
21 Temporal lobe (right side)
22 Mamillary bodies
23 Oculomotor nerve (n. III)
24 Transverse fibers of pons

◁ **Corona radiata and internal capsule,** left hemisphere. Lentiform nucleus removed (frontal pole to the left).

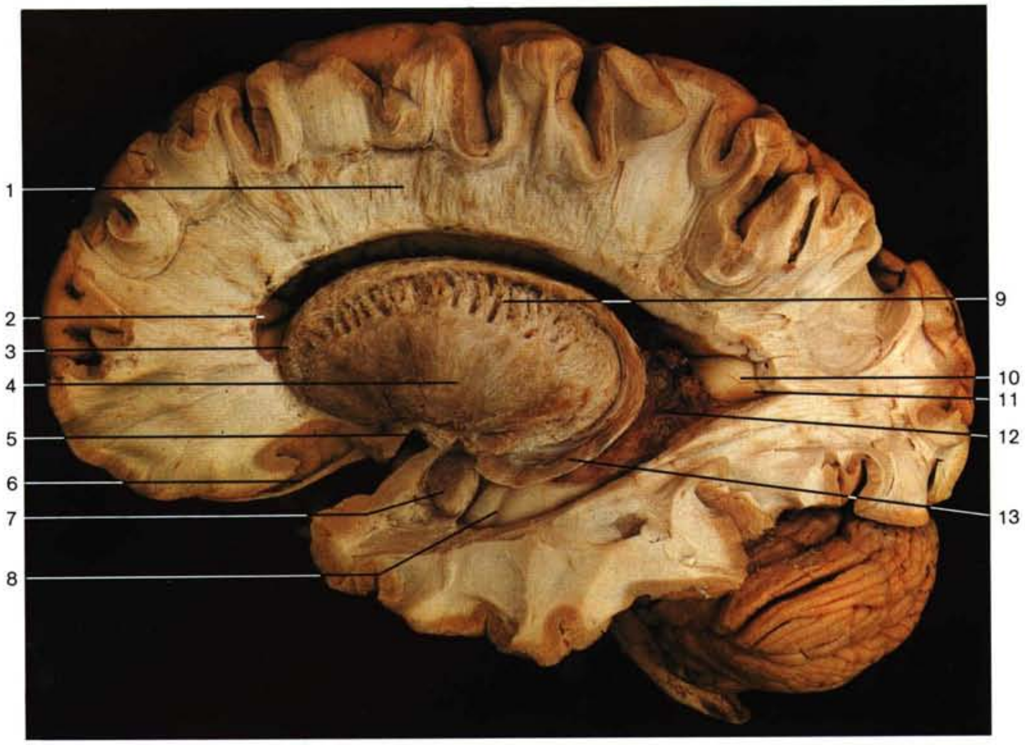

1 Corona radiata
2 Anterior horn of lateral ventricle
3 Head of **caudate nucleus**
4 **Putamen**
5 Anterior commissure
6 Olfactory tract
7 **Amygdala**
8 Hippocampal digitations
9 **Internal capsule**
10 Calcar avis
11 Posterior horn of lateral ventricle
12 Choroid plexus of lateral ventricle
13 Caudal extremity of caudate nucleus
14 **Thalamus**
15 Cerebral arcuate fibers
16 Globus pallidus (remnants)

Dissection of the subcortical nuclei and internal capsule, left hemisphere (lateral aspect). Frontal pole to the left. The lateral ventricle has been opened, and the insular gyri and claustrum have been removed, revealing the lentiform nucleus and the internal capsule.

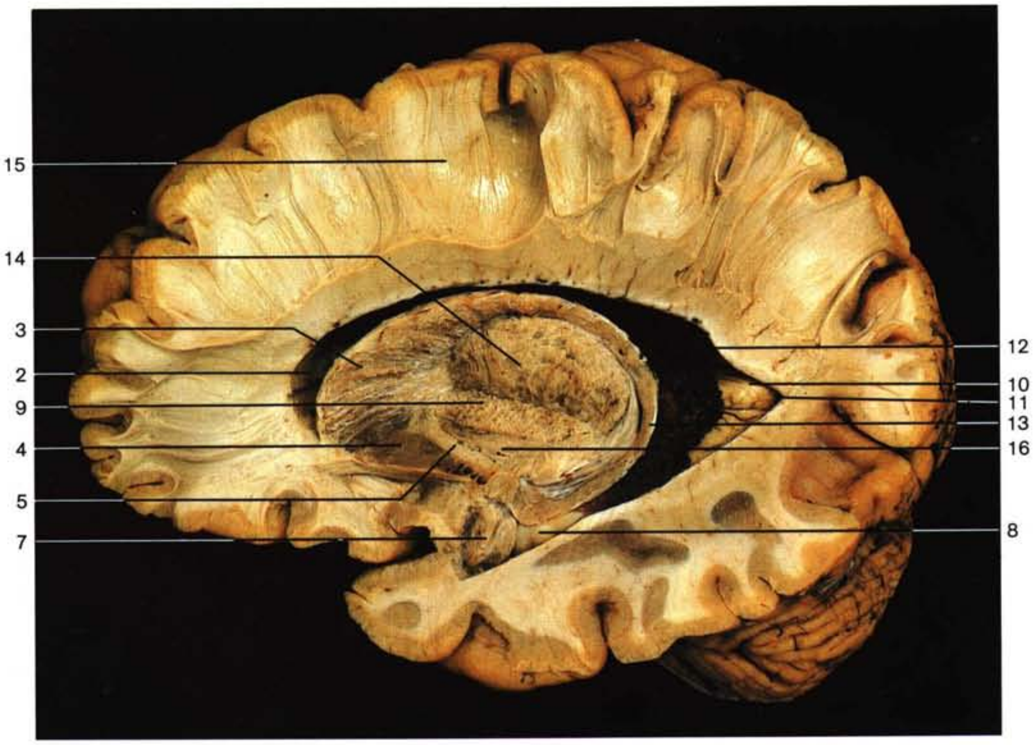

Dissection of the subcortical nuclei (lateral aspect). Lentiform nucleus removed, frontal pole to the left.

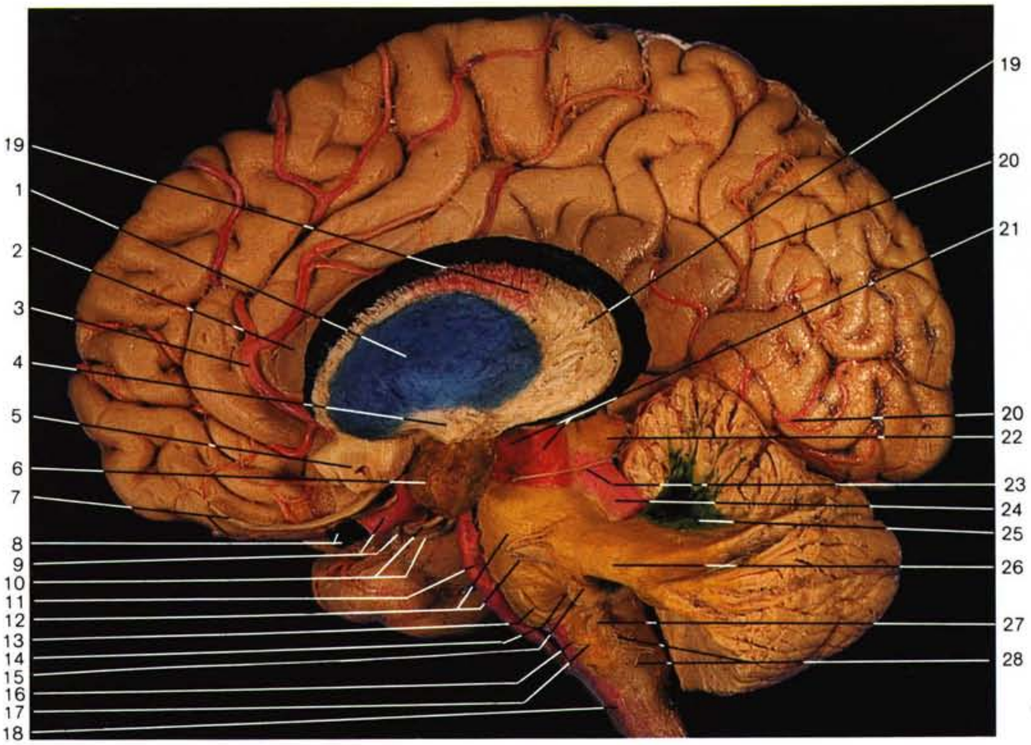

Brain stem and the connections with the cerebellum. Internal capsule (lateral aspect). Red = pyramidal tract; yellow = middle cerebellar peduncle; green = inferior cerebellar peduncle; pink = superior cerebellar peduncle.

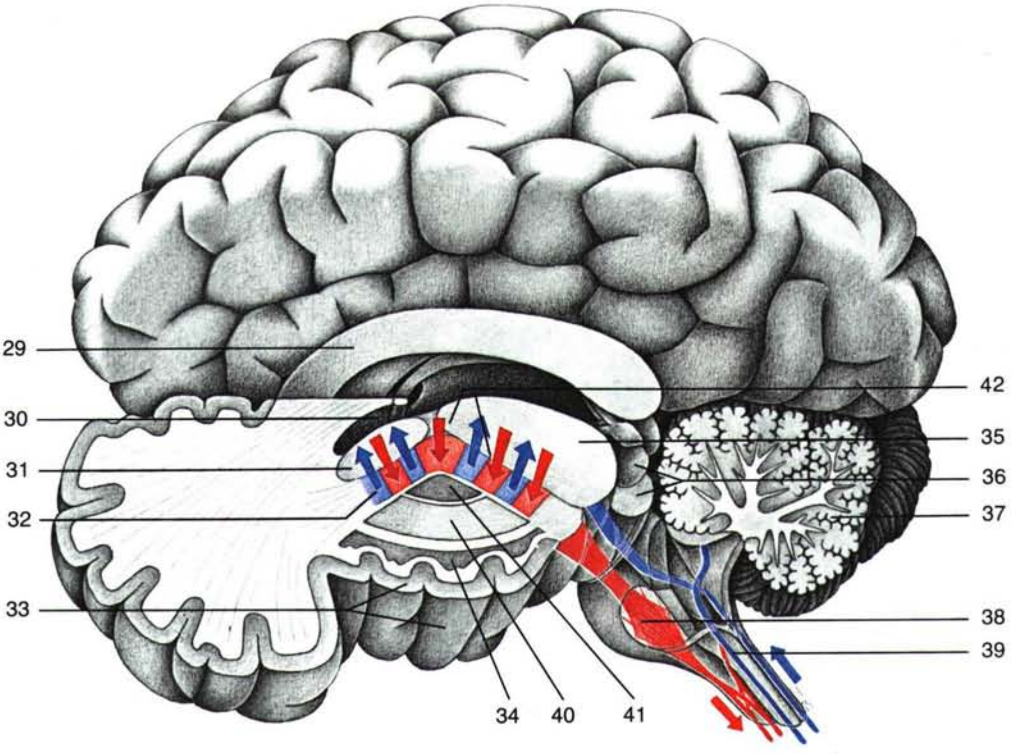

Internal capsule and subcortical nuclei. Left brain, frontal pole to the left, horizontal section. (Semischematic drawing.) Blue = afferent tracts; red = efferent tracts.

1 **Putamen**
2 Genu of corpus callosum
3 Anterior cerebral artery
4 Anterior commissure
5 Subcallosal area
6 Amygdala
7 Olfactory tract
8 Optic nerve (n. II)
9 Internal carotid artery and infundibulum
10 Oculomotor nerve (right and left nerve, n. III)
11 **Basilar artery**
12 Pons and trigeminal nerve (n. V)
13 Abducens nerve (n. VI)
14 Facial nerve (n. VII)
15 Vestibulocochlear nerve (n. VIII)
16 Hypoglossal nerve (n. XII)
17 Olive
18 Pyramidal tract
19 **Internal capsule**
20 Posterior cerebral artery
21 Cerebral peduncle
22 **Colliculi of midbrain**
23 Trochlear nerve (n. IV)
24 Superior cerebellar peduncle
25 Inferior cerebellar peduncle
26 **Middle cerebellar peduncle**
27 Glossopharyngeal nerve (n. IX)
28 Vagus (n. X) and accessory nerves (n. XI)
29 **Corpus callosum**
30 Lateral ventricle (anterior horn)
31 Caudate nucleus
32 Internal capsule (anterior limb)
33 Insula
34 **Claustrum**
35 **Thalamus**
36 Superior and inferior colliculus of midbrain
37 Cerebellum
38 Middle peduncle of cerebellum (efferent tracts)
39 Medulla oblongata (afferent tracts)
40 Putamen of lentiform nucleus
41 **Globus pallidus** of lentiform nucleus
42 Genu and posterior limb of internal capsule

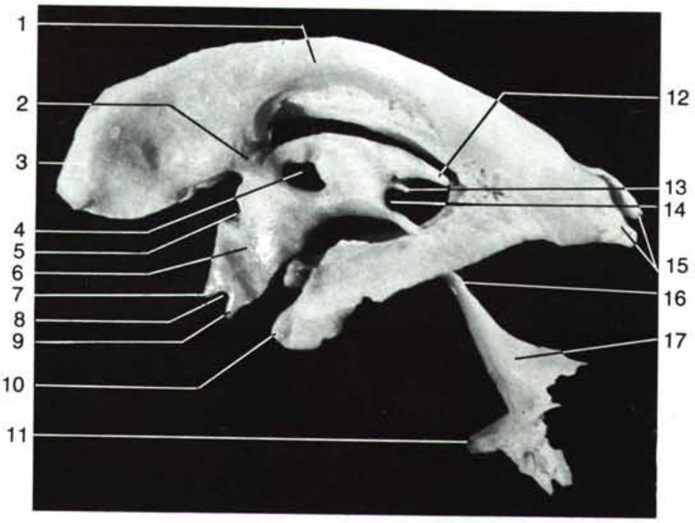

Cast of ventricular cavities of the brain (lateral aspect), frontal pole to the left.

1 Central part of the **lateral ventricle**
2 **Interventricular foramen** of Monro
3 Anterior horn of the lateral ventricle
4 Site of interthalamic adhesion
5 Notch for anterior commissure
6 **Third ventricle**
7 Optic recess
8 Notch for optic chiasma
9 Infundibular recess
10 Inferior horn of lateral ventricle with indentation of amygdaloid body
11 Lateral recess and lateral aperture of Luschka
12 Suprapineal recess
13 Pineal recess
14 Notch for posterior commissure
15 Posterior horn of lateral ventricle
16 **Cerebral aqueduct**
17 **Fourth ventricle**
18 Median aperture of Magendie
19 **Cerebellomedullary cistern**
20 Superior sagittal sinus
21 Inferior sagittal sinus
22 Intervaginal space of optic nerve
23 Arachnoid granulations of Pacchioni
24 Straight sinus

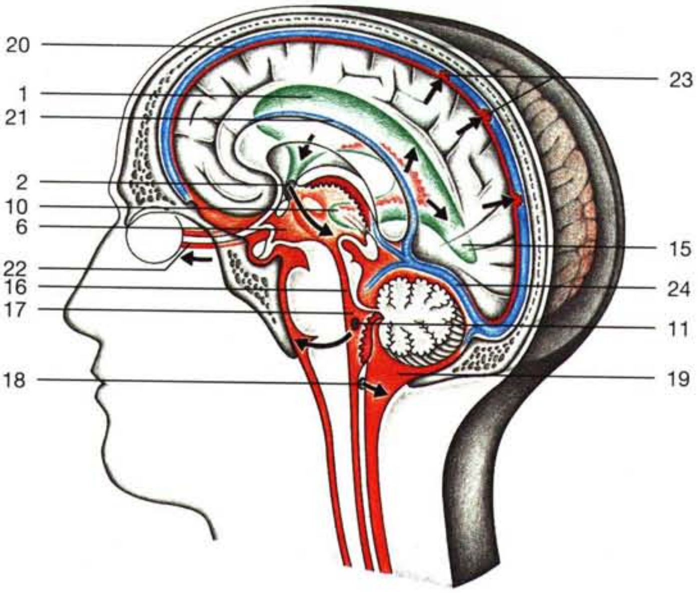

◁ **Position of ventricular cavities.** (Schematic drawing.) The direction of flow of cerebrospinal fluid is indicated by arrows.
Green = Right lateral ventricle
Red = Choroidal plexus

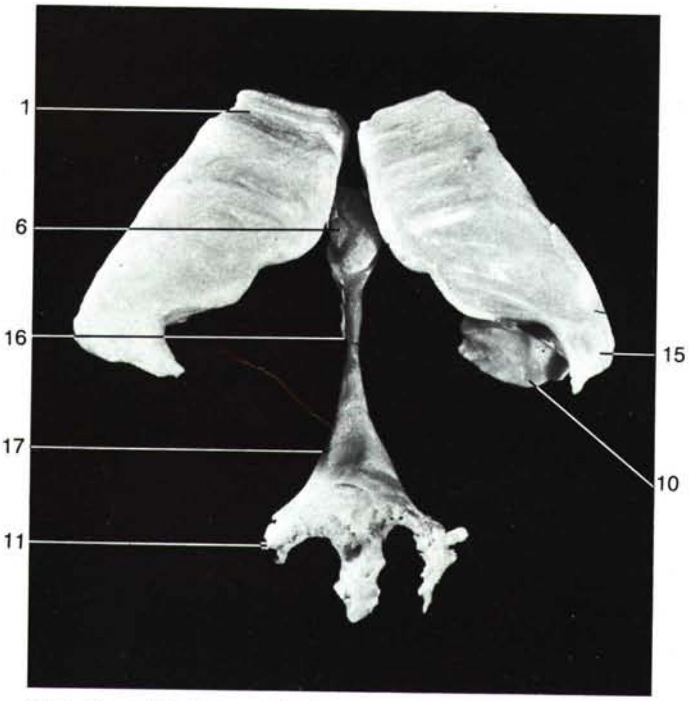

Cast of ventricular cavities (posterior aspect).

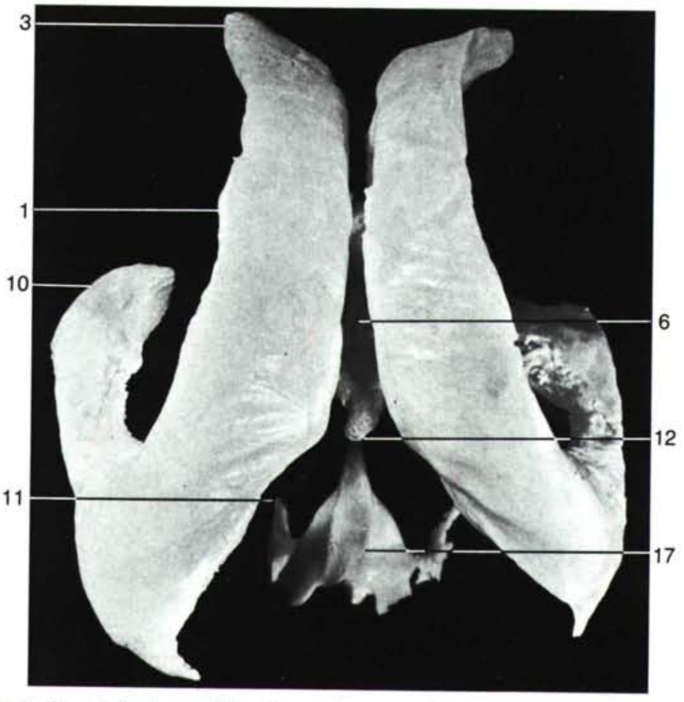

Cast of ventricular cavities (superior aspect). Frontal pole at top.

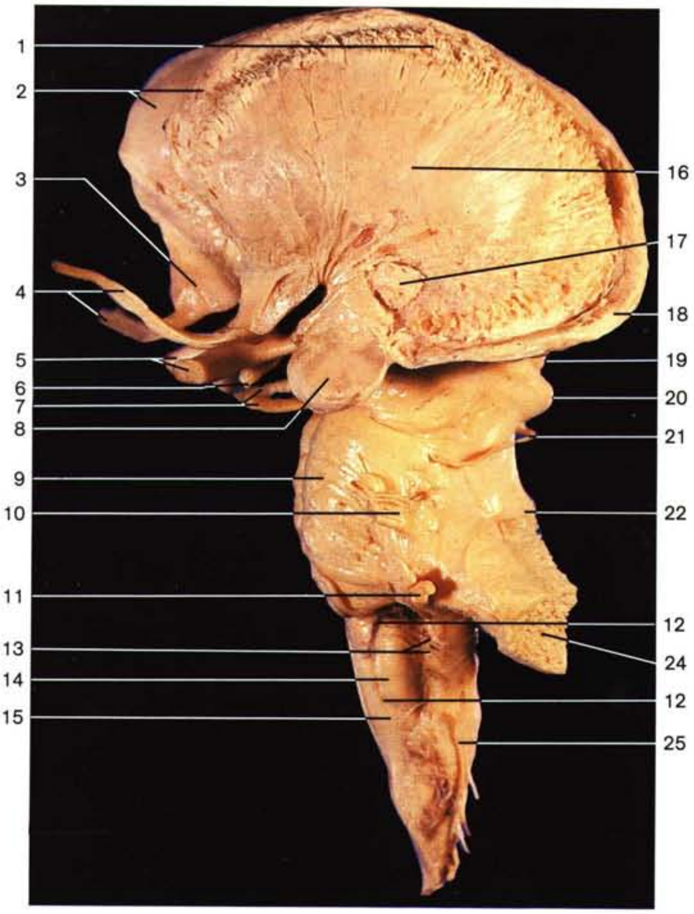

Brain stem (left lateral aspect). Cerebellar peduncles have been severed, cerebellum and cerebral cortex have been removed.

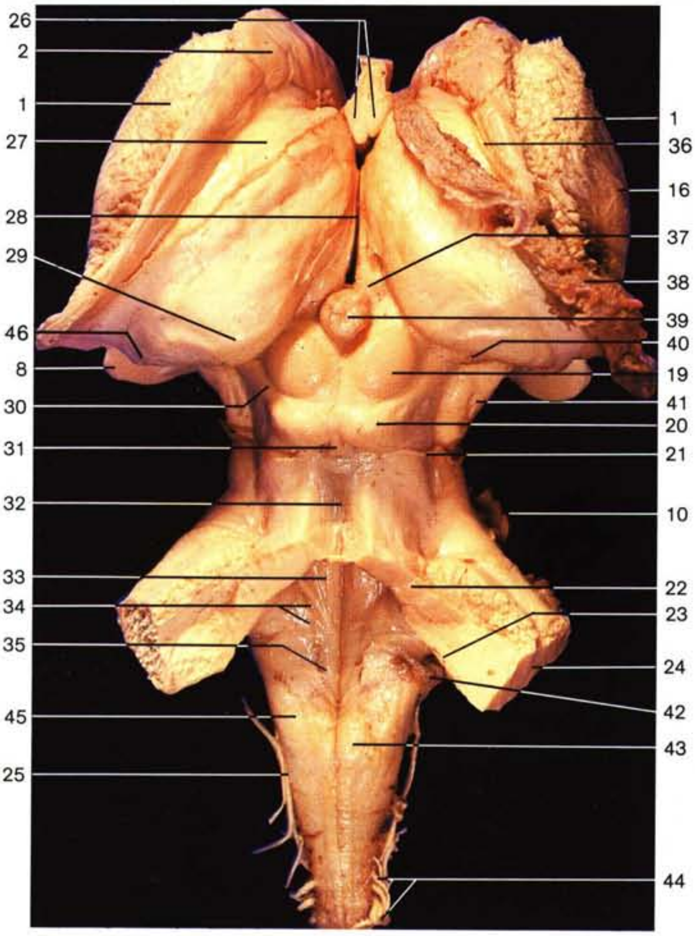

Brain stem (dorsal aspect). Cerebellum removed.

1. **Internal capsule**
2. Head of the caudate nucleus
3. Olfactory trigone
4. Olfactory tracts
5. Optic nerves
6. Infundibulum
7. Oculomotor nerve
8. **Amygdaloid body**
9. **Pons**
10. Trigeminal nerve
11. Facial and vestibulocochlear nerves
12. Hypoglossal nerve
13. Glossopharyngeal and vagus nerves
14. **Olive**
15. Medulla oblongata
16. **Lentiform nucleus**
17. **Anterior commissure**
18. Tail of caudate nucleus
19. Superior colliculus
20. Inferior colliculus
21. Trochlear nerve
22. Superior cerebellar peduncle
23. Inferior cerebellar peduncle
24. **Middle cerebellar peduncle**
25. Accessory nerve (n. XI)
26. Columns of fornix (divided)
27. Lamina affixa
28. **Third ventricle**
29. Pulvinar of thalamus
30. Inferior brachium
31. Frenulum veli
32. Superior medullary velum
33. Facial colliculus
34. Striae medullares and rhomboid fossa
35. Hypoglossal triangle
36. Stria terminalis and thalamostriate vein
37. Habenular trigone
38. Choroid plexus of lateral ventricle
39. **Pineal body**
40. Medial geniculate body
41. Cerebral peduncle
42. Choroid plexus of fourth ventricle
43. Clava
44. Dorsal root of cervical nerve
45. Cuneate tubercle
46. Lateral geniculate body

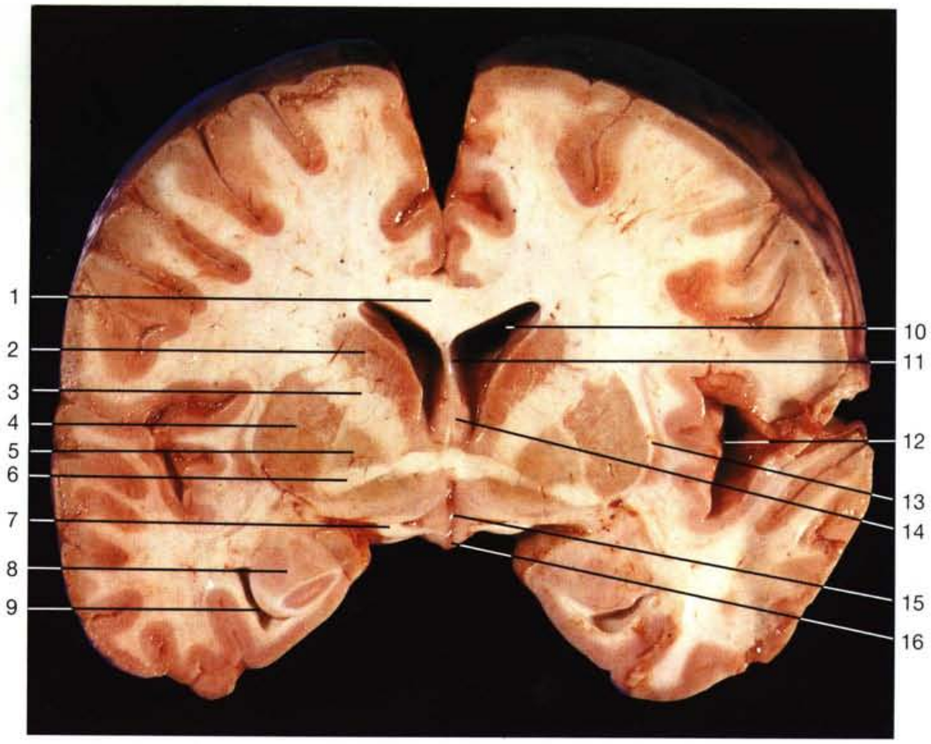

Coronal section through the brain at the level of the anterior commissure. Section 1.

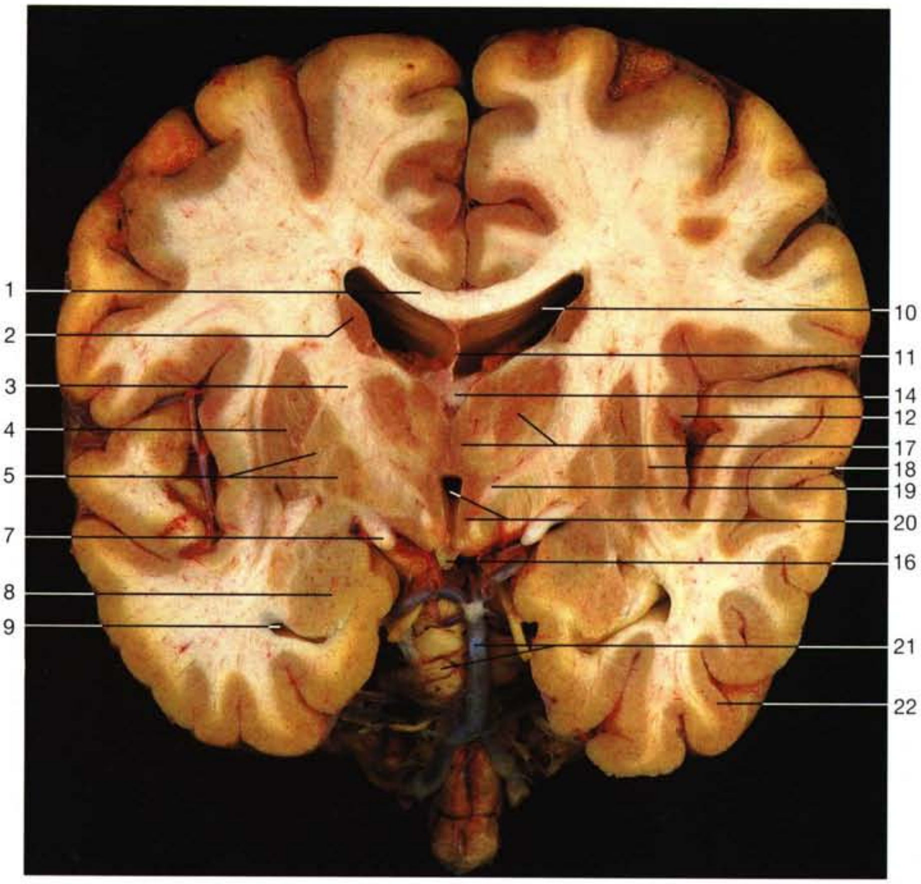

Coronal section through the brain at the level of the third ventricle and the interthalamic adhesion. Section 2.

1 Corpus callosum
2 Head of **caudate nucleus**
3 **Internal capsule**
4 **Putamen**
5 **Globus pallidus**
6 Anterior commissure
7 Optic tract
8 Amygdaloid body
9 Inferior horn of lateral ventricle
10 **Lateral ventricle**
11 Septum pellucidum
12 Lobus insularis (insula)
13 External capsule
14 Column of fornix
15 Optic recess
16 Infundibulum
17 **Thalamus**
18 Claustrum
19 Lenticular ansa
20 **Third ventricle** and **hypothalamus**
21 Basilar artery and pons
22 Cortex of temporal lobe
23 Inferior colliculus
24 Superior colliculus
25 Cerebral aqueduct
26 Red nucleus
27 Substantia nigra
28 Cerebral peduncle
29 Trochlear nerve (n. IV)
30 Gray matter
31 Nucleus of oculomotor nerve (nucleus of Edinger-Westphal)
32 Fibers of oculomotor nerve (n. III)
33 Vermis of cerebellum
34 Fourth ventricle
35 Reticular formation
36 Pons and transverse pontine fibers
37 Emboliform nucleus
38 Dentate nucleus
39 Middle cerebellar peduncle
40 Choroid plexus
41 Hypoglossal nucleus at rhomboid fossa
42 Medial longitudinal fasciculus
43 Trigeminal nerve (n. V.)
44 Inferior olivary nucleus
45 Corticospinal fibers and arcuate fibers
46 Fourth ventricle with choroid plexus
47 Vestibular nuclei
48 Nucleus and tractus solitarius
49 Inferior cerebellar peduncle (restiform body)
50 Reticular formation
51 Medial lemniscus
52 Cuneate nucleus of Burdach
53 Central canal
54 **Pyramidal tract**
55 Flocculus of cerebellum
56 Cerebellar hemisphere with pia mater
57 "Arbor vitae" of cerebellum
58 Nucleus gracilis of Goll
59 Lateral recess of choroid plexus of IVth ventricle
60 Posterior inferior cerebellar artery
61 Choroid plexus of lateral ventricle

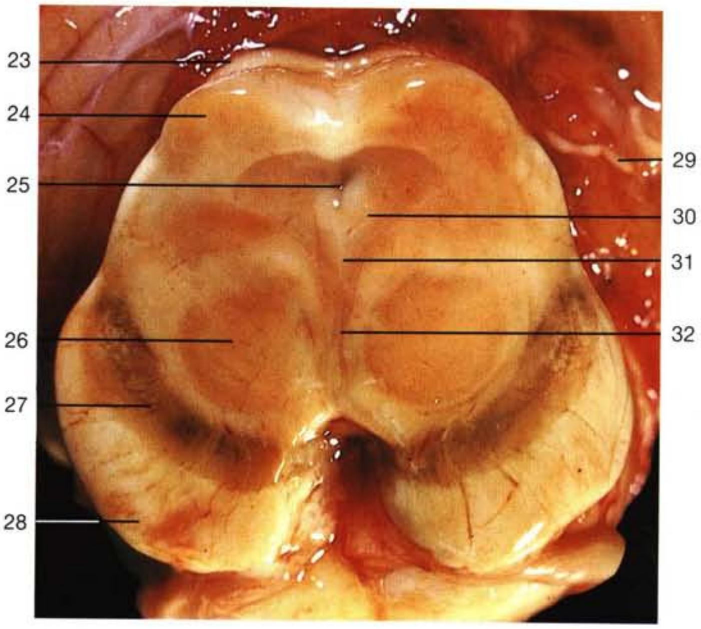
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Cross-section of the midbrain (mesencephalon) at the level of the superior colliculus (superior aspect). Section 4.

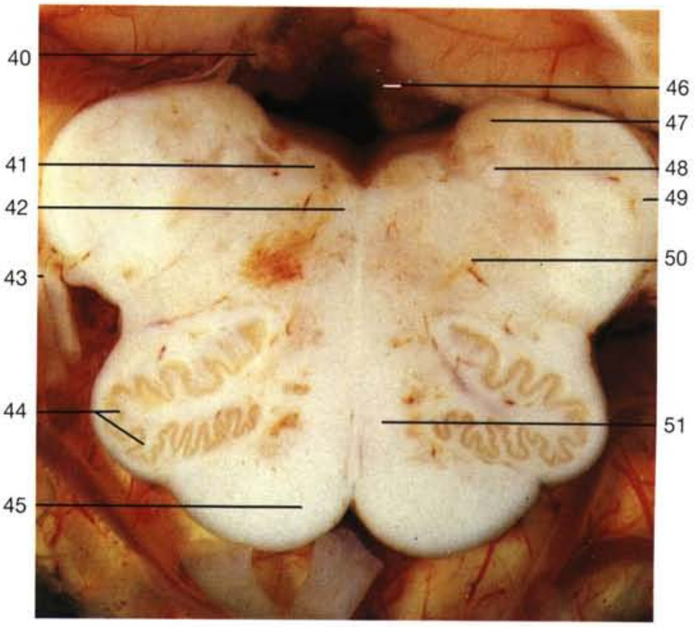
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Cross-section of the rhombencephalon at the level of the olive (inferior aspect). Section 6.

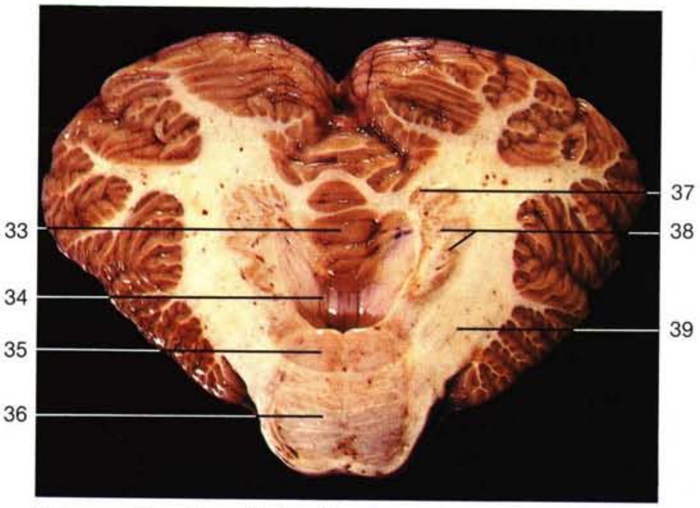
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Cross-section through the rhombencephalon at the level of pons (inferior aspect). Section 5.

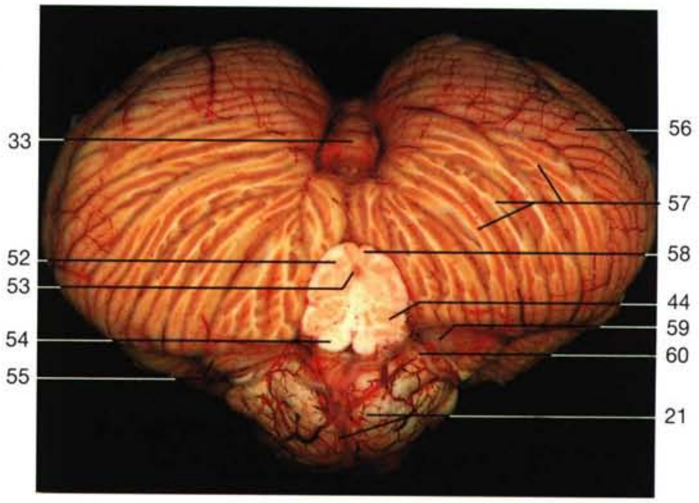
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Cross-section through medulla oblongata and cerebellum (inferior aspect). Section 7.

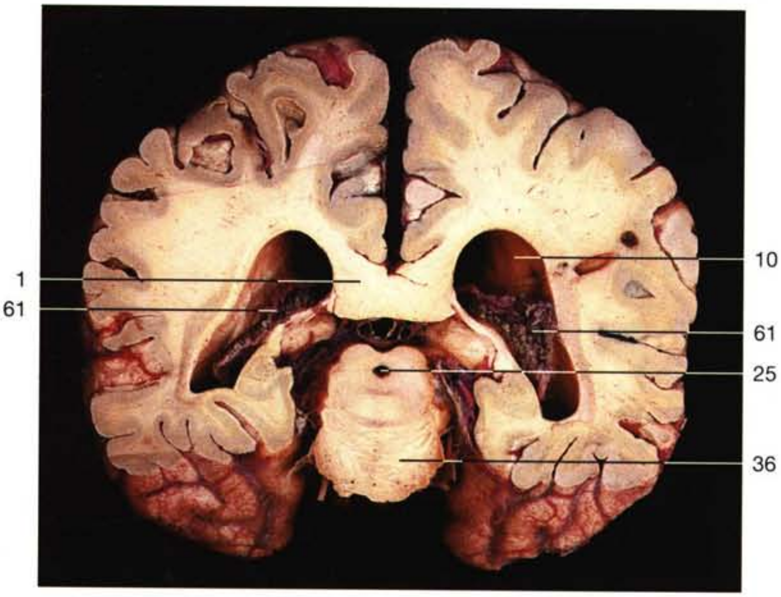
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Coronal section at the level of **inferior colliculus** (posterior aspect). Section 3.

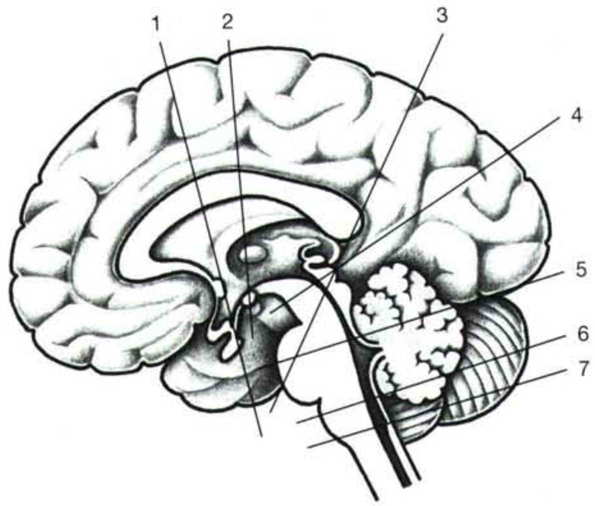

Right half of the brain. Levels of the sections are indicated.

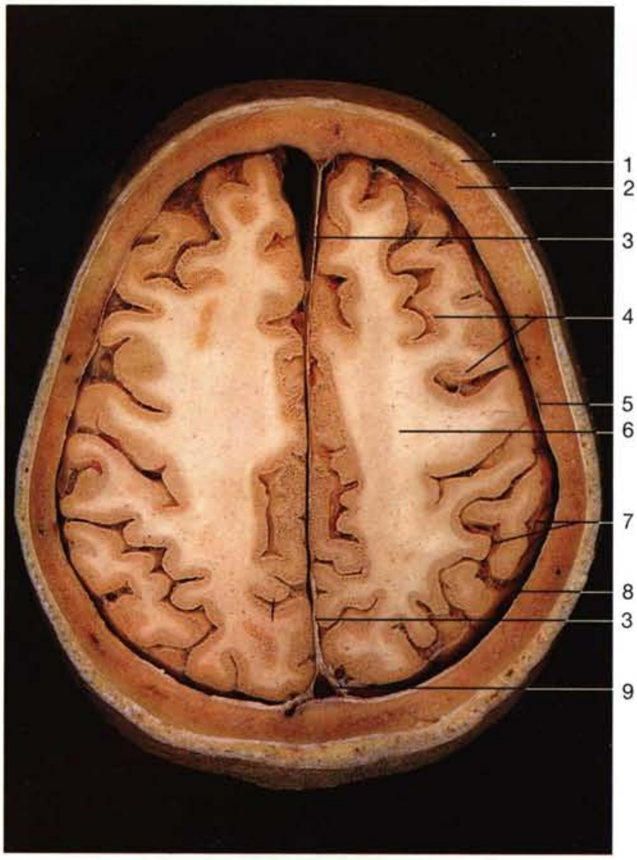

Horizontal section through the head.
Section 1.

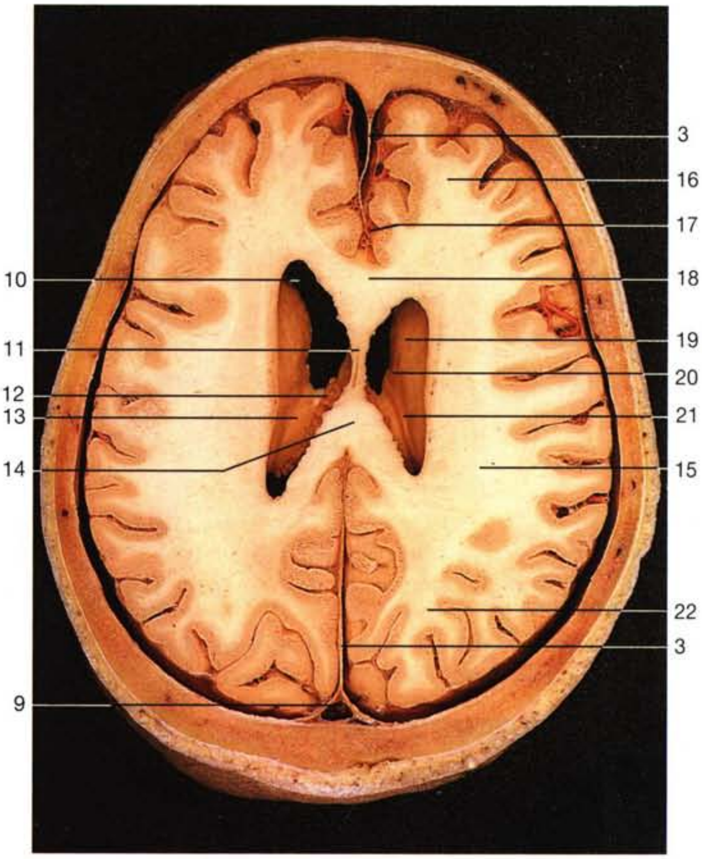

Horizontal section through the head.
Section 2.

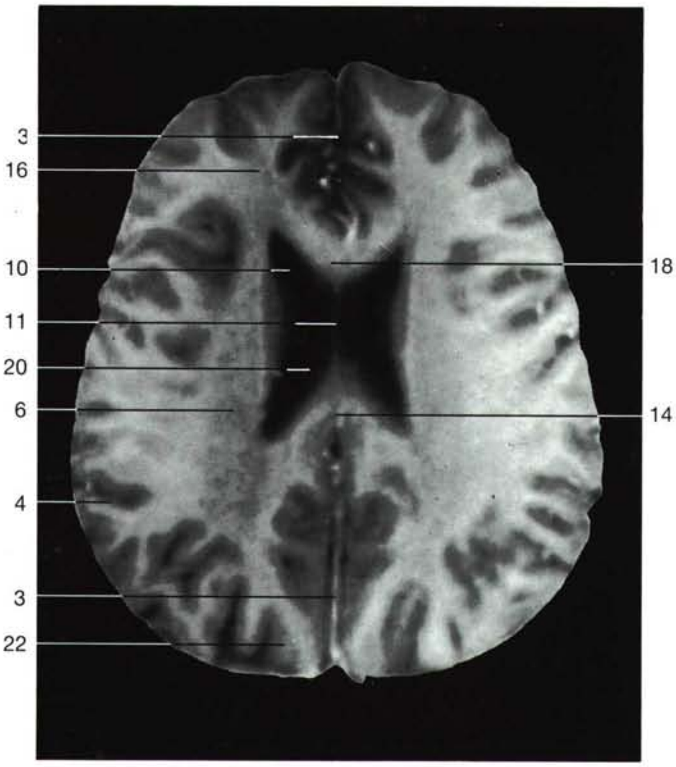

MR-Scan of the human head at the level of section 2.

1 Skin of scalp
2 Calvaria (diploe of the skull)
3 **Falx cerebri**
4 Gray matter of brain (cortex)
5 Dura mater
6 **White matter of brain**
7 Arachnoid and pia mater with vessels
8 Subdural space (slightly expanded due to shrinkage of the brain)
9 Superior sagittal sinus
10 Anterior horn of lateral ventricle
11 **Septum pellucidum**
12 Choroid plexus
13 Thalamus
14 Splenium of corpus callosum
15 Parietal lobe
16 Frontal lobe
17 Anterior cerebral artery
18 Genu of corpus callosum
19 Caudate nucleus
20 **Central part of lateral ventricle**
21 Stria terminalis
22 Occipital lobe

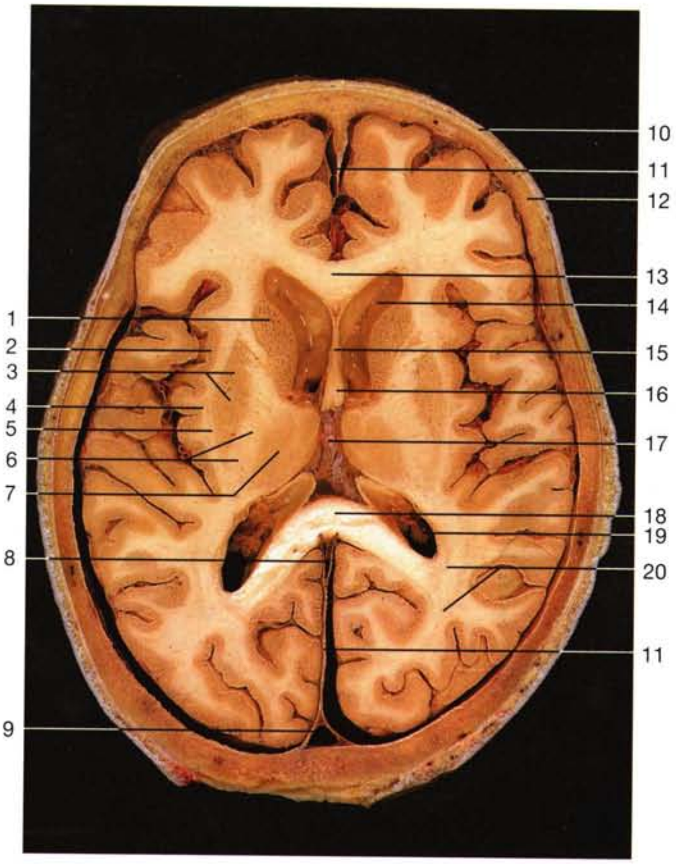

1 **Caudate nucleus**
2 Lobus insularis (insula)
3 **Lentiform nucleus**
4 Claustrum
5 External capsule
6 Internal capsule
7 **Thalamus**
8 Straight sinus (sinus rectus)
9 Superior sagittal sinus
10 Skin of scalp
11 Falx cerebri
12 Calvaria (diploe of skull)
13 Genu of corpus callosum
14 Anterior horn of lateral ventricle
15 **Septum pellucidum**
16 Column of fornix
17 Choroid plexus of third ventricle
18 Splenium of corpus callosum
19 Entrance to inferior horn of lateral ventricle with choroid plexus
20 Optic radiation
21 **Third ventricle**

Horizontal section through the head at the level of third ventricle of internal capsule and neighbouring nuclei. Section 3.

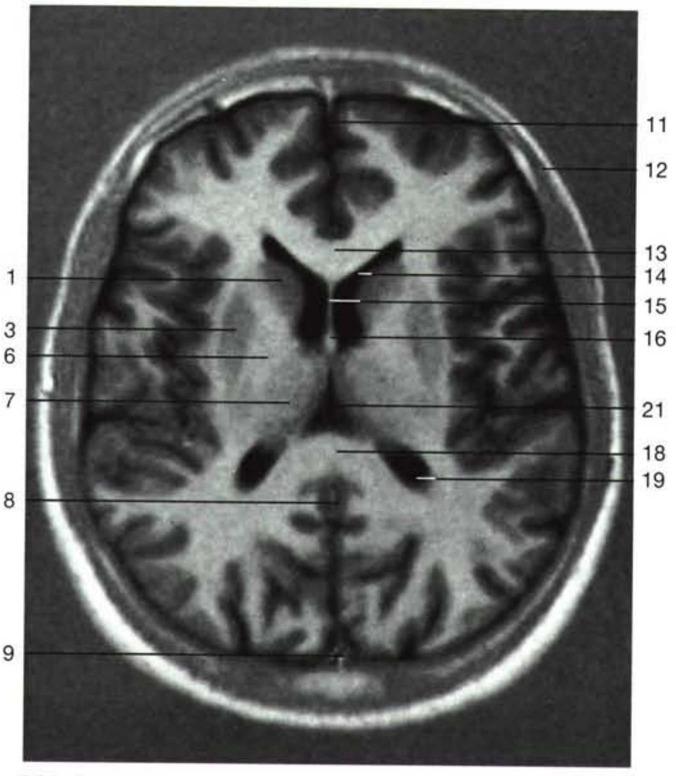

MR-Scan at the corresponding level to the above figure. Section 3.

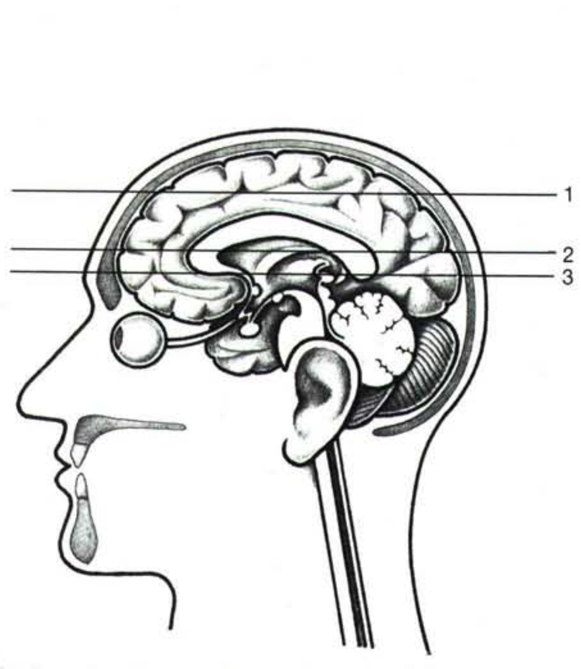

Sagittal section through the head. Levels of the horizontal sections are indicated.

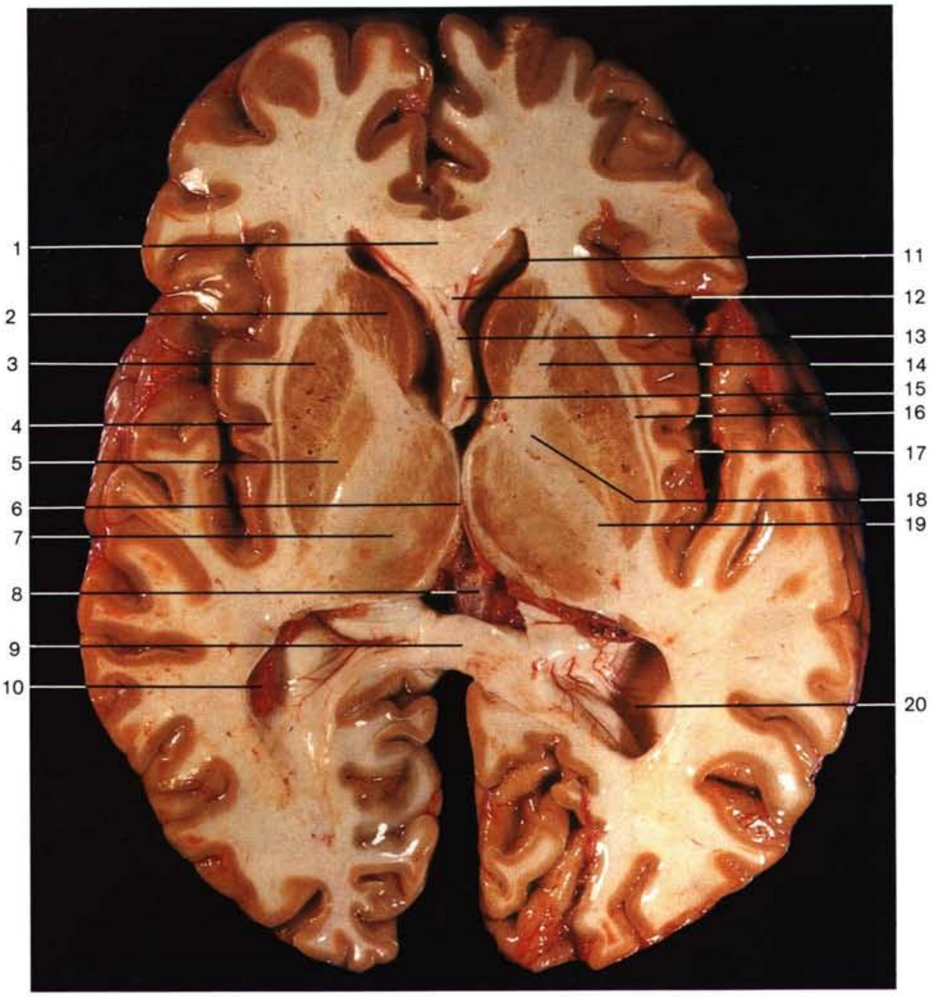

Horizontal section through the brain, showing the subcortical nuclei and internal capsule. Section 1.

1 Genu of corpus callosum
2 **Head of caudate nucleus**
3 **Putamen**
4 **Claustrum**
5 **Globus pallidus**
6 Third ventricle
7 Thalamus
8 **Pineal body**
9 Splenium of corpus callosum
10 Choroid plexus of the lateral ventricle
11 Anterior horn of lateral ventricle
12 Cavity of septum pellucidum
13 **Septum pellucidum**
14 Anterior limb of internal capsule
15 Column of fornix
16 External capsule
17 **Lobus insularis** (insula)
18 Genu of **internal capsule**
19 Posterior limb of internal capsule
20 Posterior horn of lateral ventricle
21 Anterior commissure
22 Optic radiation
23 Falx cerebri
24 **Maxillary sinus**
25 Position of auditory tube
26 Tympanic cavity
27 External acoustic meatus
28 **Medulla oblongata**
29 Fourth ventricle
30 Cerebellum (left hemisphere)
31 Temporomandibular joint
32 Tympanic membrane
33 Base of cochlea
34 Mastoid air cells
35 Sigmoid sinus
36 Vermis of cerebellum
37 Intermediate mass

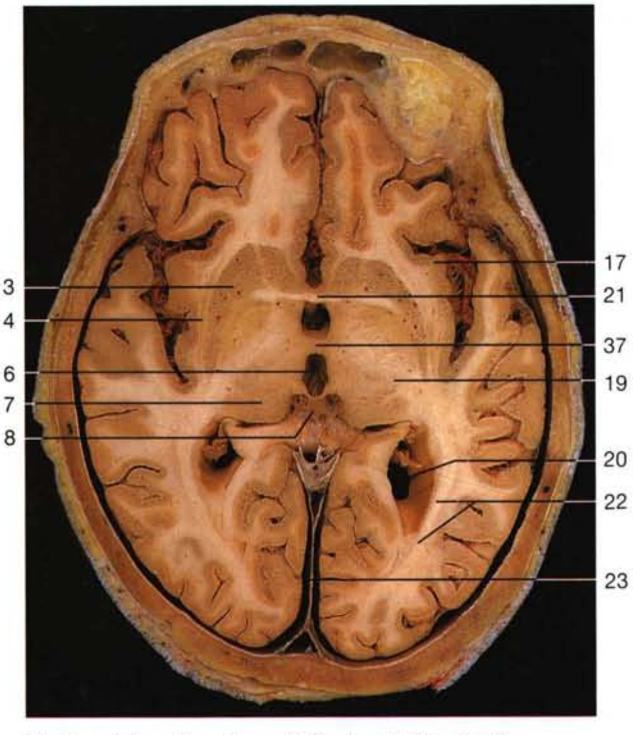

Horizontal section through the head. Section 2.

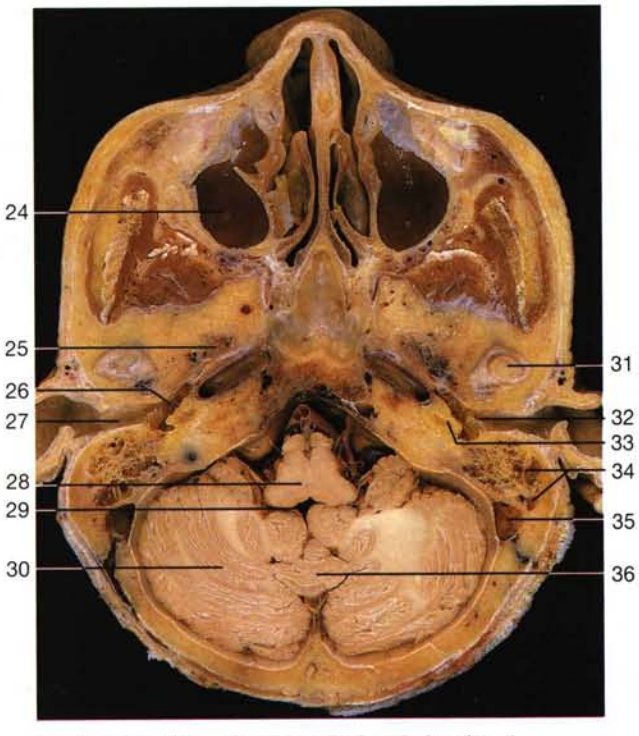

Horizontal section through the head. Section 4.

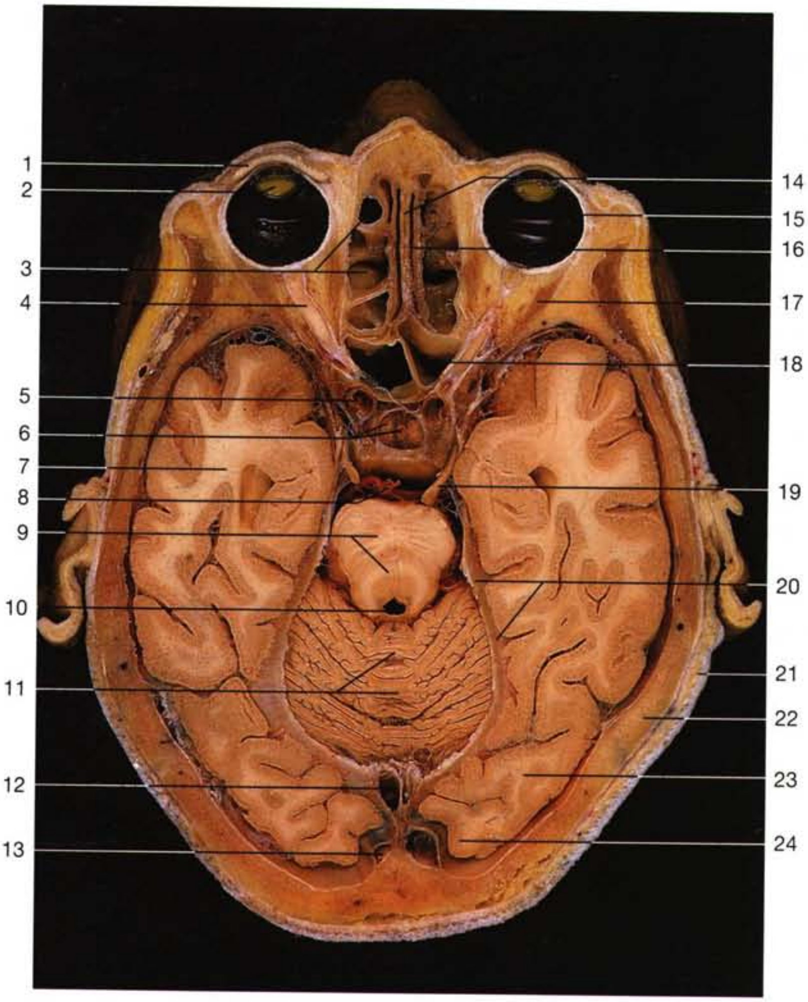

Horizontal section through the head. Section 3.

1 Upper lid (tarsal plate)
2 Lens
3 Ethmoidal sinus
4 **Optic nerve** (n. II)
5 Internal carotid artery
6 Infundibulum and **pituitary gland**
7 Temporal lobe
8 Basilar artery
9 Pons (cross section of brain stem)
10 **Cerebral aqueduct** (beginning of fourth ventricle)
11 Vermis of cerebellum
12 Straight sinus
13 Transverse sinus
14 Nasal septum
15 **Eyeball** (sclera)
16 Nasal cavity
17 Lateral rectus muscle
18 Sphenoidal sinus
19 Oculomotor nerve (n. III)
20 **Tentorium of cerebellum**
21 Skin of scalp
22 Calvaria
23 Occipital lobe
24 Striate cortex (visual cortex)

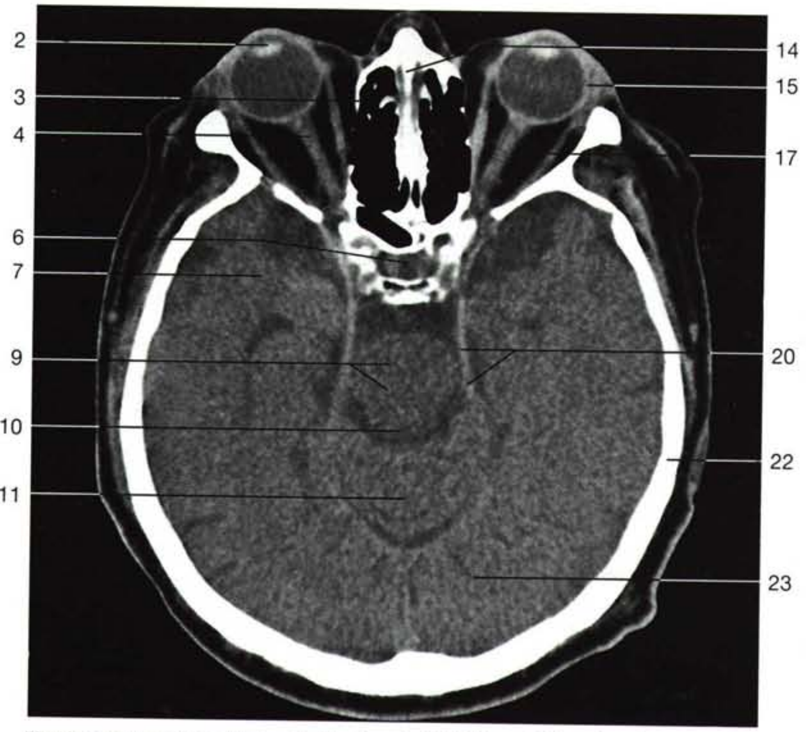

Horizontal section through the head. (CT-Scan.) Section 3.

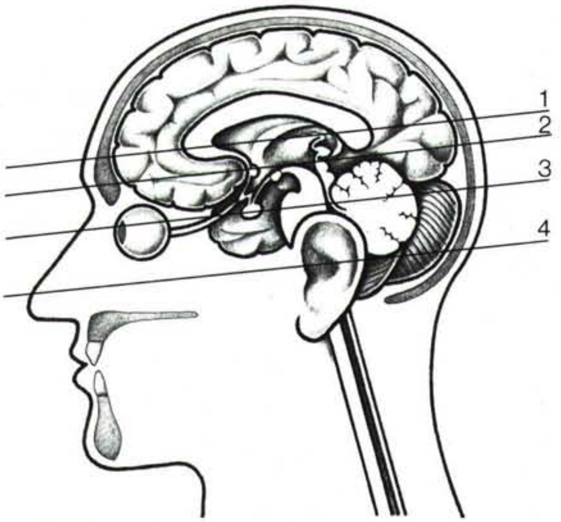

Sagittal section through the head.
Levels of the horizontal sections are indicated.

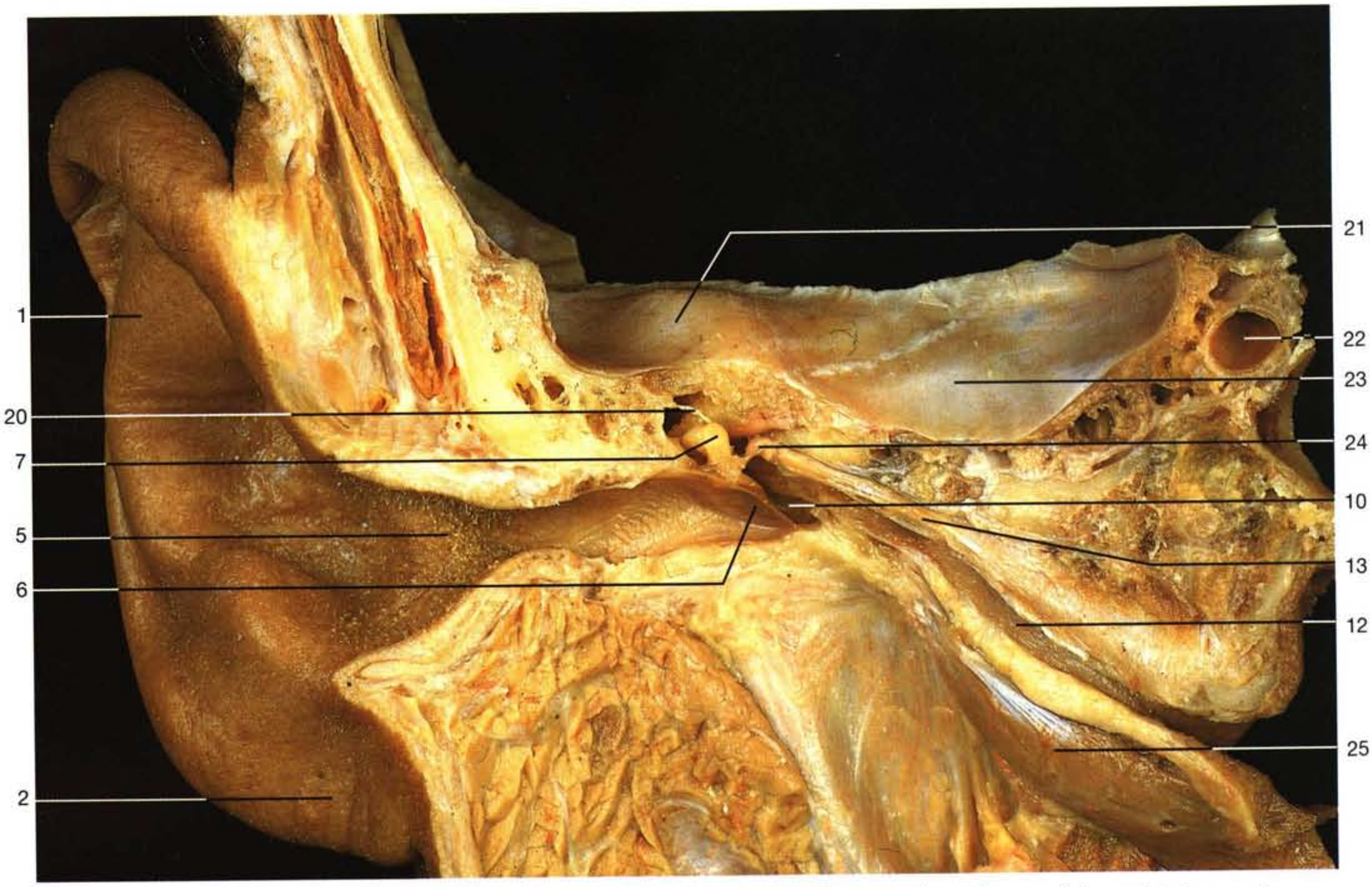

Longitudinal section through the right temporal bone I. The outer and middle ear and auditory ossicles and tube are shown (anterior aspect).

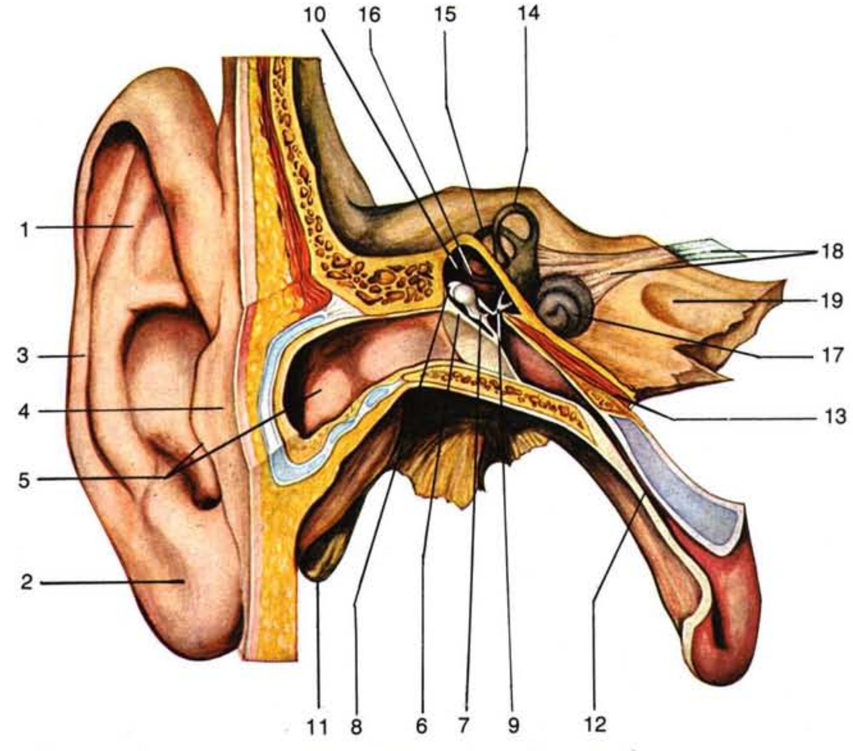

Right **auditory and vestibular apparatus** (anterior aspect). (Schematic drawing.)

Outer ear

1	Auricle
2	Lobule of auricle
3	Helix
4	Tragus
5	External acoustic meatus

Middle ear

6	Tympanic membrane
7	Malleus
8	Incus
9	Stapes
10	Tympanic cavity
11	Mastoid process
12	Auditory tube
13	Tensor tympani muscle

Inner ear

14	Anterior semicircular duct
15	Posterior semicircular duct
16	Lateral semicircular duct
17	Cochlea
18	Vestibulocochlear nerve
19	Petrous part of the temporal bone

Additional structures

20	Superior ligament of malleus
21	Arcuate eminence
22	Internal carotid artery
23	Anterior surface of pyramid with dura mater
24	Stapes
25	Levator veli palatini muscle

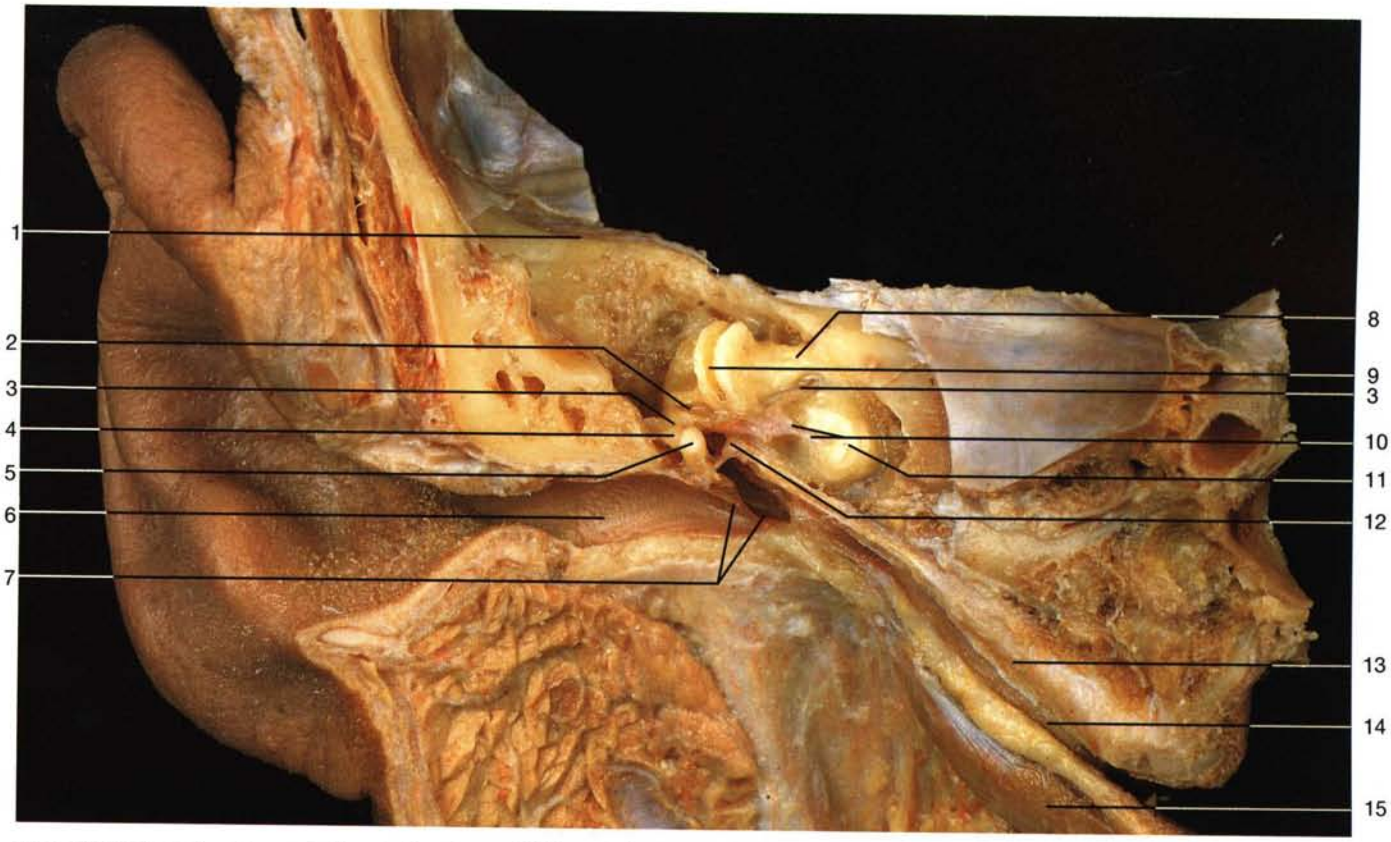

Longitudinal section through the right outer, middle and inner ear II. The cochlea and semicircular canals have been further dissected (anterior aspect).

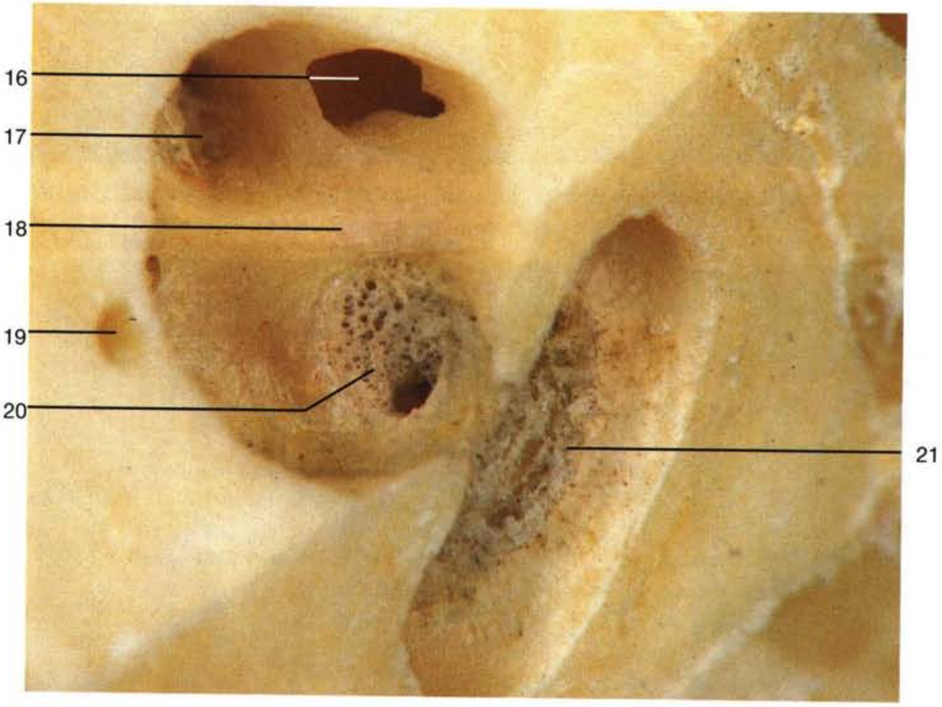

Internal acoustic meatus, left side. The bone was partly removed to show the bottom of the meatus.

1 Roof of tympanic cavity
2 **Lateral osseous semicircular canal**
3 **Facial nerve**
4 Incus
5 **Malleus**
6 External acoustic meatus
7 **Tympanic cavity** and **tympanic membrane**
8 Vestibulochochlear nerve
9 Anterior osseous semicircular canal
10 Geniculate ganglion and greater petrosal nerve
11 **Cochlea**
12 **Stapes**
13 Tensor tympani muscle
14 **Auditory tube**
15 Levator veli palatini muscle
16 Area of facial nerve
17 Superior vestibular area
18 Transverse crest
19 Foramen singulare
20 Foraminous spiral tract (outlet of cochlear part of vestibulocochlear nerve)
21 Base of cochlea

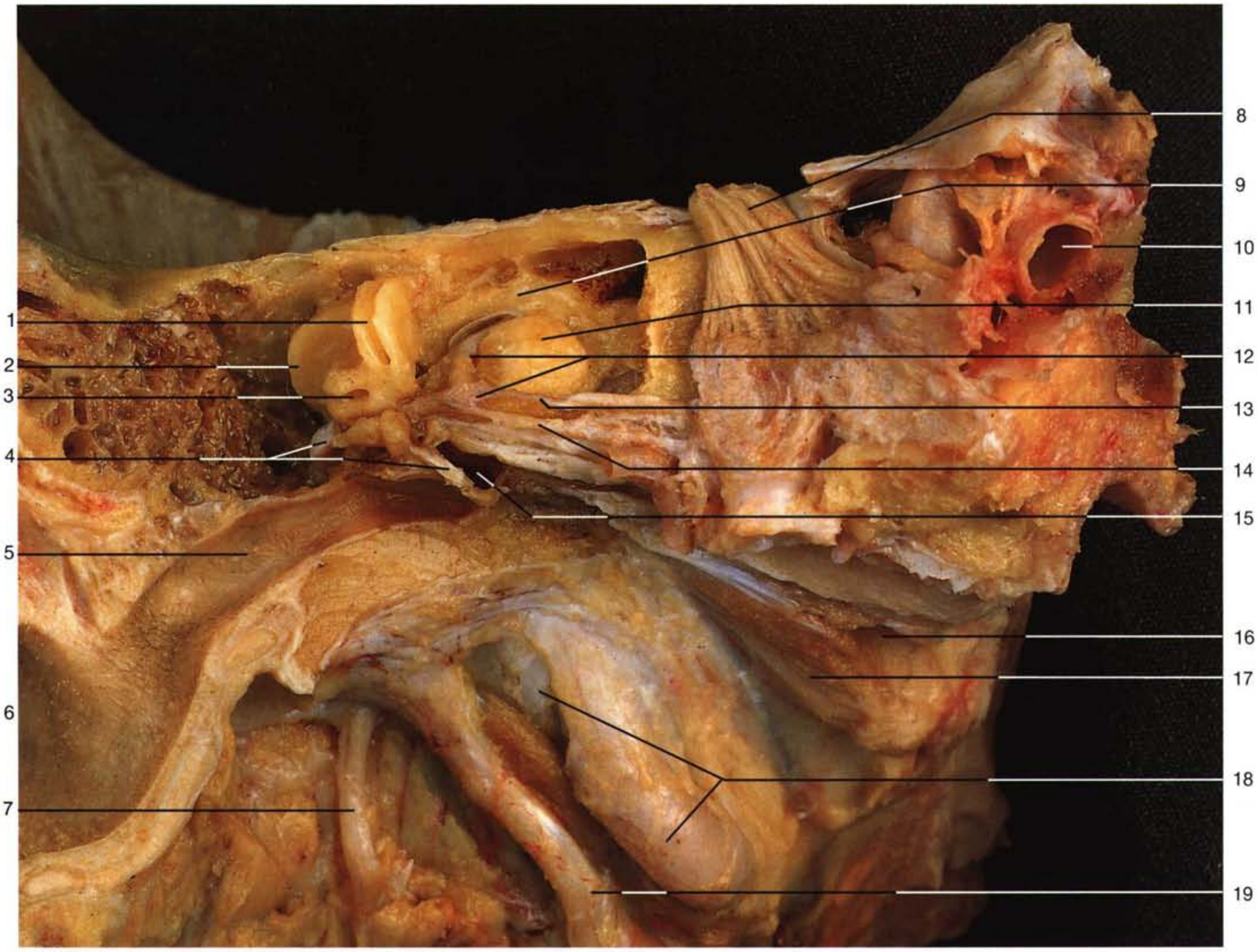

Longitudinal section through the outer, middle and inner ear III. Deeper dissection to display facial nerve and lesser and greater petrosal nerves (anterior aspect).

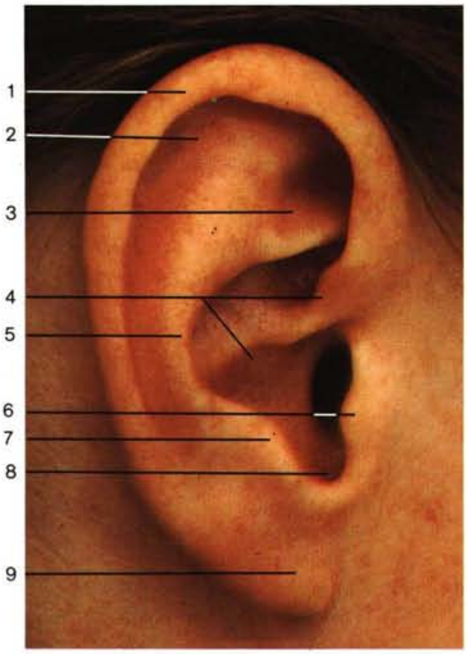

Right auricle (lateral aspect).

1 Helix
2 Scaphoid fossa
3 Triangular fossa
4 Concha
5 Antihelix
6 Tragus
7 Antitragus
8 Intertragic notch
9 Lobule

1 **Anterior osseous semicircular canal** (opened)
2 **Posterior osseous semicircular canal**
3 **Lateral osseous semicircular canal** (opened)
4 Facial nerve and chorda tympani
5 External acoustic meatus
6 Auricle
7 **Facial nerve**
8 Trigeminal nerve
9 Bony base of internal acoustic meatus
10 Internal carotid artery within cavernous sinus
11 **Cochlea**
12 **Facial nerve** with **geniculate ganglion**
13 Greater petrosal nerve
14 Lesser petrosal nerve
15 **Tympanic cavity**
16 Auditory tube
17 Levator veli palatini muscle
18 Internal carotid artery, internal jugular vein
19 Styloid process

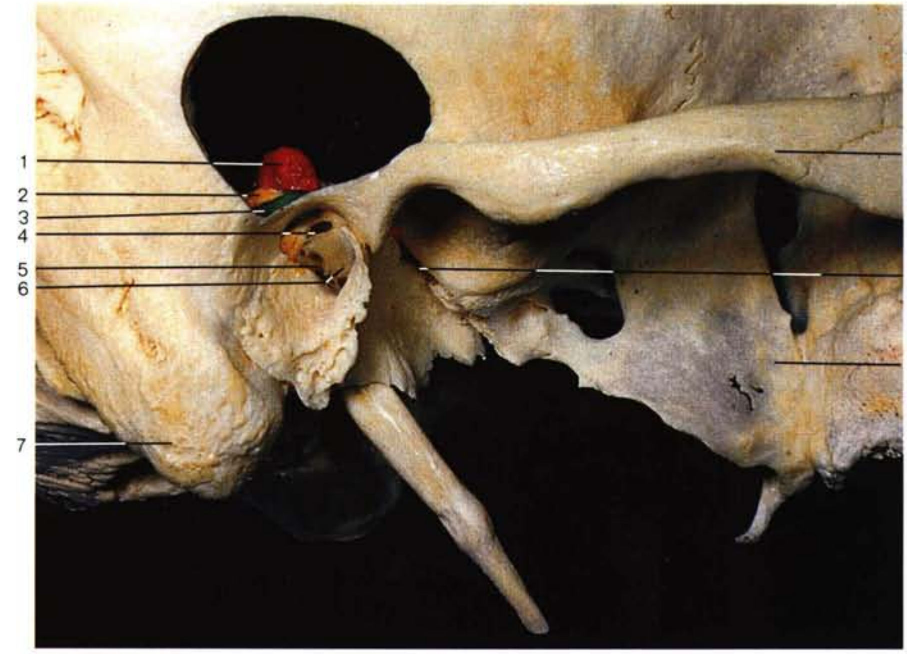

Right temporal bone (lateral aspect). Petrosquamous portion has been partly removed to display the semicircular canals.

1 Anterior semicircular canal (red)
2 Posterior semicircular canal (yellow)
3 Lateral or horizontal semicircular canal (green)
4 **Fenestra vestibuli**
5 **Fenestra cochleae**
6 Tympanic cavity
7 Mastoid process
8 **Petrotympanic fissure** (red probe: **chorda tympani**)
9 Lateral pterygoid plate
10 Mastoid air cells
11 **Facial canal** (blue)
12 Foramen ovale
13 **Carotid canal** (red)
14 **Tympanic ring**
15 Petromastoid part of temporal bone
16 Squamous part of temporal bone
17 Squamomastoid suture
18 Zygomatic process of temporal bone
19 Incisure of tympanic ring
20 **Promontory**
21 Apex of cochlea (cupula)
22 Spiral canal of cochlea at base of cochlea
23 Epitympanic recess
24 Auditory ossicles and tympanic cavity
25 Hypotympanic recess
26 Canaliculus chordae tympani (green probe)
27 Mastoid process
28 Canaliculus for stapedius nerve (red)
29 **Cochlea**
30 Canaliculus mastoideus (red probe)

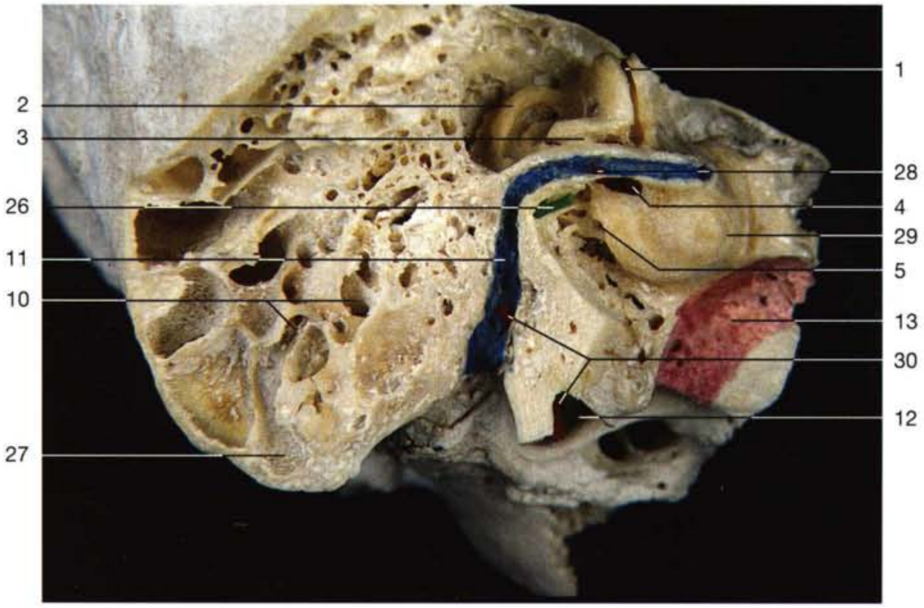

Right temporal bone (lateral aspect). Mastoid air cells and facial canal had been opened. The 3 semicircular canals were dissected.

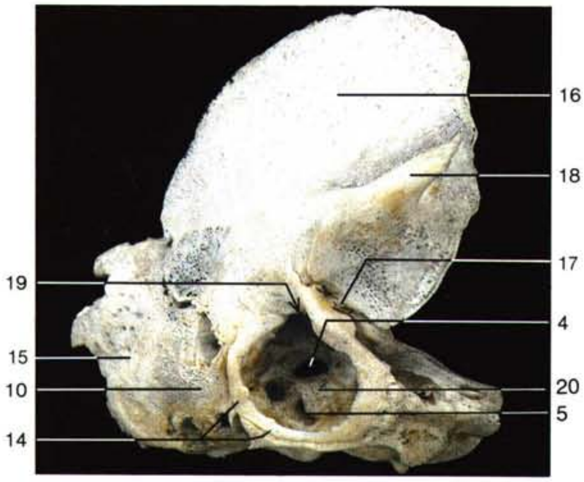

Right temporal bone of the newborn (lateral aspect).

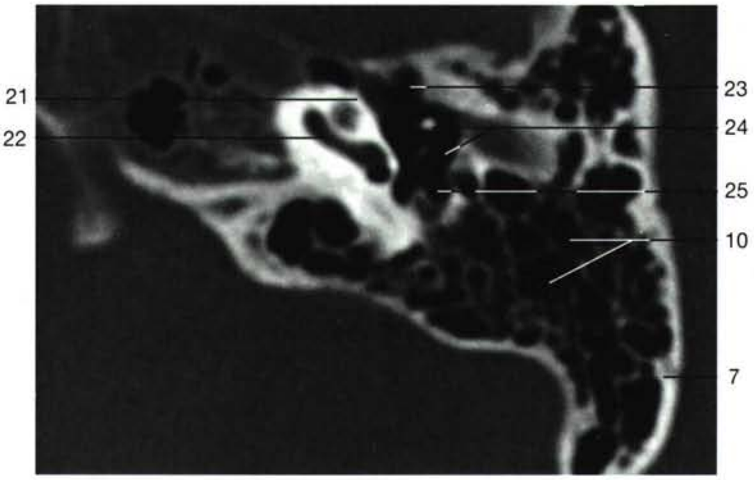

Frontal section through petrous part. (CT-Scan.)

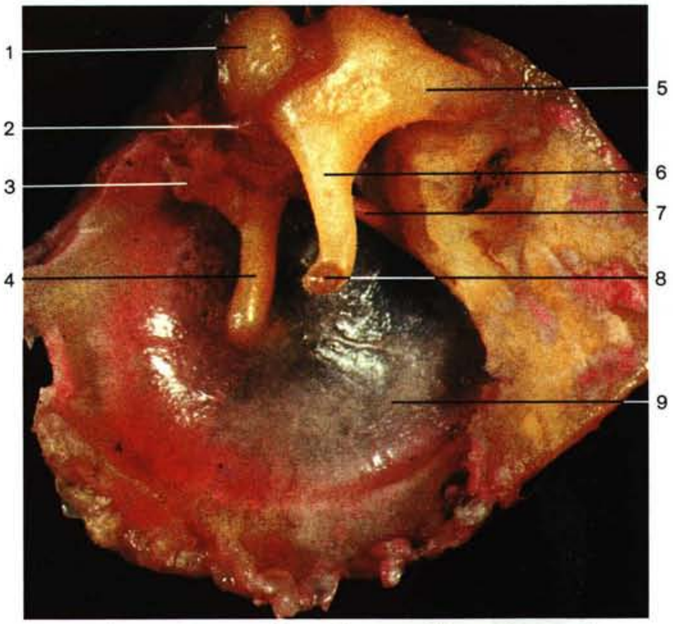

1 Head of malleus
2 Anterior ligament of malleus
3 Tendon of tensor tympani muscle
4 Handle of **malleus**
5 Short crus of incus
6 Long crus of **incus**
7 Chorda tympani
8 Lenticular process
9 **Tympanic membrane**

Tympanic membrane with malleus and incus (internal aspect; right side).

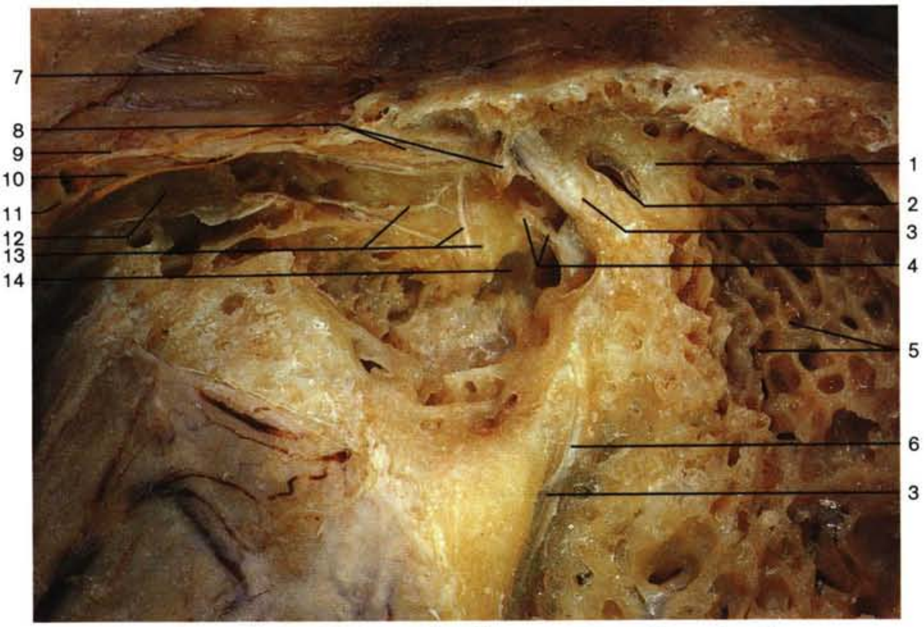

1 Tympanic antrum
2 Lateral semicircular canal (opened)
3 **Facial canal**
4 Stapes with tendon of stapedius
5 Mastoid air cells
6 Chorda tympani (intracranial part)
7 Greater petrosal nerve
8 Tensor tympani muscle (processus cochleariformis)
9 Lesser petrosal nerve
10 Anterior tympanic artery
11 Middle meningeal artery
12 **Auditory tube**
13 **Promontory with tympanic plexus**
14 Fenestra cochleae

Tympanic cavity, medial wall. External auditory meatus and lateral wall of tympanic cavity together with incus. Malleus and tympanic membrane have been removed; mastoid air cells are opened (left side).

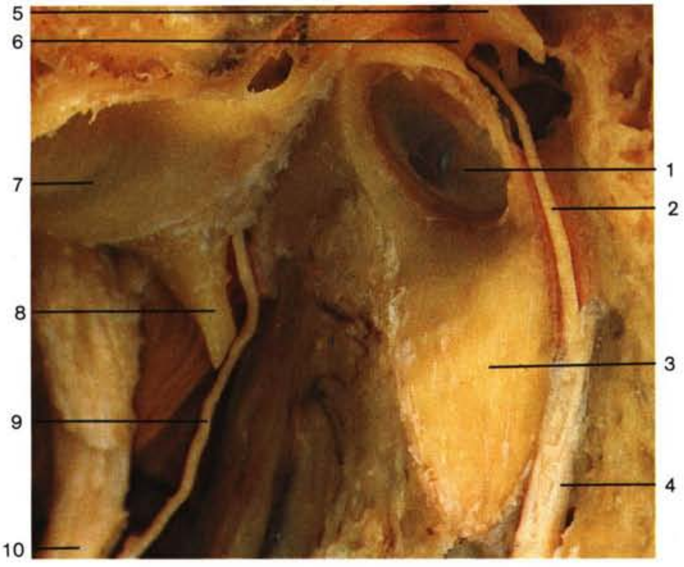

1 **Tympanic membrane**
2 Chorda tympani (intracranial part)
3 Floor of the external acoustic meatus
4 **Facial nerve** and facial canal
5 Incus
6 Head of malleus
7 Mandibular fossa
8 Spine of sphenoid
9 **Chorda tympani** (extracranial part)
10 Styloid process

Tympanic membrane (lateral aspect). External acoustic meatus and facial canal have been opened to expose the chorda tympani (magn. ~1.5×) (left side).

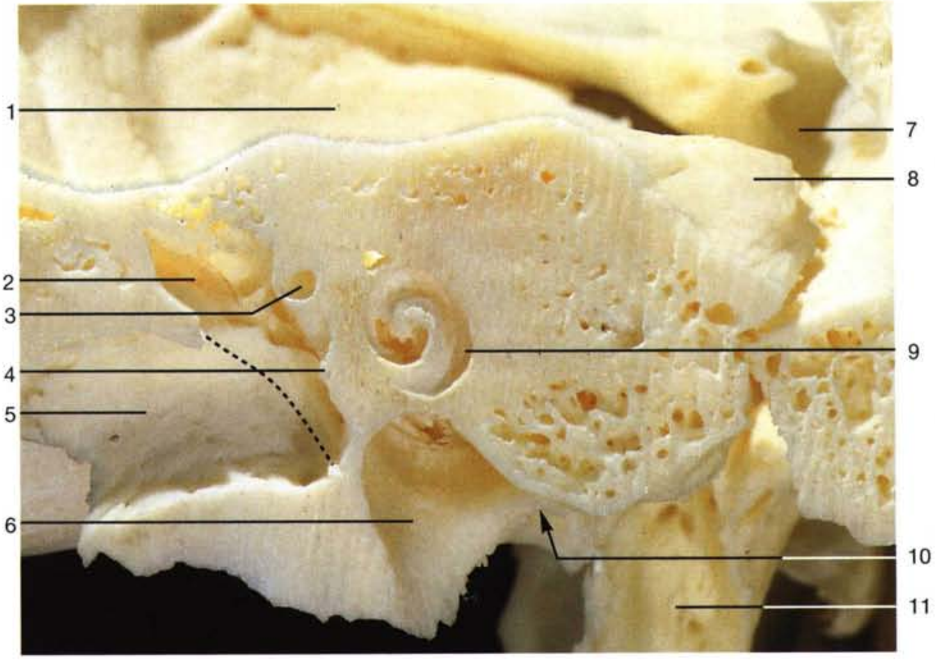

Frontal section through the petrous part of the left temporal bone at the level of the cochlea (posterior aspect). Position of tympanic membrane indicated by dotted line.

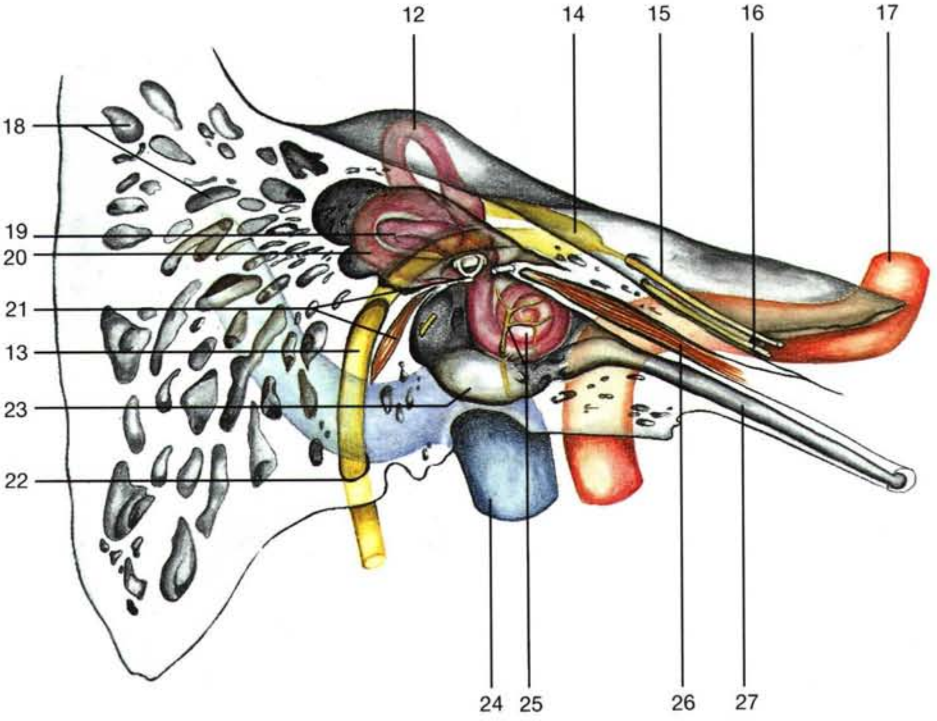

Medial wall of tympanic cavity and its relation to neighboring structures of the inner ear, facial nerve, and blood vessels. (Schematic drawing.) Frontal section through the right temporal bone (anterior aspect).

1 Anterior surface of the pyramid
2 Mastoid antrum
3 Lateral semicircular canal
4 Cochleariform process
5 External acoustic meatus
6 **Jugular fossa**
7 Foramen lacerum
8 Apex of petrous part
9 Position of **cochlea** (modiolus with crista spiralis ossea)

10 Carotid canal
11 Pterygoid process
12 Anterior semicircular duct
13 **Facial nerve**
14 Geniculate ganglion
15 Greater petrosal nerve
16 Lesser petrosal nerve
17 **Internal carotid artery**
18 Mastoid air cells
19 Lateral semicircular duct

20 Posterior semicircular duct
21 Stapes with stapedius muscle
22 Stylomastoid foramen
23 Inferior recess of tympanic cavity (hypotympanon)
24 **Internal jugular vein**
25 Promontory with tympanic plexus (position of cochlea)
26 Tensor muscle of tympanum
27 **Auditory tube**

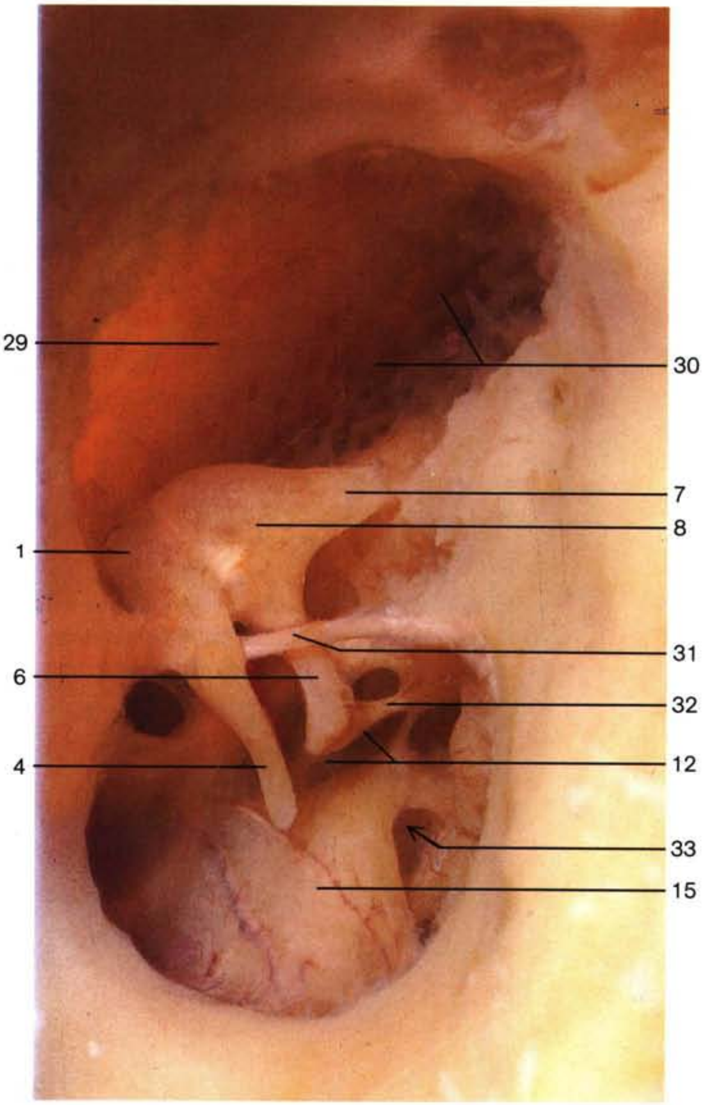

Tympanic cavity with malleus, incus and stapes, left side (lateral aspect). Tympanic membrane removed, mastoid antrum opened.

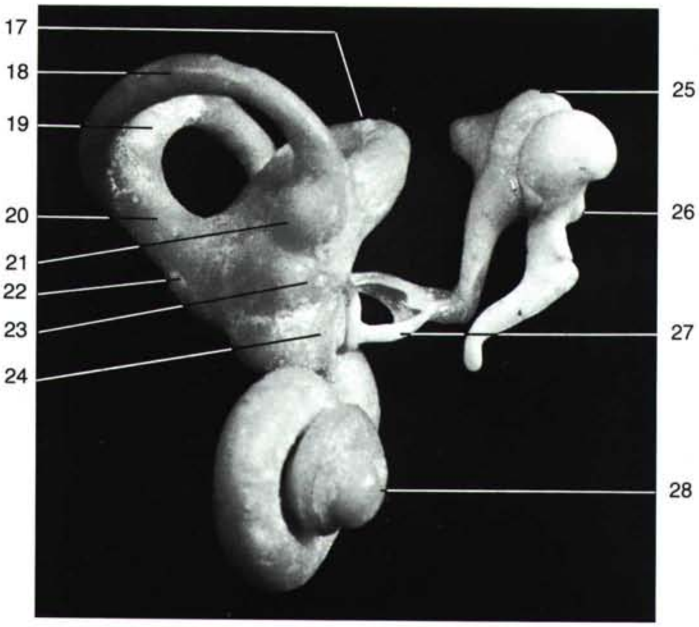

Chain of auditory ossicles in connection with the inner ear, left side (anterior-lateral aspect).

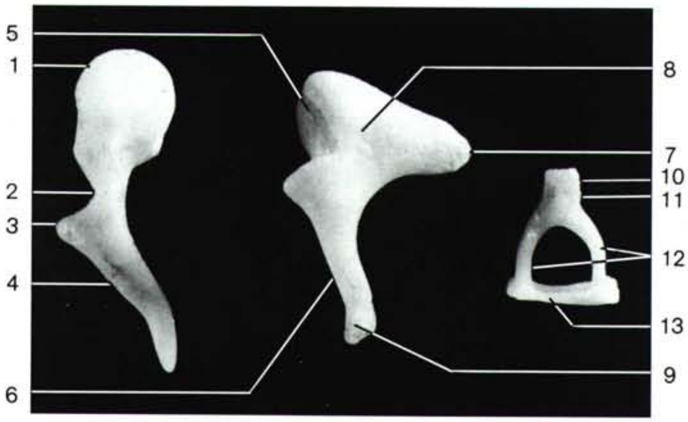

Auditory ossicles (isolated).

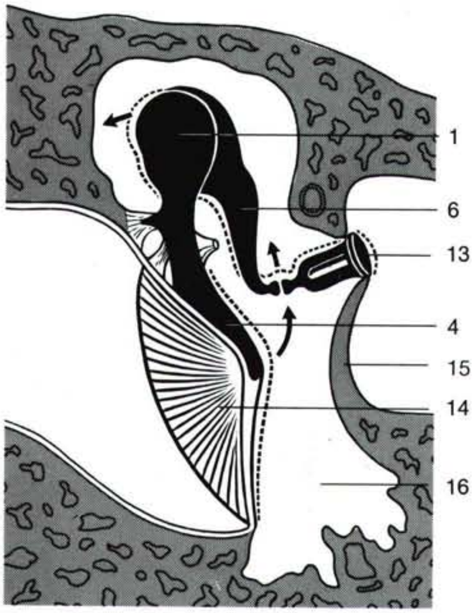

Position and movements of the auditory ossicles. (Schematic diagram.)

Malleus
1 Head
2 Neck
3 Lateral process
4 Handle

Incus
5 Articular facet for malleus
6 Long crus
7 Short crus
8 Body
9 Lenticular process

Stapes
10 Head
11 Neck
12 Anterior and posterior crura
13 Base

Walls of tympanic cavity
14 Tympanic membrane
15 Promontory
16 Hypotympanic recess of tympanic cavity

Internal ear (labyrinth)
17 Lateral semicircular duct
18 Anterior semicircular duct
19 Posterior semicircular duct
20 Common crus
21 Ampulla
22 Beginning of endolymphatic duct
23 Utricular prominence
24 Saccular prominence
25 Incus
26 Malleus
27 Stapes
28 Cochlea

Tympanic cavity
29 Epitympanic recess
30 Mastoid antrum
31 Chorda tympani
32 Tendon of stapedius muscle
33 Round window (fenestra cochleae)

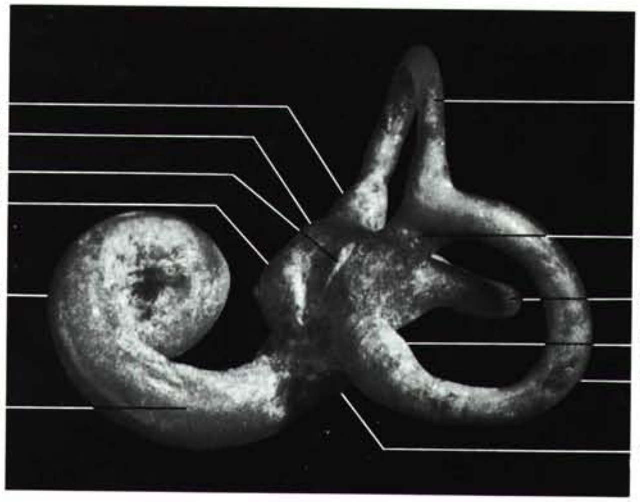

Cast of the right labyrinth (postero-medial aspect).

1 Ampulla (anterior semicircular canal)
2 Elliptical recess
3 Aqueduct of the vestibule
4 Spherical recess
5 **Cochlea**
6 Base of cochlea
7 **Anterior semicircular canal**
8 Crus commune or common limb
9 **Lateral semicircular canal**
10 Posterior bony ampulla
11 **Posterior semicircular canal** (posterior canal)
12 **Fenestra cochleae**
13 Bony ampulla
14 **Fenestra vestibuli**
15 Cupula of cochlea
16 External acoustic meatus
17 Mastoid air cells
18 Tympanic cavity and fenestra cochleae (probe)
19 External acoustic meatus
20 Facial canal
21 Base of cochlea and canalis musculotubarius
22 Malleus and incus
23 Stapes
24 Tympanic membrane
25 Tympanic cavity
26 Aqueduct of cochlea
27 Saccus endolymphaticus
28 Ductus endolymphaticus
29 Macula of utricle
30 Macula of saccule

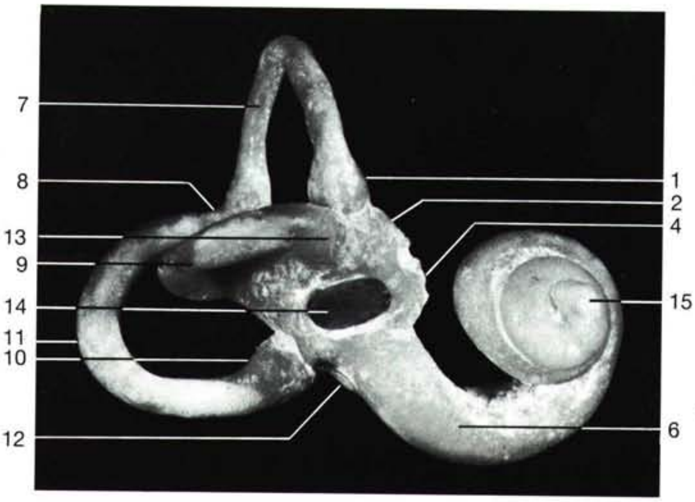

Cast of the right labyrinth (lateral aspect).

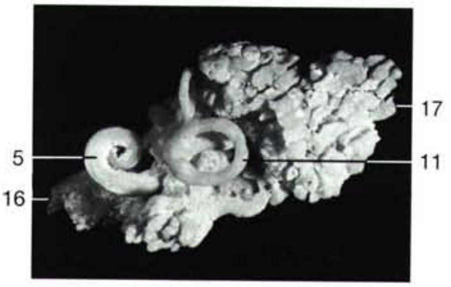

Cast of the labyrinth and mastoid cells. Life size (posterior aspect).

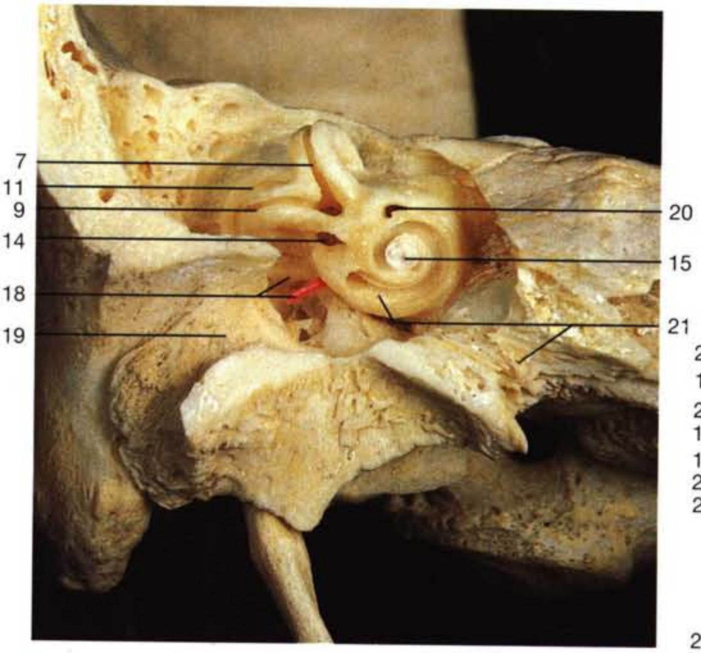

Dissection of bony labyrinth in situ. Semicircular canals and cochlear duct opened.

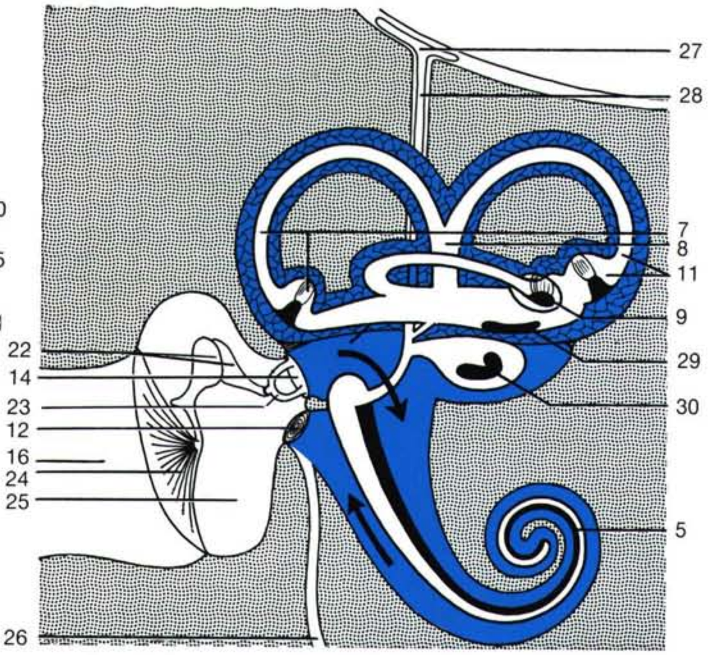

Auditory and vestibular apparatus. Arrows: direction of sound waves; blue = perilymphatic ducts. (Schematic diagram.)

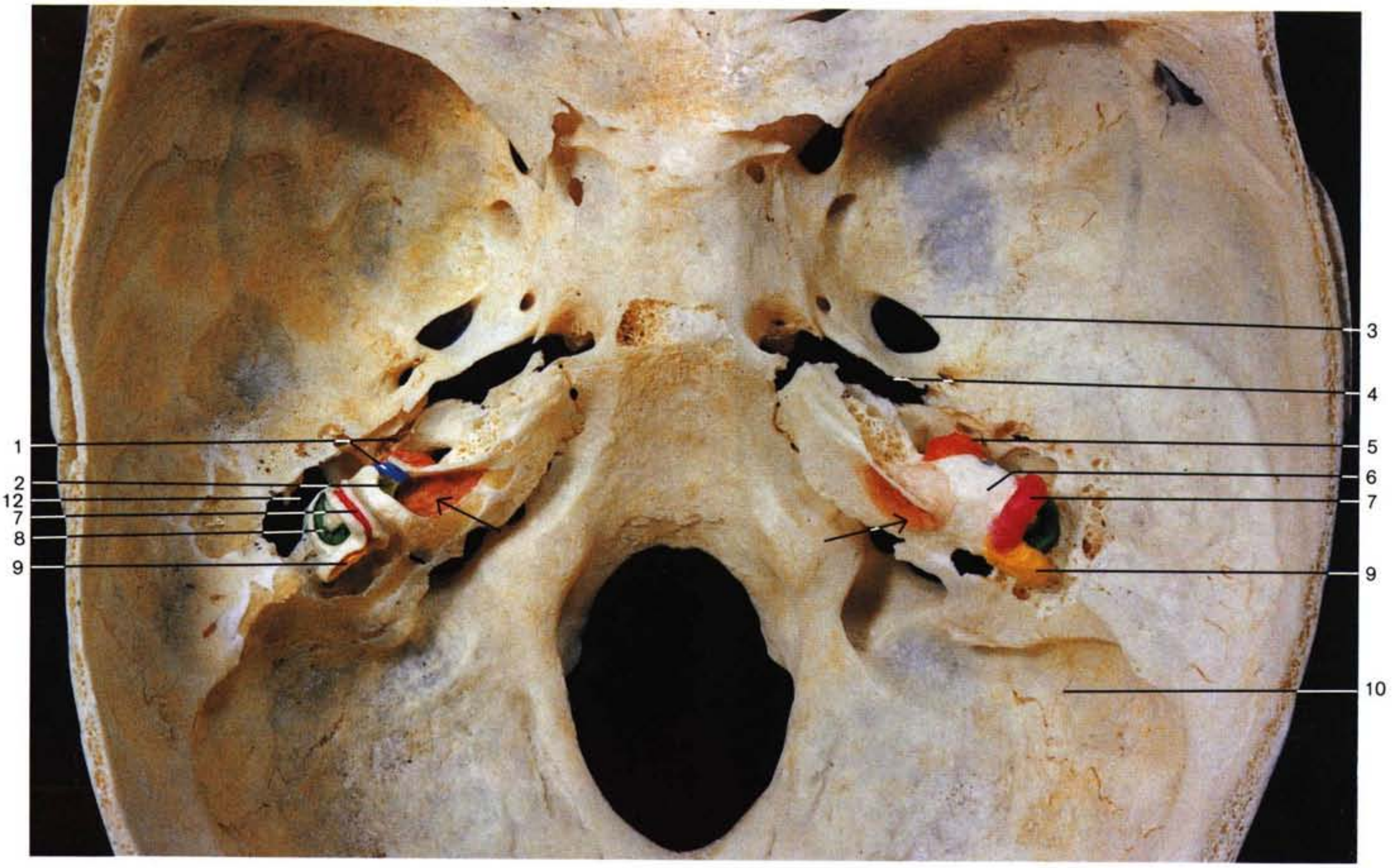

Bony labyrinth, petrous part of the temporal bone (from above). At left: semicircular canals opened, at right closed. Arrows: internal acoustic meatus.

1 Facial canal and semicanal of auditory tube
2 Superior vestibular area
3 Foramen ovale
4 Foramen lacerum
5 Cochlea
6 Vestibule
7 Anterior semicircular canal
8 Lateral semicircular canal
9 Posterior semicircular canal
10 Groove for sigmoid sinus
11 Sigmoid sinus
12 Tympanic cavity
13 Auditory tube
14 Mastoid air cells
15 Facial and vestibulocochlear nerves
16 Temporal fossa
17 Fenestra vestibuli
18 Promontory
19 Zygomatic process
20 Fenestra cochleae
21 Mastoid process

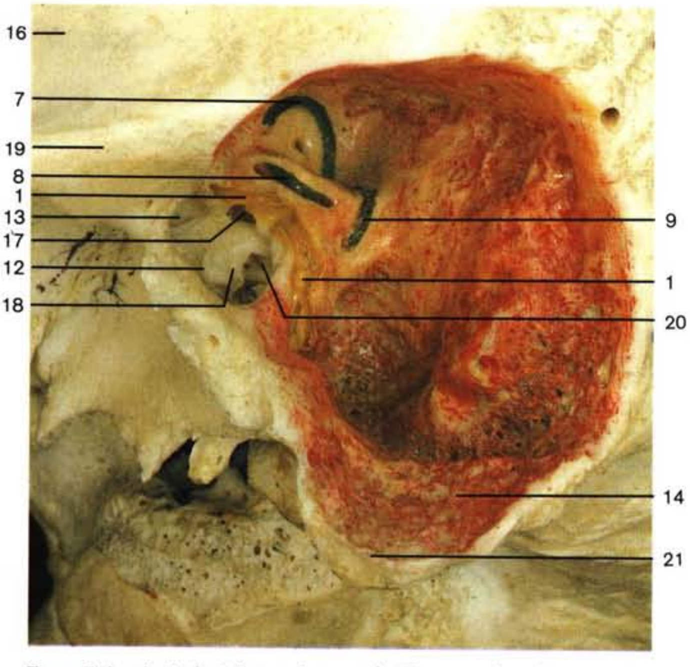

Bony labyrinth (left lateral aspect). Temporal and tympanic bone partly removed, semicircular canals opened.

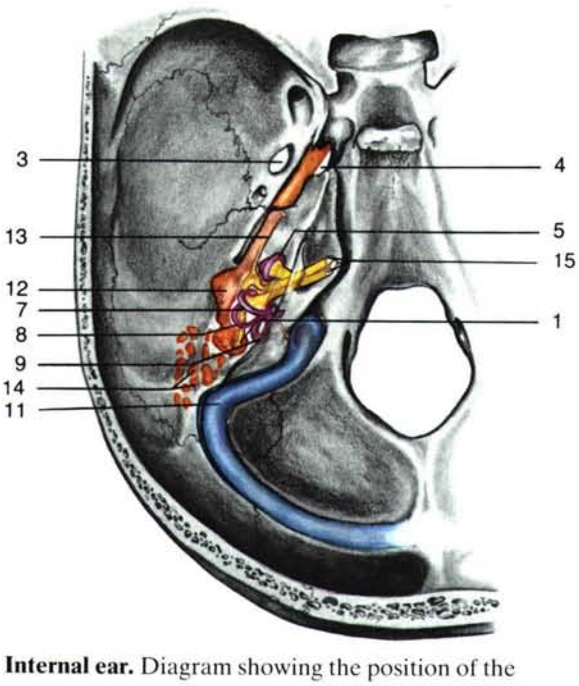

Internal ear. Diagram showing the position of the membranous labyrinth and the tympanic cavity.

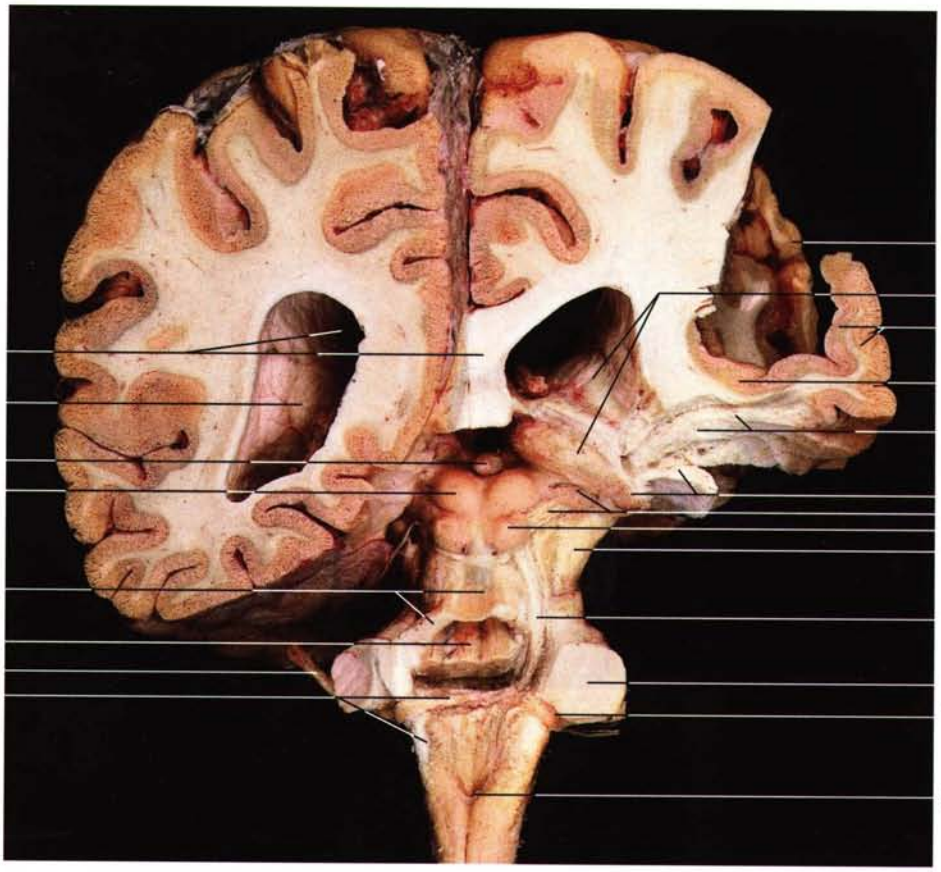

Dissection of the brain stem showing the acoustic pathway. Cerebellum and posterior part of the two hemispheres have been removed (dorsal aspect).

1 Left lateral ventricle and corpus callosum
2 Thalamus
3 Pineal gland (epiphysis)
4 Superior colliculus
5 Anterior cerebellar velum and superior cerebellar peduncle
6 Rhomboid fossa
7 **Vestibulocochlear nerve** (n. VIII)
8 **Dorsal acoustic striae** and inferior cerebellar peduncle
9 Insular lobe
10 Caudate nucleus and thalamus
11 Temporal lobe (superior temporal gyrus) (area of **acoustic centers**)
12 Transverse temporal gyri of Heschl (area of **primary acoustic centers**)
13 Acoustic radiation of internal capsule
14 Lateral geniculate body and optic radiation (cut)
15 **Medial geniculate body** and brachium of inferior colliculus
16 **Inferior colliculus**
17 Cerebral peduncle
18 **Lateral lemniscus**
19 Middle cerebellar peduncle
20 Dorsal (posterior) cochlear nucleus
21 Ventral (anterior) cochlear nucleus
22 Inferior olive with tractus olivocochlearis of Rasmussen (red)
23 Ganglion spirale
24 Obex
25 Frontal lobe
26 Temporal lobe
27 Middle temporal gyrus (area of **tertiary acoustic centers)**
28 Trapezoid body

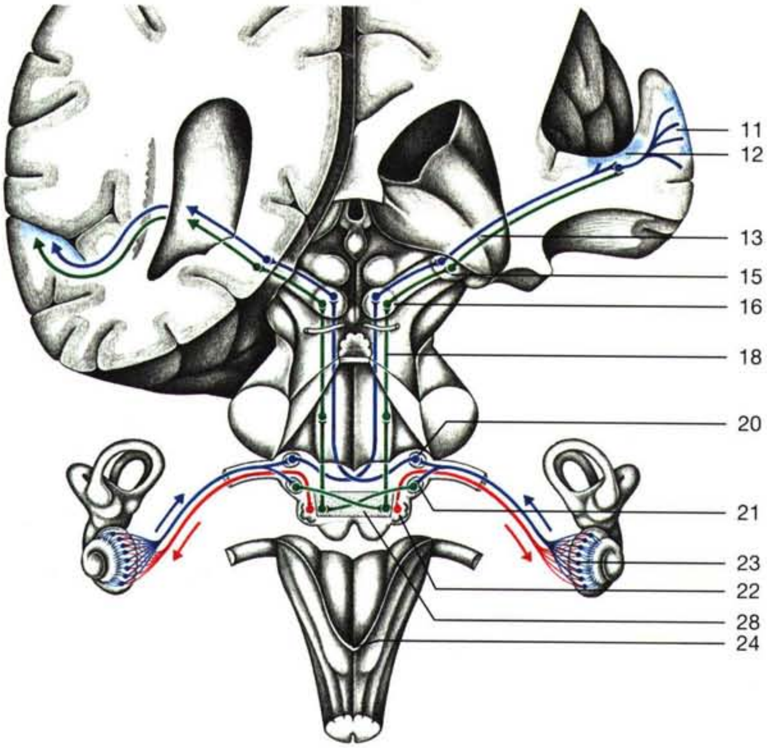

Acoustic pathway (schematic drawing, compare with figure above).

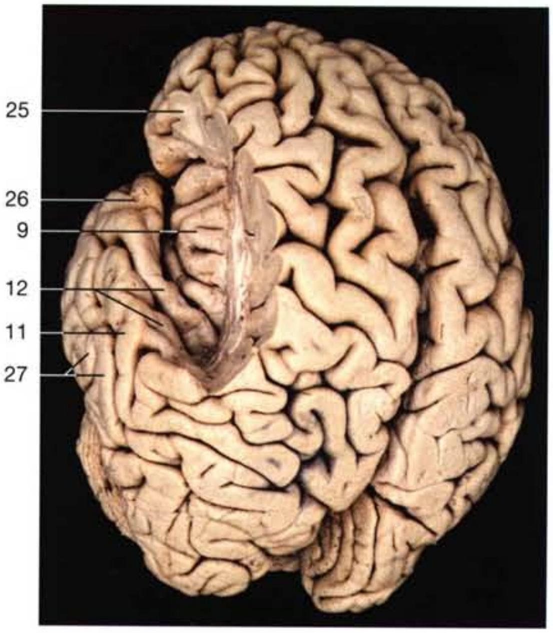

Acoustic areas in the left hemisphere (superior lateral aspect). Parts of the frontal and parietal lobe have been removed.

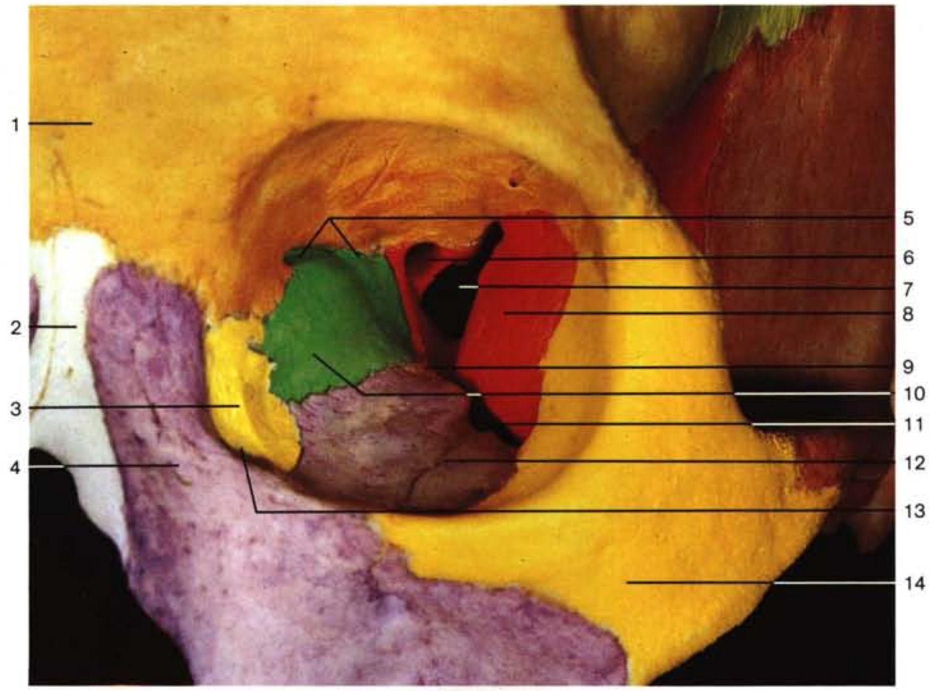

Bones of the left orbit (indicated by different colors).

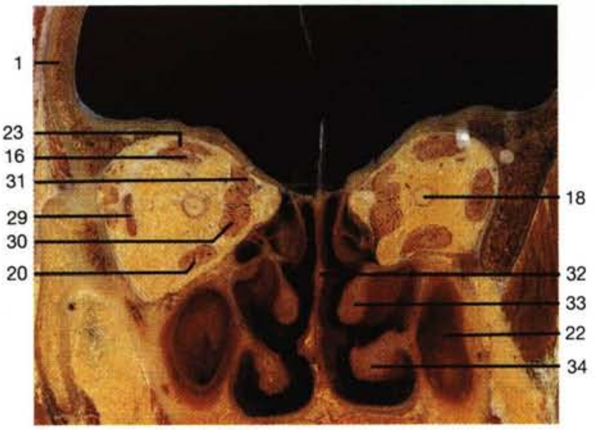

Frontal section through the posterior part of the orbit.

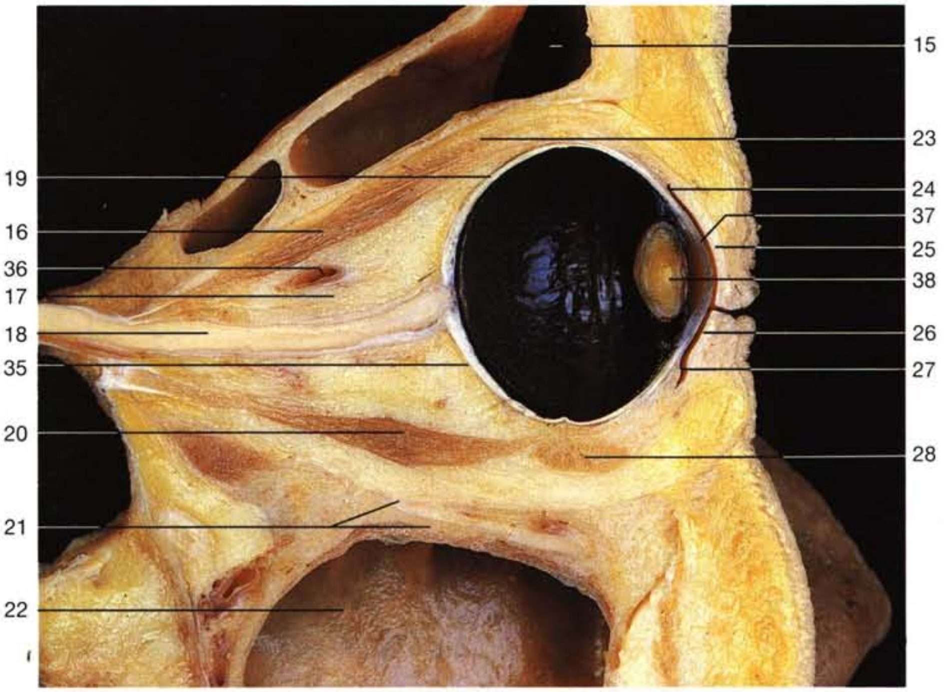

Sagittal section through orbit and eyeball.

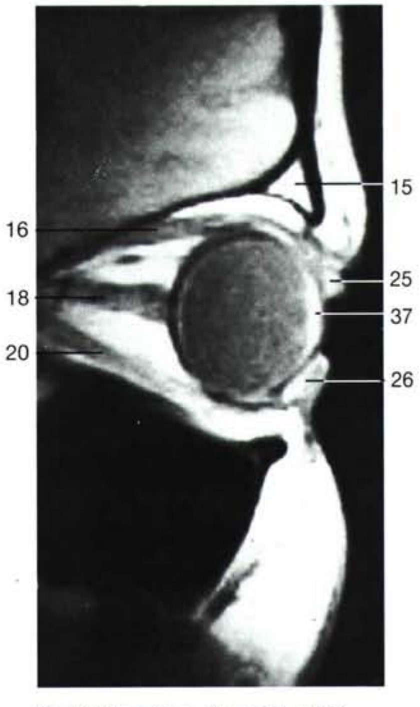

Sagittal section through orbit and eyeball. (MR-Scan.)

1 Frontal bone
2 Nasal bone
3 Lacrimal bone
4 Maxilla (frontal process)
5 Ethmoidal foramina
6 Lesser wing of sphenoid bone and optic canal
7 Superior orbital fissure
8 Greater wing of sphenoid bone
9 Orbital process of palatine bone
10 Orbital plate of ethmoid bone
11 Inferior orbital fissure
12 Infraorbital sulcus
13 Nasolacrimal canal
14 Zygomatic bone
15 Frontal sinus
16 **Superior rectus muscle**
17 Orbital fatty tissue
18 **Optic nerve**
19 **Sclera**
20 **Inferior rectus muscle**
21 Periorbita and maxilla
22 Maxillary sinus
23 Levator palpebrae superioris muscle
24 **Superior conjunctival fornix**
25 Superior tarsal plate
26 Inferior tarsal plate
27 **Inferior conjunctival fornix**
28 **Inferior oblique muscle**
29 **Lateral rectus muscle**
30 **Medial rectus muscle**
31 **Superior oblique muscle**
32 Nasal septum
33 Middle nasal concha
34 Inferior nasal concha
35 Tenon's space
36 Ophthalmic artery
37 **Cornea**
38 **Lens**

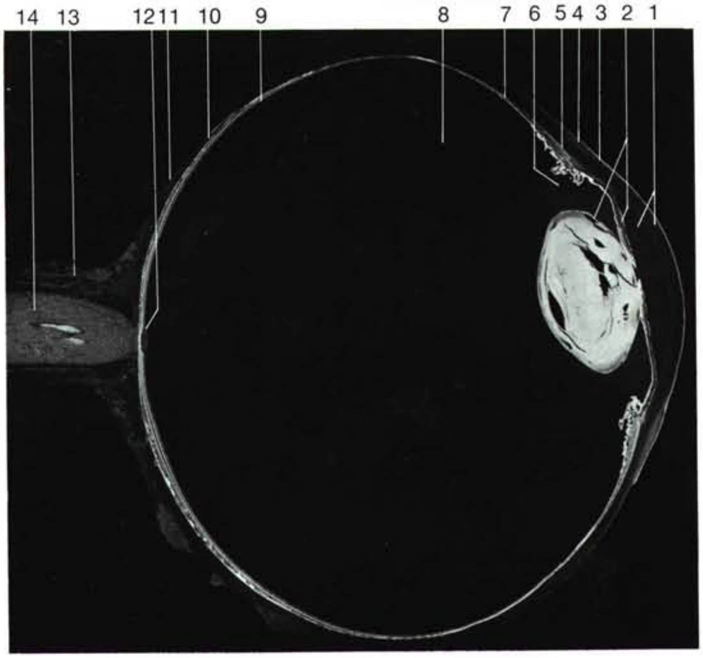

Horizontal section through the human eye (2×).

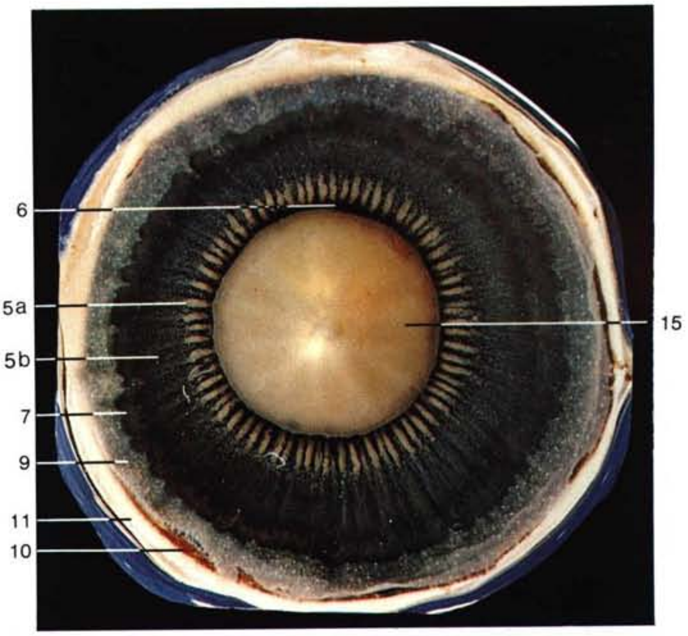

Anterior segment of the eyeball (posterior aspect). The opacity of the lens is an artifact.

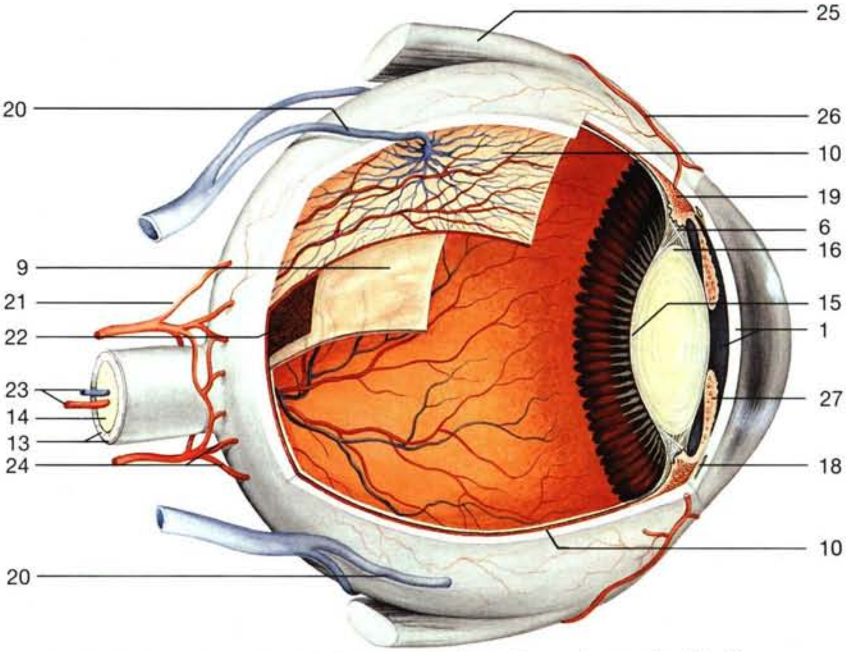

Organization of the eyeball. Demonstration of vascular tunic of bulb. (Schematic drawing.)

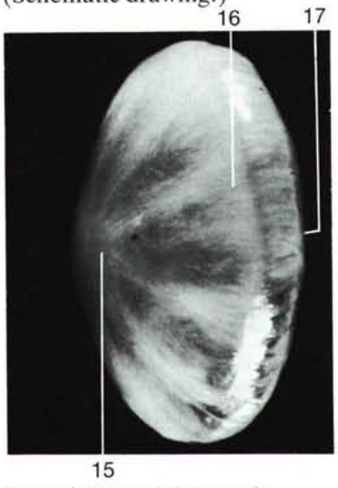

Lens (equatorial aspect), anterior pole to the right.

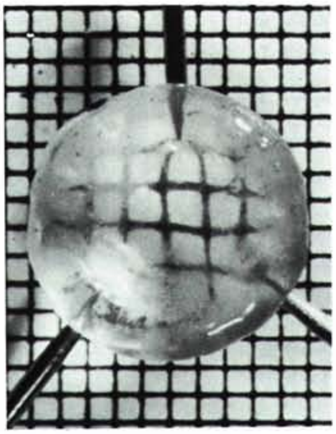

Lens (frontal aspect). Note the magnification effect.

1 **Cornea** and anterior chamber
2 Iris and lens
3 Transitional zone between corneal and conjunctival epithelium
4 Conjunctiva of the eyeball
5 **Ciliary body**
a Ciliary processes (pars plicata)
b Ciliary ring (pars plana)
6 Zonular fibers
7 **Ora serrata**
8 Vitreous body
9 **Retina**
10 **Choroid**
11 **Sclera**
12 Optic disc
13 Dura mater and subarachnoid space
14 **Optic nerve** (n. II)
15 Lens (posterior pole)
16 Equator of lens
17 **Lens** (anterior pole)
18 Canal of Schlemm
19 Ciliary muscle
20 Vena vorticosa
21 Long posterior ciliary artery
22 Retinal pigmented epithelium
23 Central retinal artery and vein
24 Short posterior ciliary arteries
25 External ocular muscle
26 Anterior ciliary artery
27 **Iris**

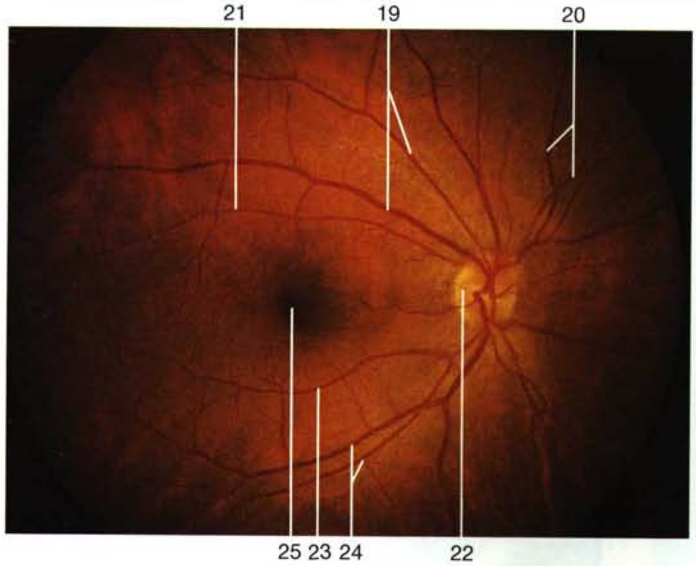

Fundus of a normal right eye (courtesy of Prof. Dr. R. Okamura, Univ. Eye Dept., Kumamoto/Japan). Notice, the arteries are smaller and lighter than the veins.

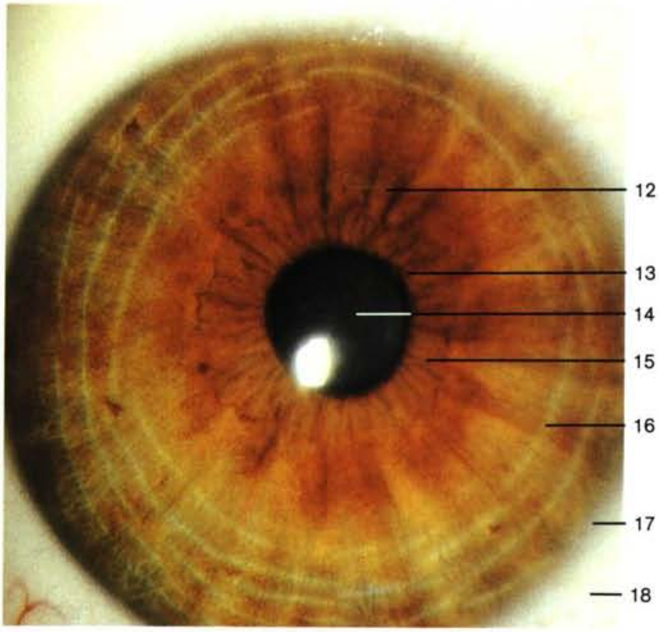

Anterior segment of the human eye (courtesy of Prof. Dr. G. O. H. Naumann, Eye Dept., University of Erlangen, FRG). Note the colored iris and the anterior lens surface.

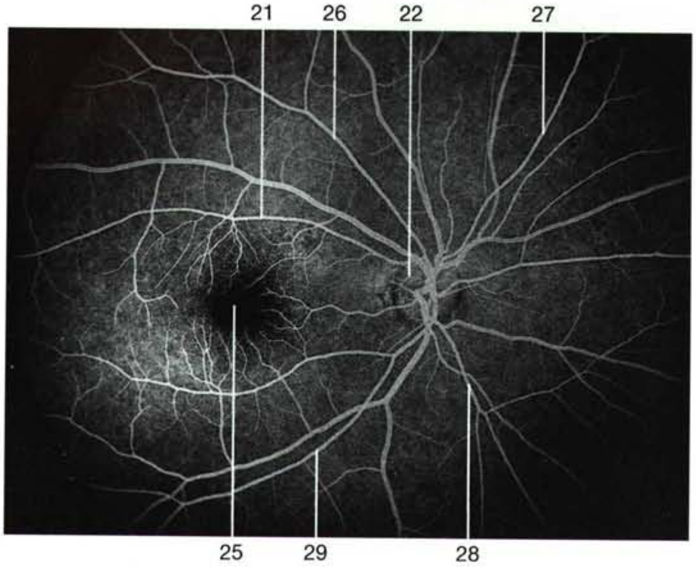

Fluorescent angiography of the right eye; retinal vessels. The same eye as above. (Courtesy of Prof. Dr. R. Okamura, Univ. Eye Dept., Kumamoto/Japan.)

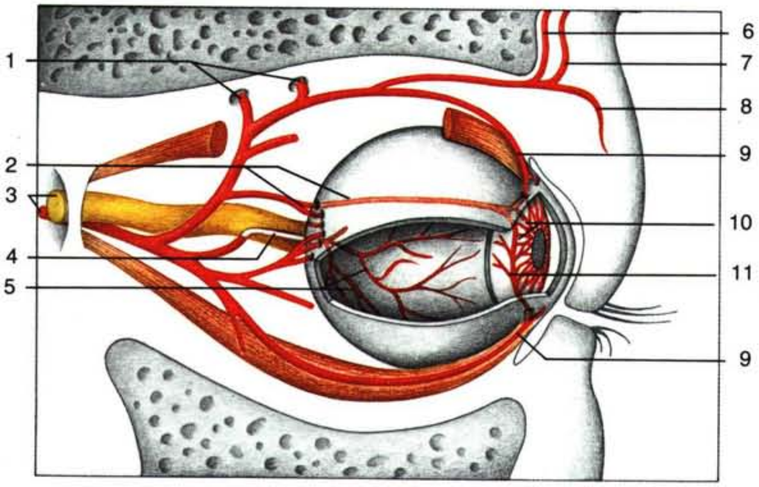

Diagram of the ophthalmic artery and its branches.

1 Posterior and anterior ethmoidal arteries
2 Long and short **posterior ciliary arteries**
3 Optic nerve and **ophthalmic artery**
4 Central retinal artery
5 Retinal arteries
6 Supratrochlear artery
7 Supraorbital artery
8 Dorsal nasal artery
9 **Anterior ciliary artery**
10 Iridial arteries
11 Circulus arteriosus major of iris
12 Iridial fold
13 Pupillary margin of iris
14 Anterior pole of lens
15 Lesser circle of **iris**
16 Greater circle of iris
17 Margin of cornea or limbus
18 Sclera
19 Superior temporal artery and vein of retina
20 Superior nasal artery and vein of retina
21 Superior macular artery
22 **Optic disc**
23 Inferior macular artery
24 Inferior temporal artery and vein
25 **Fovea centralis** and **macula lutea**
26 Superior temporal artery
27 Superior nasal artery
28 Inferior nasal artery } of retina
29 Inferior temporal artery

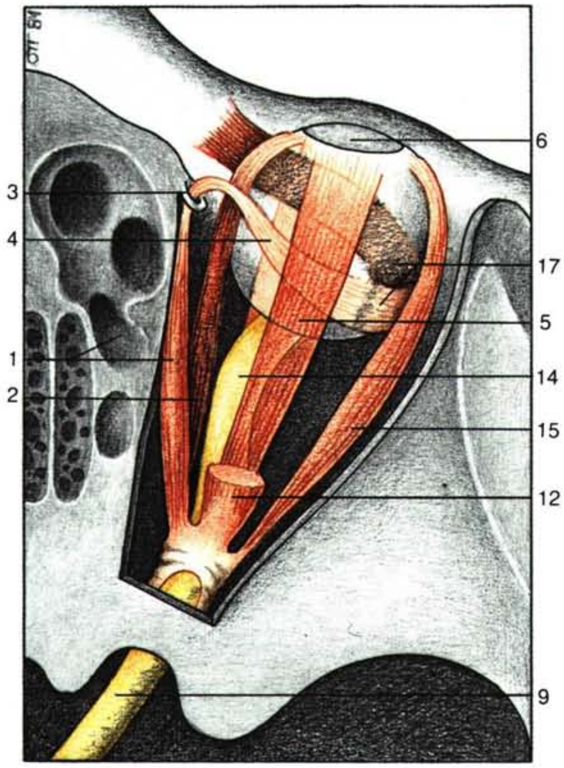

Schematic diagram of the extraocular muscles. Right orbit (from above). Levator palpebrae superioris muscle has been severed.

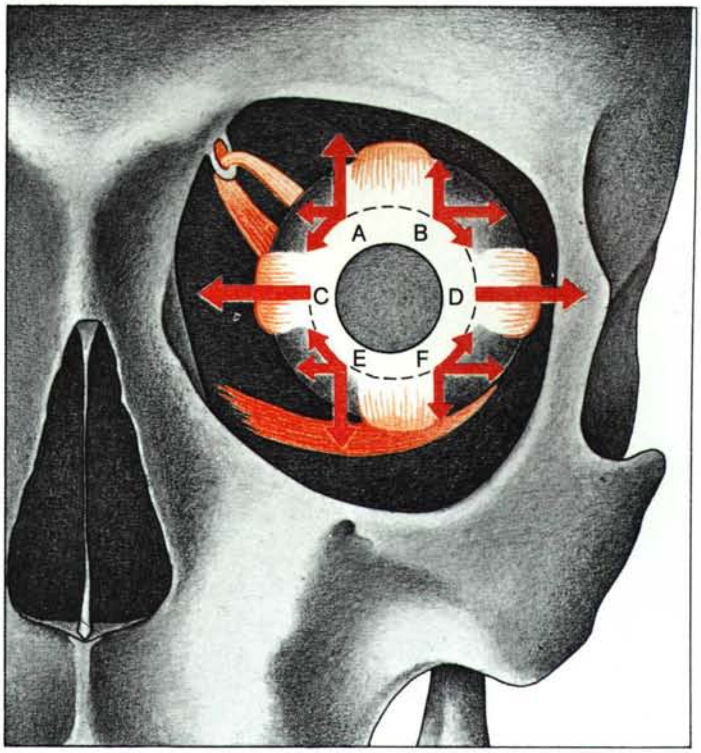

The action of the extraocular muscles. Left orbit (anterior aspect).

A Superior rectus muscle
B Inferior oblique muscle
C Medial rectus muscle
D Lateral rectus muscle
E Inferior rectus muscle
F Superior oblique muscle

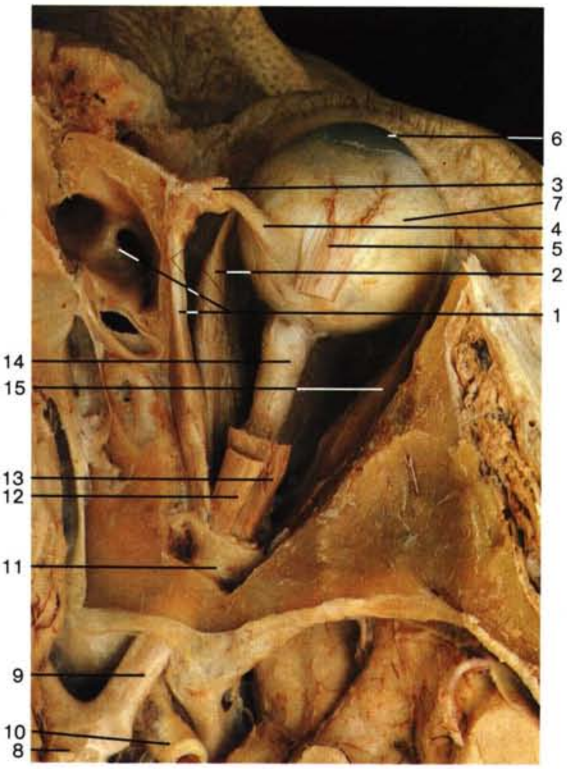

Right orbit with eyeball and extraocular muscles (from above). The roof of the orbit has been removed, the superior rectus muscle and the levator palpebrae superioris muscle have been severed.

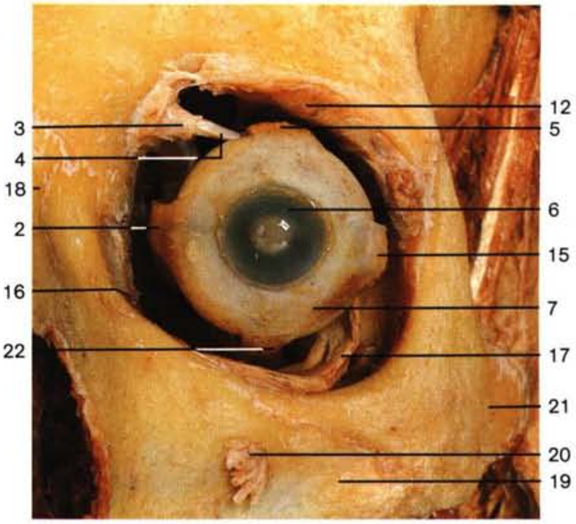

Left orbit with eyeball and extraocular muscles (anterior aspect). Lids, conjunctiva and lacrimal apparatus have been removed.

1 **Superior oblique muscle** and ethmoid air cells
2 **Medial rectus muscle**
3 Trochlea
4 Tendon of superior oblique muscle
5 **Superior rectus muscle**
6 Cornea
7 Eyeball
8 Optic chiasma
9 Optic nerve (intracranial part)
10 Internal carotid artery
11 **Common annular tendon**
12 Levator palpebrae superioris muscle
13 **Superior rectus muscle**
14 Optic nerve (extracranial part)
15 **Lateral rectus muscle**
16 Nasolacrimal duct
17 **Inferior oblique muscle**
18 Nasal bone
19 Maxilla
20 Infraorbital foramen and nerves
21 Zygomatic bone
22 **Inferior rectus muscle**

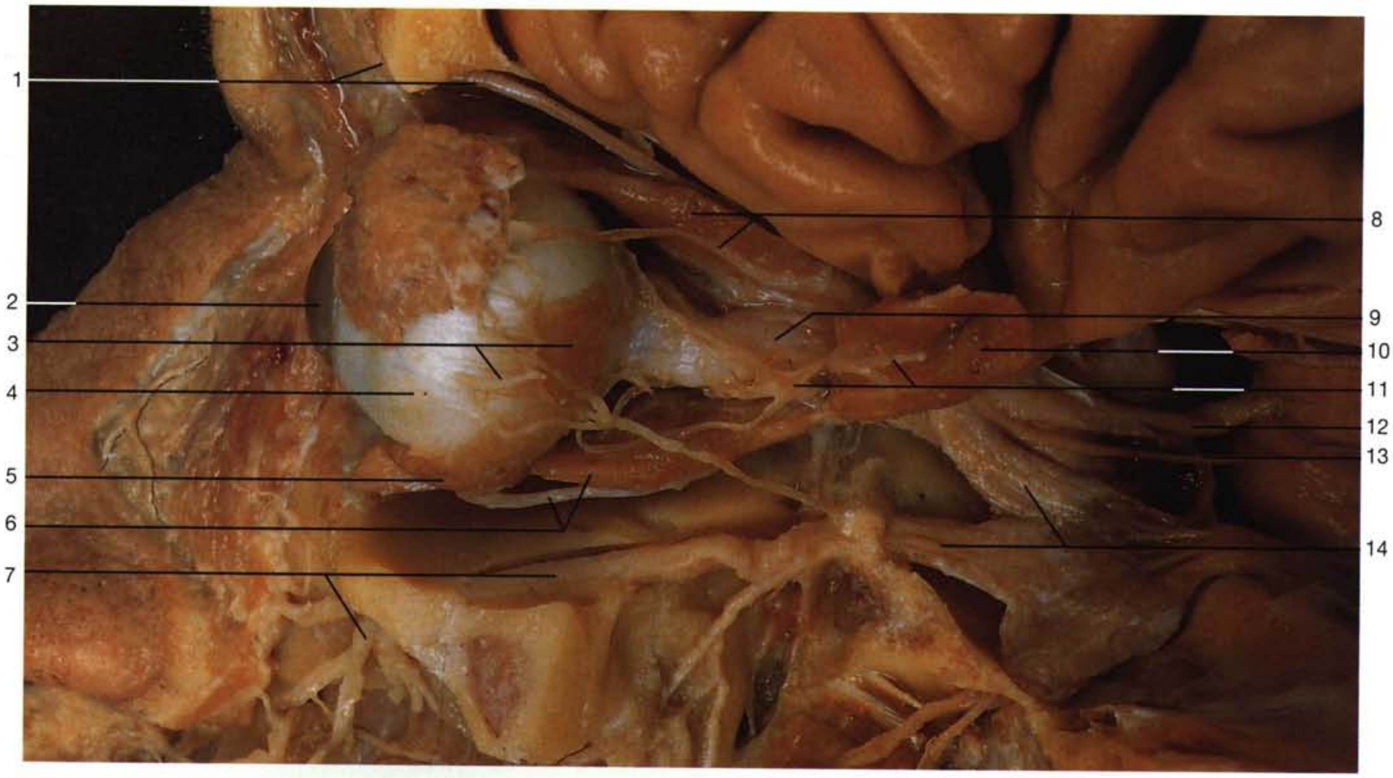

Extraocular muscles and their nerves (lateral aspect of left eye). Lateral rectus divided and reflected.

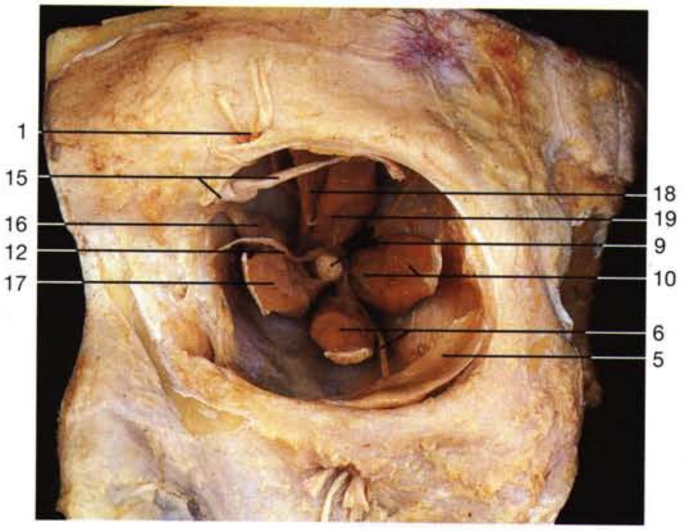

Left orbit with extraocular muscles (anterior aspect). Eyeball removed.

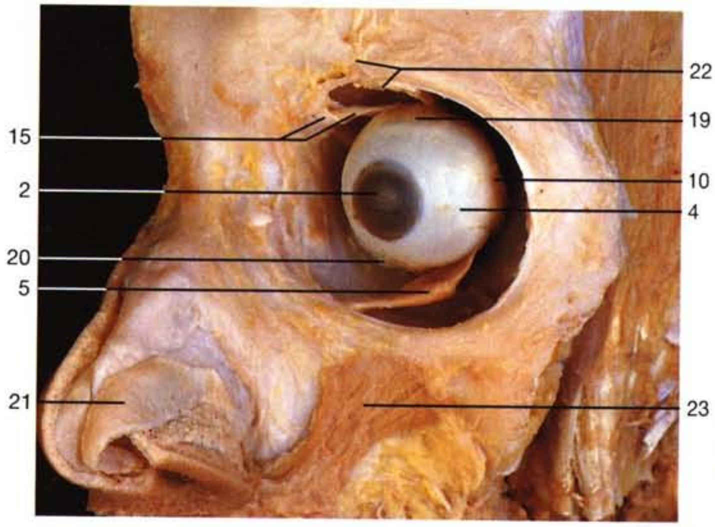

Extraocular eye muscles (anterior-lateral aspect).

1 Supraorbital nerve
2 Cornea
3 Insertion of lateral rectus muscle
4 Eyeball (sclera)
5 **Inferior oblique muscle**
6 **Inferior rectus muscle** and inferior branch of oculomotor nerve
7 Infraorbital nerve
8 Superior rectus muscle and lacrimal nerve
9 Optic nerve
10 **Lateral rectus muscle**
11 Ciliary ganglion and abducens nerve (n. VI)
12 Oculomotor nerve (n. III)
13 Trochlear nerve (n. IV)
14 Ophthalmic nerve (n. V_1) and maxillary nerve (n. V_2)
15 Trochlea and tendon of superior oblique muscle
16 **Superior oblique muscle**
17 **Medial rectus muscle**
18 Levator palpebrae superioris muscle
19 **Superior rectus muscle**
20 **Inferior rectus muscle**
21 Greater alar cartilage
22 Supraorbital nerve and levator palpebrae superioris muscle
23 Levator labii superioris muscle

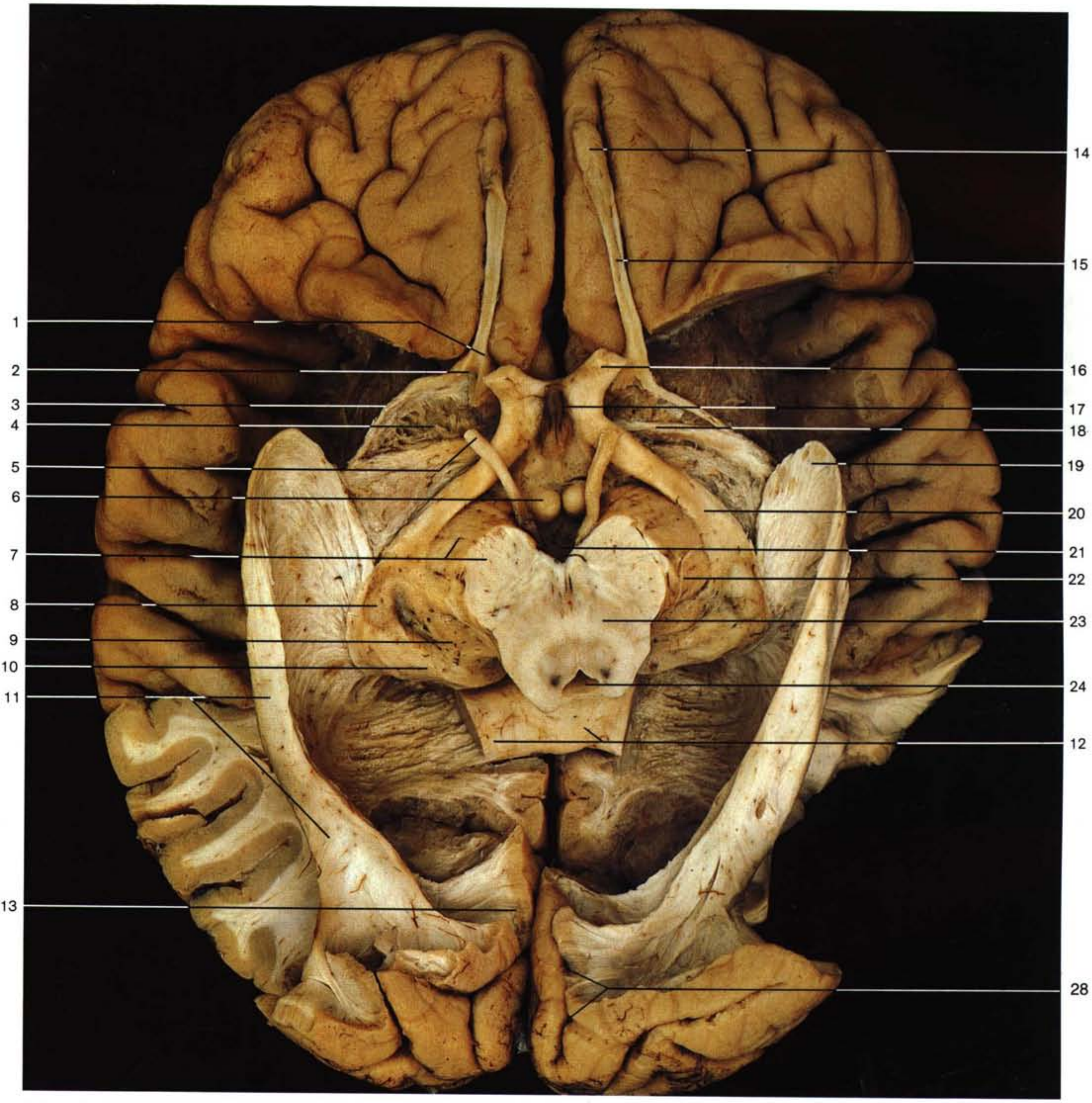

Dissection of the visual pathway (inferior aspect). Frontal pole at top, midbrain divided.

1 Medial olfactory stria
2 Olfactory trigone
3 Lateral olfactory stria
4 Anterior perforated substance
5 Oculomotor nerve (n. III)
6 Mamillary body
7 Cerebral peduncle
8 **Lateral geniculate body**
9 Medial geniculate body
10 **Pulvinar of thalamus**
11 Optic radiation
12 Splenium of the corpus callosum (commissural fibers)
13 Cuneus
14 Olfactory bulb
15 Olfactory tract
16 **Optic nerve** (n. II)
17 Infundibulum
18 Anterior commissure
19 **Genu of optic radiation**
20 **Optic tract**
21 Interpeduncular fossa and posterior perforated substance
22 Trochlear nerve (n. IV)
23 Substantia nigra
24 Cerebral aqueduct
25 **Visual cortex**
26 Line of Gennari
27 Gyrus of striate cortex
28 **Calcarine sulcus**

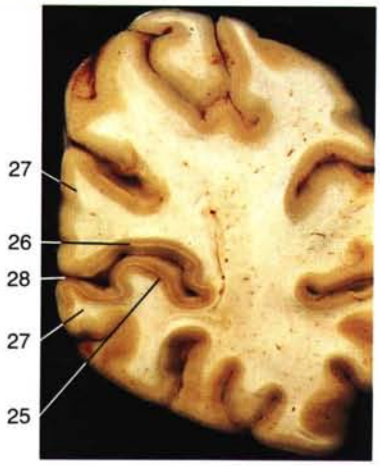

Frontal section of the striate cortex at the level of the striate area in the occipital lobe.

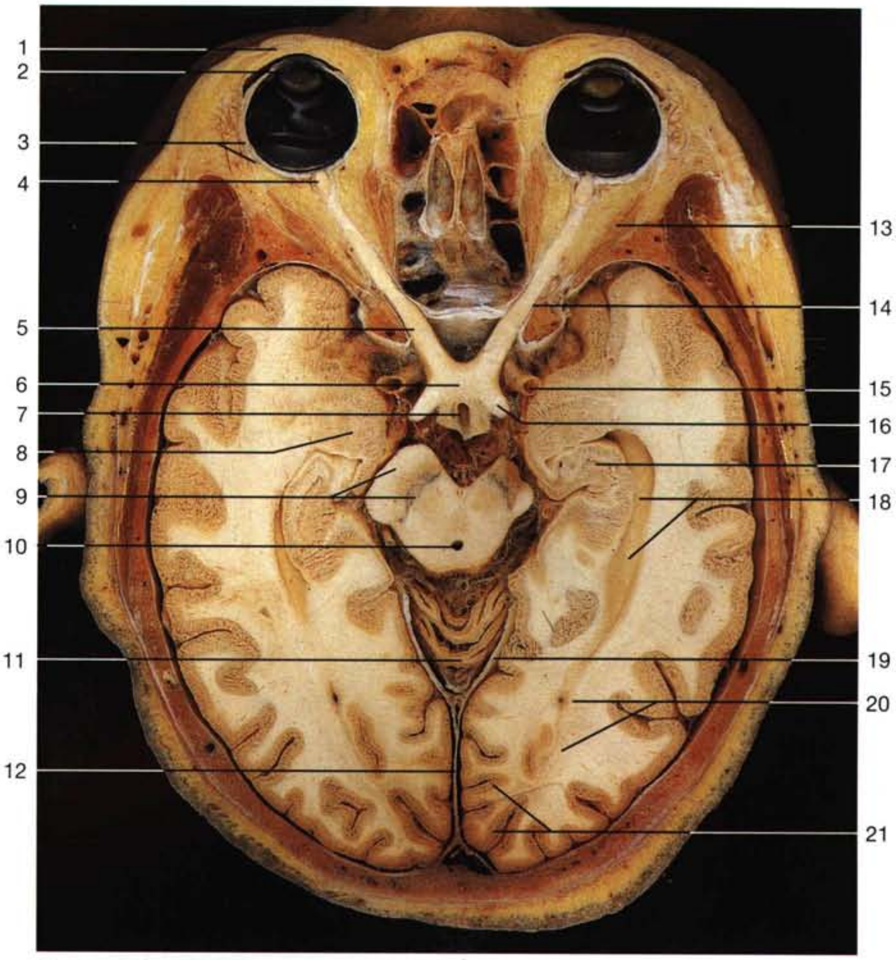

1 Upper lid
2 Cornea
3 **Eyeball** (sclera, retina)
4 Head of optic nerve
5 Optic nerve
6 **Optic chiasma**
7 Infundibular recess of hypothalamus
8 Amygdaloid body
9 Substantia nigra and crus cerebri
10 Cerebral aqueduct
11 Vermis of cerebellum
12 Falx cerebri
13 Lateral rectus muscle
14 Optic canal
15 Internal carotid artery
16 **Optic tract**
17 Hippocampus
18 Inferior horn of lateral ventricle
19 Tentorium cerebelli
20 **Optic radiation** of Gratiolet
21 **Visual cortex (area calcarina, striate cortex)**
22 Lens
23 **Eyeball**
24 Ethmoidal cells
25 Optic nerve with dura sheath
26 Cerebral peduncle
27 Aqueduct of mesencephalon
28 Vermis of cerebellum

Horizontal section through the head at the level of optic chiasma and striate cortex (superior aspect). Note the relationship of hypothalamic infundibulum to optic chiasma.

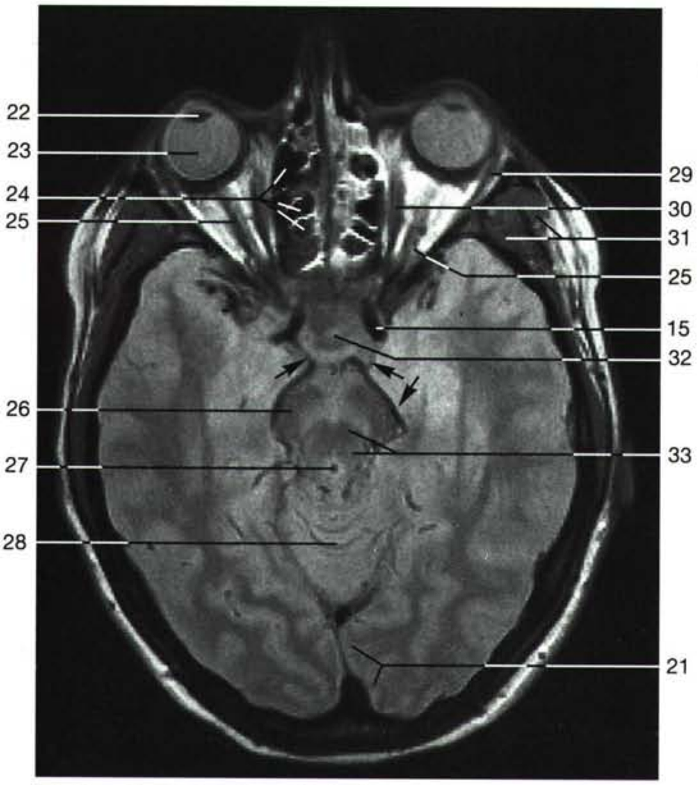

Horizontal section through the human head (MR-Scan, courtesy of Prof. W. J. Huk, Erlangen, FRG). Arrows = branches of arterial circle of Willis.

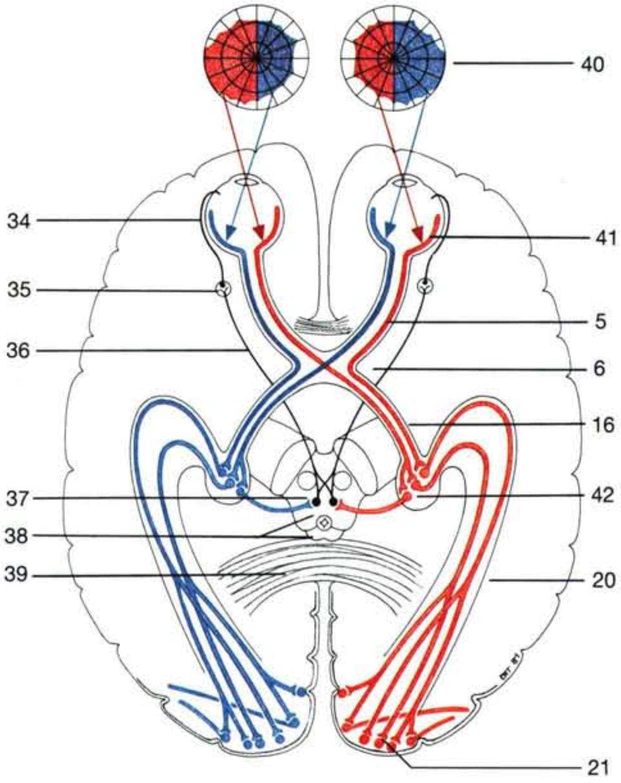

Diagram of the visual pathway and path of the light reflex.

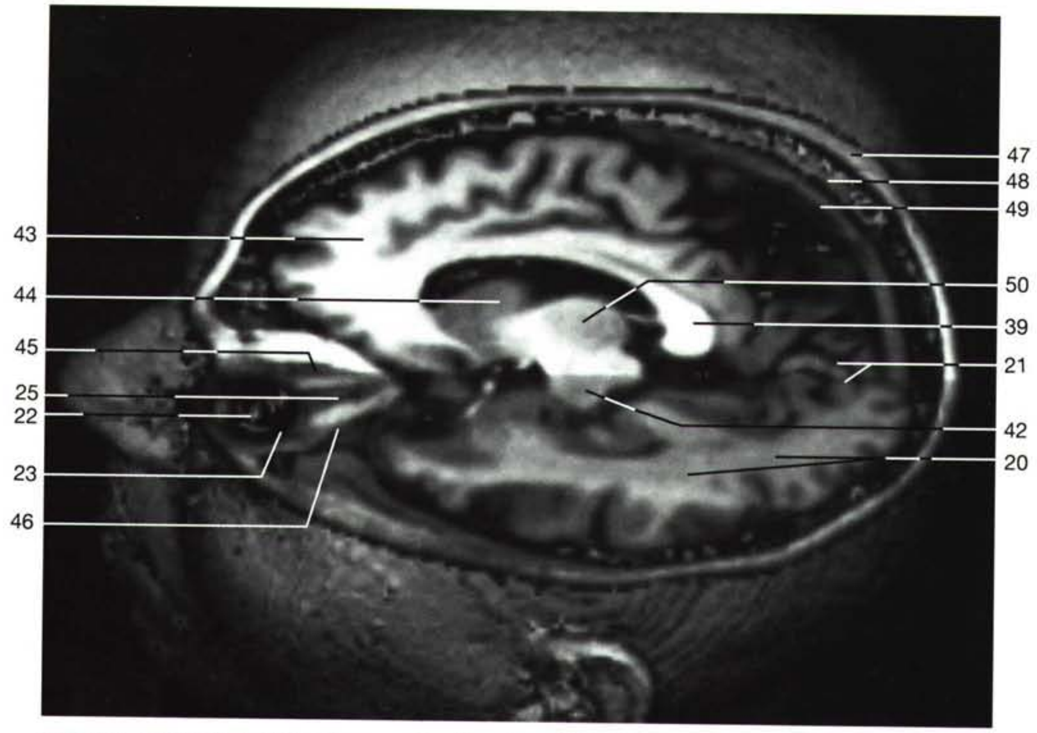

3-D-Reconstruction of the human visual system (MR-Image flash 40°, courtesy of Prof. W. J. Huk, University of Erlangen, FRG).

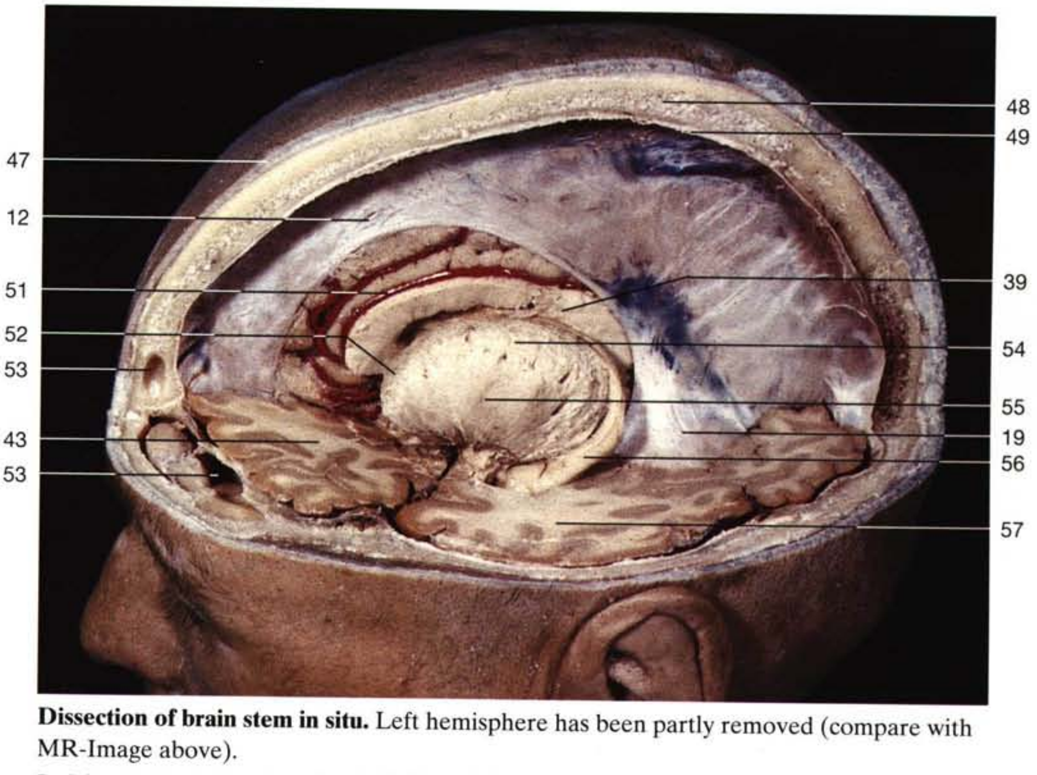

Dissection of brain stem in situ. Left hemisphere has been partly removed (compare with MR-Image above).

29	Lateral rectus muscle
30	Medial rectus muscle
31	Temporalis muscle
32	Hypophysis (pituitary gland)
33	Midbrain
34	Ciliary nerves (long and short)
35	Ciliary ganglion
36	Oculomotor nerve
37	Accessory oculomotor nucleus
38	Colliculi of midbrain
39	Corpus callosum
40	Visual field
41	Retina
42	**Lateral geniculate body**
43	Frontal lobe
44	**Caudate nucleus**
45	Medial rectus muscle
46	Lateral rectus muscle
47	Skin
48	Diploe (skull)
49	Dura mater
50	**Thalamus**
51	**Anterior cerebral artery**
52	Nucleus caudatus
53	Frontal sinus
54	**Internal capsule**
55	Lentiform nucleus (putamen)
56	**Hippocampus**
57	Temporal lobe of left hemisphere

In **binocular vision** the visual field (40) is projected upon portions of both retinae (blue and red in the drawing). In the chiasma the fibers from the two retinal portions are combined to form the left optic tract. The fibers of the two eyes remain separated from each other throughout the entire visual pathway up to their final termination in the calcarine cortex (21). **Injuries** on the optic pathway produce visual defects whose nature depends on the location of the injury. Destruction of one optic nerve produces blindness in the corresponding eye with loss of pupillary light reflex. If lesions of the **chiasma** destroy the crossing fibers of the nasal portions of the retina, both temporal fields of vision are lost (bitemporal hemianopsia). If both lateral angles of the chiasma are compressed, the nondecussating fibers from the temporal retinae are affected resulting in loss of nasal visual fields (binasal hemianopsia). Lesions posterior to the chiasma (i. e., optic tract, lateral geniculate body, optic radiation or visual cortex) result in a loss of the entire opposite field of vision (homonymous hemianopsia).

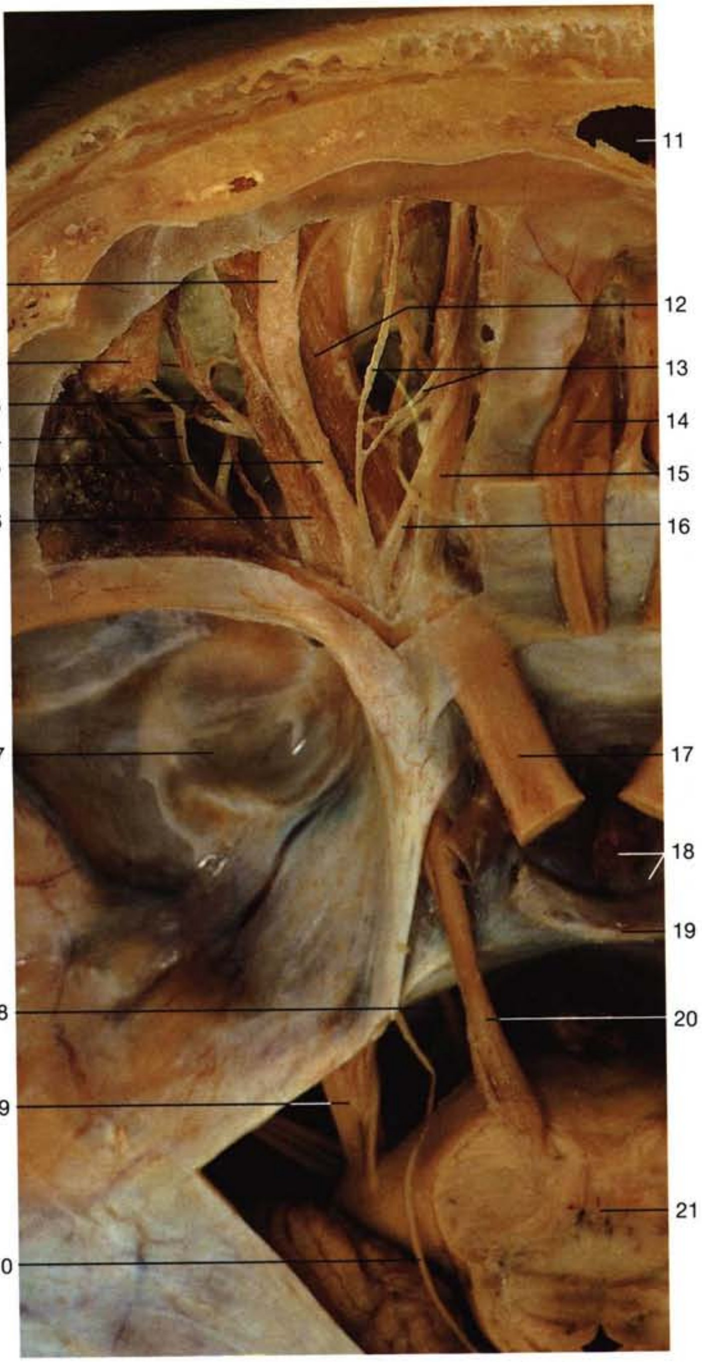

Superficial layer of the left orbit (superior aspect). The roof of the orbit and a portion of the left tentorium have been removed.

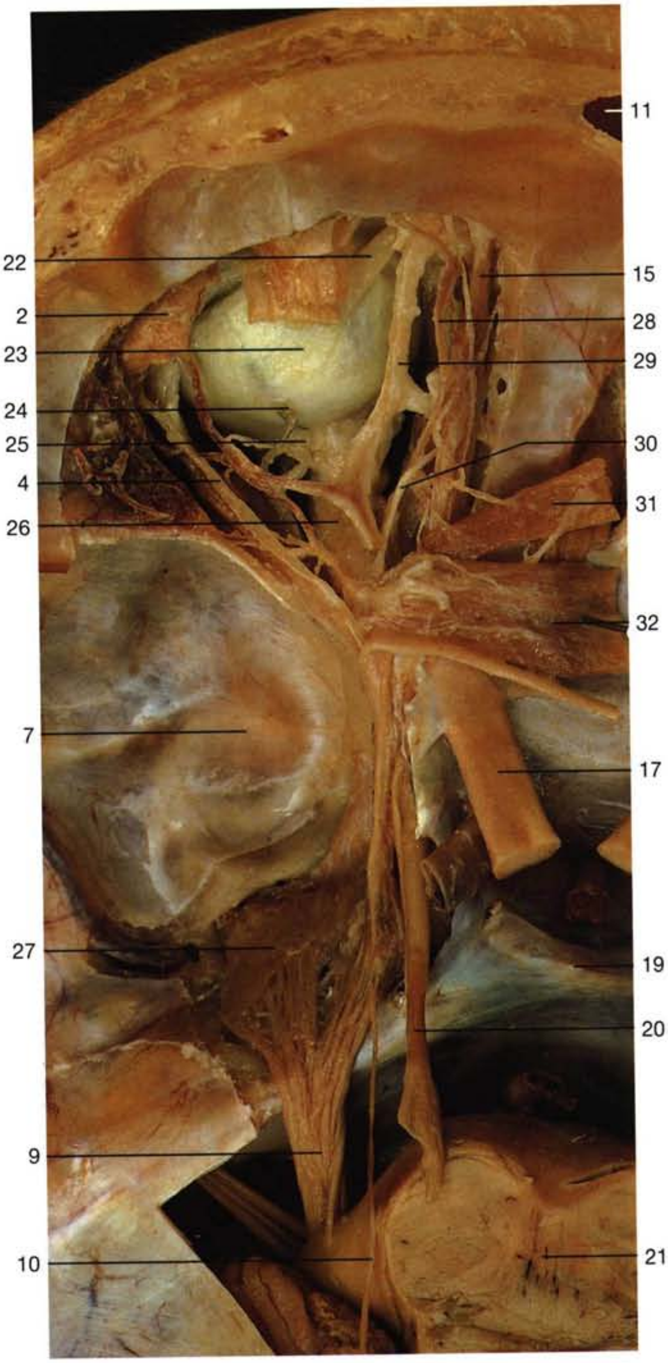

Middle layer of the left orbit (superior aspect). The roof of the orbit has been removed and the superior extraocular muscles have been divided and reflected.

1 Lateral branch of frontal nerve
2 Lacrimal gland
3 Lacrimal vein
4 Lacrimal nerve
5 **Frontal nerve**
6 Superior rectus
7 Middle cranial fossa
8 **Abducens nerve** (n. VI)
9 Trigeminal nerve (n. V)

10 **Trochlear nerve** (intracranial part) (n. IV)
11 Frontal sinus
12 Levator palpebrae superioris muscle
13 Branches of supratrochlear nerve
14 Olfactory bulb
15 Superior oblique muscle
16 **Trochlear nerve** (intraorbital part) (n. IV)
17 **Optic nerve** (intracranial part)
18 Pituitary gland and infundibulum

19 Dorsum sellae
20 **Oculomotor nerve** (n. III)
21 Midbrain
22 Tendon of superior oblique muscle
23 Eyeball
24 Vena vorticosa
25 Short ciliary nerves
26 Optic nerve (extracranial part)
27 **Trigeminal ganglion**

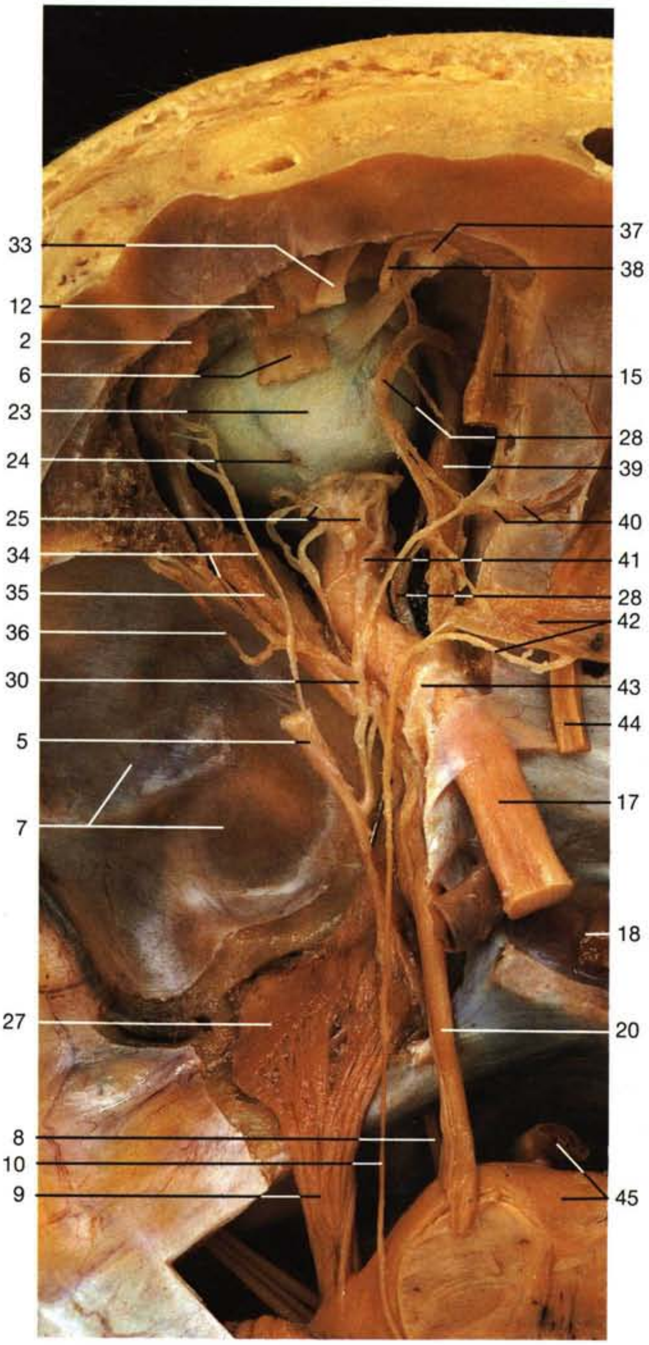
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Middle layer of the left orbit (superior aspect). The roof of the orbit and the superior extraocular muscles have been removed.

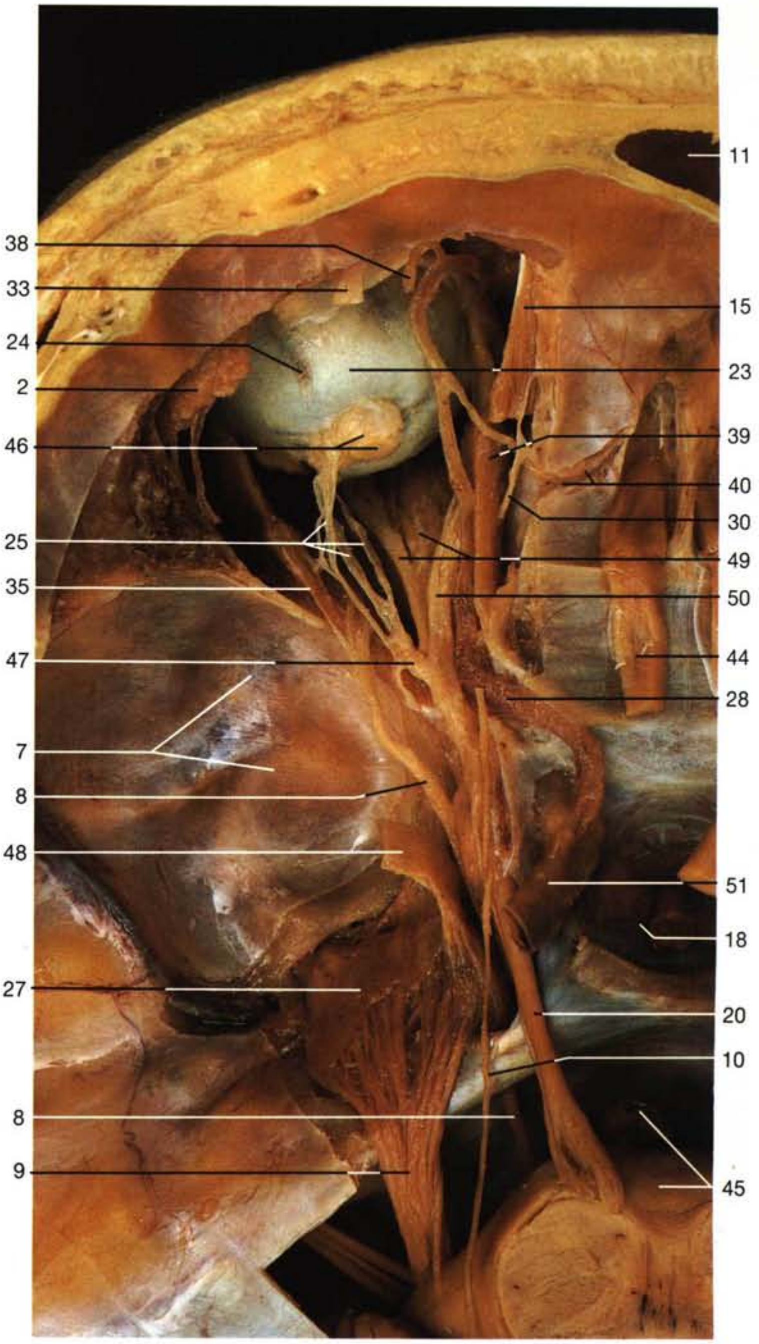
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Deeper layer of the left orbit (superior aspect). The optic nerve has now been removed.

28 **Ophthalmic artery**
29 Superior ophthalmic vein
30 **Nasociliary nerve**
31 Levator palpebrae superioris muscle (reflected)
32 Superior rectus muscle (reflected)
33 Lateral branch of supraorbital nerve
34 Lacrimal nerve and artery
35 Lateral rectus muscle
36 Meningolacrimal artery (anastomosing with middle meningeal artery)
37 Trochlea
38 Medial branch of supraorbital nerve
39 Medial rectus muscle
40 Anterior ethmoidal artery and nerve
41 Long ciliary nerve
42 Superior oblique muscle and trochlear nerve
43 Common tendinous ring
44 Olfactory tract
45 Basilar artery and pons
46 Optic nerve (external sheath of optic nerve, divided)
47 **Ciliary ganglion**
48 Ophthalmic nerve (divided, reflected)
49 Inferior branch of oculomotor nerve and inferior rectus muscle
50 Superior branch of oculomotor nerve
51 Internal carotid artery

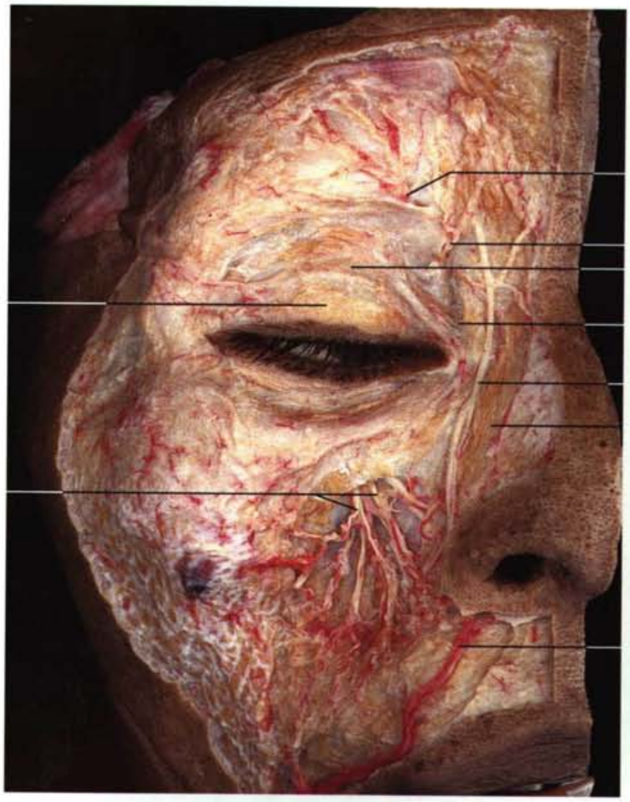

Eyelids (superficial layer, right side).

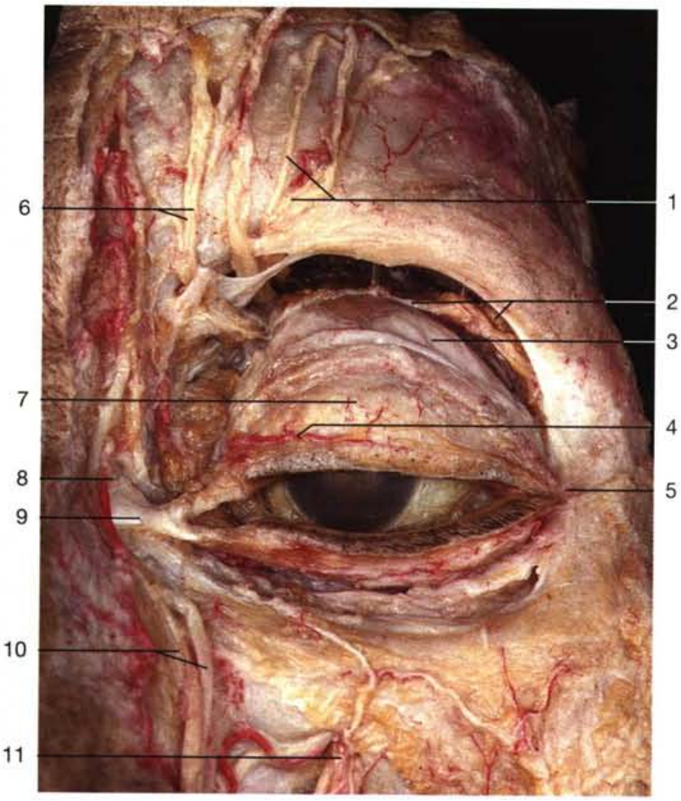

Eyelids (deeper layer, left side).

1 Supraorbital artery, supraorbital nerve, lateral branch
2 **Lacrimal gland**
3 Aponeurosis of levator palpebrae superioris muscle
4 Arterial arch of upper eyelid
5 Lateral palpebral ligament
6 Supratrochlear artery, supratrochlear nerve
7 Upper eyelid, tarsal plate
8 Lacrimal sac
9 **Medial palpebral ligament**
10 Angular artery and vein
11 Infraorbital artery, vein and nerve
12 Orbicularis oculi muscle
13 Infratrochlear nerve
14 Levator labii superioris alaeque nasi muscle
15 Facial artery and vein
16 **Superior lacrimal canaliculus**
17 **Inferior lacrimal canaliculus**
18 Lacrimal papilla and punctum
19 Lacrimal bone
20 **Lacrimal duct**
21 Mucous membrane of nasal cavity
22 Palpebral conjunctiva of lower eyelid
23 Lacrimal sac and superior lacrimal canaliculus
24 Lateral fixation of levator aponeurosis
25 Infraorbital foramen

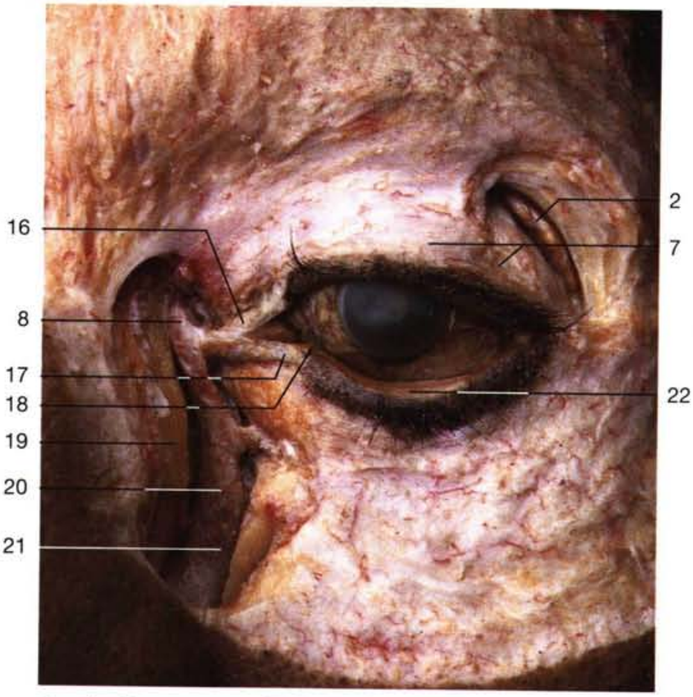

Lacrimal apparatus of left eye (anterior aspect).

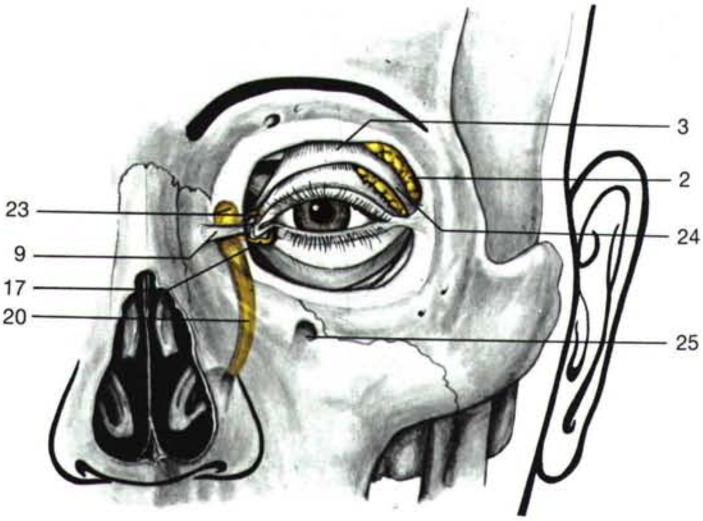

Lacrimal apparatus of left eye (anterior aspect).

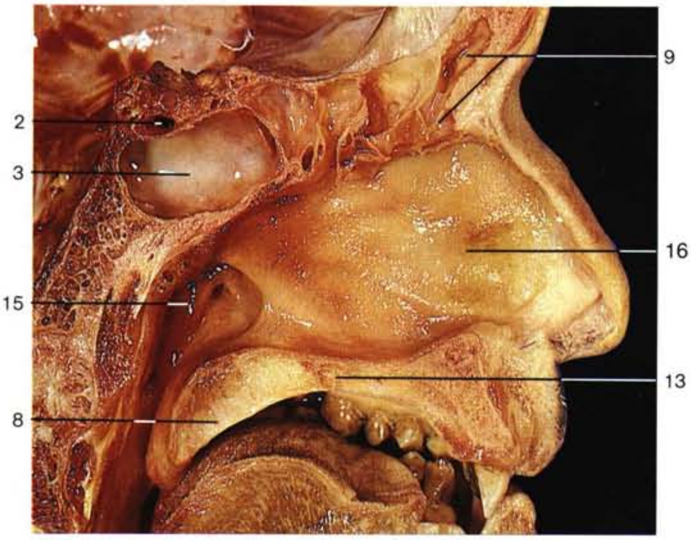

Nasal septum, covered by a mucous membrane.

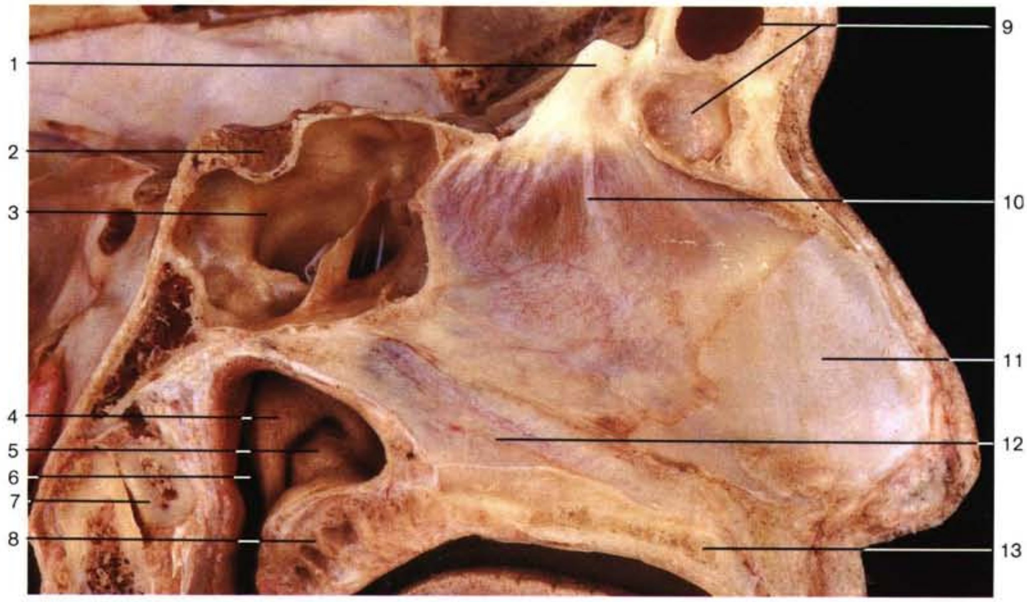

Nasal septum. Mucous membrane removed.

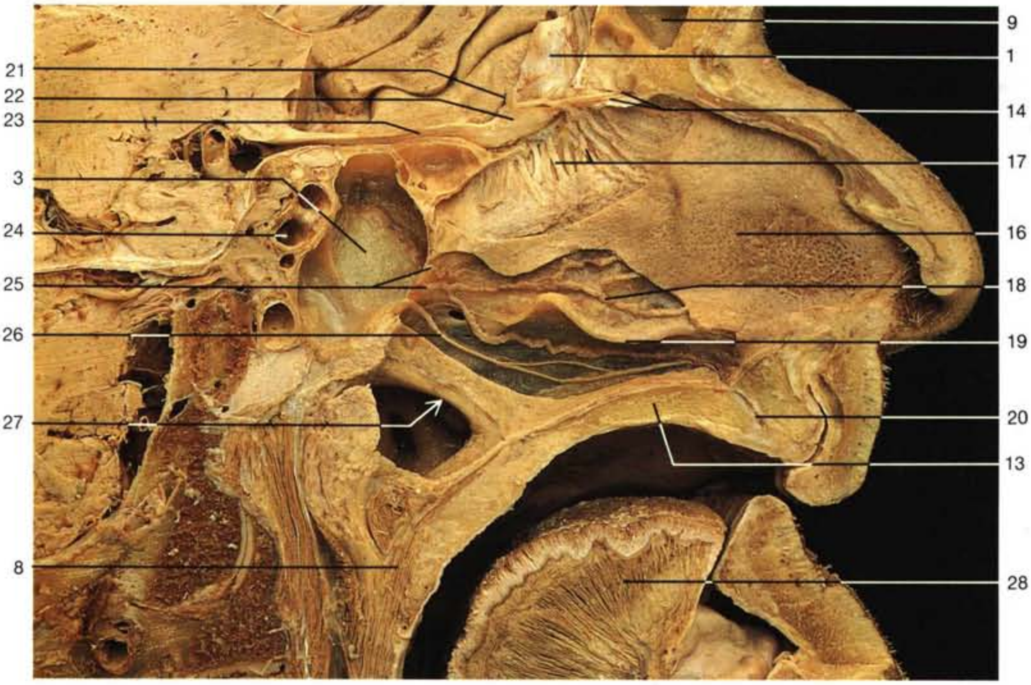

Nasal septum. Dissection of nerves and vessels.

1	Crista galli
2	Pituitary gland and sella turcica
3	**Sphenoidal sinus** (relatively large)
4	Tubal elevation
5	Pharyngeal opening of the **auditory tube**
6	Pharyngeal recess
7	Atlas (anterior arch)
8	Soft palate
9	Frontal sinus
10	Perpendicular plate of ethmoid
11	**Cartilage of nasal septum**
12	Vomer
13	Hard palate
14	Nasal branch of anterior ethmoidal artery and anterior ethmoidal nerve
15	Nasopharynx
16	Nasal septum
17	**Olfactory nerves**
18	Septal artery
19	Crest of nasal septum
20	Incisive canal
21	Anterior ethmoidal artery
22	Olfactory bulb
23	Olfactory tract
24	Internal carotid artery
25	Posterior nasal and septal arteries
26	Nasopalatine nerve
27	**Choana** (arrow)
28	Tongue

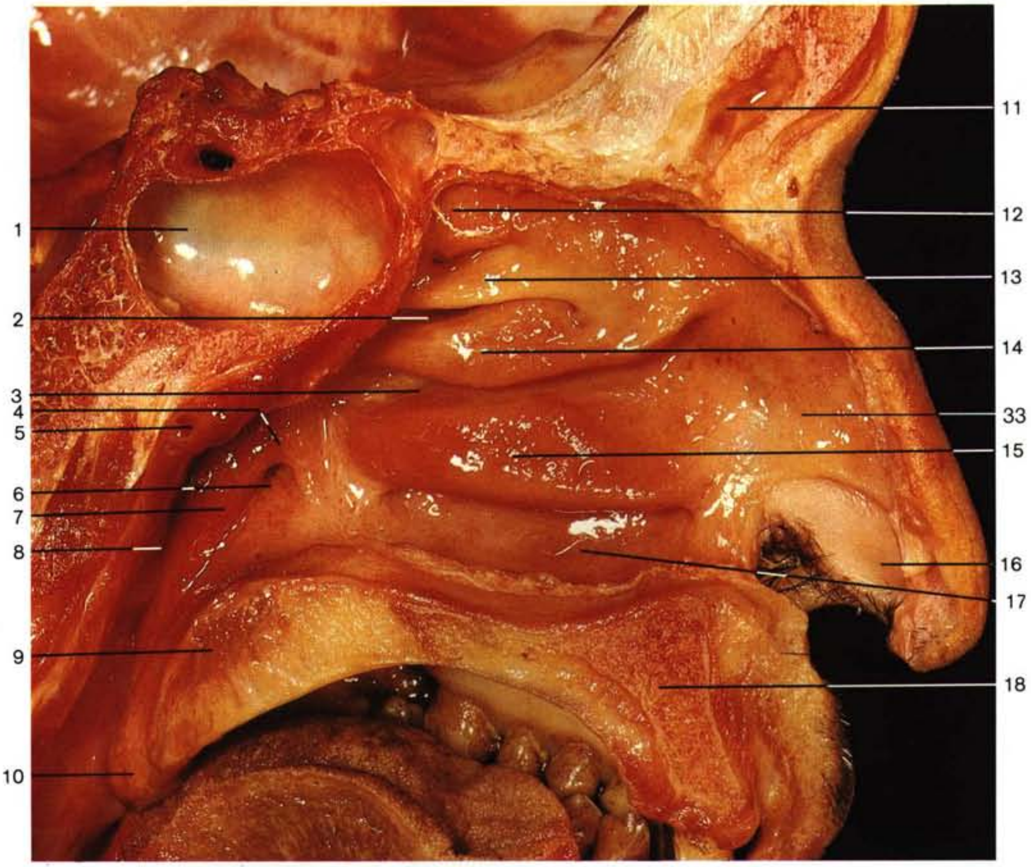

Lateral wall of the nasal cavity, septum removed.

1 Sphenoidal sinus
2 Superior meatus
3 Middle meatus
4 Tubal elevation
5 Pharyngeal tonsil
6 Pharyngeal orifice of **auditory tube**
7 Salpingopharyngeal fold
8 Pharyngeal recess
9 **Soft palate**
10 **Uvula**
11 Frontal sinus
12 Sphenoethmoidal recess
13 **Superior nasal concha**
14 **Middle nasal concha**
15 **Inferior nasal concha**
16 Vestibule
17 Inferior meatus
18 **Hard palate**
19 Grooves for the middle meningeal artery and parietal bone (light green)
20 **Maxillary hiatus**
21 Perpendicular process of palatine bone
22 Openings of ethmoidal air cells
23 Opening of frontal sinus
24 Medial pterygoid plate (red)
25 Horizontal plate of palatine process
26 **Ethmoidal air cells**
27 **Maxillary sinus**
28 Nasal septum
29 Pterygoid hamulus
30 Nasal bone (white)
31 Frontal process of maxilla (violet)
32 Palatine process of maxilla (violet)
33 Nasal atrium

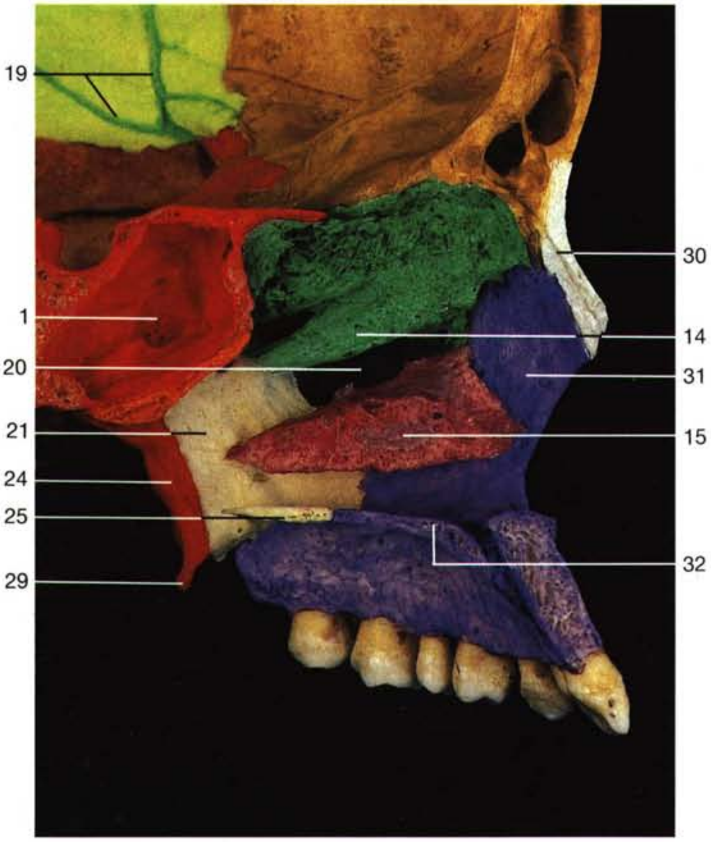

Bones of left nasal cavity, medial aspect.

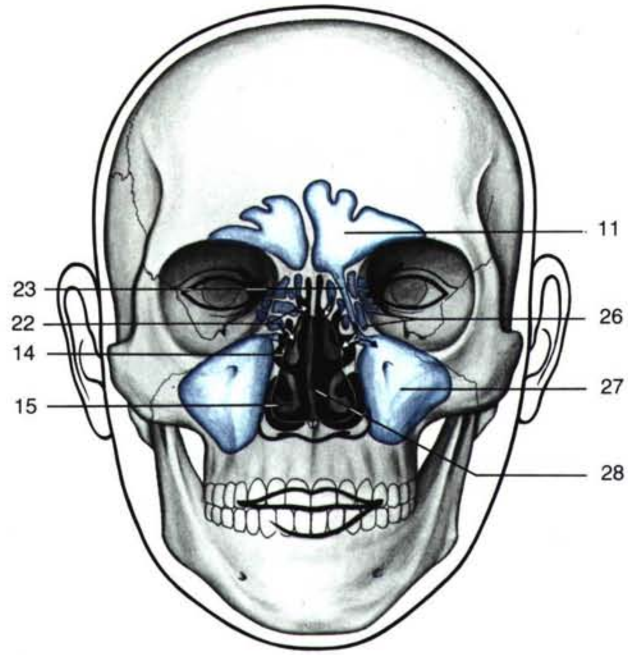

Schematic diagram showing the position of paranasal sinuses, openings indicated by arrows.

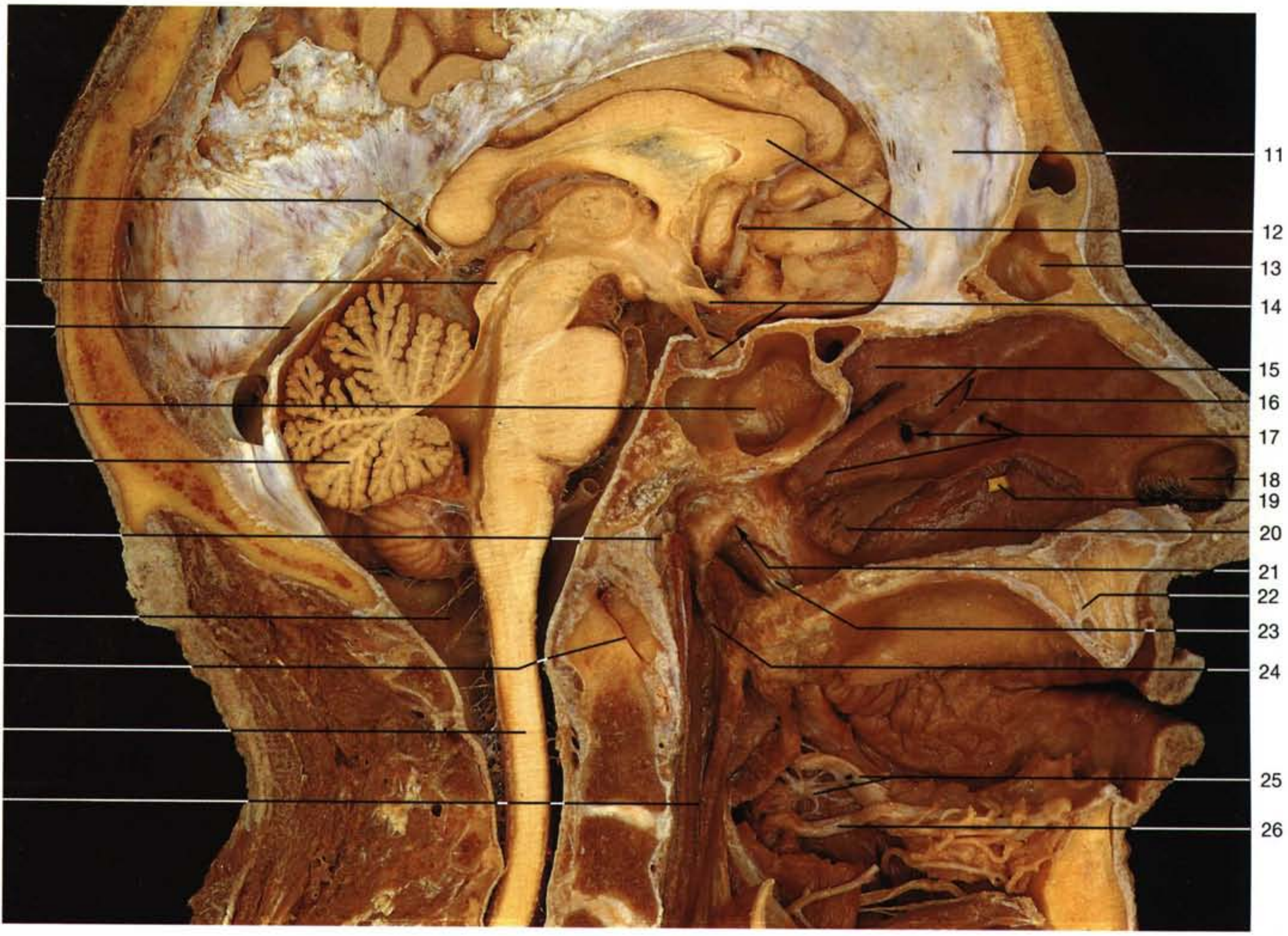

Median section through the head with nasal and oral cavity. The middle and inferior nasal conchae have been partly removed to show the openings of paranasal sinuses.

1 Great cerebral vein (Galen's vein)
2 **Tectum of midbrain**
3 Straight sinus
4 **Sphenoidal sinus**
5 Cerebellum
6 **Pharyngeal tonsil**
7 **Cerebellomedullary cistern**
8 Median atlantoaxial joint
9 Spinal cord
10 Oral part of pharynx
11 Falx cerebri
12 Corpus callosum and anterior cerebral artery
13 **Frontal sinus**
14 Optic chiasm and pituitary gland
15 Superior nasal concha and ethmoidal bulla
16 **Semilunar hiatus**
17 Accessory **openings to maxillary sinus** and cut edge of middle nasal concha
18 Vestibule
19 **Opening of nasolacrimal duct**
20 Inferior nasal concha (cut)
21 **Opening of auditory tube**
22 **Incisive canal**
23 Levator veli palatini muscle
24 Salpingopharyngeal fold
25 Lingual nerve and submandibular ganglion
26 Submandibular duct
27 **Nasofrontal duct**
28 **Nasolacrimal duct**
29 Sphenoethmoidal recess (of Rosenmüller)
30 Salpingopalatine fold

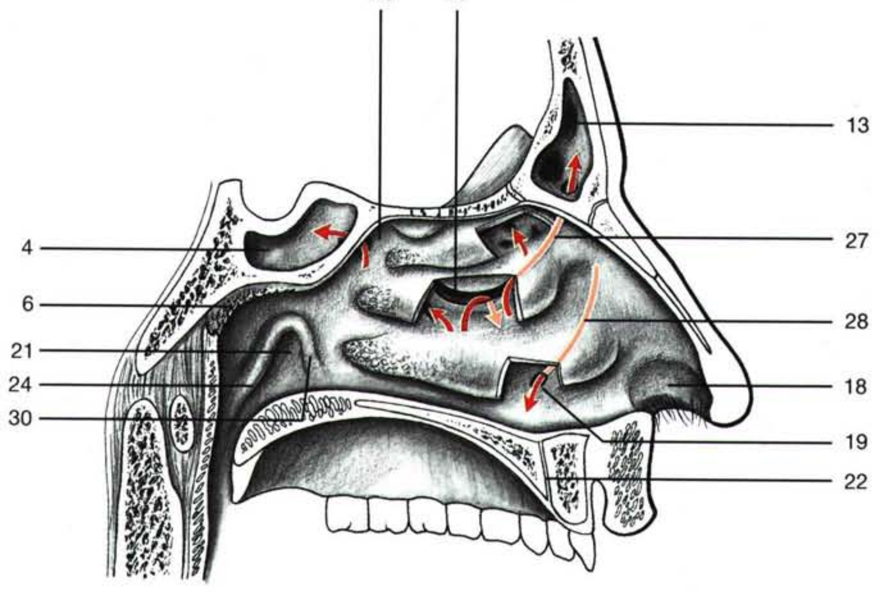

Lateral wall of nasal cavity. Openings indicated by red arrows. (Schematic drawing.)

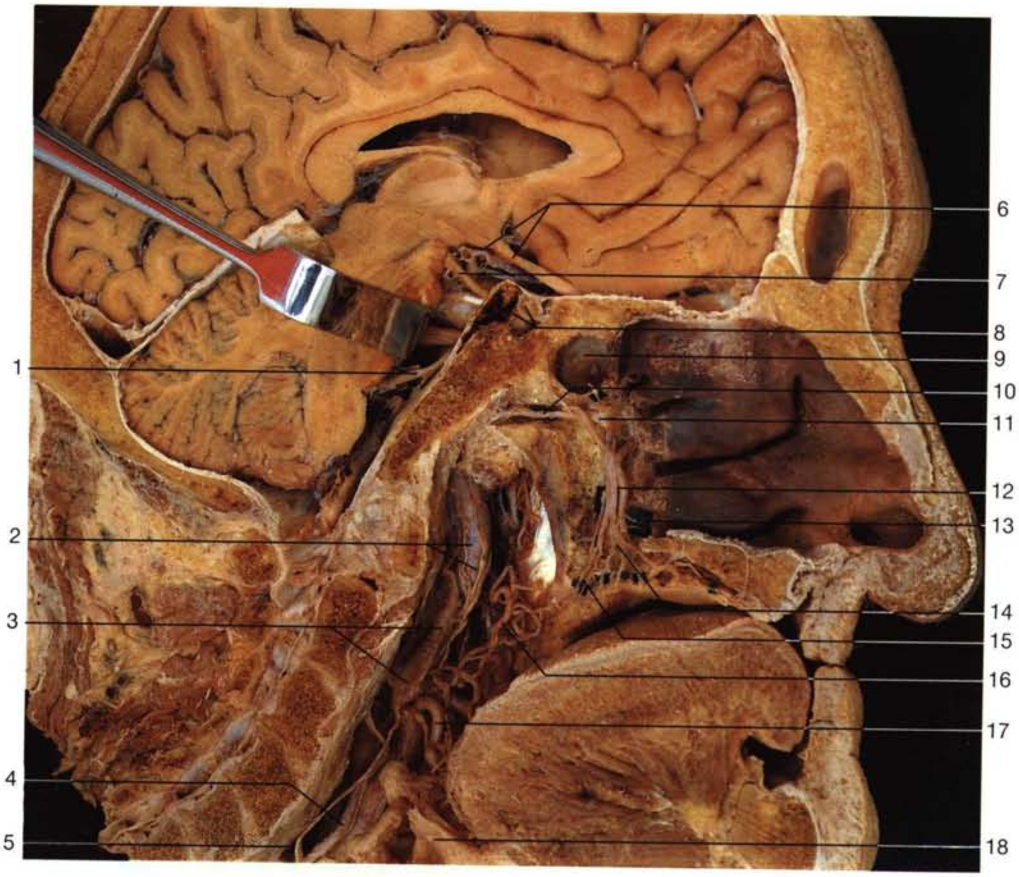

Nerves of the lateral wall of nasal cavity I. Sagittal section through the head. Mucous membranes partly removed, pterygoid canal opened.

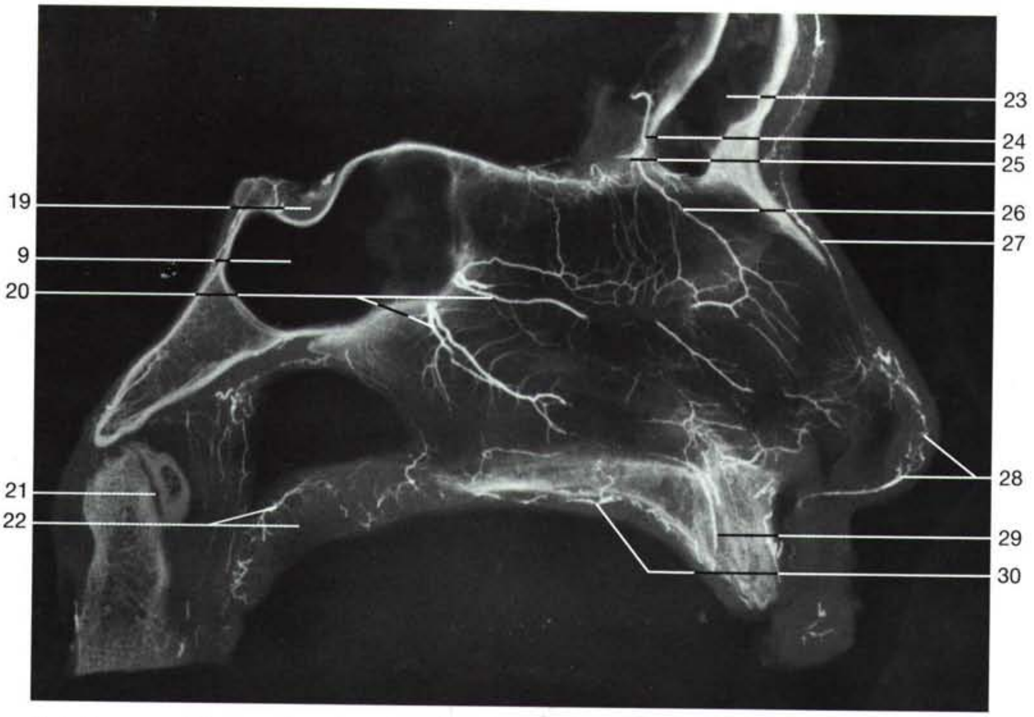

Arteriogram of the nasal septum, left side (lateral aspect).

1 Facial nerve
2 **Internal carotid artery** and **internal carotid plexus**
3 **Superior cervical ganglion**
4 Vagus nerve
5 Sympathetic trunk
6 Optic nerve and ophthalmic artery
7 Oculomotor nerve
8 Internal carotid artery and cavernous sinus
9 Sphenoidal sinus
10 Nerve of the pterygoid canal
11 **Pterygopalatine ganglion**
12 **Descending palatine artery**
13 Lateral inferior posterior nasal branches and lateral posterior nasal and septal arteries
14 Greater palatine nerves and artery
15 Lesser palatine nerves and arteries
16 Branches of ascending pharyngeal artery
17 Lingual artery
18 Epiglottis
19 **Sella turcica**
20 **Posterior lateral nasal and septal arteries** (branches of sphenopalatine artery)
21 Median atlanto-axial joint
22 Soft palate and lesser palatine arteries (branches of descending palatine artery)
23 Frontal sinus
24 Anterior meningeal artery
25 Anterior ethmoidal artery (branch of ophthalmic artery)
26 **Septal branch of anterior ethmoidal artery**
27 Dorsal nasal artery
28 Nasal branches of anterior ethmoidal artery
29 Incisive canal with nasopalatine artery
30 Hard palate and greater palatine artery (branch of descending palatine artery)
31 Tentorium cerebelli
32 Trochlear nerve
33 **Trigeminal nerve** with motor root
34 **Internal carotid plexus**
35 **Lingual nerve with chorda tympani**
36 Medial pterygoid muscle and medial pterygoid plate
37 **Inferior alveolar nerve**
38 **Sympathetic trunk**
39 Oculomotor nerve
40 **Palatine nerves**
41 Tongue
42 **Tringeminal ganglion**
43 Trigeminal nerve (n. V)
44 **Facial nerve** (n. VII)
45 Geniculate ganglion
46 Stylomastoid foramen
47 Medial pterygoid muscle

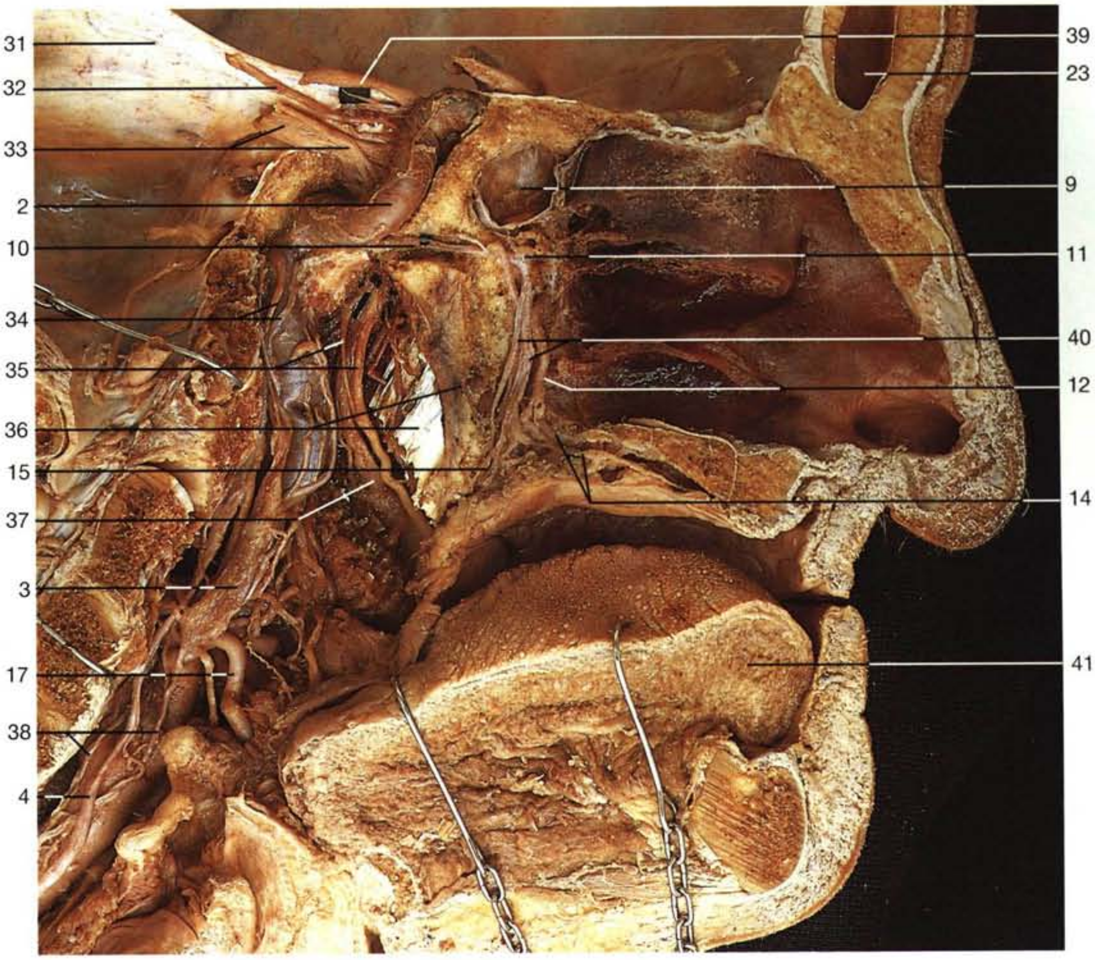
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Nerves of the lateral wall of nasal cavity II. Carotid canal opened, mucous membranes of pharynx and nasal cavity partly removed.

48 **Greater petrosal nerve**
49 Maxillary nerve
50 Olfactory bulb
51 **Olfactory nerves**
52 Internal nasal branches of anterior ethmoidal nerve
53 Lateral superior posterior nasal branches
54 Lateral inferior posterior nasal branches
55 Incisive canal with nasopalatine nerve
56 **Greater palatine nerve**
57 **Deep petrosal nerve**
58 Mandibular nerve
59 Nasal cavity and inferior nasal concha
60 Opening of auditory tube
61 Tensor veli palatini muscle
62 Levator veli palatini muscle
63 Pharyngeal recess in the nasopharynx
64 Uvula
65 Palatoglossal arch
66 Tonsillar branch of ascending palatine artery
67 **Palatine tonsil**
68 Palatopharyngeal arch

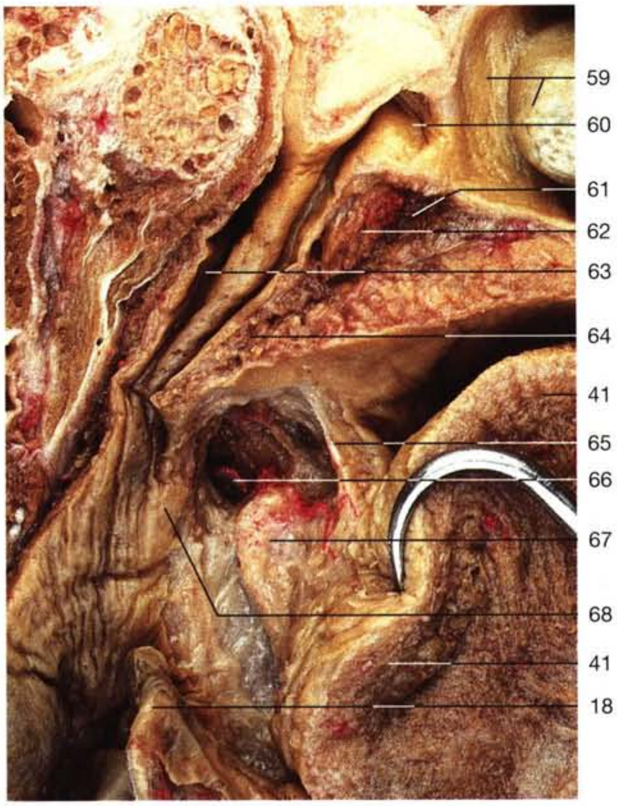
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Dissection of palatine tonsil located in the lateral wall of the nasopharynx (left side). Root of tongue reflected.

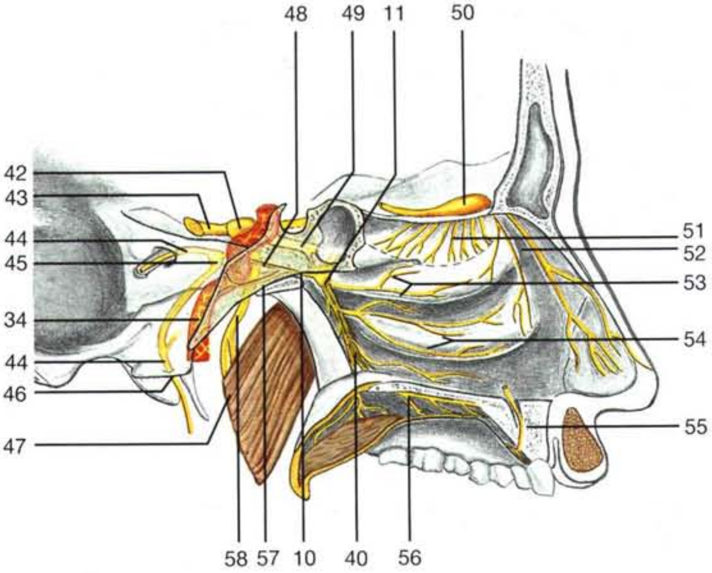
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Nerves of the lateral wall of nassal cavity. Body of sphenoid bone appears transparent (schematic drawing).

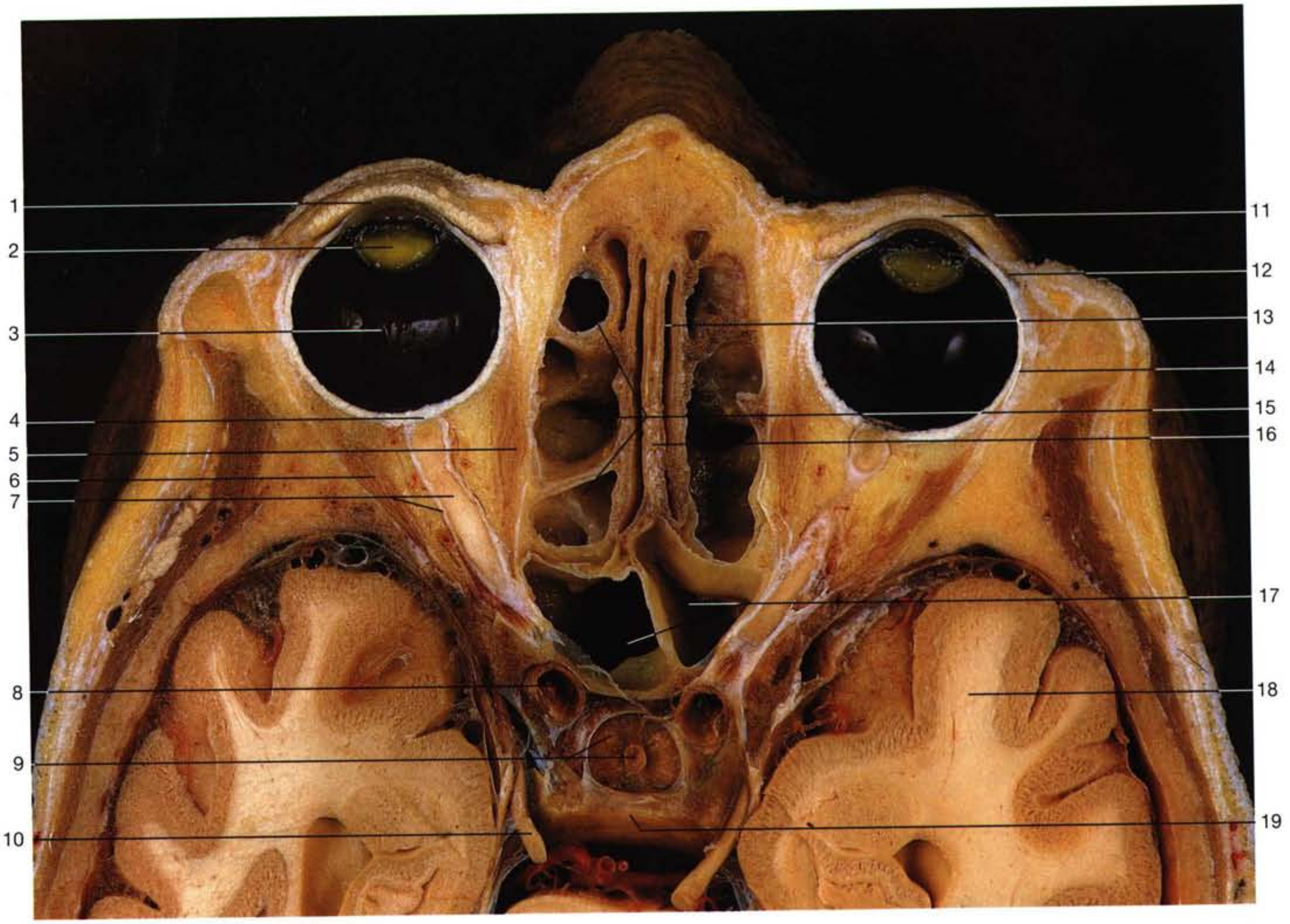

Horizontal section through the nasal cavity, the orbits and temporal lobes of the brain at the level of pituitary gland.

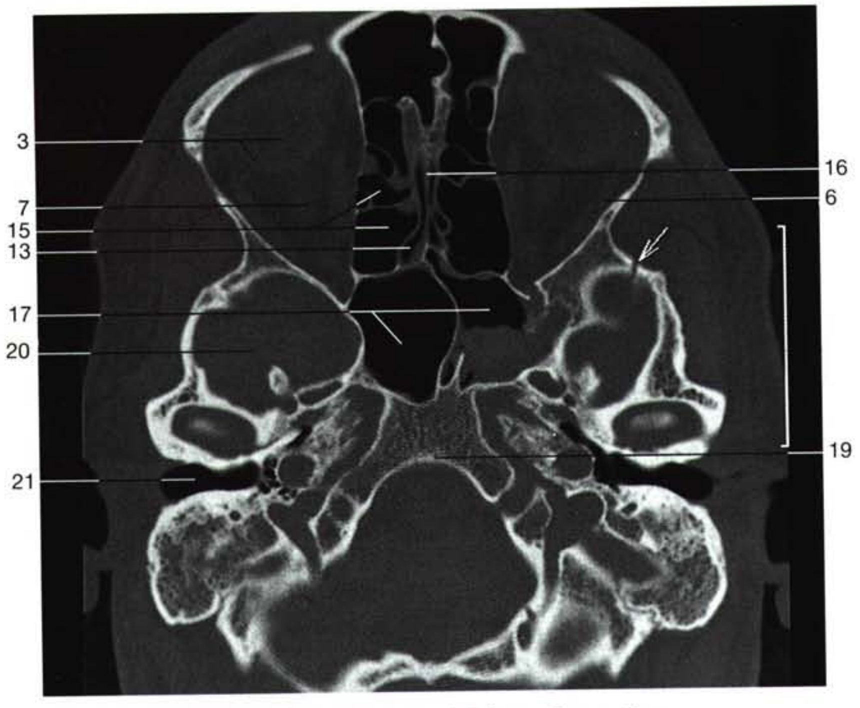

Horizontal section through the head. CT-Scan. Bar = 2 cm.
Arrow: fracture.

1 Cornea
2 Lens
3 Vitreous body (**eyeball**)
4 Head of optic nerve
5 Medial rectus muscle
6 Lateral rectus muscle
7 **Optic nerve** with dural sheath
8 Internal carotid artery
9 **Pituitary gland** and **infundibulum**
10 **Oculomotor nerve**
11 Superior tarsal plate of eye lid
12 Fornix of conjunctiva
13 **Nasal cavity**
14 Sclera
15 Ethmoidal sinus
16 **Nasal septum**
17 **Sphenoidal sinus**
18 Temporal lobe
19 Clivus
20 Middle cranial fossa
21 External acoustic meatus
22 Superior sagittal sinus
23 Falx cerebri
24 Superior rectus and levator palpebrae superioris muscles
25 Eyeball and lacrimal gland
26 Inferior rectus muscle
27 Zygomatic bone
28 **Maxillary sinus**
29 Inferior nasal concha
30 Hard palate
31 Superior longitudinal muscle of tongue
32 Median fibrosus septum of tongue

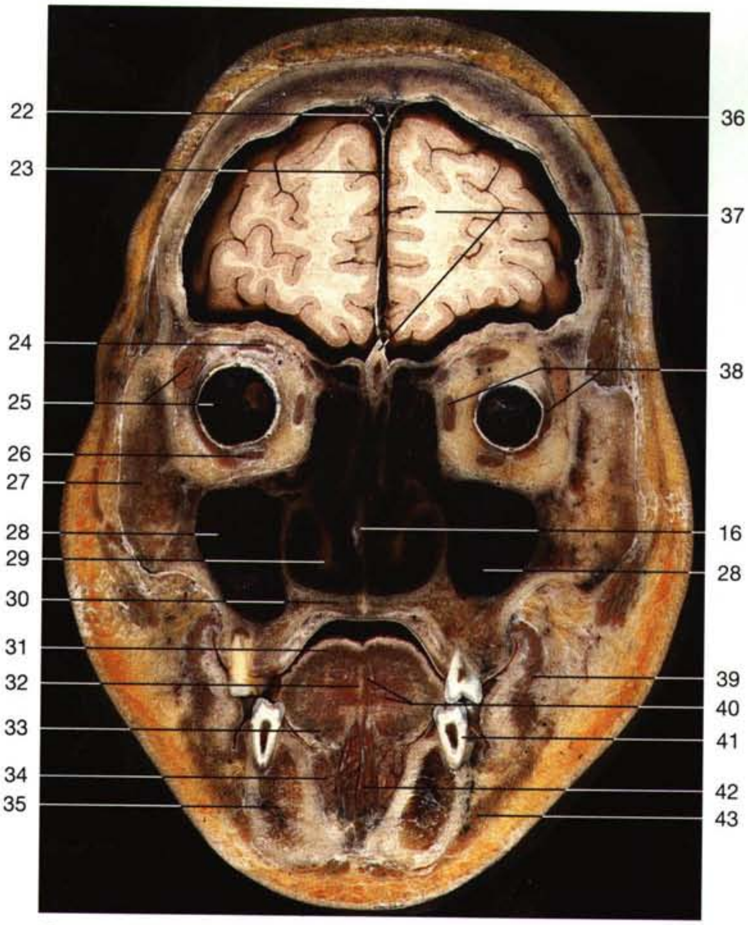
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Coronal section through the head at the level of the second premolar of the mandible.

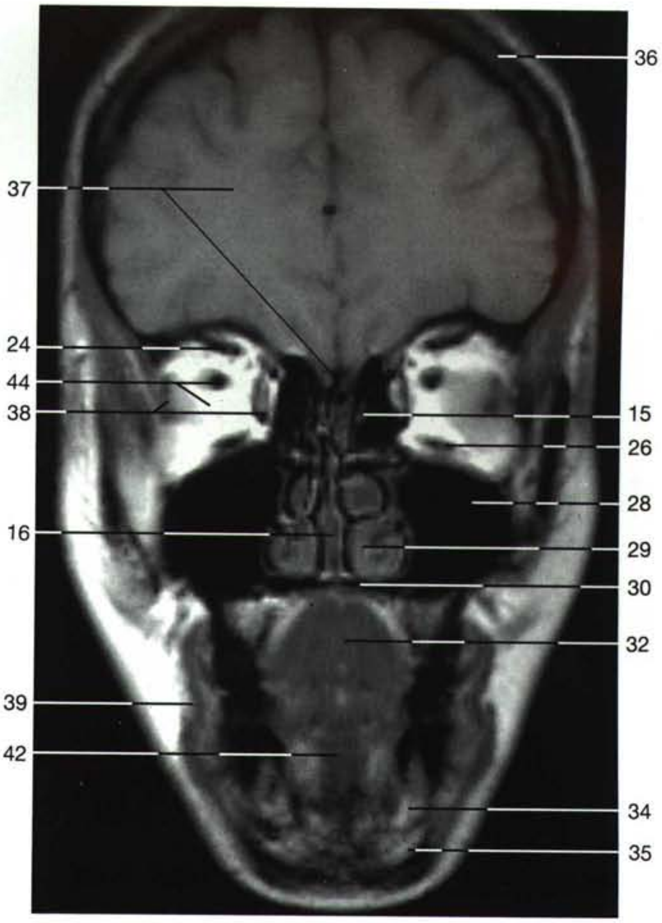
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Coronal section through the head (MR-Scan, courtesy of Dr. A. Heuck, Munich). Note the situation of the head cavities.

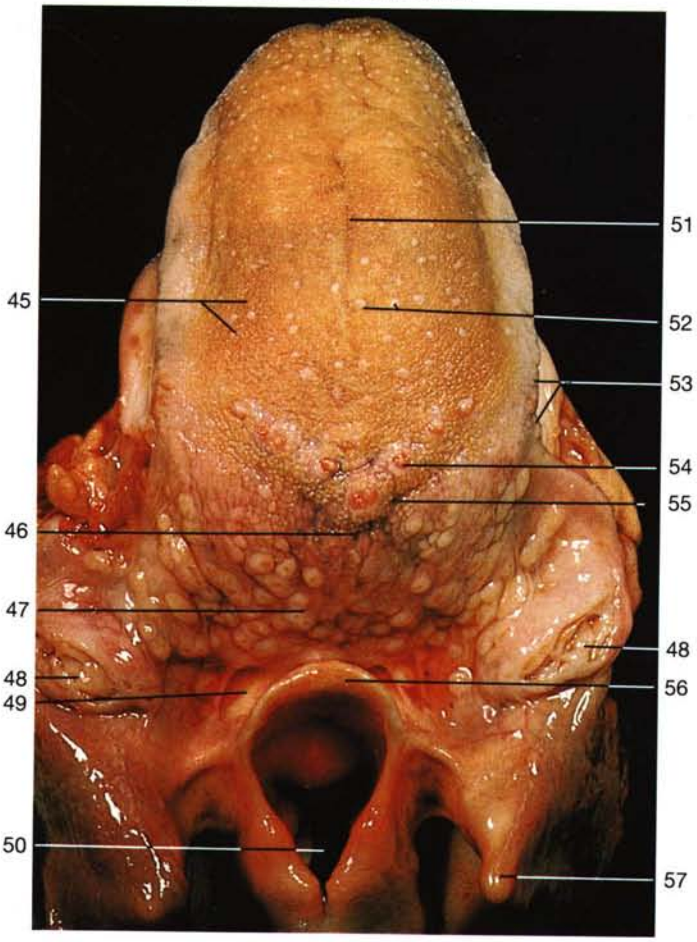
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33	Inferior longitudinal muscle of tongue
34	**Sublingual gland**
35	Mandible
36	Calvaria
37	Frontal lobe of brain and crista galli
38	Lateral and medial eye rectus muscles
39	Buccinator muscle
40	Vertical and transverse muscles of tongue
41	Second premolar of mandible
42	Genioglossus muscle
43	Platysma muscle
44	**Orbit** and **optic nerve**
45	Filiform papillae
46	**Foramen cecum**
47	**Root of tongue** (lingual tonsil)
48	**Palatine tonsil**
49	Vallecula of epiglottis
50	Vestibule of larynx
51	Median sulcus of tongue
52	Fungiform papillae
53	Foliate papillae
54	**Circumvallate papilla**
55	Sulcus terminalis
56	Epiglottis
57	Greater cornu of hyoid bone

Dorsal surface of the tongue and laryngeal inlet.

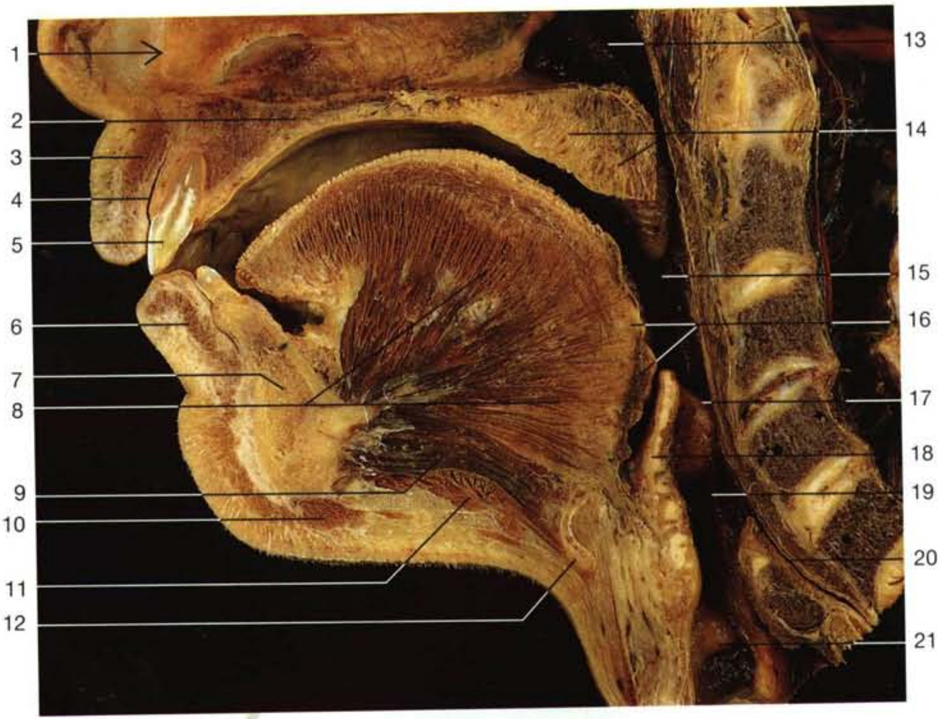

1 Nasal cavity
2 **Hard palate**
3 Upper lip and orbicularis oris muscle
4 Vestibule of oral cavity
5 First incisor
6 Lower lip and orbicularis oris muscle
7 Mandible
8 Genioglossus muscle
9 Geniohyoid muscle
10 Anterior belly of diagastric muscle
11 Mylohyoid muscle
12 **Hyoid bone**
13 **Nasopharynx**
14 **Soft palate** and **uvula**
15 **Oropharynx**
16 Root of tongue and lingual tonsil
17 **Laryngopharynx**
18 Epiglottis
19 Aryepiglottic fold
20 Laryngopharynx continuous with esophagus
21 Larynx

Median sagittal section through the oral cavity and pharynx.

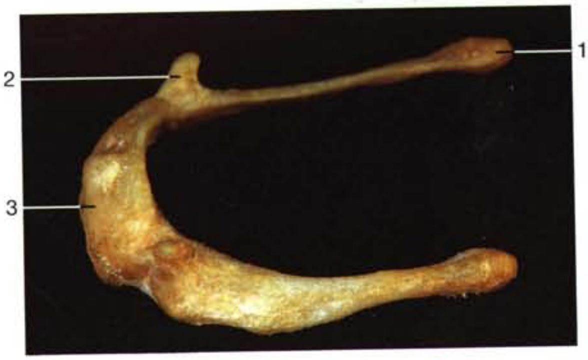

Hyoid bone (oblique lateral aspect).

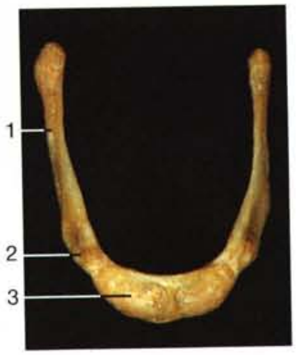

Hyoid bone (anterior aspect).

1 Greater cornu } of hyoid bone
2 Lesser cornu } of hyoid bone
3 Body } of hyoid bone

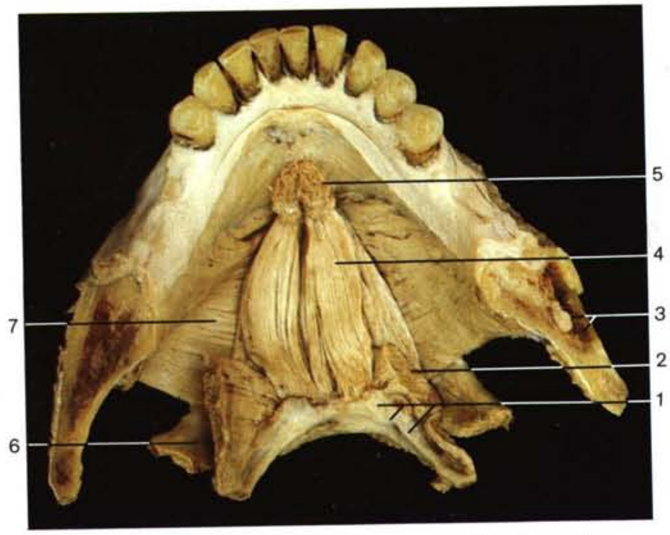

Muscles of the floor of the oral cavity (superior aspect).

1 Lesser cornu and body of hyoid bone
2 Hyoglossus muscle (divided)
3 Ramus of mandible and inferior alveolar nerve
4 **Geniohyoid muscle**
5 Genioglossus muscle (divided)
6 Stylohyoid muscle (divided)

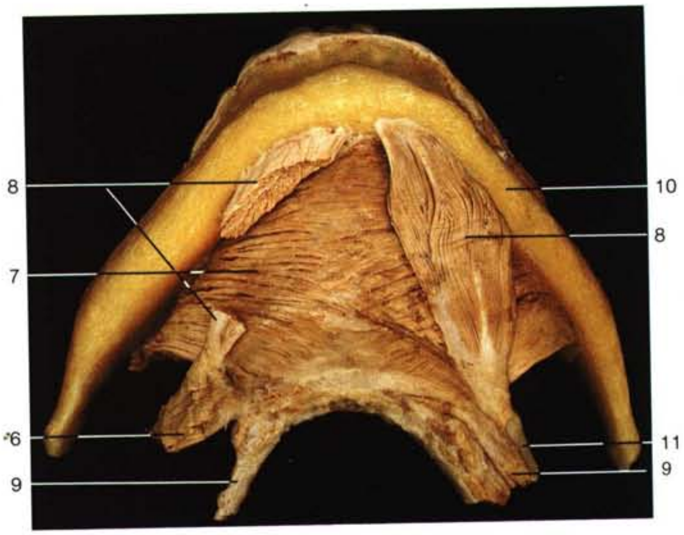

Oral diaphragm, muscles (inferior aspect). Cut on the base.

7 **Mylohyoid muscle**
8 Anterior belly of **digastric muscle**
9 Hyoid bone
10 Mandible
11 Intermediate tendon of digastric muscle

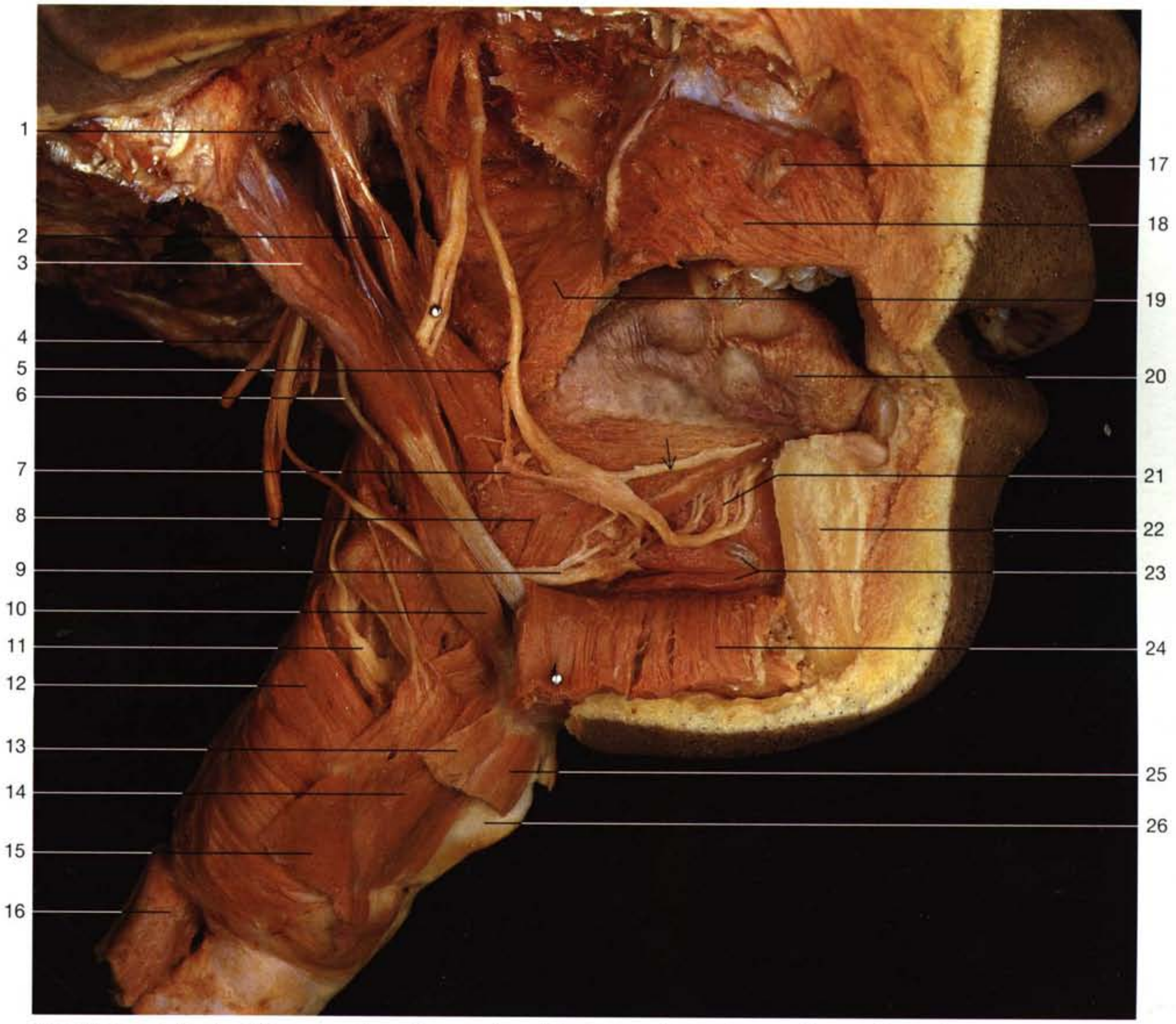

Parapharyngeal and sublingual regions. Innervation of the tongue. Lateral part of face and mandible removed, oral cavity opened. Arrow: submandibular duct.

1 Styloid process
2 Styloglossus muscle
3 Digastric muscle (posterior belly)

4 Vagus nerve (n. X)
5 **Lingual nerve** (n. V_3)
6 **Glossopharyngeal nerve** (n. IX)

7 Submandibular ganglion
8 Hyoglossus muscle
9 **Hypoglossal nerve** (n. XII)
10 Stylohyoid muscle
11 Internal branch of superior laryngeal nerve (branch of vagus nerve, not visible)
12 Middle constrictor muscle of pharynx
13 Omohyoid muscle (divided)
14 Thyrohyoid muscle
15 Sternothyroid muscle
16 Esophagus
17 Parotid duct (divided)
18 Buccinator
19 Superior constrictor muscle of pharynx
20 Tongue
21 Terminal branches of lingual nerve
22 Mandible (divided)
23 Genioglossus and geniohyoid muscles
24 Mylohyoid muscle (divided and reflected)
25 Sternohyoid muscle (divided)
26 Thyroid cartilage
27 Anterior belly of digastric muscle
28 Hyoid bone

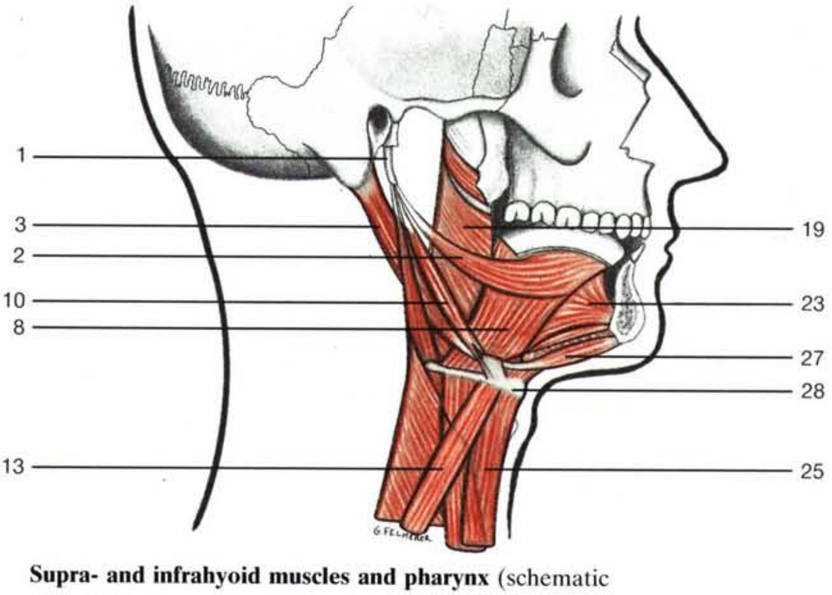

Supra- and infrahyoid muscles and pharynx (schematic drawing).

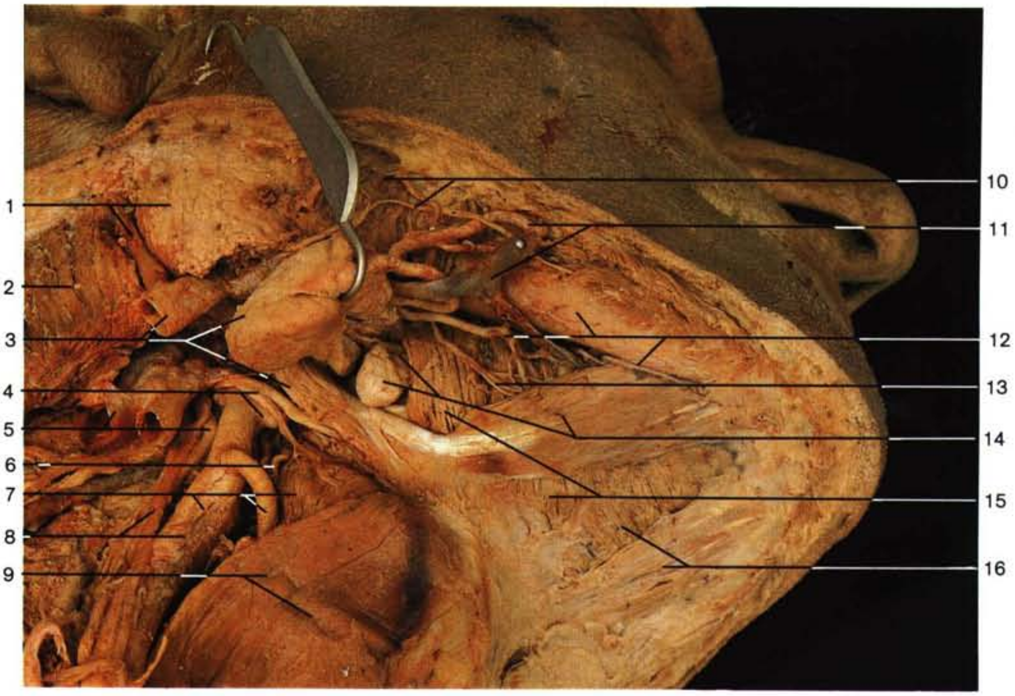

Submandibular triangle, superficial dissection. Right side (inferior aspect). Submandibular gland has been reflected.

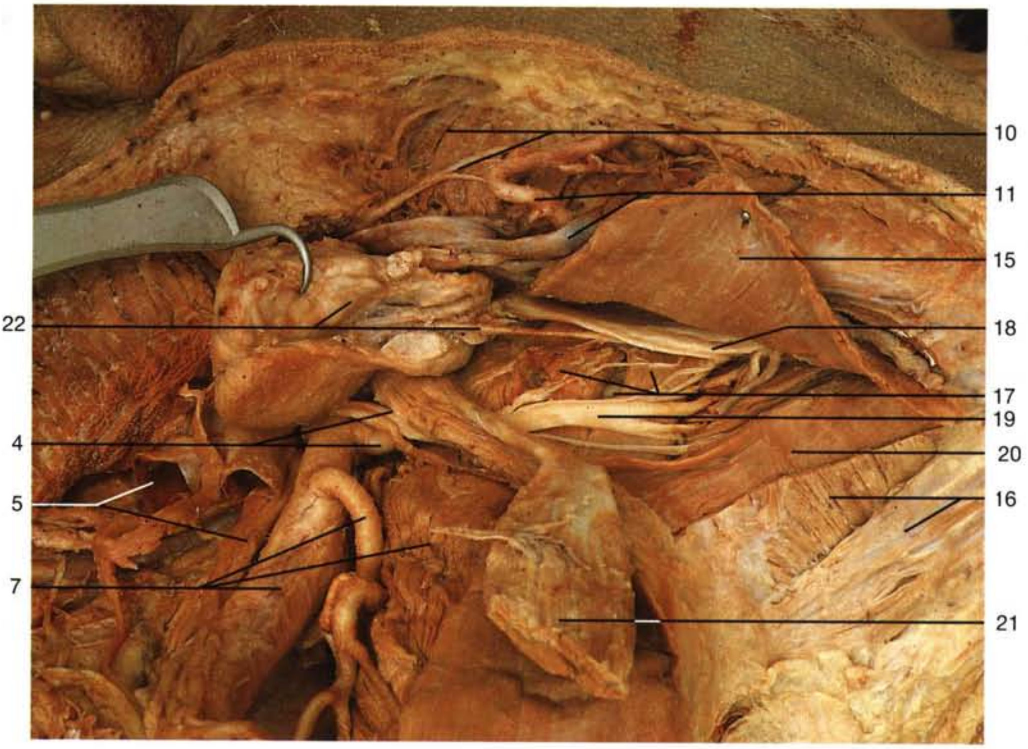

Submandibular triangle, deep dissection. Right side. Mylohyoid muscle has been severed and reflected to display the lingual and hypoglossal nerves.

1 Parotid gland and retromandibular vein
2 Sternocleidomastoid
3 Retromandibular vein, submandibular gland and stylohyoid muscle
4 Hypoglossal nerve and lingual artery
5 Vagus nerve and internal jugular vein
6 Superior laryngeal artery
7 **External carotid artery,** thyrohyoid muscle, and superior thyroid artery
8 Common carotid artery and superior root of ansa cervicalis
9 Omohyoid and sternohyoid
10 Masseter and marginal mandibular branch of facial nerve
11 **Facial artery and vein**
12 Mandible and submental artery and vein
13 Mylohyoid nerve
14 Submandibular duct, sublingual gland, and anterior belly of digastric muscle
15 Mylohyoid (right side)
16 Left mylohyoid and anterior belly of left digastric muscle
17 Hyoglossus muscle and lingual artery
18 **Lingual nerve**
19 **Hypoglossal nerve**
20 Geniohyoid muscle
21 Anterior belly of right digastric muscle
22 Submandibular gland and duct

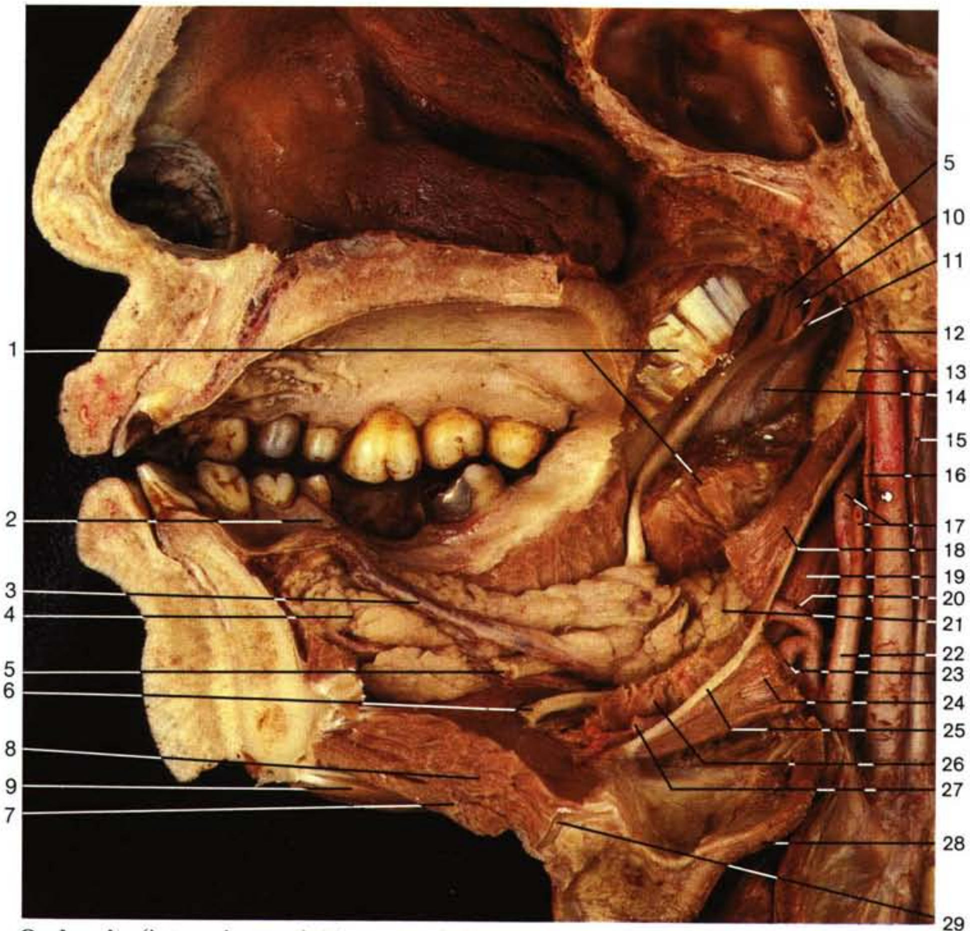

Oral cavity (internal aspect). Tongue and pharyngeal wall removed.

1 Medial pterygoid muscle
2 Sublingual papilla
3 **Submandibular duct**
4 **Sublingual gland**
5 **Lingual nerve**
6 Hypoglossal nerve
7 Mylohyoid muscle
8 Geniohyoid muscle
9 Anterior belly of digastric muscle
10 Inferior alveolar nerve
11 **Chorda tympani**
12 Internal carotid artery
13 Parotid gland
14 Sphenomandibular ligament
15 Vagus nerve
16 Glossopharyngeal nerve
17 Superficial temporal artery and ascending pharyngeal artery
18 Styloglossus muscle
19 Posterior belly of digastric muscle
20 **Facial artery**
21 Submandibular gland
22 **External carotid artery**
23 Lingual artery
24 Middle pharyngeal constrictor muscle
25 **Stylohyoid ligament**
26 Hyoglossus muscle
27 Deep lingual artery
28 Epiglottis
29 Hyoid bone
30 Buccinator muscle
31 Tongue
32 Mandible (divided)
33 **Parotid duct**
34 Masseter muscle
35 Right and left sublingual papilla

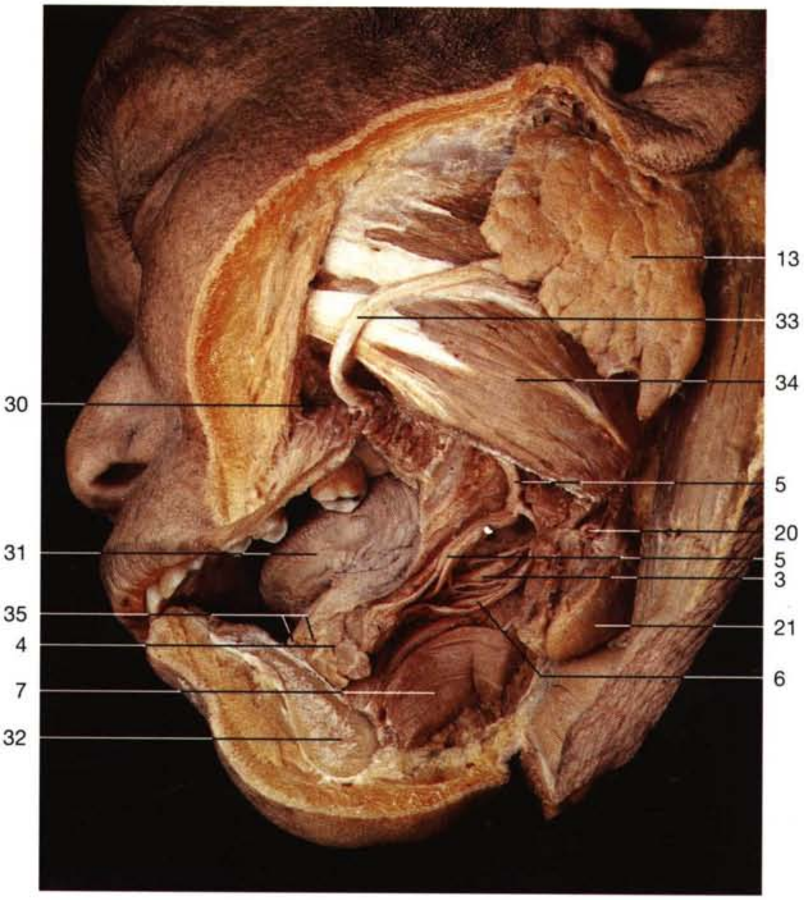

Dissection of major salivary glands. Left mandible and buccinator muscle partly removed to view the oral cavity (inferior lateral aspect).

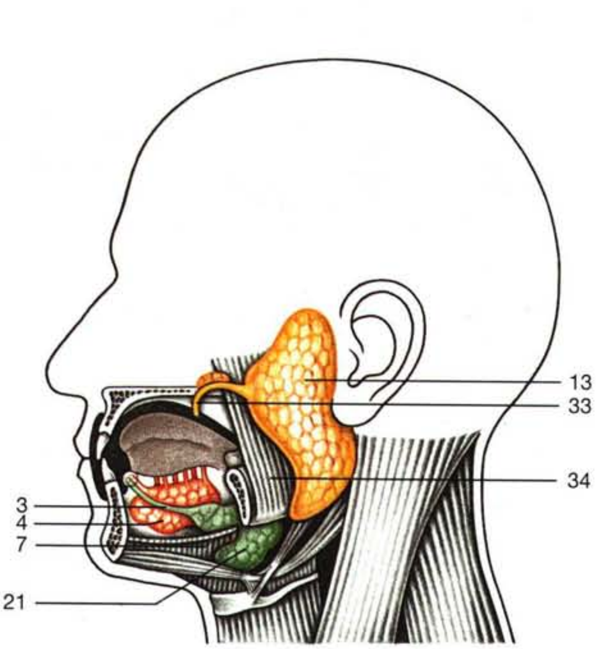

Location of the major salivary glands in relation to the oral cavity.

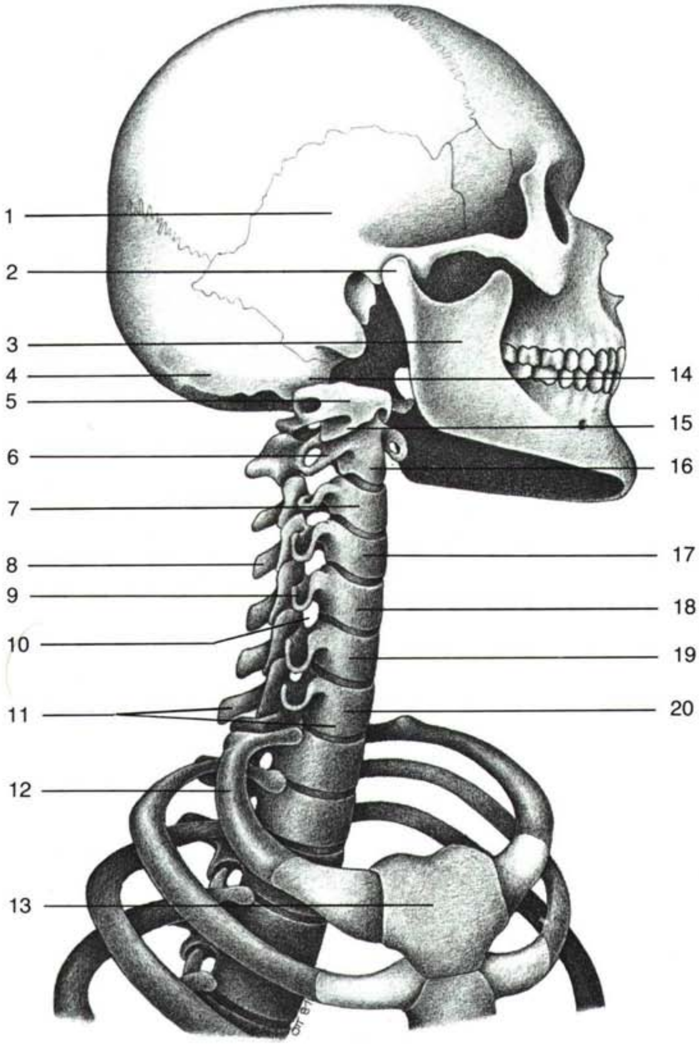

Cervical spine (oblique lateral aspect).

1 Temporal bone
2 Head of mandible
3 Mandible
4 Occipital bone
5 Atlas
6 Axis
7 Third cervical vertebra
8 Spinous process of fourth cervical vertrebra
9 Transverse process of fifth cervical vertebra with groove for spinal nerve
10 Intervertebral foramen
11 Vertebra prominens (C_7)
12 First rib
13 Sternum (manubrium sterni)
14 Atlantooccipital joint
15 Lateral atlantoaxial joint
16 Body of axis
17 Body of fourth cervical vertebra
18 Body of fifth cervical vertebra
19 Body of sixth cervical vertebra
20 Body of seventh cervical vertebra

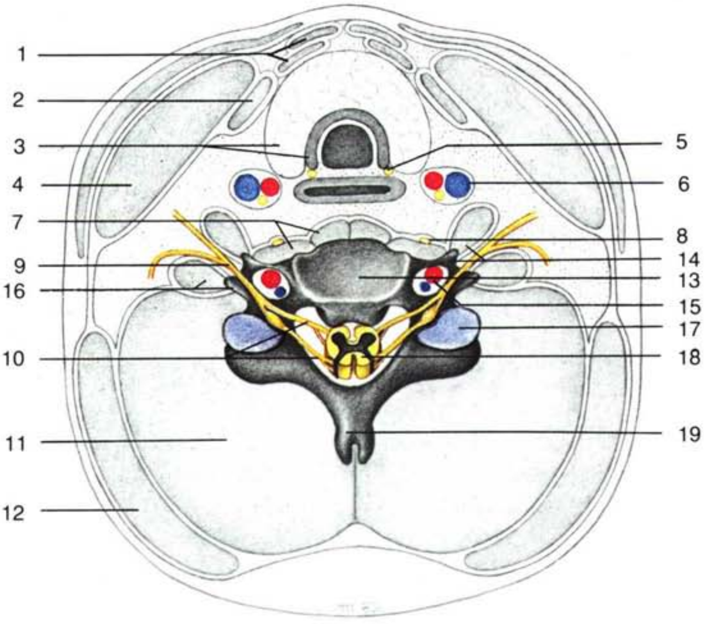

Cervical vertebra and the **organization of the neck.** (Schematic drawing.)

1 Sternohyoid and sternothyroid muscles
2 Omohyoid muscle
3 Thyroid gland and trachea
4 Sternocleidomastoid muscle
5 Recurrent laryngeal nerve
6 Internal jugular vein, common carotid artery and vagus
7 Longus colli and longus capitis muscles
8 Sympathetic trunk
9 Spinal nerve
10 Ventral and dorsal root of spinal nerve
11 True muscles of the neck
12 Trapezius muscle
13 Body of cervical vertebra
14 Anterior tubercle of transverse process and origin of scalenus anterior muscle
15 Vertebral artery and foramen transversarium
16 Posterior tubercle of transverse process and origin of scalenus medius and posterior muscles
17 Superior facet of articular process
18 Spinal cord
19 Spinous process

1	Nasal septum
2	Uvula
3	Genioglossus muscle
4	Mandible
5	Geniohyoid muscle
6	Mylohyoid muscle
7	**Hyoid bone**
8	Thyroid cartilage
9	Manubrium sterni
10	Sphenoidal sinus
11	**Nasopharynx**
12	**Oropharynx**
13	**Epiglottis**
14	**Laryngopharynx**
15	Arytenoid muscle
16	**Vocal fold**
17	Cricoid cartilage
18	**Trachea**
19	Left brachiocephalic vein
20	Thymus
21	Esophagus
22	Occipital lobe
23	Cerebellum and 4th ventricle
24	Medulla oblongata
25	Dens of axis
26	Intervertebral discs of cervical vertebral column

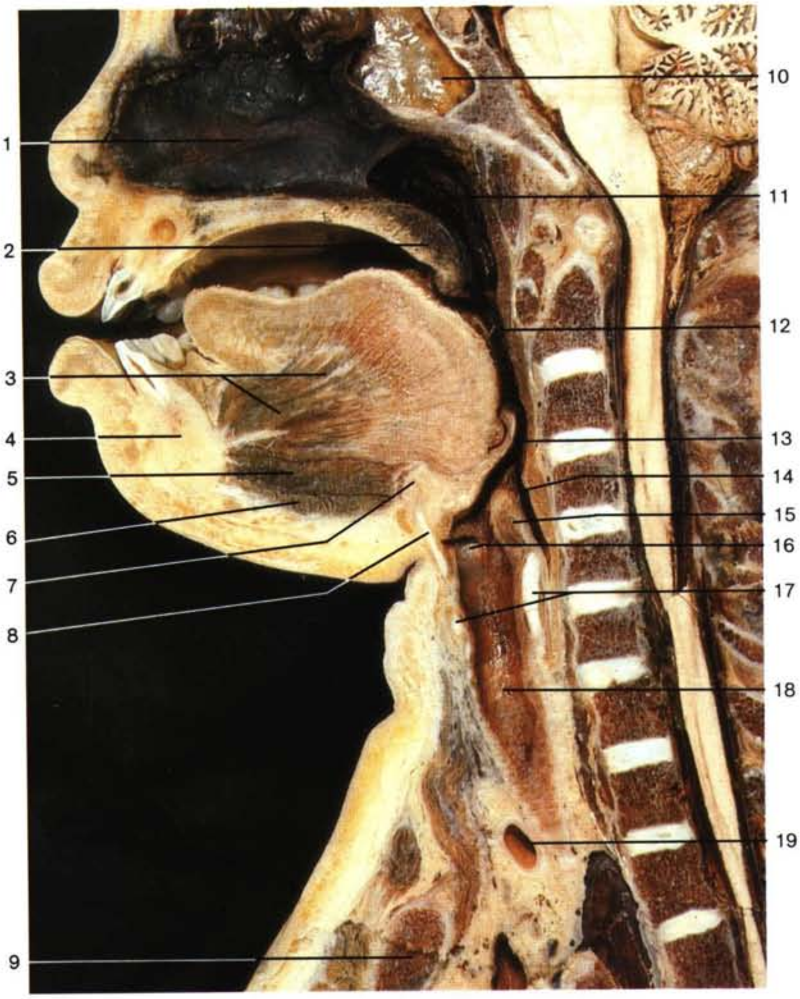

Median section through adult head and neck. Note the low position of the adult larynx when compared with that of the neonate (cf. with figure below).

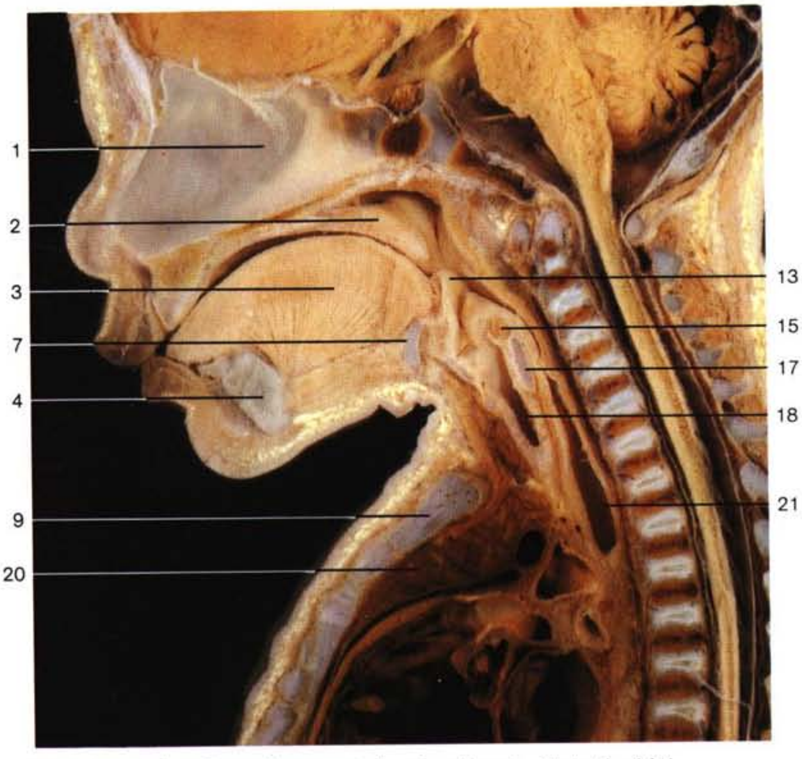

Median section through neonate head and neck. Note the high position of the larynx permitting the epiglottis nearly to reach the uvula (cf. with the figure above).

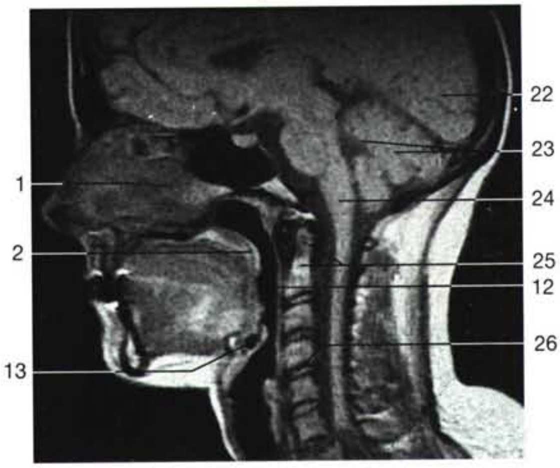

Sagittal section through the head. (MR-Scan.)

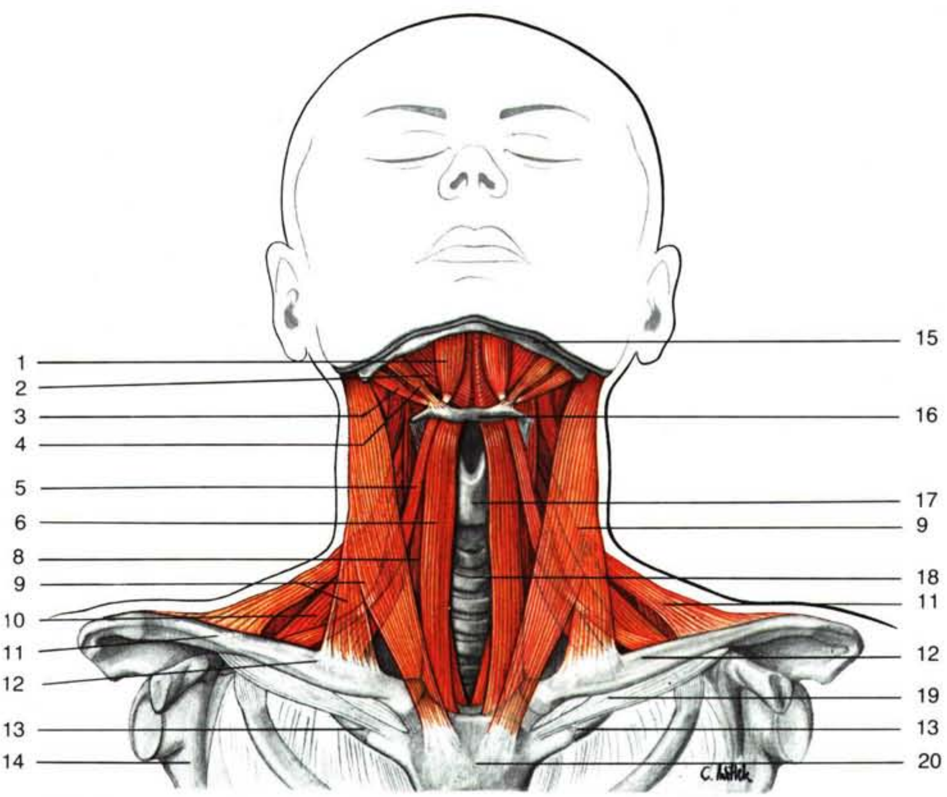

Muscles of the neck (anterior aspect).

Suprahyoid muscles

1 Anterior belly of digastric muscle
2 Mylohyoid muscle
3 Posterior belly of digastric muscle
4 Stylohyoid muscle

Infrahyoid muscles

5 Omohyoid muscle
6 Sternohyoid muscle
7 Thyrohyoid muscle
8 Sternothyroid muscle

Other structures

9 Sternocleidomastoid muscle
10 Scalenus muscles
11 Trapezius muscle
12 Clavicle
13 First rib
14 Scapula
15 Mandible
16 Hyoid bone
17 Larynx (thyroid cartilage)
18 Trachea
19 Subclavius muscle
20 Manubrium sterni
21 Mucous membrane of larynx (conus elasticus)
22 Cricoid cartilage
23 Inferior horn of thyroid cartilage
24 Esophagus
25 Body of cervical vertebra
26 Posterior root ganglion
27 Spinal cord
28 Spinous process
29 Internal jugular vein, common carotid artery, and vagus nerve
30 True muscles of the neck (semispinalis cervicis and capitis muscles)

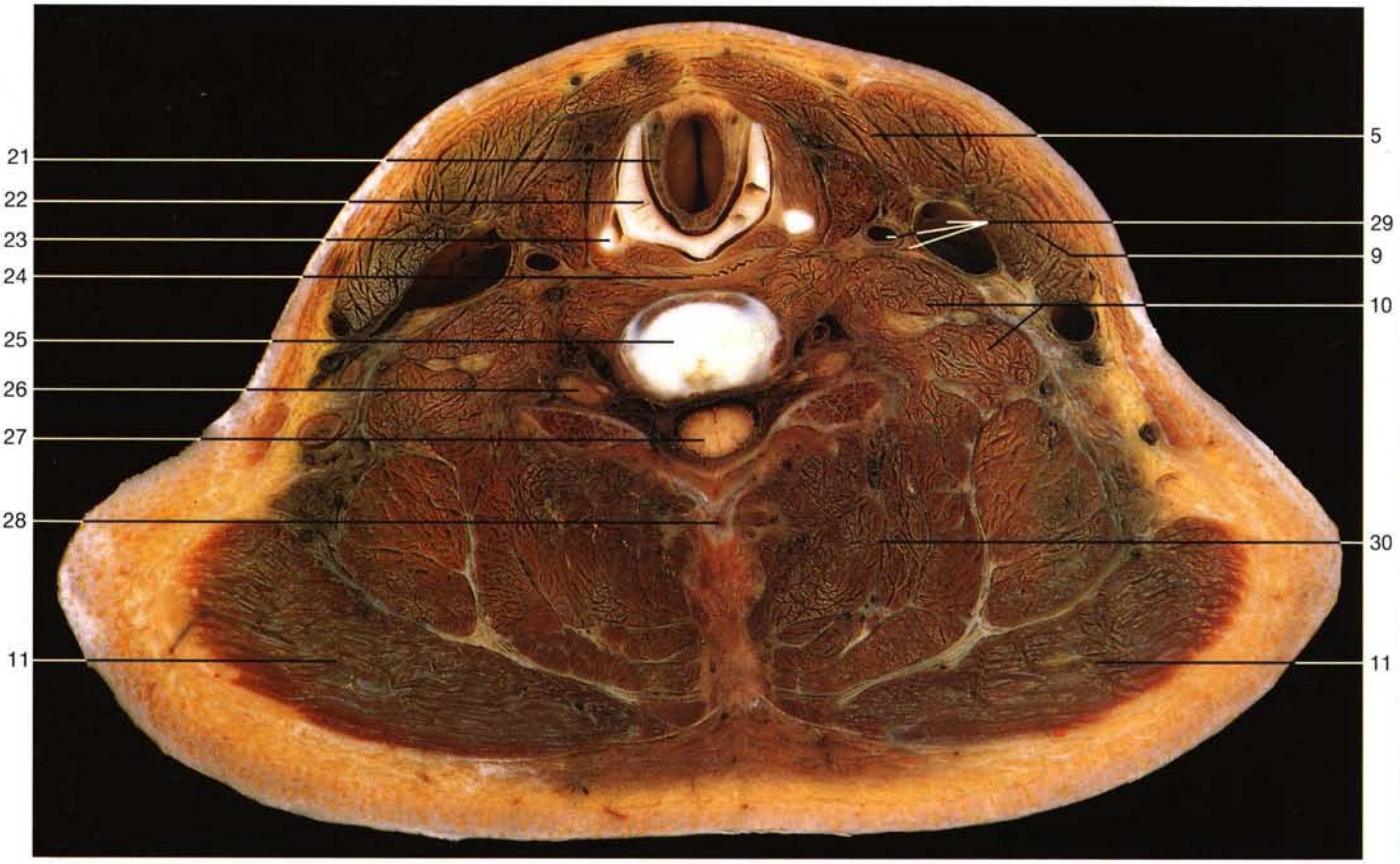

Cross-section of the neck at the level of the intervertebral disc between the 5th and 6th cervical vertebra (inferior aspect).

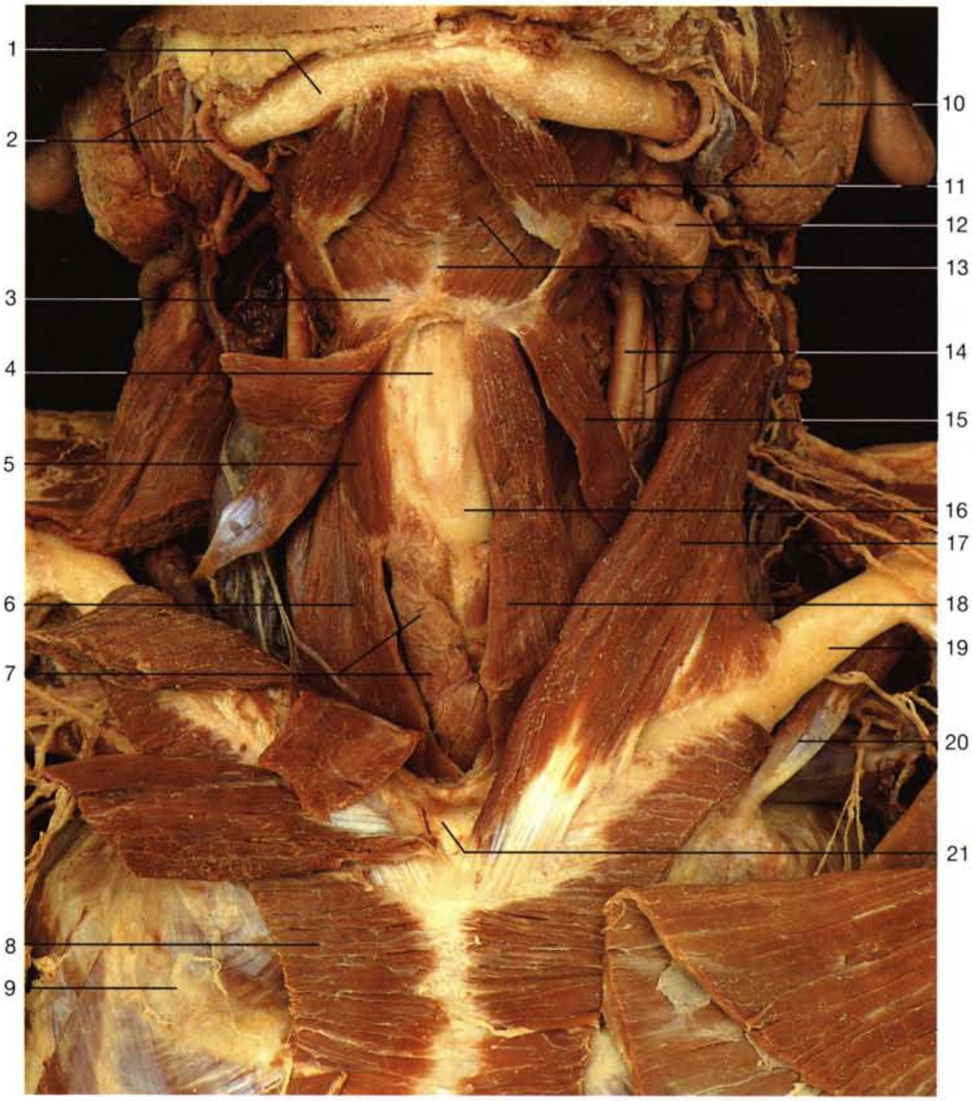

1 Mandible
2 Masseter muscle and facial artery
3 **Hyoid bone**
4 Median thyrohyoid ligament
5 **Thyrohyoid muscle**
6 **Sternothyroid muscle**
7 Thyroid gland (pyramidal lobe)
8 Pectoralis major muscle
9 Second rib
10 Parotid gland
11 Anterior belly of **digastric muscle**
12 Submandibular gland (divided)
13 **Mylohyoid muscle** and mylohyoid raphe
14 External carotid artery and vagus nerve
15 **Omohyoid muscle**
16 Thyroid cartilage
17 Sternocleidomastoid muscle
18 **Sternohyoid muscle**
19 Clavicle
20 Subclavius
21 Jugular fossa or suprasternal notch

Muscles of the neck (anterior aspect). Sternocleidomastoid and sternohyoid muscles on the right have been divided and reflected.

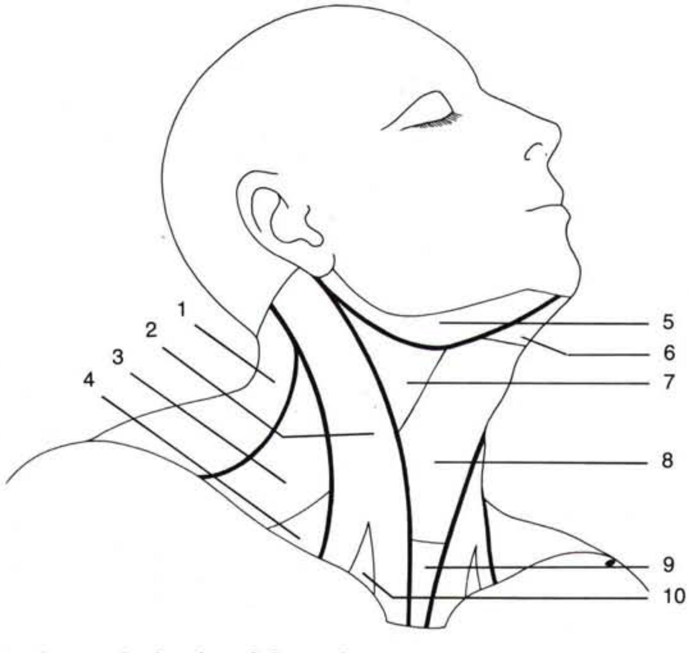

Regions and triangles of the neck.

1 Trapezius
2 Sternocleidomastoid
3 Occipital triangle
4 Supraclavicular triangle } **Posterior triangle**
5 Submandibular triangle
6 Submental triangle
7 Carotid triangle } **Anterior triangle**
8 Muscular triangle
9 Jugular fossa
10 Lesser supraclavicular fossa

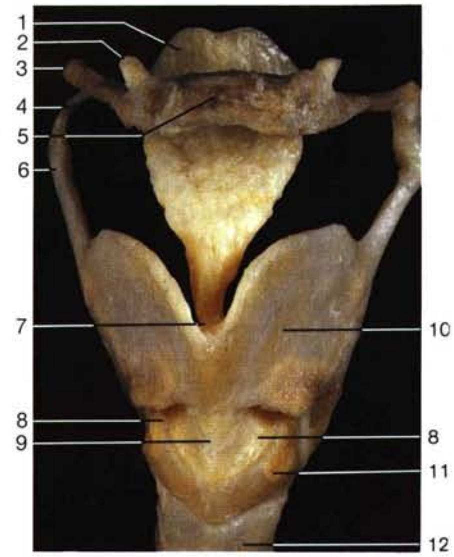

Cartilages of the larynx and the hyoid bone (anterior aspect).

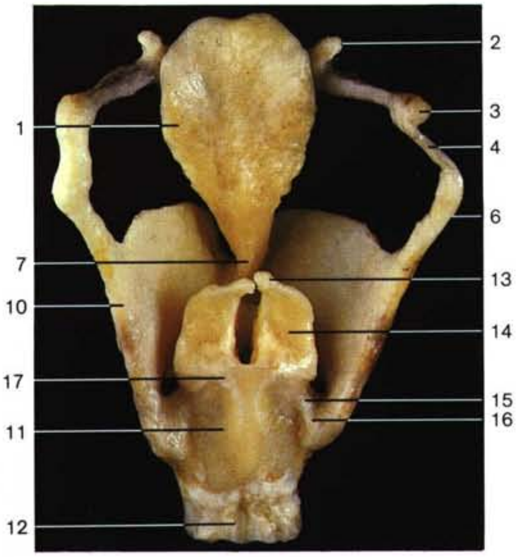

Cartilages of the larynx and the hyoid bone (posterior aspect).

1 **Epiglottis**
2 Lesser cornu of hyoid bone
3 Greater cornu of hyoid bone
4 Lateral thyrohyoid ligament
5 Body of **hyoid bone**
6 Superior cornu of thyroid cartilage
7 Thyroepiglottic ligament
8 Conus elasticus
9 Cricothyroid ligament
10 **Thyroid cartilage**
11 **Cricoid cartilage**
12 Trachea
13 Corniculate cartilage
14 **Arytenoid cartilage**
15 Posterior cricoarytenoid ligament
16 **Cricothyroid joint**
17 **Cricoarytenoid joint**

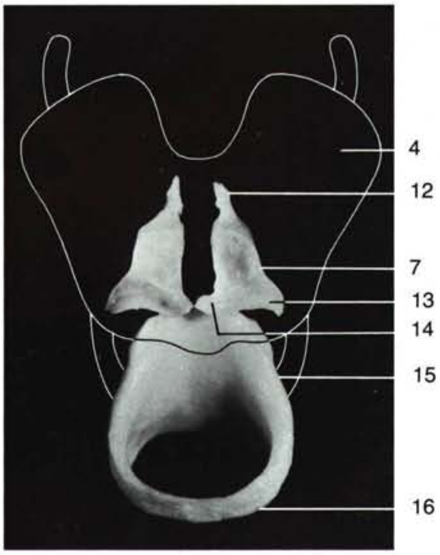

Cartilages of the larynx (anterior aspect). Thyroid cartilage is indicated by the outline.

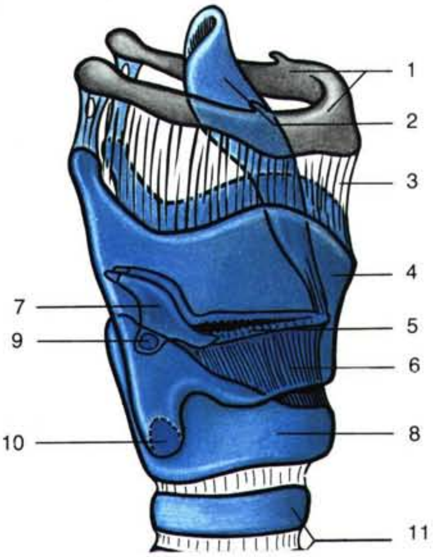

Cartilages and ligaments of the larynx (lateral aspect). (Schematic drawing.)

1 Hyoid bone
2 Epiglottis
3 Thyrohyoid membrane
4 **Thyroid cartilage**
5 **Vocal ligament**
6 Conus elasticus
7 Arytenoid cartilage
8 **Cricoid cartilage**
9 **Cricoarytenoid joint**
10 **Cricothyroid joint**
11 Tracheal cartilages
12 Corniculate cartilage
13 Muscular process of arytenoid cartilage
14 Vocal process of arytenoid cartilage
15 Lamina of cricoid cartilage
16 Arch of cricoid cartilage

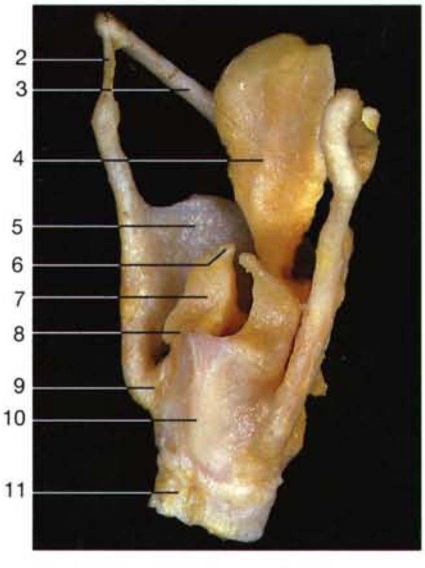

Cartilages of the larynx (oblique-posterior aspect).

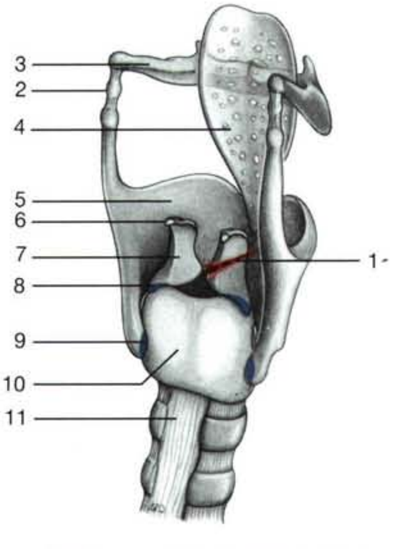

Cartilages of the larynx (oblique-posterior aspect).

1 **Vocal ligament** (red)
2 Lateral thyrohyoid ligament
3 Greater cornu of hyoid bone
4 **Epiglottis**
5 **Thyroid cartilage**
6 Corniculate cartilage
7 **Arytenoid cartilage**
8 **Cricoarytenoid joint**
9 **Cricothyroid joint**
10 **Cricoid cartilage**
11 Trachea

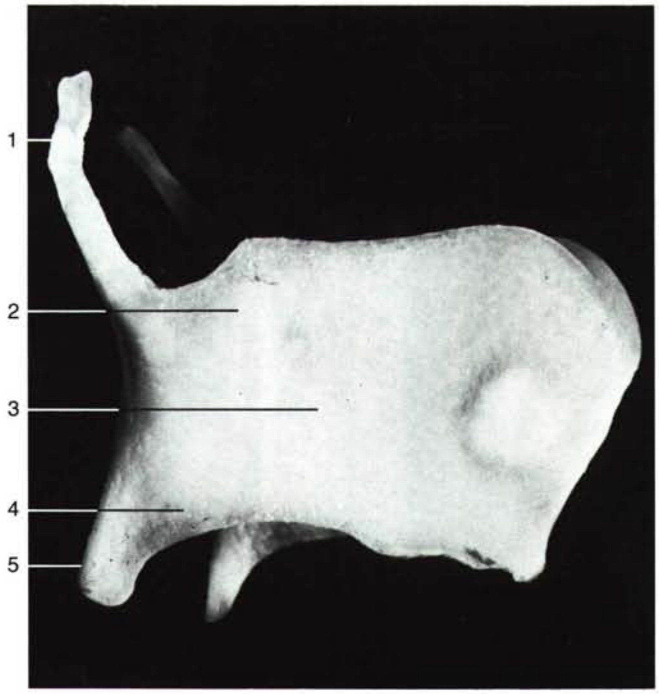

Thyroid cartilage (lateral aspect).

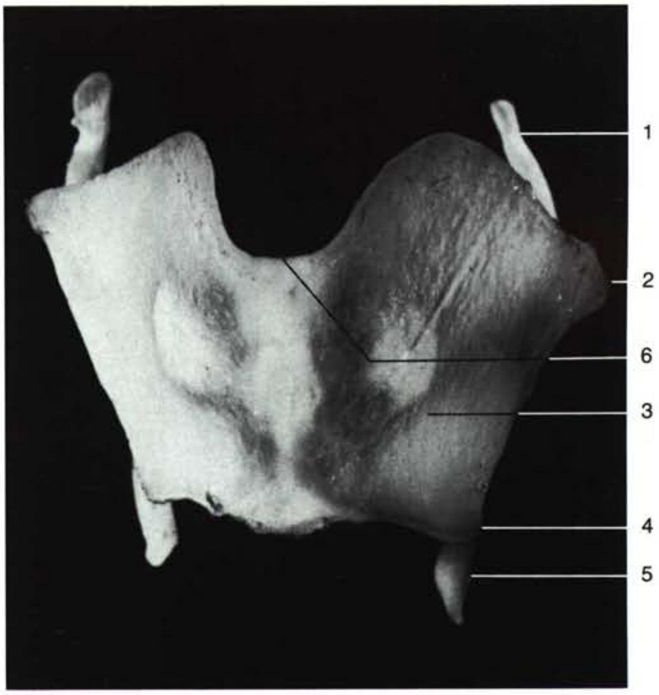

Thyroid cartilage (anterior aspect).

1 Superior cornu
2 Superior thyroid tubercle
3 Lamina of thyroid cartilage
4 Inferior thyroid tubercle
5 Inferior cornu
6 Superior thyroid notch

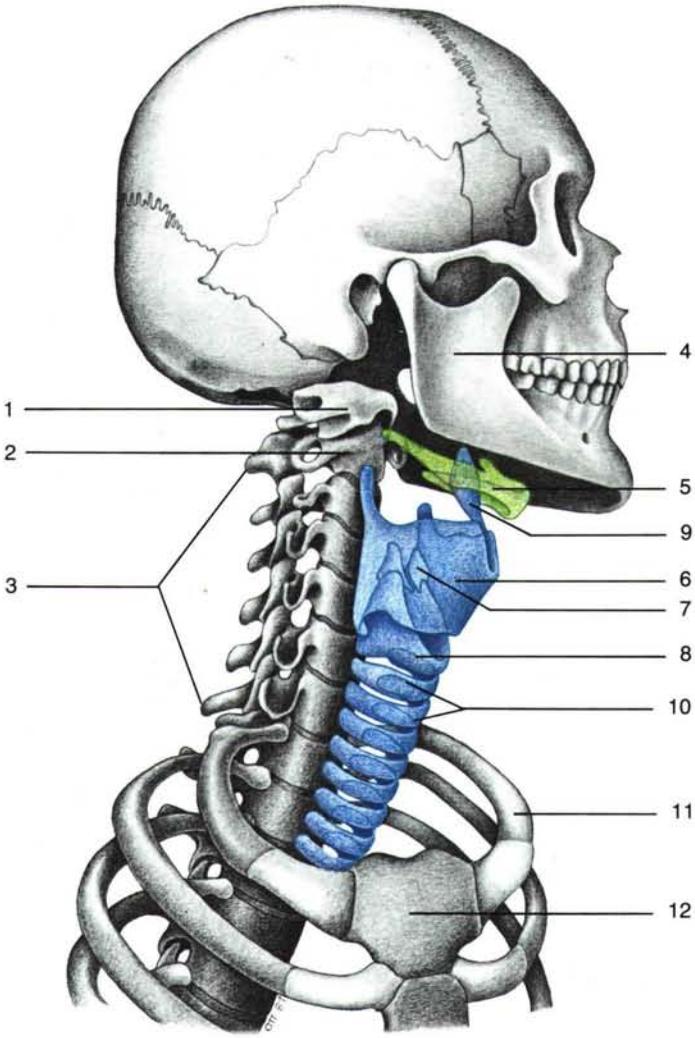

1 Atlas
2 Axis
3 Cervical vertebrae (C_2–C_7)
4 Mandible
5 **Hyoid bone**
6 **Thyroid cartilage**
7 Arytenoid cartilage
8 **Cricoid cartilage**
9 Epiglottis
10 **Tracheal cartilages**
11 First rib
12 Manubrium sterni

Position of the larynx in the neck (oblique lateral aspect). (Schematic drawing.)

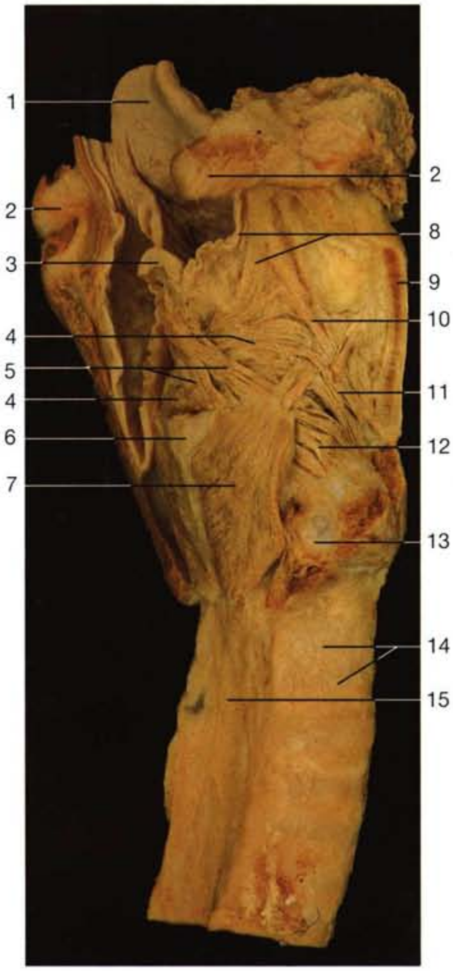

Laryngeal muscles I (lateral aspect). Thyroid cartilage and thyroarytenoid muscle have been partly removed.

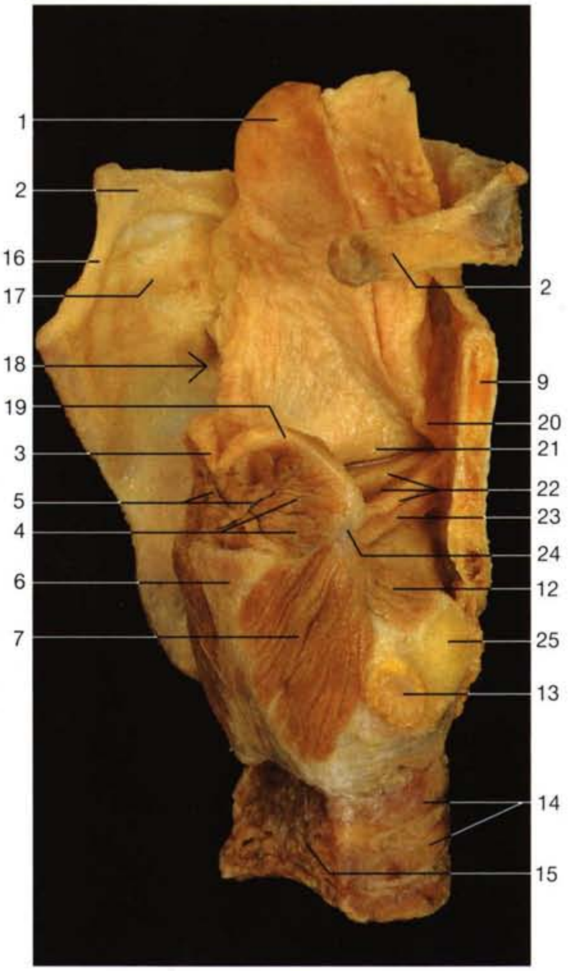

Laryngeal muscles II (lateral aspect). Half of the right side of the thyroid cartilage has been removed.

1 Epiglottis
2 Greater horn of hyoid bone
3 Corniculate cartilage
4 Transverse arytenoid muscle
5 Oblique arytenoid muscle
6 Lamina of cricoid cartilage
7 **Posterior cricoarytenoid muscle**
8 Aryepiglottic fold and muscle
9 Lamina of thyroid cartilage
10 Thyroepiglottic muscle
11 Thyroarytenoid muscle
12 **Lateral cricoarytenoid muscle**
13 Articular facet of thyroid cartilage
14 Cartilages of trachea
15 Membranous part of trachea
16 Lateral thyrohyoid ligament
17 Thyrohyoid membrane
18 Position of piriform recess
19 Arytenoid cartilage
20 Stem of epiglottis
21 Vestibular fold
22 Vocal folds and fissure of glottis
23 **Vocalis muscle**
24 Cricoarytenoid articulation
25 Arch of cricoid cartilage
26 Cricothyroid muscle
27 Cricoid cartilage
28 Piriform recess
29 Superior horn of thyroid cartilage
30 Vocal ligament

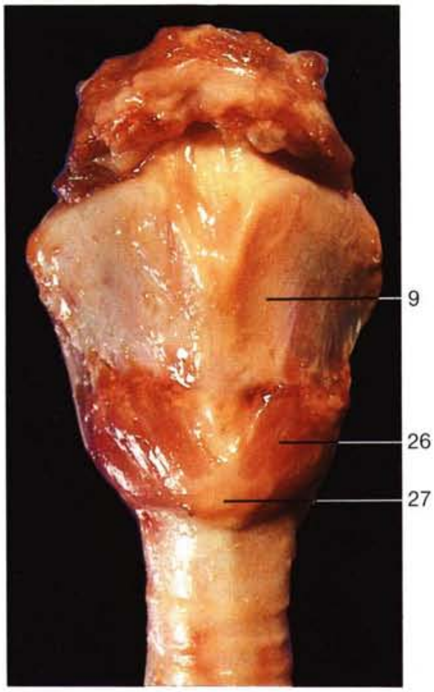

Laryngeal muscles, larynx (anterior aspect).

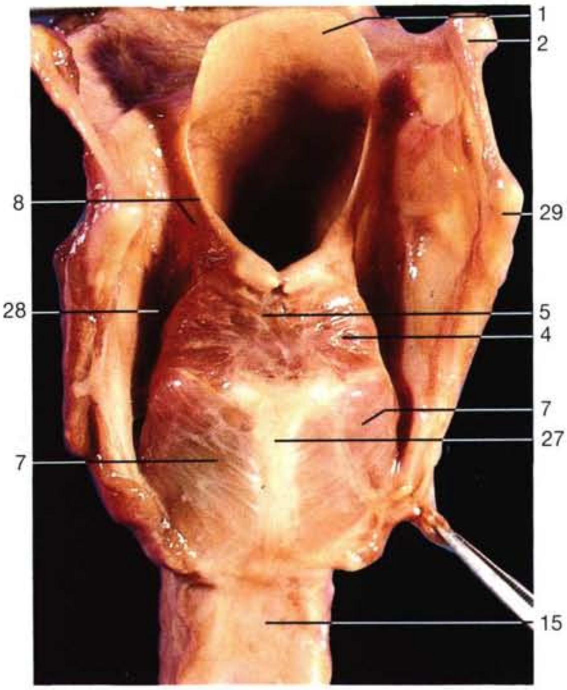

Laryngeal muscles, larynx (posterior aspect).

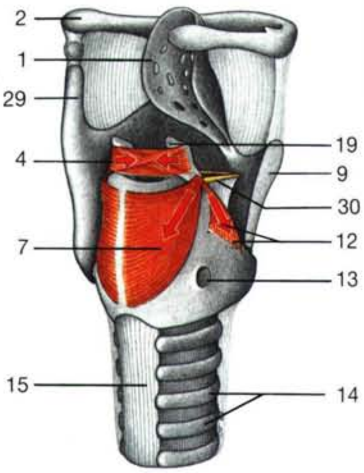

Action of internal muscles of the larynx. (Schematic drawing.)

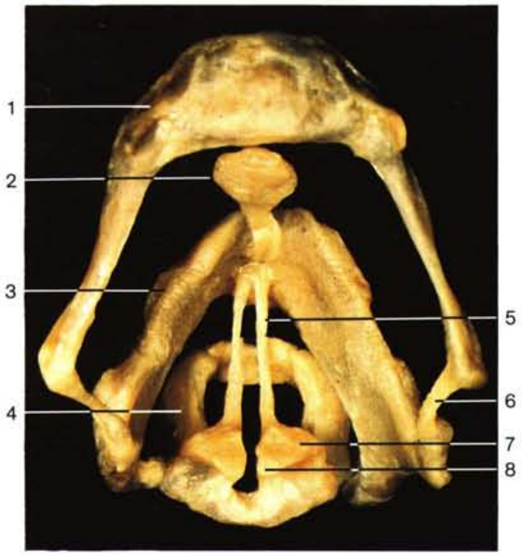

Laryngeal cartilages (superior aspect).

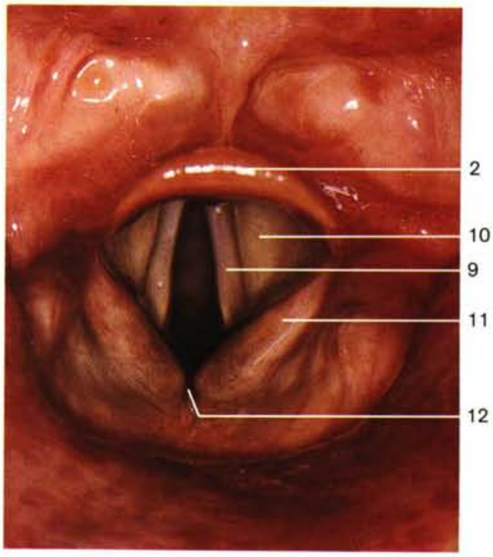

Glottis in vivo (superior aspect).

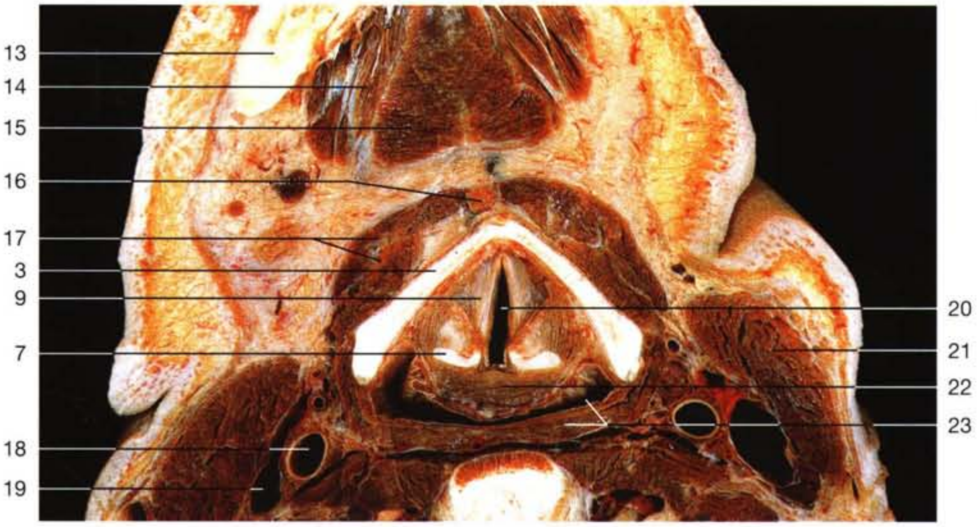

Horizontal section through the larynx at the level of the vocal folds (superior aspect).

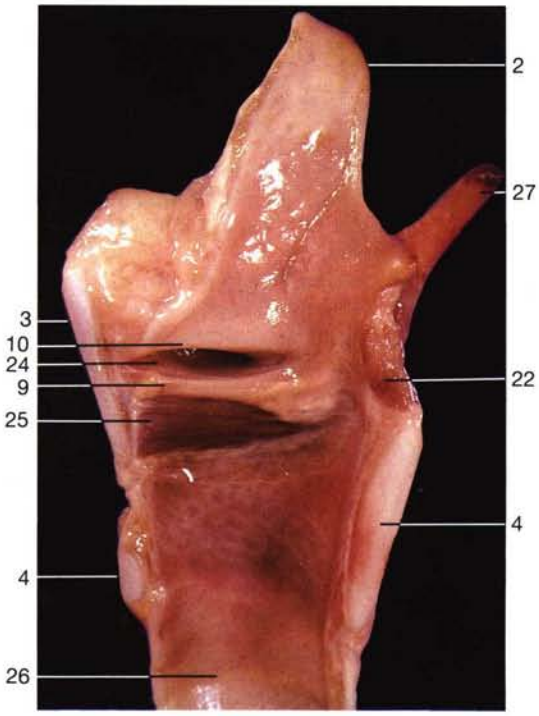

Sagittal section through the larynx.

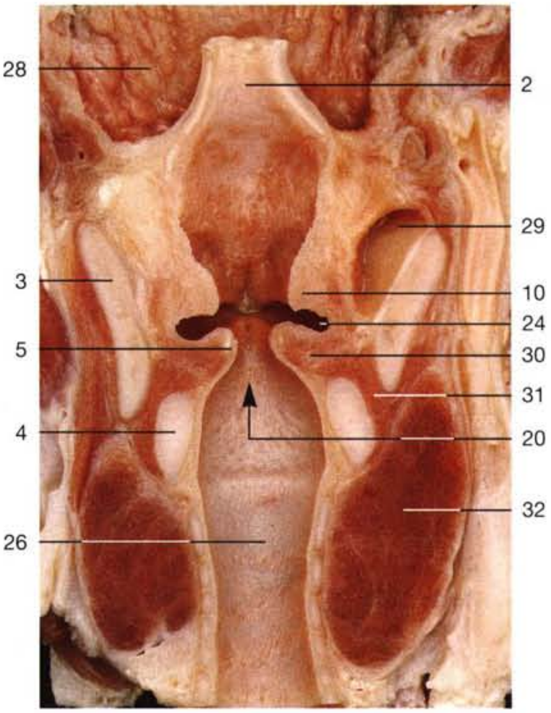

Coronal section through larynx and trachea.

1 **Hyoid bone**
2 Epiglottis
3 **Thyroid cartilage**
4 **Cricoid cartilage**
5 **Vocal ligament**
6 Thyrohyoid ligament
7 **Arytenoid cartilage**
8 Corniculate cartilage
9 **Vocal fold**
10 **Vestibular fold**
11 Aryepiglottic fold
12 Interarytenoid notch
13 Mandible
14 Anterior belly of digastric muscle
15 Mylohyoid muscle
16 Pyramidal process of thyroid gland
17 Sternohyoid and sternothyroid muscles
18 Common carotid artery
19 Internal jugular vein
20 **Rima glottidis**
21 Sternocleidomastoid muscle
22 Transverse arytenoid muscle
23 Pharynx and inferior constrictor muscle
24 Ventricle of larynx
25 **Vocalis muscle**
26 Trachea
27 Superior cornu of thyroid cartilage
28 Root of tongue (lingual tonsil)
29 Piriform recess
30 Vocalis muscle
31 Lateral cricoarytenoid muscle
32 **Thyroid gland**

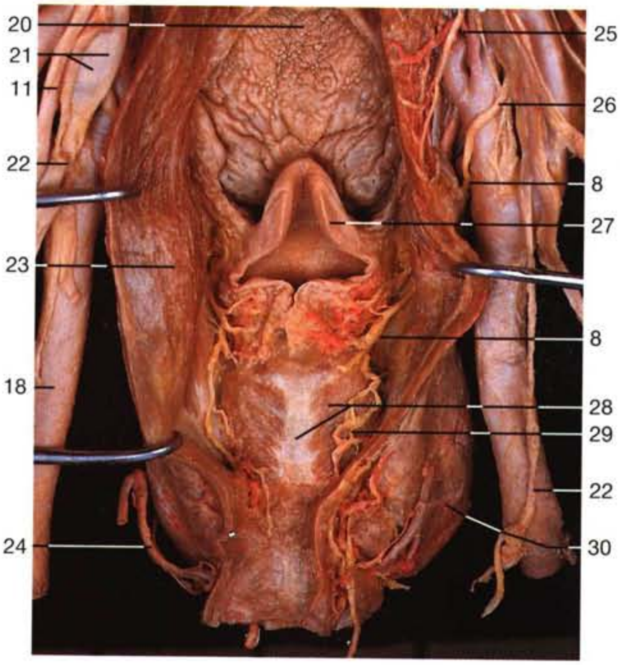

Larynx and its innervation (posterior aspect). Dissection of superior and inferior laryngeal nerves. Pharynx has been opened.

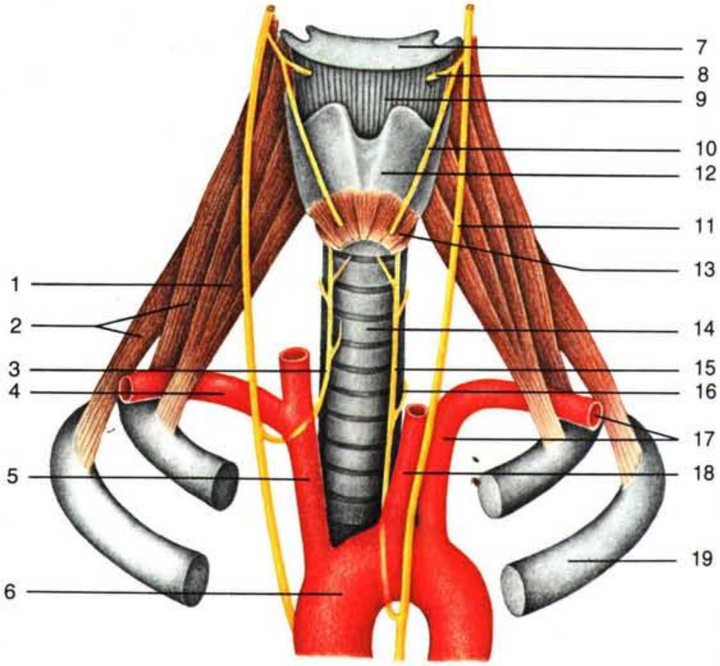

Innervation of the larynx. (Schematic diagram.)

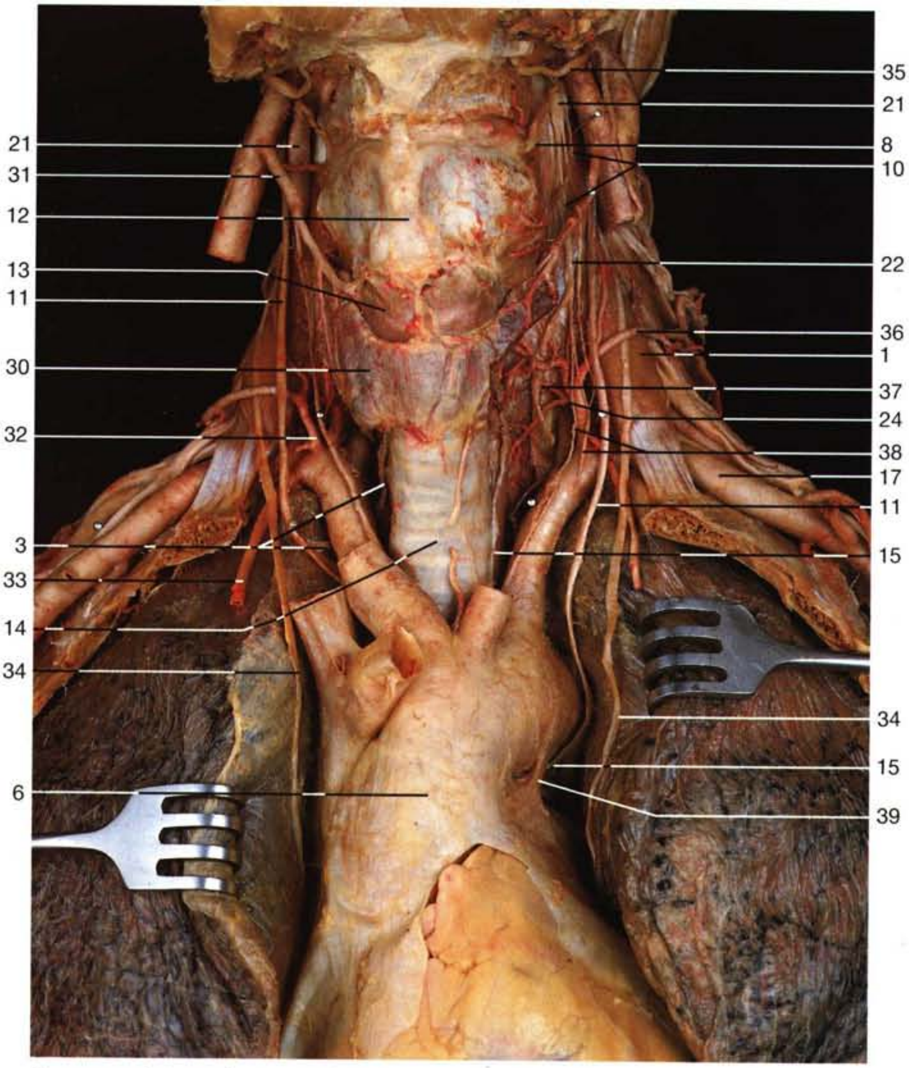

Larynx and thoracic organs (anterior aspect). Dissection of vagus and recurrent laryngeal nerves.

1 Scalenus anterior muscle
2 Scalenus medius and posterior muscles
3 Right **recurrent laryngeal nerve**
4 Right subclavian artery
5 Brachiocephalic trunk
6 Aortic arch
7 Hyoid bone
8 **Internal branch of superior laryngeal nerve**
9 Thyrohyoid membrane
10 **External branch of superior laryngeal nerve**
11 **Vagus nerve**
12 Thyroid cartilage
13 Cricothyroid muscle
14 Trachea
15 **Left recurrent larnygeal nerve**
16 Esophagus
17 Left subclavian artery
18 Left common carotid artery
19 Second rib
20 Tongue
21 Superior cervical ganglion
22 Sympathetic trunk
23 Inferior constrictor muscle of pharynx
24 **Inferior thyroid artery**
25 Glossopharyngeal nerve
26 Superior laryngeal nerve
27 Epiglottis
28 Posterior cricoarytenoid muscle and cricoid cartilage
29 Inferior laryngeal branch of recurrent laryngeal nerve
30 **Thyroid gland**
31 Superior thyroid artery
32 **Thyrocervical trunk**
33 Internal thoracic artery
34 **Phrenic nerve**
35 Hypoglossal nerve
36 Transverse cervical artery
37 Middle cervical ganglion
38 Middle cervical cardiac nerves (branches of sympathetic trunk)
39 Ligamentum arteriosum

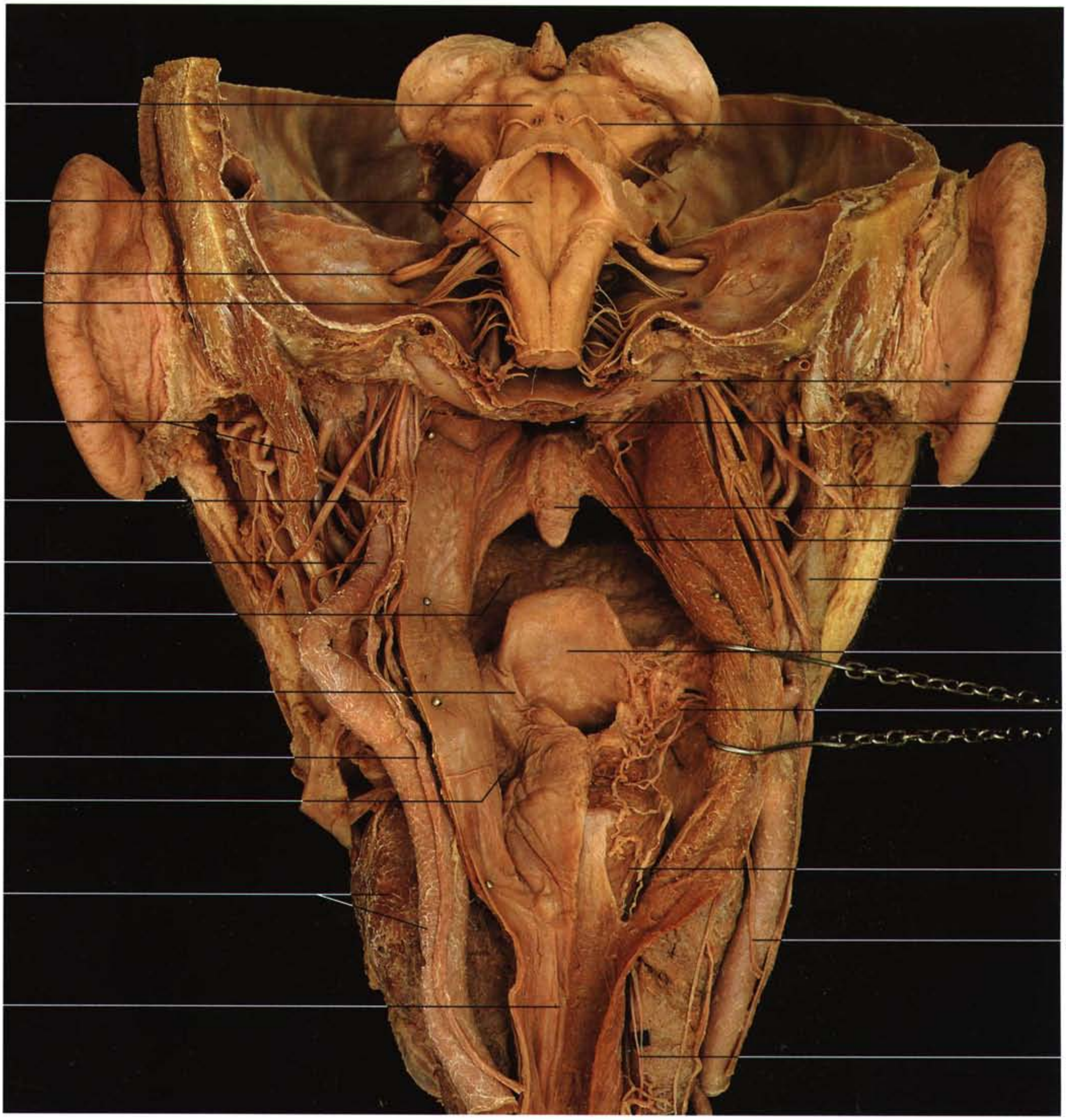

Larynx and oral cavity (posterior aspect). Mucous membrane on the right half of pharynx has been removed.

1 Midbrain (inferior colliculus)
2 Rhomboid fossa and medulla oblongata
3 Vestibulocochlear and facial nerve
4 Glossopharyngeal, vagus and accessory nerve
5 Occipital artery and posterior belly of digastric muscle
6 Superior cervical ganglion
7 **Internal carotid artery**
8 **Oral cavity** (tongue)
9 Aryepiglottic fold
10 Vagus nerve
11 **Piriform recess**
12 Thyroid gland and common carotid artery
13 Esophagus
14 Trochlear nerve
15 Occipital condyle
16 **Nasal cavity** (choana)
17 Accessory nerve
18 **Uvula** and soft palate
19 Palatopharyngeus muscle
20 External carotid artery
21 Epiglottis
22 **Internal branch of superior laryngeal nerve**
23 **Inferior laryngeal nerve**
24 Ansa cervicalis

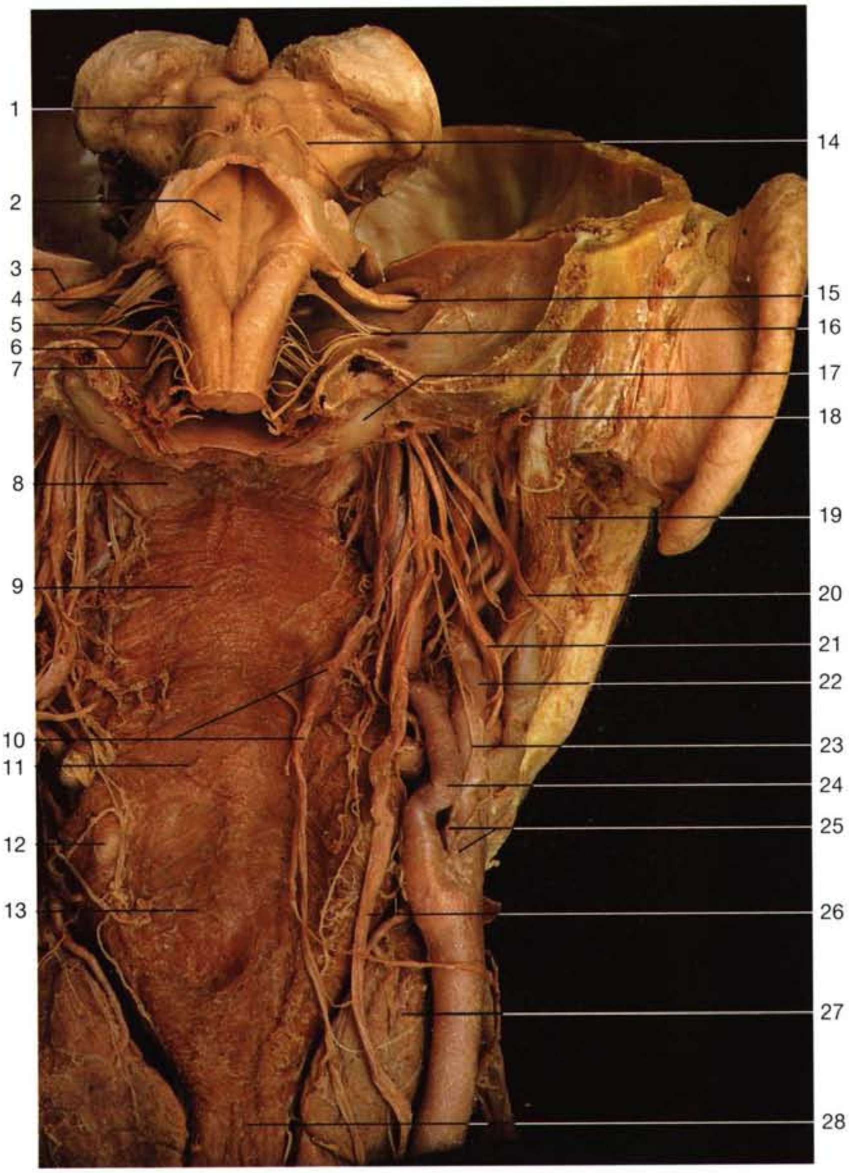

Pharynx and parapharyngeal nerves in connection with brain stem (posterior aspect).

1 Inferior colliculus of midbrain
2 Facial colliculus in **floor of rhomboid fossa**
3 Vestibulocochlear and facial nerves
4 Glossopharyngeal nerve
5 Vagus nerve
6 Accessory nerve
7 Hypoglossal nerve
8 Pharyngobasilar fascia
9 Superior constrictor muscle of pharynx
10 **Sympathetic trunk** and **superior cervical ganglion** (medially displaced)
11 Middle constrictor muscle of pharynx
12 Greater cornu of hyoid bone
13 Inferior constrictor muscle of pharynx
14 Trochlear nerve
15 **Internal acoustic meatus** with facial and vestibulocochlear nerves
16 **Jugular foramen** with glossopharyngeal, vagus and assessory nerves
17 Occipital condyle
18 Occipital artery
19 Posterior belly of digastric muscle
20 **Accessory nerve** (extracranial part)
21 **Hypoglossal nerve** (extracranial part)
22 External carotid artery
23 Carotid sinus nerve
24 **Internal carotid artery**
25 **Carotid sinus and carotid body**
26 Vagus nerve
27 Thyroid gland
28 Esophagus
29 Choanae
30 Medial pterygoid plate
31 Foramen lacerum
32 **Pharyngeal tubercle**
33 Hard palate
34 Greater and lesser palatine foramen
35 Pterygoid hamulus
36 Lateral pterygoid plate
37 Pterygoid canal
38 Foramen ovale
39 Mandibular fossa
40 Carotid canal
41 Styloid process and stylomastoid foramen

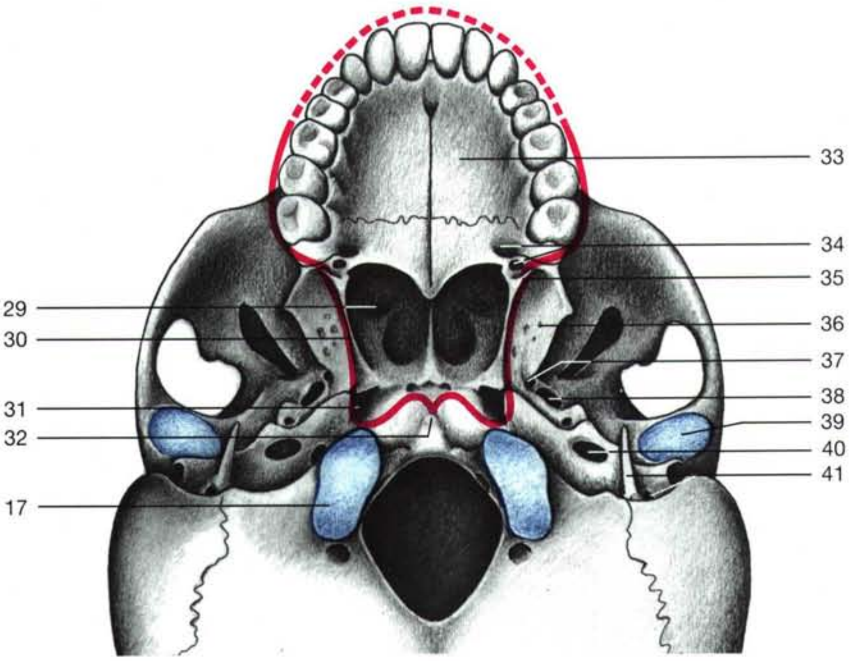

Inferior aspect of the skull. Red line = outline of superior constrictor muscle in continuation with buccinator muscle and orbicularis oris muscle. (Semischematic drawing.)

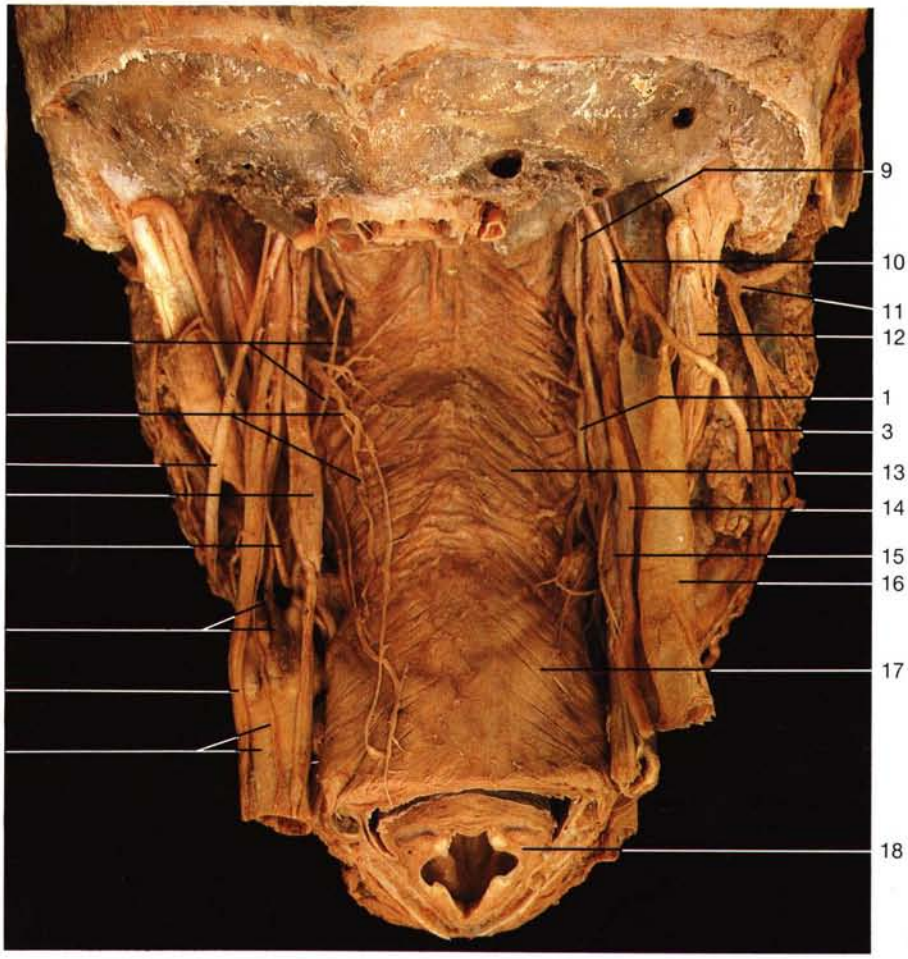

Parapharyngeal nerves and vessels. Dorsal aspect of the pharynx.

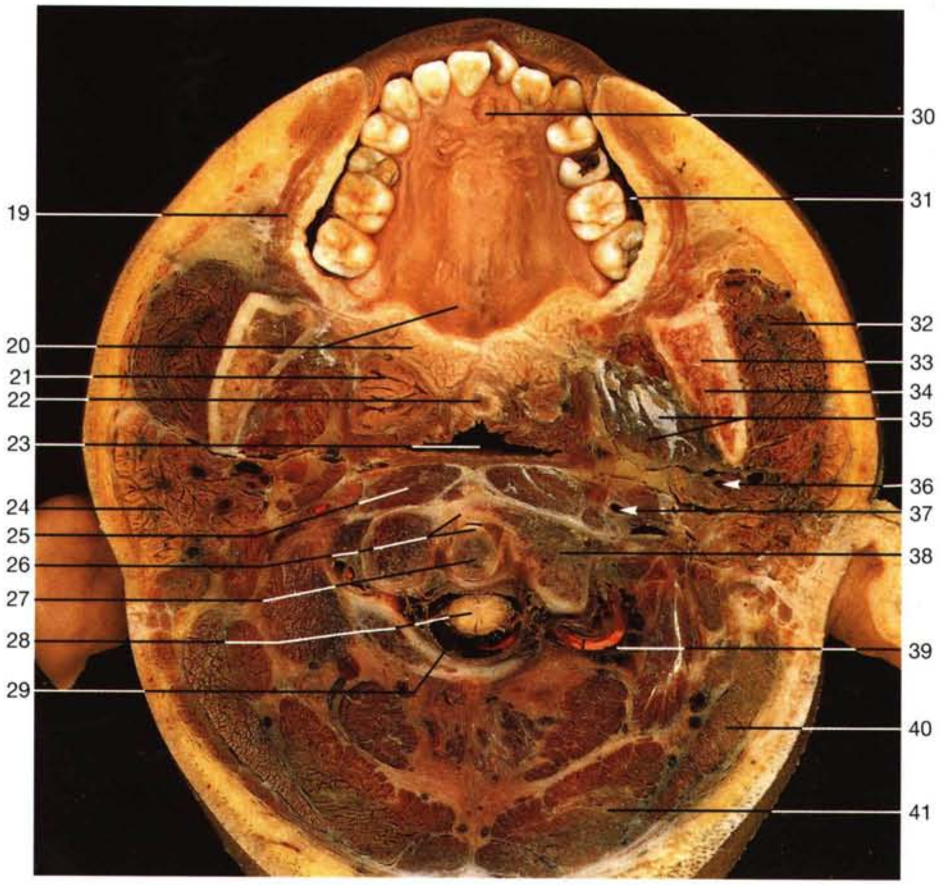

Cross-section of head and neck at the level of the atlas (inferior aspect).

1 Ascending pharyngeal artery
2 Pharyngeal plexus
3 **Accessory nerve**
4 Superior cervical ganglion of sympathetic trunk
5 Superior laryngeal nerve
6 Carotid body and carotid sinus nerve
7 Left **vagus nerve**
8 Common carotid artery and cardiac branch of vagus nerve
9 **Glossopharyngeal nerve**
10 **Hypoglossal nerve**
11 **Facial nerve**
12 Posterior belly of digastric muscle
13 Middle constrictor muscle of pharynx
14 Right vagus nerve
15 **Sympathetic trunk**
16 **Internal jugular vein**
17 Inferior constrictor muscle of pharynx
18 Larynx
19 **Buccinator muscle**
20 Soft palate and palatine glands
21 Palatine tonsil
22 Uvula of palate
23 **Pharynx** (oral part)
24 Parotid gland
25 Longus capitis muscle
26 Medioatlantoaxial joint and anterior arch of atlas
27 **Dens of axis**
28 **Spinal cord**
29 Dura mater
30 Incisive papilla
31 **Oral vestibule**
32 Masseter muscle
33 Mandible
34 Mandibular canal with vessels and nerve
35 Medial pterygoid muscle
36 External carotid artery
37 Internal carotid artery
38 **Atlas**
39 **Vertebral artery**
40 Splenius capitis muscle
41 Semispinalis capitis muscle

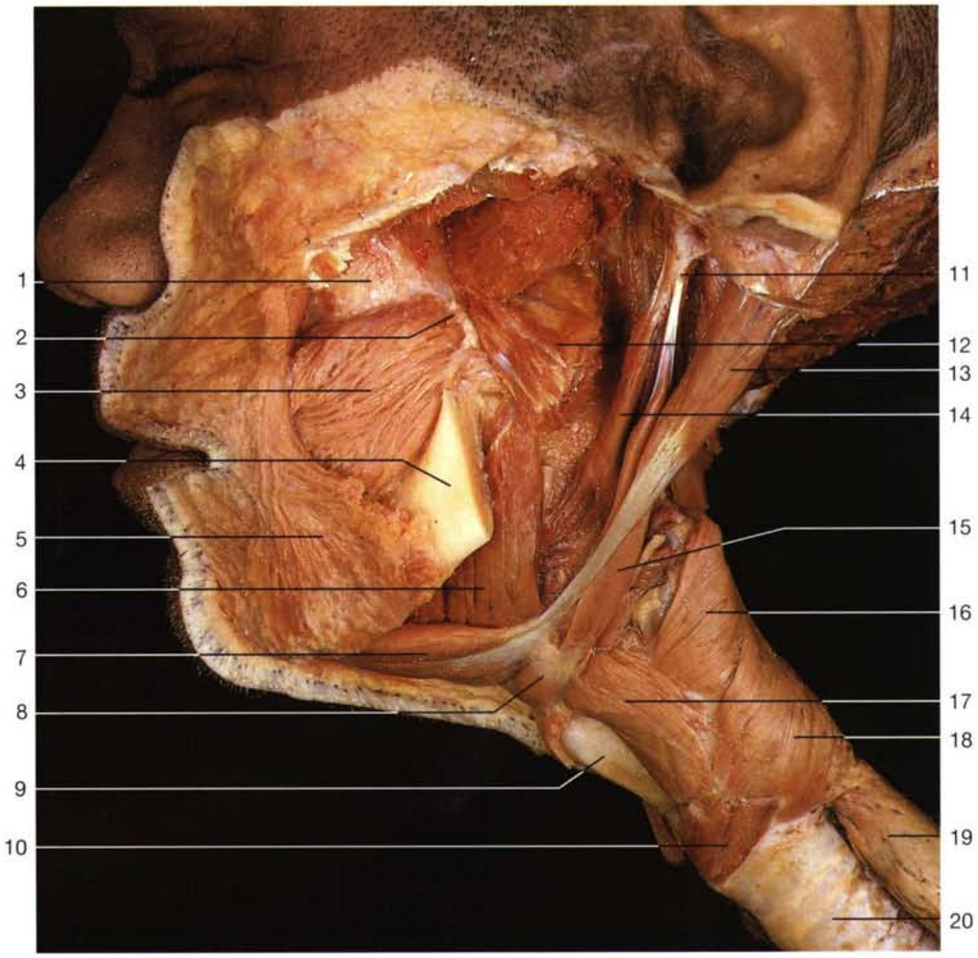

Dissection of pharynx, supra- and infrahyoid muscles I. Mandible partly removed (lateral aspect).

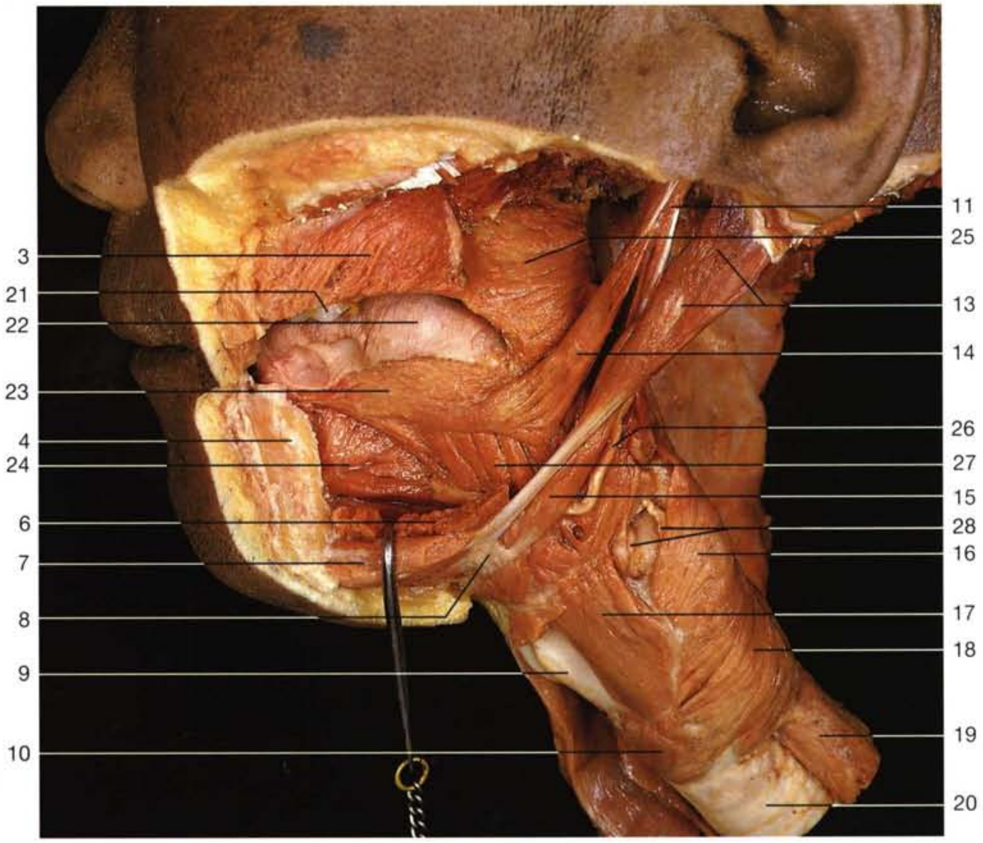

Dissection of pharynx, supra- and infrahyoid muscles II. Oral cavity opened (lateral aspect).

1 Maxilla
2 Pterygomandibular raphe
3 Buccinator muscle
4 Mandible (divided)
5 Depressor anguli oris muscle
6 Mylohyoid muscle
7 Anterior belly of digastric muscle
8 Hyoid bone
9 Thyroid cartilage
10 Cricothyroid muscle
11 Styloid process
12 Medial pterygoid muscle (divided)
13 Posterior belly of digastric muscle
14 Styloglossus muscle
15 Stylohyoid muscle
16 **Thyropharyngeal part of inferior constrictor muscle of pharynx**
17 Thyrohyoid muscle
18 **Cricopharyngeal part of inferior constrictor muscle of pharynx**
19 Esophagus
20 Trachea
21 First molar of maxilla
22 Tongue
23 Inferior longitudinal muscle of tongue
24 Genioglossus muscle
25 **Superior constrictor muscle of pharynx**
26 Hypoglossal nerve
27 Hyoglossus muscle
28 Superior laryngeal nerve and superior laryngeal artery

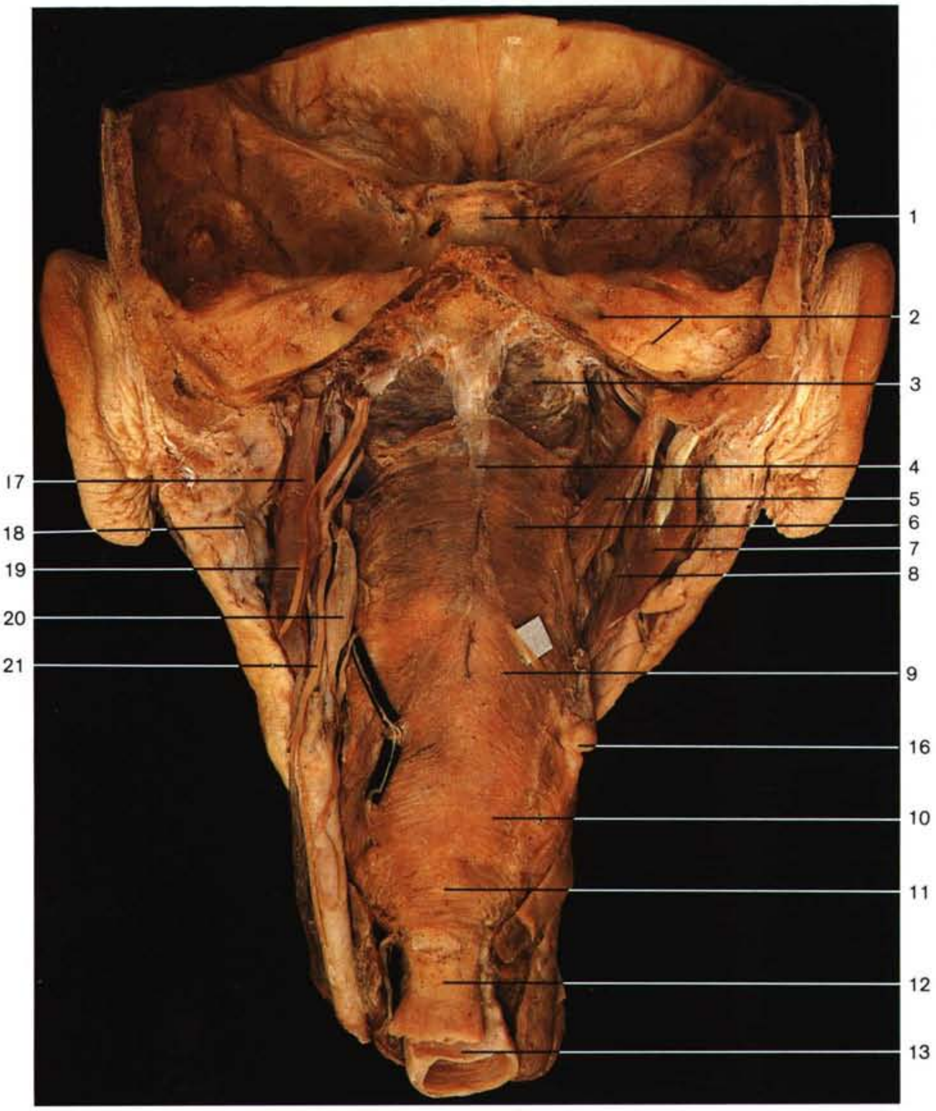

Muscles of the pharynx (posterior aspect).

1 Sella turcica
2 Internal acoustic meatus and petrous part of temporal bone
3 Pharyngobasilar fascia
4 Fibrous raphe of pharynx
5 **Stylopharyngeus muscle**
6 **Superior constrictor muscle of pharynx**
7 Posterior belly of digastric muscle
8 Stylohyoid muscle
9 **Middle constrictor muscle of pharynx**
10 **Inferior constrictor muscle of pharynx**
11 Muscle-free area (Killian's triangle)
12 Esophagus
13 Trachea
14 Thyroid and parathyroid glands
15 Medial pterygoid muscle
16 Greater horn of hyoid bone
17 Internal jugular vein
18 Parotid gland
19 Accessory nerve
20 **Superior cervical ganglion** of sympathetic trunk
21 Vagus nerve
22 Laimer's triangle (area prone to developing diverticula)
23 Orbicularis oculi muscle
24 Nasalis muscle
25 Levator labii superioris and levator labii alaeque nasi muscles
26 Levator anguli oris muscle
27 Orbicularis oris muscle
28 **Buccinator muscle**
29 Depressor labii inferioris muscle
30 **Hyoglossus muscle**
31 Thyrohyoid muscle
32 Thyroid cartilage
33 Cricothyroid muscle
34 Pterygomandibular raphe
35 Tensor veli palatini muscle
36 Levator veli palatini muscle
37 Depressor anguli oris muscle
38 Mentalis muscle
39 Styloglossus muscle

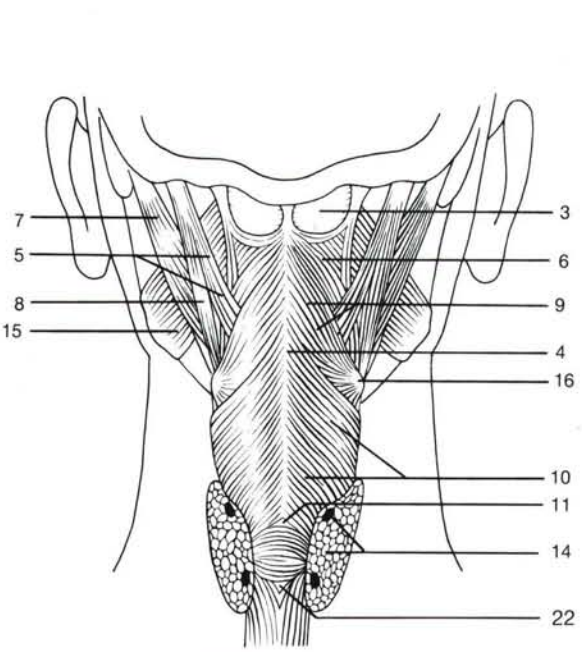

Muscles of the pharynx. (Schematic drawing.)

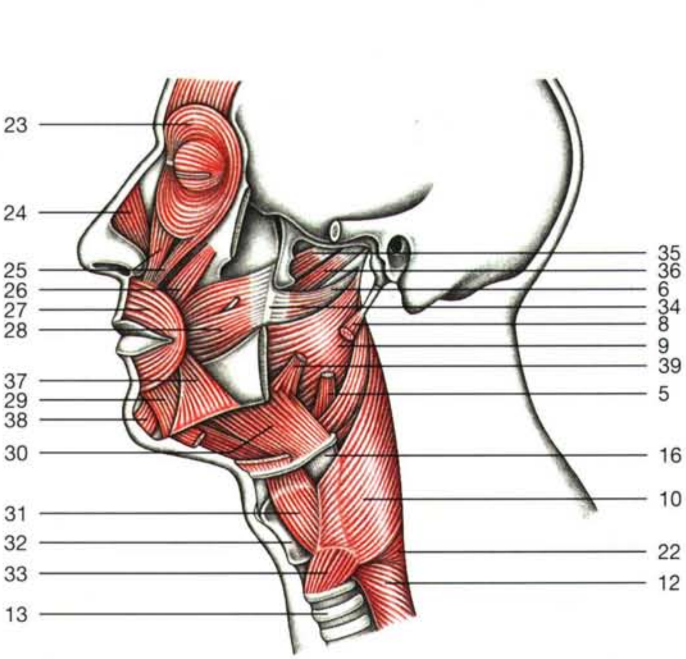

Muscles of pharynx (lateral aspect). (Schematic drawing.)

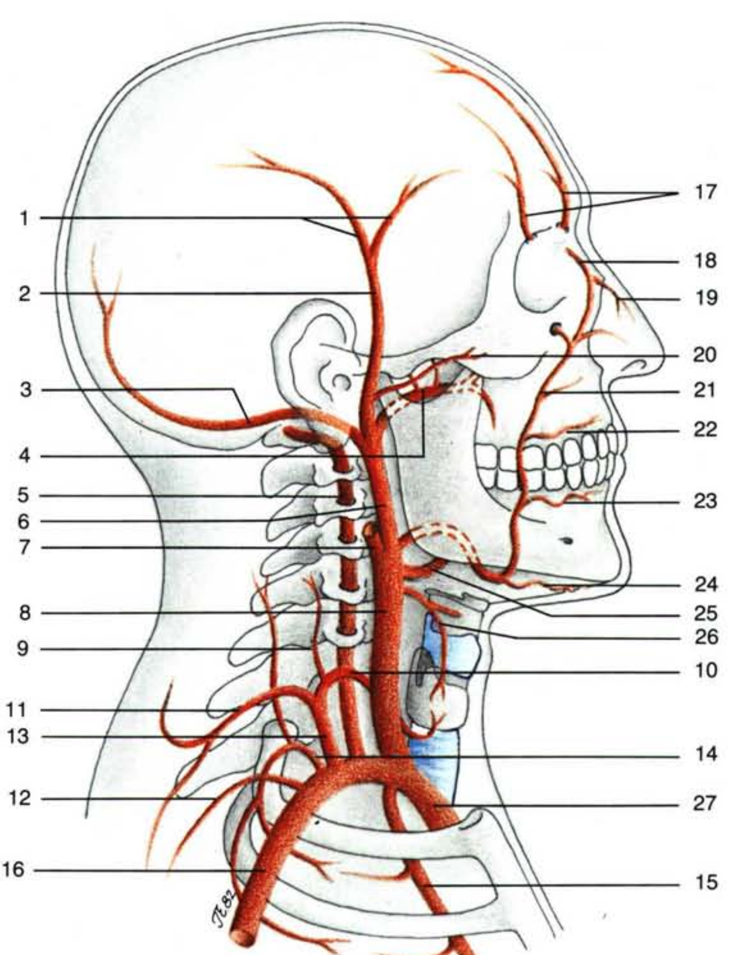

1 Frontal and parietal branches of superficial temporal artery
2 Superficial temporal artery
3 **Occipital artery**
4 **Maxillary artery**
5 **Vertebral artery**
6 **External carotid artery**
7 Internal carotid artery
8 Common carotid artery (divided)
9 Ascending cervical artery
10 Inferior thyroid artery
11 Transverse cervical artery with 2 branches (superficial cervical artery and descending scapular artery)
12 Suprascapular artery
13 **Thyrocervical trunk**
14 Costocervical trunk with 2 branches (deep cervical artery and superior intercostal artery)
15 Internal thoracic artery
16 **Axillary artery**
17 Supraorbital and supratrochlear arteries
18 Angular artery
19 Dorsal nasal artery
20 Transverse facial artery
21 **Facial artery**
22 Superior labial artery
23 Inferior labial artery
24 Submental artery
25 Lingual artery
26 Superior thyroid artery
27 Brachiocephalic trunk

Arteries of head and neck. Diagram of the main branches of external carotid and subclavian artery.

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1 Galea aponeurotica
2 Frontal branch } of superficial
3 Parietal branch } temporal artery
4 Superior auricular muscle
5 **Superficial temporal artery and vein**
6 Middle temporal artery
7 Auriculotemporal nerve
8 Branches of facial nerve
9 Facial nerve
10 **External carotid artery** within the retromandibular fossa
11 Posterior belly of digastric muscle
12 Sternocleidomastoid artery
13 Sympathetic trunk and superior cervical ganglion
14 Sternocleidomastoid muscle (divided and reflected)
15 Clavicle (divided)
16 Transverse cervical artery
17 Ascending cervical artery and phrenic nerve
18 Scalenus anterior muscle
19 Suprascapular artery
20 Dorsal scapular artery
21 Brachial plexus and **axillary artery**
22 Thoracoacromial artery
23 Lateral thoracic artery
24 Median nerve (displaced) and pectoralis minor muscle (reflected)
25 Frontal belly of occipitofrontalis muscle
26 Orbital part of orbicularis oculi muscle
27 **Angular artery** and vein
28 **Facial artery**
29 Superior labial artery
30 Zygomaticus major muscle
31 Inferior labial artery
32 Parotid duct
33 Buccal fat pad
34 **Maxillary artery**
35 Masseter muscle
36 Facial artery and mandible
37 Submental artery
38 Anterior belly of digastric muscle

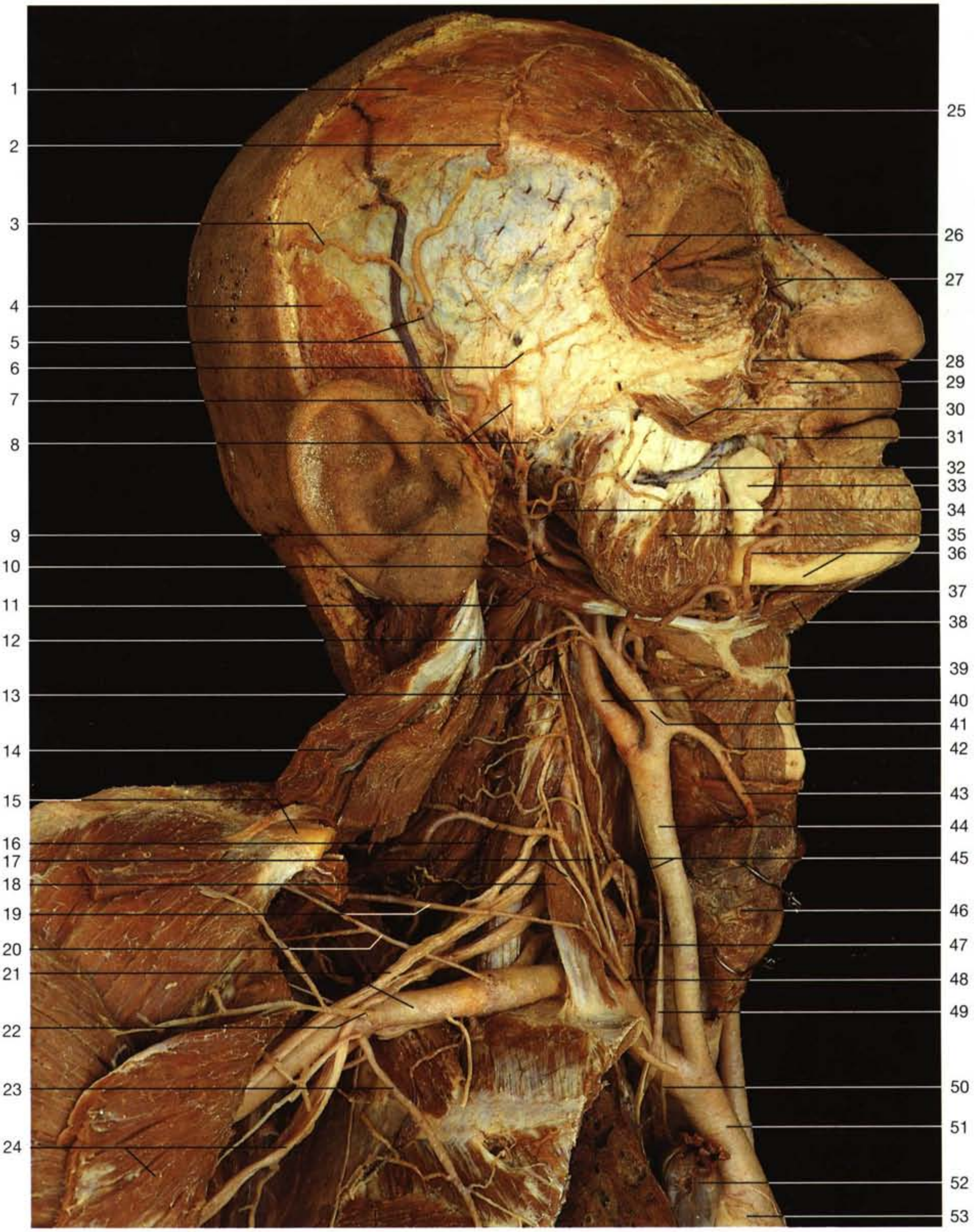
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Main branches of head and neck arteries (lateral aspect). Anterior thoracic wall and clavicle partly removed; pectoralis muscles have been reflected to display the subclavian and axillary arteries.

39 Hyoid bone
40 **Internal carotid artery**
41 **External carotid artery**
42 Superior laryngeal artery
43 Superior thyroid artery
44 **Common carotid artery**
45 Thyroid ansa of sympathetic trunk and **inferior thyroid artery**
46 Thyroid gland (right lobe)
47 **Vertebral artery**
48 **Thyrocervical trunk**
49 Vagus nerve
50 Ansa subclavia of sympathetic trunk
51 **Brachiocephalic trunk**
52 Superior vena cava (divided)
53 Aortic arch

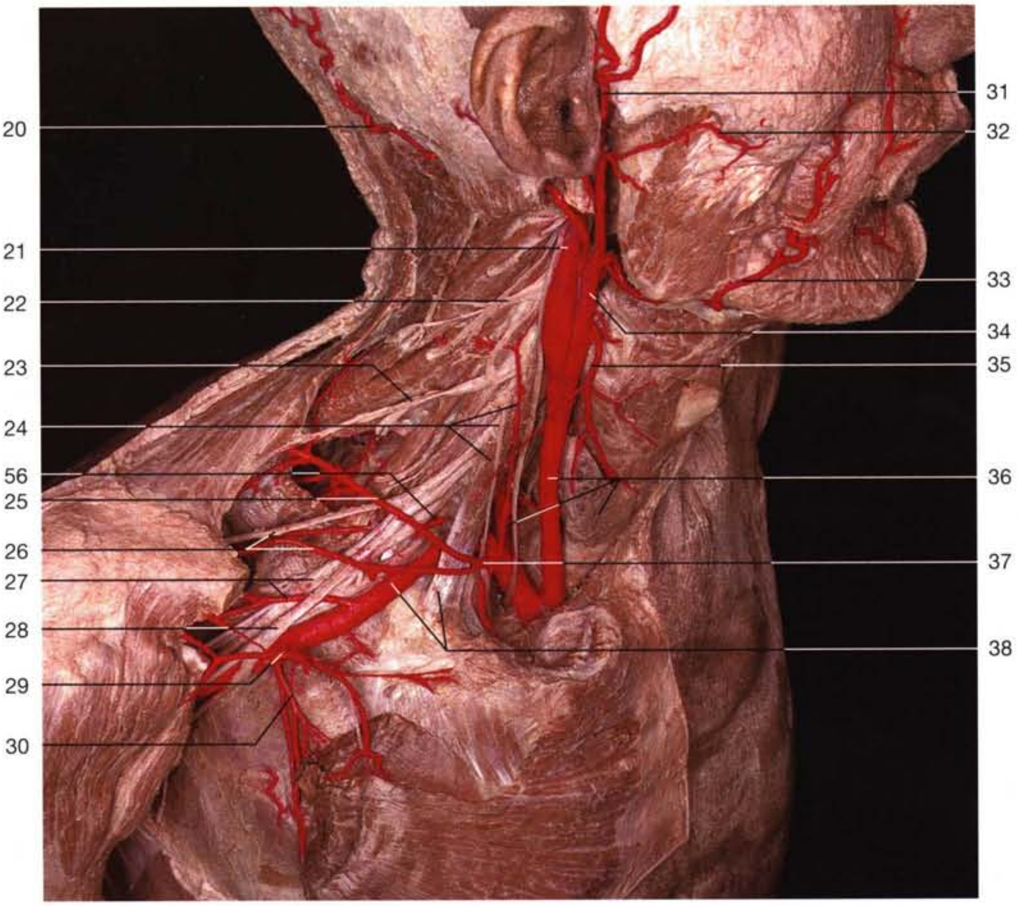

Arteries of head and neck (anterior-lateral aspect). Clavicle, sternocleidomastoid and veins have been partly removed, the arteries were colored.

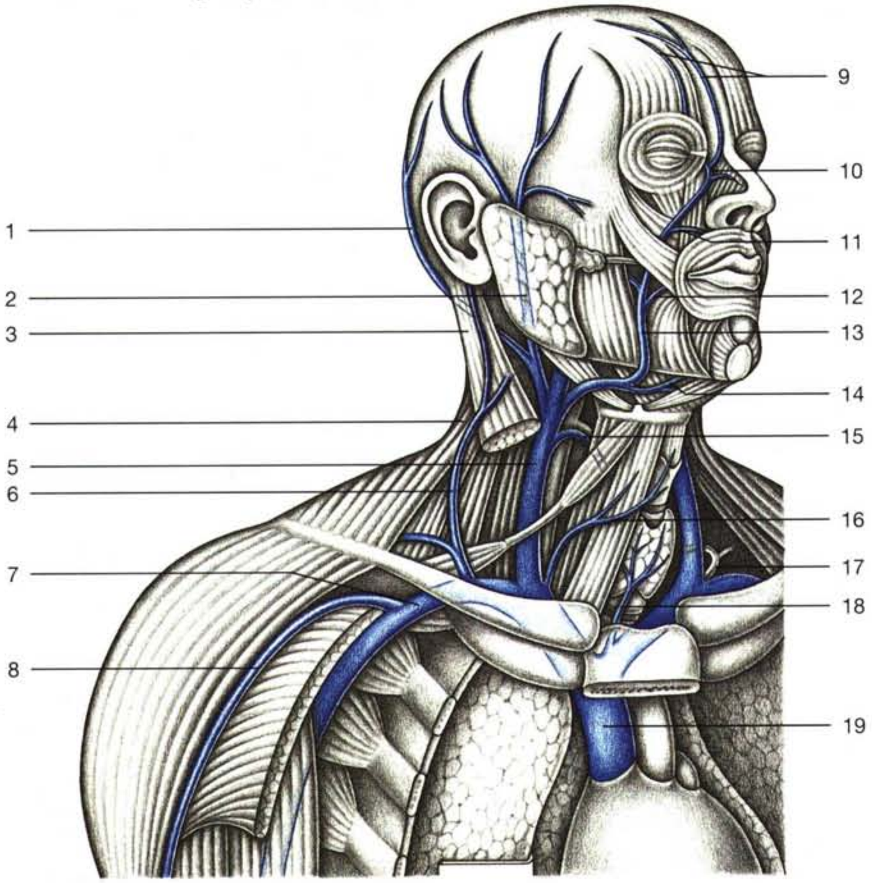

Veins of head and neck. Sternocleidomastoid muscle and anterior thoracic wall partly removed. Note the venous connection with the superior vena cava.

1 Occipital vein
2 Superficial temporal vein
3 Sternocleidomastoid muscle
4 Trapezius muscle
5 **Internal jugular vein**
6 External jugular vein
7 **Subclavian vein**
8 Cephalic vein
9 Supraorbital veins
10 Angular vein
11 Superior labial vein
12 Inferior labial vein
13 **Facial vein**
14 Submental vein
15 Superior thyroid vein
16 Anterior jugular vein
17 Thoracic duct
18 Inferior thyroid vein
19 Superior vena cava
20 Occipital artery
21 **Internal carotid artery**
22 Cervical plexus
23 Supraclavicular nerve
24 Phrenic nerve and ascending cervical artery on scalenus anterior muscle
25 Superficial cervical artery
26 Suprascapular artery and nerve
27 Brachial plexus and anterior circumflex humeral artery
28 Lateral cord of brachial plexus
29 **Thoracoacromial artery**
30 Lateral thoracic artery
31 Superficial temporal artery
32 Transverse facial artery
33 Facial artery
34 External carotid artery
35 Superior thyroid artery
36 **Common carotid artery, vagus nerve** and thyroid gland
37 **Thyrocervical trunk**
38 **Subclavian artery** and scalenus anterior muscle
39 Parotid gland and facial nerve
40 Great auricular nerve
41 External jugular vein
42 Brachial plexus
43 Cephalic vein in deltopectoral groove
44 Axillary vein and artery
45 Right brachiocephalic vein
46 **Superior vena cava**
47 Right lung (reflected)
48 Superficial temporal artery and vein
49 Facial artery and vein
50 Cervical branch of facial nerve and submandibular gland
51 **Internal jugular vein,** common carotid artery and omohyoid muscle
52 Anterior jugular vein and thyroid gland
53 Jugular venous arch
54 Left brachiocephalic vein
55 Pericardium of heart (location of right atrium)
56 Transverse cervical artery

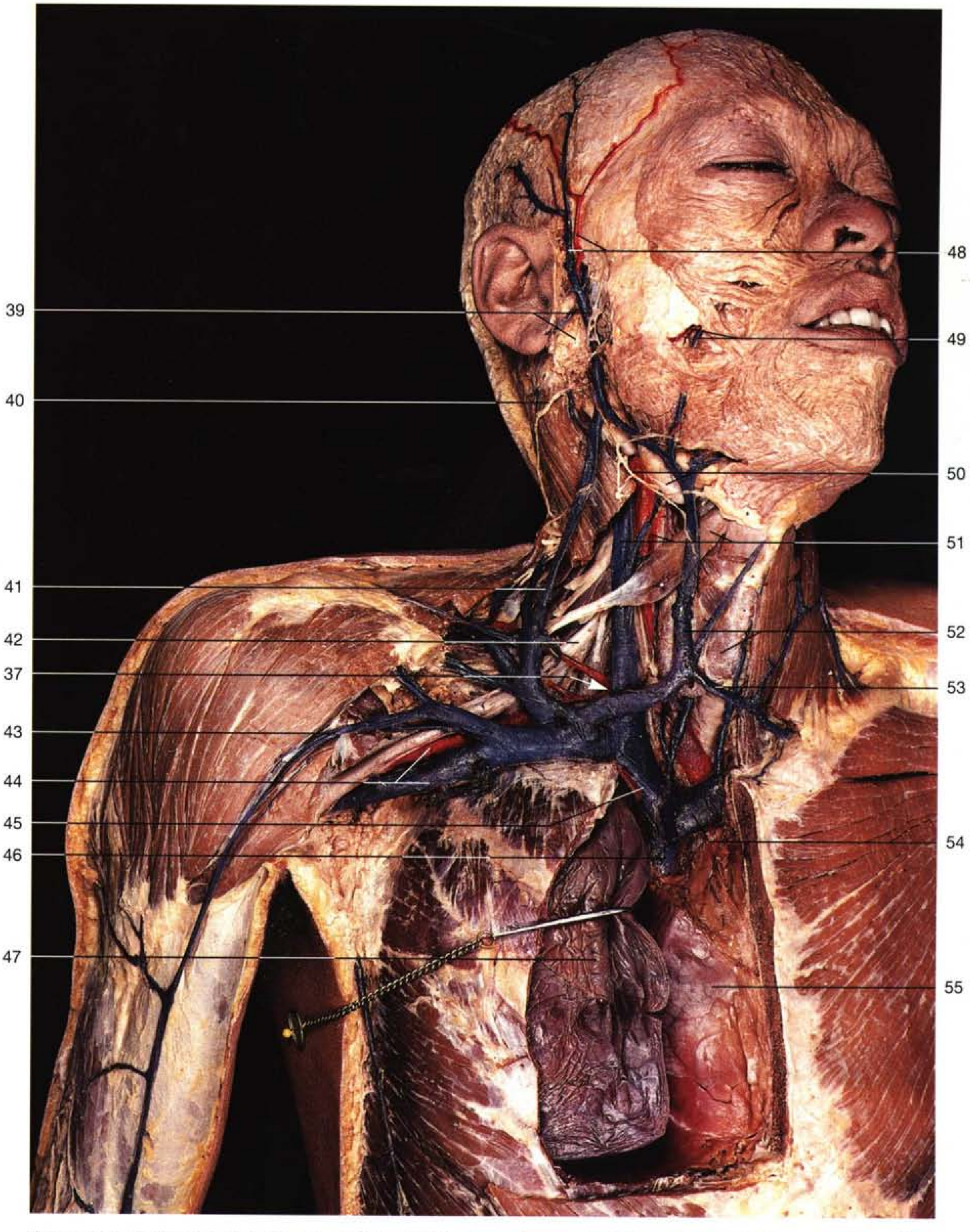

Veins of head and neck (anterior aspect). Part of the thoracic wall, clavicle and sternocleidomastoid muscle have been removed. Veins were colored blue, arteries red.

The **internal jugular vein** is the continuation of the sigmoid sinus which drains most of the venous blood from the brain together with the external cerebrospinal fluid. By joining the subclavian vein it forms the right brachiocephalic vein which continues on the right side directly into the superior vena cava. The common way to introduce the lead from a pacemaker device into the heart is by way of the cephalic vein. On the left side the thoracic duct joins the internal jugular vein at that point where the subclavian vein and the internal jugular vein form the left brachiocephalic vein. Note that the subclavian vein lies in front of the scalenus anterior muscle whereas the subclavian artery together with the plexus brachialis lies posterior to that muscle. The cephalic vein joins the axillary vein by passing into the deltopectoral triangle. The subclavian vein is strongly fixed to the first rib so that it can be punctured with a needle at that point (underneath the sternal end of clavicle) to introduce a catheter (subclavian line).

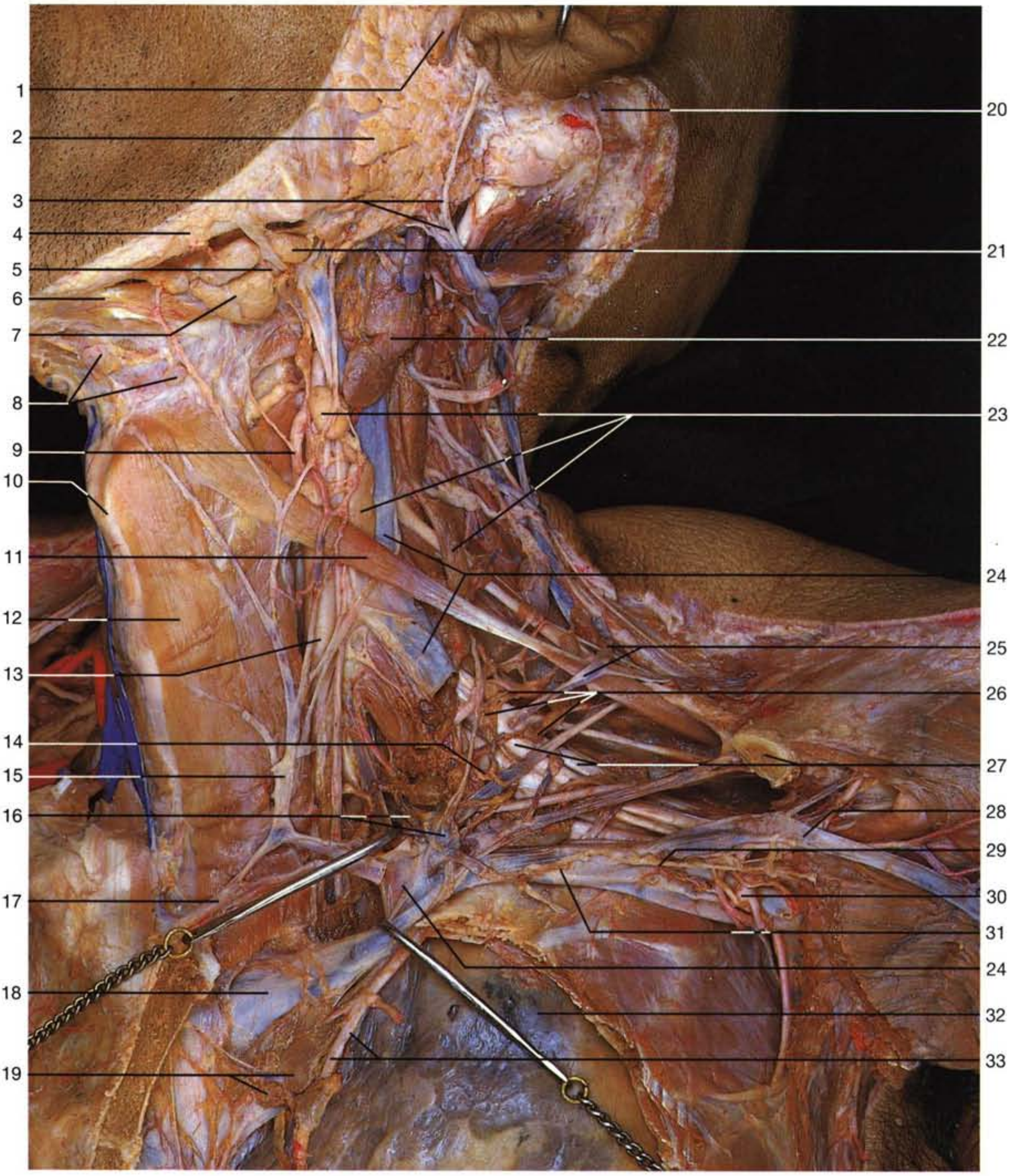

Lymph nodes and lymph vessels of the neck, left side oblique (lateral aspect). The sternocleidomastoid muscle and the left half of the thoracic wall have been removed. Lower part of the internal jugular vein has been cut and laterally displaced to show the thoracic duct.

1 **Superficial parotid lymph node**
2 Parotid gland
3 Great auricular nerve
4 Mandible
5 Facial vein
6 Anterior belly of digastric muscle
7 Submandibular gland
8 **Submental lymph nodes**
9 Superior thyroid artery
10 Thyroid cartilage
11 Omohyoid muscle
12 Sternohyoid muscle
13 Common carotid artery
14 **Supraclavicular lymph nodes**
15 Anterior jugular vein
16 Thoracic duct
17 Jugular venous arch
18 Left brachiocephalic vein
19 **Superior mediastinal lymph nodes**
20 Retroauricular lymph nodes
21 **Submandibular nodes**
22 **Superficial cervical lymph nodes**
23 **Jugulodigastric lymph nodes and jugular trunk**
24 **Internal jugular vein**
25 External jugular vein
26 **Jugulo-omohyoid lymph nodes**
27 Brachial plexus
28 Cephalic vein
29 Subclavian trunk
30 **Infraclavicular lymph nodes**
31 Subclavian vein
32 Lung
33 Internal thoracic artery and vein

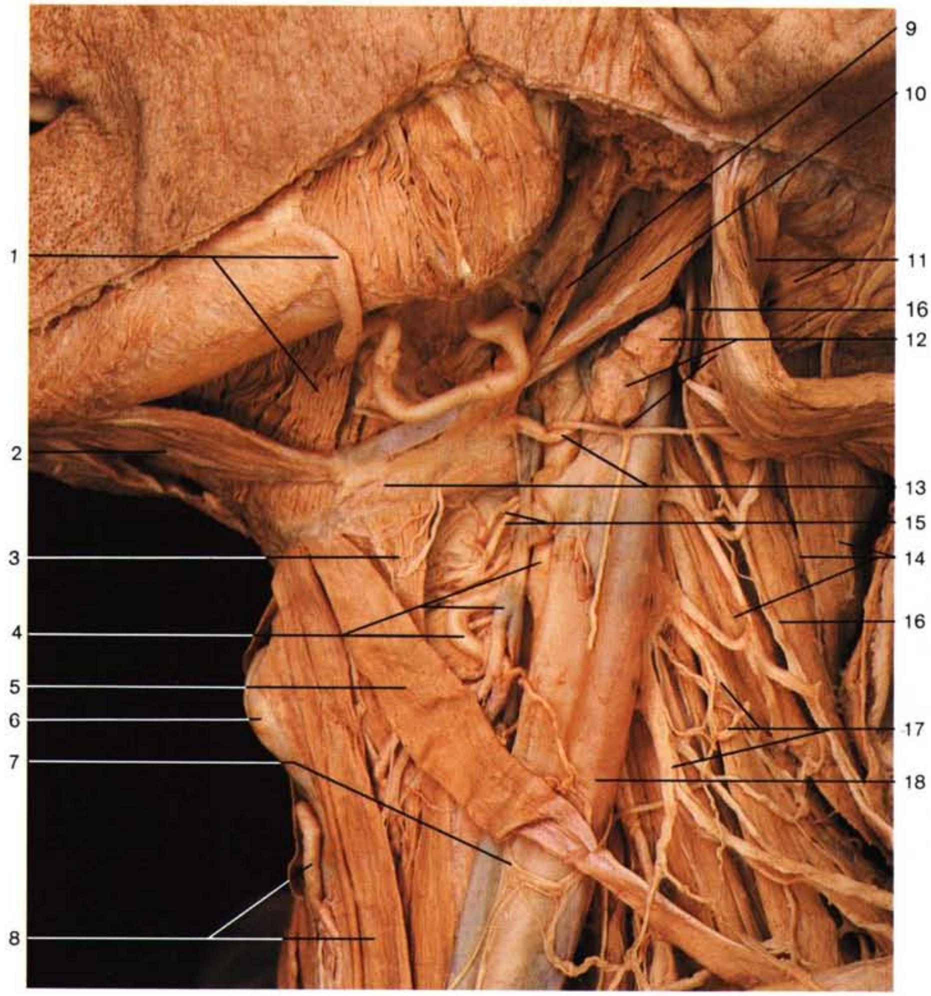

Carotid triangle, left side (lateral aspect). Sternocleidomastoid muscle reflected.

1 Mylohyoid muscle and facial artery
2 Anterior belly of digastric muscle
3 Thyrohyoid
4 **External carotid artery,** superior thyroid artery and vein
5 Omohyoid muscle
6 Thyroid cartilage
7 **Ansa cervicalis**
8 Sternohyoid muscle and superior thyroid artery
9 Stylohyoid muscle
10 Posterior belly of digastric muscle
11 Sternocleidomastoid muscle (reflected)
12 **Superior cervical lymph nodes** and sternocleidomastoid artery
13 Hyoid bone and hypoglossal nerve (n. XII)
14 Splenius capitis and levator scapulae muscles
15 Superior laryngeal artery and internal branch of superior laryngeal nerve
16 **Accessory nerve**
17 Cervical plexus
18 **Internal jugular vein**
19 Facial vein
20 Submental nodes
21 **Thoracic duct**
22 Retroauricular nodes
23 Parotid nodes
24 Occipital nodes
25 **Submandibular nodes**
26 Jugulodigastric nodes } **deep cervical nodes**
27 Jugulo-omohyoid nodes }
28 Jugular trunk
29 Subclavian trunk
30 Infraclavicular nodes
31 External jugular vein

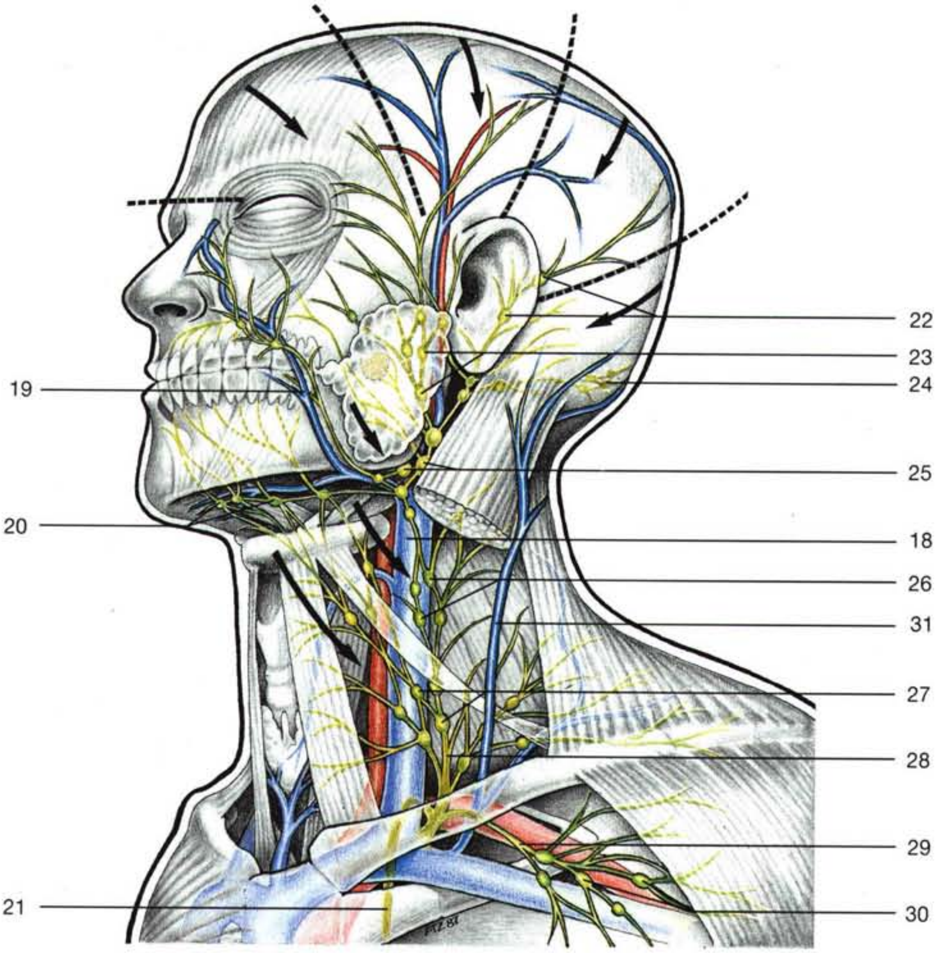

Lymph nodes and veins of head and neck. Dotted lines = border between irrigation areas; arrows: direction of lymph flow.

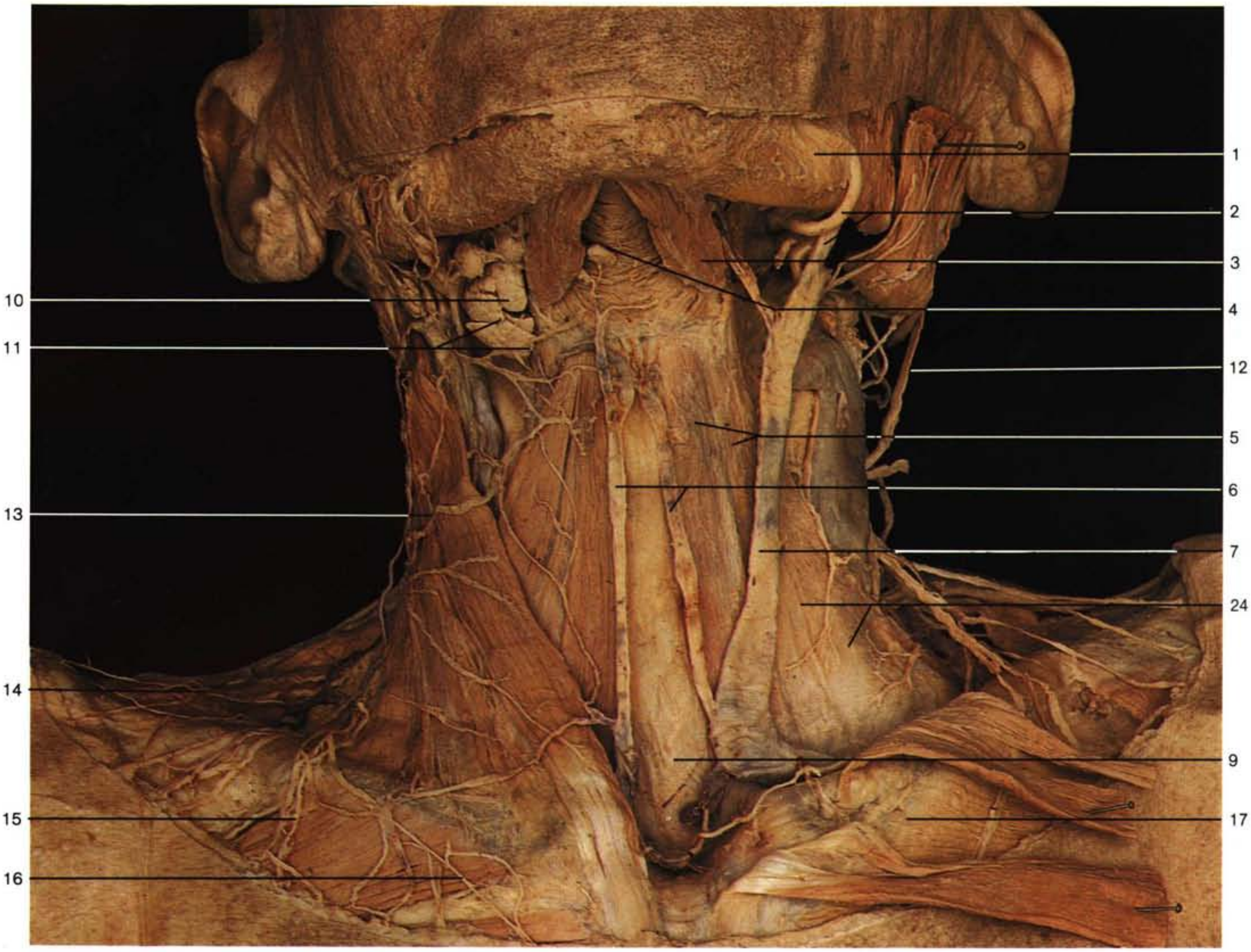

Neck (anterior aspect).
The superficial fascia has been removed.

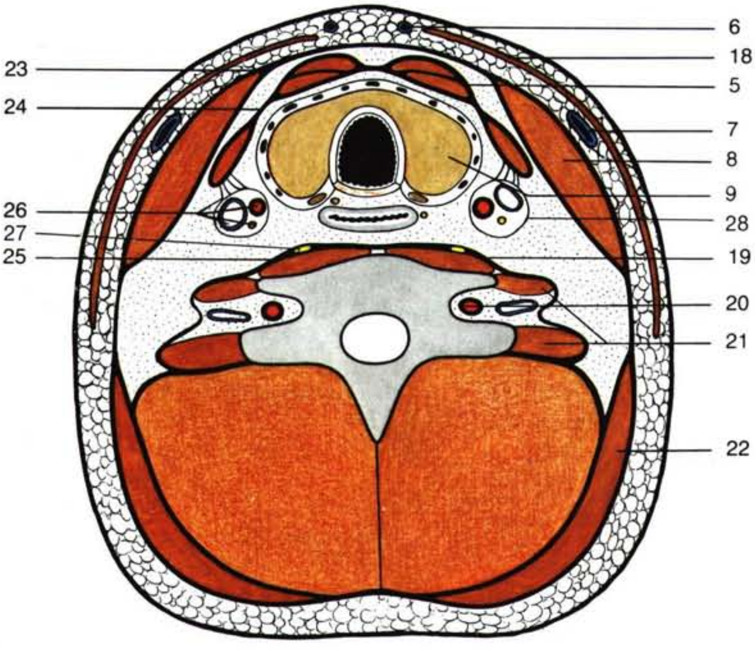

Cross-section of the neck at the level of the thyroid gland.
Notice the postion of the three laminae of cervical fascia (23, 24, 25).

1 Mandible
2 **Facial artery and vein**
3 Anterior belly of digastric muscle
4 Mylohyoid muscle
5 Infrahyoid muscles (sternohyoid, sternothyroid and omohyoid)
6 **Anterior jugular veins**
7 **External jugular vein**
8 Sternocleidomastoid muscle
9 **Thyroid gland**
10 **Submandibular gland**
11 Cervical branch of facial nerve
12 Great auricular nerve
13 Transverse cervical nerves
14 Lateral supraclavicular nerves
15 Middle supraclavicular nerves
16 Medial supraclavicular nerves
} Cutaneous branches of cervical plexus
17 Clavicle
18 Platysma muscle
19 Prevertebral lamina of cervical fascia, covering longus colli muscle
20 Vertebral artery and vein
21 Scalenus muscles
22 Trapezius muscle
23 **Superficial lamina of cervical fascia**
24 **Pretracheal lamina of cervical fascia**
25 **Prevertebral lamina of cervical fascia** with sympathetic trunk
26 **Carotid sheath** with common carotid artery, internal jugular vein and vagus nerve
27 Cervical part of sympathetic trunk
28 Carotid sheath

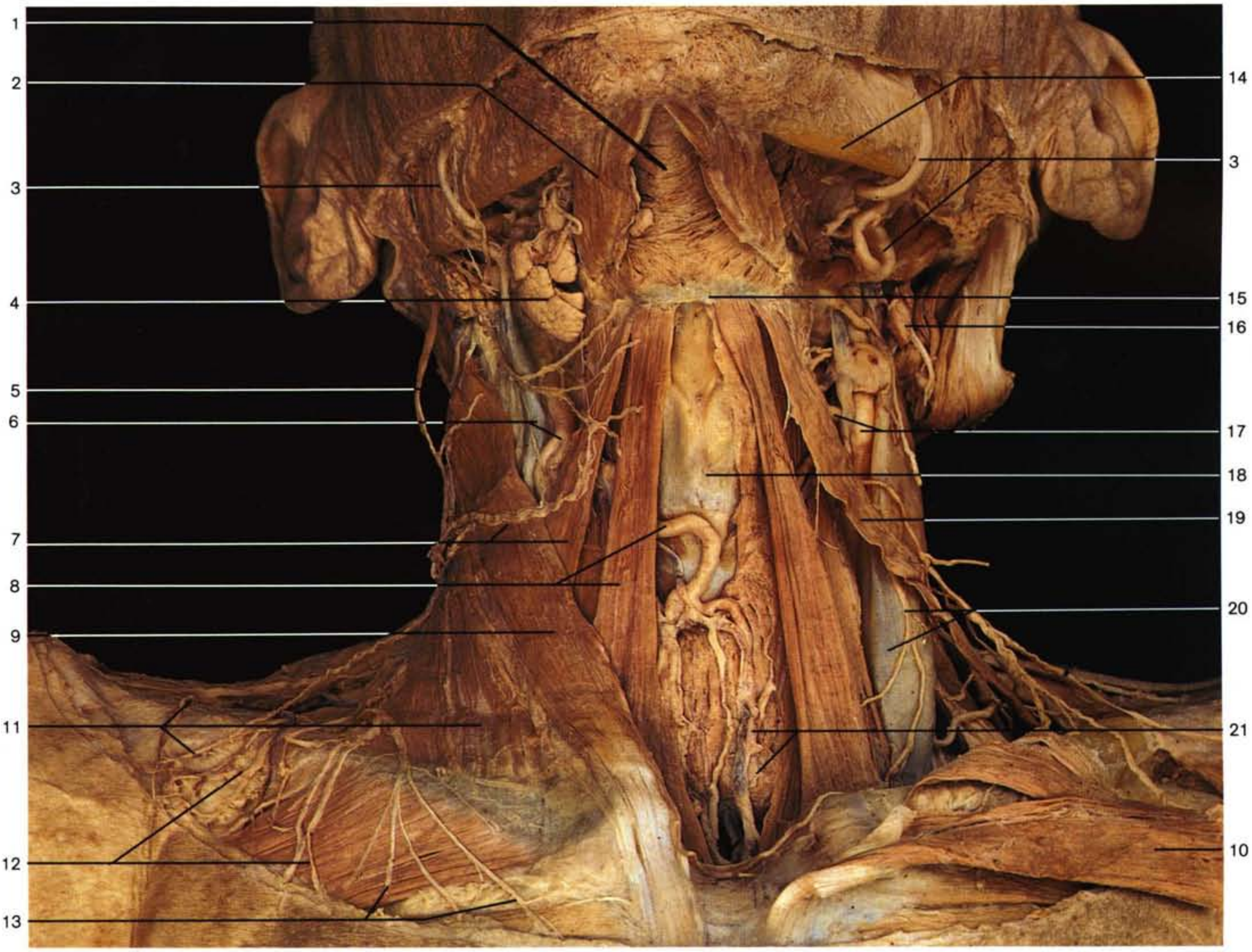

Anterior triangle (anterior aspect). The pretracheal lamina of cervical fascia and left sternocleidomastoid muscle have been removed.

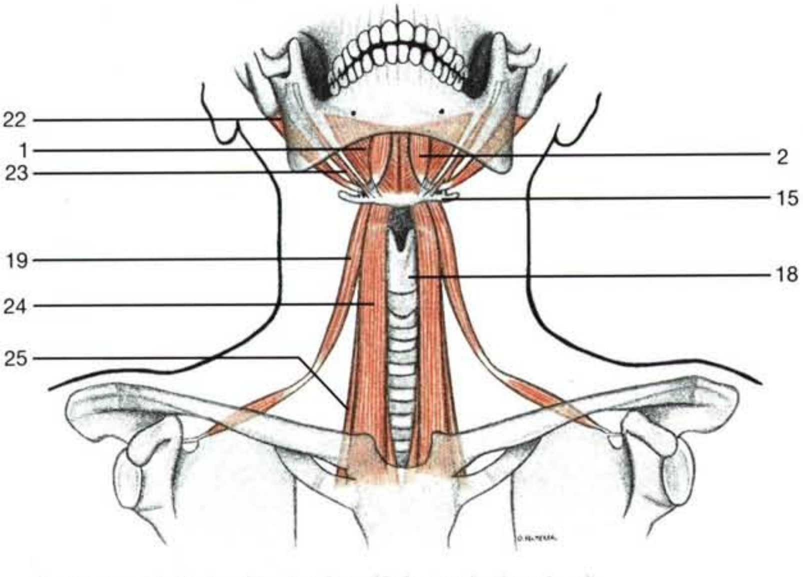

Supra- and infrahyoid muscles. (Schematic drawing.)

1 Mylohyoid muscle
2 Anterior belly of digastric muscle
3 **Facial artery**
4 **Submandibular gland**
5 Great auricular nerve
6 Internal jugular vein and common carotid artery
7 Transverse cervical nerve and omohyoid muscle
8 **Sternohyoid muscle** and **superior thyroid artery**
9 Sternocleidomastoid muscle (sternal head)
10 Left sternocleidomastoid muscle (reflected)
11 Sternocleidomastoid muscle (clavicular head) and lateral supraclavicular nerves
12 Middle **supraclavicular nerves**
13 Medial supraclavicular nerves
14 Mandible
15 **Hyoid bone**
16 Superficial cervical lymph nodes
17 Left superior thyroid artery and external carotid artery
18 **Thyroid cartilage**
19 **Omohyoid muscle** (superior belly)
20 **Internal jugular vein** and branches of ansa cervicalis
21 Thyroid gland and unpaired inferior thyroid vein
22 Posterior belly of digastric muscle
23 **Stylohyoid muscle**
24 **Sternohyoid muscle**
25 **Sternothyroid muscle**

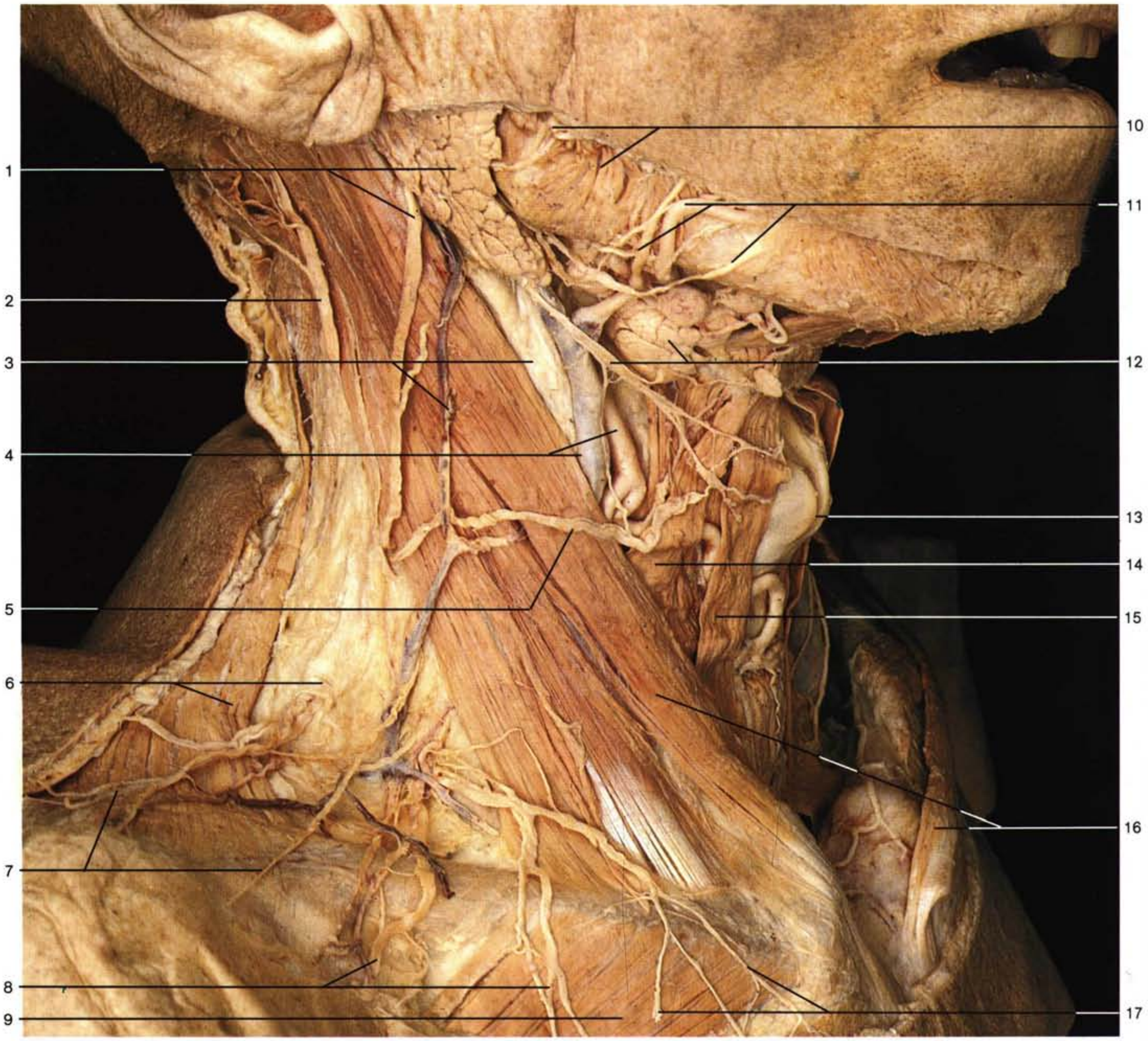

Posterior and carotid triangles (lateral aspect). Superficial dissection.

1 **Parotid gland** and **great auricular nerve**
2 **Lesser occipital nerve**
3 Internal and external jugular veins
4 Retromandibular vein and external carotid artery
5 **Transverse cervical nerve** with communicating branch to cervical branch of facial nerve
6 Trapezius muscle and superficial lamina of cervical fascia
7 Lateral supraclavicular nerves
8 Middle **supraclavicular nerves**
9 Pectoralis major muscle
10 Buccal branch of facial nerve and masseter
11 **Facial artery and vein** and mandibular branch of facial nerve
12 Cervical branch of facial nerve and submandibular gland
13 Thyroid cartilage
14 Omohyoid muscle
15 Sternohyoid muscle
16 Sternocleidomastoid muscle
17 Medial supraclavicular nerves
18 Mandibular branch of facial nerve
19 Cervical branch of facial nerve with communicating branch to transverse cervical nerve

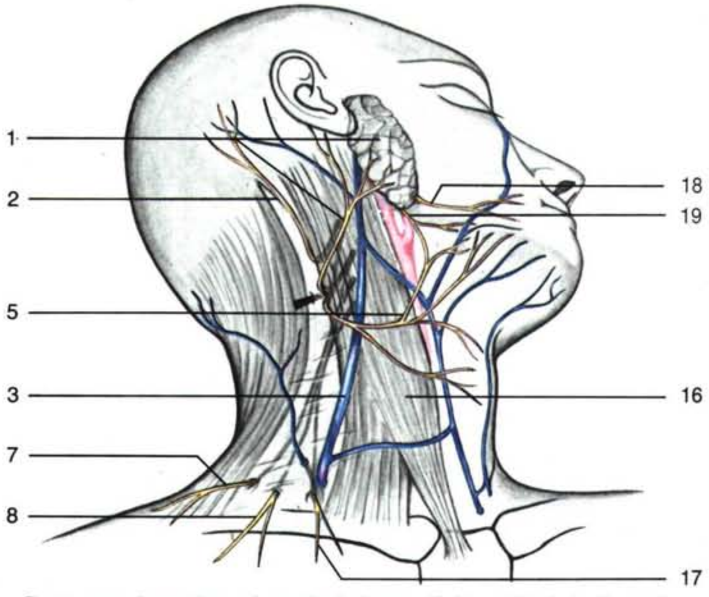

Cutaneous branches of cervical plexus. Erb's point is indicated by an arrowhead. (Schematic diagram.)

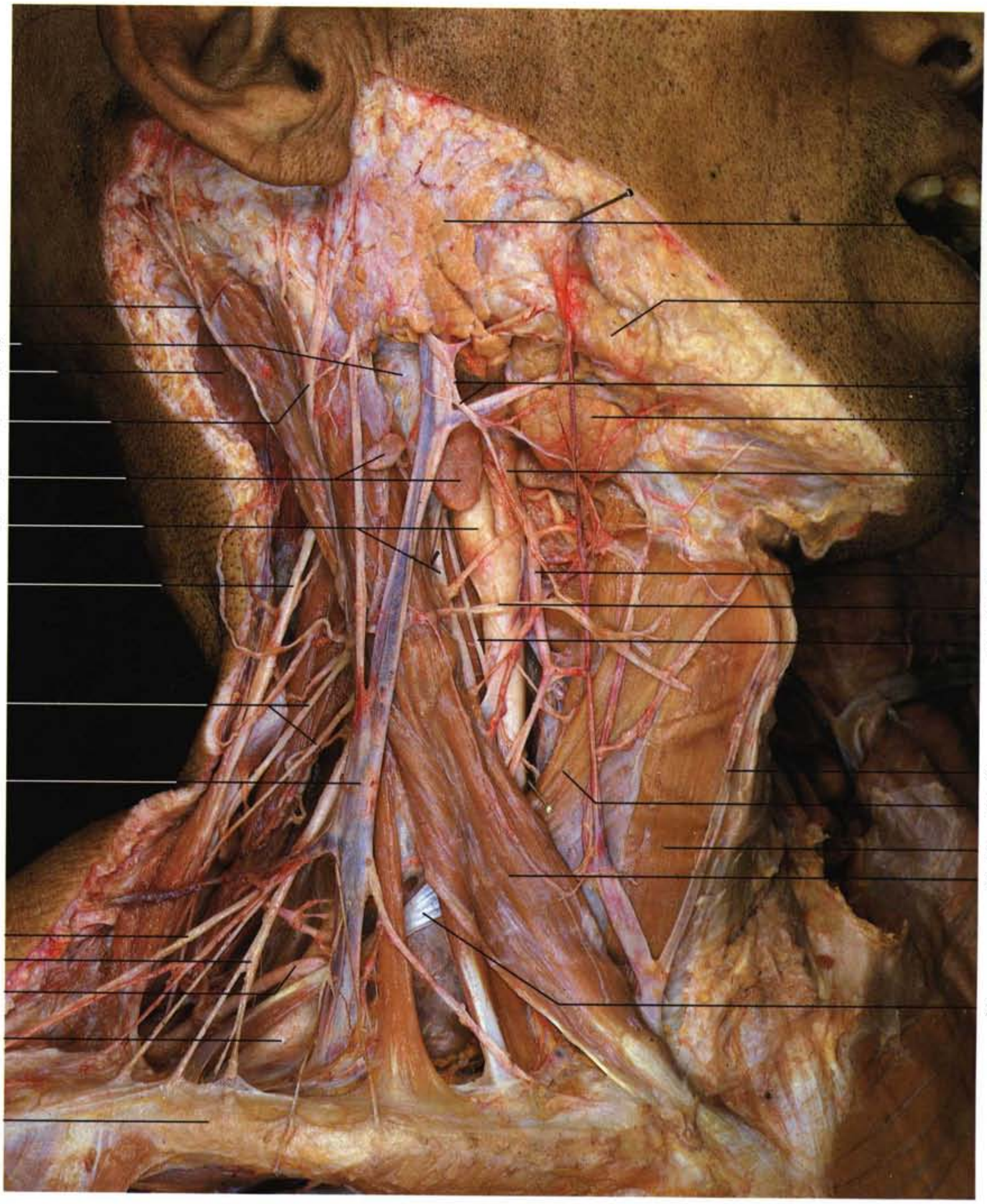

Posterior and carotid triangles (lateral aspect). Superficial dissection. The superficial lamina of cervical fascia has been removed to display the cutaneous branches of the cervical plexus and subcutaneous veins.

1 **Lesser occipital nerve**
2 **Internal jugular vein**
3 Splenius capitis muscle
4 **Great auricular nerve**
5 Submandibular nodes
6 Internal carotid artery and vagus nerve
7 **Accessory nerve**
8 Muscular branches of cervical plexus
9 External jugular vein
10 **Posterior supraclavicular nerves**
11 **Middle supraclavicular nerves**
12 Suprascapular artery
13 Pretracheal lamina of fascia of neck
14 Clavicle
15 Parotid gland
16 Mandible
17 Cervical branch of facial nerve
18 Submandibular gland
19 External carotid artery
20 Superior thyroid artery
21 Transverse cervical nerve
22 Superior root of ansa cervicalis
23 Anterior jugular vein
24 Omohyoid muscle
25 Sternohyoid muscle
26 Sternocleidomastoid muscle
27 Intermediate tendon of omohyoid muscle

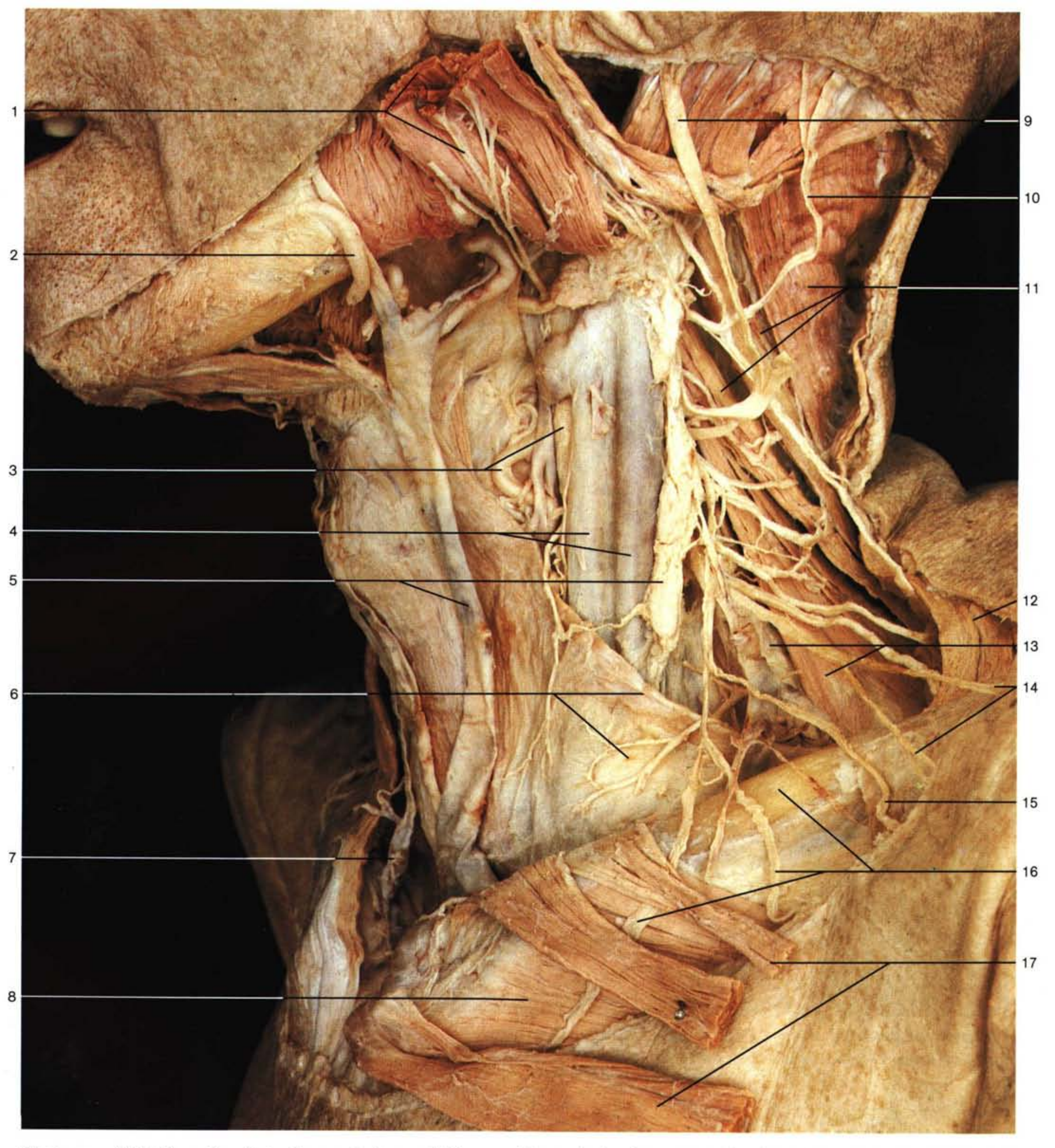

Neck, superficial dissection (lateral aspect). Sternocleidomastoid muscle has been cut and reflected to display the pretracheal lamina of the cervical fascia.

1 Sternocleidomastoid muscle (reflected) and branch of accessory nerve
2 Facial artery
3 External carotid artery and superior thyroid artery
4 **Internal jugular vein**
5 **Deep cervical lymph nodes** and external jugular vein
6 Omohyoid muscle and **pretracheal lamina of cervical fascia**
7 Anterior jugular vein
8 Pectoralis major muscle
9 **Great auricular nerve**
10 **Lesser occipital nerve**
11 Splenius capitis and levator scapulae muscles
12 Trapezius muscle
13 Scalenus medius muscle and brachial plexus
14 Posterior **supraclavicular nerves**
15 Middle supraclavicular nerve
16 Clavicle and anterior supraclavicular nerves
17 Sternocleidomastoid muscle (reflected)

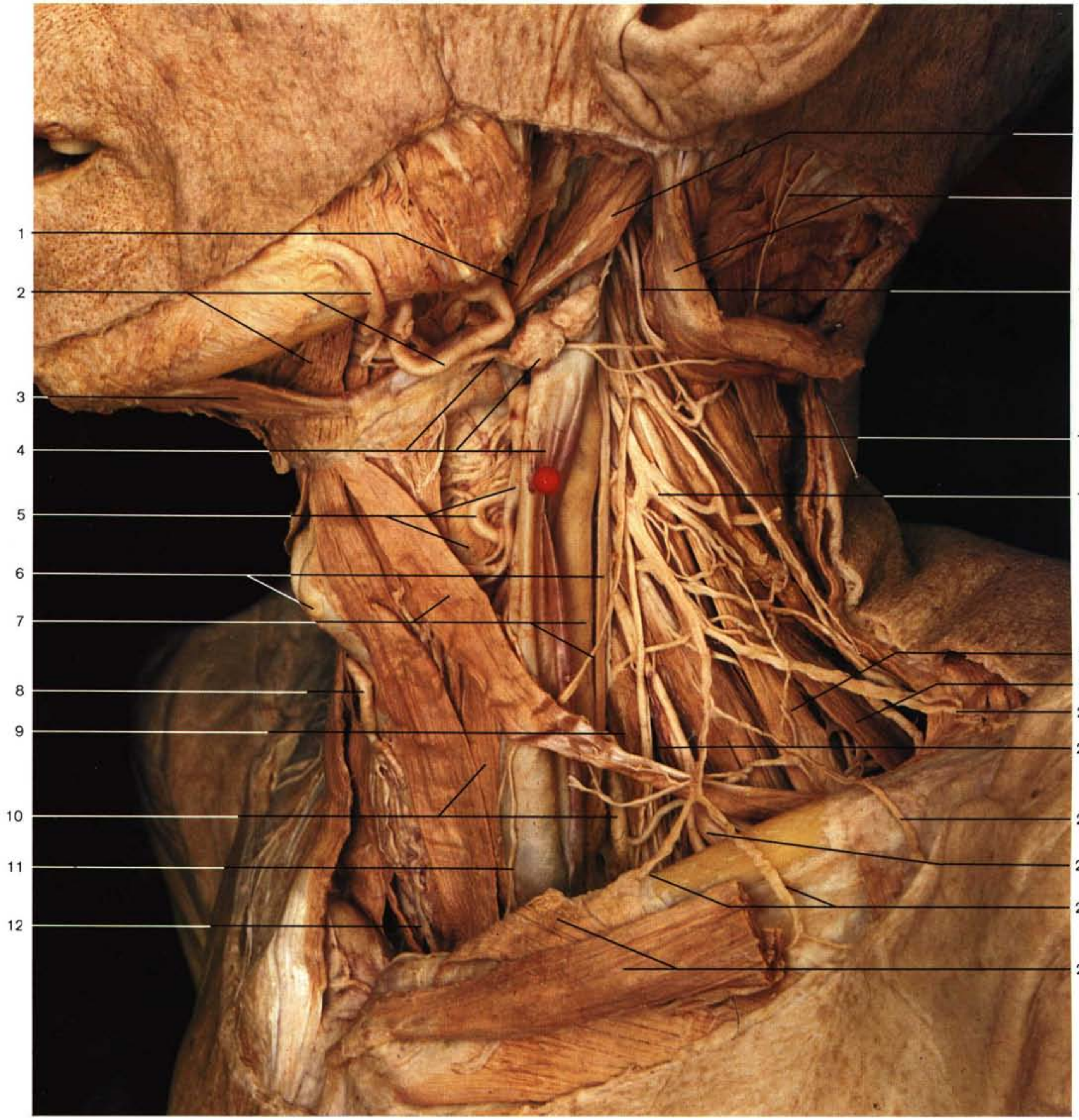

Neck, deep dissection (lateral aspect). The internal jugular vein has been reflected to expose the carotid artery and vagus nerve.

1 Stylohyoid muscle
2 Facial artery and mylohyoid muscle
3 Anterior belly of digastric muscle
4 **Internal jugular vein,** hypoglossal nerve, and superficial cervical lymph nodes
5 **Superior thyroid artery and vein** and inferior pharyngeal constrictor muscle
6 Thyroid cartilage and vagus nerve
7 **Ansa cervicalis,** omohyoid muscle, and common carotid artery
8 Right superior thyroid artery
9 Scalenus anterior muscle
10 Sternothyroid muscle and inferior thyroid artery
11 Muscular branches of ansa cervicalis to the infrahyoid muscles
12 Inferior thyroid vein
13 Posterior belly of digastric muscle
14 Sternocleidomastoid muscle and lesser occipital nerve
15 **Accessory nerve**
16 Splenius capitis muscle
17 **Cervical plexus**
18 Scalenus posterior muscle
19 Levator scapulac muscle
20 Posterior **supraclavicular nerves**
21 Phrenic nerve
22 Middle supraclavicular nerve
23 **Brachial plexus**
24 Anterior supraclavicular nerves
25 Sternocleidomastoid muscle

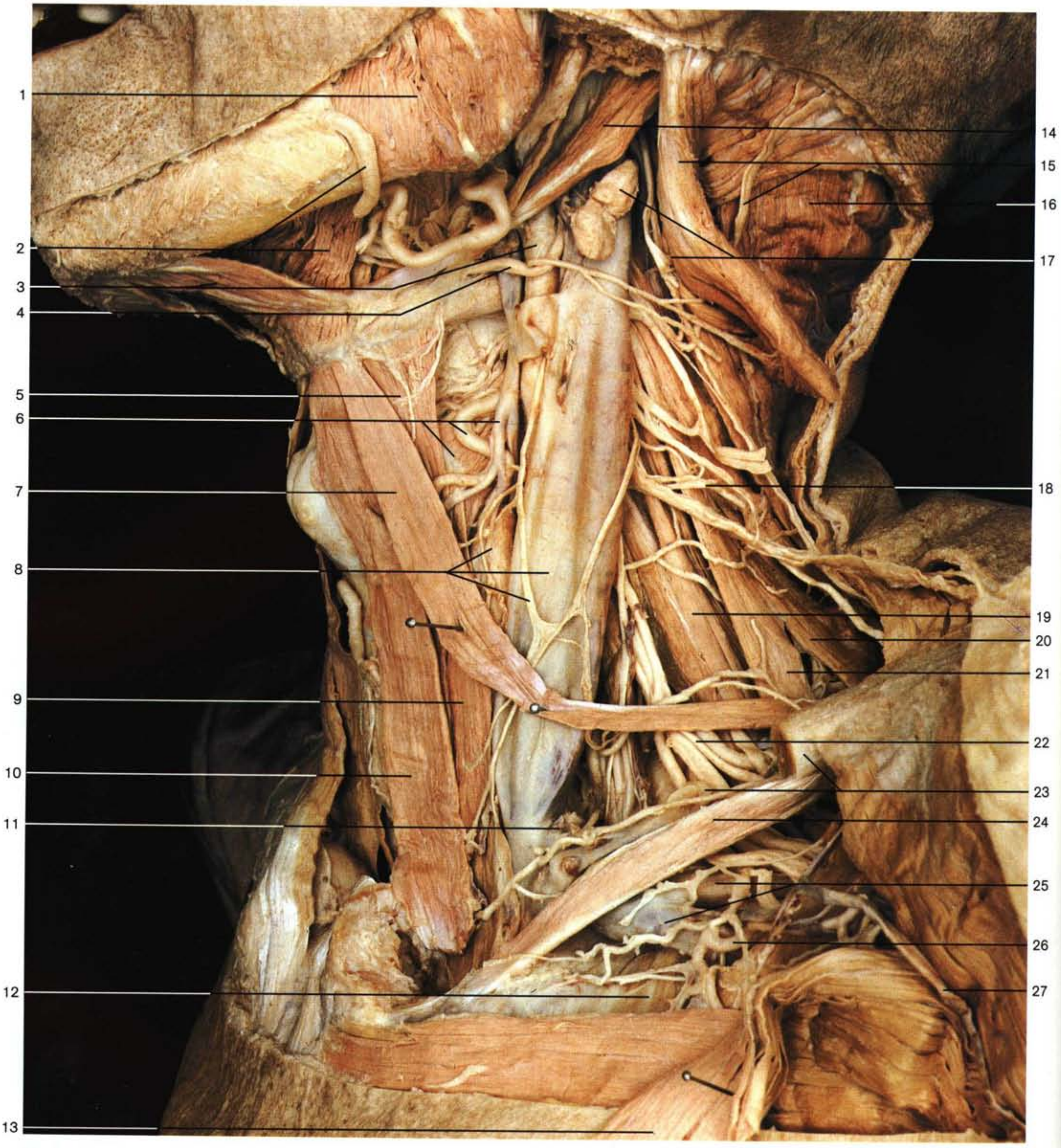

Neck, deeper dissection (lateral aspect). **Ansa cervicalis.** The cervical fascia and the clavicle are partly removed. Ansa cervicalis and infrahyoid muscles are displayed.

1 Masseter muscle
2 Mylohyoid muscle and facial artery
3 **External carotid artery** and anterior belly of digastric muscle
4 **Hypoglossal nerve**
5 Thyrohyoid muscle
6 Superior thyroid artery and vein and inferior pharyngeal constrictor muscle
7 Omohyoid muscle (superior belly)
8 **Ansa cervicalis,** thyroid gland and **internal jugular vein**
9 Sternothyroid muscle
10 Sternohyoid muscle
11 **Thoracic duct**
12 Pectoralis minor muscle
13 Pectoralis major muscle
14 Posterior belly of digastric muscle
15 Sternocleidomastoid muscle and lesser occipital nerve
16 Splenius capitis muscle
17 Superficial cervical lymph nodes and accessory nerve
18 **Cervical plexus**
19 Scalenus medius muscle
20 Levator scapulae muscle
21 Scalenus posterior muscle
22 Brachial plexus
23 Transverse cervical artery and clavicle
24 Subclavius muscle
25 **Subclavian artery and vein**
26 Thoracoacromial artery
27 Cephalic vein

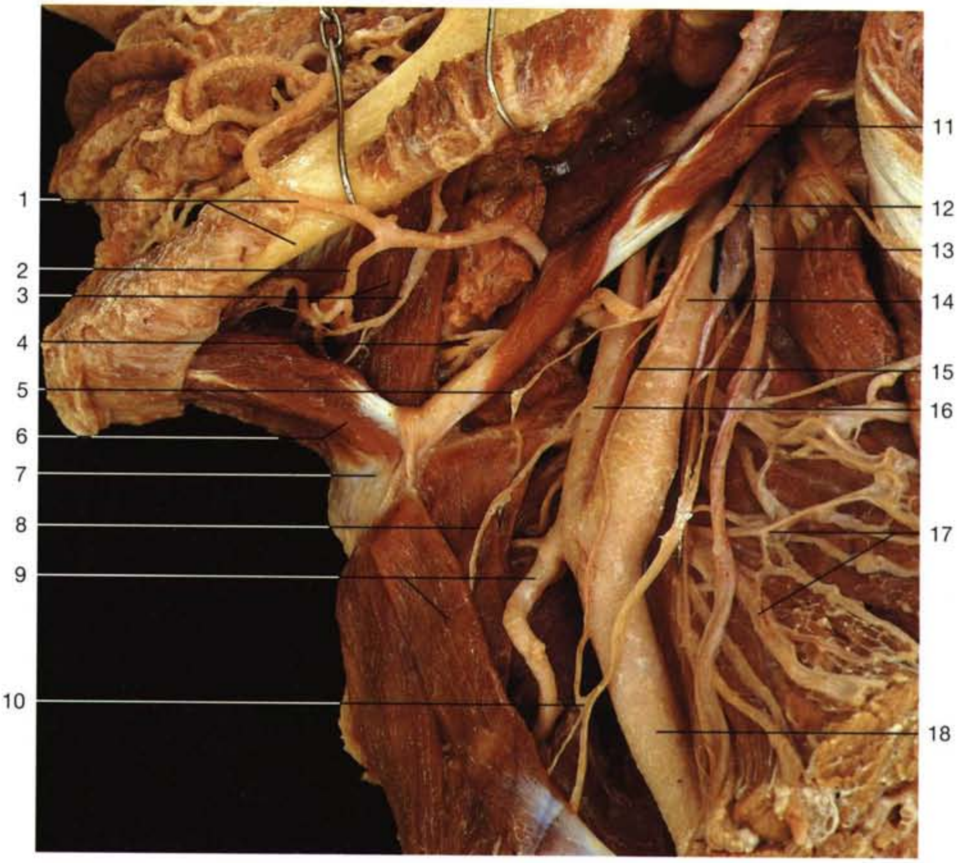

1 **Facial artery** and mandible
2 Submental artery
3 Mylohyoid muscle and nerve
4 **Hypoglossal nerve** (lingual branches)
5 Thyrohyoid branch of hypoglossal nerve (n. XII)
6 Anterior belly of digastric muscle
7 Hyoid bone
8 Omohyoid branch of hypoglossal nerve (n. XII)
9 Omohyoid muscle and superior thyroid artery
10 **Ansa cervicalis**
11 Posterior belly of digastric muscle
12 **Hypoglossal nerve** (n. XII)
13 **Vagus nerve** (n. X)
14 Internal carotid artery
15 Superior root of ansa cervicalis
16 **External carotid artery**
17 Cervical plexus
18 Common carotid artery

Neck, submandibular region (lateral aspect). **Hypoglossal nerve** (n. XII). Mandible slightly elevated.

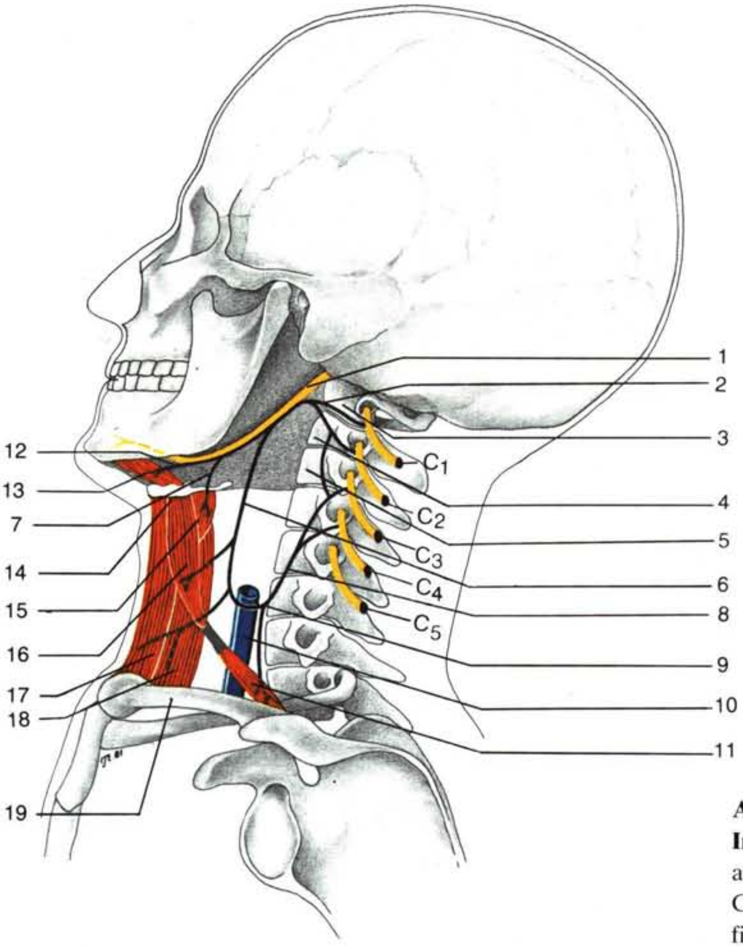

1 **Hypoglossal nerve** (n. XII)
2 Communication from the ventral ramus of the first cervical spinal nerve
3 Atlas
4 Axis
5 Third cervical vertebra
6 Superior root of ansa cervicalis
7 Thyrohyoid branch of hypoglossal nerve
8 Inferior root of ansa cervicalis
9 **Ansa cervicalis**
10 Internal jugular vein
11 Inferior belly of omohyoid muscle
12 Geniohyoid branch of hypoglossal nerve
13 Geniohyoid muscle
14 Hyoid bone
15 Thyrohyoid muscle
16 Superior belly of omohyoid muscle
17 Sternohyoid muscle
18 Sternothyroid muscle
19 Clavicle

Ansa cervicalis.
Innervation of infrahyoid muscles. Cervical plexus and its communication with the hypoglossal nerve. C_1–C_4 = ventral rami of cervical spinal nerves of the first four segments.

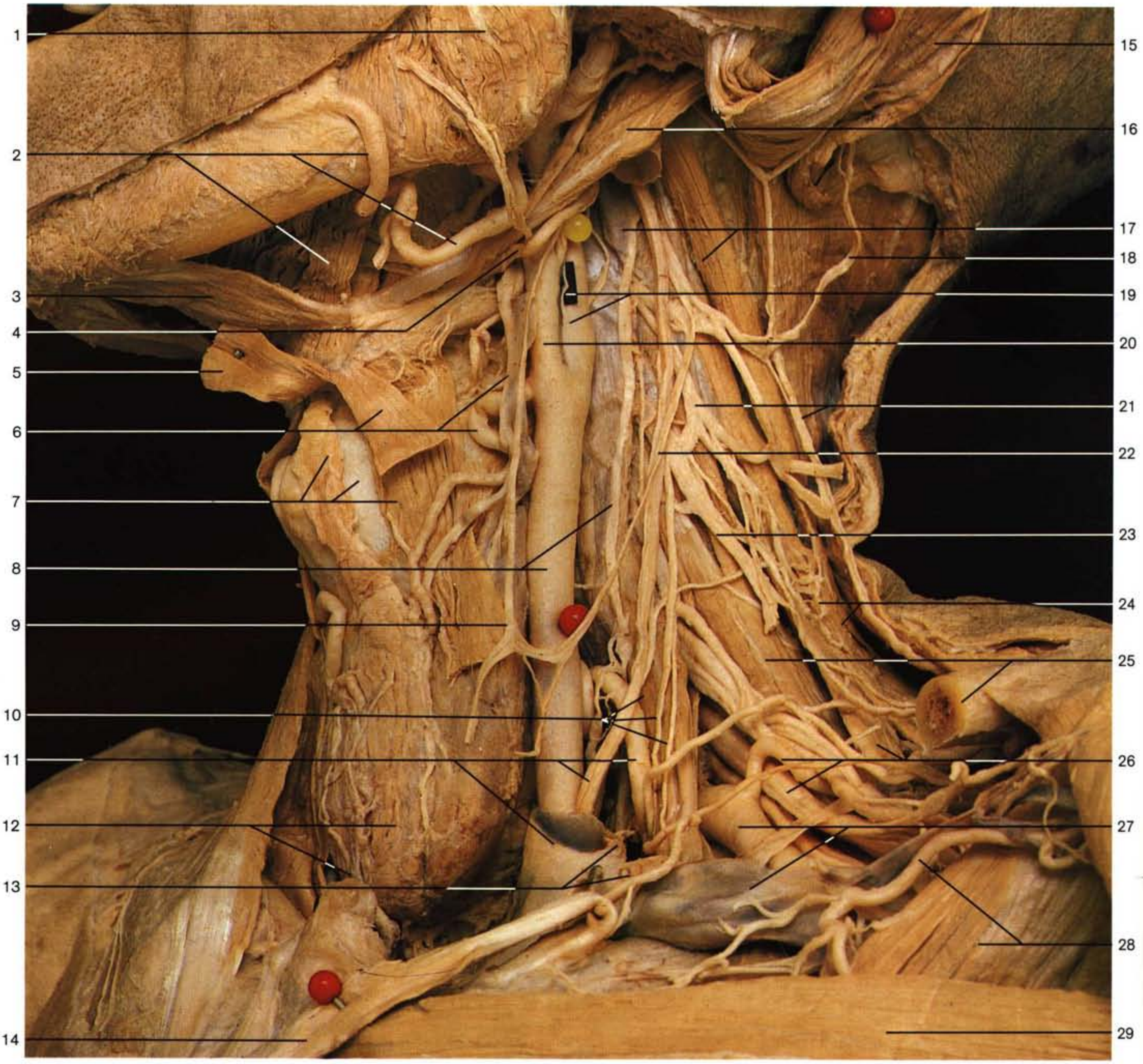

Neck, deep dissection (lateral aspect). Clavicle partly removed to show the slit between the scalenus muscles. Internal jugular vein removed.

1 Masseter muscle
2 Mylohyoid muscle and **facial artery**
3 Anterior belly of digastric muscle
4 **Hypoglossal nerve**
5 Sternohyoid muscle
6 Omohyoid muscle, superior thyroid artery and vein
7 Sternothyroid muscle, thyroid cartilage, and pyramidal lobe of thyroid gland
8 Common carotid artery and sympathetic trunk
9 **Ansa cervicalis**
10 **Phrenic nerve,** ascending cervical artery and anterior scalenus muscle
11 Inferior thyroid artery, vagus nerve and internal jugular vein (cut)
12 **Thyroid gland** and unpaired inferior thyroid venous plexus
13 Thoracic duct and left subclavian trunk
14 Subclavius muscle (reflected)
15 Sternocleidomastoid muscle (reflected)
16 Posterior belly of digastric muscle
17 **Superior cervical ganglion** and splenius muscle
18 **Lesser occipital nerve**
19 Internal carotid artery and branch of the glossopharyngeal nerve to the carotid body
20 **External carotid artery**
21 **Cervical plexus** and **accessory nerve**
22 Inferior root of ansa cervicalis
23 Supraclavicular nerve
24 Levator scapulae muscle
25 Scalenus medius muscle and clavicle
26 Transverse cervical artery, brachial plexus, and scalenus posterior muscle
27 **Subclavian artery and vein**
28 Thoracoacromial artery and pectoralis minor muscle
29 Pectoralis major muscle

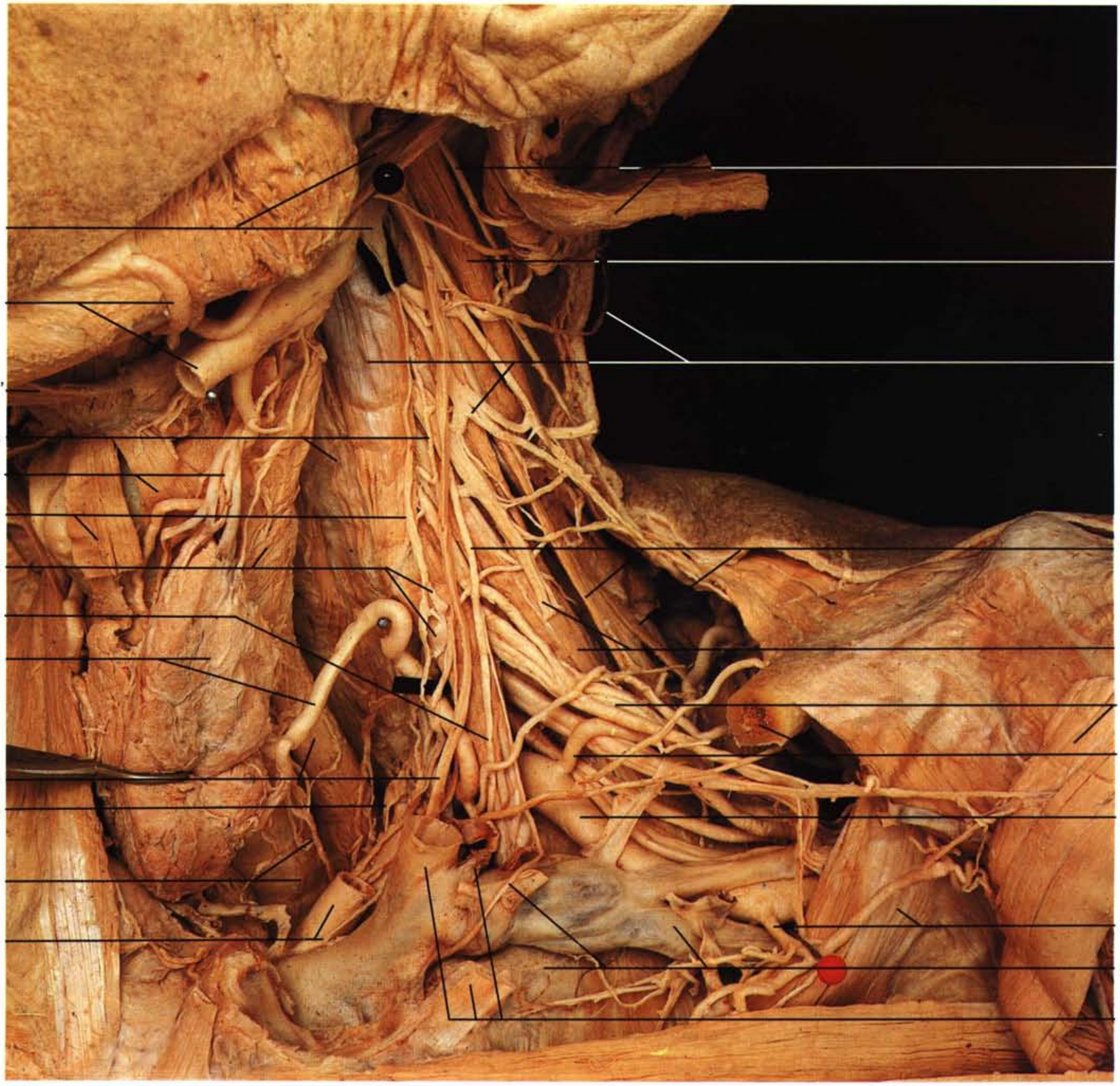

Neck, deepest dissection (anterolateral aspect). Thyroid gland reflected to expose the esophagus and the recurrent laryngeal nerve.

1 **Superior cervical ganglion** of sympathetic trunk and posterior belly of digastric muscle
1' Anterior belly of digastric muscle
2 **Facial artery** and common carotid artery (reflected anteriorly)
3 Ascending cervical artery and longus colli muscle
4 Omohyoid muscle and superior thyroid artery
5 **Sympathetic trunk** and sternohyoid muscle
6 Middle cervical ganglion and inferior pharyngeal constrictor muscle
7 Scalenus anterior muscle and phrenic nerve
8 **Thyroid gland** and **inferior thyroid artery**
9 Vagus nerve and esophagus
10 **Stellate ganglion**
11 **Recurrent laryngeal nerve** and trachea
12 Common carotid artery and cervical cardiac branch of vagus nerve
13 Sternocleidomastoid muscle and accessory nerve
14 Splenius capitis muscle
15 Lesser occipital nerve, longus capitis muscle and cervical plexus
16 **Phrenic nerve,** scalenus posterior muscle and levator scapulae muscle
17 Supraclavicular nerves and scalenus medius muscle
18 Brachial plexus and pectoralis major muscle (clavicular head)
19 Transverse cervical artery and clavicle
20 **Subclavian artery**
21 **Thoracoacromial artery** and pectoralis minor muscle
22 First rib, accessory phrenic nerve and subclavian vein
23 Internal jugular vein, thoracic duct and subclavius muscle

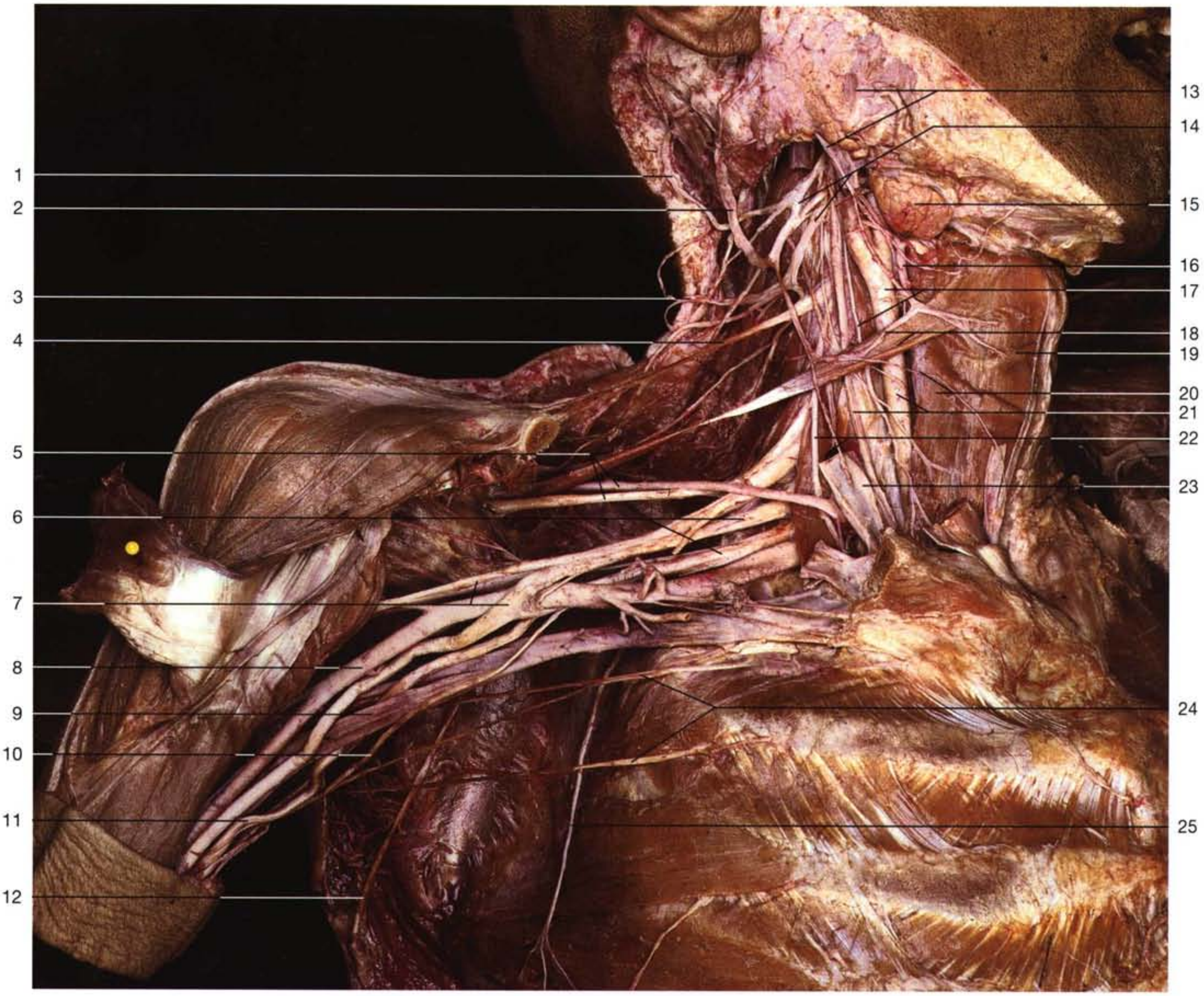

Neck and arm, deepest dissection (anterior-lateral aspect). Cervical and brachial plexus and their relation to the blood vessels are shown. Note the location and content of scalene triangle. Sternocleidomastoid muscle and clavicle have been removed; the internal jugular vein was divided to display the roots of cervical and brachial plexus.

1 Lesser occipital nerve
2 Great auricular nerve
3 Cutaneous branches of cervical plexus
4 Supraclavicular nerve
5 Suprascapular nerve and artery
6 **Brachial plexus**
7 **Median nerve** (with two roots) and musculocutaneous nerve
8 Axillary artery
9 Axillary vein
10 Medial brachial cutaneous nerve
11 **Ulnar nerve**
12 Thoracodorsal nerve
13 Parotid gland and facial nerve (cervical branch)
14 **Cervical plexus**
15 Submandibular gland
16 Superior thyroid artery
17 Common carotid artery dividing in internal and external carotid artery and superior root of ansa cervicalis
18 Omohyoid muscle and cervical branch of facial nerve joining the transverse cervical nerve (C_2, C_3)
19 Sternohyoid muscle
20 Transverse cervical nerve and sternothyroid muscle
21 **Common carotid artery** and **vagus nerve**
22 **Phrenic nerve** and scalenus anterior muscle
23 Internal jugular vein
24 Intercostobrachial nerves
25 Long thoracic nerve

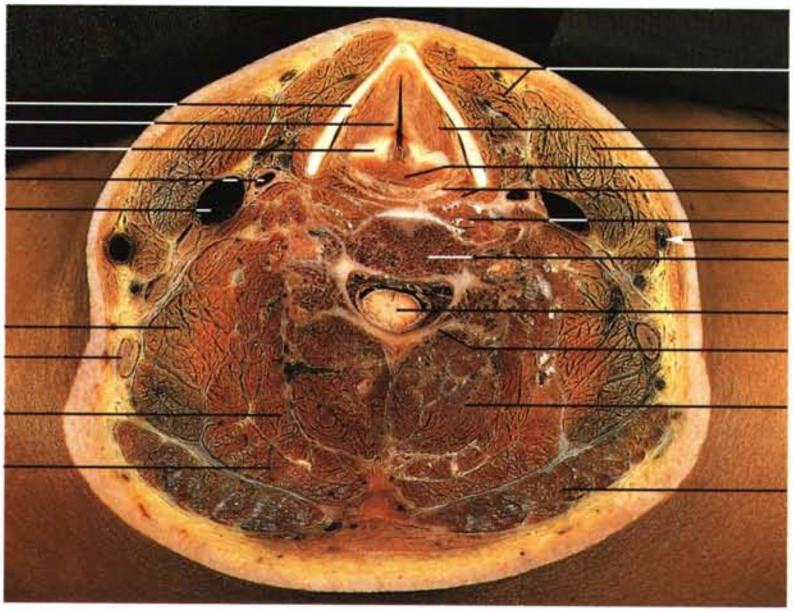

◁ **Horizontal section through the neck** at the level of the fissure of glottis, viewed from above.

1 **Thyroid cartilage**
2 **Vocal fold** and **glottis** (rima glottidis)
3 Arytenoid cartilage
4 Common carotid artery
5 **Internal jugular vein**
6 Infrahyoid muscles
7 Lateral thyroarytenoid muscle
8 Sternocleidomastoid muscle
9 Transverse arytenoid muscle
10 Laryngopharynx and inferior constricor muscle of pharynx
11 Longus colli muscle
12 External jugular vein
13 Body of cervical vertebra (C_5)
14 **Spinal cord**
15 Vertebra arch
16 Deep muscles of neck (semispinalis cervicis muscle)
17 Trapezius muscle
18 Rima glottidis
19 Levator scapulae muscle
20 Lymph node
21 Semispinalis capitis muscle
22 Splenius capitis muscle

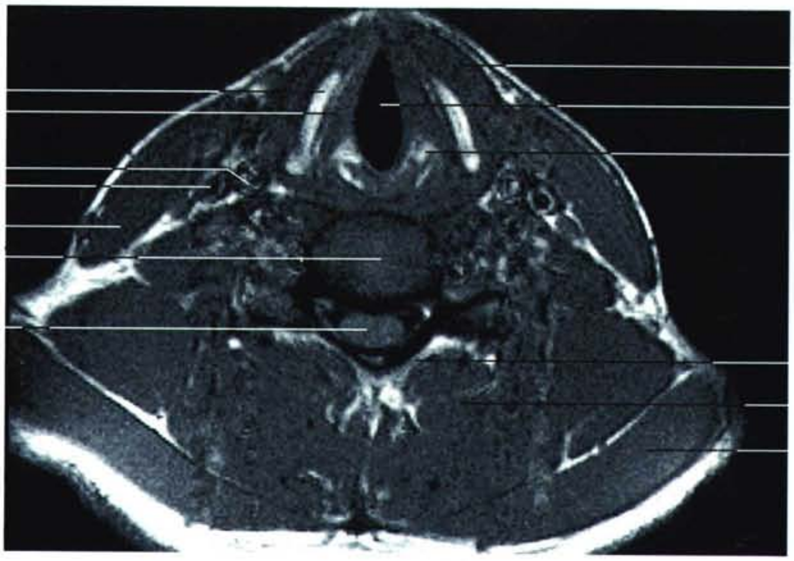

◁ **Section through the neck at the level of larynx.** (MR-Scan.)

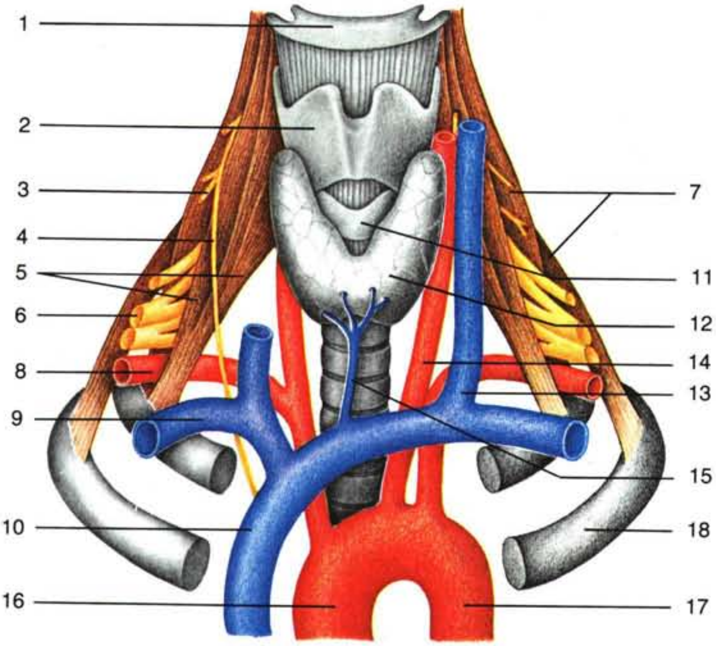

1 Hyoid bone
2 Thyroid cartilage
3 **Cervical plexus** (C_1-C_4)
4 **Phrenic nerve** (C_4)
5 Sealenus anterior muscle
6 **Brachial plexus** (C_5-T_1)
7 Scalenus medius and posterior muscles
8 Subclavian artery
9 Subclavian vein
10 Superior vena cava
11 Cricoid cartilage
12 Thyroid gland
13 **Internal jugular vein**
14 **Common carotid artery**
15 Inferior thyroid vein
16 Ascending aorta
17 Descending aorta
18 Second rib

◁ **Scalene triangle, arrangements of blood vessels, and brachial plexus at the lower part of the neck.** (Schematic diagram.)

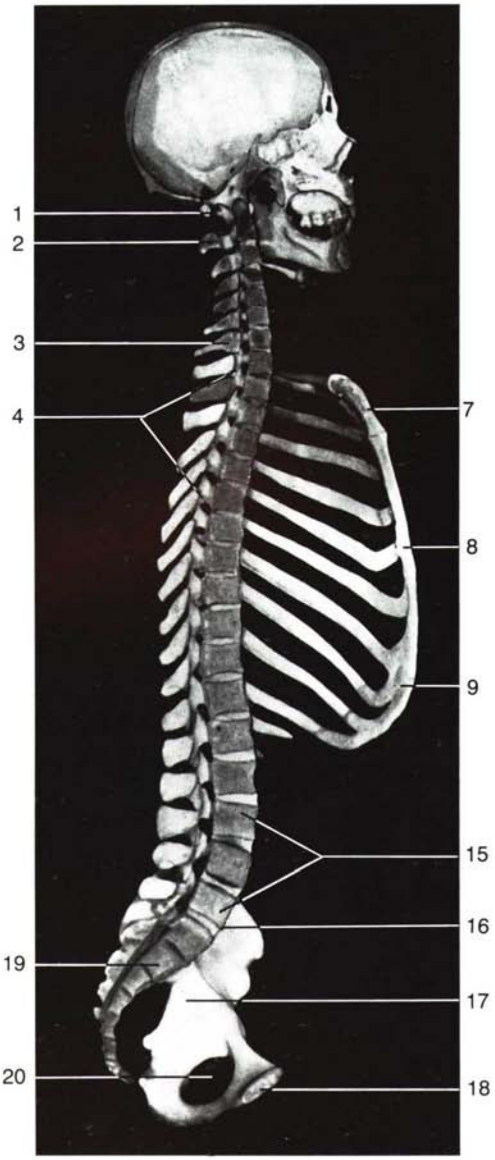

Median sagittal section through the vertebral column, head, and thorax of the adult.

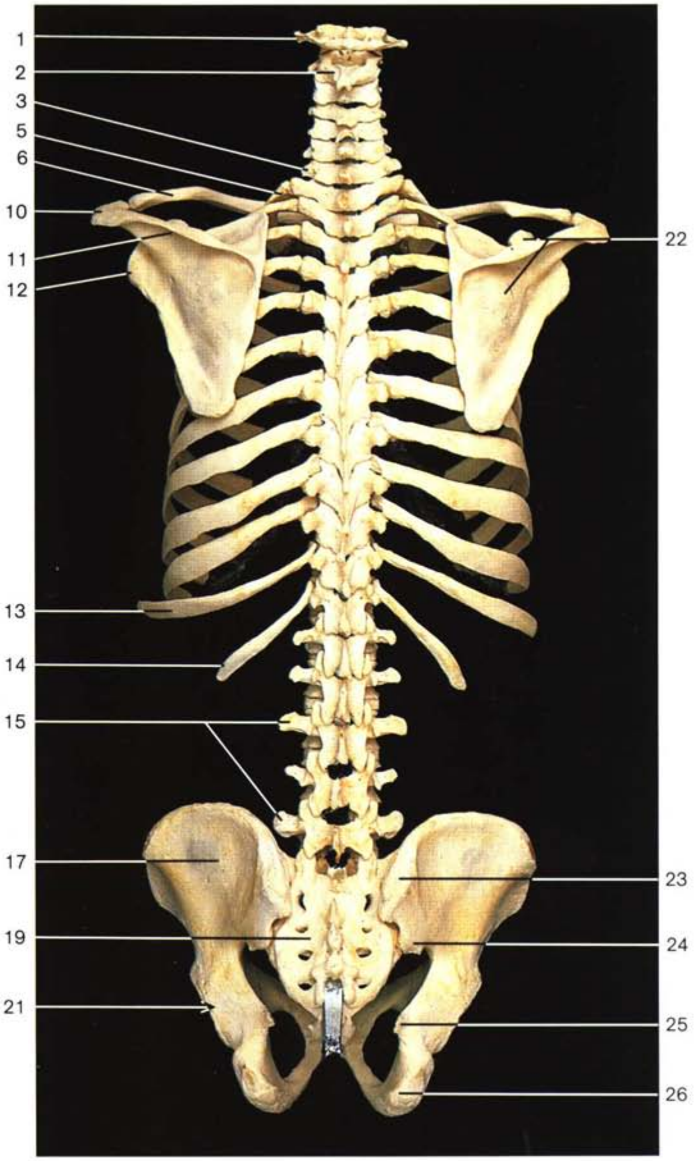

Skeleton of the trunk, vertebral column, thorax, and pelvis (posterior aspect).

1	Atlas	14	Twelfth rib
2	Axis	15	Lumbar vertebrae
3	Seventh cervical vertebra (vertebra prominens)	16	Sacral promontory
4	Vertebral canal	17	Hip bone
5	First rib	18	Symphysis pubis
6	Clavicle	19	Sacrum
7	Manubrium sterni	20	Obturator foramen
8	Body of sternum	21	Acetabulum
9	Costal arch	22	Scapula with coracoid process
10	Acromion	23	Posterior superior iliac spine
11	Spine of scapula	24	Posterior inferior iliac spine
12	Glenoid cavity (lateral angle of scapula)	25	Ischial spine
13	Eleventh rib	26	Ischial tuberosity

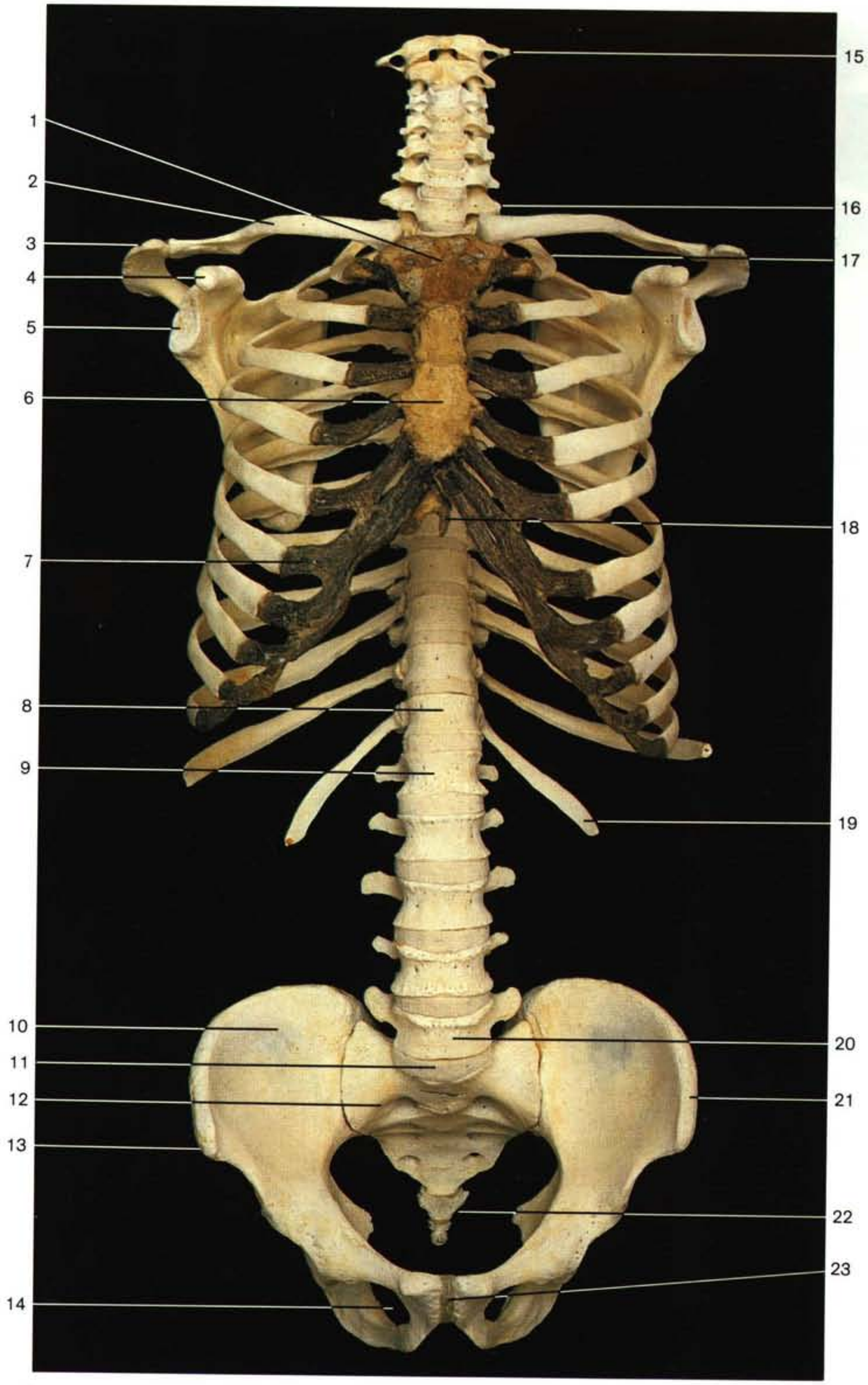

1 Manubrium sterni
2 **Clavicle**
3 Acromion
4 Coracoid process
5 Glenoid cavity
6 Body of **sternum**
7 Costal cartilage
8 Body of the twelfth **thoracic vertebra**
9 Body of the first **lumbar vertebra**
10 Hip bone
11 Sacral promontory
12 **Sacrum**
13 Anterior superior iliac spine
14 Obturator foramen
15 Atlas
16 Seventh **cervical vertebra**
17 First rib
18 Xiphoid process
19 Twelfth rib
20 Body of the fifth lumbar vertebra
21 Iliac crest
22 **Coccyx**
23 Symphysis pubis

Skeleton of the trunk, vertebral column, pelvis, thorax, and shoulder girdle (anterior aspect).

The trunk is divided into segments best visible in the thoracic region, where each segment consists of a pair of ribs connected anteriorly by the sternum and posteriorly by a thoracic vertebra. In the lumbar part of the vertebral column only vestiges of ribs are present which form what appear to be the transverse processes. In cervical vertebrae, remnants of ribs are part of the transverse processes. Each segment also comprises muscles (e.g. intercostal muscles), nerves, and vessels. However, in the cervical and lumbar region the muscular segments fuse with each other forming large muscle plates, for example, the oblique muscles of the abdomen, while vessels and nerves still retain their segmental pattern.

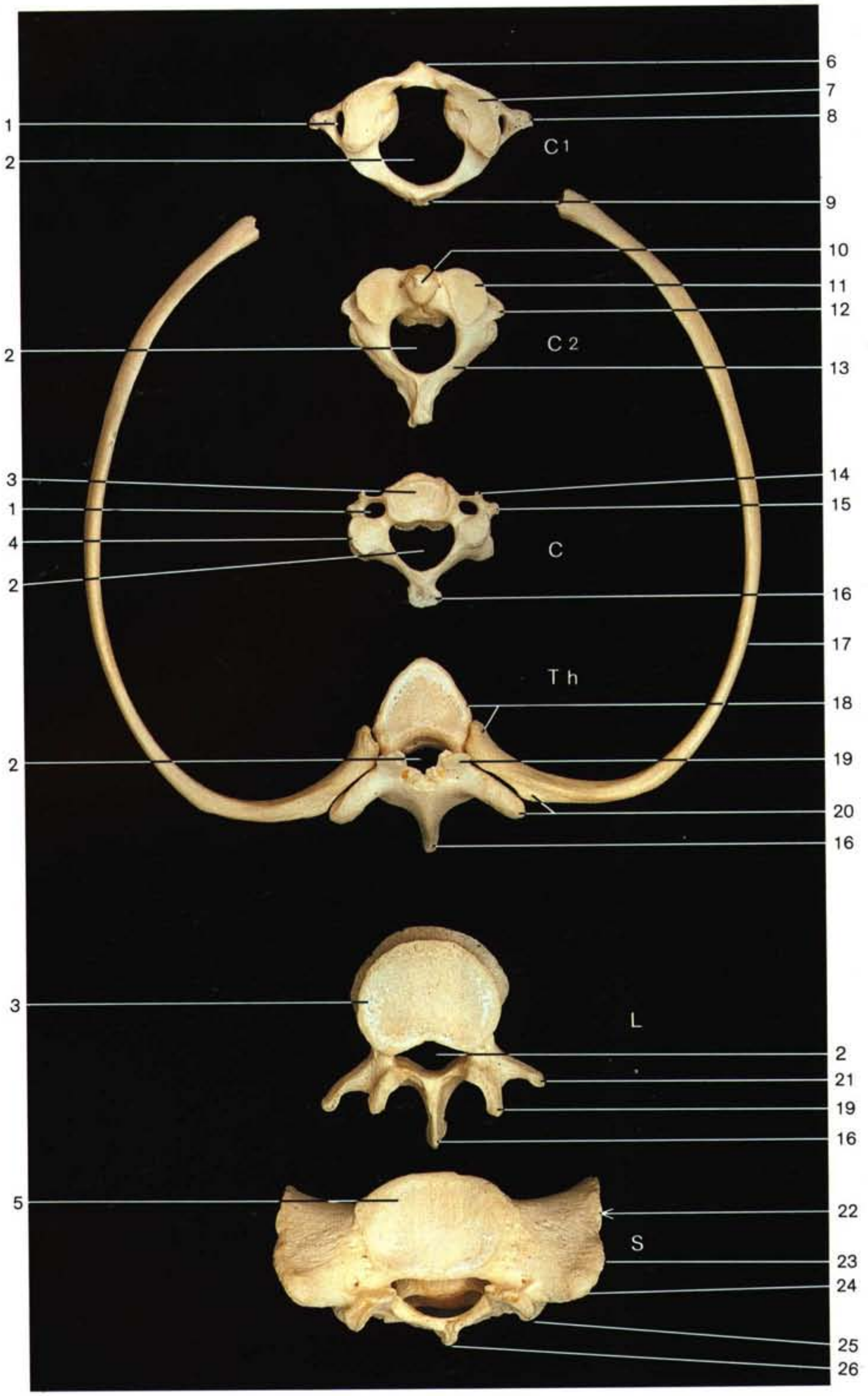
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Representative vertebrae from each region of the vertebral column (superior aspect). From top to bottom: atlas (C_1), axis (C_2), cervical vertebra (C), thoracic vertebra (Th), lumbar vertebra (L), and sacrum (S).

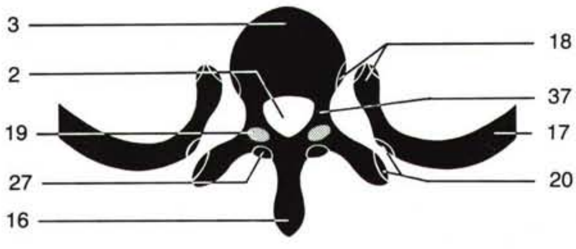
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General organization of ribs and vertebrae. (Schematic diagram.)

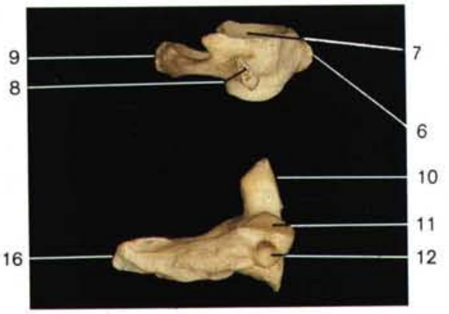
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Atlas and axis

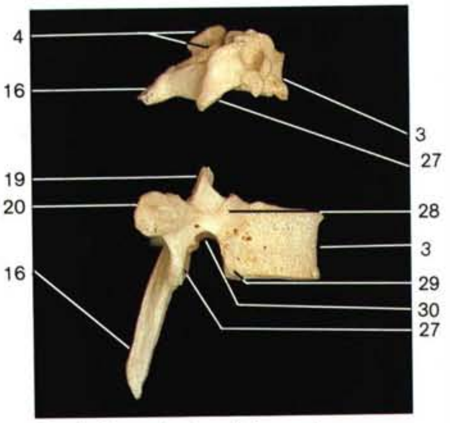
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Typical cervical and thoracic vertebrae

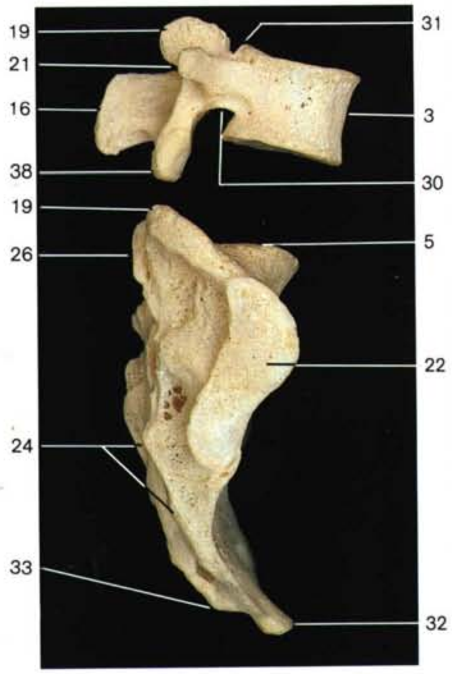
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Typical lumbar vertebra and sacrum

Representative vertebrae from each region of the vertebral column (lateral aspect, ventral surface on the right).

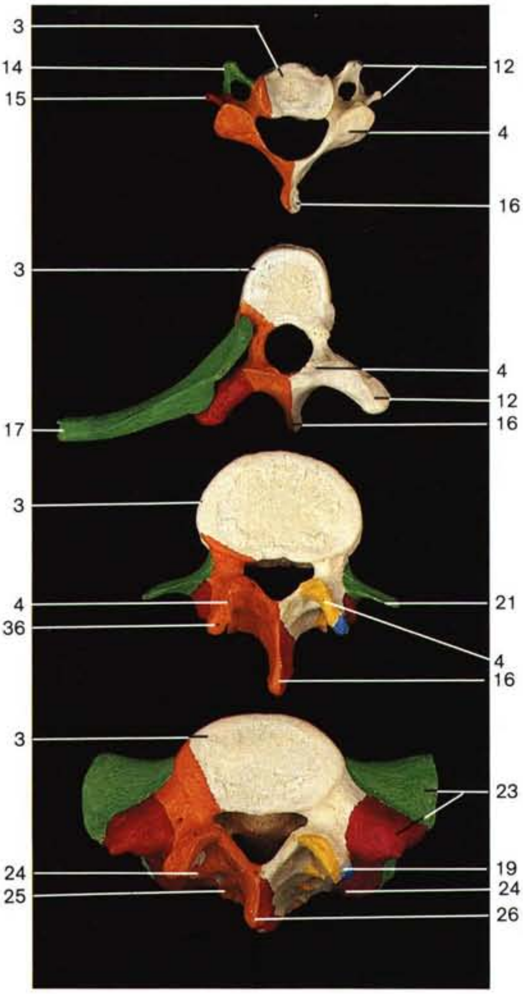

General characteristics of the vertebrae. Typical cervical, thoracic, lumbar vertebrae and sacrum.

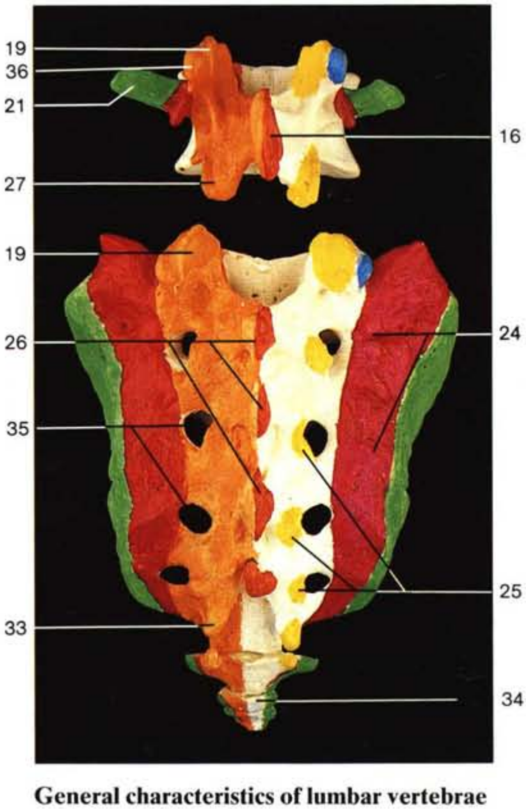

General characteristics of lumbar vertebrae and sacrum (posterior aspect).

1 Foramen transversarium
2 Vertebral foramen
3 Body of vertebra
4 Superior articular facet
5 Base of sacrum
6 Anterior tubercle of atlas
7 Superior articular facet of atlas
8 Transverse process
9 Posterior tubercle of atlas
10 Dens of axis
11 Superior articular surface
12 Transverse process
13 Arch of vertebra
14 Anterior tubercle of transverse process
15 Posterior tubercle of transverse process
16 Spinous process
17 Shaft of rib
18 Body of vertebra and head of rib articulating with each other (costovertebral joint)
19 Superior articular process
20 Transverse process and tubercle of rib articulating with each other (costotransverse joint)
21 Transverse process
22 Auricular surface
23 Lateral part of sacrum
24 Lateral sacral crest
25 Intermediate sacral crest
26 Median sacral crest
27 Inferior articular facet
28 Superior demifacet for head of rib
29 Inferior demifacet for head of rib
30 Inferior vertebral notch
31 Superior vertebral notch
32 Apex of the sacrum
33 Sacral cornu
34 Coccyx
35 Dorsal sacral foramina
36 Mamillary process
37 Pedicle
38 Inferior articular process

Green = Ribs or homologous processes
Red = Muscular processes (transverse and spinous processes)
Orange = Laminae and articular processes
Yellow = Articular facets

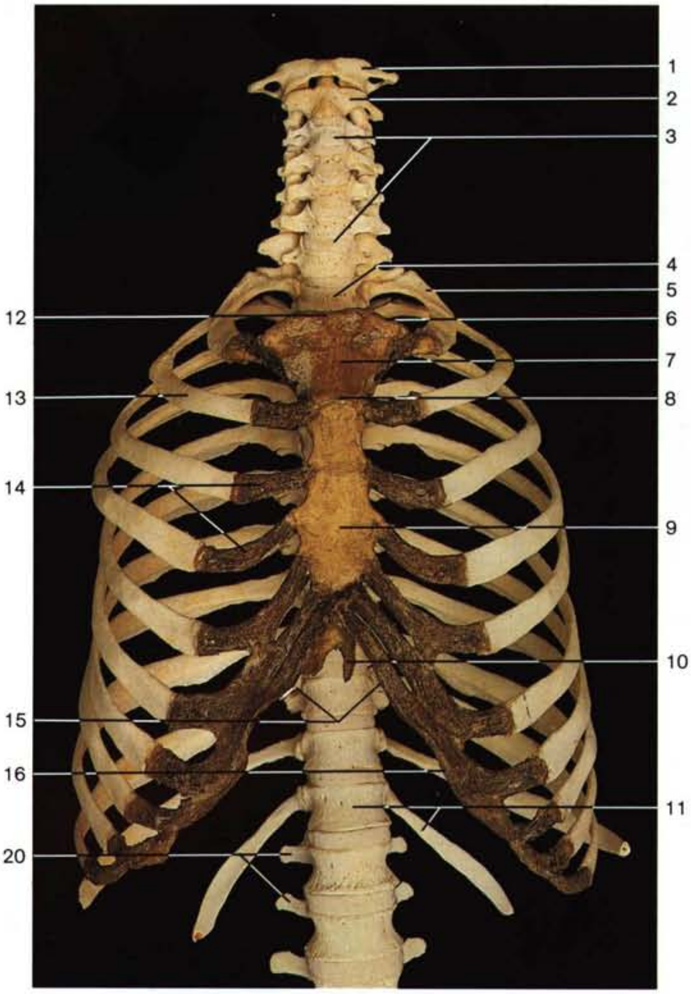

Skeleton of the thorax (anterior aspect).

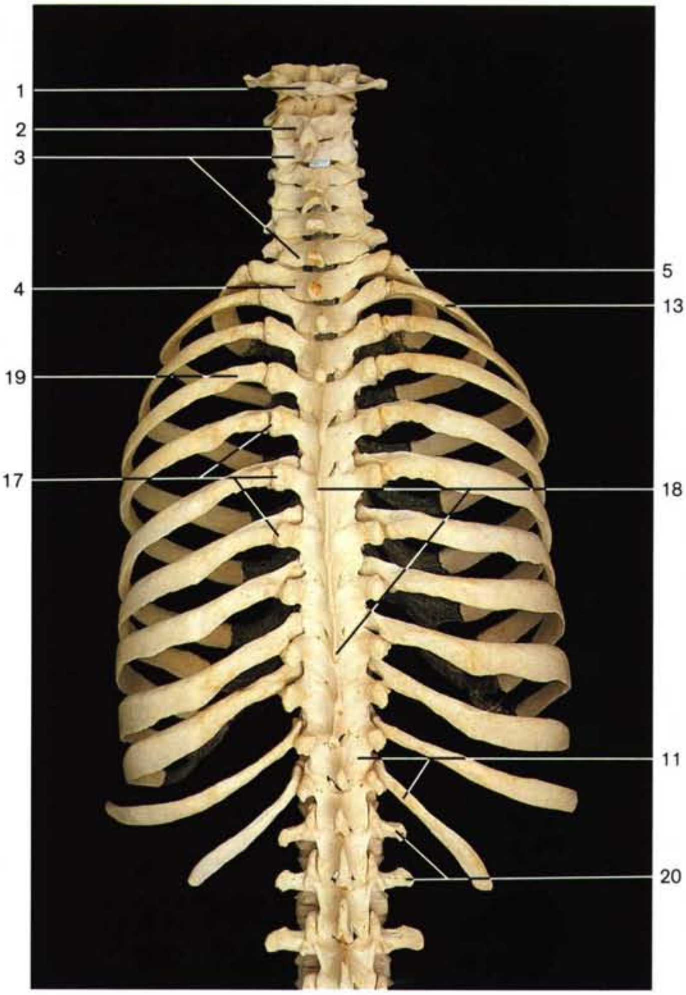

Skeleton of the thorax (posterior aspect).

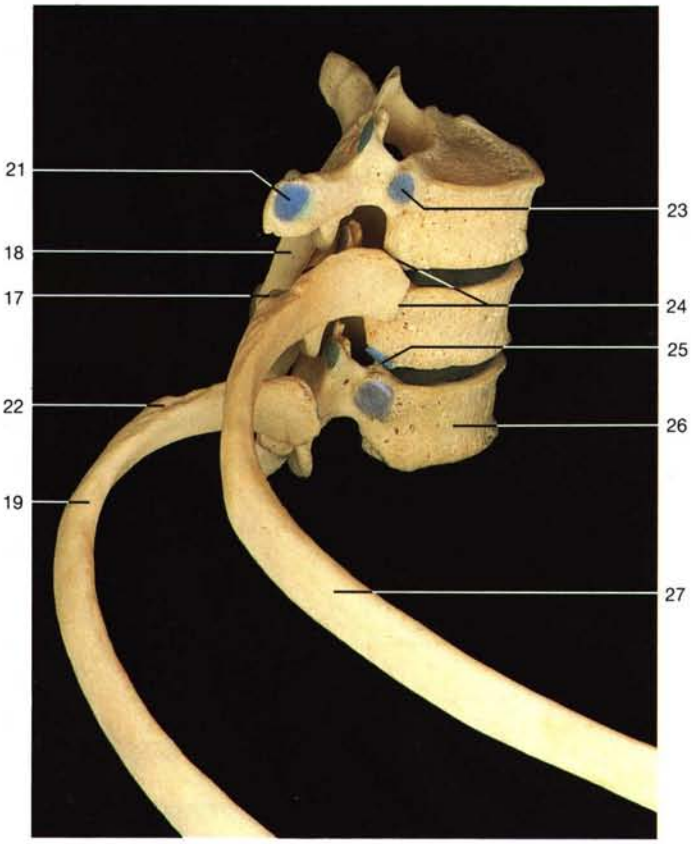

Costovertebral articulation (right lateral aspect).

1 Atlas
2 Axis
3 **Cervical vertebrae**
4 First thoracic vertebra
5 First rib
6 Facet for clavicle and clavicular notch
7 **Manubrium sterni**
8 Sternal angle
9 Body of sternum
10 Xiphoid process
11 Twelfth thoracic vertebra and rib
12 Jugular notch
13 Second rib
14 **Costal cartilages**
15 Infrasternal angle
16 **Costal arch**
17 Costotransverse joints between the transverse processes of thoracic vertebra and the tubercles of the ribs
18 Spinous processes
19 Costal angle
20 Transverse processes of lumbar vertebrae
21 Facet for articulation with rib
22 Tubercle of rib
23 Superior facet for articulation with head of rib
24 Articulation of head of rib with two vertebrae
25 Inferior facet for articulation with head of rib
26 Body of thoracic vertebra
27 Body or shaft of rib

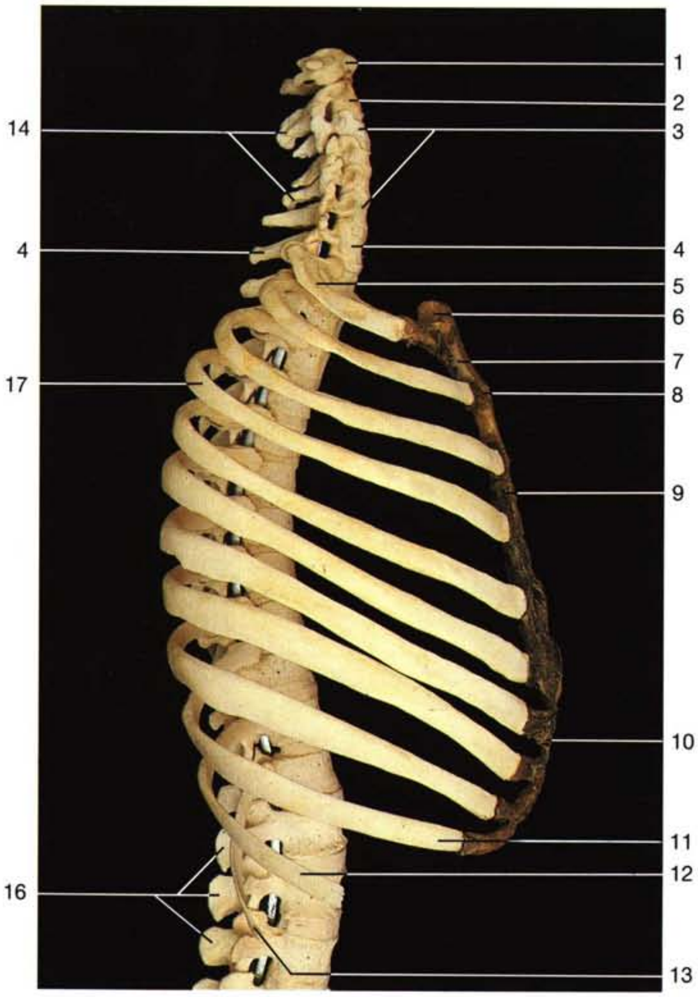
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Skeleton of the thorax (right lateral aspect).

1 Atlas
2 Axis
3 **Cervical vertebrae**
4 Seventh cervical vertebra (vertebra prominens)
5 First rib
6 Facet for clavicle
7 **Manubrium sterni**
8 Sternal angle
9 Body of sternum
10 Costal arch
11 Tenth rib
12 Eleventh rib
13 Twelfth rib
14 Spinous processes of cervical vertebrae
15 Spinous processes of thoracic vertebrae
16 Spinous processes of lumbar vertebrae
17 Costal angle
18 Intervertebral foramina
19 Intervertebral discs
20 **Cervical curvature**
21 **Thoracic curvature**
22 **Lumbar curvature**
23 Sacrum
24 Coccyx

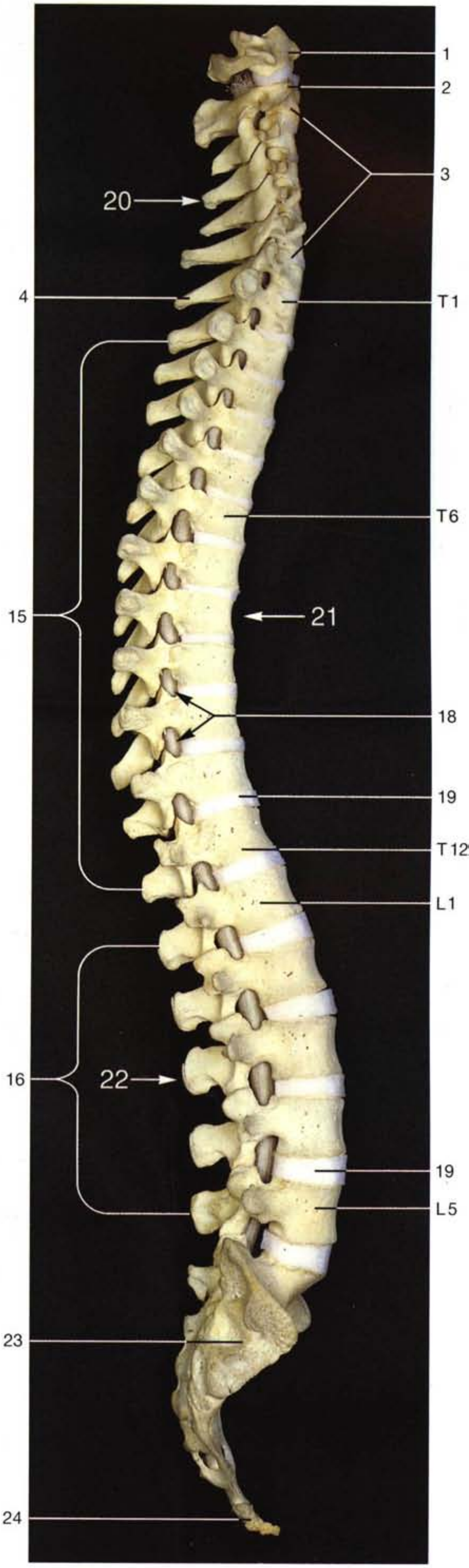
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Vertebral column (right lateral aspect).

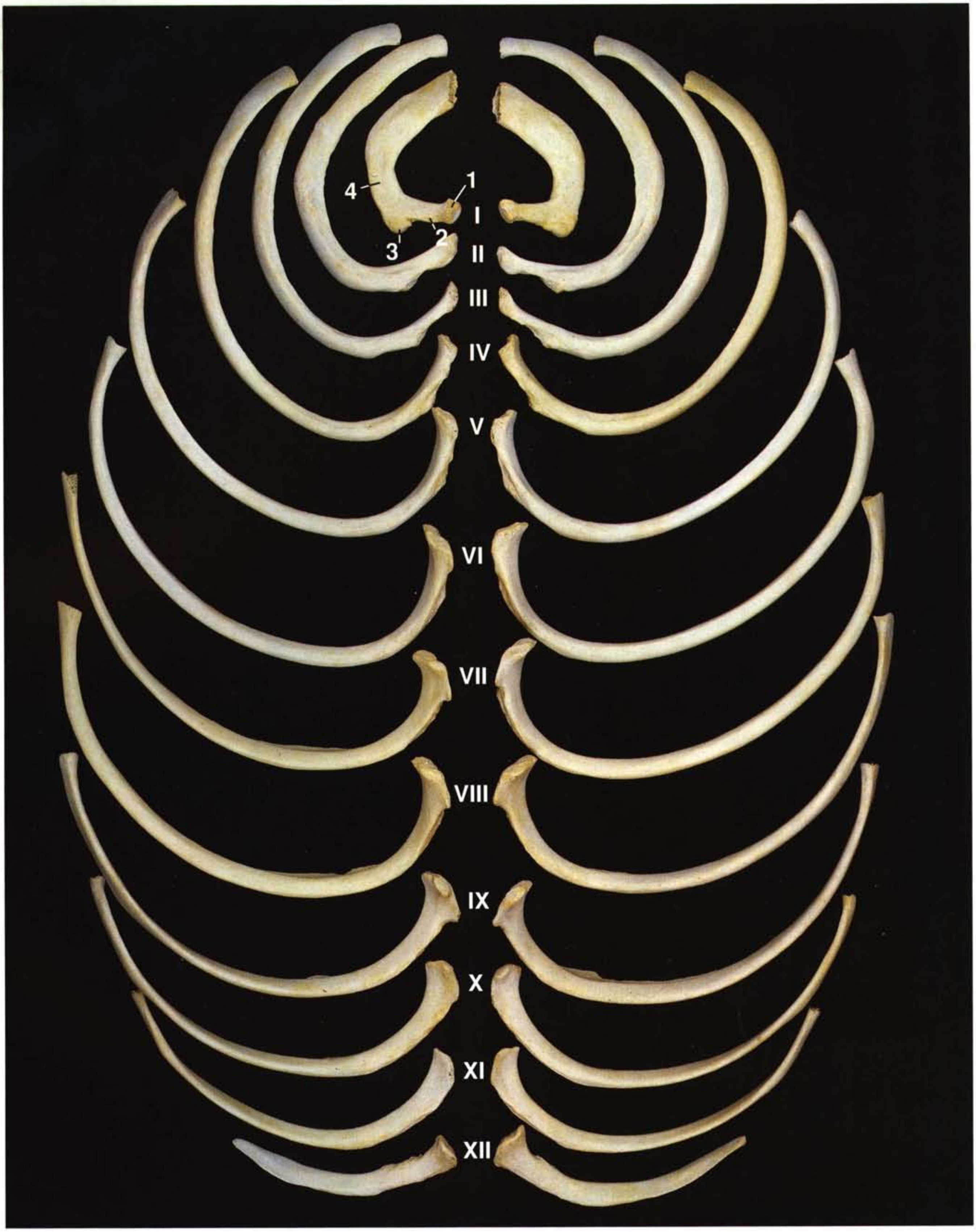

Disarticulated ribs. The twelve ribs arranged in a craniocaudal direction, first rib at top. I–XII = pairs of ribs; 1 = head of rib; 2 = neck of rib; 3 = tubercle of rib; 4 = body of rib.

The head of a typical rib articulates with the bodies of adjacent vertebrae and the intervening intervertebral disc. The first seven ribs are directly connected through the costal cartilages (not depicted) to the sternum (true ribs) while the remaining five ribs are only indirectly connected to the sternum (false ribs, ribs VIII to X) or end freely in the lateral wall of the trunk (floating ribs, ribs XI and XII).

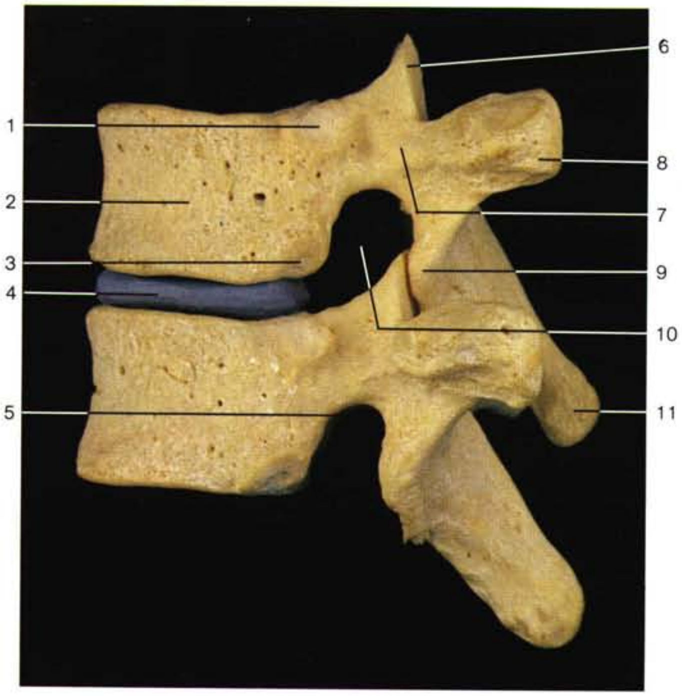

Two **thoracic vertebrae** (left lateral aspect).

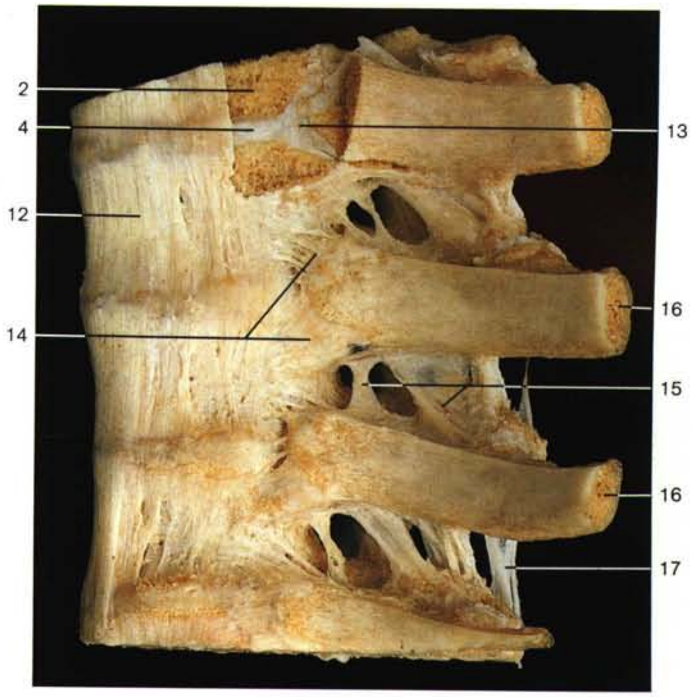

Ligaments of thoracic vertebrae and costovertebral joints (left anterolateral aspect).
In the upper joint, most of the radiate ligament and the anterior part of the head of the rib have been removed to expose the two joint cavities and the interposed intra-articular ligament.

1 Superior demifacet for head of rib
2 Body of vertebra
3 Inferior demifacet for head of rib
4 Intervertebral disc
5 Inferior vertebral notch
6 Superior articular facet and superior articular process
7 Pedicle
8 Transverse process and facet for tubercle of rib
9 Inferior articular process
10 Intervertebral foramen
11 Spinous process
12 Anterior longitudinal ligament
13 Intraarticular ligament
14 Radiate ligament
15 Superior costotransverse ligament
16 Body of rib
17 Intertransverse ligament

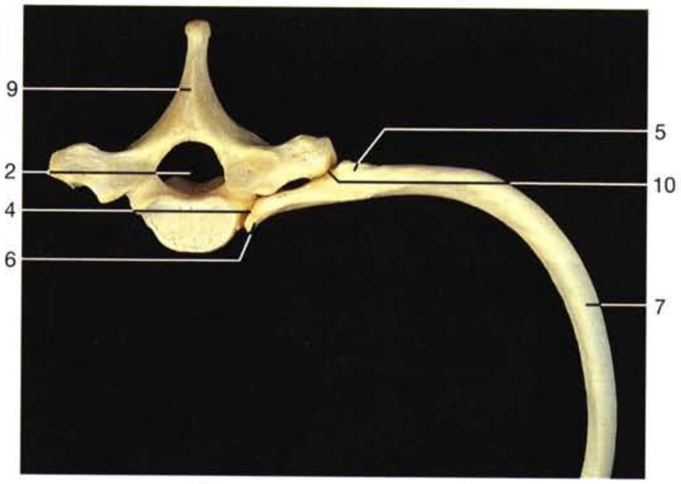

Location of costovertebral joints (superior aspect).

Costovertebral joints. Two thoracic vertebrae with an articulating rib (separated). Axis of movement indicated by dotted line. Blue = articular facets. (Schematic diagram.)

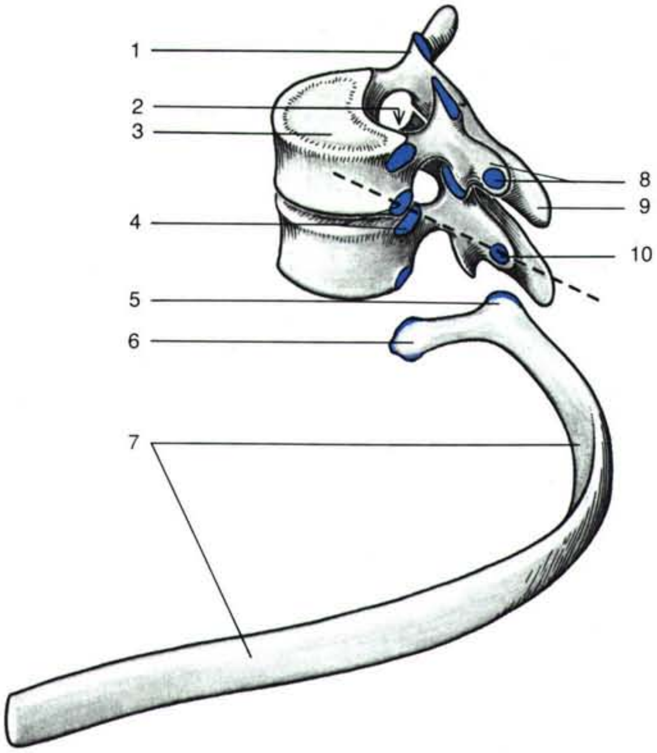

1 Superior articular process
2 Vertebral canal
3 Body of thoracic vertebra
4 Costovertebral joint (articular facets)
5 Tubercle of rib
6 Head of rib
7 Shaft or body of rib
8 Transverse process with articular facet
9 Spinous process
10 Costotransverse joint (articular facets)

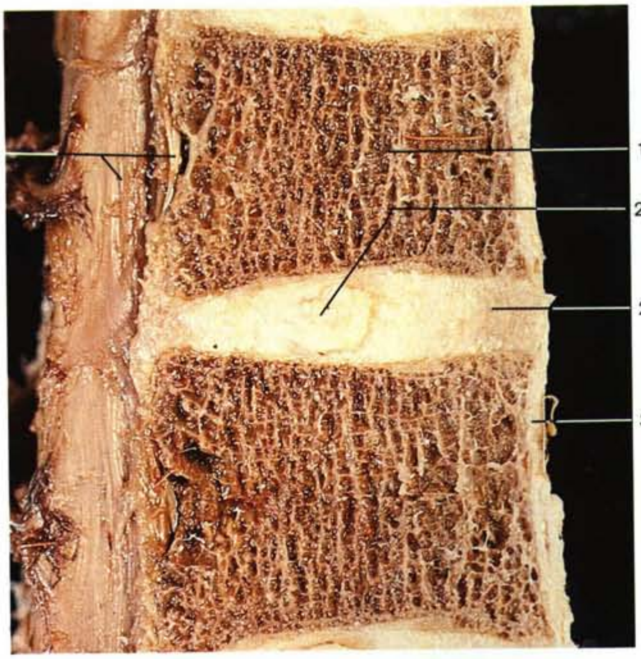

Median-sagittal section of the bodies of the vertebrae showing the **intervertebral discs,** each of which consists of an outer laminated portion and an inner core.

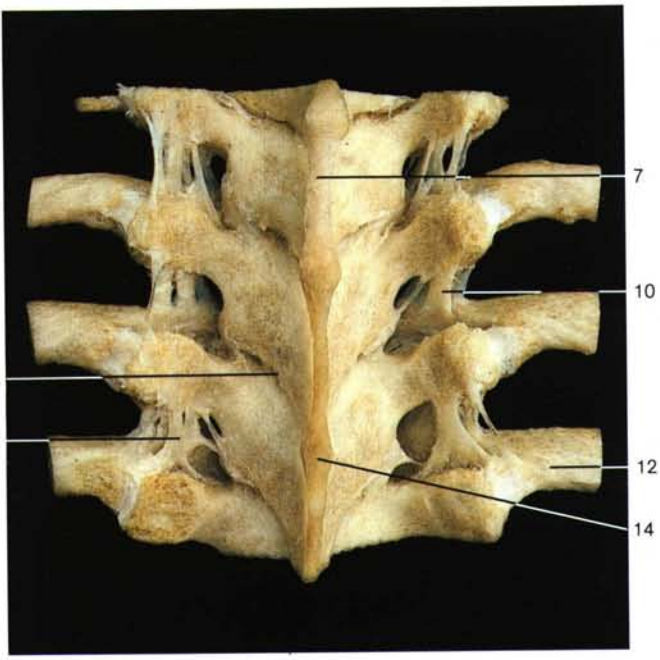

Ligaments of the vertebral column (dorsal aspect).

1 Body of vertebra
2 **Intervertebral disc**
  a Outer portion (anulus fibrosus)
  b Inner core **(nucleus pulposus)**
3 Anterior longitudinal ligament
4 Posterior longitudinal ligament and spinal dura mater
5 Transverse process of lumbar vertebra
6 Sacrum
7 **Supraspinous ligament**
8 Interspinous ligament
9 **Intertransverse ligament**
10 Superior costotransverse ligament
11 Transverse process of thoracic vertebra
12 Rib
13 **Ligamentum flavum**
14 Spinous process
15 Intervertebral foramen

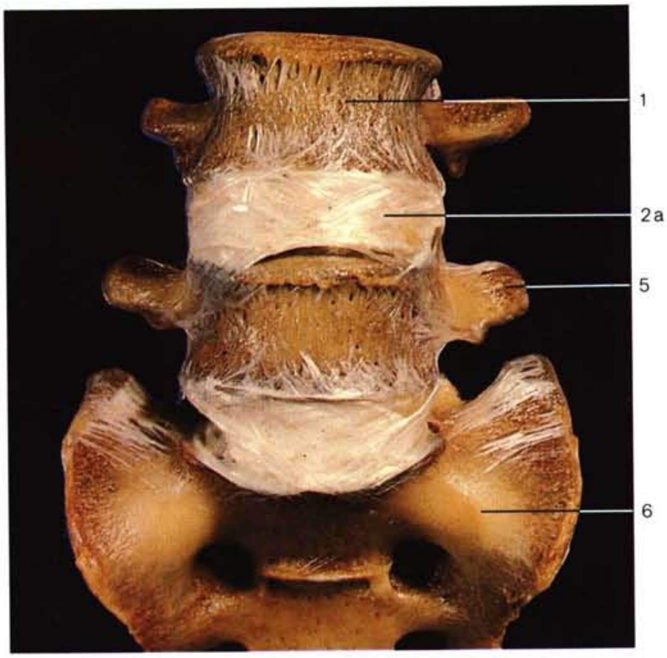

The two caudal lumbar vertebrae and the sacrum with their intervertebral discs (anterior aspect). Anterior longitudinal ligament removed.

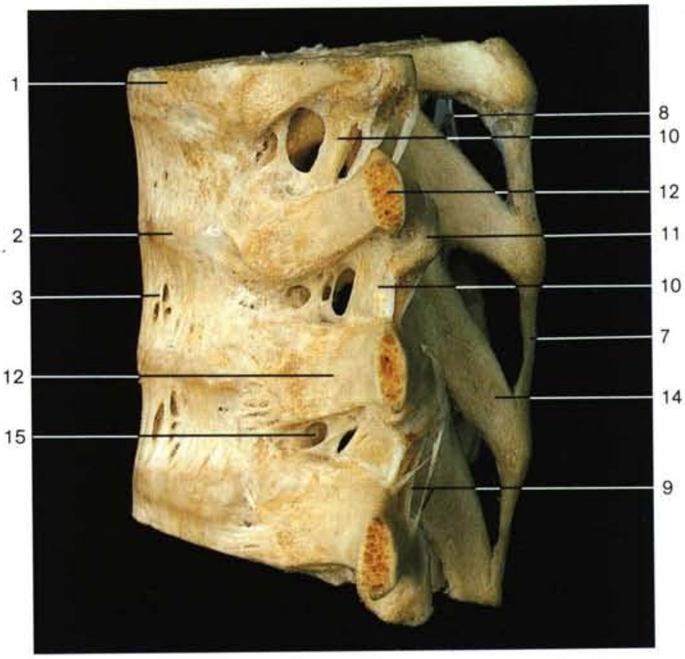

Ligaments of the vertebral column, thoracic part (left lateral aspect).

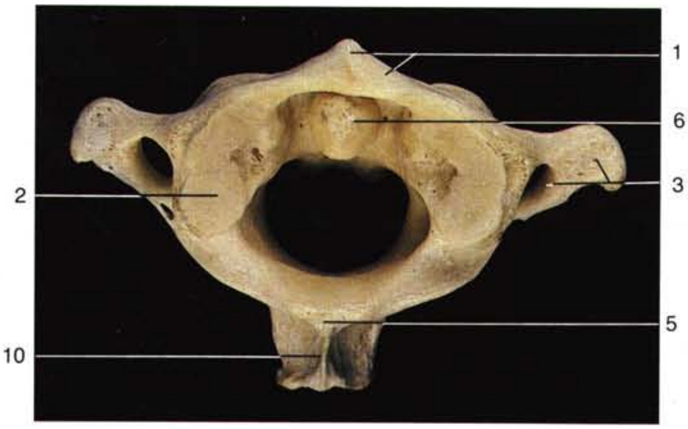

Atlas and axis (from above).

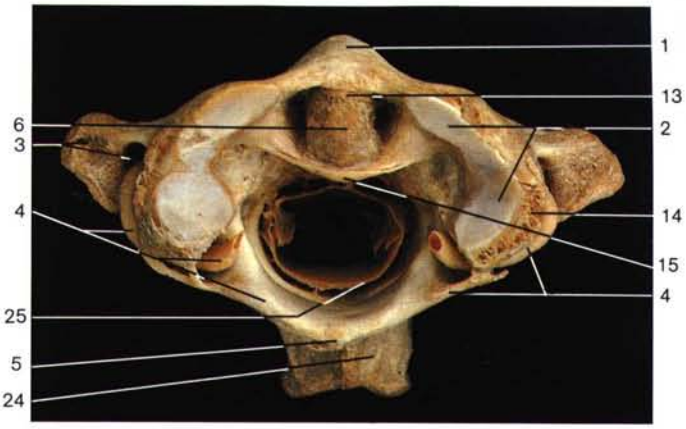

Median atlantoaxial joint and transverse ligament of atlas (from above). Dens of axis partly severed.

1 Anterior arch of **atlas** with anterior tubercle
2 Superior articular facet of atlas
3 **Foramen transversarium** and transverse process
4 Posterior arch of atlas and vertebral artery
5 Posterior tubercle of atlas
6 **Dens of axis**
7 Superior articular surface of axis
8 Body of axis
9 Pedicle and lamina of axis
10 Spinous process
11 Inferior articular process
12 Transverse process and vertebrarterial foramen (foramen transversarium)
13 **Median atlantoaxial joint** (anterior part)
14 Articular capsule of **atlantooccipital joint**
15 Transverse ligament of atlas
16 Occipital bone
17 **Atlantooccipital joint**
18 **Lateral atlantoaxial joint**
19 Third cervical vertebra
20 Superior longitudinal band of cruciform ligament
21 Alar ligaments
22 Transverse ligament of atlas
23 Inferior longitudinal band of cruciform ligament
24 Spinous process of axis
25 Dura mater

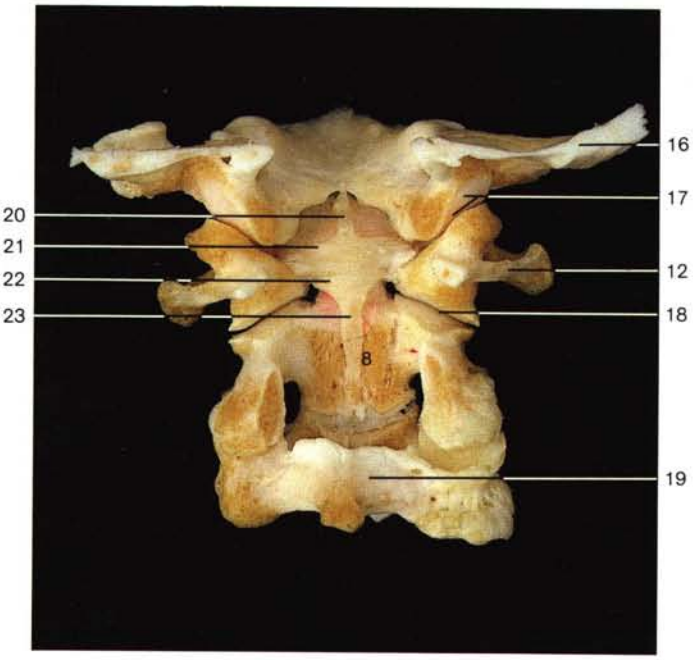

Atlantooccipital and atlantoaxial joints (posterior aspect). Posterior part of occipital bone, posterior arch of atlas and axis have been removed to show the cruciform ligament.

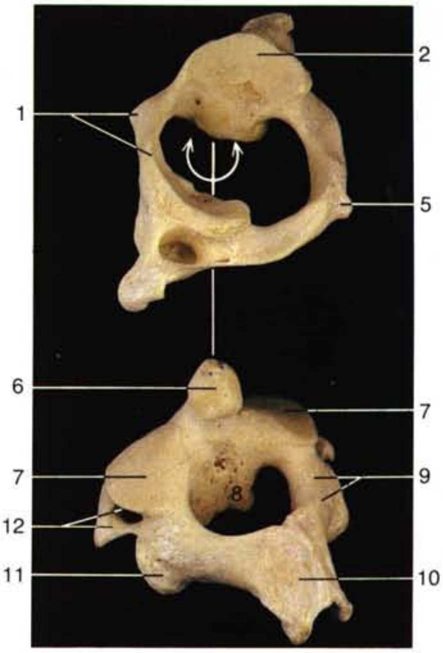

Atlas and axis. Left oblique posterolateral aspect, demonstrating the articulation of the dens of axis with atlas (cf. arrows).

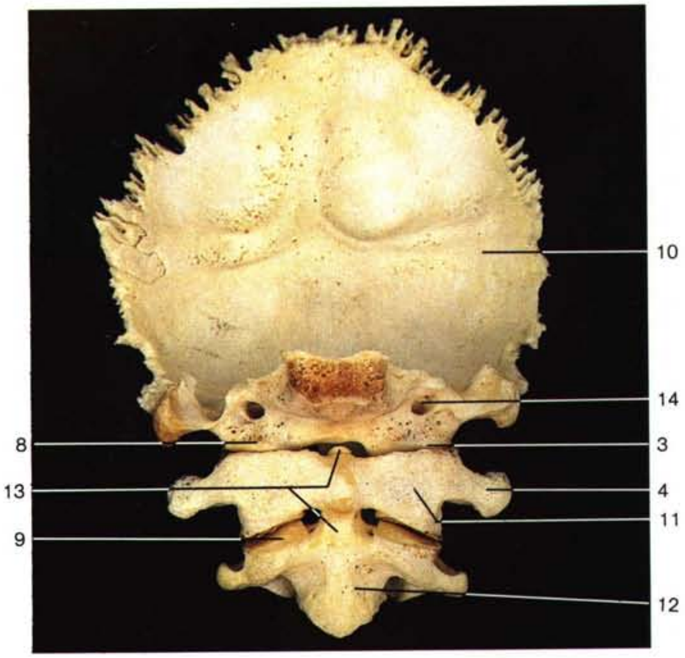

Occipital bone, atlas and axis (anterior aspect).

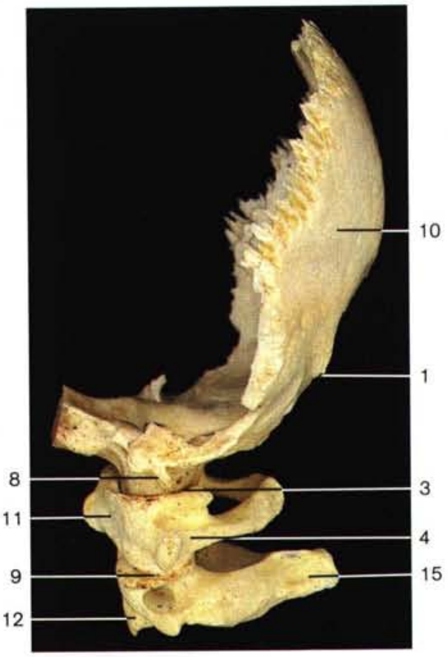

Occipital bone, atlas and axis (left lateral aspect).

1 External occipital protuberance
2 Foramen magnum
3 Atlantooccipital joint
4 Transverse process of atlas
5 Membrana tectoria
6 Posterior longitudinal ligament
7 Spinous process of third cervical vertebra
8 Occipital condyle
9 Lateral atlantoaxial joint
10 Occipital bone
11 Atlas
12 Axis
13 Dens of axis
14 Hypoglossal canal
15 Spinous processes of axis
16 Anterior longitudinal ligament

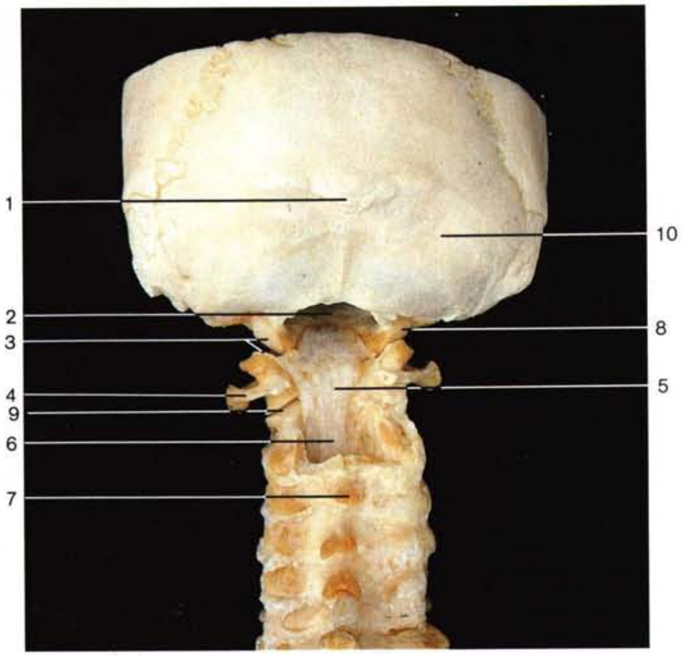

Cervical vertebral column and skull with ligaments (posterior aspect). Posterior arch of atlas and axis removed to show the membrana tectoria.

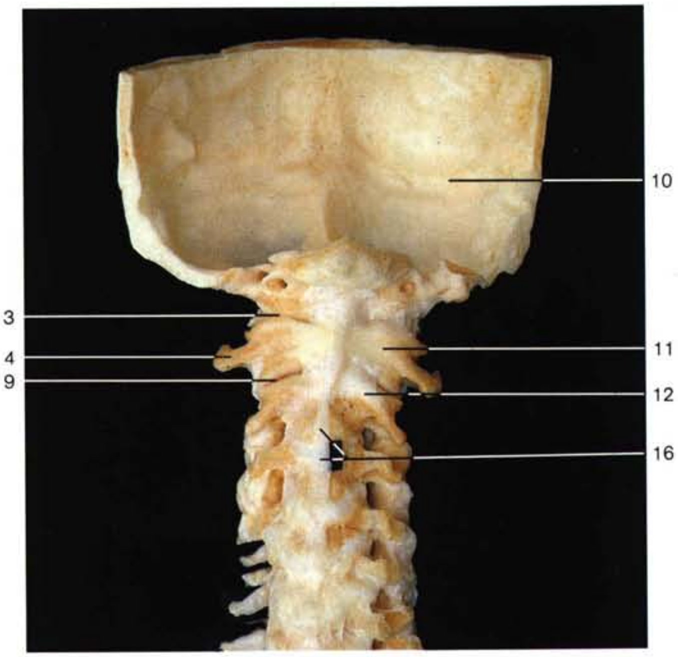

Cervical vertebral column and skull with ligaments (anterior aspect). Anterior part of occipital bone removed.

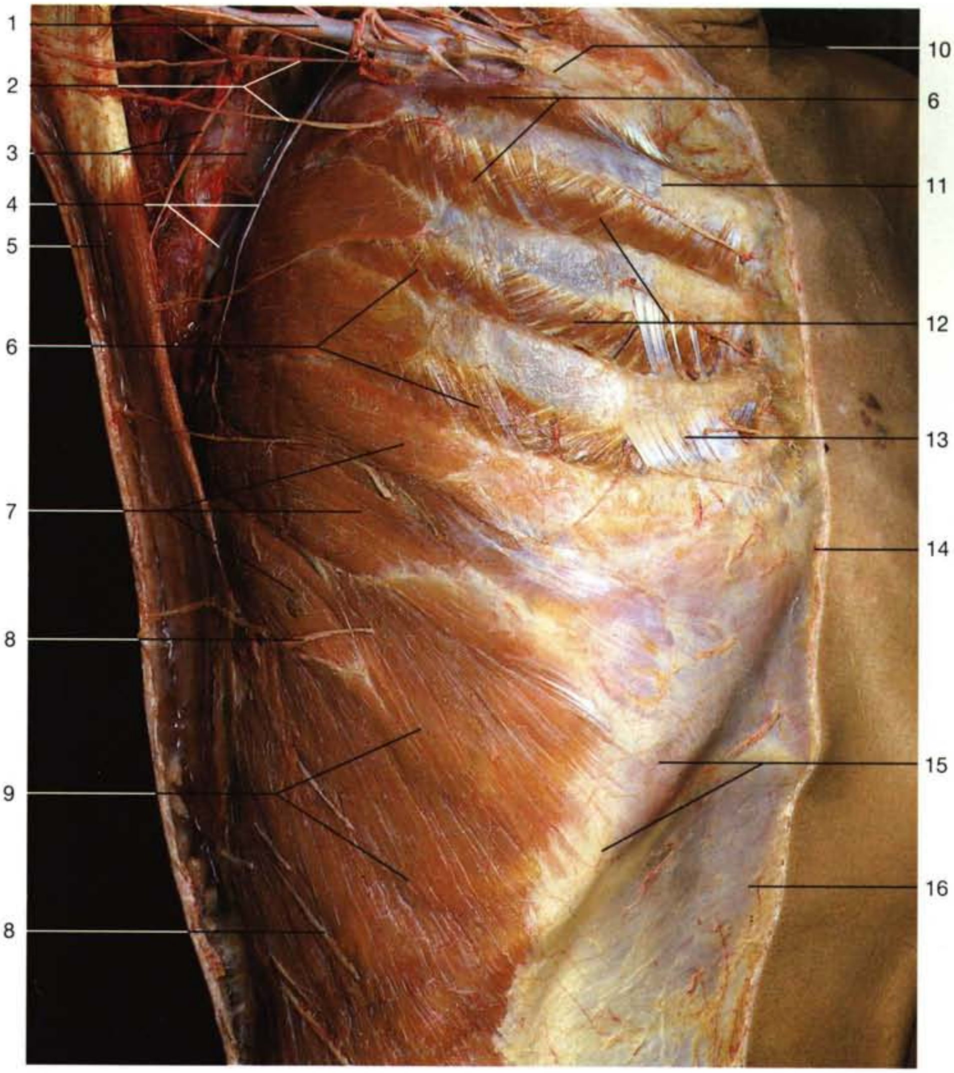

1 Axillary vein
2 Intercostobrachial nerves
3 Subscapularis muscle and thoracodorsal nerve
4 Long thoracic nerve, lateral thoracic artery and vein
5 Latissimus dorsi muscle
6 **External intercostal** muscles
7 **Serratus anterior** muscle
8 Lateral cutaneous branches of intercostal nerves
9 External abdominal oblique muscle
10 Clavicle (divided)
11 Second rib (costo-chondral junction)
12 **Internal intercostal muscles**
13 External intercostal membrane
14 Position of xiphoid process
15 Costal arch or margin
16 Anterior layer of rectus sheath

Muscles of the thorax, superficial layer (lateral aspect). Upper limb elevated. Pectoralis major and minor muscles have been removed.

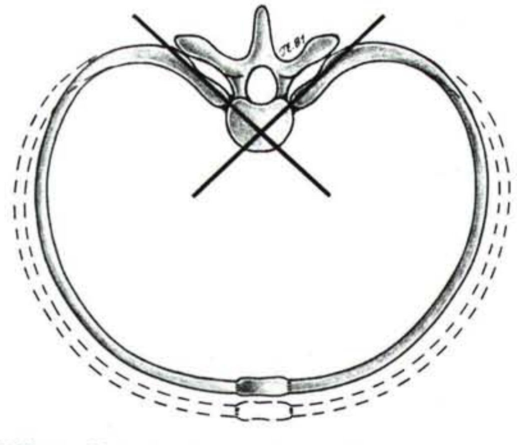

Effect of intercostal muscles on the costovertebral and costotransverse joints. Axes of movement indicated by lines; direction of movements indicated by arrows.

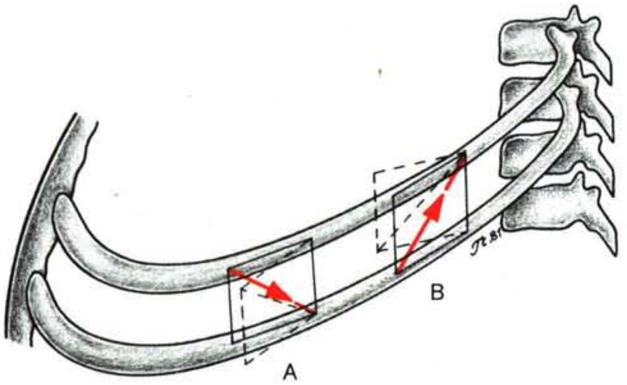

A Action of internal intercostal muscles (expiration)
B Action of external intercostal muscles (inspiration)

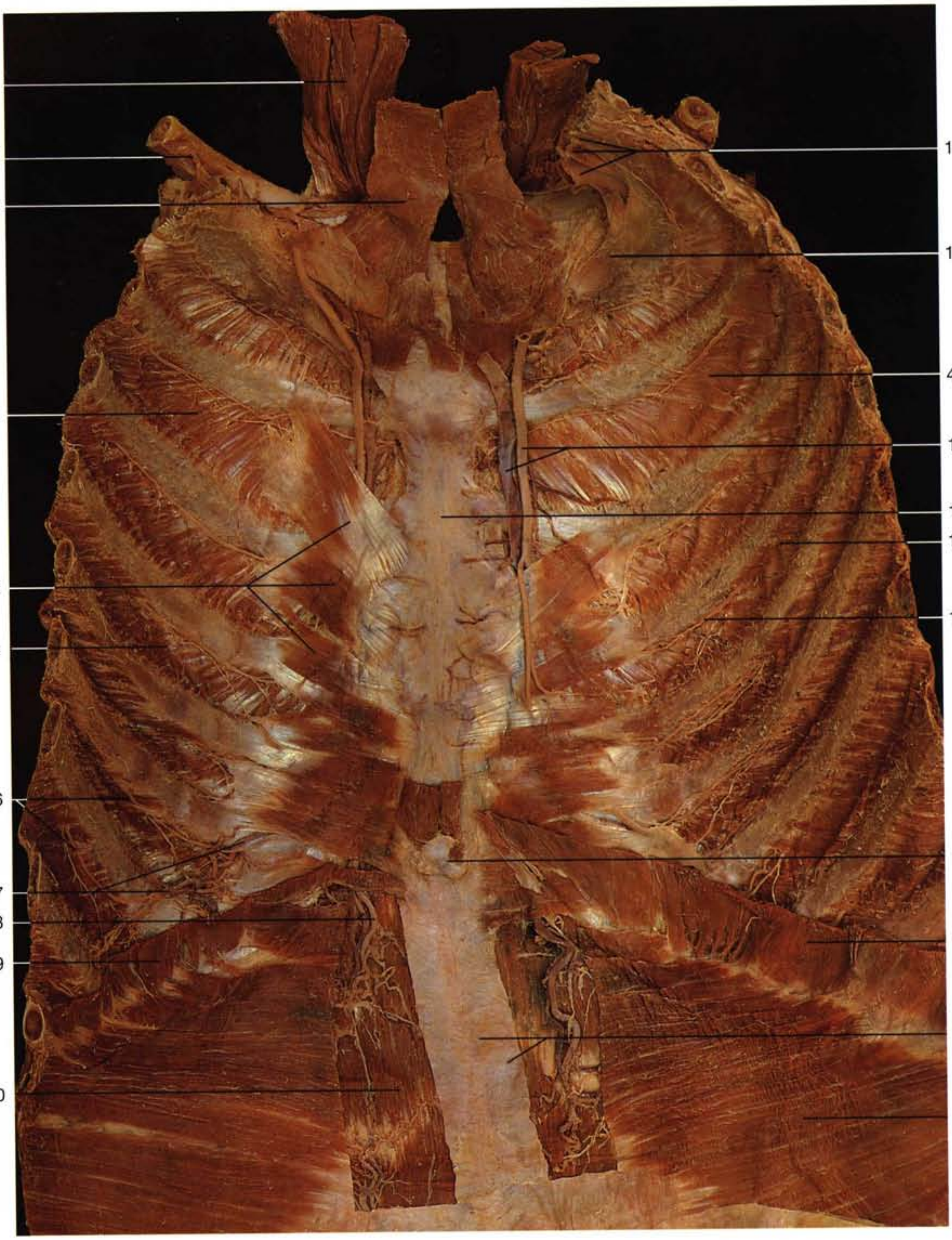

Anterior thoracic wall (posterior aspect). Diaphragm partly removed, posterior layer of rectus sheath fenestrated on both sides.

1	Sternocleidomastoid muscle (divided)
2	Clavicle
3	Sternothyroid muscle
4	**Internal intercostal muscle**
5	**Transversus thoracis muscle**
6	Intercostal arteries and nerves
7	Musculophrenic artery
8	Superior epigastric artery and vein
9	Diaphragm (divided)
10	Rectus abdominis muscle
11	Subclavian artery and brachial plexus
12	First rib
13	Internal thoracic artery and vein
14	Sternum
15	Innermost intercostal muscle
16	Intercostal artery and vein
17	Xiphoid process
18	Linea alba and posterior layer of rectus sheath
19	**Transversus abdominis muscle**

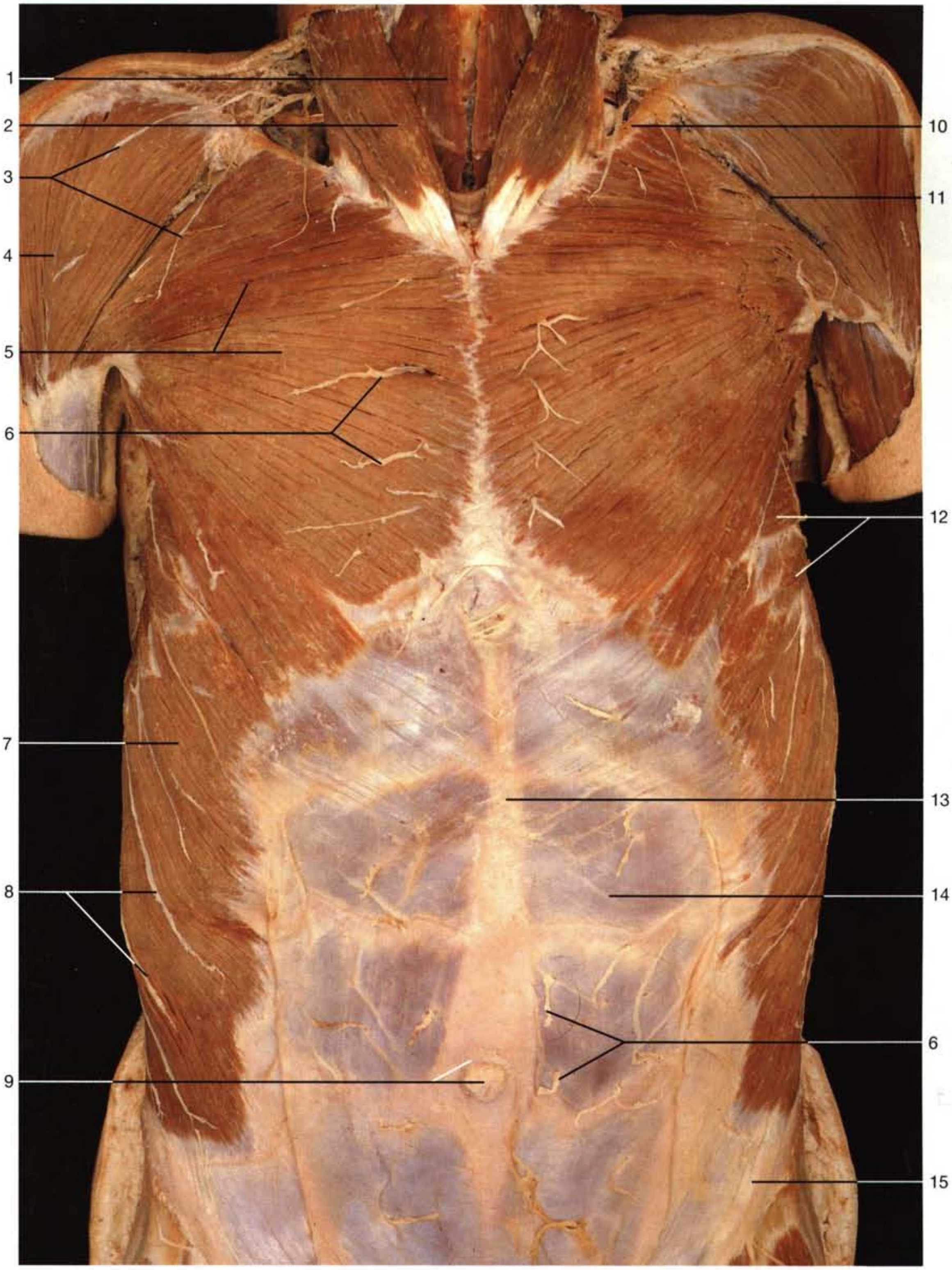

Superficial muscles of the anterior thoracic and abdominal wall. The fascia of pectoralis major muscle and the abdominal wall have been removed; the anterior layer of the sheath of the rectus abdominis muscle is displayed.

1 Sternohyoid muscle
1 Sternocleidomastoid muscle
3 Supraclavicular nerves (branches of cervical plexus)
4 Deltoid muscle
5 **Pectoralis major muscle**
6 **Anterior cutaneous branches of intercostal nerves**
7 External abdominal oblique muscle
8 **Lateral cutaneous branches of intercostal nerves**
9 Umbilicus and umbilical ring
10 Clavicle
11 Cephalic vein
12 Serratus anterior muscle
13 Linea alba
14 **Sheath of rectus abdominis** muscle (anterior layer)
15 Inguinal ligament

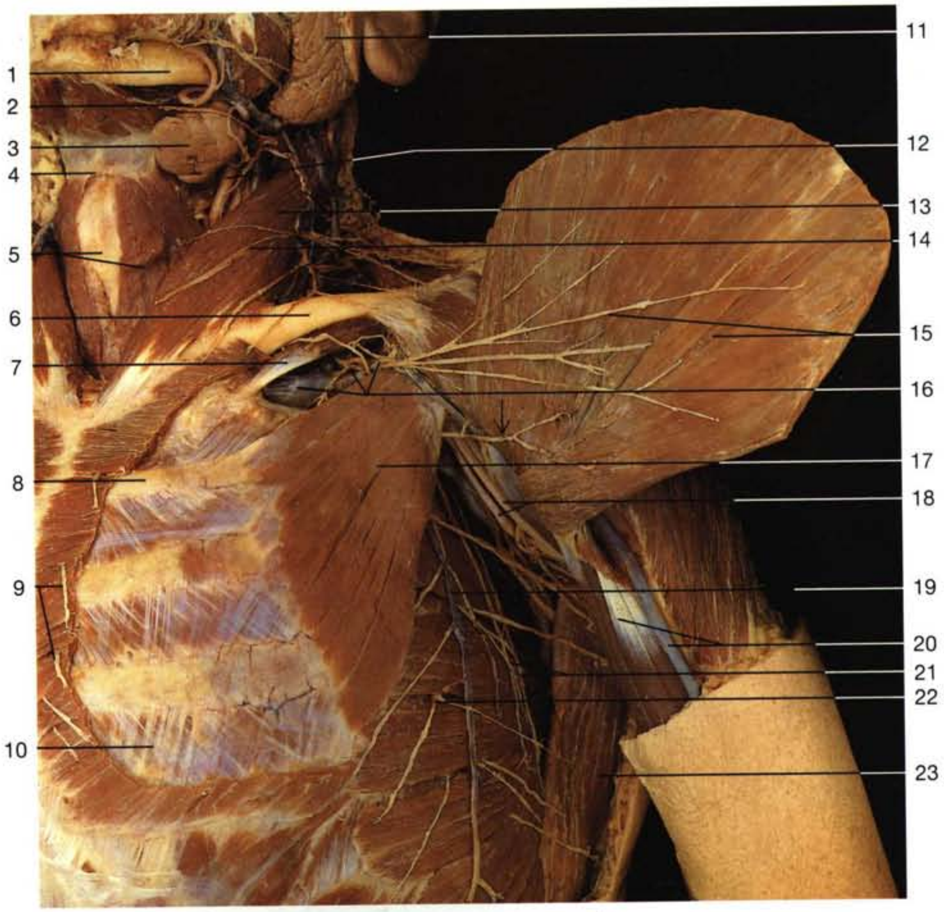

Thoracic wall I (anterior aspect). Left pectoralis major muscle has been divided and reflected. Note the connection of the cephalic vein with the subclavian vein. Arrow: medial pectoral nerve.

1 Mandible
2 Facial artery
3 Submandibular gland
4 Hyoid bone
5 Thyroid cartilage and sternohyoid muscle
6 Clavicle
7 Subclavius muscle
8 Second rib
9 Anterior cutaneous branches of intercostal nerves
10 External intercostal membrane
11 Parotid gland
12 External carotid artery
13 Sternocleidomastoid muscle and cutaneous branches of cervical plexus
14 Supraclavicular nerves
15 Pectoralis major muscle and lateral pectoral nerves
16 Thoracoacromial artery and subclavian vein
17 **Pectoralis minor muscle**
18 **Median and ulnar nerve**
19 Thoracoepigastric vein
20 Cephalic vein and long head of biceps brachii muscle
21 **Lateral thoracic artery and long thoracic nerve**
22 Lateral cutaneous branches of intercostal nerve
23 Latissimus dorsi muscle
24 Median nerve
25 Axillary artery
26 Intercostobrachial nerves
27 **Thoracodorsal nerve**
28 Long thoracic nerve
29 Latissimus dorsi muscle
30 **Serratus anterior muscle**
31 Thoracoacromial artery
32 Clavicle
33 External intercostal muscle
34 Third rib
35 **Internal intercostal muscle**
36 Anterior intercostal artery and vein
37 Costal arch or margin

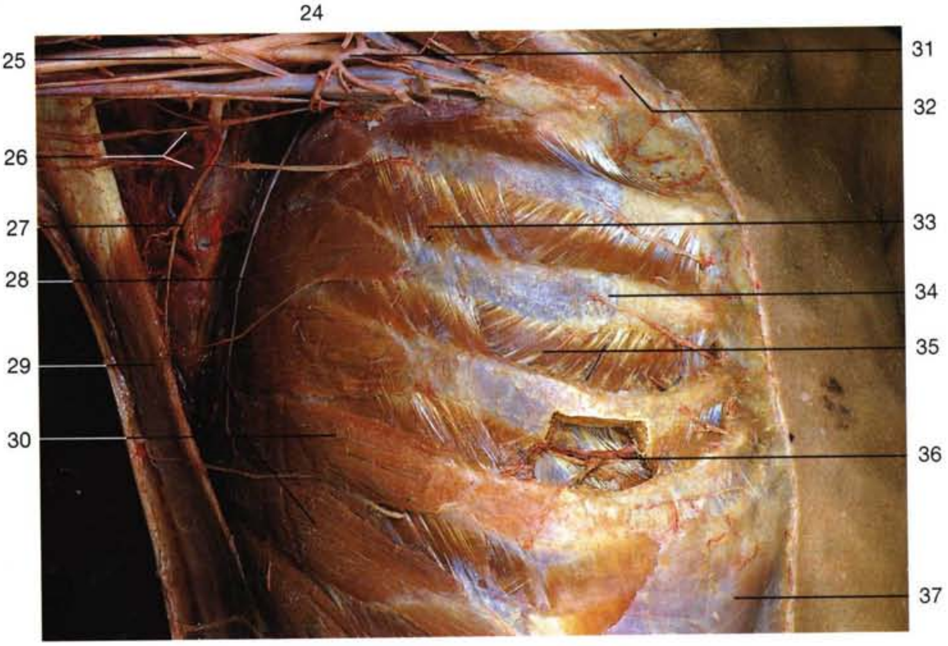

Thoracic wall (lateral aspect). Pectoralis major and minor muscles have been removed. A section of the 4th rib has been cut and removed to display the intercostal vessels and nerve.

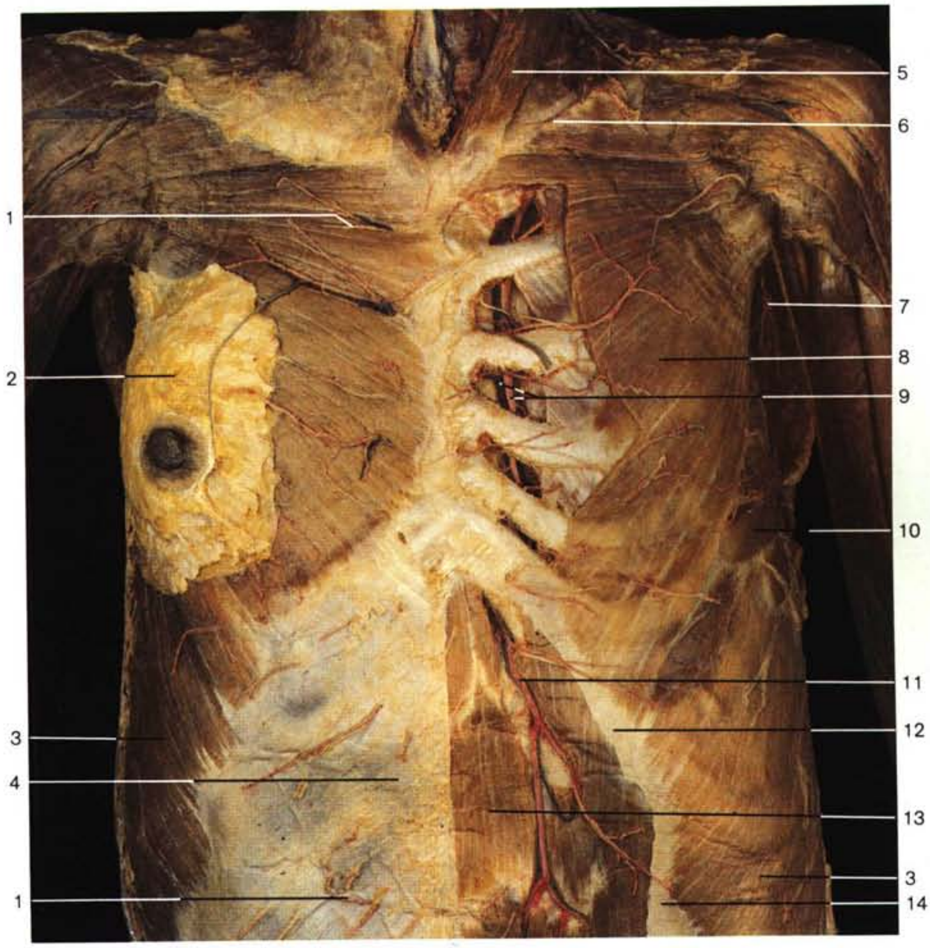

Thoracic wall II (anterior aspect). Dissection of the **internal thoracic artery and vein.** Left pectoralis major muscle partly removed. Anterior lamina of the rectus sheath on the left side has been removed.

1. Anterior perforating branches of intercostal nerve
2. Mammary gland
3. External abdominal oblique muscle
4. Rectus sheath (anterior layer)
5. Sternocleidomastoid muscle
6. Clavicle
7. Lateral thoracic artery and vein
8. Pectoralis major muscle
9. **Internal thoracic artery and vein**
10. Serratus anterior muscle
11. **Superior epigastric artery and vein**
12. Costal margin
13. Rectus abdominis muscle
14. Cut edge of the anterior layer of the rectus sheath
15. Subclavian artery
16. Highest intercostal artery
17. Internal thoracic artery
18. Musculophrenic artery
19. Superficial epigastric artery
20. Deep circumflex iliac artery
21. Superior epigastric artery
22. Inferior epigastric artery
23. Superficial circumflex iliac artery

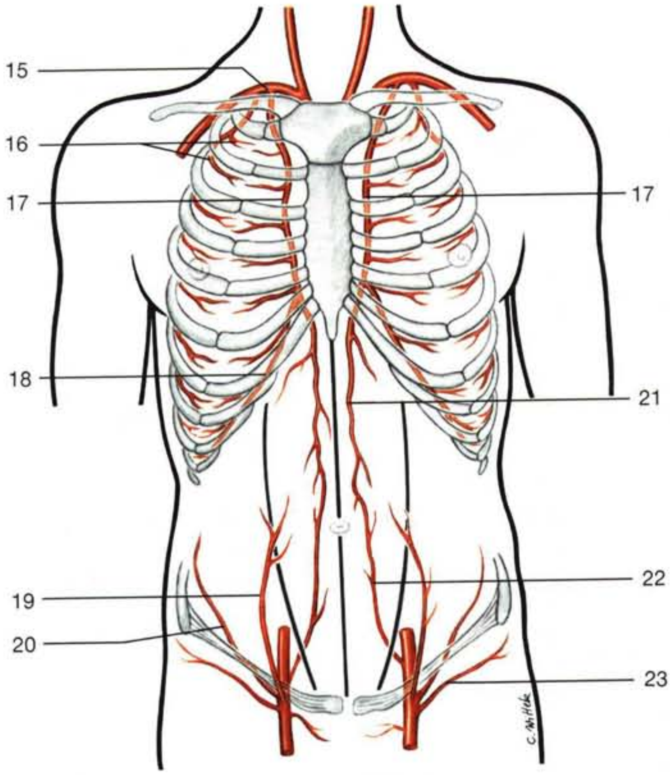

Main arteries of thoracic and abdominal wall.

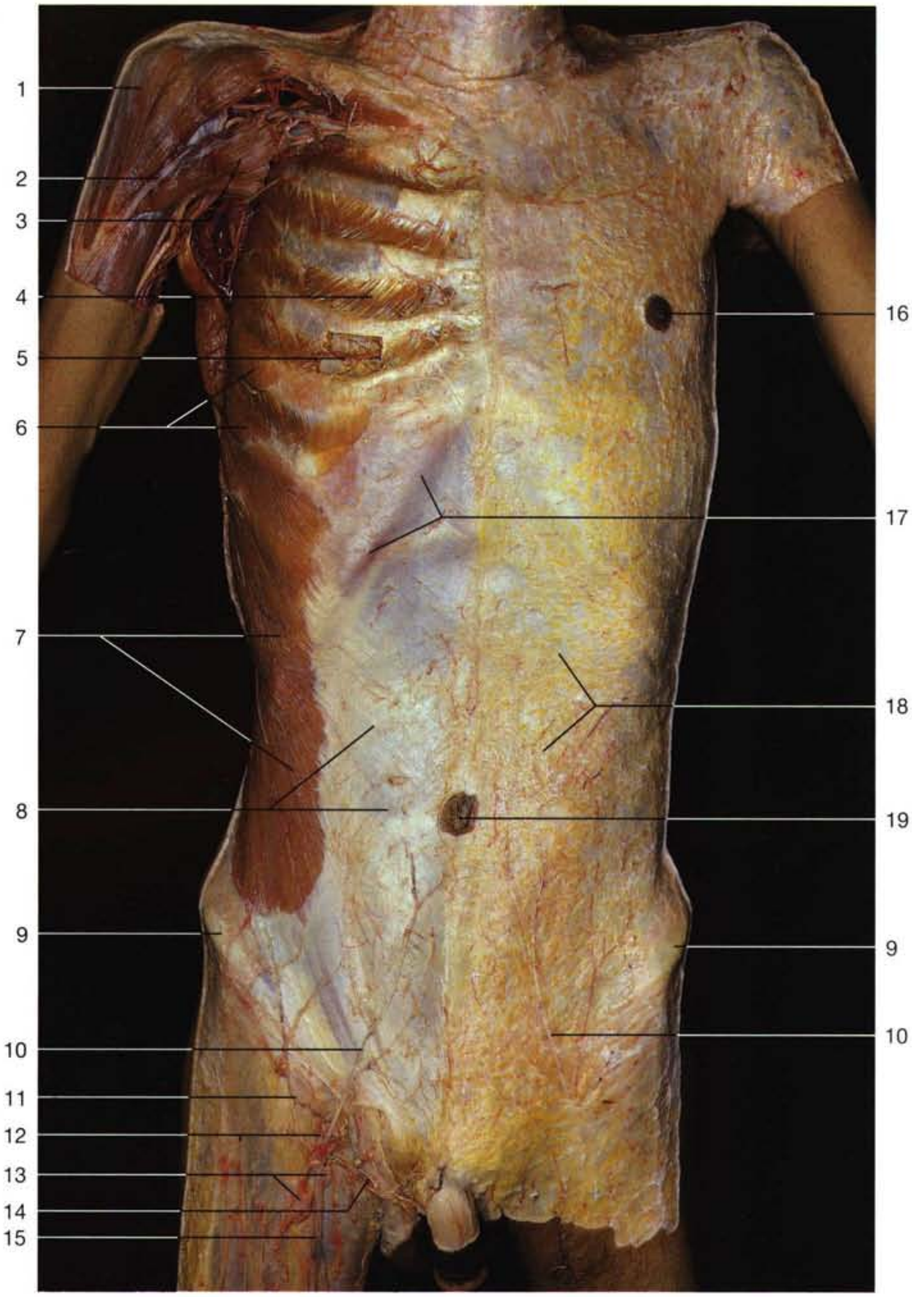

1 Deltoid muscle
2 Cephalic vein
3 Pectoralis major muscle (divided)
4 **Internal intercostal muscle**
5 **Intercostal artery and vein** (intercostal space, fenestrated)
6 Serratus anterior muscle
7 **External abdominal oblique muscle**
8 **Anterior layer of rectus sheath**
9 Iliac crest
10 Superficial epigastric vein
11 Superficial circumflex iliac vein
12 Saphenous opening
13 Superficial inguinal lymph nodes
14 Superficial external pudendal veins
15 Great saphenous vein
16 Nipple
17 Costal margin
18 Subcutaneous fatty tissue
19 Umbilicus
20 Anterior layer of rectus sheath
21 Rectus abdominis muscle
22 Posterior layer of rectus sheath
23 **Internal abdominal oblique muscle**
24 **External abdominal oblique muscle**
25 **Transversus abdominis muscle**
26 Transversal fascia and peritoneum
27 Psoas major muscle
28 Body of lumbar vertebra (L_4)
29 Quadratus lumborum muscle
30 Medial tract of erector spinae muscle
31 Lateral tract of erector spinae muscle (longissimus and iliocostalis muscles)
32 Small intestine
33 Left ureter
34 **Abdominal aorta**
35 **Inferior vena cava**
36 Descending colon
37 Spinous process

Thoracic and abdominal wall I. Right pectoralis major and minor muscles are divided. Muscles of thoracic and abdominal wall on right side are displayed.

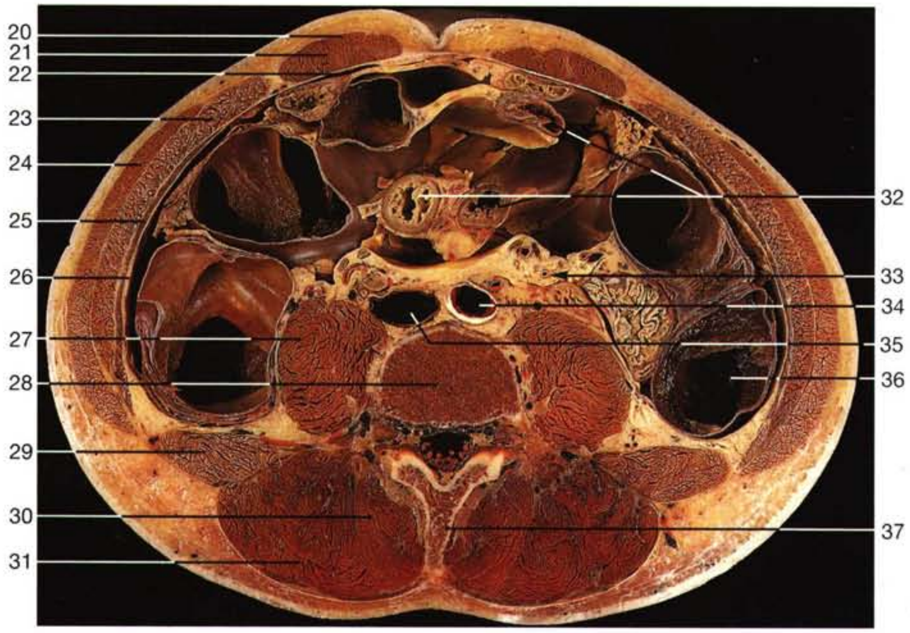

Horizontal section of the trunk at the level of the umbilicus, superior to arcuate line (inferior aspect).

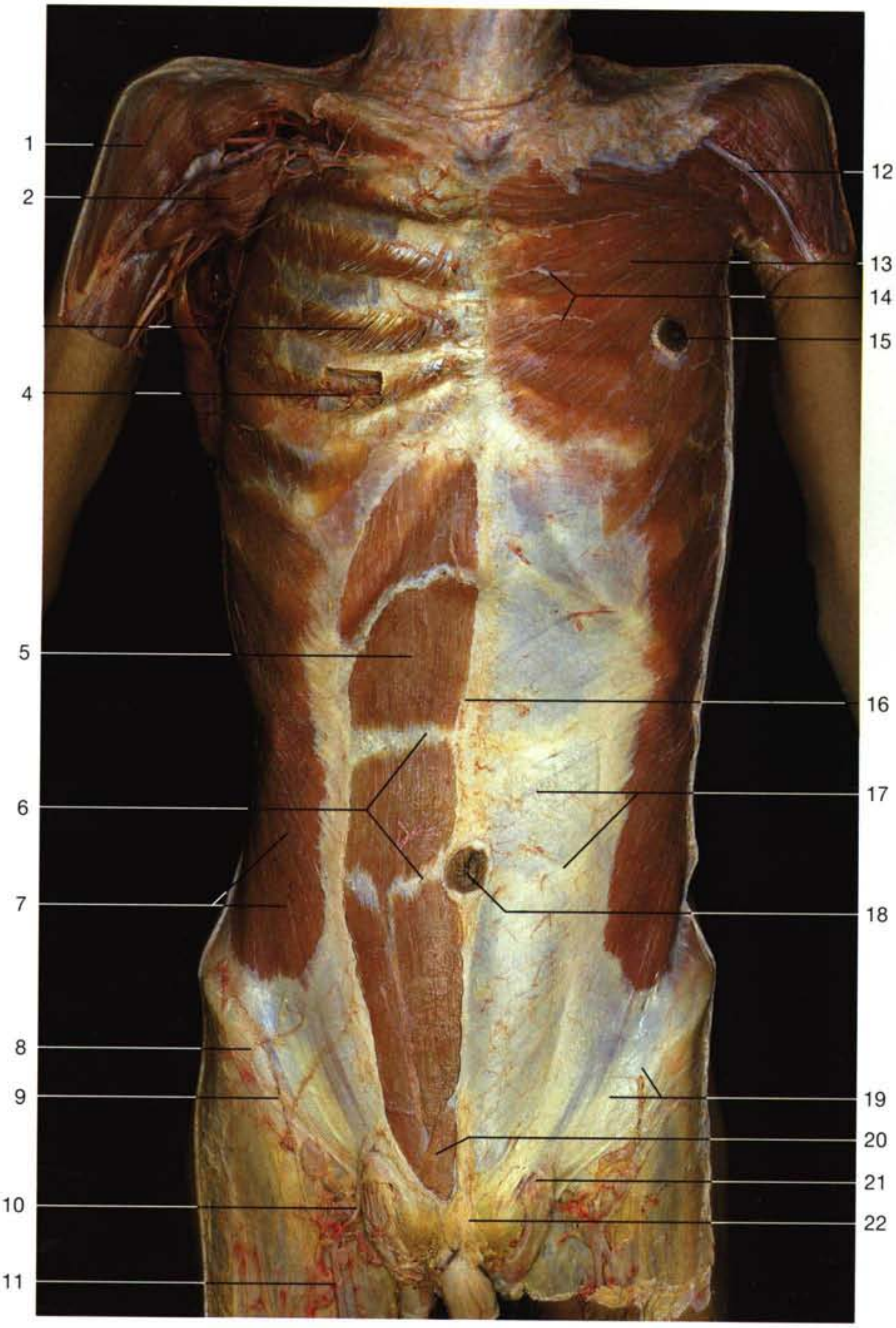

Thoracic and abdominal wall II. Right pectoralis major and minor muscles and anterior layer of rectus sheath have been removed on the right side.

1 Deltoid muscle
2 Pectoralis major muscle (divided)
3 **Internal intercostal muscle**
4 Intercostal artery and vein
5 **Rectus abdominis muscle**
6 Tendinous intersections
7 **External abdominal oblique muscle**
8 Anterior superior iliac spine
9 Superficial circumflex iliac vein
10 Superficial epigastric vein
11 Great saphenous vein
12 Cephalic vein
13 **Pectoralis major muscle**
14 Anterior cutaneous branches of intercostal nerves
15 Nipple
16 Linea alba
17 **Anterior layer of rectus sheath**
18 Umbilicus
19 **Inguinal ligament**
20 Pyramidalis muscle
21 Superficial inguinal ring and spermatic cord
22 Suspensory ligament of penis
23 Longissimus and iliocostalis muscles
24 Multifidus muscle
25 Quadratus lumborum muscle
26 Latissimus dorsi muscle
27 Psoas major muscle
28 Spinous process
29 Body of 1st lumbar vertebra
30 **Transversus abdominis muscle**
31 **Internal abdominal oblique muscle**

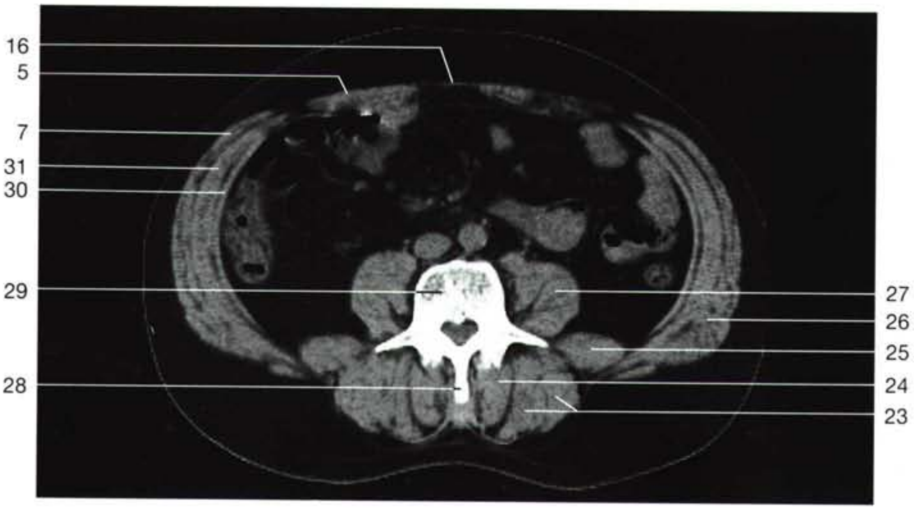

Horizontal section through the body at the level of 4th lumbar vertebra; seen from below. (CT-Scan.)

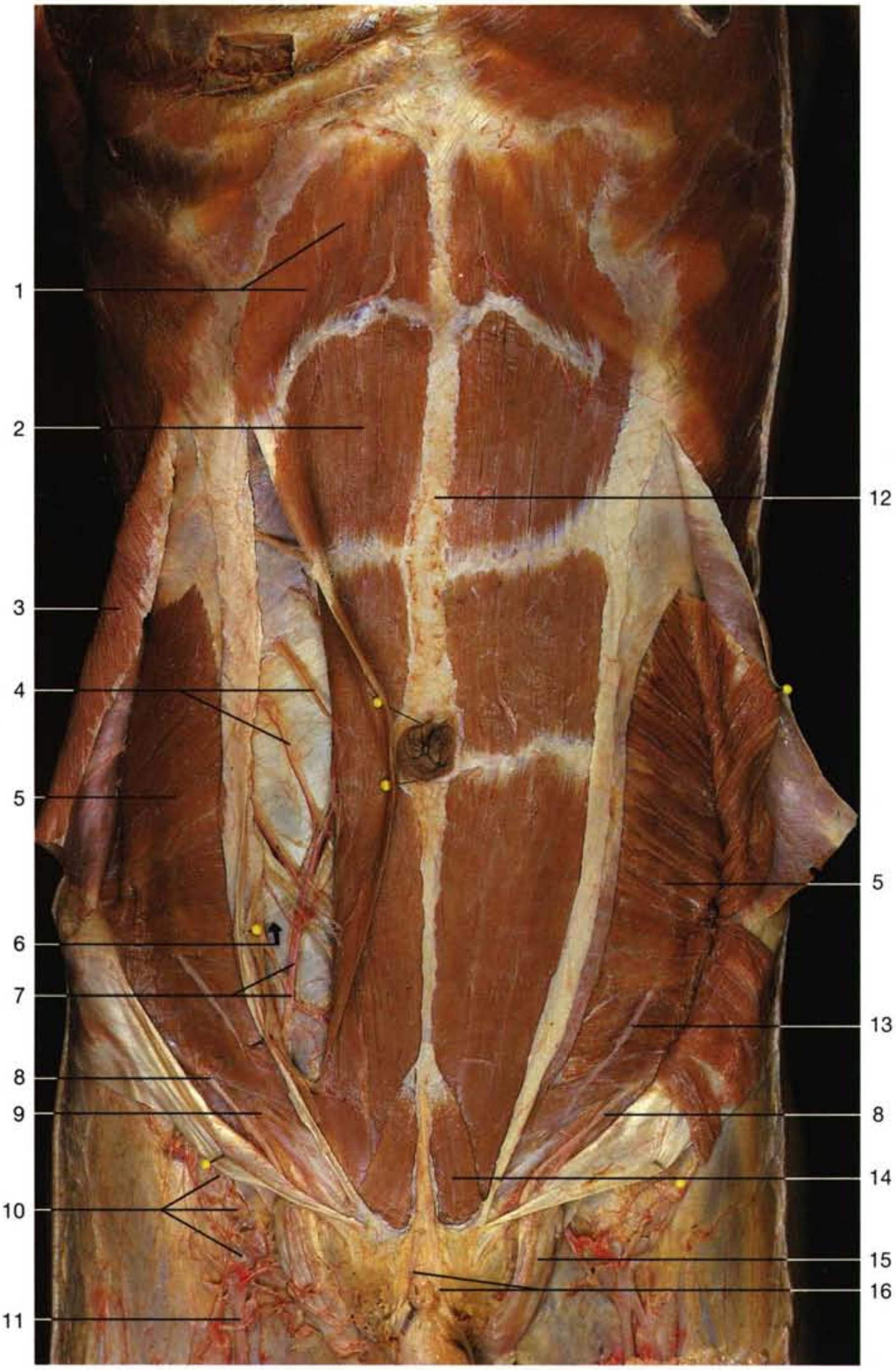

1 Costal margin
2 **Rectus abdominis muscle**
3 External abdominal oblique muscle (reflected)
4 Thoracoabdominal (intercostal) nerves with accompanying vessels
5 Internal abdominal oblique muscle
6 **Arcuate line** (arrow)
7 **Inferior epigastric artery and vein**
8 Ilioinguinal nerve
9 Position of deep inguinal ring
10 Superficial inguinal lymph nodes
11 Great saphenous vein
12 Linea alba
13 Iliohypogastric nerve
14 **Pyramidalis** muscle
15 Spermatic cord
16 Fundiform ligament of penis

Thoracic and abdominal wall III. External abdominal oblique muscle has been divided and reflected on both sides. The right rectus muscle has been reflected medially to display the posterior layer of rectus sheath. Arrow: location of arcuate line.

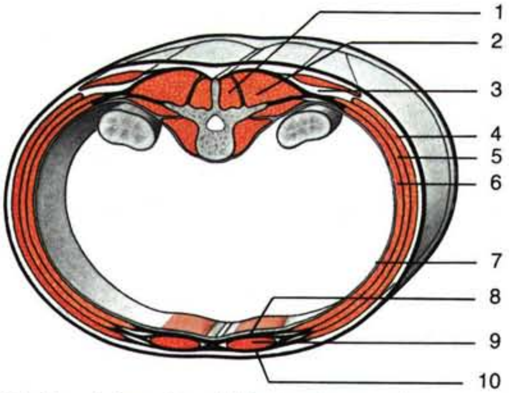

Horizontal-section of the trunk superior to arcuate line. (Schematic drawing.)

1 Medial column of intrinsic muscles of the back
2 Lateral column of erector spinae muscle
3 Thoracolumbar fascia with superficial and deep layer
4 External oblique muscle
5 Internal oblique muscle
6 Transversus abdominis muscle
7 Transversalis fascia
8 Posterior layer of rectus sheath
9 Rectus abdominis muscle
10 Anterior layer of rectus sheath

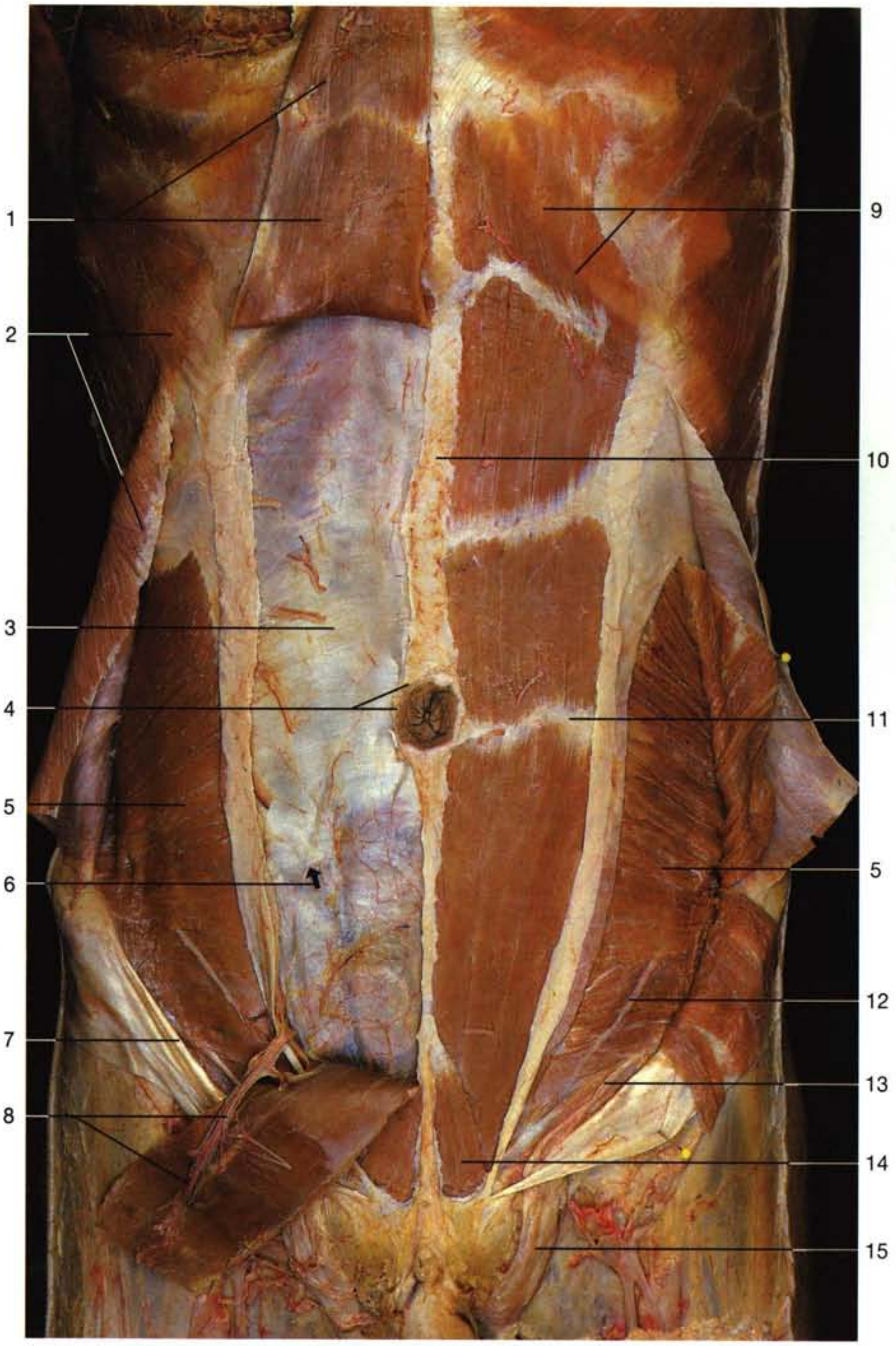

1. **Rectus abdominis muscle** (reflected)
2. External abdominal oblique muscle (divided)
3. Posterior layer of rectus sheath
4. Umbilical ring
5. **Internal abdominal oblique muscle**
6. Arcuate line (arrow)
7. Inguinal ligament
8. **Inferior epigastric artery and vein** and rectus abdominis muscle (divided and reflected)
9. Costal margin
10. Linea alba
11. Tendinous intersection
12. Iliohypogastric nerve
13. **Ilioinguinal nerve**
14. **Pyramidalis** muscle
15. Spermatic cord

Thoracic and abdominal wall IV. External abdominal oblique muscle has been divided and reflected on both sides. The right rectus muscle has been cut and reflected to display the posterior layer of rectus sheath. Arrow: location of arcuate line.

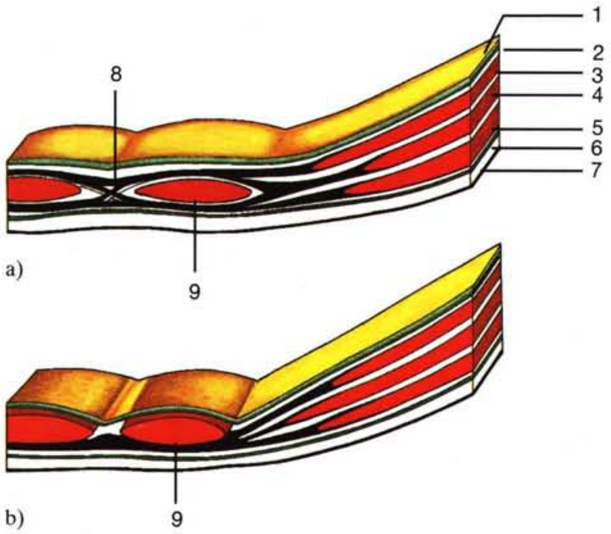

1. Peritoneum
2. Transversalis fascia (green)
3. Transversus abdominis muscle
4. Internal abdominal oblique muscle
5. External abdominal oblique muscle
6. Fascia of external abdominal oblique muscle (green)
7. Skin
8. Linea alba
9. Rectus abdominis muscle

Transverse sections through the abdominal wall superior (a) and inferior (b) to arcuate line.

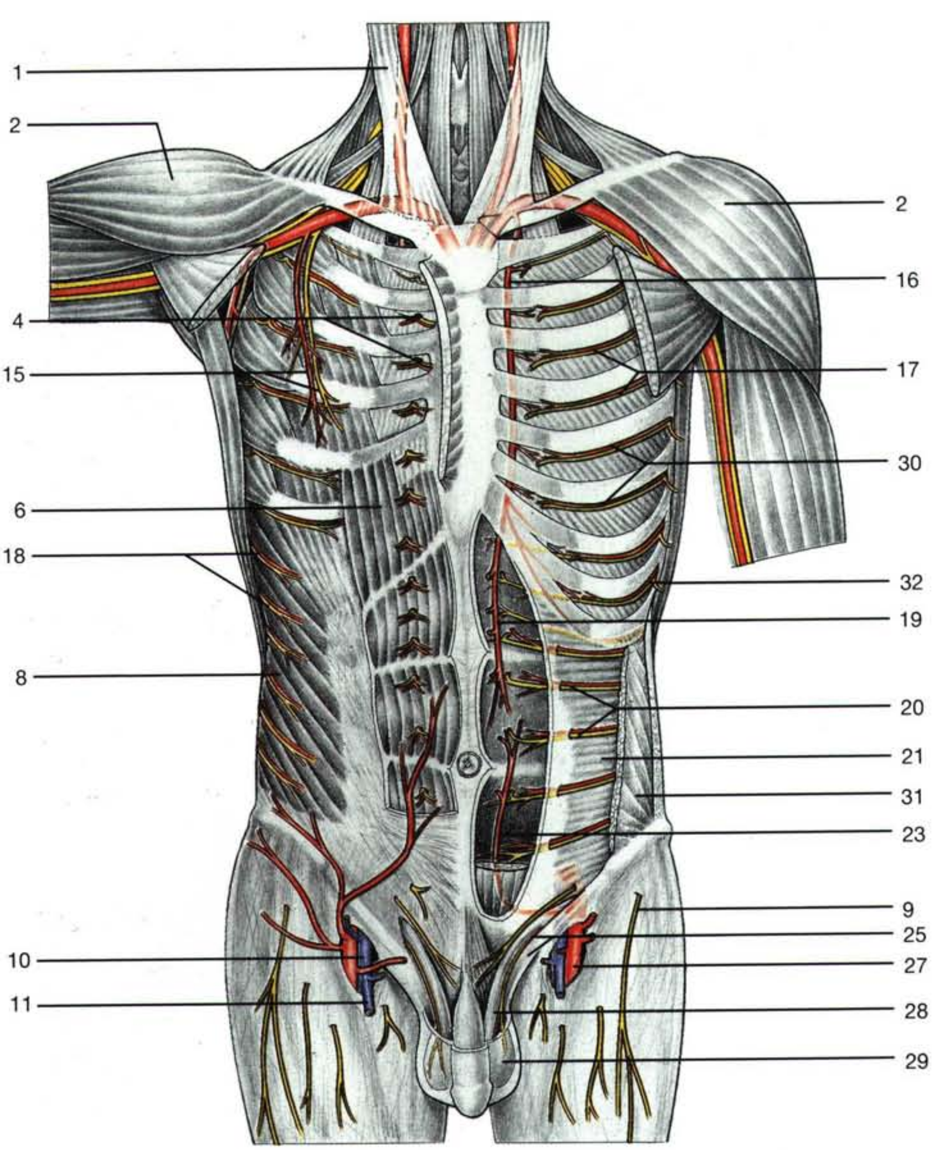

Thoracic and abdominal wall (schematic drawing). Note the segmental organization of the blood vessels and nerves. Right side: superficial layers; left side: deeper layers.

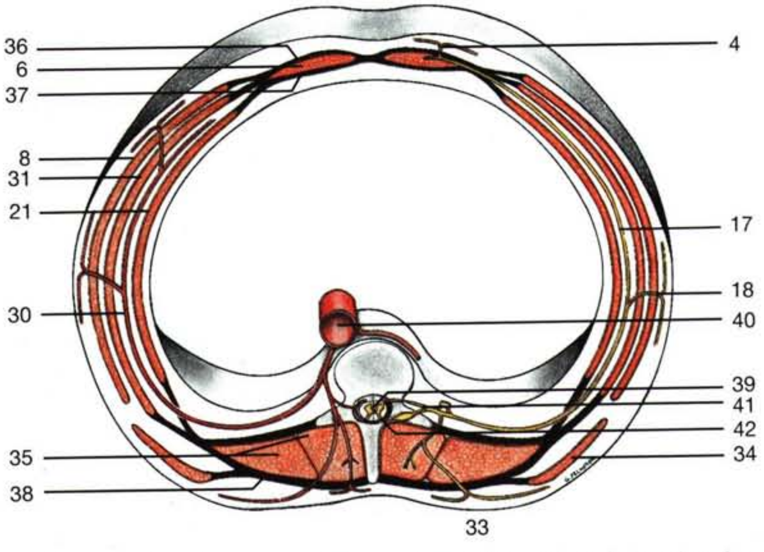

Horizontal section of the abdominal wall (from above) showing the location of the intercostal arteries (left side) and nerves (right side).

1 Sternocleidomastoid muscle
2 Deltoid muscle
3 Pectoralis major muscle
4 **Anterior cutaneous branches of intercostal nerves**
5 Cut edge of anterior layer of rectus sheath
6 **Rectus abdominis muscle**
7 Tendinous intersection
8 External abdominal oblique muscle
9 Lateral femoral cutaneous nerve
10 Femoral vein
11 Great saphenous vein
12 Medial supraclavicular nerves
13 Pectoralis minor muscle (reflected) and medial pectoral nerves
14 Axillary vein
15 Long thoracic nerve and lateral thoracic artery
16 Internal thoracic artery
17 **Intercostal nerves**
18 **Lateral cutaneous branches of intercostal nerves**
19 Superior epigastric artery
20 Thoracoabdominal (intercostal) nerves
21 Transversus abdominis muscle
22 Posterior layer of rectus sheath
23 **Inferior epigastric artery**
24 Lateral femoral cutaneous nerve
25 Inguinal ligament and ilioinguinal nerve
26 Femoral nerve
27 Femoral artery
28 Spermatic cord
29 Testis
30 **Posterior intercostal arteries**
31 Internal abdominal oblique muscle
32 Lateral cutaneous branch of intercostal nerve
33 Dorsal branch of spinal nerve
34 Latissimus dorsi muscle
35 Deep muscles of the back (medial and lateral tract)
36 Anterior layer of rectus sheath
37 Posterior layer of rectus sheath
38 Thoracolumbar fascia
39 Spinal cord
40 Aorta
41 Ventral root } of spinal
42 Dorsal root } nerve

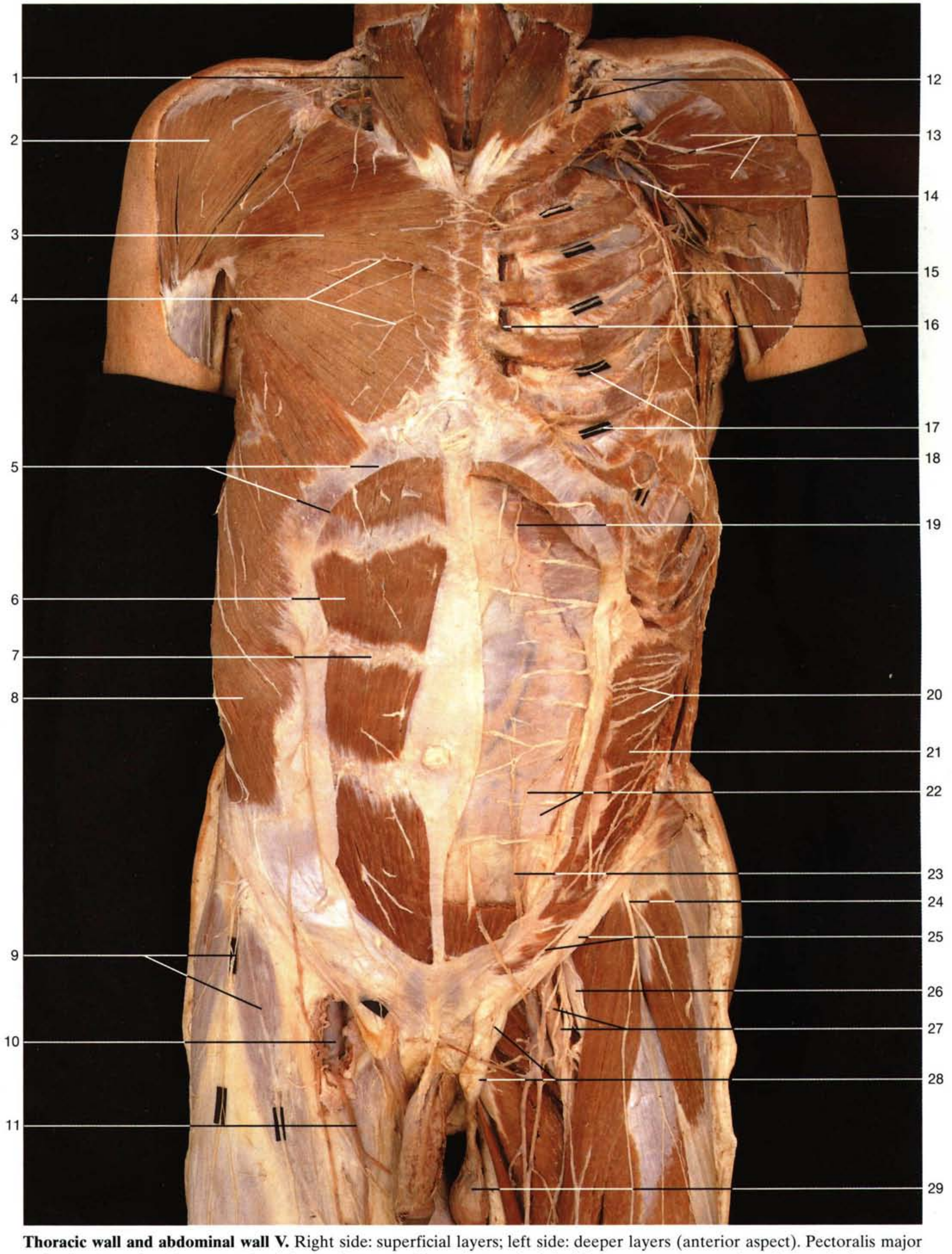
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Thoracic wall and abdominal wall V. Right side: superficial layers; left side: deeper layers (anterior aspect). Pectoralis major and minor muscles, the external and internal intercostal muscles on the left side have been removed to display the intercostal nerves. The anterior layer of rectus sheath, the left rectus abdominis muscle and the external and internal abdominal oblique muscle have been removed to show the thoracoabdominal nerves within the abdominal wall.

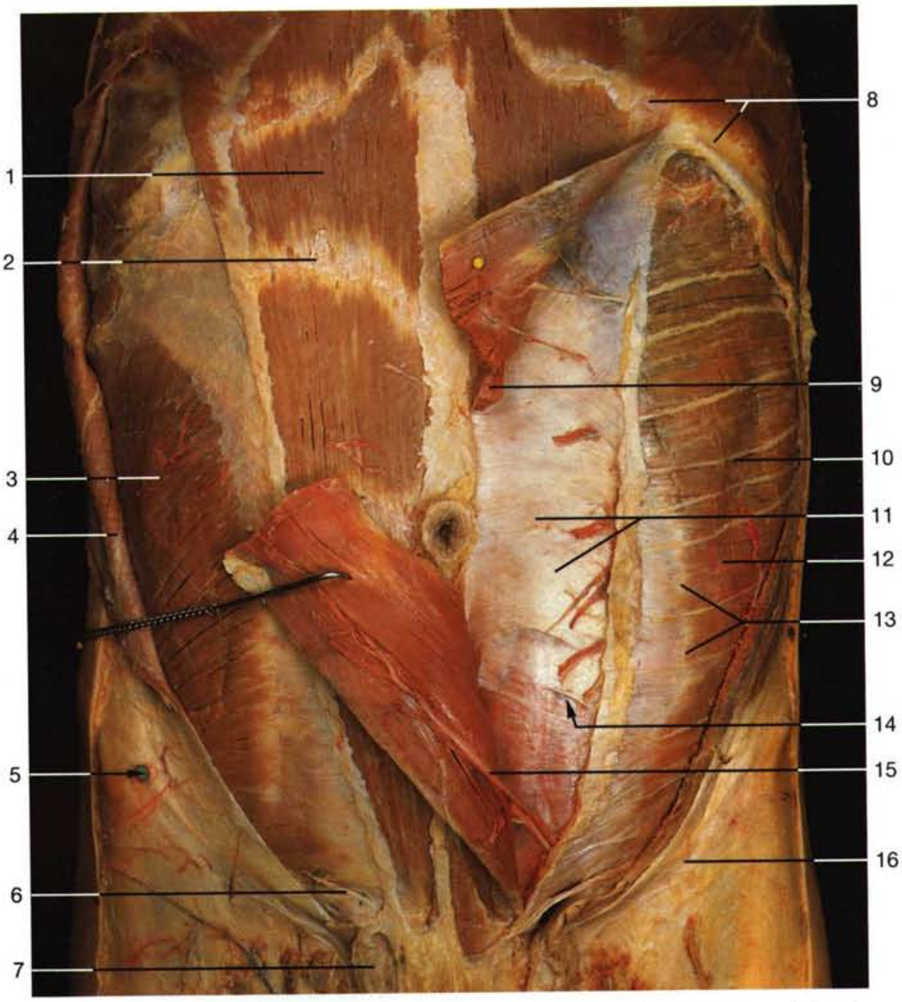

Abdominal wall with vessels and nerves. The left rectus abdominis muscle has been divided and reflected to display the inferior epigastric vessels. The left internal abdominal oblique muscle has been removed to show the thoracoabdominal nerves.

1 **Rectus abdominis muscle**
2 Tendinous intersection
3 **Internal abdominal oblique muscle**
4 External abdominal oblique muscle (reflected)
5 Anterior superior iliac spine
6 Ilioinguinal nerve
7 Spermatic cord
8 Costal margin
9 Superior epigastric artery
10 **Thoracoabdominal** (intercostal) **nerves**
11 Posterior layer of rectus sheath
12 **Transversus abdominis muscle**
13 Semilunar line
14 Arcuate line
15 **Inferior epigastric artery**
16 Inguinal ligament

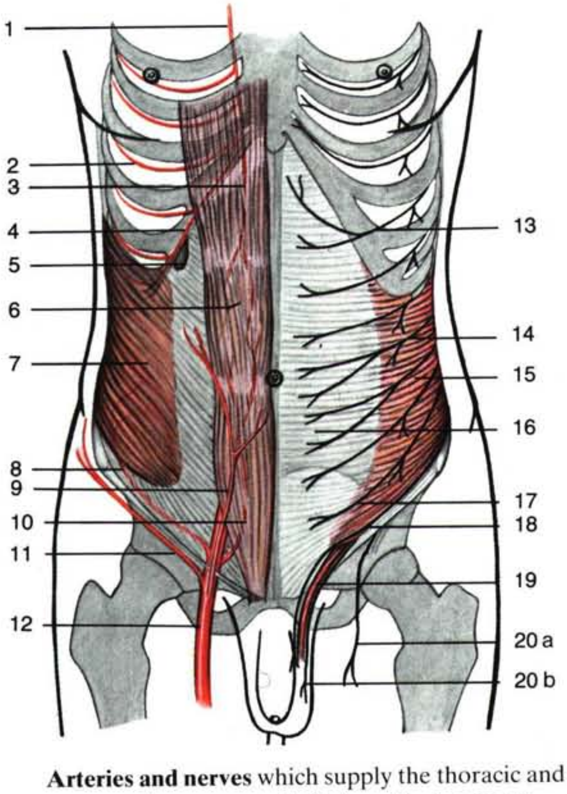

Arteries and nerves which supply the thoracic and abdominal wall. Note their segmental arrangement. (Schematic drawing.)

1 Internal thoracic artery
2 Intercostal artery
3 Superior epigastric artery
4 Musculophrenic artery
5 Gallbladder
6 Rectus abdominis muscle
7 External abdominal oblique muscle
8 Deep circumflex iliac artery
9 Superficial epigastric artery
10 Inferior epigastric artery
11 Superficial circumflex iliac artery
12 Femoral artery
13 Intercostal nerve
14 Thoracoabdominal nerve (T_{10})
15 Transversus abdominis muscle
16 Posterior layer of the rectus sheath
17 Iliohypogastric nerve (L_1)
18 Ilioinguinal nerve (L_1)
19 Spermatic cord
20 Genitofemoral nerve (L_1, L_2)
  a Femoral branch
  b Genital branch

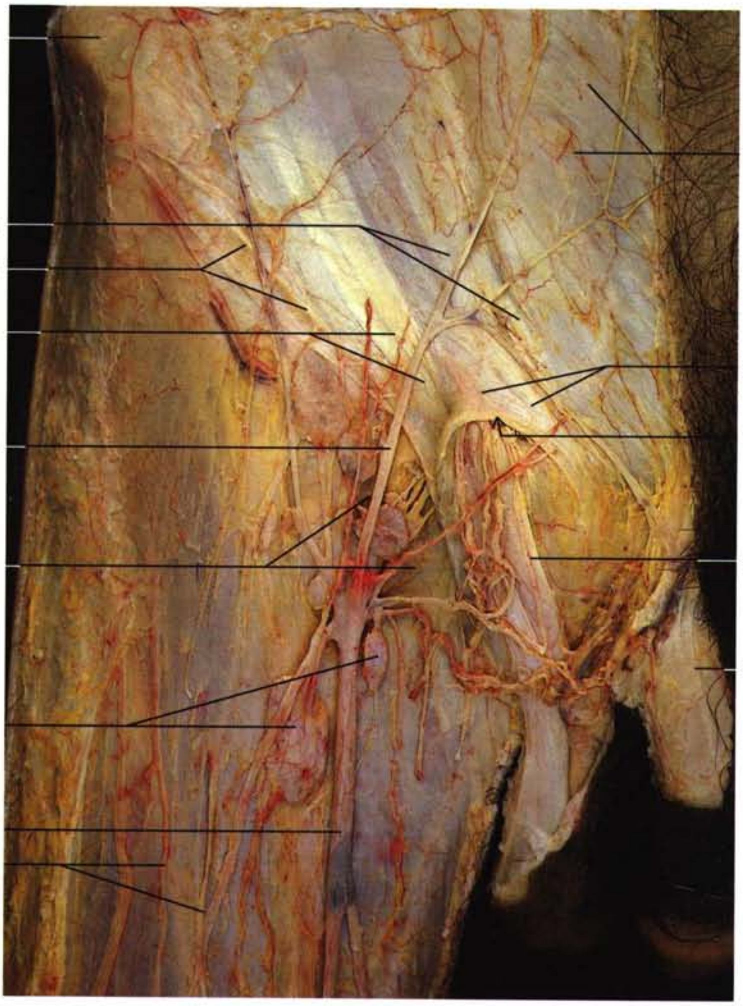

Inguinal canal in the male I. Dissection of superficial layer, right side (anterior aspect).

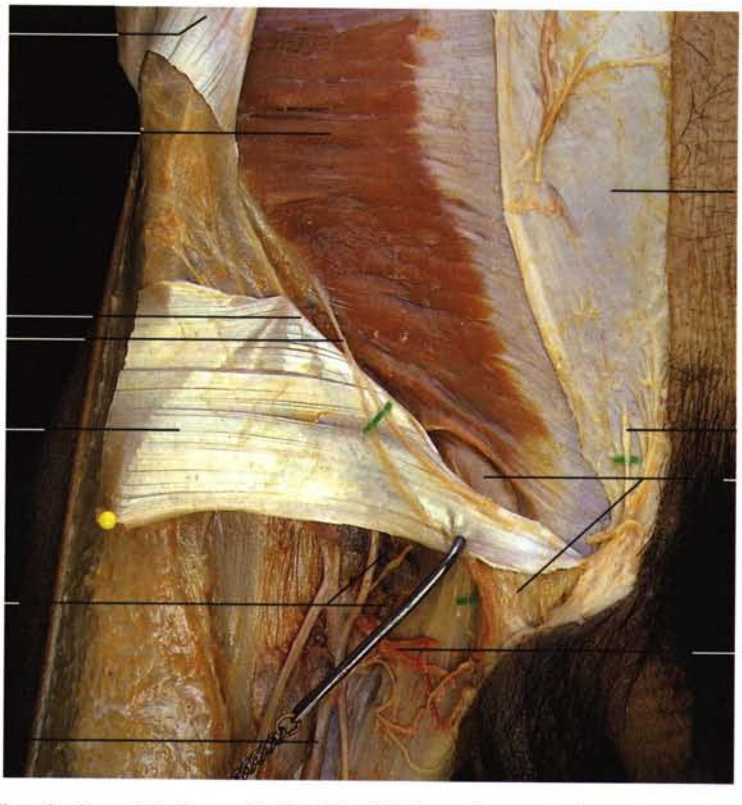

Inguinal canal in the male II, right side (anterior aspect). The external abdominal oblique muscle has been divided to display the inguinal canal.

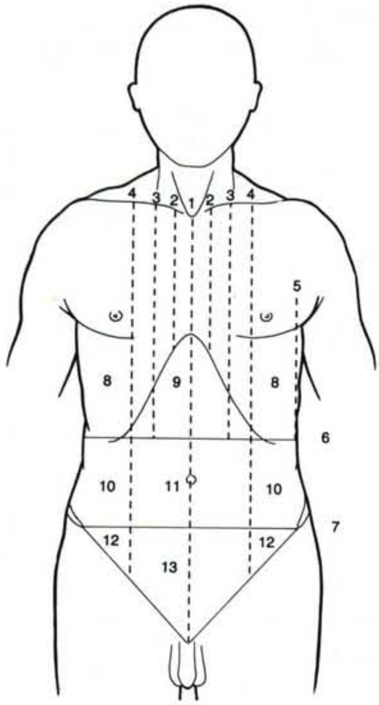

Regions and reference lines for delineating surface projections.

Reference lines and regions

1 Median line
2 Lateral sternal line
3 Parasternal line
4 Left lateral or midclavicular line
5 Midaxillary line
6 Transpyloric plane
7 Transtubercular plane
8 Hypochondriac region
9 Epigastric region
10 Lumbar region
11 Umbilical region
12 Iliac region
13 Hypogastric region

1 Anterior superior iliac spine
2 Medial crus of inguinal ring
3 Inguinal ligament
4 Lateral crus of inguinal ring
5 Superficial epigastric vein
6 Saphenous opening
7 **Superficial inguinal lymph nodes**
8 **Great saphenous vein**
9 Anterior cutaneous branches of femoral nerve
10 **Anterior layer of rectus sheath**
11 Intercrural fibers
12 **Superficial inguinal ring**
13 Spermatic cord and genital branch of genitofemoral nerve
14 Penis
15 Aponeurosis of external abdominal oblique muscle (divided and reflected)
16 **Internal abdominal oblique muscle**
17 Ilioinguinal nerve
18 Anterior cutaneous branches of iliohypogastric nerve
19 Superficial external pudendal veins

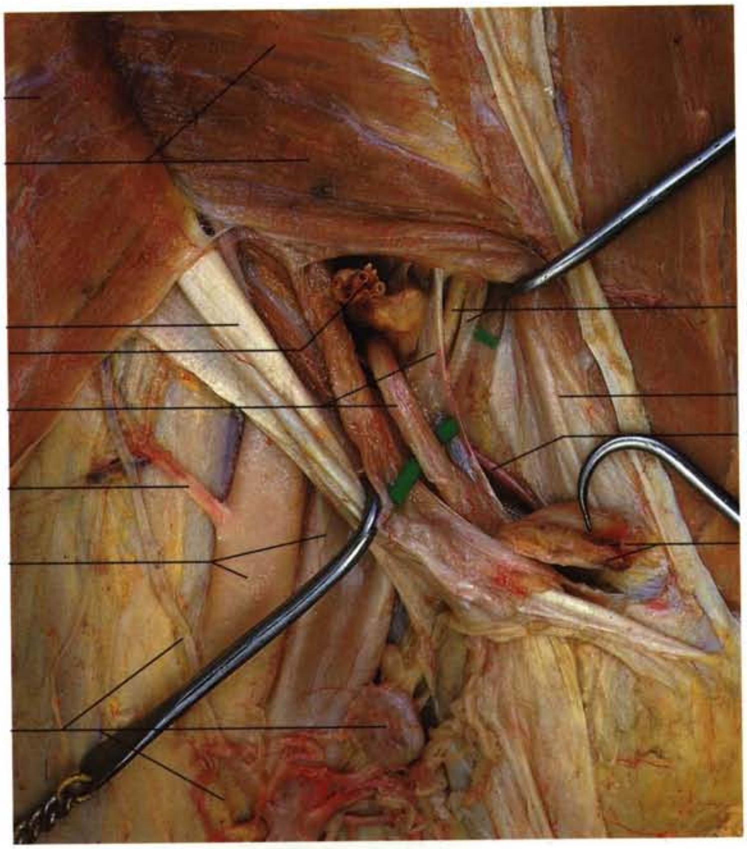

Inguinal canal in the male III. Deep dissection (anterior aspect, right side). Spermatic cord with exception of ductus deferens (probe) has been divided and reflected.

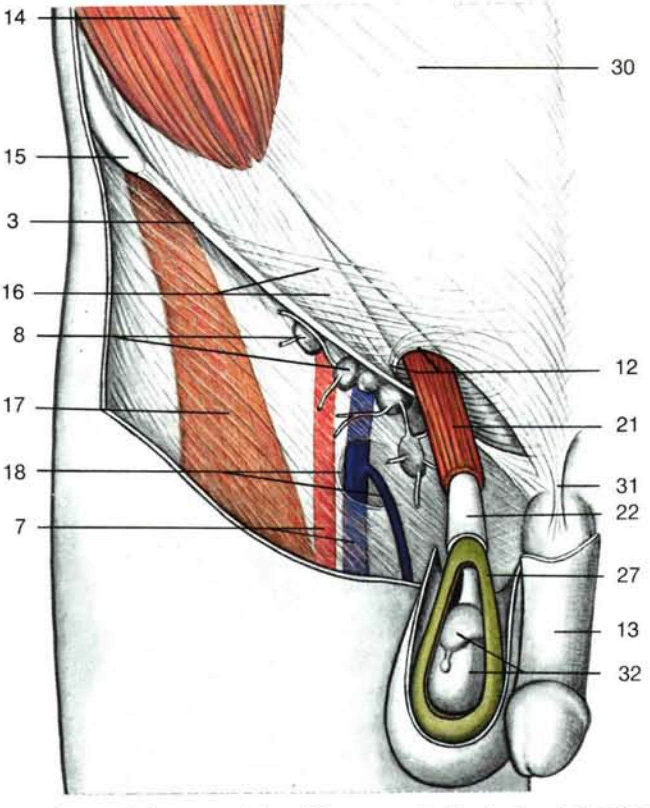

General characteristics of lower part of anterior abdominal wall and inguinal canal. (Schematic drawing.)

1 Internal abdominal oblique muscle (reflected)
2 Transversus abdominis muscle
3 Inguinal ligament
4 **Spermatic cord** with the exception of the ductus deferens (divided and reflected)
5 **Ductus deferens** and interfoveolar ligament
6 Superficial circumflex iliac artery
7 **Femoral artery and vein**
8 Superficial inguinal lymph nodes and inguinal lymph vessel
9 **Inferior epigastric artery and vein**
10 Falx inguinalis or conjoint tendon (cut)
11 Pubic branch of inferior epigastric artery
12 Superficial inguinal ring
13 Penis
14 External abdominal oblique muscle
15 Anterior superior iliac spine
16 Intercrural fibers
17 Fascia lata and sartorius muscle
18 Saphenous opening and great saphenous vein
19 Deep inguinal ring
20 Skin of scrotum and dartos muscle
21 Cremaster muscle
22 Internal spermatic fascia
23 Ductus deferens
24 Epididymis
25 Peritoneum (blue)
26 Remnant of processus vaginalis
27 Tunica vaginalis testis
28 Rectus abdominis muscle
29 Spermatic cord with ductus deferens covered by external spermatic fascia
30 Anterior layer of rectus sheath
31 Suspensory ligament of penis
32 **Testis and epididymis**
33 Ductus deferens
34 Pampiniform venous plexus and testicular artery
35 Inferior epigastric artery
36 Lateral femoral cutaneous nerve
37 Ilioinguinal nerve
38 **Femoral nerve**
39 Sartorius muscle
40 Deep dorsal vein of penis

Inguinal hernias may either pass through the inguinal canal lateral to the inferior epigastric artery (indirect or lateral inguinal hernias, A and C) or directly penetrate the abdominal wall through the inguinal triangle located medial to the inferior epigastric artery (direct or medial inguinal hernias, B). The lateral hernias can be congenital if the vaginal process remains open (C) or acquired (A) if the hernia develops independently of a patent processus vaginalis.

Femoral hernias generally protrude through the femoral ring below the inguinal ligament. Proper assessment of the site of herniation requires the identification of both the inguinal ligament and the epigastric artery.

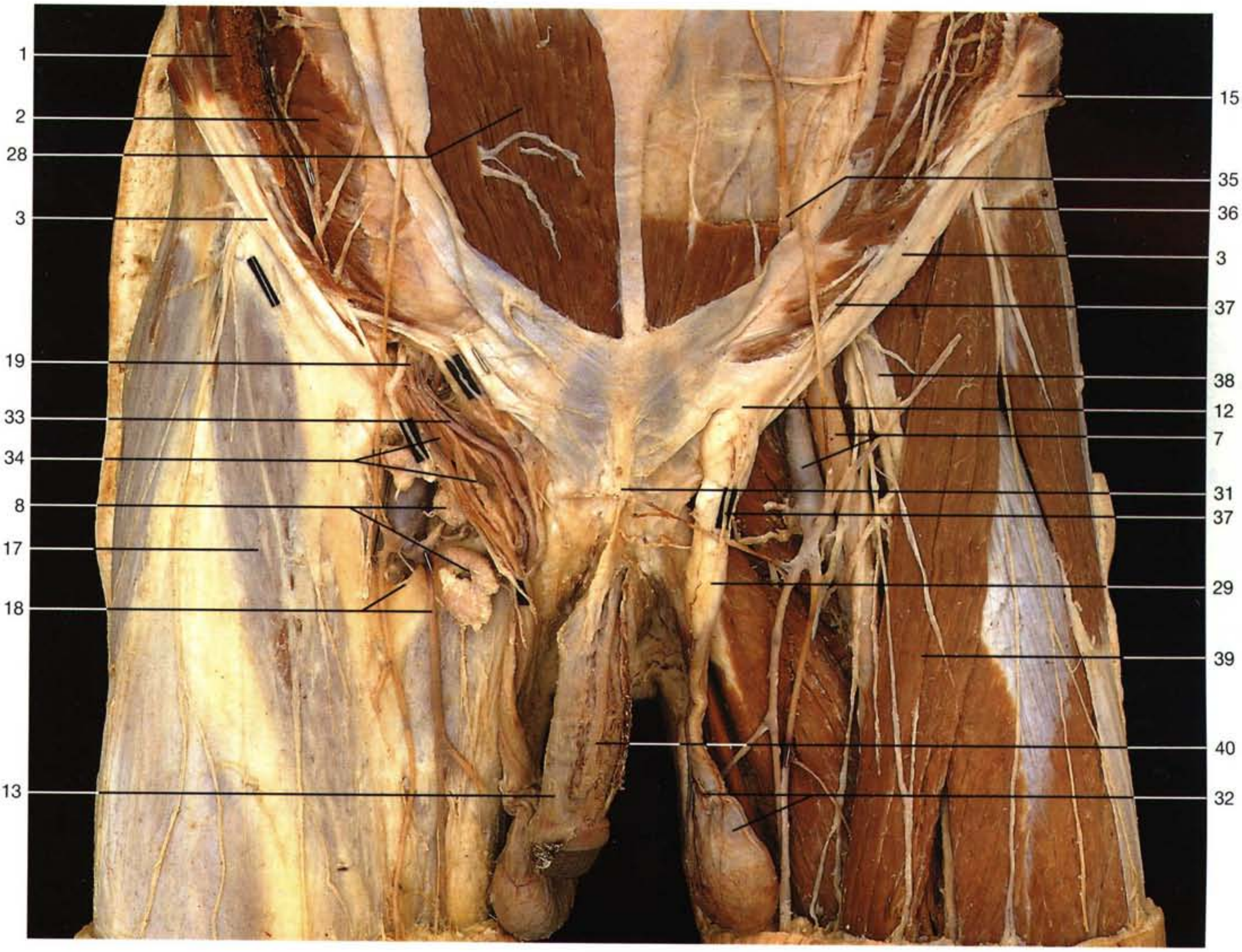
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Inguinal and femoral region in the male (anterior aspect). On the right, the spermatic cord was dissected to display the ductus deferens and the accompanying vessels and nerves. The fascia lata on the left side has been removed.

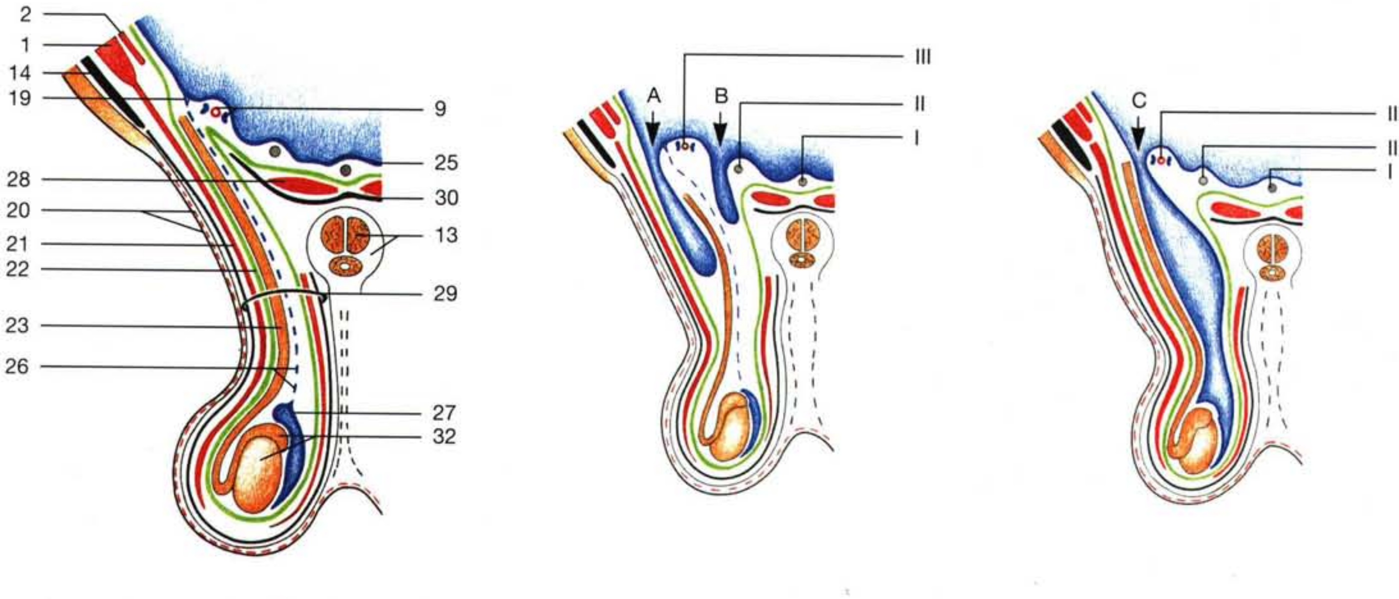
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Layers of spermatic cord and types of hernias. Left: Normal situation; middle: Location of acquired inguinal hernias; A = indirect; B = direct inguinal hernia. Right: congenital indirect inguinal hernia (C); the vaginal process remained open.

I = Median umbilical fold, containing urachus chord.
II = Medial umbilical fold with remnants of umbilical artery and vein.
III = Lateral umbilical fold with inferior epigastric artery and vein.

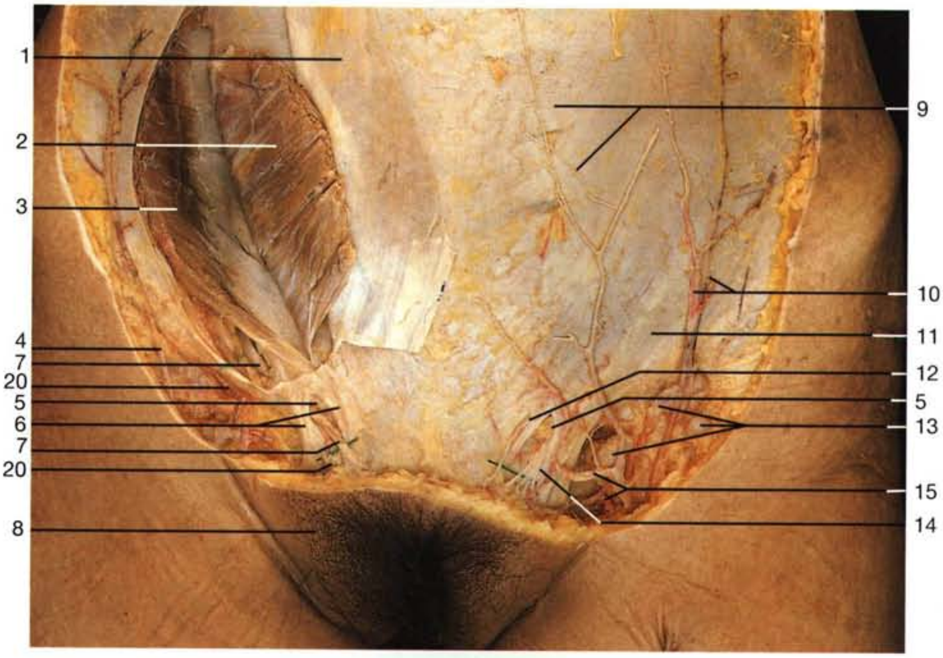

Inguinal region in the female (anterior aspect). Left side: superficial layer; right side: external and internal abdominal oblique muscle divided and reflected.

1 Aponeurosis of external abdominal oblique muscle
2 Internal abdominal oblique muscle (divided and reflected)
3 Transversus abdominis muscle
4 Superficial circumflex iliac artery and vein
5 Superficial inguinal ring with fat pad
6 Medial and lateral crural fibers
7 **Round ligament** (ligamentum teres uteri)
8 Labium majus pudendi
9 Anterior layer of rectus sheath
10 Superficial epigastric artery and vein
11 **Inguinal ligament**
12 Cutaneous branch of ilioinguinal nerve
13 Superficial inguinal lymph nodes
14 Entrance of round ligament into the labium majus
15 External pudendal artery and vein
16 Position of deep inguinal ring
17 **Ilioinguinal nerve**
18 Internal abdominal oblique muscle
19 Pubic branch of inferior epigastric artery
20 Genital branch of genitofemoral nerve
21 Fat pad of inguinal canal
22 Ilioinguinal nerve
23 Sheath of round ligament (inguinal canal)
24 Transversalis fascia

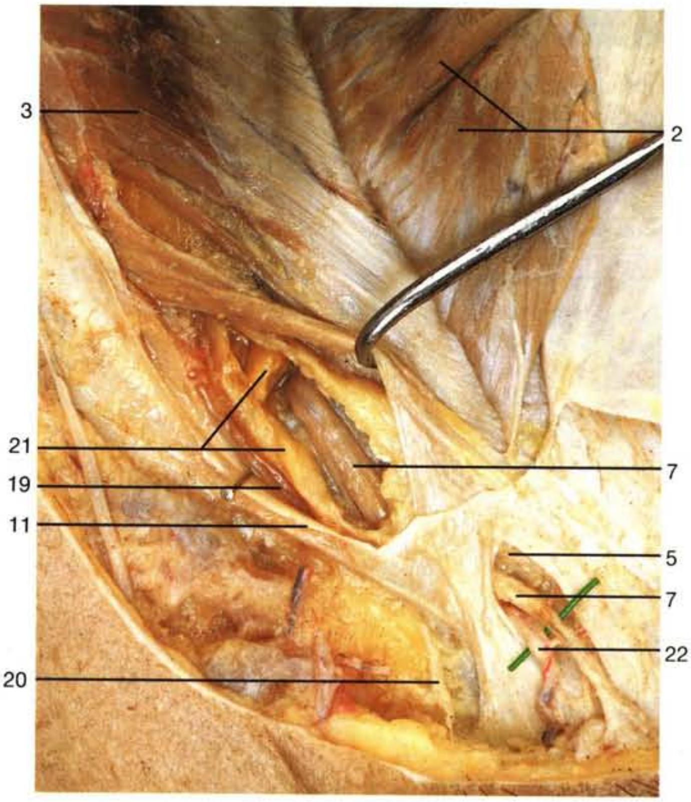

Inguinal canal of the female I (anterior aspect, right side). The external abdominal oblique muscle has been divided and reflected, to display the ilioinguinal nerve and the round ligament.

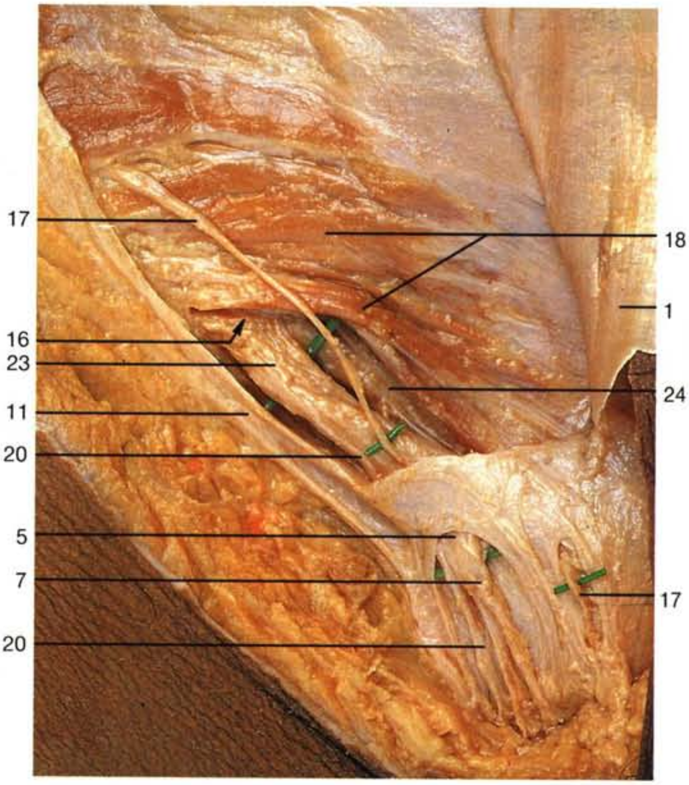

Inguinal canal of the female II (anterior aspect, right side). The external and internal abdominal oblique muscle have been divided and reflected to show the content of the inguinal canal.

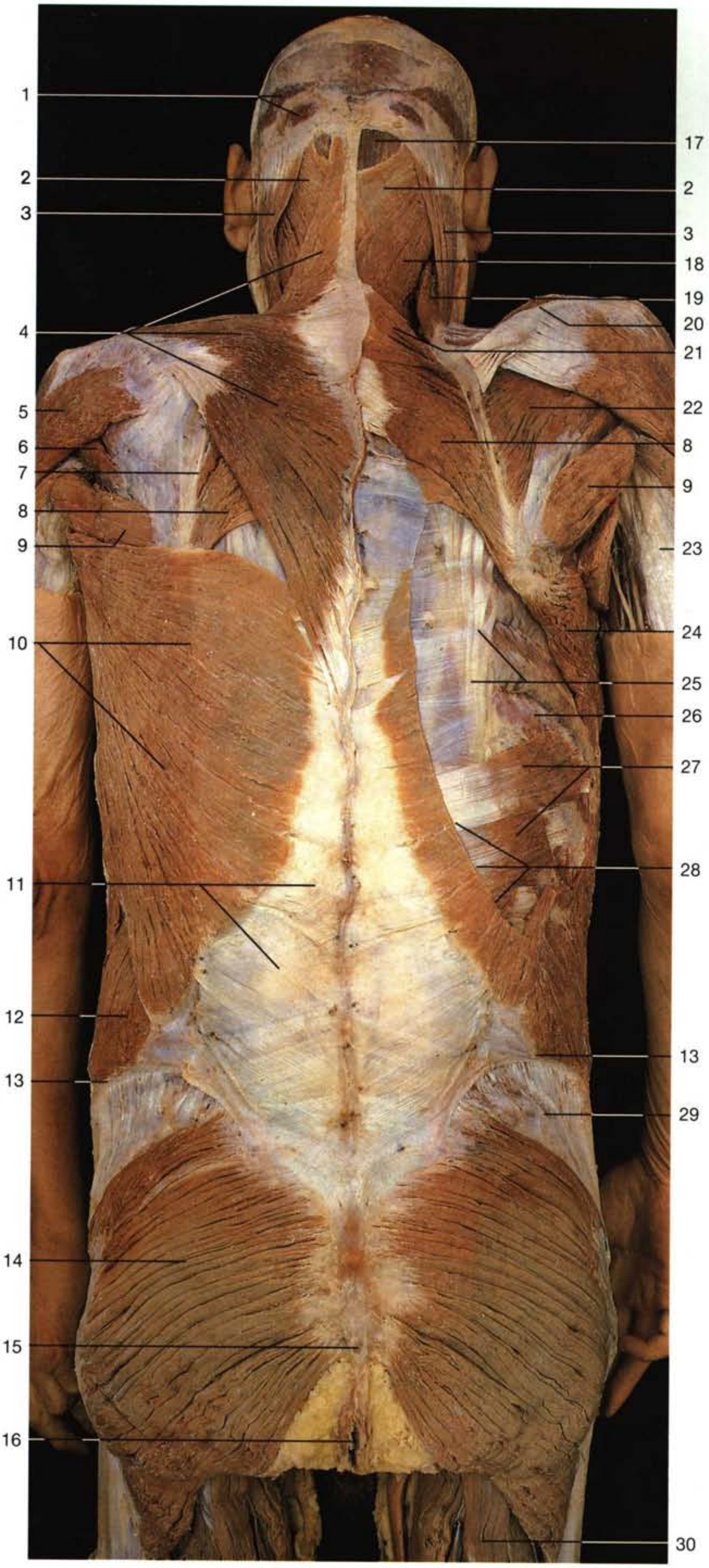

1 Occipital belly of occipitofrontalis muscle
2 Splenius capitis muscle
3 Sternocleidomastoid muscle
4 **Trapezius muscle**
5 Deltoid muscle
6 Teres minor muscle
7 Medial margin of scapula
8 **Rhomboid major muscle**
9 Teres major muscle
10 **Latissimus dorsi muscle**
11 Thoracolumbar fascia
12 External abdominal oblique muscle
13 Iliac crest
14 **Gluteus maximus muscle**
15 Position of last coccygeal vertebra
16 Anus
17 Semispinalis capitis muscle
18 Splenius cervicis muscle
19 Levator scapulae muscle
20 Spine of scapula
21 Rhomboideus minor muscle
22 Infraspinatus muscle
23 Triceps brachii muscle
24 Serratus anterior muscle
25 **Iliocostalis muscle**
26 External intercostal muscle
27 **Serratus posterior inferior muscle**
28 Latissimus dorsi muscle (cut edge)
29 Fascia over gluteus medius muscle
30 Long head of biceps femoris muscle

Muscles of the back I. Superficial layer on the left, deeper layer on the right. Right latissimus dorsi and trapezius muscles are removed.

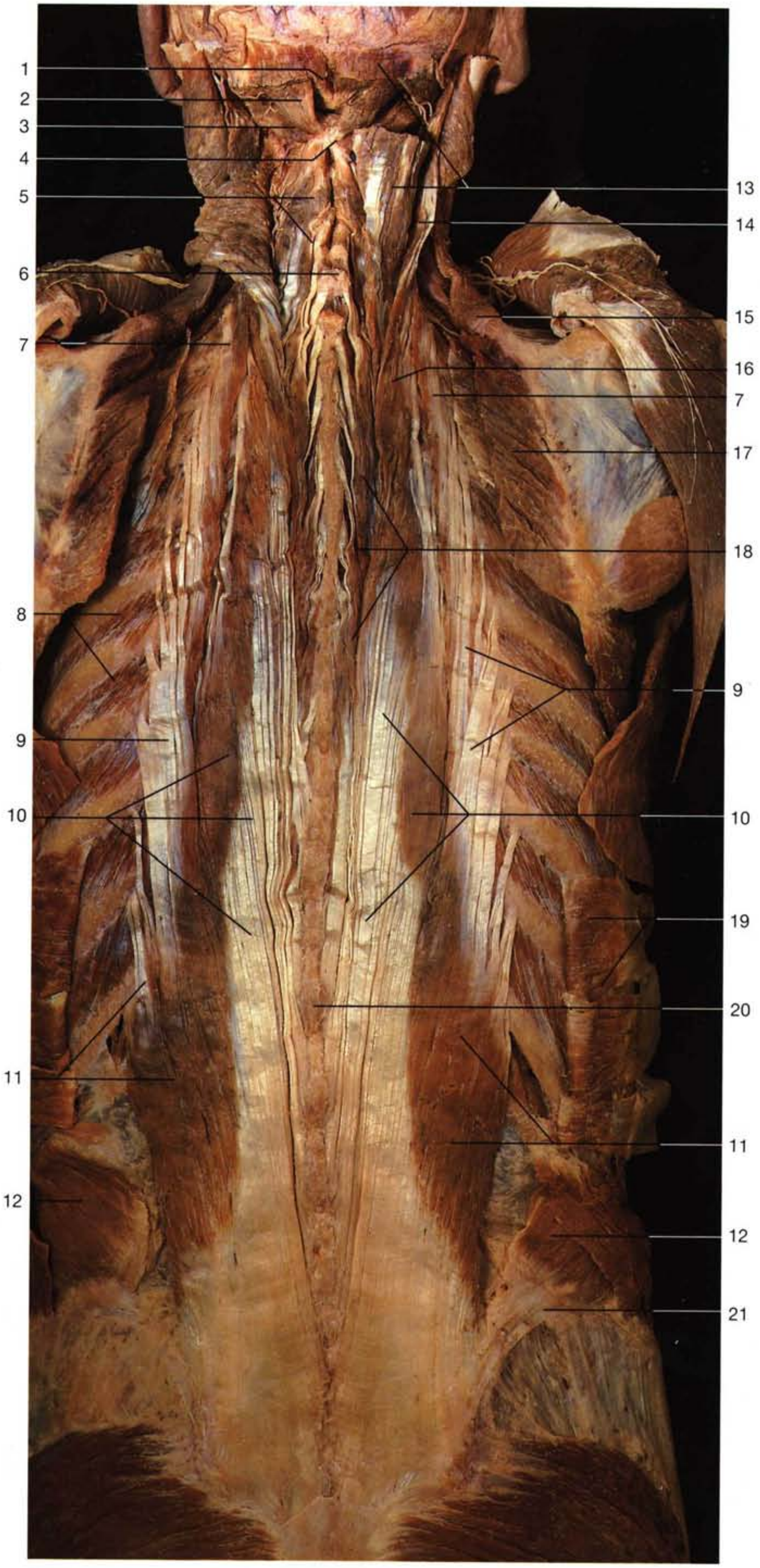

Muscles of the back II. Dissection of deep muscles. Erector spinae muscle.

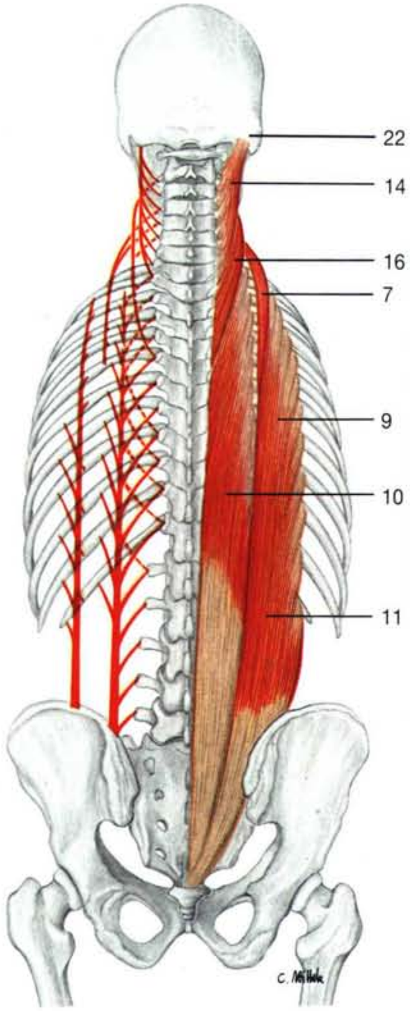

Origin and insertion of iliocostalis and longissimus muscles. (Schematic drawing.)

1 Rectus capitis posterior minor muscle
2 Rectus capitis posterior major muscle
3 Obliquus capitis inferior muscle
4 Spinous process of axis
5 Semispinalis cervicis muscle
6 Spinous process of seventh vertebra
7 **Iliocostalis cervicis muscle**
8 External intercostal muscles
9 **Iliocostalis thoracis muscle**
10 **Longissimus thoracis muscle**
11 **Iliocostalis lumborum muscle**
12 Internal abdominal oblique muscle
13 Semispinalis capitis muscle (divided)
14 **Longissimus capitis muscle**
15 Levator scapulae muscle
16 **Longissimus cervicis muscle**
17 Rhomboid major muscle
18 **Spinalis thoracis muscle**
19 Serratus posterior inferior muscle (reflected)
20 Spinous process of second lumbar vertebra
21 Iliac crest
22 Mastoid process

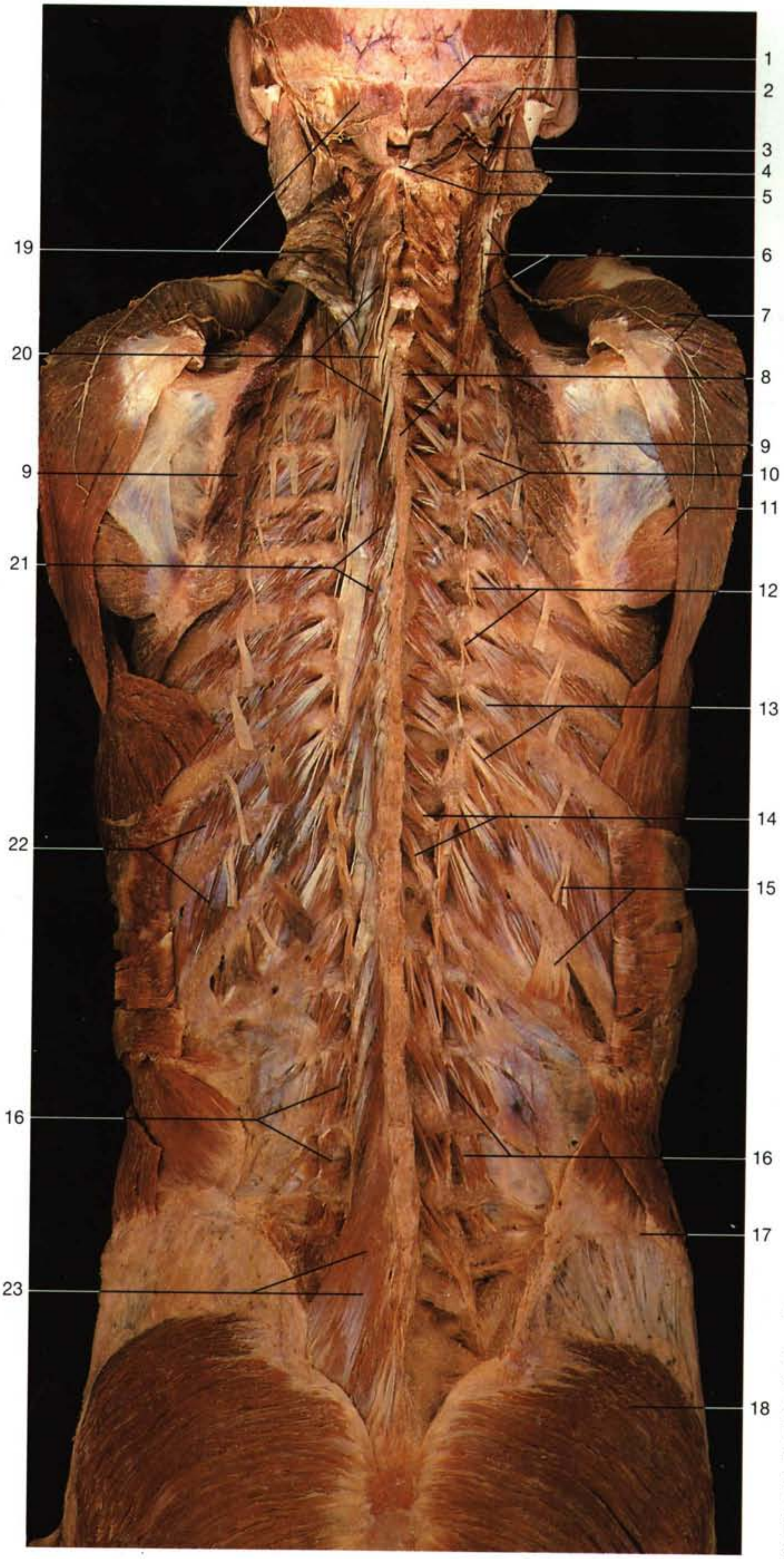

Muscles of the back III. Transversospinal muscles, deepest layer on the right, where all parts of semispinalis and multifidus muscles have been removed.

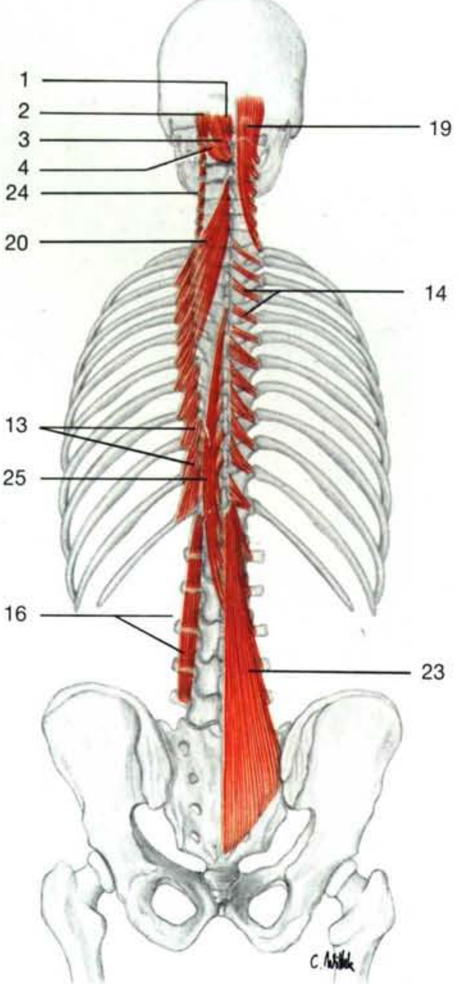

Medial column of intrinsic muscles of the back. Transversospinal and intertransversal system. (Schematic drawing.)

1 Rectus capitis posterior minor muscle
2 Obliquus capitis superior muscle
3 Rectus capitis posterior major muscle
4 Obliquus capitis inferior muscle
5 Spinous process of axis
6 **Longissimus capitis muscle**
7 Trapezius muscle (reflected) and accessory nerve (n. XI)
8 Spinous processes
9 Rhomboid major muscle
10 Transverse processes of thoracic vertebrae
11 Teres major muscle
12 Intertransverse ligaments
13 **Levatores costarum muscles**
14 **Rotatores muscles**
15 Tendons of iliocostalis muscle
16 Intertransversarii lumborum muscle (lateral)
17 Iliac crest
18 Gluteus maximus muscle
19 Semispinalis capitis muscle
20 **Semispinalis cervicis muscle**
21 Semispinalis thoracis muscle
22 **External intercostal muscles**
23 **Multifidus muscle**
24 Intertransversarii posterior cervicis muscle
25 Spinalis thoracis muscle

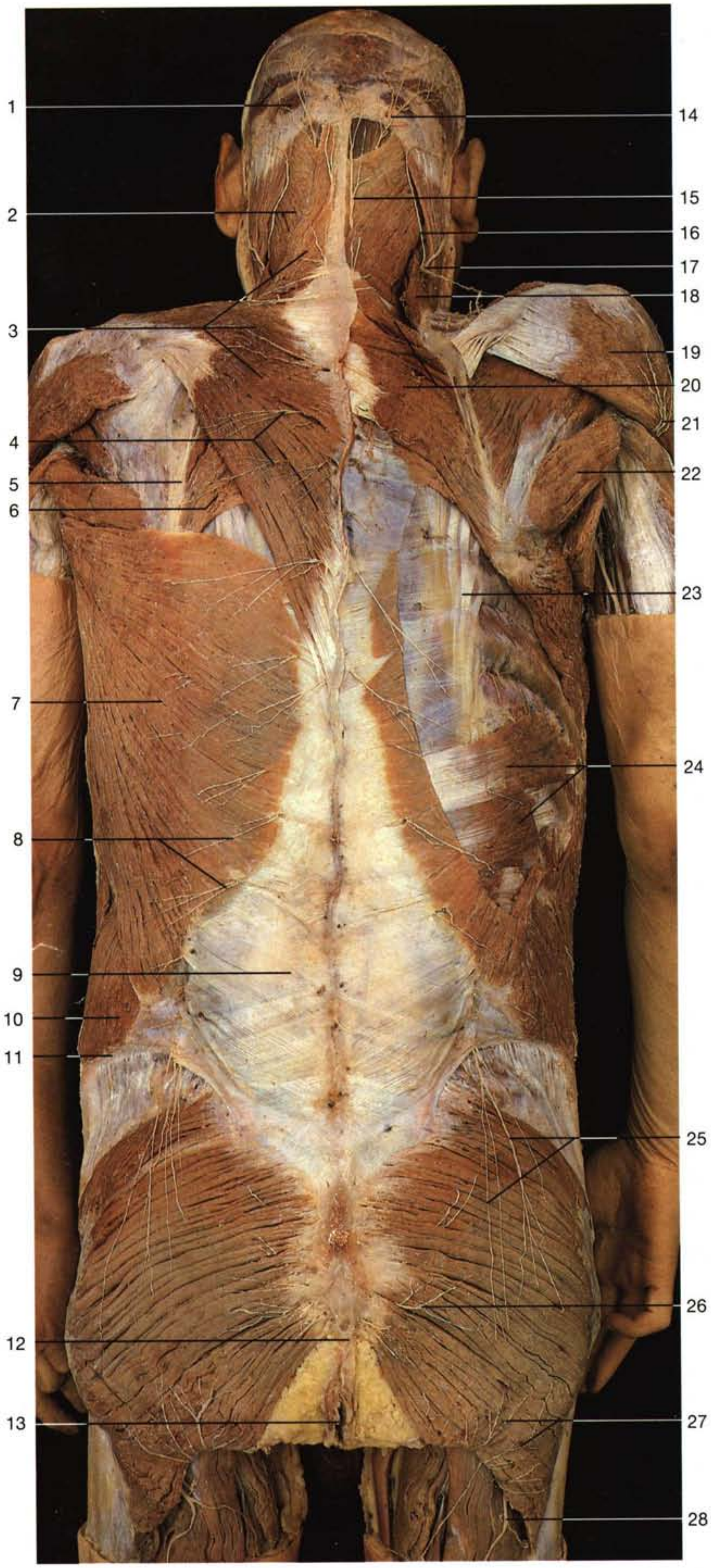

Innervation of the back I. Superficial (left) and deeper (right) layers. Right trapezius and latissimus dorsi muscles removed.

1 Occipital belly of occipitofrontalis muscle
2 Splenius capitis muscle
3 **Trapezius muscle**
4 **Medial cutaneous branches of dorsal rami of spinal nerves**
5 Medial margin of scapula
6 Rhomboid major muscle
7 **Latissimus dorsi muscle**
8 **Lateral cutaneous branches of dorsal rami of spinal nerves**
9 Thoracolumbar fascia
10 External abdominal oblique muscle
11 Iliac crest
12 Last coccygeal vertebra
13 Anus
14 Greater occipital nerve
15 Third occipital nerve
16 Lesser occipital nerve
17 Cutaneous branches of cervical plexus
18 Levator scapulae muscle
19 Deltoid muscle
20 **Rhomboid major and minor muscles**
21 Upper lateral cutaneous nerve of arm (branch of axillary nerve)
22 **Teres major muscle**
23 Iliocostalis thoracis muscle
24 Serratus posterior inferior muscle
25 Superior cluneal nerves
26 Middle cluneal nerves
27 Inferior cluneal nerves
28 Posterior femoral cutaneous nerve

▷
To page 213:
1 **Trapezius muscle**
2 Infraspinatus muscle
3 Left **latissimus dorsi muscle**
4 Thoracolumbar fascia
5 Splenius cervicis muscle
6 Serratus posterior superior muscle
7 **Medial branches of dorsal rami of thoracic spinal nerves**
8 **Lateral branches of dorsal rami of thoracic spinal nerves**
9 Iliocostalis muscle
10 Serratus posterior inferior muscle
11 Latissimus dorsi muscle (reflected)

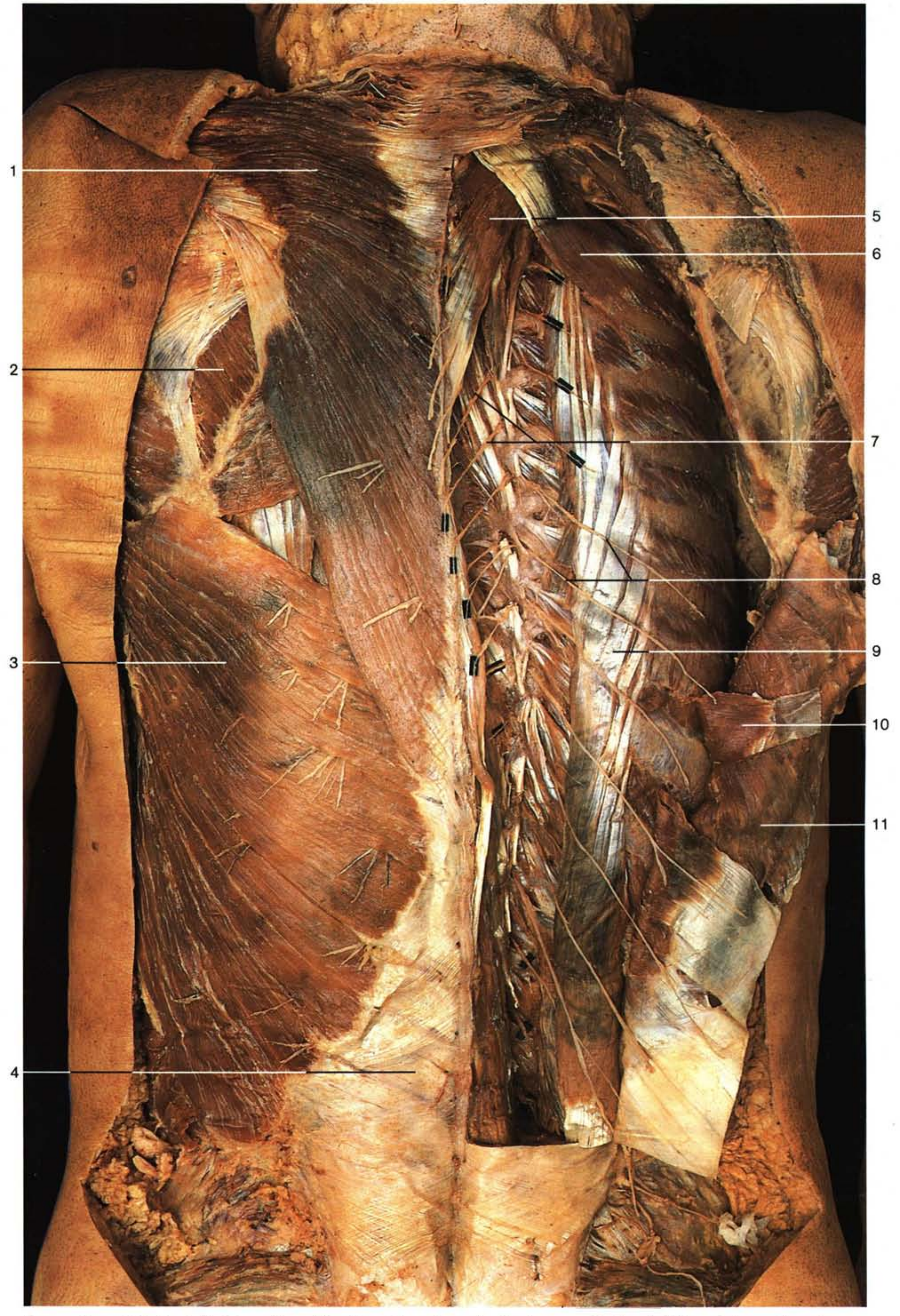

Innervation of the back II. Dissection of the dorsal branches of spinal nerves. On the right, longissimus thoracis muscle has been removed and iliocostalis muscle laterally reflected.

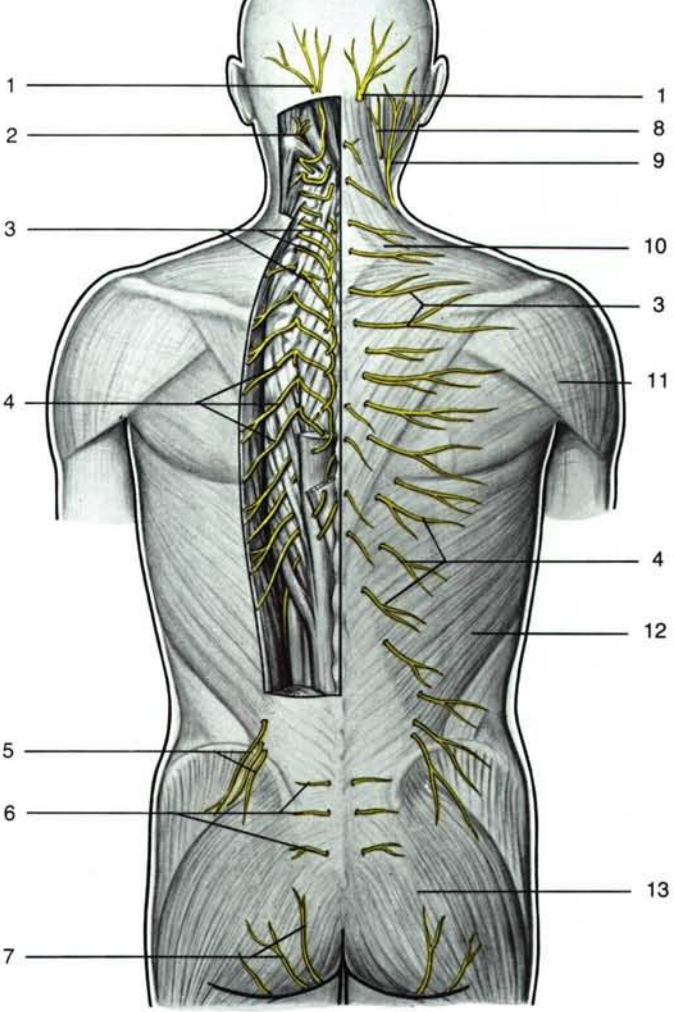

General characteristics of the innervation of the back. Distribution of dorsal branches of spinal nerves. Note the segmental arrangement of the innervation of the dorsal part of the trunk. (Schematic drawing.)

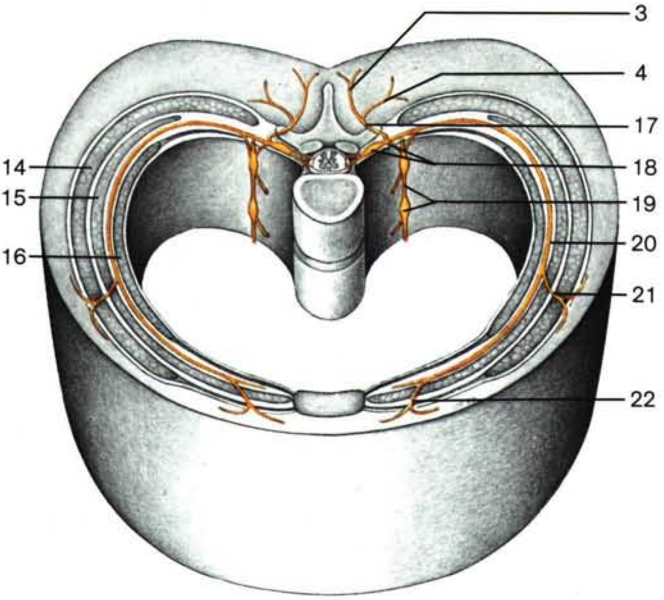

Position and branches of spinal nerves in one segment of thoracic wall. (Schematic drawing.)

1. Greater occipital nerve (C_2)
2. Suboccipital nerve (C_1)
3. **Medial branches of dorsal rami of spinal nerves**
4. **Lateral branches of dorsal rami of spinal nerves**
5. Superior cluneal nerves (L_1–L_3)
6. Middle cluneal nerves (S_1–S_3)
7. Inferior cluneal nerves (derived from branches of the sacral plexus, ventral rami)
8. Lesser occipital nerve
9. Great auricular nerve
10. Trapezius muscle
11. Deltoid muscle
12. Latissimus dorsi muscle
13. Gluteus maximus muscle
14. External intercostal muscle
15. Internal intercostal muscle
16. Innermost intercostal muscle
17. Dorsal ramus of spinal nerve
18. **Spinal nerve** and **spinal ganglion**
19. Sympathetic trunk with ganglion
20. Intercostal nerve
21. Lateral cutaneous branch
22. Anterior cutaneous branch

} of **intercostal nerve**

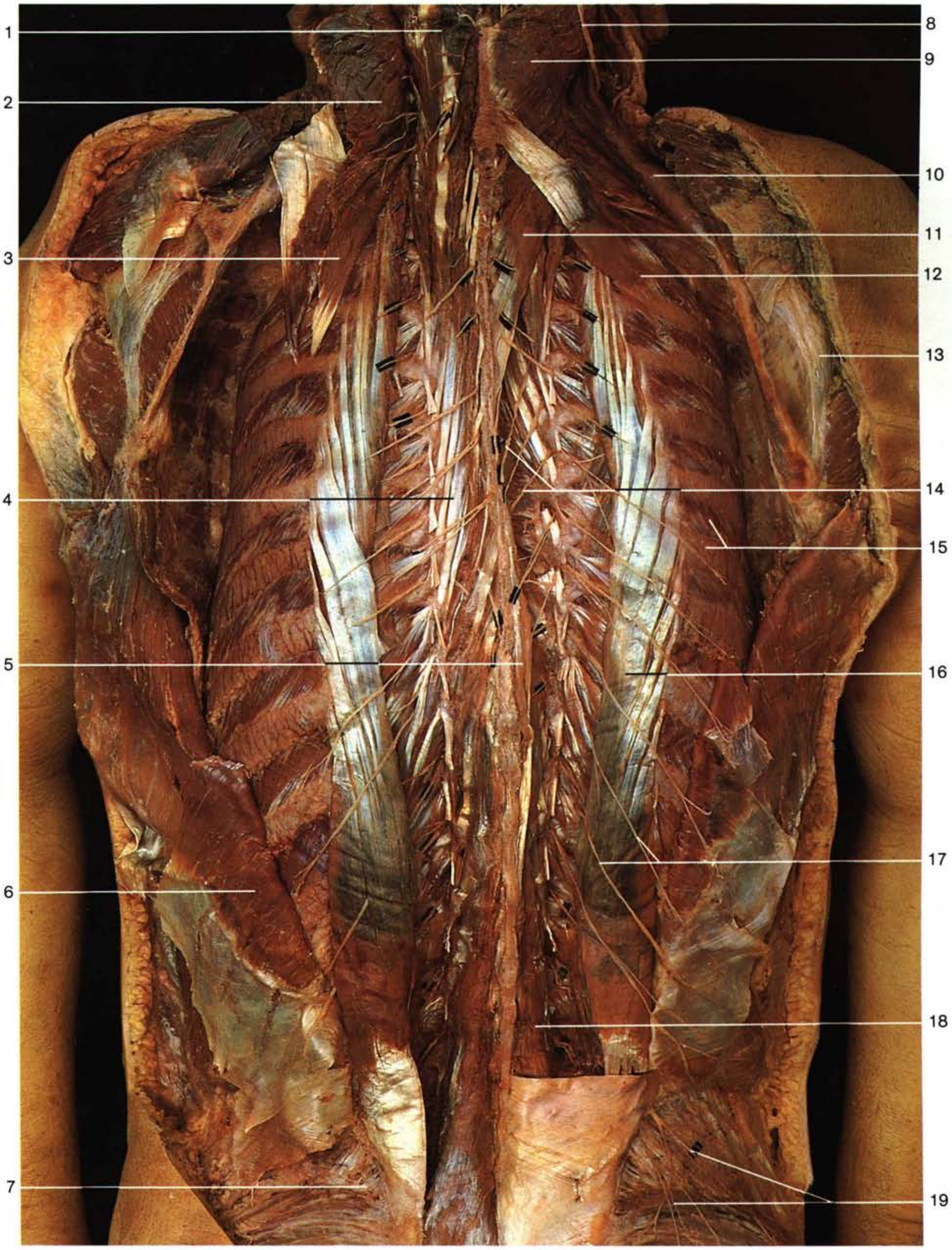

Innervation of the back III. Deeper layer (dorsal aspect).

1 Semispinalis capitis muscle
2 Left splenius capitis muscle (cut and reflected)
3 Left splenius cervicis muscle (cut and reflected)
4 Semispinalis thoracis muscle
5 **Spinalis thoracis muscle**
6 Latissimus dorsi muscle (reflected)
7 Iliac crest
8 Lesser occipital nerve
9 Splenius capitis muscle
10 Levator scapulae muscle
11 **Splenius cervicis muscle**
12 Serratus posterior superior muscle
13 Scapula
14 **Medial branches of dorsal rami of spinal nerves**
15 Rib and external intercostal muscle
16 Iliocostalis thoracis muscle
17 **Lateral branches of dorsal rami of spinal nerves**
18 Multifidus muscle
19 Superior cluneal nerves

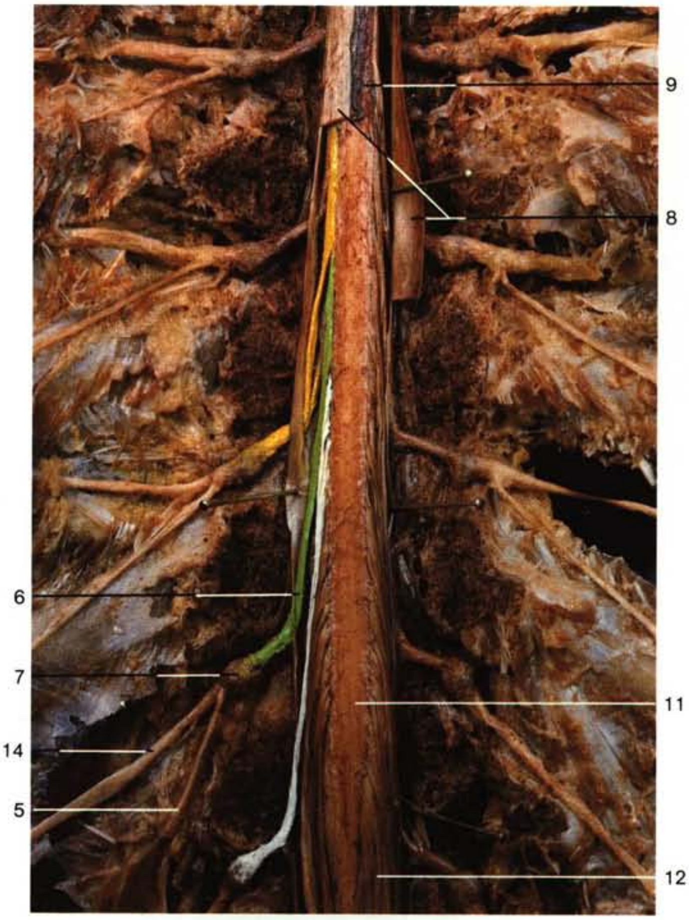

Lumbar portion of spinal cord. Note the relation between the nervous and muscular segments.

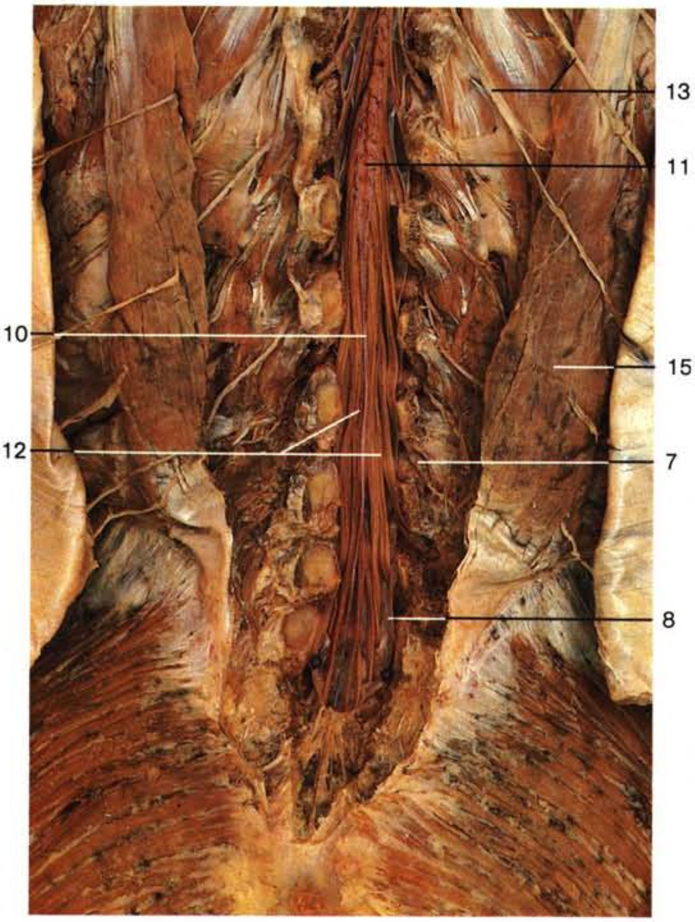

Terminal part of spinal cord. Dura removed.

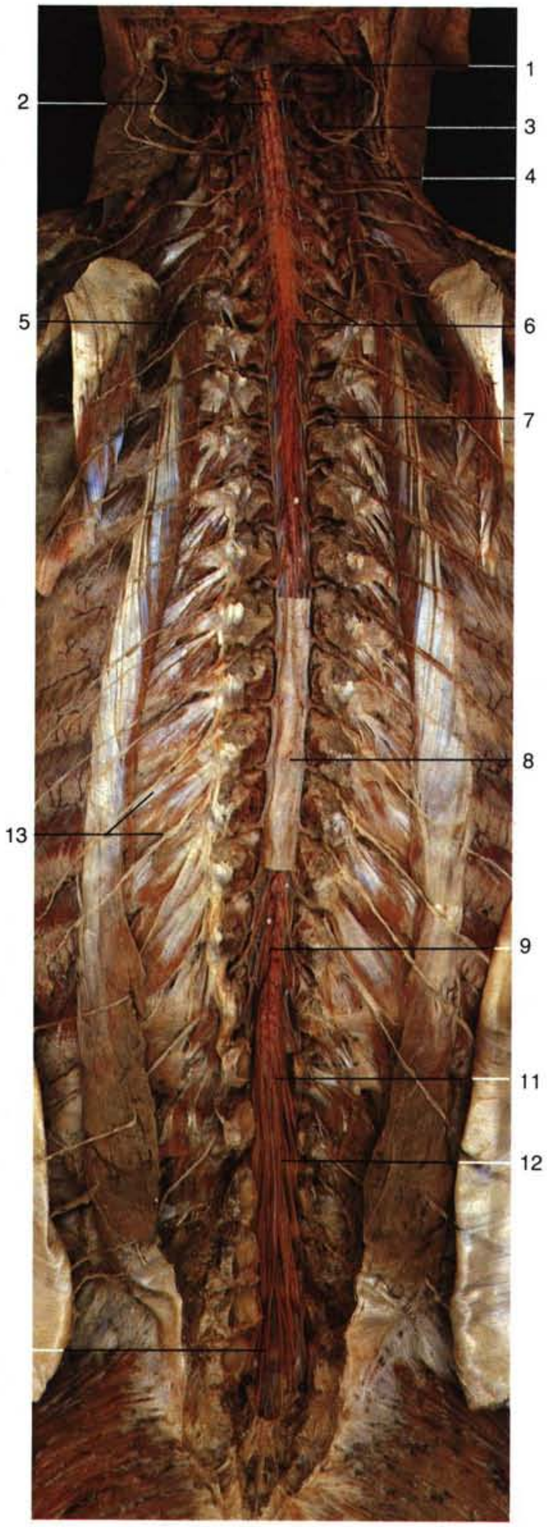

Innervation of the back IV. Spinal cord in the vertebral canal (opened). Longissimus dorsi muscle has been removed and iliocostal muscle reflected.

1 Cerebellomedullary cistern and cerebellum
2 Medulla oblongata
3 Greater occipital nerve (C_2)
4 Third cervical nerve (C_3)
5 Dorsal primary ramus
6 Dorsal roots
7 Spinal ganglion
8 Spinal dura mater
9 Spinal arachnoid mater
10 Filum terminale
11 Conus medullaris
12 Cauda equina
13 Lateral branches of dorsal rami of spinal nerves
14 Ventral ramus of spinal nerve (intercostal nerve)
15 Iliocostalis muscle

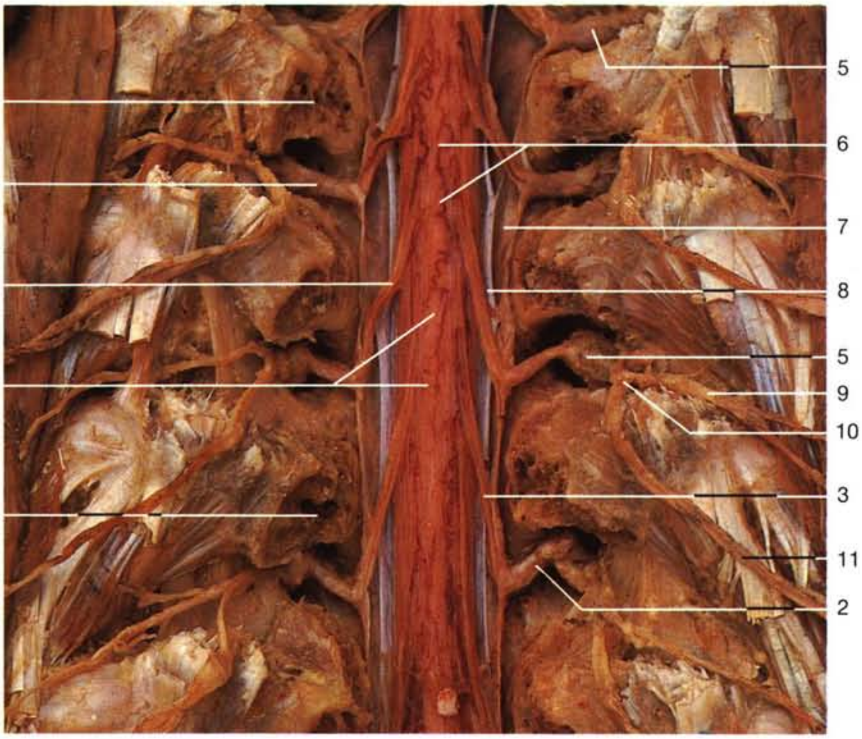

Thoracic portion of spinal cord (dorsal aspect). Vertebral canal and dura mater opened.

1 Arch of vertebra (divided)
2 Spinal nerve with meningeal coverings
3 Dorsal roots of thoracic spinal nerves
4 Spinal cord (thoracic portion)
5 Spinal ganglia with meningeal coverings
6 Pia mater with blood vessels
7 Dura mater (opened)
8 Denticulate ligament
9 Lateral branch of dorsal ramus
10 Dorsal ramus of spinal nerve (dividing into a medial and lateral branch)
11 Medial branch of dorsal ramus of spinal nerve
12 Spinal dura mater
13 Spinal nerves of sacral segments
14 Filum terminale

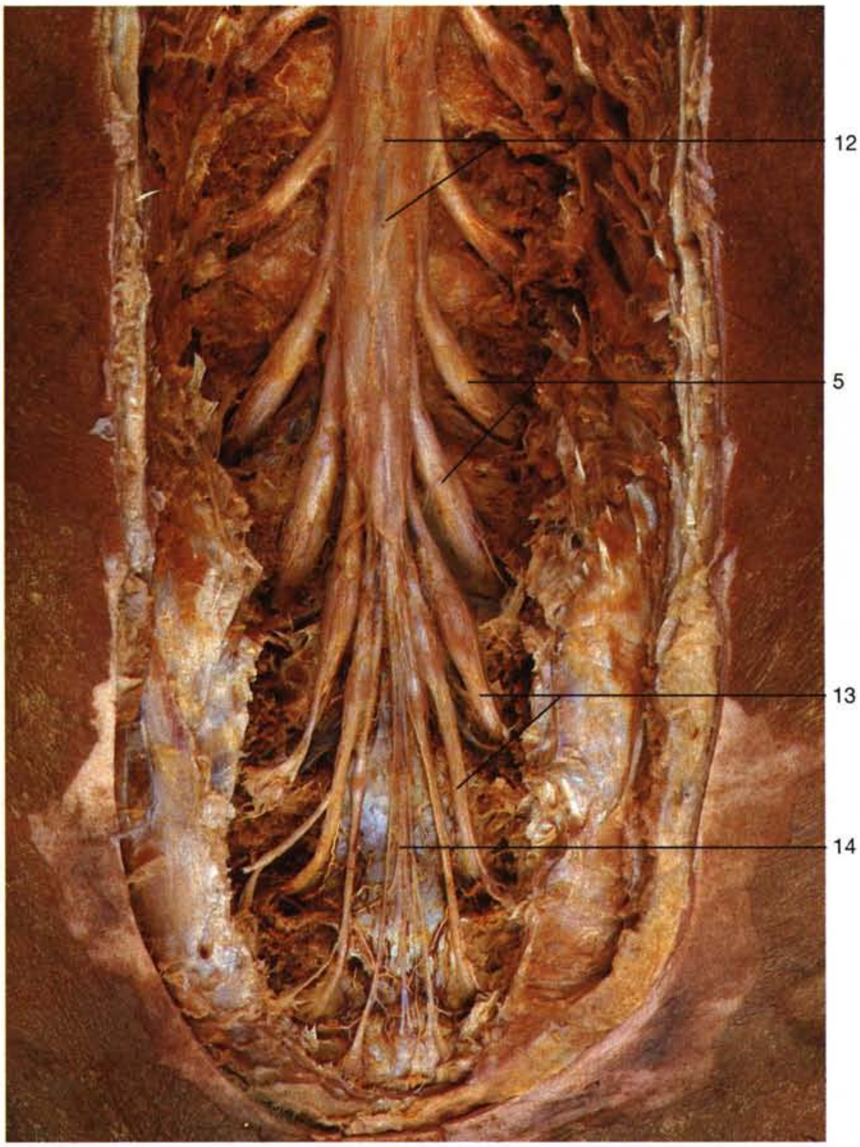

Terminal part of spinal cord with dura mater (dorsal aspect). Dorsal part of sacrum removed.

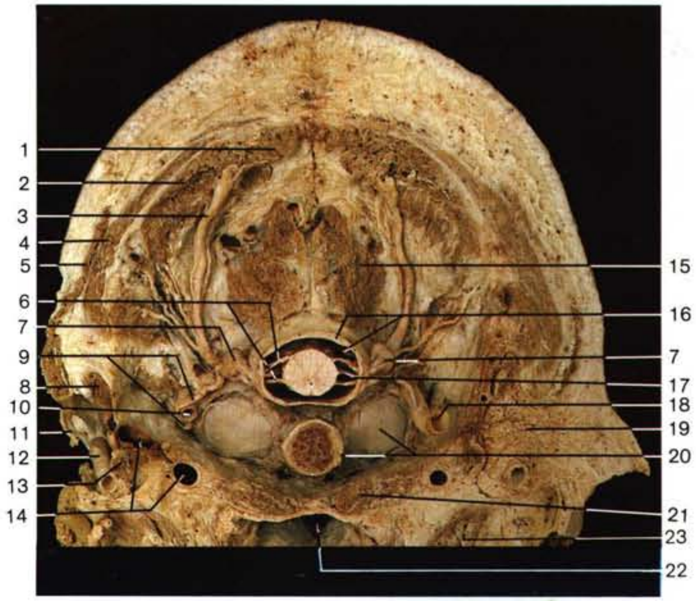

Horizontal section of the neck. Dissection of the second cervical spinal nerve. Posterior surface at top of figure.

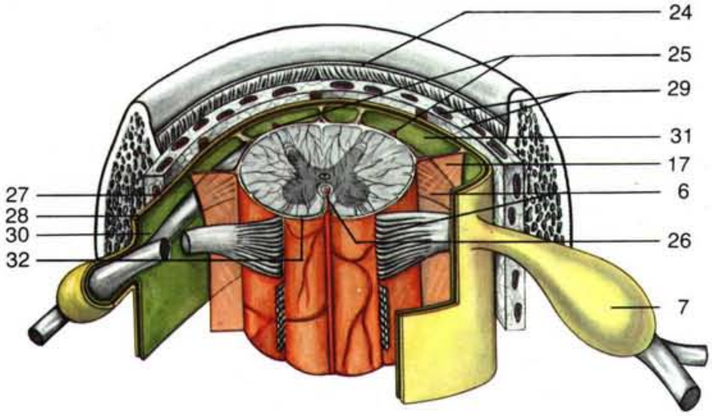

Meningeal coverings of the spinal cord (anterior aspect). (Schematic drawing.)

1 Trapezius muscle
2 Semispinalis capitis muscle
3 **Dorsal ramus of spinal nerve**
4 Sternocleidomastoid muscle
5 Platysma muscle
6 **Dorsal and ventral roots of spinal nerves**
7 **Spinal ganglion**
8 Posterior belly of digastric muscle
9 **Ventral ramus of spinal nerve**
10 Vertebral artery
11 Great auricular nerve
12 Superficial temporal artery
13 Styloid process
14 Internal jugular vein and internal carotid artery
15 Rectus capitis posterior major muscle
16 Dura mater and subarachnoid space
17 Denticulate ligament
18 Vertebral artery
19 Parotid gland
20 Dens of axis (divided) and inferior articular facet of atlas
21 Longus capitis muscle
22 Pharyngeal cavity
23 Medial pterygoid muscle
24 Periosteum of vertebral canal
25 Posterior spinal arteries
26 Anterior spinal artery

Meningeal coverings

27 Dura mater
28 Subdural space
29 Extradural or epidural space with venous plexus and fatty tissue
30 Arachnoid (green)
31 Subarachnoid space
32 Pia mater (pink)
33 Nucleus pulposus
34 Crus of diaphragm
35 Intervertebral disc
36 Body of first lumbar vertebra
37 Spinal cord
38 Conus medullaris
39 Cauda equina
40 Filum terminale
41 Spinous process

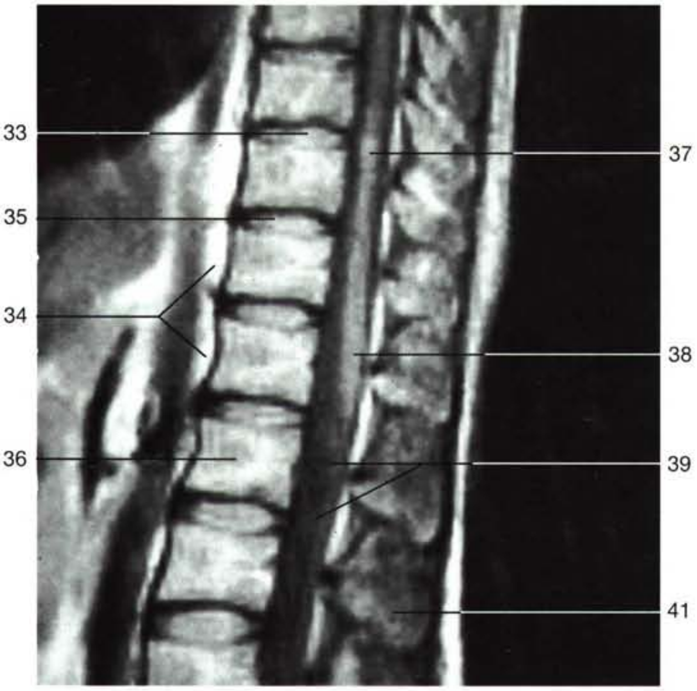

Sagittal section through the vertebral canal, T_9–L_2. (MR-Scan.)

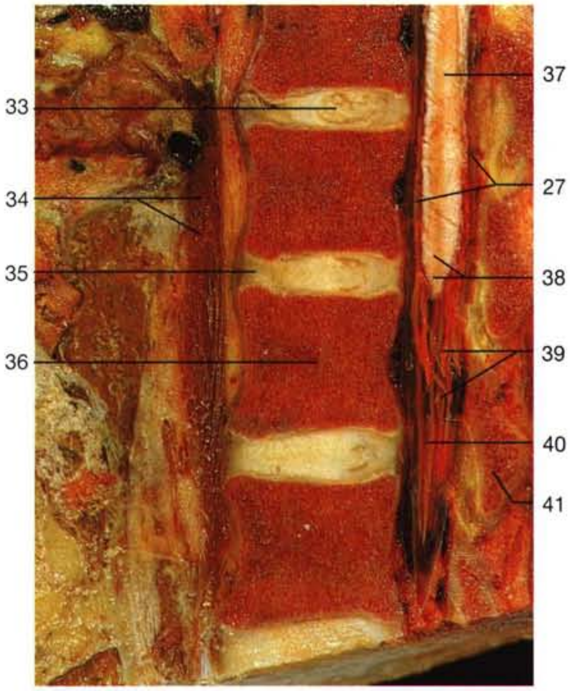

Sagittal section through vertebral canal, T_{12}–L_2. Notice red bone marrow (unfixed).

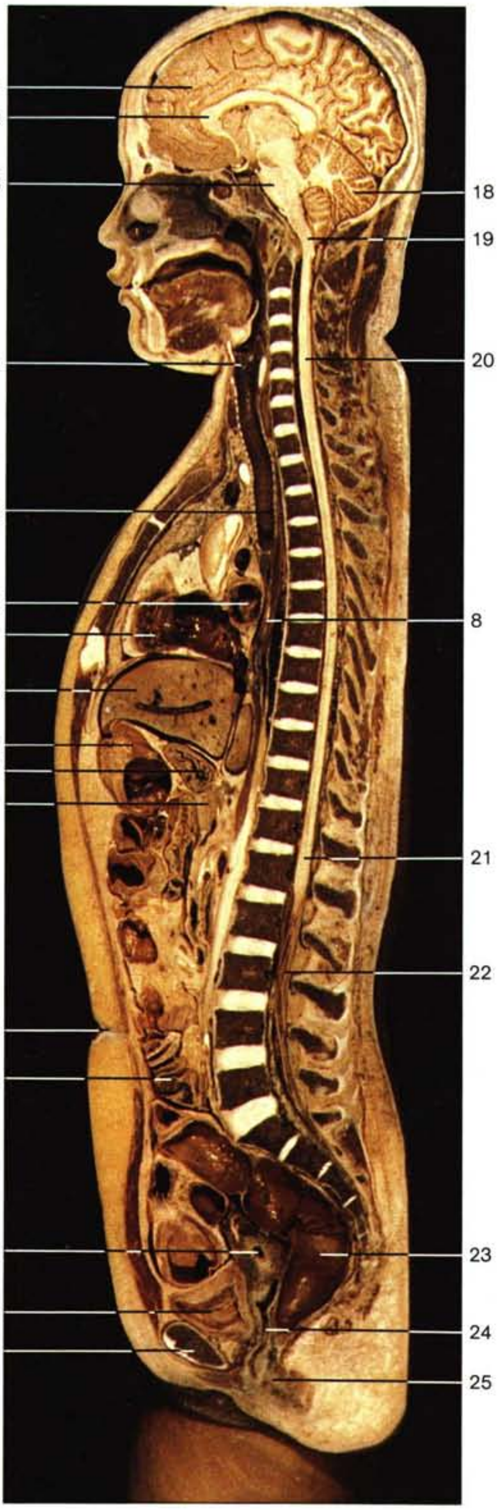
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Median section of the head and trunk in the adult (female). The conus medullaris of the spinal cord is located at the level of L_1.

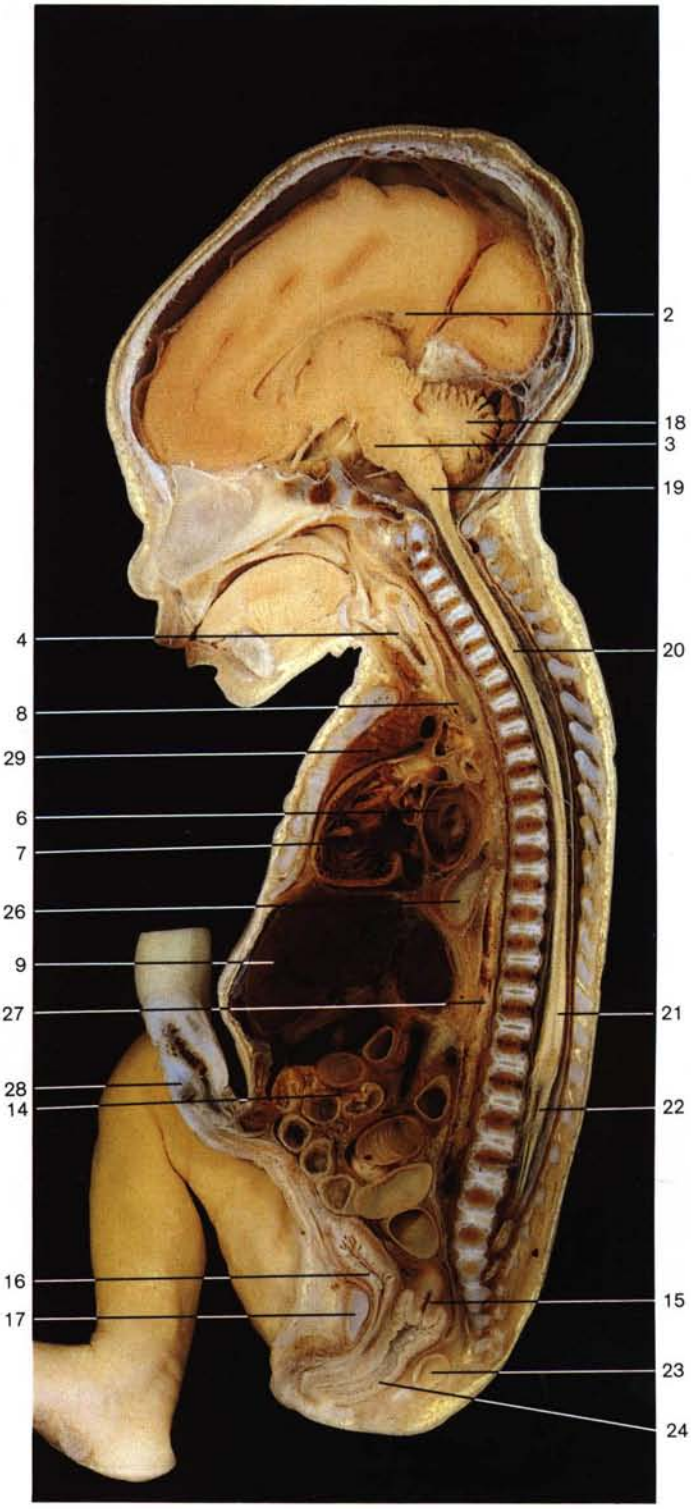
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Median section of the head and trunk in the neonate. Note that in the neonate the conus medullaris of the spinal cord extends far more caudally than in the adult.

1 Cerebrum
2 Corpus callosum
3 Pons
4 Larynx
5 Trachea
6 Left atrium
7 **Right ventricle**
8 Esophagus
9 **Liver**
10 Stomach
11 Pancreas
12 Transverse colon
13 Umbilicus
14 Small intestine
15 Uterus
16 Urinary bladder
17 Pubic symphysis
18 Cerebellum
19 Medulla oblongata
20 **Spinal cord**
21 **Conus medullaris**
22 **Cauda equina**
23 Rectum
24 Vagina
25 Anus
26 Inferior vena cava
27 Aorta
28 Umbilical cord
29 Thymus

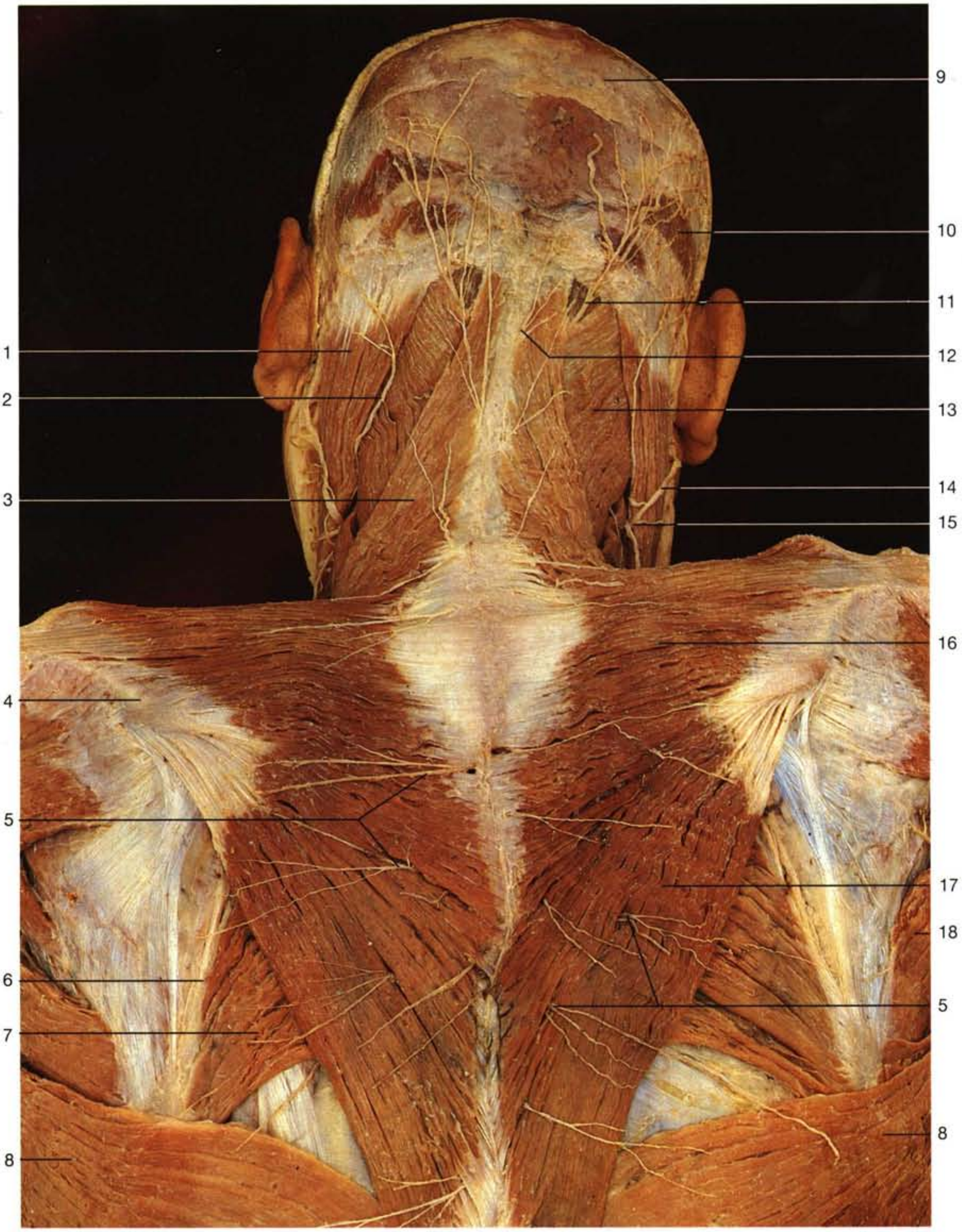

Dorsal aspect of the neck I. Superficial layer. Nuchal region and shoulder.

1	Sternocleidomastoid muscle	10	Occipital belly of occipitofrontalis muscle
2	**Lesser occipital nerve**	11	**Greater occipital nerve**
3	Descending fibers of trapezius muscle	12	Third occipital nerve
4	Spine of scapula	13	Splenius capitis muscle
5	**Medial cutaneous branches of dorsal rami of spinal nerves**	14	**Great auricular nerve**
6	Medial margin of scapula	15	Cutaneous nerves of cervical plexus
7	Rhomboid major muscle	16	Transverse fibers of trapezius muscle
8	Latissimus dorsi muscle	17	Ascending fibers of trapezius muscle
9	Galea aponeurotica	18	Teres major muscle

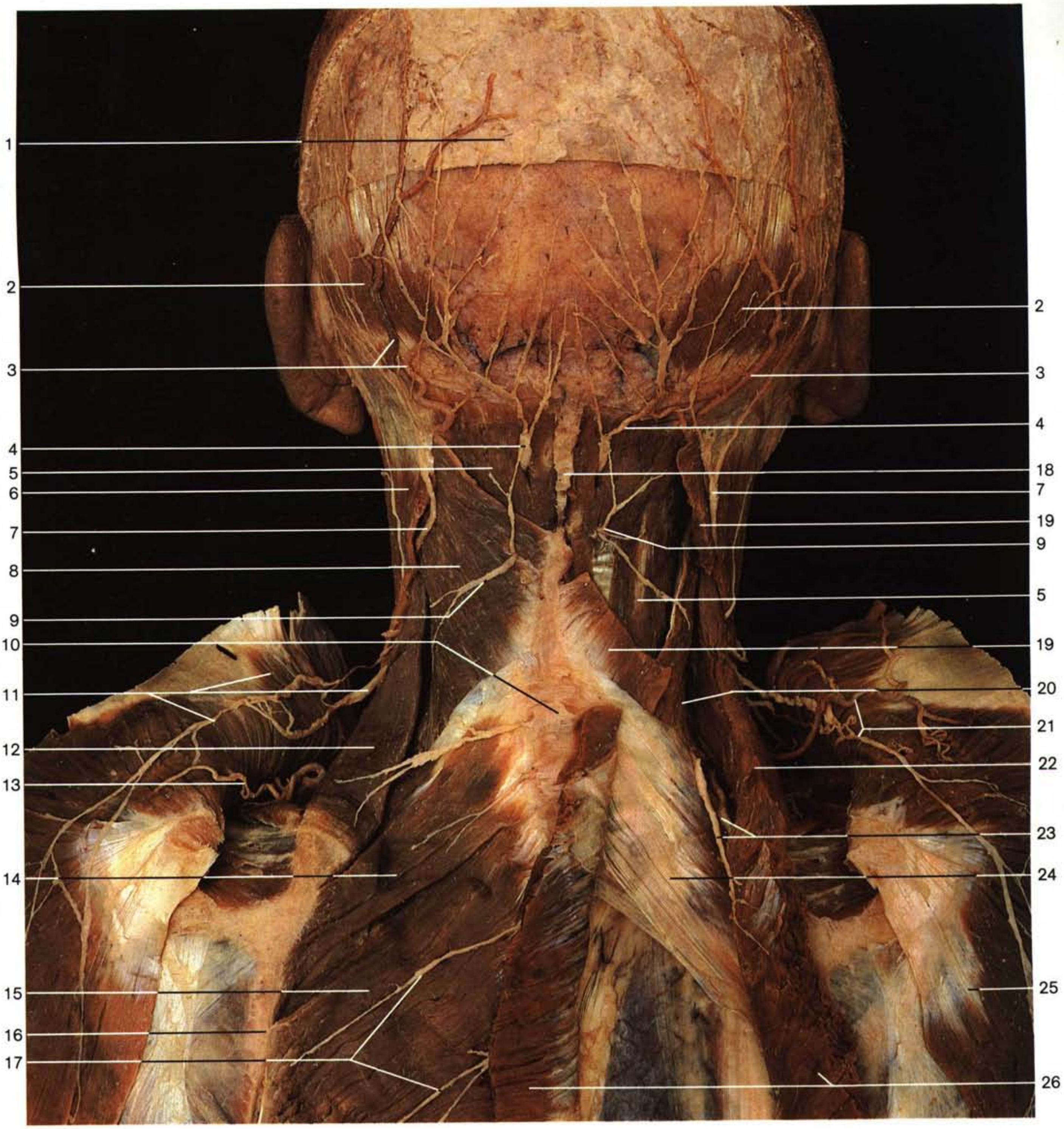

Dorsal aspect of neck II. Deeper layer. The left trapezius muscle has been divided and reflected. On the right, trapezius, rhomboid and splenius muscles have been divided. Right levator scapulae muscle has been slightly reflected.

1 Galea aponeurotica
2 Occipital belly of occipitofrontalis muscle
3 Occipital artery
4 **Greater occipital nerve** (C_2)
5 Semispinalis capitis muscle
6 Sternocleidomastoid muscle
7 Lesser occipital nerve
8 Left splenius capitis muscle
9 Third occipital nerve (C_3)
10 Spinous process of vertebra prominens (C_7)
11 Left trapezius muscle and **accessory nerve**
12 Levator scapulae muscle
13 Superficial branch of transverse cervical artery
14 Thomboid minor muscle
15 Rhomboid major muscle
16 Medial margin of scapula
17 **Medial branches of dorsal rami of spinal nerves**
18 Ligamentum nuchae
19 Splenius capitis muscle (divided)
20 Splenius cervicis muscle
21 Right **accessory nerve** and superficial branch of transverse cervical artery
22 Right levator scapulae muscle
23 Dorsal scapular nerve and deep branch of transverse cervical artery
24 Serratus posterior superior muscle
25 Right trapezius muscle (divided and reflected)
26 Right rhomboid major muscle (divided and reflected)

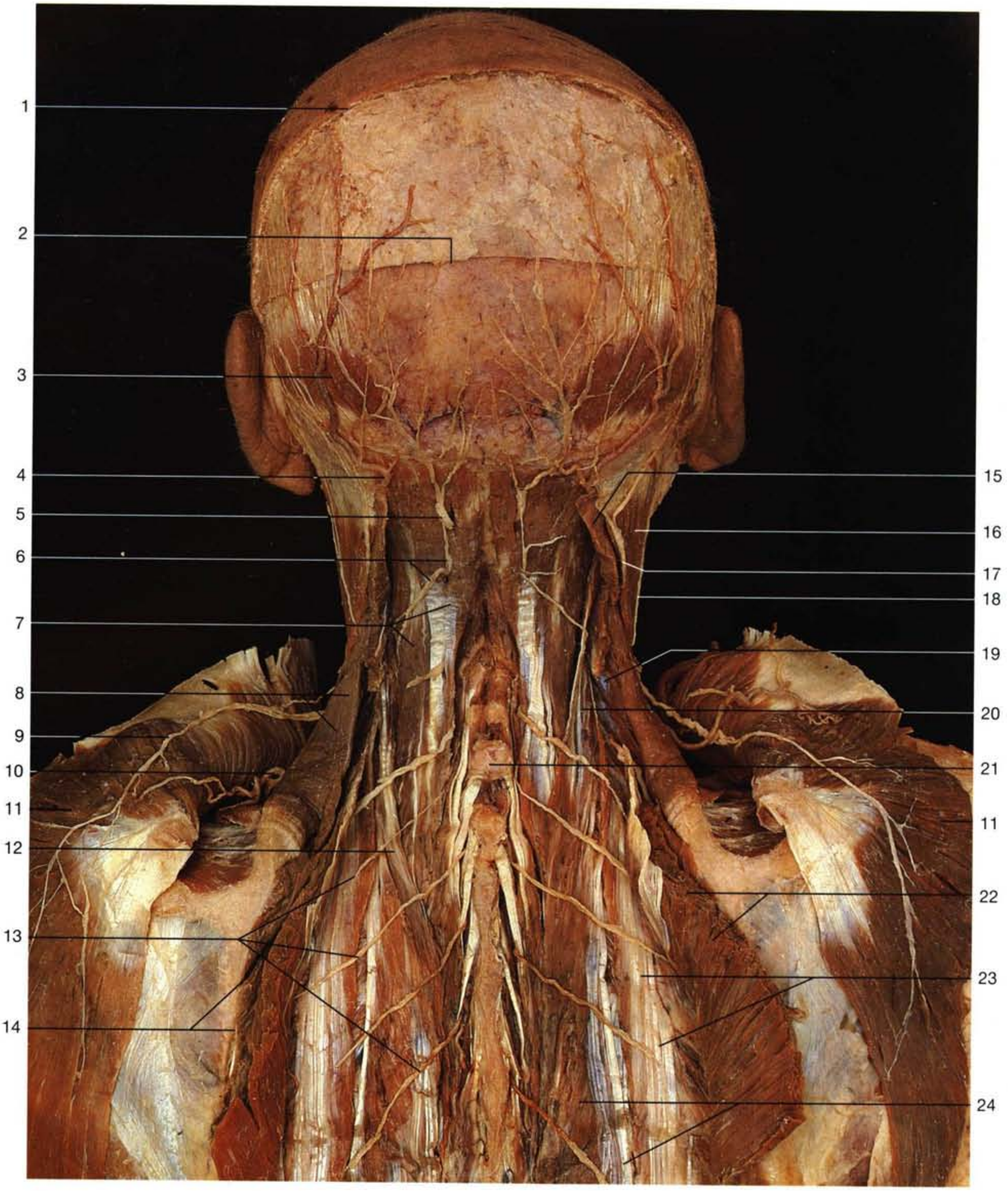

Dorsal aspect of neck III. Deepest layer. Nuchal region. Trapezius muscle and splenius capitis and cervicis muscles have been divided and partly removed or reflected.

1 Skin of scalp
2 Galea aponeurotica
3 Occipital belly of occipitofrontalis muscle
4 **Occipital artery**
5 **Greater occipital nerve**
6 Third occipital nerve
7 Semispinalis capitis muscle
8 Levator scapulae muscle

9 **Accessory nerve** (n. XI)
10 Superficial cervical artery
11 Trapezius muscle (reflected)
12 Longissimus cervicis muscle
13 **Medial cutaneous branches of dorsal rami of spinal nerves**
14 Medial margin of scapula
15 Splenius capitis muscle (divided)
16 Sternocleidomastoid muscle

17 **Lesser occipital nerve**
18 Great auricular nerve
19 Splenius cervicis muscle
20 Longissimus cervicis muscle
21 Spinous process of seventh cervical vertebra (vertebra prominens)
22 Rhomboid muscles (divided)
23 Iliocostalis thoracis muscle
24 Longissimus thoracis muscle

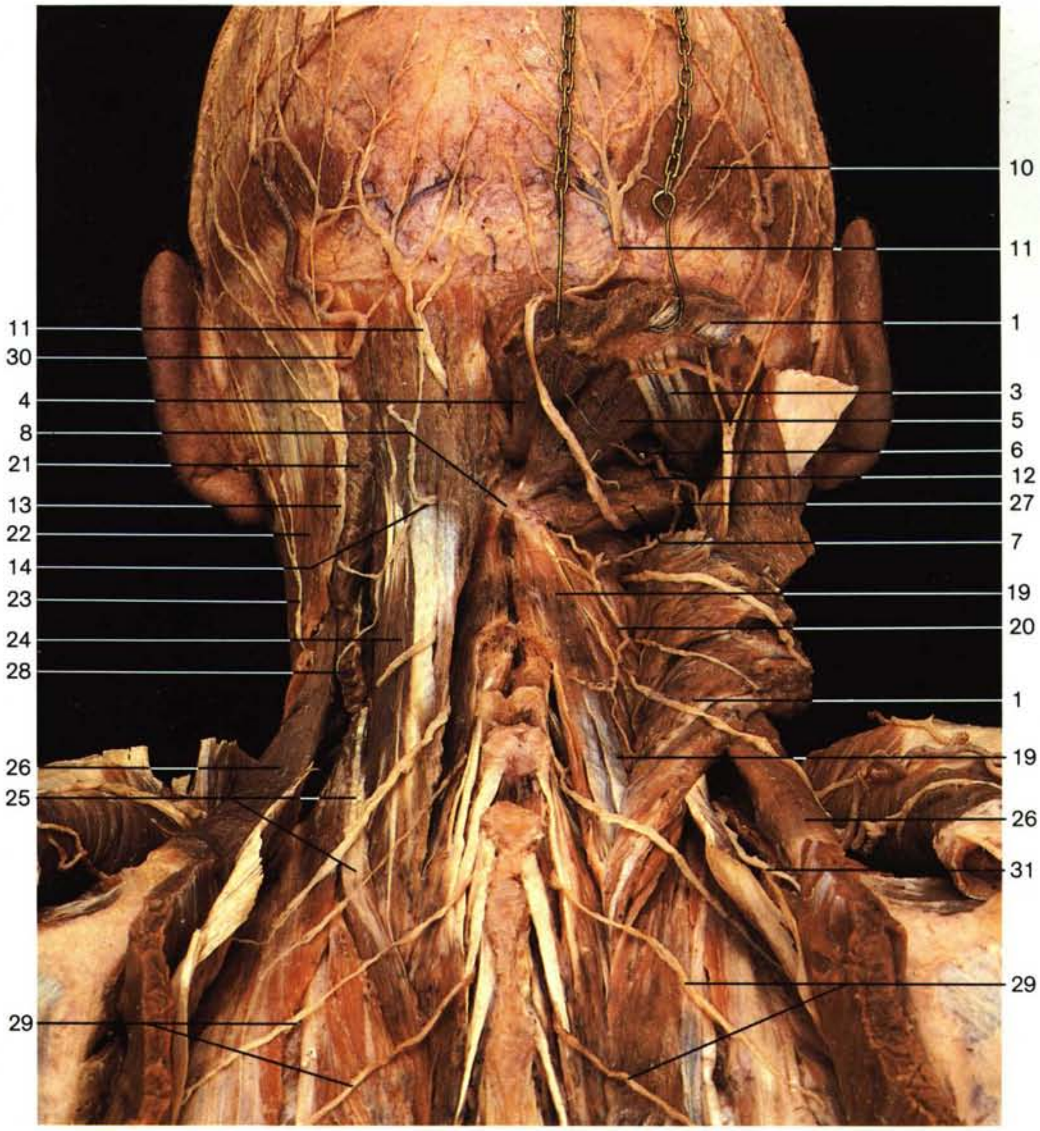

Dorsal aspect of neck IV. Deepest layer, suboccipital triangle; right semispinalis capitis muscle divited and reflected.

1. Semispinalis capitis muscle (divided)
2. External occipital protuberance
3. Obliquus capitis superior muscle
4. Rectus capitis posterior minor muscle
5. Rectus capitis posterior major muscle
6. Vertebral artery
7. Obliquus capitis inferior muscle
8. **Spinous process of axis**
9. Third cervical vertebra
10. Occipital belly of occipitofrontalis muscle
11. **Greater occipital nerve**
12. Suboccipital nerve (C_1)
13. Lesser occipital nerve
14. Third occipital nerve (C_3)
15. Mastoid process and splenius capitis muscle
16. Atlas
17. Axis
18. Spinous process of third cervical vertebra
19. Right semispinalis cervicis muscle
20. Deep cervical artery
21. Left splenius capitis muscle (divided)
22. Left sternocleidomastoid muscle
23. Great auricular nerve
24. Left **semispinalis capitis muscle**
25. Left longissimus cervicis muscle
26. Levator scapulae muscle
27. Muscular branch of vertebral artery
28. Left semispinalis cervicis muscle (divided)
29. **Medial branches of dorsal rami of spinal nerves**
30. **Occipital artery**
31. Dorsal scapular nerve

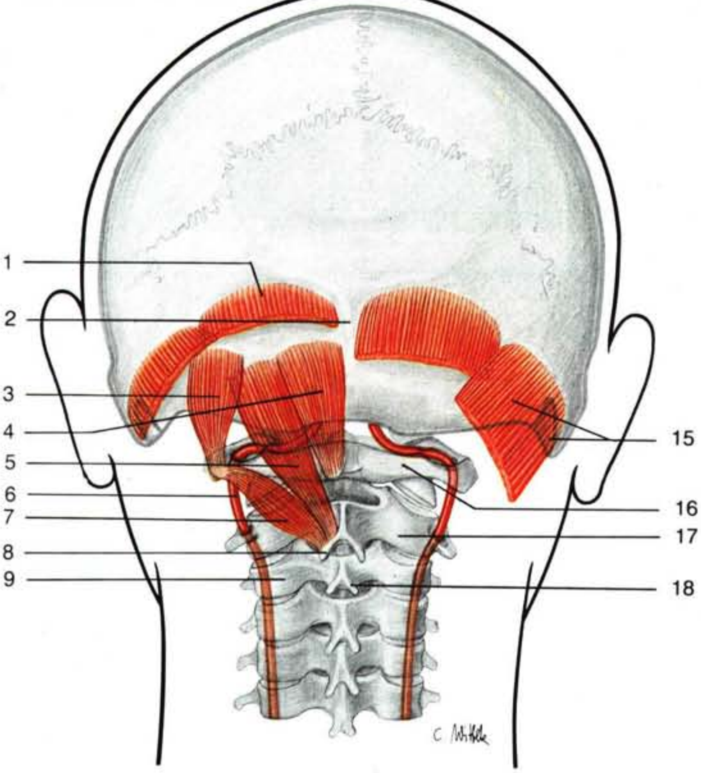

Suboccipital triangle and position of the vertebral artery. (Schematic drawing.)

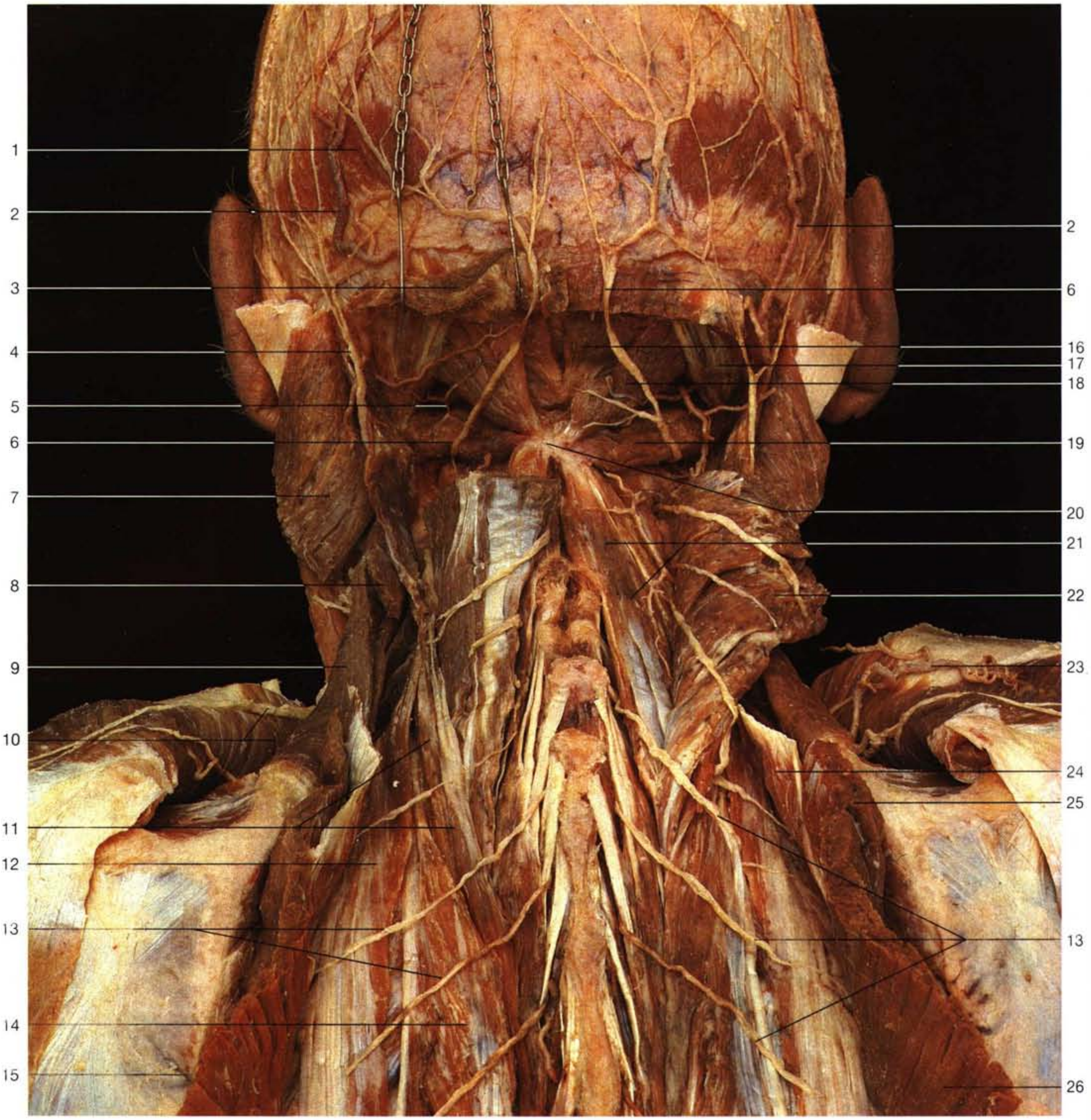

Dorsal aspect of neck V. Nuchal region. Deepest layer. Dissection of suboccipital triangle on both sides.

1 Occipital belly of occipitofrontalis muscle
2 **Occipital artery**
3 Insertion of semispinalis capitis muscle (divided)
4 Lesser occipital nerve (from cervical plexus)
5 Suboccipital nerve (C_1)
6 **Greater occipital nerve** (C_2)
7 Splenius capitis muscle (reflected)
8 Splenius cervicis muscle
9 Levator scapulae muscle
10 Accessory nerve (n. XI), trapezius muscle
11 Longissimus cervicis muscle
12 Iliocostalis cervicis muscle
13 **Medial cutaneus branches of dorsal rami of spinal nerves** (C_7, C_8)
14 Longissimus thoracis muscle
15 Medial margin of scapula
16 **Rectus capitis posterior minor muscle**
17 **Obliquus capitis superior muscle**
18 **Rectus capitis posterior major muscle**
19 **Obliquus capitis inferior muscle**
20 Spinous process of axis
21 Semispinalis cervicis muscle
22 Semispinalis capitis muscle (divided and reflected)
23 Transverse cervical artery (superficial branch)
24 Serratus posterior superior muscle (divided and reflected)
25 Rhomboid minor muscle (divided and reflected)
26 Rhomboid major muscle (divided and reflected)

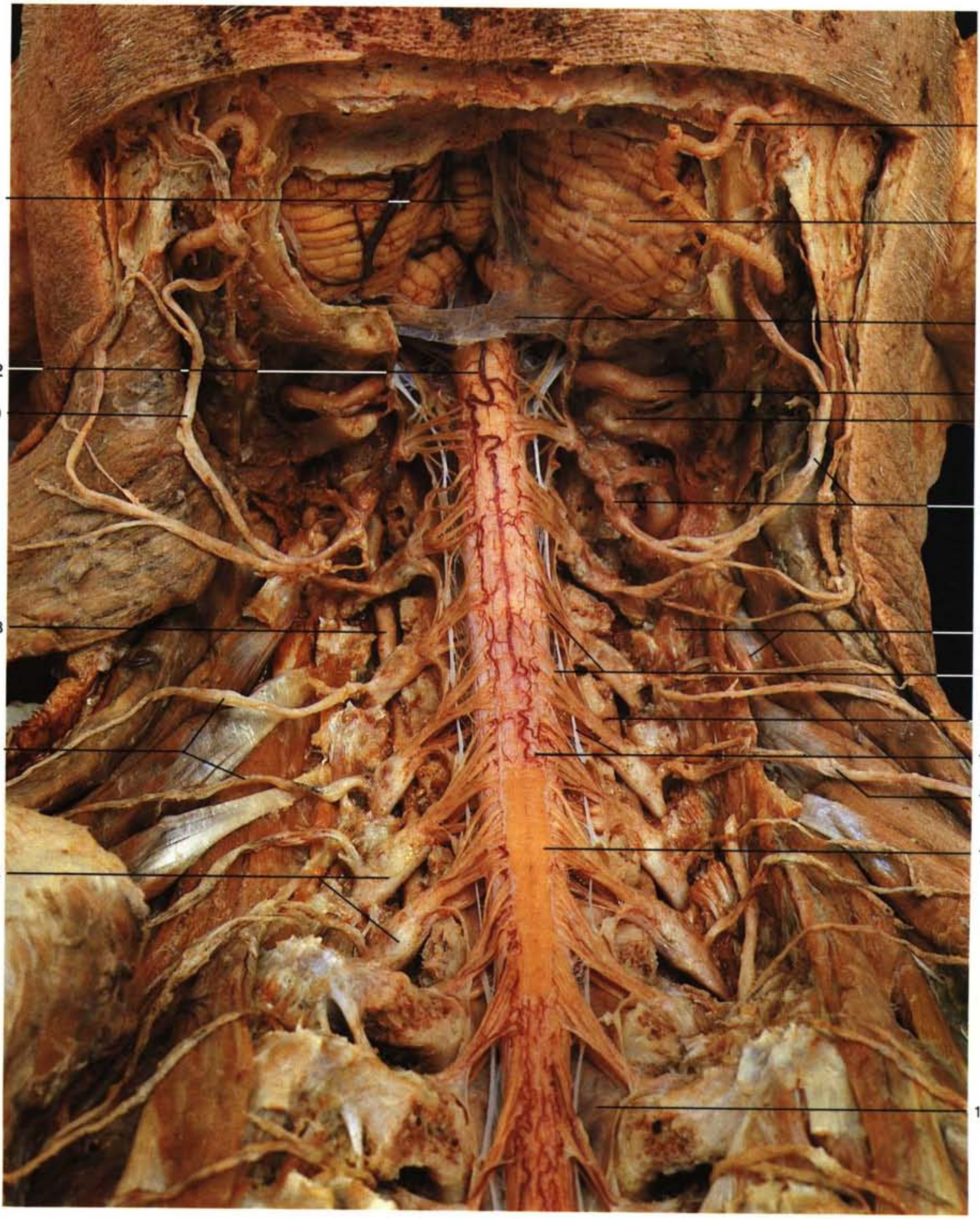

Neck, deepest layer. Spinal cord and medulla oblongata (dorsal aspect). Cranial cavity opened.

1 Vermis of the cerebellum
2 Medulla oblongata and posterior spinal artery
3 Vertebral artery
4 **Spinal ganglion**
5 Occipital artery
6 Cerebellum
7 **Cerebellomedullary cistern**
8 Atlas

9 Greater occipital nerve (C_2)
10 Levator scapulae muscle and intertransverse ligament
11 **Dorsal roots of spinal nerves**
12 Vertebral arch
13 **Denticulate ligament and arachnoid mater**
14 Area where pia mater has been removed
15 Dura mater
16 **Dorsal rami of spinal nerves**

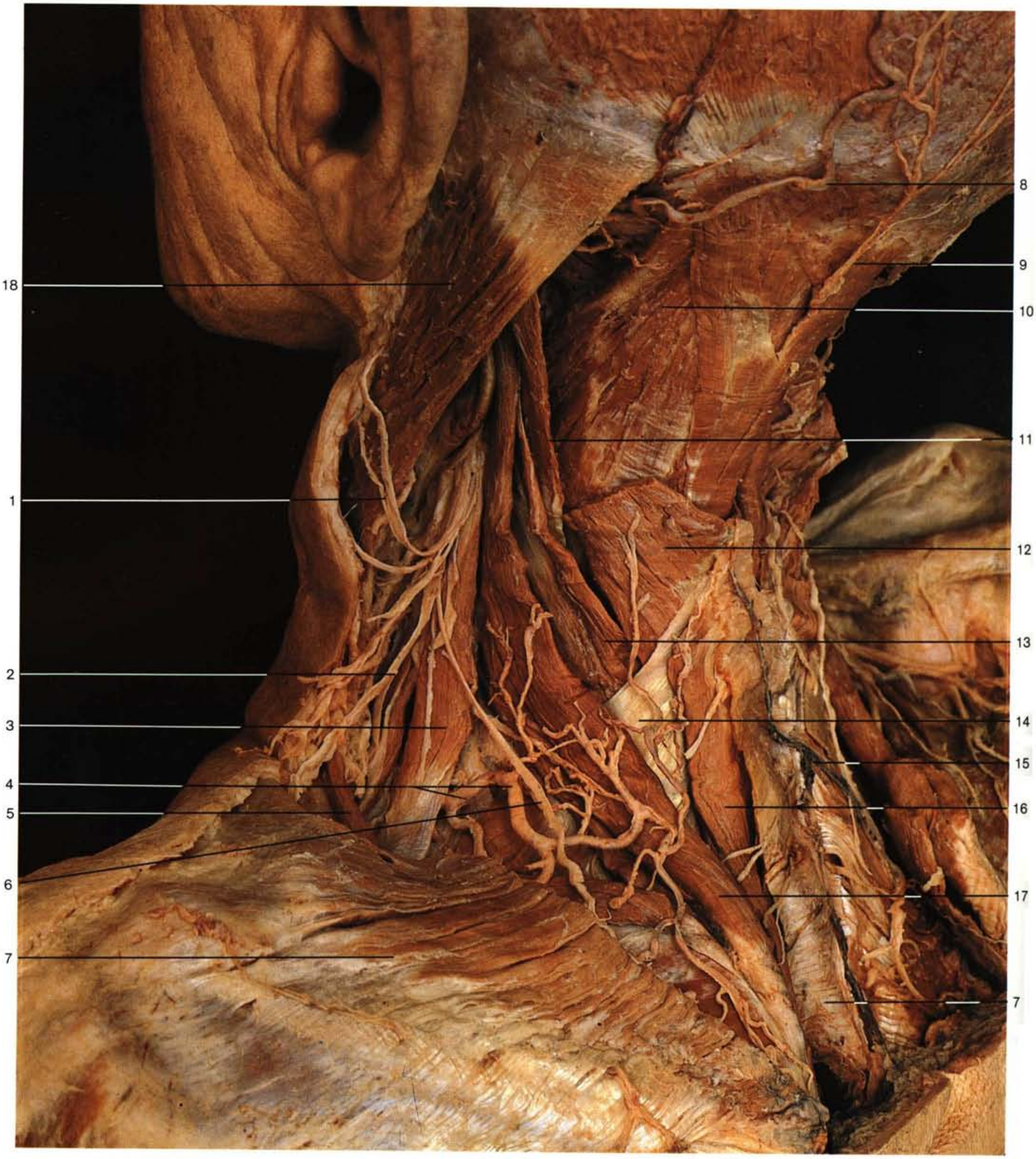

Deeper layer of the dorsal neck (oblique lateral aspect). Trapezius and semispinalis capitis muscles have been divided and partly removed.

1 Great auricular nerve
2 Accessory nerve (n. XI)
3 Scalenus posterior muscle
4 Transverse cervical artery
5 Omohyoid muscle
6 Muscular branch of cervical plexus

7 Trapezius muscle
8 Occipital artery
9 Greater occipital nerve
10 Semispinalis capitis muscle
11 Longissimus capitis muscle
12 Splenius capitis muscle

13 Splenius cervicis muscle
14 Serratus posterior superior muscle
15 Deep cervical vein (variant)
16 Rhomboid minor muscle
17 Levator scapulae muscle
18 Sternocleidomastoid muscle

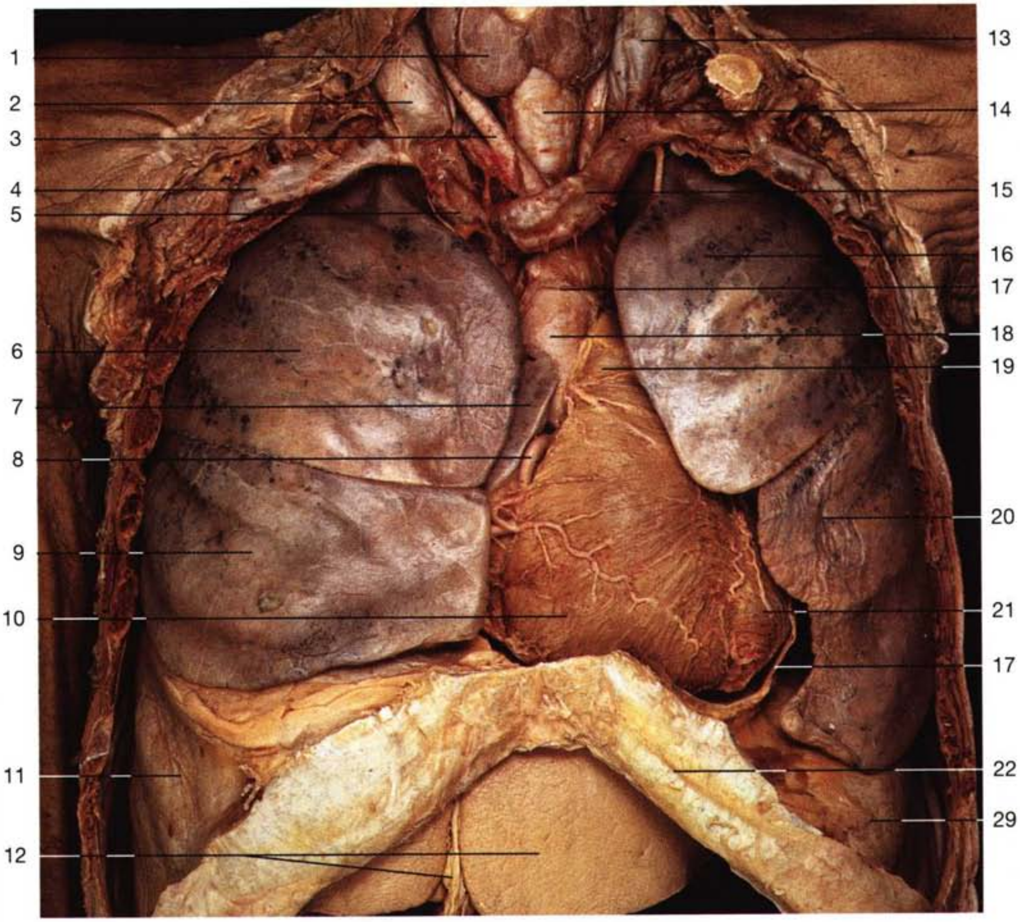

1	Thyroid gland
2	Internal jugular vein
3	Right common carotid artery
4	Right axillary vein
5	Right brachiocephalic vein
6	Superior lobe of right lung
7	Right atrium
8	Right coronary artery
9	Middle lobe of right lung
10	**Right ventricle**
11	Diaphragm
12	Liver (left lobe) and falciform ligament
13	Left internal jugular vein
14	**Trachea**
15	Left brachiocephalic vein
16	Superior lobe of left lung
17	Cut edge of pericardium
18	**Ascending aorta**
19	**Pulmonary trunk**
20	Inferior lobe of left lung
21	**Left ventricle**
22	Costal margin
23	Right pulmonary artery
24	Esophagus
25	Descending aorta
26	Pericardium
27	Aortic valve
28	Thymus
29	Diaphragm

Thoracic organs, heart and lungs in situ (ventral aspect). Anterior thoracic wall, parietal pleura and pericardium had been removed.

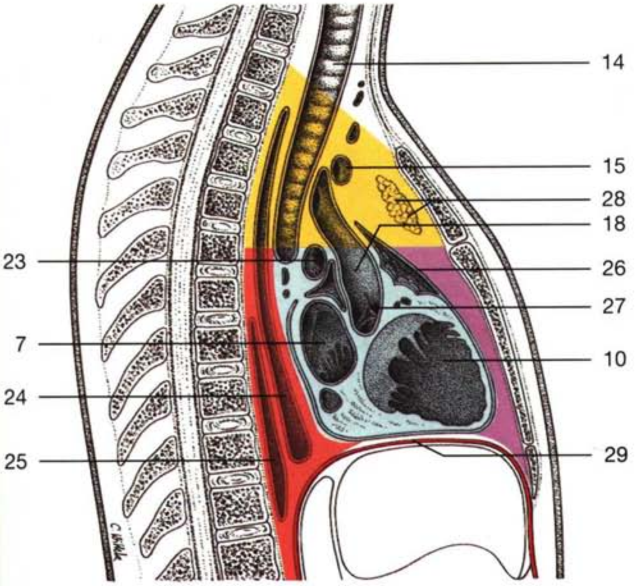

Sagittal section through thoracic cavity. The divisions of the mediastinum are indicated by colors.

Divisions of mediastinum	**Main content**
Superior mediastinum (yellow)	Trachea, brachiocephalic veins, thymus, aortic arch, esophagus, thoracic duct
Middle mediastinum (light blue)	Heart, ascending aorta, pulmonary trunk, pulmonary veins, phrenic nerves
Posterior mediastinum (red)	Esophagus with vagus nerves, descending aorta, thoracic duct, sympathetic trunks
Anterior mediastinum (pink)	Small vessels, connective and fatty tissue, and thymus in a child

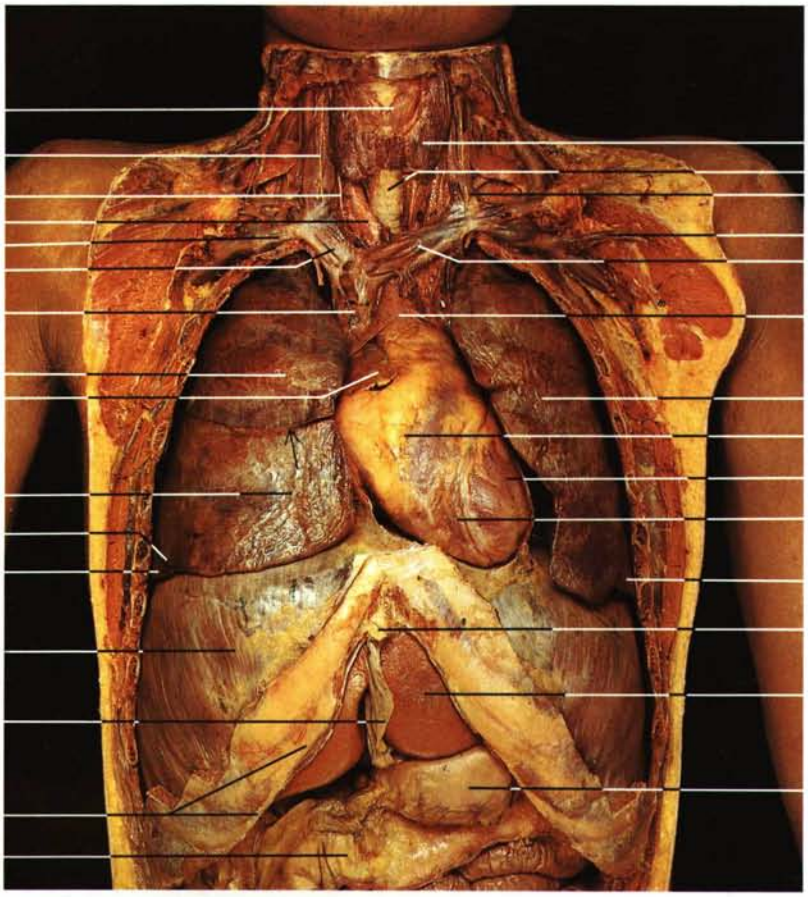
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Positions of thoracic organs. The anterior thoracic wall has been removed. Arrow: horizontal fissure of right lung.

1 Cricothyroid muscle
2 Right internal jugular vein
3 Vagus nerve
4 Right common carotid artery
5 Right subclavian vein
6 Right brachiocephalic vein
7 Superior vena cava
8 Upper lobe of right lung
9 Right auricle
10 Middle lobe of right **lung**
11 Oblique fissure of right lung
12 Lower lobe of right lung
13 **Diaphragm**
14 Falciform ligament
15 Costal margin
16 Transverse colon
17 Thyroid gland
18 Trachea
19 Left internal jugular vein
20 Left cephalic vein
21 Left brachiocephalic vein
22 Pericardium (cut edge)
23 Upper lobe of left **lung**
24 **Right ventricle**
25 **Left ventricle**
26 Anterior interventricular sulcus
27 Lower lobe of left lung
28 Xiphoid process
29 **Liver**
30 **Stomach**
31 Pectoralis major muscle

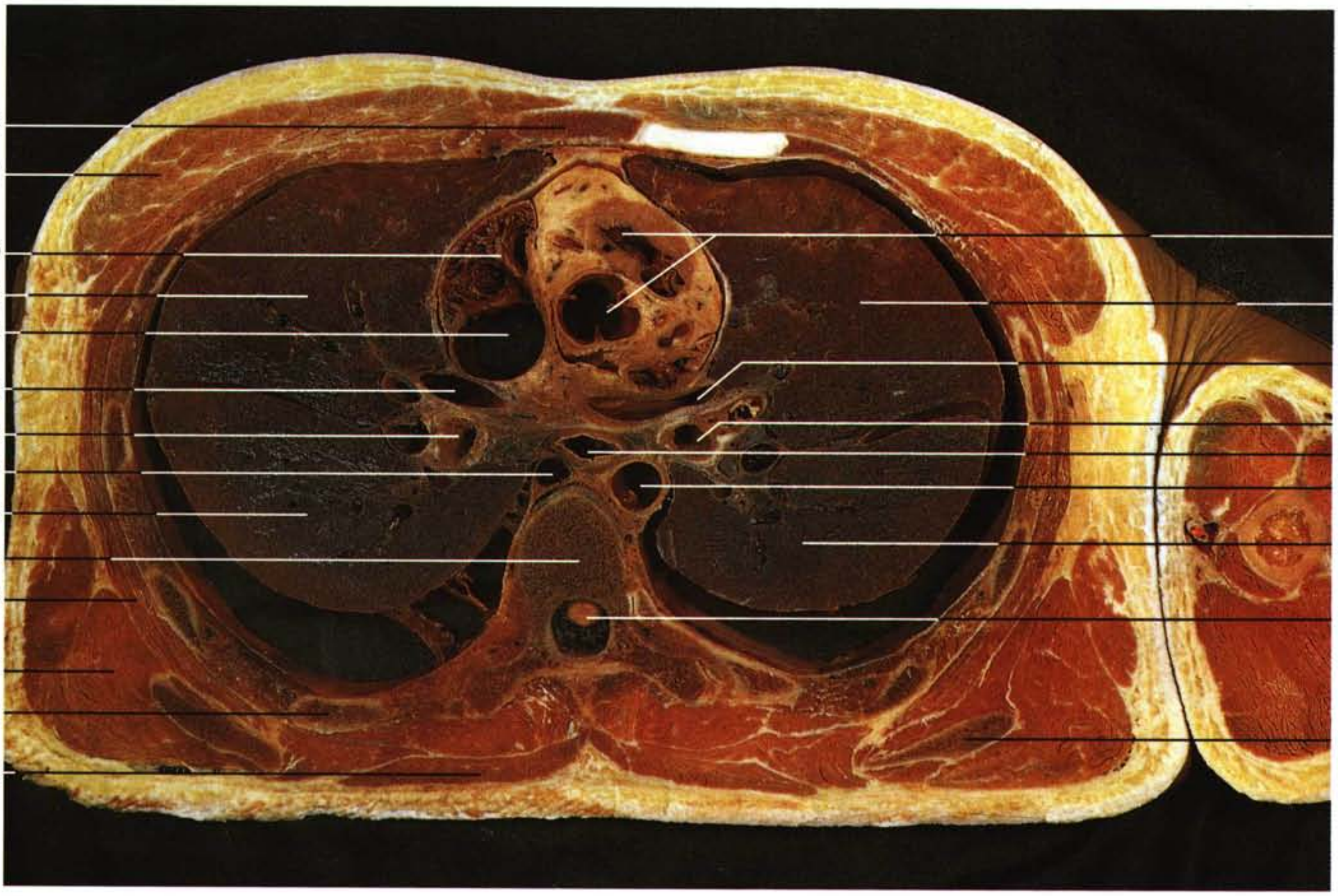
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Horizontal section through the thorax at the level of the 7th thoracic vertebra (from below).

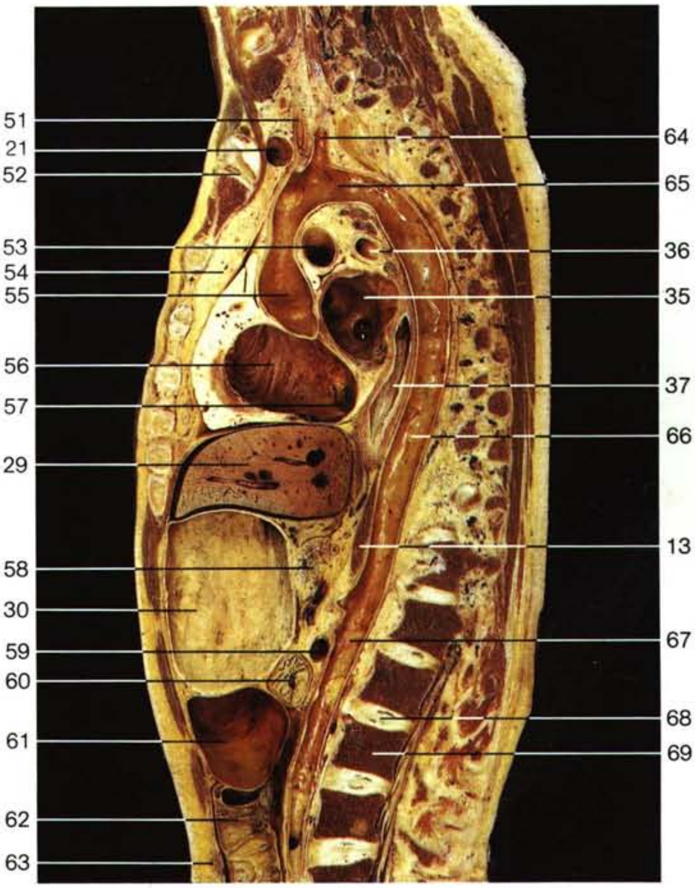
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Sagittal section through the left thorax, 2 cm lateral to the median plane.

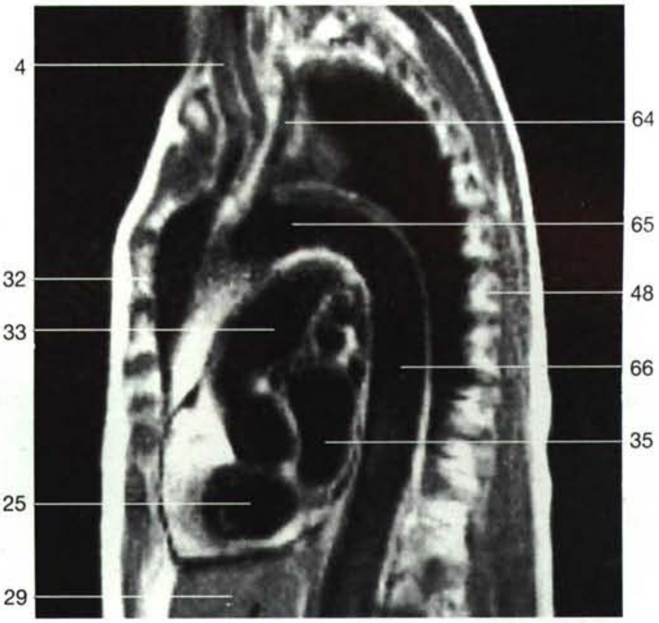
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Sagittal section through the thorax. MR-Scan.

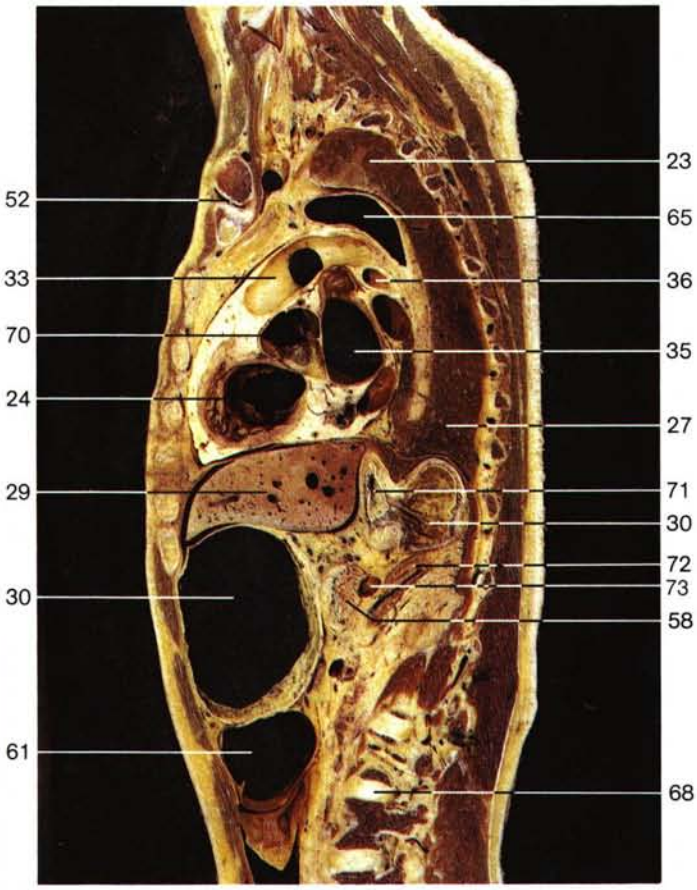
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Sagittal section through the left thorax, 3.5 cm lateral to the median plane.

32 Sternum
33 Pulmonary trunk
34 Left ventricle and bulb of aorta
35 Left atrium
36 Left main bronchus
37 **Esophagus**
38 Descending aorta
39 Serratus anterior muscle
40 Teres major muscle
41 Rib
42 Trapezius muscle
43 Right atrium
44 Left pulmonary vein
45 Right pulmonary vein
46 Right main bronchus
47 Azygos vein
48 Body of vertebra
49 Spinal cord
50 Scapula
51 Left common carotid artery
52 Sternoclavicular articulation with disc
53 Right pulmonary artery
54 Remnants of thymus
55 Aortic bulb
56 Right atrium
57 Entrance of inferior vena cava in right atrium
58 **Pancreas**
59 Left renal vein
60 **Duodenum**
61 Transverse colon (dilated)
62 Small intestine
63 Umbilicus
64 Left subclavian artery
65 Aortic arch
66 **Thoracic aorta**
67 Abdominal aorta
68 Intervertebral disc
69 Body of lumbar vertebra
70 Aortic valve
71 Cardia of stomach
72 Suprarenal gland
73 Splenic vein

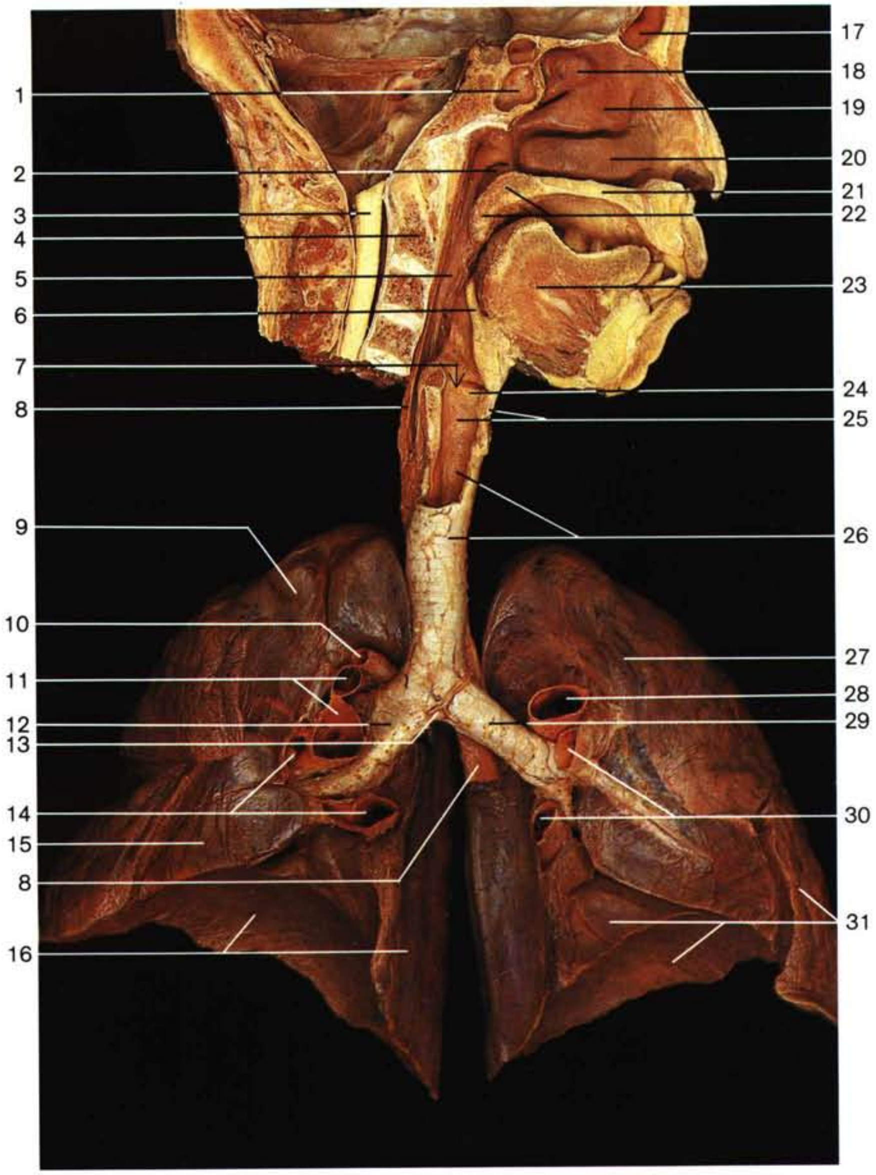

Respiratory system. The lungs have been fixed in expiration and turned laterally. Head bisected and turned laterally.

1 Sphenoid sinus
2 Pharyngeal opening of auditory tube
3 Spinal cord
4 Dens of axis
5 **Oropharynx** (oropharyngeal isthmus)
6 Epiglottis
7 Entrance of larynx
8 Esophagus
9 Upper lobe of right lung
10 Azygos vein
11 Branches of pulmonary artery
12 **Right main bronchus**
13 **Bifurcation of trachea**
14 Tributaries of right pulmonary veins
15 Middle lobe of right lung
16 Lower lobe of right lung
17 Frontal sinus
18 Superior nasal concha
19 Middle nasal concha
20 Inferior nasal concha
21 Hard palate
22 Soft palate with uvula
23 Tongue
24 Vocal fold
25 Larynx
26 Trachea
27 Upper lobe of left lung
28 Left pulmonary artery
29 **Left main bronchus**
30 Left pulmonary veins
31 Lower lobe of left lung

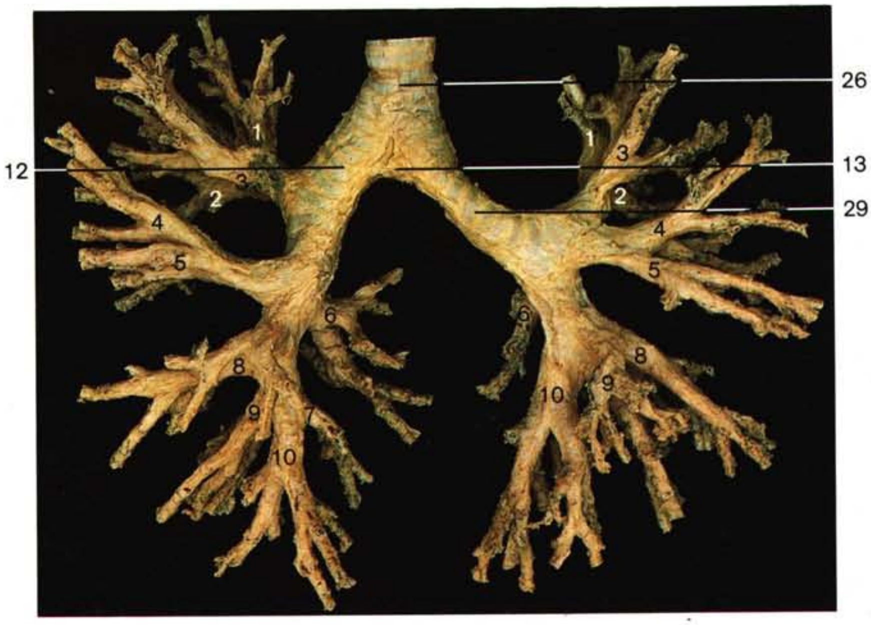

Bronchial tree (ventral aspect). The lung tissue has been removed. The bronchopulmonary segments are numbered 1–10.

▷

To page 231:

1 Nasal cavity
2 Pharynx
3 Larynx (thyroid cartilage)
4 Trachea
5 Upper lobe of right lung
6 Bifurcation of trachea
7 Right main bronchus
8 Horizontal fissure of right lung
9 Middle lobe of right lung
10 Oblique fissures of lungs
11 Lower lobe of right lung
12 Clavicle
13 Upper lobe of left lung
14 Left main bronchus
15 Bronchi supplying bronchopulmonary segments
16 Lower lobe of left lung
17 Costal margin
18 Hyoid bone
19 Right superior lobe bronchus
20 Right middle lobe bronchus
21 Right inferior lobe bronchus
22 Left superior lobe bronchus
23 Left inferior lobe bronchus
24 Segmental bronchi
25 Branches of pulmonary arteries
26 Branches of pulmonary veins

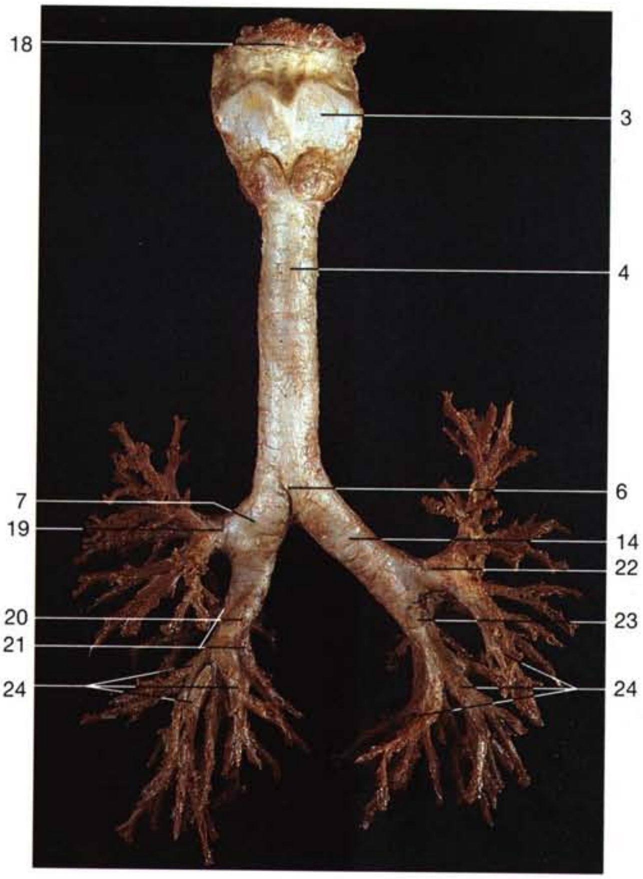
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Larynx, trachea and bronchial tree (anterior aspect).

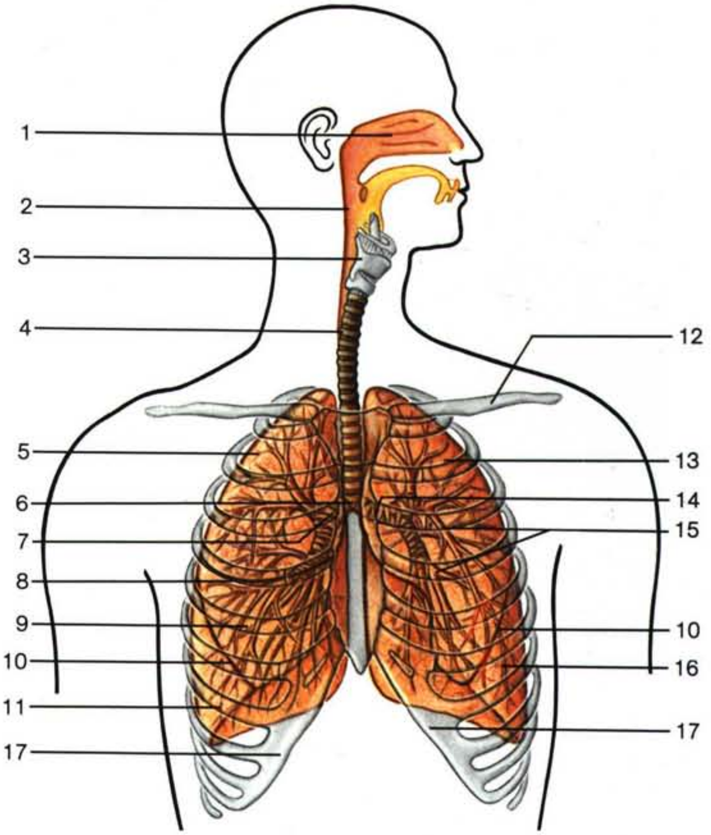
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Organization and positions of respiratory organs.
(Schematic drawing.)

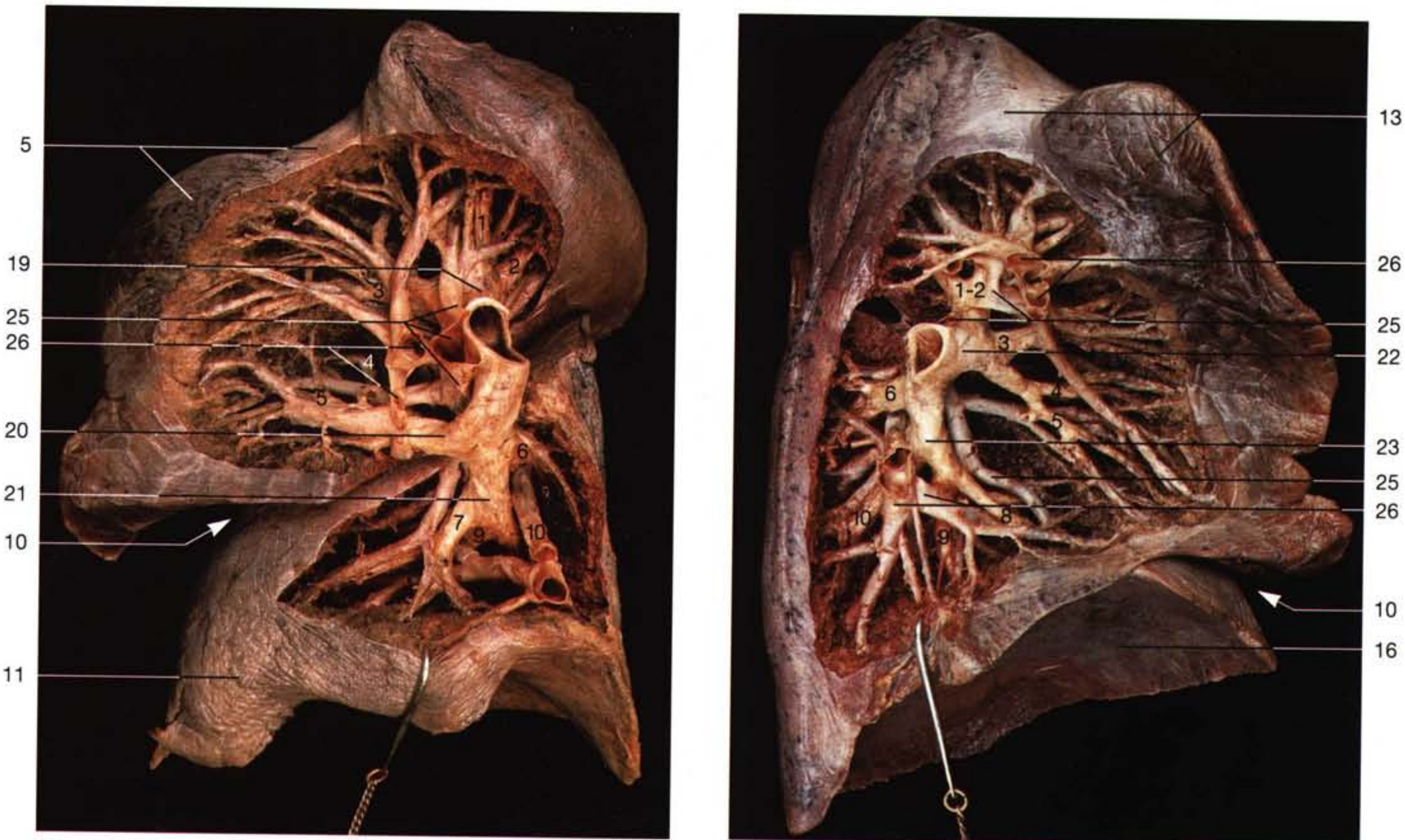
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Mediastinal dissection of the bronchial tree, pulmonary veins, and pulmonary arteries of right lung (left) and left lung (right) (medial aspect). Segmental bronchi are numbered 1–10.

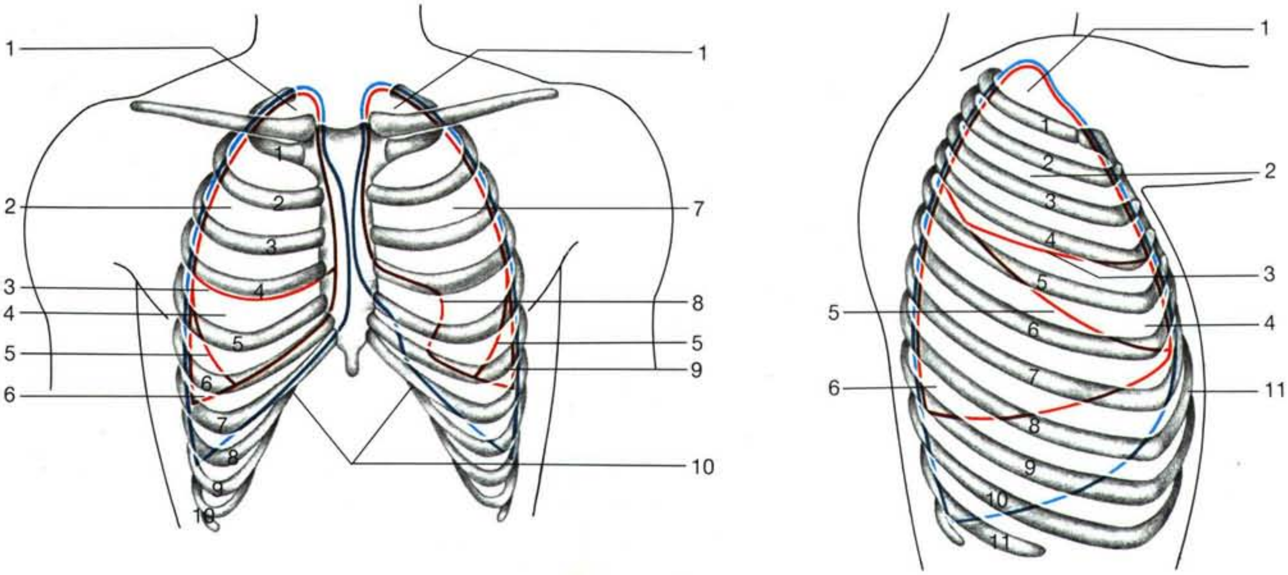
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Surface projections of lungs and pleura on the thoracic wall. Left: anterior aspect; right: right-lateral aspect. Red = margins of the lung; blue = margins of pleura. The numbers indicate ribs.

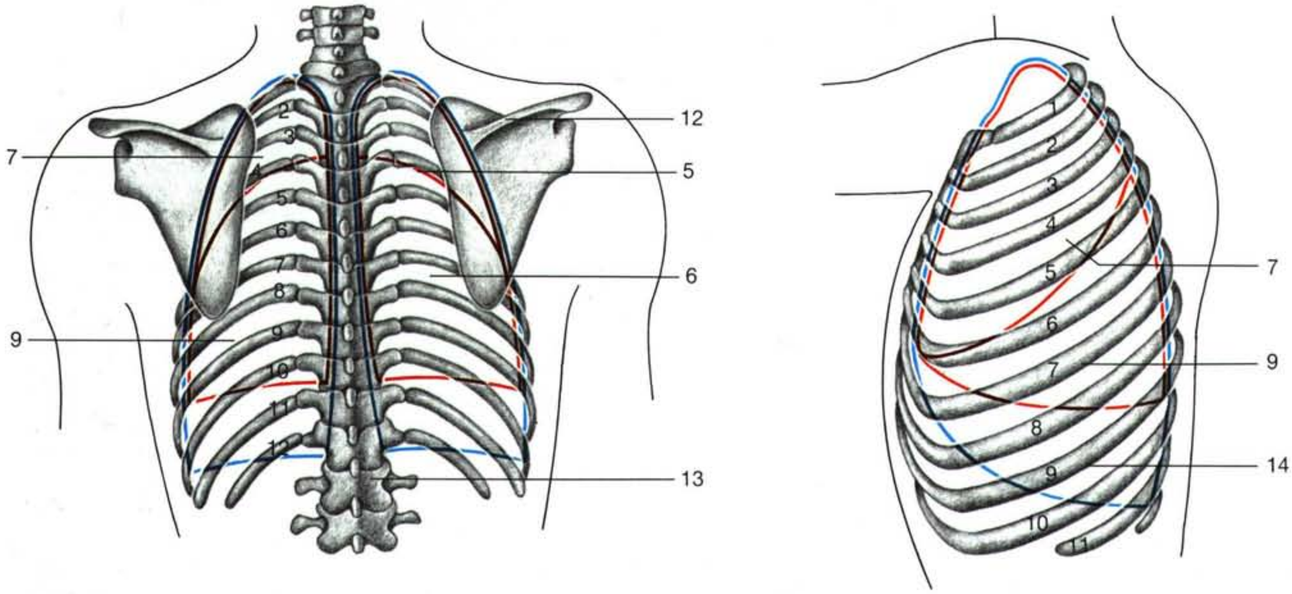
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Surface projections of lungs and pleura on thoracic wall. Left: posterior aspect; right: left-lateral aspect. Red = margins of lung; blue = margins of pleura. The number indicate ribs.

1 Apex of lung
2 Upper lobe of right lung
3 Horizontal fissure of right lung
4 Middle lobe of right lung
5 Oblique fissures of lungs
6 Lower lobe of right lung
7 Upper lobe of left lung
8 Cardiac notch of left lung
9 Lower lobe of left lung
10 Infrasternal angle
11 Costal margin
12 Spine of scapula
13 1st lumbar vertebra
14 Space between border of lung and pleura (costodiaphragmatic recess)

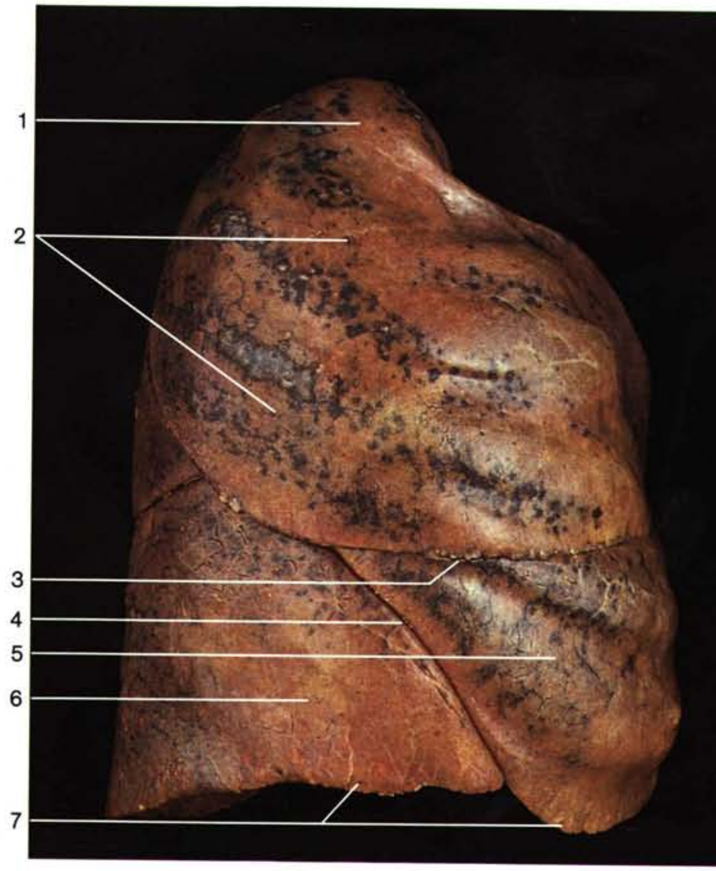

Right lung (lateral aspect).

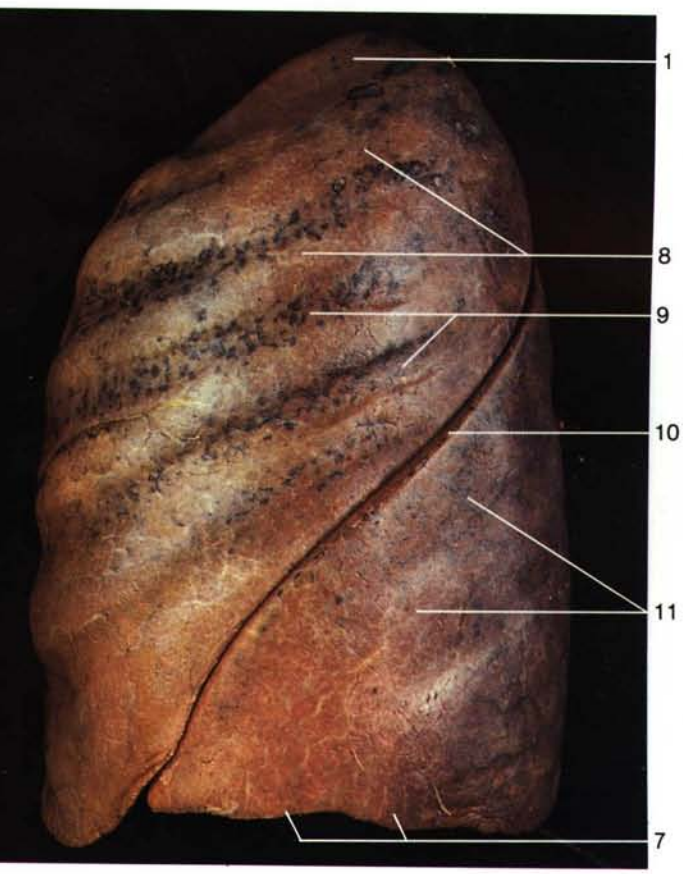

Left lung (lateral aspect).

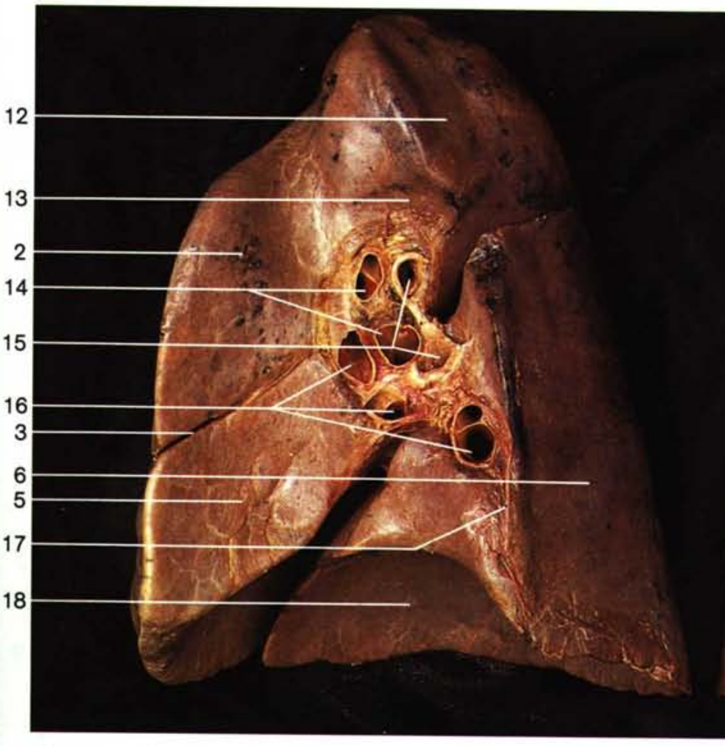

Right lung (medial aspect).

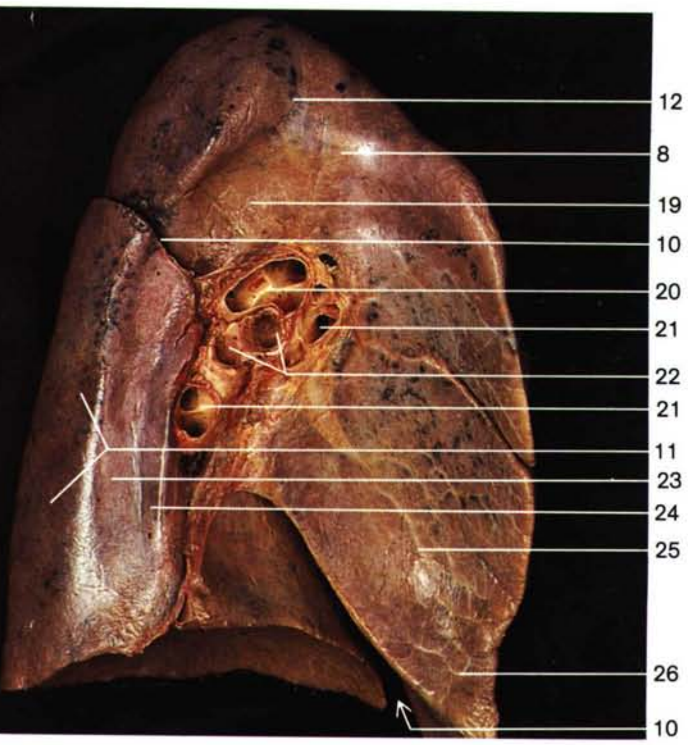

Left lung (medial aspect).

1 Apex of lung
2 Upper lobe of right lung
3 Horizontal fissure of right lung
4 Oblique fissure of right lung
5 Middle lobe of right lung
6 Lower lobe of right lung
7 Inferior border
8 Upper lobe of left lung
9 Impressions of ribs
10 Oblique fissure of left lung
11 Lower lobe of left lung
12 Groove of subclavian artery
13 Groove of azygos arch
14 Branches of right pulmonary artery
15 Bronchi
16 Right pulmonary veins
17 Pulmonary ligament
18 Diaphragmatic surface
19 Groove of aortic arch
20 Left pulmonary artery
21 Branches of left pulmonary veins
22 Left secondary bronchi
23 Groove of thoracic aorta
24 Groove of esophagus
25 Cardiac impression
26 Lingula

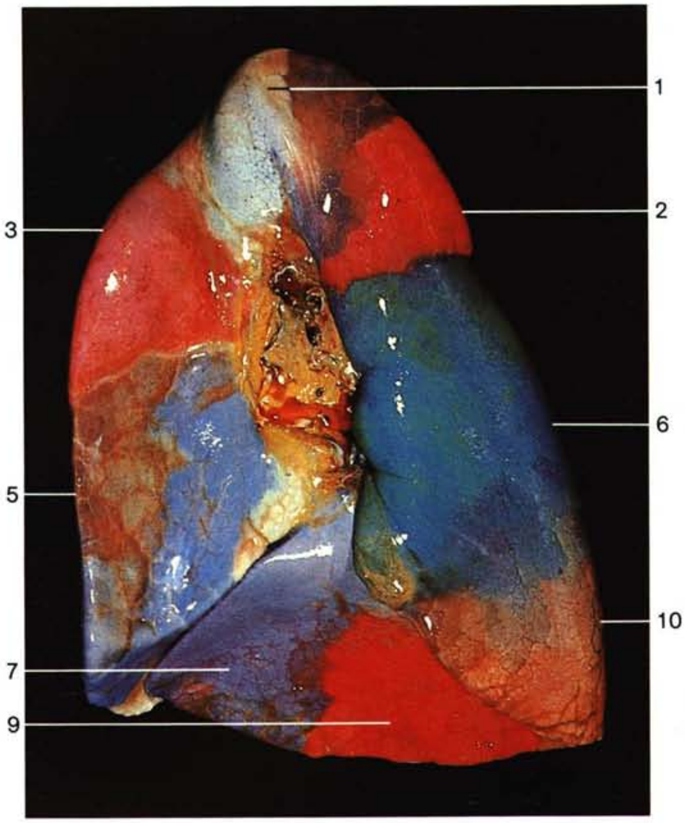

Right lung (medial aspect).

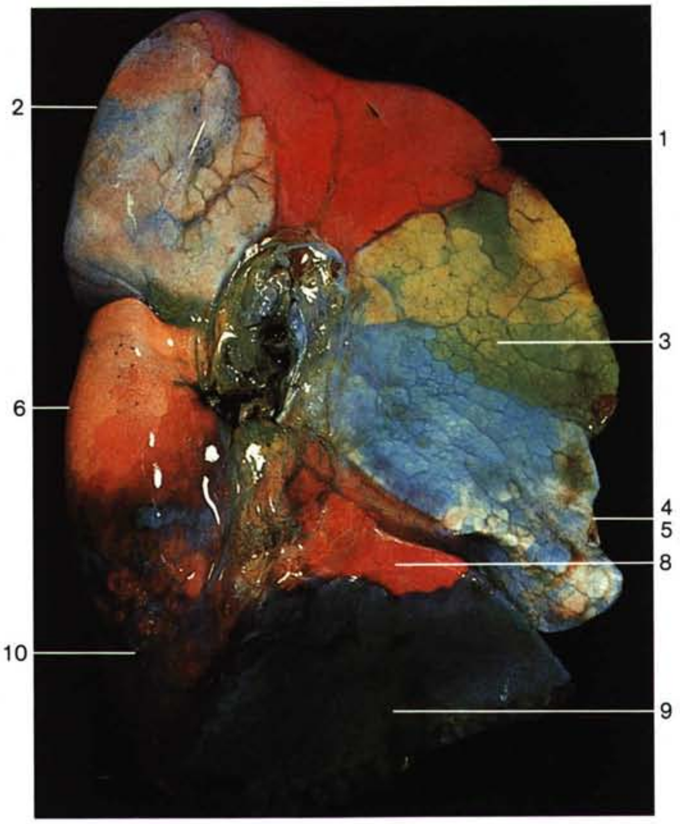
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Left lung (medial aspect).

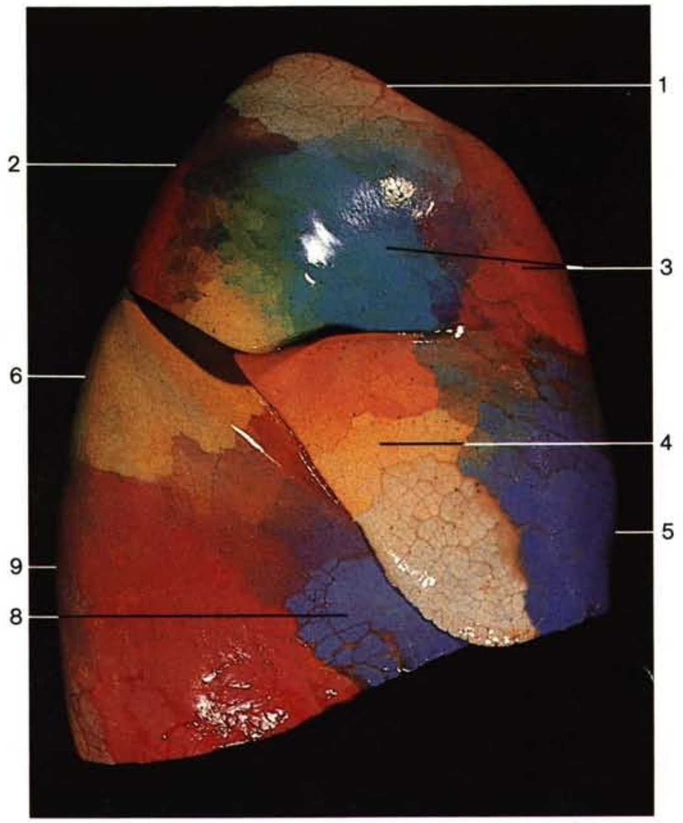

Right lung (lateral aspect).

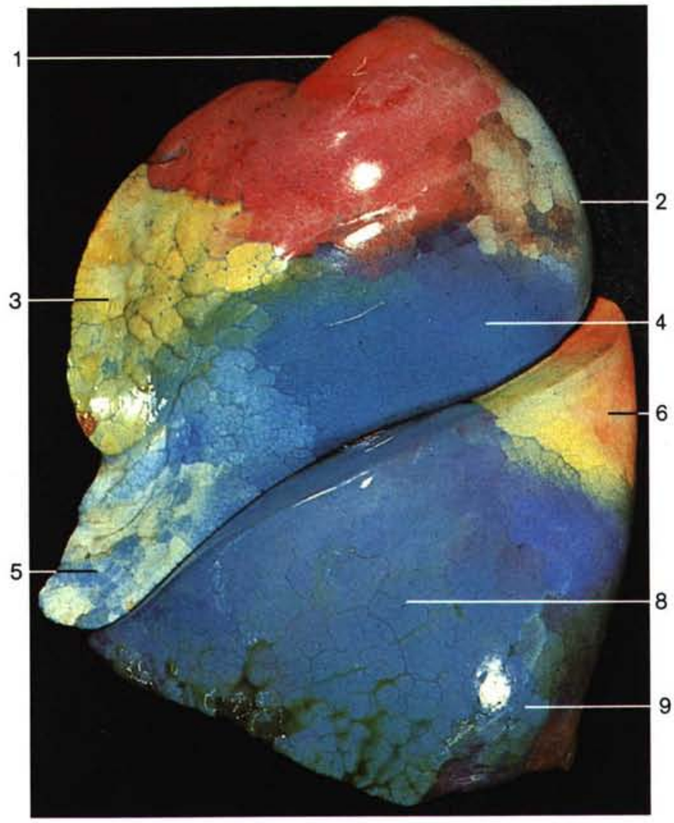

Left lung (lateral aspect).

The bronchopulmonary segments of the lungs are differentiated by the various colors. Notice that there is no segment in the left lung that corresponds to the 7th segment of the right lung. Compare with the schematic drawing on the facing page.

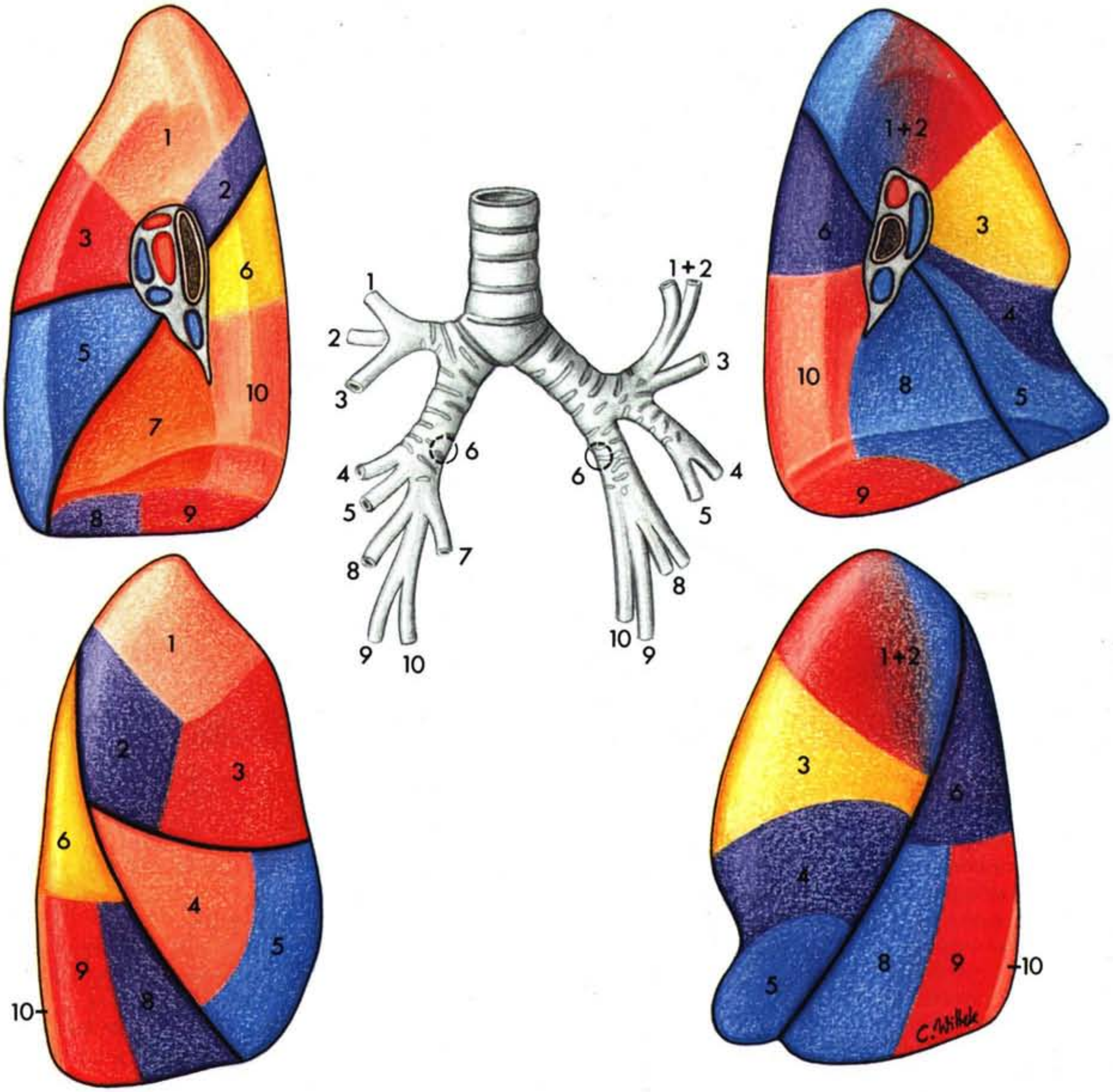

Distribution of bronchopulmonary segments of the lungs and their relation to the bronchial tree (after J. F. Huber).
The bronchopulmonary segments are morphologically and functionally separate independent respiratory units of the lung tissue. Each segment is surrounded by connective tissue which is continuous with the visceral pleura. The segmental bronchi in a segment are central, closely accompanied by branches of the pulmonary arteries whereas the tributaries of the pulmonary veins run **between** the segments. Thus, the veins serve two adjacent segments which drain for the most part into more than one vein. A bronchopulmonary segment is therefore not a complete vascular unit, but segmentation is the result of a specific architecture of the lung vasculature.

	Right lung			**Left lung**		
1	Apical segment	Upper lobe bronchus	1+2	Apico-posterior segment	Superior division	Upper lobe bronchus
2	Posterior segment					
3	Anterior segment		3	Anterior segment		
4	Lateral segment	Middle lobe bronchus	4	Superior lingular segment	Inferior division	
5	Medial segment		5	Inferior lingular segment		
6	Superior (apical) segment	Lower lobe bronchus	6	Superior (apical) segment		Lower lobe bronchus
7	Medial basal segment		7	Absent		
8	Anterior basal segment		8	Anteromedial basal segment		
9	Lateral basal segment		9	Lateral basal segment		
10	Posterior basal segment		10	Posterior basal segment		

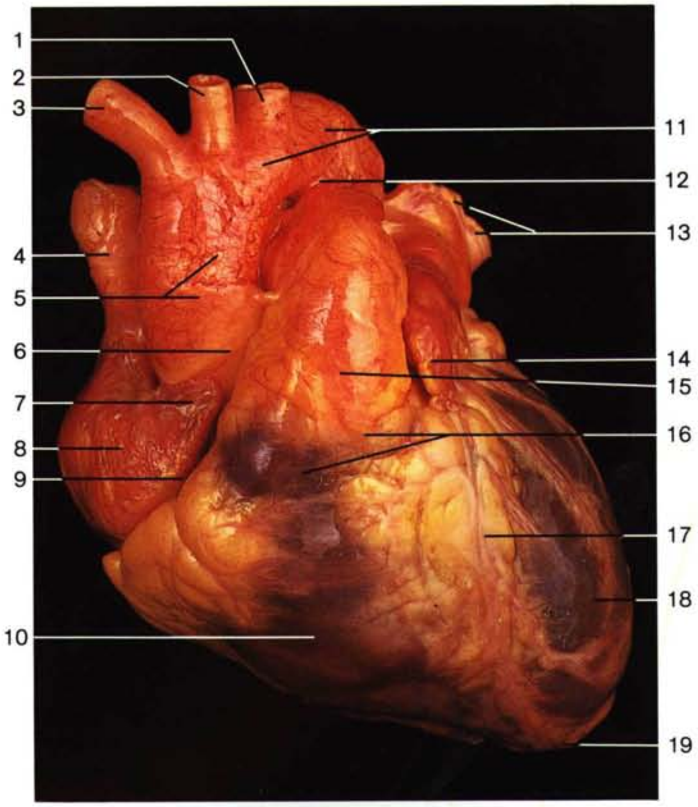

Heart of 30-year-old woman (anterior aspect).

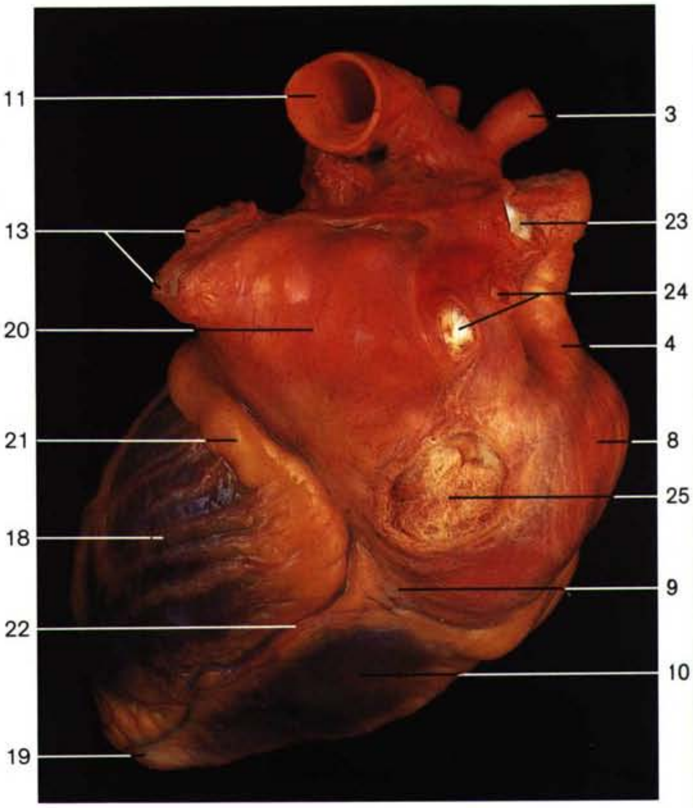

Heart of 30-year-old woman (oblique posterior view).

1 Left subclavian artery
2 Left common carotid artery
3 Brachiocephalic trunk
4 Superior vena cava
5 Ascending aorta
6 Bulb of the aorta
7 Right auricle
8 **Right atrium**
9 Coronary sulcus
10 **Right ventricle**
11 Aortic arch
12 Ligamentum arteriosum
13 Left pulmonary veins
14 Left auricle
15 **Pulmonary trunk**
16 Sinus of pulmonary trunk
17 Anterior interventricular sulcus
18 **Left ventricle**
19 Apex of the heart
20 **Left atrium**
21 Epicardial fat overlying coronary sinus
22 Posterior interventricular sulcus
23 Right pulmonary artery
24 Right pulmonary veins
25 Inferior vena cava

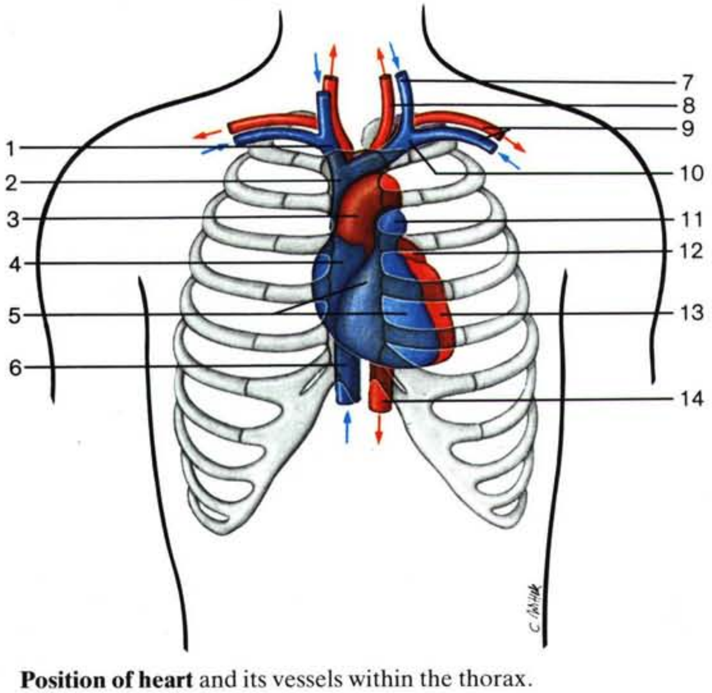

Position of heart and its vessels within the thorax.
(Schematic drawing.)

1 Right brachiocephalic vein
2 Superior vena cava
3 Ascending aorta
4 Right atrium
5 Right ventricle
6 Inferior vena cava
7 Left internal jugular vein
8 Left common carotid artery
9 Left axillary artery and vein
10 Left brachiocephalic vein
11 Pulmonary trunk
12 Left auricle
13 Left ventricle
14 Descending aorta

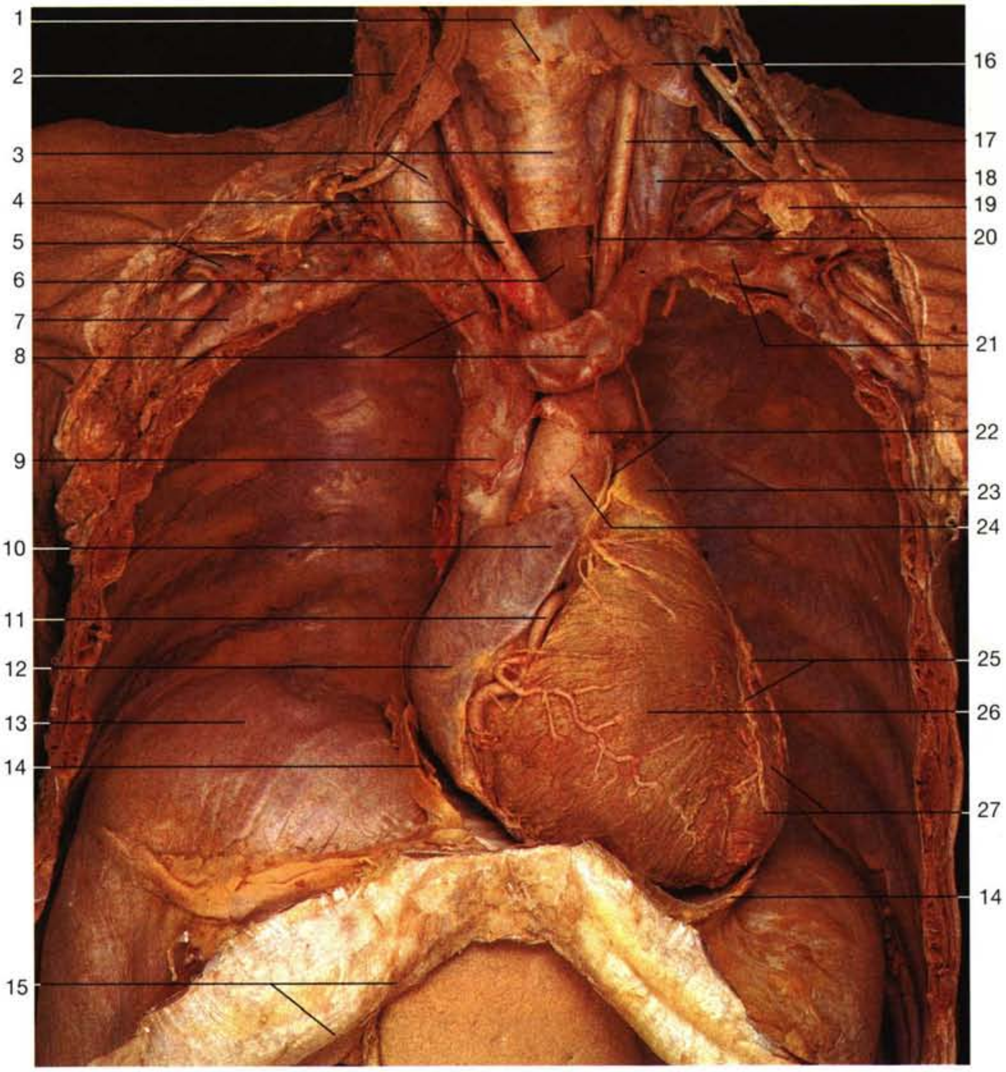

Heart and related vessels in situ (anterior aspect). Anterior thoracic wall, pericardium and epicardium have been removed; trachea divided.

1 Larynx (thyroid cartilage)
2 Sternocleidomastoid muscle (divided)
3 Trachea (divided) and right internal jugular vein
4 Vagus nerve
5 Right common carotid artery and cephalic vein
6 Esophagus
7 Right axillary vein
8 Right and left brachiocephalic veins
9 **Superior vena cava**
10 Right auricle
11 Right **coronary artery**
12 **Right atrium**
13 Diaphragm
14 Pericardium (cut edges)
15 Costal margin
16 Omohyoid muscle
17 Left **common carotid artery**
18 Left internal jugular vein
19 Clavicle (divided)
20 Left recurrent laryngeal nerve
21 **Subclavian vein**
22 Pericardial reflection
23 **Pulmonary trunk**
24 **Ascending aorta**
25 Anterior interventricular sulcus and anterior interventricular branch of left coronary artery
26 **Right ventricle**
27 **Left ventricle**
28 Aortic valve
29 Tricuspid or right atrioventricular valve
30 Inferior vena cava
31 Pulmonary veins
32 Pulmonary valve
33 Left atrioventricular (bicuspid or mitral) valve

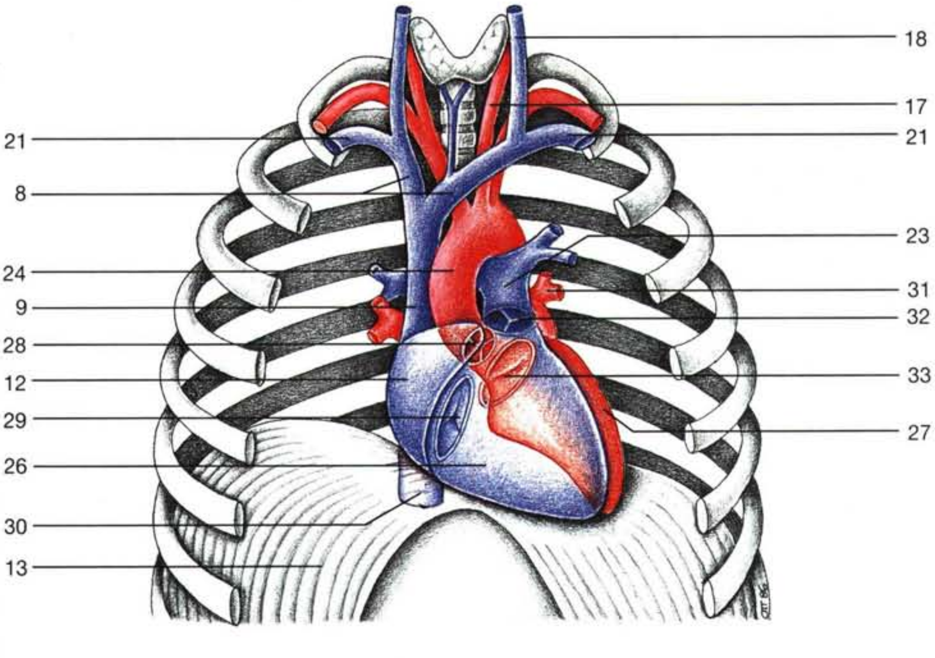

Heart in situ. Position of valves (anterior aspect). (Schematic drawing.)

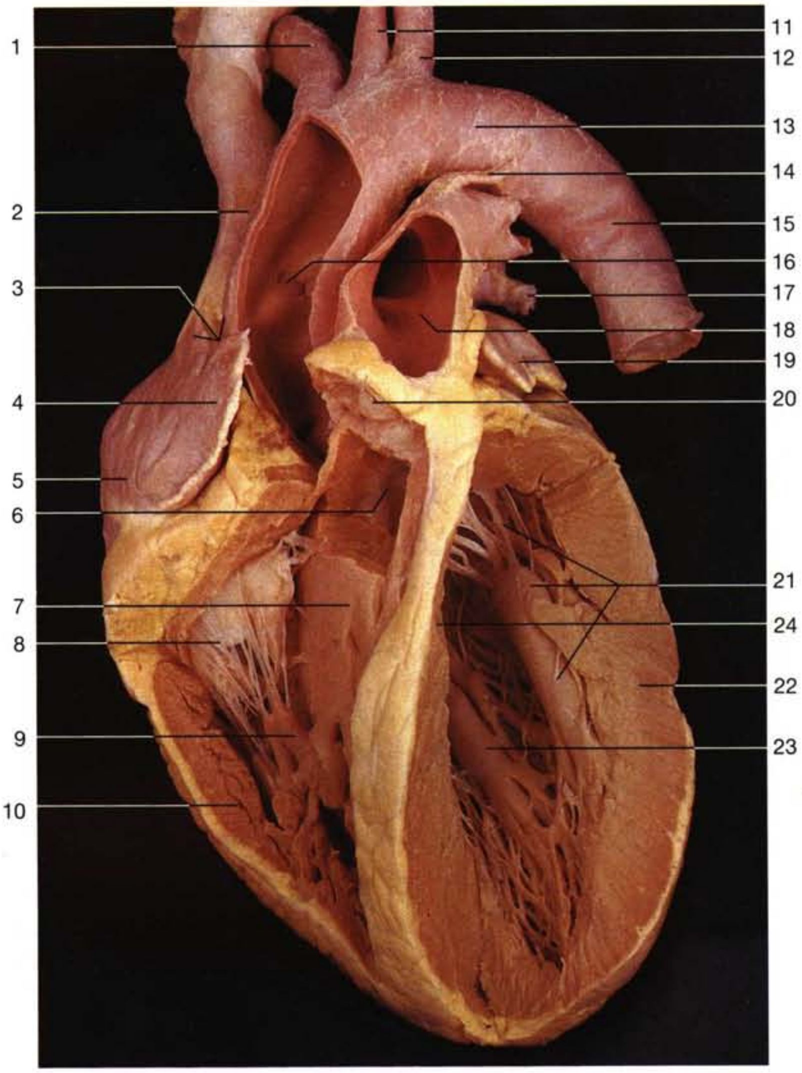

Anterior aspect of the heart. The anterior walls of the ventricles and of the aorta and pulmonary trunk have been fenestrated to show the aortic valve.

1 Brachiocephalic trunk
2 Superior vena cava
3 Sulcus terminalis
4 Right auricle
5 Right atrium
6 **Aortic valve**
7 Conus arteriosus (interventricular septum)
8 **Right atrioventricular (tricuspid) valve**
9 **Anterior papillary muscle**
10 Myocardium of right ventricle
11 Left common carotid artery
12 Left subclavian artery
13 **Aortic arch**
14 Ligamentum arteriosum (remnant of ductus arteriosus)
15 Thoracic aorta (descending aorta)
16 **Ascending aorta**
17 Left pulmonary vein
18 **Pulmonary trunk**
19 Left auricle
20 Pulmonic valve
21 **Anterior papillary muscle** with chordae tendineae
22 Myocardium of left ventricle
23 Posterior papillary muscle
24 Interventricular septum
25 Right and left brachiocephalic veins
26 **Chordae tendineae**
27 Papillary muscles of right ventricle
28 Left atrium
29 Infundibulum
30 Anterior papillary muscle of left ventricle
31 Left atrioventricular (bicuspid or mitral) valve and chordae tendineae
32 Apex of heart

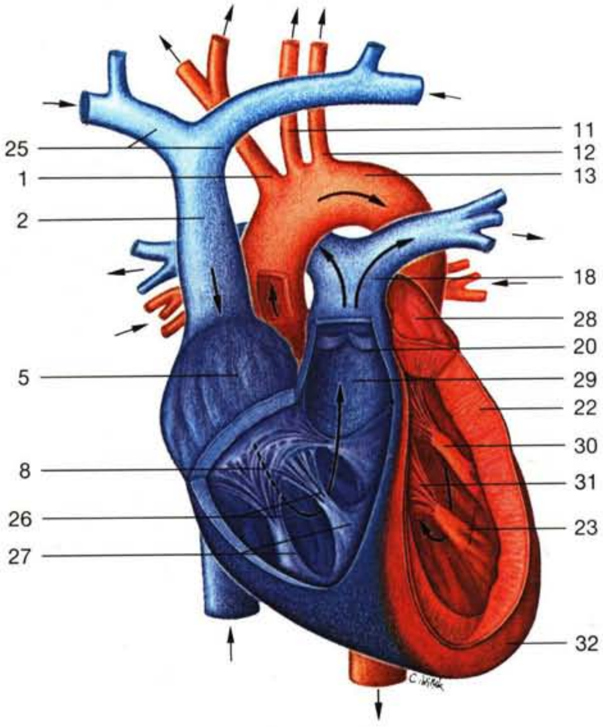

Circulation within the heart. (Schematic drawing.) The arrows indicate the direction of the blood flow through the heart. Blue = right heart; red = left heart.

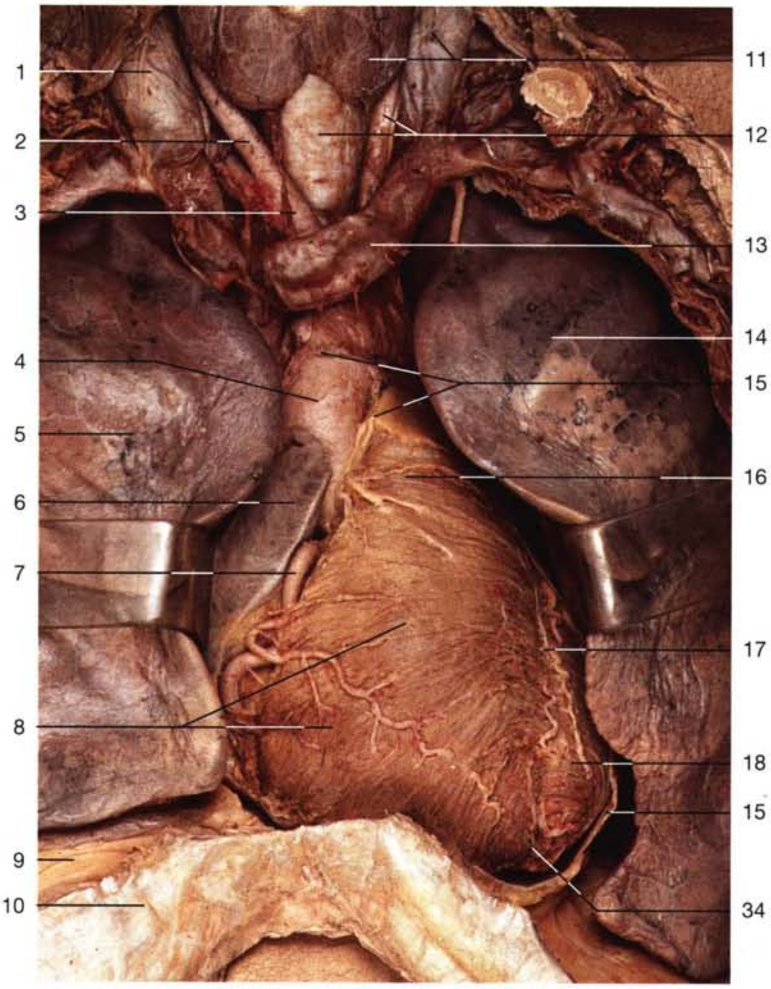

Heart in situ. Myocardium and coronary arteries (anterior aspect).

1 Internal jugular vein
2 Common carotid artery
3 Brachiocephalic trunk
4 **Ascending aorta**
5 Right lung
6 Right auricle
7 **Right coronary artery**
8 **Myocardium of right ventricle**
9 Diaphragm
10 Costal margin
11 Thyroid gland and internal jugular vein
12 Trachea and left common carotid artery
13 Left brachiocephalic vein
14 Left lung
15 **Pericardium** (cut edge)
16 Pulmonary trunk
17 Anterior interventricular artery
18 **Myocardium of left ventricle**
19 **Muscular vortex** (right ventricle)
20 Posterior interventricular sulcus
21 Anterior interventricular sulcus
22 **Muscular vortex** (left ventricle)
23 Aortic arch
24 Left atrium
25 Coronary sinus
26 Superior vena cava
27 Right pulmonary vein
28 Right atrium
29 Inferior vena cava
30 Coronary sulcus
31 Myocardium of left ventricle
32 Left pulmonary artery
33 Left pulmonary vein
34 Apex of heart

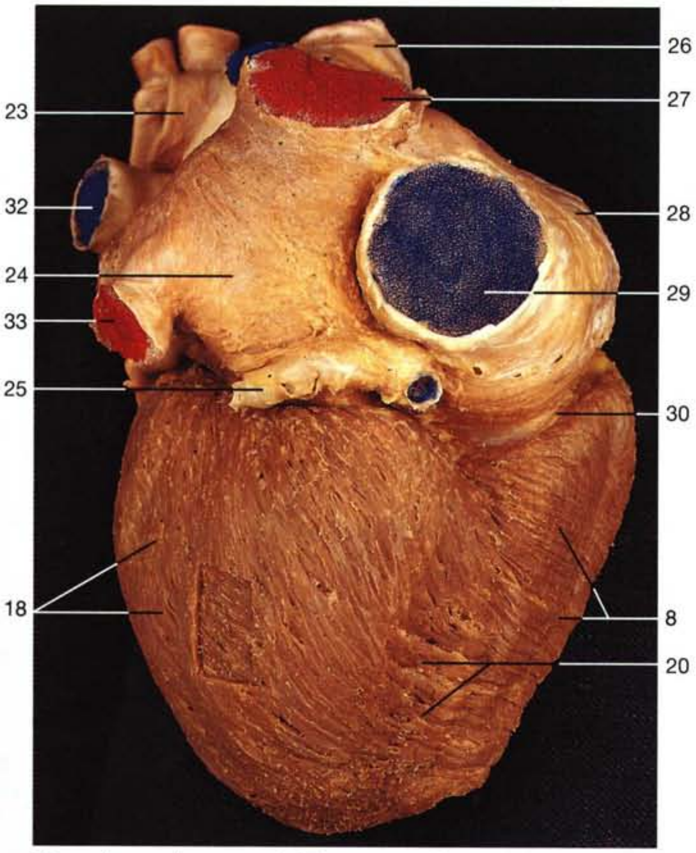

Heart (posterior aspect). The myocardium of the left ventricle has been fenestrated to show the muscle fiber bundles of the deeper layer with their more circular course.

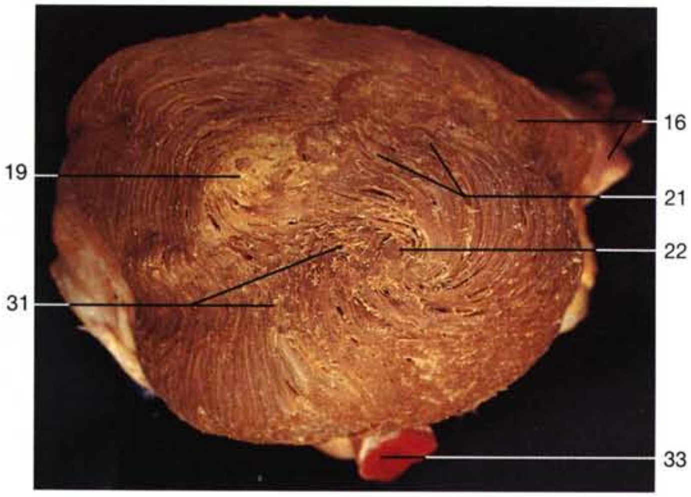

Vortex of cardiac muscle fibers (from below).

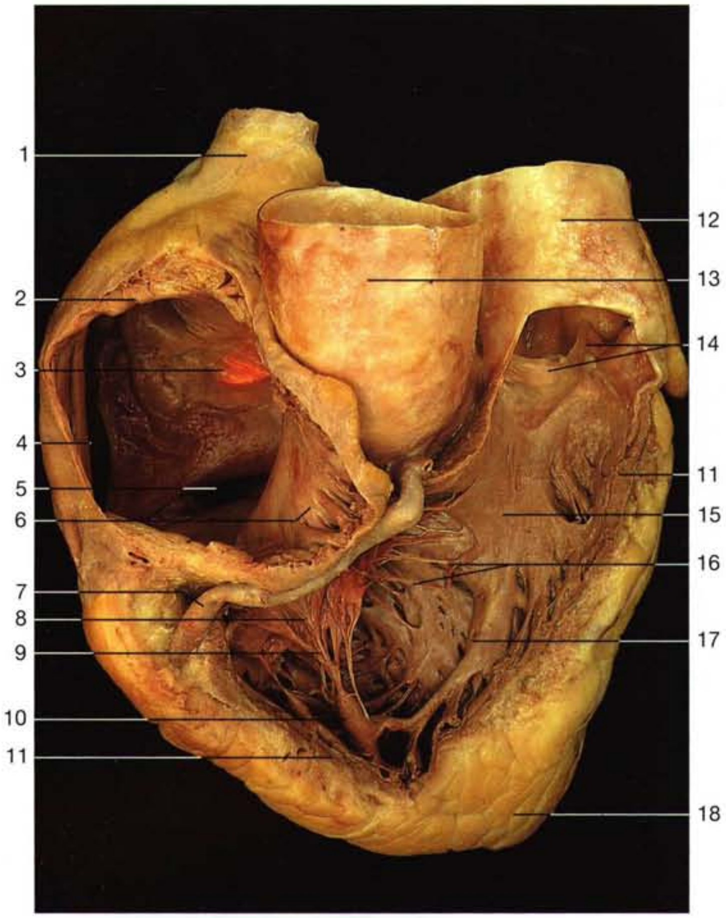

Right heart (anterior aspect). Anterior wall of right atrium and ventricle removed.

1 Superior vena cava
2 Crista terminalis
3 Fossa ovalis
4 Opening of inferior vena cava
5 Opening of coronary sinus
6 Right auricle
7 Right coronary artery and coronary sulcus
8 **Anterior cusp** of **tricuspid valve**
9 Chordae tendineae
10 **Anterior papillary muscle**
11 Myocardium
12 Pulmonary trunk
13 Ascending aorta
14 **Pulmonic valve**
15 Conus arteriosus (interventricular septum)
16 Septal papillary muscles
17 Septomarginal or moderator band
18 Apex of heart
19 Left auricle
20 **Aortic valve**
21 **Left ventricle**
22 Pulmonary veins
23 Position of fossa ovalis
24 **Left atrium**
25 **Left atrioventricular** (bicuspid or **mitral**) **valve**
26 Coronary sinus
27 Left coronary artery
28 Posterior papillary muscle
29 Left subclavian artery
30 Descending aorta
31 Left pulmonary artery

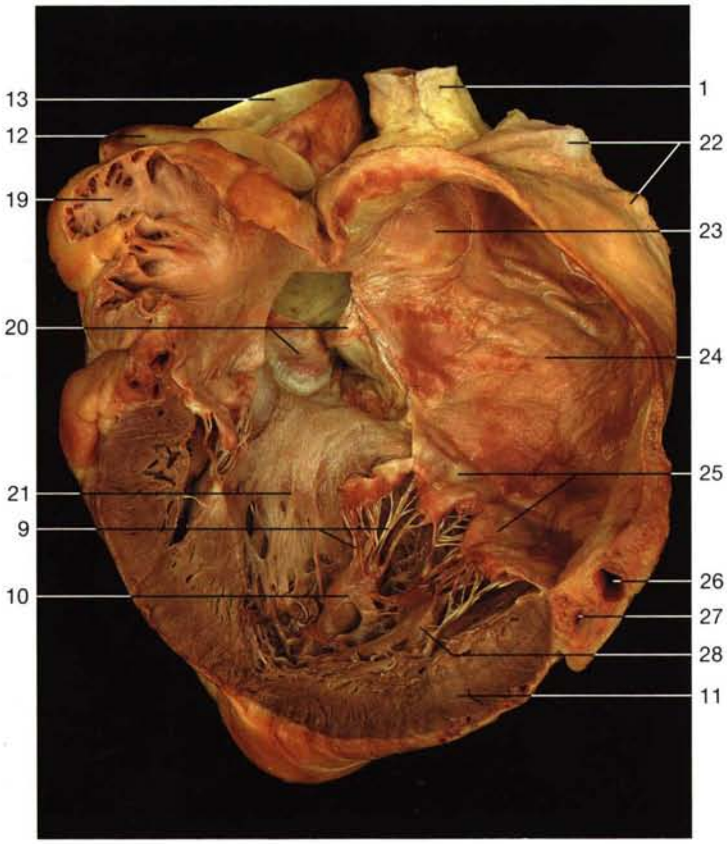

Left heart. Left atrium and ventricle opened. Aortic and mitral valve cut open.

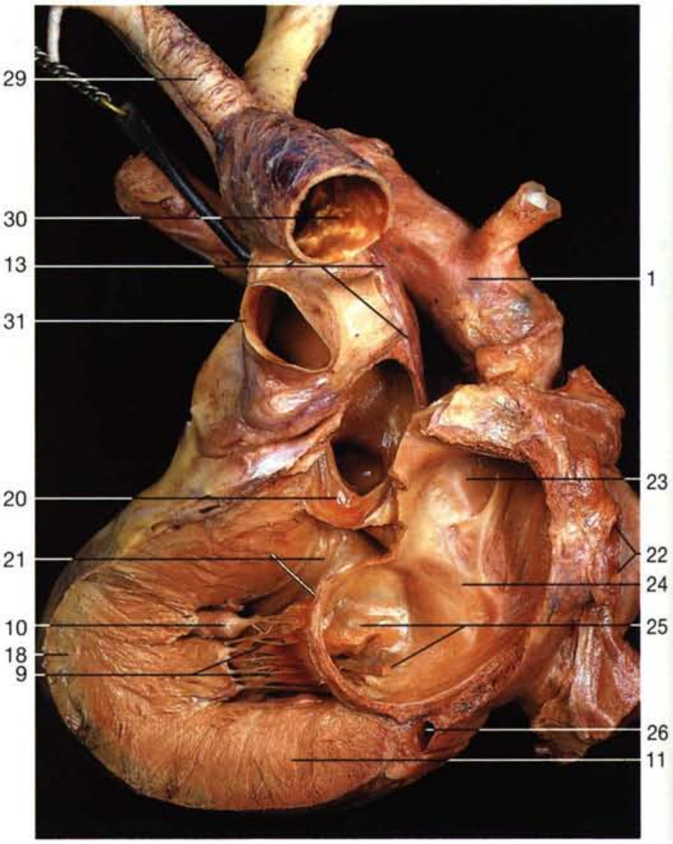

Left heart. Aortic valve cut open. Left atrium and ventricle opened. The atrial wall was cut near the anulus fibrosus of the mitral valve.

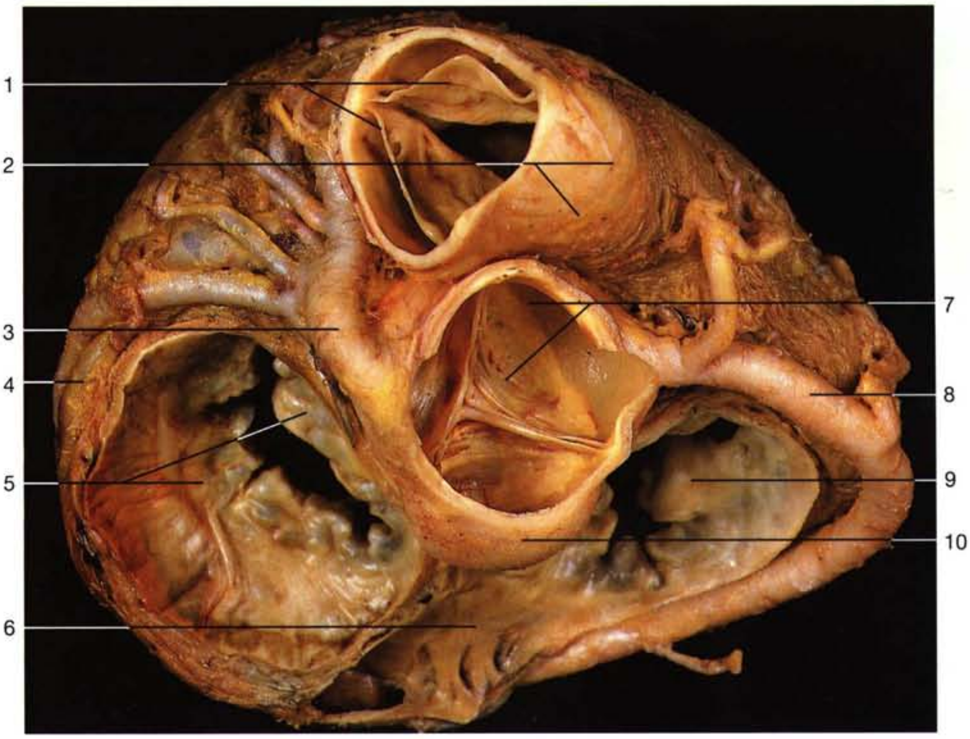

Valves of heart (superior aspect). Left and right atrium removed. Dissection of coronary arteries. Above: anterior wall of the heart.

1 **Pulmonic valve**
2 Sinus of pulmonary trunk
3 **Left coronary artery**
4 Great cardiac vein
5 **Left atrioventricular (mitral) valve**
6 **Coronary sinus**
7 **Aortic valve**
8 **Right coronary artery**
9 **Right atrioventricular (tricuspid) valve**
10 Bulb of aorta
11 Anterior semilunar cusp of pulmonic valve
12 Left semilunar cusp of pulmonic valve
13 Right semilunar cusp of pulmonic valve
14 Left semilunar cusp of aortic valve
15 Right semilunar cusp of aortic valve
16 Posterior semilunar cusp of aortic valve
17 Right atrium
18 Anterior cusp of tricuspid valve
19 **Chordae tendineae**
20 Trabeculae carneae
21 Interventricular septum
22 Septal cusp of tricuspid valve
23 **Anterior papillary muscle**
24 Myocardium of right ventricle

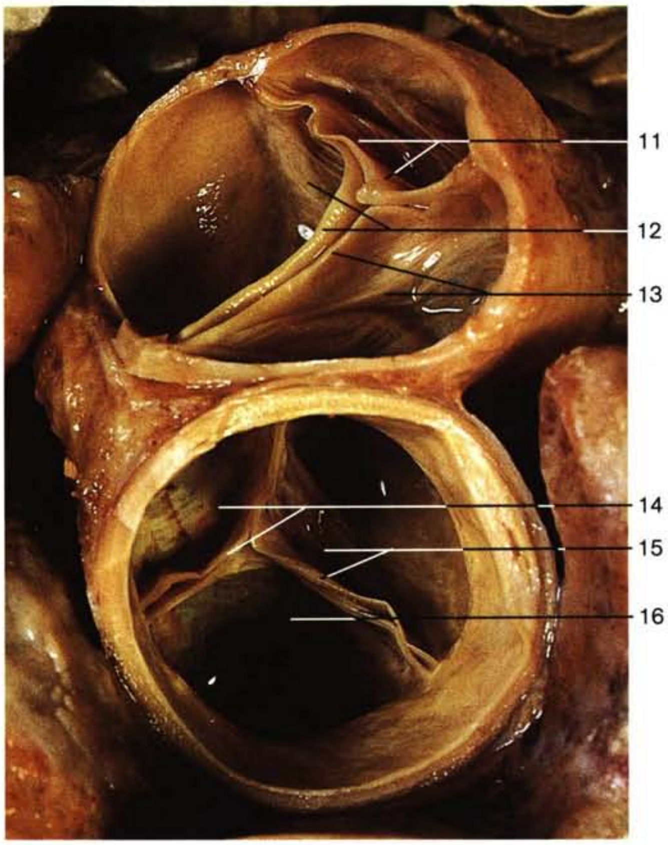

Pulmonic and aortic valves (from above). Anterior wall of the heart at the top. Both valves are closed.

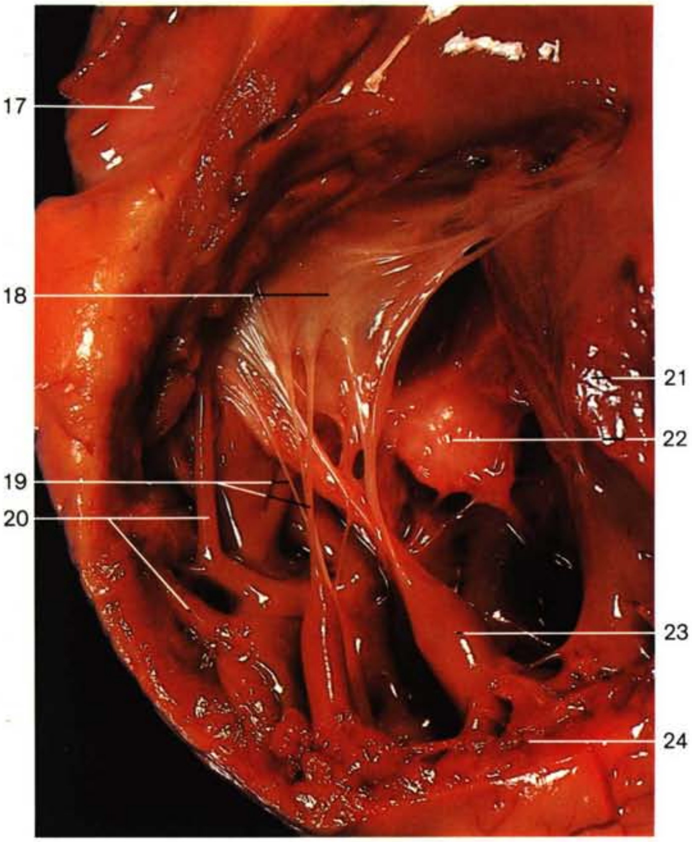

Right atrioventricular (tricuspid) valve (anterior aspect after removal of the anterior wall of the right ventricle).

1 Ascending aorta
2 Superior vena cava
3 Right auricle
4 **Right atrium**
5 Coronary sulcus
6 **Right ventricle**
7 Pulmonary trunk
8 Left auricle
9 Anterior interventricular sulcus
10 **Left ventricle**
11 Right pulmonary artery
12 Sulcus terminalis with sinuatrial node
13 Line indicating plane of position of valves
14 Myocardium of right atrium
15 Inferior vena cava
16 Valve of pulmonary trunk
17 Tricuspid valve
18 Myocardium of right ventricle

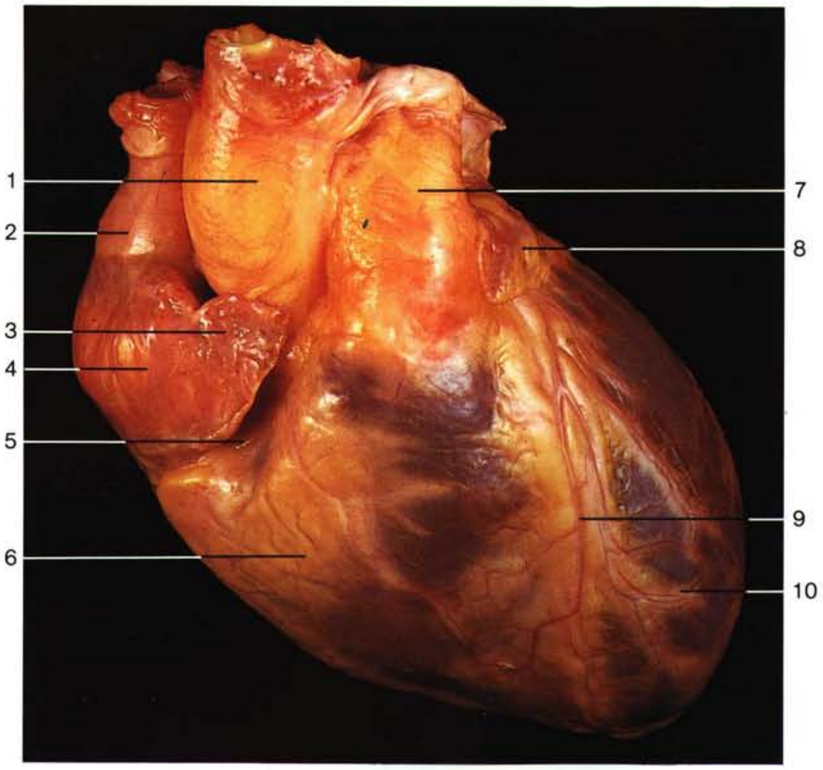

Heart, fixed in **diastole** (anterior aspect). The ventricles are relaxed, atria contracted.

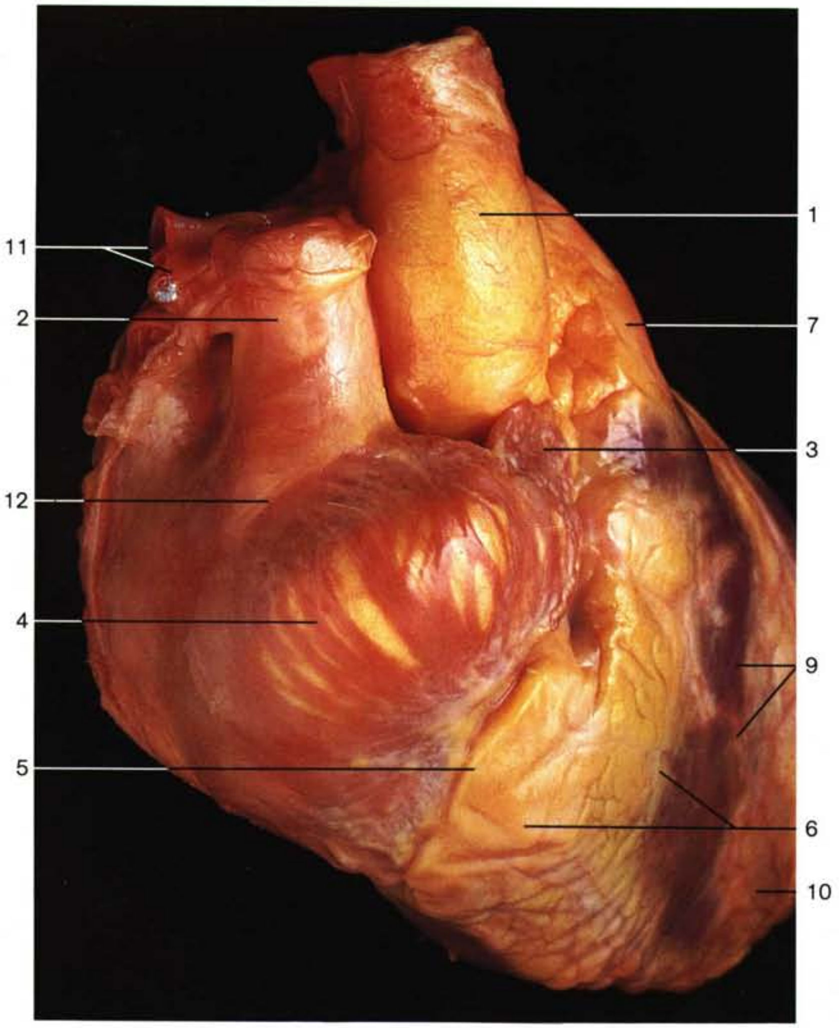

Heart, fixed in **systole** (anterolateral aspect). The ventricles are contracted, atria dilated.

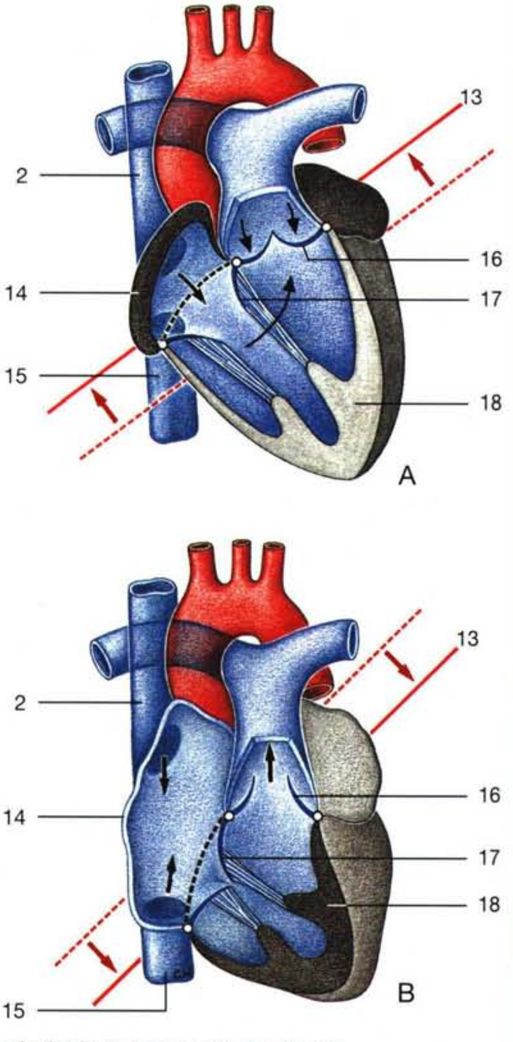

Morphological changes during heart movements. Note the changes in positon of the valves (arrows). Contracted portions of heart are indicated in red.

A. **Diastole,** muscles of the ventricles relaxed; atrioventricular valves open, semilunar valves closed.

B. **Systole,** muscles of ventricles contracted; atrioventricular valves closed, semilunar valves open.

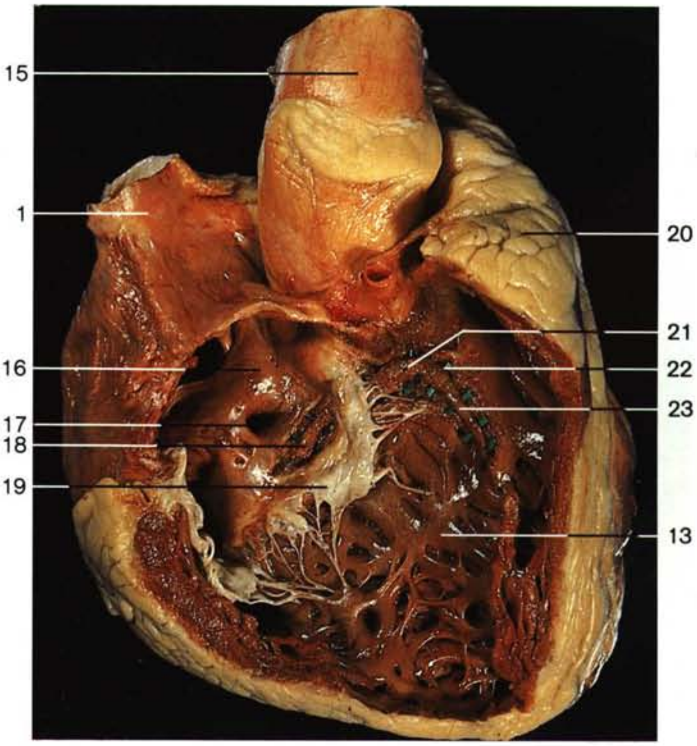

Right ventricle, dissection of **atrioventricular node, atrioventricular bundle (bundle of His)** and right limb or bundle branch (probes).

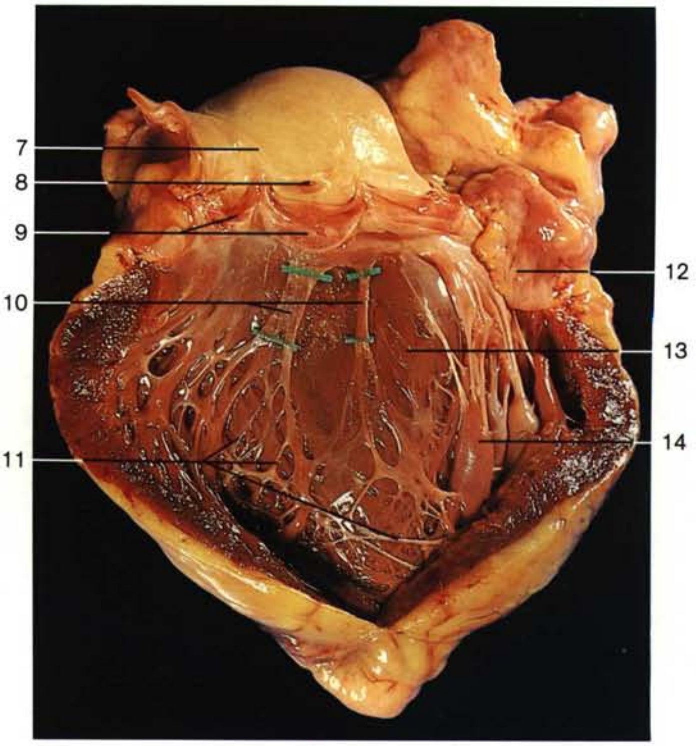

Left ventricle, dissection of the left limb or bundle branch of conducting system (probes).

1 Superior vena cava
2 Sulcus terminalis
3 Bulb of aorta
4 Sinuatrial node (arrows)
5 Muscle fiber bundles of right atrium
6 Coronary sulcus (with right coronary artery)
7 Aortic sinus
8 Entrance to left coronary artery
9 Aortic valve
10 Branches of **left bundle branch**
11 Purkinje fibers
12 Left auricle
13 Interventricular septum
14 Papillary muscles
15 Ascending aorta
16 Right atrium
17 Opening of coronary sinus
18 **Atrioventricular node**
19 Septal cusp of tricuspid valve
20 Pulmonary trunk
21 **Atrioventricular bundle** (bundle of His)
22 Bifurcation of atrioventricular bundle
23 **Right bundle branch**
24 Inferior vena cava
25 Left atrium
26 Left bundle branch
27 Papillary muscles with Purkinje fibers

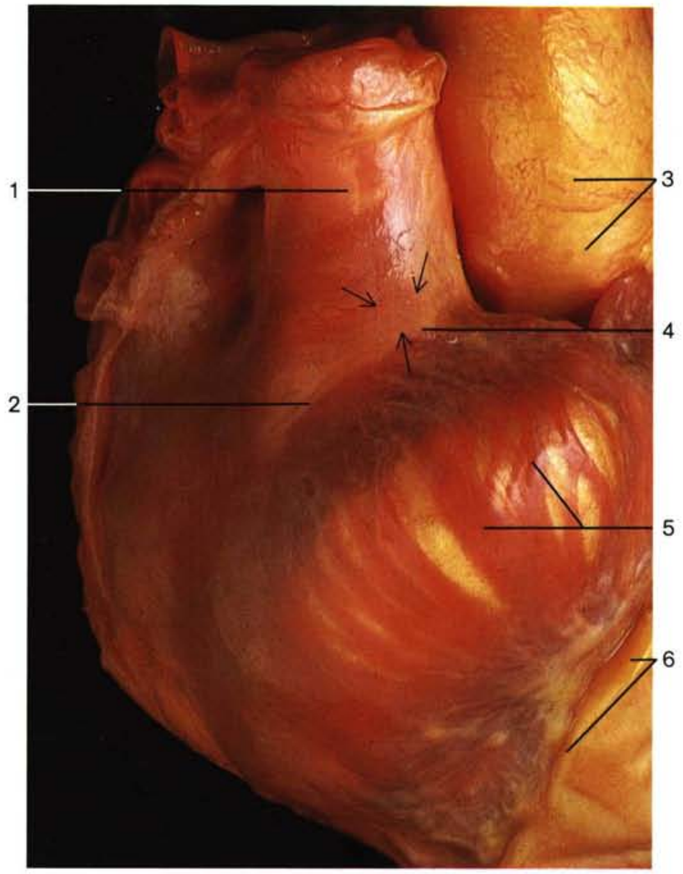

Right atrium, anterior wall, showing the location of the **sinuatrial node** (arrows).

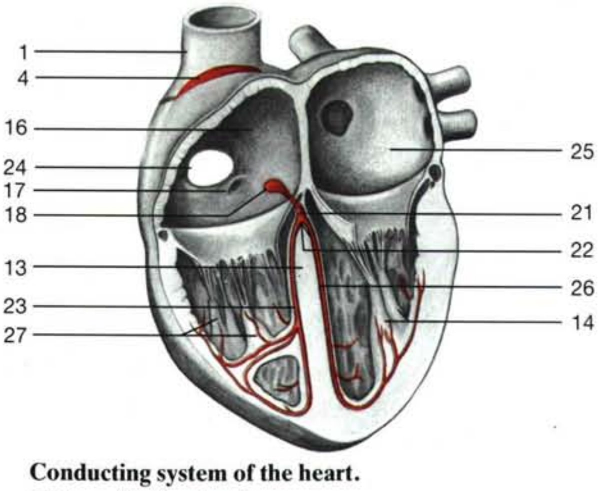

Conducting system of the heart.
(Schematic drawing.)

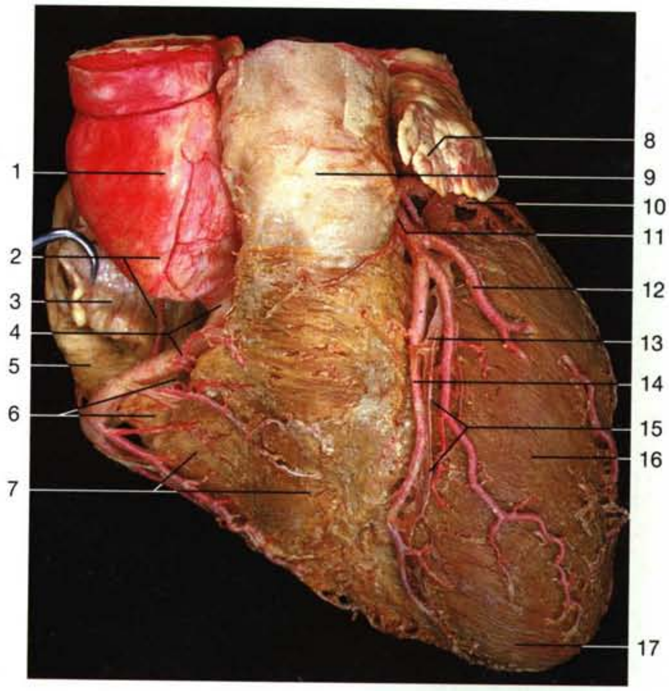

Coronary arteries (anterior aspect). The epicardium and subepicardial fatty tissue have been removed. The arteries have been injected with red resin from the aorta.

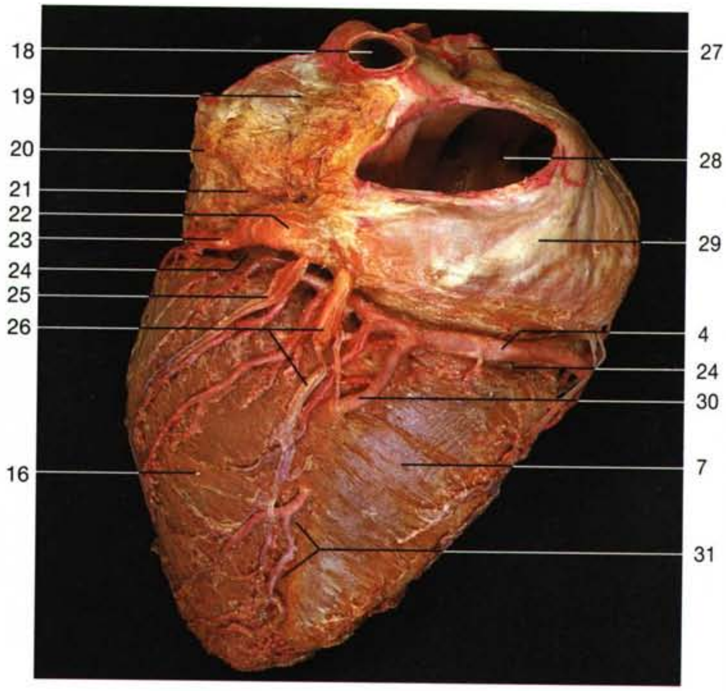

Right coronary artery and veins of the heart (dorsal aspect). The epicardium and subepicardial fatty tissue have been removed.

1 Ascending aorta
2 Aortic bulb and (in the above specimen) sinuatrial branch of right coronary artery
3 Right auricle
4 **Right coronary artery**
5 Right atrium
6 Coronary sulcus
7 Right ventricle
8 Left auricle
9 Pulmonary trunk

10 Circumflex branch of left coronary artery
11 **Left coronary artery**
12 Diagonal branch of left artery
13 Great cardiac vein
14 Anterior interventricular artery
15 Anterior interventricular sulcus
16 Left ventricle
17 Apex of heart
18 Right pulmonary vein
19 Left atrium
20 Left pulmonary veins
21 Oblique vein of left atrium (Marshall's vein)
22 **Coronary sinus**
23 **Great cardiac vein**
24 Coronary sulcus (posterior portion)
25 Posterior vein of left ventricle
26 **Middle cardiac vein**
27 Left pulmonary artery
28 Inferior vena cava
29 Right atrium
30 Posterior interventricular branch of right coronary artery
31 Posterior interventricular sulcus
32 Superior vena cava
33 Right marginal branch
34 Branch of sinuatrial node
35 Minimal cardiac veins
36 **Small cardiac vein**

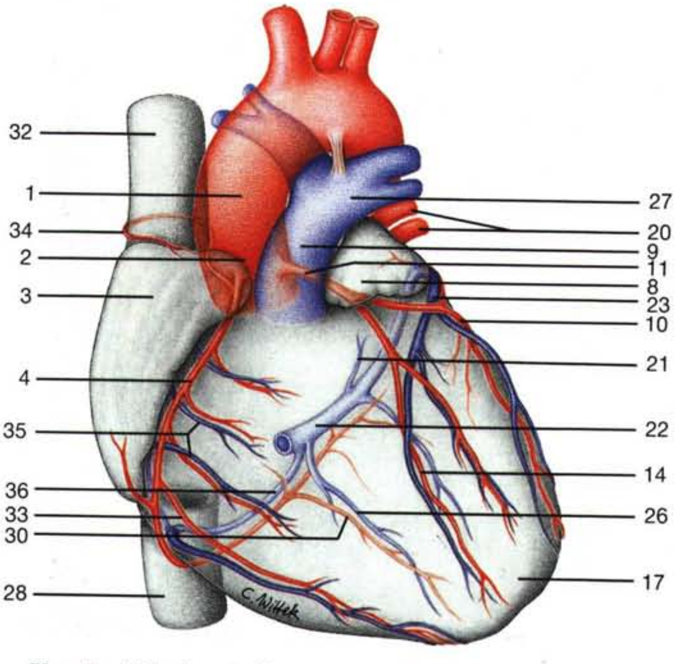

Vessels of the heart. Coronary arteries (red) and veins (blue) of the heart (anterior aspect).

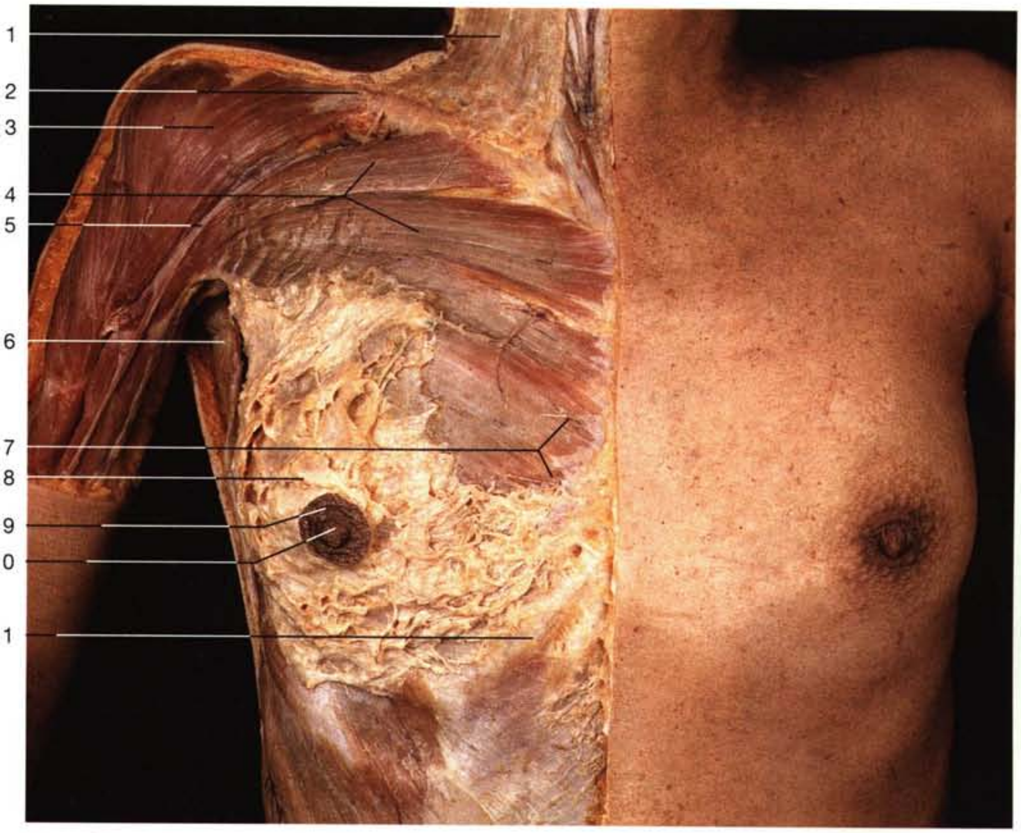

Dissection of mammary gland (anterior aspect).

1 Platysma muscle
2 Clavicle
3 Deltoid muscle
4 Pectoralis major muscle
5 Deltopectoral groove and cephalic vein
6 Latissimus dorsi muscle
7 Medial mamarian branches of intercostal nerves
8 Breast tissue
9 Areola
10 Nipple (papilla)
11 Costal margin
12 Pectoral fascia
13 Mammary gland
14 Serratus anterior muscle
15 Lactiferous sinus
16 Lactiferous ducts

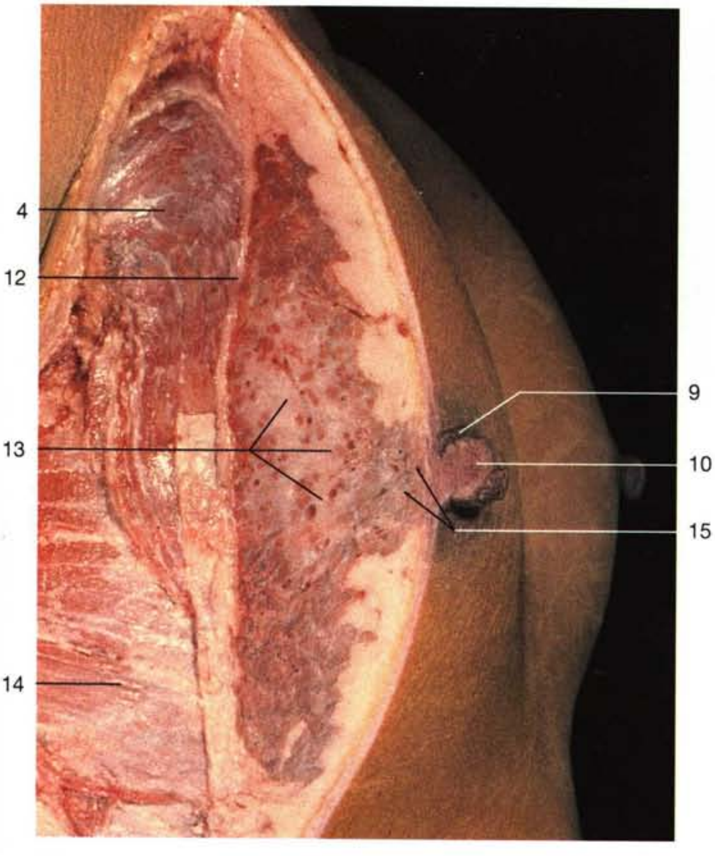

Mammary gland (sagittal section; pregnant female).

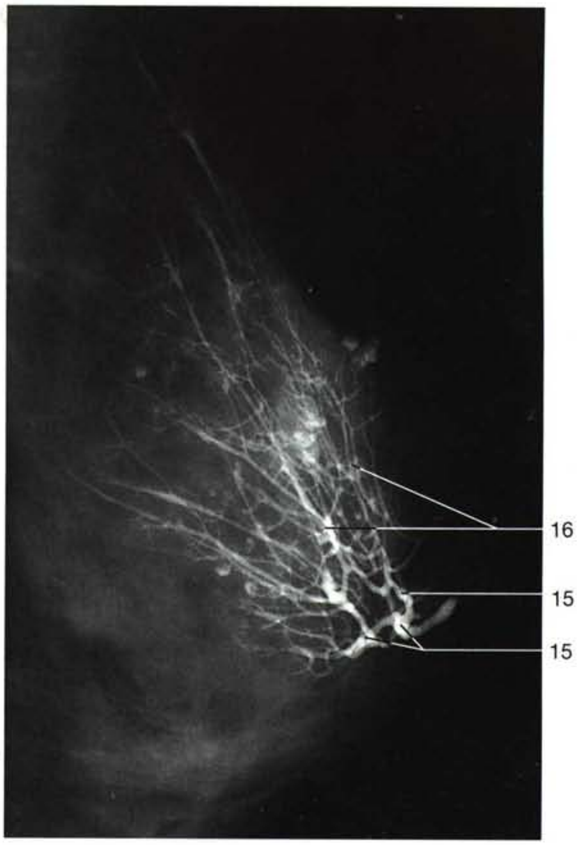

Galactogram of mammary gland (adult female). Notice multiple duct cysts.

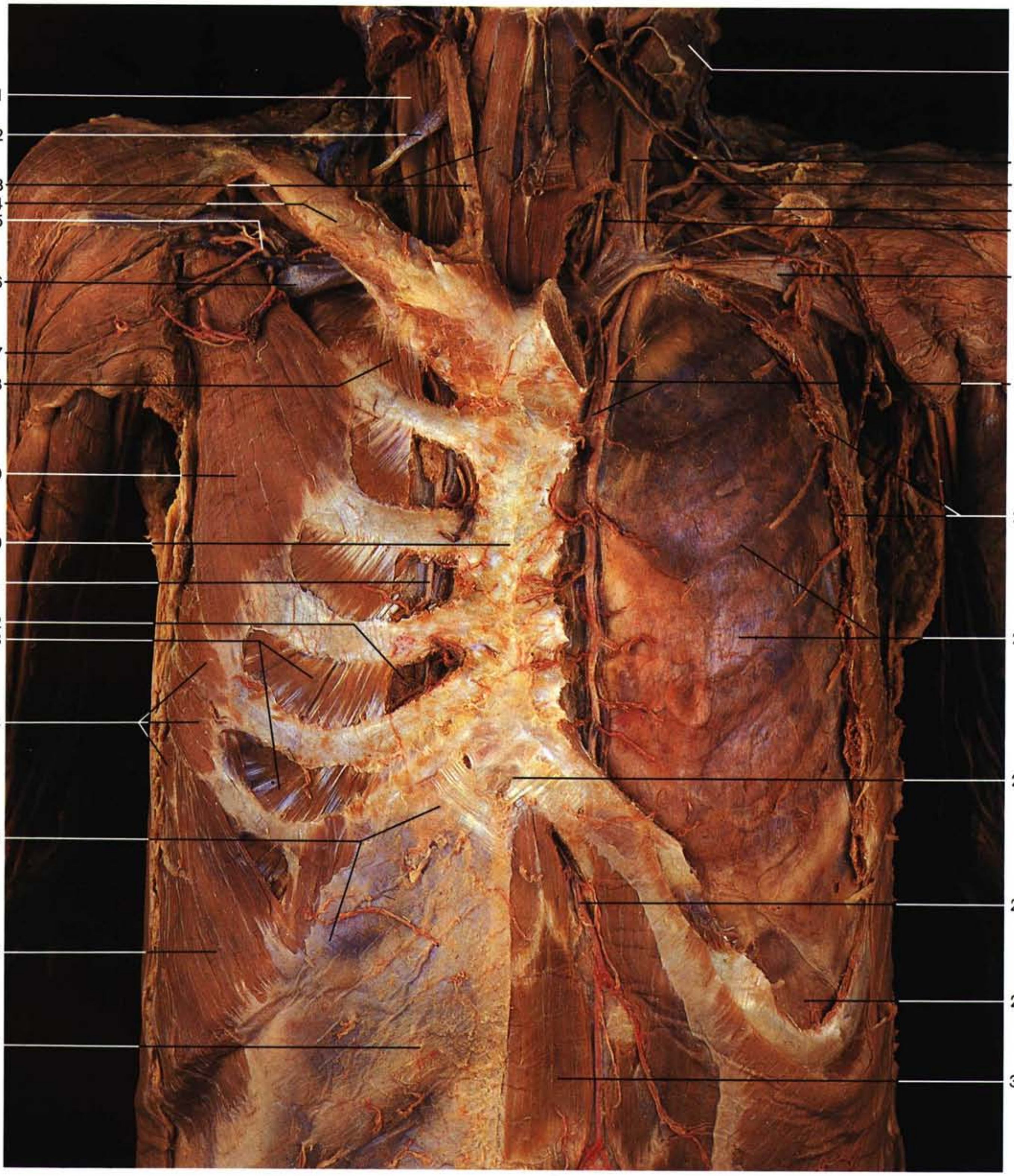

Thoracic wall and organs (ventral aspect). The left clavicle and ribs have been partially removed, and the right intercostal spaces have been opened to show the internal thoracic vein and artery.

1 Right internal jugular vein
2 Omohyoid muscle
3 Sternohyoid muscle and external jugular vein
4 Clavicle
5 Thoracoacromial artery
6 Right **subclavian vein**
7 Pectoralis major muscle
8 External intercostal muscle
9 Pectoralis minor muscle
10 Body of sternum
11 Right internal thoracic artery and vein
12 Fascicles of transversus thoracis muscle
13 **Internal intercostal muscles**
14 Serratus anterior muscle
15 Costal margin
16 External abdominal oblique muscle
17 Anterior sheath of rectus abdominis muscle
18 Sternocleidomastoid muscle
19 Left internal jugular vein
20 Transverse cervical artery
21 Brachial plexus
22 Vagus nerve
23 Left axillary vein
24 Left **internal thoracic artery and vein**
25 Ribs and thoracic wall (cut)
26 Costal pleura
27 Xiphoid process
28 **Superior epigastric artery**
29 Diaphragm
30 Rectus abdominis muscle

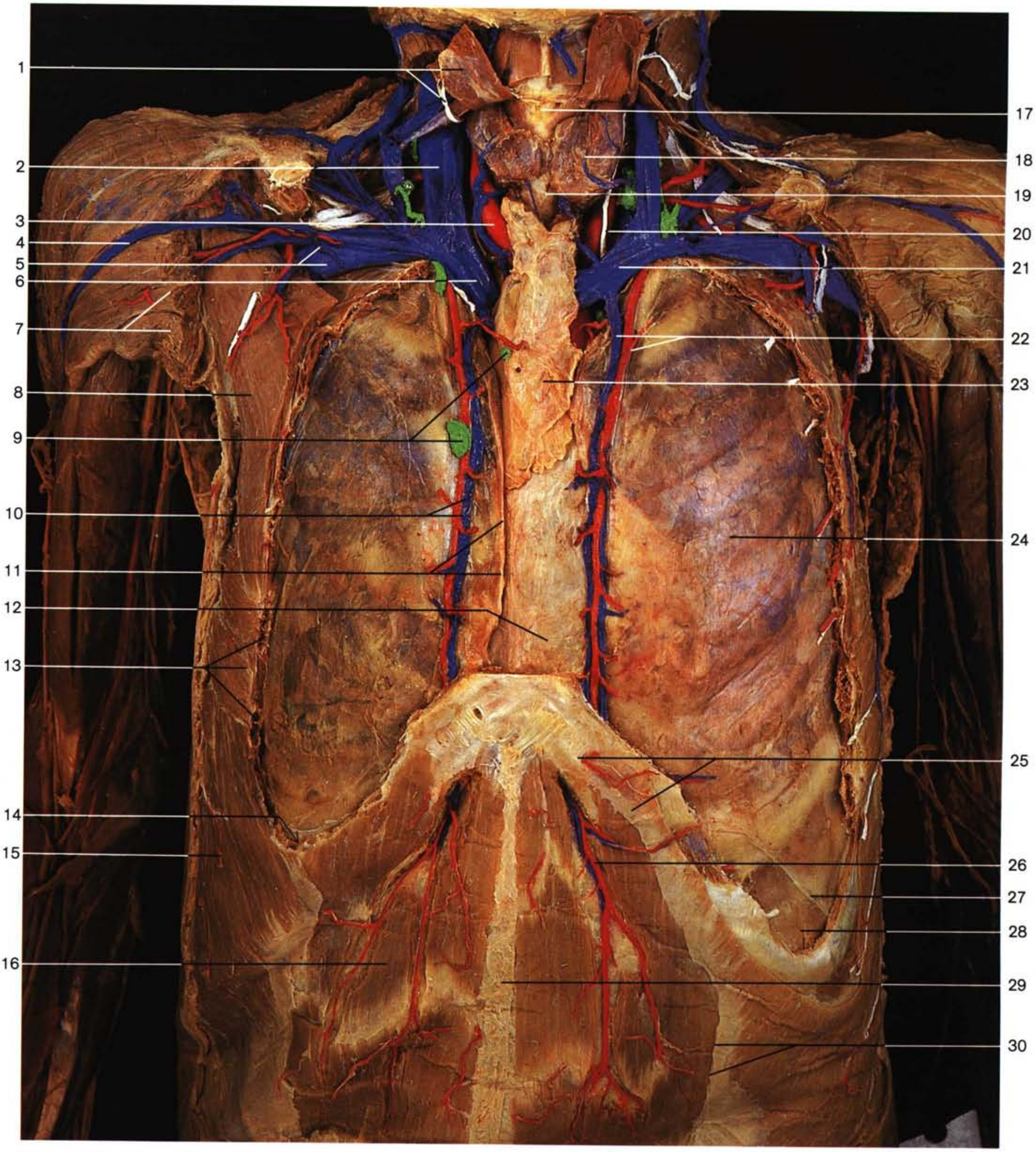

Thoracic organs, anterior mediastinum and pleura. Ribs, clavicle and sternum have been partly removed. Red = arteries; blue = veins; green = lymph vessels and nodes.

1 Sternothyroid muscle and its nerve (a branch of the ansa cervicalis)
2 Right **internal jugular vein**
3 Right common carotid artery
4 Cephalic vein
5 Right **subclavian vein**
6 **Right brachiocephalic vein**
7 Pectoralis major muscle (divided)
8 Pectoralis minor muscle (divided)
9 Parasternal lymph nodes
10 Internal thoracic artery and vein
11 Anterior margin of costal pleura
12 **Pericardium**
13 5th and 6th ribs (divided) and serratus anterior muscle
14 **Costodiaphragmatic recess**
15 External abdominal oblique muscle
16 Rectus abdominis muscle
17 Larynx (thyroid cartilage)
18 Thyroid gland
19 Trachea
20 Left vagus nerve
21 Left brachiocephalic vein
22 Left **internal thoracic artery and vein**
23 Thymus
24 **Costal pleura**
25 Costal margin
26 **Superior epigastric artery**
27 Margin of costal pleura
28 **Diaphragm**
29 **Linea alba**
30 Cut edge of anterior sheath of rectus abdominis muscle

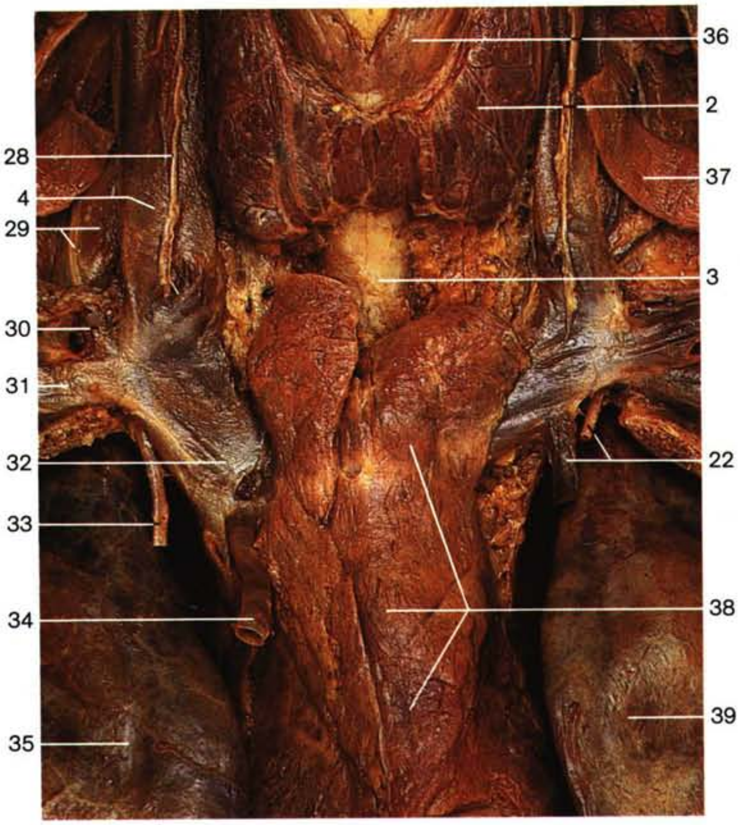

The **thymus** above the heart, showing its position and size.

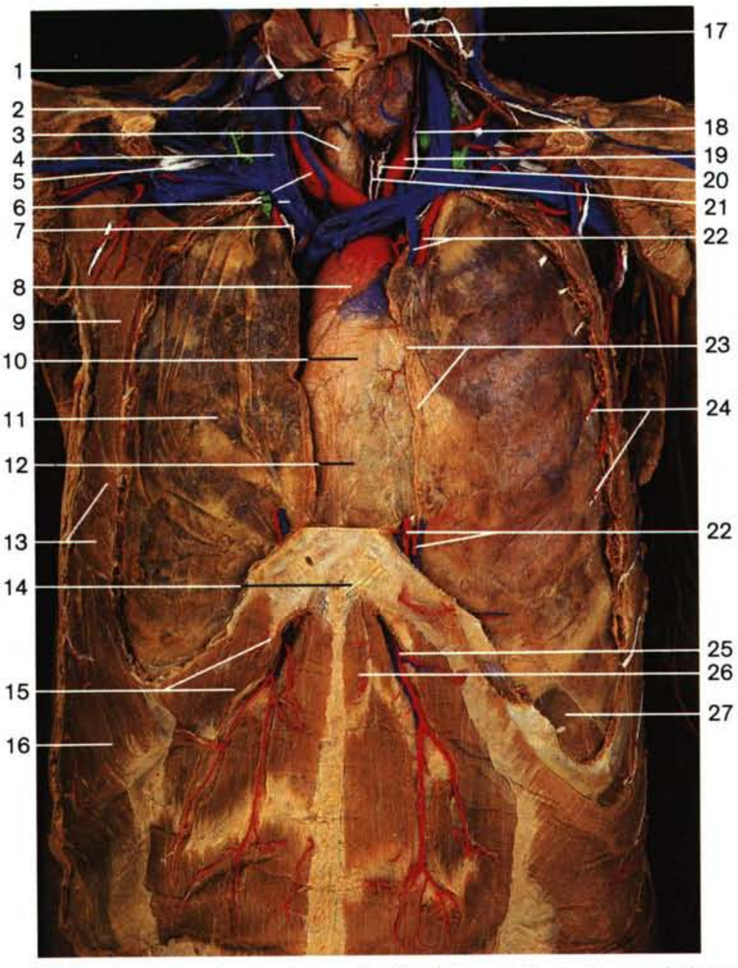

Thoracic organs (ventral aspect). The internal thoracic vessels have been removed, and the anterior margins of the pleura and lungs have been slightly reflected to display the **anterior** and **middle mediastinum,** including the **heart** and **great vessels.**

1 Larynx (thyroid cartilage)
2 Thyroid gland
3 **Trachea**
4 Internal jugular vein
5 Brachial plexus
6 Right brachiocephalic vein and common carotid artery
7 Right phrenic nerve
8 **Ascending aorta**
9 Pectoralis minor muscle (divided)
10 Pulmonary trunk (covered by pericardium)
11 **Costal pleura**
12 Pericardium and **heart**
13 Serratus anterior muscle
14 Xiphoid process
15 Costal margin
16 External abdominal oblique muslce
17 Sternothyroid muscle (divided and reflected)
18 Vagus nerve
19 Left common carotid artery
20 Left sympathetic trunk
21 Left recurrent laryngeal nerve
22 Left internal thoracic artery and vein (divided)
23 Margin of costal pleura
24 Intercostal nerves and vessels
25 Superior epigastric artery
26 Rectus abdominis muscle
27 **Diaphragm**
28 Ansa cervicalis
29 Phrenic nerve and scalenus anterior muscle
30 External jugular vein (divided)
31 Right subclavian vein
32 Right brachiocephalic vein
33 Internal thoracic artery (divided)
34 Internal thoracic vein (divided)
35 Right lung
36 Cricothyroid muscle
37 Omohyoid muscle
38 **Thymus**
39 Left lung

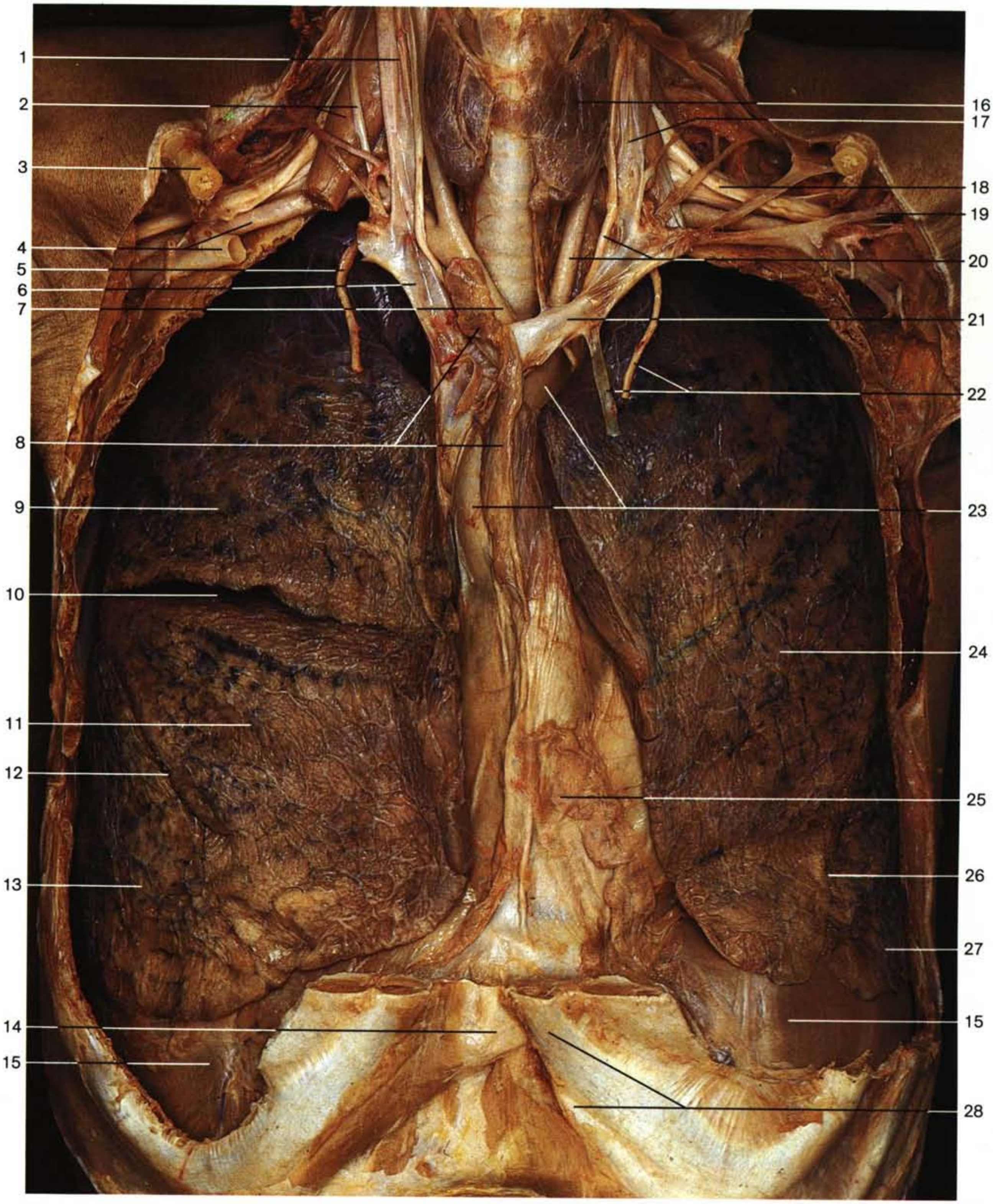

Thoracic organs (ventral aspect). The pleura has been opened and the lungs exposed. Remnants of the thymus and pericardium are seen.

1 Right internal jugular vein
2 Phrenic nerve and scalenus anterior muscle
3 Clavicle (divided)
4 Right subclavian artery and vein
5 Internal thoracic artery
6 **Right brachiocephalic vein**
7 Brachiocephalic trunk
8 Thymus (atrophic)
9 Upper lobe of right **lung**
10 Horizontal fissure of right lung (incomplete)
11 Middle lobe of right lung
12 Oblique fissure of right **lung**
13 Lower lobe of right lung
14 Xiphoid process
15 **Diaphragm**
16 **Thyroid gland**
17 Left internal jugular vein
18 Brachial plexus
19 Left cephalic vein
20 Left common carotid artery and vagus nerve
21 **Left brachiocephalic vein**
22 Internal thoracic artery and vein (divided)
23 **Ascending aorta** and aortic arch
24 Upper lobe of left **lung**
25 **Pericardium**
26 Oblique fissure of left lung
27 Lower lobe of left lung
28 Costal margin

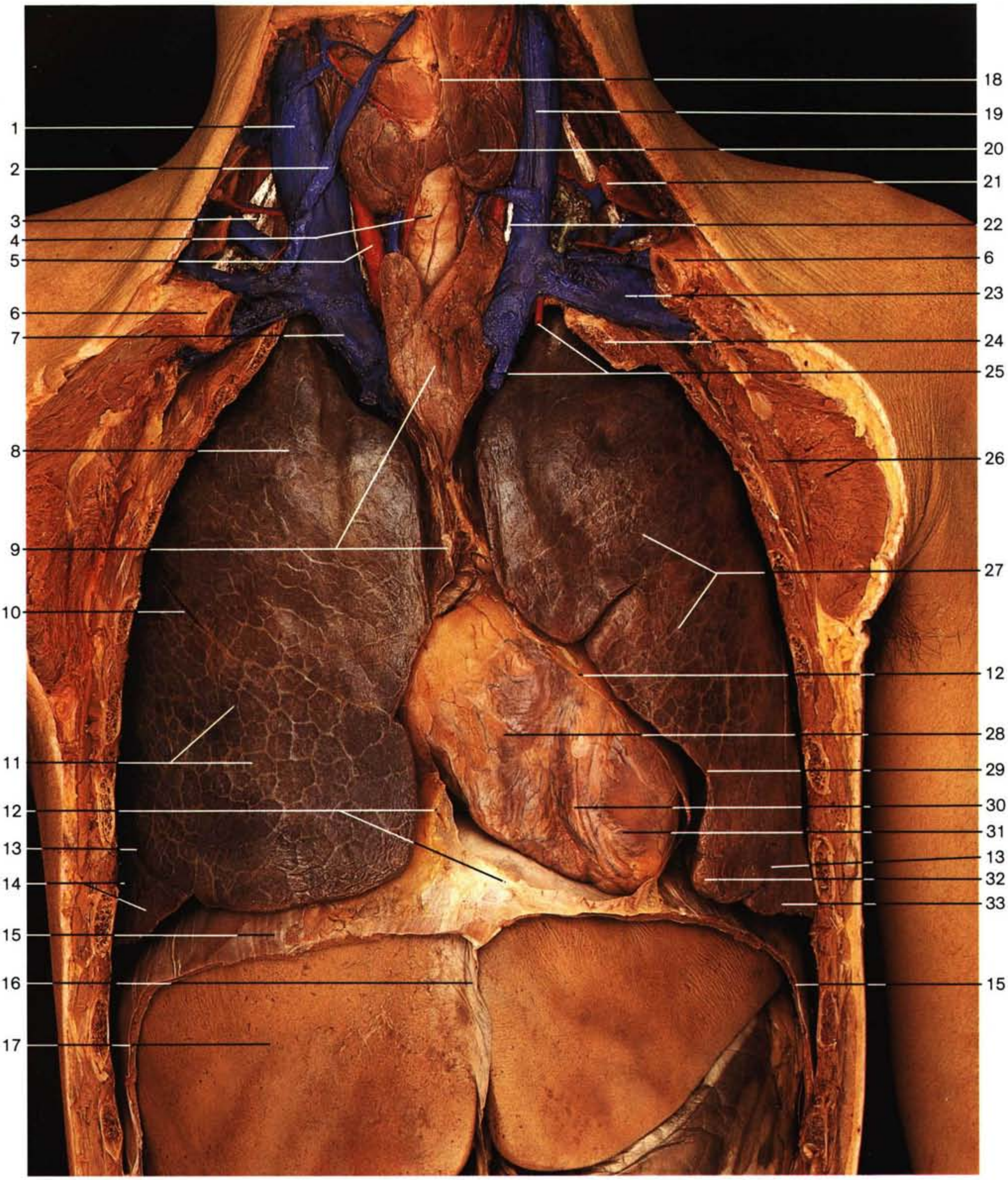

Thoracic organs (ventral aspect). The thoracic wall, costal pleura, pericardium and diaphragm have been partly removed.

1 Internal jugular vein
2 External jugular vein (displaced medially)
3 Brachial plexus
4 Trachea
5 Right common carotid artery
6 Clavicle (divided)
7 Right brachiocephalic vein
8 Upper lobe of right lung
9 **Thymus** (atrophic)
10 Horizontal fissure of right lung
11 Middle lobe of right lung

12 Pericardium (cut edges)
13 Oblique fissure of lung
14 Lower lobe of right lung
15 **Diaphragm**
16 Falciform ligament
17 **Liver**
18 Location of larynx
19 Left internal jugular vein
20 Thyroid gland
21 Omohyoid muscle (divided)
22 Vagus nerve

23 Left subclavian vein
24 1st rib (divided)
25 Internal thoracic artery and vein
26 Pectoralis major and pectoralis minor muscles (cut edges)
27 **Upper lobe of left lung**
28 **Right ventricle**
29 Cardiac notch of left lung
30 Interventricular sulcus of heart
31 **Left ventricle**
32 Lingula
33 Lower lobe of left lung

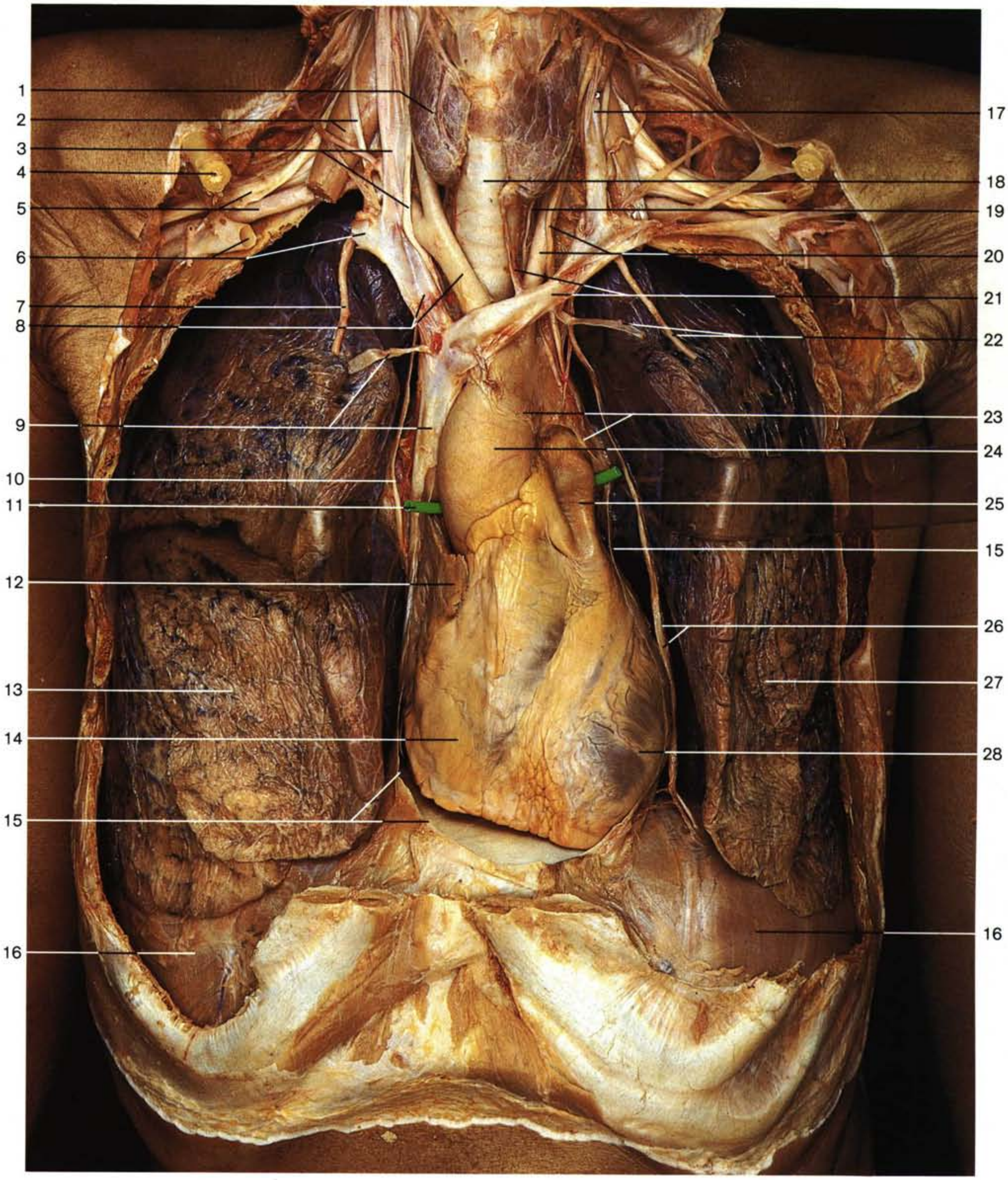

Thoracic organs, position of the heart, middle mediastinum (ventral aspect). The anterior wall of the thorax, the costal pleura and the pericardium have been removed and the lungs slightly reflected.

1 Thyroid gland
2 Phrenic nerve and scalenus anterior muscle
3 Vagus nerve and internal jugular vein
4 Clavicle (divided)
5 Brachial plexus and subclavian artery
6 Subclavian vein
7 Internal thoracic artery
8 Brachiocephalic trunk and right brachiocephalic vein
9 **Superior vena cava** and thymic vein
10 **Right phrenic nerve**
11 Transverse pericardial sinus (probe)
12 Right auricle
13 Middle lobe of right lung
14 **Right ventricle**
15 Cut edge of pericardium
16 Diaphragm
17 Internal jugular vein
18 Trachea
19 Left recurrent laryngeal nerve
20 Left common carotid artery and vagus nerve
21 Left brachiocephalic vein and inferior thyroid vein
22 Left internal thoracic artery and vein (divided)
23 Upper margin of pericardial sac
24 **Ascending aorta**
25 Pulmonary trunk
26 **Left phrenic nerve** and left pericardiacophrenic artery and vein
27 Upper lobe of left lung
28 Left ventricle

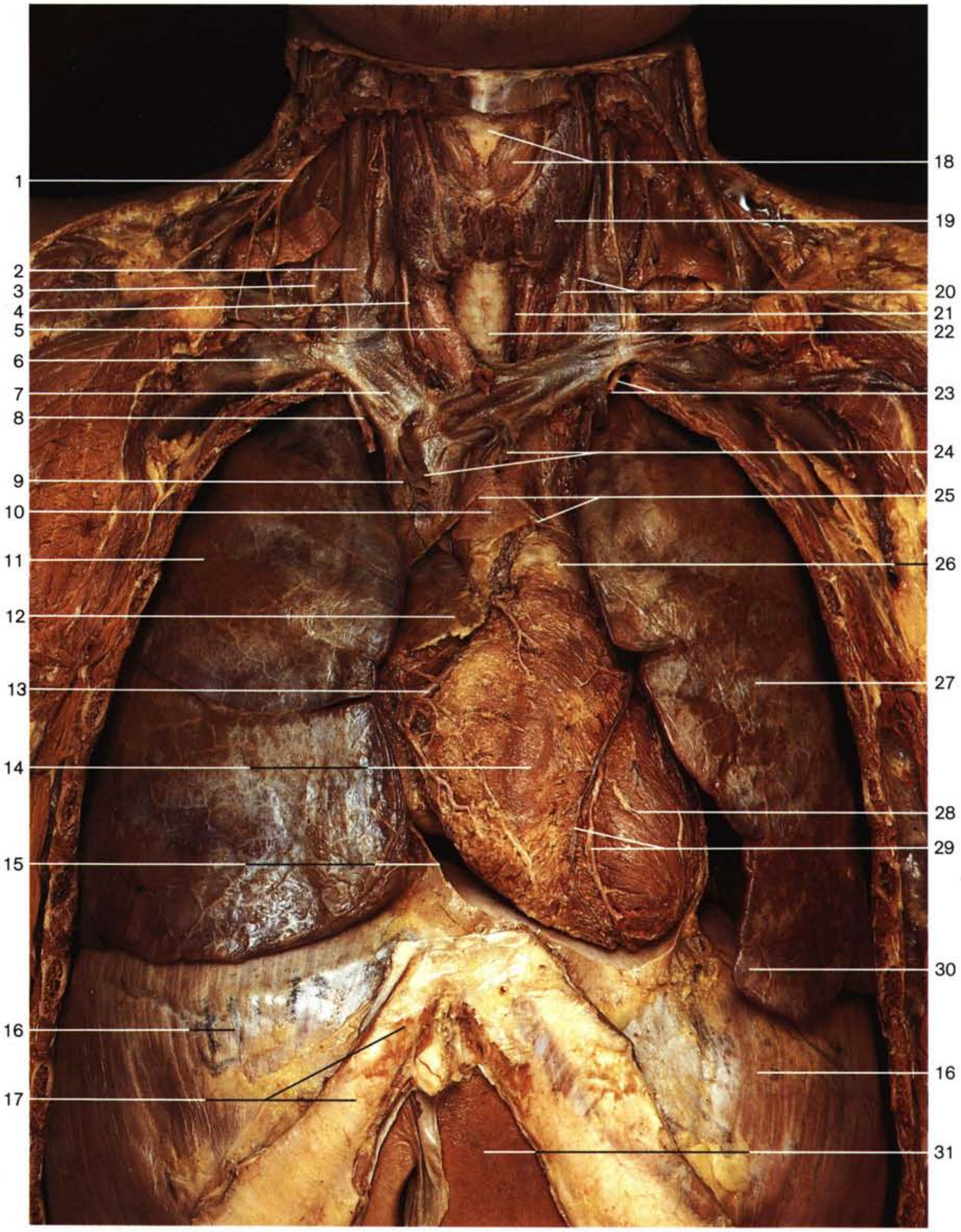

Thoracic organs, position of heart, dissection of coronary vessels in situ (ventral aspect). The anterior wall of thorax, costal pleura and pericardium have been removed.

1 Intermediate supraclavicular nerve
2 Internal jugular vein
3 Right phrenic nerve
4 Right vagus nerve
5 Right common carotid artery
6 Right subclavian vein
7 Right brachiocephalic vein
8 Right internal thoracic artery
9 **Superior vena cava**
10 Ascending aorta
11 Right lung

12 Right atrium
13 **Right coronary artery** and small cardiac vein
14 **Right ventricle**
15 Cut edge of pericardium
17 Costal margin
18 Larynx (cricothyroid muscle and thyroid cartilage)
19 Thyroid gland
20 Left common carotid artery and left vagus nerve

21 Left recurrent laryngeal nerve
22 Trachea
23 Left internal thoracic artery and vein (divided)
24 Thymic veins
25 Margin of pericardial sac
26 Pulmonary trunk
27 Left lung
28 Left ventricle
29 Anterior interventricular artery and vein
30 Lingula
31 Liver

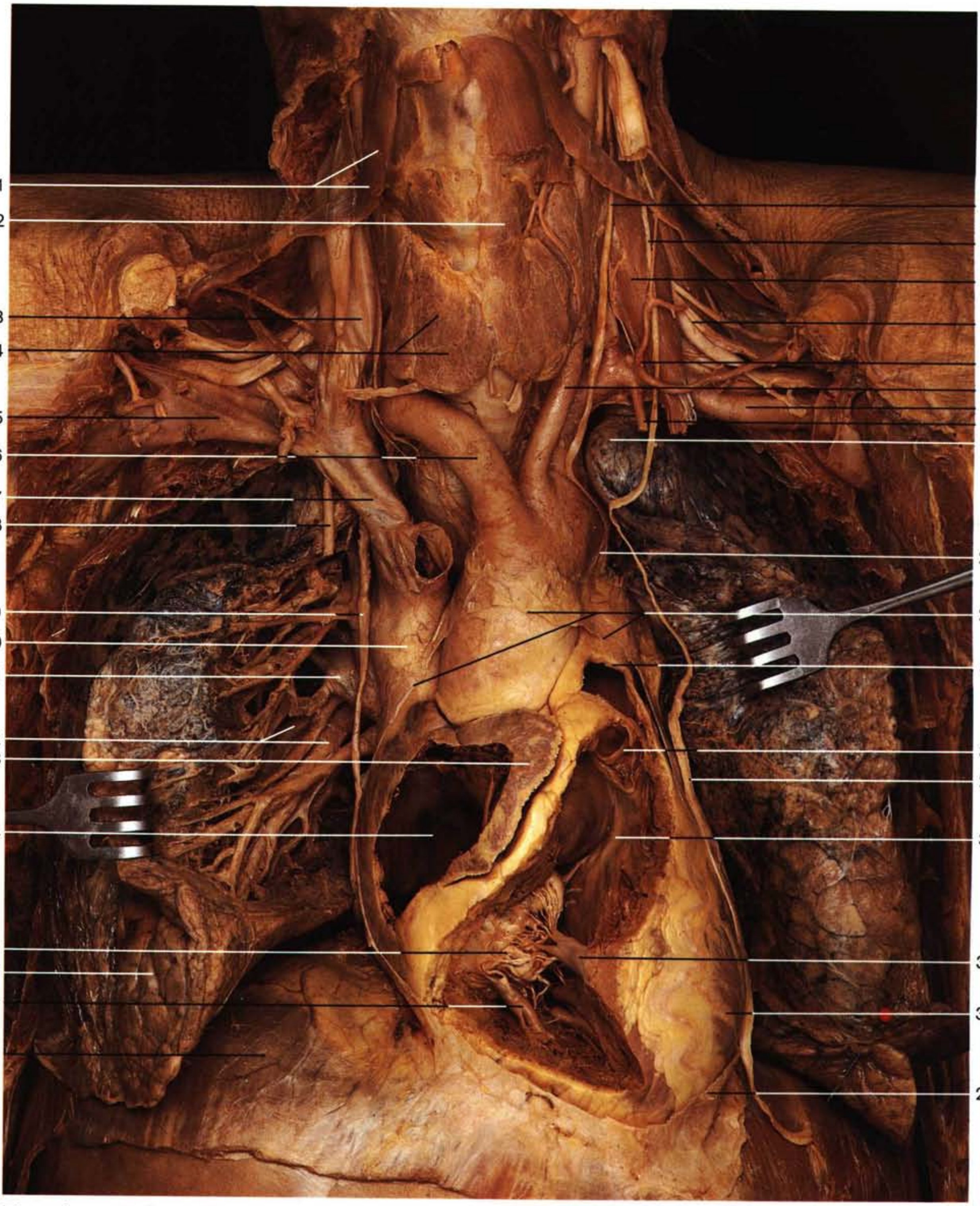

Thoracic organs, heart with valves in situ (ventral aspect). Anterior wall of thorax, pleura and anterior portion of pericardium have been removed. The right atrium and ventricle have been opened to show the right atrioventricular and pulmonary valves.

1 Omohyoid muscle
2 Pyramidal lobe of thyroid gland
3 Internal jugular vein
4 Thyroid gland
5 Right subclavian vein
6 Brachiocephalic trunk
7 **Right brachiocephalic vein**
8 Right internal thoracic artery
9 Right phrenic nerve
10 **Superior vena cava**
11 Pulmonary vein
12 Branches of pulmonary artery
13 Right auricle
14 **Right atrium**
15 **Right atrioventricular (tricuspid) valve**
16 Right lung
17 Posterior papillary muscle
18 Diaphragm
19 Left **vagus nerve**
20 Left **phrenic nerve**
21 Scalenus anterior muscle
22 Brachial plexus
23 Thyrocervical trunk
24 Left common carotid artery
25 Left subclavian artery
26 Left internal thoracic artery
27 Apex of left lung
28 Left recurrent laryngeal nerve
29 Cut edge of **pericardium**
30 Pulmonary trunk (fenestrated)
31 Pulmonic valve
32 Supraventricular crest
33 **Anterior papillary muscle**
34 **Left ventricle**

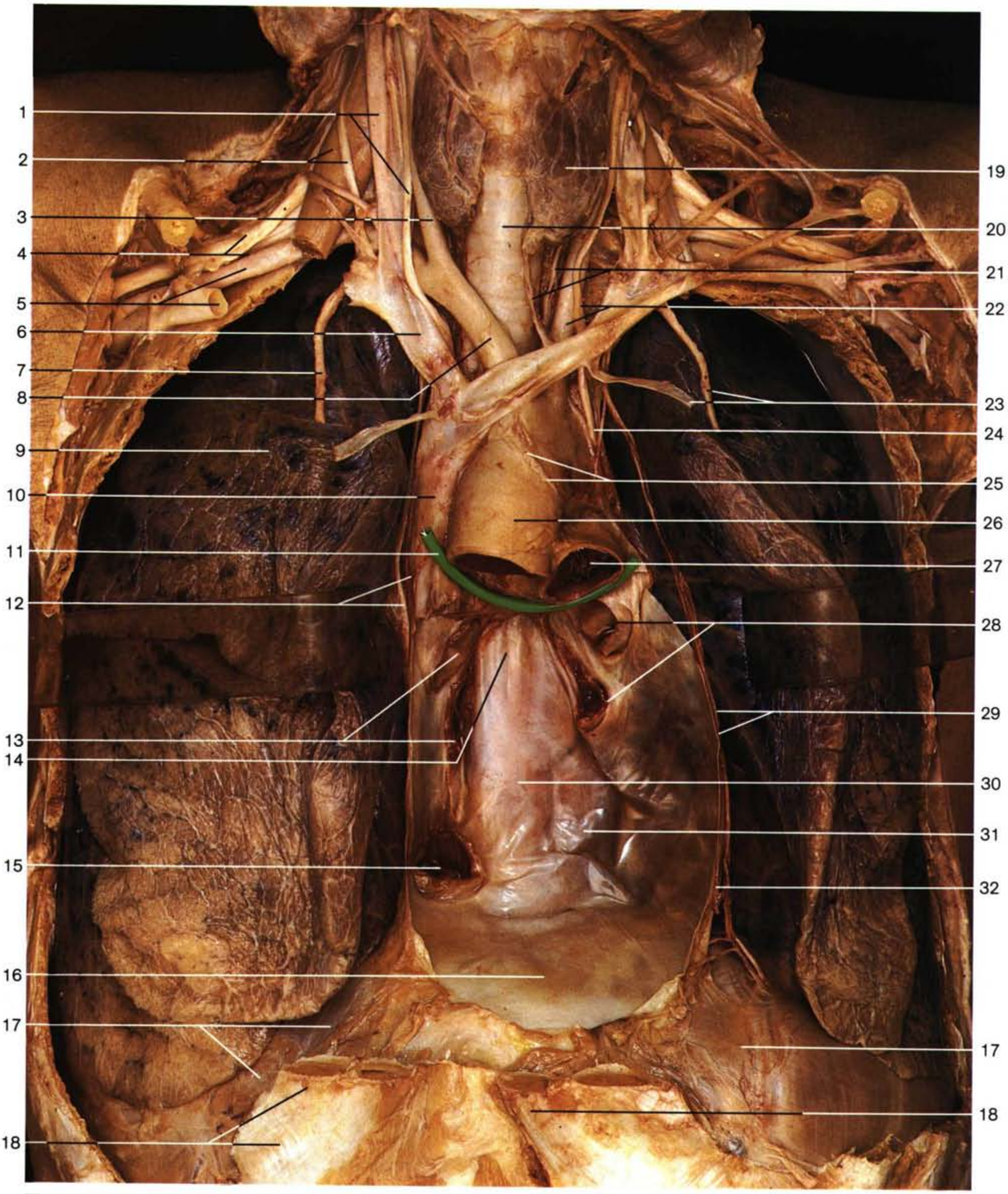

Thoracic organs, pericardium and **mediastinum** (ventral aspect). Anterior wall of thorax and heart have been removed and the lungs slightly reflected. Note probe within transverse pericardial sinus.

1 Right internal jugular vein and right vagus nerve
2 Right phrenic nerve and scalenus anterior muscle
3 Right common carotid artery
4 Brachial plexus
5 Right subclavian artery and vein
6 Right brachiocephalic vein
7 Right internal thoracic artery (divided)
8 **Brachiocephalic trunk**
9 Upper lobe of right lung
10 **Superior vena cava**
11 Transverse pericardial sinus (probe)
12 Right **phrenic nerve** and right pericardiacophrenic artery and vein
13 Right pulmonary veins
14 Oblique sinus of pericardium
15 **Inferior vena cava**
16 Diaphragmatic part of pericardium
17 Diaphragm
18 Costal margin
19 Thyroid gland
20 **Trachea**
21 Left recurrent laryngeal nerve and inferior thyroid vein
22 Left common carotid artery and left vagus nerve
23 Left internal thoracic artery and vein (divided)
24 **Vagus nerve** at aortic arch
25 Cut edge of pericardium
26 **Ascending aorta**
27 Pulmonary trunk (divided)
28 Left pulmonary veins
29 Left phrenic nerve and left pericardiacophrenic artery and vein
30 Contour of esophagus beneath pericardium
31 Contour of aorta beneath pericardium
32 **Pericardium** (cut edge)

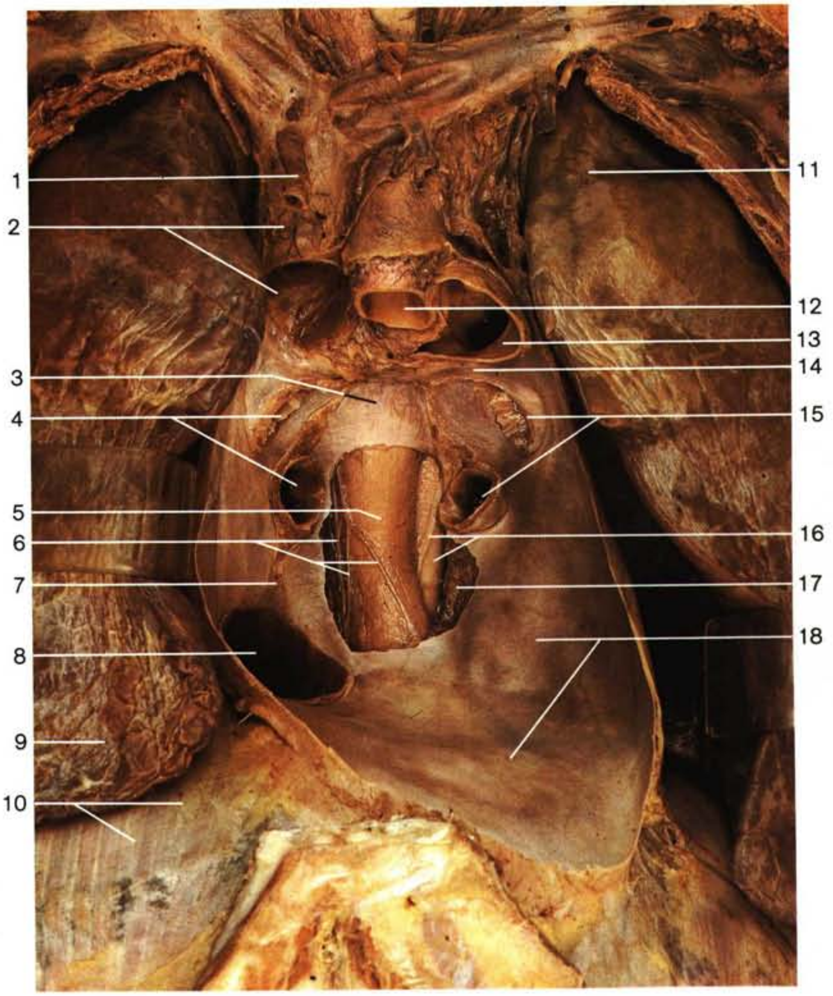
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1 Internal thoracic vein
2 Superior vena cava
3 Oblique sinus of pericardium
4 Right pulmonary veins
5 Esophagus
6 Branches of right vagus nerve
7 Mesocardium
8 Inferior vena cava
9 Middle lobe of right lung
10 Diaphragm
11 Upper lobe of left lung
12 Ascending aorta
13 **Pulmonary trunk**
14 Transverse pericardial sinus
15 Left pulmonary veins
16 Descending aorta and left vagus nerve
17 Left lung (adjacent to pericardium)
18 **Pericardium**
19 Left subclavian artery
20 Vagus nerve
21 Left recurrent laryngeal nerve
22 Descending aorta
23 Pulmonary artery
24 **Left atrium**
25 **Left ventricle**
26 Coronary sinus
27 Left common carotid artery
28 Brachiocephalic trunk
29 Azygos arch
30 **Right atrium**
31 **Right ventricle**
32 Aortic arch

Pericardial sac (ventral aspect). The heart has been removed, and the posterior wall of the pericardium has been opened to show the adjacent esophagus and aorta.

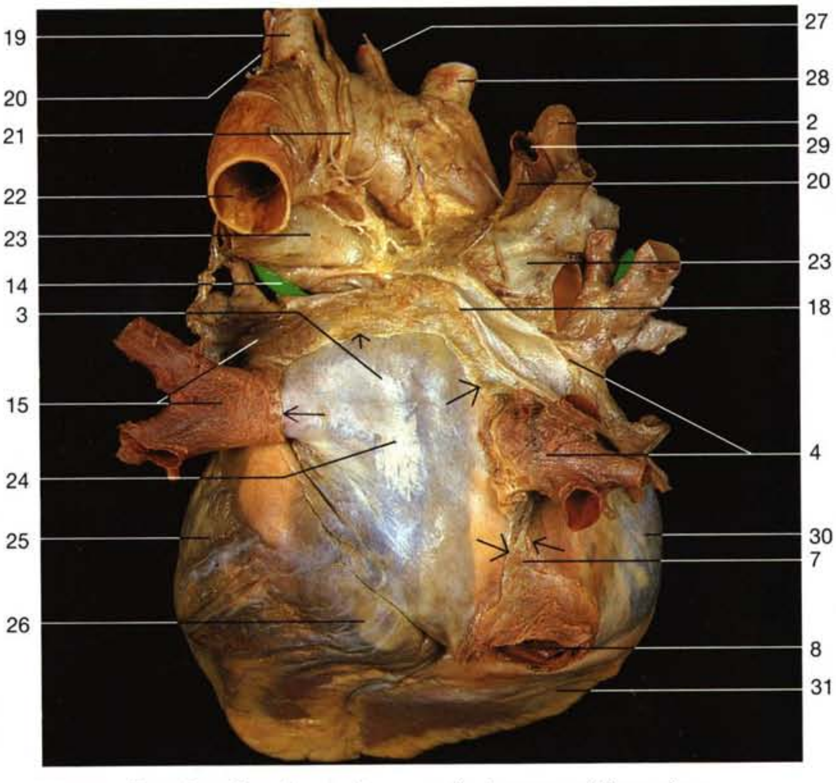
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Heart with epicardium (posterior aspect). Arrows: oblique sinus.

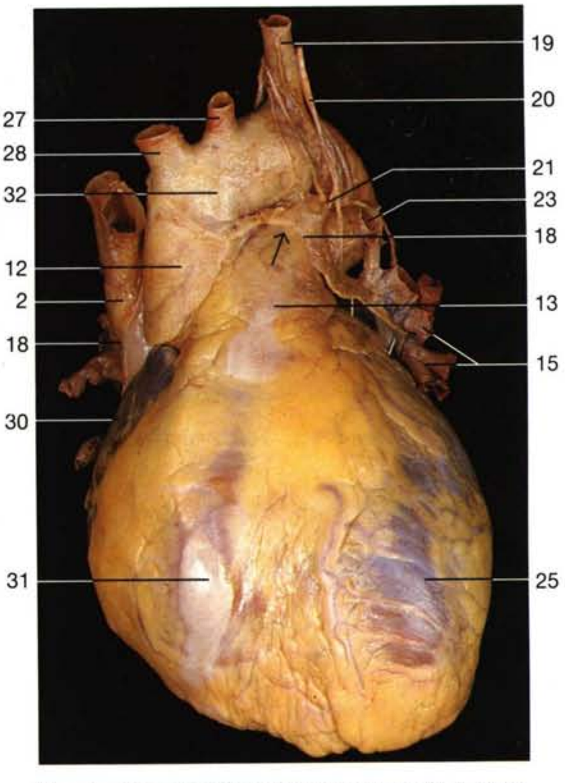
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Heart with epicardium (anterior aspect). Arrow: pericardial reflection.

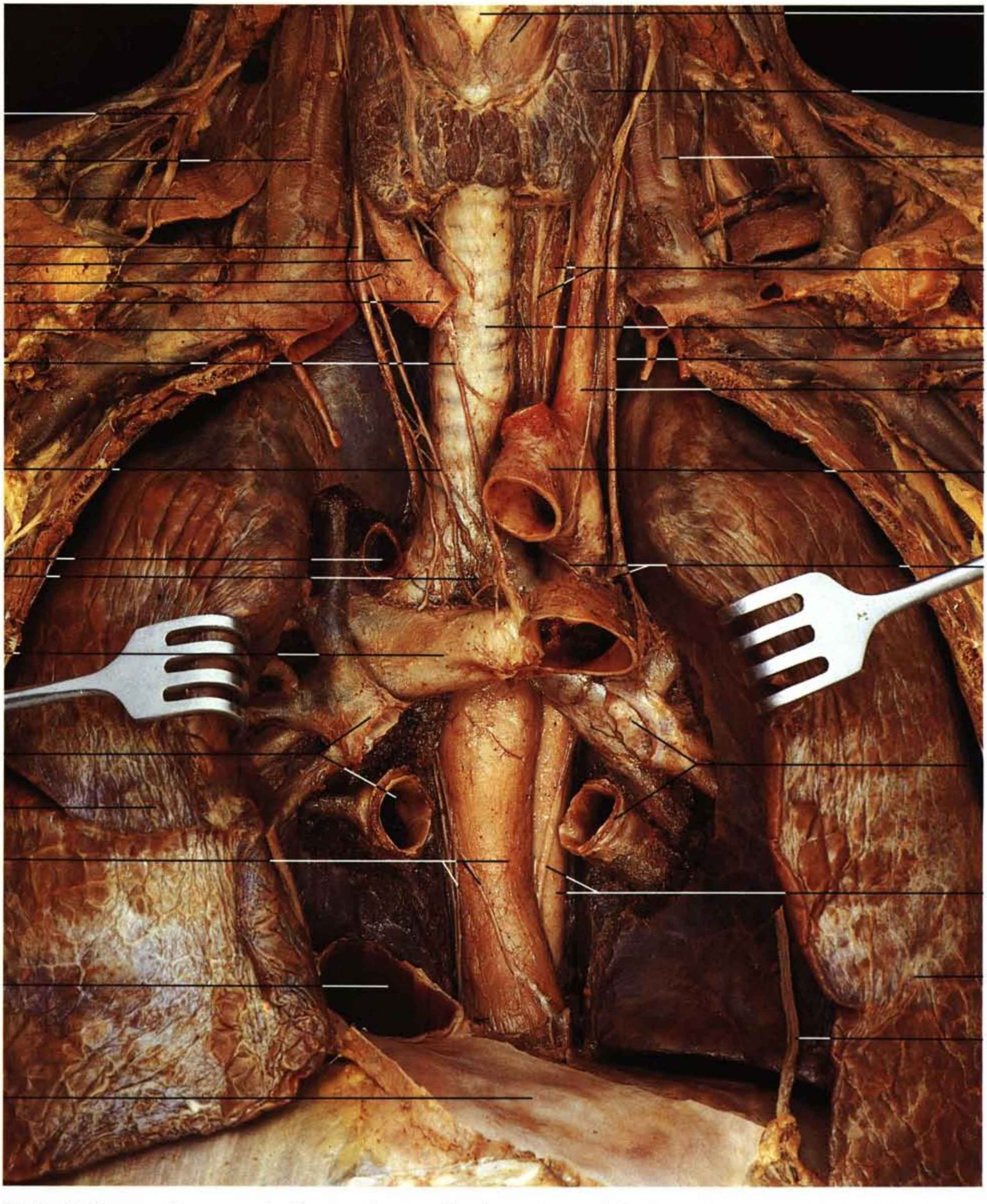

Mediastinal organs after removal of heart and pericardium (ventral aspect). Both lungs have been slightly reflected.

1 Supraclavicular nerves
2 Internal jugular vein
3 Omohyoid muscle
4 **Right vagus nerve**
5 Right common carotid artery
6 Right subclavian artery
7 Brachiocephalic trunk
8 Right brachiocephalic vein
9 Superior cervical cardiac branch of vagus nerve
10 Inferior cervical cardiac branches of vagus nerve
11 Azygos arch (divided)
12 Bifurcation of trachea
13 Right **pulmonary artery**
14 Right **pumonary veins**
15 Right lung
16 **Esophagus** and branches of right vagus nerve
17 Inferior vena cava
18 Pericardium
19 Larynx (thyroid cartilage, cricothyroid muscle)
20 Thyroid gland
21 Internal jugular vein
22 Esophagus and left recurrent laryngeal nerve
23 **Trachea**
24 **Left vagus nerve**
25 Left common carotid artery
26 Aortic arch
27 Left recurrent laryngeal nerve branching off from vagus nerve
28 Left pulmonary veins
29 **Thoracic aorta** and left vagus nerve
30 Left lung
31 Left phrenic nerve (divided)

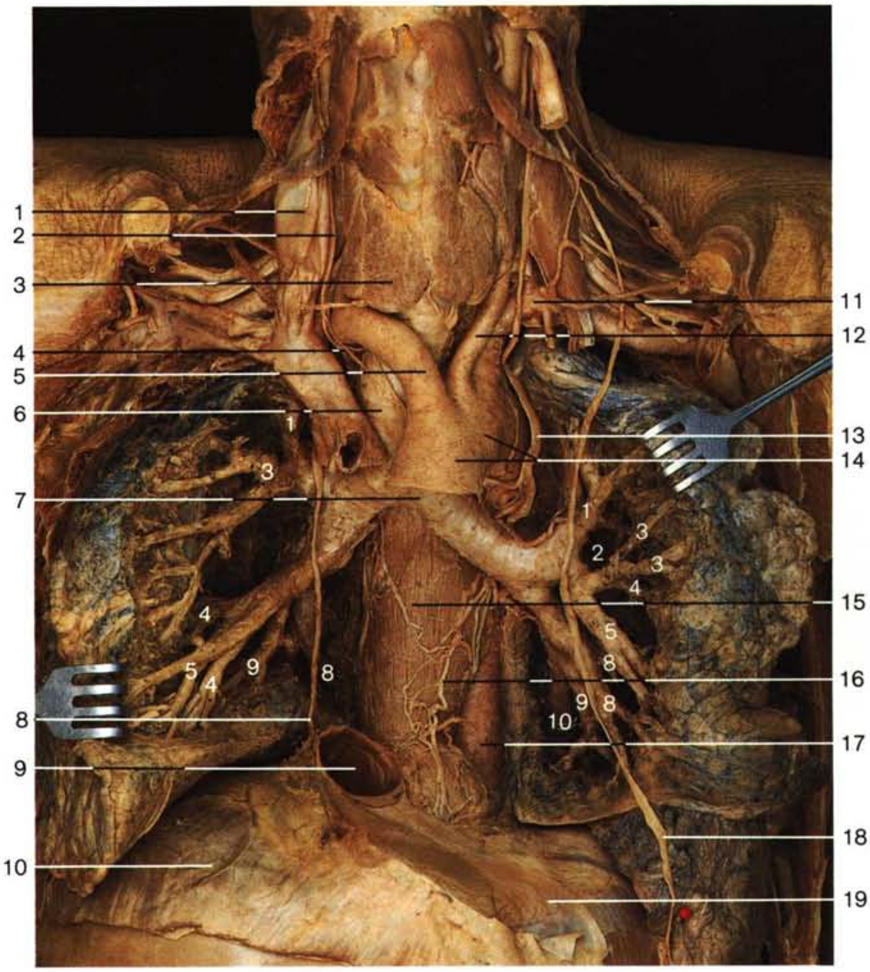
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Bronchial tree in situ (ventral aspect). Heart and pericardium have been removed; the bronchi of the bronchopulmonary segments are dissected. 1–10 = numbers of segments.

1 Internal jugular vein
2 Right vagus nerve
3 **Thyroid gland**
4 Right recurrent laryngeal nerve
5 Brachiocephalic trunk
6 Trachea
7 **Bifurcation of trachea**
8 **Right phrenic nerve**
9 Inferior vena cava
10 Diaphragm
11 Left subclavian artery
12 Left common carotid artery
13 Left **vagus nerve**
14 Aortic arch
15 **Esophagus**
16 Esophageal plexus
17 Thoracic aorta
18 **Left phrenic nerve**
19 Pericardium at the central tendon of diaphragm
20 Right pulmonary artery
21 Left pulmonary artery
22 Tracheal lymph nodes
23 Superior tracheobronchial lymph nodes
24 Bronchopulmonary lymph nodes

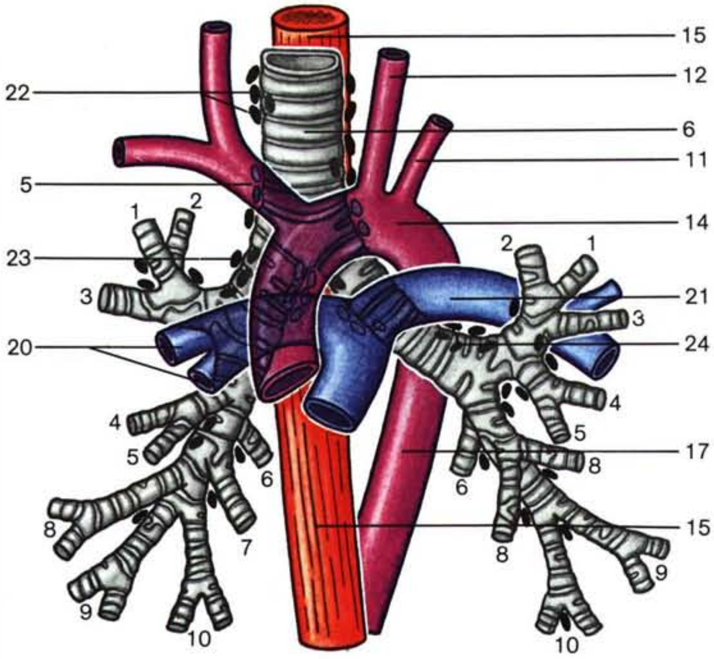
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Relation of aorta, pulmonary trunk and esophagus to trachea and bronchial tree. (Schematic drawing.)
1–10 = number of segments (cf. p. 230 and 235).

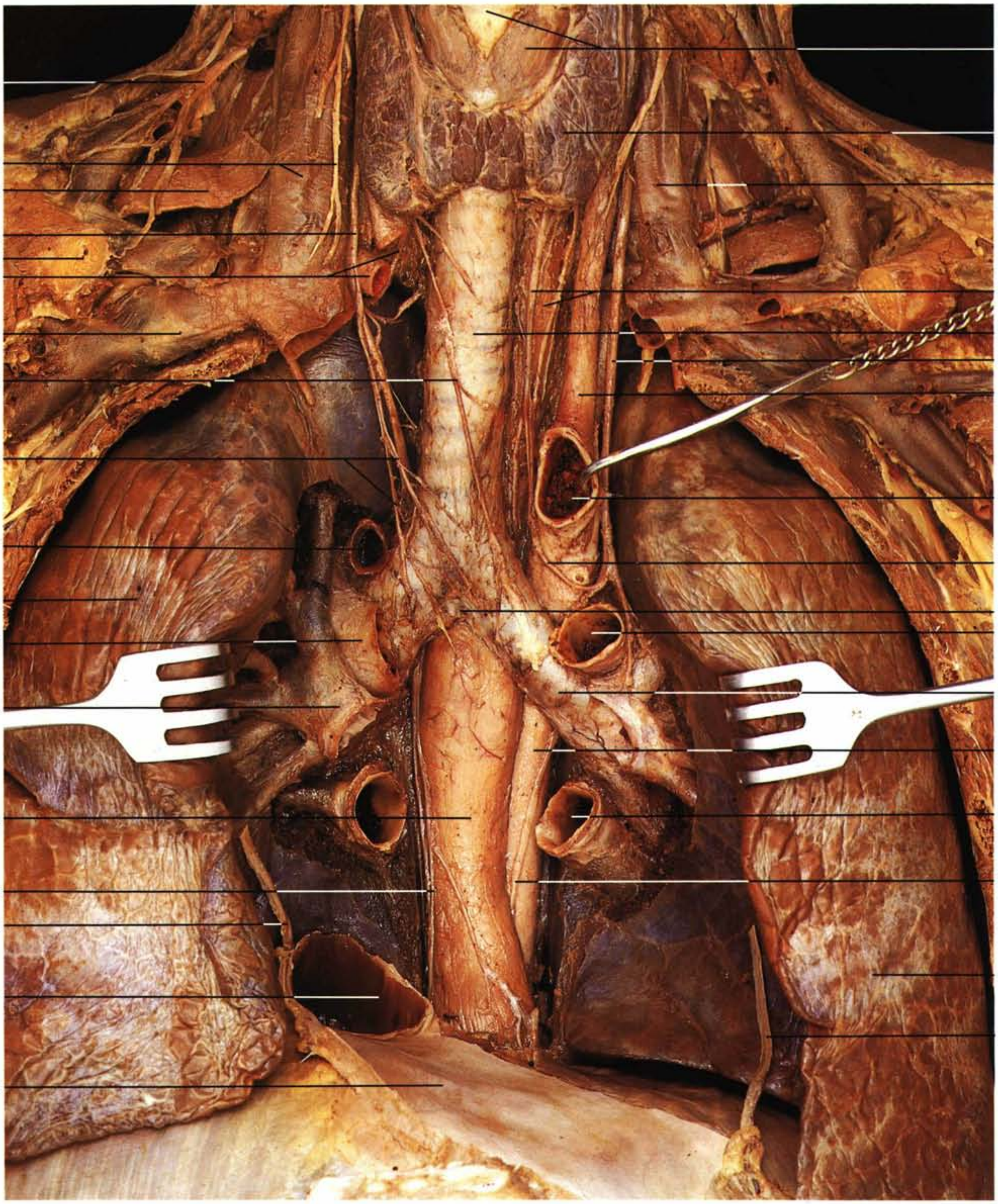

Organs of posterior mediastinum (ventral aspect). The heart with the pericardium has been removed, and the lungs and aortic arch have been slightly reflected to show the vagus nerves and their branches.

1	Supraclavicular nerves	12	**Right pulmonary artery**	24	**Left vagus nerve**
2	Right internal jugular vein with ansa cervicalis	13	**Right pulmonary veins**	25	Left common carotid artery
3	Omohyoid muscle	14	**Esophagus**	26	Aortic arch
4	**Right vagus nerve**	15	Esophageal plexus	27	Left recurrent laryngeal nerve
5	Clavicle	16	Right phrenic nerve (divided)	28	**Bifurcation of trachea**
6	Right subclavian artery and recurrent laryngeal nerve	17	Inferior vena cava	29	**Left pulmonary artery**
7	Right subclavian vein	18	Pericardium covering the diaphragm	30	Left primary bronchus
8	Superior cervical cardiac branch of vagus nerve	19	Larynx (thyroid cartilage and cricothyroid muscle)	31	Descending aorta
9	Inferior cervical cardiac branch of vagus nerve	20	Thyroid gland	32	Left pulmonary veins
10	Azygos arch (divided)	21	Left internal jugular vein	33	Branch of left vagus nerve
11	**Right lung**	22	Esophagus and left recurrent laryngeal nerve	34	**Left lung**
		23	Trachea	35	Left phrenic nerve (divided)

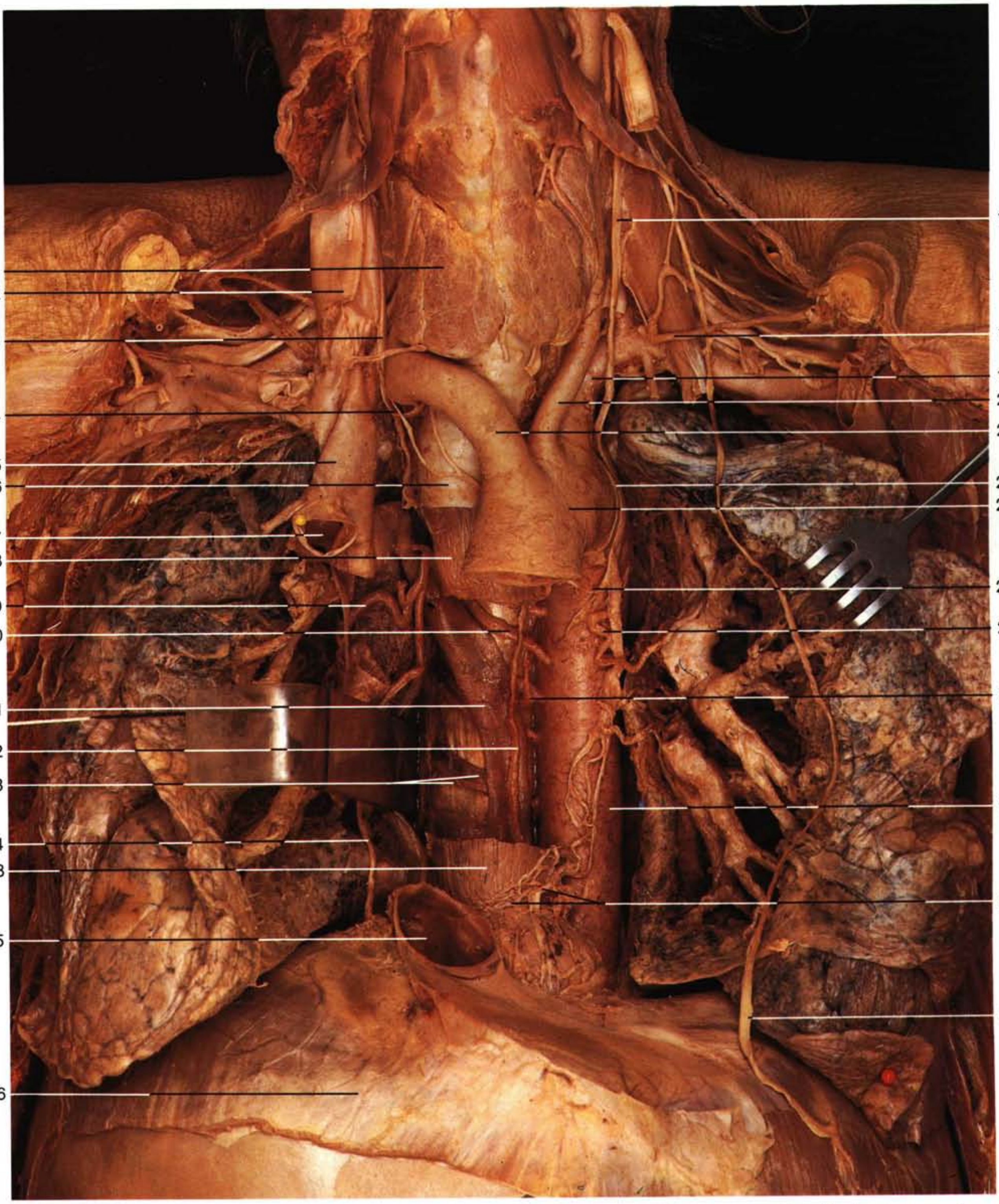

Mediastinal organs (ventral aspect). Heart and distal part of esophagus have been removed to display the vessels and nerves of the posterior mediastinum.

1 Thyroid gland
2 Right internal jugular vein
3 Right vagus nerve
4 Point, where right recurrent laryngeal nerve is branching off the vagus nerve
5 Right brachiocephalic vein
6 Trachea
7 Left brachiocephalic vein (reflected)
8 Esophagus
9 Right bronchial artery
10 Posterior intercostal artery
11 **Azygos vein**
12 **Thoracic duct**
13 Posterior intercostal artery and vein (in front of the vertebral column)
14 Right phrenic nerve
15 Inferior vena cava
16 Diaphragm
17 **Left vagus nerve**
18 Thyrocervical trunk
19 Left subclavian artery
20 Left common carotid artery
21 Brachiocephalic trunk
22 Left vagus nerve
23 **Aortic arch**
24 Left recurrent laryngeal nerve
25 Left bronchial artery
26 Lymph node
27 Thoracic aorta
28 Esophageal plexus
29 Left phrenic nerve

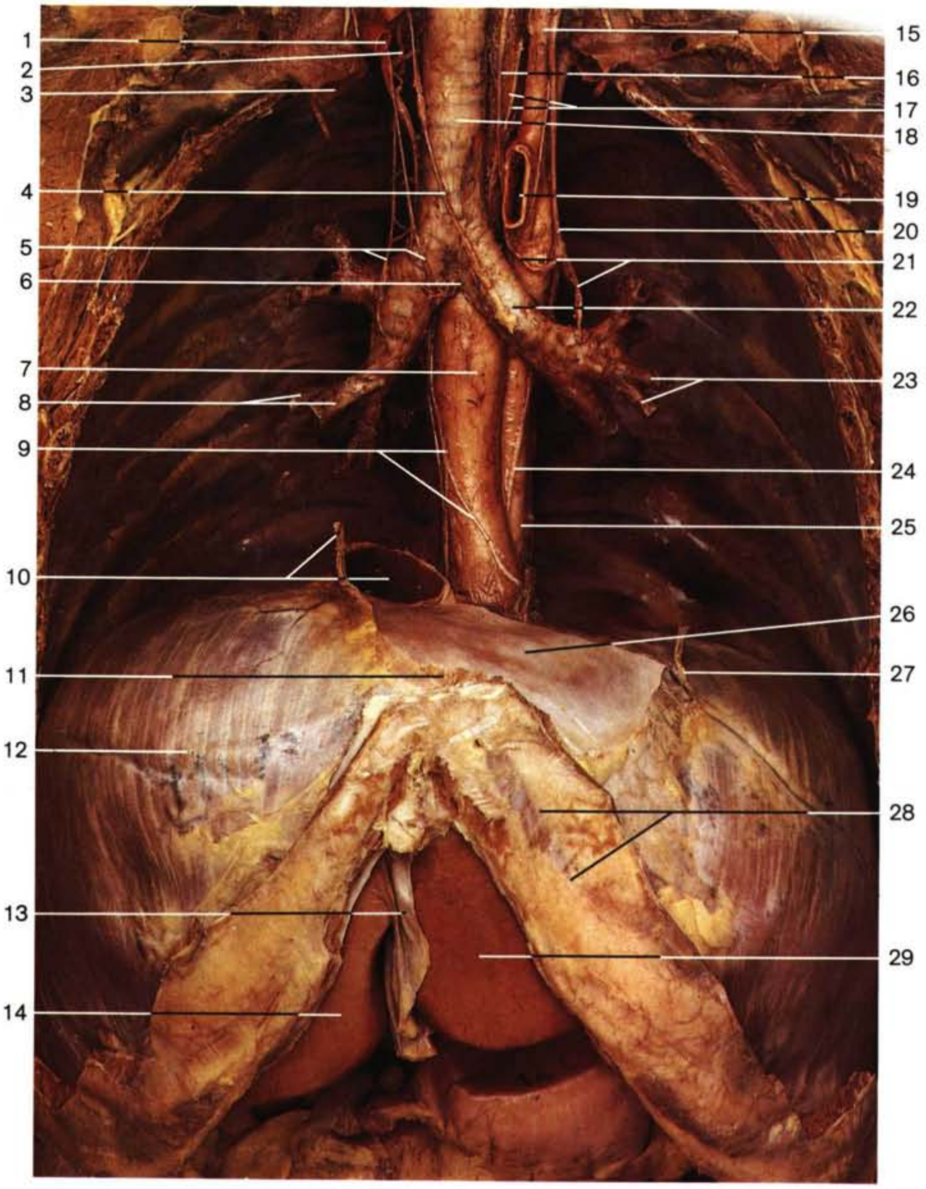

Diaphragm and organs of mediastinum (anterior aspect). Heart and lungs have been removed; the costal margin remains in place. Note the different courses of left and right vagus.

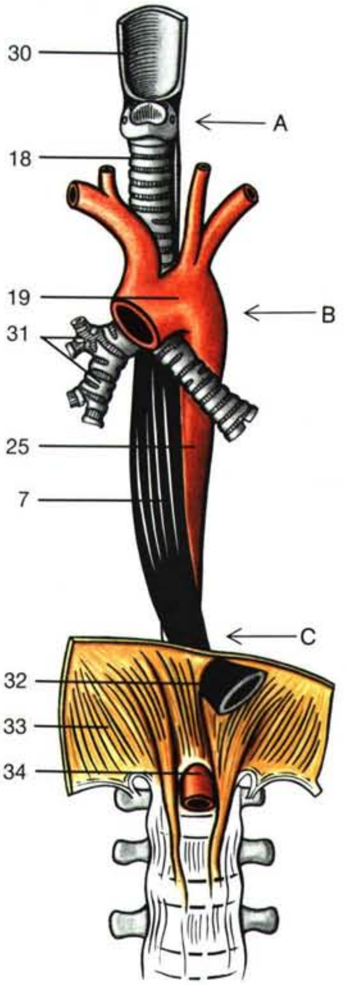

Organs of posterior mediastinum (ventral aspect). (Schematic drawing.) Three regions in which the esophagus is narrowed are shown:

A at the level of the cricoid cartilage;

B at the level of the aortic arch;

C at the level of the diaphragm.

1 Right subclavian artery
2 Right recurrent laryngeal nerve
3 Right brachiocephalic vein
4 Superior cervical cardiac nerve
5 Inferior cervical cardiac nerves and pulmonary branches
6 **Bifurcation of trachea**
7 **Esophagus** (thoracic part)
8 Bronchi of lateral and medial segments of middle lobe
9 Esophageal plexus and branches of right vagus nerve
10 Inferior vena cava and right phrenic nerve (cut)
11 Sternal part of diaphragm
12 Costal part of **diaphragm**
13 Falciform ligament of liver
14 Liver (quadrate lobe)
15 Left common carotid artery
16 Left recurrent laryngeal nerve
17 Esophageal branches of left vagus nerve and esophagus
18 **Trachea**
19 Aortic arch
20 Left vagus nerve
21 Left recurrent laryngeal nerve with inferior cardiac nerve
22 Left primary bronchus
23 Superior and inferior lingular bronchi
24 Esophageal plexus of left vagus nerve
25 **Descending aorta**
26 Central tendon of diaphragm covered with pericardium
27 Left phrenic nerve (divided)
28 Costal margin
29 **Liver,** left lobe
30 Pharynx
31 Secondary bronchi
32 Esophagus (abdominal part)
33 Diaphragm
34 Abdominal aorta

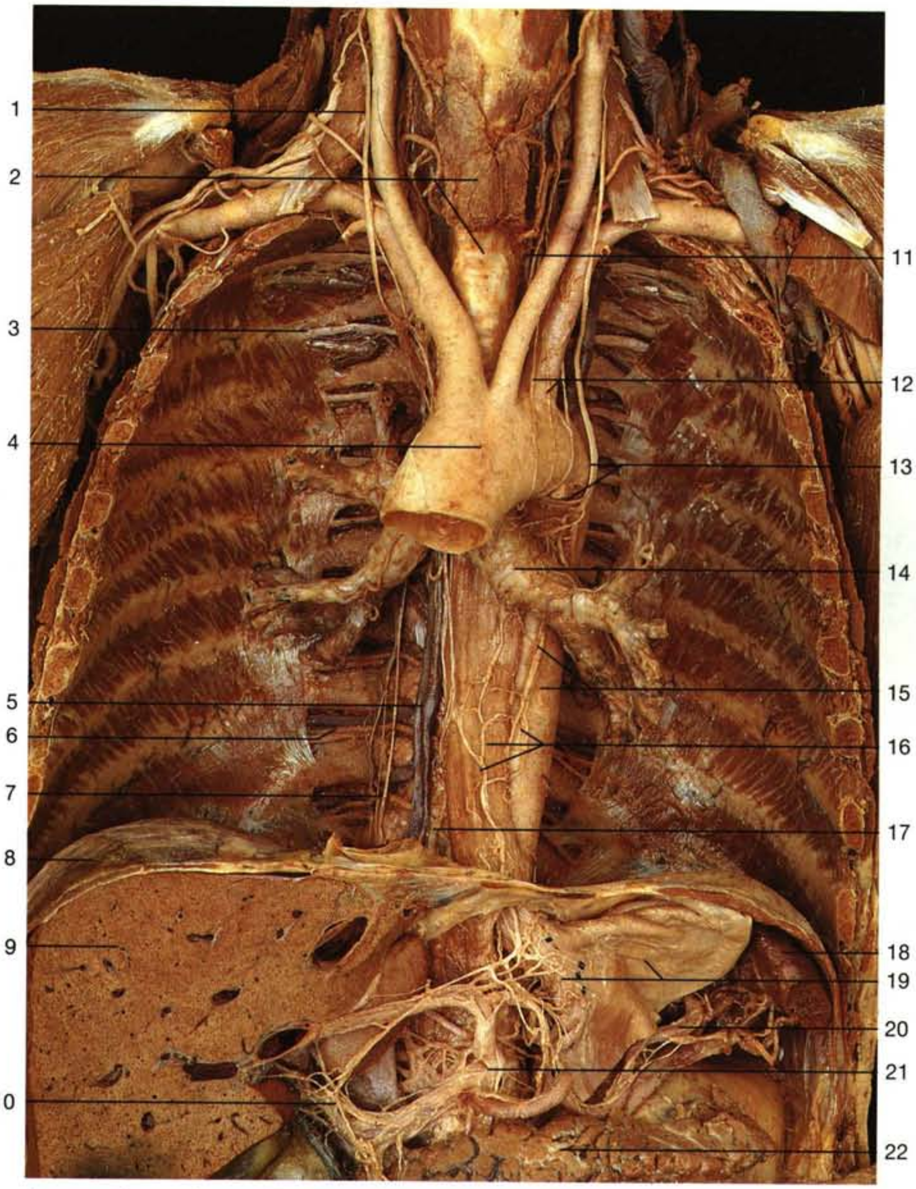

Organs of posterior mediastinum (anterior aspect).

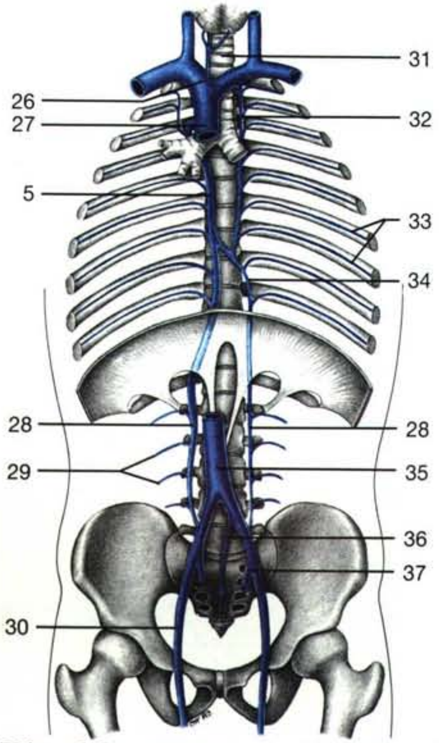

Veins of the posterior wall of thoracic and abdominal cavity. (Schematic drawing.)

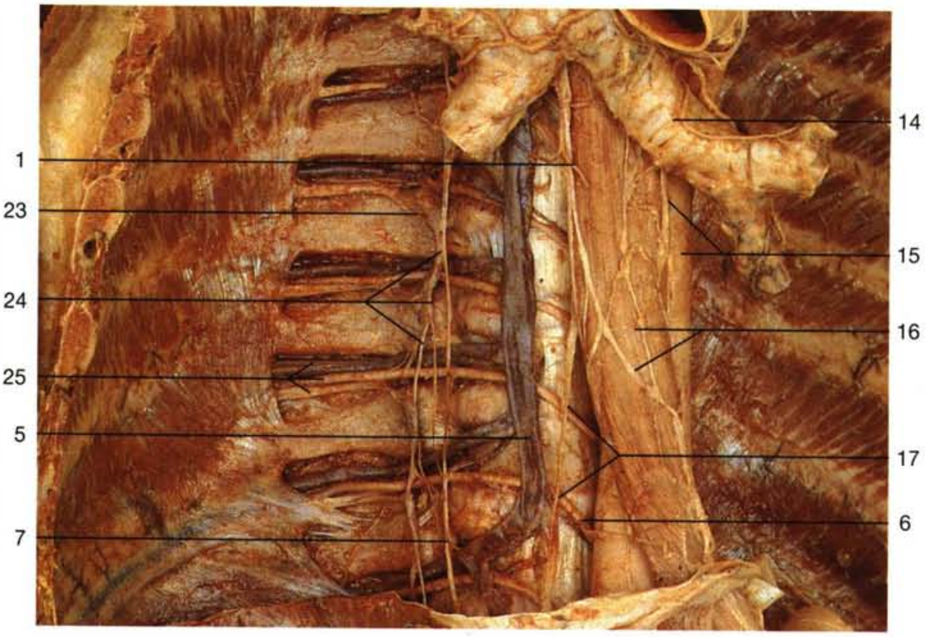

Inferior segment of posterior mediastinum (anterior aspect).

1 Right vagus nerve
2 Thyroid gland and trachea
3 Intercostal nerve
4 Aortic arch
5 **Azygos vein**
6 Posterior intercostal artery
7 **Greater splanchnic nerve**
8 Diaphragm
9 Liver
10 Proper hepatic artery and hepatic plexus
11 Left recurrent laryngeal nerve
12 Inferior cervical cardiac nerves
13 Left vagus nerve and left recurrent laryngeal nerve
14 Left primary bronchus
15 Thoracic aorta and left vagus nerve
16 Esophagus and esophageal plexus
17 **Thoracic duct**
18 Spleen
19 Anterior gastric plexus and stomach (divided)
20 Splenic artery and splenic plexus
21 **Celiac trunk** and **celiac plexus**
22 Pancreas
23 Ramus communicans
24 **Sympathetic trunk** and **sympathetic ganglion**
25 **Posterior intercostal vein** and **artery** and **intercostal nerve**
26 Right brachiocephalic vein
27 Superior vena cava
28 Ascending lumbar vein
29 Lumbar veins
30 Right external iliac vein
31 Trachea
32 Accessory hemiazygos vein
33 Posterior intercostal veins
34 Hemiazygos vein
35 Inferior vena cava
36 Median sacral vein
37 Internal iliac vein

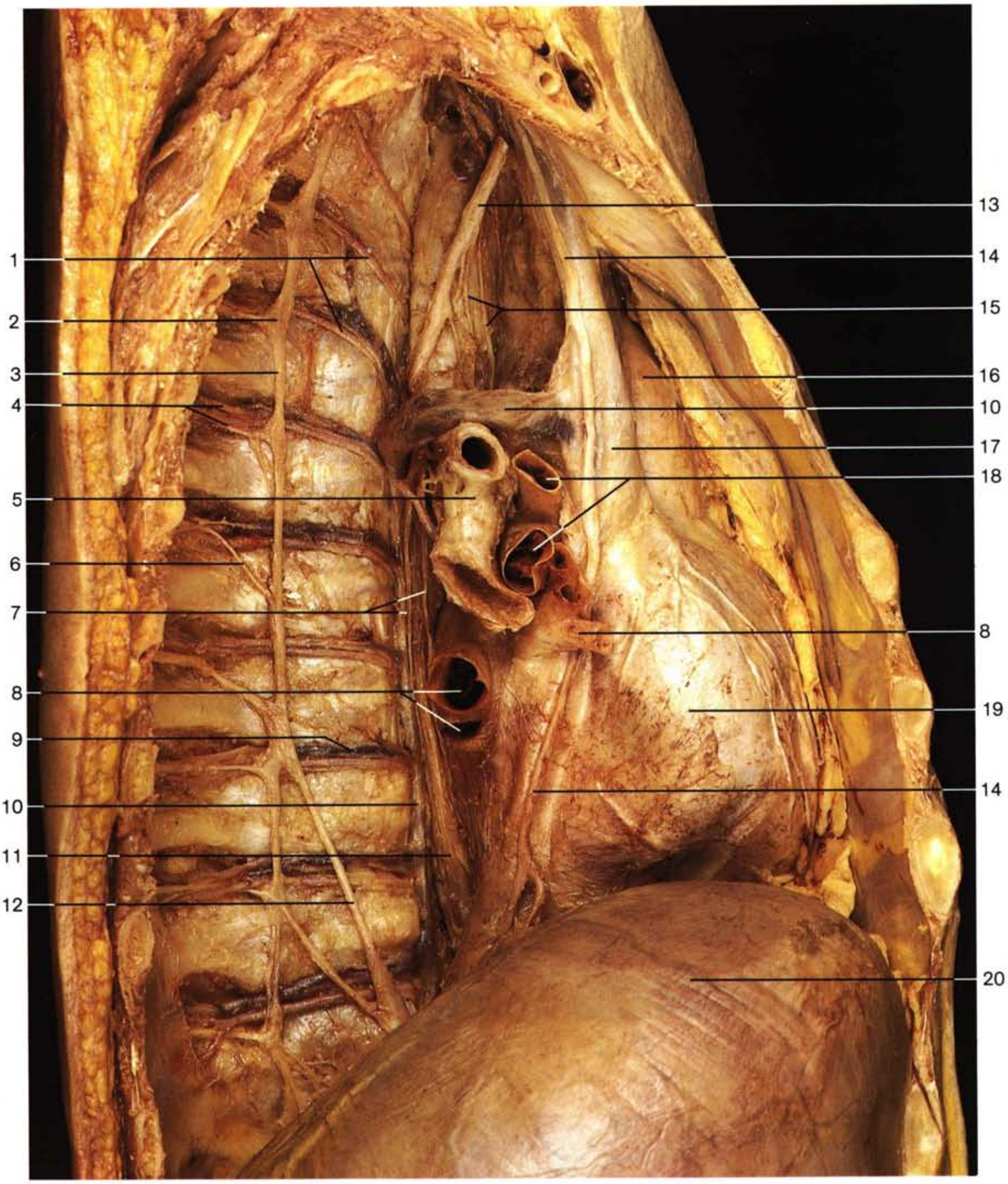

Mediastinal organs (right lateral aspect). Right lung and pleura of right half of the thorax have been removed.

1 Posterior intercostal arteries
2 Ganglion of sympathetic trunk
3 **Sympathetic trunk**
4 Vessels and nerves of the intercostal space (from above: Posterior intercostal vein and artery and intercostal nerve)
5 Right primary bronchus
6 Ramus communicans of sympathetic trunk
7 Esophageal plexus (branches of right vagus nerve)
8 Pulmonary veins
9 Posterior intercostal vein
10 **Azygos vein**
11 Esophagus
12 Greater splanchnic nerve
13 **Right vagus nerve**
14 **Right phrenic nerve**
15 Inferior cervical cardiac branches of vagus nerve
16 **Aortic arch**
17 Superior vena cava
18 Right pulmonary artery
19 **Heart with pericardium**
20 Diaphragm

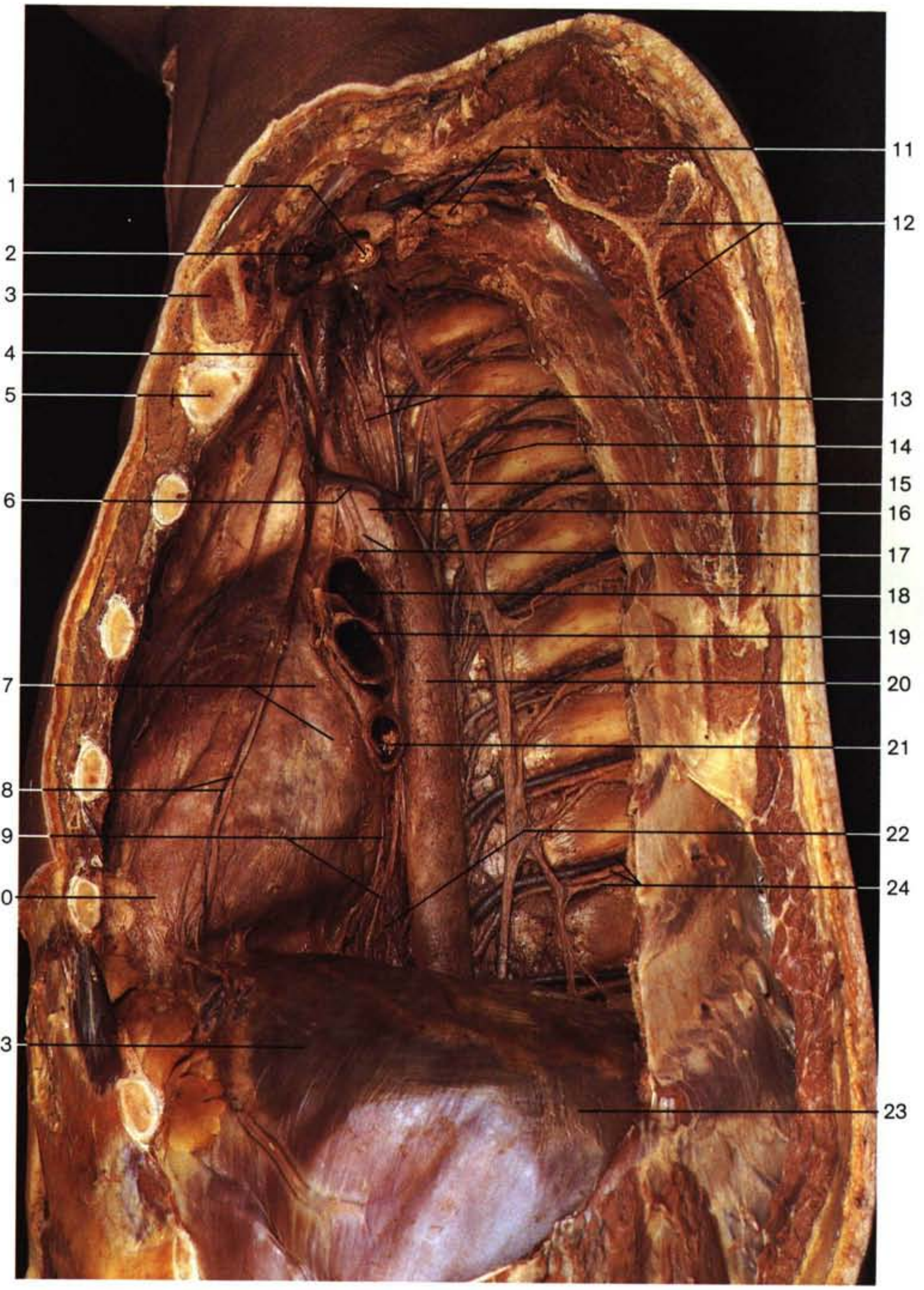

Organs of posterior and superior mediastinum (left lateral aspect).

1 Subclavian artery
2 Subclavian vein
3 Clavicle (divided)
4 **Left vagus nerve**
5 First rib (divided)
6 Left superior intercostal vein
7 **Left atrium with pericardium**
8 **Left phrenic nerve** and pericardiacophrenic artery and vein
9 Esophageal plexus (branches derived from left vagus nerve)
10 **Apex of heart with pericardium**
11 Brachial plexus
12 Scapula (divided)
13 Posterior intercostal arteries
14 Ramus communicans of sympathetic trunk
15 **Sympathetic trunk**
16 Aortic arch
17 Left vagus nerve and left recurrent laryngeal nerve
18 Left pulmonary artery
19 Left primary bronchus
20 **Thoracic aorta**
21 Pulmonary vein
22 Esophagus (thoracic part)
23 **Diaphragm**
24 Posterior intercostal artery and vein and intercostal nerve

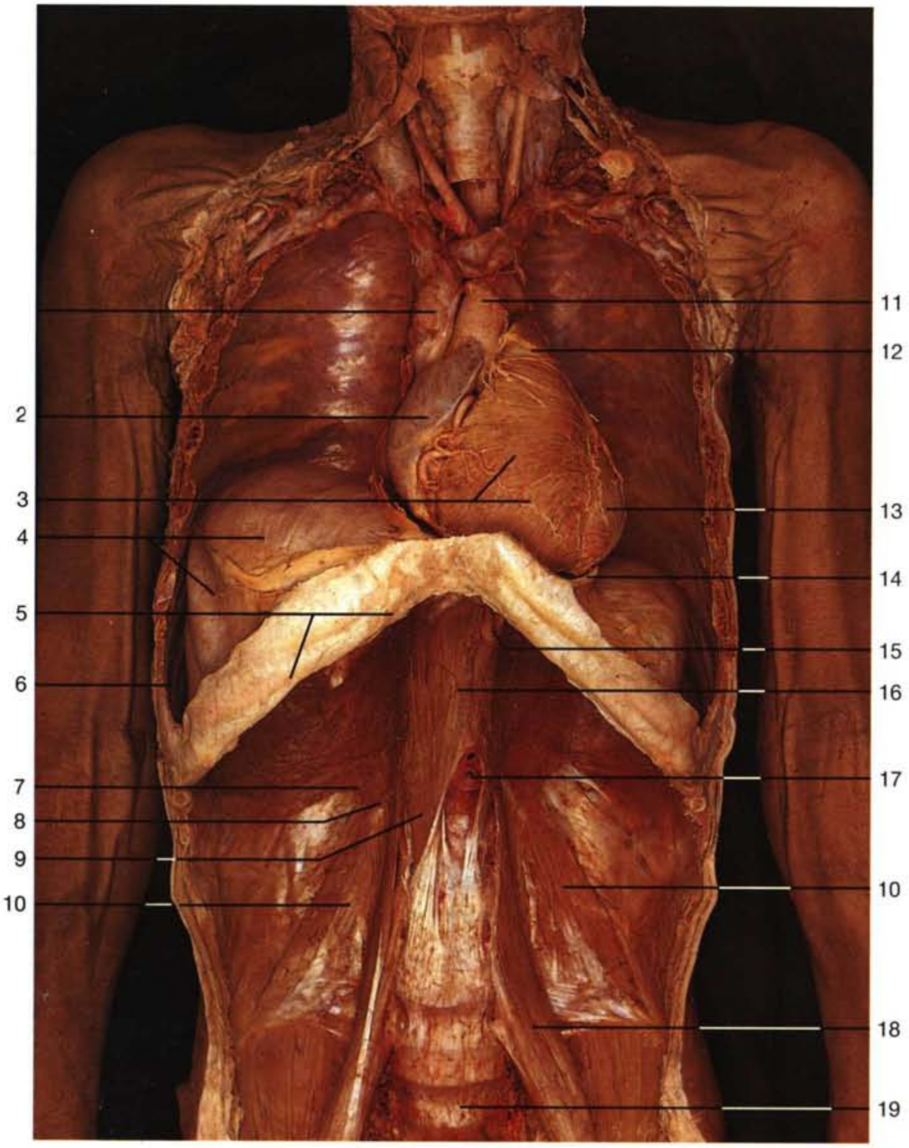

1 Superior vena cava
2 Right atrium
3 Right ventricle
4 **Costal part of diaphragm**
5 Costal margin
6 Position of costodiaphragmatic recess
7 **Lateral arcuate ligament**
8 **Medial arcuate ligament**
9 Right crus of lumbar part of diaphragm
10 Quadratus lumborum muscle
11 Ascending aorta
12 Pulmonary trunk
13 Left ventricle
14 Pericardium, diaphragm
15 Esophageal hiatus and abdominal part of esophagus (cut)
16 **Lumbar part of diaphragm**
17 Aortic hiatus
18 Psoas major muscle
19 Lumbar vertebra

Diaphragm in situ (anterior aspect). Anterior walls of thoracic and abdominal cavities have been removed. Natural position of the heart above the central tendon on the diaphragm is shown.

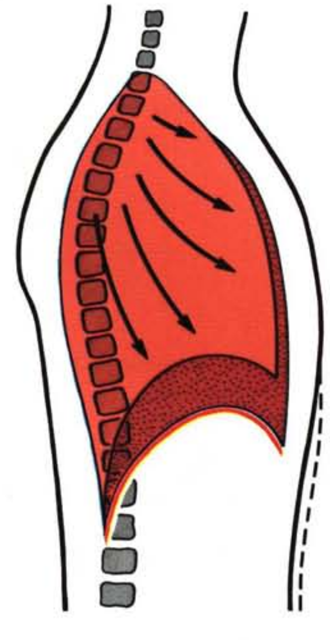

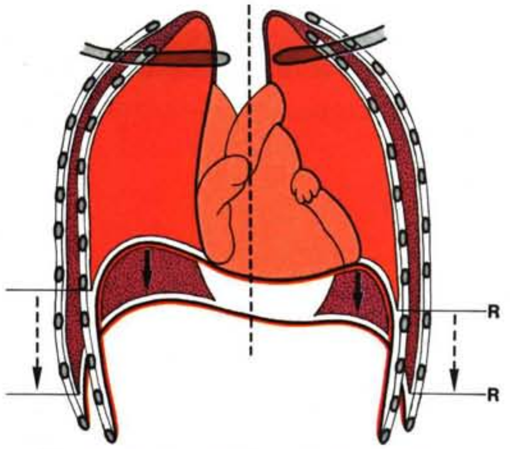

Changes in the position of the diaphragm and thoracic cage during respiration. Left: lateral aspect; right: anterior aspect. During inspiration the diaphragm moves downwards and the lower part of the thoracic cage expands forward and laterally, causing the costodiaphragmatic recess (R) to enlarge (cf. dotted arrows).

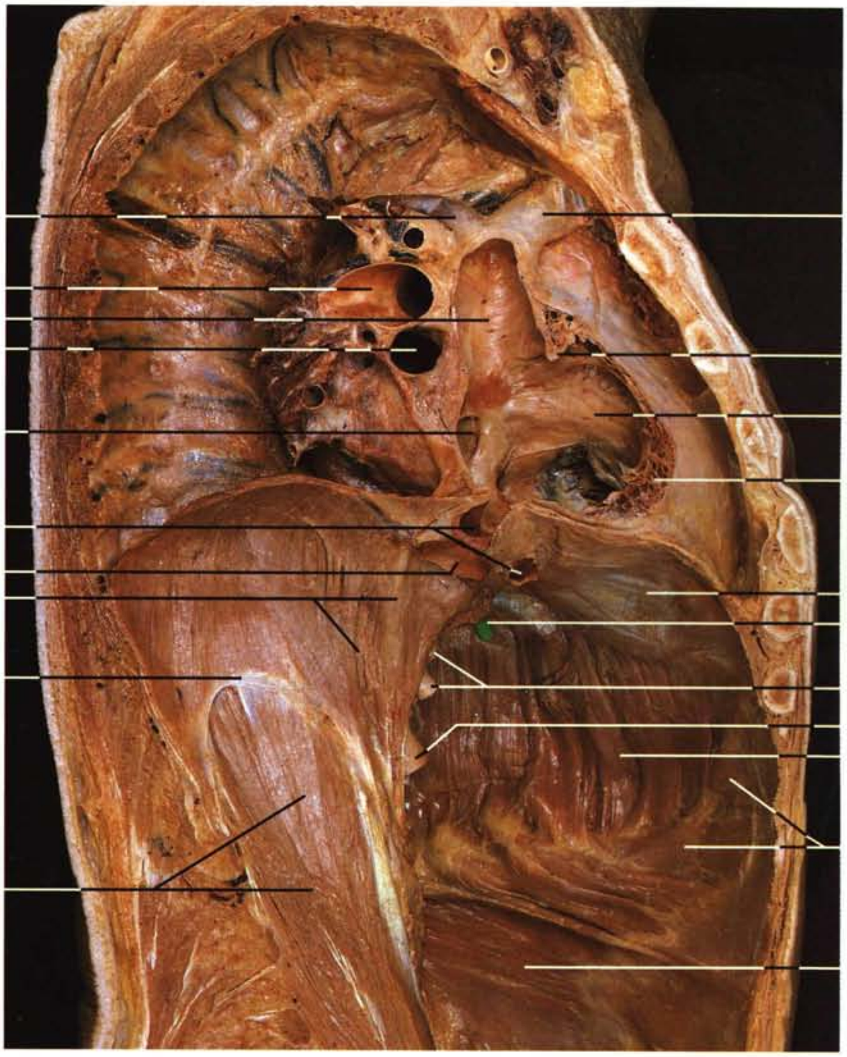

1	Azygos venous arch
2	Right pulmonary artery
3	**Superior vena cava**
4	Right pulmonary vein
5	Fossa ovalis
6	Hepatic veins
7	Inferior vena cava
8	Right crus of lumbar part of **diaphragm**
9	Medial arcuate ligament
10	Psoas major muscle
11	Left brachiocephalic vein
12	Terminal crista
13	**Right atrium**
14	Right auricle
15	Central tendon of diaphragm
16	Esophagus
17	Celiac trunk and superior mesenteric artery
18	Aorta
19	Costal part of diaphragm
20	Costal margin
21	Transversus abdominis muscle

Diaphragm. Paramedian section to the right of the median plane through thoracic and upper abdominal cavity. The plane passes through the superior and inferior vena cava just to the right of the vertebral bodies. Most of the heart remains in situ to the left of this plane (specimen is viewed from the right side).

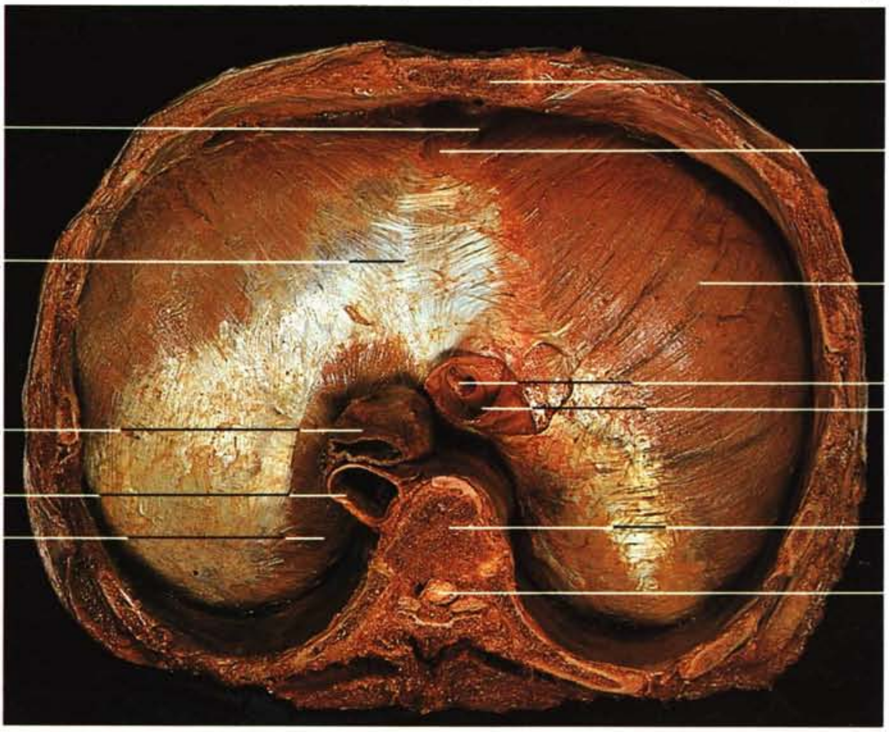

1	Sternocostal triangle
2	Central tendon (from above)
3	Esophagus
4	Aorta
5	Lumbar part of diaphragm
6	Sternum
7	Sternal part of diaphragm
8	Costal part of diaphragm
9	Entrance of hepatic veins
10	Inferior vena cava
11	Body of 9th thoracic vertebra
12	Spinal cord

Diaphragm (superior aspect). The pleura and thoracic wall have been removed.

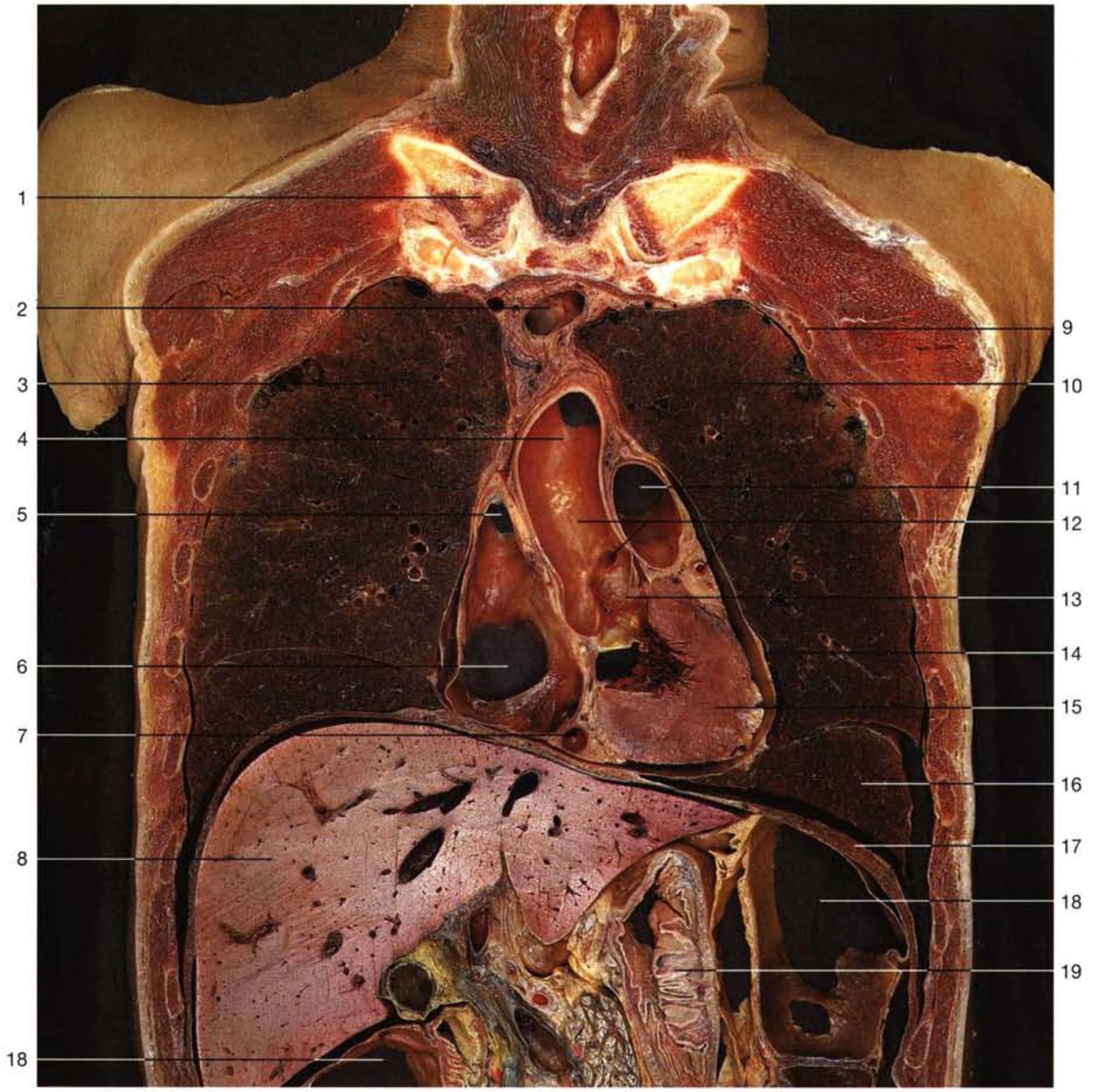

Coronal section through the thorax at the level of ascending aorta (anterior aspect).

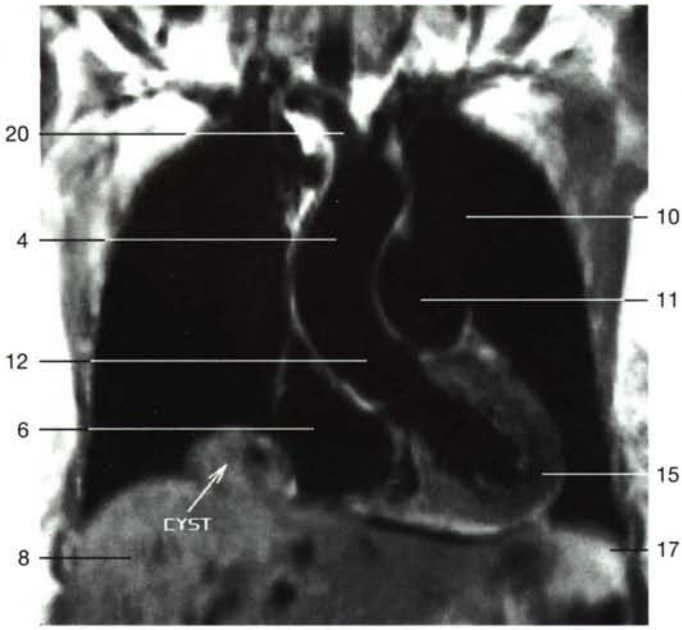

Coronal section through the thorax at the level of ascending aorta. (MR-Scan.)

1 Clavicle
2 Left brachiocephalic vein
3 Superior lobe of right lung
4 Aortic arch
5 Superior vena cava
6 Right atrium (entrance of inferior vena cava)
7 Coronary sinus
8 Liver
9 Second rib
10 Superior lobe of left lung
11 Pulmonary trunk
12 Ascending aorta and left coronary artery
13 Aortic valve
14 Pericardium
15 Myocardium of left ventricle
16 Lower lobe of left lung
17 Diaphragm
18 Colic flexures
19 Stomach
20 Brachiocephalic trunk

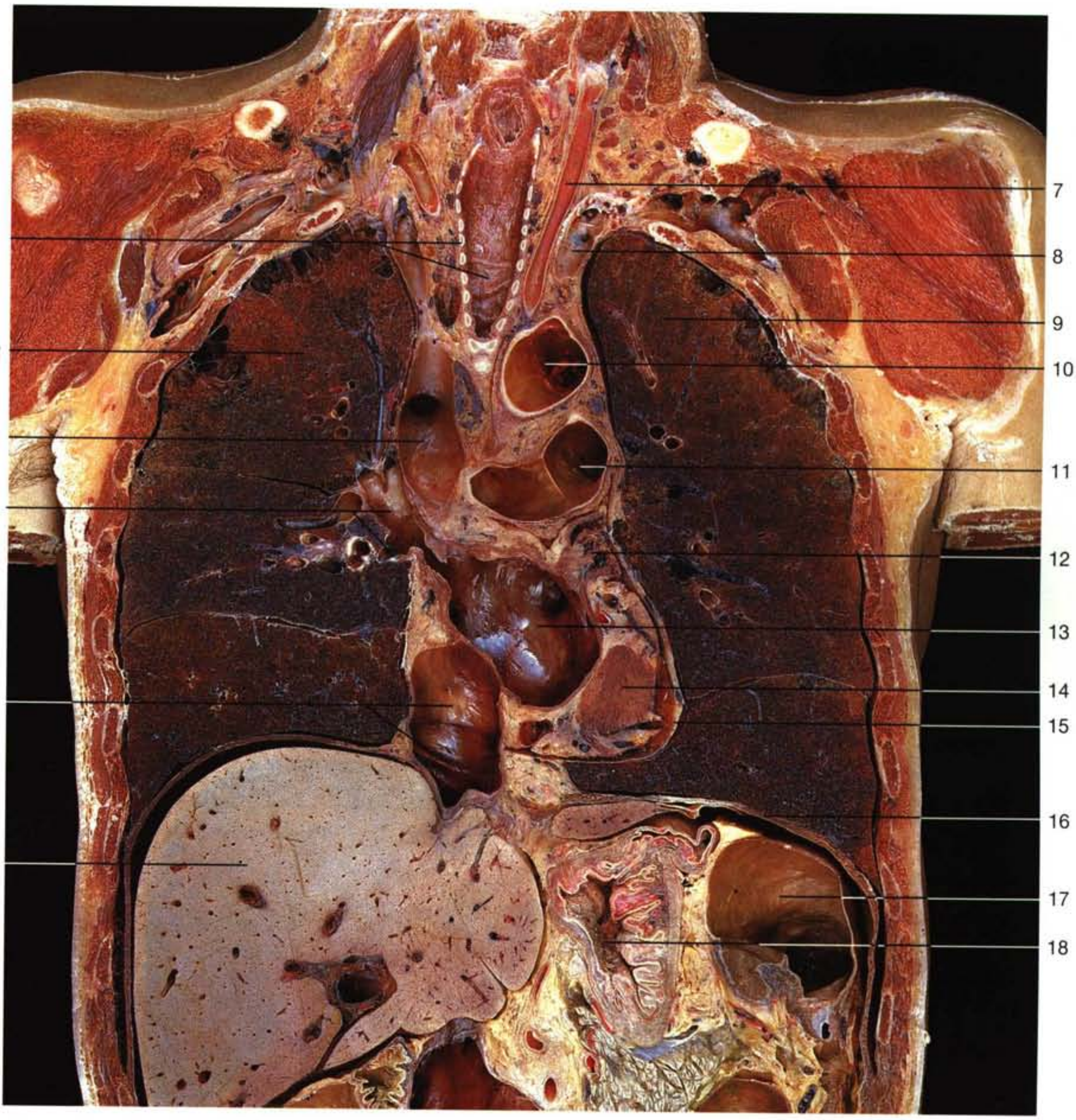

Coronal section through the thorax at the level of superior and inferior vena cava (anterior aspect).

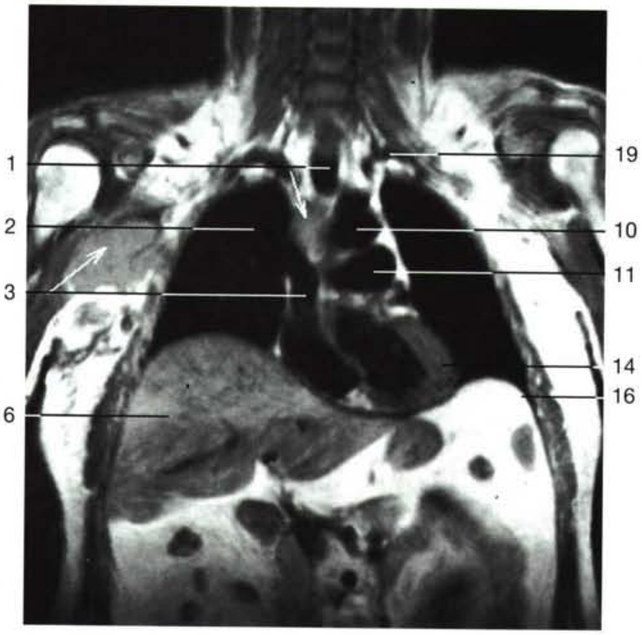

Coronal section through the thorax at the level of superior vena cava. (MR-Scan.)

1 Trachea
2 Upper lobe of right lung
3 **Superior vena cava**
4 Right pulmonary veins
5 Inferior vena cava and right atrium
6 Liver
7 Left common carotid artery
8 Left subclavian vein
9 Upper lobe of left lung
10 Aortic arch
11 Left pulmonary artery
12 Left auricle
13 **Left atrium** with orifices of pulmonary veins
14 Left ventricle (myocardium)
15 Pericardium
16 Diaphragm
17 Left colic flexure
18 Stomach
19 Left subclavian artery

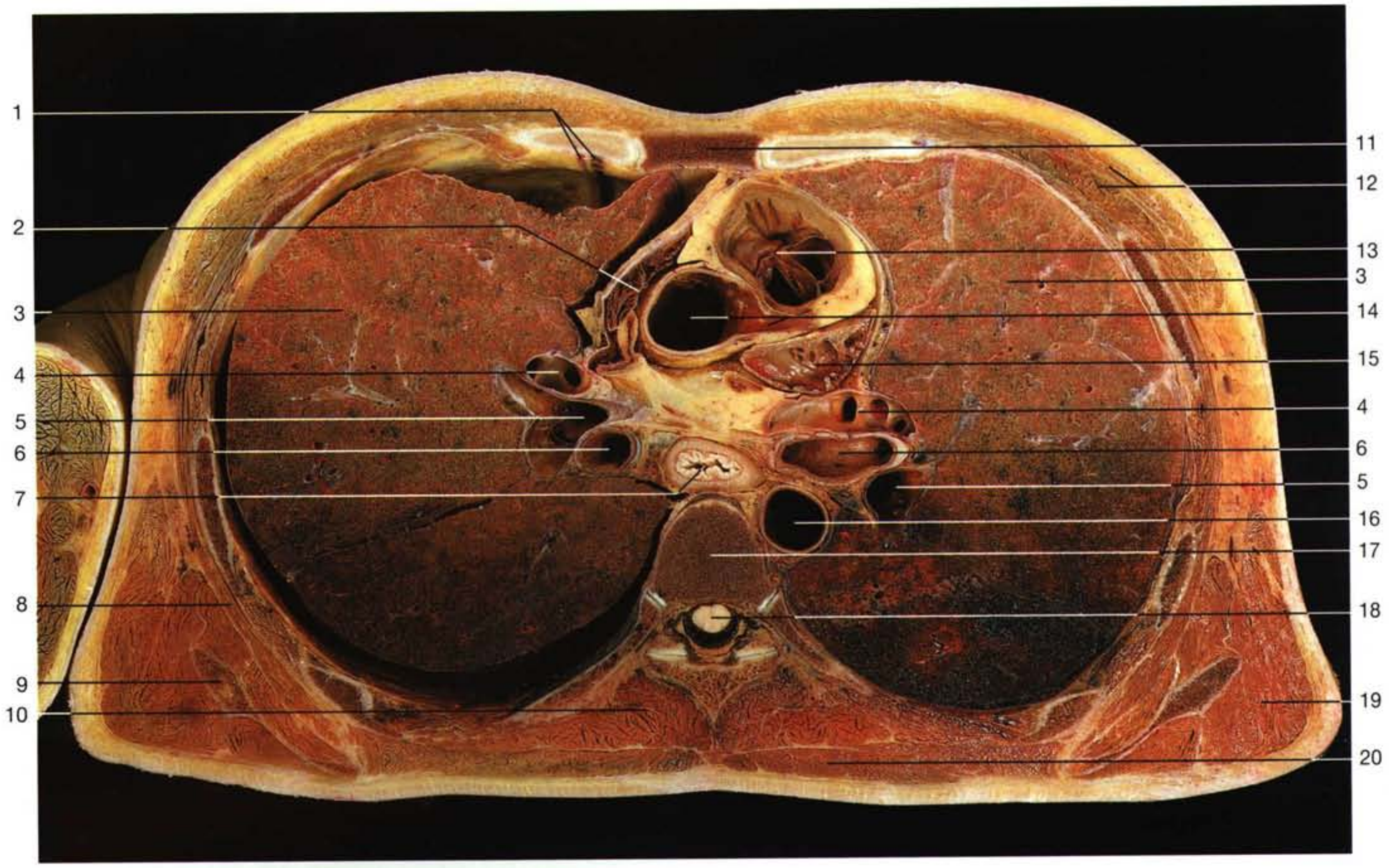

Horizontal section through the thorax at level 1 (from below).

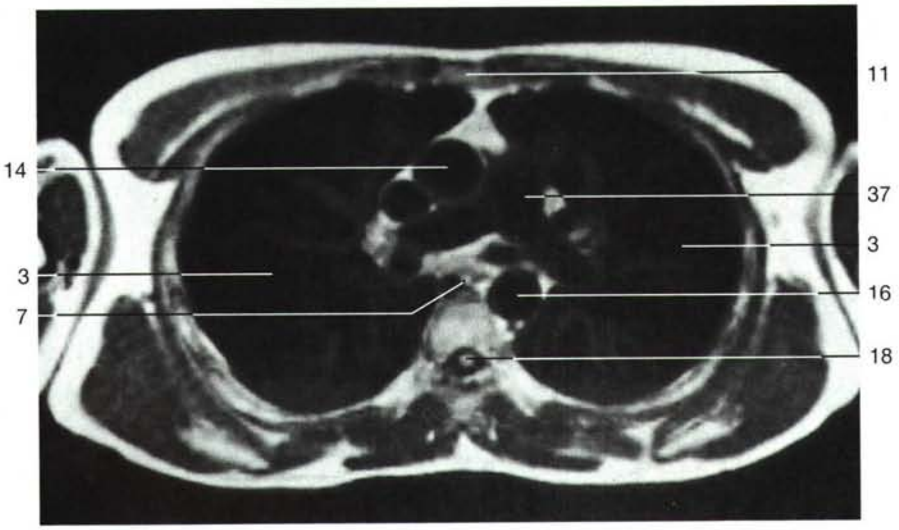

Horizontal section through the thorax at level 1 (from below). (MR-Scan.)

1 Internal thoracic artery and vein
2 Right atrium
3 Lung
4 Pulmonary artery
5 Pulmonary vein
6 Primary bronchus
7 Esophagus
8 Serratus anterior muscle
9 Scapula
10 Longissimus thoracis muscle
11 Sternum
12 Pectoralis major and minor muscles
13 Conus arteriosus (right ventricle), pulmonic valve
14 Ascending aorta and left coronary artery (only in upper figure)
15 **Left atrium**
16 **Descending aorta**
17 Thoracic vertebra
18 Spinal cord
19 Latissimus dorsi muscle
20 Trapezius muscle

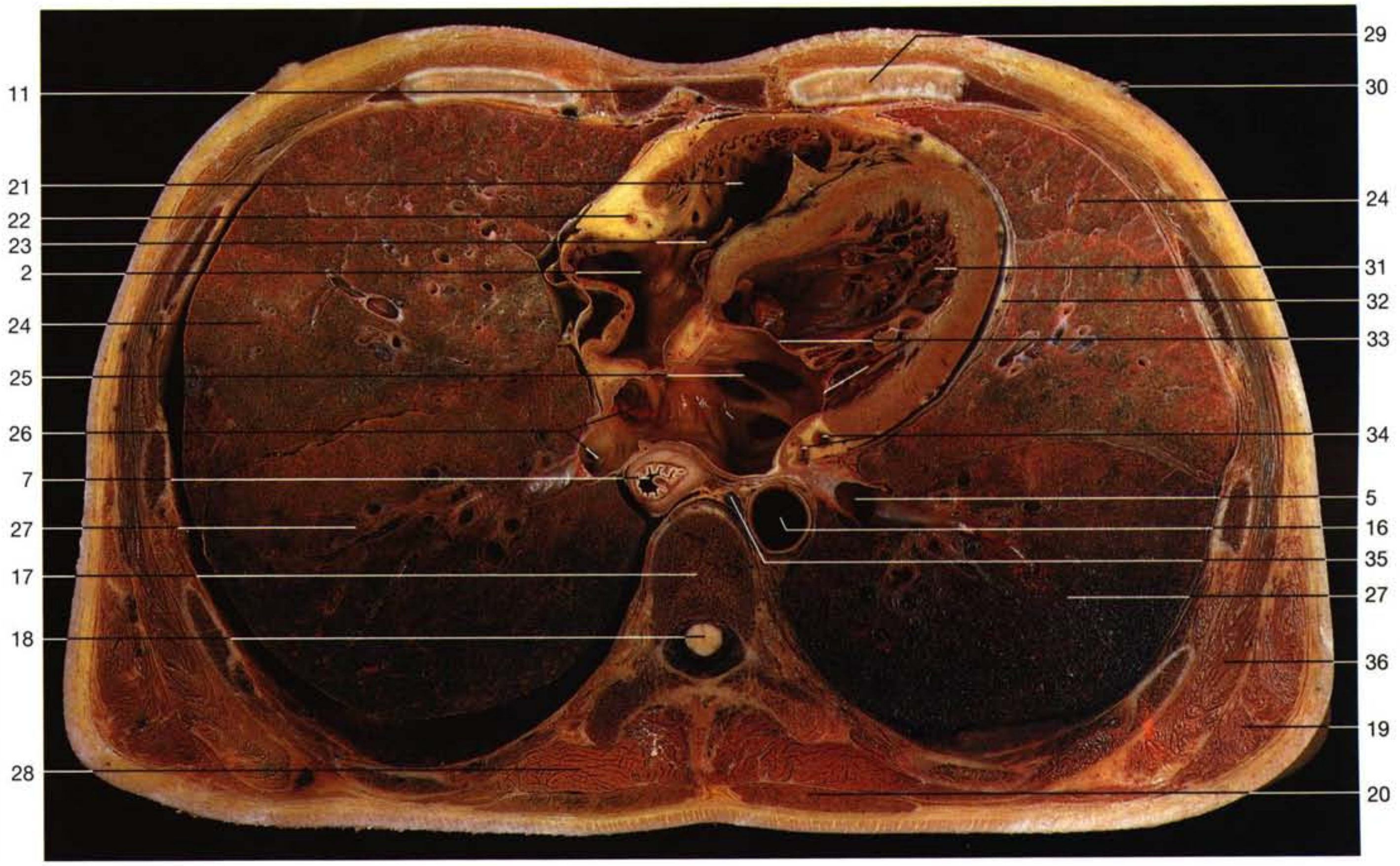
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Horizontal section through the thorax at level 2 (from below).

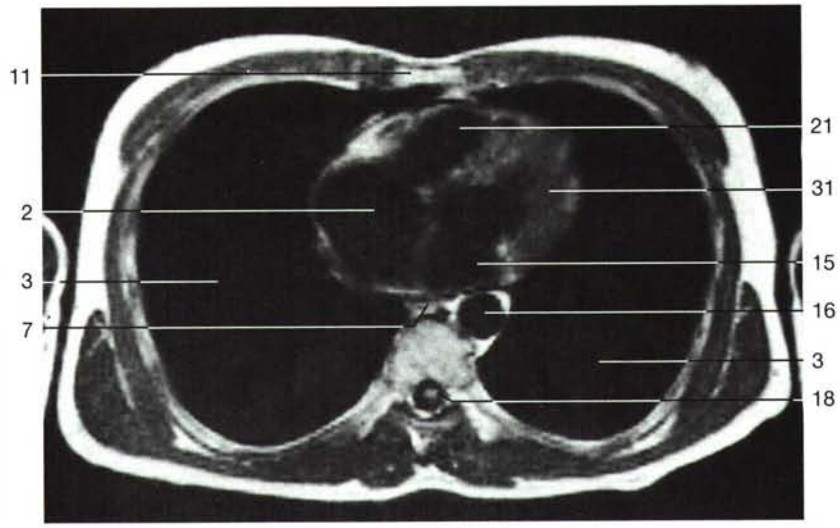
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Horizontal section through the thorax at level 2 (from below). (MR-Scan.)

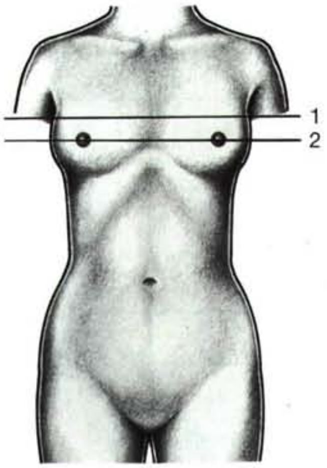

Levels of sections.

21 **Right ventricle**
22 Right coronary artery
23 Right atrioventricular valve
24 Lung (upper lobe)
25 **Left atrium**
26 Pulmonary veins
27 Lung (lower lobe)
28 Erector muscle of spine
29 Third costal cartilage
30 Nipple

31 **Left ventricle**
32 Pericardium
33 Left atrioventricular valve
34 Left coronary artery and coronary sinus
35 Accessory hemiazygos vein
36 Serratus anterior muscle
37 Pulmonary trunk

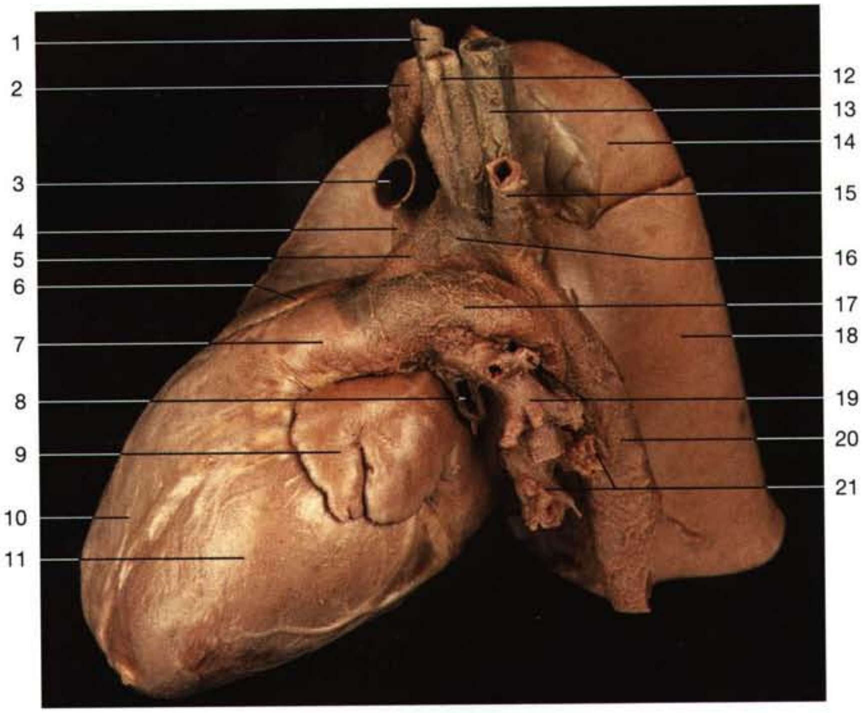

Heart and right lung of the fetus (viewed from left side). The left lung has been removed. Note the ductus arteriosus (Botalli).

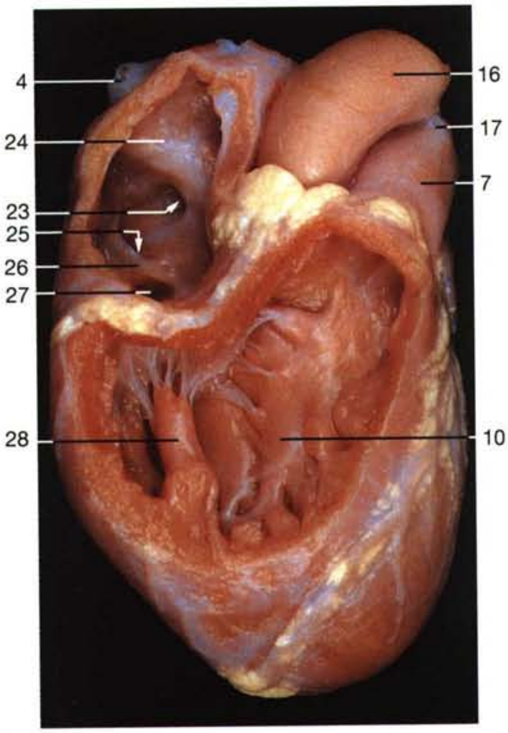

Heart of the fetus (anterior aspect). Right atrium and ventricle opened.

Shunts in the fetal circulation system		
1. Ductus venosus (of Arantius)	between umbilical vein and inferior vena cava	bypass of liver circulation
2. Foramen ovale	between right and left atrium	bypass of pulmonary circulation
3. Ductus arteriosus (Botalli)	between pulmonary trunk and aorta	

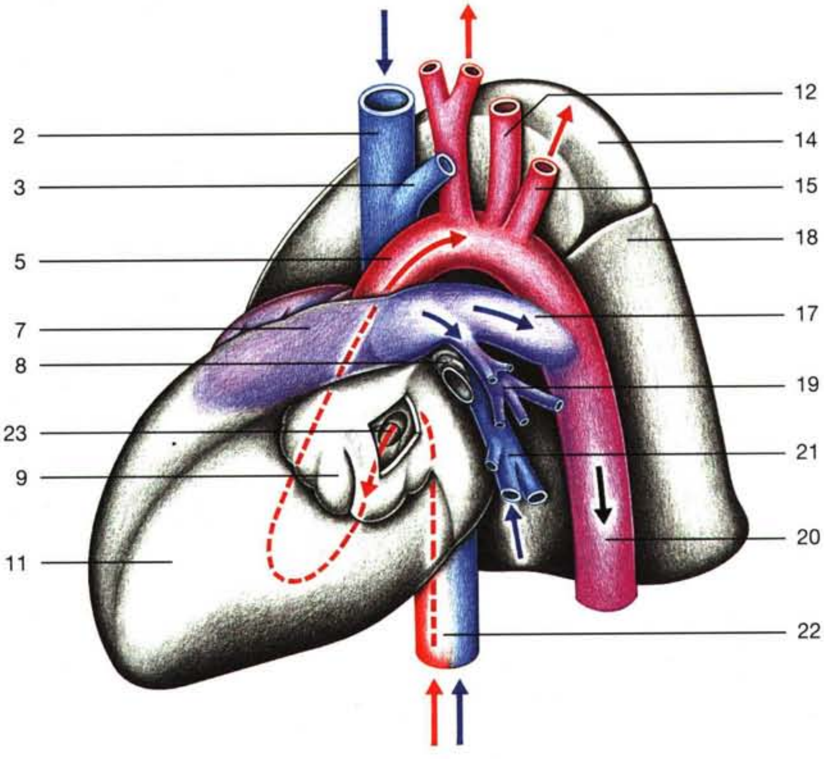

◁ **Heart of the fetus** (schematic drawing). Direction of blood flow indicated by arrows. Note the change in oxygenation of blood after ductus arteriosus entry into aorta.

1	Right common carotid artery
2	Right brachiocephalic vein
3	Left brachiocephalic vein
4	Superior vena cava
5	**Ascending aorta**
6	Right auricle
7	**Pulmonary trunk**
8	Left primary bronchus
9	Left auricle
10	Right ventricle
11	Left ventricle
12	Left common carotid artery
13	Trachea
14	Superior lobe of right lung
15	Left subclavian artery
16	Aortic arch
17	**Ductus arteriosus (Botalli)**
18	Inferior lobe of right lung
19	Left pulmonary artery with branches to the left lung
20	**Descending aorta**
21	Left pulmonary veins
22	Inferior vena cava
23	**Foramen ovale**
24	Right atrium
25	Opening of inferior vena cava
26	Valve of inferior vena cava (Eustachian valve)
27	Opening of coronary sinus
28	Anterior papillary muscle of right ventricle

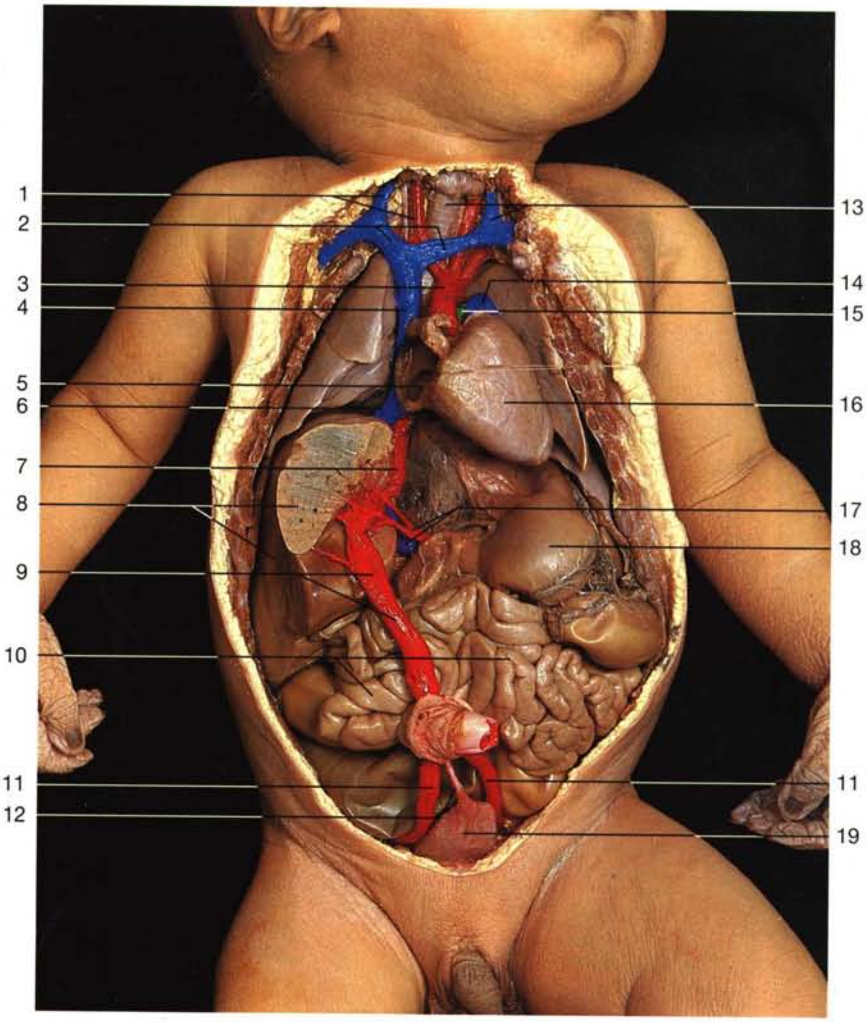

Thoracic and abdominal organs in the newborn (anterior aspect). The right atrium has been opened to show the foramen ovale. The left lobe of the liver has been removed.

1 Internal jugular vein and right common carotid artery
2 Right and left brachiocephalic vein
3 Aortic arch
4 Superior vena cava
5 **Foramen ovale**
6 Inferior vena cava
7 **Ductus venosus**
8 Liver
9 **Umbilical vein**
10 Small intestine
11 **Umbilical artery**
12 Urachus
13 Trachea and left internal jugular vein
14 Left pulmonary artery
15 **Ductus arteriosus** (Botalli)
16 Right ventricle
17 Hepatic arteries (red) and portal vein (blue)
18 Stomach
19 Urinary bladder
20 Portal vein
21 Pulmonary veins
22 Descending aorta
23 Placenta

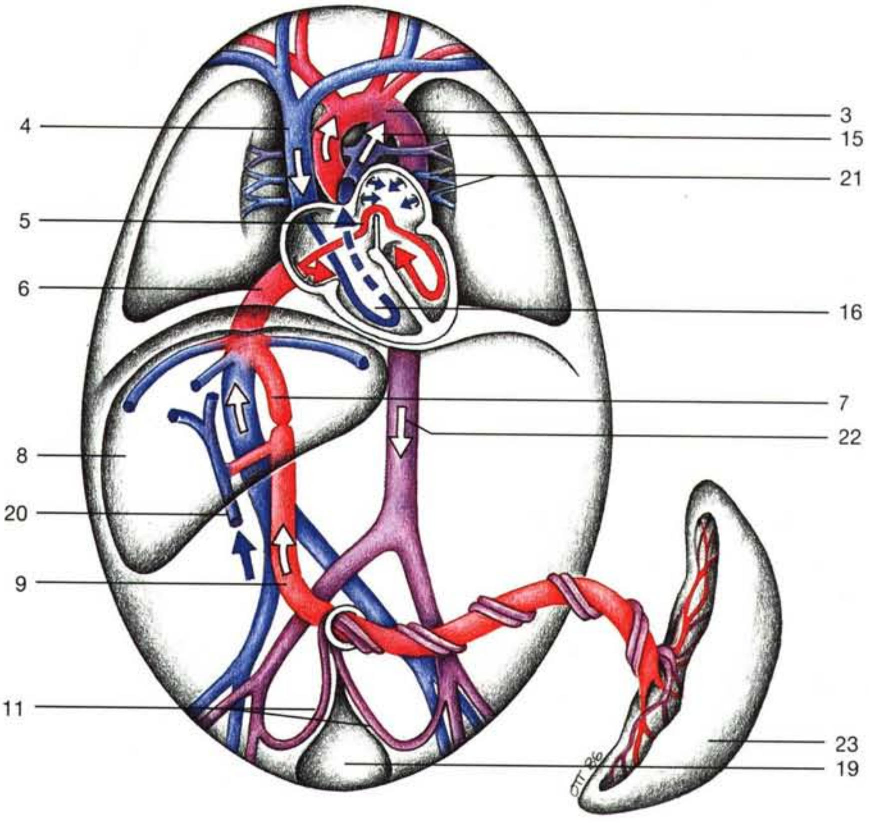

◁ **Fetal circulatory system.** (Schematic drawing.) The oxygen gradient is indicated by color.

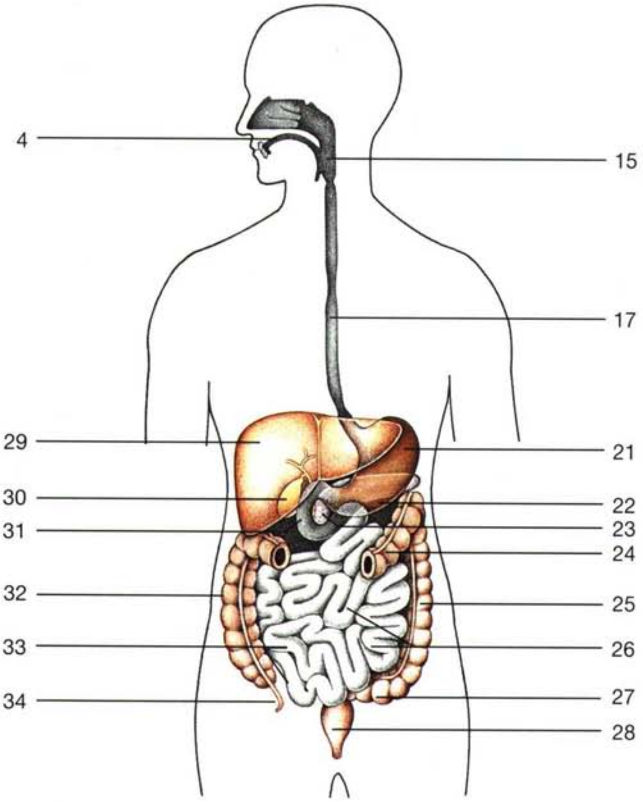

Organization of digestive system. Position of abdominal organs.

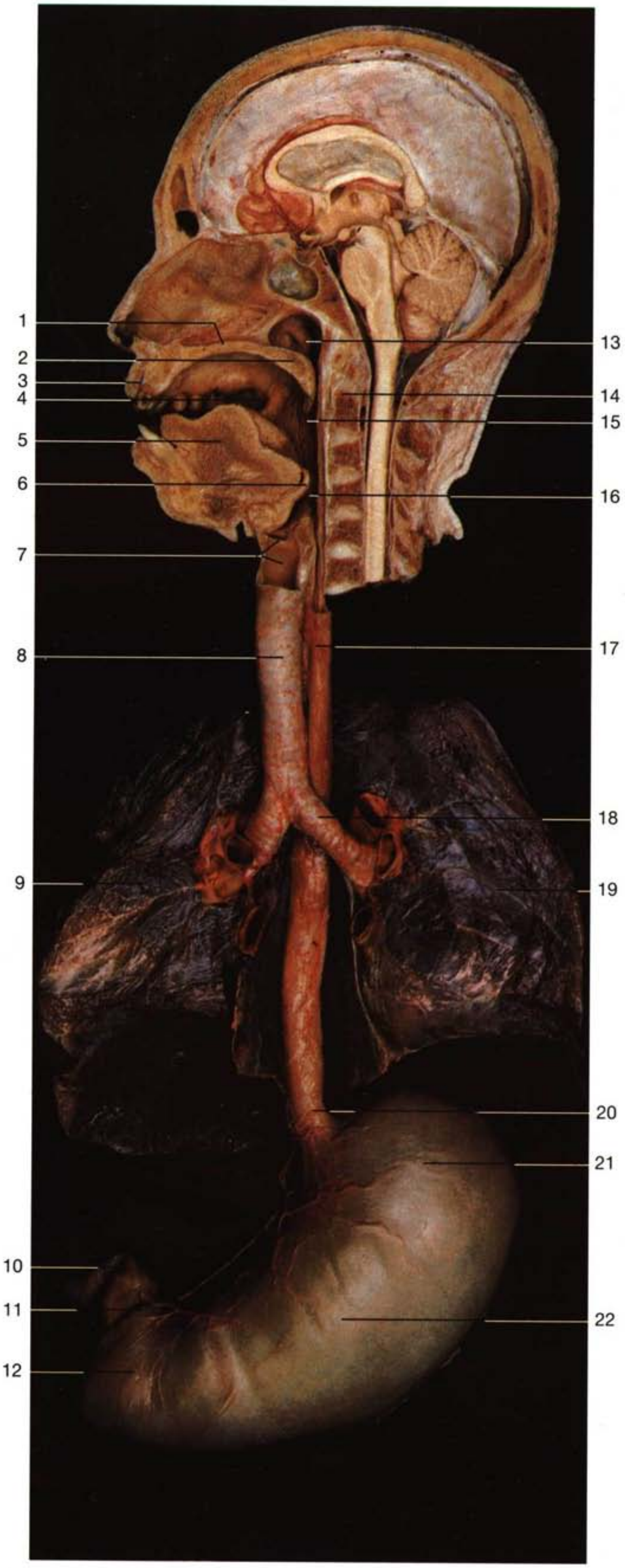

Survey of upper portion of digestive system. Oral cavity, pharynx, esophagus, and stomach.

1	Hard palate
2	Soft palate with uvula
3	Vestibule of the mouth
4	Oral cavity proper
5	Tongue
6	Epiglottis
7	Vocal ligament and larynx
8	Trachea
9	Right lung
10	Superior part of duodenum
11	Pylorus
12	Pyloric antrum
13	Nasopharynx
14	Dens of axis
15	Oropharynx
16	Laryngopharynx
17	Esophagus (thoracic part)
18	Left primary bronchus
19	Left lung
20	Abdominal part of esophagus and cardia
21	Fundus of stomach
22	Body of stomach
23	Pancreas
24	Transverse colon (divided)
25	Descending colon
26	Jejunum
27	Sigmoid colon
28	Rectum
29	Liver
30	Gall bladder
31	Duodenum
32	Ascending colon
33	Ileum
34	Vermiform appendix

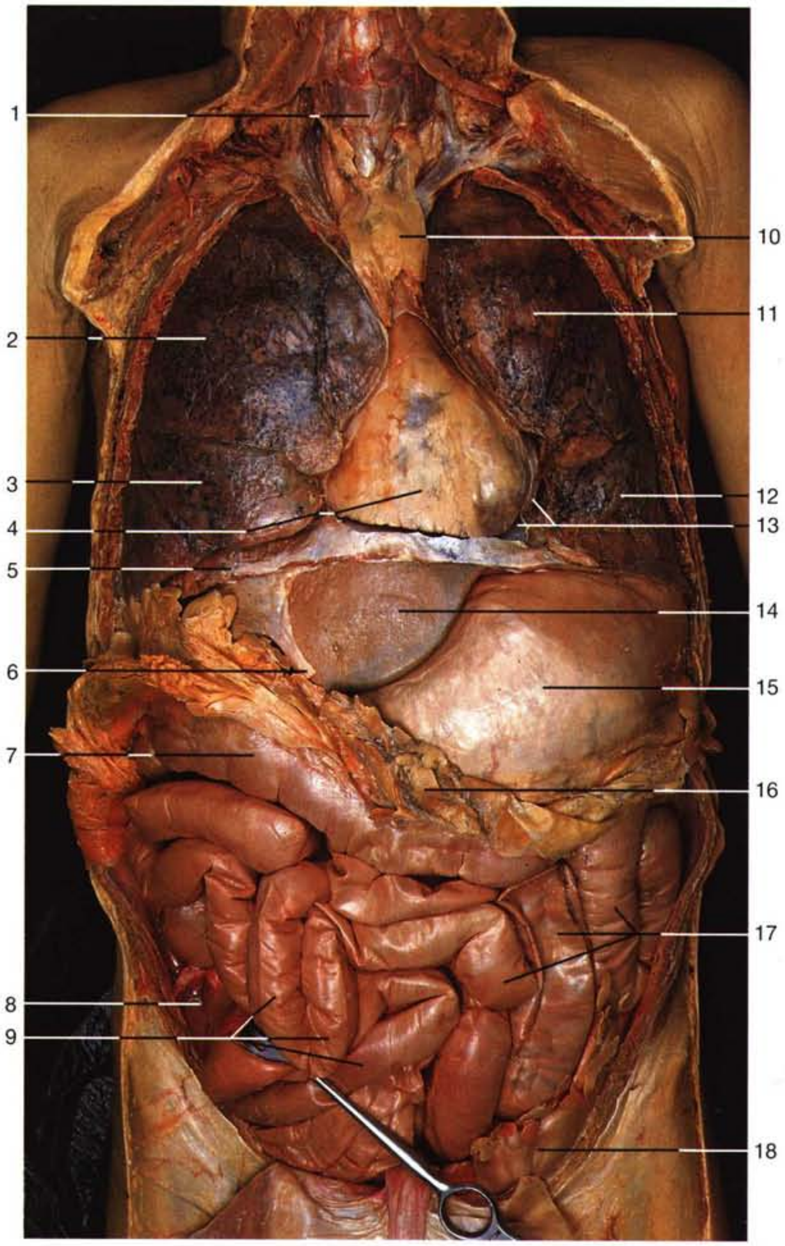

Abdominal organs in situ. The greater omentum has been partly removed or reflected.

1 Thyroid gland
2 Upper lobe of right lung
3 Middle lobe of right lung
4 Heart
5 Diaphragm
6 Round ligament of liver (ligamentum teres)
7 **Transverse colon**
8 Cecum
9 Small intestine (ileum)
10 Thymus
11 Upper lobe of left lung
12 Lower lobe of left lung
13 Pericardium (cut edge)
14 **Liver** (left lobe)
15 **Stomach**
16 Greater omentum
17 **Small intestine** (jejunum)
18 Sigmoid colon
19 Rectus abdominis muscle
20 Small intestine (section)
21 Rib
22 Common bile duct, duodenum and pancreas
23 Inferior vena cava
24 Liver
25 Body of second lumbar vertebra
26 Right kidney
27 Cauda equina and dura mater
28 Linea alba
29 Stomach and pylorus
30 Superior mesenteric artery and vein
31 Abdominal aorta
32 Left renal artery and vein
33 Left kidney
34 Psoas major muscle
35 Deep muscles of the back
36 Pancreas adjacent to lesser sac (bursa omentalis)
37 Falciform ligament with ligamentum teres

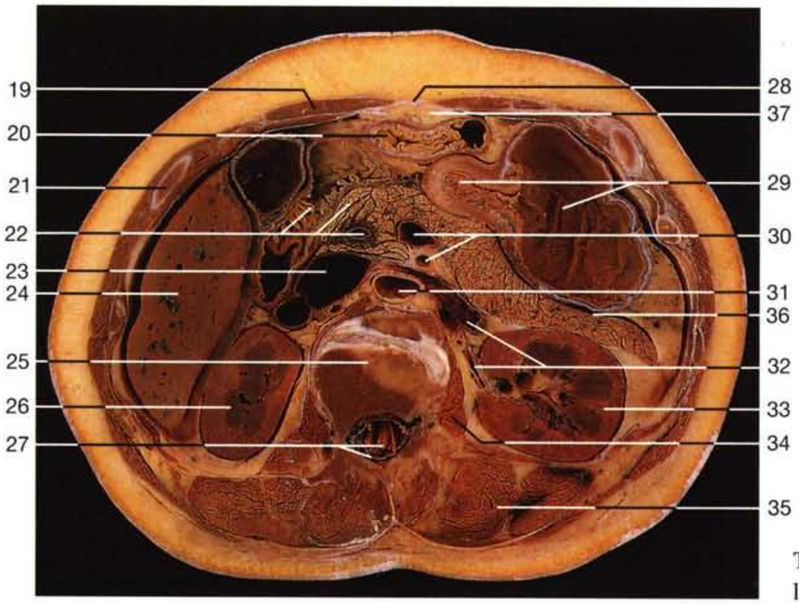

Transverse section through the abdominal cavity at the level of the second lumbar vertebra (from below).

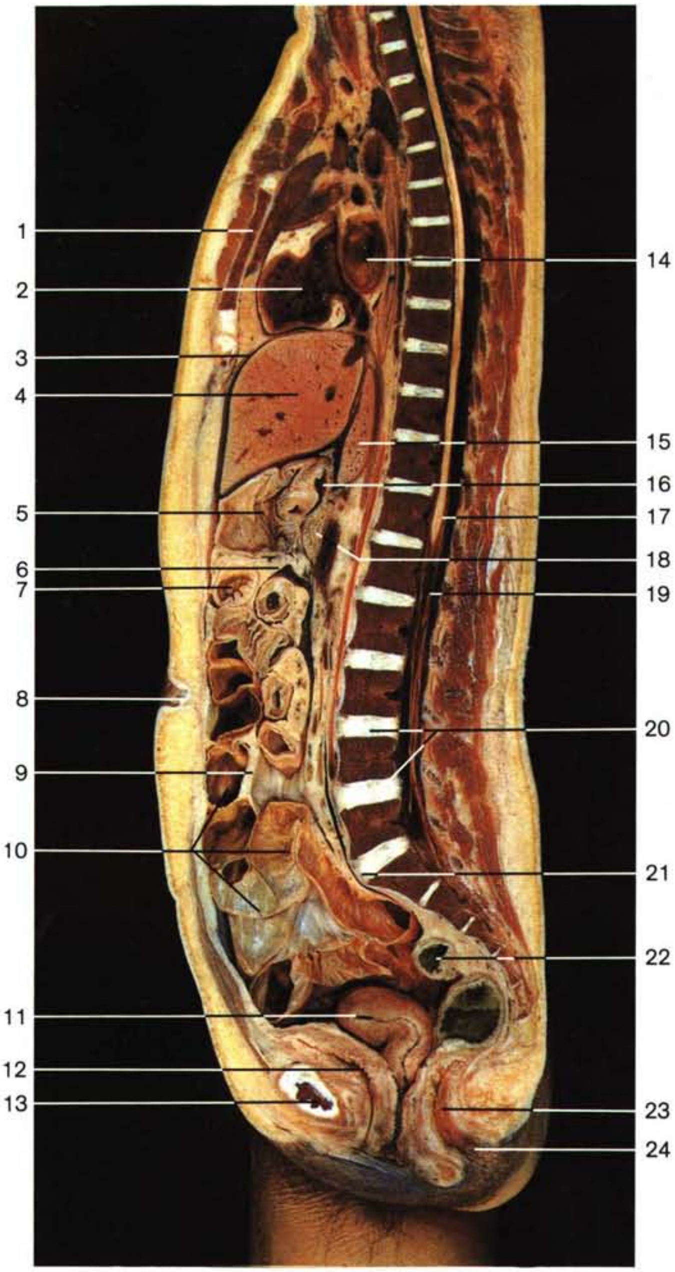
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Midsagittal section through the trunk (female).

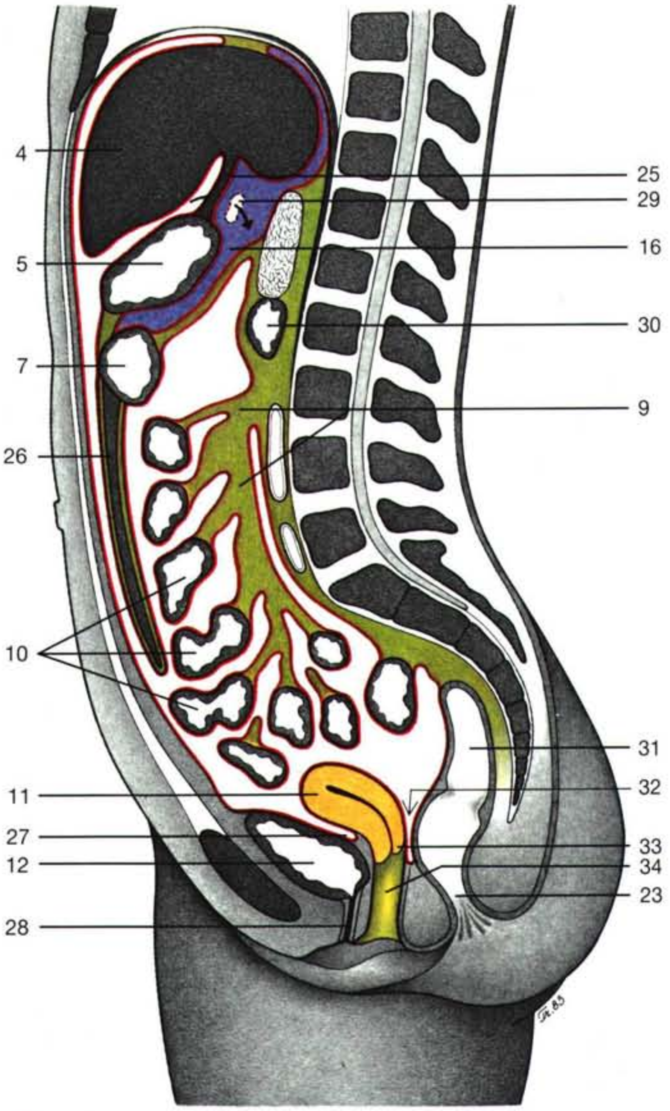
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Midsagittal section through the tunk (female).
(Schematic drawing.)
Blue = omental bursa; red = peritoneum.

1 Sternum
2 Right ventricle of heart
3 Diaphragm
4 Liver
5 Stomach
6 Transverse mesocolon
7 Transverse colon
8 Umbilicus
9 Mesentery
10 Small intestine
11 Uterus
12 Urinary bladder
13 Pubic symphysis
14 Left atrium of heart
15 Caudate lobe of liver
16 Omental bursa or lesser sac
17 Conus medullaris
18 Pancreas
19 Cauda equina
20 Intervertebral discs (lumbar vertebral column)
21 Sacral promontory
22 Sigmoid colon
23 Anal canal
24 Anus
25 Lesser omentum
26 Greater omentum
27 Vesicouterine pouch
28 Urethra
29 Epiploic (omental) foramen
30 Duodenum
31 Rectum
32 Rectouterine pouch
33 Vaginal part of cervix of uterus
34 Vagina

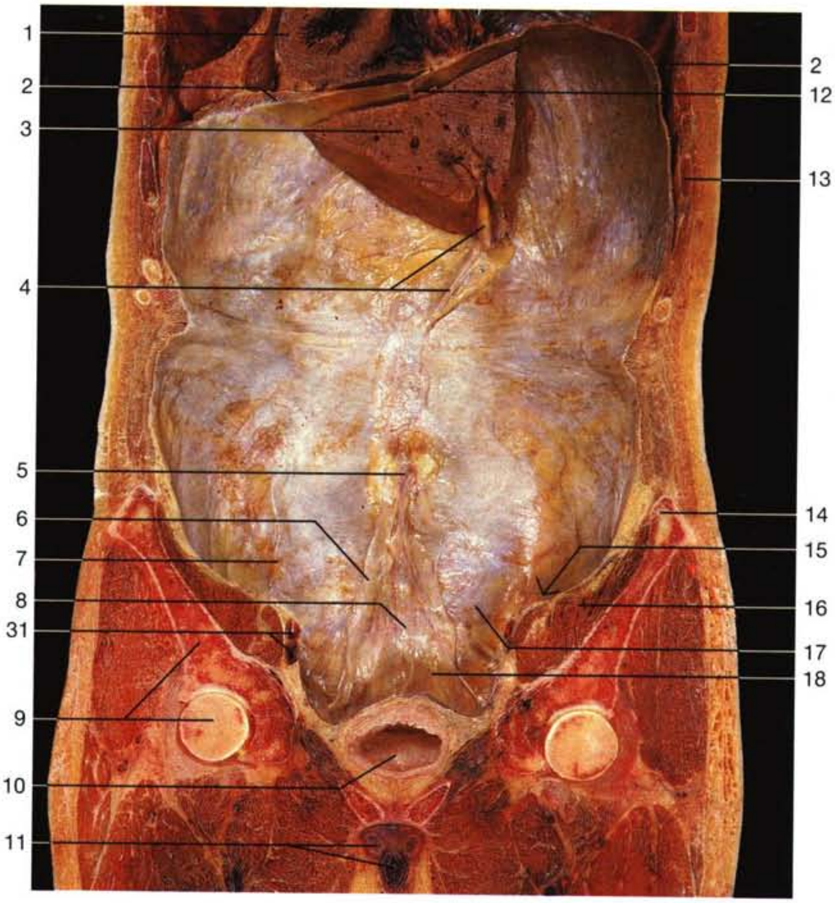

Anterior abdominal wall with pelvic cavity and thigh (frontal section, male) (internal aspect).

1 Left ventricle with pericardium
2 Diaphragm
3 Remnant of liver
4 Ligamentum teres (free margin of falciform ligament)
5 Site of umbilicus
6 **Medial umbilical fold** (containing the obliterated umbilical artery)
7 **Lateral umbilical fold** (containing inferior epigastric artery and vein)
8 **Median umbilical fold** (containing remnant of urachus)
9 Head of femur and pelvic bone
10 Urinary bladder
11 Root of penis
12 Falciform ligament of liver
13 Rib (divided)
14 Iliac crest (divided)
15 Site of **deep inguinal ring** and lateral inguinal fossa
16 Iliopsoas muscle (divided)
17 Medial inguinal fossa
18 Supravesical fossa
19 Posterior layer of rectus sheath
20 Transversus abdominis muscle
21 Umbilicus and arcuate line
22 **Inferior epigastric artery**
23 Femoral nerve
24 Iliopsoas muscle
25 Remnant of umbilical artery
26 Femoral artery and vein
27 Tendinous intersection of rectus abdominis muscle
28 Rectus abdominis muscle
29 Interfoveolar ligament
30 Pubic symphysis (divided)
31 External iliac artery and vein

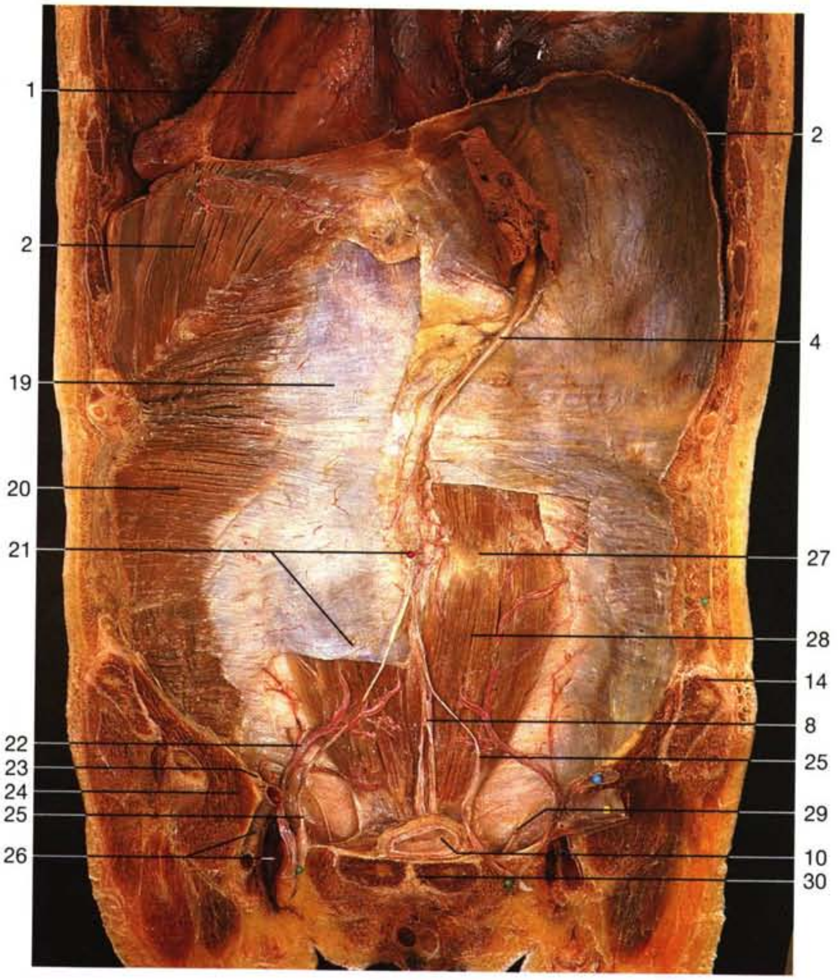

Anterior abdominal wall (male) (internal aspect). The peritoneum and parts of the posterior layer of rectus sheath have been removed. Dissection of inferior epigastric arteries and veins.

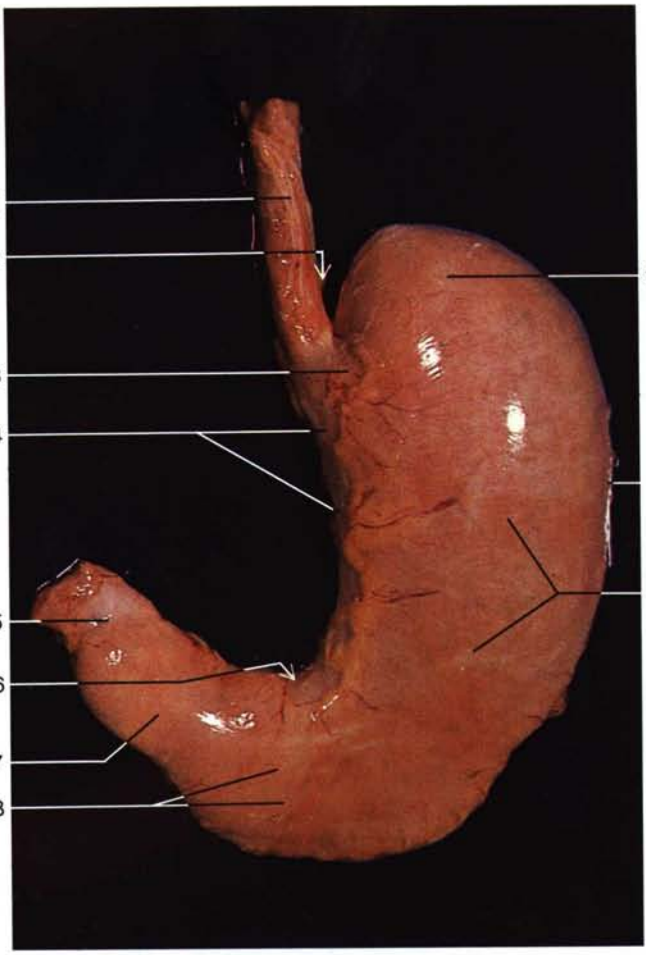

Stomach (ventral aspect).

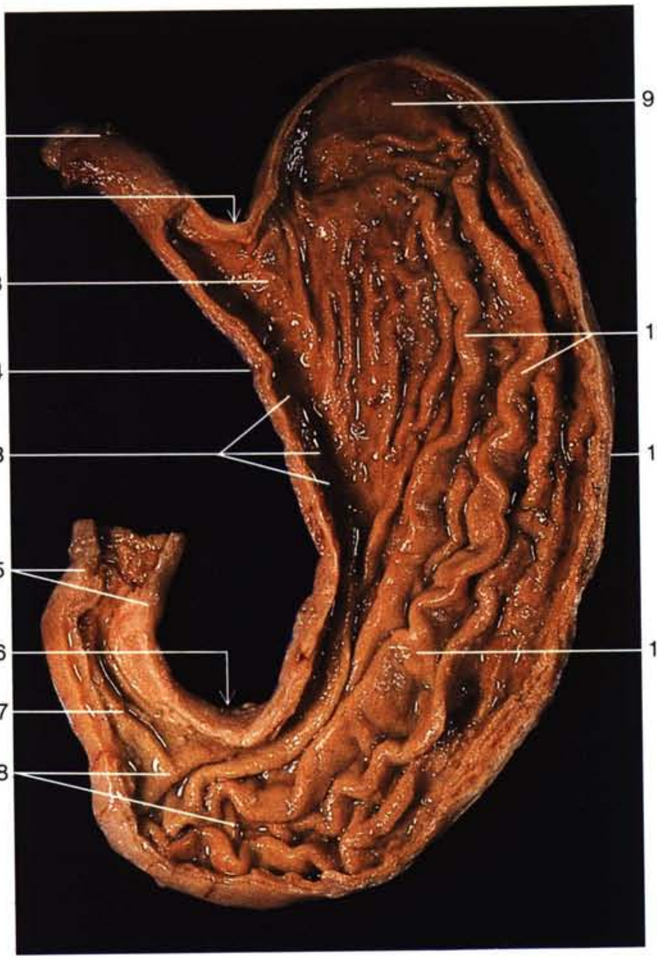

Mucosa of posterior wall of stomach (ventral aspect).

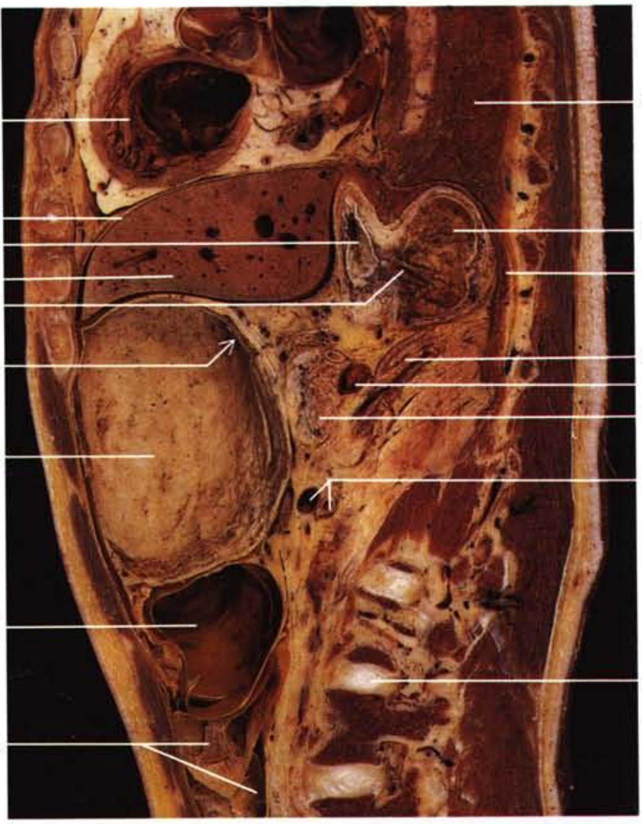

Parasagittal section through upper part of left abdominal cavity 3.5 cm lateral to median plane.

1 Esophagus
2 Cardiac notch
3 **Cardiac part of stomach**
4 Lesser curvature of stomach
5 **Pyloric sphincter**
6 Angular notch (incisura angularis)
7 **Pyloric canal**
8 Pyloric antrum
9 Fundus of stomach
10 Greater curvature of stomach
11 Body of stomach
12 Folds of mucous membrane (gastric rugae)
13 **Gastric canal**
14 Right ventricle of heart
15 Diaphragm (cut edge)
16 Abdominal portion of esophagus
17 **Liver**
18 Cardiac part of stomach (cut edge)
19 Position of pyloric canal
20 Body of stomach
21 Transverse colon
22 Small intestine
23 Lung (cut edge)
24 Fundus of stomach (section)
25 Lumbar portion of diaphragm (cut edge)
26 Suprarenal gland
27 Splenic vein
28 Pancreas
29 Superior mesenteric artery and vein
30 Intervertebral disc

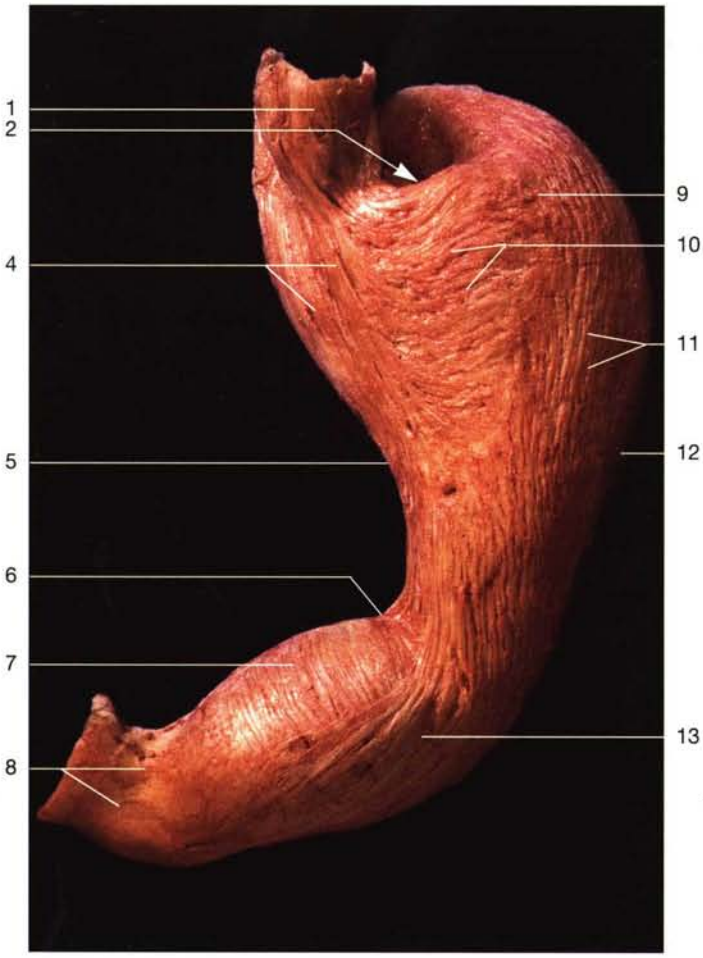

Muscular coat of stomach, outer layer (ventral aspect).

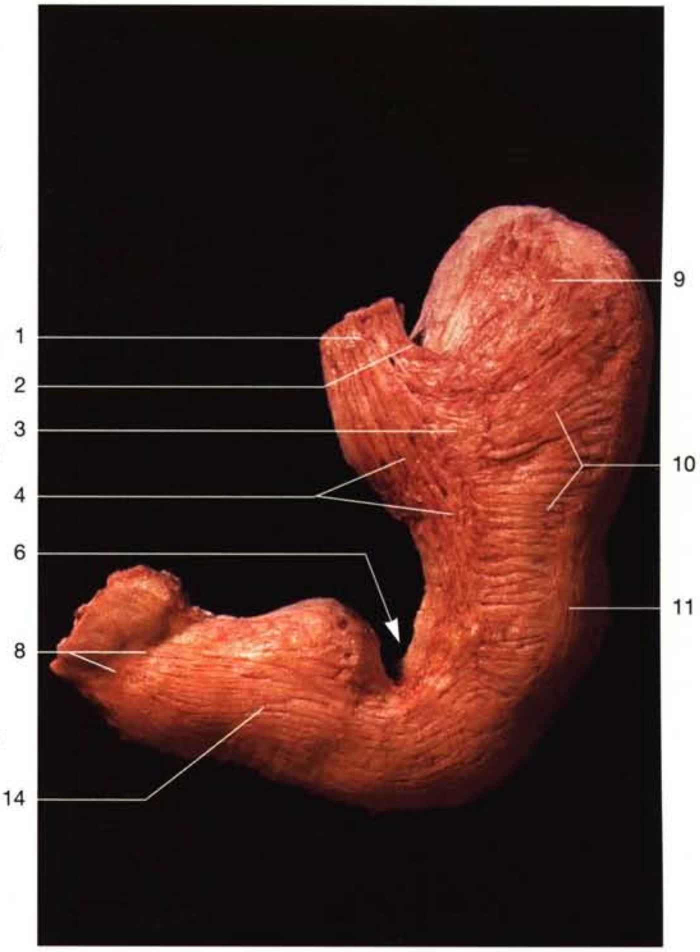

Muscular coat of stomach, middle layer (ventral aspect).

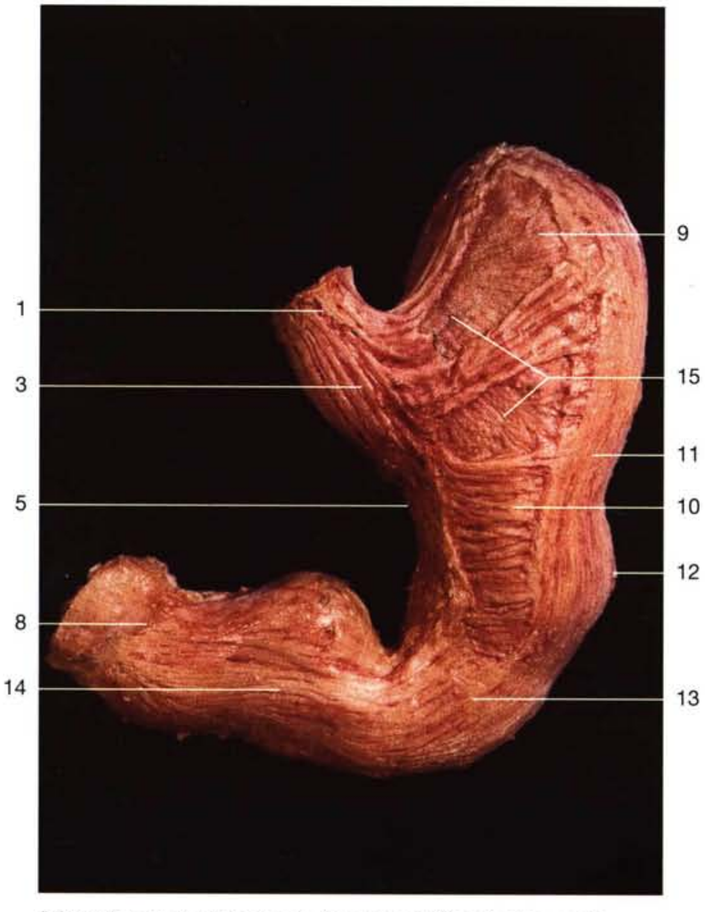

Muscular coat of stomach, inner layer (ventral aspect).

1	Esophagus (abdominal part)
2	Cardiac notch
3	Cardiac part of stomach
4	Longitudinal muscle layer at lesser curvature of stomach
5	Lesser curvature
6	Incisura angularis
7	Circular muscle layer of pyloric part of stomach
8	Pyloric sphincter muscle
9	Fundus of stomach
10	Circular muscle layer of fundus of stomach
11	Longitudinal muscle layer of greater curvature of stomach
12	Greater curvature of stomach
13	Longitudinal muscle layer (transition from body to pyloric part of stomach)
14	Pyloric part of stomach
15	Oblique muscle fibers

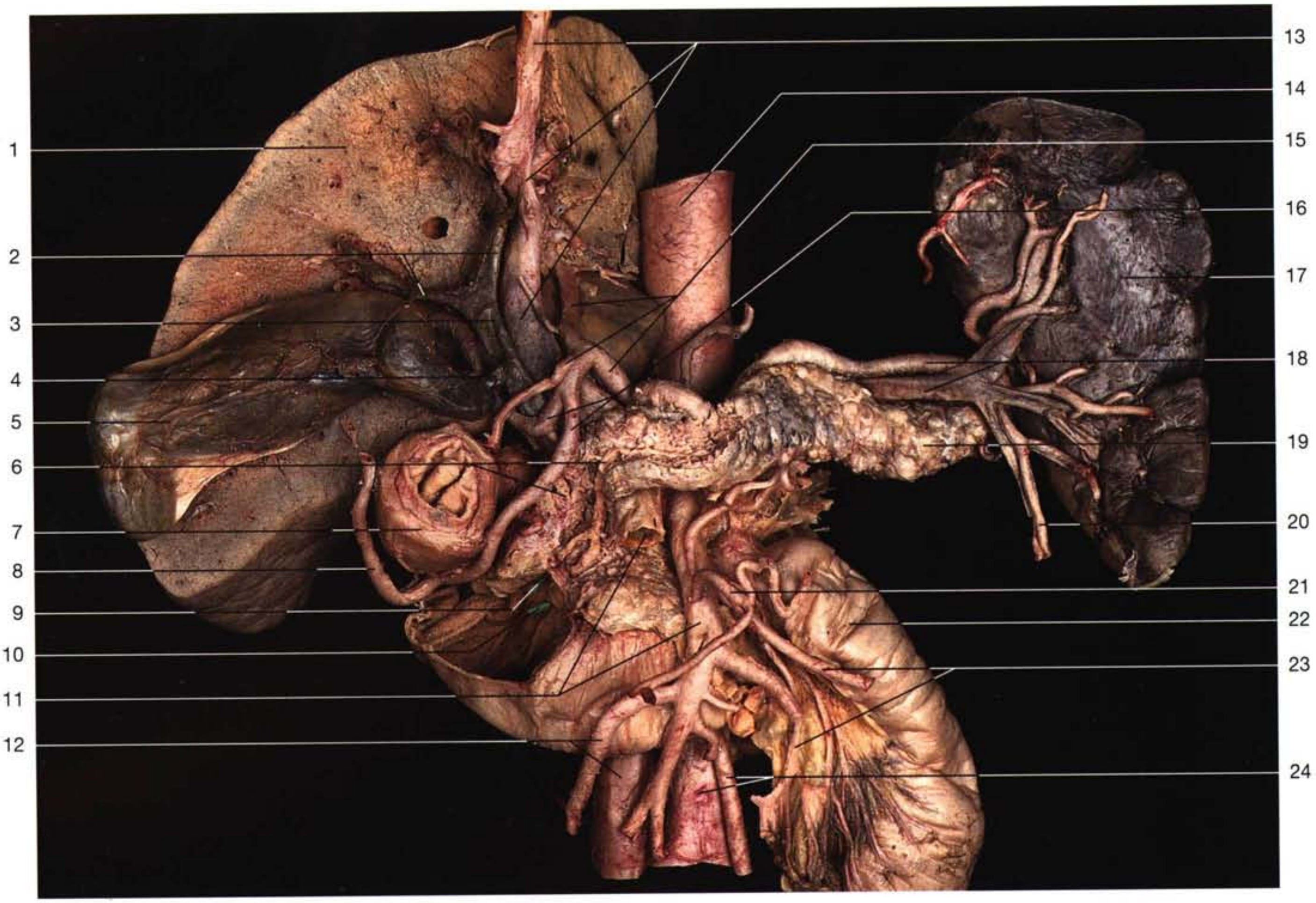

Pancreas with adjacent duodenum, spleen, liver and related arteries. The pancreatic ducts have been partly dissected. The duodenal papillae are indicated by probes. Left half of liver has been removed.

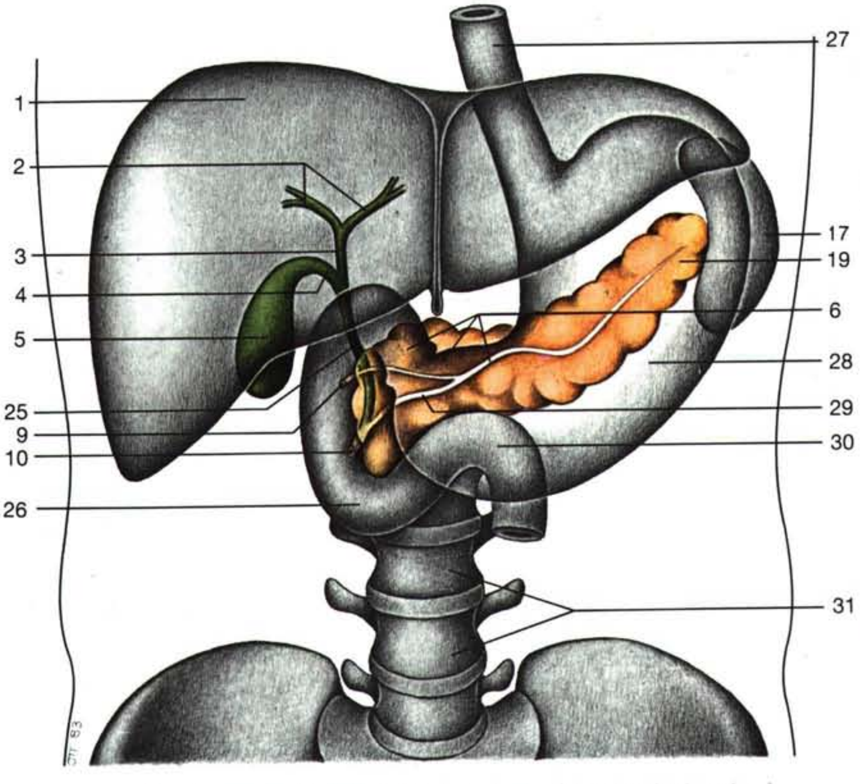

Pancreas, duodenum and extrahepatic bile ducts. (Schematic drawing.)

1 Liver
2 Left and right hepatic ducts
3 Common hepatic duct
4 **Cystic duct**
5 **Gall bladder**
6 **Pancreatic duct** and **head of pancreas**
7 Pylorus (cut)
8 Right gastro-omental (gastroepiploic) artery
9 Minor duodenal papilla (probe)
10 Major duodenal papilla (probe)
11 **Superior mesenteric artery and vein**
12 Inferior vena cava and iliocolic artery
13 **Portal vein,** lig. teres of liver and lig. venosum
14 Aorta
15 Common hepatic artery, left branch of hepatic artery proper, and right gastric artery
16 **Gastroduodenal artery** and right branch of hepatic artery proper
17 Spleen
18 Splenic artery and vein
19 **Tail of pancreas**
20 Left gastro-omental artery
21 Middle colic artery
22 Jejunum
23 Jejunal arteries
24 Aorta and inferior mesenteric artery
25 **Common bile duct**
26 Horizontal part of duodenum
27 Esophagus
28 Stomach
29 **Pancreatic duct**
30 Duodenojejunal flexure
31 Lumbal vertebrae

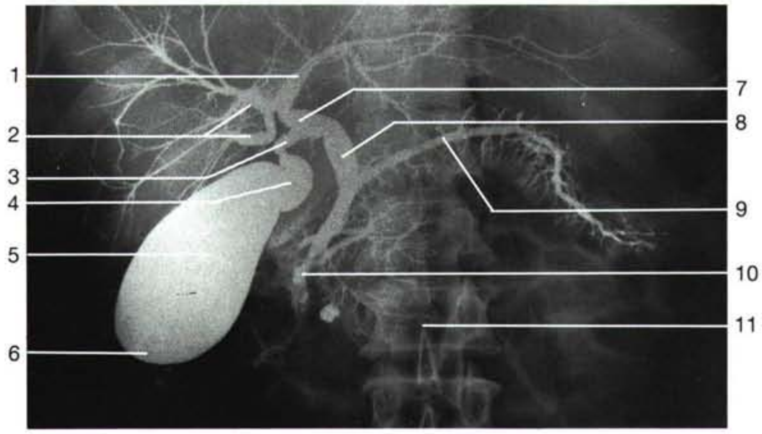

Radiograph of biliary ducts, gallbladder and pancreatic duct (anterior-posterior view).

1 Left hepatic duct
2 Right hepatic duct
3 Cystic duct
4 Neck of gallbladder
5 Body of gallbladder
6 Fundus of gallbladder
7 Common hepatic duct
8 **Common bile duct**
9 **Pancreatic duct**
10 **Greater duodenal papilla**
11 Second lumbar vertebra
12 Folds of mucous membrane of gallbladder
13 Muscular coat of gallbladder
14 Neck of gallbladder (opened)
15 Cystic duct with spiral fold
16 **Lesser duodenal papilla**
17 **Accessory pancreatic duct**
18 Uncinate process
19 Plica circularis of duodenum (Kerckrings's fold)
20 Head of pancreas
21 Body of pancreas
22 Tail of pancreas
23 Descending part of duodenum
24 Incisure of pancreas

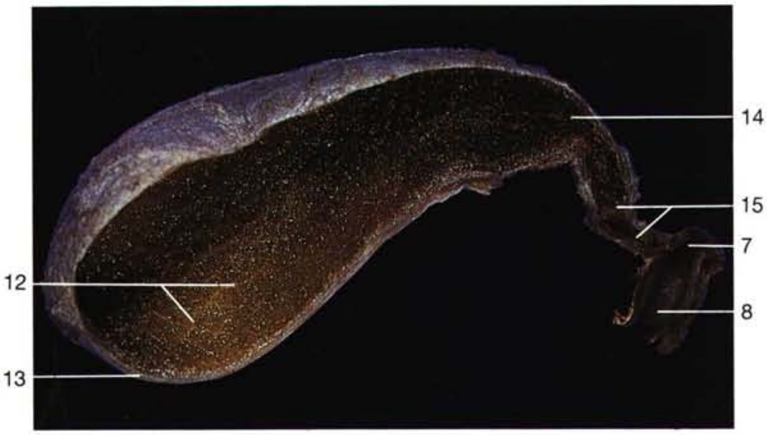

Isolated gallbladder and cystic duct (anterior aspect).
The gallbladder has been opened to display the mucous membrane.

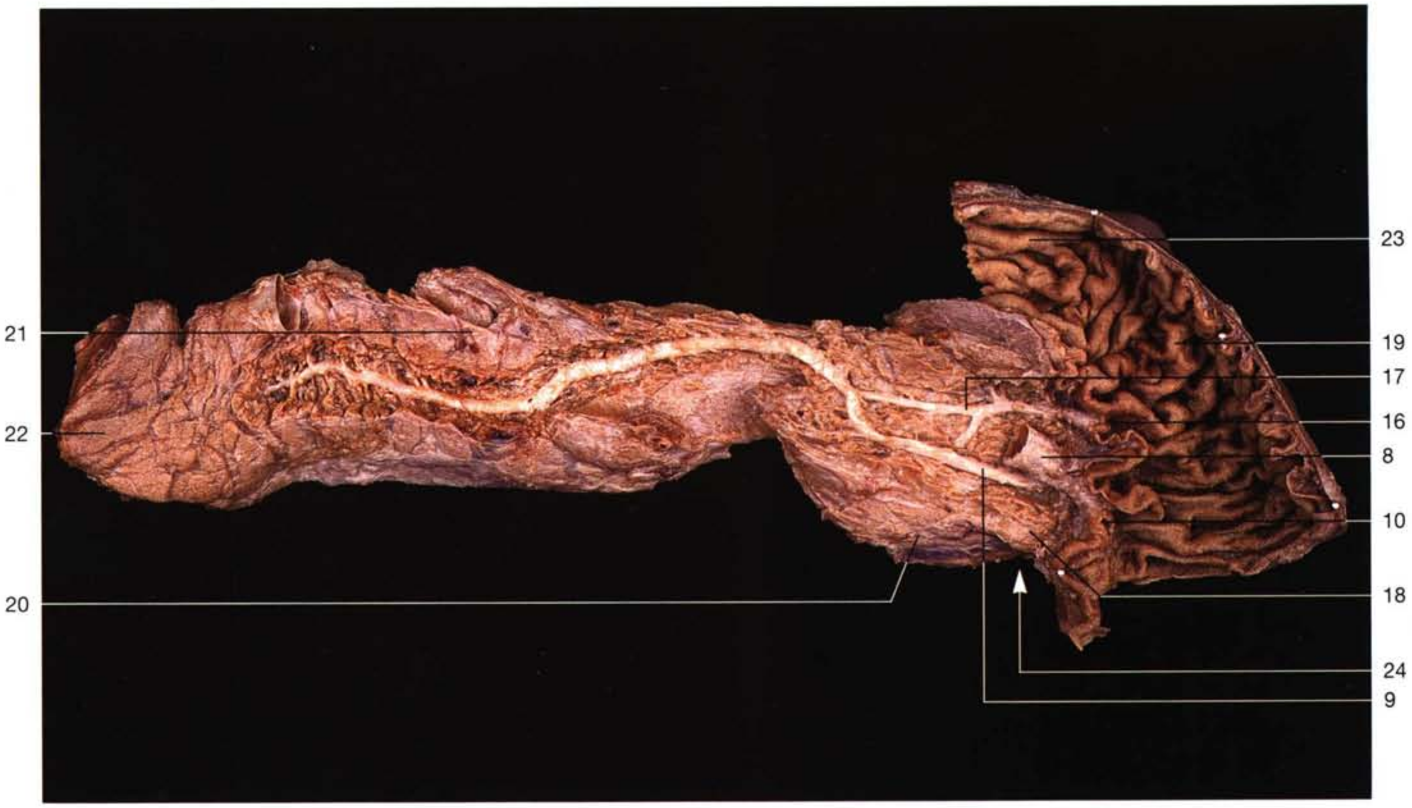

Pancreas with descending part of duodenum (posterior aspect). The duodenum was opened to display the duodenal papillae. Pancreatic duct has been dissected, the common bile duct has been divided. The sphincter of Oddi is shown.

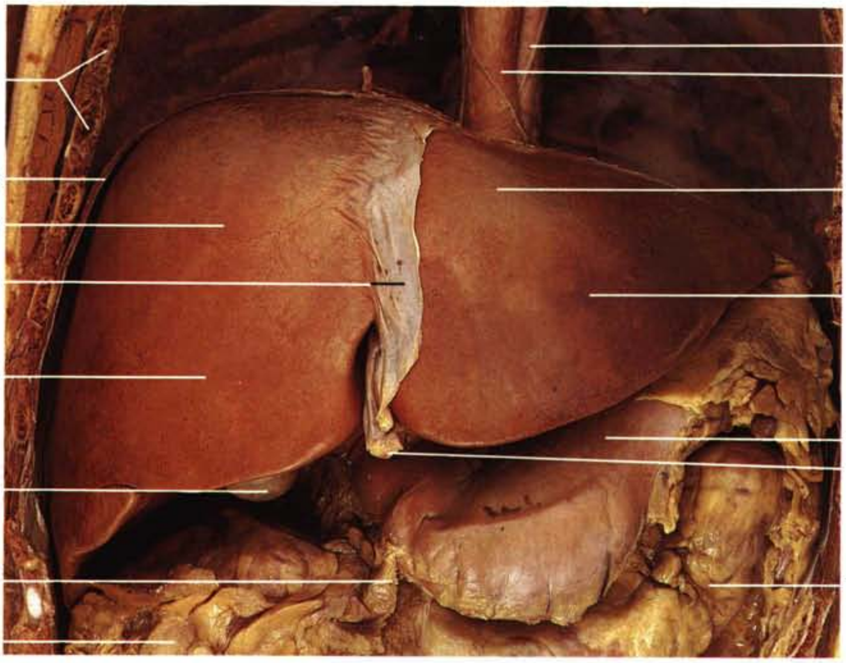

Liver in situ (ventral aspect). Part of the diaphragm has been removed.

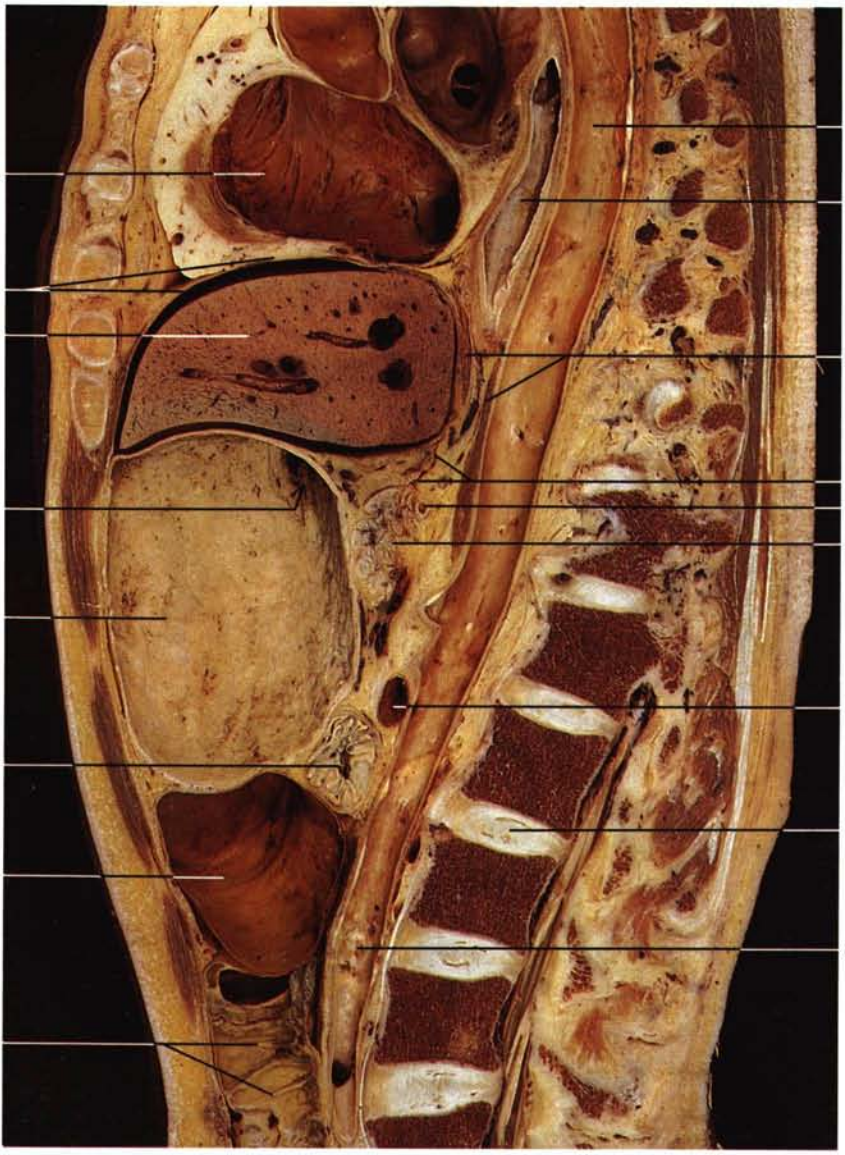

Liver in situ. Parasagittal section through the left side of the abdomen 2 cm lateral to median plane.

1 Ribs (cut edges)
2 Diaphragm
3 Diaphragmatic surface of liver
4 **Falciform ligament of liver**
5 Right lobe of liver
6 Fundus of gallbladder
7 Gastrocolic ligament
8 Greater omentum
9 Aorta
10 Esophagus
11 Left lobe of liver
12 Stomach
13 **Ligamentum teres**
14 Transverse colon
15 Right atrium of heart
16 Central tendon and sternal portion of diaphragm
17 Liver (cut edge)
18 Entrance to duodenum (pylorus)
19 Stomach
20 Duodenum
21 Transverse colon (divided, dilated)
22 Small intestine
23 Thoracic aorta (longitudinally divided)
24 Esophagus (longitudinally divided)
25 Esophageal hiatus of diaphragm
26 **Omental bursa** (lesser sac)
27 Splenic artery
28 Pancreas
29 Left renal vein
30 Intervertebral disc
31 Abdominal aorta (longitudinally divided)

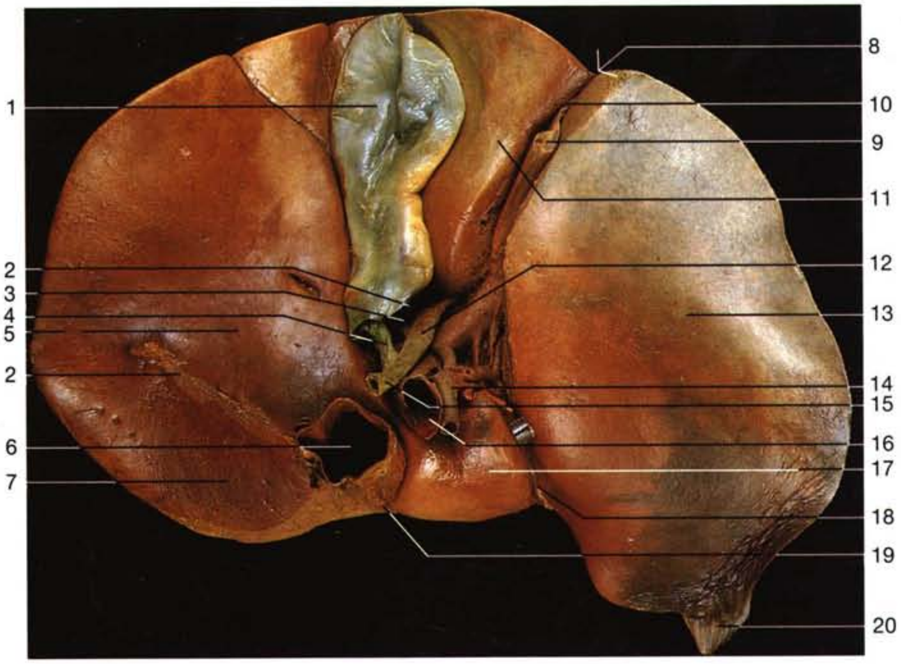

Liver (inferior aspect). Dissection of porta hepatis. Gallbladder partly collapsed. Ventral margin of liver above.

1 Fundus of **gallbladder**
2 Peritoneum (cut edges)
3 Cystic artery
4 **Cystic duct**
5 **Right lobe of liver**
6 Inferior vena cava
7 Bare area of liver
8 Notch for ligamentum teres and falciform ligament
9 Ligamentum teres
10 Falciform ligament of liver
11 **Quadrate lobe of liver**
12 Common hepatic duct
13 **Left lobe of liver**
14 Hepatic artery proper
15 **Common bile duct**
16 **Portal vein**
Portal triad
17 **Caudate lobe of liver**
18 Ligamentum venosum
19 Ligament of inferior vena cava
20 Appendix fibrosa (left triangular ligament)
21 Coronary ligament of liver
22 Hepatic veins
23 Porta hepatis

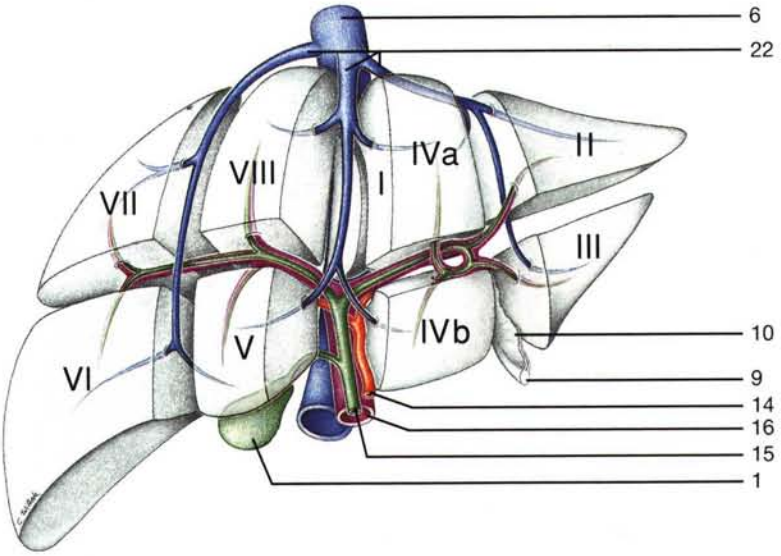

Segmentation of the liver (anterior aspect). Liver segments indicated by roman numerals.

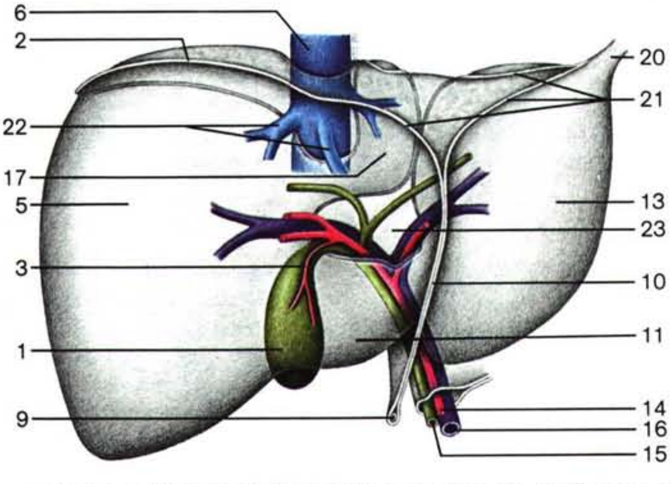

Liver (ventral aspect) (transparent drawing illustrating margins of peritoneal folds).

It should be noted that the anatomical left and right lobes of the liver do not reflect the internal distribution of the hepatic artery, portal vein, and biliary ducts. Using these structures as criteria the left lobe includes both the caudate and quadrate lobes and thus the line dividing the liver into left and right functional lobes passes through the gallbladder and inferior vena cava. The three main hepatic veins drain segments of the liver which have no visible external markings.

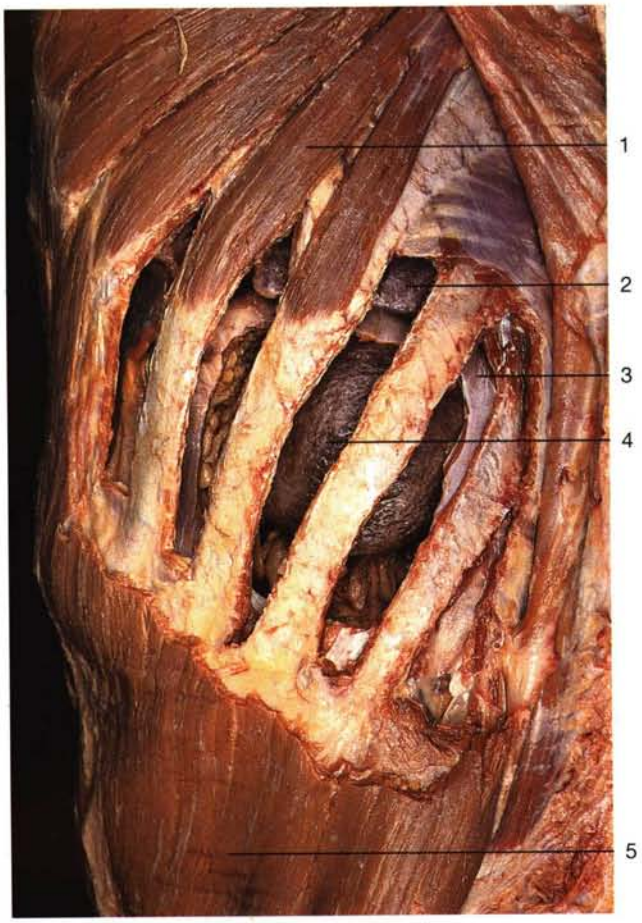

Location of the spleen in situ (left-lateral aspect). Intercostal spaces and diaphragm have been fenestrated.

1 Serratus anterior muscle
2 Left lung
3 Diaphragm
4 Spleen
5 External abdominal oblique muscle
6 Gastrosplenic ligament
7 **Splenic artery**
8 Pancreas tail
9 Superior margin of spleen
10 Anterior border of spleen
11 Inferior vena cava
12 **Hepatic veins**
13 Liver
14 **Portal vein**
15 Paraumbilical veins within falciform ligament
16 **Superior mesenteric vein**
17 Middle colic vein
18 Right colic vein
19 Ascending colon
20 Ileocolic vein
21 Vermiform appendix and appendicular vein
22 Spleen
23 Gastric and esophageal veins
24 **Splenic vein**
25 **Inferior mesenteric vein**
26 Right gastroepiploic vein
27 Ileal veins
28 Descending colon
29 Ileum
30 Sigmoid veins
31 Superior rectal veins

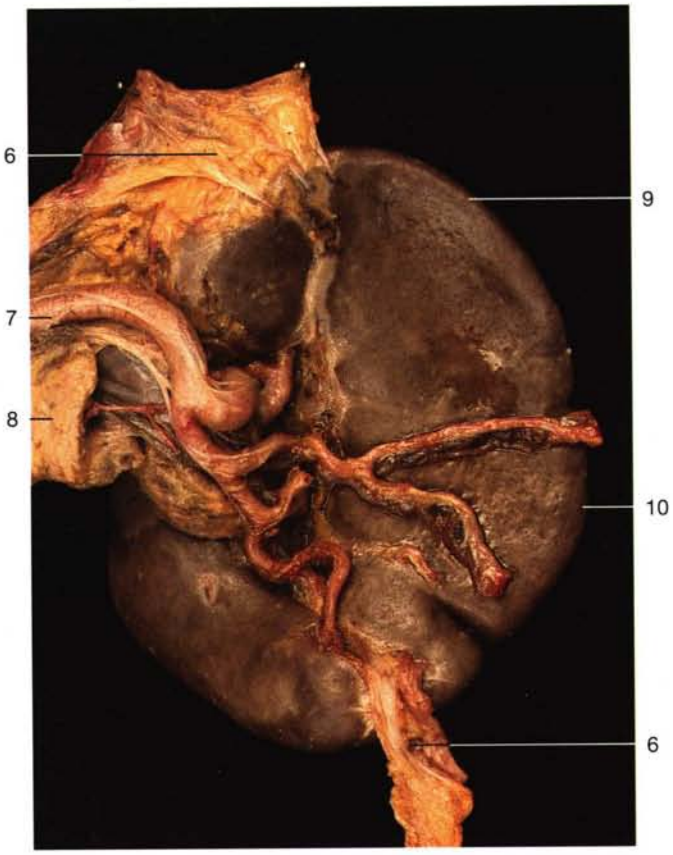

Spleen (visceral surface), hilum of spleen with vessels, nerves and ligaments.

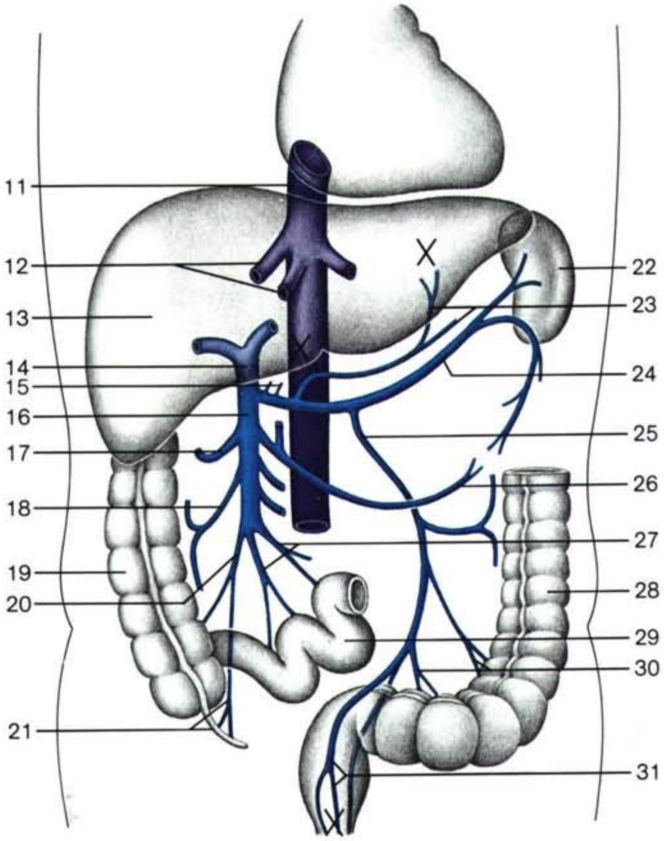

Main tributaries of portal vein. (Schematic drawing of portal circulation.) X = sites of portocaval anastomoses.

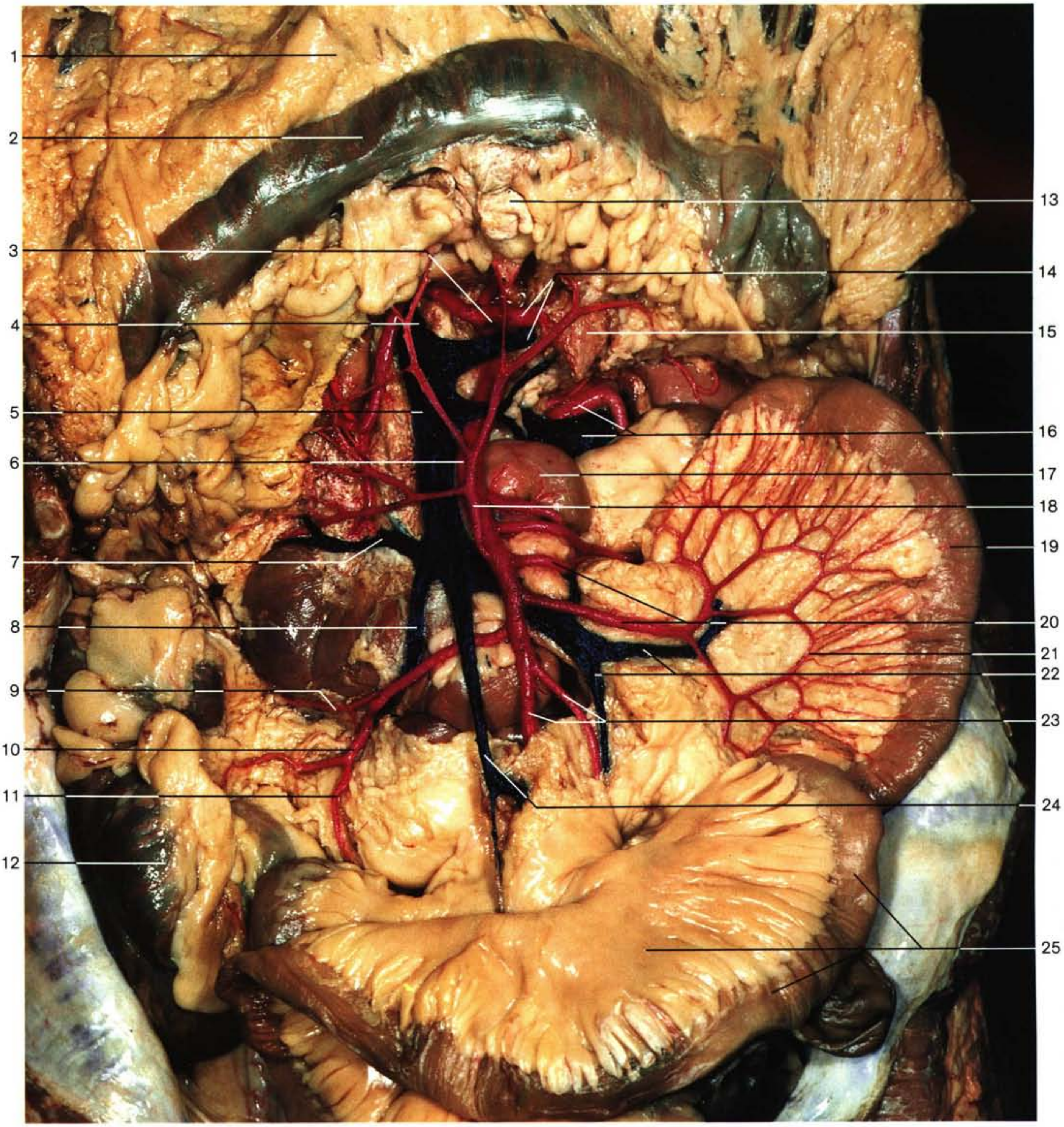

Tributaries of portal vein and branches of superior mesenteric artery (injected with colored solutions). Blue = veins; red = arteries. One layer of peritoneum has been removed to display the vascular arcades of the intestine. Part of the head of the pancreas and the mesocolon have also been removed to show the deeper vessels.

1 Greater omentum (reflected)
2 Transverse colon (raised cranially)
3 Celiac trunk
4 **Portal vein**
5 Superior mesenteric vein
6 **Superior mesenteric artery**
7 Right colic vein
8 Iliocolic vein
9 Right colic artery
10 Iliocolic artery
11 Appendicular artery
12 Cecum
13 Transverse mesocolon
14 **Splenic artery and vein**
15 Pancreas (divided)
16 Renal artery and vein
17 Duodenojejunal flexure
18 Middle colic artery
19 Jejunum
20 Jejunal arteries
21 Arterial arcades to intestine
22 Jejunal veins
23 Ileal arteries
24 Ileal vein
25 Ileum with mesentery

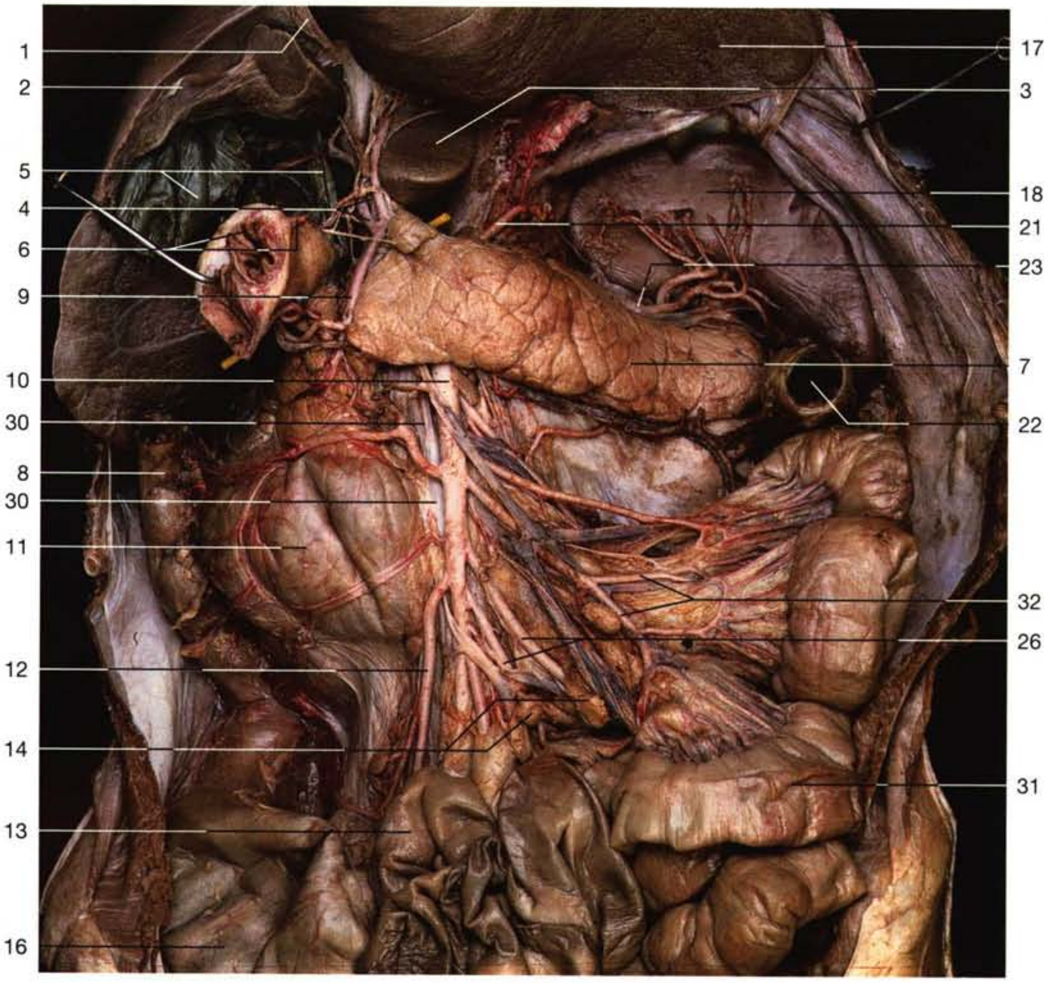

Superior mesenteric artery in relation to pancreas and duodenum. Stomach and transverse colon has been removed and the liver elevated. Note the location of the spleen. A yellow probe is inserted through the omental foramen.

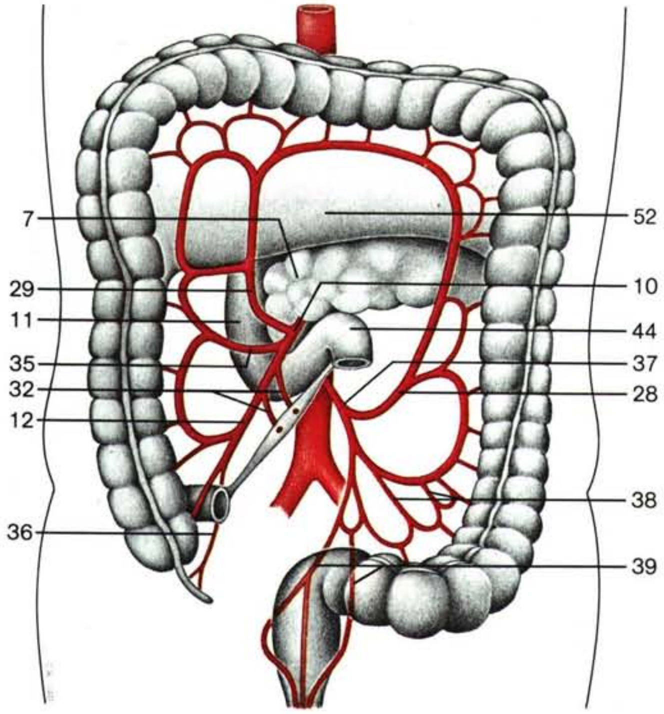

Main branches of superior and inferior mesenteric arteries. (Schematic drawing.)

1 Ligamentum teres
2 Liver
3 Caudate lobe of liver
4 Proper hepatic artery and portal vein
5 Gallbladder and common bile duct
6 Right gastric artery and pylorus
7 **Pancreas**
8 Ascending colon
9 Gastroduodenal artery
10 **Superior mesenteric artery**
11 Duodenum
12 **Iliocolic artery**
13 Terminal part of ileum
14 Mesenteric lymph nodes
15 Right common iliac artery
16 Cecum
17 Left lobe of liver
18 **Spleen**
19 Left gastro-omental (gastroepiploic) artery
20 Stomach
21 Left gastric artery
22 Left colic flexure (cut)
23 **Splenic artery**
24 Right gastro-omental (gastroepiploic) artery
25 Renal artery
26 **Ileal arteries**
27 Left kidney
28 Left colic artery
29 Middle colic artery
30 **Superior mesenteric vein**
31 Jejunum
32 **Jejunal arteries**
33 Inferior vena cava
34 Sigmoid colon
35 Right colic artery
36 Appendicular artery
37 **Inferior mesenteric artery**
38 Sigmoid arteries
39 Superior rectal artery
40 Fundus of gallbladder
41 Common bile duct
42 Portal vein
43 Beginning of jejunum
44 Duodenojejunal flexure
45 Ureter
46 Splenic artery
47 **Celiac trunk**
48 Renal vein
49 Abdominal aorta
50 Descending colon
51 Left common iliac artery
52 Transverse mesocolon

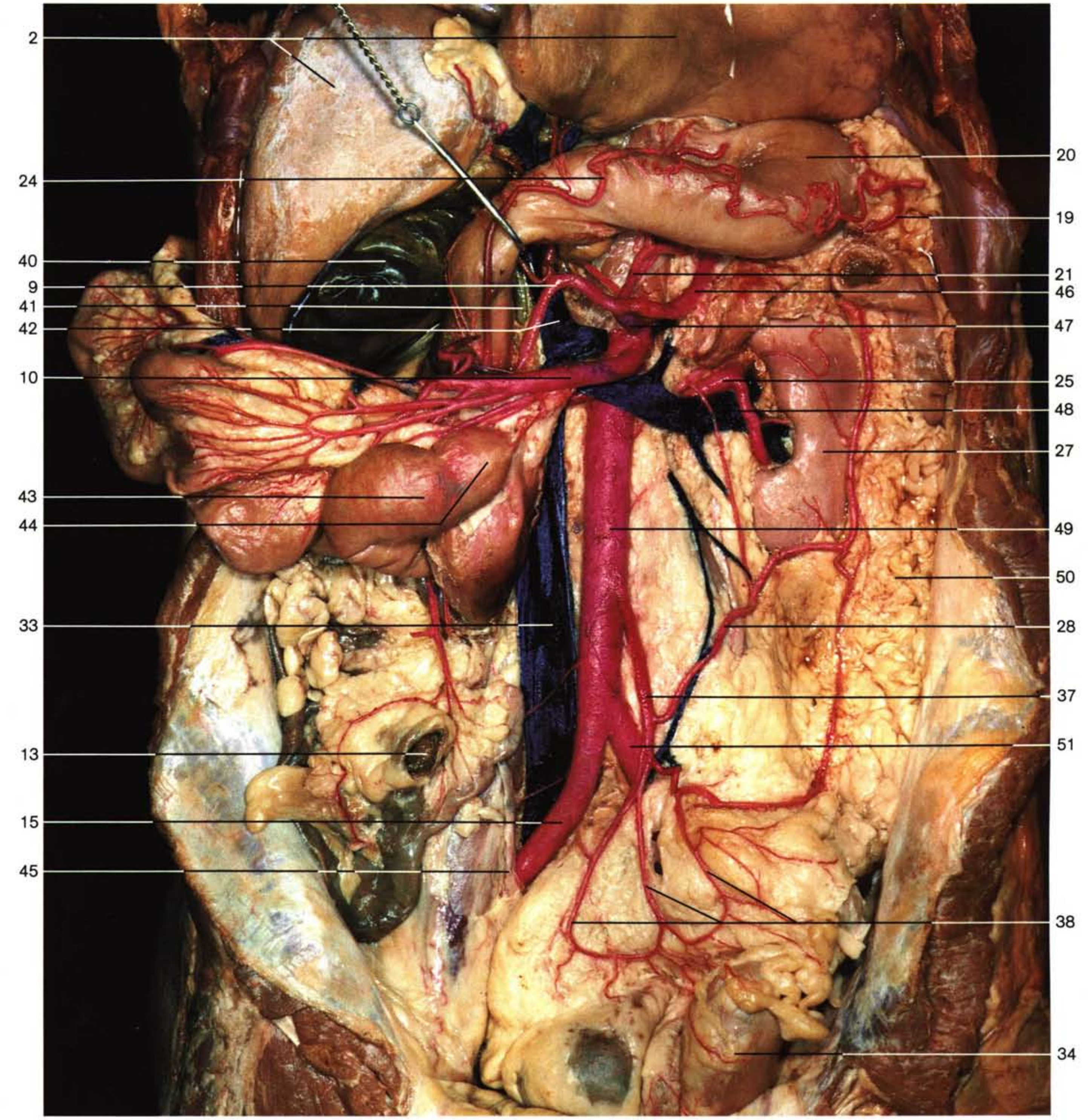

Vessels of abdominal organs; dissection of inferior mesenteric artery and celiac trunk (injected with colored solutions). Blue = veins; red = arteries. The small intestine including the duodenojejunal flexure has been reflected laterally and the stomach and liver have been raised. The peritoneum of the posterior abdominal wall has been removed to display the inferior mesenteric artery and its branches to the colon.

The **superior mesenteric artery** arises at the level of L_1 vertebra branching of the abdominal aorta. It supplies jejunum and ileum as the ascending and transverse colon. At the left colic flexure branches of the middle colic artery (from the superior mesenteric artery) and of the left colic artery (from the inferior mesenteric artery) anastomose (so-called **Riolani's anastomosis**). The arteries unite to form loops or arches called arterial arcades from which straight vessels (vasa recta) arise. The vasa recta do not anastomose within the mesentery. Thus occlusion of these vessels may lead to necrosis of the segment of bowel concerned and ileus. Within the wall of the intestine there are many anastomoses of blood vessels so that blockage of a single vessel is usually not dangerous. The arteries are paralleled by veins which convey blood to the portal vein. Closely related to the venous drainage are the lymph vessels which pass the mesenteric lymph nodes and finally enter the cisterna chyli.

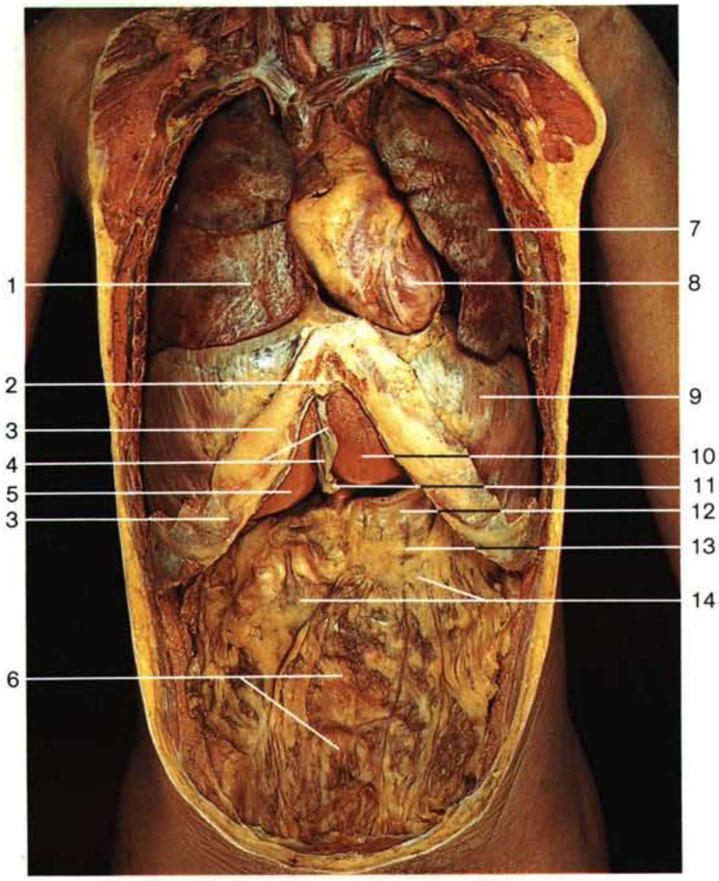

Abdominal organs. The anterior thoracic and abdominal walls have been removed.

1 Middle lobe of right lung
2 Xiphoid process
3 Costal margin
4 Falciform ligament of liver
5 Quadrate lobe of liver
6 Greater omentum
7 Upper lobe of left lung
8 Heart
9 Diaphragm
10 Left lobe of liver
11 Ligamentum teres
12 Stomach
13 Gastrocolic ligament
14 Transverse colon
15 Taenia coli
16 Appendices epiploicae
17 Cecum
18 Taenia coli
19 Ileum
20 Transverse mesocolon
21 Jejunum
22 Sigmoid colon
23 Position of root of mesentery
24 Vermiform appendix
25 Duodenojejunal flexure
26 Mesentery

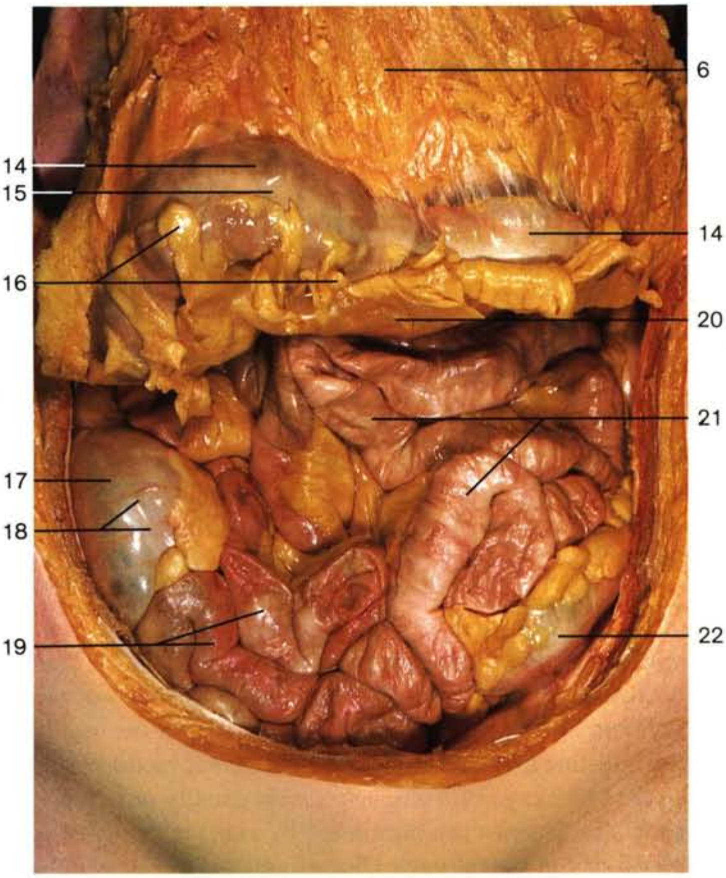

Abdominal organs. The greater omentum which is fixed to the transverse colon has been raised.

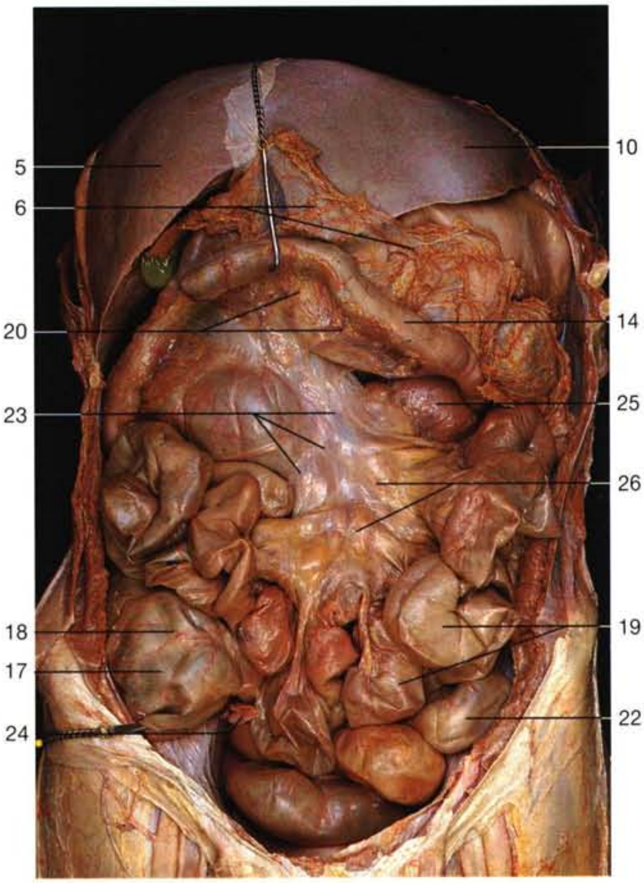

Abdominal organs (anterior aspect). The transverse colon has been reflected.

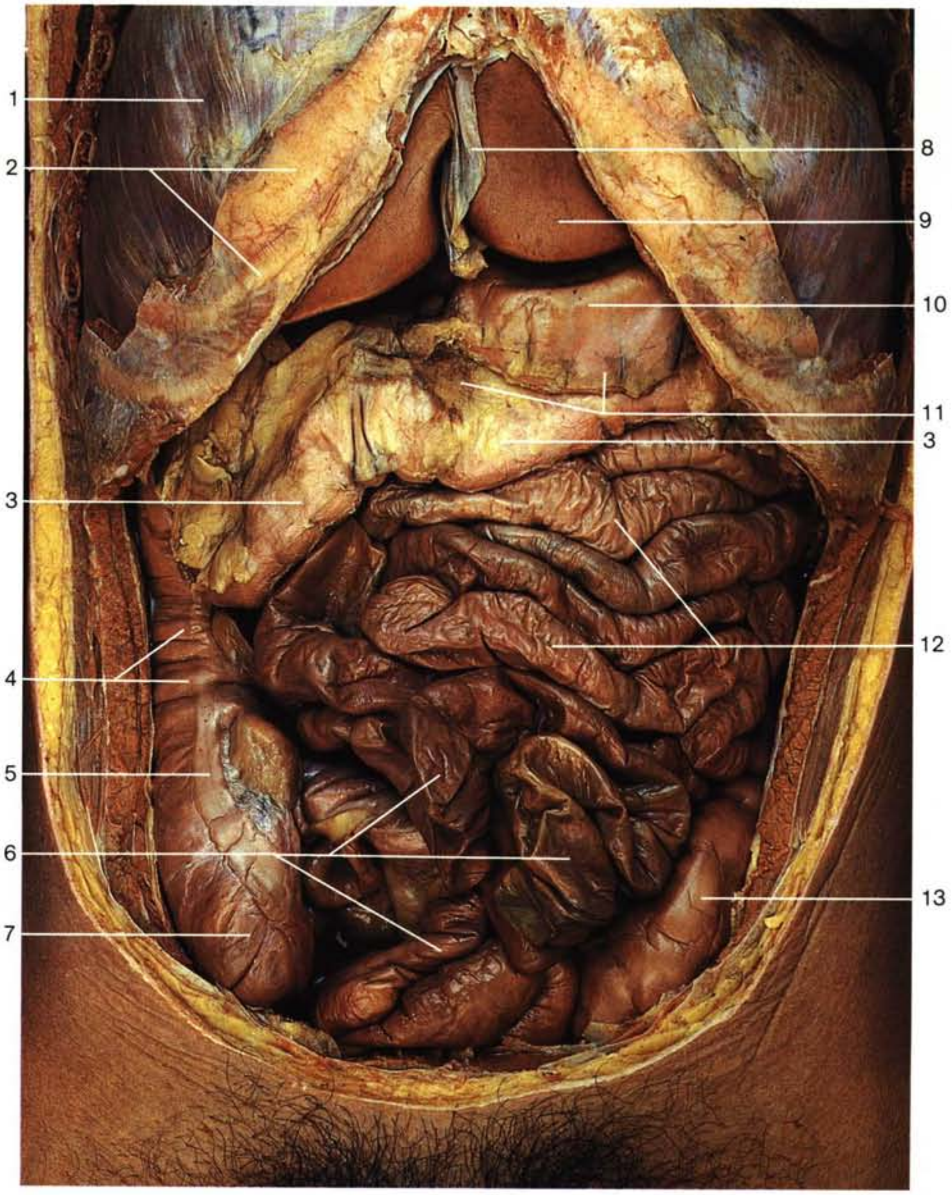

Abdominal organs in situ. The greater omentum has been removed.

1 Diaphragm
2 Costal margin
3 Transverse colon
4 Ascending colon with haustra
5 Free taenia of cecum
6 **Ileum**
7 **Cecum**
8 **Falciform ligament of liver**
9 Liver
10 Stomach
11 Gastrocolic ligament
12 Jejunum
13 Sigmoid colon
14 **Vermiform appendix**
15 Terminal ileum
16 **Mesoappendix**
17 Mesentery

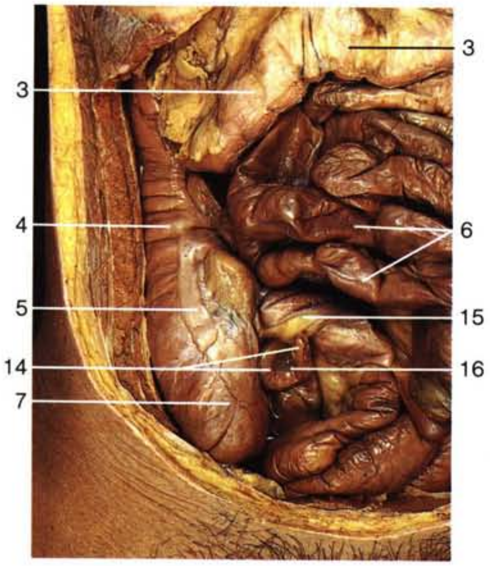

Ascending colon, cecum and vermiform appendix (detail of the preceding figure).

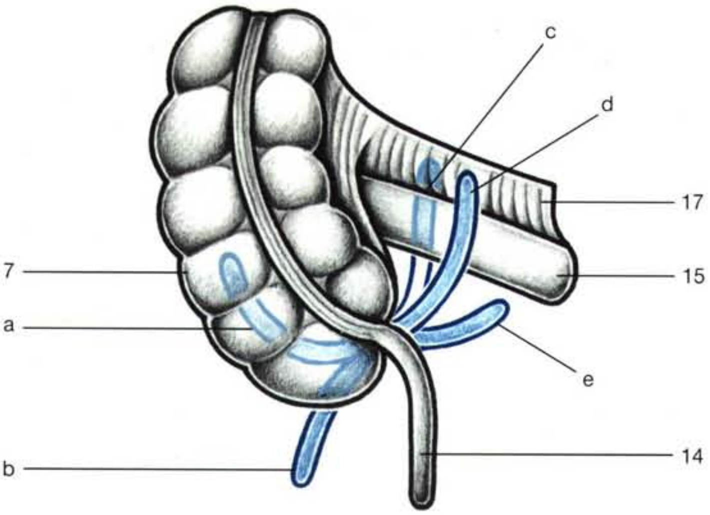

Variations in the position of the vermiform appendix. a = retrocecal; b = paracolic; c = retroileal; d = preileal; e = subcecal.

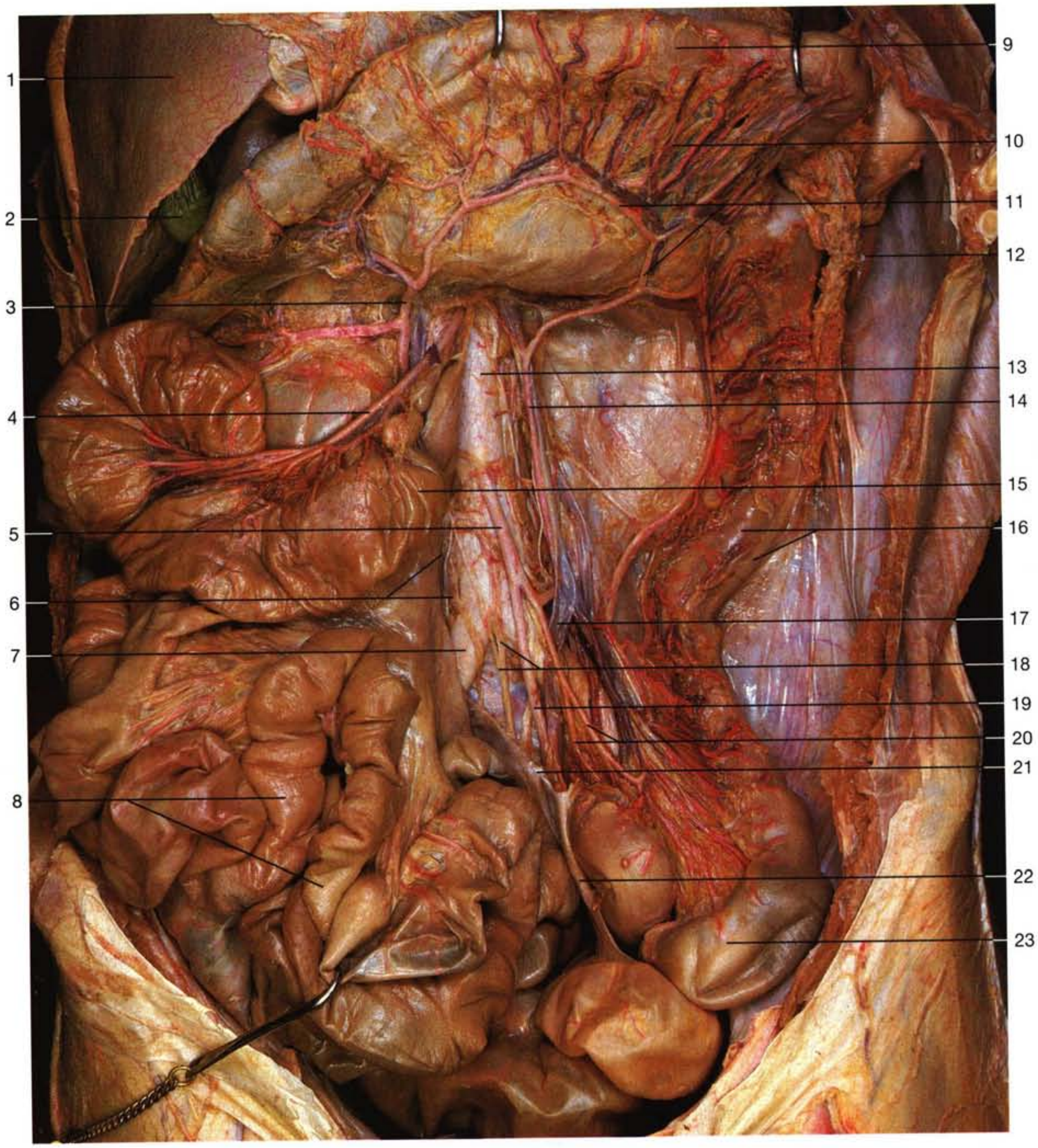

Abdominal organs. Dissection of inferior mesenteric artery and autonomic plexus. The transverse colon with mesocolon has been raised and the small intestine reflected.

1 Liver
2 Gallbladder
3 **Middle colic artery**
4 Jejunal artery
5 **Inferior mesenteric artery**
6 Sympathetic nerves and ganglia
7 Right common iliac artery
8 Small intestine (ileum)
9 Transverse colon (reflected)
10 Transverse mesocolon
11 Anastomosis between middle and left colic artery
12 Spleen
13 **Abdominal aorta**
14 **Left colic artery**
15 Duodenojejunal flexure
16 Descending colon (free taenia of colon)
17 Inferior mesenteric vein
18 Superior hypogastric plexus
19 **Superior rectal artery**
20 Sigmoid arteries
21 Peritoneum (cut edge)
22 Sigmoid mesocolon
23 Sigmoid colon

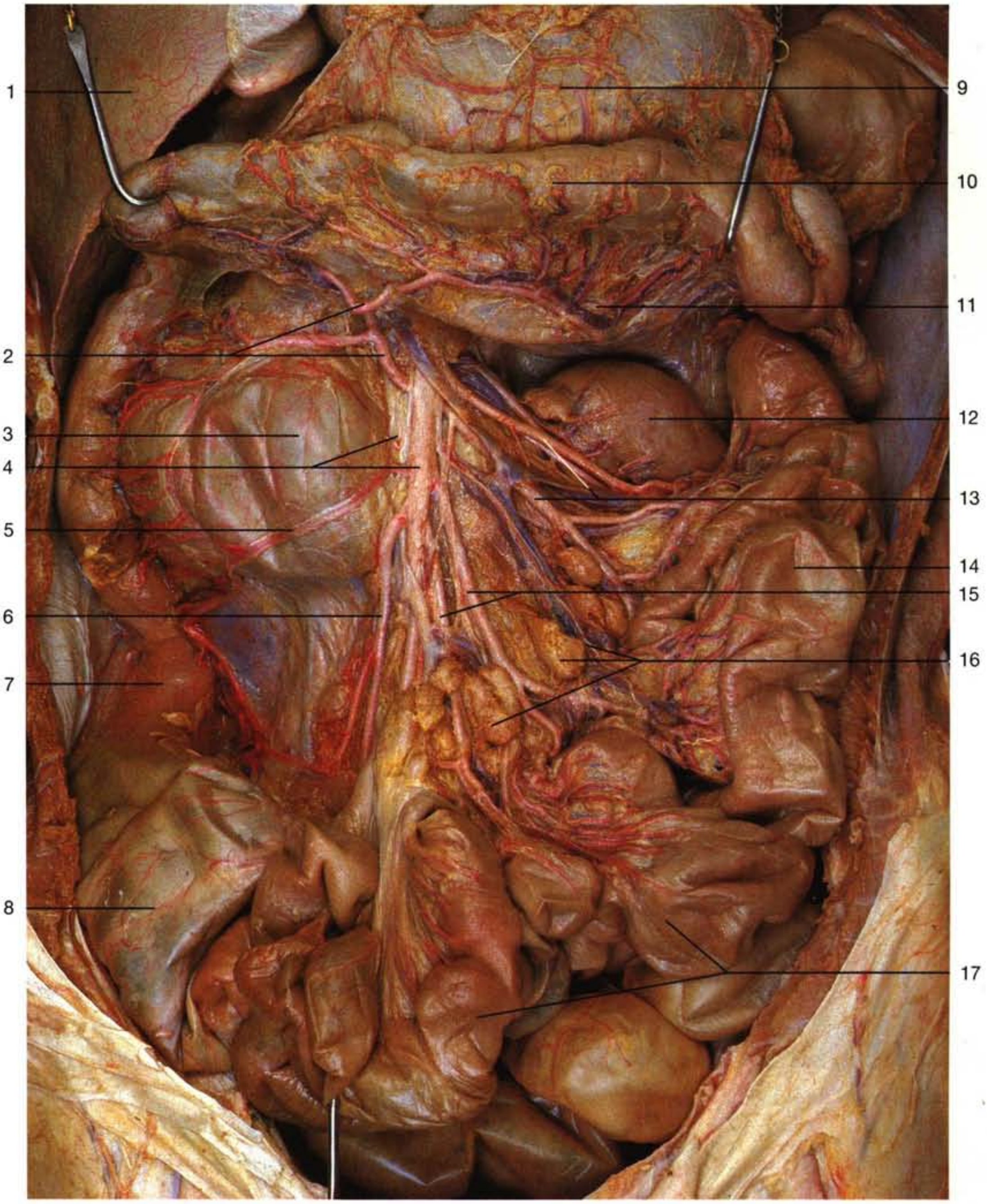

1 Liver
2 Middle colic artery
3 Horizontal part of duodenum (extended)
4 **Superior mesenteric artery and vein**
5 **Right colic artery**
6 **Iliocolic artery**
7 Ascending colon
8 Cecum
9 Greater omentum (reflected)
10 Transverse colon
11 Transverse mesocolon
12 Duodenojejunal flexure
13 **Jejunal arteries**
14 Jejunum
15 **Ileal arteries**
16 **Mesenteric lymph nodes and lymph vessels**
17 Ileum
18 Abdominal aorta
19 Inferior vena cava
20 Stomach
21 Spleen
22 Splenic artery
23 Head of pancreas
24 Superior mesenteric artery

Abdominal organs. Superior mesenteric artery. Mesenteric lymph nodes. Transverse colon reflected.

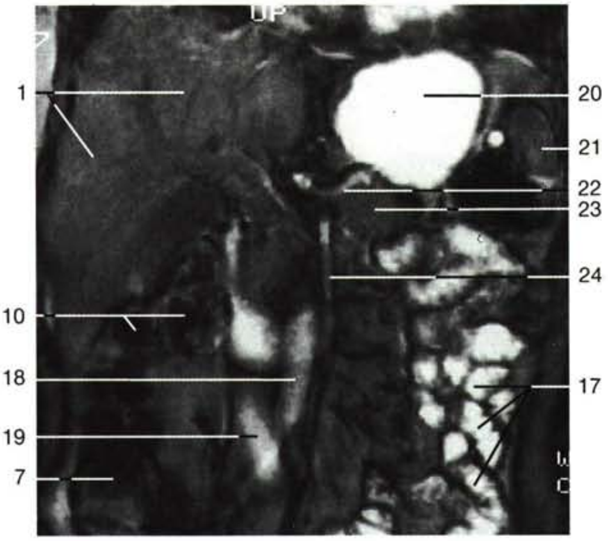

Frontal section through the abdominal cavity. (MR-Scan: the intestinal tract and vessels are filled with a paramagnetic substance [Gadolinium]; courtesy of Dr. W. Rödl, Erlangen.)

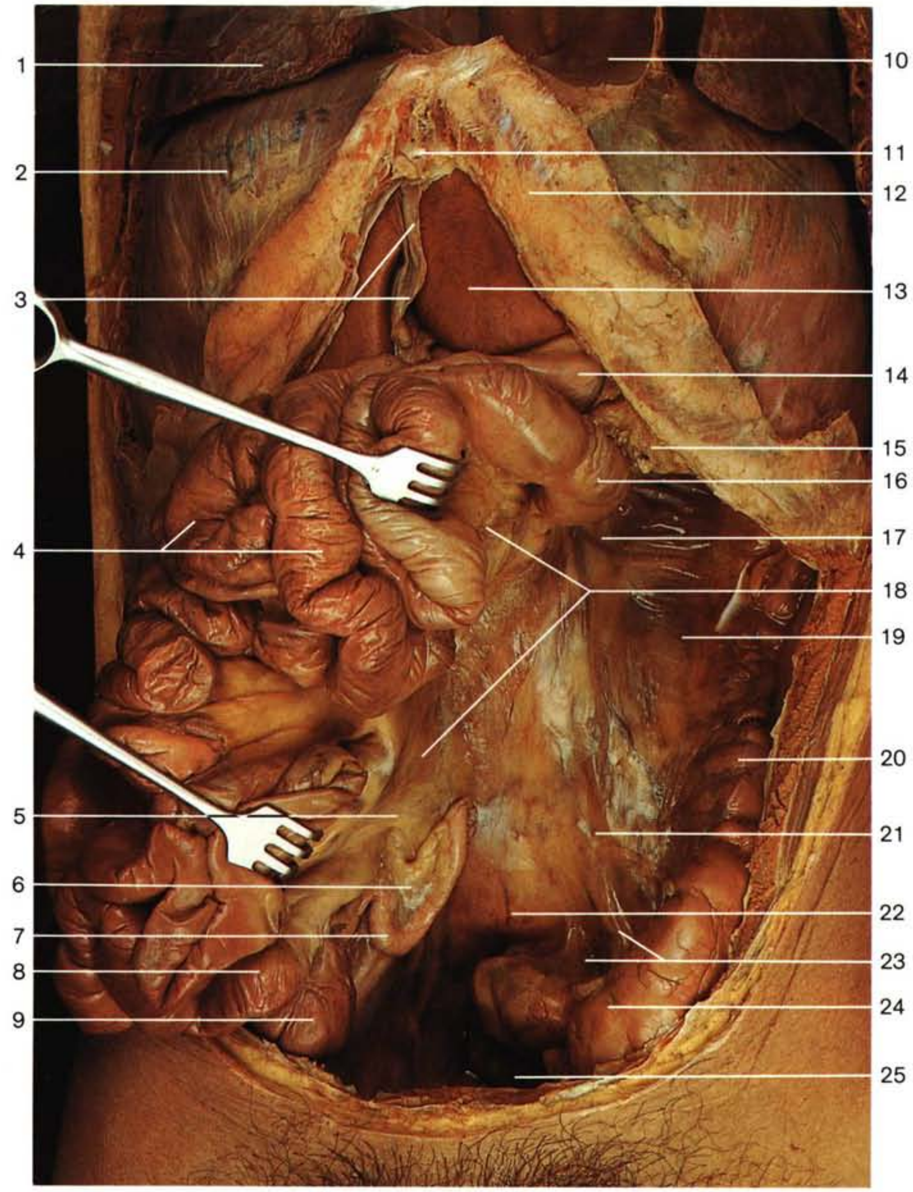

Abdominal cavity. Mesenteries. The small intestine has been reflected laterally to demonstrate the mesentery.

1	Lung
2	Diaphragm
3	Falciform ligament of liver
4	Jejunum
5	Ileocecal fold
6	Mesoappendix
7	Vermiform appendix
8	**Ileocecal junction**
9	**Cecum**
10	Pericardial sac
11	Xiphoid process
12	Costal margin
13	Liver
14	Stomach
15	Transverse colon
16	**Duodenojejunal flexure**
17	Inferior duodenal fold
18	Mesentery
19	Position of left kidney
20	Descending colon
21	Position of left common iliac artery
22	Sacral promontory
23	Sigmoid mesocolon
24	Sigmoid colon
25	Rectum
26	Beginning of jejunum
27	Peritoneum of posterior abdominal wall
28	Transverse mesocolon
29	Superior duodenal fold
30	Superior duodenal recess
31	Retroduodenal recess
32	Free taenia of ascending colon
33	**Ileocecal valve**
34	Frenulum of ileocecal valve
35	Orifice of vermiform appendix (probe)
36	**Ileocolic artery**
37	Vermiform appendix with appendicular artery
38	Ascending colon

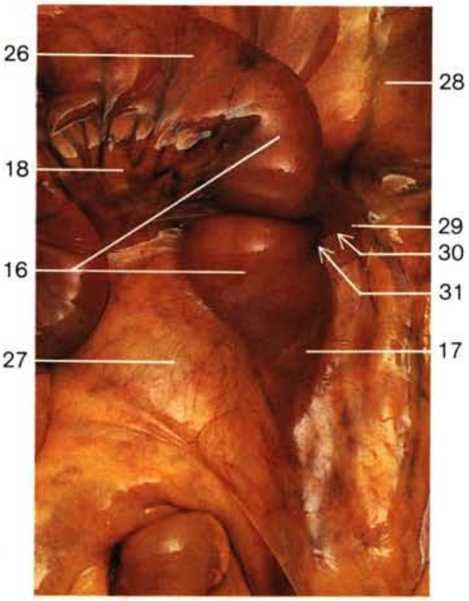

Duodenojejunal flexure (enlargement of preceding figure).

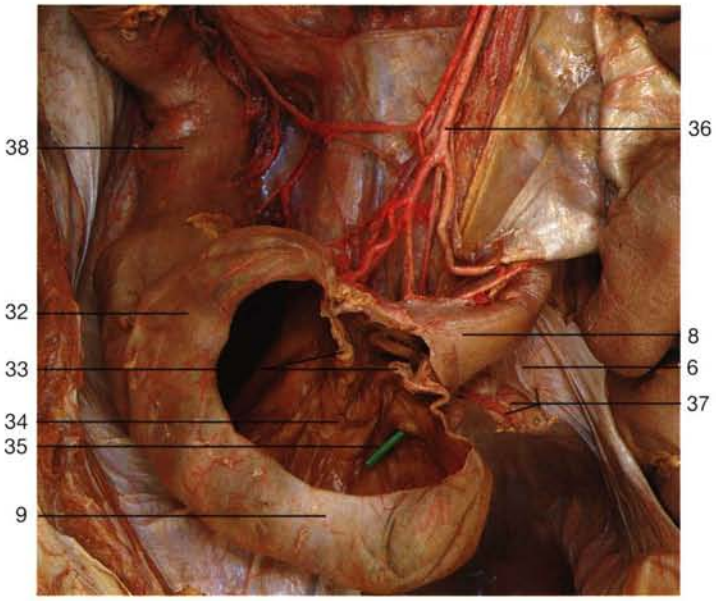

Ileocecal valve (ventral aspect). The cecum and terminal part of the ileum have been opened.

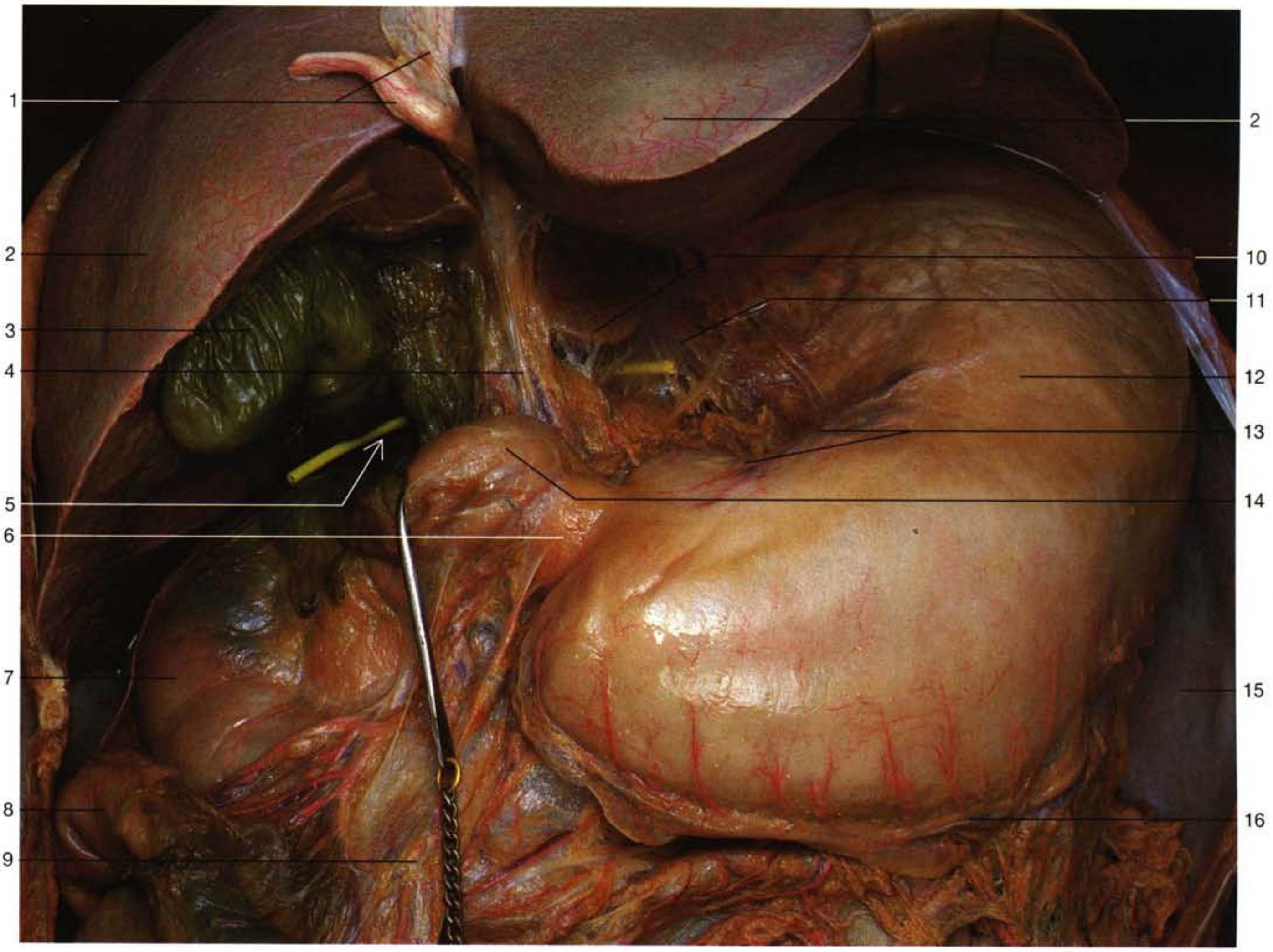

Upper abdominal organs. Thorax and anterior part of diaphragm have been removed and the liver raised to display the lesser omentum. A probe has been inserted into the epiploic foramen and lesser sac.

1 Falciform ligament and ligamentum teres
2 Liver
3 Gallbladder (fundus)
4 Hepatoduodenal ligament
5 **Epiploic foramen** (probe)
6 Pylorus
7 Descending part of duodenum
8 Right colic flexure
9 **Gastrocolic ligament**
10 Caudate lobe of liver (behind lesser omentum)
11 **Lesser omentum**
12 Stomach
13 Lesser curvature of stomach
14 Superior part of duodenum
15 Diaphragm
16 Greater curvature of stomach with gastroepiploic vessels
17 Twelfth thoracic vertebra
18 Right kidney
19 Right suprarenal gland
20 Inferior vena cava
21 Falciform ligament of liver
22 Abdominal aorta
23 Spleen
24 Lienorenal ligament
25 Gastrosplenic ligament
26 Pancreas
27 Lesser sac

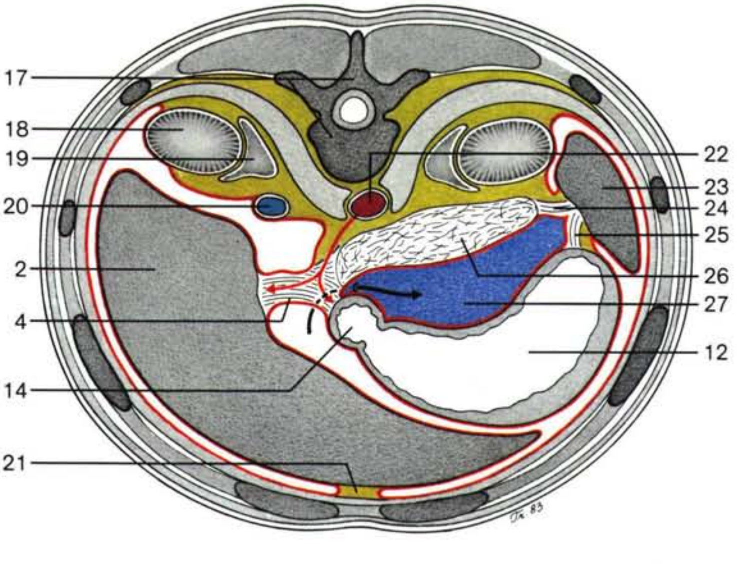

Horizontal section through omental bursa above the level of epiploic foramen (black arrow). Viewed from above. Red arrows: routes of the arterial branches of celiac trunk to liver, stomach, duodenum, and pancreas. (Schematic drawing.)

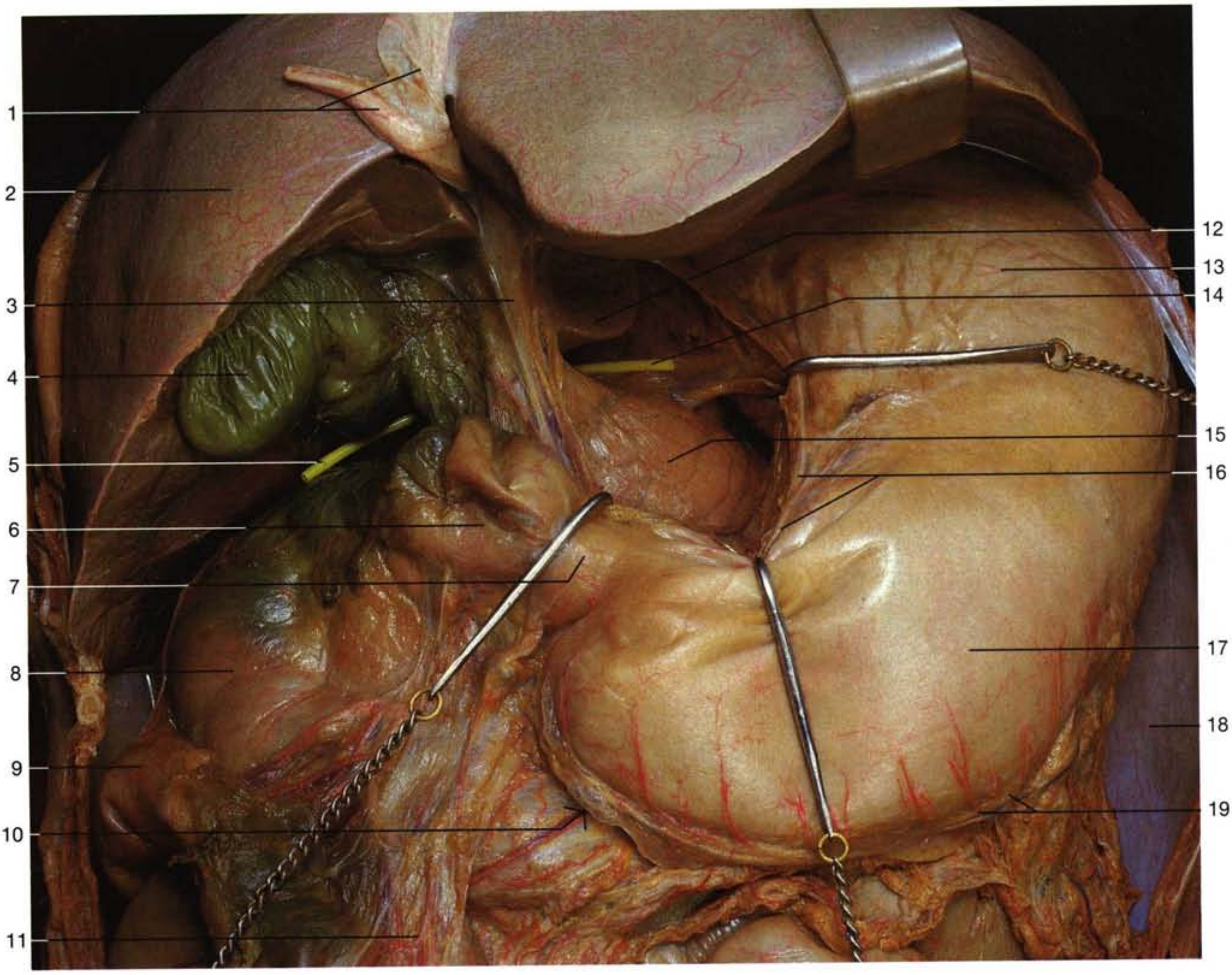

Upper abdominal organs, lesser sac, omental bursa (anterior aspect). Lesser omentum partly removed, liver and stomach slightly reflected.

1 Falciform ligament and ligamentum teres
2 Liver
3 **Hepatoduodenal ligament**
4 Gallbladder
5 Probe within the epiploic foramen
6 Superior part of duodenum
7 Pylorus
8 Descending part of duodenum
9 Right colic flexure
10 Gastrocolic ligament
11 **Greater omentum**
12 Caudate lobe of liver
13 Fundus of stomach
14 Probe at the level of the vestibule of lesser sac
15 **Head of pancreas**
16 Lesser curvature of stomach
17 **Body of stomach**
18 Diaphragm
19 Greater curvature with gastroepiploic vessels
20 Head of pancreas and gastropancreatic fold
21 **Spleen**
22 **Tail of pancreas**
23 Left colic flexure
24 Root of transverse mesocolon
25 Transverse mesocolon
26 Gastrocolic ligament (cut edge)
27 **Transverse colon**
28 Umbilicus
29 Small intestine
30 Lesser omentum
31 Lesser sac (omental bursa)
32 Duodenum
33 Mesentery
34 Sigmoid colon

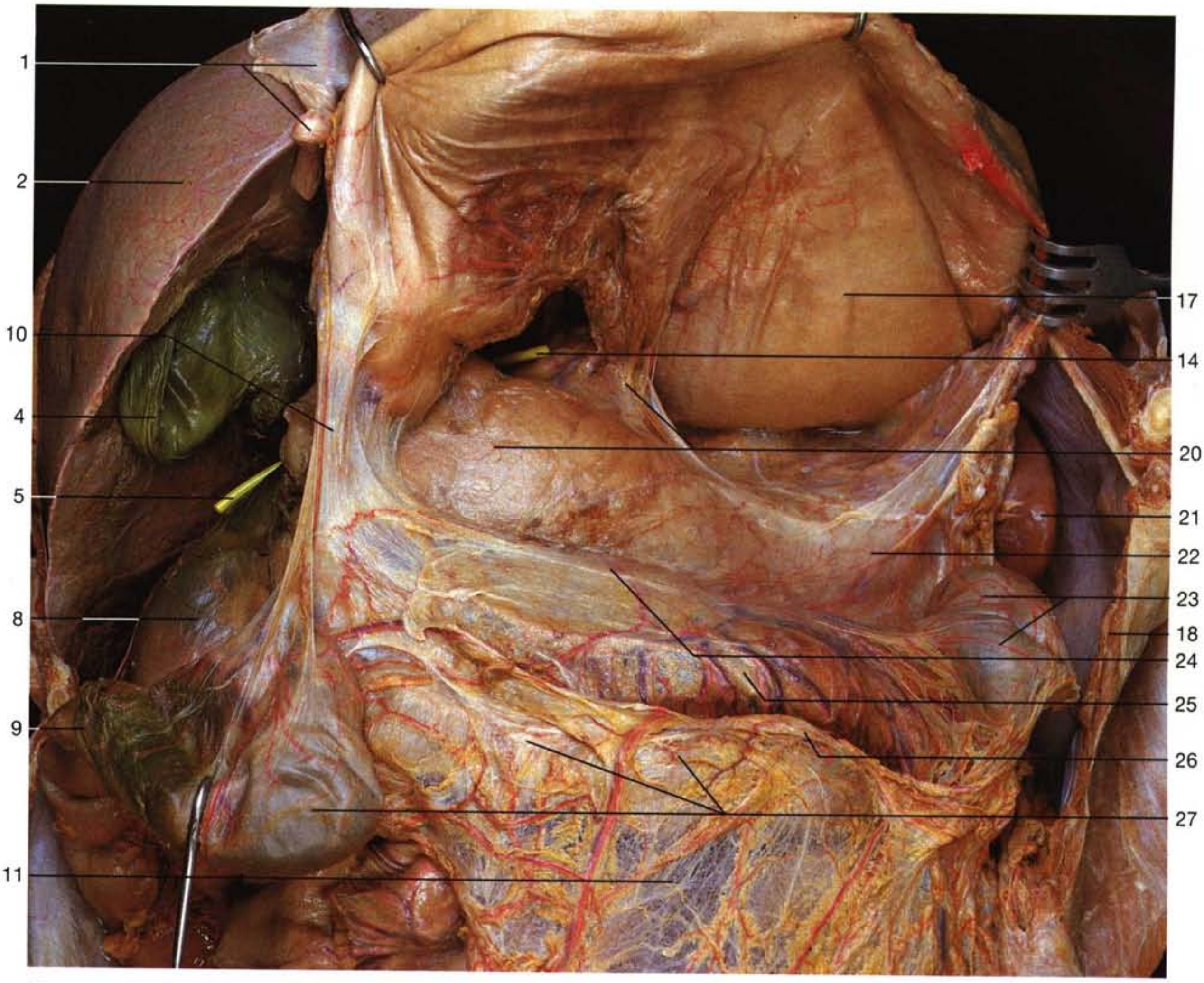
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Upper abdominal organs, lesser sac, omental bursa (anterior aspect). The gastrocolic ligament has been divided and the whole stomach raised to display the posterior wall of the lesser sac.

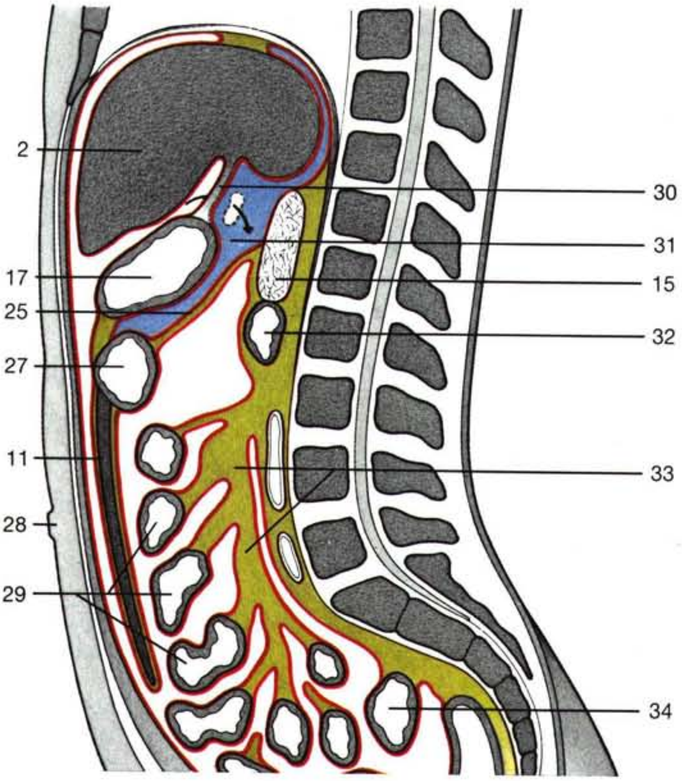
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Midsagittal section through abdominal cavity demonstrating the site of lesser sac (blue). (Schematic drawing.) The epiploic foramen, entrance to the lesser sac, is indicated by an arrow. Red = peritoneum.

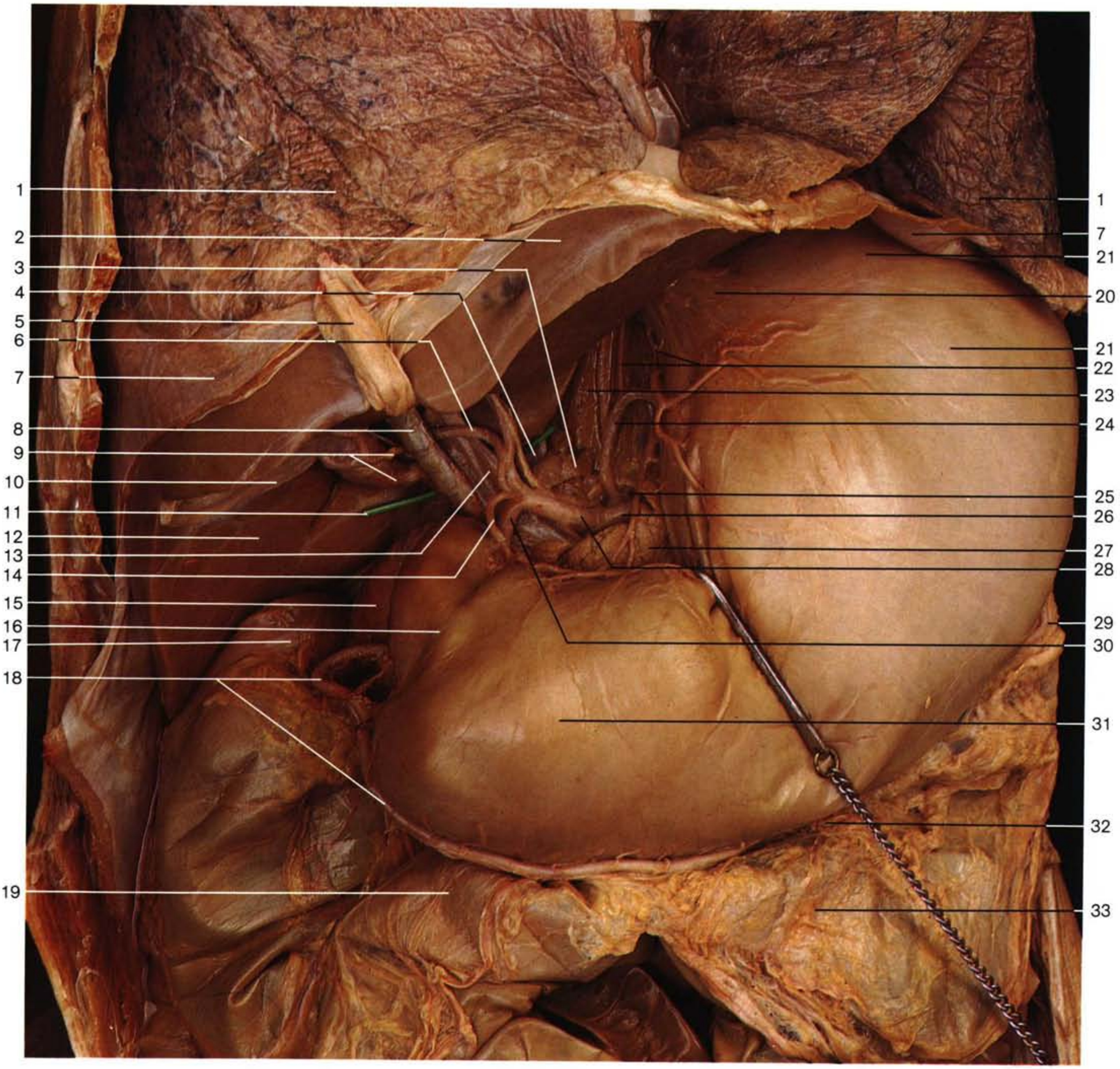
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Arteries of upper abdominal organs; dissection of celiac trunk. The lesser omentum has been removed and the lesser curvature of the stomach reflected to display the branches of the celiac trunk.

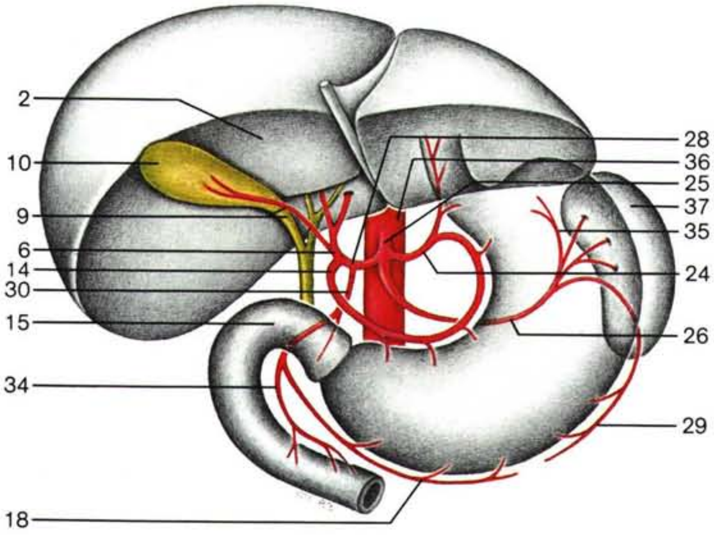
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Branches of celiac trunk.
(Schematic drawing.)

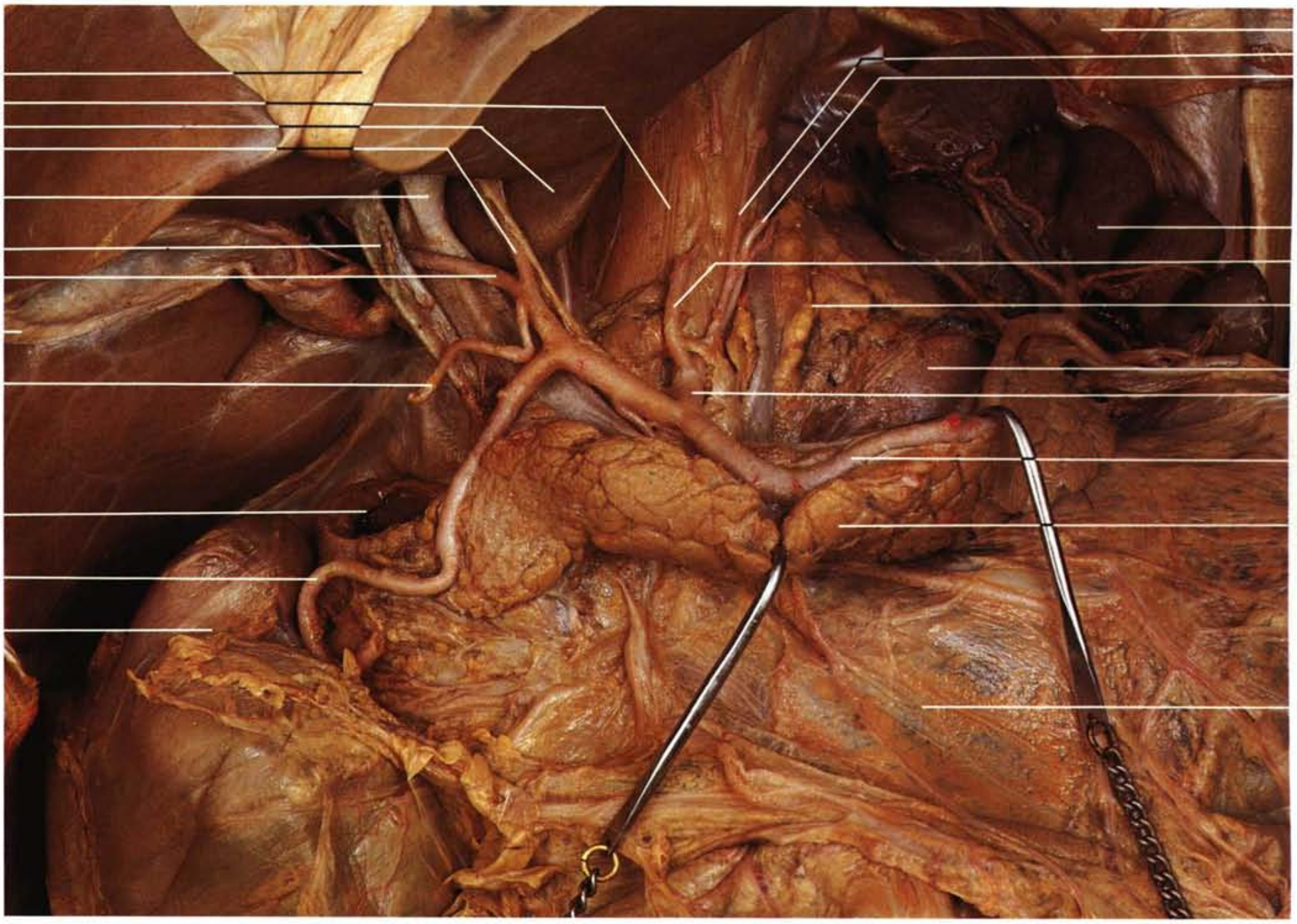

Branches of celiac trunk; blood supply of liver, pancreas and spleen. The stomach, superior part of duodenum and celiac ganglion have been removed to reveal the anterior aspect of the posterior wall of the lesser sac (omental bursa) and the vessels and ducts of the hepatoduodenal ligament. The pancreas has been slightly reflected anteriorly.

1 Lung
2 Liver (visceral surface)
3 Lymph node
4 Inferior vena cava
5 Ligamentum teres (reflected)
6 Right branch of hepatic artery proper
7 Diaphragm
8 **Common hepatic duct** (dilated)
9 Cystic duct and artery
10 Gallbladder
11 Probe in epiploic foramen
12 Right lobe of liver
13 **Portal vein**
14 **Right gastric artery**
15 Duodenum
16 Pylorus
17 Right colic flexure
18 **Right gastro-omental** (gastroepiploic) **artery**
19 Transverse colon
20 Abdominal part of esophagus (cardiac part of stomach)
21 Fundus of stomach
22 Esophageal branches of left gastric artery
23 Lumbar part of diaphragm
24 Left gastric artery
25 **Celiac trunk**
26 **Splenic artery**
27 Pancreas
28 **Common hepatic artery**
29 Left gastro-omental (gastroepiploic) artery
30 **Gastroduodenal artery**
31 Pyloric part of stomach
32 Greater curvature of stomach
33 Gastrocolic ligament
34 Superior pancreaticoduodenal artery
35 Short gastric arteries
36 Aorta
37 Spleen
38 Caudate lobe of liver
39 Left branch of hepatic artery proper
40 Descending part of duodenum (cut)
41 Left inferior phrenic artery
42 Suprarenal gland
43 Kidney
44 Transverse mesocolon

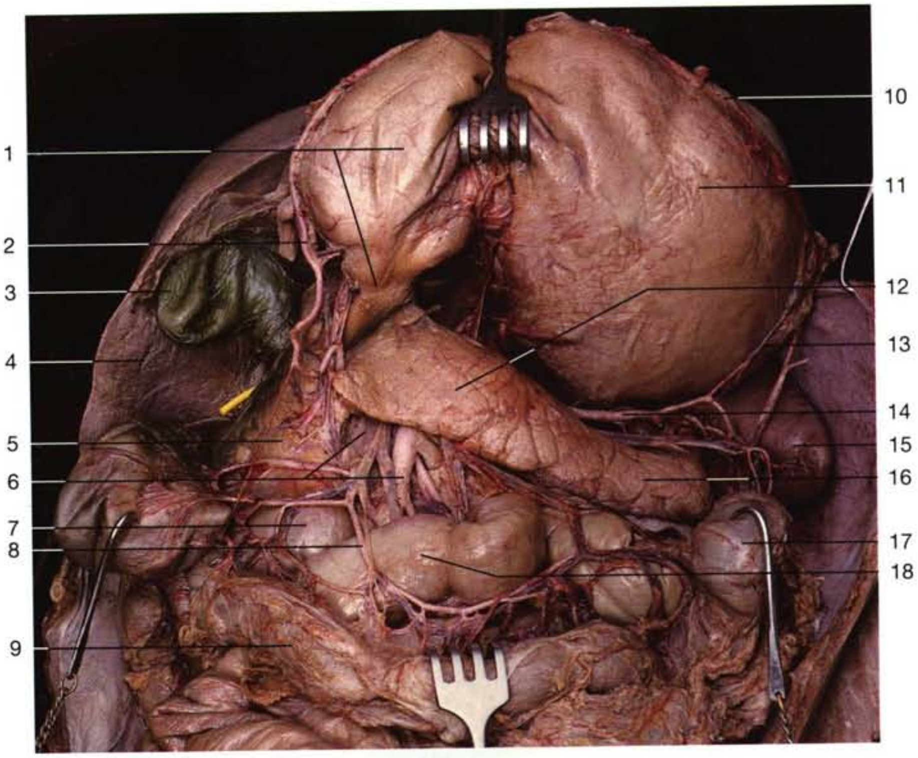

Pancreas and extrahepatic bile ducts in situ (anterior aspect). The gastrocolic ligament has been divided, the transverse colon and the stomach were replaced to display pancreas and superior mesenteric vessels.

1 Stomach (pyloric part) and pylorus
2 Right gastro-omental (gastroepiploic) artery
3 **Fundus of gall bladder**
4 Liver, right lobe
5 Head of pancreas
6 **Superior mesenteric artery** and **vein**
7 Duodenum
8 Middle colic artery
9 Transverse colon
10 Greater curvature of stomach (remnants of gastrocolic ligament)
11 **Body of stomach**
12 **Body of pancreas**
13 Left gastro-omental (gastroepiploic) artery
14 **Splenic artery**
15 **Spleen**
16 Tail of pancreas
17 Left colic flexure
18 Jejunum
19 Lung (inferior lobe of right lung)
20 **Common hepatic duct** and caudate lobe of liver
21 Portal vein and hepatic artery proper
22 Cystic duct and right gastric artery
23 **Common bile duct** and gastroduodenal artery
24 Pylorus (cut)
25 Major and minor duodenal papillas (probes)
26 Duodenum (inferior part)
27 Right kidney, ureter and ovarian artery
28 Iliocolic artery and inferior vena cava
29 Right and left vagal trunk
30 **Esophagus**
31 Diaphragm
32 Cut edge of esophagus, left gastric artery with esophageal branch
33 Celiac trunk
34 Common hepatic artery, main pancreatic duct and **pancreas**
35 Renal vein
36 Duodenojejunal flexure
37 Left kidney
38 Jejunal arteries
39 Abdominal aorta and left ureter
40 Cystic artery
41 Hepatic proper artery
42 **Celiac trunk**
43 Right gastric artery
44 **Common hepatic artery**
45 Gastroduodenal artery
46 **Superior mesenteric artery**
47 Superior posterior pancreaticoduodenal artery
48 Superior anterior pancreaticoduodenal artery
49 Short gastric arteries
50 Left gastric artery
51 Posterior pancreatic branch of splenic artery
52 Inferior pancreaticoduodenal artery

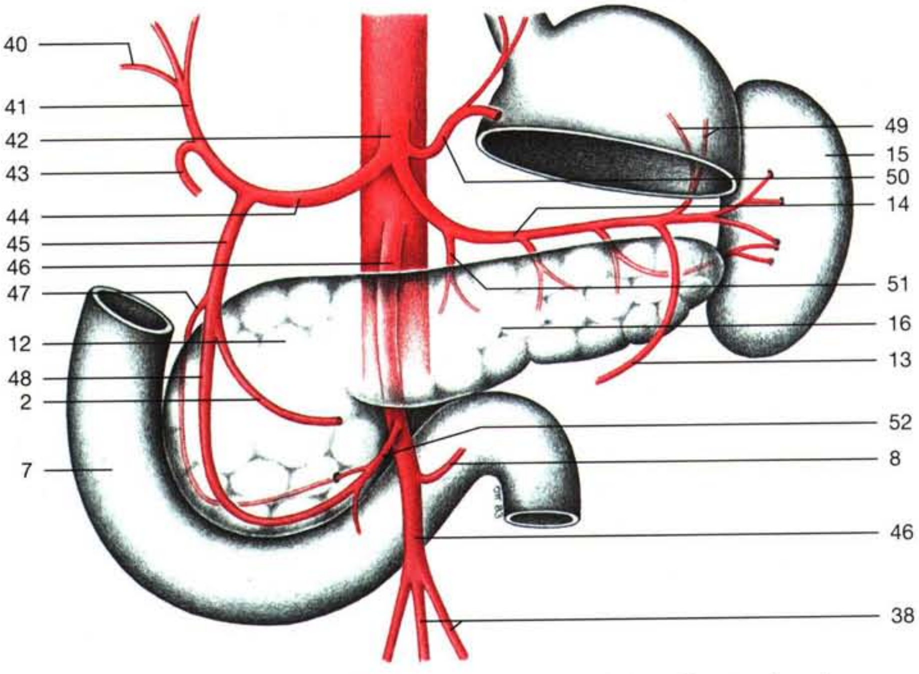

Blood supply of upper abdominal organs (branches of the celiac trunk and superior mesenteric artery). (Schematic drawing.)

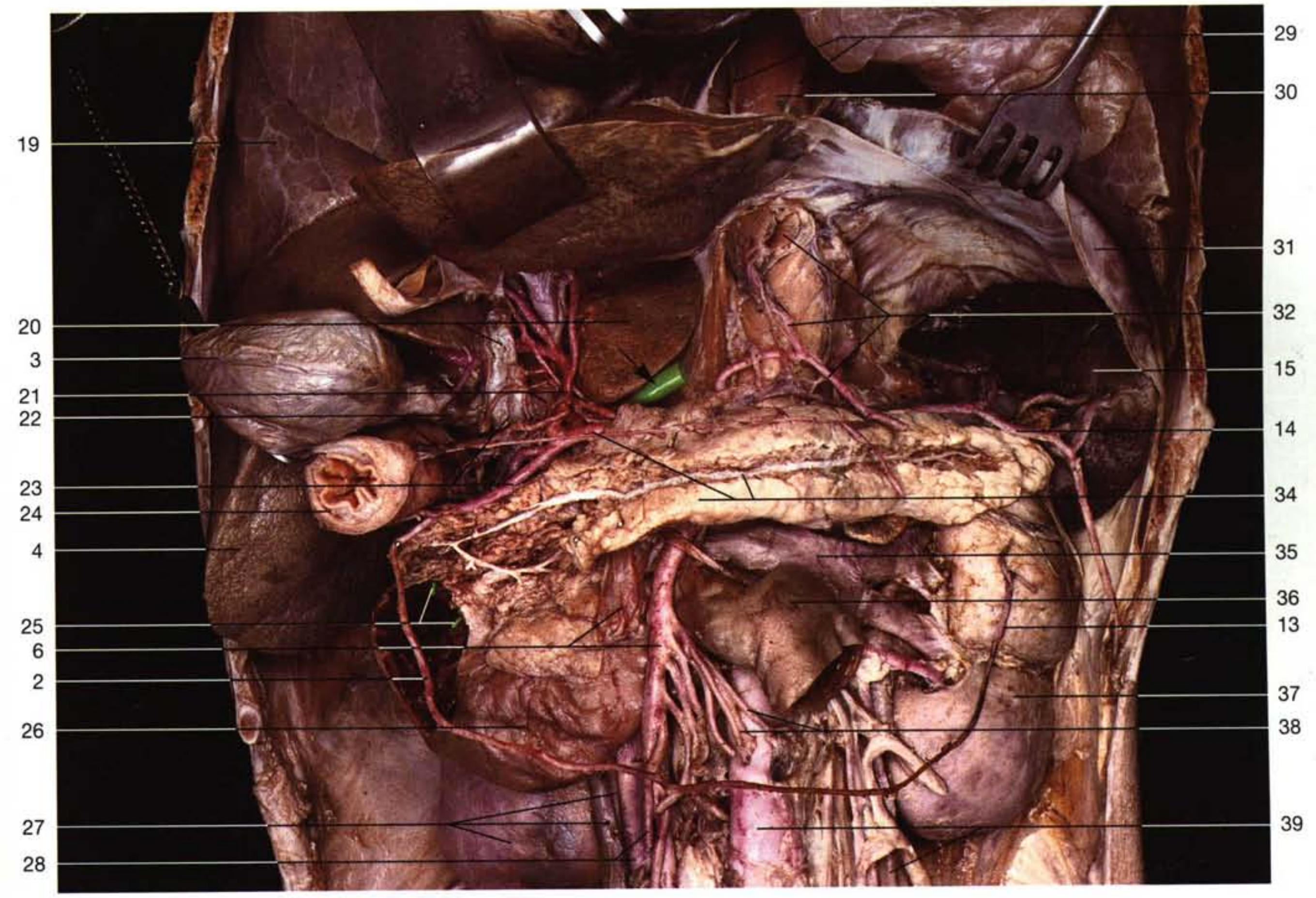
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Pancreas, extrahepatic bile ducts, spleen and liver with their vessels in situ. The stomach has been removed, the liver elevated, and the descending part of duodenum opened to display the openings of pancreatic ducts. The pancreatic ducts were dissected. Note the location of superior mesenteric artery and vein between duodenum and pancreas. Arrow: probe within the epiploic foramen.

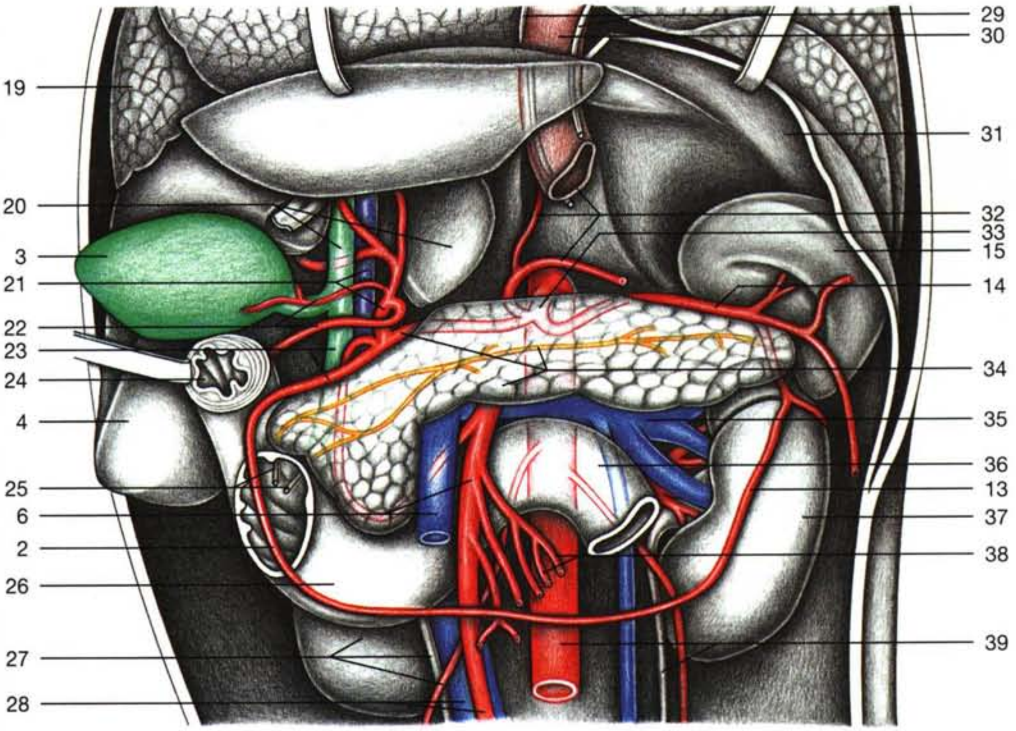
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Schematic drawing of the specimen depicted above. Note the branching of the celiac trunk (partially covered by the body of the pancreas), and the main arterial supply of liver, spleen, pancreas, stomach, and duodenum.

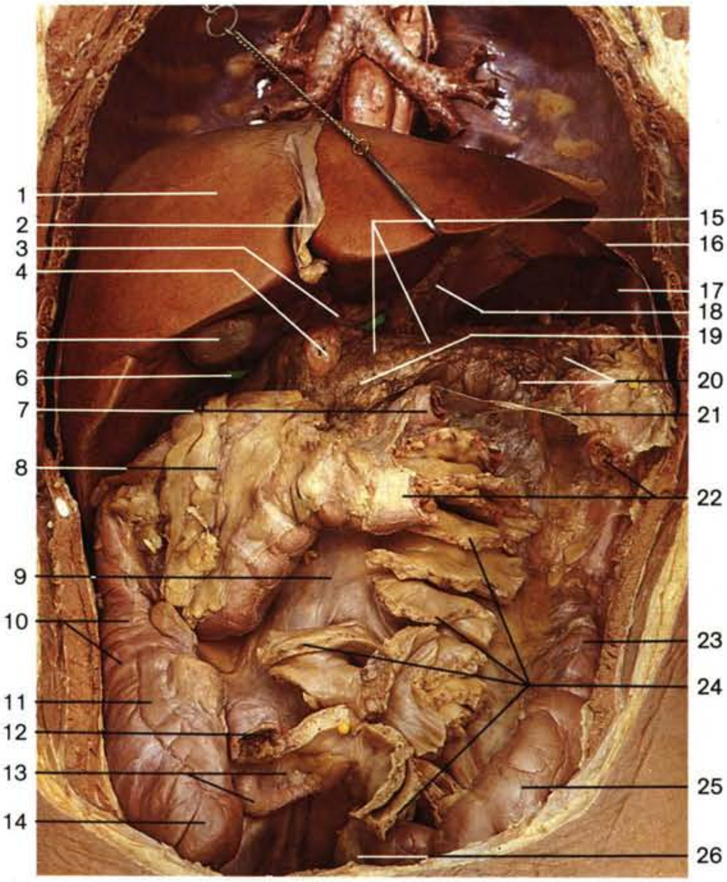

Abdominal cavity after removal of stomach, jejunum, ileum and part of the transverse colon. Liver has been slightly raised.

1 Liver
2 Falciform ligament
3 Hepatoduodenal ligament
4 Pylorus (divided)
5 Gallbladder
6 Probe within the epiploic foramen
7 Duodenojejunal flexure (divided)
8 **Greater omentum**
9 Root of mesentery
10 Ascending colon
11 Free colic taenia
12 End of ileum (divided)
13 Vermiform appendix with mesoappendix
14 Cecum
15 Pancreas and site of lesser sac
16 Diaphragm
17 Spleen
18 Cardia (part of stomach, divided)
19 Head of pancreas
20 Body and tail of pancreas
21 **Transverse mesocolon**
22 Transverse colon (divided)
23 Descending colon
24 Cut edge of mesentery
25 Sigmoid colon
26 Rectum
27 Attachment of bare area of liver
28 Inferior vena cava
29 Kidney
30 Attachment of right colic flexure
31 Root of transverse mesocolon
32 Junction between descending and horizontal parts of duodenum
33 Bare surface for ascending colon
34 **Ileocecal recess**
35 **Retrocecal recess**
36 Root of mesoappendix
37 Superior recess
38 Isthmus (opening) } of **lesser sac (omental bursa)**
39 Splenic recess
40 **Superior duodenal recess**
41 **Inferior duodenal recess**
42 Bare surface for descending colon
43 **Paracolic recesses**
44 **Root of mesentery**
45 Root of mesosigmoid
46 **Intersigmoid recess**
47 Hepatic veins
48 Duodenojejunal flexure
49 Attachment of left colic flexure
50 Esophagus
51 Entrance to lesser sac through the epiploic foramen

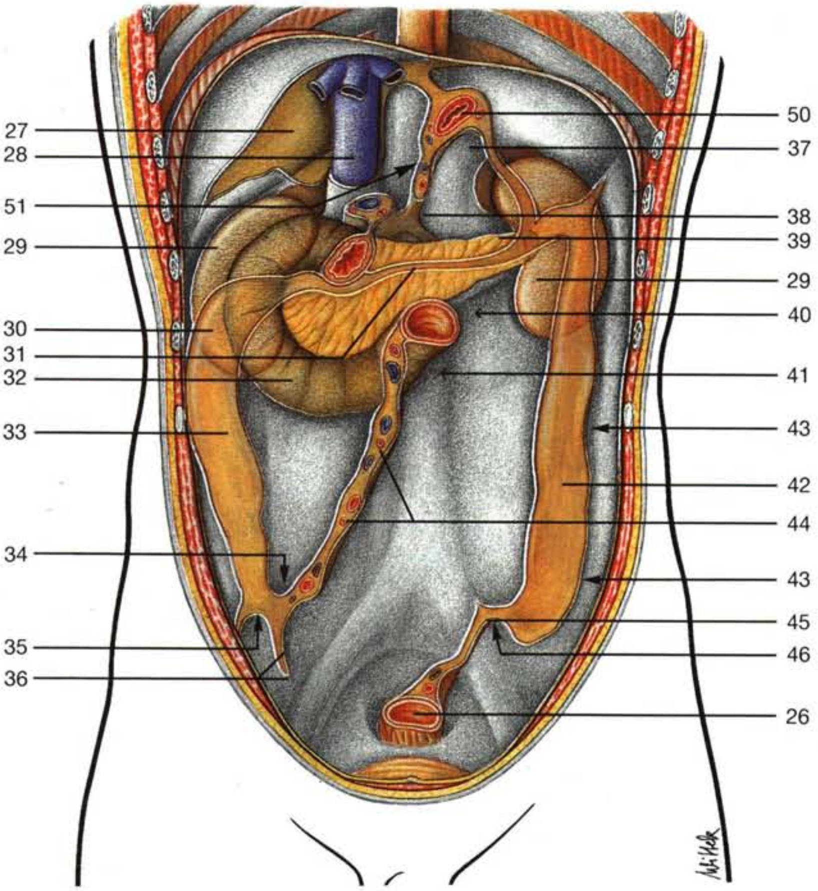

Peritoneal reflections from organs and the position of root of mesentry and peritoneal recesses on the posterior abdominal wall. (Schematic drawing.)

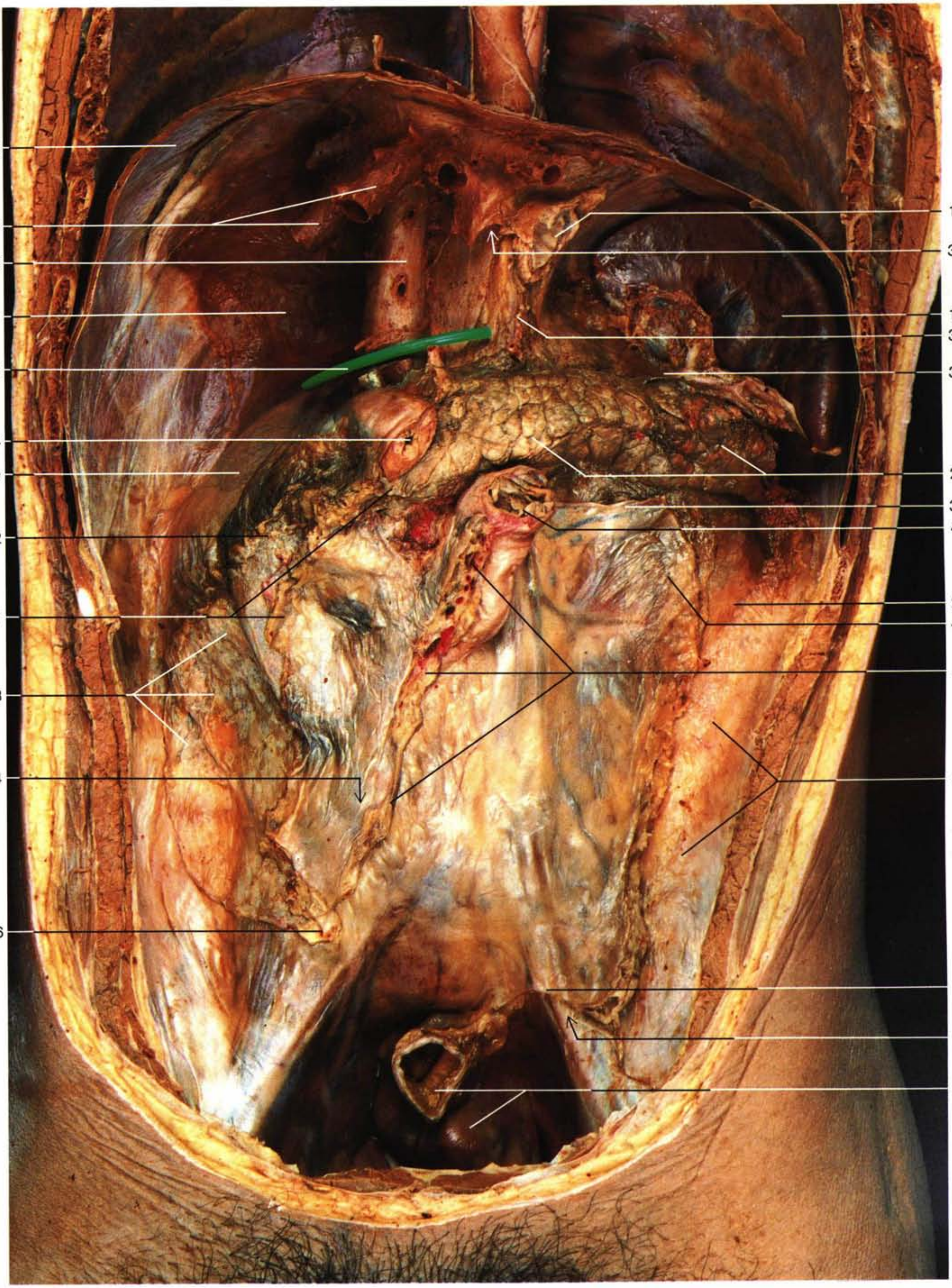
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Peritoneal recesses on the posterior abdominal wall. The liver, stomach, jejunum, ileum, and colon have been removed. The duodenum, pancreas, and spleen have been left in place.

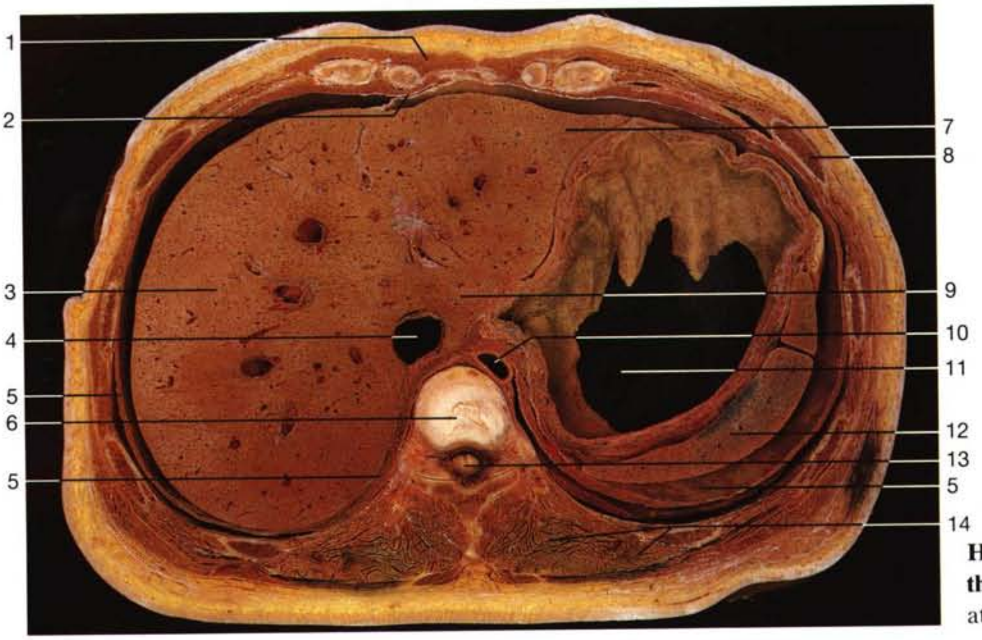

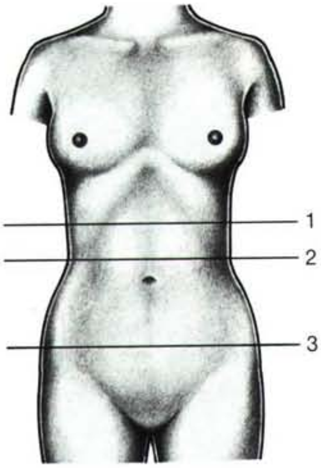

Horizontal section through the abdominal cavity at level 1 (from below).

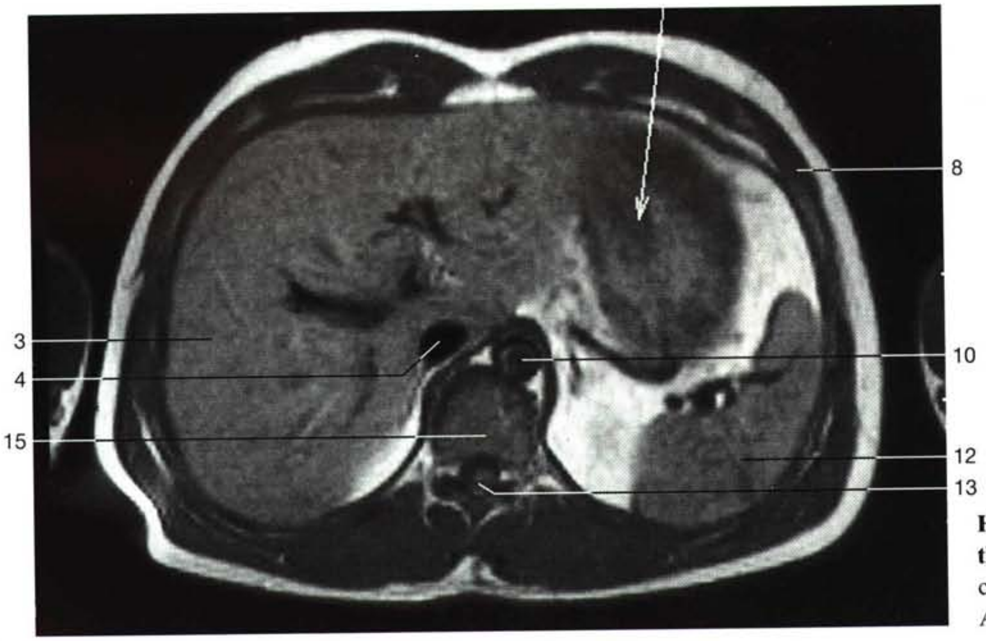

Horizontal section through the body. MR-Scan, corresponding to level 1. Arrow: stomach.

1 Rectus abdominis muscle
2 Falciform ligament
3 **Liver** (right lobe)
4 Inferior vena cava
5 Diaphragm
6 Intervertebral disc
7 Liver (left lobe)
8 Rib
9 Liver (caudate lobe)
10 Abdominal (descending) aorta
11 **Stomach**
12 **Spleen**
13 Spinal cord
14 Longissimus and iliocostalis muscles
15 Body of vertebra
16 Abdominal rectus muscle
17 External abdominal oblique muscle
18 Transverse colon
19 **Head of pancreas**
20 **Greater duodenal papilla**
21 Duodenum
22 Suprarenal gland and ureter
23 **Kidney**
24 Round ligament of liver
25 Superior mesenteric artery and vein
26 Psoas major muscle
27 Descending colon
28 Quadratus lumborum muscle
29 Cauda equina
30 Right renal vein
31 **Small intestine**
32 Iliacus muscle
33 Ilium
34 **Ileocecal valve**
35 Cecum
36 Common iliac artery and vein
37 Gluteus medius muscle
38 Vertebral canal and dura mater

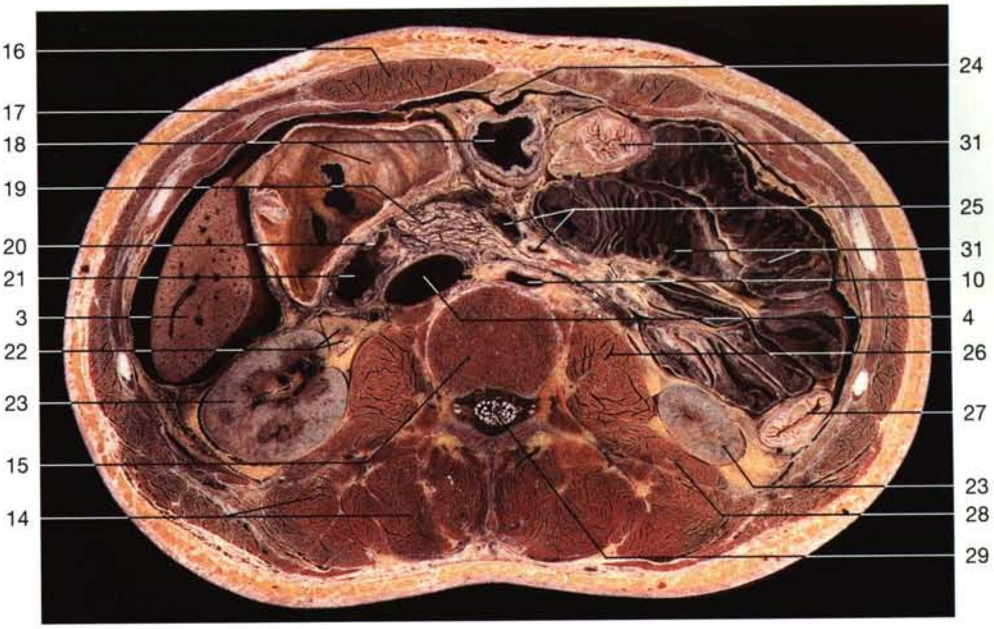
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Horizontal section through the abdominal cavity at the level of greater duodenal papilla (from below).

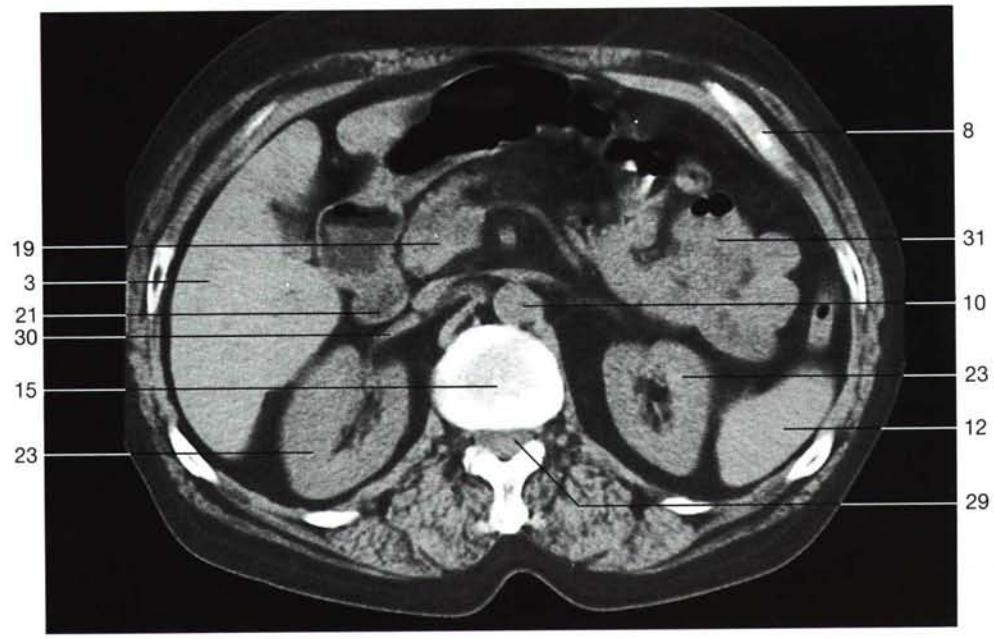
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Horizontal section through the body. CT-Scan, corresponding to level 2.

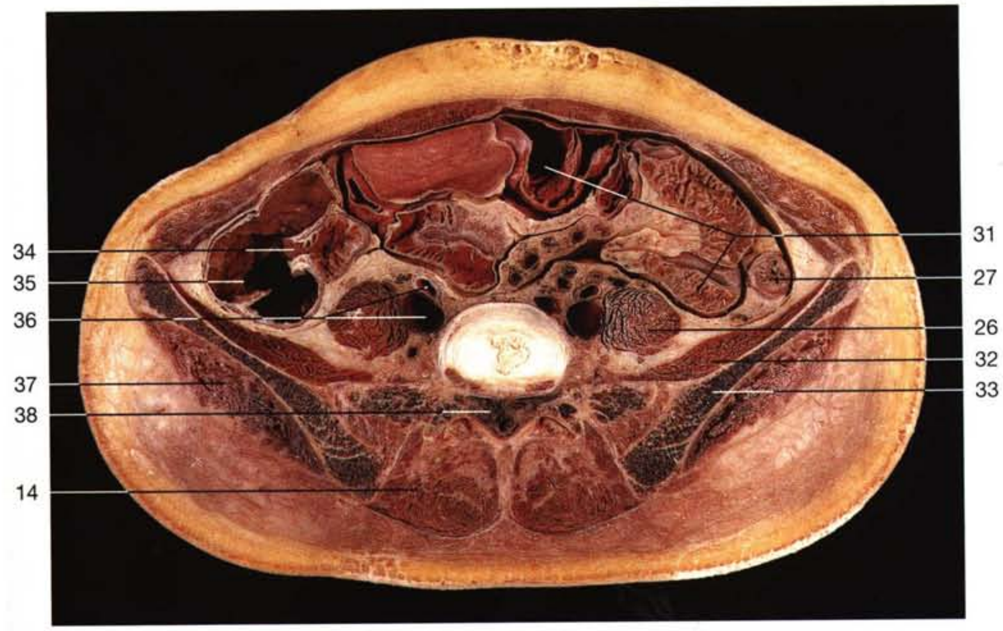
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Horizontal section through the abdominal cavity at level 3 (from below).

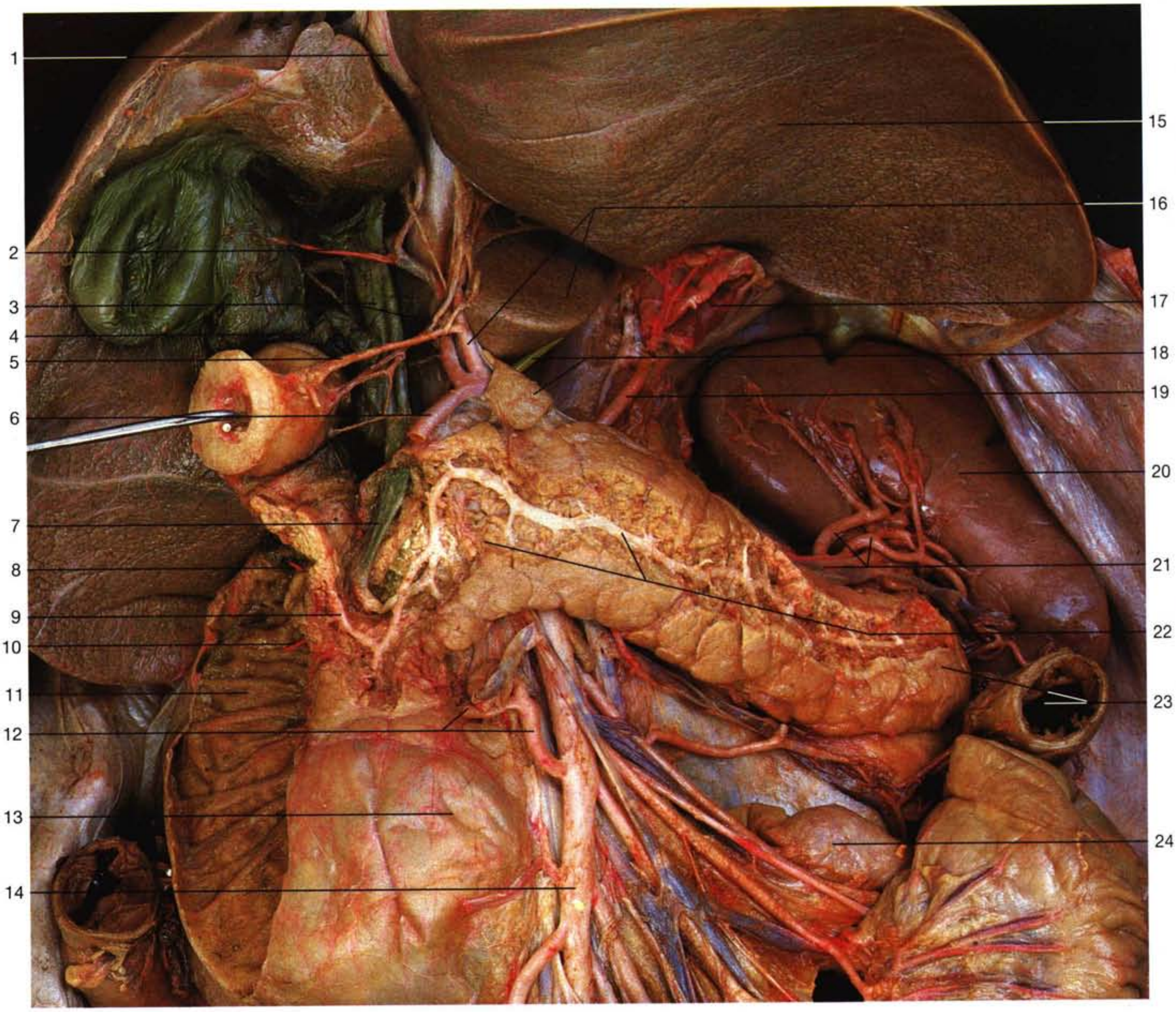

Posterior abdominal wall with duodenum, pancreas and spleen (anterior aspect). Dissection of pancreatic and common bile duct. The stomach has been removed, the liver raised and the duodenum anteriorly opened.

1 Ligamentum teres
2 Gallbladder and cystic artery
3 Common hepatic duct and portal vein
4 Cystic duct
5 Right gastric artery (pylorus with superior part of duodenum, cut and reflected)
6 Gastroduodenal artery
7 **Common bile duct**
8 Probe within the minor duodenal papilla
9 **Accessory pancreatic duct**
10 Probe within the major duodenal papilla
11 Descending part of duodenum (opened)
12 Middle colic artery and inferior pancreaticoduodenal artery
13 Horizontal part of duodenum (distended)
14 **Superior mesenteric artery**
15 Liver (left lobe)
16 Caudate lobe of liver and hepatic artery proper
17 Abdominal part of esophagus (cut)
18 Probe in epiploic foramen and lymph node
19 Left gastric artery
20 **Spleen**
21 Splenic vein and branches of splenic artery
22 **Pancreatic duct and head of pancreas**
23 Left colic flexure and tail of pancreas
24 Duodenojejunal flexure

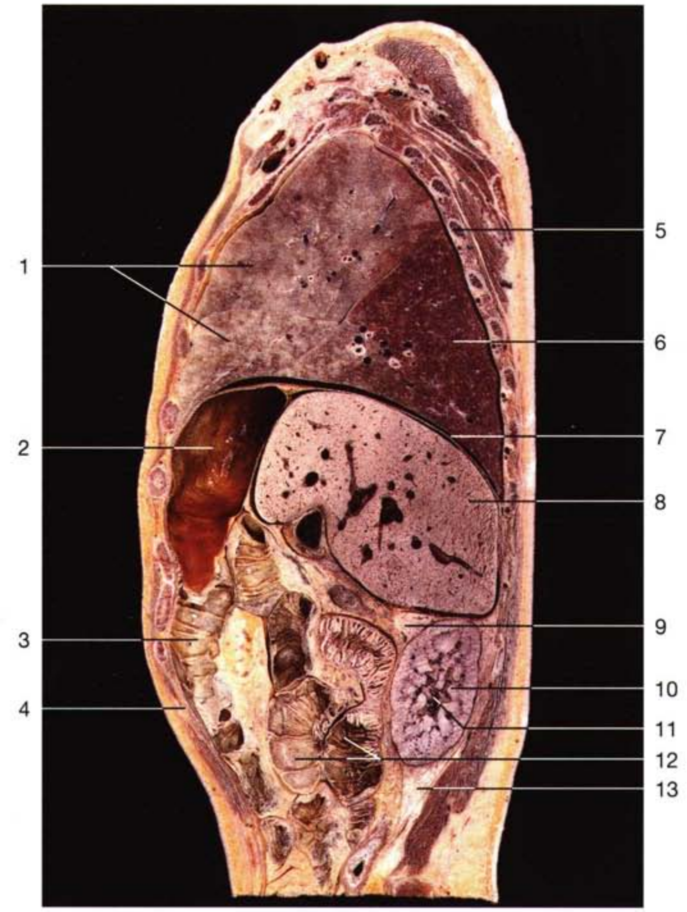

Parasagittal section through the thoracic and abdominal cavities (right side, medial aspect).

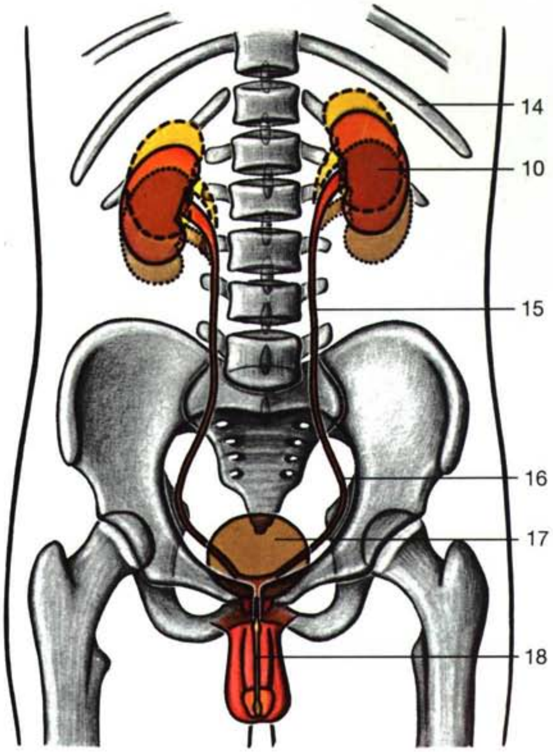

Position of kidneys and urinary system (anterior view). The excursions of the kidneys with the respiratory movements of the diaphragm are indicated. (Schematic drawing.)

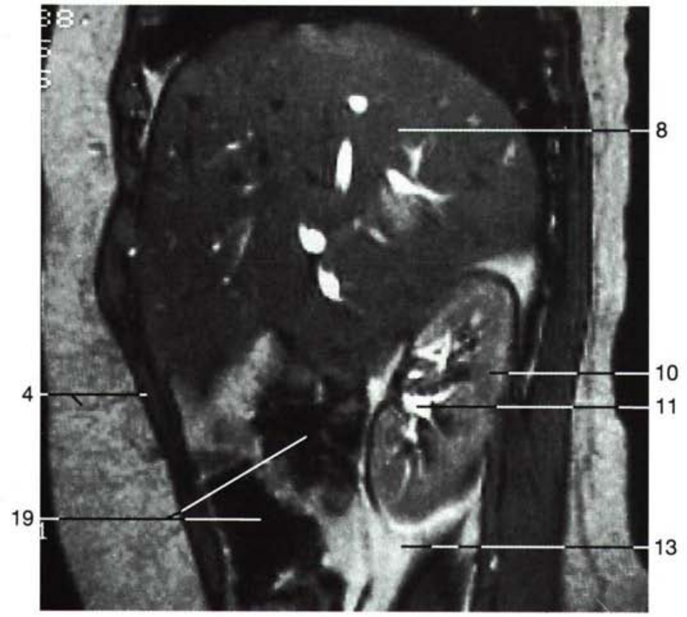

Parasagittal section through the abdominal cavity. (MR-Scan, courtesy of Prof. W. Rödl, Erlangen).

1	Right lung (superior and middle lobes)
2	Transverse colon
3	Jejunum
4	Abdominal wall
5	Fourth rib
6	Right lung (inferior lobe)
7	Diaphragm
8	**Liver**
9	Suprarenal gland
10	**Kidney**
11	Renal pelvis
12	Small intestine
13	Perirenal fat pad
14	Eleventh rib
15	Ureter (abdominal part)
16	Ureter (pelvic part)
17	**Urinary bladder**
18	Urethra
19	Colon

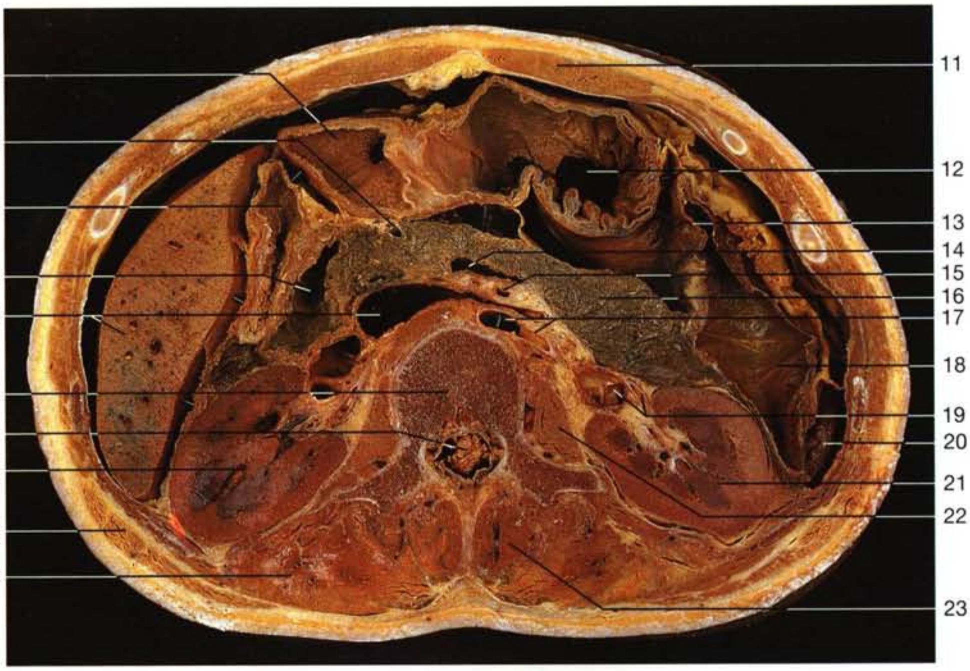

Horizontal section through the abdominal cavity at the level of the first lumbar vertebra (from below).

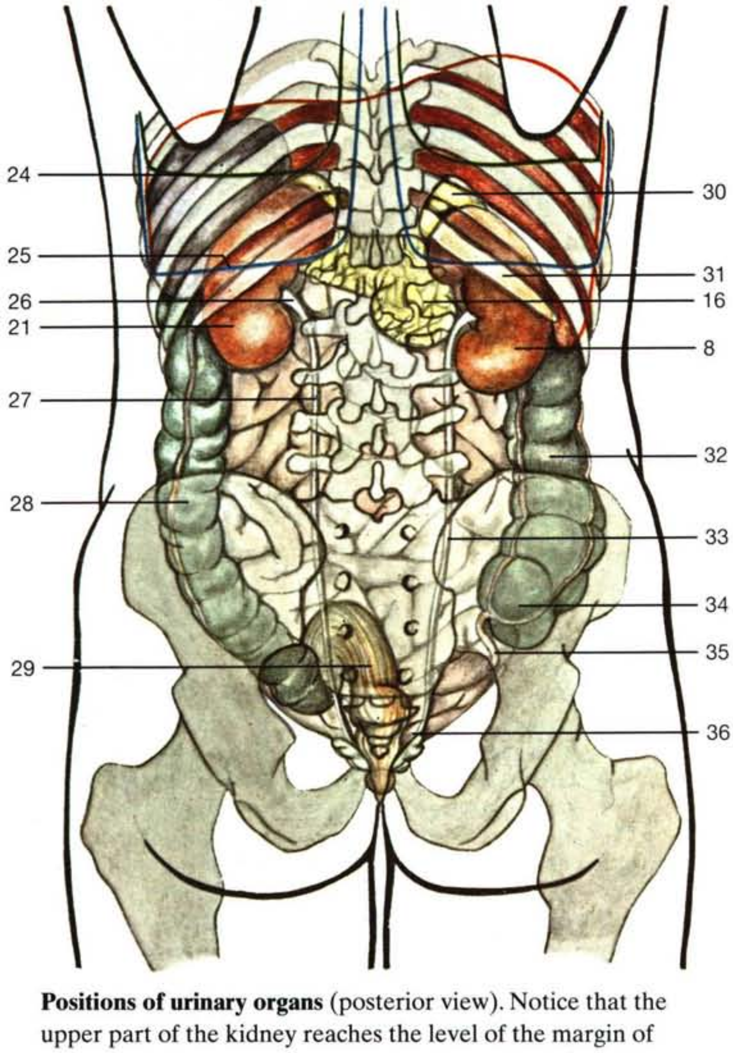

Positions of urinary organs (posterior view). Notice that the upper part of the kidney reaches the level of the margin of pleura and lung.

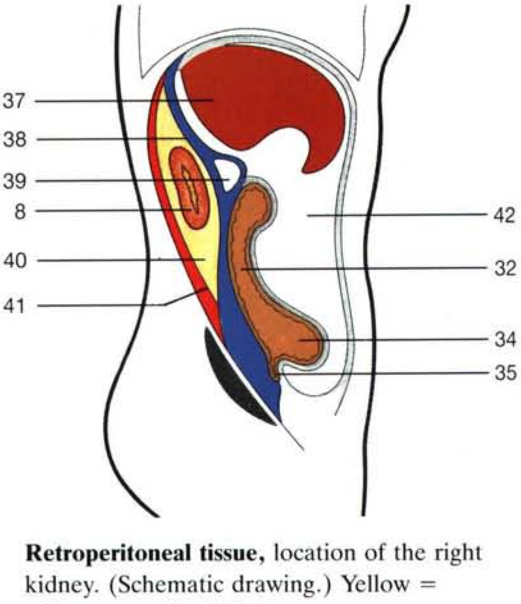

Retroperitoneal tissue, location of the right kidney. (Schematic drawing.) Yellow = adipose capsule of kidney.

1 Pyloric antrum
2 Gastroduodenal artery
3 Descending part of duodenum
4 Vestibule of lesser sac
5 Inferior vena cava and liver
6 Body of first lumbar vertebra
7 Cauda equina
8 **Right kidney**
9 Latissimus dorsi muscle
10 Iliocostalis muscle
11 Rectus abdominis muscle
12 Stomach
13 Lesser sac
14 Splenic vein
15 Superior mesenteric artery
16 Pancreas
17 Aorta and left renal artery
18 Transverse colon
19 Renal artery and vein
20 Spleen
21 **Left kidney**
22 Psoas major muscle
23 Multifidus muscle
24 Margin of lung
25 Margin of pleura
26 Renal pelvis
27 **Left ureter**
28 Descending colon
29 Rectum
30 Right suprarenal gland
31 12th rib
32 Ascending colon
33 **Right ureter**
34 Cecum
35 Vermiform appendix
36 Urinary bladder
37 Liver
38 Anterior layer of renal fascia
39 Duodenum
40 Perirenal fatty tissue
41 Posterior layer of renal fascia
42 Abdominal cavity

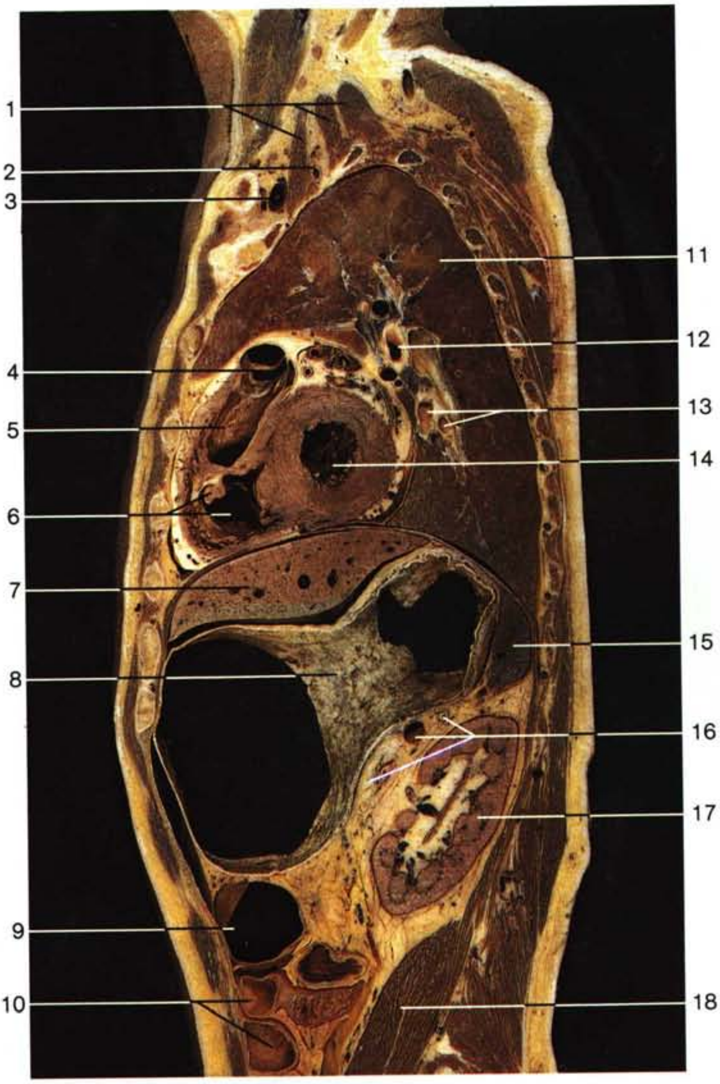

Parasagittal section through the thoracic and abdominal cavities at the level of the left kidney
(5.5 cm left of median plane).

1	Scalenus anterior, medius and posterior muscles	
2	Left subclavian artery	
3	Left subclavian vein	
4	Pulmonic valve	
5	Arterial cone	
6	Right ventricle of heart	
7	Liver	
8	Stomach	
9	Transverse colon	
10	Small intestine	
11	Left lung	
12	Left main bronchus	
13	Branches of pulmonary vein	
14	Left ventricle of heart	
15	Spleen	
16	Splenic artery and vein and pancreas	
17	**Left kidney**	
18	Psoas major muscle	
19	Inferior vena cava	
20	**Renal vein**	
21	Body of 12th thoracic vertebra and vertebral canal	
22	**Right kidney**	
23	Superior mesenteric artery	
24	Superior mesenteric vein	
25	Pancreas	
26	Abdominal aorta	
27	Left psoas major and quadratus lumborum muscles	
28	Anterior layer of renal fascia	} of Gerota
29	Posterior layer of renal fascia	
30	Perirenal fatty tissue	
31	Abdominal cavity	
32	Descending and sigmoid colon	

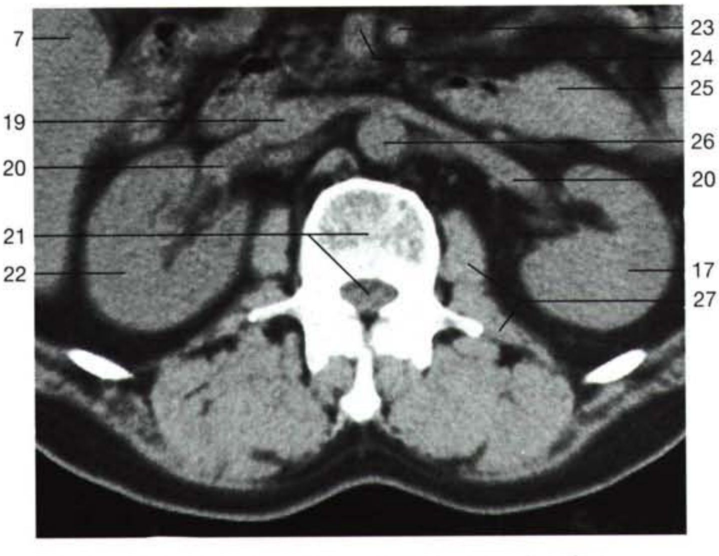

Horizontal section through the retroperitoneal region at level of 12th thoracic vertebra. (CT-Scan, from below.)

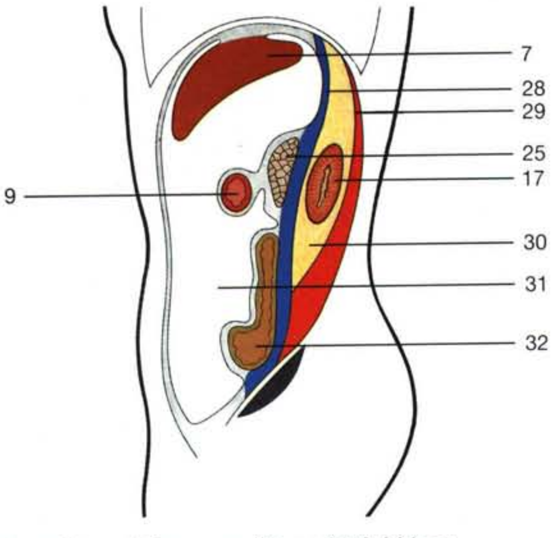

Retroperitoneal tissue, position of left kidney. (Schematic drawing.)

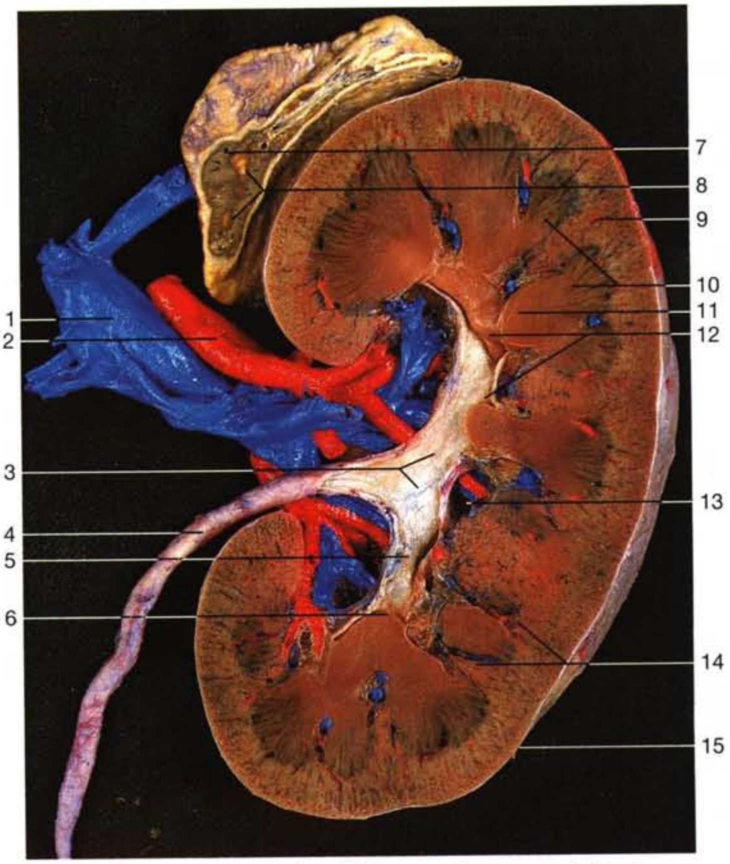

Coronal section through right kidney and suprarenal gland (posterior view). The renal pelvis has been opened and the fatty tissue removed to display the renal vessels.

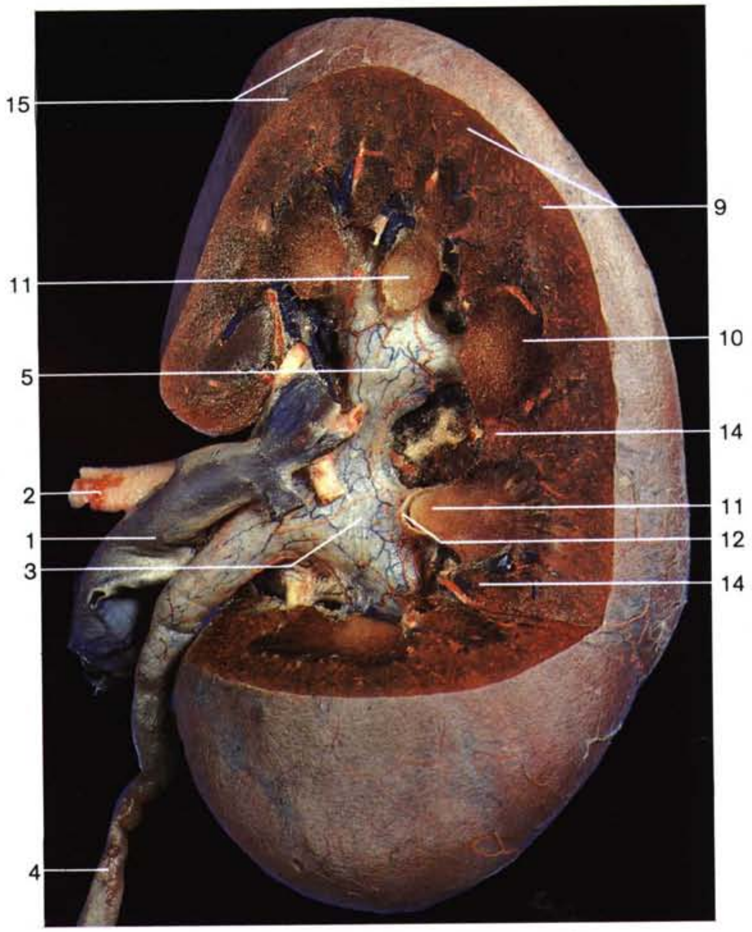

Right kidney (posterior view). Partial coronal section to expose internal aspect of the kidney.

1	Renal vein
2	Renal artery
3	**Renal pelvis**
4	Abdominal part of ureter
5	**Major renal calyx**
6	Cribriform area of renal papilla
7	Cortex of suprarenal gland
8	Medulla of suprarenal gland
9	**Cortex of kidney**
10	**Medulla of kidney**
11	Renal papilla
12	**Minor renal calyx**
13	Renal sinus
14	Renal columns
15	**Fibrous capsule** of kidney

Each kidney can be divided in five segments supplied by individual interlobar arteries considered as end arteries. Thus, obstruction leads to infarcts marking the trace of segment borders. The anterior kidney surface reveals four segments, the posterior only three (No. 1, 4 and 5).

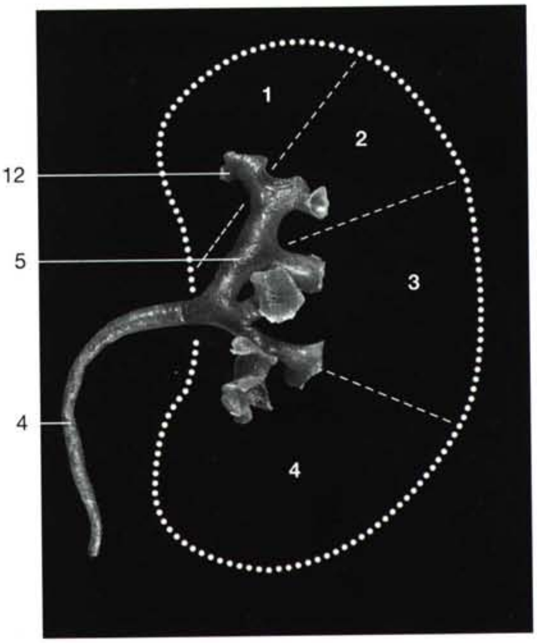

Cast of renal pelvis and calices.
1–4 = Renal segments on anterior surface.

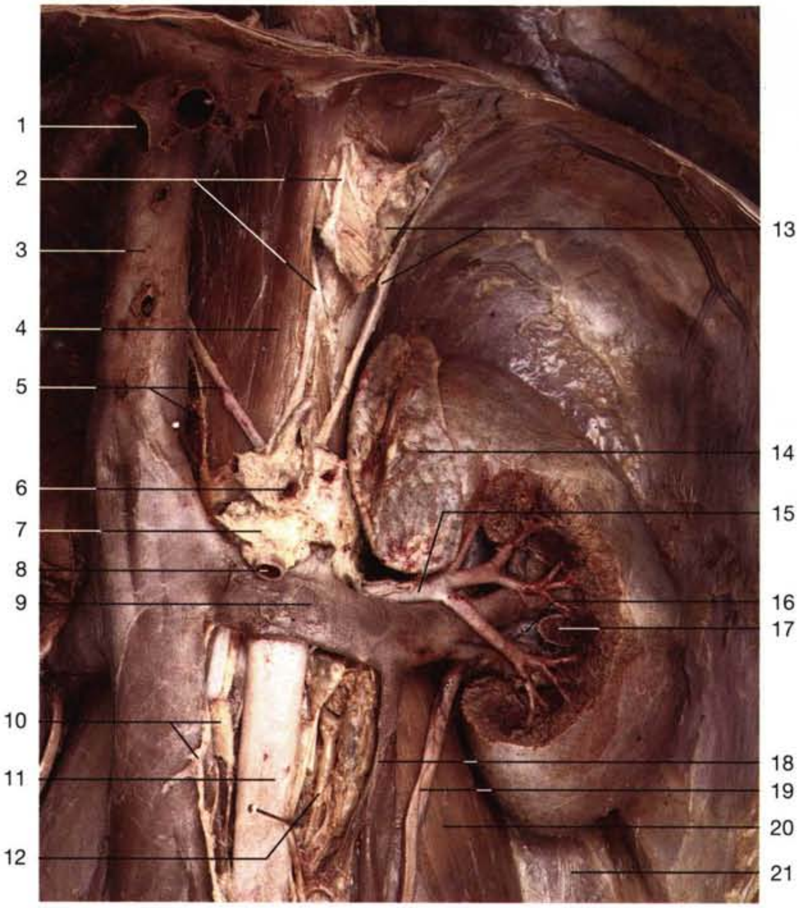

Left kidney and suprarenal gland in situ. The anterior cortical layer of the kidney has been removed to display the renal pelvis and papillae.

1 Hepatic vein
2 Anterior and posterior vagal trunk
3 Inferior vena cava
4 Lumbar part of diaphragm
5 Right greater and lesser splanchnic nerves
6 Celiac trunk
7 Celiac ganglion and plexus
8 Superior mesenteric artery
9 Left renal vein
10 Right sympathetic trunk and ganglion
11 Abdominal aorta
12 Left sympathetic trunk
13 Esophagus (cut),
left greater splanchnic nerve
14 **Left suprarenal gland**
15 Left renal artery
16 Renal pelvis
17 Renal papilla with minor calyx
18 Left testicular vein
19 Left ureter
20 Psoas major muscle
21 Quadratus lumborum muscle
22 **Glomerulus**
23 Afferent arteriole of glomerulus
24 **Glomeruli**
25 Radiating cortical artery
26 Subcortical or arcuate artey
27 Subcortical or arcuate vein
28 Interlobular vein
29 Interlobular artery
30 **Interlobar artery and vein**
31 Vessels of renal capsule
32 Efferent arteriole of glomerulus
33 **Vasa recta** of renal medulla
34 Spiral arteries of renal pelvis

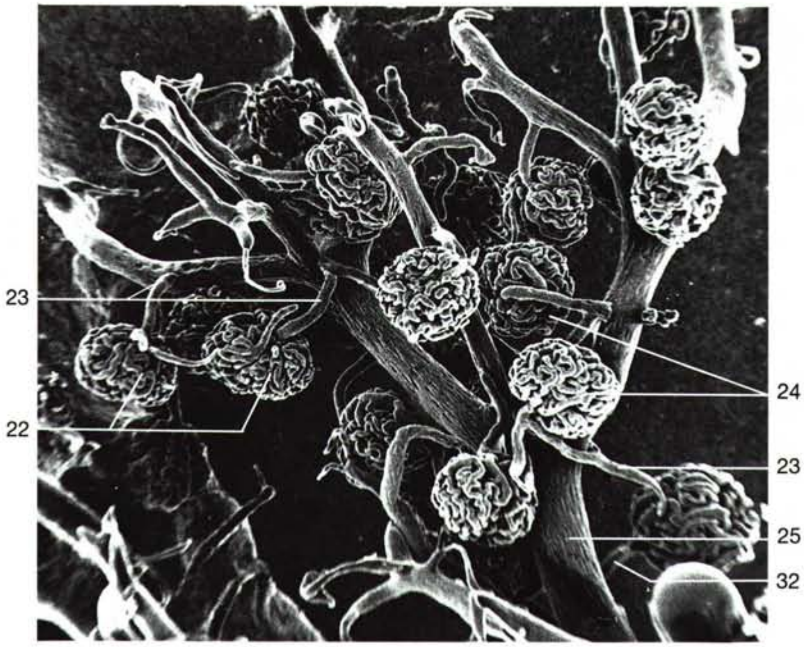

Glomeruli (210×). Scanning electron micrograph showing glomeruli and associated arteries.

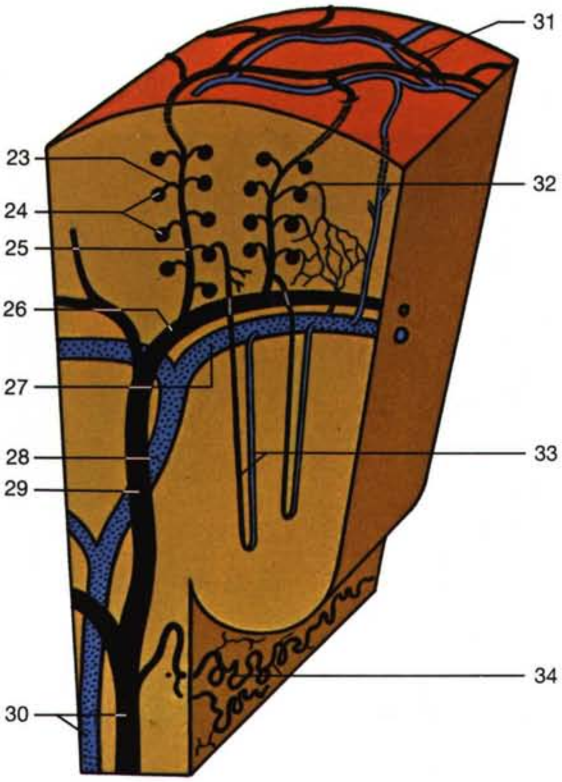

Architecture of vascular system of kidney. (Schematic drawing.)

1 Arteriolae rectae of renal medulla
2 Interlobar artery
3 Interlobular arteries
4 Cortical glomeruli
5 Juxtamedullary glomeruli
6 Body of first lumbar vertebra
7 Left renal artery
8 Abdominal aorta with catheter
9 Upper pole of kidney
10 Anterior branch } of renal artery
11 Posterior branch } of renal artery
12 Anterior inferior segmental artery
13 Lower pole of kidney
14 Celiac trunk
15 Superior mesenteric artery
16 Middle colic artery
17 Splenic artery

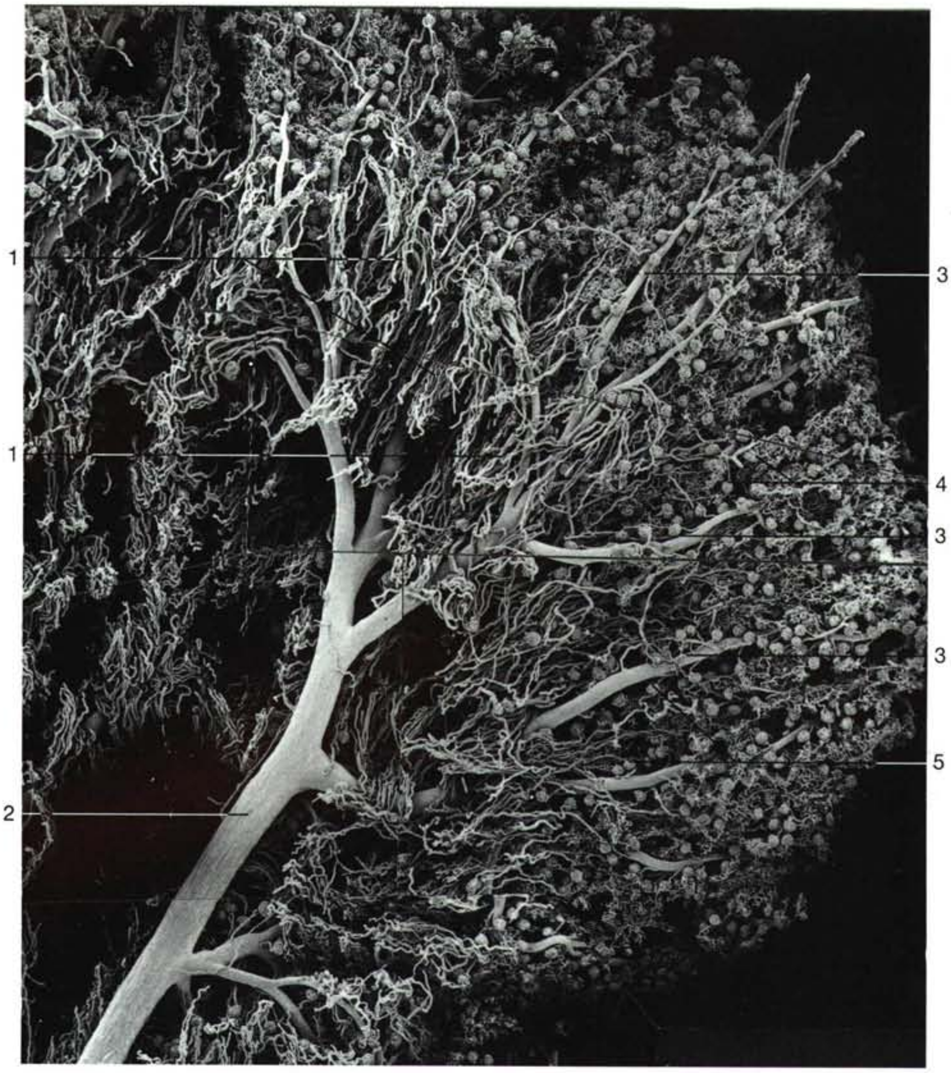

Resin cast of kidney arteries. (Scanning electron micrograph.)

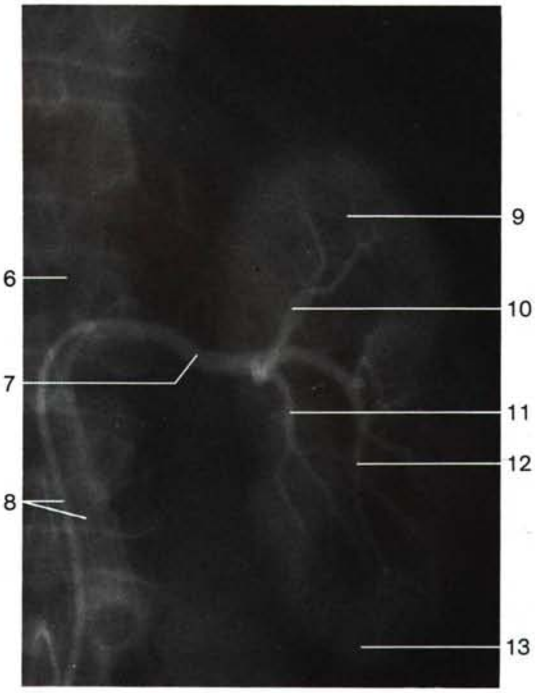

Left kidney. (Arteriogram.)

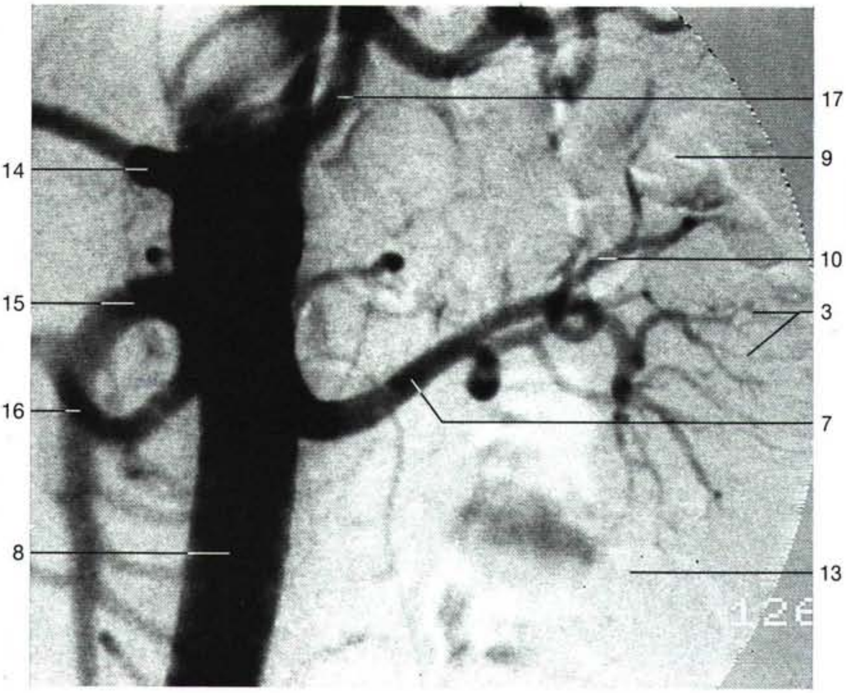

Abdominal aorta. (Subtraction angiograph.)

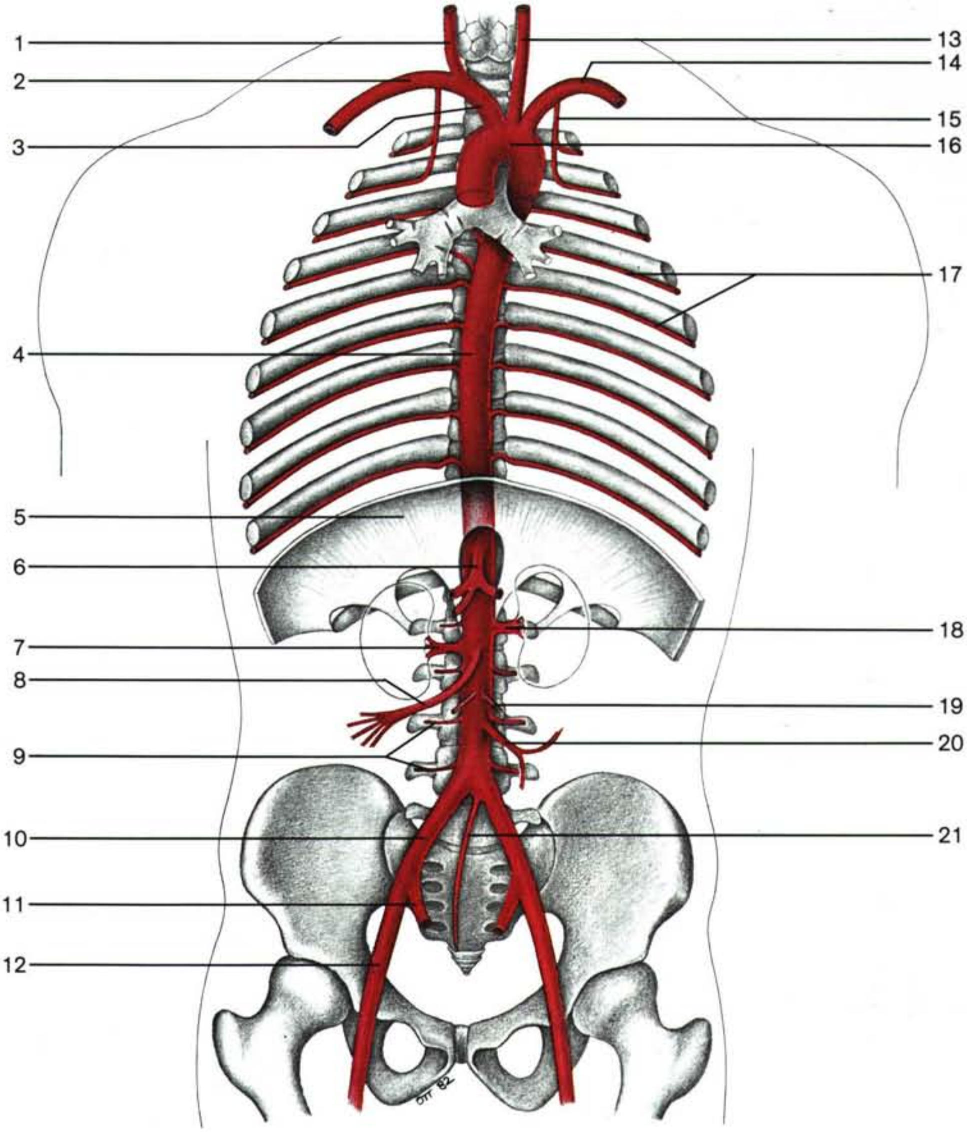

Main branches of descending aorta. (Schematic drawing.)

1 Right common carotid artery
2 Right subclavian artery
3 **Brachiocephalic trunk**
4 Thoracic aorta
5 Diaphragm
6 **Celiac trunk**
7 Right **renal artery**
8 **Superior mesenteric artery**
9 Lumbar arteries
10 Right **common iliac artery**
11 Internal iliac artery
12 **External iliac artery**
13 Left common carotid artery
14 Left subclavian artery
15 Highest intercostal artery
16 Aortic arch
17 **Posterior intercostal arteries**
18 Left renal artery
19 Left testicular (or ovarian) artery
20 Inferior mesenteric artery
21 Median sacral artery
22 **Superior suprarenal artery**
23 Upper capsular artery
24 Anterior branch of renal artery
25 Perforating artery
26 Lower capsular artery
27 Ureter
28 Right inferior phrenic artery
29 Left inferior phrenic artery
30 **Middle suprarenal artery**
31 **Inferior suprarenal artery**
32 Posterior branch of renal artery

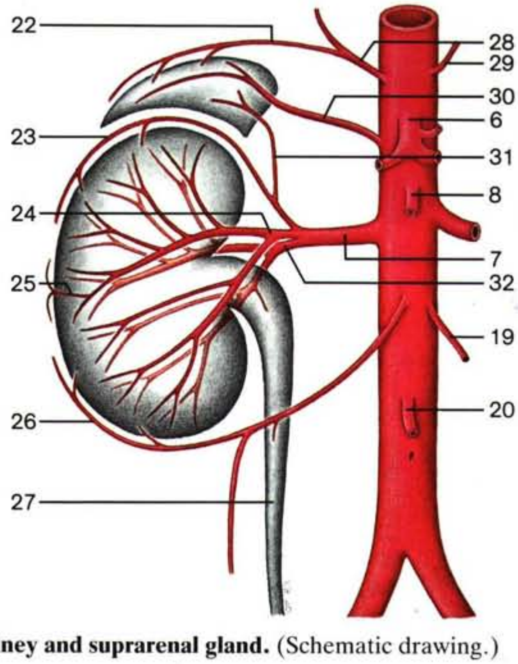

Arteries of kidney and suprarenal gland. (Schematic drawing.)

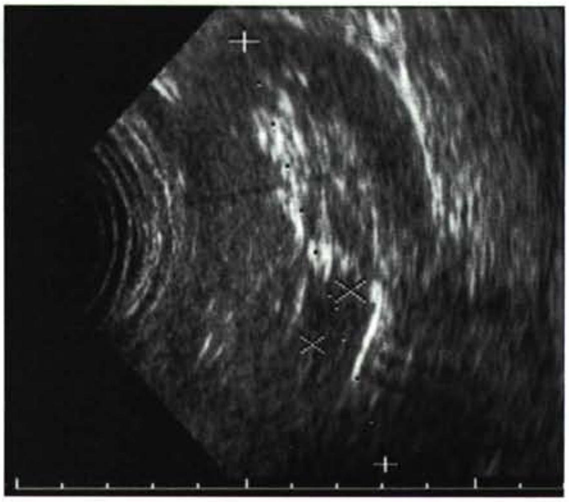

Ultrasound image of the right kidney (upper and lower border of the kidney marked by crosses. × = small cortical cyst).

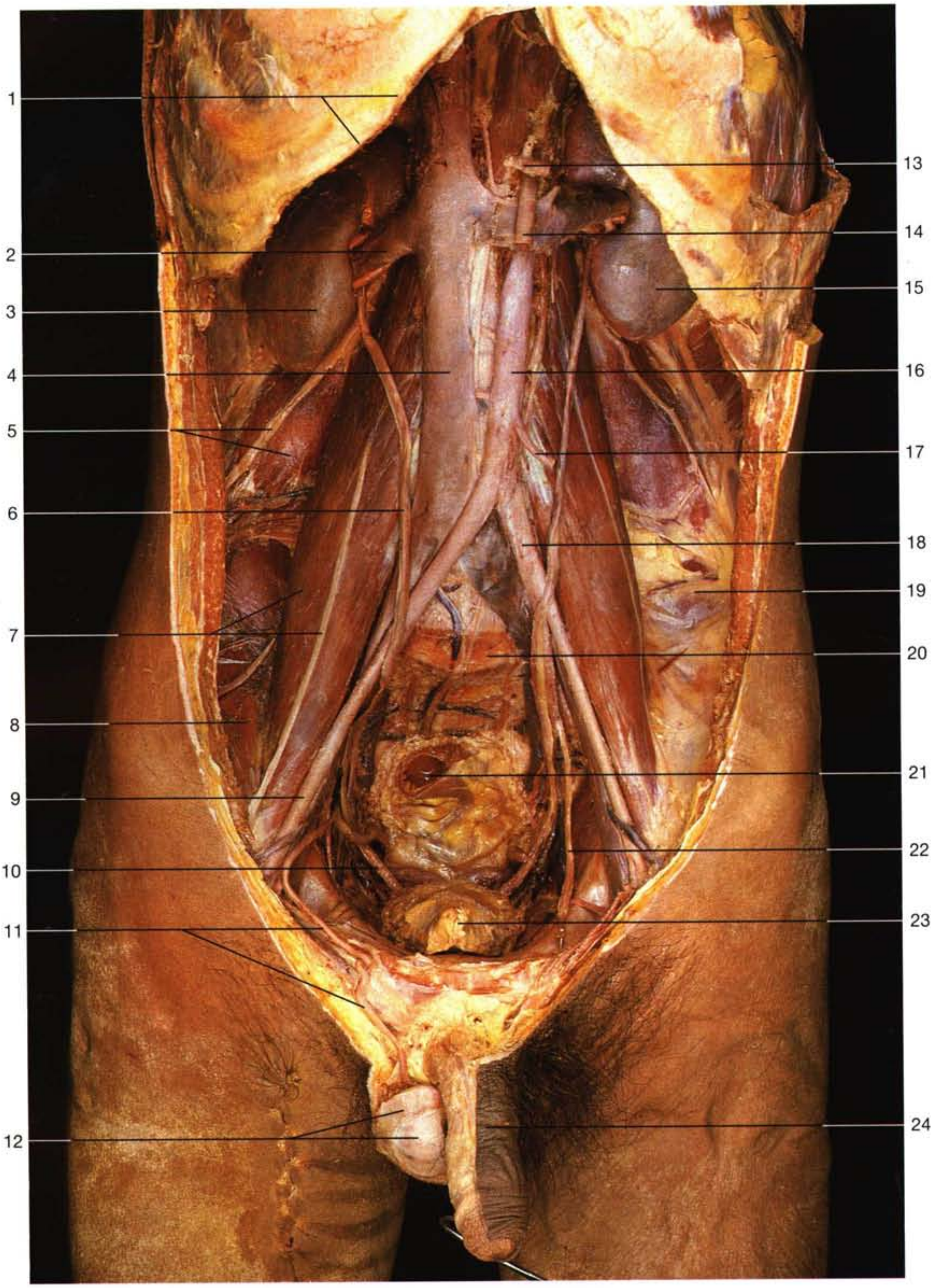

Retroperitoneal organs, urinary system in the male (anterior view). The peritoneum has been removed.

1	Costal arch
2	Right renal vein
3	**Right kidney**
4	Inferior vena cava
5	Iliohypogastric nerve and quadratus lumborum
6	**Ureter** (abdominal part)
7	Psoas major muscle and genitofemoral nerve
8	Iliacus muscle
9	External iliac artery
10	**Ureter** (pelvic part)
11	Ductus deferens
12	Testis and epididymis
13	Celiac trunk
14	Superior mesenteric artery
15	**Left kidney**
16	Abdominal aorta
17	Inferior mesenteric artery
18	Common iliac artery
19	Iliac crest
20	Sacral promontory
21	Rectum (cut)
22	Medial umbilical ligament
23	**Urinary bladder**
24	Penis

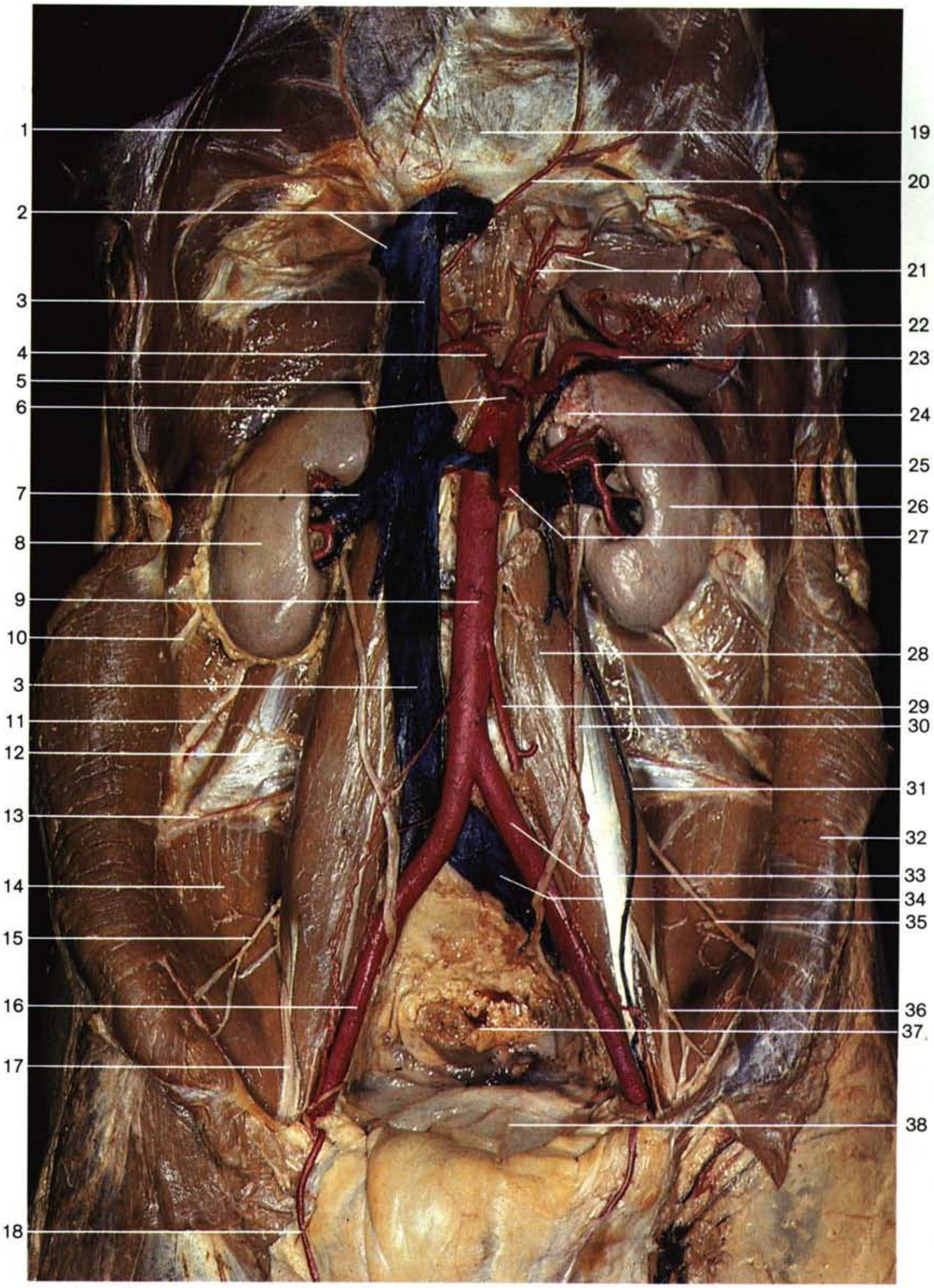

Retroperitoneal organs, urinary system in situ (anterior view). The peritoneum has been removed. Red = arteries; blue = veins.

1 Diaphragm
2 Hepatic veins
3 **Inferior vena cava**
4 Common hepatic artery
5 Right suprarenal gland
6 Celiac trunk
7 **Right renal vein**
8 Right kidney
9 **Abdominal aorta**
10 Subcostal nerve
11 Iliohypogastric nerve
12 Quadratus lumborum muscle
13 Iliac crest
14 Iliacus muscle
15 Right lateral femoral cutaneous nerve
16 **External iliac artery**
17 Femoral nerve
18 Right inferior epigastric artery
19 Central tendon of diaphragm
20 Inferior phrenic artery
21 Cardiac part of stomach and esophageal branches of left gastric artery
22 Spleen
23 Splenic artery
24 Left suprarenal gland
25 **Left renal artery**
26 Left **kidney**
27 Superior mesenteric artery
28 Psoas major muscle
29 Inferior mesenteric artery
30 **Ureter**
31 Testicular artery and vein
32 Transversus abdominis muscle
33 Left common iliac artery
34 Left common iliac vein
35 Lateral femoral cutaneous nerve
36 Genitofemoral nerve
37 Rectum (cut)
38 Urinary bladder

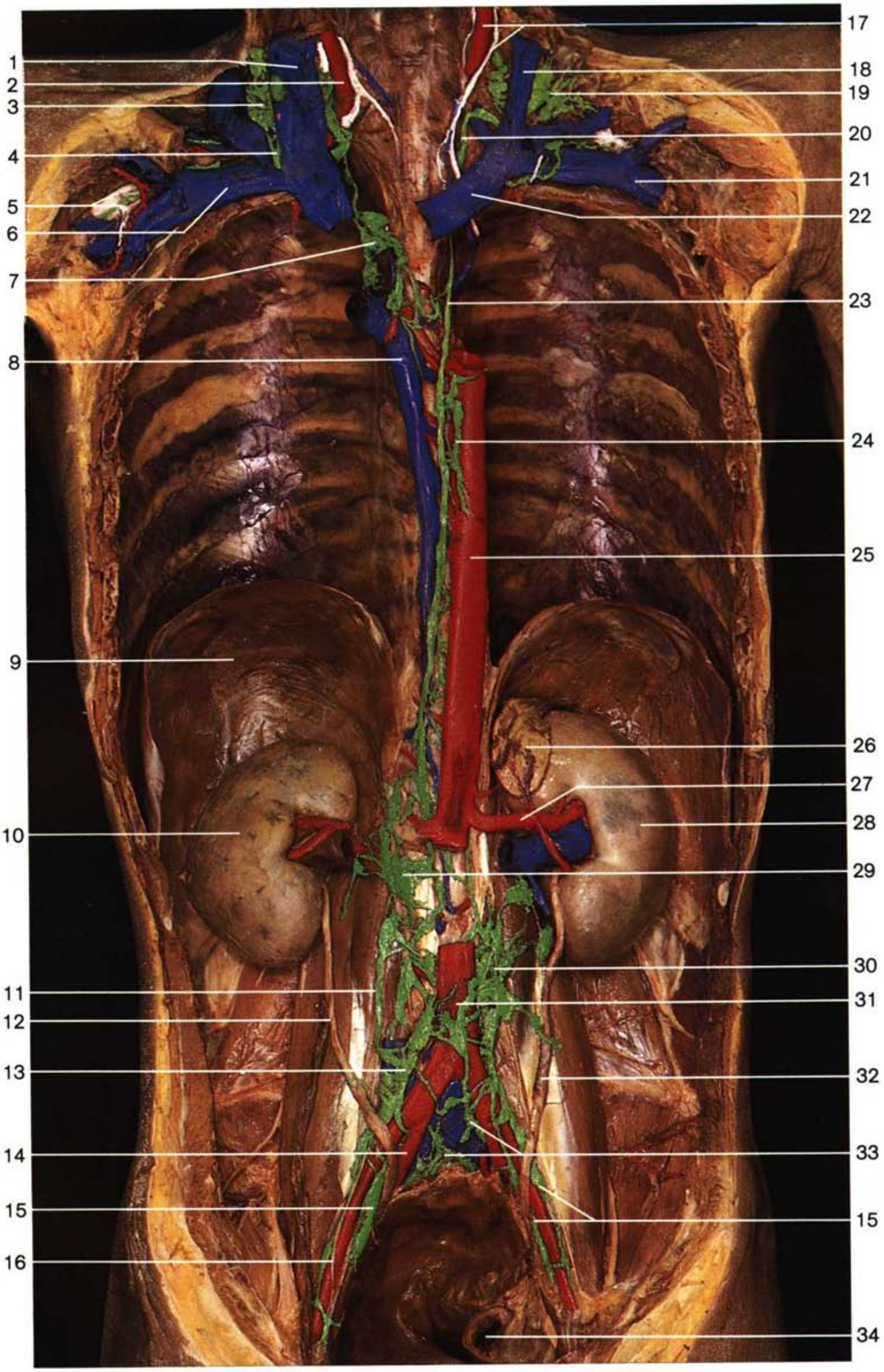

1 Internal jugular vein
2 Right common carotid artery and right vagus nerve
3 Jugulo-omohyoid lymph node
4 Right lymphatic duct
5 Subclavian trunk
6 Right subclavian vein
7 Bronchomediastinal trunk
8 Azygos vein
9 Diaphragm
10 Right kidney
11 Right lumbar trunk
12 Right ureter
13 Common iliac lymph nodes
14 Right internal iliac artery
15 External iliac lymph nodes
16 Right external iliac artery
17 Left common carotid artery and left vagus nerve
18 Internal jugular vein
19 Deep cervical lymph nodes
20 Thoracic duct entering left jugular angle
21 Left subclavian vein
22 Left brachiocephalic vein
23 **Thoracic duct**
24 Mediastinal lymph nodes
25 Thoracic aorta
26 Left suprarenal gland
27 Left renal artery
28 Left kidney
29 Cisterna chyli
30 Lumbar lymph nodes
31 Abdominal aorta
32 Left ureter
33 Sacral lymph nodes
34 Rectum (cut edge)

Lymph vessels and lymph nodes of the posterior wall of thoracic and abdominal cavities (anterior aspect). Green = lymph vessels and nodes; blue = veins; red = arteries; white = nerves.

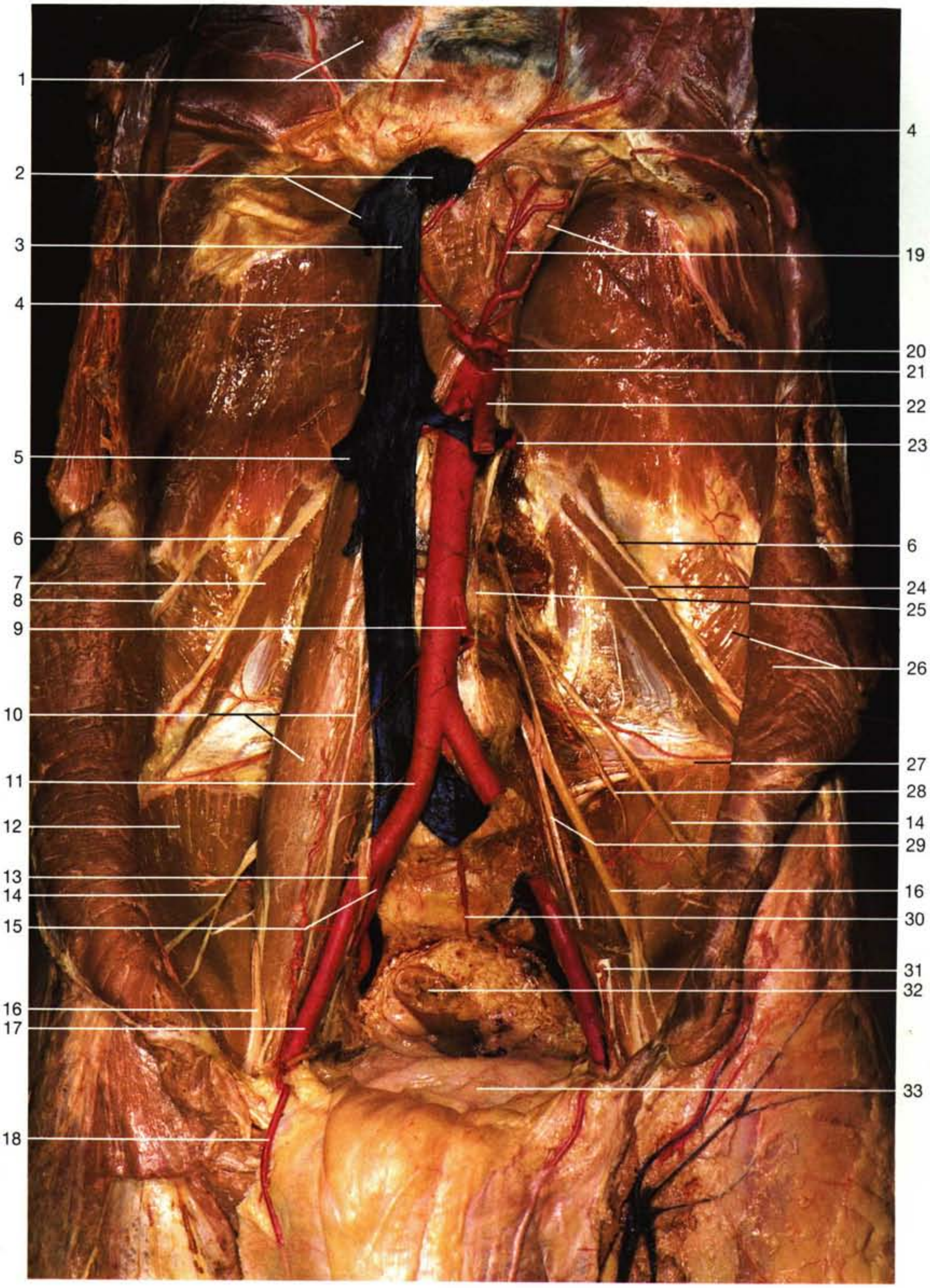

Vessels and nerves of posterior abdominal wall (anterior aspect). Part of the left psoas major muscle has been removed to display the lumbar plexus. Red = arteries, blue = veins.

1 Diaphragm
2 Hepatic veins
3 **Inferior vena cava**
4 Inferior phrenic artery
5 Right renal vein
6 **Iliohypogastric nerve**
7 Quadratus lumborum muscle
8 Subcostal nerve
9 Inferior mesenteric artery
10 Right genitofemoral nerve and psoas major muscle
11 Common iliac artery
12 Iliacus muscle
13 Right ureter (divided)
14 Lateral femoral cutaneous nerve
15 Internal iliac artery
16 **Femoral nerve**
17 **External iliac artery**
18 Inferior epigastric artery
19 Cardiac part of stomach and oesophageal branches of left gastric artery
20 Splenic artery
21 Celiac trunk
22 **Superior mesenteric artery**
23 Left renal artery
24 **Ilioinguinal nerve**
25 Sympathetic trunk
26 Transversus abdominis muscle
27 Iliac crest
28 Left **genitofemoral nerve**
29 Left **obturator nerve**
30 Median sacral artery
31 Psoas major muscle (divided) with supplying artery
32 Rectum (cut)
33 Urinary bladder

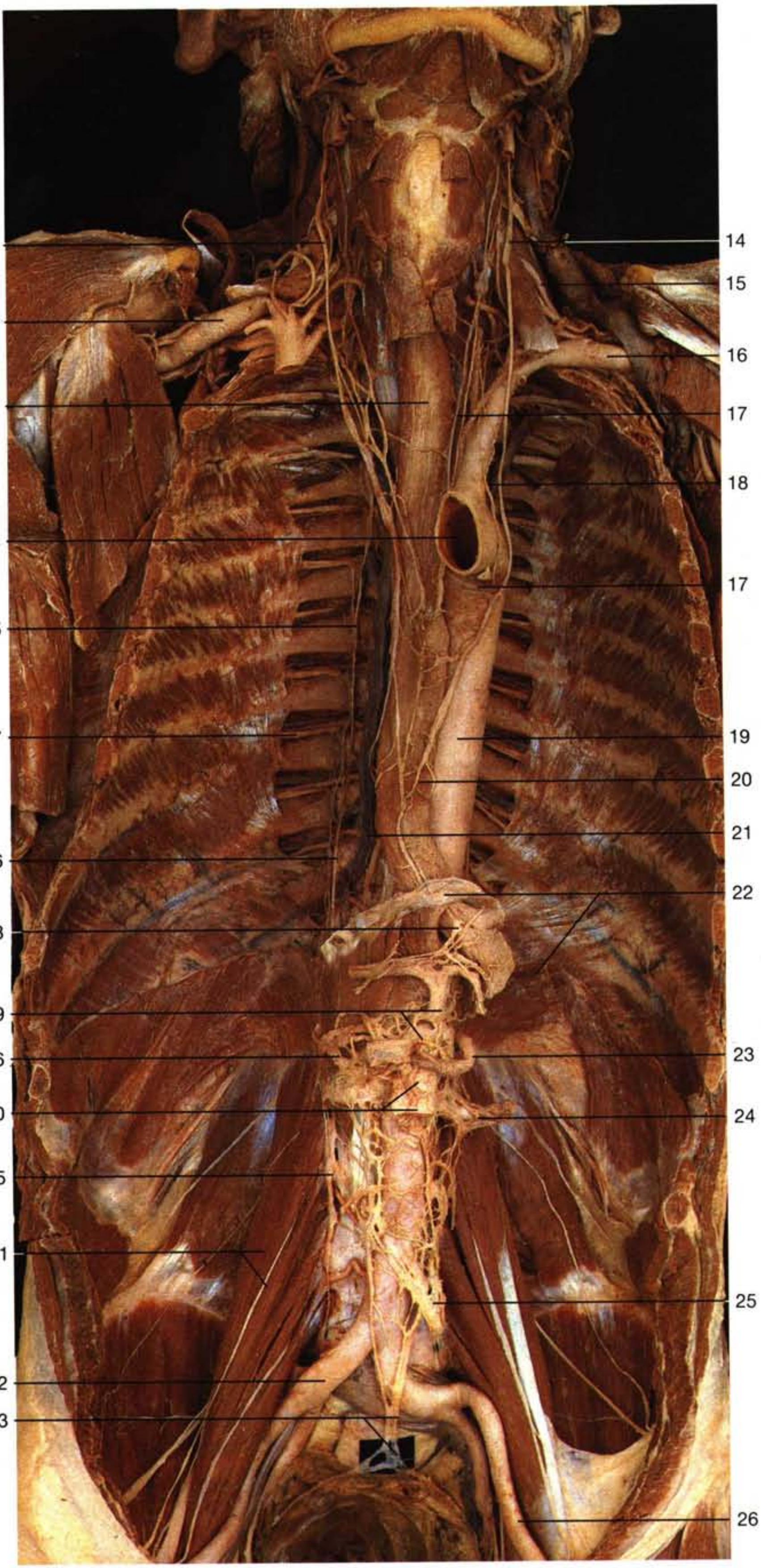
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Posterior wall of thoracic and abdominal cavities with sympathetic trunk, vagus nerve and autonomic ganglia (anterior view). Thoracic and abdominal organs removed, except esophagus and aorta.

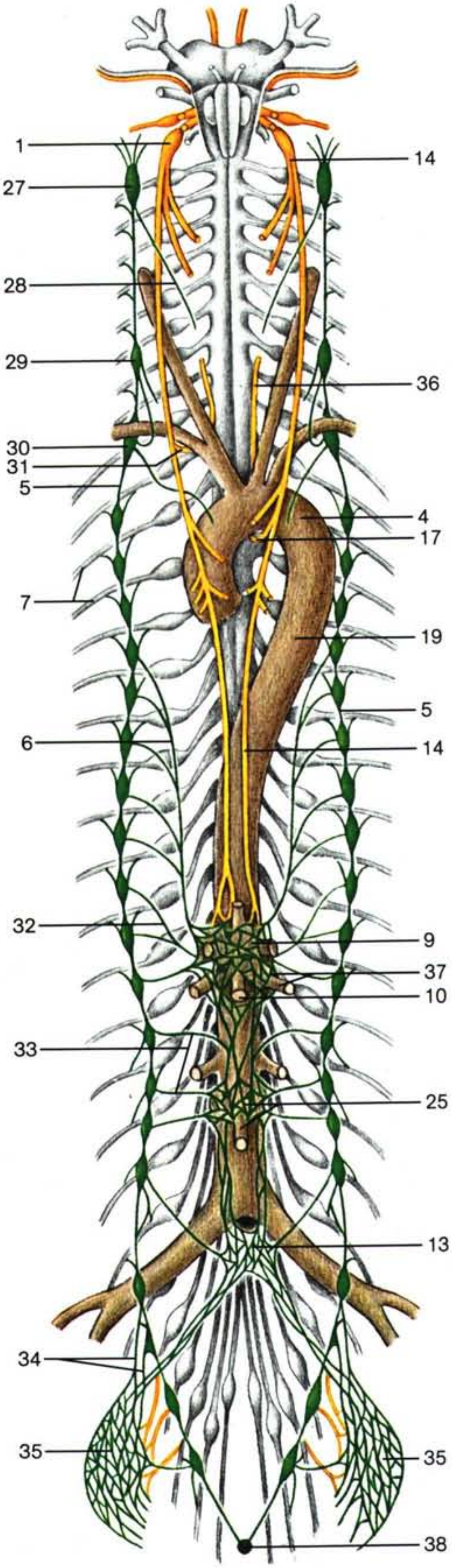
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Organization of autonomic nervous system (after Mattuschka). (Schematic drawing.) Yellow = parasympathetic nerves; green = sympathetic nerves.

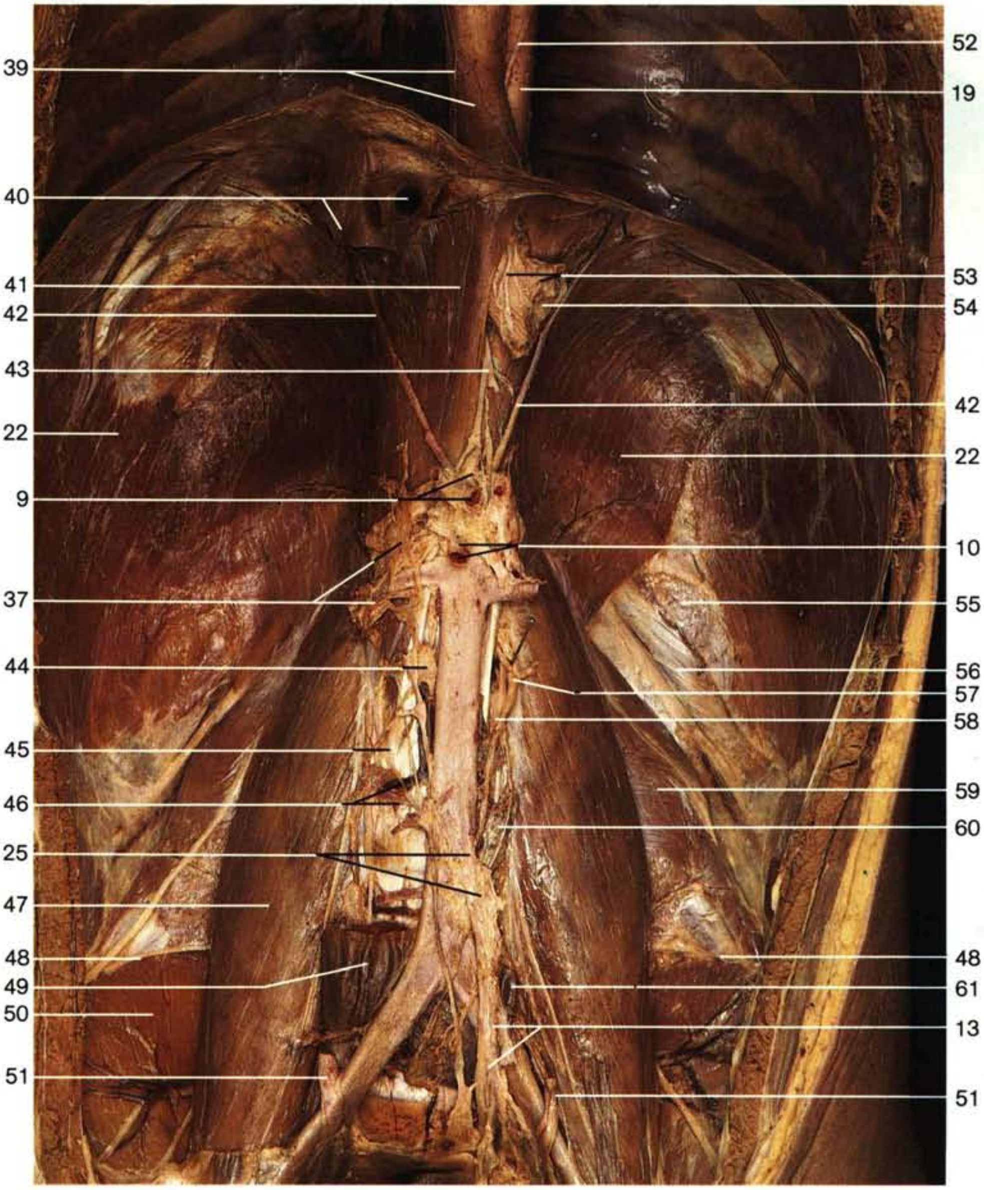

Ganglia and plexus of the autonomic nervous system within the retroperitoneal space (anterior view). The kidneys and the inferior vena cava with its tributaries have been removed (compare pp. 264 and 265).

1 **Right vagus nerve**
2 Right subclavian artery
3 Esophagus
4 Aortic arch
5 **Sympathetic trunk**
6 Greater splanchnic nerve
7 Intercostal nerve
8 Abdominal part of esophagus and vagal trunk
9 **Celiac trunk with celiac ganglion**
10 **Superior mesenteric artery and ganglion**
11 Psoas major muscle and genitofemoral nerve
12 Common iliac artery
13 **Superior hypogastric plexus and ganglion**
14 **Left vagus nerve**
15 Brachial plexus
16 Left subclavian artery
17 Left recurrent laryngeal nerve
18 Inferior cervical cardiac nerve
19 Thoracic aorta
20 Esophageal plexus
21 Azygos vein
22 Diaphragm
23 Splenic artery
24 Left renal artery and plexus
25 **Inferior mesenteric ganglion and artery**
26 Left external iliac artery
27 **Superior cervical ganglion** of sympathetic trunk
28 Superior cardiac branch of sympathetic trunk
29 Middle cervical ganglion of sympathetic trunk
30 **Inferior cervical ganglion** of sympathetic trunk
31 Right recurrent laryngeal nerve
32 Lesser splanchnic nerve
33 Lumbar splanchnic nerves
34 Sacral splanchnic nerves
35 **Inferior hypogastric ganglion and plexus**
36 Left recurrent laryngeal nerve
37 **Aorticorenal plexus** and renal artery
38 Ganglion impar
39 Esophagus with branches of vagus nerve
40 Hepatic veins
41 Right crus of diaphragm
42 Inferior phrenic artery
43 Right vagus nerve entering the celiac ganglion
44 Right lumbar lymph trunk
45 Lumbar part of right sympathetic trunk
46 Lumbar artery and vein
47 **Psoas major muscle**
48 Iliac crest
49 Inferior vena cava
50 **Iliacus muscle**
51 Ureter
52 Left vagus nerve forming the esophageal plexus
53 Left vagus nerve forming the gastric plexus
54 Esophagus continuing into the cardiac part of stomach
55 Lumbocostal triangle
56 Position of 12th rib
57 Left lumbar lymph trunk
58 Ganglion of sympathetic trunk
59 **Quadratus lumborum muscle**
60 Lumbar part of left sympathetic trunk
61 Iliac lymph vessels

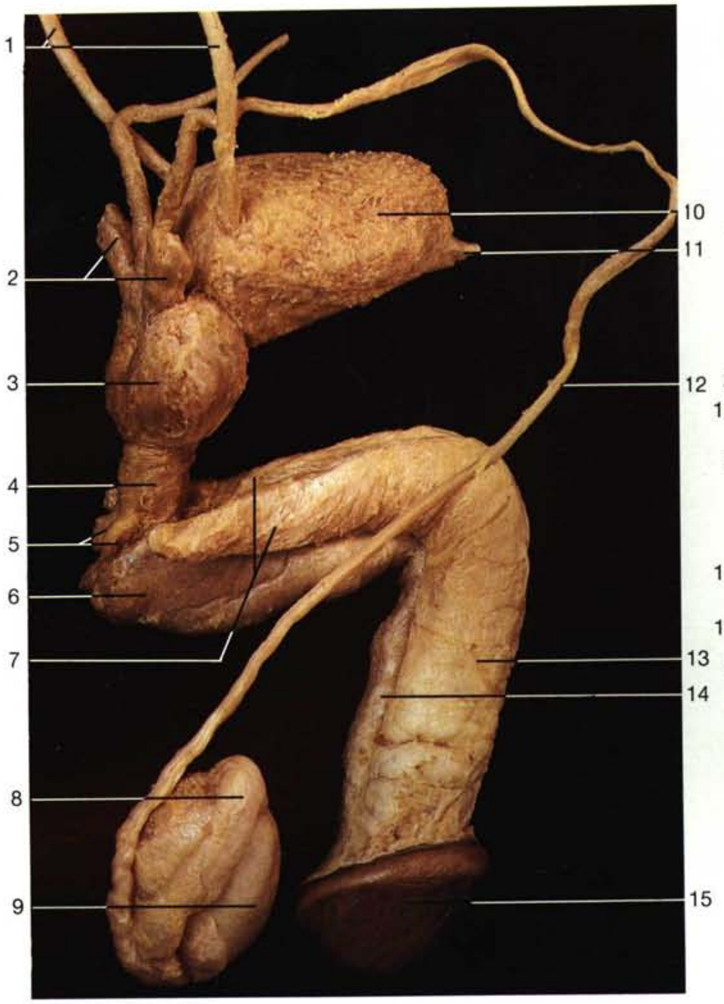
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Male genital organs isolated (right lateral aspect).

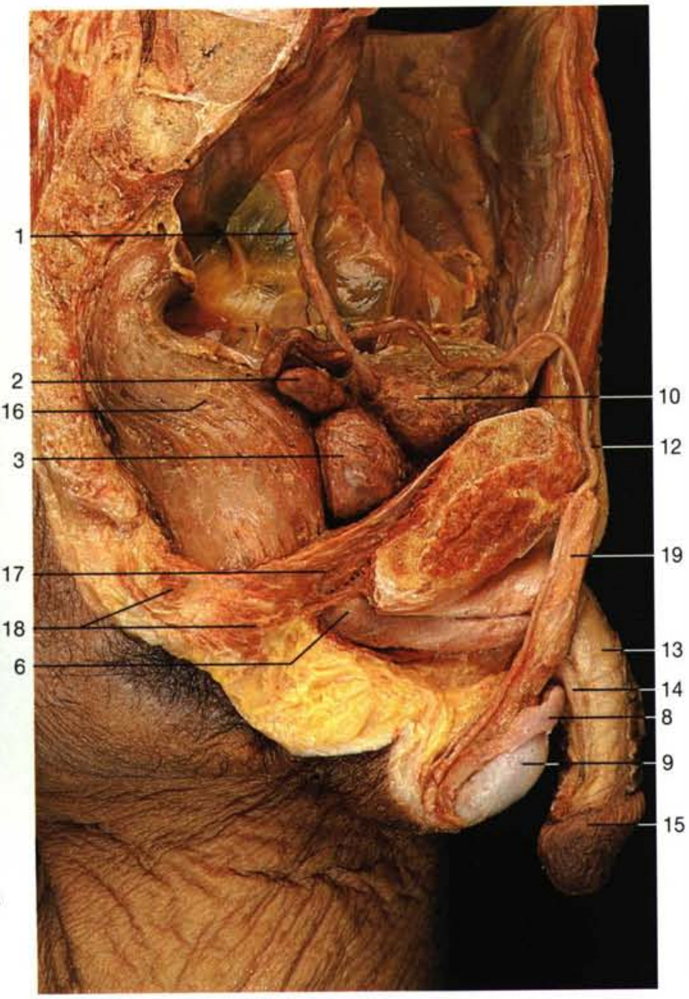
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Male genital organs in situ (right lateral aspect).

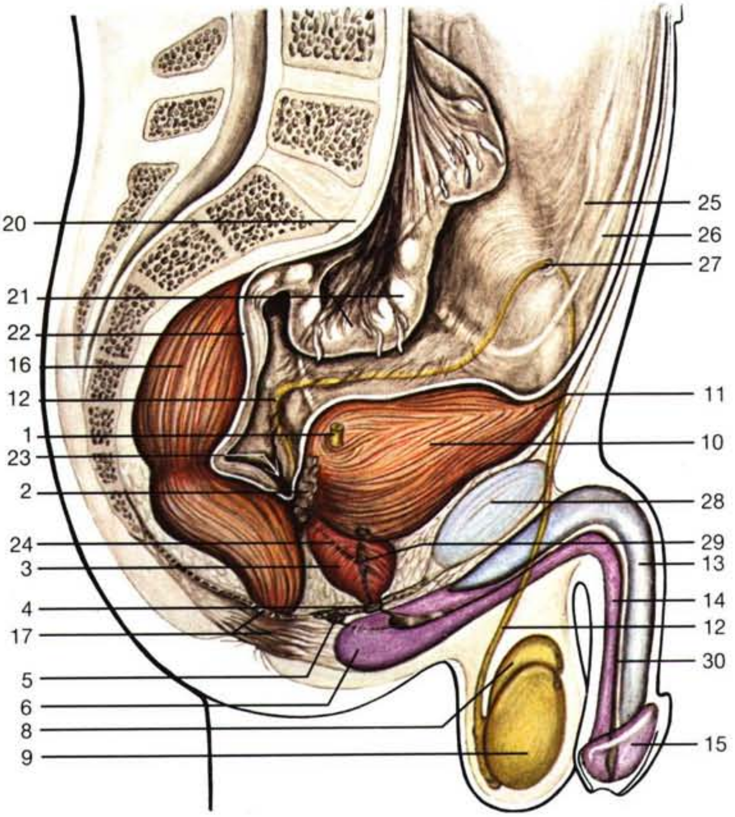
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Positions of male genital organs (right lateral aspect).
(Schematic drawing.)

1 Ureter
2 **Seminal vesicle**
3 **Prostate gland**
4 Urogenital diaphragm and membranous part of urethra
5 Bulbourethral or Cowper's gland
6 Bulb of penis
7 Left and right crus penis
8 **Epididymis**
9 **Testis**
10 **Urinary bladder**
11 Apex of urinary bladder
12 **Ductus deferens**
13 **Corpus cavernosum of penis**
14 **Corpus spongiosum of penis**
15 Glans penis
16 Ampulla of rectum
17 Levator ani muscle
18 Anal canal and external anal sphincter muscle
19 Spermatic cord (cut)
20 Sacral promontory
21 Sigmoid colon
22 Peritoneum (cut edge)
23 **Rectovesical pouch**
24 Ejaculatory duct
25 Lateral umbilical fold
26 Medial umbilical fold
27 Deep inguinal ring and ductus deferens
28 Pubic symphysis
29 Prostatic part of urethra
30 Spongy urethra

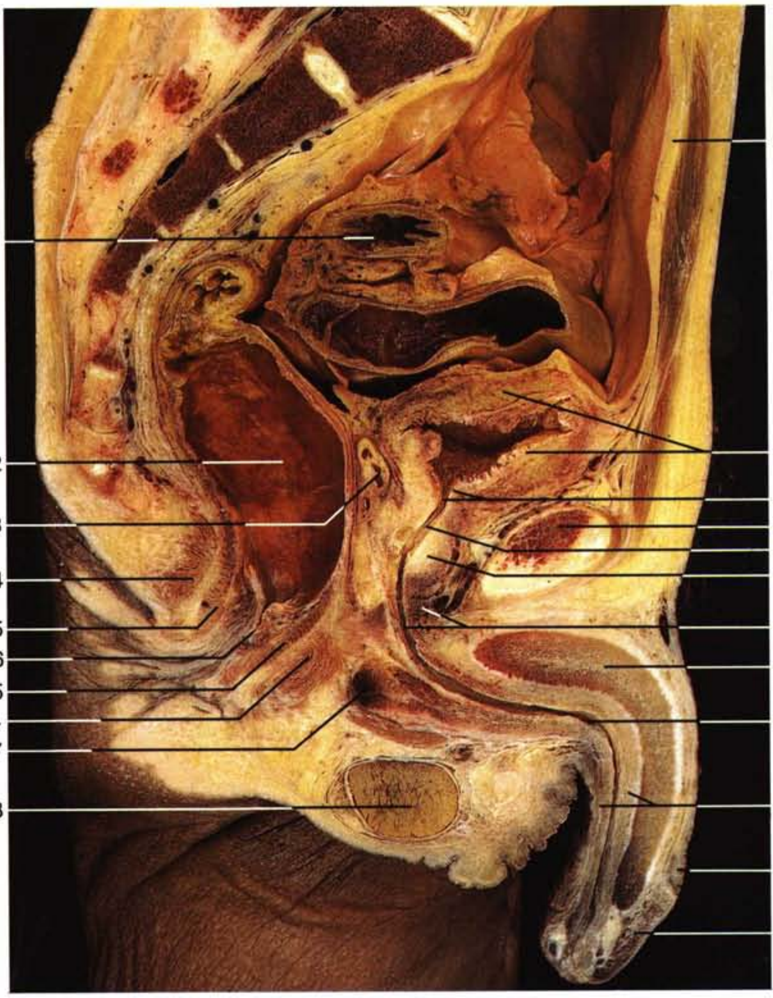

Midsagittal section through the male pelvis.

1 Sigmoid colon
2 **Ampulla of rectum**
3 Ampulla of ductus deferens
4 External anal sphincter muscle
5 Internal anal sphincter muscle
6 **Anal canal**
7 Bulb of penis
8 **Testis** (cut surface)
9 Median umbilical ligament
10 **Urinary bladder**
11 Internal urethral orifice and sphincter muscle (sphincter vesicae)
12 Pubic symphysis
13 Prostatic part of urethra
14 **Prostate gland**
15 Membranous urethra and external urethral sphincter muscle
16 **Corpus cavernosum of penis**
17 **Spongy urethra**
18 Corpus spongiosum of penis
19 Foreskin or prepuce
20 Glans penis
21 Kidney
22 Renal pelvis
23 Abdominal part of ureter
24 Pelvic part of ureter
25 Seminal vesicle
26 Ejaculatory duct
27 Bulbourethral or Cowper's gland
28 **Ductus deferens**
29 **Epididymis**
30 Umbilicus
31 Trigone of bladder and ureteric orifice
32 Navicular fossa of urethra
33 External urethral orifice
34 **Testis**

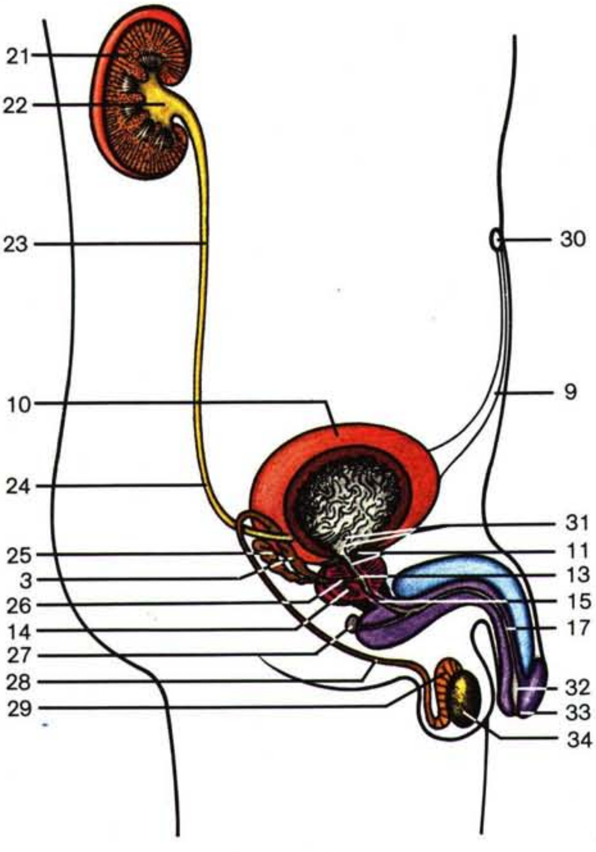

Male urogenital system. (Schematic drawing.)

The **prostate** is located between bladder and urogenital diaphragm. The penis includes the **urethra** and thus serves for both ejaculation and micturition. The internal (involuntary) and external (voluntary) urethral sphincters are widely separated. The **ureter** having crossed the ductus deferens enters the urinary bladder at its base. The peritoneum is reflected off the posterior surface of the bladder onto the rectum thus forming the rectovesical pouch.

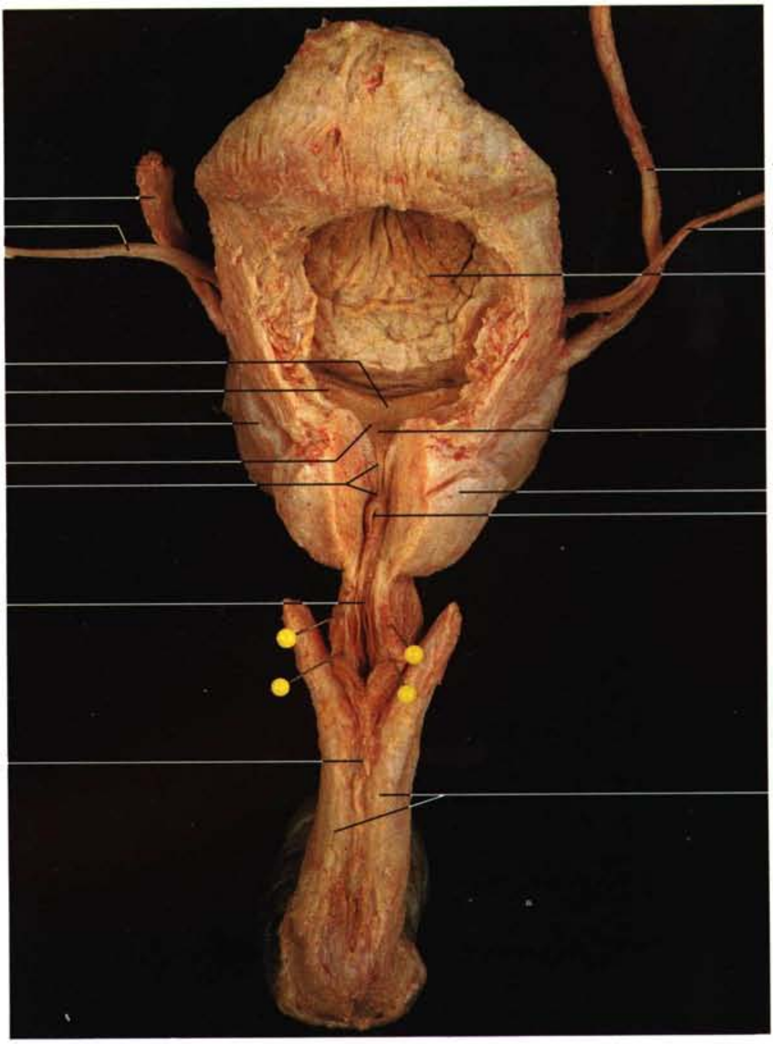

Male urogenital organs; isolated (anterior view). Urinary bladder, prostate and urethra have been opened. The urinary bladder is contracted.

1 Ureter
2 Ductus deferens
3 Interureteric fold
4 Ureteric orifice
5 Seminal vesicle
6 Trigone of bladder
7 Prostatic urethra with seminal colliculus and urethral crest
8 Deep transverse perineal muscle
9 Membranous urethra
10 **Spongy urethra**
11 Mucous membrane of **urinary bladder**
12 Internal urethral orifice and uvula of bladder
13 **Prostate**
14 Prostatic utricle
15 Right and left **corpus cavernosum of penis**
16 Ejaculatory duct
17 **Sphincter urethrae muscle**
18 **Median umbilical fold** with remnant of urachus
19 Medial umbilical fold with remnant of umbilical artery
20 **Urinary bladder**
21 Rectovesical pouch
22 Rectum
23 Sacrum
24 Deep iliac circumflex artery
25 Deep inguinal ring and ductus deferens
26 External iliac artery and vein
27 **Femoral nerve**
28 Obturator nerve
29 Ilium and sacrum
30 Inferior epigastric artery
31 Iliopsoas muscle

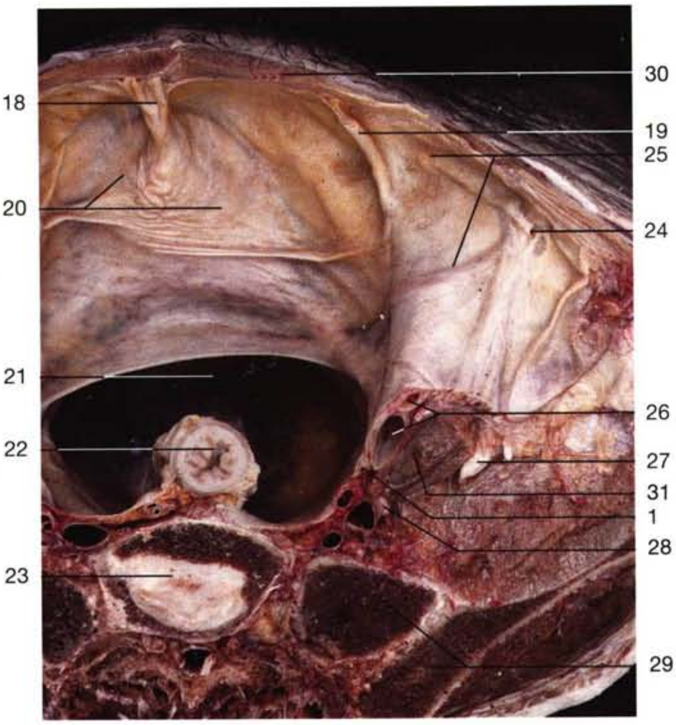

Pelvic cavity in the male (viewed from above).

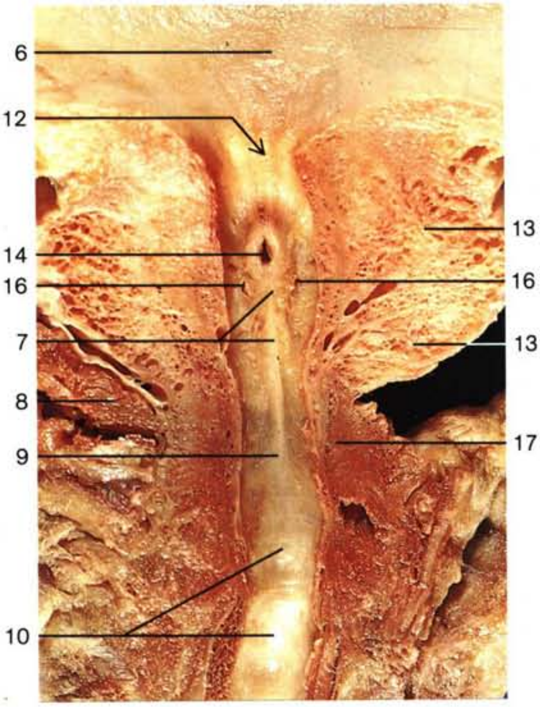

Posterior half of male urethra and prostate in continuity with neck of bladder (anterior view).

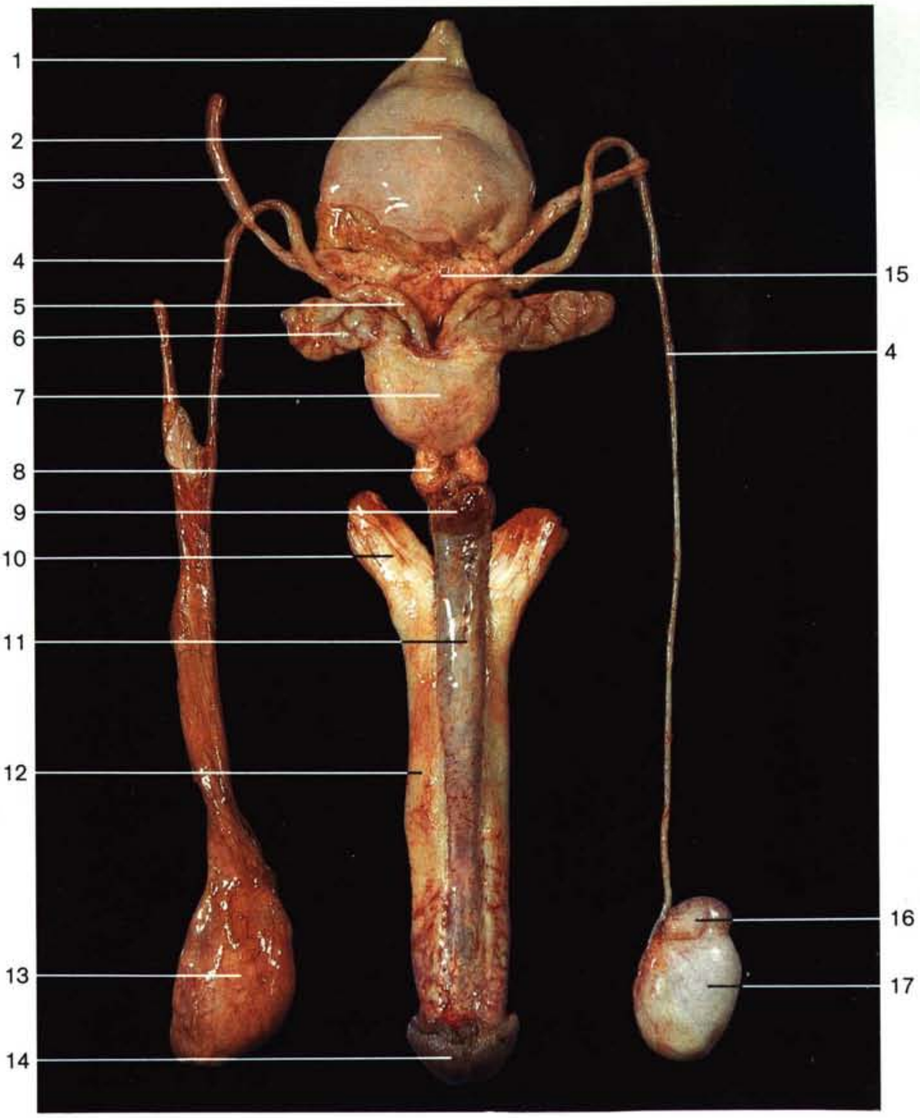

Male genital organs, isolated (posterior view).

1 Apex of urinary bladder with urachus
2 **Urinary bladder**
3 Ureter
4 **Ductus deferens**
5 Ampulla of ductus deferens
6 **Seminal vesicle**
7 **Prostate**
8 **Bulbourethral or Cowper's gland**
9 **Bulb of penis**
10 Crus penis
11 **Corpus spongiosum of penis**
12 **Corpus cavernosum of penis**
13 Testis and epididymis with coverings
14 Glans penis
15 Fundus of bladder
16 **Head of epididymis**
17 **Testis**
18 Mucous membrane of bladder
19 Trigone of bladder
20 Ureteric orifice
21 Internal urethral orifice
22 Seminal colliculus
23 Prostate
24 Prostatic urethra
25 Membranous urethra
26 Spongy (penile) urethra
27 Skin of penis
28 Deep dorsal vein of penis (unpaired)
29 Dorsal artery of penis (paired)
30 **Tunica albuginea of corpora cavernosa**
31 Septum of penis
32 Deep artery of penis
33 Tunica albuginea of corpus spongiosum
34 Deep fascia of penis

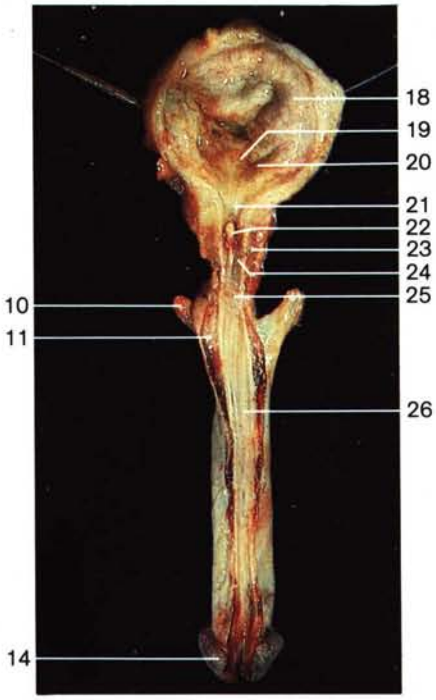

Urinary bladder, urethra and penis (anterior view, open longitudinally).

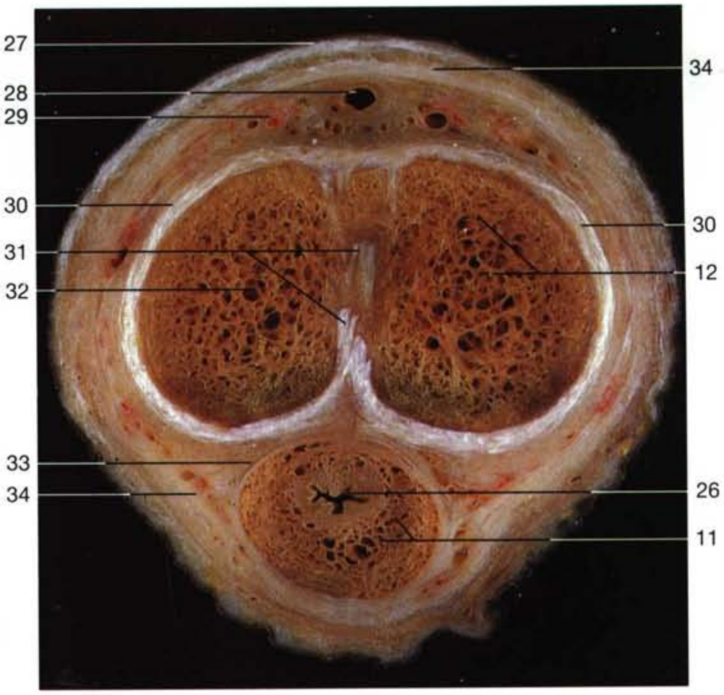

Cross-section of penis (anterior view).

1 **Corpus cavernosum of penis**
2 **Corpus spongiosum of penis**
3 Corona of glans penis
4 **Glans penis**
5 Suspensory ligament of penis
6 Inferior pubic ramus
7 Crus penis
8 **Bulb of penis**
9 Deep dorsal vein of penis
10 Septum pectiniforme
11 Dorsal artery of penis
12 Bulbourethral or Cowper's gland
13 Urinary bladder
14 **Seminal vesicle**
15 Ampulla of ductus deferens
16 Ductus deferens
17 Membranous urethra
18 **Prostate**
19 Ureter

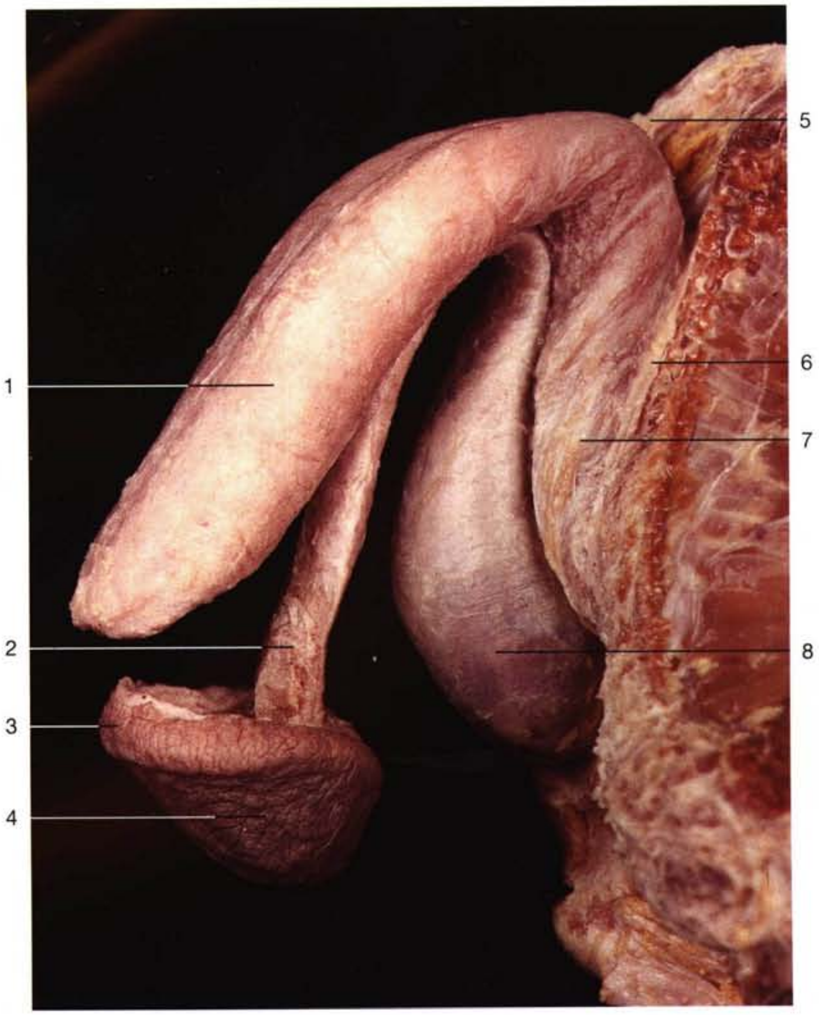

Male external genital organs (lateral view). The corpus spongiosum of the penis with the glans penis has been isolated and reflected.

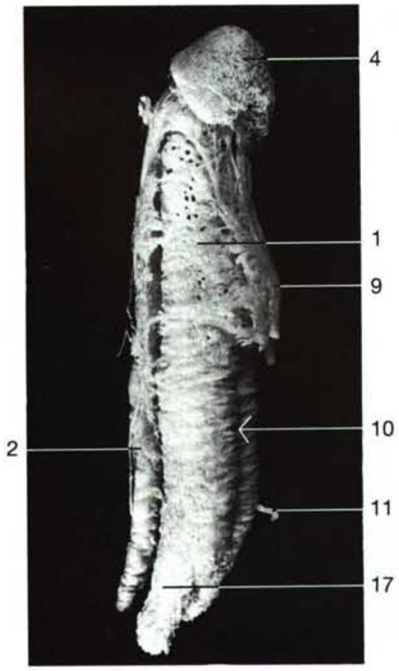

Resin cast of erected penis.

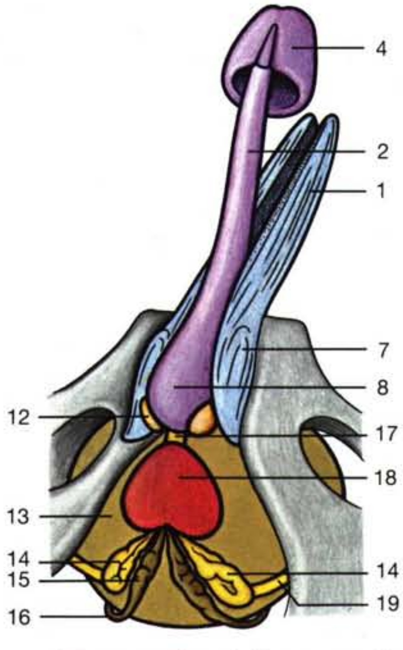

Male external genital organs and accessory glands. (Schematic drawing.)

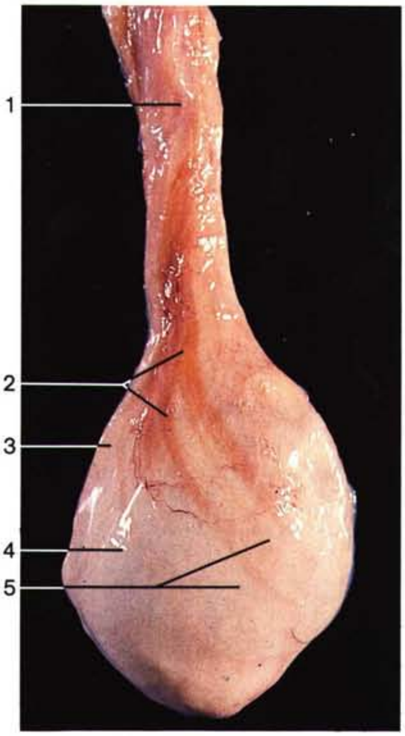

Testis and epididymis with investing layers (lateral view).

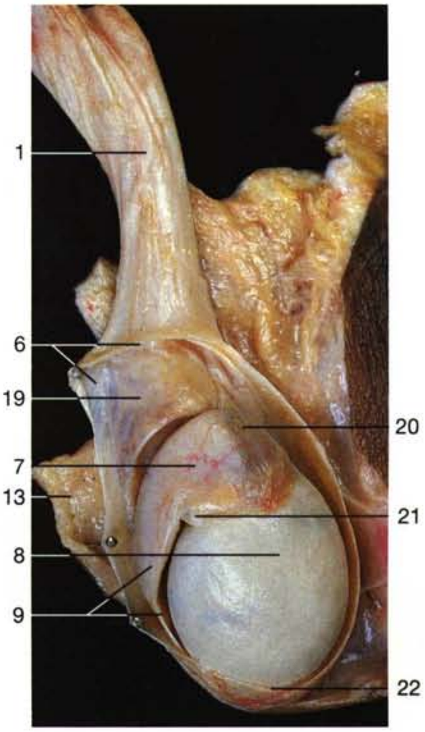

Testis and epididymis (lateral view). The tunica vaginalis has been opened.

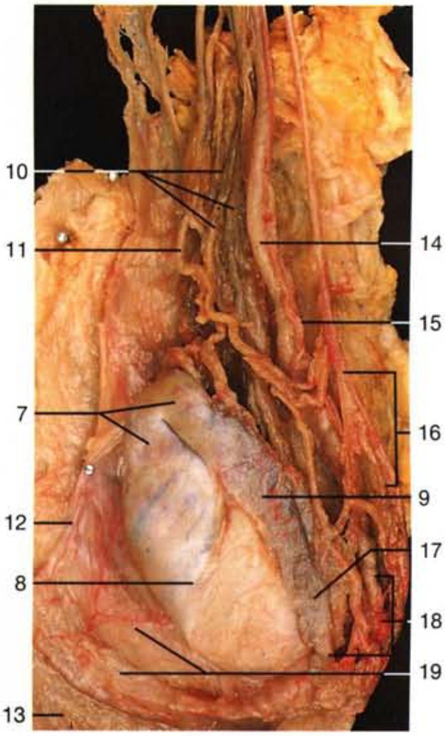

Testis, epididymis and spermatic cord. Dissection of spermatic cord and ductus deferens (left side, posterolateral aspect).

1 Spermatic cord covered with cremasteric fascia
2 **Cremaster muscle**
3 Position of epididymis
4 Internal spermatic fascia
5 Position of testis
6 Internal spermatic fascia with adjacent investing layers of testis (cut surface)
7 **Head of epididymis**
8 **Testis with tunica vaginalis** (visceral layer)
9 Body of epididymis
10 Pampiniform venous plexus (anterior veins)
11 **Testicular artery**
12 Tunica vaginalis (parietal layer, cut edge)
13 Skin and dartos muscle (reflected)
14 **Ductus deferens**
15 Artery of ductus deferens
16 Posterior veins of pampiniform plexus
17 Tail of epididymis
18 Transition of epididymal duct to ductus deferens and venous plexus
19 Parietal layer of tunica vaginalis
20 Appendix of epididymis
21 Appendix of testis
22 Gubernaculum testis

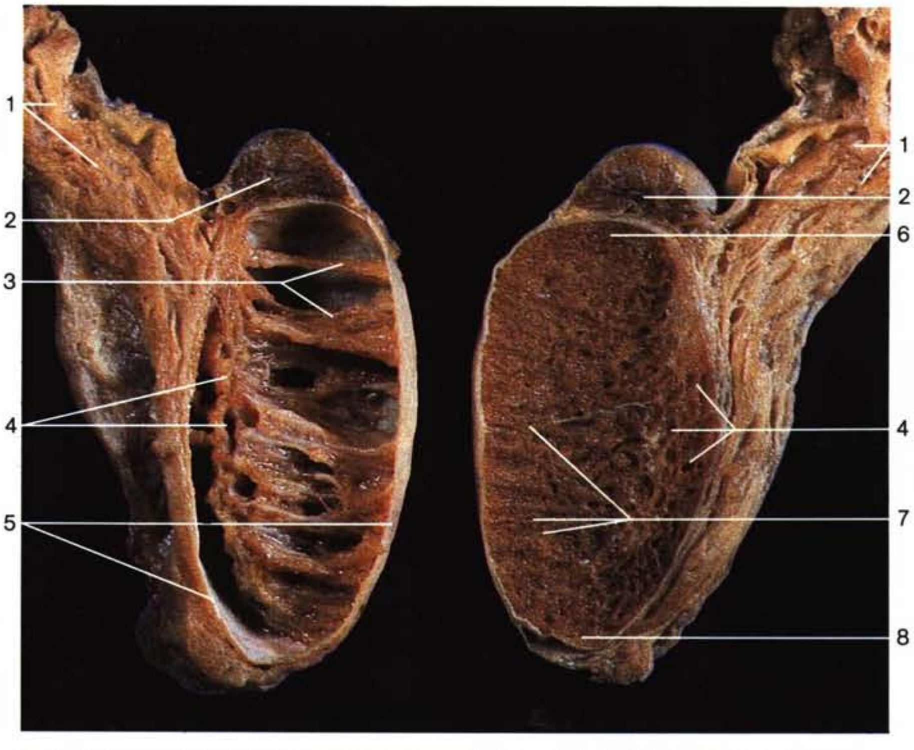

Longitudinal section through testis and epididymis. The left figure shows the testicular septa after removal of the seminiferous tubules.

1 Spermatic cord (cut surface)
2 Head of epididymis (cut surface)
3 Septa of testis
4 Mediastinum testis
5 Tunica albuginea
6 Superior pole of testis
7 Convoluted seminiferous tubules
8 Inferior pole of testis

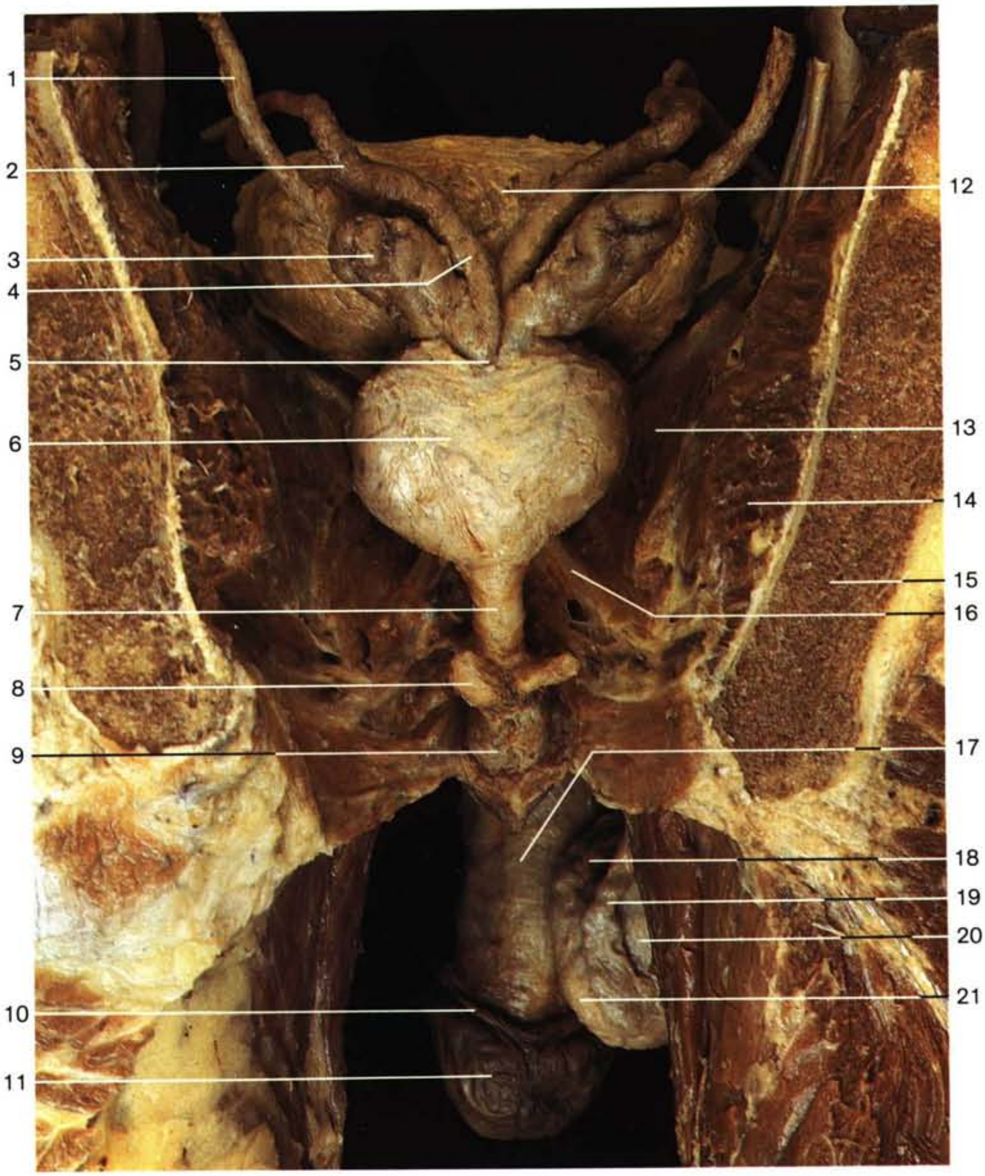

Accessory glands of male genital organs in situ. Coronal section through the pelvic cavity. Posterior aspect of urinary bladder, prostate and seminal vesicles.

1 Ureter
2 **Ductus deferens**
3 **Seminal vesicle**
4 **Ampulla of ductus deferens**
5 Ejaculatory duct (proximal portion)
6 **Prostate**
7 Membranous urethra
8 **Bulbourethral or Cowper's gland**
9 Bulb of penis
10 Penis
11 Glans penis
12 **Urinary bladder**
13 Levator ani muscle
14 Obturator internus muscle
15 Pelvic bone (cut edge)
16 Puboprostatic ligament
17 **Corpus spongiosum of penis**
18 Head of epididymis
19 Beginning of ductus deferens
20 Testis
21 Tail of epididymis
22 Corpus cavernosum of penis
23 Spermatic cord
24 Pectineus and adductor muscles
25 Pubic bone
26 **Prostatic part of urethra** (seminal colliculus)
27 Rectum
28 Sciatic nerve
29 Great saphenous vein
30 Sartorius muscle
31 Femoral artery and vein
32 Rectus femoris muscle
33 Tensor fasciae latae muscle
34 Pectineus muscle
35 Iliopsoas muscle
36 Vastus lateralis muscle
37 Obturator externus muscle
38 Femur
39 Ischial tuberosity
40 Gluteus maximus muscle

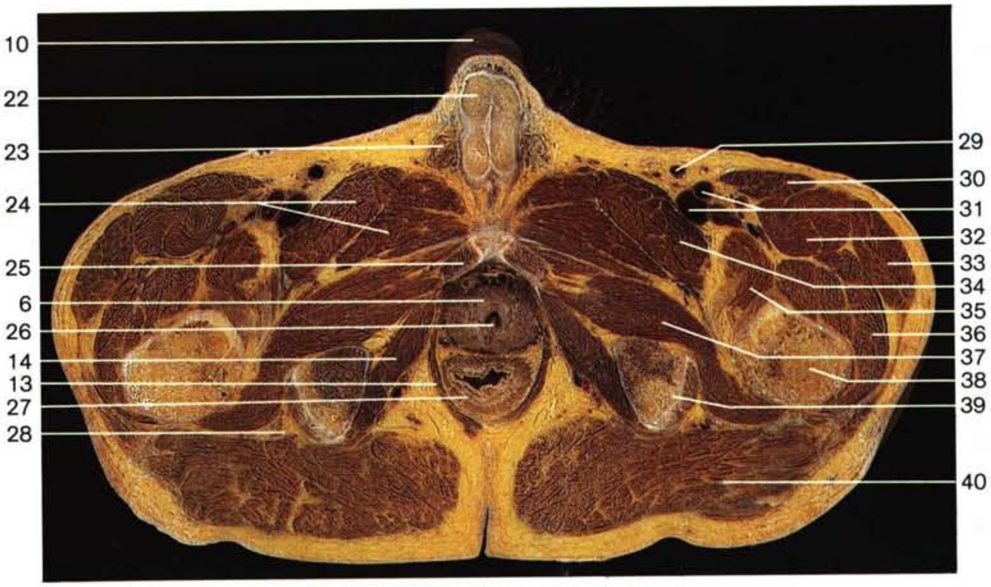

Horizontal section through pelvic cavity at level of prostate.

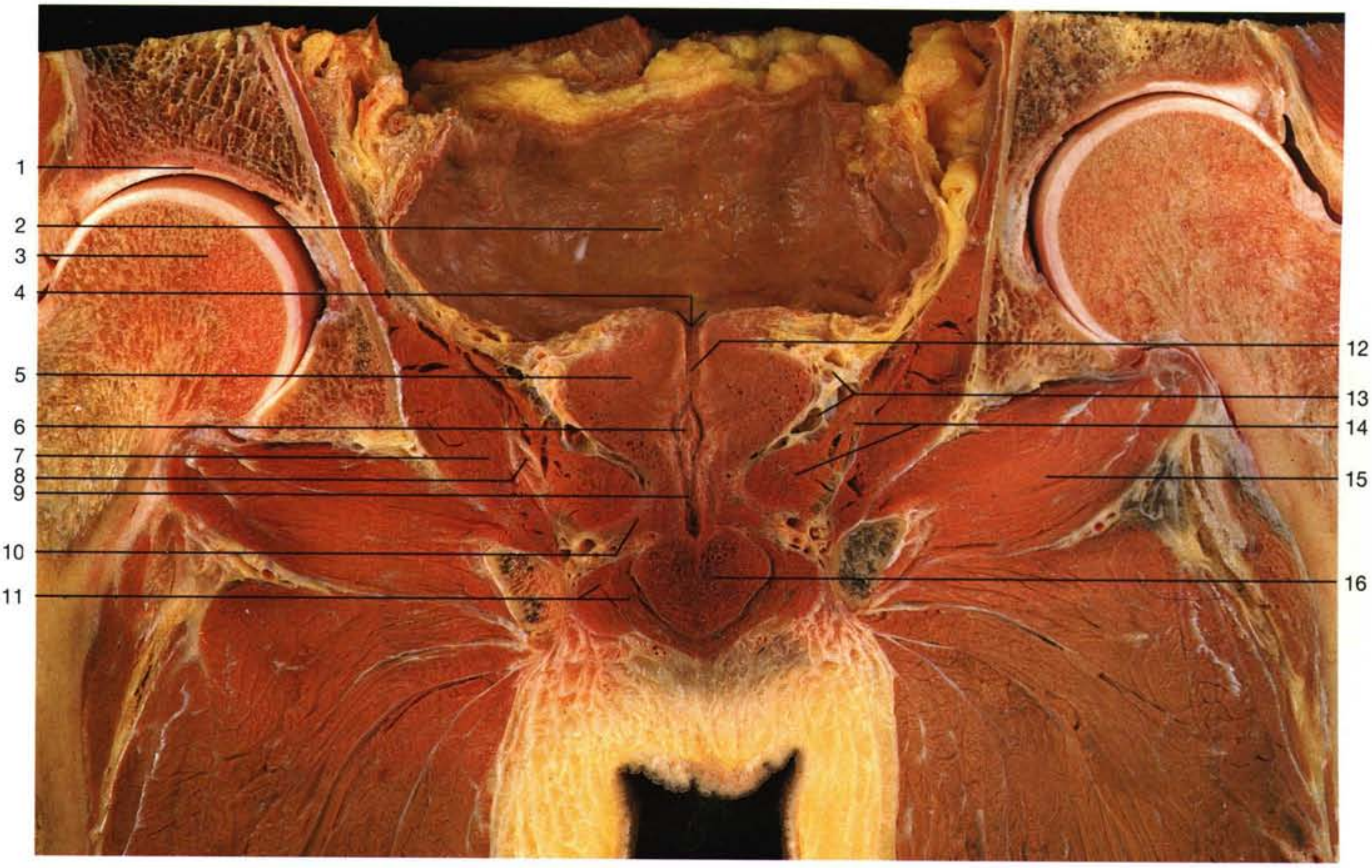

Coronal section through pelvic cavity at the level of prostate and hip joint (anterior aspect).

1 Acetabulum of hip joint
2 **Urinary bladder**
3 Head of femur
4 Internal urethral orifice
5 **Prostate**
6 **Seminal colliculus**
7 Obturator internus muscle
8 Ischiorectal fossa
9 Membranous urethra
10 Deep transverse perineus muscle
11 **Crus penis** and **ischiocavernosus muscle**
12 Prostatic part of urethra
13 Prostatic plexus
14 Levator ani muscle
15 Obturator externus muscle
16 **Bulb of penis**
17 Ampulla of rectum
18 **Anal canal**
19 Seminal vesicle
20 Internal anal sphincter muscle
21 External anal sphincter muscle
22 Anus
23 Psoas major muscle
24 Intervertebral disc
25 Ilium
26 Ligament of the head of the femur
27 Sacral promontory

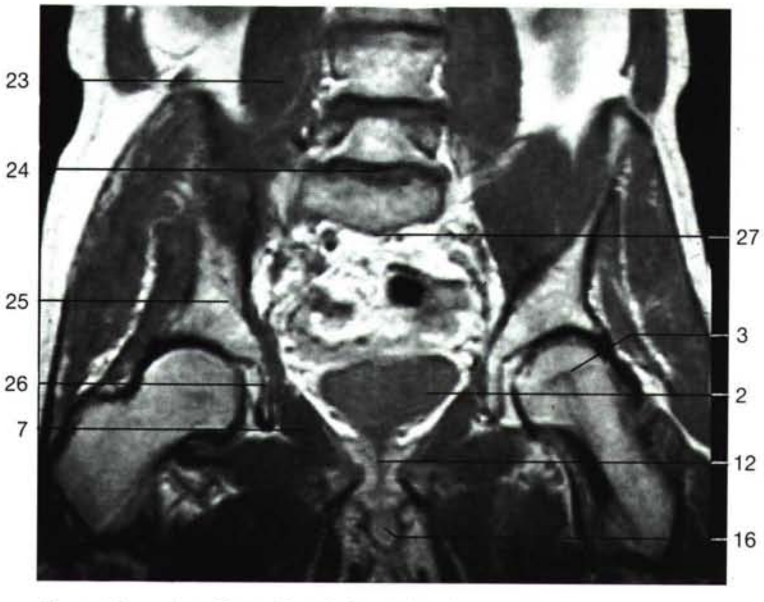

Coronal section through pelvic cavity. (MR-Scan.)

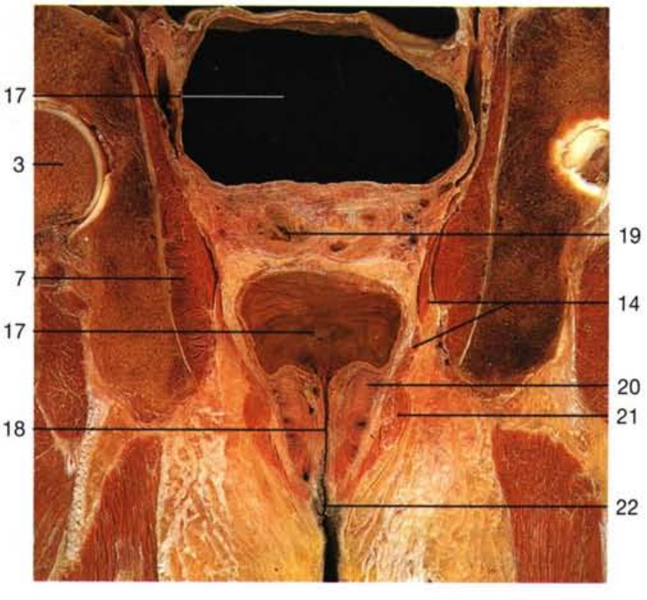

Coronal section through anal canal.

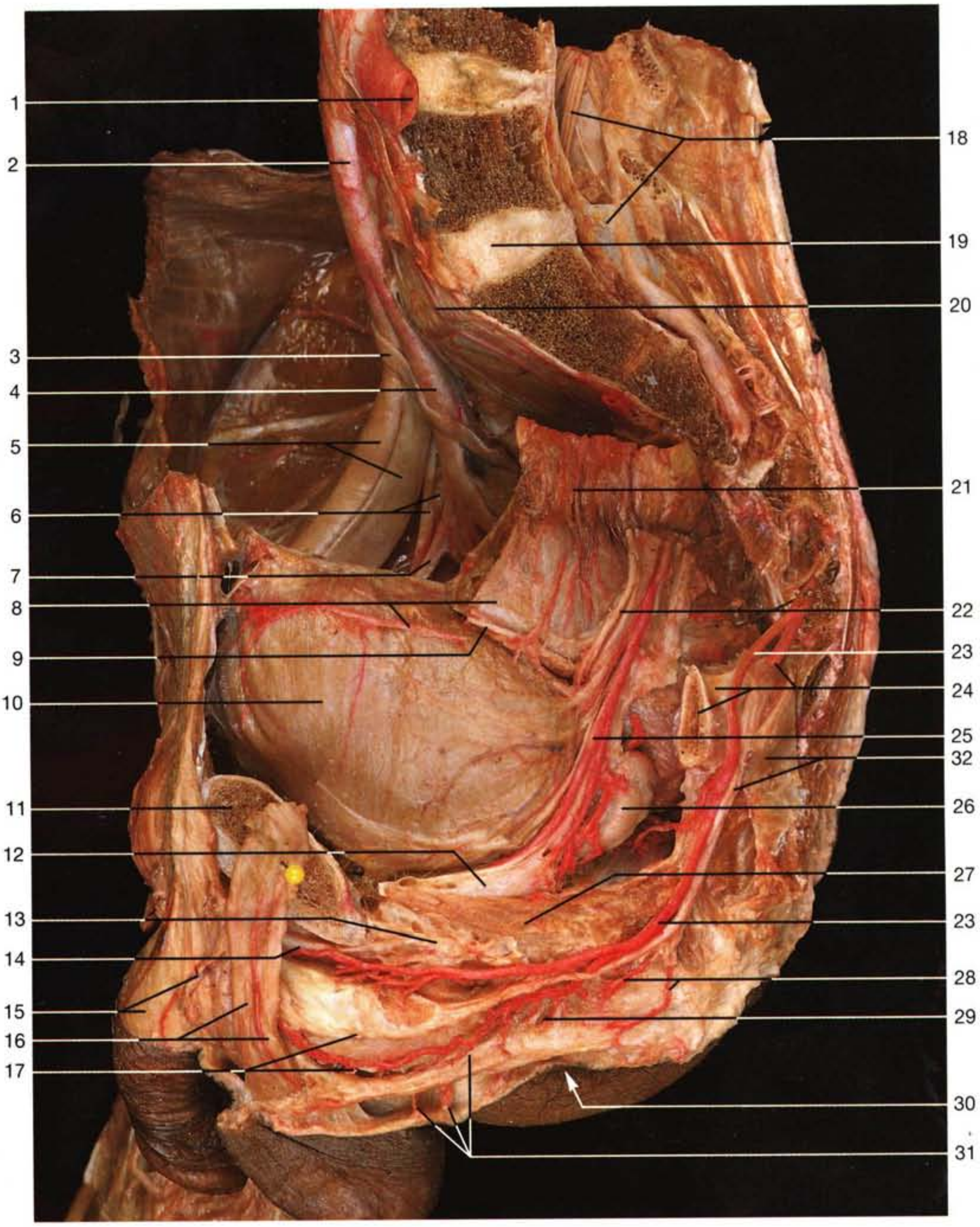

Pelvic cavity in the male (right half of parasagittal section). The arteries have been injected with red resin. The parietal layer of peritoneum has been removed. The urinary bladder is filled to a great extent.

1 Left common iliac artery
2 Right common iliac artery
3 Right **ureter**
4 Right **internal iliac artery**
5 Right external iliac artery and vein
6 Right **obturator artery and nerve**
7 Umbilical artery
8 Sigmoid and superior vesical artery
9 Left ductus deferens
10 **Urinary bladder**
11 Pubic bone (cut)
12 **Prostate**
13 Vesicoprostatic venous plexus
14 Deep dorsal vein of penis and dorsal artery of penis
15 Penis and superficial dorsal vein
16 **Spermatic cord and testicular artery**
17 **Bulb of penis** and deep artery of penis
18 Cauda equina and dura mater (divided)
19 Intervertebral disc between fifth lumbar vertebra and sacrum
20 **Sacral promontory**
21 Mesosigmoid
22 Left ureter
23 Left internal pudendal artery
24 Ischial spine (cut), sacrospinal ligament, inferior gluteal artery
25 Left **inferior vesical artery**
26 **Seminal vesicle**
27 Levator ani muscle
28 Branches of inferior rectal artery
29 Perineal artery
30 Anus
31 Posterior scrotal branches
32 **Pudendal nerve** and sacrotuberal ligament

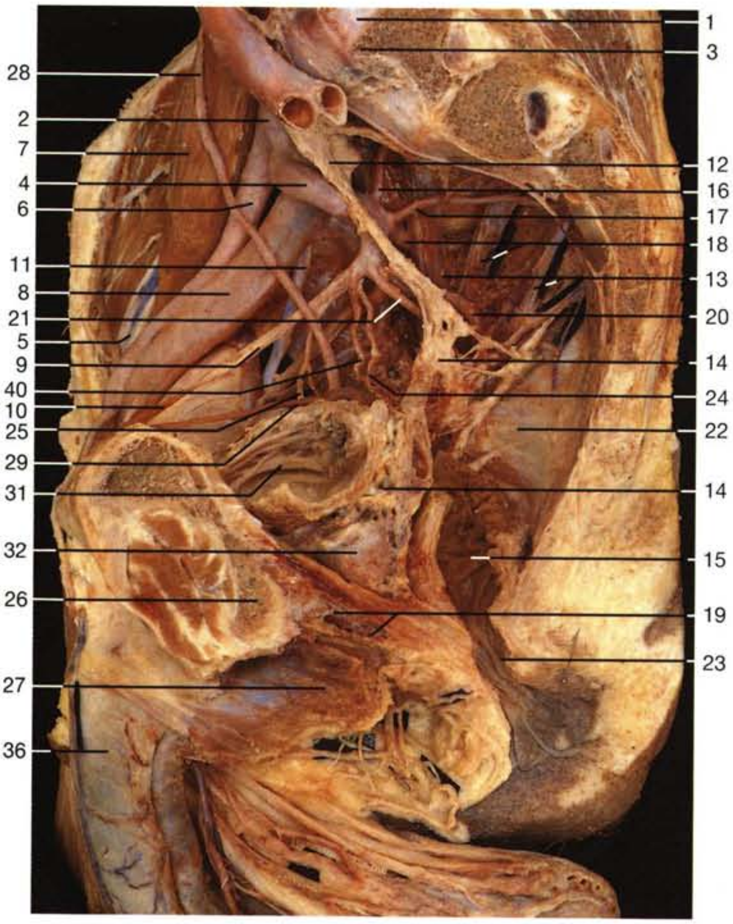

Vessels of pelvic cavity in the male (midsagittal section, right side, medial aspect). Urinary bladder and rectum have been partly removed; the hypogastric plexus is displayed.

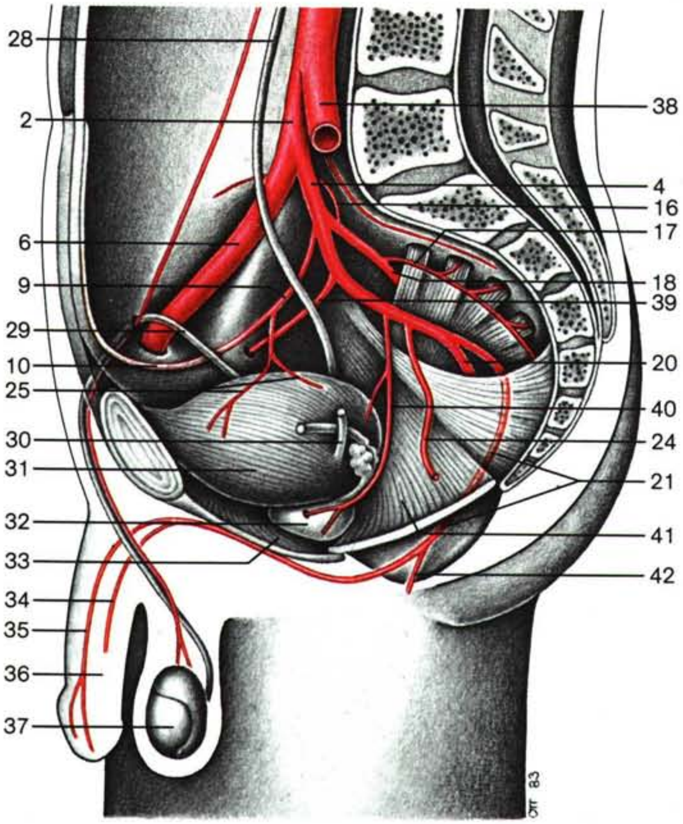

Main branches of internal iliac artery in the male. (Schematic drawing.)

1 Intervertebral disc between 5th lumbar vertebra and sacrum
2 Right common iliac artery
3 Sacral promontory
4 Right **internal iliac artery**
5 Femoral nerve
6 Right external iliac artery
7 Psoas major muscle
8 Right external iliac vein
9 **Umbilical artery**
10 Medial umbilical ligament with obliterated umbilical artery
11 Obturator nerve
12 Superior hypogastric plexus
13 Sacral spinal nerve (of sacral plexus)
14 **Inferior hypogastric plexus**
15 Rectum
16 Iliolumbar artery
17 Lateral sacral artery
18 Superior gluteal artery and sacral spinal nerve
19 Pudendal and coccygeal plexus
20 Inferior gluteal artery
21 **Internal pudendal artery**
22 Coccygeus muscle overlying sacrospinous ligament
23 **Anal canal**
24 Middle rectal artery
25 **Superior vesical artery** and branch to the ductus deferens
26 Pubic bone (cut)
27 Bulbospongiosus muscle
28 Right ureter
29 Right ductus deferens
30 Left ureter
31 **Urinary bladder**
32 **Prostate**
33 Urogenital diaphragm
34 Deep artery of penis
35 Dorsal artery of penis
36 Penis
37 Testis
38 Left common iliac artery
39 **Obturator artery**
40 **Inferior vesical artery**
41 Levator ani muscle
42 Inferior rectal artery

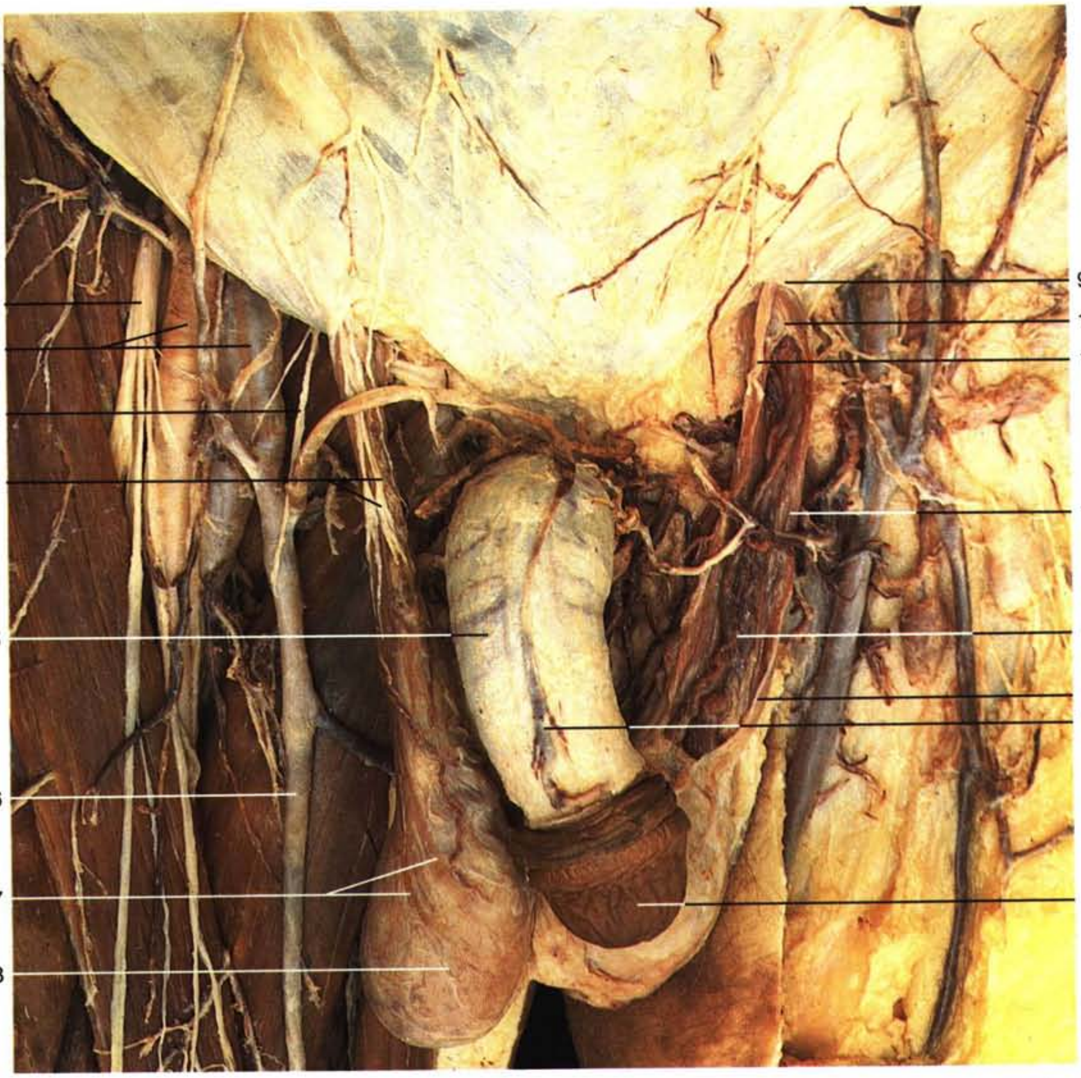
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Male external genital organs with penis, testis, and spermatic cord, superficial layers (anterior view).

1 Femoral nerve
2 Femoral artery and vein
3 Femoral branch of genitofemoral nerve
4 **Spermatic cord** with genital branch of genitofemoral nerve
5 **Penis** with deep fascia
6 Great saphenous vein
7 Cremaster muscle
8 **Testis with cremaster muscle**
9 Superficial inguinal ring
10 Internal spermatic fascia (cut edge)
11 Ilioinguinal nerve
12 Left spermatic cord
13 Pampiniform venous plexus
14 External spermatic fascia
15 Superficial dorsal vein of penis
16 **Glans penis**

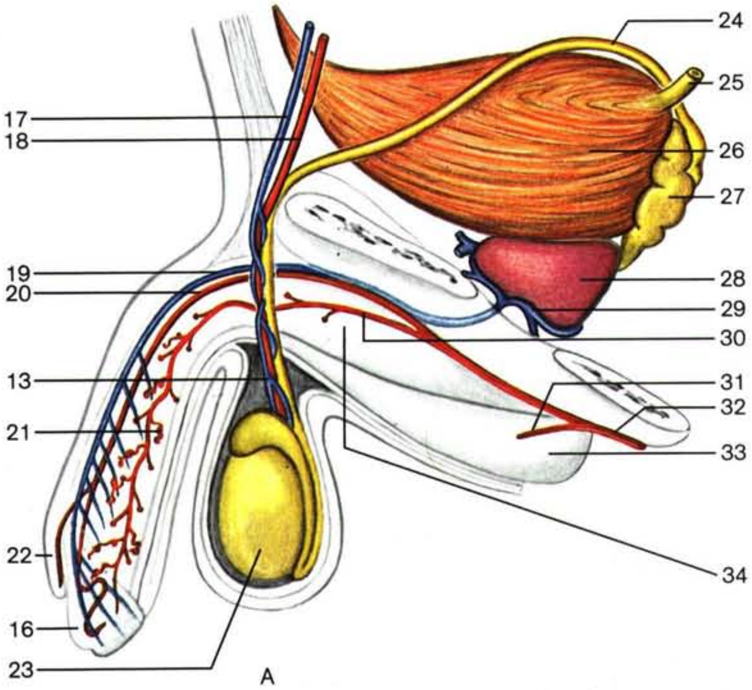
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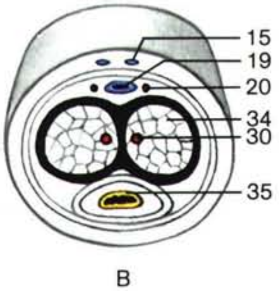
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Vessels of male genital organs. (Schematic drawing.)
A = lateral aspect; B = cross-section of penis.

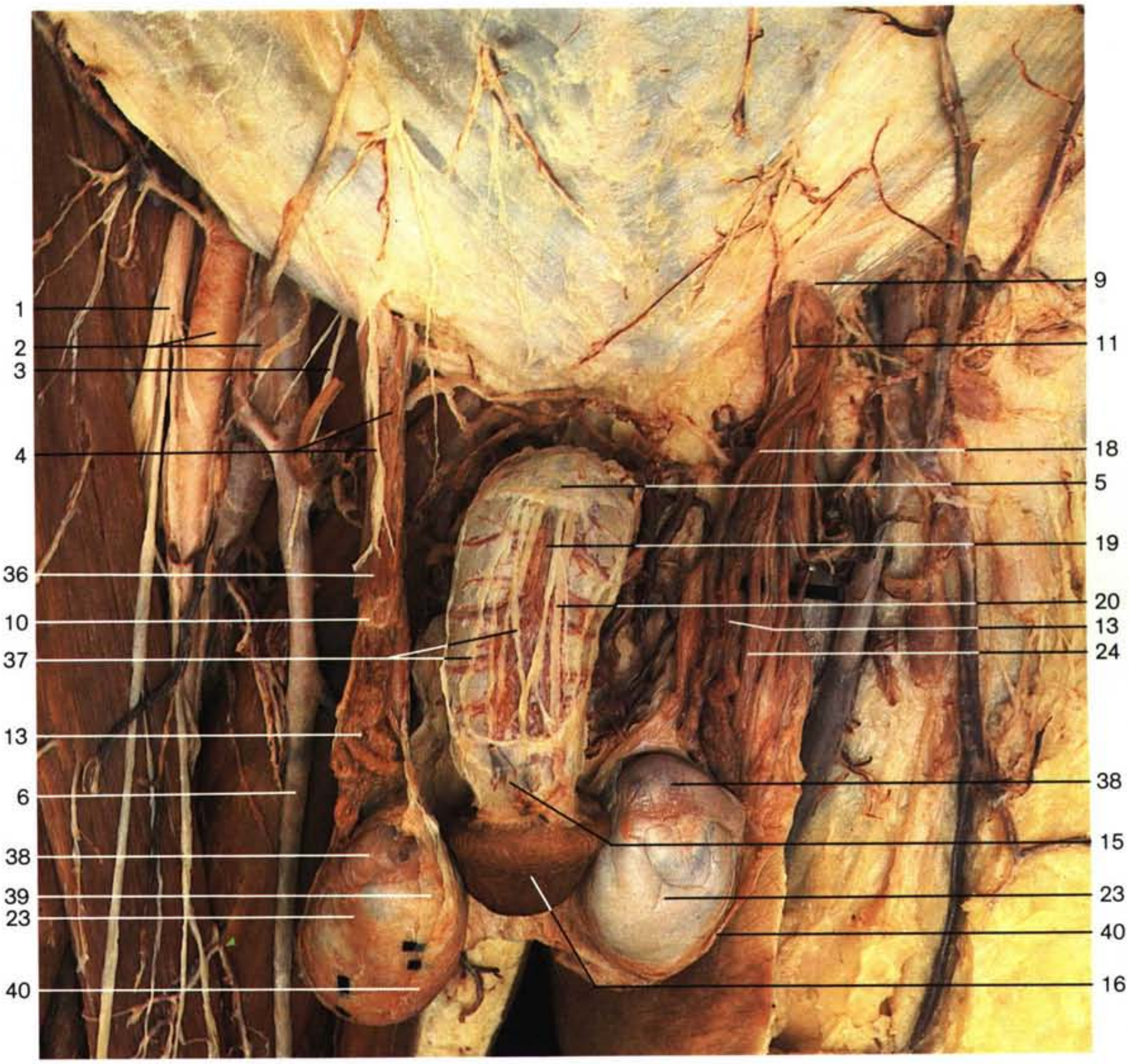

Male external genital organs with penis, testis and spermatic cord, deeper layers (ventral aspect). The deep fascia of the penis has been opened to display the dorsal nerves and vessels.

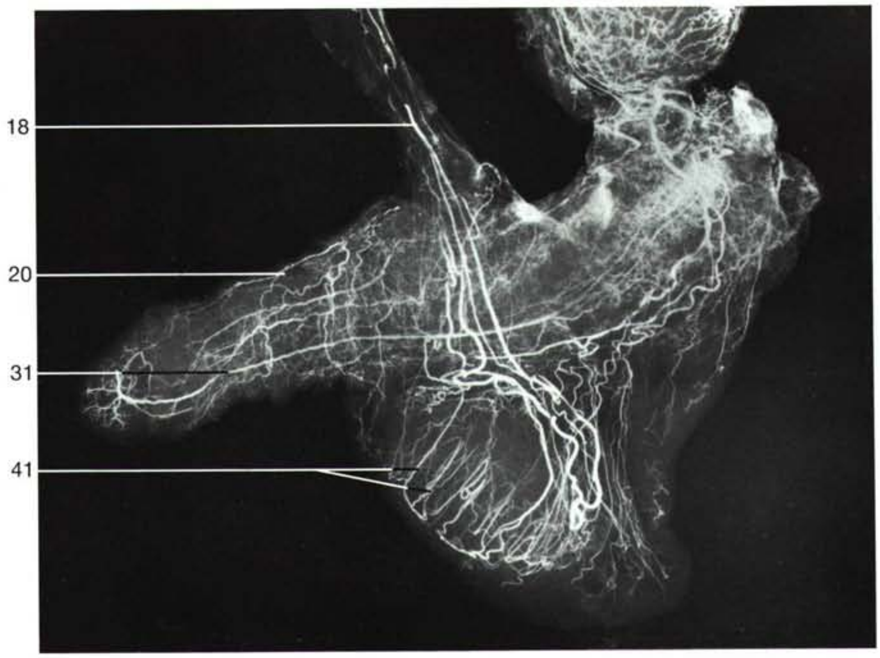

Male genital organs (lateral aspect). (Arteriogram.)

17	Testicular vein
18	Testicular artery
19	Deep dorsal vein of penis
20	**Dorsal artery of penis**
21	**Helicine arteries**
22	Prepuce
23	**Testis** with **tunica albuginea**
24	Ductus deferens
25	Ureter
26	Urinary bladder
27	**Seminal vesicle**
28	**Prostate**
29	Vesicoprostatic venous plexus
30	**Deep artery of penis**
31	Artery of bulb of penis
32	Internal pudendal artery
33	Corpus spongiosum of penis
34	Corpus cavernosum of penis
35	Urethra
36	Cremasteric fascia with cremaster muscle
37	Dorsal nerve of penis
38	**Epididymis**
39	**Tunica vaginalis** (visceral layer)
40	Tunica vaginalis (parietal layer)
41	Testis with vascular loops

1 Glans penis
2 **Corpus spongiosum of penis**
3 **Corpus cavernosum of penis**
4 Gracilis muscle
5 Adductor muscles
6 Ischiocavernosus muscle overlying crus of penis
7 Perineal body
8 Gluteus maximus muscle
9 Coccyx
10 **Bulbospongiosus** muscle
11 Deep transverse perineus muscle covered by inferior fascia of urogenital diaphragm
12 Superficial transverse perineus muscle
13 Anus
14 **External anal sphincter muscle**
15 **Levator ani muscle**
16 Anococcygeal ligament
17 Obturator internus muscle
18 Urethra
19 **Deep transverse perineus muscle**

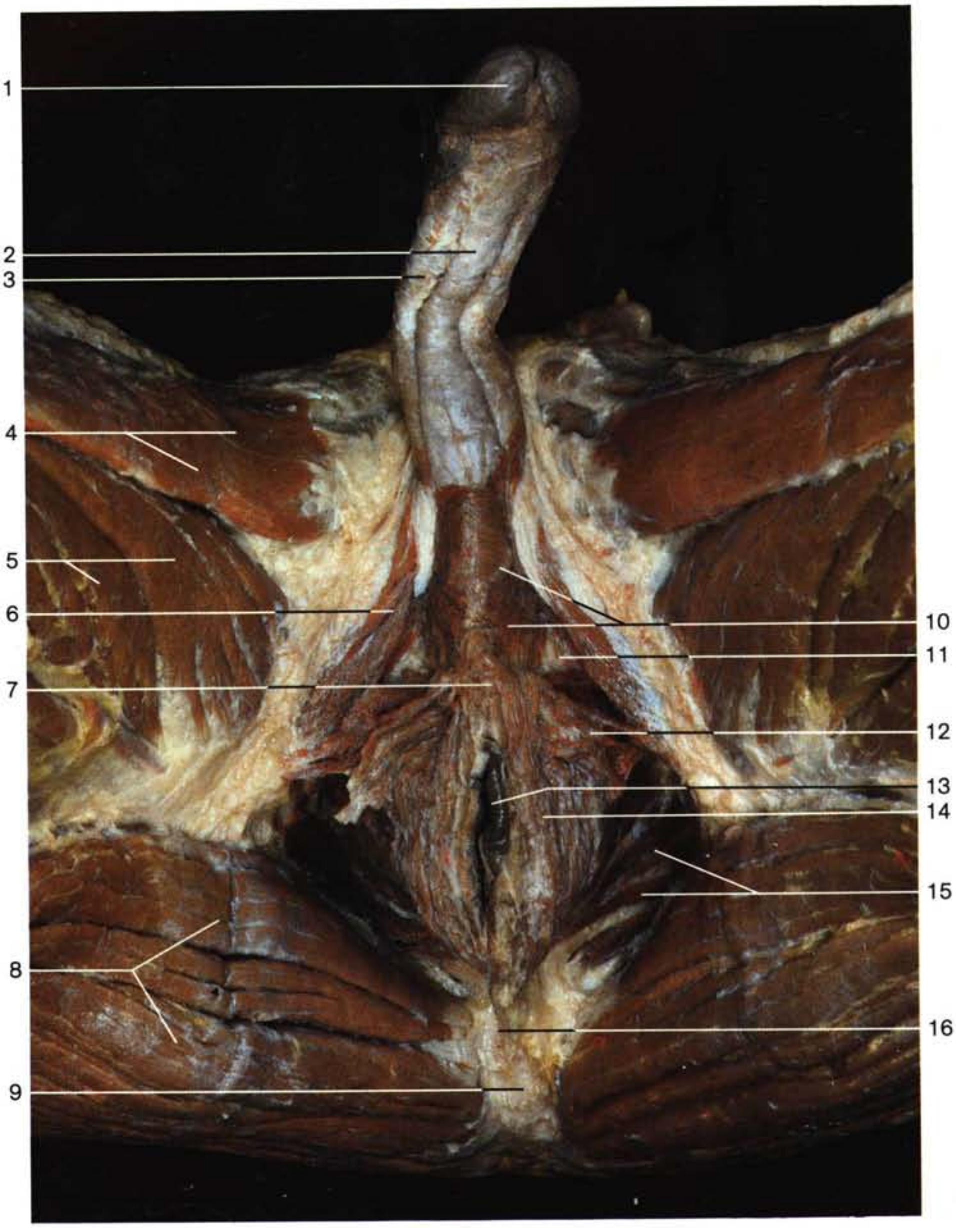

Muscles of urogenital and pelvic diaphragms in the male (from below).

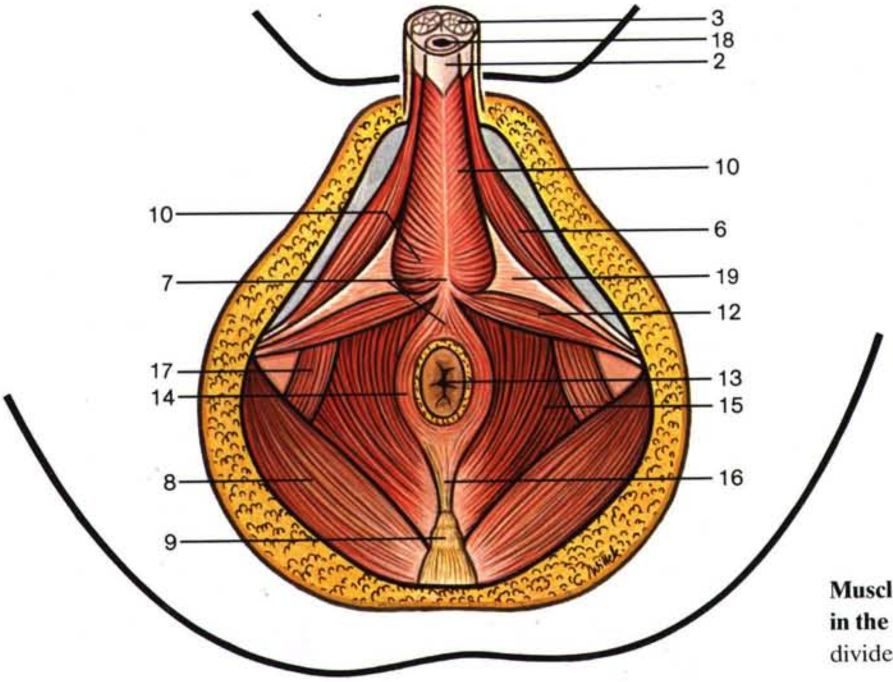

Muscles of urogenital and pelvic diaphragms in the male (from below). The penis has been divided. (Schematic drawing.)

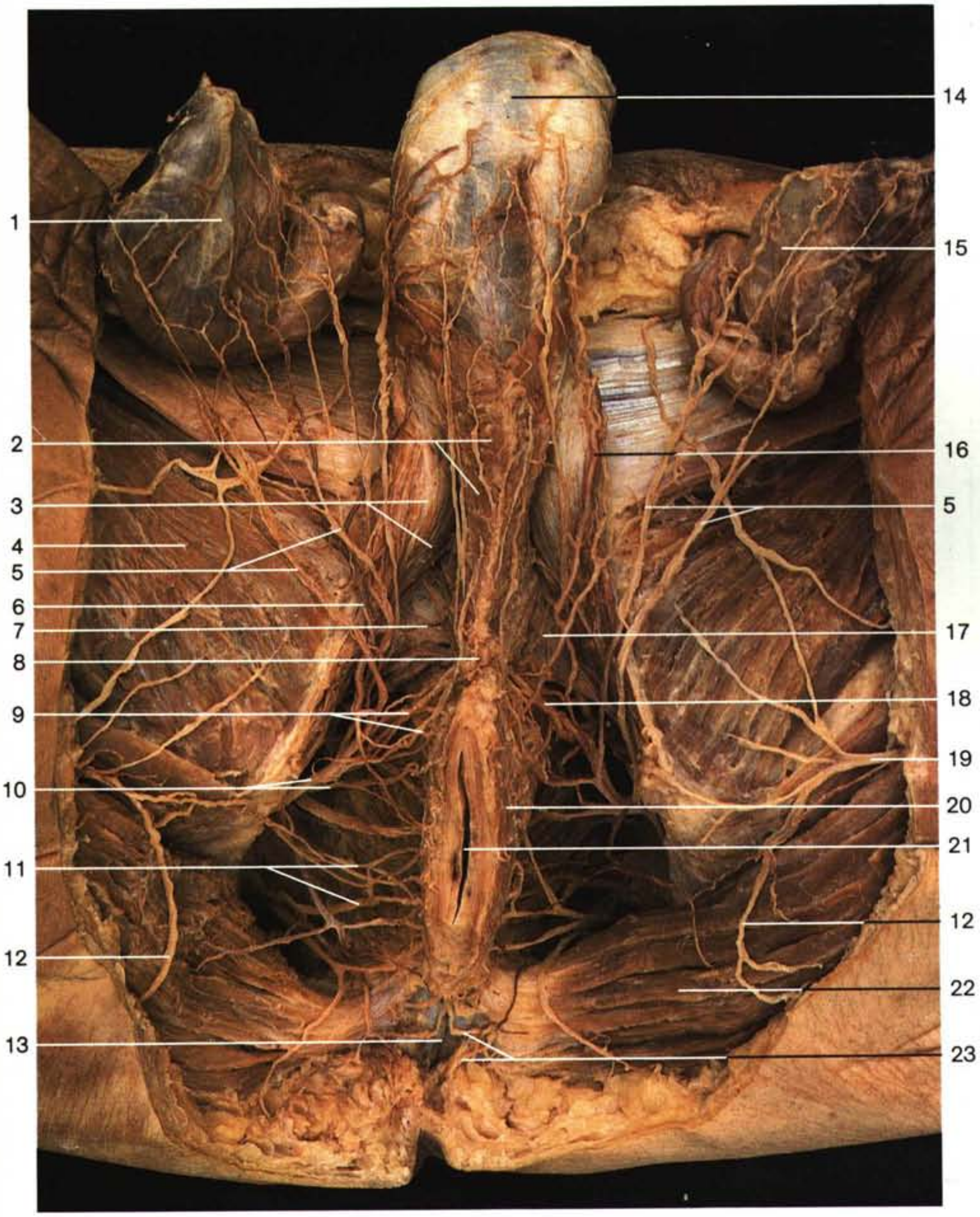

Urogenital diaphragm and external genital organs in the male with vessels and nerves (from below). The testes have been reflected laterally.

1 Right testis (reflected laterally and upward)
2 Bulbospongiosus muscle
3 Ischiocavernosus muscle
4 Adductor magnus muscle
5 **Posterior scrotal nerves** and superficial perineal arteries
6 Posterior scrotal artery and vein
7 Right artery of bulb of penis
8 Perineal body
9 Perineal branches of pudendal nerve
10 **Pudendal nerve** and **internal pudendal artery**
11 **Inferior rectal arteries** and **nerves**
12 Inferior cluneal nerve
13 Coccyx (location)
14 Penis
15 Left testis (reflected laterally)
16 Left posterior scrotal artery
17 **Deep transverse perineal muscle**
18 Left artery of bulb of penis
19 **Posterior femoral cutaneous nerve**
20 External anal sphincter muscle
21 **Anus**
22 Gluteus maximus muscle
23 Anococcygeal nerves
24 Acetabulum (femur removed)
25 Ligament of femoral head
26 Body of ischium (cut)
27 Sciatic nerve
28 Coccygeus muscle
29 **Levator ani muscle**
  a iliococcygeus muscle
  b pubococcygeus muscle
  c puborectalis muscle
30 Prostatic venous plexus
31 Body of pubis
32 Testis

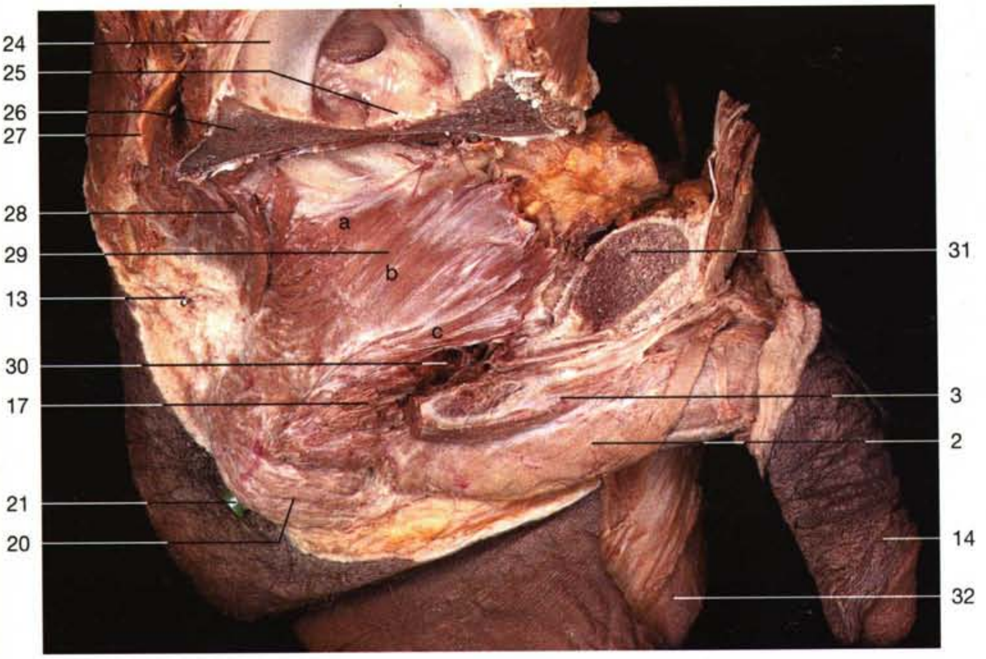

Pelvic diaphragm and external genital organs in the male. The right half of the pelvis including obturator internus muscle and femur had been removed to display the right half of levator ani muscle.

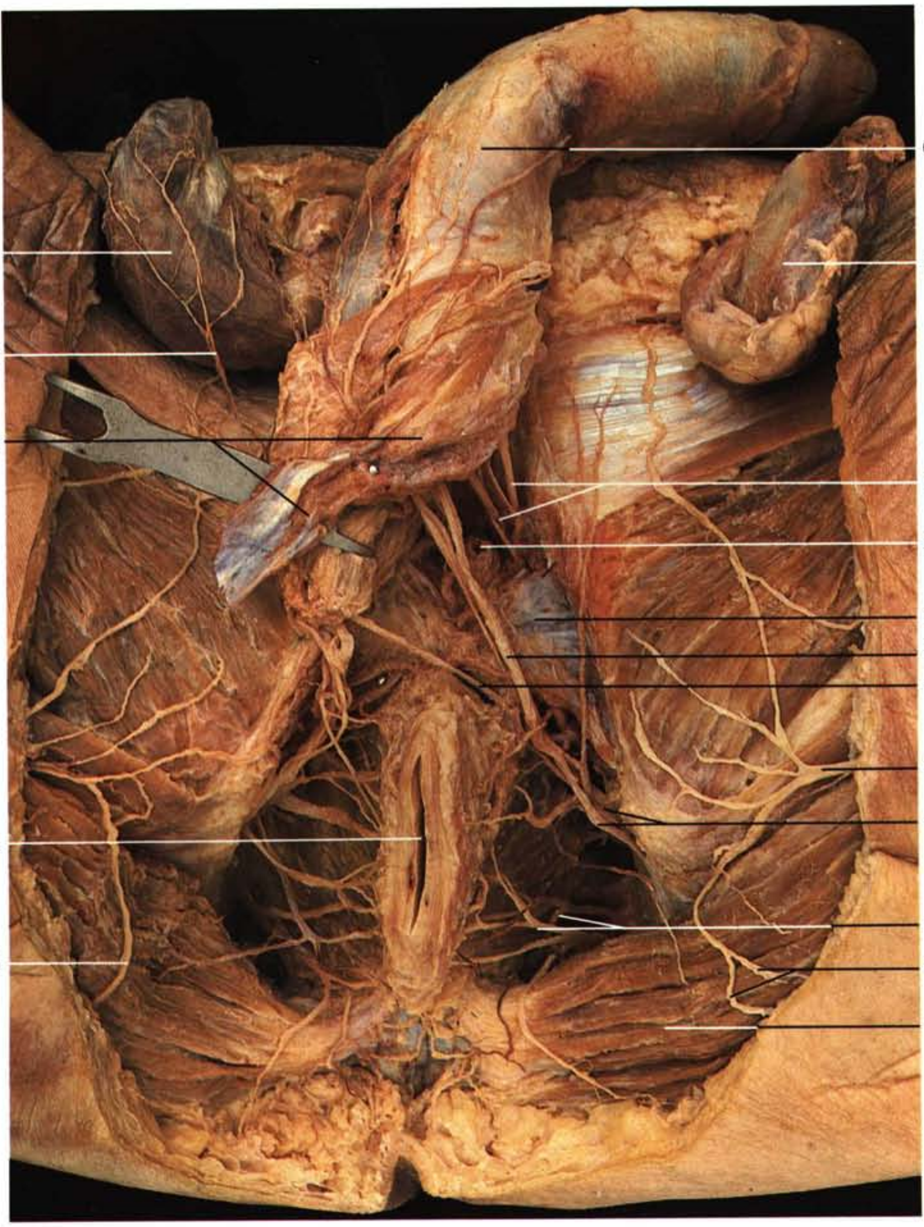

Urogenital diaphragm and external genital organs in the male (from below).
The left crus penis has been isolated and reflected laterally together with the bulb of the penis. The urethra has been cut.

1 Right testis (reflected)
2 Posterior scrotal nerves
3 Left crus penis with ischiocavernosus muscle
4 **Anus**
5 Inferior cluneal nerves
6 **Penis**
7 Left testis (reflected)
8 Dorsal artery and nerve of penis
9 Urethra
10 **Deep transverse perineus muscle**
11 **Perineal branch of pudendal nerve**
12 Artery of bulb of penis (reflected)
13 Branch of posterior femoral cutaneous nerve
14 **Internal pudendal artery** and **pudendal nerve**
15 Inferior rectal arteries and nerves
16 Gluteus maximus muscle
17 Dorsal nerve of penis
18 Posterior femoral cutaneous nerve
19 Perineal branches of pudendal nerve
20 Inferior rectal nerves
21 **Bulbocavernosus muscle** (inside: dorsal artery of penis)
22 Perineal artery
23 **External anal sphincter muscle**
24 Inferior rectal artery and veins

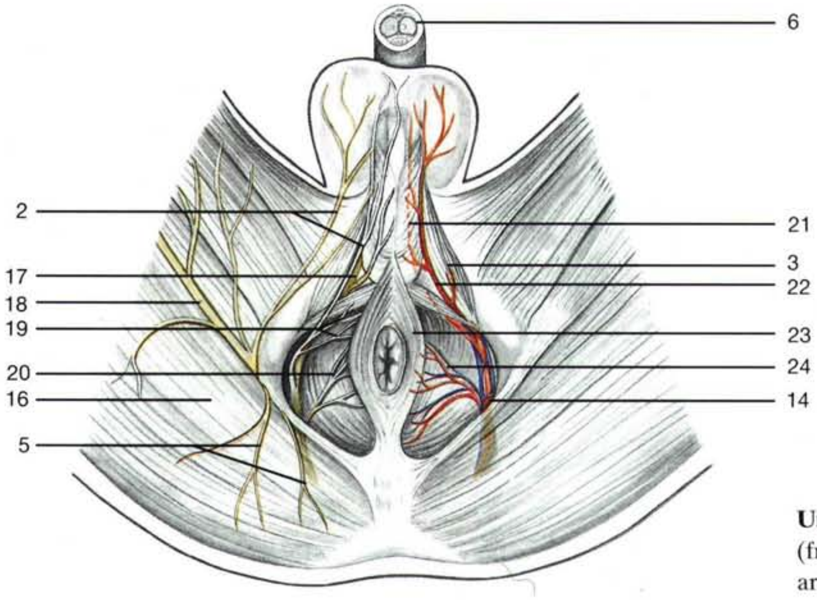

Urogenital and anal region in the male (from below). Right side: nerves; left side: arteries and veins.

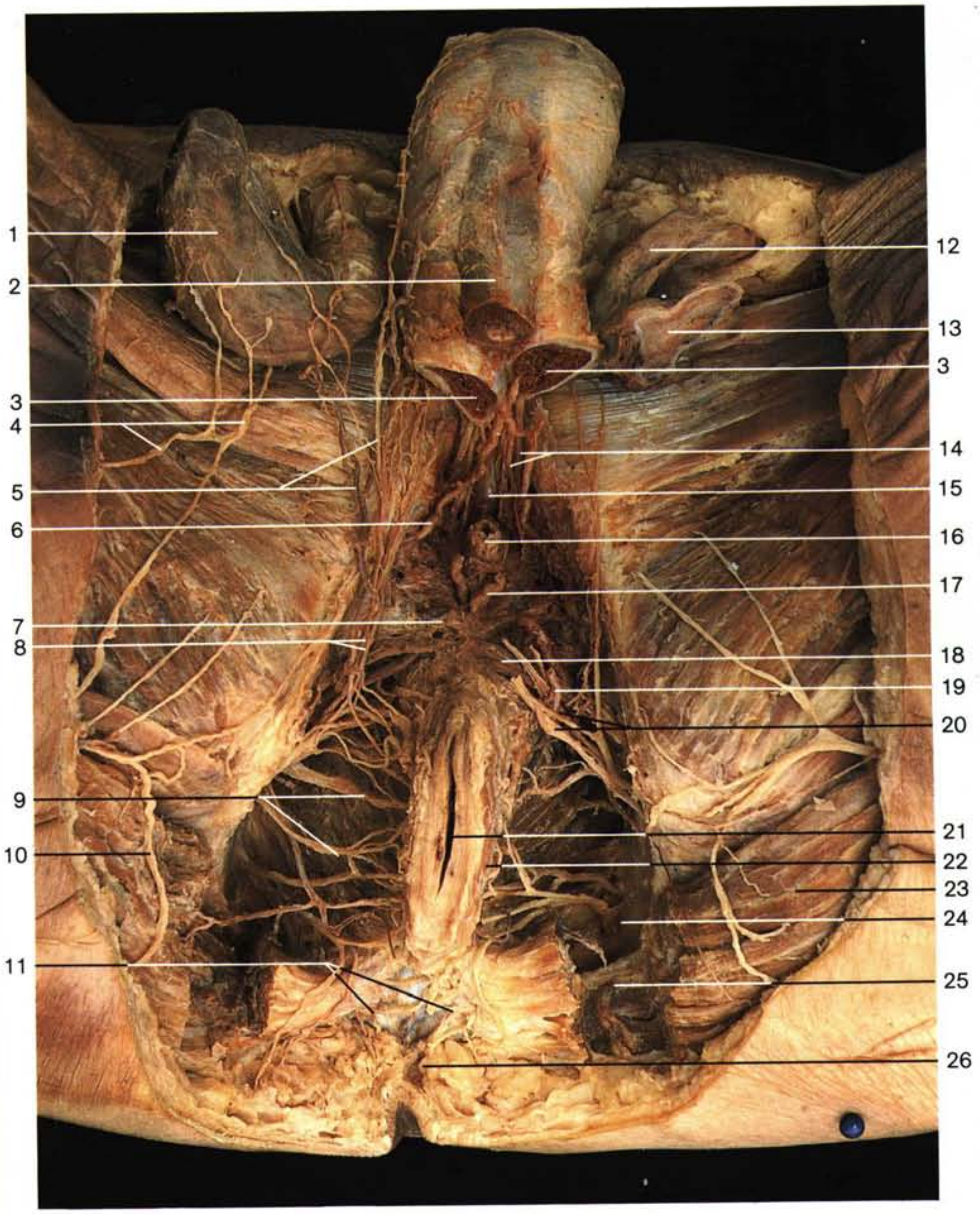

Anal and urogenital region in the male (from below). The root of penis has been cut. Dissection of the urogenital diaphragm.

1 Right testis (reflected)
2 **Corpus spongiosum of penis**
3 **Corpus cavernosum of penis**
4 Perineal branch of posterior femoral cutaneous nerve
5 Posterior scrotal arteries and nerves
6 Deep artery of penis
7 Deep transverse perineal muscle
8 Right **perineal nerves**
9 **Inferior rectal nerves**
10 Inferior cluneal nerve
11 Anococcygeal nerves
12 Left spermatic cord
13 Left testis (cut surface)
14 Dorsal artery and nerve of penis
15 Deep dorsal vein of penis
16 **Urethra** (cut)
17 Artery of bulb of penis
18 Superficial transverse perineus muscle
19 Left artery of bulb of penis
20 Perineal branch of pudendal nerve
21 **Anus**
22 **External anal sphincter muscle**
23 Gluteus maximus muscle
24 Internal pudendal artery and pudendal nerve
25 Sacrotuberous ligament
26 Coccyx
27 Urogenital diaphragm (deep transverse perineus muscle)
28 Tendinous center of perineum (perineal body)
29 **Levator ani muscle**
30 Anococcygeal ligament
31 Obturator internus muscle
32 Dorsal artery of penis

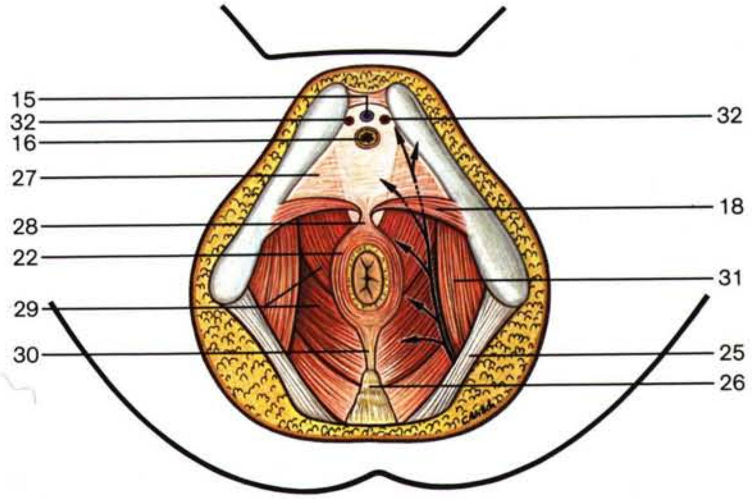

Urogenital and pelvic diaphragms in the male (from below). The penis has been removed. The arrows indicate the course of vessels and nerves. (Schematic drawing.)

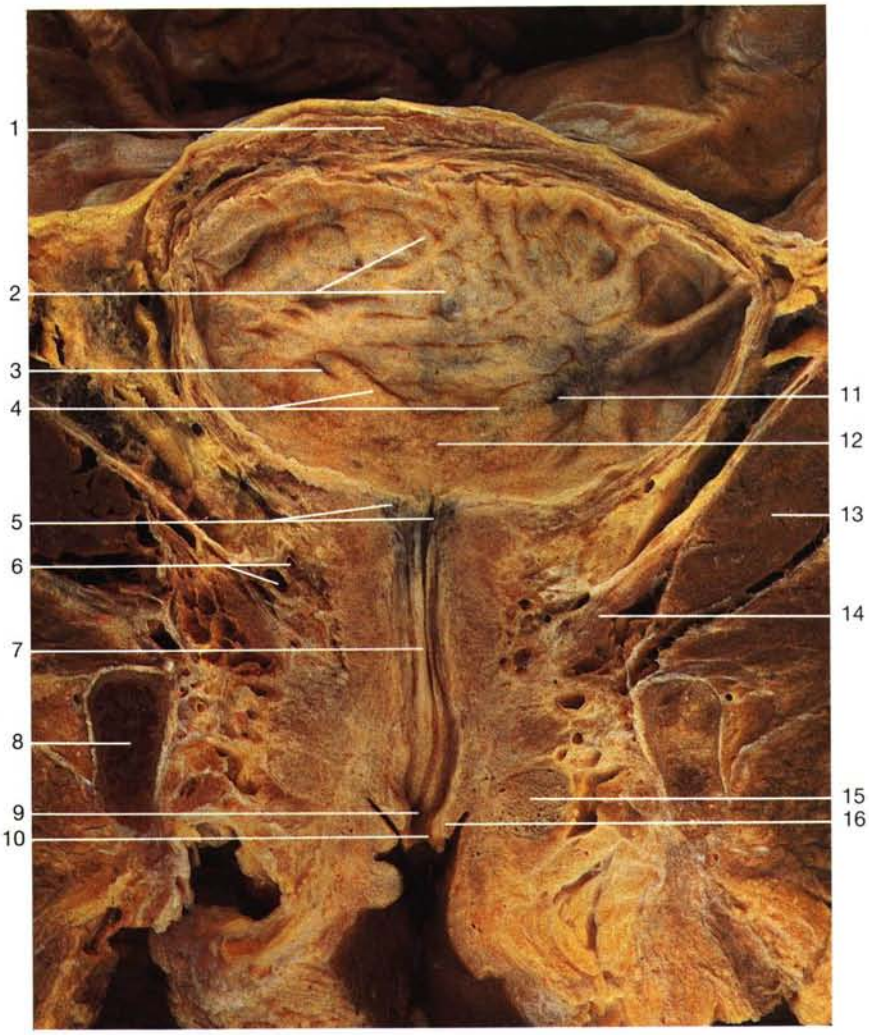

Coronal section through the female urinary bladder and urethra (anterior view).

1 Muscular coat of **urinary bladder**
2 Folds of mucous membrane of urinary bladder
3 Right ureteric orifice
4 Interureteric fold
5 Internal urethral orifice
6 Vesicouterine venous plexus
7 **Urethra**
8 Pubic bone (cut edge)
9 External urethral orifice
10 Vestibule of vagina
11 Left ureteric orifice
12 Trigone of bladder
13 Obturator internus muscle
14 Levator ani muscle
15 Bulb of the vestibule
16 Left labium minus
17 **Uterine tube**
18 Mesosalpinx
19 **Ovary**
20 Sigmoid colon
21 Saphenous opening
22 Urinary bladder
23 Vesicouterine pouch
24 **Fundus of uterus**
25 Rectouterine pouch (of Douglas)
26 Ampulla of rectum
27 Kidney
28 Abdominal part of ureter
29 Pelvic part of ureter
30 Anal canal
31 Perineum (perineal body)
32 Umbilicus
33 Infundibulum of uterine tube
34 Vaginal portion of cervix of uterus
35 Vagina
36 Pubic symphysis
37 Clitoris
38 Deep transverse perineus muscle

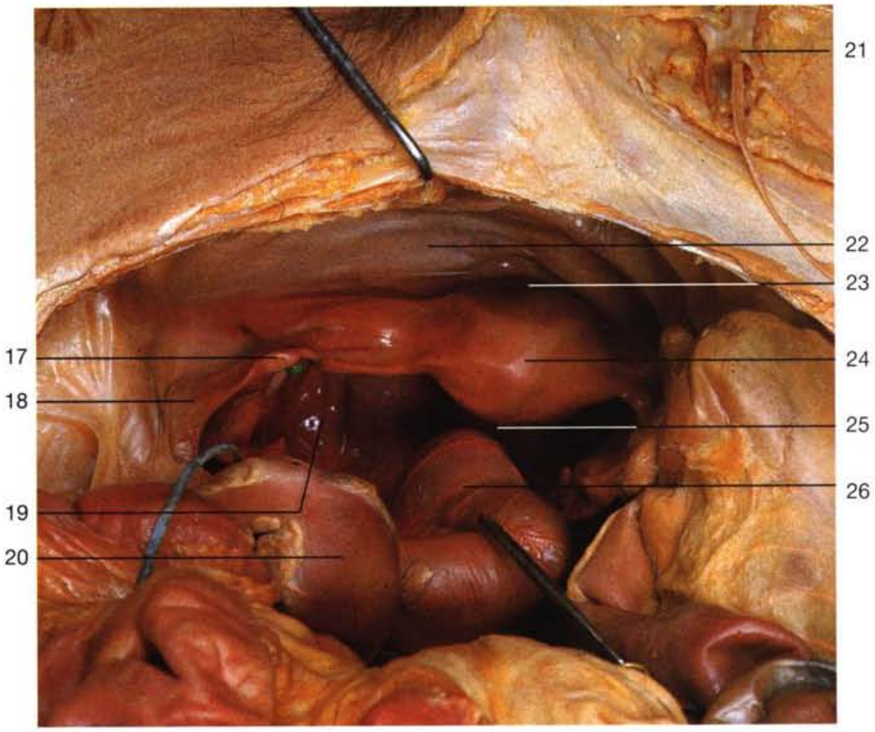

Femal internal genital organs. Pelvic cavity (from above).

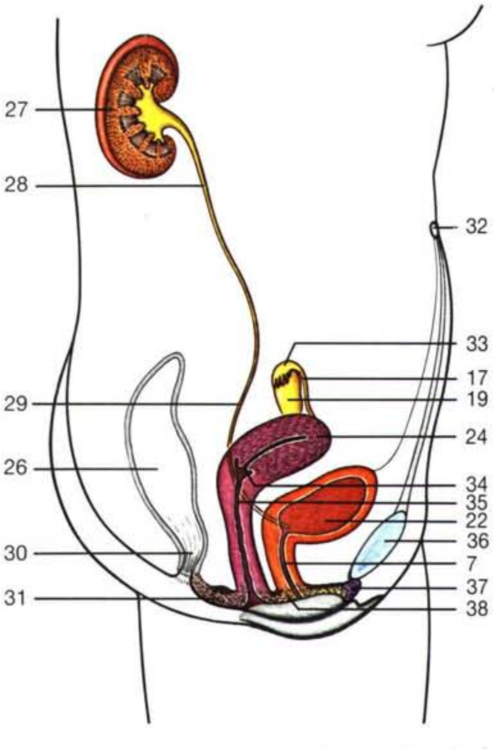

Female urogenital system (midsagittal section). (Schematic drawing.)

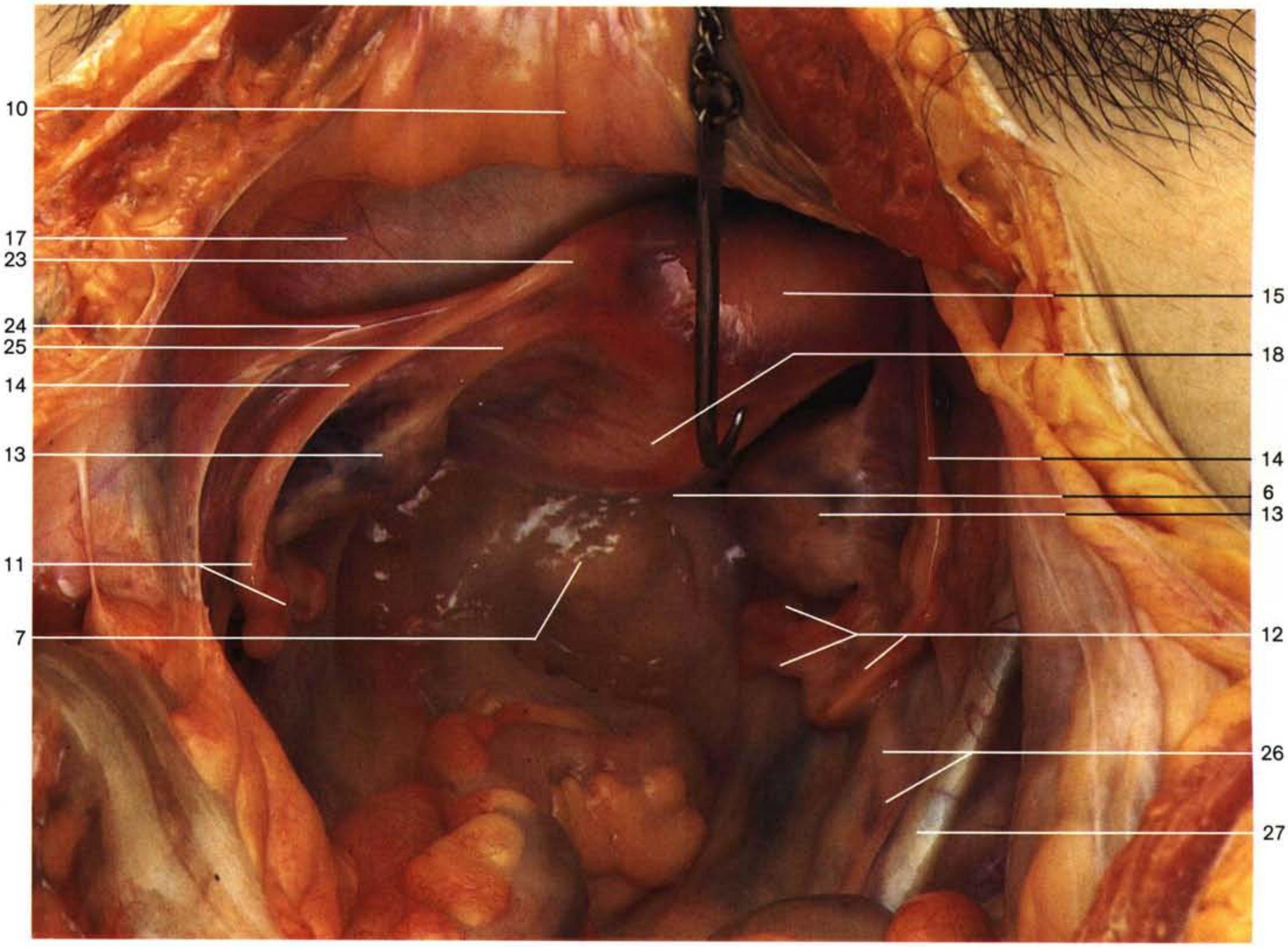

Female internal genital organs. Pelvic cavity, seen from above. The uterus has been reflected to the right.

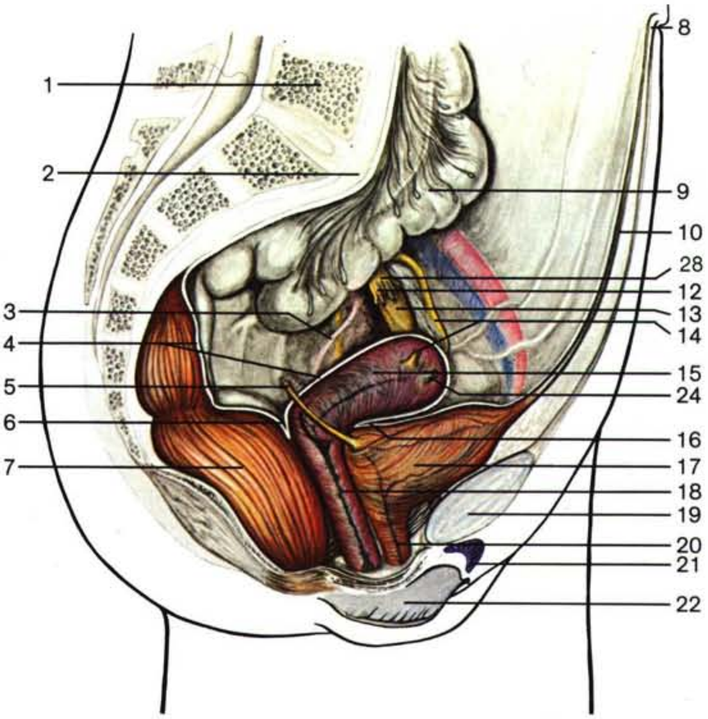

Regional relations of female internal genital organs (medial aspect). (Schematic drawing.)

1 Body of 5th lumbar vertebra
2 Sacral promontory
3 Left ureter
4 Peritoneum (cut edge)
5 Right ureter (divided)
6 **Recto-uterine pouch** (of Douglas)
7 Rectum
8 Umbilicus
9 Sigmoid colon
10 Median umbilical fold with urachus
11 Ampulla of uterine tube
12 Fimbriae of uterine tube
13 **Ovary**
14 **Uterine tube** (isthmus)
15 **Uterus**
16 **Vesico-uterine pouch**
17 Urinary bladder
18 Vagina
19 Pubic symphysis
20 Urethra
21 Clitoris
22 Labium minus
23 Insertion of uterine tube at fundus of uterus
24 Round ligament of uterus
25 Ligament of the ovary
26 Suspensory ligament of ovary
27 Right common iliac artery (covered by peritoneum)
28 Infundibulum of uterine tube

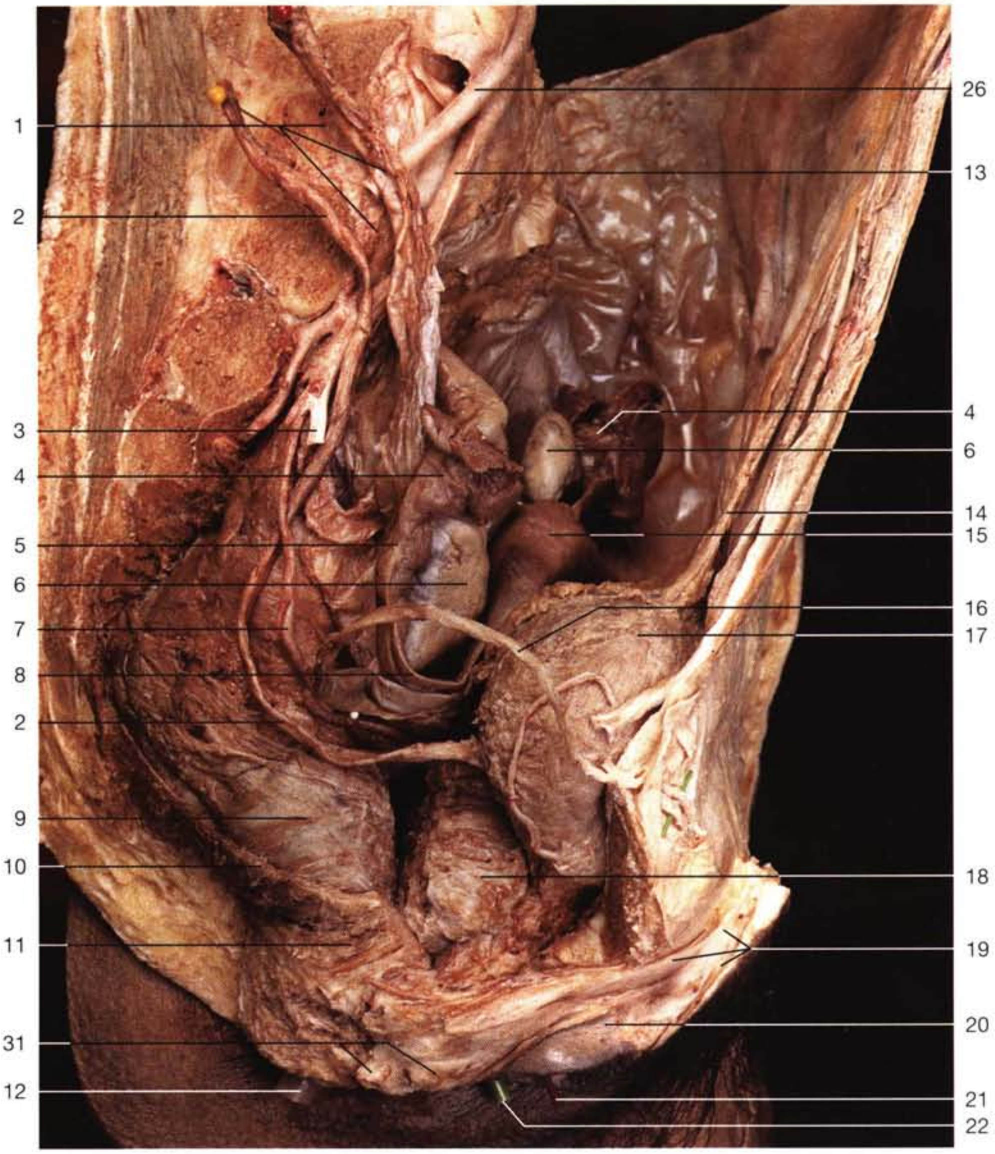

Female internal genital organs in situ. Right half of the pelvis and sacrum have been removed.

1 Body of 5th lumbar vertebra, **suspensory ligament of ovary** and sacral promontory
2 Ureter
3 Medial umbilical ligament (remnant of umbilical artery) (cut)
4 Infundibulum of uterine tube
5 Ampulla of uterine tube
6 **Ovary**
7 **Uterine artery**
8 **Uterine tube**
9 Rectum
10 Levator ani muscle (pelvic diaphragm – cut edge)
11 External anal sphincter muscle
12 Anus (probe)
13 Internal iliac artery
14 Remnant of urachus (median umbilical ligament)
15 **Uterus**
16 Round ligament of uterus
17 **Urinary bladder**
18 **Vagina**
19 **Clitoris**
20 Labium minus
21 External orifice of urethra (red probe)
22 Vaginal orifice (green probe)
23 Lateral umbilical ligament
24 Inferior epigastric artery
25 Obturator artery, vein and nerve
26 External iliac artery
27 **Recto-uterine pouch** (of Douglas)
28 Recto-uterine fold
29 Vesico-uterine pouch
30 Suspensory ligament of ovary
31 Greater vestibular gland and bulb of the vestibule

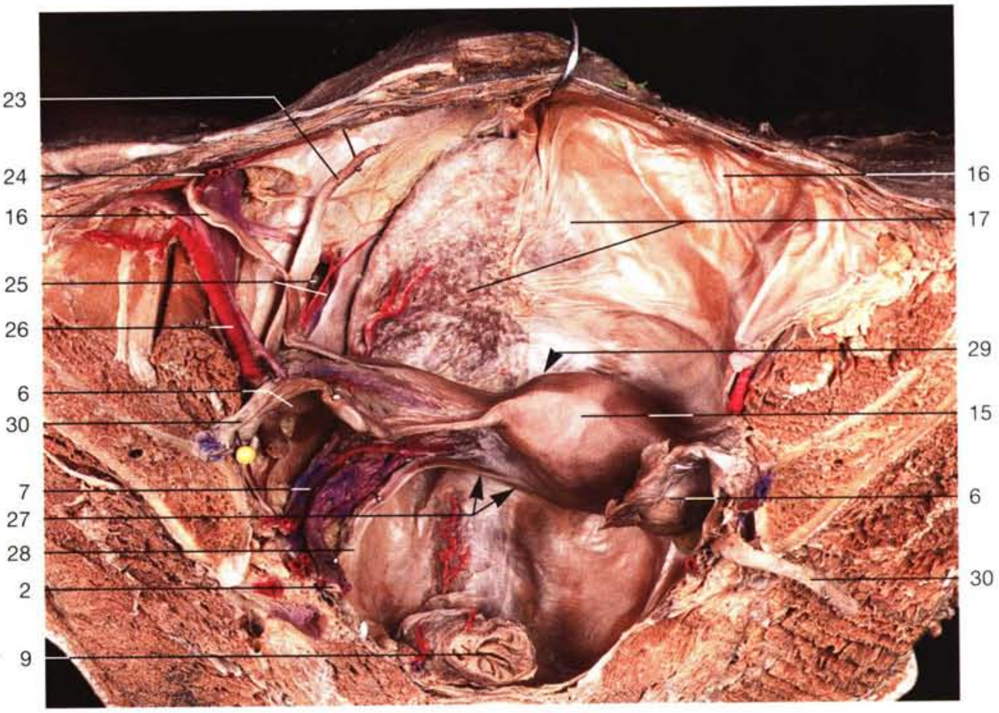

Female internal genital organs in situ (seen from above). The peritoneum at the left half of pelvic cavity has been removed to display uterine tube, vessels, and nerves.

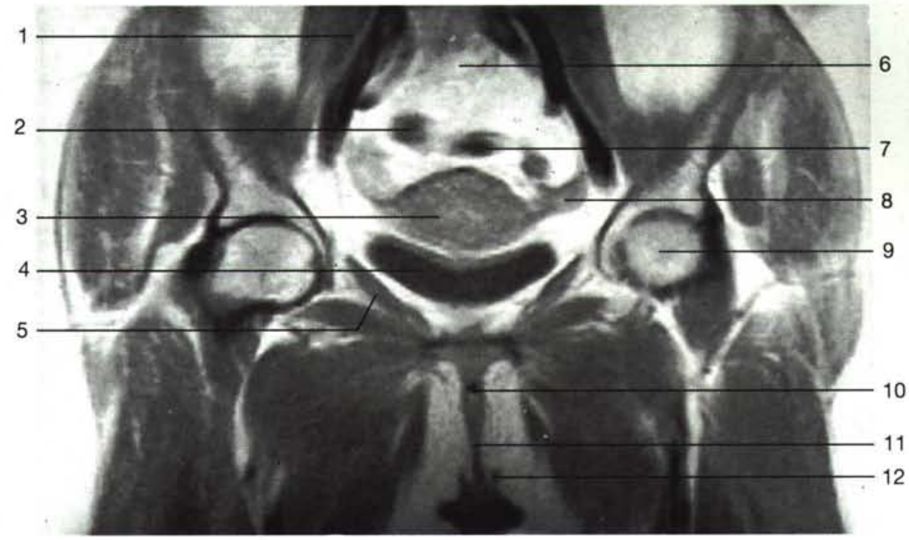

Coronal section through the pelvic cavity of the female. (MR-Scan.)

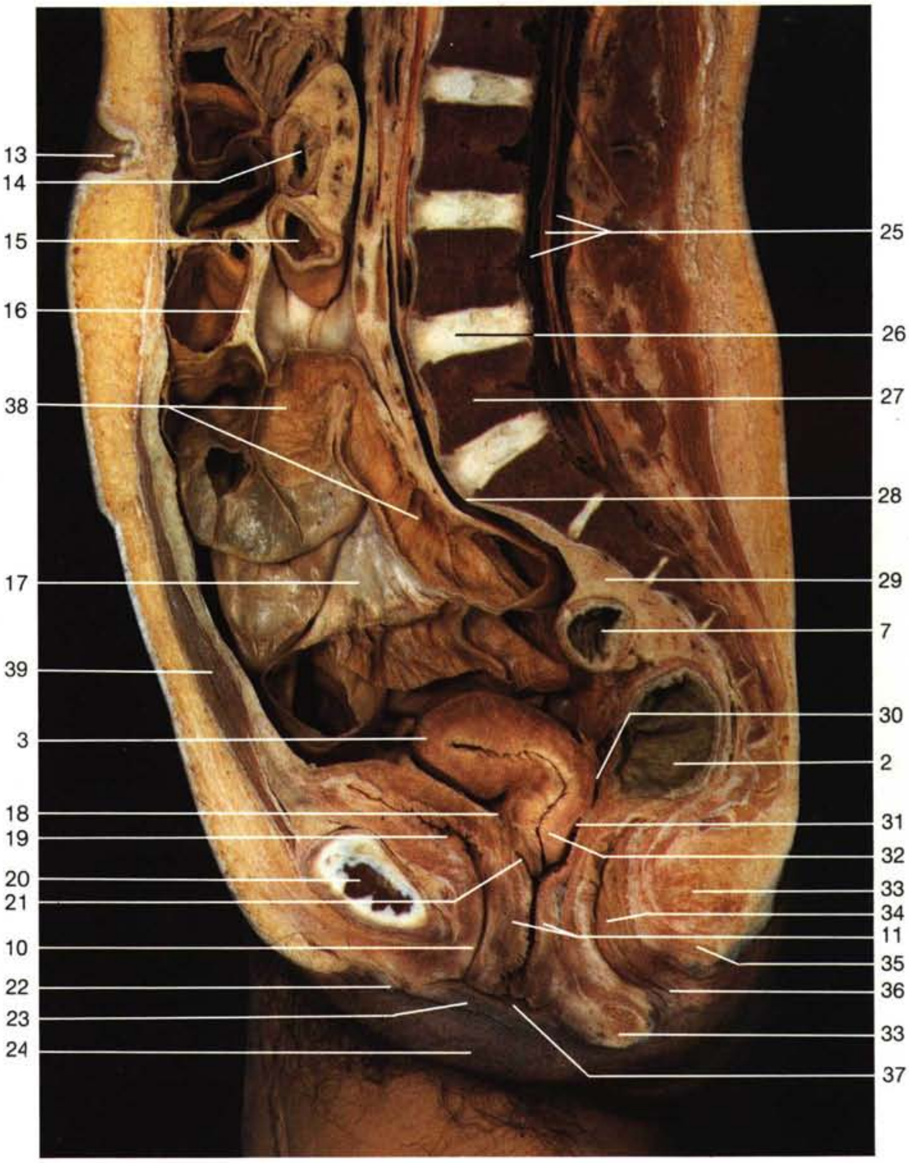

Midsagittal section through the female trunk. The urinary bladder is empty, the position and shape of the uterus are normal.

1 Psoas major muscle
2 Ampulla of rectum
3 **Uterus**
4 **Urinary bladder**
5 Obturator internus muscle
6 Promontory
7 Sigmoid colon
8 **Uterine tube**
9 Head of femur
10 Urethra
11 Vagina
12 Labium minus
13 Umbilicus
14 Duodenum
15 Ascending part of duodenum
16 Root of mesentery
17 Mesentery
18 Vesico-uterine pouch
19 **Urinary bladder** (collapsed)
20 Pubic symphysis
21 Anterior fornix of vagina
22 Clitoris
23 Labium minus
24 Labium majus
25 Vertebral canal with cauda equina
26 Intervertebral disc
27 Body of 5th lumbar vertebra
28 Sacral promontory
29 Mesosigmoid
30 **Recto-uterine pouch** (of Douglas)
31 Posterior fornix of vagina
32 Cervix of uterus
33 External anal sphincter muscle
34 Anal canal
35 Internal anal sphincter muscle
36 Anus
37 Hymen
38 Small intestine
39 Rectus abdominis muscle

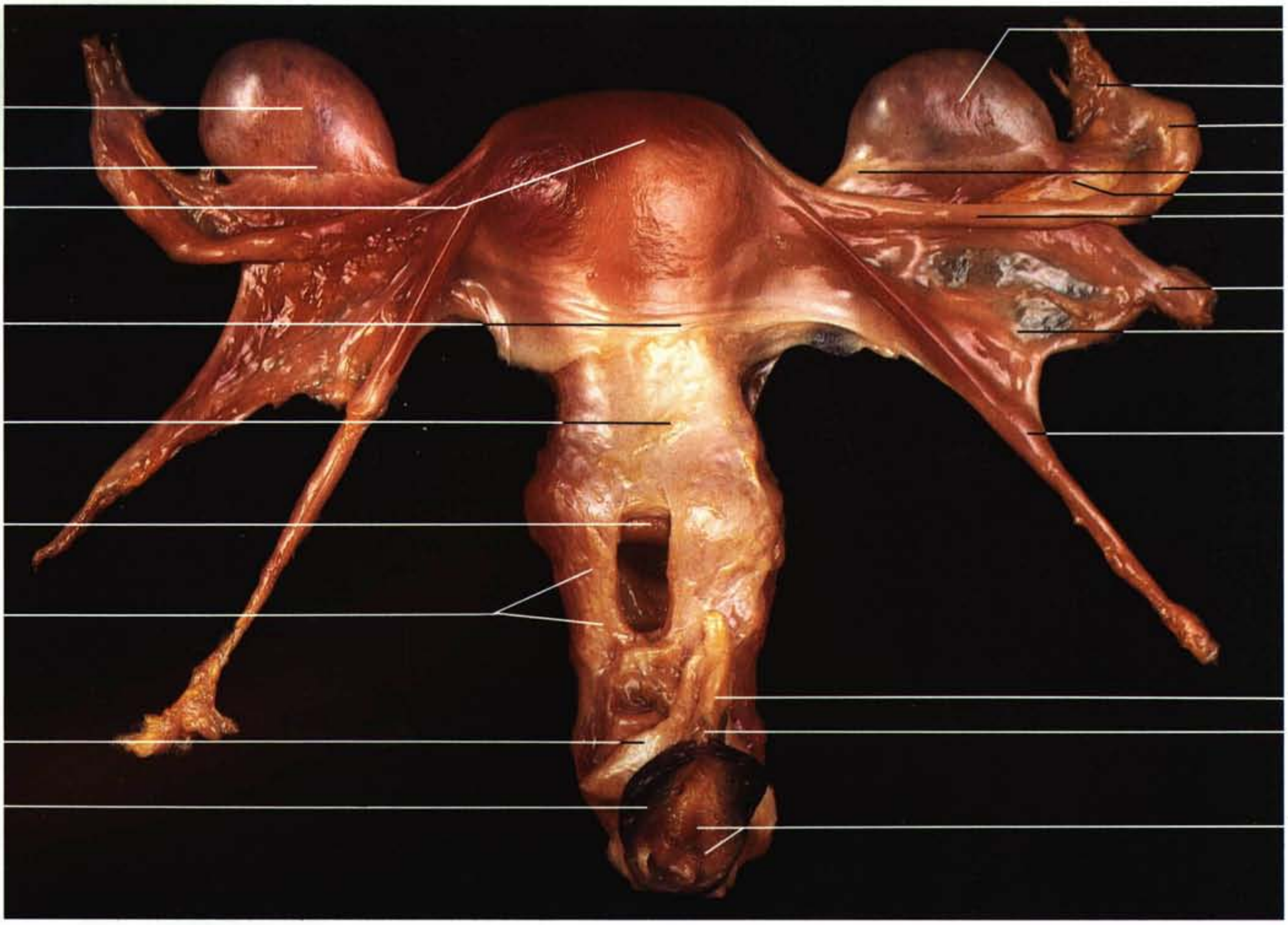

Female genital organs, isolated (anterior view). The anterior wall of the vagina has been opened to display the vaginal portion of the cervix.

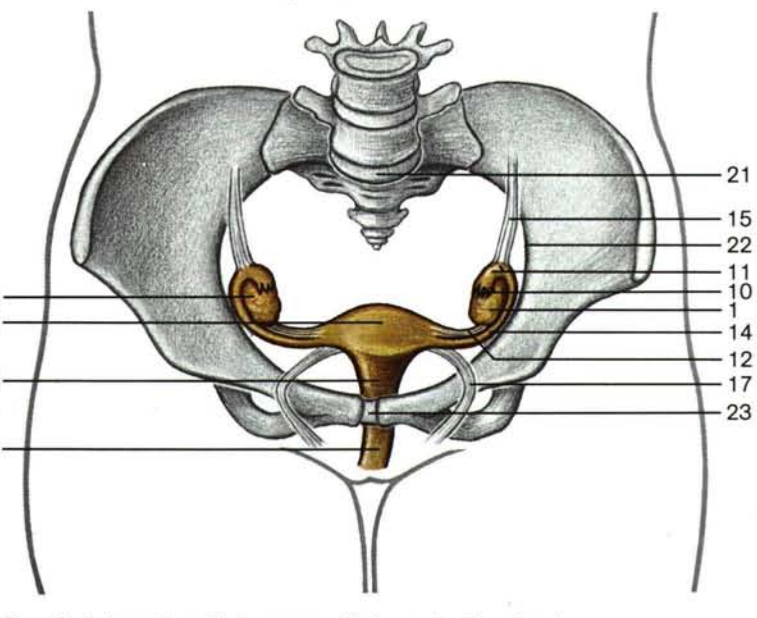

Female internal genital organs. (Schematic drawing.)

1 **Ovary**
2 Mesovarium
3 **Fundus of uterus**
4 Vesico-uterine pouch
5 **Cervix of uterus**
6 Vaginal portion of cervix
7 **Vagina**
8 Crus of clitoris
9 Labium minus
10 Fimbriae of uterine tube
11 Infundibulum of uterine tube
12 Ligament of the ovary
13 Mesosalpinx
14 Uterine tube
15 Suspensory ligament of ovary (caudally displaced)
16 Broad ligament of uterus
17 Round ligament of uterus
18 Corpus cavernosum of clitoris
19 Glans of clitoris
20 **Hymen, vaginal orifice**
21 Promontory
22 Linea terminalis of pelvis
23 Pubic symphysis

1 **Fundus of uterus**
2 Uterine tube
3 **Ligament of the ovary**
4 **Ovary**
5 Infundibulum of uterine tube
6 Fimbriae of uterine tube
7 **Ureter**
8 Rectum
9 Apex of urinary bladder and median umbilical ligament
10 Urinary bladder
11 Round ligament of uterus
12 **Mesosalpinx**
13 **Mesovarium**
14 **Rectouterine pouch** (of Douglas)
15 Suspensory ligament of ovary
16 Scarring of ovary (following ovulation)
17 Abdominal opening of uterine tube
18 Body of uterus
19 **Cervical canal**
20 Vaginal portion of cervix of uterus (congestion)
21 Vagina
22 Mucous membrane of uterus
23 Anterior fornix of vagina

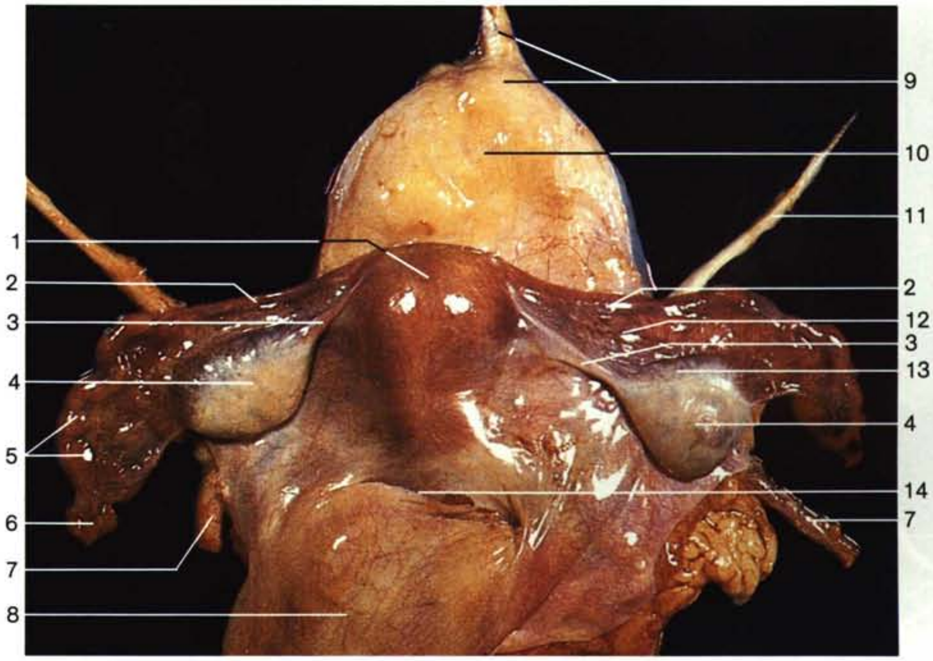

Female internal genital organs, isolated (superior-posterior view).

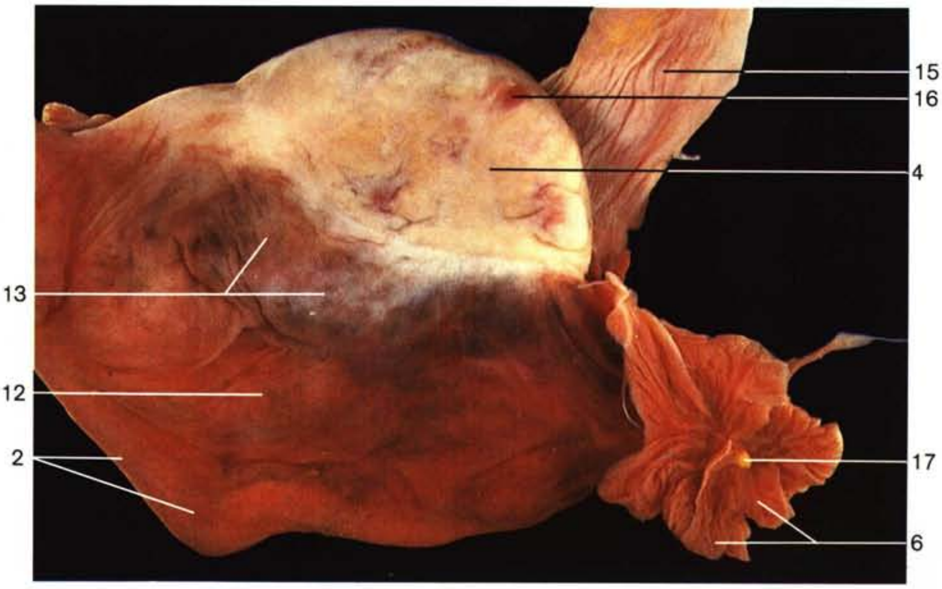

Right ovary and uterine tube, isolated (superior-posterior view). The fimbriae of the uterine tube have been reflected to show the abdominal ostium.

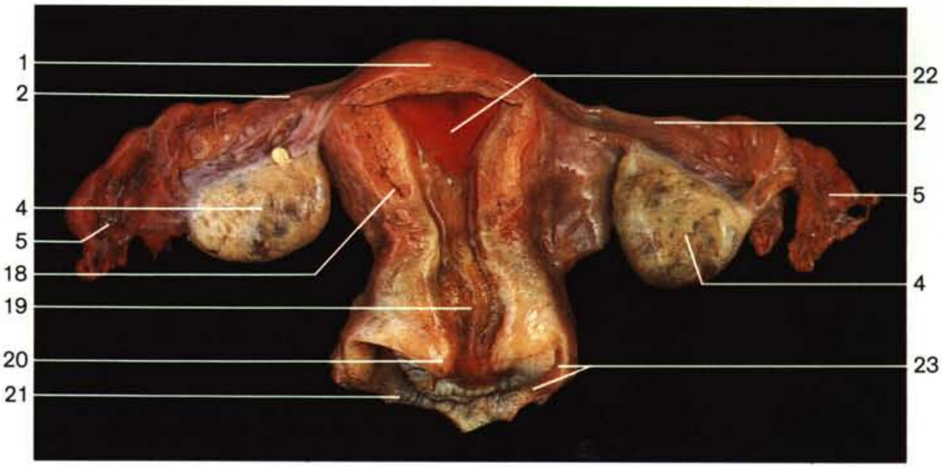

Uterus and related organs (posterior view). The posterior wall of the uterus has been opened.

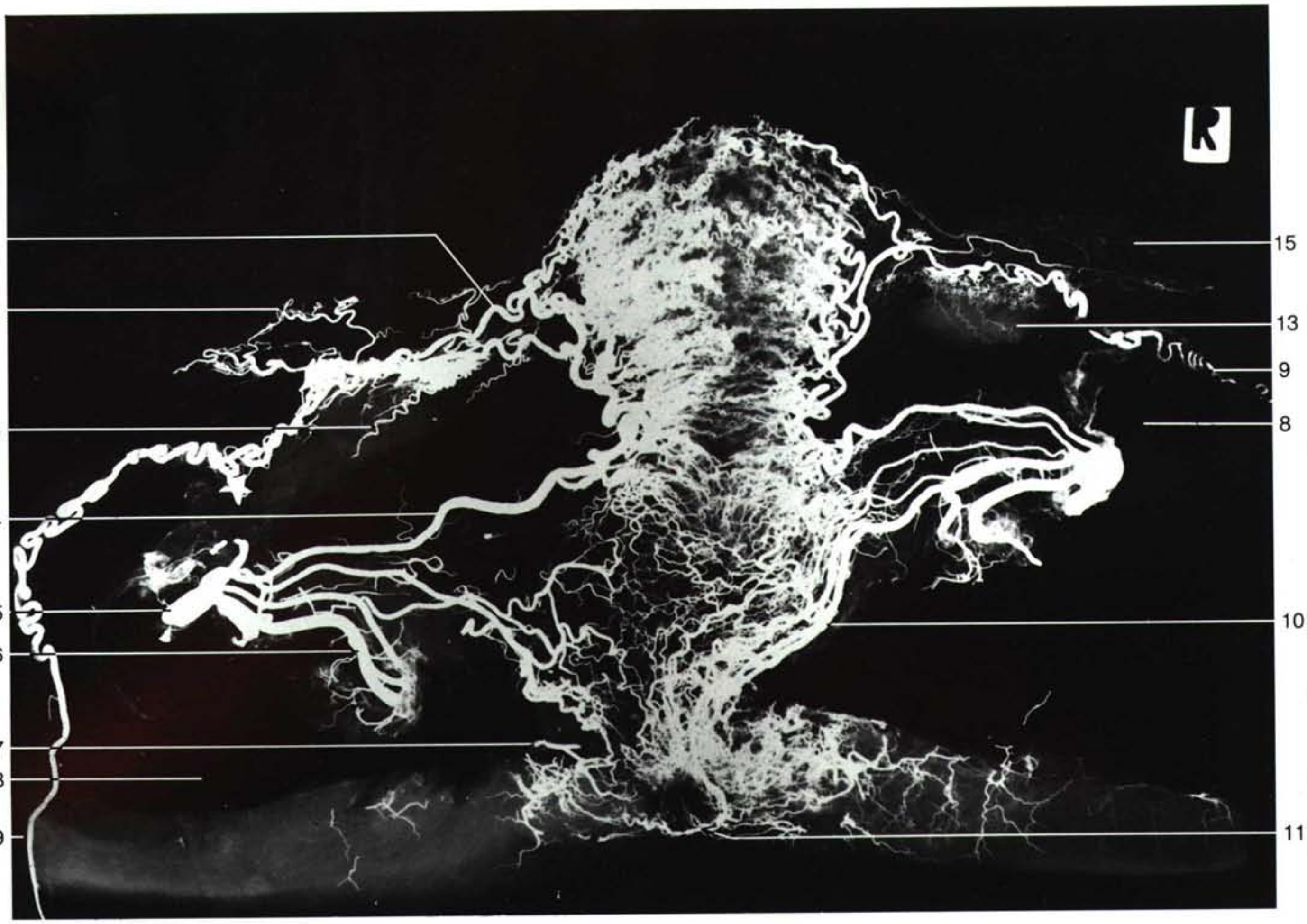

Arteriogram of female genital organs (anterior-posterior view). Notice the helicine arteries supplying uterus and ovary.

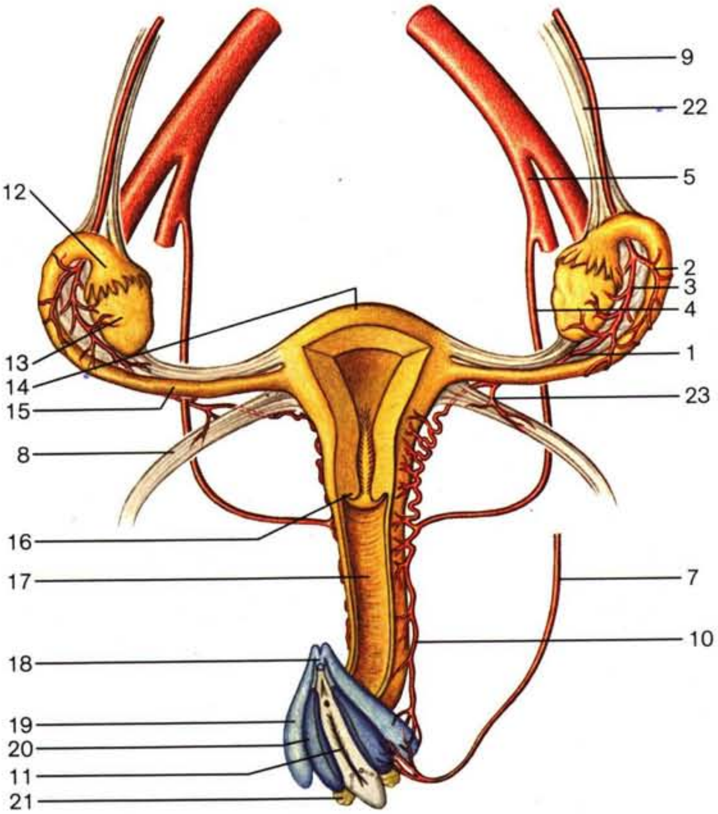

Arteries of female genital organs. (Schematic drawing.)

1 Ovarian branch of uterine artery (anastomoses with ovarian artery)
2 Tubal branch of ovarian artery
3 Ovarian branch of ovarian artery
4 **Uterine artery**
5 Internal iliac artery
6 Inferior gluteal artery
7 **Internal pudendal artery**
8 Round ligament of uterus
9 **Ovarian artery**
10 Vaginal artery
11 Vaginal orifice
12 Infundibulum of uterine tube
13 Ovary
14 Fundus of uterus
15 Uterine tube
16 Vaginal portion of cervix of uterus
17 Vagina
18 Clitoris
19 Corpus cavernosum of clitoris
20 Bulb of vestibule
21 Greater vestibular gland
22 Suspensory ligament of ovary
23 Artery of round ligament

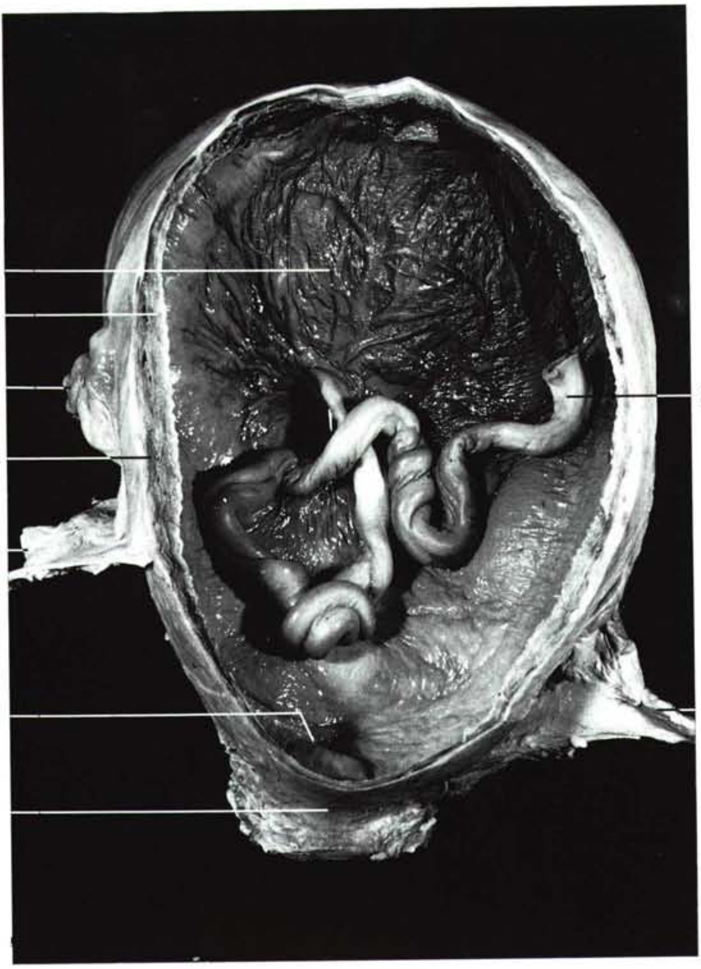

Full term uterus with placenta (anterior view). The anterior wall of the uterus has been removed to show the location of the placenta.

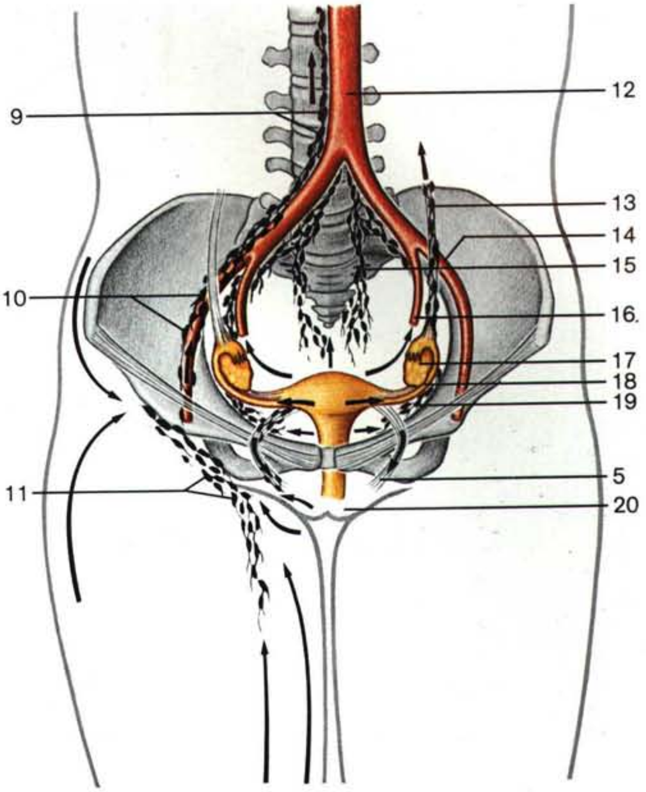

Main drainage routes of lymph vessels of uterus and its adnexa (indicated by arrows). (Schematic drawing.)
Red = arteries; black = lymph vessels and nodes; yellow = internal genital organs.

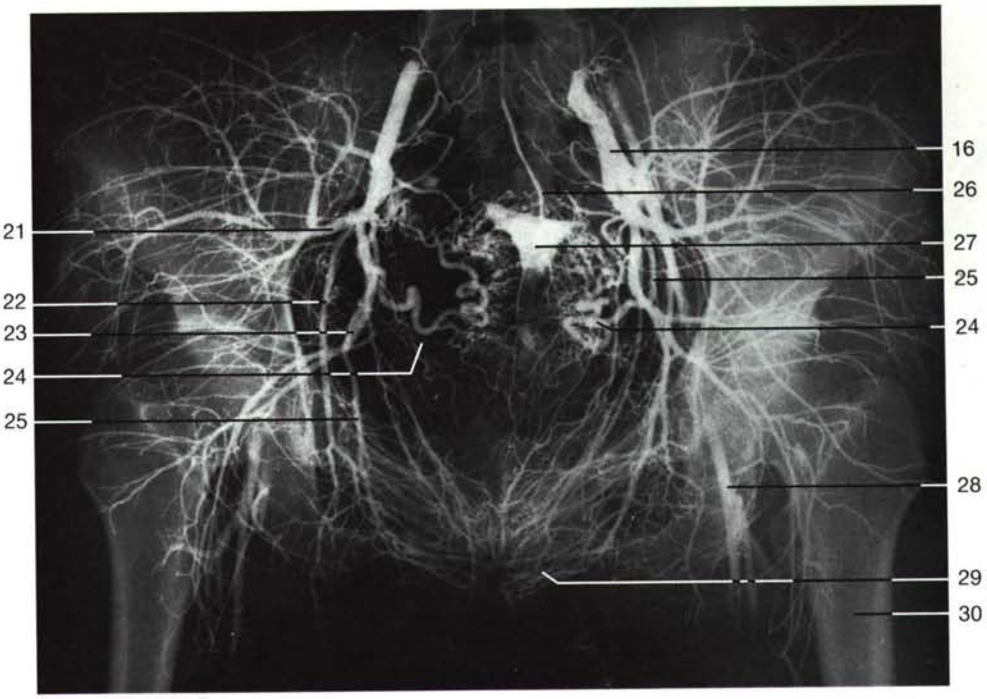

Pelvic vessels in the female (anterior-posterior view). (Arteriogram.)

1 Placenta
2 Amnion and chorion
3 Adnexa of uterus (uterine tube and ovaries)
4 Myometrium
5 Round ligament of uterus
6 Internal orifice of uterus
7 Cervix of uterus
8 **Umbilical cord**
9 Lumbar lymph nodes
10 External iliac lymph nodes
11 Inguinal lymph nodes
12 Abdominal aorta
13 Suspensory ligament of ovary
14 External iliac artery
15 Sacral lymph nodes
16 Internal iliac artery
17 Ovary
18 Uterine tube
19 Internal iliac lymph nodes
20 External genital organs
21 Superior gluteal artery
22 **Obturator artery**
23 Inferior gluteal artery
24 **Uterine artery**
25 **Internal pudendal artery**
26 Middle sacral artery
27 **Uterine cavity**
28 Femoral artery
29 Vessels of labium majus
30 Femur

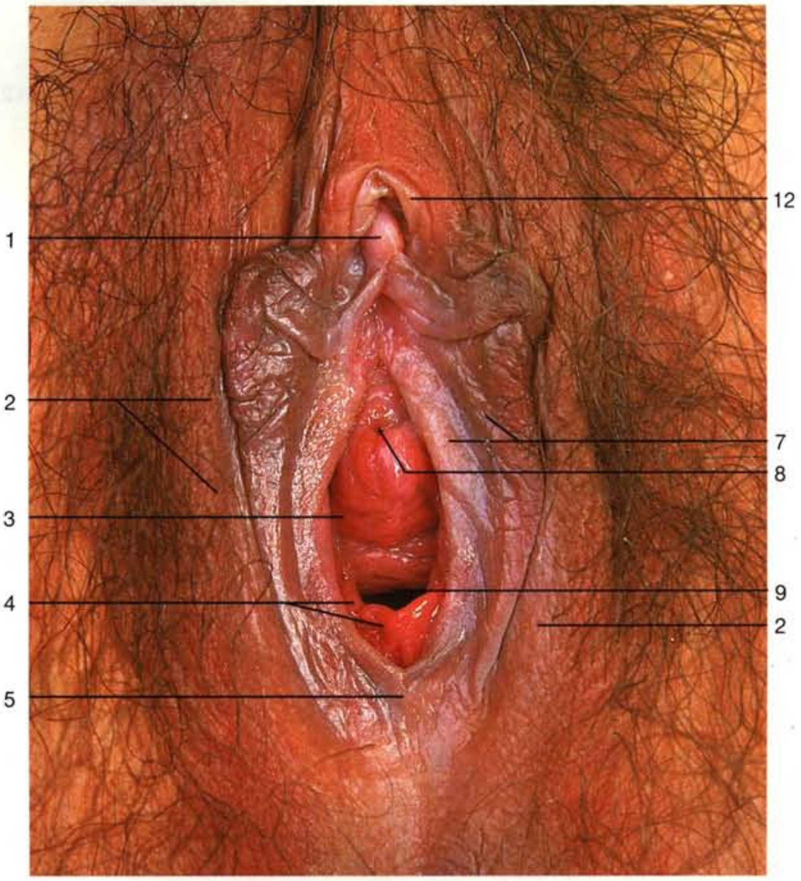

External genital organs in the female (anterior aspect). Labia reflected.

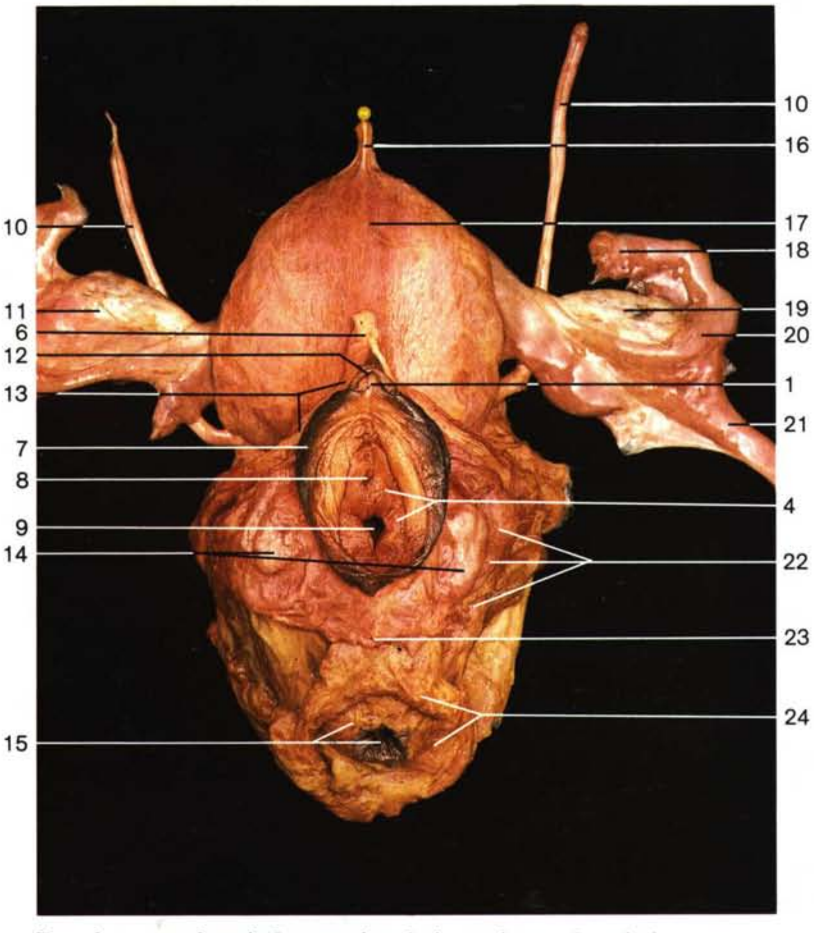

Female external genital organs in relation to internal genital organs and urinary system (isolated, anterior aspect).

1 **Glans clitoris**
2 Labium majus
3 Vestibule of vagina
4 **Hymen**
5 Posterior labial commissure
6 **Body of clitoris**
7 Labium minus
8 **External orifice of urethra**
9 **Vaginal orifice**
10 Ureter
11 Adnexa of uterus
12 Prepuce of clitoris
13 Crus of clitoris
14 Greater vestibular glands
15 Anus and internal anal sphincter muscle
16 Median umbilical ligament containing urachus
17 **Urinary bladder**
18 Infundibulum of uterine tube
19 Ovary
20 Ampulla of uterine tube
21 Suspensory ligament of the ovary
22 Bulbospongiosus muscle and bulb of vestibule
23 Central tendon of perineum (perineal body)
24 External anal sphincter muscle

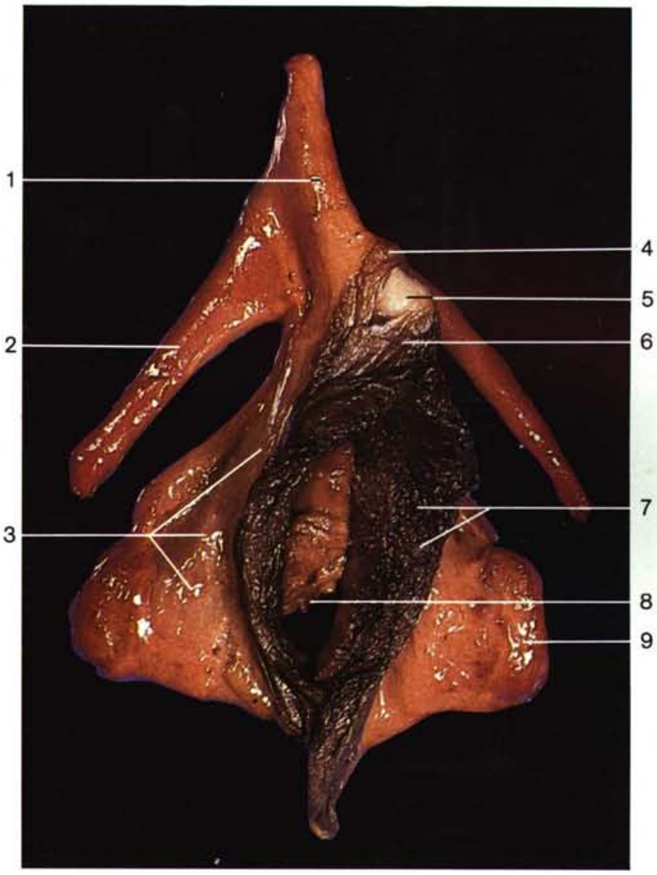

Cavernous tissue of female external genital organs, isolated (anterior aspect).

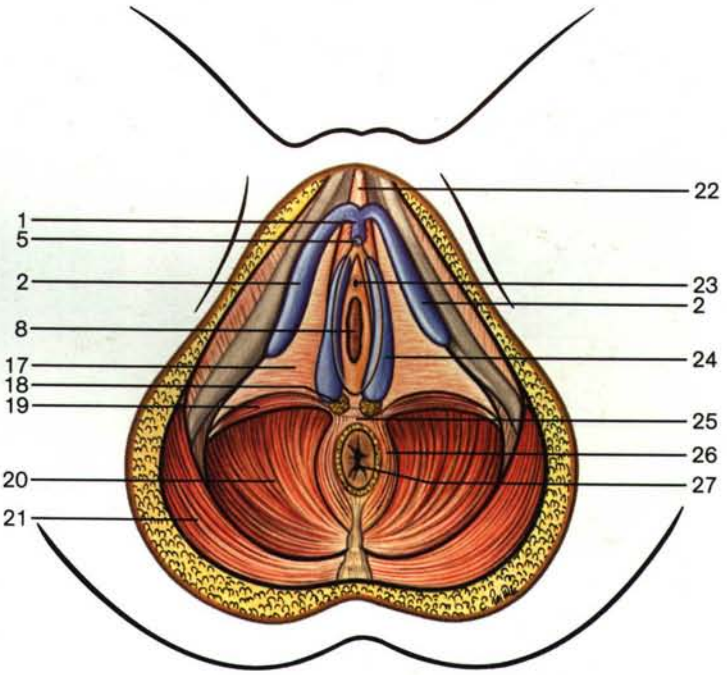

Urogenital and pelvic diaphragms (anterior aspect). (Schematic drawing.)
Blue = cavernous tissue of clitoris and bulb of vestibule.

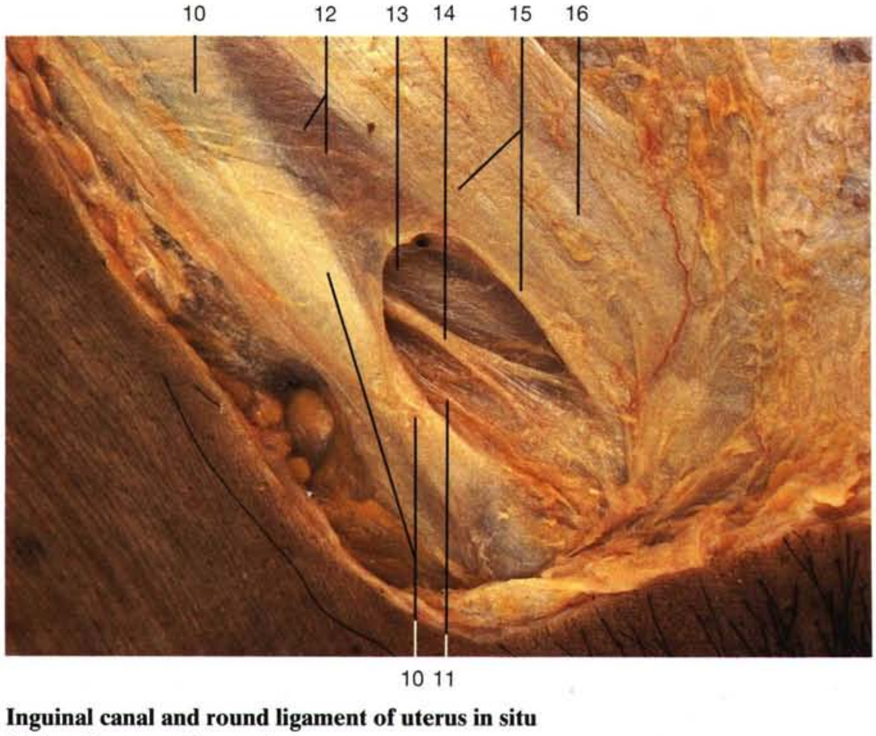

Inguinal canal and round ligament of uterus in situ (right side, ventral aspect).

1 Body of clitoris
2 Crus of clitoris
3 Bulb of vestibule
4 Prepuce of clitoris
5 **Glans of clitoris**
6 Frenulum of clitoris
7 **Labium minus**
8 **Vaginal orifice**
9 **Greater vestibular gland**
10 Lateral crus of superficial inguinal ring
11 Ilioinguinal nerve
12 Intercrural fibers
13 Superficial inguinal ring
14 **Round ligament of uterus**
15 Medial crus of superficial inguinal ring
16 Aponeurosis of external abdominal oblique muscle
17 Deep transverse perineus muscle with fascia
18 Greater vestibular gland
19 Superficial transverse perineus muscle
20 Levator ani muscle
21 Gluteus maximus muscle
22 Suspensory ligament of clitoris
23 External orifice of urethra
24 Bulb of vestibule
25 Perineal body
26 External anal sphincter muscle
27 Anus

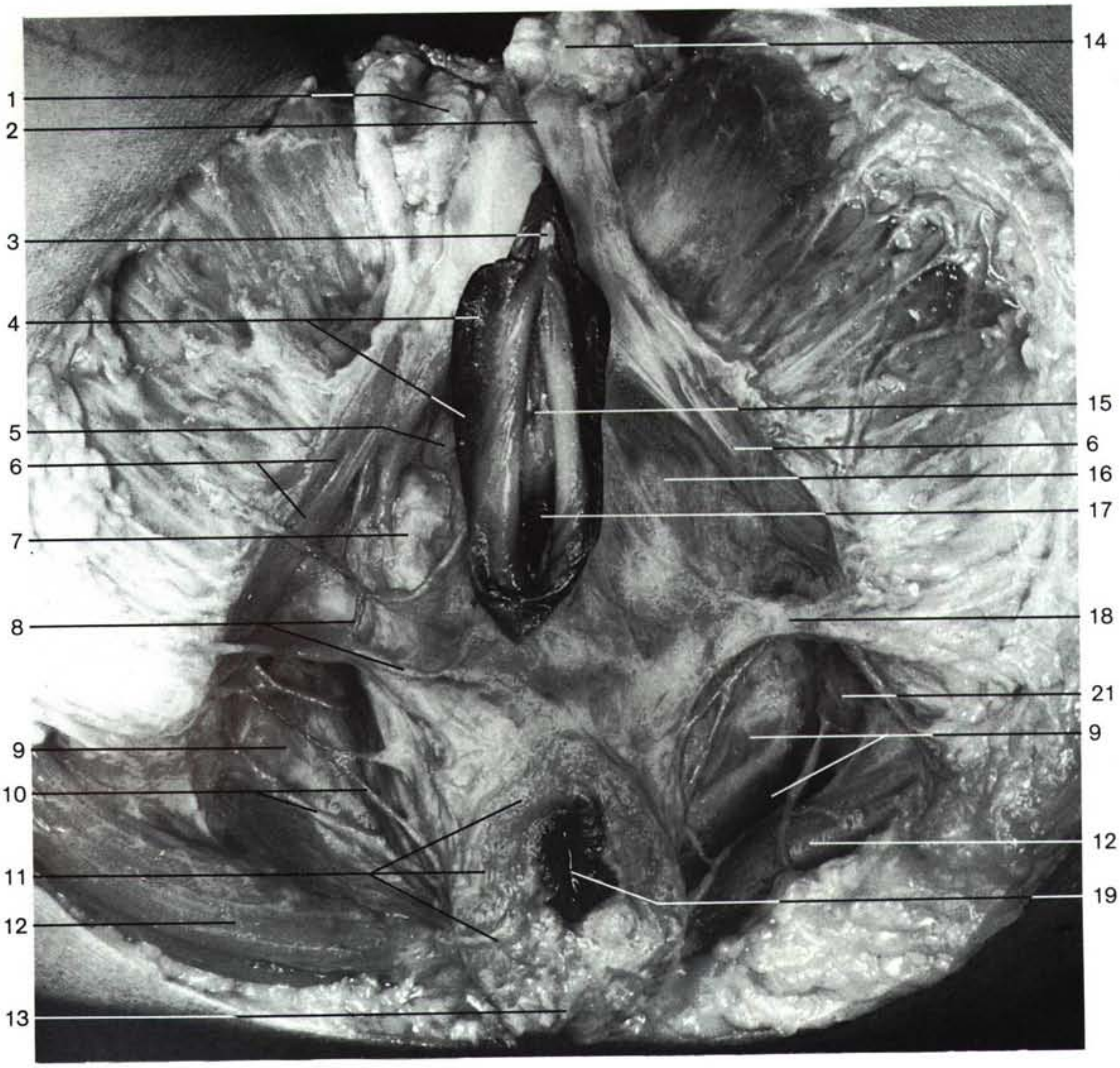

Female urogenital diaphragm and external genital organs, superficial layer (from below).

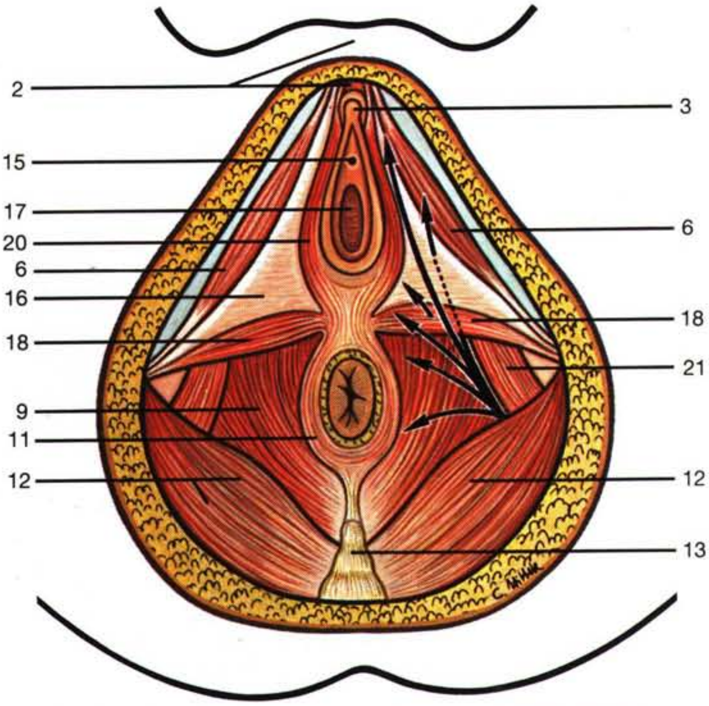

Muscles of pelvic and urogenital diaphragms (from below).
(Schematic drawing.)

1 Fatty tissue encasing round ligament
2 Position of pubic symphysis
3 Clitoris
4 Labium minus
5 Bulb of vestibule
6 Ischiocavernosus muscle
7 **Greater vestibular gland**
8 Perineal branches of pudendal nerve
9 Levator ani muscle
10 Inferior rectal nerves
11 External anal sphincter muscle
12 Gluteus maximus muscle
13 Coccyx
14 Fatty tissue of mons pubis
15 **External orifice of urethra**
16 Urogenital diaphragm with fascia of deep transverse perineus muscle
17 **Vaginal orifice**
18 Superficial transverse perineal muscle
19 **Anus**
20 Bulbospongiosus muscle
21 Obturator internus muscle

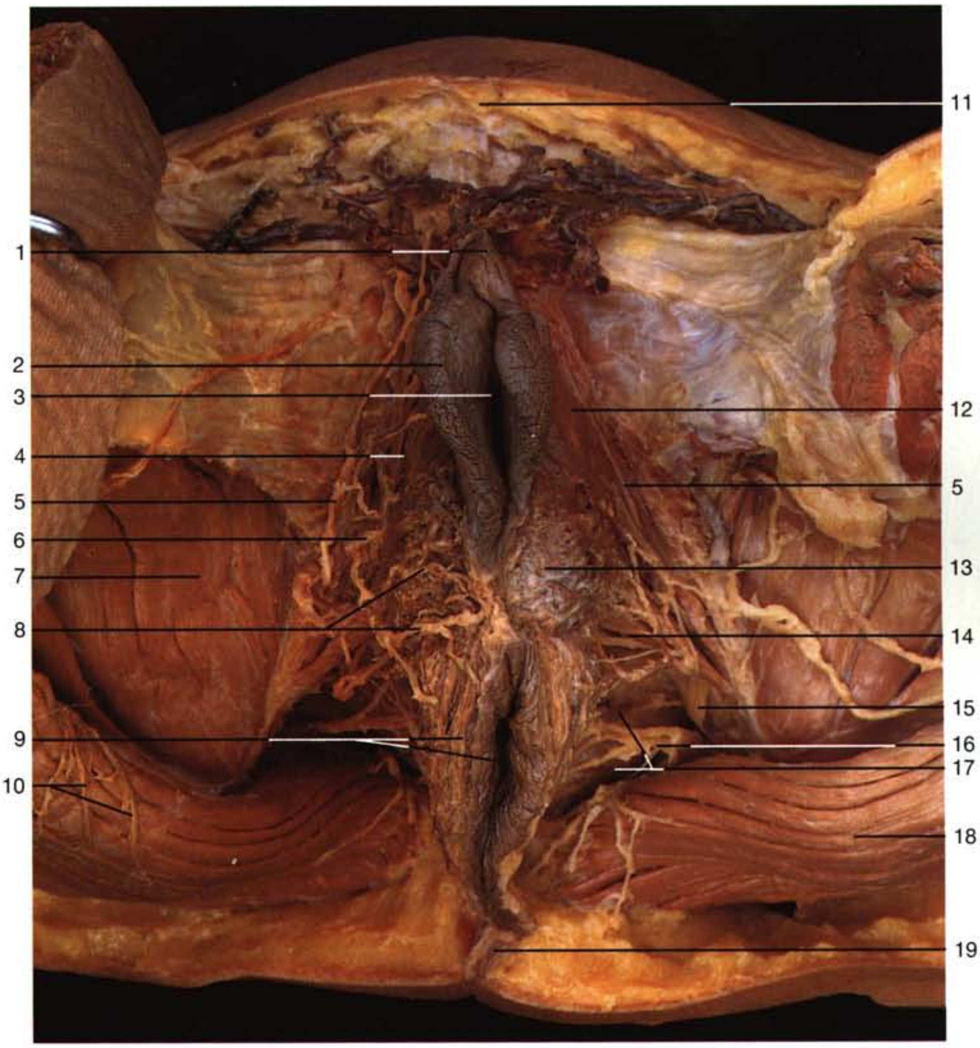

Urogenital diaphragm and external genital organs in the female, superficial layer (from below). On the right side the bulb of vestibule has been removed.

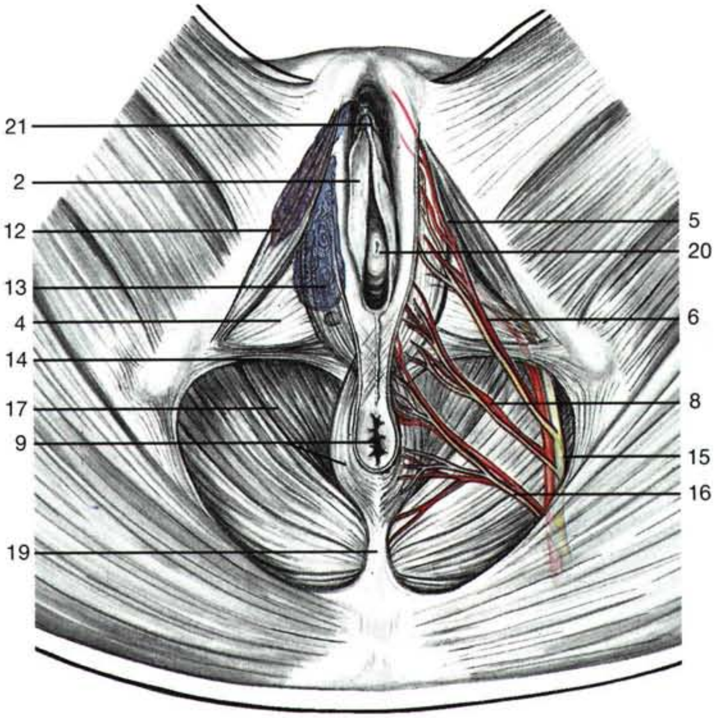

External female genital organs. Position of arteries and nerves; bulb of vestibule in blue. (Schematic drawing.)

1 **Prepuce of clitoris**
2 Labium minus
3 **Vaginal orifice**
4 Deep transverse perineus muscle
5 Dorsal nerve of clitoris
6 Posterior labial nerves
7 Great adductor muscle
8 Perineal branches of pudendal nerve
9 **Anus** and **external anal sphincter muscle**
10 Inferior cluneal nerves
11 Mons pubis
12 Crus of clitoris with ischiocavernosus muscle
13 Bulb of vestibule
14 Superficial transverse perineus muscle
15 **Pudendal nerve** and **internal pudendal artery**
16 Inferior rectal nerves
17 Levator ani muscle
18 Gluteus maximus muscle
19 Anococcygeal ligament
20 External urethral orifice
21 Glans of clitoris

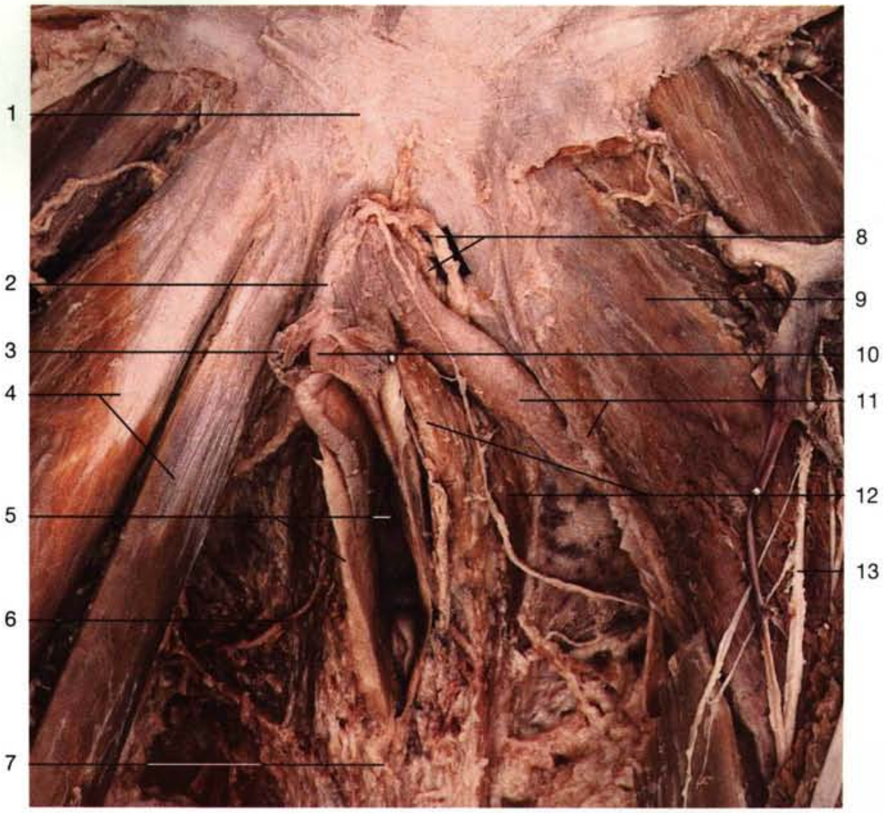

External female genital organs (inferior aspect). The clitoris has been dissected and slightly reflected to the right. The prepuce of clitoris has been divided to display the glans.

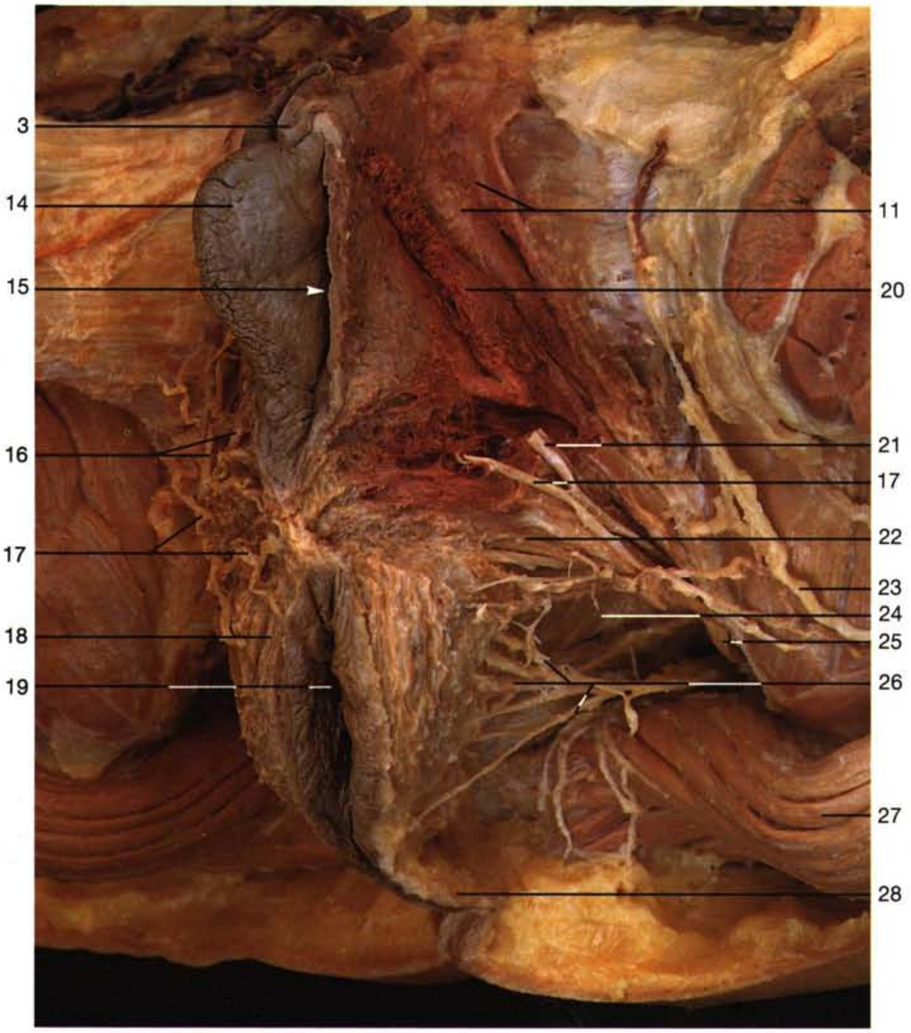

Urogenital diaphragm and external genital organs in the female (lateral inferior view). The bulb of vestibule has partly been removed, the left labium minus was cut away.

1 Position of pubic symphysis
2 Body of clitoris
3 Prepuce of clitoris
4 Adductor longus and gracilis muscles
5 External orifice of vagina and labium minus
6 Posterior labial nerve
7 Perineal body
8 Deep artery of clitoris and dorsal nerve of clitoris
9 Adductor brevis muscle
10 **Glans of clitoris**
11 Crus of clitoris and ischiocavernosus muscle
12 **Bulb of vestibule** and bulbospongiosus muscle
13 Anterior branch of obturator nerve
14 Labium minus
15 **Vaginal orifice**
16 Posterior labial nerves
17 Branches of pudendal nerve
18 External sphincter of anus
19 **Anus**
20 Bulb of vestibule (divided)
21 Dorsal artery of clitoris
22 Superficial transverse perineus muscle
23 Perineal branch of posterior femoral cutaneous nerve
24 Levator ani muscle
25 **Pudendal nerve** and **internal pudendal artery**
26 Inferior rectal nerves
27 Gluteus maximus muscle
28 Anococcygeal ligament

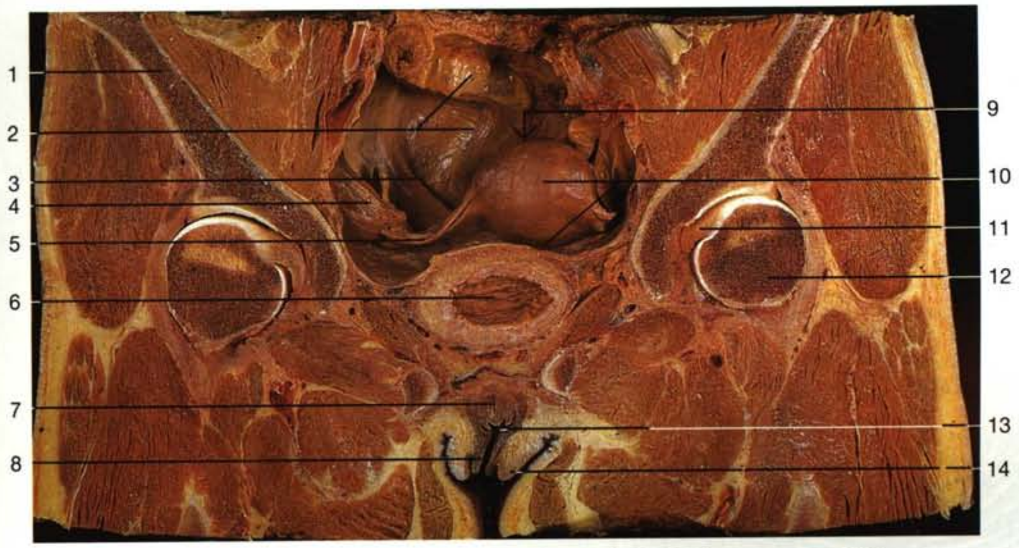

Coronal section through the pelvic cavity of the female (cf. MR-Scan on page 335).

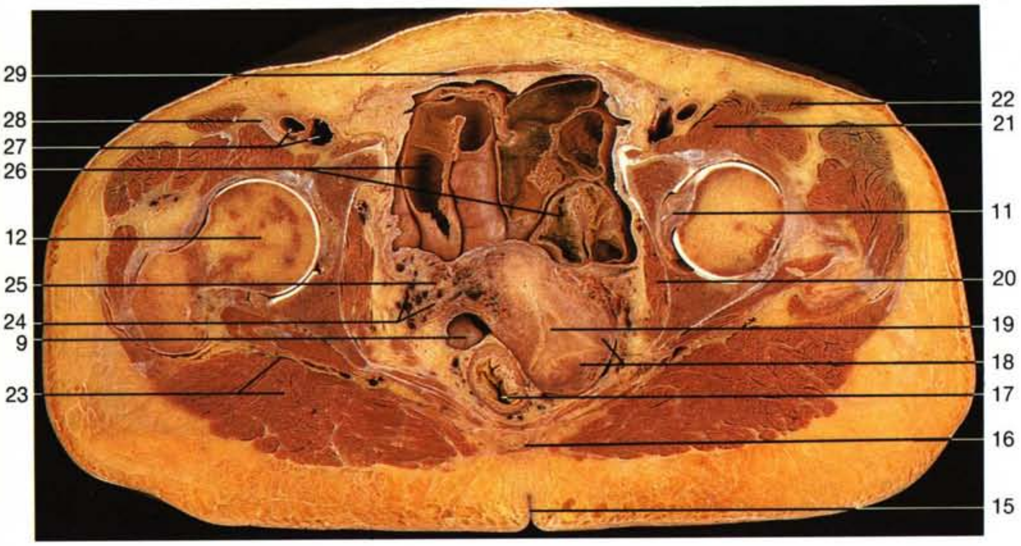

Horizontal section through pelvic cavity at level of uterus (from below). The uterus is retroverted to the left.

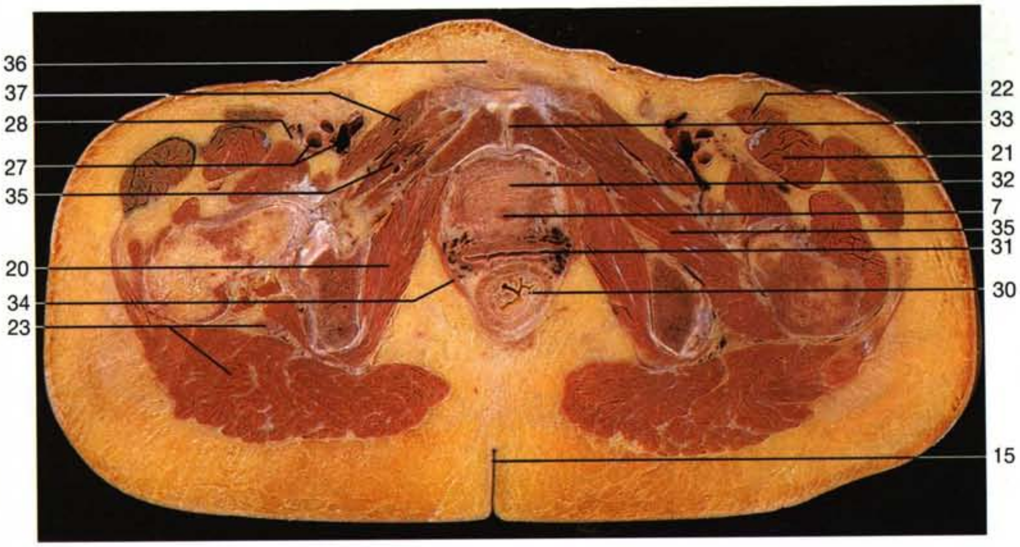

Horizontal section through the pelvic cavity at level of the urethral sphincter and vagina (from below).

1 Ilium
2 Rectum
3 Rectouterine fold
4 **Ovary**
5 **Uterine tube**
6 **Urinary bladder**
7 **Urethra**
8 Labium minus
9 Rectouterine pouch of Douglas
10 **Uterus** (uterovesical pouch)
11 Ligament of the head of the femur
12 Head of femur
13 Vestibule of vagina
14 Labium majus
15 Anal cleft
16 Coccyx
17 Rectum
18 Myometrium of uterus
19 Uterine cavity
20 Obturator internus muscle
21 Iliopsoas muscle
22 Sartorius muscle
23 Sciatic nerve and gluteus maximus muscle
24 Uterine venous plexus
25 Broad ligament
26 Small intestine
27 Femoral artery and vein
28 Femoral nerve
29 Pyramidalis muscle
30 Rectum (anal canal)
31 Vagina
32 Urethral sphincter muscle (base of urinary bladder)
33 Pubic symphysis
34 Levator ani muscle
35 Obturator externus muscle
36 Mons pubis
37 Pectineus muscle

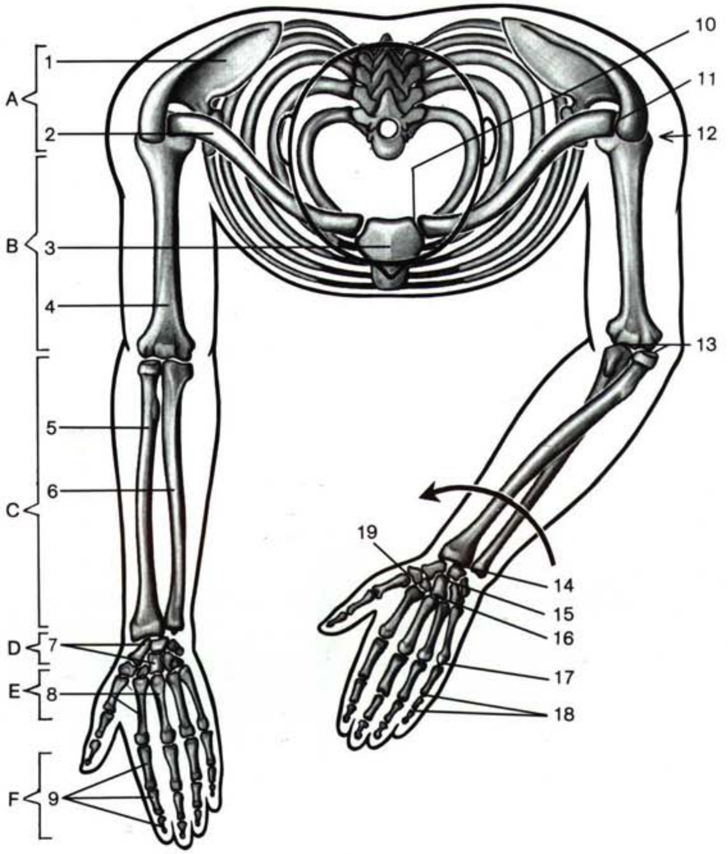

A	Pectoral girdle
B	Arm
C	Forearm
D	Wrist
E	Palm of hand
F	Finger
	Bones
1	Scapula
2	Clavicle
3	Sternum
4	Humerus
5	Radius
6	Ulna
7	Carpal bones
8	Metacarpal bones
9	Phalanges
	Joints
10	Sternoclavicular joint
11	Acromioclavicular joint
12	Shoulder joint
13	Elbow joint
14	Radiocarpal joint
15	Midcarpal joint
16	Carpometacarpal joint
17	Metacarpophalangeal joint
18	Interphalangeal joints of fingers
19	Carpometacarpal joint of thumb

Organization of shoulder girdle and upper limb (superior aspect). The two positions of the forearm essential to manual skills in the human, supination (right arm) and pronation (left arm) are shown.

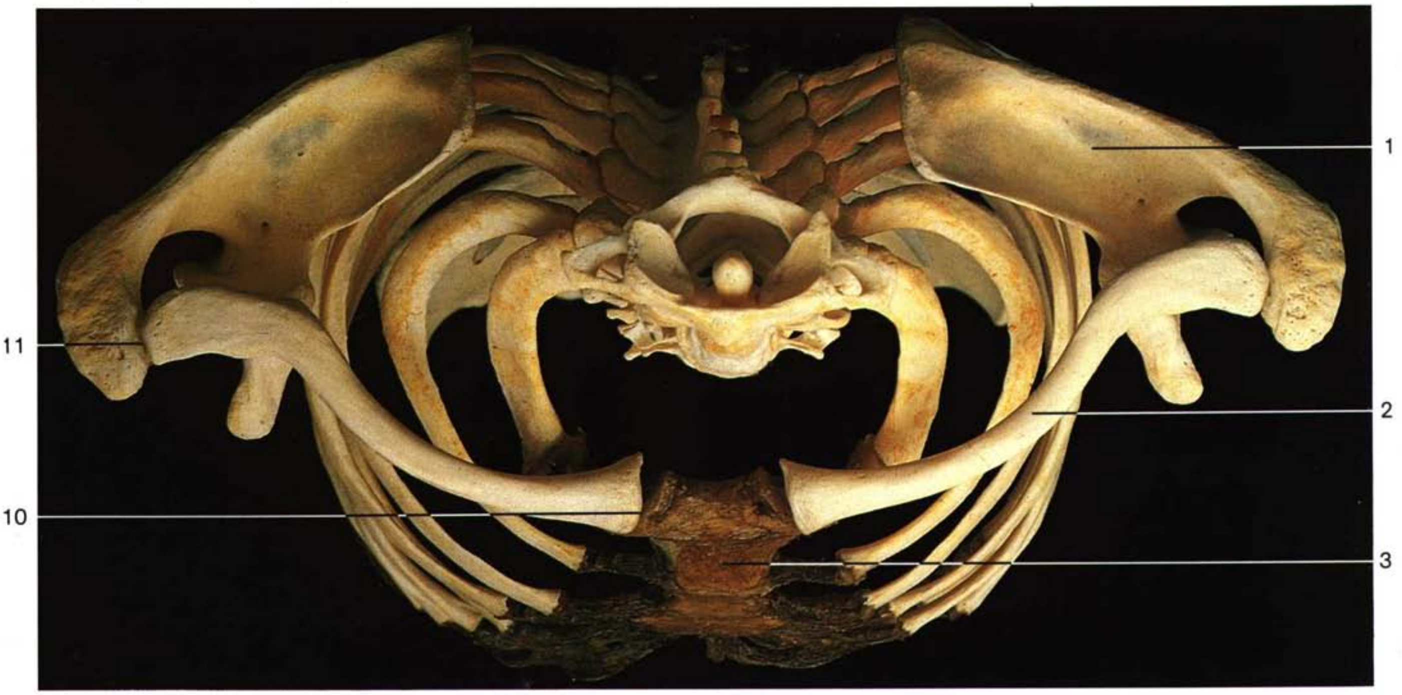

Bones of shoulder girdle articulated with the thorax (superior aspect).

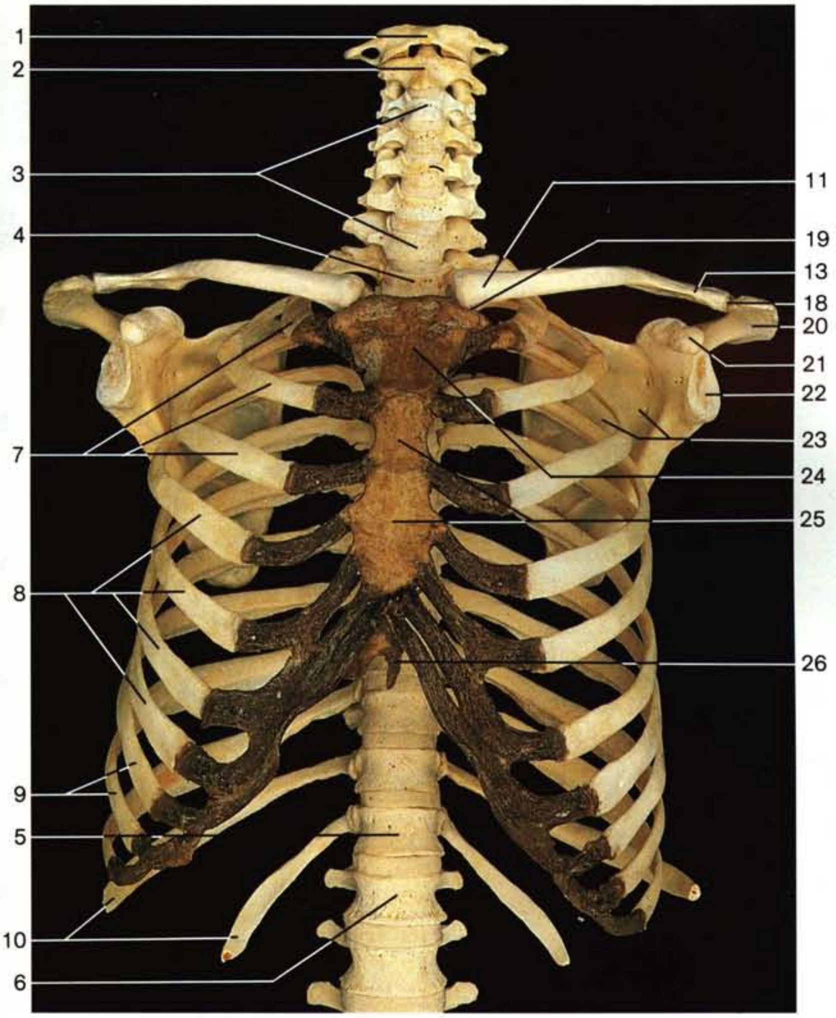

Skeleton of shoulder girdle and thorax (anterior aspect). The cartilaginous parts of the ribs appear dark brown.

Vertebral column

1 Atlas
2 Axis
3 3rd-7th cervical vertebrae
4 1st thoracic vertebra
5 12th thoracic vertebra
6 1st lumbar vertebra

Ribs

7 1st–3rd ribs } True ribs
8 4th–7th ribs
9 8th–10th ribs } False ribs
10 11th and 12th ribs (floating ribs)

Clavicle

11 Sternal end
12 Articular facet for sternum
13 Acromial end
14 Articular facet for acromion
15 Impression for costoclavicular ligament
16 Conoid tubercle
17 Trapezoid line
18 Site of acromioclavicular joint
19 Site of sternoclavicular joint

Scapula

20 Acromion
21 Coracoid process
22 Glenoid cavity
23 Costal surface

Sternum

24 Manubrium
25 Body
26 Xiphoid process

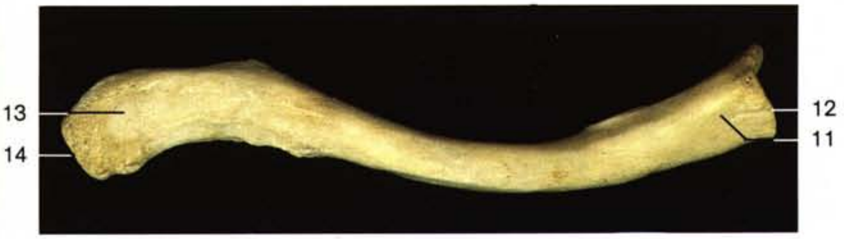

Right clavicle (superior aspect).

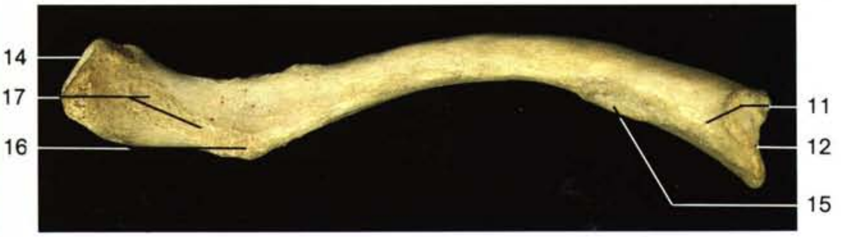

Right clavicle (inferior aspect).

Because of his upright posture, man's upper limb has developed a high degree of mobility. The shoulder girdle is to a great extent movable in the thorax and is connected with the trunk only by the sternoclavicular joint. A further characteristic of man's forearm is the capacity for rotation (i.e., pronation and supination).

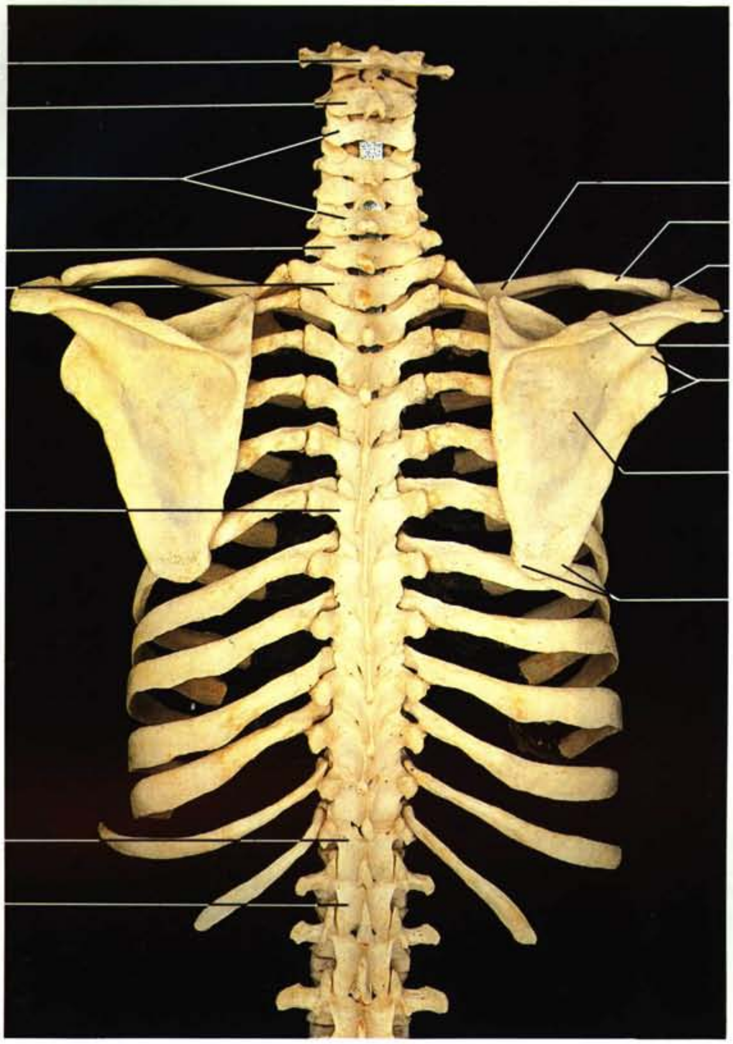

Skeleton of shoulder girdle and thorax (posterior view).

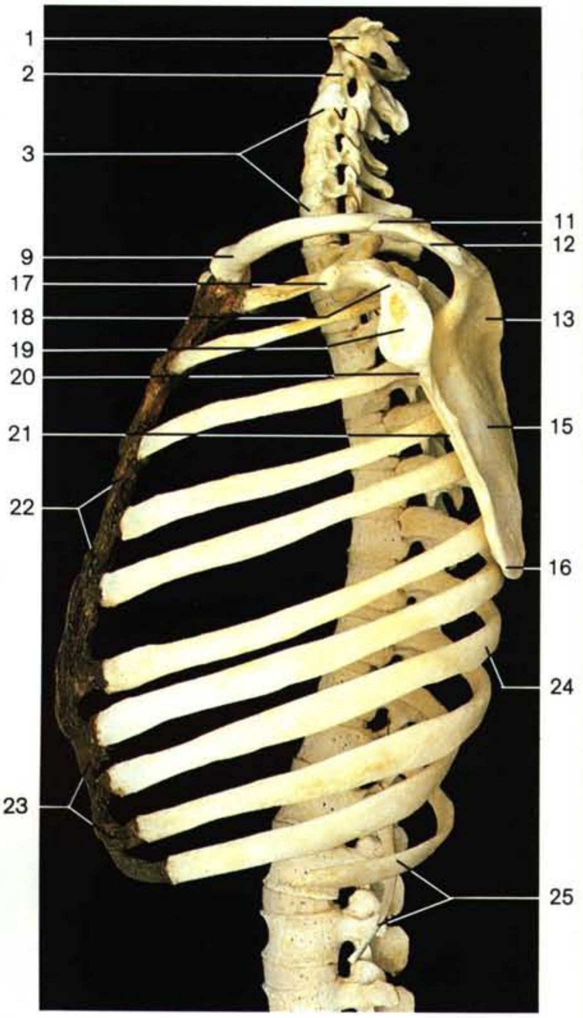

Skeleton of shoulder girdle and thorax (lateral view).

Vertebral column

1 Atlas
2 Axis
3 3rd–6th cervical vertebrae
4 7th vertebra (vertebra prominens)
5 1st thoracic vertebra
6 6th thoracic vertebra
7 12th thoracic vertebra
8 1st lumbar vertebra

Clavicle

9 Sternal end
10 Acromial end
11 Site of acromioclavicular joint

Scapula

12 Acromion
13 Spine of scapula
14 Lateral angle
15 Posterior surface
16 Inferior angle
17 Coracoid process
18 Supraglenoid tubercle
19 Glenoid cavity
20 Infraglenoid tubercle
21 Lateral margin

Thorax

22 Body of sternum
23 Costal arch
24 Angle of ribs
25 Free ribs

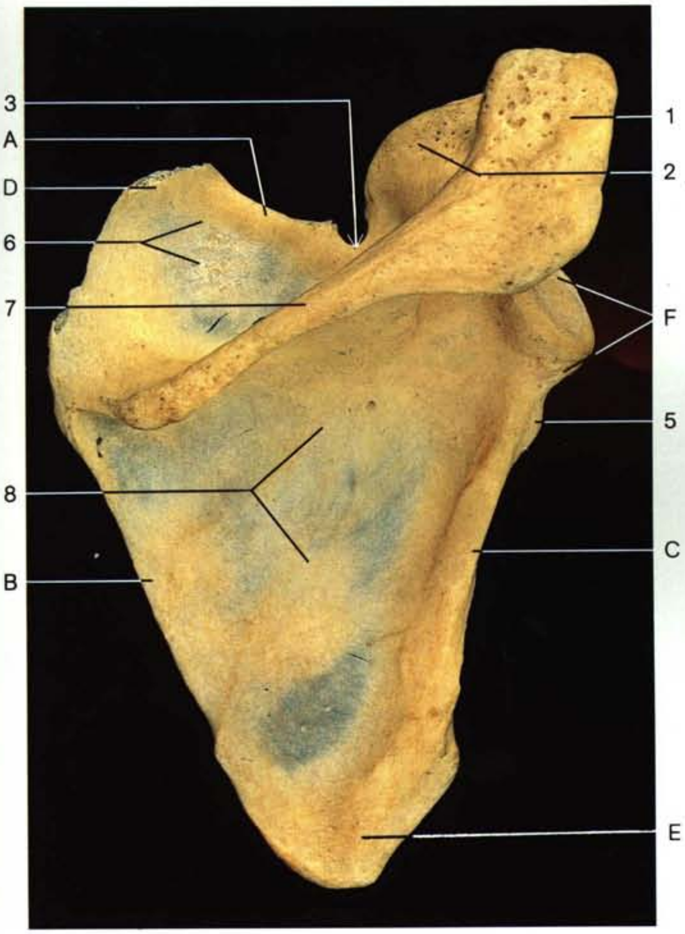

Right scapula (posterior aspect).

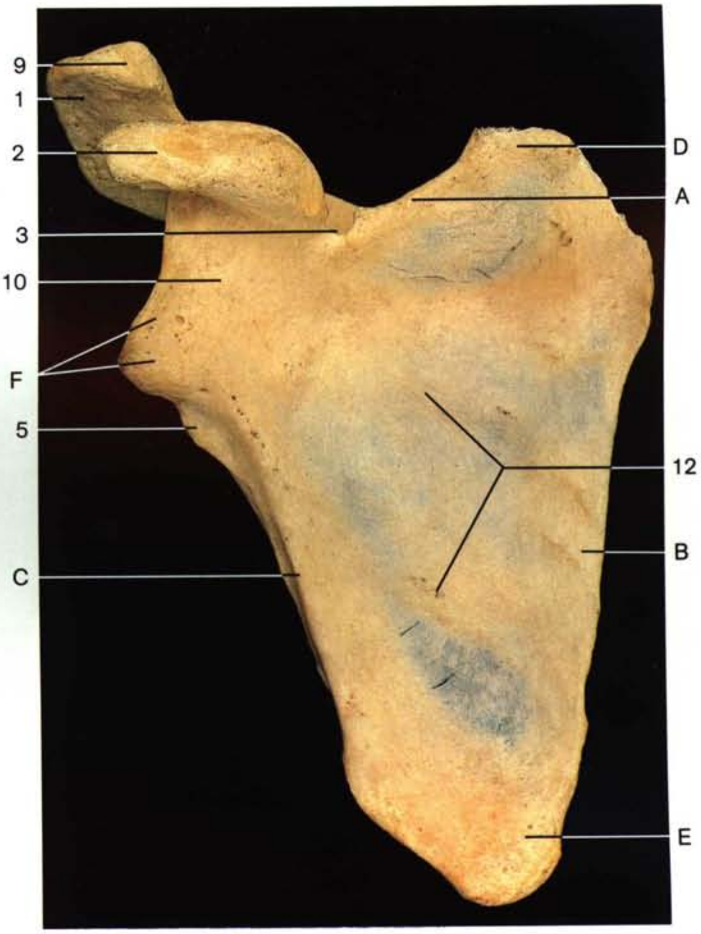

Right scapula (anterior aspect costal surface).

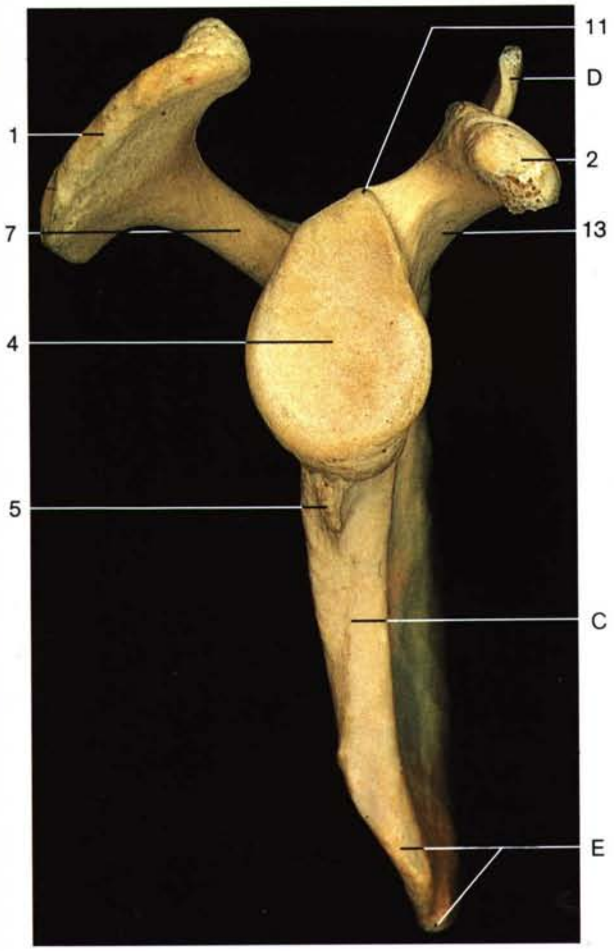

Right scapula (lateral view).

Scapula

A Superior border
B Medial border
C Lateral border
D Superior angle
E Inferior angle
F Lateral angle

1 Acromion
2 Coracoid process
3 Scapular notch
4 Glenoid cavity
5 Infraglenoid tubercle
6 Supraspinous fossa
7 Spine
8 Infraspinous fossa
9 Articular facet for acromion
10 Neck
11 Supraglenoid tubercle
12 Costal (anterior) surface
13 Base of coracoid process

1	1st rib
2	Position of costotransverse joints
3	4th–7th ribs
4	**Clavicle**
5	Position of acromioclavicular joint
6	Acromion
7	Scapular notch
8	Spine of scapula
9	Head of humerus
10	Glenoid cavity
11	Surgical neck of humerus
12	Posterior surface of **scapula**
13	Coracoid process
14	Infraglenoid tubercle
15	Greater tubercle of **humerus**
16	Anatomical neck of humerus

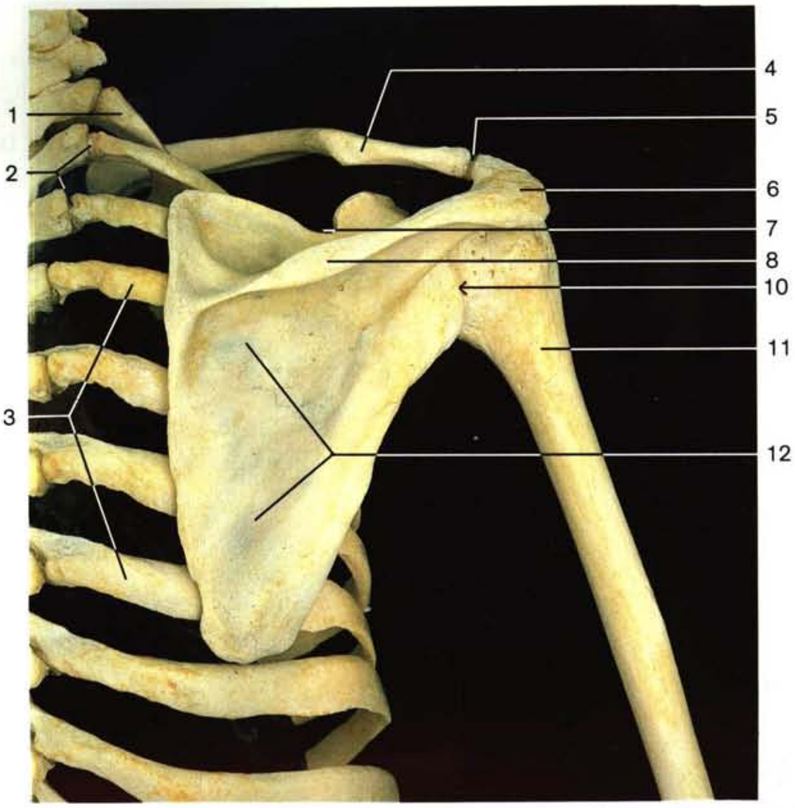

Bones of shoulder joint (posterior aspect).

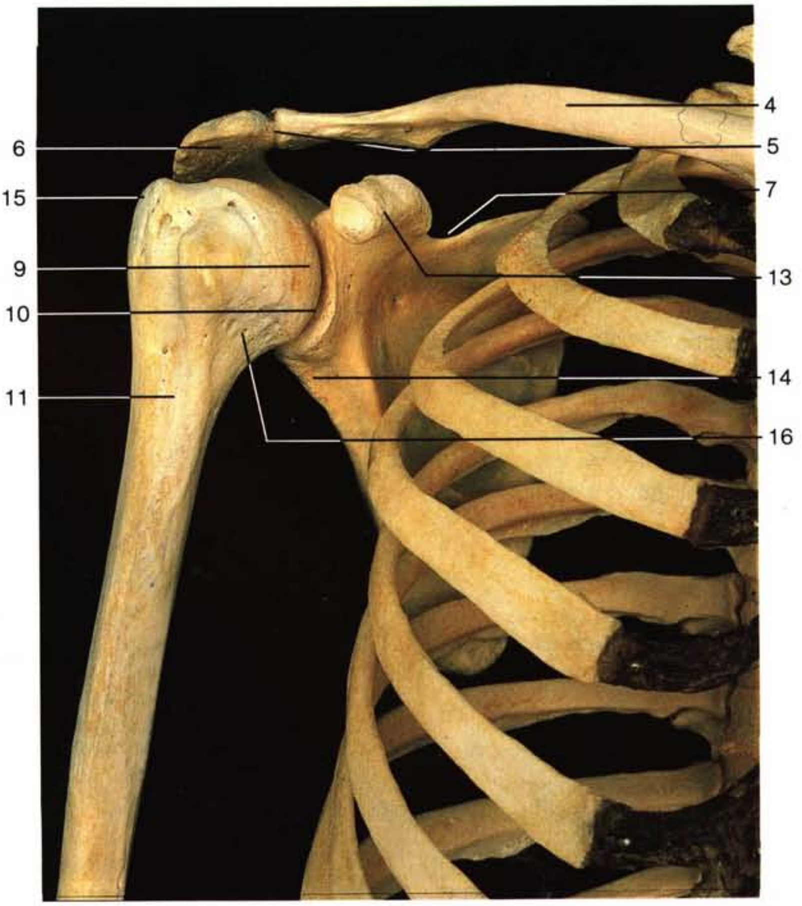

Bones of shoulder joint (anterior aspect).

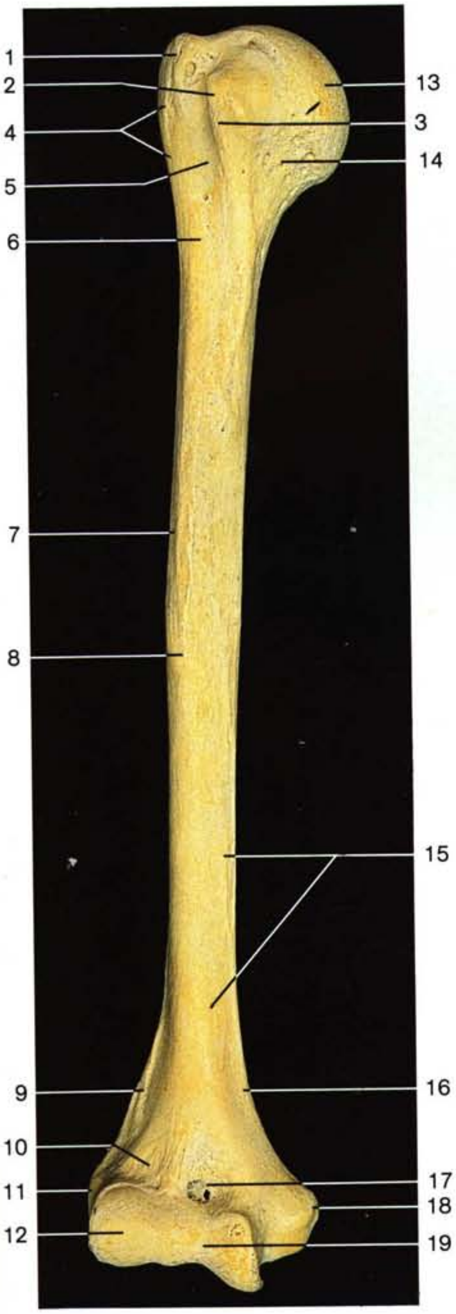
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Right humerus (anterior aspect).

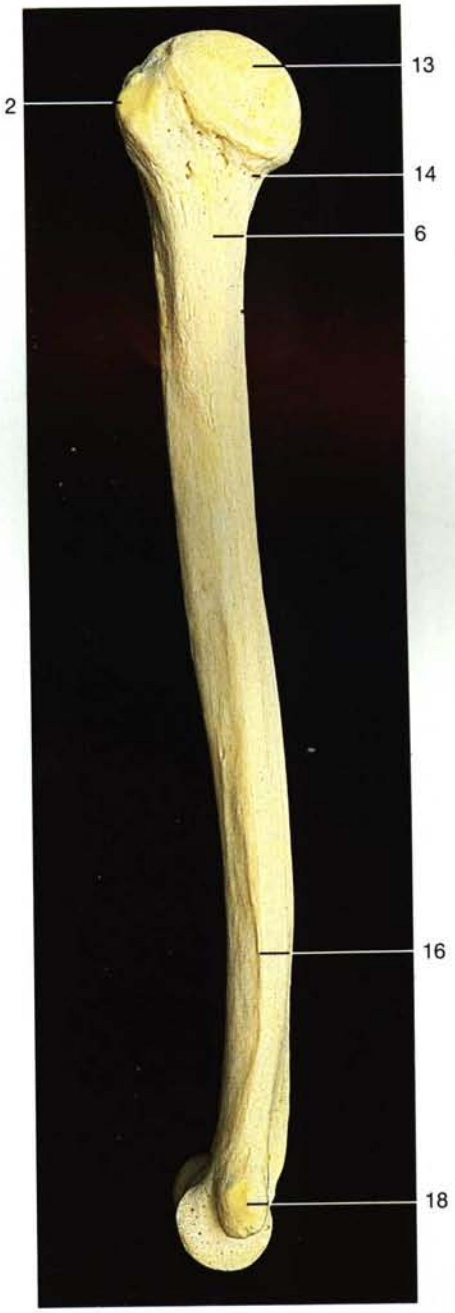
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Right humerus (medial aspect).

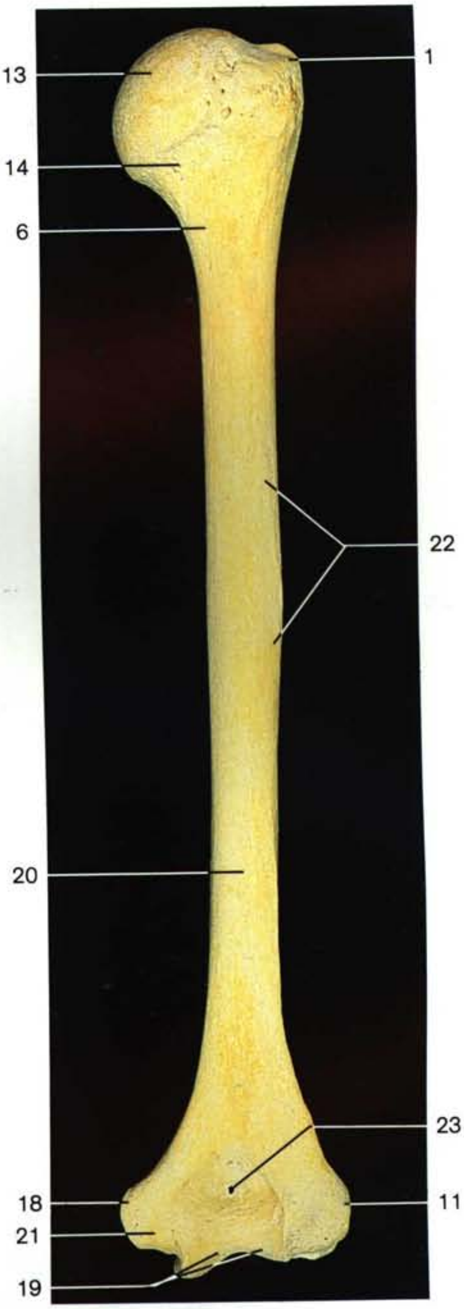
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Right humerus (posterior aspect).

Humerus

1 Greater tubercle
2 Lesser tubercle
3 Crest of lesser tubercle
4 Crest of greater tubercle
5 Intertubercular sulcus
6 Surgical neck
7 Deltoid tuberosity
8 Anterolateral surface
9 Lateral supracondylar ridge
10 Radial fossa
11 Lateral epicondyle
12 Capitulum
13 Head
14 Anatomical neck
15 Anteromedial surface
16 Medial supracondylar ridge
17 Coronoid fossa
18 Medial epicondyle
19 Trochlea
20 Posterior surface
21 Groove for ulnar nerve
22 Groove for radial nerve
23 Olecranon fossa

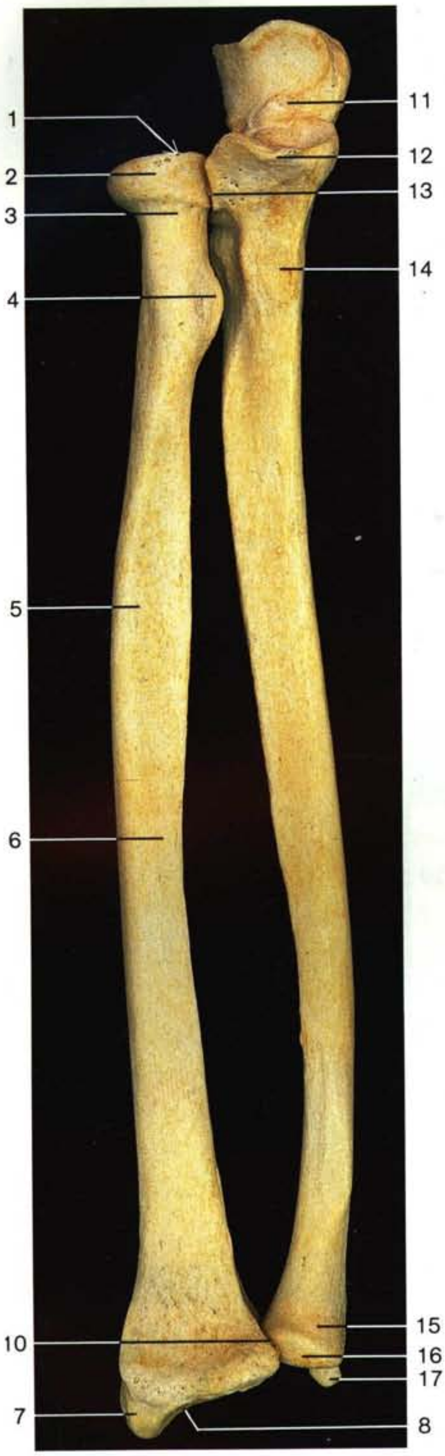

Bones of right forearm, radius and ulna (anterior aspect).

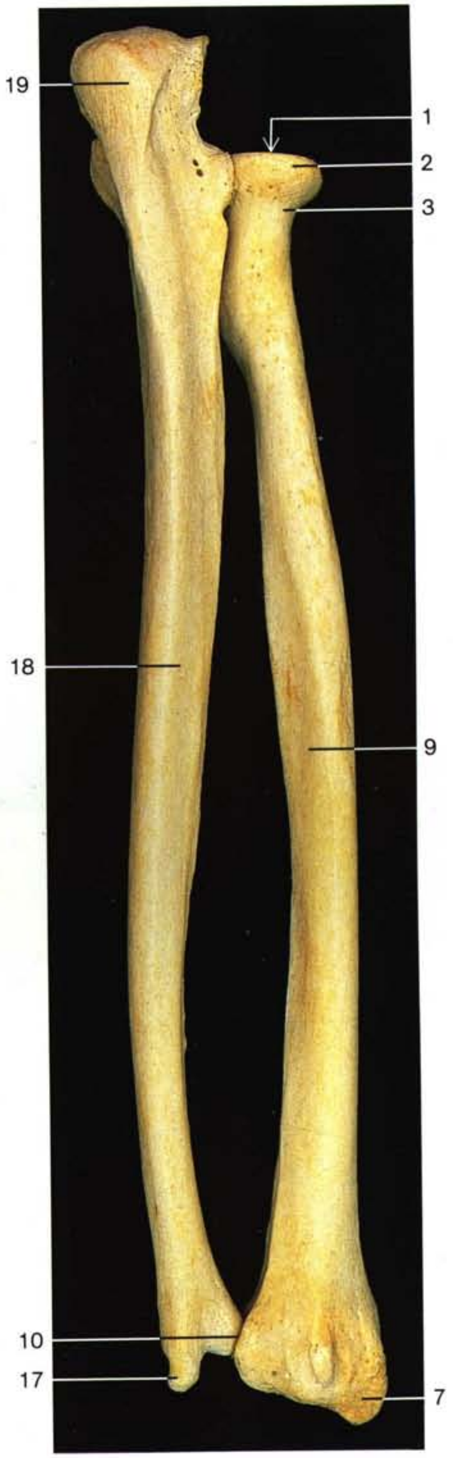

Bones of right forearm, radius and ulna (posterior aspect).

Radius

1	Head
2	Articular circumference
3	Neck
4	Radial tuberosity
5	Shaft
6	Anterior surface
7	Styloid process
8	Articular surface
9	Posterior surface
10	Ulnar notch

Ulna

11	Trochlear notch
12	Coronoid process
13	Radial notch
14	Ulnar tuberosity
15	Head
16	Articular circumference
17	Styloid process
18	Posterior surface
19	Olecranon

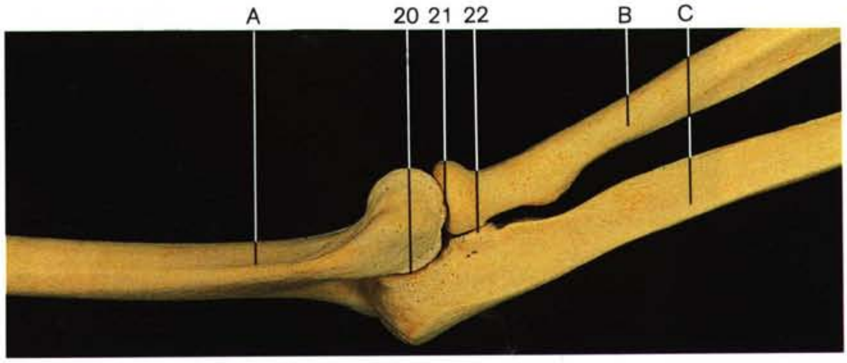

Bones of right elbow joint (lateral aspect).

Articulations at the right elbow

20	Site of humeroulnar joint
21	Site of humeroradial joint
22	Site of proximal radioulnar joint
A	Humerus
B	Radius
C	Ulna

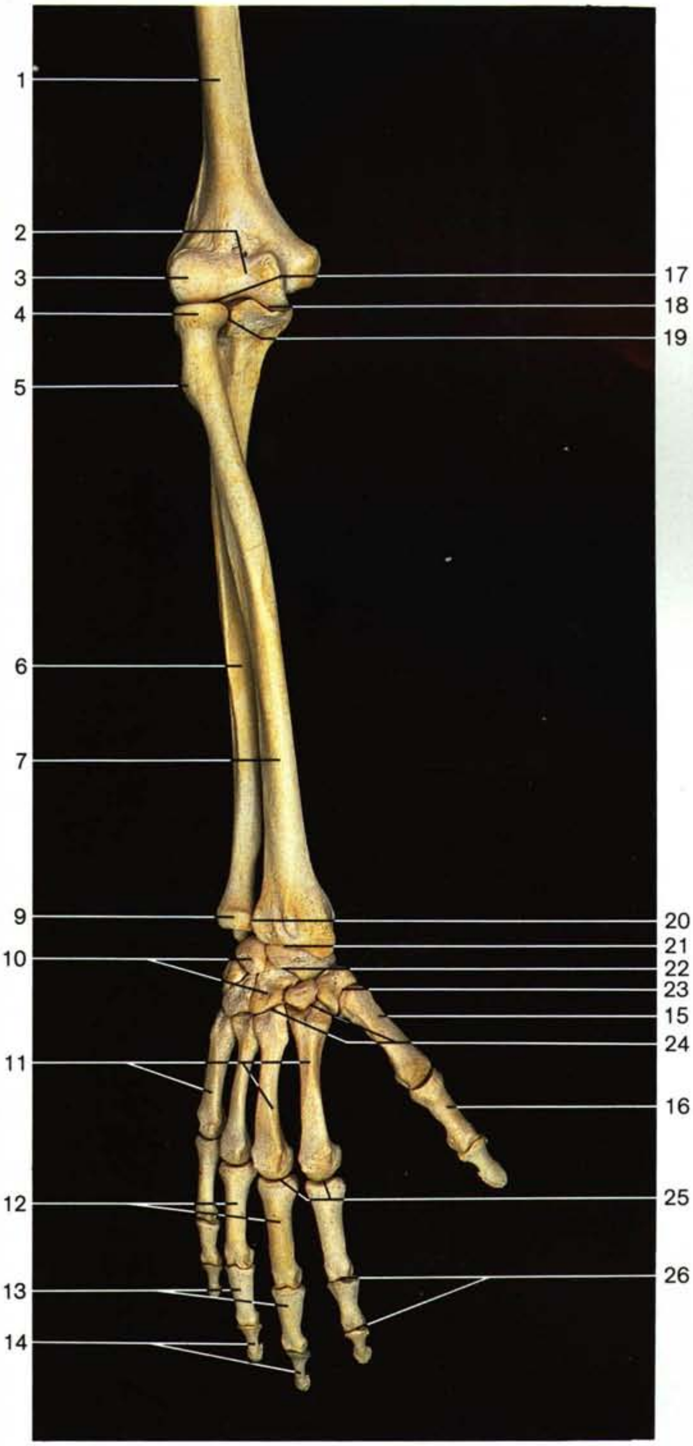
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Skeleton of right forearm and hand in pronation.

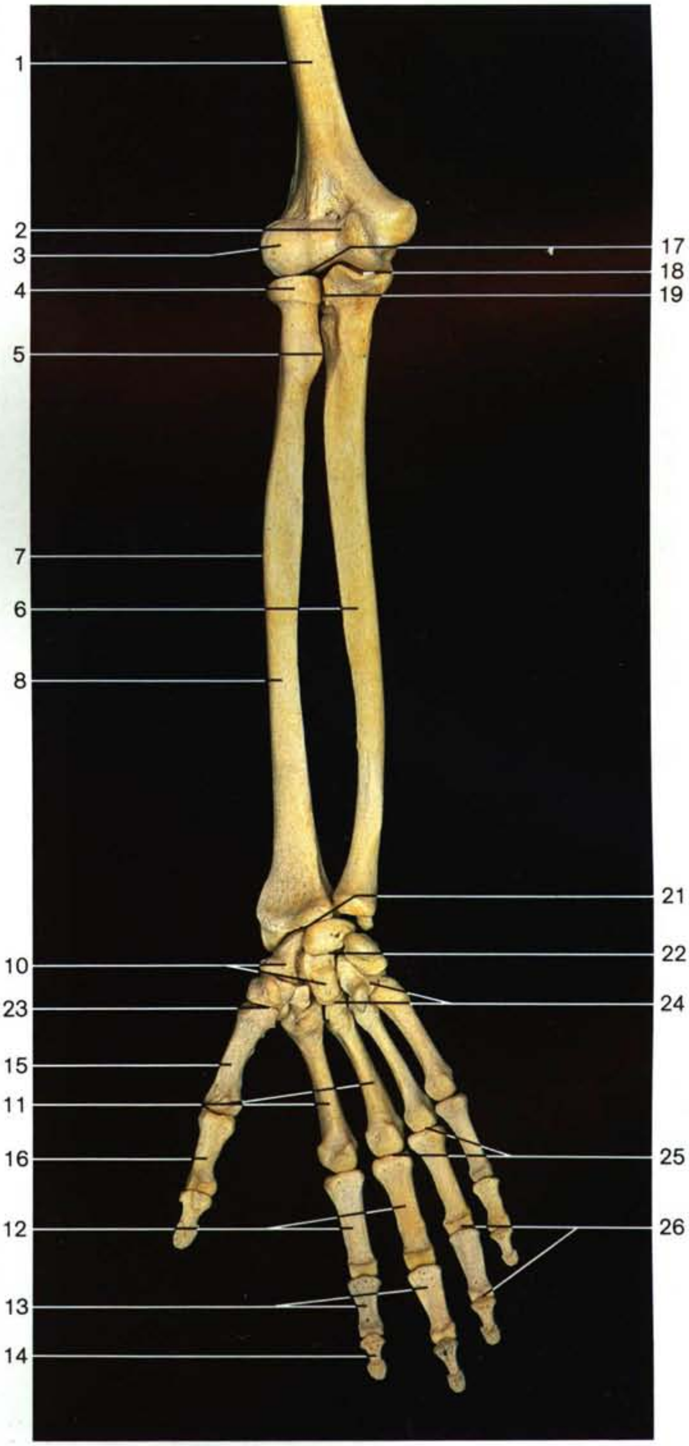
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Skeleton of right forearm and hand in supination.

1 Humerus
2 Trochlea of humerus
3 Capitulum of humerus
4 Articular circumference of radius
5 Radial tuberosity
6 Anterior surface of **ulna**
7 Posterior surface of **radius**
8 Anterior surface of radius
9 Articular circumference of ulna
10 **Carpal bones**

11 **Metacarpal bones**
12 Proximal phalanges
13 Middle phalanges
14 Distal phalanges
15 Metacarpal bone of thumb
16 Proximal phalanx of thumb

Sites of joints
17 Humeroradial joint
18 Humeroulnar joint
19 Proximal radioulnar joint
20 Distal radioulnar joint
21 Radiocarpal joint
22 Midcarpal joint
23 Carpometacarpal joint of thumb
24 Carpometacarpal joints
25 Metacarpophalangeal joints
26 Interphalangeal joints of fingers

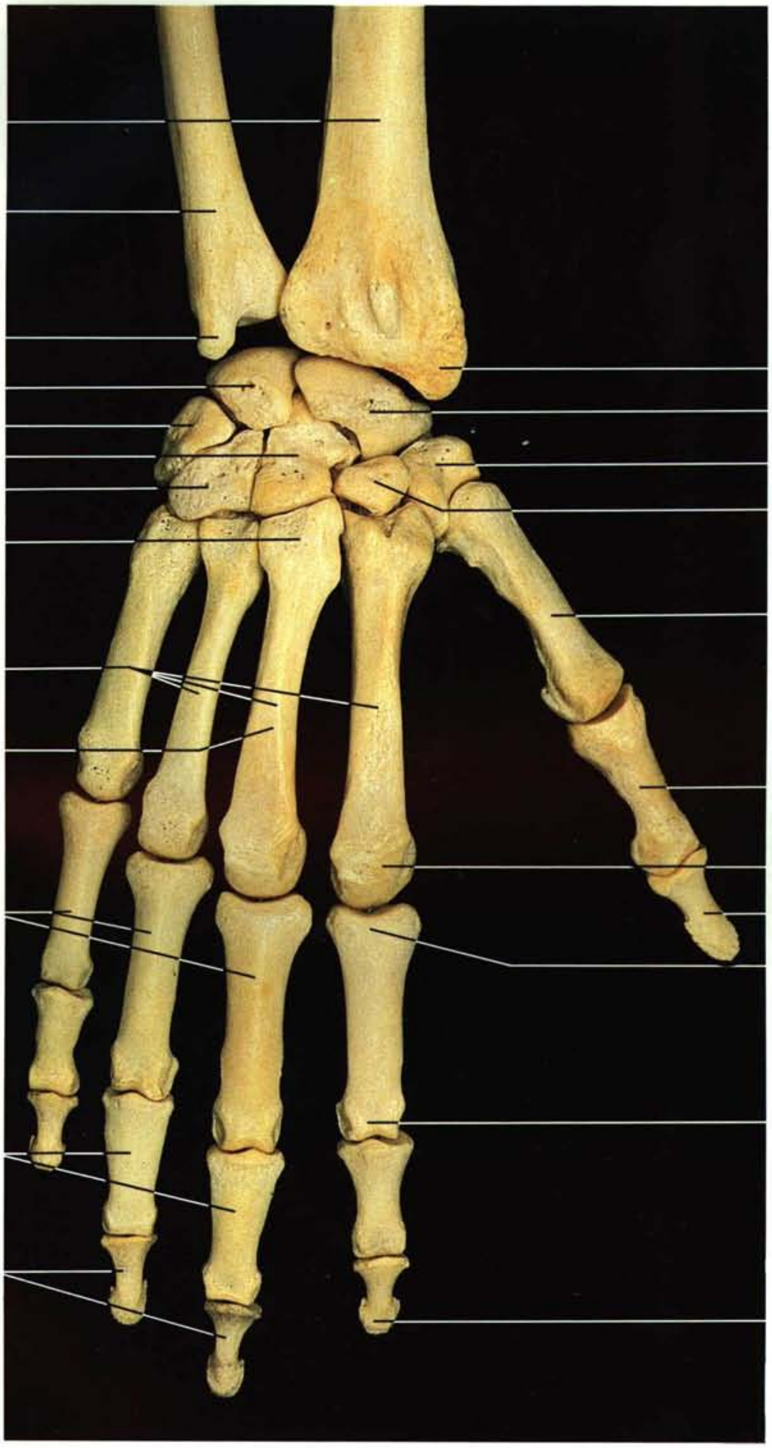
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Skeleton of right wrist and hand (dorsal aspect).

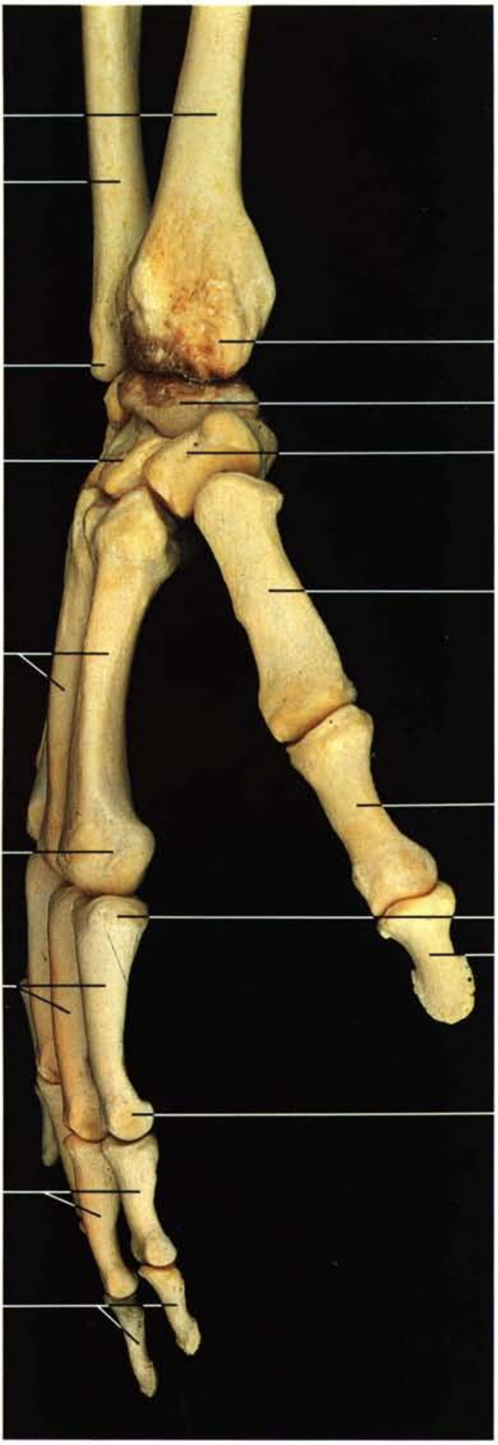
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Skeleton of right wrist and hand (medial aspect).

1 **Radius**
2 **Ulna**
3 Styloid process of ulna
4 Lunate bone
5 Triquetral bone
6 Capitate bone
7 Hamate bone
} **Carpal bones** (4–7)

8 Base of third metacarpal bone
9 **Metacarpal bones**
10 Head of metacarpal bone
11 Proximal phalanges of hand
12 Middle phalanges of hand
13 Distal phalanges of hand
14 Styloid process of radius

15 Scaphoid bone
16 The trapezium
17 Trapezoid bone
} **Carpal bones** (15–17)
18 Metacarpal bone of thumb
19 Proximal phalanx of thumb
20 Distal phalanx of thumb
21 Base of second proximal phalanx

22 Head of second proximal phalanx
23 Tuberosity of distal phalanx
24 Body of third metacarpal bone

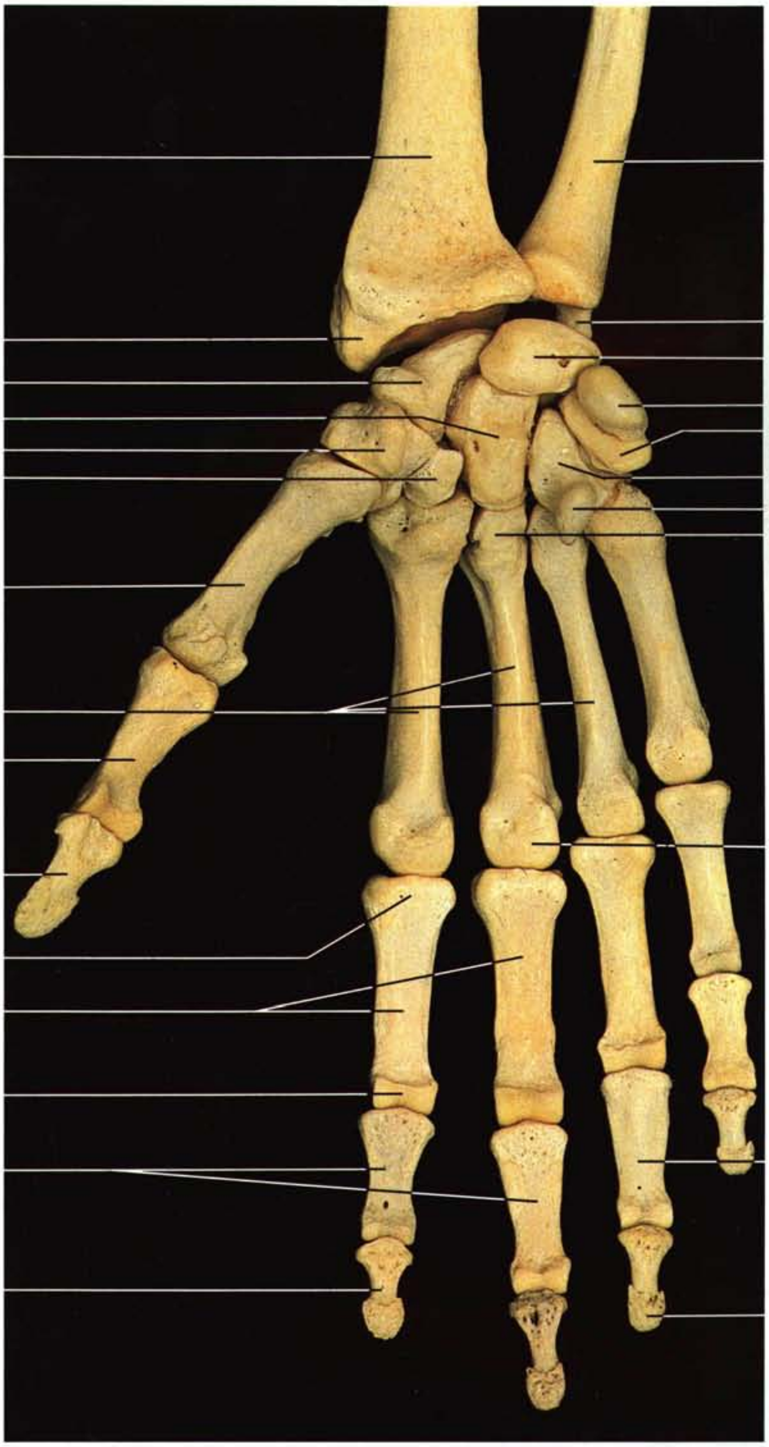

1	Radius	
2	Styloid process of radius	
3	Scaphoid bone	**Carpal bones**
4	Capitate bone	
5	Trapezium	
6	Trapezoid bone	
7	First metacarpal bone	
8	Second to fourth metacarpal bones	
9	Proximal phalanx of thumb	
10	Distal phalanx of thumb	
11	Base of second proximal phalanx	
12	Proximal phalanges	
13	Head of second proximal phalanx	
14	Middle phalanges	
15	Distal phalanx	
16	Ulna	
17	Styloid process of ulna	
18	Lunate bone	**Carpal bones**
19	Pisiform bone	
20	Triquetral bone	
21	Hamate bone	
22	Hamulus or hook of hamate bone	
23	Base of third metacarpal bone	
24	Head of metacarpal bone	
25	Tuberosity of distal phalanx	

Skeleton of right wrist and hand (palmar aspect).

The human hand is one of the most admirable structures of the human body. The carpometacarpal joint of the thumb, a saddle joint, enjoys wide mobility, so that the thumb can get in contact with all other fingers, thus enabling the hand to become an instrument for grasping and psychologic expression. During evolution these newly developed functions appeared after the erect posture of the human body was achieved. An inevitable prerequisite for the development of human cultures is not only the differentiation of the brain but also the development of an organ capable of realizing its ideas: the human hand.

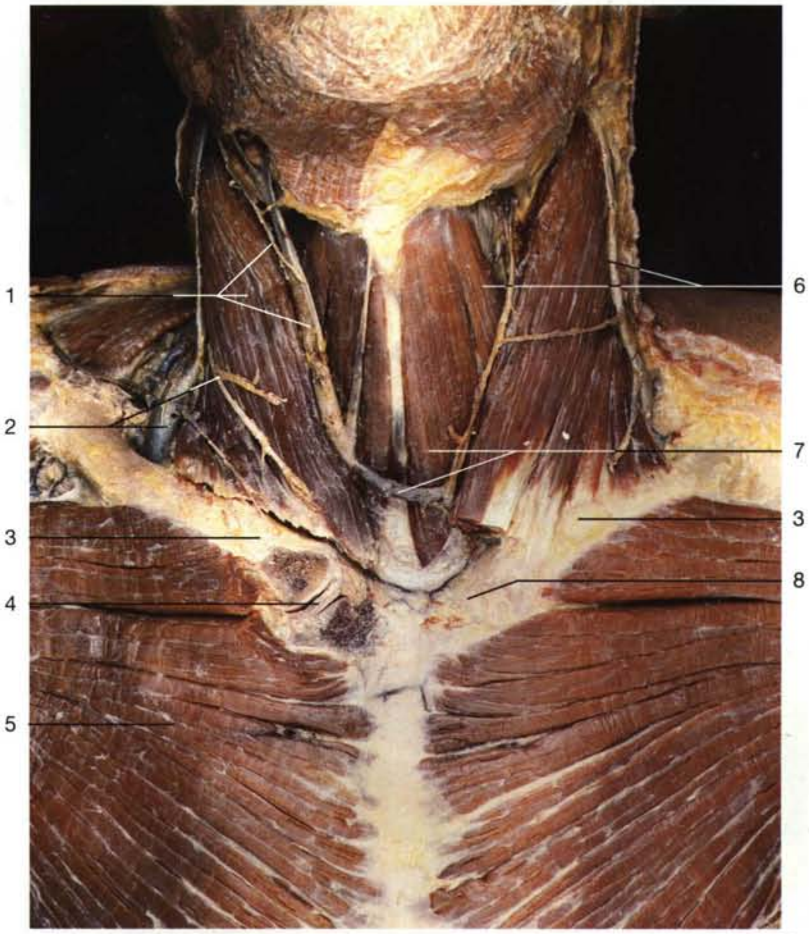

Right sternoclavicular joint (anterior aspect). On the right side the joint has been opened by a coronal section. Note the articular disk.

1 Sternocleidomastoid muscle, cervical branch of facial nerve and anterior jugular vein
2 External jugular vein and transverse cervical nerve (inferior branch)
3 Clavicle
4 **Sternoclavicular joint** (opened) with articular disk
5 Pectoralis major muscle
6 Omohyoid muscle and external jugular vein
7 Jugular venous arch and sternohyoid muscle
8 Sternoclavicular joint (not opened)
9 Acromial end of clavicle
10 **Acromioclavicular joint**
11 Acromion
12 Tendon of supraspinatus muscle (attached to the articular capsule)
13 Coraco-acromial ligament
14 Tendon of long head of biceps brachii muscle
15 Tendon of subscapularis muscle (attached to the articular capsule)
16 Intertubercular sulcus
17 Articular capsule of shoulder joint
18 Humerus
19 Trapezoid ligament
20 Coracoid process
21 Glenoid labrum
22 **Shoulder joint** (joint cavity)
23 Scapula
24 Supraspinatus muscle
25 Cartilage of glenoid cavity
26 Tendon of long head of triceps brachii muscle
27 Head of humerus (articular cartilage)
28 Epiphyseal line

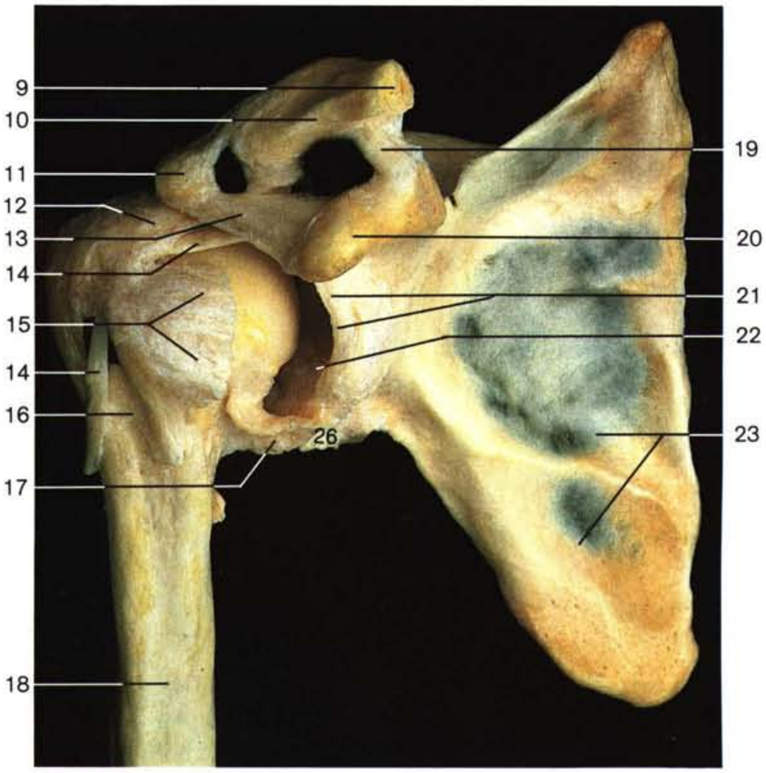

Right shoulder joint. The anterior part of the articular capsule has been removed and the head of the humerus has been slightly rotated outward to show the cavity of the joint.

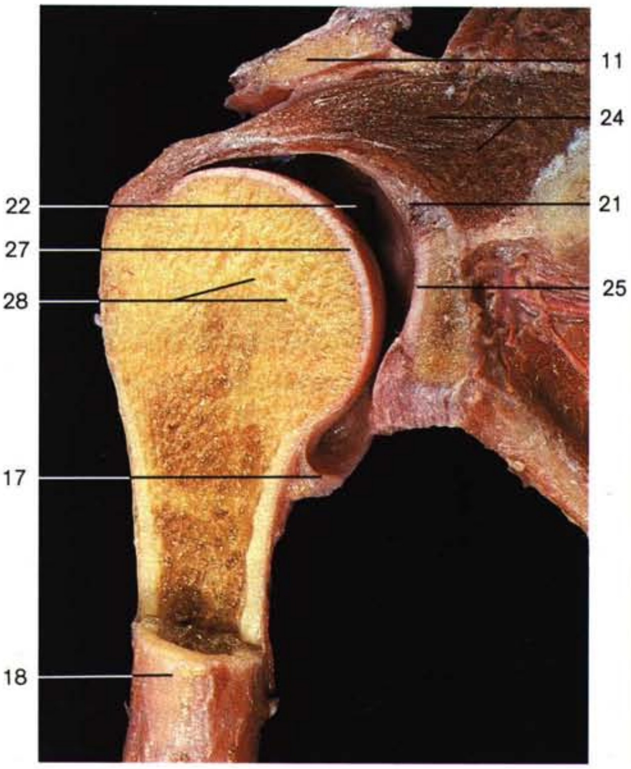

Coronal section of the right shoulder joint (anterior aspect).

1 Humerus
2 Lateral epicondyle of humerus
3 Articular capsule
4 Annular ligament of proximal radioulnar joint
5 Radius
6 Tendon of biceps brachii muscle
7 Medial epicondyle of humerus
8 Ulnar collateral ligament
9 Oblique cord
10 Ulna
11 Interosseous membrane
12 Radial fossa
13 Capitulum of humerus
14 Head of radius
15 Radial collateral ligament
16 Coronoid fossa
17 Trochlea of humerus
18 Coronoid process of ulna
19 Olecranon
20 Radial tuberosity

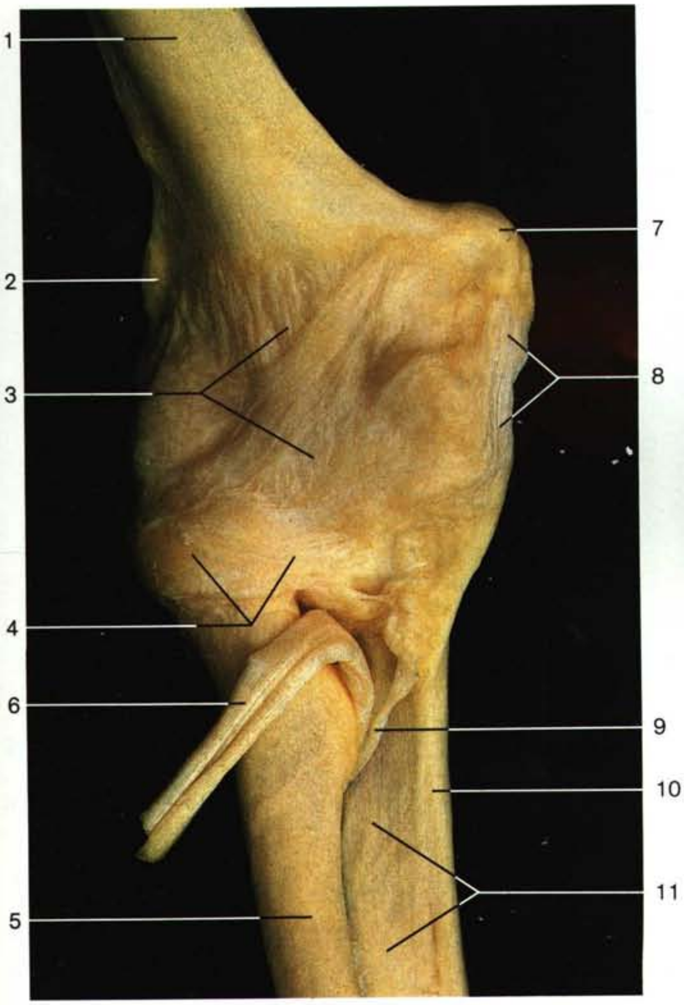

Ligaments of elbow joint (anterior aspect).

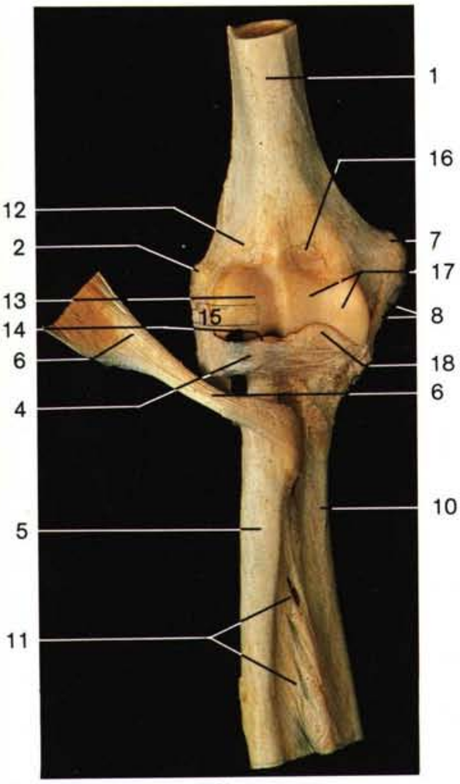

Elbow joint with ligaments (anterior aspect). Articular capsule has been removed to show the annular ligament.

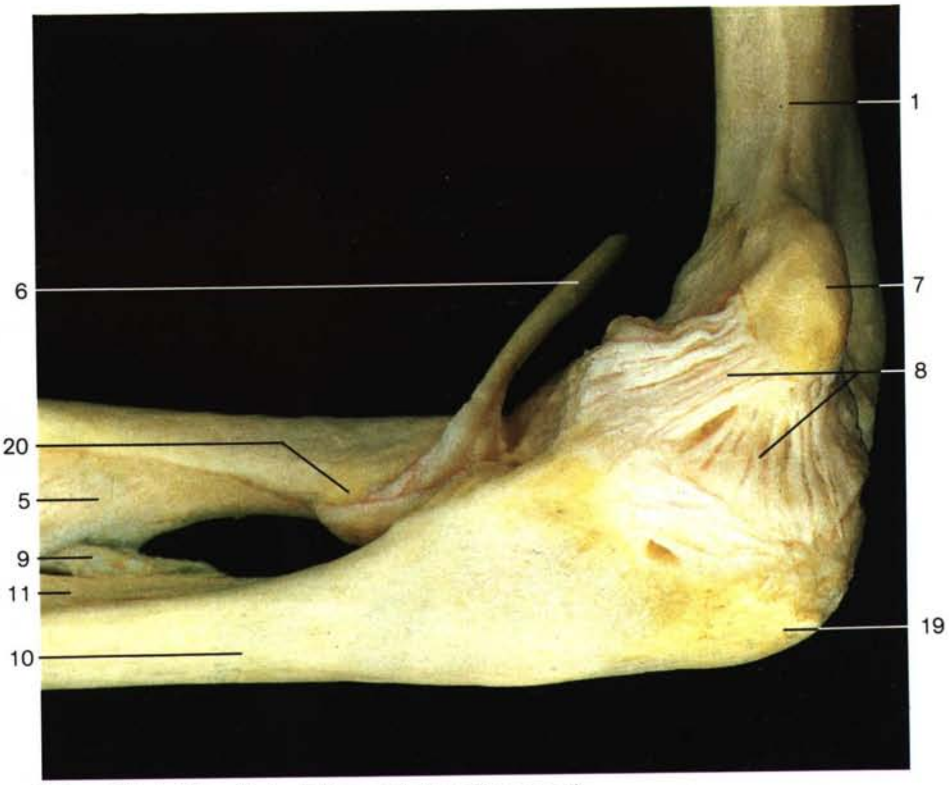

Elbow joint with collateral ligaments (medial aspect).

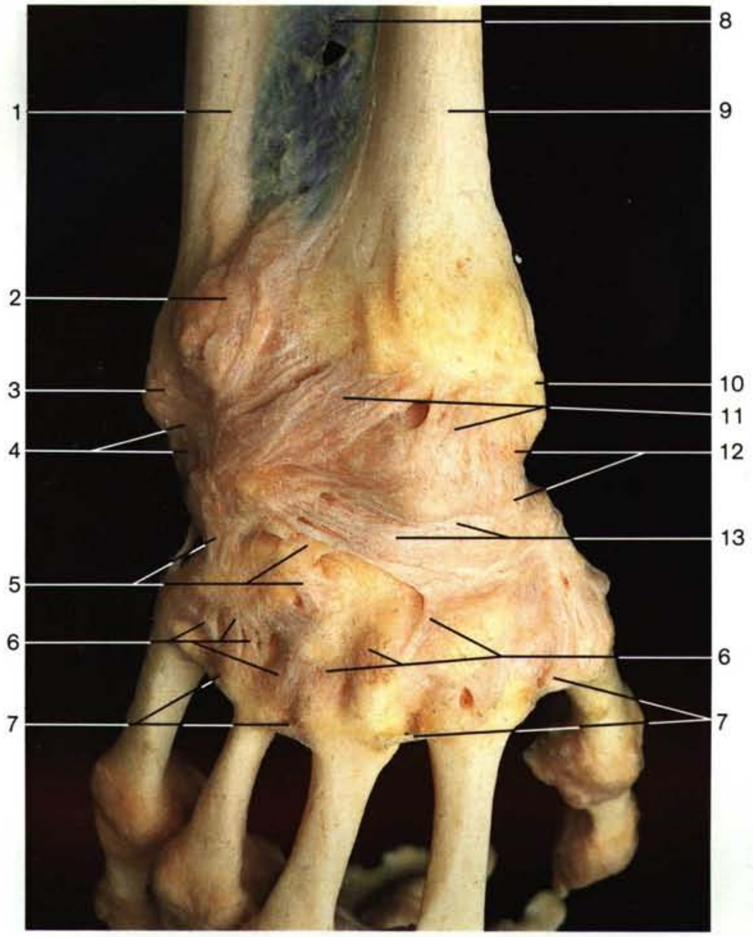

Ligaments of hand and wrist (dorsal aspect).

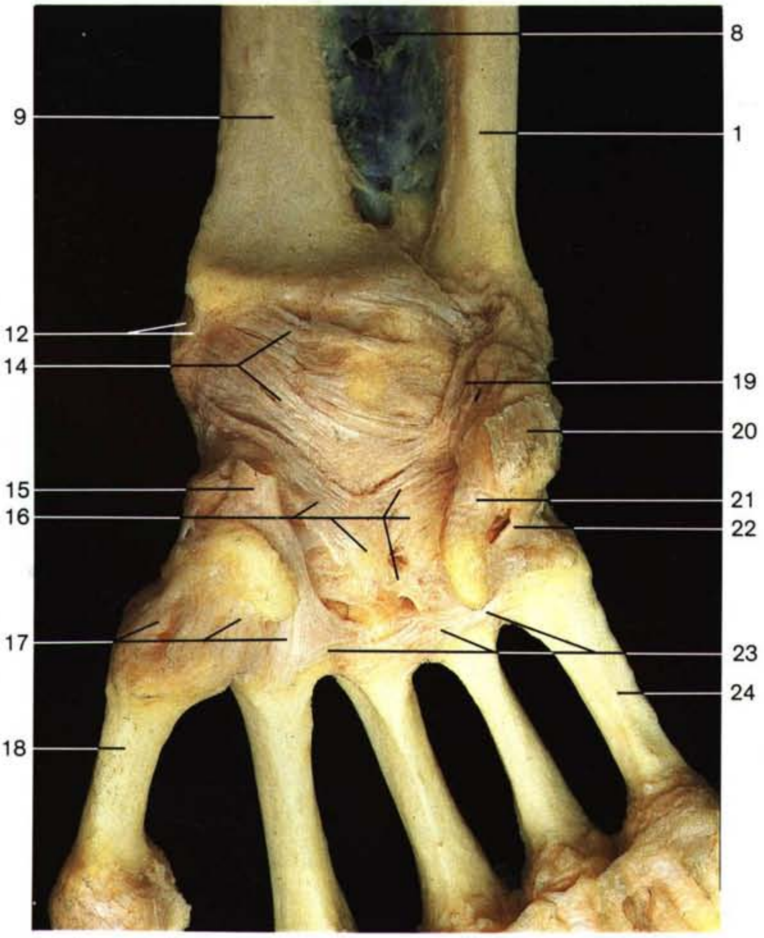

Ligaments of hand and wrist (palmar aspect).

1 Ulna
2 Exostosis (pathological)
3 Head of ulna
4 **Ulnar carpal collateral ligament**
5 Deep intercarpal ligaments
6 Dorsal carpometacarpal ligaments
7 Dorsal metacarpal ligaments
8 Interosseous membrane
9 Radius
10 Styloid process of radius
11 **Dorsal radiocarpal ligament**
12 Radial collateral ligament
13 Articular capsule and dorsal intercarpal ligaments
14 **Palmar radiocarpal ligament**
15 Tendon of flexor carpi radialis muscle (cut)
16 Radiating carpal ligament
17 Palmar carpometacarpal ligaments
18 1st metacarpal bone
19 Palmar ulnocarpal ligament
20 Tendon of flexor carpi ulnaris muscle (cut)
21 **Pisohamate ligament**
22 **Pisometacarpal ligament**
23 Palmar metacarpal ligaments
24 5th metacarpal bone

1 Radius
2 Styloid process of radius
3 Palmar radiocarpal ligament
4 Tendon of flexor carpi radialis muscle (cut)
5 Radiating carpal ligament
6 Articular capsule of **carpometacarpal joint of thumb**
7 Articular capsule of **metacarpophalangeal joint of thumb**
8 Palmar ligaments and articular capsule of metacarpophalangeal joints
9 Palmar ligaments and articular capsule of interphalangeal joints
10 Articular capsule
11 Interosseous membrane
12 Ulna
13 **Distal radioulnar joint**
14 Styloid process of ulna
15 Palmar ulnocarpal ligament
16 **Pisiform bone with tendon of flexor carpi ulnaris muscle**
17 Pisometacarpal ligament
18 Pisohamate ligament
19 Metacarpal bone
20 Deep transverse metacarpal ligament
21 Tendons of extensor muscles and articular capsule
22 Collateral ligament of **interphalangeal joint**
23 Collateral ligaments of **metacarpophalangeal joints**
24 Second metacarpal bone

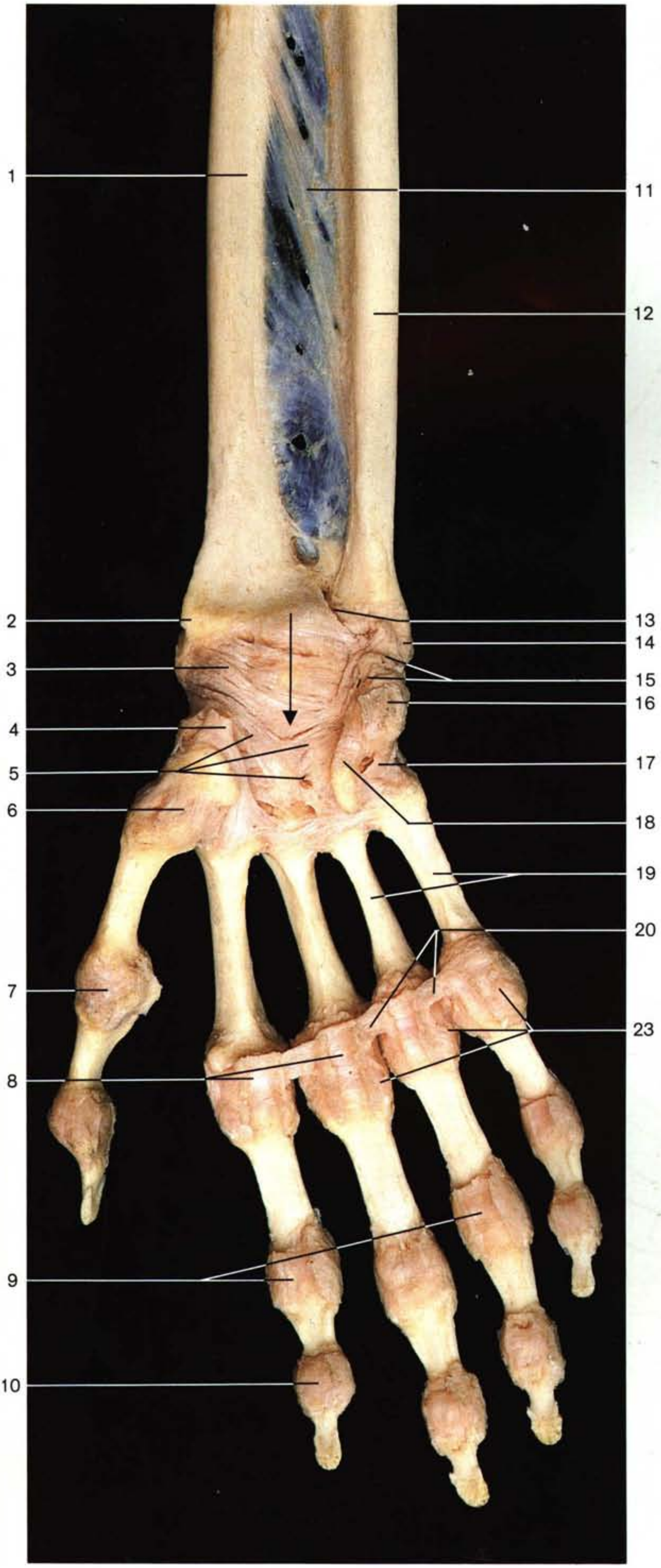

Ligaments of right forearm, hand and fingers (palmar aspect). The arrow indicates the location of the carpal tunnel.

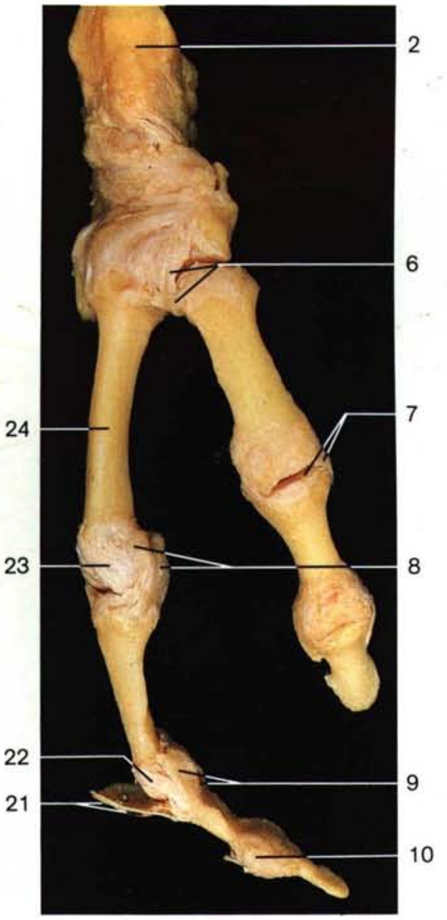

Ligaments of fingers (lateral aspect).

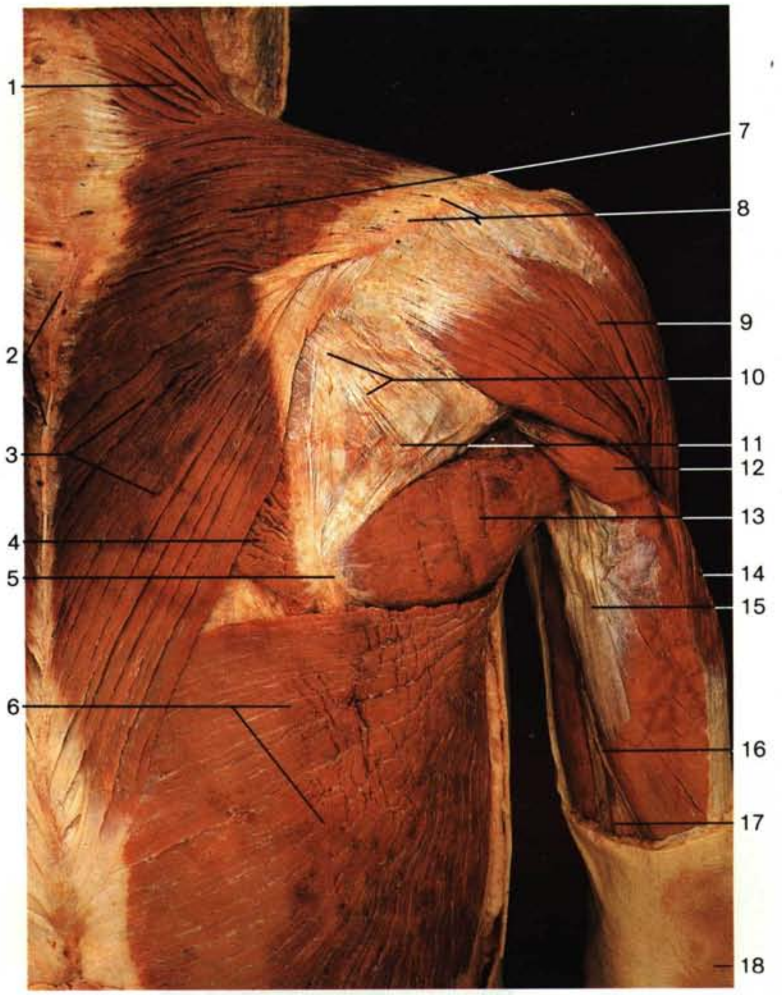

1 Descending fibers of **trapezius muscle**
2 Spinous processes of thoracic vertebrae
3 Ascending fibers of trapezius muscle
4 Rhomboid major muscle
5 Inferior angle of scapula
6 **Latissimus dorsi muscle**
7 Transverse fibers of trapezius muscle
8 Spine of scapula
9 Posterior fibers of **deltoid muscle**
10 Infraspinatus muscle and infraspinous fascia
11 Teres minor muscle and fascia
12 Long head of triceps brachii muscle
13 **Teres major muscle**
14 Lateral head of triceps brachii muscle
15 Medial head of triceps brachii muscle
16 Medial intermuscular septum
17 Ulnar nerve
18 Olecranon

Muscles of shoulder and arm, superficial layer (dorsal aspect).

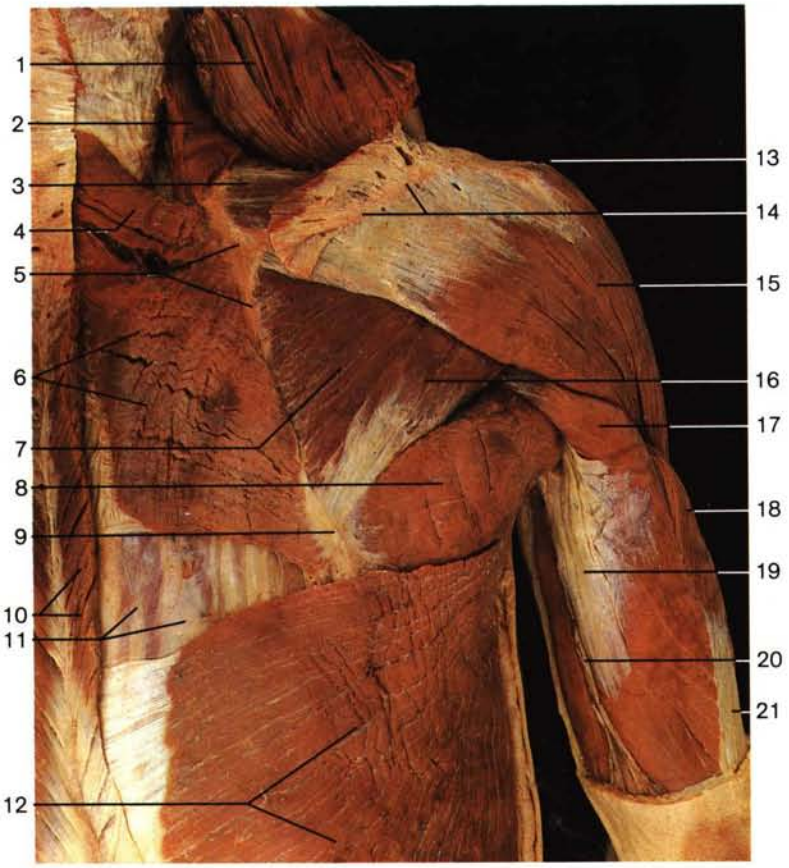

1 Trapezius muscle (reflected)
2 Levator scapulae muscle
3 Supraspinatus muscle
4 Rhomboid minor muscle
5 Medial border of scapula
6 **Rhomboid major muscle**
7 **Infraspinatus muscle**
8 **Teres major muscle**
9 Inferior angle of scapula
10 Cut edge of trapezius muscle
11 Intrinsic muscles of back with fascia
12 **Latissimus dorsi muscle**
13 Acromion
14 Spine of scapula
15 **Deltoid muscle**
16 Teres minor
17 Long head of triceps brachii muscle
18 Lateral head of triceps brachii muscle
19 Medial head of triceps brachii muscle
20 Medial intermuscular septum
21 Tendon of triceps brachii muscle

Muscles of shoulder and arm, deeper layer (right side, dorsal aspect). The trapezius has been cut near its origin at the vertebral column and reflected upward.

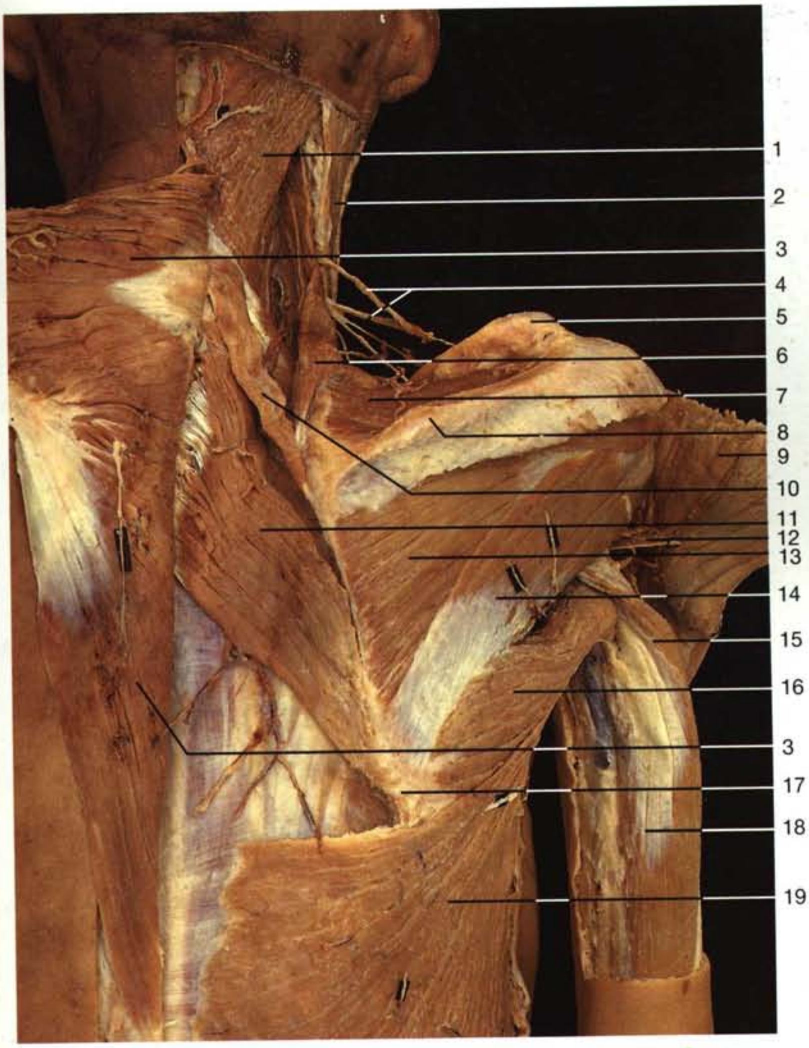

1 **Splenius capitis muscle**
2 Sternocleidomastoideus muscle
3 Trapezius muscle (reflected)
4 **Lateral supraclavicular nerves**
5 Clavicle
6 Levator scapulae muscle
7 Supraspinatus muscle
8 Spine of scapula
9 Deltoid muscle (reflected)
10 Rhomboid minor muscle
11 **Rhomboid major muscle**
12 **Axillary nerve and posterior circumflex humeral artery**
13 **Infraspinatus muscle**
14 **Teres minor muscle**
15 Long head of triceps brachii muscle
16 **Teres major muscle**
17 Inferior angle of scapula
18 Triceps brachii muscle
19 **Latissimus dorsi muscle**

Muscles of shoulder and arm, deeper layer, right side (dorsal aspect). The trapezius and deltoid muscles have been divided and reflected.

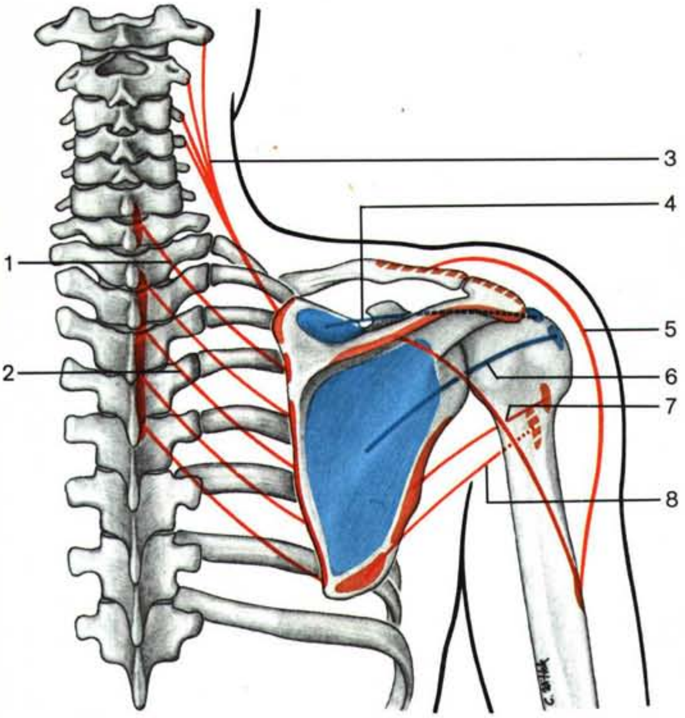

Shoulder muscles, schematic diagram illustrating the course of the main muscles of the dorsal aspect of the shoulder.

1 Rhomboid minor muscle (red)
2 Rhomboid major muscle (red)
3 Levator scapulae muscle (red)
4 Supraspinatus muscle (blue)
5 Deltoid muscle (red)
6 Infraspinatus muscle (blue)
7 Teres minor muscle (red)
8 Teres major muscle (red)

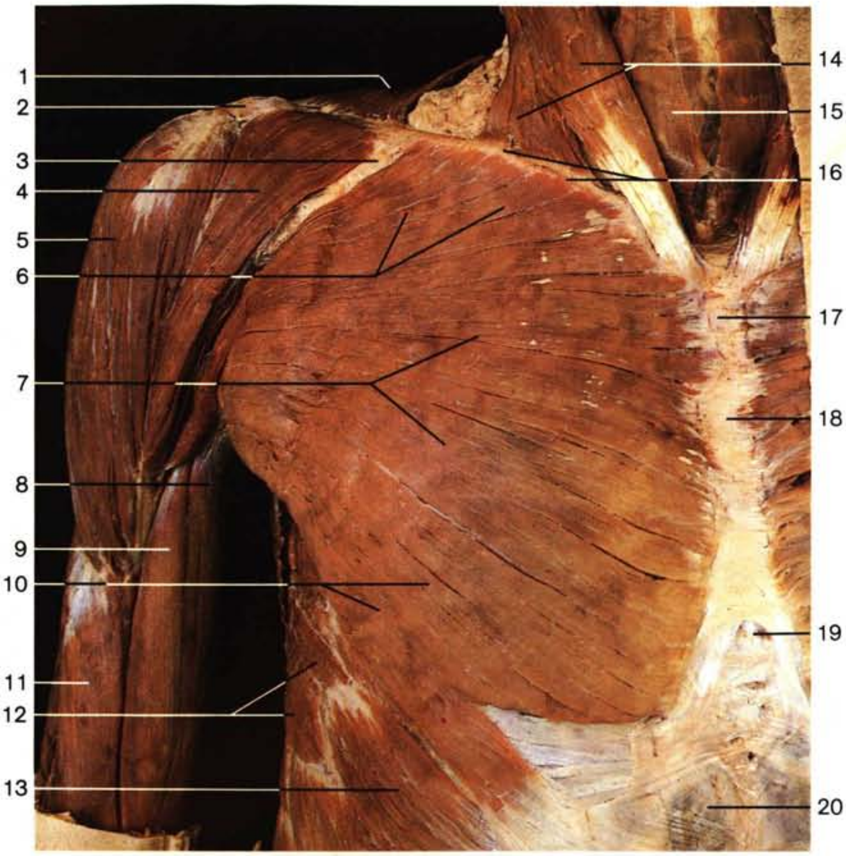

1	Trapezius muscle
2	Acromion
3	Deltopectoral triangle
4	Clavicular part of deltoid muscle (anterior fibers)
5	Acromial part of deltoid muscle (central fibers)
6	Clavicular part of pectoralis major muscle
7	Sternocostal part of pectoralis major muscle
8	Short head of biceps brachii muscle
9	Long head of biceps brachii muscle
10	Abdominal part of pectoralis major muscle
11	Brachialis muscle
12	Serratus anterior muscle
13	External abdominal oblique muscle
14	Sternocleidomastoid muscle
15	Infrahyoid muscles
16	Clavicle
17	Manubrium sterni
18	Body of sternum
19	Xiphoid process
20	Anterior layer of sheath of rectus abdominis muscle

Muscles of shoulder and arm, superficial layer (ventral aspect).

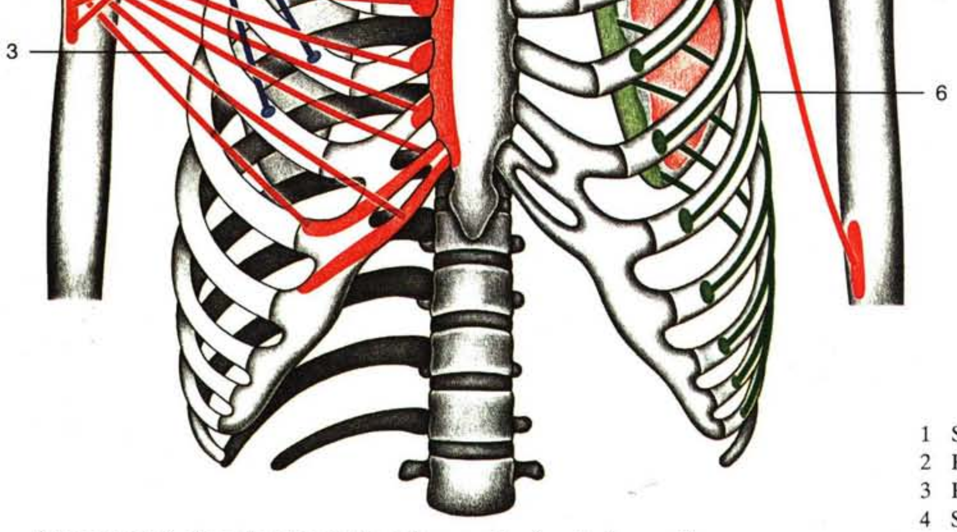

Arrangement of pectoral and shoulder muscles (ventral aspect). (Schematic drawing.)

1	Subclavius muscle (blue)
2	Pectoralis minor muscle (blue)
3	Pectoralis major muscle (red)
4	Subscapularis muscle (red)
5	Coracobrachialis muscle (light-blue)
6	Serratus anterior muscle (green)

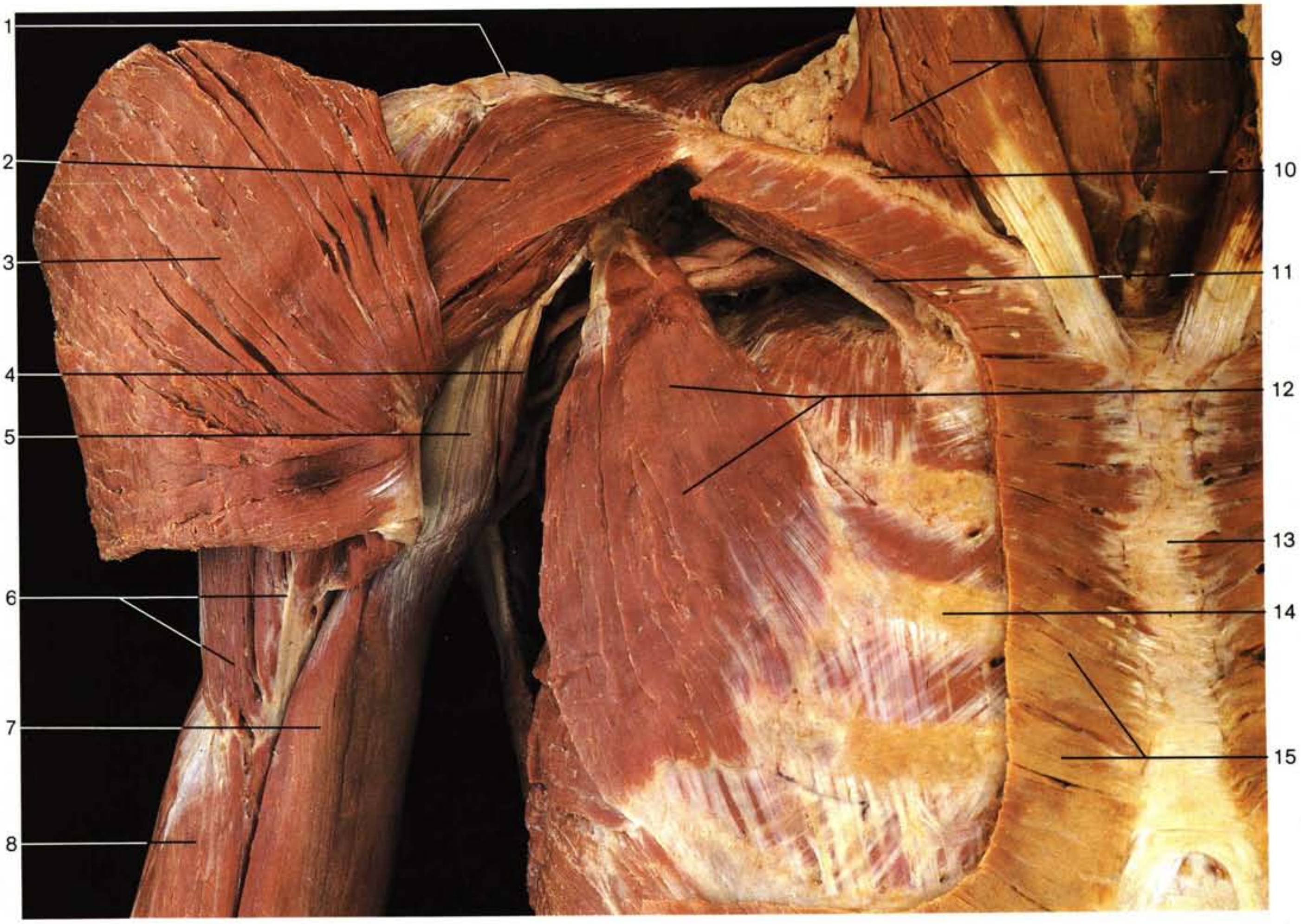

Muscles of shoulder and arm, deep layer (ventral aspect).

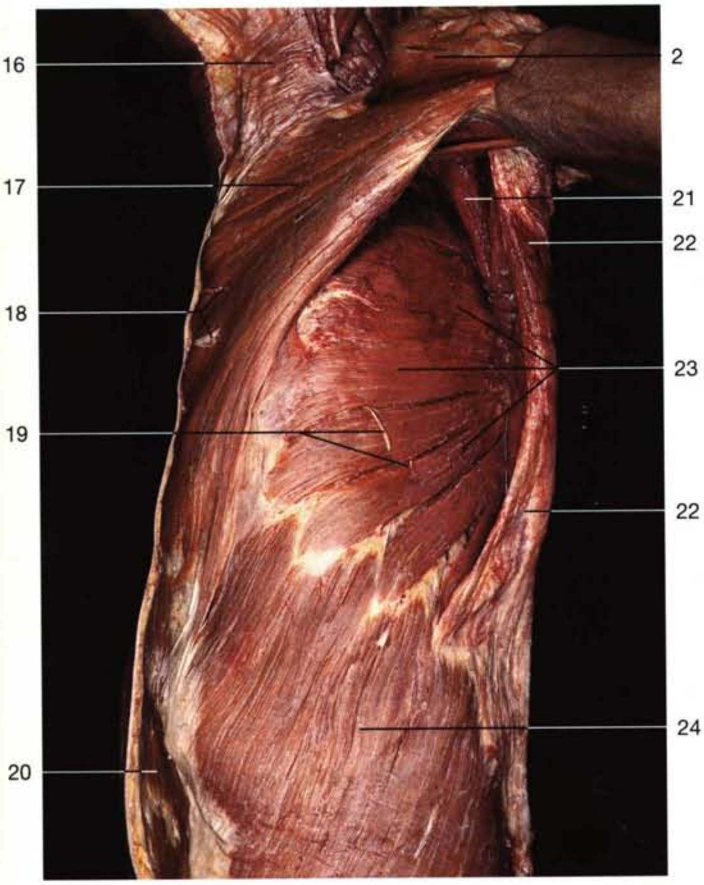

1 Acromion
2 Clavicular part of deltoid muscle
3 Pectoralis major muscle (reflected)
4 Coracobrachialis muscle
5 Short head of biceps brachii muscle
6 Deltoid muscle (insertion on humerus)
7 Long head of biceps brachii muscle
8 Brachialis muscle
9 Sternocleidomastoid muscle
10 Clavicle
11 Subclavius muscle
12 Pectoralis minor muscle
13 Sternum
14 3rd rib
15 Pectoralis major muscle
16 Platysma muscle
17 Pectoralis major muscle forming the anterior axillary fold
18 Anterior cutaneous branches of intercostal nerves
19 Lateral cutaneous branches of intercostal nerves
20 Rectus abdominis muscle
21 Subscapularis muscle
22 **Latissimus dorsi muscle** forming the posterior axillary fold
23 **Serratus anterior muscle** forming the medial wall of the axilla
24 External abdominal oblique muscle

Axillary fossa and serratus anterior muscle (left side, lateral aspect).

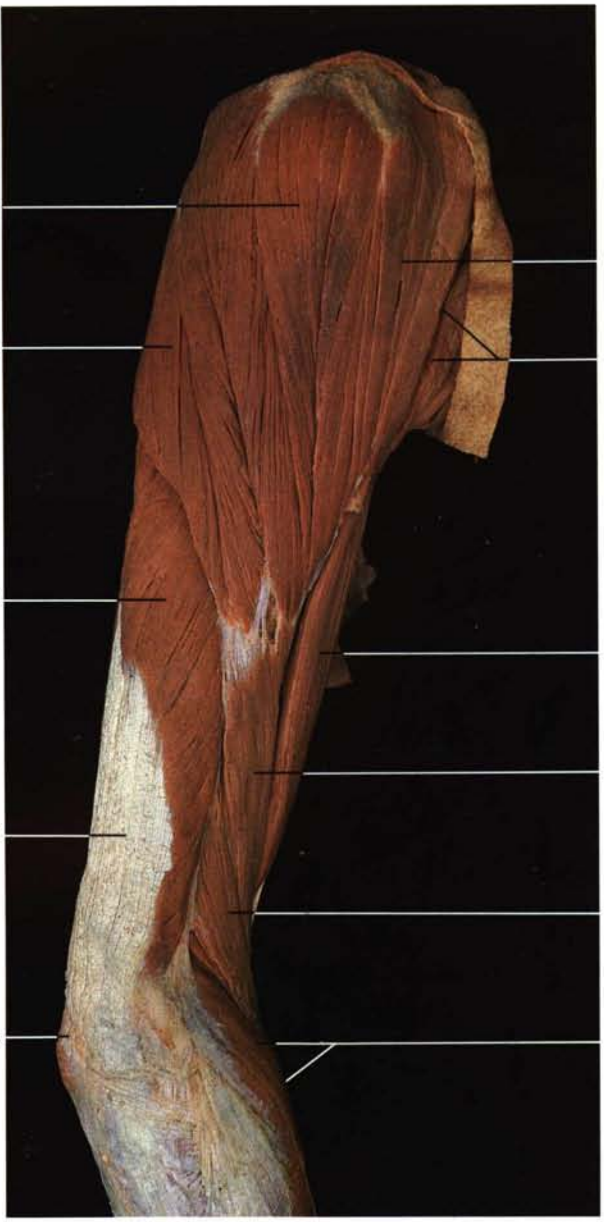
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Muscles of right arm (lateral aspect).

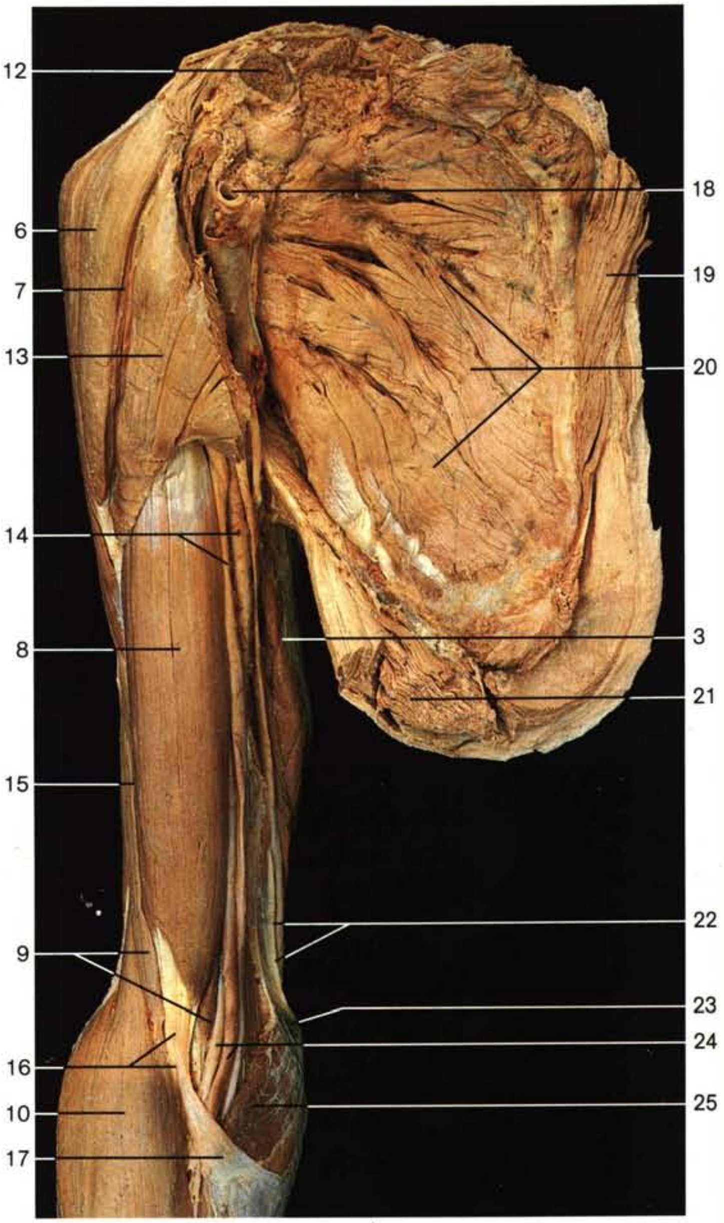
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Muscles of right arm (ventral aspect). The arm with the scapula and attached muscles has been removed from the trunk.

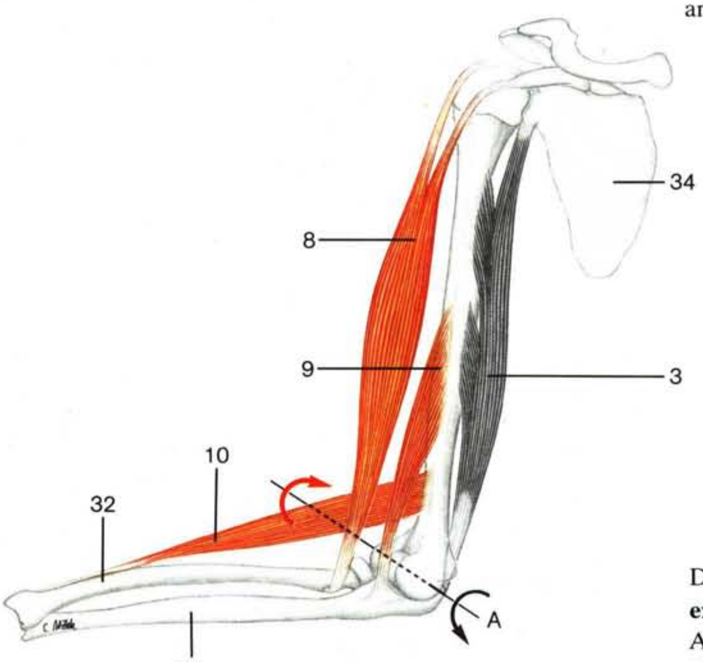
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Diagram illustrating the position of the **flexor and extensor muscles of the arm** and their effect on the elbow joint. A = axis; arrows = direction of movements; red = flexion; black = extension.

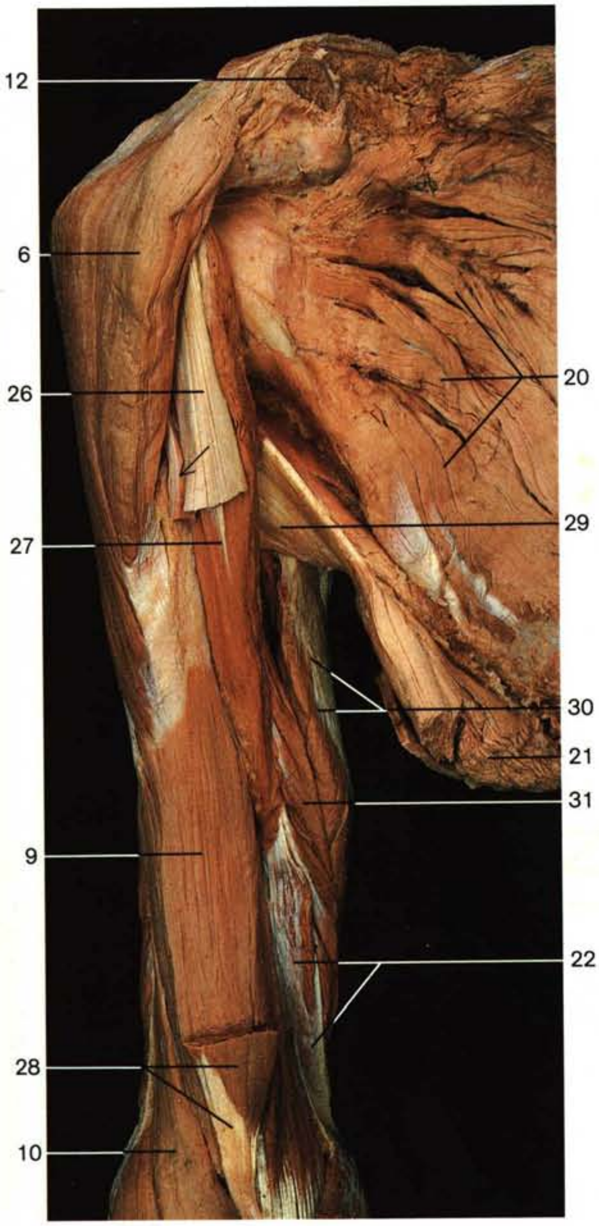

Flexor muscles of right arm (ventral aspect). Part of the biceps brachii muscle has been removed. Arrow: tendon of long head of biceps brachii muscle.

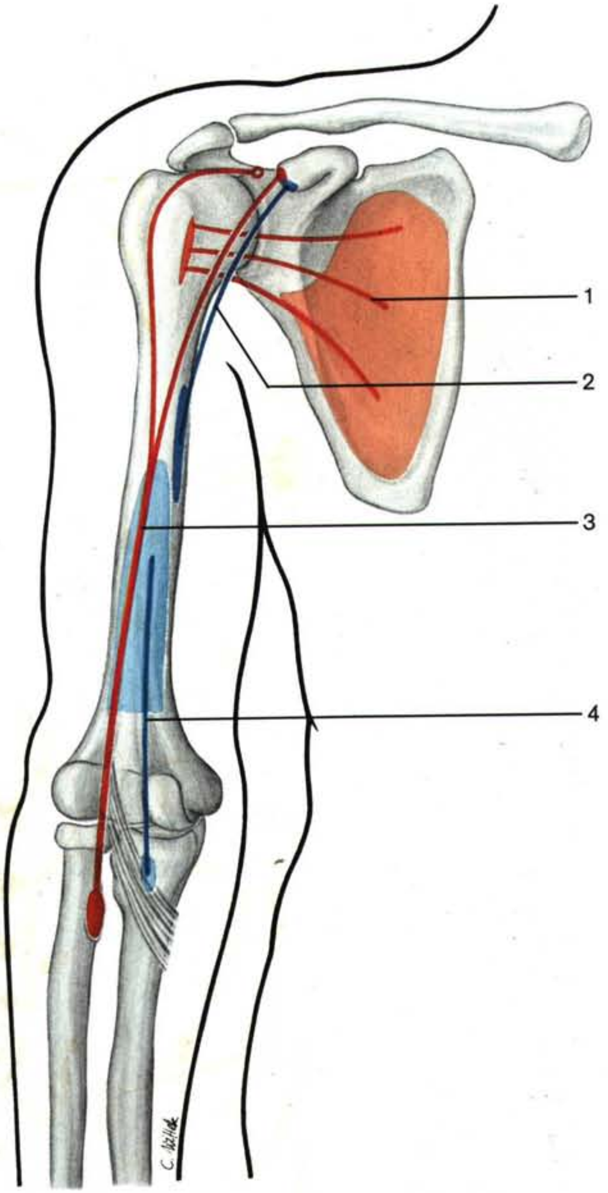

Position and course of flexors of arm. (Schematic drawing.)

1 Subscapularis muscle (red)
2 Coracobrachialis muscle (blue)
3 Biceps brachii muscle (red)
4 Brachialis muscle (blue)

1 Acromial part of deltoid muscle (central fibers)
2 Scapular part of deltoid muscle (posterior fibers)
3 Triceps brachii muscle
4 Tendon of triceps brachii muscle
5 Olecranon
6 Clavicular part of deltoid muscle (anterior fibers)
7 Deltopectoral groove
8 **Biceps brachii muscle**
9 **Brachialis muscle**
10 **Brachioradialis muscle**
11 Extensor carpi radialis longus muscle
12 Clavicle (divided)
13 Pectoralis major muscle
14 Medial intermuscular septum with vessels and nerves
15 Lateral intermuscular septum
16 Tendon of biceps brachii muscle
17 Bicipital aponeurosis
18 Axillary artery
19 Rhomboid major muscle
20 **Subscapularis muscle**
21 Latissimus dorsi muscle (divided)
22 Medial intermuscular septum
23 Medial epicondyle of humerus
24 Brachial artery and median nerve
25 Pronator teres muscle
26 Tendon of short head of biceps brachii muscle
27 Coracobrachialis muscle
28 Distal part of biceps brachii muscle
29 Teres major muscle
30 Long head of triceps brachii muscle
31 Medial head of triceps brachii muscle
32 Radius
33 Ulna
34 Scapula

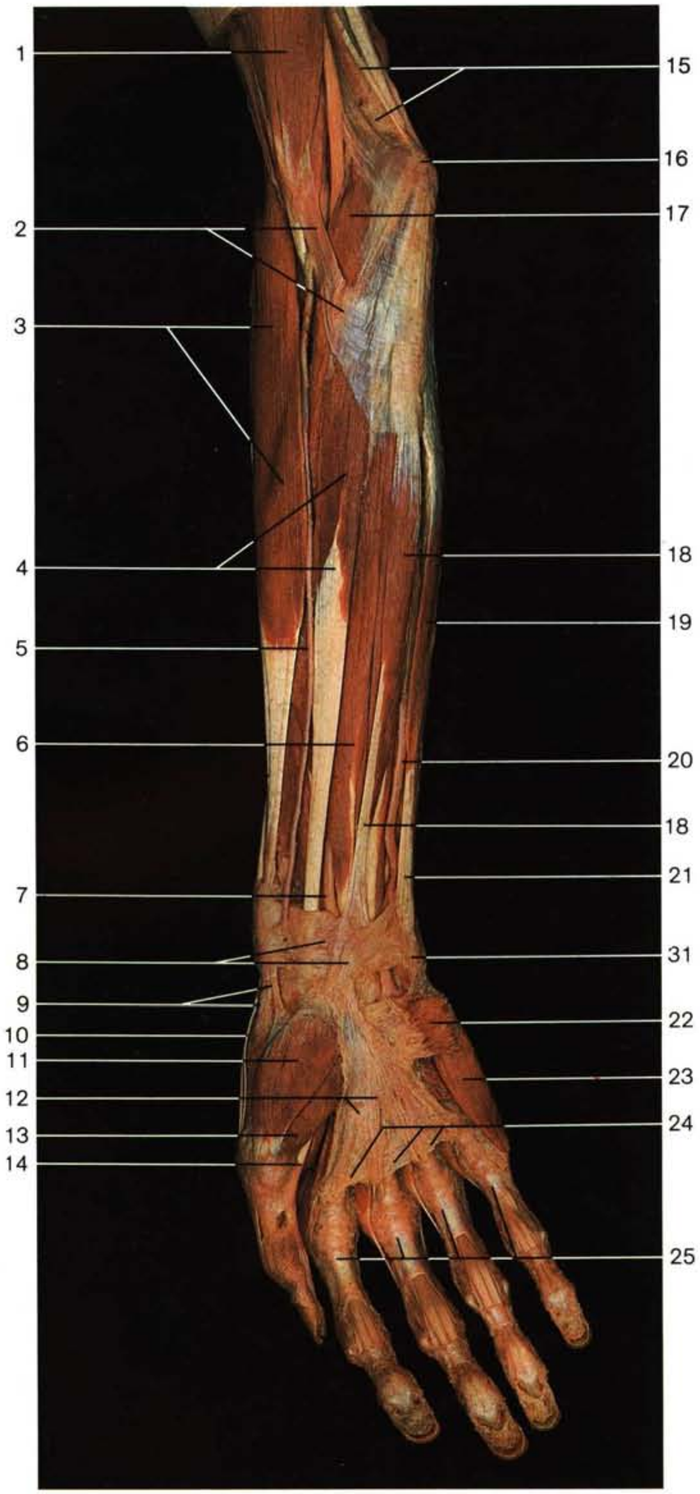
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Forearm muscles, superficial layer (ventral aspect).

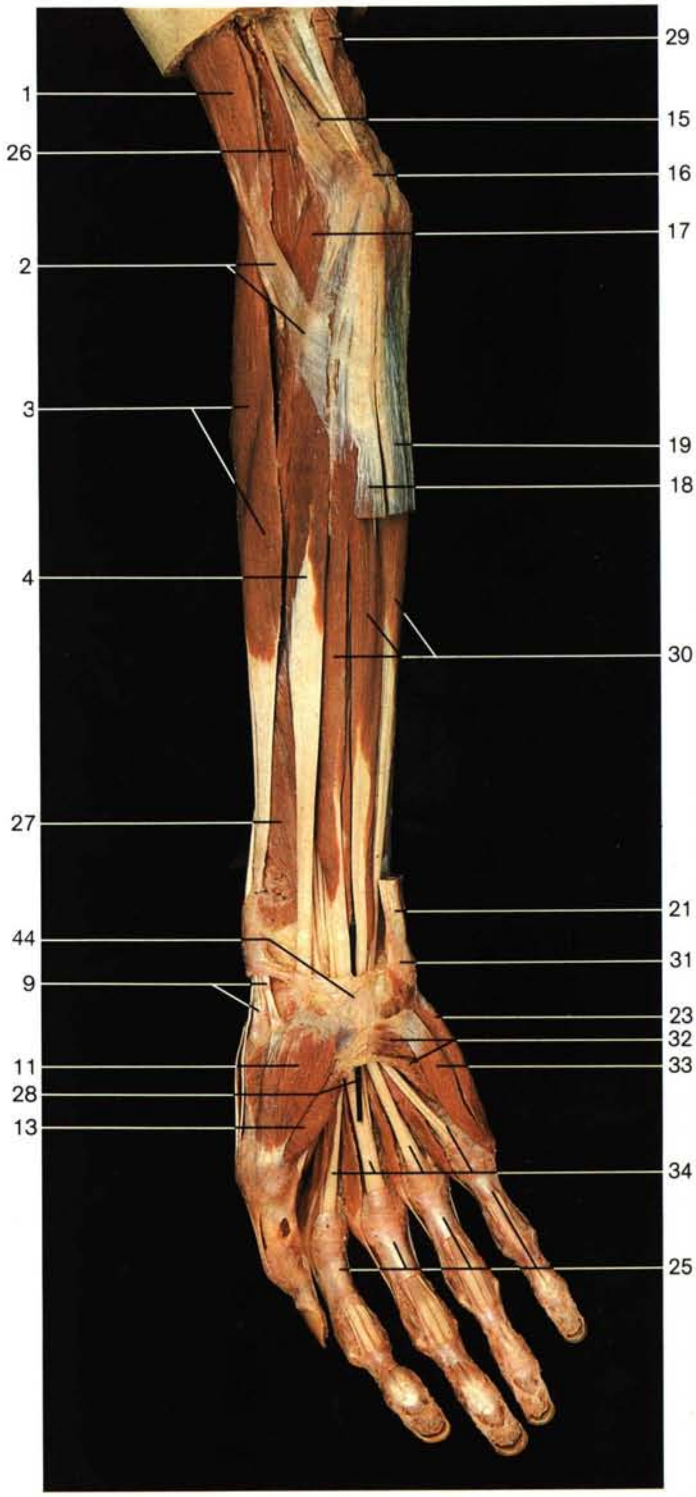
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Forearm muscles, superficial layer (ventral aspect). The palmaris longus and flexor carpi ulnaris muscles have been removed.

1 Biceps brachii muscle
2 Bicipital aponeurosis
3 **Brachioradialis muscle**
4 **Flexor carpi radialis muscle**
5 Radial artery
6 **Flexor digitorum superficialis muscle**
7 Median nerve
8 Antebrachial fascia and tendon of palmaris longus muscle
9 Tendon of abductor pollicis longus muscle
10 Tendon of extensor pollicis brevis muscle
11 Abductor pollicis brevis muscle
12 **Palmar aponeurosis**
13 Superficial head of flexor pollicis brevis muscle
14 Tendon of flexor pollicis longus muscle
15 Medial intermuscular septum
16 Medial epicondyle of humerus
17 Humeral head of pronator teres muscle
18 **Palmaris longus muscle**
19 **Flexor carpi ulnaris muscle**
20 **Ulnar artery**
21 Tendon of flexor carpi ulnaris muscle
22 Palmaris brevis muscle

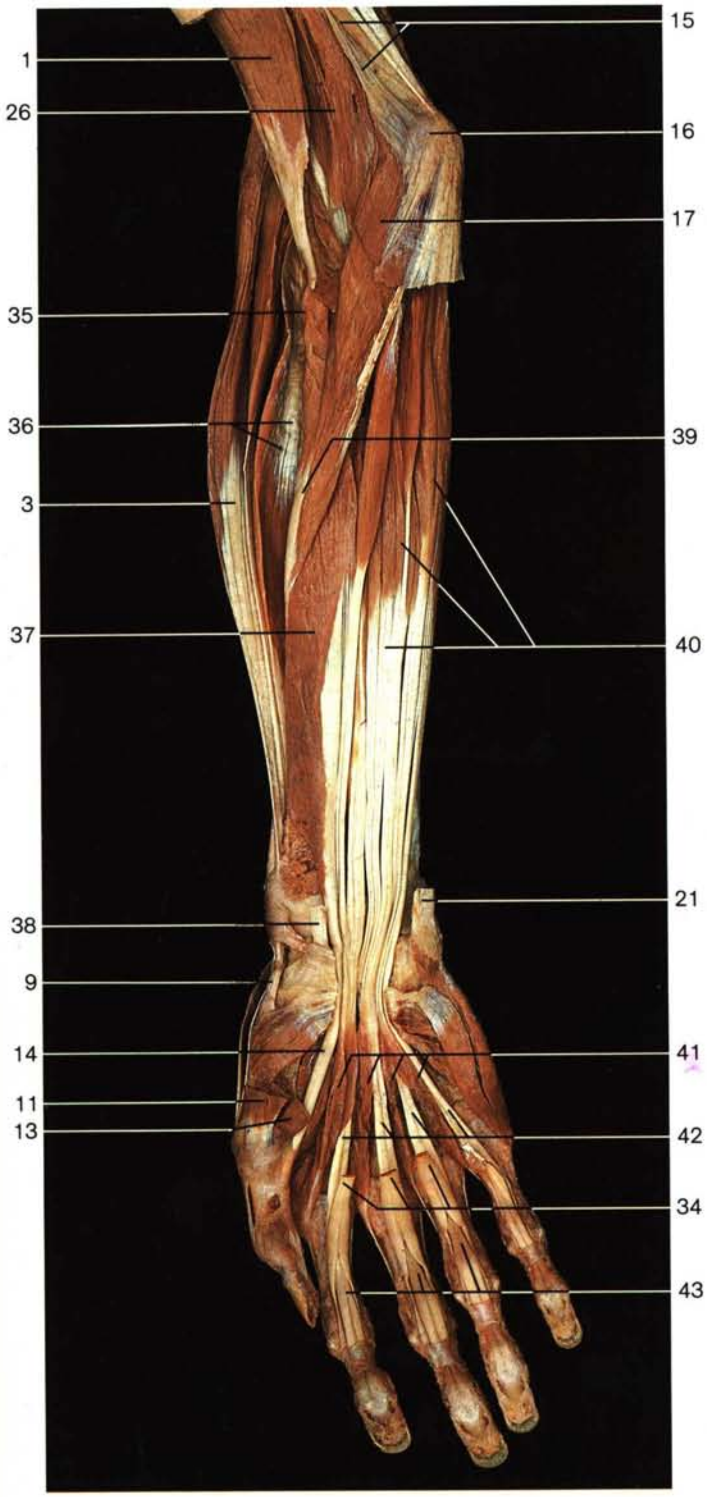

Forearm muscles, middle layer (ventral aspect). The palmaris longus, flexor carpi radialis and ulnaris muscles have been partly removed. The flexor retinaculum has been divided.

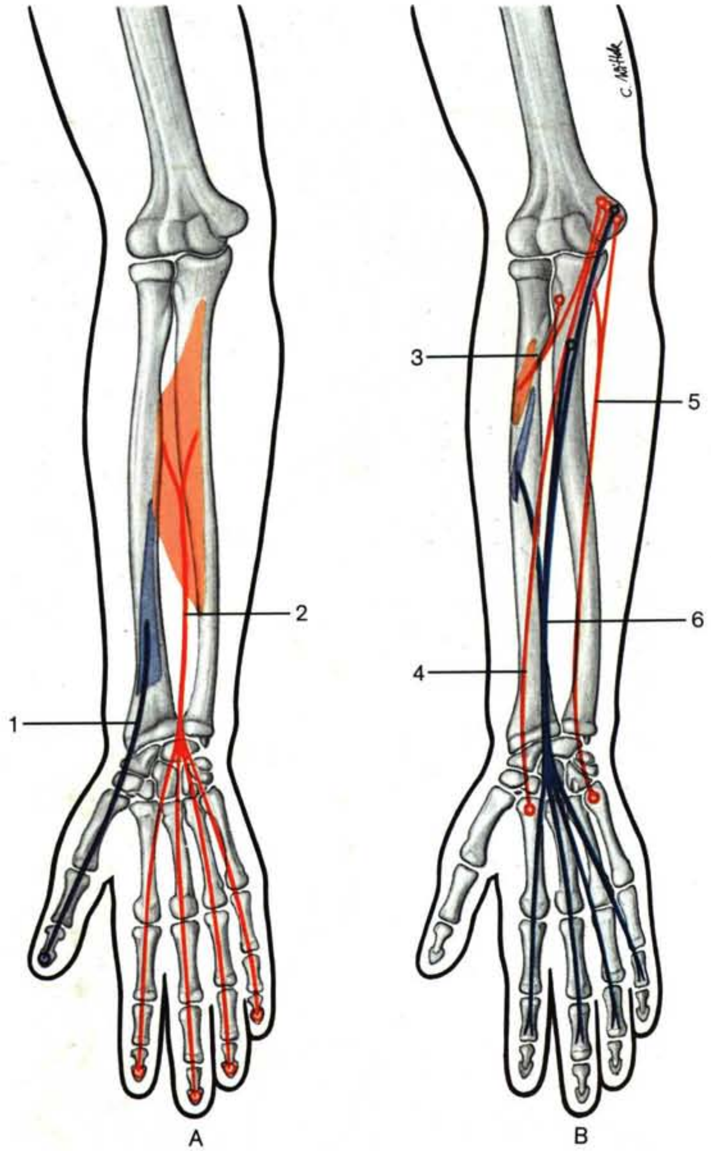

Position of flexors of fingers and hand. (Schematic drawing.)

A Deep layer
B Superficial layer
△
1 Flexor pollicis longus muscle (blue)
2 Flexor digitorum profundus muscle (red)
3 Pronator teres muscle (red)
4 Flexor carpi radialis muscle (red)
5 Flexor carpi ulnaris muscle (red)
6 Flexor digitorum superficialis muscle (blue)

23 Abductor digiti minimi muscle
24 Transverse fasciculi of palmar aponeurosis
25 Digital fibrous sheaths of tendons of flexor digitorum muscle
26 Brachialis muscle
27 Flexor pollicis longus muscle
28 Carpal tunnel (canalis carpi, probe)
29 Triceps brachii muscle
30 Flexor digitorum superficialis muscle
31 Pisiform bone
32 Opponens digiti minimi muscle
33 Flexor digiti minimi brevis muscle
34 Tendons of flexor digitorum superficialis muscle
35 Supinator muscle
36 Extensor carpi radialis brevis muscle
37 **Flexor pollicis longus muscle**
38 Tendon of flexor carpi radialis muscle
39 **Pronator teres muscle** (insertion of radius)
40 **Flexor digitorum profundus muscle**
41 **Lumbrical muscles**
42 Tendons of flexor digitorum profundus muscle
43 Tendons of flexor digitorum profundus muscle having passed through the divided tendons of the flexor digitorum superficialis muscle
44 Flexor retinaculum

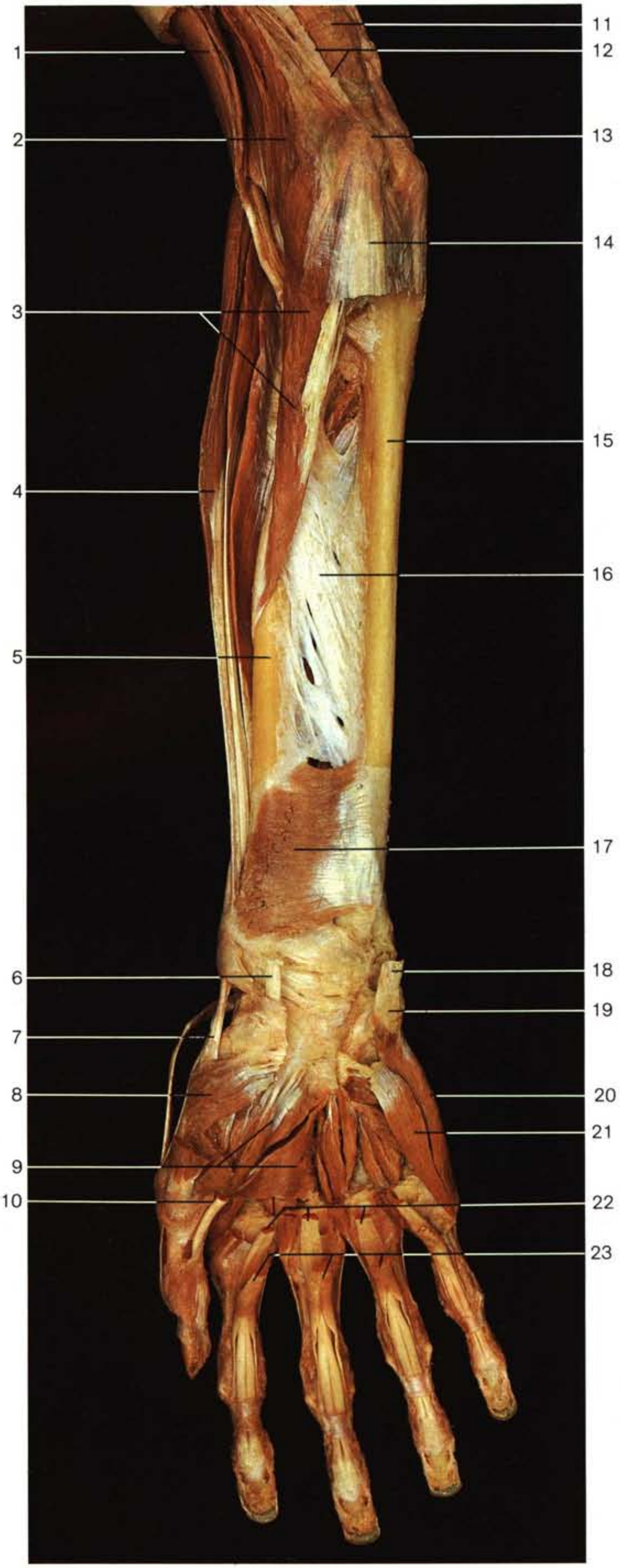

Muscles of the forearm, deep layer (ventral aspect). All flexors have been removed to display the pronator quadratus and pronator teres muscles together with the interosseous membrane. Forearm in supination.

1 Biceps brachii muscle
2 Brachialis muscle
3 **Pronator teres muscle**
4 Brachioradialis muscle
5 **Radius**
6 Tendon of flexor carpi radialis muscle
7 Tendon of abductor pollicis longus muscle
8 Opponens pollicis muscle
9 Adductor pollicis muscle
10 Tendon of flexor pollicis longus muscle
11 Triceps brachii muscle
12 Medial intermuscular septum
13 Medial epicondyle of humerus
14 Common flexor mass (divided)
15 **Ulna**
16 **Interosseous membrane**
17 **Pronator quadratus muscle**
18 Tendon of flexor carpi ulnaris muscle
19 Pisiform bone
20 Abductor digiti minimi muscle
21 Flexor digiti minimi brevis muscle
22 Tendons of flexor digitorum profundus muscle
23 Tendons of flexor digitorum superficialis muscle
24 Flexor retinaculum
25 Hypothenar muscles
26 Thenar muscles
27 Common synovial sheath of flexor tendons
28 Synovial sheath of tendon of flexor pollicis longus muscle
29 Digital synovial sheaths of flexor tendons

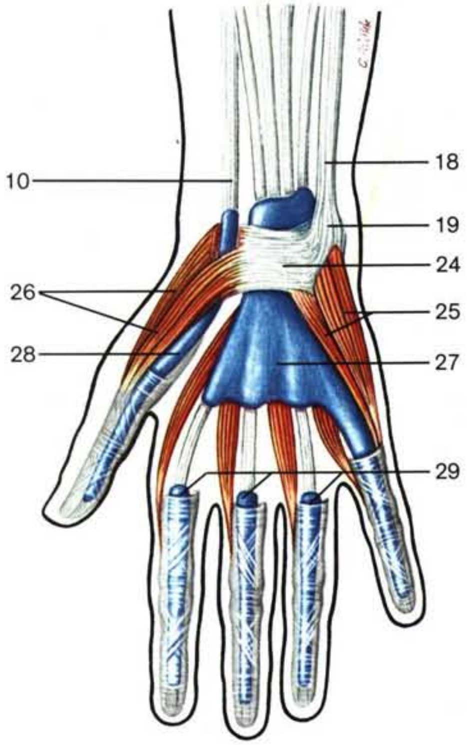

Synovial sheaths of flexor tendons (palmar aspect of right hand). (Semischematic drawing.)

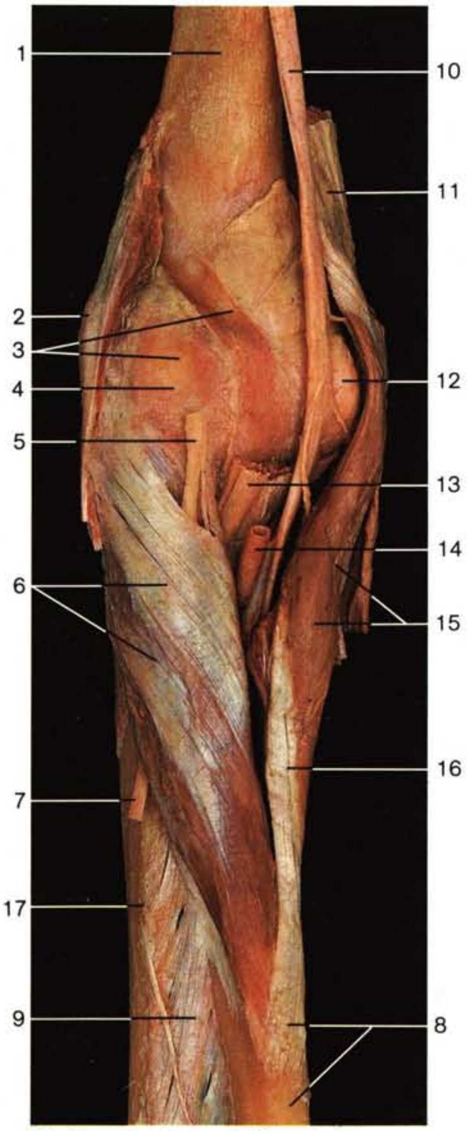

Right supinator and elbow joint (anterior aspect). Forearm in pronation.

1 Humerus
2 Lateral epicondyle of humerus
3 Articular capsule
4 Position of capitulum of humerus
5 Deep branch of radial nerve
6 **Supinator muscle**
7 Entrance of deep branch of radial nerve to extensor muscles
8 Radius and insertion of pronator teres muscle
9 Interosseous membrane
10 Median nerve
11 Triceps brachii muscle
12 Trochlea of humerus
13 Tendon of biceps brachii muscle
14 Brachial artery
15 **Pronator teres muscle**
16 Tendon of pronator teres muscle
17 Ulna
18 **Pronator quadratus muscle**
19 Tendon of flexor carpi radialis muscle
20 Thenar muscles
21 Synovial sheath of tendon of flexor pollicis longus muscle
22 Fibrous sheath of flexor tendons
23 **Digital synovial sheath of flexor tendons**
24 Flexor digitorum superficialis muscle
25 Tendon of flexor carpi ulnaris muscle
26 **Common synovial sheath of flexor tendons**
27 Position of pisiform bone
28 Flexor retinaculum
29 Hypothenar muscles

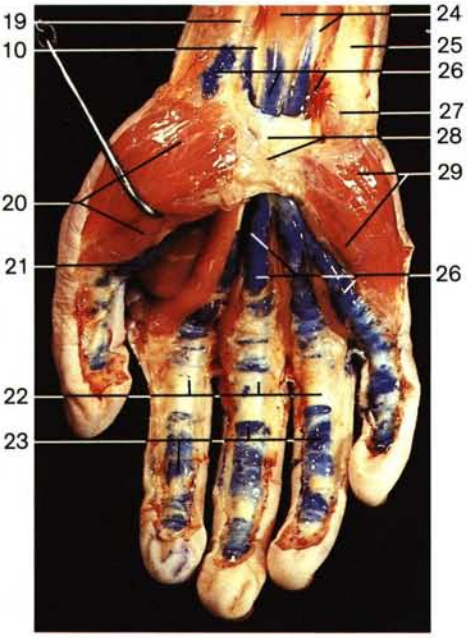

Synovial sheaths of flexor muscles (palmar aspect of right hand). Blue PVA-solution has been injected into the sheaths.

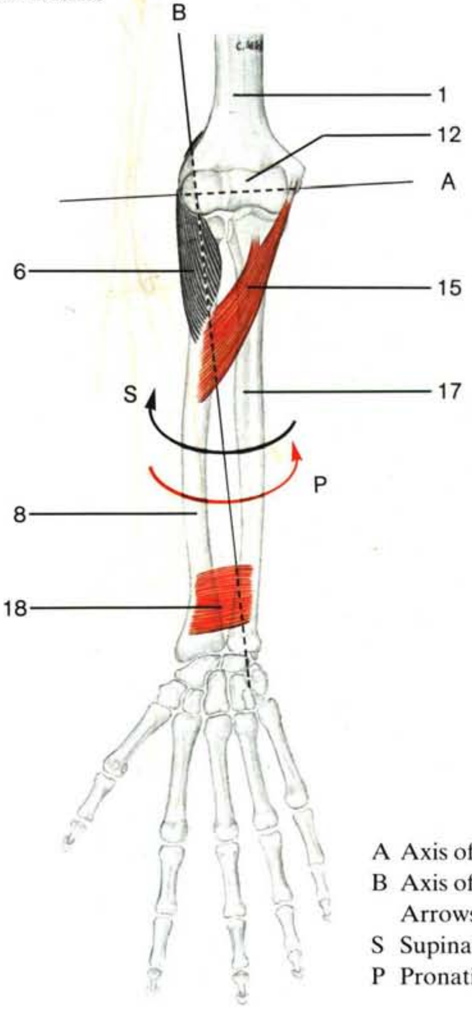

A Axis of flexion and extension
B Axis of rotation
Arrows:
S Supination
P Pronation

Diagram illustrating the two **axes of the elbow joint.**

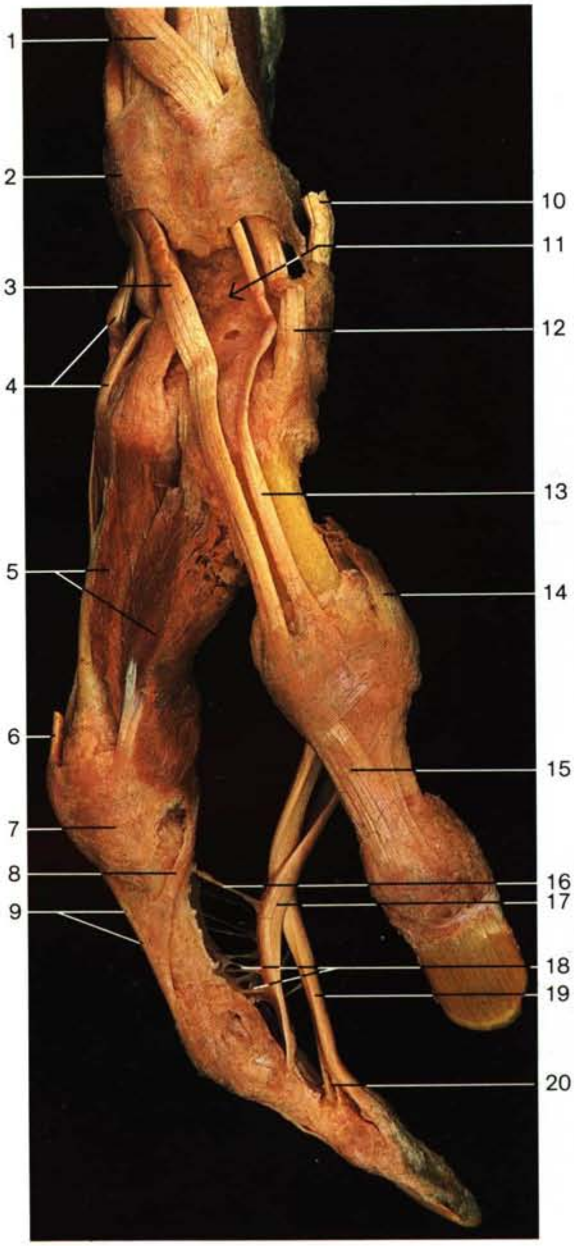

Muscles of thumb and index finger (medial aspect). The tendons of the extensor muscles of the thumb and the insertion of the flexor tendons of the index finger are displayed.

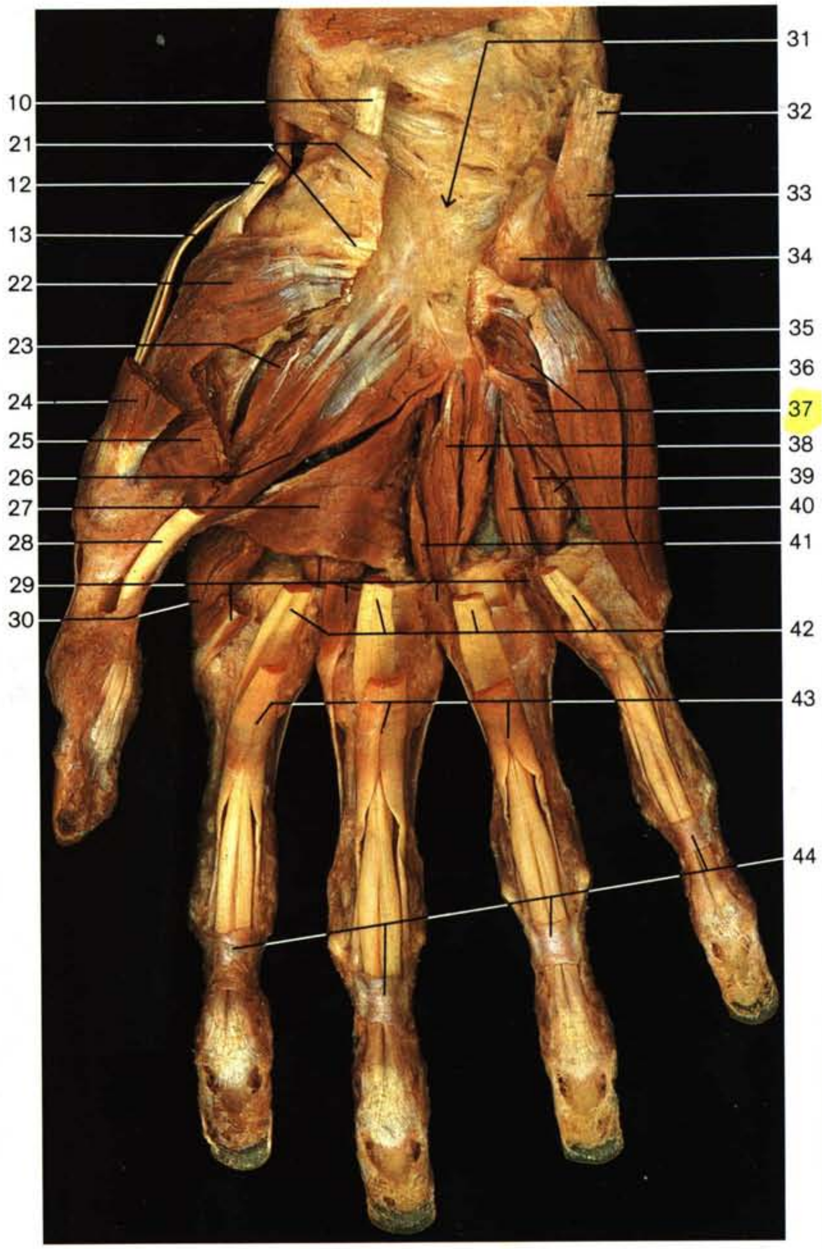

Muscles of hand (palmar aspect). The tendons of the flexor muscles and parts of the thumb muscles have been removed. The carpal tunnel has been opened.

1 Tendons of extensor pollicis brevis and abductor pollicis longus muscle
2 Extensor retinaculum
3 Tendon of extensor pollicis longus muscle
4 Tendons of extensor carpi radialis longus and brevis muscles
5 First dorsal interosseous muscle
6 Tendon of extensor digitorum muscle for index finger
7 Location of metacarpophalangeal joint
8 Tendon of lumbrical muscle
9 Extensor expansion of index finger
10 Tendon of flexor carpi radialis muscle (cut)
11 **Anatomical snuffbox**
12 Tendon of abductor pollicis longus muscle
13 Tendon of extensor pollicis brevis muscle
14 Tendon of abductor pollicis brevis muscle
15 Extensor expansion of extensor of thumb
16 Vinculum longum
17 Tendons of flexor digitorum superficialis muscle dividing to allow passage of deep tendons
18 Vincula of flexor tendons
19 Tendon of flexor digitorum profundus muscle
20 Vinculum breve
21 Radial carpal eminence (cut edge of flexor retinaculum)
22 Opponens pollicis muscle
23 Deep head of flexor pollicis brevis muscle
24 Abductor pollicis brevis muscle (cut)
25 Superficial head of flexor pollicis brevis muscle (cut)
26 Oblique head of adductor pollicis muscle
27 Transverse head of adductor pollicis muscle
28 Tendon of flexor pollicis longus muscle (cut)
29 Lumbrical muscles (cut)
30 First dorsal interosseous muscle
31 **Position of carpal tunnel**
32 Tendon of flexor carpi ulnaris muscle
33 Location of pisiform bone
34 Hook of hamate bone
35 Abductor digiti minimi muscle
36 Flexor digiti minimi brevis muscle
37 Opponens digiti minimi muscle
38 2nd palmar interosseous muscle
39 3rd palmar interosseous muscle
40 4th dorsal interosseous muscle
41 3rd dorsal interosseous muscle
42 Tendon of flexor digitorum profundus muscle (cut)
43 Tendons of flexor digitorum superficialis muscle (cut)
44 Fibrous flexor sheaths

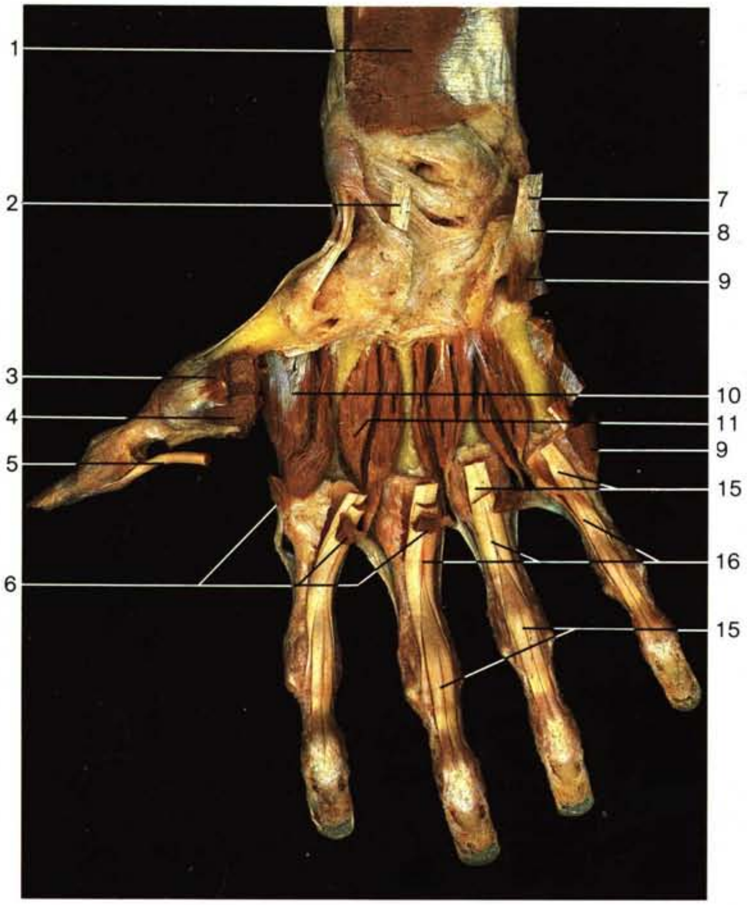

Muscles of right hand, deep layer (palmar aspect). The thenar and hypothenar muscles have been removed to display the interosseous muscles.

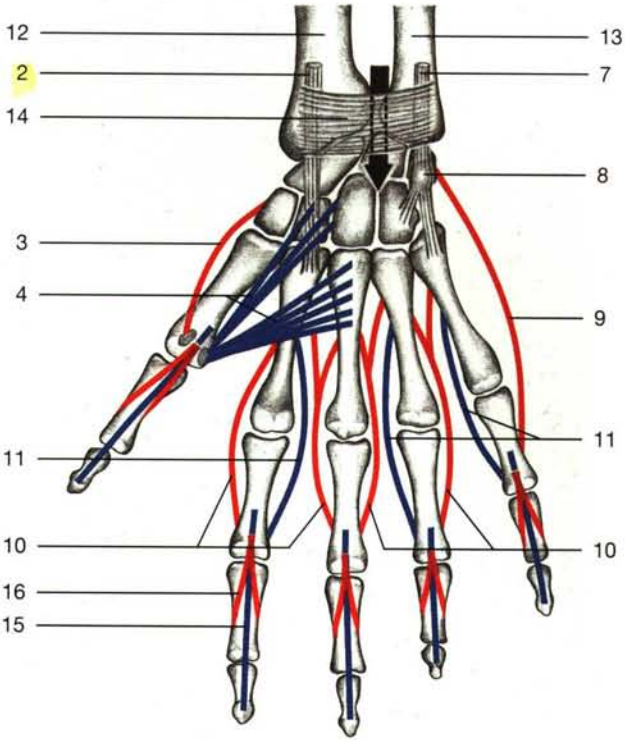

Actions of interosseous muscles in abduction and adduction of fingers (palmar aspect, schematic drawing). Arrow: carpal tunnel.
Red = **abduction**
(dorsal interosseous muscles, abductor digiti minimi and abductor pollicis brevis muscles).
Black = **adduction**
(palmar interosseous muscles, adductor pollicis muscle).

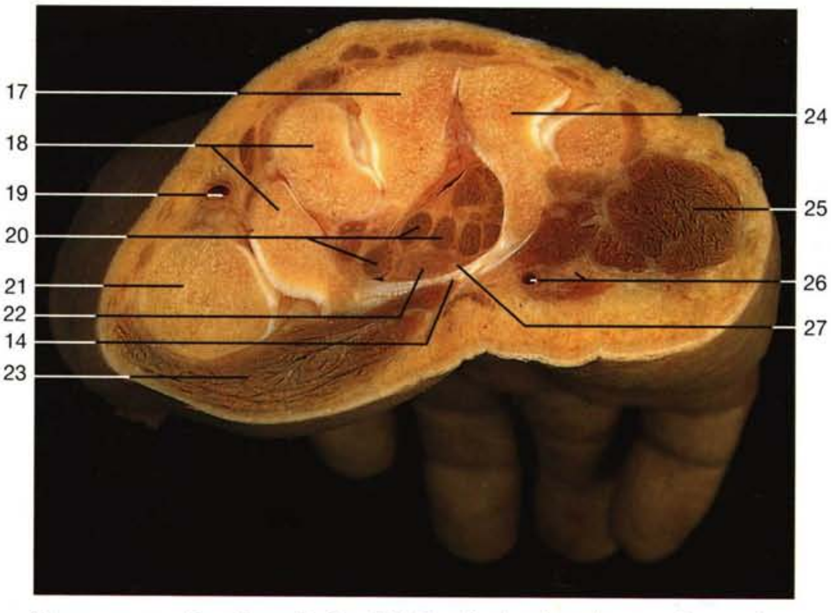

Transverse section through the right hand, showing the carpal tunnel (canalis carpi).

1	Pronator quadratus muscle
2	Tendon of flexor carpi radialis muscle
3	Abductor pollicis brevis muscle (divided)
4	Adductor pollicis muscle (divided)
5	Tendon of flexor pollicis longus muscle
6	Lumbrical muscles (cut)
7	Tendon of flexor carpi ulnaris muscle
8	Pisiform bone
9	Abductor digiti minimi muscle (divided)
10	**Dorsal interosseous muscles**
11	**Palmar interosseous muscles**
12	Radius
13	Ulna
14	**Flexor retinaculum**
15	Tendons of flexor digitorum profundus muscle
16	Tendons of flexor digitorum superficialis muscle
17	Capitate bone
18	Trapezium bone and trapezoid bone
19	Radial artery
20	Tendon of flexor muscles
21	First metacarpal bone
22	**Median nerve**
23	Thenar muscles
24	Hamate bone
25	Hypothenar muscles
26	Ulnar artery and nerve
27	**Carpal tunnel** (canalis carpi)

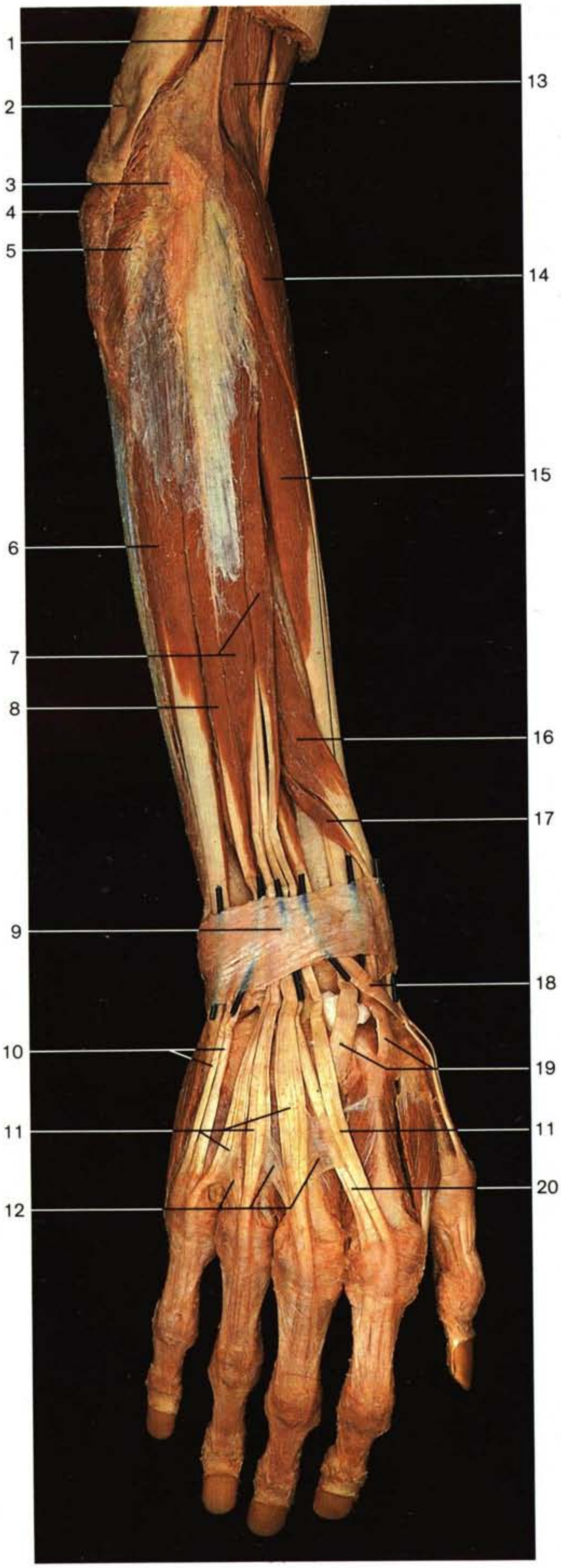

Extensor muscles of forearm and hand, superficial layer (dorsal aspect). Tunnels for extensor tendons indicated by probes.

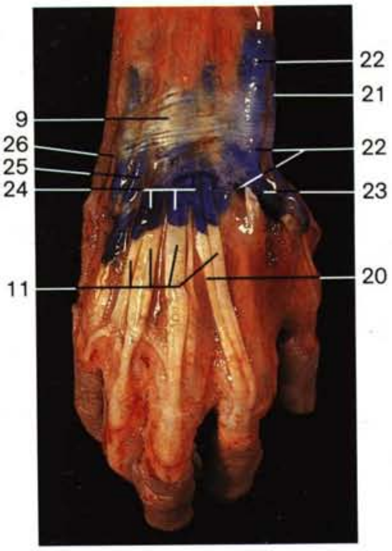

Synovial sheaths of extensor tendons. The sheaths have been injected with blue gelatin.

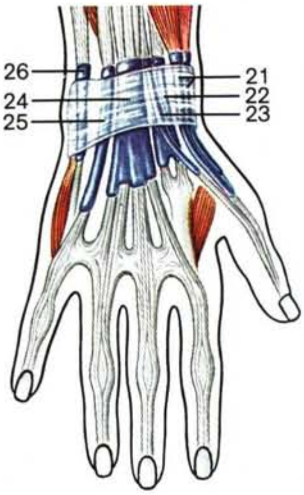

Synovial sheaths of extensor tendons on the back of right wrist (indicated in blue). Notice the six tunnels for the passage of the extensor tendons beneath the extensor retinaculum. (Semischematic drawing.)

1 Lateral intermuscular septum
2 Tendon of triceps brachii muscle
3 Lateral epicondyle of humerus
4 Olecranon
5 Anconeus
6 Extensor carpi ulnaris muscle
7 Extensor digitorum muscle
8 Extensor digiti minimi muscle
9 Extensor retinaculum
10 Tendons of extensor digiti minimi muscle
11 Tendons of extensor digitorum muscle
12 Intertendinous connections
13 Brachioradialis muscle
14 Extensor carpi radialis longus muscle
15 Extensor carpi radialis brevis muscle
16 Abductor pollicis longus muscle
17 Extensor pollicis brevis muscle
18 Tendon of extensor pollicis longus muscle
19 Tendons of both extensor carpi radialis longus and extensor carpi radialis brevis muscles
20 Tendon of extensor indicis muscle
21 1st tunnel: Abductor pollicis longus muscle
Extensor pollicis brevis muscle
22 2nd tunnel: Extensor carpi radialis longus and brevis muscles
23 3rd tunnel: Extensor pollicis longus muscle
24 4th tunnel: Extensor digitorum muscle
Extensor indicis muscle
25 5th tunnel: Extensor digiti minimi muscle
26 6th tunnel: Extensor carpi ulnaris muscle

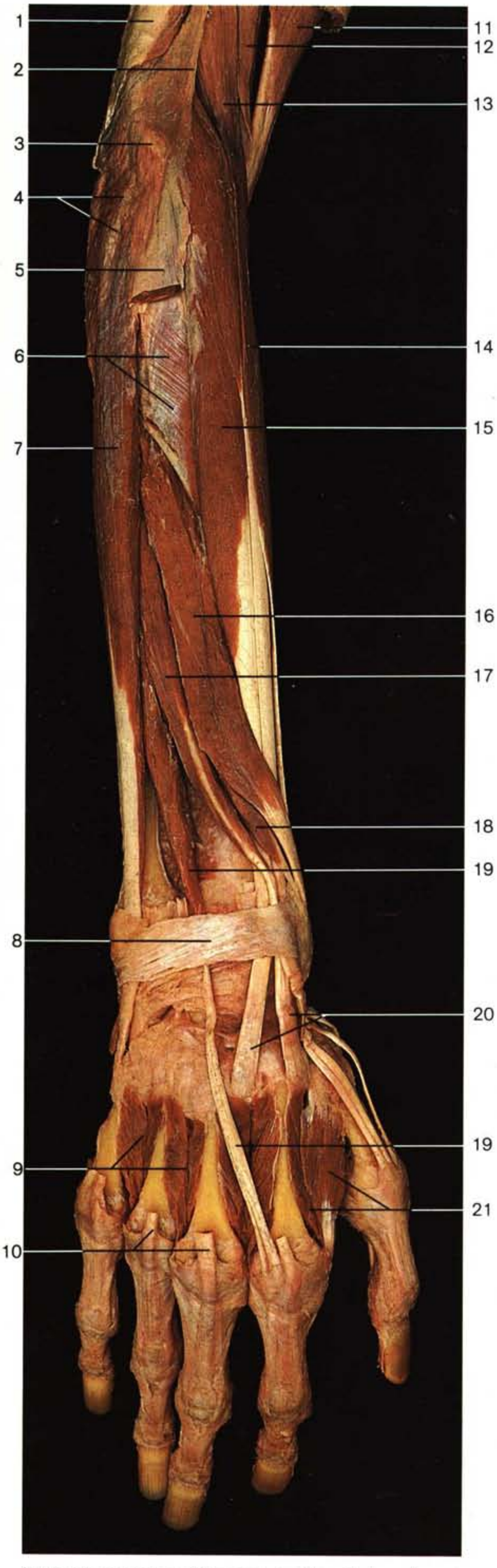

Extensor muscles of forearm and hand, deep layer (dorsal aspect).

1 Triceps brachii muscle
2 Lateral intermuscular septum
3 Lateral epicondyle of humerus
4 Anconeus muscle
5 Extensor digitorum and extensor digiti minimi muscles (cut)
6 Supinator muscle
7 Extensor carpi ulnaris muscle
8 Extensor retinaculum
9 3rd and 4th dorsal interosseous muscles
10 Tendons of extensor digitorum muscle (cut)
11 Biceps brachii muscle
12 Brachialis muscle
13 Brachioradialis muscle
14 Extensor carpi radialis longus muscle
15 Extensor carpi radialis brevis muscle
16 Abductor pollicis longus muscle
17 Extensor pollicis longus muscle
18 Extensor pollicis brevis muscle
19 Extensor indicis muscle
20 Tendons of the extensor carpi radialis longus and extensor carpi radialis brevis muscles
21 1st dorsal interosseous muscle

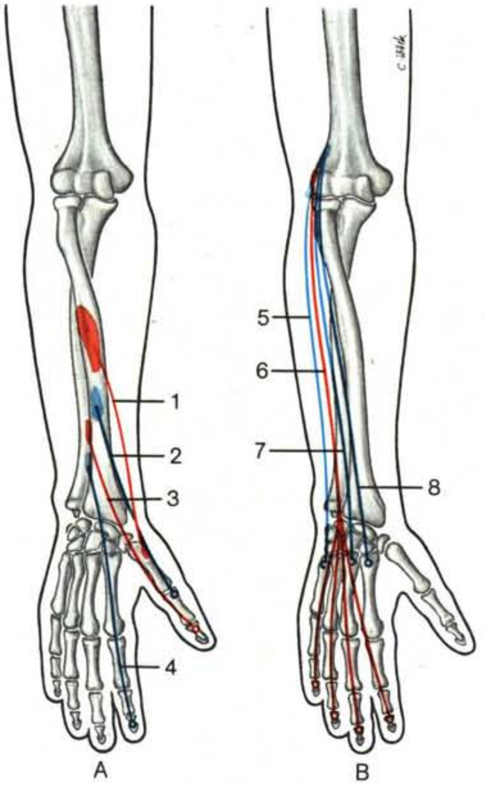

Position of extensor muscles of forearm and hand. (Semischematic drawing.)

A Extensors of thumb

1 Abductor pollicis longus muscle (red)
2 Extensor pollicis brevis muscle (blue)
3 Extensor pollicis longus muscle (red)
4 Extensor indicis muscle (blue)

B Extensors of fingers and hand

5 Extensor carpi ulnaris muscle (blue)
6 Extensor digitorum muscle (red)
7 Extensor carpi radialis brevis muscle (blue)
8 Extensor carpi radialis longus muscle (blue)

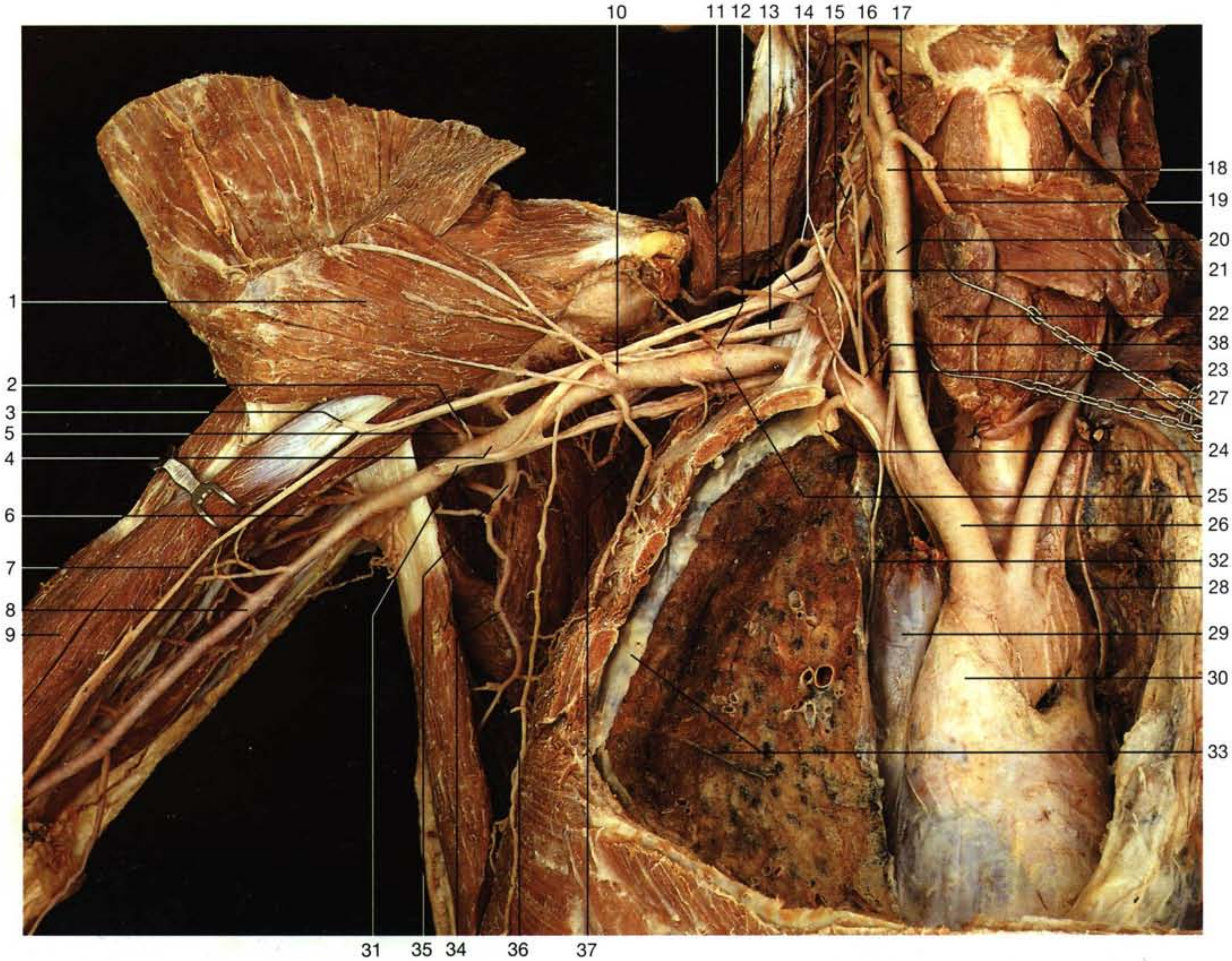

Main branches of right subclavian and axillary arteries (anterior aspect). Pectoralis muscles have been reflected, clavicle and anterior wall of thorax removed and right lung divided. Left lung with pleura and thyroid gland have been reflected laterally to display aortic arch and common carotid artery with their branches.

1 Pectoralis minor muscle (reflected)
2 Anterior circumflex humeral artery
3 Musculocutaneous nerve (divided)
4 **Axillary artery**
5 Posterior circumflex humeral artery
6 **Profunda brachii artery**
7 Median nerve (var.)
8 **Brachial artery**
9 Biceps brachii muscle
10 Thoracoacromial artery
11 Suprascapular artery
12 Descending scapular artery
13 Brachial plexus (middle trunk)
14 Transverse cervical artery
15 Scalenus anterior muscle and phrenic nerve
16 Right internal carotid artery
17 Right external carotid artery
18 Carotid sinus
19 Superior thyroid artery
20 Right common carotid artery
21 Ascending cervical artery
22 Thyroid gland
23 Inferior thyroid artery
24 Internal thoracic artery
25 Right subclavian artery
26 Brachiocephalic trunk
27 Left brachiocephalic vein (divided)
28 Left vagus nerve
29 Superior vena cava (divided)
30 **Ascending aorta**
31 Median nerve (divided)
32 Phrenic nerve
33 Right lung (divided) and pulmonary pleura
34 Thoracodorsal artery
35 Subscapular artery
36 Lateral mammary branches (variant)
37 Lateral thoracic artery
38 **Thyrocervical trunk**
39 Superior thoracic artery
40 Superior ulnar collateral artery
41 Inferior ulnar collateral artery
42 Middle collateral artery
43 Radial collateral artery
44 Radial recurrent artery
45 **Radial artery**
46 Anterior and posterior interosseous arteries
47 Princeps pollicis artery
48 **Deep palmar arch**
49 Common palmar digital arteries
50 Ulnar recurrent artery
51 Recurrent interosseous artery
52 Common interosseous artery
53 **Ulnar artery**
54 **Superficial palmar arch**
55 Median nerve and brachial artery
56 Biceps brachii muscle
57 Ulnar nerve
58 Flexor pollicis longus muscle
59 Palmar digital arteries
60 Anterior interosseous artery
61 Flexor carpi ulnaris muscle
62 Superficial palmar branch of radial artery

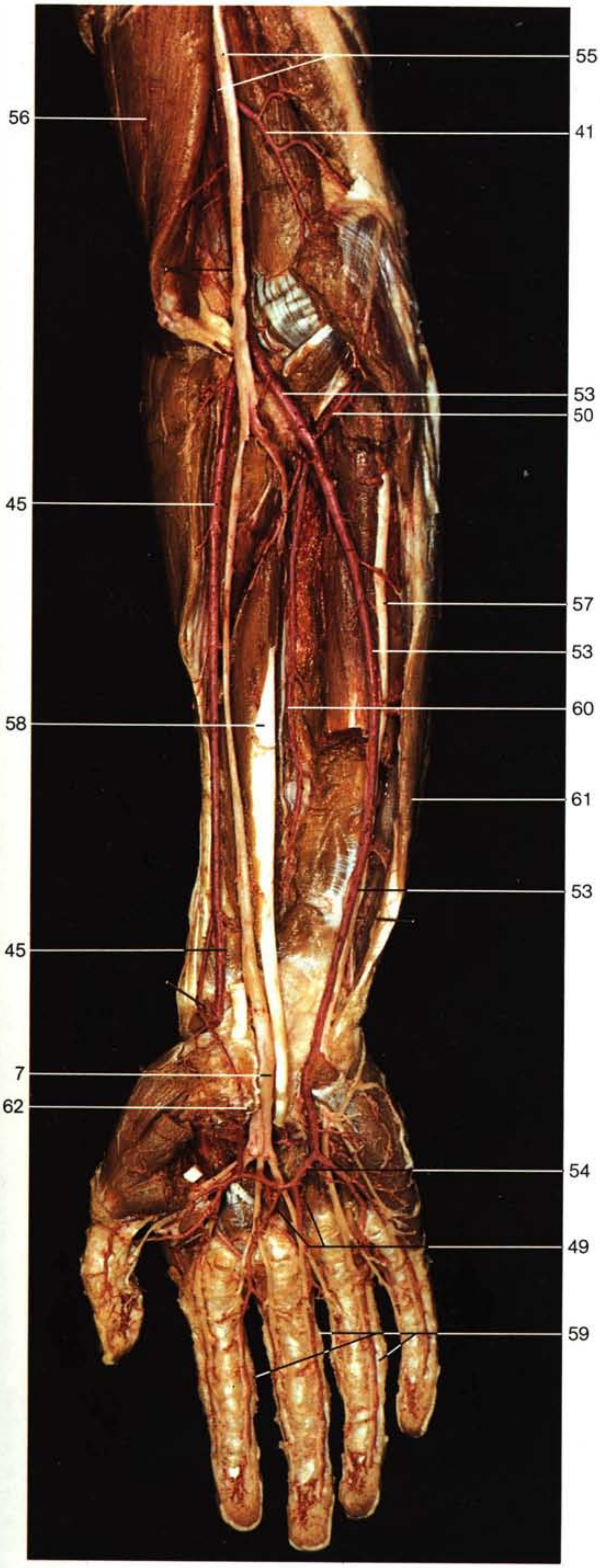
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Dissection of the arteries of forearm and hand. The superficial flexor muscles have been removed, the carpal tunnel opened and the flexor retinaculum cut. The arteries have been filled with colored resin.

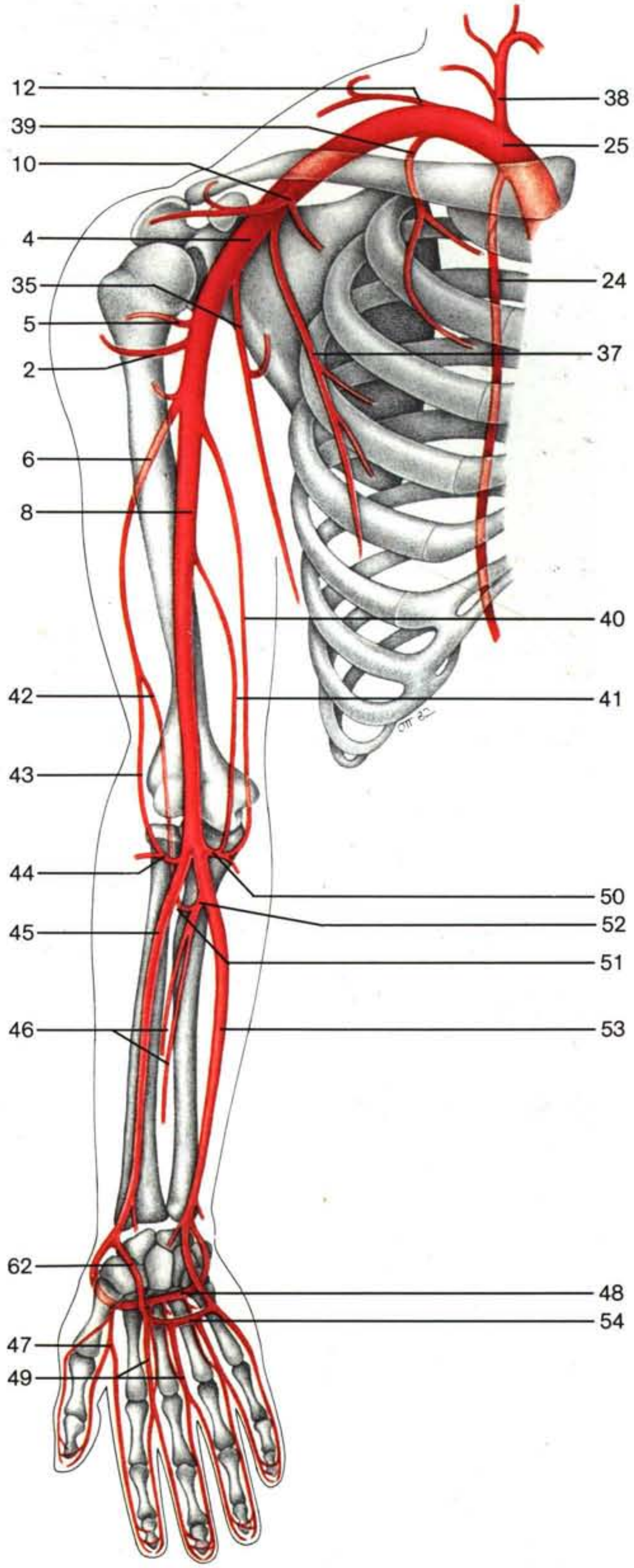
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Arteries of the upper limb. (Schematic drawing.)

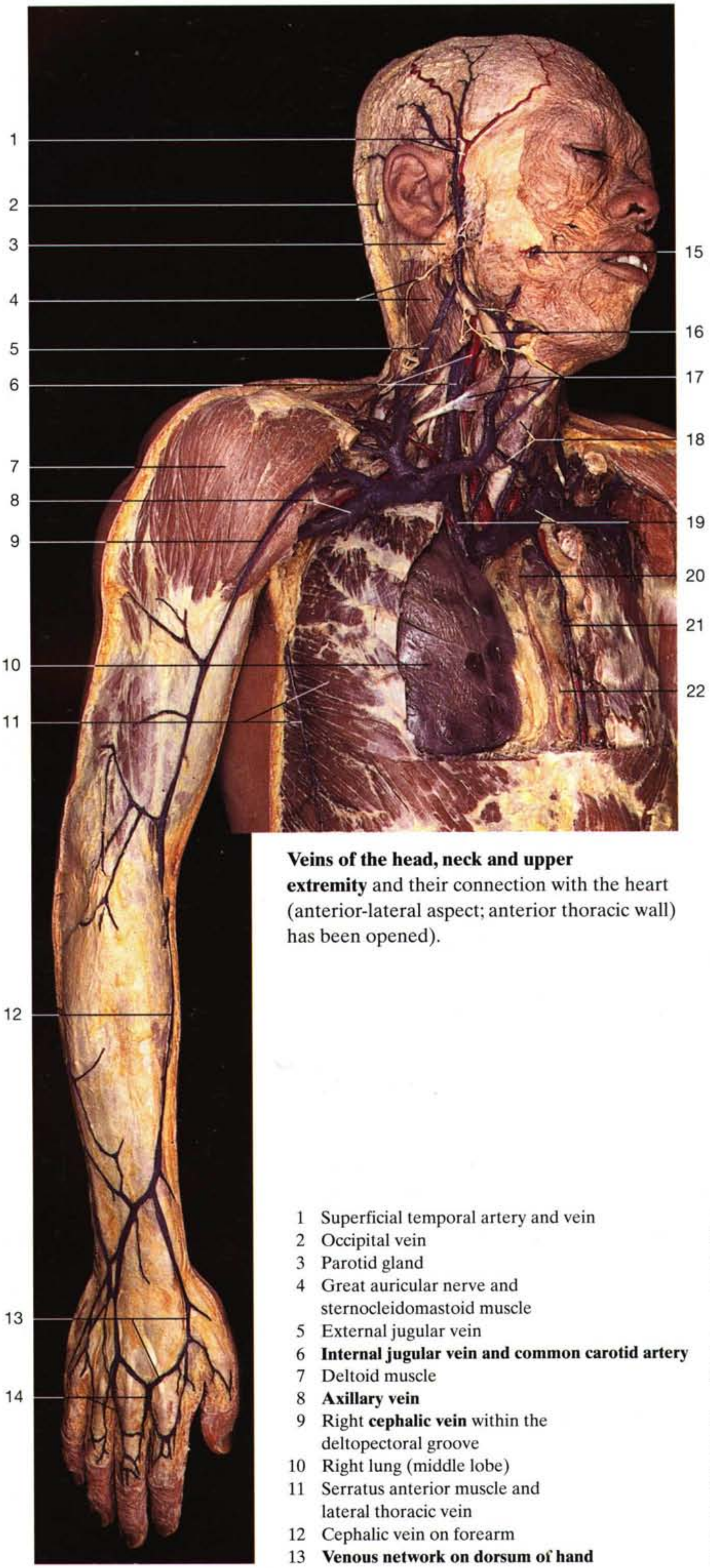

Veins of the head, neck and upper extremity and their connection with the heart (anterior-lateral aspect; anterior thoracic wall) has been opened).

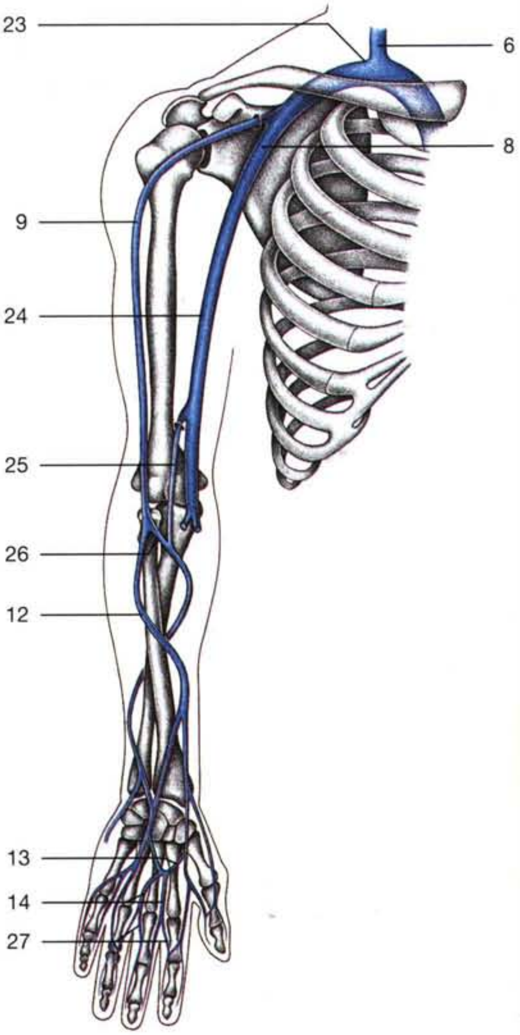

Superficial veins of upper limb. (Semischematic drawing.)

1 Superficial temporal artery and vein
2 Occipital vein
3 Parotid gland
4 Great auricular nerve and sternocleidomastoid muscle
5 External jugular vein
6 **Internal jugular vein and common carotid artery**
7 Deltoid muscle
8 **Axillary vein**
9 Right **cephalic vein** within the deltopectoral groove
10 Right lung (middle lobe)
11 Serratus anterior muscle and lateral thoracic vein
12 Cephalic vein on forearm
13 **Venous network on dorsum of hand**
14 Dorsal metacarpal veins
15 **Facial artery and vein**
16 Submandibular gland
17 Anterior jugular vein, hyoid bone and omohyoid muscle
18 Jugular venous arch and thyroid gland
19 Right and left brachiocephalic veins
20 Retrosternal body (remnant of thymus gland)
21 Internal thoracic artery and vein
22 Heart with pericardium
23 Right venous angle
24 **Brachial vein**
25 Basilic vein
26 Median cubital vein
27 Digital veins

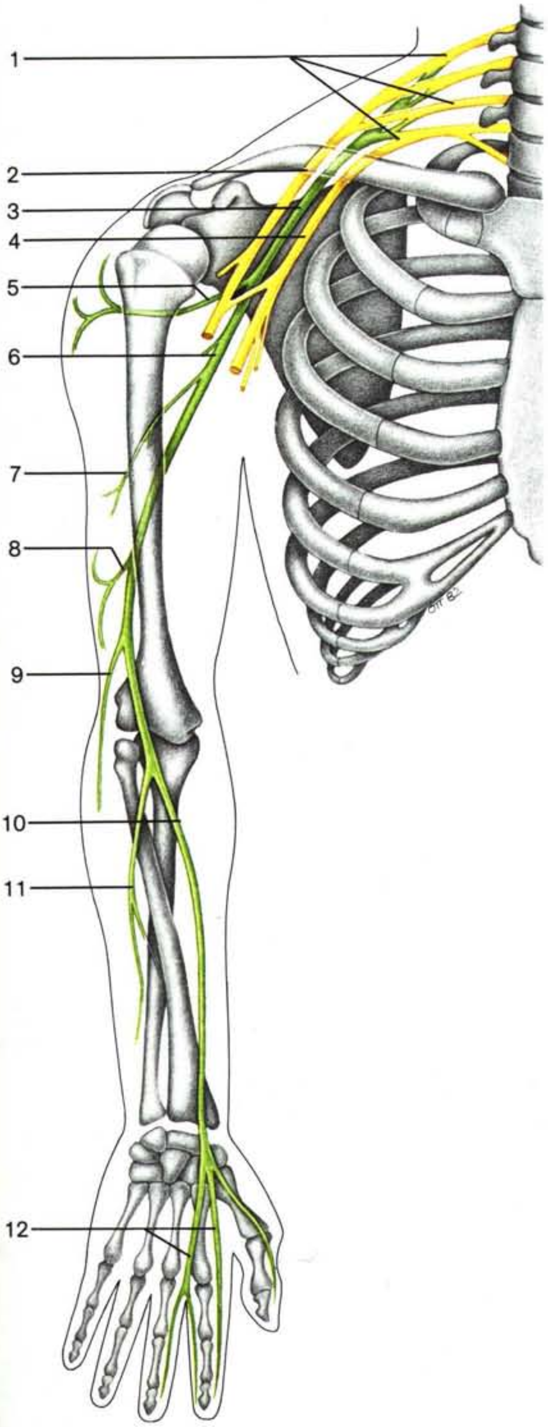

Main branches of radial nerve. (Schematic drawing.) Posterior divisions of trunks and posterior cord and its branches are indicated in green.

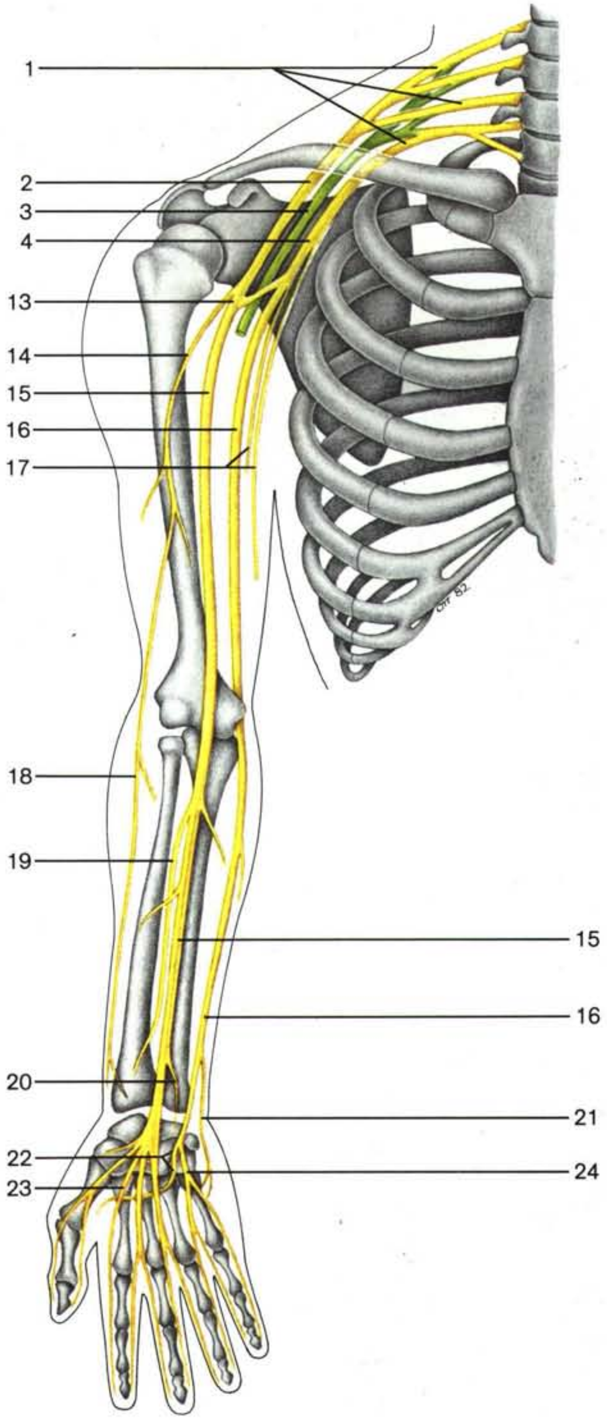

Main branches of musculocutaneous, median and ulnar nerves. (Schematic drawing.)
Anterior divisions of the trunks and all the components arising from them are indicated in yellow.

1 Brachial plexus
2 Lateral cord of brachial plexus
3 Posterior cord of brachial plexus
4 Medial cord of brachial plexus
5 **Axillary nerve**
6 **Radial nerve**
7 Posterior cutaneous nerve of arm
8 Lower lateral cutaneous nerve of arm
9 Posterior cutaneous nerve of forearm
10 Superficial branch of radial nerve
11 Deep branch of radial nerve
12 Dorsal digital nerves

13 Roots of median nerve
14 Musculocutaneous nerve
15 **Median nerve**
16 **Ulnar nerve**
17 Medial cutaneous nerves of arm and forearm
18 Lateral cutaneous nerve of forearm
19 Anterior interosseous nerve
20 Palmar branch of median nerve
21 Dorsal branch of ulnar nerve
22 Deep branch of ulnar nerve
23 Common palmar digital nerves of median nerve
24 Superficial branch of ulnar nerve

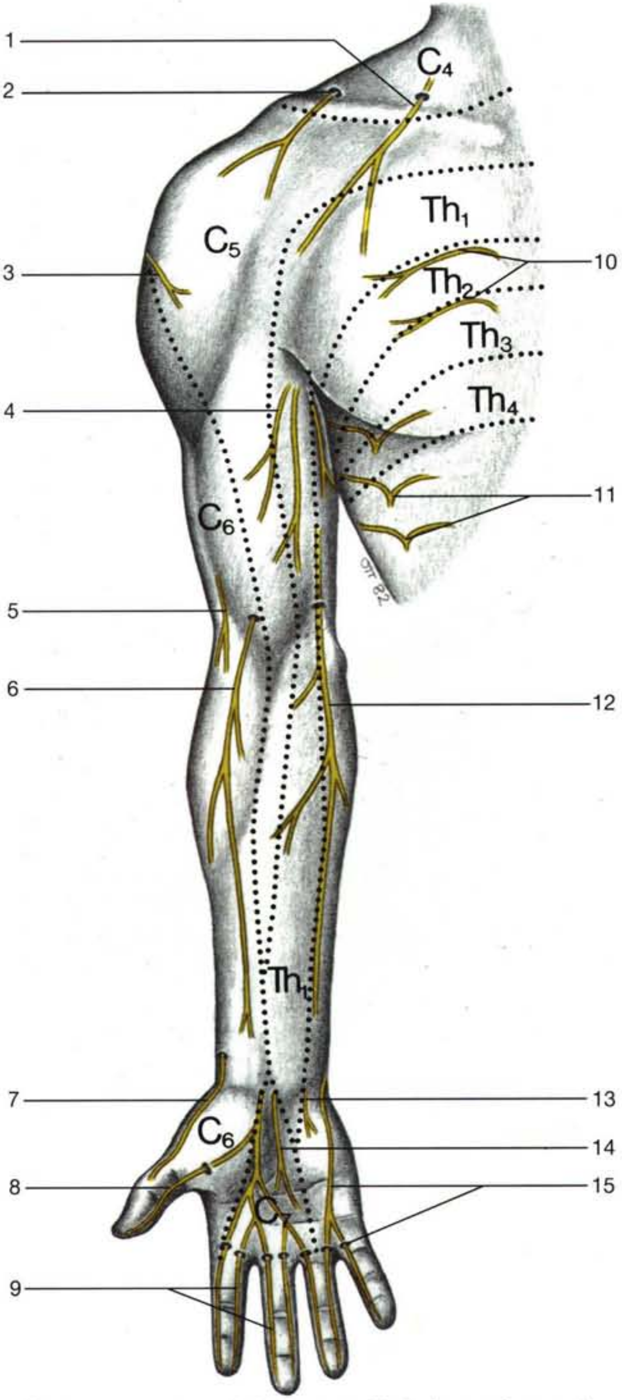

Cutaneous nerves of right upper limb (ventral aspect).
(Semischematic drawing.)

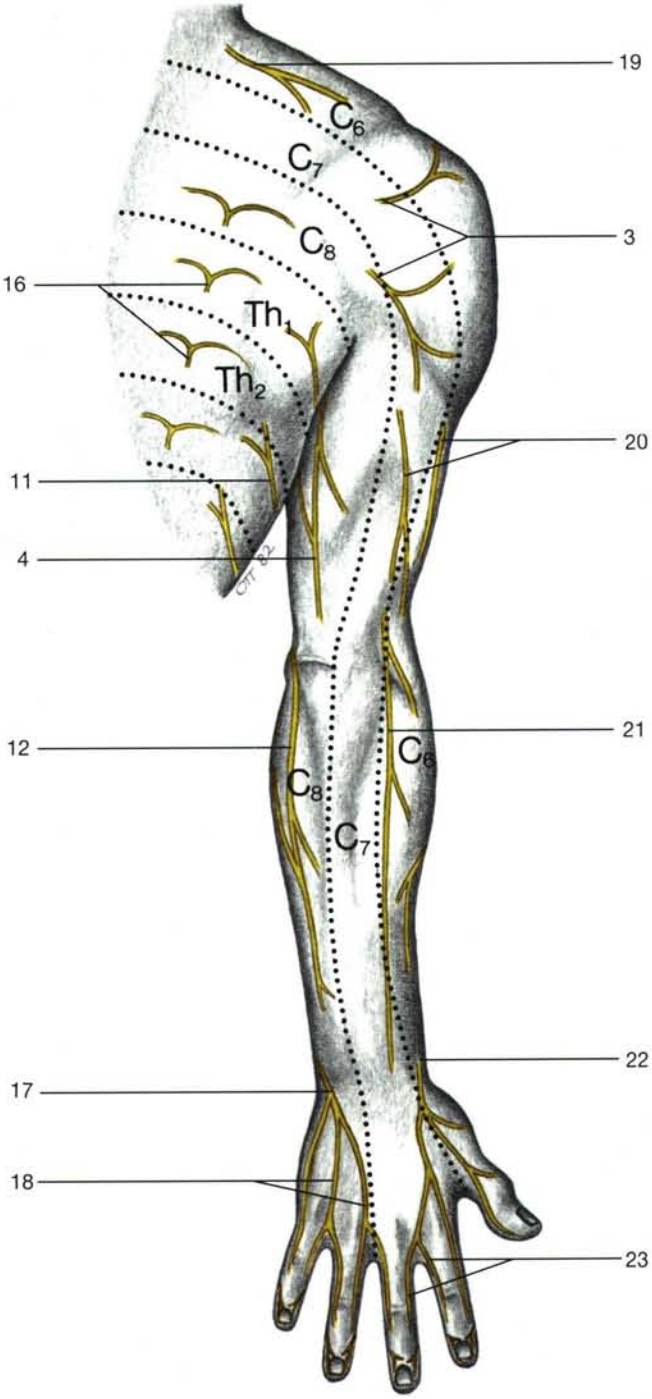

Cutaneous nerves of the upper limb (dorsal aspect).
(Semischematic drawing.)

1 Medial supraclavicular nerve
2 Intermediate supraclavicular nerve
3 Upper lateral cutaneous nerve of arm
4 Terminal branches of intercostobrachial nerves
5 Lower lateral cutaneous nerve of arm
6 Lateral cutaneous nerve of forearm
7 Terminal branch of superficial branch of radial nerve
8 Palmar digital nerve of thumb (branch of median nerve)
9 Palmar digital branches of median nerve
10 Anterior cutaneous branches of intercostal nerves
11 Lateral cutaneous branches of intercostal nerves
12 Medial cutaneous nerve of forearm

13 Palmar cutaneous branch of ulnar nerve
14 Palmar branch of median nerve
15 Palmar digital branches of ulnar nerve
16 Cutaneous branches of dorsal rami of spinal nerves
17 Dorsal branch of ulnar nerve
18 Dorsal digital nerves
19 Posterior supraclavicular nerve
20 Posterior cutaneous nerve of arm
21 Posterior cutaneous nerve of forearm
22 Superficial branch
23 Dorsal digital branches
} from radial nerve

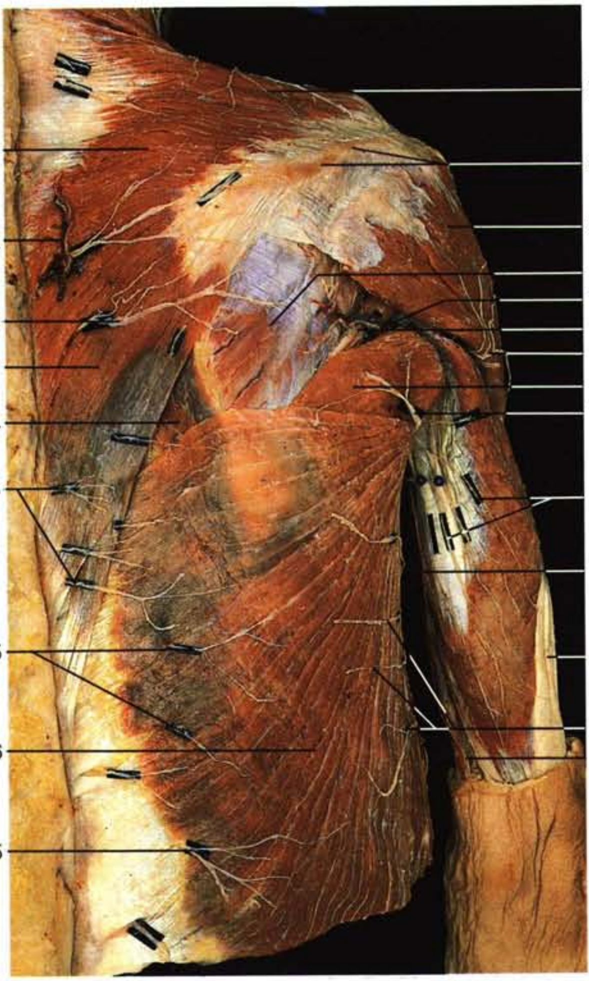

Dorsal region of shoulder, superficial layer. Note the segmental arrangement of the cutaneous nerves of the back.

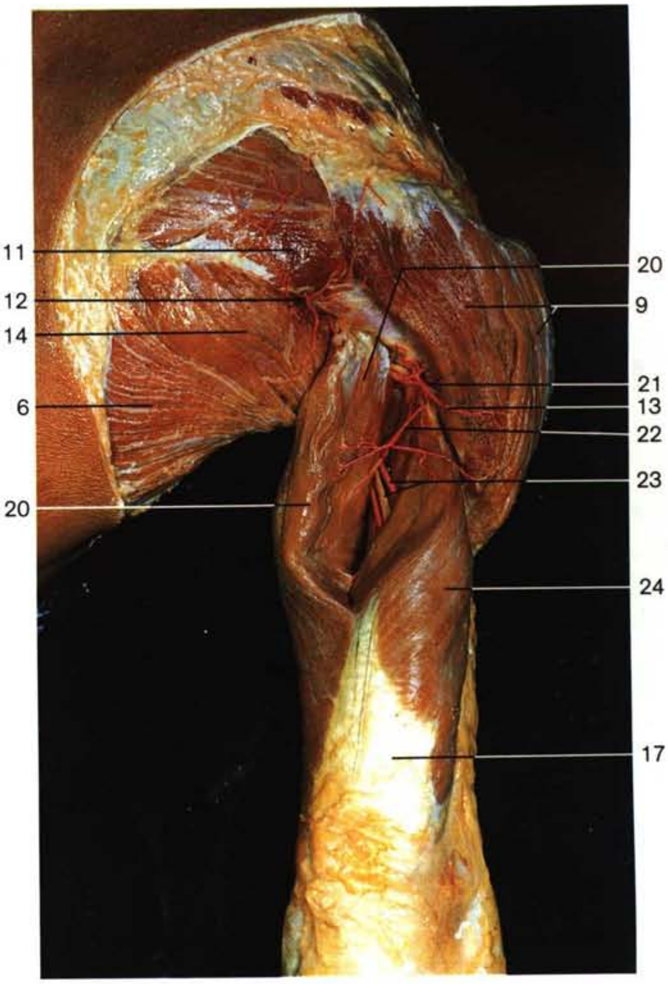

Shoulder and arm (dorsal aspect). Dissection of the quadrangular and triangular spaces of the axillary region.

1	Trapezius muscle
2	Dorsal branches of posterior intercostal artery and vein (medial cutaneous branches)
3	Medial branches of dorsal rami of spinal nerves
4	Rhomboid major muscle
5	Lateral branches of dorsal rami of spinal nerves
6	Latissimus dorsi muscle
7	Posterior supraclavicular nerves
8	Spine of scapula
9	Deltoid muscle
10	Infraspinatus muscle
11	Teres minor muscle
12	**Triangular space** with circumflex scapular artery and vein
13	Upper lateral cutaneous nerve of arm with artery
14	Teres major muscle
15	Terminal branches of intercostobrachial nerve
16	Medial cutaneous nerve of arm
17	Tendon of triceps brachii muscle
18	Lateral cutaneous branches of intercostal nerves
19	Medial cutaneous nerve of forearm
20	Long head of triceps brachii muscle
21	**Quadrangular space** with axillary nerve and posterior humeral circumflex artery
22	Anastomosis between profunda brachii artery and posterior humeral circumflex artery
23	Course of radial nerve and profunda brachii artery
24	Lateral head of triceps brachii muscle
25	Course of descending scapular artery and dorsal scapular nerve
26	Course of suprascapular nerve, artery and vein

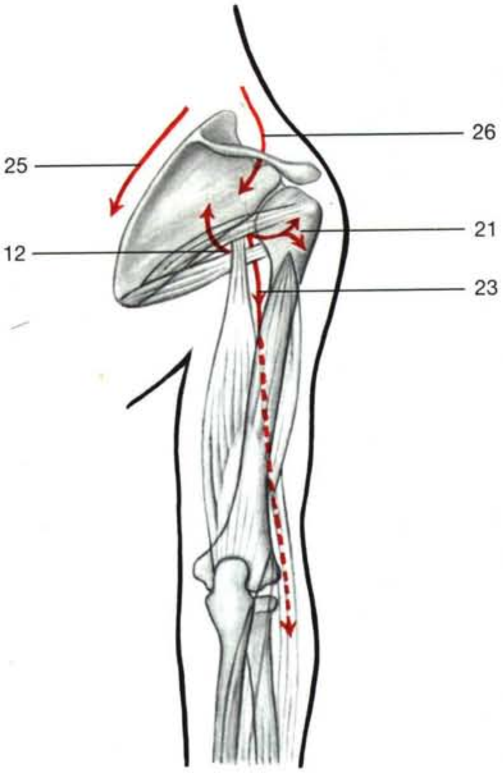

Course of vessels and nerves to shoulder and upper limb. (Schematic drawing.)

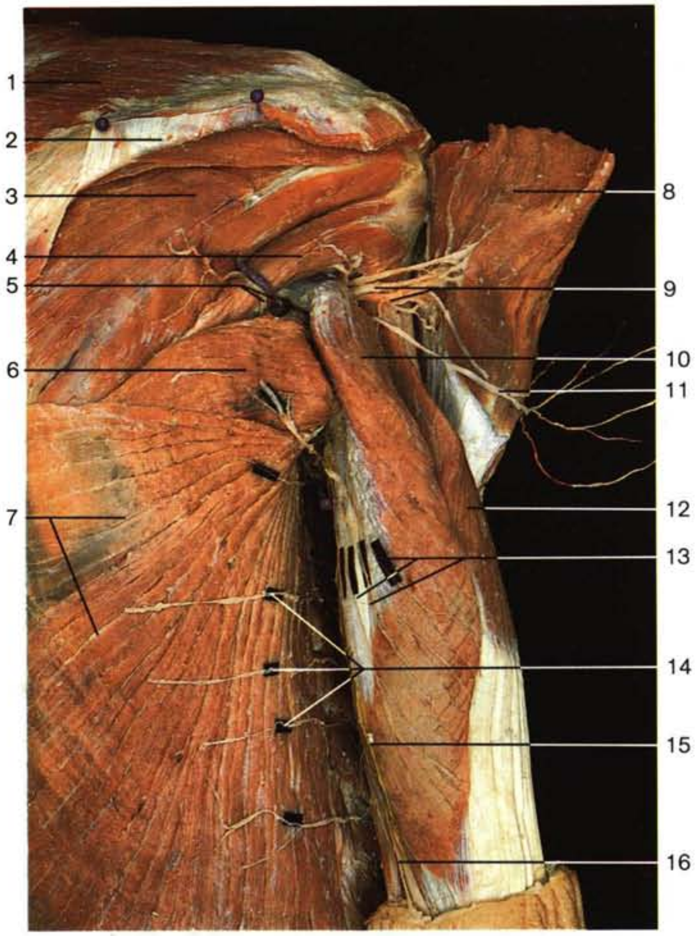

Scapular region, arm and shoulder, deep layer (dorsal aspect). Part of deltoid muscle has been cut and reflected to display the quadrangular and triangular spaces of the axillary region.

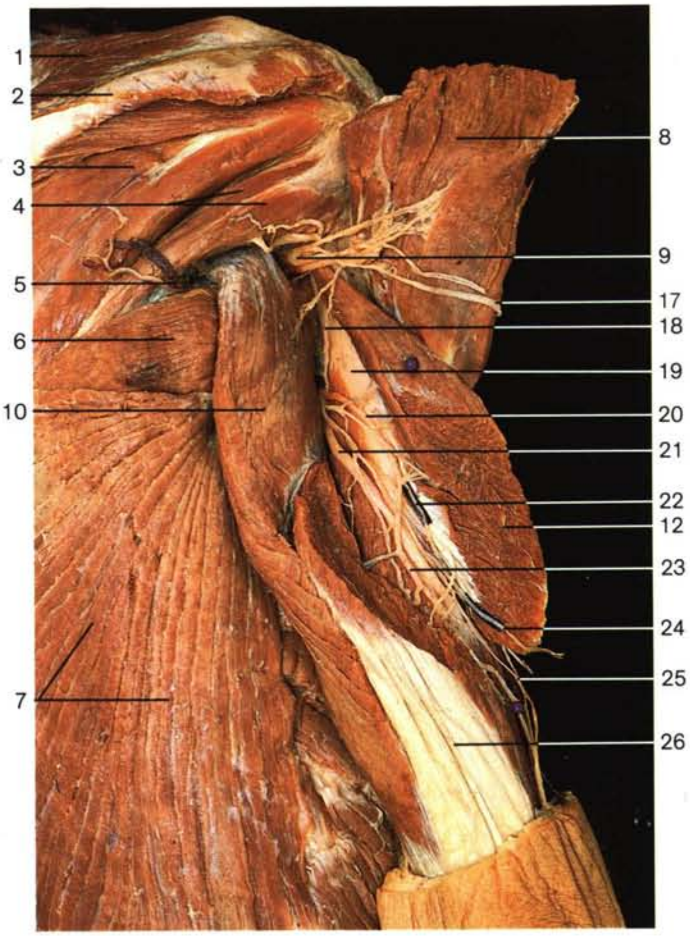

Scapular region and posterior brachial region; arm and shoulder, deep layer (dorsal aspect). The lateral head of the triceps brachii muscle has been cut to display the radial nerve and accompanying vessels.

1 Trapezius muscle
2 Spine of scapula
3 Infraspinatus muscle
4 Teres minor muscle
5 **Triangular space** containing circumflex scapular artery and vein
6 Teres major muscle
7 Latissimus dorsi muscle
8 Deltoid muscle (cut and reflected)
9 **Quadrangular space** containing axillary nerve and posterior circumflex humeral artery and vein
10 Long head of triceps brachii muscle
11 Cutaneous branch of axillary nerve
12 Lateral head of triceps brachii muscle
13 Terminal branches of intercostobrachial nerve
14 Lateral cutaneous branches of intercostal nerves
15 Medial cutaneous nerve of arm
16 Medial cutaneous nerve of forearm
17 Upper lateral cutaneous nerve of arm
18 Anastomosis between profunda brachii artery and posterior humeral circumflex artery
19 Humerus
20 **Profunda brachii artery**
21 **Radial nerve**
22 Radial collateral artery
23 Middle collateral artery
24 Lower lateral cutaneous nerve of arm
25 Posterior cutaneous nerve of forearm
26 Tendon of triceps brachii muscle

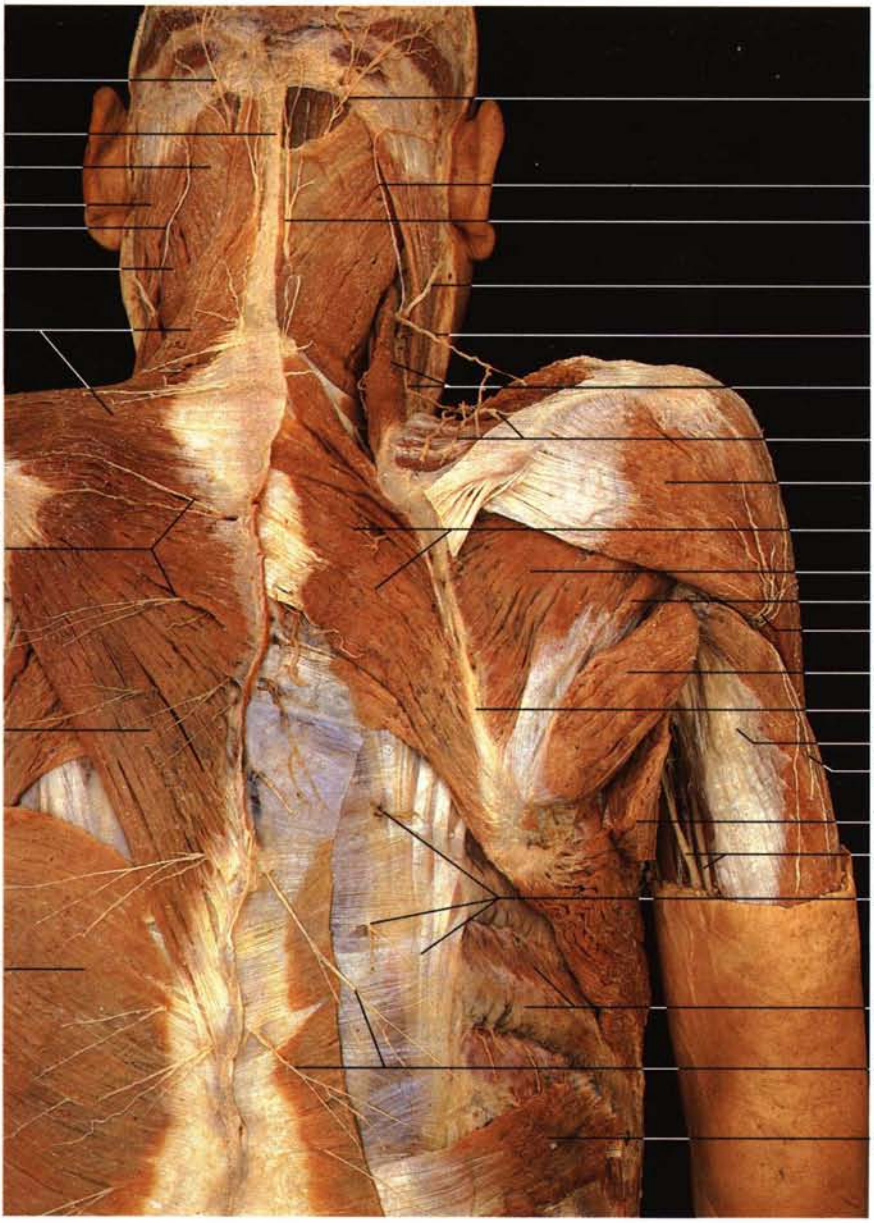

Dorsal regions of neck and shoulder (dorsal aspect). Left side: superficial layer. Right side: trapezius and latissimus dorsi muscles have been removed. Dissection of dorsal branches of spinal nerves.

1 **Greater occipital nerve**
2 Ligamentum nuchae
3 Splenius capitis muscle
4 Sternocleidomastoid muscle
5 Lesser occipital nerve
6 Splenius cervicis muscle
7 Descending and transverse fibers of trapezius muscle
8 **Medial cutaneous branches of dorsal rami of spinal nerves**
9 Ascending fibers of trapezius muscle
10 Latissimus dorsi muscle
11 Cutaneous branch of third occipital nerve
12 Great auricular nerve
13 Accessory nerve (n. XI)
14 Posterior supraclavicular nerve and levator scapulae muscle
15 Branches of suprascapular artery
16 Deltoid muscle
17 Rhomboid major muscle
18 Infraspinatus muscle
19 Teres minor muscle
20 Upper lateral cutaneous nerve of arm (branch of axillary nerve)
21 Teres major muscle
22 Medial margin of scapula
23 Long head of triceps muscle
24 Posterior cutaneous nerve of arm (branch of radial nerve)
25 Latissimus dorsi muscle (divided)
26 Ulnar nerve and brachial artery
27 **Lateral cutaneous branches of dorsal rami of spinal nerves** and iliocostalis thoracis muscle
28 External intercostal muscle and seventh rib
29 Serratus posterior inferior muscle

1 Clavicle
2 Deltoid muscle
3 **Suprascapular artery**
4 Suprascapular nerve
5 Superior transverse scapular ligament
6 Teres minor muscle
7 Axillary nerve and posterior circumflex humeral artery
8 Long head of triceps muscle
9 **Circumflex scapular artery**
10 Teres major muscle
11 Greater occipital nerve
12 Lesser occipital nerve
13 Great auricular nerve
14 Splenius capitis muscle
15 Accessory nerve (n. XI)
16 Third occipital nerve and levator scapulae muscle
17 Serratus posterior superior muscle
18 Spine of scapula
19 Descending scapular artery and dorsal scapular nerve
20 Rhomboid major muscle
21 Infraspinatus muscle and medial margin of scapula
22 Radial nerve and profunda brachii artery
23 Thoracodorsal artery
24 Thyrocervical trunk
25 Roots of brachial plexus

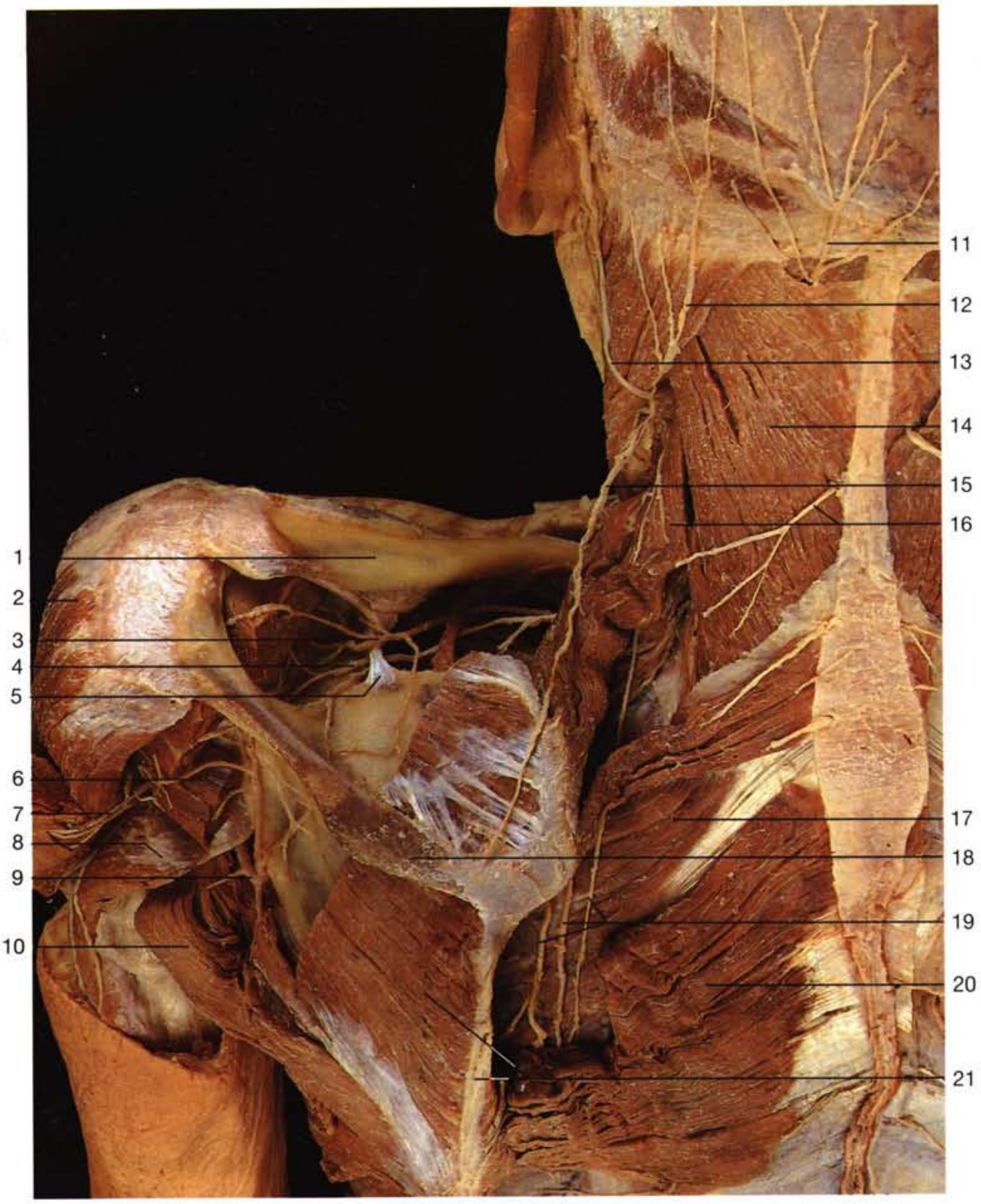

Dorsal region of shoulder; deepest layer. Rhomboid and scapular muscles fenestrated; posterior part of deltoid muscle reflected.

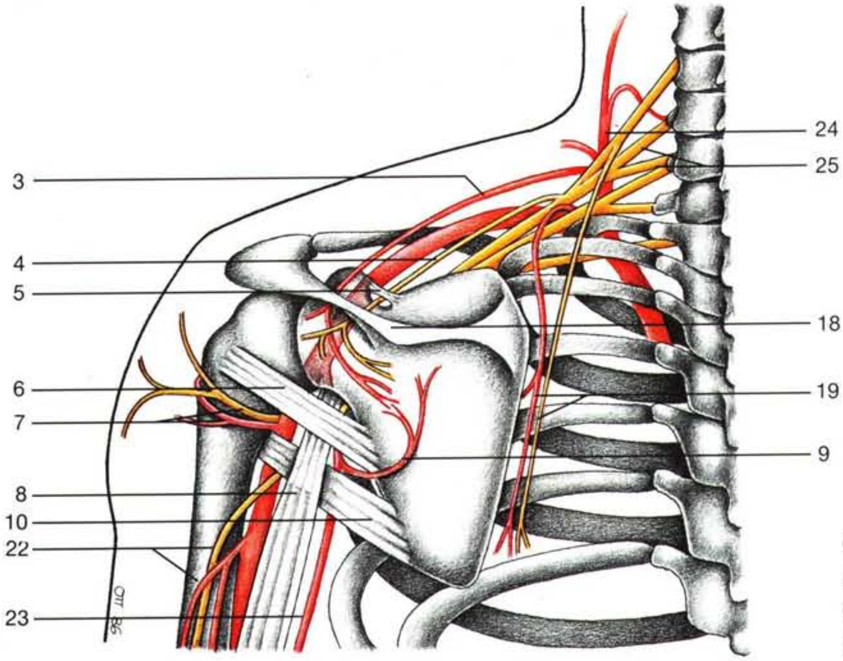

Collateral circulation of shoulder. Anastomosis of suprascapular and circumflex scapular arteries. (Semischematic drawing.)

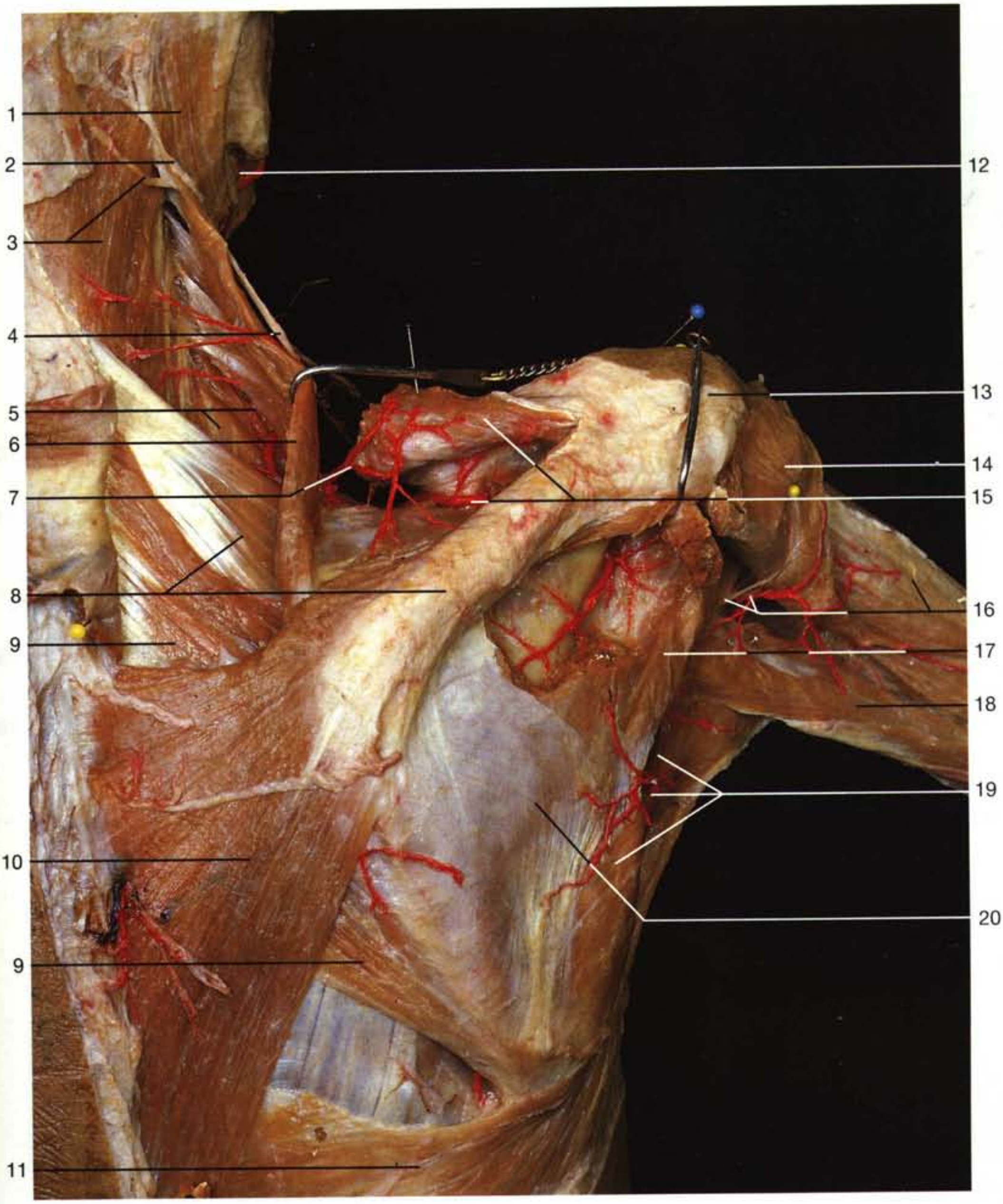

Scapular region, arm and shoulder (dorsal aspect). Arteries of scapular region are injected. Trapezius, deltoid and infraspinatus muscles are partially removed or reflected.

1	Sternocleidomastoid muscle
2	Lesser occipital nerve
3	Splenius capitis muscle and third occipital nerve
4	**Accessory nerve** (N. XI)
5	Splenius cervicis muscle and transverse cervical artery (deep branch)
6	Levator of scapula muscle
7	**Transverse cervical artery** (superficial branch)
8	Spine of scapula and serratus posterior superior muscle
9	Rhomboid major muscle
10	Trapezius muscle
11	Latissimus dorsi muscle
12	Facial artery
13	Acromion
14	Deltoid muscle
15	**Suprascapular artery** and supraspinatus muscle (reflected)
16	**Axillary nerve,** posterior circumflex humeral artery and lateral head of triceps, brachii muscle
17	Teres minor muscle
18	Long head of triceps brachii muscle
19	**Circumflex scapular artery** and teres major
20	Infraspinatus muscle

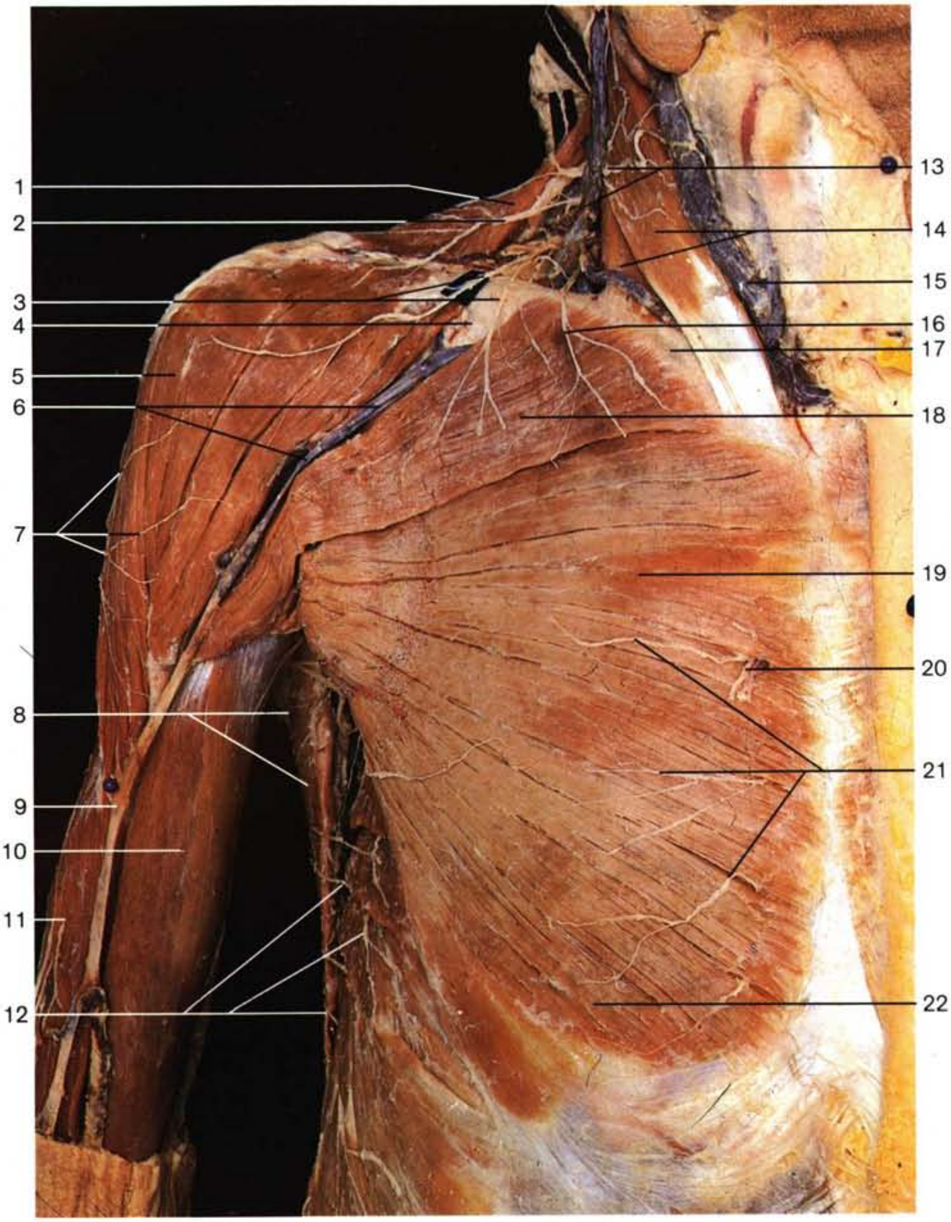

Right shoulder and thoracic wall, superficial layer (anterior aspect). Dissection of the cutaneous nerves and veins.

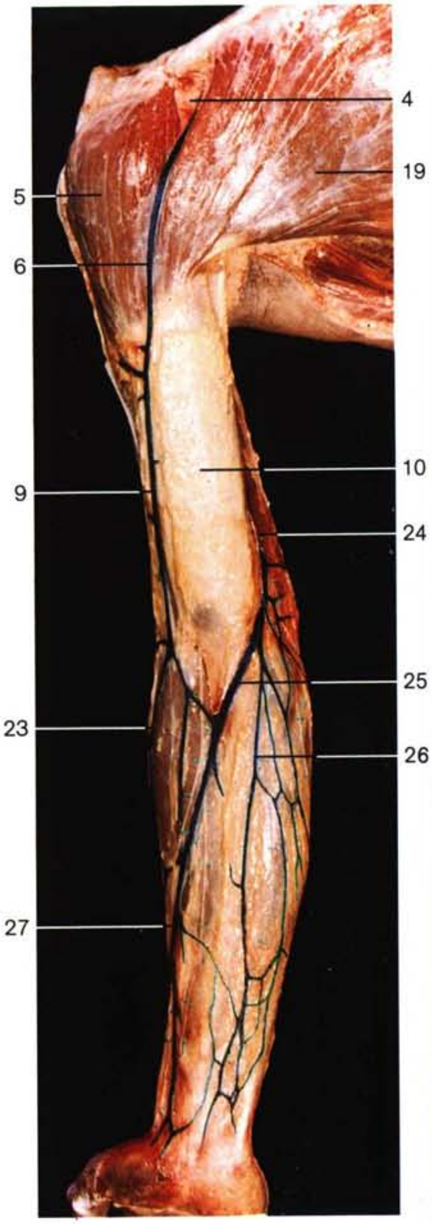

Superficial veins of right arm have been injected with blue gelatin.

1	Trapezius muscle
2	Posterior supraclavicular nerve
3	Middle supraclavicular nerve
4	Deltopectoral triangle
5	Deltoid muscle
6	Cephalic vein within the deltopectoral groove
7	Upper lateral cutaneous nerve of arm (branch of axillary nerve)
8	Latissimus dorsi muscle
9	**Cephalic vein**
10	Biceps brachii muscle
11	Triceps brachii muscle
12	Lateral cutaneous branches of intercostal nerves
13	Transverse cervical nerve and external jugular vein
14	Sternocleidomastoid muscle
15	**Anterior jugular vein**
16	Anterior supraclavicular nerve
17	Clavicle
18	Clavicular part of pectoralis major muscle
19	Sternocostal part of pectoralis major muscle
20	Perforating branch of internal thoracic artery
21	**Anterior cutaneous branches of intercostal nerves**
22	Abdominal part of pectoralis major muscle
23	Accessory cephalic vein
24	**Basilic vein**
25	**Median cubital vein**
26	Median vein of forearm
27	Cephalic vein in the forearm

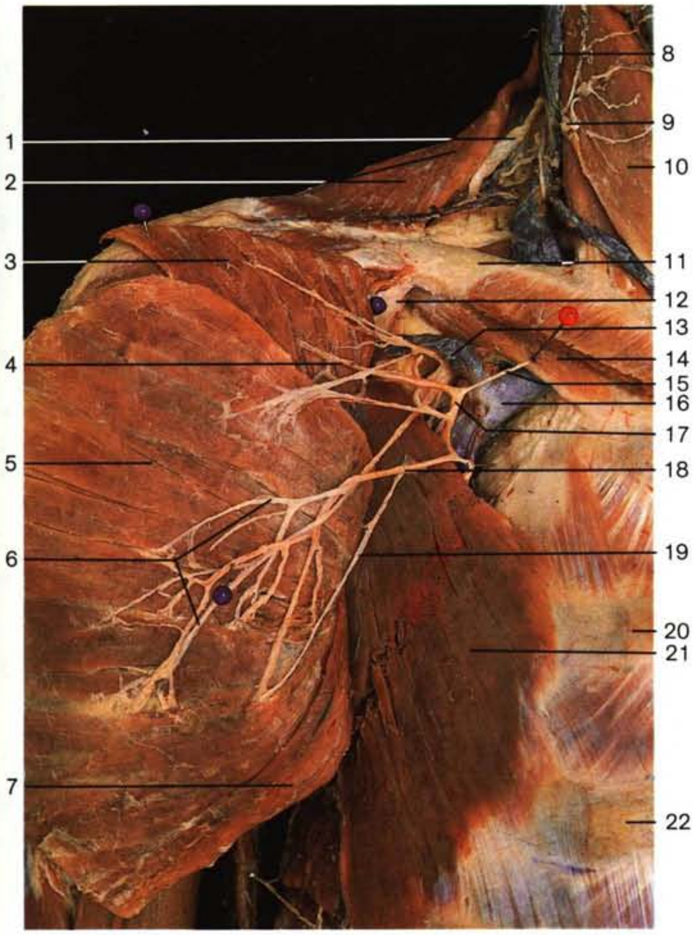

Right deltopectoral triangle, infraclavicular region (anterior aspect). The pectoralis major muscle has been cut and reflected.

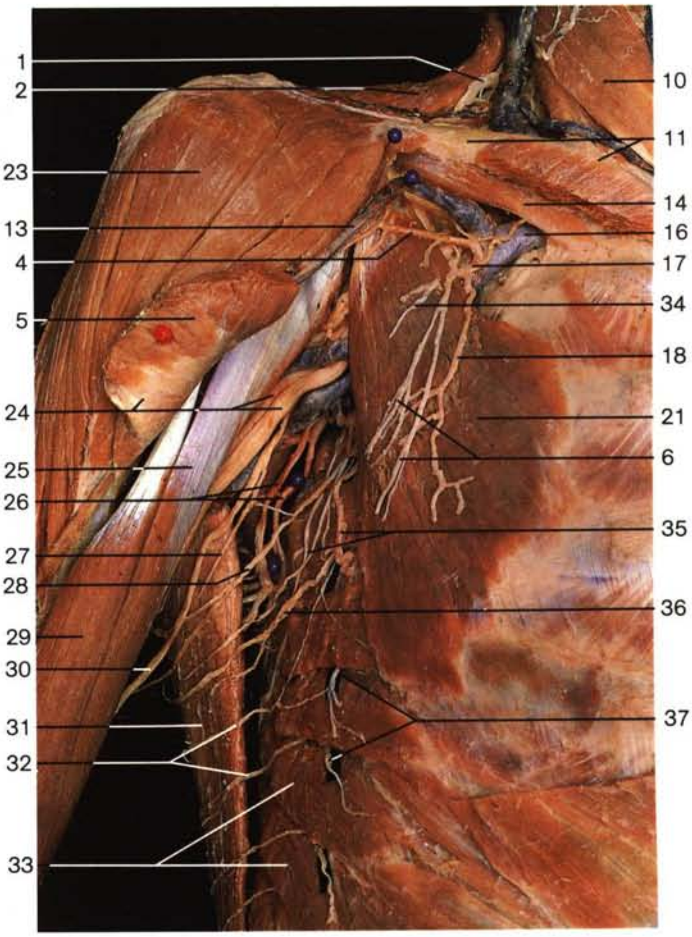

Thoracic wall and shoulder, deep layer. **Right axillary region** (anterior aspect). The pectoralis major muscle has been cut and partly removed.

1 Accessory nerve
2 Trapezius muscle
3 Pectoralis major muscle (clavicular part)
4 Acromial branch of thoracoacromial artery
5 Pectoralis major muscle
6 **Lateral pectoral nerves**
7 Abdominal part of pectoralis major muscle
8 External jugular vein
9 Cutaneous branches of cervical plexus
10 Sternocleidomastoid muscle
11 Clavicle
12 Clavipectoral fascia
13 **Cephalic vein**
14 Subclavius muscle
15 Clavicular branch of thoracoacromial artery
16 **Subclavian vein**
17 **Thoracoacromial artery**
18 Pectoral branch of thoracoacromial artery
19 Medial pectoral nerve
20 2nd rib
21 Pectoralis minor muscle
22 3rd rib
23 Deltoid muscle
24 Pectoralis major muscle (reflected), **brachial artery and median nerve**
25 Short head of biceps brachii muscle
26 Thoracodorsal artery and nerve
27 Medial cutaneous nerve of arm
28 Intercostobrachial nerve (T_2)
29 Long head of biceps brachii muscle
30 Medial cutaneous nerve of forearm
31 Latissimus dorsi muscle
32 Lateral cutaneous branches of intercostal nerves (posterior branches)
33 Serratus anterior muscle
34 Medial pectoral nerve
35 **Long thoracic nerve and lateral thoracic artery**
36 Intercostobrachial nerve (T_3)
37 **Lateral cutaneous branches of intercostal nerves** (anterior branches)

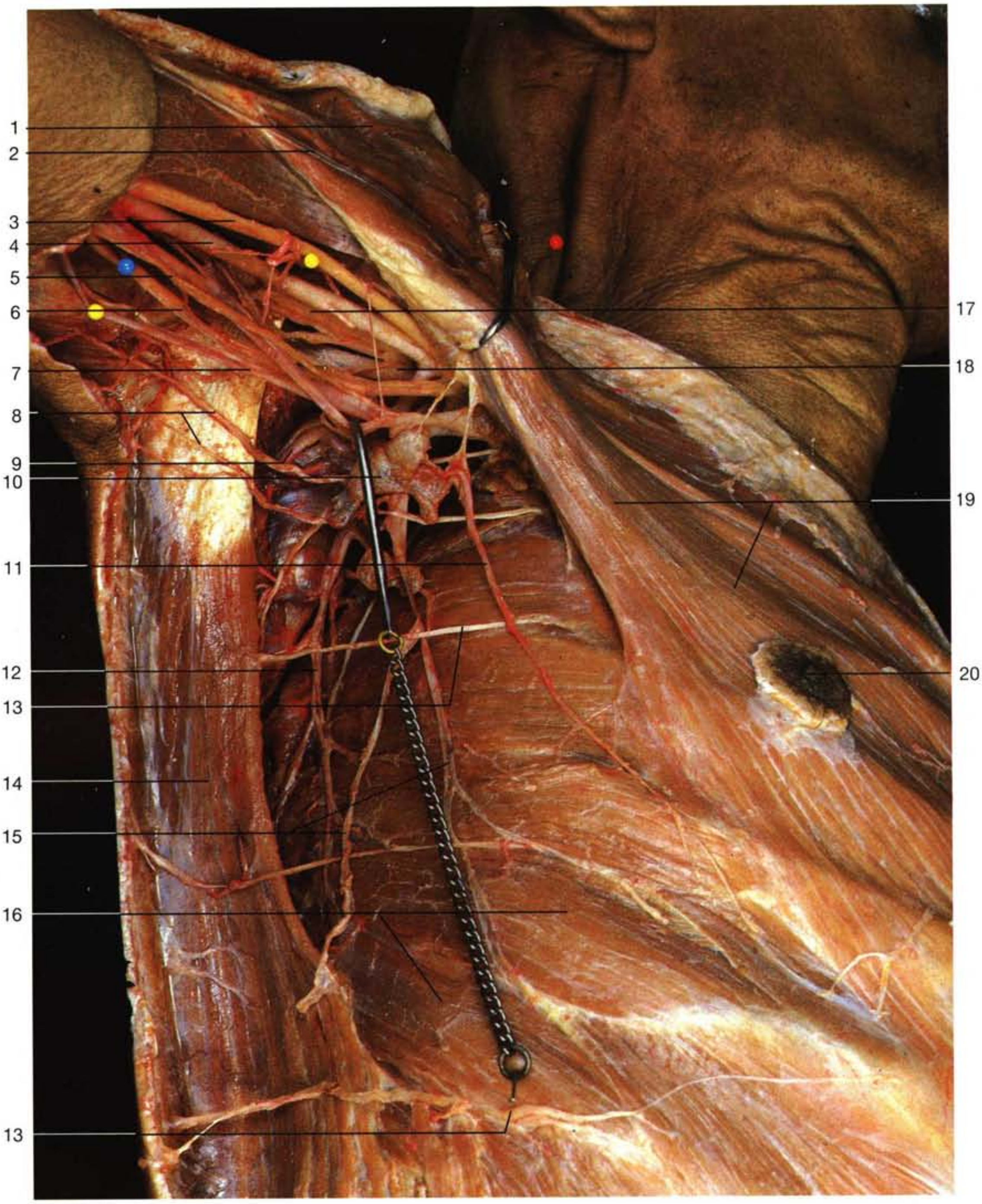

Right axillary region (inferior aspect). **Dissection of superficial axillary nodes and lymphatic vessels.** The pectoralis major muscle has been slightly elevated.

1	Deltoid muscle
2	Cephalic vein
3	Median nerve
4	Brachial artery
5	Medial cutaneous nerves of arm and forearm
6	Ulnar nerve
7	Basilic Vein
8	Intercostobrachial nerves
9	Circumflex scapular artery
10	**Superficial axillary nodes**
11	Lateral thoracic artery
12	Thoracodorsal artery
13	Lateral cutaneous branch of intercostal nerve
14	Latissimus dorsi muscle
15	Thoracoepigastric vein
16	Serratus anterior muscle
17	Musculocutaneous nerve
18	Radial nerve
19	Pectoralis major muscle
20	Nipple

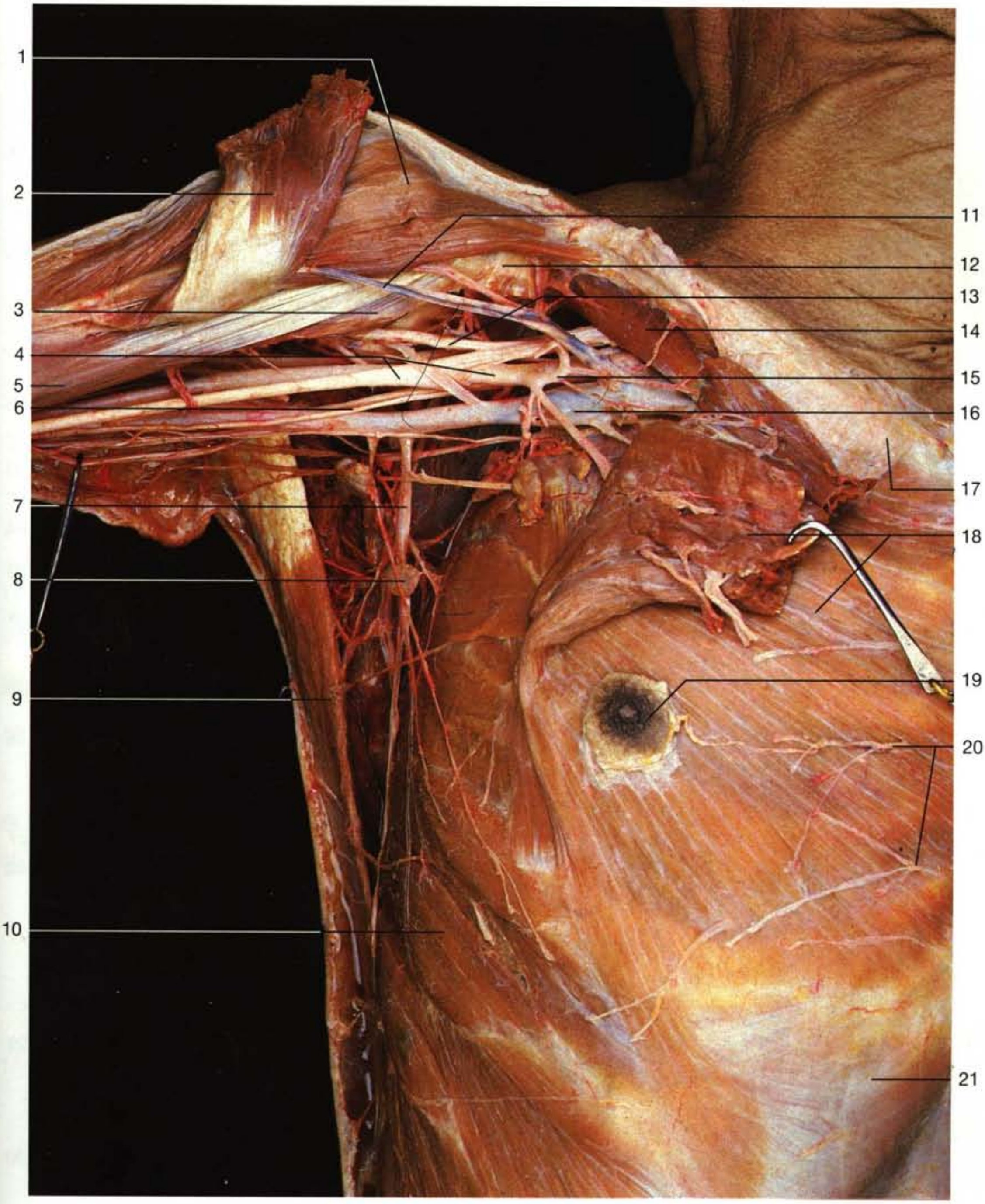

Axillary region (anterior aspect). Dissection of deep axillary nodes. Pectoralis major and minor divided and reflected. Shoulder girdle and arm elevated and reflected.

1 Deltoid muscle
2 Insertion of pectoralis major muscle
3 Coracobrachialis muscle
4 Roots of **median nerve, axillary artery**
5 Short head of biceps brachii muscle
6 **Ulnar nerve** and medial cutaneous nerve of forearm
7 Thoracoepigastric vein
8 Deep axillary node
9 Latissimus dorsi muscle
10 Serratus anterior muscle
11 Cephalic vein
12 Insertion of pectoralis minor muscle (coracoid process)
13 **Musculocutaneous nerve**
14 Subclavius muscle
15 Thoracoacromial artery
16 **Axillary vein**
17 Clavicle
18 Pectoralis major and minor muscles (reflected)
19 Nipple
20 Anterior cutaneous branches of intercostal nerves
21 Anterior layer of rectus sheaths

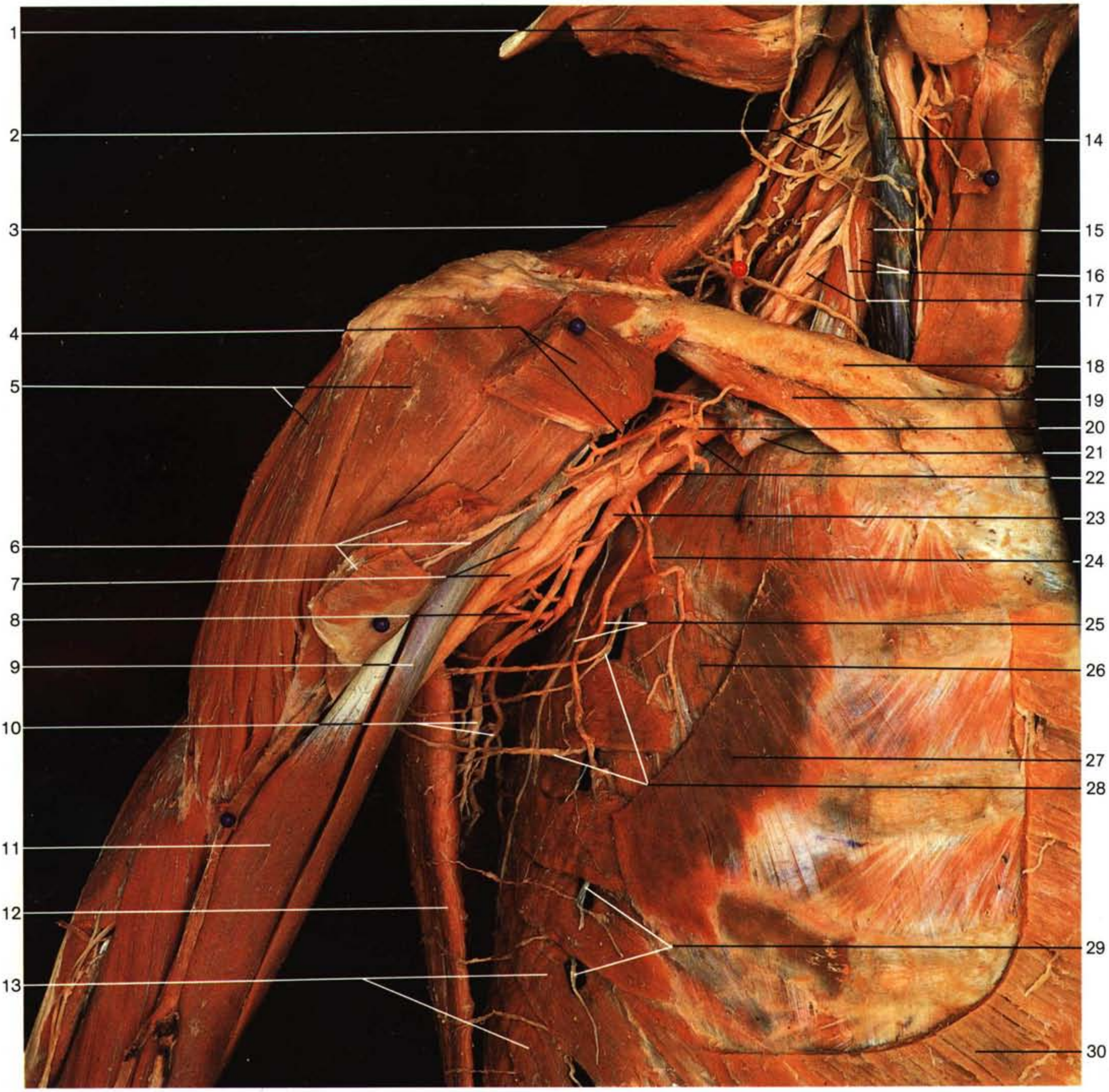

Right axillary region (anterior aspect). The pectoralis major and minor muscles have been cut and reflected to display the vessels and nerves of the axilla.

1 Sternocleidomastoid muscle (cut and reflected)
2 Cervical plexus
3 Trapezius muscle
4 Pectoralis minor muscle and medial pectoral nerve
5 Deltoid muscle
6 Pectoralis major muscle and lateral pectoral nerve
7 **Median nerve and brachial artery**
8 Circumflex scapular artery
9 Short head of biceps brachii muscle
10 **Thoracodorsal artery and nerve**
11 Long head of biceps brachii muscle
12 Latissimus dorsi muscle
13 Serratus anterior muscle
14 Internal jugular vein
15 **Scalenus anterior muscle**
16 Phrenic nerve and ascending cervical artery
17 Brachial plexus (at the levels of the trunks)
18 Clavicle
19 Subclavius muscle
20 **Thoracoacromial artery**
21 Subclavian vein (cut)
22 **Axillary artery**
23 Subscapular artery
24 Superior thoracic artery
25 **Lateral thoracic artery and long thoracic nerve**
26 External intercostal muscle
27 Insertion of pectoralis minor muscle
28 Intercostobrachial nerves
29 Lateral cutaneous branches of intercostal nerves
30 Insertion of pectoralis major muscle

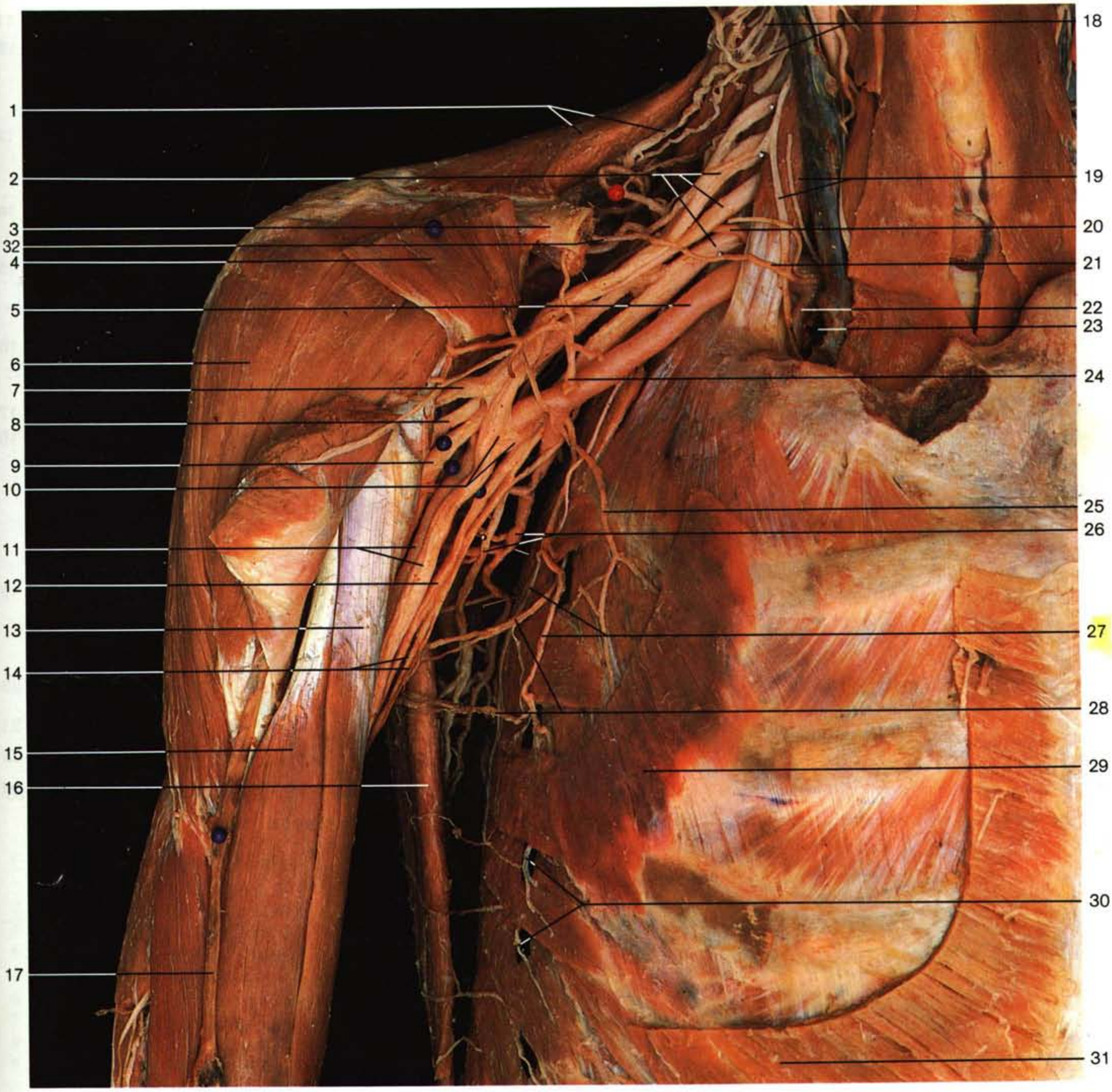

Shoulder and arm. Axillary region with brachial plexus (anterior aspect). The pectoralis major and minor muscles have been partly removed. The clavicle has been cut.

1 Trapezius muscle and accessory nerve
2 Brachial plexus
3 Clavicle (cut)
4 Pectoralis minor muscle
5 **Axillary (subclavian) artery**
6 Deltoid muscle
7 **Musculocutaneous nerve**
8 **Axillary nerve**
9 **Radial nerve**
10 Medial and lateral roots of the median nerve
11 **Median nerve** and **brachial artery**
12 **Ulnar nerve**
13 Short head of biceps brachii muscle
14 Medial cutaneous nerves of arm and forearm
15 Long head of biceps brachii muscle
16 Latissimus dorsi muscle
17 Cephalic vein
18 Cervical plexus
19 **Phrenic nerve and scalenus anterior muscle**
20 Descending scapular artery
21 Suprascapular artery
22 Internal thoracic artery
23 Subclavian vein
24 Thoracoacromial artery
25 Superior thoracic artery
26 **Thoracodorsal artery and nerve**
27 **Lateral thoracic artery and long thoracic nerve**
28 Intercostobrachial nerves
29 Insertion of the pectoralis minor muscle into the 2nd–5th ribs
30 Lateral cutaneous branches of intercostal nerves
31 Abdominal part of pectoralis major muscle (cut)
32 Suprascapular nerve and artery

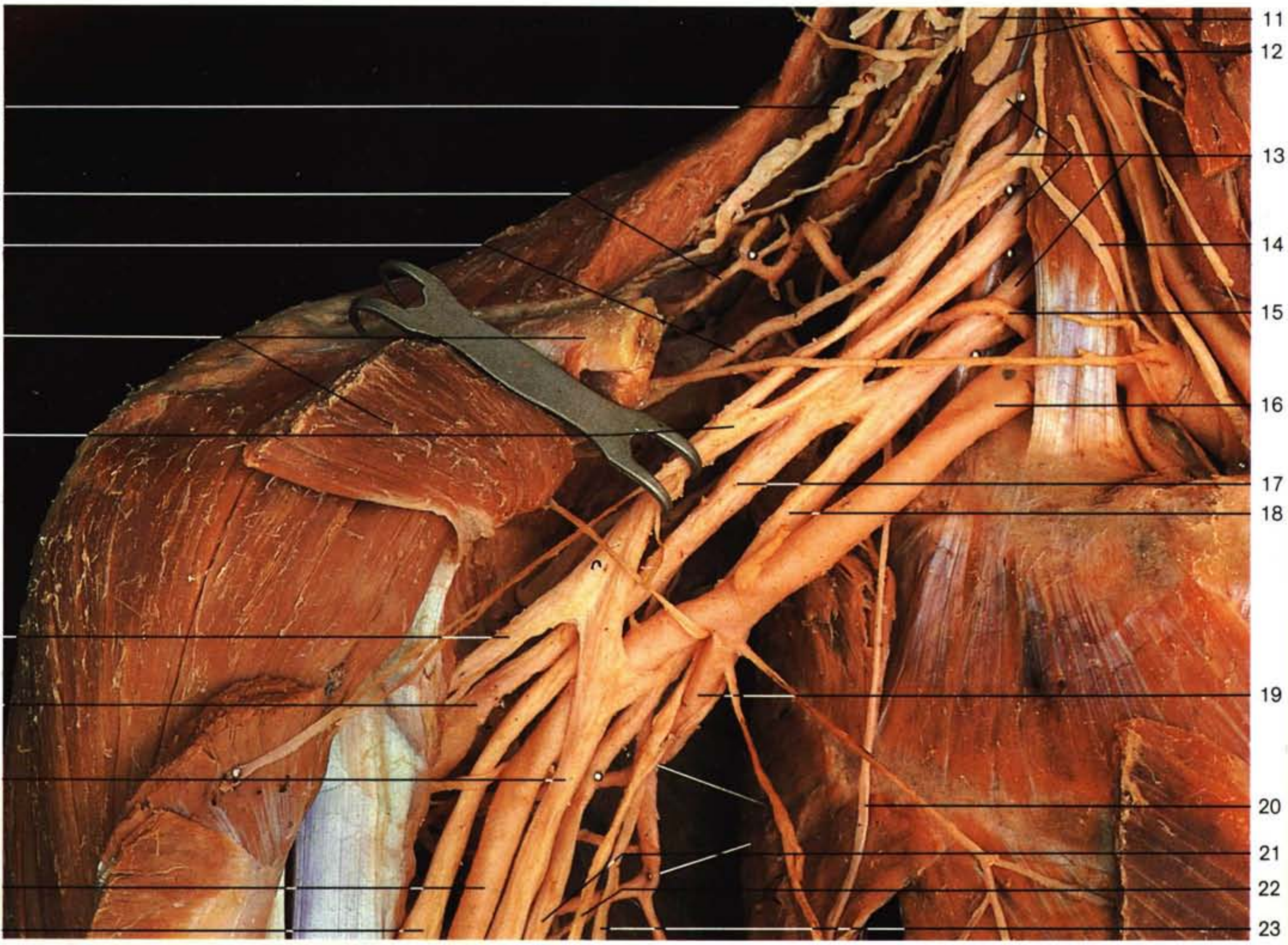

Brachial plexus (anterior aspect). Clavicle and the two pectoralis muscles have been partly removed.

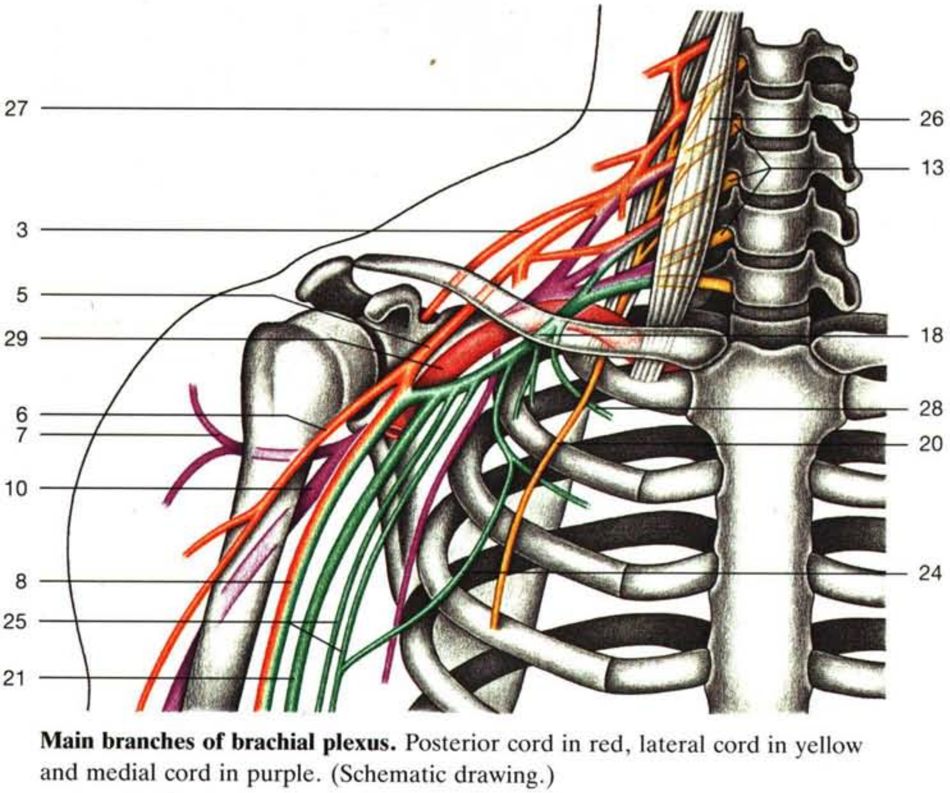

Main branches of brachial plexus. Posterior cord in red, lateral cord in yellow and medial cord in purple. (Schematic drawing.)

1 Accessory nerve
2 Dorsal scapular artery
3 Suprascapular nerve
4 Clavicle and pectoralis minor muscle
5 **Lateral cord** of brachial plexus
6 Musculocutaneous nerve
7 Axillary nerve
8 Median nerve
9 Brachial artery
10 Radial nerve
11 Cervical plexus
12 Common carotid artery
13 Roots of brachial plexus (C_5–T_1)
14 Phrenic nerve
15 Dorsal scapular artery
16 Subclavian artery
17 **Posterior cord** of brachial plexus
18 **Medial cord** of brachial plexus
19 Subscapular artery
20 Long thoracic nerve
21 Ulnar nerve
22 Medial cutaneous nerve of forearm
23 Thoracodorsal nerve
24 Intercostobrachial nerve
25 Medial cutaneous nerves of arm and forearm
26 Scalenus anterior muscle
27 Scalenus medius muscle
28 Intercostal nerve (T_1)
29 Axillary artery

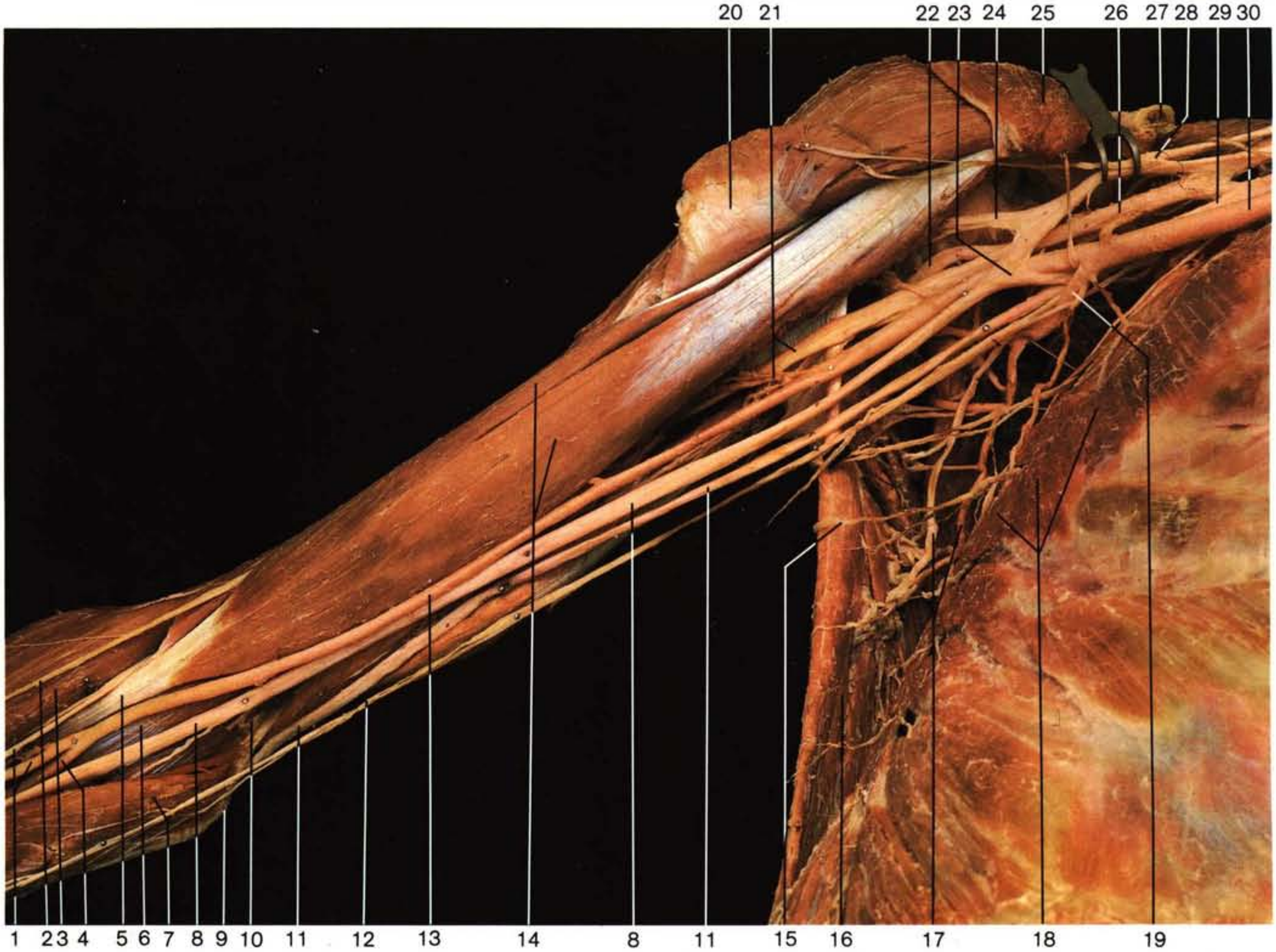

Right arm. Dissection of vessels and nerves (medial aspect). Shoulder girdle has been reflected slightly.

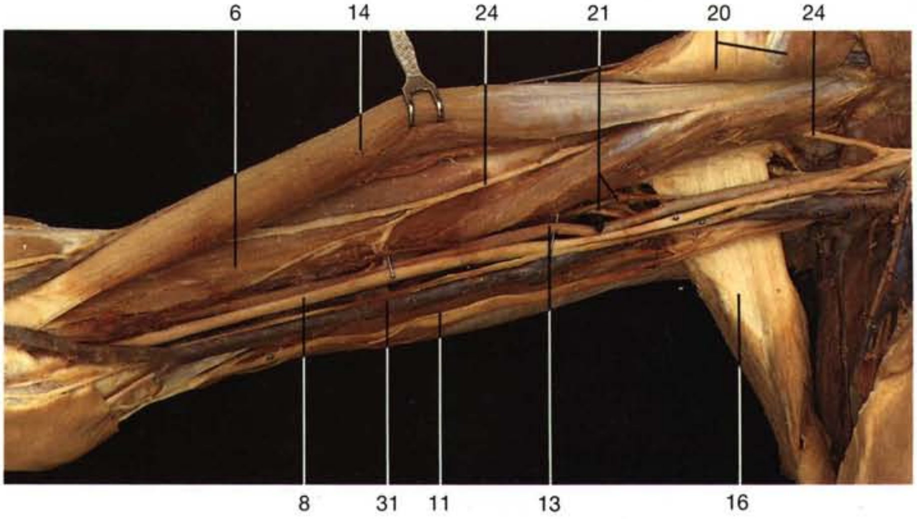

Right arm. Dissection of vessels and nerves, deeper layer. Biceps muscle has been reflected.

1 Radial artery and superficial branch of radial nerve
2 Lateral cutaneous nerve of forearm
3 Brachioradialis muscle
4 Ulnar artery
5 Tendon of biceps brachii muscle
6 Brachialis muscle
7 Pronator teres muscle
8 **Median nerve**
9 Medial epicondyle of humerus
10 Inferior ulnar collateral artery
11 **Ulnar nerve**
12 Medial cutaneous nerve of forearm
13 **Brachial artery**
14 Biceps brachii muscle
15 Intercostobrachial nerve (T_3)
16 Latissimus dorsi muscle
17 Thoracodorsal nerve and artery
18 Serratus anterior muscle
19 Subscapular artery
20 Pectoralis major muscle (reflected) and lateral pectoral nerve
21 Radial nerve and profunda brachii artery
22 Axillary nerve
23 Roots of the median nerve with axillary artery
24 **Musculocutaneous nerve**
25 Pectoralis minor muscle (reflected) and medial pectoral nerve
26 Posterior cord of brachial plexus
27 Clavicle (cut)
28 Lateral cord of brachial plexus
29 Medial cord of brachial plexus
30 Subclavian artery
31 Brachial vein

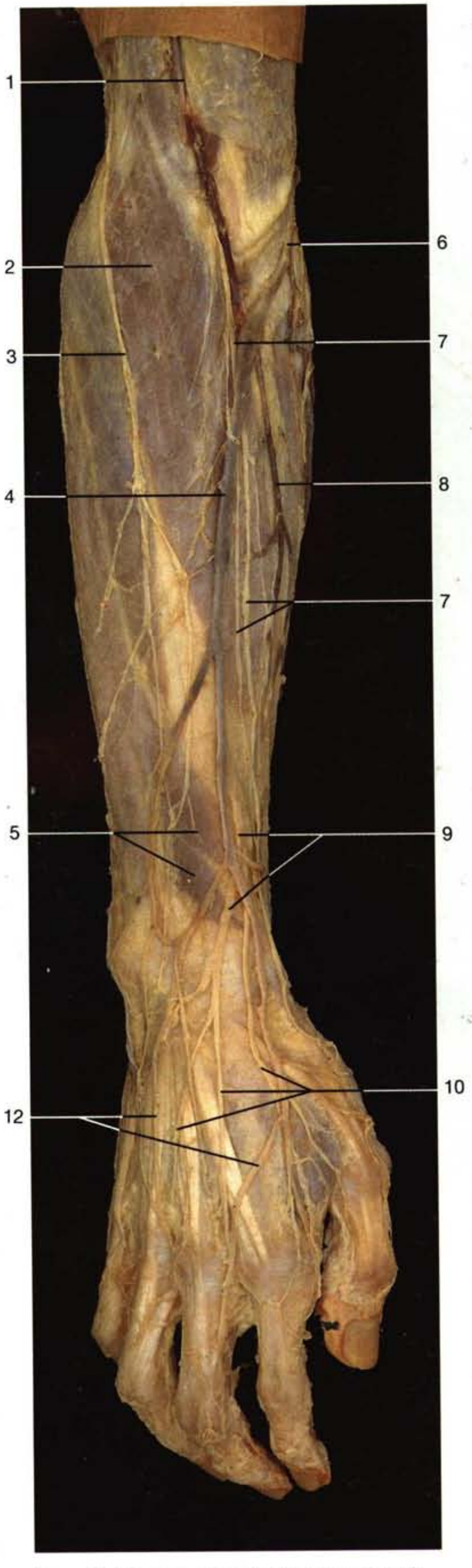

Superficial veins and cutaneous nerves of forearm and hand (anteromedial aspect).

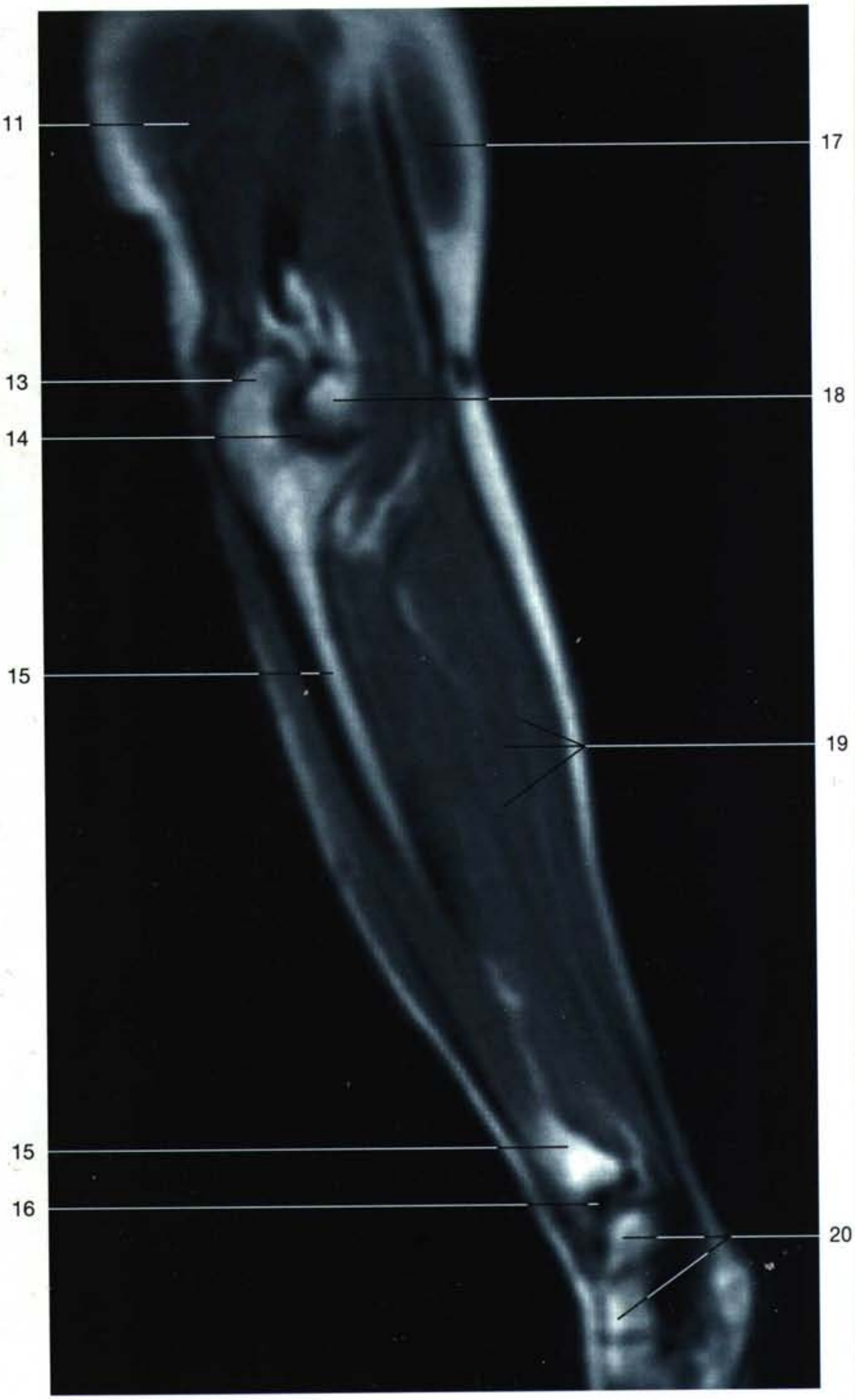

Sagittal section through the forearm at the level of the humeroulnar articulation (MR-Scan, after A. Heuck, G. Luttke, and J. W. Rohen, 1994).

1 **Cephalic vein**
2 Brachioradialis muscle covered by its fascia
3 **Posterior cutaneous nerve of forearm** (branch of radialis nerve)
4 Cephalic vein of forearm
5 Extensor pollicis longus and brevis muscles covered by their fascia
6 **Median cubital vein**
7 Lateral cutaneous nerves of forearm (branch of musculocutaneous nerve)
8 Intermedian vein of forearm
9 Superficial branch of radial nerve
10 **Dorsal digital branches of radial nerve**
11 Triceps brachii muscle
12 Venous network on the dorsum of the hand
13 Olecranon
14 **Humeroulnar articulation**
15 Ulna
16 Radiocarpal articulation
17 Biceps brachii muscle
18 Trochlea of humerus
19 Flexor muscles of forearm
20 Carpal bones

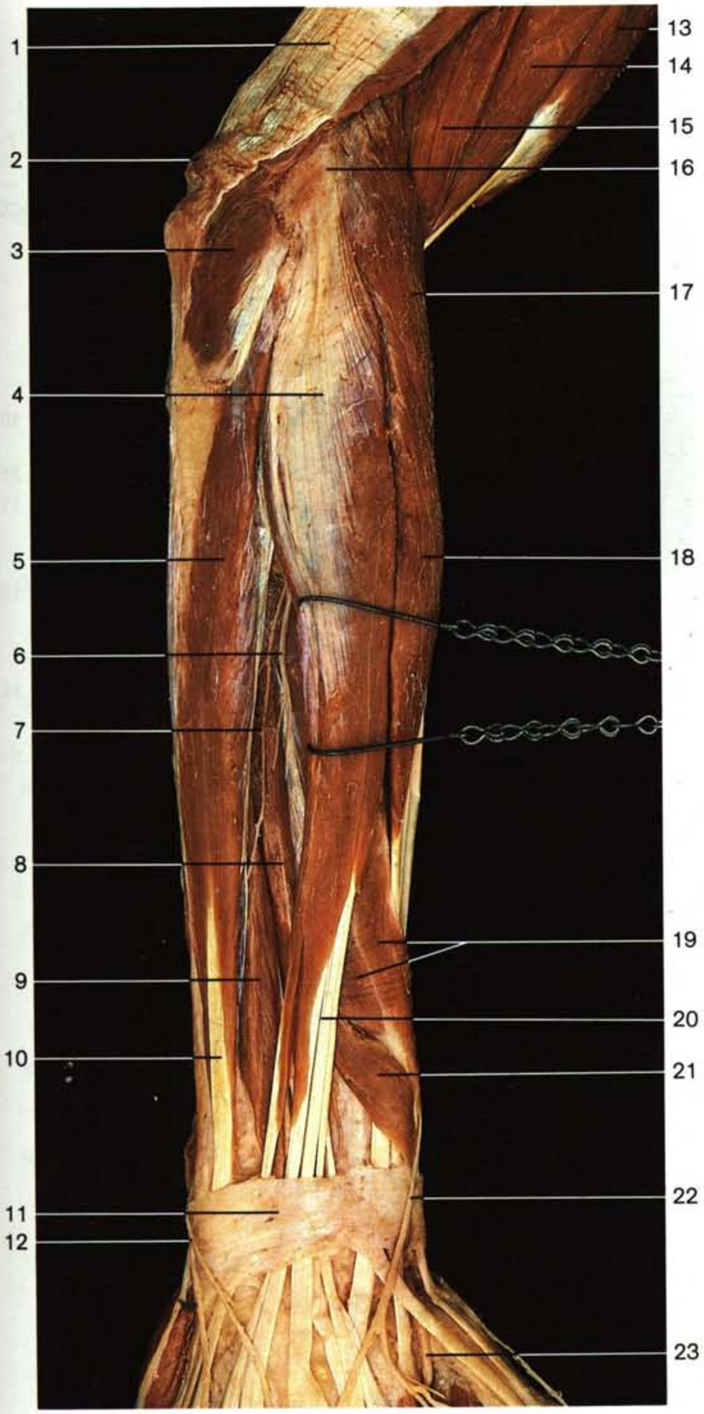

Vessels and nerves of right forearm, superficial layer (dorsal aspect).

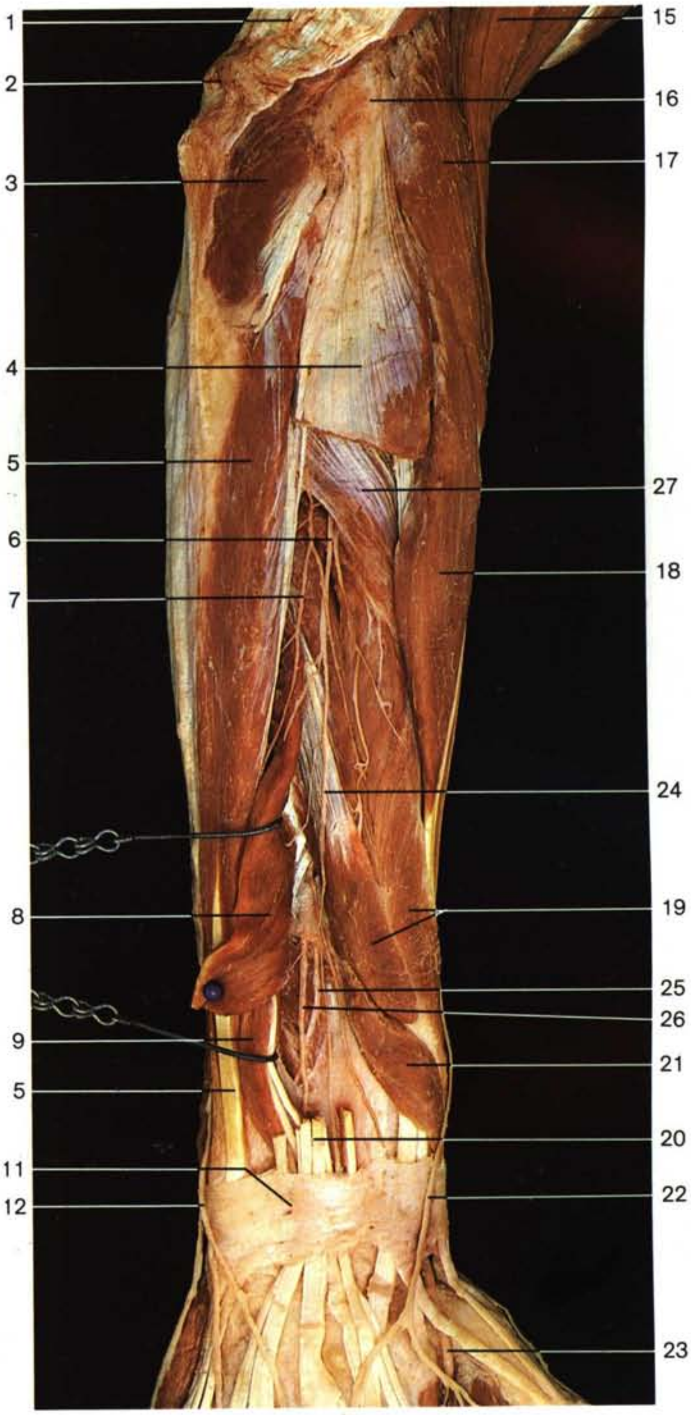

Vessels and nerves of right forearm, deep layer (dorsal aspect).

1 Tendon of triceps brachii muscle
2 Olecranon
3 Anconeus muscle
4 Extensor digitorum muscle
5 Extensor carpi ulnaris muscle
6 Deep branch of radial nerve
7 Posterior interosseous artery
8 Extensor pollicis longus muscle
9 Extensor indicis muscle
10 Tendon of extensor carpi ulnaris muscle
11 Extensor retinaculum
12 Dorsal branch of ulnar nerve
13 Biceps brachii muscle
14 Brachialis muscle
15 Brachioradialis muscle
16 Lateral epicondyle of humerus
17 Extensor carpi radialis longus muscle
18 Extensor carpi radialis brevis muscle
19 Abductor pollicis longus muscle
20 Tendons of extensor digitorum muscle
21 Extensor pollicis brevis muscle
22 Superficial branch of radial nerve
23 Radial artery
24 Posterior interosseous nerve
25 Posterior interosseous branch of radial nerve
26 Posterior branch of anterior interosseous artery
27 Supinator muscle

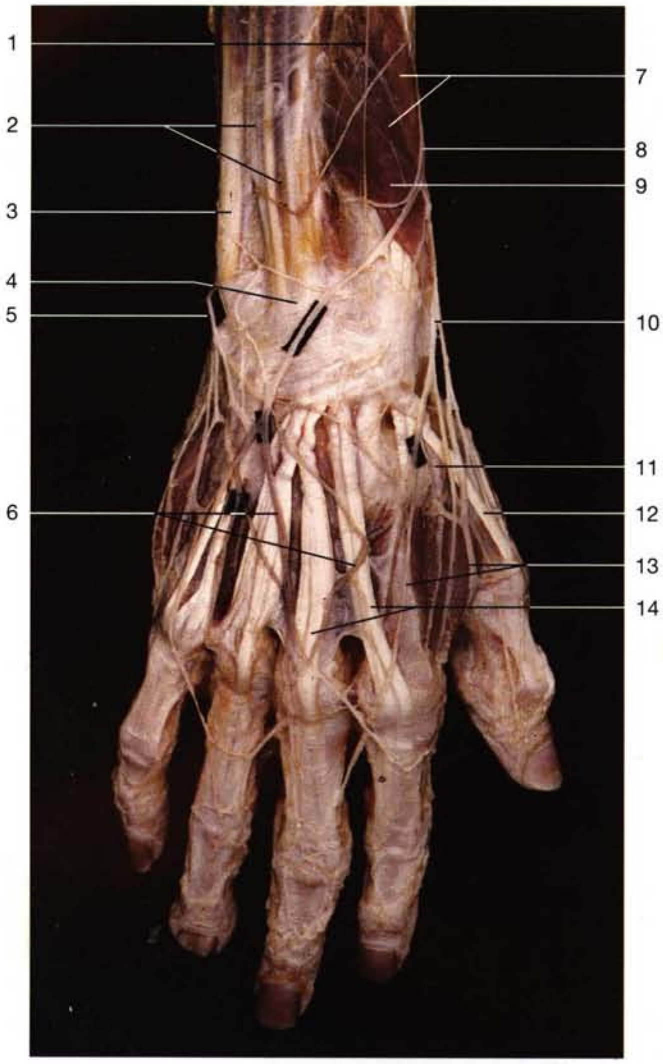

Cutaneous nerves and veins of forearm and hand (superficial layer, dorsal aspect).

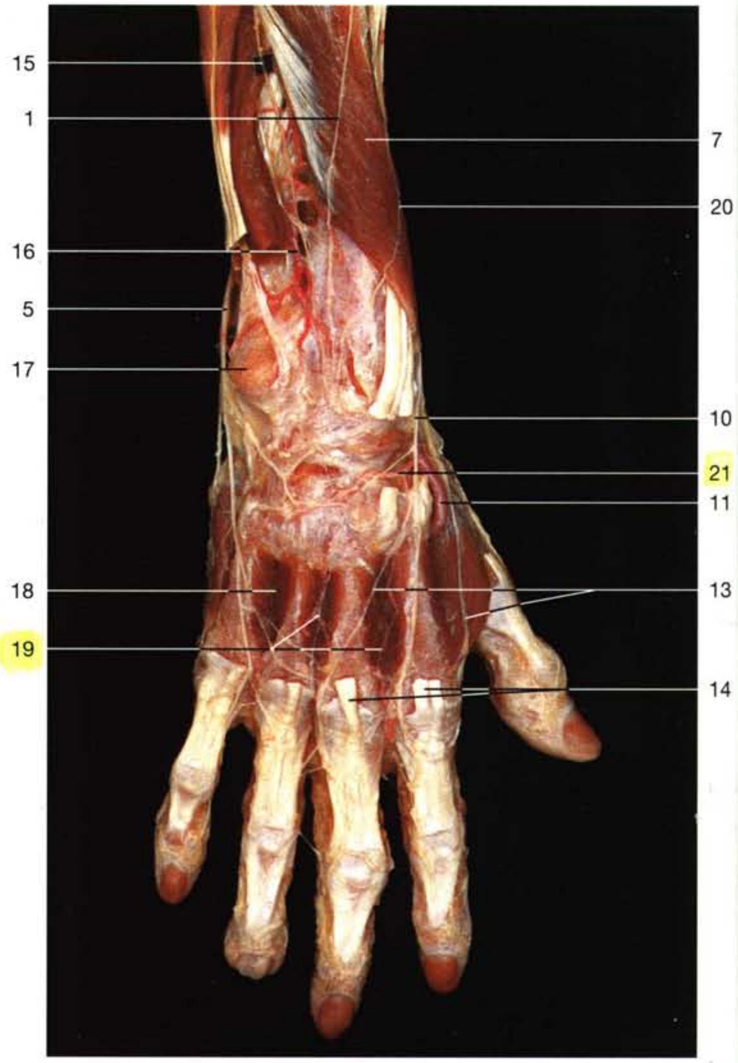

Dorsal region of forearm and hand (deeper layer). Extensor digitorum muscle has been partly removed.

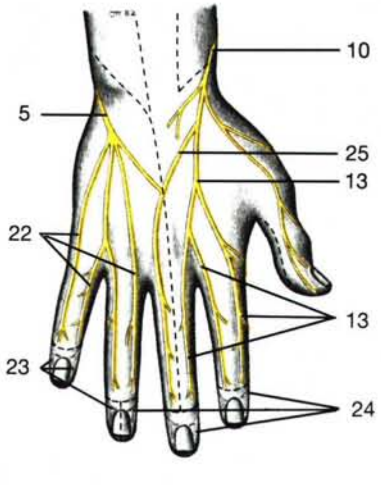

Innervation pattern of dorsal surfaces of hand
$2^1/_2$ digits by radial nerve, $2^1/_2$ digits by ulnar nerve. Note that the terminal branches to the dorsal surfaces of the distal phalanges are derived from the palmar digital nerves. The cutaneous distribution varies; often $3^1/_2$ digits are innervated by the radial and $1^1/_2$ digits by the ulnar nerve.

1 **Posterior cutaneous nerve of forearm** (branch of radial nerve)
2 Extensor digitorum muscle
3 Tendon of extensor carpi ulnaris muscle
4 Extensor retinaculum
5 **Ulnar nerve**
6 **Venous network of dorsum of hand**
7 Abductor pollicis longus muscle
8 Cephalic vein
9 Extensor pollicis brevis muscle
10 **Radial nerve,** superficial branch
11 **Radial artery**
12 Tendon of extensor pollicis longus muscle
13 Dorsal digital branches of radial nerve
14 Tendons of extensor digitorum muscle with intertendinous connections
15 Posterior interosseus nerve (branch of the deep radial nerve)
16 Posterior interosseous artery
17 Styloid process of ulna
18 Dorsal interosseus muscle IV
19 Dorsal carpal branch of radial artery
20 **Lateral cutaneous nerve of forearm** (branch of musculocutaneous nerve)
21 Dorsal metacarpal artery
22 Proper dorsal digital branches of ulnar nerve
23 Regions supplied by palmar digital nerves (ulnar nerve)
24 Regions supplied by palmar digital nerves (median nerve)
25 Communicating branch with ulnar nerve

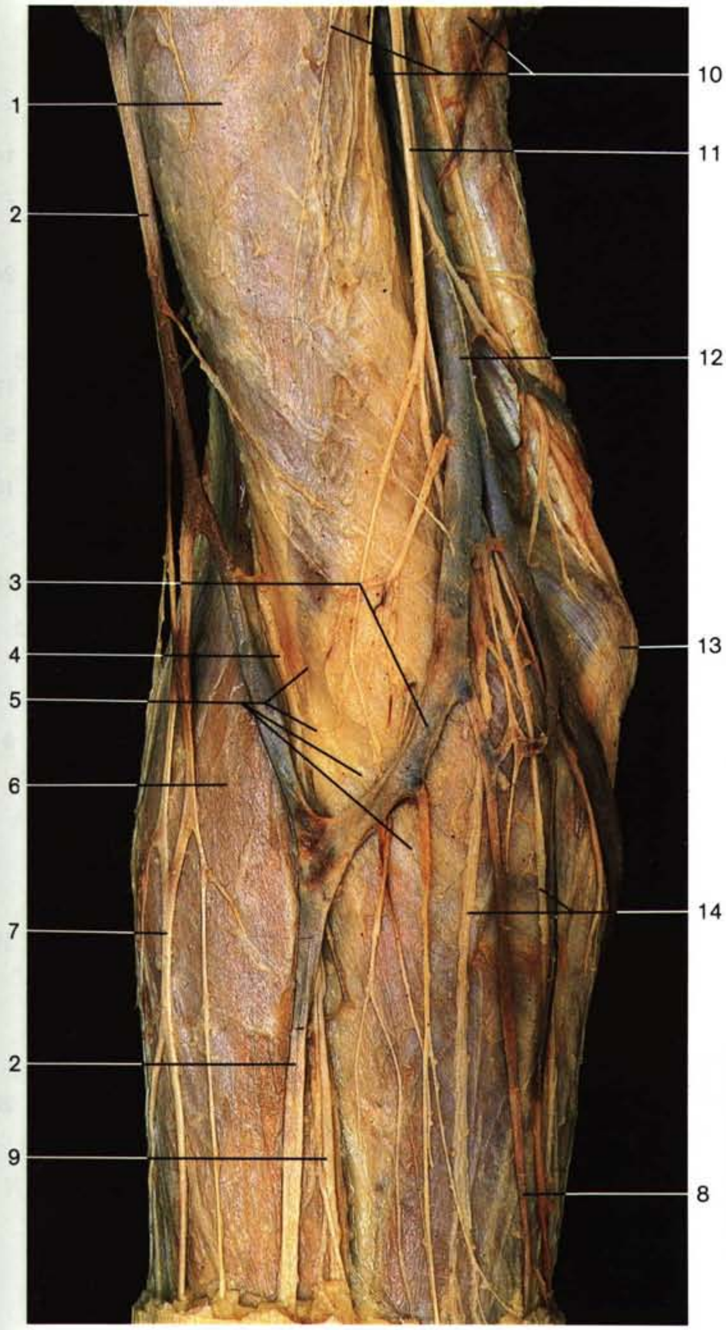

Cubital region (anterior aspect), dissection of cutaneous nerves and veins.

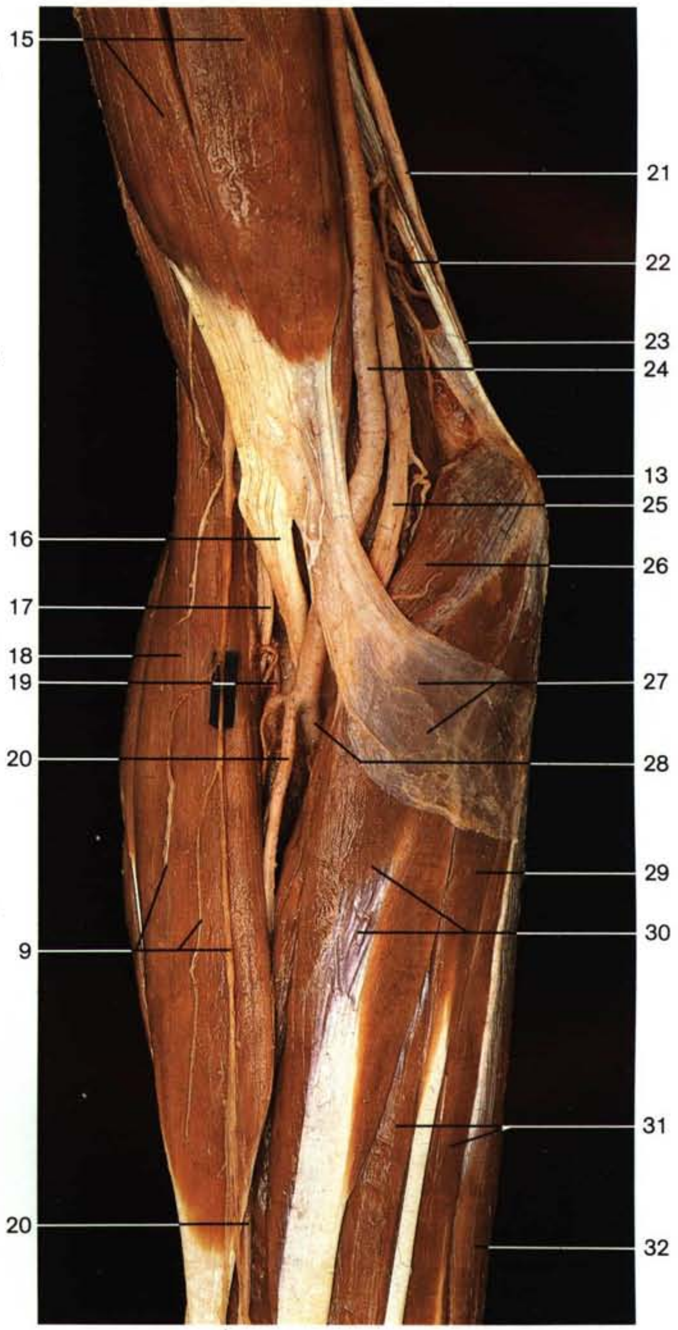

Cubital region, superficial layer (anterior aspect). The fasciae of the muscles have been removed.

1 Biceps brachii muscle with fascia
2 **Cephalic vein**
3 **Median cubital vein**
4 Lateral cutaneous nerve of forearm
5 Tendon and aponeurosis of biceps brachii muscle (covered by the antebrachial fascia)
6 Brachioradialis muscle with fascia
7 Accessory cephalic vein
8 Median vein of forearm
9 Branches of lateral cutaneous nerve of forearm
10 Terminal branches of medial cutaneous nerve of arm
11 **Medial cutaneous nerve of forearm**
12 **Basilic vein**
13 Medial epicondyle of humerus
14 Terminal branches of medial cutaneous nerve of forearm
15 Biceps brachii muscle

16 Tendon of biceps brachii muscle
17 Radial nerve
18 Brachioradialis muscle
19 Radial recurrent artery
20 **Radial artery**
21 **Ulnar nerve**
22 Superior ulnar collateral artery
23 Medial intermuscular septum
24 **Brachial artery**
25 **Median nerve**
26 Pronator teres muscle
27 Bicipital aponeurosis
28 Ulnar artery
29 Palmaris longus muscle
30 Flexor carpi radialis muscle
31 Flexor digitorum superficialis muscle
32 Flexor carpi ulnaris muscle

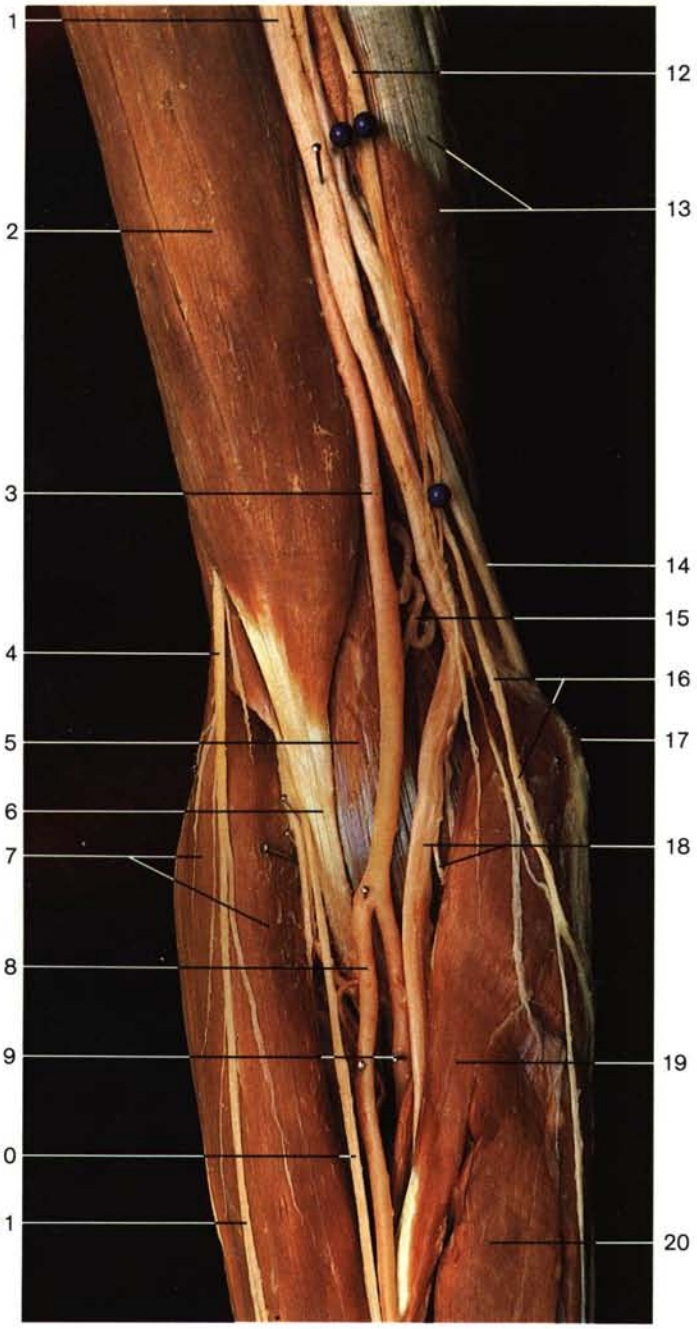

Cubital region, middle layer (anterior aspect). The bicipital aponeurosis has been removed.

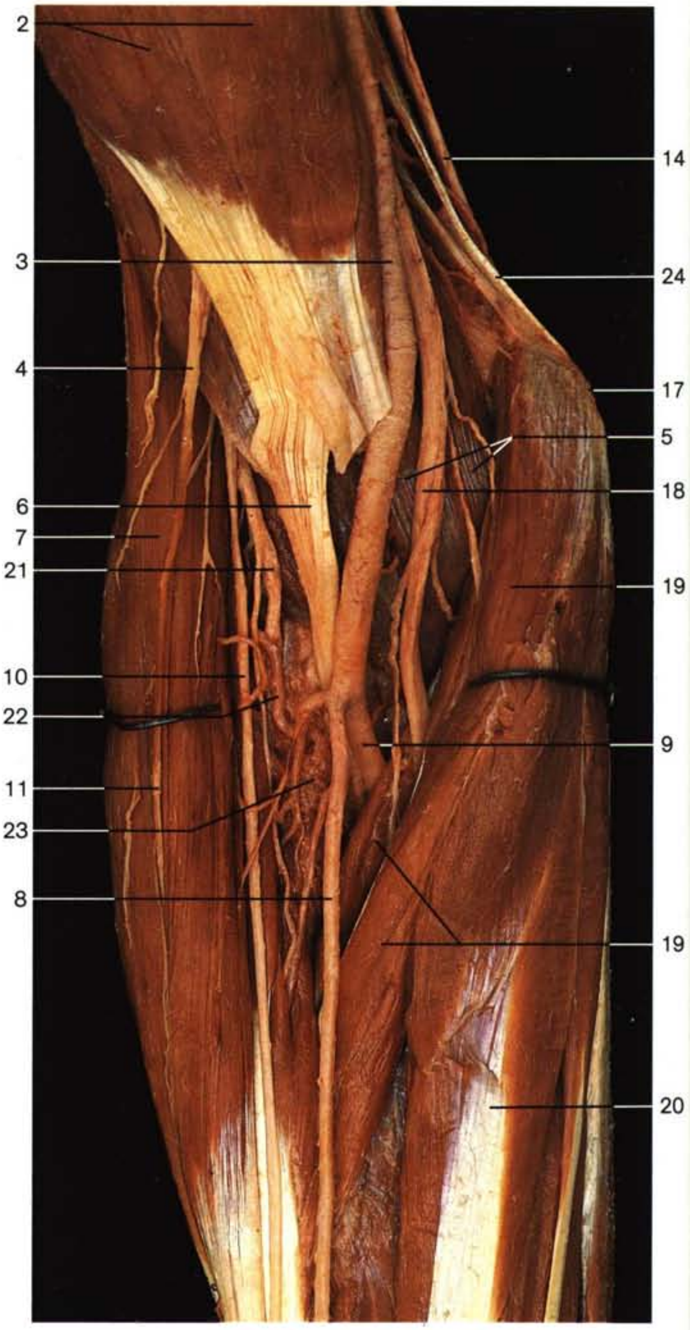

Cubital region, middle layer (anterior aspect). The pronator teres and brachioradialis muscles have been slightly reflected.

1 Median nerve
2 Biceps brachii muscle
3 Brachial artery
4 Lateral cutaneous nerve of forearm (terminal branch of **musculocutaneous nerve**)
5 Brachialis muscle
6 Tendon of biceps brachii muscle
7 Brachioradialis muscle
8 **Radial artery**
9 **Ulnar artery**
10 Superficial branch of radial nerve
11 Lateral cutaneous nerve of forearm
12 Medial cutaneous nerve of forearm
13 Triceps brachii muscle
14 **Ulnar nerve**
15 Inferior ulnar collateral artery
16 Anterior branch of medial cutaneous nerve of forearm
17 Medial epicondyle of humerus
18 **Median nerve** with branches to pronator teres muscle
19 Pronator teres muscle
20 Flexor carpi radialis muscle
21 Deep branch of radial nerve
22 Radial recurrent artery
23 Supinator muscle
24 Medial intermuscular septum of arm

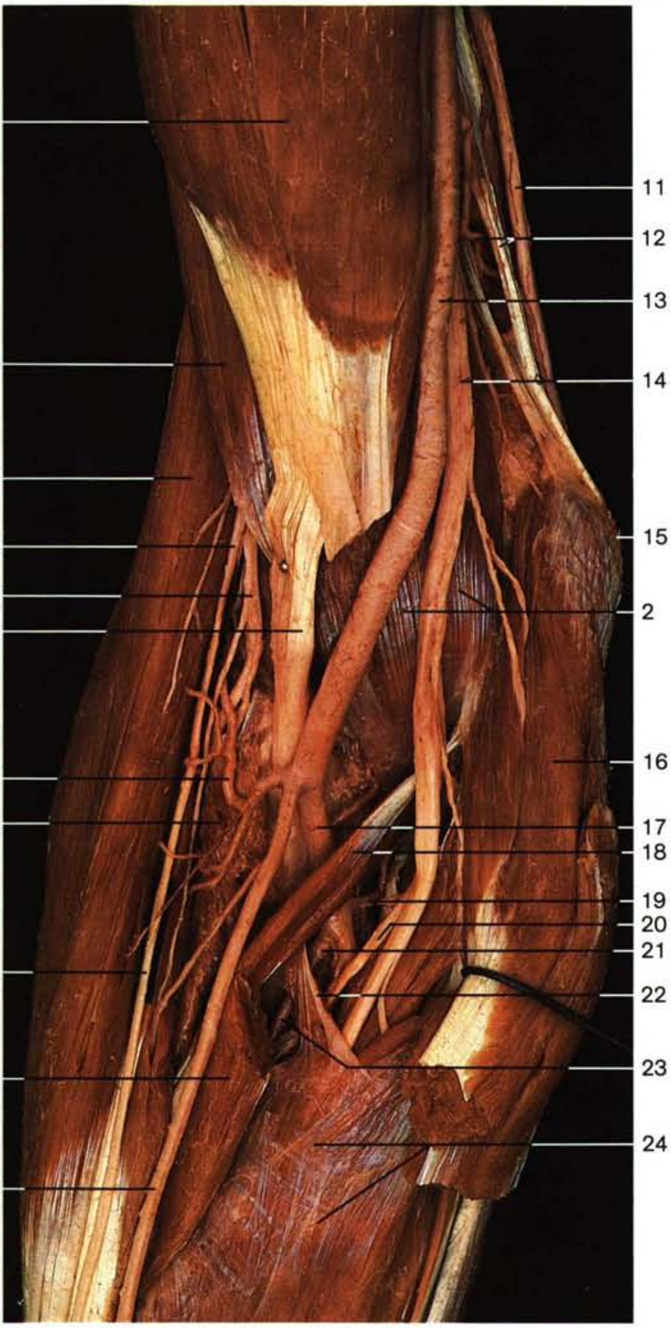

Cubital region, deep layer (anterior aspect). The pronator teres and flexor carpi ulnaris muscles have been cut and reflected.

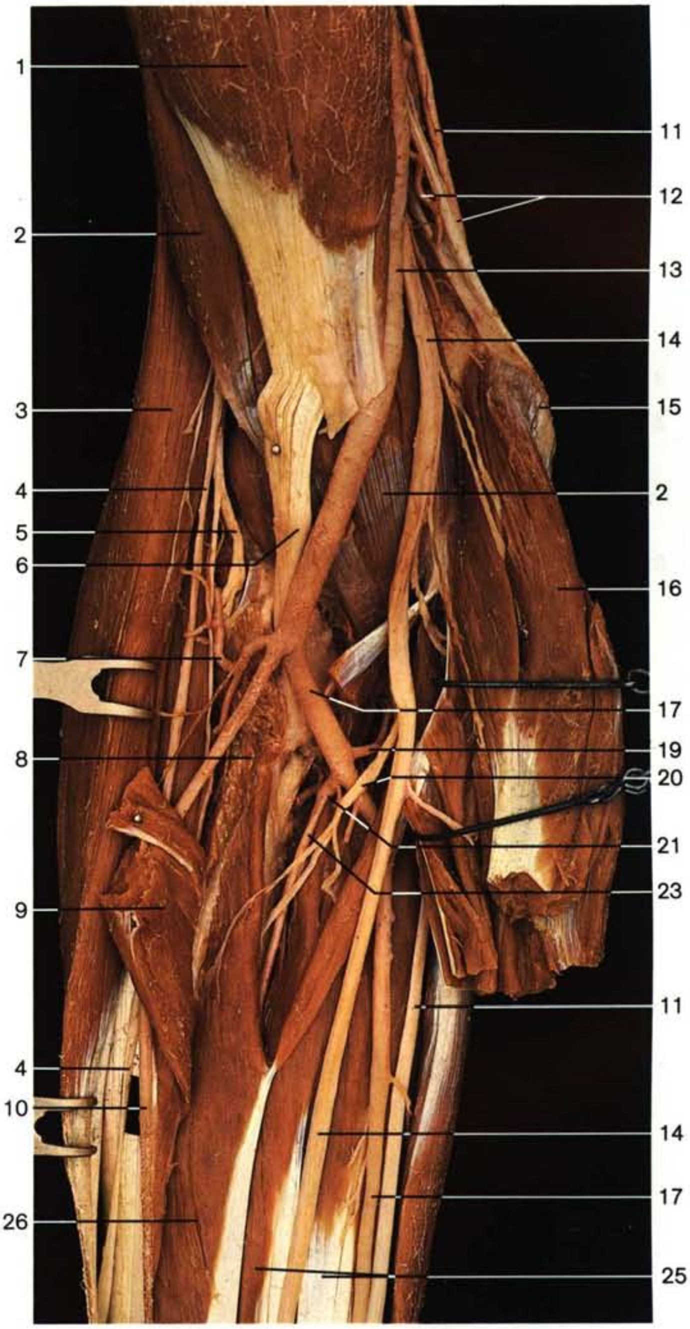

Cubital region, deepest layer (anterior aspect). The flexor digitorum superficialis and the ulnar head of the pronator teres have been cut and reflected.

1 Biceps brachii muscle
2 Brachialis muscle
3 Brachioradialis muscle
4 Superficial branch of radial nerve
5 Deep branch of radial nerve
6 Tendon of biceps brachii muscle
7 **Radial recurrent artery**
8 Supinator muscle
9 Insertion of pronator teres muscle
10 **Radial artery**
11 **Ulnar nerve**
12 Medial intermuscular septum of arm and superior ulnar collateral artery
13 **Brachial artery**
14 **Median nerve**
15 Medial epicondyle of humerus
16 Humeral head of pronator teres muscle
17 **Ulnar artery**
18 Ulnar head of pronator teres muscle
19 **Ulnar recurrent artery**
20 Anterior interosseous nerve
21 Common interosseous artery
22 Tendinous arch of flexor digitorum superficialis muscle
23 Anterior interosseous artery
24 Flexor digitorum superficialis muscle
25 Flexor digitorum profundus muscle
26 Flexor pollicis longus muscle

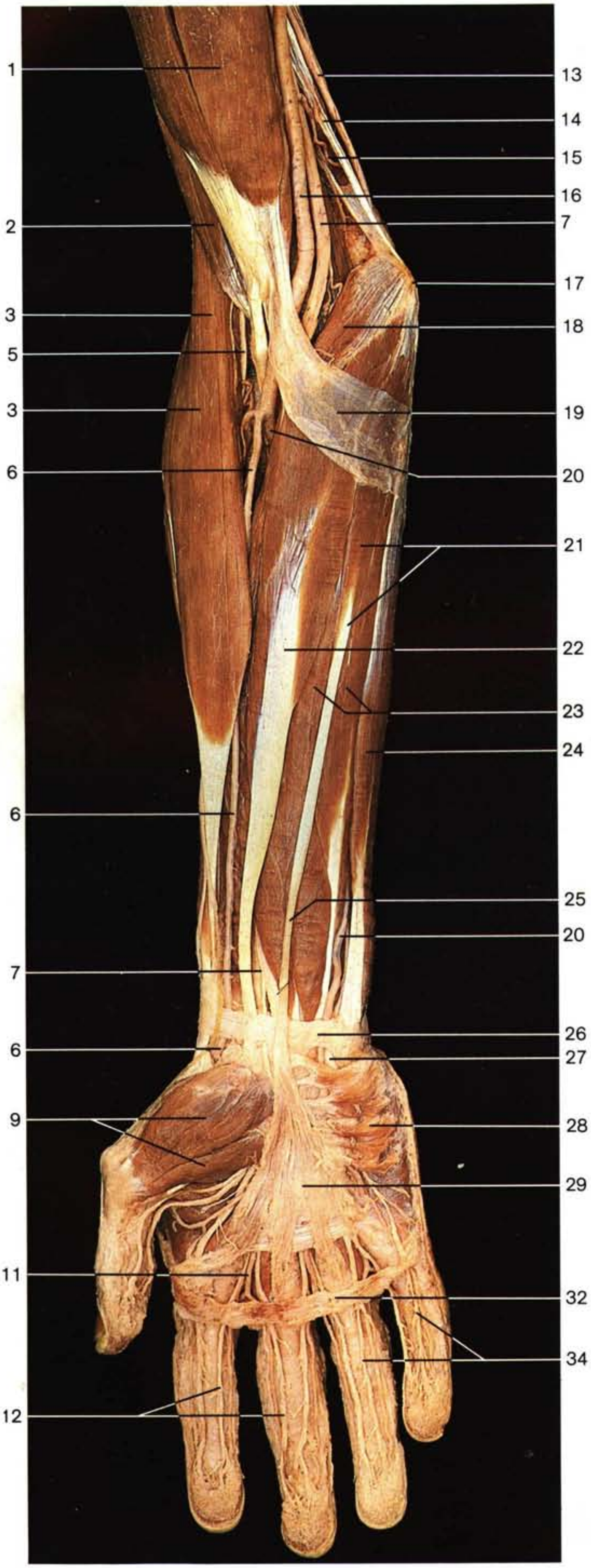
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Vessels and nerves of right forearm and hand, superficial layer (palmar aspect).

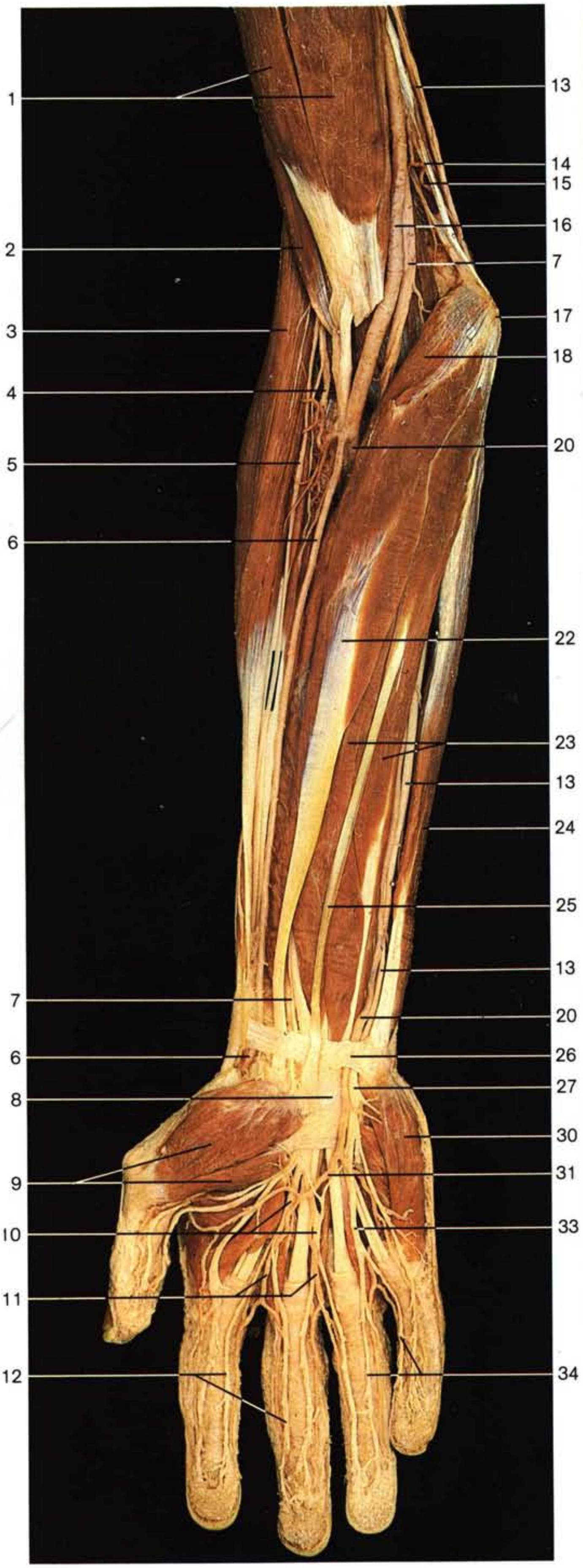
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Vessels and nerves of right forearm and hand, superficial layer (palmar aspect). The palmar aponeurosis of the hand and the bicipital aponeurosis have been removed.

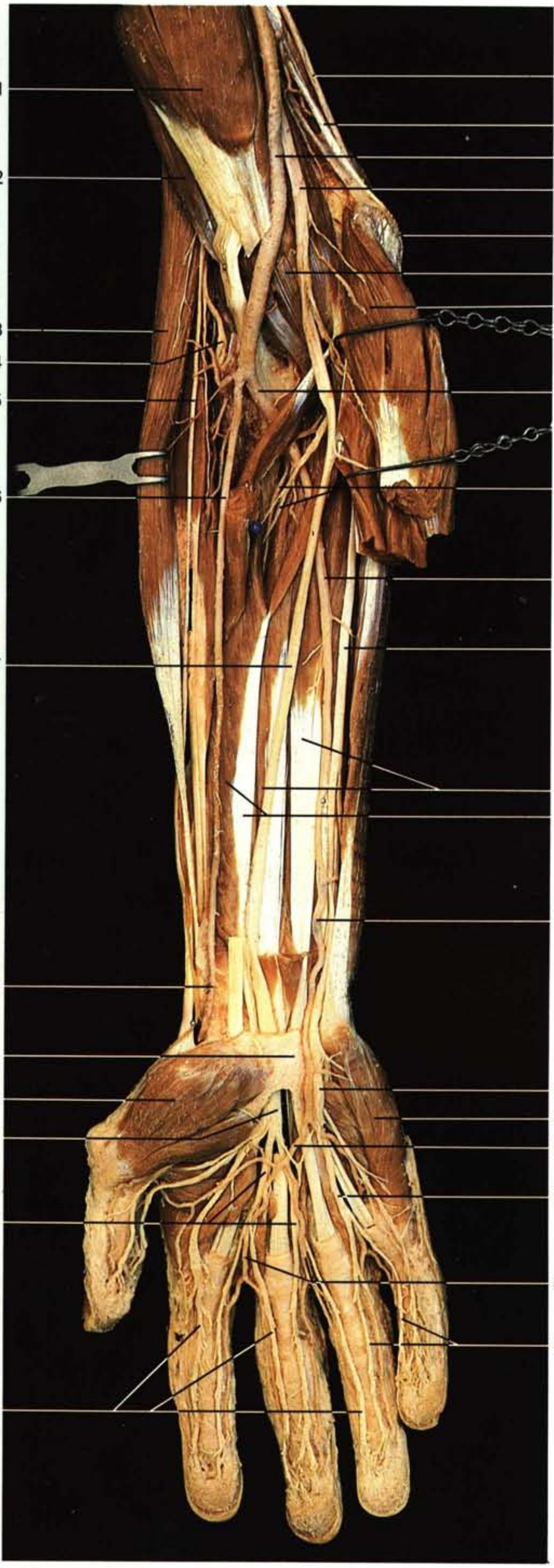

Vessels and nerves of forearm and hand, deep layer (anterior aspect). The superficial layer of the flexor muscles has been removed.

1 Biceps brachii muscle
2 Brachialis muscle
3 Brachioradialis muscle
4 **Deep branch of radial nerve**
5 **Superficial branch of radial nerve**
6 **Radial artery**
7 **Median nerve**
8 Flexor retinaculum
9 Thenar muscles
10 Common palmar digital branches of median nerve
11 Common palmar digital arteries
12 Proper palmar digital nerves (median nerve)
13 **Ulnar nerve**
14 Medial intermuscular septum of arm
15 Superior ulnar collateral artery
16 Brachial artery
17 Medial epicondyle of humerus
18 Pronator teres muscle
19 Bicipital aponeurosis
20 **Ulnar artery**
21 Palmaris longus muscle
22 Flexor carpi radialis muscle
23 Flexor digitorum superficialis muscle
24 Flexor carpi ulnaris muscle
25 Tendon of palmaris longus muscle
26 Remnant of antebrachial fascia
27 Superficial branch of ulnar nerve
28 Palmaris brevis muscle
29 Palmar aponeurosis
30 Hypothenar muscles
31 **Superficial palmar arch**
32 Superficial transverse metacarpal ligament
33 Common palmar digital branch of ulnar nerve
34 Proper palmar digital branches of ulnar nerve
35 Anterior interosseous artery and nerve
36 Flexor digitorum profundus muscle
37 Common palmar digital arteries
38 Palmar branch of median nerve
39 Flexor pollicis longus muscle
40 Palmar branch of ulnar nerve

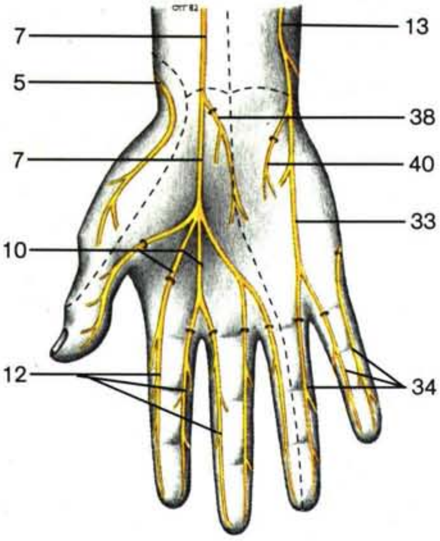

Cutaneous innervation of hand (palmar aspect). (Schematic drawing.)

Cutaneous innervation of palmar surface:
3½ digits by median nerve,
1½ digits by ulnar nerve.

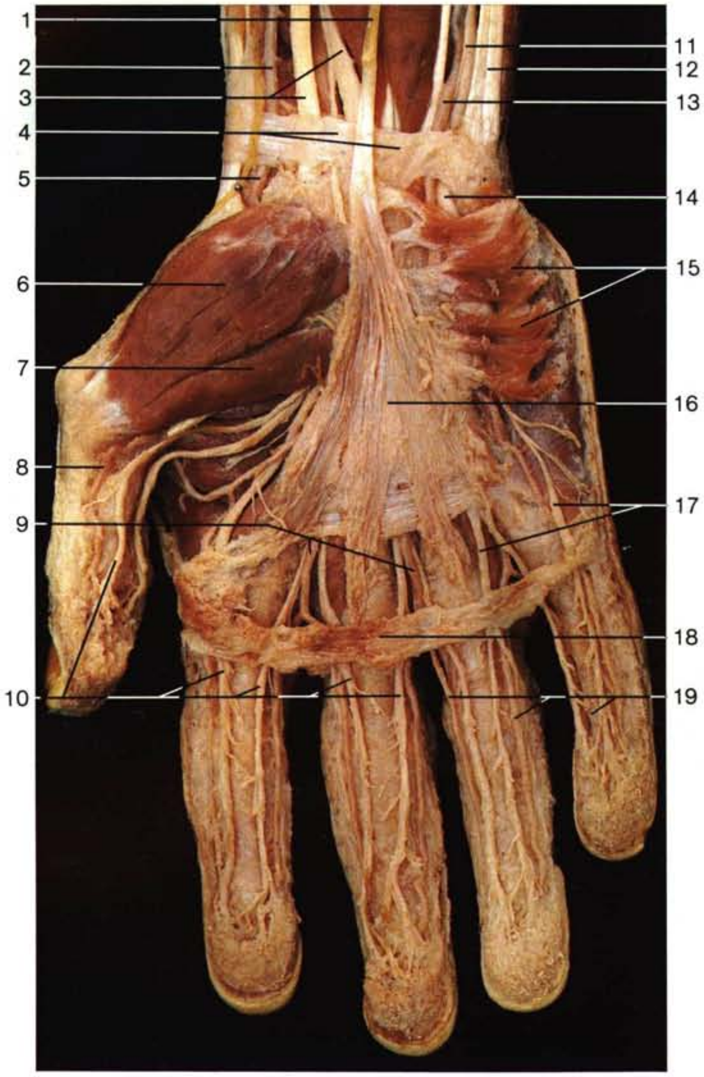

Right hand, superficial layer, dissection of vessels and nerves (palmar aspect).

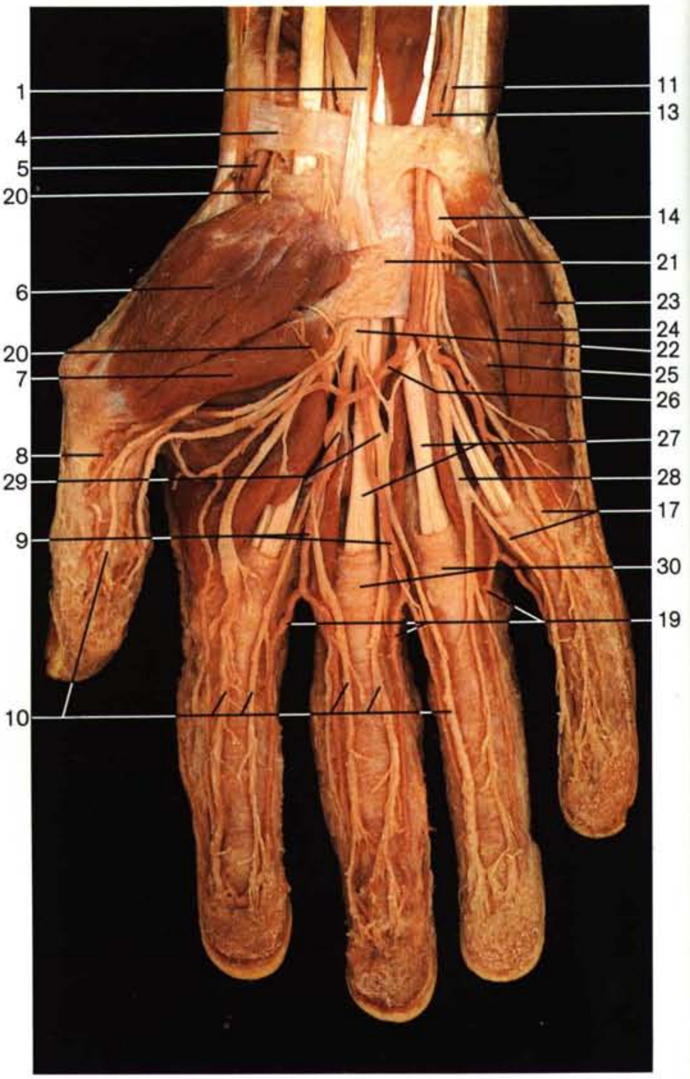

Right hand, superficial layer, dissection of vessels and nerves (palmar aspect). The palmar aponeurosis has been removed to display the superficial palmar arch.

1 Tendon of palmaris longus muscle
2 **Radial artery**
3 Tendon of flexor carpi radialis muscle and median nerve
4 Distal part of antebrachial fascia
5 Radial artery passing into the anatomical snuffbox
6 Abductor pollicis brevis muscle
7 Superficial head of flexor pollicis brevis muscle
8 Palmar digital artery of thumb
9 Common palmar digital arteries
10 Proper palmar digital nerves (median nerve)
11 **Ulmar nerve**
12 Tendon of flexor carpi ulnaris muscle
13 **Ulnar artery**
14 Superficial branch of ulnar nerve
15 Palmaris brevis muscle
16 Palmar aponeurosis
17 Palmar digital nerves (ulnar nerve)
18 Superficial transverse metacarpal ligament
19 Proper palmar digital arteries
20 Superficial palmar branch of radial artery (contributing to the superficial palmar arch)
21 Flexor retinaculum
22 **Median nerve**
23 Abductor digiti minimi muscle
24 Flexor digiti minimi brevis muscle
25 Opponens digiti minimi muscle
26 **Superficial palmar arch**
27 Tendons of flexor digitorum superficialis muscle
28 Common palmar digital branch of ulnar nerve
29 Common palmar digital branch of median nerve
30 Fibrous sheath of flexor tendons

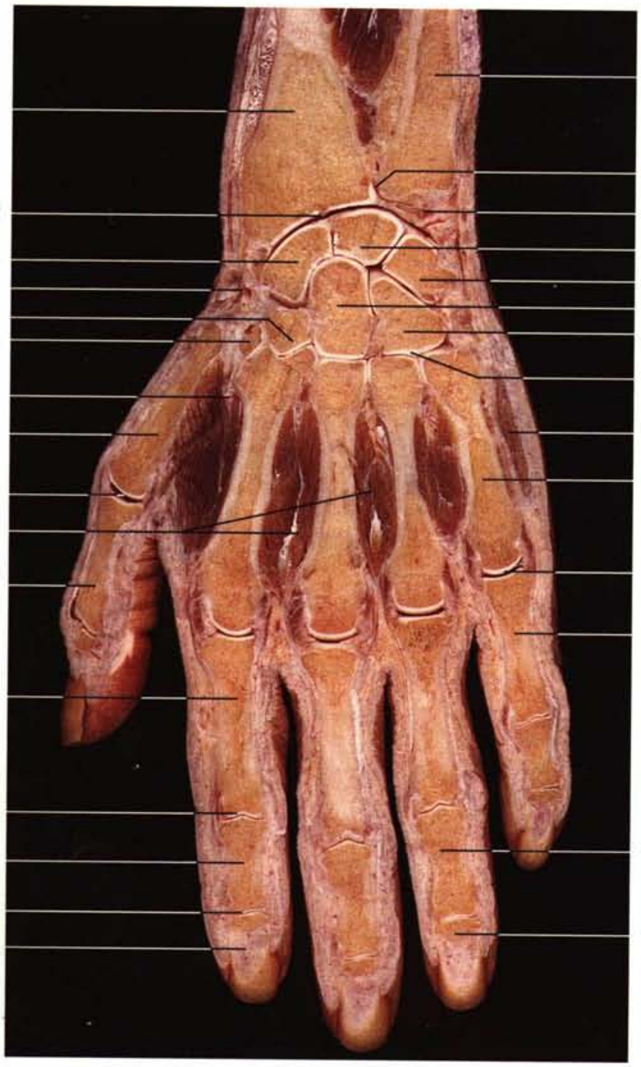
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Coronal section through the right hand (palmar aspect).

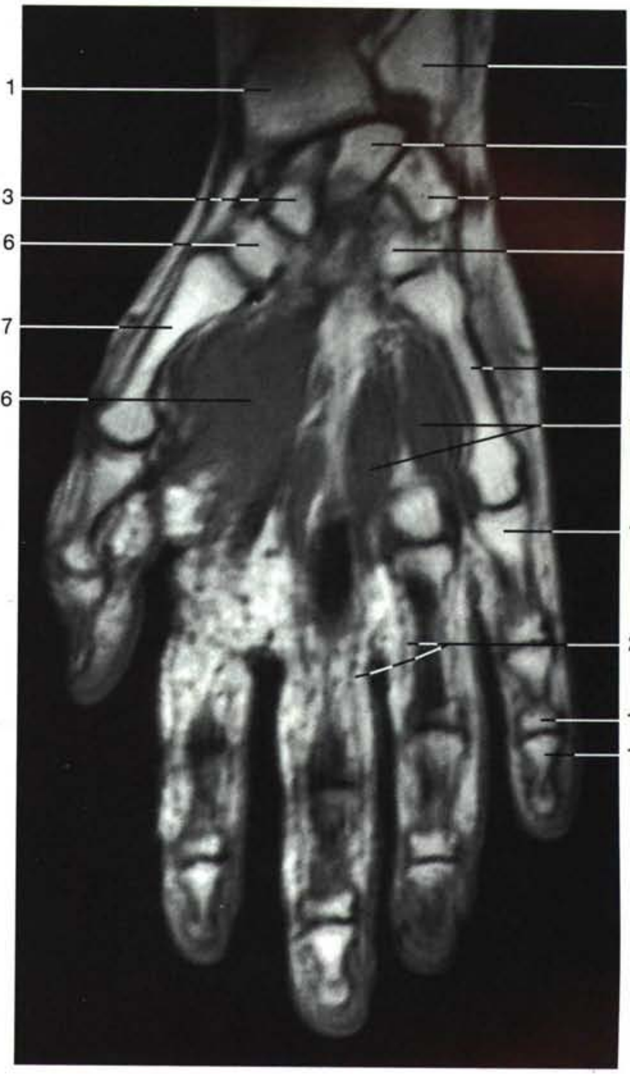
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Coronal section through the right hand (palmar aspect) (MR-Scan, courtesy of Dr. A. Heuck, Munich).

1 Radius
2 **Radiocarpal articulation**
3 **Scaphoid** (navicular) **bone**
4 **Radial artery**
5 Trapezoid bone
6 **Trapezium bone**
7 First metacarpal bone
8 Metacarpophalangeal articulation of thumb
9 Interosseous muscles
10 Proximal phalanx of thumb
11 Proximal phalanx of fingers
12 Interphalangeal articulations
13 Middle phalanx
14 Distal phalanx
15 **Ulna**
16 Distal radioulnar articulation
17 Articular disk
18 **Lunate bone**
19 **Triangular bone**
20 **Capitate bone**
21 **Hamate bone**
22 Carpometacarpal articulations
23 Abductor digiti minimi muscle
24 Fifth metacarpal bone
25 Metacarpophalangeal articulation
26 Adductor pollicis muscle
27 Proper palmar digital arteries

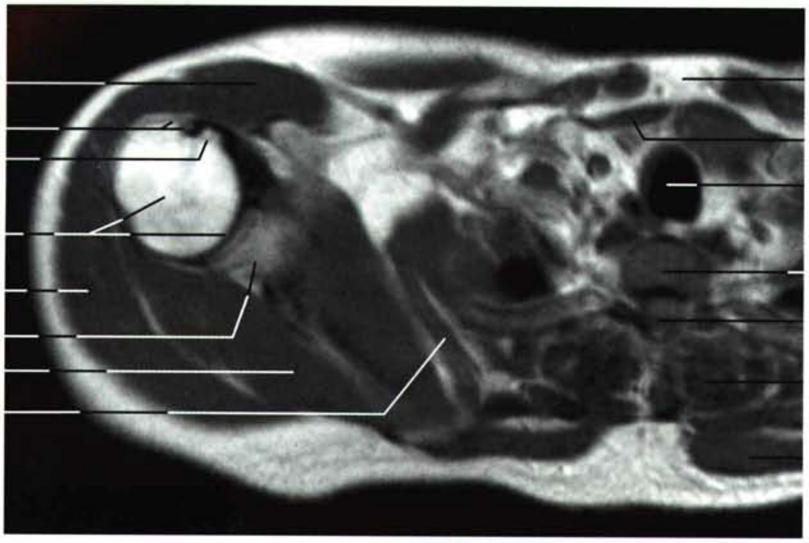
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Horizontal section through shoulder joint (section 1; MR-Image; inferior aspect).

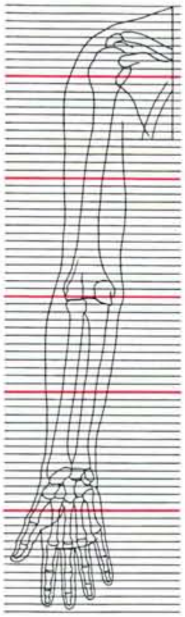

Upper extremity, location of sections 1–5 (MR-Scans, courtesy of Dr. A. Heuck, Munich).

1 Pectoralis major muscle
2 Greater tubercle and tendon of biceps muscle
3 Lesser tubercle
4 Head of humerus and articular cavity of shoulder joint
5 Deltoid muscle
6 Scapula
7 Infraspinatus muscle
8 Serratus anterior muscle
9 Sternum
10 Infrahyoid muscles
11 Trachea
12 Body of thoracic vertebra
13 Vertebral canal and spinal cord
14 Deep muscles of the back
15 Trapezius muscle
16 Brachialis muscle
17 Radial nerve and profunda brachii vessels

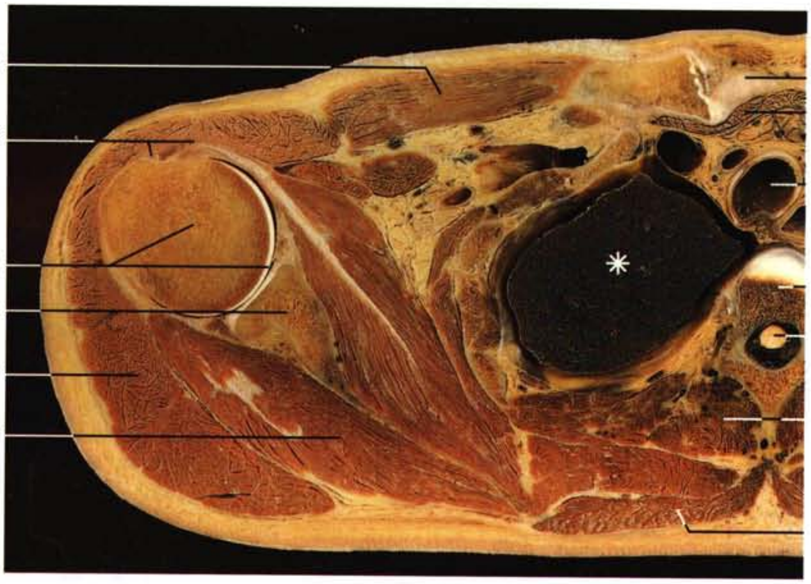
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Horizontal section through the right shoulder at the level of T_1 (section 1; inferior aspect). * = Upper lobe of lung.

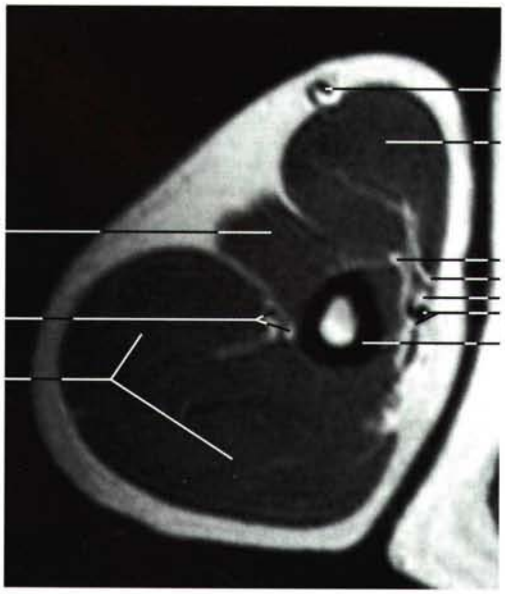
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Axial section through the middle of the right arm (section 2; MR-Image, inferior aspect).

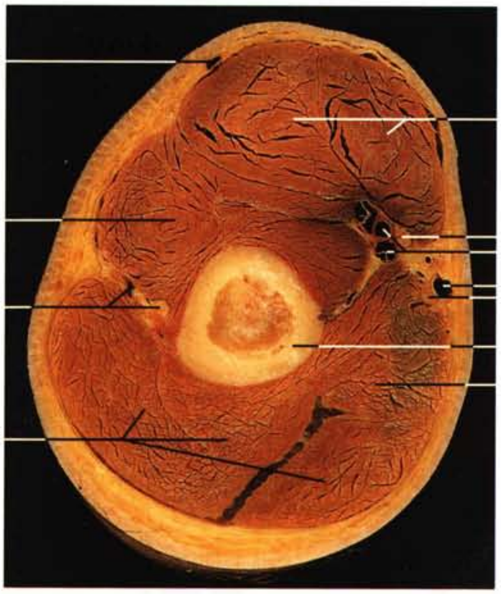
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Axial section through the middle of the right arm (section 2; inferior aspect).

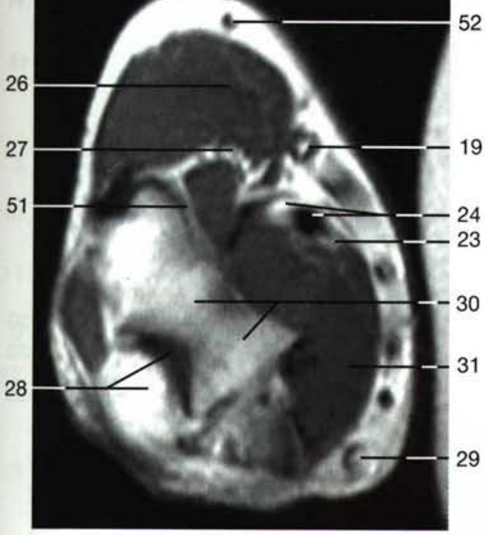

Axial section through the elbow joint (section 3; MR-Image; inferior aspect).

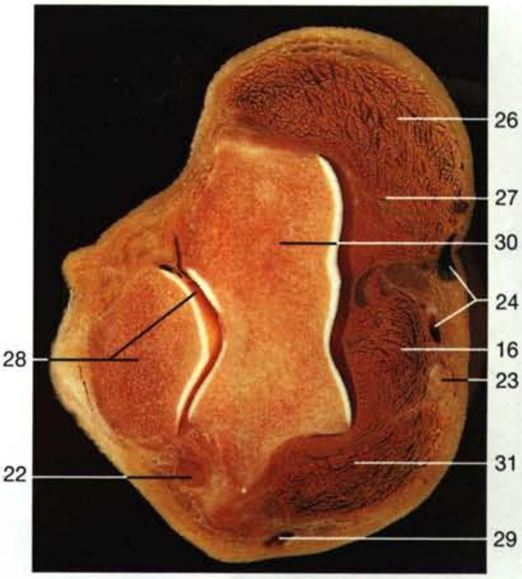

Axial section through the right elbow joint (section 3; inferior aspect).

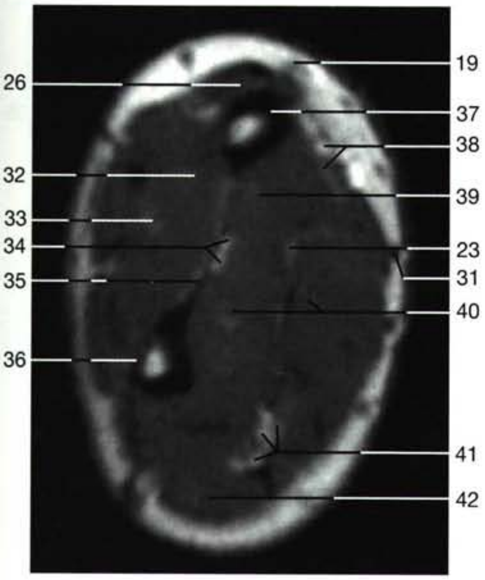

Axial section through the middle of the forearm (section 4; MR-Image; inferior aspect).

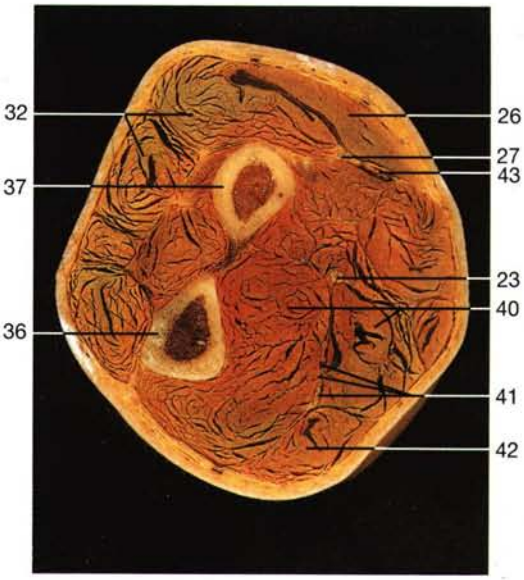

Axial section through the right forearm (section 4; inferior aspect).

18	Triceps brachii muscle
19	Cephalic vein
20	Biceps brachii muscle
21	Musculocutaneous nerve
22	**Ulnar nerve**
23	**Medianus nerve**
24	Brachial artery and vein
25	Shaft of humerus
26	Brachioradialis muscle
27	**Radial nerve**
28	Olecranon and articular cavity of elbow joint
29	Basilic vein
30	Humerus
31	Pronator teres muscle
32	Extensor muscles of forearm
33	Ramus profundus of radialis nerve
34	Anterior interosseus vessels and nerve
35	Interosseous membrane
36	Ulna
37	Radius
38	Radial artery and superficial branch of radial nerve
39	Flexor pollicis longus muscle
40	Flexor digitorum superficialis and profundus muscles
41	Ulnar nerve, ulnar artery and vein
42	Flexor carpi ulnaris muscle
43	Radial artery
44	Metacarpal bones III and IV
45	**Carpal canal** with tendons of flexor digitorum muscles
46	Hypothenar muscle
47	Median nerve
48	Interosseus muscles
49	First metacarpal bone
50	Thenar muscles
51	Articular cavity of humeroradial joint
52	Median cubital vein

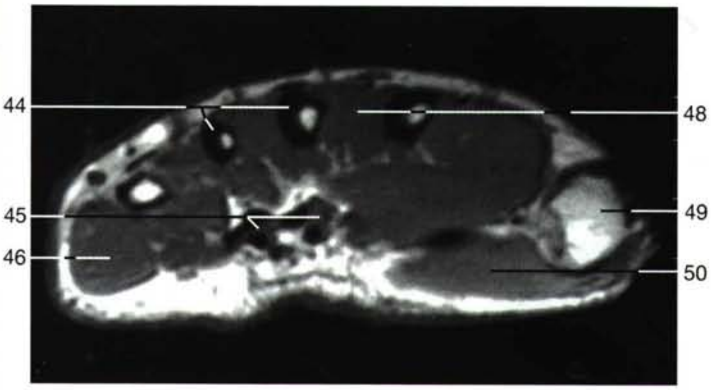

Axial section through the right hand (metacarpus; MR-Image; section 5; inferior aspect).

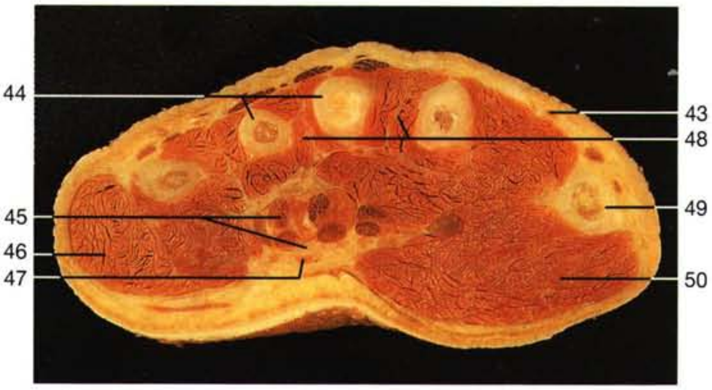

Axial section through the right hand at the level of the metacarpus (section 5; inferior aspect).

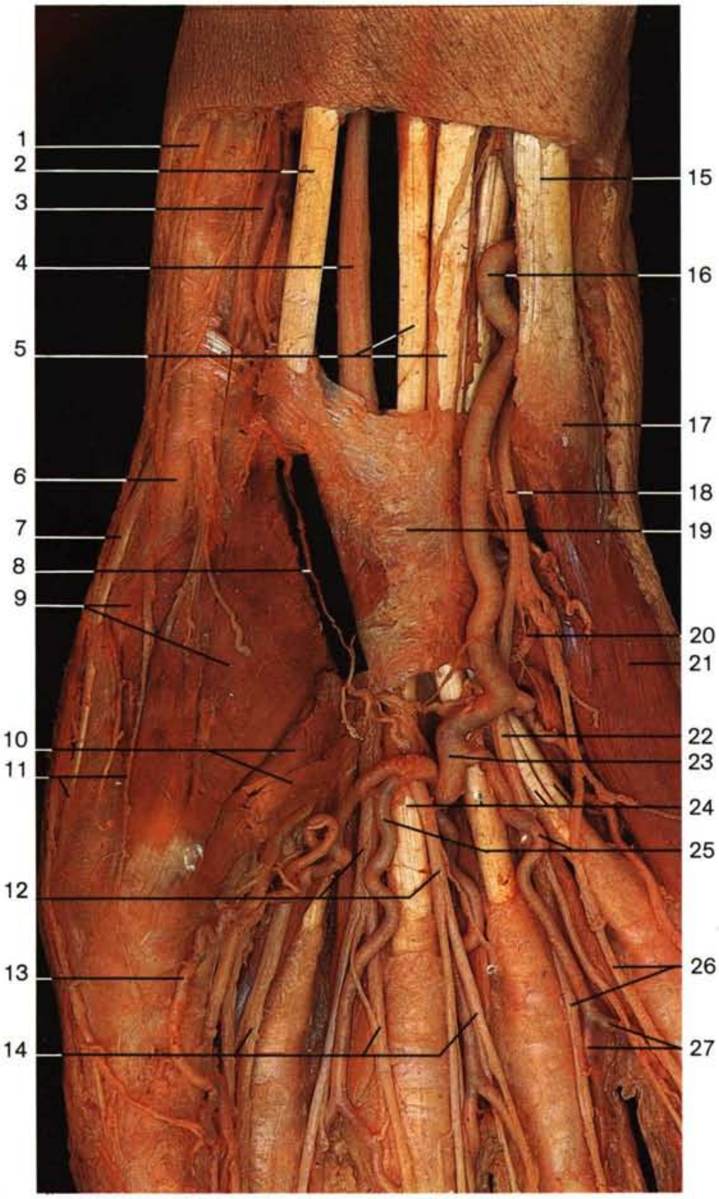
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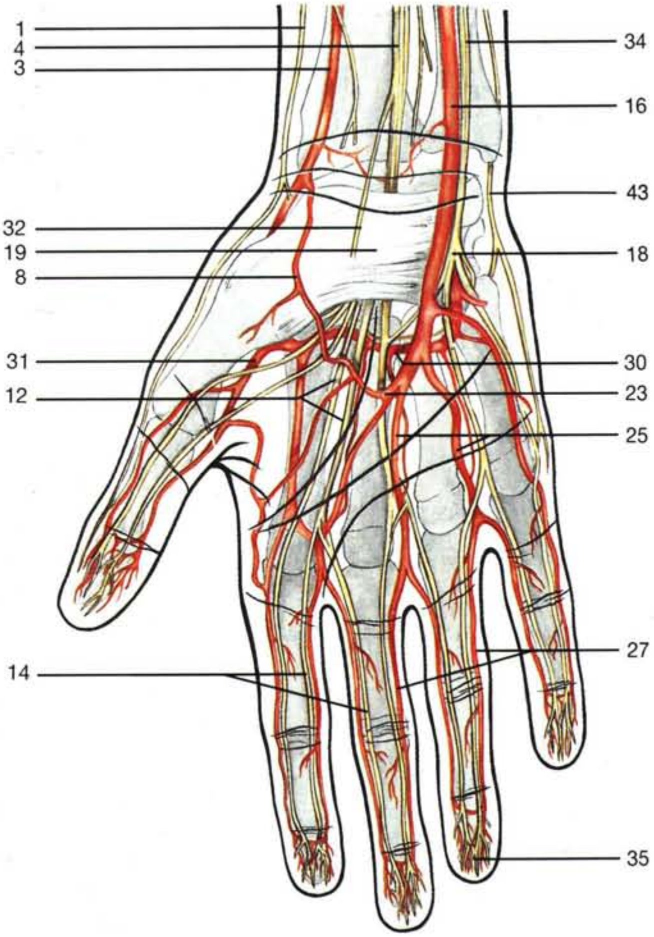
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Arteries and nerves of the right hand (palmar aspect). (Schematic drawing.)

◁

Right hand, superficial layer (palmar aspect). Dissection of the superficial palmar arch.

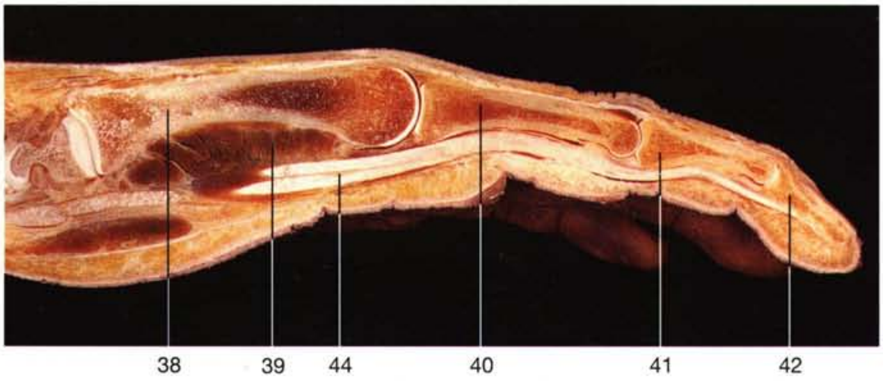
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Longitudinal section through the hand at the level of the third finger

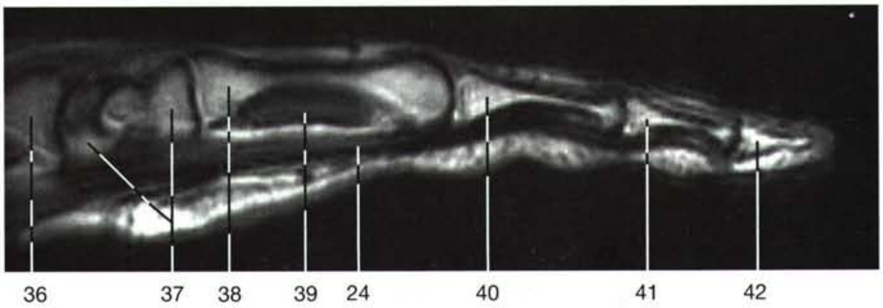
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Longitudinal section through the hand at the level of the third finger (MR-Scan, courtesy of Dr. A. Heuck, Munich).

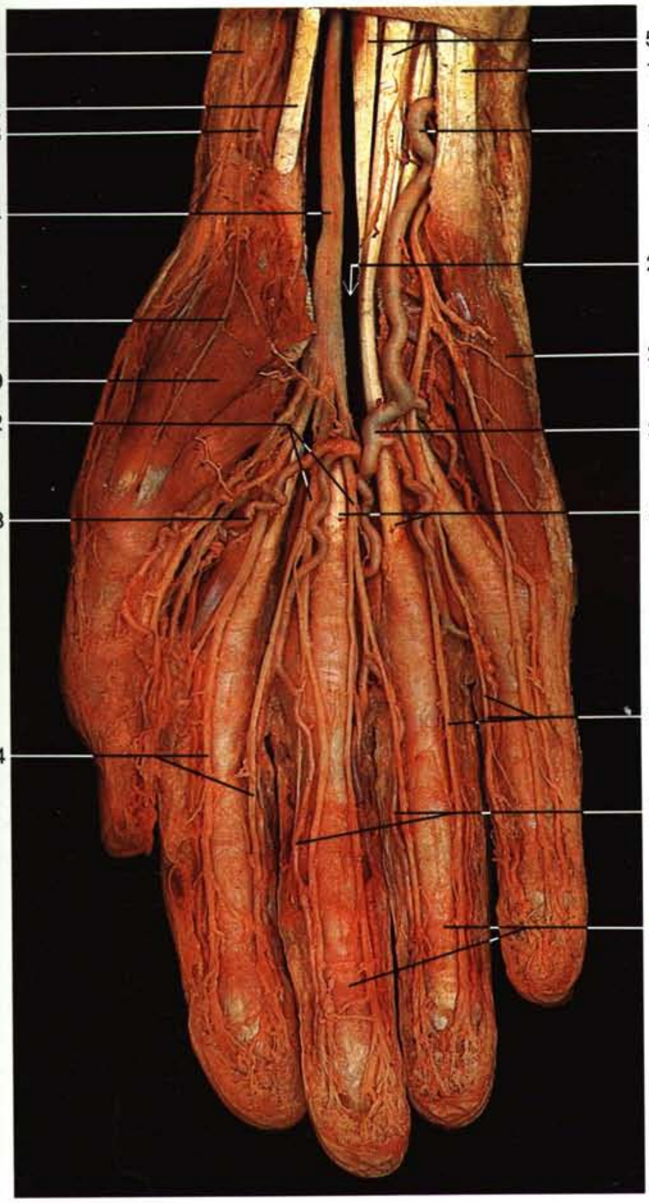

Right hand, middle layer (palmar aspect). The flexor retinaculum has been removed.

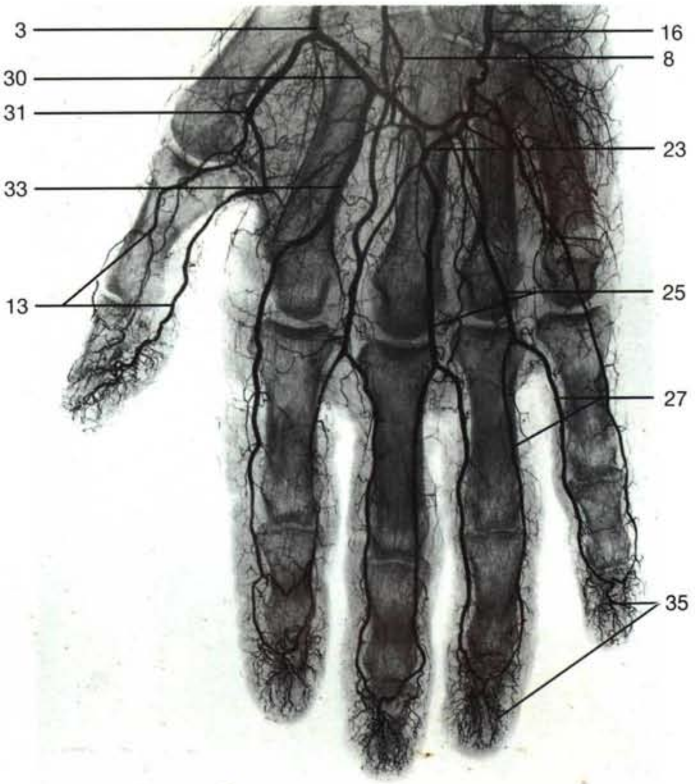

Arteriogram of the right hand (palmar aspect).

1 Superficial branch of radial nerve
2 Tendon of flexor carpi radialis muscle
3 **Radial artery**
4 **Median nerve**
5 Tendon of flexor digitorum superficialis muscle
6 Tendon of abductor pollicis longus muscle
7 Tendon of extensor pollicis brevis muscle
8 Superficial palmar branch of radial artery
9 Abductor pollicis brevis muscle
10 Superficial head of flexor pollicis brevis muscle
11 Terminal branches of superficial branch of radial nerve
12 Common palmar digital nerves (median nerve)
13 Proper palmar digital arteries of thumb
14 Proper palmar digital nerves (median nerve)
15 Tendon of flexor carpi ulnaris muscle
16 **Ulnar artery**
17 Position of pisiform bone
18 Superficial branch of ulnar nerve
19 Flexor retinaculum
20 Deep branch of ulnar nerve
21 Abductor digiti minimi muscle
22 Common palmar digital nerves (ulnar nerve)
23 **Superficial palmar arch**
24 Tendons of flexor digitorum muscles
25 Common palmar digital arteries
26 **Palmar digital nerves (ulnar nerve)**
27 **Proper palmar digital arteries**
28 **Carpal tunnel**
29 Fibrous sheaths for the tendons of flexor digitorum muscles
30 **Deep palmar arch**
31 Princeps pollicis artery
32 Palmar branch of median nerve
33 Common digital palmar artery
34 Ulnar nerve
35 Capillary network of finger
36 Radius
37 Carpal bones
38 Metacarpal bone
39 Interosseus muscles
40 Proximal phalanx
41 Middle phalanx
42 Distal phalanx
43 Dorsal branch of ulnar nerve
44 Tendons of flexor digitorum profundus (upper) and superficialis (lower) muscles

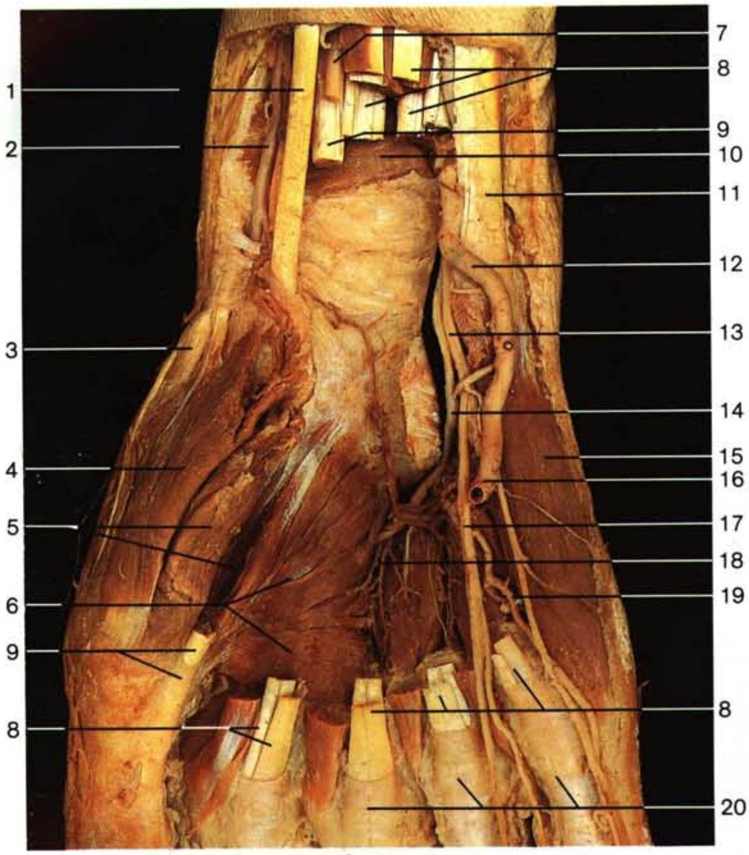

Right hand, deep layer (palmar aspect). The carpal tunnel has been opened, the tendons of the flexor muscles have been removed and the superficial palmar arch has been cut.

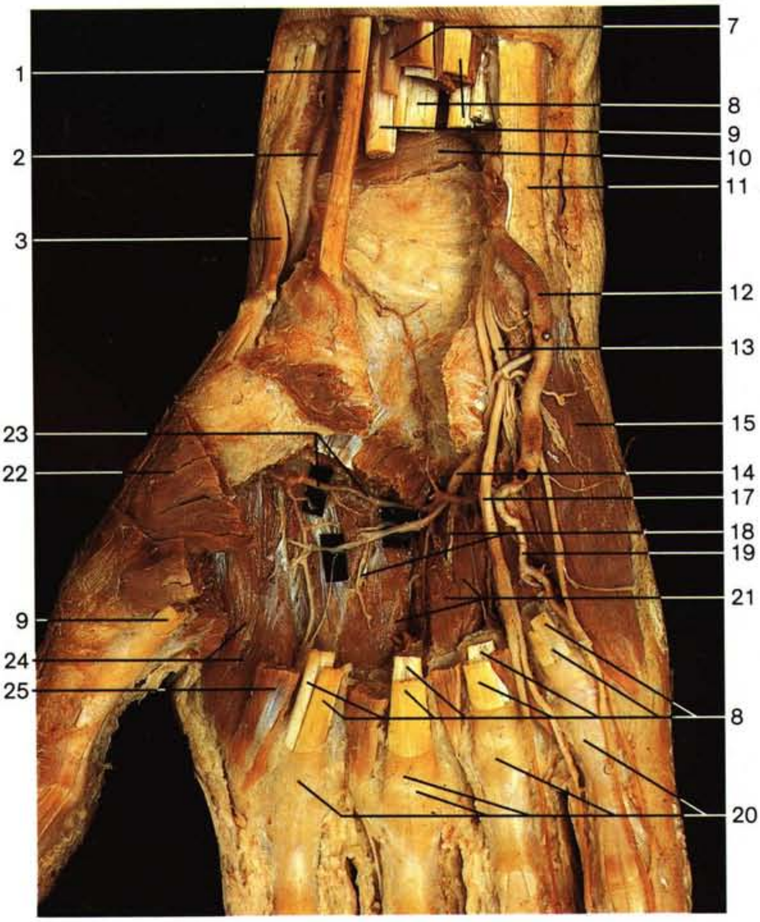

Right hand, deep layer (palmar aspect). Dissection of the deep palmar arch.

1 Tendon of flexor carpi radialis muscle
2 Radial artery
3 Tendon of abductor pollicis longus muscle
4 Abductor pollicis brevis muscle
5 Superficial and deep heads of flexor pollicis brevis muscle
6 Oblique and transverse heads of adductor pollicis muscle
7 Median nerve
8 Tendons of flexor digitorum superficialis and profundus muscles
9 Tendon of flexor pollicis longus muscle
10 Pronator quadratus muscle
11 Tendon of flexor carpi ulnaris muscle
12 Ulnar artery
13 Superficial branch of ulnar nerve
14 Deep branch of ulnar nerve
15 Abductor digiti minimi muscle
16 **Superficial palmar arch** (cut end)
17 Common palmar digital nerves (ulnar nerve)
18 Palmar metacarpal arteries of deep palmar arch
19 Palmar digital artery of the 5th finger
20 Fibrous sheaths of tendons of flexor muscles
21 Palmar interosseous muscles
22 Opponens pollicis muscle (cut)
23 **Deep palmar arch**
24 1st dorsal interosseous muscle
25 1st lumbrical muscle

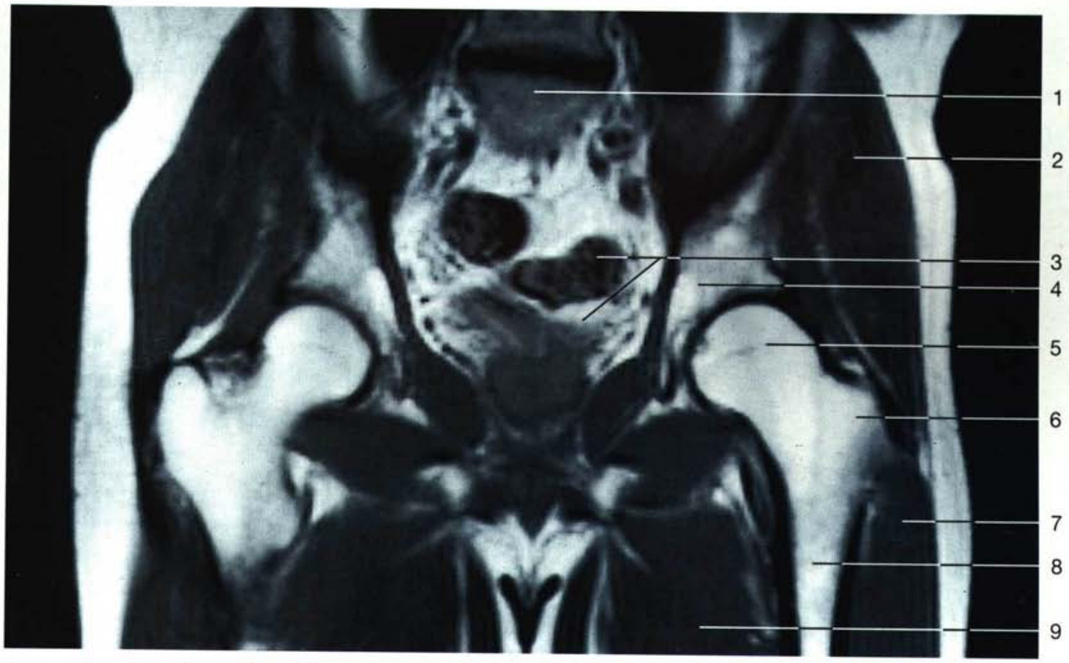

Coronal section through pelvis and thighs (MR-Scan of the male, courtesy of Dr. A. Heuck, Munich).

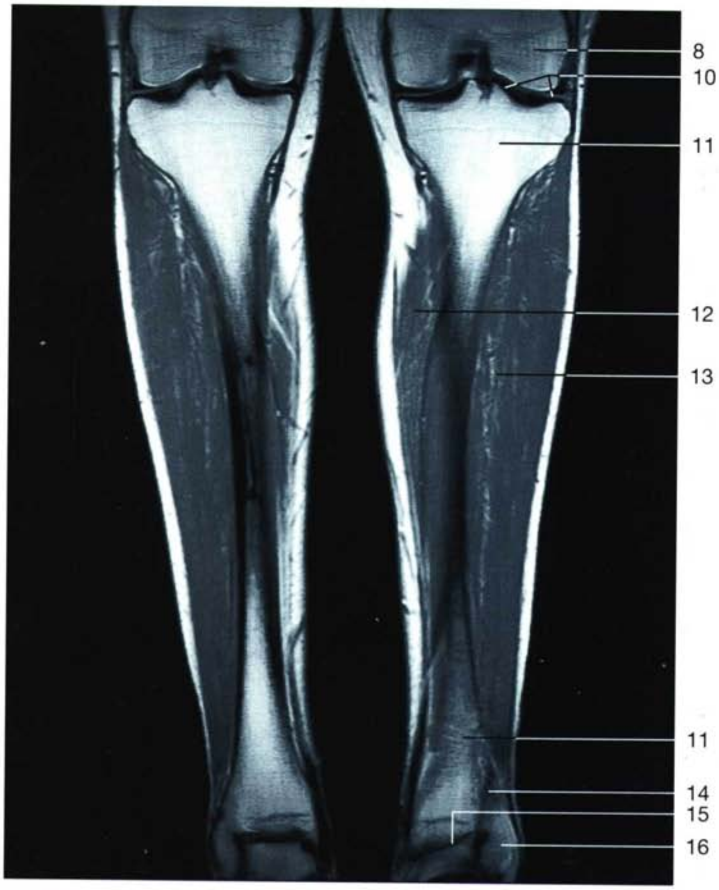

Coronal section through the legs (MR-Scan, courtesy of Dr. A. Heuck, Munich).

1	Sacral promontory
2	Gluteus medius muscle
3	Small intestine and urinary bladder
4	Acetabulum
5	**Head of femur**
6	Greater trochanter of femur
7	Vastus lateralis muscle
8	**Femur**
9	Adductor muscles
10	**Knee joint** with menisci
11	**Tibia**
12	Soleus muscle
13	Tibialis anterior muscle
14	Distal tibiofibular articulation
15	**Talocrural articulation**
16	Fibula (lateral malleolus)

The lower limb (extremity) is specialized for support of the upright posture, locomotion and maintaining balance. In contrast to the upper limb, the lower limb is more restricted in its movements, and the joints are more tight and fixed by strong ligaments. The hip joint is a ball and socket type of synovial joint between head of femur and acetabulum. The knee joint is a hinge type of synovial joint that permits only limited rotation. The talocrural joint is a hinge joint between talus, fibula, and tibia only allowing movements of flexion and extension.
The long axis of the foot is at right angle to that of the leg, thus, forming an effective arch for the upright stance of man.

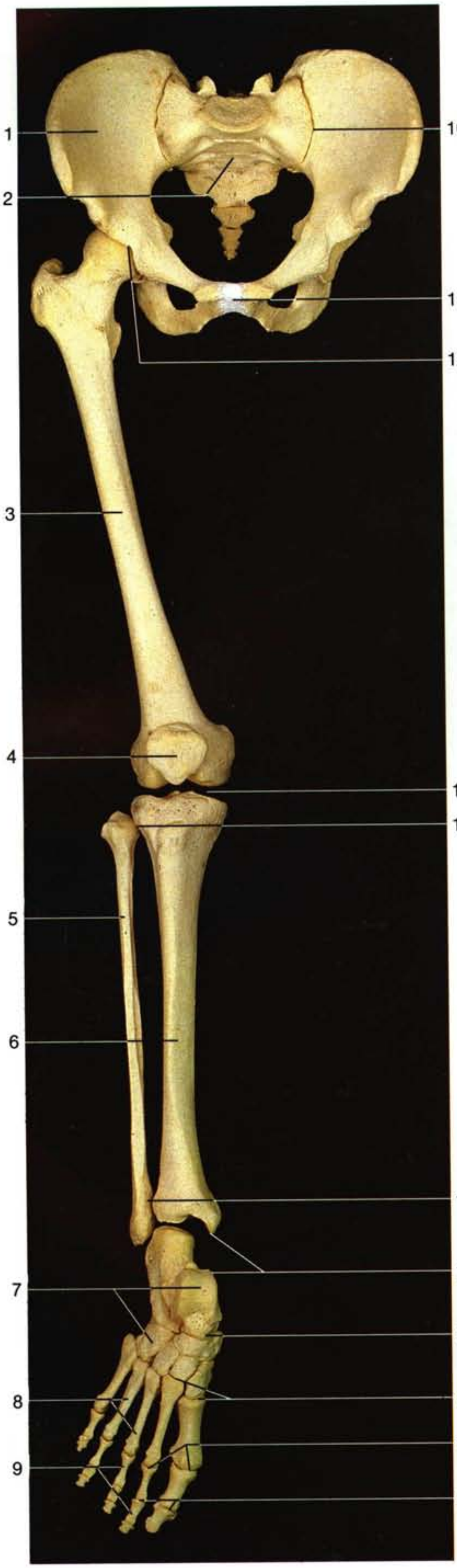

Skeleton of pelvic girdle and lower limb (anterior aspect). The talocrural joint has been dislocated.

A	Pelvic girdle
B	Thigh
C	Leg
D	Foot
1	Right hip bone
2	Sacrum
3	Femur
4	Patella
5	Fibula
6	Tibia
7	Tarsal bones
8	Metatarsal bones
9	Phalanges
10	Sacroiliac joint
11	Pubic symphysis
12	Hip joint
13	Knee joint
14	Proximal tibiofibular joint
15	Distal tibiofibular joint
16	Talocrural joint
17	Talocalcaneonavicular joint
18	Tarsometatarsal joints
19	Metatarsophalangeal joints
20	Interphalangeal joints

The pelvic girdle is firmly connected to the vertebral column at the sacroiliac joint. Therefore the body can be kept upright more easily even if only one limb is used for support (as in walking). The mobility of the lower limb is more limited than that of the upper limb.

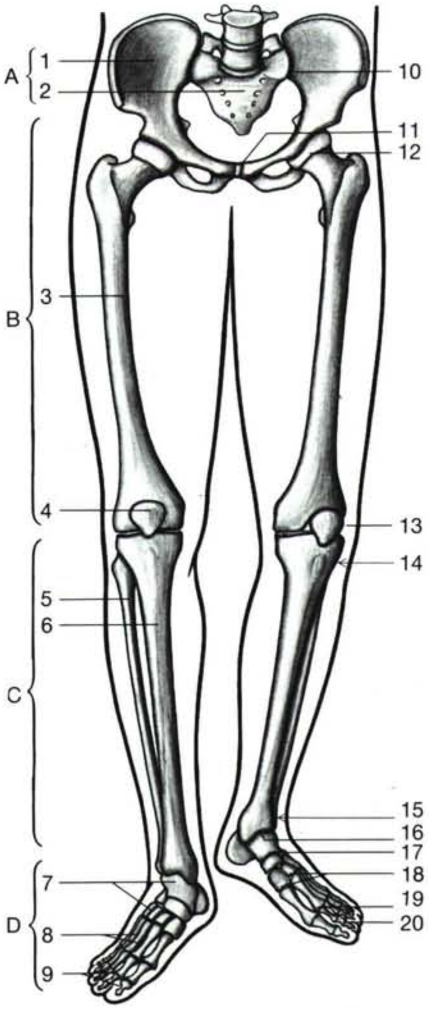

Organization of pelvic girdle and lower limb.

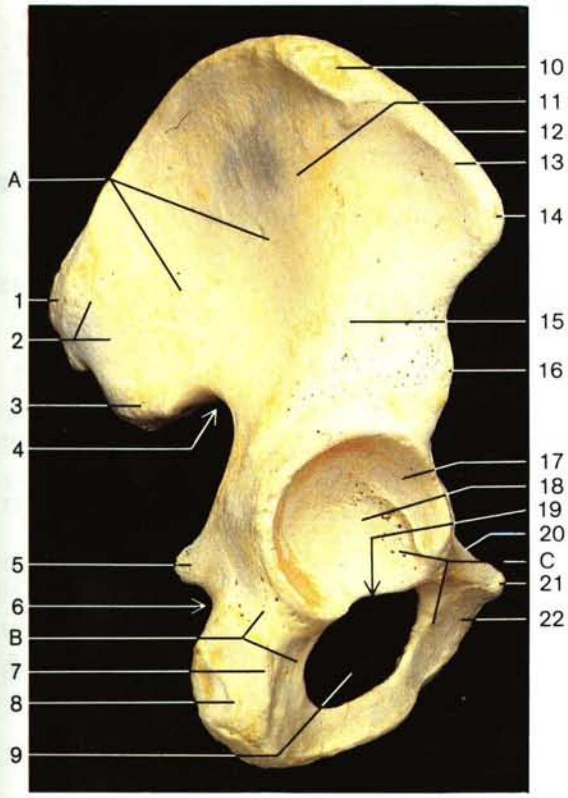

Right hip bone (lateral aspect).

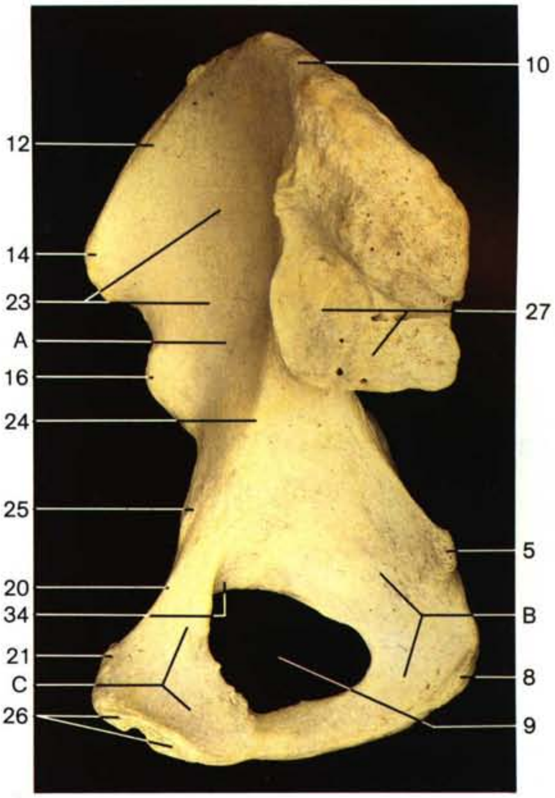

Right hip bone (medial aspect).

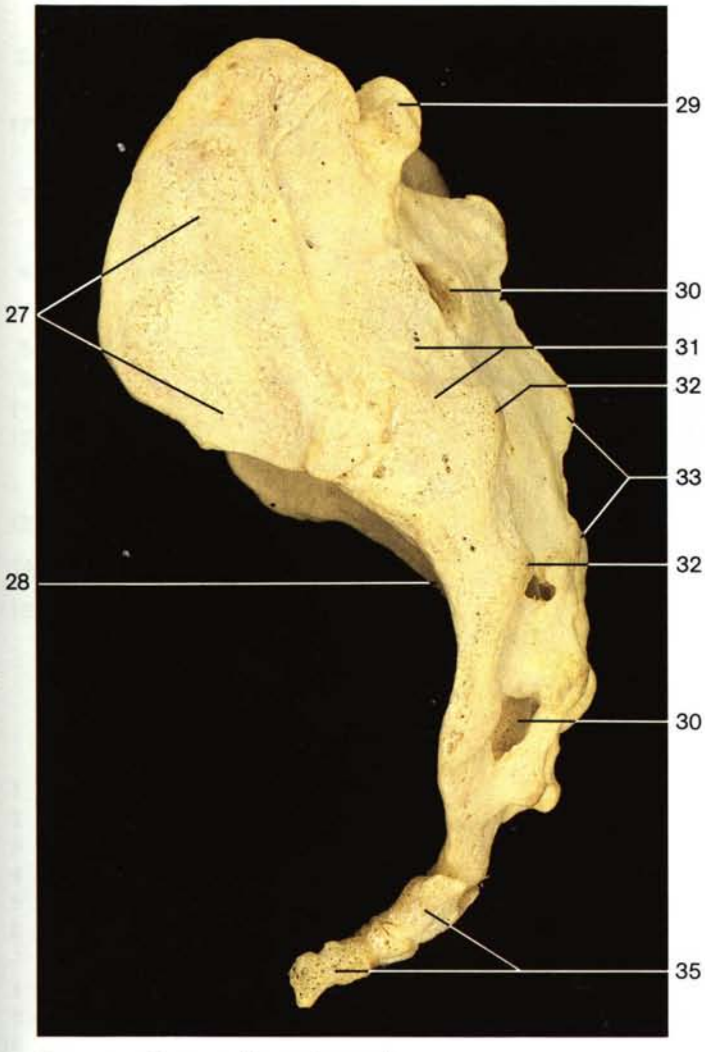

Sacrum and coccyx (lateral aspect).

A	Ilium
B	Ischium
C	Pubis
1	Posterior superior iliac spine
2	Posterior gluteal line
3	Posterior inferior iliac spine
4	Greater sciatic notch
5	Ischial spine
6	Lesser sciatic notch
7	Body of ischium
8	Ischial tuberosity
9	Obturator foramen
10	Iliac crest
11	Anterior gluteal line
12	Internal lip of iliac crest
13	External lip of iliac crest
14	Anterior superior iliac spine
15	Inferior gluteal line
16	Anterior inferior iliac spine
17	Lunate surface of acetabulum
18	Acetabular fossa
19	Acetabular notch
20	Pecten pubis
21	Pubic tubercle
22	Body of pubis
23	Iliac fossa
24	Arcuate line
25	Iliopubic eminence
26	Articular surface of pubis
27	Auricular surface of sacrum
28	Pelvic surface of sacrum
29	Superior articular process of sacrum
30	Dorsal sacral foramina
31	Sacral tuberosity
32	Lateral sacral crest
33	Median sacral crest
34	Obturator groove
35	Coccyx

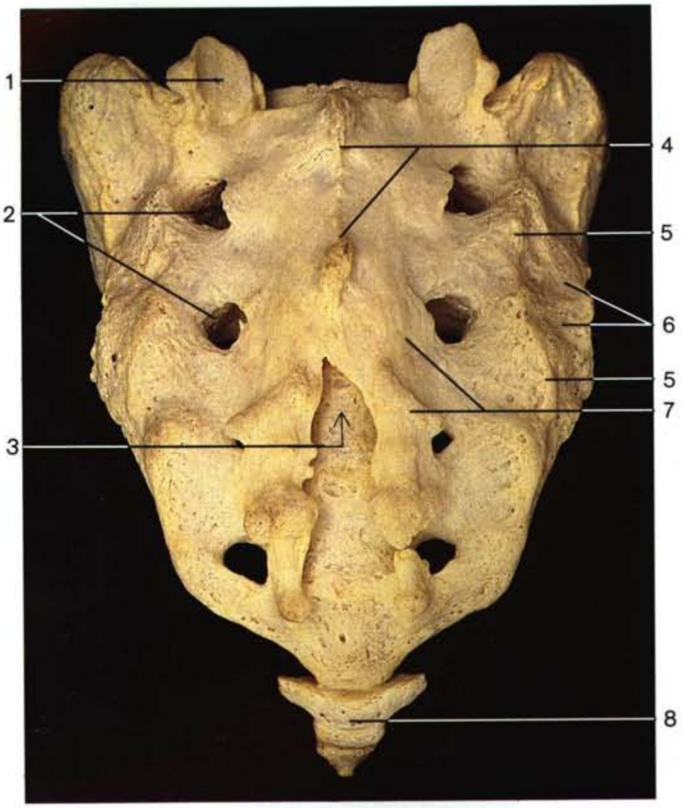

Sacrum (posterior aspect).

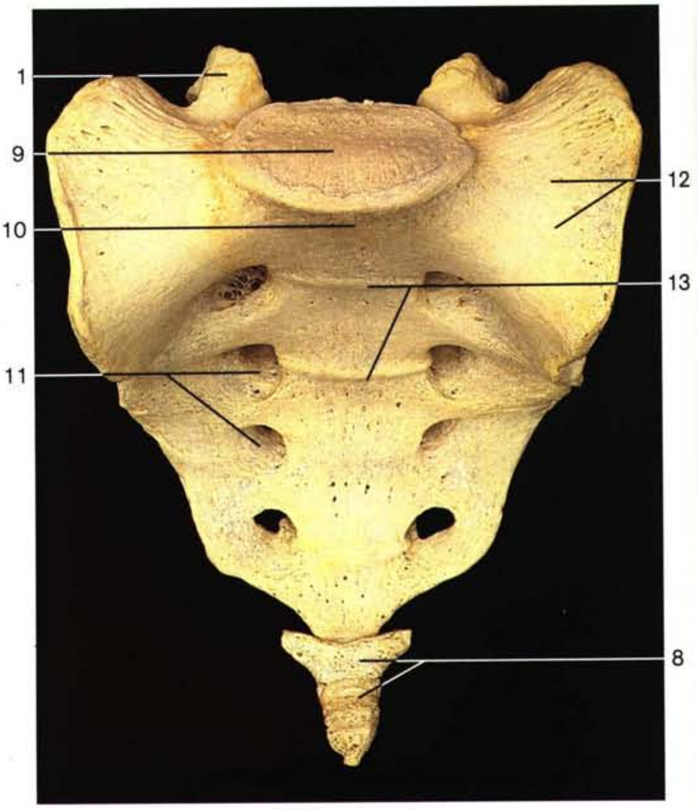

Sacrum (anterior aspect).

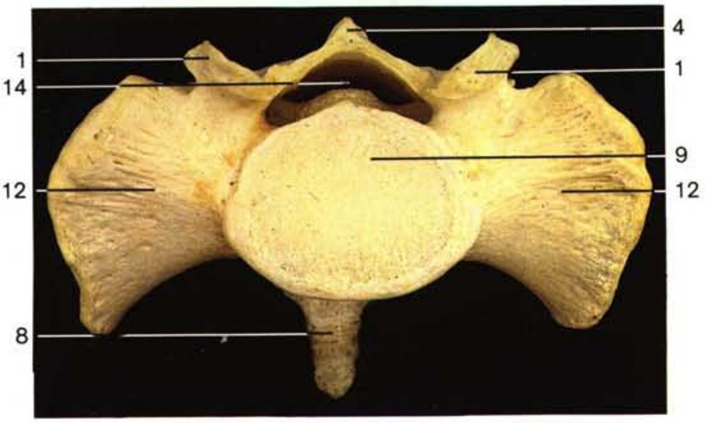

Sacrum (superior aspect).

1 Superior articular process of sacrum
2 Dorsal sacral foramina
3 Sacral hiatus
4 Median sacral crest
5 Lateral sacral crest
6 Sacral tuberosity
7 Intermediate sacral crest
8 Coccyx
9 Base of sacrum
10 Sacral promontory
11 Anterior sacral foramina
12 Lateral part of sacrum (ala)
13 Transverse line of sacrum
14 Sacral canal
15 Linea terminalis
16 True conjugate
17 Diagonal conjugate
18 Transverse diameter
19 Oblique diameter
20 Inferior pelvic aperture or outlet

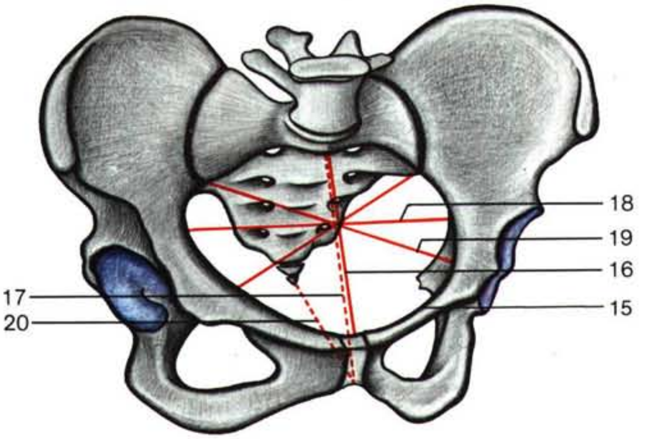

Diameters of pelvis (oblique superior aspect). (Schematic drawing.)

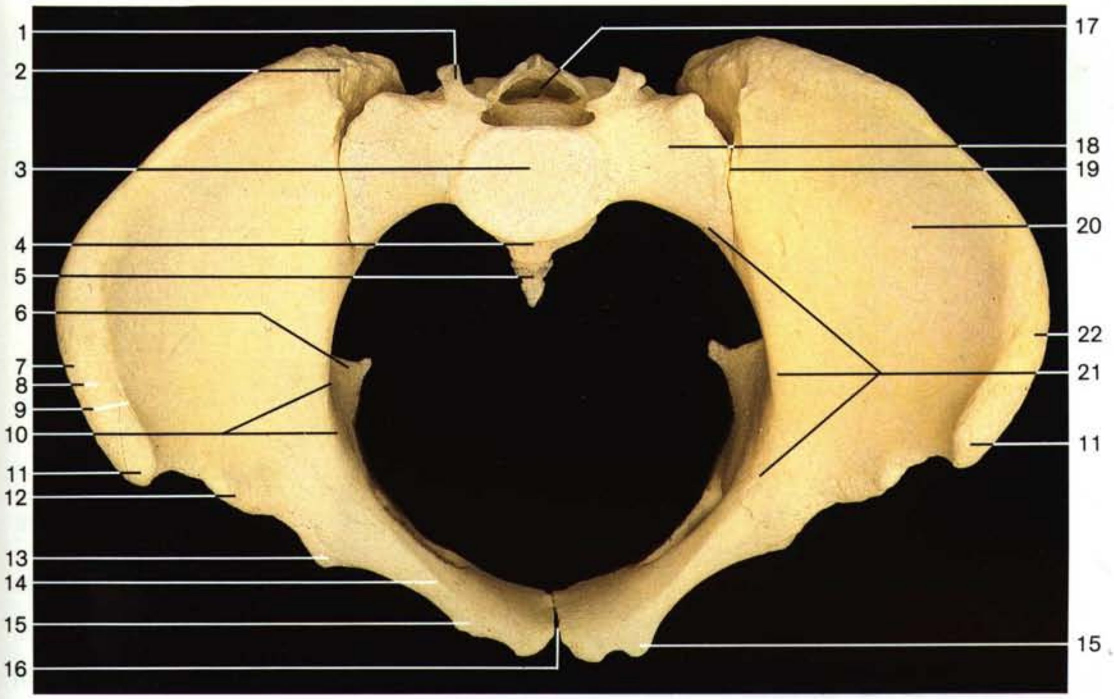
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Female pelvis (superior aspect). Note the differences between the male and the female pelvis, predominantly in the form and dimensions of the sacrum, the superior and inferior apertures and the alae of the ilium.

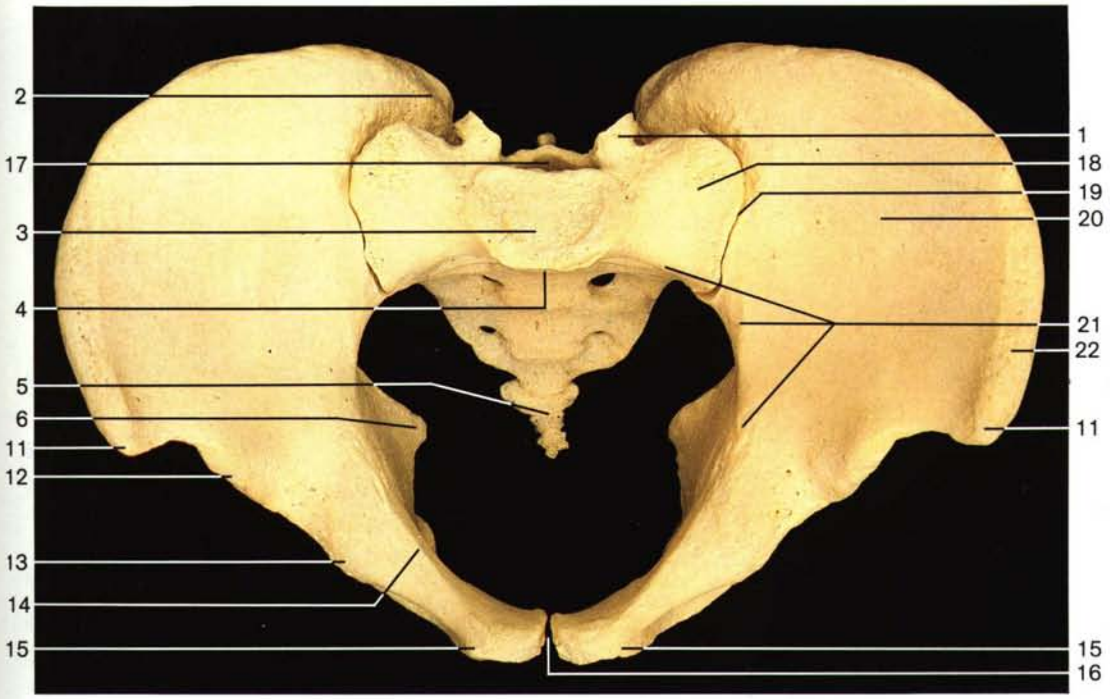
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Male pelvis (superior aspect). Compare with the female pelvis (depicted above).

1 Superior articular process of sacrum
2 Posterior superior iliac spine
3 Base of sacrum
4 Sacral promontory
5 Coccyx
6 Ischial spine
7 External lip } of iliac crest
8 Intermediate line } of iliac crest
9 Internal lip } of iliac crest
10 Arcuate line
11 Anterior superior iliac spine
12 Anterior inferior iliac spine
13 Iliopubic eminence
14 Pecten pubis
15 Pubic tubercle
16 Pubic symphysis
17 Sacral canal
18 Ala of sacrum
19 Position of sacroiliac joint
20 Iliac fossa
21 Linea terminalis
22 Iliac crest

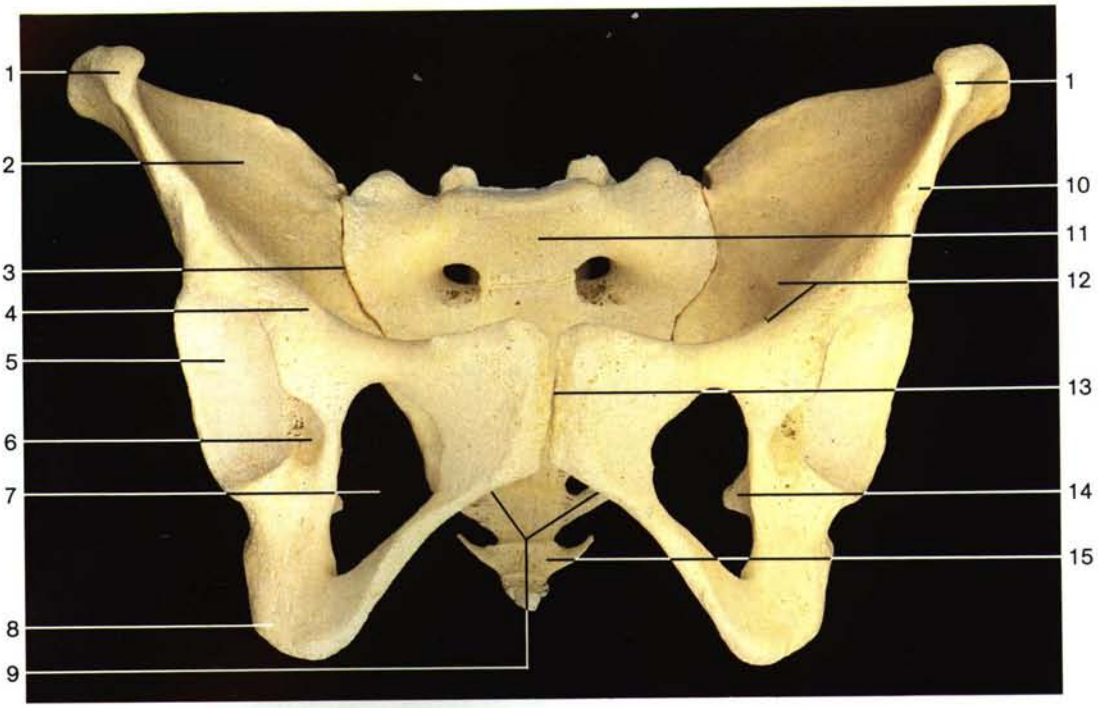

Female pelvis (anterior aspect). Note the differences between the form and dimensions of the male and the female pelvis. The female pubic arch is wider than the male. The obturator foramen in the female pelvis is triangular, while that in the male pelvis is ovoid.

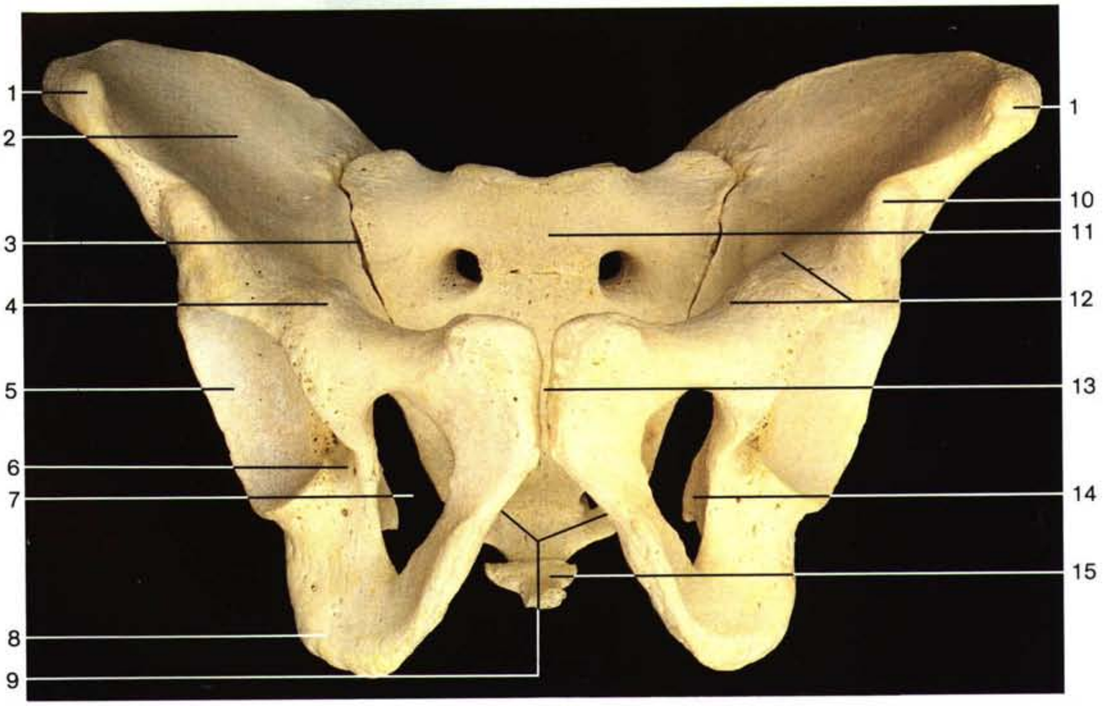

Male pelvis (anterior aspect). Compare with foregoing figure.

1 Anterior superior iliac spine
2 Iliac fossa
3 Position of sacroiliac joint
4 Iliopubic eminence
5 Lunate surface of acetabulum
6 Acetabular notch
7 Obturator foramen
8 Ischial tuberosity
9 Pubic arch
10 Anterior inferior iliac spine
11 Sacrum
12 Linea terminalis (at margin of superior aperture)
13 Pubic symphysis
14 Ischial spine
15 Coccyx

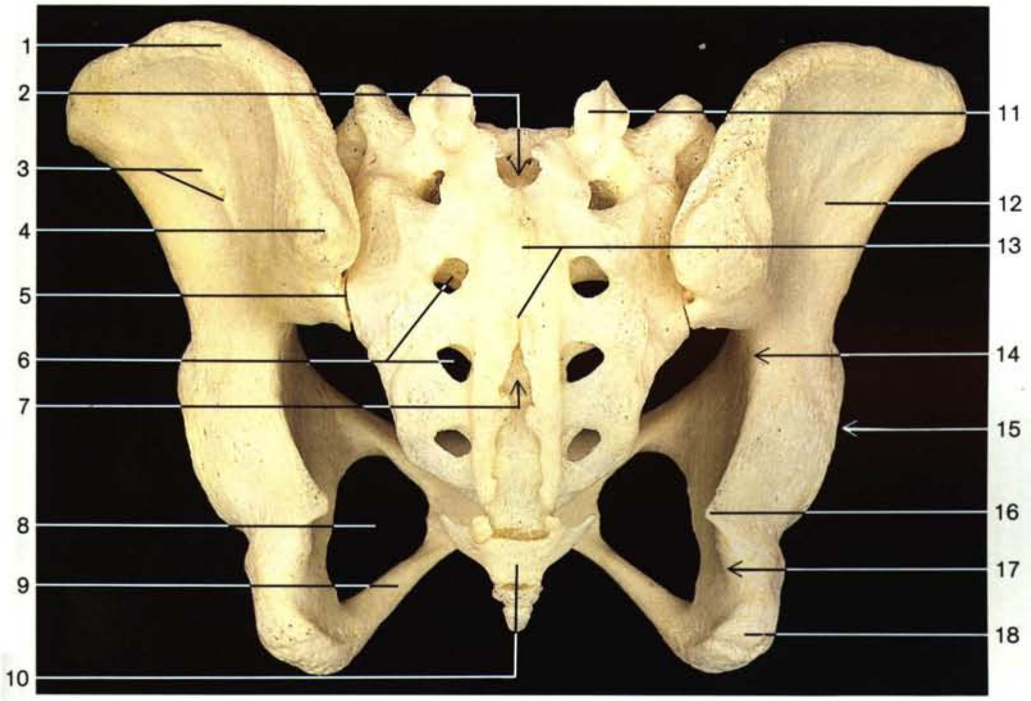

Female pelvis (posterior inferior aspect). Note the differences between the female and male pelvis, especially with respect to the inferior aperture, the shape of the sacrum, the two sciatic notches and the pubic arch.

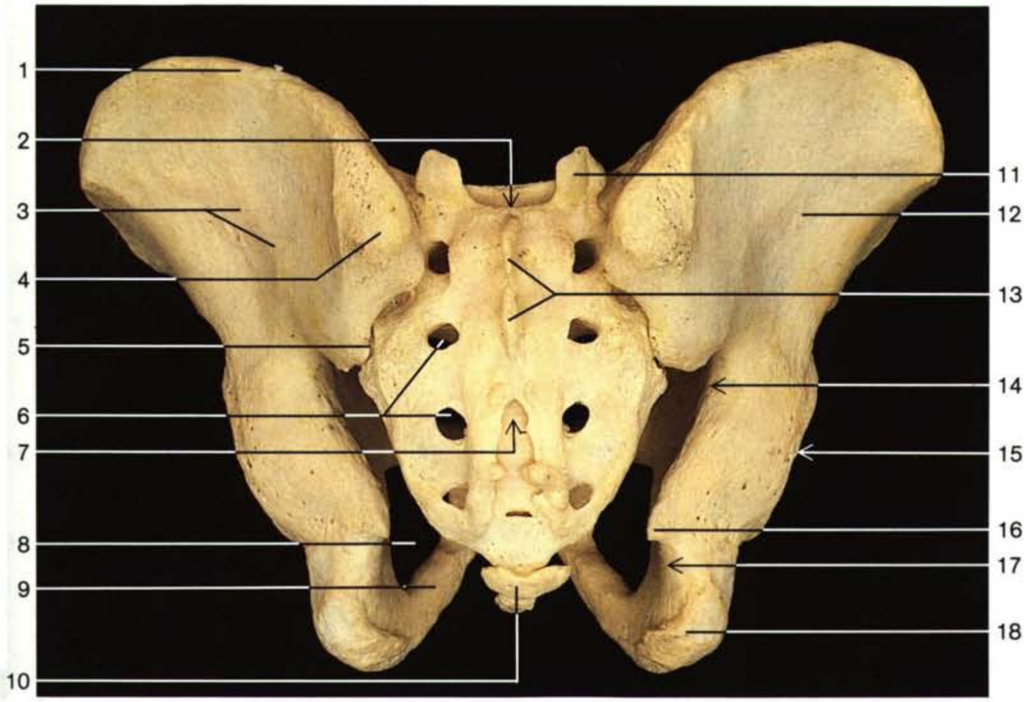

Male pelvis (posterior inferior aspect). Compare with the female pelvis (depicted above).

1	Iliac crest	10	Coccyx
2	Sacral canal	11	Superior articular process of sacrum
3	Posterior gluteal line	12	Gluteal surface of ilium
4	Posterior superior iliac spine	13	Median sacral crest
5	Position of sacroiliac joint	14	Greater sciatic notch
6	Dorsal sacral foramina	15	Position of acetabulum
7	Sacral hiatus	16	Ischial spine
8	Obturator foramen	17	Lesser sciatic notch
9	Ramus of ischium	18	Ischial tuberosity

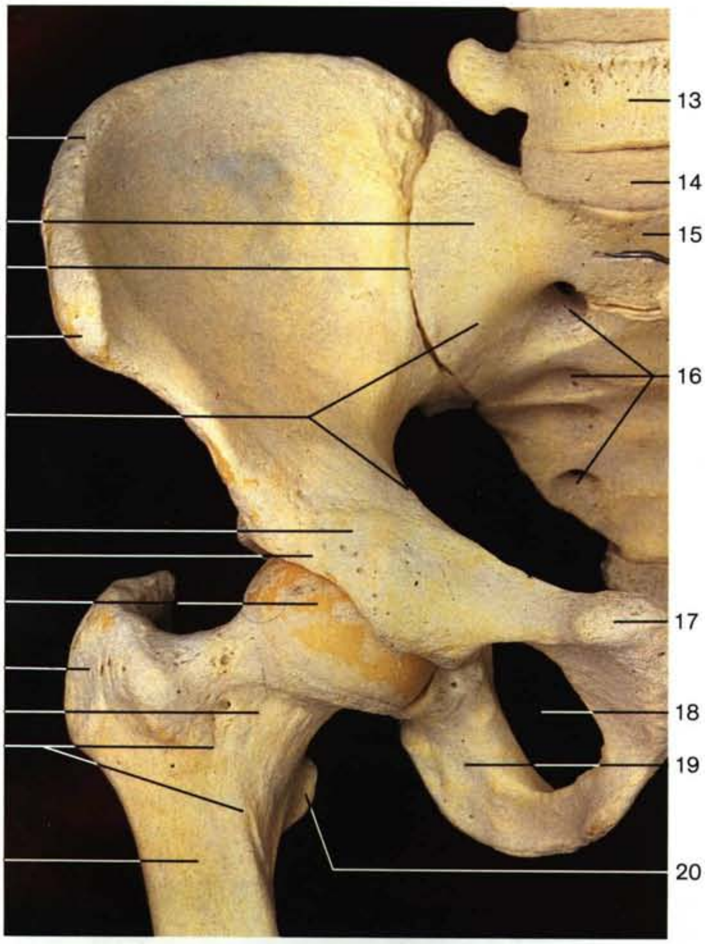

Bones of right hip joint (anterior aspect).

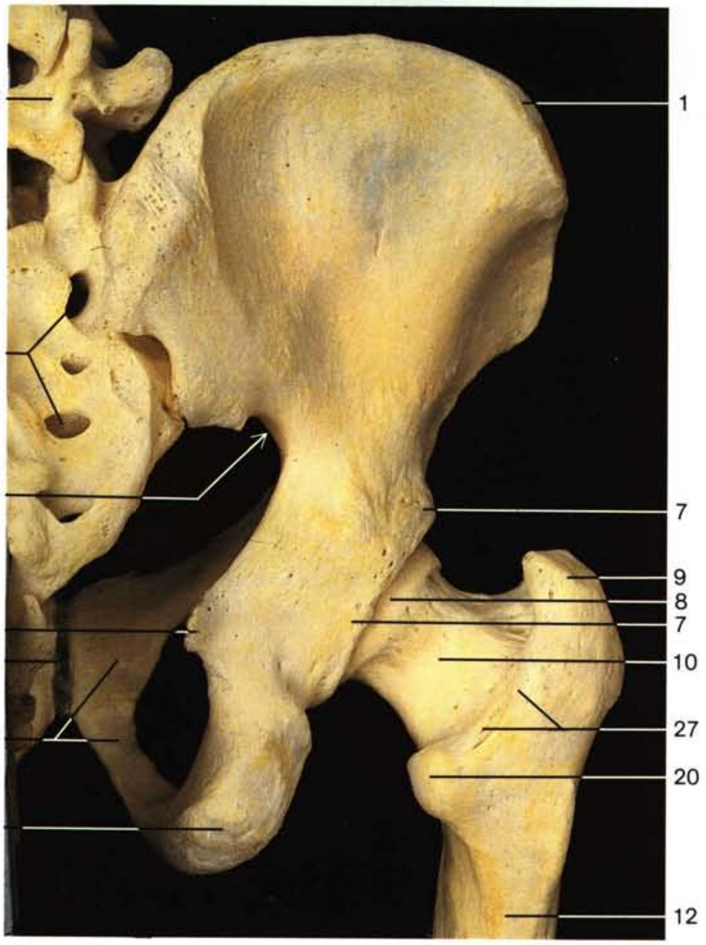

Bones of right hip joint (posterior aspect).

1 Iliac crest
2 Lateral part of sacrum (ala)
3 Position of sacroiliac joint
4 Anterior superior iliac spine
5 Linea terminalis
6 Iliopubic eminence
7 Bony margin of acetabulum
8 Head of femur
9 Greater trochanter
10 Neck of femur
11 Intertrochanteric line
12 Shaft of femur
13 5th lumbar vertebra
14 Imitation intervertebral disc between 5th lumbar vertebra and sacrum
15 Sacral promontory
16 Anterior sacral foramina
17 Pubic tubercle
18 Obturator foramen
19 Ramus of ischium
20 Lesser trochanter
21 Dorsal sacral foramina
22 Greater sciatic notch
23 Ischial spine
24 Pubic symphysis
25 Pubis
26 Ischial tuberosity
27 Intertrochanteric crest
28 Symphysial surface

Diameters of the pelvis

A True conjugate (11–11.5 cm) (Conjugata vera)
B Diagonal conjugate (12.5–13 cm)
C Largest diameter of pelvis
D Inferior pelvic aperture
E Pelvic inclination (60°)

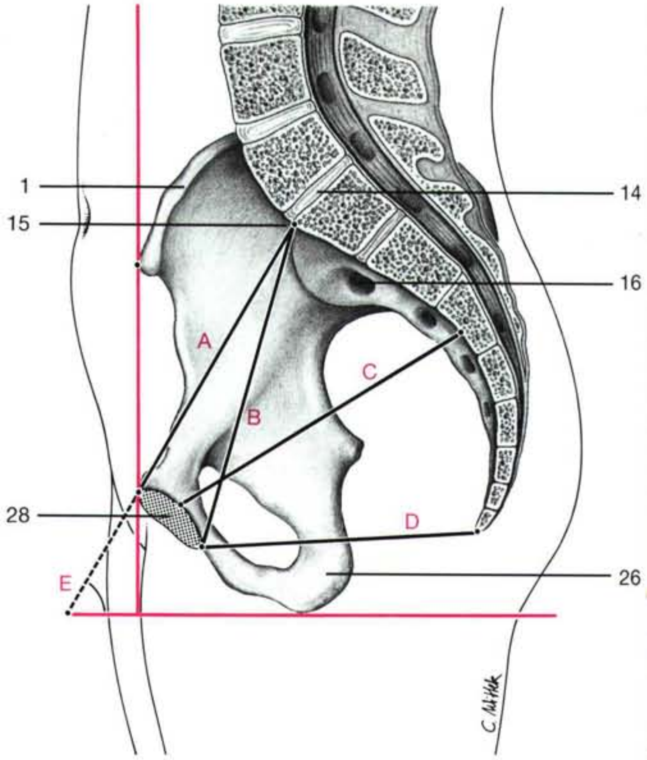

Inclination and diameters of the female pelvis, right half (medial aspect).

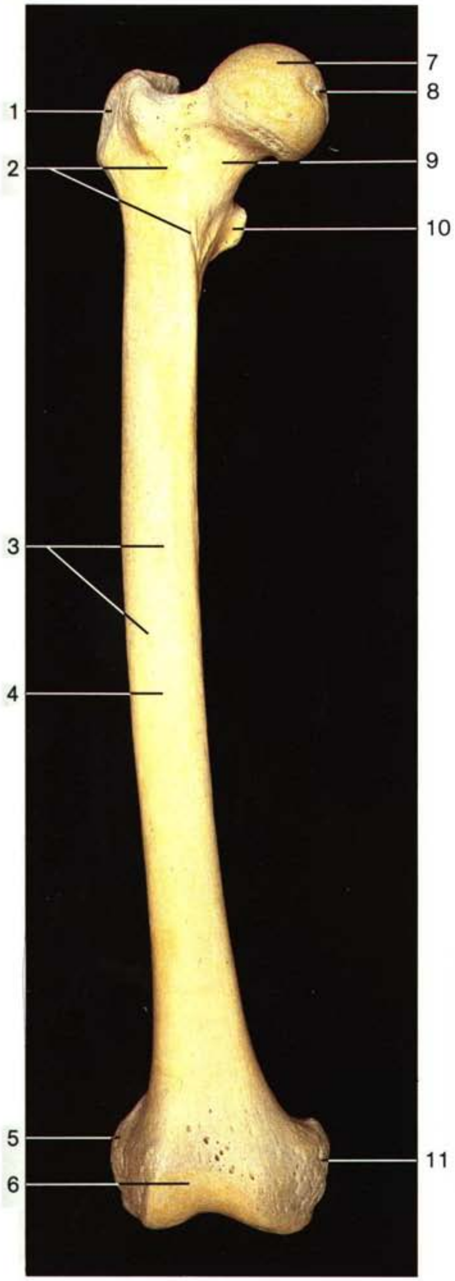
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Right femur (anterior aspect).

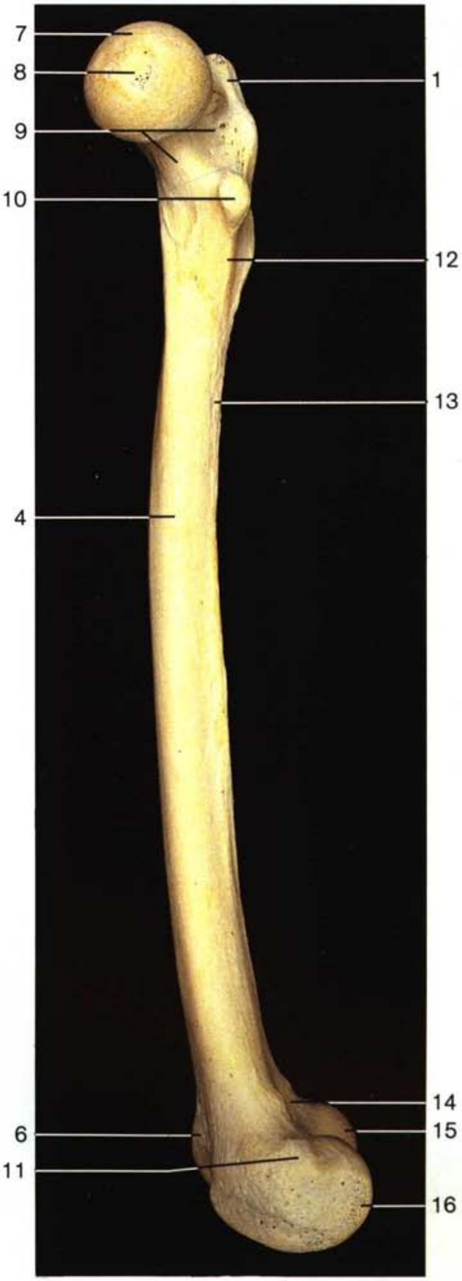
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Right femur (medial aspect).

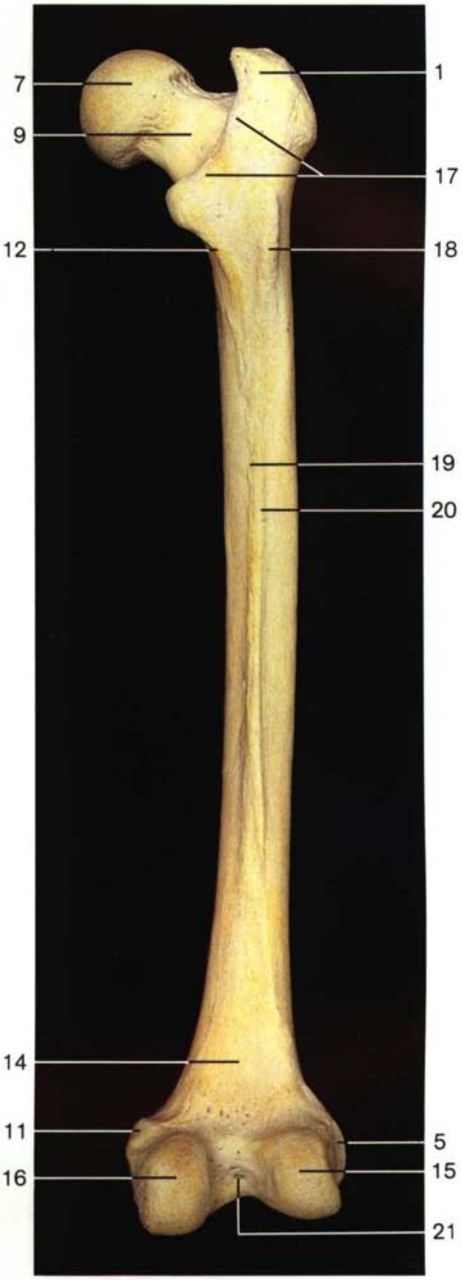
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Right femur (posterior aspect).

1 Greater trochanter
2 Intertrochanteric line
3 Nutrient foramina
4 Shaft of femur (diaphysis)
5 Lateral epicondyle
6 Patellar surface
7 Head
8 Fovea of head
9 Neck
10 Lesser trochanter
11 Medial epicondyle
12 Pectineal line
13 Linea aspera
14 Popliteal surface
15 Lateral condyle
16 Medial condyle
17 Intertrochanteric crest
18 Third trochanter
19 Medial lip of linea aspera
20 Lateral lip of linea aspera
21 Intercondylar fossa

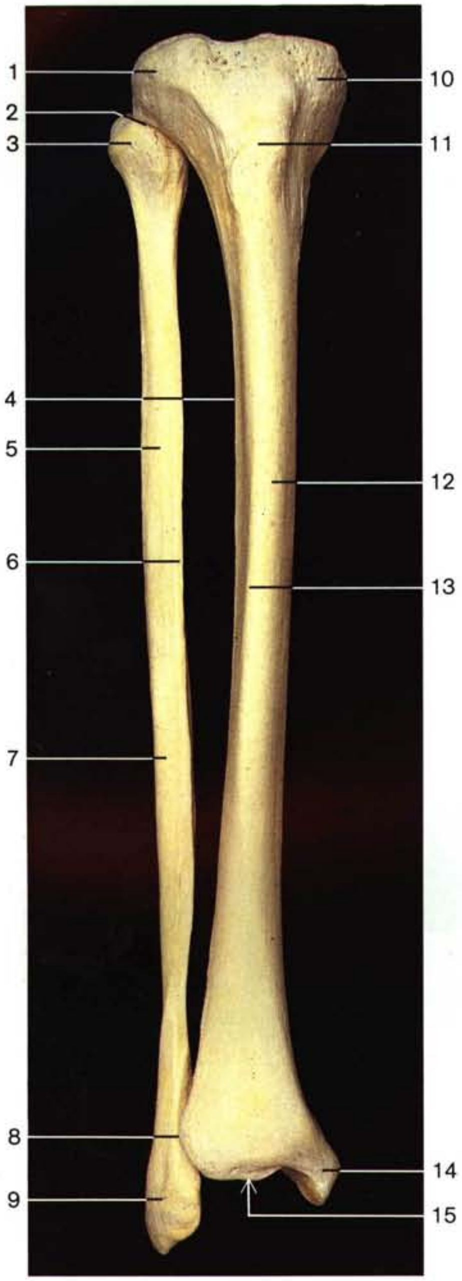

Bones of leg, right tibia and fibula (anterior aspect).

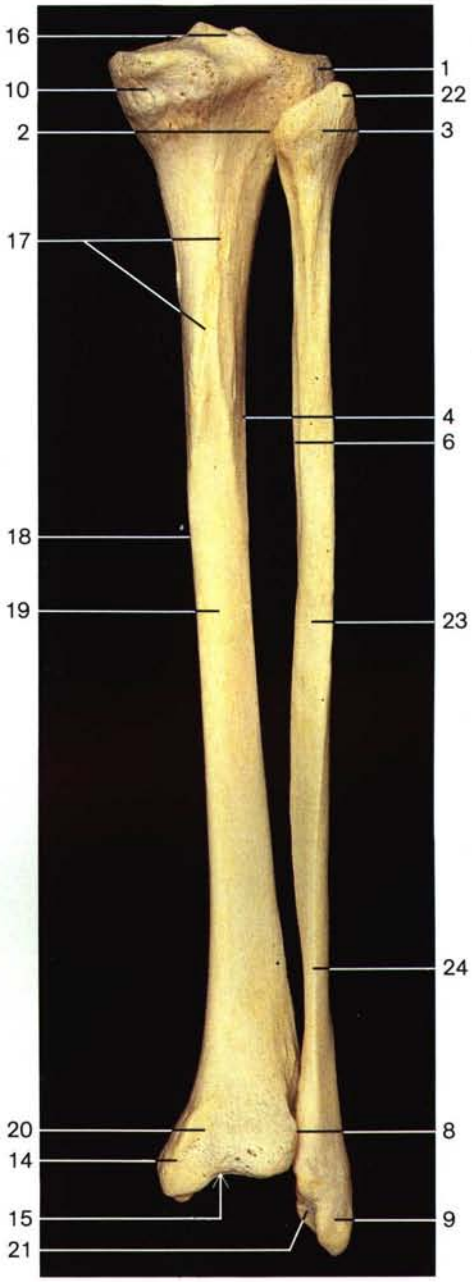

Bones of leg, right tibia and fibula (posterior aspect).

1 Lateral condyle of tibia
2 Position of tibiofibular joint
3 Head of fibula
4 Interosseous border of tibia
5 Shaft of fibula
6 Interosseous border of fibula
7 Lateral surface of fibula
8 Position of tibiofibular joint
9 Lateral malleolus
10 Medial condyle of tibia
11 Tuberosity of tibia
12 Shaft of tibia (diaphysis)
13 Anterior margin of tibia
14 Medial malleolus
15 Inferior articular surface of tibia
16 Intercondylar eminence
17 Soleal line
18 Medial border of tibia
19 Posterior surface of tibia
20 Malleolar sulcus of tibia
21 Malleolar articular surface of fibula
22 Apex of head of fibula
23 Posterior surface of fibula
24 Posterior border of fibula
25 Medial intercondylar tubercle
26 Posterior intercondylar area
27 Anterior intercondylar area
28 Lateral intercondylar tubercle

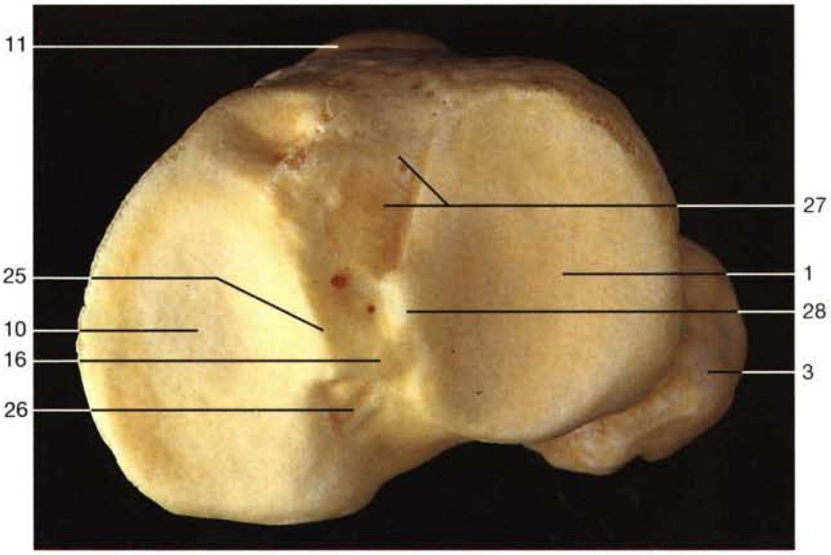

Upper end of right tibia with fibula (from above), anterior margin of tibia above. Superior articular surface of tibia.

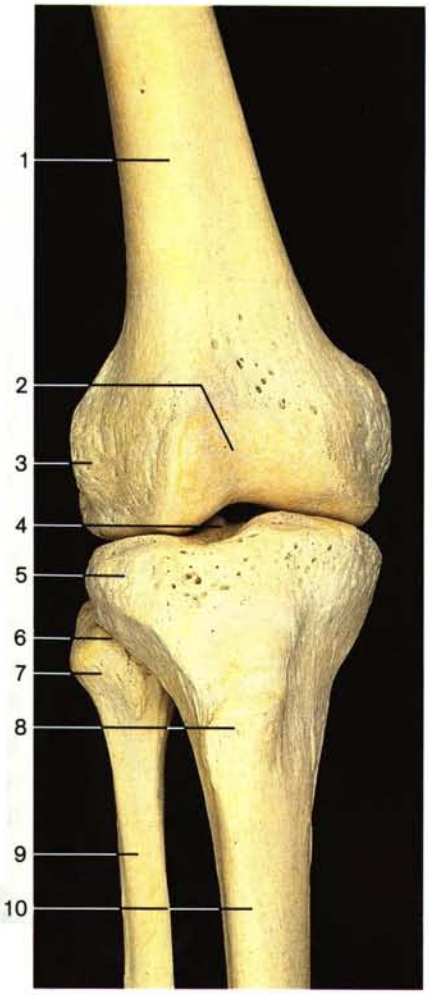

Bones of right knee joint (anterior aspect).

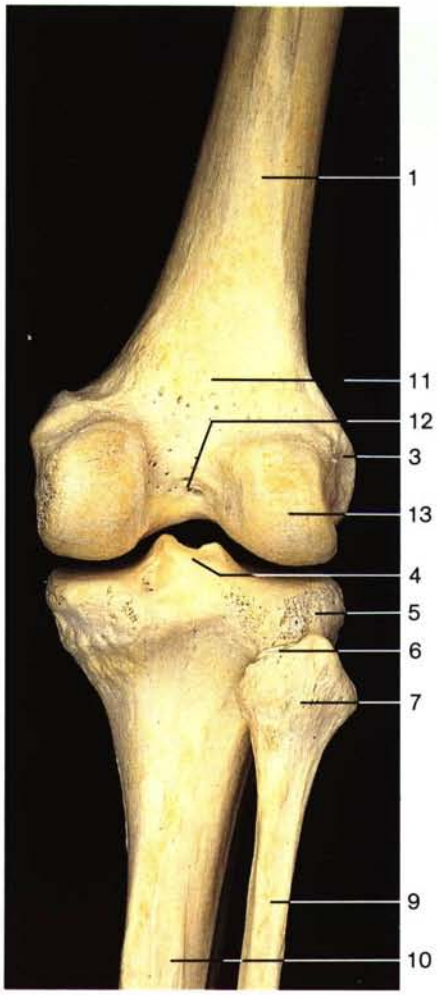

Bones of right knee joint (posterior aspect).

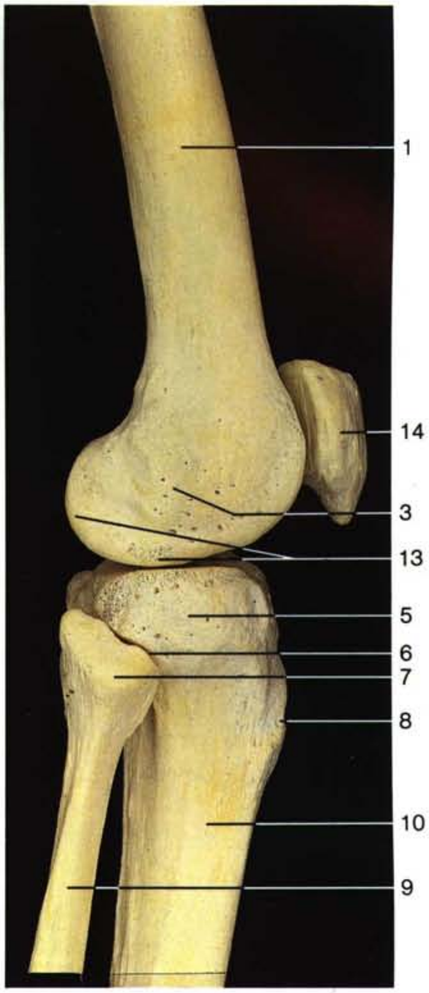

Bones of right knee joint (lateral aspect).

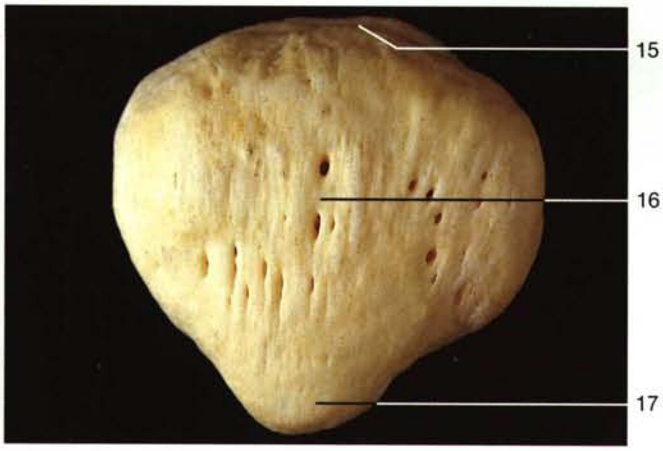

Right patella (anterior aspect).

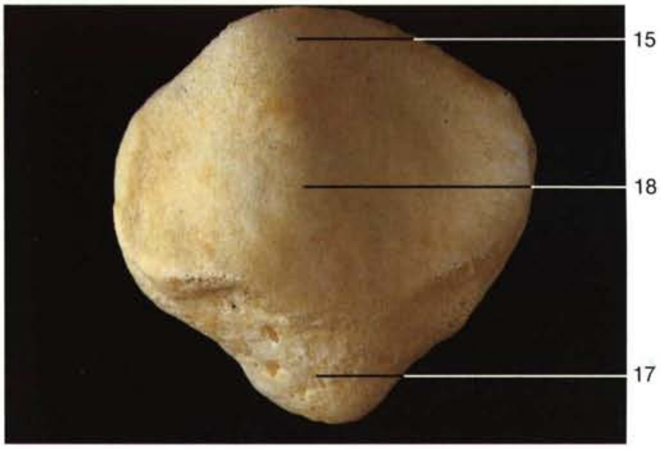

Right patella (posterior aspect).

1 **Femur**
2 Patellar surface of femur
3 Lateral epicondyle of femur
4 Intercondylar eminence of tibia
5 Lateral condyle of tibia
6 Position of tibiofibular joint
7 Head of fibula
8 Tuberosity of **tibia**
9 **Fibula**
10 Shaft of tibia
11 Popliteal surface of femur
12 Intercondylar fossa of femur
13 Lateral condyle of femur
14 **Patella**
15 Base of patella
16 Anterior surface of patella
17 Apex of patella
18 Articular surface of patella

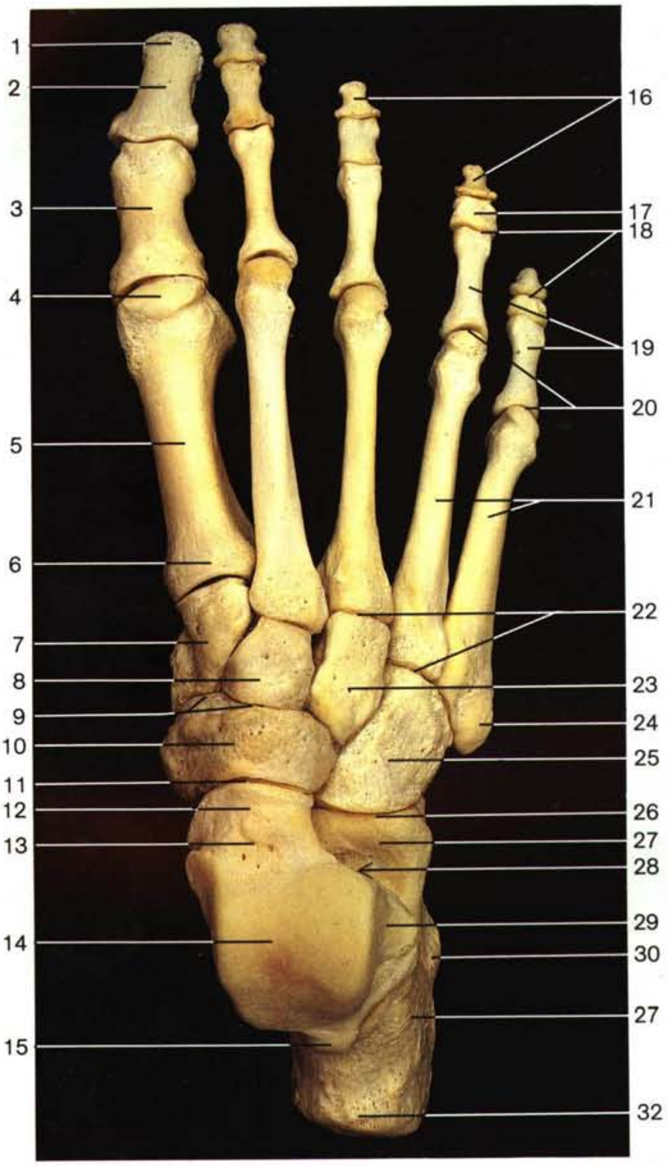
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Bones of right foot (dorsal aspect).

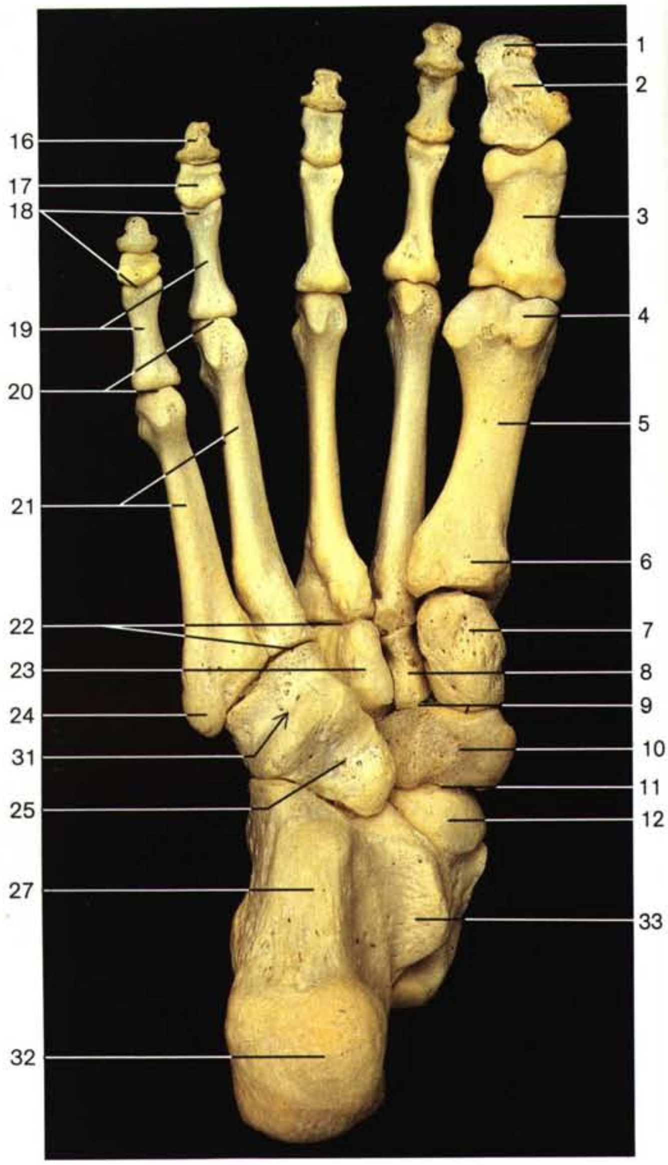
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Bones of right foot (plantar aspect).

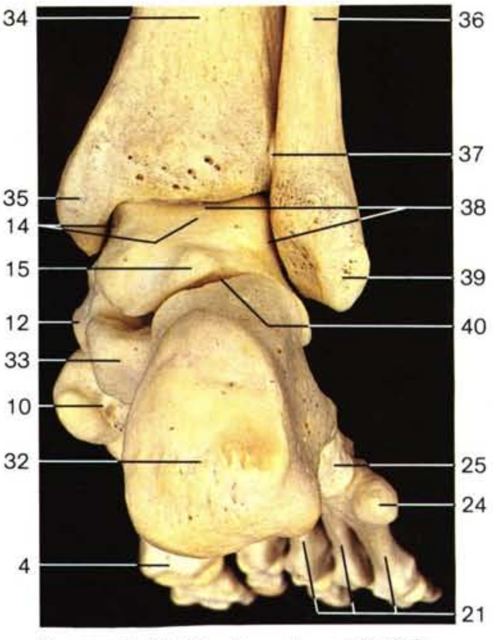
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Bones of right foot together with tibia and fibula (posterior aspect).

1 Tuberosity of distal phalanx of great toe
2 Distal phalanx of great toe
3 Proximal phalanx of great toe
4 Head of first metatarsal bone
5 First metatarsal bone
6 Base of first metatarsal bone
7 Medial cuneiform bone
8 Intermediate cuneiform bone
9 Position of **cuneonavicular joint**
10 Navicular bone

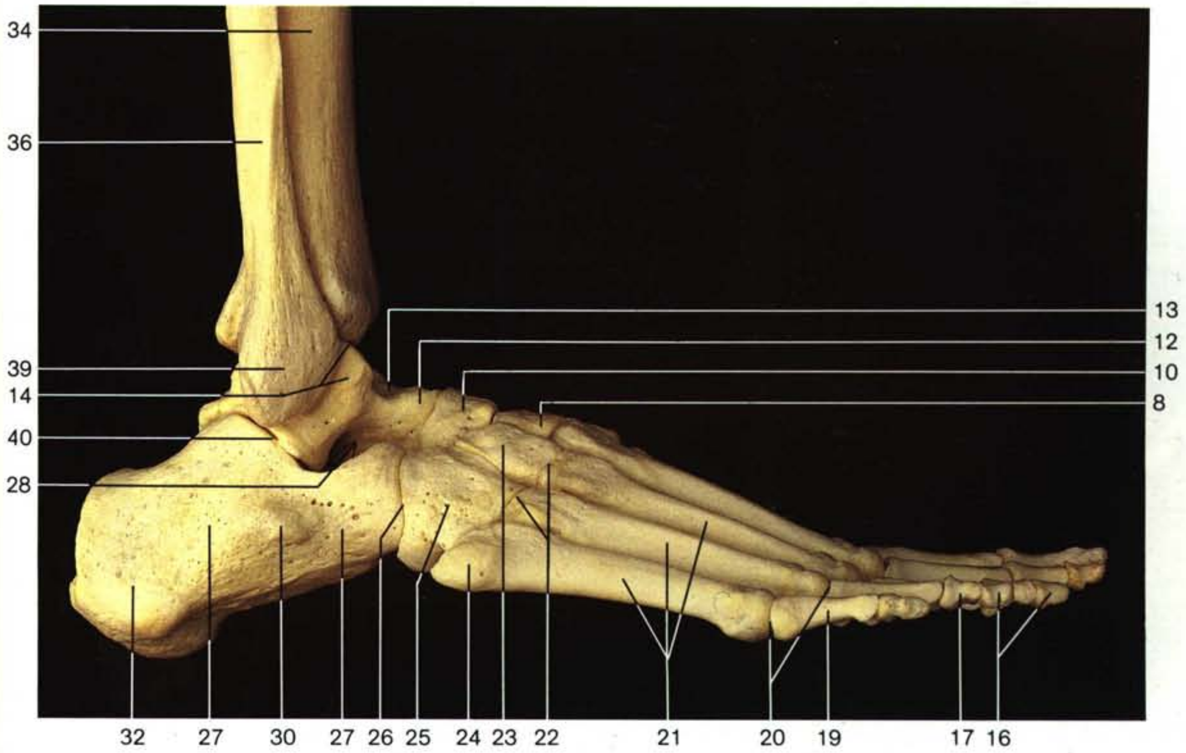

Bones of right foot, tibia and fibula (lateral aspect).

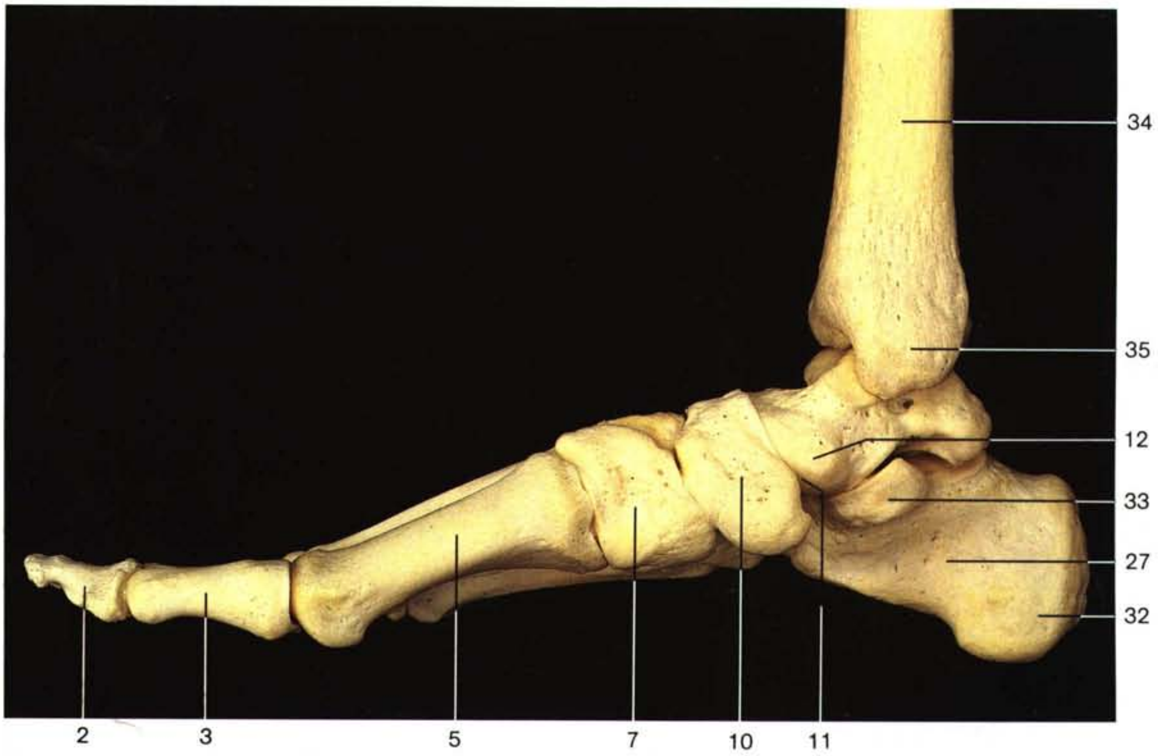

Bones of right foot, tibia and fibula (medial aspect).

11 Position of **talocalcaneonavicular joint**
12 Head of talus
13 Neck of talus
14 Trochlea of talus
15 Posterior talar process
16 Distal phalanges
17 Middle phalanges
18 Position of **interphalangeal joints**
19 Proximal phalanges
20 Position of **metatarsophalangeal joints**

21 Metatarsal bones
22 Position of **tarsometatarsal joints**
23 Lateral cuneiform bone
24 Tuberosity of 5th metatarsal bone
25 Cuboid bone
26 Position of **calcaneocuboid joint**
27 Calcaneus
28 Tarsal sinus
29 Lateral malleolar surface of talus
30 Peroneal trochlea of calcaneus

31 Groove for tendon of peroneus longus
32 Calcaneal tuberosity
33 Sustentaculum tali
34 Tibia
35 Medial malleolus
36 Fibula
37 Position of tibiofibular syndesmosis
38 Position of **talocrural joint**
39 Lateral malleolus
40 Position of **subtalar joint**

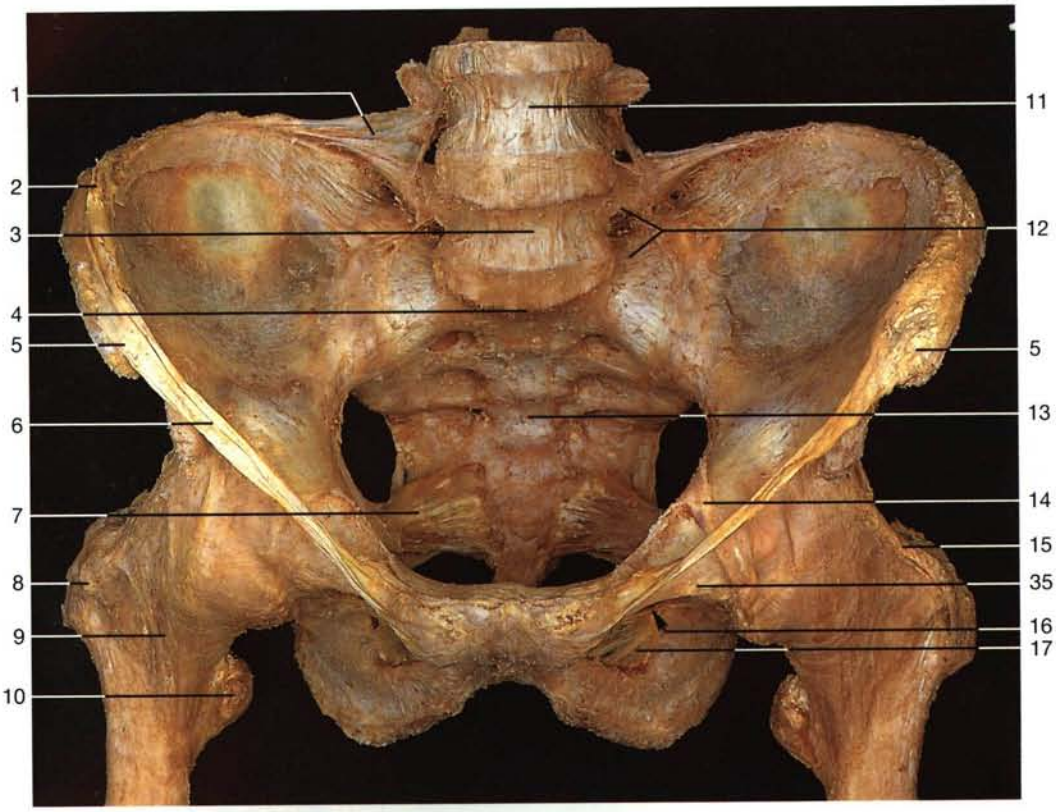

Ligaments of pelvis and hip joint (anterior aspect).

1 **Iliolumbar ligament**
2 Iliac crest
3 Fifth lumbar vertebra
4 Sacral promontory
5 Anterior superior iliac spine
6 Inguinal ligament
7 Sacrospinous ligament
8 Greater trochanter
9 **Iliofemoral ligament** (vertical band)
10 Lesser trochanter
11 Forth lumbar vertebra
12 Iliolumbar and ventral sacroiliac ligaments
13 Sacrum
14 Iliopectineal arch
15 **Iliofemoral ligament** (horizontal band)
16 Obturator canal
17 Obturator membrane
18 **Greater sciatic foramen**
19 Sacrospinous ligament
20 Sacrotuberous ligament
21 **Lesser sciatic foramen**
22 Ischial tuberosity
23 **Ischiofemoral ligament**
24 Intertrochanteric crest
25 Femur
26 Articular capsule of hip joint
27 Dorsal sacroiliac ligaments
28 Coccyx with superficial dorsal sacrococcygeal ligament
29 Head of femur
30 Articular cartilage of head of femur
31 Articular cavity of hip joint
32 Acetabular lip
33 Spongy bone
34 Ligament of head of femur
35 Pubofemoral ligament
36 Zona orbicularis

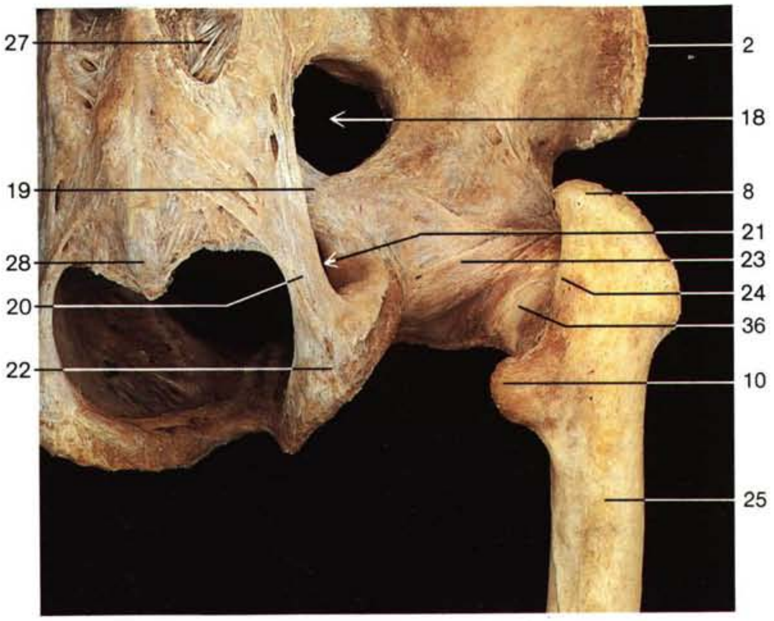

Ligaments of pelvis and hip joint (left anterior aspect).

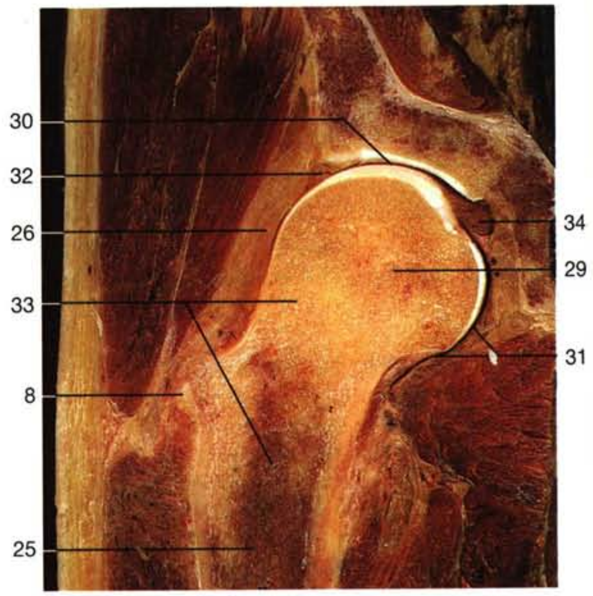

Coronal section of right hip joint (anterior view).

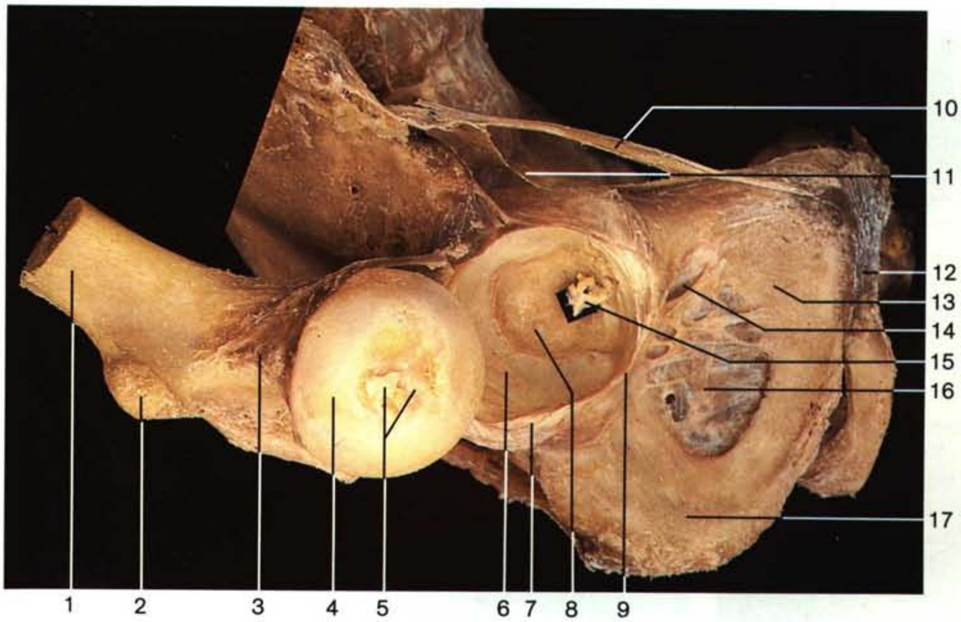

Right hip joint, opened (lateral anterior aspect). The ligament of the head of the femur has been divided and the femur has been posteriorly reflected.

1 Femur
2 Lesser trochanter
3 Neck of femur
4 Head of femur
5 Fovea of head with remnants of ligament of head
6 Lunate surface of acetabulum
7 Acetabular lip
8 Acetabular fossa
9 Transverse acetabular ligament
10 Inguinal ligament
11 Iliopectineal arch
12 Pubic symphysis
13 Pubic bone
14 Obturator canal
15 Ligament of head of femur
16 Obturator membrane
17 Ischium
18 Anterior longitudinal ligament (level of fifth lumbar vertebra)
19 Sacral promontory
20 Iliolumbar ligament
21 Iliac crest
22 Anterior superior iliac spine
23 Iliofemoral ligament (horizontal band)
24 Iliofemoral ligament (vertical band)
25 Greater trochanter
26 Pubofemoral ligament
27 Anterior inferior iliac spine
28 Ventral sacroiliac ligaments
29 **Sacrospinous ligament**
30 **Sacrotuberous ligament**
31 Intertrochanteric line
32 **Ischiofemoral ligament**
33 Zona orbicularis

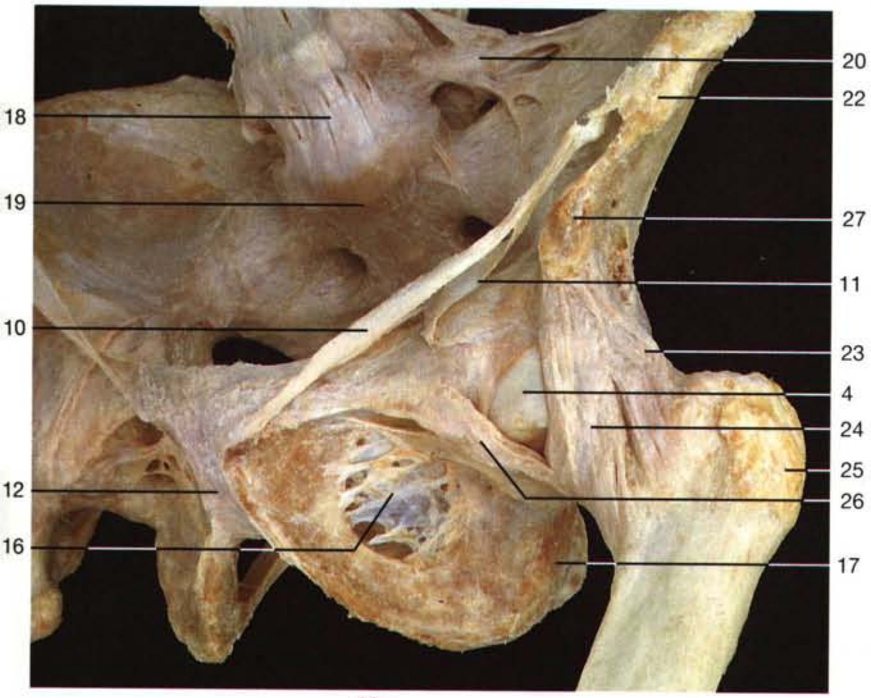

Ligaments of the pelvis and hip joint (antero-lateral aspect).

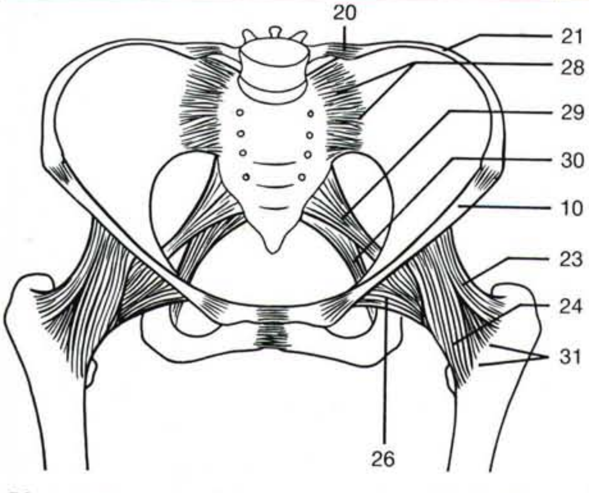

Ligaments of hip joint (anterior aspect). (Schematic drawing.)

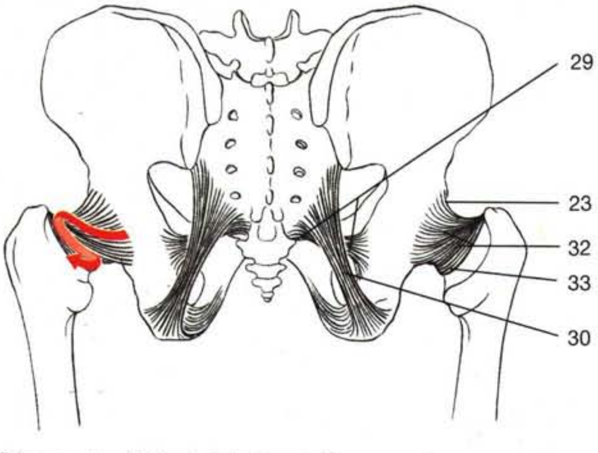

Ligaments of hip joints (posterior aspect). (Schematic drawing.)

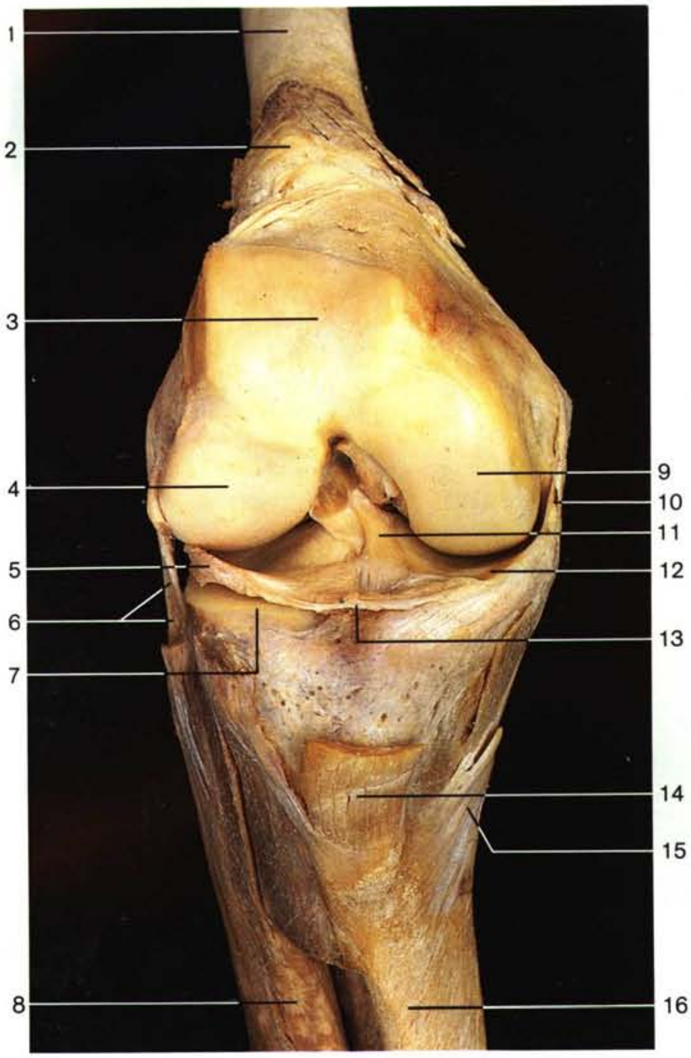

Right knee joint (opened) **with ligaments** (anterior aspect). The patella and articular capsule have been removed and the femur slightly flexed.

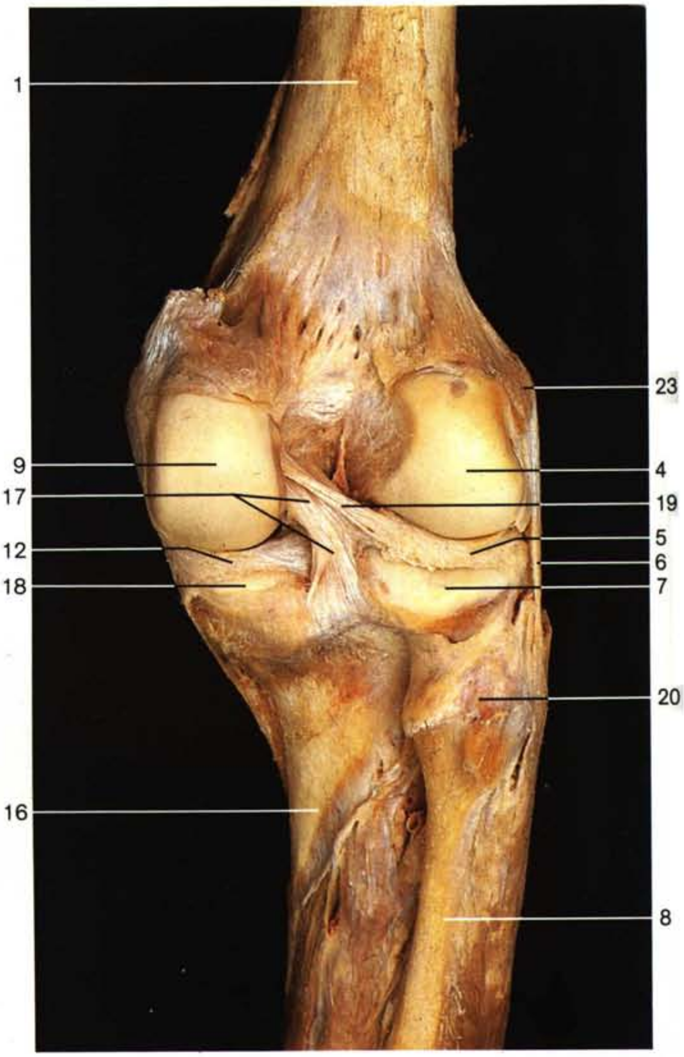

Right knee joint with ligaments (posterior aspect). The joint is extended and the articular capsule has been removed.

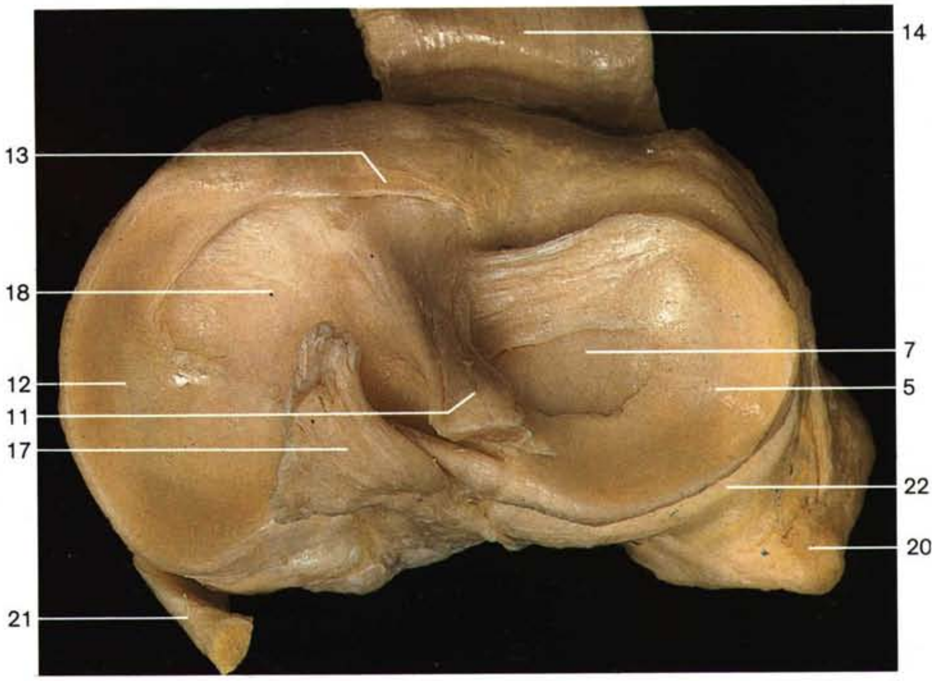

Articular surface of right tibia, menisci, and cruciate ligaments (superior aspect). Anterior margin of tibia above.

1	Femur
2	Articular capsule with **suprapatellar bursa**
3	Patellar surface
4	Lateral condyle of femur
5	**Lateral meniscus of knee joint**
6	Fibular collateral ligament
7	Lateral condyle of tibia (superior articular surface)
8	Fibula
9	Medial condyle of femur
10	Tibial collateral ligament
11	**Anterior cruciate ligament**
12	**Medial meniscus of knee joint**
13	Transverse ligament of knee
14	Patellar ligament
15	Common tendon of sartorius, semitendinosus and gracilis muscles
16	Tibia
17	**Posterior cruciate ligament**
18	Medial condyle of tibia (superior articular surface)
19	Posterior meniscofemoral ligament
20	Head of fibula
21	Tendon of semimembranosus muscle
22	Posterior attachment of articular capsule of knee joint
23	Lateral epicondyle of femur

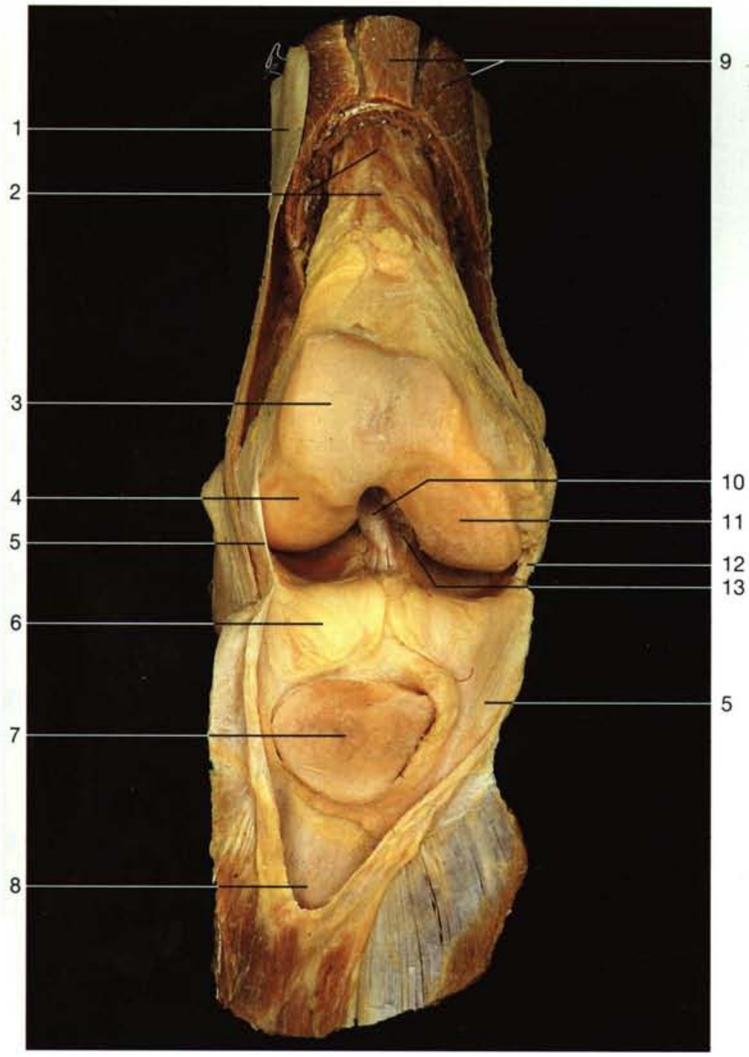

Right knee joint, opened (anterior aspect). Patellar ligament with patella reflected.

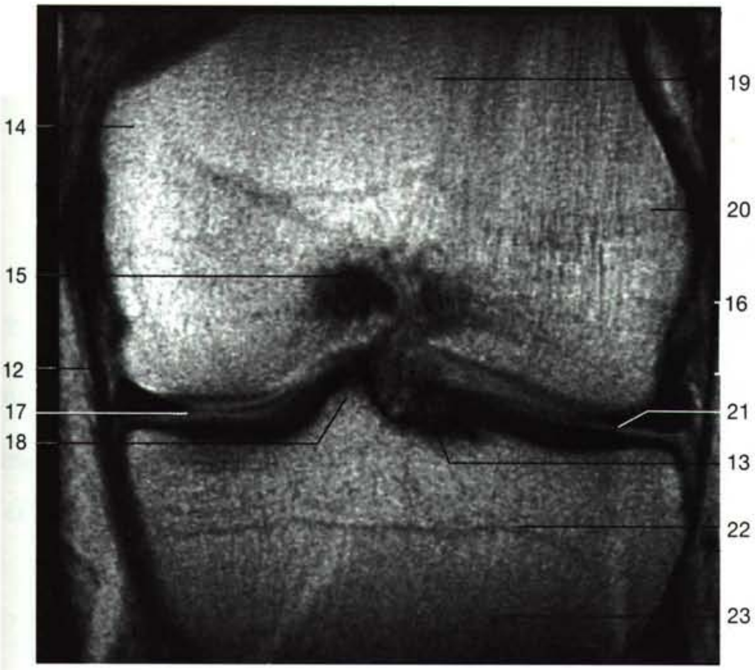

Right knee joint. Frontal section through the central part of the joint (posterior aspect, MR-Scan). (See also p. 10.)

1 Iliotibial tract
2 Articular muscle of knee
3 Patellar surface
4 Lateral condyle of femur
5 Articular capsule
6 Infrapatellar fat pad
7 **Patella** (articular surface)
8 **Suprapatellar bursa**
9 Quadriceps muscle of thigh (divided)
10 **Anterior cruciate ligament**
11 Medial condyle of femur
12 Fibular collateral ligament
13 **Posterior cruciate ligament**
14 Medial epicondyle of femur
15 Intercondylar fossa of femur
16 Tibial collateral ligament
17 **Medial meniscus** of knee joint
18 Medial intercondylar tubercle
19 Femur
20 Lateral epicondyle of femur
21 **Lateral meniscus** of knee joint
22 Epiphyseal line of tibia
23 Tibia

1 **Femur**
2 Quadriceps femoris muscle
3 Suprapatellar bursa and articular cavity
4 **Patella**
5 Patellar surface (articular cartilage)
6 Infrapatellar fat pad
7 Patellar ligament
8 **Tibia**
9 Tibial nerve
10 Adductor magnus muscle
11 Popliteal vein
12 Semitendinosus muscle
13 Semimembranosus muscle
14 **Popliteal artery**
15 Gastrocnemius muscle
16 Anterior cruciate ligament
17 Posterior cruciate ligament
18 Popliteus muscle
19 Soleus muscle
20 Deep flexor muscles of leg
21 Calcaneal tendon
22 Epiphyseal line of tibia
23 Calcaneus
24 **Talocrural joint**
25 Talus
26 Lateral meniscus
27 Epiphysial line

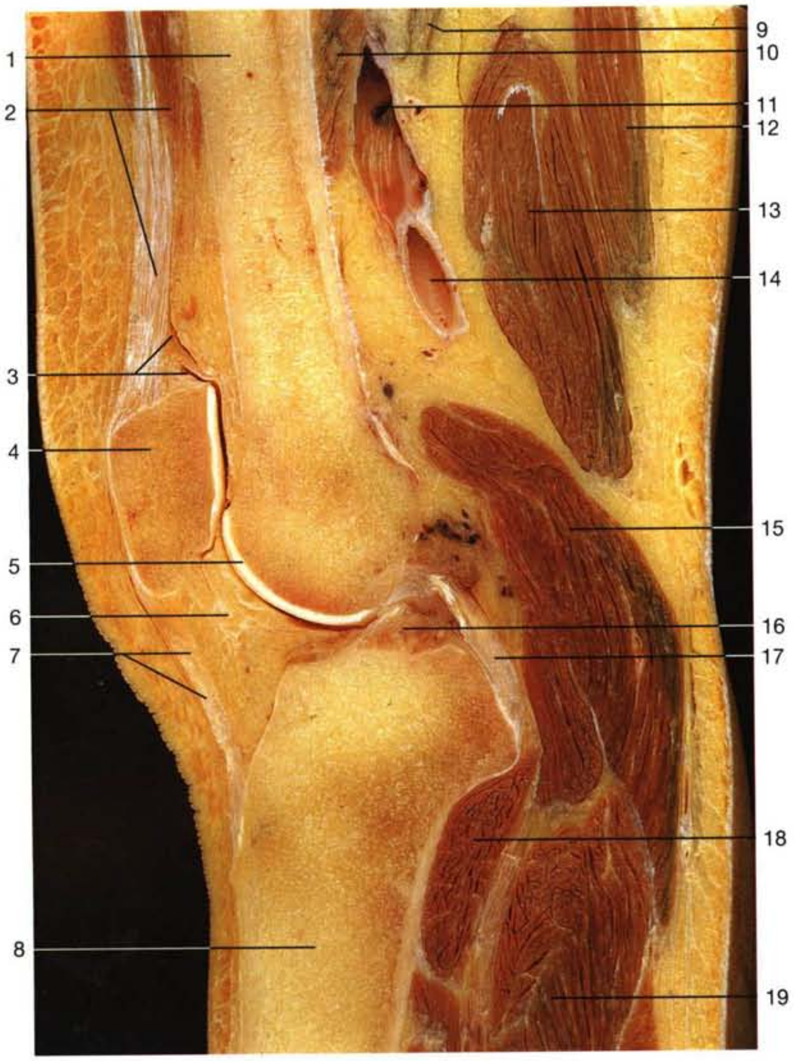

Sagittal section through the knee joint. Anterior surface to the left.

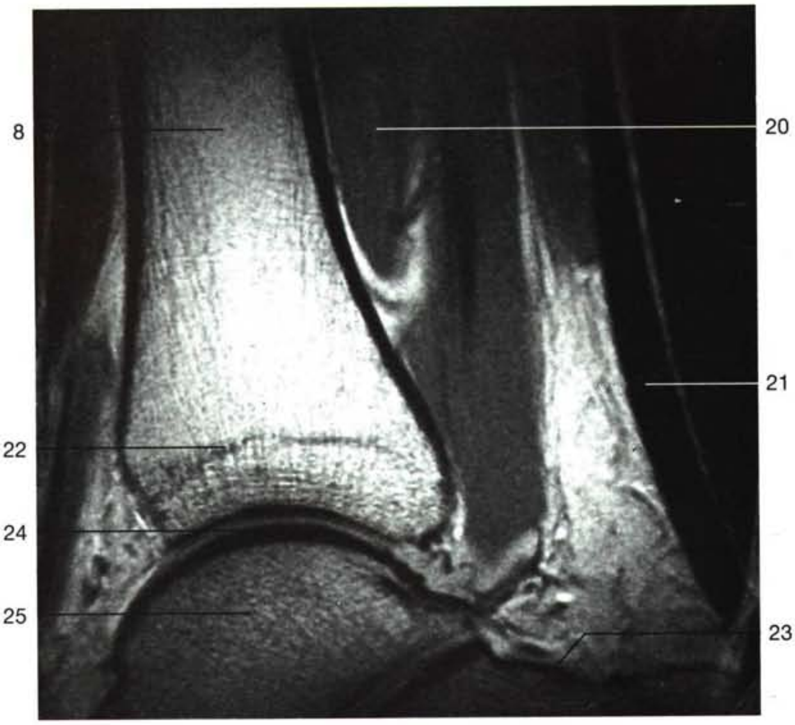

Talocrural joint. Sagittal section; anterior part to the left. (MR-Scan.)

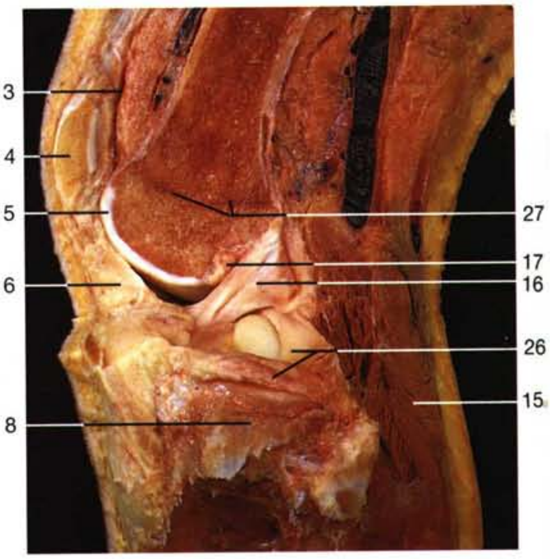

Left knee joint. Anterior cruciate ligament (lateral aspect).

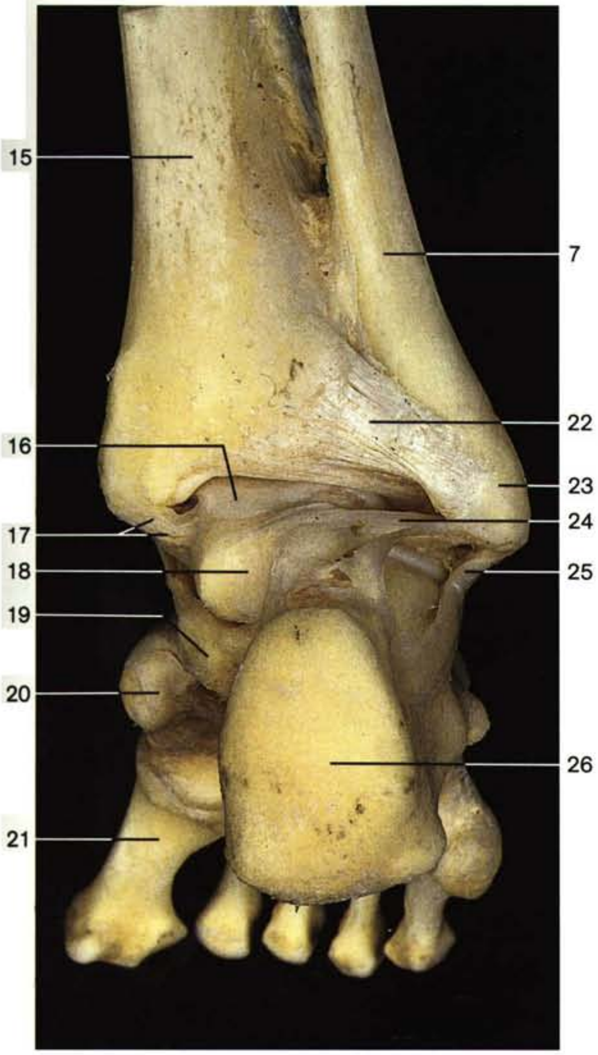

Ligaments of talocrural joint, right leg (posterior aspect).

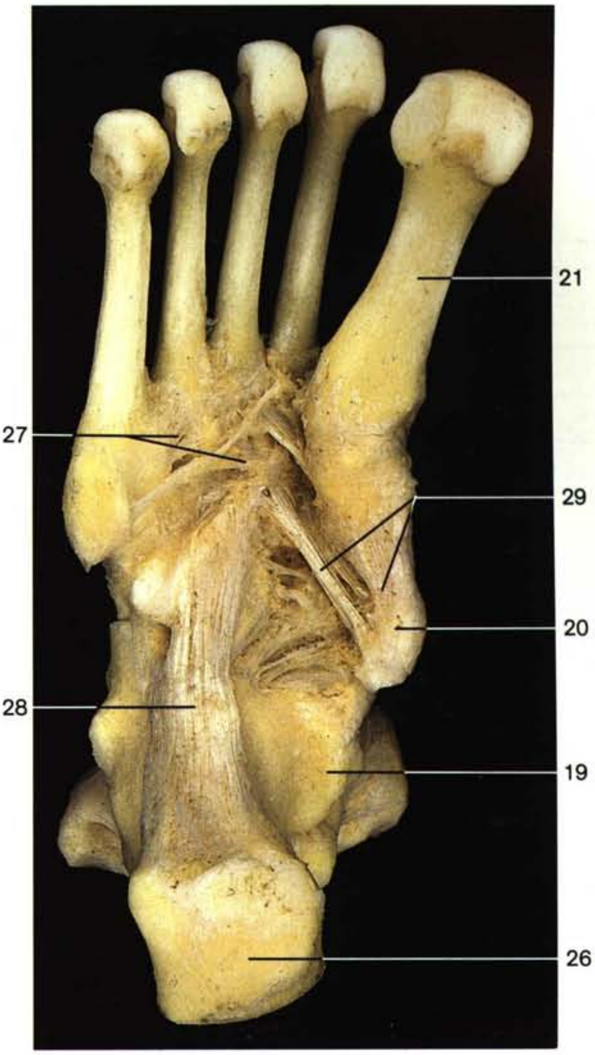

Deep ligaments of the foot, right foot (plantar aspect). The toes have been removed.

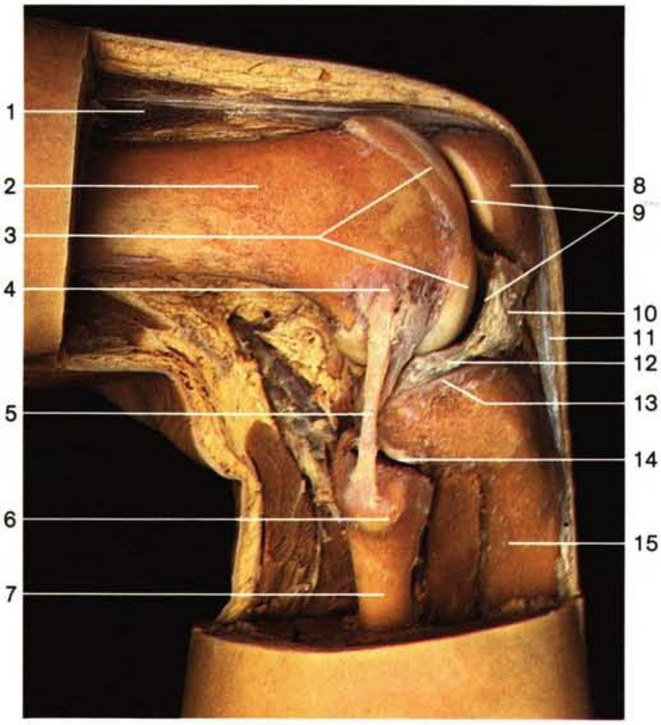

Right knee joint and tibiofibular joint with ligaments. Note the position of the lateral meniscus.

1 Quadriceps femoris muscle
2 Femur
3 Patellar surface
4 Lateral epicondyle of femur
5 **Fibular collateral ligament**
6 Head of fibula
7 **Fibula**
8 **Patella**
9 Articular cavity of knee joint
10 Infrapatellar fat pad
11 **Patellar ligament**
12 **Lateral meniscus of knee joint**
13 Lateral condyle of tibia (superior articular facet)
14 **Tibiofibular joint**
15 Tibia
16 Trochlea of talus (superior surface)
17 Deltoid ligament of ankle (posterior tibiotalar part)
18 Talus
19 **Sustentaculum tali**
20 Navicular bone
21 1st metatarsal bone
22 **Posterior tibiofibular ligament**
23 Lateral malleolus
24 Posterior talofibular ligament
25 Calcaneofibular ligament
26 Calcaneal tuberosity
27 Plantar tarsometatarsal ligaments
28 **Long plantar ligament**
29 Plantar cuneonavicular ligaments

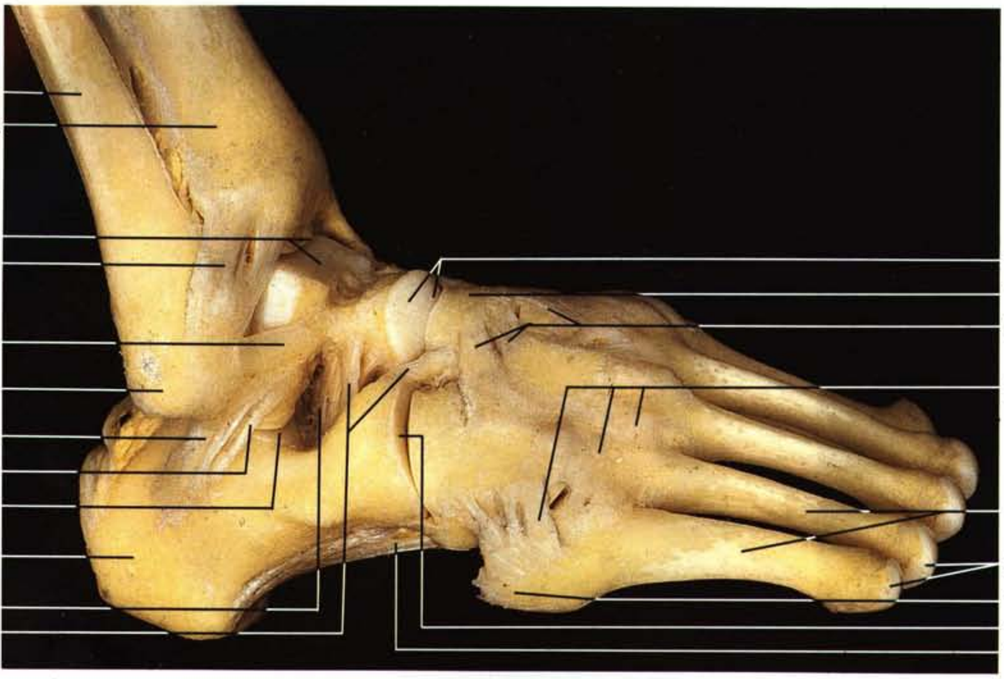

Ligaments of right foot (lateral aspect).

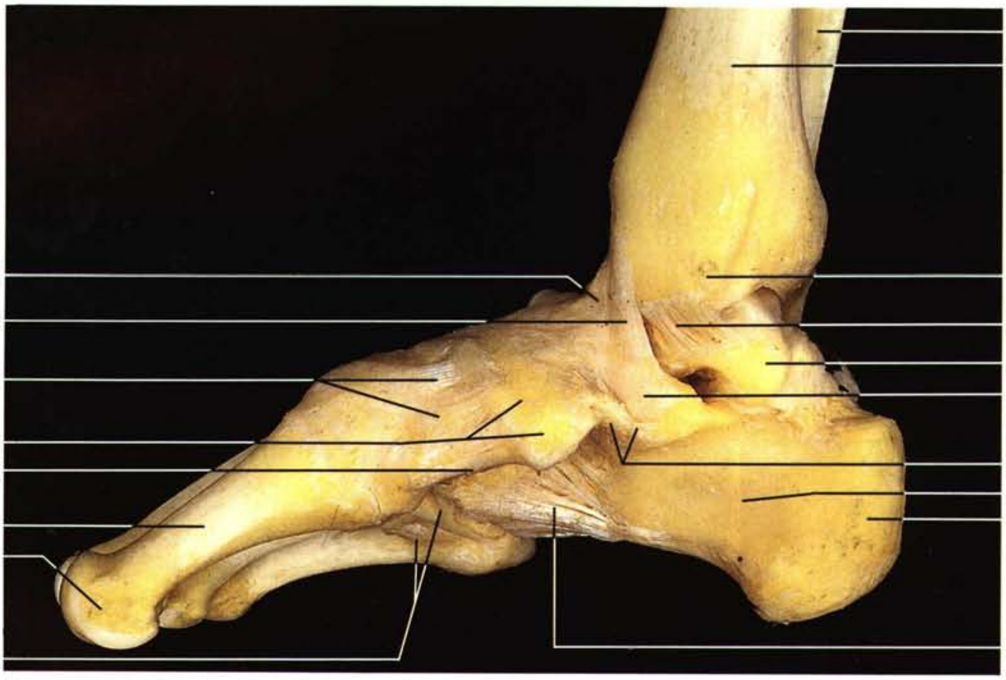

Ligaments of right foot (medial aspect).

1 Fibula
2 Tibia
3 Trochlea of talus and **talocrural joint**
4 Anterior tibiofibular ligament
5 Anterior talofibular ligament
6 Lateral malleolus
7 Calcaneofibular ligament
8 Lateral talocalcaneal ligament
9 **Subtalar joint**
10 Tuber calcanei
11 Interosseous talocalcaneal ligament
12 Bifurcate ligament
13 Long plantar ligament
14 **Calcaneocuboid joint**
15 Tuberosity of 5th metatarsal bone
16 Dorsal tarsometatarsal ligaments
17 Metatarsal bones
18 Head of talus and **talocalcaneonavicular joint**
19 Navicular bone
20 Dorsal cuneonavicular ligaments
21 Heads of metatarsal bones
22 Medial or deltoid ligament of ankle (tibionavicular part)
23 Medial or deltoid ligament of ankle (tibiocalcaneal part)
24 Dorsal cuneonavicular ligaments
25 Navicular bone
26 Plantar cuneonavicular ligament
27 1st metatarsal bone
28 Head of 1st metatarsal bone
29 Plantar tarsometatarsal ligaments
30 Plantar calcaneonavicular ligament
31 Sustentaculum tali
32 Calcaneus
33 Medial malleolus
34 Medial or deltoid ligament of ankle (posterior part)
35 Talus

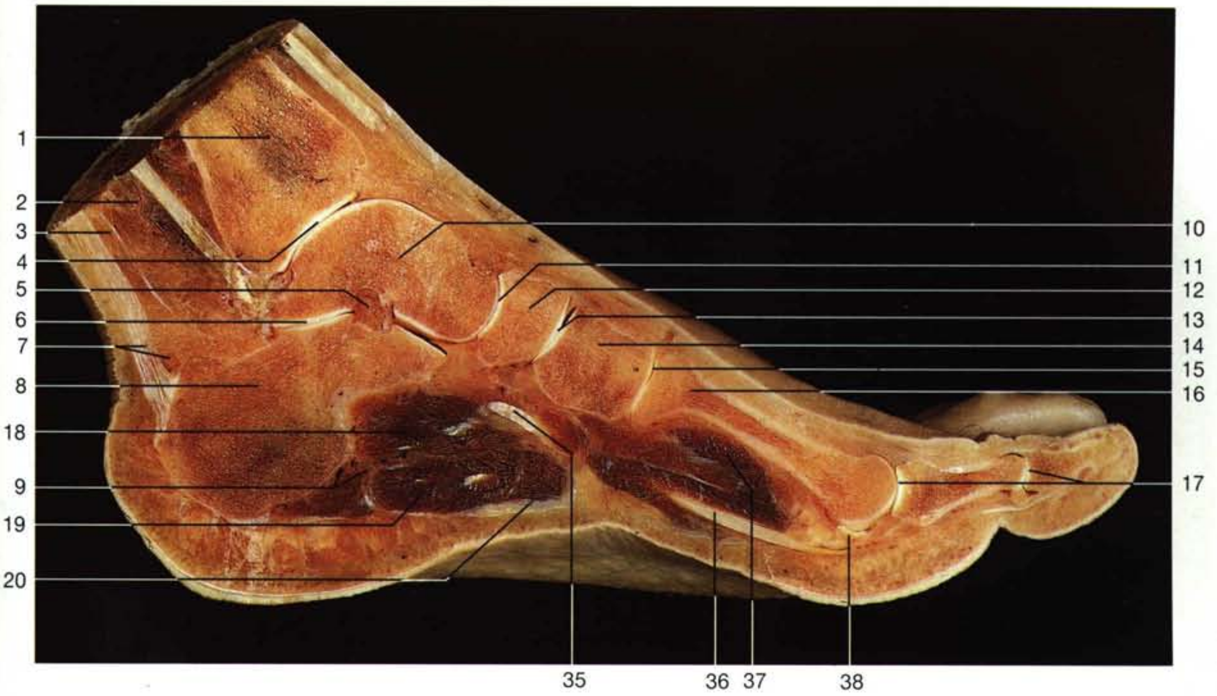

Longitudinal section through the foot at the level of first phalanx.

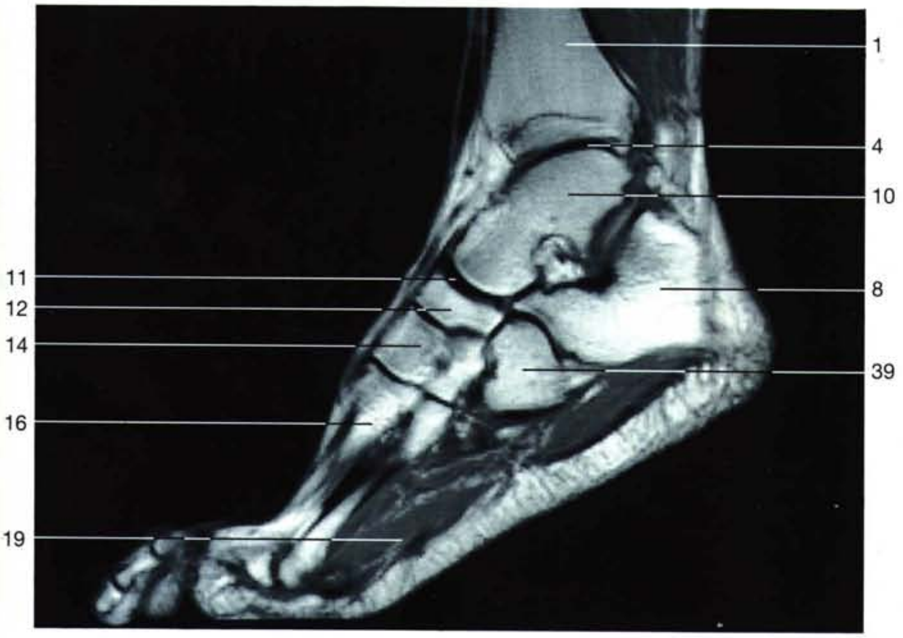

Sagittal section through the foot
(MR-Scan after A. Heuck, G. Luttke and J. W. Rohen, 1994).

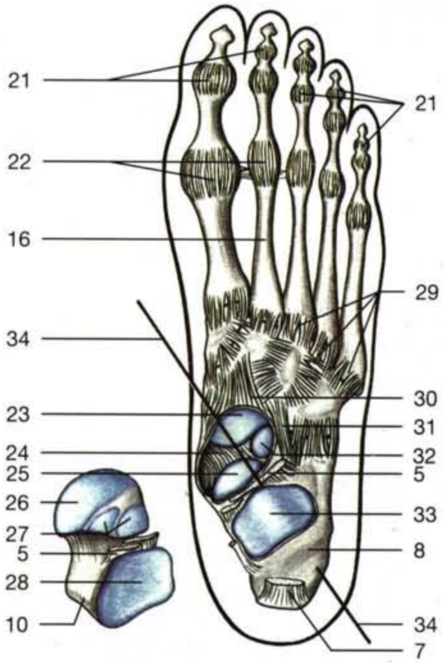

Talocalcaneonavicular joint.
The talus has been rotated to show the articular surfaces of the joint.

1 Tibia
2 Deep flexor muscles
3 Superficial flexor muscles
4 **Talocrural joint**
5 Interosseous talocalcaneal ligament
6 **Subtalar joint**
7 Calcaneal or Achilles tendon and bursa
8 Calcaneus
9 Vessels and nerves of foot
10 Talus
11 **Talocalcaneonavicular joint**
12 Navicular bone
13 **Cuneonavicular joint**
14 Intermediate cuneiform bone
15 **Tarsometatarsal joints**
16 Metatasal bones
17 **Metatarsophalangeal** and **interphalangeal joints**
18 Quadratus plantae muscle with flexor tendons
19 Flexor digitorum brevis muslce
20 Plantar aponeurosis
21 Articular capsules of interphalangeal joints
22 Articular capsules of metatarsophalangeal joints
23 Articular surface of navicular bone
24 Plantar calcaneonavicular ligament
25 Middle talar articular surface of calcaneus
26 Navicular articular surface of talus
27 Anterior and middle calcaneal surfaces of talus
28 Posterior calcaneal surface of talus
29 Dorsal tarsometatarsal ligaments
30 Talonavicular ligament
31 Bifurcate ligament
32 Anterior talar articular surface of calcaneus
33 Posterior talar articular surface of calcaneus
34 Axis for inversion and eversion
35 Tendon of tibialis posterior muscle
36 Tendon of flexor hallucis longus muscle
37 Flexor hallucis brevis muscle
38 Sesamoid bone
39 Cuboid bone

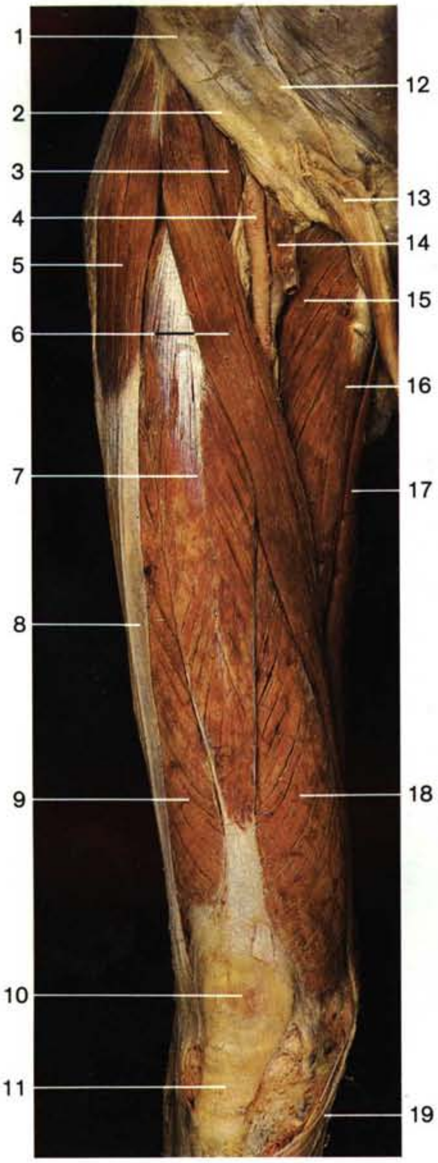

Extensor and adductor muscles of thigh, right thigh (anterior aspect).

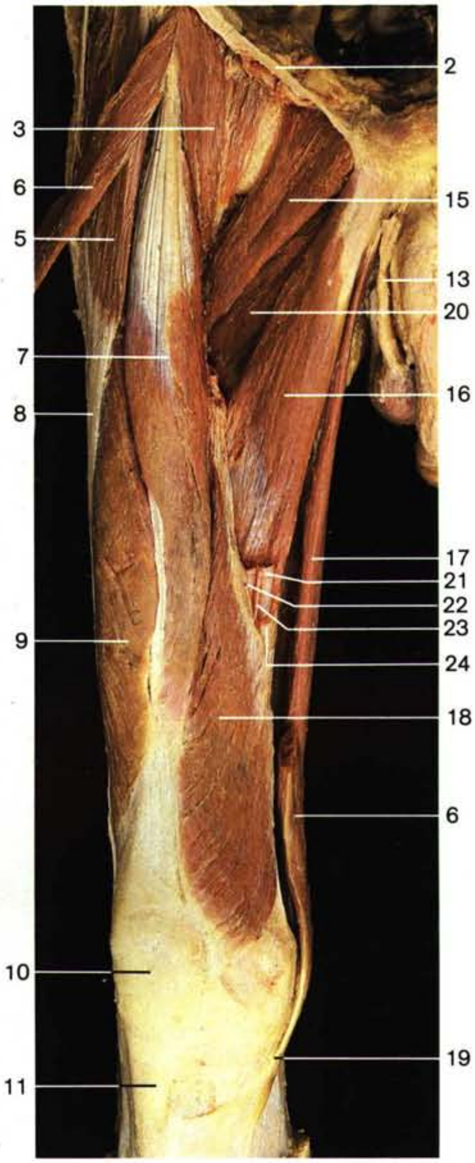

Quadriceps muscle and superficial layer of adductor muscles, right thigh (anterior aspect). The sartorius muscle has been divided.

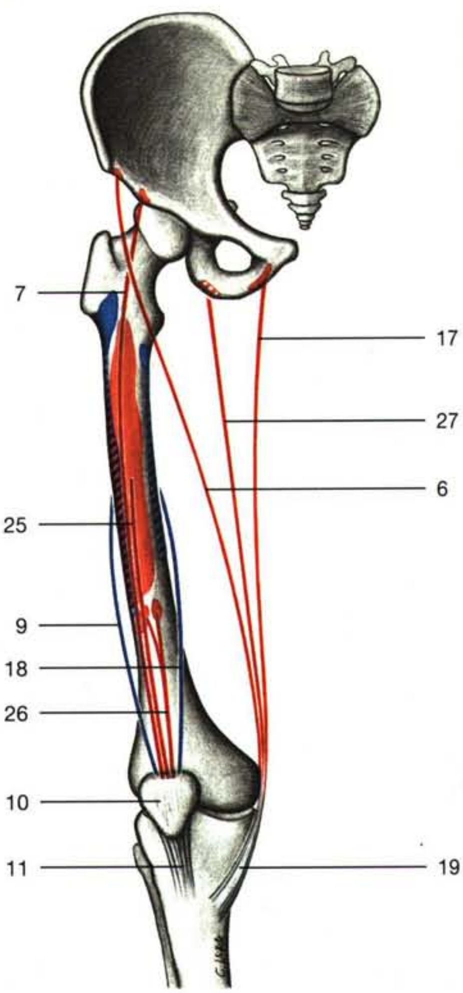

Course of extensor muscles of thigh and muscles inserting with common tendon on tibia.

1 Anterior superior iliac spine
2 Inguinal ligament
3 Iliopsoas muscle
4 Femoral artery
5 Tensor fasciae latae muscle
6 Sartorius muscle
7 **Rectus femoris muscle**
8 Iliotibial tract
9 Vastus lateralis muscle
10 Patella
11 Patellar ligament
12 Aponeurosis of external abdominal oblique muscle
13 Spermatic cord
14 Femoral vein

15 **Pectineus muscle**
16 **Adductor longus muscle**
17 Gracilis muscle
18 Vastus medialis muscle
19 Common tendon of sartorius, gracilis, and semitendinosus muscles (pes anserinus)
20 **Adductor brevis muscle**
21 Femoral artery } entering the adductor canal
22 Femoral vein
23 Saphenous nerve
24 Fascia of adductor canal
25 Vastus intermedius muscle
26 Articularis genus muscle
27 Semitendinosus muscle

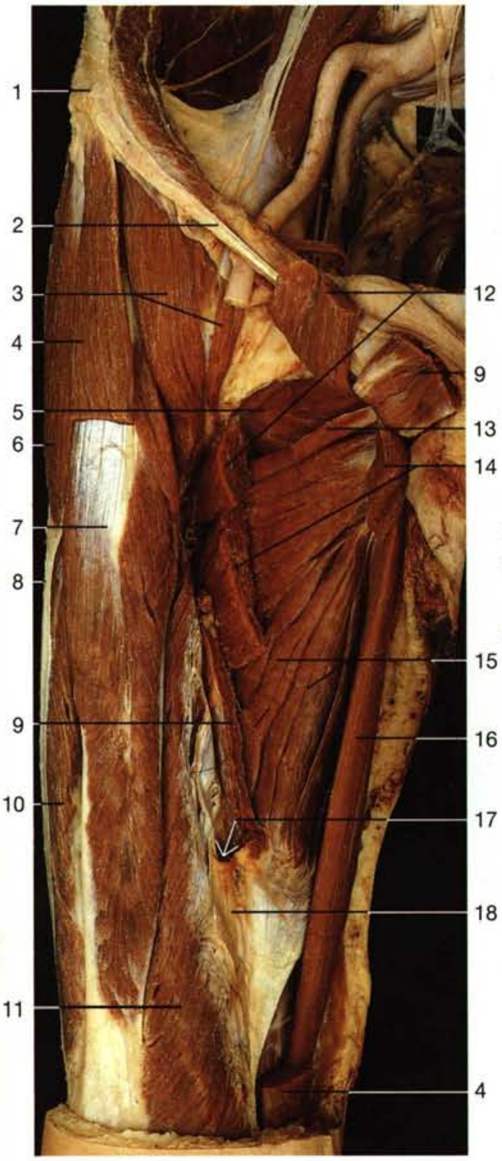

Deep layer of adductor muscles. Adductor magnus muscle (anterior aspect). Pectineus, adductor longus and brevis muscles have been divided.

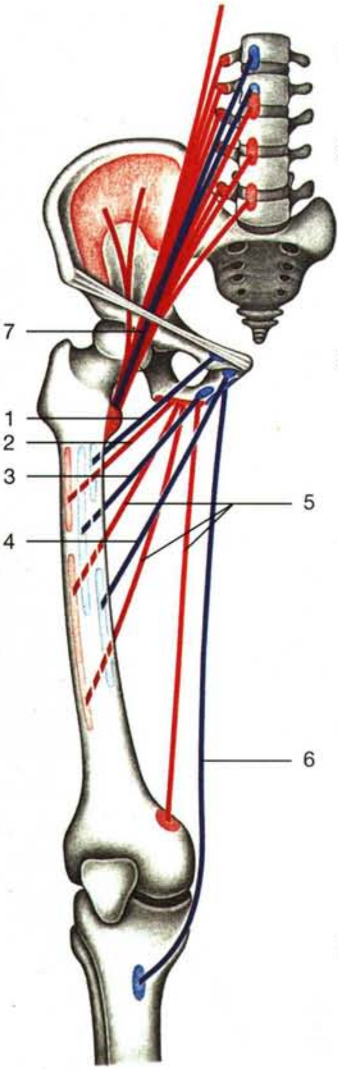

Course of adductor muscles. (Schematic drawing.)

1 Pectineus muscle (blue)
2 Adductor minimus muscle (red)
3 Adductor brevis muscle (blue)
4 Adductor longus muscle (blue)
5 Adductor magnus muscle (red)
6 Gracilis muscle (blue)
7 Iliopsoas muscle (red/blue)

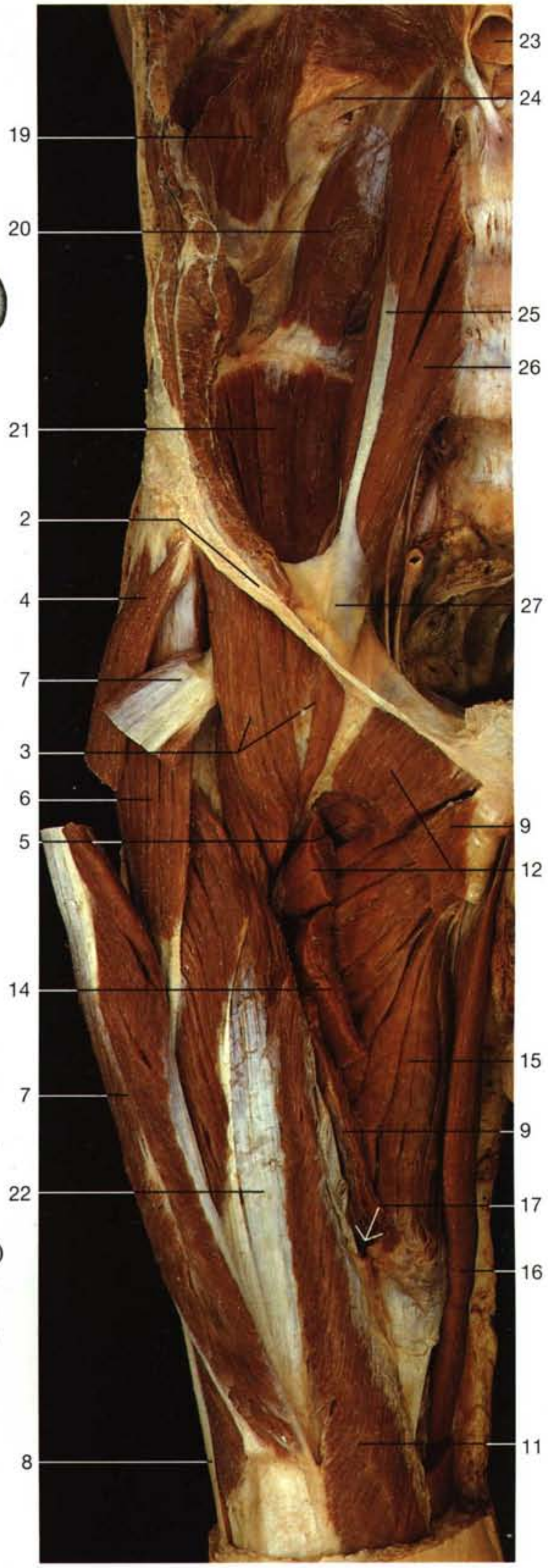

Iliopsoas and adductor muscles; deepest layer (anterior aspect). Pectineus, adductor longus and brevis, rectus femoris muscles have been divided.

1 Anterior superior iliac spine
2 Inguinal ligament
3 **Iliopsoas muscle**
4 Sartorius muscle
5 Obturator externus muscle
6 Tensor fasciae latae muscle
7 Rectus femoris muscle
8 Iliotibial tract
9 Adductor longus muscle (divided)
10 Vastus lateralis muscle
11 Vastus medialis muscle
12 Pectineus muscle (divided)
13 Adductor minimus muscle
14 Adductor brevis muscle (cut)
15 **Adductor magnus**
16 Gracilis muscle
17 Adductor hiatus
18 Vastoadductor membrane
19 Diaphragm
20 Quadratus lumborum muscle
21 **Iliacus muscle**
22 Vastus intermedius muscle
23 Aorta in aortic hiatus
24 Twelfth rib
25 **Psoas minor muscle**
26 **Psoas major muscle**
27 Iliopectineal arch

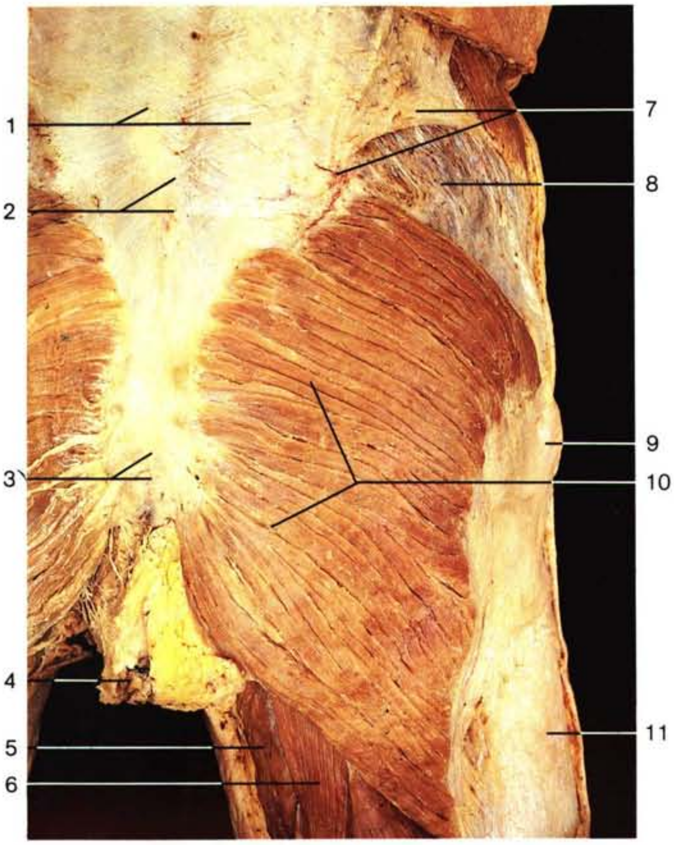
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Gluteal muscles, superficial layer (posterior aspect).

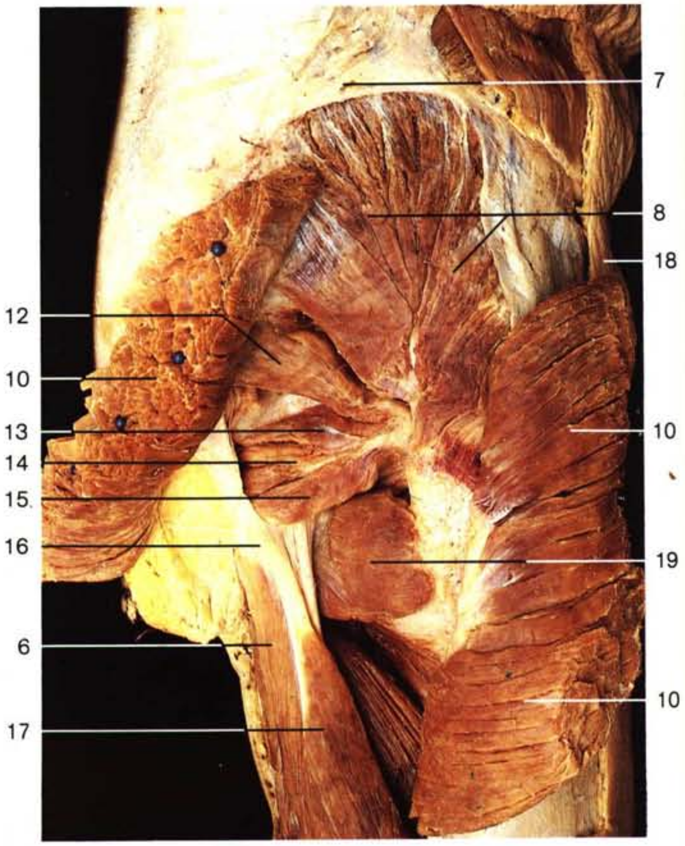
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Gluteal muscles, deeper layer (posterior aspect).

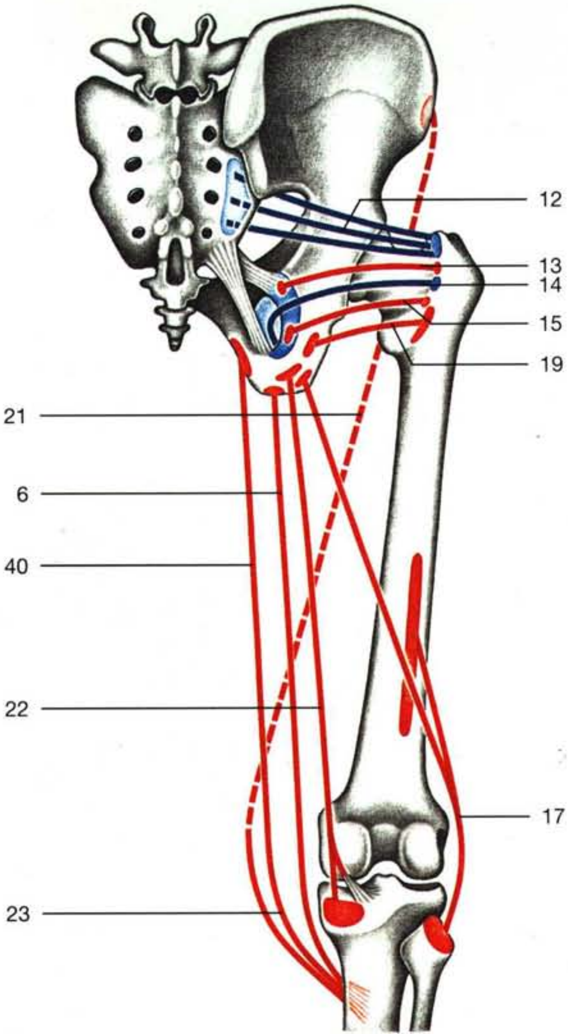
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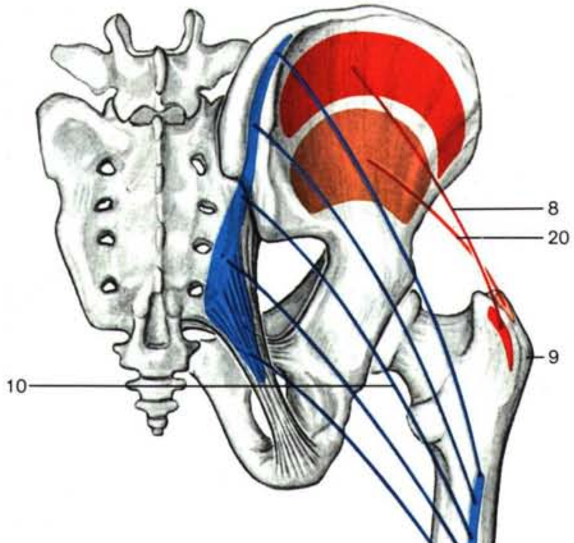

Course of gluteal muscles
(posterior aspect; schematic drawing).

◁

Course of gluteal muscles (deeper layer) **and of ischiocrural muscles** (posterior aspect).
Sartorius muscle is indicated by dotted line (schematic drawing).

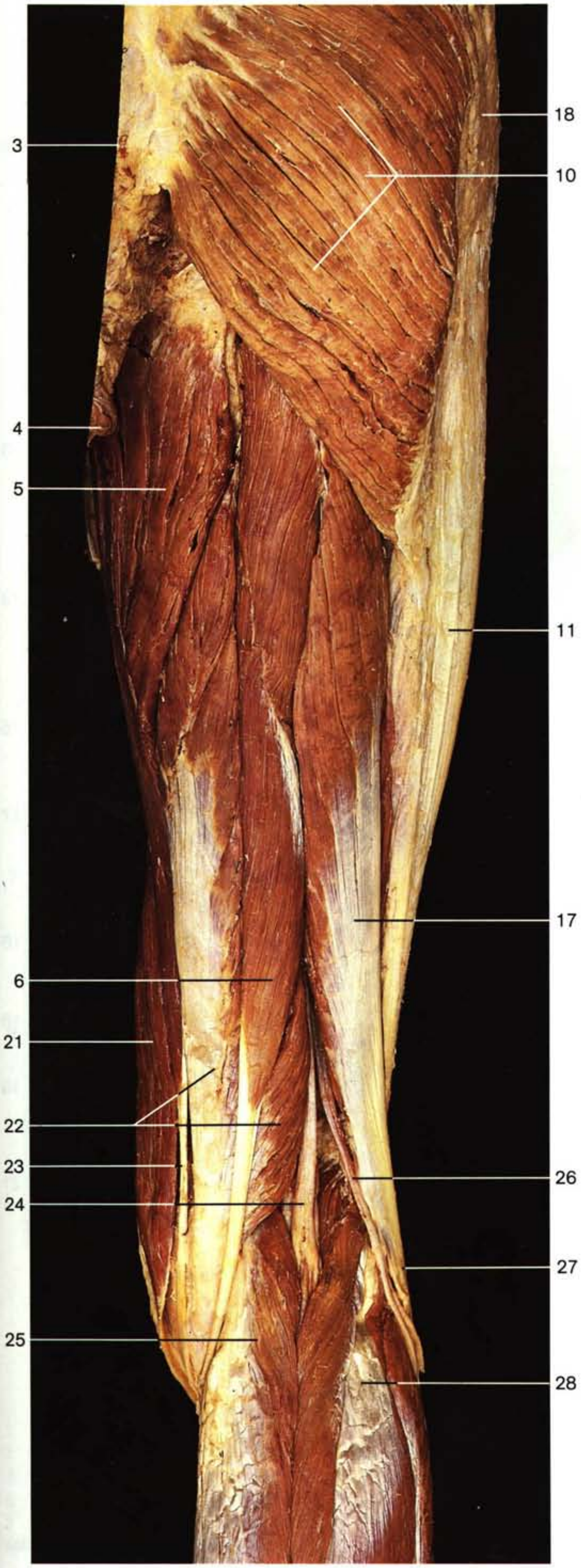

Flexors of the right thigh, superficial layer (dorsal aspect).

1 Thoracolumbar fascia
2 Spinous processes of lumbar vertebrae
3 Coccyx
4 Anus
5 Adductor magnus muscle
6 Semitendinosus muscle
7 Iliac crest
8 **Gluteus medius muscle**
9 Greater trochanter
10 **Gluteus maximus muscle**
11 Iliotibial tract
12 Piriformis muscle
13 Superior gemellus muscle
14 Obturator internus muscle
15 Inferior gemellus muscle
16 Ischial tuberosity
17 **Biceps femoris muscle**
18 Tensor fasciae latae muscle
19 Quadratus femoris muscle
20 **Gluteus minimus muscle**
21 Sartorius muscle
22 Semimembranosus muscle
23 Tendon of gracilis muscle
24 Tibial nerve
25 Medial head of gastrocnemius muscle
26 Common peroneal nerve
27 Tendon of biceps femoris muscle
28 Lateral head of gastrocnemius muscle
29 Rectus femoris muscle
30 Vastus medialis muscle
31 Vastus intermedius muscle
32 Vastus lateralis muscle
33 Sciatic nerve
34 Gluteus maximus muscle (insertion)
35 Great saphenous vein
36 Femoral artery
37 Femoral vein
38 Adductor longus muscle
39 Femur
40 Gracilis muscle
41 Septum between semitendinosus and semimembranosus muscles

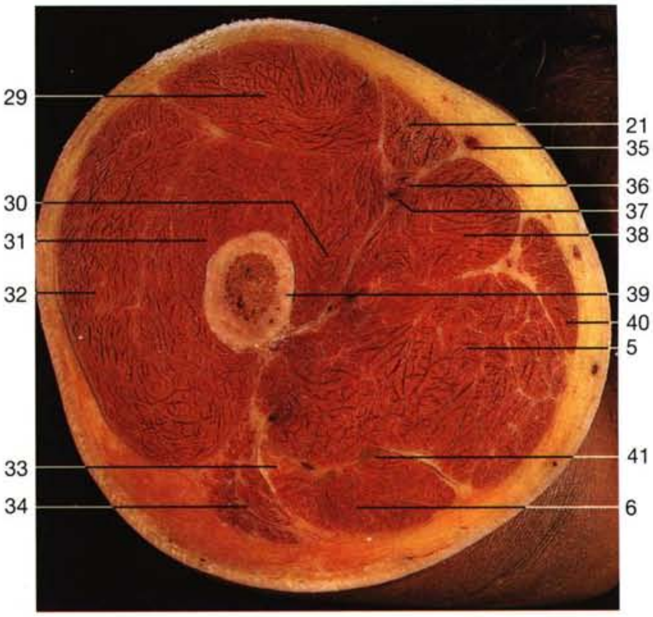

Cross section of right thigh (inferior aspect). Anterior side on top.

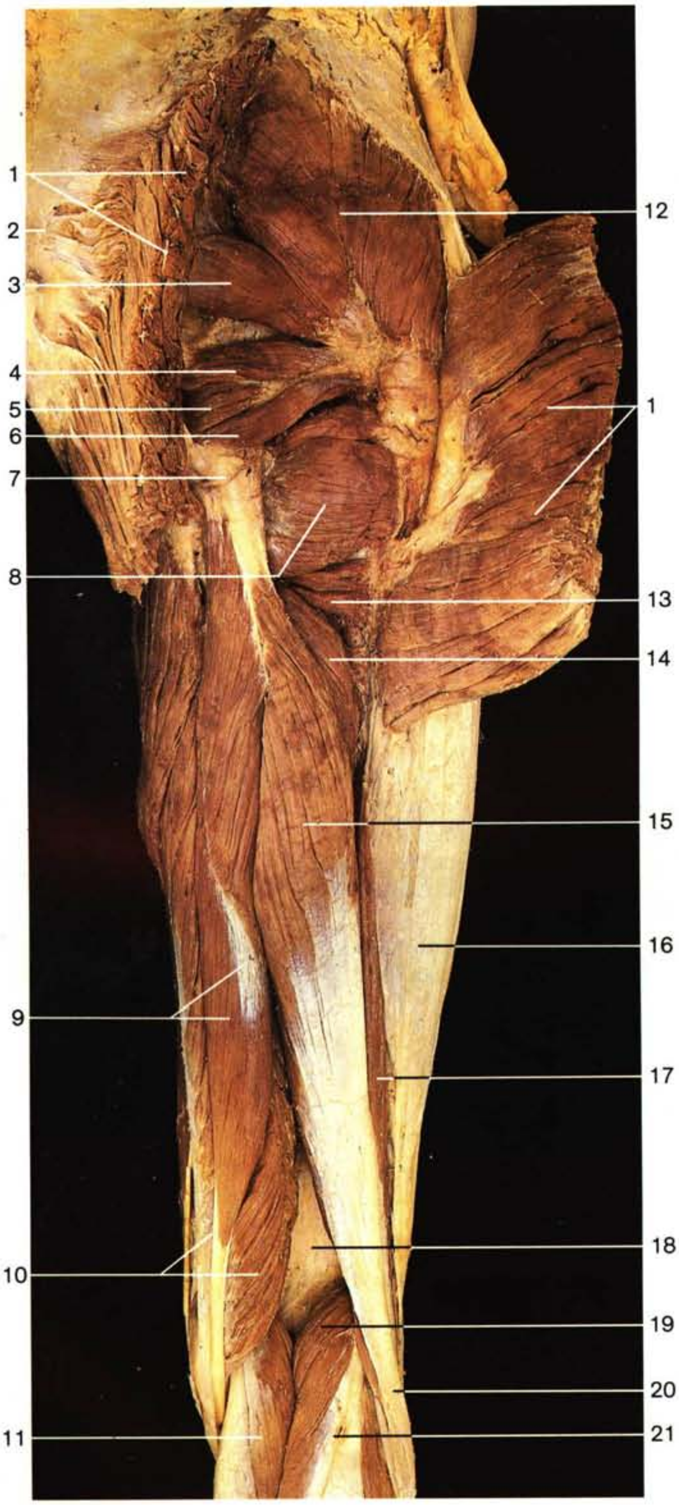

Dorsal muscles of right thigh (posterior aspect).
The gluteus maximus muscle has been cut and reflected.

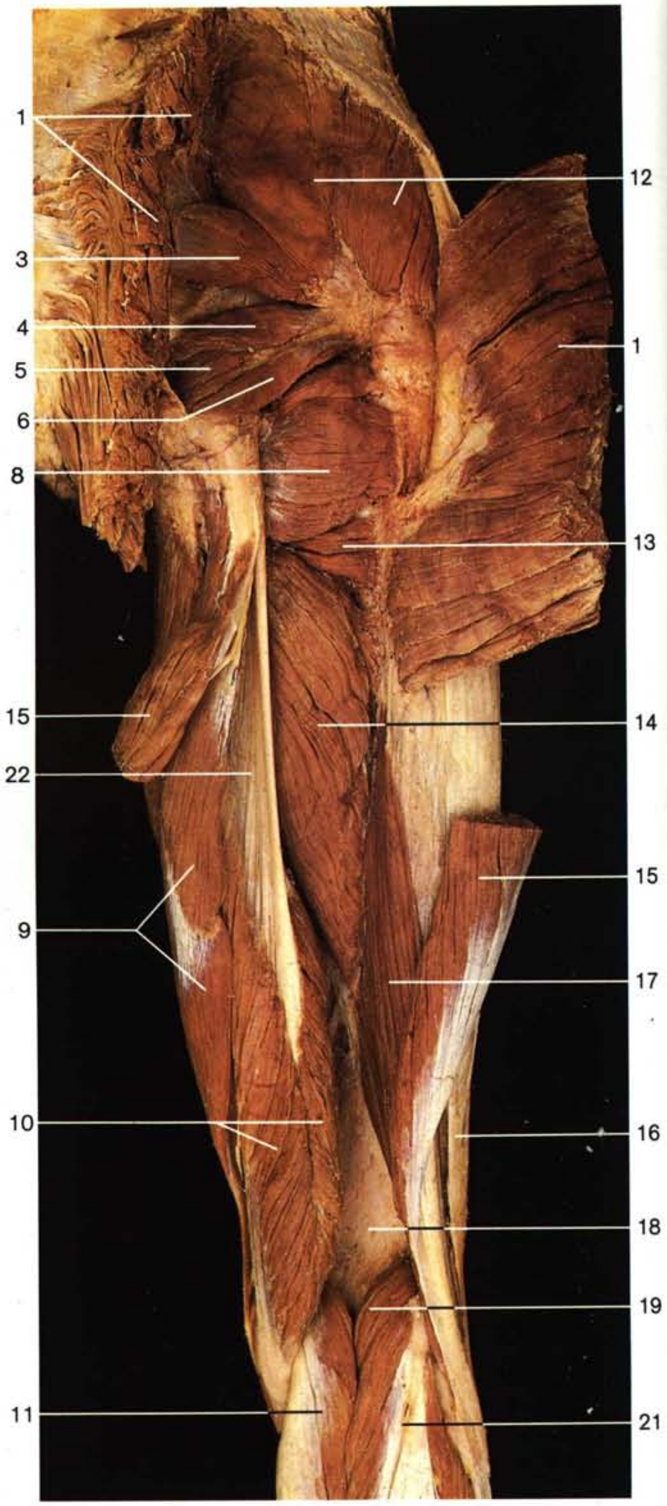

Dorsal muscles of right thigh (posterior aspect).
The gluteus maximus muscle and the long head of biceps femoris muscle have been divided and displaced.

1 Gluteus maximus muscle (divided)
2 Position of coccyx
3 Piriformis muscle
4 Superior gemellus muscle
5 Obturator internus muscle
6 Inferior gemellus muscle
7 Ischial tuberosity
8 Quadratus femoris muscle
9 Semitendinosus muscle with intermediate tendon
10 Semimembranosus muscle
11 Medial head of gastrocnemius muscle
12 Gluteus medius muscle
13 Adductor minimus muscle
14 Adductor magnus muscle
15 Long head of biceps femoris muscle
16 Iliotibial tract
17 Short head of biceps femoris muscle
18 Popliteal surface of femur
19 Plantaris muscle
20 Tendon of biceps femoris muscle
21 Lateral head of gastrocnemius muscle
22 Membranous part of semimembranosus muscle

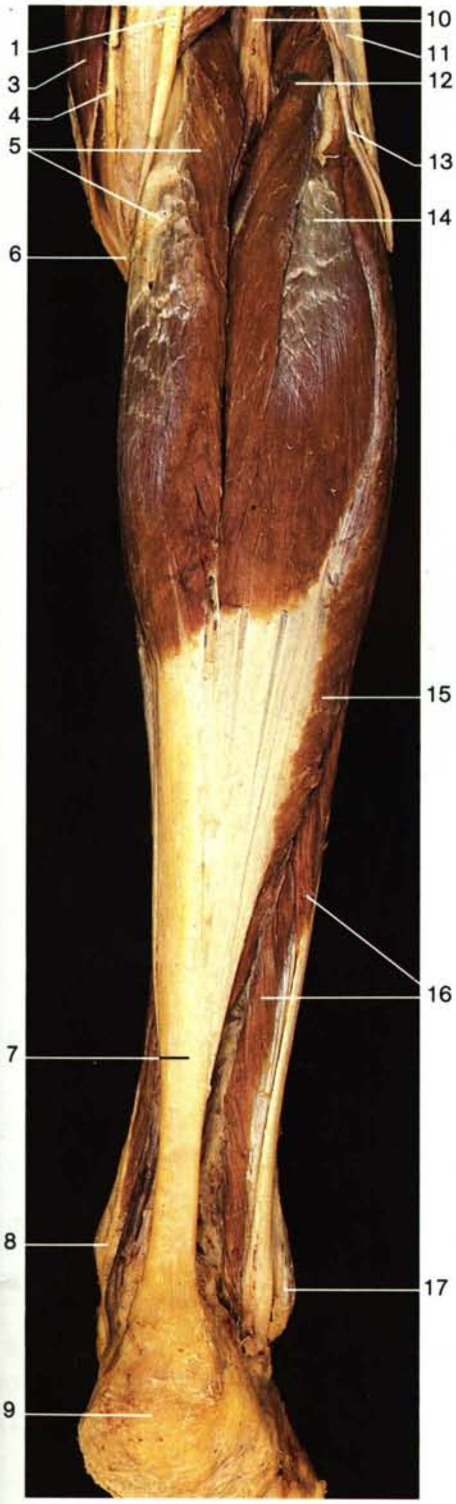

Flexor muscles of right leg (posterior aspect).

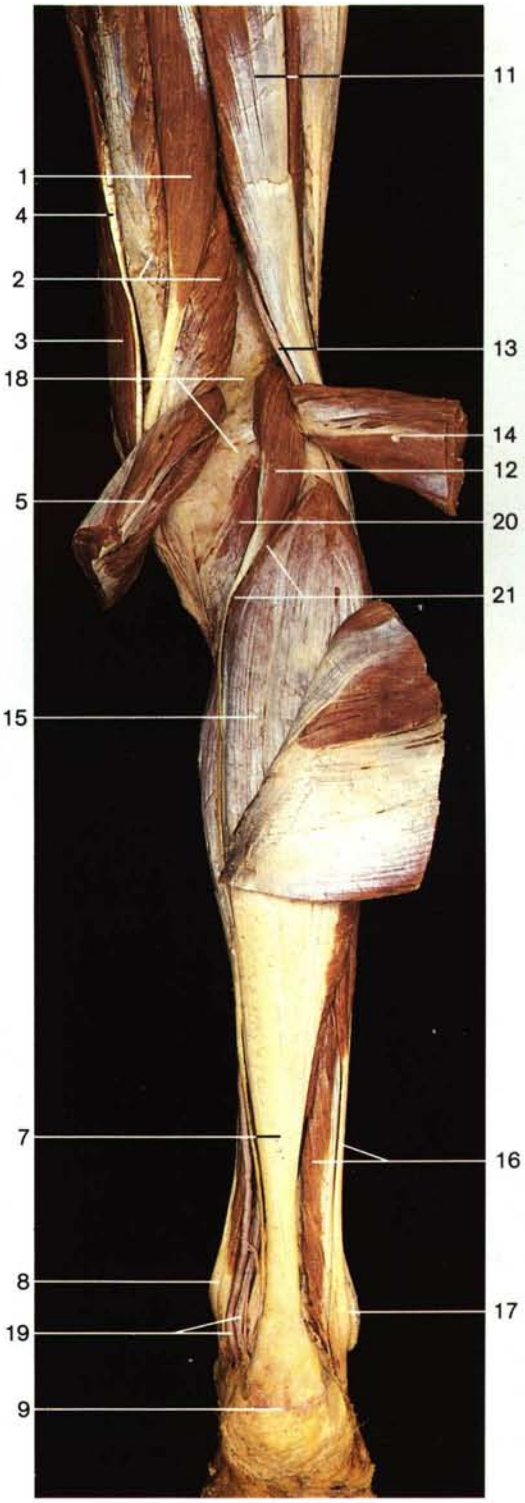

Flexor muscles of right leg (posterior aspect). Both heads of the gastrocnemius muscle have been cut and reflected.

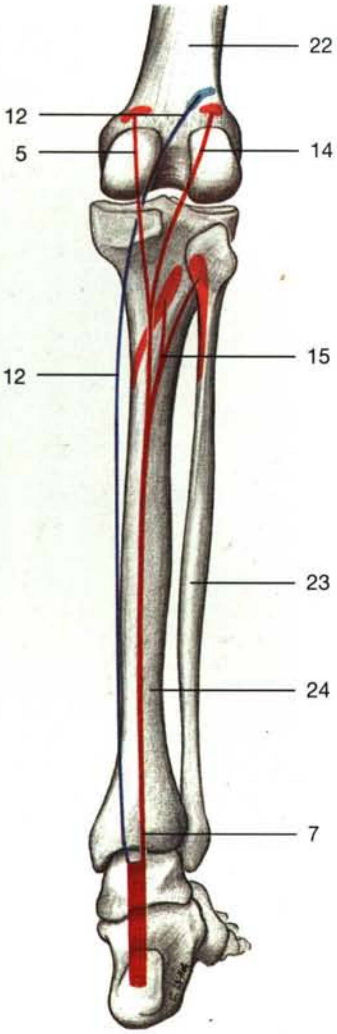

Flexor muscles of the leg (right side).

1 Semitendinosus muscle
2 Semimembranosus muscle
3 Sartorius muscle
4 Tendon of gracilis muscle
5 **Medial head of gastrocnemius muscle**
6 Common tendon of gracilis, sartorius, and semitendinosus muscles
7 Calcaneal or Achilles tendon
8 Medial malleolus
9 Calcaneal tuberosity
10 Tibial nerve
11 Biceps femoris muscle
12 Plantaris muscle
13 Common peroneal nerve
14 **Lateral head of gastrocnemius muscle**
15 **Soleus muscle**
16 Peroneus longus and brevis muscles
17 Lateral malleolus
18 Popliteal fossa
19 Tibial nerve and posterior tibial artery
20 Popliteus muscle
21 Tendinous arch of soleus muscle
22 Femur
23 Fibula
24 Tibia

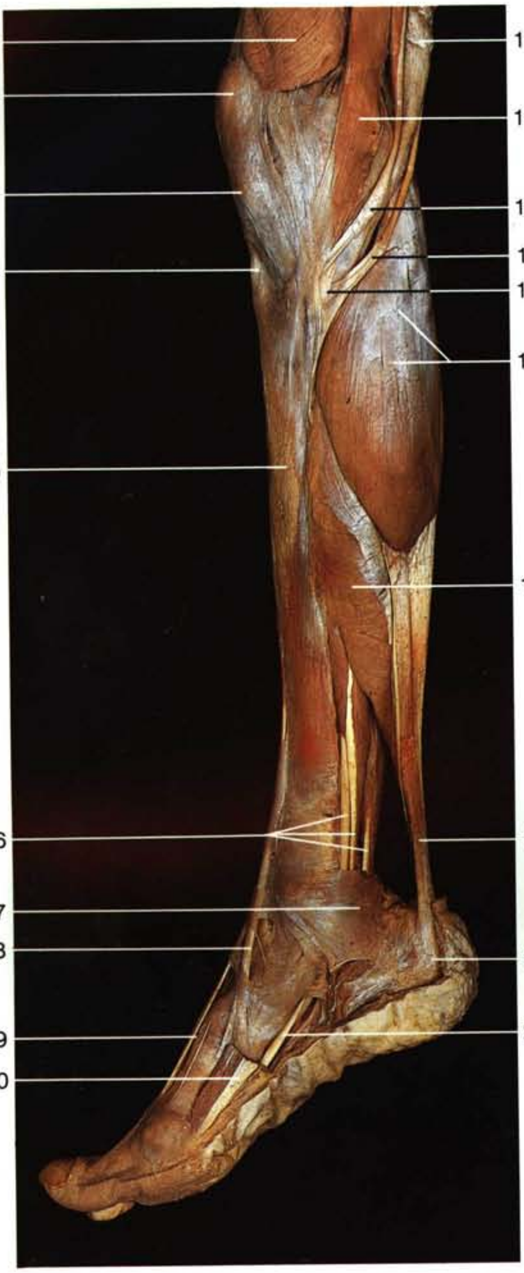

Muscles of right leg and foot (medial aspect).

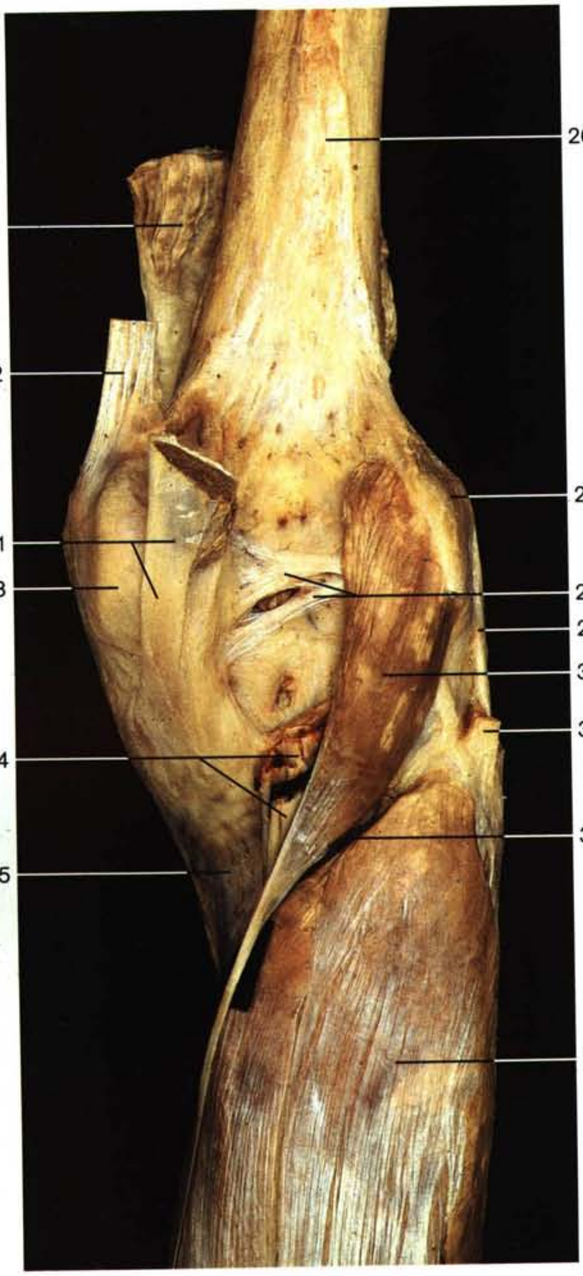

Popliteal region with plantaris and soleus, right side (dorsal aspect). Notice the insertion of the tendon of semimembranosus.

1 Vastus medialis muscle
2 Patella
3 Patellar ligament
4 Tibial tuberosity
5 Tibia
6 Tendons of deep flexor muscles (from anterior to posterior: 1. tibialis posterior; 2. flexor digitorum longus; 3. flexor hallucis longus muscles)
7 Flexor retinaculum
8 Tendon of tibialis anterior muscle
9 Tendon of extensor hallucis longus muscle
10 Abductor hallucis muscle
11 Semimembranosus muscle
12 Sartorius muscle
13 Tendon gracilis muscle
14 Tendon of semitendinosus muscle
15 Common tendon of gracilis, semitendinosus and sartorius muscles
16 **Medial head of gastrocnemius muscle**
17 **Soleus muscle**
18 Calcaneal or Achilles tendon
19 Calcaneus muscle
20 Tendon of flexor hallucis longus muscle
21 Quadriceps femoris muscle (divided)
22 Tendon of adductor magnus muscle (divided)
23 Medial condyle of femur
24 Popliteal artery and vein, tibial nerve
25 Tibia
26 Femur
27 Lateral epicondyle of femur
28 Oblique popliteal ligament
29 Lateral (fibular) collateral ligament
30 **Plantaris muscle**
31 Tendon of biceps femoris muscle (divided)
32 Tendinous arch of soleus muscle

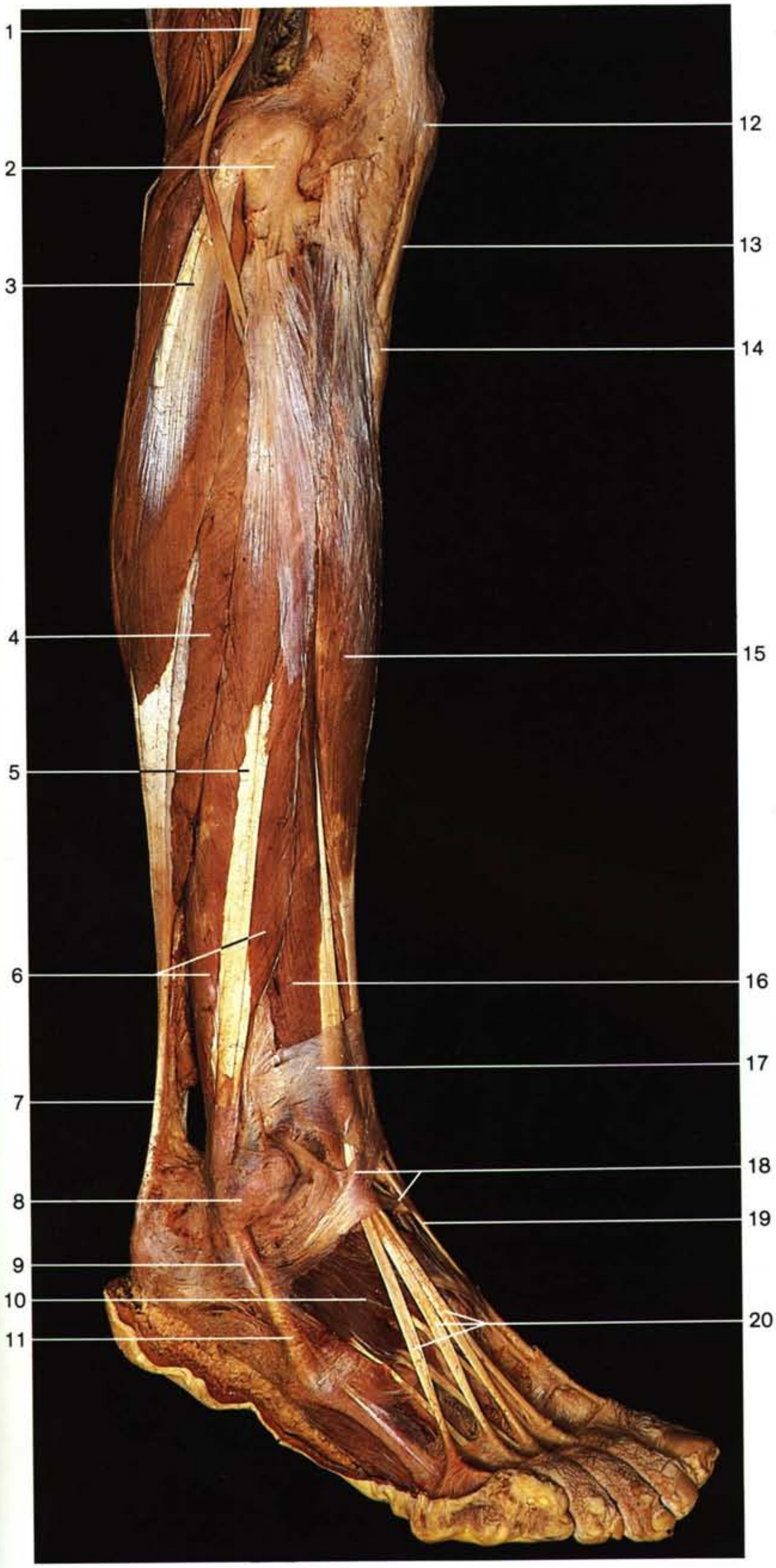

Muscles of right leg and foot (lateral aspect).

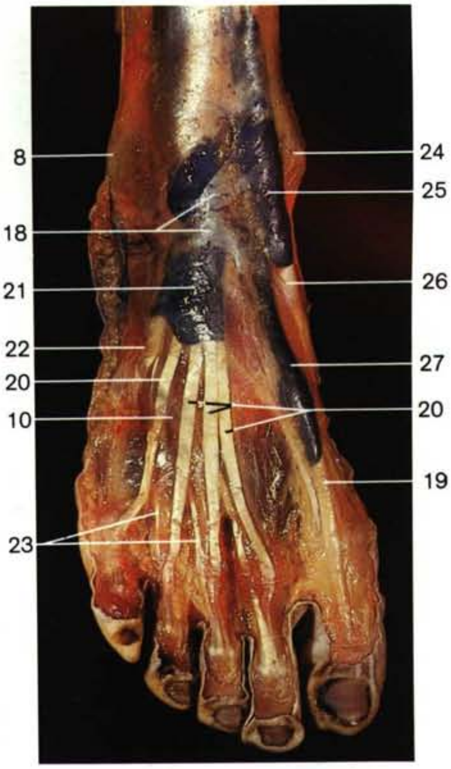

Right foot with synovial sheaths of extensor muscles (dorsal aspect). The synovial sheaths have been injected with blue solution.

1 Common peroneal nerve
2 Head of fibula
3 Lateral head of gastrocnemius muscle
4 Soleus muscle
5 Peroneus longus muscle
6 Peroneus brevis muscle
7 Calcaneal or Achilles tendon
8 Lateral malleolus muscle
9 Tendon of peroneus longus muscle
10 Extensor digitorum brevis muscle
11 Tendon of peroneus brevis muscle
12 Patella
13 Patellar ligament
14 Tuberosity of tibia
15 Tibialis anterior muscle
16 Extensor digitorum longus muscle
17 Superior extensor retinaculum
18 Inferior extensor retinaculum
19 Tendon of extensor hallucis longus muscle
20 Tendons of extensor digitorum longus muscle
21 Common synovial sheath of extensor digitorum longus muscle
22 Tendon of peroneus tertius muscle to the lateral margin of foot
23 Tendons of extensor digitorum brevis muscle
24 Medial malleolus
25 Synovial sheath of tendon of tibialis anterior muscle
26 Tendon of tibialis anterior muscle
27 Synovial sheath of tendon of extensor hallucis longus muscle

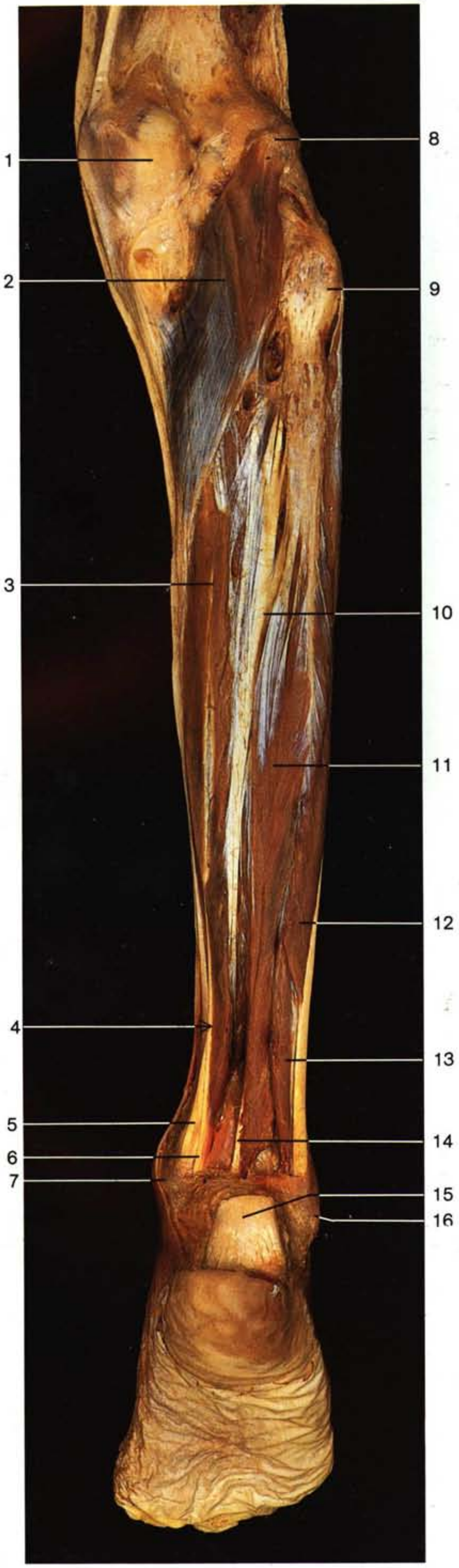

1 Medial condyle of femur
2 Popliteus muscle
3 Flexor digitorum longus muscle
4 Crosssing of tendons in leg
5 Tendon of tibialis posterior muscle
6 Tendon of flexor digitorum longus muscle
7 Medial malleolus
8 Lateral condyle of femur
9 Head of fibula
10 Tibialis posterior muscle
11 Flexor hallucis longus muscle
12 Peroneus longus muscle
13 Peroneus brevis muscle
14 Tendon of flexor hallucis longus muscle
15 Calcaneal tendon (divided)
16 Lateral malleolus

Deep flexor muscles of right leg (posterior aspect).

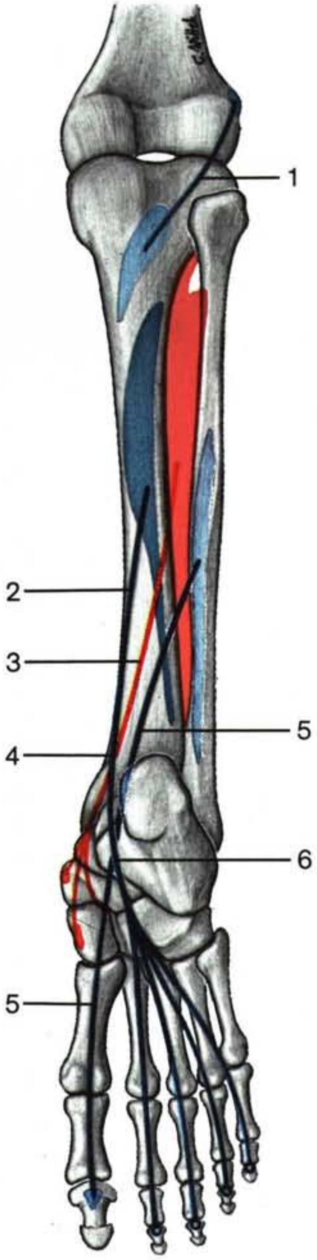

1 Popliteus muscle (blue)
2 Flexor digitorum longus muscle (blue)
3 Tibialis posterior muscle (red)
4 Crossing of tendons in leg
5 Flexor hallucis longus muscle (blue)
6 Crossing of tendons in sole

Course of deep flexor muscle of leg. (Schematic drawing.)

1 Medial condyle of femur
2 Tibia
3 Flexor digitorum longus muscle
4 Crossing of tendons in leg
5 Tendon of tibialis posterior muscle
6 Abductor hallucis muscle
7 Tendon of flexor hallucis longus muscle
8 Lateral condyle of femur
9 Head of fibula
10 Tibialis posterior muscle
11 Tendon of flexor digitorum longus muscle
12 Flexor retinaculum
13 Calcaneal tendon
14 Calcaneal tuberosity
15 Crossing of tendons in sole
16 Quadratus plantae muscle
17 Tendons of flexor digitorum longus muscle
18 Tendon of tibialis anterior muscle
19 Area of insertion of tibialis posterior muscle
20 Lumbrical muscles
21 Flexor hallucis longus muscle

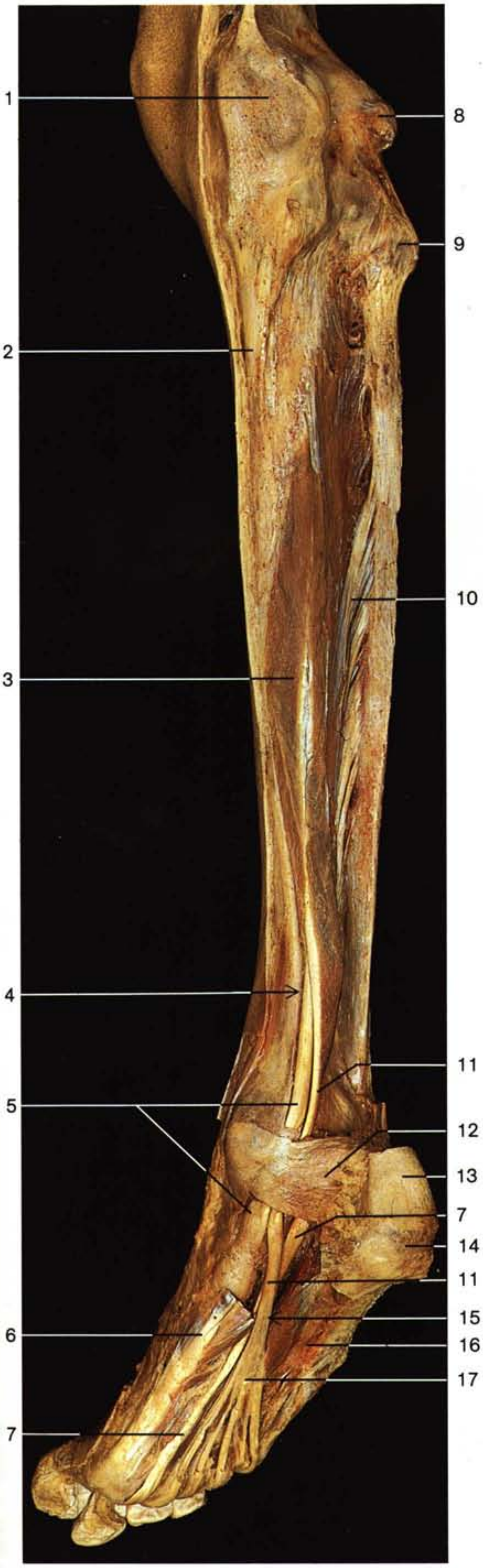

Deep flexor muscles of right leg and foot (posterior oblique medial aspect). Felxor digitorum brevis and flexor hallucis longus muscles have been removed.

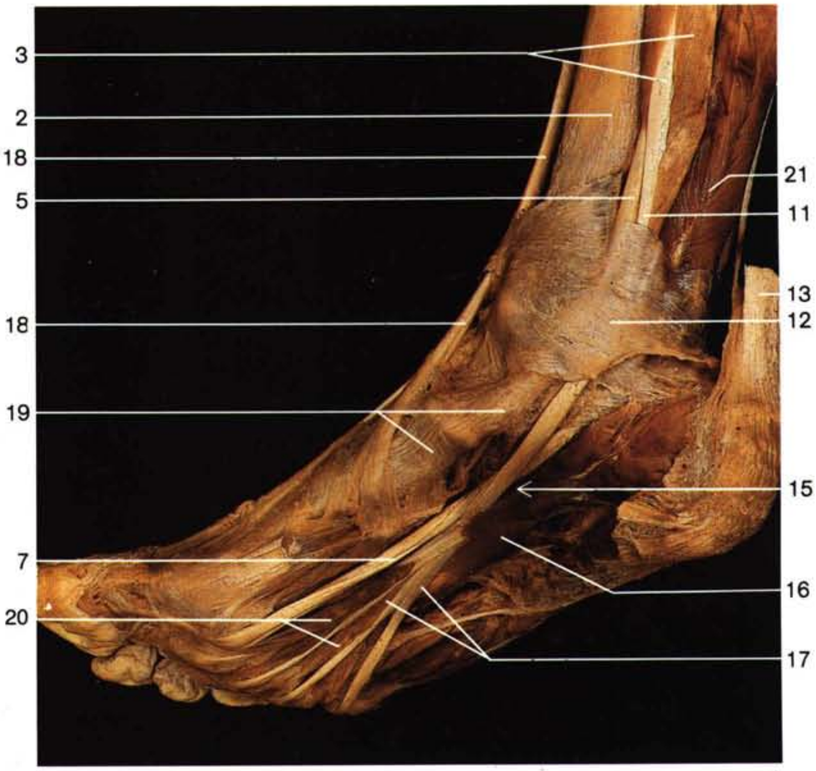

Sole of foot; tendons of long flexor muscles (oblique medial and inferior aspect).

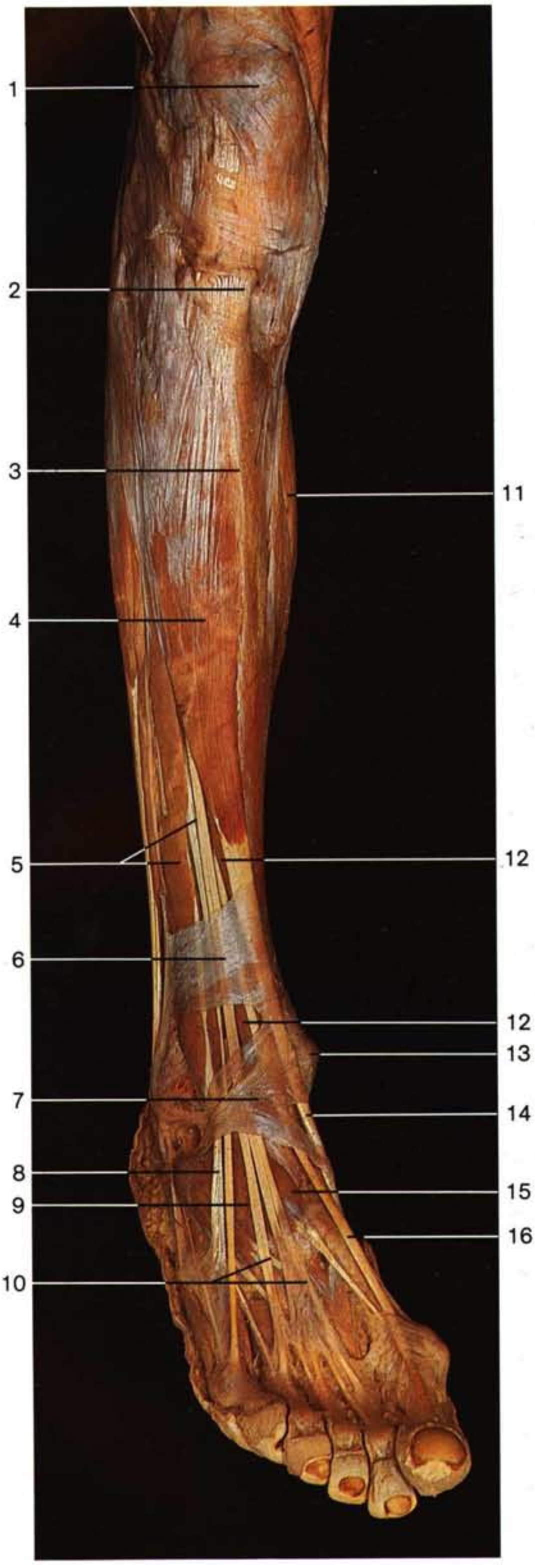

Extensor muscles of right leg and foot
(oblique anterolateral aspect).

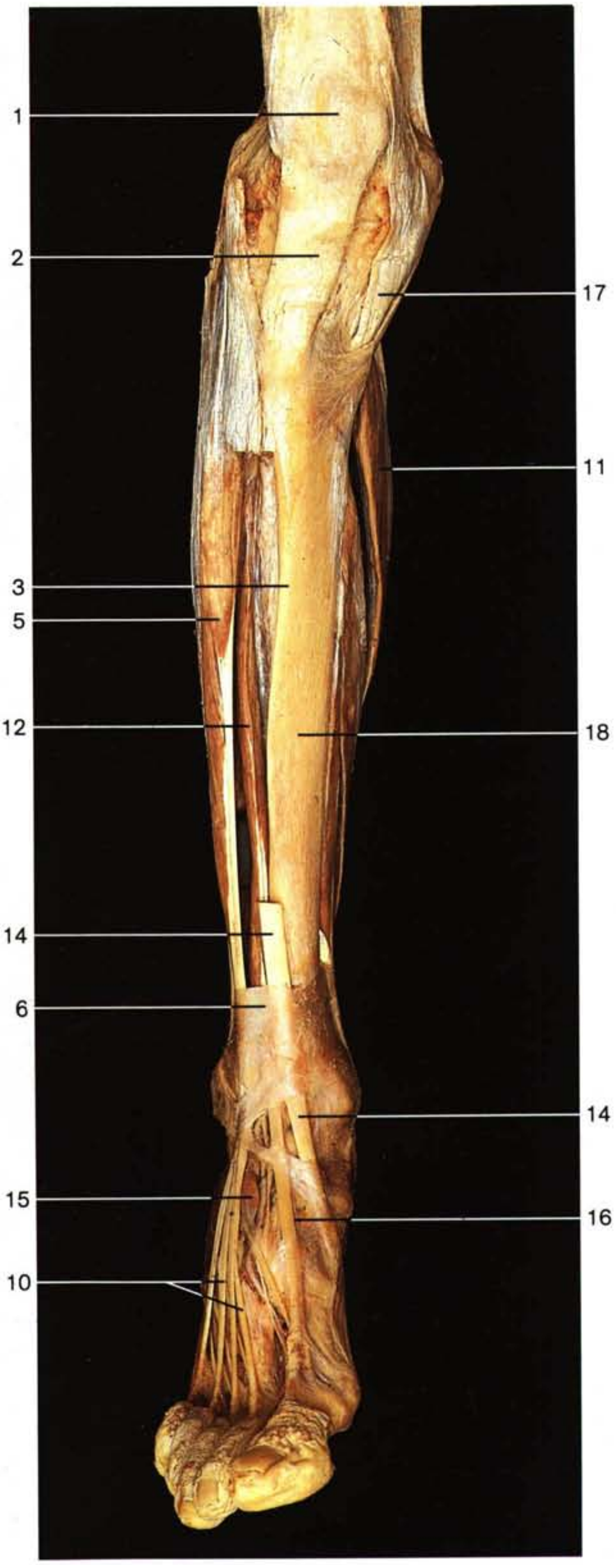

Extensors of the right leg and foot
(anterior aspect). Part of the tibialis anterior muscle has been removed.

1 Patella
2 Patellar ligament
3 Anterior margin of tibia
4 Tibialis anterior muscle
5 Extensor digitorum longus muscle
6 Superior extensor retinaculum
7 Inferior extensor retinaculum
8 Tendon of peroneus tertius muscle
9 Extensor digitorum brevis muscle
10 Tendons of extensor digitorum longus muscle
11 Soleus
12 Extensor hallucis longus muscle
13 Medial malleolus
14 Tendon of tibialis anterior muscle
15 Extensor hallucis brevis muscle
16 Tendon of extensor hallucis longus muscle
17 Common tendon of gracilis, semitendinosus and sartoris muscles
18 Tibia

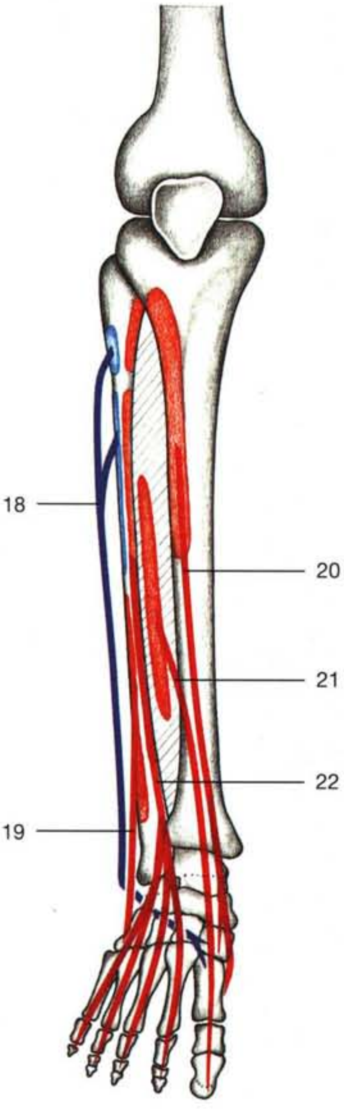

Extensor muscles of the leg (right side).

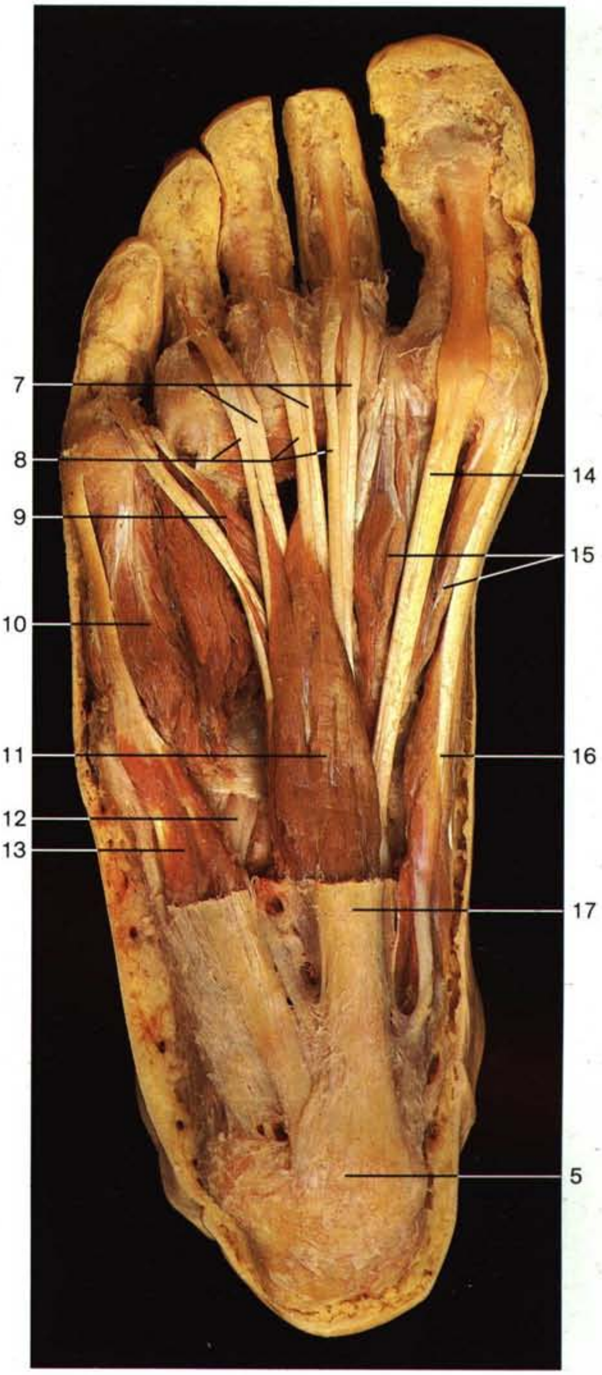

Sole of foot, first layer of muscles (from below). The plantar aponeurosis and the fasciae of the superficial muscles have been removed.

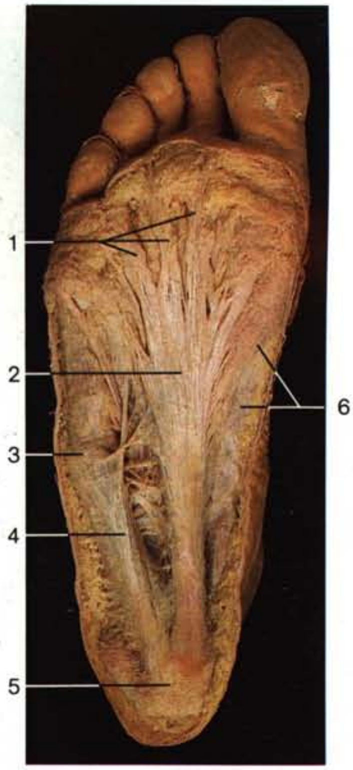

Sole of foot, plantar aponeurosis (from below).

1 Longitudinal bands of plantar aponeurosis
2 Plantar aponeurosis
3 Position of tuberosity of 5th metatarsal bone
4 Muscles of 5th toe with fascia
5 Calcaneal tuberosity
6 Muscles of great toe with fascia
7 Tendons of flexor digitorum longus muscle
8 Tendons of flexor digitorum brevis muscle
9 Lumbrical muscle
10 Flexor digiti minimi brevis muscle
11 Flexor digitorum brevis muscle
12 Tendon of peroneus longus muscle
13 Abductor digiti minimi muscle
14 Tendon of flexor hallucis longus muscle
15 Flexor hallucis brevis muscle
16 Abductor hallucis muscle
17 Plantar aponeurosis (cut)
18 Peroneus longus muscle
19 Peroneus brevis muscle
20 Tibialis anterior muscle
21 Extensor hallucis longus muscle
22 Extensor digitorum longus muscle

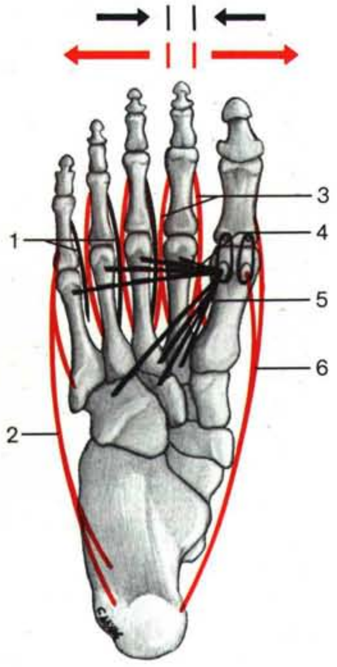

Course of abductor and adductor muscles of foot. (Schematic drawing.)
Red arrows = abduction.
Black arrows = adduction.

1 Plantar interossei muscles (black)
2 Abductor digiti minimi muscles (red)
3 Dorsal interossei muscle (red)
4 Transverse head of adductor muscle (black)
5 Oblique head of adductor muscle (black)
6 Abductor hallucis muscle (red)

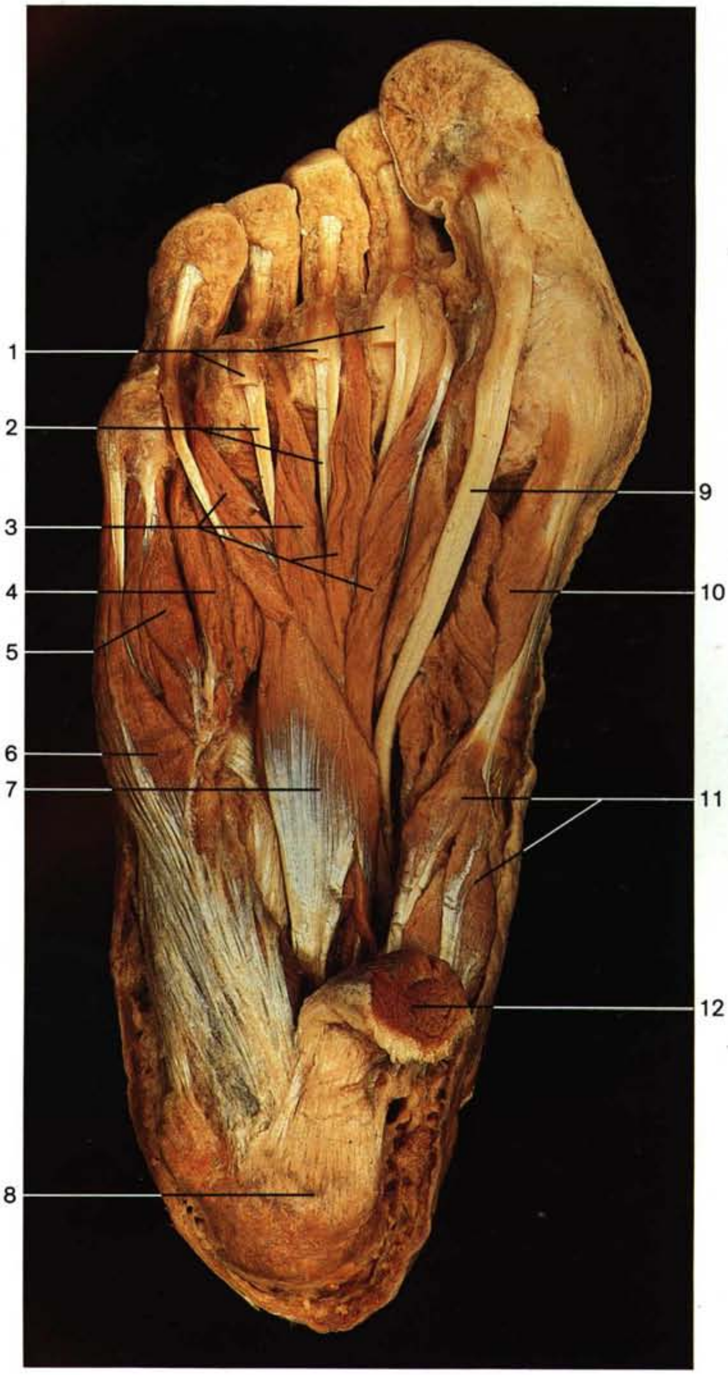

Muscles of sole of foot, second layer (from below). The flexor digitorum brevis muscle has been divided.

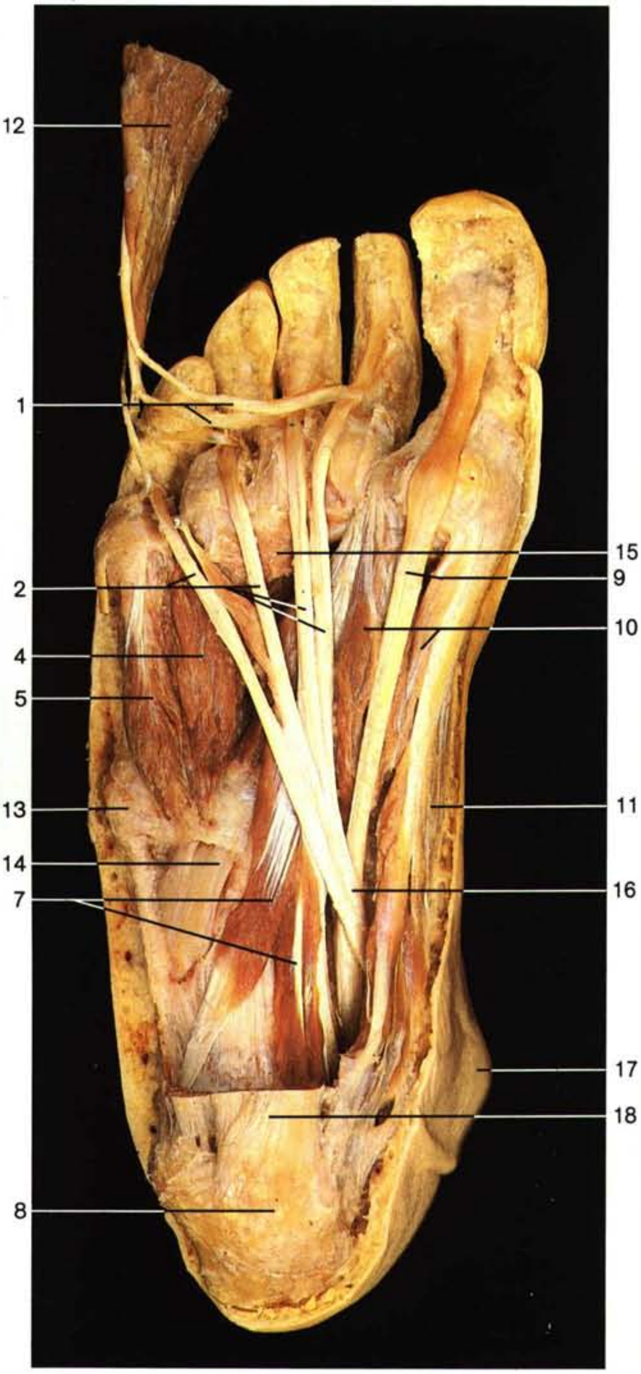

Muscles of sole of foot, second layer (from below). The tendons of the flexor muscles and the crossing of tendons are displayed. The flexor digitorum brevis muscle has been divided and reflected.

1 Tendons of flexor digitorum brevis muscle
2 Tendons of flexor digitorum longus muscle
3 Lumbrical muscles
4 Interossei muscles
5 Flexor digiti minimi brevis muscle
6 Abductor digiti minimi muscle
7 Quadratus plantae muscle
8 Calcaneal tuberosity
9 Tendon of flexor hallucis longus muscle
10 Flexor hallucis brevis muscle
11 Abductor hallucis muscle
12 Flexor digitorum brevis muscle (divided)
13 Tuberosity of 5th metatarsal bone
14 Tendon of peroneus longus muscle
15 Transverse head of adductor hallucis muscle
16 Crossing of tendons in sole of foot
17 Medial malleolus
18 Plantar aponeurosis (divided)

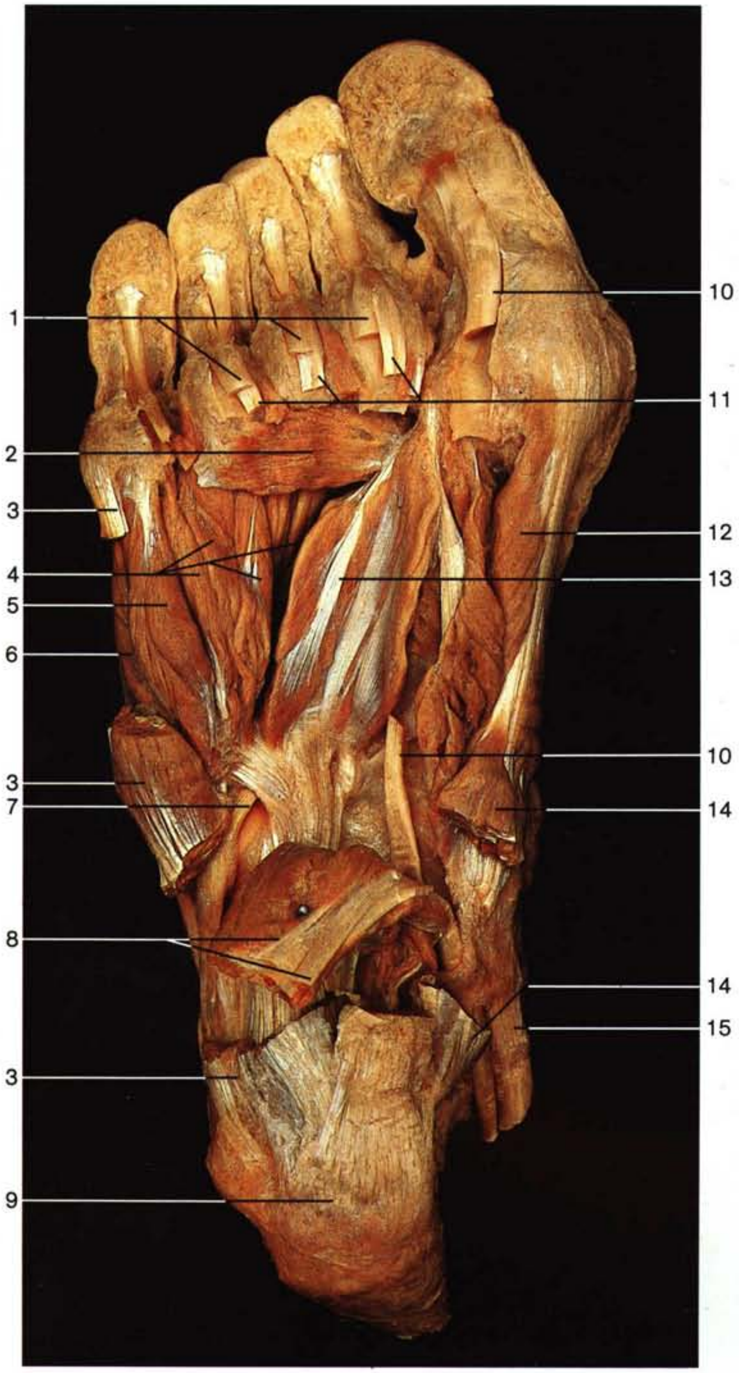

Muscles of sole of foot, third layer (from below). The flexor digitorum brevis muscle has been removed, and the quadratus plantae muscle and the abductor hallucis and digiti minimi muscles have been divided.

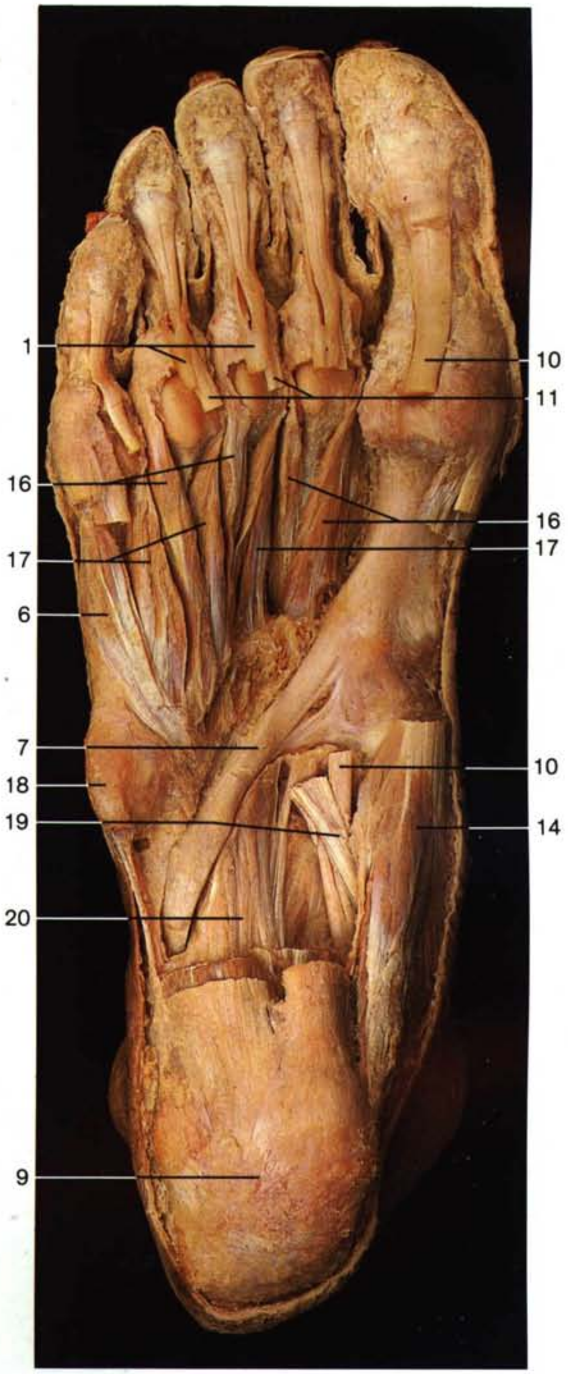

Muscles of sole of foot, fourth layer (from below). The interosseous muscles and the canal for the tendon of peroneus longus muscle are shown.

1 Tendons of flexor digitorum brevis muscle
2 Transverse head of adductor hallucis muscle
3 Abductor digiti minimi muscle
4 Interosseous muscles
5 Flexor digiti minimi brevis muscle
6 Opponens digiti minimi muscle
7 Tendon of peroneus longus muscle
8 Quadratus plantae muscle with tendon of flexor digitorum longus muscle
9 Calcaneal tuberosity
10 Tendons of flexor hallucis longus muscle (divided)
11 Tendon of flexor digitorum longus muscle
12 Flexor hallucis brevis muscle
13 Oblique head of adductor hallucis muscle
14 Abductor hallucis muscle (cut)
15 Tendon of tibialis posterior muscle
16 Dorsal interossei muscles
17 Plantar interossei muscles
18 Tuberosity of 5th metatarsal bone
19 Tendon of flexor digitorum longus muscle (crossing of plantar tendons)
20 Long plantar ligament

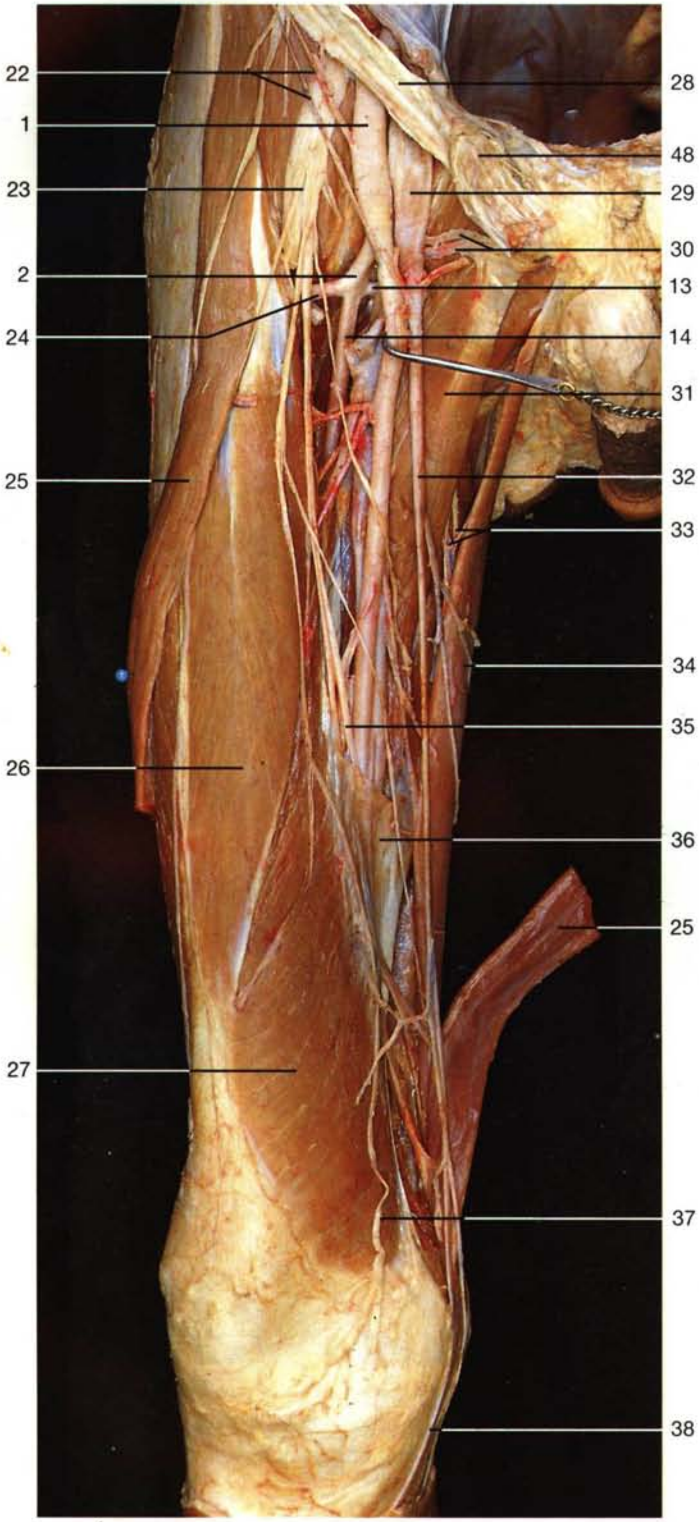
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Main arteries and nerves of right thigh (anterior aspect). Sartorius muscle has been divided and reflected. The femoral vein has been partly removed to show the deep femoral artery. Notice: the vessels enter the adductor canal to reach the popliteal fossa.

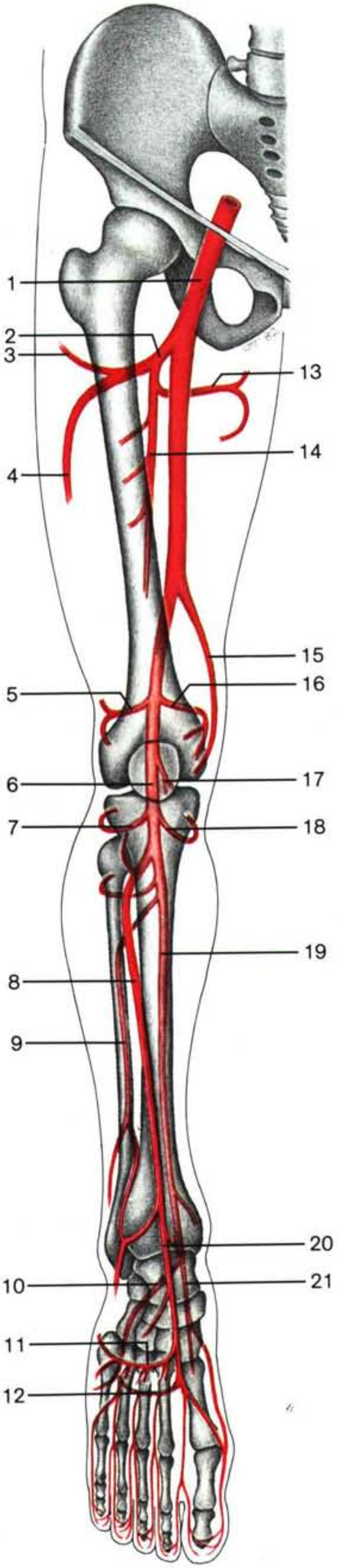
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Main arteries of lower extremity, right side (ventral aspect). (Schematic drawing.)

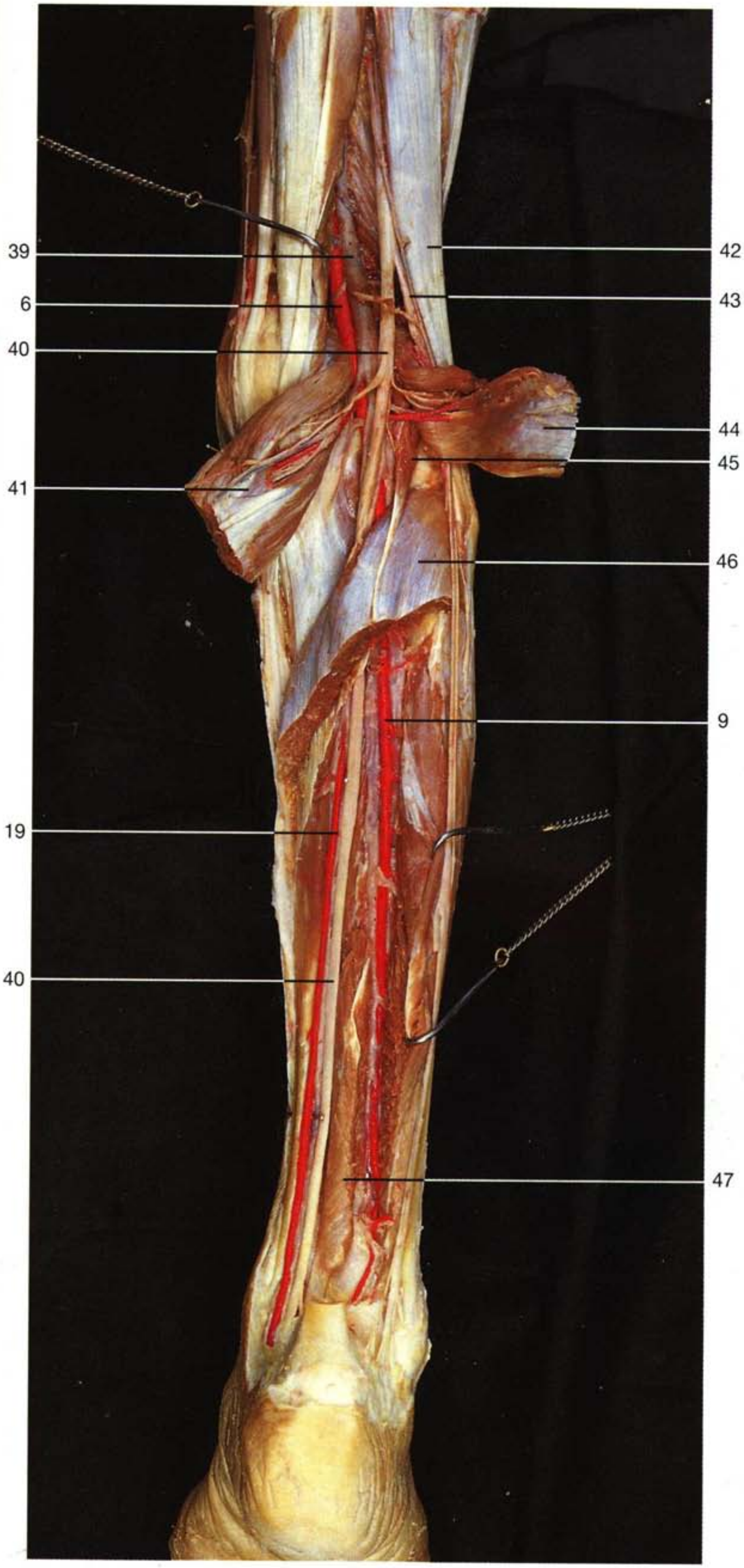

Arteries of the right leg (posterior aspect).

1	**Femoral artery**
2	**Profunda femoris artery**
3	Ascending branch of lateral circumflex femoral artery
4	Descending branch of lateral circumflex femoral artery
5	Lateral superior genicular artery
6	Popliteal artery
7	Lateral inferior genicular artery
8	**Anterior tibial artery**
9	**Peroneal artery**
10	**Lateral plantar artery**
11	Arcuate artery with dorsal metatarsal arteries
12	**Plantar arch** with plantar metatarsal arteries
13	Medial circumflex femoral artery
14	Profunda femoris artery with perforating arteries
15	Descending genicular artery
16	Medial superior genicular artery
17	Middle genicular artery
18	Medial inferior genicular artery
19	**Posterior tibial artery**
20	**Dorsalis pedis artery**
21	**Medial plantar artery**
22	Superficial and deep circumflex iliac arteries
23	**Femoral nerve**
24	Lateral circumflex femoral artery
25	Sartorius muscle (cut and reflected)
26	Rectus femoris muscle
27	Vastus medialis muscle
28	Inguinal ligament
29	**Femoral vein** (cut)
30	External pudendal artery and vein
31	Adductor longus muscle
32	Great saphenous vein
33	Obturator artery and nerve
34	Gracilis muscle
35	Saphenous nerve
36	Tendinous wall of adductor canal
37	Anterior cutaneous branch of femoral nerve
38	Infrapatellar branch of saphenous nerve
39	Popliteal vein
40	**Tibial nerve**
41	Medial head of gastrocnemius muscle
42	Biceps femoris muscle
43	Common peroneal nerve
44	Lateral head of gastrocnemius muscle
45	Plantaris muscle
43	Soleus muscle
47	Flexor hallucis longus muscle
48	Spermatic cord

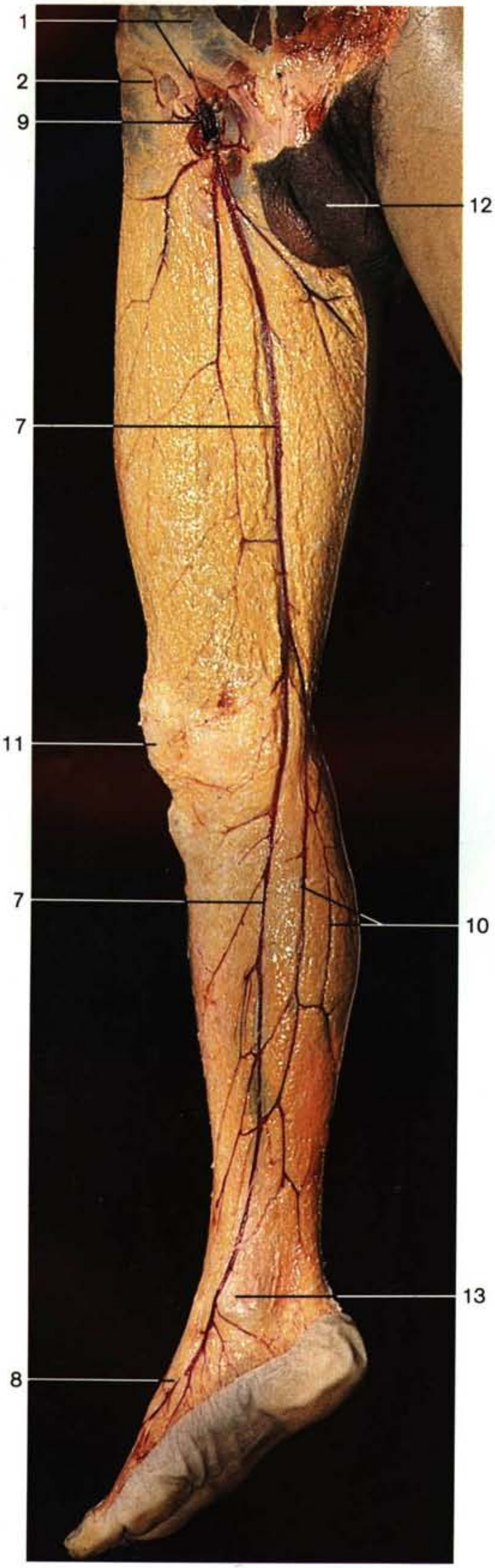

Superficial veins of lower limb, right side (medial anterior aspect). The veins have been injected with red solution.

Main veins of lower limb, right side (anterior aspect). (Schematic drawing.)

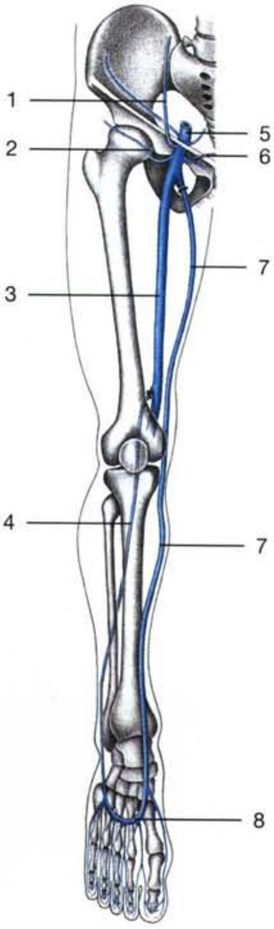

1	Superficial epigastric vein
2	Superficial circumflex iliac vein
3	Femoral vein
4	**Small saphenous vein**
5	External iliac vein
6	External pudendal vein
7	**Great saphenous vein**
8	Dorsal venous arch
9	Saphenous opening with femoral vein
10	Venous anastomoses of small saphenous vei with great saphenous vein
11	Patella
12	Penis
13	Medial malleolus
14	Popliteal fossa
15	Perforating veins
16	Lateral malleolus
17	Dorsal digital veins of foot
18	Dorsal venous arch of foot
19	Dorsal metatarsal veins of foot
20	Anterior tibial artery and veins
21	Tibia
22	**Posterior tibial artery and veins**
23	Fibula
24	Peroneal artery and vein
25	Deep layer of crural fascia
26	Superficial layer of crural fascia
27	Perforating veins I-III (of Cockett)
28	**Tibial nerve**
29	**Arcuate vein**
30	**Saphenous nerve**
31	Medial dorsal cutaneous nerve (branch of superficial peroneal nerve)
32	Posterior tibial vein

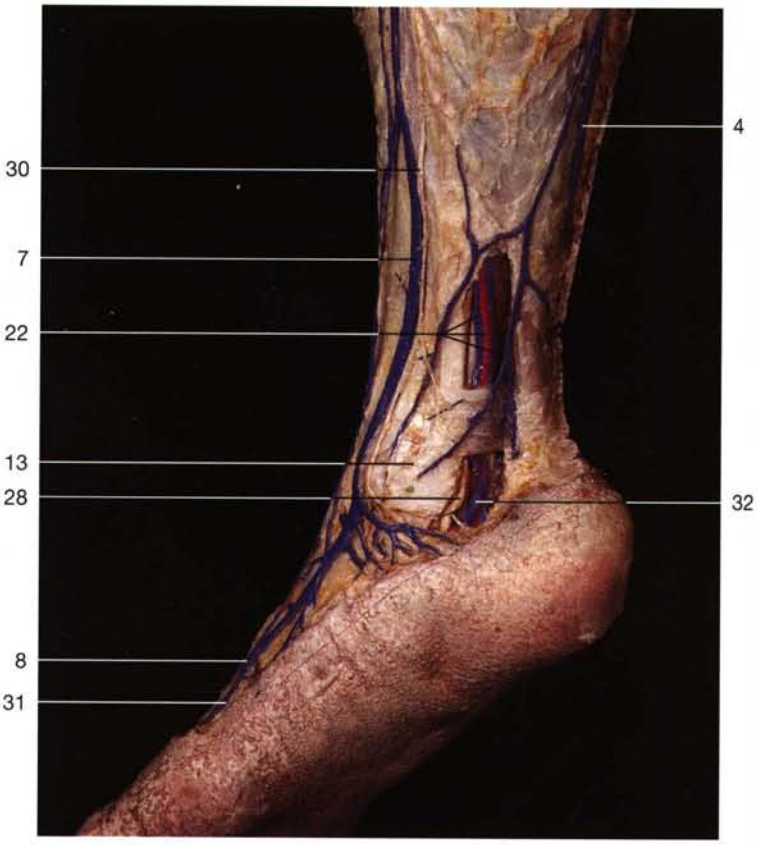

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Medial malleolar region. Dissection of tibial nerve, posterior tibial vessels, and great saphenous vein (veins injected with blue resin).

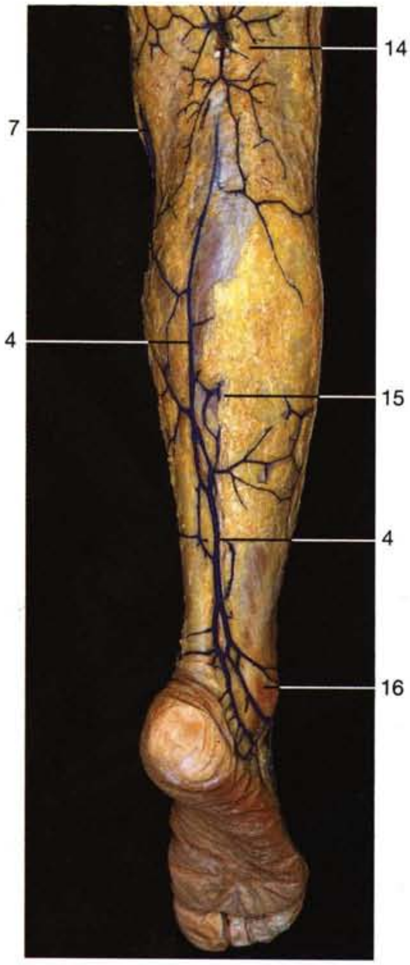

Superficial veins of leg (posterior aspect; injected with blue resin).

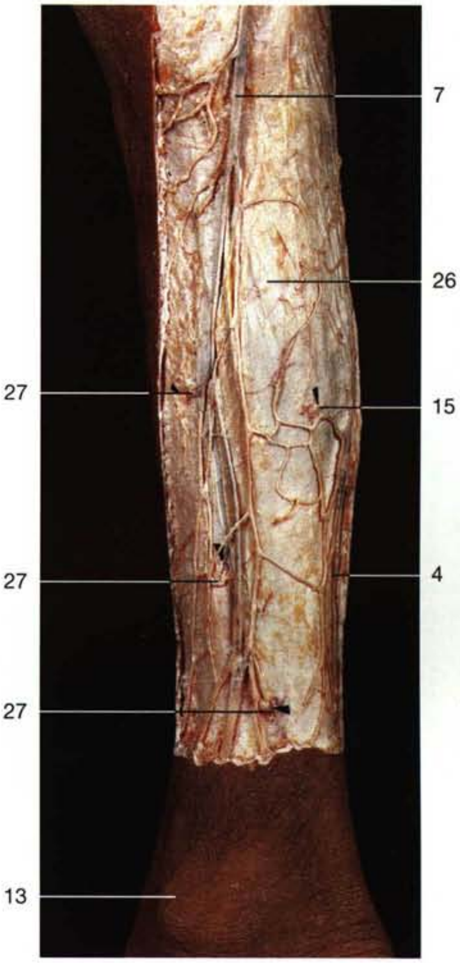
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Superficial veins of leg. The perforating veins of Cockett have been dissected.

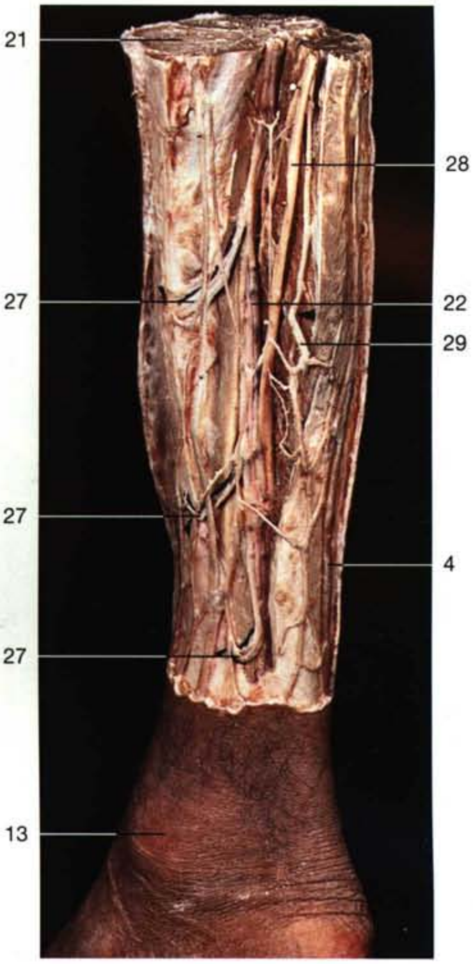
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Veins of leg. The anastomoses between superficial and deeper veins are dissected.

Anastomoses between superficial and deep veins of the leg (after Aigner). (Schematic drawing.) Arrows: directions of blood flow. ▷

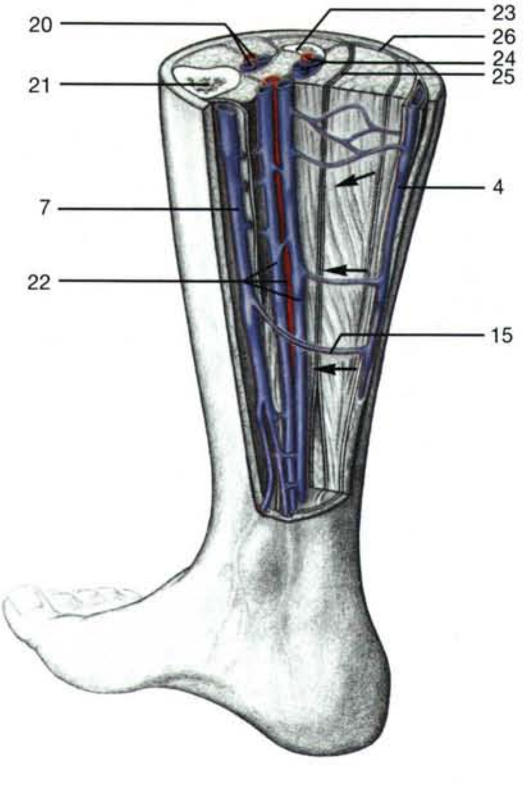
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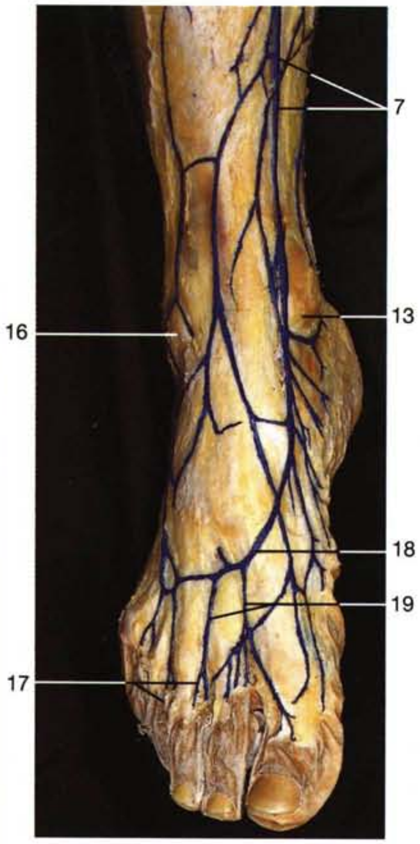
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Superficial veins on dorsum of foot (injected with blue resin).

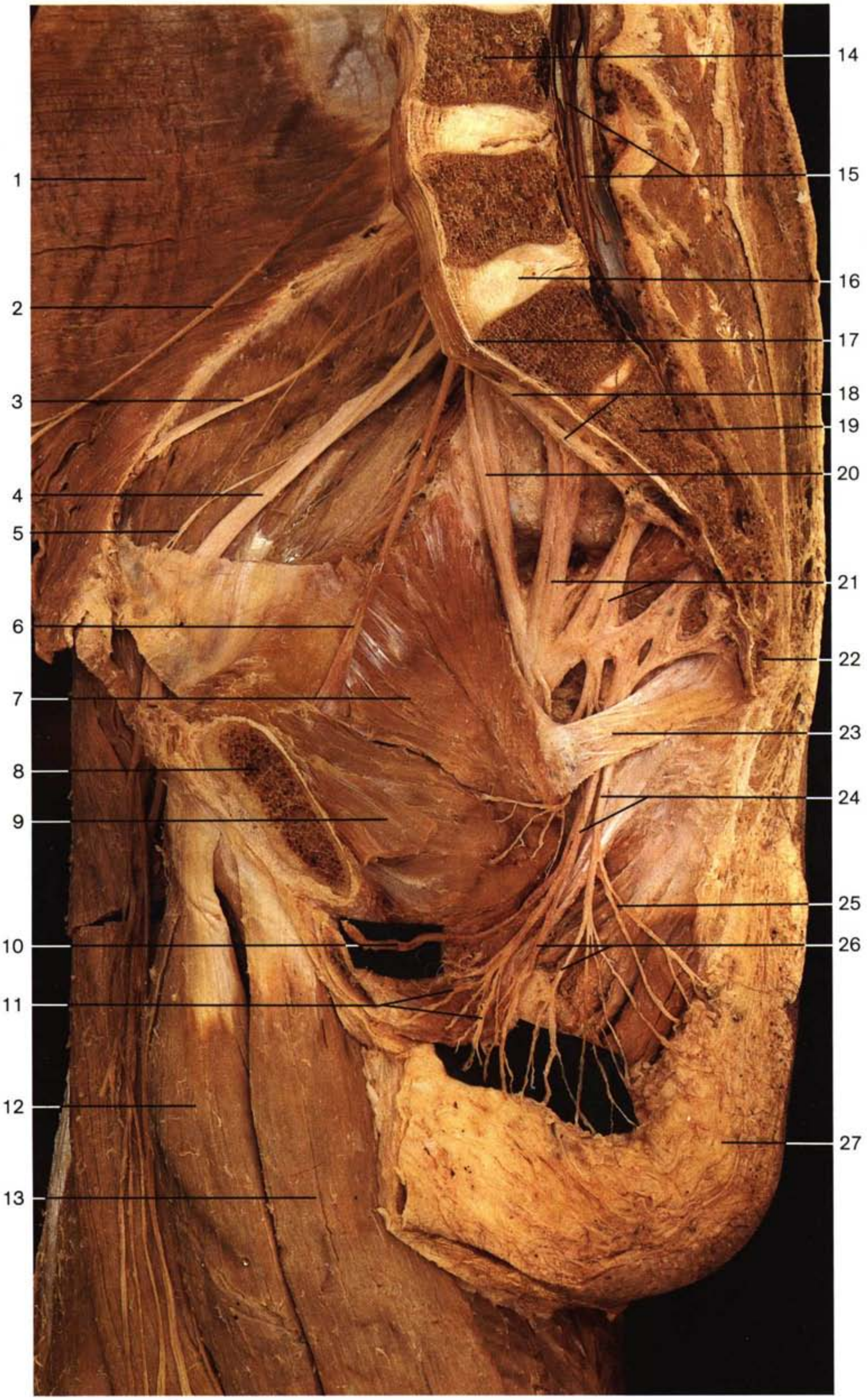

1 Transversus abdominis muscle
2 Iliohypogastric nerve
3 Ilioinguinal nerve
4 **Femoral nerve**
5 Lateral femoral cutaneous nerve
6 Obturator nerve
7 Obturator internus muscle
8 Pubic bone (cut edge)
9 Levator ani muscle (remnant)
10 Dorsal nerve of penis
11 Posterior scrotal nerves
12 Adductor longus muscle
13 Gracilis muscle
14 Body of 4th lumbar vertebra
15 Cauda equina
16 Intervertebral disc
17 Sacral promontory
18 Sympathetic trunk
19 Sacrum
20 **Lumbosacral trunk**
21 **Sciatic plexus**
22 Coccyx
23 Sacrospinous ligament
24 **Pudendal nerve**
25 Inferior rectal nerves
26 Perineal nerves
27 Subcutaneous fat tissue of gluteal region

Lumbosacral plexus in situ, right side (medial aspect).
Pelvic organs with peritoneum and part of the levator ani muscle have been removed.

1 Subcostal nerve
2 Iliohypogastric nerve
3 Ilioinguinal nerve
4 Lateral femoral cutaneous nerve
5 Genitofemoral nerve
6 **Pudendal nerve**
7 **Femoral nerve**
8 Obturator nerve
9 **Sciatic nerve**
10 Lumbar plexus (L_1–L_4)
11 Sacral plexus (L_4–S_4) } lumbosacral plexus
12 "Pudendal" plexus (S_2–S_4)
13 Inferior cluneal nerve
14 Posterior femoral cutaneous nerve
15 Common peroneal nerve
16 **Tibial nerve**
17 Lateral sural cutaneous nerve
18 Medial and lateral plantar nerves
19 Saphenous nerve
20 Infrapatellar branch of saphenous nerve
21 **Deep peroneal nerve**
22 **Superficial peroneal nerve**

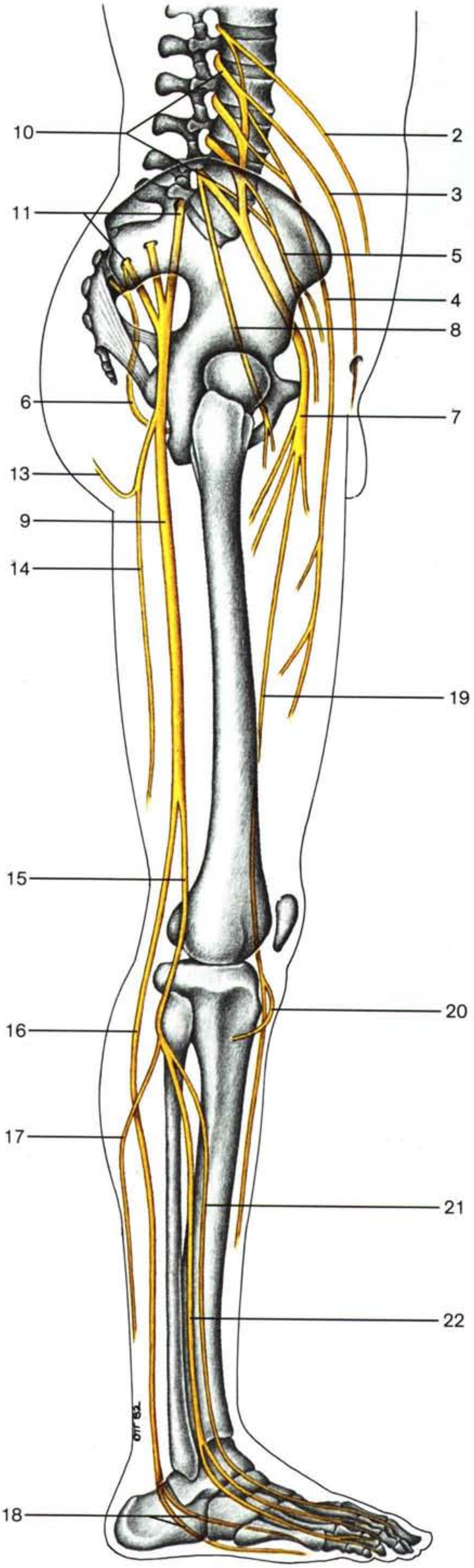

Nerves of lower limb, right side (lateral aspect). (Schematic drawing.)

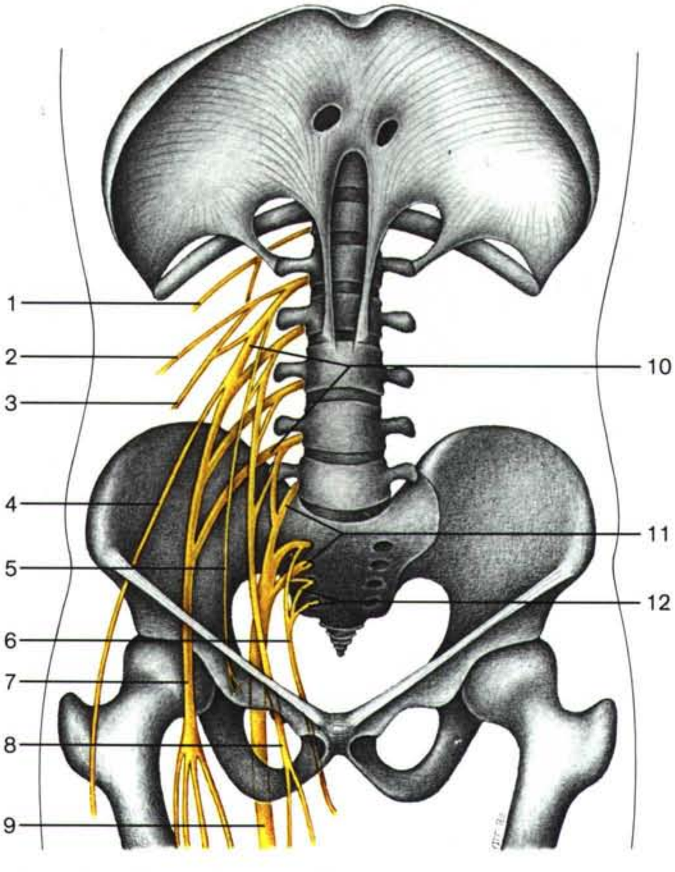

Main branches of lumbosacral plexus (ventral aspect). (Schematic drawing.)

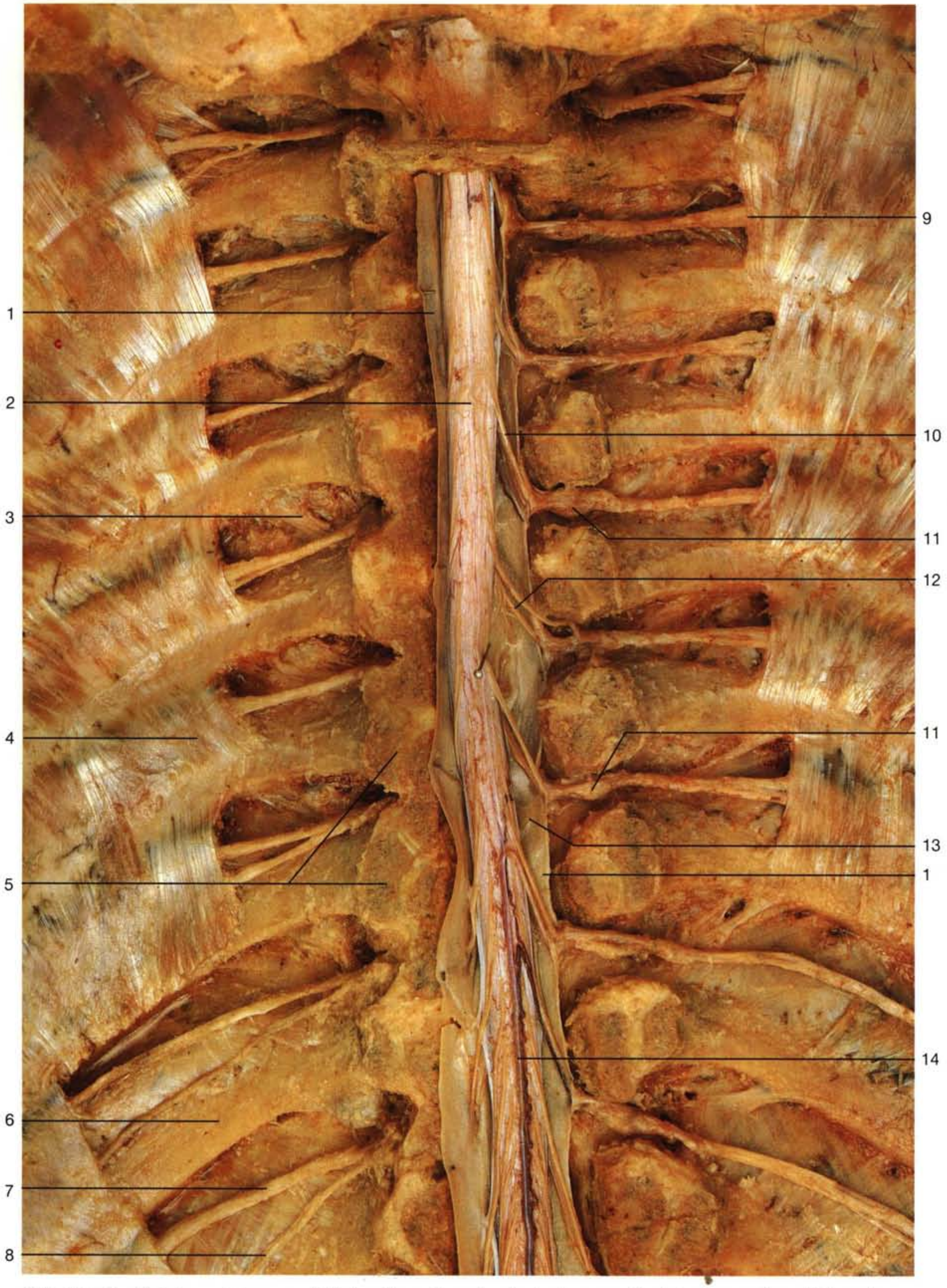

Spinal cord with intercostal nerves. Inferior thoracic region (anterior aspect). Anterior portion of thoracic vertebrae removed, dural sheath opened and spinal cord slightly reflected to the right to display the dorsal and ventral roots.

1	Dura mater	6	Eleventh rib	10	Anterior root filaments
2	**Spinal cord**	7	**Intercostal nerve**	11	Spinal (dorsal root) ganglion
3	Costotransverse ligament	8	Collateral branch of intercostal nerve	12	Posterior root filaments
4	Innermost intercostal muscle	9	Intercostal nerve (entering the intermuscular interval)	13	Arachnoid mater and denticulate ligament
5	Vertebral arches (cut surfaces)			14	Anterior spinal artery

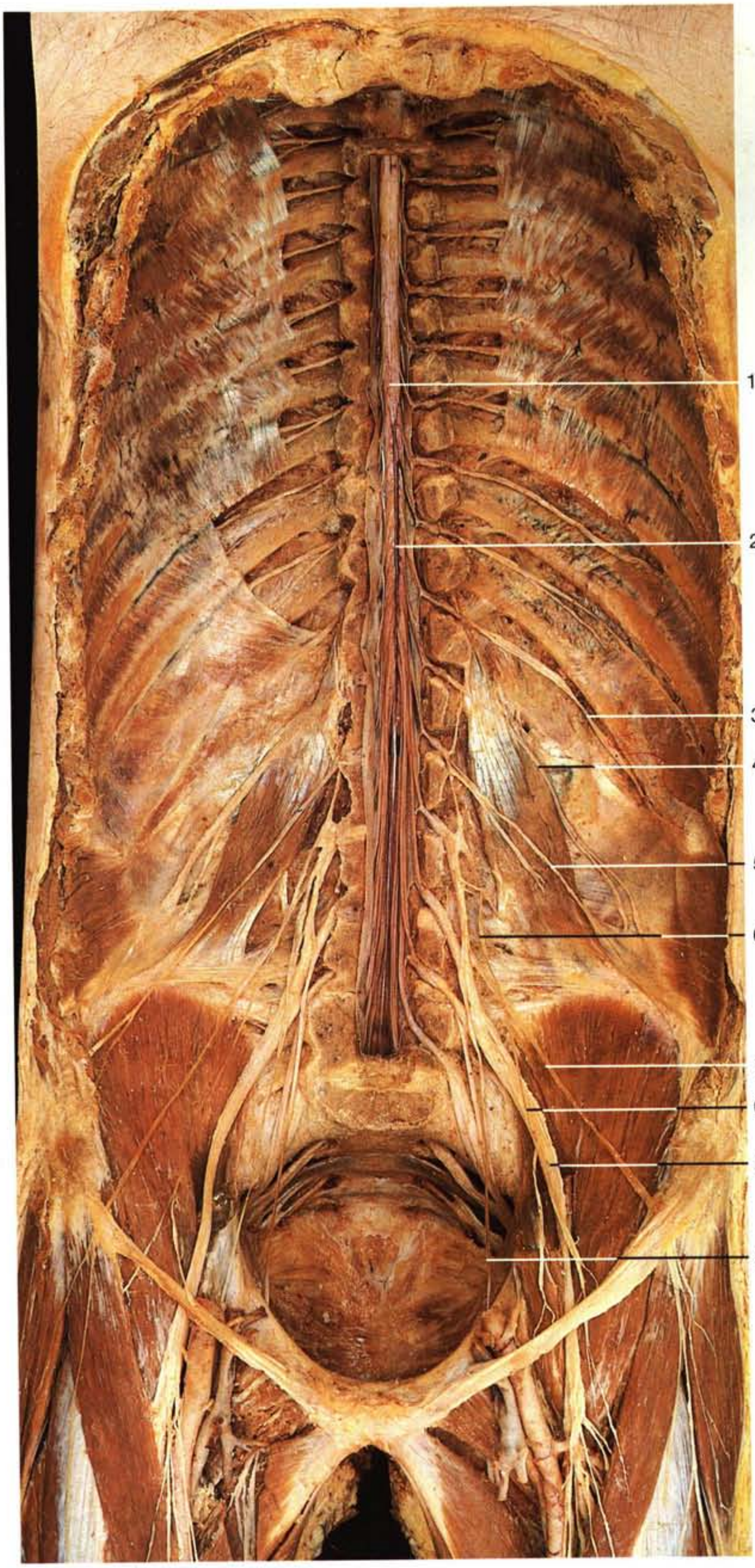
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Spinal cord and lumbar plexus in situ (anterior aspect).

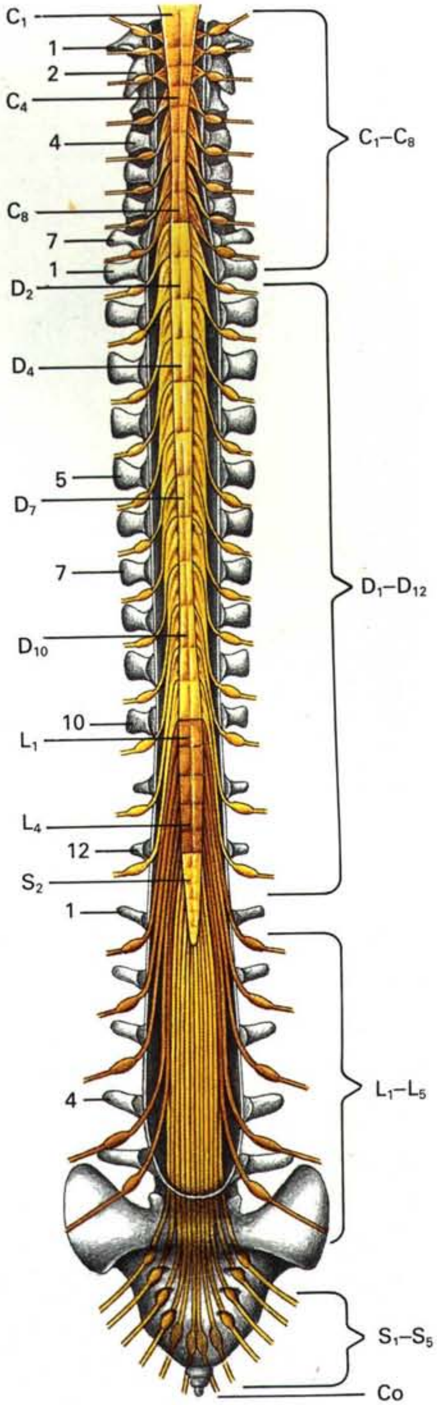
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S2
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C1–C8
D1–D12
L1–L5
S1–S5
Co

Organization of spinal cord segments in relation to the vertebral column (anterior aspect). C = cervical; D = thoracic; L = lumbar; S = sacral segments; Co = coccygeal bone.

1 Conus medullaris
2 Filum terminale
3 Subcostal nerve
4 Iliohypogastric nerve
5 Ilioinguinal nerve
6 Genitofemoral nerve
7 Lateral femoral cutaneous nerve
8 Femoral nerve
9 Obturator nerve

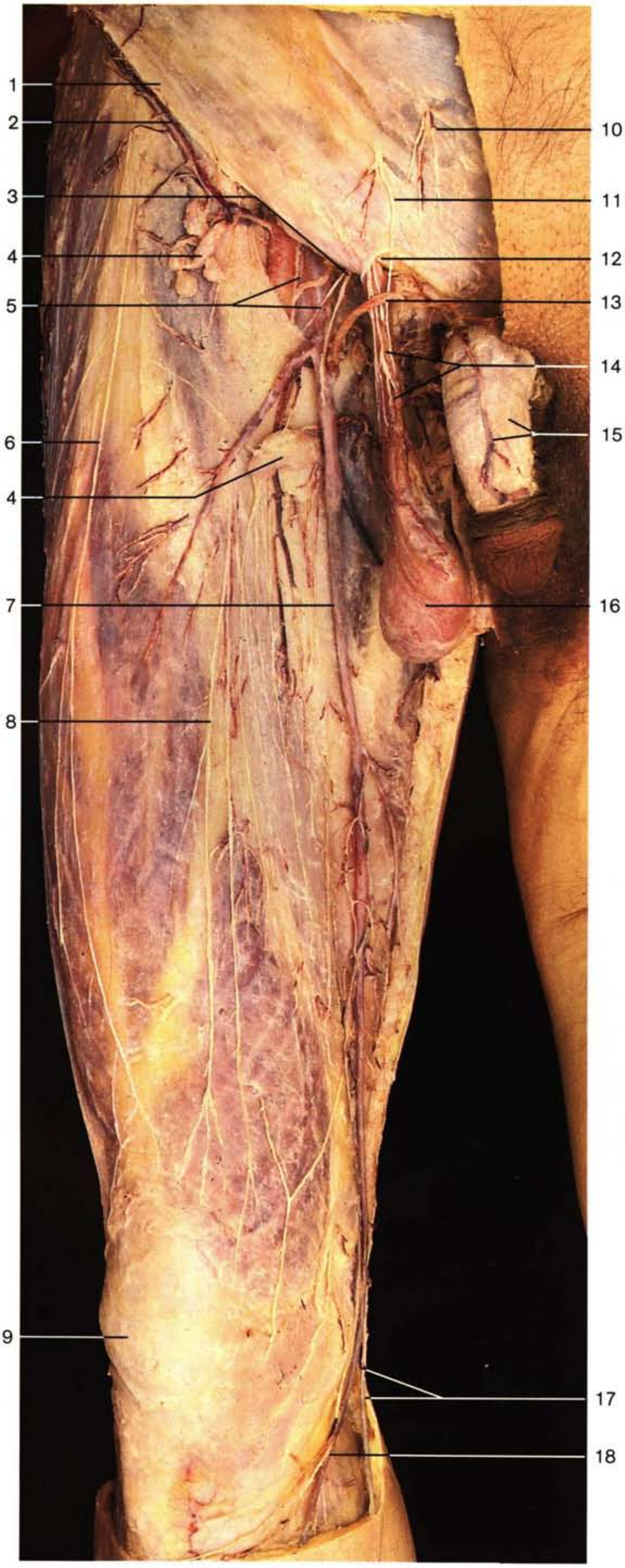
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Cutaneous nerves and veins of thigh (anterior aspect).

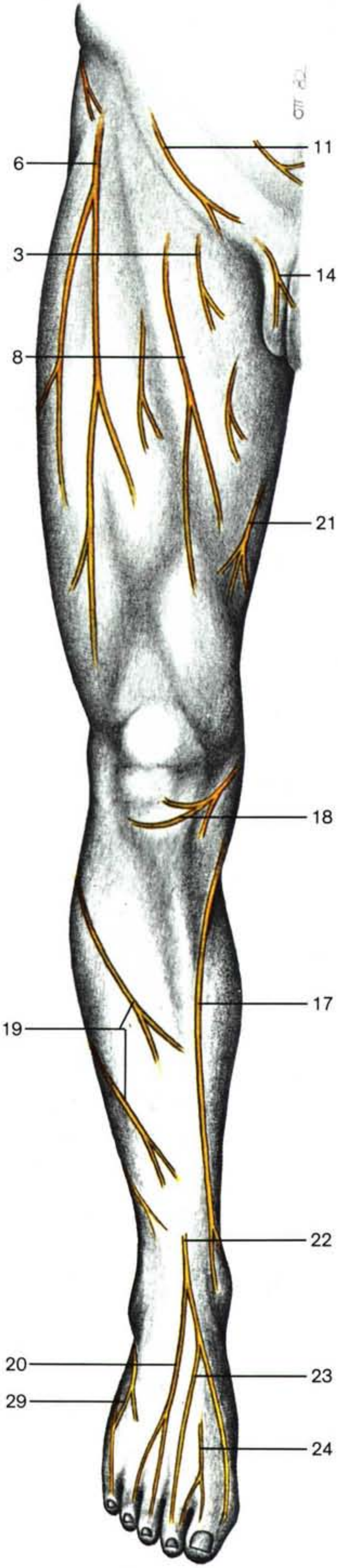
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Cutaneous nerves of lower limb (anterior aspect). (Schematic drawing.)

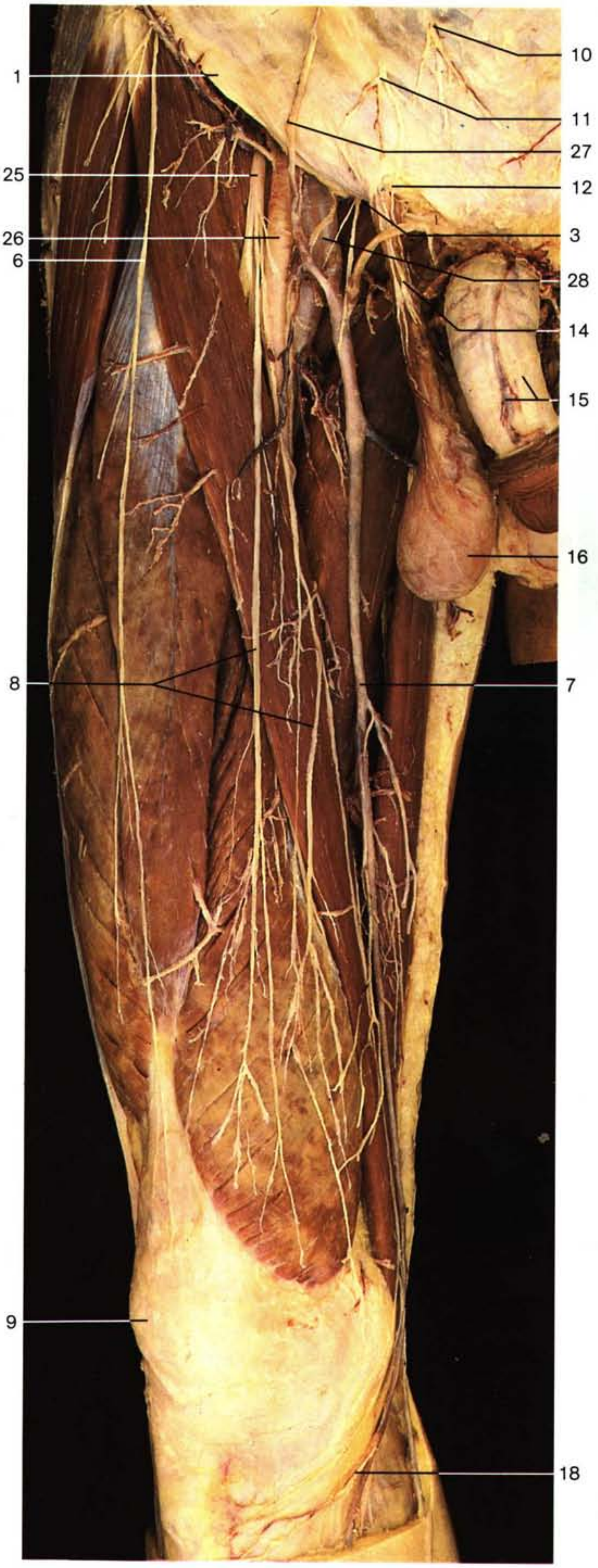

Cutaneous nerves and veins of thigh (anterior aspect). The fascia lata and fasciae of the thigh muscles have been removed.

1 Inguinal ligament
2 Superficial circumflex iliac vein
3 Femoral branch of genitofemoral nerve
4 Superficial inguinal lymph nodes
5 Saphenous opening with femoral artery and vein
6 Lateral femoral cutaneous nerve
7 Great saphenous vein
8 Anterior cutaneous branches of femoral nerve
9 Patella
10 Terminal branches of subcostal nerve
11 Terminal branches of iliohypogastric nerve
12 Superficial inguinal ring
13 External pudendal vein
14 Spermatic cord with genital branch of genitofemoral nerve
15 Penis with superficial dorsal vein of penis
16 Testis and its coverings
17 Saphenous nerve
18 Infrapatellar branch of saphenous nerve
19 Lateral sural cutaneous nerves
20 Intermediate dorsal cutaneous branch of superficial peroneal nerve
21 Cutaneous branch of obturator nerve
22 Superficial peroneal nerve
23 Medial dorsal cutaneous branch of superficial peroneal nerve
24 Deep peroneal nerve
25 **Femoral nerve**
26 **Femoral artery**
27 Superficial epigastric vein
28 **Femoral vein**
29 Lateral dorsal cutaneous branch of sural nerve
30 **Inguinal nodes** (enlarged)
31 Lymphatic vessels
32 Sartorius muscle

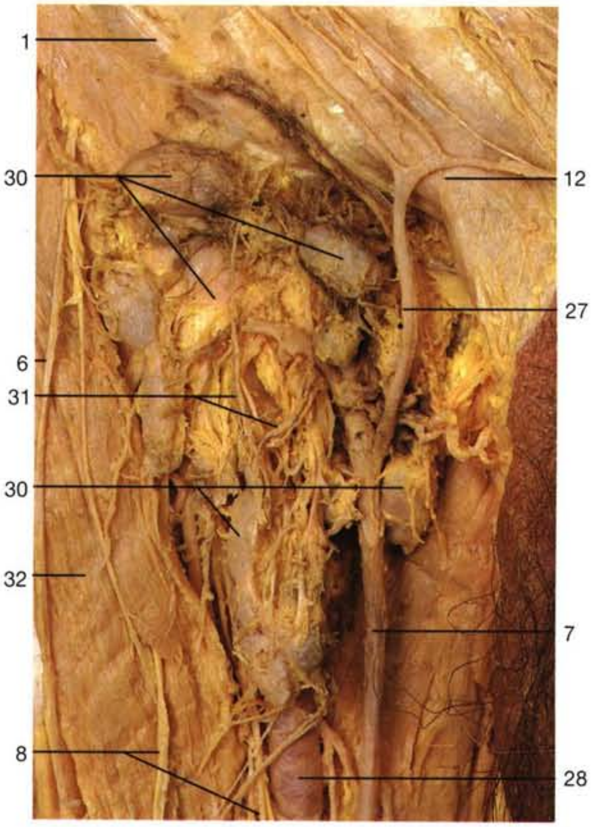

Inguinal nodes with lymphatic vessels (anterior aspect).

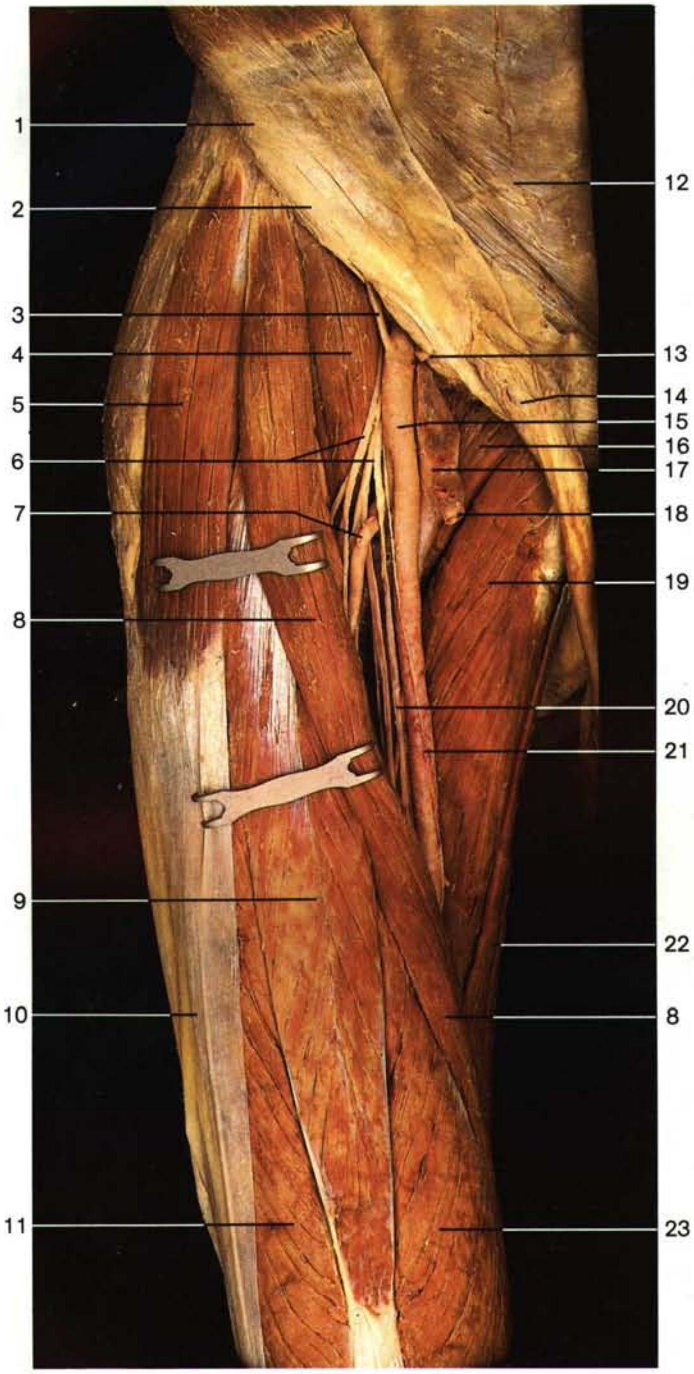

Anterior region of right thigh (anterior aspect). The fascia lata has been removed, and the sartorius muscle has been slightly reflected.

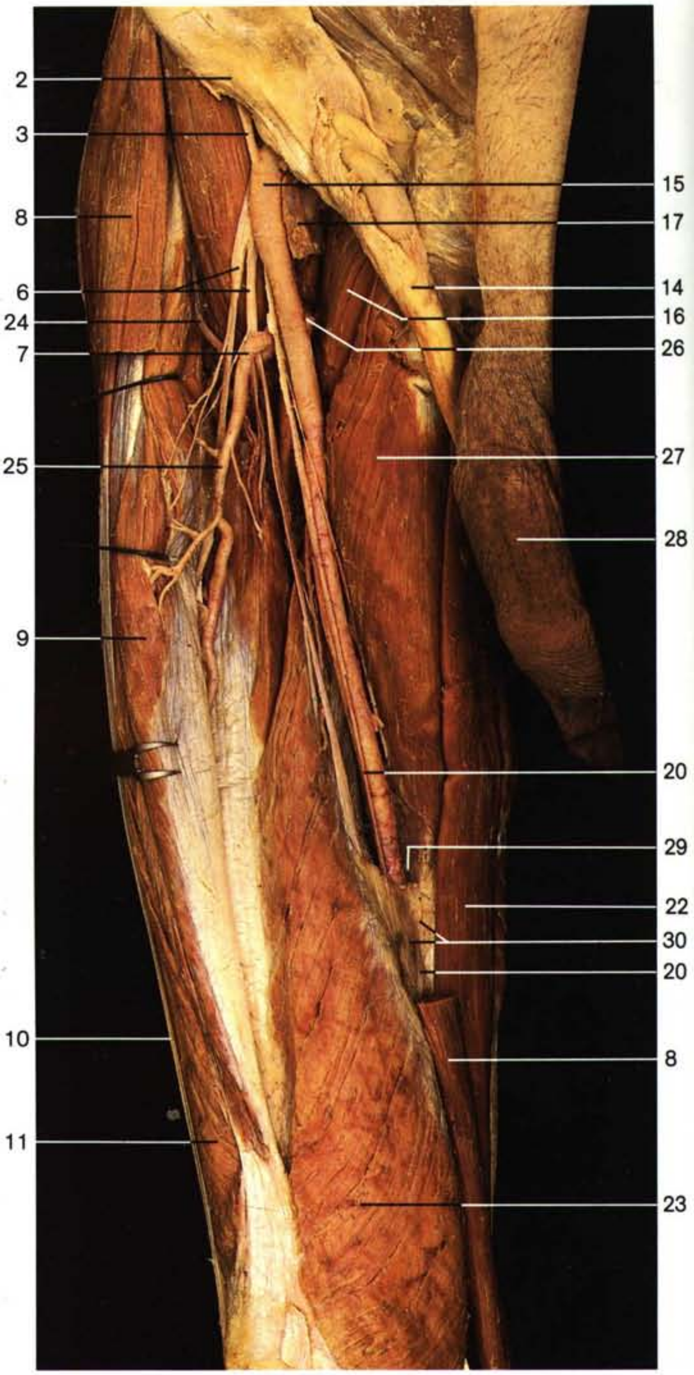

Anterior region of right thigh (anterior aspect). The fascia lata has been removed, and the sartorius muscle has been divided.

1 Anterior superior iliac spine
2 Inguinal ligament
3 **Deep circumflex iliac artery**
4 Iliopsoas muscle
5 Tensor fasciae latae muscle
6 **Femoral nerve**
7 **Lateral circumflex femoral artery**
8 Sartorius muscle
9 Rectus femoris muscle
10 Iliotibial tract
11 Vastus lateralis muscle
12 Anterior sheath of rectus abdominis muscle
13 Inferior epigastric artery
14 Spermatic cord
15 **Femoral artery**
16 Pectineus muscle
17 **Femoral vein**
18 Great saphenous vein (divided)
19 Adductor longus muscle
20 **Saphenous nerve**
21 Muscular branch of femoral nerve
22 Gracilis muscle
23 Vastus medialis muscle
24 Ascending branch of lateral circumflex femoral artery
25 Descending branch of lateral circumflex femoral artery
26 Medial circumflex femoral artery
27 Adductor longus muscle
28 Penis
29 Entrance to adductor canal
30 Vastoadductory lamina of fascia beneath sartorius muscle

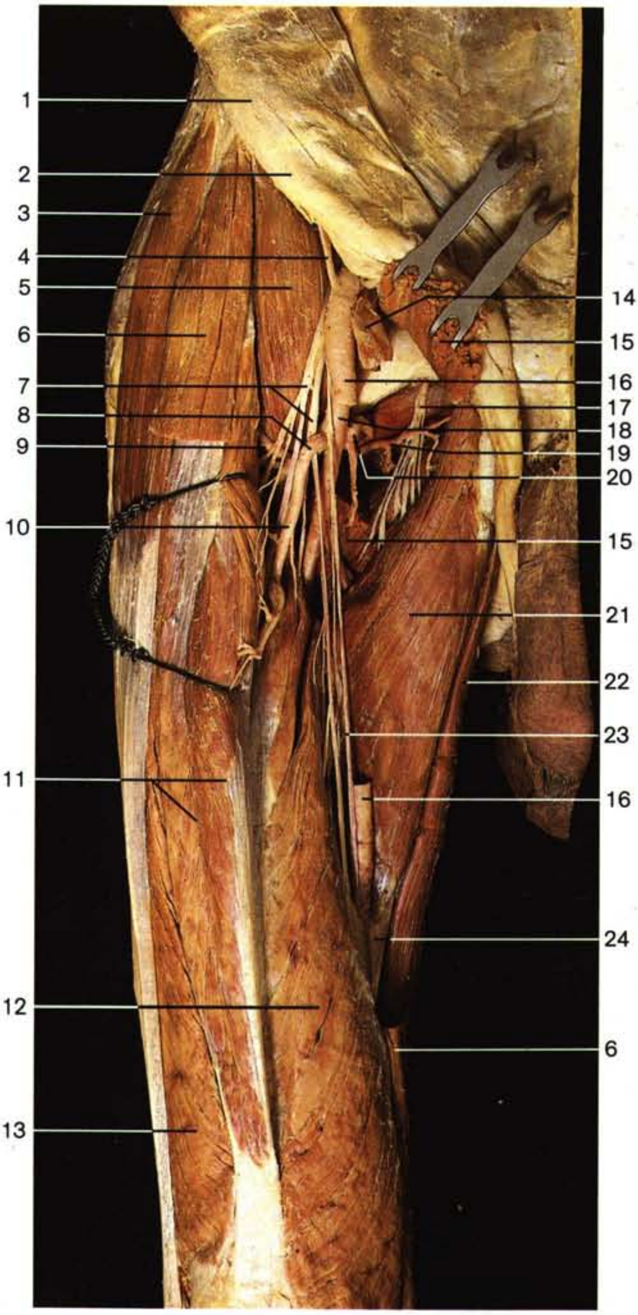

Anterior region of right thigh (anterior aspect). The fascia lata has been removed. Sartorius muscle, pectineus muscle and femoral artery have been cut to display the deep femoral artery with its branches. The rectus femoris muscle has been slightly reflected.

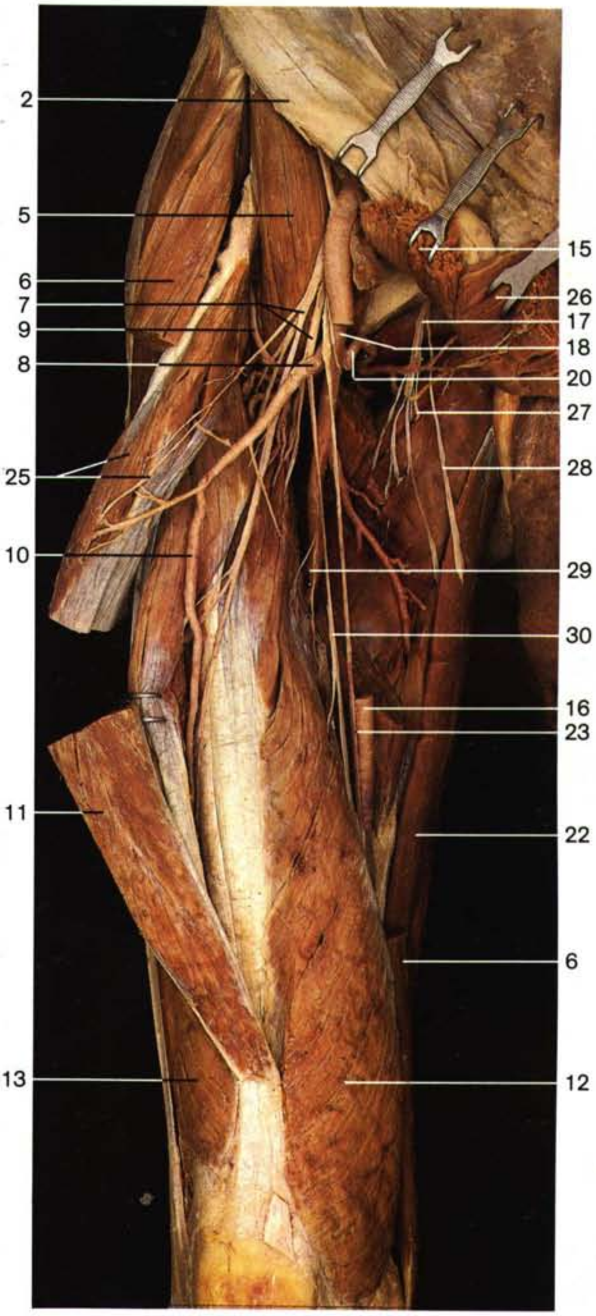

Anterior region of right thigh (anterior aspect). The sartorius, pectineus, adductor longus and rectus femoris muscles have been divided and reflected. The greater part of the femoral artery has been removed.

1 Anterior superior iliac spine
2 Inguinal ligament
3 Tensor fasciae latae muscle
4 Deep circumflex iliac artery
5 Iliopsoas muscle
6 Sartorius muscle (cut)
7 **Femoral nerve**
8 **Lateral circumflex femoral artery**
9 Ascending branch of lateral circumflex femoral artery
10 Descending branch of lateral circumflex femoral artery
11 Rectus femoris muscle
12 Vastus medialis muscle
13 Vastus lateralis muscle
14 Femoral vein
15 Pectineus muscle (cut)
16 Femoral artery (cut)
17 **Obturator nerve**
18 **Profunda femoris artery**
19 Ascending branch of medial circumflex femoral artery
20 **Medial circumflex femoral artery**
21 Adductor longus muscle
22 Gracilis muscle
23 Saphenous nerve
24 Distal part of vastoadductory lamina
25 Rectus femoris muscle with muscular branch of femoral nerve
26 Adductor longus muscle (divided)
27 Posterior branch of obturator nerve
28 Anterior branch of obturator nerve
29 Point at which perforating artery branches off from profunda femoris artery
30 Muscular branch to vastus medialis muscle

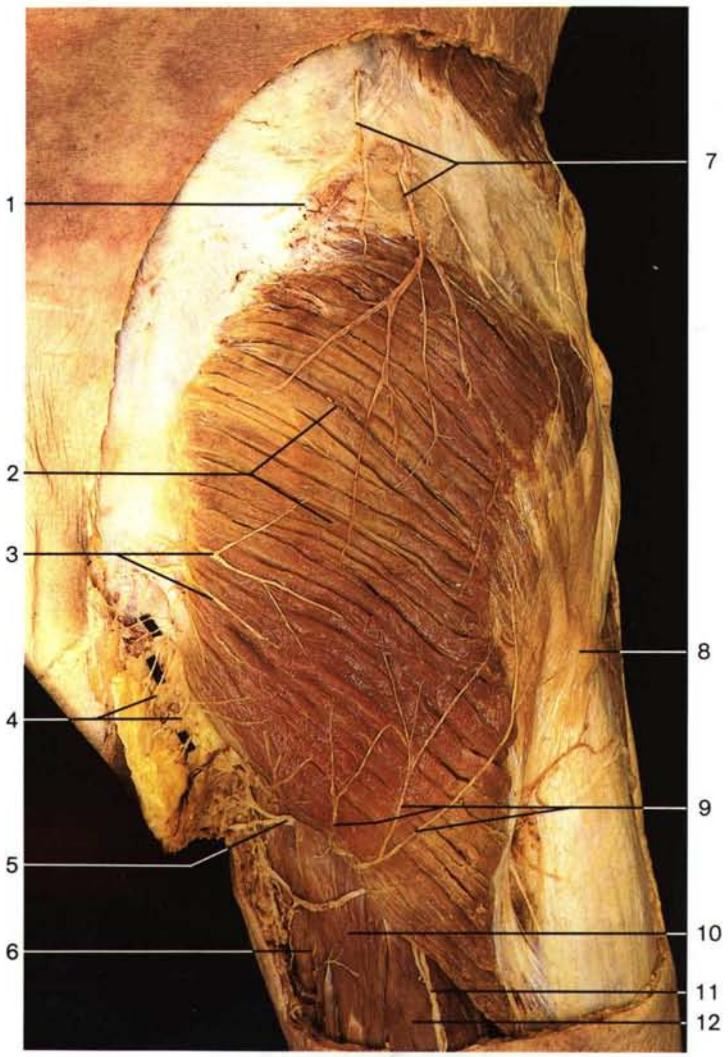

Gluteal region, right side (posterior aspect).

1 Iliac crest
2 Gluteus maximus muscle
3 **Middle cluneal nerves**
4 Anococcygeal nerves
5 Perineal branch of posterior femoral cutaneous nerve
6 Adductor magnus muscle
7 **Superior cluneal nerves**
8 Position of greater trochanter
9 **Inferior cluneal nerves**
10 Semitendinosus muscle
11 Posterior femoral cutaneous nerve
12 Long head of biceps femoris muscle

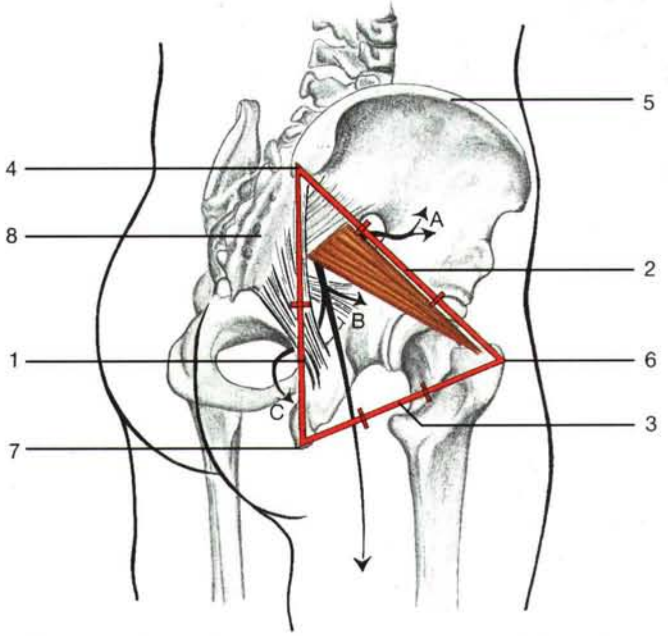

Gluteal region, right side (posterolateral aspect). Location of sciatic foramina in relation to the bones. (Schematic drawing.)

A **Suprapiriform foramen** of greater sciatic foramen

Superior gluteal artery, vein and nerve

B **Infrapiriform foramen** of greater sciatic foramen

Sciatic nerve
Inferior gluteal artery, vein and nerve
Posterior femoral cutaneous nerve
Internal pudendal artery and vein
Pudendal nerve

C **Lesser sciatic foramen**

Pudendal nerve
Internal pudendal artery and vein

Red lines

1 **Spine-tuber line.**
In the middle of this line the infrapiriform foramen is situated
2 **Spine-trochanter line.**
In the upper third the suprapiriform foramen is located
3 **Tuber-trochanter line.**
Between the middle and posterior third, the ischiadic nerve can be found

Other structures

4 Posterior superior iliac spine
5 Iliac crest
6 Greater trochanter
7 Ischial tuberosity
8 Sacrum

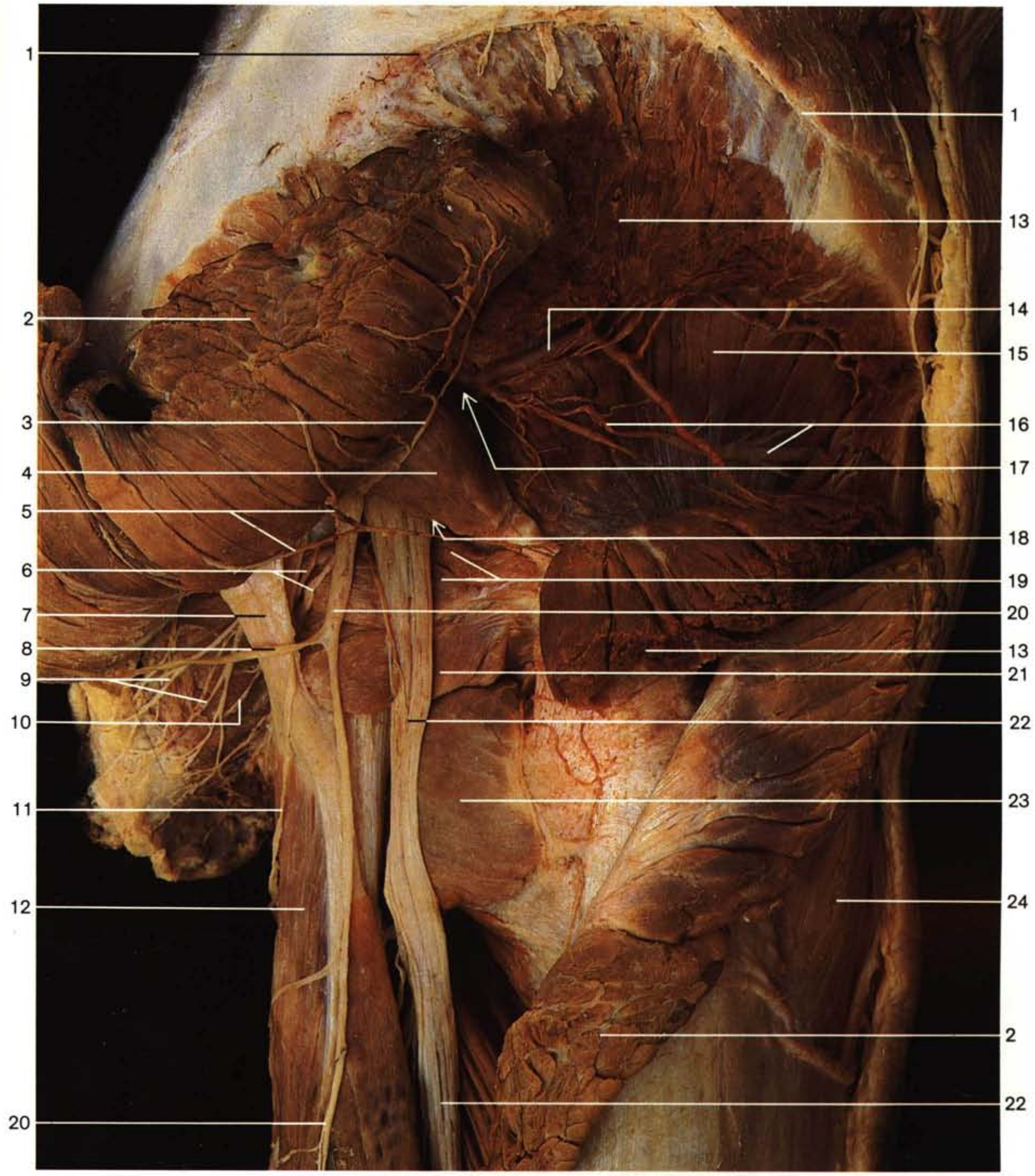

Gluteal region, right side (dorsal aspect). The gluteus maximus and gluteus medius muscles have been divided and reflected. Notice the position of the foramina above and below piriformis muscles and the lesser sciatic foramen.

1 Iliac crest
2 Gluteus maximus muscle (cut)
3 Inferior gluteal nerve
4 Piriformis muscle
5 Muscular branches of inferior gluteal artery
6 Pudendal nerve and internal pudendal artery within the **lesser sciatic foramen** (entrance to the pudendal canal)
7 Sacrotuberous ligament
8 Inferior cluneal nerve
9 Inferior rectal nerves
10 Inferior rectal arteries
11 Perforating cutaneous nerve
12 Long head of biceps femoris muscle

13 Gluteus medius muscle (cut)
14 Deep branch of superior gluteal artery
15 Gluteus minimus muscle
16 Superior gluteal nerve
17 **Suprapiriform foramen** } greater sciatic foramen
18 **Infrapiriform foramen** }
19 Tendon of obturator internus and superior gemellus muscles
20 Posterior femoral cutaneous nerve
21 Inferior gemellus muscle
22 **Sciatic nerve**
23 Quadratus femoris muscle
24 Tensor fasciae latae muscle

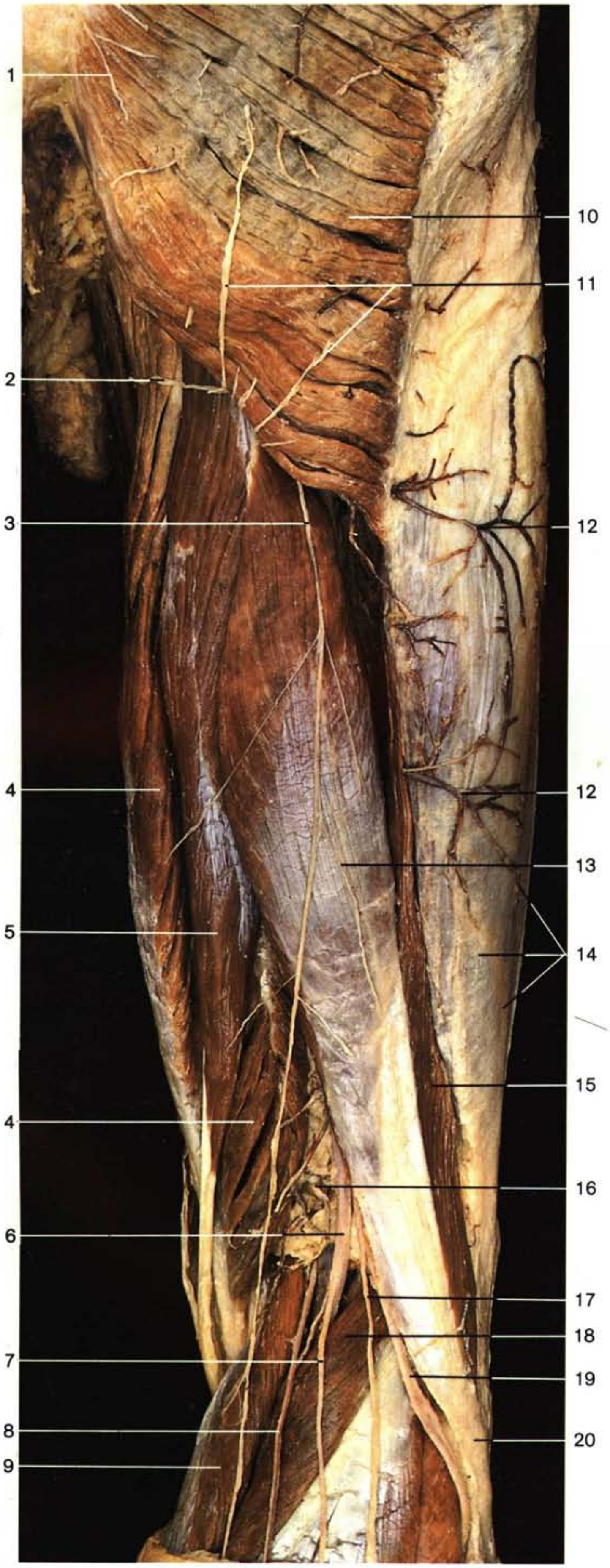

Cutaneous nerves of thigh (posterior aspect).
The fascia lata and the fasciae of muscles have been removed.

1 Middle cluneal nerves
2 Perineal branch of posterior femoral cutaneous nerve
3 **Posterior femoral cutaneous nerve**
4 Semimembranosus muscle
5 Semitendinosus muscle
6 **Tibial nerve**
7 Medial sural cutaneous nerve
8 **Small saphenous vein**
9 Medial head of gastrocnemius muscle
10 Gluteus maximus muscle
11 **Inferior cluneal nerve**
12 Cutaneous veins
13 Long head of biceps femoris muscle
14 Iliotibial tract
15 Short head of biceps femoris muscle
16 Popliteal fossa
17 Lateral sural cutaneous nerve
18 Lateral head of gastrocnemius muscle
19 **Common peroneal nerve**
20 Tendon of biceps femoris muscle
21 Inferior gluteal nerve
22 Sacrotuberous ligament
23 Inferior rectal branches of pudendal nerve
24 Anus
25 Gluteus medius muscle
26 Piriformis muscle
27 **Sciatic nerve**
28 Inferior gluteal artery
29 Gluteus maximus muscle (cut)
30 Quadratus femoris muscle
31 Sciatic nerve dividing into its two branches: the common peroneal nerve and the tibial nerve
32 Muscular branches of sciatic nerve to hamstring muscles
33 **Popliteal artery**
34 **Popliteal vein**
35 Small saphenous vein (cut)
36 Long head of biceps femoris muscle (cut)
37 **Superficial peroneal nerve**

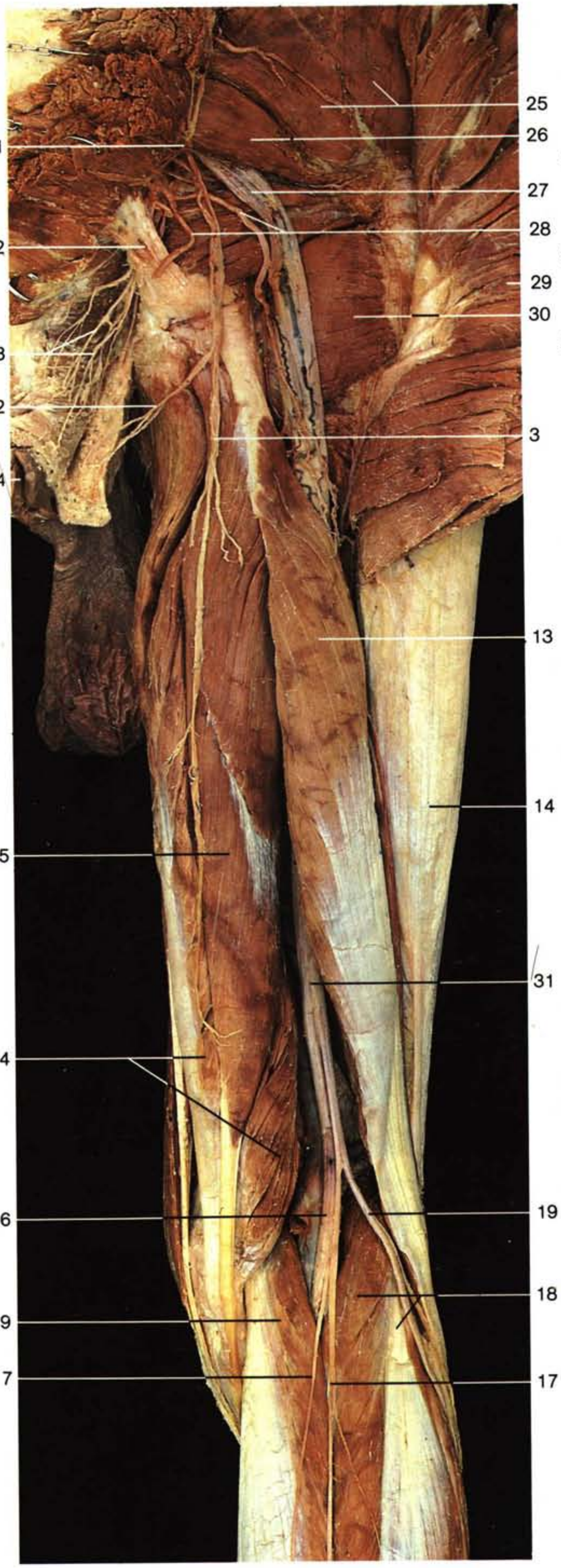
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Posterior femoral region and gluteal region, right side (posterior aspect). The gluteus maximus muscle has been divided and reflected.

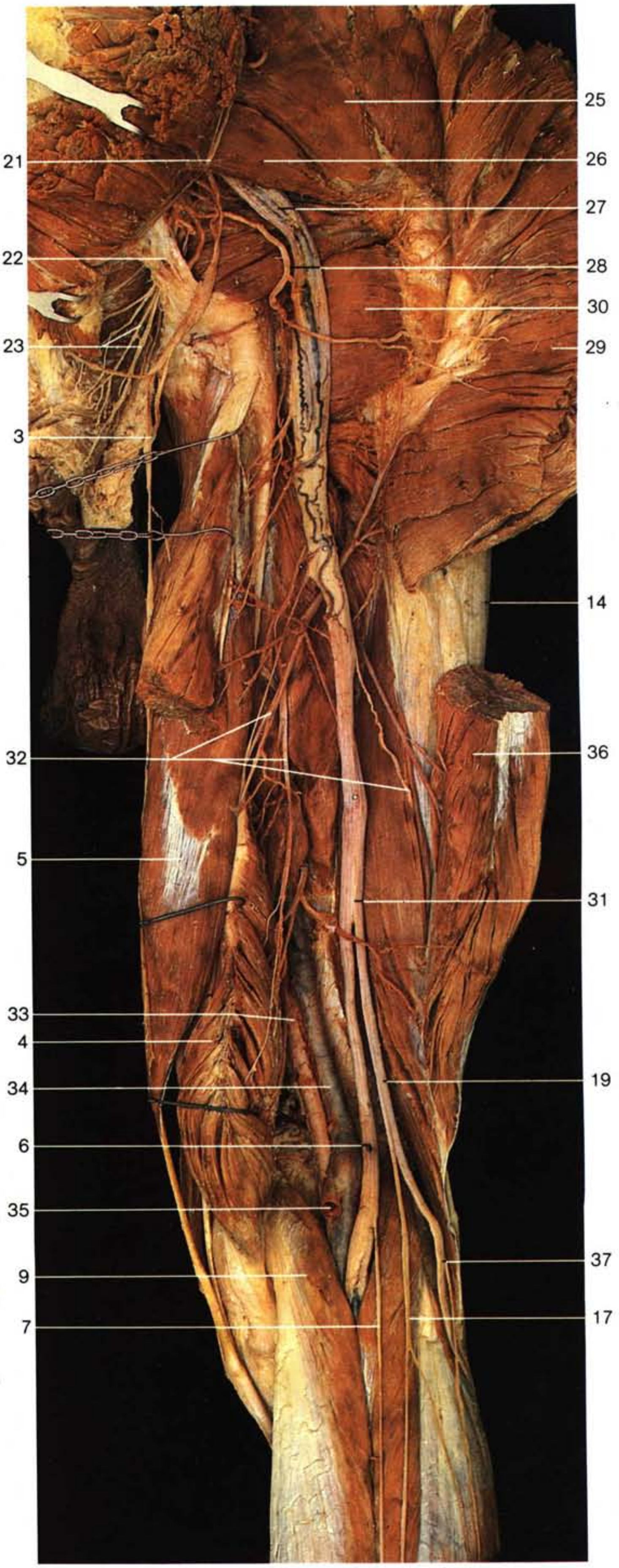
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Posterior femoral region and gluteal region, right side (posterior aspect). The gluteus maximus muscle and the long head of biceps femoris muscle have been divided and reflected.

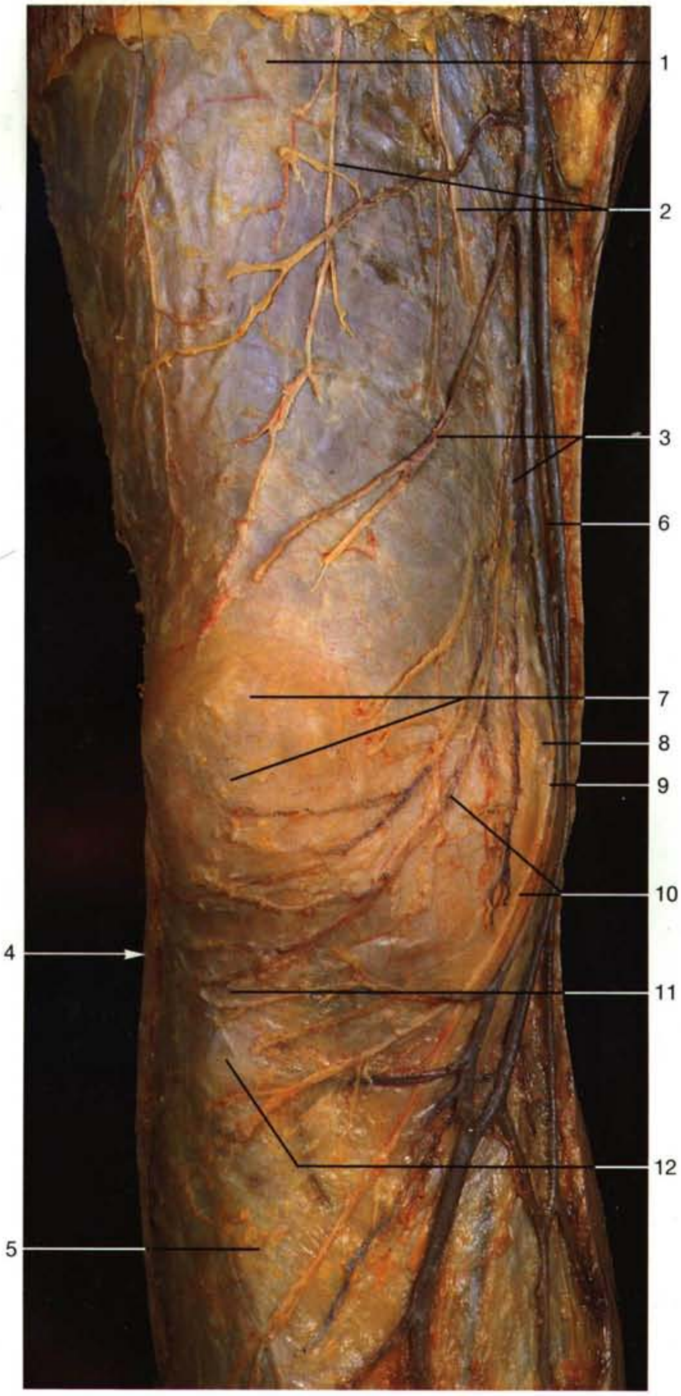

Anterior region of right knee; cutaneous nerves and veins (anterior aspect).

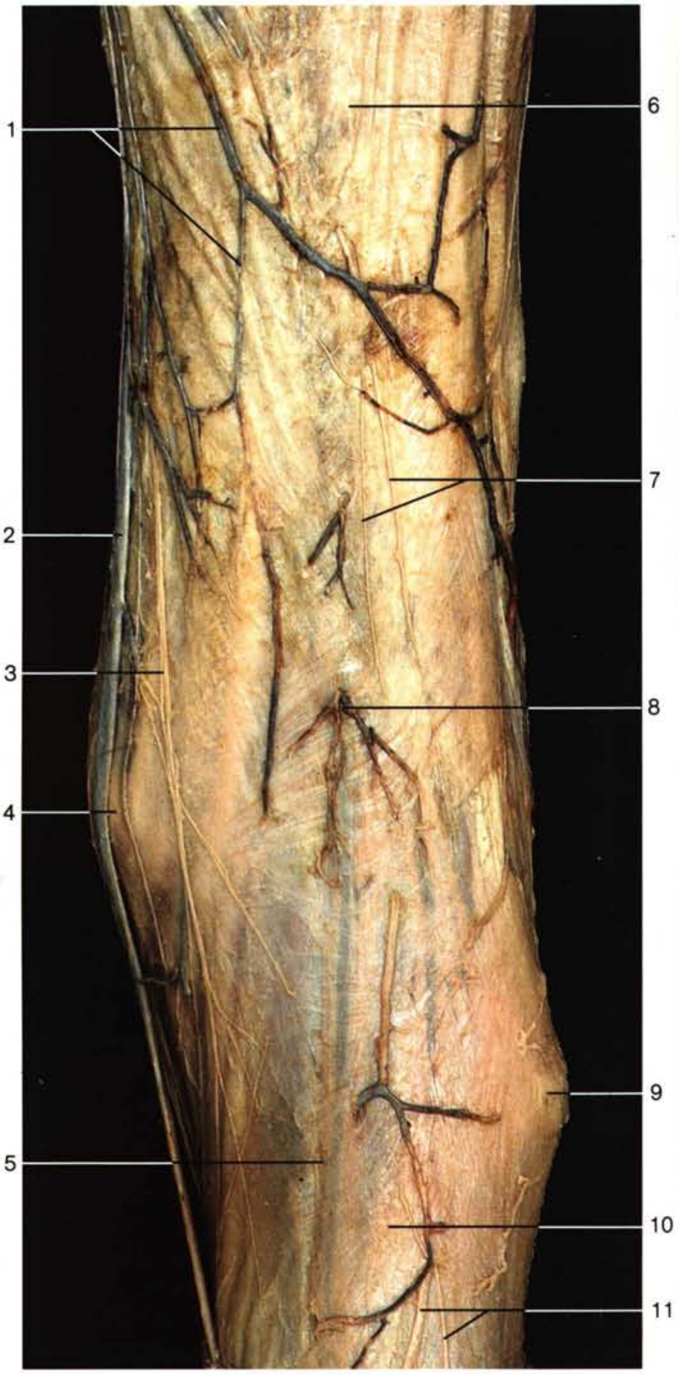

Posterior region of right kneee; cutaneous nerves and veins (posterior aspect).

1	Fascia lata
2	Terminal branches of anterior cutaneous branches of femoral nerve
3	Venous network around knee
4	Position of head of fibula
5	Superficial crural fascia
6	**Great saphenous vein**
7	Patella
8	Position of medial epicondyle of femur
9	Saphenous nerve
10	**Infrapatellar branches of saphenous nerve**
11	Patellar ligament
12	Position of tuberosity of tibia

1	Cutaneous veins (tributaries of great saphenous vein)
2	**Great saphenous vein**
3	Cutaneous branch of femoral nerve
4	Position of medial epicondyle of femur
5	Position of small saphenous vein
6	Fascia lata
7	Terminal branches of **posterior femoral cutaneous nerve**
8	Cutaneous veins of popliteal fossa
9	Position of head of fibula
10	Superficial layer of fascia cruris
11	Lateral sural cutaneous nerve

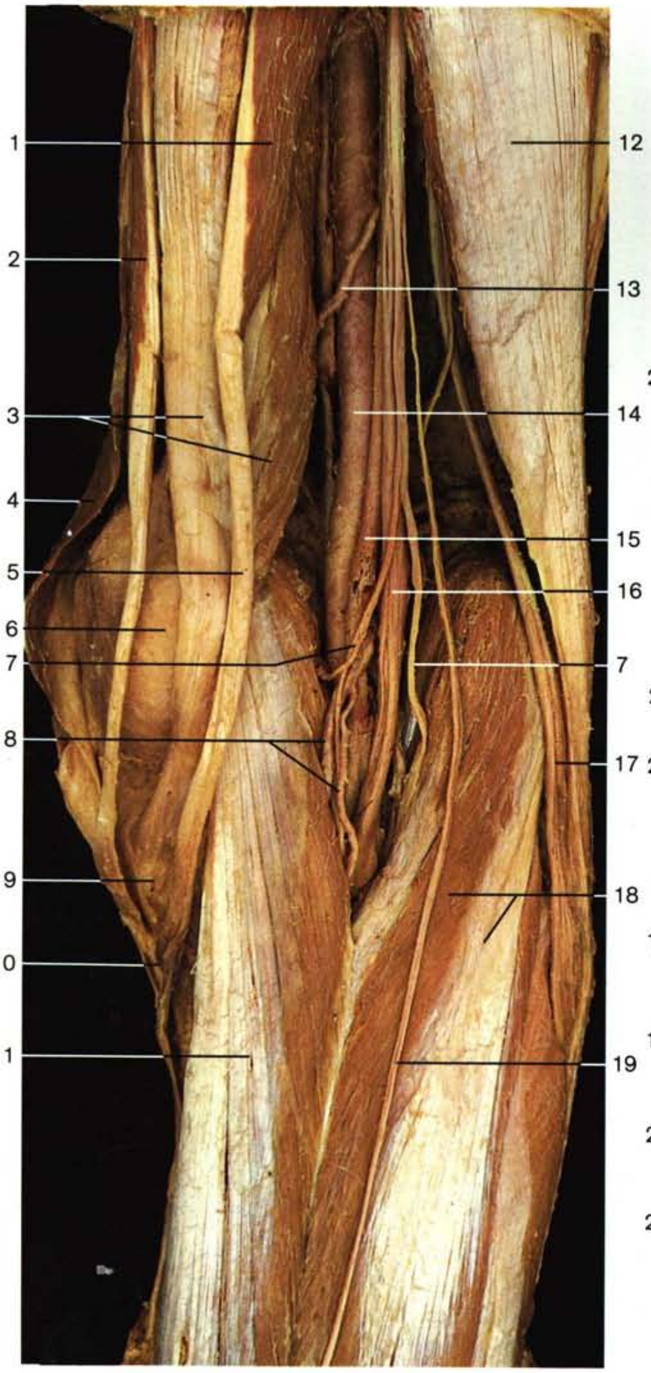

Right leg, posterior crural region (posterior aspect). The gastrocnemius muscle has been divided and reflected.

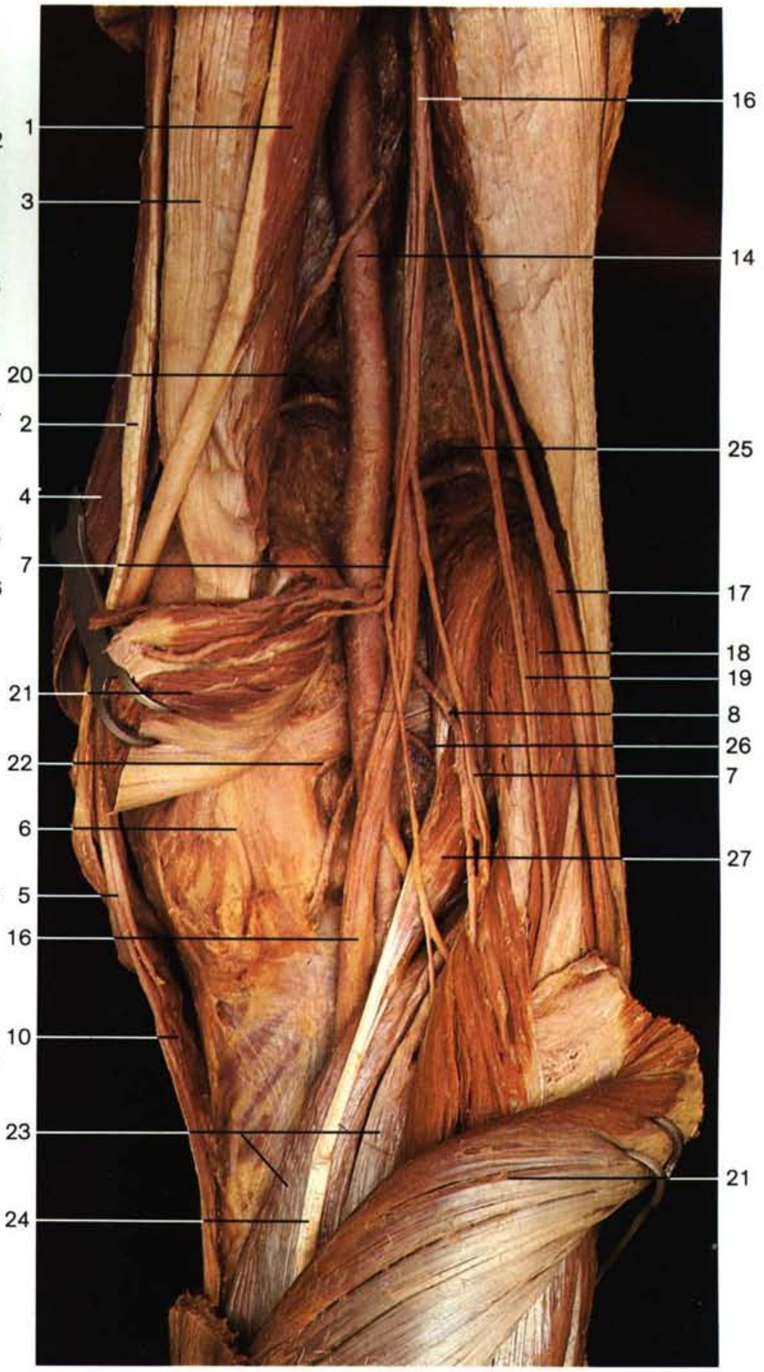

Right leg, posterior crural region, deep layer (posterior aspect). The gastrocnemius and the soleus muscles have been divided and reflected.

1 Semitendinosus muscle
2 Gracilis muscle
3 Semimembranosus muscle
4 Sartorius muscle
5 Tendon of semitendinosus muscle
6 Position of medial condyle of femur
7 Muscular branches of tibial nerve
8 Sural arteries and veins
9 Tendon of semimembranosus muscle
10 Common tendon of gracilis, semitendinosus and sartorius muscles
11 Medial head of gastrocnemius muscle
12 Biceps femoris muscle
13 Muscular branch of popliteal artery
14 **Popliteal artery**
15 **Popliteal vein**
16 **Tibial nerve**
17 **Common peroneal nerve**
18 Lateral head of gastrocnemius muscle
19 Medial sural cutaneous nerve
20 Medial superior genicular artery
21 Medial head of gastrocnemius muscle (cut and reflected)
22 Medial inferior genicular artery
23 Soleus muscle
24 Tendon of plantaris muscle
25 Lateral superior genicular artery
26 Lateral inferior genicular artery
27 Plantaris muscle

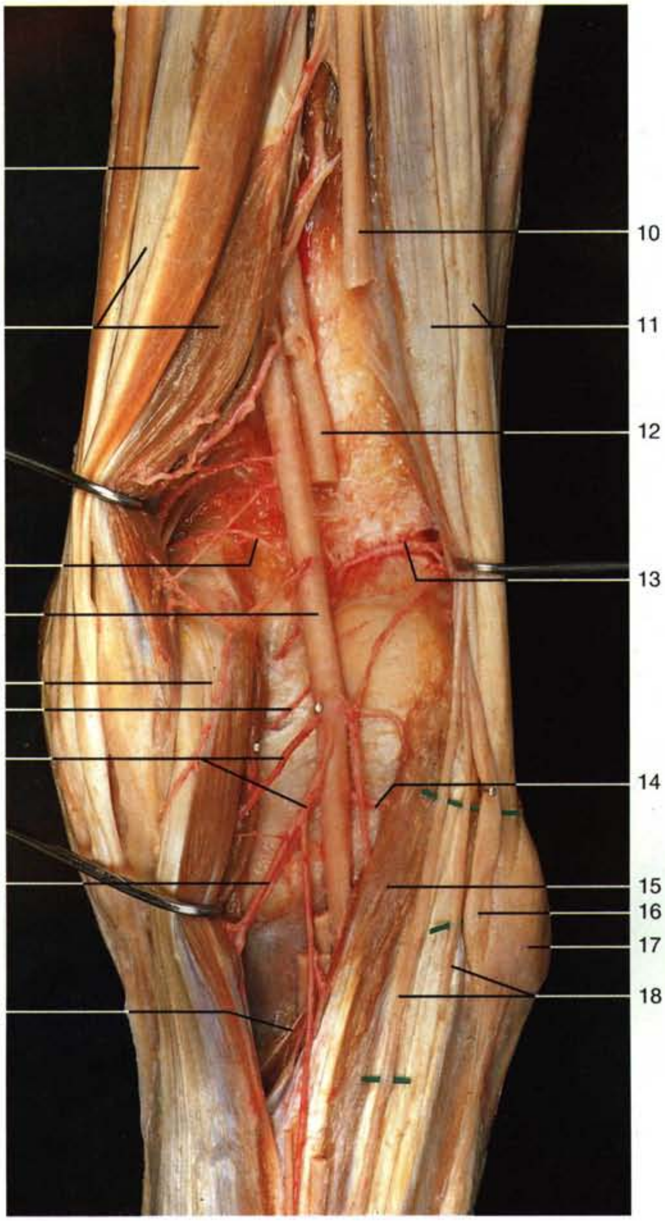

Right leg, popliteal fossa, deep layer (posterior aspect). The muscles have been reflected to display the genicular arteries.

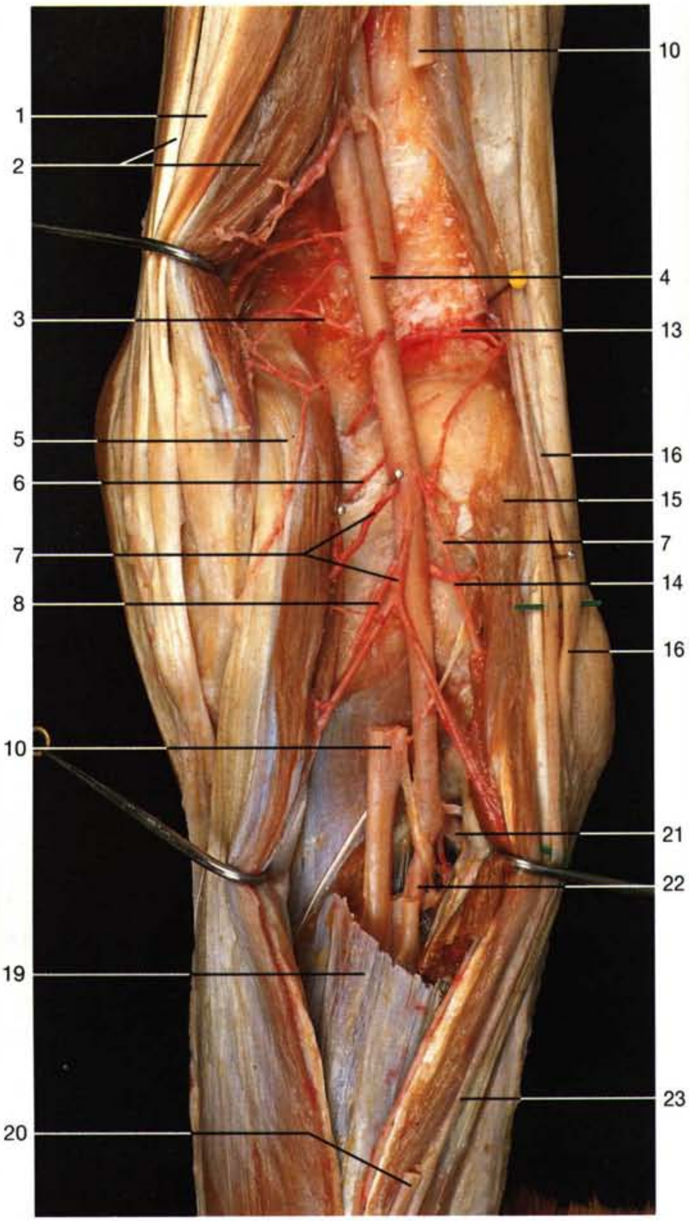

Right leg, popliteal fossa, deepest layer (posterior aspect). Tibial nerve and popliteal vein have been partly removed and a portion of the soleus muscle was cut away to display the anterior tibial artery.

1 Semitendinosus muscle
2 Semimembranosus muscle
3 Medial superior genicular artery
4 **Popliteal artery**
5 Medial head of gastrocnemius muscle
6 Middle genicular artery
7 Muscular branches
8 Medial inferior genicular artery
9 Tendon of plantaris muscle
10 **Tibial nerve** (cut)
11 Biceps femoris muscle

12 Popliteal vein (cut)
13 Lateral superior genicular artery
14 Lateral inferior genicular artery
15 Lateral head of gastrocnemius muscle
16 **Common peroneal nerve**
17 Head of fibula
18 Lateral sural cutaneous nerves
19 Soleus muscle
20 Medial sural cutaneous nerve
21 **Anterior tibial artery**
22 **Posterior tibial artery**
23 Lateral sural cutaneous nerve

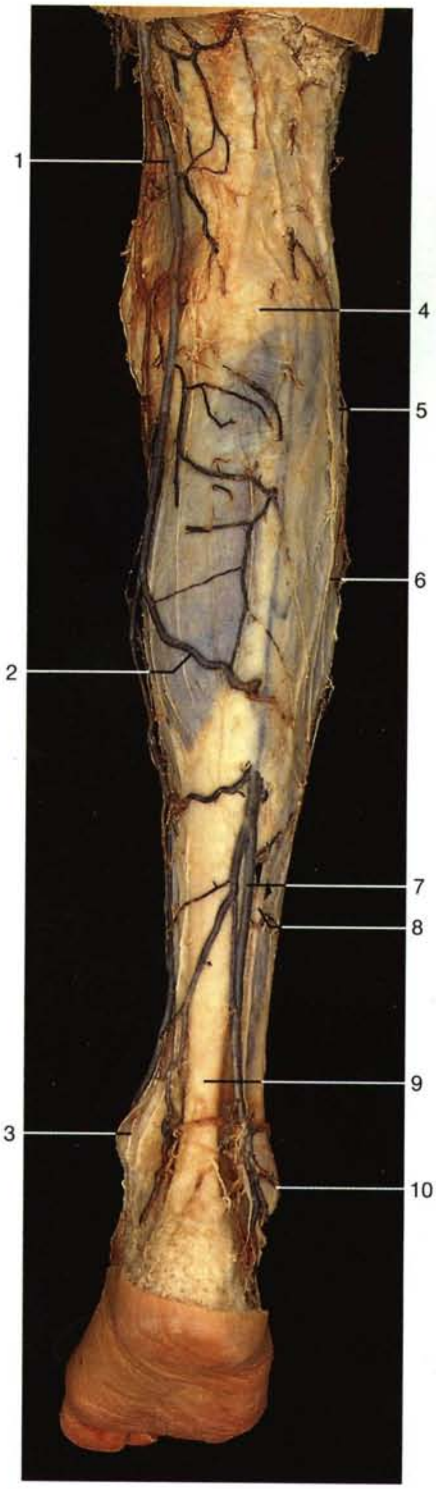

Right leg. Cutaneous veins and nerves (posterior aspect).

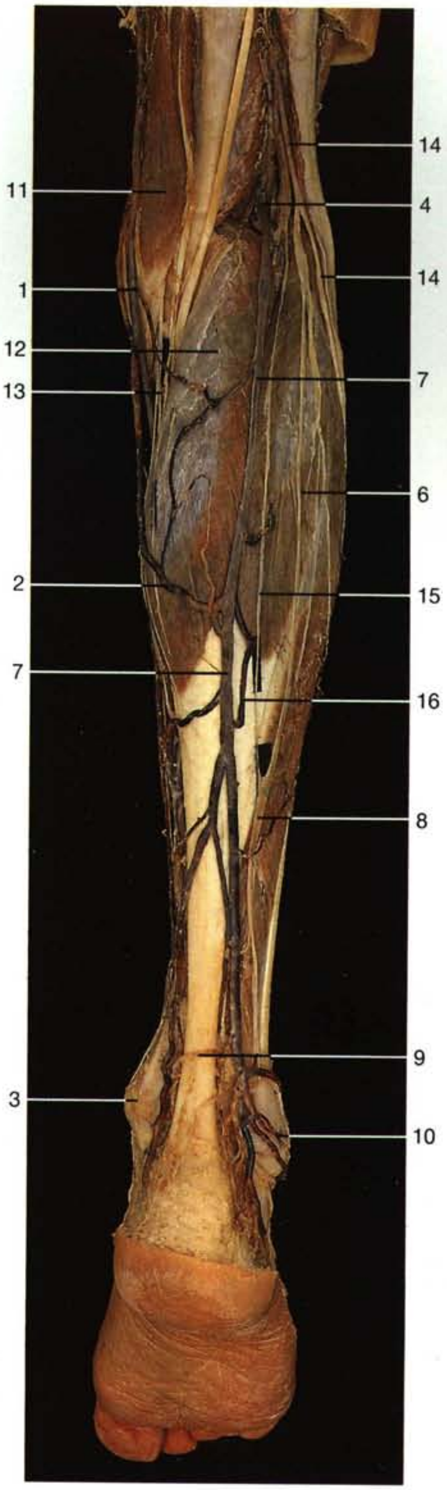

Right leg. Cutaneous nerves and veins (posterior aspect). The superficial layer of the crural fascia has been removed.

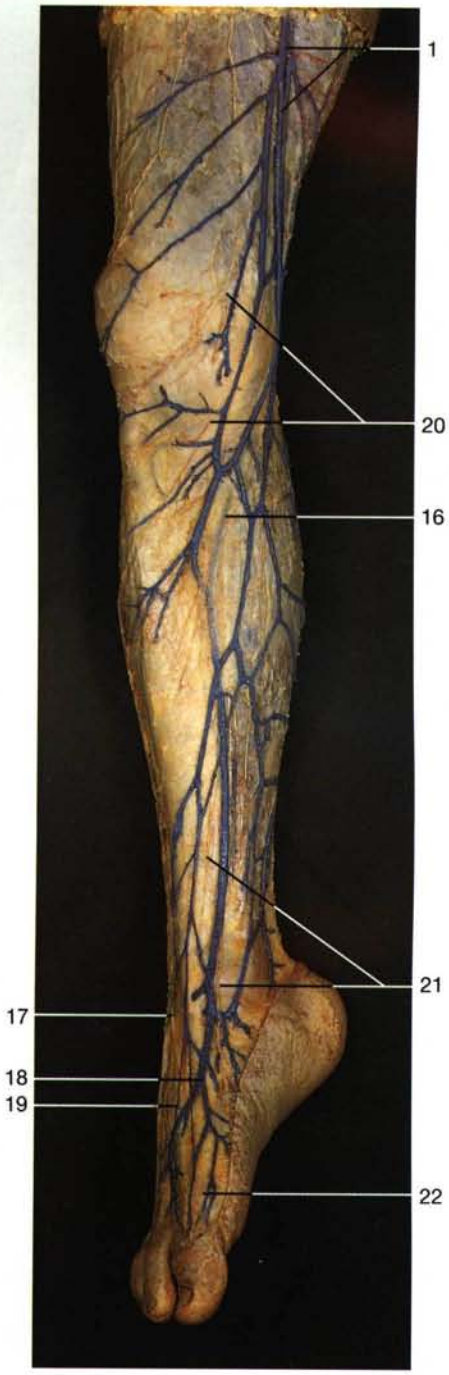

Cutaneous veins and nerves of the right leg (anterior-medial aspect; veins are colored).

1 **Great saphenous vein**
2 Venous anastomosis between small and great saphenous veins
3 Medial malleolus
4 Popliteal fossa
5 Position of head of fibula
6 Lateral sural cutaneous nerve
7 **Small saphenous vein**
8 **Sural nerve**
9 Calcaneal tendon
10 Lateral malleolus
11 Semitendinosus muscle
12 Medial head of gastrocnemius muscle
13 Saphenous nerve
14 **Common peroneal nerve**
15 Medial sural cutaneous nerve
16 Perforating veins
17 Superficial peroneal nerve
18 Dorsal venous arch
19 Intermediate dorsal cutaneous nerve
20 **Infrapatellar branches of saphenous nerve**
21 Terminal branches of saphenous nerve
22 Medial dorsal cutaneous nerve

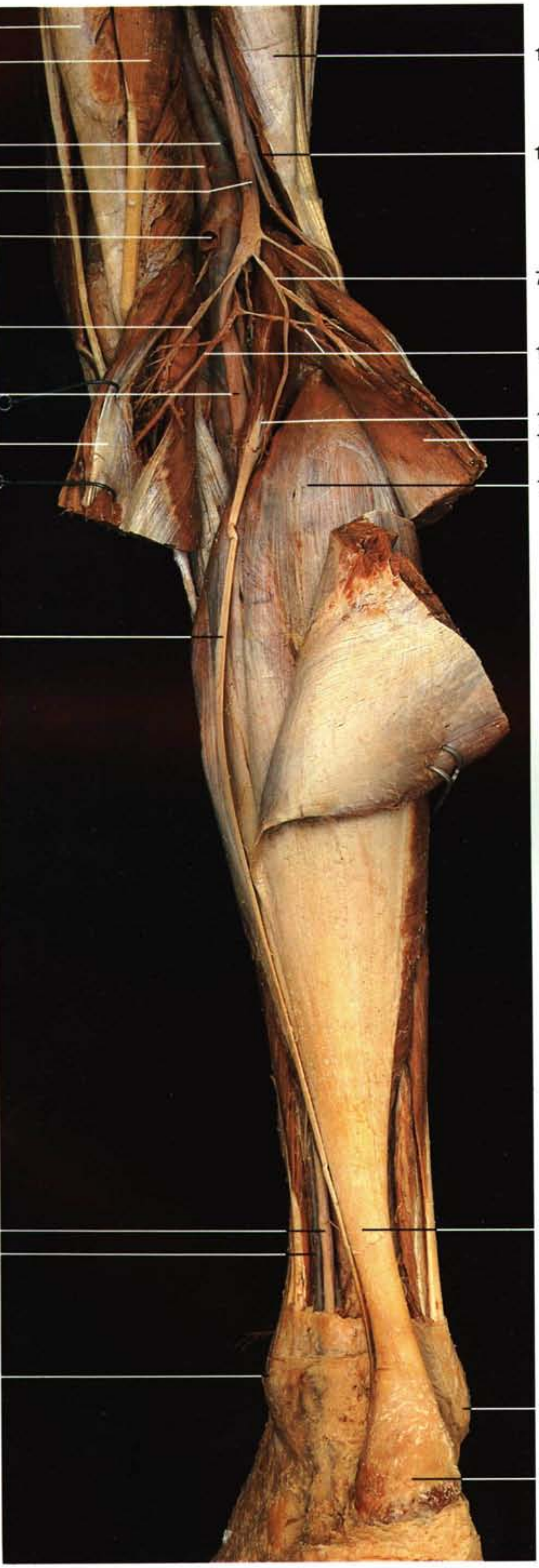
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Right popliteal fossa, middle layer (posterior aspect). The cutaneous veins and nerves have been removed.

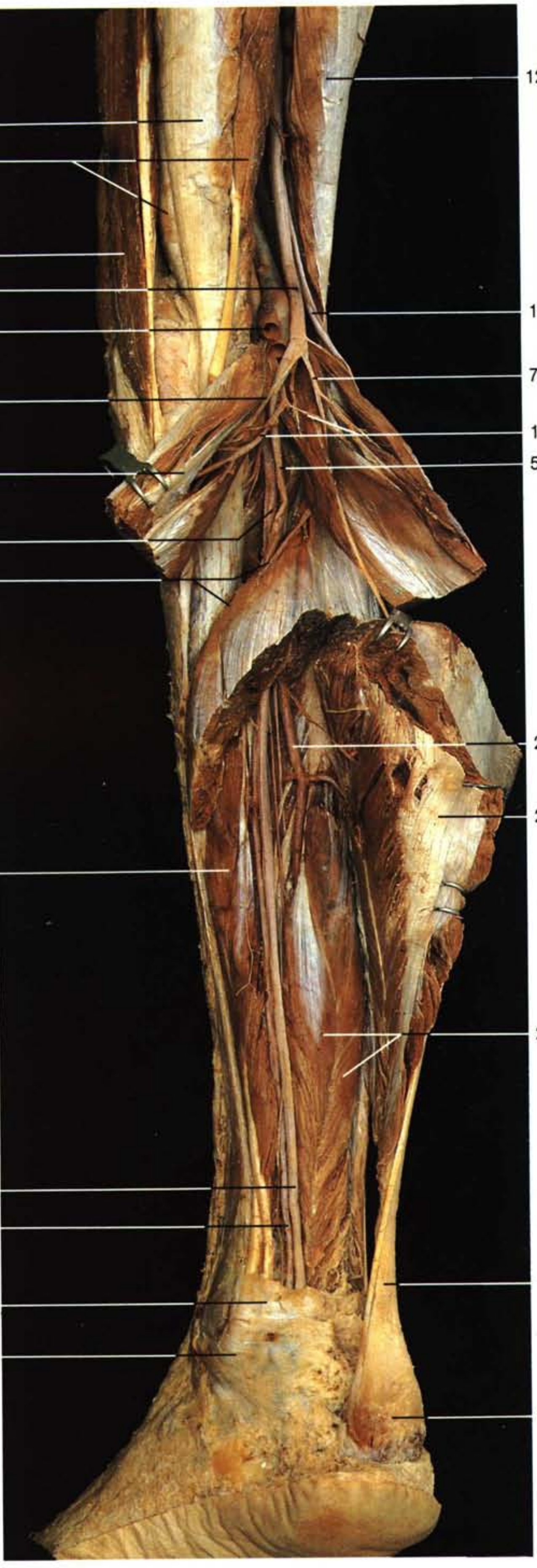
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Right popliteal fossa, deep layer (posterior aspect). The medial head of gastrocnemius muscle has been divided and reflected.

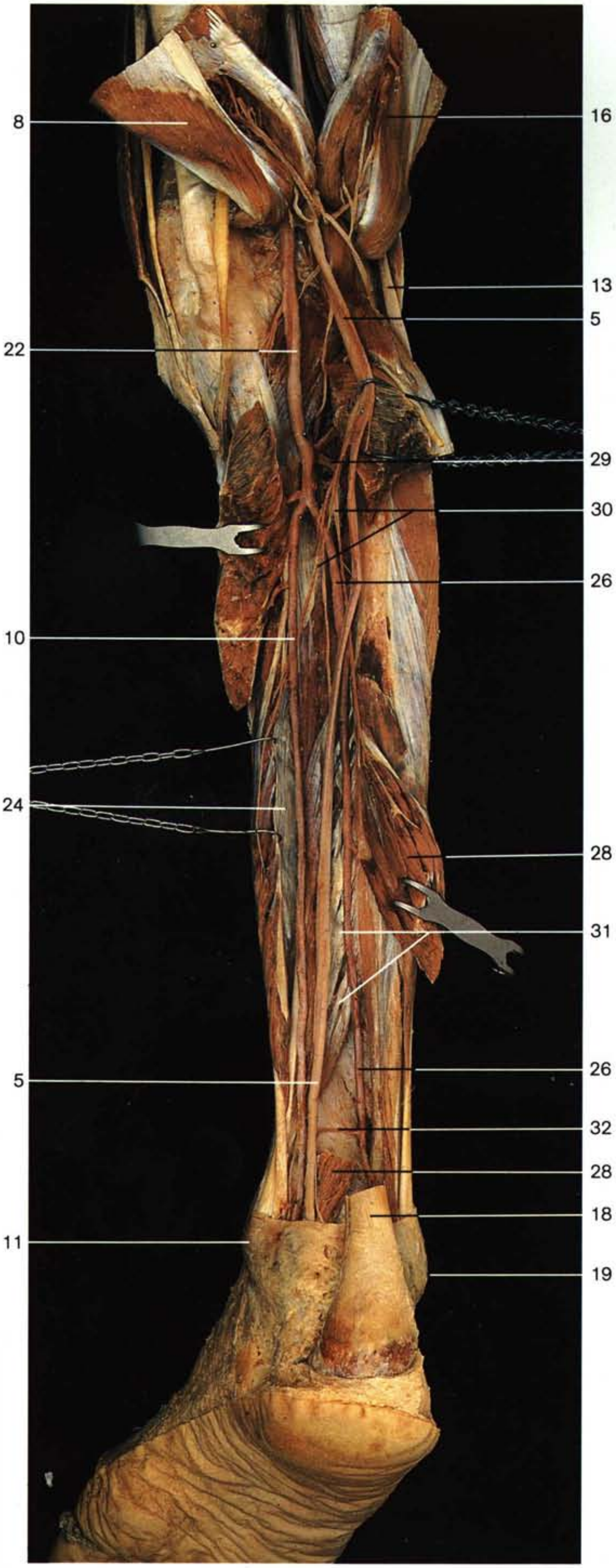

Right leg, posterior crural region, deepest layer (posterior aspect). Triceps surae (gastrocnemius and soleus) and flexor hallucis longus muscles have been cut and reflected.

1 Semimembranosus muscle
2 Semitendinosus muscle
3 **Popliteal vein**
4 Popliteal artery
5 **Tibial nerve**
6 Small saphenous vein (cut)
7 Muscular branch of tibial nerve
8 Medial head of gastrocnemius muscle
9 Tendon of plantaris muscle
10 **Posterior tibial artery**
11 Medial malleolus
12 Biceps femoris muscle
13 Common peroneal nerve
14 **Sural arteries**
15 Plantaris muscle
16 Lateral head of gastrocnemius muscle
17 Soleus muscle
18 Calcaneal tendon
19 Lateral malleolus
20 Calcaneal tuberosity
21 Sartorius muscle
22 **Popliteal artery**
23 Tendinous arch of soleus muscle
24 Flexor digitorum longus muscle
25 Flexor retinaculum
26 **Peroneal artery**
27 Soleus muscle
28 Flexor hallucis longus muscle
29 **Anterior tibial artery**
30 Muscular branches of tibial nerve
31 Tibialis posterior muscle
32 Communicating branch of peroneal artery
33 Tendon of tibialis anterior muscle
34 Tibia
35 Tendon of extensor hallucis longus muscle
36 Tendons of extensor digitorum longus muscle
37 Anterior tibialis artery
38 Fibula
39 Tendons of peroneus longus and brevis muscles

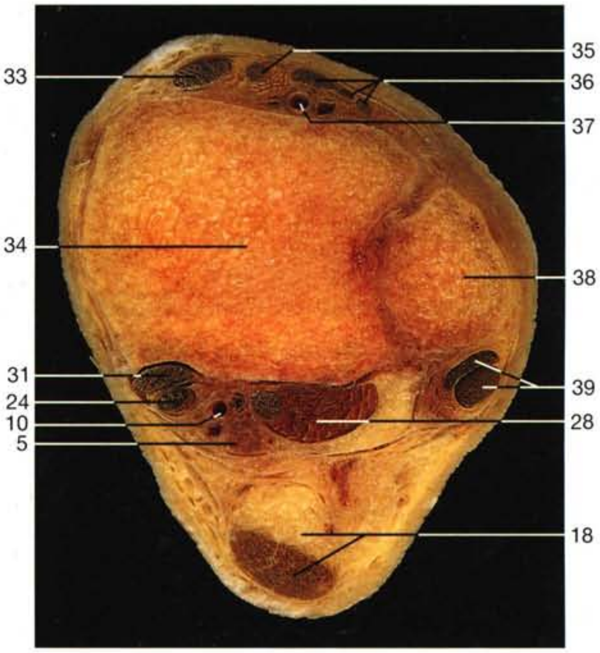

Cross-section of the leg, superior to the malleoli (from below).

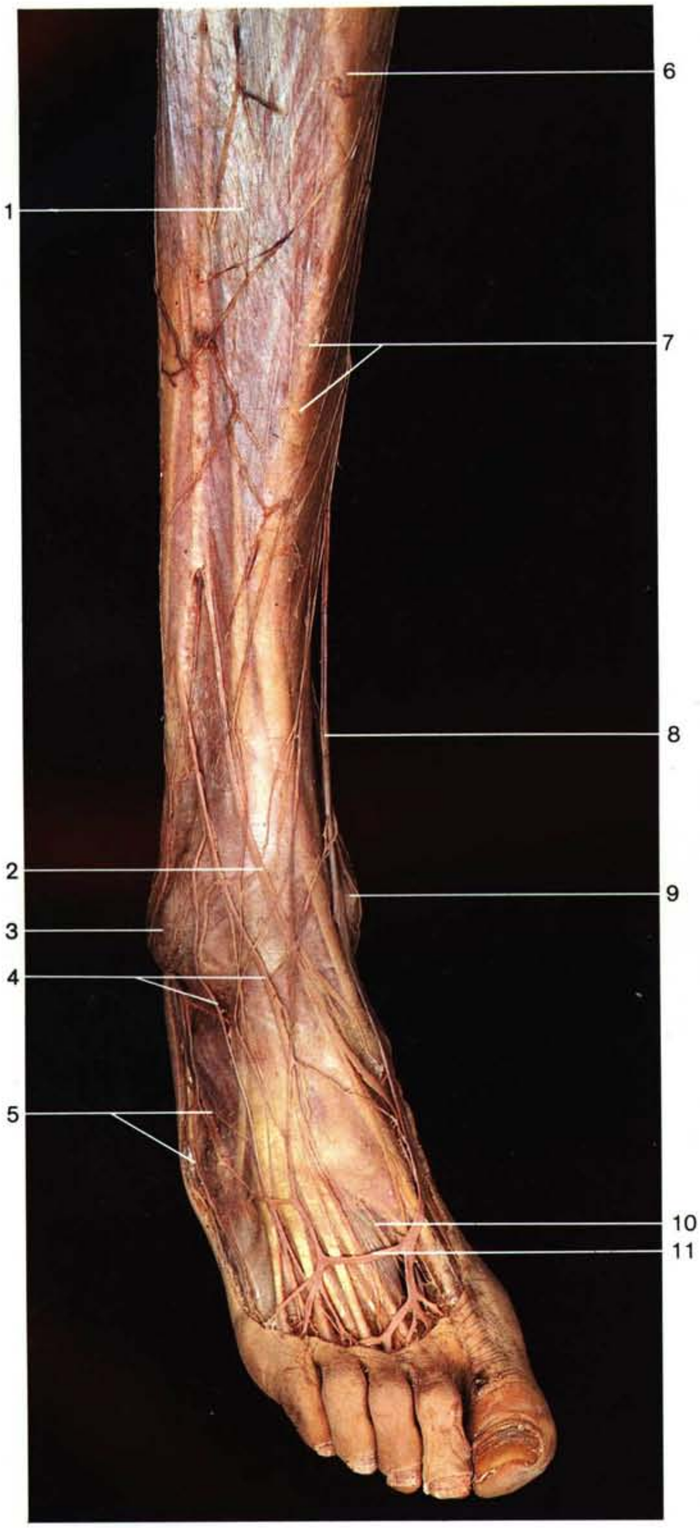

Right leg and foot, anterior crural region and dorsum of foot; cutaneous nerves and veins (anterior aspect).

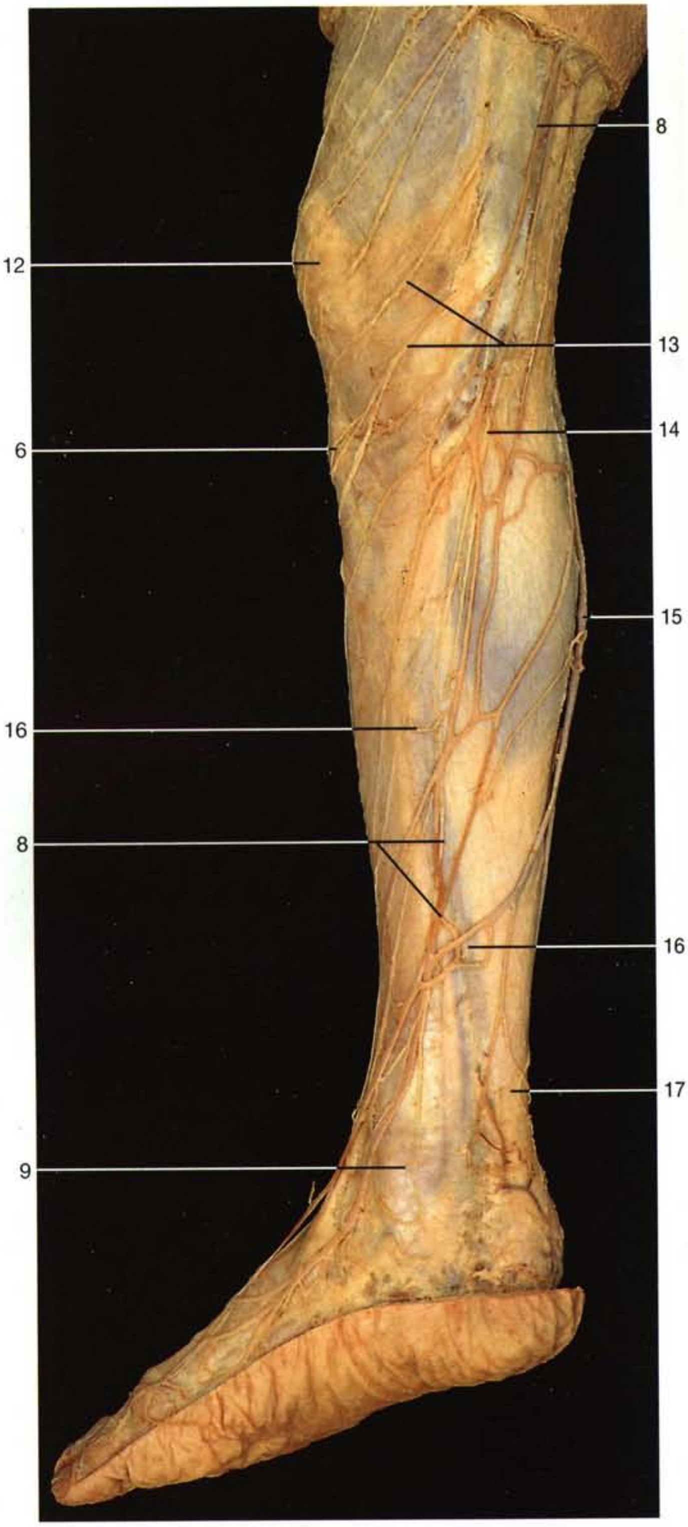

Right leg and foot; cutaneous nerves and veins (medial aspect).

1 Superficial crural fascia
2 Medial cutaneous branch of superficial peroneal nerve
3 Lateral malleolus
4 Lateral cutaneous branch of superficial peroneal nerve
5 Cutaneous branch of sural nerve
6 Position of tuberosity of tibia
7 Anterior margin of tibia
8 **Great saphenous vein**
9 Medial malleolus
10 Deep peroneal nerve
11 **Venous arch of dorsum of foot**
12 Position of patella
13 **Infrapatellar branches of saphenous nerve**
14 Saphenous nerve
15 Small saphenous vein
16 Perforating vein
17 Calcaneal tendon

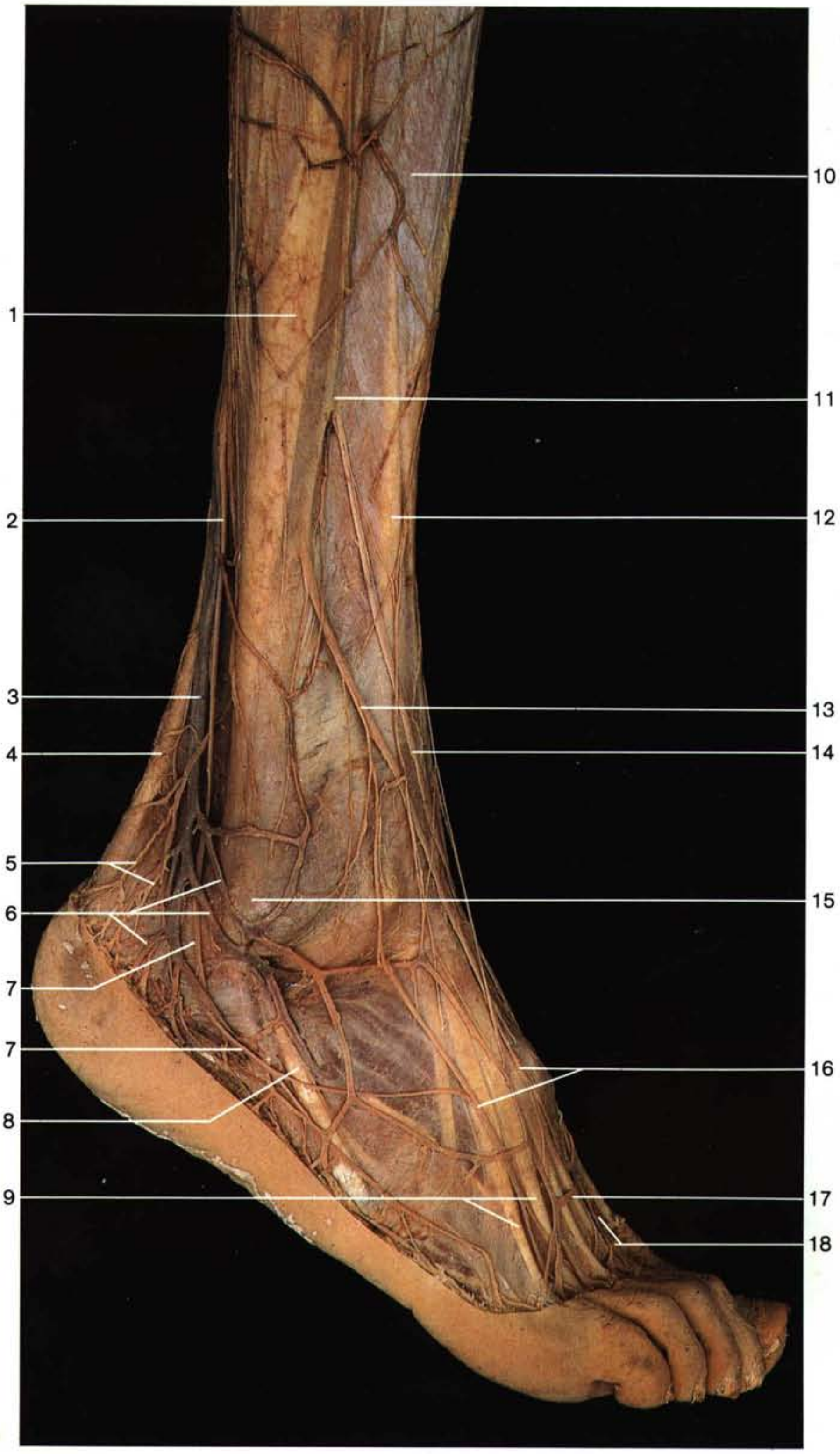

Right leg and dorsum of foot; cutaneous nerves and veins (lateral aspect).

1 Position of fibula
2 **Sural nerve**
3 **Small saphenous vein**
4 Calcaneal tendon
5 Lateral calcaneal branches of sural nerve
6 Venous network at lateral malleolus
7 Cutaneous branch of sural nerve
8 Tendon of peroneus brevis muscle
9 Tendons of extensor digitorum longus muscle

10 Fascia cruris
11 Superficial peroneal nerve
12 Position of tibia
13 Lateral cutaneous branch } of **superficial peroneal nerve**
14 Medial cutaneous branch } of **superficial peroneal nerve**
15 Lateral malleolus
16 Dorsal digital nerves
17 Dorsal venous arch
18 Deep peroneal nerve

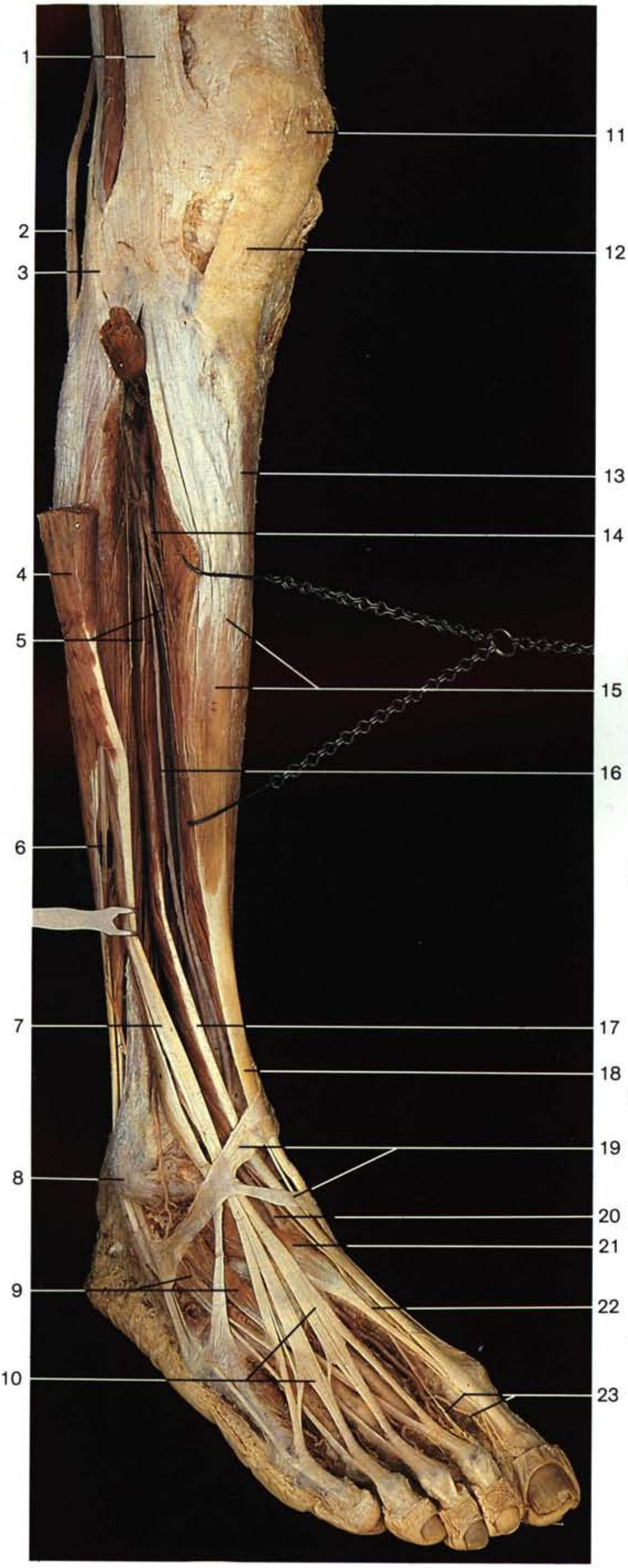
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Right leg and dorsum of foot, middle layer (anterior lateral aspect). The extensor digitorum longus muscle has been divided and reflected laterally.

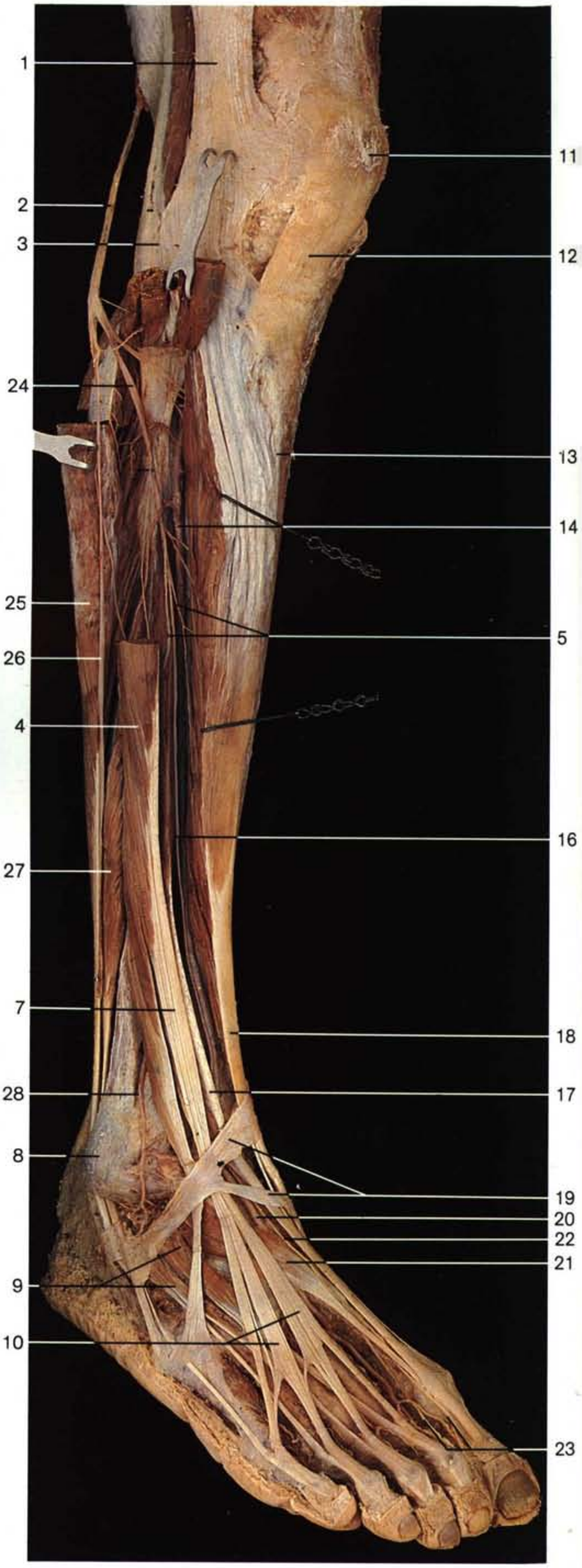
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Right leg, deep layer (anterior lateral aspect). The extensor digitorum longus and the peroneus longus muscle have been divided or removed. The common peroneal nerve has been elevated to show its course around the head of fibula.

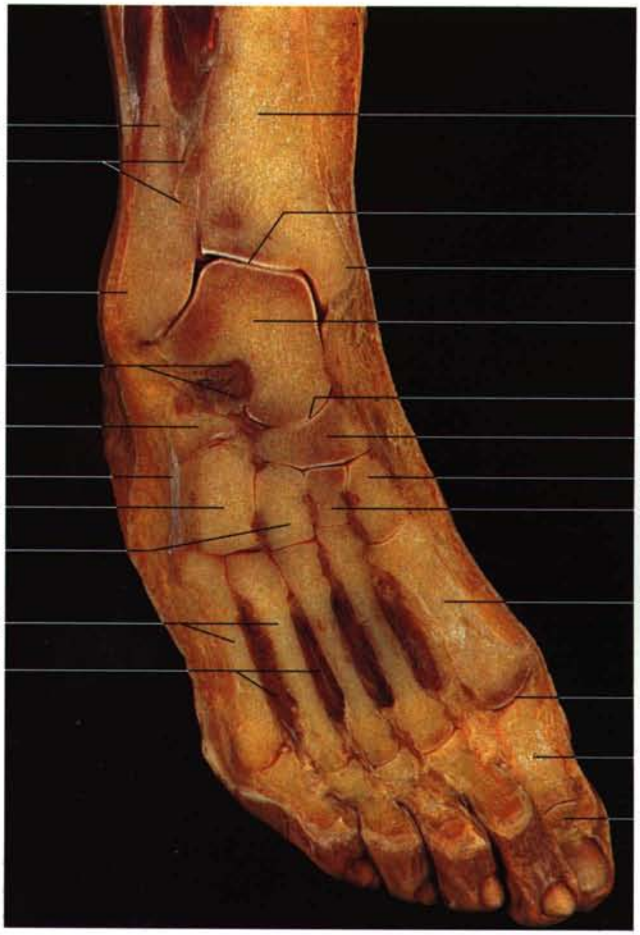

Coronal section through the foot and talocrural joint (anterior aspect).

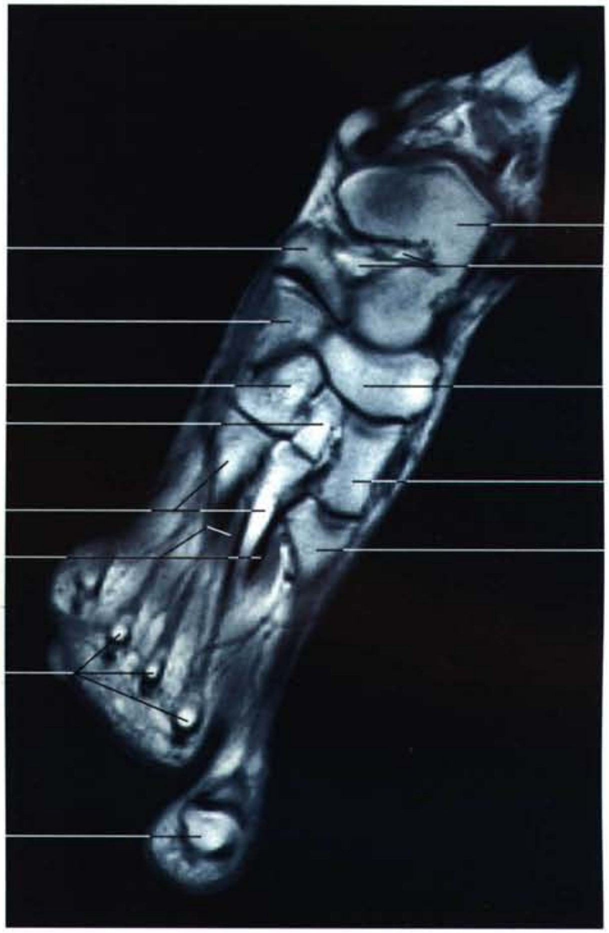

Coronal section through the foot (MR-Scan after A. Heuck, G. Luttke and J. W. Rohen, 1994).

1 Iliotibial tract
2 **Common peroneal nerve**
3 Position of head of fibula
4 Extensor digitorum longus muscle
5 Muscular branches of deep peroneal nerve
6 **Superficial peroneal nerve**
7 Tendon of extensor digitorum longus muscle
8 Lateral malleolus
9 Extensor digitorum brevis muscle
10 Tendons of extensor digitorum longus muscle
11 Patella
12 Patellar ligament
13 Anterior margin of tibia
14 **Anterior tibial artery**
15 Tibialis anterior muscle
16 Deep peroneal nerve
17 Extensor hallucis longus muscle
18 Tendon of tibialis anterior muscle
19 Extensor retinaculum
20 Dorsalis pedis artery
21 Extensor hallucis brevis muscle
22 Deep peroneal nerve (on dorsum of foot)
23 Dorsal digital nerves (terminal branches of deep peroneal nerve)
24 **Deep peroneal nerve**
25 Peroneus longus muscle (cut)
26 Superficial peroneal nerve (with peroneal muscles laterally reflected)
27 Peroneus brevis muscle
28 Lateral anterior malleolar artery
29 Fibula
30 Distal tibiofibular joint (syndesmosis)
31 Interosseous talocalcaneal ligament
32 Calcaneus
33 Tendon of peroneus brevis muscle
34 Cuboid bone
35 Lateral cuneiform bone
36 Metatarsal bones
37 Dorsal interosseous muscles
38 Tibia
39 **Talocrural joint**
40 Medial malleolus
41 Talus
42 **Talocalcaneonavicular joint**
43 Navicular bone
44 Medial cuneiform bone
45 Intermediate cuneiform bone
46 First metatarsal bone
47 Metatarsophalangeal joint of great toe
48 Proximal phalanx of great toe
49 Distal phalanx of great toe
50 Heads of metatarsal bones II-IV

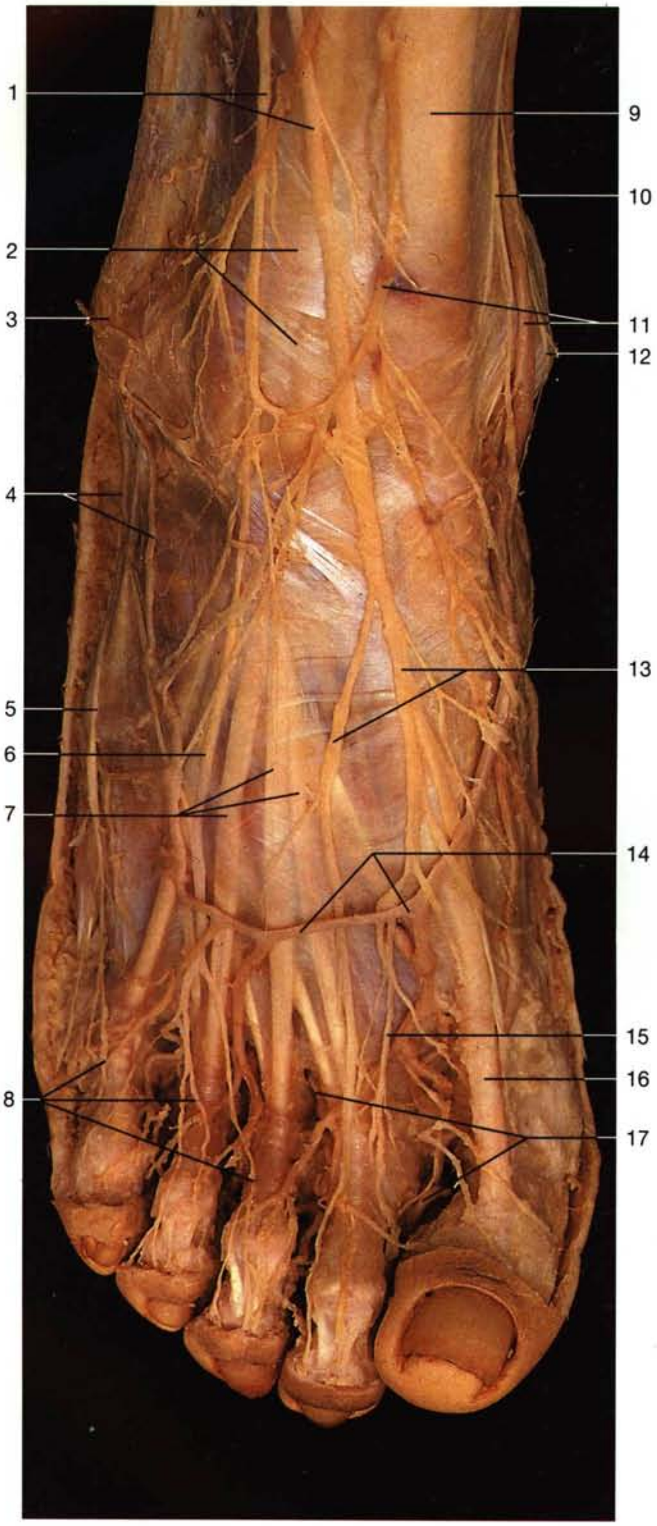

Dorsum of the right foot, superficial layer (anterior aspect).

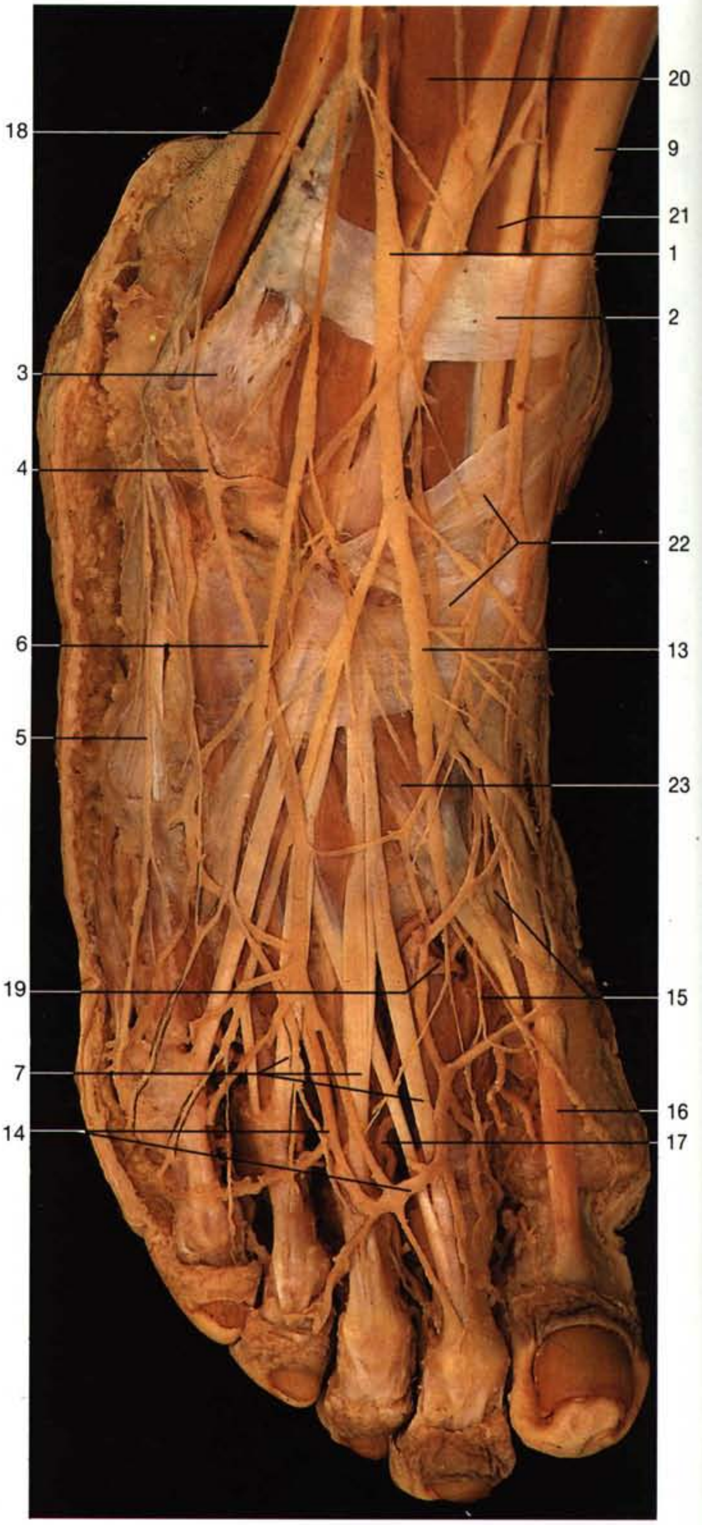

Dorsum of the right foot, superficial layer. The fascia of the dorsum has been removed.

1 **Superficial peroneal nerve**
2 Superior extensor retinaculum
3 Lateral malleolus
4 Venous network of lateral malleolus and tributaries of small saphenous vein
5 Lateral dorsal cutaneous nerve (branch of sural nerve)
6 Intermediate dorsal cutaneous nerve
7 Tendons of extensor digitorum longus muscle
8 Dorsal digital nerves
9 Tendon of tibialis anterior muscle
10 **Saphenous nerve**
11 Venous network of medial malleolus and tributaries of great saphenous vein
12 Medial malleolus
13 Medial dorsal cutaneous nerves
14 **Dorsal venous arch**
15 Dorsal digital nerve (of deep peroneal nerve)
16 Tendon of extensor hallucis longus muscle
17 Dorsal digital arteries
18 Peroneal muscles
19 Deep plantar branch of dorsalis pedis artery anastomosing with plantar arch
20 Extensor digitorum longus muscle
21 Extensor hallucis longus muscle
22 Inferior extensor retinaculum
23 Extensor hallucis brevis muscle

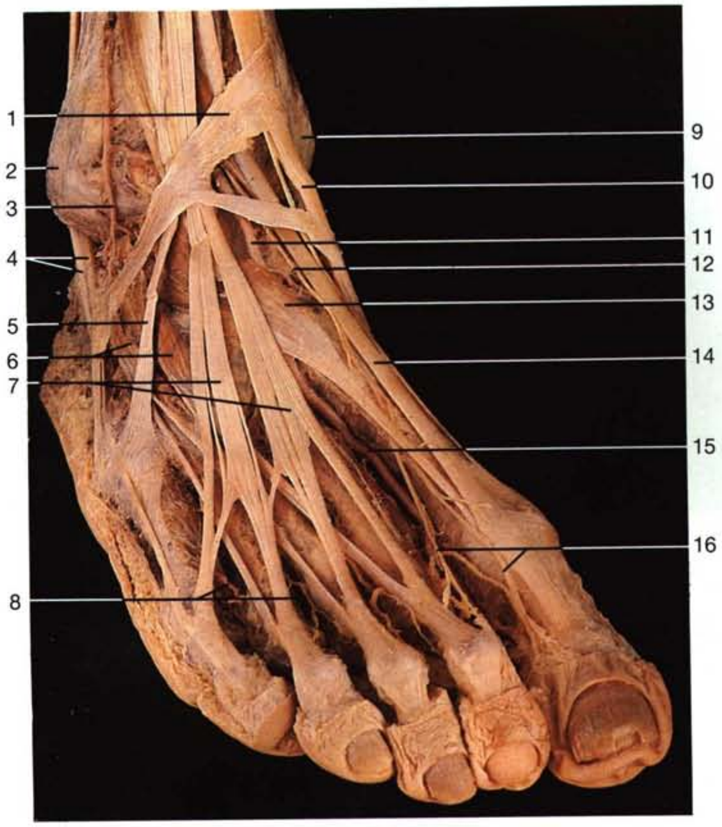

Dorsum of right foot, middle layer (anterior lateral aspect). The cutaneous nerves have been removed.

1 Extensor retinaculum
2 Lateral malleolus
3 Lateral anterior malleolar artery
4 Tendons of peroneal muscles
5 Tendon of peroneus tertius muscle
6 Extensor digitorum brevis muscle
7 Tendons of extensor digitorum longus muscle
8 Dorsal metatarsal arteries
9 Medial malleolus
10 Tendon of tibialis anterior muscle
11 **Dorsalis pedis artery**
12 Deep peroneal nerve (on dorsum of foot)
13 Extensor hallucis brevis muscle
14 Tendon of extensor hallucis longus muscle
15 Dorsalis pedis artery with deep plantar branch to the plantar arch
16 Dorsal digital nerves (terminal branches of deep peroneal nerve)
17 Lateral tarsal artery
18 Extensor digitorum brevis muscle (divided)
19 Arcuate artery
20 Dorsal interosseous muscles
21 **Deep peroneal nerve**
22 Medial cuneiform and 1st metatarsal bone
23 Tendon of peroneus longus muscle
24 Abductor hallucis and flexor hallucis brevis muscles
25 Medial plantar artery, vein and nerve
26 Fourth and fifth metatarsal bone
27 Adductor hallucis (oblique head)
28 Tendons of flexor digitorum longus muscle
29 Lateral plantar artery, vein and nerve
30 Flexor digitorum brevis muscle
31 Plantar aponeurosis

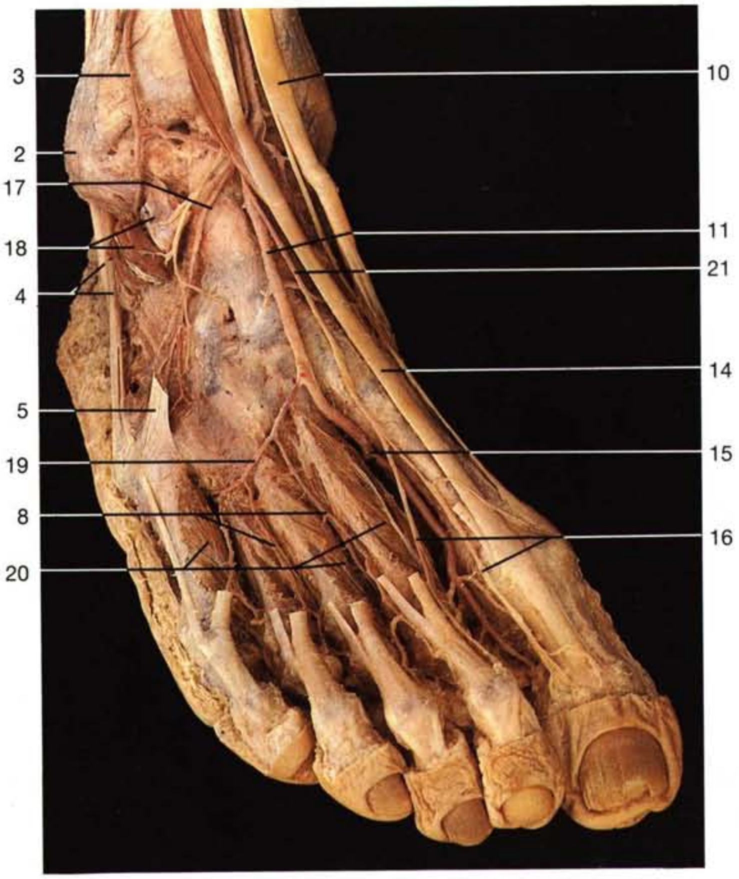

Dorsum of right foot, deep layer (anterior lateral aspect). The extensor digitorum and hallucis breves muscles have been removed.

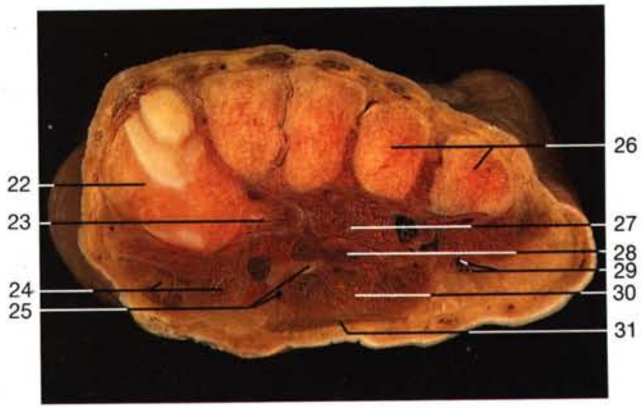

Cross-section of the rigt foot at the level of the metatarsal bones (posterior aspect).

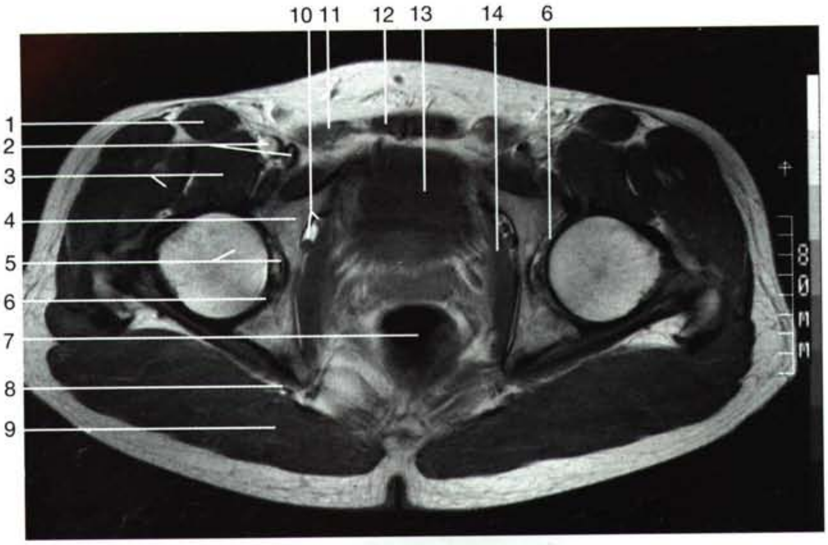
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Axial section through the pelvis and the hip joints (section 1; MR-Image; inferior aspect).

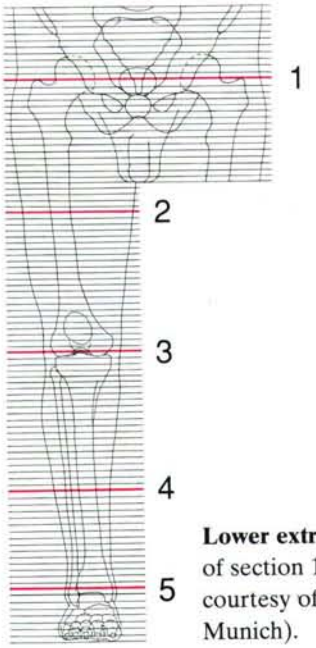

Lower extremity, location of section 1–5. (MR-Images, courtesy of Dr. A. Heuck, Munich).

1 Sartorius muscle
2 **Femoral artery and vein**
3 Iliopsoas muscle
4 Pelvic bone
5 **Femoral head** with ligament of femoral head
6 Articular cavity
7 Rectum
8 **Sciatic nerve** and accompanying artery
9 Gluteus maximus muscle
10 Obturator vessels and obturator nerve
11 Rectus abdominis muscle
12 Pyramidalis muscle
13 Urinary bladder
14 Obturator internus muscle
15 Rectus femoris muscle
16 Vastus intermedius and vastus lateralis of quadriceps femoris muscle

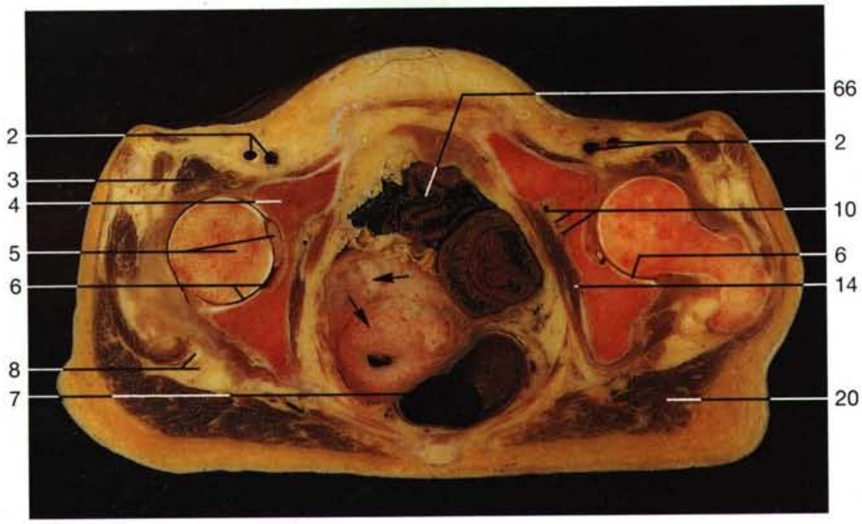
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Axial section through the pelvis and hip joints in the female (section 1, inferior aspect). (Arrows: uterus, myometrium with myoma).

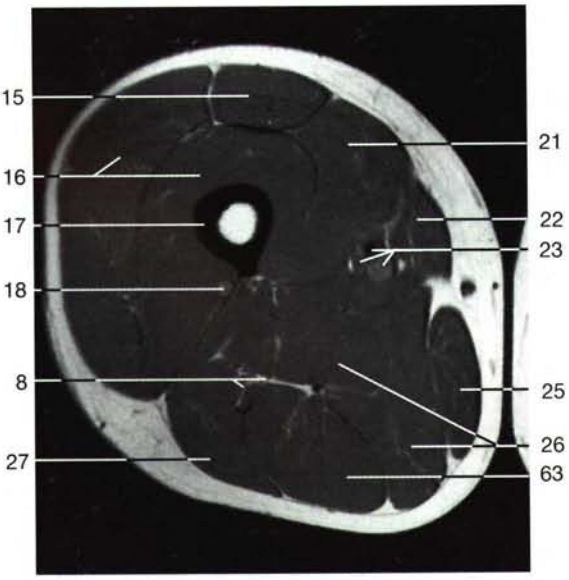
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Axial section through the middle of the thigh (section 2; MR-Image, inferior aspect).

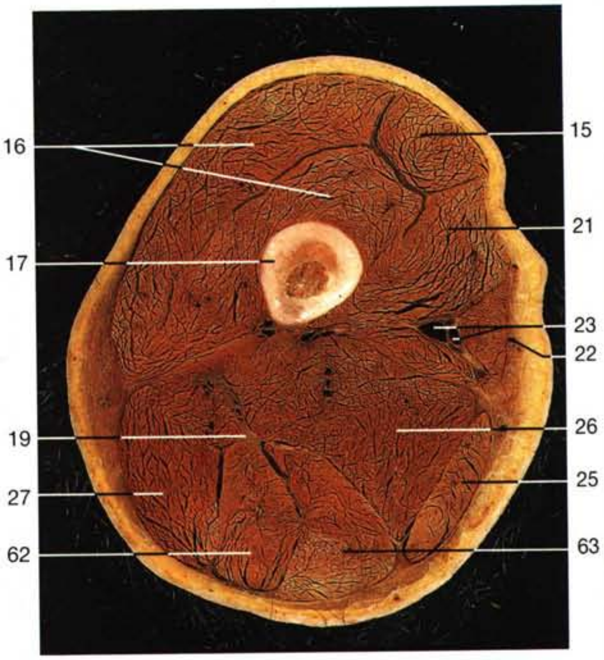
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Axial section through the middle of the right thigh (section 2, inferior aspect).

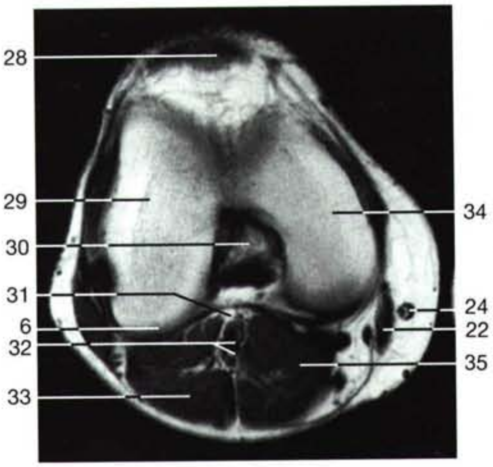

Axial section through the knee joint (section 3; MR-Image; inferior aspect).

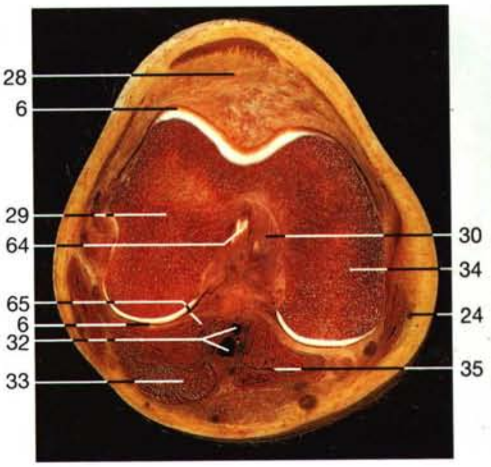

Axial section through the right knee joint (section 3, inferior aspect).

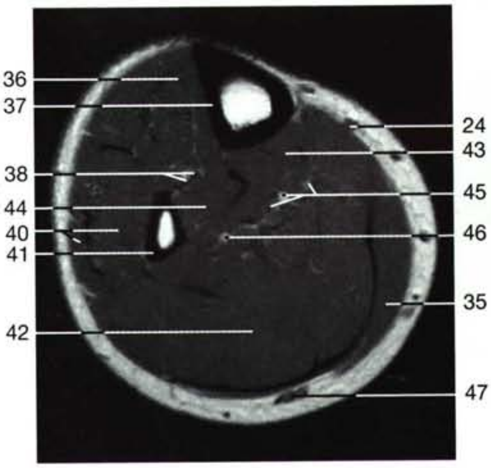

Axial section through the middle of the leg (section 4, MR-Image, inferior aspect).

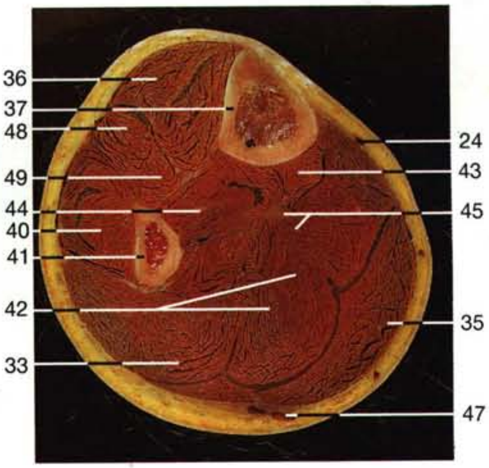

Axial section through the middle of the right leg (section 4, inferior aspect).

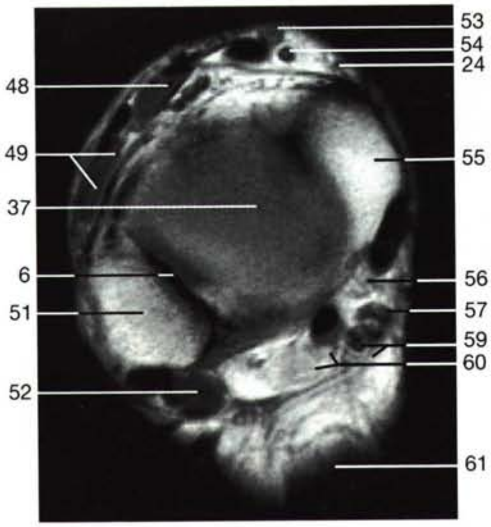

Axial section through the end of the right leg (section 5; MR-Image; inferior aspect).

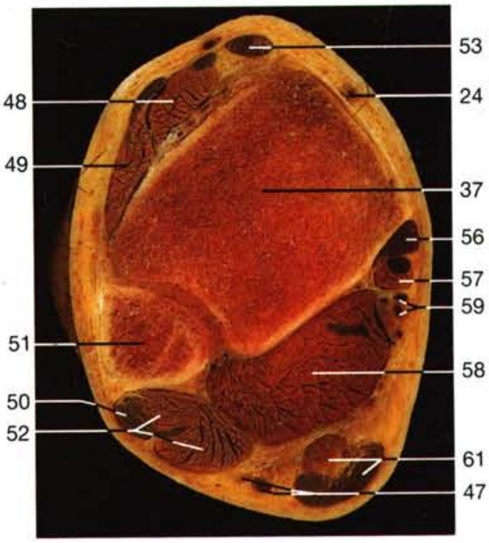

Axial section through the end of the right leg (section 5; inferior aspect).

17	**Femur**
18	Perforating artery
19	Sciatic nerve
20	Gluteus maximus muscle (insertion)
21	Vastus medialis muscle
22	Sartorius muscle
23	Femoral artery and vein
24	Great saphenous vein
25	Gracilis muscle
26	Adductor muscles
27	Biceps femoris muscle
28	Patellar ligament
29	Lateral condyle of femur
30	Posterior cruciate ligament
31	**Tibialis nerve**
32	Popliteal artery and vein
33	Lateral head of gastrocnemius muscle
34	Medial condyle of femur
35	Medial head of gastrocnemius muscle
36	Tibialis anterior muscle
37	**Tibia**
38	Deep peroneal nerve, anterior tibial artery and vein
40	Peroneus longus and brevis muscles
41	**Fibula**
42	Soleus muscle
43	Flexor digitorum longus muscle
44	Tibialis posterior muscle
45	Posterior tibial artery and vein and tibial nerve
46	Peroneal artery
47	Small saphenous vein and sural nerve
48	Extensor hallucis longus muscle
49	Extensor digitorum longus muscle
50	Tendon of peroneus longus muscle
51	Lateral malleolus (fibula)
52	Peroneus brevis muscle
53	Tibialis anterior muscle (tendon)
54	Dorsalis pedis artery
55	Medial malleolus (tibia)
56	Tibialis posterior muscle (tendon)
57	Flexor digitorum longus muscle (tendon with synovial sheath)
58	Flexor hallucis longus muscle
59	Posterior tibial artery and vein
60	Lateral and medial plantar nerves
61	Calcaneal tendon
62	Semitendinosus muscle
63	Semimembranosus muscle
64	Anterior cruciate ligament
65	Plantaris muscle
66	Small intestine

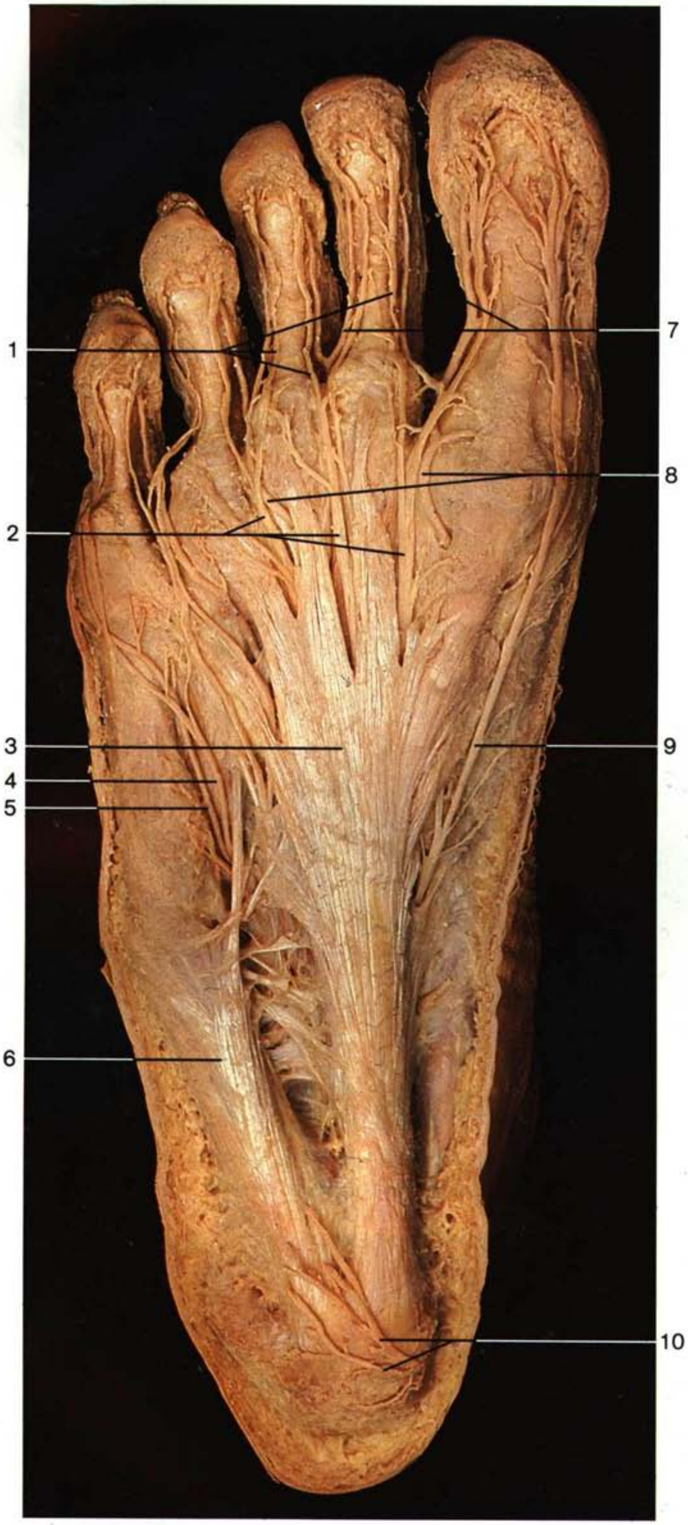

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Sole of the right foot, superficial layer (from below): dissection of cutaneous nerves and vessels.

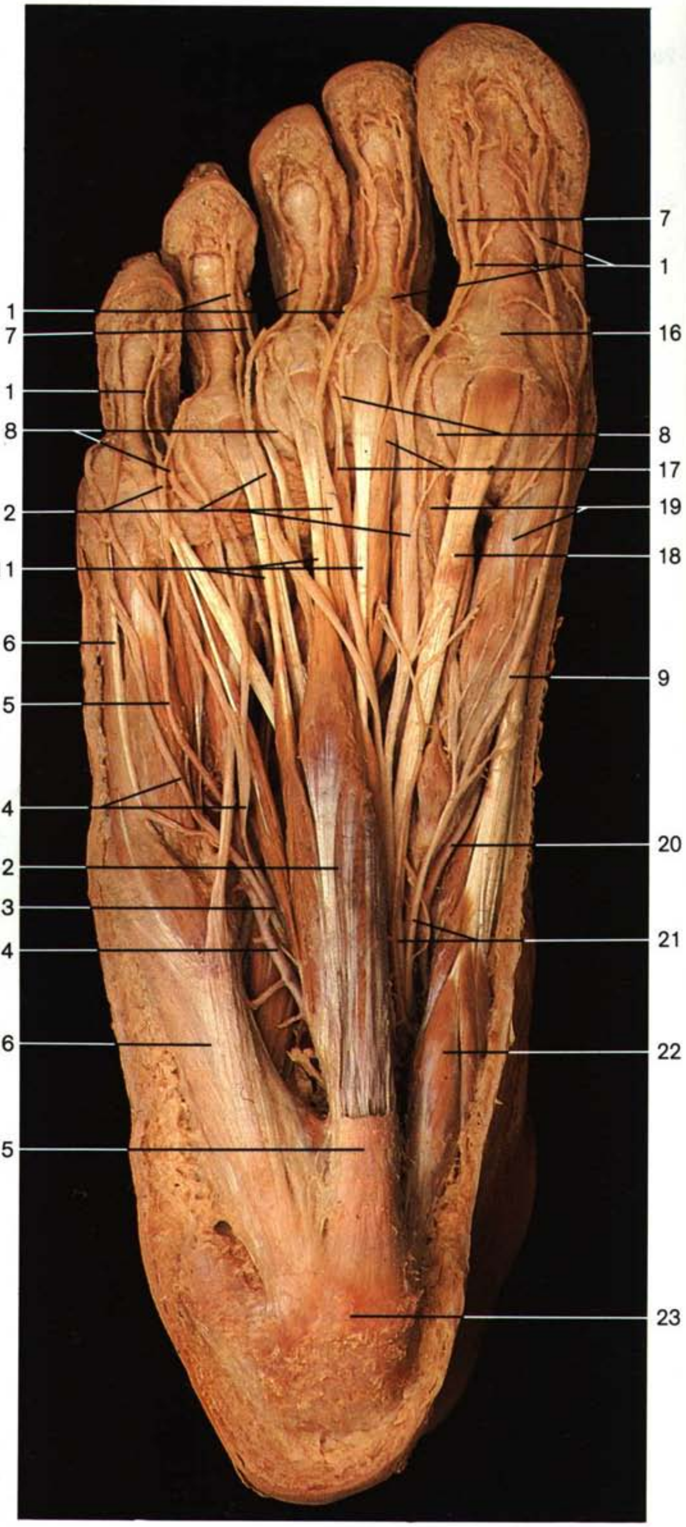

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Sole of the right foot, middle layer (from below). The plantar aponeurosis has been removed.

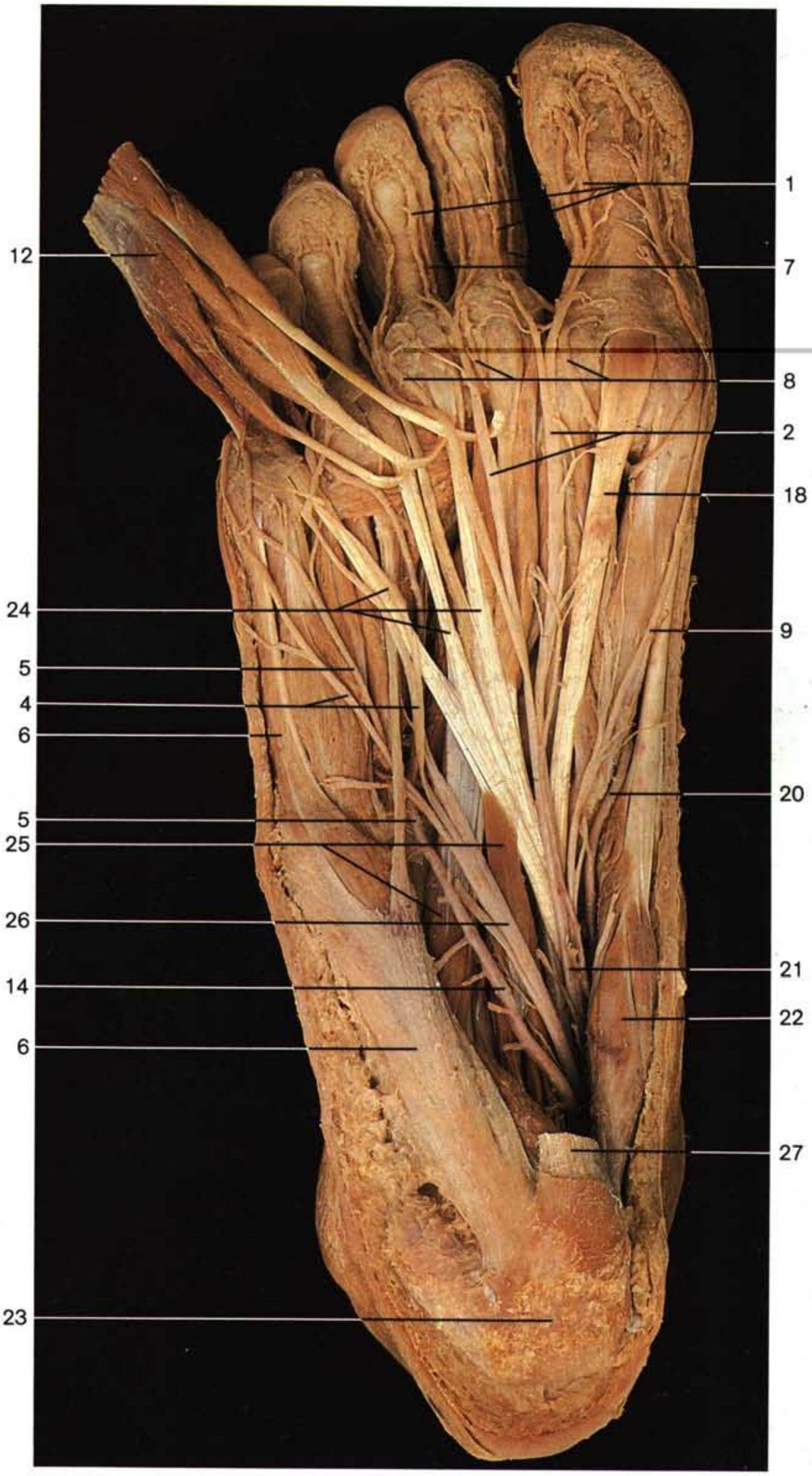

Sole of the right foot, middle layer (from below); dissection of vessels and nerves. The flexor digitorum brevis muscle has been divided and anteriorly reflected.

1 Proper plantar digital nerves
2 Common plantar digital nerves
3 Plantar aponeurosis
4 Superficial branch of lateral plantar nerve
5 Superficial branch of lateral plantar artery
6 Abductor digiti minimi
7 Proper plantar digital arteries
8 Common plantar digital arteries
9 Digital branch of medial plantar nerve to great toe
10 Medial calcaneal branches
11 Tendons of flexor digitorum brevis muscle
12 Flexor digitorum brevis muscle
13 **Superficial branch of lateral plantar nerve**
14 **Lateral plantar artery**
15 Plantar aponeurosis (remnant)
16 Digital synovial sheath
17 Lumbrical muscles
18 Tendon of flexor hallucis longus muscle
19 Flexor hallucis brevis muscle
20 **Medial plantar artery**
21 **Medial plantar nerve**
22 Abductor hallucis muscle
23 Calcaneal tuberosity
24 Tendons of flexor digitorum longus muscle
25 Quadratus plantae muscle
26 **Lateral plantar nerve**
27 Flexor digitorum brevis muscle (cut)
28 Synorial sheaths
29 Plantar arch

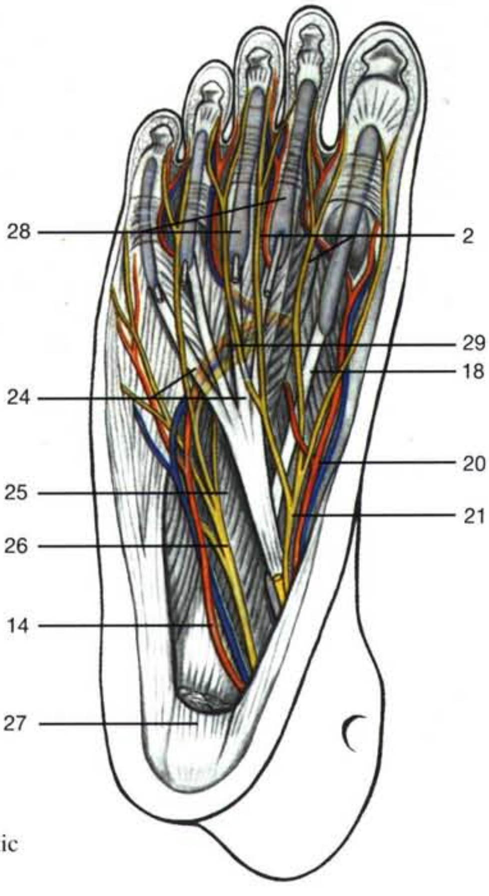

Sole of the right foot. Synovial sheaths of flexor tendons indicated in light blue. (Schematic drawing.)

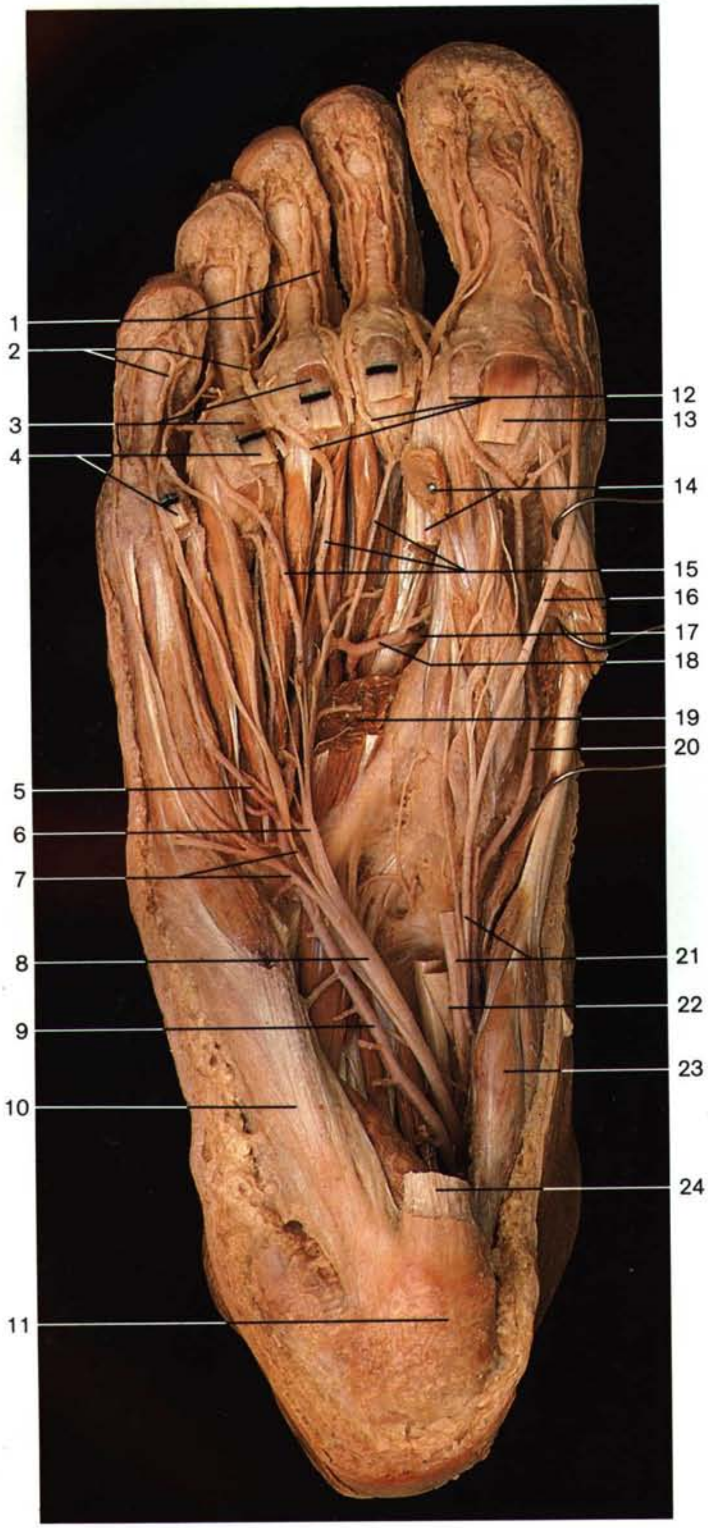

1 Proper plantar digital arteries
2 Proper plantar digital nerves
3 Tendons of flexor digitorum brevis muscle
4 Tendons of flexor digitorum longus muscle
5 Superficial branch of lateral plantar artery
6 Deep branch of lateral plantar nerve
7 Superficial branch of lateral plantar nerve
8 **Lateral plantar nerve**
9 **Lateral plantar artery**
10 Abductor digiti minimi muscle
11 Calcaneal tuberosity
12 Common plantar digital arteries
13 Tendon of flexor hallucis longus muscle
14 Insertion of both heads of adductor hallucis muscle
15 Plantar metatarsal arteries
16 Medial plantar nerve of great toe
17 Deep plantar branch of dorsalis pedis artery (perforating branch)
18 **Plantar arch**
19 Oblique head of adductor hallucis muscle (cut)
20 **Medial plantar artery**
21 **Medial plantar nerve**
22 Crossing of tendons in sole of foot (flexor hallucis longus and flexor digitorum longus muscles)
23 Abductor hallucis muscle
24 Origin of flexor digitorum brevis muscle

Sole of the right foot, deep layer (from below); dissection of vessels and nerves. The flexor digitorum brevis muscle, the quadratus plantae muscle with the tendons of the flexor digitorum longus muscle and some branches of the medial plantar nerve have been removed. The flexor hallucis brevis and adductor hallucis muscles have been cut and portions removed to show the somewhat atypical course of the medial plantar artery and deep muscles of the foot.

MUSHROOMING WITHOUT FEAR

The Beginner's Guide to Collecting Safe and Delicious Mushrooms

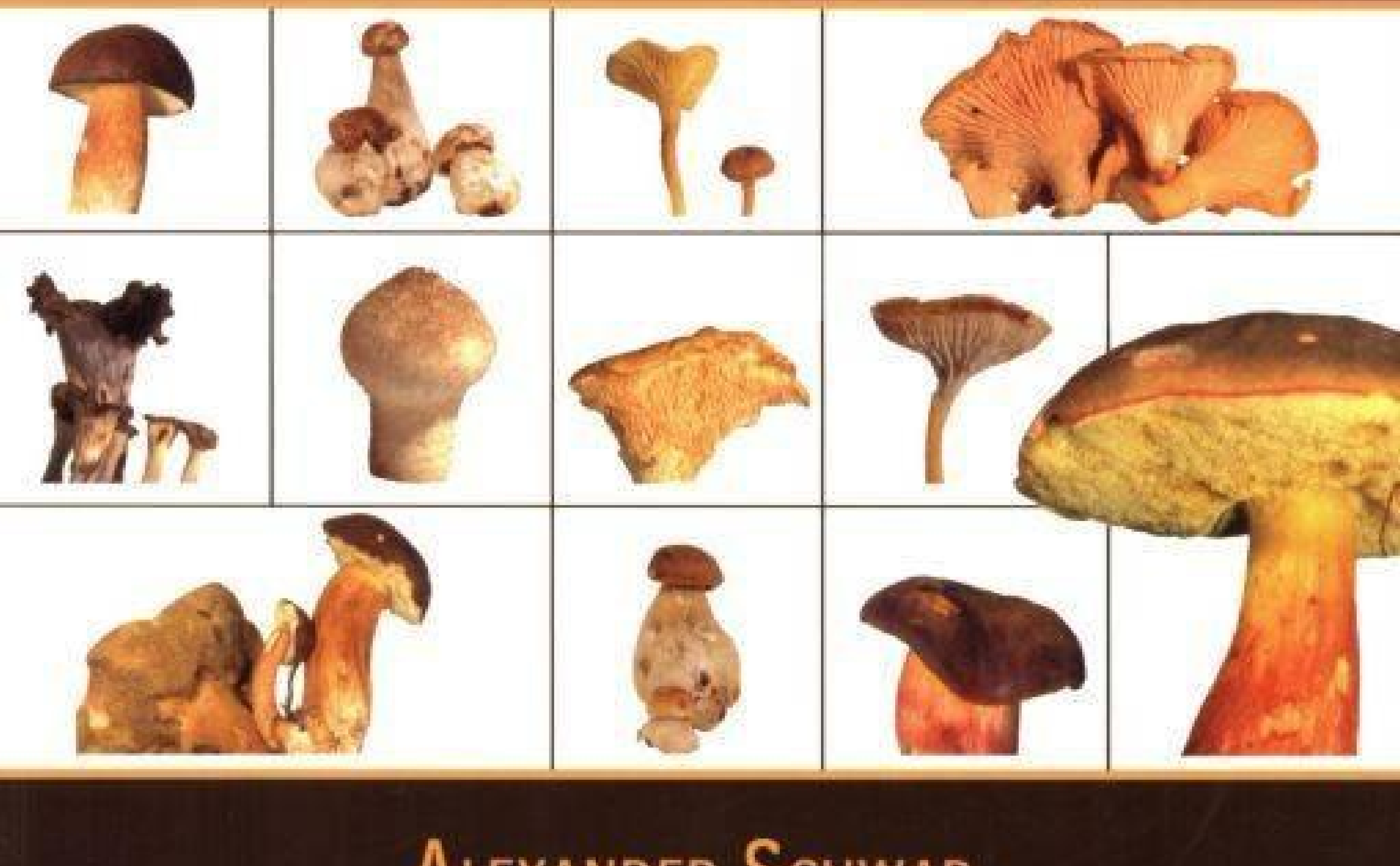

ALEXANDER SCHWAB

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It is easy to do without silver and gold
and your toga and cloak
but it is difficult to give up mushrooms.

Martial, Roman poet (AD 40 - 102)
Epigrams, Book 13, Number 48

Mushrooming Without Fear

The Beginner's Guide to Collecting Safe and Delicious Mushrooms

Alexander Schwab

Consultants Monika Lehmann and Roy Mantle

Skyhorse Publishing

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Mushrooming Without Fear

It's Safe, Easy and Fun

Follow this guide and you can enjoy picking and eating delicious mushrooms uninhibited by fear and doubt. In order to enjoy a homemade gourmet mushroom dinner you do not really need to know what *basidia or hyphae* are. Nor do you need to know how to identify dozens of tasteless or poisonous mushrooms which you wouldn't want to eat in the first place.

Even advanced mushroom pickers face many uncertainties.
The same mushroom looks different in the various stages of its development and different again when conditions are, for example, very wet or very dry. There are no end of edible mushrooms. Twenty-odd of these are of serious culinary interest, of which about a dozen are outstanding. Quality, not quantity, is what you are after. By good luck, the quality mushrooms are also among the most easily identifiable mushrooms and some of these are among the most frequently encountered.

Mushrooms may look beautiful, but that does not mean that they are edible.

You wouldn't buy a soggy, wormy, half rotten mushroom in the supermarket. So why pick it in the wood? Quality is what the discerning mushroom hunter is after.

With the safe method explained in this book, you will be able to identify the best mushrooms positively by their unique and unmistakable features.

Your part in the safe method is:

1. As a beginner, leave alone most mushrooms you pass
2. Look closely at what you see before you, not at what you wish was there
3. Stick to the rules and tick off every stage in the mushroom identification process

The fly agaric is the most well-known species. For gnomes, pixies, fairies and other such folk it is safe. For us common mortals it is poisonous! Do not believe any old wives' tales regarding the identification of poisonous mushrooms. Stick to the safe method in order to identify the best edible mushrooms.

Why is the safe method safe? If you follow the safe method to the letter, you'll automatically steer clear of deadly mushrooms or mushrooms causing permanent damage.

In the families of mushrooms presented and recommended here, there is not one deadly mushroom.

This is the reason why the field mushroom is not in this guide.
The field mushroom belongs to the group of mushrooms with gills, and especially when young, the feld mushroom can be confused with some deadly species. The safe method therefore asks you to ignore all mushrooms with gills because it is within the gilled group that all the seriously poisonous and deadly mushrooms are found. If you're absolutely sure about the field mushroom, then pick it by all means. But unless you are 100 percent certain, hunt for field mushrooms and other species with gills in the supermarket only.

Within the recommended groups you will find some slightly poisonous mushrooms but these happen to be so bitter, hot-tasting or strong-smelling that nobody sane would eat them anyway should they find their way into a meal (which they won't if you follow the safe method).
Poisonous mushrooms in the recommended groups cause gastrointestinal trouble of varying intensity. In other words: tummy ache.
Nevertheless there is absolutely no reason for complacency: a harmless tummy ache together with an existing medical condition can be dangerous.

Now, enough with the warnings. With this guide in hand, you are sure to have a safe and memorable experience collecting delicious mushrooms. Good luck and have fun!

How to use this guide

1. Read the entire book twice in order to understand the approach
2. Study the “Gills,” “Tubes,” “Spines” and “Ridges” sections until you’re confident you can correctly distinguish these features; then you’re ready for a foray
3. Double-check at home by going through the full identification process step-by-step

The size of mushrooms

The size of mushrooms varies enormously, so any measurements given in this book are only a rough average. Don’t be put off if you see an exception. The size can vary disproportionately due to weather conditions: if it is very dry, the mushrooms will be smaller than average. The other great variable is the growing medium. Don’t be surprised if near a building site, for example, you find surprisingly large mushrooms growing out of sawdust, or where woodchips have been laid at the edges of paths.

What is a Mushroom?

A mushroom is a highly complex organism. Here are the essentials:

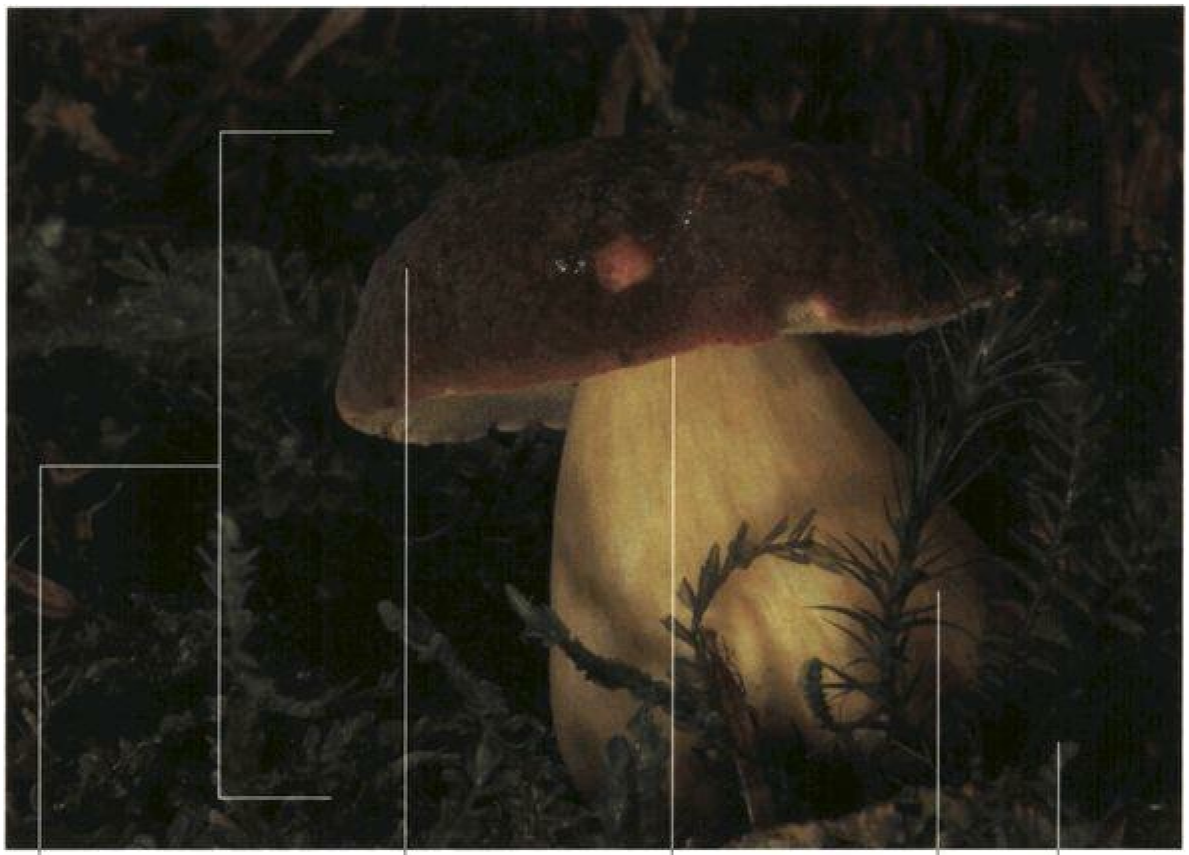

Fruitbody

The technical term for what is colloquially called the "mushroom" is the "fruitbody." Mycologically speaking, the real mushroom is the mycelium which is a fine structure of filaments on or in the forest soil. What we see as mushrooms (the fruitbody) are like the apples on an apple tree.

Cap

The caps of mushrooms have many different forms but what we're interested in is what is under the cap. Under the cap you'll find either . . .

Gills

Tubes

Spines

Ridges

Gills, tubes, spines and ridges produce, contain and release the spores. Wind and rain disperse the spores. Given the right conditions new mycelia and mushrooms form from the spores.

Stalk

Mycelium

The mycelium

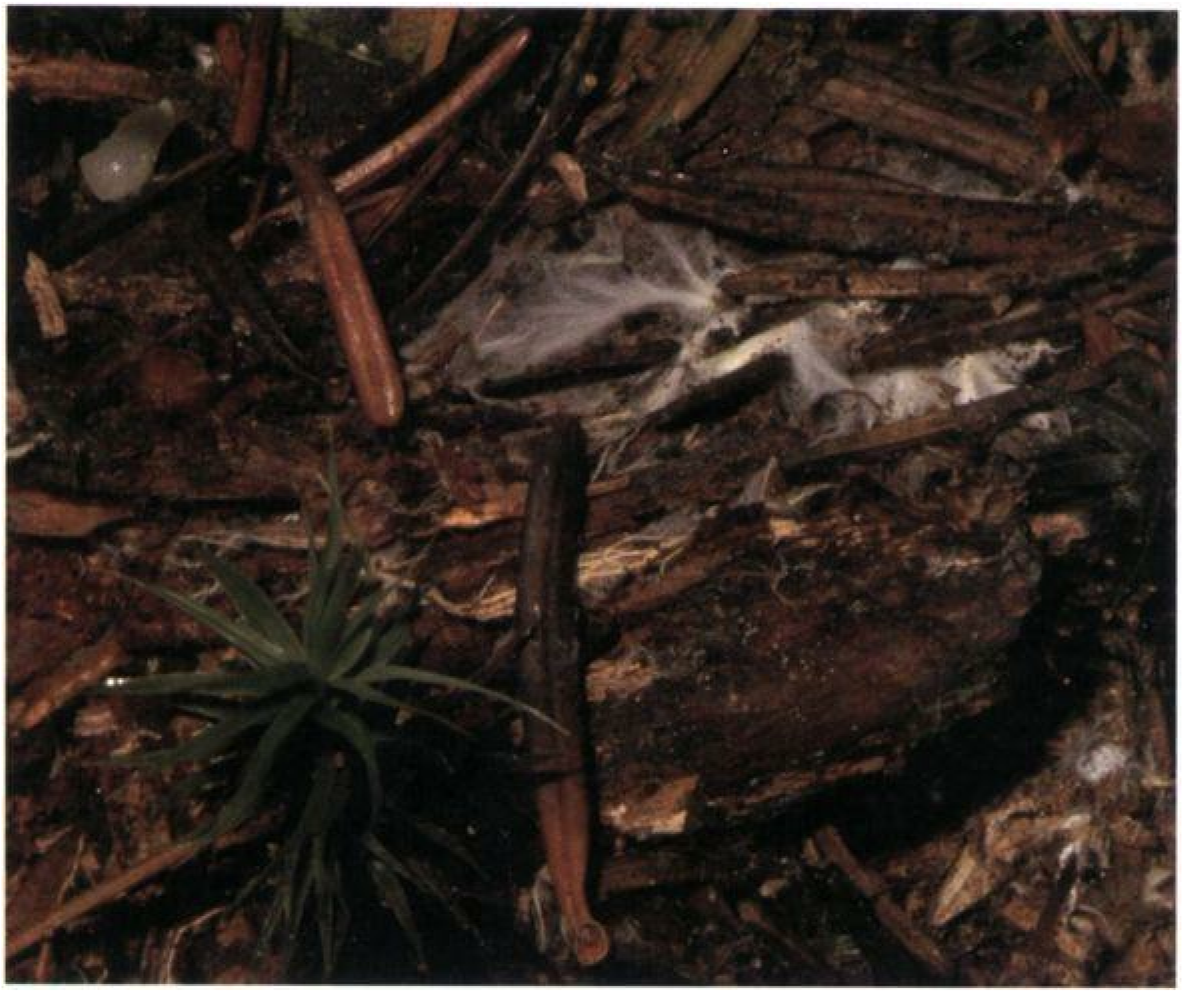

This is a close-up of about 4 mm of the mycelium above, as seen under a microscope. When conditions are right, the mycelium forms a fruitbody, pushing the mushroom up in order to disperse the spores or to wait for you to come along and pick it.

Rule number 1

Never, never take a mushroom with gills!!!

Gills

Identifying gills is the first and most important step. You must be sure that you're able to identify gills. Caps of gilled mushrooms come in many different shapes. Gills are the radiating blades on the underside of the cap. They fan out in a distinctly regular way. Gills have precise forms and come in many colors. Some of them are brittle some of them are soft. They can be rubbed off or separated from the underside of the cap quite easily. Gills are always attached to the stem or to the cap in a uniform way.

In perfect conditions the distinctly regular way in which the gills fan out is clearly visible.

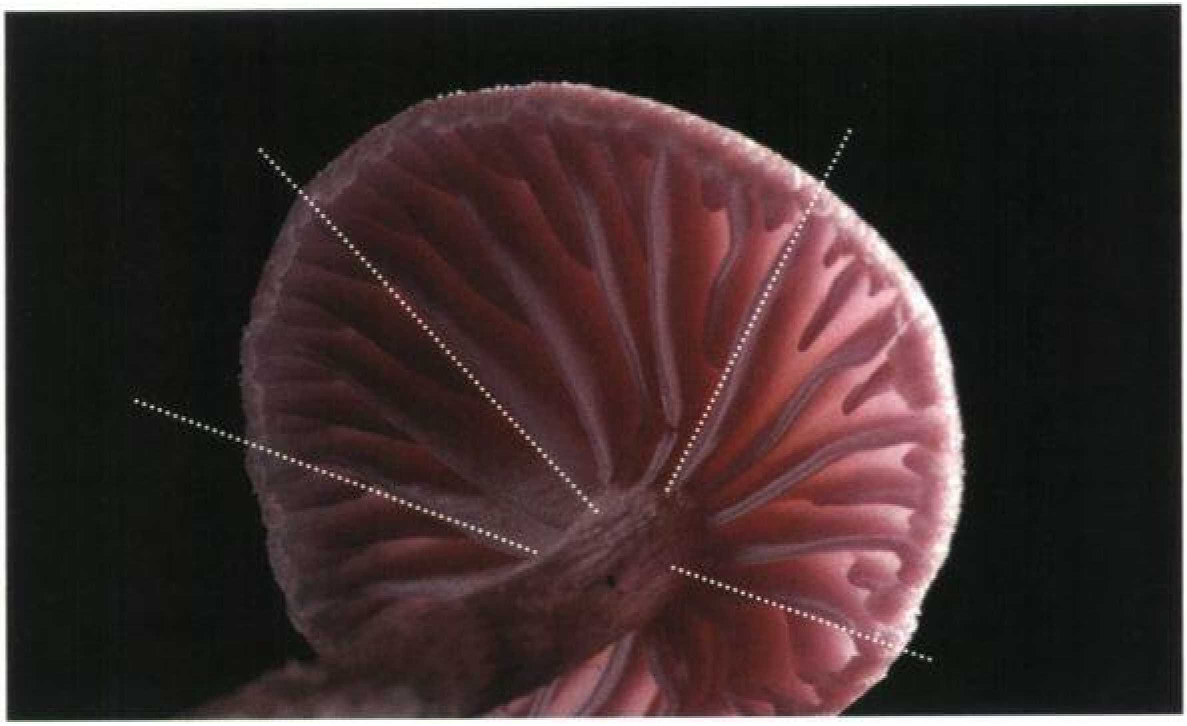

Weather-beaten or old gills might be damaged or broken but on closer inspection their regularity will become apparent. Damage or no damage: either way they look as if drawn with a ruler.

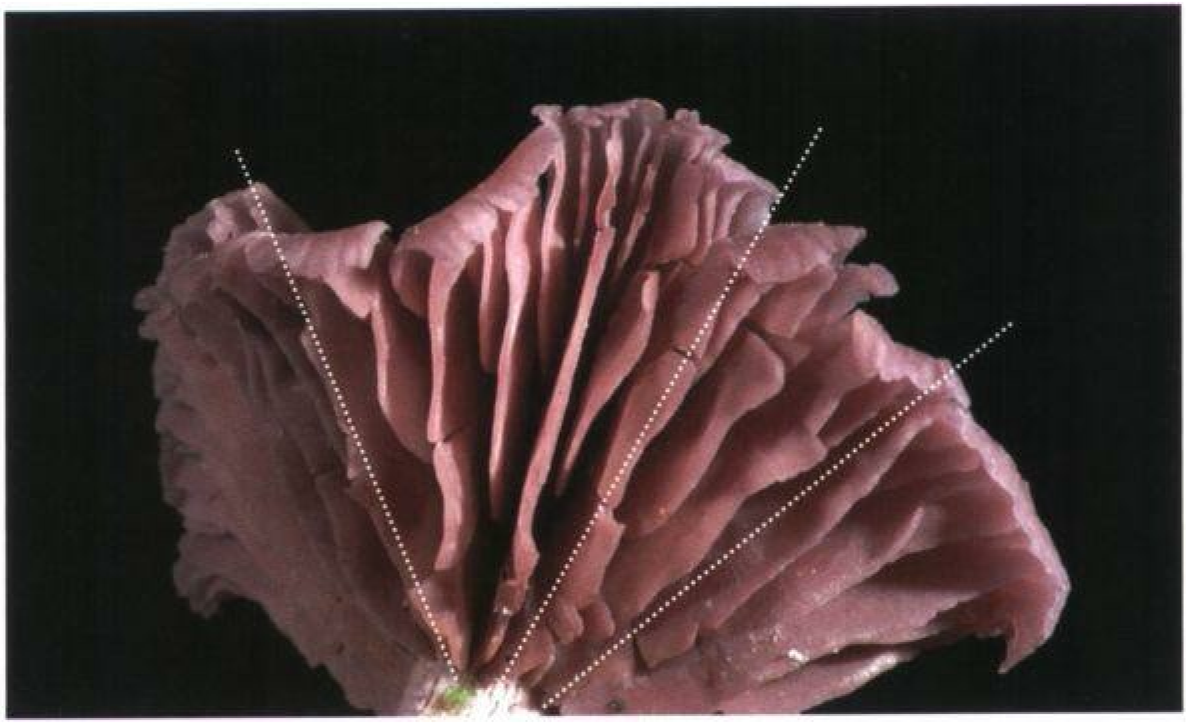

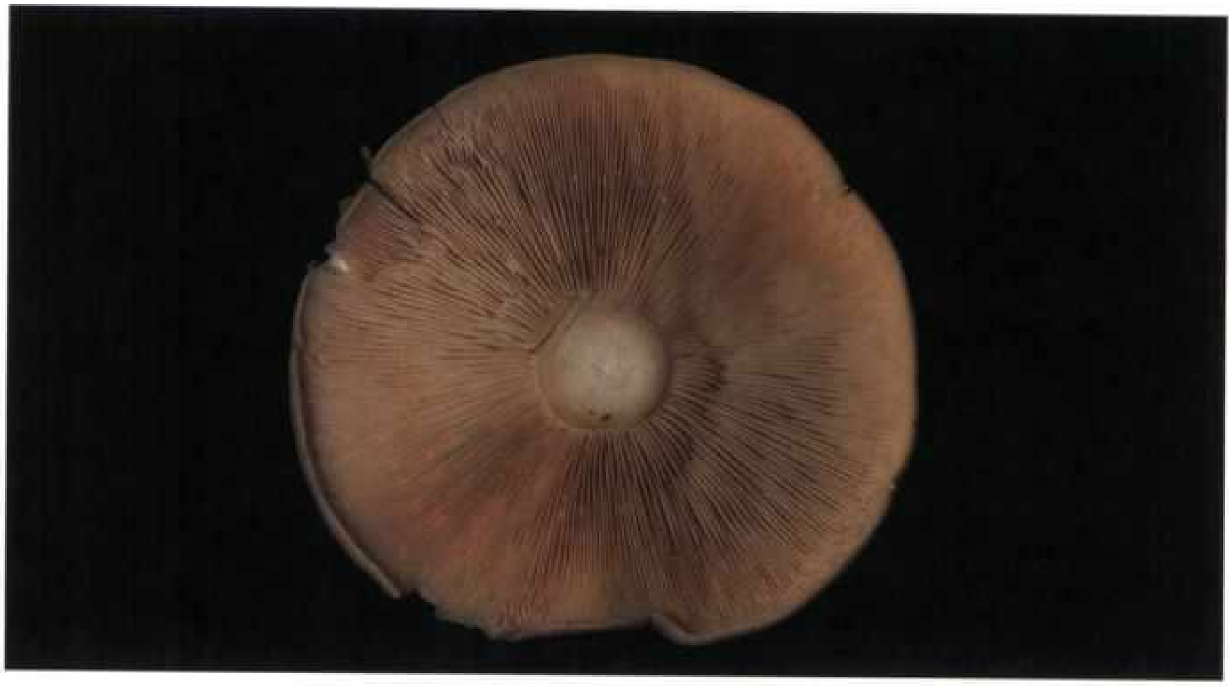

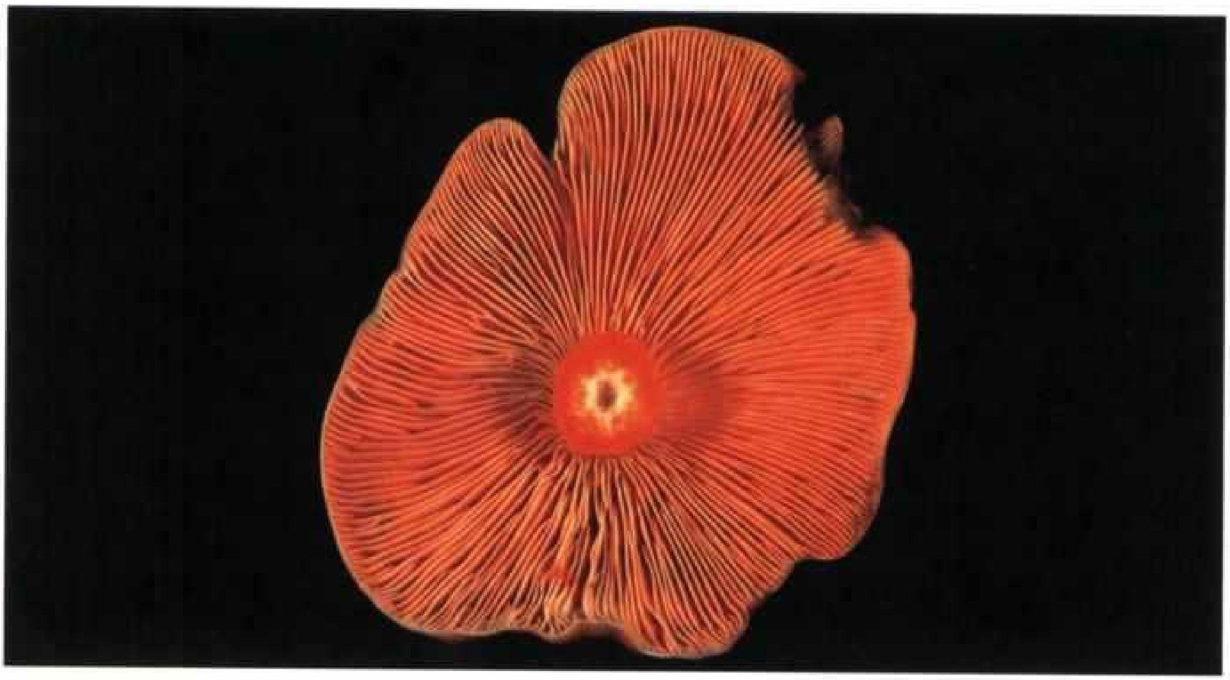

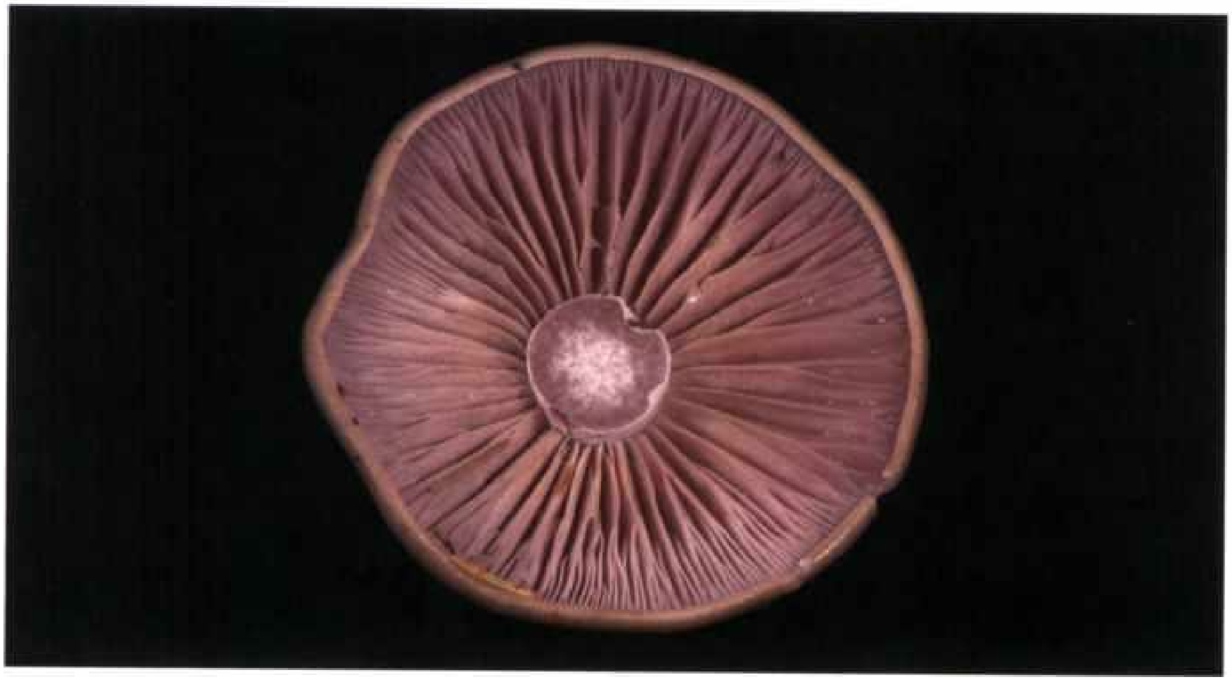

In their regular way, gills differ in spacing and formation.
For example:

Gills can fork once or more.

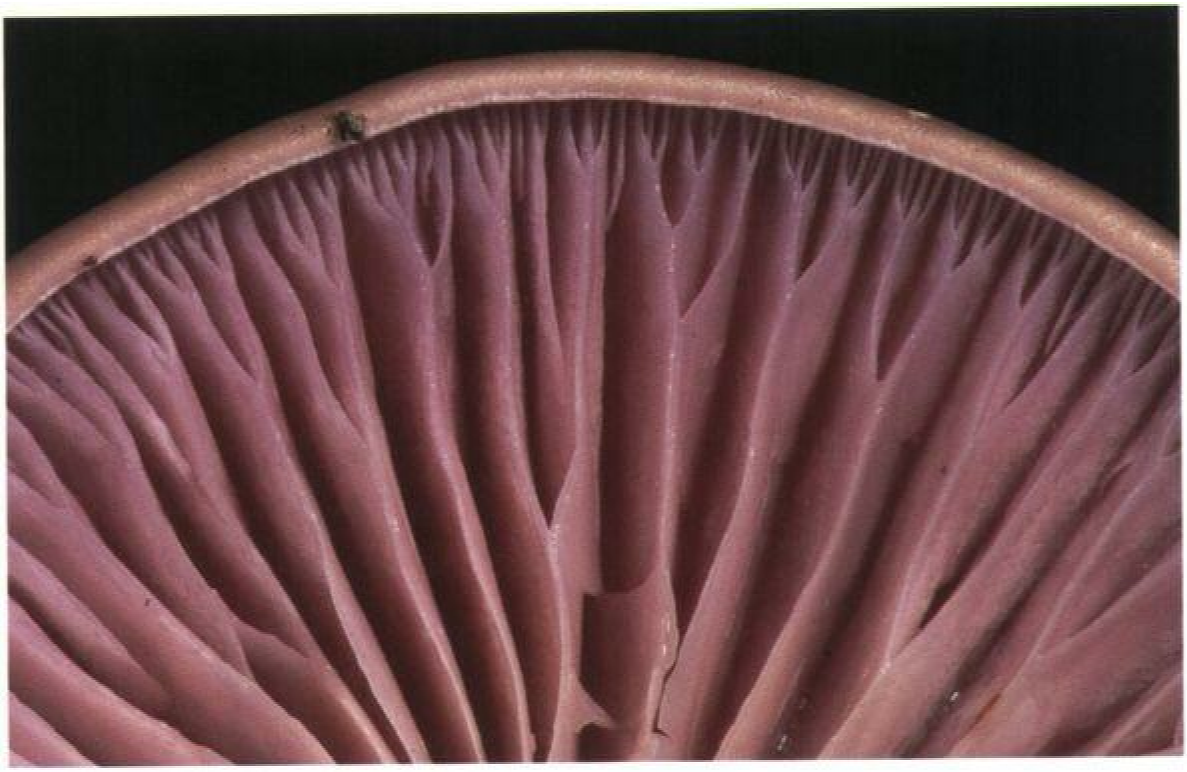

Gills can be mixed: long and short gills.

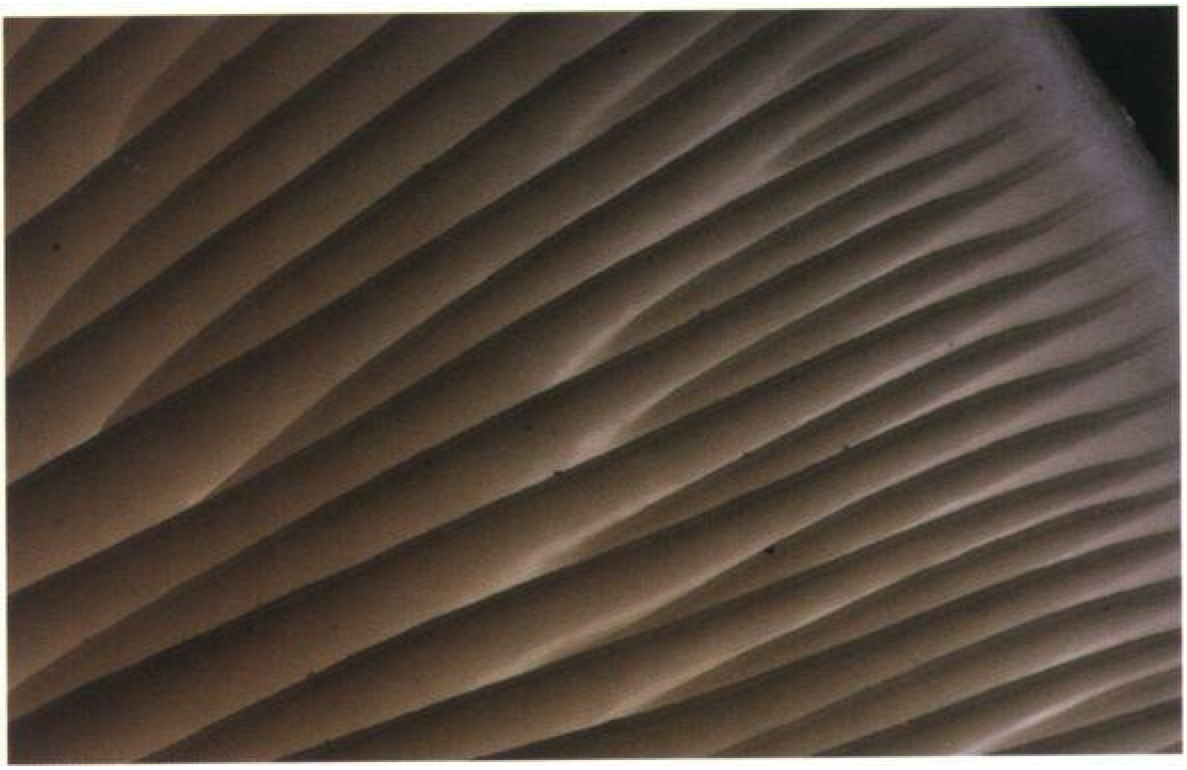

Gills can be crowded.

Gills can be distant.

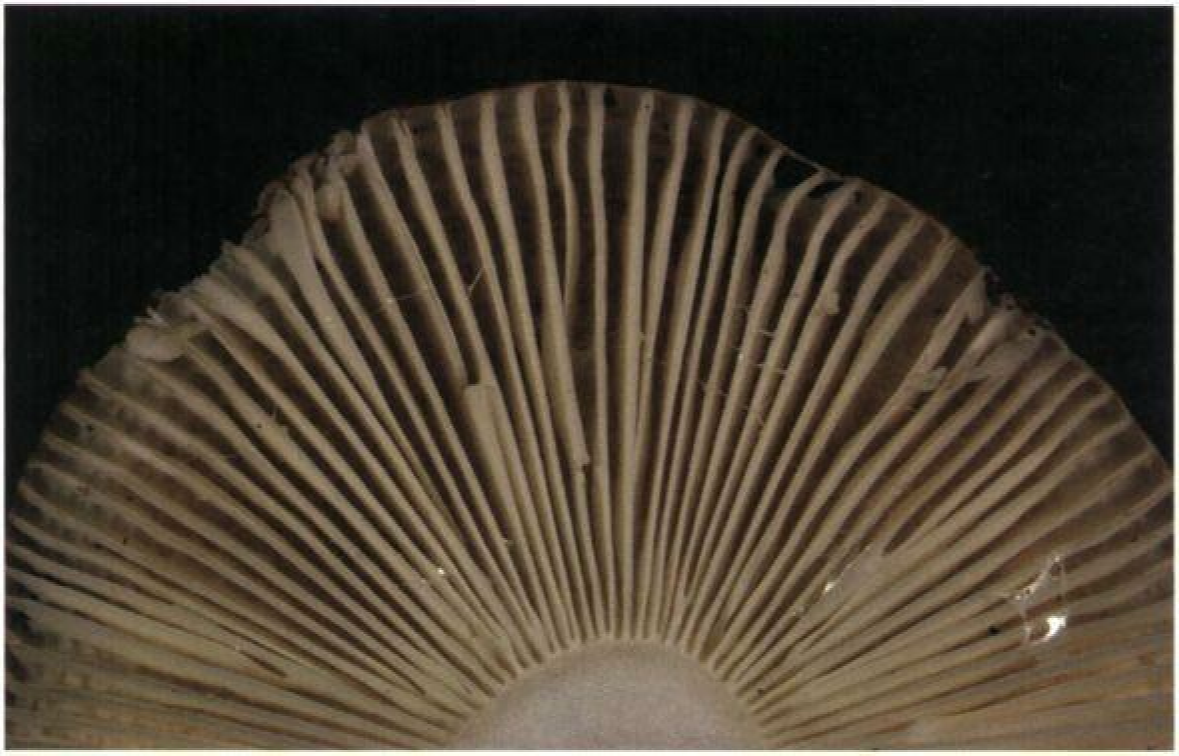

Gills are always uniformly attached to the cap or the stem. They start radiating from the same height along the stem or the same line around the cap.

Rule number 2

Only take mushrooms with tubes, spines and ridges and the mavericks portrayed in this book

Tubes
Tubes are fine and tightly packed on the underside of the cap. The openings at the ends of the tubes are called pores.

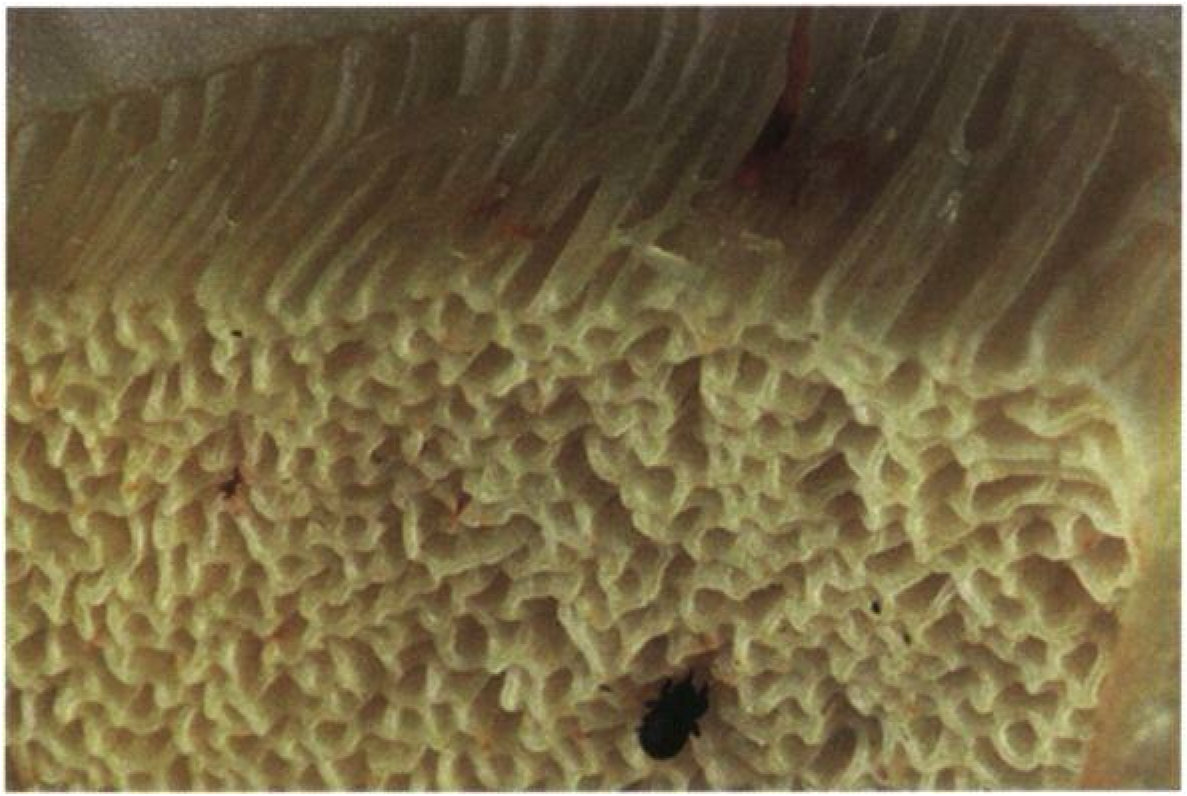

Spines
Spines hang like stalactites from the cap.

Ridges

Ridges are cross-veined, irregular and don't form a distinct pattern. Ridges are not attached to the cap: they are part of the cap.

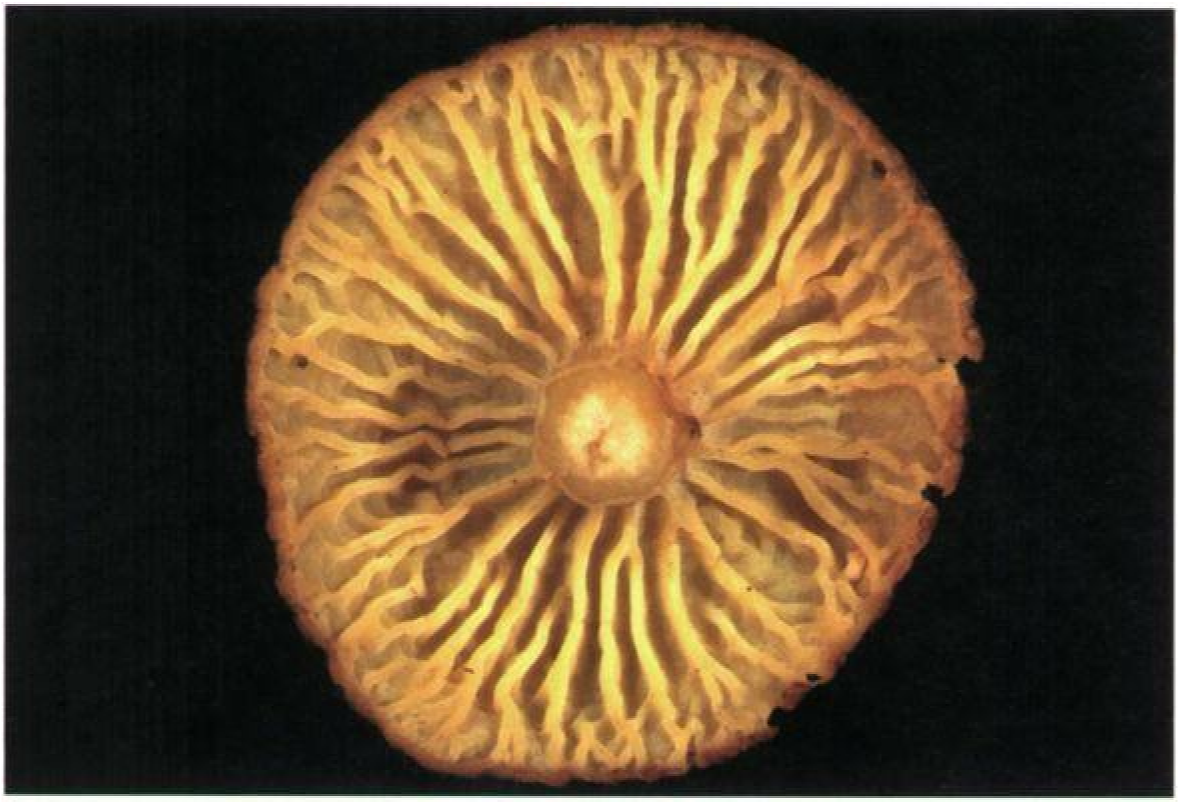

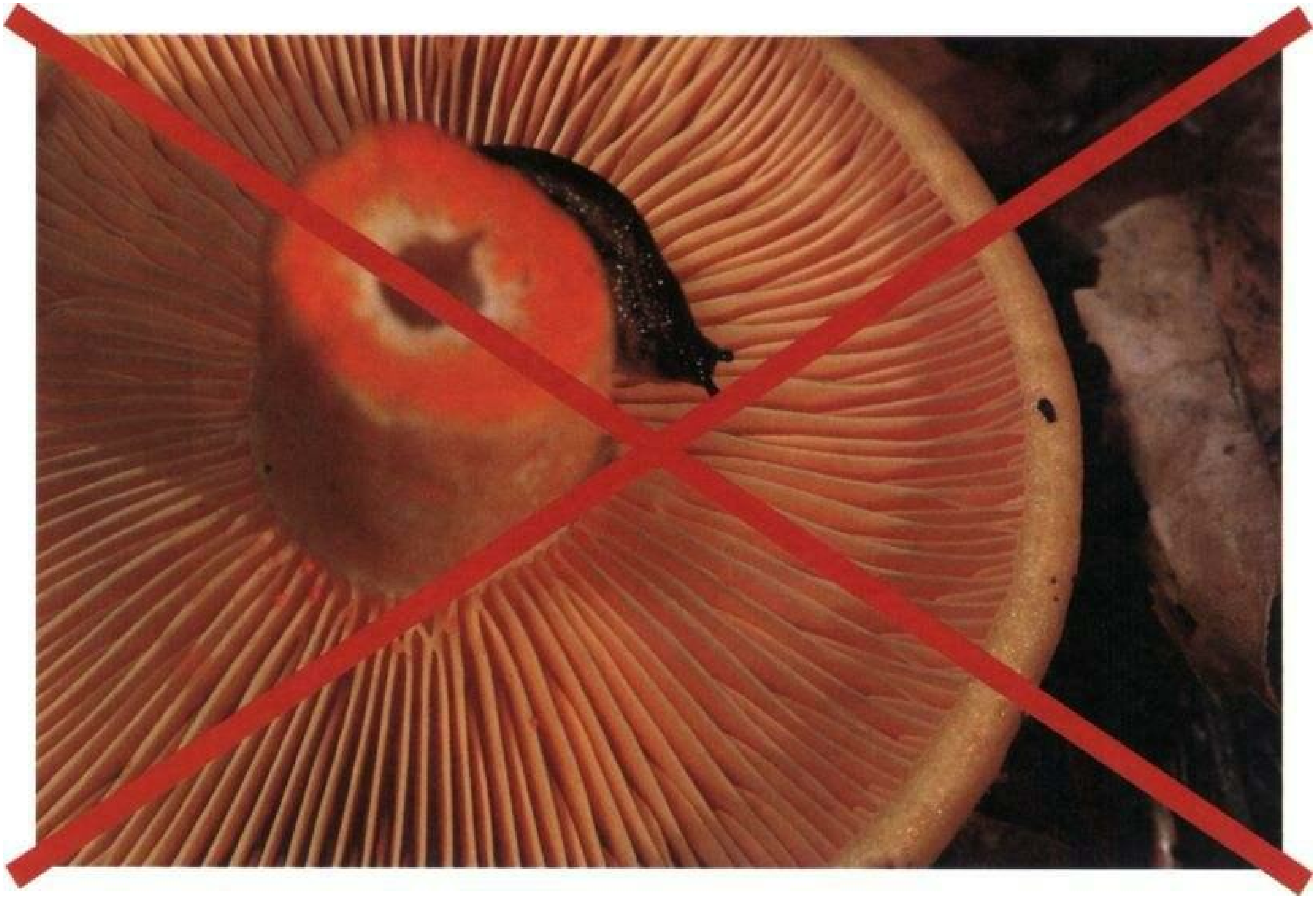

Remember Rule number 1

Never, never take a mushroom with gills!!!

Tubes

This is the underside of a cap with tubes. The tubes are fine and tightly packed and the openings at the end which are seen here are called pores. Tubes can be removed easily from the cap.

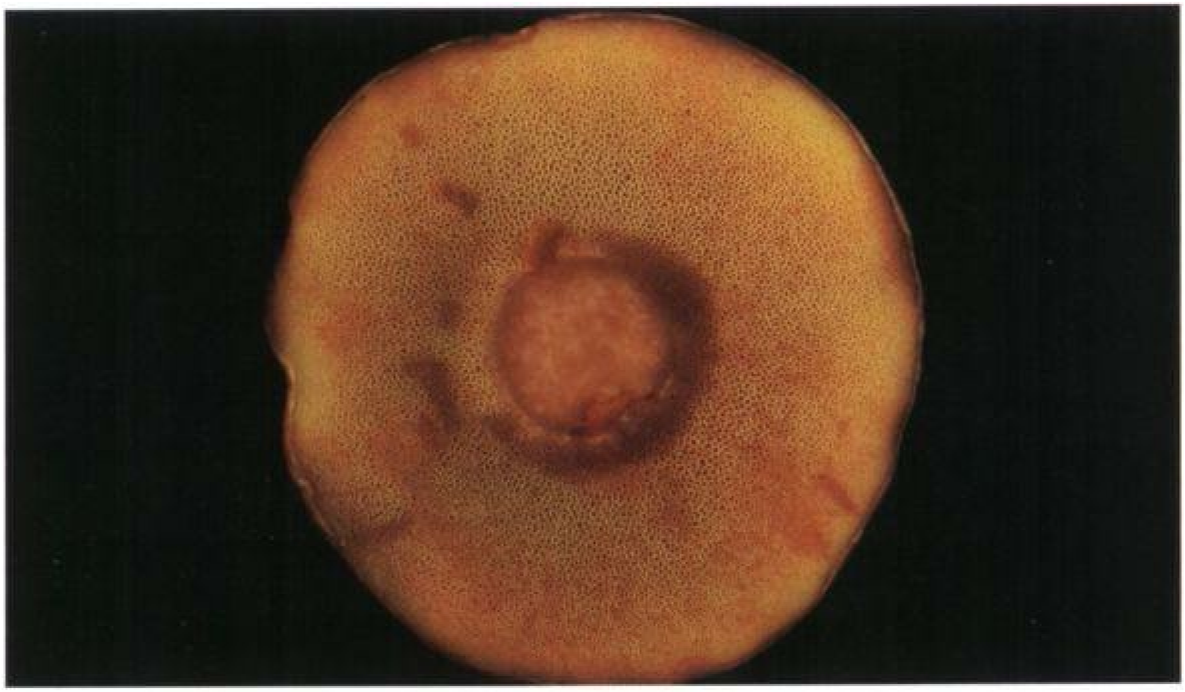

Pores form a regular pattern resembling a sponge.

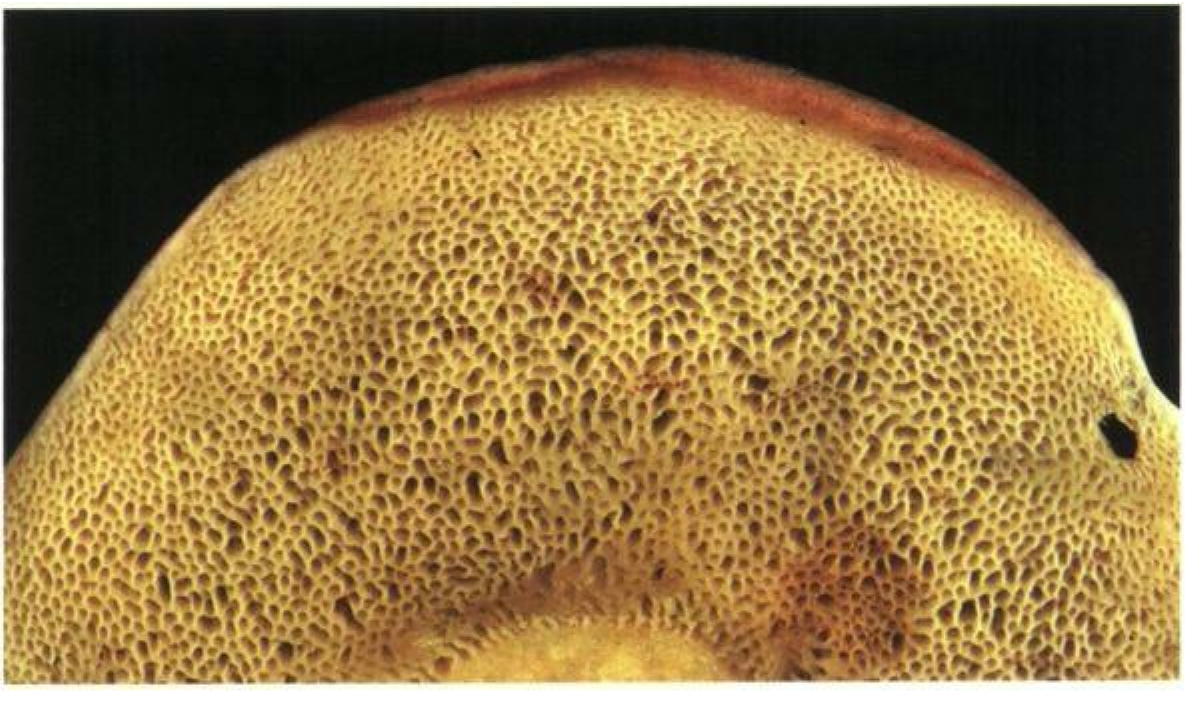

This cross-section shows the tubes and the pores.

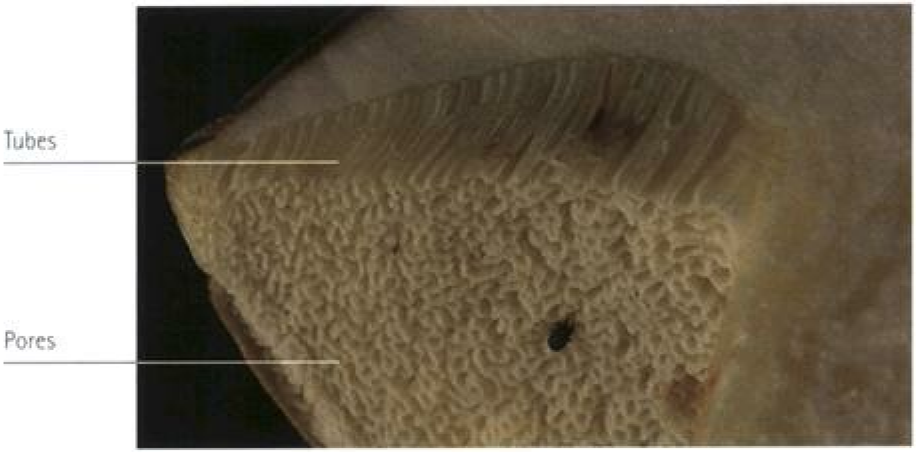
Tubes
Pores

Spines

Spines hang like stalactites from the cap.

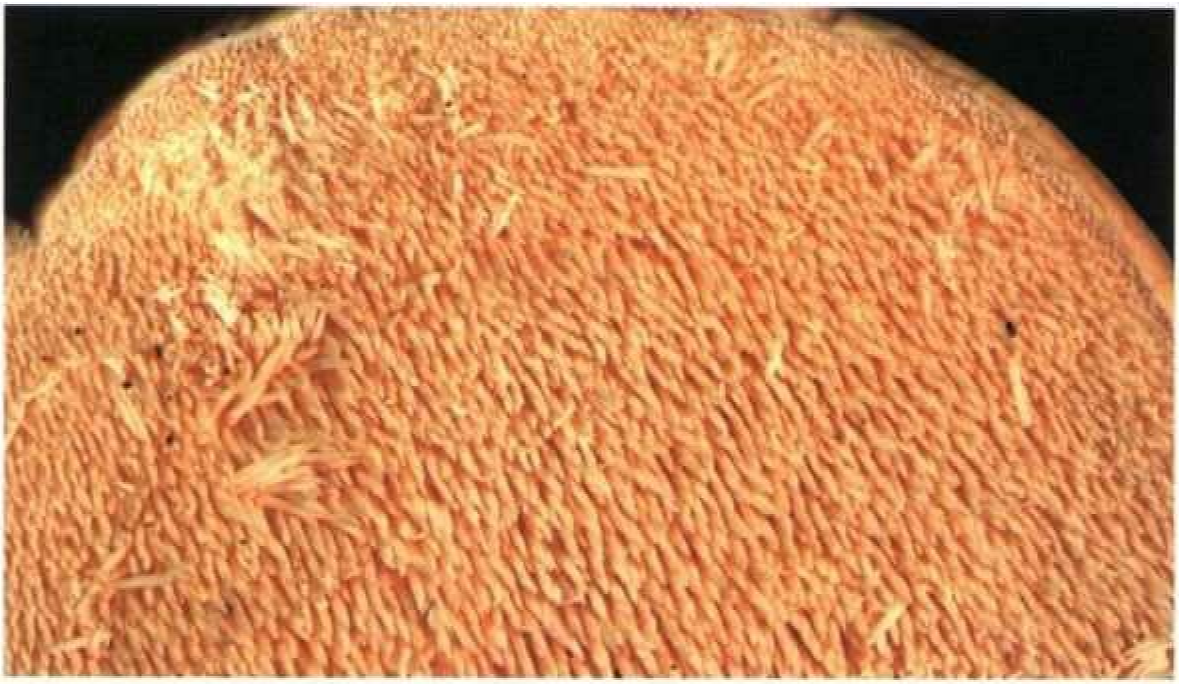

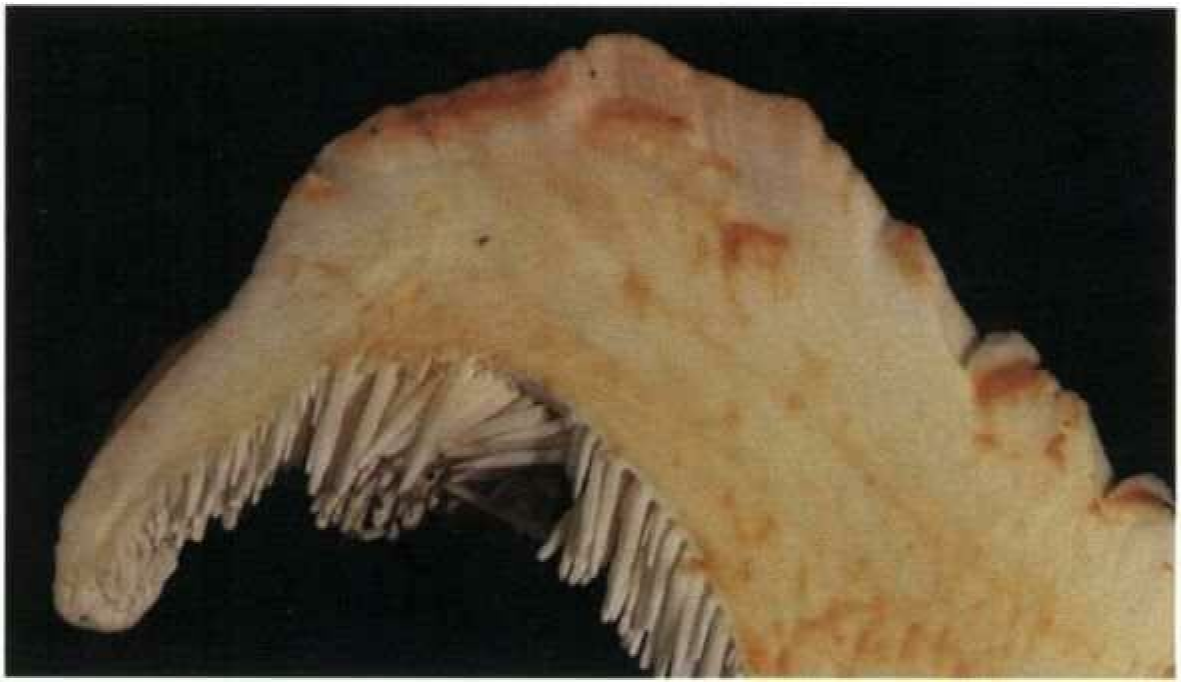

Ridges

Ridges are on the underside of the cap and are part of it. They are not just attached to the cap or stem: they're part of them, which is why you can't rub them off or pull them off easily.

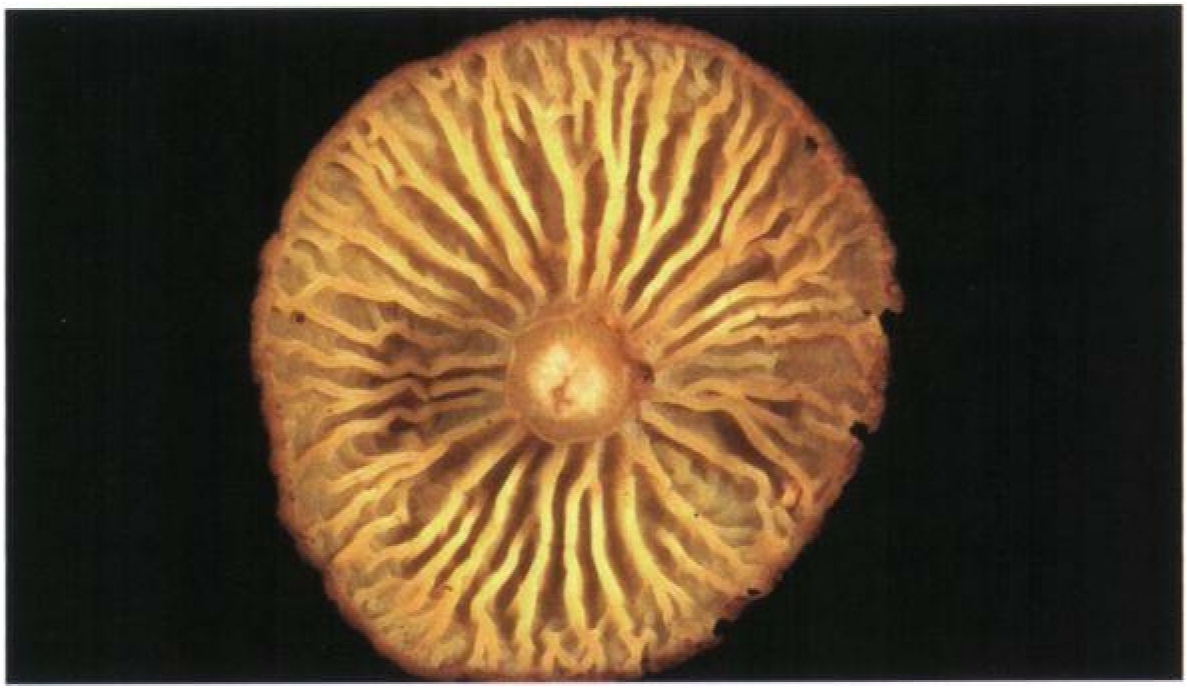

Ridges are cross-veined, irregular and they don't form a set, uniform pattern.

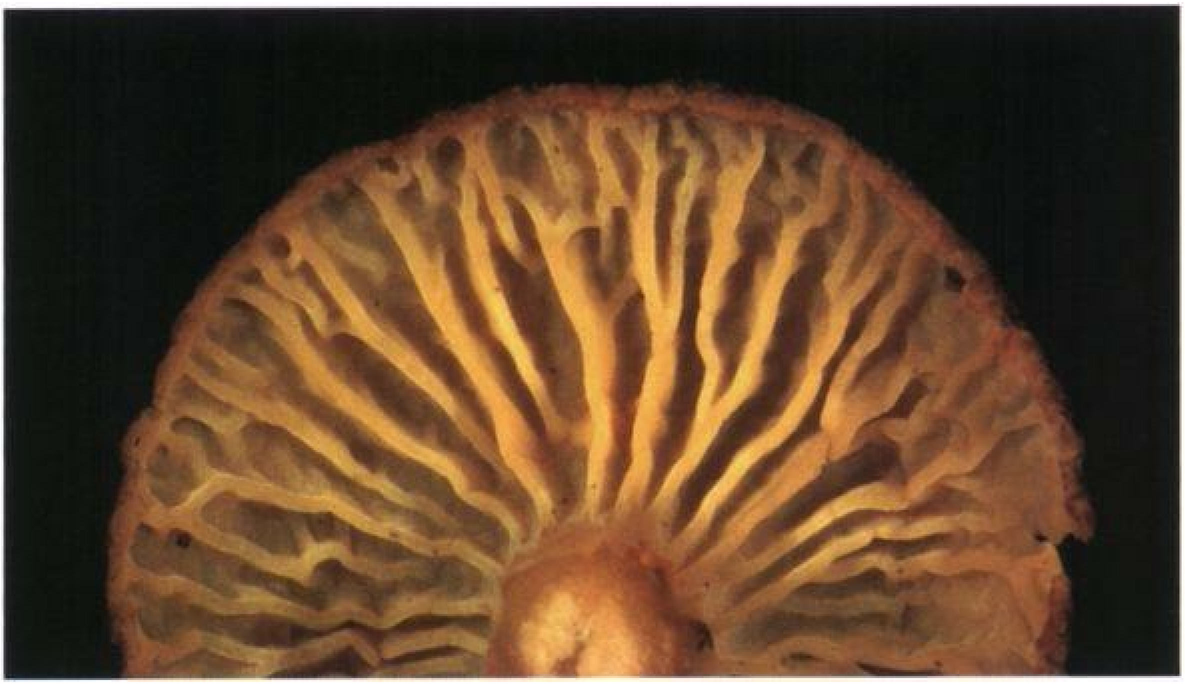

They are not attached to the stem in a distinct and regular way, as gills are: they are part of the stem.

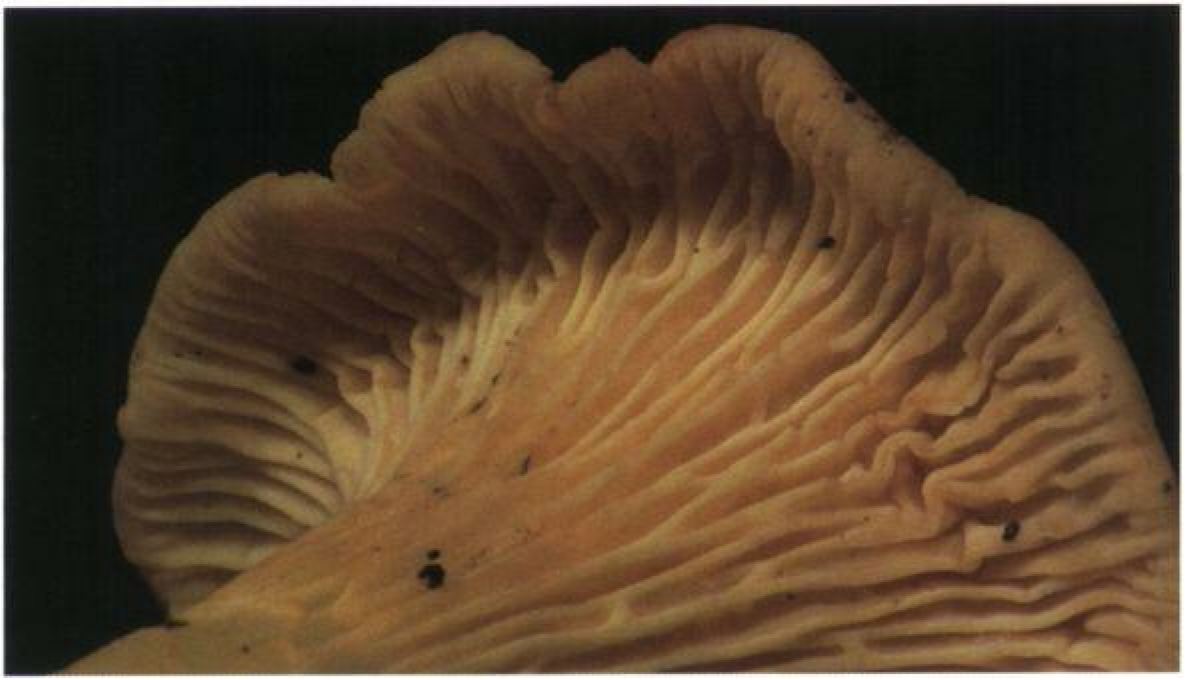

The ridges are part of the stem. There is no distinct pattern in the way they grow out of the stem. Some ridges begin further up, some further down the stem. There is no regularity.

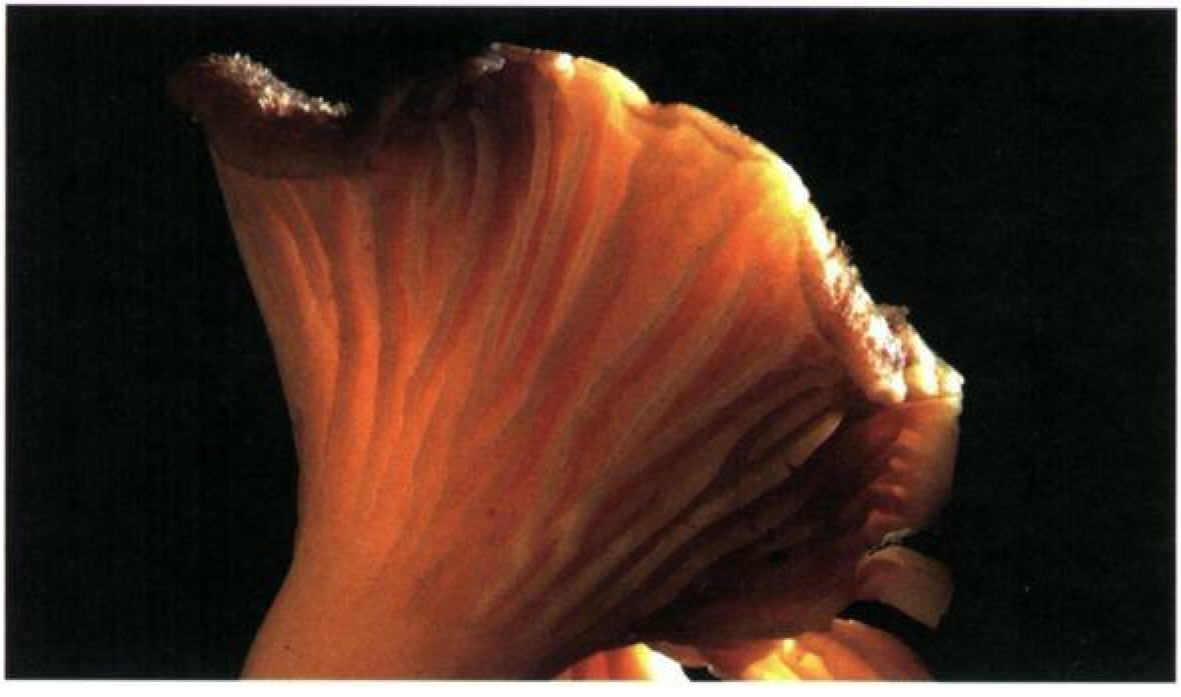

In contrast to gills and tubes, the section of a mushroom with ridges shows no typical features. Because of the irregular nature of ridges each section will look different whereas with tubes and gills you will find the same features each time.

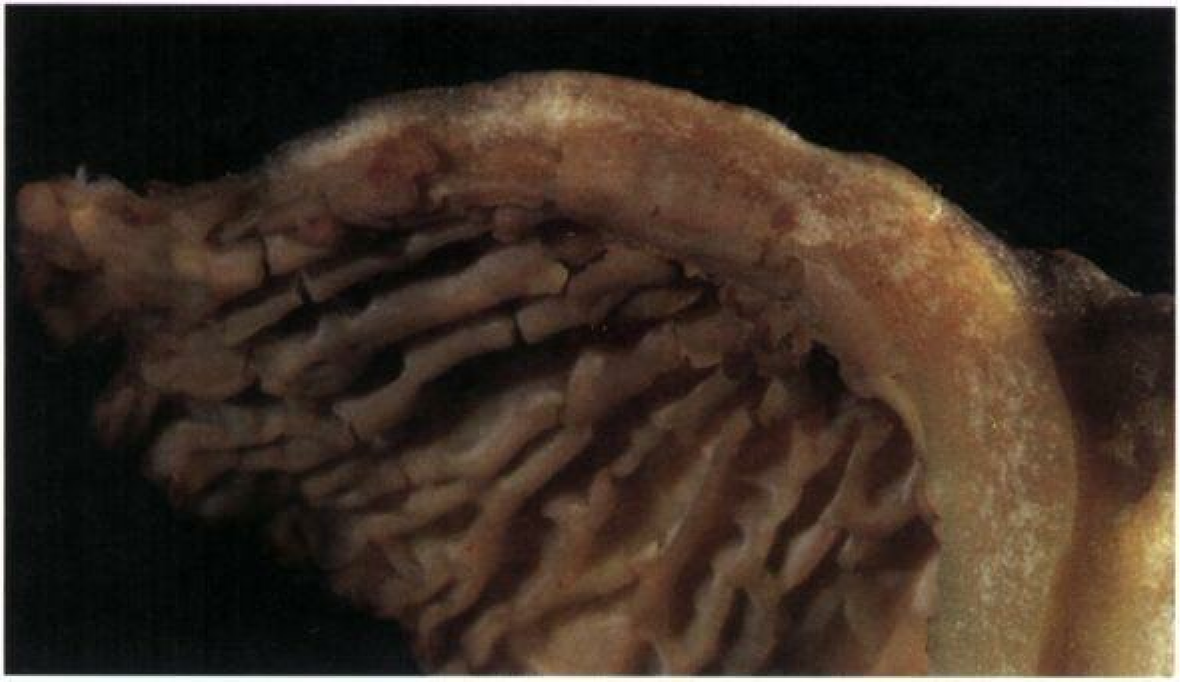

How to Pick Mushrooms

Rule number 1 says not to take anything with gills. This also means you do not touch or cut every mushroom you spot in order to check for gills.

In nine out of ten cases you can see whether a mushroom has gills or not without even touching it. Looking under the cap by kneeling down provides good exercise.

If you really can’t see what’s underneath a cap, break off just a little to see what’s there. If you want to be absolutely safe, you could use surgical gloves or a paper napkin which you discard later.

If you have established that you have, say, a mushroom with tubes and it is in reasonable condition and it tallies with the field identification card—then, and only then, should you pick it.

Rules:

Rule number 1

Never, never take a mushroom with gills!!!

This is our life insurance.

Rule number 2

Only take mushrooms with tubes, spines and ridges and the mavericks portrayed in this book

This means thoroughly understanding the information on pages 18-27 of this book.

Rule number 3

Only eat mushrooms which you have clearly identified with ALL the positive ID marks

The mushrooms you take must be a certain size in order to show all the identification marks. In their baby stage, so to speak, some deadly and poisonous mushrooms are almost indistinguishable from harmless species.

Rule number 4

If a mushroom smells rotten, it is rotten and if it feels soggy, it is soggy

There are a surprising number of people who believe that somehow a half decomposed, soggy, smelly mushroom will improve on the way home. It never does. Only take mushrooms which are in mint condition, that is, the flesh is firm and there are hardly any worms.

Rule number 5

Never, never eat wild mushrooms raw

The reasons for this are manifold but, to state the obvious, some areas in some woods are dog-ridden.

Rule number 6

Look before you cut

Always cut mushrooms, do not pull them out. You don't chop down an apple tree to pick the apples. Cut just above the ground and cover the remaining stem with a little mud or dead leaves. Whether this is of any conservational value is disputed but it does no harm. My recommendation is to cut and cover.

Picked mushrooms want to breathe. Do not suffocate them in plastic bags. Use a wicker or rattan basket or a linen bag. If possible use a proper mushroom knife with an integrated brush for cleaning. As the first cleaning of the mushroom should be done in the woods, the brush is very useful. However, any knife will do, as long as the blade can be folded into the knife handle, for safety. Common sense is your best adviser but be aware of any likelihood of ticks where you go mushrooming.

You might want a stick. It can be any kind of stick and you will find it helpful on the slopes. But you will also find it useful for pushing aside the grass and ferns, affording you a better look at the ground. Different mushrooms can be put together in your wicker basket. Better still, have a few paper bags in the basket; one paper bag (breathable) for each species. Putting, say, all trumpet chanterelles in the same bag helps you to spot the odd one out which you have inadvertently cut while not fully concentrating (see page 78).

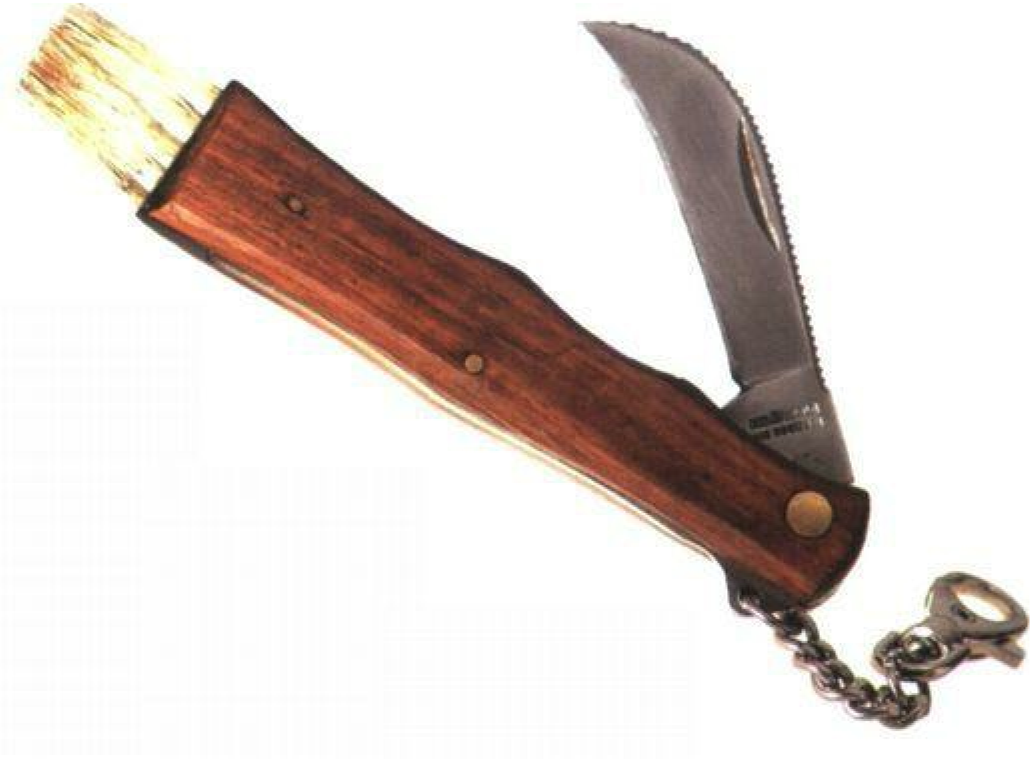

Rule number 7

Mushrooms want to breathe: Do not suffocate them in plastic bags

Either in the woods or at home.

Rule number 8

If in doubt, leave it

Now you’re ready for a foray.

Positively Identifying Mushrooms

Always remember

Rule number 1

Never, never take a mushroom with gills!!!

Rule number 2

Only take mushrooms with tubes, spines and ridges and the mavericks portrayed in this book

Rule number 3

Only eat mushrooms which you have clearly identified with ALL the positive ID marks

Rule number 4

If a mushroom smells rotten, it is rotten and if it feels soggy, it is soggy

Rule number 5

Never, never eat wild mushrooms raw

Rule number 6

Look before you cut

Rule number 7

Mushrooms want to breathe. Do not suffocate them in plastic bags

Rule number 8

If in doubt, leave it

Mushrooms With Tubes

Cep or King Bolete

Boletus edulis

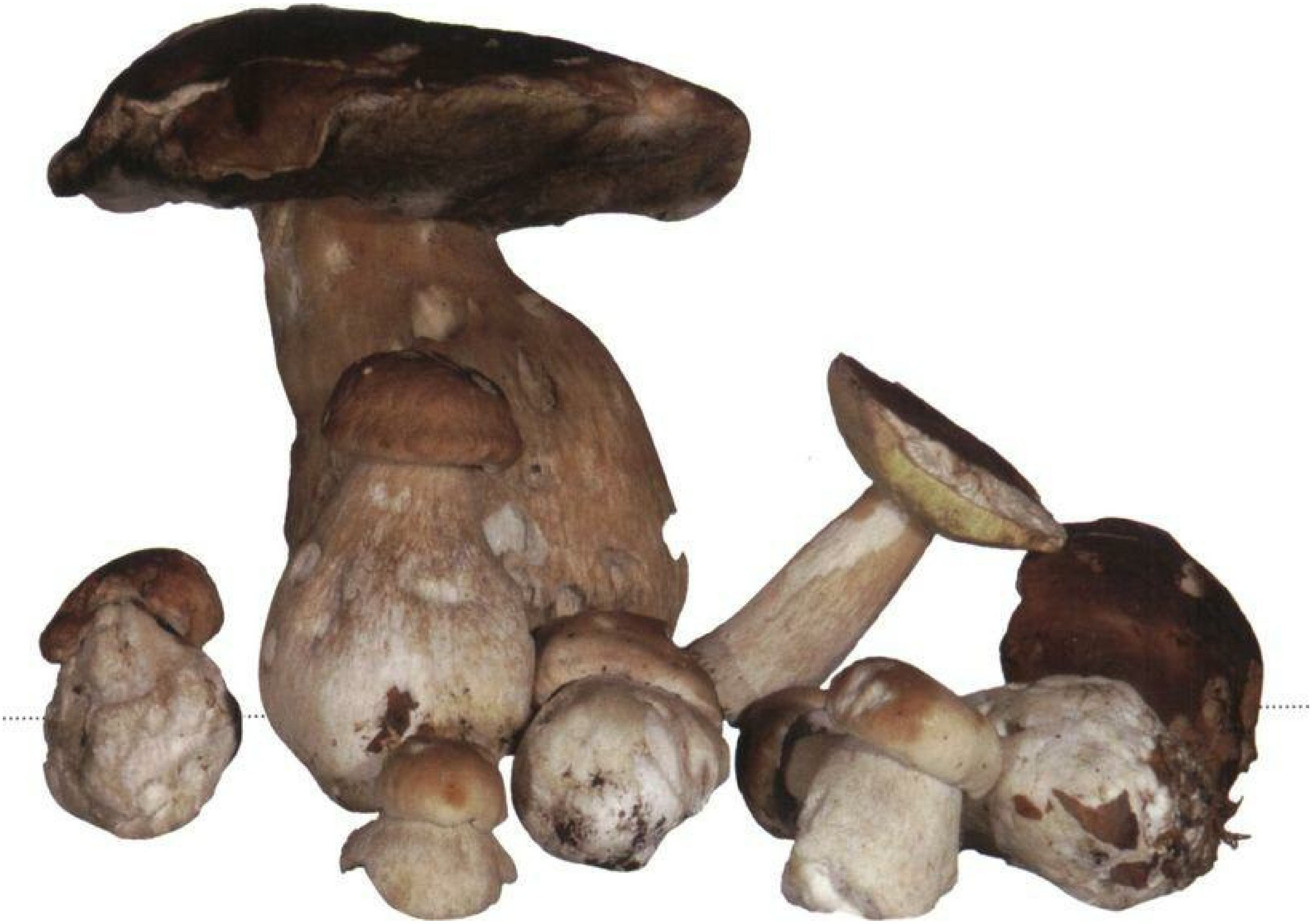

The cep is the king of mushrooms. Some truffles are rarer, pricier and confined to relatively small areas in France and Southern Europe. The cep on the other hand reigns supreme everywhere. Ceps can be found in the same location year after year. They can disappear in certain areas for a couple of years only to return spectacularly in masses.

Some people gather only ceps which is understandable because of their beauty, taste and the thrill of finding them on the same spot time after time. Ceps vary greatly in general appearance, color and size. The size of the little fellow in the foreground of the picture above is about 2 inches in height whereas the giant is about 14 inches in height.

If conditions are right (starting off with a nice wet and humid spring or early summer) you should begin to look for ceps as early as the beginning of July. July and August are the months of the summer ceps.

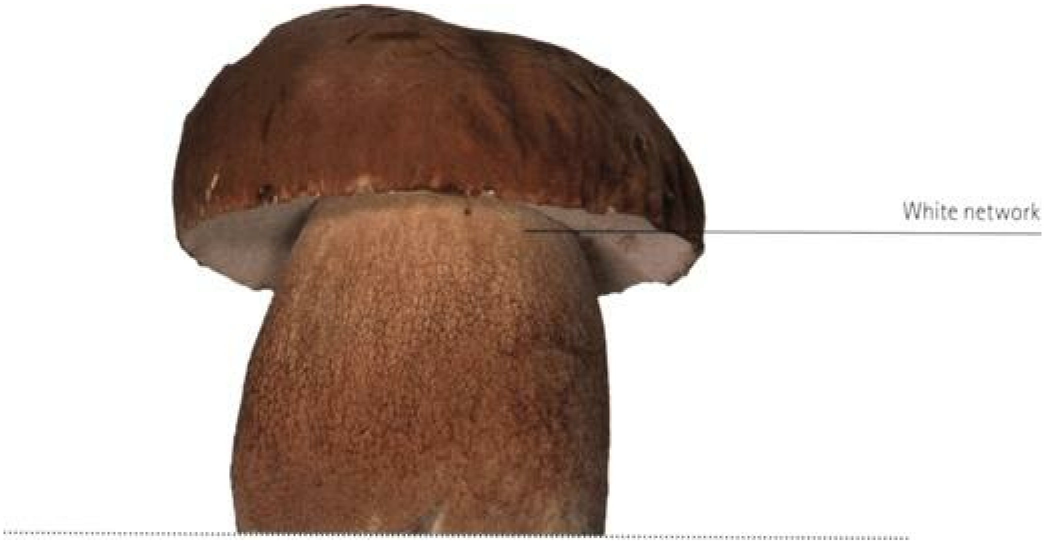
White network

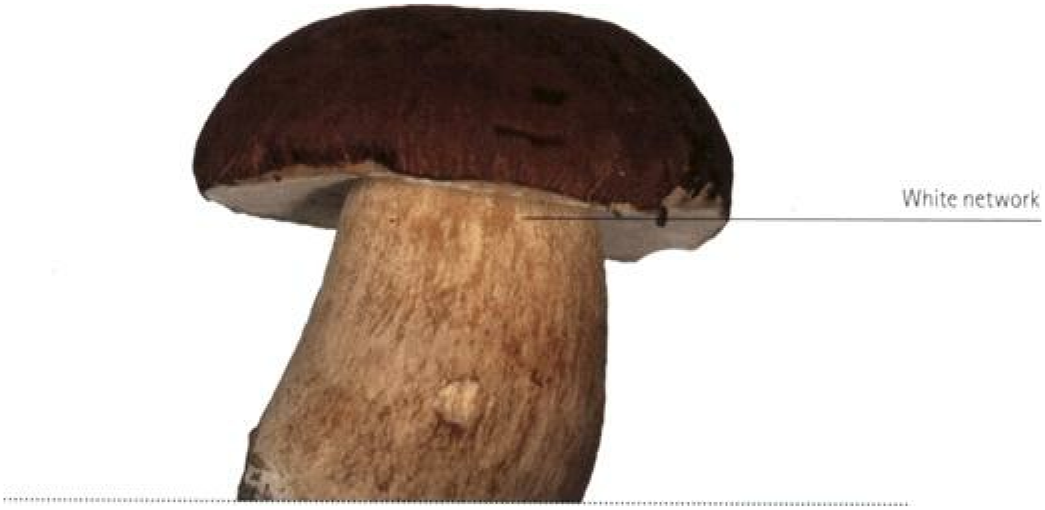
White network

These are summer ceps. However all ceps, summer or autumn, show a fine white network on the top of the stem right underneath the tubes.

A classic autumn cep, the king of mushrooms.

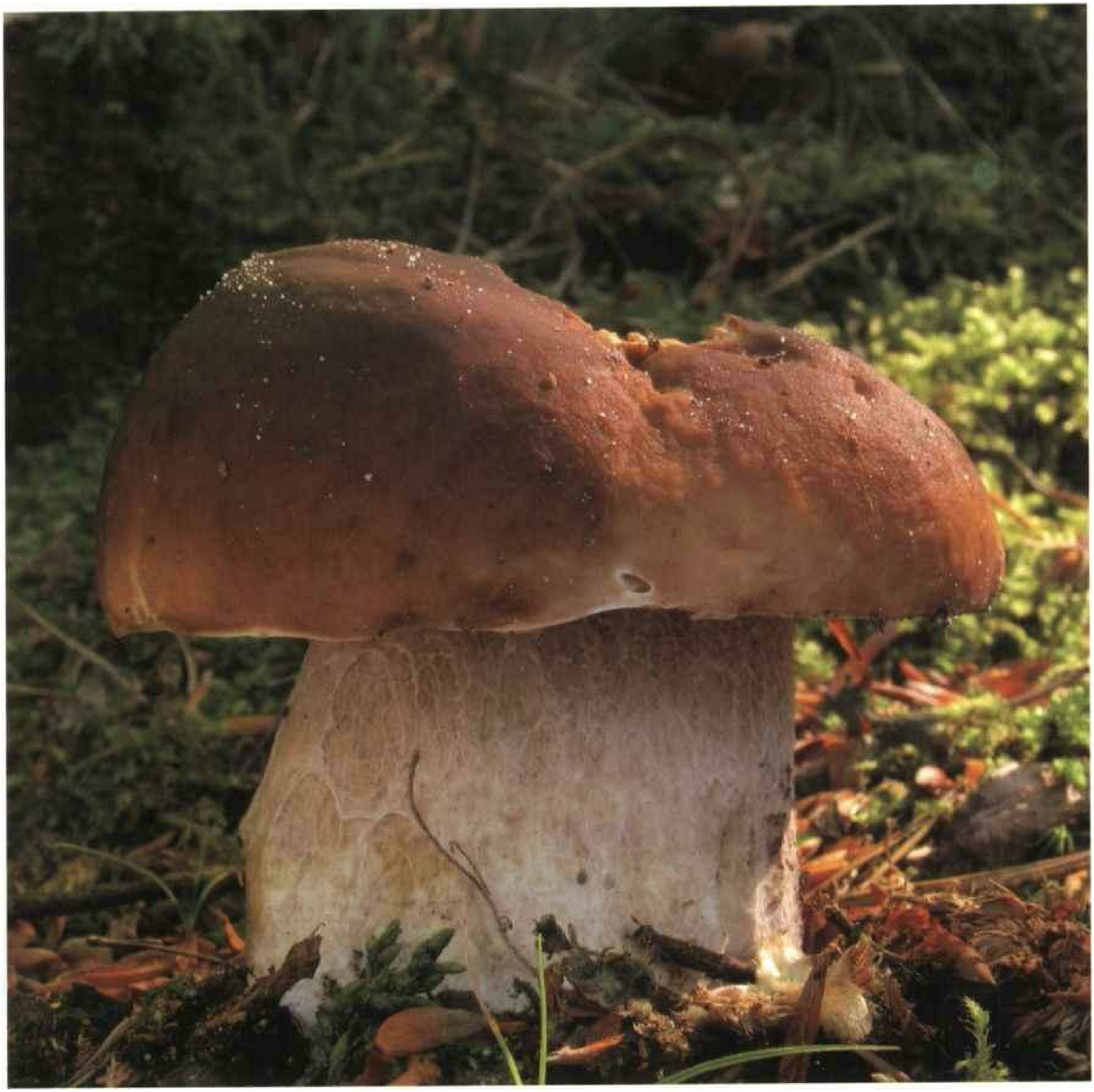

This is the key ID mark. The white net-pattern must be visible! All ceps, regardless of their time of emerging or stage of their development, have a fine white net-pattern at the top of their stalk.

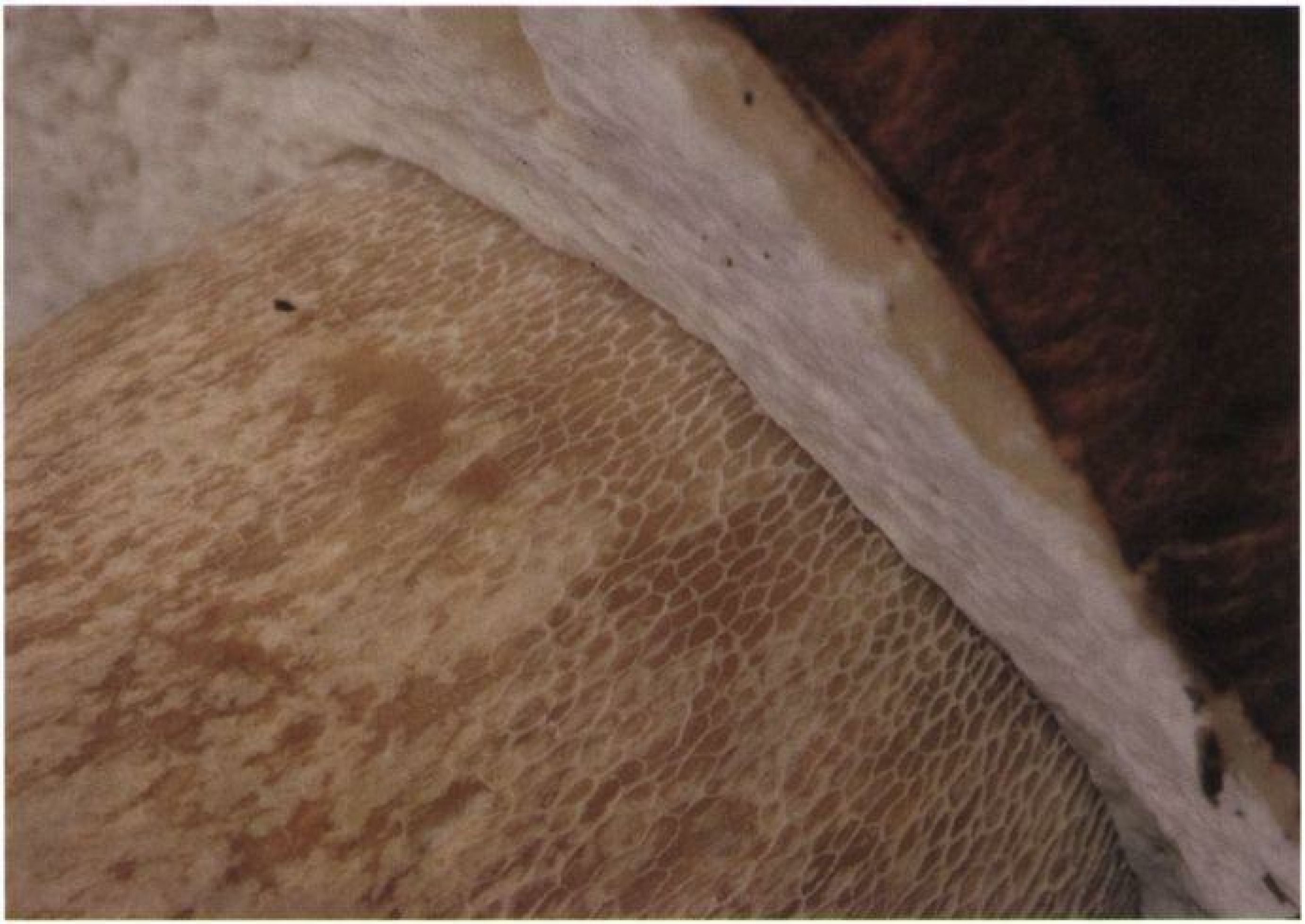

This is what a cep ideally looks like when cut. Not a single worm has even looked at this beauty. The tubes and the flesh do not change color when cut or touched.

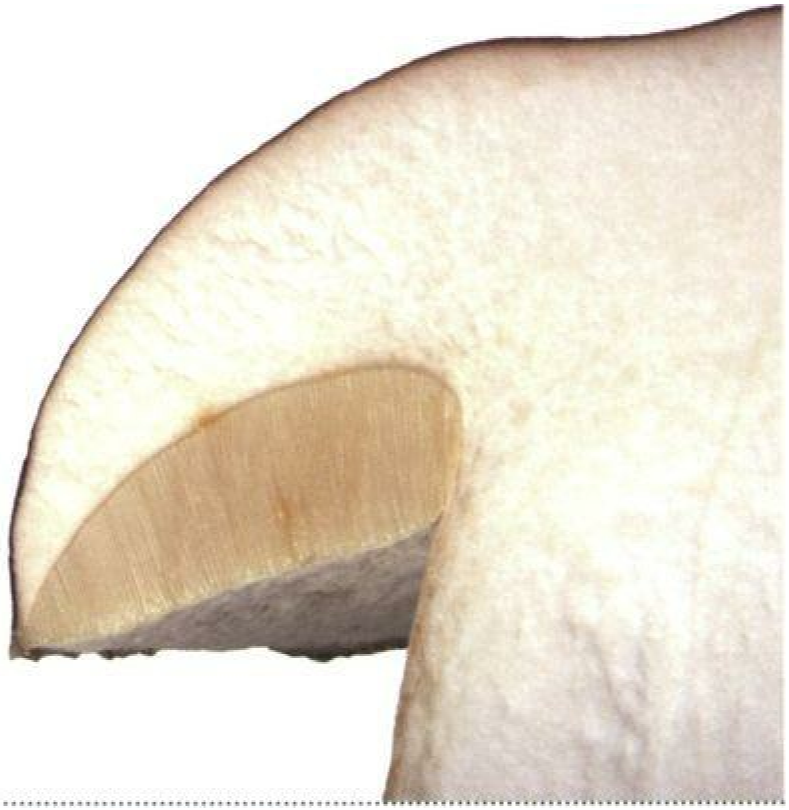

Cep tubes are off-white and firm when young. Later they turn yellow-olive and are less firm. In maturity the tubes are olive. Tubes of mature ceps are soft as a sponge and the tubes of old ones are soggy and often like those of the big fellow on page 38. This does not always mean that the inside of old ceps is rotten but more often than not, it is.

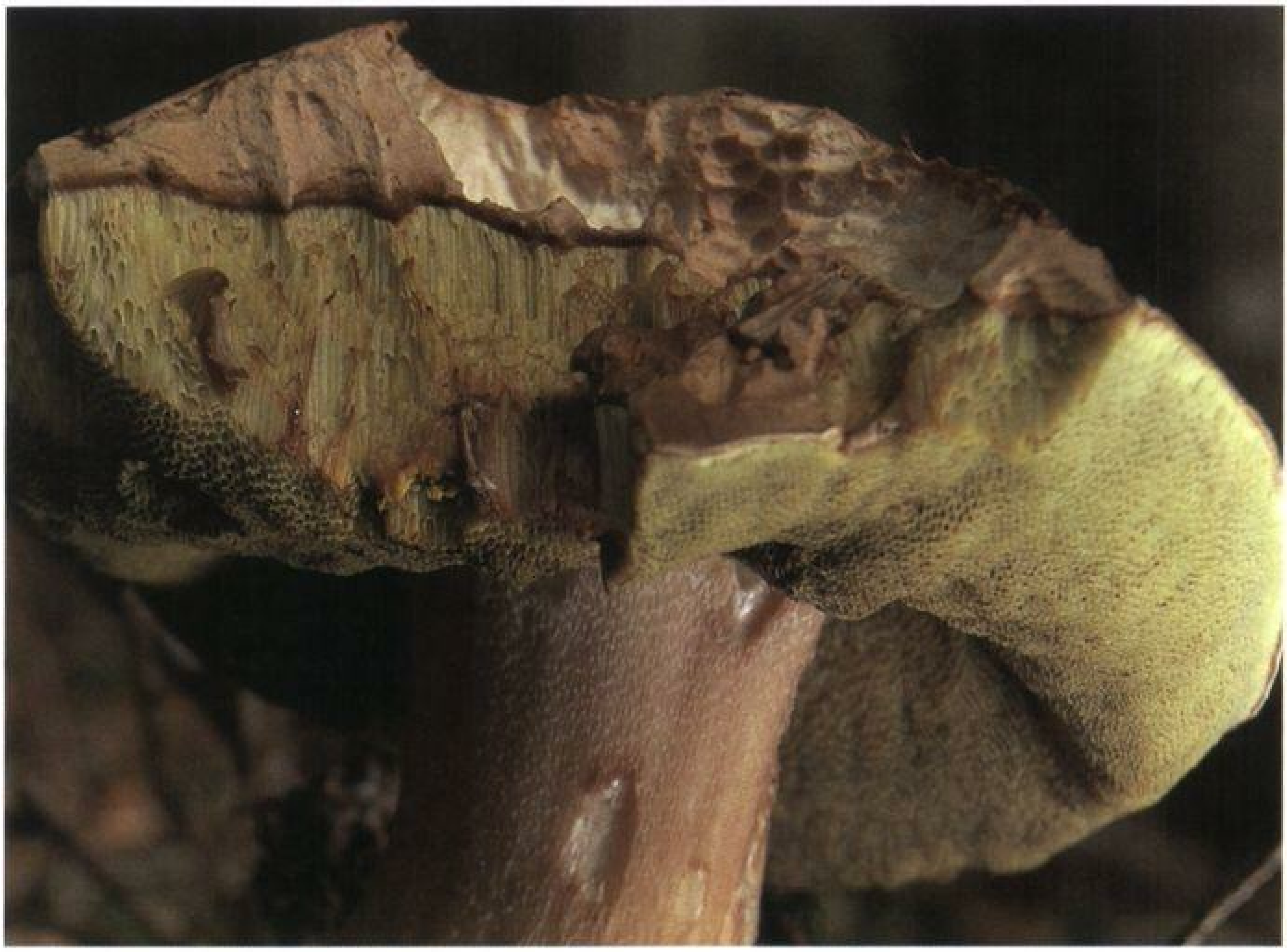

Cep stalks vary greatly in appearance. These specimens clearly show the white net-pattern all over the stalk.

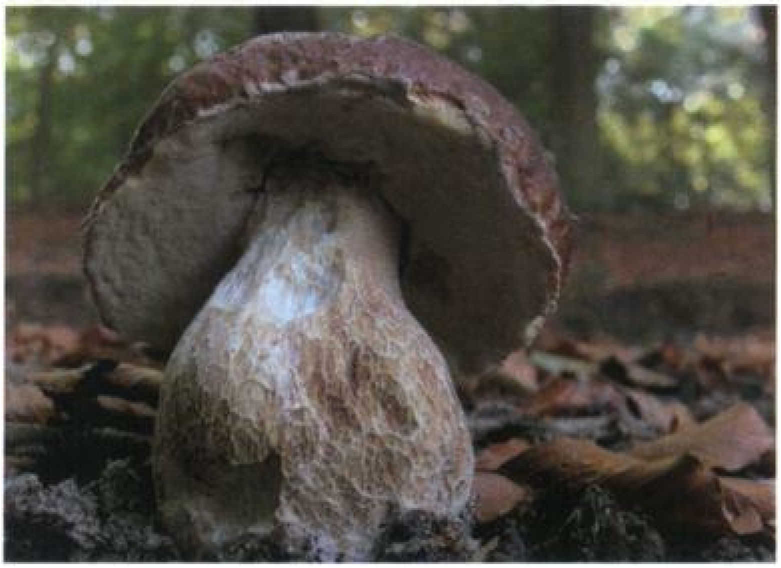

Nevertheless, it is that top section of the stalk just below the cap where it matters: there the white network must be clearly visible.

Positive ID Checklist

Cep or King Bolete

- ☐ Tubes, pores and flesh do not change color when cut or bruised
- ☐ Tubes are off-white, cream, yellow-olive or olive
- ☐ Pores do not show any pink tinge
- ☐ White network on top of stem

☐ Cap matches the color bar range (above)

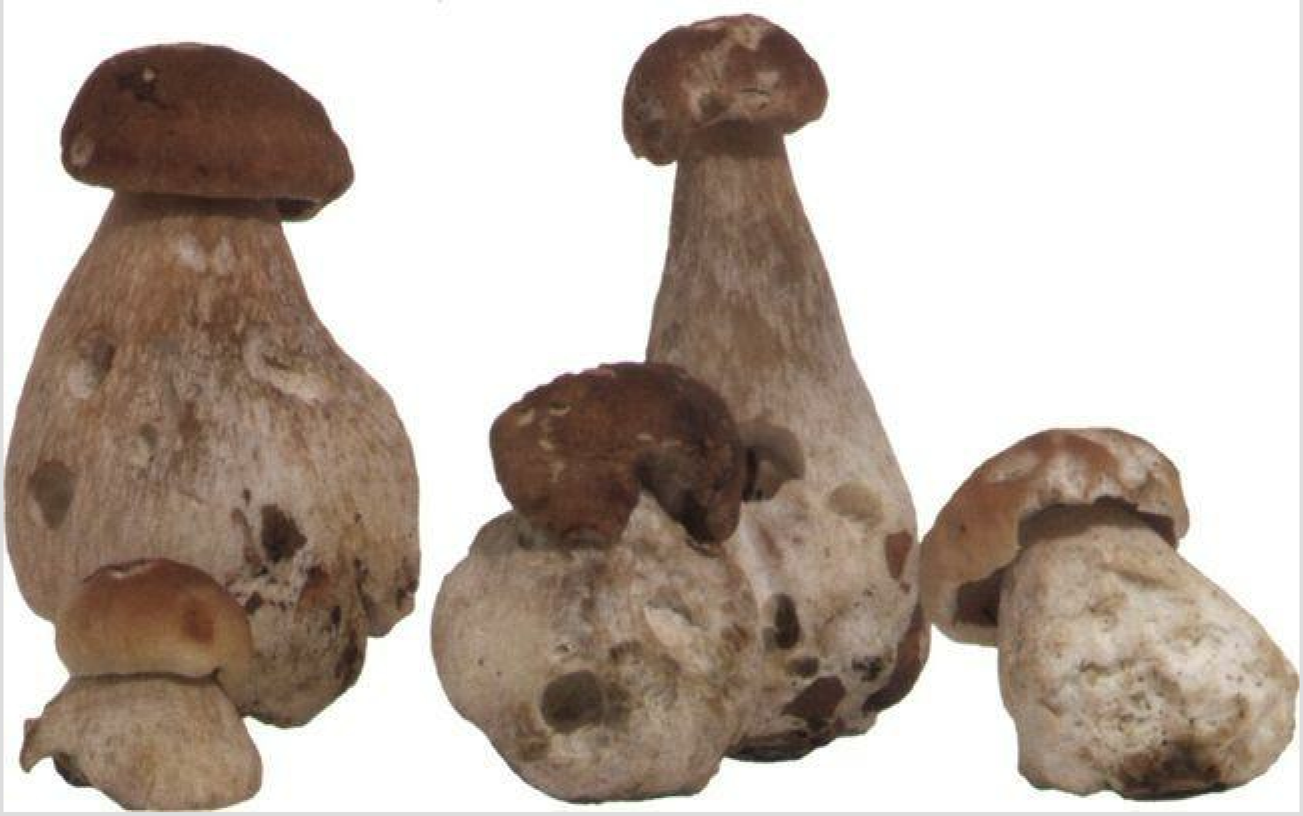

Avg. size across cap: 5 inches when mature

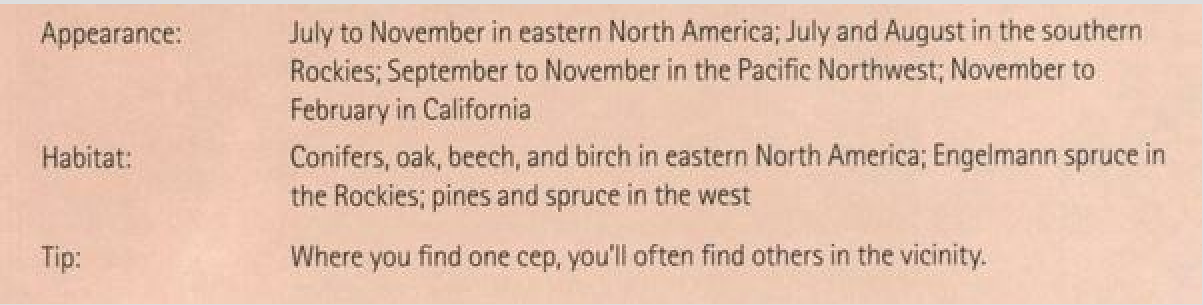

Appearance:	July to November in eastern North America; July and August in the southern Rockies; September to November in the Pacific Northwest; November to February in California
Habitat:	Conifers, oak, beech, and birch in eastern North America; Engelmann spruce in the Rockies; pines and spruce in the west
Tip:	Where you find one cep, you'll often find others in the vicinity.

Red Cracked Bolete

Xerocomus chrysenteron

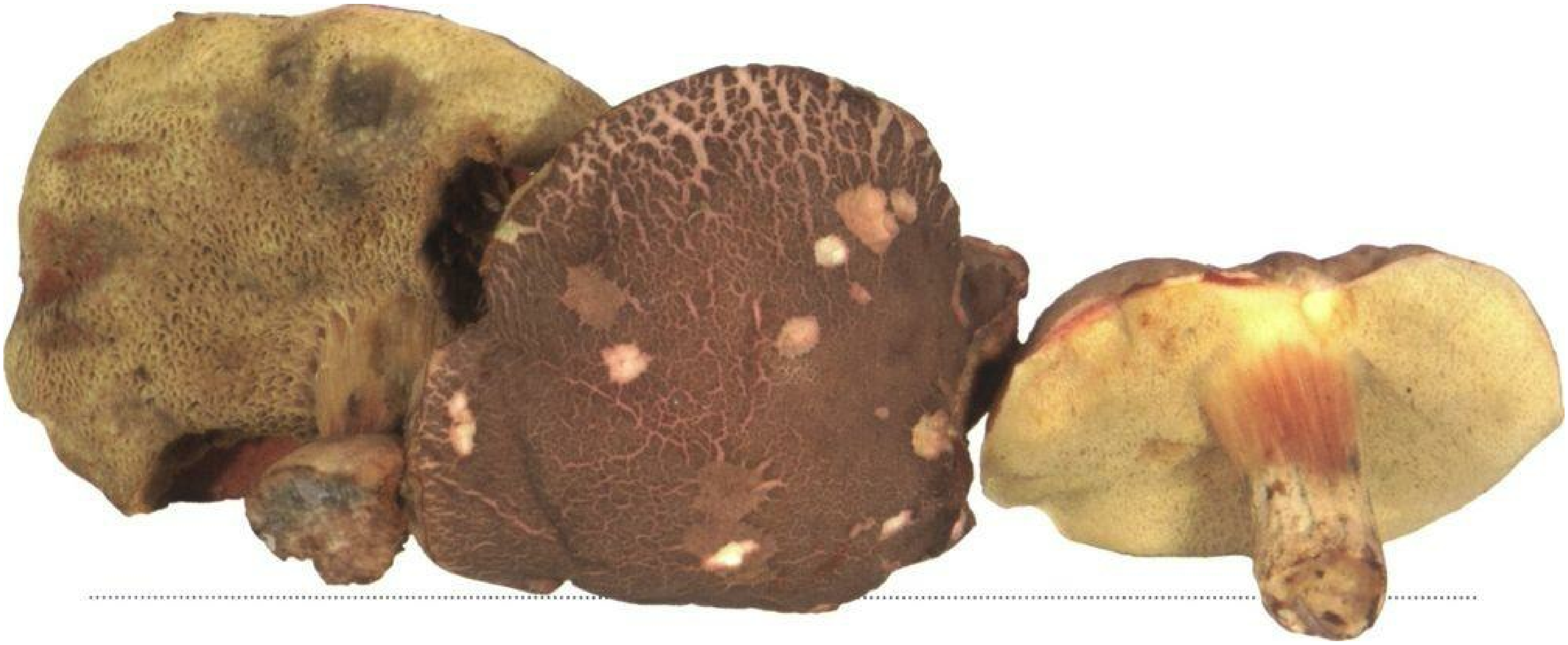

The red cracked bolete is probably the most common of all mushrooms with tubes. Its name describes its key identification feature perfectly.
As the mushroom matures, the cracks become more prominent. Some people love eating the red cracked bolete, others quite like it and there are a few who don't take to it at all. The reason is its distinct fruity smell. In any case the red cracked bolete should only be picked as long as the pores are bright yellow and firm. The ideal size of the cap is about 1 inch across. Anything larger will make your dish all slimy.

Chrysenteron means 'with golden-yellow flesh.'

The color of the cap ranges from a velvety dark brown to a light brown.

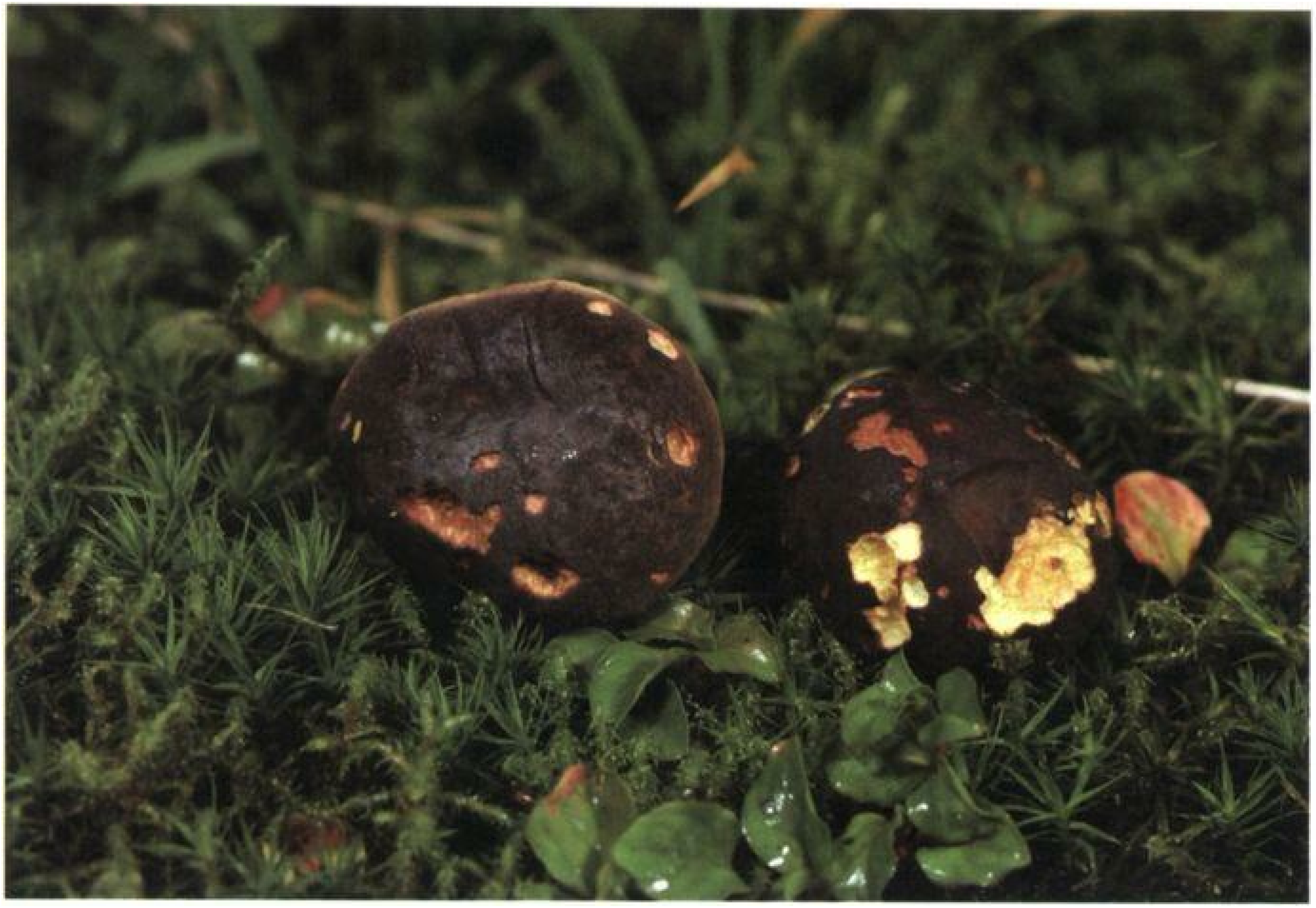

Stems vary in color from yellow, to yellow with a little red to yellow flushed with red. Note the bright yellow pores. The stem and the pores bruise blue. The intensity of the bruising varies. See picture opposite page, far left.

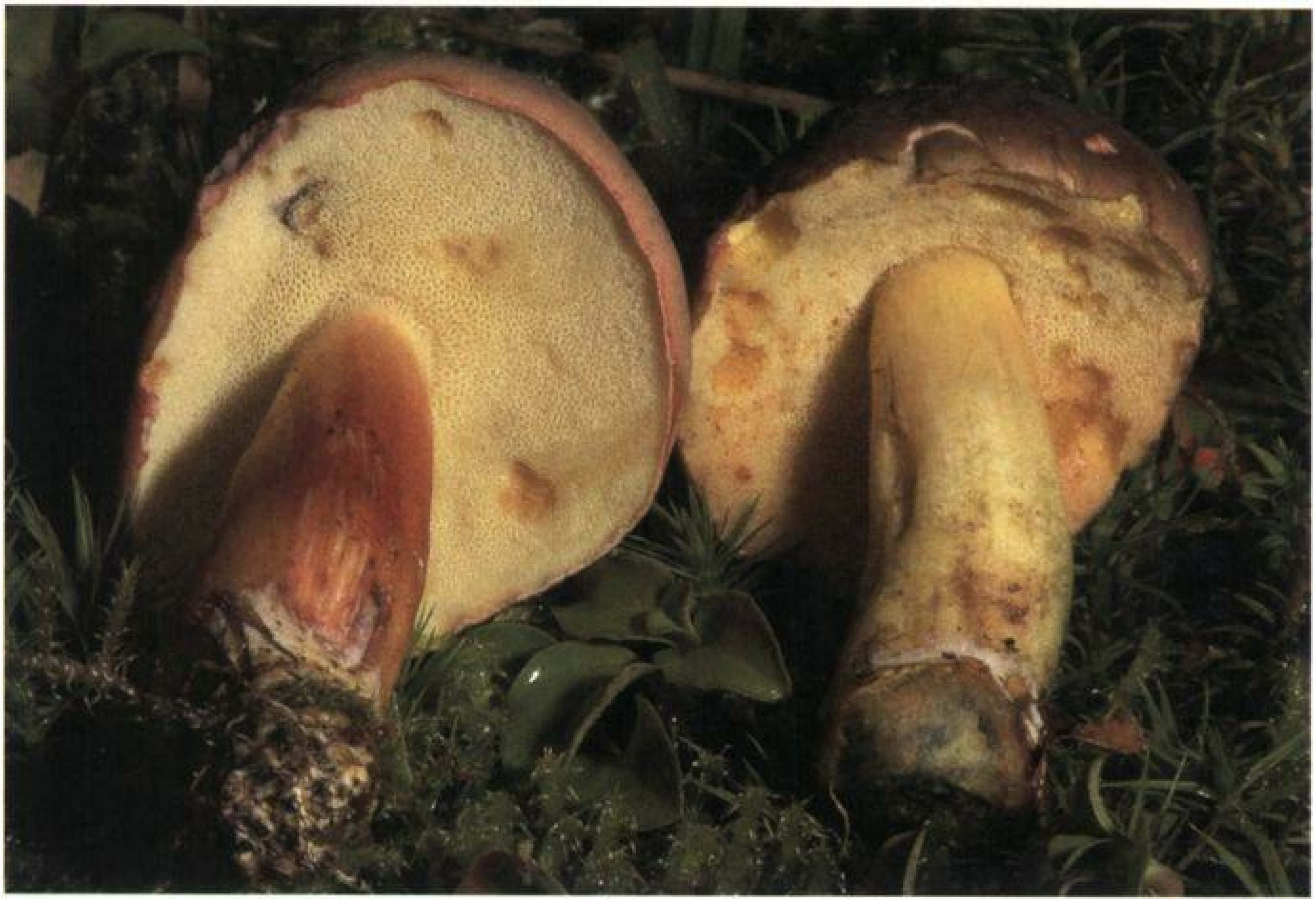

This specimen is too old for the kitchen. The pores have lost their brightness. The dull yellow signals that it's no good anymore. When the pores are this color, the mushroom feels soft-to-soggy.

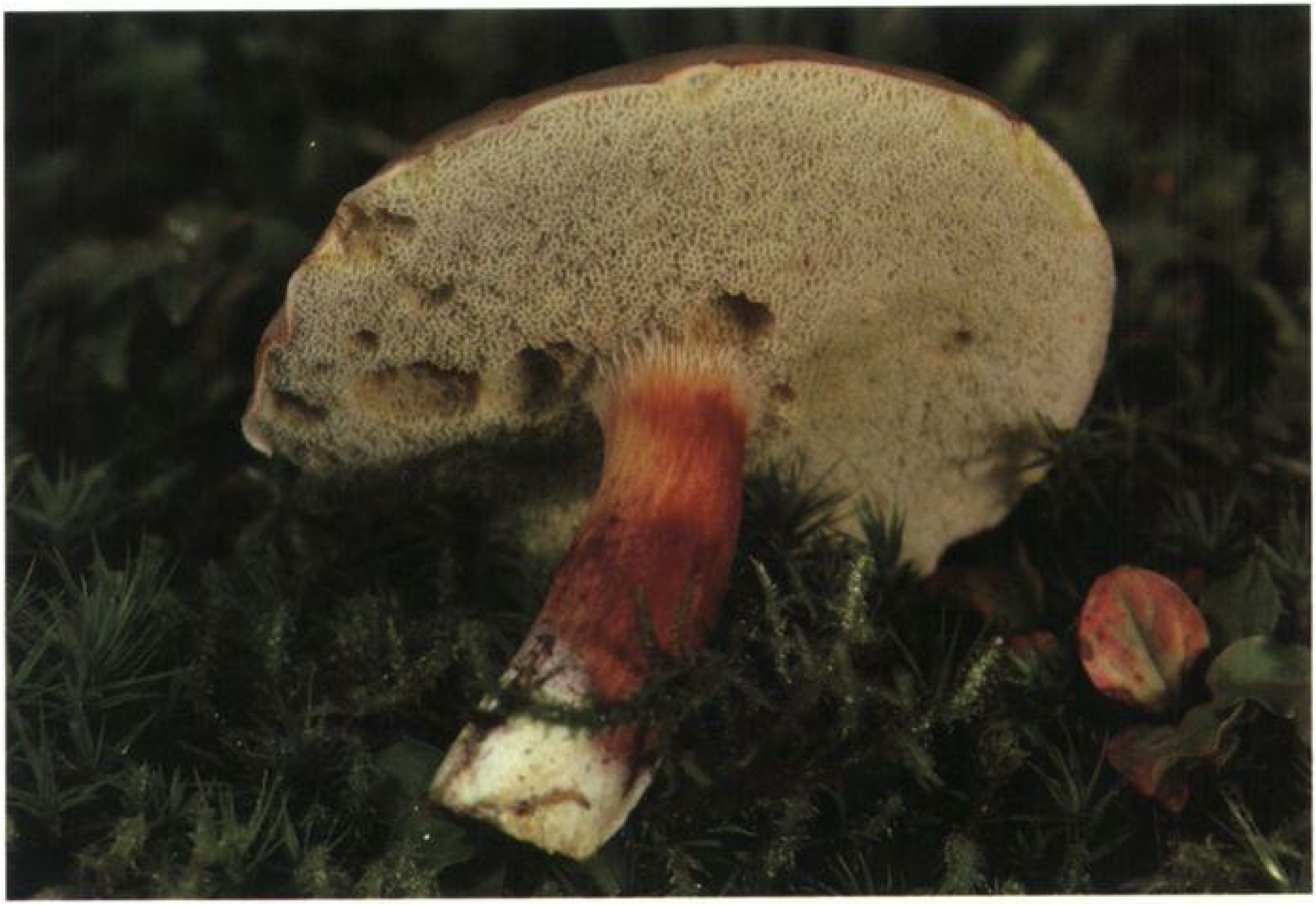

This is the perfect specimen. It has bright, firm golden-yellow pores and a nice firm cap about 1 inch across.

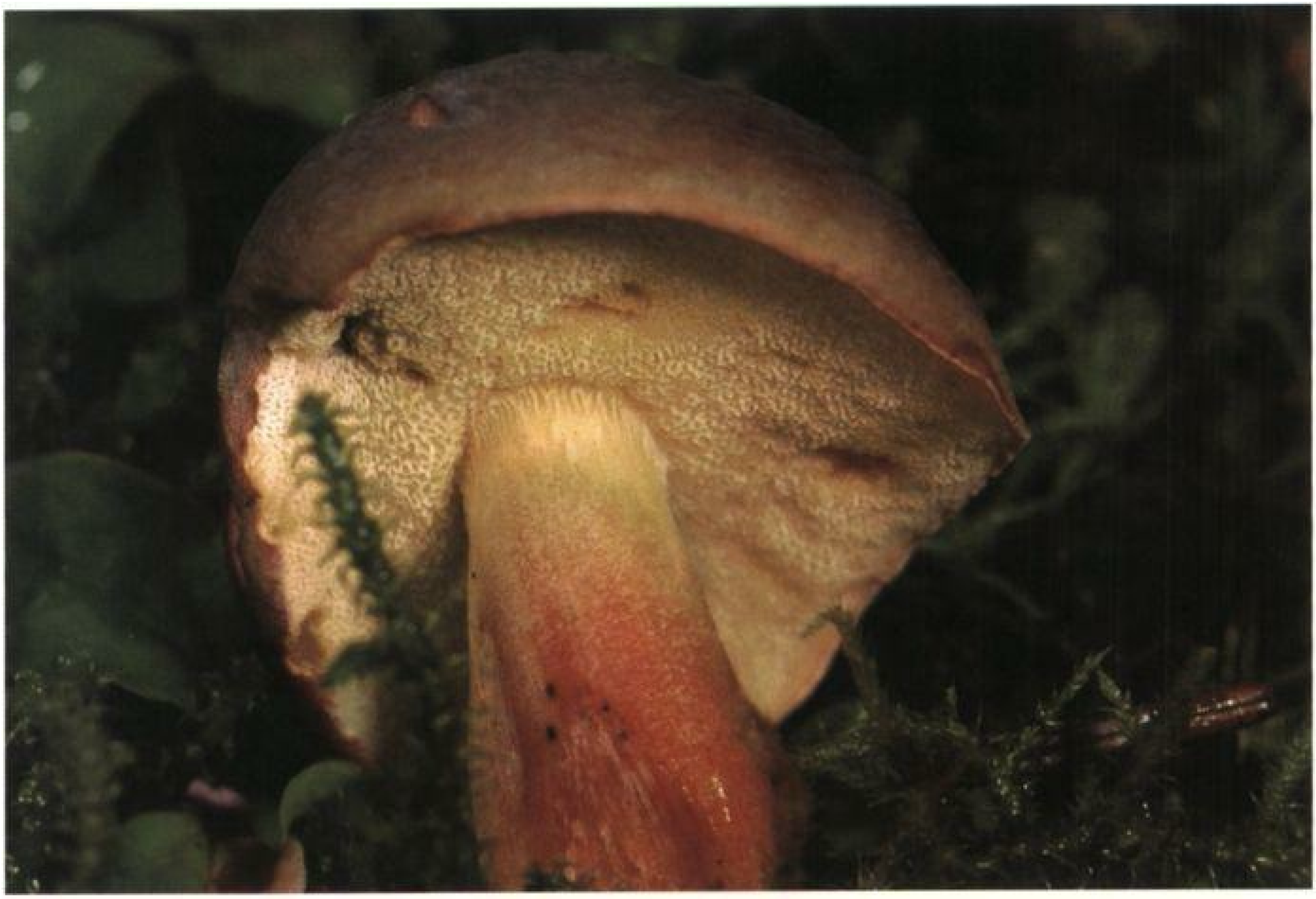

The caps are invariably cracked or lightly damaged. The typical identification mark of the red cracked bolete is the red showing through the cracks or the eaten-away patches.

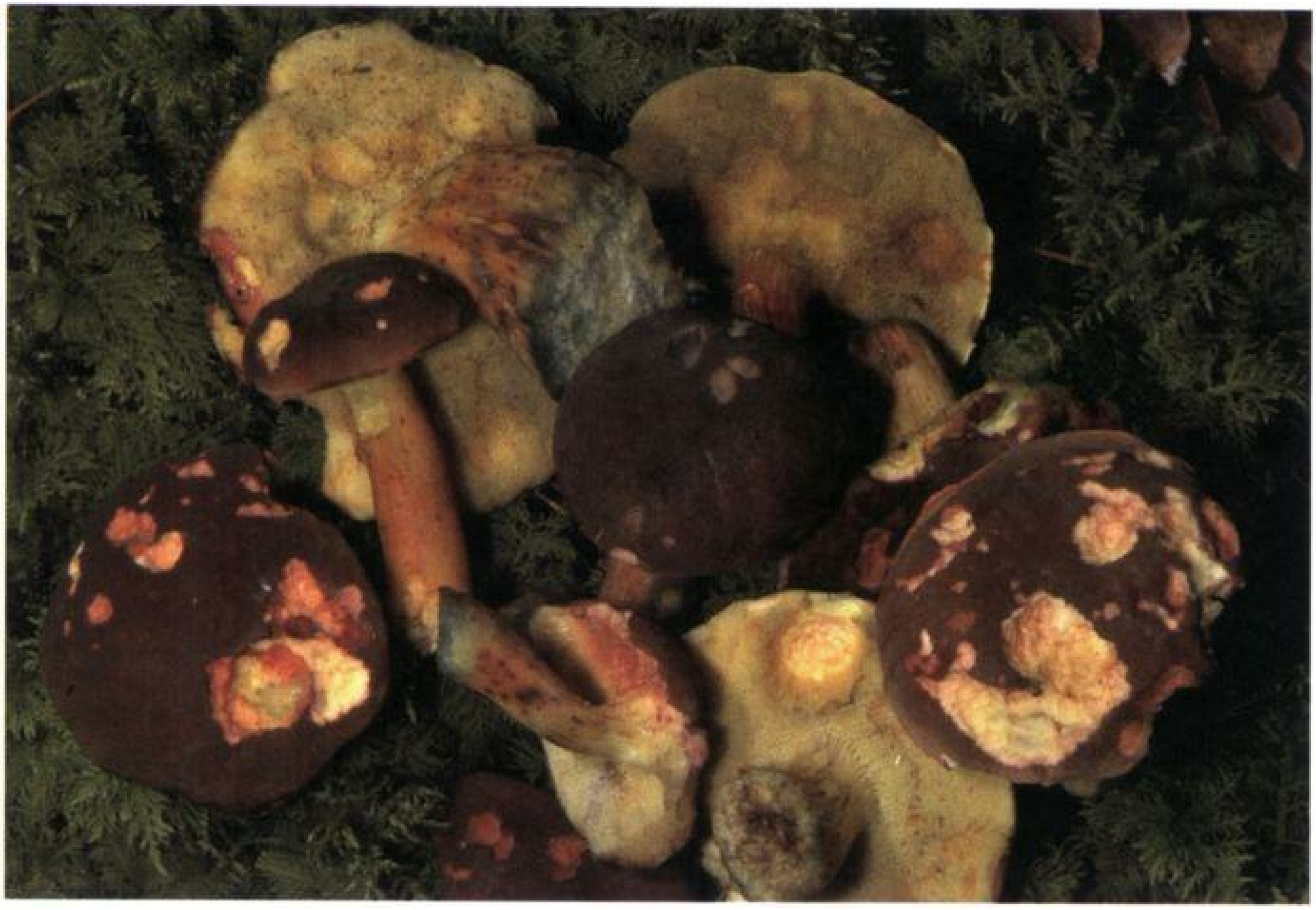

When cut, the white-to-bright-yellow flesh turns blue. This can be very light blue and confined to certain patches.

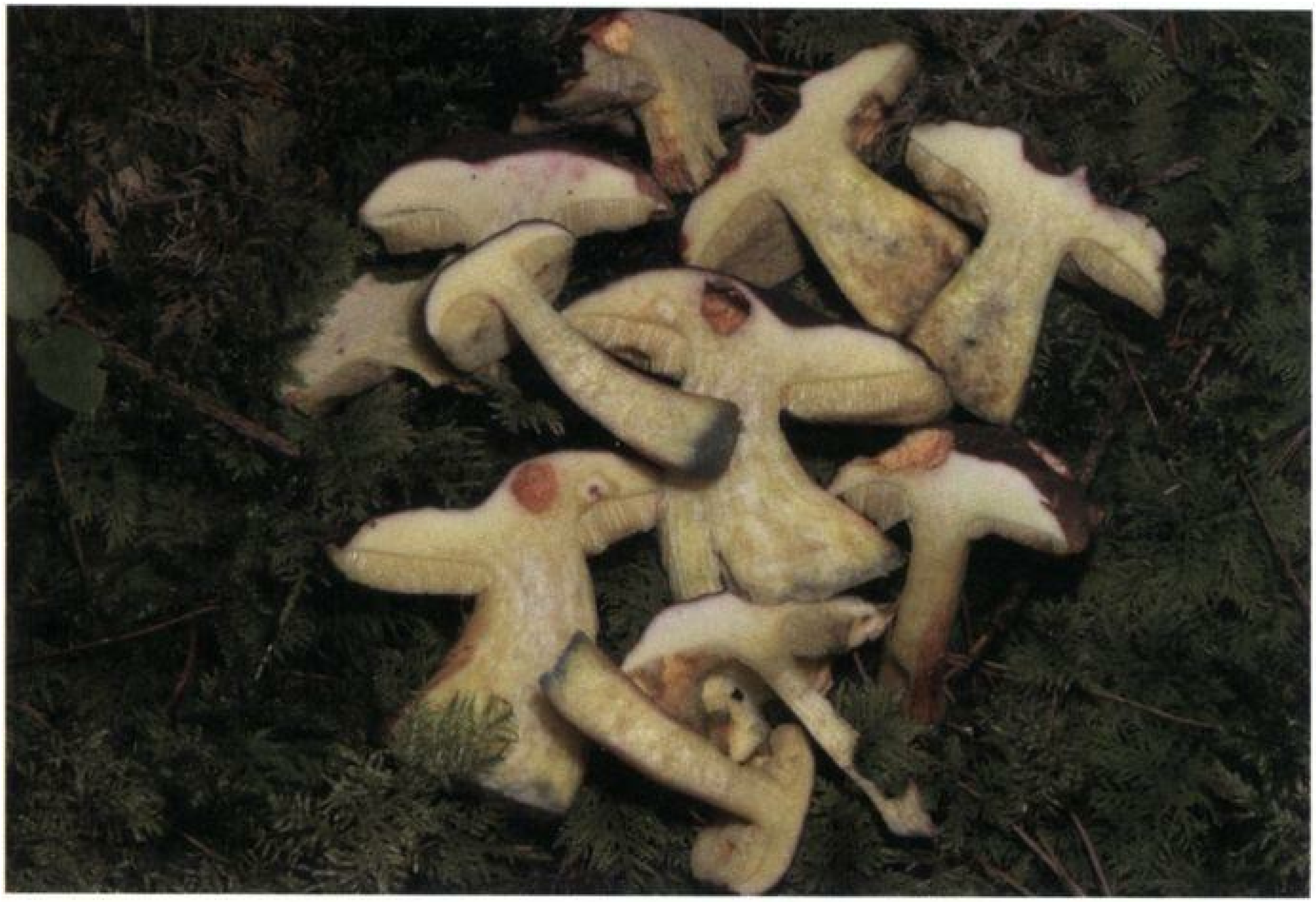

Positive ID Checklist

Red Cracked Bolete

- ☐ Yellow tubes
- ☐ Yellow pores bruise blue (varying intensity)
- ☐ Flesh bruises blue (varying intensity)
- ☐ Cracks and damaged patches in cap show a distinct red tinge
- ☐ Cap matches the color bar (above)

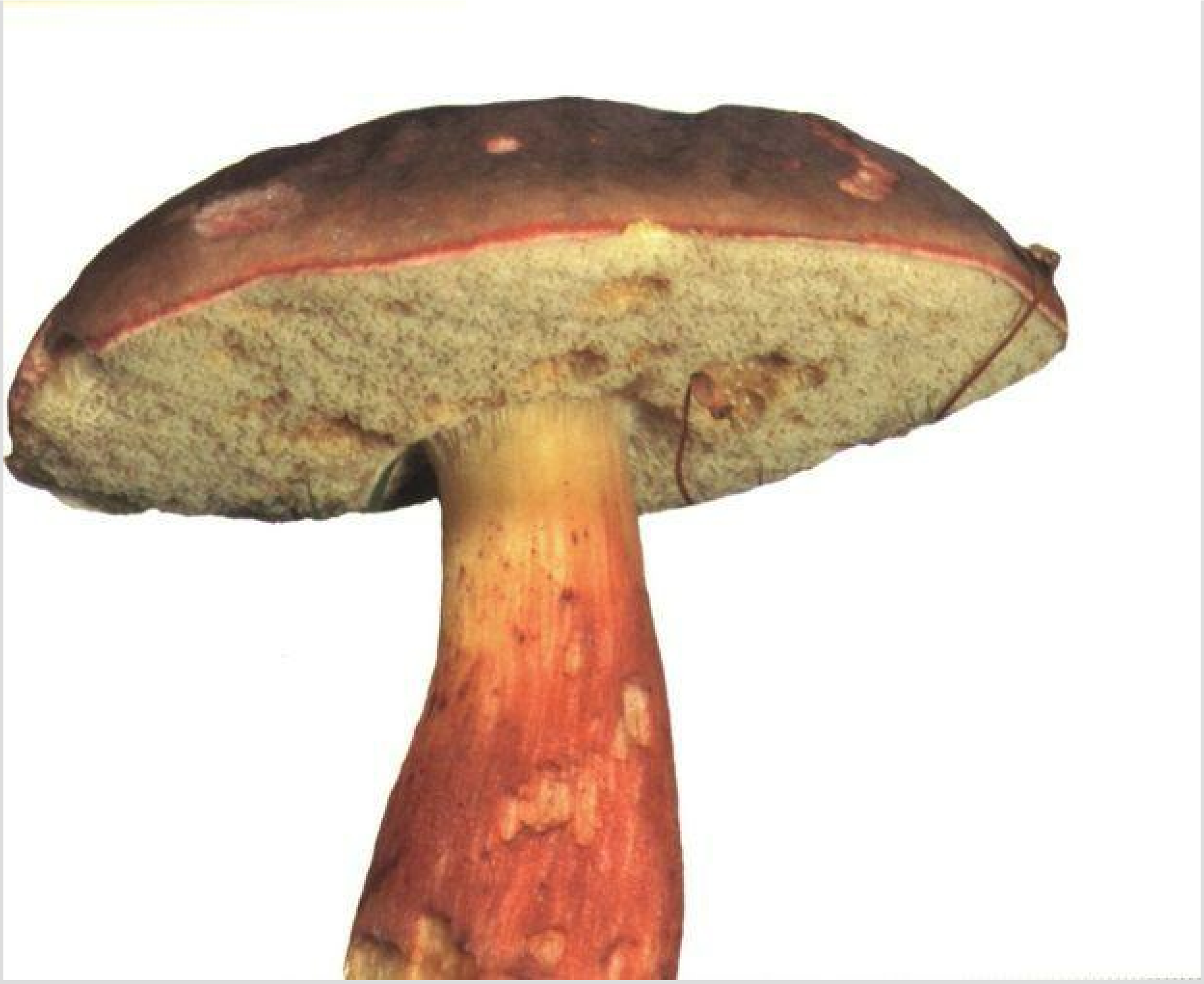

Avg. size across cap: 2 inches when mature

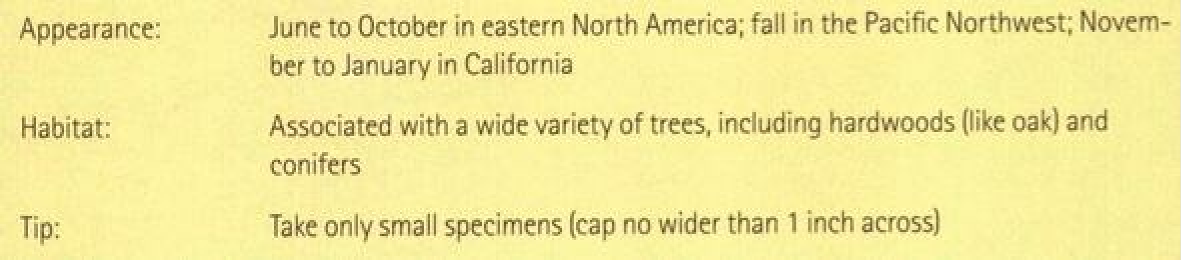

Appearance:	June to October in eastern North America; fall in the Pacific Northwest; November to January in California
Habitat:	Associated with a wide variety of trees, including hardwoods (like oak) and conifers
Tip:	Take only small specimens (cap no wider than 1 inch across)

Hen of the Woods

Grifola frondosa

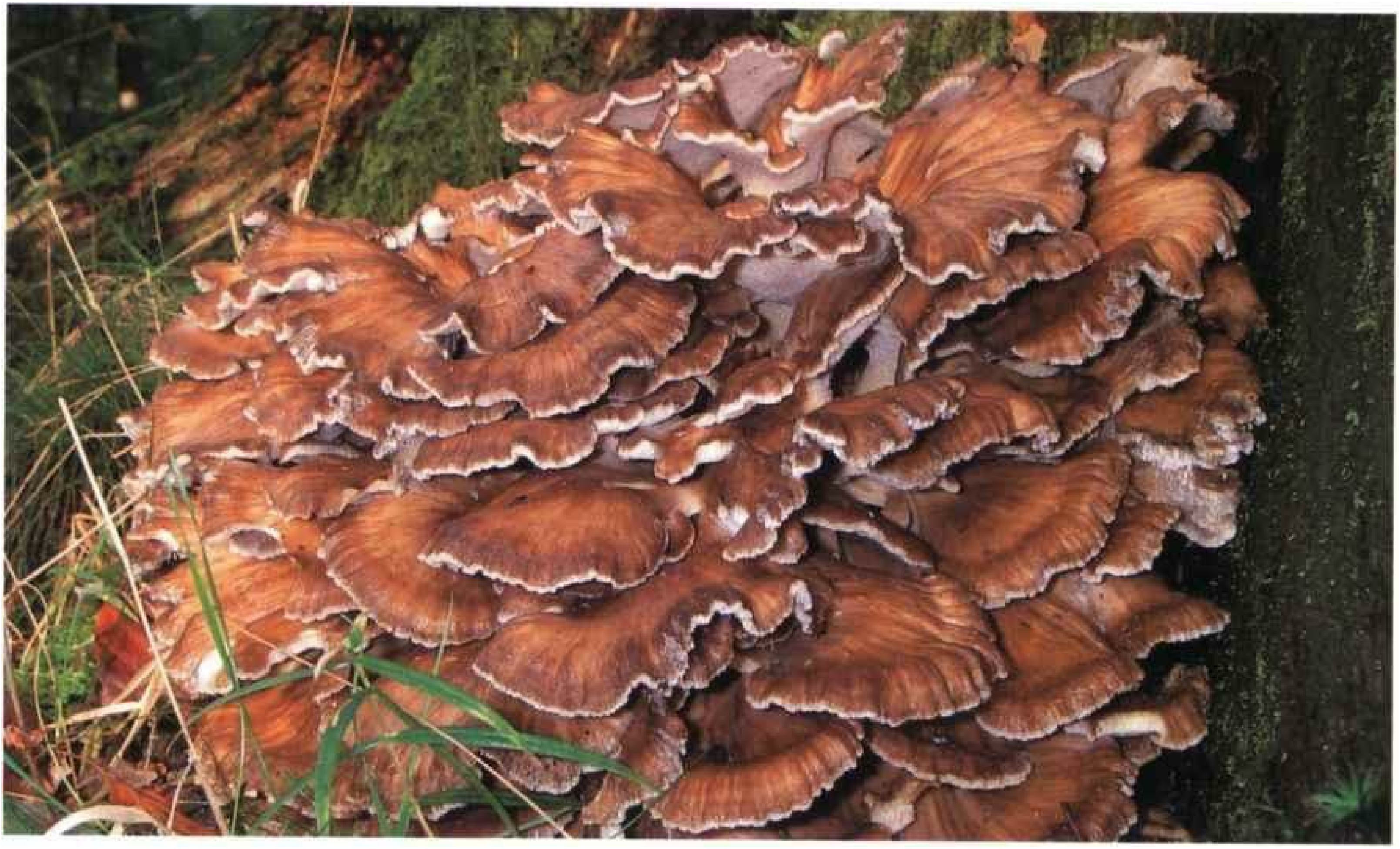

For thousands of years, the hen of the woods mushroom has been prized for its medicinal and culinary value in China and Japan. Maitake, the
Japanese name for the hen of the woods, means "dancing mushroom" and one of the many interpretations of this name is that those who found a hen of the woods started to dance with joy because it was such a highly-prized mushroom.

It can be cultivated commercially. However, the wild hen of the woods mushroom you pick is infinitely superior because, firstly, you found it yourself; and secondly because it is as different from the farmed version as is a wild salmon to a farmed one. Finding a hen of the woods is indeed a reason to dance: a culinary event of the first order—and it's good for you too. There aren't that many things in life of which that can be said.

The hen of the woods is a cluster of fan-shaped overlapping caps.

On the underside of the cap (approx. 2 inches across) the tubes are at this stage visible to the naked eye. At this point the hen of the woods reaches gourmet status. Start picking now.

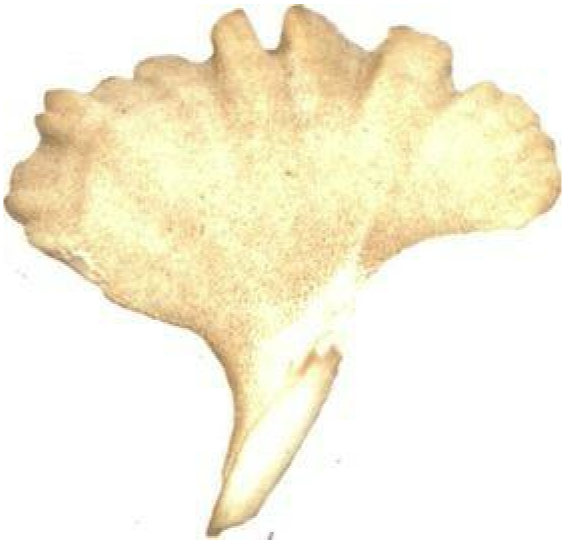

Actual size 2 inches

The fan-shaped caps with radial furrows are typical of the hen of the woods.

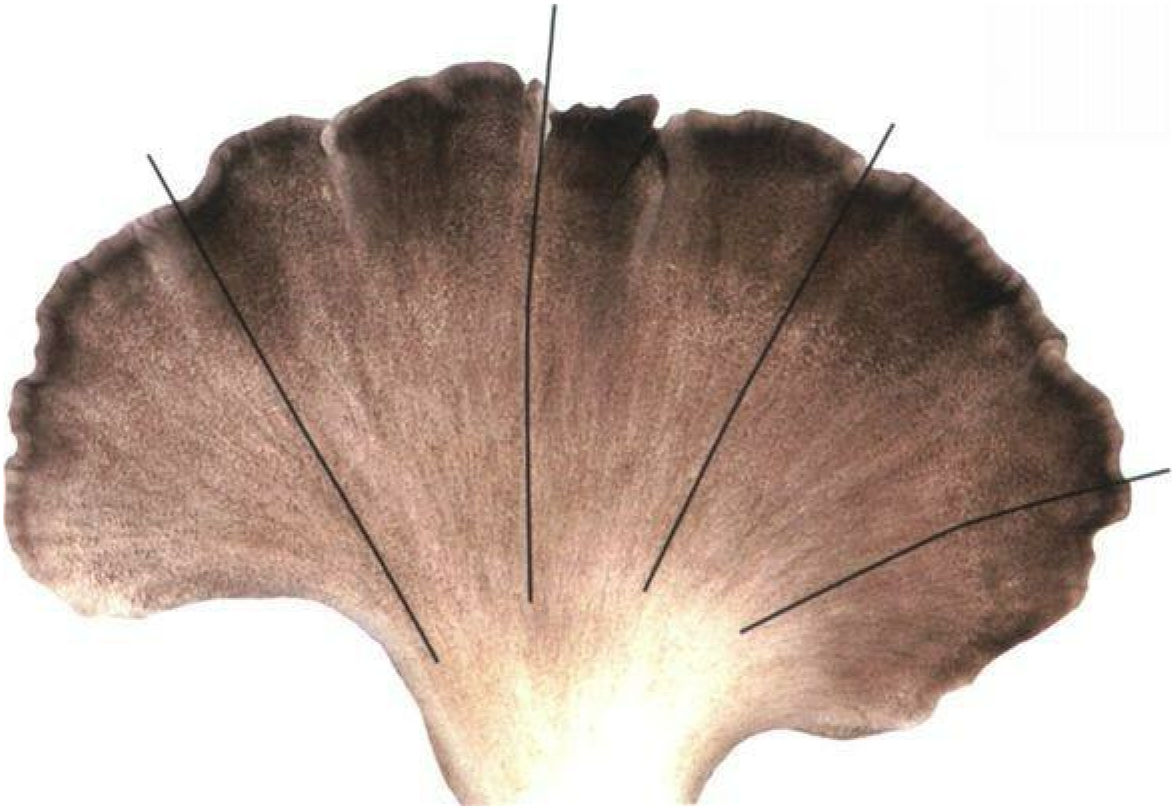

The tubes are clearly visible at this stage.

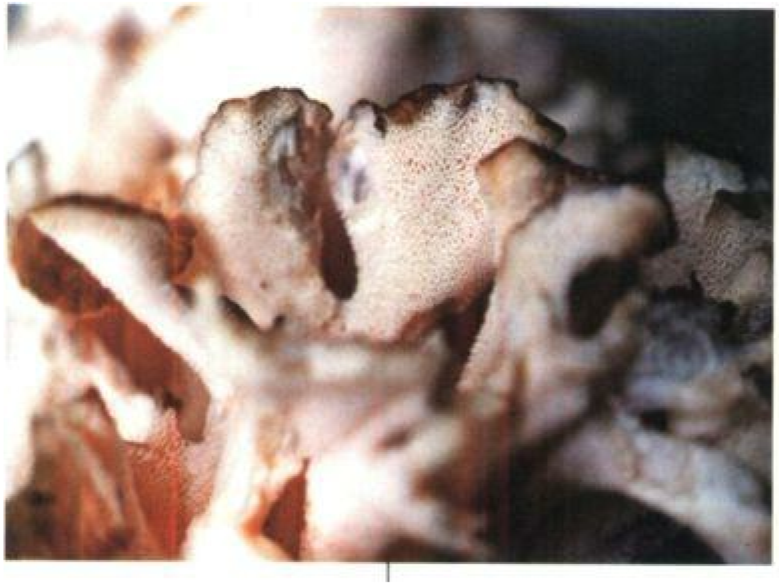

The cross-section shows a cauliflower-like structure with one central stem. The widest part of this particular specimen is approx. 12 inches.

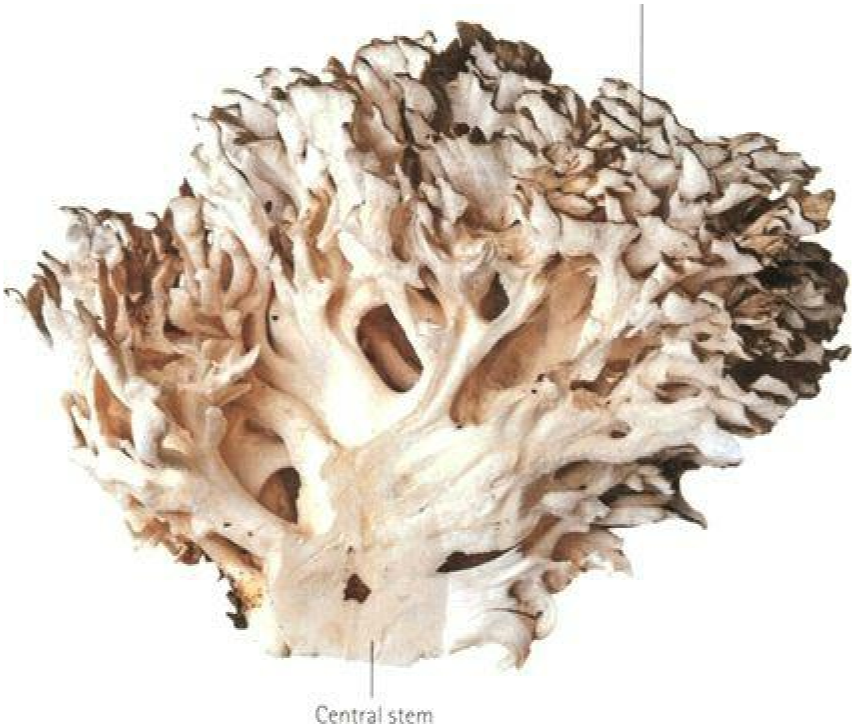

On older specimens the tubes are larger in diameter but remain whitish. As the tubes grow larger they almost look like spines-but tubes they are.

The main colors of the hen of the woods range from off-white, gray-beige, gray-brown, gray-black, brown-black to light brown-black. The hen of the woods can grow up to 30 inches across.

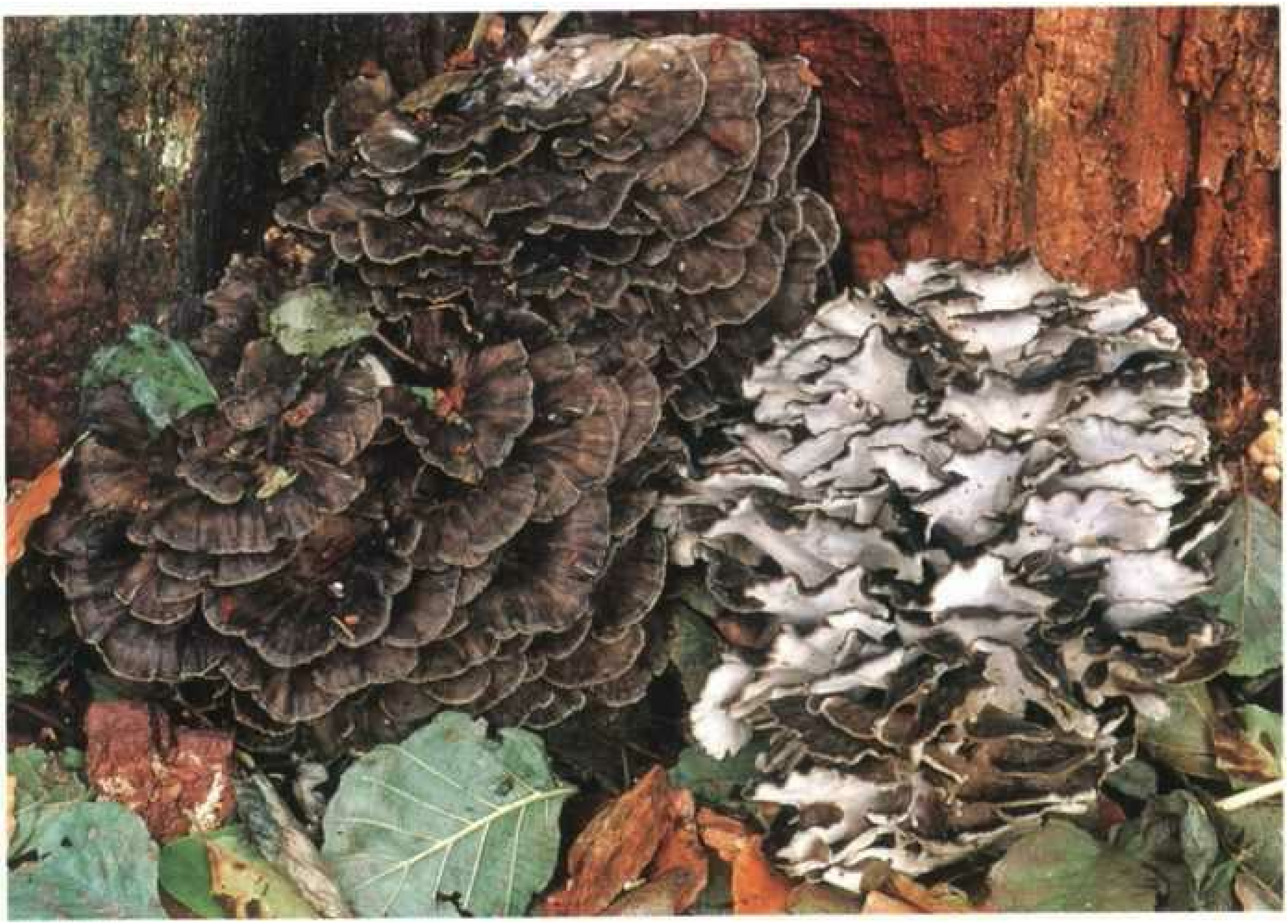

The culinary value of the hen of the woods depends on its age. Size is not always an indicator of age. Some specimens grow very big, very fast. Despite their size these are still young specimens with

white, firm, fibrous flesh with a pleasant smell.
Older specimens have a distinct unpleasant smell and their caps get more and more flabby and the edges crumble.

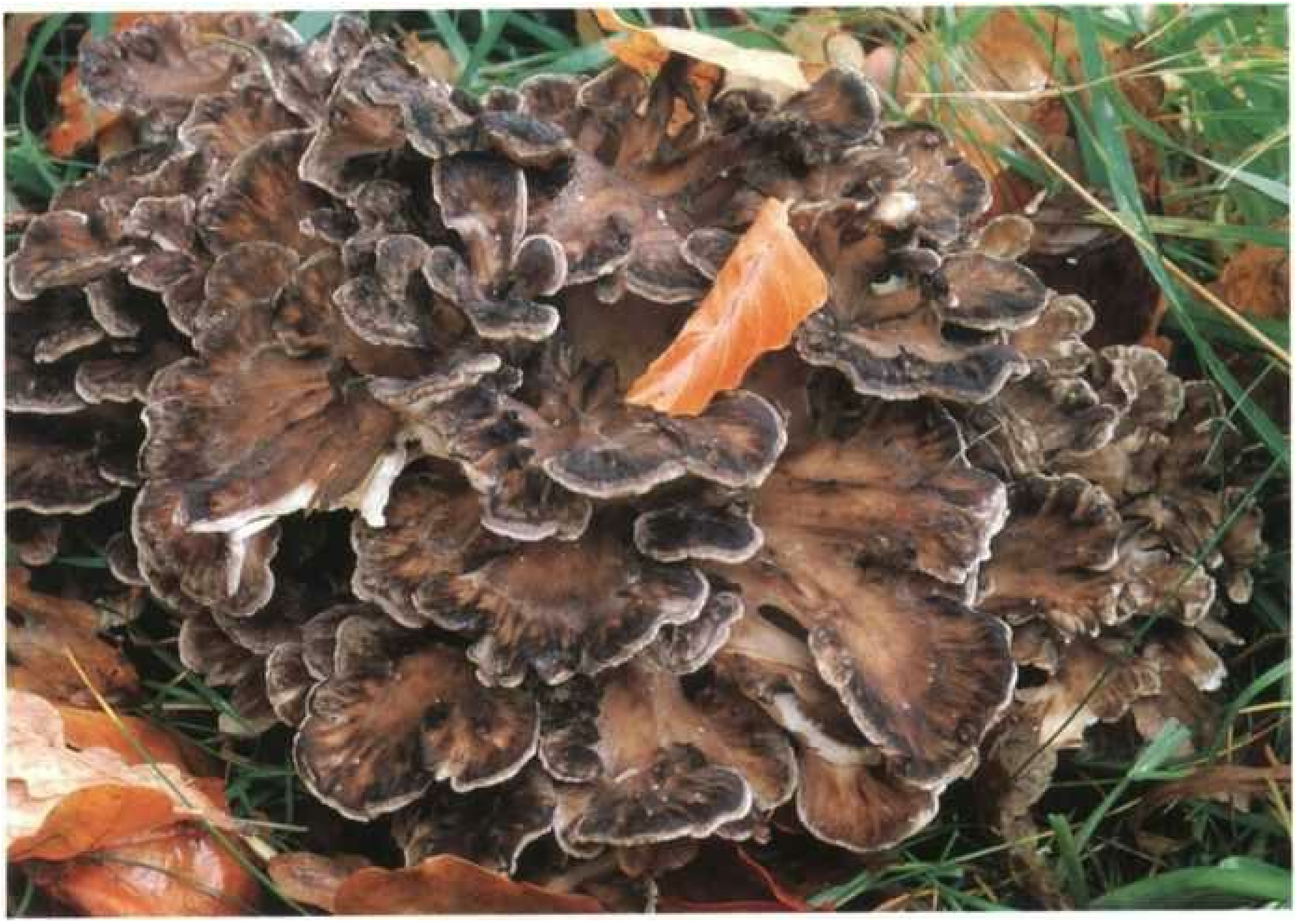

Positive ID Checklist

Hen of the Woods

☐ Central stem
☐ Fan-shaped caps
☐ Caps with dark radial streaks
☐ White flesh does not change color when cut
☐ Cauliflower-structured cross-section
☐ White tubes
☐ Tubes do not change color when bruised
☐ Main cap color matches color bar (above)

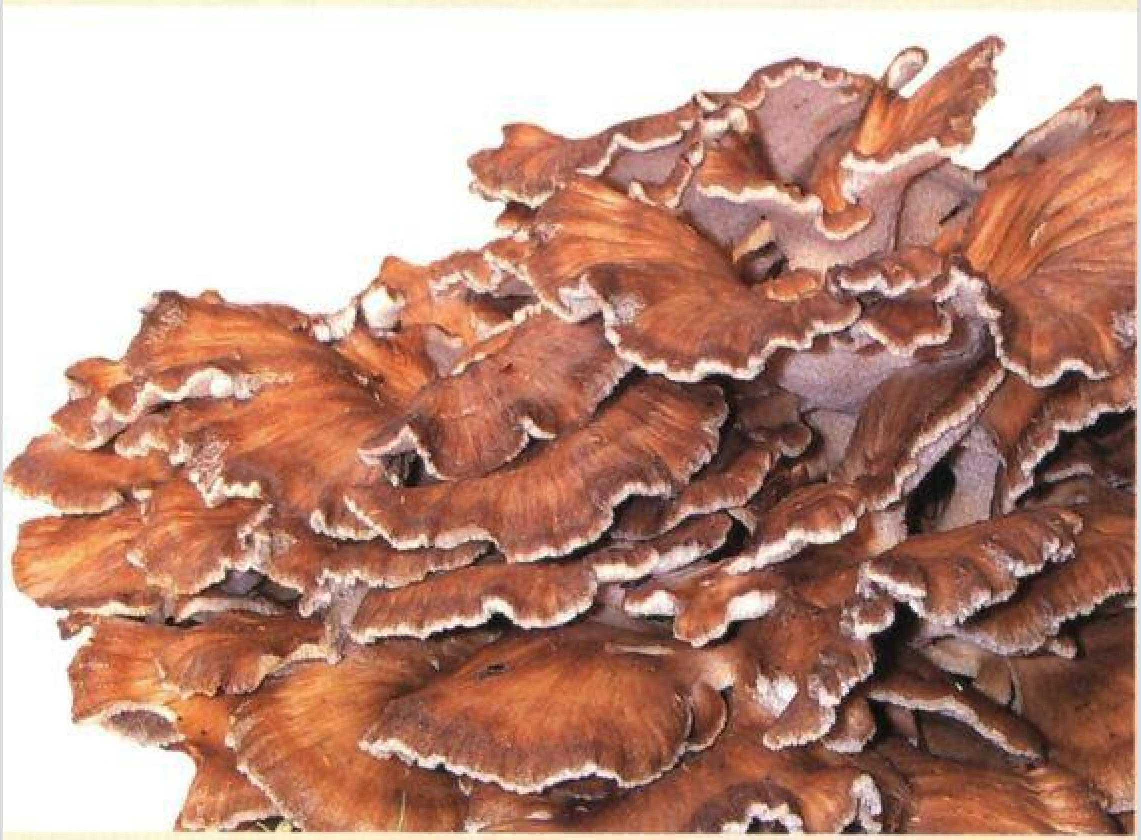

Avg. size across cap: 12 inches, but can grow up to 30 inches

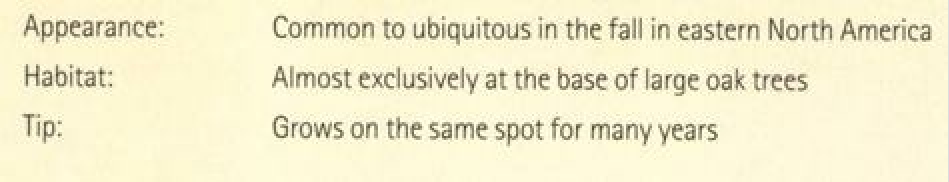

Appearance:	Common to ubiquitous in the fall in eastern North America
Habitat:	Almost exclusively at the base of large oak trees
Tip:	Grows on the same spot for many years

Larch Bolete

Suillus grevillei

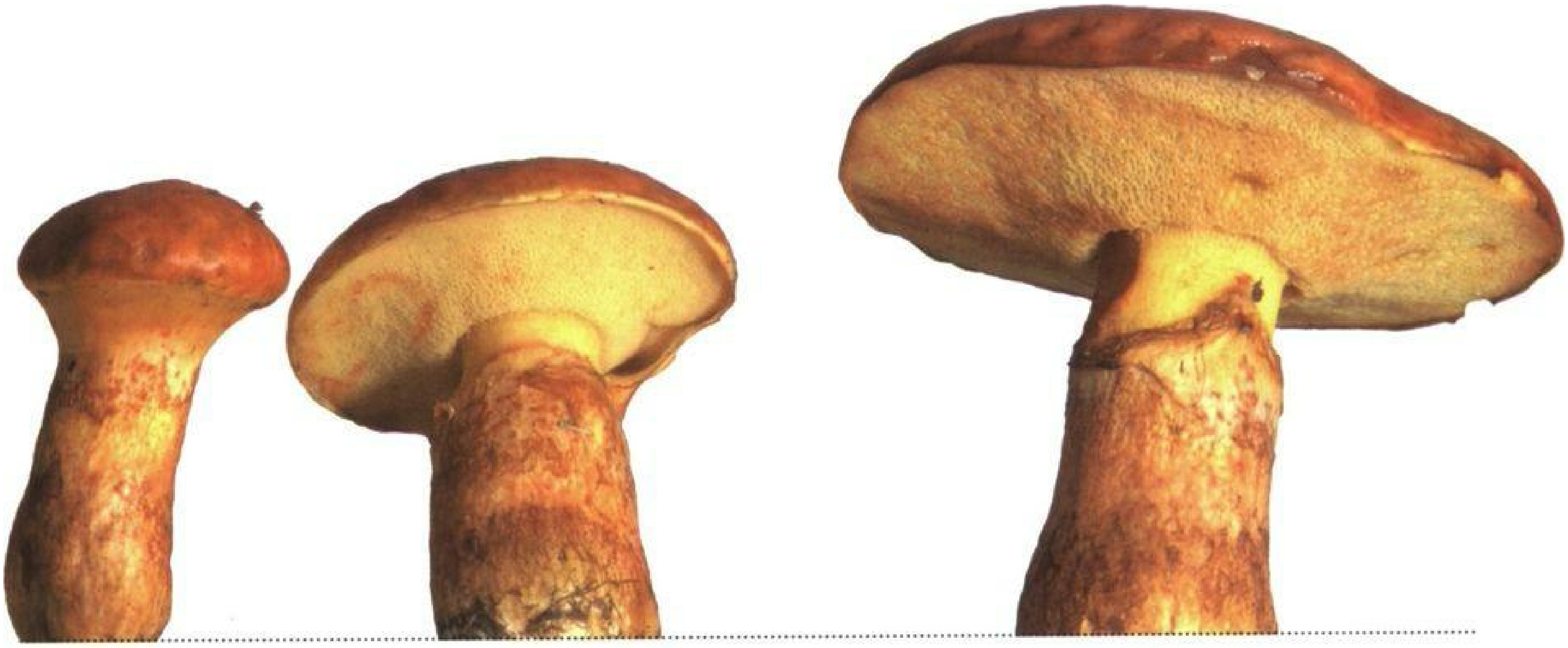

It is as if pure gold has grown out of the ground-and where there is one nugget, there are others. It’s very rare to find a single larch bolete.

More often than not larch boletes form a fairy ring. Always found near larch trees, this beautiful and delicious mushroom is covered with a yellow veil when young (above left). As the maturing mushroom grows, the veil breaks, leaving a transient ring on the stalk (above, center, and right). Always peel the cap of the larch bolete on the spot because otherwise it will make your basket and later your recipe all slimy. In wet conditions, the cap of the larch bolete is always slimy.

Grevillei refers to the Scottish mycologist R. K. Greville.

The veil still covers the cap in a ‘baby’ larch bolete.

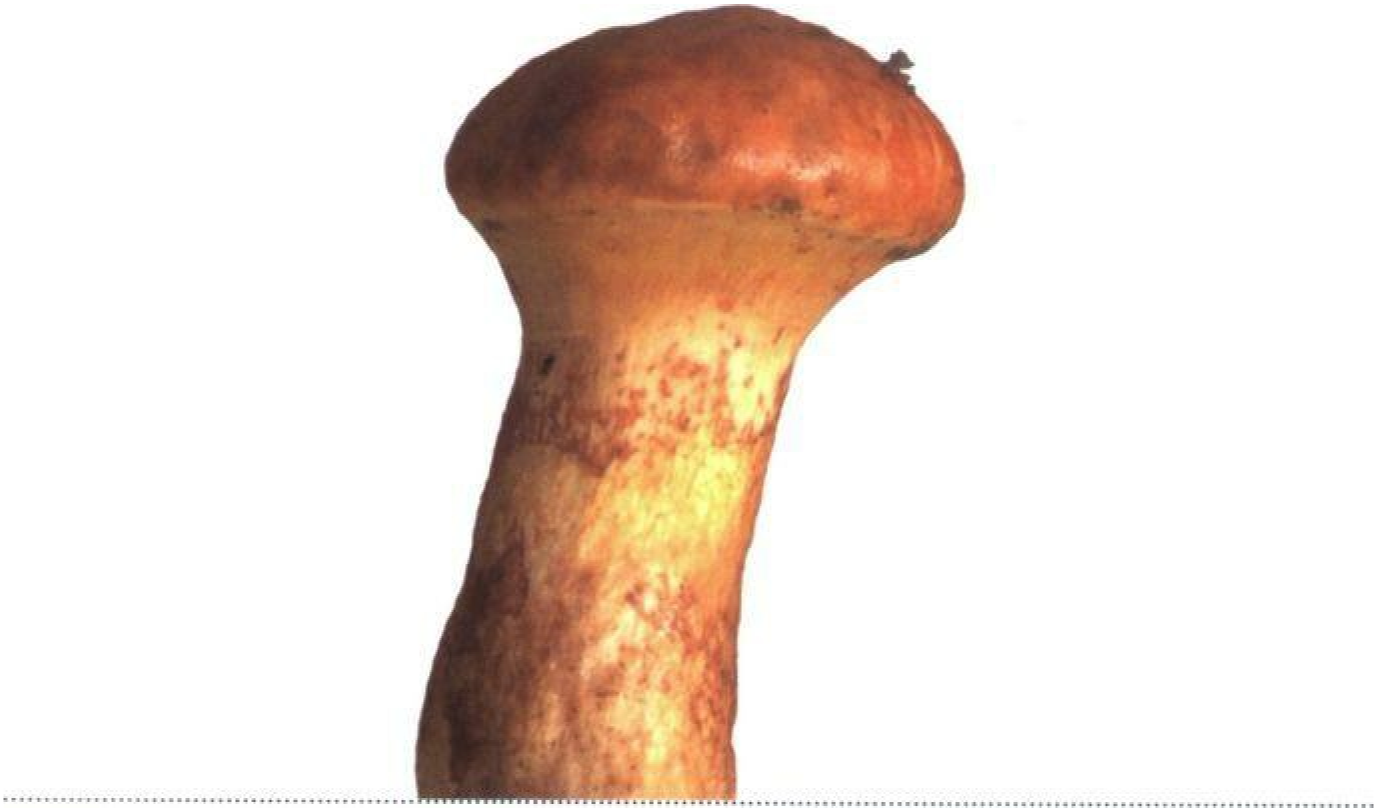

The tubes must be clearly visible when you view a cross-section.

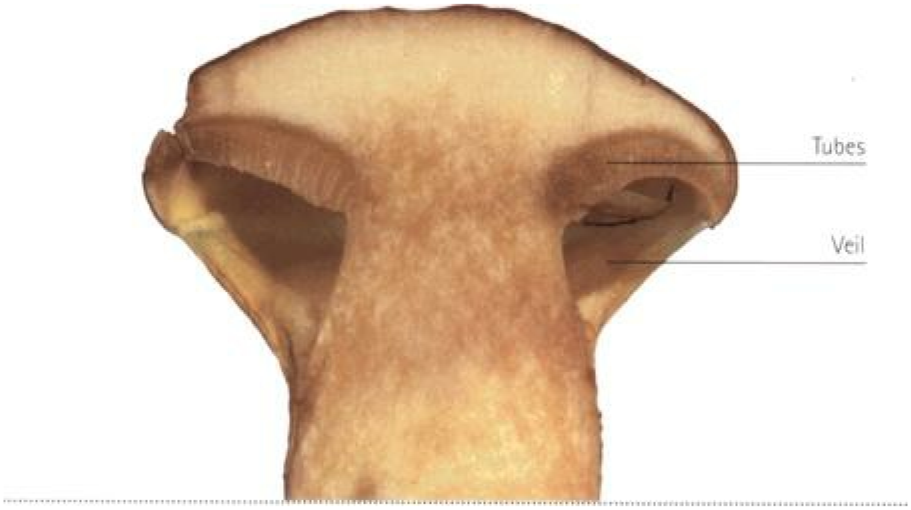

As the mushroom grows, the veil breaks. This picture (right) shows a larch bolete shortly after the breaking of the veil. The ring is transient (i.e., it often drops off) but even in the mature larch bolete you can always see a mark where the ring has been.

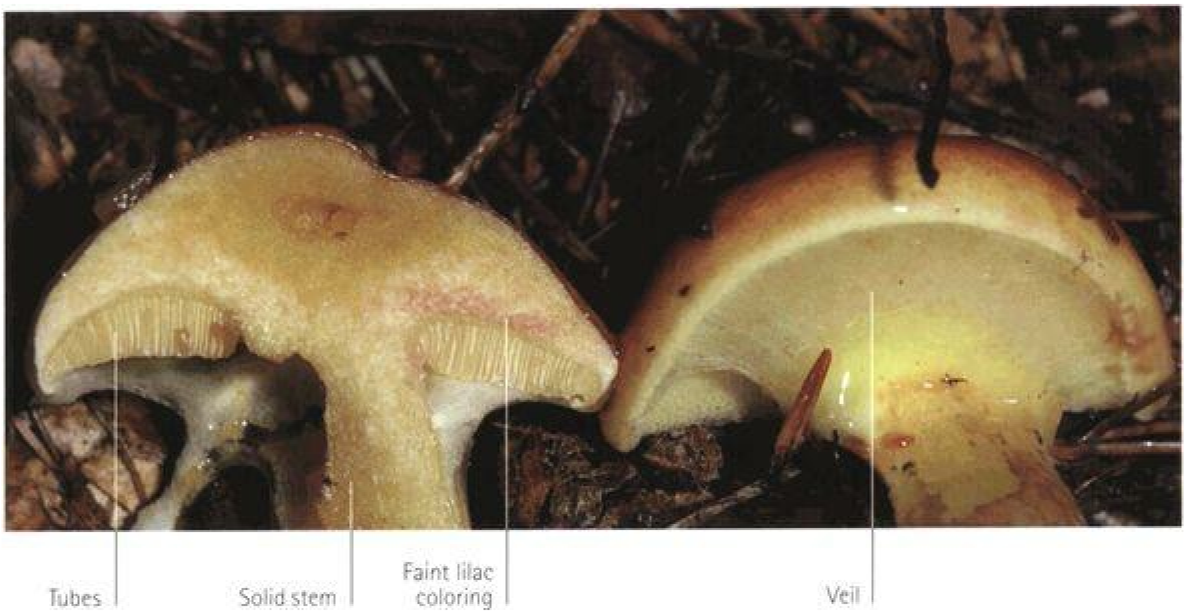
Tubes
Solid stem
Faint lilac coloring
Veil

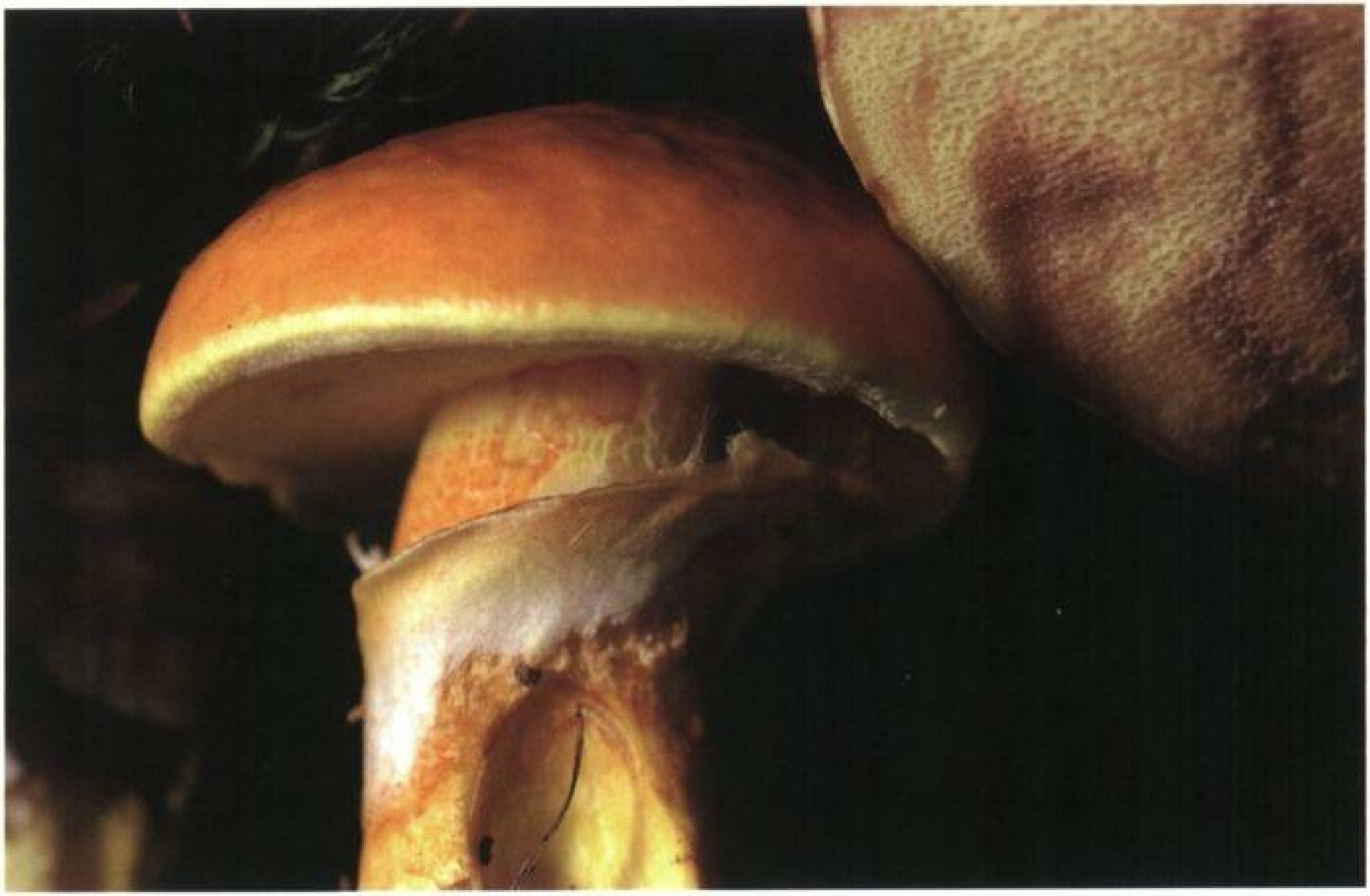

Above the ring marks: net pattern (can be very faint). Below the ring marks: mature specimens show distinct reddish-rusty streaks on the yellow stem.

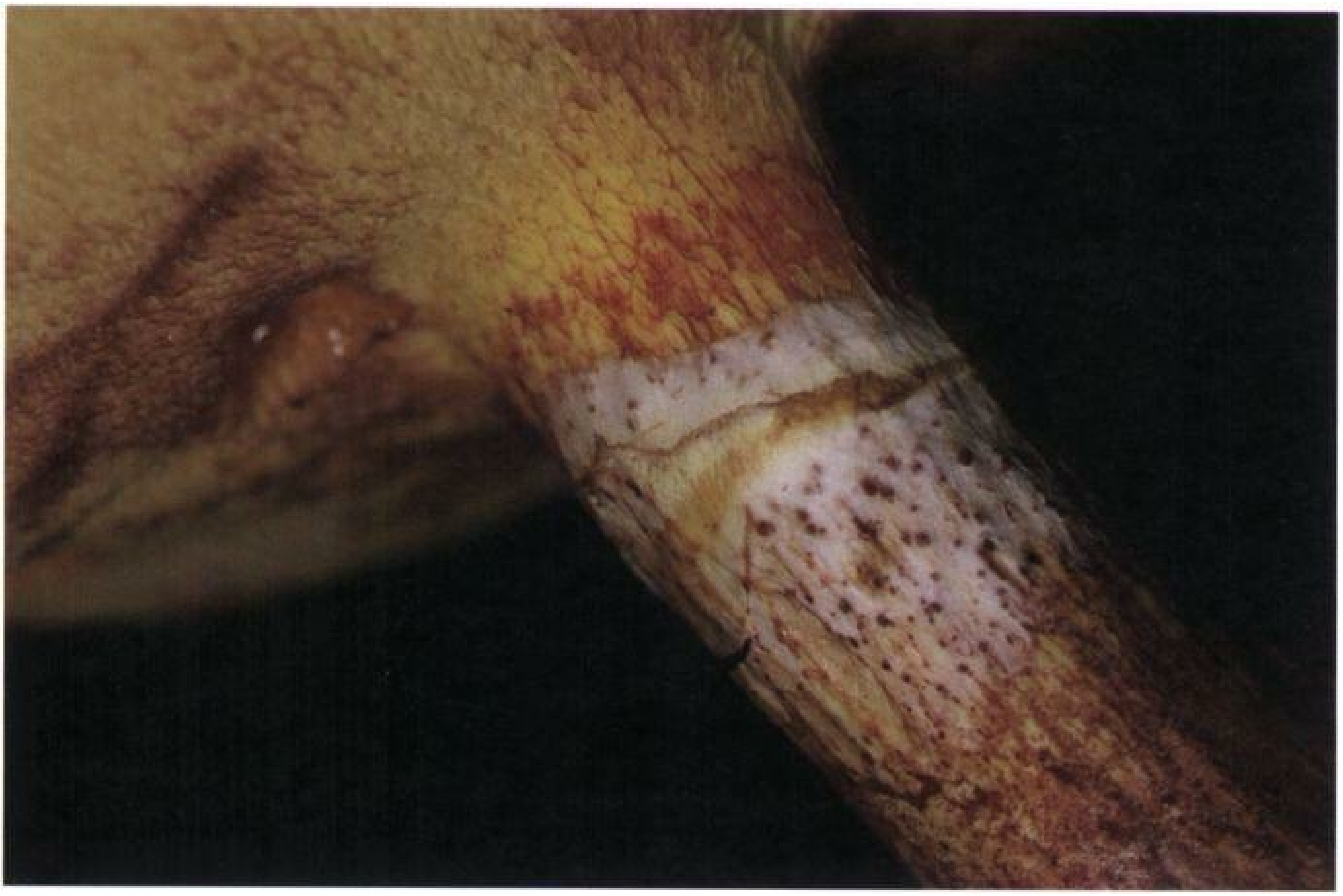

If a larch tree is nearby and you see several gold nuggets,they are bound to be larch boletes. The beautifully golden (and slimy when wet) caps are the key sign. Positive identification however requires ticking off all of the identification marks.

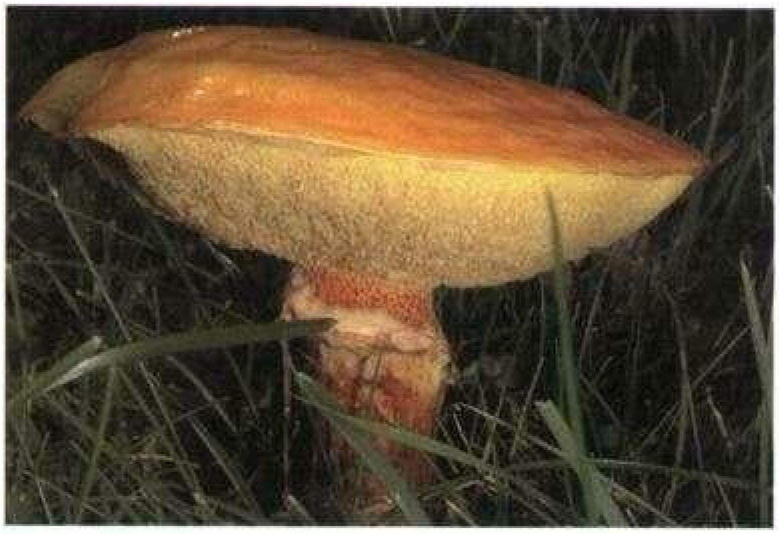
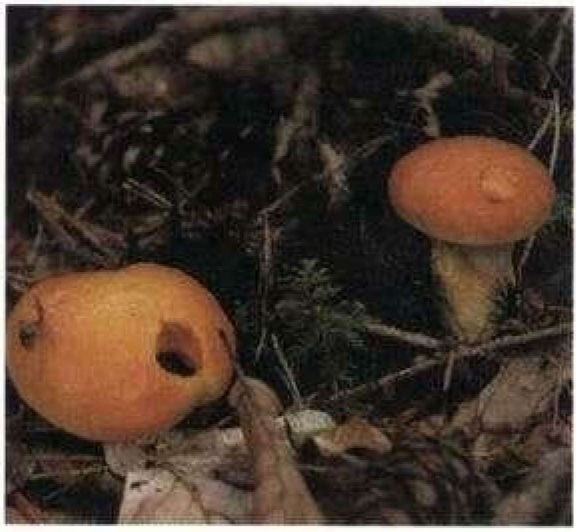
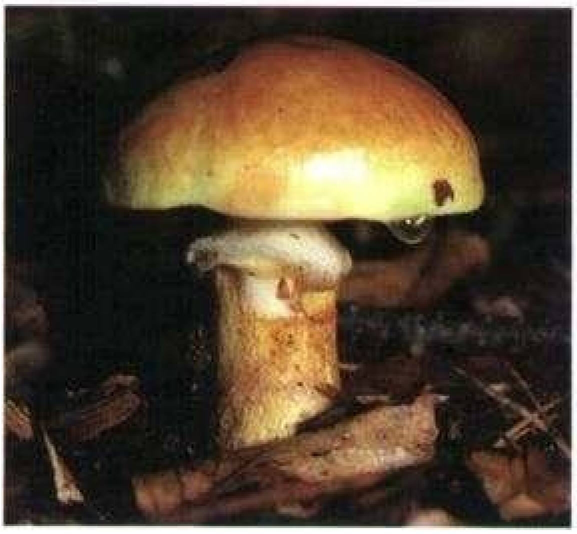
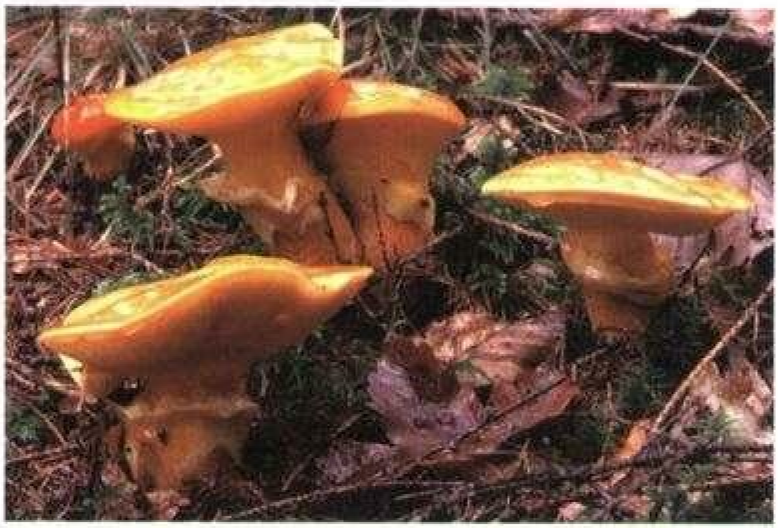

Positive ID Checklist

Larch Bolete

- ☐ Yellow tubes
- ☐ Solid stem
- ☐ Bright orange-yellow or golden-yellow sticky cap (slimy when wet).
- ☐ Flesh in cap flushes lilac (faint)
- ☐ Found near larch trees
- ☐ Other specimens found in the vicinity
- ☐ Young: tubes covered with a veil
- ☐ Intermediate stage: ring visible, faint net-pattern above ring zone
- ☐ Mature: ring zone still visible, faint network above ring zone
- ☐ Cap color matches cap color bar (above)

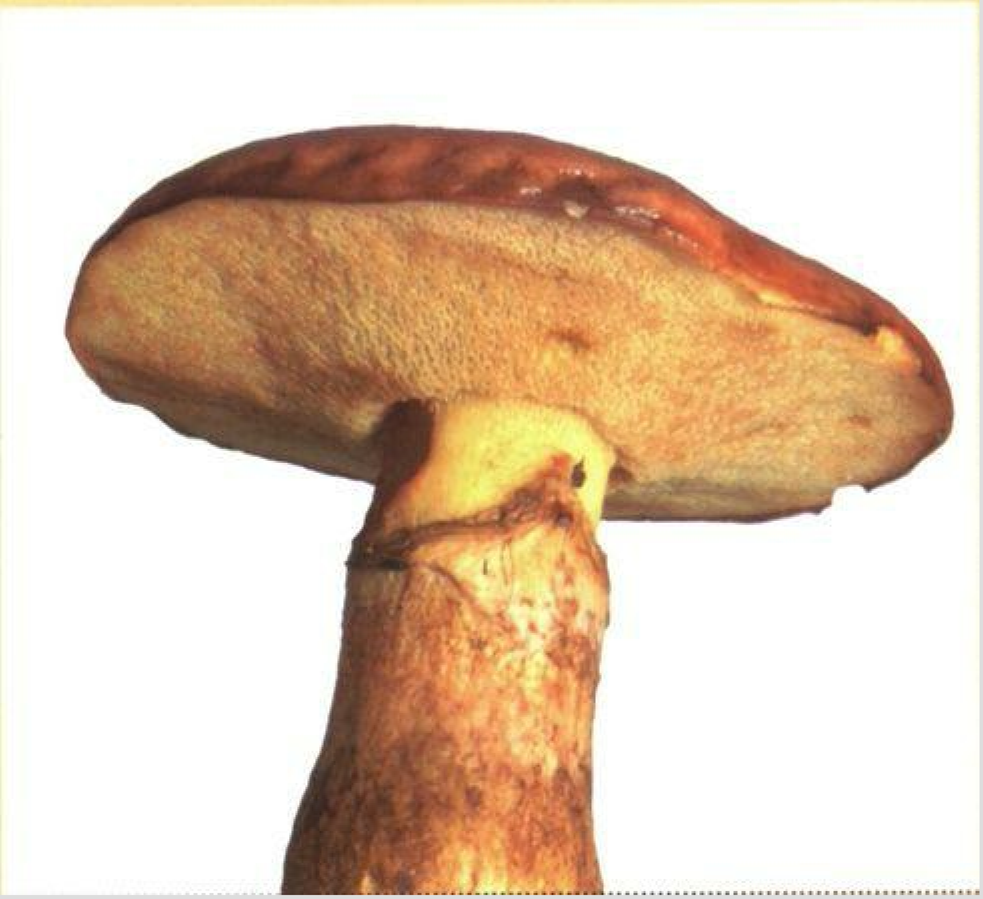

Avg. size across cap: 2.5 inches when mature

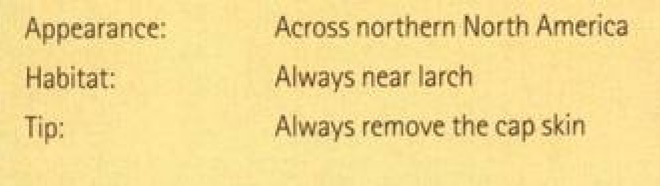

Appearance:	Across northern North America
Habitat:	Always near larch
Tip:	Always remove the cap skin

Bay Bolete

Xerocomus badius

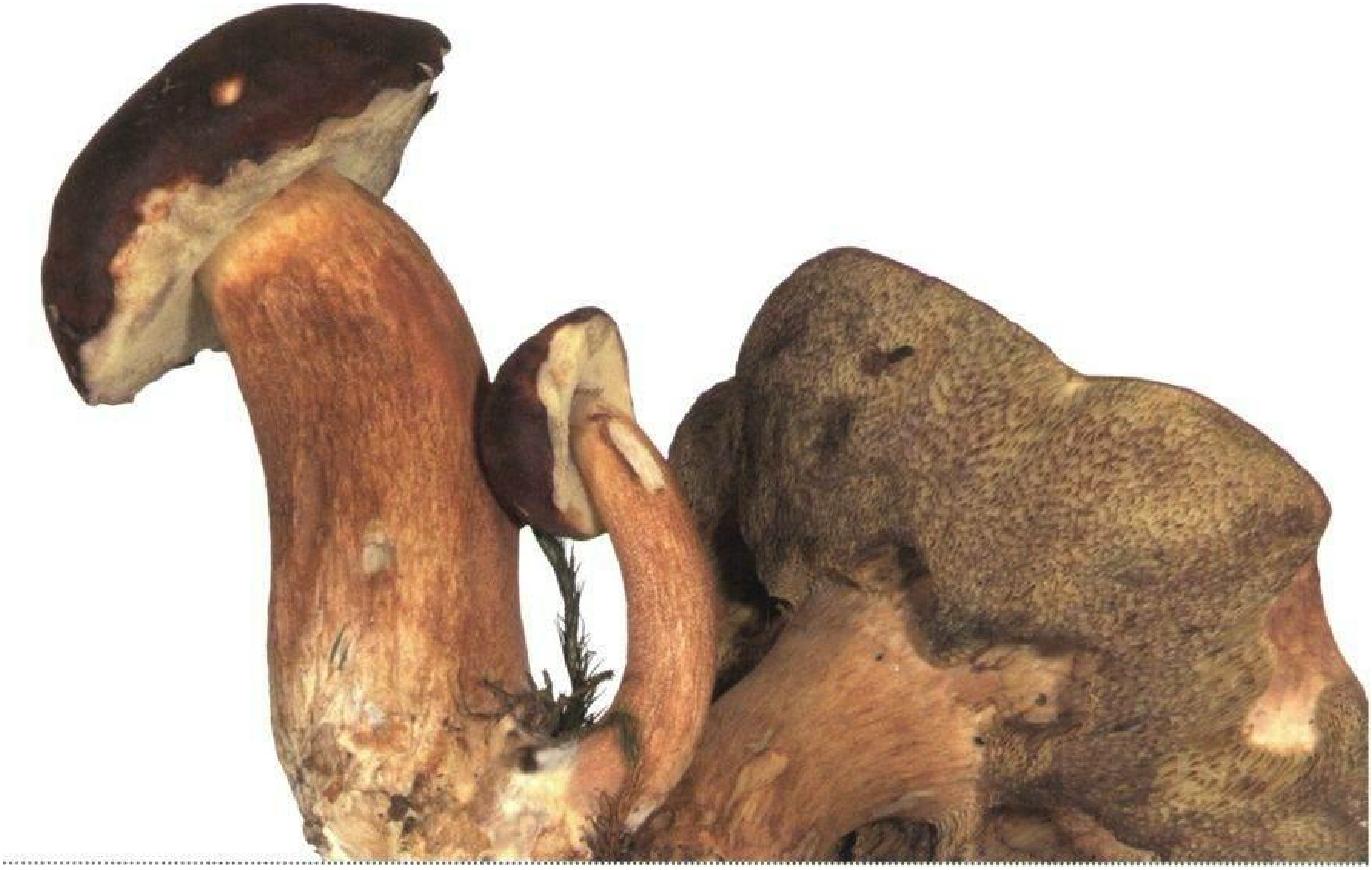

The bay bolete is an excellent mushroom and by good luck, it is also very common. The main bay bolete months are September and October but it can be found as early as June. If you find one, there are bound to be others nearby.

Badius means ‘beautifully brown.’

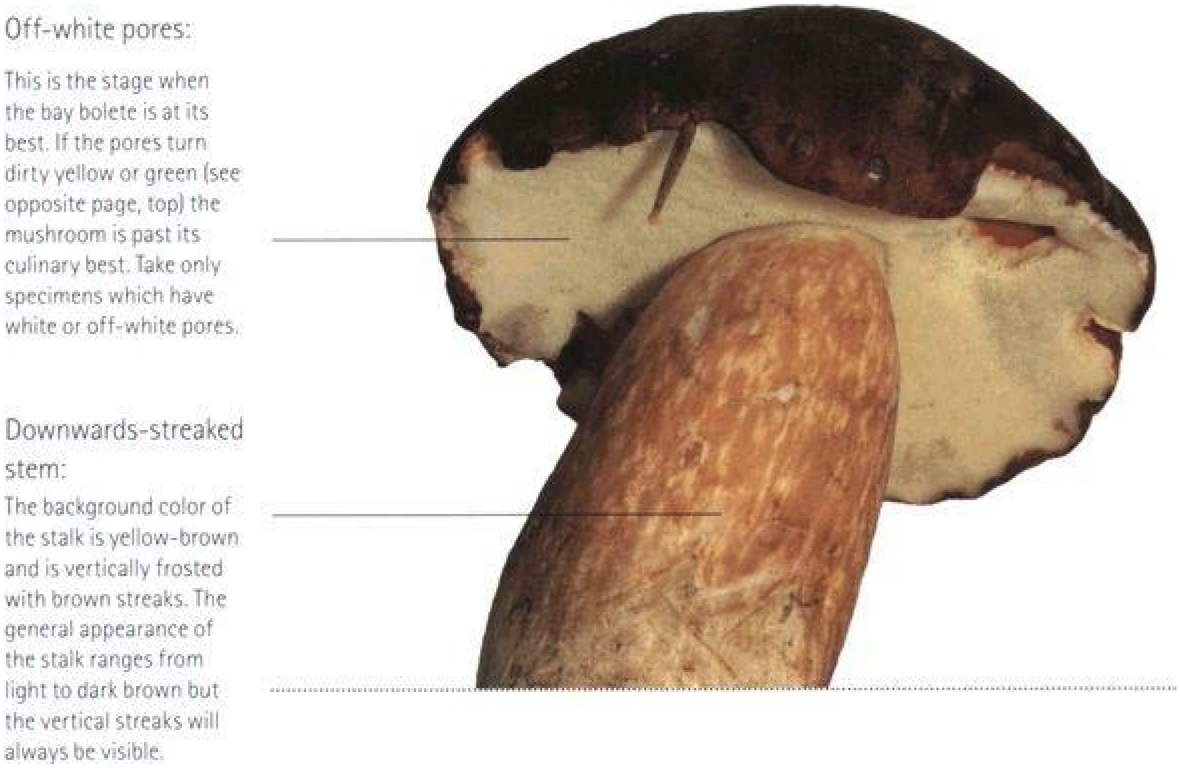

Off-white pores:

This is the stage when the bay bolete is at its best. If the pores turn dirty yellow or green (see opposite page, top) the mushroom is past its culinary best. Take only specimens which have white or off-white pores.

Downwards-streaked stem:

The background color of the stalk is yellow-brown and is vertically frosted with brown streaks. The general appearance of the stalk ranges from light to dark brown but the vertical streaks will always be visible.

The off-white pores bruise green-blue.

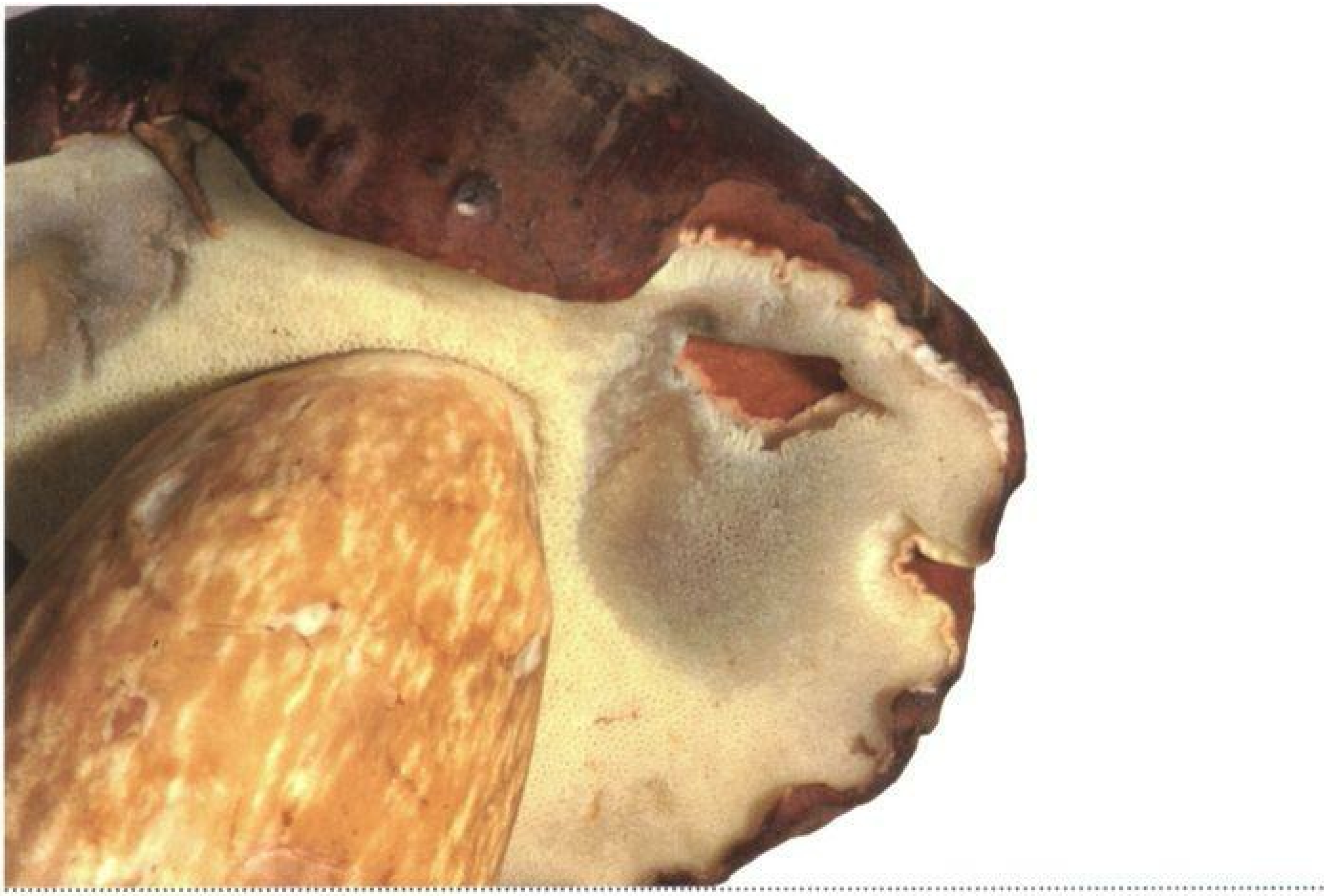

The change in color of the pores to green-blue varies in intensity. Here it’s quite extreme.

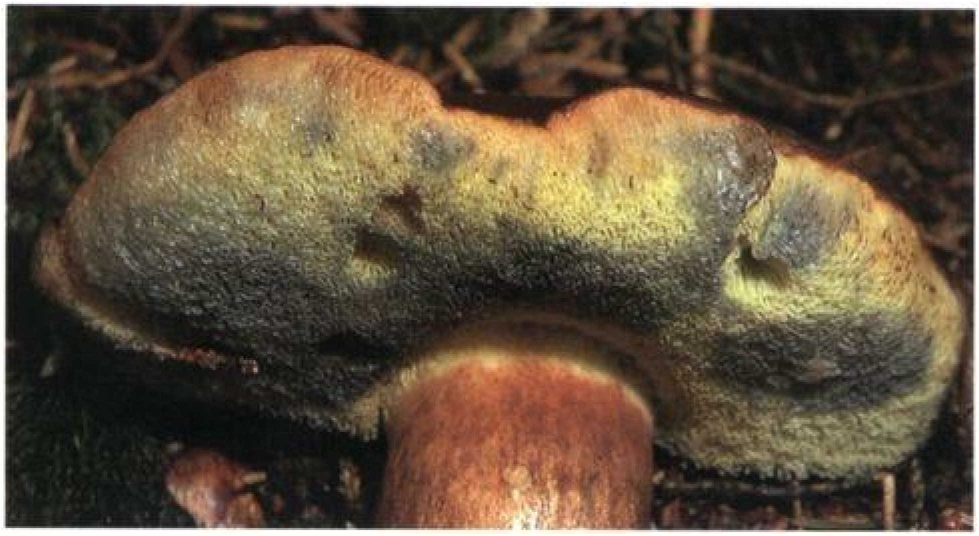

The young bay bolete has pale yellow tubes which then turn to yellow, olive-yellow and dirty olive-yellow as the mushroom matures. Whatever the stage, the tubes and the flesh bruise blue.

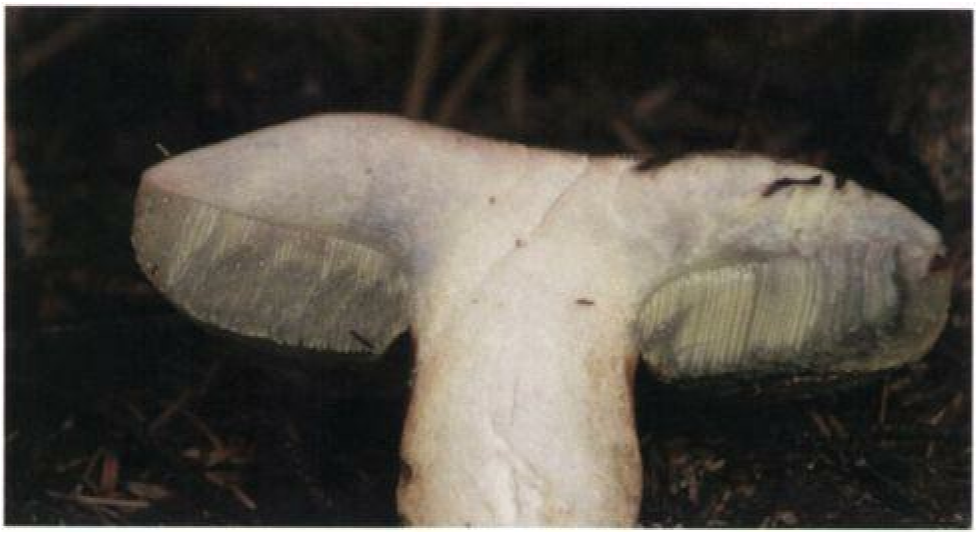

The intensity of the coloring varies but pores, tubes and flesh will always bruise green-blue.

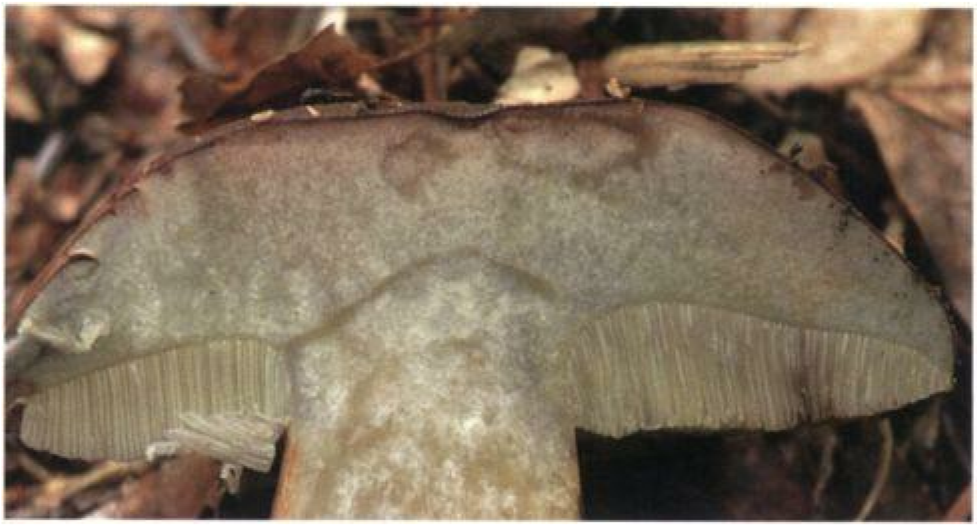

This is what the ideal bay bolete looks like: off-white pores and tubes, white to white-yellow flesh, without a trace of a worm.

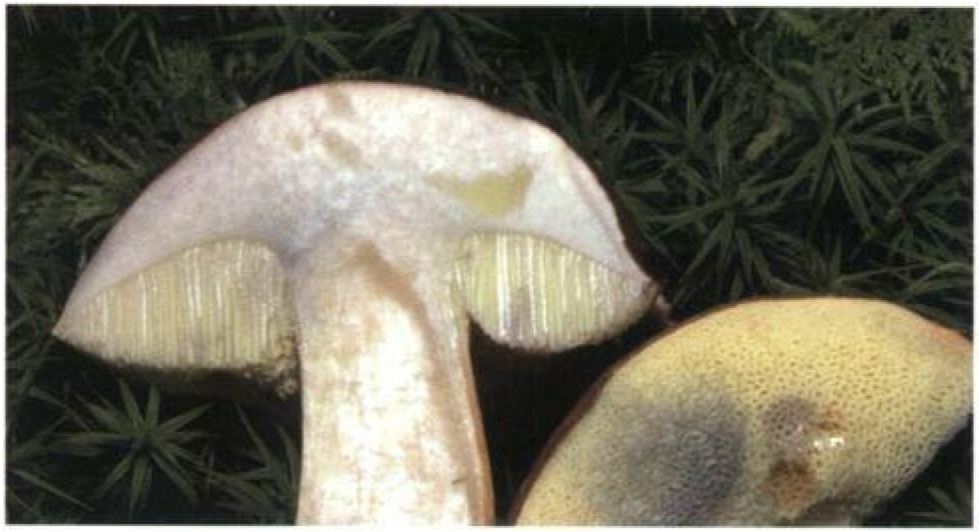

Not as good: but if you discard the soft pores and cut away the wormy parts, it will still be excellent.

The color of the cap will always be “bay” (chestnut brown) but bay has a considerable range.

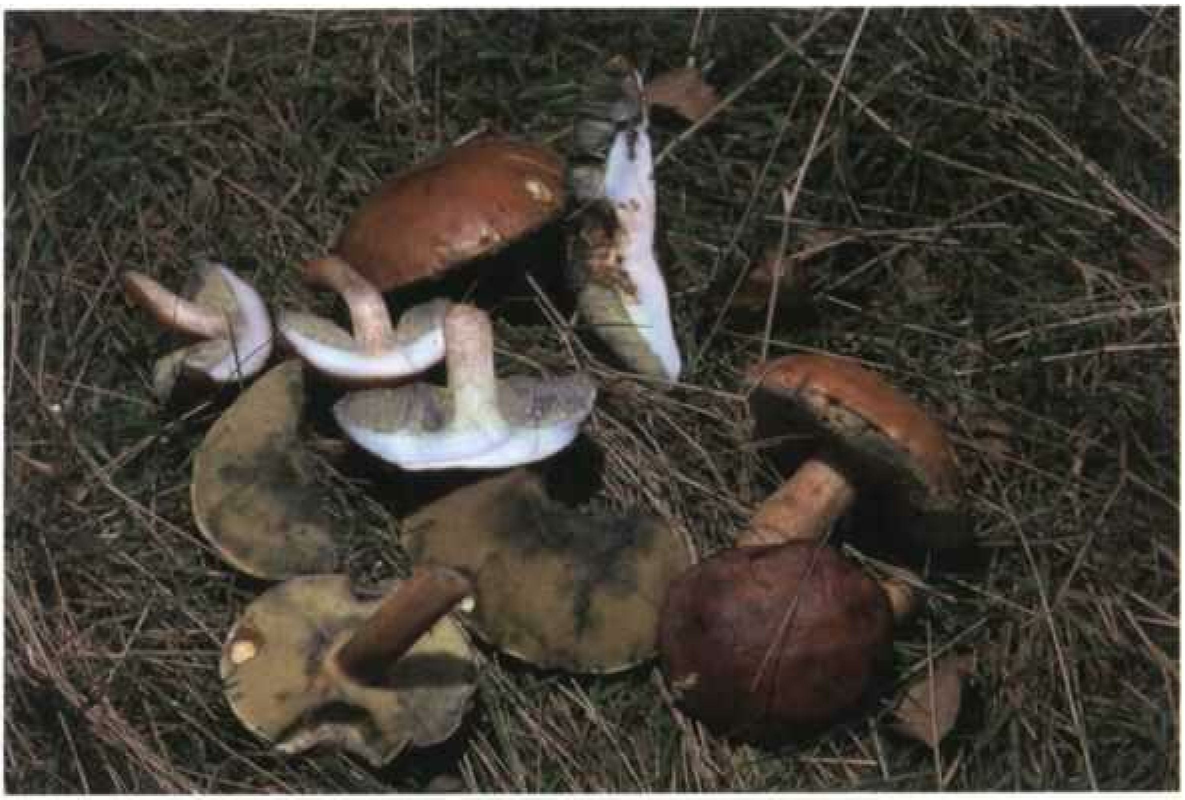

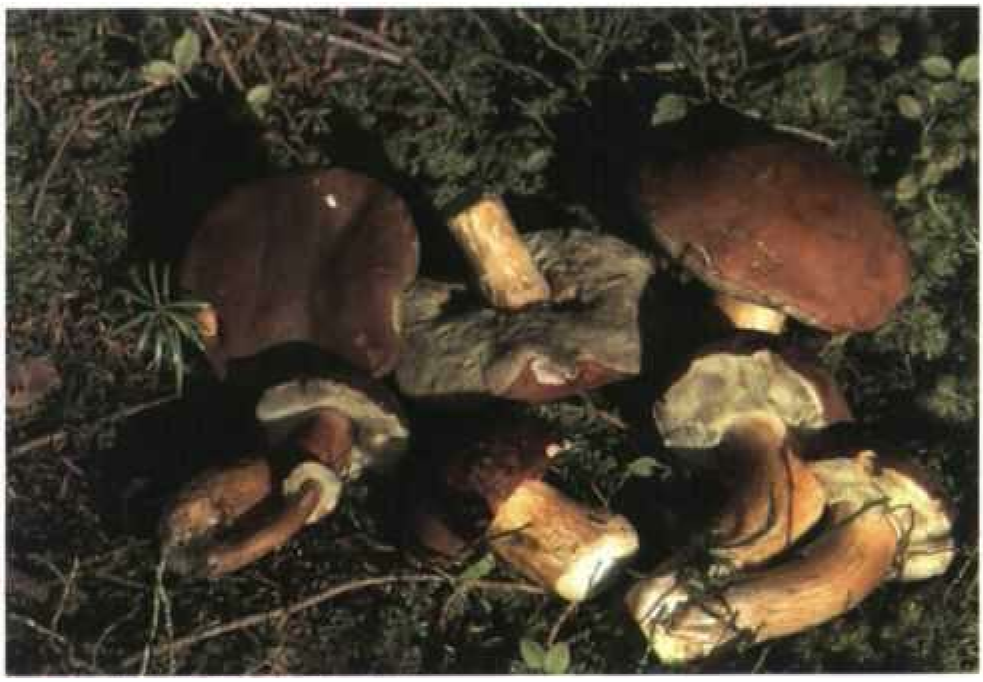

When wet, the cap will be slightly slimy and this will intensify the color of the cap.

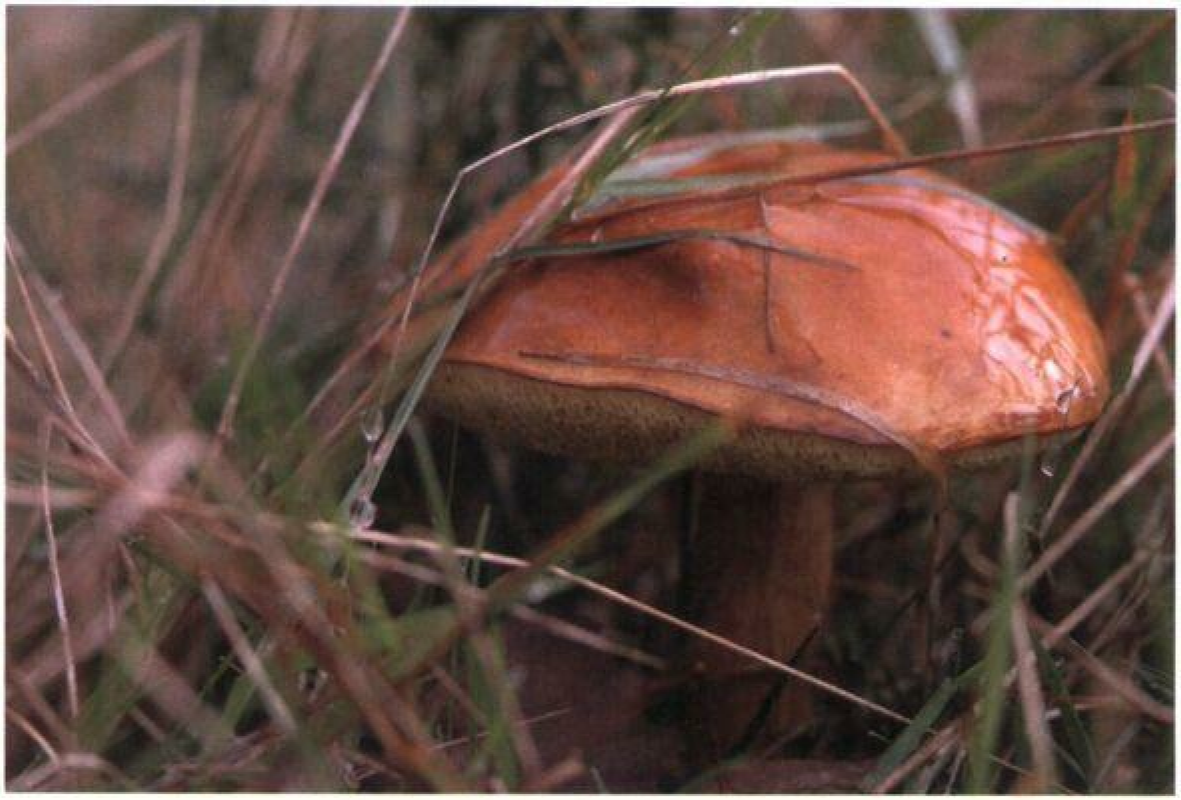

When dry, the color of the cap will be duller.

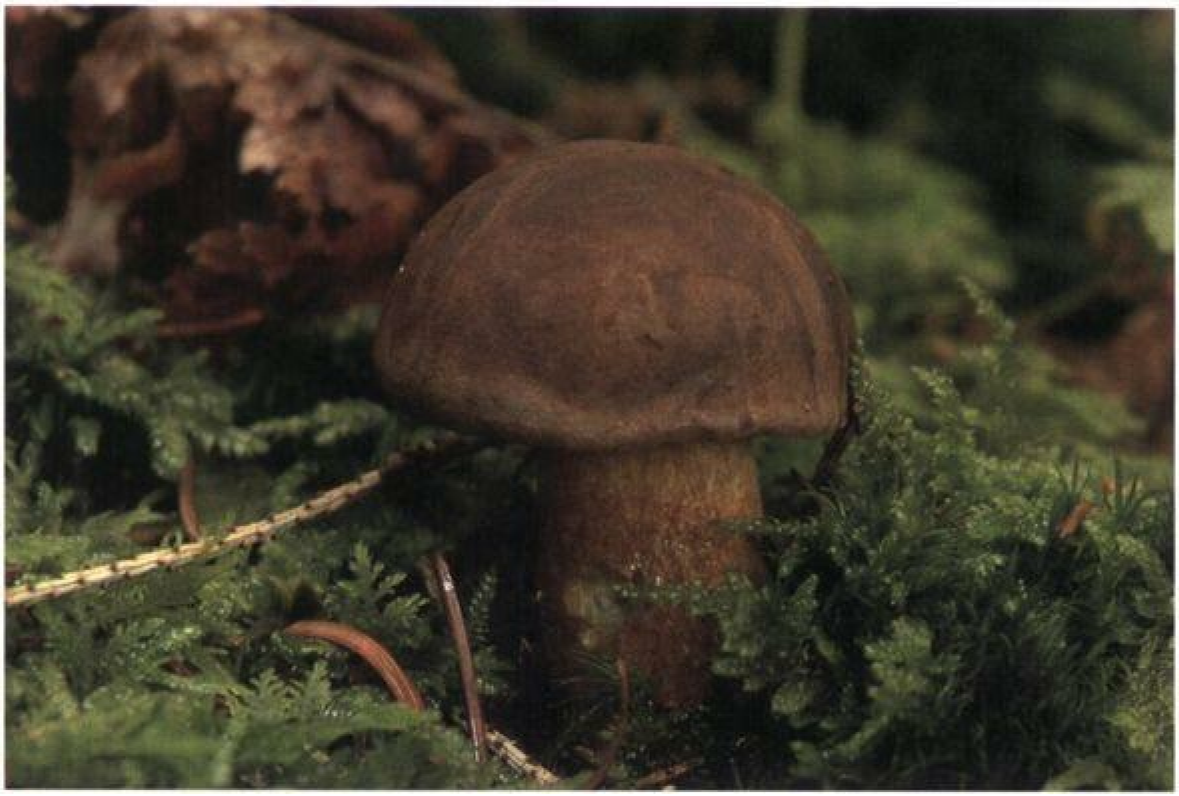

Positive ID Checklist

Bay Bolete

- ☐ Yellow tubes
- ☐ Off-white to gray pores (yellowish when aged) bruise green-blue
- ☐ Tubes and flesh bruise blue
- ☐ Stem is vertically frosted with brown streaks
- ☐ There is no net-pattern of any description on the stem
- ☐ Cap color matches cap color bar (above)

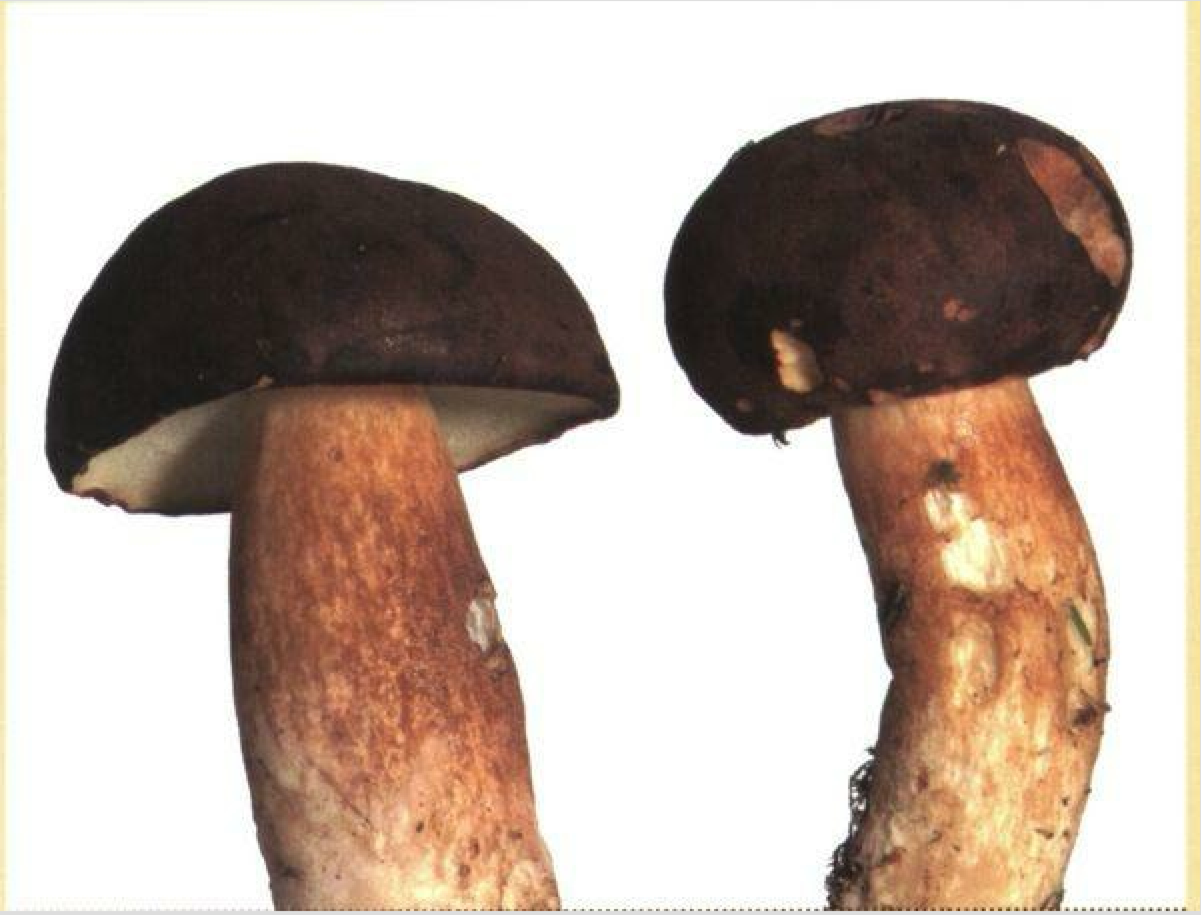

Avg. size across cap: 3.5 inches when mature

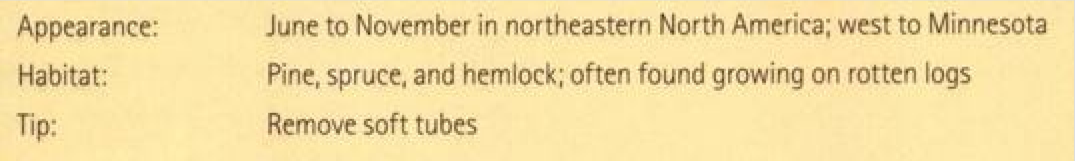

Appearance:	June to November in northeastern North America; west to Minnesota
Habitat:	Pine, spruce, and hemlock; often found growing on rotten logs
Tip:	Remove soft tubes

Birch Bolete

Leccinum scabrum

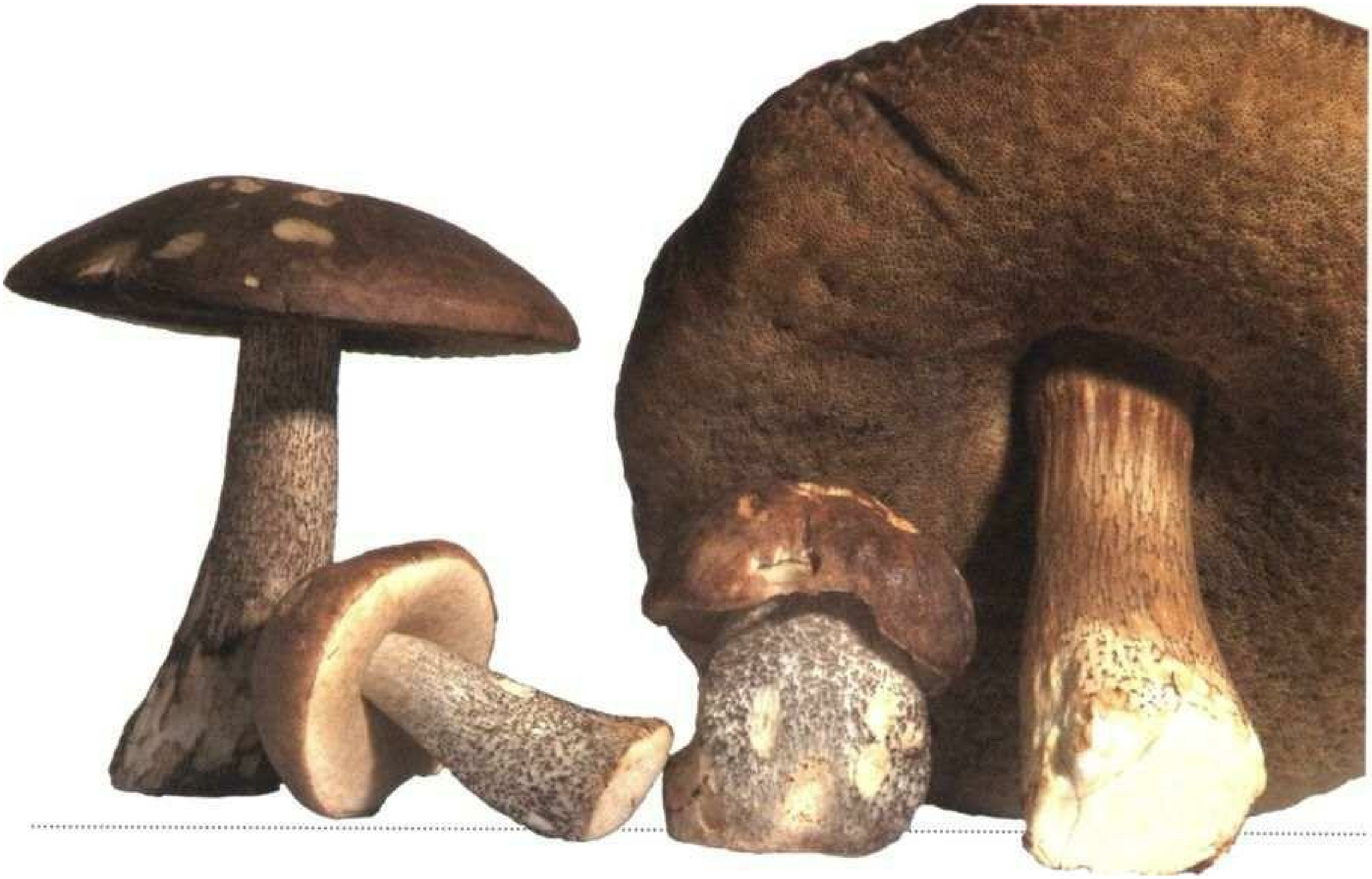

The birch bolete is the most common of the “rough stalks.” Rough stalks are mushrooms with a scaly stem. The birch bolete and its cousin, the orange birch bolete, are the most common rough stalks.
Birch woods or groups of birch trees are the places to look for them.
The birch bolete and the orange birch bolete have numerous relatives, all of which have a black or brown scaly stalk. They are all edible but it is recommended to stick to the two species presented here.

Scabrum means “rough.”

Close-up of stalk, showing black scales.

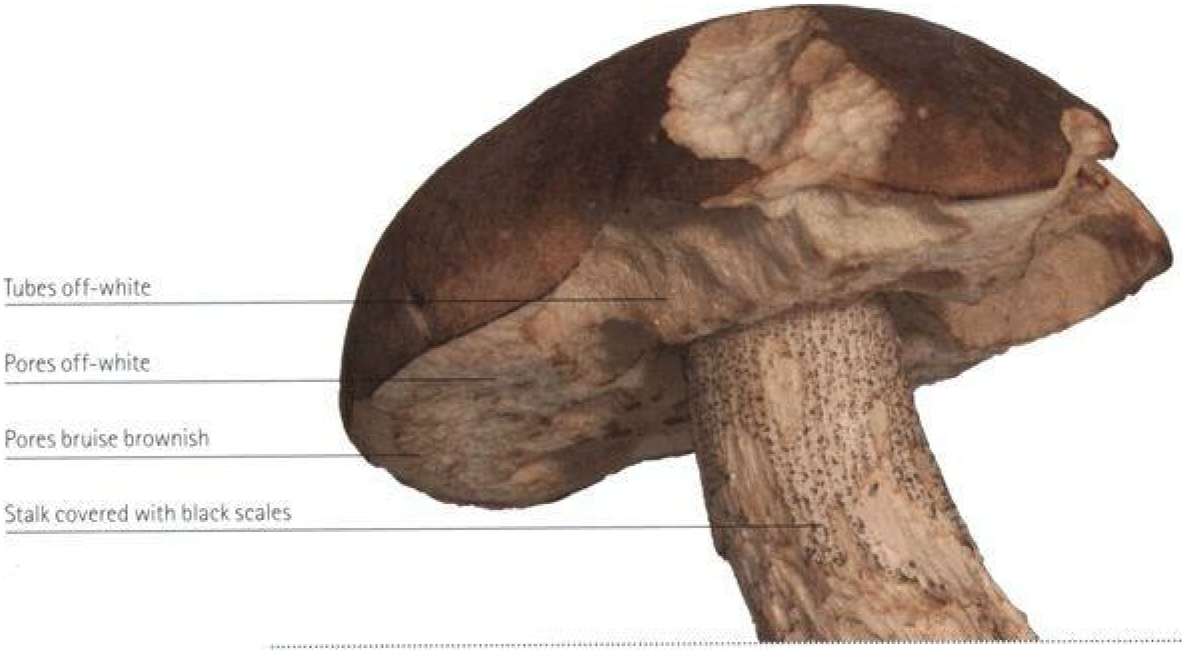
Tubes off-white
Pores off-white
Pores bruise brownish
Stalk covered with black scales

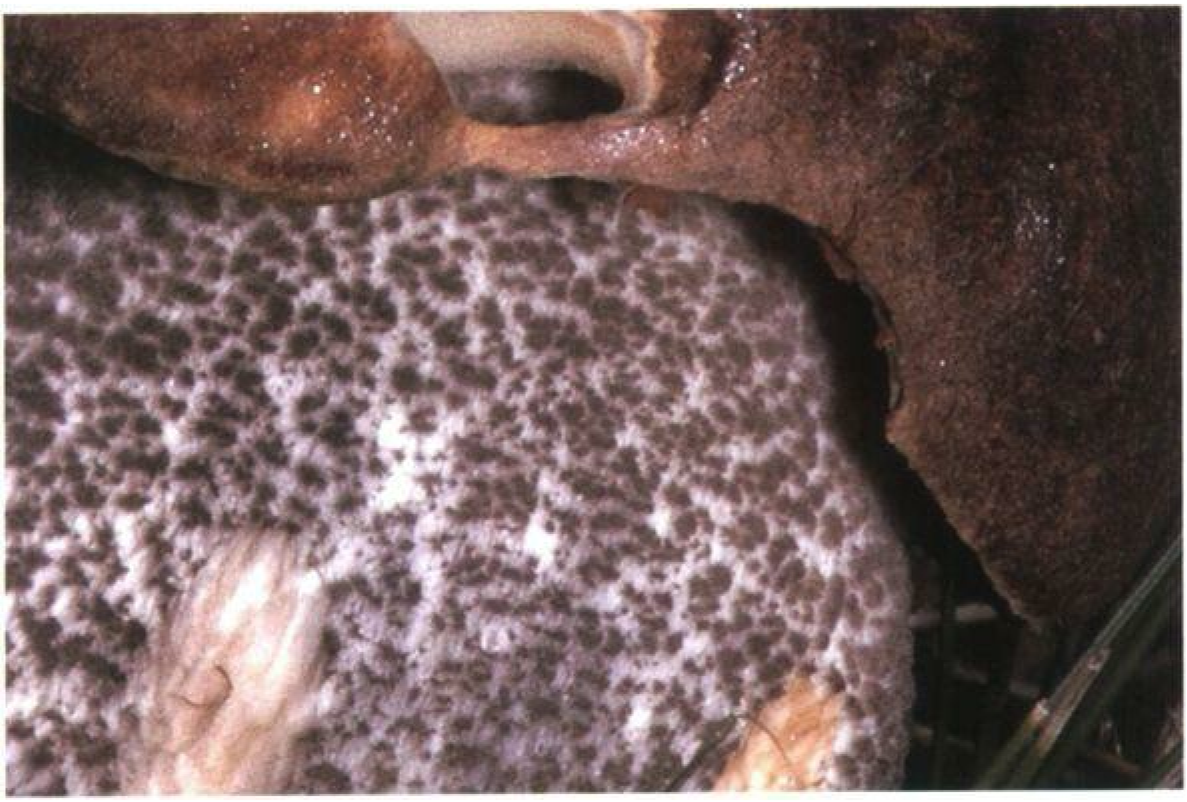

Pores and tubes change from off-white to a gray-white color as the mushroom matures. As a rule, you should only pick the birch bolete if it is firm and the pores are off-white.

Occasionally larger specimens are still nice and firm especially when conditions have been very dry.

These are the perfect birch boletes: a feast for the eyes and delicious to eat.

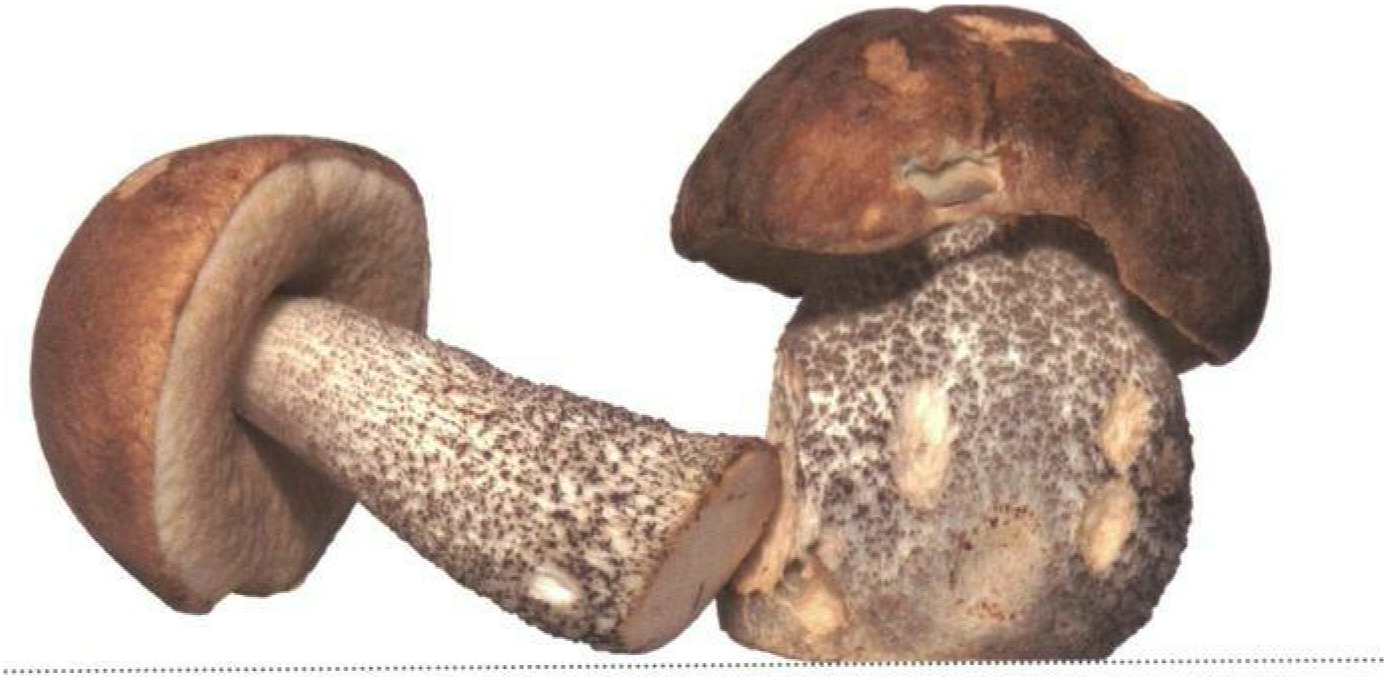

The orange birch bolete, *Leccinum versipelle,* is a beautiful mushroom. Its key identification mark is the stem covered with black scales, and of course the orange cap. When cut, the flesh turns faintly blue at the stalk base, displays traces of wine red and finally turns and stays gray. This color combination doesn’t look especially appetizing but be assured the orange birch bolete is delicious.

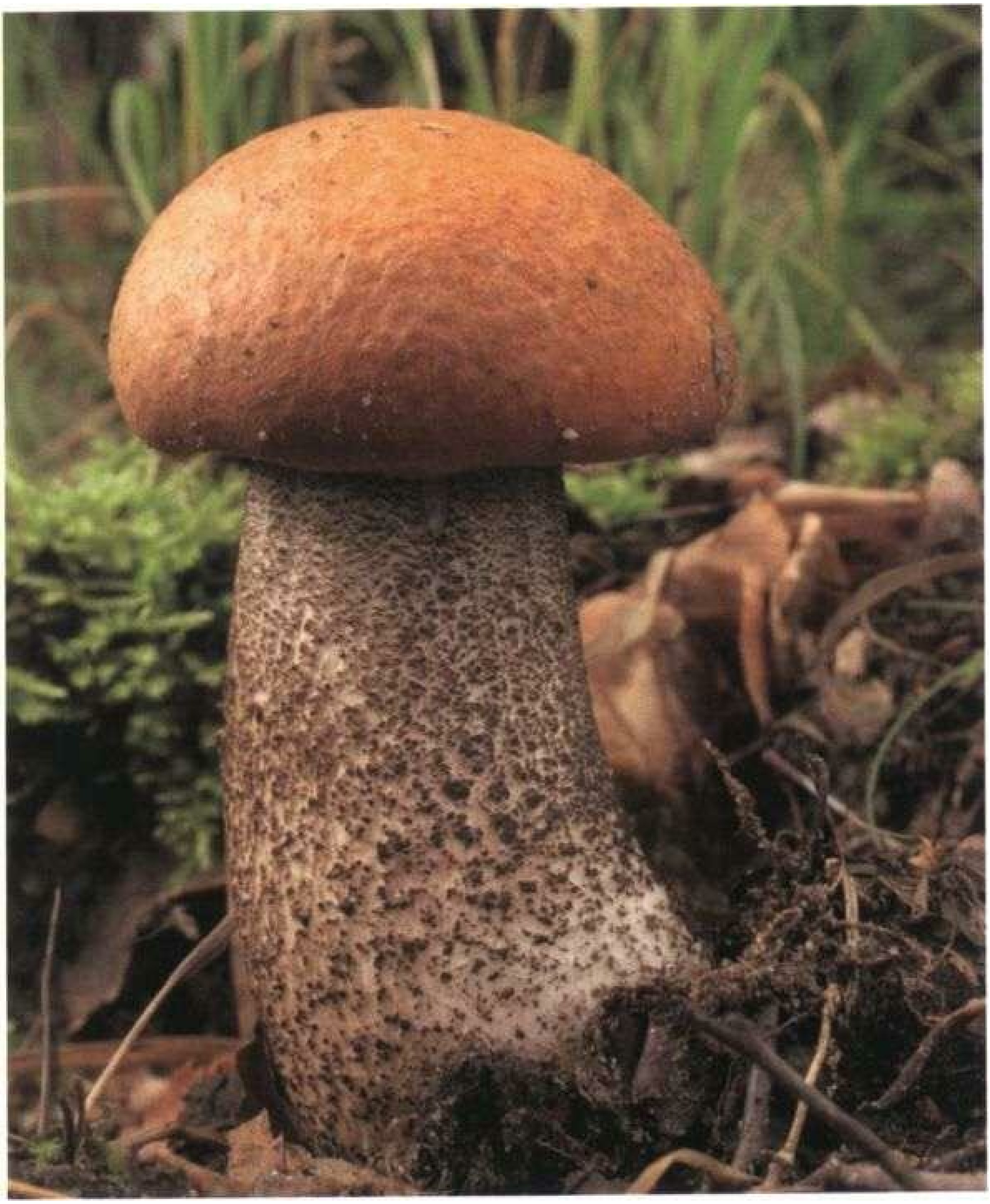

Positive ID Checklist

Birch Bolete

- ☐ Pores off-white
- ☐ Pores bruise brownish
- ☐ Stalk with small black scales
- ☐ Cap color matches cap color bar (above)

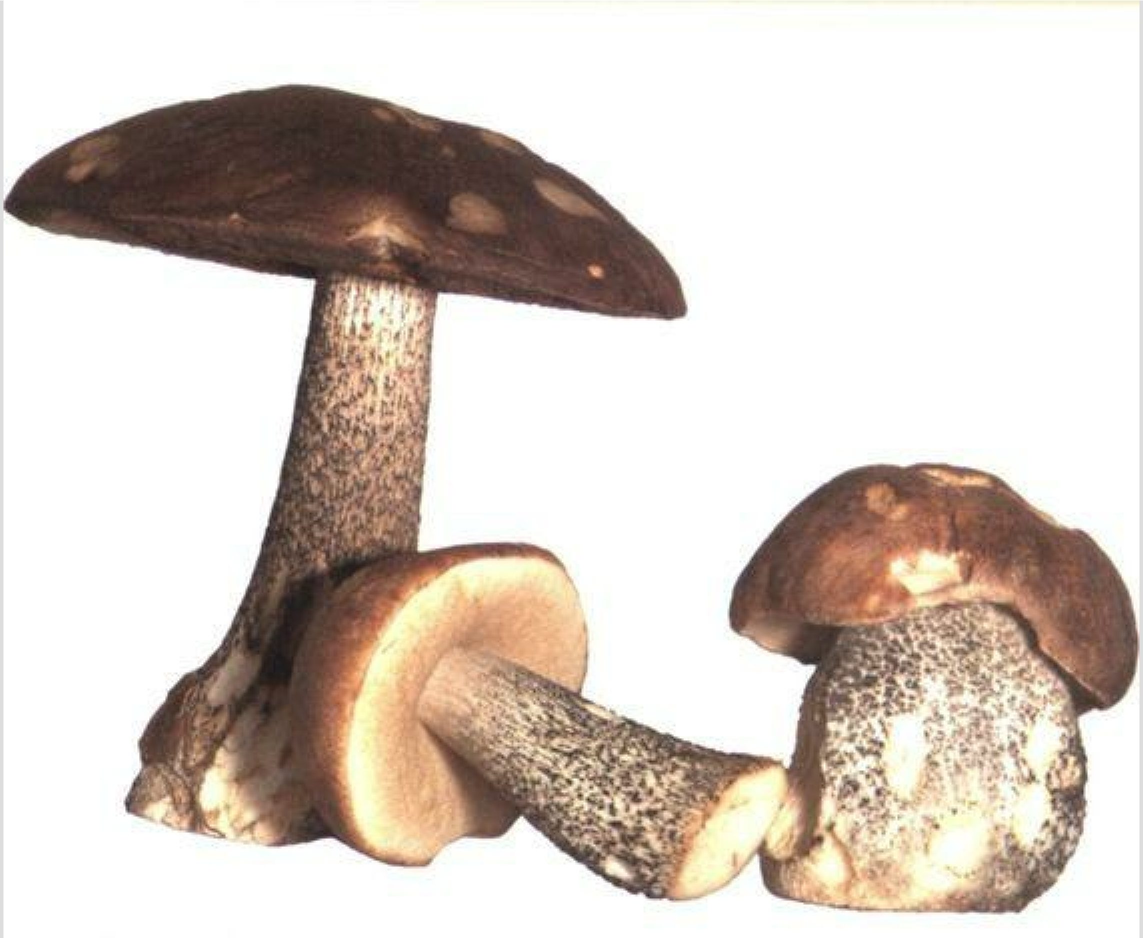

Avg. size across cap: 3.5 inches when mature

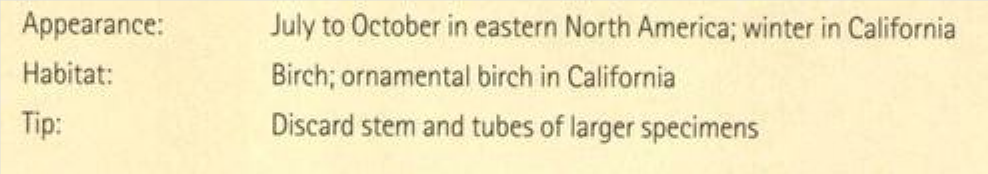

Appearance:	July to October in eastern North America; winter in California
Habitat:	Birch; ornamental birch in California
Tip:	Discard stem and tubes of larger specimens

Always remember

Rule number 1

Never, never take a mushroom with gills!!!

Rule number 2

Only take mushrooms with tubes, spines, and ridges and the mavericks portrayed in this book

Rule number 3

Only eat mushrooms which you have clearly identified with ALL the positive ID marks

Rule number 4

If a mushroom smells rotten, it is rotten and if it feels soggy, it is soggy

Rule number 5

Never, never eat wild mushrooms raw

Rule number 6

Look before you cut

Rule number 7

Mushrooms want to breathe. Do not suffocate them in plastic bags

Rule number 8

If in doubt, leave it

Mushrooms With Ridges

Chanterelle

Cantharellus cibarius

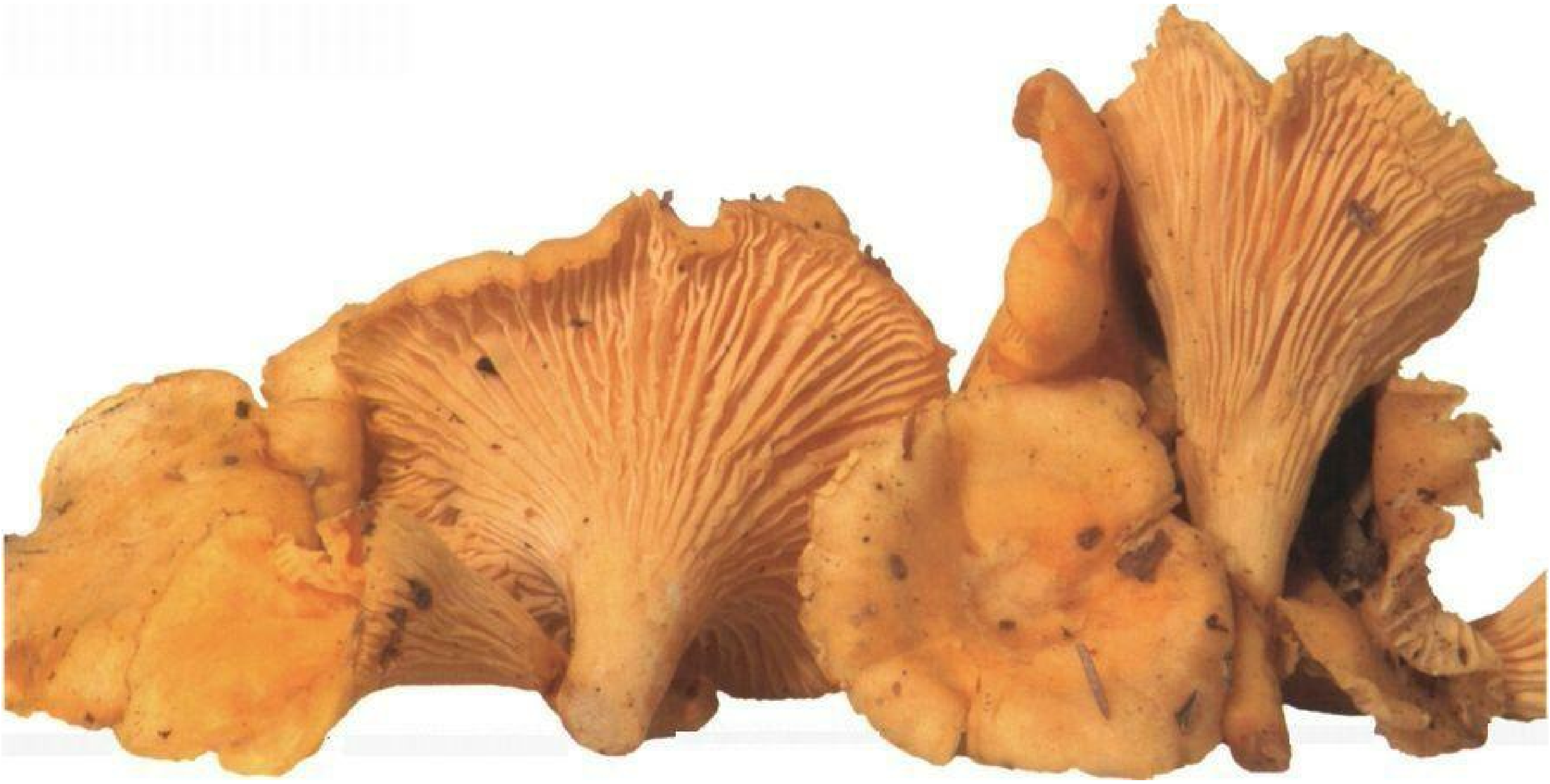

The chanterelle is not surprisingly the most popular mushroom. It is delicious and very common. As it is imported throughout the year, the supermarket is a good place to familiarize yourself with the chanterelle. There is, however, nothing like the chanterelle you find yourself. Refrain from picking tiny chanterelles, that is, little yellow buttons which hardly show the identification marks. At some time you'll come across one lonely chanterelle standing there in the middle of nowhere for no particular reason at all. Leave it.

Cibarius means "belonging to food."

The classic color of the chanterelle is egg-yolk yellow which, however, can vary from light yellow or yellow-orange to yellow-ochre. The chanterelle does not change color when bruised. The entire mushroom is of the same color.

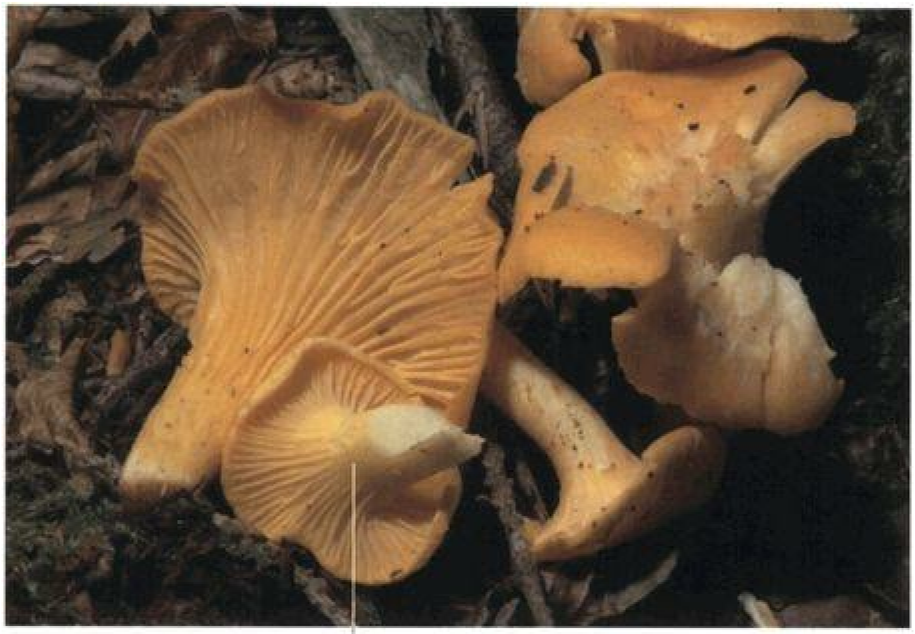

Young chanterelles have a flat cap with a slightly out-rolled margin. Do not pick any chanterelles smaller than 3 cm high.

The more mature the chanterelle, the more funnel-shaped it becomes.

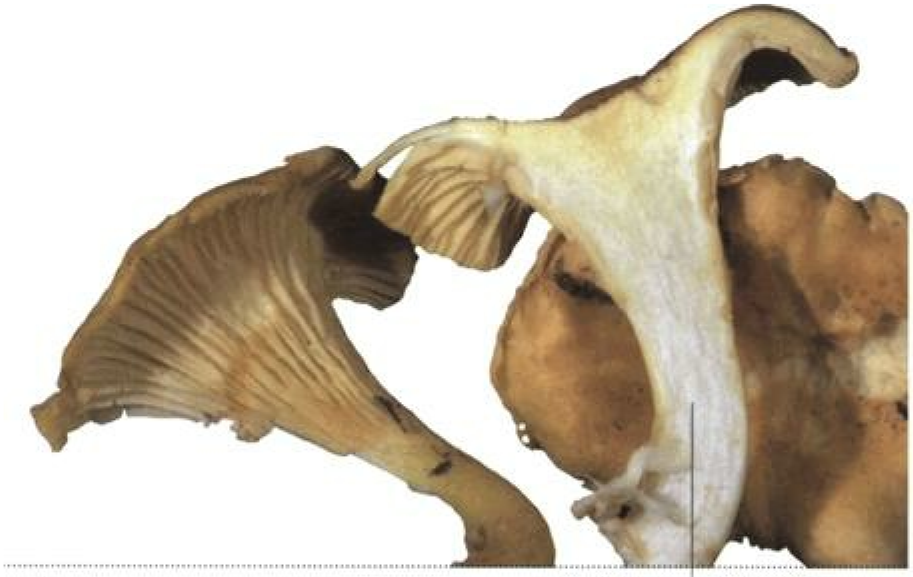

The stalk is solid. The whitish to yellowish flesh does not change color when bruised or cut.

Whether young or mature, the chanterelle’s ridges must be clearly visible.

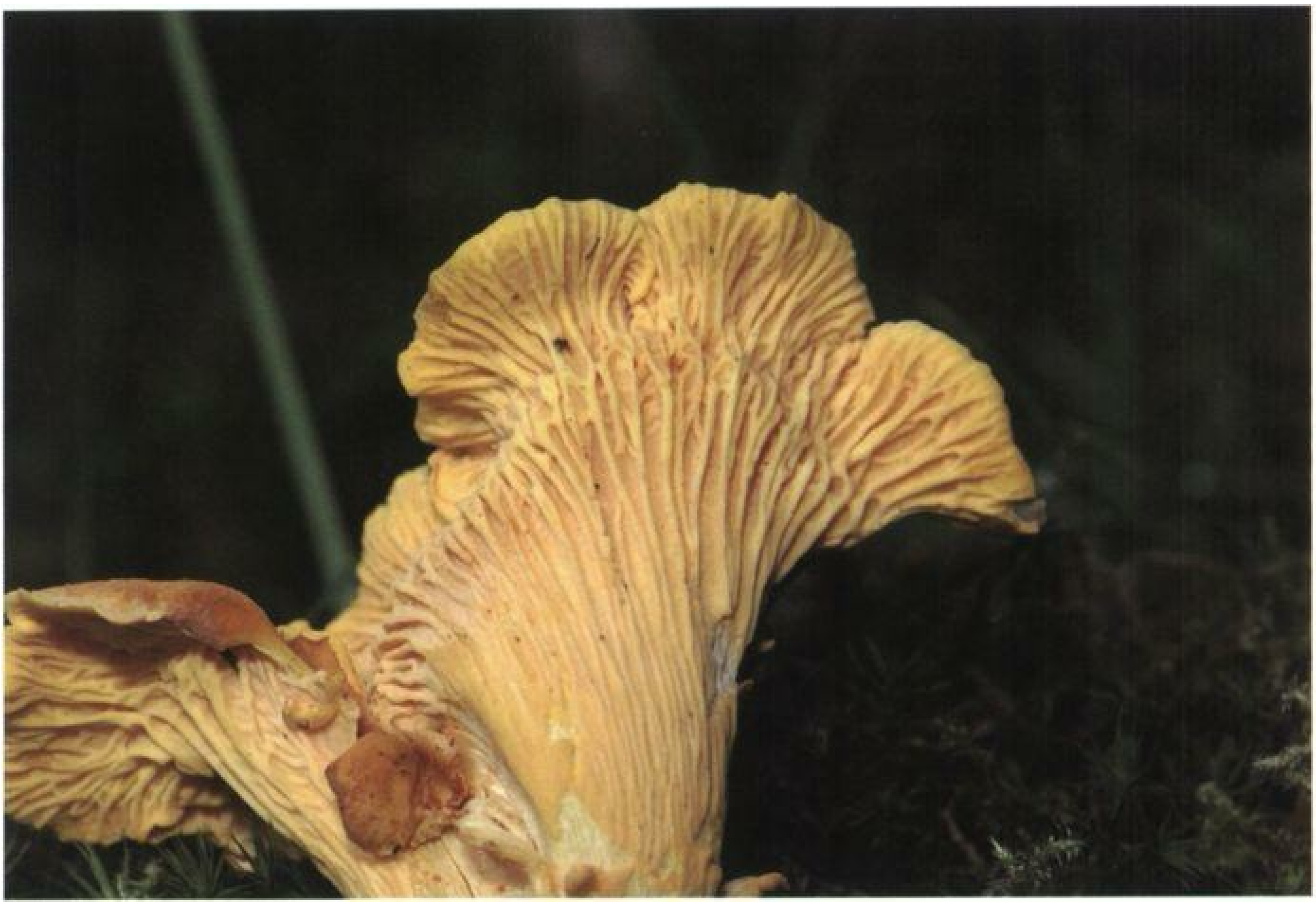

Some mature forms can look highly irregular but on closer inspection, the funnel shape will still be there.

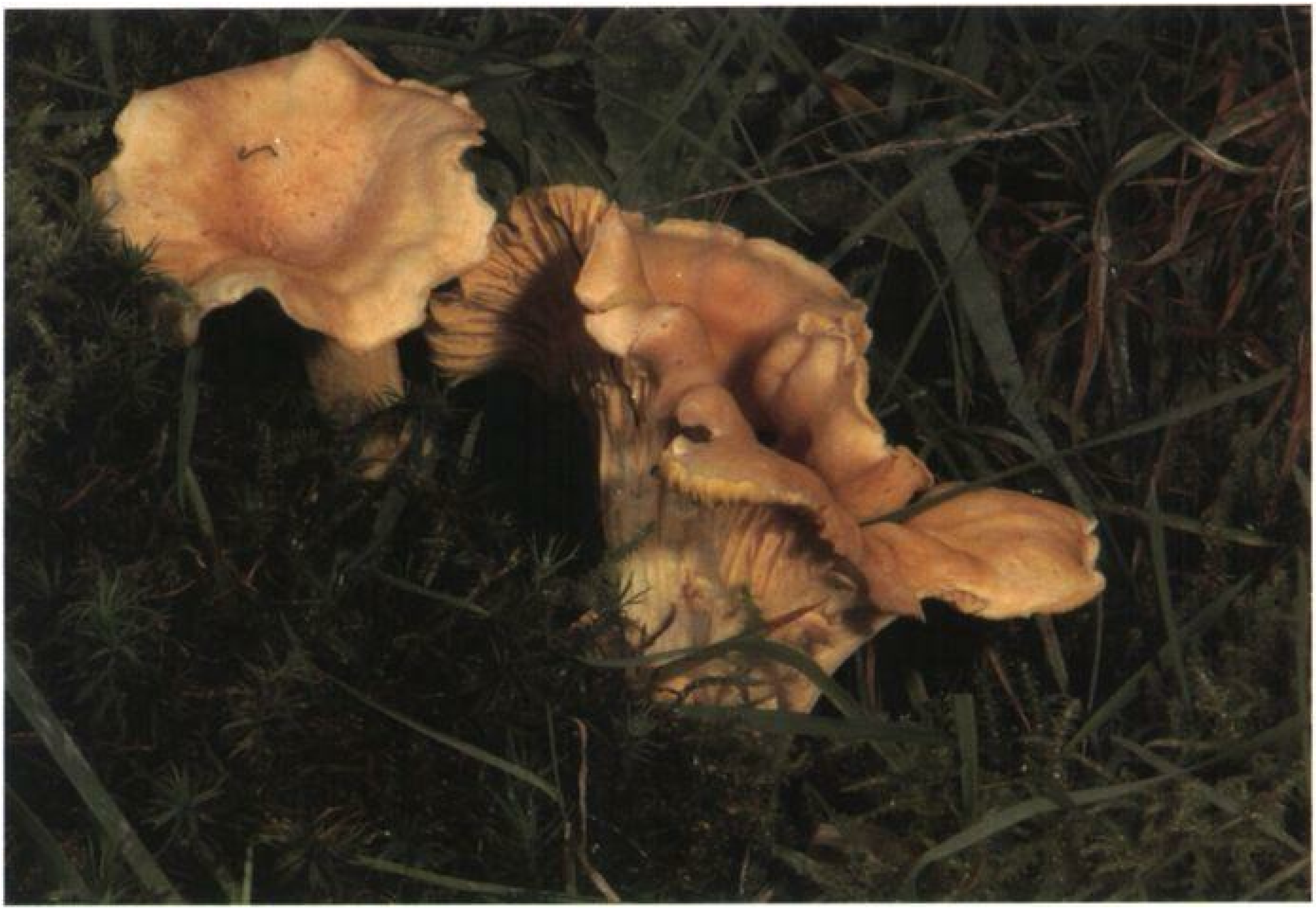

Positive ID Checklist

Chanterelle

☐ Young specimen: Flat, wavy-edged cap, slightly out-rolled margin
☐ Mature specimen: Funnel-shaped
☐ Solid stem
☐ Found in groups on the ground, but not clustered at the base of trees; never on wood
☐ Ridges must be clearly visible
☐ Color matches cap color bar range (above)

Be Careful:

Don’t mistake the chanterelle for the Jack O‘Lantern, a mushroom that grows across eastern North America. The Jack O’Lantern is orange, glows in the dark, has gills, and is not edible.

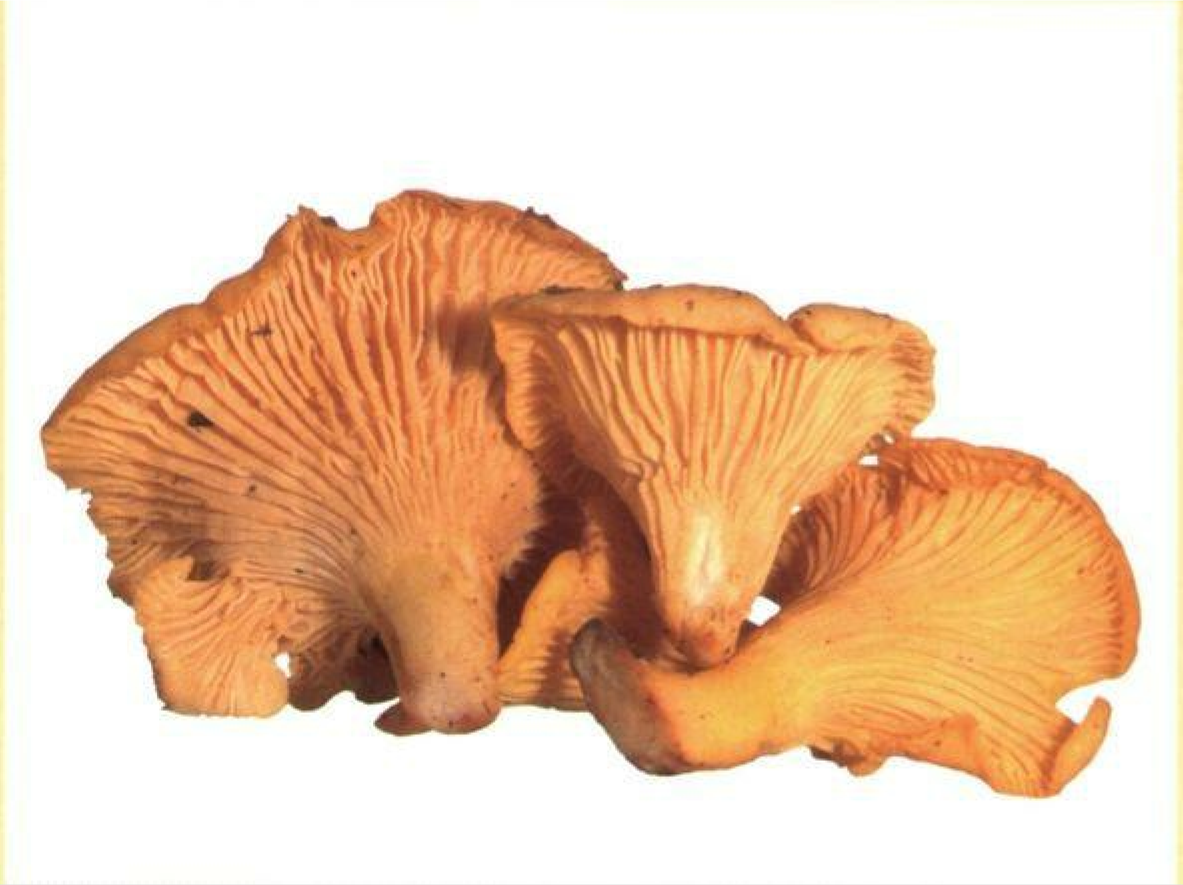

Avg. size across cap: 2 inches when mature

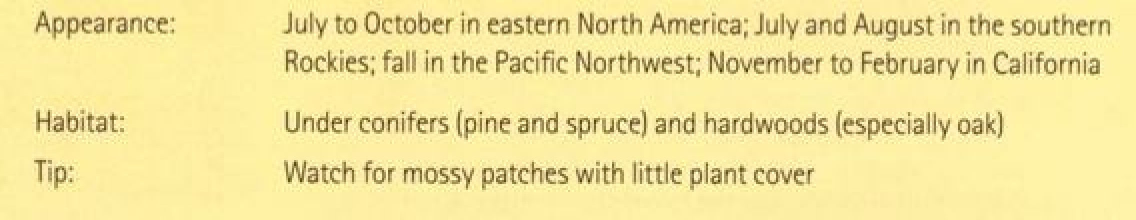

Appearance:	July to October in eastern North America; July and August in the southern Rockies; fall in the Pacific Northwest; November to February in California
Habitat:	Under conifers (pine and spruce) and hardwoods (especially oak)
Tip:	Watch for mossy patches with little plant cover

Trumpet Chanterelle

Cantharellus tubaeformis

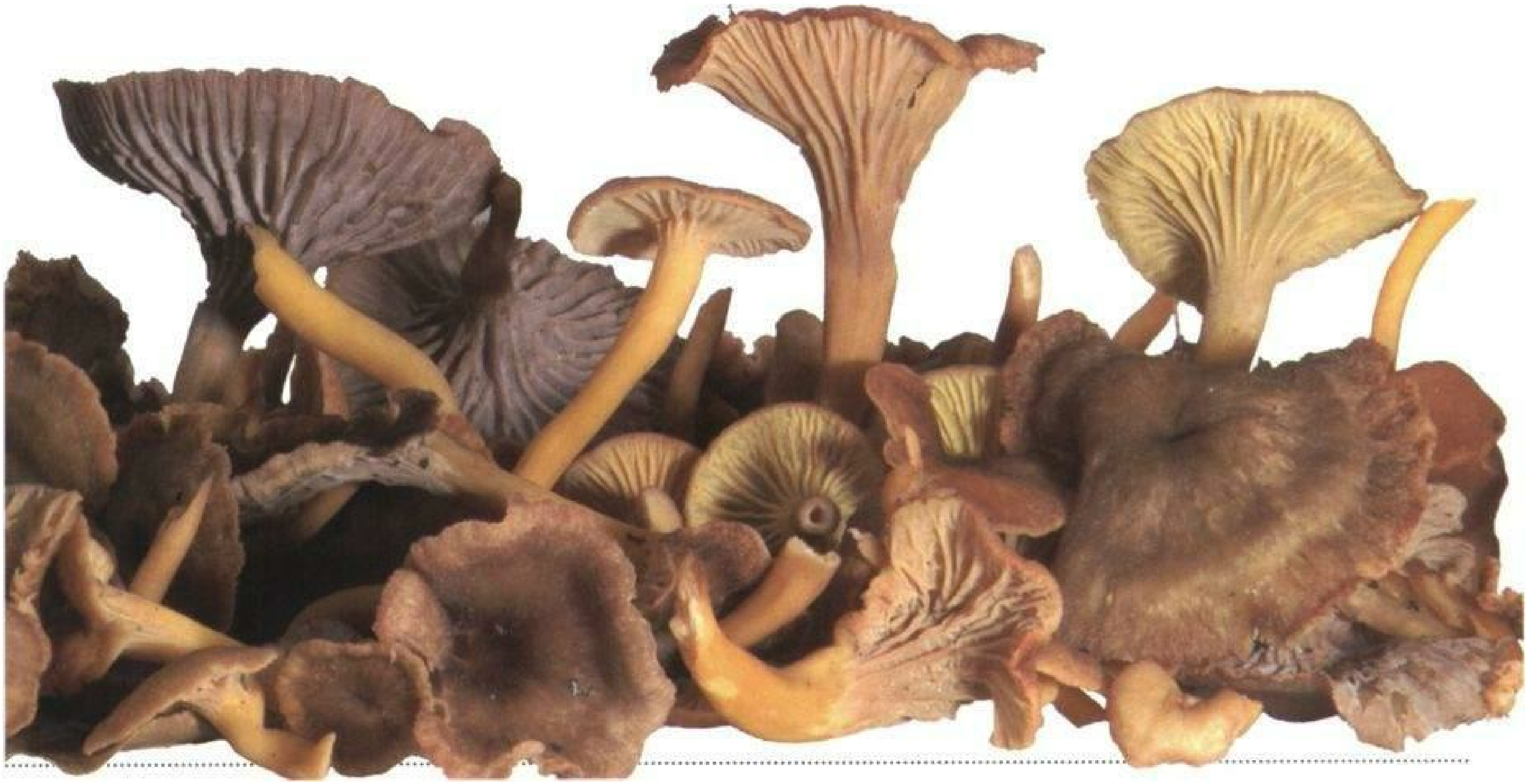

In comparison to the attractively-colored chanterelle, the trumpet chanterelle (also known as the autumn chanterelle, and winter chanterelle) looks modest. On closer inspection, however, it is just as beautiful as the chanterelle. The trumpet chanterelle pops up overnight so quickly that you could watch it grow. It is an endearing mushroom not least because it tends to appear in great numbers and is frost-resistant.

Tubaeformis means “trumpet-shaped.”

A cluster of trumpet chanterelles.

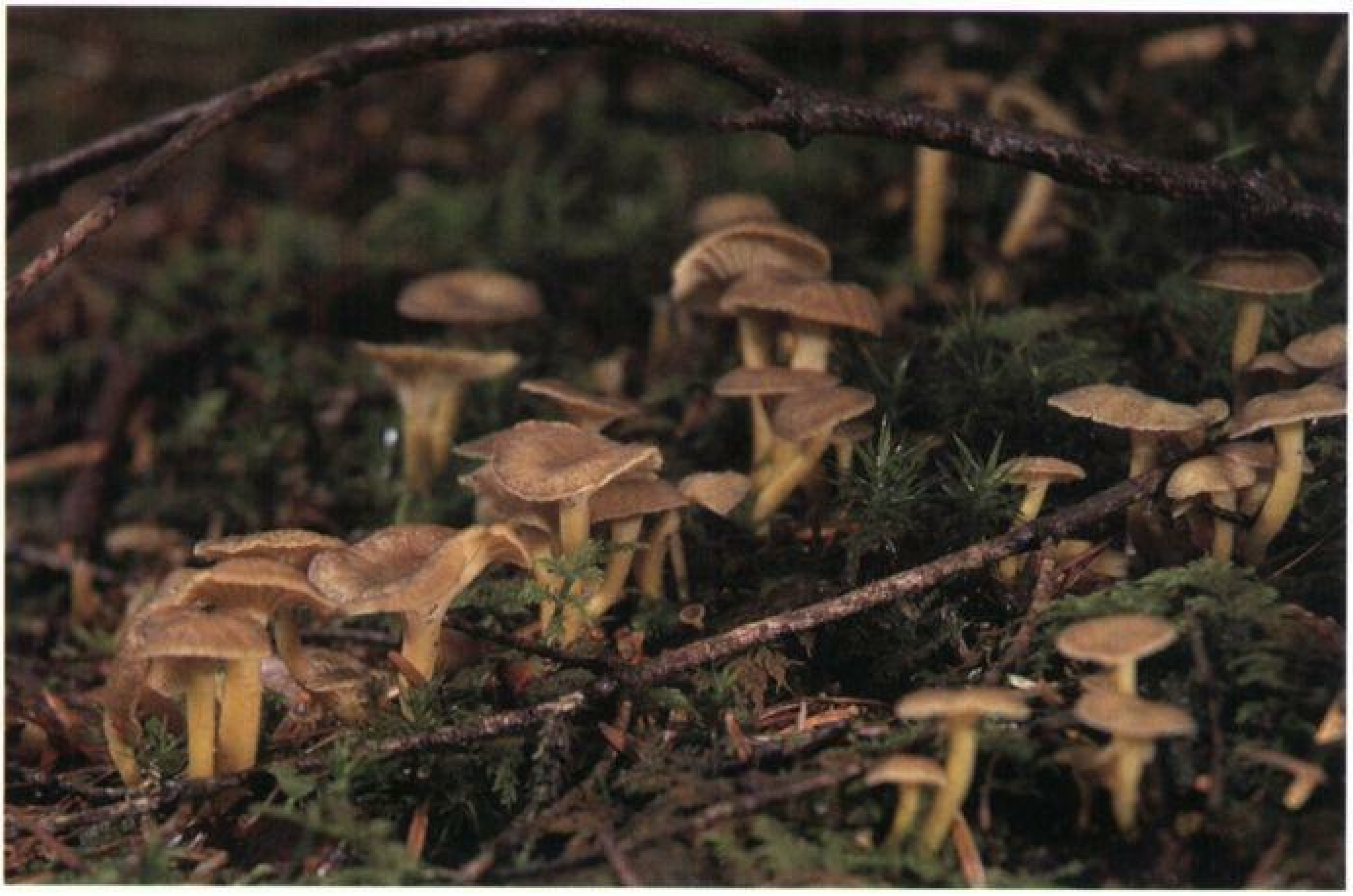

Color and shape vary according to age and weather conditions. Each individual trumpet chanterelle has more than one color. The cap is brownish and has a hole in the center. The ridges and the stalk range from brown-yellow to gray-yellow to gray-lilac.

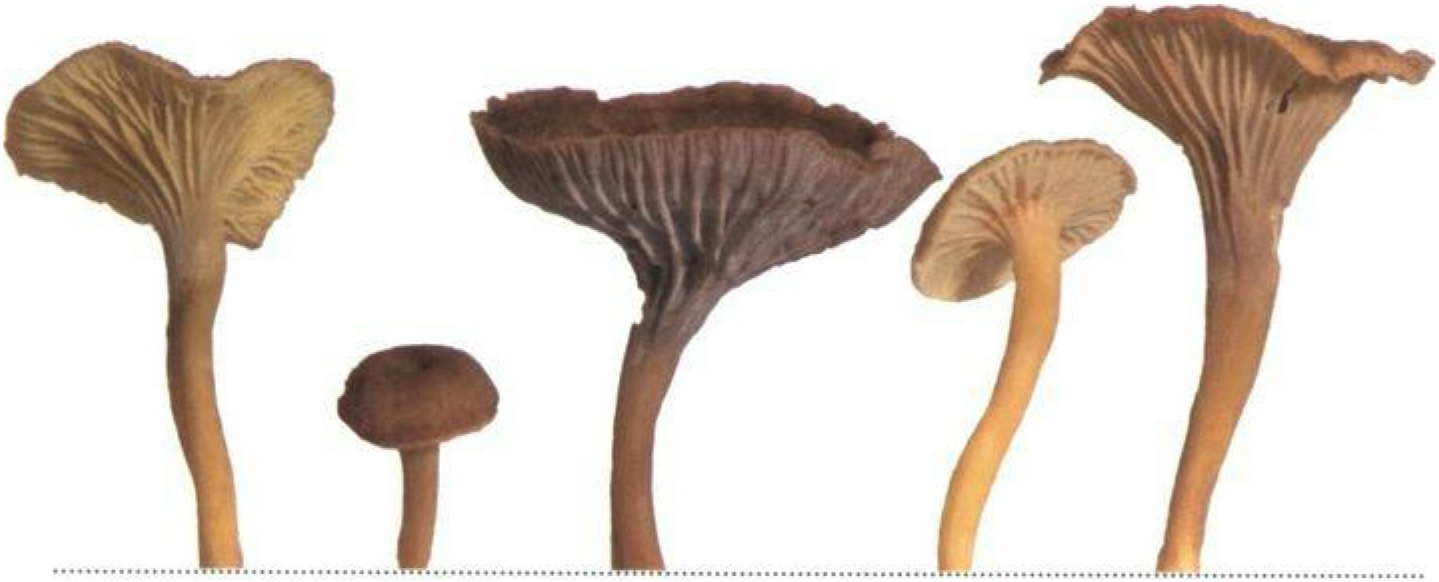

The jagged edges here are due to frost.

The advantage of having a paper bag for each species (see page 32) is seen here. You can spot the odd one out immediately.

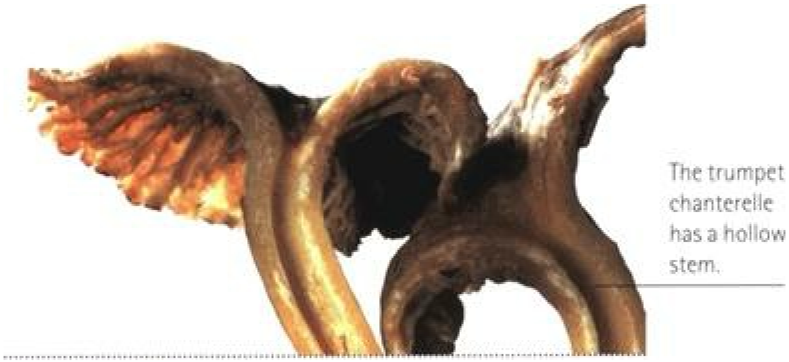
The trumpet chanterelle has a hollow stem.

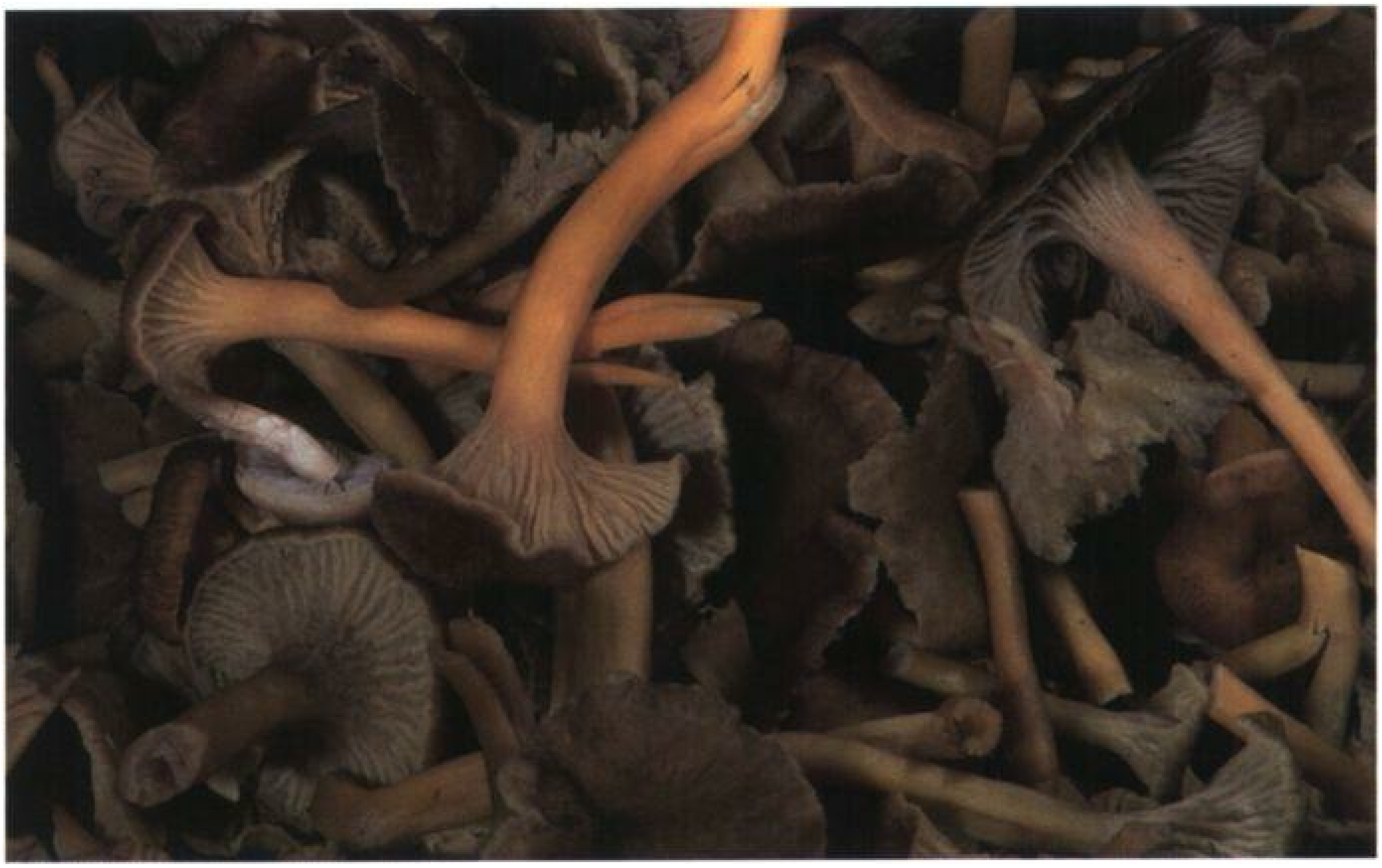

PositiveIDChecklist

Trumpet Chanterelle

☐ Found in groups
☐ Brownish, thin-fleshed, wavy-edged cap with hole in center
☐ Hollow stem
☐ Ridges
☐ Cap color matches color bar (above)

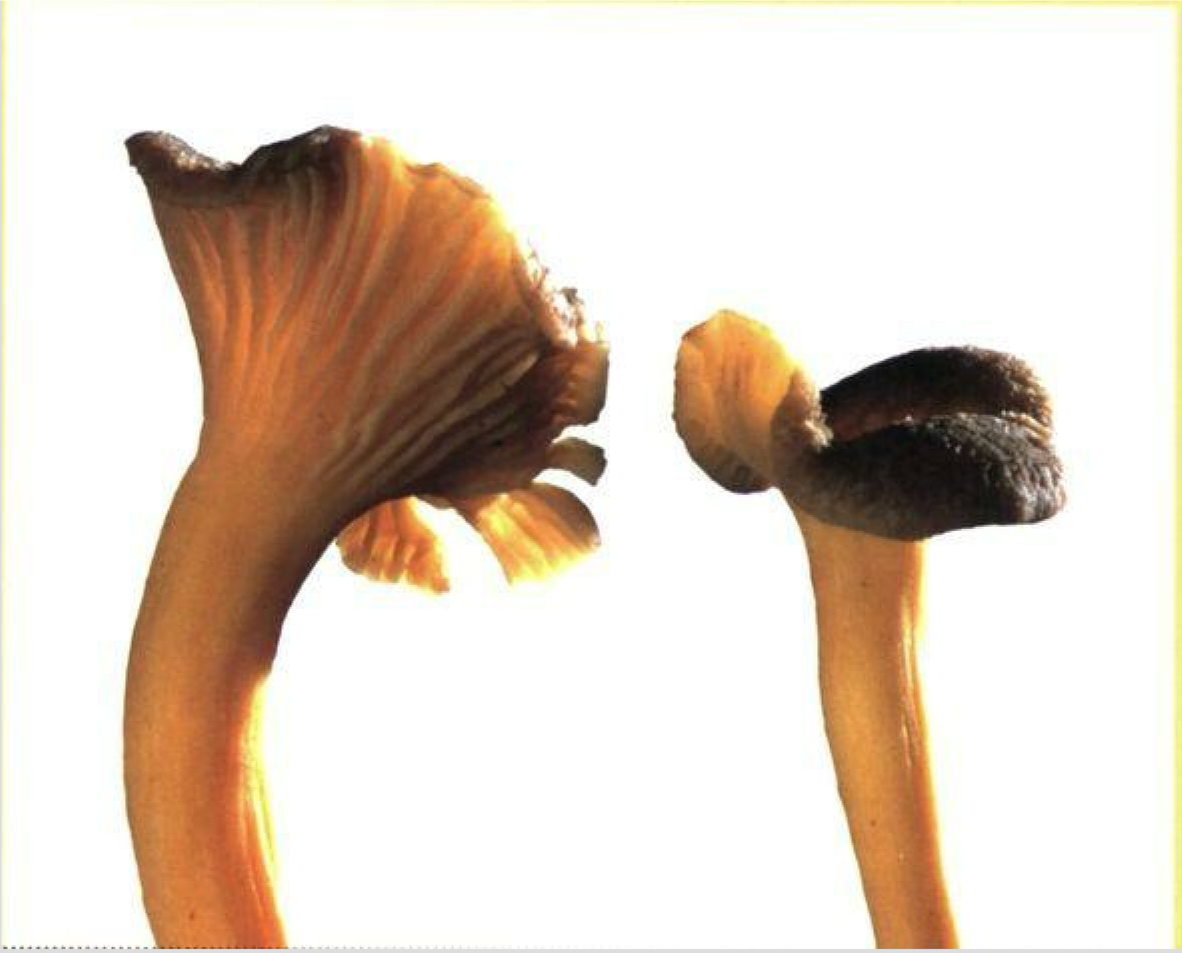

Avg. size across cap: 0.75-1 inch when mature

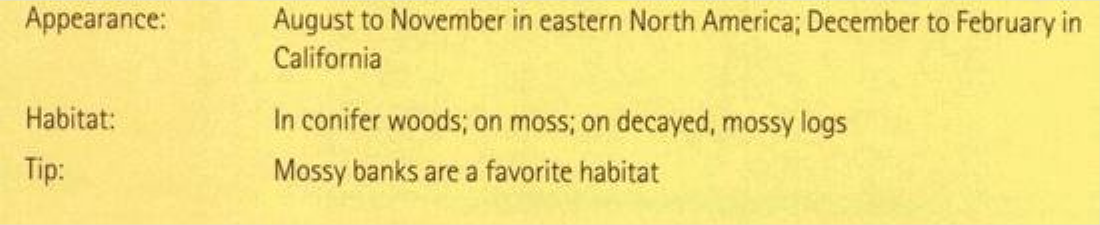

Appearance:	August to November in eastern North America; December to February in California
Habitat:	In conifer woods; on moss; on decayed, mossy logs
Tip:	Mossy banks are a favorite habitat

Always remember

Rule number 1

Never, never take a mushroom with gills!!!

Rule number 2

Only take mushrooms with tubes, spines, and ridges and the mavericks portrayed in this book

Rule number 3

Only eat mushrooms which you have clearly identified with ALL the positive ID marks

Rule number 4

If a mushroom smells rotten, it is rotten and if it feels soggy, it is soggy

Rule number 5

Never, never eat wild mushrooms raw

Rule number 6

Look before you cut

Rule number 7

Mushrooms want to breathe. Do not suffocate them in plastic bags

Rule number 8

If in doubt, leave it

Mushrooms With Spines

Hedgehog Fungus

Hydnum repandum

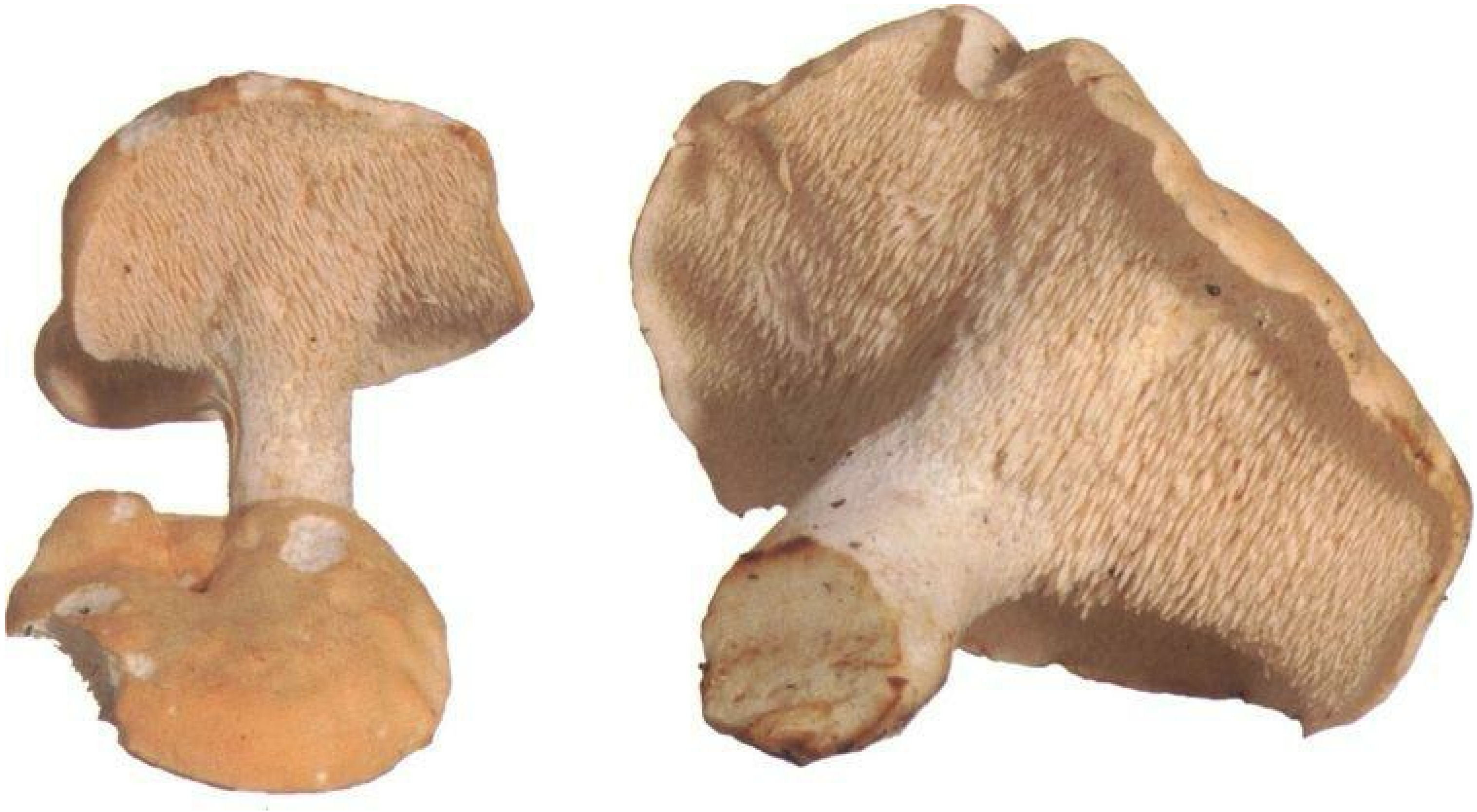

There are other mushrooms with spines but the only one of real culinary interest is the hedgehog fungus. The hedgehog fungus is a great delicacy. It grows on the ground but never on trees.

Repandum means “bent upwards” and refers to the way the cap often reveals its underside.

The spines are the key identification marks of the hedgehog fungus. The flesh is matte white and colors in places to a yellow-brown or rusty yellow.

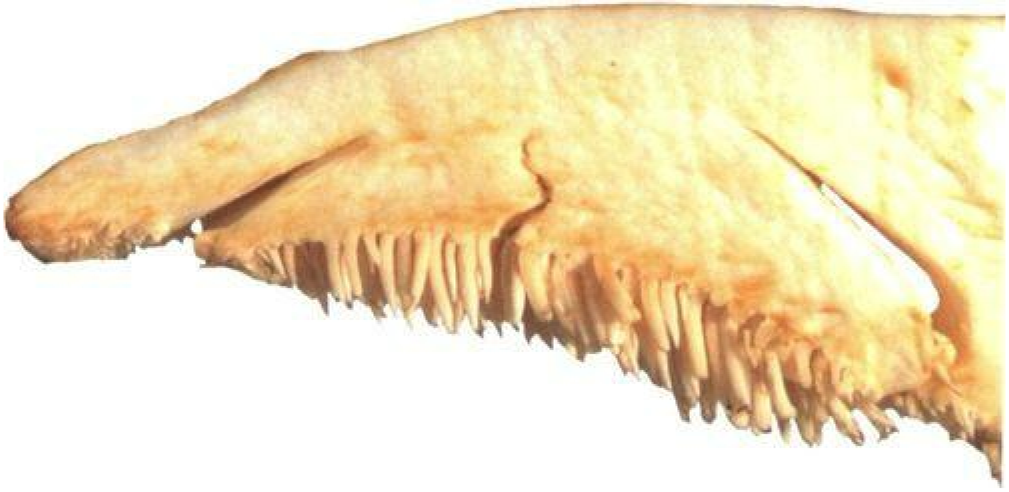

Some hedgehog fungi grow in a very irregular fashion, up to the size of two fists. Nevertheless, all hedgehog fungi have distinctive spines. The specimens here show the entire color range of the cap. No other mushroom with spines has these colors.

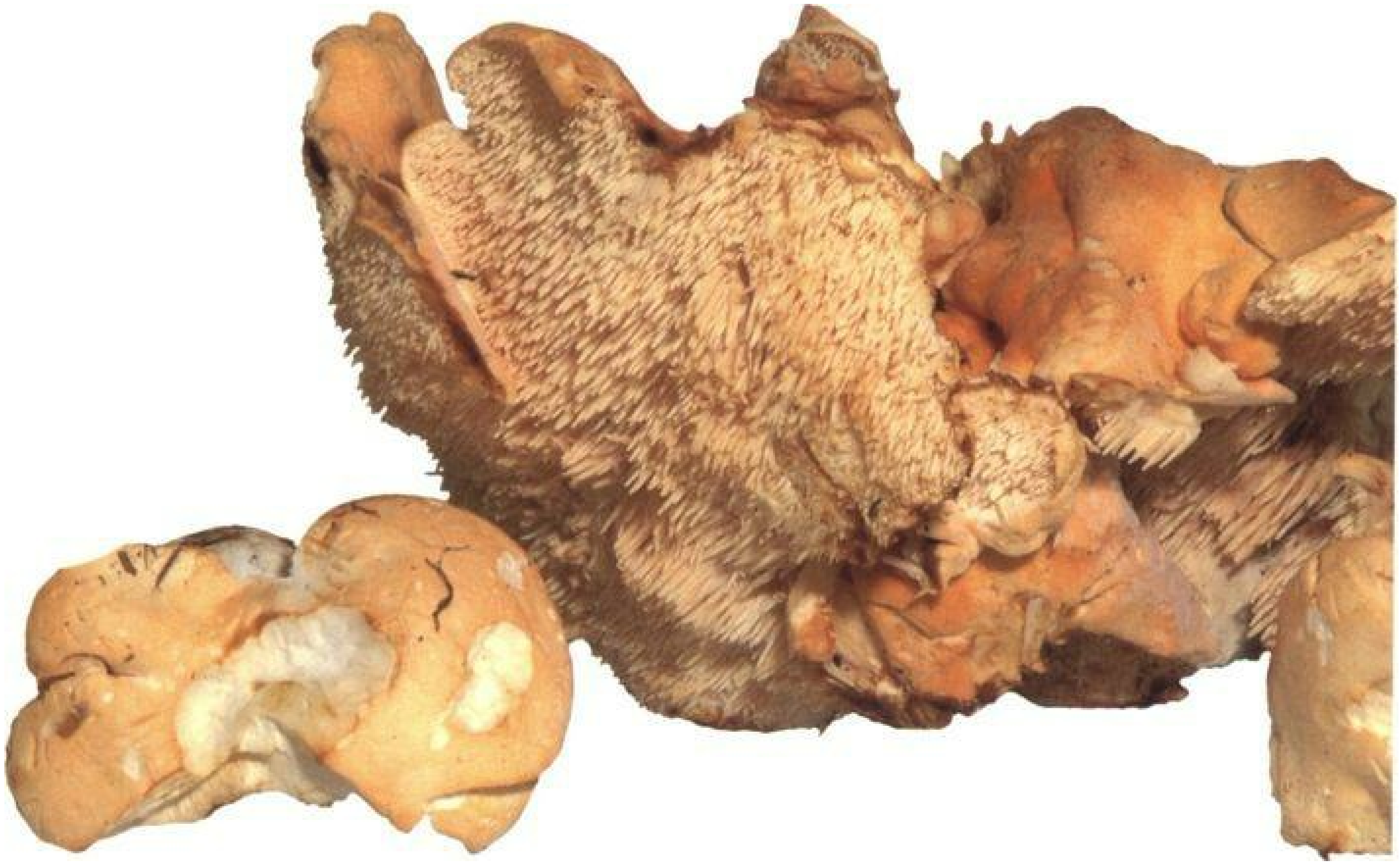

Take only specimens where the spines are clearly visible. The hedgehog fungi pictured here are the perfect size for the kitchen. The cap size is 2.5-4 inches across.

Positive ID Checklist

Hedgehog Fungus

- ☐ Spines
- ☐ Flesh matte white when freshly cut; flesh colors in places to yellow-brown or rusty yellow
- ☐ Cap margin wavy-edged
- ☐ Found on ground but not on trees
- ☐ Cap color matches color bar (above)

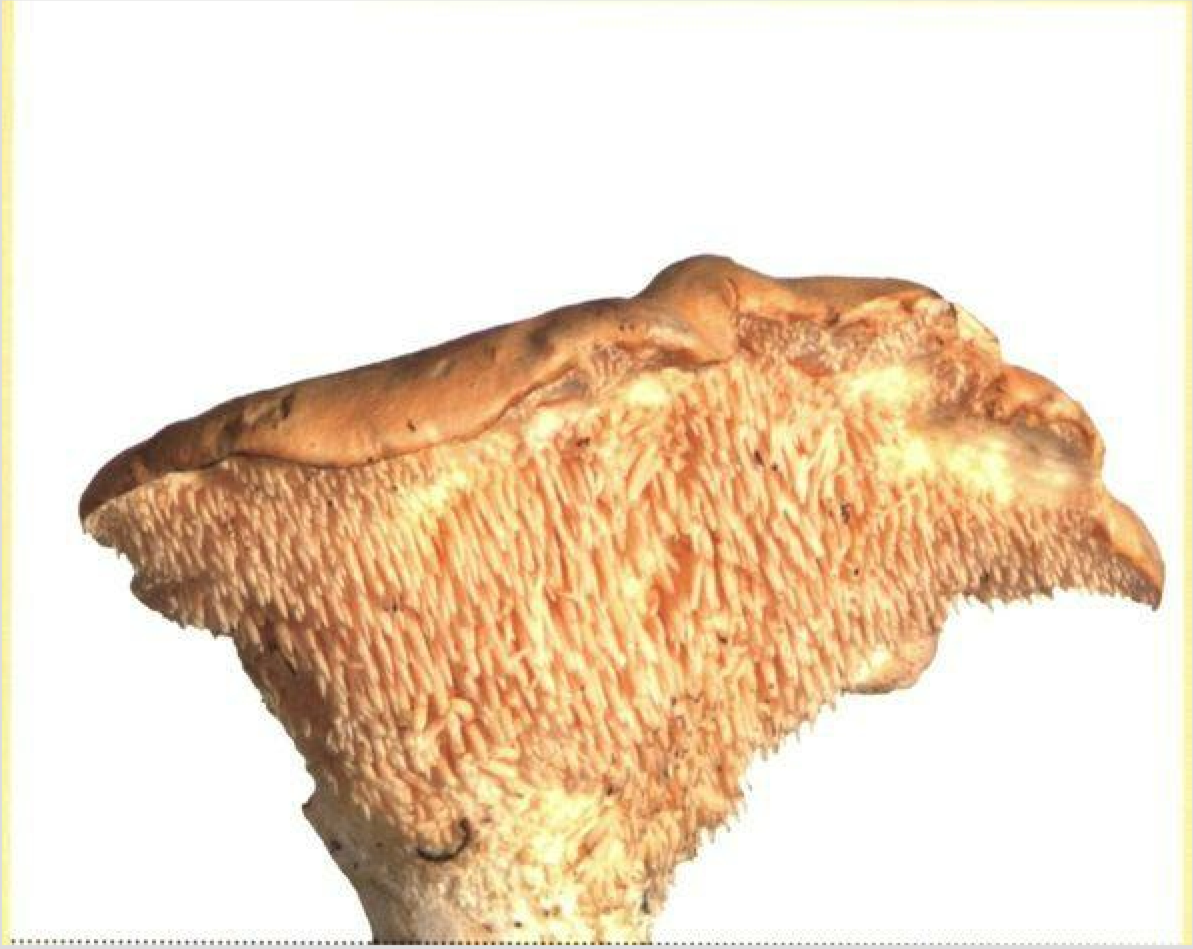

Avg. size across cap: 2.5 inches when mature

Appearance:	August to November in eastern North America; October to November in the Pacific Northwest; December to February in California
Habitat:	Common under oaks and mixed hardwoods in eastern North America; under conifers in the West and Pacific Northwest
Tip:	Avoid older specimens; they are slightly bitter

Always remember

Rule number 1

Never, never take a mushroom with gills!!!

Rule number 2

Only take mushrooms with tubes, spines, and ridges and the mavericks portrayed in this book

Rule number 3

Only eat mushrooms which you have clearly identified with ALL the positive ID marks

Rule number 4

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Rule number 5

Never, never eat wild mushrooms raw

Rule number 6

Look before you cut

Rule number 7

Mushrooms want to breathe. Do not suffocate them in plastic bags

Rule number 8

If in doubt, leave it

Mavericks

Common Puffball

Lycoperdon perlatum

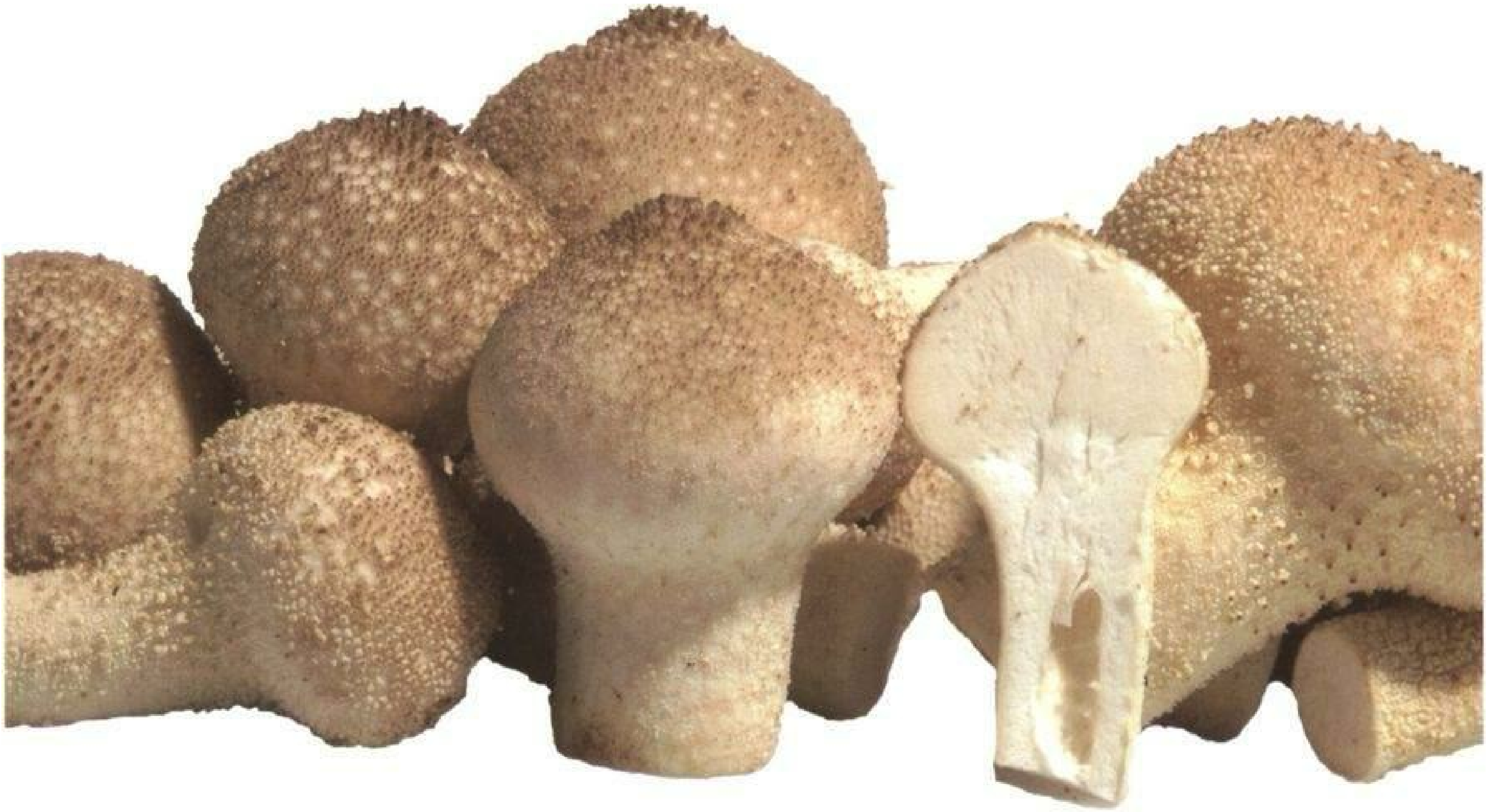

The common puffball is a curious little mushroom. One cluster of common puffballs might number merely four specimens; the next about forty. The common puffball is a welcome addition to any mix of mushrooms. Cooked on its own, it is not everyone’s cup of tea because of its distinct taste. The giant puffball is another matter and as good a reason as you’ll get for a dinner party.

Perlatum means “widely spread.”

The conical spines are visible to the naked eye and leave an unmistakeable net-pattern when rubbed off. Only pick specimens on which the white conical spines are clearly visible. The common puffball has no unpleasant smell.

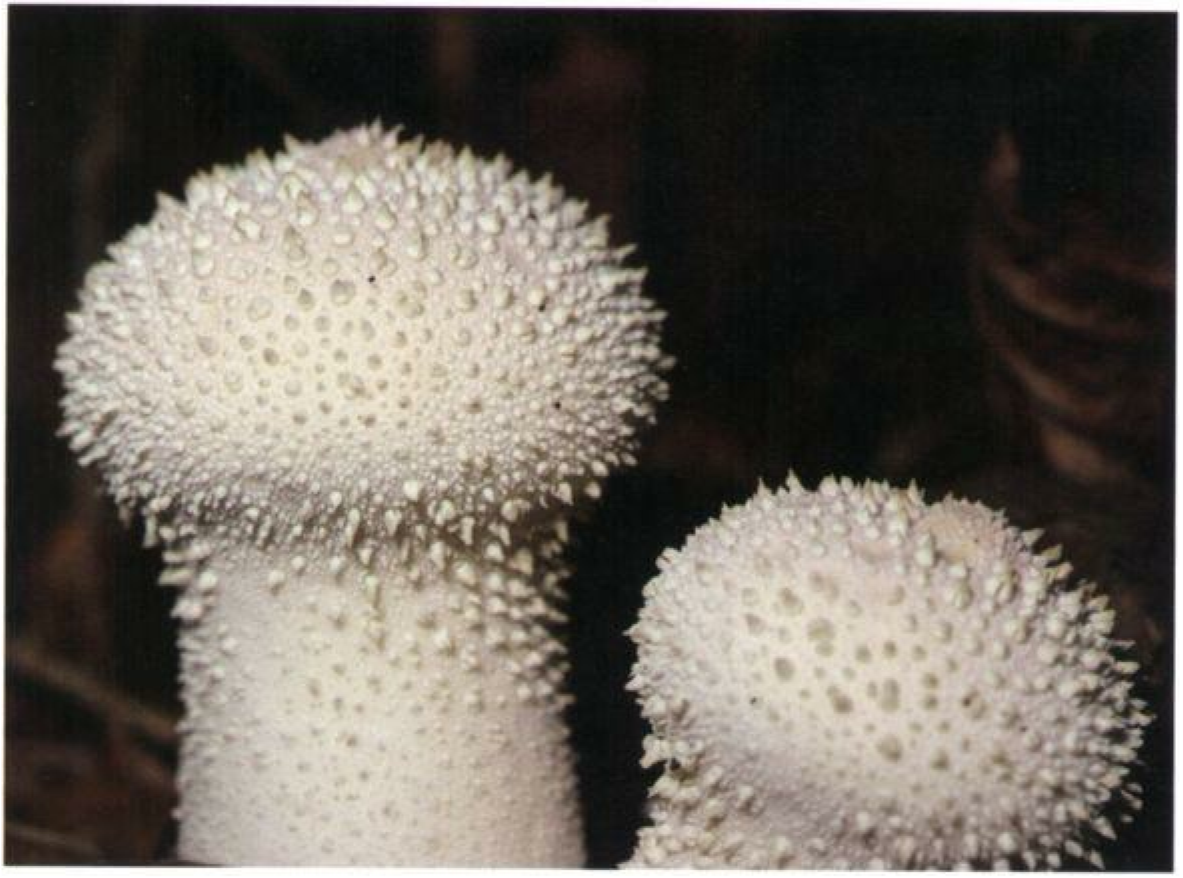

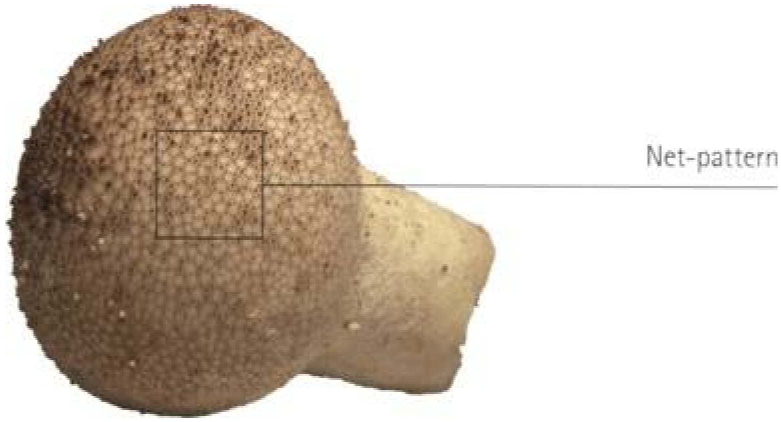

These common puffballs are the perfect size (height 1-2 inches) and condition. When cut, the inside is all white and firm. Only when the flesh is uniformly white and firm, is the mushroom all right for use.

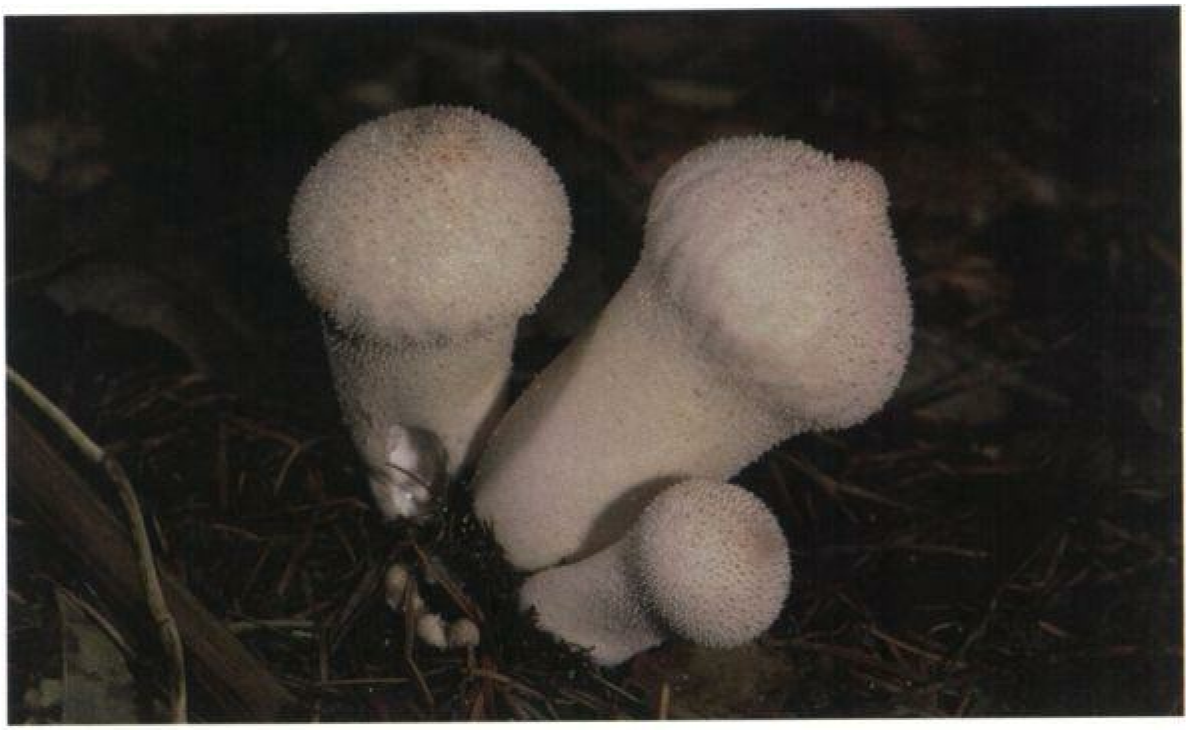

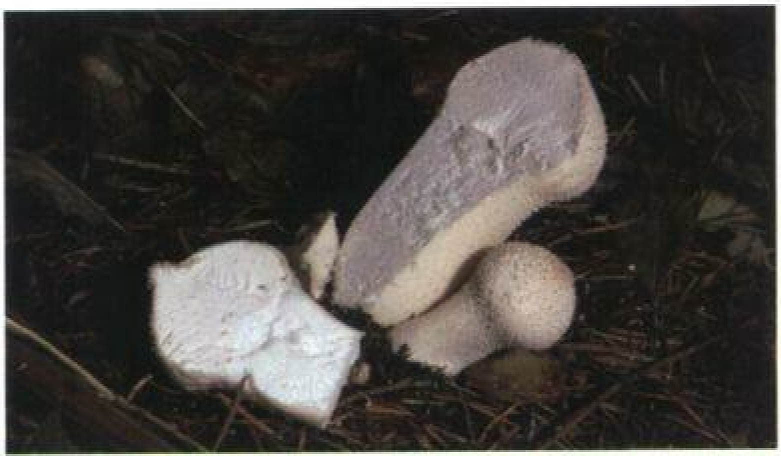

A variation of the common puffball is the pestle puffball. It too has spines but these are finer than those of the common puffball. It is pestle-shaped and it grows larger (height up to 8 inches) than the common puffball. It has no smell. If the flesh is uniformly white, and firm, it is good to eat.

The big brother of the common puffball is the giant puffball. Giant means it can grow to 3 feet in diameter. From a distance it looks all white but it can have a light yellow or yellow-brown tinge. The surface is smooth and feels rather like suede. The small specimen cut in two in the picture is about the size of a fist. When cut open, the flesh must be white and firm. Only then is the giant puffball edible- and delicious at that.

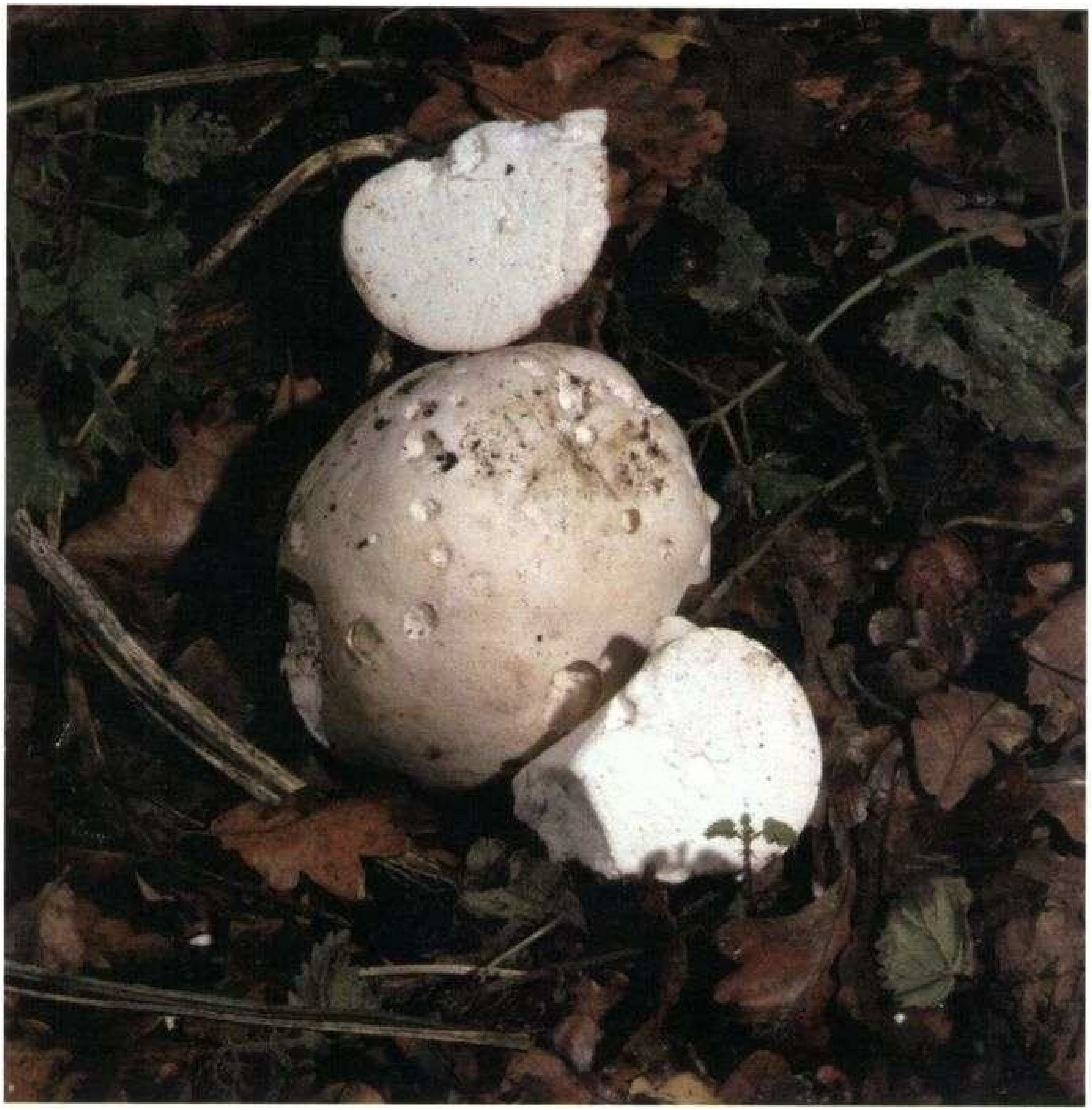

Positive ID Checklist

Common Puffball

☐ Conical spines
☐ Flesh must be firm and all-white
☐ Flesh undifferentiated, no thick rind or outline of mushroom visible in cross-section
☐ Net-patterned when spines are rubbed off
☐ Color Color white to off-white
☐ Found Found in groups
☐ No unpleasant smell

☐ Cap color matches cap color bar (above)

Be Careful:

Don’t mistake the Puffball for the Stinkhorn, which has a thick rind and black-and-white interior, or the Destroying Angel, which has gills and a differentiated interior. They are not edible.

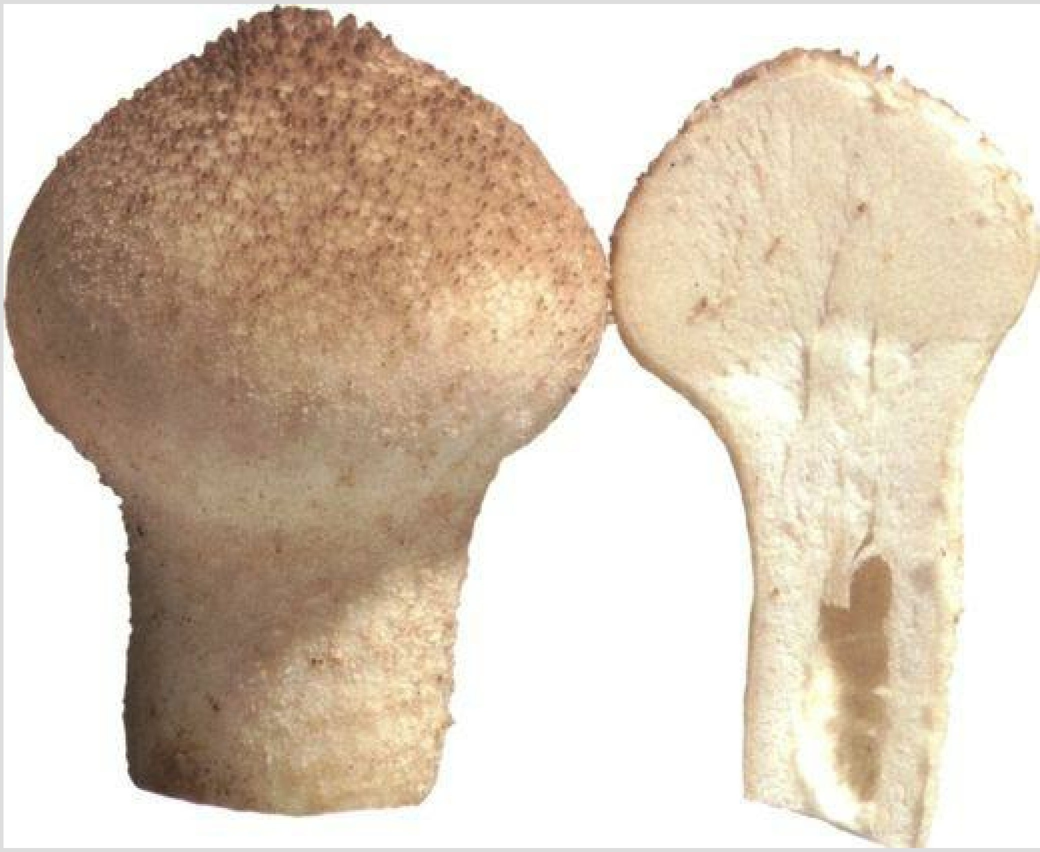

Avg. size across cap: Size of a golf ball. Giant puffball 12 inches

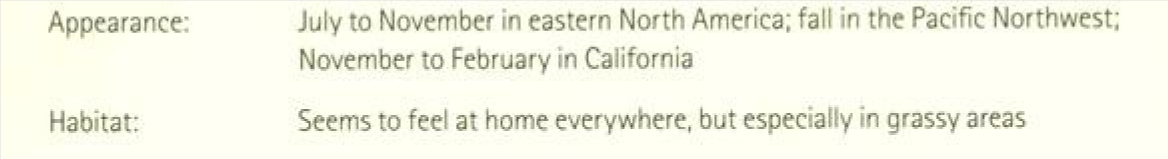

Appearance:	July to November in eastern North America; fall in the Pacific Northwest; November to February in California
Habitat:	Seems to feel at home everywhere, but especially in grassy areas

Horn of Plenty

Craterellus cornucoploides

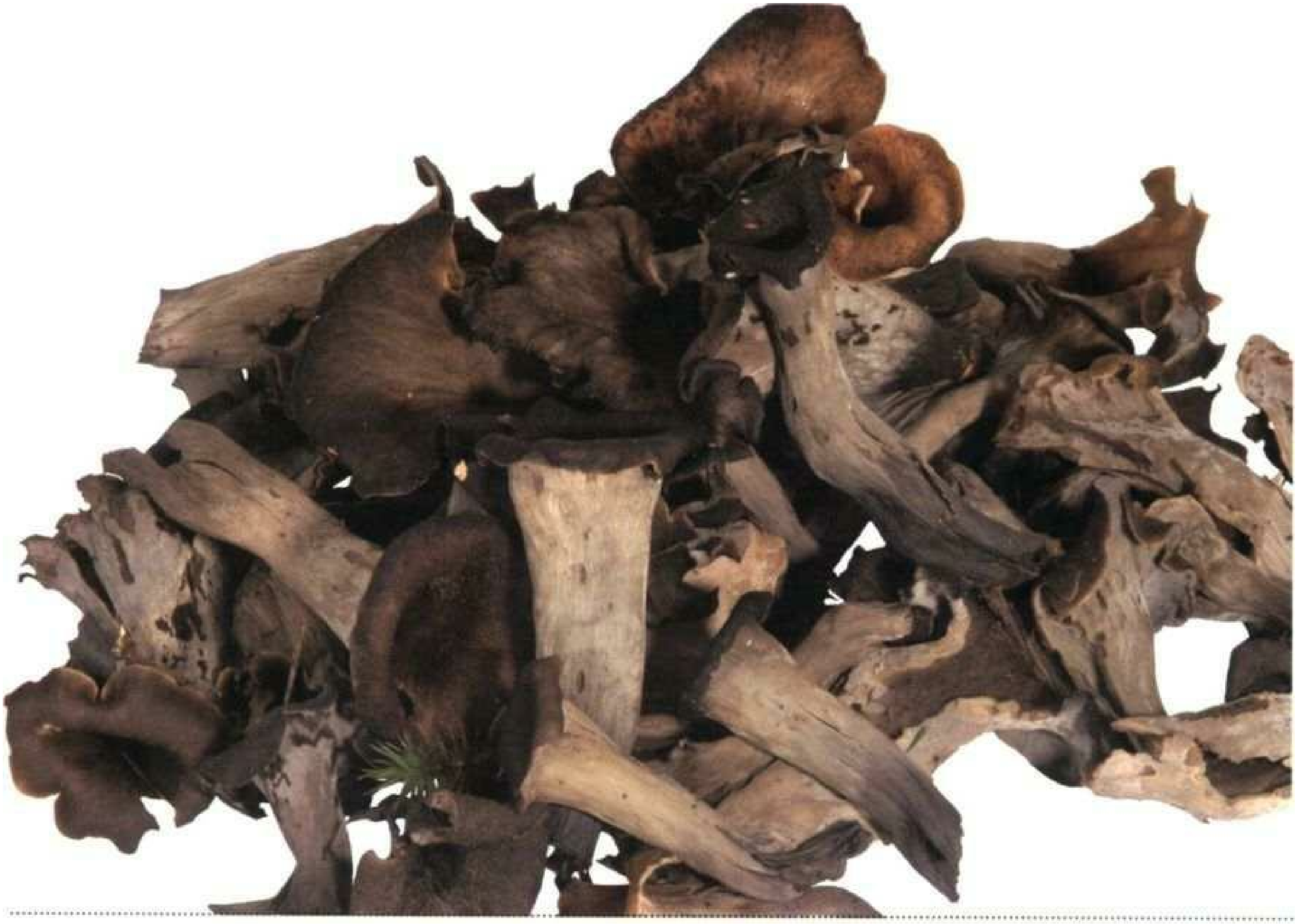

The horn of plenty is a real challenge to the mushroom forager.
Growing low on the forest-floor, it is so well-camouflaged that you can look at masses of them and not see any at all. If you spot one, there will be more: proceed with the utmost care because they are easily trampled. The horn of plenty is without a shadow of doubt one of the most delicious mushrooms in the world. But it has its price. Cleaning the horn of plenty can be quite a job but the reward is well worth the effort. Besides, when everybody joins the cleaning party, it is fun.

Cornucopioides refers to a cornucopia, or horn of plenty.

The horn of plenty is a funnel, the outer side of which looks smooth but in fact is slightly wrinkled.
The color on the outer side is ash-gray, gray or pale gray with a bluish or lilac tint.

The inside of the funnel is brown, brown-gray, soot-gray or black. The surface is scaly or flaky and the top is out-rolled. In older specimens the top is wavy and split.

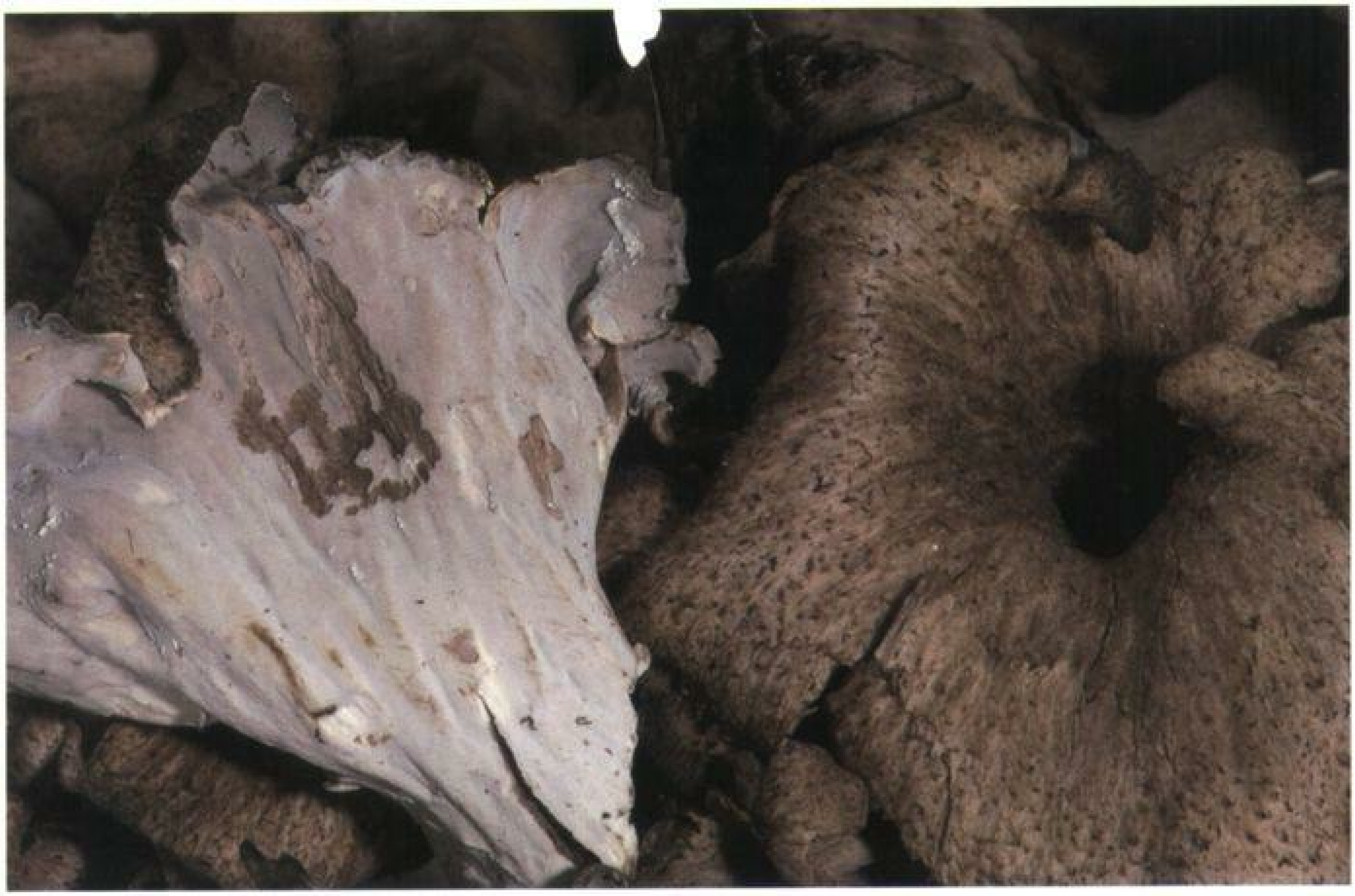

The horn of plenty seen from above in dry conditions.

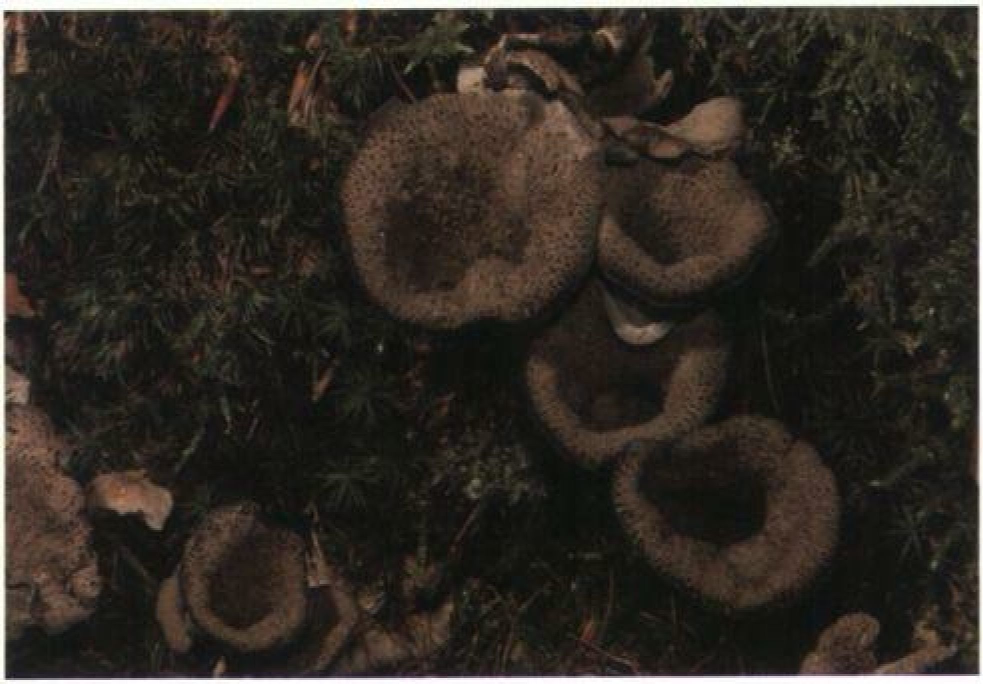

The horn of plenty seen from above in wet conditions.

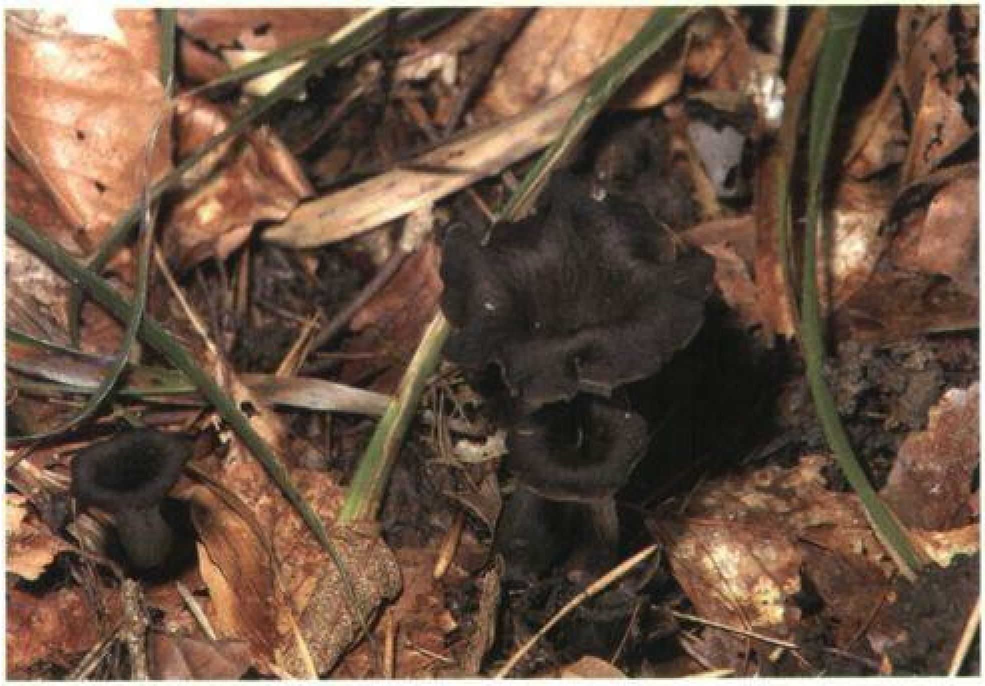

The funnel shape and the out-rolled top are typical.

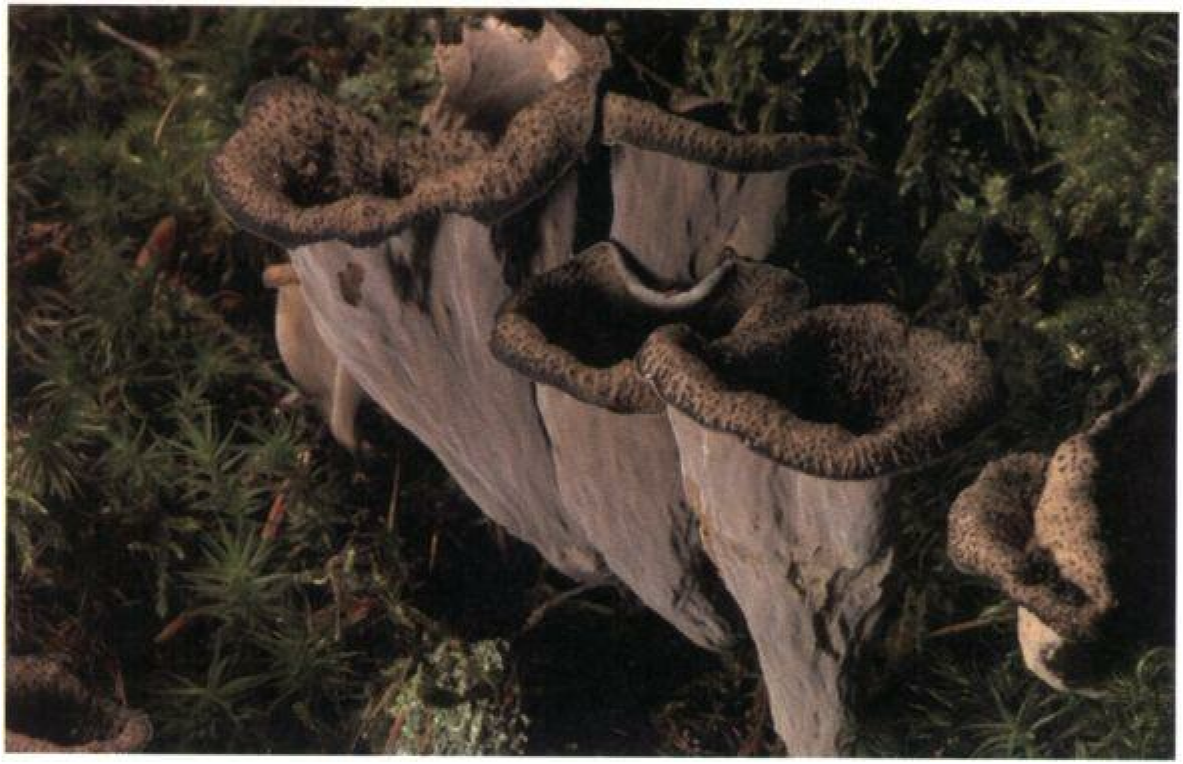

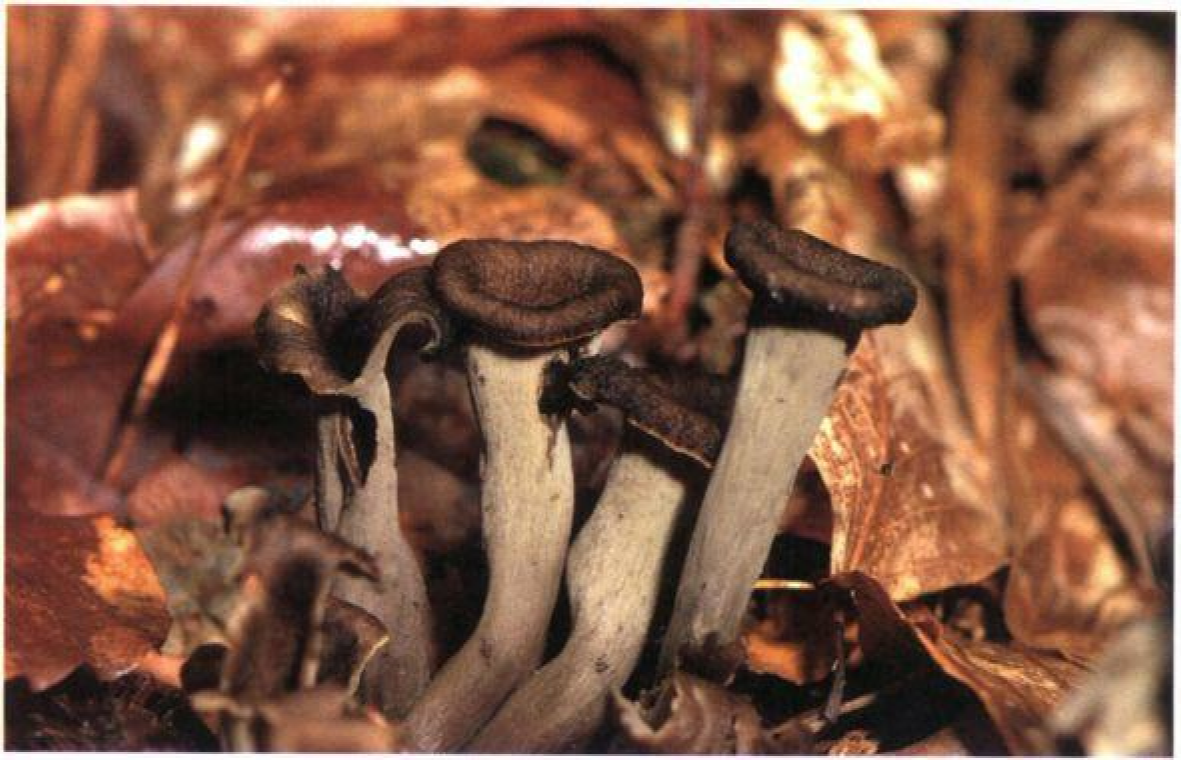

This looks a rather battered group of horn of plenty. Some of the tops have already split. Don’t be put off-they still taste good.

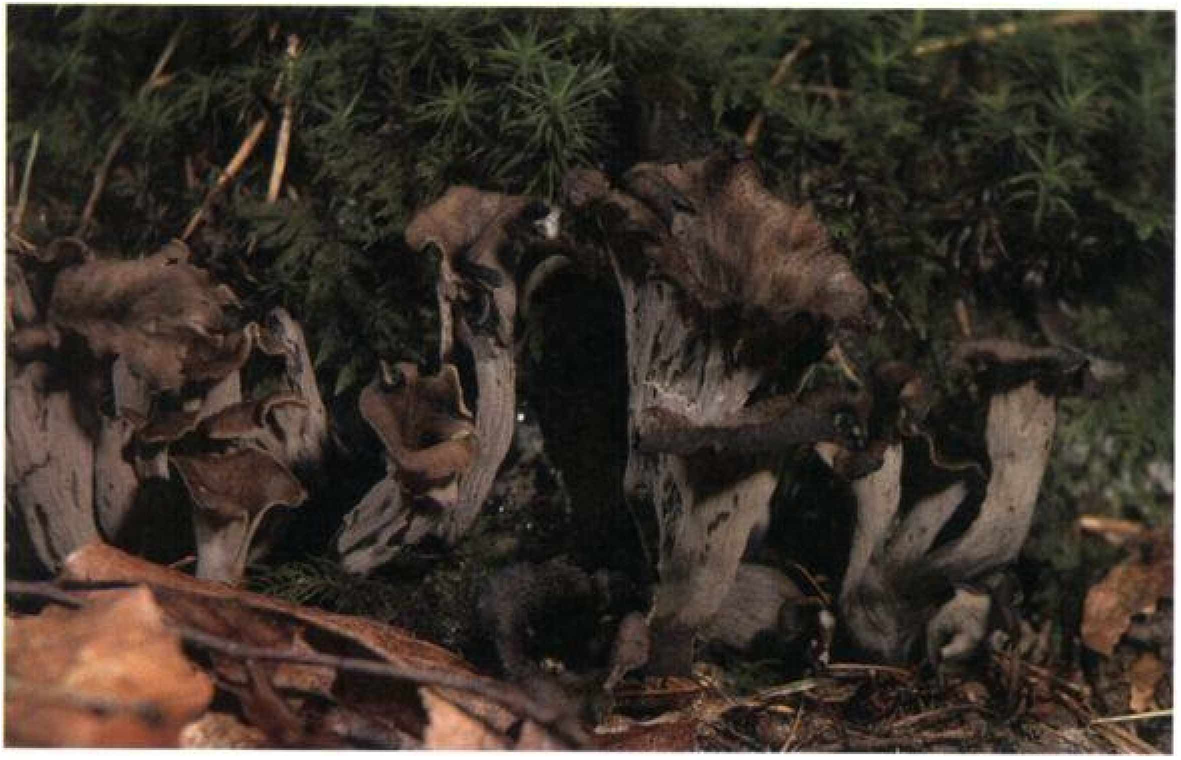

Positive ID Checklist

Horn of Plenty

- ☐ Found in groups
- ☐ Funnel shaped
- ☐ Smooth-looking but slightly wrinkled outer surface
- ☐ Scaly inside surface
- ☐ Outer surface matches color bar above (top line)
- ☐ Inside surface matches color bar above (bottom line)

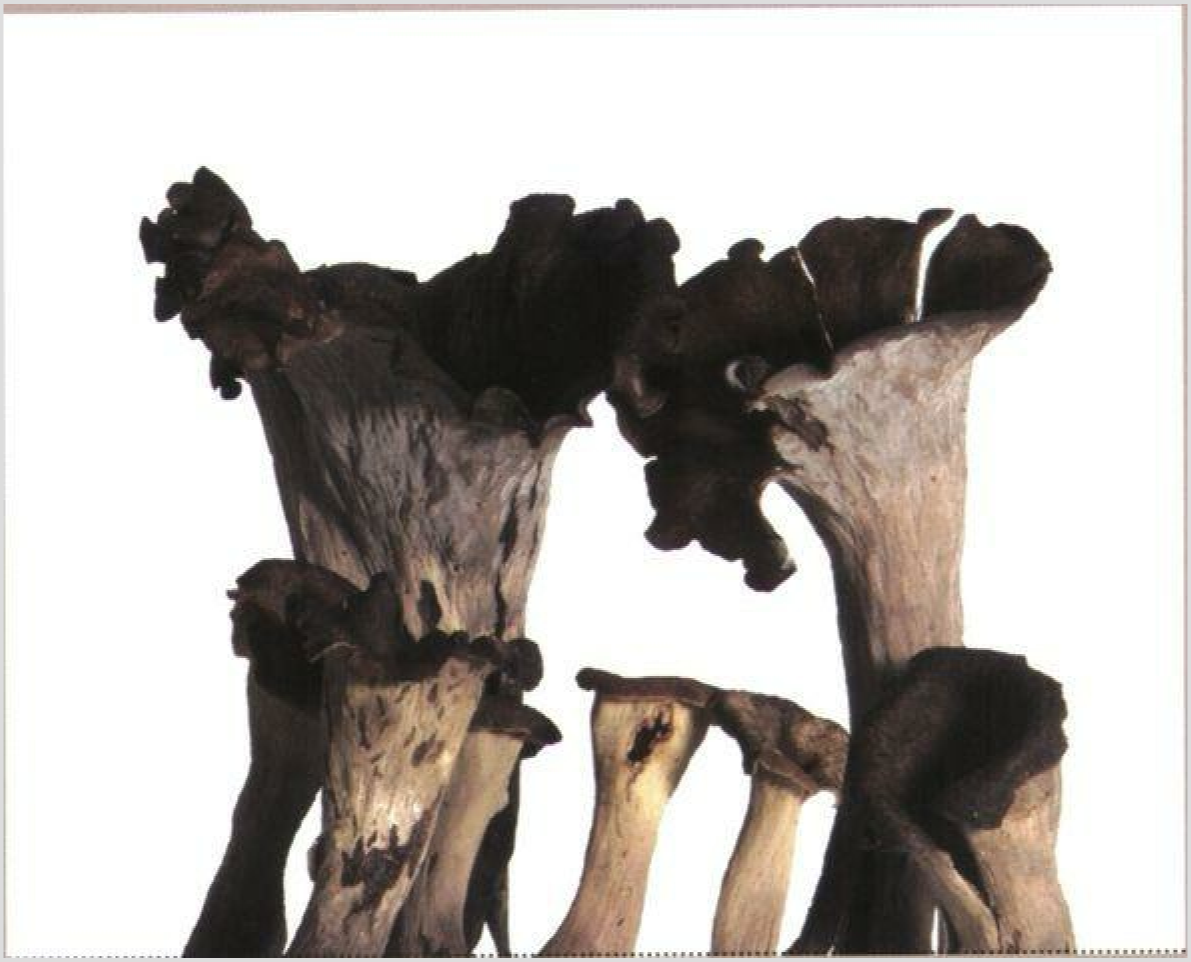

Avg. size across cap: 0.75-1 inch when mature

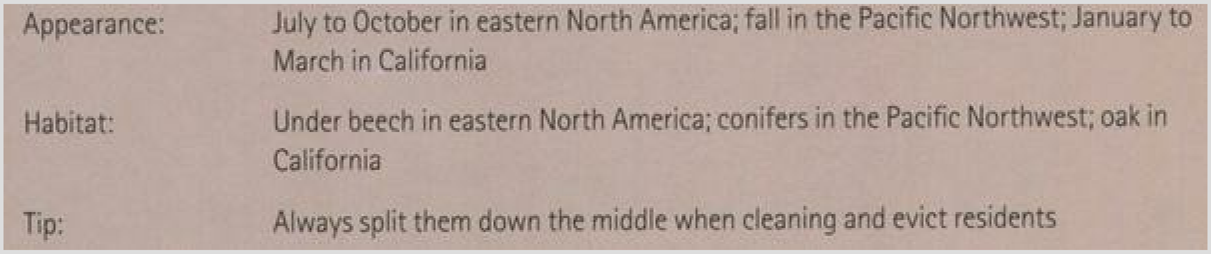

Appearance:	July to October in eastern North America; fall in the Pacific Northwest; January to March in California
Habitat:	Under beech in eastern North America; conifers in the Pacific Northwest; oak in California
Tip:	Always split them down the middle when cleaning and evict residents

Cauliflower Mushroom

Sparassis crispa

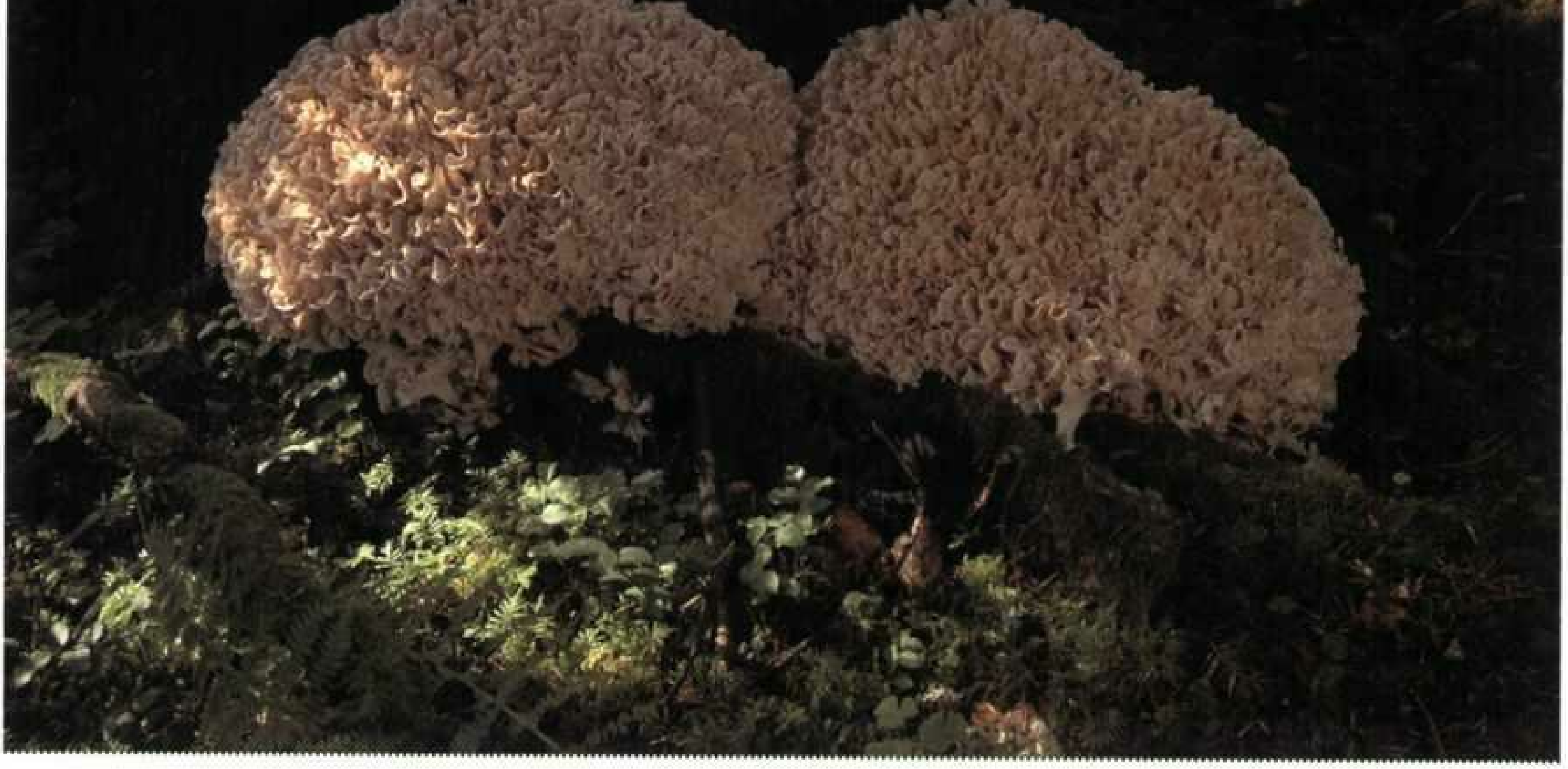

This is the mushroom of superlatives. For many people it is the very best of all. It may be a bit chewy but each bite releases a unique culinary sensation. If you fall for it, you'll be a dedicated cauliflower mushroom hunter forever. It resembles a cauliflower or a sponge.
Once you learn to recognise its spicy smell, you could identify the cauliflower mushroom blindfolded. And then there is the size: it can grow so big that people simply overlook it. This specimen weighed in at 22.5 1b.

Crispa means "frizzy."

Not all specimens grow to giant size. This one here is about the size of two fists. Its cauliflower or sponge-like appearance and the curved lobes are the key identification marks. There is nothing pointed or jagged in the cauliflower mushroom. The color ranges from creamy white to light brown. If it turns any browner than the specimen here, it has spoiled.

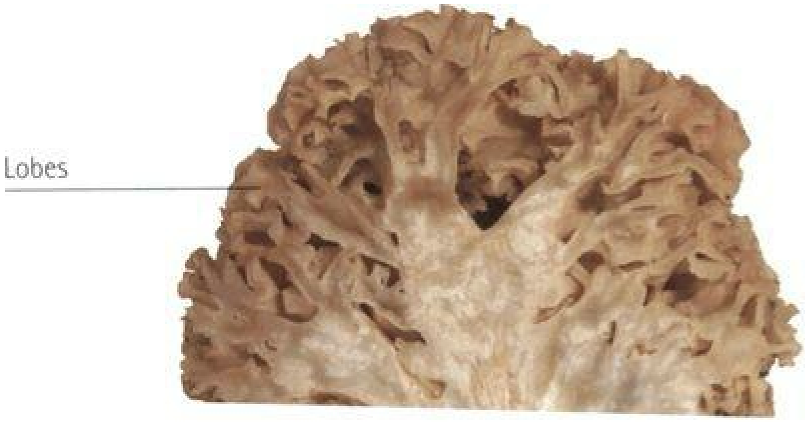

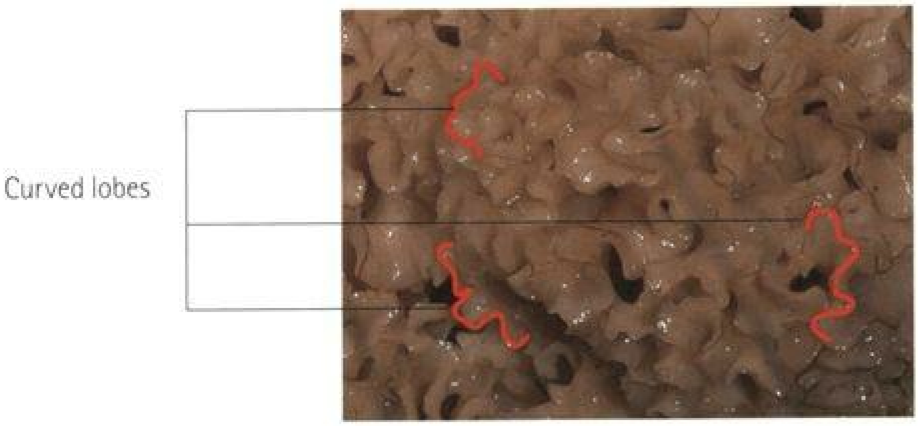
Curved lobes

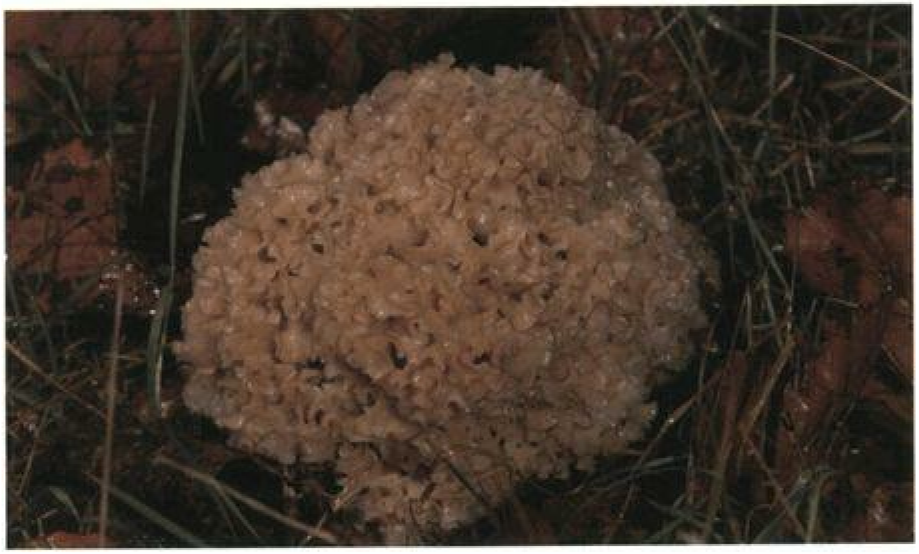

Positive ID Checklist

Cauliflower Mushroom

☐ No gills, pores, tubes or spines

- ☐ No stem
- ☐ Looks like a cauliflower or sponge
- ☐ Lobes
- ☐ Matches range of color bar (above)

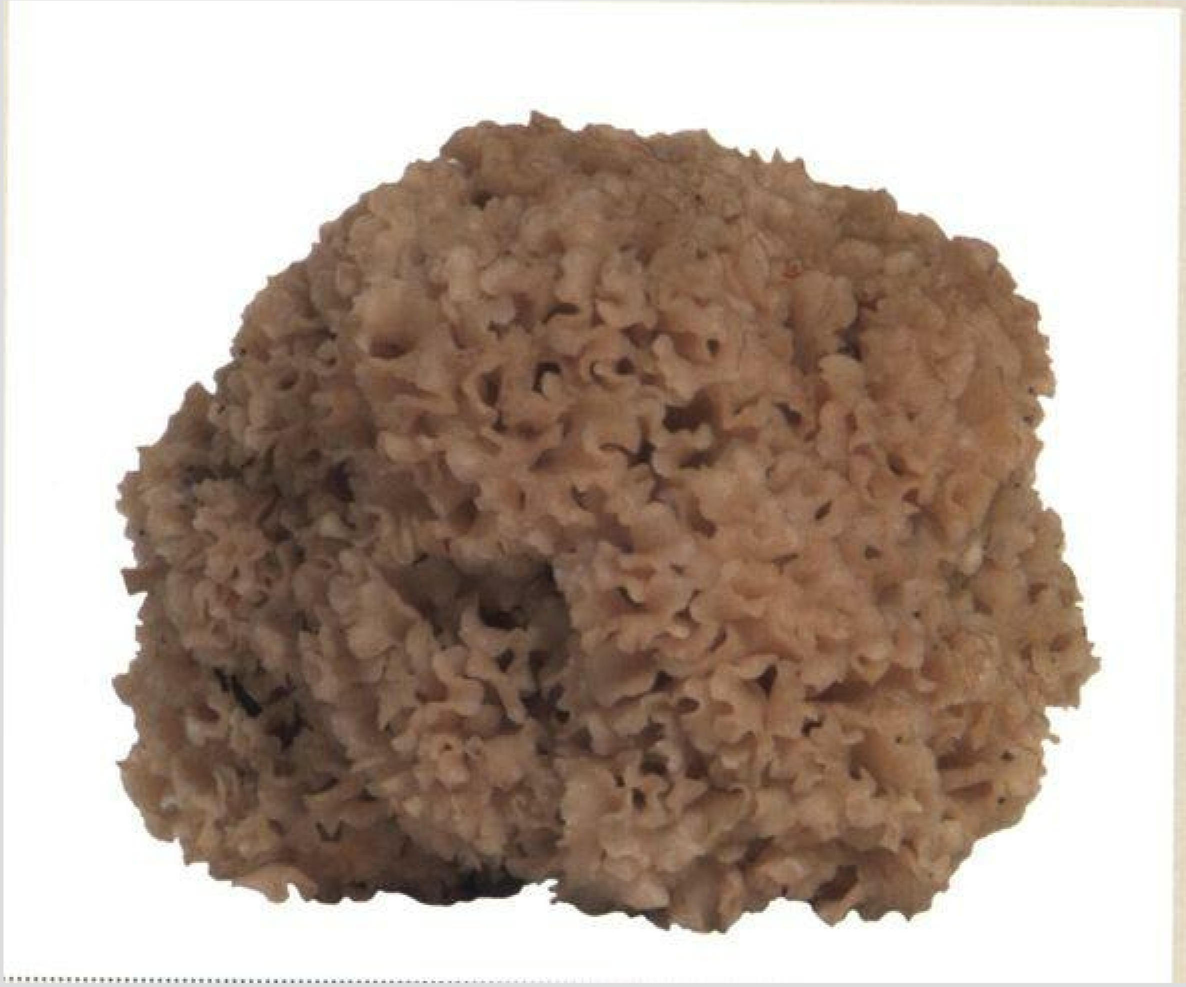

Avg. size across cap: 12 inches but can grow up to three feet

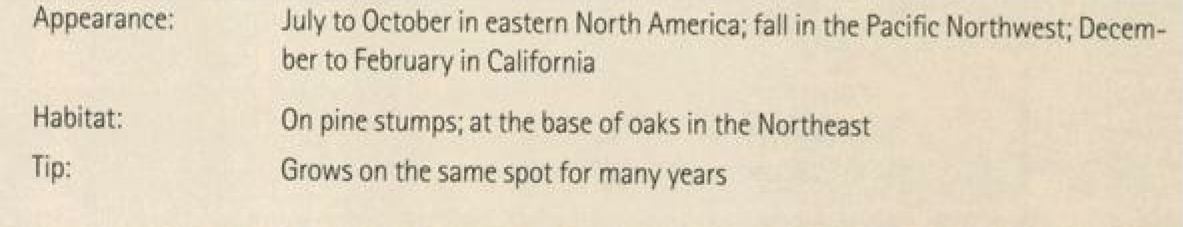

Appearance:	July to October in eastern North America; fall in the Pacific Northwest; December to February in California
Habitat:	On pine stumps; at the base of oaks in the Northeast
Tip:	Grows on the same spot for many years

Mushrooming Miscellany

The Mushrooming Regions

Eastern North America

Throughout this book, “Eastern North America” means regions primarily north of Georgia.

The Pacific Northwest

The Pacific Northwest consists primarily of Washington and Oregon (and parts of Idaho).

California

Throughout the book, “California” refers to the Bay Area, two hours north and south of San Francisco. Mushrooms also grow in Los Angeles and San Diego, but these appear toward the end of the California season.

As you can see, the timing and proliferation of mushrooms varies regionally. A good mushroom crop also depends heavily on weather conditions over the whole year. So the dedicated mushroom hunter need not confine himself to a mere couple of months of pleasure.

Trees and Mushrooms

Beech, birch, oak, pine, spruce, aspen and larch are the most important trees in mushroom-hunting, trees which are easily identifiable by their leaves or bark or both. It is most useful to know these five species of tree because if, for example, you explore a new wood, they will guide you to the mushrooms.

Beech
Especially: horn of plenty

Oak
Especially: chanterelle

Birch
Especially: birch bolete

Pine
Especially: cauliflower mushroom

Larch
Especially: larch bolete

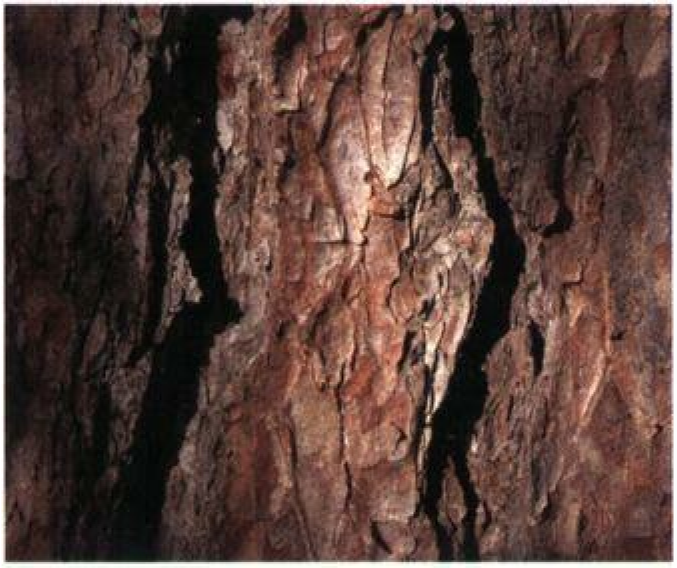

The larch is the only tree whose needles change color in autumn. You can’t miss it

Always remember

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Rule number 2

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Rule number 3

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Rule number 4

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Rule number 5

Never, never eat wild mushrooms raw

Rule number 6

Look before you cut

Rule number 7

Mushrooms want to breathe. Do not suffocate them in plastic bags

Rule number 8

If in doubt, leave it

Handling, Storage and Cooking

Handling

The first rough cleaning of the mushroom should be done in the woods. Once you’re at home you verify your spoils against the positive ID check lists and then-and only then-can you start the fine-cleaning. Do not wet mushrooms to clean them. Brush or wipe them with a cloth. Part of the cleaning process is to check the quality. Evict residents, cut away soft and soggy tubes and cut the remaining mushroom into bite-size pieces.

Storage

Drying

Drying is the classic way to store mushrooms. This method actually intensifies the taste of the mushrooms and they'll keep for years if you follow the procedure correctly. Do not dry anything you wouldn't eat fresh. Drying does not improve the overall quality of your mushrooms. There are various methods of drying mushrooms but there is only one way which guarantees consistent high-quality results and that is the only one I recommend: a dehydrator. Whatever the make, the principle is the same: warm air circulation. The sliced mushrooms are placed on trays and then dried in the dehydrator. Dried mushrooms are best stored in any air-tight container or a sealed plastic bag and then kept in a dark place. Mix all the species except the cauliflower mushroom. The more species in the mix, the better the taste. The cauliflower mushroom should be dried and stored separately (see page 115). Do not dry chanterelles. All other mushrooms in this book are suitable for drying. Dried mushrooms should be crackle-dry and snap when broken.

Freezing

Freezing is the other method. Results improved enormously when home vacuum-packaging machines became available. I recommend only freezing vacuum-packed mushrooms. Frozen mushrooms retain their color, texture and taste.

Never thaw frozen mushrooms!

Put deep frozen mushrooms in sizzling butter or hot water. Like this they keep their texture.

- Mix all the species except the cauliflower mushroom. Again: the more species in a mix, the better.
- I recommend deep freezing some cep, and horn of plenty, separately. You might want to add just a few of them for a particular dish or use the cep for a tasty starter.

The cauliflower mushroom should always be frozen separately (see page 115).

The chanterelle must be cooked before deep freezing - all other mushrooms in this book can be frozen raw.

Drying or freezing?

Either way, use only perfectly fresh mushrooms. Drying mushrooms gives them that deep, strong mushroom taste. The frozen mushroom is more subtle, but the colors of frozen mushrooms are as bright as on the day they were picked and this adds considerably to the pleasure of eating. Dried and frozen mushrooms can be mixed to get the best of both worlds.

Cooking

Famous chefs win awards for stylish cuisine. Simplicity as a rule is not in their repertoire because no stars can be won by doing as little as possible. There are some really attractive mushroom books with some really attractive recipes but my advice is: do not try to emulate the recipes of the famous chefs - you'll never get there anyway. The place to enjoy grand cuisine is in the restaurant.

Do what you can do better than the professionals and do what they can't do and you're in for a feast. Besides, it's much less trouble, expense, and frustration to do it your own way rather than to follow recipes which pre-suppose the infrastructure of a five star establishment.

So where can't the professionals compete with you?

1. Freshness

This is not to say that restaurants use old mushrooms. They're just not as fresh as yours.

Chervil is a tasty and attractive herb for mushroom dishes.

Your mushrooms have the shorter way from the wood to your kitchen. As a rule the restaurants' mushrooms come from a market and some of those mushrooms on the market have traveled a long way, some of them half way round the world.

2. Sourcing

You know where your mushrooms came from, whereas the chef in the restaurant, as a rule, knows only that it is the type of mushroom he wants. You know the very wood from which you picked them, and this is important because, for example, a cep can taste differently from one wood to another.

3. Quality

You know exactly where your mushrooms come from, and therefore you know their quality. In other words, you can be sure, for example, that your mushrooms grew in a non-polluted habitat or a dog-free zone.

4. Freedom

You are at liberty to vary the mushrooms that go into dish and to change ingredients. In top restaurants, recipes are more precise and designed to he produced time and again. Your mushroom feas the other hand, can be unique each time.

5. Soul

There is a satisfaction in picking your own wild mushrooms and cooking them yourself that not an match.

Garnishing with finely chopped vegetables makes your mushroom dish a feast for the eyes.

Mushrooms are not garnish

The mushrooms in this book are of culinary value in their own right and should be treated accordingly. Treat a wild mushroom with the same culinary respect as you would a wild salmon.

Olive oil and mushrooms

Most contemporary mushroom cookbooks recommend olive oil for cooking mushrooms, but if you really want to draw out all the subtle flavors of your mushrooms and realize their full culinary potential, then olive oil is, generally, not a good idea. Unsalted butter brings out the best in your mushrooms.

Chives are the classic garnish for mushrooms.

Kills all known germs

There is a potential but very low risk of catching something nasty from a mushroom. To reduce that risk to zero, do not eat raw mushrooms and in the cooking process, increase the heat at one stage so that the dish either boils for a couple of seconds or sizzles in the butter. For that brief moment, turn the mushrooms in the pan so that they’re exposed to the heat on all sides.

Curly or flat-leafed parsley underline the mushroom taste and add aesthetic appeal. Sprinkle on raw just before serving.

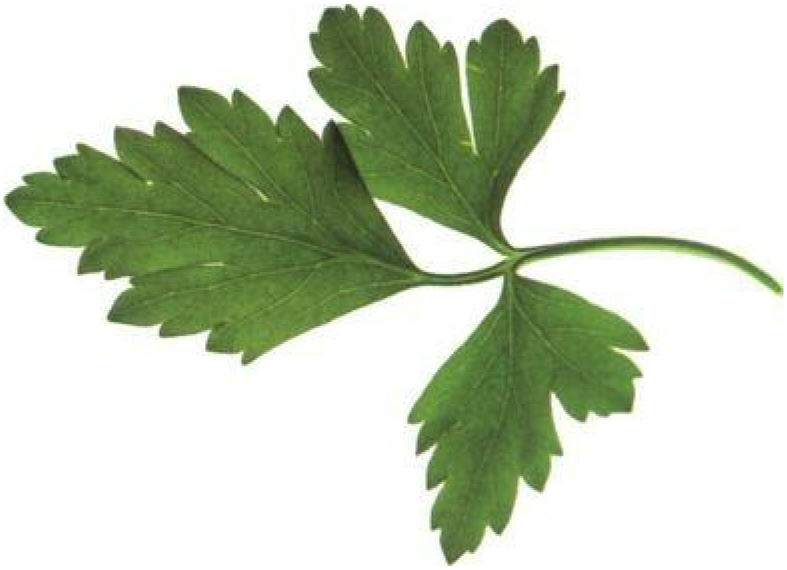

Special Cases

Chanterelle

The chanterelle must not be dried because it goes chewy. It must not be frozen without prior cooking because it will turn bitter.

Horn of Plenty

Some people like it on its own. Others use it only as a spice to add to a mix of mushrooms. In order to find out what you like best, dry and freeze separately.

Cauliflower mushroom

The cauliflower mushroom is also very distinct in taste and perhaps best on its own. Dry or deep freeze separately.

Basic preparation for fresh or frozen mushrooms

There’s a lot of flexibility in these basic preparations. The amounts stated can vary considerably and you’ll still get an excellent result. And the beauty of it is that you can’t overdo mushrooms. The key to culinary success is the quality of the mushrooms.

Serves 4

What you need
Essential:

5-8 cups fresh or frozen mushrooms
4 cups water
1 cup white wine
1 teaspoon salt
1 shallot or small onion, chopped
1 cup cream
¼ cup chives or parsley

Optional:

A mix of finely chopped vegetables, such as carrot, zucchini, and celery: approx. ½ cup
¼ cup chervil

What you do

1. Put water, white wine, salt, and shallot into a pan
2. Do not thaw frozen mushrooms. Add frozen or fresh mushrooms and bring to the boil
3. Reduce heat and simmer until approx ⅔ of liquid has evaporated
4. Add cream
5. Simmer again until approx. half the liquid has evaporated. Stir occasionally. If you feel there's too much liquid, simmer until it reduces still further. The less liquid, the more intense the taste and vice versa. Add water or cream to taste.
6. Add more salt and pepper to taste
7. You now have a wonderful mushroom sauce which you can serve with meat (chops, steak, etc.) or on its own with pasta or rice. Sprinkle with chives, parsley or chervil and the finely chopped vegetables

Basic preparation of dried mushrooms

Serves 4

What you need
Essential:

- 1-2 ounces dried mushrooms
- 4 cups lukewarm water
- 1 shallot or small onion, chopped
- ¾ cup dry white wine
- 1 teaspoon salt
- ¾ cup cream
- ¼ cup chives or parsley

Optional:

- A mix of finely chopped vegetables e.g. carrot, zucchini, and celery: approx. ½ cup
- ¼ cup chervil

What you do

1. Take the dried mushrooms and put in a bowl or pitcher. Add 4 cups of lukewarm water. Soak for 1½ hours (until the mushrooms float in brown liquid)
2. Put wine, shallot, salt, mushrooms and the brown liquid into a pan
3. Bring to the boil for 10 seconds Reduce heat and simmer until ⅔ of the liquid has evaporated
4. Add the cream

5. Simmer until approx. half the liquid has evaporated. Stir occasionally. If there is too much liquid, simmer until further reduced. The less liquid the more intense the flavor, and vice versa Add water or cream to taste
6. Add salt to taste
7. You now have a wonderful mushroom sauce which you can serve with meat (chops, steak, etc.) or on its own with pasta or rice. Sprinkle with chives, parsley, or chervil and the finely chopped vegetables

Beyond the Stove

No summer or winter woodland walk will ever be the same again once you become aware of the amazing universe of the forest floor, which in terms of color and life is a match for any coral reef. And the forest floor is right at your feet, so to speak, or at least not far from your door.

When in autumn you walk through a beech wood and marvel at the intensity and variety of the colors, think for a moment about those leaves.

There are about 2 tons of leaves to one acre of beech wood. After their job is done on the branches, they fall to the ground. If they did not decompose we would soon be swimming through a sea of leaves.

Likewise, unrotted fallen branches would in time pile up as insurmountable obstacles.

A leaf falls to the ground, inspiring on its way a poet who happens to be passing by: but on a more practical level, bacteria are the first organisms to get busy.

Shortly afterwards, it is fungi, algae and protozoans which play their part in the work of decomposition.

Soon, millions of organisms and little animals are at work on that single leaf. In due course the leaf is fully decomposed, its constituent parts recycled back into the forest soil, keeping it fertile by providing the essential substances for all the plants in the wood.

The vital role of mushrooms

Fungi are key players in maintaining tree growth and health. The reason the birch bolete is always found near birch trees, and the larch bolete always near larch trees, is that these pairs live in a symbiotic relationship. They need each other.

The mycelium of the birch bolete and the fine root-ends of the birch tree link up and exchange substances. There is a lot of chemistry going on, with a net result of mutual benefit. There are intricacies and complexities in all matters fungi and there are, so to speak, vast uncharted areas on the fungal map. However, even the most half-hearted mushroom-hunter will soon become aware of the all-encompassing interrelations in the wood. Mushrooming makes you see and appreciate the woodland differently.

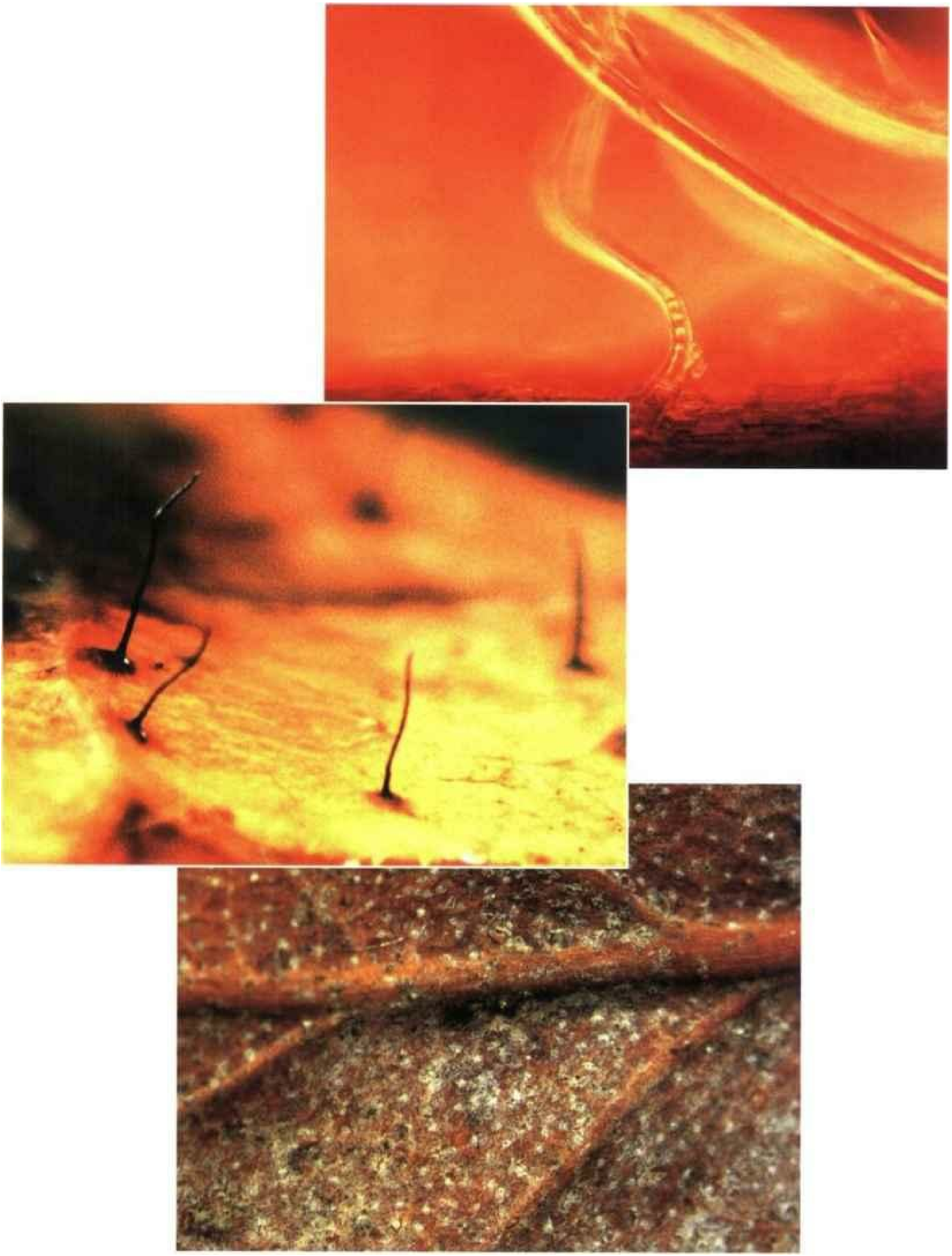

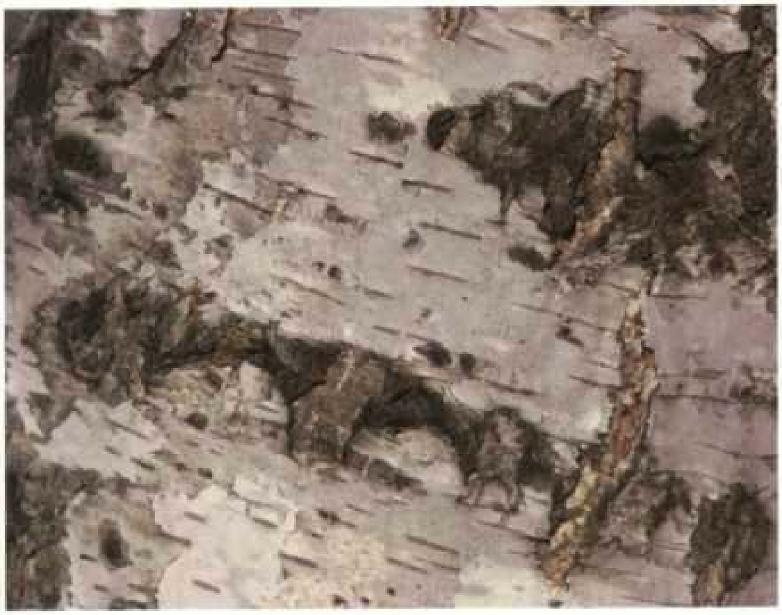
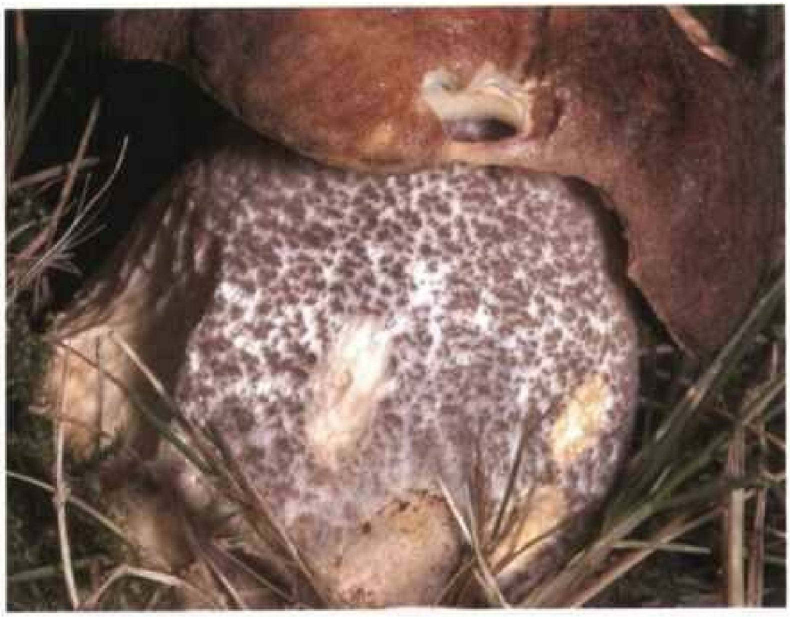
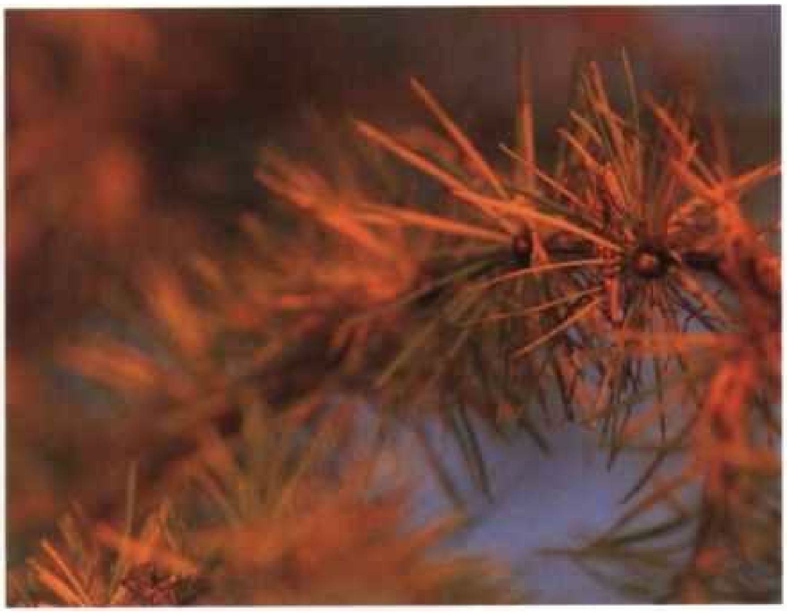
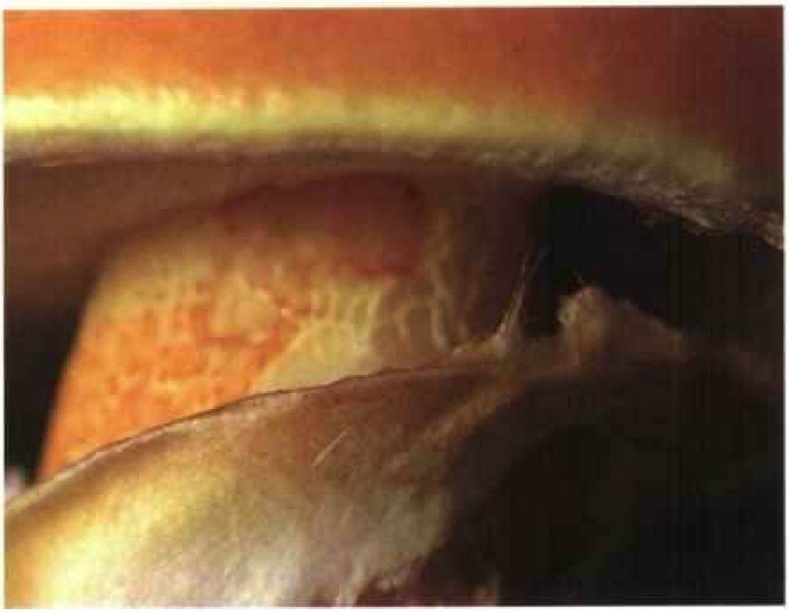

There is a practical point to these impressions which will help you in your mushrooming.

The similarity of patterning between the trunk of the birch tree and the stalk of the birch bolete is there for all to see. The similarity in color between the larch needles (once they change color in autumn) and the larch bolete seems obvious. These pointers can all act as nature's clues and reminders for the mushroom forager. But why is this so? Whatever the scientific answer, if indeed there is one, this similarity illustrates beautifully the interconnected nature or, if you prefer it, the mutual dependence, of life in the wood.

Perhaps even more intriguing is the similarity between the pine bark and the cauliflower mushroom, which grows near pine trees. It could be a coincidence or it could be a complex pattern at work. Either way, the cauliflower mushroom is utterly delicious - but if you mull over a conundrum like this, doesn’t it add interest and pleasure to mushroom hunting?

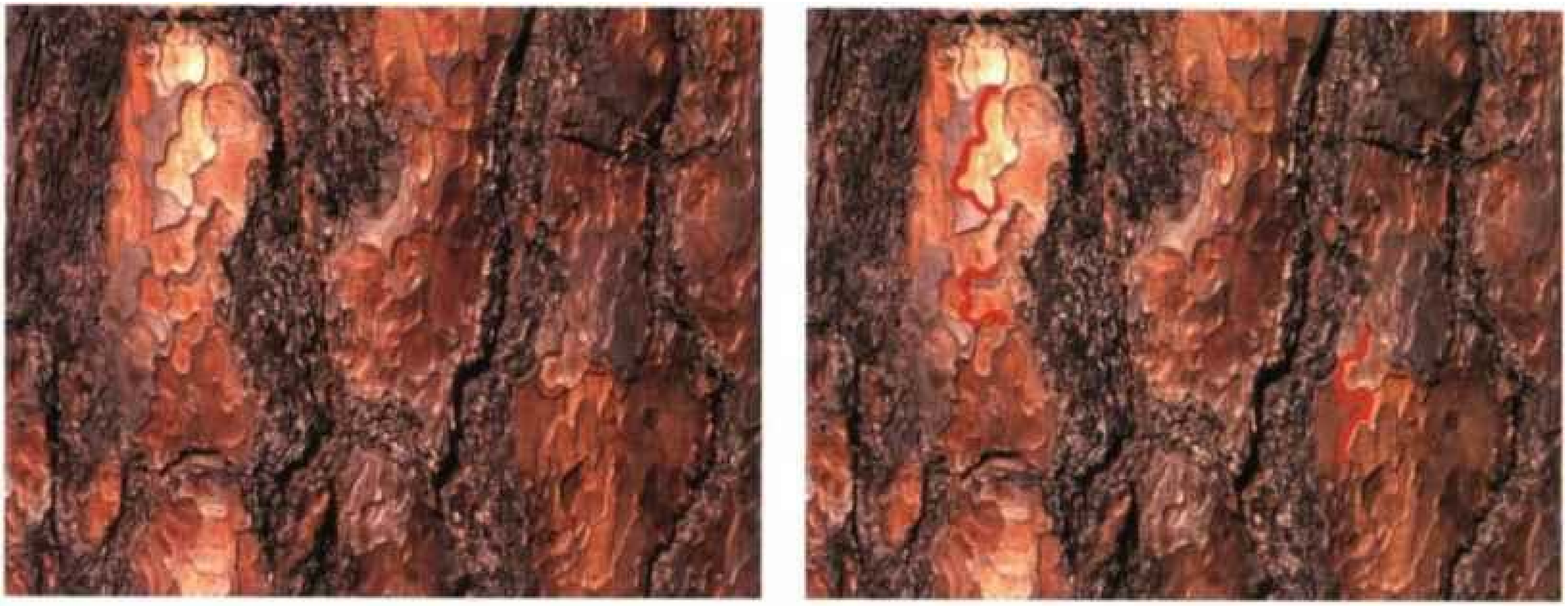

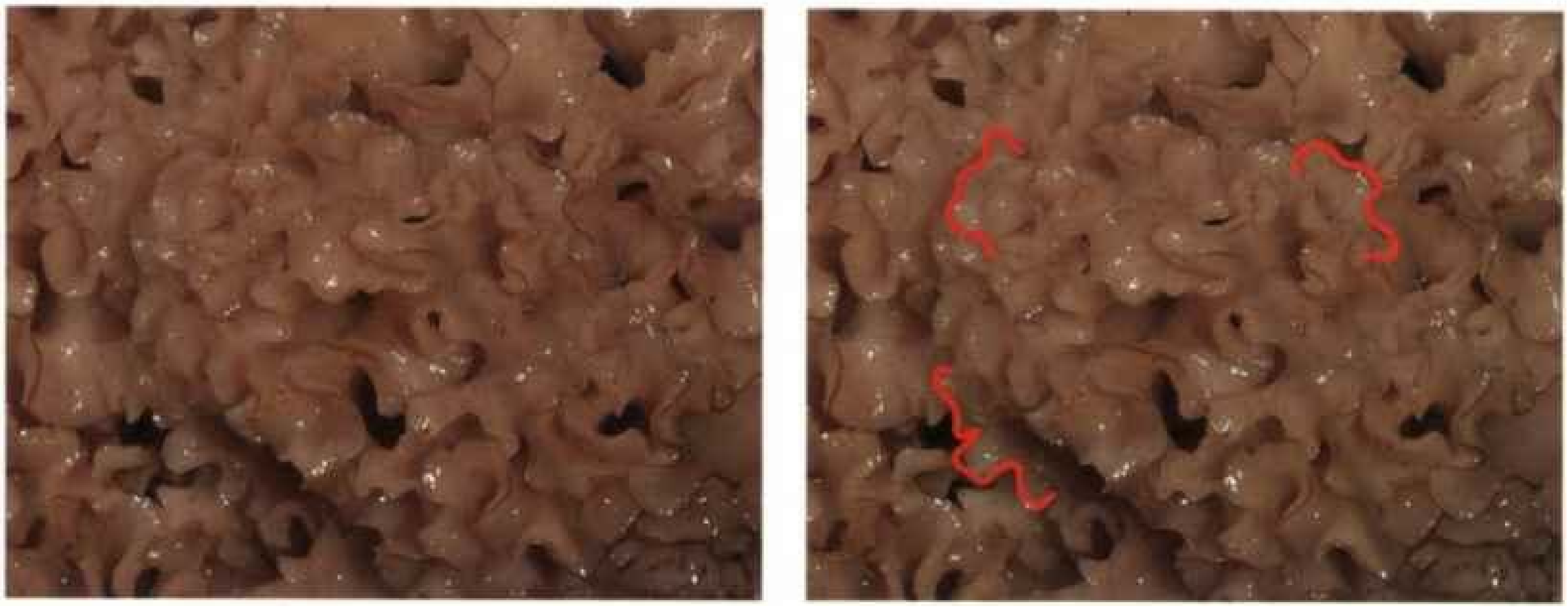

But I still want more advice on the secrets of successful mushrooming.

Mushroom hunting and the world of fungi have more than their fair share of mysterious lore, imponderables and surprises. Take that inexplicable instinct for the right spot to find mushrooms, for example. The experienced mushroomer knows his favorite haunts and whenever conditions are right, the mushrooms seem to call him. The dedicated mushroom hunter doesn’t have to make a conscious effort to memorize the perfect weather conditions for a particular species. Nor does he have to keep a log on the wind direction. Over the years, he just knows that on the right day he has to go to spot X. As vague as that sounds, the mushrooming “instinct” may well have a rational explanation, but it needn’t be a conscious one.

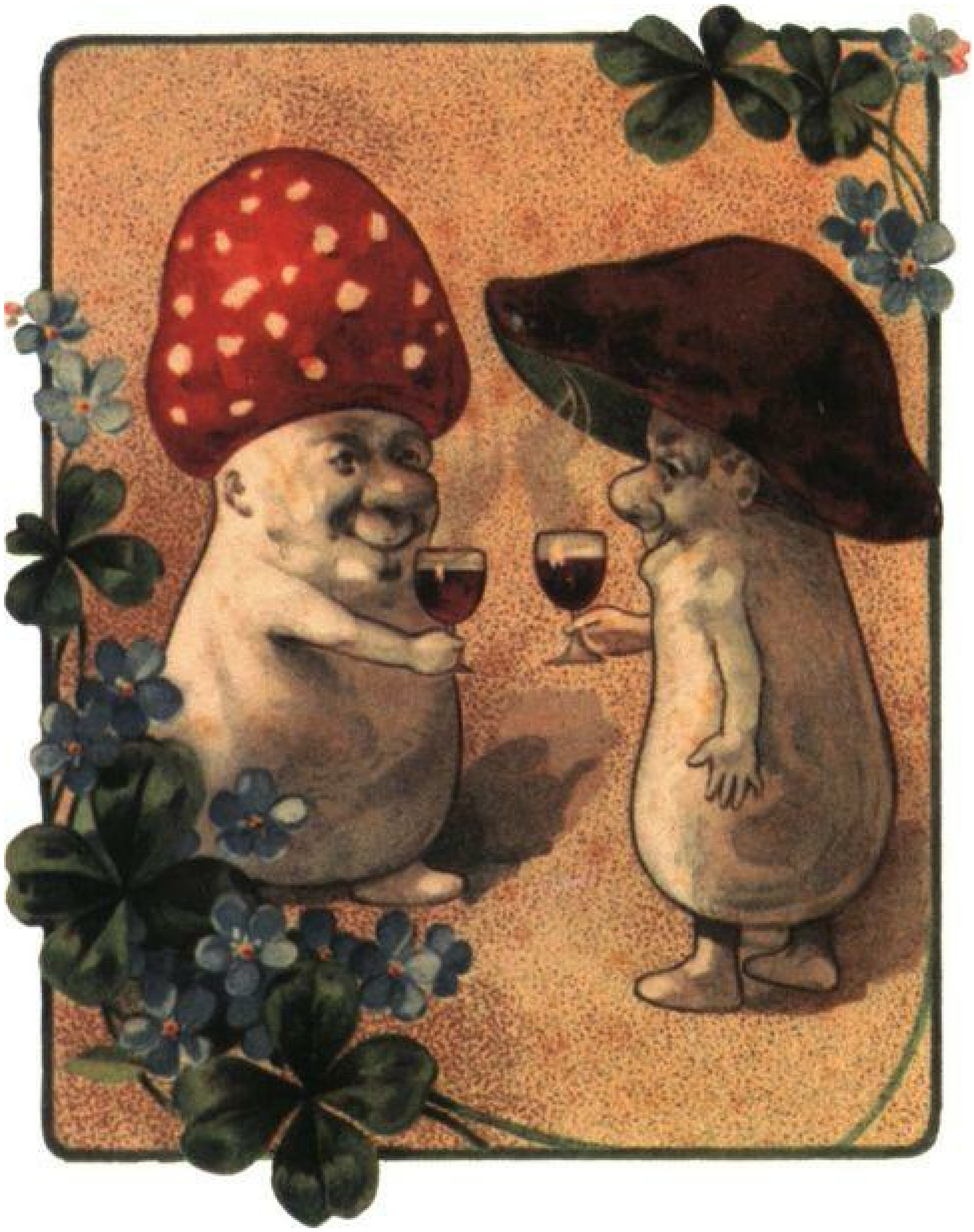

No exact science to mushrooming-hunting, then?

True, if you meet gnomes, pixies, fairies, elves or goblins in the woods, your rationality will be doubted.
But when fingers of fog creep eerily through the lonely wood, mythical creatures don’t seem far away. When out mushrooming in the twilight, you can easily understand how our forebears believed there were strange goings-on in the woods. Perhaps there were: and perhaps our modern powers of perception are just that much weaker than they used to be. The cold light of reason may have evicted all those colorful beings from the woods and now nobody is quite sure where they are anymore.

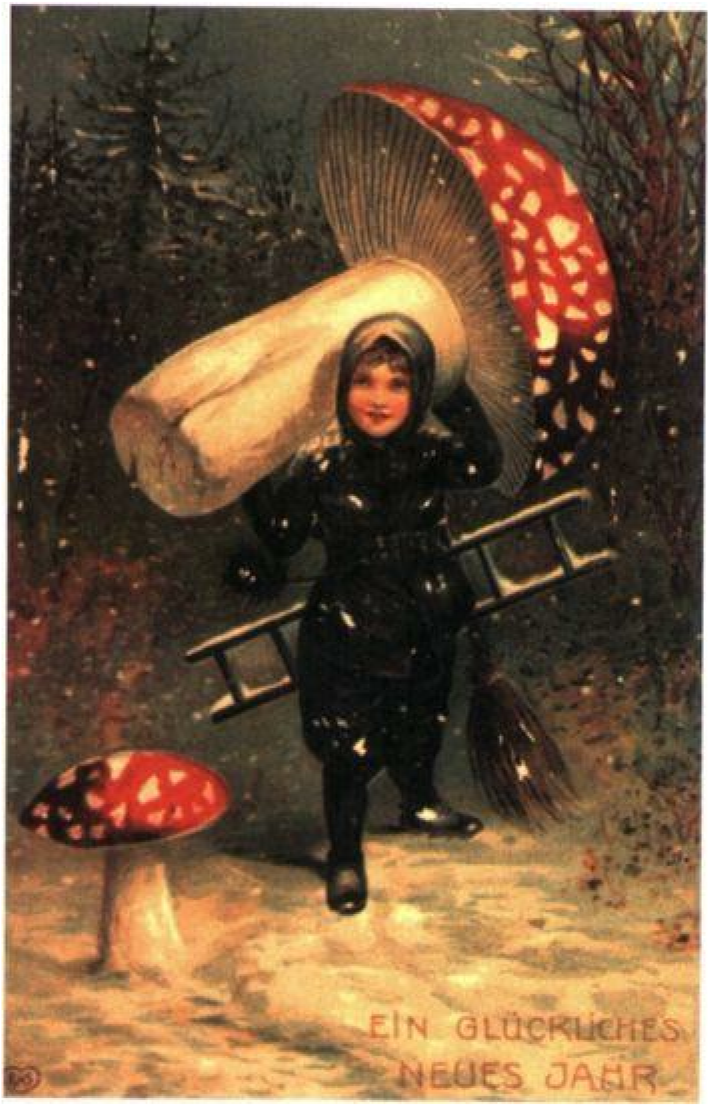

But they did leave their mark. The last bastion of mysticism is the fly agaric (left) which to this day has the power to fire the imagination. No decent fairy tale illustration is complete without the fly agaric. If the cep is the king of mushrooms, the fly agaric must be the queen. And as always with mushrooms, the mystical mixes with the scientific.

Fly agarics are useful indicators: where they are, there are often ceps nearby. Fly agarics wave and shout “Over here! Over here there are beautiful ceps!” The king is always near the queen.

Yet another mingling of fact and fiction: the fly agaric got its name from its surprising powers: it is a natural insecticide. Pieces of it are put in milk to attract flies. The flies then get drugged and die. In fact, the hallucinogenic properties of the fly agaric have inspired some mind-boggling theories and experiences.

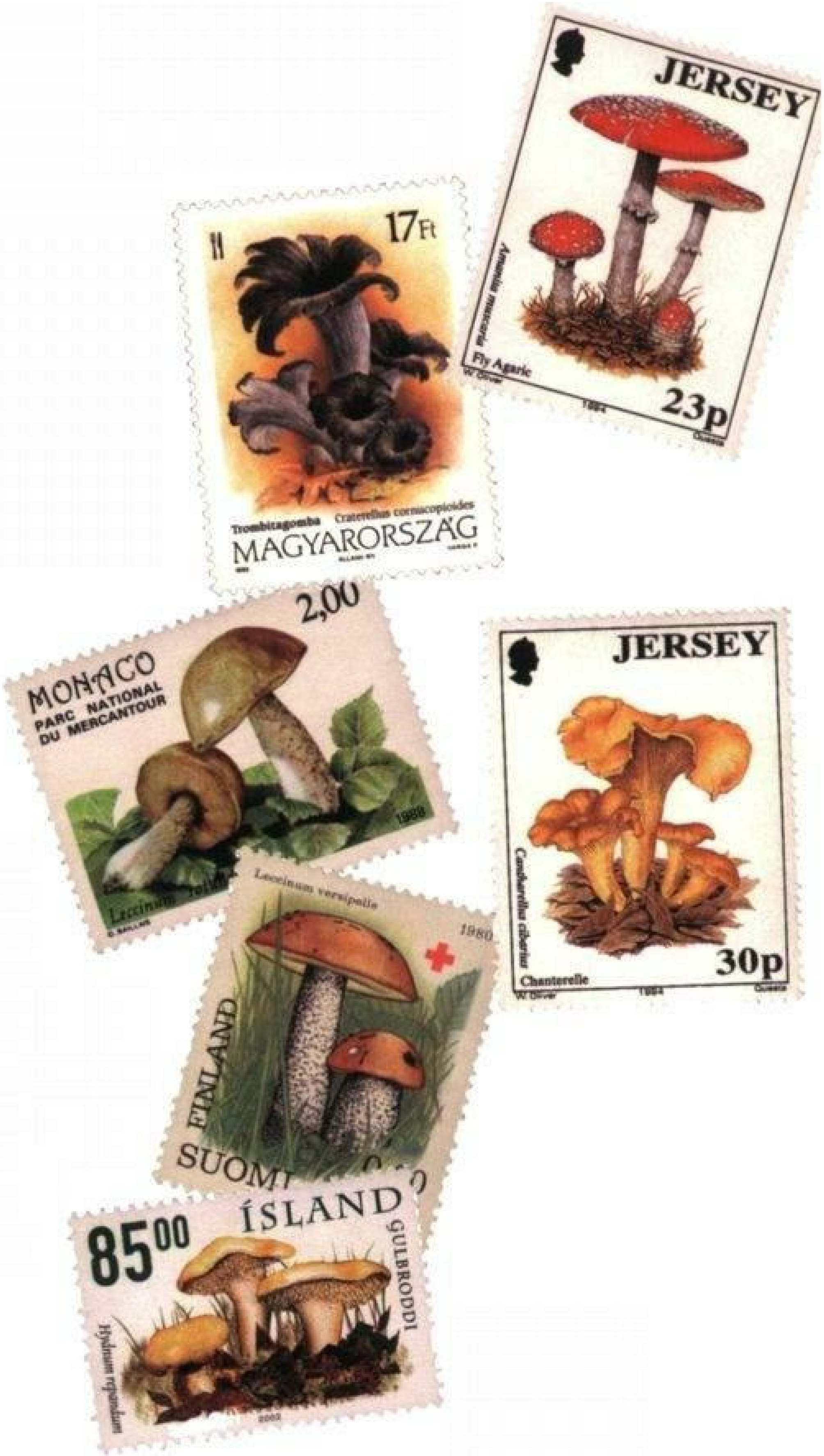
JERSEY
Amanita muscaria
Fly Agaric
23p
1994
17Ft
Trombitagomba Craterellus cornucopioides
MAGYARORSZÁG
2,00
MONACO
PARC NATIONAL
DU MERCANTOUR
1988
JERSEY
Cantharellus cibarius
Chanterelle
30p
1994
Leccinum versipelle
1980
FINLAND
SUOMI
85 00
ÍSLAND
GULBRODDI
Hydnum repandum

Shamans, or holy priests, reportedly used the hallucinogenic fly agaric to make contact with the gods, while lesser mortals joined in the ritual by drinking the urine of the shaman. This would have been little more than water with the hallucinogenic substances still active in it, because, before the ceremony, the shaman had to fast for several days before ingesting the fly agaric.

The phrase “to go berserk” refers to the Berserkers (Viking warriors) who went fearlessly into battle and were reported to fight “like mad dogs and wolves.” This is said to be the fly agaric’s work.

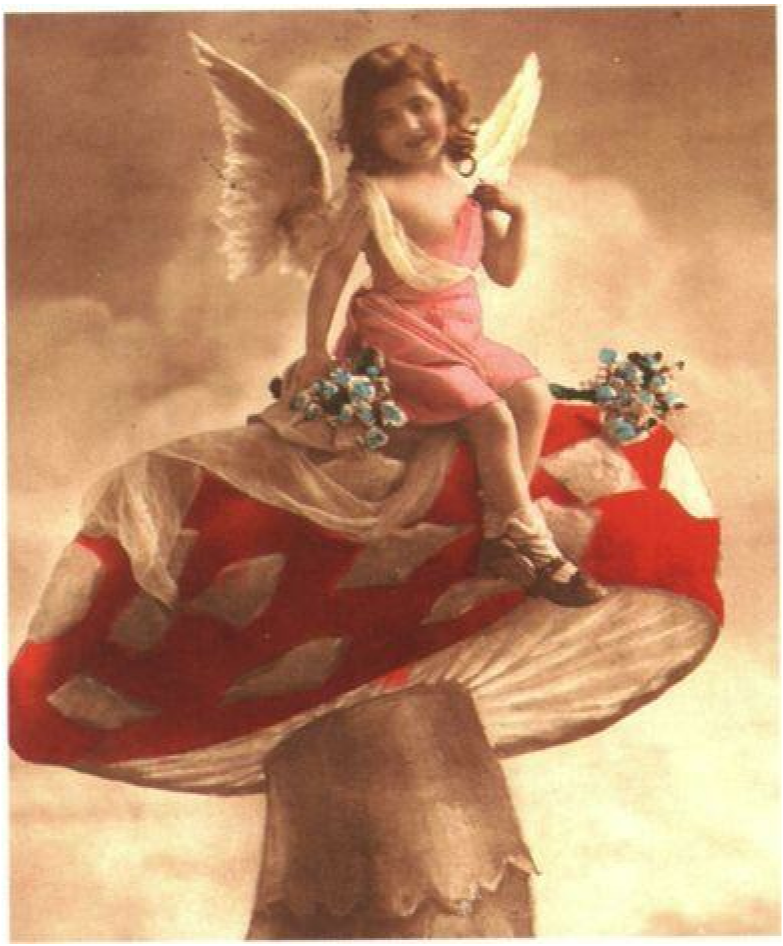

It surely now comes as no surprise that Santa Claus is also linked to the fly agaric. After all, there are the same distinctive colors: and there he is in his reindeer-powered sleigh, flying all over the world, filling stockings, and involuntarily cleaning chimneys. Only a full-blown shamanic fly agaric ritual could take Santa Claus and come up with a tale like that!

These are just a few of the theories and ideas linked to the fly agaric. Fly agarics are also supposed to bring good luck, and in certain parts of the world they remain a popular emblem in advertising, on stamps, and on Christmas and New Year’s cards. Luck is a fitting theme with which to conclude this book. Don’t trust your luck when identifying mushrooms. Follow the instructions in this book and enjoy mushrooming without fear.

~

12

Techniques of Grafting

learning objectives

- Explain the requirements for successful graftage.
- Describe the techniques of detached scion graftage, approach graftage, and repair graftage.
- Discuss the preparation for grafting—tools, accessories, machines, automation, and processing scionwood.
- Explain the craftsmanship of grafting—manual techniques, record keeping, and mechanization.
- Describe the aftercare of grafted plants—in bench grafting systems, and field and nursery grafting systems.
- Identify field, bench, and miscellaneous grafting systems.

INTRODUCTION

Since people first learned to graft plants, a myriad of grafting techniques have been developed. In *The Grafter's Handbook,* Garner (19) enumerates and describes some forty different grafts.

Here we describe the most important grafting methods. Among them, a person who can use a sharp knife can find one that meets any specific grafting need. However, success in grafting depends not only on a technically correct graft but in preparation of the scion and rootstock for graftage. Equally critical are the optimum time for grafting, and proper aftercare.

With high labor costs, only a few of the more efficient grafts are utilized in United States woody ornamental nurseries, including the side veneer, splice (whip graft), and whip-and-tongue graft; use of approach and repair graftage is limited. With fruit crops, depending on the species, a number of different apical, side, and root grafts are utilized around the world. Chip budding and T-budding, which are described in detail in Chapter 13, are two of the most common budding methods for woody ornamentals and fruit crops. Vegetable grafting has increased dramatically worldwide—and is commonly done in Asia and Europe where land is intensively used and crops are not rotated. Grafting onto rootstock resistant to soil pathogens and environmental stress helps increase yield and reduce chemical usage (12, 21, 34). For example, some of the most important grafts with cucurbit vegetables (melon, squash) include hole insertion grafting, tongued approach, and one cotyledon graft (also known as the splice, slant, or the Japanese tube graft), which are described in the chapter. Some robotic vegetable grafting machines can produce 800 grafts per hour.

This chapter is divided into three sections: (a) the **types of grafts,** (b) **production processes of graftage**—including the preparation, craftsmanship, and aftercare of grafted plants, and (c) **grafting systems,** including field grafting, bench grafting, and miscellaneous grafting systems—such as herbaceous graftage, cutting grafts, and micrografting.

REQUIREMENTS FOR SUCCESSFUL GRAFTING

For any successful grafting operation, producing a plant, as shown in Figure 12–1, requires five important elements:

1. *The rootstock and scion must be compatible.* They must be capable of uniting. Usually, but not always, closely related plants, such as two apple cultivars, can be grafted together. Distantly related plants, such as oak and apple, cannot make a successful graft combination (see Chapter 11 for a discussion of these factors).

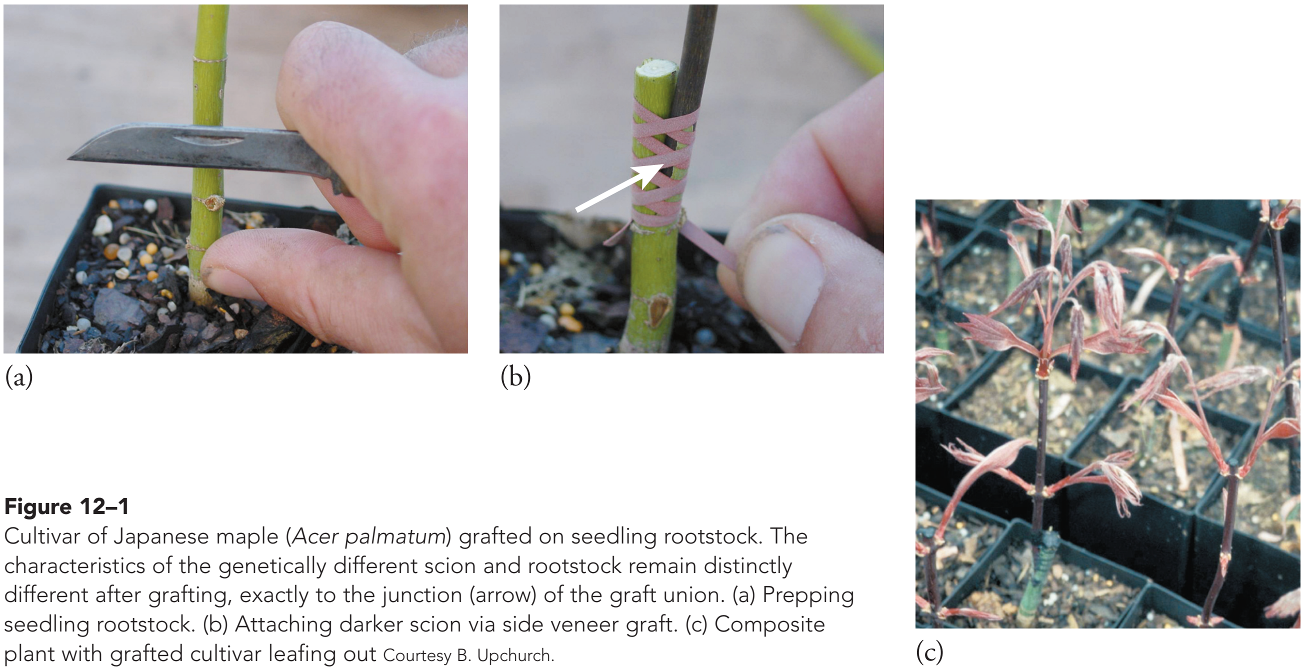
(a)

(b)

(c)

Figure 12–1
Cultivar of Japanese maple (*Acer palmatum*) grafted on seedling rootstock. The characteristics of the genetically different scion and rootstock remain distinctly different after grafting, exactly to the junction (arrow) of the graft union. (a) Prepping seedling rootstock. (b) Attaching darker scion via side veneer graft. (c) Composite plant with grafted cultivar leafing out Courtesy B. Upchurch.

2. *The* **vascular cambium** *of the scion must be placed in direct contact with that of the rootstock.* The cut surfaces should be held together tightly by wrapping, nailing, wedging, or some similar method. Rapid development of the graft union is necessary so that the scion may be supplied with water and nutrients from the rootstock by the time the buds start to open.

vascular cambium The tissue responsible for the formation of new xylem and phloem in the development of a successful graft union.

3. *The grafting operation must be done at a time when the rootstock and scion are in the proper physiological stage.* Usually, this means that the scion buds are dormant while at the same time, the cut tissues at the graft union are capable of producing the callus tissue necessary for healing of the graft. For deciduous plants, dormant scionwood is collected during the winter and kept inactive by storing at low temperatures. The rootstock plant may be dormant or in active growth, depending upon the grafting method used.
4. *Immediately after the grafting operation is completed, all cut surfaces must be protected from desiccation.* The graft union is covered with tape, grafting wax, Parafilm tape, Buddy Tape, or the grafts are placed in moist material or a covered grafting frame.
5. *Proper care must be given to the grafts for a period of time after grafting.* Shoots (suckers) coming from the rootstock below the graft will often choke out the desired growth from the scion. In some cases, shoots from the scion will grow so vigorously that they break off unless staked and tied or cut back.

TYPES OF GRAFTS

Grafting may be classified according to the part of the rootstock on which the scion is placed—a root, or various places in the top of the plant. Types of grafts can be categorized as (1) **detached scion graftage,** which includes apical, side, bark, and root graftage; (2) **approach graftage,** where the root system of the scion and the shoot system of the rootstock are not removed until after successful graft union formation occurs; and (3) **repair graftage of established trees.** The grafts that are categorized in Tables 12–1 and 12–2 are described in greater detail later in the chapter.

detached scion graftage A type of graft used when a section of the shoot of the scion is removed and grafted to the apex or side of the rootstock. It is also used in grafting roots (root graftage).

approach graftage The root system of the scion and shoot system of the rootstock are not removed until after successful graft union formation occurs.

repair graftage Graft used in repairing or reinforcing injured or weak trees.

Table 12–1
TYPES OF GRAFTS

I. **Detached Scion Graftage**
  A. **Apical Graftage**
    - Whip-and-tongue graft
    - Splice graft (whip graft; with vegetables—One cotyledon graft [OCG] or Japanese tube graft)
    - Cleft graft (split graft)
    - Wedge graft (saw-kerf graft)
    - Saddle graft
    - Four-flap graft (banana graft)
    - Hole Insertion Graft (HIG) or Terminal/Tip Insertion graft with vegetables
  B. **Side Graftage**
    - Side-stub graft
    - Side-tongue graft
    - Side-veneer graft
    - Side insertion graft (SIG) with vegetables
  C. **Bark Graftage**
    - Bark graft (rind graft)
    - Inlay bark graft
  D. **Root Graftage**
    - Whole-root and piece-root grafting
    - Nurse-root grafting

II. **Approach Graftage**
    - Spliced approach graft
    - Tongued approach graft (TAG)
    - Inlay approach graft

III. **Repair Graft**
    - Inarching
    - Bridge graft
    - Bracing

Table 12–2
UTILIZATION AND ROOTSTOCK CRITERIA OF SELECTED GRAFTS

Graft type	Diameter of rootstock	Rootstock condition	Uses
Whip-and-tongue graft	Small: 6 to 13 mm (1/4 to 1/2 in); same diameter as scions	Dormant; however, active with bench grafting of container rootstock	Bench grafting; container grafting; some topworking in field; root grafting; a popular graft
Whip graft (splice graft) —also called **One cotyledon graft (OCG) or Japanese tube graft** with vegetables.	Small: 6 to 13 mm (1/4 to 1/2 in); same diameter as scions; See Figure 12–46 for schedule.	Dormant; however, active with bench grafting of container rootstock, greenwood grafting, and vegetable crops	Bench grafting; container grafting; some topworking in field; grafting of vegetable liner plants; root grafting; a popular graft
Cleft graft (split graft)	Moderate: 2.5 to 10 cm (1 to 4 in)	Dormant—before active growth starts in spring	Topworking in field
Wedge graft (saw-kerf graft)	Moderate: 2.5 to 10 cm (1 to 4 in)	Dormant—before active growth starts in spring	Topworking in field
Saddle graft	Small: 6 to 19 mm (1/4 to 3/4 in); same diameter as scion	Dormant	Bench grafting via hand or machine; container grafting; root grafting
Four-flap graft (banana graft)	Small: up to 2.5 cm (1 in); same diameter as scions	Active; bark must be slipping	Topworking small caliper trees
Hole insertion graft (HIG) or **Terminal/Top insertion graft**			Bench grafting; container grafting of liner vegetable plants

Graft type	Diameter of rootstock	Rootstock condition	Uses
Side-stub graft	Small to moderate rootstock larger than scion: grafted on rootstock branches up to 2.5 cm (1 in) in diameter	Dormant	Topworking in field
Side-tongue graft	Small: 6 to 19 mm (1/4 to 3/4 in); diameter of scion slightly smaller than rootstock	Dormant	Bench grafting; container grafting of broad- and narrow-leaved evergreen species
Side-veneer graft	Small: 6 to 19 mm (1/4 to 3/4 in); same diameter as scion	Dormant	Bench grafting; container grafting of smaller liner potted plants; a popular graft for conifers, deciduous trees and shrubs, and fruit crops
Side insertion graft (SIG)	Works well using vegetable rootstock with wide hypocotyls.	Active	Bench grafting; container grafting of liner vegetable plants
Bark graft (rind graft)	Large: 2.5 to 30 cm (1 to 12 in).	Active; bark must be slipping	Topworking in field
Inlay bark graft	Large: 2.5 to 30 cm (1 to 12 in).	Active; bark must be slipping	Topworking in field (e.g., pecans)
Spliced approach graft	Small: 6 to 19 mm (1/4 to 3/4 in); same size as scion; exception is mango grafting in India on larger, established trees	Active	Container grafting with difficult-to-graft species; scion and stock grafted as two independent, self-sustaining plants; only limited topworking in field
Tongued approach graft (TAG)	Small: 6 to 19 mm (1/4 to 3/4 in); same size as scion	Active	Container grafting with difficult-to-graft species; scion and stock grafted as two independent, self-sustaining plants; also used with vegetables
Inlay approach graft	Small: 6 to 19 mm (1/4 to 3/4 in); bark of rootstock is thicker than scion	Active	Container grafting with difficult-to-graft species; scion and stock grafted as two independent, self-sustaining plants
Inarching	Large: 15 cm (6 in) and larger	Dormant	Used to replace a weak or damaged root system of an established tree
Bridge graft	Large: 15 cm (6 in) and larger	Active; bark must be slipping	Repair injury to trunk of tree
Bracing	Limbs of tree bound by pulling together two strong young lateral shoots from limbs to be braced	Active or dormant	Natural grafting used to strengthen scaffolding limbs of a tree

Detached Scion Graftage—Apical Graftage

There are many variations of apical graftage. As the name suggests, the scion is inserted into the top of the severed rootstock shoot.

Whip-and-Tongue Graft The whip-and-tongue graft, shown in Figures 12–2 and 12–3, is particularly useful for grafting relatively small material about 6 to 13 mm (1/4 to 1/2 in) in diameter. It is highly successful if done properly because there is considerable vascular cambium contact,

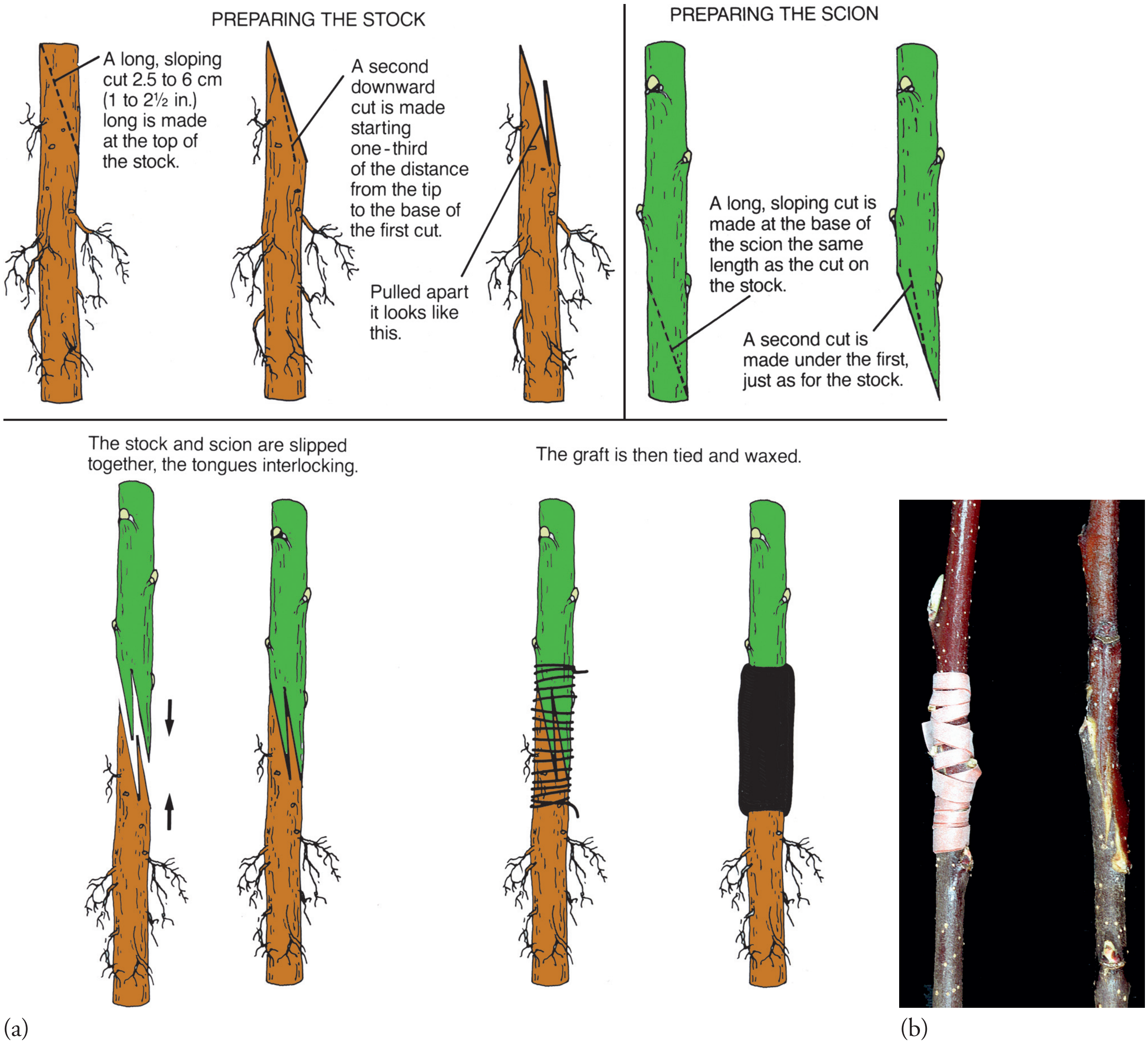
PREPARING THE STOCK
A long, sloping cut 2.5 to 6 cm (1 to 2½ in.) long is made at the top of the stock.
A second downward cut is made starting one-third of the distance from the tip to the base of the first cut.
Pulled apart it looks like this.
PREPARING THE SCION
A long, sloping cut is made at the base of the scion the same length as the cut on the stock.
A second cut is made under the first, just as for the stock.
The stock and scion are slipped together, the tongues interlocking.
The graft is then tied and waxed.
(a)
(b)

Figure 12–2
Whip-and-tongue graft. (a) This method is widely used in grafting small plant material and is especially valuable in making root grafts as illustrated here. (b) Whip-and-tongue of bench grafted pear.

plus it heals quickly and makes a strong union. Preferably, the scion and rootstock should be of equal diameter. The scion should contain two or three buds, and the graft made in the smooth internodes area below the lower bud.

The cuts made at the top of the rootstock should be the same as those made at the bottom of the scion. First, a smooth, sloping cut is made, 2.5 to 6 cm (1 to 2 1/2 in) long; longer cuts are made when working with large material. This first cut should preferably be made with one single stroke of the knife, in order to leave a smooth, flat surface. To do this, the knife must be razor sharp. Wavy, uneven cuts made with a dull knife will not result in a satisfactory union.

On each of these cut surfaces, a reverse cut is made. It is started downward at a point about one-third of the distance from the tip and should be about one-half the length of the first cut. To obtain a smooth-fitting graft, this second cut should not just split the grain of the wood but should follow along under the first cut, tending to parallel it.

The rootstock and scion are then inserted into each other, with the tongues interlocking. It is extremely important that the vascular cambium layers match along at least one side, preferably along both sides. The lower tip of the scion should not overhang the stock, because it increases the likelihood of the formation of

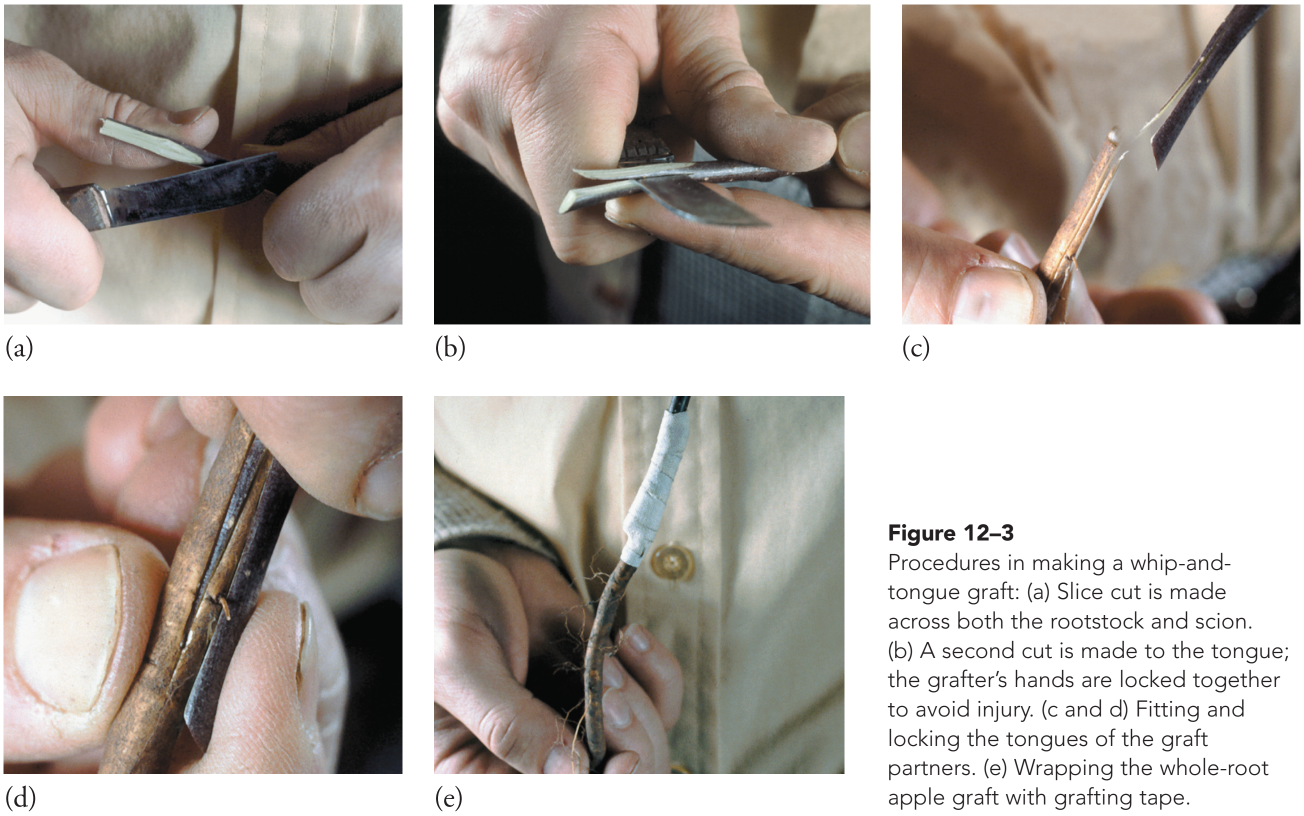

Figure 12–3
Procedures in making a whip-and-tongue graft: (a) Slice cut is made across both the rootstock and scion. (b) A second cut is made to the tongue; the grafter's hands are locked together to avoid injury. (c and d) Fitting and locking the tongues of the graft partners. (e) Wrapping the whole-root apple graft with grafting tape.

large callus knots. The use of scions larger than the rootstock should be avoided for the same reason.

After the scion and rootstock are fitted together, they are securely tied with budding rubber strips, plastic (poly) budding/grafting tape, or raffia. It is important that the tissues in the graft union area not dry out, so either sealing the graft union with grafter's wax, Parafilm, or Buddy Tape, or placing the plants under high relative humidity, is essential until the graft union has formed.

In **bench graftage** (page 502) the bare-root grafted plants can be stored in a grafting box (without sealing the graft union with grafter's wax) and packed with slightly moist peat or bark. Grafted plants in liner pots can be placed in a polytent in a temperature-controlled greenhouse (Fig. 12–4). If bare-root, bench-grafted plants are to be directly planted in a field nursery, the graft union is temporarily placed below the soil level. Any poly budding tape will need to be removed after graft union formation to prevent girdling the stem. Grafts wrapped with budding rubbers and temporarily covered with soil or media should be inspected later; the rubber decomposes very slowly below ground and may cause a constriction at the graft union.

If the whip-and-tongue graft is used in **field grafting,** the graft union of the **topworked** (page 422) plant must be tied and sealed with grafter's wax, Parafilm, or Buddy Tape. Aftercare of grafted plants is further described in the section "Production Processes of Graftage" (page 491).

Splice Graft (Whip Graft) The splice graft is simple and easy to make (Fig. 12–5). It is the same as the whip-and-tongue graft except that the second, or "tongue," cut is not made in either the rootstock or scion. A simple slanting cut of the same length and angle is made in both the rootstock and the scion. These are placed together and wrapped or tied as described for the whip graft. If the scion is smaller than the rootstock it should be set at one side of the rootstock so that the vascular cambium layers will match along that side (Fig. 12–5).

The splice graft is particularly useful in grafting plants that have a very pithy stem or that have wood that is not flexible enough to permit a tight fit when a tongue is made as in the whip-and-tongue graft. The splice graft is used in greenhouse production of vegetable crops for grafting disease-resistant rootstocks. For vegetable crops such as cucurbits or *Solanaceae,* this graft is sometimes referred to as One Cotyledon Grafting (OCG), the slant graft, or Japanese tube graft

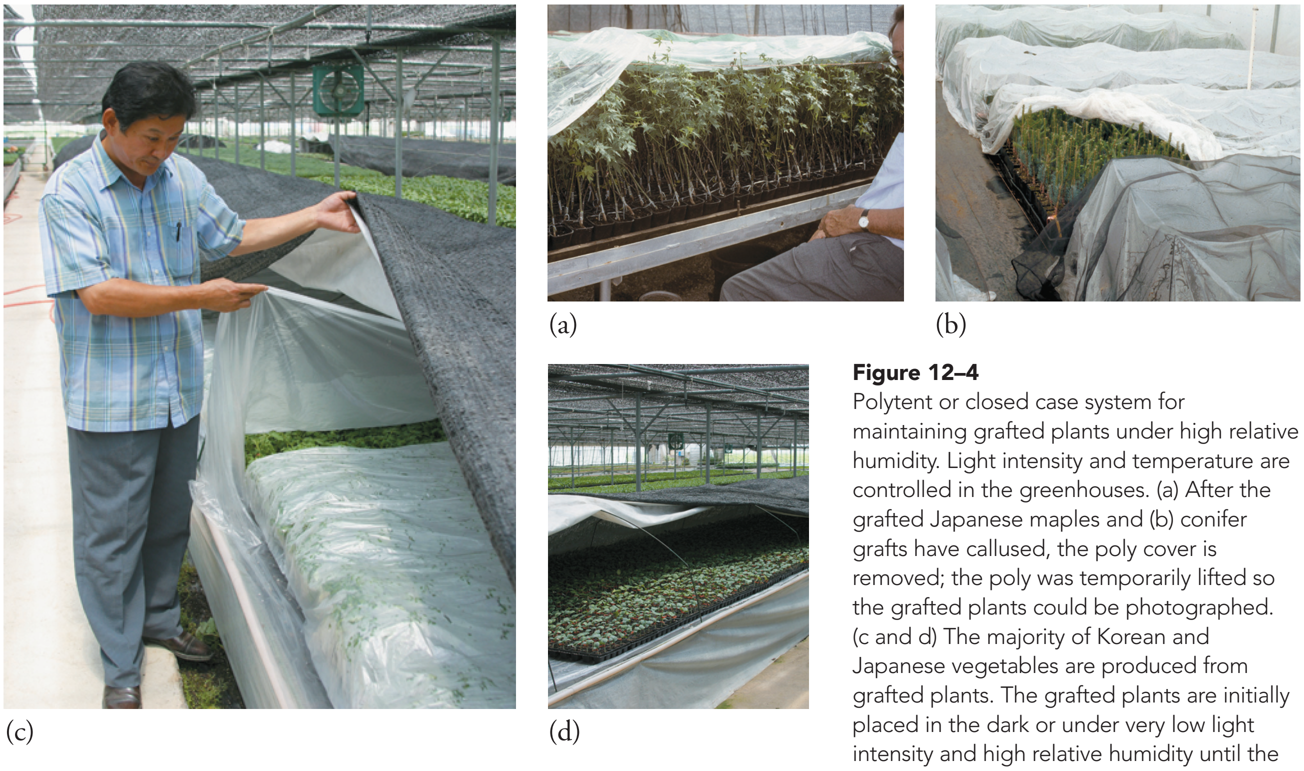

Figure 12–4
Polytent or closed case system for maintaining grafted plants under high relative humidity. Light intensity and temperature are controlled in the greenhouses. (a) After the grafted Japanese maples and (b) conifer grafts have callused, the poly cover is removed; the poly was temporarily lifted so the grafted plants could be photographed. (c and d) The majority of Korean and Japanese vegetables are produced from grafted plants. The grafted plants are initially placed in the dark or under very low light intensity and high relative humidity until the graft has healed. Photos c and d courtesy M. Peet.

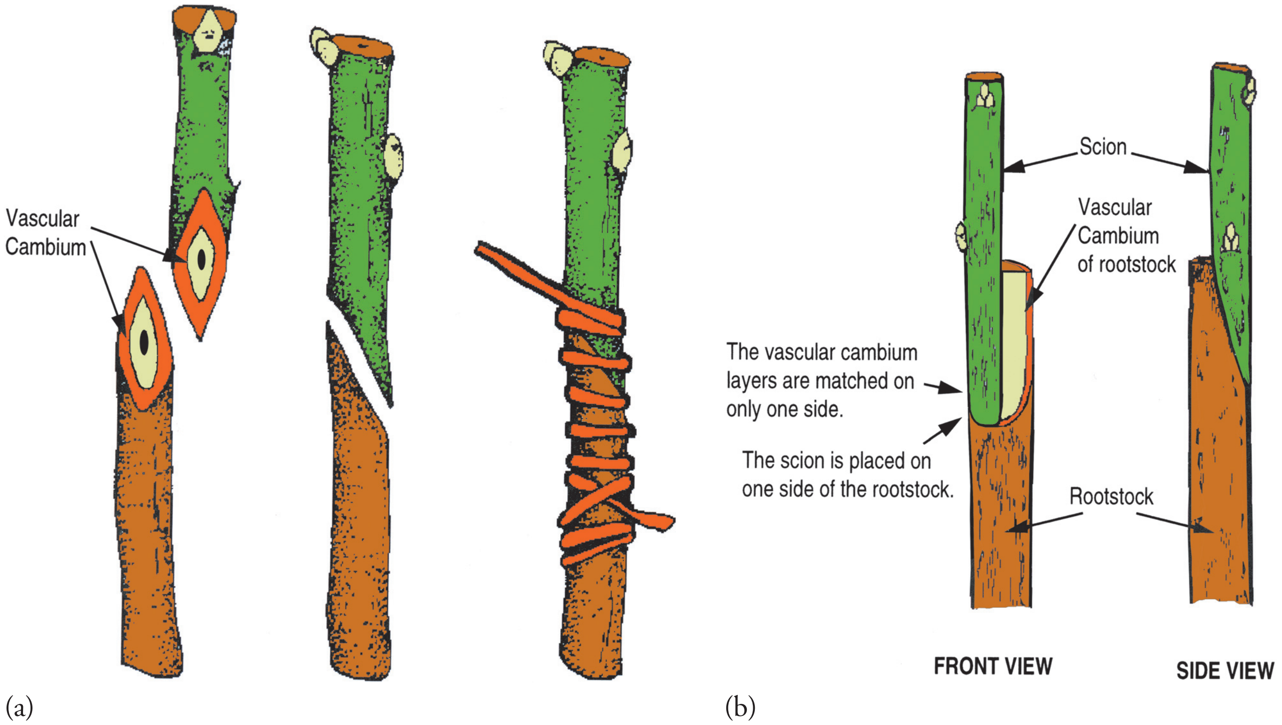
Vascular Cambium
Scion
Vascular Cambium of rootstock
The vascular cambium layers are matched on only one side.
The scion is placed on one side of the rootstock.
Rootstock
FRONT VIEW
SIDE VIEW
(a)
(b)

Figure 12–5
Splice graft (whip graft). (a) Procedures in making the splice graft with a slice cut that slants across the grafting partners. Ideally, the rootstock and scion are of the same caliber. (b) Method of making a splice graft when the scion is considerably smaller than the rootstock. It is important that the cambium layers be matched on one side.

BOX 12.1 **GETTING MORE IN DEPTH ON THE SUBJECT**

CORRECT INSERTION OF THE SCION

In all types of grafting, the scion must be inserted right side up. That is, the apical tip of the buds on the scion should be pointing upward and away from the rootstock. The graft will not be successful if this rule is not observed.

(Figs. 12–6 and 12–7) (11, 12, 21). The graft can be performed manually or with sophisticated, robotic grafting machines; see Figures 12–43, 12–44, and 12–45, pages 498–99. The rootstock and scion must be held together while tying the splice graft. In field grafting, it is not a convenient method to use at ground level, and must be performed higher up on the rootstock, where the grafter must do both the cutting and tying. The whip-and-tongue does not have this limitation, since the tongue holds the graft together, so that

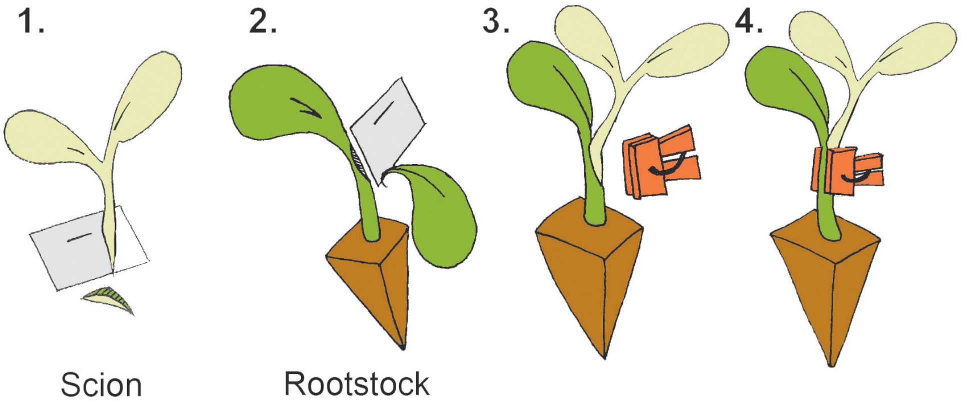

Figure 12–6
One cotyledon grafting (OCG), which is a form of the splice graft used with cucurbit vegetable crops; also called the slant graft and Japanese tube graft (12, 21). Illustrations courtesy R. L. Hassell.

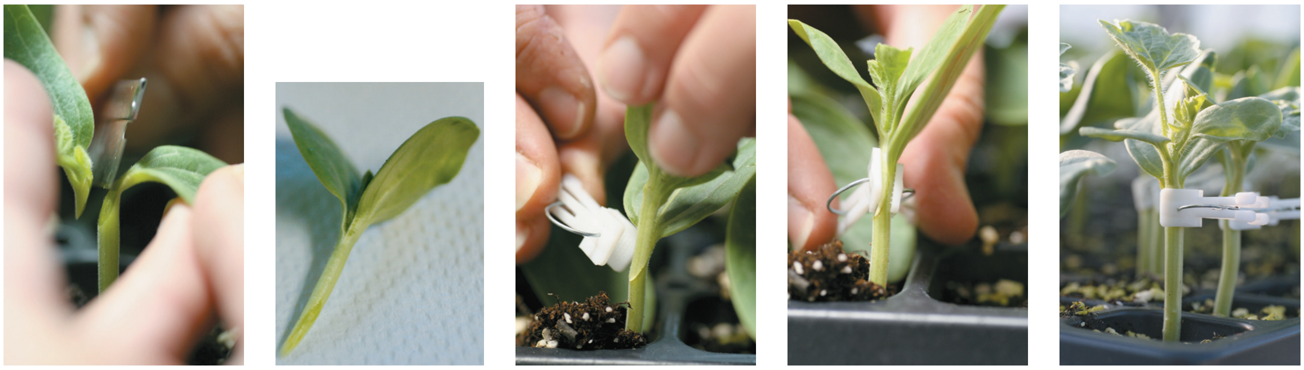
(a) (b) (c) (d) (e)

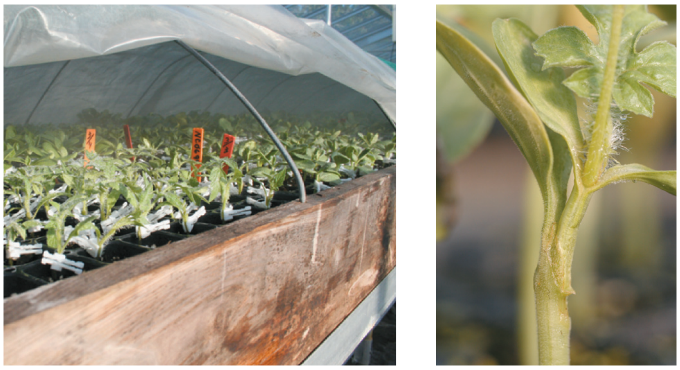
(f) (g)

Figure 12–7
One cotyledon grafting (OCG): A form of splice graft used with cucurbits. (a) Preparation of squash rootstock leaving a single cotyledon leaf. (b) Watermelon scion with slant cut. (c) Plastic clip used to hold scion and rootstock. (d and e) Plastic clips used to hold watermelon scion and squash rootstock. (f) Grafts are allowed to heal under very high humidity and dark to very low light conditions until graft union formation has occurred. (g) Successfully healed OCG. Photos courtesy of R. L. Hassell.

grafter The person cutting the stock and scion and inserting the scion piece.

Tier The person who completes the grafting process by tying, and sometimes waxing, the graft area.

the **grafter** has both hands free for tying, or the fitted graft can be left for a helper or **"tier"** to tie and seal. A splice graft is used in bench grafting and grafting of container plants.

Cleft Graft (Split Graft) The cleft or split graft is one of the oldest methods of field grafting. It is used to topwork trees, either in the trunk of a small tree or in the scaffold branches of a larger tree (Figs. 12–8 and 12–9). Cleft grafting is used for *crown grafting* (see the "Grafting Systems" section, page 504) or grafting smaller plants such as established grapevines or camellias. In topworking trees, this method should be limited to rootstock branches about 2.5 to 10 cm (1 to 4 in) in diameter, and to species with fairly straight-grained wood that will split evenly.

Although cleft grafting can be done any time during the dormant season, the chances for successful healing of the graft union are best if the work is done in early spring just when the buds of the rootstock are beginning to swell, but before active growth has started. If cleft grafting is done after the tree is in active growth, the bark of the rootstock may separate from the wood, making it difficult to obtain a good union. When this separation occurs, the loosened bark must be firmly nailed back in place. The scions should be made from dormant, 1-year-old wood. Unless the grafting is done early in the season (when the dormant scions can be collected and used immediately), the

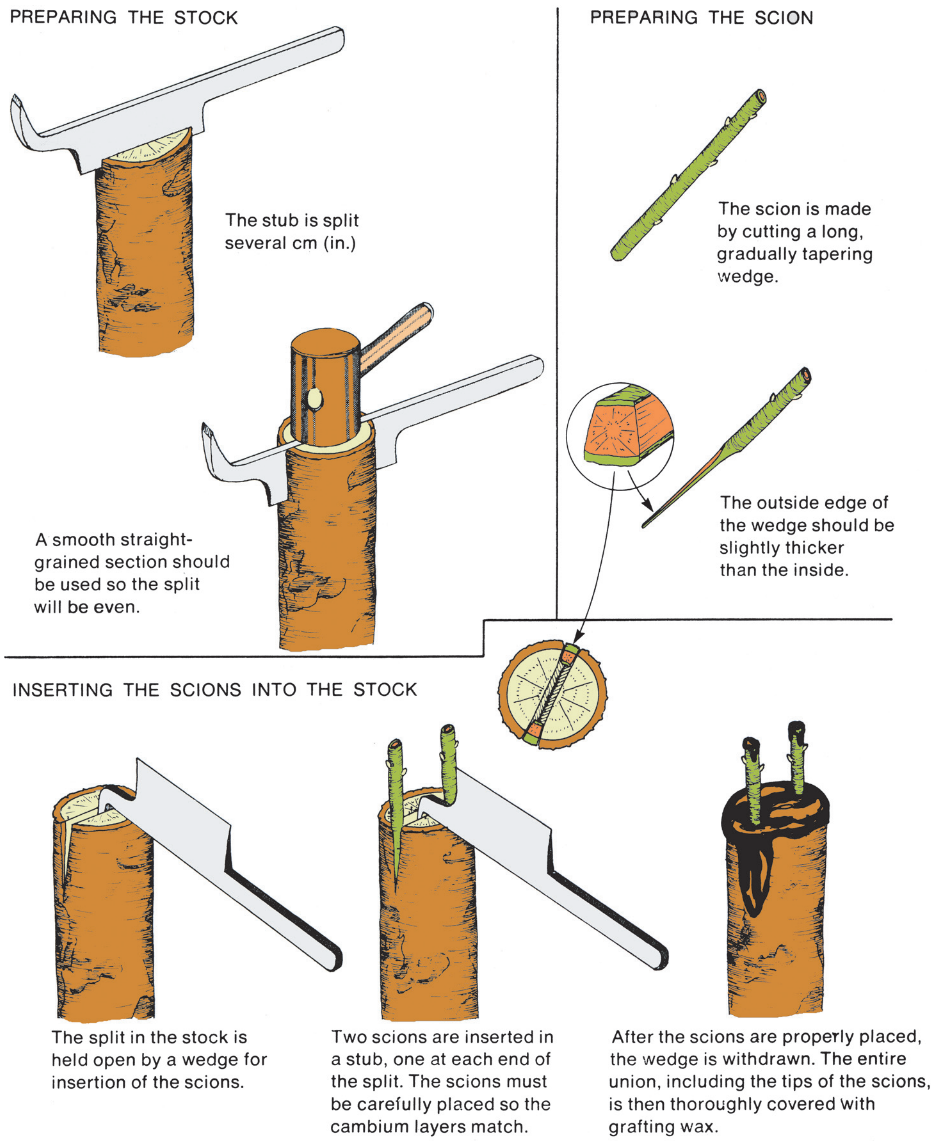
PREPARING THE STOCK
The stub is split several cm (in.)
A smooth straight-grained section should be used so the split will be even.
PREPARING THE SCION
The scion is made by cutting a long, gradually tapering wedge.
The outside edge of the wedge should be slightly thicker than the inside.
INSERTING THE SCIONS INTO THE STOCK
The split in the stock is held open by a wedge for insertion of the scions.
Two scions are inserted in a stub, one at each end of the split. The scions must be carefully placed so the cambium layers match.
After the scions are properly placed, the wedge is withdrawn. The entire union, including the tips of the scions, is then thoroughly covered with grafting wax.

Figure 12–8
Steps in making the cleft graft (split graft). This method is very widely used and is quite successful if the scions are inserted so that the cambium layers of stock and scion match properly.

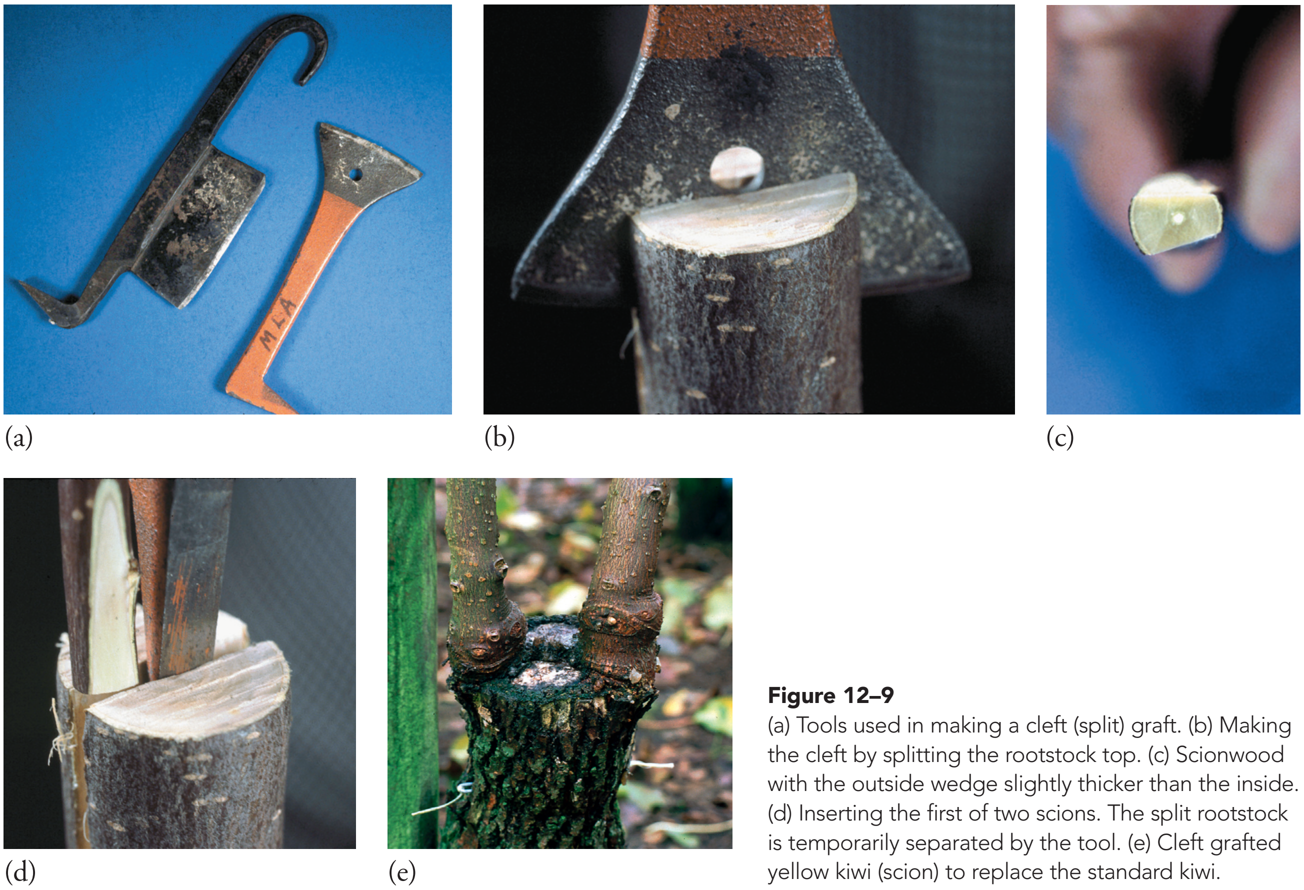
(a) (b) (c) (d) (e)

Figure 12–9
(a) Tools used in making a cleft (split) graft. (b) Making the cleft by splitting the rootstock top. (c) Scionwood with the outside wedge slightly thicker than the inside. (d) Inserting the first of two scions. The split rootstock is temporarily separated by the tool. (e) Cleft grafted yellow kiwi (scion) to replace the standard kiwi.

scionwood should be collected in advance and refrigerated. In sawing off the branch for this and other topworking methods, the cut should be made at right angles to the main axis of the branch.

In making the cleft graft, a heavy knife, such as a butcher knife, or one of several special cleft grafting tools, is used to make a vertical split for a distance of 5 to 8 cm (2 to 3 in) down the center of the stub to be grafted (Figs. 12–8 and 12–9). This split is made by pounding the knife in with a hammer or mallet. The branch is sawed off in such a position that the end of the stub that is left is smooth, straight-grained, and free of knots for at least 15 cm (6 in). Otherwise, the split may not be straight, or the wood may split one way and the bark another. The split should be in a tangential rather than radial direction in relation to the center of the tree to permit better placement of the scions for their subsequent growth. Sometimes the cleft is made by a longitudinal saw cut rather than by splitting. After a good, straight split is made, a screwdriver, chisel, or the wedge part of the cleft-grafting tool is driven into the top of the split to hold it open.

Two scions are inserted, one at each side of the stock where the vascular cambium layer is located. The scions should be 8 to 10 cm (3 to 4 in) long, about 10 to 13 mm (3/8 to 1/2 in) thick, and should have two or three buds. The basal end of each scion should be cut into a gently sloping wedge about 5 cm (2 in) long. It is not necessary that the end of the wedge come to a point. The side of the wedge which is to go to the outer side of the rootstock should be slightly wider than the inside edge. Thus, when the scion is inserted and the tool is removed, the full pressure of the split rootstock will come to bear on the scions at the position where the vascular cambium of the rootstock touches the vascular cambium layer on the outer edge of the scion. Since the bark of the rootstock is almost always thicker than the bark of the scion, it is usually necessary for the outer surface of the scion to set slightly in from the outer surface of the rootstock in order to match the vascular cambium layers.

The long, sloping wedge cuts at the base of the scion should be smooth, a single cut on each side made with a sharp knife. Both sides of the scion wedge should press firmly against the rootstock for their entire length. A common mistake in cutting scions for this type of graft is to make the cut on the scion too short and the slope too abrupt, so that the point of contact is only at the top. Slightly shaving the sides of the split in the stock will often permit a smoother contact.

After the scions are properly made and inserted, the tool is withdrawn, without disturbing the scions, which should be held tightly by the pressure of the rootstock so that they cannot be pulled loose by hand. No further tying or nailing is needed unless very small rootstock branches have been used. In this case, the top of the rootstock can be wrapped tightly with poly grafting tape or adhesive tape to hold the scions in place more securely.

Thorough waxing of the completed graft is essential. The top surface of the stub should be entirely covered, permitting the wax to work into the split in the stock. The sides of the grafted stub should be well covered with wax as far down the stub as the length of the split. The tops of the scions should be waxed but not necessarily the bark or buds of the scion. Two or three days later, all the grafts should be inspected and rewaxed where openings appear. Lack of thorough and complete waxing in this type of graft is a common cause of failure.

Wedge Graft (Saw-Kerf Graft) Wedge grafting is illustrated in Figure 12–10. Like the cleft graft, it can be made in late winter (in mild climates) or early spring before the bark begins to slip (separates easily from the wood).

The diameter of the stock to be grafted is the same as for the cleft graft—5 to 10 cm (2 to 4 in), and the scions are also the same size—10 to 13 cm (4 to 5 in) long and 10 to 13 mm (3/8 to 1/2 in) in thickness.

A sharp, heavy, short-bladed knife is used for making a V-wedge in the side of the stub, about 5 cm (2 in) long. Two cuts are made, coming together at the bottom and as far apart at the top as the width of the scion. These cuts extend about 2 cm (3/4 in) deep into the side of the stub. After these cuts are made, a screwdriver is pounded downward behind the wedge chip from the top of the stub to knock out the chip, leaving a V-shaped opening for insertion of the scion. The base of the scion is trimmed to a wedge shape exactly the same size and shape as the opening. With the two vascular cambium layers matching, the scion is tapped downward, firmly into place, and slanting outward slightly at the top so that the vascular cambium layers cross. If the cut is long enough and gently tapering, the scion should be so tightly held in place that it would be difficult to dislodge.

In a stub that is 5 cm (2 in) wide, 2 scions should be inserted 180 degrees apart; in a 10-cm (4 in) stub, 3 scions should be used, 120 degrees apart. After all scions are firmly tapped into place, all cut surfaces, including the tips of the scion, should be waxed thoroughly.

Saddle Graft The saddle graft can be bench grafted by hand or machine (see Fig. 12–41, page 497). The rootstock and scion should be the same size. The scion is prepared by cutting upward through the bark and into the wood on opposite sides of the scion (Fig. 12–11, page 476). The knife should penetrate more deeply into the wood as the cuts are lengthened. Before the knife is withdrawn, it is turned towards the middle of the scion piece, and the saddle shape is gradually formed by removing pieces of the wood. The rootstock is cut transversely and receives two upward cuts on either side to expose the vascular cambium of the rootstock, in order to match vascular cambium in the saddle of the scion. The apex of the rootstock is carved to fit the saddle. The graft needs to be tied, and all exposed cut surfaces sealed or stored in a grafting case until the graft union has formed. The saddle graft is used for bench grafting grape and *Rhododendron* cultivars (19).

Four-Flap Graft (Banana Graft) The four-flap graft is used in topworking small-caliper trees or tree limbs up to 2.5 cm (1 in) in diameter. This field graft is normally done manually [Figs. 12–12 (page 476) and 12–13 (page 477)], but there is a tool that aids in stripping the rootstock bark flaps from the wood (Fig. 12–13). Both the scion and rootstock should be of equal diameter, and the best fit is obtained when the scion is slightly larger than the rootstock. The four-flap graft is done with pecans in Texas from April to mid-May, when the rootstock bark is actively slipping (39). Scionwood, which is collected while dormant during the winter, is taken from cold storage and used immediately.

The rootstock with a primary stem or lateral limb is severed horizontally with sharp pruning shears. On the rootstock where the horizontal cut was made, 4 vertical, equally spaced cuts 4 cm (1.5 in) long are made with a grafting knife that penetrates from the bark down to the interior wood. A 15 cm (6 in) piece of scionwood with 3 axillary buds is cut on 4 sides with a knife. Cuts are made on the scion through the bark down to the wood—without removing much wood. There should be 4 thin slivers of bark, with the vascular cambium at the corners, which gives the prepared scion a square diameter appearance. The 4 flaps of bark are pulled down 4 cm (1.5 in) on the rootstock, and the inner wood is removed with pruning shears. The scion piece is inserted upright on the rootstock and the 4 flaps of the rootstock are pulled up to cover the 4 cut surfaces of the scion. A rubber band is rolled up onto the flaps to hold them in place. The cut flap areas are then tied with flagging tape, green floral tape, or white budding tape. The tip of the scion is painted with tree paint or sealed with white glue to prevent it from drying out.

Then the taped graft area is covered with aluminum foil to protect it from heat. A hole is made in the corner of a clear poly bag (freezer bag) and the poly

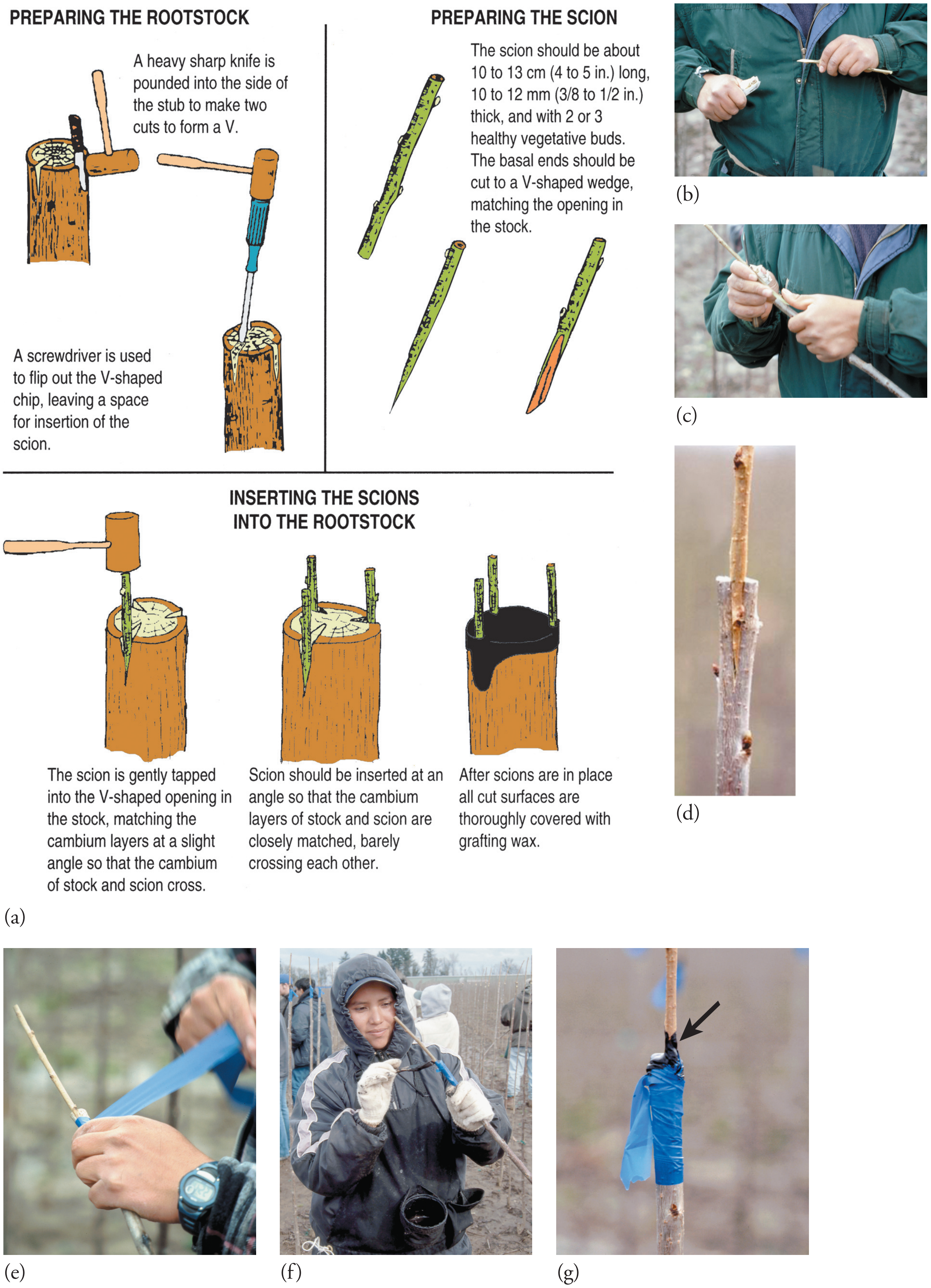

A heavy sharp knife is pounded into the side of the stub to make two cuts to form a V.

A screwdriver is used to flip out the V-shaped chip, leaving a space for insertion of the scion.

The scion should be about 10 to 13 cm (4 to 5 in.) long, 10 to 12 mm (3/8 to 1/2 in.) thick, and with 2 or 3 healthy vegetative buds. The basal ends should be cut to a V-shaped wedge, matching the opening in the stock.

The scion is gently tapped into the V-shaped opening in the stock, matching the cambium layers at a slight angle so that the cambium of stock and scion cross.

Scion should be inserted at an angle so that the cambium layers of stock and scion are closely matched, barely crossing each other.

After scions are in place all cut surfaces are thoroughly covered with grafting wax.

Figure 12–10
(a) Wedge graft (saw-kerf graft). Sometimes called the saw-kerf because the cuts in the side of the rootstock can be made with a saw, rather than with the sharp tool depicted. (b, c, d, e, and f) Wedge graft of cherry whips in field using one scion piece. (b) Trimming scionwood with grafting knife, (c and d) inserting scionwood into rootstock, (e) wrapping graft with poly, (f) sealing with grafting wax—notice wax container (arrow) and (g) tied graft with poly and grafting wax covering bottom of scion and graft union area (arrow) used to fill in tissue separation.

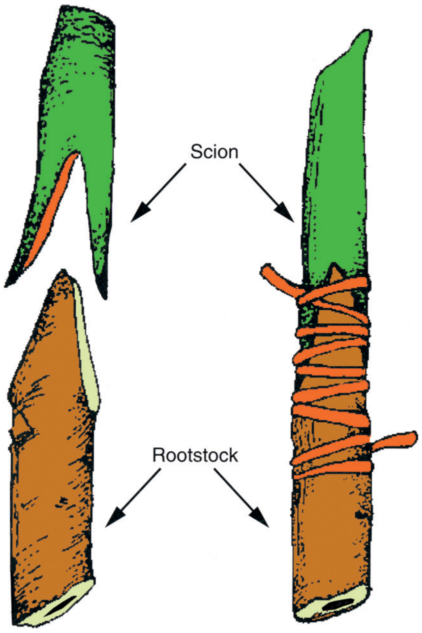

Figure 12–11
Steps in making the saddle graft. The scion is cut to have a saddle appearance and the understock to form a blunt point. The cambium layers are matched up and the graft tied.

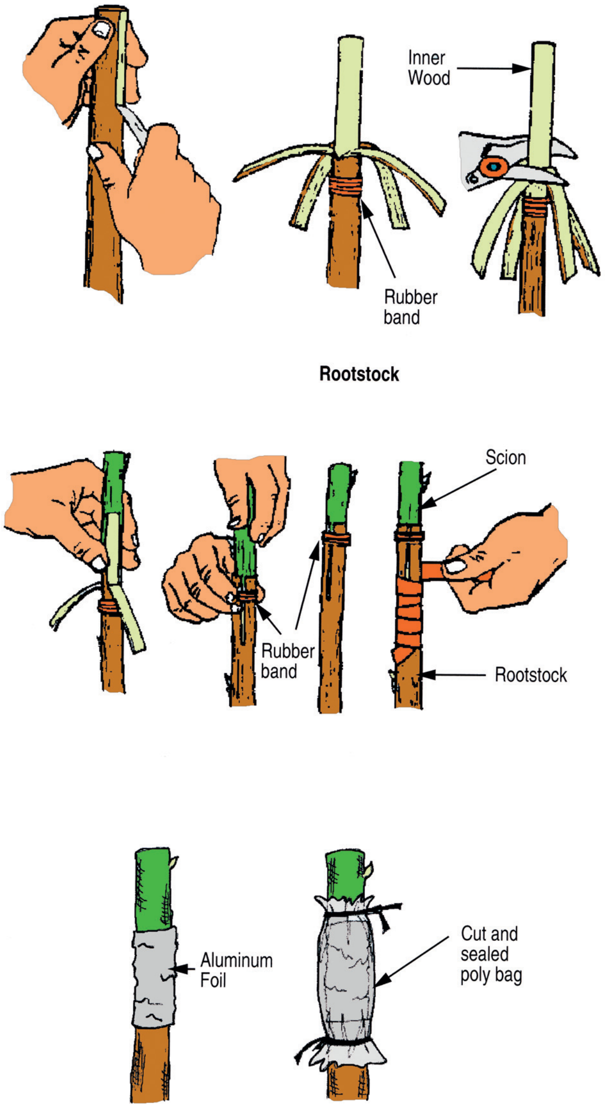

Figure 12–12
The four-flap or banana graft. *Top:* The top of the rootstock is cut horizontally, and the bark is cut vertically into four strips. The four bark flaps are peeled down and the inner wood removed. *Middle:* The scion bark is removed and the wood retained. The flaps of the rootstock cover the cut surfaces of the scionwood and are temporarily held by a rubber band. The graft is then tied with white grafting tape. *Bottom left:* Aluminum foil is wrapped around the graft to exclude heat from the graft. *Bottom right:* The grafted area covered with aluminum foil is wrapped with a cut poly bag, which is sealed to retain high relative humidity until the graft takes (39).

slid down over the graft area so that it is just covering the aluminum foil (no poly should cover the apex of the scion, nor should it touch any exposed wood). Air is expelled so the poly fits snugly over the aluminum foil, and it is tied at both ends with stretchable plastic budding tape or rubber bands. The function of the poly bag is to maintain a high relative humidity in the graft area. In 4 to 6 weeks after the graft has taken, the ties, poly bag, and aluminum foil are removed.

The vegetative growth of the rootstock plant must be kept in check, since many new shoots will appear on the rootstock below the graft. Some of these shoots are needed for maintaining tree vigor, but the rootstock shoots should not become dominant or exceed the height of the scion—the growing tips of the rootstock shoots will have to be removed several times during the growing season. After 2 to 3 years, all rootstock branches are removed below the graft and the scion becomes the dominant shoot system.

Hole Insertion Graft (HIG) or Terminal/Top Insertion Graft This technique is used for grafting watermelon to squash rootstock (12, 21). This is most popular graft used in China because it is suitable for *Lagenaria* (Cucurbita) and interspecific squash as rootstocks, requires few materials, is highly efficient (1,500+ plants/day/worker), and allows simpler management techniques (34). When both cotyledons and first true leaf start to develop, the rootstock plant is ready to graft (7 to 10 days after sowing). Remove the growing point with a sharp probe, and then open a hole on the upper portion of the rootstock hypocotyl with a bamboo needle or 1.4-mm drill bit. The scion is then cut on a 35- to 45-degree angle, on both sides, on the hypocotyls and inserted into the hole made in the rootstock. The cut surfaces are matched together, held with or without a grafting clip and transferred to a humidity chamber or healing room. Grafted plants should not be older than 33 days before transplanting (Figs. 12–14 and 12–15, page 478) (21).

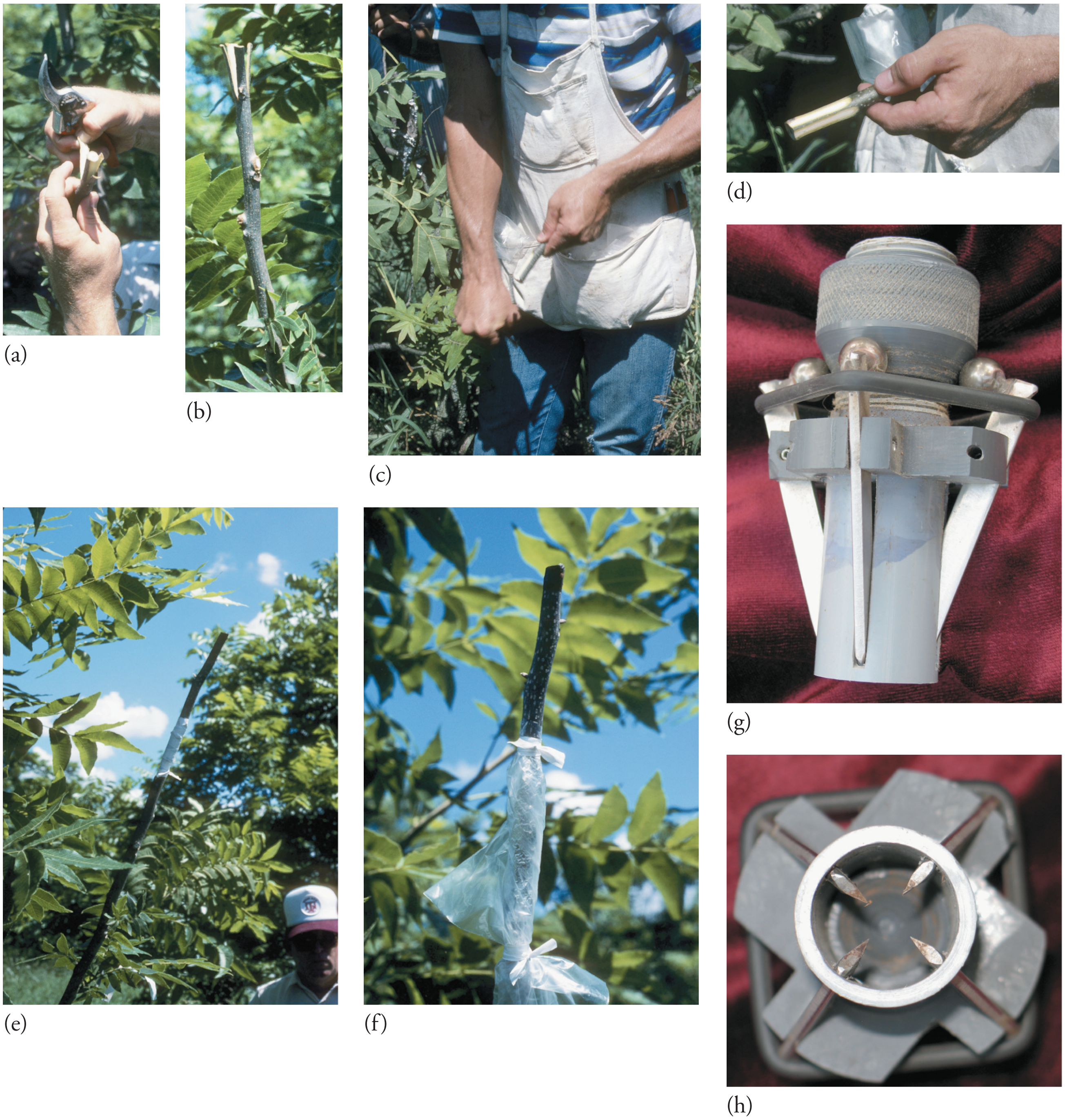

Figure 12–13
Steps in the four-flap or banana graft. (a) Preparing the rootstock by severing the rootstock top. (b) The four bark flaps of the rootstock with the "wood" of the rootstock removed. (c and d) Prepping the scion by removing the bark of the scion with wood left intact. (e and f) Flaps of the rootstock cover the cut surfaces of the scionwood and are temporarily held by grafting tape, then covered with aluminum foil and poly to prevent desiccation. (g and h) A tool for the four-flap graft, which is slid over the rootstock and used to cut and peal the four flaps.

Detached Scion Graftage—Side Grafting

There are many types of side graftage. As the name suggests, the scion is inserted into the side of the rootstock, which is generally larger in diameter than the scion. This method has proven useful for large-scale propagation of nursery trees (36). Generally, the rootstock shoot is removed after the graft takes, and the scion becomes the dominant shoot system.

Side-Stub Graft The side-stub graft is useful in grafting branches of trees that are too large for the whip-and-tongue graft, yet not large enough for other methods such

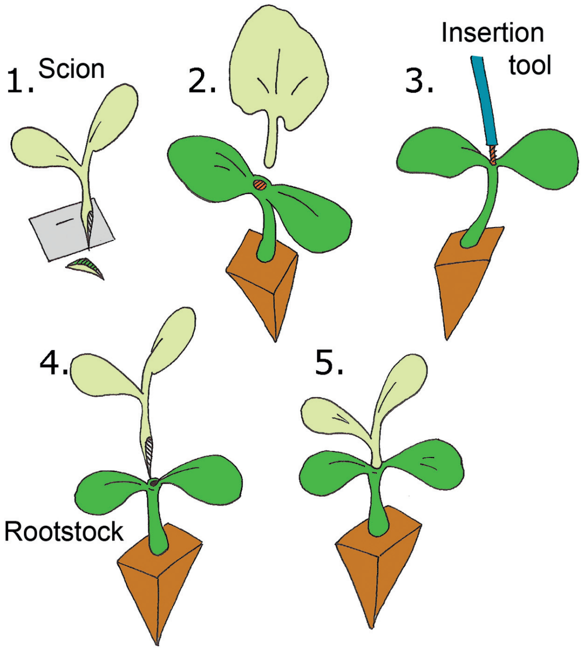

Figure 12–14
Hole insertion graft (HIG) or terminal/top insertion graft (12, 21). Illustrations courtesy R. L. Hassell.

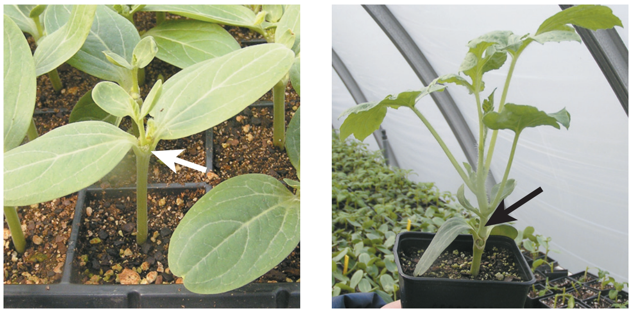
(a) (b)

Figure 12–15
(a and b) Hole insertion graft (HIG) for grafting watermelon to squash rootstock. This is the most popular graft used in China because it is suitable for Lagenaria (Cucurbita) and interspecific squash as rootstocks, requires few materials, has high efficiency, 1500+ plants/day/worker, and simpler management techniques (34). Photos courtesy of R. L. Hassell.

as the cleft or bark graft. For this type of side graft, the best rootstocks are branches about 2.5 cm (1 in) in diameter. An oblique cut is made into the rootstock branch with a chisel or heavy knife at an angle of 20 to 30 degrees. The cut should be about 2.5 cm (1 in) deep and at such an angle and depth that when the branch is pulled back, the cut will open slightly but will close when the pull is released.

The scion should contain two or three buds and be about 7.5 cm (3 in) long and relatively thin. At the basal end of the scion, a wedge about 2.5 cm (1 in) long is made. The cuts on both sides of the scion should be very smooth, each made by one single cut with a sharp knife. The scion must be inserted into the rootstock at an angle, as shown in Figure 12–16, to obtain maximum contact of the vascular cambium layers. The grafter inserts the scion into the cut while the upper part of the rootstock is pulled backward, being careful to obtain the best cambium contact, then the rootstock is released. The pressure of the rootstock should grip the scion tightly. The scion can be further secured by driving two small flat-headed wire nails [20 gauge, 1.5 cm (5/8 in) long] into the stock through the scion. Wrapping the rootstock and scion at the point of union with nursery tape also may be helpful. After the graft is completed, the rootstock may be cut off just above the union. This must be done very carefully or the scion may become dislodged. The entire graft union must be thoroughly covered with grafting wax, sealing all openings. The tip of the scion also should be covered with wax or sealed with white glue (57).

Side-Tongue Graft The side-tongue graft, shown in Figure 12–17, page 480, is useful for small plants, especially some of the broad- and narrow-leaved evergreen species. The rootstock plant should have a smooth section in the stem just above the crown of the plant. The diameter of the scion should be slightly smaller than that of the rootstock. The cuts at the base of the scion are made in the same way as for the whip-and-tongue graft. Along a smooth portion of the stem of the rootstock a thin piece of bark and wood, the same length as the cut surface of the scion, is completely removed. Then a reverse cut is made downward in the cut on the rootstock starting one-third of the distance from the top of the cut. This second cut in the rootstock should be the same length as the reverse cut in the scion. The scion is then inserted into the cut in the rootstock, the two tongues interlocking, and the vascular cambia matching. The graft is wrapped tightly, using one of the methods described for the whip-and-tongue graft.

The top of the rootstock is left intact for several weeks until the graft union has started to heal. Then it may be cut back above the scion gradually or all at once to force the buds on the scion into active growth.

Side-Veneer Graft The side-veneer graft is widely used for grafting small potted liner plants such as seedling conifers, deciduous trees and shrubs, and fruit crops (Figs. 12–18, 12–19, and 12–20, pages 480–83). A shallow downward and inward cut from 25 to 38 mm (1 to 1 1/2 in) long is made in a smooth area just above the crown of the rootstock. At the base of this cut, a second

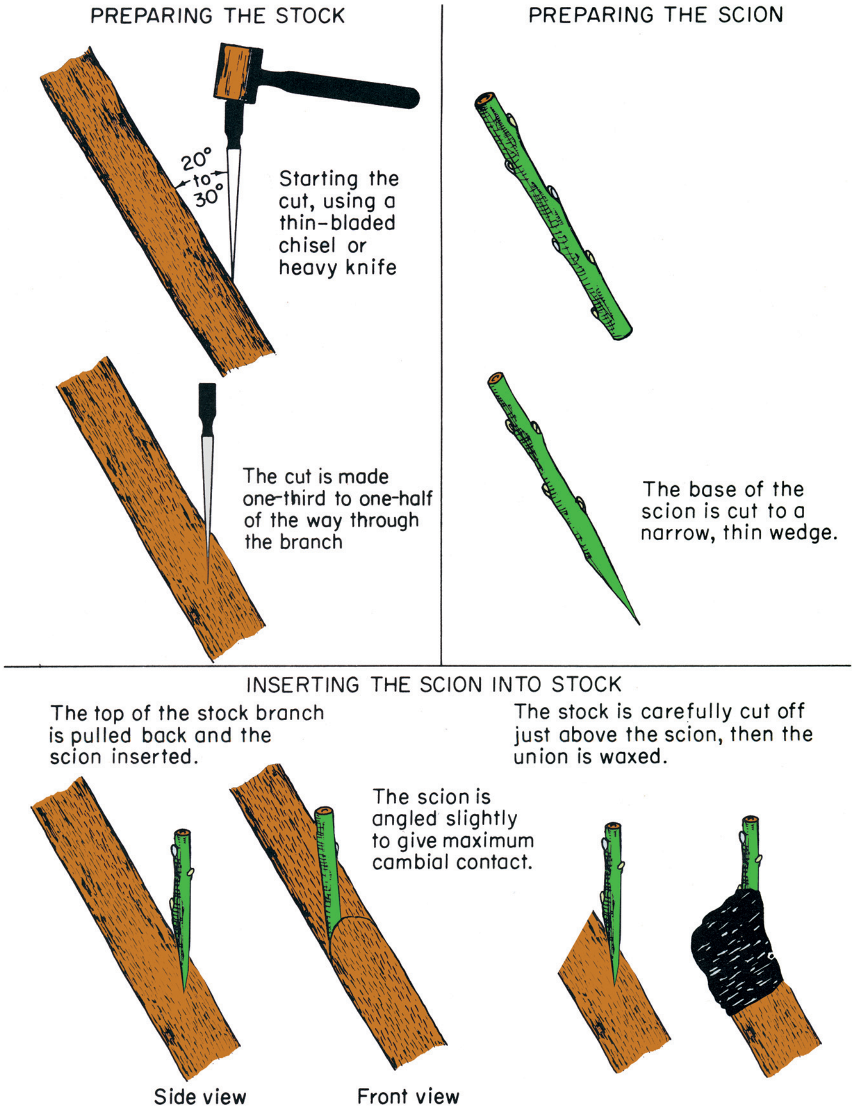
PREPARING THE STOCK
20° to 30°
Starting the cut, using a thin-bladed chisel or heavy knife
The cut is made one-third to one-half of the way through the branch
PREPARING THE SCION
The base of the scion is cut to a narrow, thin wedge.
INSERTING THE SCION INTO STOCK
The top of the stock branch is pulled back and the scion inserted.
The scion is angled slightly to give maximum cambial contact.
The stock is carefully cut off just above the scion, then the union is waxed.
Side view
Front view

Figure 12–16
Steps in preparing the side-stub graft. A thin-bladed chisel, as illustrated here, is ideal for making the cut, but a heavy butcher knife could be used satisfactorily.

short inward and downward cut is made, intersecting the first cut, that removes the piece of wood and bark. The scion is prepared with a long cut along one side and a very short one at the base of the scion on the opposite side. These scion cuts should be the same length and width as those made in the rootstock so that the vascular cambium layers can be matched as closely as possible.

After inserting the scion, the graft is tightly wrapped with poly budding strips, budding rubbers, Buddy Tape, or with nursery adhesive tape. The graft may or may not be covered with wax, depending upon the species. A common practice in side grafting small potted plants of some woody ornamental species is to plunge the grafted plants into a slightly moist medium, such as peat moss, so that it just covers the graft union. Inserting the grafted liner plants in polytents in temperature-controlled greenhouses is another common practice (Fig. 12–4). To maintain high humidity, the newly grafted plants may also be placed for healing in a mist propagating house (but the grafts are not directly placed under mist), or set in grafting cases. The latter are closed boxes with a transparent cover, which permits retention of high humidity around the grafted plant until the union has healed. The grafting cases are kept closed for a week or so after the grafts are put in, and then gradually opened over a period of several weeks; finally, the cover is taken off completely.

After the union has healed, the rootstock can be cut back above the scion either in gradual steps or all at once.

Side Insertion Graft (SIG) The Side Insertion Graft (SIG) has been largely replaced by the OCG or Japanese tube graft, hole insertion graft (HIG), and tongue approach graft (TAG) (12, 21). The SIG is suitable for rootstocks with wide hypocotyls (Fig. 12–21, page 483). Production of rootstocks and scions is the

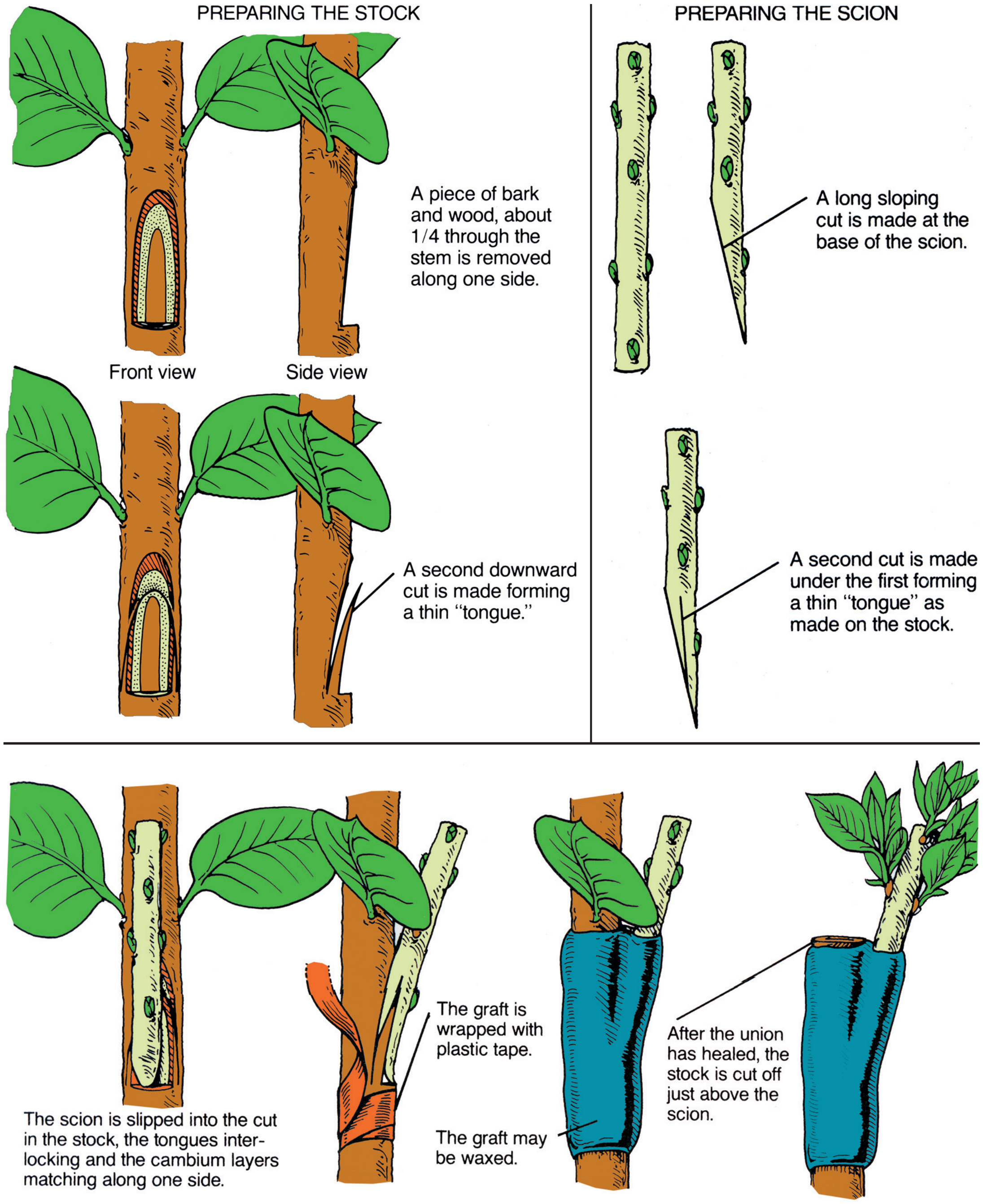
PREPARING THE STOCK
PREPARING THE SCION
A piece of bark and wood, about 1/4 through the stem is removed along one side.
A long sloping cut is made at the base of the scion.
Front view
Side view
A second downward cut is made forming a thin "tongue."
A second cut is made under the first forming a thin "tongue" as made on the stock.
The scion is slipped into the cut in the stock, the tongues interlocking and the cambium layers matching along one side.
The graft is wrapped with plastic tape.
The graft may be waxed.
After the union has healed, the stock is cut off just above the scion.

Figure 12–17

Sidetongue graft. This method is very useful for grafting broadleaved evergreen plants. Final tying may be done with budding rubbers, poly tape, or waxed string. The graft may be waxed, or wrapped with a sealing tape such as Parafilm or Buddy Tape.

same as that described for hole insertion grafting. A slit is cut on the hypocotyl of the rootstock with a razor blade and held open with a toothpick. A 35- to 45-degree-angle cut, on both sides is made on the hypocotyl of the scion. Then the scion is inserted into the slit in the hypocotyl of the rootstock and the toothpick is removed. Two cut surfaces are matched together and held with a grafting clip or silicone sleeve. The top of the rootstock is cut off 5 days after grafted plants are moved from the high-humidity growth chamber (21).

Detached Scion Graftage—Bark Grafting

Bark grafting is done in topworking established plants. The rootstock must be in an active stage of growth so that the bark will slip. The scion is inserted between the bark and wood of the rootstock. Bark grafting can be

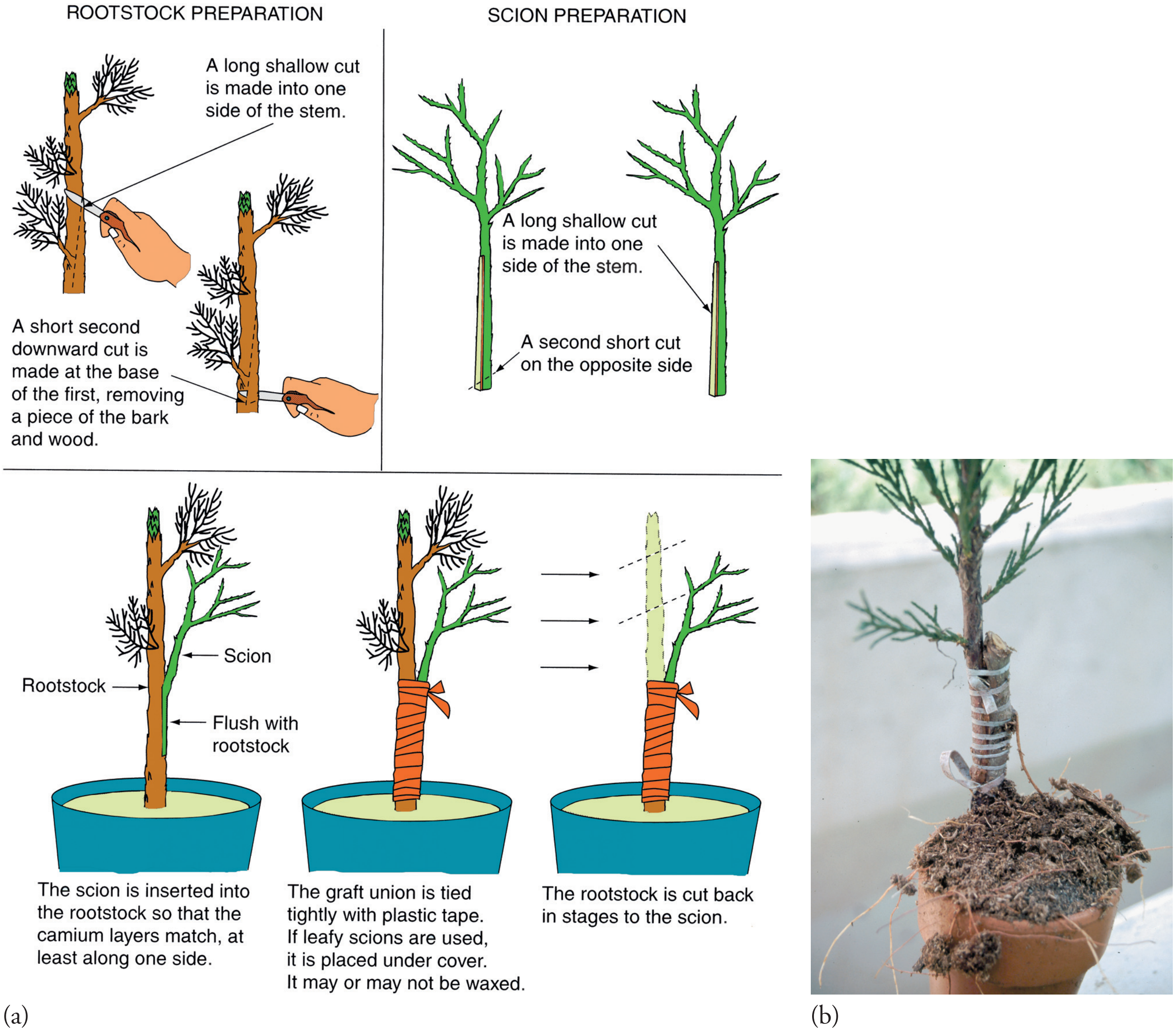
ROOTSTOCK PREPARATION
A long shallow cut is made into one side of the stem.
A short second downward cut is made at the base of the first, removing a piece of the bark and wood.
SCION PREPARATION
A long shallow cut is made into one side of the stem.
A second short cut on the opposite side
Scion
Rootstock
Flush with rootstock
The scion is inserted into the rootstock so that the camium layers match, at least along one side.
The graft union is tied tightly with plastic tape. If leafy scions are used, it is placed under cover. It may or may not be waxed.
The rootstock is cut back in stages to the scion.
(a)
(b)

Figure 12–18
(a) Steps in making the side-veneer graft. This method is one of the most popular grafts for propagating conifers and shrubs. The graft is quite versatile and can be used on a larger number of species than other grafts, such as the whip-and-tongue. (b) Side-veneer grafted connifer.

performed on branches ranging from 2.5 cm (1 in) up to 30 cm (1 ft) or more in diameter. The latter size is not recommended, because it is difficult to heal over such large stubs before decay-producing organisms attack.

Scions must be collected for deciduous species during the dormant season and held under refrigeration. For evergreen species, freshly collected scionwood can be used. In the bark graft, scions are not as securely attached to the rootstock as in some of the other methods and are more susceptible to wind breakage during the first year, even though healing has been satisfactory. Therefore, the new shoots arising from the scions probably should be staked during the first year, or cut back to about half their length, especially in windy areas. After a few years' growth, the bark graft union is as strong as the unions formed by other methods. *Two modifications of the bark graft are described next.*

Bark Graft (Rind Graft) Several scions are inserted into each rootstock stub (Fig. 12–22, page 484). For each scion, a vertical knife cut 2.5 to 5 cm (1 to 2 in) long is made at the top end of the rootstock stub through the bark to the wood. The bark is then lifted slightly along both sides of this cut, in preparation for the insertion of the scion. The dormant scions should be 10 to 13 cm (4 to 5 in) long, contain 2 or 3 buds, and be 6 to 13 mm (1/4 to 1/2 in) thick. One cut—about 5 cm (2 in) long— is made along one side at the base of the scion. With large scions,

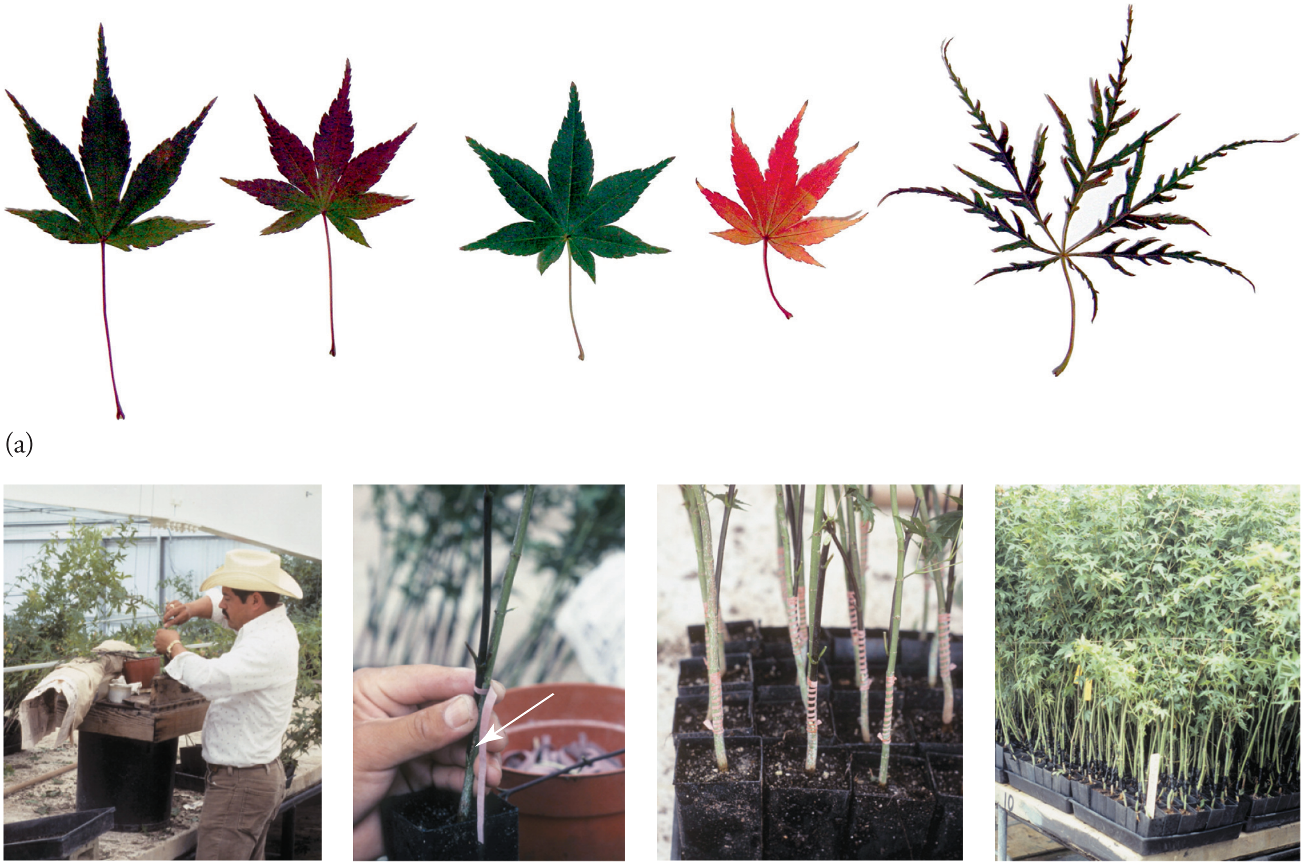

(a)

(b) (c) (d) (e)

Figure 12–19
(a) Cultivars of the highly diverse Japanese maple (Acer palmatum) are grafted onto seedling rootstock. (b and c) A budding rubber (arrow) is used to wrap the dormant, leafless scion to the rootstock. (d) Side-veneer-grafted Japanese maples in potted liner pots which will be moved to a polytent area for callusing, and (e) post-allusing liner production.

this cut extends about one-third of the way into the scion, leaving a "shoulder" at the top. This shoulder reduces the thickness of the scion to minimize the separation of bark and wood after insertion in the rootstock. The scion should not be cut too thin, or it will be mechanically weak and break off at the point of attachment to the rootstock. If small scions are used, no shoulder is necessary. On the side of the scion opposite the first long cut, a second, shorter cut is made, as shown in Figure 12–22, bringing the basal end of the scion to a wedge shape. The scion is then inserted between the bark and the wood of the rootstock, centered directly under the vertical cut through the bark. The longer cut on the scion is placed against the wood, and the scion's shoulder is brought down until it rests on top of the stub. The scion is then ready to be fastened in place. The scion is nailed into the wood, using two nails per scion. Flat-headed nails 15 to 25 mm (5/8 to 1 in) long, of 19- or 20-gauge wire, depending on the size of the scions, are satisfactory. The bark on both sides of the scion should be nailed down securely or it will tend to peel back from the wood.

Another method commonly used with soft-barked trees, such as the avocado, is to insert all the scions in the stub and then hold them in place by wrapping waxed string, adhesive tape, or poly budding tape around the stub. This method is more effective than nailing for preventing the scions from blowing out, but probably does not give as tight a fit. A combination of nailing and wrapping are advisable for maximum strength. If a wrapping material is used, it must be checked to avoid constricting the rootstock. After the stub has been grafted and the scions fastened by nailing or tying, all cut surfaces, including the end of the scions, should be covered thoroughly with grafting wax.

Inlay Bark Graft Two knife cuts about 5 cm (2 in) long are made through the bark of the rootstock down to the wood, rather than just one (Fig. 12–23, page 485). The distance between these two cuts should be exactly the same as the width of the scion. The piece of bark between the cuts should be lifted and the terminal two-thirds cut off. The scion is prepared with a smooth

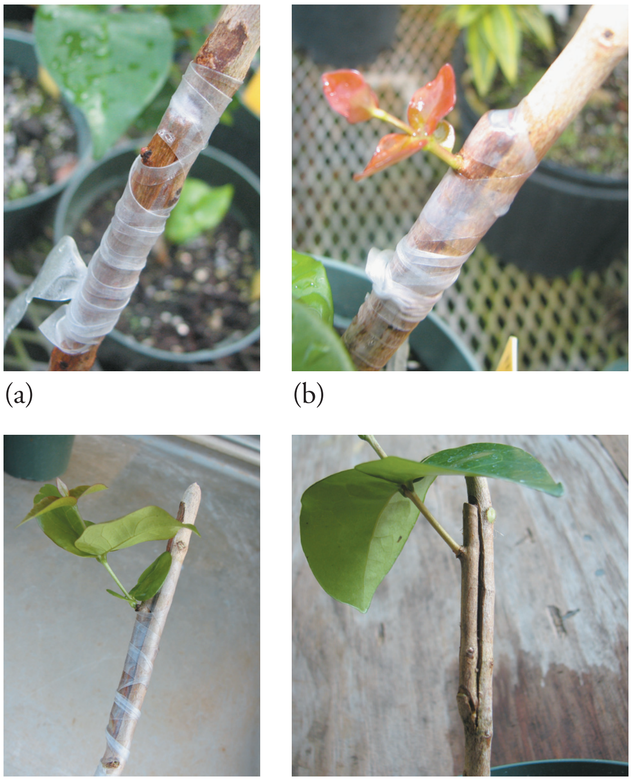
(a) (b)

(c) (d)

Figure 12–20
Side veneer graft of Eugenia (Myrtaceae). (a, b, and c) Graft wrapped with Parafilm tape. (d) Healed graft. Photos courtesy John Griffis.

slanting cut along one side at the basal end, completely through the scion. This cut should be about 5 cm (2 in) long but without the shoulder, in contrast to the bark graft. On the opposite side of the scion, a cut about 13 mm (1/2 in) long is made, forming a wedge at the base of the scion. The scion should fit snugly into the opening in the bark with the longer cut inward and with the wedge at the base slipped under the flap of remaining bark.

The scion should be nailed into place with two nails, the lower nail going through the flap of bark covering the short cut on the back of the scion. If the bark along the sides of the scion should accidentally become disturbed, it must be nailed back into place. Flat-point staples in the vertical position, or budding or flagging tape have all been used to secure the graft (40). The inlay bark graft is well adapted for use with thick-barked trees, such as walnuts and pecans, on which it is not feasible to insert the scion under the bark; it is used when topworking an existing orchard (Fig. 12–24, page 486).

Detached Scion Graftage—Root Graftage

A number of plants are propagated commercially by root grafting—apples, pears, grapes, and selected woody ornamental shrubs and trees (17, 18).

Root Grafting (Whole-Root and Piece-Root Graftage)

In root grafting, the rootstock seedling, rooted cutting, or layered plant is dug up, and the roots are used as the rootstock for the graft. The entire root system may be used (**whole-root graft**—Figs. 12–3 and 12–25, page 487), or the roots may be cut up into small pieces and each piece used as a rootstock (**piece-root graft**—Fig. 12–25). Both methods give satisfactory results. Since the roots used are relatively small [0.6 to 1.3 cm (1/4 to 1/2 in) in diameter], the **whip-and-tongue graft** is frequently used. In England, Rhododendron cultivars are saddle-grafted on roots of *R. ponticum;* the root graft is then tied and placed in a propagation case (19). Tree peony and herbaceous peony are root-grafted with a cleft graft using the root of herbaceous peony. Root grafts are usually bench-grafted indoors during the late winter or early spring. The scionwood collected previously is held in storage, while the rootstock plants are also dug in the late fall and stored under cool [1.5 to 4.5°C (35 to 40°F)] and moist conditions until the grafting is done. The term *bench grafting* is given to this process, because it is performed indoors with dormant scions and rootstocks at benches by skilled grafters as part of a large-scale operation.

In making root grafts, the root pieces should be 7.5 to 15.0 cm (3 to 6 in) long and the scions about the same length, containing 2 to 4 buds. After the grafts are

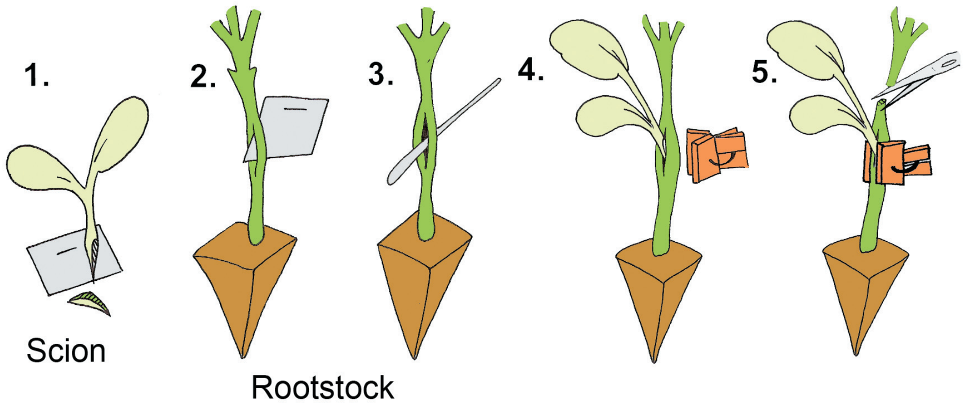

Figure 12–21
Steps in preparing the Side Insertion Graft (SIG). The SIG has been largely replaced by the OCG or Japanese tube graft hole insertion graft (HIG), and tongue approach graft (TAG). The SIG is suitable for rootstocks with wide hypocotyls (12, 21). Illustrations courtesy R. L. Hassell.

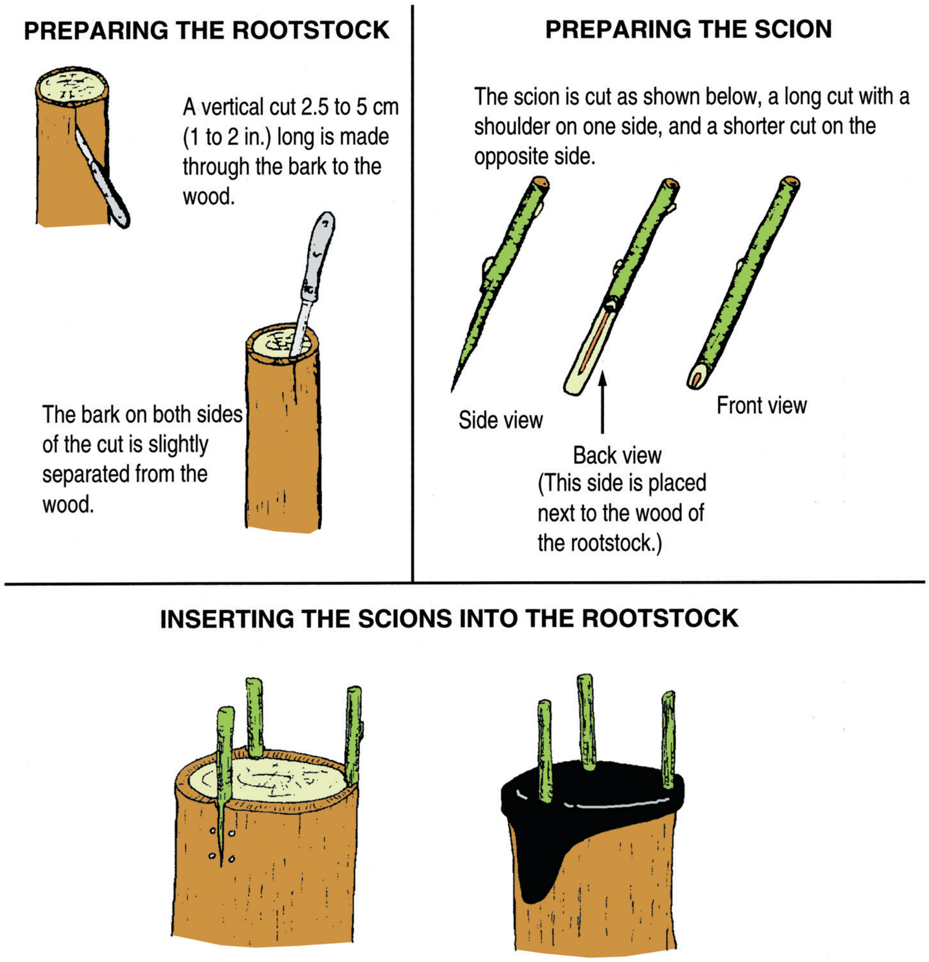
PREPARING THE ROOTSTOCK
A vertical cut 2.5 to 5 cm (1 to 2 in.) long is made through the bark to the wood.
The bark on both sides of the cut is slightly separated from the wood.
PREPARING THE SCION
The scion is cut as shown below, a long cut with a shoulder on one side, and a shorter cut on the opposite side.
Side view
Back view (This side is placed next to the wood of the rootstock.)
Front view
INSERTING THE SCIONS INTO THE ROOTSTOCK

Figure 12–22
Steps in preparing the bark graft (rind graft). In grafting some thick-barked plants, the vertical cut in the bark is unnecessary; the scion is inserted between the bark and wood of the stock.

made and properly tied, they are bundled together in groups of 50 to 100 and stored for callusing in damp sand, peat moss, or other packing material.

Nurse-Root Grafting Stem cuttings of a difficult-to-root species can sometimes be induced to develop adventitious roots by making a temporary "nurse-root" graft. The plant to be grown on its own roots is temporarily grafted as the scion. The scion may be made longer than usual and the graft planted deeply, with the major portion of the scion below ground. **Scion rooting** can be promoted by applying an auxin, such as indole-3-butyric acid, into several vertical cuts made through the bark at the base of the scion, above the graft union before planting. The grafts are set deeply, so that most of the scion is covered (mound layered) with soil (28). After one season of growth the scions have roots, and the temporary nurse rootstock is cut off and discarded. The rooted scion is replanted to grow on its own roots; it can later be used as a rootstock and grafted to a scion fruit cultivar.

scion rooting The development of adventitious roots from the grafted scion, desirable in **nurse-root grafting**, which is a temporary graft, but problematic in other grafts where the size control or disease-resistant characteristics of the rootstock may be lost.

Methods of nurse-root grafting include *reversing the polarity of the nurse-root rootstock.* The rootstock piece will eventually die if it is grafted onto the scion in an inverted position (Fig. 12–26, page 487) (37). A graft union is formed—the inverted rootstock piece sustains the scion until it roots—but the rootstock fails to receive sufficient carbohydrates from the scion and eventually dies, leaving the scion on its own roots. Another method is *girdling the rootstock just above the graft union at the scion base.* The rootstock is girdled with budding rubber strips (0.016 gauge) (7). Budding rubbers disintegrate within a month when exposed to sun and air; however, when buried in the soil, they will last as long as 2 years, allowing sufficient time for the scion to become rooted. In a third method, an *incompatible rootstock is used.* When the graft is planted deeply, scion roots will gradually become more dominant in sustaining the plant. Examples of this are apple scions on pear rootstock, and lilac scions on ash rootstock.

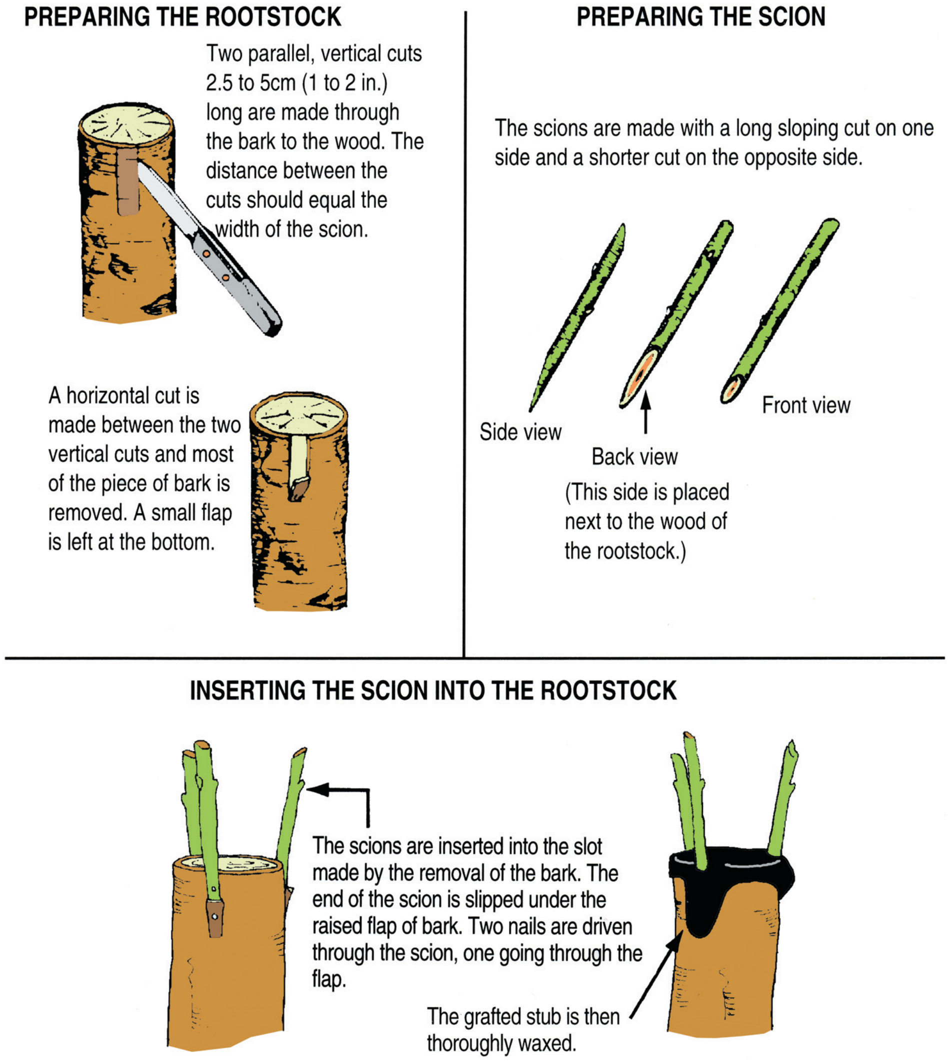

PREPARING THE ROOTSTOCK

Two parallel, vertical cuts 2.5 to 5cm (1 to 2 in.) long are made through the bark to the wood. The distance between the cuts should equal the width of the scion.

A horizontal cut is made between the two vertical cuts and most of the piece of bark is removed. A small flap is left at the bottom.

PREPARING THE SCION

The scions are made with a long sloping cut on one side and a shorter cut on the opposite side.

(This side is placed next to the wood of the rootstock.)

INSERTING THE SCION INTO THE ROOTSTOCK

The scions are inserted into the slot made by the removal of the bark. The end of the scion is slipped under the raised flap of bark. Two nails are driven through the scion, one going through the flap.

The grafted stub is then thoroughly waxed.

Figure 12–23
Inlay bark graft. With Texas pecans, the scion of the inlay bark graft is stapled or nailed, and aluminum foil and a cut poly bag are used instead of grafting wax (40).

Approach Graftage

The distinguishing feature of approach grafting is that two independent, self-sustaining plants are grafted together. After a union has occurred, the top of the rootstock plant is removed above the graft, and the base of the scion plant is removed below the graft. Sometimes it is necessary to sever these parts gradually rather than all at once. Approach grafting provides a means of establishing a graft union between certain plants which are otherwise difficult to successfully graft. It is usually performed with one or both of the plants growing in a container. Rootstock plants in containers may also be placed adjoining an established plant that is to furnish the scion part of the new, grafted plant (Fig. 12–27, page 488).

This type of grafting should be done at times of the year when growth is active and rapid healing of the graft union will take place. Three useful methods of making approach grafts are described as follows, and illustrated in Figure 12–28.

Spliced Approach Graft In the spliced approach graft, the two stems should be approximately the same size (Fig. 12–28, page 489). An exception to this is the spliced approach graft of mango in India, where the scion is considerably smaller than the field-grown rootstock; the scion, in a pot, is hung from the branch of the larger rootstock (19). At the point where the union is to occur, a slice of bark and wood 2.5 to 5 cm (1 to 2 in) long is cut from both stems. This cut should be the same size on each so that identical cambium patterns are made. The cuts must be perfectly smooth and as nearly flat as possible so that when they are pressed together there will be close contact of the vascular cambium layers. The two cut surfaces are bound tightly together with raffia or poly grafting tape, then the

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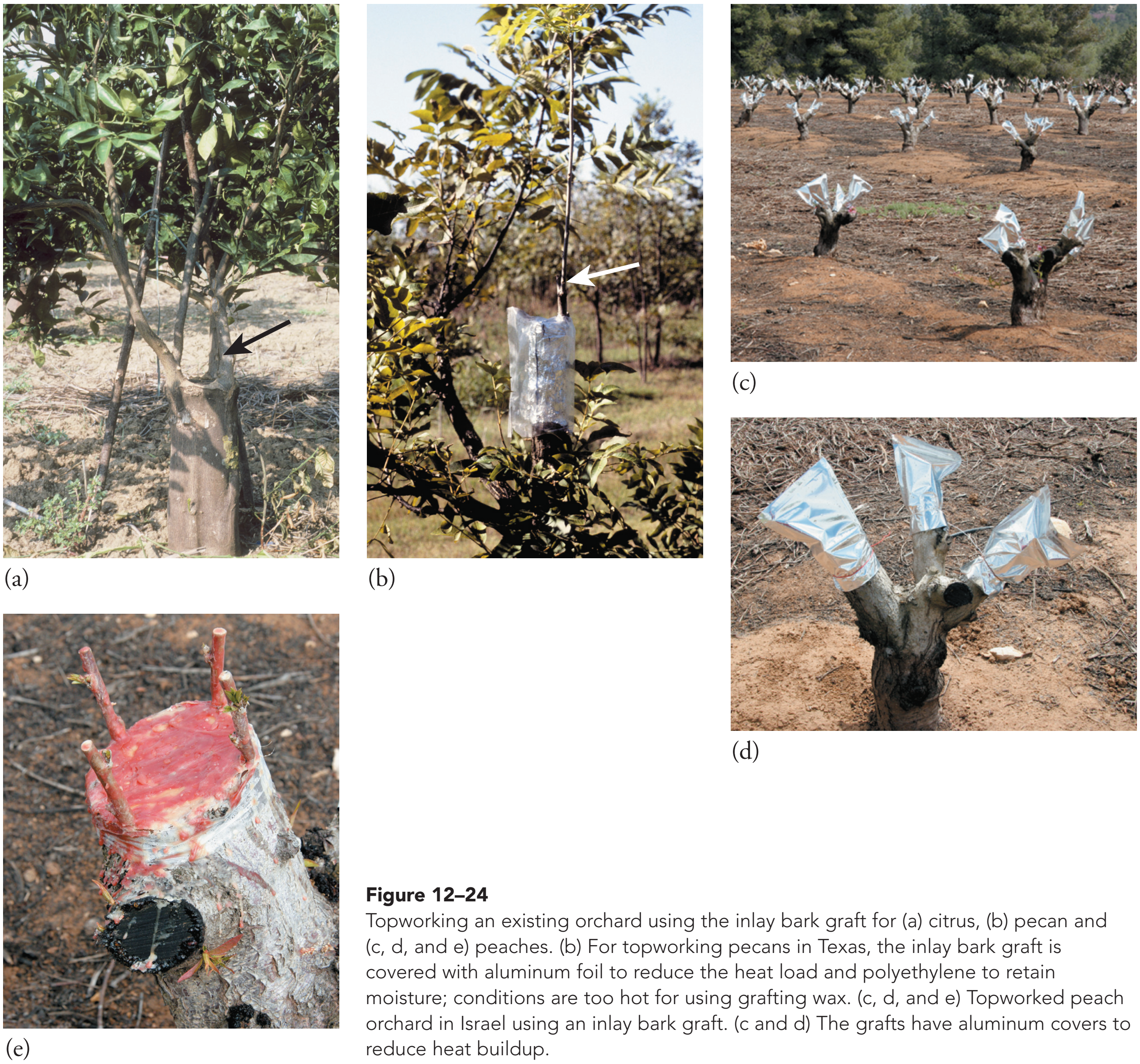

Figure 12–24
Topworking an existing orchard using the inlay bark graft for (a) citrus, (b) pecan and (c, d, and e) peaches. (b) For topworking pecans in Texas, the inlay bark graft is covered with aluminum foil to reduce the heat load and polyethylene to retain moisture; conditions are too hot for using grafting wax. (c, d, and e) Topworked peach orchard in Israel using an inlay bark graft. (c and d) The grafts have aluminum covers to reduce heat buildup.

whole union should be covered with grafting wax. After the parts are well united (which may require considerable time in some cases) the rootstock above the union, and the scion below the union are cut, and the graft is completed. It may be necessary to reduce the leaf area of the scion if it is more than the root system of the rootstock can initially sustain.

Tongued Approach Graft (TAG) The tongued approach graft is the same as the spliced approach graft, except that after the first cut is made in each stem to be joined, a second cut—downward on the stock and upward on the scion—is made, thus providing a thin tongue on each piece. By interlocking these tongues a very tight, closely fitting graft union can be obtained (Fig. 12–29, page 489).

For grafting vegetable crops, after the rootstock has fully developed cotyledons and scion has cotyledon and first true leaf, plants are pulled out from the tray (21). Make a cut at a 35- to 45-degree angle into the hypocotyl of the rootstock approximately halfway with a razor blade, and make a cut of the opposite angle on the hypocotyl of the scion. Cuts need to be made so that the scion will be on top of the rootstock when completed. Two cut hypocotyls are placed together and sealed with aluminum foil or Buddy Tape to help healing and prevent the graft from drying out. The two plants are transplanted into a bigger cell that will accommodate the two root balls. The top of the rootstock is cut off 5 days after grafting, and the bottom of the scion is cut off 7 days after the top of the rootstock is removed (Fig. 12–29).

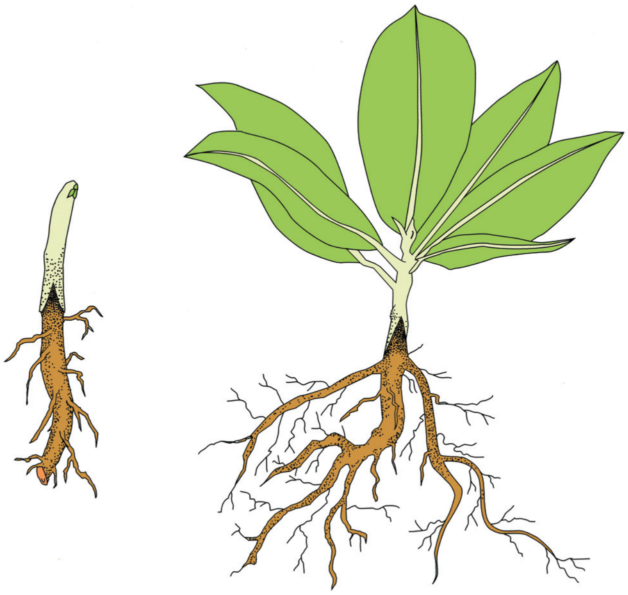

Figure 12–25
Root graftage with a saddle graft on a small root section or piece-root (*left*) and a whole root rootstock (*right*). See Figure 12–3 which is a whip and tongue graft using a whole root apple rootstock.

Inlay Approach Graft The inlay approach graft may be used if the bark of the rootstock plant is considerably thicker than that of the scion plant. A narrow slot, 7.5 to 10 cm (3 to 4 in) long, is made in the bark of the rootstock plant by cutting two parallel channels and removing the strip of bark between (Fig. 12–28); this can be done only when the rootstock plant is actively growing and the bark "slipping." The slot should be exactly as wide as the scion to be inserted. The stem of the scion plant, at the point of union, should be given a long, shallow cut along one side, of the same length as the slot in the rootstock plant and deep enough to go through the bark and slightly into the wood. This cut surface of the scion branch should be laid into the slot cut in the rootstock plant and held there by nailing with two or more small, flat-headed wire nails. Then the entire union must be thoroughly covered with grafting wax. After the union has healed, the rootstock can be cut off above the graft and the scion below the graft.

Repair Graftage

Inarching Inarching is similar to approach grafting in that both rootstock and scion plants are on their own roots at the time of grafting. It differs in that the top of the new rootstock plant usually does not extend above the point of the graft union, as it does in approach grafting. Inarching is used to replace roots damaged by cultivation equipment, rodents, or disease. It can be used to very good advantage to save a valuable tree or improve its root system (Fig. 12–30, page 489).

Seedlings (or rooted cuttings) planted beside the damaged tree, or suckers arising near its base, are grafted into the trunk of the tree to provide a new root system to supplant the damaged roots. The seedlings to be inarched into the tree should be spaced about 13 to 15 cm (5 to 6 in) apart around the circumference of the tree if the damage is extensive. A damaged tree usually will stay alive for some time unless the injury is very severe. The procedure for inarching is to plant seedlings of a compatible species around the tree during the dormant season, and graft when active growth commences in early spring. Inarching may also enhance growth of uninjured, older trees (22).

As illustrated in Figures 12–30 and 12–31 (page 490), the graft is similar to an inlay bark graft. The upper end of the seedling, which should be 6 to 13 mm (1/4 to 1/2 in) thick, is cut shallowly along the side for 10 to 15 cm (4 to 6 in). This cut should be on the side next to the trunk of the tree and deep enough to remove some of the wood, exposing two strips of cambium tissue. Another, shorter cut, about 13 mm (1/2 in) long, is made on the side opposite the long cut, creating a sharp, wedge-shaped end on the seedling stem.

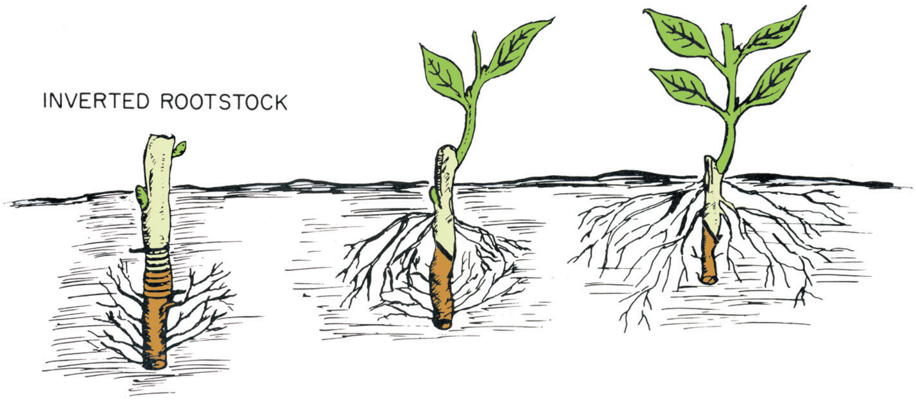

Figure 12–26
Reversing the polarity of the rootstock piece of the root graft is one method of "nurse-root" grafting. The nurseroot graft is a temporary graft used to induce the scion to develop its own roots. The nurse root sustains the plant until the scion roots form, then it dies. In the method shown, the rootstock piece is inverted, so the distal of the rootstock is temporarily joined to the proximal of the scion.

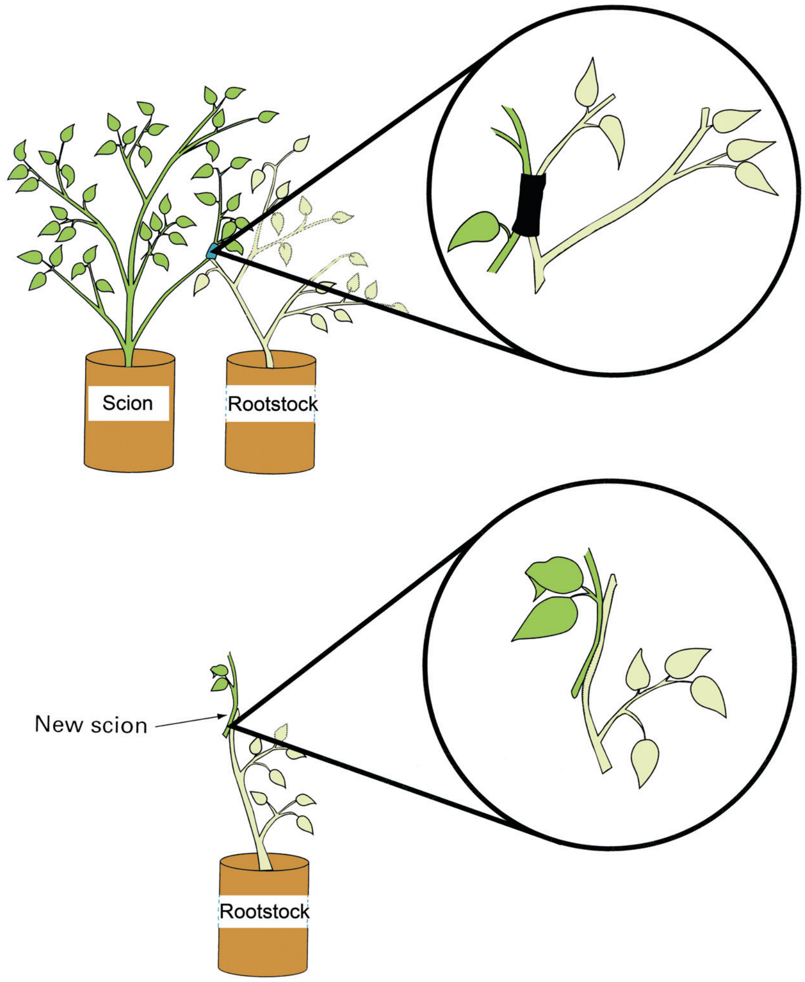

Figure 12–27
Approach grafting. *Top:* Initial grafting of the containerized scion and rootstock plants. *Below:* Completed graft union with scion severed from its own roots, and shoots of rootstock severed above the graft union.

A long slot is cut in the trunk of the tree by removing a piece of bark the width of the seedling and just as long as the cut surface made on the seedling. A small flap of bark is left at the upper end of the slot, under which the wedge end of the seedling is inserted. The seedling is nailed into the slot with four or five small, flat-headed wire nails. The nail at the top of the slot should go through the flap of bark and through the end of the seedling. If the bark of the tree along the sides of the seedling is accidentally pulled loose, it should be nailed back into place. The entire area of the graft union should then be thoroughly waxed.

Bridge Grafting Bridge grafting is another form of repair grafting—used when there is injury to the trunk, such as by cultivation equipment, rodents, disease, or winter injury. If the damage to the bark is extensive, the tree is almost certain to die, because the roots will be deprived of their carbohydrate supply from the top of the tree. Trees of some species, such as the elm, cherry, and pecan, can compartmentalize extensively injured areas by the development of a wound periderm of callus tissue. However, most woody species with severely damaged bark should be bridge grafted if they are to be saved, as illustrated in Figure 12–32, page 491.

An ***interstock bridge graft system*** has been used with mature apple trees for grafting M9 dwarfing rootstock (as the interstock) onto semi-dwarfing apple rootstock, leading to 20 percent reduced shoot growth, but a 30 percent increase in yield and increased soluble sugars and starch in the scion (53). A ring of bark 8 cm wide was removed from the trunk about 30 cm from ground level. Bridge grafts composed of 1-cm-wide split interstocks were inserted perpendicular around the ring, and then tightly wrapped with plastic during graft healing (New Zealand).

Bridge grafting is best performed in early spring as active growth of the tree is beginning and the bark is slipping easily. The scions should be obtained when dormant from 1-year-old growth, 6 to 13 mm (1/4 to 1/2 in) in diameter, of the same or compatible species, and refrigerated until grafted. In an emergency, one

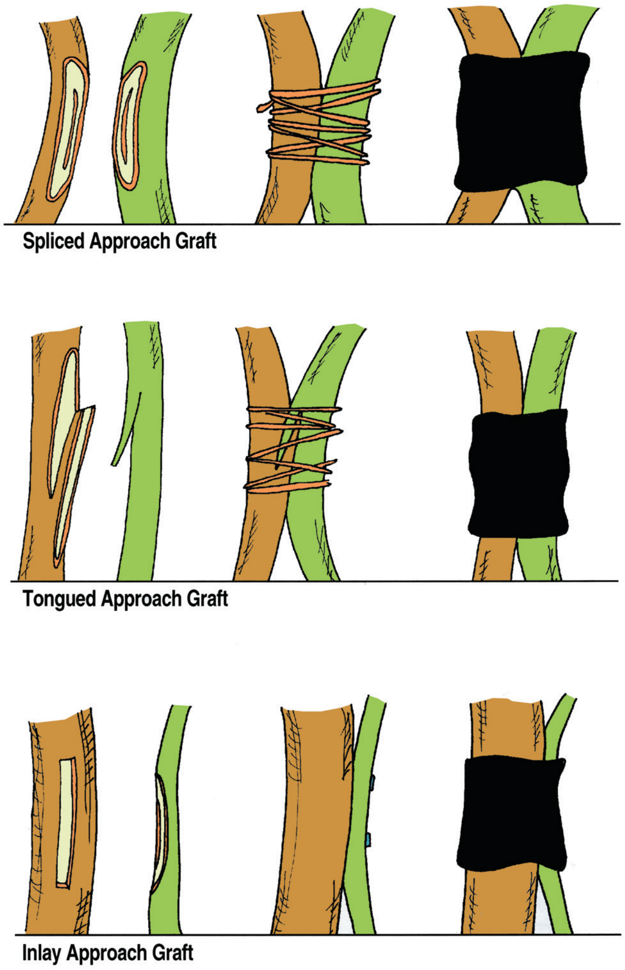

Figure 12–28
Three methods of making an approach graft: spliced-, tongued- and inlay-approach graft.

may successfully perform bridge grafting late in the spring, using scionwood whose buds have already started to grow; the developing buds or new shoots are removed.

The first step in bridge grafting is to trim the wounded area back to healthy, undamaged tissue by removing dead or torn bark. A scion is inserted every 5 to 7.5 cm (2 to 3 in) around the injured section and attached at both the upper and lower ends into live, undamaged bark. It is important that the scions are right side up. If reversed, a union may form, but the scions will not enlarge in diameter as they would if inserted correctly. Figure 12–33, page 491 shows the details of making a bridge graft.

After all the scions have been inserted, the cut surfaces must be thoroughly covered with grafting wax; particular care should be taken to work the wax around the scions, especially at the graft unions.

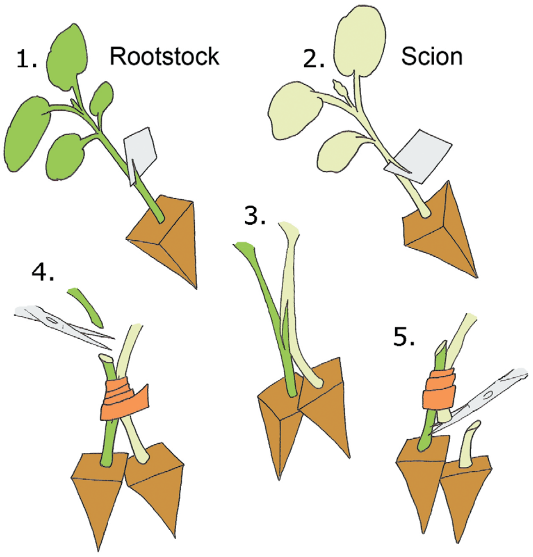

Figure 12–29
Tongued Approach Graft (TAG) with cucurbits. An easy graft that requires no special equipment or graft healing chambers, has a high success rate, but is labor intensive (12, 21). Illustrations courtesy R. L. Hassell.

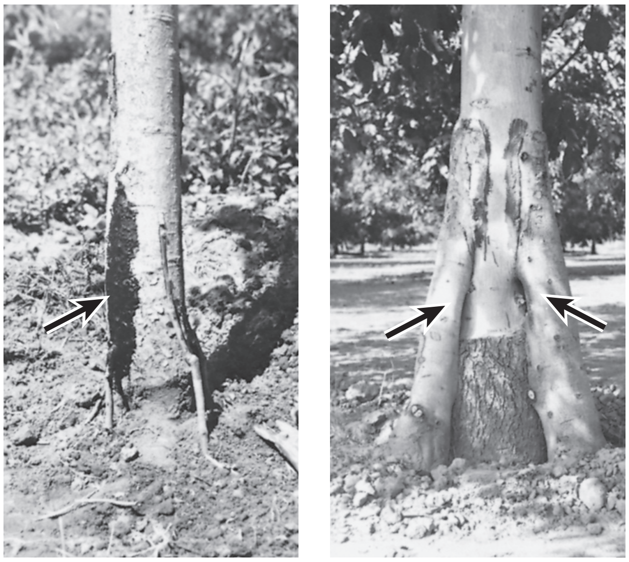
(a) (b)

Figure 12–30
(a) Inarches that have just been inserted (arrows). The one on the left has been waxed. The one on the right has been nailed into place and is ready for waxing. (b) Inarching can be used for invigorating established trees by replacing a weak rootstock with a more vigorous one. Here a Persian walnut tree has been inarched with Paradox hybrid seedlings (Juglans hindsii × J. regia).

Bracing Bracing is a form of natural branch grafting that is used by fruit producers to strengthen scaffolding limbs of a tree in order to support the weight of the fruit crop. Natural grafting of roots or shoot systems occurs in species such as fig (*Ficus*), rubber trees

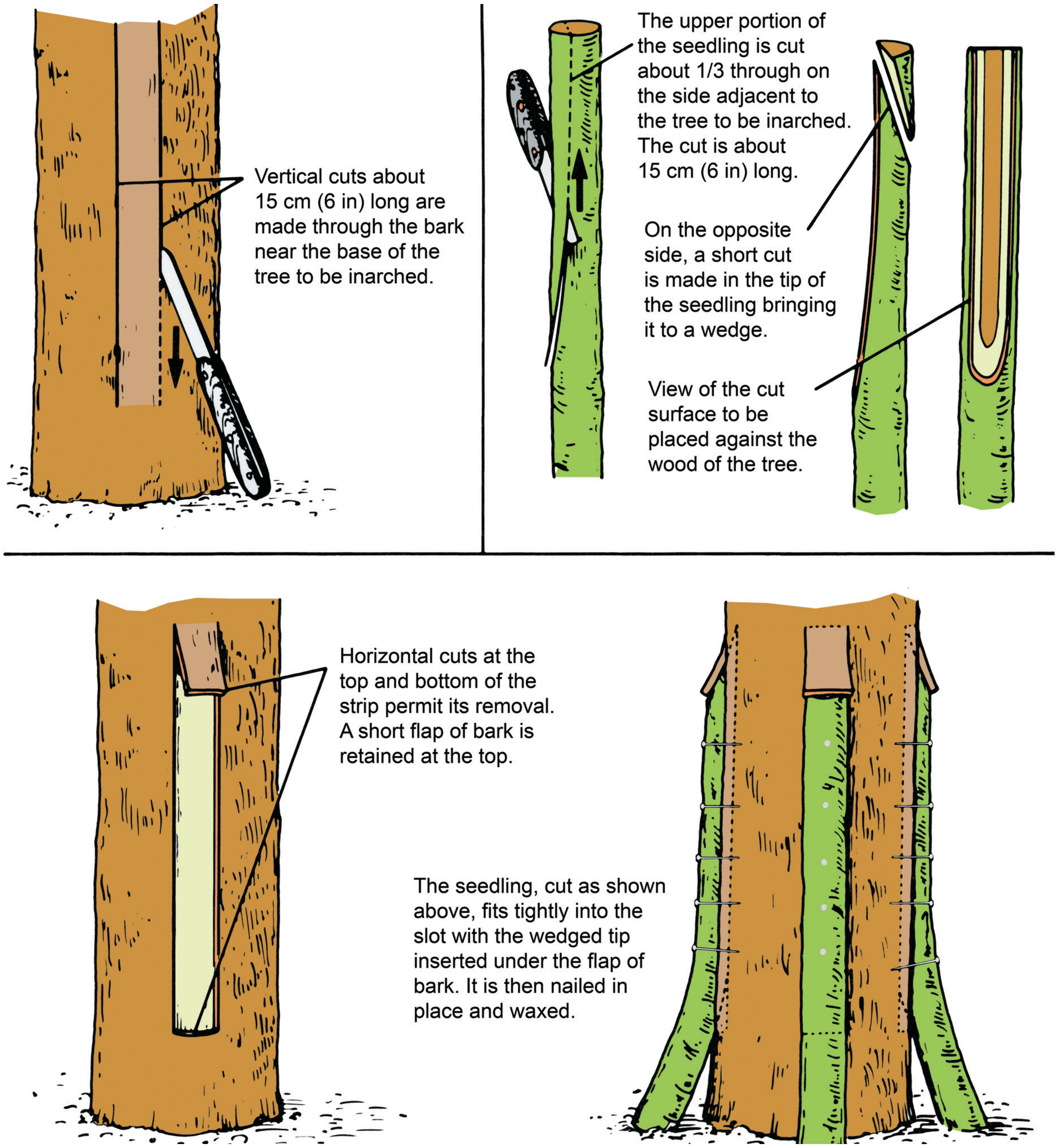
Vertical cuts about 15 cm (6 in) long are made through the bark near the base of the tree to be inarched.
The upper portion of the seedling is cut about 1/3 through on the side adjacent to the tree to be inarched. The cut is about 15 cm (6 in) long.
On the opposite side, a short cut is made in the tip of the seedling bringing it to a wedge.
View of the cut surface to be placed against the wood of the tree.
Horizontal cuts at the top and bottom of the strip permit its removal. A short flap of bark is retained at the top.
The seedling, cut as shown above, fits tightly into the slot with the wedged tip inserted under the flap of bark. It is then nailed in place and waxed.

Figure 12–31
Steps in inarching a large plant, with smaller ones planted around its base.

(*Hevea*), birch (*Betula*), beech (*Fagus*), ash (*Fraxinus*), maple (*Acer*), pine (*Pinus*), and climbing species such as English ivy (*Hedera*) (see Chapter 11). Branches and trunks can naturally graft when they come in contact with each other during early development. The union begins with compression and constant and increasing pressure that ruptures the outer bark of the graft partners, followed by continued secondary growth, which leads to graft union formation and the joining of the independent vascular systems of the partners.

When bracing limbs, fruit producers will pull together two strong, young lateral shoots from the limbs to be braced. A rope or cord is used to temporarily brace the larger limbs. The weaved smaller shoots, which will naturally graft, are tied with waxed string or poly tape to keep them together (Fig. 12–34, page 492).

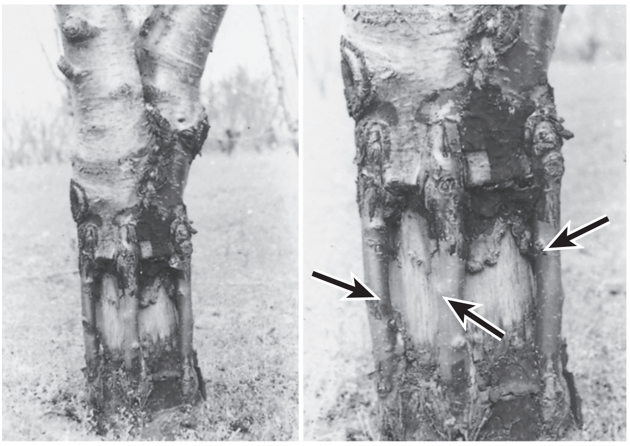

Figure 12–32
Injured trunk of a cherry tree successfully bridge grafted (arrows) by a modification of the bark graft.

PRODUCTION PROCESSES OF GRAFTAGE

Success in grafting depends 45 percent on preparation, including the quality and preparation of the scion and rootstock material, 10 percent on craftsmanship, and 45 percent on the aftercare of the grafted plant (26, 38). The production goals of grafting are achieving a high success rate, or "take," and obtaining high speed and accuracy in performing the graft. Preparation for grafting begins with the proper tools and accessories, as well as the selection and handling of the scion and rootstock (Table 12–3). Since grafting is a repetitive, labor-intensive process, grafting machines and grafting automation, including robotics, continue to play a greater role.

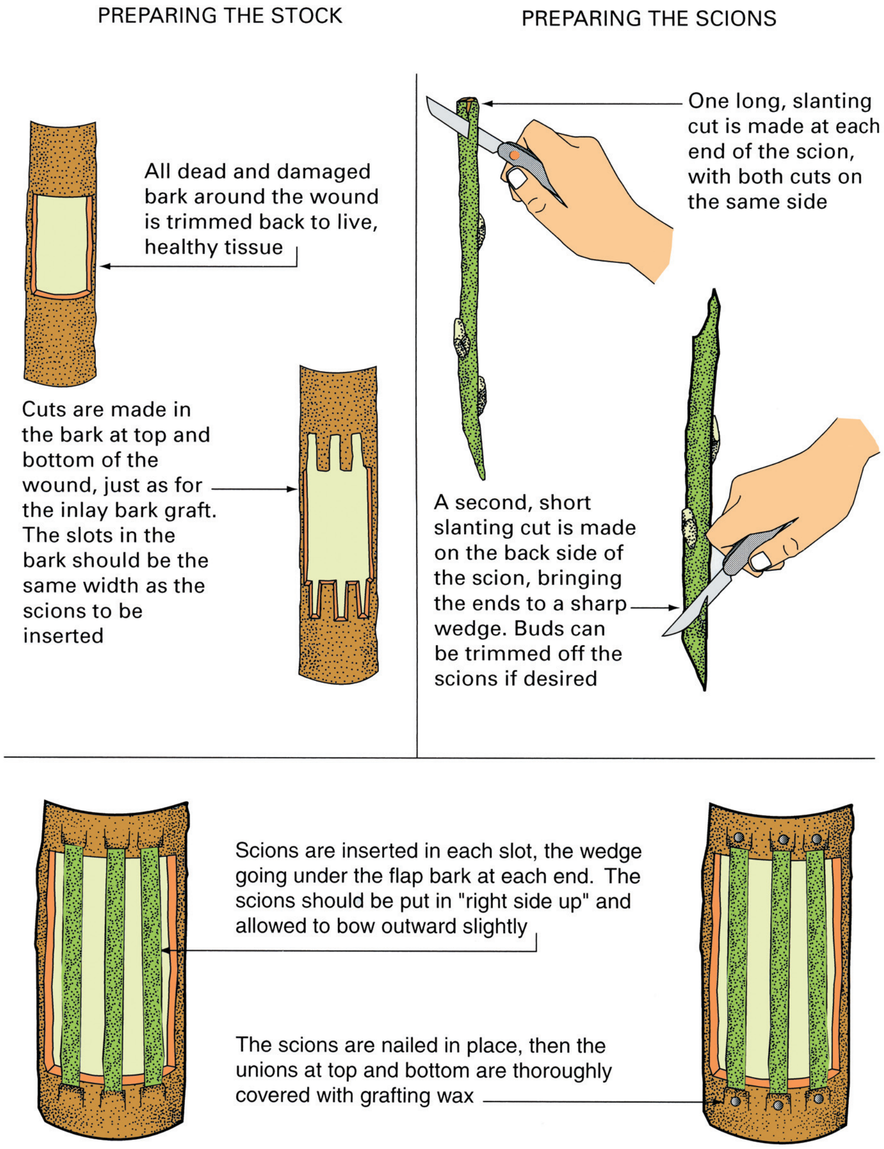
PREPARING THE STOCK
PREPARING THE SCIONS
All dead and damaged bark around the wound is trimmed back to live, healthy tissue
Cuts are made in the bark at top and bottom of the wound, just as for the inlay bark graft. The slots in the bark should be the same width as the scions to be inserted
One long, slanting cut is made at each end of the scion, with both cuts on the same side
A second, short slanting cut is made on the back side of the scion, bringing the ends to a sharp wedge. Buds can be trimmed off the scions if desired
Scions are inserted in each slot, the wedge going under the flap bark at each end. The scions should be put in "right side up" and allowed to bow outward slightly
The scions are nailed in place, then the unions at top and bottom are thoroughly covered with grafting wax

Figure 12–33
A satisfactory method of making a bridge graft, using a modification of the inlay bark graft.

BOX 12.2 GETTING MORE IN DEPTH ON THE SUBJECT

LARGE-SCALE BRIDGE GRAFTING

After World War I, thousands of fruit trees were bridge grafted in France to repair damage that occurred during the war. Alternatively, trunks from mutilated trees less than 20 cm (8 in) in diameter were cut off and crown grafted (23).

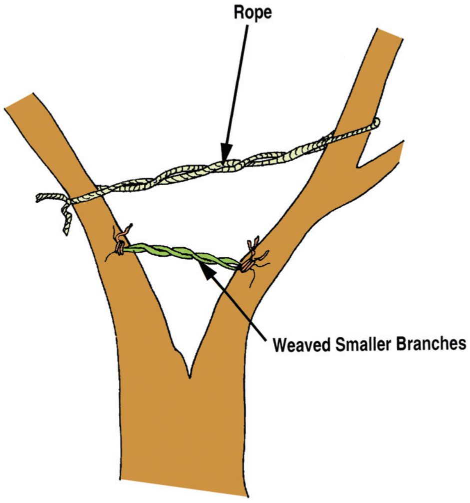

Figure 12–34
Bracing of fruit tree limbs by encouraging natural grafting. The tree limbs are braced with a twisted rope or electrical cord, and smaller shoots from the limbs are woven together and graft naturally as secondary growth occurs.

Preparation for Grafting

Tools and Accessories for Grafting Common tools and accessories used for grafting include grafting knives, tying and wrapping materials, and grafting waxes. Special equipment needed for any particular method of grafting is illustrated, along with the description of the method, in the remaining pages of this chapter. For example, grafting planes are sometimes used for more accurate fitting of scions with a hard and thick wood (Fig. 12–35) (61).

Knives. The two general types of knives used for propagation work are the budding knife and the grafting knife (Fig. 12–36). Where a limited amount of either budding or grafting is done, the budding knife can be used satisfactorily for both operations. The knives have either a folding or a fixed blade. The fixed-blade type is stronger, and if a holder of some kind is used to protect the cutting edge, it is probably the most desirable. A well-built, sturdy knife of high-carbon steel is essential. Grafting blades are flat on one side and have a tapered edge on the other to make a sharp, clean cut. Grafting knives are available for either right- or left-handed people.

Tying and Wrapping Materials. Grafting methods, such as the whip-and-tongue, splice (whip), and side-veneer graft, and budding methods, such as chip budding and T-budding, require that the graft union be held together by tying until the parts unite. A number of materials can be used for tying or wrapping grafts and budding. Some of these tying materials can also seal and help maintain a high relative humidity in the graft union area, which can help eliminate production

Table 12–3
PRODUCTION PROCESSES OF GRAFTAGE

Preparation for Graftage
- Tools and accessories for grafting
- Grafting machines and grafting automation/robotics
- Selection, handling, and storage of scionwood
- Handling of rootstock.

The Craftsmanship of Grafting
- Manual techniques: speed, accuracy, enhancing success rates
- Record keeping

Aftercare of Grafted Plants
- In bench grafting systems
- In field and nursery grafting systems

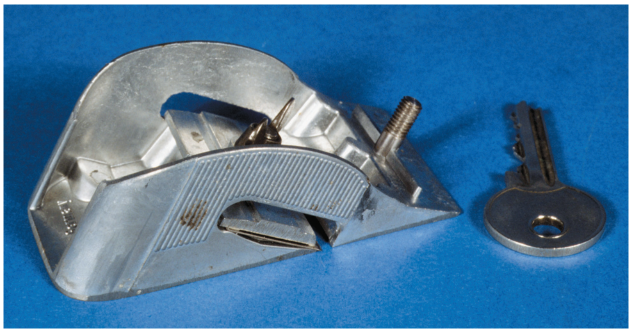

Figure 12–35
The grafting plane is a small woodworking plane equipped with a disposable heavy-duty razor blade. It allows more precise fitting of scions with hard and thick wood (61).

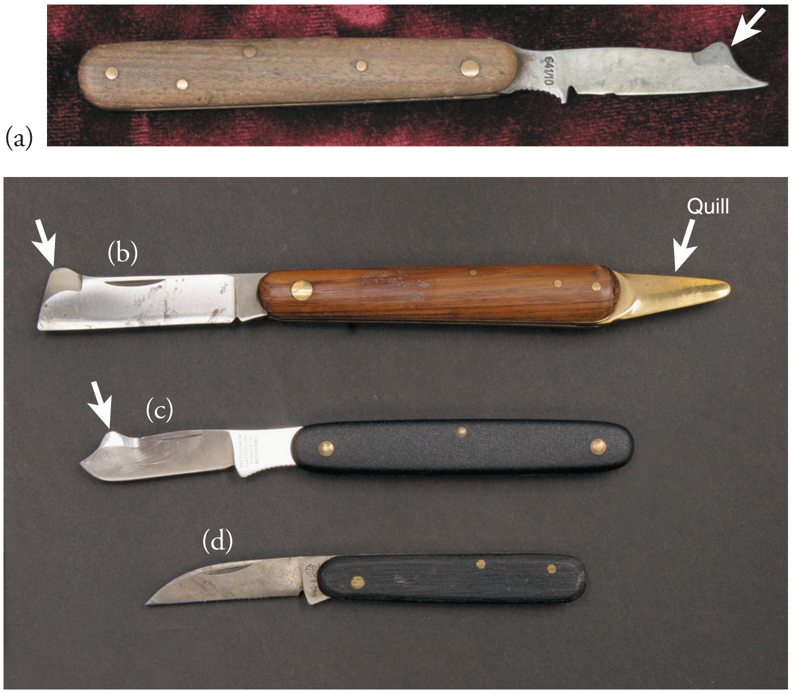

Figure 12–36
Folding, budding-grafting knives. (a) Tina budding-grafting knife. (a, b, and c) The metal flap (arrow) opposite the sharp end of the blade is used to separate the bark during the "T"–cut of the rootstock. (b) The quill is also used to separate the bark during T-budding. (d) Grafting knives are sharpened on one side, so there is a flat side of the blade for better control.

steps for applying a hot wax sealant on top of the tying materials, or the need for maintaining the grafts in special poly chambers or "sweat boxes."

Some common tying materials for budding and grafting include:

- **Budding rubbers** (also used in grafting).
- Clear or colored polyethylene or polyvinyl chloride **(PVC) budding and grafting strips,** which are 0.5 to 1.3 cm (3/16 to 1/2 in) wide and slightly elastic, allowing for a more secure wrap; this is also called flagging tape, green floral tape, white budding tape, or orange grafting tape.
- **Plastic clips and silicon tubing** (for manual and robotic grafting).
- **Raffia** (strips of palm leafstalk fiber—an older wrapping material, but still used).

Since PVC budding and grafting strips are not self-adhesive, they must be tied with a half-hitch knot (Fig. 12–37), which is done at the final turn of the tape by slipping it under the previous turn. With the exception of budding rubber, which deteriorates in full sunlight (but not when buried with the graft below ground), or Buddy Tape, the wrapping materials must be removed later to prevent girdling the plant.

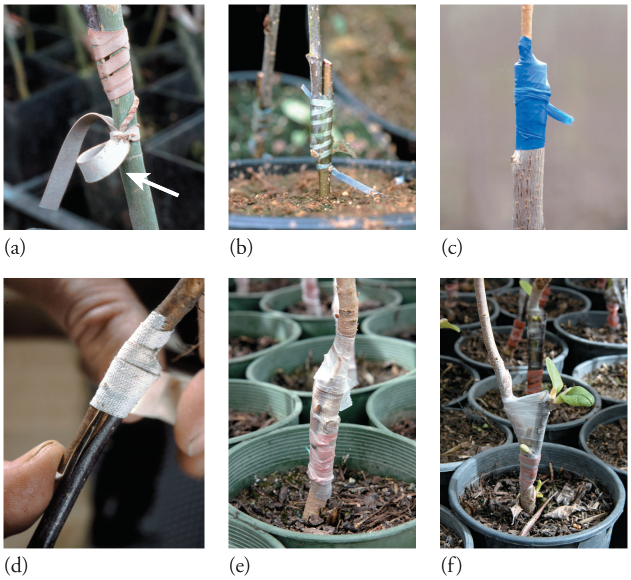

Figure 12–37
(a) Sometimes a loop is included in the final half-hitch knot of the rubber (arrow) or polyethylene budding and grafting strips. This allows easy unraveling of the strips after the graft has "taken" and avoids potential girdling problems in this side veneer graft of Japanese maple. Various tying materials: (b) raffia, (c) poly tape, (d) nursery tape, and (e and f) Buddy Tape (similar to Parafilm) used to cover magnolia scion pieces.

Self-Adhering Tying Materials. A time-tested tying material is **waxed string** or **twine,** which adheres to itself and to the plant parts without tying. It should be strong enough to hold the grafted parts together, yet weak enough to be broken by hand.

Nursery adhesive tape is similar to surgical adhesive tape but lighter in weight and not sterilized; it is more convenient to use than waxed cloth tape. Adhesive tape is useful for tying and sealing whip grafts. When using any kind of tape or string for wrapping grafts, it is important not to use too many layers or the material may eventually girdle the plant unless it is cut. When this type of wrapping is covered with soil, it usually rots and breaks before damage can occur. On a limited scale, adhesive tapes, such as **duct** and **electrical tape** can be used, while **masking tape** tends to unravel (54). Regardless of the wrapping material, it is best to remove or cut it *after* the graft has taken to avoid girdling.

Self-sealing tying materials include **Parafilm tape,** which has been used with successful results to wrap graft unions rapidly (5) and for chip-budding roses (Fig. 13–6). This material is a waterproof, flexible, stretchable, thermoplastic film with a paper backing. The film is removed from the paper, wrapped around the graft union, and pressed into place by hand. **Buddy Tape** (buddytape.com) is similar to Parafilm tape, but thinner and more economical. It seals and holds the graft or bud piece in place, and is thin enough for the bud to elongate and pass through it once the graft "takes" (Fig. 12–37). Sometimes budding rubbers are used to tie a graft, which is then sealed with Parafilm tape. Self-sealing cure **crepe rubber sheets** are used for herbaceous grafts and small woody plant material. Rubber patches up to 4 cm (1 1/2 in) are fixed with a staple and used for budding (Fig. 12–38).

Miscellaneous Fastenings and Wrapping Material. Miscellaneous fastenings and wrapping material include 18-gauge, 2-cm (3/4-in) **nails,** 1.6-cm (5/8-in) **flat-point staples,** as used in the inlay bark graft of pecans (40), and **plastic graft clips,** used in manual and machine splice grafting of vegetable crops (Figs. 12–7 and 12–39). The combination of **aluminum foil** and **polyethylene bags** wrapped around a four-flap or inlay bark graft replaces the need for waxing the graft (which would melt and be unsuitable in spring field grafting in Texas or other warm regions) (Figs. 12–13 and 12–24). **Metal shoot guide clips** (Fig. 13–4) are used for field budded, dormant rootstock to compel upright growth from the bud. **Silicon tubing** has been used to hold graft unions of single-node scions of oak and ash with high rooting success (Fig. 12–40, page 496) (14).

Splints made of *toothpicks, bamboo,* or *metal skewers* are used with bench grafting of herbaceous plants such as cacti. The splints are later removed after the graft has taken.

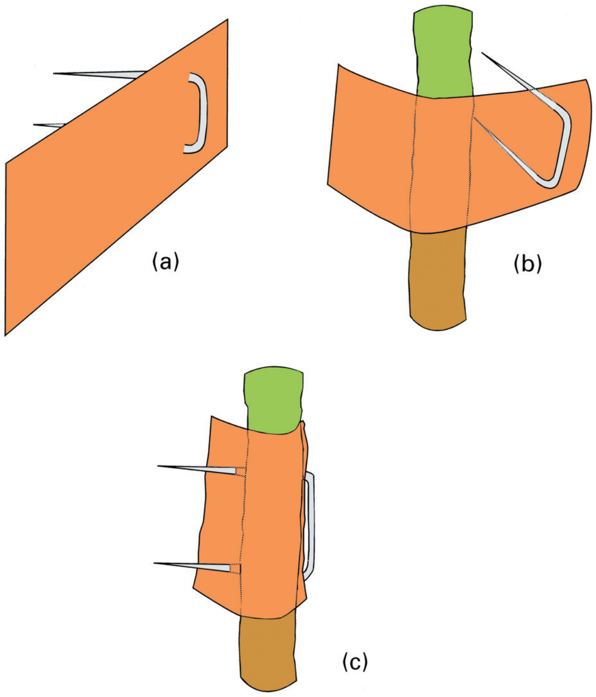

Figure 12–38
Rubber patch tying materials: (a) Rubber patches that come with a fixed stainless steel staple. (b) The rubber sheet is pulled over the bud and pulled securely around the rootstock. (c) The staple is pushed through the flap to secure the patch. The rubber patch normally deteriorates later with UV light from the sun or can easily be removed.

In a novel approach for developing robotic grafting systems for vegetable crops in Japan, Chinese cabbage seedling (scions) are horizontally grafted to turnip rootstocks. In grafting *Solanaceae* and *Cucurbitacae* vegetable crops, the graft partners are joined by a chemical adhesive, followed by spraying a chemical hardener to set up and solidify the adhesive around the graft (see Fig. 12–43, page 498 (29, 34, 47, 48)).

Whether a sealant, such as grafting wax, may be applied depends on the type of graft, the grafting system, and type of material used. Sealants are generally not used with budding, since tying with budding rubbers, rubber patches, Buddy Tape, or Parafilm tape is sufficient to alleviate desiccation problems. If the bench-grafted plant is to be placed in a high relative humidity graft box or temperature-controlled polytent, or immediately outplanted in the field with the union below the soil surface, waxing may be omitted.

Grafting Waxes. Grafting wax has two chief purposes: (a) It seals over the graft union, thereby preventing the

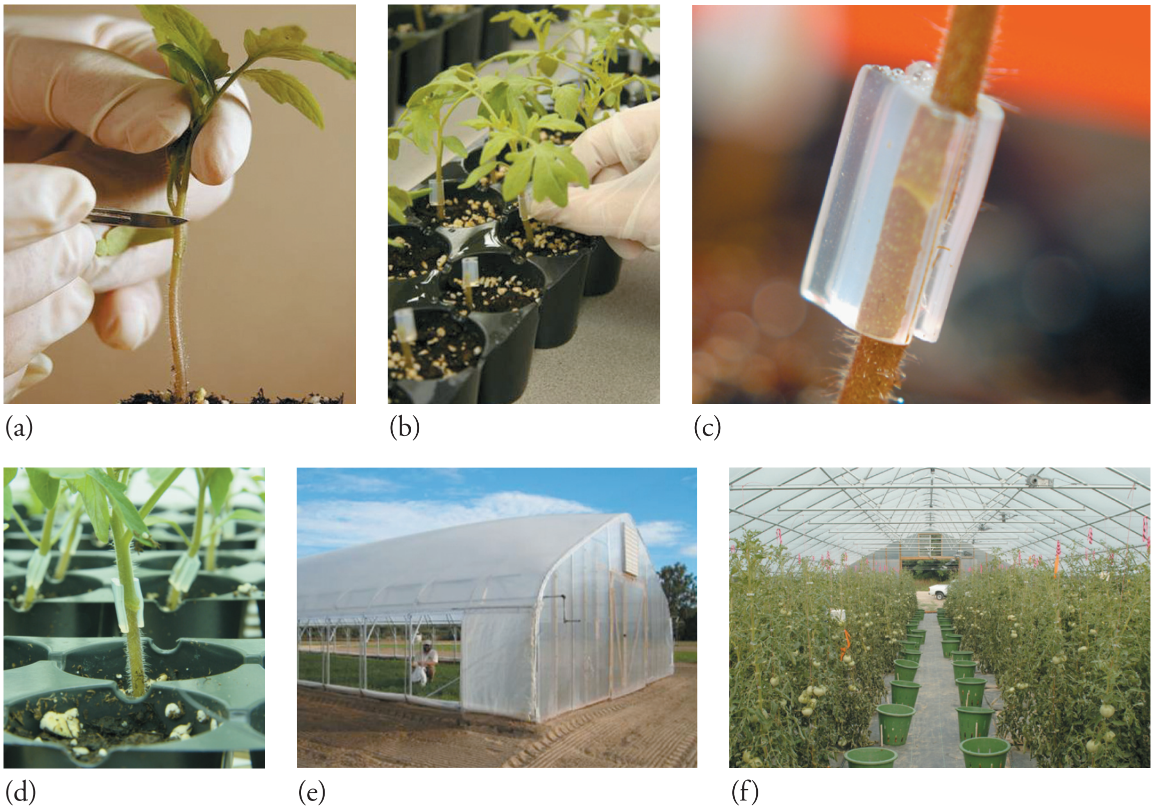
(a) (b) (c) (d) (e) (f)

Figure 12–39
Grafting of heirloom tomatoes in high tunnels can lead to increased yield, earlier season extension (compared to field-grown), soil-borne disease resistance and increased nutrient uptake with a potential reduction in fertilizer inputs. (a, b, c, and d) OCG or Japanese tubegrafting system. (c and d) Plastic clip holding graft. (e and f) High tunnel production of grafted heirloom tomatoes. The system enhances IPM—integrated pest management—and organic production systems for vegetable crops (52).
Photos courtesy S. O'Connell, M. Peet, C. Rivard, F. Louws, and S. McDonough.

loss of moisture and death of the tender, exposed cells of the cut surfaces of the scion and rootstock. These cells are essential for callus production and healing of the graft union. (b) It prevents the entrance of various decay-producing organisms that rot wood.

An ideal grafting wax should adhere well to the plant surfaces, not be washed off by rains, not be so brittle as to crack and chip during cold weather or so soft that it will melt and run off during hot days, but still be pliable enough to allow for the swelling of the scion and the growth enlargement of the rootstock without cracking. **Hot waxes** require heating, while **cold waxes** contain volatile solvents that keep the wax liquid. The cold wax solidifies when the solvents evaporate. Most nurseries develop their own hot wax, which is low-melting, soft, and flexible, so that subsequent handling of the graft does not cause cracking and flaking. Thermostatically controlled wax heaters are available to provide instant liquid wax when needed. *The wax should be hot enough to flow easily, yet not be boiling, which damages plant tissue.*

hot waxes Waxes that are paraffin based and must be heated to melt and apply.

cold waxes Waxes that contain a volatile solvent that preserves the wax liquid. After application the solvents evaporate and the wax hardens.

Various recipes for making hot and cold waxes are listed by Garner (19). For hot wax, blocks of premixed grafting wax containing the necessary ingredients (e.g., TrowBridge's grafting wax, Walter E. Clark & Son, Orange, Conn., USA) can be purchased from nursery supply houses.

Grafting Machines Several *bench grafting* machines or devices have been developed to prepare graft and bud unions, and a few have been widely used, especially in propagating grapevines (2, 3).

Various bench grafting machines for the wedge graft or French-V are available, including a portable and

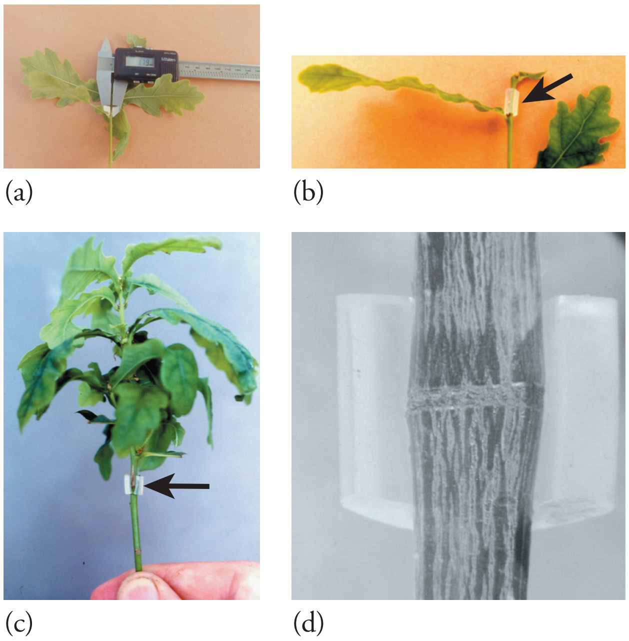
(a) (b) (c) (d)

Figure 12–40
High grafting success has been obtained using silicone tubing to hold graft unions together of single-node scions of oak and ash: (a) Digital caliper to measure stem diameter. (b) Single node of oak grafted using silicone tube (arrow). (c) Oak graft after 8 weeks (arrow showing tubing). (d) Healed ash graft after 12 weeks. Photographs courtesy of G. Douglas (14).

bench-mountable device made in New Zealand by Raggett Industries, Ltd., Gisborne (www.raggettindustries.co.nz) (Fig. 12–41). This device makes a type of wedge graft, cutting out a long V-notch in the rootstock and a corresponding long, tapered cut at the base of the scion. By reversing the position of the rootstock and scion, it could also make a saddle graft (Fig. 12–11). Although the cuts fit together very well, the operation is slow because the graft union must be either tied with a budding rubber or poly tape or stapled together. This machine has been used successfully in propagating grapes and fruit trees.

There are machines for making omega grafts, which are hand-operated (Fig. 12–42) or foot-operated. One device for grape grafting is the Pfropf-Star grafting machine manufactured in Germany. It cuts through both the rootstock and scion, one laid on top of the other, making an omega-shaped cut and leaving the two parts interlocked. While these machines work fine for grape grafting, most ornamental nurseries that graft do not use machines. Instead, they rely on hand-grafting, which may be faster and more reliable given the larger number of genera and species grafted (35). Without question, finding skilled grafters is a severe production problem; hence the importance of developing mechanized and automated grafting systems.

Grafting Automation/Robotics Prototypes and commercial robotic machines for grafting vegetable seedlings have been developed (Figs. 12–43, 12–44, and 12–45, pages 498–99). The production of grafted vegetable crops is becoming more common in the United States. However, grafted vegetable seedlings are used extensively in heavily populated countries such as Japan, Korea, some other Asian countries, and in parts of Europe, where the land use is highly intensive, farming areas quite small, and crops are not rotated. Grafted seedlings account for 81 percent of the commercial outdoor and greenhouse vegetable production in Korea, and 54 percent and 81 percent, respectively, for Japan (12, 29, 30, 33). Vegetable rootstock used are resistant to soil-borne pathogens and nematodes, which build up under these intensive cultivation conditions. Some of the commercialized grafting robots can graft 800 or more *Solanaceae* vegetable seedlings per hour (Figs. 12–43 and 12–45) (49).

Selection, Handling, and Storage of Scionwood.

Kind of Wood. Since bench or field grafting of deciduous species takes place in winter or early spring, it is necessary to use the scionwood that grew the previous fall.

In selecting such scion material the following points should be observed:

- For most species, the wood should be 1 year old or less (current season's growth). Avoid including older growth, although with certain species, such as the fig or olive, 2-year-old wood is satisfactory, or even preferable, if it is of the proper size.
- Healthy, well-developed vegetative buds should be present. Avoid wood with flower buds. Usually, vegetative buds are narrow and pointed, whereas flower buds are round and plump (see Fig. 13–3).
- The best type of scion material is vigorous (but not overly succulent), well-matured, hardened shoots from the upper part of the tree, which have grown 60 to 90 cm (2 to 3 ft) the previous summer. Such growth develops on relatively young, well-grown, vigorous plants; high production of scion material can be promoted by pruning the plant back heavily the previous winter. Water sprouts from older trees sometimes make satisfactory scionwood, but suckers arising from the base of grafted trees should not be used, since they

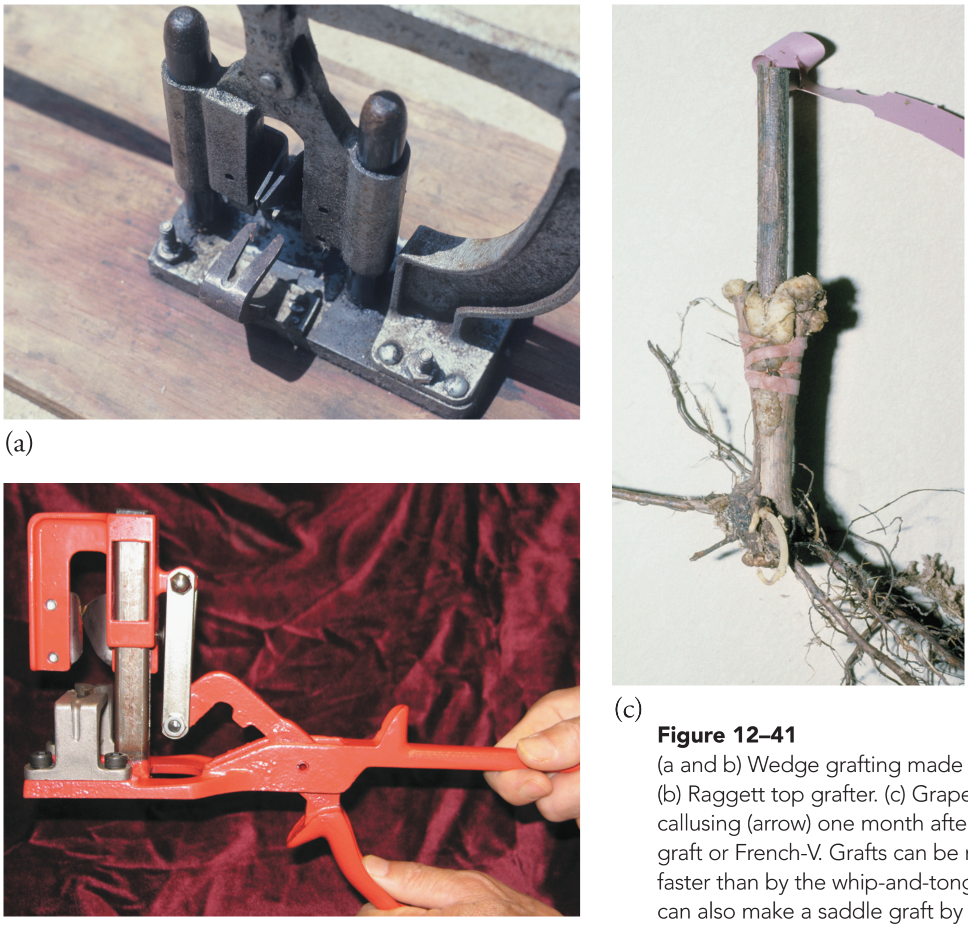

(a)

(b)

(c)

Figure 12–41
(a and b) Wedge grafting made by French-V grafting devices. (b) Raggett top grafter. (c) Grape graft union healing with profuse callusing (arrow) one month after bench grafting with a wedge graft or French-V. Grafts can be made with these devices much faster than by the whip-and-tongue graft method. These machines can also make a saddle graft by these machines, by reversing the cuts so the scion piece has the saddle shape (see Fig. 12–11).

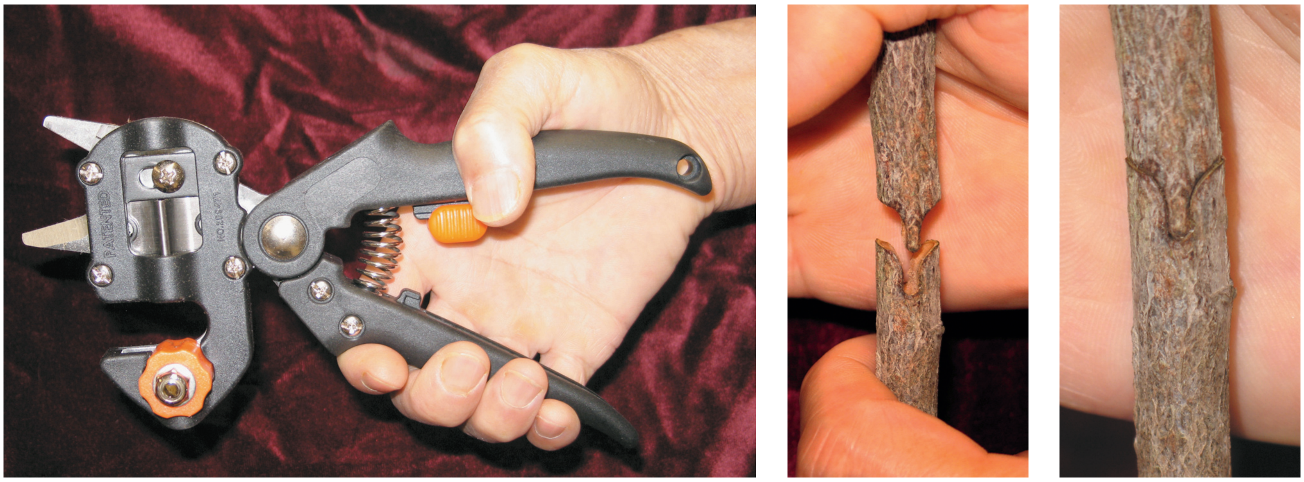

(a) (b) (c)

Figure 12–42
(a) Grafting tool for making an omega graft. (b and c) Omega graft locks in place and then is held together with grafting tape. The scion and stock must be the same diameter.

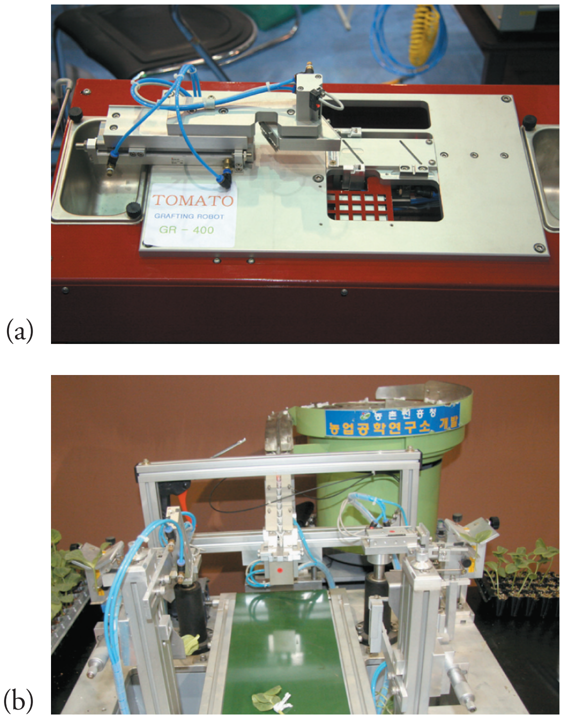

Figure 12–43
Commercial grafting robot for Solanaceae (tomatoes, melons, cucurbits) vegetables on seedling rootstock suitable for intensive planting and resistant to disease, insect and environmental stress. Plant vigor and yield can also be enhanced with superior rootstock. (a) Tomato and (b) melon grafting robots.

may consist of rootstock material. A satisfactory size is from 0.6 to 1.2 cm (1/4 to 1/2 in) in diameter.

- The best scions are obtained from the center portion or from the basal two-thirds of the shoots. The terminal sections, which are likely to be too succulent, pithy, and low in stored carbohydrates, should be discarded. Mature wood with short internodes should be selected.

Source of Material. Scionwood should be taken from source plants of the correct cultivar known to be pathogen-tested and genetically true-to-type (see Chapter 16). Virus-diseased, undesirable sports, chimeras, and virus-like genetic disorders must be avoided. Source plants may be of three basic types:

1. Plants produced in an orchard, vineyard, ornamental field, container nursery, or landscape are selected when the flowering, fruiting, and growth habits are known. It is best to take propagation material from bearing plants whose production history is known. Visual inspection, however, may not reveal the true condition of the proposed source plant and, appropriate indexing and progeny tests are required to be sure (see Chapter 16).
2. In commercial nurseries, special scion blocks, where plants are grown particularly for propagation, may be maintained. Such plants are handled differently than they would be for producing a crop. For example, fruit trees may be pruned back each year to produce a large annual supply of long, vigorous shoots well-suited for scionwood. Such special blocks would usually be handled to conform to registration and certification programs and would be subject to isolation, indexing, and inspection requirements. In addition, it is important to maintain source identity of scion material through the entire propagation sequence, so that over a period of time proper

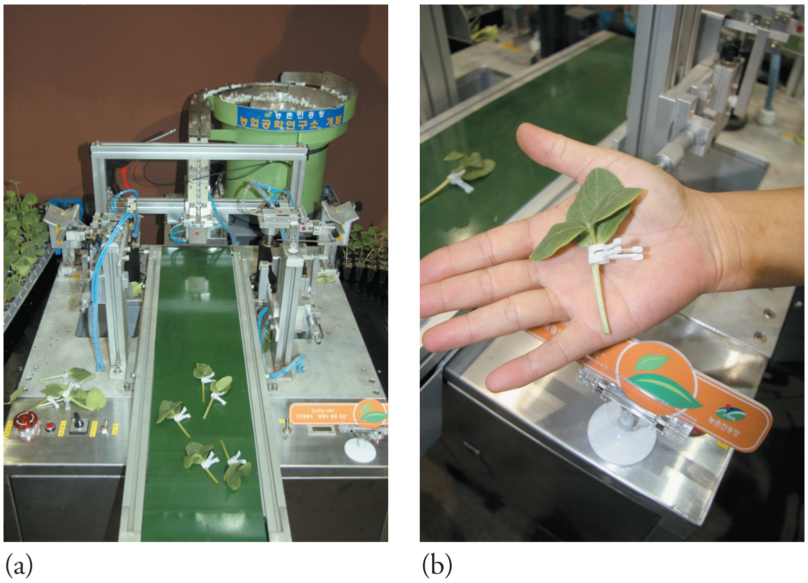

Figure 12–44
Finished grafts from a commercial melon grafting robot. (a) The grafted plants are moved on a conveyor belt system for processing. (b) Splice grafted scion and rootstock held together by a grafting clip.

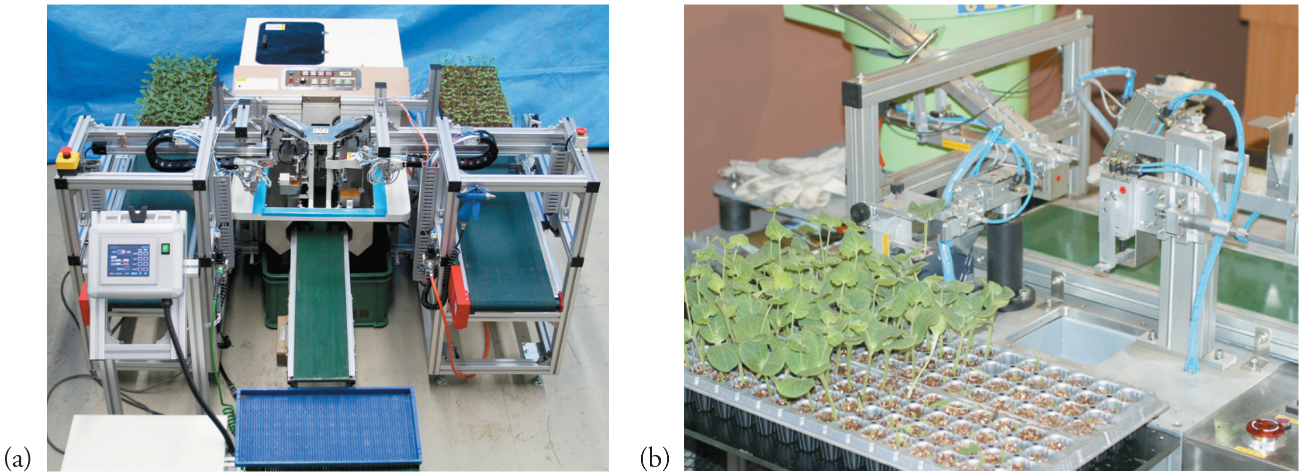

Figure 12–45
Two techniques used in herbaceous grafting are manual and robotic grafting. (a) Fully automated grafting robot for cucurbits (BRAIN, Saitama, Japan), and (b) semiautomated Korean grafting machine. Plants are grafted at the 2 to 4 leaf stage. The advent of OCG, "tube-grafting" or "Japanese top-grafting" has become the most popular graft for tomato. Grafting robots can make up to 800 grafts/hr, whereas an individual can make 1,000 grafts/day. Photos a and b courtesy of C. Kubota and M. Peet, respectively.

sources of the various cultivars can be identified and maintained.

3. For vegetable grafting, commercial seed from selected rootstocks and scions are sown under protected cultural conditions. Selected rootstock for vegetable grafting is listed in Table 12–4. A timeline for grafting heirloom tomatoes, starting with sowing rootstock seed 2 to 5 days prior to sowing scion seed, is depicted in Figure 12–46.

Collection and Handling. For deciduous plants to be grafted in early spring, the scionwood can be collected almost any time during the winter season when the plants are fully dormant (6). In climates with severe winters, the wood should not be gathered when it is frozen, and any wood that shows freezing injury should not be used. Where considerable winter injury is likely, it is best to collect dormant scionwood and put it in cold storage after leaf fall but before the onset of winter.

Storage. Scionwood collected prior to grafting must be properly stored. It should be kept slightly moist and at a low enough temperature to prevent elongation of the buds. A common method is to wrap the wood, in bundles of 25 to 100 sticks, in heavy, waterproof paper or in polyethylene sheets or bags. *All bundles must be labeled accurately.*

Polyethylene bags are useful for storing small quantities of scionwood. They allow the passage of oxygen and carbon dioxide, which are exchanged during

Table 12–4
SELECTED SCION AND ROOTSTOCK COMBINATIONS FOR VEGETABLE GRAFTING (50)

Scion	Rootstock
Watermelon (*Citrullus vulgaris* syn. *C. lanatus*)	Bottle gourd (*Lagenaria siceraria*) White gourd (*Benincasa hispida*) *Cucurbita* spp.
Melon (*Cucumis melo*)	White gourd (*Benincasa hispida* Cogn.) *Cucumis* spp.; *Cucurbita* spp. *C. moschata xC. maima*
Cucumber (*Cucumis sativus* L.)	Pumpkin (*Cucurbita* spp.) *Cucurbita ficifolia*
Aubergine (*Solanum melongena* L.)	*Solanum integrifolium;* *Solanum torvum; Solanum melongena*
Tomato (*Lycopersicon esculentum*)	Tomato (*Lycopersicon esculentum*)

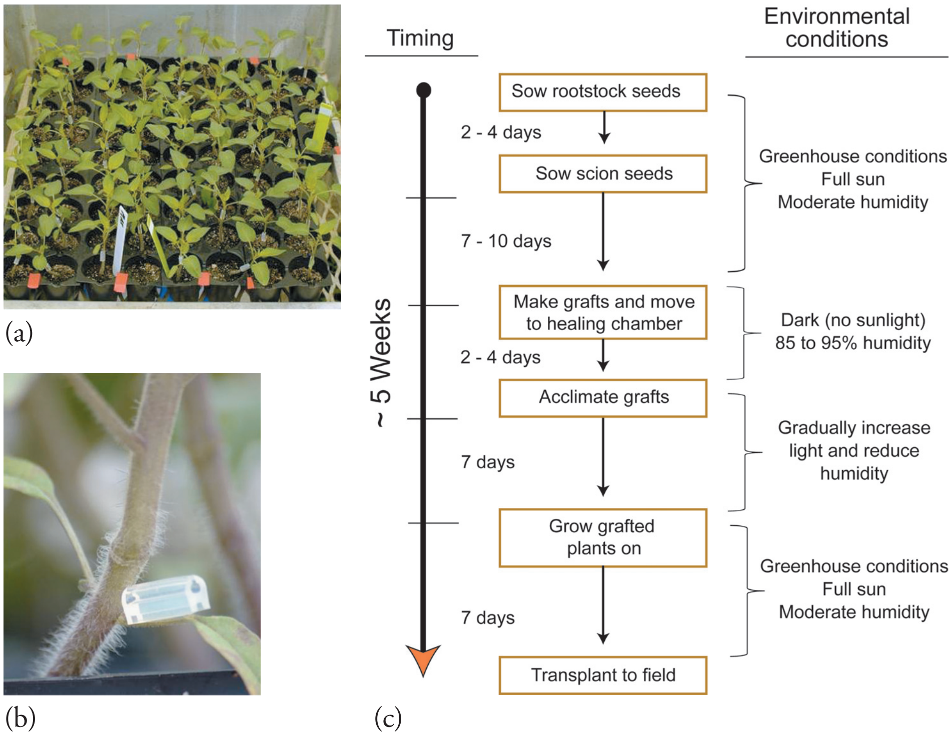
(a)
(b)
(c)
Timing
Environmental conditions
~ 5 Weeks
Sow rootstock seeds
2 - 4 days
Sow scion seeds
7 - 10 days
Make grafts and move to healing chamber
2 - 4 days
Acclimate grafts
7 days
Grow grafted plants on
7 days
Transplant to field
Greenhouse conditions
Full sun
Moderate humidity
Dark (no sunlight)
85 to 95% humidity
Gradually increase light and reduce humidity
Greenhouse conditions
Full sun
Moderate humidity

Figure 12–46 Grafting timeline for heirloom tomatoes. (a) Grafts in healing chamber. (b) Hardened-off grafted plant, with grafting clip falling off—ready for transplanting (52). Illustrations courtesy of C. Rivard and F. Louws.

the respiration process of the stored wood, but retard the passage of water vapor. Sometimes the natural moisture in the wood is sufficient, so slightly moist packing material is not needed in the sealed poly bags. In commercial field rose production, the scionwood (budwood) is harvested dormant, wrapped in slightly moist newspaper and sealed in poly bags, and maintained at –1.7 to –0.6°C (29 to 31°F) for up to 7 months.

The temperature at which the wood is stored is important. If it is to be kept only 2 or 3 weeks before grafting, the temperature of a home refrigerator—about 5°C (40°F)—is satisfactory. If stored for a period of 1 to 3 months, scionwood should be held at about 0°C (32°F) (6) to keep the buds dormant. However, buds of some species, such as the almond and sweet cherry, will start growth after about 3 months, even at such low temperatures. Do not store scionwood in a home freezer because the very low temperatures, about –18°C (0°F), can injure the buds.

Storage of scions should not be attempted if succulent, herbaceous plants are being grafted; such scions should be obtained at the time of grafting and used immediately. Certain broad-leaved evergreen species, such as camellias, olives, and citrus, can be grafted in the spring before much active growth starts, without previous collection and storage of the scionwood. Grafts are taken directly from the tree as needed, using the basal part of the shoots containing dormant, axillary buds. The leaves are removed at the time of collection.

Attempting to use scionwood in which the buds are starting active growth is almost certain to result in failure. In such cases, the buds quickly leaf out before the graft union has healed; consequently, the leaves withdraw water from the scions by transpiration, and cause the scions to die. In addition, the strong competing sink of a developing shoot can interfere with graft union formation.

In topworking pecans (4), good results are obtained by using precut scions; that is, scions cut in advance by skilled persons at a convenient time, that are then held in cold storage in polyethylene bags for up to 9 days before being inserted in the graft unions. Grafting success is reduced only slightly by the use of precut scions.

Handling of Rootstock for Bench Grafting. Seedling rootstock of maple (*Acer*) is established in liner pots for 1 year, brought into a greenhouse in the fall after leaf drop, and placed in bottom-heated benches at 13 to 16°C (55 to 60°F). Bench grafting of the container rootstock with a splice graft is done in January and February (Canada), when white roots appear along the perimeter of the rootballs (26).

In North Carolina, rootstock liners of woody ornamental plants are allowed to harden-off in minimum-temperature–controlled poly houses in the fall, and maintained just above freezing. When new roots emerge from the rootstock in late winter, plants are

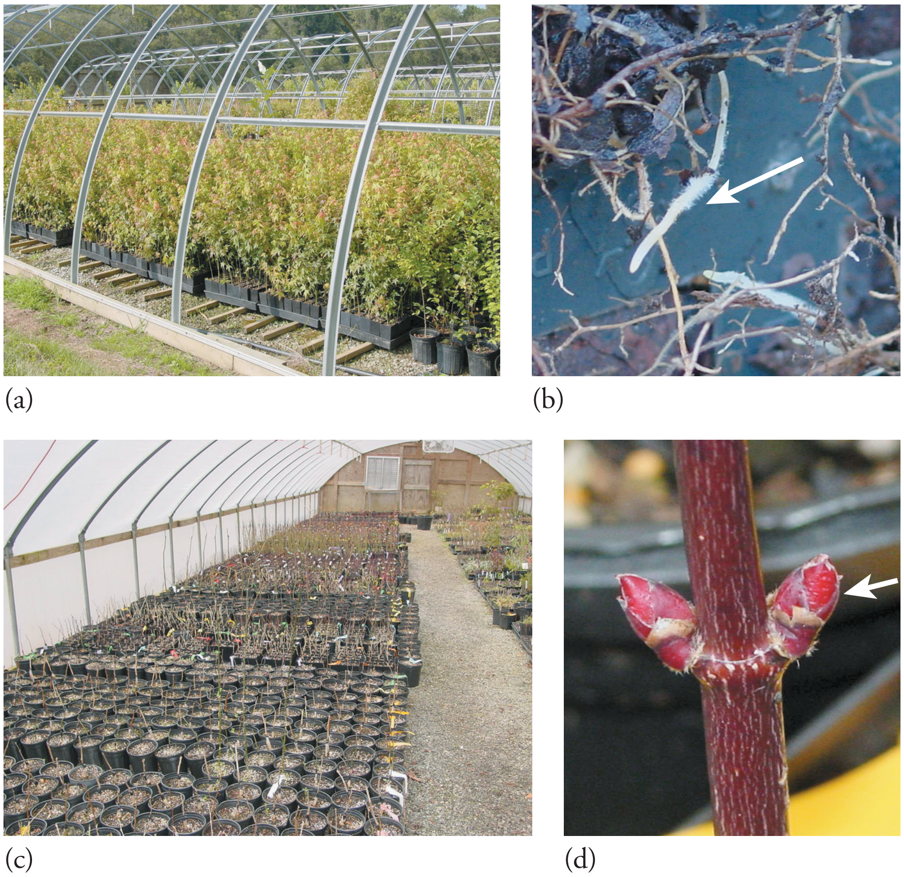

Figure 12–47
Proper rootstock preparation. (a) Hardening-off Acer palmatum rootstock liners in late September (North Carolina). (b) New roots emerging from rootstock in January prior to grafting. (c) Proper after-care of grafted, labeled plants in poly covered, temperature-controlled hoop house. (d) Buds swelling on grafted A. palmatum 'Fireglow' in mid to late March (56).
Courtesy B. L. Upchurch.

ready for grafting (Fig. 12–47) (56). In general, bench grafting is best when new, white root tips of 6 mm (1/4 in) occur or buds start to swell on the rootstock of potted liner plants.

The Craftsmanship of Grafting

Grafting is both an art and a skill. Successful grafting is a **repetitive task** that requires a high degree of accuracy and speed; to become skilled, it is essential for the grafter to eliminate all unnecessary movements. To increase grafting efficiency, it is important to organize the workplace so that scion material, knives, and grafting tape are all within easy reach (42). Grafting is generally more efficient with a **team approach,** in which each worker performs a certain task, in order to reduce inefficient motion of materials and repetitive picking up and putting down of different tools.

Manual Techniques: Speed, Accuracy, and Enhancing Success Rates Tips on improving grafting techniques and ergonomics include the following (42):

- Concentrate on accuracy first, and allow grafting speed to build up—aim at initially completing at least 200 bench grafts a day.
- Use a graft method that is less time-consuming (yet still successful!) and that can be done with lesser skill and preparation of the rootstock [e.g., bench grafting with a splice (whip) graft, compared to a whip-and-tongue or side-veneer graft (43)]; this works well with *Betula, Cornus, Fagus, Ginkgo, Quercus,* and *Acer* (26).
- Grafting is best with two people: in bench grafting with the whip-and-tongue, one person does the graft, and the other moves the potted liner rootstocks and waxes the graft union. In T-budding field roses, the budder prepares the rootstock and inserts the shield bud of the scion, while the "tier" follows and ties the budding rubber around the budded graft (see Fig. 13–13).
- The grafting knife should always be held with a relaxed grip to improve accuracy and reduce repetitive strain injuries (e.g., **carpal tunnel syndrome**); it is necessary to restrict and control your arm movements.
- There are two basic cuts in grafting: the **slice cut,** which is made using the arm and shoulder to pull the knife [e.g., in the making of a splice (**whip**) graft]; and the **cross cut,** in which the grafter's arm and knife are rotated using the thumb

carpal tunnel syndrome
Nerve damage in the wrist caused by the stress of repetitive hand-arm movements.

as a pivot, with both hands joined to prevent the knife from cutting the grafter—a whip-and-tongue is created when the scion and rootstock are sliced and then cut across in **four** (economical) movements.

- Hang the grafting tape around your neck so that you know where it is and it stays free of contamination.
- In most cases, speed is more important than 100 percent accuracy; increase speed by developing a routine when grafting, and avoiding useless movements.
- Try to hold the grafting knife in your hand at all times (e.g., in your little finger).
- Make sure that everything is at a height that is easy to reach.

Record Keeping Maintaining good records is important for successful grafting.

- *Keep records on the grafters* to determine daily quantities grafted; some operations pay on a **piecework** or bonus system (see Chapter 10). Records kept by the supervisor can be constructively used to help grafters improve their technique and efficiency (9).

piecework A bonus system awarded to workers when they exceed daily graft production quotas.

- *Keep records on the plant material* to determine the optimum windows of time to graft (43) and to assure having the best available material to graft. Records should be kept on the conditions of the grafting material, grafting problems encountered, and aftercare of the grafts. Should a crop failure occur, records can generally help pinpoint the cause and help managers improve efficiency (9).
- *Importance of developing and sticking to a grafting time-line schedule.* A timeline schedule is critical for commercial success (Fig. 12–46).

AFTERCARE OF GRAFTED PLANTS

In Bench Grafting Systems

A common method of bench grafting is to wrap the union with budding rubbers, poly or plastic tape, plastic clips and silicone tubing, biodegradable cloth tape, or older materials such as raffia. Depending on the wrapping material, the entire union may be covered with grafting wax.

Root Grafting The root grafts may be placed under refrigeration at 7°C (45°F) for about 2 months. For general callusing purposes, temperatures from 7 to 21°C (45 to 70°F) are the most satisfactory. The callusing period for apples can be shortened to around 30 days if the grafts are stored at a temperature of about 21°C (70°F) and at a high humidity. To use this higher callusing temperature, the material should be collected in the fall and the grafts made before any cold weather has overcome the rest period of the scion buds. After the unions are well healed, the grafts must be stored at cool temperatures—2 to 4°C (35 to 40°F)—to overcome the "rest period" of the buds and to hold them dormant until planting (24). The root grafts are lined-out in early spring in the nursery row directly from the low-temperature storage conditions.

Hot-Pipe Callusing System With some plants, the graft union should be kept warm, 24 to 27°C (75 to 82°F), but the roots and the buds on the scion should be kept cool, about 5°C (41°F), to prevent premature growth before the graft union has callused and healed together. An ingenious system for regulating temperature was developed for whip-grafting hazelnut (*Corylus*), which are notoriously difficult to root graft (Fig. 12–48). This hot-pipe callusing system keeps the graft union warm by recirculating hot water in a PVC pipe onto which the graft is placed. The scion and roots protrude into areas of lower temperatures to keep the plant dormant until ready for transplanting. This hot-pipe callusing system, when used outdoors in late winter or early spring, has increased the root grafting "takes" of hazelnut and other difficult-to-graft species (31). Some aeration of the callusing grafts is required, so airtight containers should not

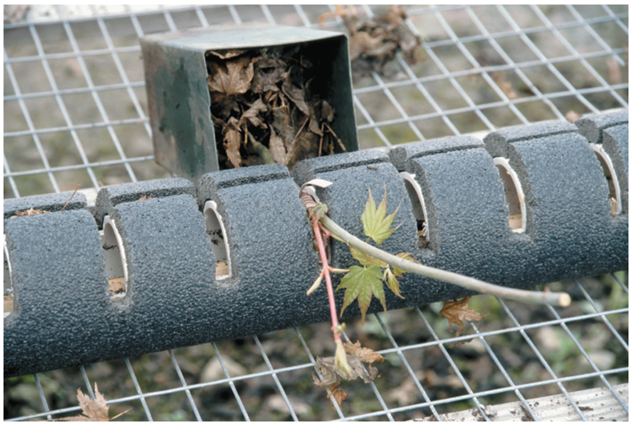

Figure 12–48
Hot-pipe callusing system for bench grafting difficult plants. The graft union is placed in a slot in a large plastic pipe. Inside the large pipe is a smaller pipe through which thermostatically controlled hot water circulates. Insulating material laid over this pipe retains the heat. The protected roots and scions protrude into areas of cooler temperatures, which retards their development.

be used. Virtually any graft used in bench grafting can be callused with the hot-pipe system, including apples, pears, peaches, and plums (32), and ornamentals such as *Acer, Cedrus, Corylus,* and *Fagus.* Not all species respond—the higher graft union temperature does not enhance graftage of spruce (*Picea*), for instance.

Closed Case Waxing may be omitted if the **bare-root grafts** are to be protected from drying by packing the grafts in boxes containing slightly moist peat. Some producers still dip the grafts in rose wax from the scion end to the taped union of the graft prior to boxing (51). Then the boxes are moved to a callusing room at 21°C (70°F) for about 12 days. Once the grafts have formed sufficient callus, the boxed grafts are held in cold storage at 2°C (35°F) until outplanted in the field (51). Another form of the closed case is the use of a **polytent** in a heated greenhouse for callusing the grafts of **potted rootstock liners** (Fig. 12–4). Provided light irradiance is controlled, glass mason jars can be used as a closed-case system for grafted plants in containers (Fig. 12–49).

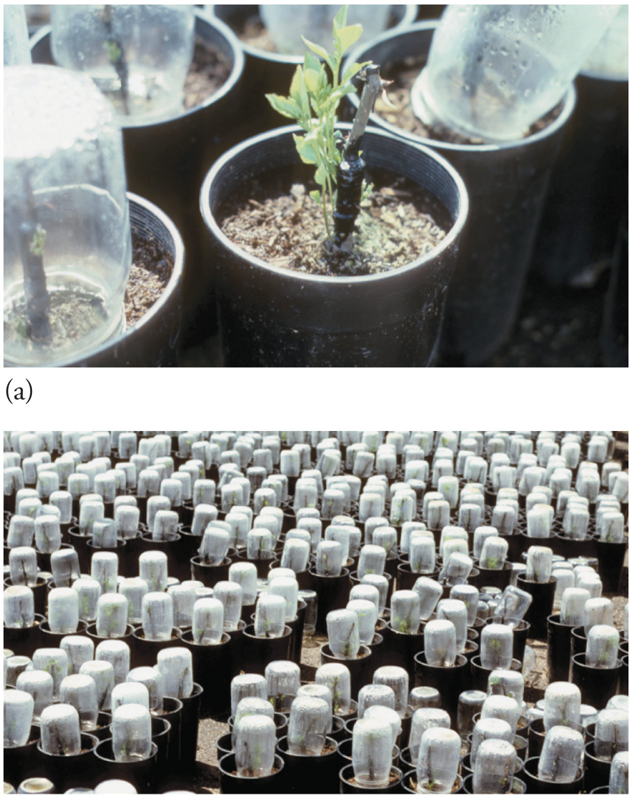

Figure 12–49
(a and b) A closed case system of covering containerized grafted plants with glass Mason jars. (a) Uncovered plant. Condensate is visible inside the glass jars. (b) These grafted plants are maintained under shade to reduce the light irradiance and minimize heat buildup.

Open Case (Open Bench) Grafting is also done in a temperature-controlled greenhouse or unheated polyhouse (depending on the season). Waxing can be omitted in the bench grafting of **potted rootstock liners** by plunging the container and burying the graft in slightly moist peat moss or bark in a temperature-controlled greenhouse. The medium is bottom heated and kept at 18 to 21°C (65 to 70°F) for 3 to 6 weeks for callusing; ideally, the air temperature should be cooler to discourage any initial top growth. Wrapping a graft with poly grafting tape is also sufficient without waxing. Optimum periods for grafting selected ornamental species in a greenhouse are listed in Table 12–5.

Outplanting of Bare-Root Grafts. As soon as the ground can be prepared in the spring, the grafts are lined-out in the nursery row 10 to 15 cm (4 to 6 in) apart. Grafts should be planted before growth of the buds or roots begins. If growth starts before the grafts can be planted, they should be moved to lower temperatures (−1 to 2°C, 30 to 35°F). The grafts are usually planted deep enough so that the graft union is just below the ground level, but if the roots are to arise only from the rootstock, the graft should be planted with the union well above the soil level [i.e., 7 to 15 cm (3 to 6 in)]. It is very important to prevent *scion rooting* where certain definite influences, such as dwarfing or disease resistance, are expected from the rootstock.

After one summer's growth, the grafts should be large enough to transplant to their permanent location. If not, the scion may be cut back to one or two buds, or headed-back somewhat to force out scaffold branches and allowed to grow a second year. With the older root system—a strong, vigorous top is obtained the second year.

Aftercare in Field and Nursery Grafting Systems

Aftercare of field- and nursery-grafted plants is described in "Production Processes of Graftage" starting on page 492. In the section "Types of Grafts" (page 466), see the descriptions for grafting and aftercare using such grafts as the whip-and-tongue, four-flap, and inlay bark graft. Chapter 11 describes heading-back (**lopping**) as well as the **crippling** techniques that are used in field and container nurseries to encourage the

crippling or lopping
Bending (restriction) or cutting halfway through the rootstock stem above the bud union to help force out the bud and maintain growth of the grafted plant. The rootstock tops are later cut off.

Table 12–5
"Optimum Windows" of the Year When Selected Ornamental Species Can Be Grafted in the Greenhouse in Oregon, USA (43)

	Month											
Crop	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Abies	X	X										X
Acer palmatum	X	X	X	X	X	X	X	X	X	X		
Aesculus	X	X	X				X	X	X			X
Carpinus	X	X	X	X						X	X	
Cedrus	X	X	X						X			
Cercis		X	X	X			X	X				
Cornus	X	X	X						X	X		
Fagus	X	X	X	X					X	X	X	
Ginkgo	X	X	X	X				X	X			
Hamamelis	X	X	X	X				X	X	X		
Larix	X	X										
Liquidambar		X	X					X	X			
Liriodendron		X	X						X	X		
Picea	X	X					X	X				X
Pinus spp.	X	X									X	X
Wisteria	X	X	X	X								

scions of grafted and budded plants to overcome the apical dominance of the rootstock and begin final production development.

Aftercare in Topworking Systems (Top-Grafting and Top-Budding) After the actual top-grafting (or top-budding) operation is finished, much important work needs to be done before the topworking is successfully completed. A good grafting job can be ruined by improper care of the grafted trees.

The trees should be carefully inspected 3 to 5 days after grafting, and the graft unions rewaxed if cracks or holes appear in the wax. However, using wax in top-grafting pecan trees is not feasible, given the high-temperature conditions of Texas, so inlay bark grafts are covered with aluminum foil and polybags to control desiccation and heat stress during the grafting process (Figs. 12–13 and 12–24). In Israel the grafts of topworked peaches have aluminum covers to reduce heat buildup (Fig. 12–24).

FIELD, BENCH, AND MISCELLANEOUS GRAFTING SYSTEMS

Some of the different grafting systems have been described in the sections on **types of grafting** and the **production processes of graftage. Grafting systems** are categorized as field, bench, and miscellaneous grafting systems (Table 12–6).

Field Grafting Systems

Crown Grafting The **crown graft** originally referred to scions grafted onto larger rootstock. The large rootstock stem was grafted with a number of scions, which sometimes were in a crown-like circle (19). Today, the term includes grafting onto an established rootstock with single or multiple scions, using the whip-and-tongue, cleft, wedge, side-veneer, inlay bark graft, and others. The choice of the graft depends on the species and size of the rootstock. In California, seedling walnut trees are planted in the nursery and then grafted at the crown—close to the junction of the root and shoot—of the rootstock.

crown grafting
Grafting that is done at the **crown** of the rootstock, which is the junction of the root and shoot system. In earlier times it referred to grafting several scions in a crown-like circle onto an established larger rootstock.

Crown grafting of deciduous plants is done from late winter to late spring. In each species, grafting should take place shortly before new growth starts. The scions should be prepared from mature, dormant wood of the previous season's growth.

If the graft is above the soil level, the union must be well tied (or nailed) and sealed to firmly hold the graft and prevent desiccation. However, when the operation is performed just below, at, or just above the soil

Table 12–6
FIELD, BENCH, AND MISCELLANEOUS GRAFTING SYSTEMS

Field Grafting Systems
- Crown graftage
- Topworking
- Frame working
- Repair graftage—see page 487
- Double-working (by grafting and budding)—sometimes bench grafted

Bench Grafting Systems—see page 502
- Root graftage
- Nurse-root graftage
- Grafting of plants in liner pots under protected culture
- Herbaceous grafting—including grafting of vegetable crops
- Approach graftage—sometimes field grafted

Miscellaneous Grafting Systems
- Cutting grafts—simultaneous rooting and grafting (stenting) of roses, citrus, etc.
- Micrografting

level, it is possible to cover the graft union, or even the entire scion, with soil and thus eliminate the necessity for waxing or ceiling. In all cases, the union should be tied securely with tape to hold the grafted parts together until the graft takes.

Topworking **Topworking** is used primarily to change the cultivar of an established plant—tree, shrub, or vine—by grafting (see Fig. 12–24). Topworking can be done with any of the apical or side graftage grafts described earlier in this chapter, depending on the plant species. This procedure may be preferred to removal and replacement of the entire plant, since a return to flowering and fruiting is faster with topworking an established plant than with transplanting a new nursery plant—particularly if the topworked plant is young, healthy, and well cared for. Plants that are old, diseased, or of a short-lived species are not satisfactory candidates for topworking.

topworking Using either top-grafting or top-budding when a scion is grafted or budded onto an established plant in the orchard.

Preparation for Topworking. Top-grafting is usually done in the spring, shortly before new growth starts. The exact time depends on the method to be used. The cleft, side, whip, and wedge grafts can be done before the bark is slipping, but the bark graft must be done when the bark is slipping, preferably just as the buds of the stock tree are starting to grow.

It is usually advisable to obtain an ample amount of good-quality scionwood prior to grafting and store it under the proper conditions, although for broad-leaved evergreens, such as avocado or citrus, scionwood can be collected at the time of the grafting operation. See the earlier section on the selection and handling of scionwood (page 496).

In preparing for topworking, one must decide for each individual rootstock tree how many scaffold branches, if any, should be used (usually 3 to 5). However, no scaffold branches are retained when topworking pecans in Texas with the inlay bark method.

Double-Working (Grafting or Budding) A double-worked plant has three genetically distinct parts: the rootstock, the interstock, and the scion (Fig. 12–50). Such a plant has two unions, one between the rootstock and interstock and one between the interstock and the scion. The interstock may be less than 25 mm (1 in) in length or extensive enough to include the trunk and secondary scaffold branches of a tree.

Double-working is used for various purposes (see Chapter 11 and Chapter 13). Examples of double-working are (a) the propagation of 'Bartlett' pears on quince as a dwarfing rootstock by using a compatible interstock such as 'Old Home' or 'Hardy' pear (Fig. 12–50, page 506), and (b) the propagation of dwarfed apple trees consisting of the scion cultivar grafted onto a dwarfing 'M 9' or 'M 27' interstock that is grafted onto a more vigorous rootstock such as 'MM 106,' 'M 111,' or apple seedlings (Fig. 11–11) (10). Another form of double working is using a bridge-graft with a dwarfing rootstock (as the interstock) on older, mature apple rootstock in an established orchard, as previously described (53).

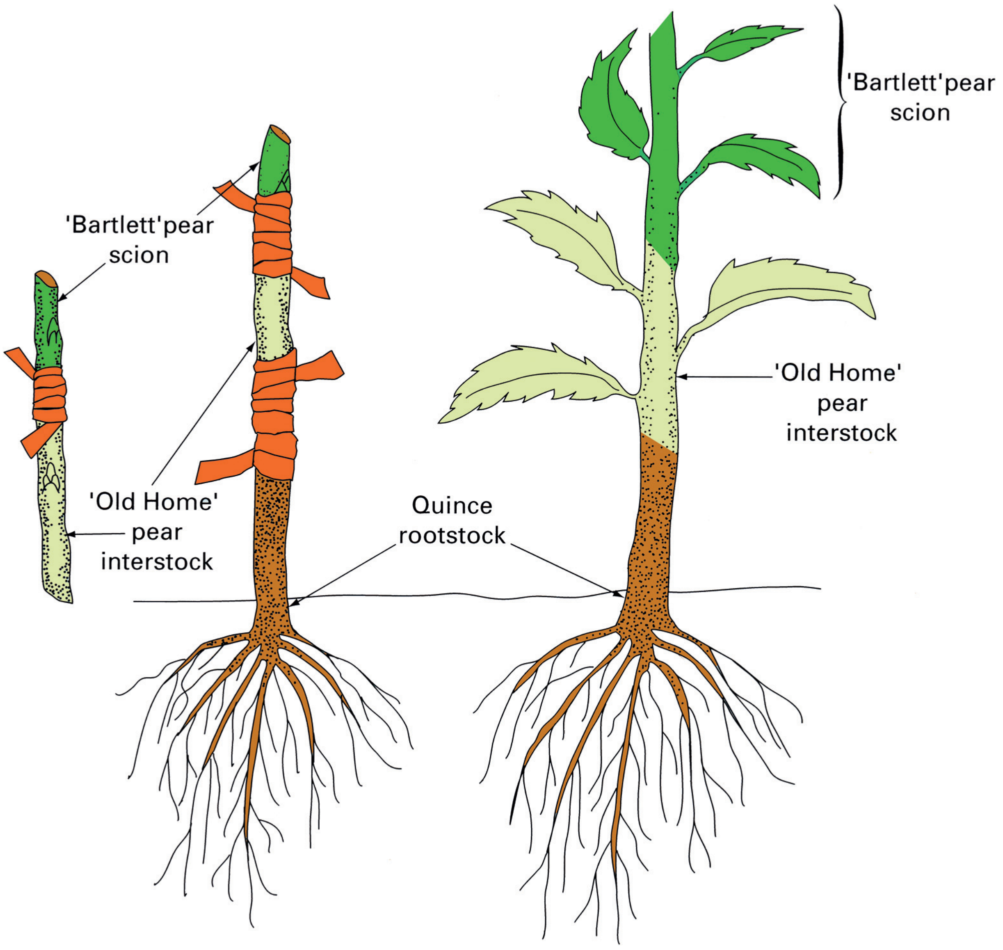

Figure 12–50 There are three genetically distinct parts and two graft unions in a doubleworked plant. The 'Bartlett' pear scion is grafted on an 'Old Home' pear interstock—then grafted to quince rootstock.

Several methods are used for developing double-worked nursery trees. The grafting in these techniques can be done with the whip graft:

- Rootstock "liners"—seedlings, clonal rooted cuttings, or rooted layers—are set out in the nursery row in early spring. These are then fall-budded with the interstock buds, growth from which, a year later, is fall-budded with the scion cultivar buds. Generally, 3 years are required to produce a nursery tree by this method.
- The interstock piece is bench grafted onto the rooted rootstock—either a seedling or a clonal stock—in late winter. After callusing, the grafts are lined-out in the nursery row in the spring, and fall-budded to the scion cultivar. By this method, the nursery tree is propagated in 2 years.
- A variation of the previous method is to prepare, by bench grafting, two graft unions—the scion grafted to the interstock and the interstock grafted to the rooted rootstock. After callusing, the completed graft, with two unions, is lined-out in the nursery row. Depending on growth rate, a nursery tree can be obtained in 1 or 2 years.
- Double-shield budding (T-budding) is used for double-working in one operation by budding (Fig. 13–21). A nursery tree is produced in 1 year or, if growth is slow, 2 years after budding.
- The interstock shoots still on the plant can be T-budded in late summer with the scion buds inserted about 15 cm (6 in) apart. During late winter, the budded interstock shoots are removed with the budded scion at the terminal end of each piece and bench grafted with a whip graft onto seedling rootstocks. After callusing, the completed graft—now consisting of rootstock interstock and a budded scion—is ready for planting in the nursery row (16).

Bench Grafting Systems

The term **bench grafting (bench working)** traditionally refers to any graft procedure performed on a rootstock and scion that are not initially planted, including root graftage, nurse-root graftage, or any graftage performed on bare-root rootstock. Bench grafting also applies to potted liner rootstock that is grafted on a bench or table, as is commonly done with selected

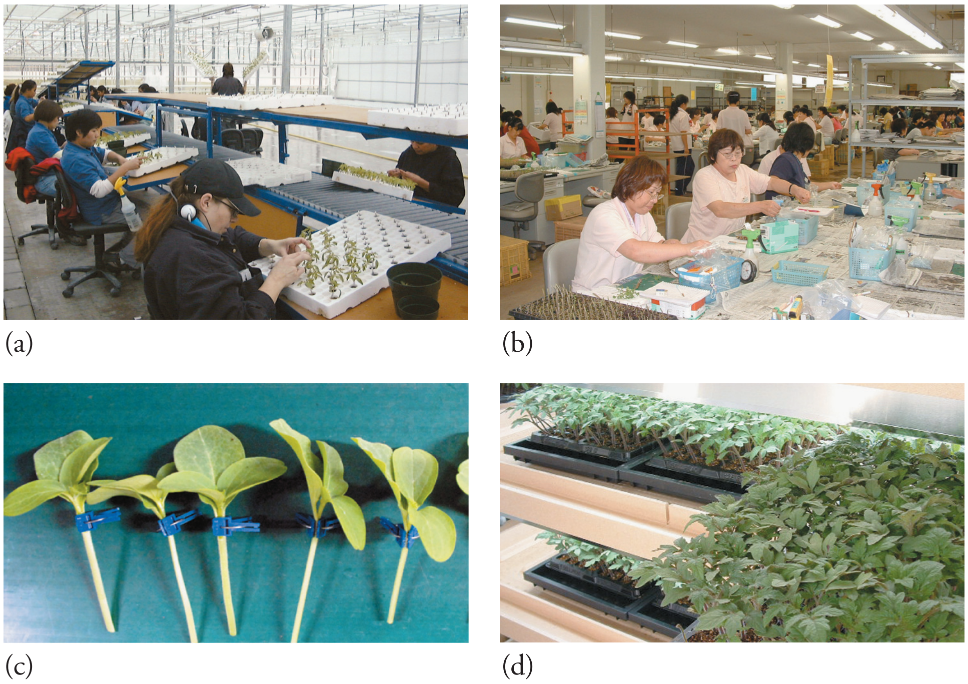

Figure 12–51
(a and b) Bench grafting of vegetables in Canada and Japan. (c) Machine grafted cucumber cuttings. (d) Growing grafted seedlings indoors under artificial lights (29). Courtesy C. Kubota.

woody ornamental species (43) or selected vegetable crops (Fig. 12–51) (29). Certain approach grafts are bench grafted, while others, such as the spliced approach graft of mangos in India, are field grafted, with the potted rootstock grafted to the established scion in the field.

Herbaceous types of plants are grafted for various purposes, such as studying virus transmission, stock-scion physiology, and grafting compatibility, as well as for the commercial greenhouse and field production of selected vegetable crops, particularly in Japan, Korea, and Europe (Fig. 12–51). The rootstock is grafted shortly after seed germination, while the plants are quite small. Such material is generally very soft, succulent, and susceptible to injury. The one cotylendon graft (OCG) or Japanese tube graft, is described in detail (see Figs. 12–6, 12–7, and 12–46) (21). Automated procedures of vegetable grafting using robotics and plastic grafting clips were described earlier (Figs. 12–43, 12–44, and 12–45).

Miscellaneous Grafting Systems

Cutting-Grafts In the cutting-graft, a leafy scion is grafted onto a leafy, unrooted stem piece (which is to become the rootstock), and the combination is placed in a rooting medium under intermittent mist for simultaneous grafting and rooting of the rootstock. Leaves must be retained on the rootstock piece in order for it to root. This procedure was utilized many years ago in studying stock-scion physiology in citrus (20), and has been used in commercial propagation of various types of citrus on clonal dwarfing rootstocks (13). It is also of value in propagating certain difficult-to-root conifers (55), rhododendrons (15, 41), and macadamias (1), as well as a number of apple, plum, and pear cultivars (44). It is used in the Netherlands and Israel in propagating greenhouse roses, where it is called **stenting** (Figs. 12–52 and 12–53) (58, 59).

stenting A Dutch term for simultaneously grafting and rooting the rootstock.

For citrus, a simple splice graft is used. The slope of the cut is at a 30-degree angle 1.3 to 2 cm (1/2 to 3/4 in) long; the union is tied with a rubber band. The base of the rootstock is dipped into an auxin, such as IBA, and then the grafts are placed under mist, or in a closed case, in flats of the rooting medium over bottom heat. After healing of the union and rooting of the stock, the grafts are allowed to harden by discontinuing the mist and bottom heat for about 2 weeks. Then the grafts are ready to be planted in 3.8-liter (1-gal) containers.

Micrografting Grafting of tiny plant parts can be done aseptically using tissue culture techniques described in Chapters 17 and 18, in which the small grafts are grown in closed containers until they are large enough to be transferred to open conditions. Micrografting has been used mostly with citrus, apple, and some *Prunus* species to develop virus-free plants, where a virus-free shoot tip can be obtained but cannot be rooted. The shoot tip is grafted aseptically onto a virus-free seedling, thus providing a complete virus-free plant from which other

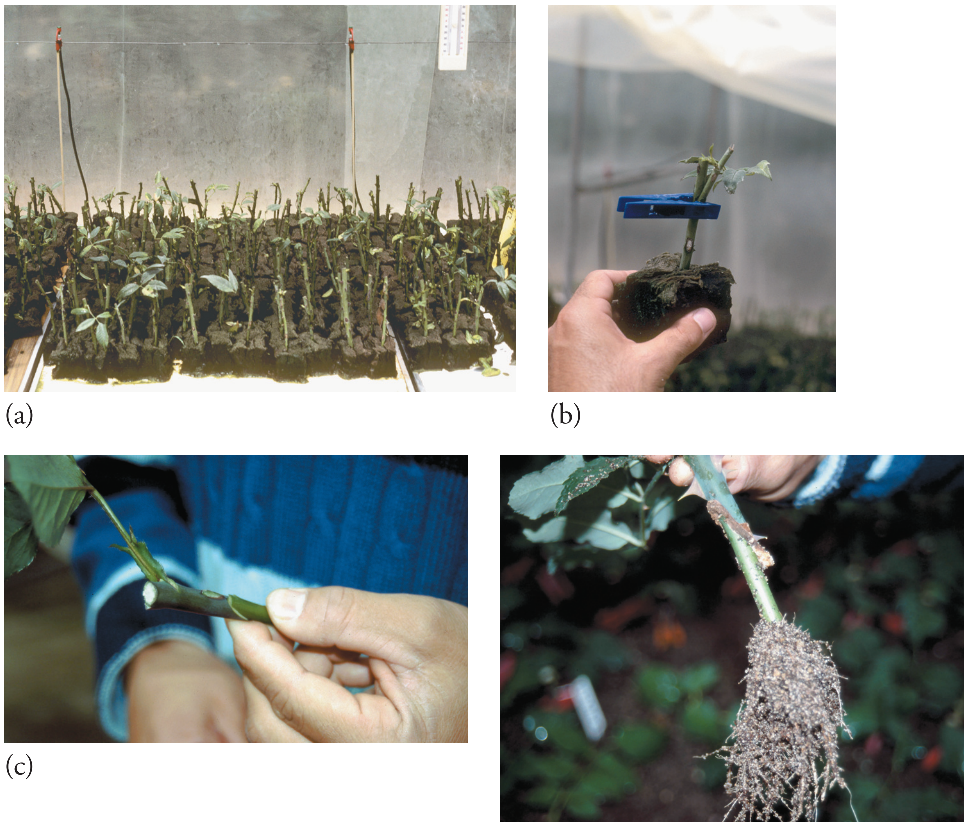
(a) (b) (c) (d)

Figure 12–52
Simultaneously grafting and rooting roses for cut flower production in Israel. (a and b) Rooting in Rockwool rooting blocks. (b and c) Grafted rose with plastic graft clip for simultaneous rooting and successful callus bridge formation. (d) Rooted, stented rose.

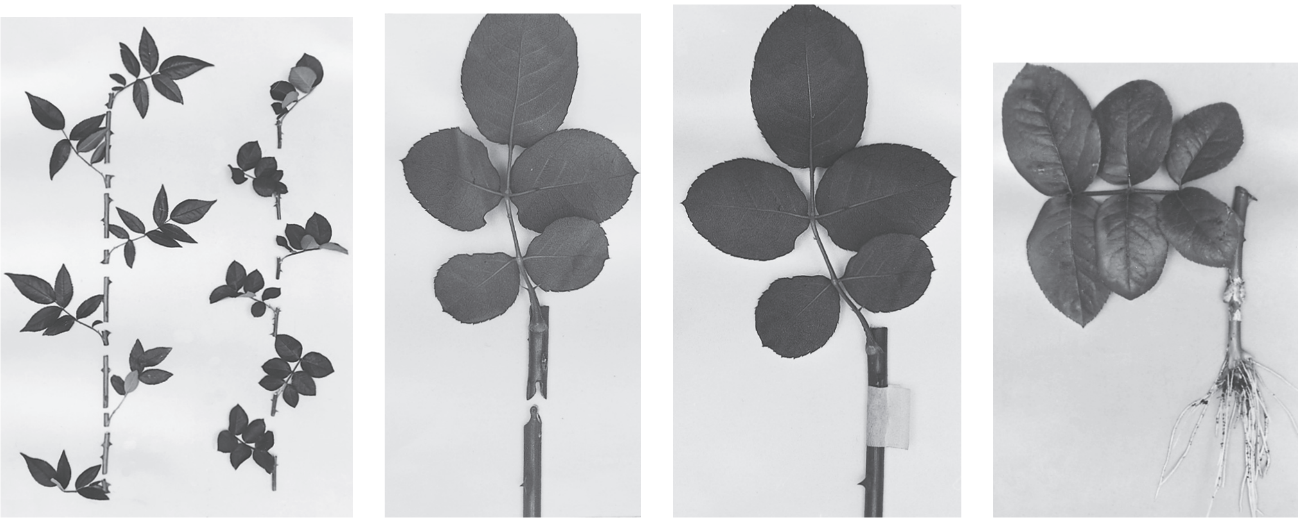
(a) (b) (c) (d)

Figure 12–53
Roses in the Netherlands being propagated by simultaneous rooting and grafting. (a) *Left:* Shoot cut apart to be used for rootstocks. Only internodes are used. *Right:* Sections cut for scions. One leaf is used per scion. (b) Saddle graft made with an Omega grafting machine. (c) Graft wrapped with tape for healing. (d) Completed graft with union healed and stock well rooted, ready for planting. In the Netherlands this process is called “stenting,” a contraction of the Dutch words stekken (“to strike a cutting”) and enten (“to graft”). Courtesy P. A. Van de Pol (58, 59).

"clean" plants can then be propagated (8, 25, 27, 46). Tests conducted some years after the shoot-tip grafts were made and the resultant trees were fruiting showed that the fruits were normal for the cultivar, disease-free, and with no variations appearing (45). The procedures for micrografting are described in Chapter 17.

Micrografting can also be done without tissue culture techniques. The non-aseptic propagation of very small nursery trees by grafting tiny seedlings with match-like scions, then growing the minute grafts long enough to have a viable plant, is a promising procedure (60). This is useful particularly in the tropics, where nursery plants sometimes must be shipped long distances, often by air, into inaccessible regions. Quantities of such tiny plants can be transported much more readily than full-sized nursery trees.

DISCUSSION ITEMS

1. What are five important requirements necessary for successfully producing a grafted plant?
2. What are the three major types (classifications) of grafts, and what criteria are used to categorize a specific graft into one of these three types?
3. What are the three types of nurse-root grafts? Why use an expensive process such as nurse-root grafting?
4. How does approach graftage differ from repair graftage? Give examples of grafts used.
5. Why are grafting waxes not used as much today as in the past? What kinds of substitutes are being used in their place?
6. Why is there increased interest in grafting automation/robotics?
7. What are some important considerations in the collection, handling, and storage of scionwood for grafting?
8. The craftsmanship of grafting includes both art and skill. How can an individual improve techniques and ergonomics to become a better grafter?
9. What are some good cultural techniques to enhance aftercare in topworking (topgrafting) an orchard with a new cultivar?
10. How do field grafting systems differ from bench grafting systems? Include examples of the various types of grafts in your answer.
11. Why the interest in herbaceous grafting, and with what crops is this technique of commercial importance? Why does this type of grafting lend itself to automation/robotics?
12. Contrast cutting grafts with micrografting, and give examples of their commercial use.

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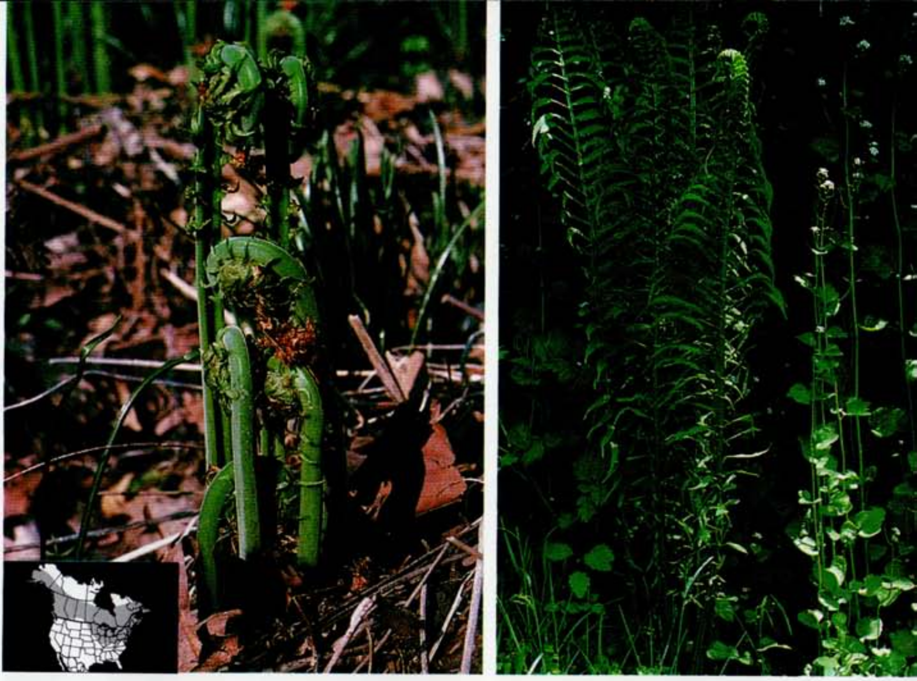

Ostrich fern: young fronds, or fiddleheads, left; and mature summer leaves (Dykeman).

Wild onion: entire plants and flowers (NYBG).

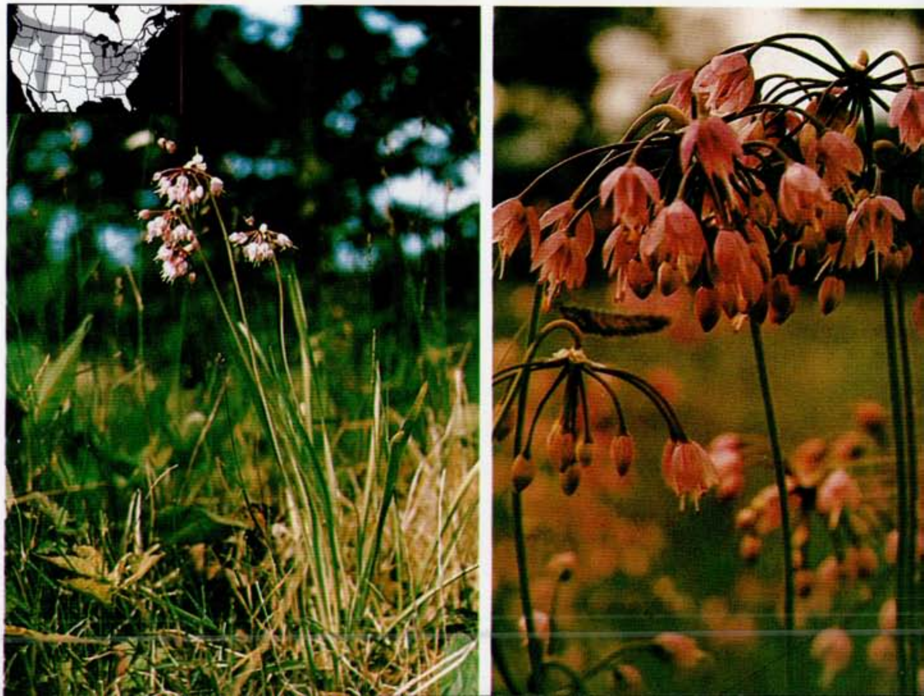

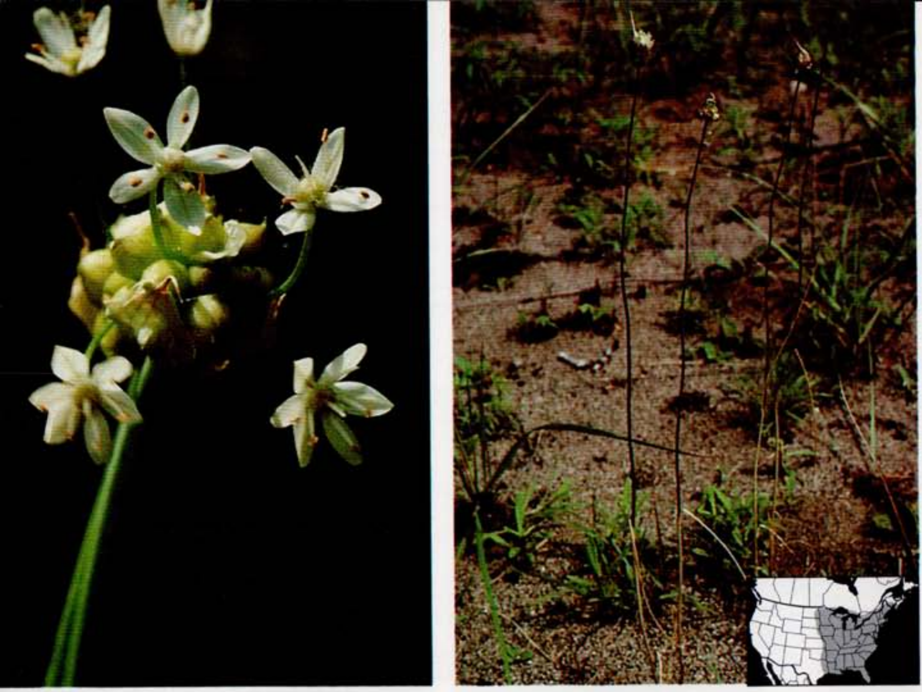

Wild garlic: flowers (Speas). Entire plant (Kavasch).

Wild leek: rootstocks and entire plants (Dykeman).

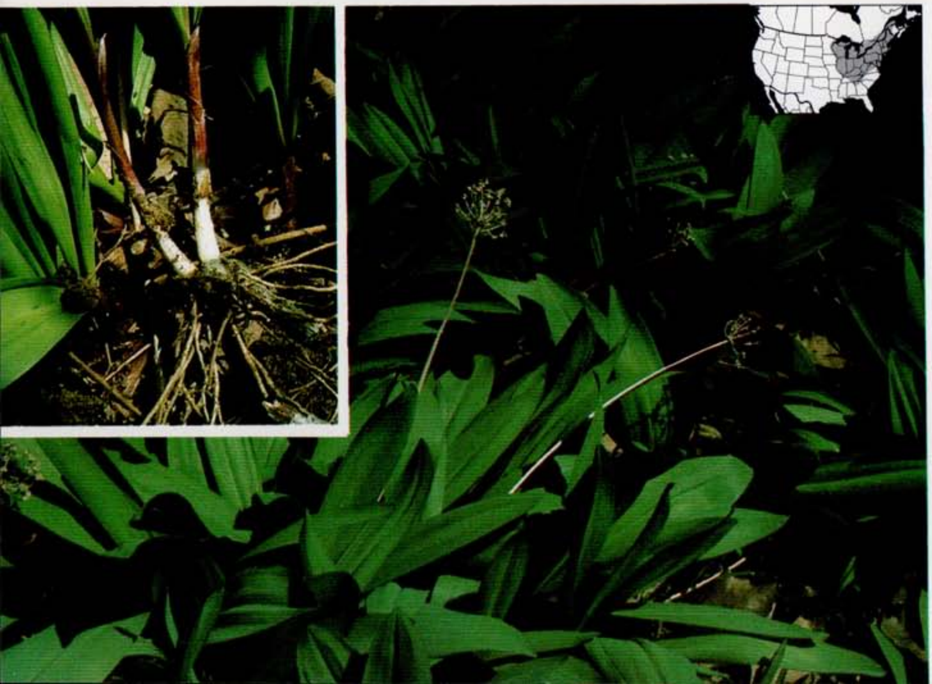

Wild garlic *Allium canadense*

Also edible summer, autumn

Habitat: common, open woodlands, fields, prairies. **Identification:** ***perennial herb*** to 58 cm (23 in) high; ***underground bulb brown, egg-shaped to nearly globe-shaped, 2–3 cm*** (0.8–1.2 in) ***across.*** Stem (scape) erect. ***Leaves*** several, from or near base, linear, to 35 cm (13.8 in) long, 2–5 mm (0.1–0.2 in) wide, rarely wider, flat, flexible, ***with strong onion odor when broken,*** shiny green. ***Flower*** (spring) ***clusters consist of several tiny white to purple bulbils*** (miniature bulbs) ***and zero to few pink to white flowers on long, flexible stalks. Fruiting capsules*** rounded or nearly so, 2–3 mm (0.1 in) long, 3-parted, ***smooth on top;*** seeds triangular, tiny, black. **Harvest:** Use whole plant in early spring before flower stalk appears, or use bulbs in spring and fall. Bundle bulbs with 15–20 cm (6–8 in) stems and dry at room temperature for later use. Pick green top bulb clusters on flower stalk in late spring before ripe. **Preparation:** For salad or vegetable, remove tough outer layers of young whole plant. Chop into green salad or boil whole for ½ hr in salted water, then drain, season with butter, and serve. For soup, use drained-off water to make cream of onion soup. Combine 1 qt onion water, 2 tbsp butter, 1 cup half-and-half. Add smooth mixture of 2 tbsp flour in milk, heat to simmer, and serve. Use this plant in any soup recipes calling for onions or with many cooked vegetables and meats. For other uses, see WILD ONION (preceding). **Related edible species:** WILD ONION, WILD LEEK (next), and several other *Allium* species. **Poisonous look-alikes:** See WILD ONION.

Wild leek, Ramp *Allium tricoccum*

Also edible summer, autumn

Habitat: rich, neutral, moist woods, frequently under maples. **Identification:** ***colonial herb. Leaves directly from bulb, 2 or 3 in number, 10–30 cm (4–12 in) long, 2–6 cm (0.8–2.4 in) wide, light green, smooth, fleshy, onion scented, appearing in early spring, shrivel by flowering in midsummer.*** Flowers small, white, in hemispherical cluster on leafless stalk 15–40 cm (6–16 in) tall. Fruit capsule small, 3-lobed, each lobe with 1 hard seed. **Harvest:** young tops before they unfurl into broad leaves; bulbs from early spring through autumn. **Preparation:** add fine-chopped young leaves to salads or boil whole for 20 min in salted water, drain, season, and serve. Excellent in soup. Bulbs excellent pickled, chopped in salads, cooked alone, or with meat or other vegetables. Add chopped fine bulbs to mashed potatoes. For fried leeks parboil 3 min, drain, add more water, boil until tender. Saute in butter, serve covered with bread crumbs. *Caution:* Leeks are often very strong flavored and may cause gastric distress. Eat sparingly. **Related edible species:** WILD ONION, WILD GARLIC (preceding), and several other *Allium* species. **Poisonous look-alikes:** See WILD ONION.

Corn lily, Clinton's lily *Clintonia borealis*

Habitat: rich woodlands, deep thickets, higher elevations, cool moist sites. **Identification:** ***perennial herb*** to 40 cm (16 in) high, from a slender underground stem (rhizome); ***each plant with 2–5 large basal leaves. Leaves*** usually broadest near or above the middle, ***10–38 cm*** (4–15 in) ***long,*** 4–14 cm (1.6–5.5 in) wide, pointed at tip, entire along margin, dark shiny green. ***Flowers 3–8 at top of erect stalk,*** nodding, each with 6 greenish-yellow, narrow petallike structures 1.3–1.8 cm (0.5–0.7 in) long. ***Fruits are globe-shaped, bright blue berries 8–10 mm*** (0.3–0.4 in) ***in diameter.*** **Harvest:** Gather leaves before fully unfurled. Fully formed leaves are tough and unpleasant tasting. **Preparation:** Chop young leaves into salad with other greens of the season. Boil leaves about 10 min and serve with butter and seasonings. **Related edible species:** White clintonia *(C. umbellata)* has white flowers and black fruit. **Poisonous look-alikes:** *Be positive* of corn lily's young-growth identification features because some similar-looking species are poisonous.

Asparagus *Asparagus officinalis*

Habitat: roadsides, disturbed sites, especially sandy and well-drained soils. **Identification:** ***perennial herb*** 1–2 m (3.3–6.6 ft) high from thick, white, underground stem (rhizome); ***stems*** upright, often branched, ***green***, becoming very slender at top. ***Leaves*** alternate, ***reduced to small scales, lance-shaped,*** to 2.5 cm (1 in) long. ***Flowers produced along upper stems, usually singly or in pairs, hanging on slender stalk, narrowly bell-shaped, 3–6 mm*** (0.1–0.2 in) ***long, yellow to greenish-yellow, 6-lobed. Fruits*** are ***globe-shaped berries 4–8 mm*** (0.2–0.3 in) ***in diameter, bright red,*** fleshy, containing 3–6 black seeds. **Harvest:** identical to cultivated asparagus. Locate by presence of dried Christmas-tree-shaped stalks of previous year. Slice off young stalks just below ground level when green shoots protrude only a few inches. More shoots will grow, allowing reharvesting. *Caution: Avoid older stalks and other parts, which are mildly toxic.* **Preparation:** Wash stalks and peel off any tough covering near base. Tie stalks in bundle and steam or boil until tender, usually 10–15 min. Serve with butter and seasonings or cream sauce. Excellent prepared as cream soup. See any vegetable cookbook for other recipes. **Related edible species:** none. **Poisonous look-alikes:** none.

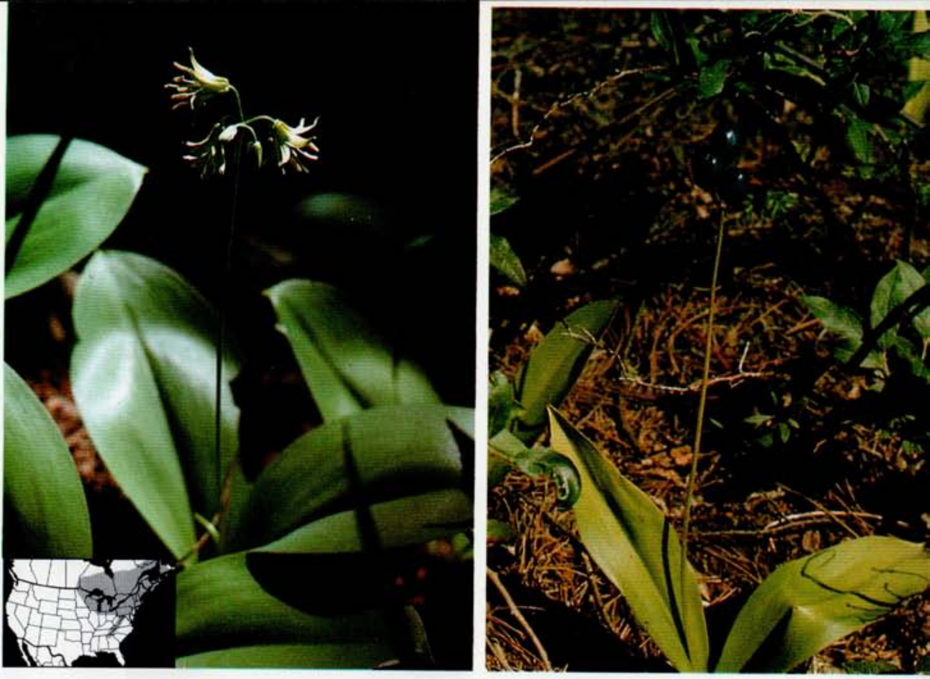

Corn lily: flowering and fruiting plants (NYBG).

Asparagus: young shoots (Dykeman). Mature branch with fruit (Elias).

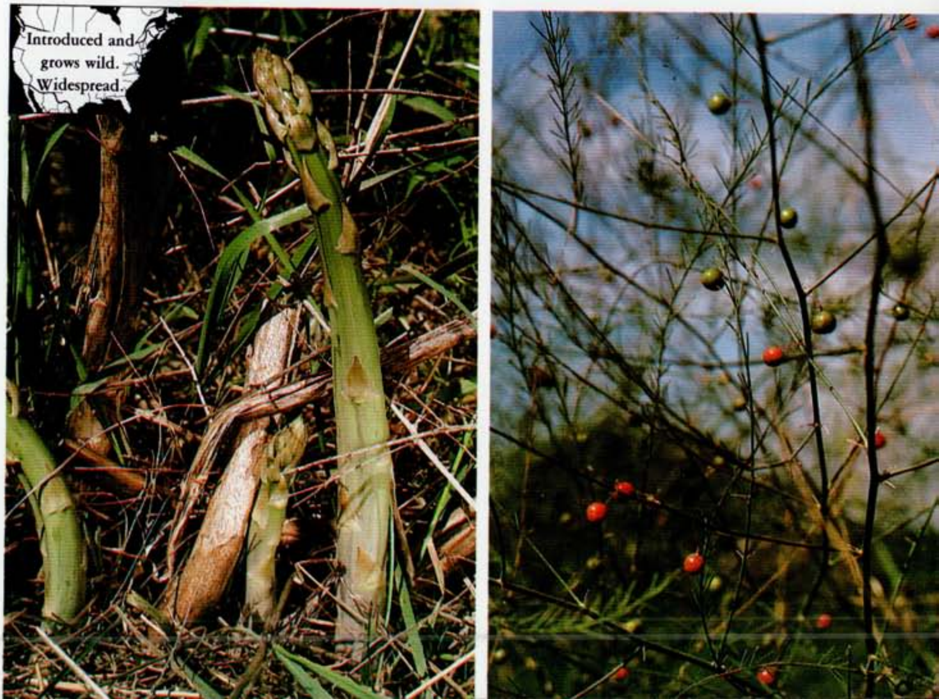
Introduced and grows wild. Widespread.

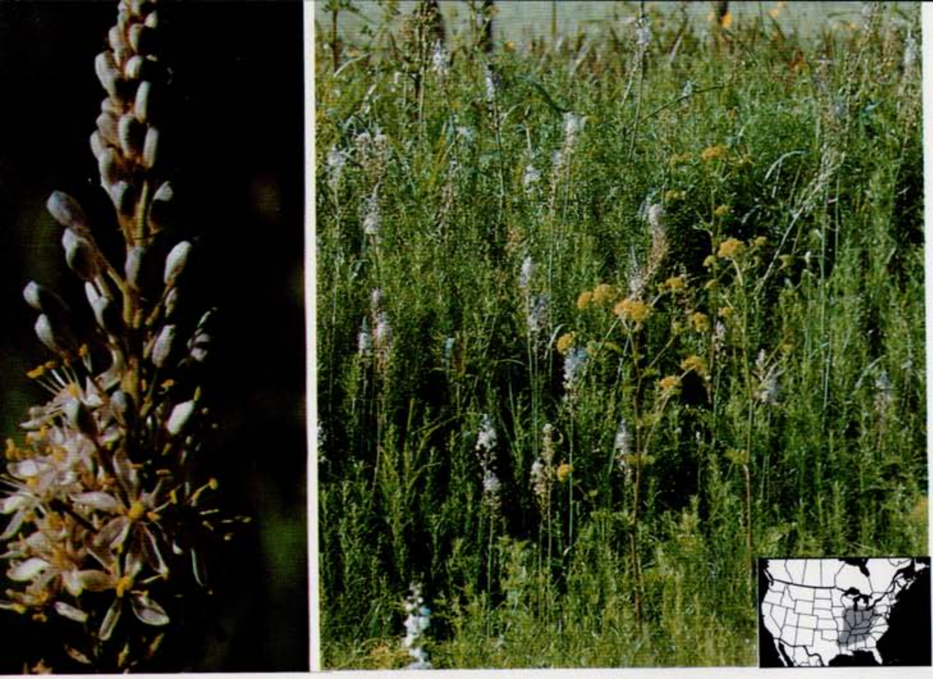

Eastern camass: flower and field (NYBG).

Common greenbrier: fruiting branch (Elias). Flowers (NYBG).

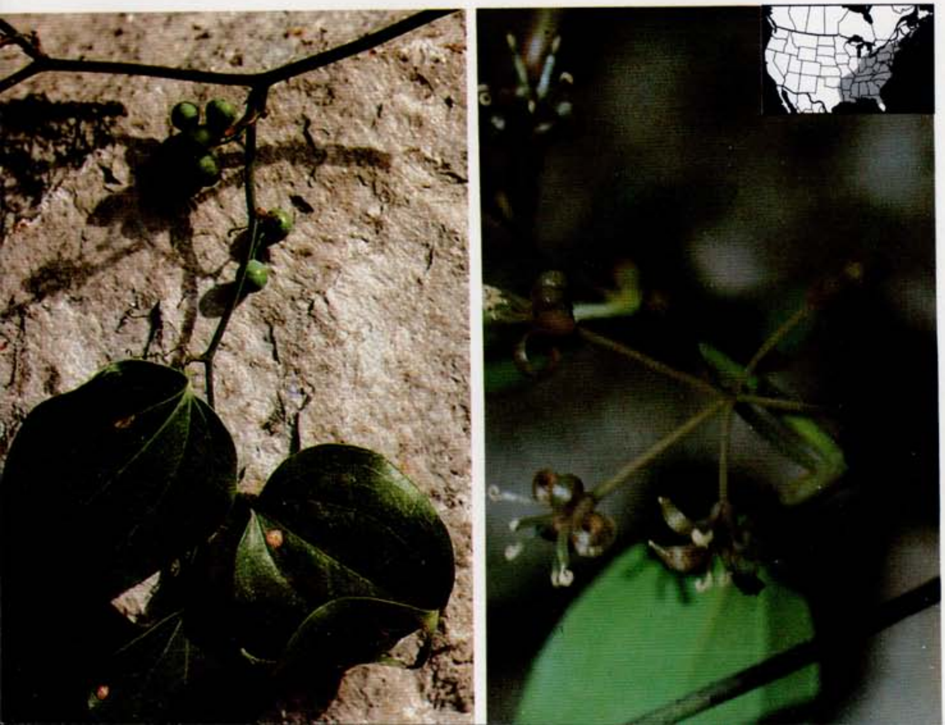

Eastern camass, Camass lily *Camassia scilloides*

Also edible summer, autumn, winter

Habitat: fields, wet meadows, moist open woodlands. **Identification:** ***perennial herb*** from a globe-shaped bulb 1–3 cm (0.4–1.2 in) in diameter. ***Leaves attached at base, long-narrow, 20–60 cm*** (7.9–23.6 in) ***long, 5–17 mm*** (0.2–0.7 in) ***wide,*** pointed at tip. ***Flowering stalk upright to 60 cm (24 in) tall;*** stalked flowers in narrow cluster; ***each flower with 6 white, blue, or violet petals*** or petallike structures 7–12 mm (0.3–0.5 in) long. ***Fruit*** small, nearly globe-shaped, ***3-parted capsule*** 6–12 mm (0.2–0.5 in) in diameter. **Harvest:** Dig or pull bulbs any season; safest when blue flowers distinguish it from DEATH CAMASS. Dig and transplant in ground free of DEATH CAMASS. Study descriptions of DEATH CAMASS carefully. **Preparation:** Raw bulbs are palatable. May be boiled 25–30 min or baked in foil for 45 min at 175°C (350°F) but best preparation is the pit method used by Indians and described in the Introduction, in which eastern camass is baked for 1–3 days. The baked bulbs are very dark and sugary. Slice pit-baked or boiled bulbs. Then dry in sun or warm oven before storing in paper bag in dry place. Bulbs can be used as a potato substitute. **Related edible species:** WESTERN CAMASS. **Poisonous look-alikes:** DEATH CAMASS, narrow-leaved plants with green, white, or bronze flowers, single or several in narrow spike.

Common greenbrier, Catbrier *Smilax rotundifolia*

Also edible summer

Habitat: common plant of roadsides, secondary woodlands, woodland clearings, streamsides, thickets. **Identification:** ***climbing perennial vine, stems*** tough, becoming woody, ***often strongly 4-sided,*** green, tendrils many, ***armed with stout, sharp thorns. Leaves*** alternate, deciduous to almost evergreen (southern part of range), 4–10 cm (1.6–4 in) long, nearly as wide, ***broadest near base to nearly circular,*** pointed at tip, entire along margin, ***leathery,*** dark shiny green. Vines bearing either male or female flowers in several-flowered, flat-topped clusters, green or yellow. ***Fruits bluish-black berries,*** globe-shaped 5–9 mm (0.2–0.4 in) in diameter, often containing 2 or 3 seeds. **Harvest:** Gather new shoots and growing tips, plus uncurling leaves and tendrils, while they are still crisp and tender during spring and summer. **Preparation:** excellent raw as trail nibble. For salads use tenderest parts raw or boil slightly older tips 2–3 min, drain and cool. Add your favorite salad dressing. Steam or boil bundled shoots like asparagus or boil tendrils, leaves, and shoots together like spinach. Cook until tender and serve with sauces and seasonings as you would other vegetables. **Related edible species:** several other *Smilax* species, including BULLBRIER and CARRION FLOWER (next). **Poisonous look-alikes:** none.

Bullbrier, Greenbrier *Smilax bona-nox*

Also edible summer

Habitat: open woodlands, fields, abandoned farmlands, roadsides, disturbed sites. **Identification:** perennial ***climbing vine, stems 4-sided,*** becoming woody, frequently branching, green, tendrils present, with scattered stiff thorns or thornless. ***Leaves*** alternate, deciduous, 4–8 cm (1.6–3.2 in) long, triangular in shape, broadest near base, pointed at tip, entire or with few sharp teeth along ***thickened margin,*** almost leathery texture. Vines with either male or female flowers in several-flowered, rounded or flat-topped stalked clusters. ***Fruits black berries,*** globe-shaped or nearly so, ***6–9 mm*** (0.2–0.4 in) ***in diameter,*** usually 1-seeded. **Harvest and preparation:** shoots, tips, tendrils, leaves same as COMMON GREENBRIER. Also, dig and clean tuberous roots. Cut them into short pieces and pound them in metal container until fibers are separated and gelatinous sediment is released. Wash sediment from fibers and allow to settle. Strain out fibers and other floating matter. Carefully pour off water and allow sediment to dry and turn red. Boil 1 tbsp powdered sediment per cup of water for 10 min. Cool to make jelly or dilute and sweeten for drink. Also use powder as thickener for stews or substitute for part of flour in pancake batter. **Related edible species:** COMMON GREENBRIER (preceding) and CARRION FLOWER (next). Other tuberous-rooted *Smilax* species, such as China-root *(S. tamnoides)* in the East and *S. californica* in the West, are usable for gelatin. **Poisonous look-alikes:** none.

Carrion flower *Smilax herbacea*

Also edible summer

Habitat: open woodlands, margins of woodlands, roadsides, fields. **Identification:** perennial climbing ***vine; green stems, never woody,*** freely branching, tendrils present, ***lacking prickles or thorns. Leaves*** alternate, deciduous, broadest near base to almost rounded, pointed to rounded at tip, heart-shaped to rounded at base, entire along margin, becoming leathery. Vines bearing either male or female ***flowers on long stalks from junctions of uppermost leaves;*** flowers in densely-clustered rounded heads. Fruits in dense, rounded clusters, each ***fruit a berry***, globe-shaped, ***8–12 mm*** (0.3–0.5 in) ***in diameter, dark blue to bluish-black,*** containing several seeds. **Harvest and preparation:** same as for COMMON GREENBRIER and BULLBRIER (preceding). **Related edible species:** COMMON GREENBRIER and BULLBRIER. **Poisonous look-alikes:** none.

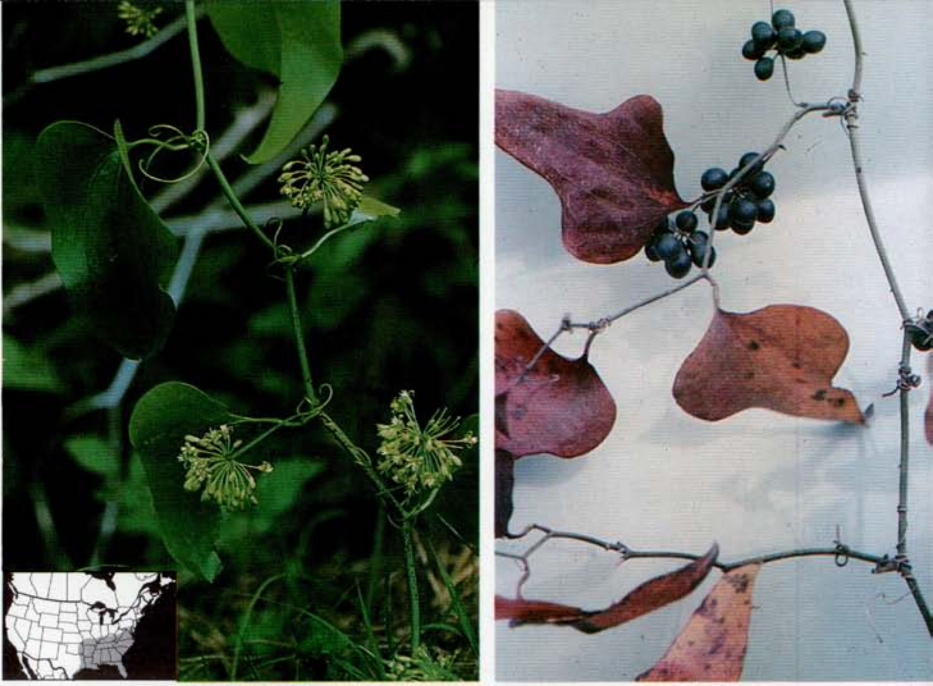

Bullbrier: flowering and fruiting branches (NYBG).

Carrion flower: flowering branch (NYBG). Fruiting branch (Kavasch).

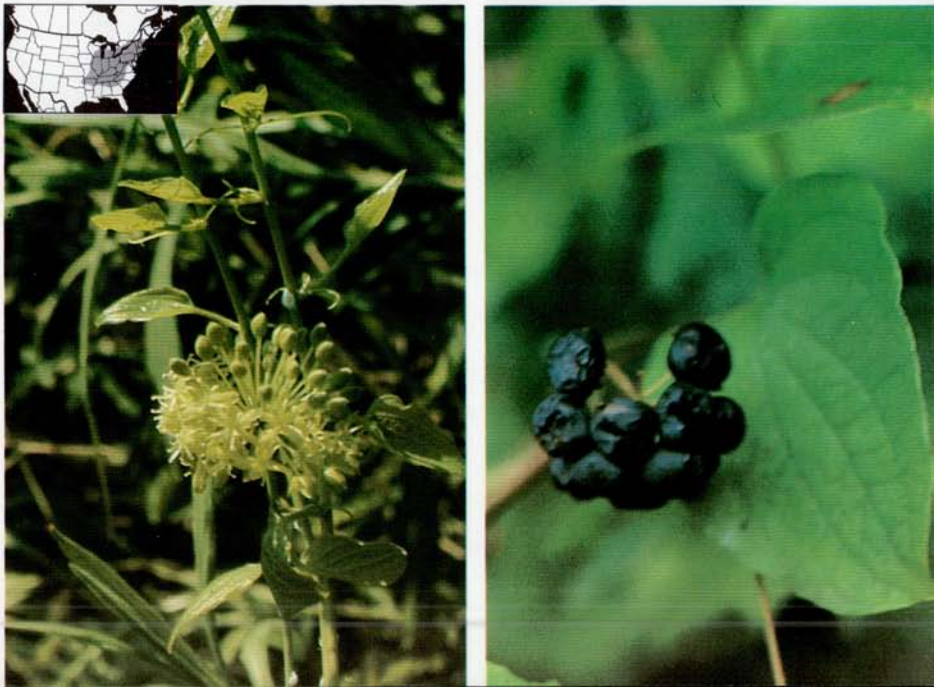

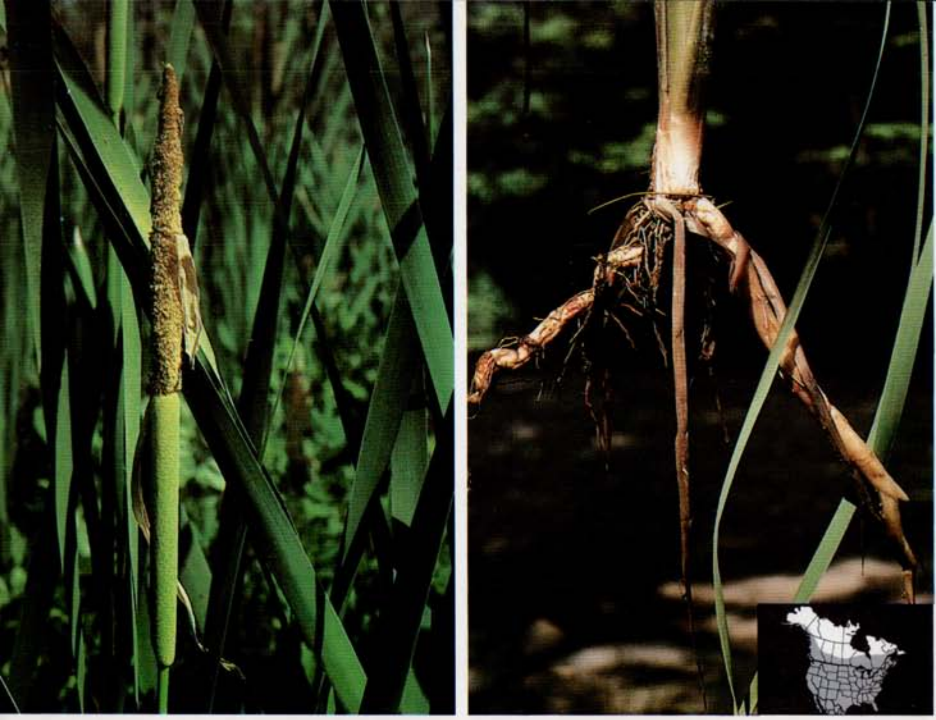

Cattail: flowering stalk and roots (Dykeman).

Narrow-leaved cattail: entire plants and flowers (Elias).

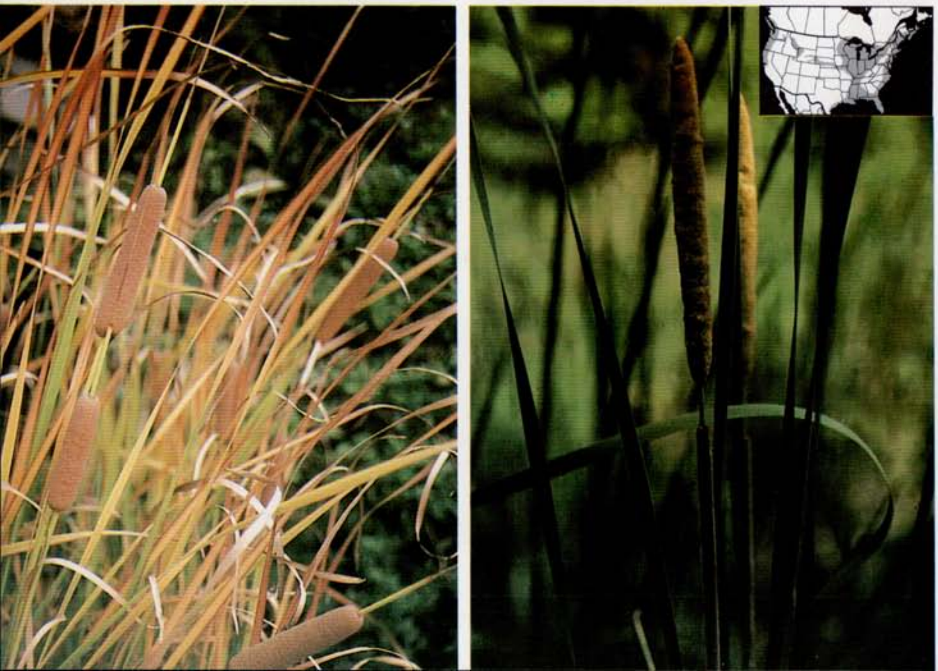

Cattail *Typha latifolia*

Also edible summer, autumn, winter

Habitat: shallow water of lakes, ponds, bays, ditches, marshes. **Identification:** large upright perennial herb to 3 m (9.8 ft) tall, with large stout, horizontal underground stems (rhizomes). ***Leaves*** sheathing at the base of stem, ***1–2.5 m*** (3.2–8.2 ft) ***long, 8–24 mm*** (0.3–0.9 in) ***wide, narrow, swordlike,*** pointed at tip, ***grayish green.*** Flowers at tip of erect stalks, tiny male flowers densely clustered in narrow, cylinder-shaped mass directly above female flowers densely clustered in a cylinder-shape 5–20 cm (2–8 in) long. ***Fruits*** in ***cigar-shaped clusters 2–3.5 cm*** (0.8–1.4 in) ***thick*** which break apart in soft downy-haired seeds in autumn. **Harvest and preparation:** In early spring, dig up roots to locate small, pointed dormant sprouts at ends of roots. Sprouts are edible raw or cooked. Later, similar sprouts appear on roots at bases of leaves. From then until plants are 60–90 cm (2–3 ft) tall, grasp leafy stalks below water surface and pull straight up, usually breaking stalks off at root. Peel away tough leafy layers to tender core, about 12 mm (0.5 in) diameter and to 30 cm (12 in) long. This "Cossack asparagus" is excellent raw, eaten like celery, or sliced into a salad. Or, cover cores with boiling water and simmer about 10 min. Serve with butter, salt and pepper or with oil-and-vinegar. Later pick green bloom spikes while still in papery sheaths and before pollen ripens above them. Remove sheaths and boil spikes in slightly salted water until tender. Eat like corn on cob, or scrape buds from cores for "corn" casserole. As pollen ripens, shake and rub it off stalks into container. Sift through fine screen to remove nonpollen materials. Substitute for part of flour in muffin, fritter, or pancake batter. For white flour, dig roots from fall through early spring. Wash and peel roots, crush cores thoroughly in container of water, and strain out fibers. Wash resulting starch several times, letting it settle and carefully pouring off water after each washing. Dry thoroughly for storage or use wet. **Related edible species:** NARROW-LEAVED CATTAIL (next). **Poisonous look-alikes:** stalks and roots of wild iris species (including YELLOW FLAG, BLUE FLAG). Harvest cattails where old stalks are abundant.

Narrow-leaved cattail *Typha angustifolia*

Also edible summer, autumn, winter

Habitat: ponds, lakes, swamps, bays, ditches. **Identification:** ***large*** upright ***perennial herb*** to 2 m (6.6 ft) tall, with thick, horizontal, underground stems (rhizomes). ***Leaves*** sheathing at base of stem, 0.6–1.5 m (2–5 ft) long, ***3–8 mm*** (0.1–0.3 in) ***wide, very narrow***, strap-shaped, flattened, pointed at tip. ***Flowers*** at tip of erect stalks, ***tiny male flowers*** densely clustered in narrow, cylinder-shaped column 2.5–7.5 cm (1–3 in), ***spaced at intervals above the larger, brown, cylinder-shaped clusters of female flowers*** 3–12 cm (1.2–4.7 in) long. ***Fruits are narrow, cigar-shaped clusters 5–15 cm*** (2–6 in) ***long*** which break apart into soft, downy-haired seeds in autumn. **Harvest and preparation:** same as for CATTAIL (preceding). **Related edible species:** CATTAIL. **Poisonous look-alikes:** See CATTAIL for details.

Hard-stem bulrush *Scirpus acutus*

Also edible summer, autumn, winter

Habitat: shores of ponds, lakes, streams, rivers, marshes. **Identification:** ***perennial herb*** 1–3 m (3.2–9.8 ft) high, from thick, tough, brownish underground stems (rhizomes); ***stems upright***, rounded, ***stiff, yellowish-green, unbranched,*** leaf blades absent or sometimes present, to 10 cm (4 in) long. ***Flowering heads (spikes) densely clustered and originating from one place near the tip of the stem,*** with 1 to several stalks each bearing several heads, each head cylinder-shaped, 8–18 mm (0.3–0.7 in) long, composed of several overlapping scales. Fruits are hard, somewhat flattened seeds 2–3 mm (0.1 in) long. **Harvest:** See GREAT BULRUSH (next). **Preparation:** Peel and cut firm older roots into sections. Crush them and boil in water until you have white gruel. Separate out any fibers and dry gruel into flour. For biscuit dough, add oil and water to reach right consistency. Add salt and baking powder, knead and roll to about ½-in thickness. Bake at 230°C (450°F) or twisted on stick by campfire. Also prepare flour by drying cleaned roots thoroughly, crush, and remove fibers. Pound and grind remaining material into flour. Use pollen as flour additive. Also grind seeds to use alone or with pollen and root flour for baking. Also see GREAT BULRUSH. **Related edible species:** All North American *Scirpus* species may be edible. **Poisonous look-alikes:** none because the fruiting pattern is distinctive.

Great bulrush, Tule *Scirpus validus*

Also edible summer, autumn, winter

Habitat: shallow water of lakeshores, ponds, and streams; fresh and brackish water marshes. **Identification:** ***perennial herb*** to 3 m (9.8 ft) high from tough, reddish scaly underground stems (rhizomes); ***stems upright, rounded, soft, pale green, unbranched;*** leaf blades absent. ***Flowering heads (spikes) produced near stem tips,*** with several stalked, branched clusters, each head egg-shaped, 0.4–1 cm (0.1–0.4 in) long, somewhat flattened, composed of a series of overlapping scales. Fruits hard, flattened seeds 2–3 mm (0.1 in) long. **Harvest:** Bulrushes, like CATTAILS, provide food year-round. Cut off young shoots in early spring or when they've formed in autumn. Later remove cores from bases of older stalks. Shake and beat pollen from stalks into bucket in summer and return to collect seeds the same way from late summer into winter. Dig up roots year-round to use firm, sweet ones as vegetable or as sugar source and older ones for flour. **Preparation:** Peel new shoots and youngest rootstocks and separate cores from older stalks. Eat them raw, sliced in salads, or boiled. Roast young shoots and roots, or slice and fry like potatoes. Bruise young roots and boil for several hours, boiling off water to produce sweet syrup. For other preparations, see HARD-STEM BULRUSH (preceding). **Related edible species:** HARD-STEM BULRUSH. **Poisonous look-alikes:** none.

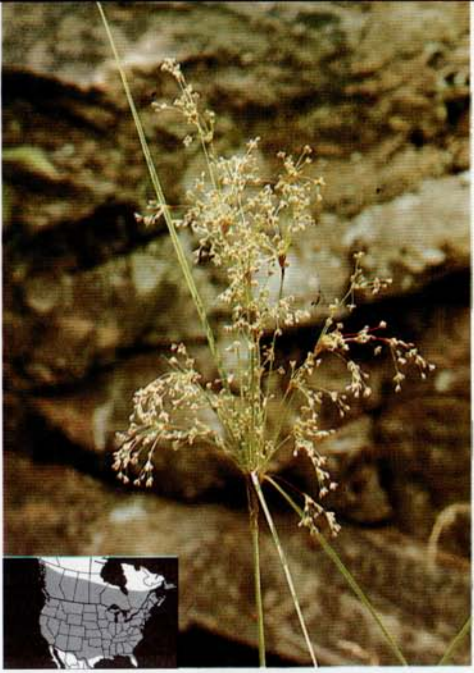

Hard-stem bulrush: flowers (Speas).

Great bulrush: fruiting (Kavasch).

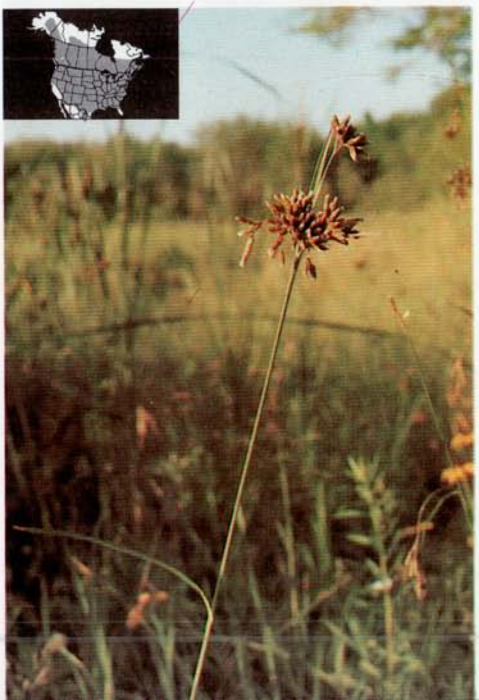

Pigweed, Redroot *Amaranthus retroflexus*

Also edible summer, autumn

Habitat: common and widespread; especially recently abandoned land, waste areas, roadsides. **Identification:** ***coarse annual herb*** to 2 m (6.6 ft) high; stem upright, stout, usually branched. ***Leaves*** alternate, ***long-stalked,*** broadest near base, ***5–10 cm*** (2–4 in) ***long, 2.5–6 cm*** (1–2.4 in) ***wide,*** blunt to short-pointed at tip, wavy along margin. ***Flowers*** late summer and fall, ***densely crowded on narrow spikes*** 6–18 cm (2.4–7.1 in) long, on upper part of stem. ***Fruits*** flattened, 1–2 mm (0.1 in) across, dry, each ***partially enclosed by rigid pointed bracts 5–8 mm*** (0.2–0.3 in) ***long;*** seeds rounded, shiny black, tiny. **Harvest:** For greens, pick young leaves when plants are only a few inches tall and before stem becomes woody. Use leaves fresh or dry. Pick seed clusters as plants mature but before seeds begin to drop. Dry, thresh by shaking or trampling, winnow by shifting in breeze. Dry on tray at 190°C (375°F) for 40–50 min, stirring occasionally. Store in paper bag in dry place. **Preparation:** Fresh greens excellent as potherb. Boil for 10–20 min until tender and serve with seasonings and butter. For livelier flavor, boil with other greens such as mustard or dandelion, or add vinegar, bacon, hard-boiled eggs, or grated cheese. For salad, use fresh young leaves as major component of tossed salad. Use dried leaves in soups. Seeds edible whole or ground into meal using food mill or stones. For muffins, combine 1 cup pigweed meal, ½ cup whole-wheat flour, 2 tsp baking powder, ½ tsp salt, 3 tbsp honey, brown sugar, or molasses. Add 2 egg yolks, 1¼ cups milk, and ¼ cup butter. Blend until mix is moist. Beat 2 egg whites until stiff and fold into mix. Bake in greased muffin tin about 20 min at 190°C (375°F). Makes approximately 18. Thin batter with milk for pancakes. **Related edible species:** GREEN PIGWEED (next) and several other *Amaranthus* species. **Poisonous look-alikes:** Since pigweed is a concentrator of nitrates, plants from nitrate-fertilized areas should be eaten only in moderation.

Green pigweed *Amaranthus hybridus*

Also edible summer, autumn

Habitat: common and widespread in eastern and midwestern North America; fields, roadsides, disturbed sites. **Identification:** ***coarse annual herb*** to 2 m (6.6 ft) high; stems upright, with several upright branches. ***Leaves*** alternate, long stalked, broadest below or near middle, ***8–15 cm*** (3.2–6 in) ***long, 2–5 cm*** (0.8–2 in) ***wide,*** short-pointed at tip, wavy along margin. ***Flowers*** tiny, ***densely crowded in slender, green to red spikes.*** Fruits tiny, flattened, 1.5–2 mm (0.1 in) across, dry, ***partially enclosed by short, flexible bracts*** to 2 mm (0.1 in) long; seeds tiny, rounded, shiny black. **Harvest and preparation:** Same as for PIGWEED (preceding). **Related edible species:** PIGWEED and related species. **Poisonous look-alikes:** See PIGWEED.

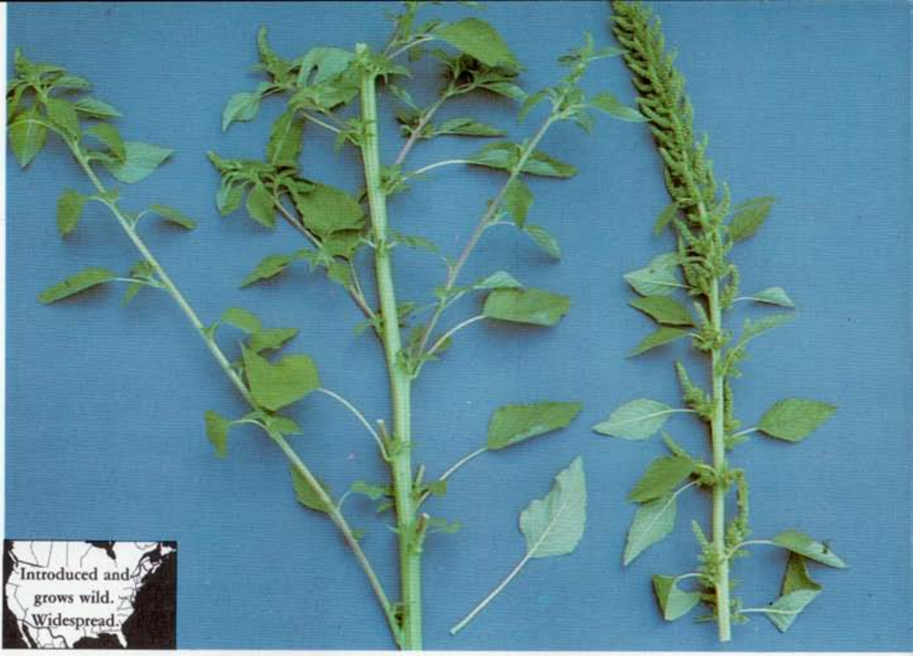
Introduced and
grows wild.
Widespread.

Pigweed: basal stalk and flowering head (USDA).

Green pigweed: fruiting stalks (Hardin).

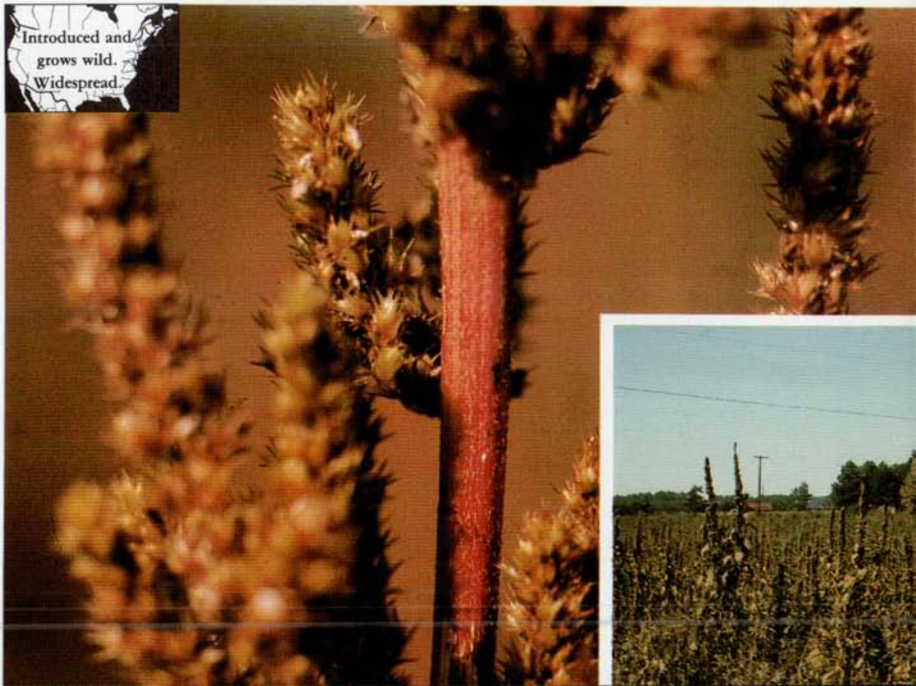
Introduced and
grows wild.
Widespread.

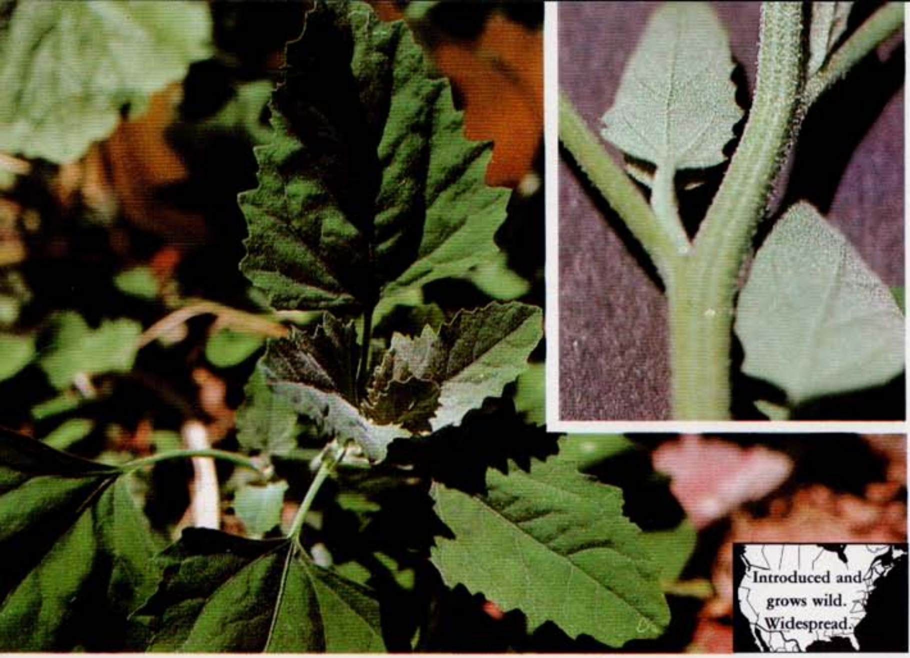
Introduced and
grows wild.
Widespread.

Lamb's quarters: basal leaves of young plant and mature stem (Dykeman).

Poverty weed: entire plant (Weber).

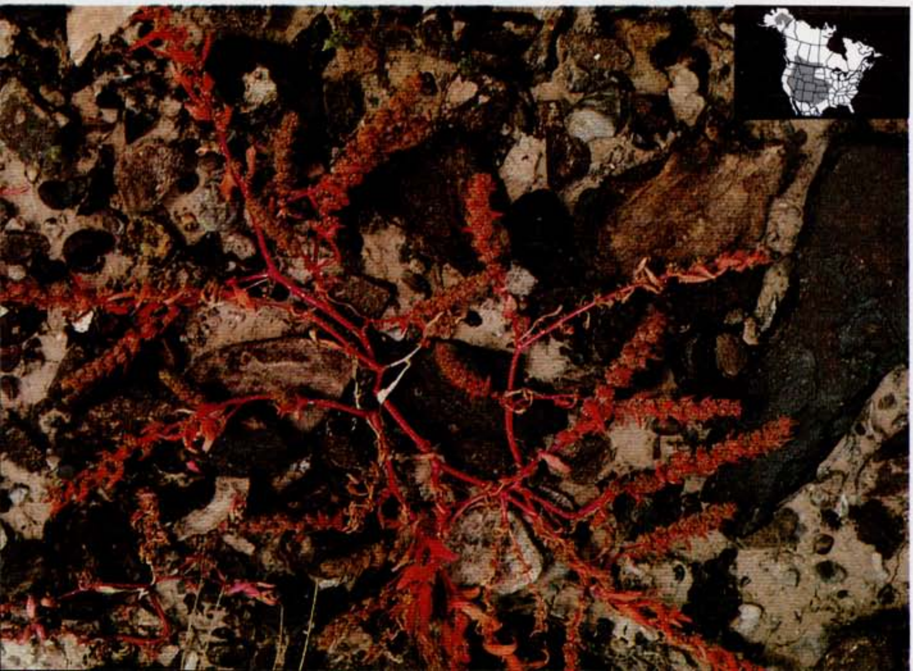

Lamb's quarters *Chenopodium album*
Also edible autumn

Habitat: common and widespread; yards, vacant lots, roadsides, waste areas, disturbed sites; introduced from Europe. **Identification:** small to medium-size annual ***herb*** to 0.6 m (2 ft) high; stems erect, usually branched, ***with a pale green or whitish cast. Leaves*** alternate, lower ones ***almost triangular,*** 3–10 cm (1.2–4 in) long, ***blunt at tip, coarsely toothed along margin, mealy white beneath,*** stalked, upper ones smaller. ***Flowers*** in late spring to autumn, ***tiny, inconspicuous, produced in dense short spikes in junctions of upper leaves and at tip.*** Fruits tiny, globe-shaped but depressed at tip, enclosed in persistent calyx lobes, in short dense spikes. **Harvest:** Pick young leafy stems to 25 cm (10 in) tall or tender growing tips of older plants. Gather abundant seeds in autumn by rubbing fruiting spikes into paper bag and winnow away chaff. **Preparation:** a superlative green vegetable, lacking strong flavor and high in vitamins A and C. Use leafy stems alone in salad or mix with stronger greens. For potherb, use large quantity of greens because cooking greatly diminishes bulk. Boil young leafy stems in small quantity of water about 5 min until tender. Add butter, salt and pepper or sauce of ¼ cup diced onion, 4 slices crisp bacon chopped fine, ¼ cup vinegar, salt and pepper, simmered gently. Use same sauce on raw greens as salad dressing. Soften seeds by boiling, crush, grind in food mill or blender. This produces nutritious black flour, good mixed with wheat flour for pancakes and muffins. **Related edible species:** Berlandier's lamb's quarters *(C. berlandieri)*, Fremont's lamb's quarters *(C. fremontii)*. **Poisonous look-alikes:** Species of *Chenopodium* that have bad odor and taste can be somewhat toxic.

Poverty weed *Monolepis nuttalliana*
Also edible autumn

Habitat: dry areas of high salinity or alkaline soils. **Identification:** ***annual herb*** to 55 cm (22 in) tall, spreading; branches numerous, stout, somewhat fleshy, upright or nearly so. ***Leaves*** alternate, ***triangular to lance-shaped,*** 1–4 cm (0.4–1.6 in) long, pointed at the tip, entire or irregularly toothed along the margin, sharply lobed at the base. ***Flowers small, numerous, inconspicuous, produced in junction of upper, smaller leaves, each bisexual, greenish, petals absent.*** Fruits are small, flattened, brown; winged seeds 1 mm (less than 0.1 in) across. **Harvest:** Pick young leafy stems. Roots are edible but usually not tasty. If you have the patience, strip seeds from stems when fully ripe late in growing season. **Preparation:** Like its relative, LAMB'S QUARTERS (preceding), which it superficially resembles, poverty weed is a good green vegetable. Boil young stems in small quantity of water until tender, but avoid overcooking. Serve with butter and seasonings or the following sauce hot: Simmer together for a few minutes ¼ cup dried onion, 4 slices crisp bacon (chopped fine), ¼ cup vinegar, salt and pepper. Southwestern Indians ground seeds with corn and mesquite beans to make pinole. **Related edible species:** Species of the *Chenopodium* genus (including LAMB'S QUARTERS) are of the same family as poverty weed. **Poisonous look-alikes:** none.

Glasswort *Salicornia europaea*

Also edible summer, autumn

Habitat: sea coast, salt marshes, alkaline soils. **Identification:** ***annual herb*** to 40 cm (16 in) high; ***stems*** erect to spreading, ***stiff, succulent*** (may be unbranched to many branched), green turning orange or red in autumn; leaves opposite, minute, scalelike, ***appearing leafless. Flowers*** (late summer) tiny, numerous, produced ***in erect*** to slightly spreading ***spikes 2–6 cm*** (0.8–2.4 in) ***long,*** joints longer than broad. Fruits are seeds, tiny, egg-shaped, 1.2–3 mm (0.1 in) in diameter. **Harvest:** Pick tender tips from branches midspring to autumn. **Preparation:** Tips are crispy and salty; good for trail nibble. Or chop and serve raw as salad with spicy vinegar dressing or add to other salad greens. For pickles pack jars with very tender, clean, raw tips or older tips that have been boiled in a little water for 5 min. Make pickling liquid from 4 cups cider or wine vinegar, 3 tbsp pickling spices, 1 grated onion, ½ cup honey or sugar, plus garlic, bay leaves, or other spices. Combine ingredients and boil 5–6 min. Cover glasswort with boiling liquid and seal jars. Store at least 1 month. For vegetable, place tips in boiling water and cook until tender 5–10 min. Serve buttered. **Related edible species:** Other species of *Salicornia* look very similar and are edible; one is perennial *(S. virginica)*. **Poisonous look-alikes:** none.

Russian thistle, Saltwort *Salsola kali*

Also edible summer

Habitat: sandy beaches on East Coast; dry, alkaline soils in West. **Identification:** ***annual herb*** to 1 m (3.2 ft) high; stems branching, upright to spreading, smooth, hairy, or with mealy appearance. ***Leaves alternate,*** simple, ***fleshy, rounded, 2–5 cm*** (0.8–2 in) ***long, lance- to needle-shaped, spine-tipped,*** entire along margins, lacking distinct leafstalk. Flowers numerous in narrow, elongated spikes in junctions of stems of upper leaves and at branch tips; each flower tiny, bisexual, sepals 5, winged on margins; petals absent. ***Fruits are flattened, winged, and nearly circular, 3–6 mm*** (0.1–0.2 in) ***across,*** yellowish to slate-colored. **Harvest:** Pull up shoots of new spring growth when less than 15 cm (6 in) tall; also succulent new plants after rains in late spring and in summer. Beware of spines at leaf tips. *Caution:* Plants occasionally contain toxic levels of nitrates and oxalates. **Preparation:** Cut off roots. Wash tops and boil for about 15 min. Serve like spinach with butter and seasonings, cream sauce, or vinegar. Mix with other greens of season. **Related edible species:** other *Salsola* species mainly in the Southwest. **Poisonous look-alikes:** none.

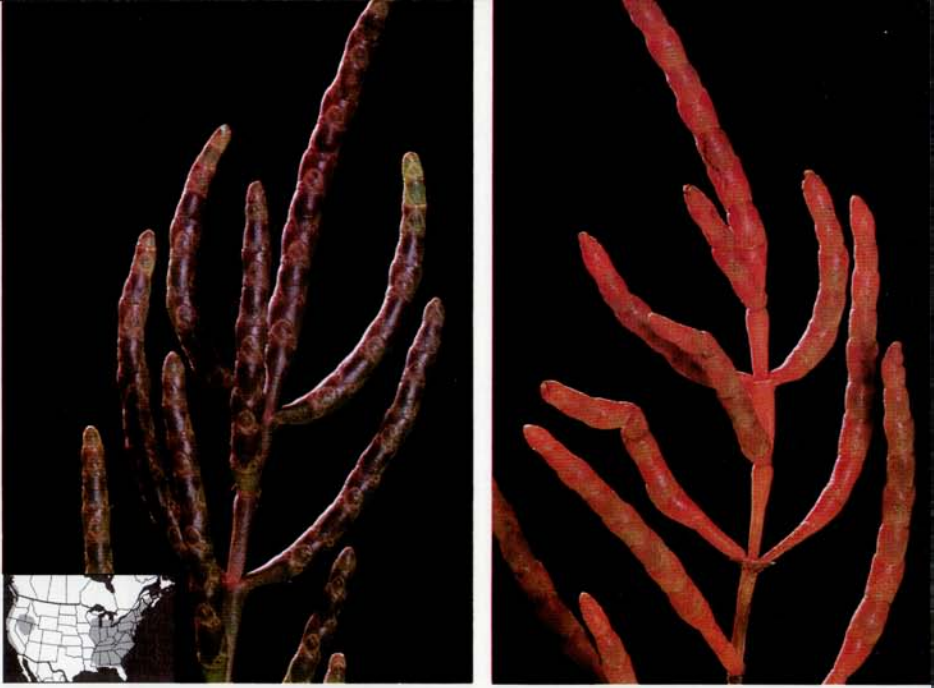

Glasswort: stems showing two color phases (NYBG).

Russian thistle: flowering branches (NYBG).

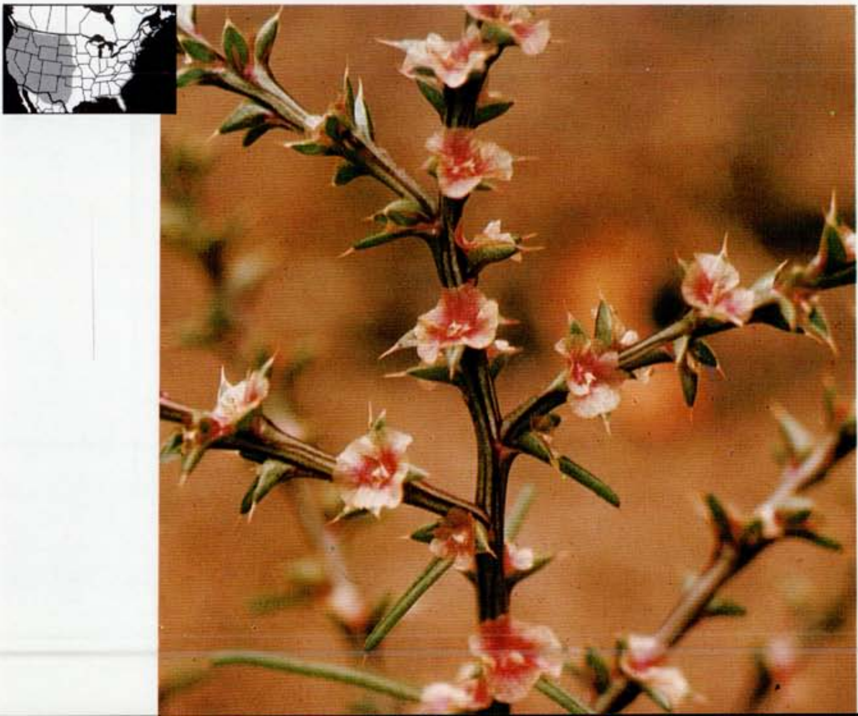

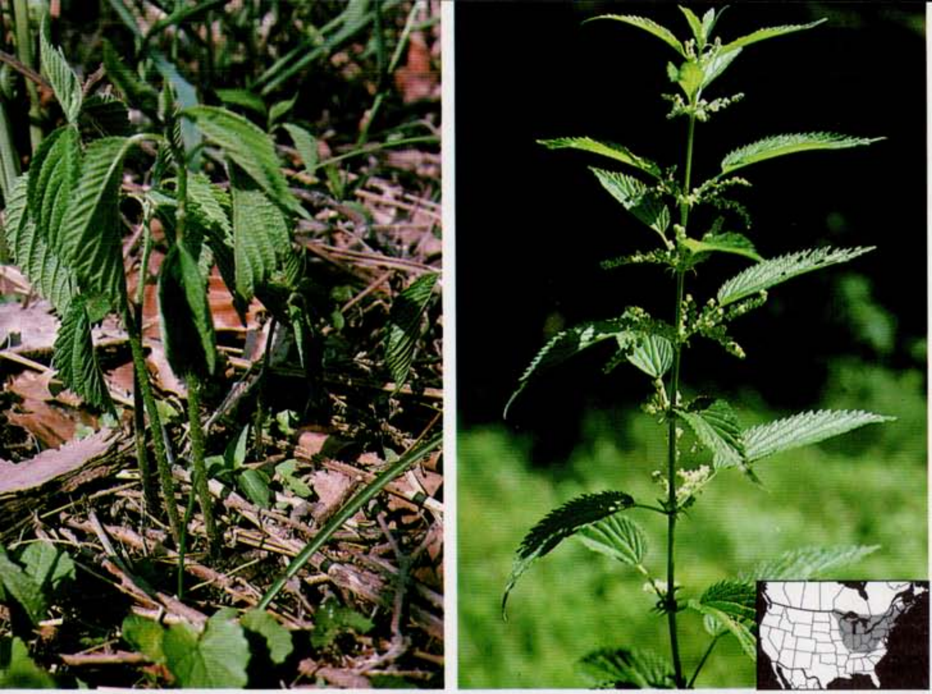

Stinging nettle: young plants and flowering plant (Elias).

Plantain: young plant (Dykeman). Mature plant (Elias).

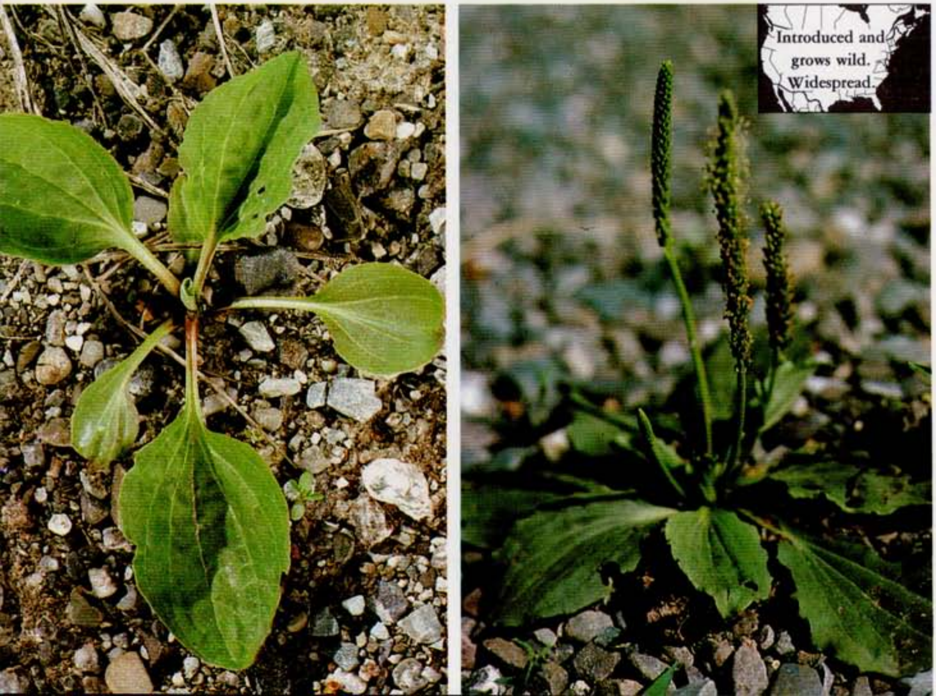
Introduced and grows wild. Widespread.

Stinging nettle, Nettle *Urtica dioica*

Habitat: widespread, especially in moist fertile soils in disturbed areas, margins of woods, trails, stream banks, roadsides, vacant lots. **Identification:** perennial, upright, to 1 m (3.2 ft); erect ***stem with bristly, stinging hairs. Leaves opposite, long-stalked,*** blade 5–14 cm (2–5.5 in) long, broadest near base, coarsely toothed, veins depressed, ***with stiff, stinging hairs on both surfaces.*** Each plant either male or female. Flowers produced in junctions of leafstalks, each flower tiny, male or female, borne in many-flowered, loosely branched, elongated, cream-colored clusters. Fruits tiny, inconspicuous, hard, nutletlike, about 2 mm (0.1 in) long. **Harvest:** In spring, wear gloves to avoid stinging hairs, or use scissors to cut young shoots and tender top leaves directly into pot or bag. Later leaves are tough and gritty. **Preparation:** Boiling destroys irritant. As potherb, barely cover with water and simmer until tender. Drain, add seasonings, butter, lemon juice, or wine vinegar. Use cooking water as beverage with lemon and sugar or as soup with salt, pepper, and vinegar. To make a simple stinging nettle puree, rub 2 cups cooked stinging nettles with juice through sieve, or puree in blender. Reheat, add 2 tbsp butter, salt to taste, simmer 10 min more. Stir in ¼ cup light cream; season with black pepper. A versatile plant, stinging nettle cooking juice may also be used as rennet (milk coagulant) for junket pudding and as beer ingredient. Plant is high in vitamins A and C, protein, and minerals. **Related edible species:** wood nettle *(Laporta canadensis)*, slender nettle *(U. gracilis)*. **Poisonous look-alikes:** none.

Plantain *(Also edible summer, autumn)* *Plantago major*

Habitat: yards, roadsides, disturbed sites; common weed introduced from Europe. **Identification:** ***perennial herb*** with fibrous root system. ***Leaves basal,*** numerous, broadest near or below middle, ***5–20 cm*** (2–8 in) ***long, 2.5–12 cm*** (1–4.7 in) ***wide,*** rounded to pointed at tip, toothed, entire or wavy along margin, ***rough on both surfaces,*** smooth or hairy. ***Flowers tiny, numerous along upper part of erect spike*** to 20 cm (8 in) high, each flower with 4 translucent petals. Fruits are tiny capsules produced along spike; each capsule contains 10–18 seeds. **Harvest:** Pick young leaves before flower stalk appears or pick new leaves through summer; otherwise leaves develop stringy veins that are tough to chew. Strip ripe seeds from flower stalks from late spring through fall. **Preparation:** Use tenderest leaves in salads with other greens of season. For cooked vegetable, soak leaves in salt water for 5 min. Boil with little water in covered pot until tender but not overcooked. For beverage, steep handful of leaves in pint of boiling water for ½ hr or longer. Dry seeds thoroughly and grind into flour. For pancakes, combine 2 cups plantain flour with 3 tsp baking powder, ½ tsp salt, 3 tbsp sugar, 2 eggs, 3 tbsp cooking oil, 1 cup milk. Mix thoroughly. Add more milk or flour for proper consistency; add fruit, if desired. Cook on hot griddle. **Related edible species:** Species of the *Plantago* genus are found throughout North America; most are edible. Boil leaves of bitter species in sweetened water. Seaside plantain *(P. juncoides)* is one of the best and is found only along East Coast. **Poisonous look-alikes:** none.

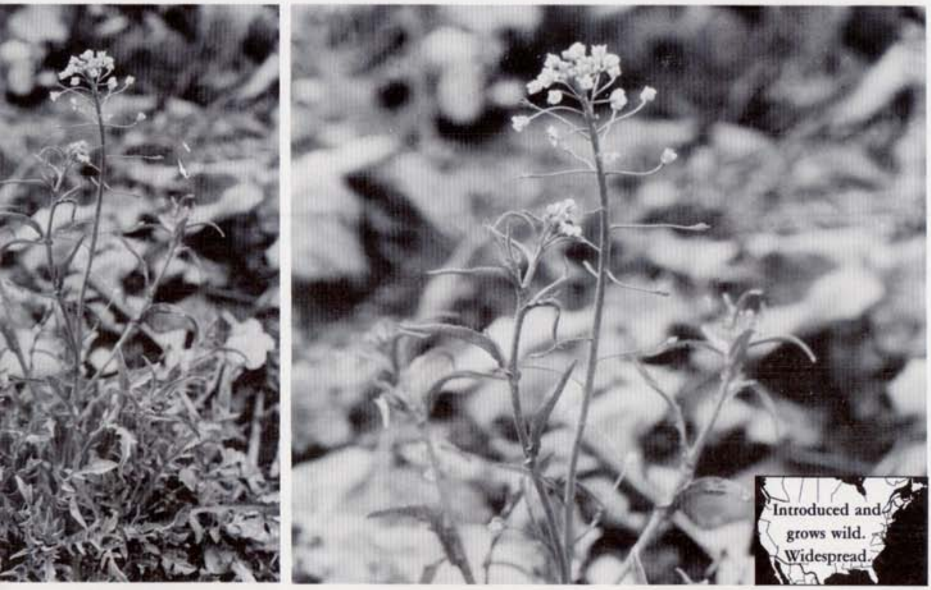
Introduced and grows wild. Widespread.

Shepherd's purse: entire plant and flowering stalks (Elias).

Toothwort: flowering plant (NYBG).

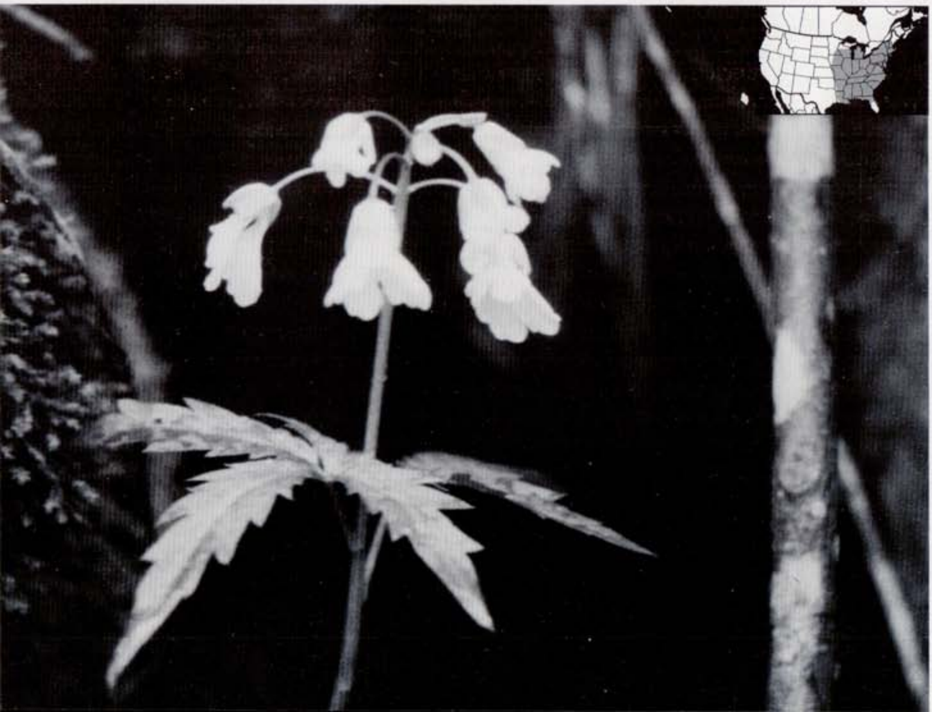

Shepherd's purse *Capsella bursa-pastoris*

Habitat: yards, vacant lots, roadsides, other disturbed areas; widespread weed, introduced from Europe. **Identification:** small to medium-size ***annual or biennial herb*** to 60 cm (2 ft) high, unbranched or sparingly branched, ***with a flattened, basal rosette of leaves,*** the ***basal leaves*** 4–10 cm (1.6–4 in) long, uniformly wide to broadest near tip, ***shallowly to deeply lobed along sides.*** Upright stems with few, smaller, narrower leaves. Flowers produced in narrow elongate cluster, each tiny, stalked, with 4 white petals 2–4 mm (0.1 in) long. ***Fruits slightly flattened, heart-shaped, notched at tip, 4–10 mm*** (0.2–0.4 in) ***long.*** **Harvest:** Gather leaves before flowering stage. If too peppery, bleach by covering with sawdust, leaves, or flower pots for week or more. Strip off seed pods as they ripen. **Preparation:** Use raw leaves as salad greens, if not too peppery, or with other milder greens. For a potherb, boil leaves in water for about 20 min with one change of water if needed. Season with salt and vinegar. Use dried pods and seeds as seasoning in soups and stews. Western Indians once ground seeds into meal, but process is tedious. **Related edible species:** red shepherd's purse *(C. rubella)* and slender shepherd's purse *(C. gracilis)*. **Poisonous look-alikes:** none.

Toothwort *Dentaria laciniata*

Habitat: moist deciduous woodlands, ravines, floodplains. **Identification:** perennial herb from a jointed, white underground stem (rhizome); stem upright, to 40 cm (15.7 in) high. Basal leaves absent at flowering, ***stem leaves in a whorl of 3 on upper half, deeply 3-parted, leaf segments lance-shaped, coarsely toothed to nearly entire,*** the terminal segment often deeply parted. ***Flowers*** produced in a terminal, elongate, hairy cluster, each flower stalked, ***with 4 white petals*** 1.2–2 cm (0.5–0.8 in) long. Fruits narrow, elongate, 2–4 cm (0.8–1.6 in) long, splitting open lengthwise at maturity to release the tiny seeds. **Harvest:** Dig rootstocks in small numbers from areas where plentiful. Other plants will grow from pieces of perennial root remaining in the soil. **Preparation:** Use as spicy trail nibble. Wash roots, chop and grind them in vinegar, add a dash of salt; use like horseradish. Add chopped roots to wild tossed green salads to liven flavor. **Related edible species:** At least six other species, similar in appearance, are distributed in moist woodlands of the East and West. All may be used like the species described. **Poisonous look-alikes:** none.

Peppergrass *Lepidium virginicum*

Habitat: fields, vacant lots, roadsides, other disturbed areas, waste sites. **Identification:** annual or biennial ***herb,*** upright to 50 cm (19.7 in) high, occasionally taller. ***Basal rosette of leaves 4–10 cm*** (1.6–3.9 in) ***long,*** 0.8–2 cm (0.3–0.8 in) wide, broadest near tip, ***doubly toothed, lobed, or deeply dissected*** along margin; stem leaves smaller, toothed or entire, becoming linear near top. ***Flowers*** produced in several, narrow, elongate clusters; each flower stalked, ***with 4 small white petals. Fruits flattened, widest near middle to almost circular, 2–4 mm*** (0.1 in) ***long,*** nearly as wide, ***slightly notched at tip,*** containing tiny reddish-brown seeds. **Harvest:** young shoots and leaves in spring. **Preparation:** another member of the mustard family. Use peppergrass greens sparingly in salad with less bitter species. As a potherb boil in 1 or 2 changes of water. Try recipes given for other MUSTARDS. Leaves high in vitamins A and C. Peppery seeds can be used to season meats, soups, and salads. **Related edible species:** Fremont's peppergrass *(L. fremontii)* and FIELD CRESS (next). **Poisonous look-alikes:** none.

Field cress, Cow cress *Lepidium campestre*

Habitat: fields, vacant lots, roadsides, disturbed sites; introduced from Europe. **Identification:** annual or biennial ***herb,*** upright to 60 cm (2 ft) high, ***stems densely hairy.*** Basal leaves 4–8 cm (1.6–3.2 in) long, 1–1.6 cm (0.4–0.6 in) wide, narrow but broadest near tip, coarsely toothed, lobed or dissected along margin; ***stem leaves*** smaller, almost circular in shape, ***lobed at base. Flowers*** produced in several, narrow, elongate clusters; each flower stalked, ***with 4 small, white petals. Fruits flattened,*** widest near tip to ***almost round in outline, 2–3 mm*** (0.1 in) ***long,*** slightly notched at tip, narrowly winged, containing tiny dark brown seeds. **Harvest and preparation:** same as for PEPPERGRASS (preceding). **Related edible species:** PEPPERGRASS and related species. **Poisonous look-alikes:** none.

Field pennycress *Thlaspi arvense*

Habitat: fields, vacant lots, waste areas, other disturbed sites; more common in northern portion of its range. **Identification:** ***annual herb*** 40–80 cm (16–32 in) high; stems branched, upright, smooth. Basal leaves narrow, widest near tip, withering and absent at flowering. ***Stem leaves 2–10 cm*** (0.8–4 in) ***long,*** 0.4–3 cm (0.2–1.2 in) wide, ***lance-shaped*** to narrow but broadest near tip, wavy or coarsely toothed or entire along margin, ***lobed at base, lobes pointed. Flowers*** numerous in narrow, elongate clusters (racemes), each flower stalked, ***with 4 white petals. Fruits flattened, nearly circular in outline, 0.8–1.8 cm (0.3–0.7 in) in diameter, deeply notched at tip, broadly winged,*** containing several tiny black seeds. **Harvest:** young shoots and leaves in spring. **Preparation:** Since plant has characteristic bitterness of MUSTARD family, boil shoots and leaves in 1 or 2 changes of water for 15–25 min. Serve with butter, salt and pepper. Use tender greens if not too bitter with other species in tossed salads. **Related edible species:** pennycress *(T. perfoliatum)* and many other members of mustard family Cruciferae. **Poisonous look-alikes:** none.

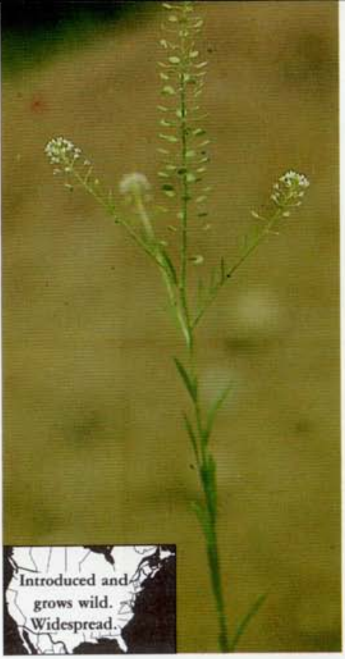
Introduced and grows wild. Widespread.

Peppergrass: fruiting plant (Elias).

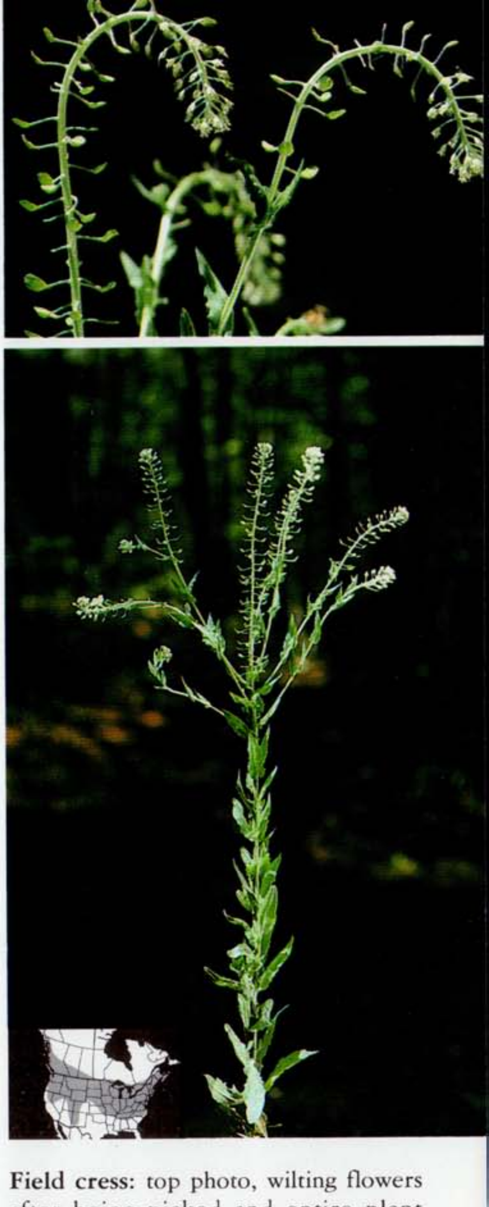

Field cress: top photo, wilting flowers after being picked and entire plant (Dykeman).

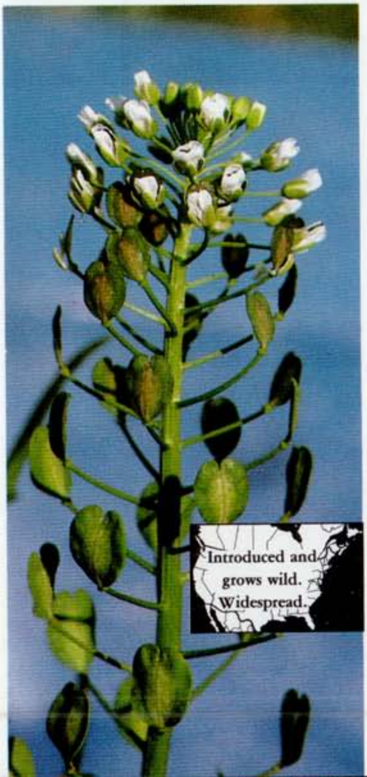
Introduced and grows wild. Widespread.

Field pennycress: flowers, top, and fruits on lower portion of flowering cluster (Dykeman).

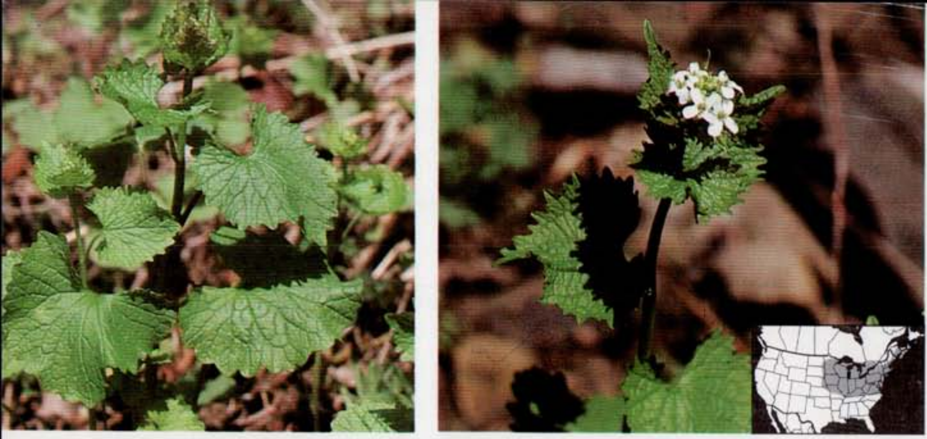

Garlic mustard: young plants and flowering plant (Dykeman).

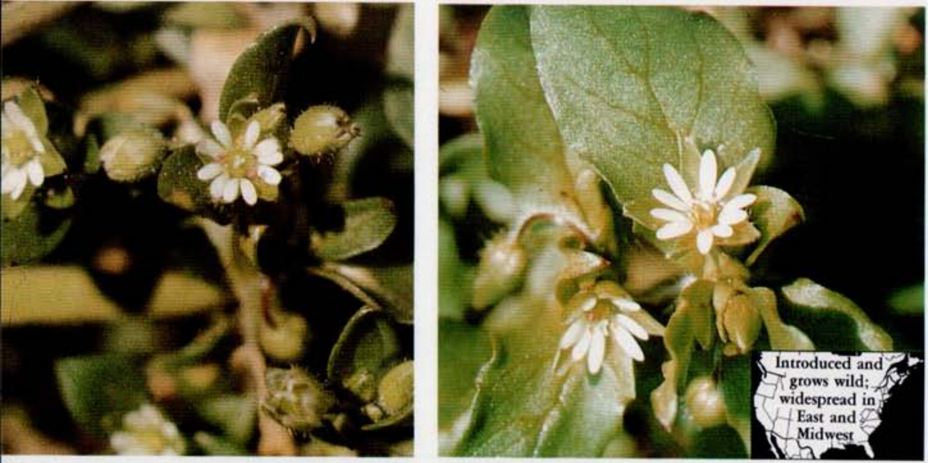
Introduced and
grows wild;
widespread in
East and
Midwest

Common chickweed: flowering plants (NYBG).

James chickweed: flowering branch and flower (NYBG).

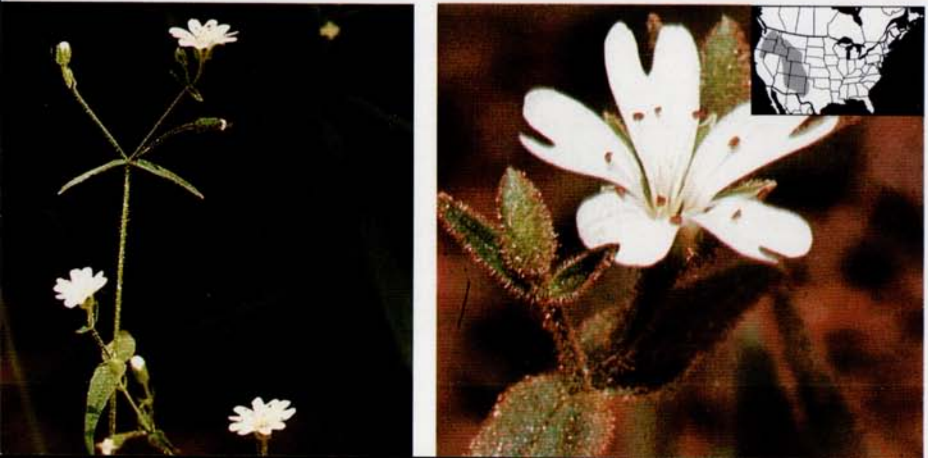

Garlic mustard *(Also edible summer)* *Alliaria officinalis*
Habitat: partially shaded roadsides, paths in open woods, shady disturbed areas. **Identification:** ***biennial herb, 2nd year growth to 90 cm (3 ft). Leaves triangular to heart-shaped, coarsely toothed, long-stalked, with garlic odor when crushed. Flowers white,*** 6–8 mm (0.2–0.3 in) across, in ***clusters at tips of stems and at leaf bases,*** April–June. Fruits are very ***slender pods (siliques) to 5 cm (2 in) long,*** containing numerous tiny seeds. **Harvest:** young leaves, blossoms, and seed pods in spring and early summer. **Preparation:** chop tender growth raw in salad; for cooked vegetable steam or boil in little water, season with salt and butter. Use for garlic flavor with meats and vegetables. **Related edible species:** no other *Alliaria* species present; many other members of MUSTARD family *(Cruciferae)* are edible. **Poisonous look-alikes:** none.

Common chickweed *(Also edible summer, autumn, winter)* *Stellaria media*
Habitat: yards, disturbed sites, moist and wet areas, cultivated land, woodlands; common weed introduced from Europe. **Identification:** annual herb sometimes to 30 cm (12 in) high; stems weak, trailing along ground before becoming upright, with rows of hairs. ***Leaves opposite,*** simple, ***1–3.5 cm*** (0.4–1.4 in) ***long, about ⅔ as wide,*** usually broadest near base or middle, pointed at tip, entire along margin, rounded at base, lower leaves with a conspicuous leafstalk. ***Flowers single*** or in few-flowered clusters at tips, ***long-stalked, each flower with 5 deeply lobed, white petals that are shorter than sepals.*** Fruits are small reddish-brown capsules 5–8 mm (0.2–0.3 in) long, egg-shaped, containing many small seeds. **Harvest:** Pick tender leaves and stems from young plants any time they are not blooming; available year-round in some regions. Quicker method, pull up the whole plant and cut off tender growth with scissors. **Preparation:** Mild flavored chickweed is excellent by itself or with other, stronger greens. Use generously raw in salads. Boil only 2–5 min; add it to other less delicate greens near end of their cooking period. Serve with butter, seasonings, and a little chopped onion. Also see JAMES CHICKWEED (next). **Related edible species:** JAMES CHICKWEED. **Poisonous look-alikes:** none.

James chickweed *(Also edible summer, autumn)* *Stellaria jamesiana*
Habitat: mountain meadows, seepage areas, woodlands, usually between 1,220–2,590 m (4,000–8,500 ft) elevation. **Identification:** ***small perennial herb*** to 35 cm (14 in) tall from slender roots with thickened tuberlike structures; stems erect or nearly so, branched frequently, hairy. ***Leaves opposite,*** simple, ***4–15 cm*** (1.6–6 in) ***long, about one-fourth as wide, lance-shaped,*** long pointed at tip, entire along margin. ***Flowers produced in loose, spreading clusters at tips*** and at junctions of upper leaves in spring and early summer. ***Each flower with 5 deeply notched white petals.*** Fruits are small tan capsules, 3–5 mm (0.2 in) long, containing many tiny, dark brown seeds. **Harvest:** same as COMMON CHICKWEED (preceding). **Preparation:** Add chickweed to soups and stews. For pancakes, drain and blot 1–2 cups leaves. Blend into prepared pancake batter (2 cups mix to 1½ cups water). Adjust consistency. Fry and serve with butter and tart jelly. **Related edible species:** COMMON CHICKWEED, star chickweed *(S. pubera),* and mouse-ear chickweed *(Cerastium vulgatum)*. **Poisonous look-alikes:** none.

Cleavers, Goosegrass, Bedstraw *Galium aparine*

Also edible summer

Habitat: wide spread on moist sites, rich woodlands, along streams, lakes, vacant lots and fields. **Identification:** ***annual herb;*** stems weak, slender, often leaning on other plants or rambling along ground, 4-sided, with numerous tiny, stiff, hooked hairs causing plants to cling to clothing; ***leaves in whorls of 8,*** each very narrow but ***widest above middle,*** 4–8 cm (1.6–3.2 in) long, 2–6 mm (0.1–0.2 in) wide, with recurved hairs along margin. Flowers tiny, white, produced in usually 3-flowered, stalked clusters in junction of upper leaves in late spring or early summer. ***Fruits consist of twin, fused, globe-shaped, dry structures 2–4 mm (0.1 in) long, covered with numerous hairs hooked at tip.*** **Harvest and preparation:** Pick young greens in spring when tender. Steam leafy stems in strainer or colander over boiling water for 5–10 min or boil in small amount of water until tender. Serve with butter and seasonings. Combines well with nettle greens. For salad take 3 cups boiled, cooled cleavers and add 1 cup cooked asparagus cut in 1 in lengths, ½ cup slivered nuts, ¾ cup French dressing. Gather fruits in June and July as they turn brown. For excellent noncaffeine coffee substitute, roast fruits in warm oven 150°C (300°F) until dark and crisp, about 1 hr. Grind in blender or crush on any hard surface. Simmer ¾ cup prepared fruits in 1 qt water until medium to dark brown. Strain and serve. **Edible related species:** NORTHERN BEDSTRAW (next). *Note:* The many species of cleavers or bedstraw in North America are difficult to tell apart; however, none of them is known to be poisonous. **Poisonous look-alikes:** none.

Northern bedstraw *Galium boreale*

Habitat: stream banks, fields, open woodlands. **Identification:** ***perennial herb;*** stems usually upright, to 1 m (3.2 ft), slender, 4-sided, smooth. ***Leaves in whorls of 4, each narrowly lance-shaped, 2.5–5 cm*** (1–2 in) ***long,*** 2–7 mm (0.1–0.3 in) wide, with 3 main veins, finely hairy along margins. Flowers tiny, white, produced in compact many-flowered, branched, elongated clusters (inflorescences) at or near growing tips. ***Fruits consist of 2 fused, globe-shaped structures (rarely 1) that are 2–3 mm (0.1 in) in diameter, smooth or with long straight hairs or shorter ones hooked at tip.*** **Harvest and preparation:** same as for CLEAVERS (preceding). **Edible related species:** See CLEAVERS. **Poisonous look-alikes:** none.

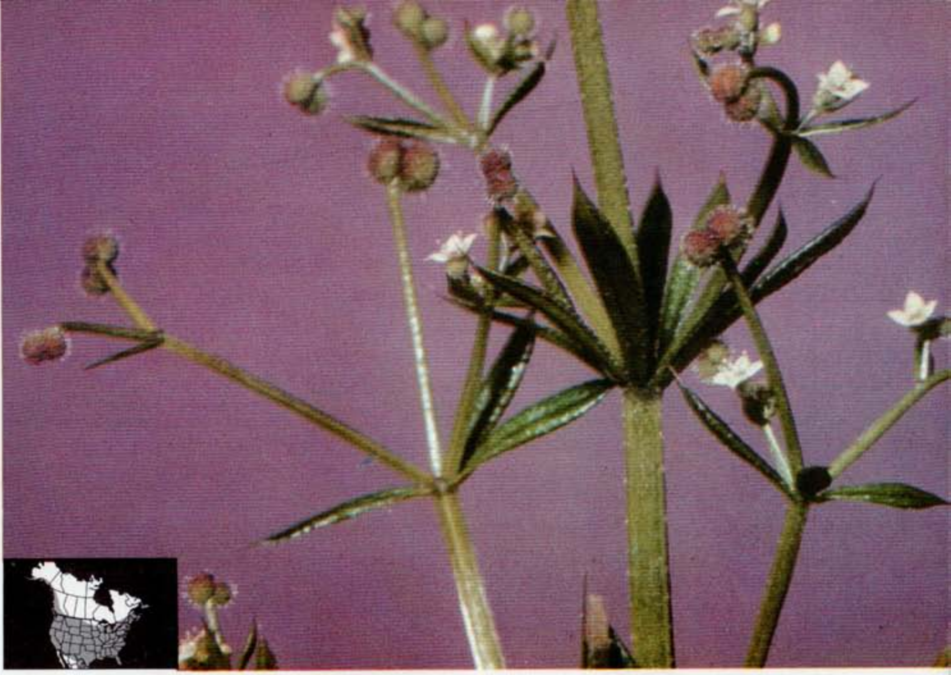

Cleavers: flowering stalks (C. S. Webber, Jepson Herbarium).

Northern bedstraw: flowering stalks (NYBG).

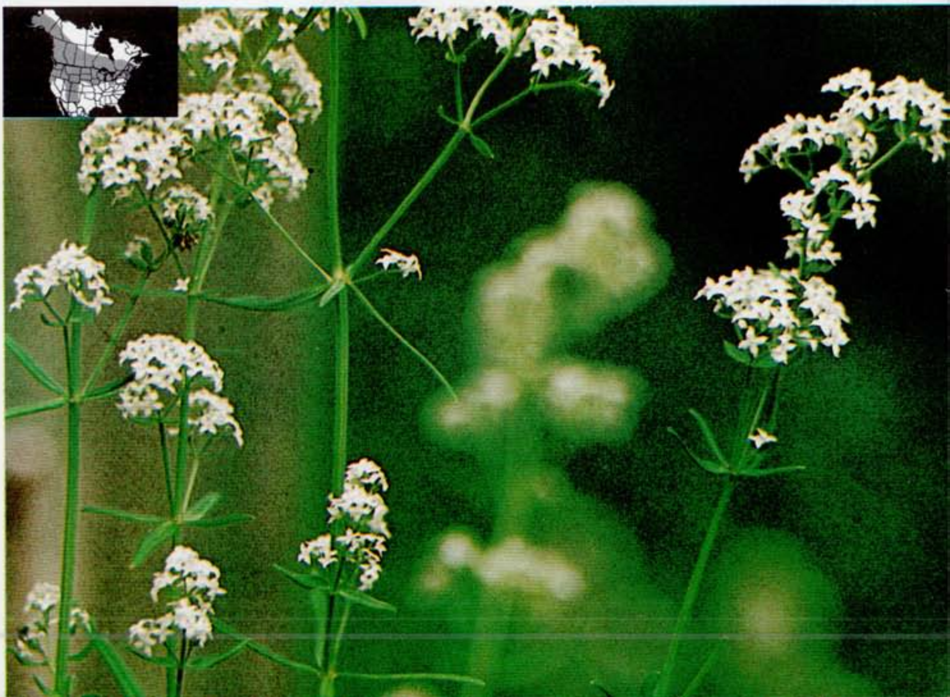

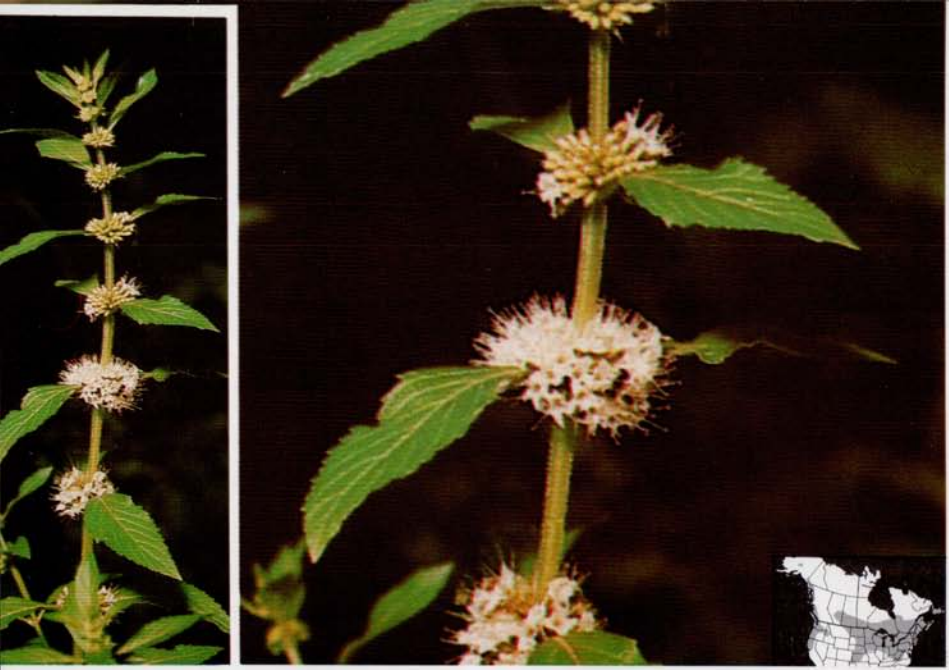

Bugleweed: flowering stalk and flowers (NYBG).

Edible valerian: flowering stalks (NYBG).

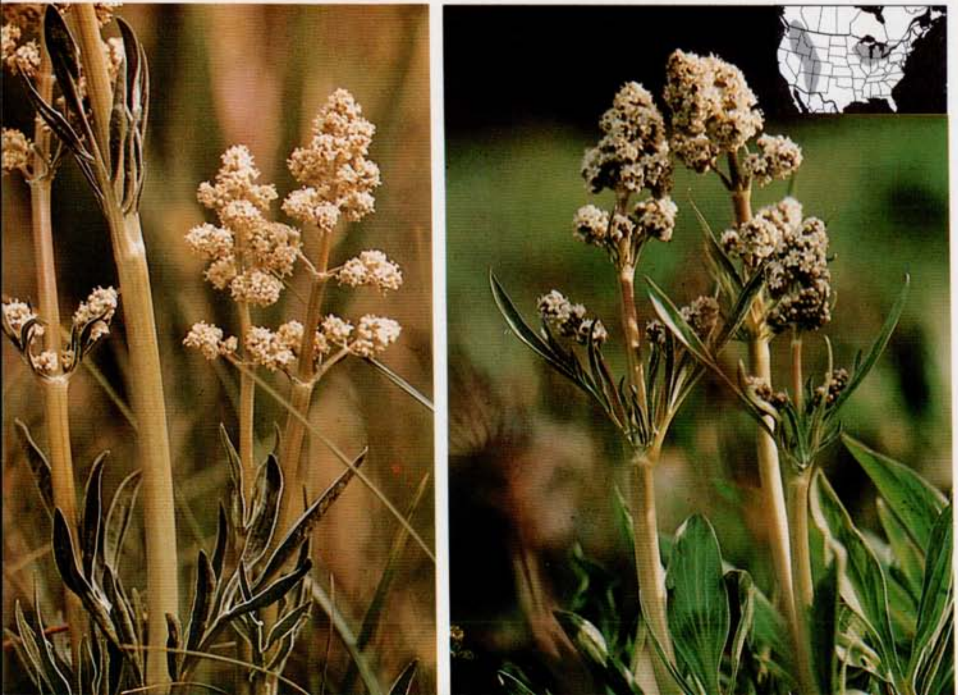

Bugleweed *Lycopus uniflorus*

Also edible autumn, winter

Habitat: low wet or boggy ground in North, wet woodlands and mountain bogs in South. **Identification:** ***perennial herb*** to 1 m (3.2 ft) tall; stems upright, unbranched or sparingly branched, finely hairy. ***Leaves opposite,*** simple, 3–10 cm (1.2–4 in) long, 0.6–3.4 cm (0.2–1.3 in) wide, ***lance-shaped*** to almost uniformly wide, pointed at tip, ***with few teeth along margin,*** tapering at base, light green and papery; leafstalks absent. ***Flowers produced in compact, many-flowered clusters in junctions of upper leaf stems;*** each flower tiny, ***petals white,*** fused, with 2 upper and 3 lower lobes. Fruits are tiny, flattened, irregular nutlets 1–2 mm (less than 0.1 in) long, with small bumps (tubercles) on top. **Harvest:** Tubers grow best close to the base of old stems in loose sandy soil. Dig tubers from fall through early spring when they are highest in stored nutrients. **Preparation:** Add peeled, sliced tubers to tossed salad or chop fine as mild relish. Boil tubers in salted water until tender, about 10–15 min. Serve with butter and seasonings. For pickles, peel tubers, boil in water about 5 min, drain and cover with wine vinegar. Store for several weeks before using. **Related edible species:** sessile-leaved water horehound *(L. amplectens)* is found in sandy East Coast areas. Other species of *Lycopus* lack tubers. **Poisonous look-alikes:** none.

Edible valerian *Valeriana edulis*

Also edible autumn, winter

Habitat: open moist sites, meadows, prairies, ditches, swamps. **Identification:** ***perennial herb*** to 1.2 m (3.8 ft) from large, elongated root. ***Leaves opposite,*** featherlike (pinnate) divided; ***basal leaves spoon-shaped,*** widest near tip, 12–30 cm (4.7–12 in) long, ***entire or sometimes featherlike (pinnate) divided*** with narrow lateral segments, thick, hairy along margins; stem leaves pinnately divided into few narrow segments, smaller. ***Flowers tiny, produced in*** tightly branched, elongated, ***many-flowered clusters*** at tips in late spring; each flower white to pink, 3–5 mm (0.1–0.2 in) long. Fruits dry, flattened, 1-seeded, egg-shaped, 3–4 mm (0.2 in) long. **Harvest and preparation:** Dig roots in autumn and early spring, when firm. Steam 24 hr or longer to remove disagreeable odor. Then use in soups as you would potato or squash. Dry and grind steamed roots into flour for use in bread, as did the Indians. Bake Indian pit style 2 days. **Related edible species:** Other valerians have been used in folk medicine. **Poisonous look-alikes:** toxicity of look-alikes not well documented.

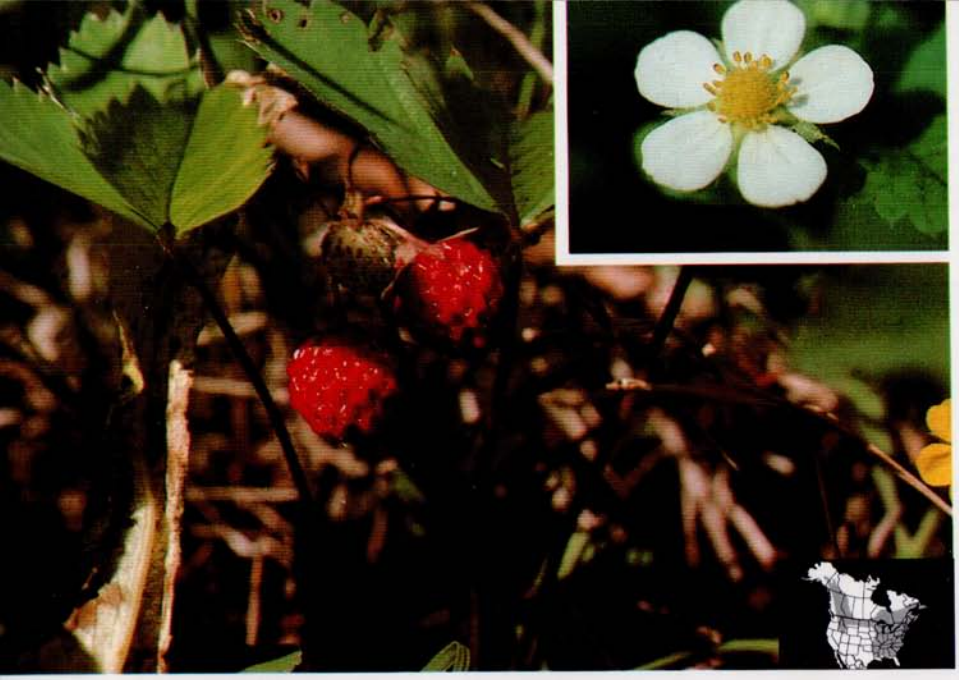

Wild strawberry: mature fruits and flower (Elias).

Spring beauty: flowering stalk (NYBG).

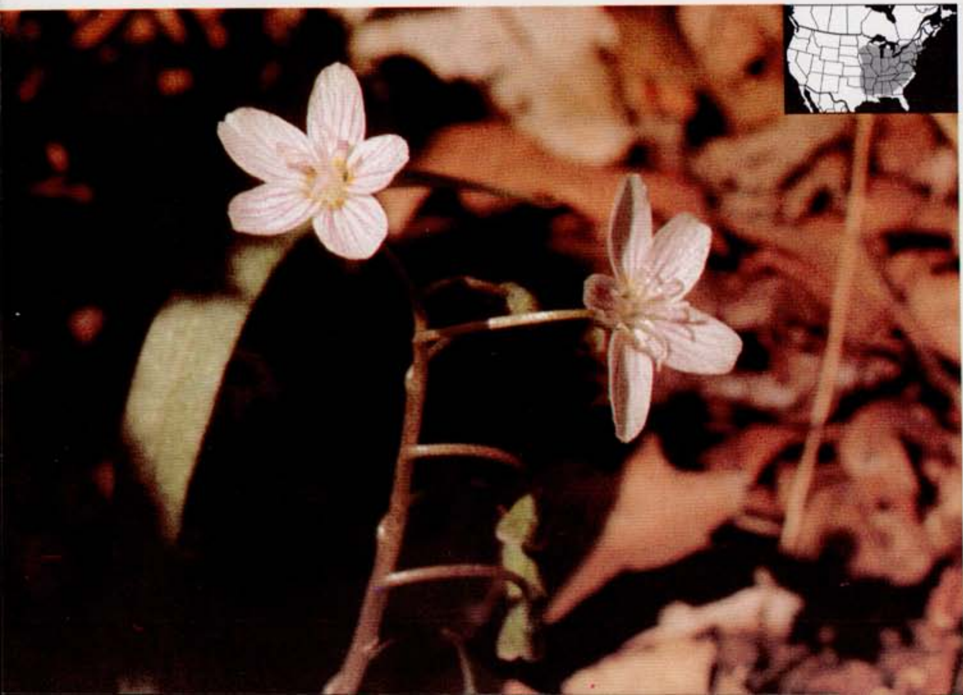

Wild strawberry *Fragaria virginiana*

Also edible summer

Habitat: open woodlands, margins of woodlands, fields. **Identification:** small perennial herb, lacking distinct stem, sometimes producing runners. ***Leaves basal, compound and 3-parted*** (trifoliolate), leaflets widest near or above middle, 2–10 cm (0.8–4 in) long, sharply toothed along margin, hairy beneath. ***Flowers*** several in short spreading cluster, each ***with 5 white petals*** 8–14 mm (0.3–0.5 in) long. ***Fruits are tiny, hard (achenes), embedded in large, fleshy tissue (receptacle)*** that is 0.5–2 cm (0.2–0.8 in) in diameter, ***red, sweet.*** **Harvest:** one of the best wild fruits. Locate your site early and check regularly from early June for ripe berries. Collect leaves anytime but best in late summer. **Preparation:** Use wild strawberries in any strawberry recipes. For quick beverage, crush handful of berries and mix with 1 cup water and a little sugar. For fruit leather, add ½ tbsp sugar or honey to each cup of fruit. Bring just to boil, cool, and process through food mill. Pour no more than 5 mm (0.2 in) thick onto Teflon cookie sheet. Heat in oven at lowest setting for 6–7 hr. When leathery, roll and seal in plastic wrap. Stores well at any temperature. See basic pie and jam recipes in book's introductory material. For tea high in vitamin C, steep 2 handfulls fresh or ½ cup dried leaves in 1 qt boiling water for 5 min. To dry leaves, spread on clean surface in warm, dry area (sun or shade). When thoroughly dried (use warm oven, if necessary), crumble leaves and store in paper bag in dry place. **Related edible species:** Several are widely distributed, basically alike, and easy to identify. **Poisonous look-alikes:** none.

Spring beauty *Claytonia virginica*

Habitat: rich woodlands, wooded floodplains, wet fields. **Identification:** ***perennial herb*** to 40 cm (16 in) tall, ***from globe-shaped, bulblike tuber 1–5 cm*** (0.4–2 in) ***in diameter;*** stems several, upright, weak, sometimes leaning. ***Leaves*** simple, ***5–14 cm*** (2–5.5 in) ***long, 0.2–2 cm*** (0.1–0.8 in) ***wide, linear*** to narrow but widest above the middle, blade gradually merging with leafstalk. ***Flowering stem with 5–20 weakly stalked flowers, each flower white to pink with dark pink veins, petals 5,*** 1.2–2 cm (0.5–0.8 in) across. Fruits are egg-shaped to nearly globe-shaped capsules 5–10 mm (0.2–0.4 in) long, containing numerous, tiny, dark red seeds. **Harvest:** Because this is a beautiful spring flower, use only where very abundant or when desperately needed. In spring, pick young leaves and dig tubers when identifiable by blossoms. Keep only largest tubers; replant others. **Preparation:** Use leaves as trail nibble or chop a few in green salads. Boil leaves for a few minutes in salted water for edible but not exceptional vegetable. Eat washed tubers raw or add to salads. Boil tubers with jackets in salted water about 10–15 min. Peel and serve whole or mashed, fried, or in salad like potatoes. Tubers also good baked; peel before eating. **Related edible species and poisonous look-alikes:** See ALPINE SPRING BEAUTY (next).

Alpine spring beauty *Claytonia megarhiza*

Habitat: rocky crevices, rock slides in alpine zone, tundra. **Identification:** ***low perennial herb*** from thick, fleshy, purple to dark-red taproot. ***Basal leaves spreading, forming large rosette,*** leaves 2–15 cm (0.8–6 in) long, ***broadest near tip to almost circular in outline,*** pointed to rounded at tip, entire along margin, gradually tapering and winged at base; stem leaves alternate, linear to narrow and broadest near tip. ***Flowers*** stalked, produced in elongate cluster; each flower 1.2–2.5 cm (0.5–1 in) across, ***with 5 white to pink petals with red veins,*** 6–10 mm (0.2–0.4 in) long. Fruits are tiny, 3-parted, egg-shaped capsules. **Harvest:** Because of habitat and scarcity, use as survival food only. Pick rosettes of leaves or pull up whole plant for fleshy root. **Preparation:** similar to SPRING BEAUTY (preceding). Peel roots before boiling to avoid strong flavor and use like tubers of SPRING BEAUTY. **Related edible species:** SPRING BEAUTY, WESTERN SPRING BEAUTY (next); also Carolina spring beauty *(C. caroliniana),* widely distributed in northern U. S. **Poisonous look-alikes:** To avoid confusion with poisonous lilies, learn to identify leaves or collect when in bloom.

Western spring beauty *Claytonia lanceolata*

Habitat: mid to high mountain slopes, moist woodlands to alpine zone. **Identification:** ***perennial herb*** to 20 cm (8 in) high, ***from nearly globe-shaped,*** bulblike underground ***stem base*** (corm) 1–2 cm (0.4–0.8 in) in diameter; stems 1 to several, upright. Basal leaves 1 or 2, 4–8 cm (1.6–3.2 in) long, broadly lance-shaped; ***stem leaves 2, opposite, 3–6 cm*** (1.2–2.4 in) ***long,*** narrow to broadly lance-shaped, 0.8–2 cm (0.3–0.8 in) wide. ***Flowering stems*** upright, ***with 3–15 stalked flowers, each bowl-shaped, with 5 pink petals*** 0.8–1.2 cm (0.3–0.5 in) long. Fruits are egg-shaped capsules 3–5 mm (0.1–0.2 in) long, containing a few shiny, black seeds. **Harvest and preparation:** Because of habitat and scarcity, use as survival food only. Similar to SPRING BEAUTY. Leaves are edible but not exceptional; boil 10–15 min. Crispy but small tubers are good raw or cooked for about 25 min at about 1,640 m (5,400 ft) altitude. **Related edible species and poisonous look-alikes:** See ALPINE SPRING BEAUTY (preceding).

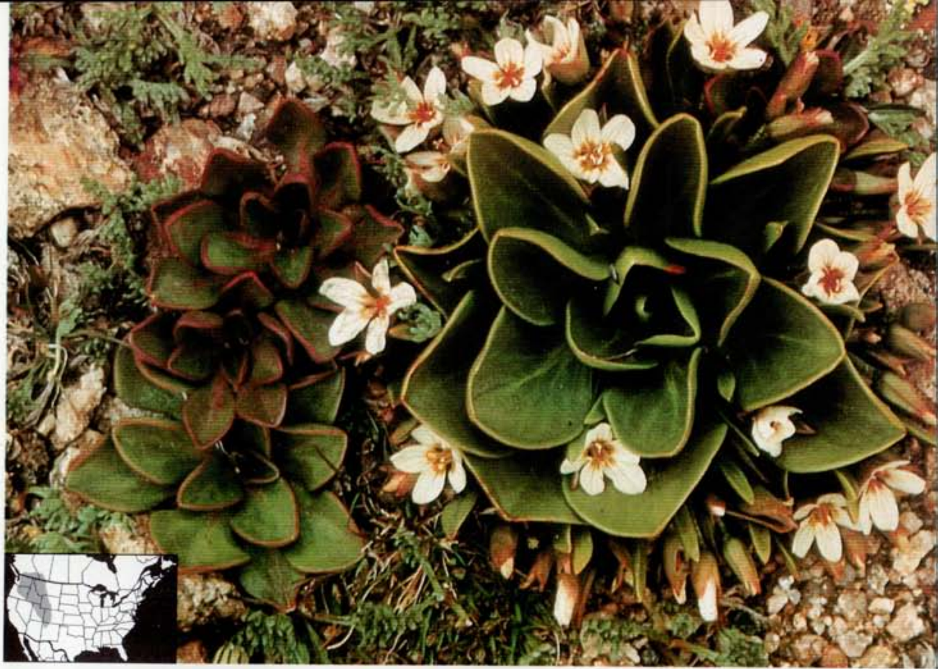

Alpine spring beauty: flowering plant (NYBG).

Western spring beauty: flowering plant (NYBG).

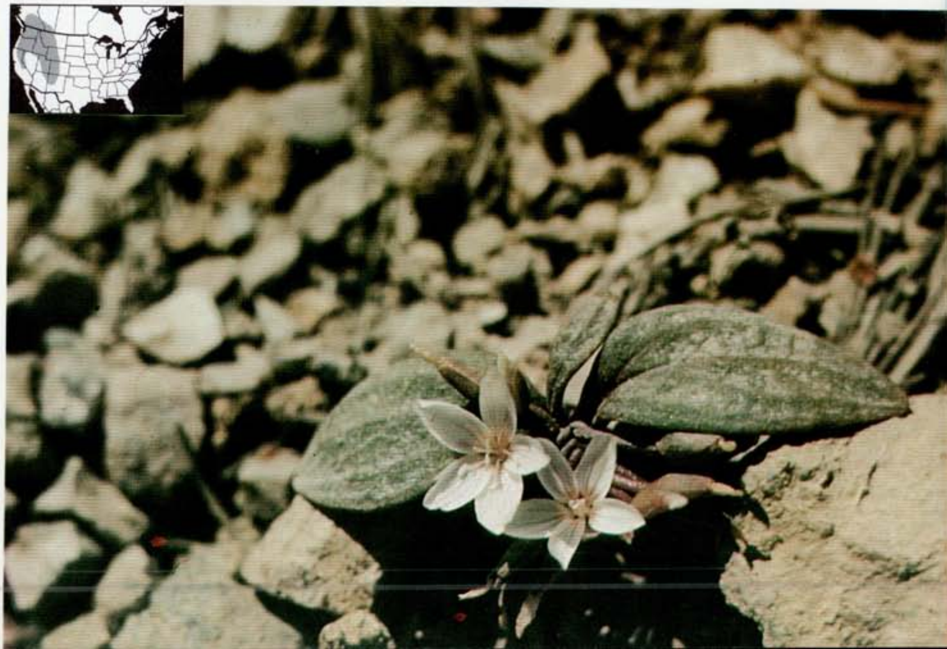

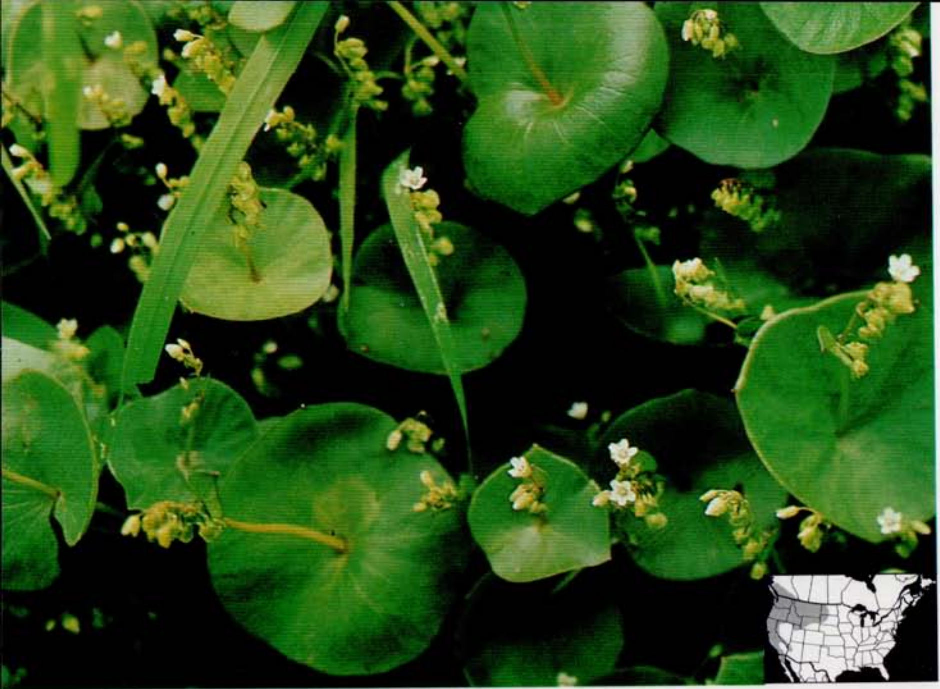

Miner's lettuce: flowering plants (NYBG).

Canada violet: flower and flowering plant (NYBG).

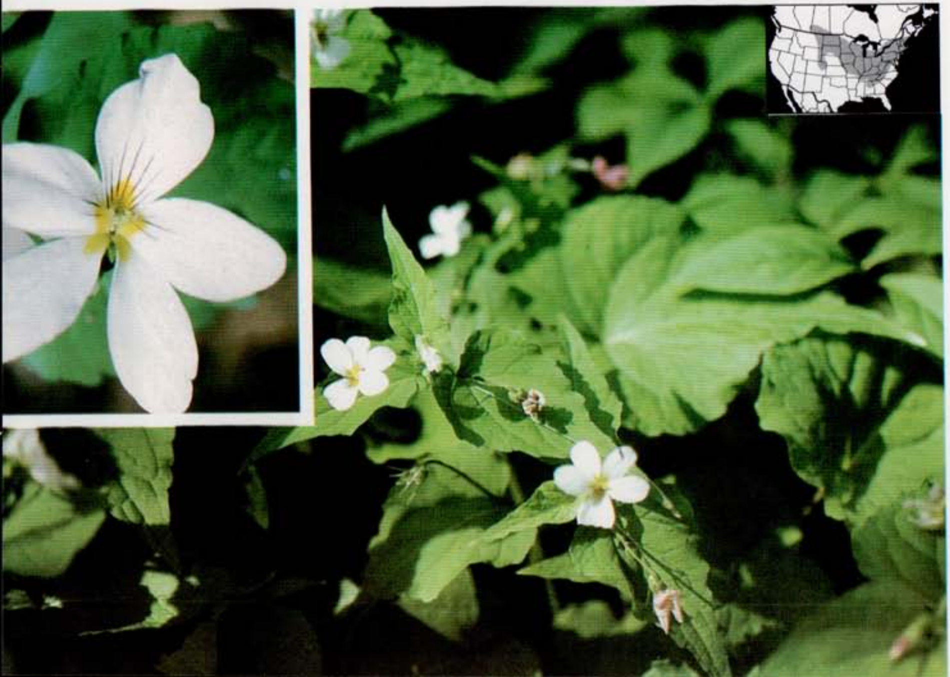

Miner's lettuce *Montia perfoliata*
Also edible summer (synonym: *Claytonia perfoliata*)

Habitat: valleys, lower mountain slopes, springs, moist sites. Introduced from Europe; miner's lettuce has expanded its range in the East. **Identification:** ***annual herb*** to 30 cm (12 in) high, ***from fibrous root system.*** Leaves mostly basal, simple, 6–20 cm (2.4–8 in) long including the long leafstalk, blade variable, usually broadest below or above middle, entire along margin, smooth; ***stem leaves 2, opposite and fused into a circular disc just below flowering stalk.*** Flower stalk elongate, bearing numerous, whorled, short-stalked flowers, each tiny, with 5 white, clawed petals 3–6 mm (0.1–0.2 in) long. Fruits are tiny, 3-parted capsules containing 1–3 shiny, black seeds. **Harvest:** blossoms, leaves, stems, and roots any time during growing season. **Preparation:** Young upper leaves and stems are excellent as picked or in salads. Include blossoms when available. For salad add chopped hard-boiled eggs and oil and vinegar dressing. For cooked vegetable, boil leaves and stems in very little water until tender; boil young leaves as little as 3–4 min. Excellent source of vitamin C. Wash roots and boil for just a few minutes. Butter and lightly season to bring out water chestnut flavor. **Related edible species:** Siberian miner's lettuce *(M. sibirica)* of southern Alaska. **Poisonous look-alikes:** none.

Canada violet *Viola canadensis*
Also edible summer

Habitat: mixed deciduous woodlands, bluffs, rocky to deep, rich soils. **Identification:** perennial herb with thick underground stem (rhizome); stems upright, smooth, to 40 cm (16 in) high. ***Leaves*** basal and along stem, simple *4–12 cm* ***(1.6–4.7 in) long, nearly as wide, broadest near base, long pointed at tip,*** toothed along margin, ***heart-shaped at base,*** leafstalks long, ***with small, lance-shaped bract (stipule)*** at base of each leaf. ***Flowers*** produced on upper third of plant, each stalked, ***white often with purple on back, 2–3 cm*** (0.8–1.2 in) ***across, petals 5, lateral ones fringed.*** Fruits are egg-shaped to nearly globe-shaped capsules 5–10 mm (0.2–0.4 in) long, containing several tiny brown seeds. **Harvest:** Strip blossoms from plants, avoiding stems. When possible gather bright green leaves which are young and tender, but even older leaves in late summer are edible. **Preparation:** Leaves and blossoms are superior sources of vitamin C; the leaves are high also in vitamin A. Use blossoms as snack straight from plant or for jelly, jam, syrup, and candy. For jelly, see book's introduction. Use leaves and flowers raw with other ingredients in tossed salad. Cook chopped leaves with minimum water in covered pot for about 15 min. Season and serve alone or with mustard greens. For tea, dry leaves in warm shade and store in paper bag in cool dry places. Steep 1 oz dried leaves per cup of boiling water. **Related edible species:** PALE VIOLET (next), and WOOD VIOLET, and SOUTHERN WOOD VIOLET. It is likely that all of the species of violets are edible, with some more palatable than others. Some, especially yellow-flowered violets, may be cathartic. Thus, moderate initial consumption is advised. **Poisonous look-alikes:** Violet leaves may resemble leaves of other wildflowers, some of which are toxic. So it's safest to collect violet leaves only when flowers are in bloom.

Pale violet *Viola striata*

Also edible summer

Habitat: wooded floodplains, meadows, stream banks. **Identification:** ***perennial herb*** with short thick underground stem (rhizome); stems several, upright or reclining, smooth, to 50 cm (20 in) high. Basal leaves soon withering; ***stem leaves*** simple, ***3–8 cm*** (1.2–3.2 in) ***long,*** as wide or nearly so, ***broadest near base and almost circular in outline,*** pointed to blunt at tip, toothed along margin, shallowly heart-shaped at base, leafstalks long; ***with large, leaflike bract (stipule) at base of each leaf. Flowers*** usually produced at tips of stems, each on a slender stalk, ***creamy white with purplish-brown veins near base, 2–2.5 cm (0.8–1 in) across, petals 5, lateral ones densely fringed, forming spur 3–6 mm*** (0.1–0.2 in) ***long on backside.*** Fruits are egg-shaped to globe-shaped capsules 4–8 mm (0.2–0.3 in) long. **Harvest and preparation:** same as for CANADA VIOLET (preceding). **Related edible species:** CANADA VIOLET. **Poisonous look-alikes:** See CANADA VIOLET for details.

Pokeweed *Phytolacca americana*

Habitat: woodland margins, disturbed sites, waste ground, roadsides, fencerows. **Identification:** ***large, perennial herb*** to 3 m (9.8 ft) tall with thick fleshy roots; stems branched, upright, smooth, ***with disagreeable odor when broken.*** Leaves alternate, 9–30 cm (3.5–12 in) long, 3–12 cm (1.2–4.7 in) wide, broadest near base, pointed at tip, entire along margin; leafstalks to 5 cm (2 in) long. ***Flowers greenish to white, produced in narrow elongate clusters*** (racemes); each flower 2–4 mm (0.1 in) long, petals absent. ***Fruits are 5–12-parted berries, wider than long, 6–10 mm*** (0.2–0.4 in) ***in diameter, green turning purplish-black at maturity.*** **Harvest:** young shoots up to 15 cm (6 in) long in late spring before leaves unfold. Identify from presence of previous year's stalks. Cut stems from perennial root as you would asparagus. *Caution: The root is poisonous; avoid all parts of the plant except young shoots.* If shoots show any purple coloration, avoid them as well as mature stems. For winter use, dig root in fall and plant in large container of soil. After hard freeze move to warm area and water regularly. Harvest shoots as above. **Preparation:** Boil shoots 10 min with 1 or 2 water changes; drain, add fresh boiling water and season, cover, and simmer until tender. Serve like broccoli or asparagus with butter, cheese, or other sauces. For casserole, alternate layers of cooked pokeweed shoots, white sauce, and sliced, boiled eggs. Top with seasoned bread crumbs. Bake 30 min at low temperature 165°C (330°F). Boiled, peeled shoots may also be pickled. **Related edible species:** none. **Poisonous look-alikes:** None, but see *caution* above.

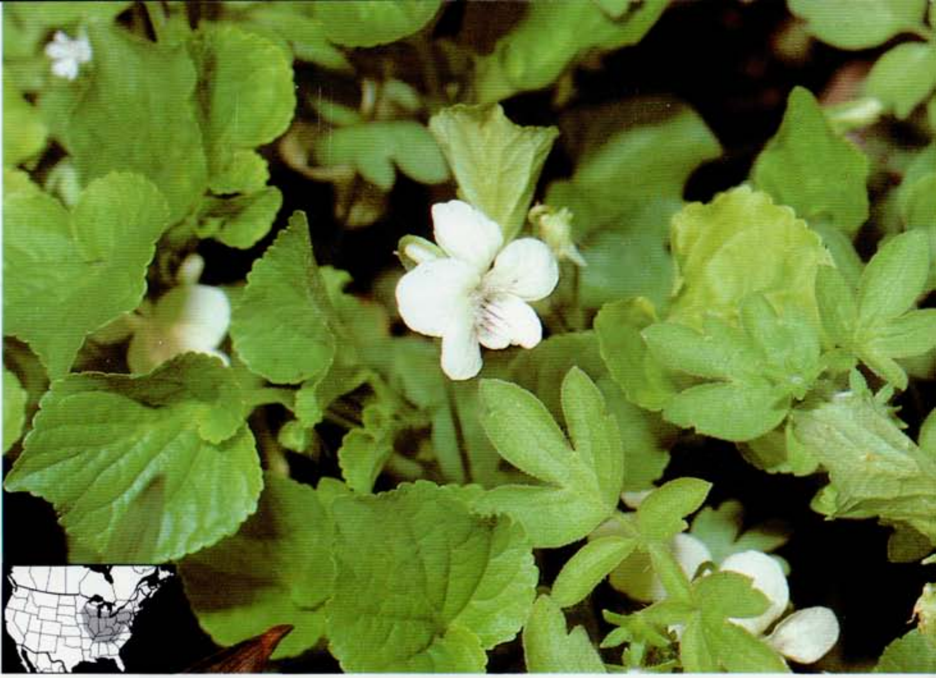

Pale violet: flowering plant (Mohlenbrock).

Pokeweed: fruiting stalks (Crow). Flowers (Elias). Young shoots attached to cut root top (Dykeman).

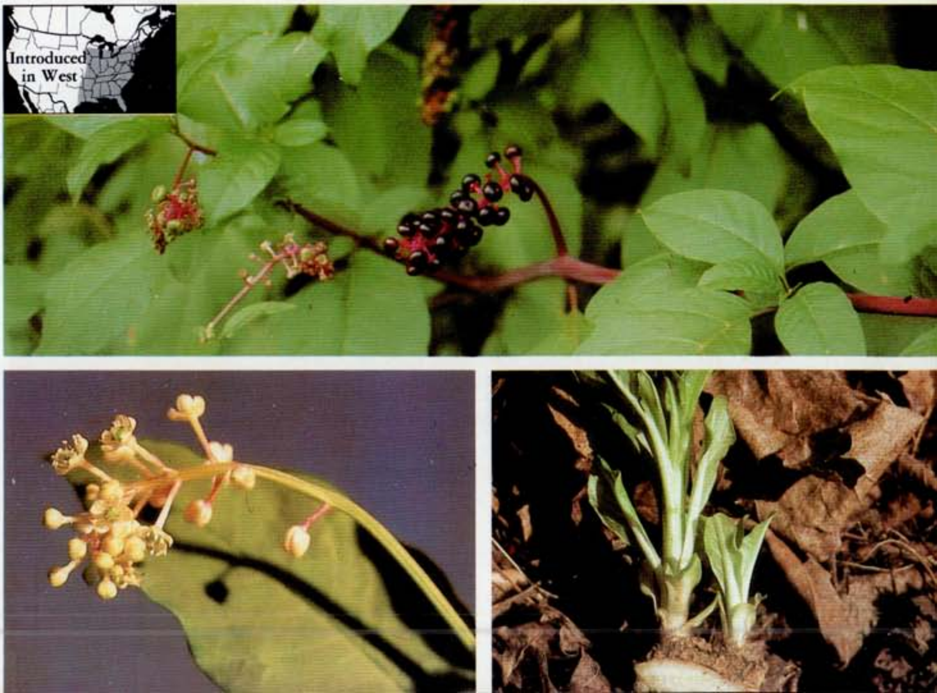
Introduced in West

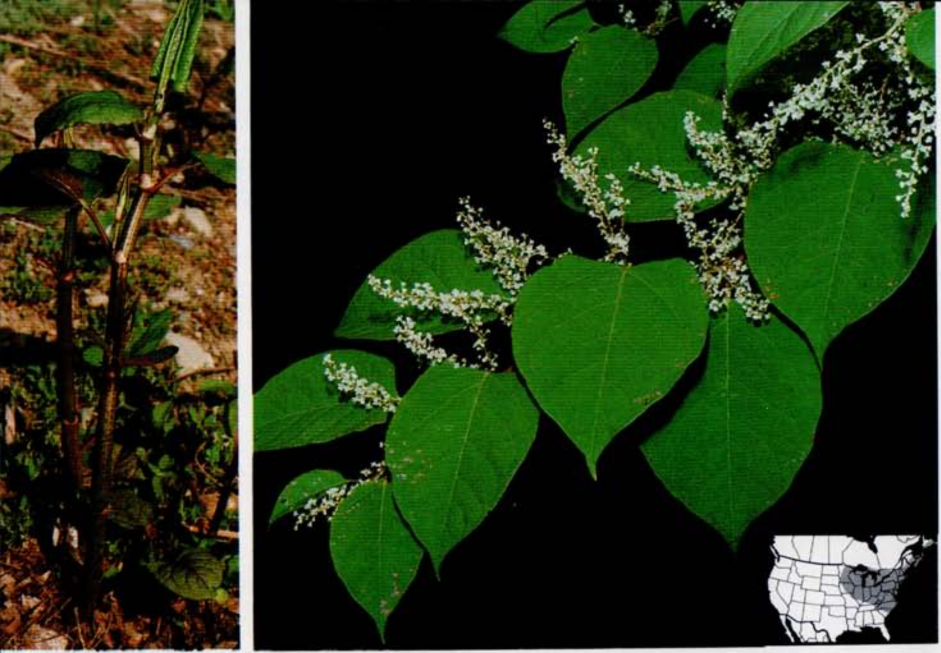

Japanese knotweed: young shoots (Dykeman). Flowering branch (Feldman).

Wintercress: entire plant, leaf, and flowering head (Dykeman).

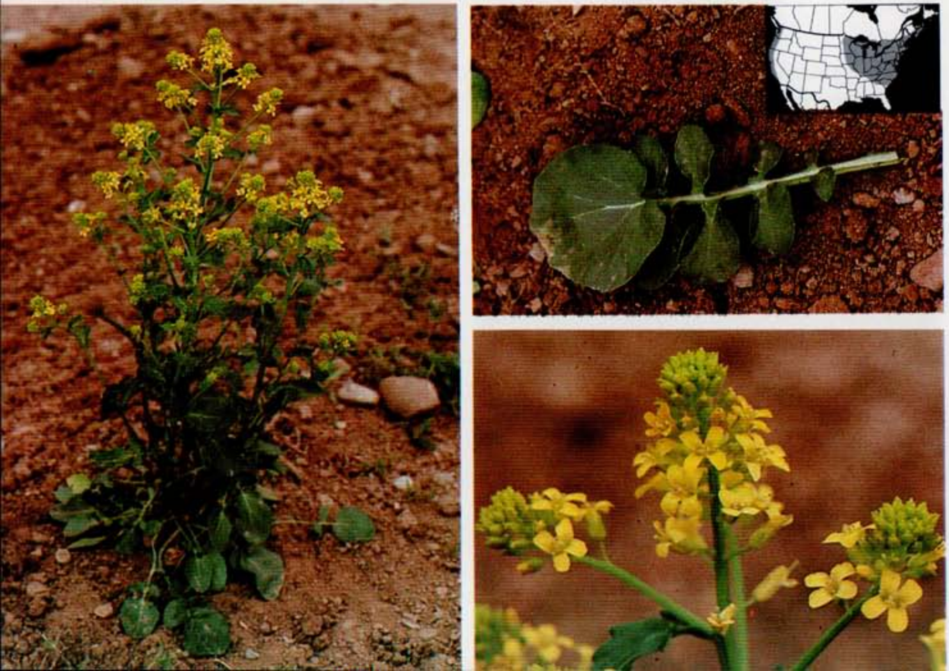

Japanese knotweed *Polygonum cuspidatum*

Habitat: disturbed and waste sites, vacant lots, roadsides; introduced weed from Asia. **Identification:** ***large perennial herb to 3 m*** (9.8 ft) ***high,*** often forming dense colonies; ***stems*** upright, ***with hollow core,*** smooth, mottled, frequently branching. ***Leaves*** alternate, simple, ***10–16 cm*** (4–6.3 in) ***long, 6–12 cm*** (2.4–4.7 in) ***wide, broadest near base,*** long tipped, ***wavy along margin,*** squared to rounded at base, almost leathery; ***leafstalk*** stout and ***enclosed at base by membranous sheath that also surrounds stem.*** Flowers produced in elongate, branched clusters in junctions of upper leaves, each flower tiny, 1–2 mm (less than 0.1 in) long, white. Fruits are dark brown, shiny, winged nutlets. **Harvest:** Locate papery dry stalks of previous year. Gather young shoots up to 30 cm (1 ft) long for potherb, up to 90 cm (3 ft) for other use. **Preparation:** Boil tips of young shoots in salt water or steam 4–5 min. Serve like ASPARAGUS, hot on toast with butter or white sauce, or cold in salad. Also, force cooked shoots through mill for puree. Add salt, butter, sweetener, to taste, and reheat. Or prepare casserole of cooked young shoots, bread crumbs, grated cheese, cream, and seasonings; bake at 200°C (390°F) until top is browned. Peel older stalks 30–90 cm (1–3 ft) and use like rhubarb. For sauce combine 4 cups peeled and cut shoots, 1 cup sugar, and nutmeg. Simmer until soft. Serve hot or cold. See basic jam recipe in book's Introduction. Prepare pie from peeled shoots using rhubarb pie recipes. **Related edible species:** giant knotweed *(P. sachalinense),* Alaskan knotweed *(P. alaskanum),* AMERICAN BISTORT, ALPINE BISTORT, LADY'S THUMB and others. Some may cause a light-sensitive skin reaction. **Poisonous look-alikes:** none.

Wintercress *Barbarea vulgaris*

Also edible autumn, winter

Habitat: fields, wet meadows, ditches, roadsides; common and widespread, introduced from Europe. **Identification:** ***biennial or perennial herb*** to 0.7 m (28 in) high; stems erect, sparingly branched above. Lower ***stem leaves*** broadest near or above middle, 7–15 cm (2.8–6 in) long, ***deeply lobed along sides,*** stalked; leaves of upper stem much smaller, stalkless and lobed at base, coarsely toothed. ***Flowers from April to June, numerous in cylinder-shaped clusters, each flower*** narrow, stalked, ***with 4 narrow, yellow petals. Fruit pods very narrow, 1.5–3 cm (0.6–1.2 in) long, tipped with short beak to 3 mm (0.1 in) long,*** splitting open lengthwise to release tiny seeds. **Harvest:** Pick leaves after frosty weather and into spring until flower stalks appear. Leaf rosettes grow on warm winter days; become bitter in spring. Leaves blanch and lose bitterness if you tie them in bundle with plant rooted and cover with a bucket. Pick buds and flowers until blooming is over, April or May. **Preparation:** Use early and blanched leaves in salads with other late-winter foods such as COMMON DAY LILY tubers and WATERCRESS. Boil later, bitter leaves in 2 changes of water until tender and treat as for BLACK MUSTARD (next). Buds and flowers are excellent with cheese sauce. Cover clusters with boiling water for 1 min. Drain, cover with fresh boiling water, heat, and boil 3 min more. Drain, season, and cool for 5 min. **Related edible species:** early wintercress *(B. verna)*. **Poisonous look-alikes:** none.

Black mustard *(Also edible summer)* *Brassica nigra*

Habitat: common and widespread, fields, yards, disturbed sites; introduced from Europe. **Identification:** ***medium-size to large annual herb*** to 1.2 m (4 ft) high; stems erect, hairy on lower parts. Leaves alternate, stalked, usually broadest above or near the middle, 8–18 cm (3.2–7 in) long, ***lower leaves lobed, upper leaves narrower, wavy toothed. Flowers few in narrow, elongate, loose clusters,*** each ***flower*** stalked, about 1 cm (0.4 in) across, ***with 4 yellow petals. Fruits*** narrow linear ***capsules 1–2 cm*** (0.4–0.7 in) ***long, roughly 4-sided,*** upright, ***beaked, beak 1–2 cm*** (0.4–0.8 in) ***long,*** splitting open lengthwise to release tiny seeds. **Harvest:** leaves very early in spring or blanch later leaves as with WINTERCRESS (preceding). Pick buds and flowers until nearly all flowers have opened. Avoid bitter leaves. For seeds, harvest during summer when oldest pods open. Pile them on fine cloth or plastic tarp and sun-dry for several days. Beat with flail to release seeds, remove stalks, winnow seed from chaff. **Preparation:** Use early and blanched leaves in salads. Boil older greens with 1 change of water for about 30 min. Season with butter and vinegar or mix with crumbled bacon and chopped wild onions. Top with hard-boiled egg slices and French dressing or vinegar. Excellent source of vitamins A, B, and C. For buds and flowers, treat as WINTERCRESS. Sprinkle seeds lightly on salad. To make mustard, grind seeds in food mill; use dried. Or for mustard spread, combine equal parts mustard powder and oven-browned flour with half-and-half mix of vinegar and water. Add other spices to taste. **Related edible species:** field mustard *(B. rapa),* Chinese mustard *(B. juncea),* and others. **Poisonous look-alikes:** none.

Marsh marigold, Cowslip *Caltha palustris*

Habitat: freshwater swamps, wet meadows, along streams, ponds, lakes. **Identification:** ***perennial herbs*** to 70 cm (28 in) high; stems partially spreading to upright, hollow, smooth. ***Basal leaves long-stalked, blade rounded to almost kidney-shaped, 1–2.8 cm*** (0.4–1.1 in) ***long, 0.4–2.2 cm*** (0.2–0.8 in) ***wide,*** rounded at tip, toothed along margin, heart-shaped at base; stem leaves smaller, lacking stalks. ***Flowers large, showy,*** 2.5–4 cm (1–1.6 in) across, ***with 5 bright yellow petallike sepals.*** Fruits are elongate, somewhat rounded, 1–1.7 cm (0.4–0.7 in) long, splitting open along one side when mature to release small seeds. **Harvest:** Cut leaves from plant when young, best before flowers open. Pick tightly closed buds for pickling. **Preparation:** *Raw leaves and buds are poisonous until properly treated!* Wash leaves and cover with boiling water. Reheat to boiling, then drain. Repeat 2 or 3 times, then cook in very little water until tender. Drain and serve with butter and seasonings or with cream or cheese sauce. For pickles, treat buds with boiling water as described for leaves. Do not boil. Drain and pack in jars. Cover with hot pickling liquid and seal. Store for at least a month before eating. Do not consume used pickling juice. To make pickling liquid, slowly add mix of ¼ cup salt, ½ cup sugar, 1 tbsp ground mustard, and 1 tbsp celery seed to 2 cups vinegar and 1 cup water. Boil 10 min with stirring. **Related edible species:** none. **Poisonous look-alikes:** Flowers resemble COMMON BUTTERCUPS yet leaves are very different.

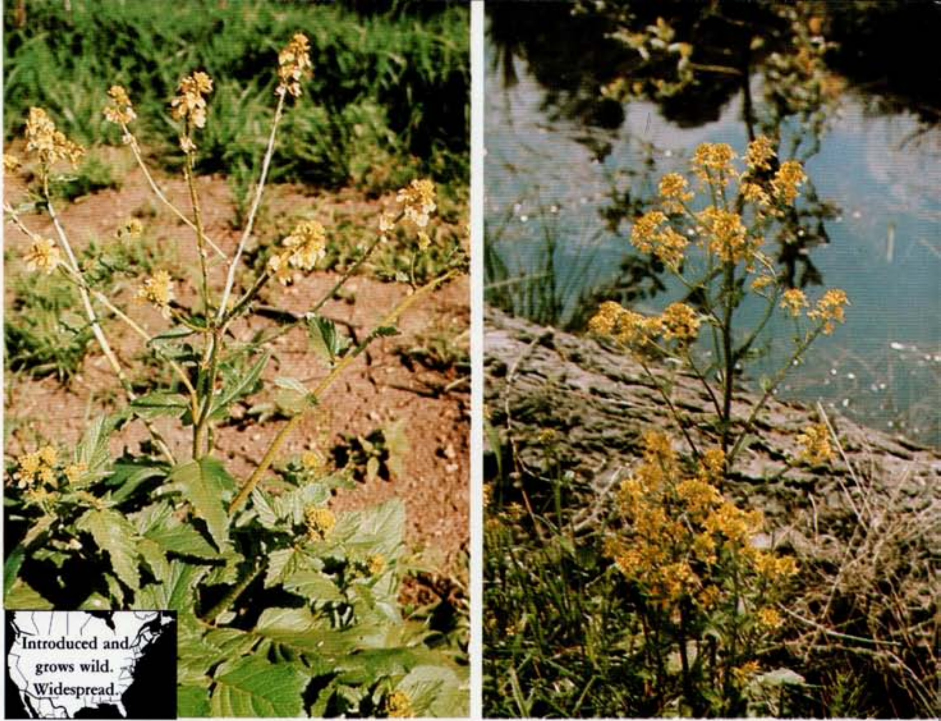
Introduced and grows wild. Widespread.

Black mustard: entire plants (NYBG).

Marsh marigold: plants in typical streamside habitat and entire plant (Dykeman).

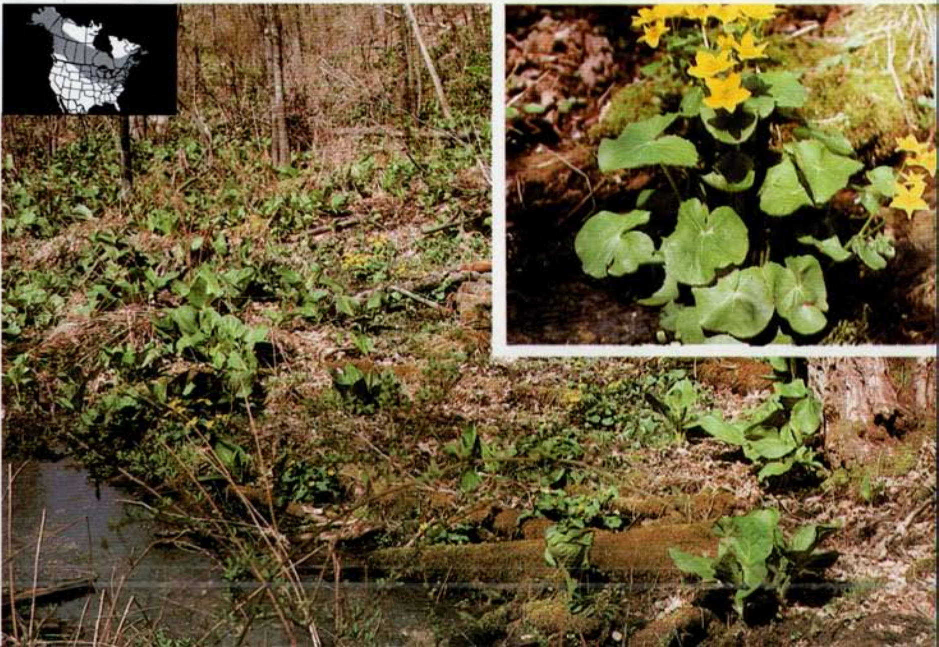

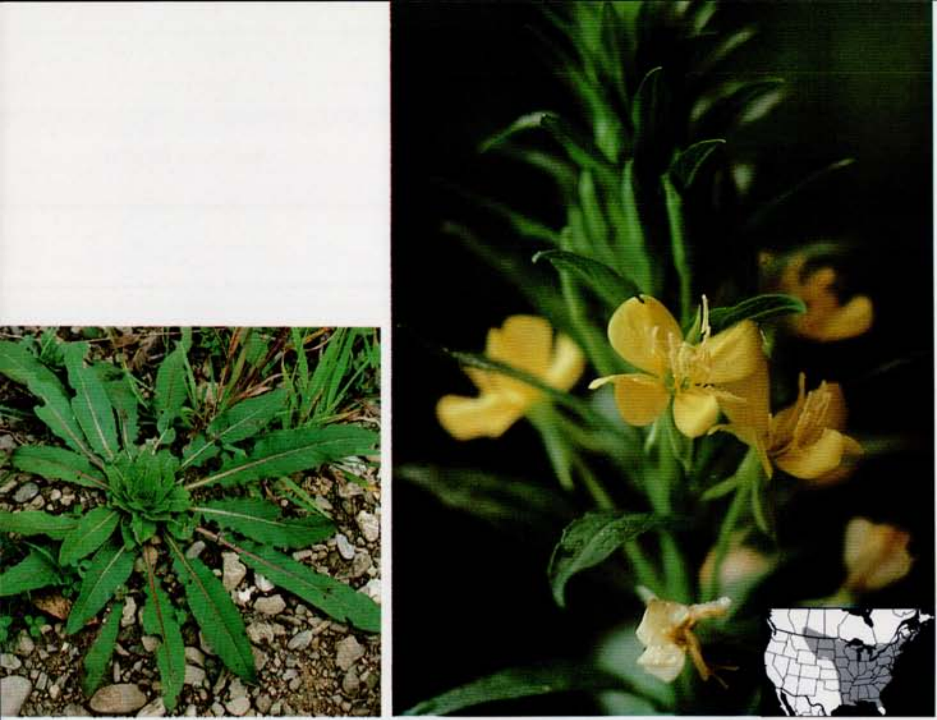

Evening primrose: basal leaves (Dykeman). Flowering stalks (Pawloski).

Sow thistle: fruiting head, left, and flower (Mathisen).

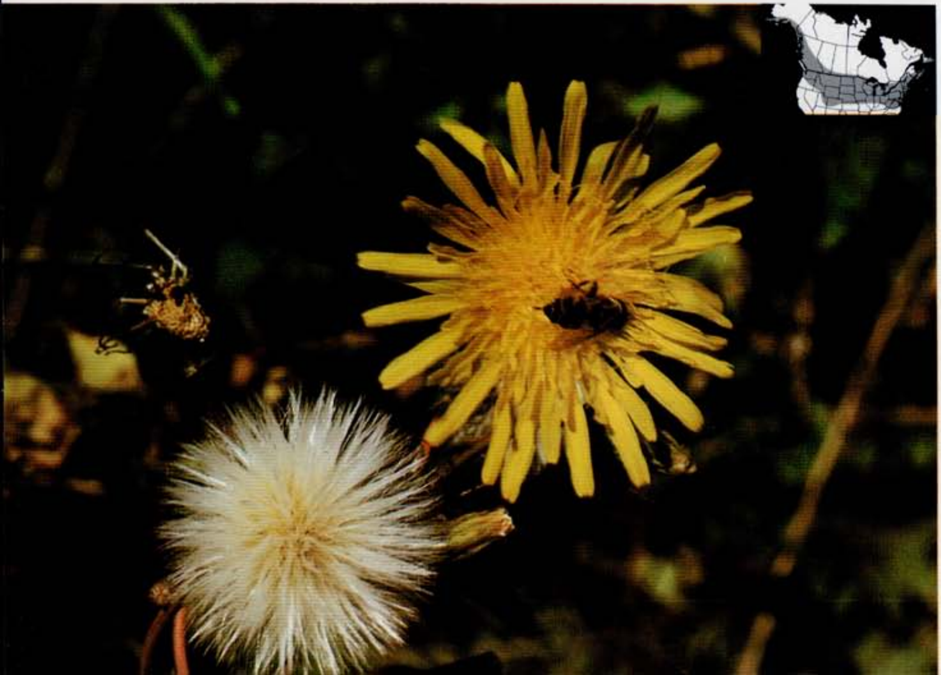

Evening primrose *Oenothera biennis*

Also edible autumn, winter

Habitat: disturbed sites, along roads, prairies, fields. **Identification:** biennial herb of 1.6 m (5.3 ft) high, from elongated taproot; stems upright, hairy. Leaves of first year in low rosette; second year leaves on flower stalk, alternate, lance-shaped to broadest near middle, 8–18 cm (3.2–7 in) long, 2–6 cm (0.8–2.4 in) wide, pointed at tip, entire to toothed along margin, tapering at base, hairy. ***Flowers second year, many in terminal, elongated cluster, each flower with narrow, tubular calyx 1.5–3 cm*** (0.6–1.2 in) ***long, 4 large spreading, bright yellow petals 1.5–3 cm*** (0.6–1.2 in) ***long. (Flowers open after dusk and often close by midmorning.) Fruits are cylinder-shaped, angled capsules 1–4 cm*** (0.4–1.6 in) ***long,*** containing many small, reddish seeds. **Harvest:** Dig taproots of first year growth between autumn and early spring. Pick leaves from rosettes in early spring or even earlier from areas clear of snow. **Preparation:** Peel taproots and boil in 2 changes of water for 20–30 min. Serve with butter and seasonings or slice and fry. Cook sliced roots with meat or in stews, partially boiling roots first if flavor is too strong. Simmer boiled roots in sugar syrup for 20–30 min until candied. Peel leaves and use sparingly in salads. Or boil leaves 15–20 min in 2 changes of water and serve with butter or vinegar. **Related edible species:** other species of this large genus. **Poisonous look-alikes:** none, but don't confuse leaves with those of other early-blooming species.

Sow thistle *Sonchus arvensis*

Habitat: disturbed sites such as roadsides, fields, railroad right-of-ways, gravel banks; introduced weed from Europe. **Identification:** Not to be mistaken for the more common and generally more palatable thistles of the *Cirsium* genus, sow thistle is a ***perennial herb*** to 1 m (3.2 ft) high with deep vertical and spreading horizontal coarse roots; stems upright, smooth, with milky sap. ***Leaves*** alternate, simple, broadest near or above middle, 10–35 cm (4–14 in) long, 4–14 cm (1.6–5.5 in) wide, ***deeply lobed along margin, upper leaves less so, spiny-toothed, lobed leaf bases clasping stems,*** usually smooth. ***Flowering heads*** produced in loosely branched, elongated, erect cluster, each head ***3–5 cm*** (1.2–2 in) ***across,*** with lance-shaped bracts on the outside and many small ***yellow flowers*** within. Fruits are small, dark-brown nutlets 2.5–3 mm (0.1 in) long. **Harvest:** Locate by noting concentrations of mature plants the previous year. Pick when only a few inches tall; leaves become increasingly bitter with age. *Caution: Sow thistle occasionally contains toxic levels of nitrates.* **Preparation:** If not too bitter, cut and mix leaves with other, blander salad greens. Boil in very little water for 3–4 min, change water, and then boil until tender. Serve with butter and seasonings or vinegar. If too bitter, mix with blander greens such as LAMB'S QUARTERS. **Related edible species:** Several species of the *Sonchus* genus are variously distributed and edible when very young. Some have leaf spines that must be removed. **Poisonous look-alikes:** none.

Prickly lettuce *Lactuca serriola* (synonym: *L. scariola*)
Habitat: disturbed sites such as fields, roadsides, vacant lots; introduced weed from Europe. **Identification:** ***annual or biennial herb*** to 2 m (6.6 ft) high, ***with milky juice in stems and leaves,*** stems upright, slender, usually armed with spreading prickles. Stem ***leaves*** alternate, ***lance-shaped,*** 5–25 cm (2–10 in) long, 1.5–12 cm (0.6–4.7 in) wide, ***with several deep lobes or lobeless, toothed and spiny along margin*** and spiny along main vein on lower leaf surface, with pointed lobes at base and often clasping stem. ***Flowering heads*** sparingly produced in branched clusters, each head ***1–1.5 cm*** (0.4–0.6 in) ***long,*** 3–6 mm (0.1–0.2 in) ***across, containing 6–12 yellow flowers.*** Fruits are tiny gray to brown nutlets 3–4 mm (0.1 in) long. **Harvest:** Like other wild lettuce species, prickly lettuce is good only when very young. Pick leaves when plants are less than 20 cm (8 in) tall. **Preparation:** Use alone or with other greens in tossed salad. Boil leaves in very little water for 2–3 min. Serve with butter and seasonings. For wilted lettuce pour boiling water over lettuce leaves and let sit for 5 min. Drain. Make dressing of 3 slices of crisp bacon crumbled into ¼ cup hot vinegar with 1 tsp sugar and ½ tsp salt. Pour over hot lettuce. *Caution: Large quantity of raw young leaves may cause digestive upset.* **Related edible species:** many species of the *Lactuca* genus widely distributed; most noticeable of these is wild lettuce *(L. canadensis),* which lack prickles on leaves and lower stem. **Poisonous look-alikes:** none.

Dandelion *Taraxacum officinale*
Also edible autumn, winter

Habitat: lawns, yards, disturbed sites; common weed introduced from Europe. **Identification:** ***perennial herb, with large,*** sometimes branched ***taproot. Leaves all basal,*** 8–40 cm (3.2–16 in) long, 0.8–14 cm (0.3–5.5 in) wide, widest near tip, rounded to pointed at tip, ***variously and irregularly lobed along margin,*** tapering to narrow base, hairy beneath, ***with milky juice.*** Flowers produced throughout spring in large heads at tip of hollow stalks. ***Flowering heads 2–5 cm*** (0.8–2 in) ***across, composed of numerous, small, narrow, orange-yellow flowers, remaining closed on cloudy days. Fruits*** on elongated, upright hollow stalks, ***forming delicate ball*** composed of many tiny seeds each tipped with white featherlike tuft (pappus) easily dispersed by wind. **Harvest:** Best lawn areas are those with taller grass. Dig roots with crown at top of root and leaves attached from time leaves (rich in vitamin A) appear until they are too bitter to use. Dig older roots in fall and winter. Cut out developing bud clusters and pick fully opened flowers in spring. **Preparation:** For flowers, leaves, and older roots, see CHICORY. Peel young roots, slice thin, and boil in 2 changes of water for about 20 min, adding pinch of baking soda to first water. Serve with butter and seasonings or saute cooked slices in butter until brown. Season with paprika. Boil buds just a few minutes, butter and serve. Dip blossoms in fritter batter; fry in oil and serve with syrup or garlic salt. **Related edible species:** several other species of *Taraxacum,* all similar to common dandelion in appearance/preparation. Also, CHICORY in early growth. **Poisonous look-alikes:** none.

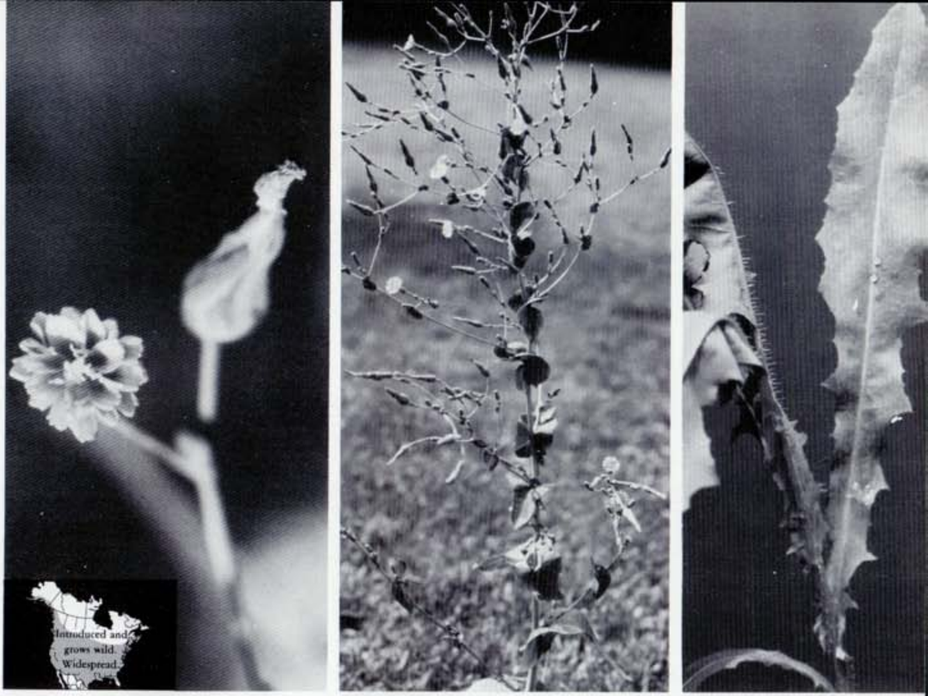
Introduced and
grows wild.
Widespread.

Prickly lettuce: flowering branch and entire plant (Kavasch). Leaves (Dykeman).

Dandelion: flowering plant (Elias).

Introduced and
grows wild.
Widespread.

Goat's beard *Tragopogon pratensis*

Habitat: roadsides, fields, other disturbed sites; introduced from Europe. **Identification:** ***perennial*** or biennial ***herb*** to 76 cm (30 in) high with taproot and milky juice; stems upright. ***Leaves*** alternate, linear, ***grasslike, 15–30 cm*** (6–12 in) ***long, 1–2 cm*** (0.4–0.8 in) ***wide,*** pointed at tip, entire along margin, base partially circling stem, smooth. ***Flowering heads*** produced singly at tip of stems, ***resembling dandelion, with 8 lance-shaped outer bracts, many yellow flowers.*** Fruiting heads globe-shaped, light, fluffy, consisting of numerous small nutlets, each tipped with light, featherlike bristles. **Harvest:** See SALSIFY (preceding). Roots of goat's beard may be smaller, tougher, less palatable. **Preparation:** Same as SALSIFY. Cool boiled roots and saute in oil until browned or prepare like potatoes. Roasted and ground roots make coffee substitute. Use very young leaves in salad if not bitter or boil for 5–10 min and serve with butter and seasonings. **Related edible species:** SALSIFY, yellow goat's beard *(T. dubius)*. **Poisonous look-alikes:** none in the flowering stage.

Common milkweed *Asclepias syriaca*

Also edible summer

Habitat: fields, meadows, roadsides, woodland margins. **Identification:** ***perennial herb*** to 1.8 m (6 ft) tall; stems upright, usually unbranched, hairy. ***Leaves opposite,*** broadest near base or middle, ***10–28 cm*** (4–11 in) ***long, 4–12 cm*** (1.6–4.7 in) ***wide,*** pointed at tip, entire to wavy along margin, ***thick, leathery, hairy above, with milky sap. Flowers in dense, rounded heads 6–10 cm*** (2.4–4 in) ***across, each flower rose, dull purple to greenish-white,*** 8–12 cm (3.2–4.7 in) long, with 5 reflexed petals. ***Fruits are elongated pods,*** broadest near base and gradually tapering to curved point, 8–14 cm (3.2–5.5 in) long, covered with small, soft, green projections. Seeds small, each with conspicuous, soft, featherlike hairs at one end. **Harvest:** Cut new shoots when less than 20 cm (8 in) tall. Pick newly opened leaves until buds are formed; then pick clusters of buds and flowers. Later pick firm pods 2–3 cm (0.8–1.2 in) long. **Preparation:** To remove bitterness from all parts, cover with boiling water and bring back to boil. Discard water and repeat 2–3 times with boiling water. Do not use cold water in process. Cook treated shoots like ASPARAGUS. After treatment boil young leaves, bud clusters, and pods until tender, usually 10–15 min. Serve with butter and seasonings or with sauce. Use treated pods in soup like okra *(Hibiscus esculentus)*. **Related edible species:** Showy milkweed *(A. speciosa)* is good. **Poisonous look-alikes:** all narrow-leaved milkweed species, especially BUTTERFLY WEED; some are more toxic than others. Young DOGBANE, also with milky sap, has branches (common milkweed does not) and its young shoots lack hairs.

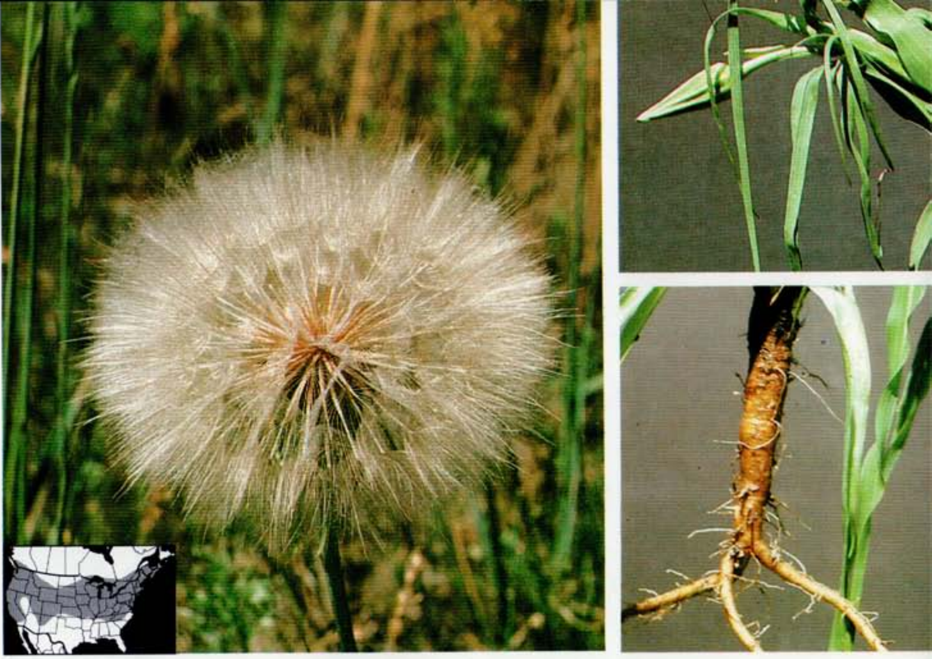

Goat's beard: fruiting head, flower bud, rootstock (Dykeman).

Common milkweed: flowering head and entire plant (Elias).

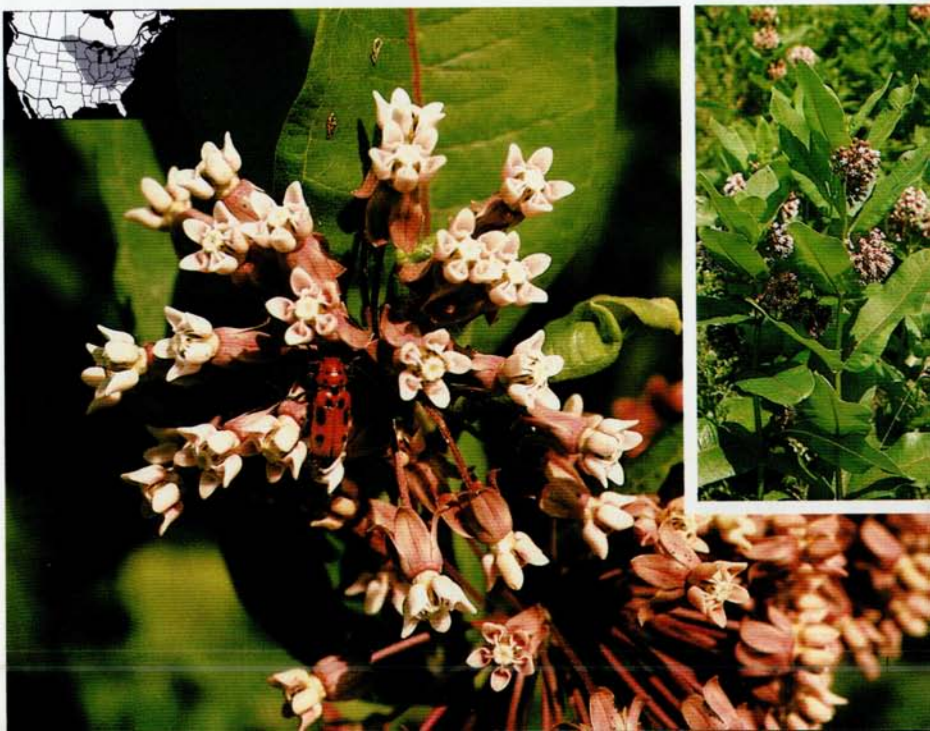

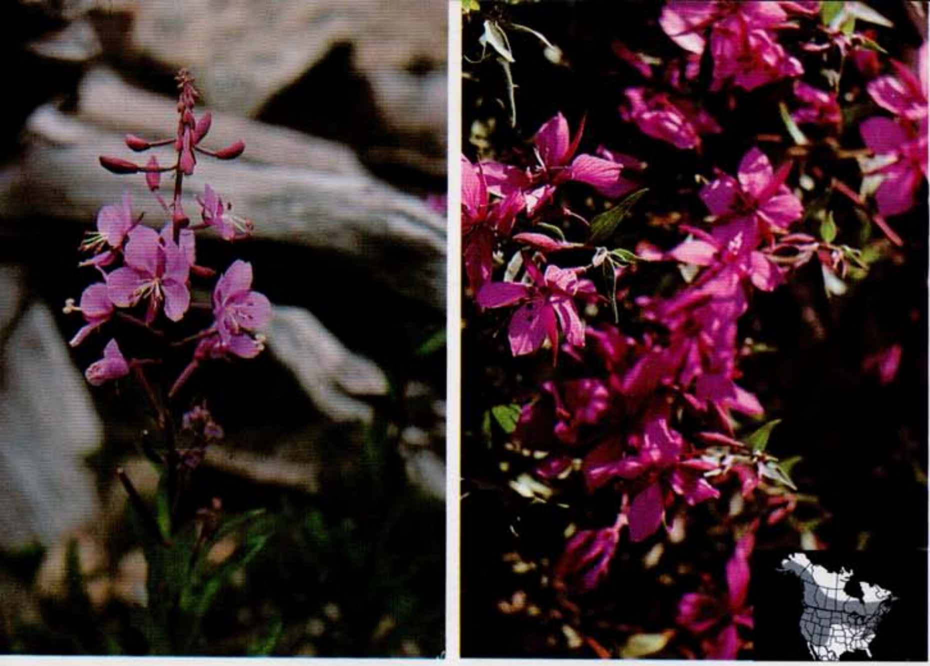

Fireweed: flowering stalk (Elias). Flowers (NYBG).

Alfilaria: entire plant with flowers and fruits (Ross).

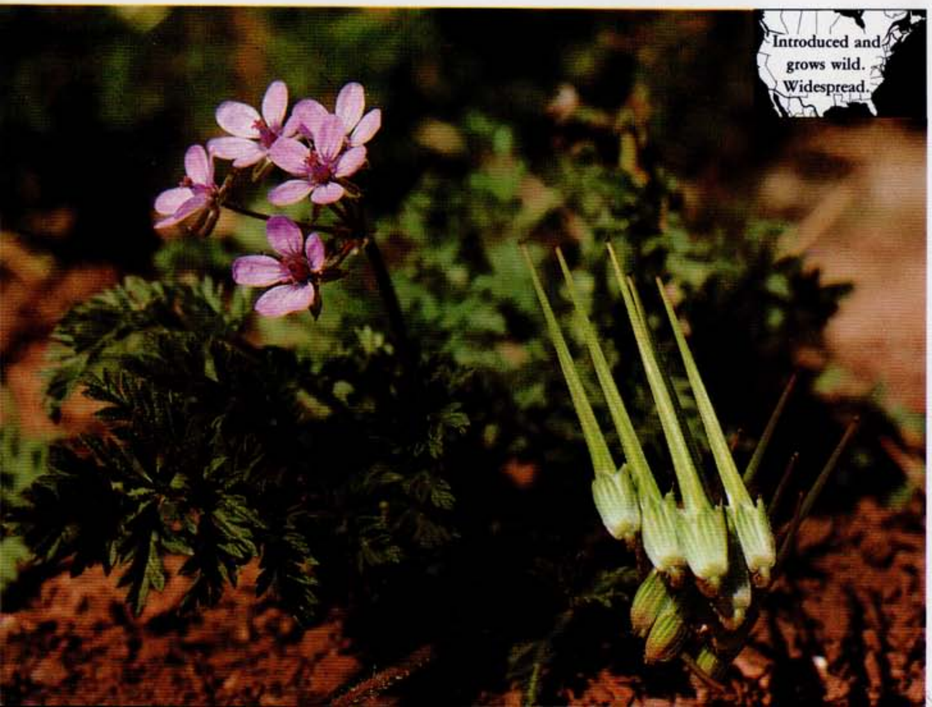
Introduced and grows wild. Widespread.

Fireweed *Epilobium angustifolium*

Also edible summer

Habitat: woodlands, ravines, clearings; commonly grows after fires. **Identification:** ***perennial herb*** 1–2 m (3.2–6.5 ft) high; stems erect, usually single, smooth. Leaves alternate, narrow and broadest near base, 5–20 cm (2–8 in) long, to 3 cm (1.2 in) wide, nearly stalkless, long-pointed at tip, entire or nearly so along margin. ***Flowers*** many on elongate spikes; each flower stalked, spreading, ***with 4 pink to purple, rarely white, clawed petals*** 1–2 cm (0.4–0.8 in) long. ***Fruit a narrow capsule 3–8 cm*** (1.2–3.2 in) ***long,*** with reddish or purplish cast, 4-parted. **Harvest:** Cut young shoots in spring; new leaves, flower bud clusters, and mature stems later. Older leaves are good for tea but too bitter for potherb. **Preparation:** Not a very tasty food plant but widespread, abundant, easy to identify, and has several edible parts. Cook young shoots like ASPARAGUS and season with butter, hollandaise, or cheese sauce. Use young leaves and later flower-bud clusters in salad with other greens. For potherb, stir 4 cups small leaves and 3 tbsp water into 2 tbsp melted butter in skillet over high heat. Cover and cook 2–3 min, season and serve. Boil flower bud clusters 10–15 min and serve with butter, salt and pepper. Peel stems too old for cooking and chew on raw pith or use pith in soups. Dry mature leaves and blend with other suitable leaves for a tea. **Related edible species:** dwarf fireweed *(E. latifolium)* and other related but smaller species. **Poisonous look-alikes:** none.

Alfilaria, Filaree, Storksbill *Erodium cicutarium*

Habitat: fields, pastures, roadsides, other disturbed sites; common weed introduced from Europe. **Identification:** ***annual or biennial herb*** with 1 to several spreading stems, hairy. ***Leaves*** emerge at base and along stem, alternate, ***2–10 cm*** (0.8–4 in) ***long, featherlike (pinnate) compound, leaflets (pinnae) cleft and coarsely toothed. Flowers*** 2–10 in small, branched, rounded-headed cluster at tips of shoots; each flower about 2.5 cm (1 in) across, ***with 5 rose-purple petals.*** Fruits are narrow, elongate capsules 2–4 cm (0.8–1.6 in) long, opening from base toward tip. **Harvest:** Gather young, overwintered leaves in early spring when other wild foods are scarce. Be certain leafstalks are hairy. **Preparation:** Chop leaves for salad with other greens. Boil leaves in lightly salted water until tender, about 10–20 min. Serve with butter, lemon juice, and herbs. **Related edible species:** none recommended. **Poisonous look-alikes:** Leaves resemble those of the parsley family including POISON HEMLOCK. Picking only hairy-stemmed leaves very early in spring should help you avoid errors. Be sure of identification!

Live-forever, Orphine *Sedum purpureum*

Also edible autumn, winter

Habitat: roadsides, open slopes, woodlands, and disturbed sites; introduced European weed. **Identification:** ***perennial herb*** to 80 cm (32 in) tall, from fleshy tubers. ***Stems upright, succulent; leaves*** alternate or whorls of 3, simple, ***fleshy, 3–6 cm*** (1.2–2.4 in) ***long***, 1–3 cm (0.4–1.2 in) wide, pointed or blunt at tip, entire or toothed along margin, green to bluish-green. ***Flowers*** produced in a compact, branched cluster at tips of branches, each flower bisexual, 6–10 mm (0.2–0.4 in) across, ***with 5 reddish-purple to deep pink petals.*** Fruits small capsules 4–6 mm (0.2 in) long, splitting open along 1 side only. **Harvest:** young leaves in spring and tubers from fall through spring, as long as they are firm and crisp. **Preparation:** Add raw, very young leaves to salads. Boil leaves gathered through early summer for 5–10 min and serve as cooked green. Pour hot pickling liquid over tubers and leave for several days before eating. For pickling liquid boil 2 tbsp mixed pickle spices in cloth bag in solution of 1 qt vinegar and 1 cup sugar. Boil tubers like those of COMMON DAY LILY for about 20 min. Serve with butter and seasonings. **Related edible species:** Other *Sedum* species provide edible leaves; some are more pungent than others. Roseroot *(S. rosea)* is the most frequently used. **Poisonous look-alikes:** none.

Lady's thumb *Polygonum persicaria*

Also edible summer

Habitat: disturbed sites, especially low wet ground, along roadsides, lakes, streams, ponds; widespread weed introduced from Europe. **Identification:** ***annual herb*** to 1 m (3.2 ft) high; stems soon branching, spreading to upright, smooth. ***Leaves*** alternate, ***narrowly lance-shaped,*** 4–12 cm (1.6–4.7 in) long, 0.6–3 cm (0.2–1.2 in) wide, ***often with irregular or triangular purplish spot above,*** pointed at tip, wavy along margin, tapering at base, ***enclosed at base by membranous sheath that also surrounds stem.*** Mature stems reddish. ***Flowers*** numerous, dense ***in cylinder-shaped spikes*** 2–4 cm (0.8–1.6 in) long, each flower ***pink to rose.*** Fruits are tiny, broadly egg-shaped nutlets 2–2.5 mm (0.1 in) long. **Harvest:** Gather young leaves, mainly in spring but later if not too peppery. **Preparation:** Add chopped raw leaves to tossed salad. Boil leaves in small amount of water for 5–10 min. Serve with vinegar. **Related edible species:** ALPINE BISTORT, JAPANESE KNOTWEED. Known as the smartweeds, other *Polygonum* species may be as good as lady's thumb, and none are known to be poisonous. *Caution: Some species may cause light-sensitive reactions.* **Poisonous look-alikes:** none.

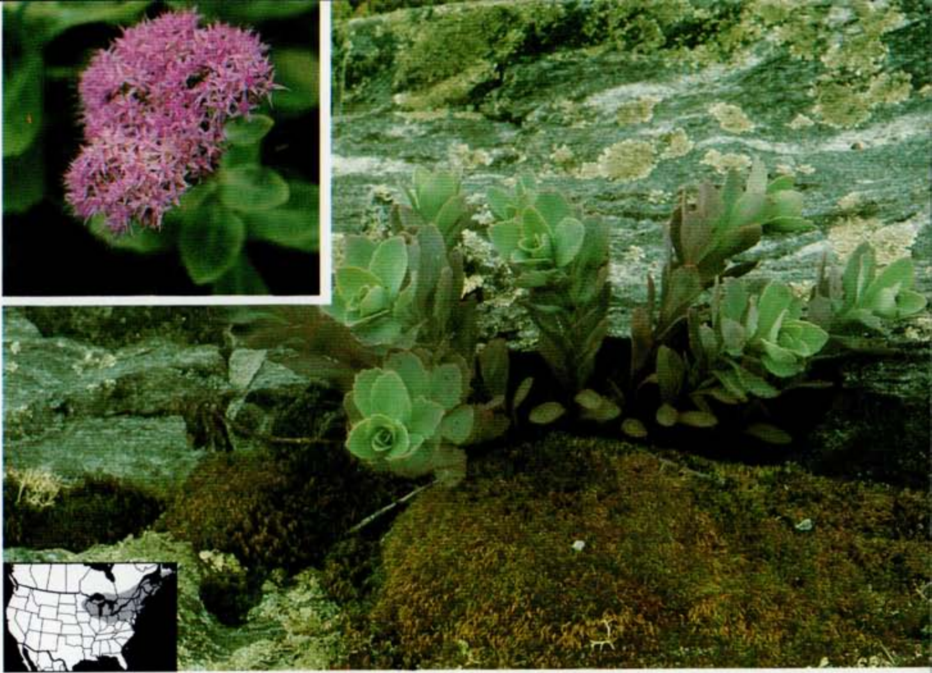

Live-forever: flowering head (Kavasch). Entire plant (Speas).

Lady's thumb: entire plant and stem (Dykeman).

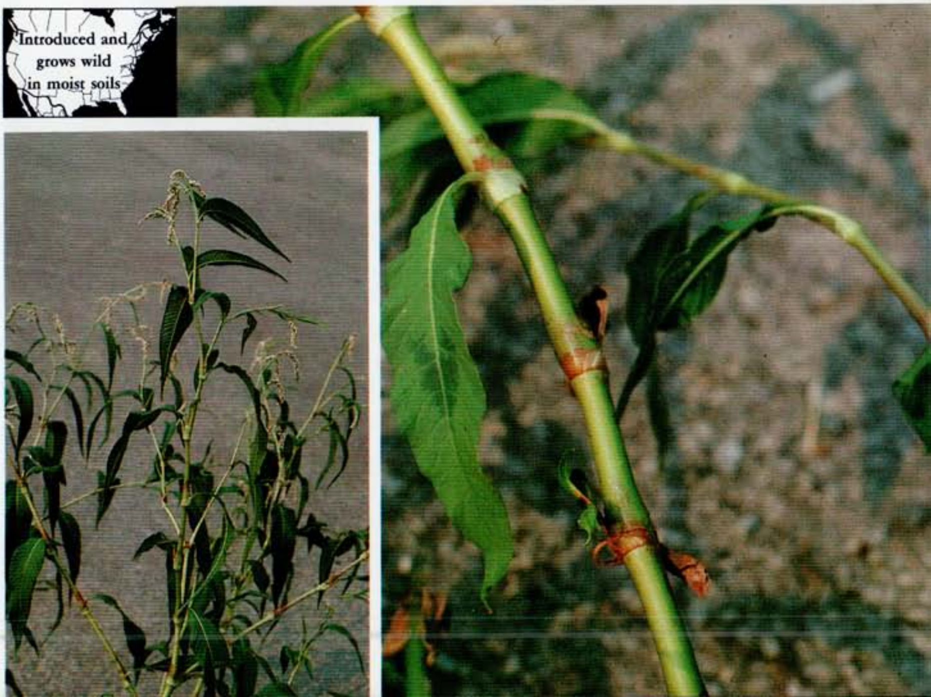
Introduced and grows wild in moist soils

Common burdock *Arctium minus*

Also edible summer, autumn

Habitat: roadsides, vacant lots, disturbed sites; introduced from Europe and Asia. **Identification:** ***biennial herb*** to 1.8 m (6 ft) high; stems upright, often branched, usually smooth. ***Leaves*** alternate, ***basal leaves large, 30–50 cm*** (12–20 in) ***long, 20–30 cm*** (8–12 in) ***wide,*** widest near base, ***deeply lobed at base,*** with conspicuous hollow stalk; upper-stem leaves smaller and not lobed at base. ***Flowering heads produced during second year along upper stems*** or in branched elongated clusters; heads 1.7–2.8 cm (0.7–1.1 in) across, outer bracts spine-tipped; ***flowers pink to purple***. Seeds small, hard nutlets 4–6 mm (0.2 in) long. **Harvest:** Dig roots of first-year plants during summer, later if necessary. Pick first-year basal leafstalks and young flower stalks of second year. **Preparation:** Peel roots, slice ½-in thick and boil 20 min with pinch of baking soda. Change water and boil until tender. Serve with butter and seasonings, or mash pieces and make fried patties. Peel flower stalk, removing all green rind. Eat like celery, slice into salad, or boil until tender. Good in casseroles and many other recipes. Simmer pieces of cooked flower stalk in maple syrup to make candy. Eat peeled leafstalks raw or boiled, but since they are hollow, there's not much left after peeling. **Related edible species:** Just as good, great burdock *(A. lappa)* is larger, with larger burrs on solid leafstalks. **Poisonous look-alikes:** Leaves resemble rhubarb leaves but flowers are greatly different.

Salsify, Oyster plant *Tragopogon porrifolius*

Habitat: roadsides, fields, railroad right-of-ways, other disturbed sites; introduced weed from Europe. **Identification:** ***biennial or perennial herb*** to 1 m (3.2 ft) with long taproot and milky juice; ***stems*** upright, ***swollen just below flowering heads.*** Leaves alternate, lance-shaped, 18–32 cm (7–12.6 in) long, to 2 cm (0.8 in) wide, long-pointed at tip, entire along margin, base circling stem. ***Flowering heads*** solitary, ***usually 3–4 cm*** (1.2–1.6 in) ***long, with 6–11 lance-shaped outer bracts and numerous purple flowers.*** Fruiting heads globe-shaped, fluffy, consisting of many small nutlets, each tipped with featherlike bristles. **Harvest:** This is the cultivated species of salsify or oyster plant that also grows wild. Roots and leaves must be harvested before plant produces flowerstalk. This is a problem since grasslike leaves grow among leaves of many other plants. Learn to recognize leaves so you can harvest them and dig roots while still palatable. **Preparation:** Scrub and scrape roots as you would carrots, putting them in cold water to prevent discoloring. Cut into ½-in slices. If they are tough, add pinch of baking soda to cooking water and boil for 10 min, then change water and cook until tender. Drain and serve with butter and seasonings or with white sauce. For other uses see GOAT'S BEARD (next). **Related edible species:** GOAT'S BEARD. **Poisonous look-alikes:** none in flowering stage.

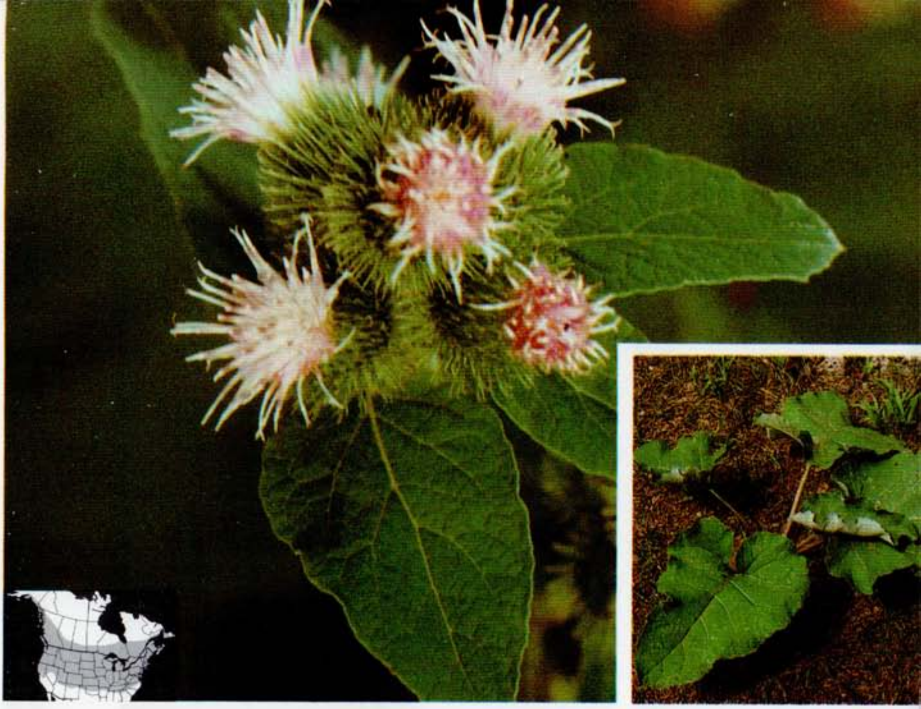

Common burdock: flowering stalk (Speas). Basal leaves (Dykeman).

Salsify: flowers, side view (NYBG). Flower (Ross).

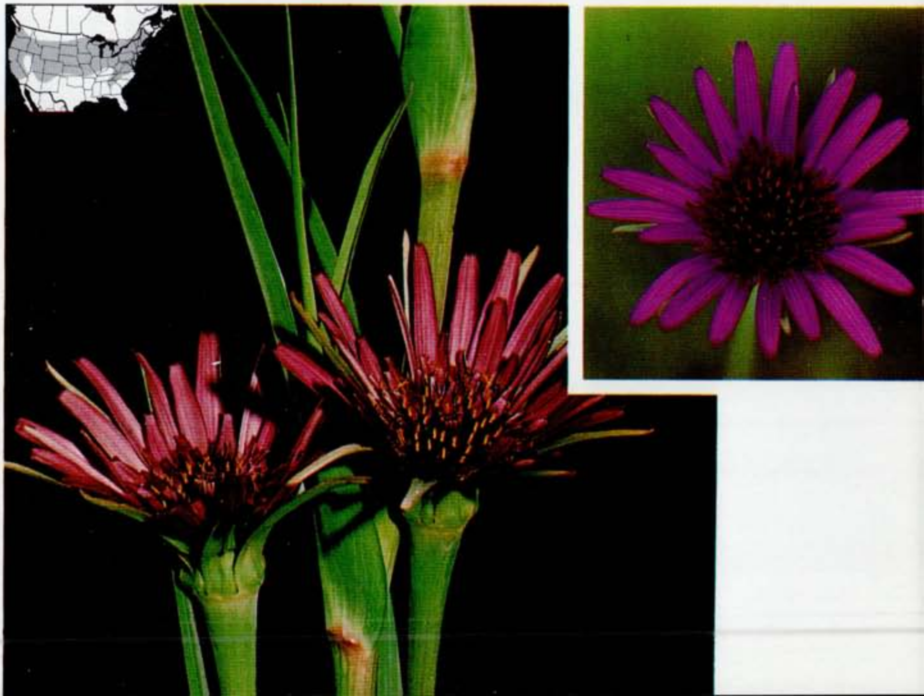

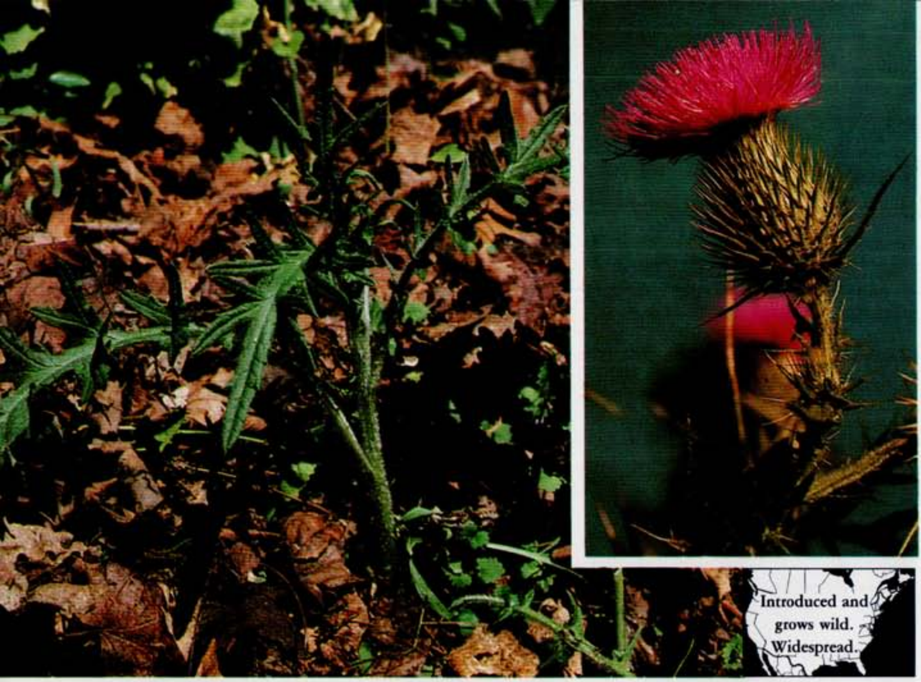
Introduced and grows wild. Widespread.

Bull thistle: young plant (Dykeman). Flowering head (Elias).

Chicory: basal leaves and young plants (Dykeman). Flowers (NYBG).

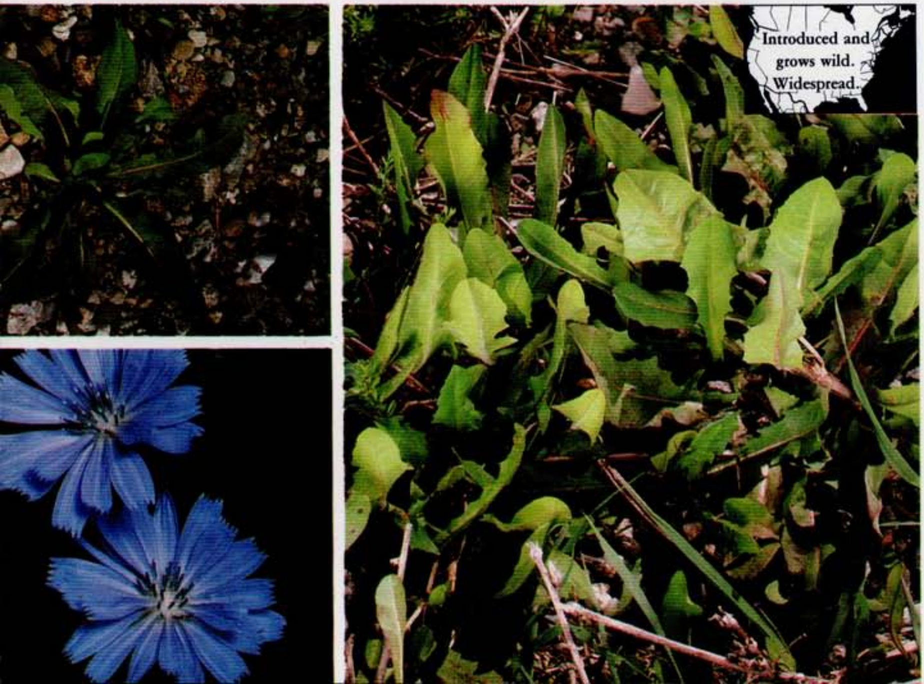
Introduced and grows wild. Widespread.

Bull thistle *Cirsium vulgare*

Habitat: fields, meadows, roadsides, disturbed sites; introduced from Europe and Asia. **Identification:** ***biennial herb*** to 1.8 m (6 ft) high, from taproot; ***stems*** upright, hairy, ***winged, wings lobed and armed with spines. Leaves*** alternate, broadest near or above middle, ***deeply and variously dissected along margin,*** 8–30 cm (3.2–12 in) long, 4–12 cm (1.6–4.7 in) wide, ***stiff, spiny,*** stiffly hairy above, with soft white to green hairs below, leaf bases extending onto stem. ***Flowering heads*** second year, several, outer bracts spiny, 2–4 cm (0.8–1.6 in) long; flowers ***purple.*** Seeds are hard, 3–4 mm (0.2 in) long and tipped with bristles. **Harvest:** Dig roots of first-year growth (thistles without stems). With gloves and knife, harvest leaves and young second-year stems at top of root early in growing season. **Preparation:** Peel young stems and remove spines from leaves before using raw in salad or boiling until tender for green vegetable. Remove all spiny covering from core of leaf bases. Boil cores with washed, peeled roots for about 15 min, changing water if necessary to remove bitterness. Serve salted with butter or vinegar. Slice boiled roots and fry until browned. Boil roots several hours until mushy, dry and grind into flour. Because of spines, you may prefer to use thistles only as survival food. **Related edible species:** Many species of thistles are available; some are more palatable than others. **Poisonous look-alikes:** HORSE NETTLE is a low herb with prickly stems but no spines on leaves.

Chicory *Cichorium intybus*

Also edible autumn, winter

Habitat: roadsides, fields, vacant lots, other disturbed sites; introduced weed from Europe. **Identification:** ***perennial herb*** to 1.5 m (5 ft) high, ***with large deep taproot;*** stems erect or nearly so, often branching. ***Leaves*** alternate, lance-shaped to broadest above middle, ***10–32 cm*** (4–12.6 in) ***long,*** 2–8 cm (0.8–3.1 in) wide, upper leaves reduced, ***toothed and often lobed along margin,*** sap milky. ***Flowering heads produced along upper part of stems in junctions of upper smaller leaves; each head*** 1–1.6 cm (0.4–0.6 in) long, ***3–4 cm*** (1.2–1.6 in) ***across in flower, containing many bright blue, rarely pink or white, 5-lobed flowers.*** Fruits are tiny, brown or black nutlets 2–4 mm (0.1 in) long. **Harvest:** Pick leaves, including crown at top of root, as early as possible. Dig root, fall through spring. Chicory leaves are similar to those of DANDELION; collect and use leafy parts of the two together. **Preparation:** Slice bleached underground portion of leaf crown for use raw in salad, along with oil and vinegar or with other spring edibles. Boil crown bases about 5 min and serve with butter and seasonings. Same for leaves but water changes may be needed to remove bitterness, especially later in spring. For coffee substitute, scrub roots and roast slowly in oven until brown throughout. Grind and brew like coffee. **Related edible species:** none, but similar to DANDELION in early stages. **Poisonous look-alikes:** none.

Henbit *Lamium amplexicaule*

Habitat: fields, yards, vacant lots, disturbed sites; introduced from Eurasia, common and widespread. **Identification:** small ***annual herb*** to 40 cm (16 in) tall; ***stems*** usually branching with upper parts upright, ***4-sided. Leaves opposite,*** mainly on lower half of stem, 0.7–3.4 cm (0.3–1.3 in) long, ***nearly rounded, coarsely round-toothed along margin,*** heart-shaped at base, hairy above, lower leaves long-stalked. ***Flowers purple,*** produced near tip, each ***narrow, funnel-shaped,*** 12–18 mm (0.5–0.7 in) long, ***2-lipped,*** lower lip 2-lobed, upper lip 3-lobed, hairy on outer surface. Fruits are 4 small nutlets, partially enclosed by persistent calyx. **Harvest:** young leaves and shoots in spring. **Preparation:** Combine with other greens in salads; use young leafy shoots as potherb. For spiced henbit, chop 4 cups shoots, cover with water, and boil 10 min. Separately melt 3 tbsp butter or margarine, add 1 tsp curry powder, 2 whole cloves, and ¼ tsp ground cinnamon. Stir and cook 1 min. Stir in 2 tbsp flour and cook 1 more min. Add ½ cup water from boiling henbit and stir until smooth. Add cooked henbit and ¾ cup sour cream. Simmer 15 min gently. **Related edible species:** Henbit *(L. purpureum),* with the same distribution, is very similar except leaves are stalked. **Poisonous look-alikes:** none.

Wood violet *Viola palmata*

Also edible summer

Habitat: wooded floodplains, rich deciduous forests, especially on slopes and ledges. **Identification:** ***perennial herb*** from thick, elongated underground stem (rhizome); above ground stem absent. ***Leaves*** simple, ***6–12 cm*** (2.4–4.7 in) ***long,*** often wider, broadest near base, ***blade deeply 5- to 11-lobed,*** lobes variously toothed, smooth or hairy, leafstalks long, to 20 cm (8 in); with linear to narrowly lance-shaped bracts (stipules) at base of each leaf. ***Flowers produced singly at tip of stalk as long as leaves, deep reddish-violet to violet,*** 1.7–4 cm (0.7–1.6 in) across, petals 5, lateral ones bearded, with short spur in back. Fruits are egg-shaped capsules 6–12 mm (0.2–0.5 in) long. **Harvest:** Gather flowers, leaving stems behind. Give preference to bright-green, young, tender leaves; but older darker-green summer leaves are edible too. **Preparation:** Use fresh flowers as trail snack or for jelly, jam, syrup, candy. For jelly, cover 2 cups flowers with boiling water in jar and leave overnight. Then strain and discard flowers. Add juice of 1 lemon and 1 pkg pectin. Bring to boil and add 4 cups sugar. Boil again for 1 min. Pour into sterilized jars and seal. For syrup, pour 2 cups boiling water over 6 cups flowers and leave overnight. Strain and discard flowers. Combine liquid with 2 cups sugar. Boil until syrup thickens. Store in covered jars in refrigerator. For other uses, see CANADA VIOLET. **Related edible species:** CANADA VIOLET, PALE VIOLET, western mountain violet, *(V. purpurea),* and southern wood violet *(V. hirsutula).* It is likely that all of the violet species are edible, with some more palatable than others. Some may have a cathartic effect. **Poisonous look-alikes:** Violet leaves resemble leaves of other wildflowers, some of which are toxic. So it's safest to collect leaves only when flowers are in bloom.

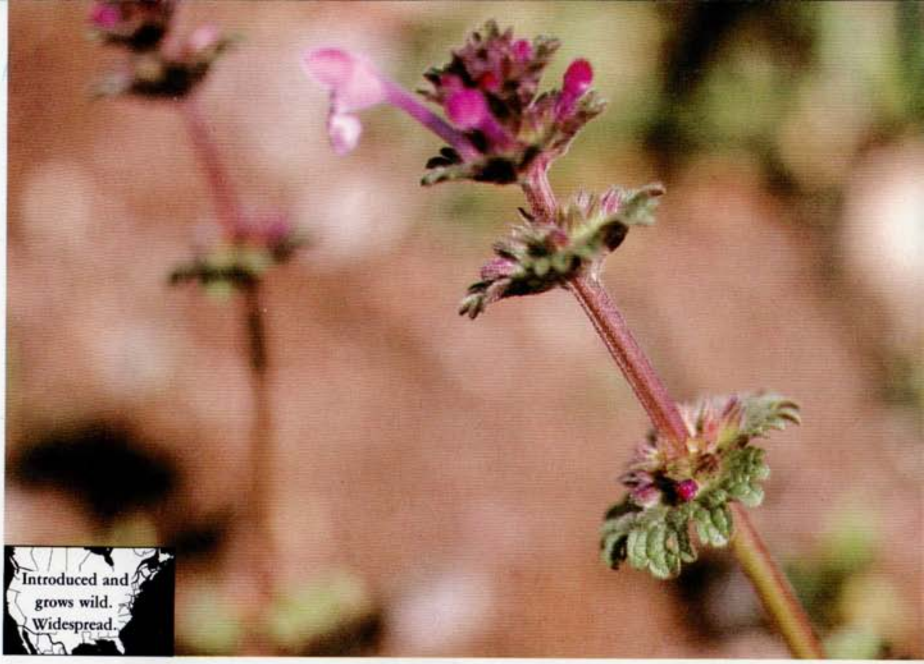
Introduced and grows wild. Widespread.

Henbit: flowering stock (Elias).

Wood violet: flowering plant (Elias).

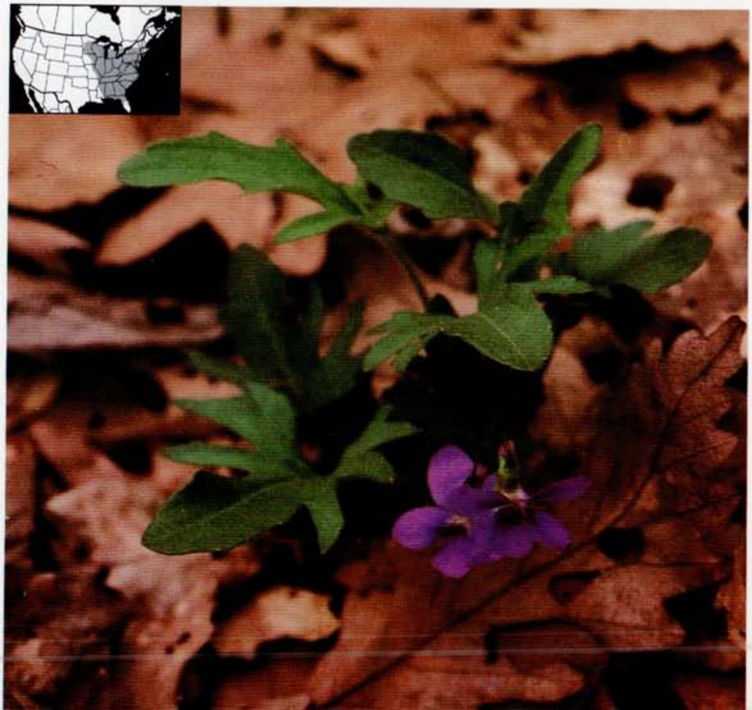

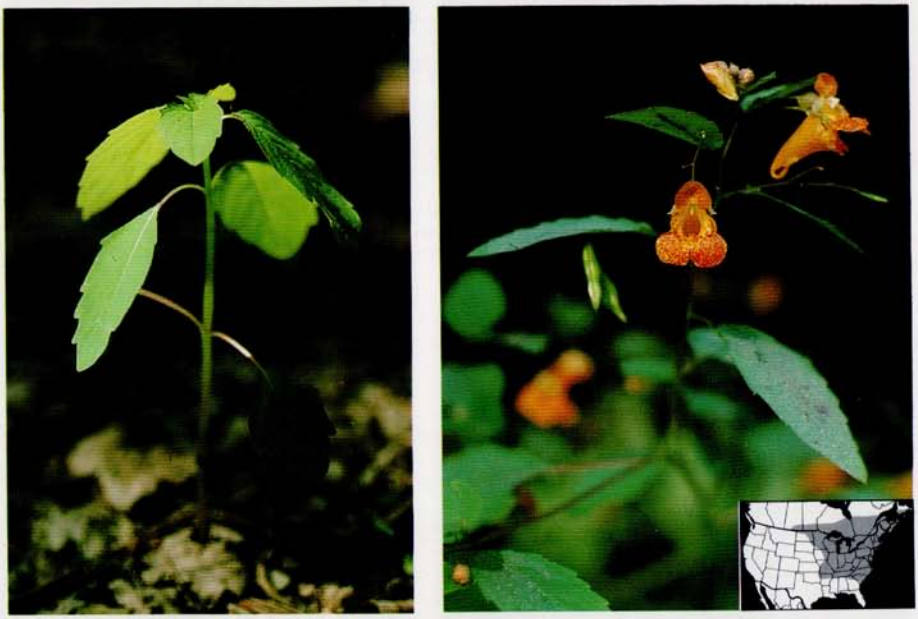

Orange-flowered jewelweed: flowering plant (Dykeman). Young plant (Elias).

Yellow-flowered jewelweed: flowering stalks (Elias).

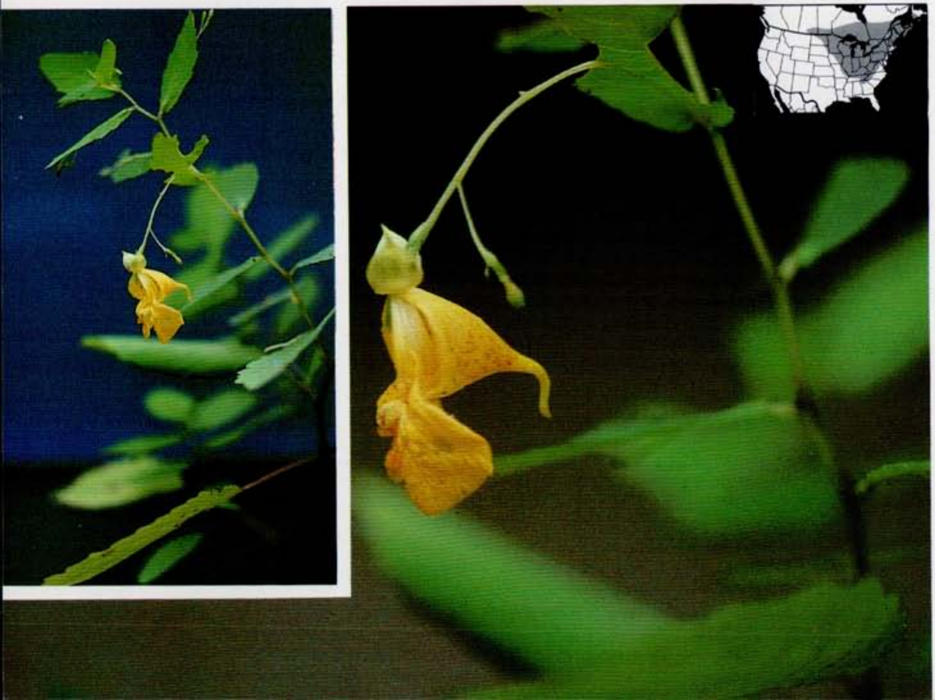

Orange-flowered jewelweed, Spotted touch-me-not *Impatiens biflora* (synonym: *I. capensis*)

Habitat: widespread in wet areas, along streams, ponds, springs, swamps, low moist woodlands, floodplains, bottomlands. **Identification:** annual herb; ***stems*** upright, to 1.5 m (5 ft) high, branched, ***very juicy,*** smooth. Leaves alternate, 4–12 cm (1.6–4.7 in) long, 3–7 cm (1.2–2.8 in) wide, broadest at or below middle, blunt- or round-toothed along margin, long-stalked. Flowers showy, in few-flowered, spreading clusters; each ***flower*** stalked, ***with conspicuous saclike spur in rear, orange to orange-yellow spotted with reddish, yellow, or white spots on face. Fruit*** elongate, cylinder-shaped capsule 1.5–2.5 cm (0.6–1 in) long, at maturity ***exploding suddenly when touched to scatter seeds.*** **Harvest and preparation:** For potherb, pick ***young shoots*** to 15 cm (6 in) high; wilts quickly, so use immediately. Cover with water; boil 10–15 min, draining and adding fresh boiling water twice. Season and butter. *Caution:* Frequent use as a potherb is not recommended because of abundance of calcium oxalate crystals. Seeds: As pods ripen, shake plant over fine net; separate seeds from rest of fruit. Tastes like BUTTERNUTS; eat as gathered or use as topping for desserts. Medicinal use: Applied to skin, juice prevents and relieves symptoms of POISON IVY, NETTLES, and fungal dermatitis. Apply raw juice or concentrated boiled juice of crushed stems. Extract spoils quickly, but frozen extract retains medicinal properties. Antifungal agent is 2-methoxy-1, 4-naphthoquinone. **Related edible species:** YELLOW-FLOWERED JEWELWEED (next). **Poisonous look-alikes:** none.

Yellow-flowered jewelweed, Pale touch-me-not *Impatiens pallida*

Habitat: moist woodlands, wet meadows; not as abundant and usually occurring in slightly drier sites than ORANGE-FLOWERED JEWELWEED. **Identification:** annual herb; ***stems*** upright, to 2 m (6.6 ft) high, freely branched, ***very juicy,*** smooth. Leaves alternate, long stalked, blades 4–14 cm (1.6–5.5 in) long, 3–8 cm (1.2–3.2 in) wide, broadest at or below middle, blunt or round toothed along margin. ***Flowers showy, in few-flowered clusters*** in junctions of upper leaves; ***each flower*** stalked, ***with conspicuous saclike spur in rear, pale yellow with reddish spots on face. Fruit elongate, cylinder-shaped capsule 2–2.6 cm (0.8–1 in) long, at maturity exploding suddenly when touched to scatter seeds.*** **Harvest and preparation:** same as for ORANGE-FLOWERED JEWELWEED (preceding). **Related edible species:** ORANGE-FLOWERED JEWELWEED. **Poisonous look-alikes:** none.

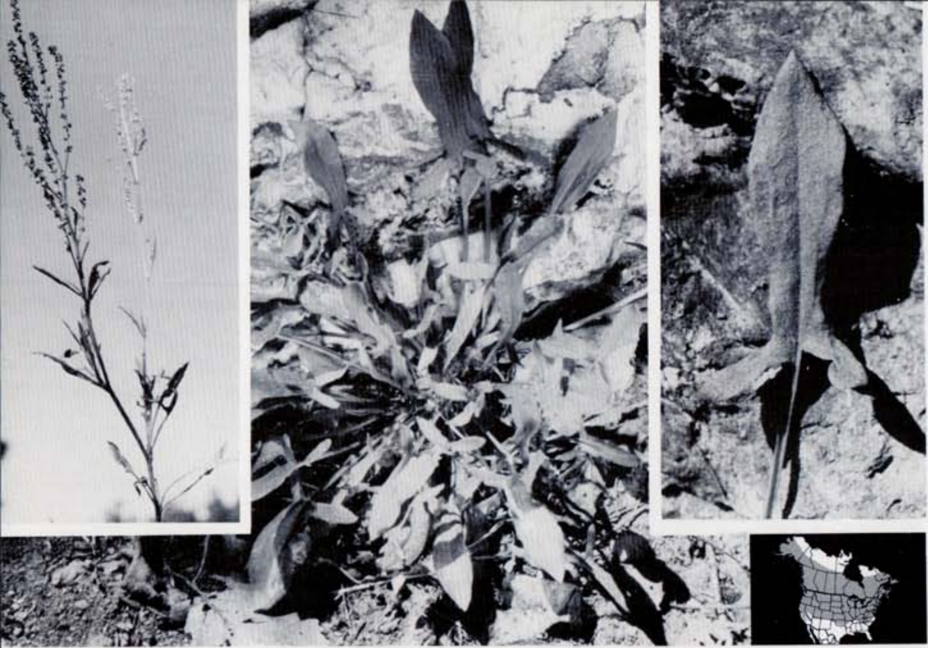

Sheep sorrel: flowering stalk (Elias). Basal leaves and leaf (Dykeman).

Sour dock: flowering stalks (Elias).

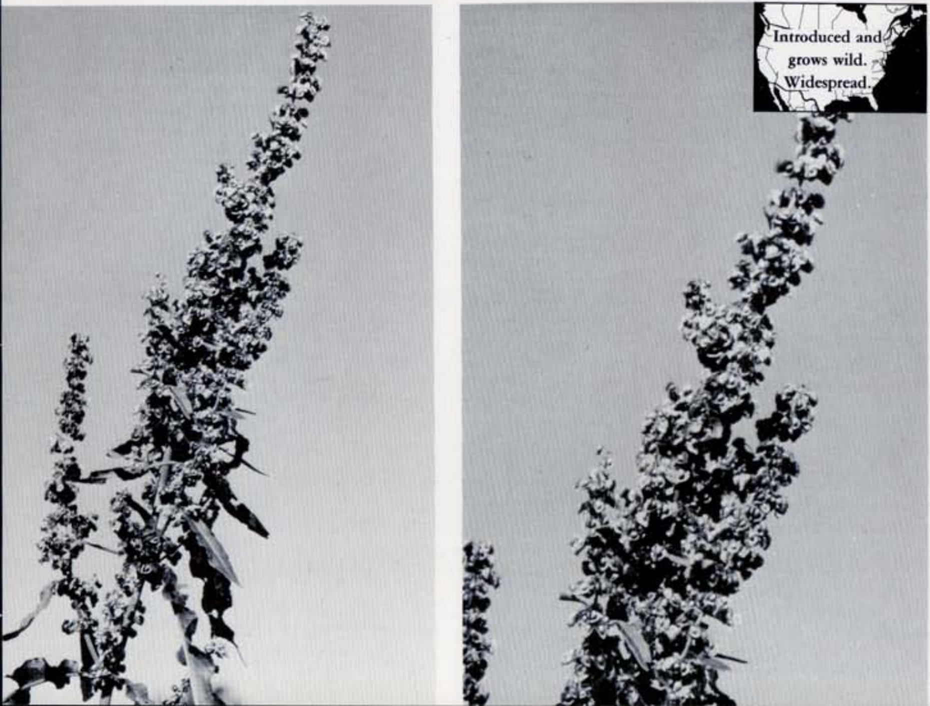
Introduced and grows wild. Widespread.

Sheep sorrel *Rumex acetosella*

Also edible summer, autumn

Habitat: disturbed sites, gardens, old fields, mainly on acid soils. **Identification:** annual or perennial ***herb*** to 50 cm (20 in); stems upright, 4-sided, unbranched or branched. Basal leaves present, shaped like a narrow arrowhead. ***Stem leaves 2.4–5 cm*** (1–2 in) ***long,*** 0.5–2 cm (0.2–0.8 in) wide, ***narrow arrowhead-shaped,*** pointed at tip, ***with slender pointed lobes at base,*** with papery sheath around stem where leaves are attached. ***Flowers tiny,*** green, yellow, red to purple, ***clustered on narrow elongate spikes.*** Fruits are tiny nutlets 1.2–1.8 mm (less than 0.1 in) long, 3-angled, shiny yellow-brown, enclosed by persistent calyx. **Harvest:** Pick or cut leaves from healthy, deep green clumps from spring until autumn, but flowering clumps may be tough. **Preparation:** Sour taste makes sheep sorrel leaves an excellent thirst-quenching trail nibble. Use leaves liberally with bland greens in tossed salad. For beverage boil 1 cup loosely packed leaves in 1 qt water for 2–3 min; then cover and steep for at least 15 min. Strain, add sugar or honey to taste, and serve hot or cold. Boil leaves in 2 changes of water for pleasantly sour potherb or mix with other cooked greens. Use leaves with chicken broth to make soup or sauce to use with fish, rice, or vegetables. *Caution: Large quantity may cause stomach upset.* **Related edible species:** Many species of dock, including SOUR DOCK (next), are edible; sheep sorrel has the most distinctive sour flavor. **Poisonous look-alikes:** none.

Sour dock, Curled dock, Yellow dock *Rumex crispus*

Also edible summer, autumn, winter

Habitat: common in disturbed sites, fields, roadsides, vacant lots. **Identification:** ***large herb,*** usually biennial, to 1.5 m (5 ft) tall; stems upright, smooth, ribbed. ***Leaves*** 14–24 cm (5.5–9.4 in) long, 2–6.5 cm (0.8–2.5 in) wide, uniformly wide to widest near base, pointed at tip, ***strongly wavy and curled along margin,*** rounded to heart-shaped at base, dark green, ***with papery, straw-colored sheath around stem where leaves are attached.*** Flowers small, usually greenish, stalked, densely clustered on 1 to several narrow, elongated stalks. ***Fruits 3-parted,*** 4–6 mm (0.2 in) across, dark red to reddish-brown, each ***enclosing*** 3 ***nutlets*** 1.5–3 mm (0.1 in) in diameter. **Harvest:** leaves in early spring, or even through late winter when they may be tinged with red and yellow. Strip seeds from stalks in late summer and autumn. **Preparation:** Young leaves cooked for about 10 min in small amount of water taste like young beet greens. Older leaves may need longer cooking with 1–2 water changes to make them tender and remove bitterness. Cook with other wild greens of season. Serve with butter, bacon, hard-boiled egg, seasonings. *Caution: Large quantity may cause stomach upset.* With much effort seeds can be hulled, winnowed, ground, and sifted to produce palatable flour. Use half and half with regular flour. **Related edible species:** While most species of dock are likely edible, sour dock is one of the most flavorful. **Poisonous look-alikes:** none.

Eastern hemlock *Tsuga canadensis*

Habitat: cool moist ravines, protected valleys, lowlands. **Identification:** medium or large ***evergreen tree*** to 25 m (82 ft), rarely taller, with deeply furrowed, reddish-brown or cinnamon red bark. ***Leaves small,*** 0.7–1.6 cm (0.3–0.6 in) long, 1–2 mm (less than 0.1 in) wide, ***linear, arranged in 1 plane horizontal to ground, flattened,*** dark yellowish-green ***with 2 whitish bands underneath.*** Male flowering cones tiny, yellowish, at tips of branches; female cones small, green, leathery. ***Fruiting cones 1.2–1.9 cm*** (0.5–0.7 in) ***long,*** hanging, widest near middle, rounded or pointed at tip, ***light brown;*** cone scales nearly rounded; seeds tiny, egg-shaped, winged. **Harvest:** needles any time but preferably young ones in spring. Inner bark best in winter and early spring. **Preparation:** For tea, boil needles in covered pot and steep about 10 min. Tea is high in vitamin C. To avoid damage to tree, use inner bark only in emergency. It may be eaten raw or boiled, or dried and ground to mix with flour. **Related edible species:** Carolina hemlock *(T. caroliniana),* western hemlock *(T. heterophylla),* mountain hemlock *(T. mertensiana).* **Poisonous look-alikes:** AMERICAN YEW is a commonly cultivated shrub that has longer needles and bright red, fleshy pulp surrounding seeds.

Yellow birch *Betula alleghaniensis*
Also edible autumn, winter (synonym: *B. lutea*)

Habitat: rich woodlands, lower slopes, and occasionally cool marshlands, usually below 1,000 m (3,300 ft) elevation. **Identification:** medium-size tree with rounded crown and peeling ragged-edged, reddish-brown ***bark*** turning ***dull yellow or yellowish-brown. Broken twigs have mild wintergreen fragrance.*** Leaves alternate, deciduous, simple, 7–11 cm (2.8–4.3 in) long, 3–5 cm (1.2–2 in) wide, usually broadest near base, with double row of sharp-pointed teeth along margin. Male and female flowers in separate catkins on same tree in spring. ***Fruits broad, upright cones 2.5–3.5 cm (1–1.4 in) long,*** with numerous 3-lobed scales and tiny winged seeds. **Harvest:** For sap, tap like SUGAR MAPLE, 3–4 weeks after maple sap flow begins. Flow copious but sugar content lower than from maple. For use of twigs and inner bark, see instructions under more flavorful SWEET BIRCH (next). **Preparation:** Boil sap in shallow open container outdoors, adding more as volume decreases, until evaporation leaves viscous, molasses-flavored syrup with temperature about 104°C (220°F). Ratio of sap to ultimate syrup is far greater than for SUGAR MAPLE. Store in sterilized, filled, sealed jars. **Related edible species:** SWEET BIRCH. **Poisonous look-alikes:** none.

Sweet birch, Black birch *(Also edible summer, autumn, winter)* *Betula lenta*

Habitat: forest or open woods, especially moist, north-facing, protected slopes, in deep, rich, well-drained soils. **Identification:** medium-size tree with rounded crown and ***smooth, dark red to almost black bark. Broken twigs have wintergreen fragrance.*** Leaves alternate, deciduous, simple, 6–15 cm (2.4–6 in) long, 4–8 cm (1.6–3.2 in) wide, broadest near base, ***with double row of fine, sharp-pointed teeth along margin.*** Male and female flowers in separate, small catkins on same tree in spring. Fruits in erect, brownish cones 2.5–3 cm (1–1.2 in) long, containing many tiny, winged seeds. Fruits maturing in late summer and early

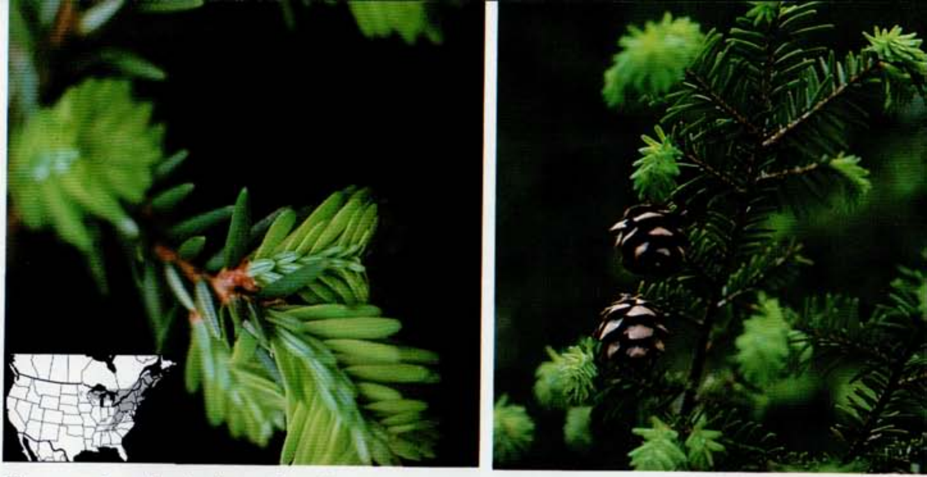

Eastern hemlock: branch with young leaves and branch with mature cones (Elias).

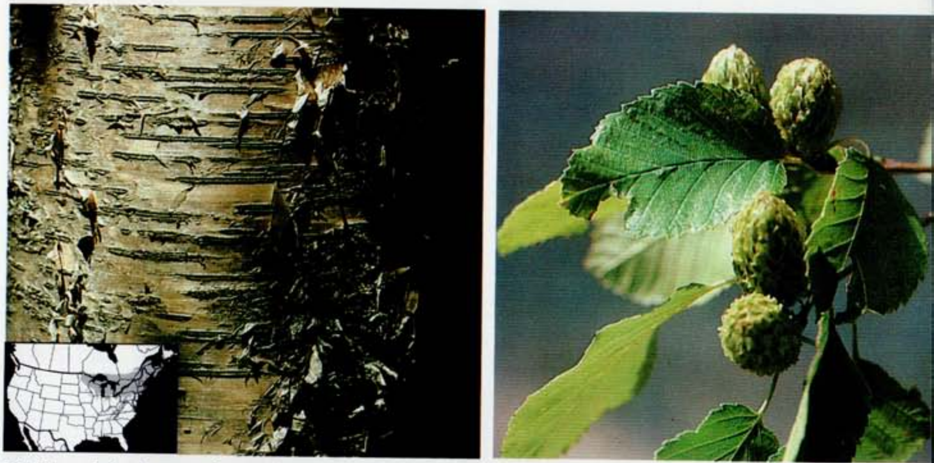

Yellow birch: trunk (Dykeman). Branch with fruits (Elias).

Sweet birch: spring branch with male flowers (Dykeman). Fruit in summer (Elias). Trunk (Dykeman).

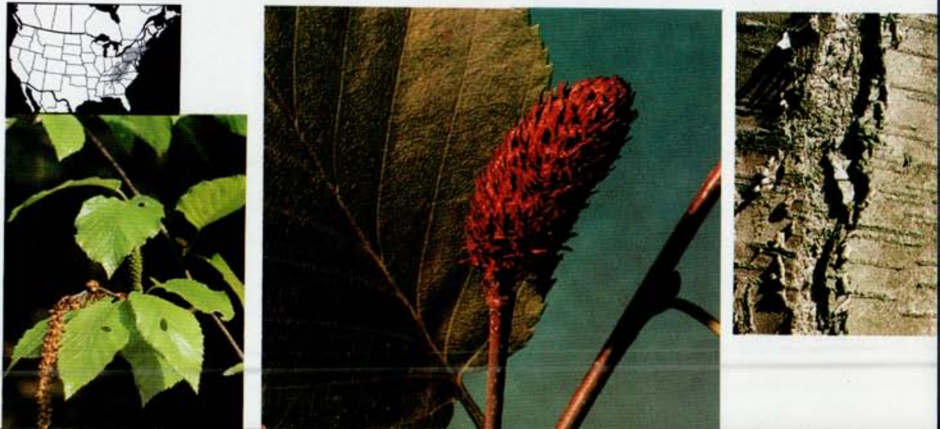

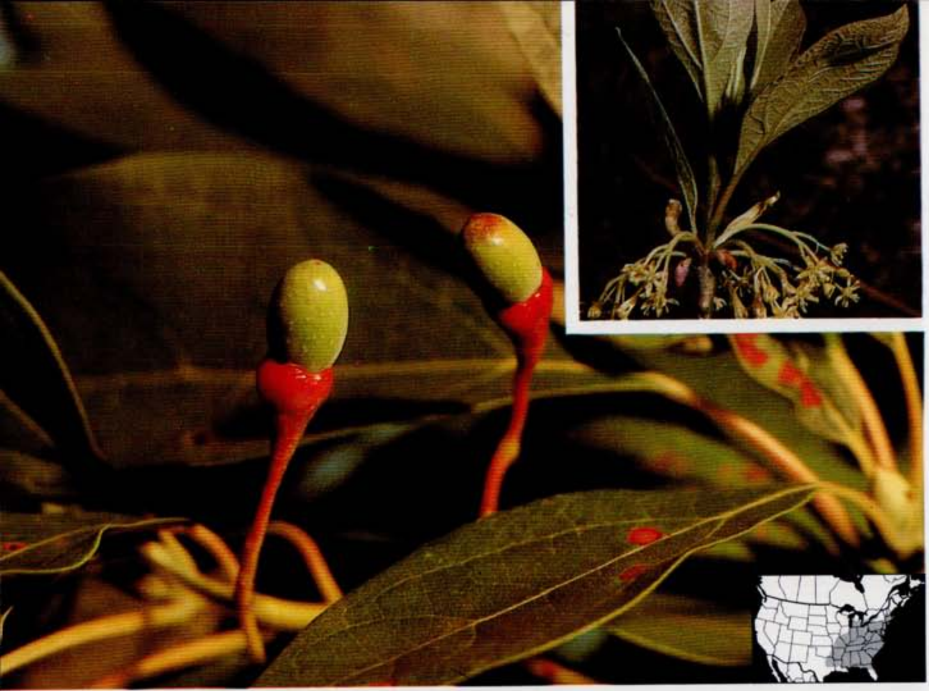

Sassafras: summer branch with fruits (Elias). Spring branch with flowers (NYBG).

Sugar maple: fruiting branch (Soderstrom).

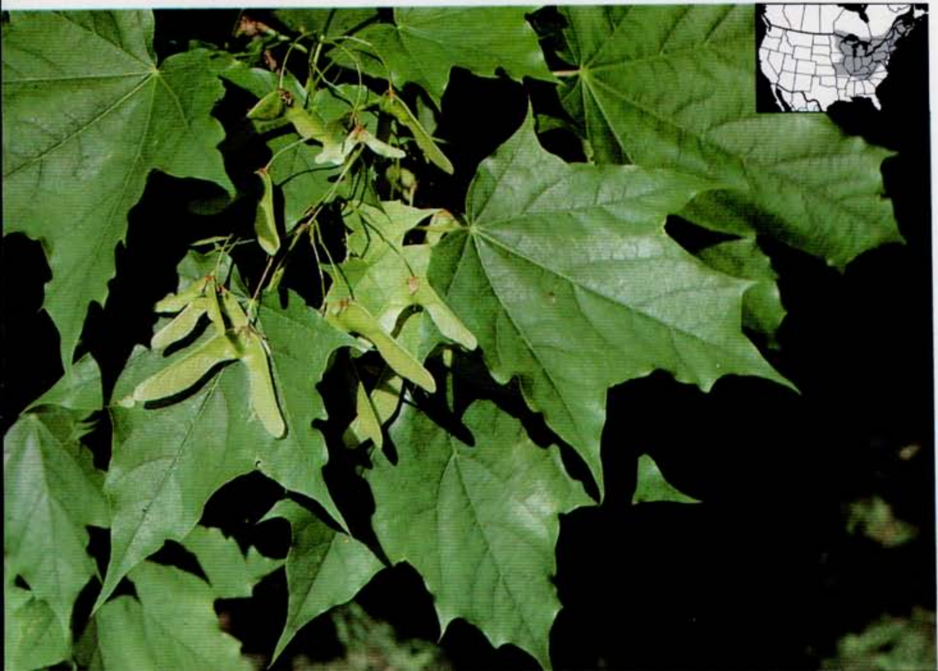

fall. **Harvest:** twigs, red inner bark, larger roots: year-round but best in spring. For sap in spring, 3–4 weeks later than SUGAR MAPLE. See instructions under YELLOW BIRCH (preceding). **Preparation:** inner bark raw as emergency food, boiled like noodles, or dried and ground into flour. Dry inner bark at room temperature; store in sealed jars. For tea, steep (do not boil) twigs or fresh or dried inner bark in water or, preferably, birch sap. Boiling destroys volatile wintergreen oil. For birch beer, pour solution of 4 gal birch sap and 1 gal honey (or 5 gal sap and 3 lb sugar), which has been boiled 10 min, over 4 qt fine twigs in crock. Cool, strain to remove twigs, add 1 cake yeast. Cover; ferment about 1 week, until cloudiness starts to settle. Bottle and cap tightly. For birch syrup, see YELLOW BIRCH. **Related edible species:** YELLOW BIRCH. **Poisonous look-alikes:** none.

Sassafras *(Also edible summer, autumn, winter)* *Sassafras albidum*

Habitat: bottomlands, moist soil of open woodlands, lower slopes. **Identification:** small to medium-size tree with open, flat-topped crown and smooth to deeply and irregularly furrowed, reddish-brown bark on older trees. Leaves alternate, deciduous, simple, ***in 3 shapes (entire or with 2 or 3 lobes), 10–15 cm (4–6 in) long,*** 5–10 cm (2–4 in) wide, broadest near base, ***bright green, with spicy odor when crushed.*** Flowers produced in clusters in spring, each small, yellow, and either male or female (each tree male or female). Fruits egg-shaped 1–1.5 cm (0.4–0.6 in) long, dark blue, stalked, enclosed at base by small red cup. **Harvest and preparation:** year-round. Carefully pull several suckers near base of parent tree to obtain small roots. For larger harvest, brittle roots require digging. Flavor is in root bark. Boil washed roots or root bark in water (or maple sap) until liquid is red. Sweeten to taste; drink hot or cold. Roots may be reused. Dried, pulverized root bark is pungent meat spice. Dried, pulverized leaves flavor and thicken soups and gravies. Use green winter buds and young leaves in salads. *Caution:* Sassafras reportedly has carcinogenic properties. Basic jelly recipe: Make jelly with 3 cups strong sassafras tea, 3 oz powdered pectin, ½ tsp citric acid, 4 cups sugar; or use 2 cups tea, 1 pkg pectin, 3 cups honey, powdered root bark to taste. **Related edible species:** SPICE BUSH. **Poisonous look-alikes:** none.

Sugar maple *(Also edible summer, winter)* *Acer saccharum*

Habitat: eastern deciduous forest, common and widespread, especially at lower elevations. **Identification:** medium-size to tall ***tree*** to 30 m (98 ft) with rounded crown, slightly fissured to furrowed dark gray bark. ***Leaves opposite,*** simple, 7.5–20 cm (3–8 in) long and broad, broadest near base, ***3- to 5-lobed, lobes with a few coarse teeth along margin,*** bright green, smooth above and below. Flowers small, bisexual, produced in slender hanging clusters before leaves emerge. ***Fruits are winged (samaras), 3–3.5 cm*** (1.2–1.4 in) ***long,*** wings spreading at 60° angle. **Harvest:** Obtain sap from first spring flow, until buds swell. Good sap flow requires freezing nights and warm days. Drill hole [11 mm (7/16 in) for commercial spile] slightly upward and 5–8 cm (2–3 in) into trunk. Drive spile in far enough to hold bucket, not so hard to split wood. Collect sap and store cold until you have 25–30 gal. Collect winged seeds before fully ripe, usually from June to September. **Preparation:** Boil sap outdoors, indoors only if you like sticky walls. Use large surfaced, open pan, adding sap as water boils off. After adding all sap, continue boiling until temperature is 4°C (7°F) above that of boiling water on that particular day. You may wish to boil for the last two degrees on a controllable stove. Pour syrup through milk filter, filling sterilized canning jars, and seal. Yields about 3 qt. For maple sugar, boil 1 pt syrup in saucepan with frequent stirring until temperature is at least 110°C (230°F). Remove from heat, cool and stir until surface loses sheen. Pour quickly onto foil or waxed paper. When partially hardened, score into pieces with knife. Use sap fresh as beverage, fermented to form mild vinegar, or reduced by boiling to ¼ original volume as base for teas. Soak seeds and remove wings. Boil until tender, drain, season, and roast for 10–15 min. **Related edible species:** Sap of all native maples may be used for syrup. Sugar maple is sweetest. **Poisonous look-alikes:** none; avoid Norway maple *(A. platanoides),* which has milky sap.

Summer

By summer most of the leafy edibles that were tender in spring have toughened and become unpalatable. Yet many late-starting plants are usable through the summer and include the mints of fields and water's edge as well as purslane from the untended garden. Spring strawberries are succeeded by a host of other delicious fruits including raspberries, mulberries, blueberries, blackberries, serviceberries, and beach plums. So summer is the prime season for pies, jams, jellies, and juices, as well as food-drying projects.

As the days grow shorter in late August and September, fewer and fewer shrubs and trees yield juicy, flavorful fruits. Yet this slow period before the fall fruit and nut season can still keep a forager busy. Now you can find ripe seed clusters from many of the same plants whose greens served as edibles in spring; some of these include lamb's quarters, amaranth, plantain, and dock. Threshed, winnowed, and ground, these seeds provide tasty and nutritious flour supplements.

Of course, summer is also the season to beware of stinging nettles, poison ivy, and pesky briars, the briars coming in many disguises.

Additional summer edibles

Plants listed below have parts that are edible in summer and at least one additional season. Descriptions and photos of these plants appear in a seasonal section other than "Summer," as indicated.

Allegheny chinkapin (*Castanea pumila*), p. 234
Arrowhead (*Sagittaria latifolia*), p. 212
Black mustard (*Brassica nigra*), p. 100
Bullbrier (*Smilax bona-nox*), p. 66
Butternut (*Juglans cinerea*), p. 246
California grape (*Vitis californica*), p. 216
California rose (*Rosa californica*), p. 220
Canada violet (*Viola canadensis*), p. 94
Carrion flower (*Smilax herbacea*), p. 66
Cattail (*Typha latifolia*), p. 68
Common burdock (*Arctium minus*), p. 112
Common chickweed (*Stellaria media*), p. 84
Common greenbrier (*Smilax rotundifolia*), p. 64
Common milkweed (*Asclepias syriaca*), p. 106
Eastern camass (*Camassia scilloides*), p. 64
Fireweed (*Epilobium angustifolium*), p. 108
Frost grape (*Vitis vulpina*), p. 214
Garlic mustard (*Alliaria officinalis*), p. 84
Glasswort (*Salicornia europea*), p. 76
Great bulrush (*Scirpus validus*), p. 70
Green pigweed (*Amaranthus hybridus*), p. 72
Hard-stem bulrush (*Scirpus acutus*), p. 70
James chickweed (*Stellaria jamesiana*), p. 84
Lady's thumb (*Polygonum persicaria*), p. 110
Lotus lily (*Nelumbo lutea*), p. 210
Miner's lettuce (*Montia perfoliata*), p. 94
Narrow-leaved cattail (*Typha angustifolia*), p. 68
Pale violet (*Viola striata*), p. 96
Pigweed (*Amaranthus retroflexus*), p. 72
Plantain (*Plantago major*), p. 78
Riverside grape (*Vitis riparia*), p. 214
Russian thistle (*Salsola kali*), p. 76
Sassafras (*Sassafras albidum*), p. 124
Sheep sorrel (*Rumex acetosella*), p. 120
Sour dock (*Rumex crispus*), p. 120
Spice bush (*Lindera benzoin*), p. 218
Squashberry (*Viburnum edule*), p. 226, 252
Sugar maple (*Acer saccharum*), p. 124, 256
Sweet birch (*Betula lenta*), p. 122, 252
Sweetbrier rose (*Rosa eglanteria*), p. 222
Wild garlic (*Allium canadense*), p. 60
Wild leek (*Allium tricoccum*), p. 60
Wild onion (*Allium cernuum*), p. 58
Wild potato vine (*Ipomoea pandurata*), p. 216
Wild rose (*Rosa carolina*), p. 222
Wild strawberry (*Fragaria virginiana*), p. 90
Wintercress (*Barbarea vulgaris*), p. 98
Wood violet (*Viola palmata*), p. 116
Wrinkled rose (*Rosa rugosa*), p. 222
Yellow pond lily (*Nuphar advena*), p. 212

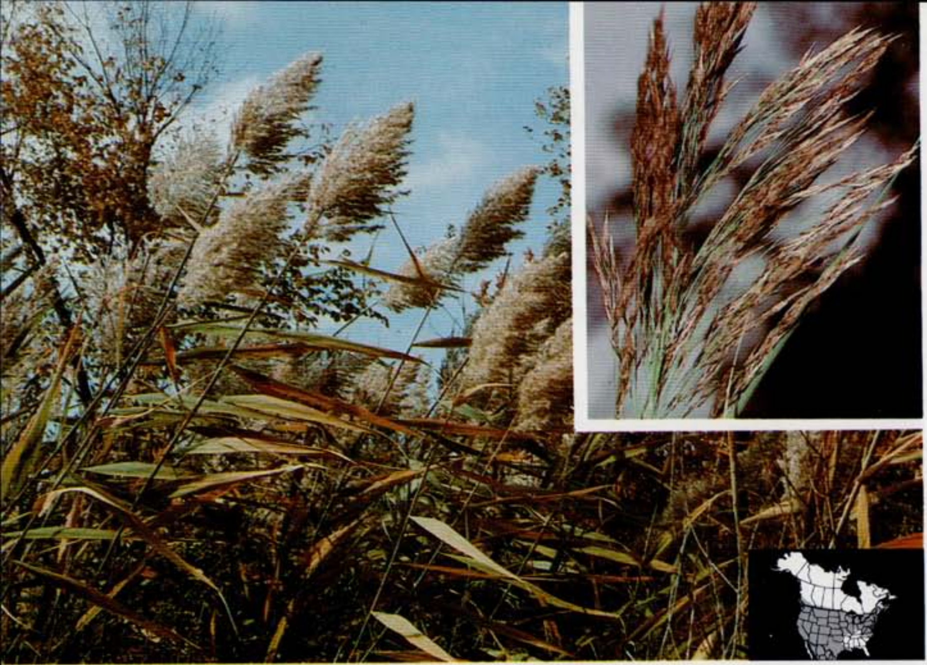

Reed grass: flowering plants (Feldman). Flowers (Mohlenbrock).

Wild rice: flower stalk with male flowers topmost and stalks with female flowers (Elias).

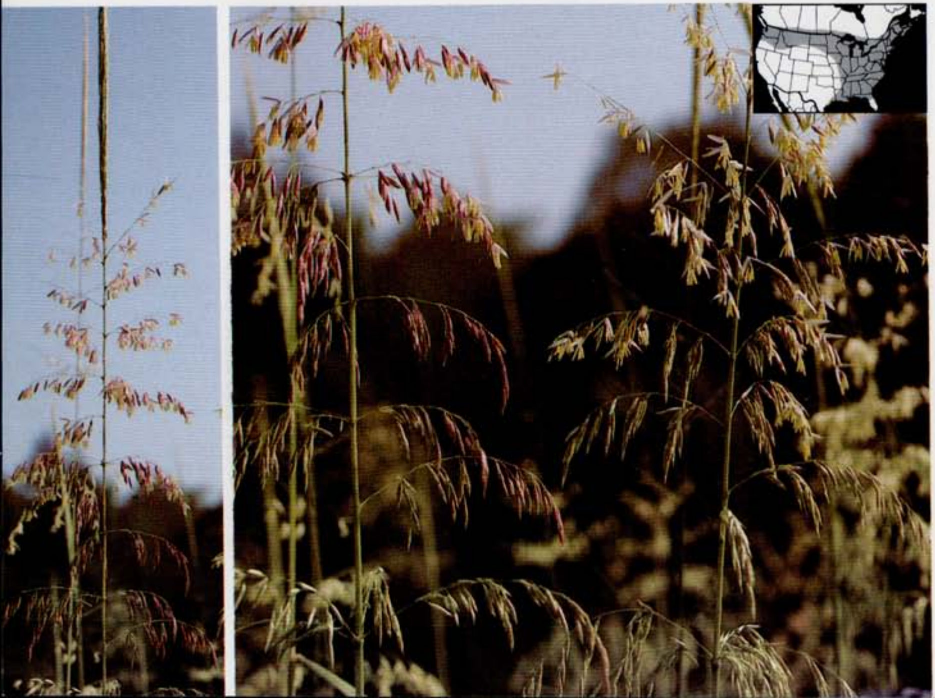

Reed grass, Phragmites *(Also edible autumn, winter, spring)* *Phragmites communis*

Habitat: margins of streams, lakes, ponds, marshes, springs, ditches. **Identification:** ***tall perennial grass,*** with long, spreading underground stems (rhizomes), often forming dense clumps; ***stems upright, 2–4 m*** (6.6–13 ft) ***high,*** stout; ***leaf blades*** flat, long, ***18–60 cm*** (7–24 in) ***long,*** narrow, 1–6 cm (0.4–2.4 in) wide, smooth, base of leaf sheathing part of stem. ***Flowers many in large, dense, elongated, branched, plumelike clusters 15–40 cm*** (6–16 in) ***long,*** purplish at first, turning tan to whitish at maturity, side branches ascending, each spikelet (small simple cluster of flowers sharing the same stalk) 1–1.6 cm (0.4–0.6 in) long, ***with numerous long, silky hairs.*** Fruits are tiny, hard, reddish grains (seeds) many people overlook. **Harvest:** Gather new shoots (at base of old stalks) and leaves early in growing season. Collect hardened sap from wounded stems. Cut whole stems before blooming. Gather seed heads in late summer and autumn. Failure to produce seed is common. Dig roots and underground stems all year. **Preparation:** Eat early shoots raw, or boil or steam until tender; serve as vegetable. Eat hardened gum fresh or toast near fire. Dry stems in sun, beat or grind, sift out fine powder. Moisten powder and place near fire to swell and toast like marshmallows. For gruel, remove seeds by hand. Crush seeds with hulls and mix with spicy berries. Add boiling water and cook until thin reddish gruel, about 30 min; add sweetener. For use of roots and underground stems, see CATTAIL. **Related edible species:** none. **Poisonous look-alikes:** none, but avoid roots and shoots of iris (YELLOW FLAG, BLUE FLAG) and other inedibles.

Wild rice *(Also edible autumn)* *Zizania aquatica*

Habitat: marshes, shallow ponds, lakes, streams, or bays of fresh and brackish water. **Identification:** ***tall annual grass;*** stems upright, usually 1–3 m (3–10 ft), stout; leaf blades long, narrow 0.3–1 m (12–39 in) long, 2–5 cm (0.8–2 in) wide, soft. ***Flowers many, in large, open, branched, elongate, plumelike clusters to 60 cm (2 ft) high,*** side branches 15–20 cm (6–8 in) long, ***lower branches*** spreading to ascending and ***only with male flowers; upper branches erect, bearing only female flowers,*** each about 2 cm (0.8 in) long; seed case tipped with long, stiff, hairlike structures; seed narrow, hard, brown. **Harvest and preparation:** Grains ripen in late summer to early fall. Timing is critical; ripe seeds easily fall from plant. Small, shallow-draft boat or canoe provides best harvesting container. Carefully bend stalks over boat and knock ripe grains into it. Several visits days apart needed for maximum harvest. Spread grains to dry; then parch, stirring occasionally, for 3 hr at 175°C (350°F). Thresh husks from grains by pounding or rubbing. Winnow by pouring from one container to another in natural or fan-generated breeze. Wash grains in cold water to eliminate smoky flavor. Use like cultivated rice. Cooking: Bring 3 cups water and 1 tsp salt to boil. Stir in 1½ cups rice grains and return to boil. Cover and simmer until tender, 30–45 min. Serve buttered or with sweetener. For flour, substitute ground rice for part of wheat flour in baking recipes. **Related edible species:** Texas wildrice *(Z. texana)*. **Poisonous look-alikes:** none, but poisonous pink or purple fungus (*Claviceps* species) occasionally replaces some grains. Learn to recognize and avoid it.

Chufa, Yellow nut grass *Cyperus esculentus*

Also edible autumn, winter, spring

Habitat: ditches, margins of ponds and streams, low wet soils, waste places. **Identification:** ***perennial herb with*** slender underground stems (rhizomes) and ***nearly rounded tubers*** 6–10 mm (0.2–0.4 in) in diameter; ***stems triangular in cross section,*** upright, 20–90 cm (8–36 in) tall, stout, smooth; stem leaves narrow, 5–10 mm (0.2–0.4 in) wide; ***with 3–10 leaves at base of flowering clusters*** but much longer than flower clusters. ***Flowering clusters broadly cylinder-shaped to almost globe-shaped,*** composed of numerous spikelets (small simple cluster of flowers on same stalk); spikelets narrow, elongate, 0.5–3 cm (0.2–1.2 in) long, 4-sided, many-flowered. Fruits are small ***nutlets, 1–1.5 mm*** (less than 0.1 in) ***long, triangular-shaped, yellowish.*** **Harvest:** Gather tubers best from loose or sandy soil where whole plant with tubers is easily pulled or dug from depth of less than a few inches. Gather any time ground is not frozen. **Preparation:** Tubers palatable and useful raw, boiled, candied, dried, and ground into flour, and as beverage base. For flour, dry slowly until tubers break apart instead of mash when hammered lightly. Grind fine in blender or food mill. Use flour half and half with wheat flour. For beverage soak 1½–2 cups tubers for 2 days. Drain and mash or blend in 1 qt water with ¼ cup sugar or honey. Strain out solids before drinking. For coffee substitute, roast tubers until dark brown throughout. Grind and brew 1 tbsp per cup. **Related edible species:** Several species of *Cyperus* have tubers or tuberlike structures. **Poisonous look-alikes:** none.

Pickerelweed *Pontederia cordata*

Also edible autumn

Habitat: along shores or in shallow water of lakes, ponds, slow moving streams, bays. **Identification:** ***perennial herb*** to 1 m (3.2 ft) high, with short, thick underground stem. ***Leaves basal, blade*** 6–20 cm (2.4–8 in) long, 2–12 cm (0.8–4.7 in) wide, broadest near base to very narrow, shape variable but usually ***arrowhead-shaped,*** smooth; ***leafstalk stout, 6–32 cm*** (2.4–13 in) ***long.*** Flowering stalk slightly taller than leaves, bearing 1 or 2 leaflike bracts, ***attractive blue flowers densely clustered on spike 5–16 cm*** (2–6.3 in) ***long, each flower funnel-shaped, 2-lipped.*** Fruits are stiff, egg-shaped capsules 4–10 mm (0.2–0.4 in) long, enclosed by persistent ragged remains of flower. **Harvest:** Pick young leafstalks in early summer before leaves are fully unfurled. Strip fruits off spikes as they ripen in early autumn. **Preparation:** Wash, chop, and add young leafstalks to salads. As potherb boil leafstalks about 10 min, drain, and season. Fruits each contain a solid seed, edible as trail snack or dried and ground like grain. **Related edible species:** LANCE-LEAVED PICKERELWEED (next), used the same as this species. **Poisonous look-alikes:** none.

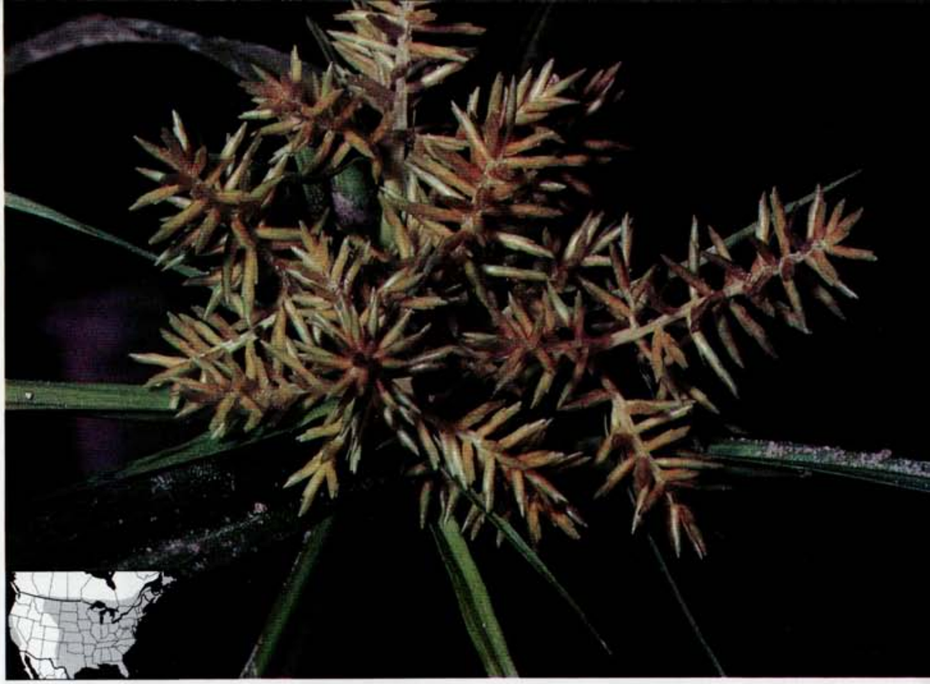

Chufa: fruiting cluster (Mohlenbrock).

Pickerelweed: flowering stalk (NYBG). Plants (Dykeman).

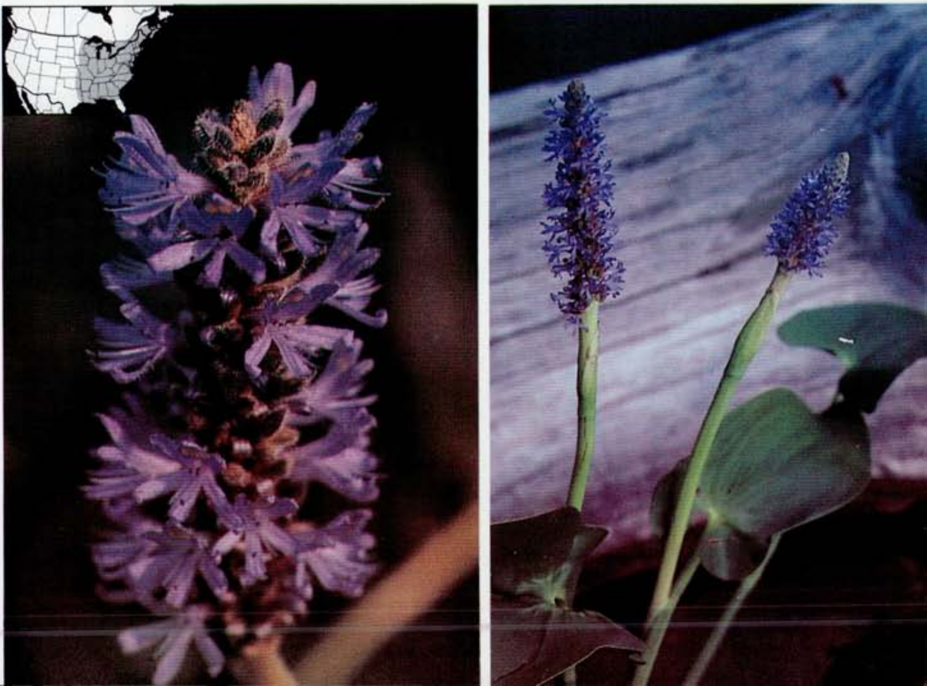

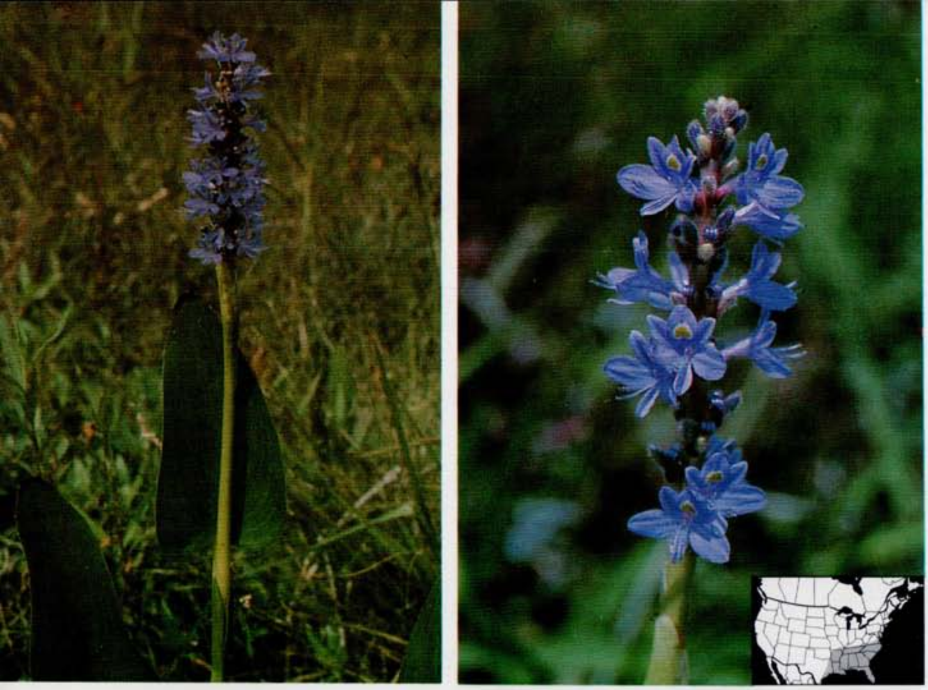

Lance-leaved pickerelweed: plant and flowering stalk (NYBG).

Sweet flag: leaves (Dykeman). Flowering spike (Elias). Rootstock (Dykeman).

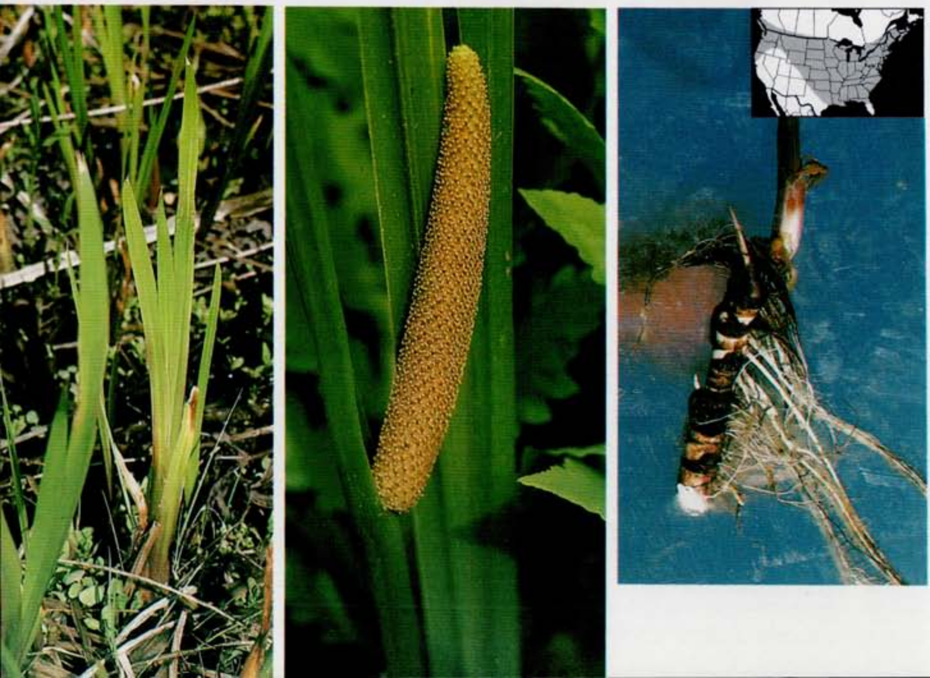

Lance-leaved pickerelweed *Pontederia lanceolata*

Also edible autumn

Habitat: shallow water along shores of lakes, ponds, streams, marshes. **Identification:** perennial herb to 1 m (3.2 ft) tall with thick, creeping underground stem (rhizome). ***Leaves mainly basal,*** blade 6–20 cm (2.4–8 in) long, 2–12 cm (0.8–4.7 in) wide, variable in shape but usually narrowly heart-shaped to arrowhead-shaped, smooth; ***leafstalk stout, 8–30 cm*** (3.2–12 in) ***long.*** Flowering stalk as tall or slightly taller than leaves, usually with a leaflike bract about midway; flowers densely clustered on narrow spike 6–18 cm (2.4–7 in) long, ***each flower blue to purple,*** funnel-shaped, 2-lipped, ***covered with short glandular hairs. Fruits*** stiff, ***egg-shaped capsules 4–8 mm*** (0.2–0.3 in) ***long, usually as broad or broader than long.*** **Harvest and preparation:** See PICKERELWEED (preceding). **Related edible species:** PICKERELWEED. **Poisonous look-alikes:** none.

Sweet flag, Calamus *Acorus calamus*

Habitat: ditches, swamps, pond edges, lakes, and streams; may grow with BLUE FLAG, water flag, and CATTAILS. **Identification:** perennial herb with large, stout, aromatic underground stem (rhizome). ***Leaves*** crowded near base, erect, narrow, ***linear, swordlike but flexible, usually 1–1.5 m*** (3–5 ft) ***long,*** rarely to 2 m (6.6 ft), 1–3 cm (0.4–1.2 in) wide, ***midvein off-center, greenish-yellow, with aromatic, almost spicy, odor when cut.*** Underground stem portions red. ***Flowers*** tiny, bisexual, ***numerous on narrow, tapering spike (spadix) produced about ⅓ of way up leaflike stalk;*** spikes often overlooked. Fruits inconspicuous, borne on flowering spike. **Harvest and preparation:** Harvest tender young stalks when less than 30 cm (1 ft) tall with short underground stems. Grasp and pull firmly. Vertical stem usually breaks off at rhizome. To obtain underground stem, dig with trowel to sever anchoring roots. Inner portions of tender young stems provide spicy trail snack or salad ingredient. For candy, use especially red underground part of stem. Remove roots, wash, peel, slice into 1 cm (0.4 in) long pieces. Cook in several changes of boiling water until pungency is tolerable. Simmer 20 min in syrup of 1 cup water to 2 cups sugar. Drain, dry, roll in sugar. **Related edible species:** none. **Poisonous look-alikes:** Irises (YELLOW FLAG, BLUE FLAG) cause severe digestive upset. Iris leaves lack spicy odor when cut. Flowers are showy.

Spanish bayonet, Datil *(Also edible spring)* *Yucca baccata*

Habitat: dry slopes, usually in sandy or rocky soils from 920–2,440 m (3,000–8,000 ft). **Identification:** ***long-lived perennial*** with short inconspicuous trunk, sometimes in clumps. ***Leaves clustered near base, blade lance-shaped, 50–76 cm*** (20–30 in) ***long, 3–7 cm*** (1.2–2.8 in) ***wide,*** stiff, tip sharp-pointed and ending in stout spine, with coarse, recurved fibers along margin, flattened or concave, grayish-green. Flowering stalk in spring, upright 1–1.5 m (3.2–5 ft) high, densely flowered along upper half, flowers showy, fleshy, sepals 3, reddish-brown on outer surface, petals 3, cream-white, 6–12 cm (2.4–4.7 in) long. ***Fruits are fleshy capsules, 14–18 cm*** (5.5–7 in) ***long,*** broadest near the middle, 3-parted, turning reddish brown at maturity and splitting open to release seeds. **Harvest:** young flower stalks before buds expand and fruits as they are available late spring through summer. Use buds and flowers as described for SOAPWEED (next), but not as good. **Preparation:** Cut young flower stalks into sections, boil 25–30 min or roast until core is tender. Peel off tough rind. Serve with butter, lemon juice, and seasonings. Eat fruit raw or cooked. Roast whole fruits until tender, scrape out pulp and separate from seeds. Sweeten if desired. Use raw pulp for pie. Strain pulp and dry by boiling to paste and finishing in oven as thick sheet. Eat dry or dissolve for beverage. Roast seeds at 190°C (375°F) until dry and crisp. Grind coarsely and boil as vegetable until tender. **Related edible species and poisonous look-alikes:** See SOAPWEED.

Soapweed *(Also edible spring)* *Yucca glauca*

Habitat: prairies, roadsides, pastures—usually in dry, well-drained sandy or rocky soils. **Identification:** perennial with short stem. ***Leaves densely clustered near base*** and covering stem, ***blade linear, 38-60 cm*** (15-24 in) ***long, 0.8-1.2 cm*** (0.3-0.5 in) ***wide,*** stiff, hard and sharp-pointed at tip, with narrow white band and occasional loose threadlike strands along margin, concave, gray-green. Flowering stalk in spring, upright to 1 m (3.3 ft), with stalked flowers along upper half, flowers bowl-shaped, showy, with 3 greenish-white sepals, 3 white petals 4.5–5.5 cm (1.8–2.2 in) long. ***Fruits are cylinder-shaped dry capsules 5–8 cm*** (2–3.2 in) ***long,*** 3–4.5 cm (1.2–1.8 in) in diameter, turning brown, 3-parted and splitting open at maturity to release seeds. **Harvest:** Pick young flower stalks before buds expand. Pick flowers and buds as available. **Preparation:** Cover 1 cup flowers or buds with water and boil until tender, 15–20 min. Drain and chop coarsely. Add with pimento or green pepper to several eggs and little milk. Cook like scrambled eggs. For salad boil 1 cup flowers and buds as above. Drain, chop, and cool. Add celery, chopped apple, raisins, nutmeats, cabbage, and mayonnaise as in Waldorf salad. For flower stalks see SPANISH BAYONET (preceding). Unripe fruits are bitter but can be made palatable by boiling or baking. **Related edible species:** all *Yucca* species including SPANISH BAYONET. Flower and bud uses apply best to dry-fruited species, fruit uses to fleshy-fruited species. Spiny leaved *Agave* looks similar and is also edible. **Poisonous look-alikes:** none.

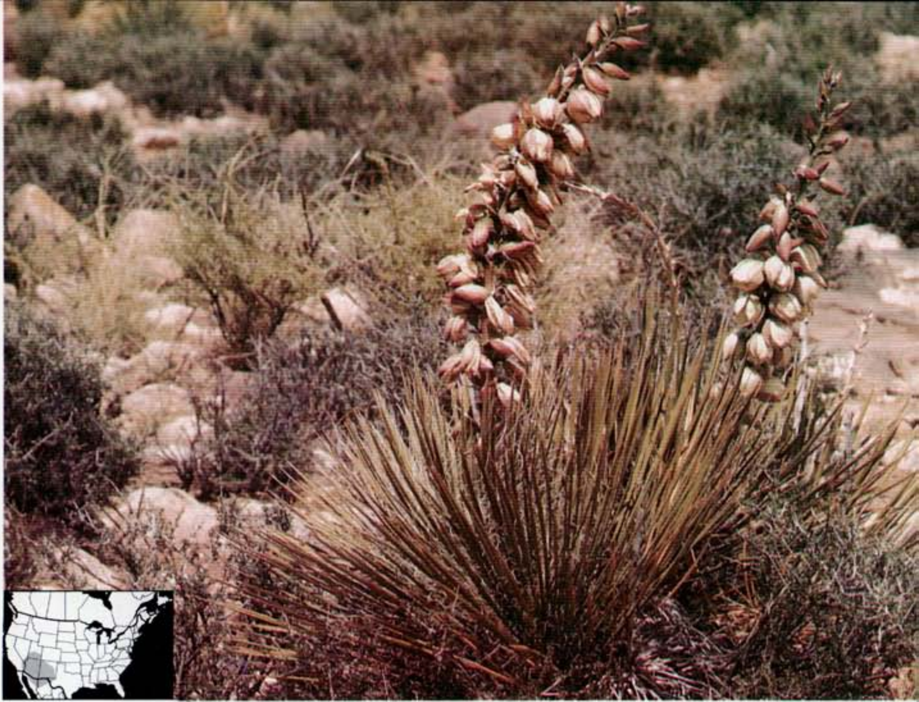

Spanish bayonet: plants (NYBG).

Soapweed: flowering stalk (NYBG). Plants (NYBG).

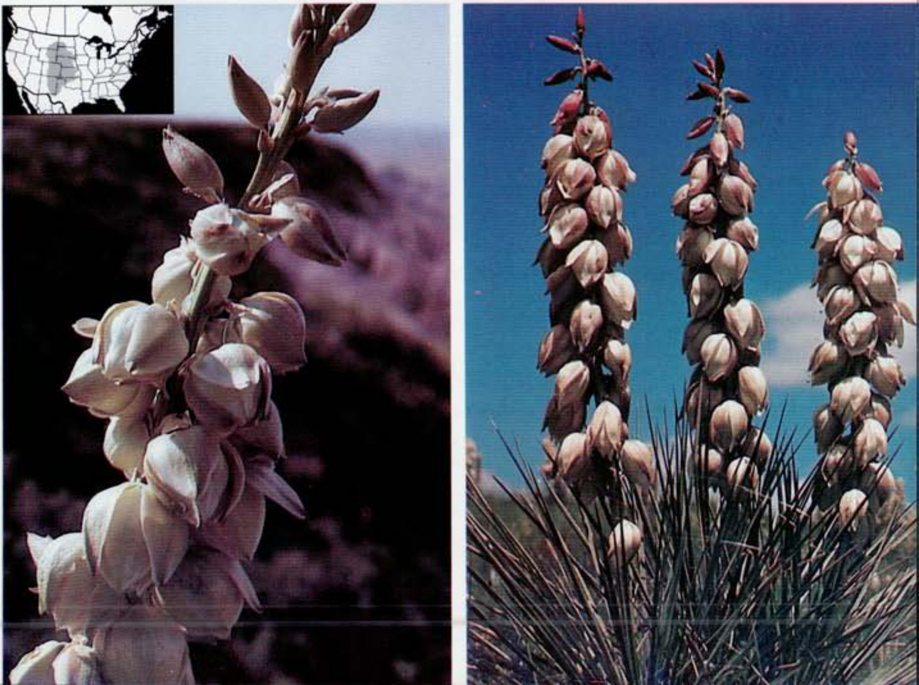

Common day lily *Hemerocallis fulva*

Also edible autumn, spring

Habitat: garden plant that commonly grows wild in abandoned home sites, vacant lots, along roads. **Identification:** large perennial herb from a fibrous root system with short, fingerlike tubers, with numerous ***long, narrow basal leaves.*** Each leaf 0.5–1.5 m (1.7–5 ft) long, 1.5–3 cm (0.6–1.2 in) wide, gradually tapering to long narrow tip, tapering with edges folded inward at base, light green to greenish-yellow. Flowers in clusters of 3–5 at tip of upright stalks, stalks to 2 m (6.6 ft); flower buds narrow, tubular; each ***flower 10–15 cm*** (4–6 in) ***long,*** narrowly tubular at base, ***funnel-shaped*** above, ***with 6 large, showy petallike segments, orange to tawny-orange,*** darker inside, flowering from late May to July, each flower open 1 day only. Fruits fleshy, 3-parted capsules. **Harvest:** tubers 1 cm (0.4 in) × 2–3 cm (0.8–1.2 in). Spade roots over; pick only firm tubers all year. Replant roots. Tubers regenerate rapidly. Pick buds when half to nearly full size. Pick flowers when fully opened or wilting. **Preparation:** Raw tubers give sweet nutty flavor to salads, or boil in salted water until tender, season. Excellent potato substitute. Boil buds a few minutes, butter, and season. Great cooked vegetable; raw they irritate the throat. Dip buds or flowers in egg batter and fry in hot oil or add them to soups at end of preparation for gelatinous quality. Dry buds and flowers at air temperature about a week; store in sealed jars for later use in soups or other recipes. *Caution: Eat in moderation to avoid laxative effect.* **Related edible species:** none. **Poisonous look-alikes:** Leaves slightly resemble those of iris (YELLOW FLAG, BLUE FLAG), but common day lily leaves arch over with tip pointed to ground; iris leaves are upright and darker.

Western camass, Camass lily *Camassia quamash*

Also edible autumn, winter, spring

Habitat: coastal mountain forests, wet meadows of interior mountains. **Identification:** ***perennial herb*** to 80 cm (32 in) high, from bulb 2–3 cm (0.8–1.2 in) across; ***grasslike leaves*** several from base, narrowly lance-shaped, 20–50 cm (8–20 in) long, 0.6–1.8 cm (0.2–0.7 in) wide, pointed at tip. Flower stalk 20–80 cm (8–32 in) high, ***flowers several, stalked, showy, with 6 blue to bluish-violet petals*** or petallike structures, each 2–3.6 cm (0.8–1.4 in) long. Fruits are dry capsules 0.8–2.4 cm (0.3–1 in) long, egg-shaped, splitting open at maturity to release seeds. **Harvest:** Dig or pull bulbs any season, safest when blue flowers distinguish it from DEATH CAMASS. Dig and transplant to safe place where you know there is no DEATH CAMASS. *Be certain of identification!* **Preparation:** Raw bulbs are palatable potato substitute. May be boiled 25–30 min or baked in foil for 45 min at 175°C (350°F). Indians baked bulbs in pit up to 3 days, the resulting product being very dark and sugary. Slice pit-baked or boiled bulbs, dry in sun or warm oven, store in paper bag in dry place. **Related edible species:** EASTERN CAMASS. **Poisonous look-alikes:** DEATH CAMASS (*Zigadenus* species), narrow-leaved plants with green, white, or bronze flowers, single or several in narrow stalk.

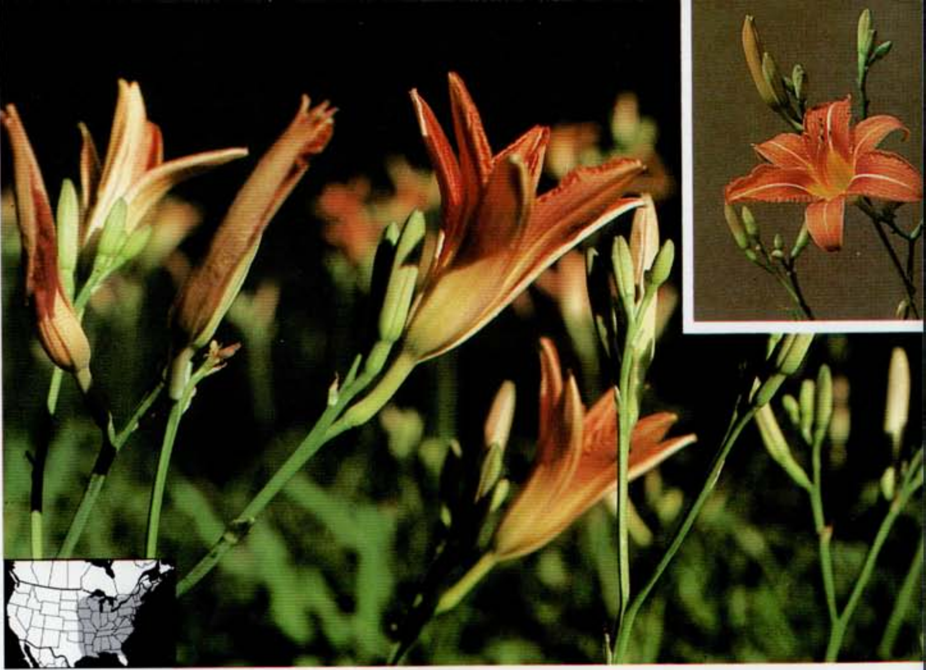

Common day lily: flowers (Dykeman).

Western camass: field of camass (Ross). Flowering stalks (NYBG). Flowers (Ross).

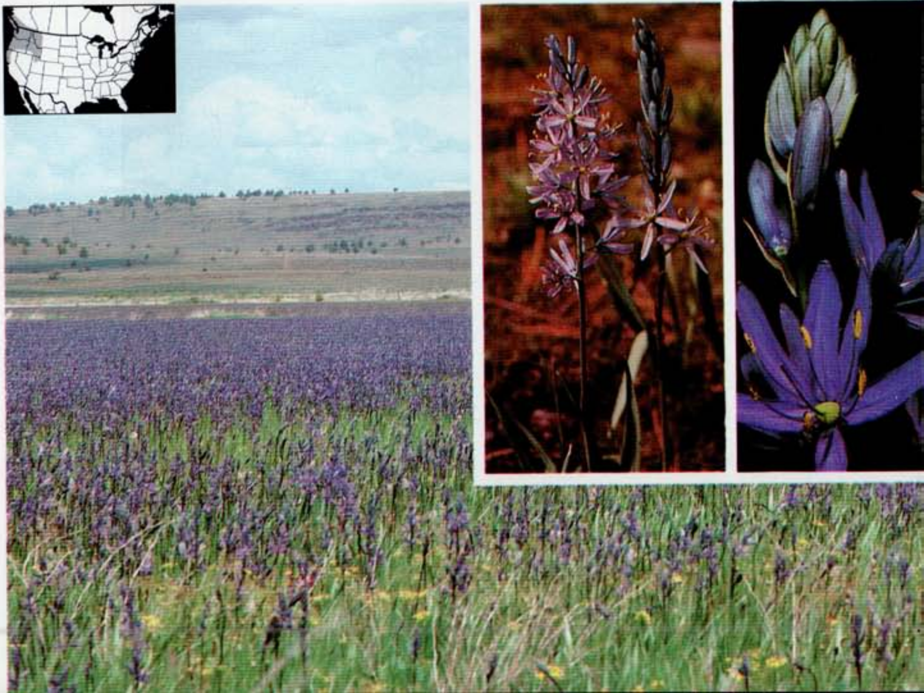

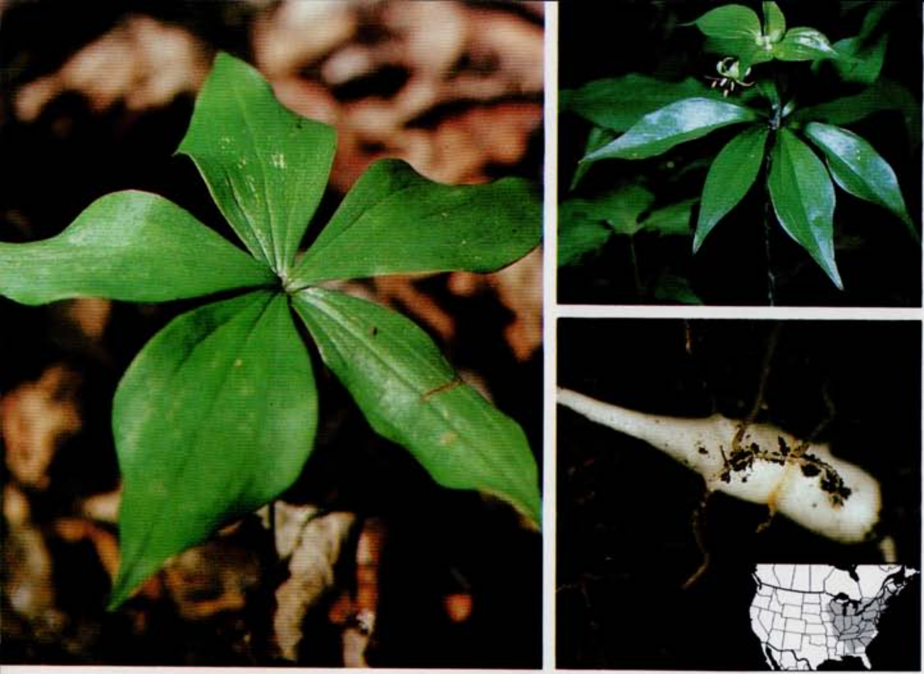

Indian cucumber: leaves and root (Dykeman). Flowering plant (NYBG).

Indian fig: plant (Folkerts).

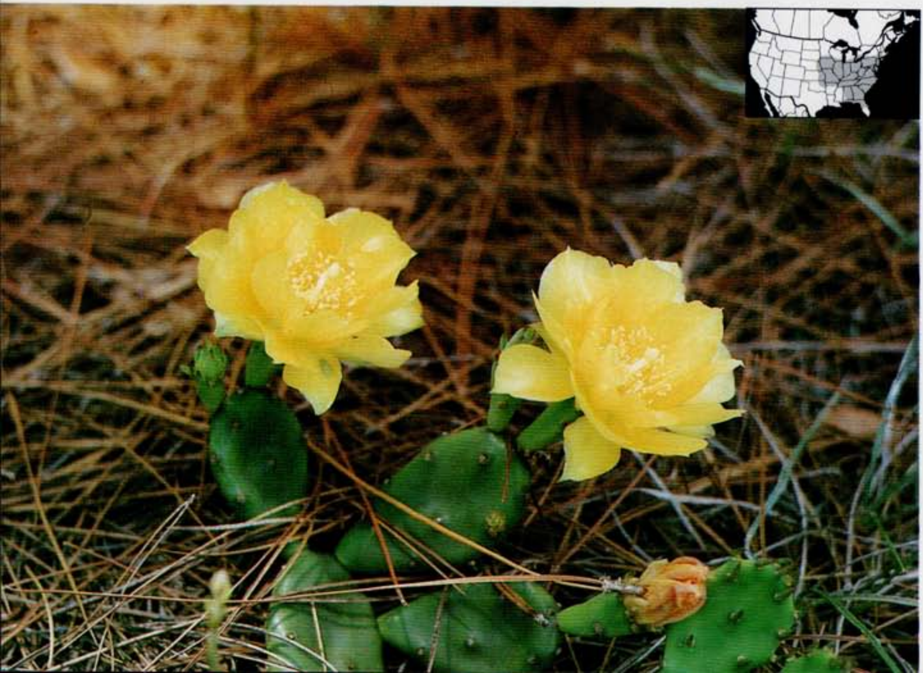

Indian cucumber *Medeola virginiana*

Habitat: rich moist woodlands, protected slopes, margin of bogs and swamps. **Identification:** ***perennial herb, with*** swollen ***tuberlike white underground stems (rhizomes)*** horizontal to ground; stem erect, to 80 cm (2.8 ft), usually about 30 cm (1 ft), slender, covered with wooly hairs when young, ***bearing a whorl of 5–10 leaves about midway and another whorl of 3 leaves near top.*** Leaves simple, parallel-veined, to 10 cm (4 in) long, and uniformly wide to broadest near tip; upper leaves smaller and broadest near base. ***Stalked flowers 3–9 in cluster at tip of stem, some flowers hanging beneath upper leaves,*** in May and June, each flower with 6 pale greenish-yellow petals 6–10 mm (0.2–0.4 in) long. ***Fruits*** small, rounded, dark purple berries 6–8 mm (0.2–0.3 in) in diameter, ***not edible.*** **Harvest:** common, easily identified plant a reliable source of limited quantity of tubers for trail food. Digging destroys plant, but any remaining tubers will produce new growth. **Preparation:** Wash and eat tubers raw as trail snack or in salad. Has delicate cucumber flavor. For pickles combine 1½ cups tubers, ½ cup water, ½ cup vinegar, 1 tbsp salt, 2 tsp sugar, 1 clove garlic, ¼ small, chopped red pepper, 1 tsp pickling spice. Bring to boil, place in small hot sterilized jars, covering tubers with liquid, and seal. Store at least 2 months. **Related edible species:** none. Unrelated, inedible starflower *(Trientalis borealis)* looks similar except for net-veined leaves. **Poisonous look-alikes:** none.

Indian fig, Prickly pear *(Also edible spring, autumn)* *Opuntia humifusa*

Habitat: rocky bluffs, sand dunes, dry rocky or sandy grasslands. **Identification:** perennial herb with fibrous root system, sprawling along ground, often forming clumps. ***Fleshy segments or joints nearly circular*** to broadest above middle, sometimes uniformly wide, ***5–20 cm*** (2–8 in) ***long, strongly flattened,*** pale to dark green, dotted with small reddish-brown bumps containing numerous tiny, barbed hairs; spines absent or occasionally 1. ***Flowers*** produced June–July on upper part of segments, ***showy, yellow with red center,*** 5–9 cm (2–3.5 in) across, usually with 10–12 petals. ***Fruit*** broadest above middle to nearly club-shaped, ***3–6 cm*** (1.2–2.4 in) ***long, red to purple, becoming fleshy,*** containing many flattened, nearly circular seeds. **Harvest:** Wear leather gloves to ward off spines and barbed hairs. Cut young segments during spring and summer. Pick fruits as they ripen in late summer and autumn. **Preparation:** Flame segments to remove spines, roast segments over fire, then peel or peel first, then slice and use like string beans. Edible but somewhat sticky. Also, deep fry like onion rings. Dry pulp for later use. To eat fruits fresh, chill if possible, trim off both ends, cut skin lengthwise, scoop out sweet pulp. Or, dip 1–2 min in boiling water and peel. Be careful, fruits also have fine, spiny bristles. Dry fruit pulp for later use, stew it for dessert, or boil it down and strain out seeds to make syrup or to prepare jelly. Briefly roast seeds and grind into meal for soup thickener or flour. For emergency water, peel and chew leafy segments. **Related edible species:** Fleshy fruits and segments of all flat-stemmed *Opuntia* species are edible. **Poisonous look-alikes:** none.

Prickly pear, Indian fig *Opuntia phaeacantha*

Also edible autumn, spring

Habitat: hills, canyons, valleys, usually in rocky or sandy soils. **Identification:** shrub to 1 m (3.2 ft), sometimes sprawling or forming clumps to 6 m (19.7 ft) in diameter. ***Fleshy cactus segments or joints rounded or nearly so,*** sometimes widest above middle, ***10–25 cm*** (4–10 in) ***long, flattened, bluish-green; cacti spines usually on upper half, 1–6 per cluster, 2.5–7.5 cm*** (1–3 in) ***long, straight or curved. Flowers*** produced near top of upper segments, ***showy, yellow,*** 6–8 cm (2.4–3.2 in) long, to 8 cm (3.2 in) in diameter, with many petallike structures. ***Fruits elongate,*** usually broadest above middle, ***3–6 cm (1.2–2.4 in) long, to 3.8 cm (1.5 in) in diameter, fleshy, red,*** depressed at tip, containing numerous, flattened and rounded seeds. The several varieties of this prickly pear differ primarily in segment shape, spine distribution, color, and length. **Harvest and preparation:** INDIAN FIG (preceding). **Related edible species:** all flat-stemmed prickly pear cacti. **Poisonous look-alikes:** none.

May apple, Mandrake *Podophyllum peltatum*

Habitat: rich deciduous woodlands, meadows, moist shaded road banks. **Identification:** ***perennial herb*** to 50 cm (20 in) tall, frequently in large dense patches with creeping underground stems and thick, fibrous roots, short stem, first-year plant with 1 leaf, second-year flowering plants with 2. ***Leaves*** large, umbrellalike, ***12–36 cm*** (4.7–14 in) ***in diameter, nearly circular in outline, deeply 5–9-parted,*** toothed; ***leafstalk attached at center of leaf. Flowers solitary, produced in junction of 2 leaves,*** stalked, nodding, each with 6 sepals, 6–9 waxy white petals 2.5–4 cm (1–1.6 in) long. Fruit an egg-shaped berry 2.5–5 cm (1–2 in) long, usually yellow, but red in one form. **Harvest:** Gather fruit when yellow; practically falls from plant into your hand. Leaves will be turning yellow by this time. Unripe fruit and other parts of plant contain poison podophyllin. The root has a long history of medicinal use. **Preparation:** Eat ripe fruit fresh; taste sensation varies from person to person. For preserves, jam, or pie filling, remove both ends, quarter fruit, and force through food mill to remove seeds before cooking. If skins are desired in final product, squeeze pulp from quartered fruit before removing seeds. Chop skins and add to pulp later. See recipes for jam and pie early in book. Also combine juice with lemonade, sumac ade, or other juices for new flavors. **Related edible species:** none. **Poisonous look-alikes:** none; do not attempt to use unripe May apples or any other part of the plant.

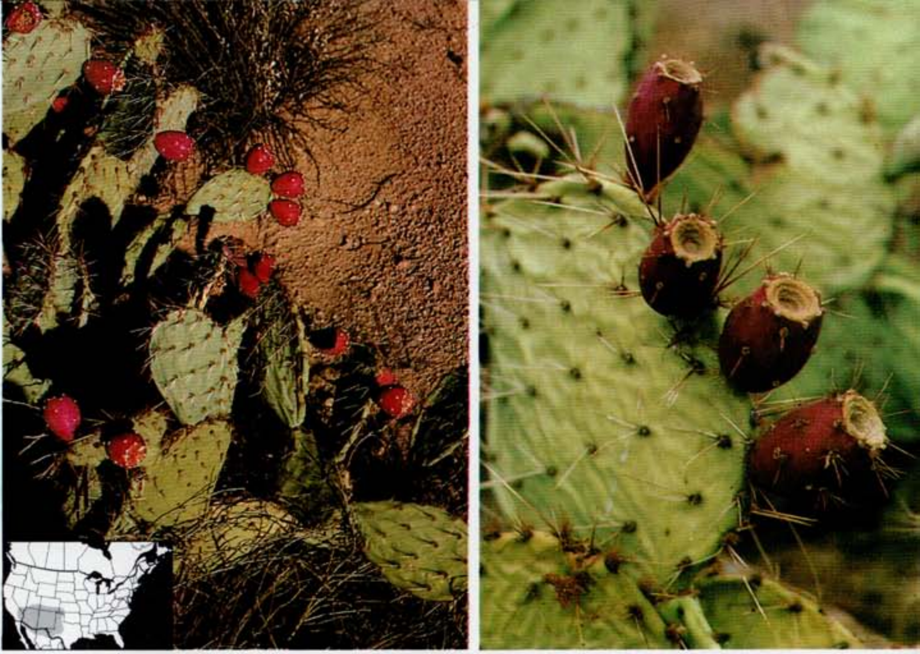

Prickly pear: plant (Elias). Fruits (Dykeman).

May apple: flowering plant (Dykeman). Fruit (NYBG).

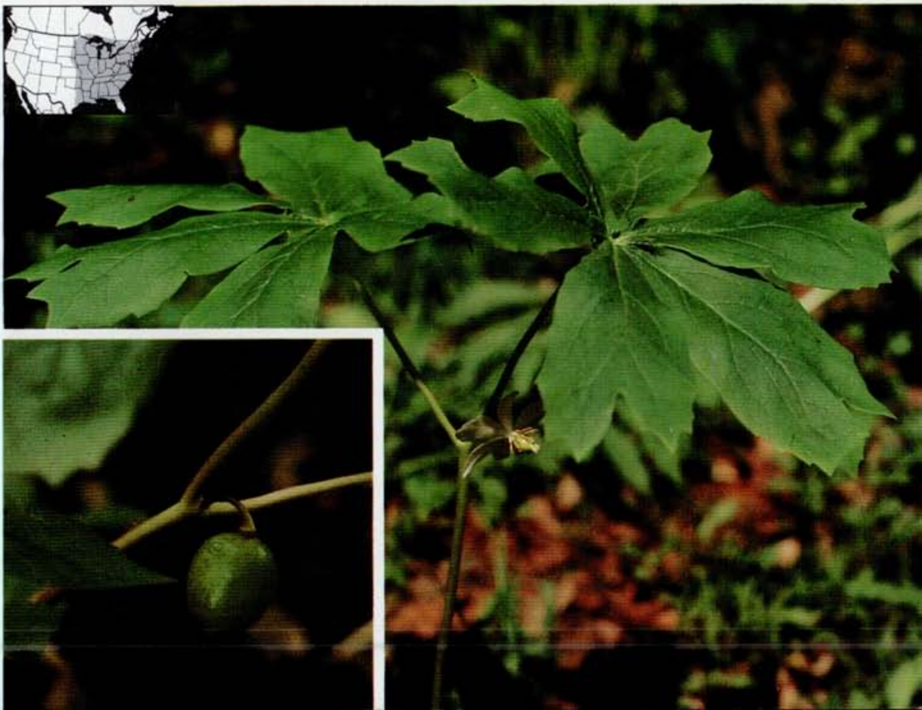

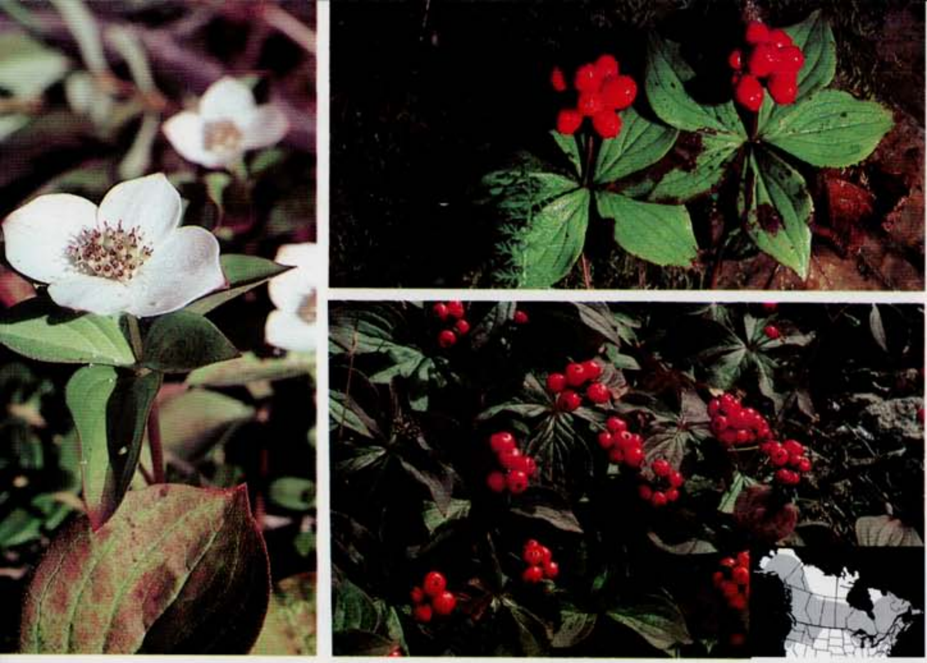

Bunchberry: flowers and fruiting plants (Elias).

Peppermint: flowering stalks (Speas).

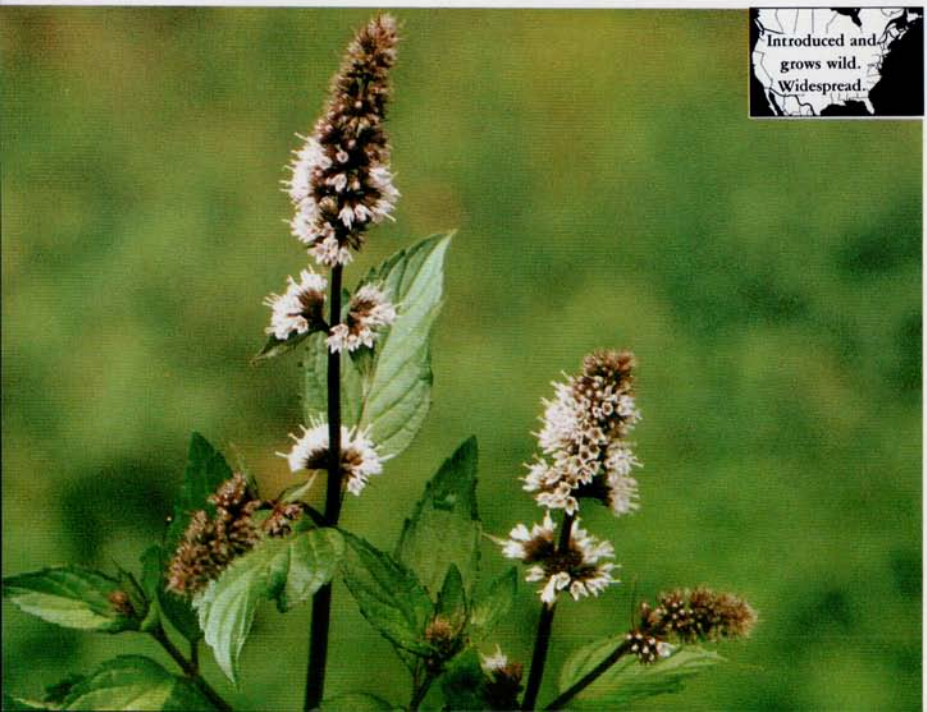
Introduced and
grows wild.
Widespread.

Bunchberry *Cornus canadensis*

Habitat: northern moist woods, bogs, woodlands, mountains especially in southern part of range. **Identification:** perennial, forming mats from spreading underground stems (rhizomes); aboveground stems 8–24 cm (3.2–9.4 in) high, ***each stem with whorl of 4–6 leaves near top*** and 1–2 pair smaller leaves below. Leaves 4–7 cm (1.6–2.8 in) long, 1.5–3.5 cm (0.6–1.4 in) wide, broadest near base or tip, pointed at tip, with 2–3 pair lateral veins. ***Flowers*** produced in May or June, ***tiny, in tight, dense clusters surrounded by 4 conspicuous, white, petallike bracts*** (flower clusters plus bracts resemble a single flower). Fruit produced in midsummer to autumn, in dense clusters, each a fleshy stone-fruit, globe-shaped, 6–8 mm (0.2–0.3 in) in diameter. **Harvest:** Berries ripen through July in clusters of a few to 12. Ripe when scarlet; usually plentiful and easily picked in quantity. **Preparation:** Eat nearly tasteless berries raw, but pulp is difficult to separate from seeds. Better cooked and strained for use with more flavorful fruits or for pudding. **Related edible species:** Swedish bunchberry *(C. suecica)* in northern regions has sweeter and more acid fruits. Laplanders make pudding from this species by boiling fruits with whey until thick. **Poisonous look-alikes:** none.

Peppermint *Mentha piperita*

Habitat: wet places, especially ditches, along streams, wet meadows. **Identification:** perennial herb, stems erect, 0.6–1.1 m (2–3.6 ft) tall, ***4-sided,*** purplish, smooth to slightly hairy. ***Leaves opposite,*** each pair alternating along stem, ***each with short leafstalk,*** blade 3.2–6.4 cm (1.3–2.5 in) long, 1–1.6 cm (0.4–0.6 in) wide, usually broadest near base, sharply toothed along margins, ***with distinct peppermint smell when broken or crushed.*** Flowers tiny, light purple, crowded together in dense, many-flowered, interrupted spikes at tips, June–October. Fruits with 4 tiny nutlets enclosed by persistent calyx. **Harvest and preparation:** Pick leaves at any stage. Great variation in flavor among populations from different areas. Collect leaves on dry day and dry on paper in warm area. Store in tight container. Jelly: Add 2 cups boiling water to 2 cups crushed fresh leaves in saucepan. Place inverted lid on saucepan, with small amount of ice and water in lid to condense water vapor and flavorful oils. Bring mint mix to simmer, remove from heat, steep 10 min. Strain; add 4 cups sugar and ¼ cup cider vinegar to 2 cups mint flavored water. Add green food coloring, if desired. Stir until sugar is dissolved. Dissolve 1 pkg powdered pectin in ¾ cup water, heat and boil hard 1 min. Add pectin solution to mint syrup, stir, pour into sterilized glasses, and seal. For other uses, see SPEARMINT (next). **Related edible species:** SPEARMINT, several hybrids of native and introduced species. **Poisonous look-alikes:** none.

Spearmint *Mentha spicata*

Habitat: grows in wild, especially in wet areas along roads, ditches, streams. **Identification:** perennial, spreading by creeping rootstock; ***stems*** erect to 1 m (3.2 ft), ***4-sided,*** smooth or nearly so. ***Leaves opposite,*** each pair alternating along stem, leafstalks absent or nearly so, blade 2.5–7.5 cm (1–3 in) long, 0.8–2.4 cm (0.3–1 in) wide, broadest at or below middle, toothed along margin, with ***strong smell of spearmint when crushed or broken.*** Flowers tiny, light purple to near white, produced in dense, elongate, many-flowered clusters 4–12 cm (1.6–4.7 in) long, at growing tips. Fruits tiny nutlets enclosed in persistent calyx. **Harvest and preparation:** Pick leaves at any stage. Great variation in flavor among plants from different areas. Collect leaves on dry day and dry on paper in warm area. Store in tight container. For tea pour 1 cup boiling water over ½ tsp crumbled, dried leaves or ¼–½ cup fresh leaves. Cover; steep 5 min. Do not boil. Strain, add sweetener and lemon to taste. High in vitamin C. Chop fresh leaves in green salad. Crush fresh leaves in iced tea. For candy wash and pat dry 2 doz fresh leaves. Beat 1 egg white until stiff. Dip leaves, one at a time in egg white, then in confectioner's sugar. Dry in oven at low heat, about 100°C (210°F), for 30 min or until crisp. Real mint-leaf candy! For jelly recipe see PEPPERMINT (preceding). **Related edible species:** PEPPERMINT, several other *Mentha* species, and many hybrids between native and cultivated species. **Poisonous look-alikes:** none.

American brooklime *Veronica americana*

Also edible spring

Habitat: common, along stream banks, swamps, clear ponds, springs, often with watercress. **Identification:** ***Perennial herb, usually creeping*** or sprawling; stems smooth, fleshy. ***Leaves opposite,*** lanceshaped to broadest near base, 3–8 cm (1.2–3.2 in) long, 1–4 cm (0.4–1.6 in) wide, pointed at tip, toothed along margin, stalked. ***Flowers stalked, produced along terminal, elongated spikes;*** each ***flower with 4 pale violet to lilac petals, 4–8 mm (0.2–0.3 in) across.*** Fruits are small, nearly round capsules, 3–5 mm (0.1–0.2 in) across, almost as long. **Harvest:** young growth tips from unpolluted water during late spring and summer. If water quality is questionable, wash tips in clean water to which iodide purifying tablets sold in camping stores have been added. Rinse with potable water. **Preparation:** Use like WATERCRESS in salads or as potherb with bland greens to offset bitterness of brooklime. **Related edible species:** several other species of speedwells (*Veronica* spp.), some widely distributed. **Poisonous look-alikes:** none.

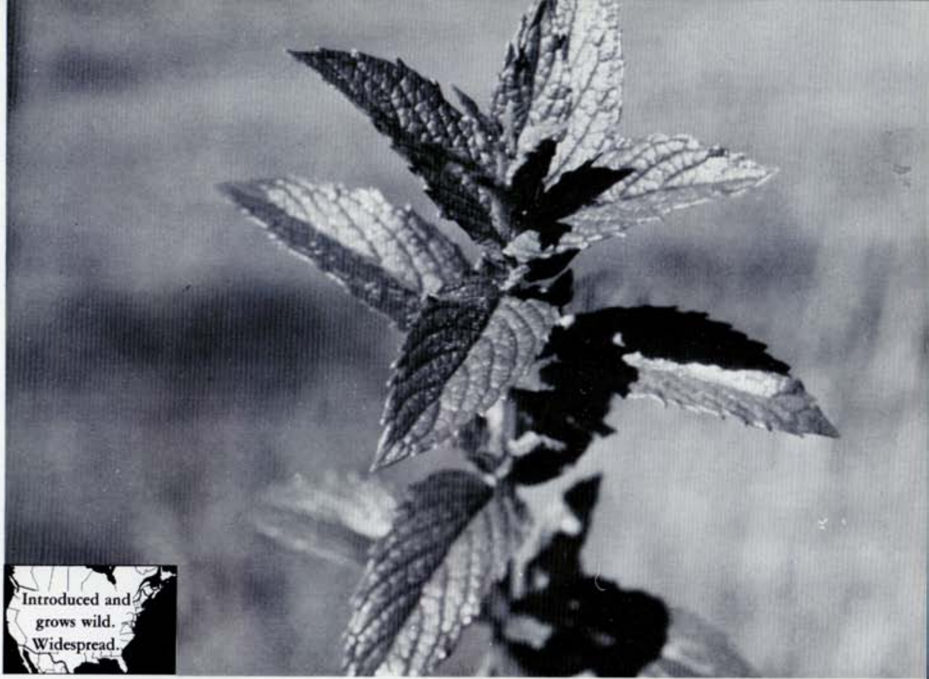
Introduced and grows wild. Widespread.

Spearmint: (Elias photo).

American brooklime: flowering stalk (Dykeman).

Marsh mallow *(Also edible autumn, winter)* *Althaea officinalis*

Habitat: edges of brackish and salt marshes; introduced from Europe and now grows wild. **Identification:** ***perennial herb*** from 0.6–1.2 m (2–4 ft) tall, from thick, large taproot; stems upright, often branched, stout, hairy. ***Leaves*** alternate, simple, broadest near base, 6–12 cm (2.4–4.7 in) long, about ⅔ as wide, ***often shallowly 3-lobed,*** short-pointed at tip, rounded at base, ***irregularly and coarsely toothed along margin,*** densely hairy. ***Flowers*** several ***in cluster at base of upper leaves in summer; each with 5 pink, spreading petals*** 2–3 cm (0.8–1.2 in) long. ***Fruit is dry, flattened disc, divided into 15–20 segments.*** **Harvest:** leaves in early summer, flower buds in summer, and roots from late summer through winter. **Preparation:** whole plant contains mucilagelike material; roots are best source. Use young leaves in early summer as okra-like soup thickener or as potherb. Pickle flower buds. Boil thin sliced, peeled roots for 20 min in enough water to cover them. Strain off roots; for candy sweeten the liquid and boil until very thick. Beat and drop spoonfuls on waxed paper to cool. Roll pieces in confectioner's sugar. For vegetable, fry boiled root slices with butter and chopped onion until browned. Use water from boiling any parts of plant as substitute for egg white in meringue or chiffon pies. Also used for hand lotion and cough syrup. Use leaves for poultices for infected wounds. **Related edible species:** other Mallow family species, especially those of genus *Malva*. Eat *Malva* fruits raw or substitute roots for meringue. **Poisonous look-alikes:** none.

Watercress *Nasturtium officinale*
Also edible autumn, winter, spring (synonym: *Rorippa nasturtium-aquaticum*)

Habitat: slow moving clear water, especially springs, cool streams; introduced from Eurasia. **Identification:** ***perennial herb, growing in shallow water*** or mud; stems weak, partially floating in water or lying flat in mud with white roots growing from floating stems. ***Leaves alternate,*** 4–16 cm (1.6–6.3 in) long, 2–5 cm (0.8–2 in) wide, ***dissected into 3–11 lobed and usually rounded dark green leaflets;*** upper leaves nearly rounded. ***Flowers numerous in narrow, elongate clusters,*** each flower stalked, with ***4 white petals,*** 3–5 mm (0.2 in) long. Fruits narrow, slender, capsulelike, 1–2.5 cm (0.4–1 in) long, beaked, containing several tiny reddish-brown seeds. **Harvest:** Collect young growth nearly all year from unpolluted water sources. Removal does not hurt plant. If water quality is questionable and plant is to be eaten raw, disinfect shoots by washing in water with iodide purifying tablets sold in camping stores. Rinse in potable water. **Preparation:** As potherb, cook and serve just like spinach or add to more bland potherb greens, or stir-fry 4–5 min in skillet with 2 tbsp cooking oil and 1 tbsp fresh grated ginger root. Serve with soy sauce. Watercress is an excellent soup ingredient. Use radish-tasting stems and blossoms as garnish or as main salad ingredient. For nasturtium salad: Make slightly sweetened oil and vinegar dressing. Mix 1 cup young watercress leaves, 1 cup watercress buds and blossoms, 2 cups mixed mild greens, and 1 chopped scallion in large bowl. Add dressing, toss and serve. Vary ratio of watercress to other greens to get desired taste. High in vitamins and minerals. **Related edible species:** none. **Poisonous look-alikes:** none.

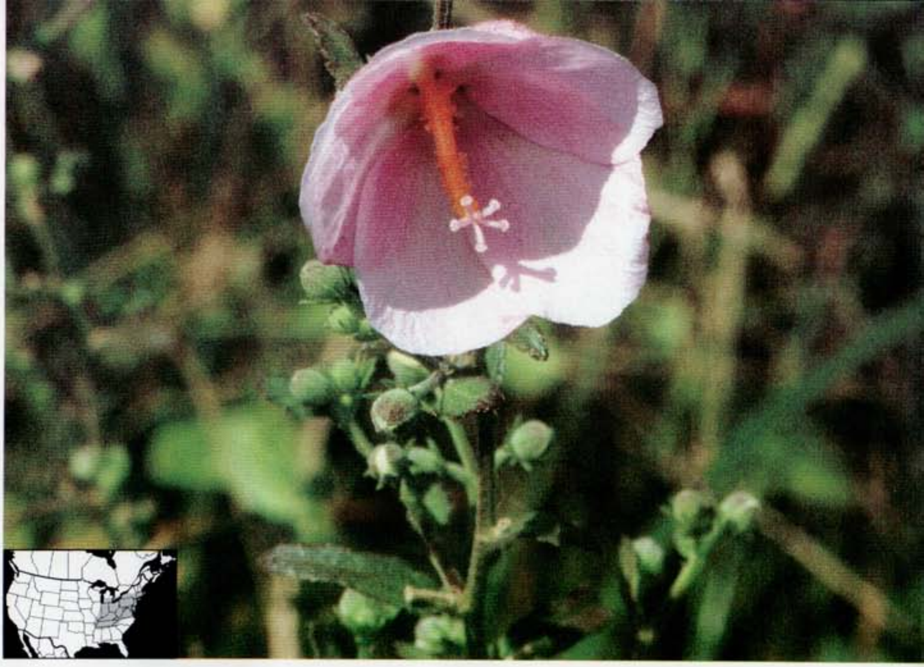

Marsh mallow: flowering stalk (Speas).

Watercress: flowering plant (Mohlenbrock).

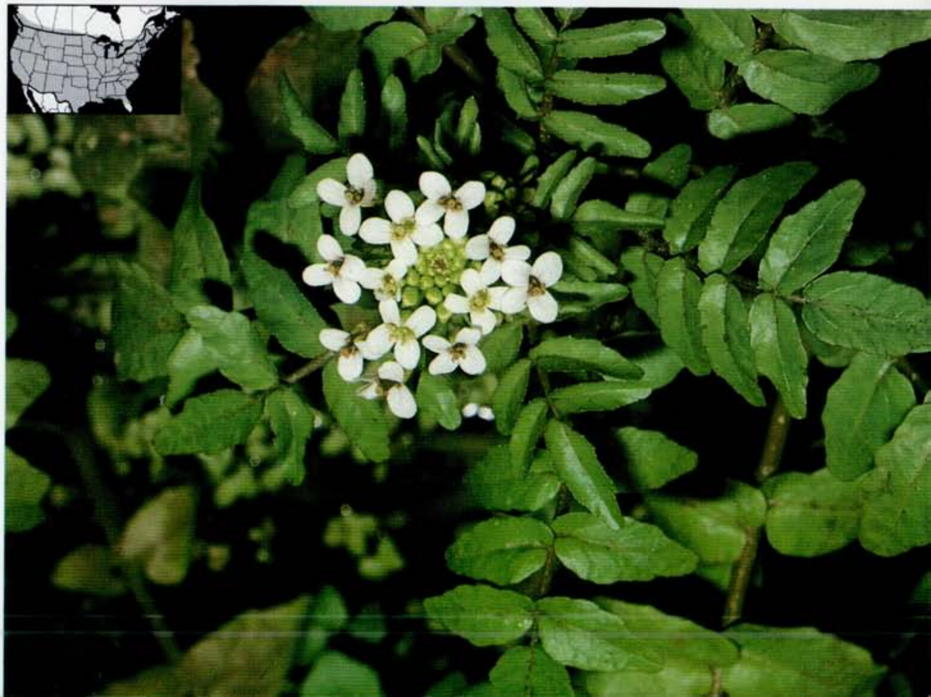

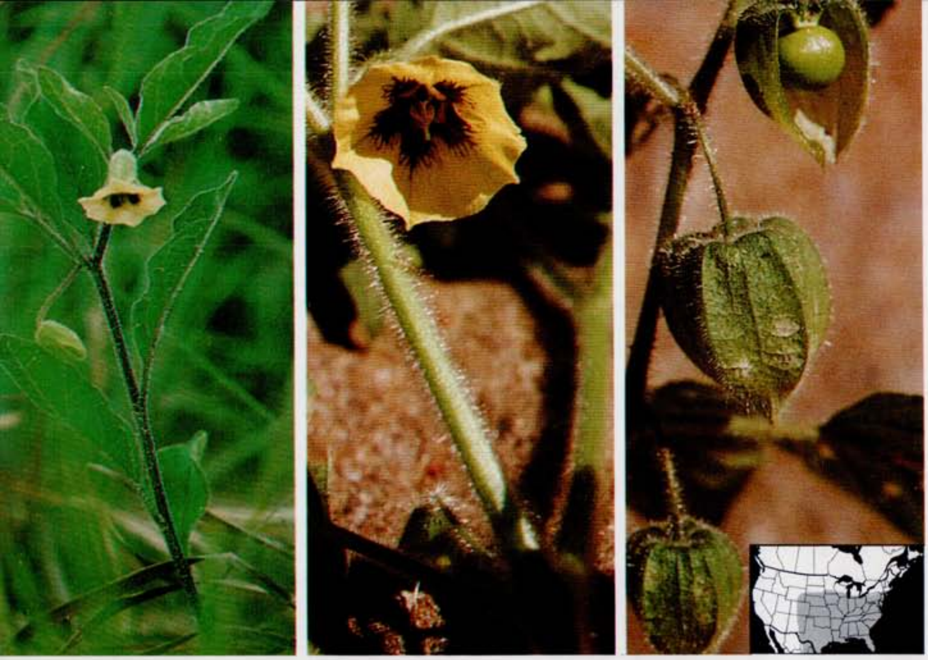

Ground cherry: flowering plant (NYBG). Flower and fruits (Pawloski).

Ground nut: flowering plant (NYBG). Underground tuber (Kavasch).

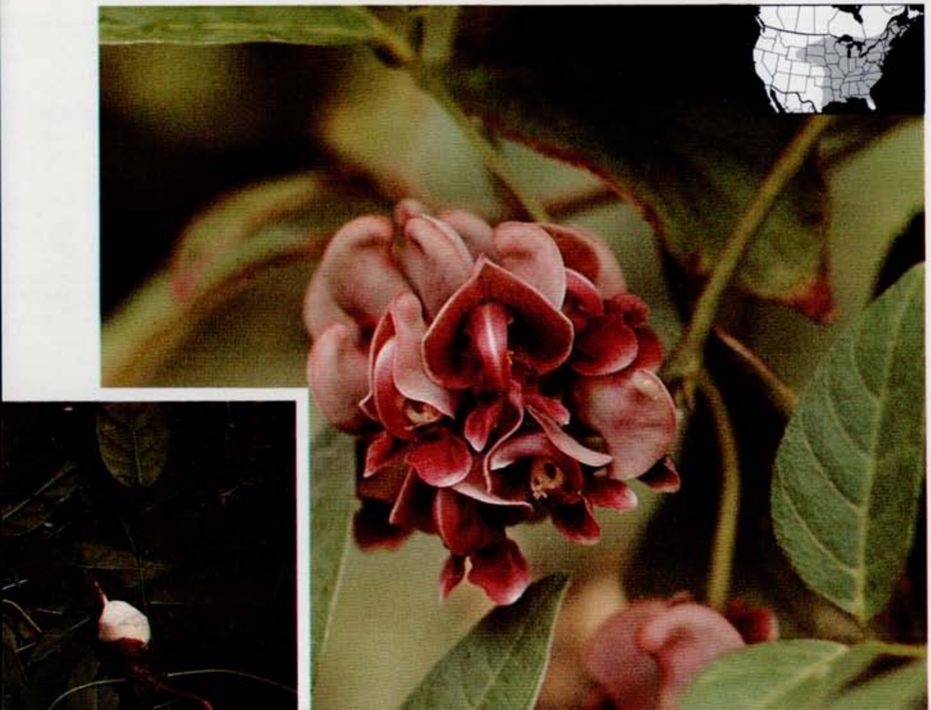

Ground cherry *Physalis pubescens*

Habitat: moist sites, open woodlands, recently cultivated fields, disturbed sites. **Identification:** ***annual herb*** to 60 cm (24 in) high; ***stems*** weak, wide branching, ***often trailing,*** hairy. ***Leaves*** alternate, simple, broadest near base, 3.5–8 cm (1.4–3.2 in) long, 1.7–6 cm (0.7–2.4 in) wide, pointed at tip, variably rounded at base, nearly entire, ***thin, pale green, hairy,*** long stalked. ***Flowers*** stalked, in junction of upper leaf stems, 5–10 cm (2–4 in) across, ***yellow with dark center. Fruit a sweet yellow berry*** 1.2–1.8 cm (0.5–0.7 in) in diameter, ***enclosed by 5-sided inflated persistent calyx resembling paper lantern 2–3 cm*** (0.8–1.2 in) long, ***angled,*** with conspicuous veins. **Harvest:** Fruits fall before fully ripe. So pick mid to late summer and ripen in husks a few weeks until fruits are yellow and sweet. Unripe fruit and green plant parts are strong flavored and somewhat poisonous. **Preparation:** excellent trail snack and dessert. For pie recipe, see book's Introduction. To preserve fruits boil until clear and tender in syrup of 1 cup sugar, 2 cups water, 3 tbsp lemon juice. Seal in sterilized jars. For jam boil for 5 min 1 qt crushed fruits, ¼ cup lemon juice, ½ cup water, and 1 pkg pectin. Add 3 cups sugar, boil again to reach jelly point, 115°C (240°F). Seal in sterilized jars. Use cherries in relishes. **Related edible species:** Several *Physalis* species are distributed throughout North America. Ripe fruits yellow, red, purple, or blue-black according to species; all are identifiable by lanternlike husk. Use only ripe fruit! **Poisonous look-alikes:** Learn to distinguish species of *Physalis* from poisonous nightshades *(Solanum)* (see JIMSON WEED and HORSE NETTLE).

Groundnut *(Also edible autumn, winter, spring)* *Apios americana*

Habitat: moist woodlands, bottomlands, thickets. **Identification:** ***perennial vine*** from 1 or more fleshy tubers arranged in a row, the tubers 1–2 cm (0.4–0.8 in) thick; stems smooth, twining around nearby plants; very white and easy to spot when mature, milky juice. ***Leaves*** alternate, ***featherlike compound*** (pinnate), 10–20 cm (4–8 in) long, ***composed of 5–9 leaflets,*** rarely less, leaflets usually 3–6 cm (1.2–2.4 in) long, lance-shaped, pointed at tip, rounded at base, smooth to hairy. ***Flowers*** July-September, densely clustered on short stalk 5–15 cm (2–6 in) long, each flower ***with 5 brownish-purple petals, resembling pea flower;*** fragrance resembles that of the violets. Fruits are dry, linear pods 5–12 cm (2–4.7 in) long, 4–7 mm (0.2–0.3 in) broad, containing 2 to several seeds, splitting open lengthwise into 2 spirally twisting valves. **Harvest:** Pick pods in midsummer to autumn as seeds mature; pods seldom abundant though. Dig tubers, starting at base of stem, working along root to obtain whole string. Good all year. **Preparation:** Roast pods at 190°C (375°F) for 20–25 min. Cool; remove seeds and brown in oil over low heat. Boil tubers in heavily salted water until tender. Season. Slice and fry leftovers, or grease and roast to regain tenderness, flavor. Also thinly slice raw tubers and fry like potatoes in butter or pork; season. Or bake at 175°C (350°F) 45–60 min until tender. Flavor turnip-like. **Related edible species:** groundnut *(A. priceana)* with 1 large tuber. **Poisonous look-alikes:** species of vetchlings *(Lathyrus),* rattlebox *(Crotalaria),* milk vetches *(Astragalus),* and point locoweeds *(Oxytropis).*

Common breadroot *Psoralea esculenta*

Habitat: prairies, plains, dry rocky woodlands. **Identification:** ***perennial herb*** to 38 cm (15 in) tall, ***developing from 1 or more swollen, elongated taproots*** 4–10 cm(1.6–4 in) long; stems short, stout, frequently branched, hairy. ***Leaves*** alternate, ***handlike (palmate) compound,*** long-stalked, ***composed of 5 leaflets,*** each 3–6 cm (1.2–2.4 in) long, uniformly wide to widest above middle, covered with long hairs. ***Flowers produced in dense elongate clusters 3–8 cm (1.2–3.2 in) long,*** each flower with leaflike bract, flowers ***blue,*** composed of 5 petals shaped like clover flower. Fruits are small pods 5–8 mm (0.2–0.3 in) long, broadest near base, long beaked, splitting open lengthwise along 2 valves. **Harvest:** Dig taproot from its hard prairie soil in early summer as stems and leaves begin to turn brown. Later above-ground parts dry and blow away making roots nearly impossible to locate. **Preparation:** important wild food staple. Peel and eat root raw, roast in campfire or boil until tender. Season like potatoes. For storage, peel and dry slowly. Grind dried root into flour or meal and use for baking. Indians cooked meal with meat and corn. Reconstitute with water to use as vegetable. **Related edible species:** *P. hypogala,* also of the plains region, produces a smaller but similar taproot. **Poisonous look-alikes:** Scurf pea *(P. tenuifolia)* and other *Psoralea* species have been toxic to horses and cattle, and so should not be eaten.

Wintergreen, Checkerberry *Gaultheria procumbens*

Also edible autumn, winter, spring

Habitat: woodlands, clearings, usually in poor acid soils. **Identification:** small herb with slender stems creeping along soil surface and erect leafy stems to 18 cm (7 in). ***Leaves*** crowded near top, each widest near or above middle, 2–5 cm (0.8–2 in) long, entire or with tiny rounded teeth along margin, ***leathery texture, shiny, with wintergreen smell when crushed. Flowers usually solitary on short drooping stalk, white,*** urn-shaped to cylinder-shaped, 5-parted at tip, 6–10 mm (0.2–0.4 in) long. ***Fruits bright red berries 6–10 mm (0.2–0.4 in) in diameter,*** globe-shaped to elongate. **Harvest:** leaves any time of year; berries from fall through winter. **Preparation:** Use leaves as trail nibble or brew into tea. Cover 1 qt young leaves with boiling water, cover container loosely and steep 1–2 days. Reheat gently, sweeten, and enjoy. Wintergreen oil concentration in tea increases with prolonged steeping. Berries ripen in fall but improve with freezing so look for them in winter and spring and use as trail nibble; add to pancakes and muffins, or, if plentiful, make uncooked jam. Combine in blender 2 cups fresh berries, 1 oz lemon juice, 1 cup strong wintergreen tea. Blend until smooth, pour into mixing bowl, add 4 cups sugar. In saucepan bring to hard boil 1 pkg pectin and ¾ cup water. Boil 1 min and stir into berry mix. Mix thoroughly, ladle into sterile jars, and seal. Store in refrigerator or freezer. Leaves and fruits contain aspirin like methyl salicylate and effectively reduce fevers and minor aches and pains. **Related edible species:** CREEPING SNOWBERRY (next). **Poisonous look-alikes:** none.

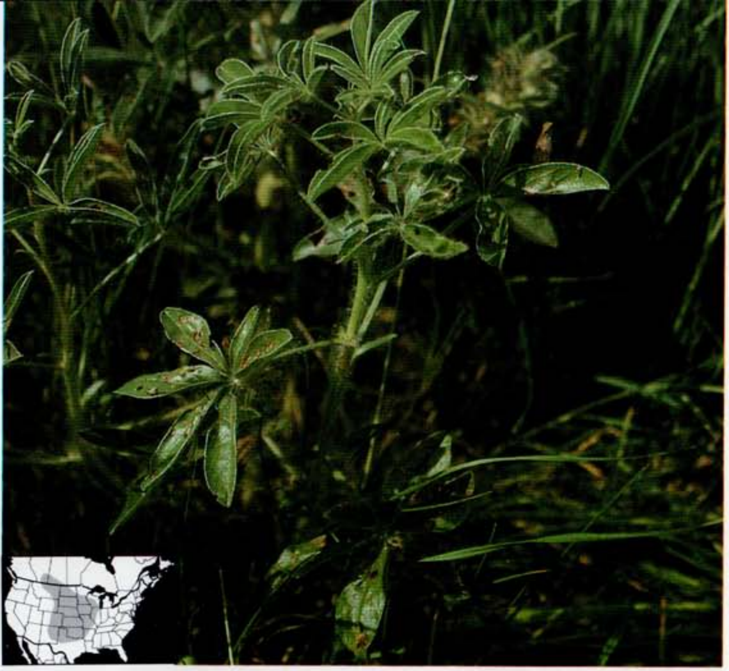

Common breadroot: July plant with remnant flower cluster on right (Young).

Wintergreen: fruiting plant, top (Dykeman). Flowering plant (Elias).

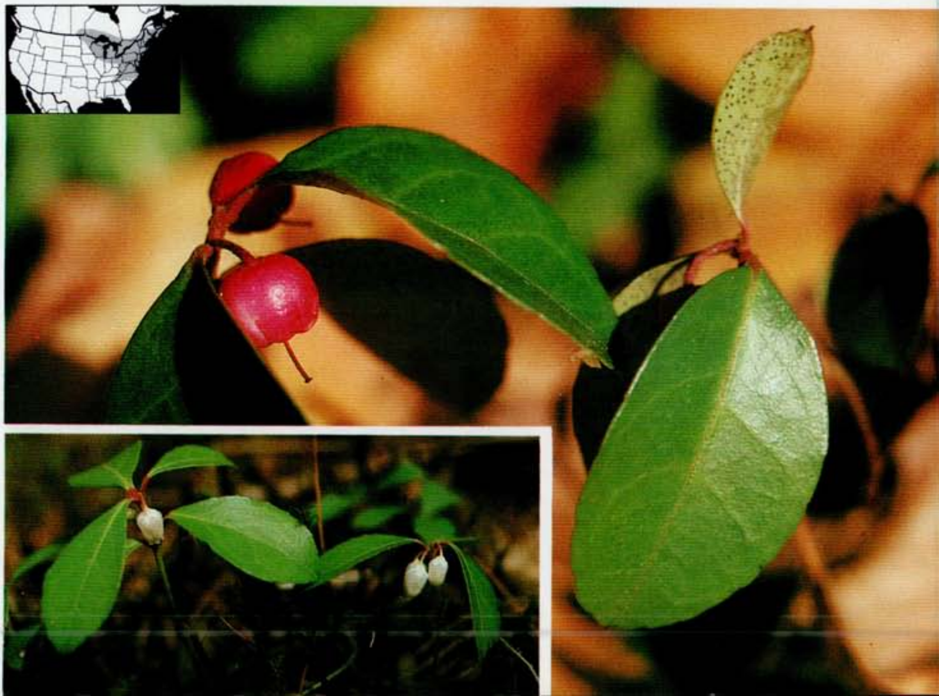

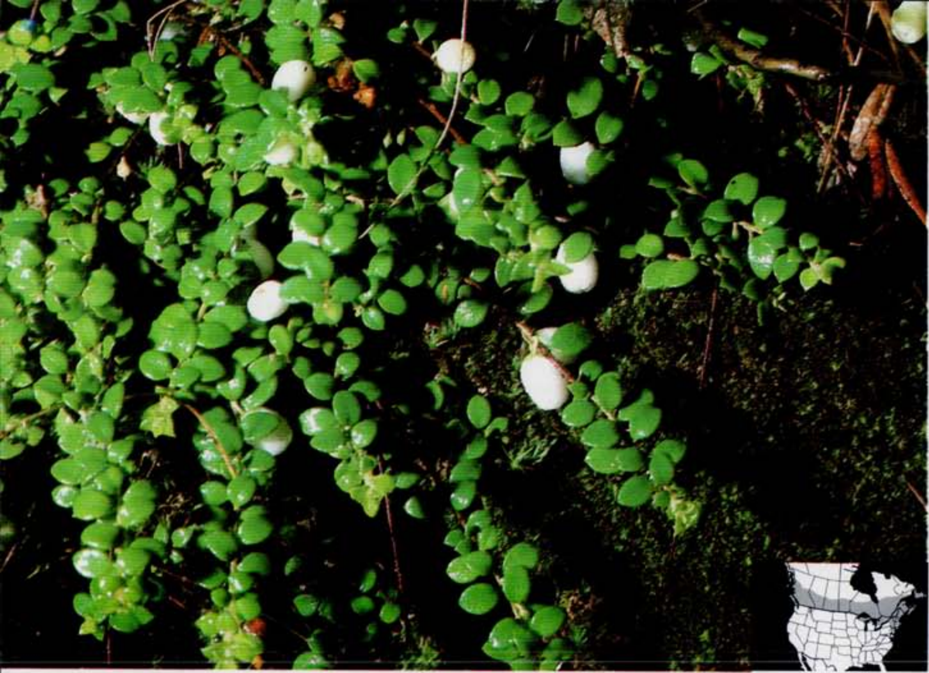

Creeping snowberry: fruiting plant (Elias).

Mountain sorrel: fruiting plant (Elias).

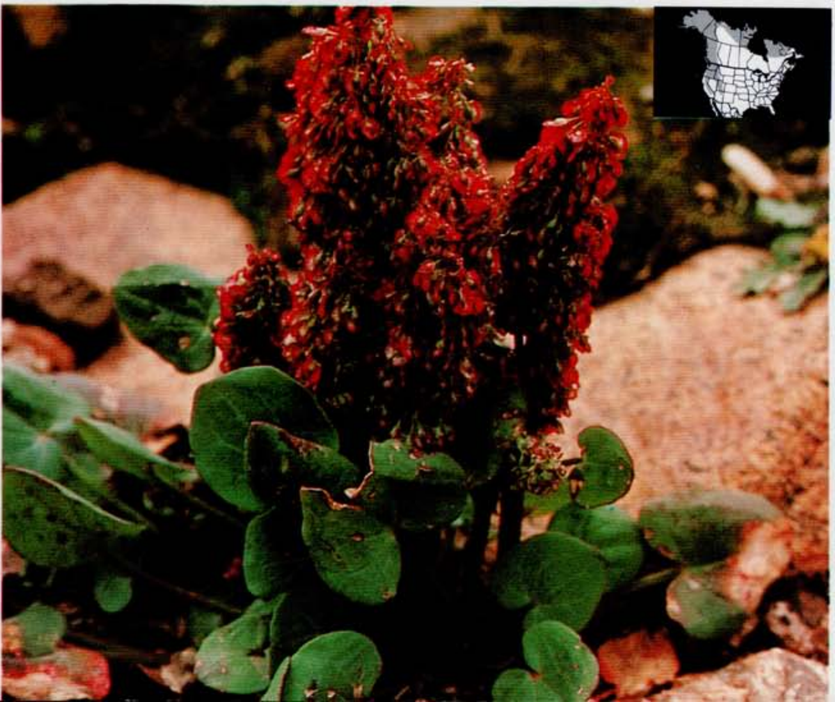

Creeping snowberry *Gaultheria hispidula*

Also edible autumn, winter, spring

Habitat: northern coniferous forests, mountains in subalpine and alpine zone. **Identification:** ***small creeping herb*** with very leafy stems; ***leaves*** alternate, simple, ***evergreen,*** broadest near base, to ***almost round, 0.5–1 cm (0.2–0.4 in) long,*** entire, bright green and smooth above, paler with long stiff hairs beneath. Flowers May-June, solitary in junction of leaves, each tiny, white, bell-shaped, 2–3 mm (0.1 in) long, on short drooping stalk. ***Fruits are fleshy bright white berries 6–10 mm (0.2–0.4 in) long,*** slightly longer than wide, with spicy aromatic smell when crushed, bristly. Ripen by August. **Harvest and preparation:** leaves same as WINTERGREEN (preceding). Also prepare as cooked green vegetable. Fruits ripen mid through late summer. Excellent fresh and in baked goods, jam (see WINTERGREEN), and preserves. For no-cook preserves wash and smash or grind fruit thoroughly. Add equal amount of sugar slowly with constant stirring. Pack in sterile jars and seal. **Related edible species:** WINTERGREEN, CREEPING WINTERGREEN, SALAL, and *G. ovatifolia,* also called salal, of northwest U. S. **Poisonous look-alikes:** none.

Mountain sorrel *Oxyria digyna*

Habitat: high mountains, subalpine and alpine fields, usually in rocky places 2,450–3,950 m (8,000–13,000 ft). **Identification:** perennial herb to 40 cm (16 in) high; stems upright, simple or sparingly branched, smooth. ***Leaves*** alternate, sometimes kidney shaped, simple, ***mostly basal, blades usually rounded,*** 1.6–3.2 cm (0.6–1.3 in) across, entire, smooth, long-stalked, stalk 6–12 cm (2.4–4.7 in) long. ***Flowers*** small, ***arranged in densely flowered, elongate, compact clusters;*** each flower stalked, bisexual, with 4 red to greenish sepals that persist in fruiting. ***Fruits*** flattened, ***broadly winged, rounded, dark red, small, dry, hard, 1-seeded,*** not splitting open at maturity. **Harvest:** leaves while still tender, before plant flowers. **Preparation:** Use fresh leaves as trail nibble or in salad. Combination of sour mountain sorrel and pungent species such as WATERCRESS works well with other, more neutral greens. Use a plain oil dressing. Add leaves to other greens for added flavor when cooked. In arctic regions, natives ferment mountain sorrel as sauerkraut. For puree, mash greens with food mill or blender and add to small amount of boiling water. Boil 5–10 min. Add 3 cups puree to 1 qt hot milk (or 1 cup milk and 3 cups chicken stock). Salt and pepper to taste. Bring to boil and simmer 5–10 min with stirring. Slowly add 3 beaten egg yolks. Add flour paste for desired thickness. Blend in 4 tbsp melted butter. For other uses see SHEEP SORREL. **Related edible species:** none, but SHEEP SORREL and SOUR DOCK are used similarly. **Poisonous look-alikes:** Some species of dock (RUMEX) accumulate sour-tasting oxalates.

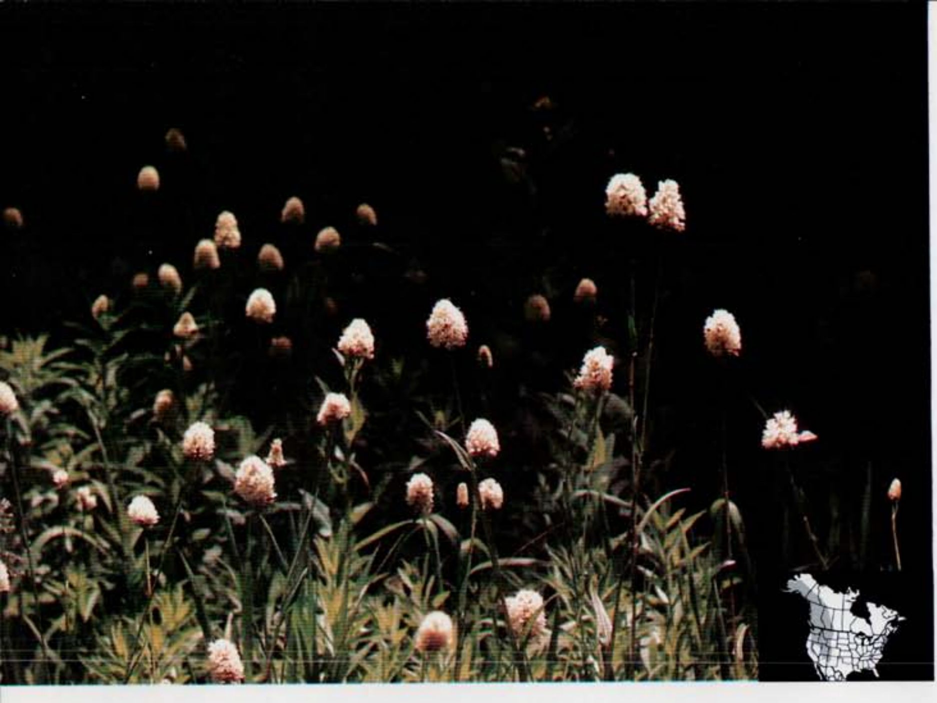

American bistort: flowering plants (NYBG).

Alpine bistort: flowering stalks (NYBG).

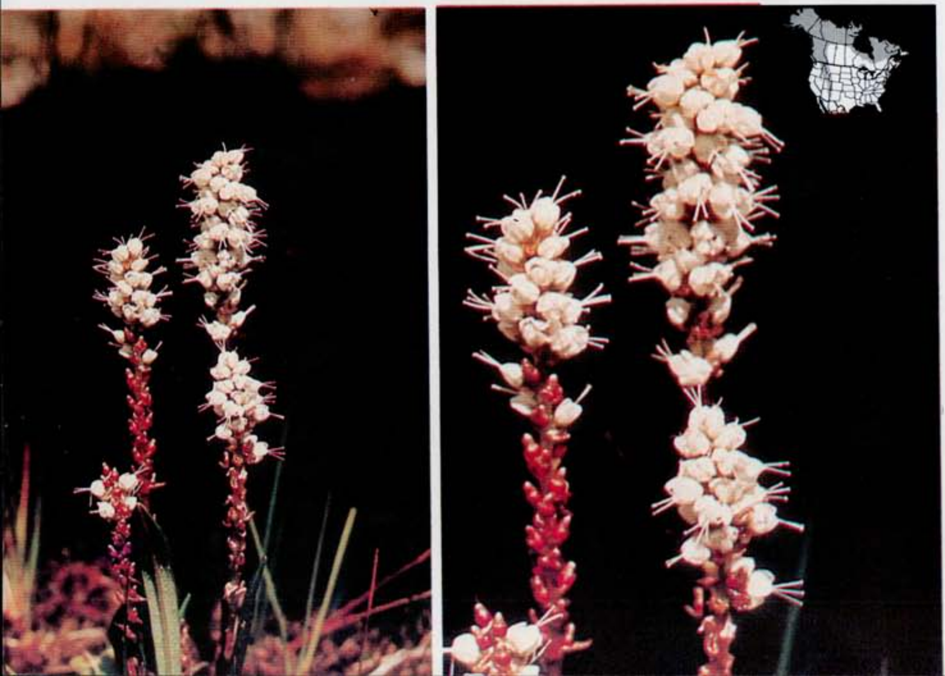

American bistort, Western bistort *Polygonum bistortoides*

Also edible autumn, spring

Habitat: along streams, wet meadows, subalpine meadows. **Identification:** ***perennial herb*** to 70 cm (28 in) high, from ***thick, fleshy, horizontal rootstock;*** stems erect, slender, smooth. Leaves alternate, entire, mostly basal, 10–25 cm (4–10 in) long, 2–5 cm (0.8–2 in) wide, lower leaves uniformly wide to broadest near tip, upper ones lance-shaped and smaller, stalked, each sheathing stem at base. ***Flowering spikes cylinder-shaped at end of stem, 2–6 cm*** (0.8–2.4 in) ***long,*** to 1.5 cm (0.6 in) thick, ***pink to white,*** individual flowers tiny, lacking petals. Fruits are small, shiny brown nutlets 3–4 mm (0.1–0.2 in) long. **Harvest and preparation:** Use rootstocks and young leaves as for ALPINE BISTORT (next). Rootstock larger in American bistort, but edible bulblets are absent from flower stalks. Both species provide valuable survival fare in mountain regions where other wild foods may be unavailable. **Related edible species and poisonous look-alikes:** See ALPINE BISTORT.

Alpine bistort, Alpine smartweed *Polygonum viviparum*

Also edible autumn, spring

Habitat: arctic regions, alpine and subalpine slopes, gravelly and rocky soils. **Identification:** ***perennial herb*** to 45 cm (18 in) high, ***from short, thickened, usually twisted, underground stem;*** stem upright, sheathed at base of leaves. ***Lower leaves*** alternate, simple, ***3–10 cm*** (1.2–4 in) ***long, to 2.5 cm*** (1 in) ***wide, narrowly lance-shaped,*** pointed at tip, tapering at base, long stalked, upper leaves much smaller. Flowering spike 3–8 cm (1.2–3.2 in) long, ***upper flowers pink or white,*** tiny, lacking petals, lower flowers producing tiny reddish or purple bulbils. Fruits are small, reddish-brown, 3-angled nutlets 2–4 mm (0.1–0.2 in) long. **Harvest and preparation:** Strip tiny bulbils from lower part of flower stalks and eat raw. Dig rootstocks (easiest to find during growing season) and eat raw, boil, or roast. Young roots tender but older ones may require cooking. Boil 40 min or bake at 165°C (330°F) for 40 min. Season like potatoes. Though appearance of unpeeled roots may not be inviting, flavor is good. Use young leaves in salad with other greens or prepare as cooked greens. Boil until tender and season with butter, salt and pepper. **Related edible species:** AMERICAN BISTORT (preceding) and LADY'S THUMB used as cooked or salad green. Also JAPANESE KNOTWEED, giant knotweed *(P. sachalinense),* Alaskan knotweed *(P. alaskanum),* and others. **Poisonous look-alikes:** No species of *Polygonum* are known to be poisonous. But some may cause light-sensitive skin reaction. They vary in usefulness as cooked or salad greens, some being very peppery or acid; some, like tartary buckwheat *(P. tataricum),* produce edible seeds.

Purslane, Pusley *Portulaca oleracea*

Habitat: fields, vacant lots, waste sites; common garden weed. **Identification:** annual ***herb, lying flat on ground*** or nearly so and ***forming mats to 1 sq ft, stems smooth, fleshy, shiny, often reddish purple. Leaves*** alternate and opposite, 2–5 cm (0.8–2 in) long, 1–2 cm (0.4–0.8 in) wide, ***fleshy, broadest near the rounded tip,*** entire along margin. ***Flowers*** single, or few clustered at tips of branches, flower 0.5–1 cm (0.2–0.4 in) wide, ***with 5 yellow petals. Fruits are capsules,*** 4–8 mm (0.2–0.3 in) long, broadest near base and rounded at tip, ***top portion falling away at maturity*** to expose dark red to black seeds. **Harvest:** Pinch or cut young leafy tips June–September. Pick larger stems in midsummer for pickles. To gather seeds, spread whole mature plants on sheet to dry for 2 weeks, then sieve and winnow. **Preparation:** One of best wild shoots cooked or in salad. Common and nutritious; acid taste; high in iron. For tossed salad combine raw shoots with other ingredients. Use oil and vinegar dressing. Cook young plants as potherb 10 min and season with butter and salt. For casserole chop cooked shoots, stir in 1 beaten egg and enough bread crumbs to make damp mix. Add salt and pepper, bake in moderate oven. Pickle stems same as cucumbers. Blanch and freeze tips for later use. To dry, boil thick stems in a little water for 20 min. Drain, dry in warm shady area, store in paper bag for later use in soups or stews as thickener. Dry seed 1 week in shade, store in paper bag. Grind and use half and half with flour. **Related edible species:** at least 2 *(P. neglecta* and *P. retusa)* which are very similar. **Poisonous look-alikes:** none.

Sunflower *(Also edible autumn)* *Helianthus annuus*

Habitat: prairies, plains, roadsides, disturbed sites. **Identification:** ***perennial herb 1–2.5 m (3.2–8.2 ft) high,*** from large taproot; stem upright, unbranched to branched, with stiff hairs. ***Leaves*** mostly alternate, simple, ***6.5–30 cm*** (2.6–12 in) ***long,*** nearly as wide at base, ***broadly to narrowly triangular,*** tapering to short- or long-pointed tip, toothed near tip, heart-shaped at base, with stiff hairs on both surfaces. Flowers produced in heads to 15 cm (6 in) across, single, stalked, base of head cup-shaped, ***ray flowers with yellow petals 2.5–5 cm*** (1–2 in) ***long,*** central disc flowers lacking showy petals, brown. Fruit flattened, dry, 1-seeded, 4–6 mm (0.2 in) long. **Harvest:** Gather seed heads in late summer to early autumn before seeds are dry enough to be released. Hang in warm, dry place. **Preparation:** Indians parched then ground unshelled seeds into fine meal. Meal was added to water and drunk or mixed with marrow to form dough and eaten. To separate nutmeats from shells, break hulls with chopper, very coarse grinder, or food mill. Pour broken seeds into water, stir vigorously, let settle. Nutmeats will sink and shells will rise to top. Skim shells for making coffee. For use in nut recipes, drain, dry, and roast nutmeats. Grind nutmeats into meal and use for part of flour in muffin and bread recipes. For nut butter grind raw nutmeats into paste; add honey or maple syrup if necessary to improve flavor. To produce oil, thoroughly crush or grind raw seeds. Boil in water. Skim oil off broth. **Related edible species:** All of the nearly 60 species in North and South America are edible. **Poisonous look-alikes:** none.

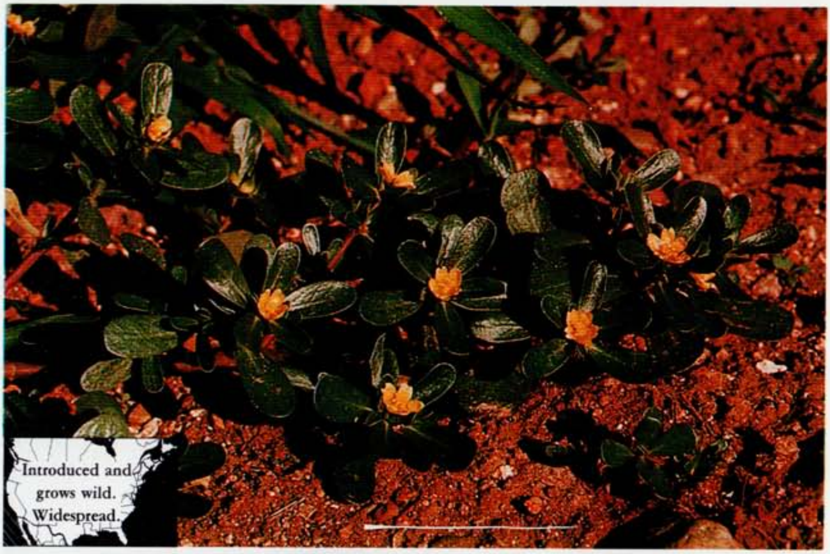
Introduced and
grows wild.
Widespread.

Purslane: flowering plant (NYBG).

Sunflower: flowering stalks (Elias). Cultivated form with larger flowering head (Feldman).

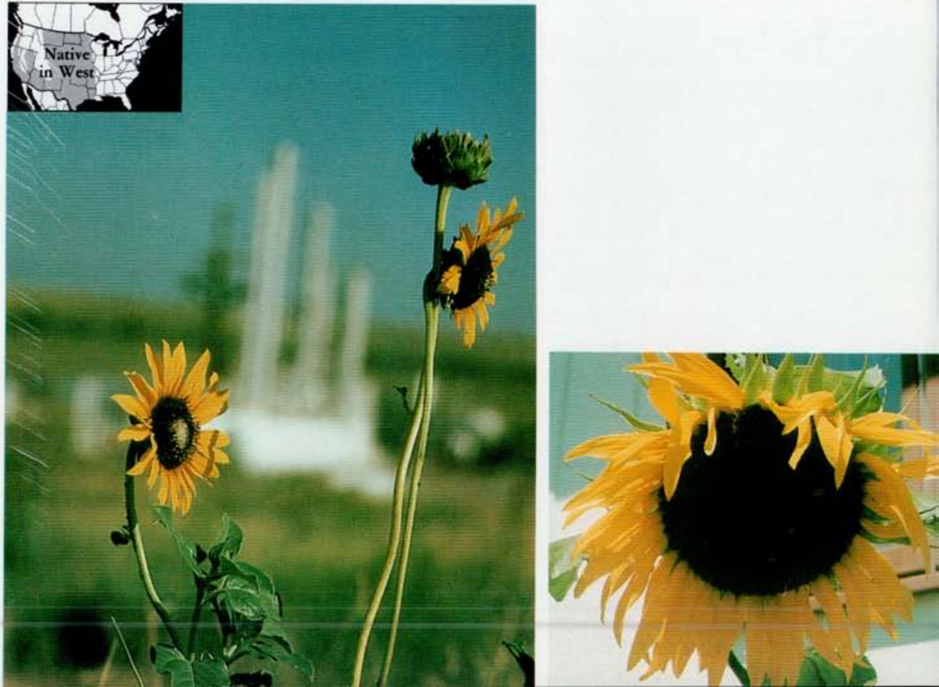
Native
in West

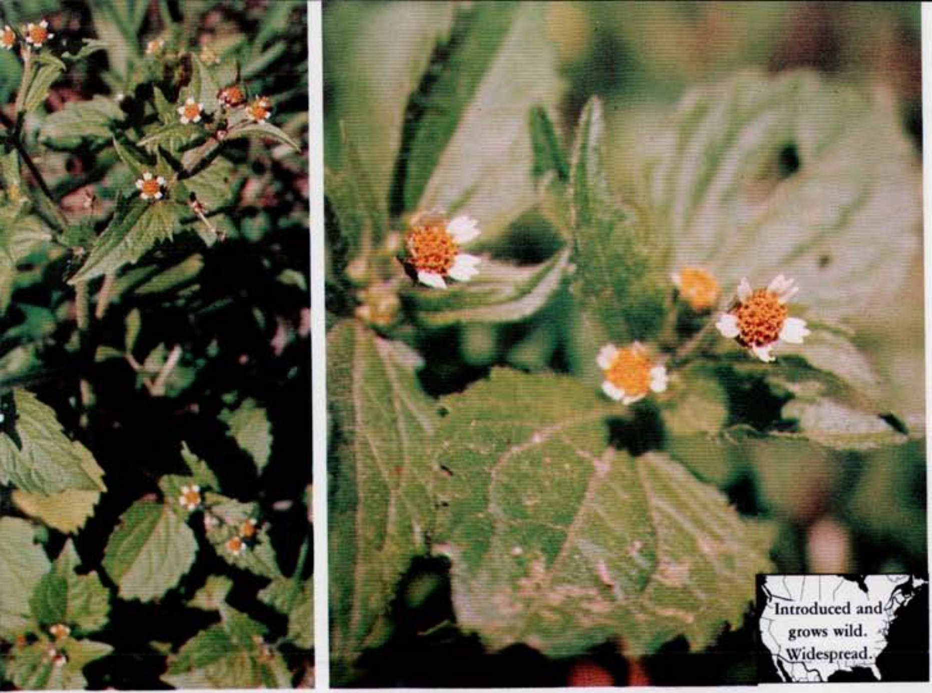
Introduced and grows wild. Widespread.

Quickweed: flowering plant and flowers (NYBG).

Bearberry: fruiting branches (Elias).

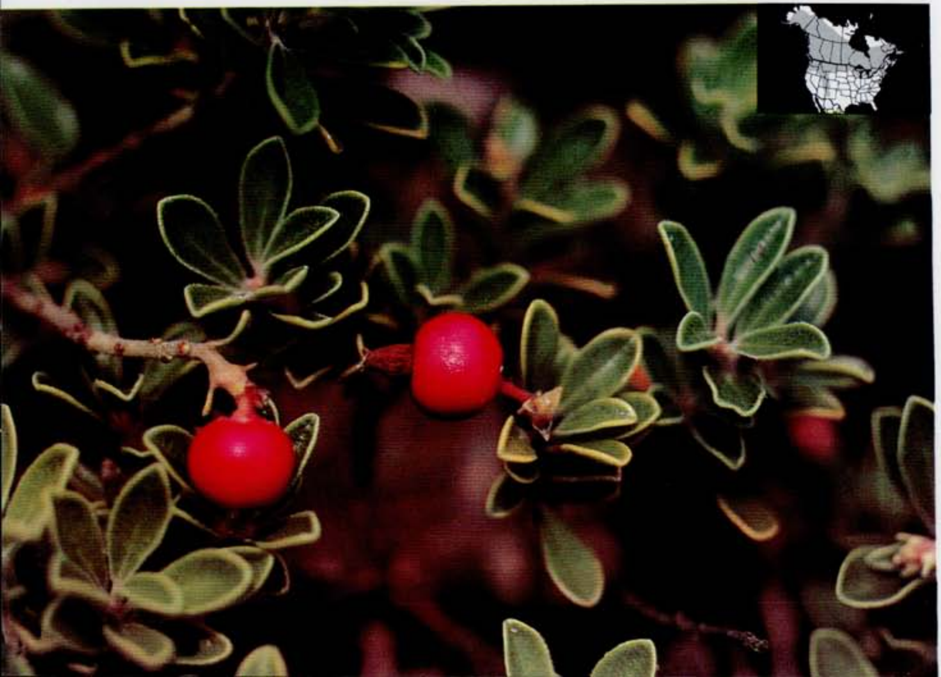

Quickweed, Galinsoga *Galinsoga parviflora*

Habitat: disturbed sites, roadsides, yards; also garden weed. **Identification:** annual herb to 70 cm (28 in) high, often bushy, stems usually spreading, smooth to slightly hairy. ***Leaves opposite,*** simple, usually lance-shaped, 2.5–8 cm (1–3.1 in) long, 1.2–4 cm (0.5–1.6 in) wide, pointed at tip, small blunt teeth along margin, tapering to rounded at base, with 3 principal veins, papery, usually stalked. ***Flowers tiny, produced in heads, 4–5 outer scale-like bracts (involucre) 2–3 mm (0.1 in) high, green; outer (ray) flowers white, inner (disc) flowers yellow.*** Fruits small hard nutlets 1–1.5 mm (0.1 in) long, nearly black, hairy. **Harvest:** young plants during middle of growing season. **Preparation:** Discard roots. Boil tops about 15–25 min and serve with salt, pepper, and butter. Add more flavorful greens and vinegar to compensate for quickweed blandness. **Related edible species:** *G. ciliata* (also called quickweed) plus a few other *Galinsoga* species, all introduced from southwest U.S., Mexico, and points south. **Poisonous look-alikes:** none.

Bearberry, Kinnikinick *Arctostaphylos uva-ursi*

Habitat: circumboreal, subarctic; sandy or rocky soils, higher elevations in southern part of range. **Identification:** ***low spreading shrub, forming mats*** with tough flexible twigs. ***New twigs hairy and sticky; mature ones*** dark reddish-brown or gray, ***papery and peeling. Leaves*** alternate, simple, ***evergreen, 1–3 cm*** (0.4–1.2 in) ***long,*** broadest near rounded tip, entire, shiny above, leathery. Flowers tiny, 5–12 per elongated cluster, each white to pale pink, urn-shaped, 4–6 mm (0.2 in) long. ***Fruits bright or dull red berries 4–10 mm (0.2–0.4 in) in diameter, mealy,*** not tasty. **Harvest and preparation:** leaves called *kinnikinick,* an Indian tobacco substitute also used by frontiersmen. For smoking, leaves are mildest in summer; dry in sun or near fire, crumble, and light up. Dried leaves make medicinal tea, good for indigestion. Fruits ripen late in growing season. Raw, they are bland and dry, but cooked they become palatable with cream and sugar. Not great snack but useful survival food. **Related edible species:** alpine bearberry *(A. alpina)* and several manzanitas plus many species in other genera in heath family. **Poisonous look-alikes:** none.

Salal, Western wintergreen *(Also edible autumn)* *Gaultheria shallon*

Habitat: woods, clearings, brushy areas below 800 m (2,630 ft), from West Coast to west slope of Cascades. **Identification:** ***upright, many branched shrub*** 0.3–2.5 m (1–8.2 ft) tall, frequently forming dense thickets. ***Leaves evergreen,*** alternate, simple, uniformly wide to broadest near middle, 3–10 cm (1.2–4 in) long, finely toothed, dark, shiny above, paler beneath. Flowering clusters narrow, elongate, composed of 5–15 stalked flowers, each urn-shaped, white or pink, 8–10 mm (0.3–0.4 in) long; prominent leaflike bract and 2 bractlets at base of flower stem. ***Fruits dark-purple berries,*** 7–8 mm (0.3 in) in diameter, nearly round, thick skinned, star-shaped depression on end, with several seeds. **Harvest:** Fruits ripen in summer and persist several weeks. **Preparation:** edible fresh but sometimes quite spicy and not juicy; better cooked. Also dry in sun or warm attic. Good in jam, jelly, pies, baked goods. See basic jelly and jam recipes, in book's Introduction. For beverage crush and boil berries, extract juice, and add equal amount of water. Sweeten, if necessary. **Related edible species:** WINTERGREEN, CREEPING WINTERGREEN (next), CREEPING SNOWBERRY, and *G. ovatifolia,* also called salal, of northwest U.S. **Poisonous look-alikes:** none.

Creeping wintergreen *(Also edible autumn, winter)* *Gaultheria humifusa*

Habitat: subalpine and alpine zones and moist slopes of western and Pacific Northwest mountains. **Identification:** low shrub with short spreading branches along ground. ***Leaves*** alternate, simple, ***evergreen,*** broad, ***broadest near base or middle, 1–2 cm (0.4–0.8 in) long, almost as wide,*** entire or with tiny teeth along margin, leathery. Flowers solitary in junction of leaves, each white, urn-shaped, 3–4 mm (0.1–0.2 in) long. ***Fruits are dry berries 4–8 mm*** (0.2–0.3 in) ***in diameter,*** rounded, ***red at maturity.*** **Harvest and preparation:** same as WINTERGREEN. Dryness makes fruit less palatable than other *Gaultheria* species. **Related edible species:** See SALAL (preceding). **Poisonous look-alikes:** none.

Labrador tea *(Also edible autumn, winter, spring)* *Ledum groenlandicum*

Habitat: bogs, fens, heaths, northern woods, exposed bluffs. **Identification:** low shrub up to 1 m (3.2 ft) high, with erect, reddish-brown branches, densely hairy when young. ***Leaves*** alternate, simple, ***evergreen,*** fragrant, crowded near tip of twigs, 1.5–5 cm (0.6–2 in) long, 4–12 mm (0.2–0.5 in) wide, uniformly wide to slightly wider at middle, rounded at tip, ***margin entire and rolled under, leathery,*** dull dark green above, ***densely hairy beneath, white at first, turning rusty.*** Flowers produced in late spring or summer in rounded clusters, each with 5 cream-white petals, stalked. Fruits are dry capsules 4–6 mm (0.2 in) long, slender, long-stalked, splitting open from base. **Harvest:** any time but least good in midwinter. Pick leaves when dense pile beneath is rust colored. Dry in sun, over low fire, or in oven. **Preparation:** Steep 1 tbsp dried leaves in 1 cup boiling hot water for 10 min. Do not boil water with leaves in it, which may release a harmful alkaloid. Serve hot or cold. **Related edible species:** northern Labrador tea *(L. palustre).* **Poisonous look-alikes:** mountain Labrador tea *(L. glandulosum)* is described by some sources as poisonous.

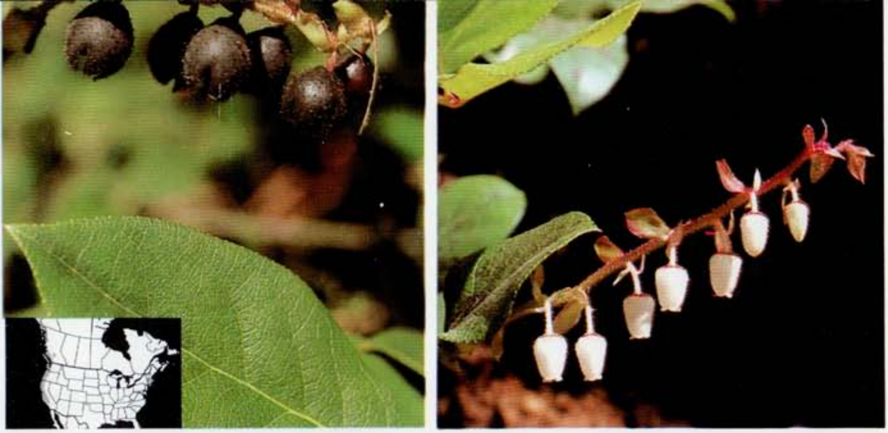

Salal: fruiting and flowering branches (Ross).

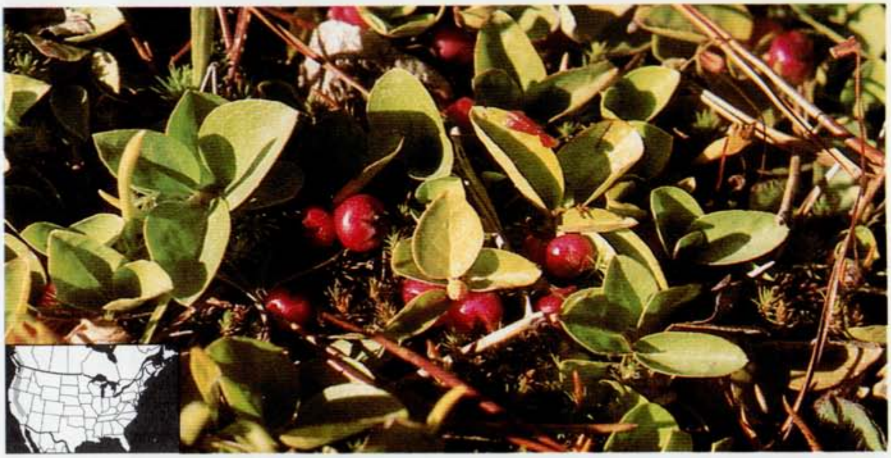

Creeping wintergreen: fruiting plants (Mulligan).

Labrador tea: flowering plant (Elias).

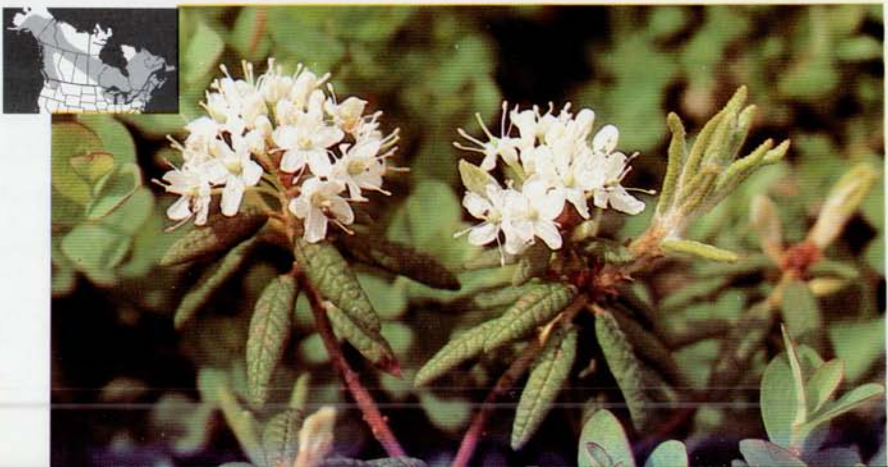

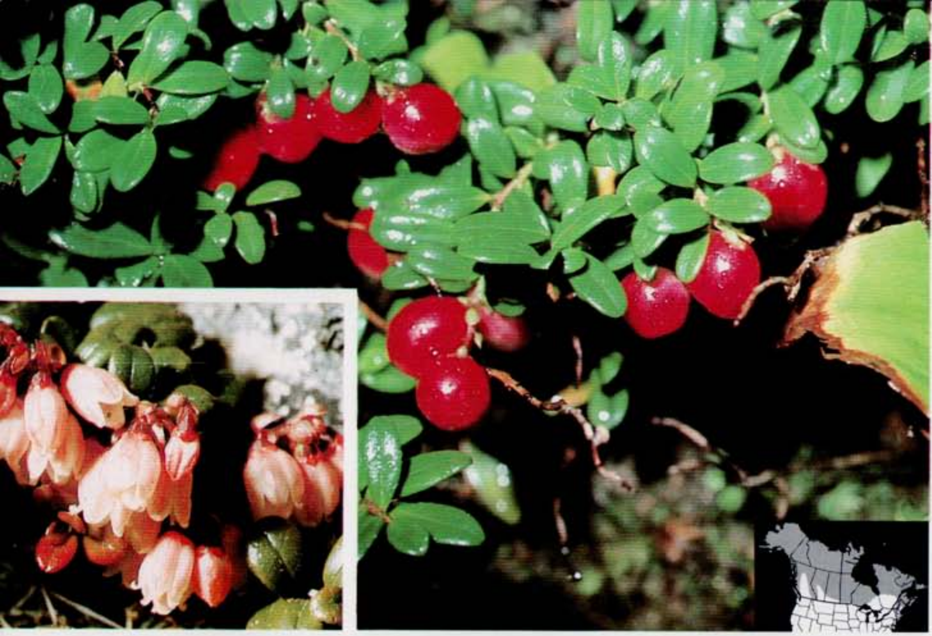

Mountain cranberry: flowers (NYBG). Fruiting plant (Elias).

Cranberry: flowering plants (NYBG). Fruit (Elias).

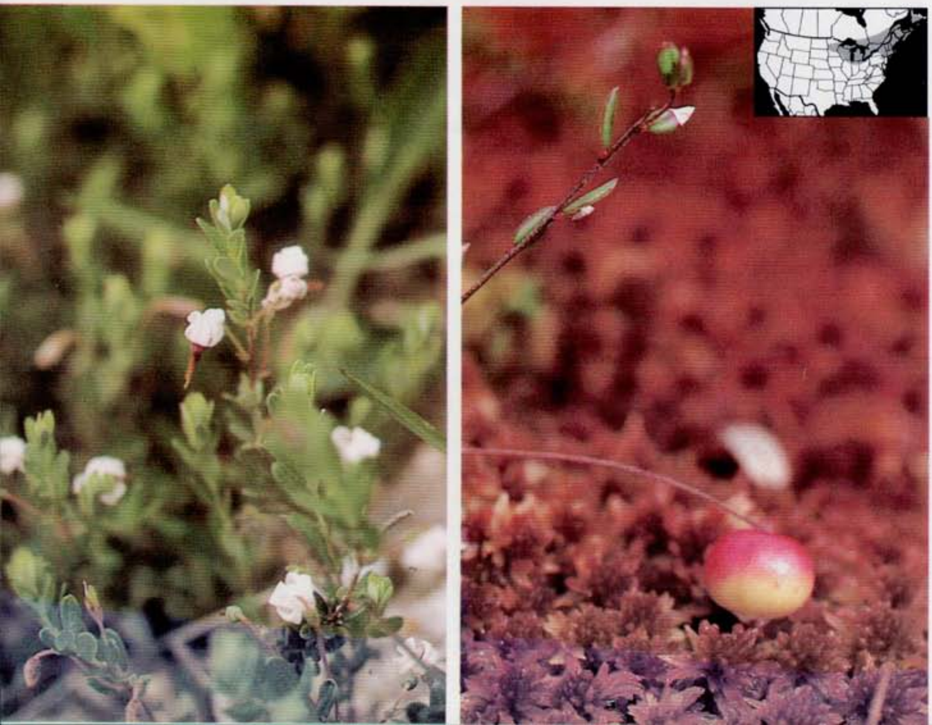

The BLUEBERRY and CRANBERRY GENUS *Vaccinium*

Blueberries, cranberries, huckleberries, and bilberries are all closely related groups of species of the *Vaccinium* genus. There are perhaps 35 species in North America, but hybridization is common. Fruits of most species are edible and range in taste from tart to sweet. The domesticated blueberries are selections of the highbush blueberry *(V. corymbosum)*. Wild blueberries sold commercially are commonly obtained from late sweet blueberry *(V. angustifolium)* or velvet-leaved blueberry *(V. myrtilloides)*. The supermarket cranberry *(V. macrocarpon)* is the same as the wild. Berries are rich in vitamin C.

Mountain cranberry, Lingenberry, Foxberry *Vaccinium vitis-idaea*

Also edible autumn, winter

Habitat: widespread subarctic and alpine plant, bogs, cold seepage areas, rocky acid soils. **Identification:** ***small, creeping plant,*** to 15 cm (6 in) with slender stems; ***leaves*** alternate, simple, ***evergreen,*** broadest above middle, ***0.6–1.8 cm (0.2–0.7 in) long, 4–10 mm (0.2–0.4 in) wide,*** entire, leathery, with scattered black glandular hairs beneath, midrib furrowed. Flowers tiny, pink to reddish, 6–8 mm (0.2–0.3 in) long, narrowly bell-shaped. ***Fruits red berries, rounded, 6–10 mm (0.2–0.4 in) in diameter,*** often persisting over winter, slightly acid tasting. **Harvest and preparation:** Fruits ripen August and September; many persist on plant through winter. Tart to bitter at first; flavor improves after frost. Good trail snack, better used in any cooked cranberry recipes. **Related edible species:** CRANBERRY (next). **Poisonous look-alikes:** none.

Cranberry *(Also edible autumn, winter)* *Vaccinium macrocarpon*

Habitat: widespread northern plant; bogs, swamps, shores of cold acid lakes. **Identification:** ***low, trailing shrub*** with slender brown, flaky-barked stems; ***leaves*** alternate, simple, ***evergreen,*** uniformly wide to broadest near middle, ***5–16 mm (0.2–0.6 in) long,*** rounded at tip, leathery, whitish beneath. Flowers single or in few-flowered clusters on long stalks in junction of upper leaves, each stalk with 2 leaflike bracts, each flower pink, urn-shaped, 4 petals bent back, 6–10 mm (0.2–0.4 in) long. ***Fruits*** are ***berries 1–2 cm (0.4–0.8 in) in diameter,*** globe-shaped, green turning ***bright red at maturity,*** each on long slender stalk. **Harvest:** Fruits ripen September through October and persist into winter in protected areas. Fruits may be harvested with toothed scoop. **Preparation:** Fresh acidic fruits keep well in cool storage. Freeze or dry for long storage. To dry berries, spread on tray or foil in oven for 4 hr at 110°C (230°F). Experiment with substituting dried, powdered berries for part of flour in baking recipes. Most common use of fresh and frozen berries is in sauce served with roast turkey. Bring to boil 2 lb fresh cranberries, 2 cups sugar, 1 cup water (or berries plus 1 cup maple sugar and 1 cup cider). Reduce heat and simmer until all berries pop, and mix looks glassy. For storage, ladle into sterile jars and seal. Check recipe books. **Related edible species:** MOUNTAIN CRANBERRY (preceding); small cranberry *(V. oxycoccos)* is similar but smaller. HIGHBUSH CRANBERRY is not related but has almost identical fruits. **Poisonous look-alikes:** none.

Bog bilberry *Vaccinium uliginosum*

Habitat: widespread boreal and arctic plant; bogs, rocky outcrops, high mountain slopes. **Identification:** ***low shrub to 0.6 m*** (2 ft) high; branches stout, usually spreading; ***leaves*** alternate, simple, ***deciduous, broadest near tip or middle to uniformly wide, 0.5–2 cm*** (0.2–0.8 in) ***long,*** rounded at tip, entire, firm to leathery texture, dull green. Flowers ***solitary or in clusters of 2–4 on short stalks*** in junctions of leaves; each pink to whitish, urn-shaped. ***Fruits fleshy berries 5–8 mm (0.2–0.3 in) in diameter, dark blue to black,*** sweet, with many tiny seeds. **Harvest and preparation:** same as LATE SWEET BLUEBERRY. **Related edible species:** See LATE SWEET BLUEBERRY. **Poisonous look-alikes:** none.

Highbush blueberry, Swamp blueberry *Vaccinium corymbosum*

Habitat: widespread in eastern North America; bogs, low wet woodlands, swamps, occasionally drier soils. **Identification:** ***shrubs,*** variable in shape, ***1–4.5 m*** (3.2–14.8 ft) ***high; leaves*** alternate, simple, ***deciduous,*** broadest near base or middle, sometimes narrowly so, ***3–8 cm (1.2–3.2 in) long,*** 2–3 cm (0.8–1.2 in) wide, usually entire, greenish-yellow. ***Flowers densely clustered,*** each tubular to urn-shaped, white to pink, 5–10 mm (0.2–0.4 in) long. ***Fruits fleshy berries, rounded, 6–12 mm (0.2–0.5 in) in diameter, dark blue to bluish-black, sweet,*** containing many tiny seeds. **Harvest:** Gather ripe fruits in late summer. They can be eaten as trail snack or stored for later use. Fruits ripen as do those of LATE SWEET BLUEBERRY (next), but are easier to gather. Hand pick or shake berries onto blanket or plastic tarp spread beneath bush. **Preparation:** Same as LATE SWEET BLUEBERRY. Also see basic recipes early in book. Add cup dried blueberries to favorite stew recipe. For fritters prepare batter from 1 cup biscuit mix, 3 tbsp sugar, ⅓ cup milk, 1 beaten egg, 1 cup fresh blueberries. Drop spoonfuls into hot cooking oil; brown both sides. Drain; dust with sugar. **Related edible species:** See LATE SWEET BLUEBERRY. **Poisonous look-alikes:** none.

Late sweet blueberry *Vaccinium angustifolium*

Habitat: dry rocky soils, barrens, mountain slopes, occasionally bogs; northcentral and northeastern North America. **Identification:** ***low shrub to 0.3 m*** (1 ft), much branched, often forming thickets. ***Leaves*** alternate, simple, deciduous, ***narrow*** and broadest at or below middle, 1–3 cm (0.4–1.2 in) long, ***finely toothed along margins,*** bright green, smooth. ***Flowers produced in short tight clusters,*** each nearly cylinder-shaped, white to pinkish tinged, 5–6 mm (0.2 in) long. ***Fruits*** are ***fleshy berries 5–12 mm*** (0.2–0.5 in) ***in diameter,*** rounded, ***bright blue,*** white bloom, sweet. **Harvest:** This and other blueberry species ripen in summer, generally after raspberries (RED RASPBERRY) and before blackberries (COMMON BLACKBERRY) where those berries grow. Pick by hand. **Preparation:** Blueberries were probably the most important fruit to American Indians. Excellent dried like raisins and fresh, both raw and in most berry recipes, especially pies, jams, and breads (see basic recipes early in book). Dry thoroughly in sun or warm attic about 10 days or in 100°C (210°F) oven for 4–5 hr; store in sealed containers. For bannock, blend 2 cups sifted flour, 3 tsp baking powder, ½ tsp

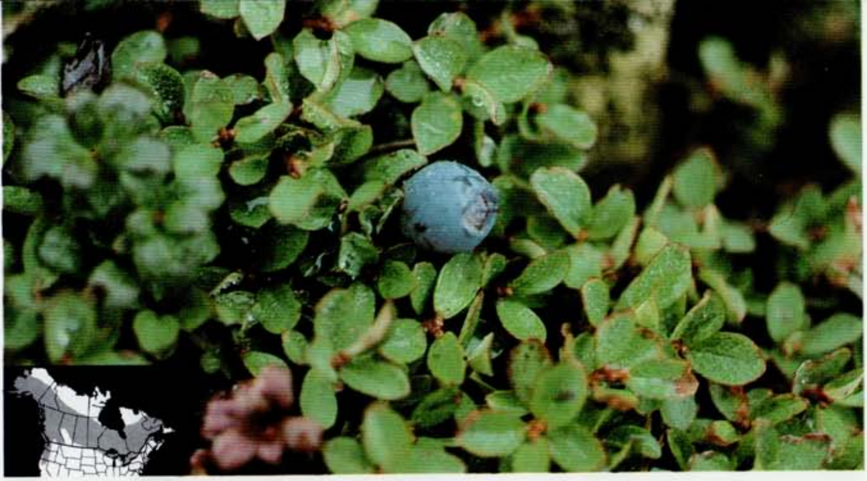

Bog billberry: fruiting plant (Elias).

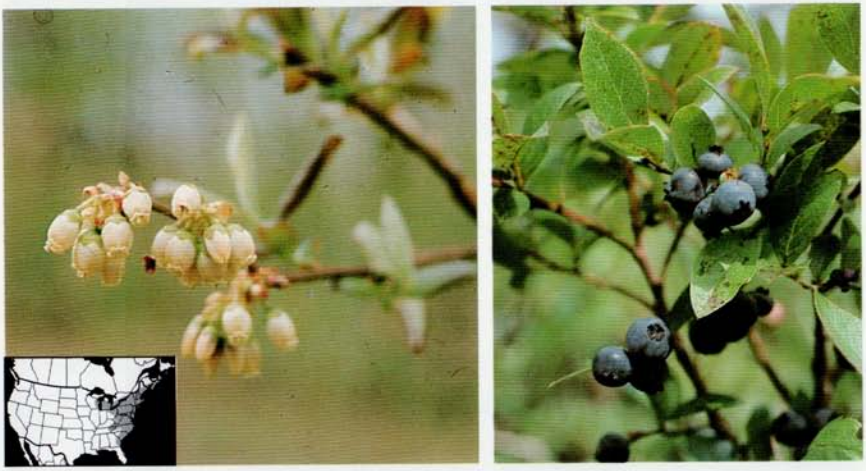

Highbush blueberry: flowering branch (NYBG). Fruiting branch (Elias).

Late sweet blueberry: flowering and fruiting branches (Speas).

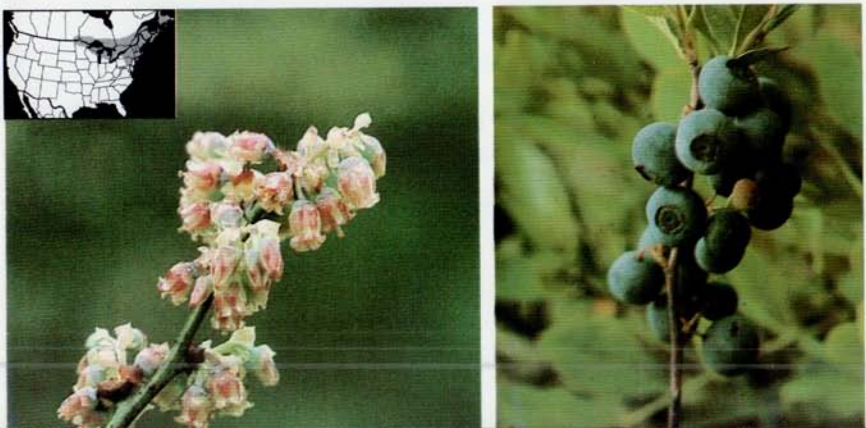

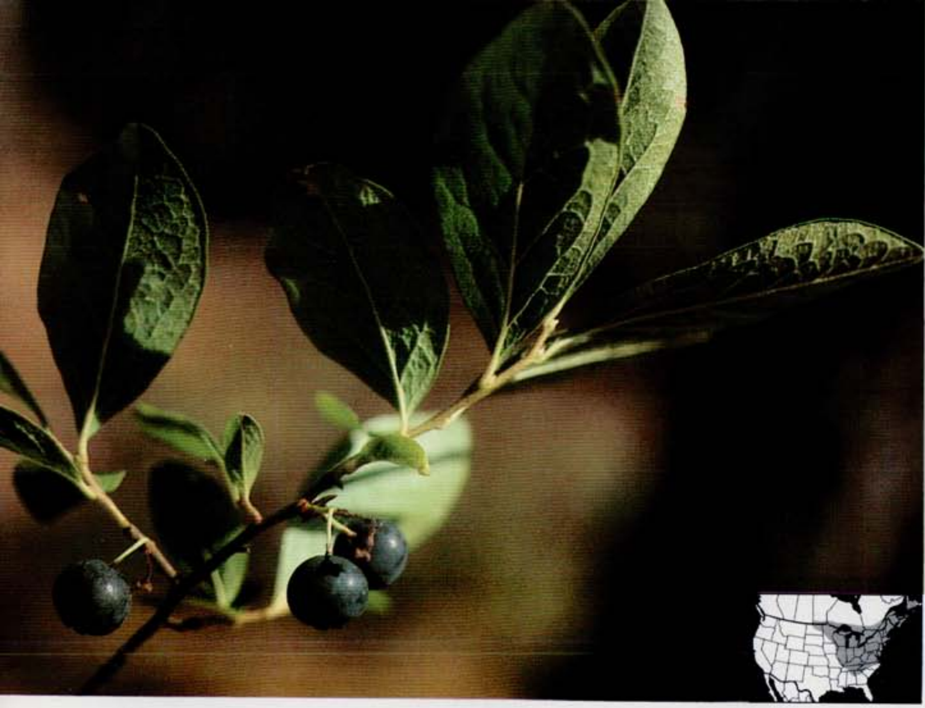

Black huckleberry: fruiting branch (Elias).

Beach plum: fruiting branches (Elias).

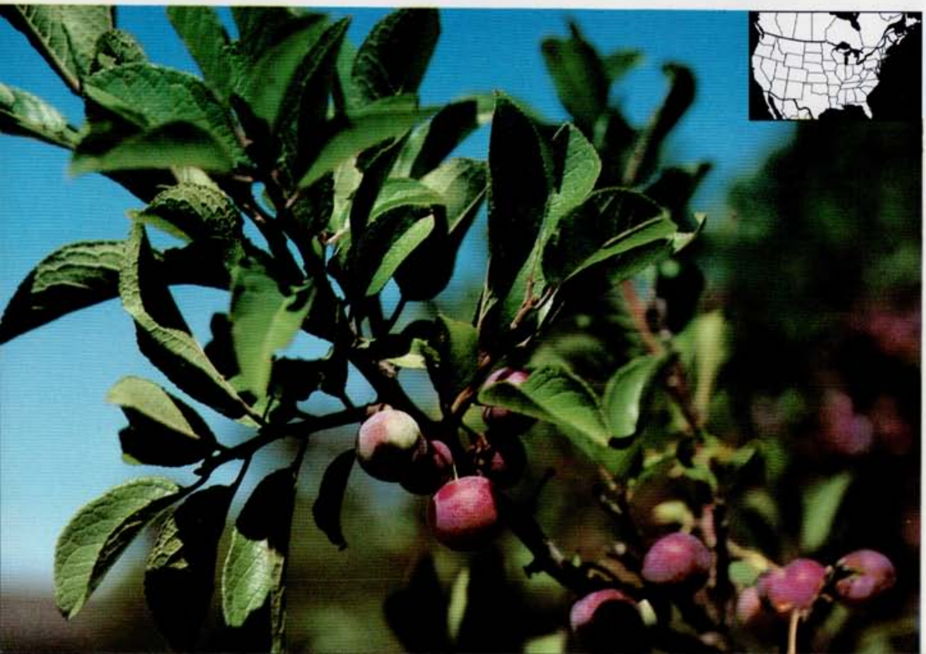

salt, 6 tbsp shortening, 4 tbsp powdered milk. Mix in 1 cup blueberries, then ⅓ cup water. Shape into 1 in thick cake, dust with flour, place in heated frying pan. Cook over coals until bottom is crusty. Turn with spatula and bake until done; test with straw or sliver. See HIGHBUSH BLUEBERRY (preceding) for other uses. **Related edible species:** Other *VACCINIUM*. **Poisonous look-alikes:** none.

Black huckleberry *Gaylussacia baccata*

Habitat: woodlands, clearings, dry to moist soils. **Identification:** shrub to 1.2 m (4 ft), often forming low thickets; branches numerous, stiff, resembling blueberry bush. ***Leaves*** alternate, simple, deciduous, ***3–6 cm*** (1.2–2.4 in) ***long,*** uniformly wide to broadest near or below middle, entire, ***gland-dotted above and below. Flowers few on short elongated clusters, each white,*** small, cone-shaped to almost tubular, 4–7 mm (0.2–0.3 in) long. ***Fruits fleshy berries 6–9 mm*** (0.2–0.4 in) ***in diameter, black at maturity,*** containing 10 tiny seeds, sweet. **Harvest and preparation:** Pick berries as they ripen in late June in south to September in far north. Eat as fresh fruit or use in desserts, pancakes, jam, and jelly. For pancakes add 1 cup berries to 3–4 cups batter. To dry, spread berries in single layer on tray, foil, or paper in warm attic; dry about 10 days or until squashed berry releases no juice. Store in sealed container. Use dried berries in baking or pemmican. Or add ½–1 cup dried berries to beef stew. See LATE SWEET BLUEBERRY and HIGHBUSH BLUEBERRY for other recipes. **Related edible species:** Dwarf huckleberry *(G. dumosa),* box huckleberry *(G. brachycera),* and dangleberry *(G. frondosa)* all yield berries edible but inferior to blueberries. **Poisonous look-alikes:** none.

Beach plum *Prunus maritima*

Also edible autumn

Habitat: coastal regions, sandy soils. **Identification:** shrub to 2.5 m (8 ft) or low and straggling; branches hairy when young, smooth later. ***Leaves*** alternate, simple, deciduous, ***3–7 cm*** (1.2–2.8 in) ***long,*** 1.5–3.5 cm (0.6–1.4 in) wide, broadest at or below middle, rarely widest above middle, pointed at tip, ***sharply toothed along margin,*** dull green and smooth above, softly hairy beneath. ***Flowers 2–4 per cluster, each 1–1.5 cm*** (0.4–0.6 in) ***across,*** with 5 ***white*** petals. ***Fruits rounded*** or nearly so, ***1.5–2.5 cm*** (0.6–1 in) ***in diameter, deep purple to reddish-black at maturity,*** fleshy, sour tasting, enclosing large stone. **Harvest:** Pick fruit from August through October, depending on location. Slightly unripe fruit best for jelly. **Preparation:** similar to AMERICAN PLUM but fruit is more tart. Use jelly and jam recipes early in book. Also, make jellies and jams from blend of plum and other fruits. Combine with peaches or other sweet pulpy fruit for pie filling; see basic plum pie recipe early in book. To dry fruit for later use, slit skin and remove pit. Pits contain toxic hydrocyanic acid. Spread fruit in sun or warm oven until no juice can be squeezed from them, about 4–6 hr. Makes tart trail snack. **Related edible species:** AMERICAN PLUM, FLATWOOD PLUM, and several others. **Poisonous look-alikes:** none.

CURRANT or GOOSEBERRY GENUS *Ribes*

This large group of about 120 species is centered in western North America and the Andes Mountains of South America. They are shrubs, sometimes armed with spines, with simple, maplelike, alternate leaves, flowers in small clusters, and a 1-celled pulpy berry, sometimes transparent, variously colored, containing several seeds. North American species are sometimes difficult to distinguish. Fortunately, none is known to be poisonous. We recommend 2 common yellow-flowered species with smooth fruits and 2 pink- to purple-flowered species with glandular hairy fruits. **Harvest:** Pick fruits in summer as they ripen. **Preparation:** Sweetness and juiciness vary greatly among species. Some fruits can be eaten fresh. Some are spiny and so require cautious eating. Adapt recipes to berry characteristics. For no-cook currant or gooseberry preserves, wash and mash fruits thoroughly. Slowly mix in sugar equal to volume of crushed fruit. Pour into sterilized jelly glasses and seal. For preserves wash and stem 1 lb currants; add ¾ lb sugar and let stand overnight. Bring slowly to boiling point and boil 3–5 min. Let stand overnight, pour into jelly glasses, and seal. To make

Golden currant: flowers (NYBG). Fruiting branches (USDA).

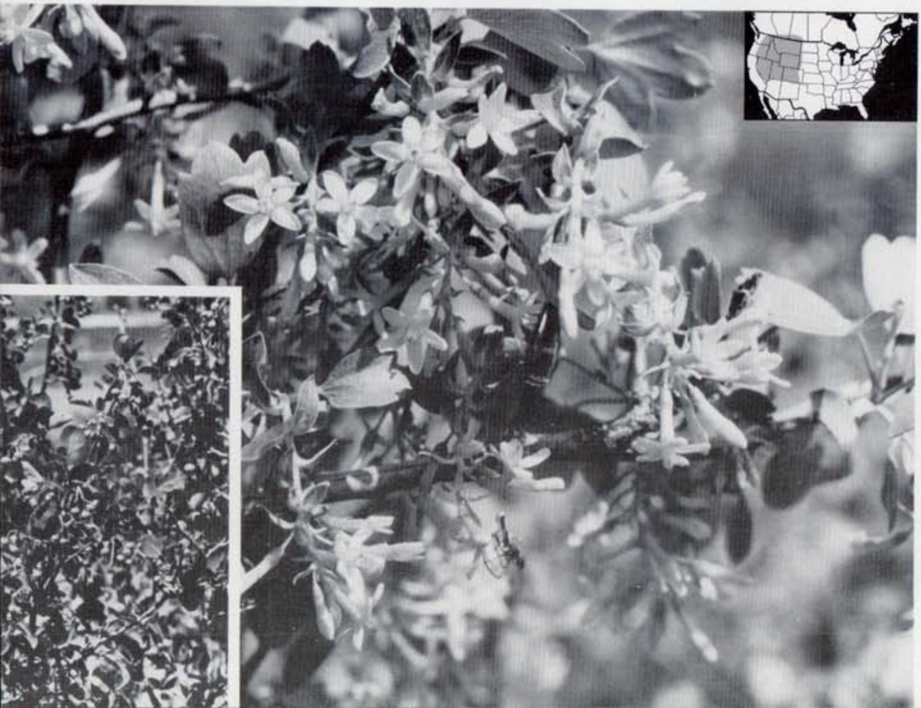

currant/gooseberry conserve, wash and stem 3 lb berries. Grate rind of 3 oranges and cut up pulp. Mix berries, orange rind and pulp, 1 lb seeded raisins, and 3 lb sugar, cook slowly until thick. Pour into sterilized jars and seal. For simple currant/gooseberry pie wash and stem 1 pt berries. Cook in saucepan with 1 cup sugar and small amount of water about 15 min until berries soften. Pour into pie crust, add top crust, bake at 175°C (350°F) oven until crust is done. Add fresh or dried berries to kuchen dough and muffins. To dry whole or mashed berries spread in thin layer on baking sheet; place in sun or 105°C (220°F) oven until dry. Store in paper bag in dry place. To make pemmican mix 1 lb dried and finely ground or pounded meat with ¼ cup brown sugar and ½ cup dried berries. Add ¾ lb melted suet and blend into paste. Form into bars and store dry. Eat as is, boil, or fry. For pie and cooked jelly see recipes early in book. **Related edible species:** many in addition to the four described; widely distributed. **Poisonous look-alikes:** Sticky currant *(R. viscosissimum)* is reported to be a strong vomitory. It has a sticky substance on the leaves, twigs, and fruit. Some fruits are covered with short, bristly hairs.

Golden currant *Ribes aureum*

Habitat: along streams, ravines, washes, mountain slopes, mainly between 750–2,380 m (2,460–7,800 ft) elevation. **Identification:** shrub, erect, open, to 2 m (6.6 ft); branches stiff, nearly smooth. ***Leaves*** alternate, deciduous, 1.2–4.5 cm (0.5–1.8 in) long, 1.5–5 cm (0.6–2 in) wide, ***broadly rounded to widest near base, 3-lobed,*** rounded at tip, entire to coarsely toothed along margin, ***light green,*** smooth, stalked. ***Flowers*** produced in drooping, 5–15-flowered, elongated clusters in late spring, each flower ***bright yellow,*** 5-parted, 6–10 mm (0.2–0.4 in) long, ***smooth. Fruits stalked berries,*** rounded, 6–9 mm (0.2–0.4 in) in diameter, ***red*** or occasionally black, ***smooth, beaked*** (persistent floral parts), produced in summer. **Harvest and preparation:** See CURRANTS, GOOSEBERRIES (preceding). This species both wild and cultivated was much used by western Indians; one of the best flavored species.

Wax currant *Ribes cereum*

Habitat: canyons, dry ravines, hillsides, prairies, open woodlands. **Identification:** open spreading shrub to 1 m (3.2 ft) high; branches stiff, crooked. ***Leaves*** alternate, simple, deciduous, 2–2.5 cm (0.8–1 in) long, 2.5–3 cm (1–1.2 in) wide, ***broadly rounded, wider than long, shallowly 3-lobed,*** rounded at tip, irregularly ***round toothed along margin,*** yellowish-green, glandular hairy on both surfaces, leafstalk 8–15 mm (0.3–0.6 in) long. ***Flowers*** in drooping, 1–6-flowered, elongated clusters in late May or June, each flower ***white to pinkish,*** 5-parted, 6–10 mm (0.2–0.4 in) long. ***Fruits stalked berries, globe-shaped,*** 8–12 mm (0.3–0.5 in) in diameter, ***dull to bright red, with stalked glandular hairs,*** beaked (the persistent floral parts), produced in July or August. **Harvest and preparation:** See CURRANTS, GOOSEBERRIES (preceding). Wax currant is native in West, though frequently cultivated in East.

Subalpine prickly currant *Ribes montigenum*

Habitat: along streams, wet forests, ravines, washes, mainly in subalpine zone 2,140–3,800 m (7,000–12,500 ft) elevation. **Identification:** ***shrub,*** open, spreading, sometimes straggling, to 0.7 m (28 in) high; branches tough, ***densely covered with glandular hairs, stiff bristlelike prickles with small spines at leaf bases. Leaves*** alternate, deciduous, simple, 0.8–3 cm (0.3–1.2 in) long, as wide or wider, almost circular in outline, ***deeply 5-lobed,*** pointed at tip, sharply toothed along margin, glandular hairy on both surfaces, stalked. Flowers produced in drooping, few-flowered clusters in late spring or early summer, each ***flower*** stalked, ***purplish,*** 5-parted, 4–8 mm (0.2–0.3 in) long, ***covered with glandular hairs. Fruits*** stalked ***berries,*** rounded, 4–6 mm (0.2 in) in diameter, ***red, covered with glandular hairs,*** produced in summer. **Harvest and preparation:** See CURRANTS, GOOSEBERRIES (preceding).

Fragrant golden currant *Ribes odoratum*

Habitat: prairies, open woodlands, bluffs, ledges, ravines. **Identification:** ***shrub,*** upright, open, to 1.5 m (5 ft); branches tough, reddish-brown, hairy, ***spineless. Leaves*** alternate, simple, deciduous, 3–6 cm (1.2–2.4 in) long, slightly wider, broadly rounded to widest near base, ***3–5-lobed,*** pointed to blunt at tip, coarsely toothed along margin, hairy, stalked. ***Flowers*** produced in drooping, few-flowered clusters from older wood in spring, each flower ***pale yellow,*** 5-parted, 12–16 mm (0.5–0.6 in) long, smooth. ***Fruits, produced in summer, stalked berries, globe-shaped, 9–12 mm*** (0.4–0.5 in) ***in diameter, purplish-black, smooth,*** with beaked persistent floral parts. **Harvest and preparation:** See CURRANTS, GOOSEBERRIES (preceding).

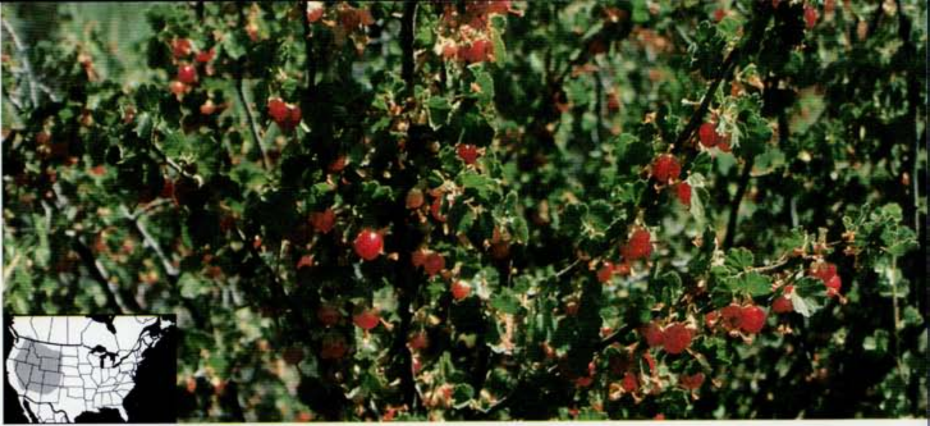

Wax currant: fruiting branches (Ross).

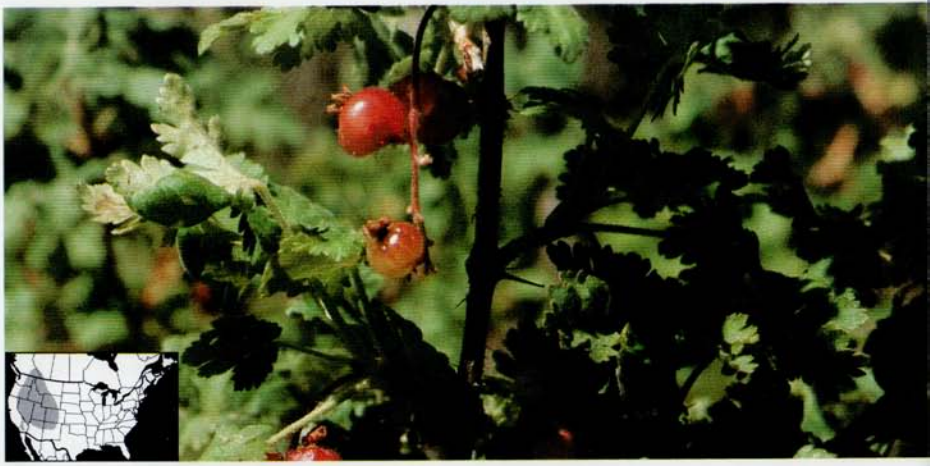

Subalpine prickly currant: fruiting branch (Dykeman).

Fragrant golden currant: fruiting branches (Kavasch).

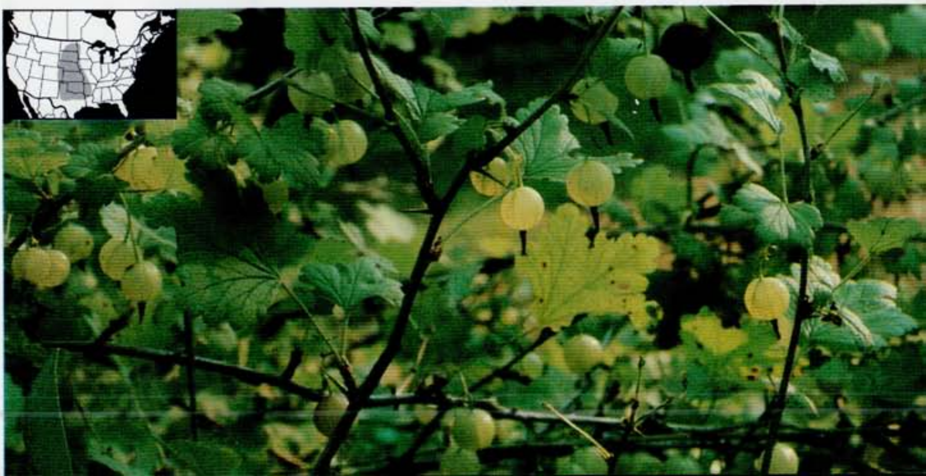

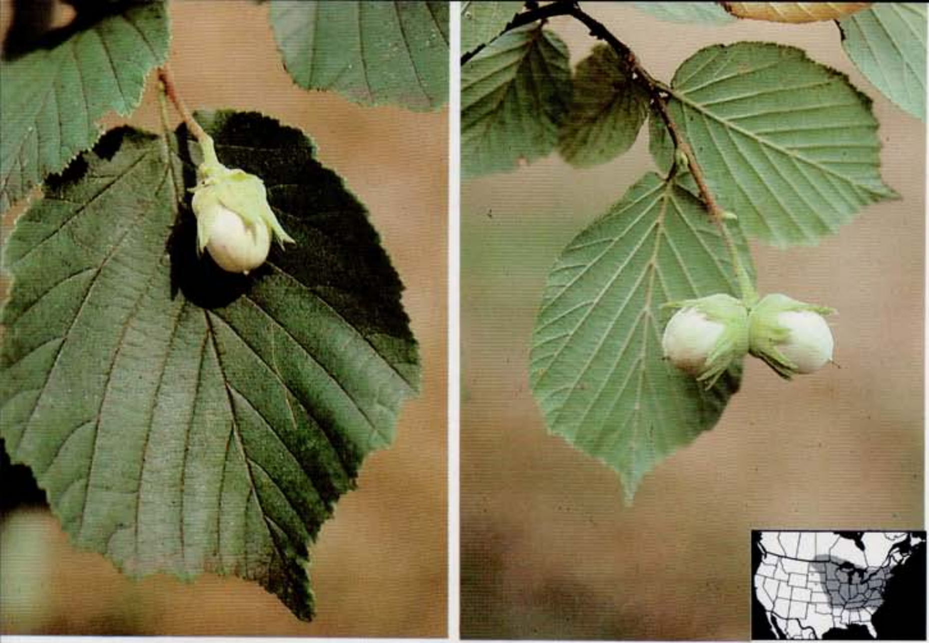

American hazelnut: fruiting branches (Elias).

Beaked hazelnut: fruits (Speas).

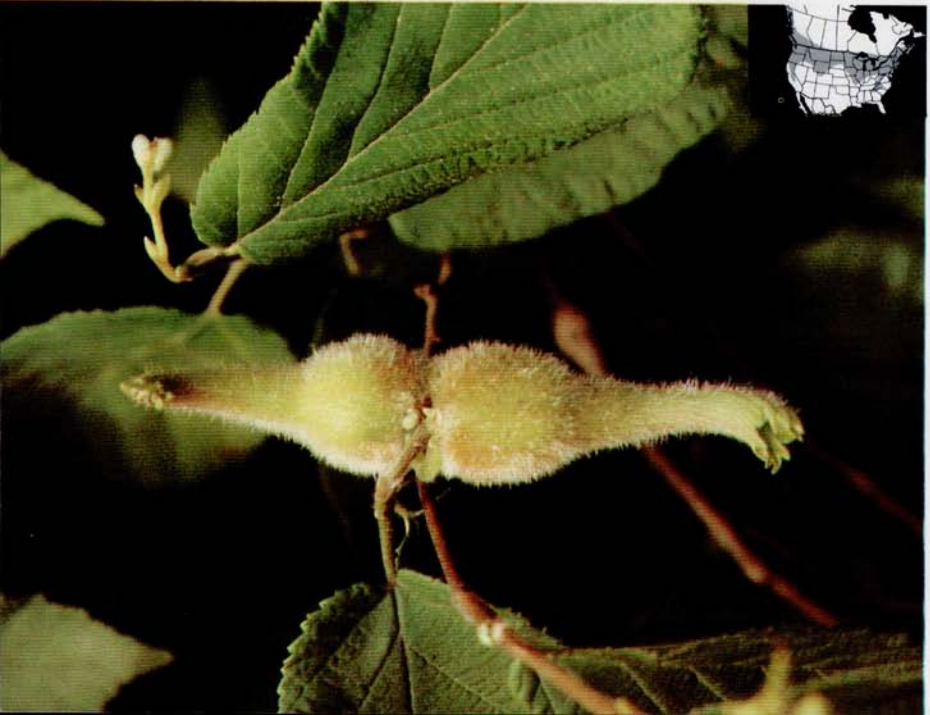

American hazelnut *Corylus americana*

Also edible autumn

Habitat: widespread, dry to moist woodlands, thickets. **Identification:** shrub to 5 m (16.4 ft) with rounded head and glandular hairy twigs. ***Leaves*** alternate, simple, deciduous, 5–15 cm (2–6 in) long, 3–12 cm (1.2–4.7 in), broadest below or above middle, long-pointed at tip, ***doubly toothed*** along margin, usually hairy beneath. Male flowers in dense slender catkins in early spring. Female flowers usually solitary or paired, tiny, inconspicuous in early spring. ***Fruits are hard-shelled nuts, broader than long,*** 1–1.5 cm (0.4–0.6 in) across, ***partially enclosed by 2 ragged-edged leaflike bracts,*** nutmeat sweet. **Harvest:** Nuts mature in late summer or autumn. **Preparation:** Remove husk, shell, and eat as is, or use in any recipe calling for nuts. For no-cook candy, mix 1 egg white with 2 cups confectioner's sugar. Add 2 tsp butter or margarine and blend until smooth. Work in 2 cups chopped hazelnuts and form into balls. Eat and enjoy. For hazelnut hot cakes, finely grind 0.2 kg (½ lb) dried hazelnuts. Boil in 2 cups water until mushy, about 30 min. Add 1 tsp maple syrup and ⅓ cup fine cornmeal, stir well, let stand for 20 min or until thick. Heat ⅓ cup frying oil in skillet. Drop batter by tablespoonfuls into hot oil. Brown on one side, flip, flatten, brown on other side. Drain and serve hot or cold. See also BEAKED HAZELNUT (next). **Related edible species:** BEAKED HAZELNUT. **Poisonous look-alikes:** none.

Beaked hazelnut *Corylus cornuta*

Also edible autumn

Habitat: dry or moist woodlands, hills or mountain slopes, absent on Coastal Plain. **Identification:** shrub to 3 m (9.8 ft), often forming thickets; twigs hairy when young. Leaves alternate, simple, deciduous, 3–10 cm (1.2–4 in) long, 2–8 cm (0.8–3.2 in) wide, broadest near base, long-pointed at tip, doubly toothed along margin, hairy beneath. Male flowers in dense, slender catkins in early spring. Female flowers solitary or few per cluster, tiny, inconspicuous. ***Fruits*** are ***thin-shelled nuts,*** broadest near base, 1–1.5 cm (0.4–0.6 in) in diameter, ***enclosed by 2 bristly leaflike bracts 4–7 cm*** (1.6–2.8 in) ***long which form narrow beak;*** nutmeat sweet. **Harvest:** Nuts mature in late summer or autumn. **Preparation:** Remove husk. Shell and eat as is or use in recipes calling for nuts or grind into meal to use as flour. For hazelnut torte preheat moderate oven 175°C (350°F). Beat 11 egg yolks well, add 0.5 kg (1 lb) confectioner's sugar, continuing to beat. Add 0.5 kg (1 lb) ground hazelnuts and 1 tsp instant coffee. Fold in 11 stiffly beaten egg whites. Bake in 30 cm (12 in) greased and floured spring baking form for 50–60 min. See also AMERICAN HAZELNUT (preceding). **Related edible species:** AMERICAN HAZELNUT. **Poisonous look-alikes:** none.

Sweet fern *Comptonia peregrina*

Also edible winter, spring

Habitat: dry rocky, sandy, or gravelly soils of clearings, pastures, poor open woodlands. **Identification:** small shrub 0.4–1.2 m (1.3–4 ft) high, with rounded shape; young branches hairy. ***Leaves*** in fernlike pattern, alternate, simple, deciduous, ***6–14 cm*** (2.4–5.5 in) ***long, 0.8–1.2 cm*** (0.3–0.5 in) ***wide,*** widest near middle or base, ***deeply lobed along margin, fragrant due to numerous resinous glands*** on leaves and twigs. Male and female flowers produced in separate small catkins on same bush in spring. ***Fruits small, green burrs 1–2 cm*** (0.4–0.8 in) ***in diameter,*** each partially or totally enclosing 1–4 nutlets, maturing in mid to late summer. **Harvest:** leaves any time for fragrant tea. Immature nutlets during June and July while still tender. **Preparation:** For tea add 1 tsp dried or 2 tsp fresh leaves per cup boiling water; steep. When camping, put 8 tsp fresh, chopped leaves per qt of water in glass jar. Cap and place in sun 3 hr or until water is dark. Strain, dilute to taste, sweeten if desired. Not bitter like many brewed teas. Strong tea (infusion) has been used to alleviate dysentery. Using thumbnail, separate nutlets from burrs when immature and eat raw. **Edible related species:** northern bayberry *(Myrica pensylvanica),* SOUTHERN BAYBERRY and SWEET GALE (next). **Poisonous look-alikes:** none.

Southern bayberry, Wax myrtle *Myrica cerifera*

Also edible autumn, winter

Habitat: coastal plain, swamps, along ponds and lakes, pine barrens, wet sandy soils. **Identification:** shrub or small tree to 8 m (26 ft) with rounded crown and slender, hairy, ***gland-dotted twigs. Leaves*** alternate, simple, deciduous but often persisting until second year, ***3.5–10 cm*** (1.4–4 in) ***long,*** 0.6–1.2 cm (0.2–0.5 in) wide, ***narrow*** but broadest near tip, ***coarsely toothed along margin, yellow-green, gland-dotted, fragrant when rubbed.*** Male and female flowers on separate bushes in spring; male flowers in slender catkins 1.2–1.9 cm (0.5–0.7 in) long; female flowers in broader catkins 0.6–1.2 cm (0.2–0.5 in) long on older twigs. ***Fruits few to several clustered on short spikes, each rounded, 2–4 mm (0.1 in) in diameter, covered with light blue waxlike coating.*** **Harvest and preparation:** Pick leaves any time available but best in early summer. Wash and spread to dry thoroughly in warm shaded area. Store in sealed jars in dark place. Crumble and blend into stews and sauces for cooking and serving meats. Also use berries picked from late summer into winter as seasoning and to provide wax used in candles. **Related edible species:** northern bayberry *(M. pensylvanica)* and other wax myrtle species are used the same way. Also SWEET GALE (next) is used for seasoning but fruits lack wax. **Poisonous look-alikes:** none.

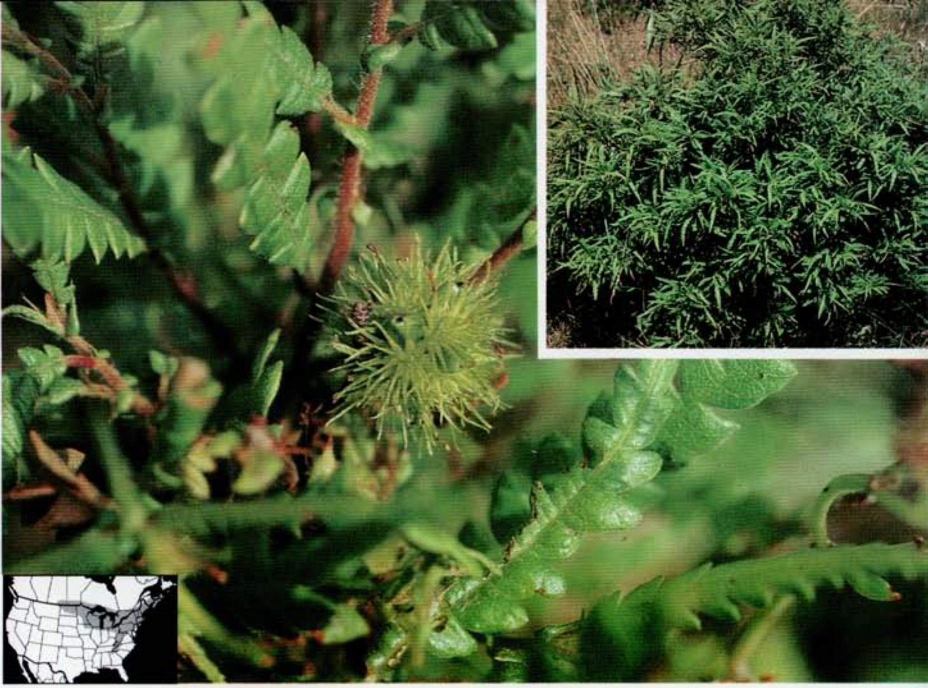

Sweet fern: mature plant and branch with fruit (Elias).

Southern bayberry: fruiting branches (NYBG).

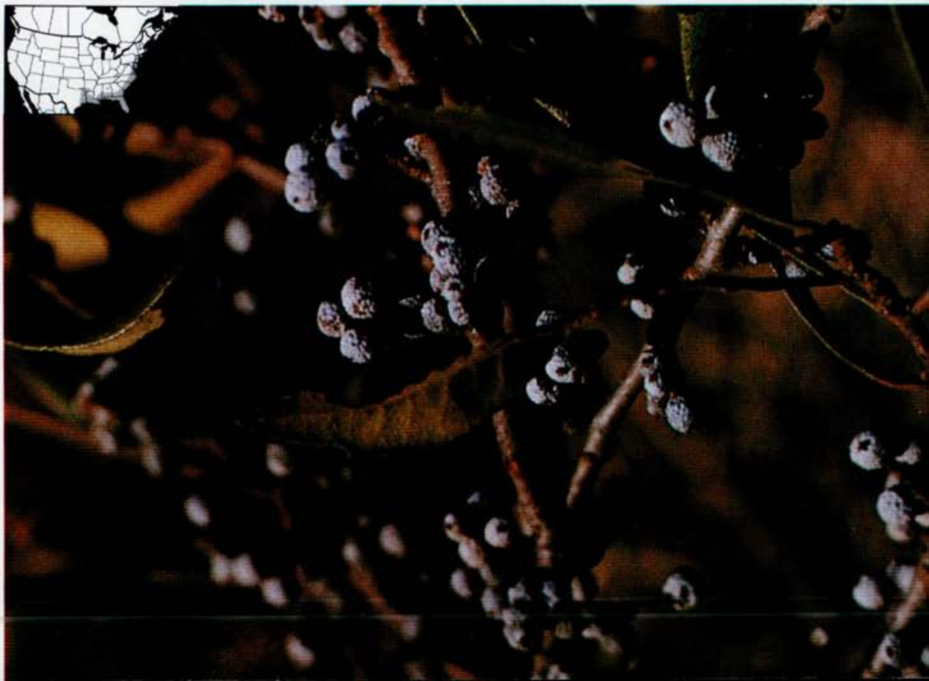

Sweet gale *Myrica gale*

Also edible autumn, winter

Habitat: swamps and shallow water along ponds and streams. **Identification:** shrub 0.3–2 m (1–6.6 ft) tall with upright brown branches. ***Leaves*** alternate, simple, ***deciduous, wedge shaped,*** rounded, ***broadest near tip,*** toothed near tip, ***dark green above, pale beneath, downy on veins,*** 2–7 cm (0.8–2.8 in) long, ***aromatic*** when crushed. ***Male flowers in spikelike catkins at end of twigs; female flowers usually on separate plants,*** about 8 mm (0.3 in) long, ***at base of leaves. Fruit small nutlike, not waxy,*** resin dotted, aromatic, with 2 winglike scales, ***in small conelike clusters.*** **Harvest:** Pick leaves as described for SOUTHERN BAYBERRY (preceding) and aromatic nutlets from summer through winter. **Preparation:** Dry and use leaves as described for SOUTHERN BAYBERRY and for making hot tea. Use nutlets like dried leaves for seasoning. **Related edible species:** See SOUTHERN BAYBERRY. **Poisonous look-alikes:** none.

New Jersey tea *Ceanothus americanus*

Habitat: open woodlands and prairies, in well-drained rocky, gravelly, or sandy soils. **Identification:** ***shrub*** to 1 m (3.2 ft) with slender, reddish-brown, densely hairy twigs. ***Leaves*** alternate, simple, 3-ribbed, deciduous, ***4–8 cm*** (1.6–3.2 in) ***long,*** 2–4 cm (0.8 –1.6 in) wide, broadest near base, rounded at tip, ***finely toothed along margin,*** green above, gray and hairy beneath. ***Flowers tiny, white, produced in dense, short cylinder-shaped, branched clusters in spring,*** each with 5 white petals shaped like tiny tobacco pipes. Clusters from leaf junctions. ***Fruits*** produced in rounded clusters in late spring or early summer, each ***capsulelike, 5–6 mm*** (0.2 in) ***long,*** splitting open to release tiny, reddish-brown seeds. **Harvest:** Gather fresh leaves in summer, best when bushes are flowering. Dry leaves thoroughly in sun, by fire, or in warm oven. **Preparation:** For tea, steep 1 tbsp fresh or 1 tsp dried leaves in 1 cup boiling water for 15 min. Sweeten to taste. Caffeine free. Dried root bark tea was used as sedative by Indians. **Related edible species:** Red root *(C. ovatus)* is also known as New Jersey tea. *C. americanus* has wider leaves and flower clusters at leaf junctions instead of at end of twig. **Poisonous look-alikes:** none.

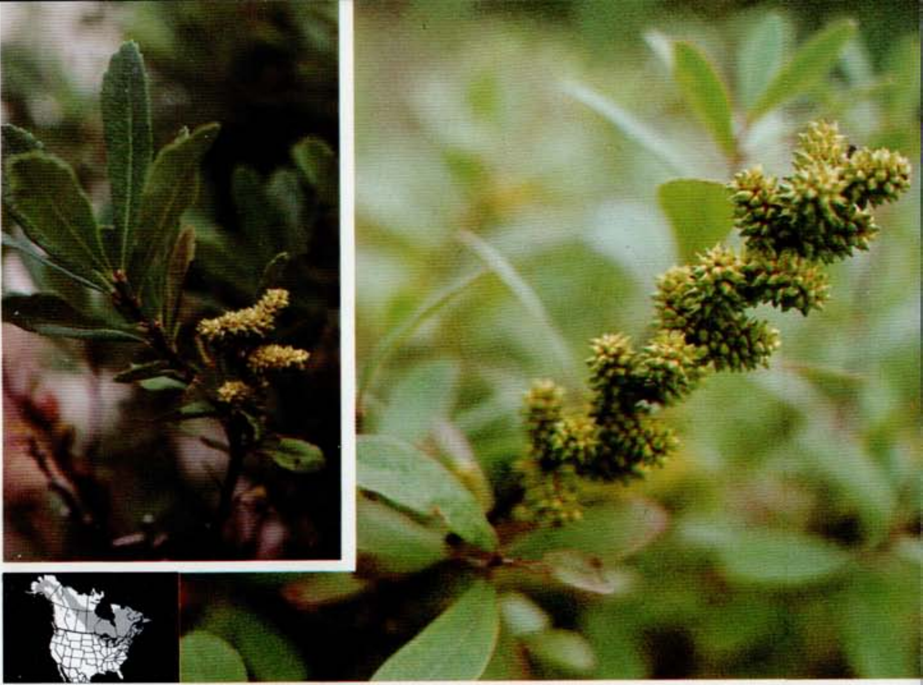

Sweet gale: fruiting branch and fruits (Elias).

New Jersey tea: flowers (Mohlenbrock). Flowering branch (NYBG).

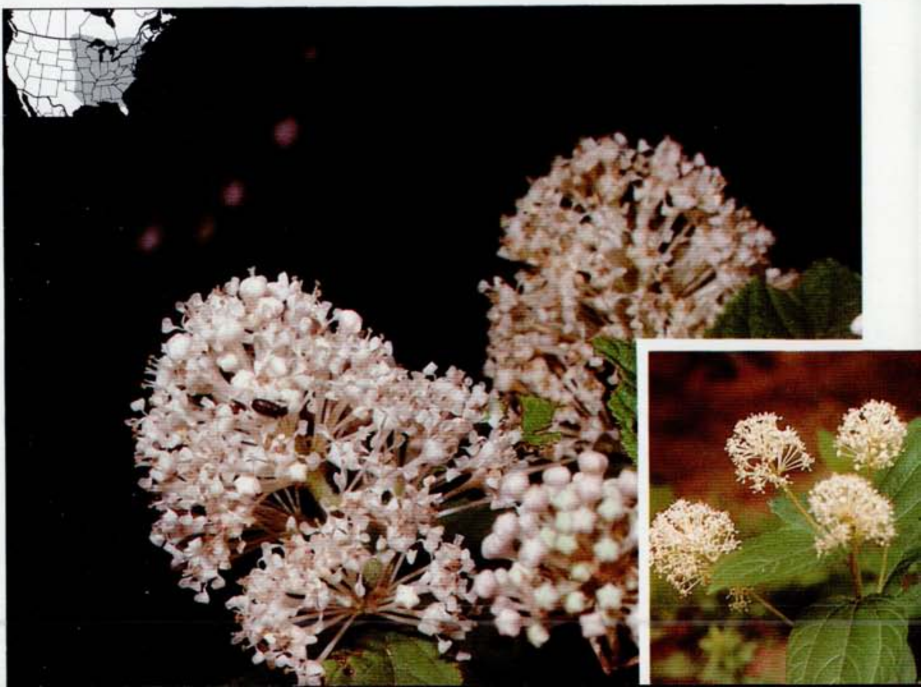

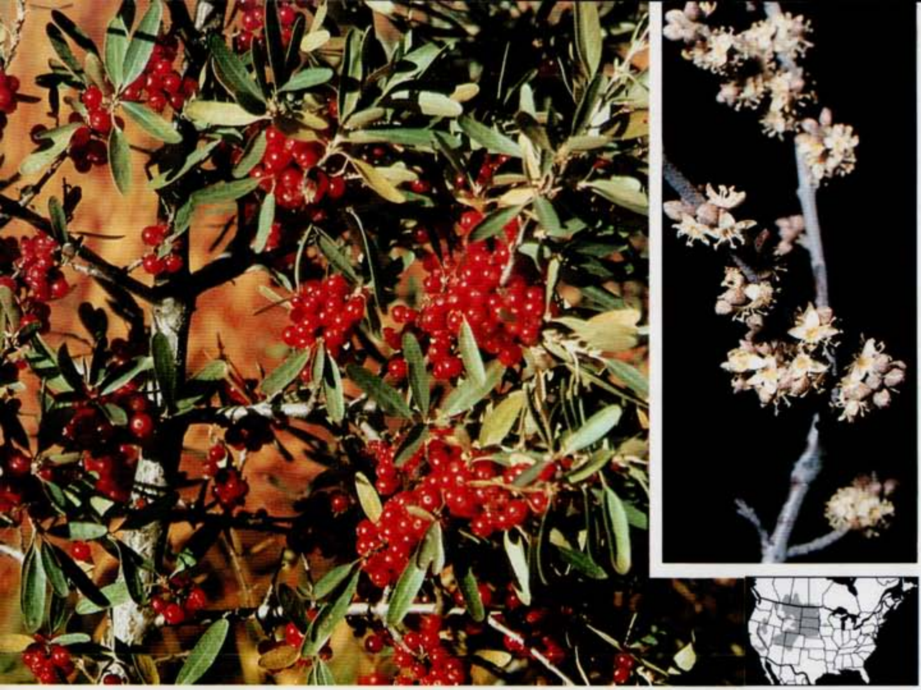

Silver buffaloberry: fruiting branches (Elias). Flowering branch (NYBG).

BRAMBLES, BLACKBERRIES, RASPBERRIES *Rubus*

This is a large and variable group of approximately 300 to 400 species in the temperate regions of the world. Members of this genus are shrubs or trailing, often prickly, vines, collectively known as brambles. Fruits may or may not separate from the spongy core of the fruit base when picked. The genus normally is divided into subcategories; one containing blackberries and dewberries, another containing thimbleberries, another raspberries. Most of the species have edible fruits; many have delicious fruits. Six of the more common species are treated on the following pages. **Harvest and preparation:** Pick fruit as it ripens. Berries of most species are excellent fresh, except for thimbleberries which have a rather dry taste and may require mixing with other berries. The berries are good with cream and sugar, in pancakes, on cereals, and in jams, jellies, and pies. To make berry bannock over campfire, mix 2 cups flour, 3 tsp double-acting baking powder, ½ tsp salt, 6 tbsp margarine or butter, and 4 tbsp powdered milk until uniformly mixed into mealy texture. Add 1 cup washed damp berries; mix gently to coat fruit. Add ⅓ cup water to make workable dough. Shape into 1-in-thick

Silver buffaloberry *Shepherdia argentea*

Also edible autumn

Habitat: riverbanks, low meadows, plains, canyons. **Identification:** spreading shrub or small tree to 5 m (16 ft) with dull gray bark shredding in long strips; ***branches*** stout, ***covered with silvery-white scales,*** usually ***thorny. Leaves opposite,*** simple, deciduous, 3–5 cm (1.2–2 in) long, 7–10 mm (0.3–0.4 in) wide, uniformly wide to widest near middle, entire, ***leathery, densely covered with silvery scales on both surfaces.*** Male and female flowers on separate trees; flowers small, inconspicuous, lacking petals. ***Fruits berrylike, rounded,*** 6–9 mm (0.2–0.4 in) long, smooth, ***bright red,*** slightly fleshy, enclosing single flattened seed. **Harvest:** late summer fruits pleasantly tart, better after frost has sweetened them. Shrub is frequently prolific fruit producer. Handpick or spread tarp beneath shrub and shake branches. **Preparation:** Use fruit fresh or dry thoroughly in sun. Use prefrost berries for jelly. Eat ripe fruit fresh or dried; add sugar as desired. Seeds are chewable. For beverage crush 1 cup fresh berries with 1 cup sugar in 3 cups hot water or mash 1 cup dried berries in 1 pt water. Add sugar to taste. Strain and drink. Cook berries with meat or prepare like CRANBERRY sauce for use with meat. For dessert mash fresh fruits and whip or blend into froth. Blend in sugar if needed. **Related edible species:** Canadian buffaloberry *(S. canadensis)* and silverberry *(Elaeagnus argentea)* are edible but less flavorful, and are improved by cooking and adding sugar. **Poisonous look-alikes:** none.

cake, dust with flour, place in warm, greased fry pan. Cook over moderate heat until crust forms on bottom. Turn over with spatula and cook until browned and no dough sticks to fork inserted into center of dough. Adapt other berry recipes from your favorite cookbooks. Tender growth tips of many species are edible, and leaves of many are good for tea. **Related edible species:** See above. **Poisonous look-alikes:** none.

Red raspberry *Rubus idaeus* var. *strigosus* (synonym: *R. strigosus*)

Habitat: margins of woodlands, clearings, roadsides, abandoned fields. **Identification:** subshrub to 2 m (6.6 ft) high; ***branches*** spreading to trailing along ground, often with a whitish cast, ***armed with usually numerous prickles*** and stiff hairs. ***Leaves*** alternate, deciduous, compound on nonflowering canes, ***with 3–7 leaflets,*** each leaflet broadest near base, 2–10 cm (0.8–4 in) long, long-pointed at tip, coarsely and sharply toothed along margin, ***pale green to whitish and hairy beneath.*** Flowers white to greenish-white, 1.2–1.8 cm (0.5–0.7 in) across, produced June–July in small clusters of 2–5 flowers along upper part of canes. ***Fruits globe-shaped or nearly so, 1.2–2 cm*** (0.5–0.8 in) ***in diameter, bright red,*** juicy, ***separating easily from fruiting stalk and base,*** maturing from July–September. **Harvest and preparation:** See BRAMBLES (preceding).

Wineberry *Rubus phoenicolasius*

Habitat: introduced from Asia; grows wild in disturbed sites, along streams, rivers, roads, especially in coastal eastern U.S. **Identification:** shrub to 2.5 m (8 ft) high; ***branches*** spreading, often arching over, ***lacking spines but with dense, red, gland-tipped hairs. Leaves*** alternate, deciduous, ***3-parted*** (trifoliolate), ***broadest near base and often as broad as long, 4–10 cm (1.6–4 in) long and wide,*** often lobed, toothed. ***Flowers white,*** produced in elongate, many-flowered clusters; ***each 2–3 cm (0.8–1.2 in) across (including calyx lobes), petals shorter than the narrow, pointed, calyx lobes. Fruits globe-shaped, 0.8–1.2 cm (0.3–0.5 in) in diameter, bright red*** at maturity, juicy, maturing from midsummer to early autumn. **Harvest and preparation:** See BRAMBLES (preceding).

Thimbleberry *Rubus parviflorus*

Habitat: widespread from sea level to mountains; woodlands, canyons, open areas, along roads, trails, streams. **Identification:** shrub to 2 m (6.6 ft) high with ***upright to spreading branches, without spines*** but with glandular hairs. ***Leaves*** alternate, deciduous, ***simple, 5-lobed, 5–15 cm (2–6 in) long and wide,*** sharply toothed along margin. ***Flowers*** large, ***white to pink, 2–5 cm (0.8–2 in) across,*** produced in loose, 2–9-flowered, spreading clusters. ***Fruits large,*** globe-shaped, ***1.2–1.8 cm (0.5–0.7 in) across, bright red to scarlet,*** sweet, juicy, maturing throughout season. **Harvest and preparation:** See BRAMBLES (preceding).

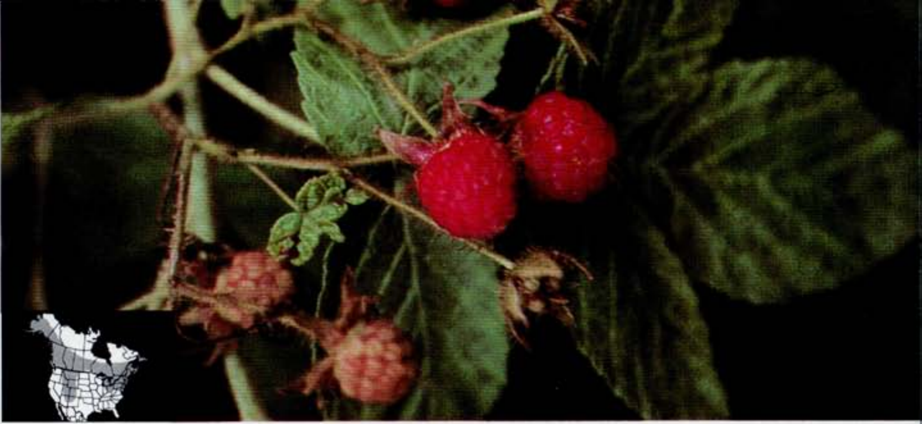

Red raspberry: fruiting branch (Elias).

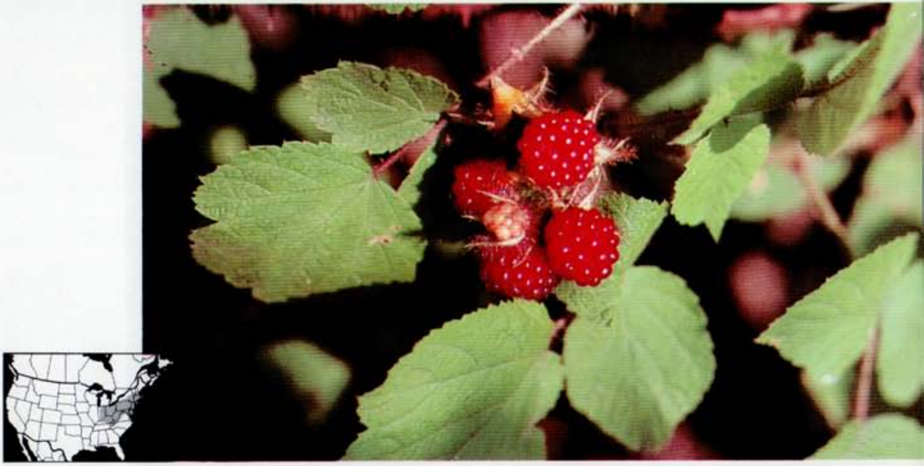

Wineberry: fruiting branch (Elias).

Thimbleberry: fruiting branch (McNeal).

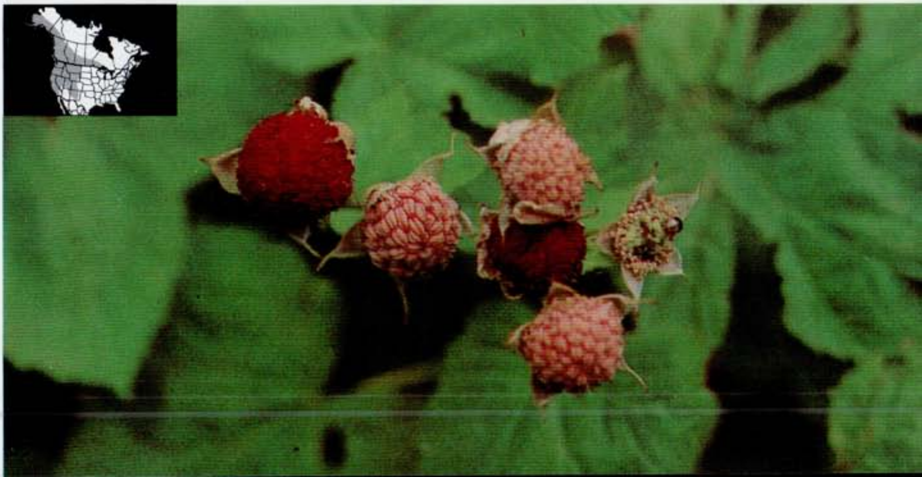

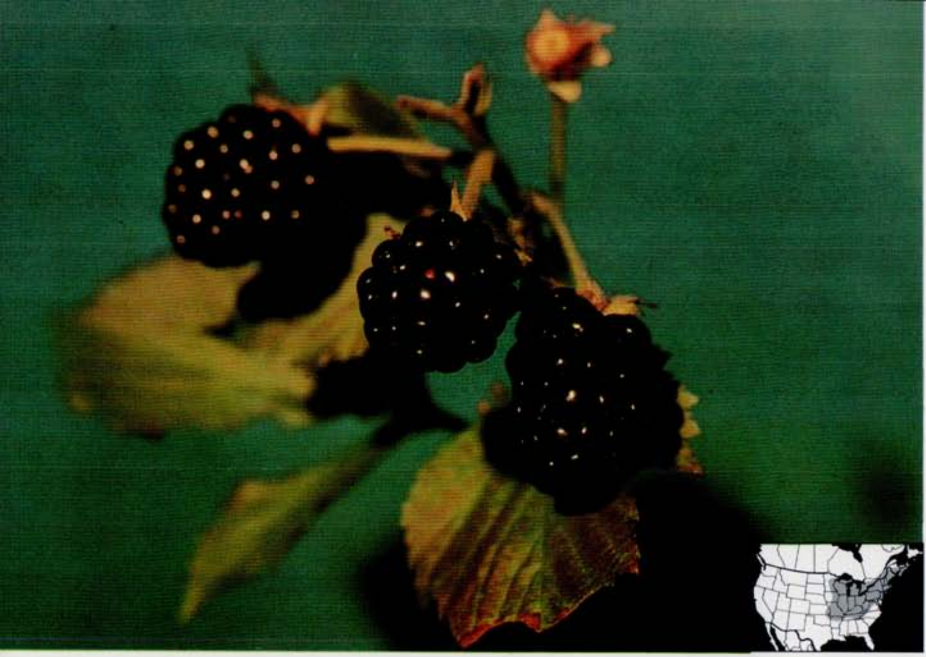

Common blackberry: mature fruits (Elias).

Black raspberry: fruiting branch (Elias). Flowering branch (Dykeman).

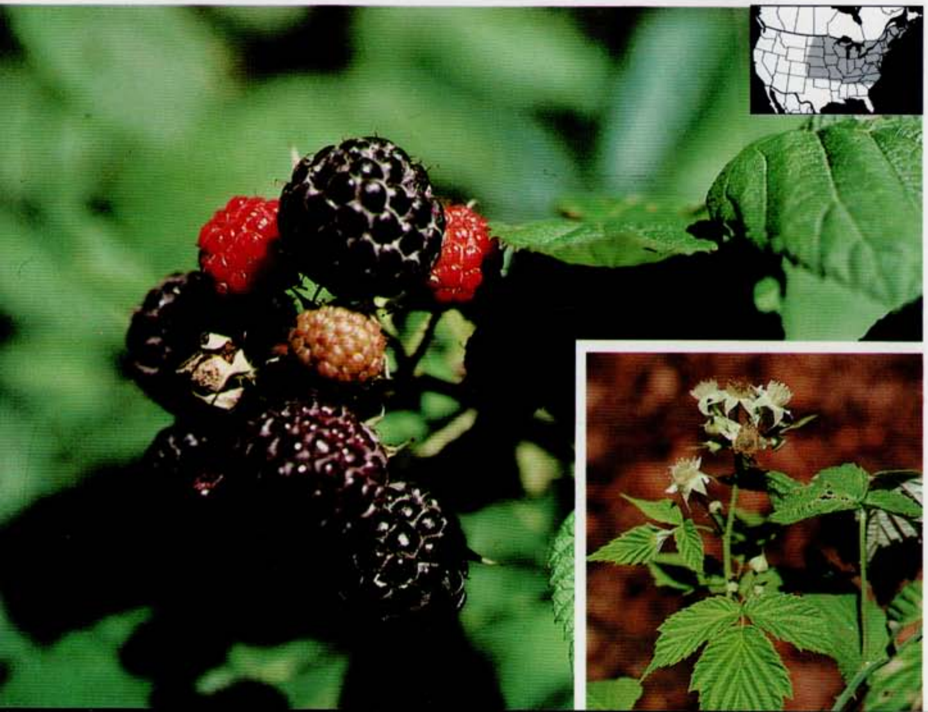

Common blackberry *Rubus allegheniensis*

Habitat: margins of woodlands, old fields, fencerows; also roadsides, thickets, mountain slopes. **Identification:** shrub, sometimes to 3 m (9.8 ft), branches upright to spreading, sometimes trailing, with scattered straight spines. ***Leaves*** alternate, deciduous, palmately compound, ***usually with 5 leaflets,*** sometimes 3, variable, typically broadest near or just below middle, long-pointed at tip, usually 10–18 cm (4–7 in) long, with numerous sharp-pointed teeth along margin, ***pale green beneath. Flowers white,*** 1.7–2.5 cm (0.7–1 in) across, produced in May, June, or early July (usually about 2–3 weeks later than black raspberry) ***in elongated 6–15-flowered clusters. Fruits globe- to short cylinder-shaped, to 2 cm (0.8 in) long,*** juicy, sweet, black at maturity; maturing in late July or August. **Harvest and preparation:** See BRAMBLES (preceding).

Black raspberry *Rubus occidentalis*

Habitat: disturbed areas, especially margins of woodlands, ravines, fields, thickets; sometimes in full shade. **Identification:** shrub with upright to spreading ***branches, sometimes arching to ground; stems with scattered, straight or curved, stout spines. Leaves*** alternate, deciduous, compound, each leaf ***with 3–5 leaflets,*** terminal leaflets broadest near base, pointed at tip, sharp and irregularly toothed along margin; lateral leaflets smaller, ***whitish beneath.*** Flowers white, produced in May or June in 3- to 7-flowered nearly flat clusters. ***Fruits purplish-black to black, 0.8–1.2 cm (0.3–0.5 in) across,*** rounded or nearly so, ***easily separated as a unit*** from fruiting stalk and base, juicy, sweet, maturing in June or July. **Harvest and preparation:** See BRAMBLES (preceding).

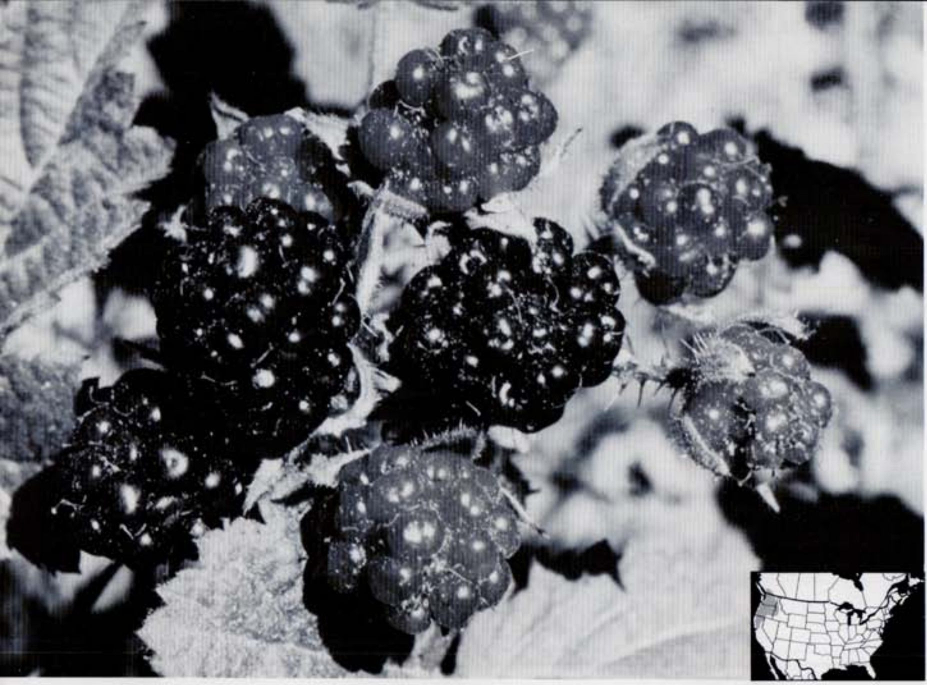

California blackberry: fruits (Ross).

Smooth sumac: fruiting branch (Dykeman). Fruits (Elias).

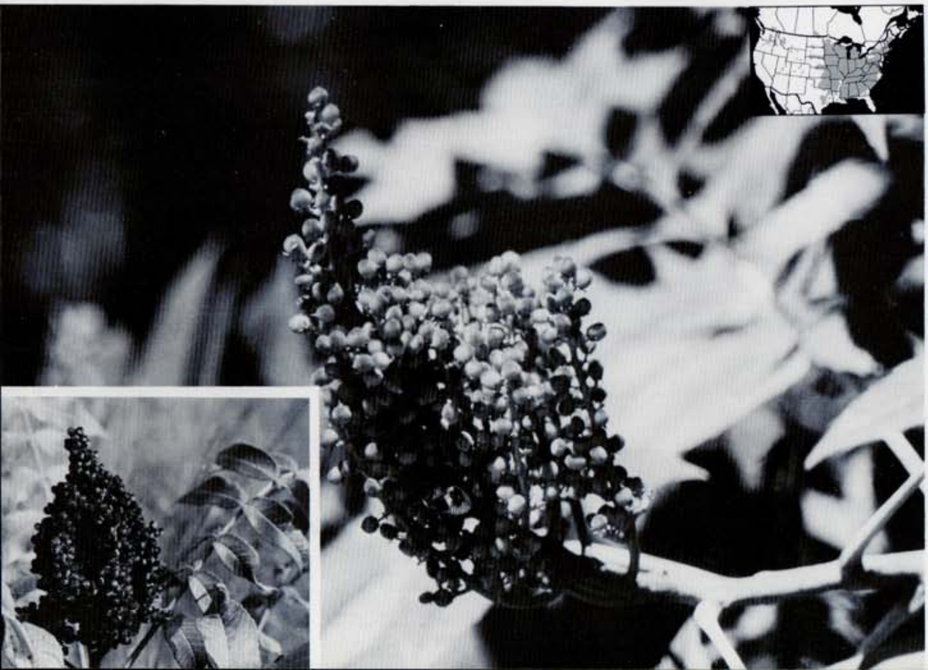

California blackberry *Rubus ursinus*

Habitat: disturbed sites, along trails, roads, canyons, fields, open woodlands; common at lower elevations, below 1,000 (3,200 ft). **Identification:** ***shrub, often low; branches spreading to trailing along ground;*** armed with slender, slightly flattened spines. ***Leaves*** alternate, deciduous, ***usually 3-parted (trifoliolate),*** sometimes simple; ***leaflets broadest near base, 6–12 cm (2.4–4.7 in) long, 4–10 cm (1.6–4 in) wide,*** coarsely toothed, occasionally shallowly lobed. Flowers white, produced in elongate, loose, 3–12-flowered clusters; each 1–3 cm (0.4–1.2 in) across. ***Fruits short cylinder-shaped to nearly cone-shaped, 1–2 cm (0.4–0.8 in) long, black at maturity,*** juicy, sweet. **Harvest and preparation:** See BRAMBLES (preceding).

Smooth sumac *Rhus glabra*

Also edible autumn

Habitat: common and widespread; abandoned farmlands, fields, margins of woodlands, along streams. **Identification:** shrub or small ***tree*** to 7 m (23 ft) ***with smooth stout branches*** and open rounded crown. ***Leaves*** alternate, deciduous, ***featherlike (pinnate) compound, with 11–31 leaflets,*** leaflets usually lance-shaped, 5–9.5 cm (2–3.7 in) long, 1.2–3 cm (0.5–1.2 in) wide, long pointed at tip, sharply toothed along margin, dark shiny green above, whitish beneath. Male and female flowers on different plants, produced in dense, cone-shaped clusters 10–25 cm (4–10 in) long. ***Fruits produced in autumn in large cone-shaped clusters, each fruit berrylike, rounded, 3–5 mm (0.1–0.2 in) in diameter, dark red, fuzzy.*** **Harvest:** Pick fruit clusters when glazelike bloom appears on bright red berries. Lick like lollipop for delicious lemony thirst quencher. Flavor is washed out by rains more quickly than in STAGHORN SUMAC. **Preparation:** same as STAGHORN SUMAC. Make delicious jelly from 2 cups sumac extract (see beverage under STAGHORN SUMAC) and 2 cups elderberry juice. Boil juice and extract with 1 pkg powdered pectin. Add 5 cups sugar. Bring to hard boil, boil 1 min, remove from heat, skim, pour into jars, seal. For other recipes, see SQUAWBUSH and STAGHORN SUMAC (next). See *caution* under STAGHORN SUMAC. **Related edible species:** STAGHORN SUMAC, SQUAWBUSH, plus lemonade sumac *(R. integrifolia)* of southern California and sugar bush *(R. ovata)* of the Southwest. **Poisonous look-alikes:** Poison sumac *(Toxicodendron vernix)* grows in wet areas and has white fruits. Avoid white fruited sumacs. POISON IVY and poison oak *(T. diversiloba)* are in the sumac genus.

Squawbush *Rhus trilobata*

Also edible autumn

Habitat: foothills, canyons, slopes, washes, often in dry rocky soils. **Identification:** ***shrub*** to 2 m (6.6 ft) with numerous spreading branches and ***densely hairy twigs, with strong odor when broken. Leaves*** alternate, deciduous, ***with 3 leaflets*** (trifoliolate), occasionally 1 leaflet, leaflets broadest near base or tip, 1–3 cm (0.4–1.2 in) long, nearly as wide, ***with large rounded teeth along margin,*** rounded at tip, hairy. Flowers yellow, small, densely clustered in short spikes in spring. ***Fruits berrylike, rounded, 4–6 mm (0.2 in) in diameter, red, hairy, sticky.*** **Harvest:** Gather fruits from end of August. **Preparation:** Suck on fresh fruits for refreshing sour taste. For beverage and jelly see SMOOTH SUMAC (preceding) and STAGHORN SUMAC (next). For syrup combine ½ cup dried, ground, sifted berries with 1⅓ cups water and ¾ cup honey (or 1 cup sugar). Cover, boil mix 30 sec, reduce heat, simmer 15 min. Uncover and boil until mix thickens, stirring constantly. Pour into jar and refrigerate for further thickening. Good dessert topping or spread on bread. If fresh berries are used, crush, simmer, and strain before adding honey or sugar. Then boil and complete process as above. See *caution* under STAGHORN SUMAC. **Related edible species:** See SMOOTH SUMAC. **Poisonous look-alikes:** Leaves resemble those of poison oak *(R. diversiloba)* and POISON IVY, both with white fruits. See also SMOOTH SUMAC.

Staghorn sumac *Rhus typhina*

Also edible autumn, winter

Habitat: woodland margins, fencerows, roadsides, old fields, streambanks. **Identification:** shrub or small ***tree*** to 10 m (33 ft) ***with thick densely hairy branches and twigs.*** Leaves alternate, deciduous, featherlike (pinnate) compound, 40–60 cm (16–24 in) long, with 11–31 leaflets, leaflets usually lance-shaped, 5–12 cm (2–4.7 in) long, 2–4 cm (0.8–1.6 in) wide, sharply toothed along margin. Male and female flowers on same or separate trees, produced in crowded cone-shaped clusters. ***Fruits produced in dense, cone-shaped clusters 10–20 cm (4–8 in) long; each fruit berrylike, rounded, 3–5 mm (0.1–0.2 in) in diameter, densely covered with dark red hairs.*** **Harvest:** Pick fruit clusters late summer to autumn when deep red and fruits have developed strong lemony taste. Dense hairs on fruits prevent rain from penetrating cluster and washing out all malic acid flavor so fruits are usable though less potent through winter. Dry some clusters for winter use. **Preparation:** For beverage separate fruits from twigs. Steep in near boiling water (no less than 1 cup fruits to 1 qt water) for at least 15 min. Strain through cloth, dilute, sweeten to taste. Drink hot or cold but in moderation; some people show allergic reaction. Using whole heads of fruits will include small arthropods within them, and twigs may add slight bitterness. See other uses under SMOOTH SUMAC and SQUAWBUSH (preceding). **Related edible species:** SMOOTH SUMAC and SQUAWBUSH, and lemonade berry *(R. integrifolia)*. **Poisonous look-alikes:** See SMOOTH SUMAC.

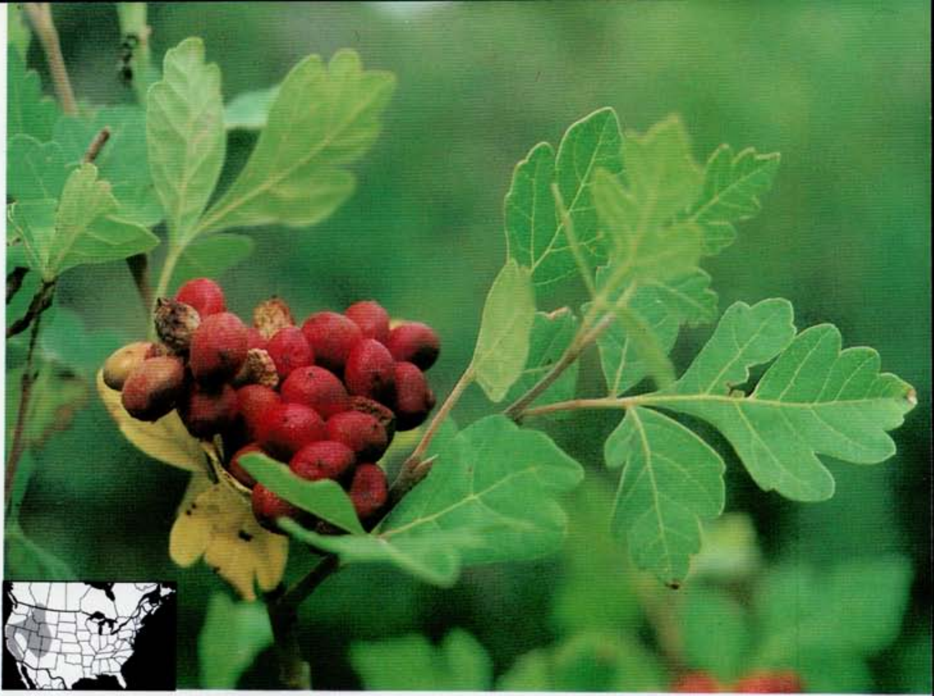

Squawbush: fruiting branch (Dykeman).

Staghorn sumac: fruiting branch, left (Dykeman). Fruits (Elias).

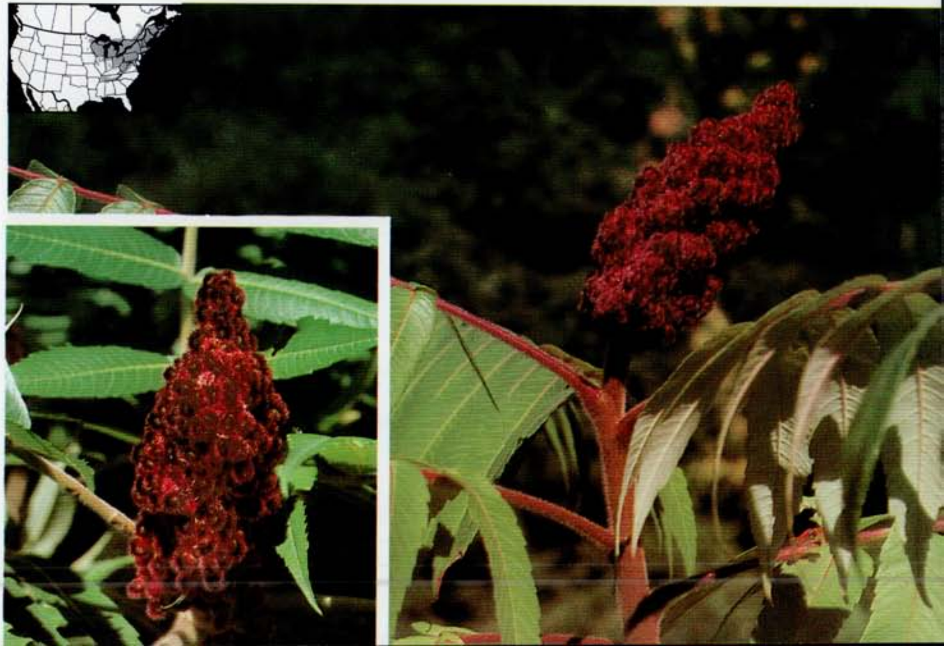

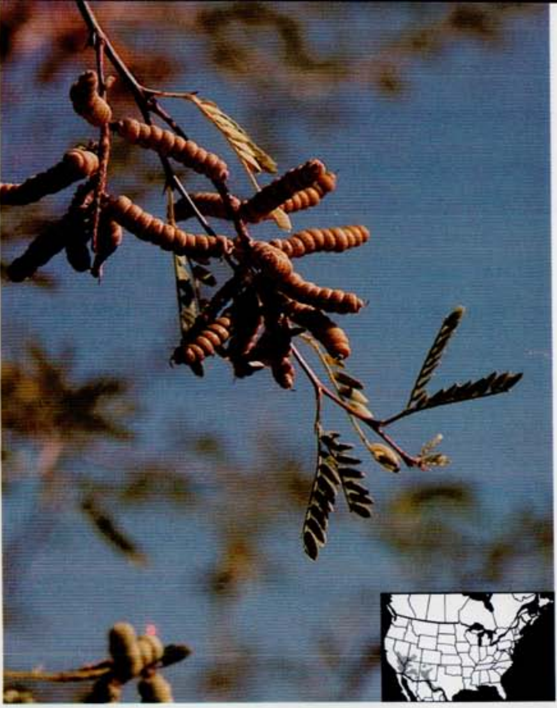

Screwbean mesquite: fruiting branch (Feldman).

Glandular mesquite: fruiting tree (Feldman). September branches (Hutchins).

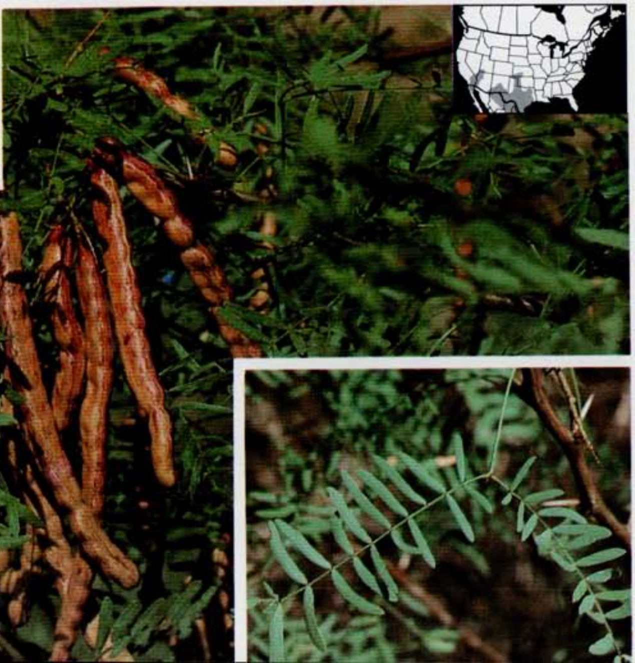

Screwbean mesquite *Prosopis pubescens*
Also edible autumn

Habitat: gullies, washes, stream banks, riverbottoms, floodplains. **Identification:** shrub or ***small spreading tree*** to 10 m (33 ft) with slender ***branches armed with pair of sharp spines at each leaf base. Leaves*** alternate, deciduous, ***twice compound and featherlike*** (bipinnate), with 1 or 2 pairs of side branches (pinnae), each 3.8–5 cm (1.5–2 in) long, composed of 5–8 pairs of small leaflets. Flowers produced in densely flowered cylinder-shaped spikes 5–7.5 cm (2–3 in) long, each flower greenish-white to yellow, 3–4 mm (0.2 in) long. ***Fruits*** are ***spiral twisted pods 3–5 cm*** (1.2–2 in) ***long,*** brown, hairy, becoming hard and tough at maturity. **Harvest:** Gather and clean immature pods, the younger the tenderer. **Preparation:** Boil until soft or cook with other vegetables. The pods can be boiled down to make a sweet syrup with many uses. **Related edible species:** GLANDULAR MESQUITE (next) and mesquite *(P. veluntina)*. **Poisonous look-alikes:** slightly similar to CORALBEAN, which has poisonous seeds.

Glandular mesquite *Prosopis glandulosa*
Also edible autumn

Habitat: desert valleys, open range, grazing lands where plant becomes a pest. **Identification:** shrub or small spreading tree to 8 m (26 ft) with slender ***branches*** that ***have paired, sharp-pointed spines where each leaf is attached. Leaves*** alternate, deciduous, ***twice compound and featherlike*** (bipinnate), with 1 pair of side branches (pinnae), each 12–20 cm (4.7–8 in) long and composed of 7–18 pairs of leaflets. Flowers produced from May to August in densely flowered, narrow, cylinder-shaped clusters; each flower yellow, 3–4 mm (0.2 in) long. ***Fruits long, narrow, straight pods 10–25 cm*** (4–10 in) ***long,*** rounded, slightly constricted between seeds. **Harvest:** Gather flower clusters as they open and fruits as they ripen during summer. **Preparation:** Suck sugar-rich nectar from newly open flowers. The yellowish gelatinous to mealy pulp surrounding seeds in mature pods contains up to 30% sugar and can be eaten fresh. Make beverage by boiling clean pods in fresh water and straining off residue. Dry pods, grind, mix with little water to form dry, mealy dough; bake in sun for several hours or over very low heat. Soak seeds in water several hours for lemon-flavored drink or grind dry seeds into meal and use to make porridge. Discard those seeds infested with larvae of bean beetle. **Related edible species:** SCREWBEAN MESQUITE (preceding) and mesquite *(P. veluntina)*. **Poisonous look-alikes:** may resemble CORALBEAN, which has toxic seeds.

American elder, Common elder *(Also edible spring)* *Sambucus canadensis*

Habitat: rich moist soil of woodland margins, stream and river banks, fencerows and right-of-ways. **Identification:** mainly shrubby, 1–4 m (3–13 ft), with upright to spreading branches and broad rounded crown. ***Leaves opposite,*** deciduous, featherlike (pinnate) ***compound,*** 15–25 cm (6–10 in) long, composed of ***5–11 leaflets,*** each leaflet broadest near base to uniformly wide, 6–12 cm (2.4–4.7 in) long, 2–4 cm (0.8–1.6 in) wide, pointed, toothed, dark shiny green. ***Twigs*** with prominent ***white pith. Flowers*** white, small, in branched, ***round or flat-topped showy clusters*** in late spring or early summer. ***Fruits berrylike,*** rounded, 4–6 mm (0.2 in), ***deep purple,*** juicy, 3-seeded, in large clusters, maturing in mid to late summer. **Harvest:** When flowers are fully open, pick whole clusters or shake petals of old flowers into container. When fruit is deep purple, pick whole clusters or strip berries from bush. **Preparation:** Dip flower cluster in fritter batter and deep fry; dust with sugar and sprinkle with orange juice. Add cup of blossoms to pancake batter. Extract juice from fresh fruit by simmering mix of 1 cup water per 1 qt mashed berries 20–25 min; strain through cloth. Sweetened juice good with tart juices. Use juice with (STAGHORN SUMAC) extract in jelly. Fresh fruit has rank flavor; improves with drying; use dried fruit for pies and breads. Dry fruit in sun or warm attic; before using stew in little water. Flowers and fruit excellent for wine. Fruits high in vitamin C. *Warning:* Roots, stems, leaves, unripe fruits are somewhat toxic. **Related edible species:** BLUE ELDER (next). **Poisonous look-alikes:** See BLUE ELDER.

Blue elder *(Also edible spring)* *Sambucus cerulea*

Habitat: stream banks, gullies, washes, margins of fields, woodlands, pastures. **Identification:** shrub or small tree with broad rounded crown. Leaves ***opposite,*** deciduous, featherlike (pinnate) ***compound,*** 12–18 cm (4.7–7.1 in) long, composed of ***5–9 leaflets,*** leaflets broadest at middle to uniformly wide, 5–15 cm (2–6 in) long, 1.2–5 cm (0.5–2 in) wide, long-pointed at tip, coarsely-toothed, bright green above. ***Flowers*** tiny, yellowish-white, produced in spreading, ***many-flowered, flat-topped clusters*** in late spring or early summer. ***Fruits*** in clusters, each ***berrylike,*** rounded, 6–10 mm (0.2–0.4 in), ***dark blue to nearly black,*** juicy, maturing in mid to late summer. **Harvest:** Flowers in early summer, fruits in late summer, can be eaten raw or dried like raisins. **Preparation:** Prepare tea from blossoms. For jelly, wash berries, partially crush, cover with water, cook over low heat 10 min. Pour contents into wet jelly bag and collect juice; do not squeeze bag. Add 2 cups elderberry juice to 3 cups apple juice prepared in similar manner. Heat to boil, add 1 pkg pectin; stir until dissolved. Bring to rapid boil, add 6 cups sugar. Stir until rolling boil cannot be stirred down; continue for 1 min. Pour mix into prepared jelly jars; cover with ¼ in paraffin; seal with lid. For other uses see AMERICAN ELDER (preceding). **Related edible species:** AMERICAN ELDER, Mexican elder *(S. mexicana),* and black berried elder *(S. melanocarpa).* **Poisonous look-alikes:** Red fruited elder *(S. pubens)* of East and Midwest somewhat toxic. Pacific elder *(S. callicarpa)* bitter but not poisonous.

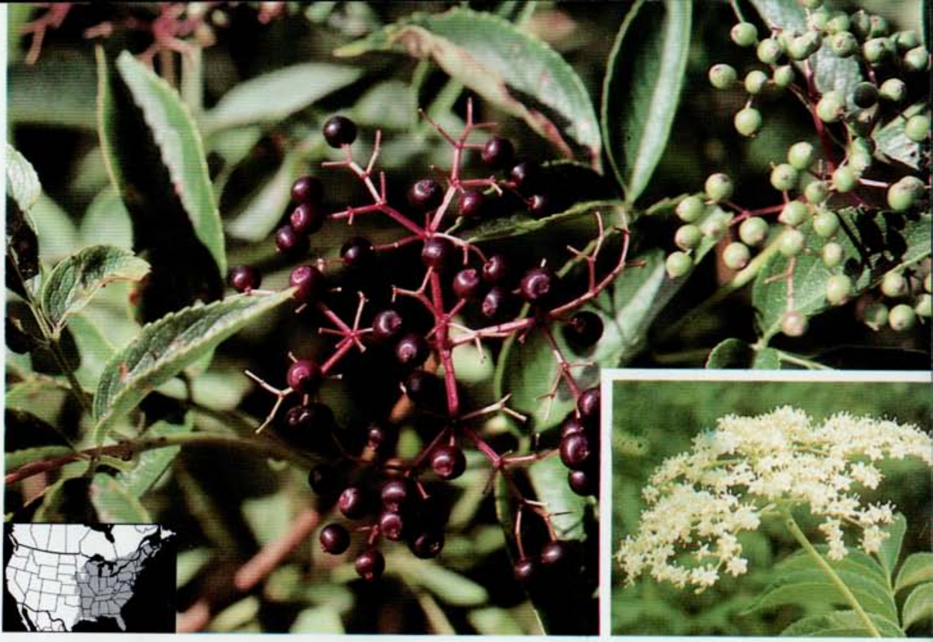

American elder: fruiting branches (Elias). Flowers (NYBG).

Blue elder: fruiting bush and fruits (Kavasch).

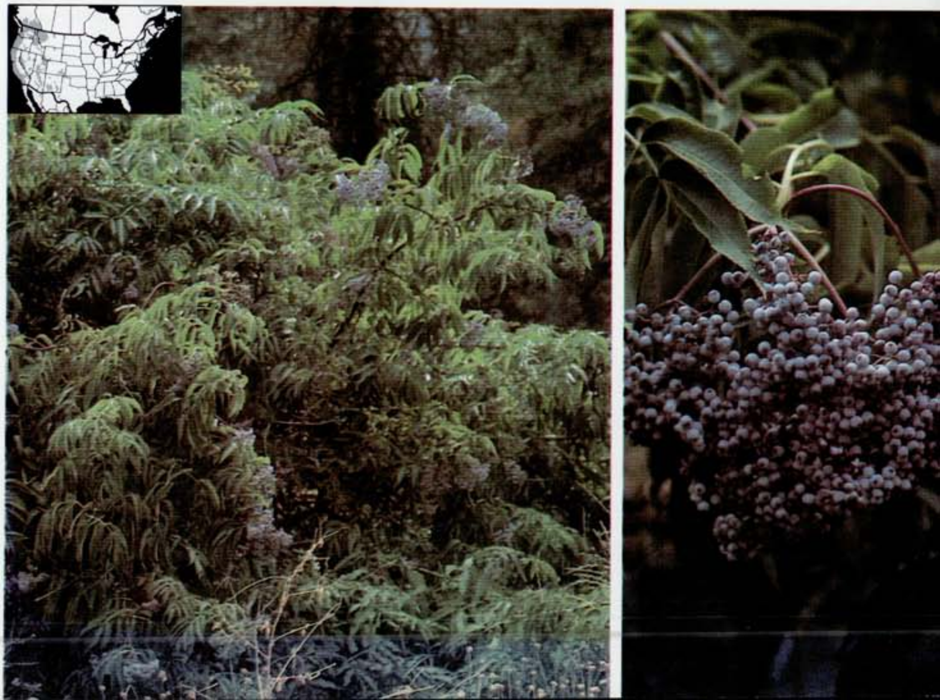

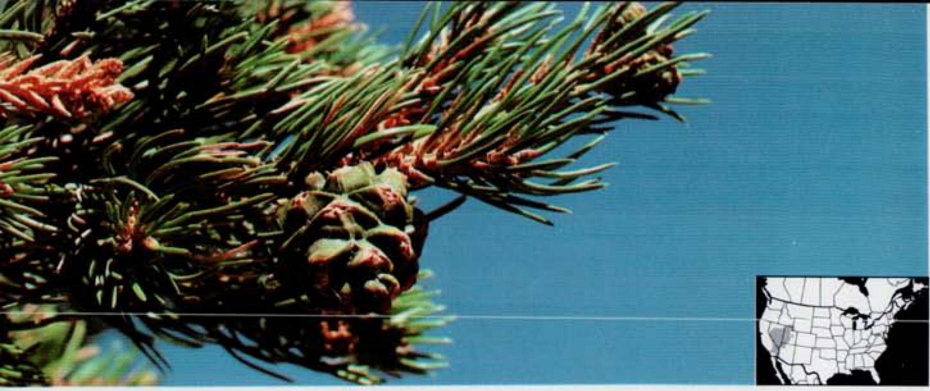

Singleleaf pinyon pine: branch with immature cone (Dykeman).

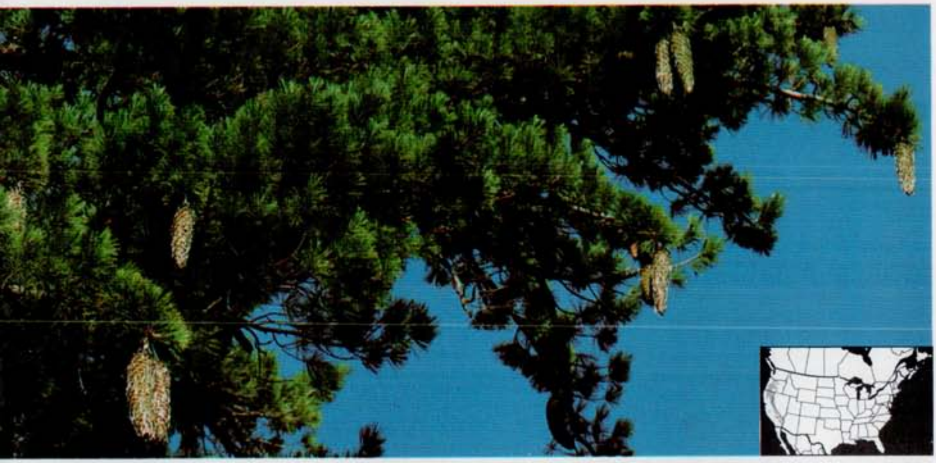

Sugar pine: branches with cones (McNeal).

Digger pine: leader and cones (McNeal).

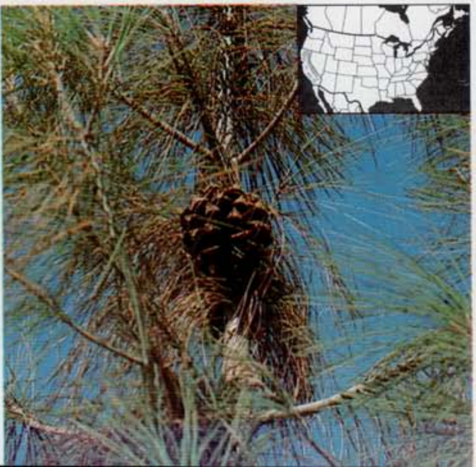

Singleleaf pinyon pine *Pinus monophylla*

Habitat: lower mountain slopes, foothills, canyons from 650–2,350 m (2,100–7,800 ft) elevation; often growing with junipers. **Identification:** small, spreading tree with rough, irregularly furrowed, dark brown bark. ***Leaves (needles) 1 per sheath, 2.5–5 cm (1–2 in) long, sharp-pointed, stiff, often curved toward branches,*** yellowish-green to gray-green; only native North American pine with single leaves. Fruits hard, egg-shaped cones 5–7.6 cm (2–3 in) long, composed of thick, stiff, light brown, blunt scales, each scale bearing 2 large, ***egg-shaped, brown, wingless seeds 1.8–2 cm*** (0.7–0.8 in) ***long.*** Trees produce moderate to large cone crops every 2–3 yr. Each cone requires 2 growing seasons to mature. **Harvest and preparation:** Gather second year cones in August or September. Oily seeds, rich in protein and oils, have nutty taste and can be eaten fresh. Thin shell can be cracked with teeth. Roast nearly ripe cones to facilitate seed removal and improve flavor. Store cones or seeds for later use, especially after roasting. Several cones tossed into campfire coals 10–20 min yield an excellent snack. Carry roasted cones or seeds in backpack for trail snack. If large numbers of seeds are available, roast and grind into meal and use in breads, soups, or mixed with cornmeal or flour. **Related edible species:** SUGAR PINE, DIGGER PINE, PINYON PINE, Mexican pinyon pine *(P. cembroides).* **Poisonous look-alikes:** none.

Sugar pine *Pinus lambertiana*

Habitat: mountain slopes from 750–3,000 m (2,500–9,850 ft) elevation. **Identification:** tall trees to 65 m (213 ft) with tall, straight trunk and thick, deeply, irregularly furrowed, dark, reddish-brown to purplish-brown bark. ***Leaves*** (needles) ***5 per sheath, 8.8–10 cm*** (3.5–4 cm) ***long, stout, stiff, deep bluish-green and marked with silvery lines. Fruits large woody cones, 27–46 cm*** (10.6–18 in) ***long,*** to 12 cm (4.7 in) in diameter; seeds nearly egg-shaped to football-shaped, 1.2–1.5 cm (0.5–0.6 in) long, dark chocolate-brown, nearly black, winged. **Harvest:** See SINGLELEAF PINYON PINE (preceding). *Note:* Cones with seeds are difficult to obtain because of height of the trees. **Preparation:** same as for SINGLELEAF PINYON PINE. **Related edible species:** Coulter pine *(P. coulteri),* DIGGER PINE (next), and the PINYON PINES. **Poisonous look-alikes:** none.

Digger pine *Pinus sabiniana*

Habitat: foothills, lower mountain slopes from 20–1,000 m (66–3,300 ft) elevation, often found with BLUE OAK. **Identification:** medium-size spreading tree to 15 m (50 ft) with short, thick trunk, soon branching, with irregular, scaly, dark brown to almost black bark. ***Leaves*** (needles) ***3 per sheath, 17–43 cm*** (6.7–17 in) ***long, slender, flexible, dull blue-green. Fruits large 15–25 cm*** (6–10 in) ***long,*** to 18 cm (7 in) broad, light reddish-brown, ***scales thick, each armed with clawlike spine;*** seeds 1.7–2 cm (0.7–0.8 in) long, egg-shaped, with hard, dark brown to almost black shell. **Harvest and preparation:** same as for SINGLELEAF PINYON PINE. **Related edible species:** PINYON PINES, Coulter pine *(P. coulteri),* SUGAR PINE (preceding). **Poisonous look-alikes:** none.

JUNIPER GENUS *Juniperus*

The 13 species of junipers native to North America are mostly common widespread trees and shrubs. These evergreen conifers are more abundant in the drier western states, although eastern redcedar and southern redcedar are prevalent in the eastern U.S. All junipers provide excellent cover for small game and food for many birds. Only three species, all western, are recommended for their edible fruits and then primarily as a survival food. The stems, leaves, and fruits contain varying amounts of resins which affect fragrance and taste.

Rocky Mountain juniper *Juniperus scopulorum*

Also edible autumn, winter

Habitat: bluffs, ridges, cliffs, dry rocky hillsides from sea level to 3,000 m (9,850 ft) elevation. **Identification:** large evergreen shrub or small tree to 15 m (49 ft) with reddish-brown to gray scaly bark separating in long narrow strips. ***Leaves tiny, scalelike, opposite each other,*** closely pressed against branchlets, 2–4 mm (0.1 in) long with tiny gland on back, ***pale green to grayish green,*** resinous. Male and female flowers on separate trees in spring, inconspicuous and easily overlooked. ***Fruits small, fleshy, sweet, berrylike cones, nearly rounded, 6–9 mm*** (0.2–4 in) ***in diameter, bright blue, maturing in 2 seasons,*** containing 1–2 seeds. **Harvest:** Gather ripe berries from summer to early winter. Use fresh or dry and store for later use. **Preparation:** Although high in sugars, ripe fruits have an unpleasant resinous taste, so fresh fruits become strictly survival fare. Use a few fresh berries as substitute for sage in flavoring meats. Roast dried fruits, grind, and use as coffee substitute. **Related edible species:** UTAH JUNIPER and CALIFORNIA JUNIPER (next). **Poisonous look-alikes:** Take care in identification of junipers. Fruits of most species have such high resin content that they are unpalatable or may cause stomach upset.

California juniper *Juniperus californica*

Also edible autumn, winter

Habitat: dry slopes, canyons, desert slopes from 125–1,350 m (410–4,500 ft) elevation. **Identification:** large shrub or small tree with fluted and ridged trunk and reddish-brown to ash-gray bark that splits into long, loose, shredding strips. ***Leaves tiny, scalelike, arranged in 3s,*** overlapping and closely pressed against branchlets, 2–4 mm (0.1 in) long, with tiny gland on back, light yellowish-green. Male and female flowers on separate trees in spring, inconspicuous and easily overlooked. ***Fruits*** are ***leathery, berrylike cones, almost rounded, 10–16 mm*** (0.4–0.6 in) ***in diameter, dry, sweet, not resinous, light reddish-brown,*** maturing in 2 seasons, each containing 1–3 seeds. **Harvest and preparation:** same as for ROCKY MOUNTAIN JUNIPER (preceding) except that nonresinous fruits are superior to those of other junipers as wild food source. **Related edible species:** UTAH JUNIPER (next), ROCKY MOUNTAIN JUNIPER. **Poisonous look-alikes:** same as for ROCKY MOUNTAIN JUNIPER.

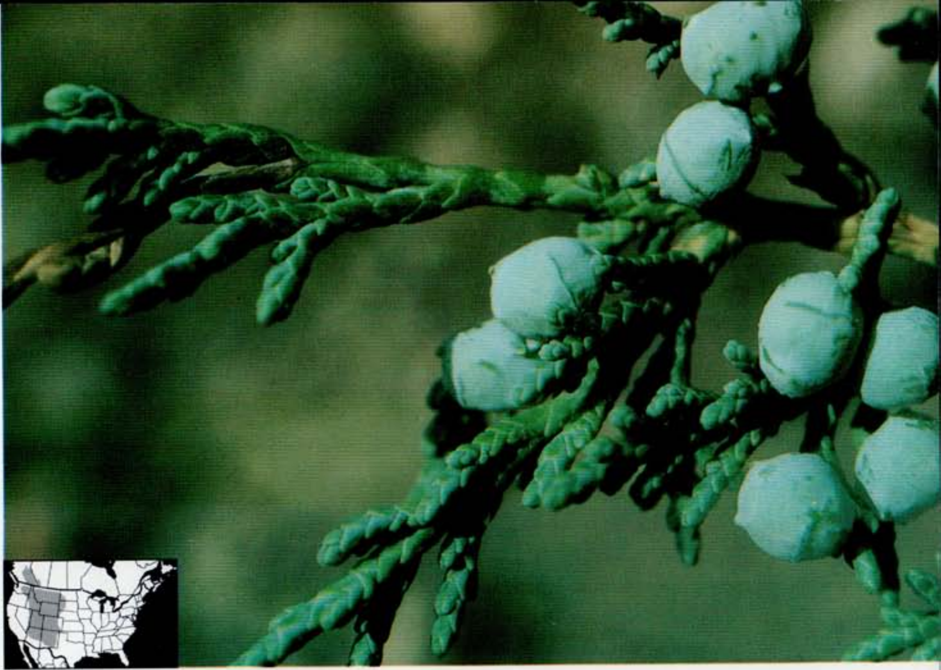

Rocky mountain juniper: fruiting branch (Dykeman).

California juniper: fruiting branch (Webber, Jepson Herbarium).

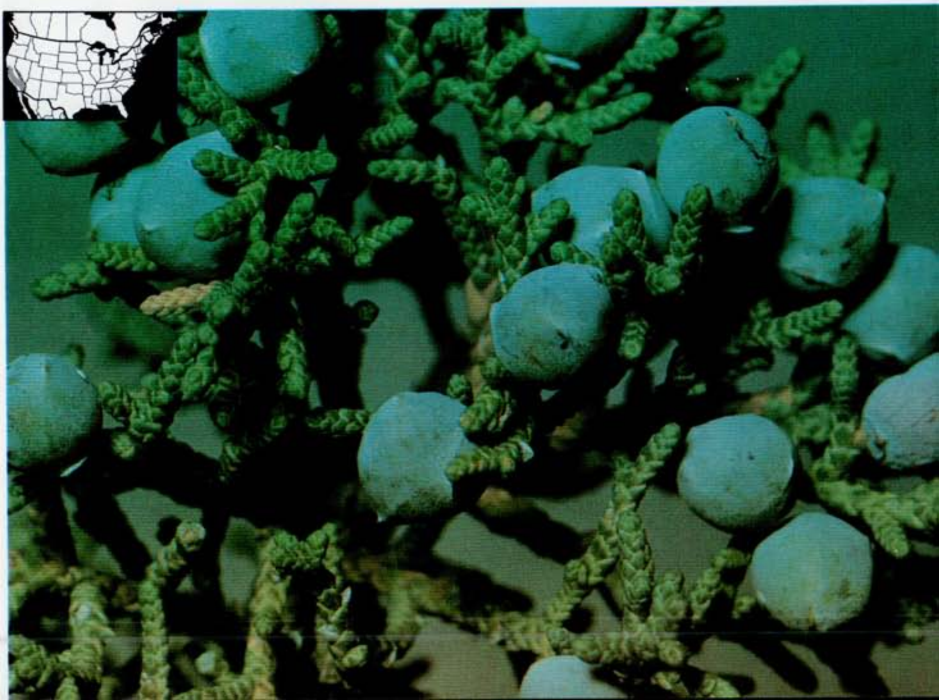

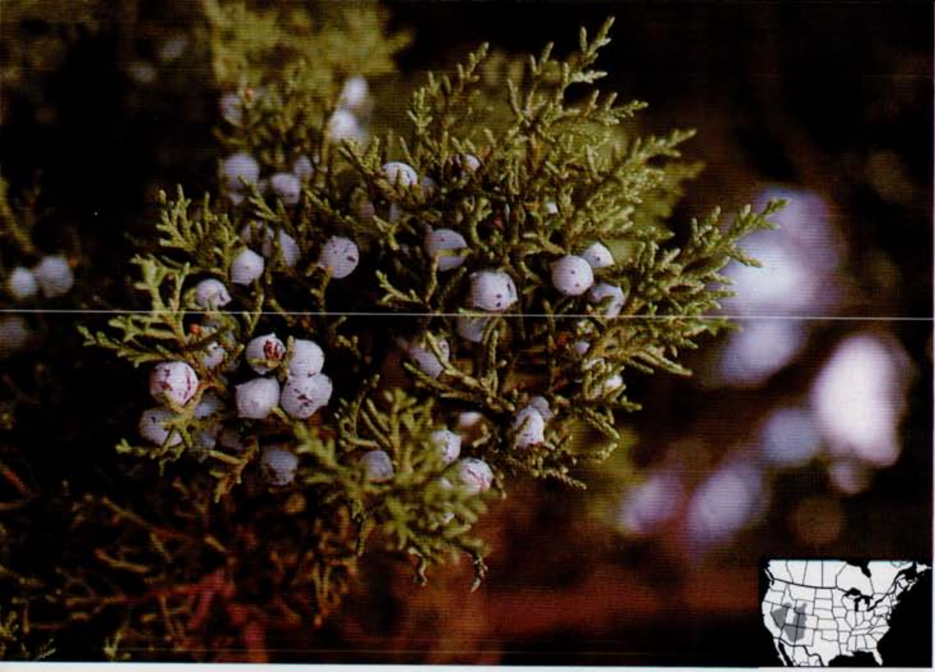

Utah juniper: fruiting branch (Pawloski).

Sea grape: fruiting and flowering branches (Elias).

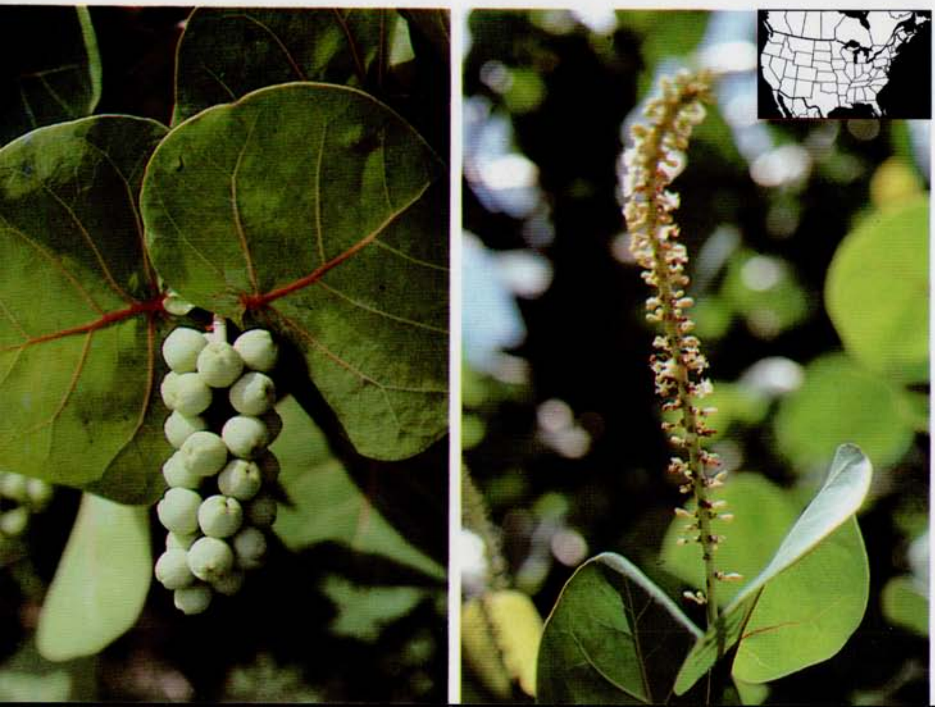

Utah juniper *Juniperus osteosperma*

Also edible autumn, winter (synonym: *J. utahensis*)

Habitat: mesas, mountain slopes, high plains, principally from 1,000–2,650 m (3,300–8,700 ft) elevation in dry rocky or gravelly soils. **Identification:** large ***shrub*** or small ***bushy tree*** to 8 m (26 ft) high with ***furrowed ash-gray bark that shreds in long, loosely attached strips. Leaves*** tiny, ***scalelike, opposite and overlapping one another in 2s, closely pressed against branchlets,*** 3–4 mm (0.1–0.2 in) long, usually gland-dotted on back, ***sharp-pointed at tip, yellowish-green.*** Male and female flowering cones usually produced in spring on separate trees, inconspicuous and usually overlooked. ***Fruits small, leathery berries 6–9 mm*** (0.2–0.4 in) ***in diameter, nearly globe-shaped, reddish-brown, resinous, sweet,*** with mealy texture, containing 1, rarely 2, seeds. **Harvest and preparation:** same as for ROCKY MOUNTAIN JUNIPER. **Related edible species:** CALIFORNIA JUNIPER and ROCKY MOUNTAIN JUNIPER (preceding). **Poisonous look-alikes:** same as for ROCKY MOUNTAIN JUNIPER.

Sea grape *Coccoloba uvifera*

Habitat: beaches, along sea shores; Southern Florida, Bermuda, Bahama Islands, the West Indies. **Identification:** very distinctive large shrub or tree to 15 m (50 ft) with compact rounded crown, trunk short, covered with pale blotchy bark. ***Leaves*** alternate, simple, ***persistent and appearing evergreen, 10–27 cm*** (4–10.6 in) ***long, 12–25 cm*** (4.7–10 in) ***wide, almost circular in outline,*** rounded at tip, entire, heart-shaped at base, ***thick, leathery,*** dark shiny green above. Flowering clusters produced along narrow, elongate stalks to 30 cm (12 in) long. ***Fruits crowded together in long, hanging clusters,*** each fruit nearly rounded, 1.8–2.5 cm (0.7–1 in) long, greenish-white to purple, with thin, juicy flesh; seed hard, nutlike. **Harvest:** Since fruits do not ripen uniformly, spread sheet under bush and shake branches vigorously. Ripe fruits will fall while green ones persist in cluster. **Preparation:** best used for jelly. Partially crush 2 qt clean ripe fruits with ½ cup water and cook for 20 min. Strain juice through jelly bag. Boil juice with equal amount of sugar until jelling point is reached. Skim off foam, pour into sterilized jars, seal with paraffin. **Related edible species:** dove plum *(C. diversifolia)* of coastal southeastern Florida, but not a recommended substitute for sea grape. **Poisonous look-alikes:** none.

California laurel, California bay *Umbellularia californica*

Also edible autumn, spring

Habitat: lower mountain slopes, hillsides, flatlands, in variety of soils; Pacific coastal regions and western slopes of Sierra Nevada. **Identification:** small to medium-size tree to 20 m (66 ft) with thin, dark brown bark. ***Leaves*** alternate, simple, ***evergreen,*** 8.6–13 cm (3.4–5.1 in) long, lance-shaped to broadest near middle, usually pointed at tip, ***entire, dark green and shiny, leathery, with spicy odor when crushed.*** Flowering clusters flat-topped, containing 4–9 flowers, each small, 1–1.4 cm (0.4–0.6 in) across, yellow. ***Fruits resembling an olive,*** globe-shaped to broadest near base, ***2–2.6 cm*** (0.8–1 in) ***long,*** slightly fleshy, green turning yellowish-green or purplish-green at maturity, containing single large seed. **Harvest:** Pick young unblemished leaves, wash and leave in sun until thoroughly dry. Store in cool dry place for later use. Pick ripe fruits in late summer or autumn, remove and clean seeds. **Preparation:** Use dried leaves as substitute for bay leaves. California laurel is more potent, so cut recipe amount by ⅓ unless stronger flavoring is desired. Good in stews, chili, spaghetti sauce, soups. Roast seeds in campfire, split open, and eat or grind into flour for bread and other recipes. Indians of California used leaves in lodges to repel fleas. **Related edible species:** none. **Poisonous look-alikes:** none.

Pawpaw, Papaw *Asimina triloba*

Also edible autumn

Habitat: river valleys and bottomlands, usually in deep, rich, moist soils; grows in association with sweetgum, swamp chestnut, black gum, cherrybark oak. **Identification:** large shrub or small tree with thin, smooth bark (dark brown with gray blotches) 3–12 m (10–40 ft) tall. Leaves alternate, deciduous, simple, 18–30 cm (7–12 in) long, 8–14 cm (3.2–5.5 in) wide, usually broadest near tip, entire along margin, papery textured, light green. Flowers ***green turning deep purple, produced in spring along stems of previous year, bell-shaped,*** with 3 sepals, 6 thick, almost rounded petals 2–2.6 cm (0.8–1 in) long. Fruits irregular, cylinder-shaped, 4–10 cm (1.6–4 in) long, aromatic, green turning yellow then black and fleshy at maturity; mature in late summer or early autumn. **Harvest:** when fruits mature or while still green but full size; store in cool place (safe from small animals) until ripe. **Preparation:** Tasty sweet pulp of fruit can be eaten raw. Cook creamy, custardlike pulp, minus seeds and skin, and use in puddings, breads, ice cream. *Caution:* Fruits disagree with some people. **Related edible species:** dwarf pawpaw *(A. parviflora)*. **Poisonous look-alikes:** none.

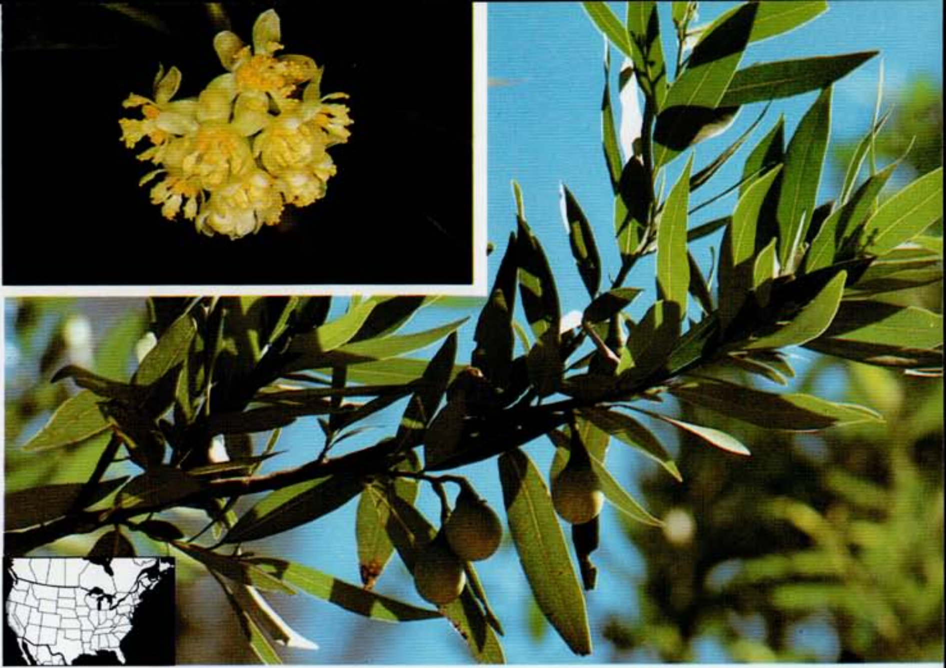

California laurel: flower and fruiting branch (U. of Cal., Davis).

Pawpaw: flowering branch (Folkerts). Fruiting branch (Elias).

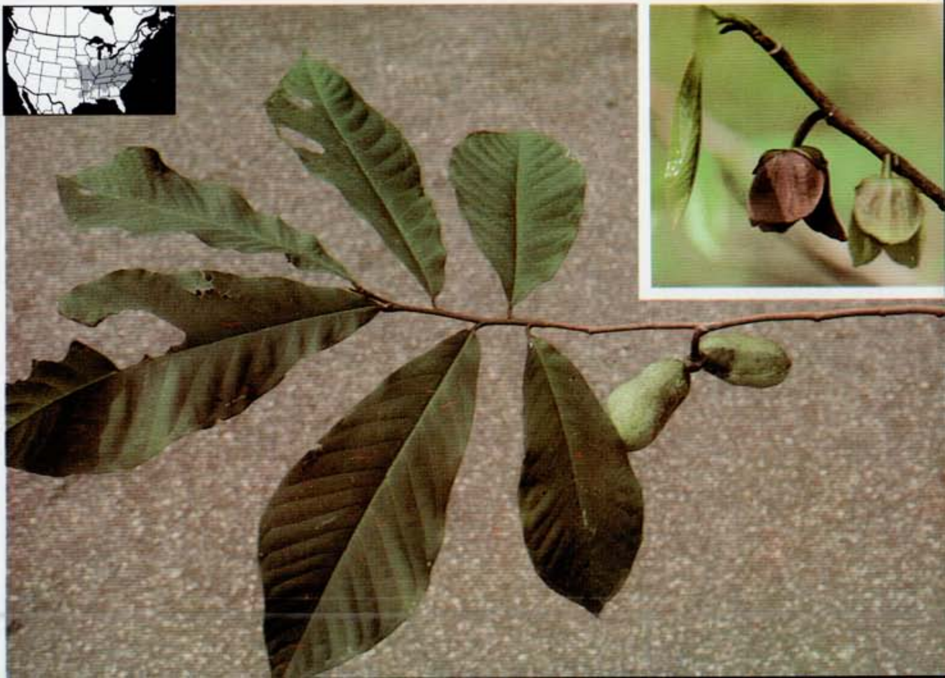

White mulberry *(Also edible spring)* *Morus alba*

Habitat: introduced and cultivated tree that now grows wild along fencerows, roadsides, margins of abandoned fields, and in woodlands. **Identification:** medium-size tree with widespreading, rounded crown and thick, irregularly furrowed, light to dark gray to yellowish-brown bark and ***milky sap. Leaves*** alternate, deciduous, simple, ***6–16 cm (2.4–6.3 in) long, 3–8 cm (1.2–3.2 in) wide, broadest near base,*** pointed at tip, ***unlobed or 2–3 lobed, sharply toothed along margin.*** Male flowers tiny, clustered on short spikes; female flowers tiny, clustered in round heads, both appearing in spring on new growth. ***Fruits globe-shaped to short cylindrical, 1–2 cm (0.4–0.8 in) long, blackberrylike, fleshy, white to pinkish at maturity*** (June–July). **Harvest and preparation:** Pick fruits as they ripen from late May through July. Fully ripe berries may be shaken from tree onto plastic sheets but tend to be very syrupy and too sweet for most palates. Dry like raisins for breads, cookies, and puddings. Use plastic or aluminum screen supported so air can reach all sides of fruit. If solar drying, protect from dew condensation at night. Dry until crushed fruit lacks any watery juice. Drying time: bright sun, 2 days; warm attic, 4 days; warm oven, 10–15 hr. Store dried berries in sealed containers. Afghans grind dried fruit with almonds for nutritious combination. Substitute any other type of nut, roll small balls of ground mix in confectioner's sugar, eat as candy. Pick shoots and prepare as RED MULBERRY (next). **Related edible species:** RED MULBERRY, Texas mulberry *(M. microphylla)*, black mulberry *(M. nigra)*. **Poisonous look-alikes:** none; see RED MULBERRY caution.

Red mulberry *(Also edible spring)* *Morus rubra*

Habitat: river valleys, floodplains, lower slopes of hills, usually in rich, moist soils. **Identification:** small to medium-size tree with broad, rounded crown and irregularly fissured, dark reddish-brown bark and ***milky sap. Leaves*** alternate, deciduous, simple, ***7.5–10 cm (3–4 in) long, 5–5.8 cm (2–2.3 in) wide, broadest near base to almost rounded, unlobed or 1–3-lobed, heart-shaped at base, pointed at tip, with coarse teeth along margin, with whitish hairs on lower surface.*** Male flowers tiny, crowded together in slender, hanging clusters; female flowers tiny, crowded in broader, elongated clusters. ***Fruits cylinder-shaped, blackberrylike, 2.2–3 cm*** (1–1.2 in) ***long, fleshy, red turning dark purple to almost black, sweet,*** maturing from May to July. **Harvest and preparation:** Pick ripe fruit from ladder, or spread tarps beneath tree and shake limbs. Delicious as picked or with cream. Do not let persistent small stem and axis of fruit bother you. For beverage mash and squeeze fruit through cheesecloth or use electric juicer or blender. Add sweetener and lemon juice to taste. Serve with ice and, if desired, club soda. Also good for pies, jams, jellies. Use like other berries in breads, muffins, cakes. Pick shoots as leaves are beginning to unfold. Boil 20 min, drain, add butter and seasoning. *Caution:* Raw shoots and unripe fruits contain hallucinogens. **Related edible species:** WHITE MULBERRY (preceding), Texas mulberry *(M. microphylla)*, black mulberry *(M. nigra)*. **Poisonous look-alikes:** none.

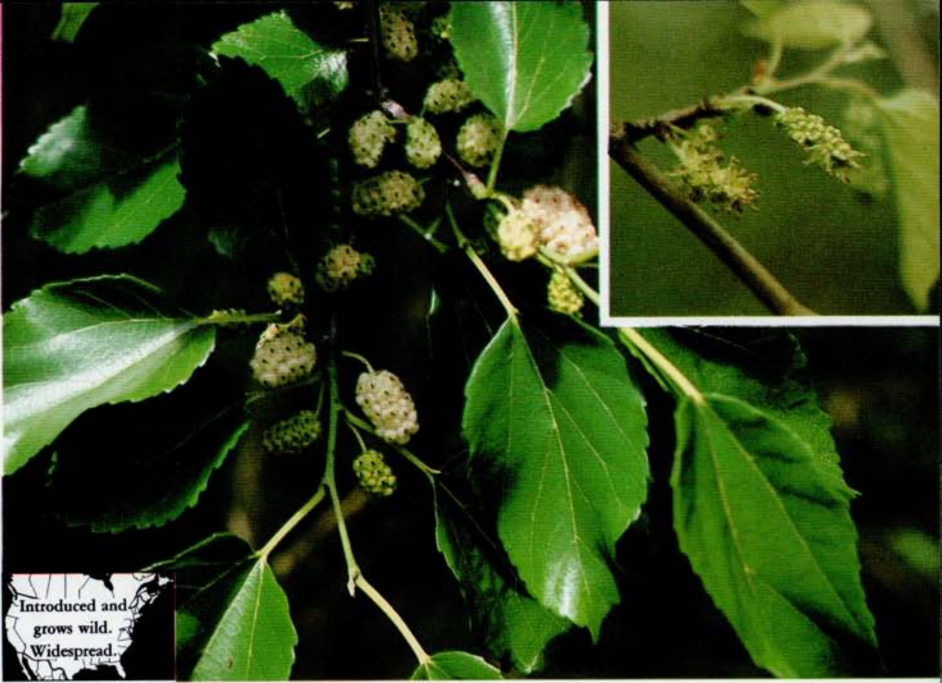
Introduced and grows wild. Widespread.

White mulberry: flowering branch (NYBG). Fruiting branch (Elias).

Red mulberry: fruiting branch (Elias).

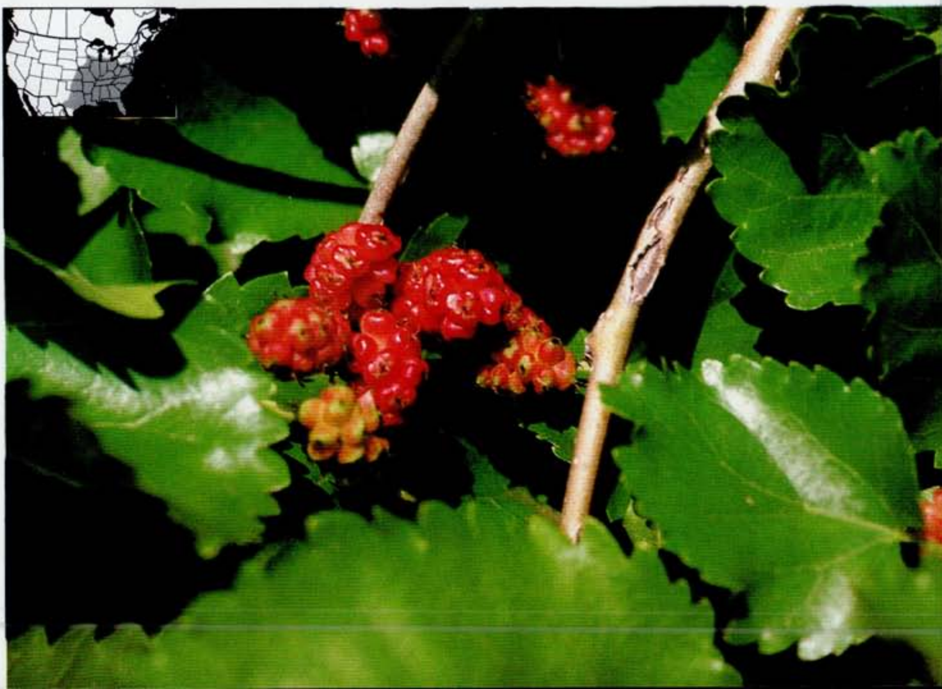

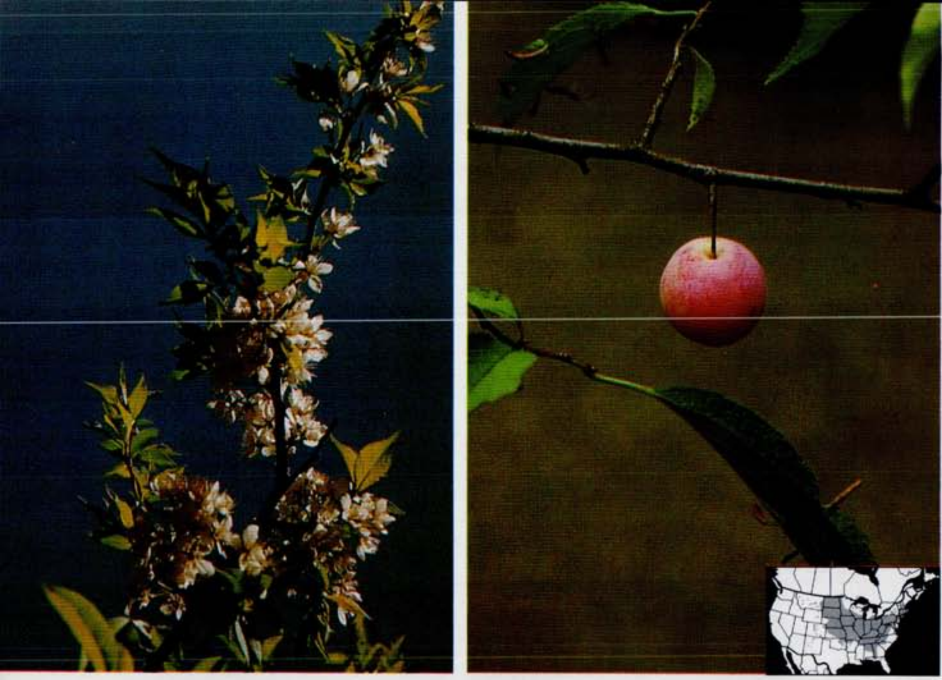

American plum: flowering branch (Weber). Fruiting branch (Elias).

Flatwood plum: flowering and fruiting branches (Anderson).

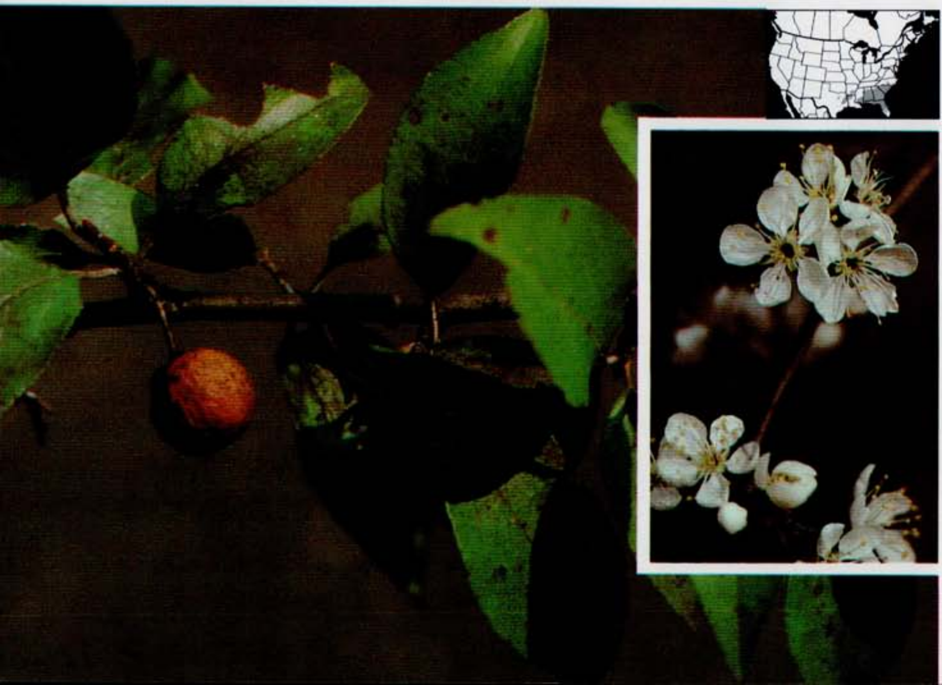

American plum, Wild plum *Prunus americana*

Habitat: common, mixed deciduous woodlands, along streams, fencerows, margins of fields. **Identification:** shrub or small tree to 11 m (36 ft) with spreading crown and ***spiny*** branches. ***Leaves*** alternate, simple, deciduous, ***6–10 cm*** (2.4–4 in) ***long, 3.5–4.5 cm*** (1.4–1.8 in) ***wide, with double row of sharp pointed teeth along margin,*** dark green and smooth. ***Flowers produced 2–5 per cluster*** in early spring, like cherry blossoms, each with 5 rounded, ***white*** petals 9–12 mm (0.4–0.5 in) long. ***Fruits*** solitary or 2–4 per cluster, each ***rounded or nearly so, 1.8–2.5 cm*** (0.7–1 in) ***in diameter, orange to red,*** juicy. **Harvest:** ripe fruits in mid to late summer. **Preparation:** Boil unripe fruits with sugar for emergency food. Use fresh ripe fruits in any cultivated plum recipes. Especially good in jams and jellies. For plum butter, puree pulp and skins after extracting juice for jelly. Blend with equal amount of maple sugar or honey in crock or bean pot and bake at 165°C (330°F) for 3 hr with occasional stirring. Seal in hot, sterilized jars. For jam add ½ cup water to each 2 cups raw pitted fruit. Boil until skins are tender, 10–15 min. Add 1 cup sugar for each cup of fruit pulp. Mix and cook about 15 min to jelly stage with constant stirring. Pour into sterilized jars and seal. For pie, use plums with equal volume of sweeter fruit such as peaches and use basic pie recipe. **Related edible species:** several throughout the country, including BEACH PLUM, FLATWOOD PLUM (next), and cherries. **Poisonous look-alikes:** none. Pits and seeds contain hydrocyanic acid which can react with stomach acids to release highly poisonous cyanin.

Flatwood plum *Prunus umbellata*

Habitat: coastal plain, piedmont; along rivers, in swamps and hammocks. **Identification:** small tree to 6 m (20 ft) with irregular rounded crown and reddish bark. ***Leaves*** alternate, simple, deciduous, ***5–7 cm (2–2.8 in) long, 2.5–4 cm (1–1.6 in) wide, broadest at or above middle,*** rounded to slightly heart-shaped at base, ***with fine, sharp-pointed teeth along margin,*** dark green and smooth. ***Flowers 2–4 per cluster*** in early spring before leaves appear, each with 5 ***white*** rounded petals. ***Fruits*** solitary or in small clusters, ***rounded, 1.2–1.5 cm*** (0.5 in) ***in diameter, dark red to almost black,*** sour, containing flattened stone. **Harvest:** Handpick fruits as they mature from June to September. **Preparation:** See AMERICAN PLUM (preceding), but use additional sugar as with BEACH PLUM. **Related edible species:** BEACH PLUM, AMERICAN PLUM, and several other species. **Poisonous look-alikes:** none.

Black cherry *Prunus serotina*

Habitat: widely distributed; mixed hardwood forests, woodlands. **Identification:** tree to usually 20 m (66 ft), rarely taller, with rounded crown and dark reddish-brown to nearly black bark; inner bark with odor of almond extract. ***Leaves*** alternate, simple, deciduous, 5–15 cm (2–6 in) long, 2.5–4 cm (1–1.6 in) wide, narrow but widest near base to uniformly wide, ***with numerous blunt teeth along margin,*** dark green and shiny. ***Flowers and fruits produced in narrow elongated clusters 10–15 cm*** (4–6 in) ***long,*** each flower with 5 white rounded petals. ***Fruits fleshy, rounded, 8–10 mm*** (0.3–0.4 in) ***in diameter, dark red to black at maturity*** (late summer), juicy, enclosing egg-shaped stone, slightly bitter tasting. **Harvest:** Handpick fruit or if fully ripe shake loose onto tarp August through September. **Preparation:** Eat fresh as trail snack or with sugar and cream as dessert, though pits make eating an effort. Prepare jelly as described under COMMON CHOKECHERRY (next) but use 2 cups each of apple and cherry juice. Also use black cherries for brandied cherries, breads, beverages, pies, wine. For pie add 1½ cups sugar, 2 tbsp cornstarch or flour, and ¼ tsp salt to 1 qt pitted cherries (a pitter makes the task easier). Mix and pour into uncooked 9-in piecrust. Add top crust or lattice of pastry. Bake at 230°C (450°F) for 20 min, then reduce heat to 190°C (375°F) and bake 10 more min. Indians prepared and used dried black cherries as described under COMMON CHOKECHERRY. **Related edible species:** See COMMON CHOKECHERRY. **Poisonous look-alikes:** See COMMON CHOKECHERRY for details.

Common chokecherry *(Also edible autumn)* *Prunus virginiana*

Habitat: common and widespread; moist soils of roadsides, fencerows, woodland margins. **Identification:** shrub or small tree to 8 m (26 ft) with smooth usually reddish-brown bark. ***Leaves*** alternate, simple, deciduous, 5–10 cm (2–4 in) long, 2.5–5 cm (1–2 in) wide, uniformly wide to broadest near base, pointed at tip, ***with numerous sharp teeth along margin,*** dark green and smooth. ***Flowers produced in short cylinder-shaped clusters 8–15 cm*** (3.2–6 in) ***long,*** each with 5 white, rounded petals. ***Fruits fleshy, rounded, 8–10 mm*** (0.3–0.4 in) ***in diameter, usually dark red or black,*** juicy, enclosing egg-shaped stone. **Harvest:** Pick fruit from midsummer to October, depending on location. **Preparation:** Best use, aside from trail thirst quencher, is for jelly. Prepare juice by crushing 1 qt unpitted cherries in 1 cup water. Simmer, stirring about 30 min and strain out juice. Quarter several whole apples, cover with water, simmer until tender. Strain off juice. Combine 2 cups apple juice with 1 cup cherry juice. Add 4 cups sugar and stir until dissolved. Boil rapidly until jelly temperature is reached. Pour into sterilized jelly glasses and seal. Or use sour cherry jelly recipe accompanying pectin package. Indians ground whole fruits, leached poison from seeds, formed pulp into cakes, and dried them in sun for sauce and pemmican. **Related edible species:** BLACK CHERRY (preceding) and several other sweet and sour fruited species, with various ranges. **Poisonous look-alikes:** Autumn and wilted leaves and pits of fruits contain hydrocyanic acid. Do not eat them! Also, Carolina laurelcherry *(P. caroliniana)* fruits are somewhat toxic.

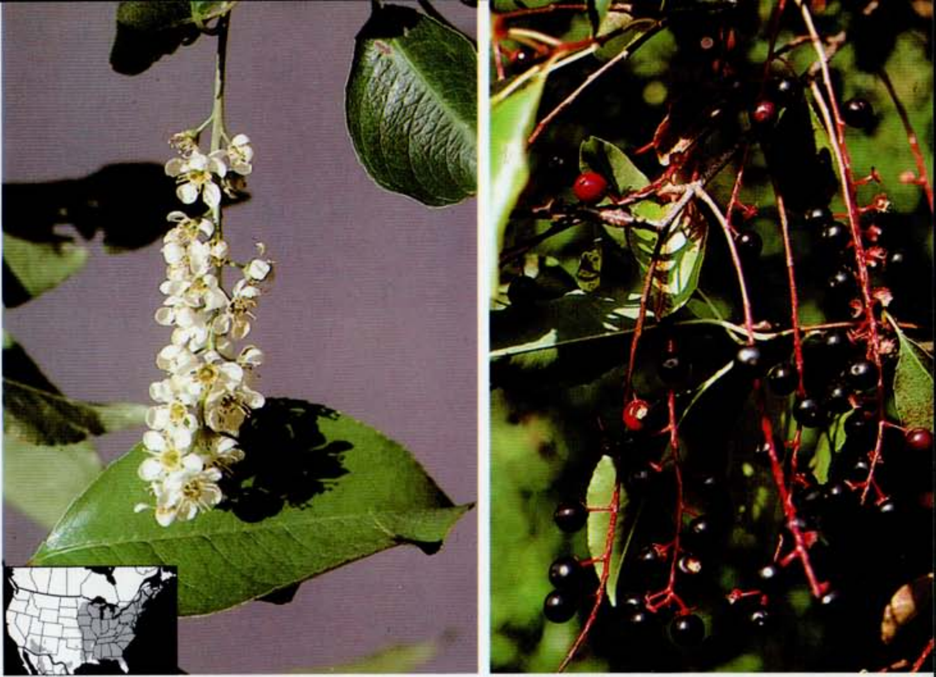

Black cherry: flowering branch (Dykeman). Fruiting branch (Elias).

Common chokecherry: fruiting branch (Elias).

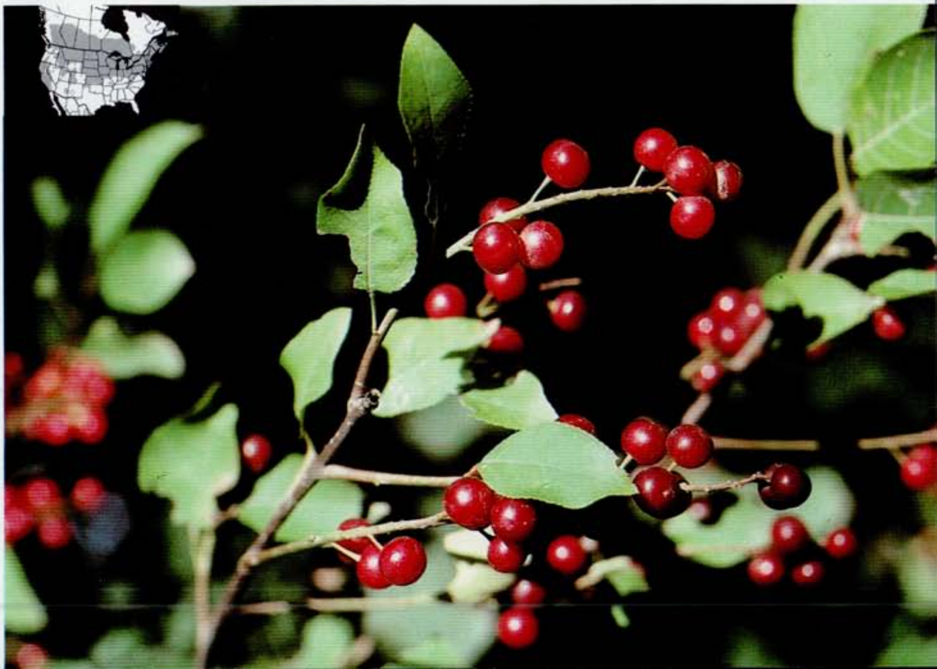

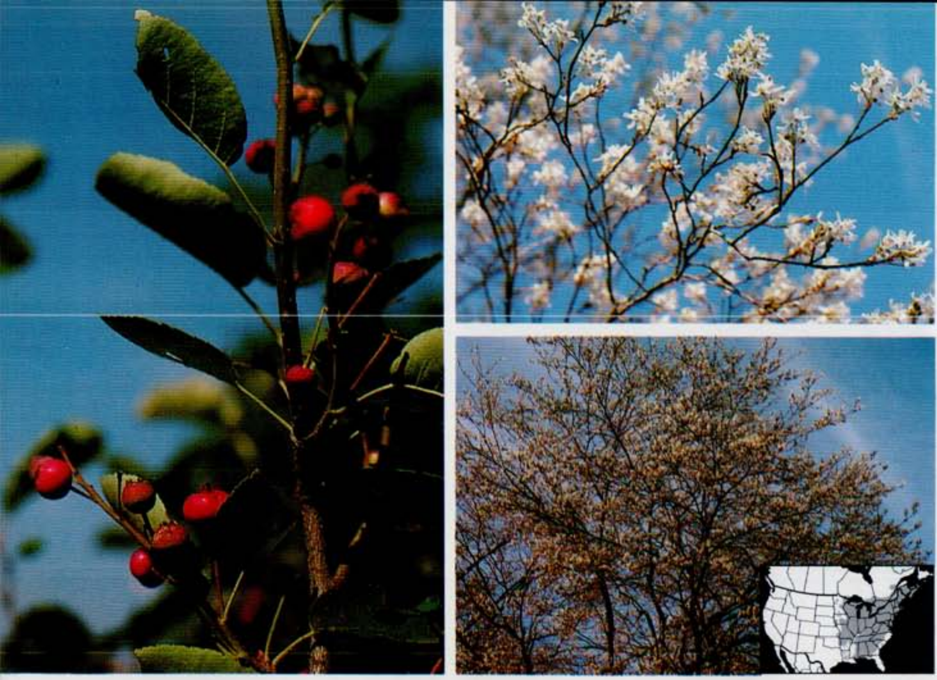

Downy serviceberry: fruiting branch (Elias). Flowering branch and tree (Dykeman).

Saskatoon serviceberry: flowering and fruiting branches (Ross).

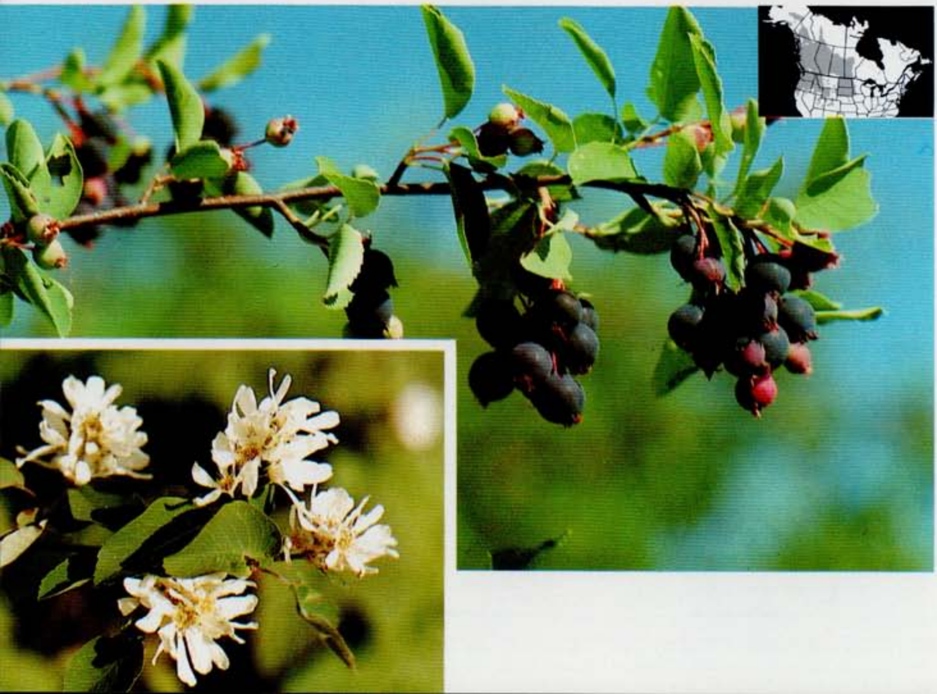

SERVICEBERRY GENUS *Amelanchier*

There are about 25 species of serviceberries native to North America, Europe, Northern Africa, and Asia. In North America, they are small trees or shrubs that occur in deciduous forests and mountains, where their attractive white flowers announce spring. Many birds and wildlife eat the small fruits produced in summer.

Downy serviceberry *Amelanchier arborea*

(synonym: *A. laevis*)

Habitat: woodlands, rocky slopes, river banks, and along swamps; often growing with OAK, hickory, tulip tree, SWEET BIRCH. **Identification:** shrub or ***small tree*** with rounded crown and thick, slightly ridged and furrowed, ash-gray to nearly black bark. ***Leaves*** alternate, deciduous, simple, 5–9 cm (2–3.5 in) long, 2.5–3.5 cm (1–1.4 in) wide, widest at or near middle, ***finely toothed along margin. Flowers white, attractive,*** produced in spring (February in South to May in North), each ***with 5 strap-shaped petals 1–1.4 cm (0.4–0.6 in) long.*** Fruits in clusters, each rounded, 6–10 mm (0.2–0.4 in) in diameter, red to dark purple, fleshy, containing 5–8 black seeds. **Harvest and preparation:** Pick berries when ripe, usually mid to late summer. Eat as picked. Use fresh in recipes for jelly, jam, pie; fresh or dried in breads. For fruit sauce, stew 3 cups berries with 1 cup sugar for about 20 min. Mix dried berries with dried beef and suet to form pemmicanlike product. **Related edible species:** SASKATOON SERVICEBERRY (next) and other less common species. **Poisonous lookalikes:** none.

Saskatoon serviceberry *Amelanchier alnifolia*

(synonym: *A. florida*)

Habitat: mountain slopes, moist hillsides, prairies, margins of lakes and streams. **Identification:** shrub or small tree, sometimes forming thickets, with rounded crown and thin, smooth, or finely furrowed, brown bark. ***Leaves*** alternate, deciduous, simple, 2–6 cm (0.8–2.4 in) long, 2.5–4 cm (1–1.6 in) wide, broadest near base to uniformly wide, ***entire near base, sharply and coarsely toothed along upper margin. Flowers showy, white, produced in early spring,*** each with 5 ***strap-shaped petals 0.9–1.5 cm*** (0.4–0.6 in) long. Fruits in clusters, each rounded to egg-shaped, 6–11 mm (0.2–0.4 in) long, dark reddish-purple to almost black. **Harvest and preparation:** Fruits ripen in mid to late summer; eat raw or dried but better cooked. Use fruits in recipes calling for fruit, as in cakes, pies, jellies, puddings. To make jelly, wash fruits thoroughly, drain, partially crush, cover with water, and cook over low to medium heat until soft. Pour contents into wet jelly bag. For clear jelly do not squeeze bag. Simmer juice 5 min, removing any surface foam. Add sugar while stirring (1 cup juice to ⅔ cup sugar). Simmer 10–15 min or until mix shows sign of jelling. Pour mix into properly prepared jelly jars to within ¼ in of top. Cover with ¼ in melted paraffin. **Related edible species:** DOWNY SERVICEBERRY (preceding) and other less common species. **Poisonous look-alikes:** none.

Autumn

Autumn is the season for fruits and nuts. These come mainly from trees and shrubs that require a full growing season before flowers transform into mature seeds and fruits. Oaks, beech, hickories, walnuts, hawthorns, viburnums, and grapes are common sources and easy to identify. In autumn you can gather large quantities of edibles and consume them then or store them. The oaks, beech, walnuts, and hickories are cyclic in nut production, or mast crop. That is, a large mast crop is normally followed by two or three years of smaller crops. So one year you may encounter a large crop of hickory nuts and the next year run into the acorn bounty of oaks instead.

This is also the time to note or even map populations of native edible plants (other than nuts) for harvest the next year. Keep track of the edible populations, especially immature ones; and avoid overharvesting them. Many plant species have been seriously depleted by greedy collectors. On the other hand, if you harvest fruits and nuts, you don't destroy the trees and shrubs. They will live to produce again, and their offspring will eventually be producers too—especially if you plant a fruit or nut now and then.

Additional autumn edibles

Plants listed below have parts that are edible in autumn and at least one additional season. Descriptions and photos of these plants appear in a seasonal section other than "Autumn," as indicated.

Alpine bistort (*Polygonum viviparum*), p. 154
American bistort (*Polygonum bistortoides*), p. 154
American hazelnut (*Corylus americana*), p. 172
Beach plum (*Prunus maritima*), p. 166
Beaked hazelnut (*Corylus cornuta*), p. 172
Bugleweed (*Lycopus uniflorus*), p. 88
California juniper (*Juniperus californica*), p. 194
California laurel (*Umbellularia californica*), p. 198
Cattail (*Typha latifolia*), p. 68
Chicory (*Cichorium intybus*), p. 114
Chufa (*Cyperus esculentus*), p. 130
Common burdock (*Arctium minus*), p. 112
Common chickweed (*Stellaria media*), p. 84
Common chokecherry (*Prunus virginiana*), p. 204
Common day lily (*Hemerocallis fulva*), p. 136
Cranberry (*Vaccinium macrocarpon*), p. 162
Creeping snowberry (*Gaultheria hispidula*), p. 152
Creeping wintergreen (*Gaultheria humifusa*), p. 160

Dandelion (*Taraxacum officinale*), p. 104
Eastern camass (*Camassia scilloides*), p. 64
Edible valerian (*Valeriana edulis*), p. 88
Evening primrose (*Oenothera biennis*), p. 102
Glandular mesquite (*Prosopis glandulosa*), p. 188
Glasswort (*Salicornia europea*), p. 76
Great bulrush (*Scirpus validus*), p. 70
Green pigweed (*Amaranthus hybridus*), p. 72
Groundnut (*Apios americana*), p. 148
Hard-stem bulrush (*Scirpus acutus*), p. 70
Indian fig (*Opuntia humifusa*), p. 138
James chickweed (*Stellaria jamesiana*), p. 84
Labrador tea (*Ledum groenlandicum*), p. 160
Lamb's quarters (*Chenopodium album*), p. 74
Lance-leaved pickerelweed (*Pontederia lanceolata*), p. 132
Live-forever (*Sedum purpureum*), p. 110
Marsh mallow (*Althaea officinalis*), p. 146
Mountain cranberry (*Vaccinium vitis-idaea*), p. 162
Narrow-leaved cattail (*Typha angustifolia*), p. 68
Pawpaw (*Asimina triloba*), p. 198
Pickerelweed (*Pontederia cordata*), p. 130
Pigweed (*Amaranthus retroflexus*), p. 72
Plantain (*Plantago major*), p. 78
Poverty weed (*Monolepis nuttalliana*), p. 74
Prickly pear (*Opuntia phaeacantha*), p. 140
Reed grass (*Phragmites communis*), p. 128
Rocky Mountain juniper (*Juniperus scopulorum*), p. 194
Salal (*Gaultheria shallon*), p. 160
Sassafras (*Sassafras albidum*), p. 124
Screwbean mesquite (*Prosopis pubescens*), p. 188
Sheep sorrel (*Rumex acetosella*), p. 120
Silver buffaloberry (*Shepherdia argentea*), p. 178
Smooth sumac (*Rhus glabra*), p. 184
Sour dock (*Rumex crispus*), p. 120
Southern bayberry (*Myrica cerifera*), p. 174
Squawbush (*Rhus trilobata*), p. 186
Staghorn sumac (*Rhus typhina*), p. 250
Sunflower (*Helianthus annus*), p. 156
Sweet birch (*Betula lenta*), p. 122, 252
Sweet gale (*Myrica gale*), p. 176
Utah juniper (*Juniperus osteosperma*), p. 196
Watercress (*Nasturtium officinale*), p. 146
Western camass (*Camassia quamash*), p. 136
Wild garlic (*Allium canadense*), p. 60
Wild leek (*Allium tricoccum*), p. 60
Wild onion (*Allium cernuum*), p. 58
Wild rice (*Zizania aquatica*), p. 128
Wild strawberry (*Fragaria virginiana*), p. 90
Wintergreen (*Gaultheria procumbens*), p. 150
Yellow birch (*Betula alleghaniensis*), p. 122, 254

Jerusalem artichoke

Helianthus tuberosus

Also edible winter, spring

Habitat: damp or rich thickets, waste areas, roadsides; often cultivated today as by Indians in past. **Identification:** perennial herb to 3 m (9.8 ft) tall, forming colonies; stems upright, rough-hairy, from a root system with elongated, fleshy, edible tubers 7.5–12.5 cm (3–5 in) long. ***Leaves opposite or in whorls of 3 on lower part of stems, alternate above,*** broadest near base, ***to 25 cm*** (10 in) ***long, 6–15 cm*** (2.4–6 in) ***wide,*** tapered at tip and base, ***hairy above, rough, leathery. Flower heads yellow*** with rounded central disc 1–2.5 cm (0.4–1 in) across, ***10–20 ray flowers,*** each about 4 cm (1.6 in) long, ***several flower heads per plant, on slender stems from leaf bases on upper part of stems.*** **Harvest:** Identify colonies in summer when in bloom; dig tubers from first frost through winter. **Preparation:** Peel or scrub tubers before using. Slice raw in salad, make potato salad, boil and mash, roast with meat, slice and fry. For pickles, peel and boil 3–4 min, cover with wine vinegar, age 3–5 weeks. Adapt to many potato and carrot recipes. Food value equal to potato. The carbohydrates are mostly inulin and suitable for low starch diets. **Related edible species:** other SUNFLOWERS (*Helianthus* species) produce edible seeds. **Poisonous look-alikes:** none.

Lotus lily, American lotus

Nelumbo lutea

Also edible spring, summer

Habitat: lakes, ponds, slow-moving streams, bays and tidal waters. **Identification:** ***aquatic perennial herb;*** roots large, thick with swollen tubers. ***Leaves large,*** 20–70 cm (8–28 in) across, circular, often ***rising above water level, center depressed,*** bluish-green; ***leafstalk attached at center of blade,*** variable in length, strong but flexible. ***Flowers*** solitary on long stalks, ***showy,*** 14–26 cm (5.5–10.2 in) across, ***with numerous pale yellow petals*** or petallike structures. ***Fruits produced in large cone-shaped, flat-topped receptacles*** raised above water level; each fruit dry, hard, nutlike, globe to egg-shaped, 1–2 cm (0.4–0.8 in) long. **Harvest:** Some part edible most of year. Pick unopened leaves and young stalks in spring. Pick seed receptacle either before or after seeds ripen during summer through autumn. Dig up tuberous root in autumn or early spring if you can overcome the difficulty of its deep water bed. **Preparation:** Leaves and young stalks are edible, but not exceptional, potherbs. Immature seeds are excellent raw, boiled, or roasted. Mature seeds are hard-shelled; crack shells before boiling to soft chestnutlike texture. Or roast *fresh* mature seeds, crack, and remove shells. Eat like nuts, or grind into meal and substitute for part of flour in bread and muffin recipes. Bake or boil tubers like sweet potatoes until tender. Peel and mash. To every cup add 1 tbsp butter, ¼ tsp salt, and a little hot milk. Beat to smooth texture. **Related edible species:** various species of YELLOW POND LILY (next) and water lily *(Nymphaea)*. **Poisonous look-alikes:** none.

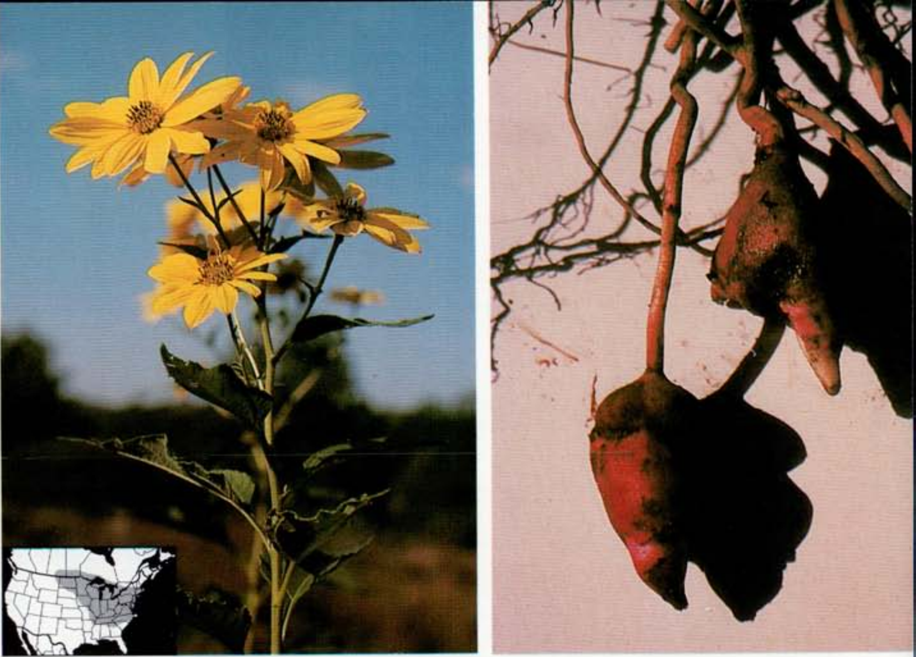

Jerusalem artichoke: flowers and tubers (Elias).

Lotus lily: receptacle with protruding fruits and flower (Feldman).

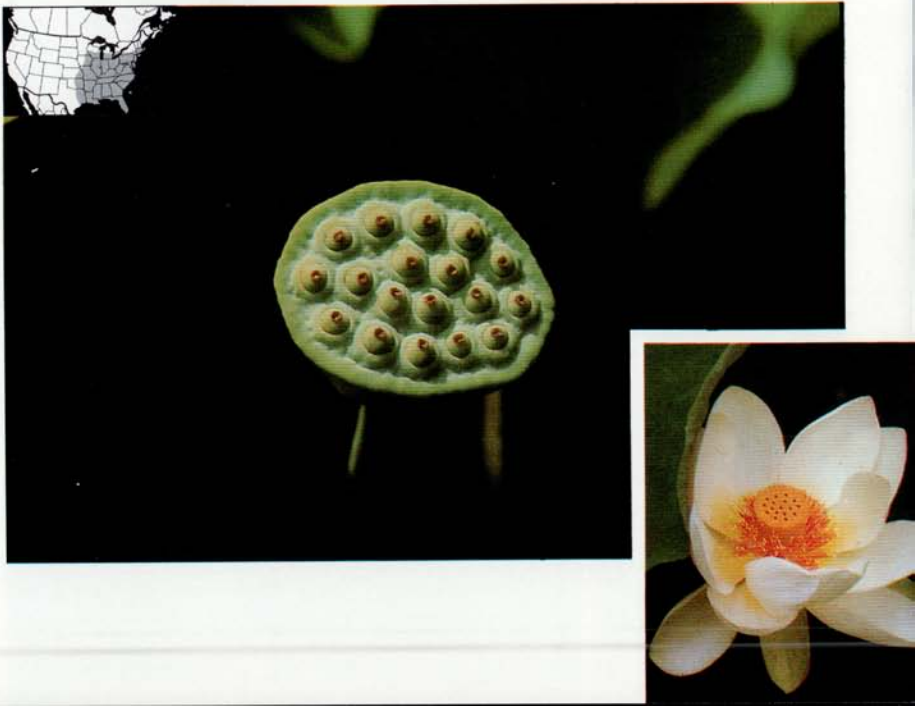

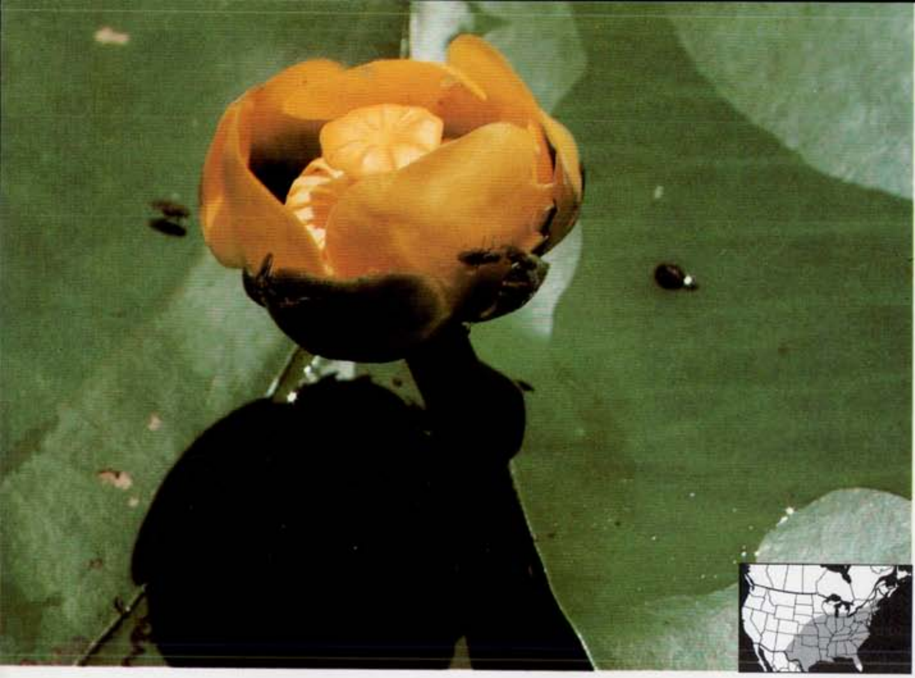

Yellow pond lily: flower prior to seed development (Elias).

Arrowhead: flower and whole plant (NYBG).

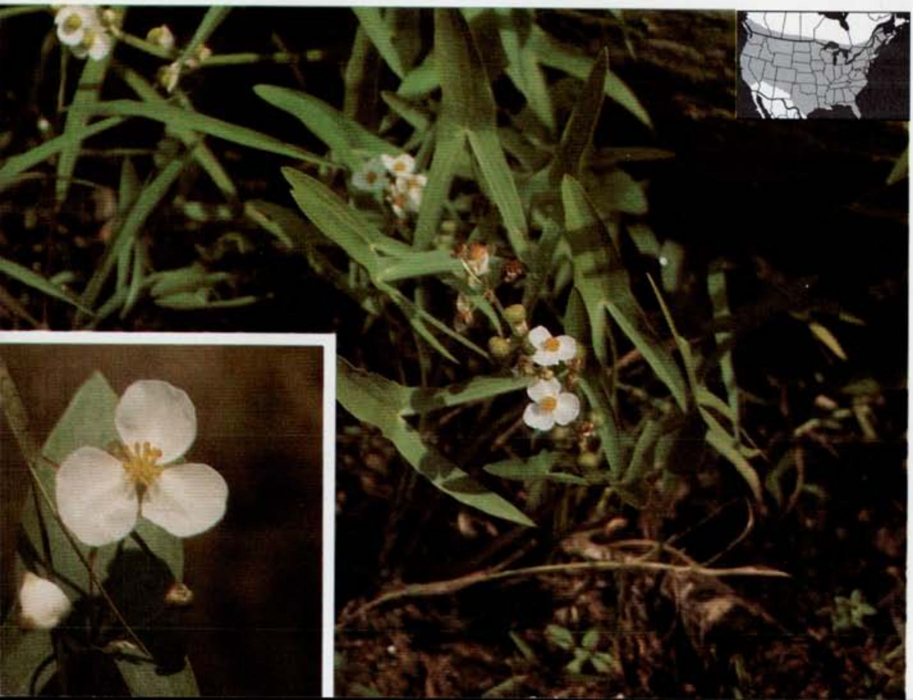

Yellow pond lily, Spatterdock *Nuphar advena*

Also edible winter, spring, summer

Habitat: lakes, ponds, slow streams, swamps, tidal waters. **Identification:** ***aquatic perennial herb;*** roots (actually stems or rhizomes) large, thick, to 13 cm (5 in) in diameter, elongate, branching, covered with leaf scars. ***Leaves large,*** 10–40 cm (4–16 in) long, 5–16 cm (2–6.3 in) wide, broadest below middle, ***deeply lobed at base to form U- or V-shaped cleft,*** shiny green, ***usually raised above water level,*** sometimes floating; leafstalk thick, stout, attached at base of cleft. ***Flowers*** solitary on long stalks, ***showy,*** 3–10 cm (1–4 in) across, ***with numerous yellow, green-tipped petals. Fruits broadly urn-shaped,*** 2–5 cm (0.8–2 in) long, with short thick neck and flattened top, ***ribbed,*** green, containing numerous, yellowish-brown, small, egg-shaped seeds. **Harvest:** Cut fruits free of stalk as they ripen (late summer or fall). Air-dry until fruits pull apart to separate seeds. Dump seeds in bucket of water. After 5–6 hr good ones sink; dry in sun or warm oven. Loosen tuberous roots from mud in bottom of pond from autumn to spring. Indians used their toes. **Preparation:** Seeds store well. Pop seeds like popcorn or remove shells by parching over coals or in oven, pounding lightly to crack shells, and winnowing. Then boil nutmeats like rice or grind and use like cornmeal. Peel, slice, and boil roots in 2 water changes. Mash, season, and serve like potatoes or dry and use like flour. **Related edible species:** several other species of yellow pond lilies *(Nuphar)*, most important is cow lily *(N. polysepalum)* in West. **Poisonous look-alikes:** none.

Arrowhead, Duck potato, Wapato *Sagittaria latifolia*

Also edible winter, spring, summer

Habitat: shores of lakes, ponds, streams, ditches, bogs, wet meadows; common and widespread. **Identification:** ***perennial herb*** 0.6–1.2 m (2–4 ft) high, with fibrous roots developing small tubers (potatolike) 0.5–5 cm (0.2–2 in) in diameter. ***Leaves all at base,*** blades 10–25 cm (4–10 in) long, 1–25 cm (0.4–10 in) wide, ***arrowhead-shaped with long pointed lobes at base, leaf shape highly variable*** from extremely narrow to very broad, smooth or hairy; leafstalks flexible, to 1 m (3.2 ft) long. Flowering stalk taller than leaves; ***flowers in clusters of 3s along upper part of spike, each flower with 3 delicate, white petals.*** Fruiting heads globe-shaped or nearly so, containing numerous flat, winged seeds. **Harvest:** Collect tubers from late summer through early spring, whenever there is no ice. Dislodge tubers from roots in mud beneath water with rake or hoe, or wade in as the Indians did and loosen them with your toes. Tubers will float to surface and are easily collected. **Preparation:** Tubers are edible but not always tasty raw; better cooked like potatoes. Bake or boil about 30 min until tender; peel after cooking. Serve topped with mixture of butter and lemon juice or STAGHORN SUMAC extract. Use in potato recipes. To dry tubers for storage, boil until tender, drain, slice about ½-in thick, dry thoroughly in sun or warm oven. Store in warm dry place. Before using soak 20 min; allow 20 min cooking time. **Related edible species:** several other arrowhead species *(Sagittaria)*; all have arrowhead leaves; PICKERELWEED has similar leaves but lacks tubers. **Poisonous look-alikes:** none.

WILD GRAPES *Vitis*

North America has about 50 native species of grapes along with several introduced ones that now grow wild. While it is easy to identify a grape vine, determining grape species can be challenging. It is best to familiarize yourself with the grapes in your region and the variation in fruit quality. Grapes are climbing vines with large lobed or toothed leaves, numerous small flowers in elongate clusters, and then fruit bunches. Three of the more common grapes are described here. **Harvest:** Gather leaves in spring when young and tender but full grown. Collect fruits between August and October, depending upon species and region. **Preparation:** Boil leaves until tender, and serve with other vegetables. Check cookbook recipes for stuffed grape leaves. Most fresh grapes are too acid to eat in quantity. Best to make juice, jelly, preserves, pie, and wine. For jelly, use mixture of ripe and unripe (for pectin) fruits. Wash, drain, remove stems, and mash in kettle. Add small amount of water and cook until fruit comes apart, about 15–20 min. Strain juice through jelly bag. Prevent crystallization in jelly by letting juice sit overnight or cooking 1 cup tart apples with each 4 cups of grapes. Boil 4

Riverside grape *Vitis riparia*

Also edible spring, summer

Habitat: stream and river banks, margins of woodlands, thickets. **Identification:** ***large vine,*** usually climbing; branches tough, rounded, becoming smooth, pith chambered. ***Leaves*** alternate, simple, deciduous, ***12–20 cm*** (4.7–8 in) ***long,*** 8–16 cm (3–6 in) wide, nearly circular in outline to broadest near base, ***usually 3-lobed, long-pointed at tip,*** coarsely toothed along margin, heart-shaped at base, smooth above, ***hairy beneath.*** Flowers tiny, produced in many-flowered, elongate clusters to 10 cm (4 in) long. Fruits are dense bunches of ***berries,*** each ***rounded, 8–14 mm*** (0.3–0.6 in) ***in diameter, black with whitish bloom,*** sour tasting. **Harvest and preparation:** See WILD GRAPES (preceding).

Frost grape *Vitis vulpina*

Also edible spring, summer

Habitat: streams and river banks, low wetlands, thickets. **Identification:** ***large vine,*** often climbing; branches stout, rounded, becoming smooth, pith chambered. ***Leaves*** alternate, simple, deciduous, ***10–18 cm*** (4–7 in) ***long, almost as wide,*** very broad, widest near base to almost round, ***usually unlobed or slightly 3-lobed,*** pointed at tip, coarsely toothed along margins, heart-shaped at base, smooth above, smooth below except for junctions of major veins. Flowers tiny, produced in many-flowered, elongated clusters to 18 cm (7 in) long. Fruits are clusters of ***berries,*** each ***rounded, 4–10 mm*** (0.2–0.4 in) ***in diameter, black,*** sour tasting until frost, then sweet. **Harvest and preparation:** See WILD GRAPES (preceding).

cups juice with 4 cups sugar until jelling point is reached. Skim off foam, pour into sterilized jars, seal with paraffin. For pie, squeeze skins from 4 cups ripe grapes. Simmer pulp until it comes apart; sieve to remove seeds. Chop skins and combine with strained pulp, 1½ cups sugar, 2 tbsp flour, ¼ tsp salt, 1 tbsp lemon juice, 2 tbsp melted butter. Mix well and pour into unbaked pie shell. Fit and slit top crust. Bake at 205°C (400°F) for 30–40 min until crust is browned. For juice, use ripe fruit. Crush in kettle, heat and simmer for 30 min, but do not boil. Press through sieve and strain through jelly bag. Sweeten to taste. For wild grape butter, puree remaining pulp. Add equal amount to maple sugar or honey and blend in bean pot. Bake in preheated 160°C (320°F) oven, stirring occasionally, for 3 hr. Seal in sterilized jars. For emergency water source, cut off large vine and drain sap. **Poisonous look-alikes:** moonseed *(Memispermum canadense)* is a vine with simple entire or shallowly lobed leaves and clusters of black fruits resembling a bunch of grapes. The leafstalk is attached on the lower surface of the blade above the base (peltate) and the leaves are not coarsely toothed as those of most grapes. Single seed a flat crescent.

Riverside grape: fruiting branch (Elias).

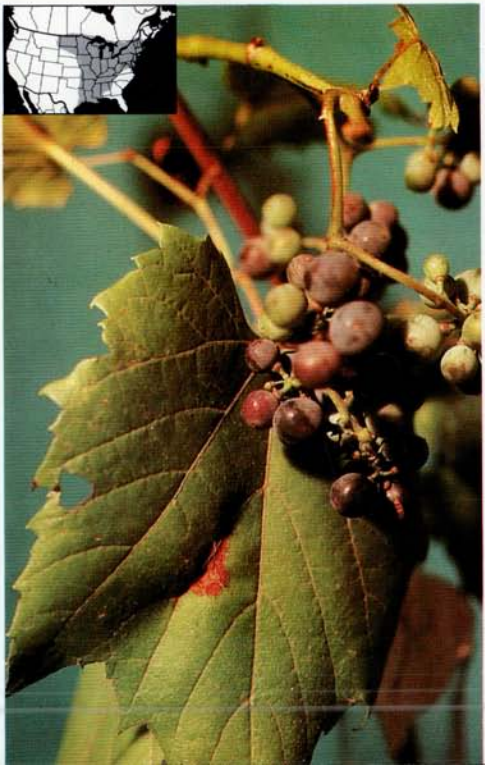

Frost grape: fruiting branch (Elias).

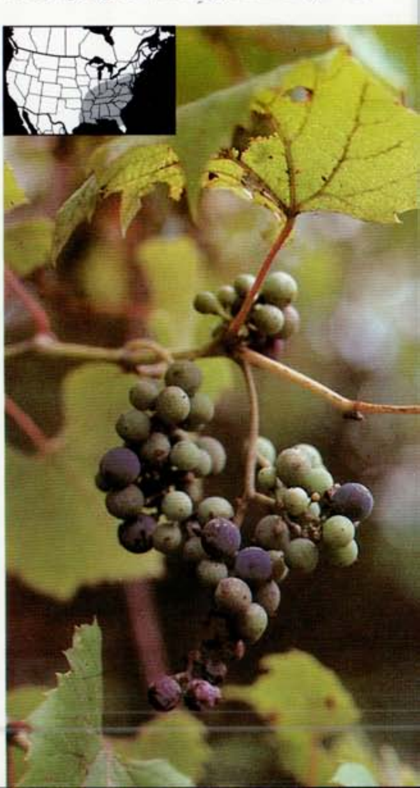

California grape *Vitis californica*

Also edible spring, summer

Habitat: stream and river banks, moist canyons, margins or clearings of forests. **Identification:** large ***woody vine,*** climbing; branches stout, rounded, with shredding bark, pith chambered. ***Leaves*** alternate, simple, deciduous, ***6–14 cm*** (2.4–5.5 in) ***long,*** nearly as wide, ***circular in outline, nearly unlobed to 3-lobed,*** short-pointed at tip, coarsely toothed along margin, deeply lobed at base, hairy above, dense cobweblike hairs beneath. Flowers tiny, produced in many-flowered, branched, elongated clusters. ***Fruits*** are dense bunches of ***berries,*** each rounded, ***6–10 mm*** (0.2–0.4 in) ***in diameter, dark purple and covered with whitish bloom.*** **Harvest and preparation:** See WILD GRAPES (preceding).

Wild potato vine *Ipomoea pandurata*

Also edible spring, summer

Habitat: fields, fencerows, roadsides; dry, open or partly shaded areas. **Identification:** ***perennial*** trailing or slightly twining ***vine,*** 0.9–3.6 m (3–12 ft) long, ***often purplish along stem,*** branching, ***from a large tuberous root to 9 kg*** (20 lbs), ***vertical, deep, slightly milky,*** resemble a yam. ***Leaves 4–8 cm*** (1.6–3.2 in) ***long, 3–8 cm*** (1.2–3.2 in) ***wide, heart-shaped, pointed at the tip, entire along the margins. Flowers*** to 7.5 cm (3 in) across, with a ***white*** (sometimes purple-centered), ***funnel-shaped*** corolla, like a morning glory flower. Fruit a 2-chambered capsule 0.8–1.2 cm (0.3–0.5 in) long, broadest near the base and tapering to a tip. **Harvest:** Dig deep root any time when ground is not frozen, but best not in summer when starch level is low. Young roots are preferred to older, woody ones. **Preparation:** Boil or bake roots like sweet potatoes. When boiling, change water 2 or 3 times for bitter ones; others will not need changing. All roots have tough outer skins and require peeling. Serve with butter and seasonings. Some older roots may be too woody to use. Dry peeled slices of root for later use. **Related edible species:** Bush morning glory *(I. leptophylla)* of the West is variously described from excellent to nearly inedible. Edibility of other species has not been reported. **Poisonous look-alikes:** Flowers may resemble those of JIMSON WEED; however, JIMSON WEED is an upright herb with large, coarsely toothed leaves.

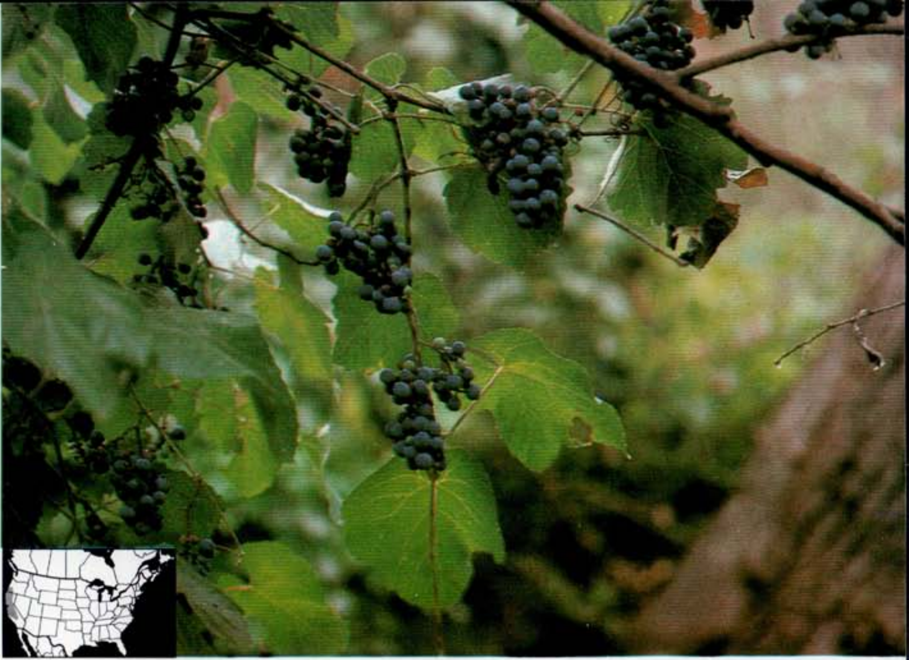

California grape: fruiting branch (Ornduff).

Wild potato vine: flower (Mohlenbeck).

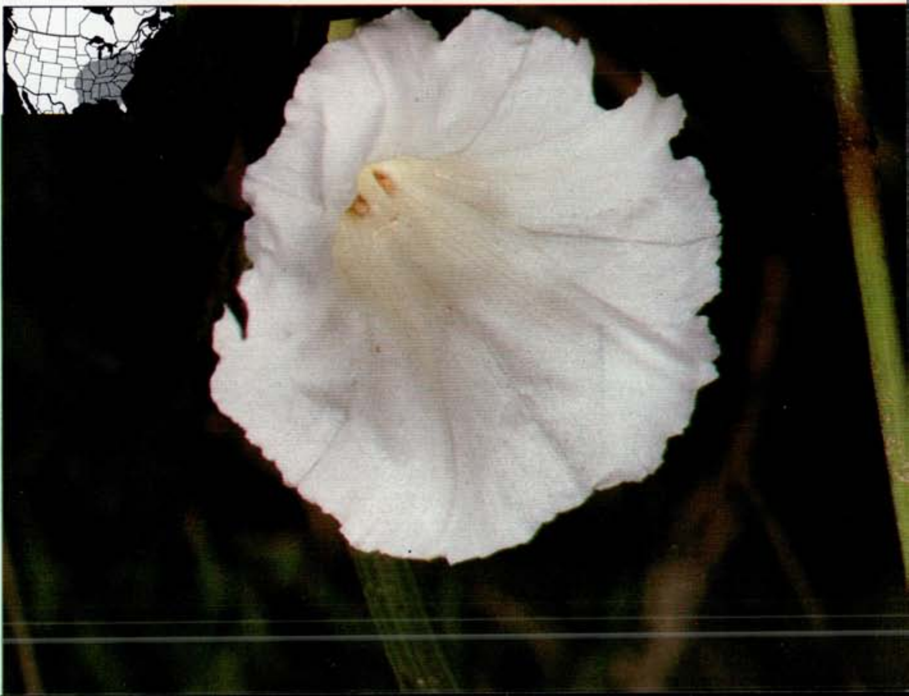

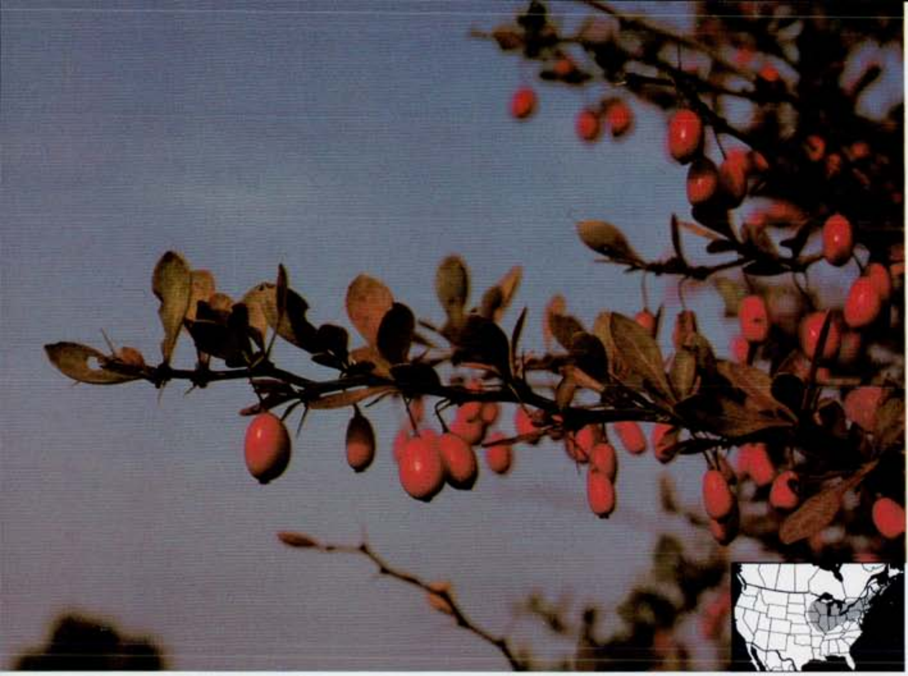

Common barberry: fruiting branch (Dykeman).

Spice bush: fruiting branch (Elias). Flowers (NYBG).

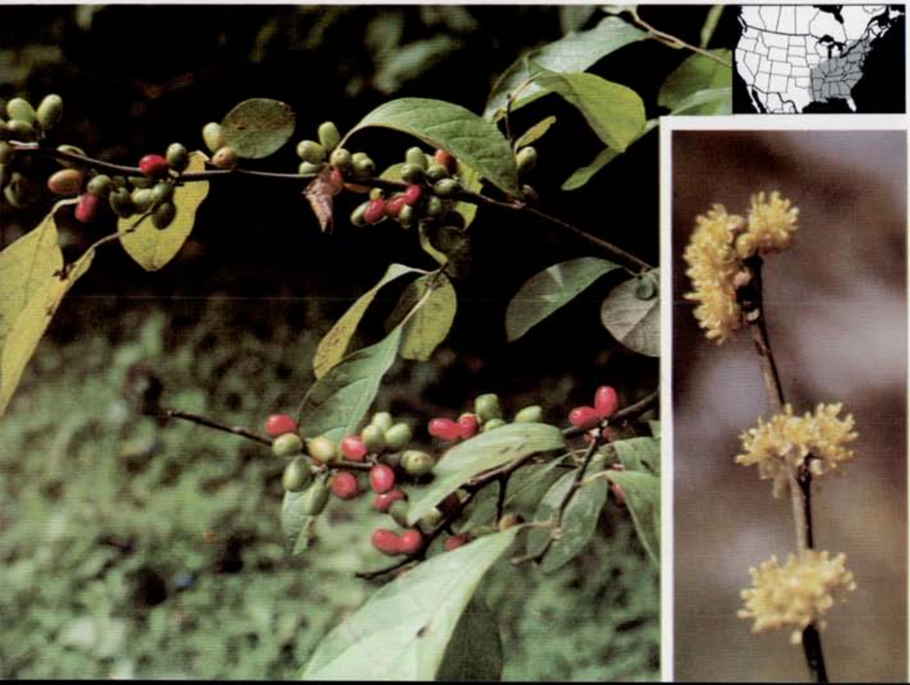

Common barberry *Berberis vulgaris*

Habitat: widely planted European shrub; also grows wild, the seeds spread by birds; disturbed woodlands, fencerows, fields, roadsides. **Identification:** shrub 1–3 m (3–10 ft) high, with rounded crown. Branches grooved, yellowish-red, turning gray by second season, with ***3-forked sharp-spines. Leaves*** alternate, simple, deciduous, ***often crowded together on short shoots,*** 2–4.8 cm (0.8–2 in) long, 0.8–2.4 cm (0.3–1 in) wide, ***broadest above middle, rounded at tip, finely sharp-toothed along margin.*** Flowers produced in spring, stalked, in 10–20-flowered, elongated, narrow clusters, each flower greenish-yellow. ***Fruits in drooping clusters*** in late summer or early autumn, ***berries 8–12 mm*** (0.3–0.5 in) ***long, orange-red to scarlet.*** **Harvest and preparation:** Pick fruits in autumn when full color has developed. For jelly, 4 cups crushed barberries, 2 whole oranges, chopped, 2 cups water, 1½ cups sugar, 1 pkg pectin. Combine berries, oranges, and water. Bring to boil, simmer until tender, about 20 min. Strain juice through cloth or jelly bag. Combine juice and sugar; bring to rolling boil. Add pectin; bring to boil. Pour into hot, sterilized jars; seal. Yields 3 pt. For straight barberry jelly, cook berries and extract juice. Boil juice to 105°C (200°F); pour into hot, sterilized jars; seal. Needs no pectin, very tart. Juice also good in sauces and beverages where tartness is needed. To relieve thirst, chew a few leaves. **Related edible species:** red-fruited barberry *(B. haematocarpa),* southwestern U.S.; American barberry *(B. canadensis)*, southeastern U.S.; and other species. **Poisonous look-alikes:** none.

Spice bush *Lindera benzoin*

Also edible winter, spring, summer

Habitat: rich woodlands, stream banks, especially in moist soils. **Identification:** shrub to 5 m (16.4 ft) high, with numerous, spreading to upright, smooth ***branches, with spicy fragrance when broken.*** Leaves alternate, simple, deciduous, 6–14 cm (2.4–5.5 in) long, 3–6 cm (1.2–2.4 in) wide, broadest near or above middle, long-pointed at tip, entire along margin, thin, smooth, bright green, stalked. ***Flowers in early spring before leaves appear, yellow, small, produced in dense clusters along previous year's twigs. Fruits*** produced in clusters, each ***a berry,*** widest at middle, rounded at end, ***6–10 mm (0.2–0.4 in) long,*** green turning ***bright red at maturity.*** **Harvest:** young leaves in spring; bark and twigs all year; fruits in late autumn before migrating flocks of birds eat them all. **Preparation:** For tea steep 15 leaves or handful of fresh twigs and bark in 4 cups boiling water for 15 min. Strain if necessary; serve with honey and milk for best flavor. Dry fruits thoroughly in warm oven. Grind and use as substitute for allspice. **Related edible species:** none. **Poisonous look-alikes:** none.

Desert hackberry, Spiny hackberry *Celtis pallida*

Habitat: desert foothills and mesas at 450–1,050 m (1,500–3,500 ft). **Identification:** ***shrub or small tree,*** to 5 m (16 ft) tall, single or in thickets, ***densely branched, twigs with many single or paired spines at base of leaves. Leaves simple, alternate, evergreen, broadest near or below the middle,*** 2.5–7.5 cm (1–3 in) long, ***unequal at base, toothed from mid margin to tip, rough upper surface.*** Flowers in spring, small, greenish white, in long clusters at base of younger leaves. ***Fruits single, fleshy,*** 6–8 mm (0.2–0.3 in) diameter, ***yellow to red-orange, sweet, containing 1 large seed.*** **Harvest:** fruits in late September and October; crop frequently abundant if rain was sufficient. **Preparation:** Eat fresh or dried as snack. Dry whole or mashed and formed into small cakes; dry in sun or 100°C (212°F) oven. Store in dry place. For seedy jam, mash 6 cups fresh berries in saucepan with 2 cups sugar, 3 tbsp lemon juice, and ½ cup water. Bring to boil; reduce heat and simmer with stirring until thick. Ladle into sterilized jars and seal with paraffin. If seeds are annoying, grind fruit fine before cooking. Use fresh or dried fruits in baking. **Related edible species:** American hackberry *(C. occidentalis)* and several other species are edible; palatability depends on species and weather. **Poisonous look-alikes:** none.

ROSES *Rosa*

There are about 35 species of roses native to North America and several introduced species that now grow wild on roadsides and disturbed sites. While it's easy to distinguish roses from other groups of plants, the distinctions among individual species are often difficult. Fortunately, all roses have edible parts although quality and size vary greatly. Roses are shrubs normally with spiny branches, and alternate featherlike (pinnate) compound leaves. The large attractive flowers have 5 petals, and many stamens and pistils. Four of the more common species are treated on upcoming pages. **Harvest and preparation:** Gather fruits (hips)

California rose *Rosa californica*

Also edible winter, summer

Habitat: along streams, rivers, washes, and in moist canyons. **Identification:** shrub to 3 m (9.8 ft) tall with coarse, erect to nearly erect branches, armed with stiff, flattened, usually curved spines. Leaves alternate, deciduous, compound, each with 5–7 leaflets, leaflets broadest near base and gradually tapering to a pointed to blunt tip, 1.2–3.6 cm (0.5–1.4 in) long, about half as wide, with 1 or 2 rows of sharp teeth along margin, hairy. ***Flowers in few-flowered clusters*** in spring or summer, each with green smooth floral tube (hypanthium), narrow lance-shaped sepals, ***5 white or pink petals 1.2–2.5 cm*** (0.5–1 in) ***long. Fruits*** (hips), fleshy, ***egg- to globe-shaped, 1.2–1.8 cm*** (0.5–0.7 in) ***in diameter, with distinct neck,*** red, smooth. **Harvest and preparation:** See preceding. **Related edible species:** all native roses. **Poisonous look-alikes:** none.

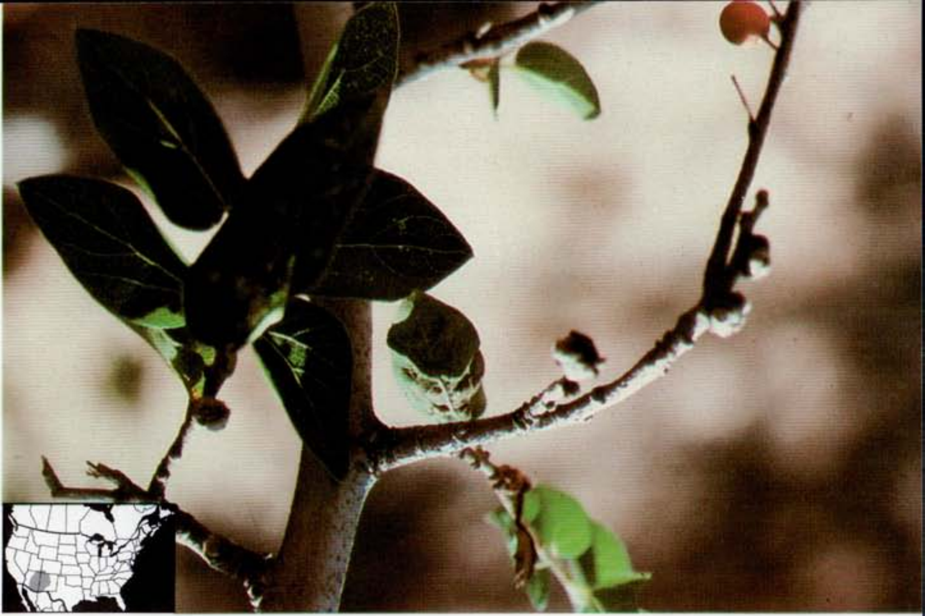

Desert hackberry: fruiting branch (Cramer).

as they ripen in autumn (after frost) or during winter, wash and remove dried persistent flower parts from top of hips, then split open and remove seeds. Eat pulpy portion fresh or in jellies or sauces. Dry whole or halved cleaned fruits for later use (soak overnight in warm water) or finely grate or grind dried hips to yield a slightly fragrant powder rich in vitamin C and essential minerals. Sprinkle on hot breakfast cereals or use to make hot tea. Also wash young leaves, cut into small pieces, and dry for hot rose tea. Flower petals can be used in candy, tea, and jellies, but fruits are more nutritious.

California rose: fruits and flower (McNeal).

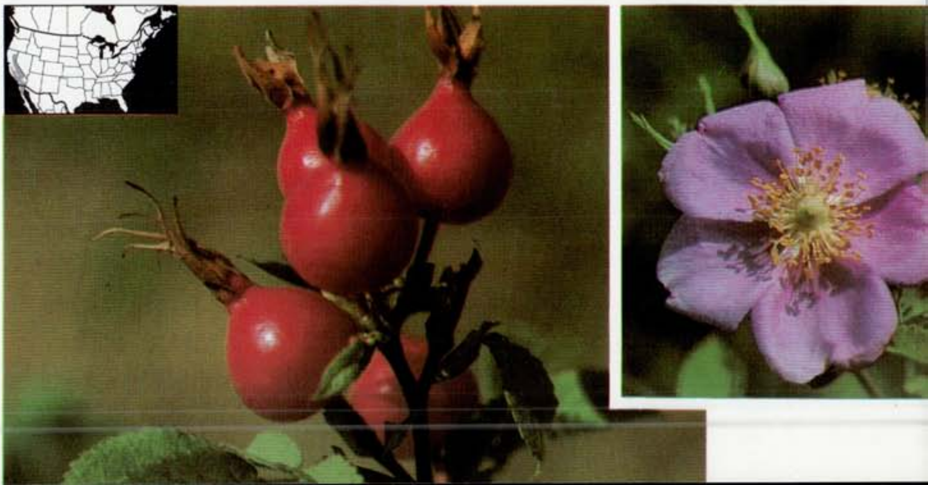

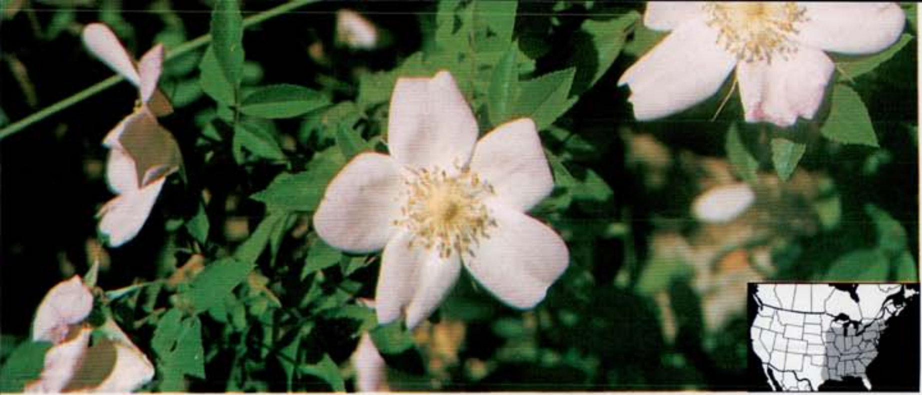

Wild rose: flowers (NYBG).

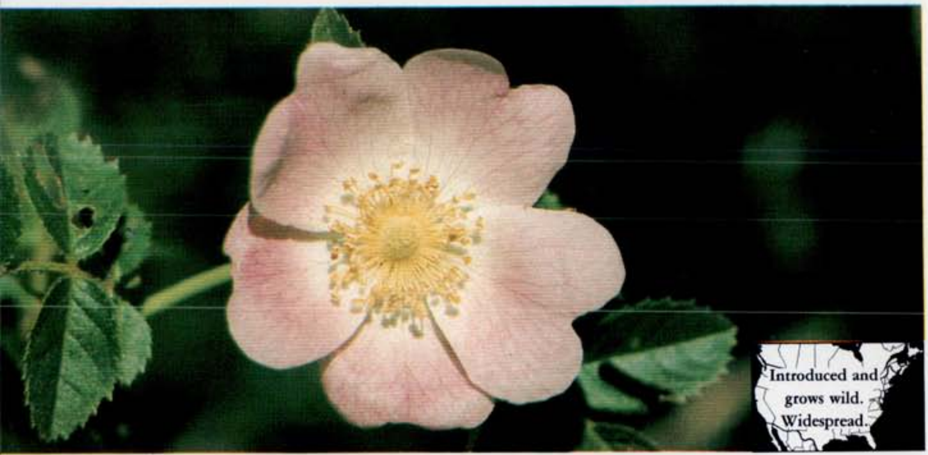
Introduced and
grows wild.
Widespread.

Sweetbrier rose: flower (Speas).

Wrinkled rose: fruits (Crow). Flower (Hardin).

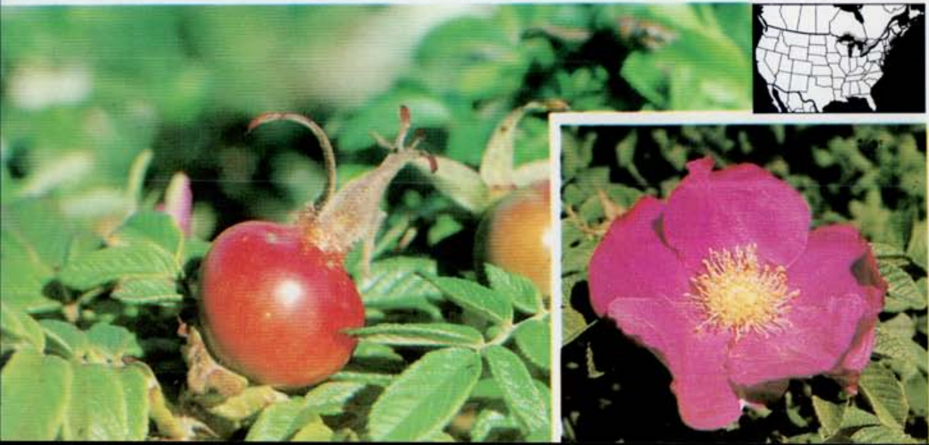

Wild rose, Pasture rose *(Also edible winter, summer)* *Rosa carolina*

Habitat: open woodlands, margins of woodlands, fields, pastures, rocky outcrops. **Identification:** low shrub to 1.5 m (5 ft) high, with slender arching branches, with stiff hairs and armed with broad-based straight or curved spines, especially on lower half. Leaves alternate, deciduous, compound, each with 3–7, rarely 9, leaflets, leaflets usually broadest near middle to almost rounded, 1.6–3.8 cm (0.6–1.5 in) long, about half as wide, pointed to blunt at tip, ***coarsely sharp-toothed along margin. Flowers*** usually solitary and produced in spring or early summer, each ***with glandular-hairy floral tube*** (hypanthium), narrow lance-shaped sepals, and 5 ***pink petals*** 2–3.2 cm (0.8–1.3 in) long. ***Fruits (hips)*** fleshy, ***nearly globe-shaped, 6–10 mm*** (0.2–0.4 in) ***in diameter,*** red, containing several seeds. **Harvest and preparation:** See ROSES. **Related edible species:** all native roses. **Poisonous look-alikes:** none.

Sweetbrier rose *(Also edible winter, summer)* *Rosa eglanteria*

Habitat: disturbed sites such as roadsides, abandoned pastures and fields, edges of woodlands, fencerows. **Identification:** shrub to 3 m (9.8 ft) high, with large arching coarse branches, new branches with laterally flattened, broad-based, spines curved or straight. Leaves alternate, deciduous, compound, apple odor when crushed, each leaf with 7–9 leaflets, ***leaflets*** broadest near or above middle, 1–4 cm (0.4–1.6 in) long, pointed or blunt at tip, ***doubly toothed and glandular along margin,*** hairy. ***Flowers*** solitary or in few-flowered clusters from May to July, each with green, ***smooth or sparsely hairy floral tube*** (hypanthium), ***featherlike*** (pinnate) ***glandular sepals,*** and 5 pink petals 1.4–2.4 cm (0.6–1 in) long. ***Fruits*** (hips) fleshy, ***elongate and broadest near middle, 1.5–2 cm*** (0.6–8 in) ***long,*** red, containing several seeds. **Harvest and preparation:** See ROSES. **Related edible species:** all native roses. **Poisonous look-alikes:** none.

Wrinkled rose *(Also edible winter, summer)* *Rosa rugosa*

Habitat: introduced from Asia; grows wild along roadsides, in dunes, and near seashores. **Identification:** shrub to 2 m (6.6 m) tall, with coarse, arching ***branches, densely covered with stiff hairs and stiff needle-shaped spines.*** Plants forming dense clumps. ***Leaves*** alternate, deciduous, compound, each leaf with 5–9 leaflets, leaflets widest near or above middle, 2–5 cm (0.8–2 in) long, about half as wide, pointed to rounded at tip, with teeth curving downward (recurved) along margin, ***dark green, deeply furrowed or wrinkled. Flowers*** solitary or in few-flowered clusters in spring, summer, or early fall, each ***with green, smooth floral tube*** (hypanthium), ***narrow spoon-shaped sepals, and 5 rose-purple to white petals*** 2.5–5 cm (1–2 in) long. ***Fruits*** (hips) fleshy, ***globe-shaped but depressed at top and bottom, 2–2.5 cm*** (0.8–1 in) ***in diameter,*** red, ***smooth,*** containing many seeds. **Harvest and preparation:** See ROSES. **Related edible species:** all native roses. **Poisonous look-alikes:** none.

Highbush cranberry *Viburnum trilobum*

Also edible winter

Habitat: stream banks, wet thickets, moist woodlands. **Identification:** Not a real cranberry, this is a ***shrub,*** upright, to 5 m (16.4 ft) high; branches upright to spreading, ash-gray with age. ***Leaves*** opposite, simple, deciduous, ***6–12 cm*** (2.4–4.7 in) ***long, almost as wide,*** broadest near base, ***deeply 3-lobed,*** long pointed at tip, coarsely toothed along margin, rounded to squared at base, dark green and sparsely hairy above, hairy beneath; ***leafstalks with 1 or 2 small glands. Flowers produced in dense, many-flowered, round-topped clusters, with showy white sterile flowers on margin of flower cluster;*** small sterile flowers in center. ***Fruits berrylike,*** rounded to egg-shaped, 8–14 mm (0.3–0.6 in) long, ***bright red, translucent*** when ripe, juicy, containing single flattened stone. **Harvest:** Fruits ripen in late summer but persist on shrub and become less sour through winter. To make sure your shrub is highbush cranberry and not its bitter look-alike, the introduced guelder rose *(V. opulus),* make a harmless taste test. Pick in fall and winter. **Preparation:** much the same as CRANBERRY except large seeds must be removed. While cooking add lemon or orange peel shavings to eliminate bad odor of berries. For sauce, cover several quarts of berries with water in kettle. Add outer peels of 2 lemons or oranges. Bring to boil and simmer 5 min. Mash thoroughly and simmer another minute or two. Force juice and pulp through coarse strainer to remove seeds. Add 1 pkg pectin to 4 cups strained fruit, bring to boil, and add 5 cups sugar. Boil again for 1 min and seal in sterile jars or refrigerate. If fruits are picked before first frost, pectin may not be needed. For juice and jelly, cook berries as above but strain through jelly bag. For juice, dilute and sweeten to taste. For jelly, proceed with 4 cups juice as for sauce. **Related edible species:** HOBBLEBUSH, NANNYBERRY, and SQUASHBERRY (next), and in the Pacific Northwest the cranberry tree *(V. pauciflorum).* **Poisonous look-alikes:** none.

Hobblebush *Viburnum alnifolium*

Habitat: stream banks, moist woodlands, ravines. **Identification:** ***shrub,*** often spreading, to 3 m (9.8 ft) high, ***branches spreading, some drooping and rooting in ground. Leaves*** opposite, simple, deciduous, 10–24 cm (4–9.4 in) long, almost as wide, ***broadest near base,*** short-pointed at tip, heart-shaped at base, finely double toothed along margin, hairy beneath. ***Flowers produced in many-flowered, round-topped clusters, with sterile flowers, each with showy pink or white petals 2–3.8 cm (0.8–1.5 in) wide on margin of flower cluster;*** tiny fertile flowers in center. ***Fruits berrylike, slightly flattened,*** egg-shaped, 6–12 mm (0.2–0.5 in) long, ***black,*** containing single flattened stone. **Harvest:** fruits in autumn, generally only on shrubs in open area, not in dense woods. **Preparation:** same as NANNYBERRY (next). **Related edible species:** See NANNYBERRY. **Poisonous look-alikes:** none.

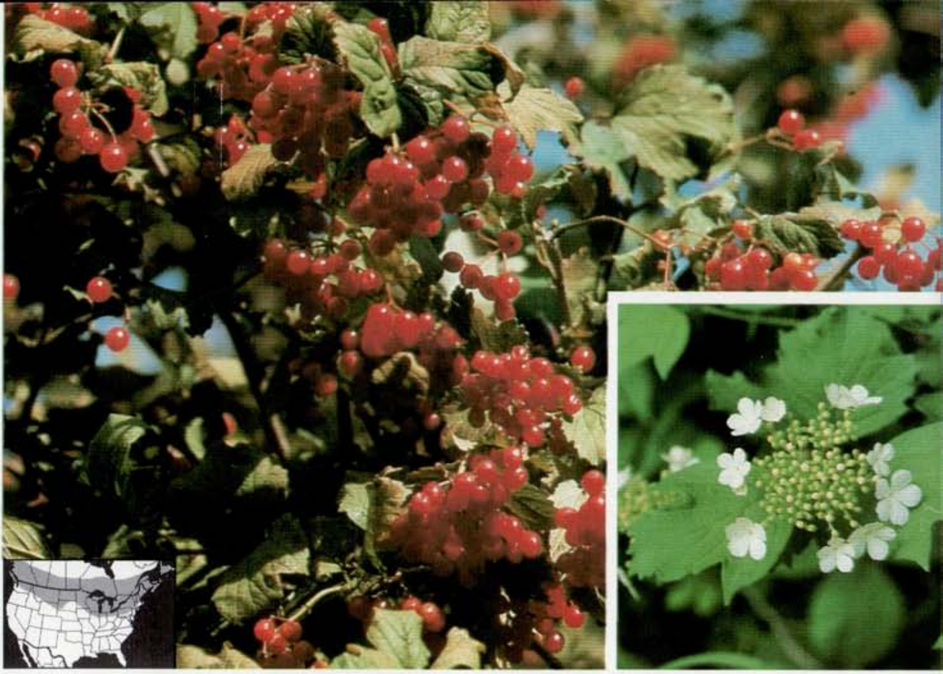

Highbush cranberry: fruiting branches (Elias). Flower cluster (Stevenson).

Hobblebush: flower cluster (NYBG). Fruiting branch (Elias).

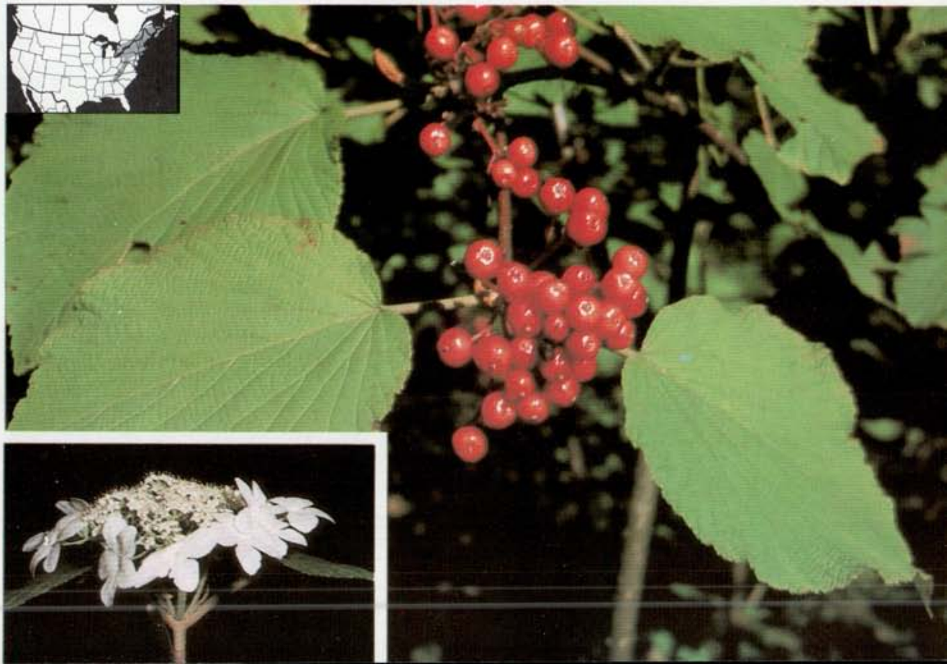

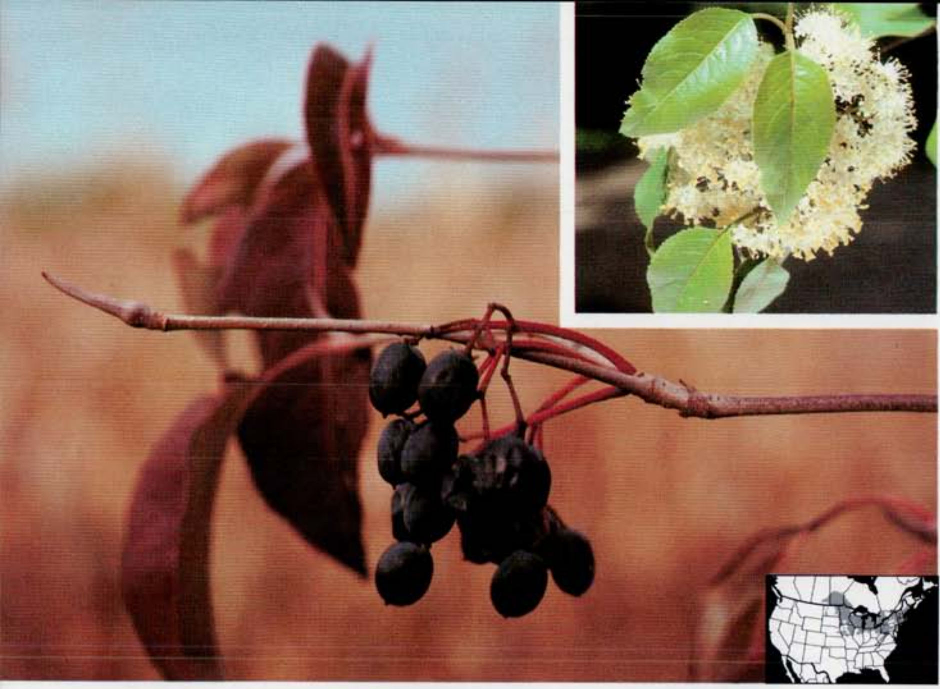

Nannyberry: fruits and flower cluster (Dykeman).

Squashberry: fruiting branch (Clawson).

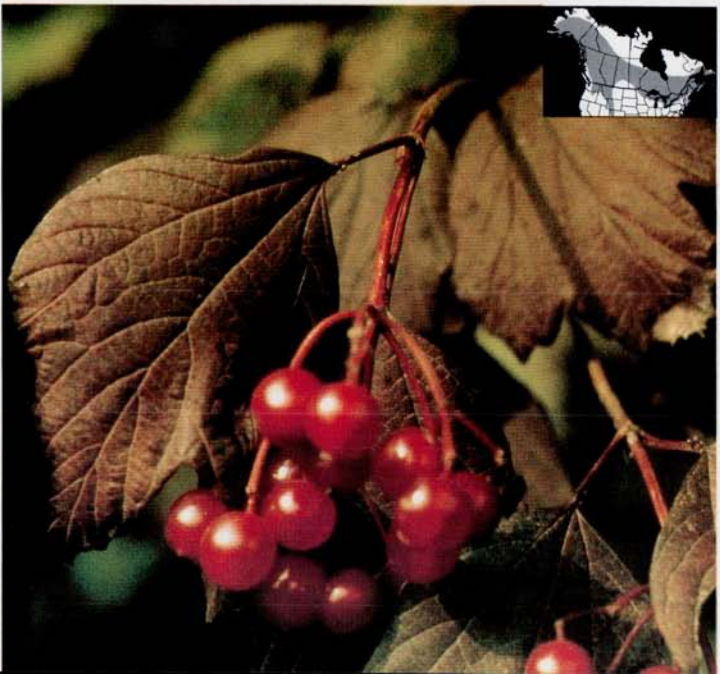

Nannyberry *Viburnum lentago*

Habitat: swamps, stream banks, rocky hillsides, margins of woodlands. **Identification:** ***shrub*** or small tree to 10 m (33 ft) with short branching trunk and slender tough, dark reddish-brown branches. ***Leaves opposite,*** simple, deciduous, 5–10 cm (2–4 in) long, 2.5–4 cm (1–1.6 in) wide, ***broadest near base or middle,*** occasionally rounded, with many fine, sharp teeth along margin, bright shiny green and smooth. ***Flowers produced in dense, many-flowered, rounded heads to 12 cm (4.7 in) in diameter,*** each flower white to cream, 5-lobed. ***Fruits berrylike, rounded,*** 8–12 mm (0.3–0.5 in) in diameter, ***dark blue to black,*** sweet, juicy, containing single flattened seed. **Harvest:** fruits when ripe in autumn as leaves are falling. **Preparation:** fruits good for trail snacks; flavor excellent, seeds a nuisance. For pudding add 1½ cups water to 1 qt fruits, boil for 5 min. Mash and work pulp through food mill. If pulp remains with seeds, scrape residue into small pan and add ½ cup water. Stir, mash, mill again. Yields about 1 cup pulpy syrup. Add 1 tbsp lemon rind, juice of ½ lemon, 1 cup sugar, ⅛ tsp cinnamon, ¾ cup water. Bring to boil and simmer 15 min. In separate pan combine ⅓ cup cornstarch with 1 cup cold water. Blend into fruit mixture. Cook slowly 15 min, pour into mold, and cool. Serve plain or with whipped cream. **Related edible species:** black haw *(V. prunifolium)*, northern wild raisin *(V. cassinoides)*, and HOBBLEBUSH (preceding); use fruits in same ways as for nannyberry. **Poisonous look-alikes:** none.

Squashberry *Viburnum edule*

Also edible winter, summer

Habitat: stream banks, wet thickets, margins of woodlands, moist low woodlands. **Identification:** ***shrub,*** often sprawling, to 2.5 m (8 ft) high; stems usually spreading, smooth. Leaves opposite, simple, deciduous, 4–11 cm (1.6–4.3 in) long and wide, ***broadly circular in outline, with 3 shallow lobes,*** sharply and irregularly toothed along margin, squared to slightly heart-shaped at base, sometimes hairy beneath. ***Flowers produced in loose, round-headed clusters 4–6 cm (1.6–2.4 in) across,*** each flower milky white, 5-lobed. ***Fruits berrylike, rounded,*** 6–10 mm (0.2–0.4 in) in diameter, ***red,*** containing single flattened seed. **Harvest:** fruits similar to HIGHBUSH CRANBERRY but smaller and less acid. Pick in late summer through winter. **Preparation:** same as HIGHBUSH CRANBERRY, except juice does not require dilution for use as beverage. **Related edible species:** See HIGHBUSH CRANBERRY. **Poisonous look-alikes:** none.

Pinyon pine *Pinus edulis*

Habitat: mesas, plateaus, lower mountain slopes, and foothills from 825–2,350 m (2,700–7,700 ft) elevation. Often occurs with JUNIPERS, GAMBEL'S OAK, and ponderosa pine. **Identification:** small, spreading, bushy tree with thin, irregularly furrowed, scaly ridged, gray to reddish-brown bark. ***Leaves (needles) 2 per bundle*** (rarely 1 or 3), ***1.2–5 cm*** (0.6–2 in) ***long,*** stiff, sharp-pointed, curved inward toward branches, bluish-green when young, turning yellowish-green with age. Fruits hard, short, egg-shaped cones 3.8–5 cm (1.5–2 in) long, composed of thick, blunt, yellowish-brown scales, each scale with 2 seeds. ***Seeds egg-shaped, 1.2–1.4 cm*** (0.5–0.6 in) ***long, wingless,*** pale yellow with reddish-brown markings, oily, sweet. **Harvest and preparation:** large cone crops produced every 3–4 yr. Gather ripe, almost open, cones in autumn. Store dry so that scales will separate to release seeds. Eat seeds fresh or after roasting 20–30 min. Roasting dries cones, facilitates seed removal, improves nutty flavor of seeds, and permits longer storage. Grind roasted nuts into meal. Seeds are rich in protein (14.5%) and fats and have high caloric content. **Related edible pines:** SINGLELEAF PINYON PINE, Mexican pinyon *(P. cembroides),* Parry pinyon *(P. quadrifolia)*. **Poisonous look-alikes:** none.

OAKS *Quercus*

This large genus of about 55 native trees and shrubs north of Mexico offers important food sources to wildlife and provides nuts edible to people as well. North American oaks are divided into two subgenera: the white oak group and the red/black oak group.

White Oak Group *Quercus* subgenus *Quercus*

This large group of related oaks occurs in the Americas, Europe, and Asia. There are 32 native species north of Mexico. They are distinguished from other oaks by a combination of characteristics: leaves entire, toothed, or lobed but never bristle-tipped; acorns maturing at end of first growing season on current year's twigs, and inner surface of acorn shell lacking hairs. Four of the most common species are discussed on upcoming pages. **Harvest and preparation:** Gather acorns in autumn as they turn brown and fall. They are usually sweet and need no leaching to remove tannins (if any bitterness exists, process as NORTHERN RED OAK acorns). Store nuts in cool dry place or shell for immediate use. For grits, dry nutmeats in air or warm oven and grind coarsely. Use like chopped nuts. For meal, regrind grits to finer texture and redry in warm oven, stirring occasionally. Use in recipes under RED OAK group. For candy combine 2 cups sugar, 1 cup water, ⅛ tsp cream of tartar, and pinch of salt in small pan and boil until carmelization begins. Maintain liquid by placing in larger pan of boiling water. Dip dried whole nutmeats in syrup and place on wax paper to harden.

White oak *Quercus alba*

Habitat: mixed deciduous forest in sandy, gravelly, loamy soils; widespread, often growing with hickories or other oaks. **Identification:** medium-size to tall

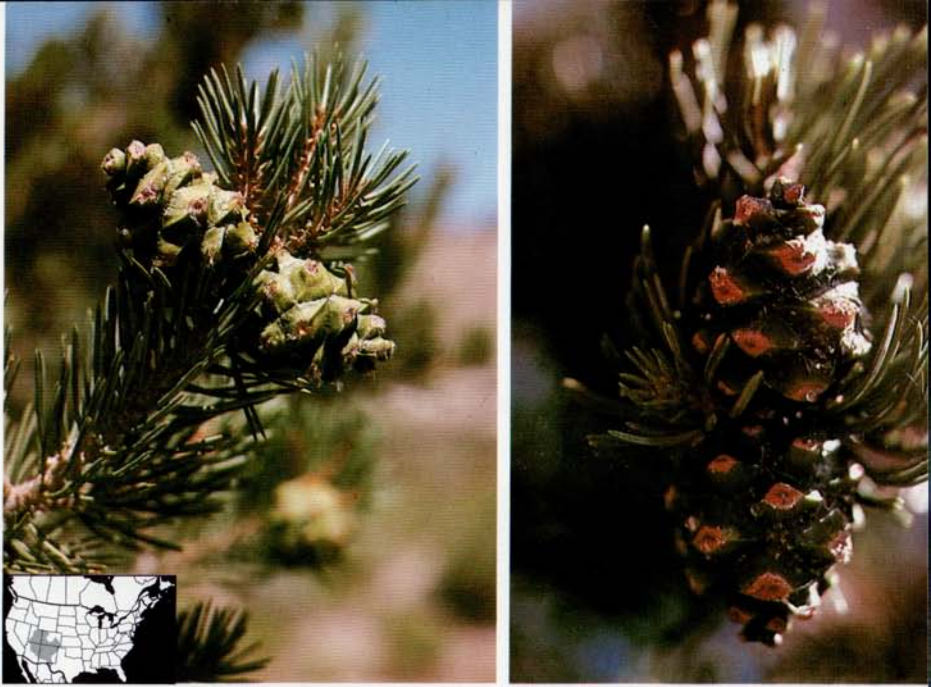

Pinyon pine: immature cones (Pawloski).

White oak: immature acorns (Elias).

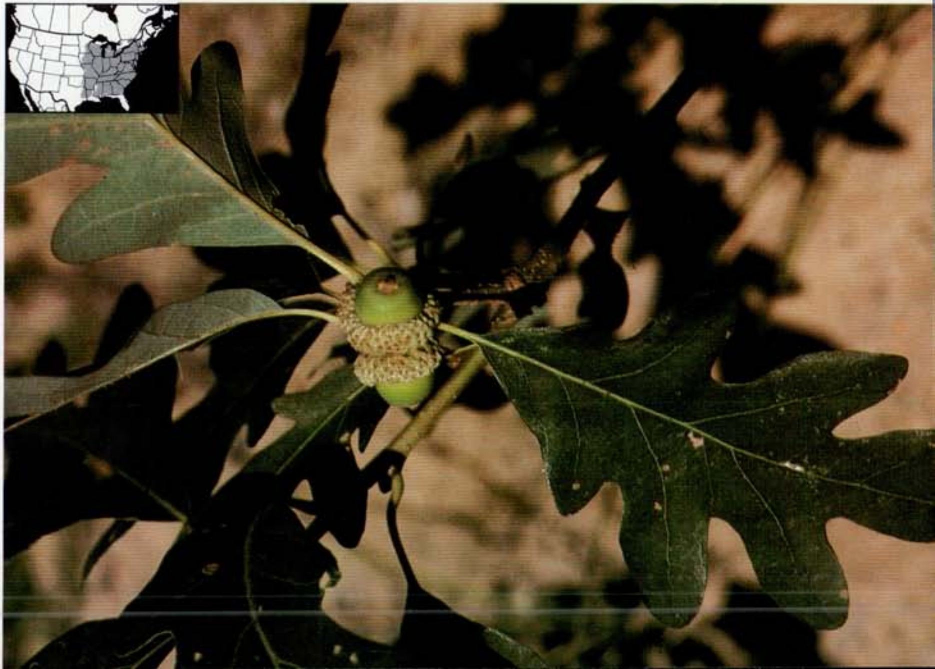

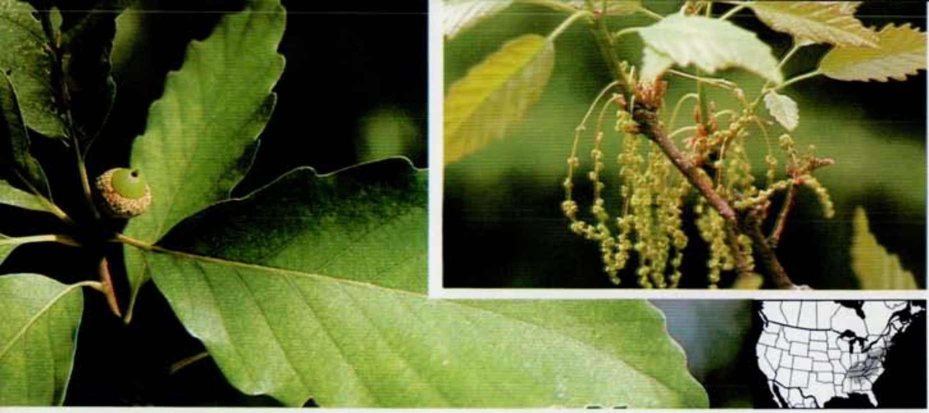

Chestnut oak: immature acorn and flowering branch (Elias).

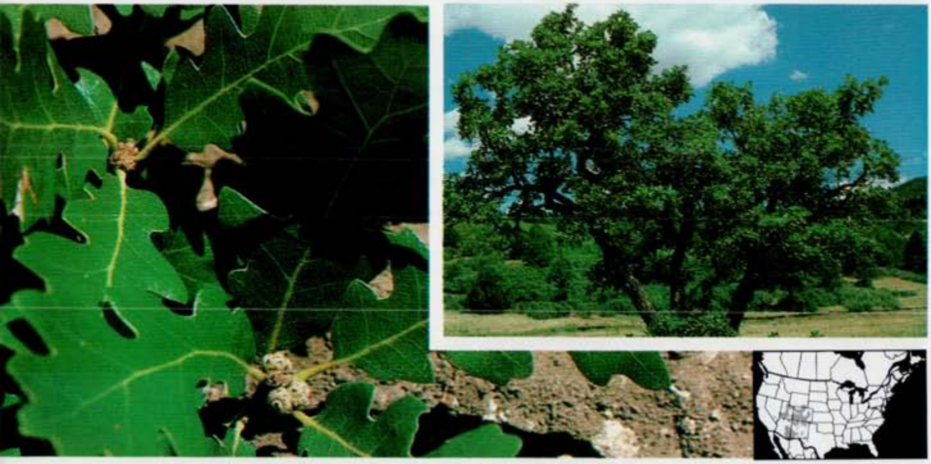

Gambel's oak: fruiting branch and tree (Dykeman).

Blue oak: mature acorns with dried leaves (Dykeman). Normal blue oak form foreground; weeping form background (Kruckeberg).

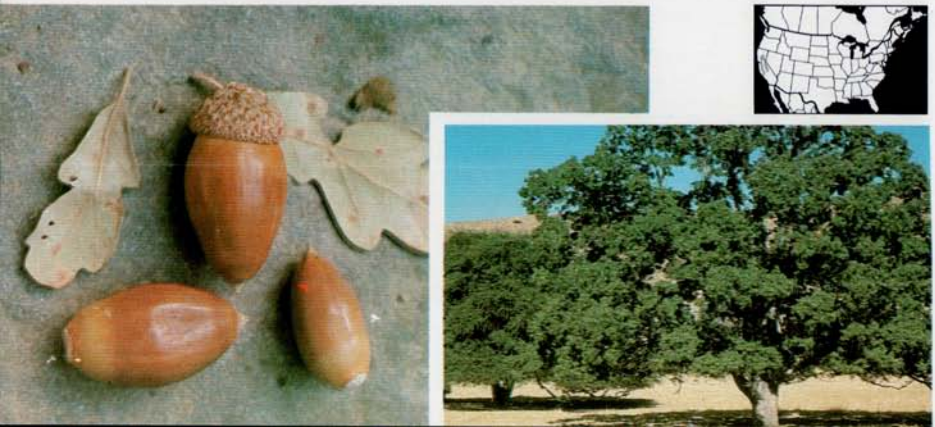

tree with broad round crown and thick, shallow to deeply furrowed, light ash-gray bark. *Leaves* alternate, deciduous, simple, *12–22 cm (4.7–8.7 in) long, 5–10 cm (2–4 in) wide, with 7–10 shallow to deeply rounded lobes along margin, bright green,* smooth. Fruits are *acorns* on current year's twigs, *1.2–2 cm (0.5–0.8 in) long,* widest near middle or base, light brown at maturity, *acorn cup bowlshaped, 8–12 mm (0.3–0.5 mm) deep, enclosing about ¼ of nut,* cup scales thick, warty; nutmeat sweet. **Harvest and preparation:** See WHITE OAK GROUP (preceding).

Chestnut oak *Quercus prinus*

Habitat: mixed deciduous woodlands, especially dry to moist well-drained slopes and ridges. **Identification:** medium-size tree with broad, open, rounded crown and thick, *deeply furrowed,* dark brown to reddish-brown *bark. Leaves* alternate, deciduous, simple, *12–25 cm* (5–10 in) *long, 3.6–7.5 cm* (1.4–3 in) *wide,* broadest above middle, *coarsely and irregularly round-toothed along margin,* greenish-yellow. Fruits are *acorns 2.5–3.8 cm* (1–1.5 in) *long,* uniformly wide to broadest near base, acorn *cup deeply bowl-shaped to top-shaped, enclosing about half of nut;* cups scales thick, warty; nutmeat sweet. **Harvest and preparation:** See WHITE OAK GROUP (preceding).

Gambel's oak *Quercus gambelii*

Habitat: dry foothills, canyons, lower mountain slopes, usually from 1,350–2,800 m (4,400–9,200 ft) elevation. **Identification:** shrub or small tree with rounded crown and thin, light gray to grayish-brown, rough, scaly bark. *Leaves* alternate, deciduous, simple, *8–16 cm* (3.2–6.3 in) *long,* 4.5–7.6 cm (1.8–3 in) wide, broadest above middle to uniformly wide, *with 5–9 moderately deep to deep lobes along margin,* leathery, *yellowish-green.* Fruits are *acorns* on current year's twigs, *2–2.5 cm* (0.8–1 in) *long,* nearly globe-shaped, *acorn cup* shallow to deeply bowl-shaped, *enclosing ¼ to ⅓ of nut,* scales thick; nutmeat sweet. **Harvest and preparation:** See WHITE OAK GROUP (preceding).

Blue oak *Quercus douglasii*

Habitat: interior valleys, rolling hills, lower mountain slopes to 1,350 m (4,400 ft) elevation. **Identification:** small to medium-size tree with rounded crown and thick, checkered, light gray bark. *Leaves* alternate, deciduous, simple, 3.8–10 cm (1.5–4 in) long, 1.9–5 cm (0.7–2 in) wide, uniformly wide to broadest above middle, *entire to shallowly and irregularly lobed along margin, bluish-green.* Fruits are acorns on current year's branches, 1.6–3.1 cm (0.6–1.2 in) long, broadest near base; *acorn cup saucer-shaped, enclosing only base of nut,* cup scales small, warty; nutmeat somewhat sweet. **Harvest and preparation:** See WHITE OAK GROUP (preceding).

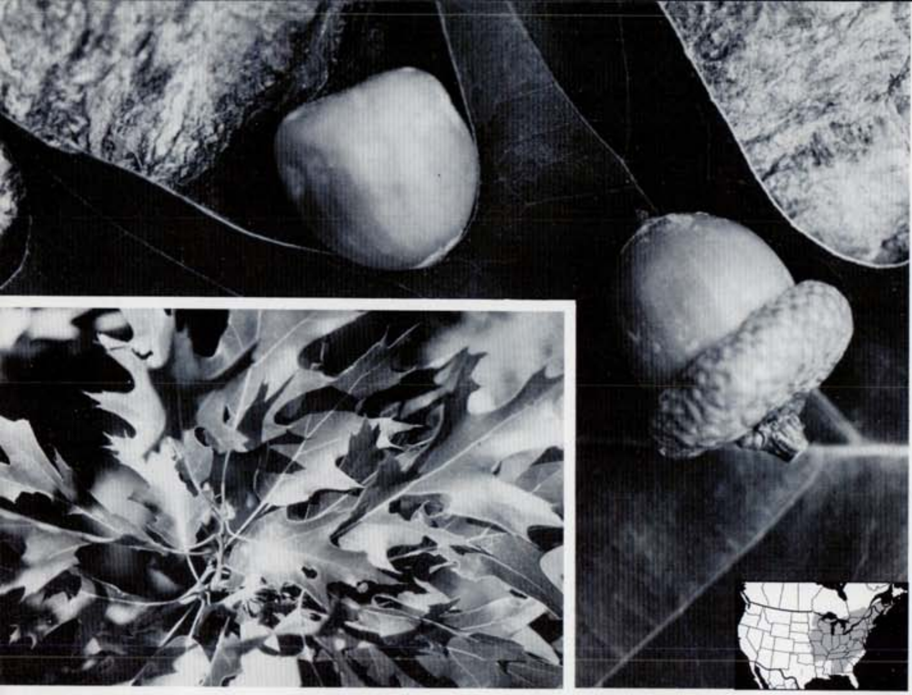

Northern red oak: acorn with cap and without. Summer branch. (Elias photos)

American beech: fruiting branch (Elias).

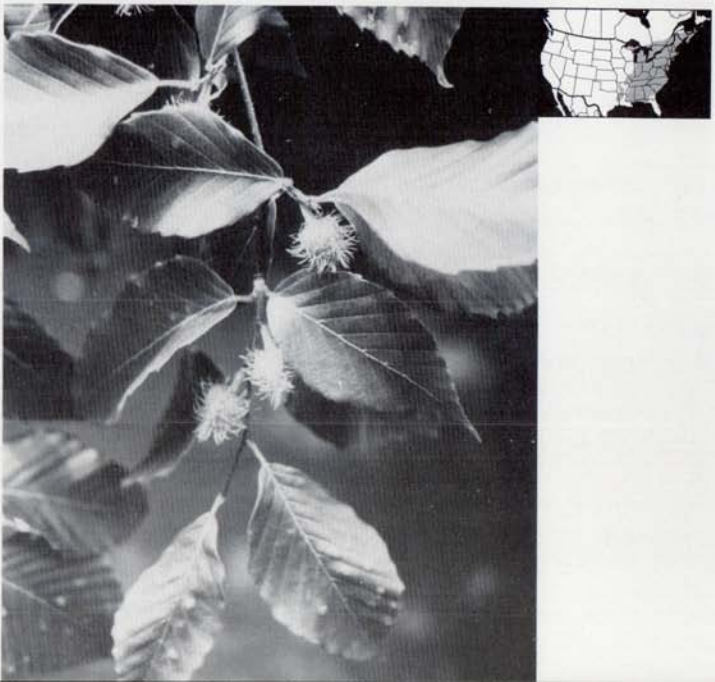

Red/Black Oak Group *Quercus* subgenus *Erythrobalanus*

The red oak species and black oak species and the numerous relatives in this subgenus occur only in the Americas. This group is characterized by leaves entire, toothed, or lobed and always with bristlelike tips extending beyond the margin of the leaf; acorns maturing at end of second year on the previous year's twigs, and the inner surface of the acorn shell hairy. Acorn nutmeats are nearly always bitter. Because of this, only 1 species is discussed here as edible, although most species can be utilized after the bitter properties have been removed.

Northern red oak *Quercus rubra*

Habitat: valleys, ravines, lower and mid slopes of hills and mountains. **Identification:** medium-size tree to 20 m (66 ft), rarely taller, with open, irregular crown and shallowly furrowed, checkered bark. ***Leaves*** alternate, deciduous, simple, ***10–22 cm*** (4–8.7 in) ***long,*** 6–12 cm (2.4–5 in) wide, widest above middle, ***with 7–9 moderately deep lobes,*** dull green and smooth above, paler beneath and with occasional tufts of hairs in junction of principal veins. Fruits are ***acorns on previous year's twigs, 1.2–2.5 cm (0.5–1 in) long, acorn cup*** saucer-shaped, ***enclosing about 1/4 of nut,*** cup scales thin, overlapping; nutmeat bitter. **Harvest and preparation:** Gather acorns in autumn as they turn brown and fall. Store in cool dry place or shell for immediate use. Place whole, chopped, or coarsely ground nutmeats in cloth (clean T-shirt will do) and tie with string. Place in boiling water until water turns brown, drain, add more boiling water. Repeat many times until water remains clear. In the field, place bag filled with nutmeats in clear running stream until nutmeats are no longer bitter, from 1 to several days. Spread leached acorns in pan and dry in sun or warm oven. Use whole nutmeats or prepare and use as grits or meal as described under WHITE OAK GROUP. For acorn muffins, cream ¼ cup butter with ½ cup sugar or molasses. Add alternately and blend 2 eggs, 1 cup milk, and dry mix of 1 cup acorn meal or grits, 2 cups flour, 4 tsp baking powder, ¾ tsp salt. Beat thoroughly. Bake in greased muffin pan at 200°C (390°F) for about 20 min. For pancake batter, repeat muffin recipe but add 1 more egg plus milk. For acorn coffee, roast acorn meal at 175°C (350°F) until dark and crisp, about 30 min. Use ½ cup roasted meal to 4 cups water. Combine, boil 15 min, strain, and serve.

American beech *Fagus grandifolia*

Habitat: river valleys, lower mountain slopes, mixed deciduous forests, usually in rich, moist soils. **Identification:** medium-size to tall tree with narrow to spreading, rounded crown and ***thin, smooth, light gray to bluish-gray bark.*** Leaves alternate, deciduous, simple, 6–14 cm (2.4–5.5 in) long, 2.5–7.2 cm (1–3 in) wide, broadest just below middle, sharply toothed along margin, leathery texture at maturity. Male flowers tiny, in globe-shaped, hanging heads; female flowers tiny, usually paired at or near tips of branches. ***Fruits consist of 2 triangular nuts enclosed in 2 spiny bracts, bracts 1.6–2.2 cm (0.6–1.9 in) long,***

opening in late summer to release oily nuts. **Harvest and preparation:** Gather nuts as they drop from trees following hard frost. Separate burrs from nuts by shaking and winnowing or singly by hand. Dry in open, warm area. Crack brown shells by heating in oven; remove shells by beating or rubbing in hands and winnowing. Nutmeats are edible raw. Grind and air dry nutmeats for flour; crush and boil in water; skim off excellent oil for cooking. Roast nutmeats at 160°C (320°F) 30–40 min and grind for coffee substitute. For beechnut pie, substitute 1½ cups beechnuts for pecans in PECAN pie recipe. Thoroughly whip 3 eggs. Slowly beat into them ½ cup melted butter or margarine, 1 cup white corn syrup, and ¾ cup sugar. Turn into unbaked 9-in pie shell and bake at 150°C (300°F) 35 min. Remove pie long enough to cover quickly with nuts. Return to oven, turn up heat to 175°C (350°F), and bake another 15 min. **Edible related species:** none. **Poisonous look-alikes:** none.

Allegheny chinkapin *Castanea pumila*

Also edible summer

Habitat: widespread; dry woodlands and mountain slopes or along coast in dry sandy soils. **Identification:** shrub or small tree to 8 m (26 ft) with a rounded crown and light reddish-brown bark. Twigs densely hairy when young. ***Leaves*** alternate, simple, deciduous, ***6.8–16 cm*** (2.7–6.3 in) ***long, 3.8–5 cm*** (1.5–2 in) wide, ***broadest near middle, with numerous large teeth along the margin,*** whitish and hairy beneath. Male flowers numerous on the upper ⅔ of semi-erect spikes; female flowers fewer on the lower ⅓ of flowering spike. ***Fruits are spiny burrs 3–4 cm (1.4 in) in diameter, enclosing 1, rarely 2, nuts;*** nuts broadest near the base and pointed at tip, nutmeat sweet. **Harvest and preparation:** Gather nuts as they ripen in late summer or early autumn. Separate nuts from burs and store whole, or shell, blanch, and dry nutmeats. To shell and blanch the nuts, cover with boiling water and boil until shell and skin can be easily removed. Then place nutmeats in shady place about 1 week until dry and shriveled. Store shelled and dried or unshelled nuts in porous bag in dry place. Before using nuts, soak in water for 30 min. Use chestnuts in stuffings, soups, desserts, as a vegetable, and as a coffee substitute. Nuts can be eaten directly by slitting shells and roasting over coals or in hot oven. For soup, combine 1½ cups dried ground chestnuts, 2 sliced carrots, 1 cup sliced acorn or butternut squash, 2 tbsp chopped fresh parsley, ½ tsp oregano or native plant seasonings, and 5 cups water. Cook until tender, about 40–50 min. For coffee, chop freshly shelled chestnuts, spread on foil, and roast at 190°C (375°F) until dark and dry. Grind to a powder as needed. Boil gently 28 grams (1 oz) powder per cup of water for 15 min. Strain and serve. **Related edible species:** American chestnut *(C. dentata)* produces large sweet nuts but the persistent chestnut blight has literally eliminated it from its native range. **Poisonous look-alikes:** Do not confuse poisonous horsechestnuts with true chestnuts. Horsechestnuts (*Aesculus* species) have compound (palmate) leaves and nuts with a large circular scar, and belong to the family Hippocastanaceae. Allegheny chinkapin and true chestnuts have simple leaves and belong to the beech family (Fagaceae).

Allegheny chinkapin: fruiting branch (Elias). Flowering branch (NYBG).

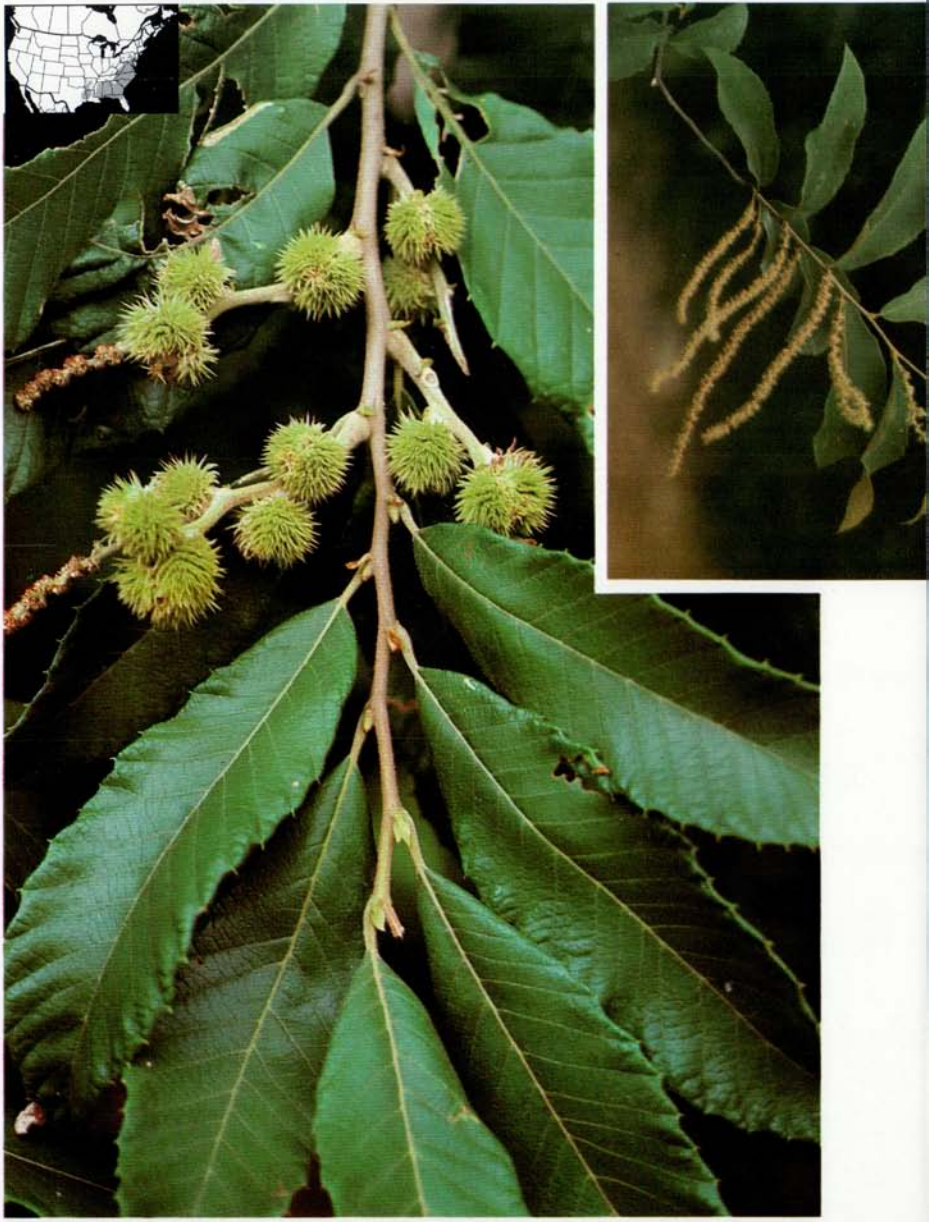

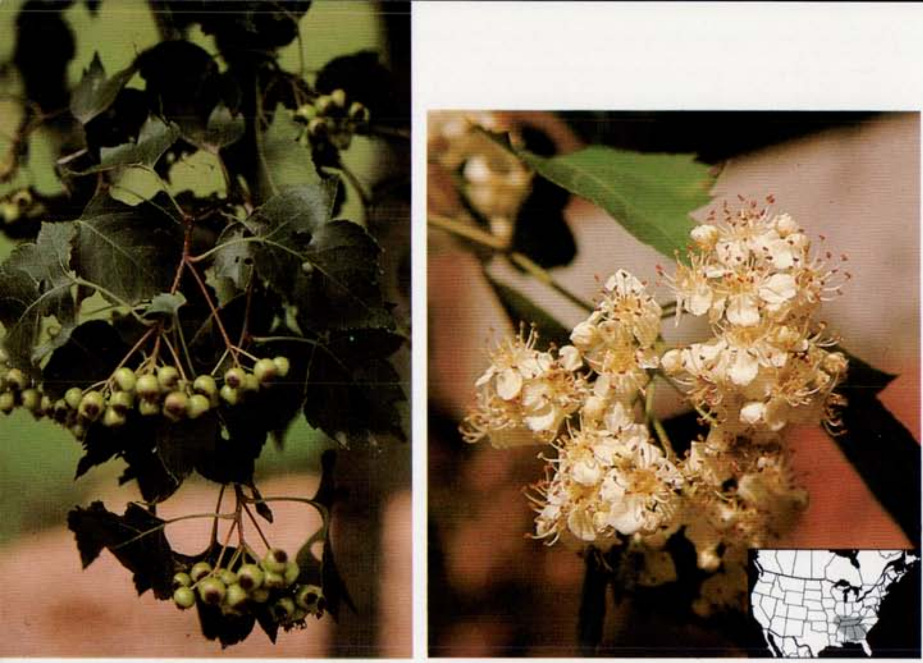

Washington hawthorn: unripe fruits (Elias). Flower clusters (Feldman).

Downy hawthorn: fruiting branch (Speas).

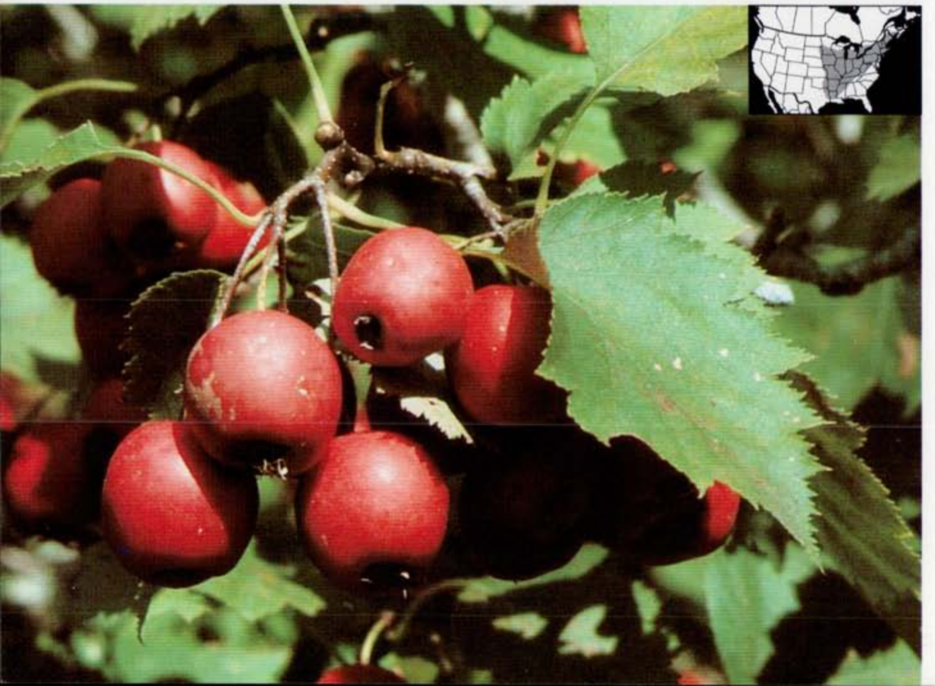

HAWTHORNS *Crataegus*

This large group of trees and shrubs contains highly variable species that are often difficult to distinguish. Nearly all of the 26 distinguishable North American species of hawthorns have edible fruits. They are mostly small spreading trees with dense branches often armed with long sharp spines. The toothed leaves may be entire, shallowly or deeply lobed. Bisexual flowers are generally white, with 5 petals and the rounded to pear-shaped fruits yellow, green, red, orange, or nearly black at maturity. Four common species are discussed on upcoming pages. **Harvest:** Most fruit ripens in autumn and may persist for several months, but some southern species, including May hawthorn *(C. aestivalis)*, have fruit ripening in late spring. The fruits vary greatly in flavor from sweet to bitter. Sample the fruits from each plant and harvest the best, but be careful of the vicious thorns. **Preparation:** Eat sweetest fruits fresh. For jelly, crush 1.4 kg (3 lb) fruit or 1 kg (2 lb) if a juicy type, cover with water, and cook until soft. Add more water if necessary. Strain juice through jelly bag. Bring 4 cups juice to boil. Unless fruits are unripe, add 1 pkg pectin, stir, add 6–7 cups sugar, stir, and bring to rolling boil. If no pectin is added, boil to 115°C (239°F). Remove from heat, skim, pour into sterilized jelly glasses, and seal. If fruits do not seem acid enough, add juice of 1 or 2 lemons. For tea, steep 2–3 tbsp crushed fruits and sprig of mint in cup of boiling water for 5–10 min. Fruits can be dried and stored for winter use. Substitute hawthorn fruits in recipes calling for rose hips. The fruits were used by Indians to some extent in pemmican. **Related edible species:** many *Crataegus* species. **Poisonous look-alikes:** none.

Washington hawthorn *Crataegus phaenopyrum*

Habitat: stream banks, old fields, openings in woodlands. **Identification:** small tree to 12 m (40 ft), with rounded, spreading crown; branches dark reddish-brown, zigzagging, ***armed with slender sharp-pointed spines 3–5 cm*** (1.2–2 in) ***long. Leaves*** alternate, simple, deciduous, 2–6 cm (0.8–2.4 in) long, 2–5 cm (0.8–2 in) wide, broadest near base, ***with 1–4 pairs of shallow lobes,*** pointed at tip, broadly rounded at base, sharply toothed along margin, dark green, shiny, smooth. ***Flowers white, attractive,*** produced in branched, spreading many-flowered clusters. ***Fruits*** are ***dry, berrylike, globe-shaped,*** 5–8 mm (0.3 in) in diameter, ***bright red.*** **Harvest and preparation:** See HAWTHORNS (preceding).

Downy hawthorn *Crataegus mollis* (syn.: *C. arnoldiana, C. canadensis, C. submollis*)

Habitat: along streams and rivers, bottomlands, lowland fields, clearings. **Identification:** small tree to 12 m (40 ft) high, with dense, wide-spreading crown; ***branches*** covered with dense white hairs when young, ***almost thornless,*** occasionally with sharp, slender dark reddish-brown spines to 5 cm (2 in) long. ***Leaves*** alternate, simple, deciduous, 3.5–10 cm (1.4–4 in) long, 3–8 cm (1.2–3.2 in) wide, usually broadest near base, sharp-pointed along margin, ***dark yellowish-green, hairy on lower surface.*** Flowers white, attractive, produced in branched, spreading clusters in spring. Fruits stalked, dry, berrylike, globe-shaped, 9–16 mm (0.4–0.6 in) in diameter, red. **Harvest and preparation:** See HAWTHORNS (preceding).

Fleshy hawthorn *Crataegus succulenta*

Habitat: along coast, hillsides, abandoned fields, usually in rocky or gravelly soils. **Identification:** shrub or small tree to 8 m (26 ft) high, with irregular, usually rounded, crown; branches stout, slightly zigzagging, gray, ***armed with frequent, stiff, slightly curving, dark reddish-brown spines*** 3–4.5 cm (1.2–1.8 in) long. ***Leaves*** alternate, simple, ***3–7 cm*** (1.2–2.8 in) ***long, 2–5.2 cm*** (0.8–2 in) ***wide,*** broadest above or below middle, ***shallowly lobed near tip, pointed*** at tip, tapering at base, ***sharply pointed*** and ***double-toothed along margin,*** dark green, shiny. Flowers white, attractive, produced in branched, spreading clusters in spring. ***Fruits*** stalked, dry, berrylike, ***globe-shaped, 0.8–1.6 cm*** (0.3–0.6 in) ***in diameter, bright red.*** **Harvest and preparation:** See HAWTHORNS (preceding).

Cockspur hawthorn *Crataegus crus-galli*

(synonyms: *C. acutifolia, C. canbyi, C. regalis, C. pyracanthoides*)

Habitat: hillsides, lower mountain slopes, river valleys, abandoned fields. **Identification:** small tree to 8 m (26 ft) high, with broad spreading, ***nearly flat-topped crown;*** branches stiff, light brown to gray, armed with stout, slender, straight to slightly curved, sharp-pointed spines. ***Leaves*** alternate, simple, deciduous, ***2–6 cm*** (0.8–2.4 in) ***long, 1–3.2 cm*** (0.4–1.3 in) ***wide, usually broadest above middle*** or near middle, ***unlobed,*** rounded to pointed at tip, gradually tapering at base, sharply toothed along upper ⅔ of margin, ***glossy, dark green. Flowers white, pink, or red,*** attractive, produced in branched, spreading clusters in spring. ***Fruits*** stalked, ***dry, berrylike,*** globe-shaped, ***0.7–1 cm*** (0.4 in) ***in diameter, dull red to green.*** **Harvest and preparation:** See HAWTHORNS (preceding).

Common persimmon *Diospyros virginiana*

Also edible winter

Habitat: rich bottomlands, especially Mississippi River Valley, margins of woodlands and fields, rocky hillsides, along fencerows and highways. **Identification:** large shrub or small to medium-size tree with thick dark gray to grayish-brown bark that forms small square blocks. ***Leaves*** alternate, deciduous, ***7–13 cm*** (2.8–5.1 in) ***long, 3.5–8 cm*** (1.4–3.2 in) ***wide,*** broadest near base or middle, entire, dark green and shiny. ***Male and female flowers on separate trees,*** produced at bases of leaves along younger branches, ***each flower tubular or urn-shaped,*** greenish-yellow to cream-white. ***Fruits are globe-shaped, 2–6 cm*** (0.8–2.4 in) ***in diameter, orange to orange-purple, fleshy,*** containing a few flattened seeds 1.2–2 cm (0.5–0.8 in) long. **Harvest:** Fruits mature in early autumn and persist on trees into early winter. Best collected after first frost when soft and skin becomes slightly wrinkled. Prior to that fruits will be very sour. To obtain many fruits, shake branches. **Preparation:** Delicious as fresh fruit. The pulp, strained to remove seeds and skin, can be used to make bread, pie, pudding, jam, even frozen for later use. See jam recipe early in book. A tea can be made from clean dried leaves. **Related edible species:** Texas persimmon *(D. texana)*. **Poisonous look-alikes:** none.

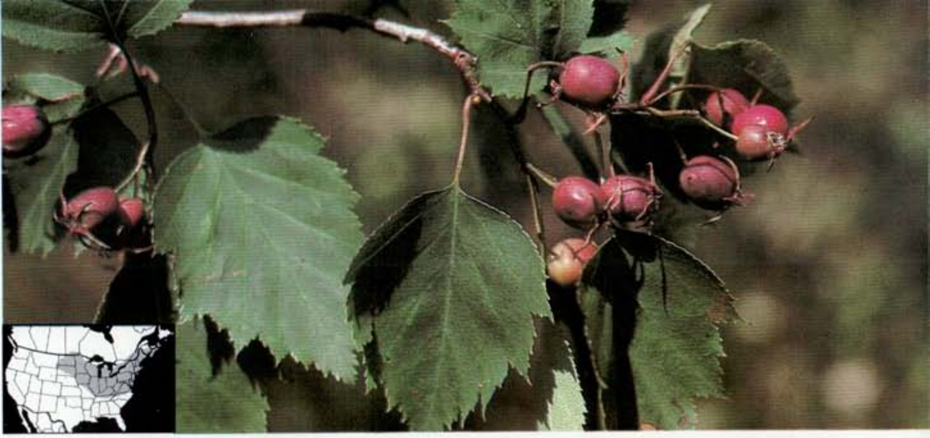

Fleshy hawthorn: fruiting branch (Elias).

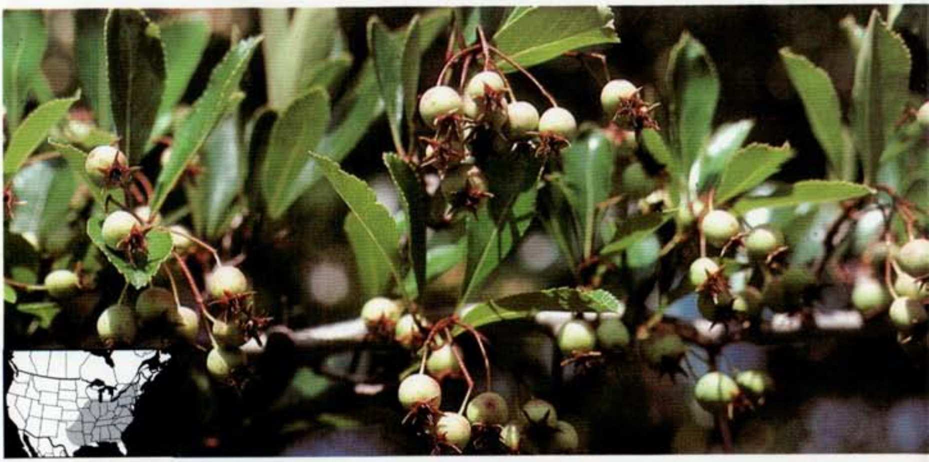

Cockspur hawthorn: fruiting branch (Elias).

Common persimmon: fruiting and flowering branches (Speas).

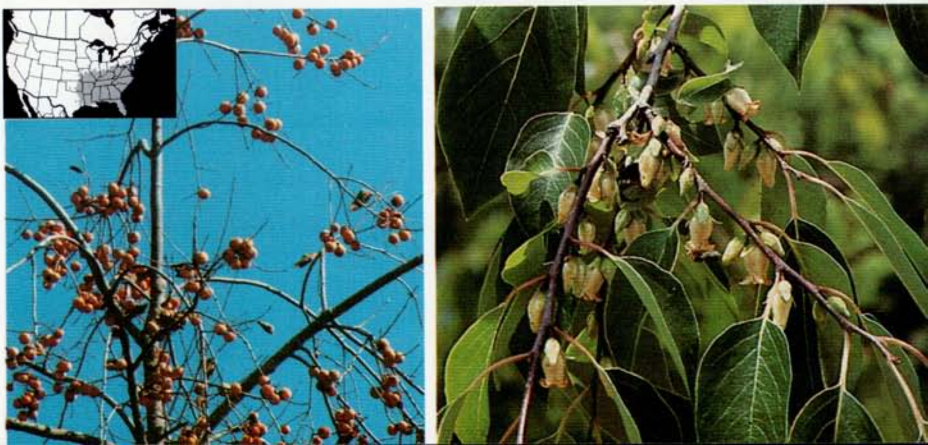

American mountain ash *Sorbus americana*

Also edible winter

Habitat: rocky slopes, seepage areas along ridges, at higher elevations. **Identification:** shrub or small tree to 9 m (30 ft) with open, rounded crown and thin, light gray smooth bark. ***Leaves alternate,*** deciduous, ***featherlike (pinnate) compound, 12–25 cm (5–10 in) long, with 9–17 leaflets, each leaflet*** 3–8 cm (1.2–3.2 in) long, lance-shaped to uniformly wide, ***finely toothed along margin,*** dull green. ***Flowers in dense, many-flowered, flat-topped clusters*** to 15 cm (6 in) across, each flower tiny, with 5 white petals. ***Fruits in large, dense clusters, persisting into winter, each fruit*** 4–8 mm (0.2–0.3 in) in diameter, ***bright orange-red, shiny,*** slightly fleshy, containing 1 or 2 seeds. **Harvest and preparation:** Fruits become palatable in winter after 1 or more freezings and are easily stripped from twigs. Edible raw but better cooked. For sauce, stew like CRANBERRIES; bring to boil 2 lb fruits and 2 cups sugar in 1 cup water, or berries plus 1 cup maple sugar (SUGAR MAPLE) and 1 cup cider. Reduce heat and simmer until berries mash easily and a drop of the sauce gels on cold plate. Pour into mold or storage jars. For pie, to sauce (above) add rind of ½ lemon and ⅛ tsp cinnamon. Line pie plate with crust, put in sauce, cover with crisscross strips of crust, leaving spaces between. Bake at 230°C (450°F) 20 min. Try basic jelly recipe with vinegar replacing about ¼ of water for sauce to serve with game. Also use regular jelly recipe. Berries keep well but must be dry for prolonged storage. **Related edible species:** European mountain ash *(S. aucuparia)*, Greene mountain ash *(S. scopulina)*, Sitka mountain ash *(S. sitchensis)*. **Poisonous look-alikes:** none.

Pecan *Carya illinoensis*

Habitat: bottomlands, rich moist soils; also extensively cultivated. **Identification:** tall tree with open round crown and thick, irregularly furrowed, dark reddish-brown bark. ***Leaves*** alternate, deciduous, ***featherlike (pinnate) compound,*** 32–52 cm (13–21 in) long with ***9–17 leaflets; leaflets*** 8–20 cm (3.2–8 in) long, 2.5–7.5 cm (1–3 in) wide, ***lance-shaped,*** coarsely toothed along margins. Male flowers in slender hanging catkins; female flowers short, inconspicuous, at tips of branches; flowers occur in early spring as leaves unfold. ***Fruits*** in clusters of 3–6, each large, uniformly wide, 3.5–5 cm (1.4–2 in) long, ***husk splitting into 4 thin sections to expose nut.*** Nuts cylinder-shaped to broadest near base, pointed at tip, light brown to reddish-brown, shell thin, meat oily, sweet. **Harvest:** Gather nuts in autumn as leaves turn and begin to fall. **Preparation:** Excellent eaten directly from shell, or use in any recipes calling for nuts. For pecan pie filling, beat 3 eggs, add ½ cup sugar, 1 cup dark corn syrup or molasses, ¼ tsp salt, 1 tsp vanilla, ⅓ cup melted butter. Spread 1 cup pecans over bottom of 9-in pie shell. Pour above ingredients over pecans and bake 10 min in 230°C (450°F) oven, then reduce heat to 175°C (350°F) and bake 35 min longer. **Related edible species:** BIG SHELLBARK HICKORY, SHAGBARK HICKORY, and MOCKERNUT HICKORY (following). **Poisonous look-alikes:** none.

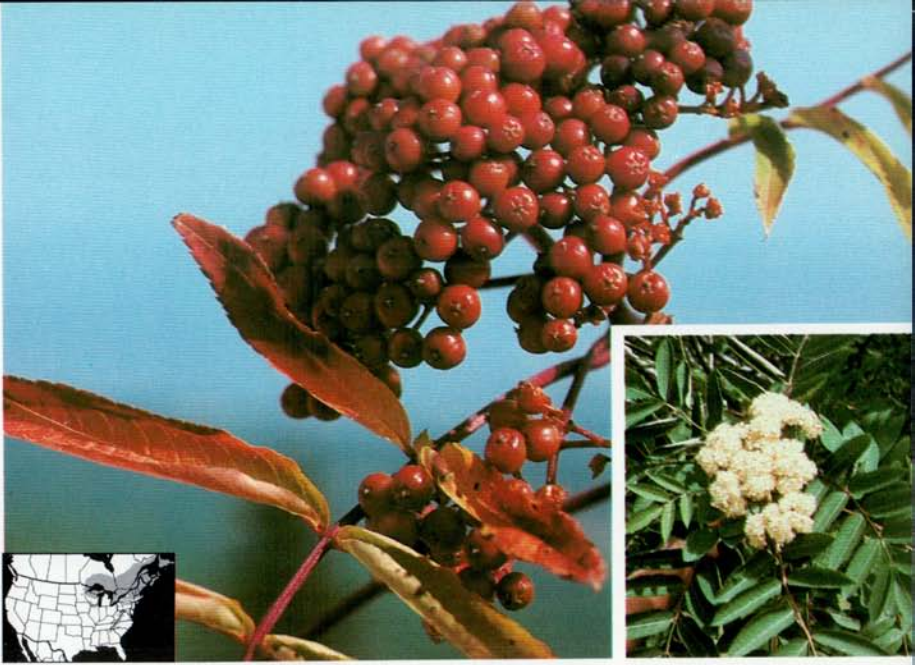

American mountain ash: fruiting and flowering branches (Elias).

Pecan: summer branches and nuts with splitting husks (Elias/Dykeman).

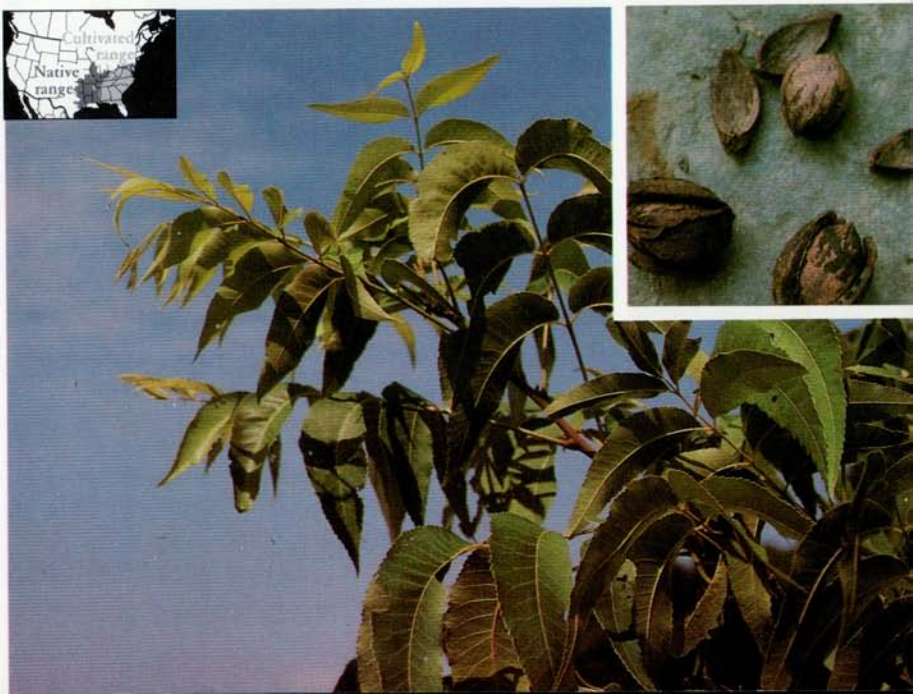
Cultivated range
Native range

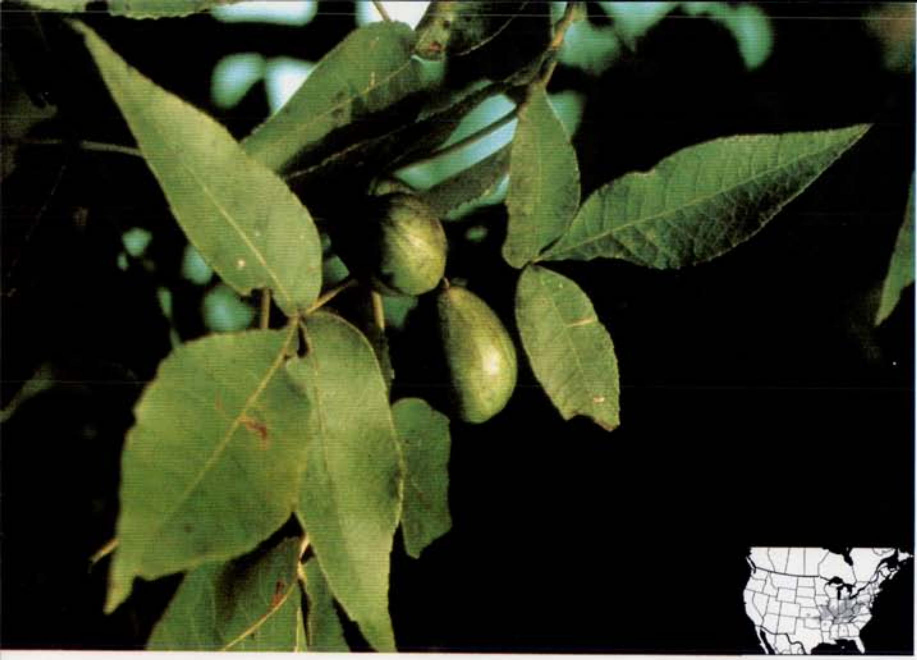

Big shellbark hickory: immature fruits (Clawson).

Shagbark hickory: flowering and fruiting branch (Elias). Bark (Dykeman).

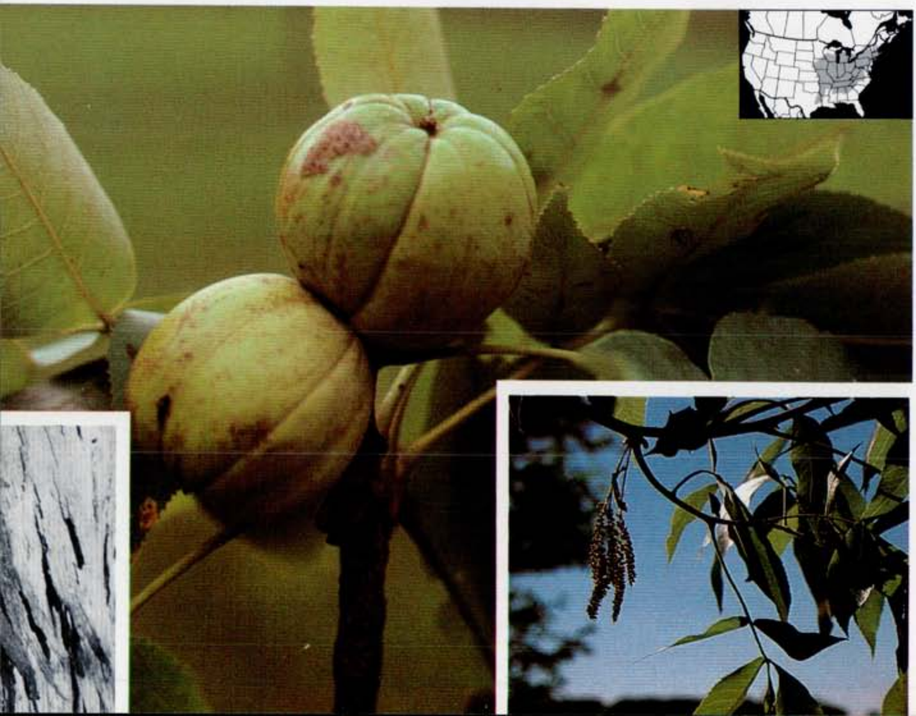

Big shellbark hickory *Carya laciniosa*

Habitat: deep rich soils of floodplains and bottomlands, especially of Ohio and Mississippi River valleys. **Identification:** large tree with rounded crown and ***light gray, somewhat shaggy bark. Leaves*** alternate, deciduous, featherlike (pinnate) compound, 25–60 cm (10–24 in) long, ***with 5–9 leaflets, usually** 7;* leaflets 6–25 cm (2.4–10 in) long, 3.7–12.5 cm (1.5–5 in) wide, lance-shaped to broadest near base, sharp-pointed at tip, with numerous tiny teeth along margin. Male flowers in slender hanging catkins; female flowers short, inconspicuous, at ends of branches; both produced in early spring as leaves unfold. Fruits solitary or in pairs, globe- to egg-shaped, 3.5–7 cm (1.4–2.8 in) long, thick husk splitting lengthwise into 4 parts to expose nut. ***Nut egg-shaped,*** usually ridged, ***shell thick, hard, nutmeat sweet.*** **Harvest:** Gather nuts in autumn as leaves turn and fall; PECAN (preceding) and SHAGBARK (next) nuts are superior because they have thinner shells. **Preparation:** Remove nutmeats from shells; see SHAGBARK HICKORY. Use in any nut recipes. For nut-corn pudding, combine thoroughly 1½ cups cooked corn, ½ cup shelled, dried hickory nuts, 2 tbsp nut butter or oil, 1 cup boiling water, 2 beaten eggs, 2 tbsp honey, 2 tbsp fine cornmeal, ¼ cup seeds, raisins, or edible blossoms. Pour into well-greased casserole. Sprinkle top with more hickory nutmeats. Bake in preheated 175°C (350°F) oven for 1 hr. Serve hot. See other hickory species for additional uses. Trees can be tapped in late winter for sap. Prepare syrup as with SUGAR MAPLE. **Related edible species:** PECAN, SHAGBARK HICKORY, MOCKERNUT HICKORY. **Poisonous look-alikes:** none.

Shagbark hickory *Carya ovata* (synonym: *C. carolinae-septentrionalis*)

Habitat: dry upland slopes, well-drained soils of lowlands and valleys. **Identification:** medium-size to tall tree with open rounded crown and ***light to dark gray, shaggy bark.*** Leaves alternate, deciduous, featherlike (pinnate) compound, 20–36 cm (8–14.2 in) long, ***usually with** 5,* sometimes 7, ***leaflets;*** leaflets broadest near middle or tip, 8–18 cm (3–7 in) long, 1.5–6 cm (0.6–2.4 in) wide, ***with fine, sharp-pointed teeth along margin.*** Male flowers in slender, hairy catkins 10–13 cm (4–5.1 in) long; female flowers short, inconspicuous, at tips of branches; flowers occur in spring as leaves unfold. Fruits produced singly or in 2s, egg- to globe-shaped, 3–5 cm (1.2–2 in) long, husk thick, splitting lengthwise into 4 equal parts to expose the egg-shaped, ***4-sided nuts.*** Nuts with thin shell and sweet nutmeat. **Harvest and preparation:** Gather nuts in early autumn as they fall with leaves. Crack nuts with hammer and remove meats with nutpick. For efficient extraction, crack nuts enough to identify and eliminate wormy ones. Then smash enough to loosen meats. Place pounded nutmeats in pot, cover with water, and bring to boil. Most of meats will rise and can be skimmed off if desired. Indians boiled mix slowly and skimmed oil from surface to use as butter; then meats were skimmed and mixed with potatoes or meal, or dried into cakes. Boiled mix separated from shells is nutritious soup Indians called *powcohicora*. For hickory pie, use PECAN pie recipe, but increase amount of nuts to 1½ cups. See other hickory recipes. **Related edible species:** PECAN, BIG SHELLBARK HICKORY (preceding), MOCKERNUT HICKORY (next). **Poisonous look-alikes:** none.

Mockernut hickory *Carya tomentosa* (synonym: *C. alba*)

Habitat: ridges, hills, slopes, river valleys. **Identification:** large tree with rounded crown and dark gray, shallowly furrowed bark. ***Leaves*** alternate, deciduous, featherlike (pinnate) compound, 14–32 cm (5.5–12.6 in) long, ***with 5 or 7 leaflets; leaflets 8–22 cm (3–9 in) long, 6–12.5 cm (2.4–5 in) wide, narrow, broadest above middle,*** pointed at tip, toothed along margin. Male flowers in slender, stalked, 3-clustered catkins; female flowers small, 2–5 at tips of branches. Fruits solitary or few-clustered, globe- to egg-shaped, 4–8 cm (1.6–3.2 in) long, almost as wide, husk splitting lengthwise to expose nutmeat. ***Nut nearly rounded, often 4-sided, shell thick, hard, nutmeat sweet.*** **Harvest:** Gather nuts in autumn as leaves turn; PECAN and SHAGBARK HICKORY (preceding) are superior because of thin shells. **Preparation:** Remove nutmeats from shell; see SHAGBARK HICKORY instructions. Use any nut recipe including those for other hickories. For salad dressing, combine ½ cup ground hickory nuts, 1¼ cups vegetable oil, 3 tbsp lemon juice or STAGHORN SUMAC extract, 2 tbsp vinegar, ¼ tsp pepper, 1 chopped clove garlic. Shake well and use on salads. Tap trees in late winter for sap and prepare syrup as with SUGAR MAPLE. **Related edible species:** PECAN, SHAGBARK HICKORY, BIG SHELLBARK HICKORY. **Poisonous look-alikes:** none.

Black walnut *Juglans nigra*

Habitat: bottomlands, floodplains, rich low mixed deciduous forest, especially in well-drained soils. **Identification:** large tree with open rounded crown and thick, deeply furrowed, light to grayish-brown to almost black bark. ***Leaves*** alternate, deciduous, ***featherlike*** (pinnate) ***compound,*** 20–60 cm (8–24 in) long, ***with 15–23 leaflets;*** leaflets 4–9 cm (1.6–3.5 in) long, 2–3.5 cm (0.7–1.4 in) wide, broadest near base to broadly lance-shaped, with numerous fine, sharp-pointed teeth along margin. Male and female flowers separate, appearing in spring. ***Fruits large, rounded, 4–6 cm*** (1.6–2.4 in) ***in diameter, with thick husk enclosing globe-shaped nut,*** nut 3–4 cm (1.2–1.6 in) in diameter, ***shell irregularly and deeply furrowed,*** thick, nutmeat 4-lobed at base, sweet. **Harvest:** Gather nuts in autumn as they fall from trees. Remove thick brown-staining husks immediately by partially crushing, then rubbing with gloved hands or scrubbing with stiff brush to remove all remaining husk material. (Indians first suspended nuts in mesh bag in running water for several days.) Allow hulled nuts to dry thoroughly before using. **Preparation:** Crack shell with hammer, rock, or vise, applying blow or pressure at right angles to seam. Use nutpick. Indians crushed shells well to obtain oil and meats. See SHAGBARK HICKORY. After boiling crushed nuts for 30 min or more, allow shells and nutmeats to settle; then skim off oil. Boil again and use sieve to skim nutmeats as they rise above shells. Remove coarse shell pieces, dry and grind nutmeats. Use oil like that of hickories. Use nutmeats in baking or grind with honey or herbs to make nut butter. Use sap under SUGAR MAPLE. For other uses, see BUTTERNUT, hickory species, and book's Introduction. **Related edible species:** BUTTERNUT, CALIFORNIA WALNUT (next), Texas black walnut *(J. microcarpa)*, Arizona walnut *(J. major)*, Hinds walnut *(J. hindsii)*. **Poisonous look-alikes:** none.

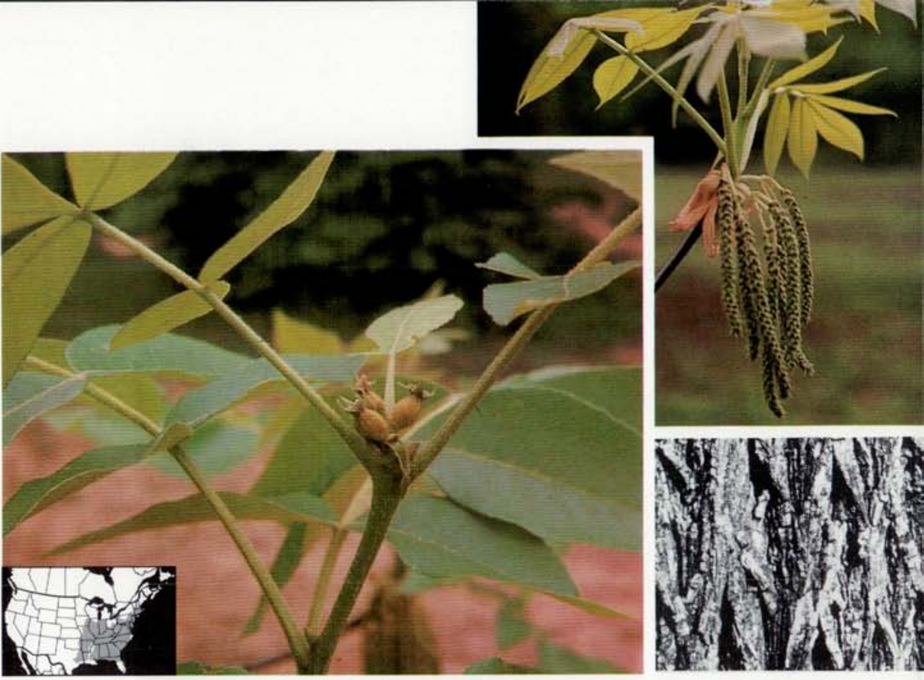

Mockernut hickory: immature fruits, male flowers, bark (Eye).

Black walnut: nearly mature fruits (Elias).

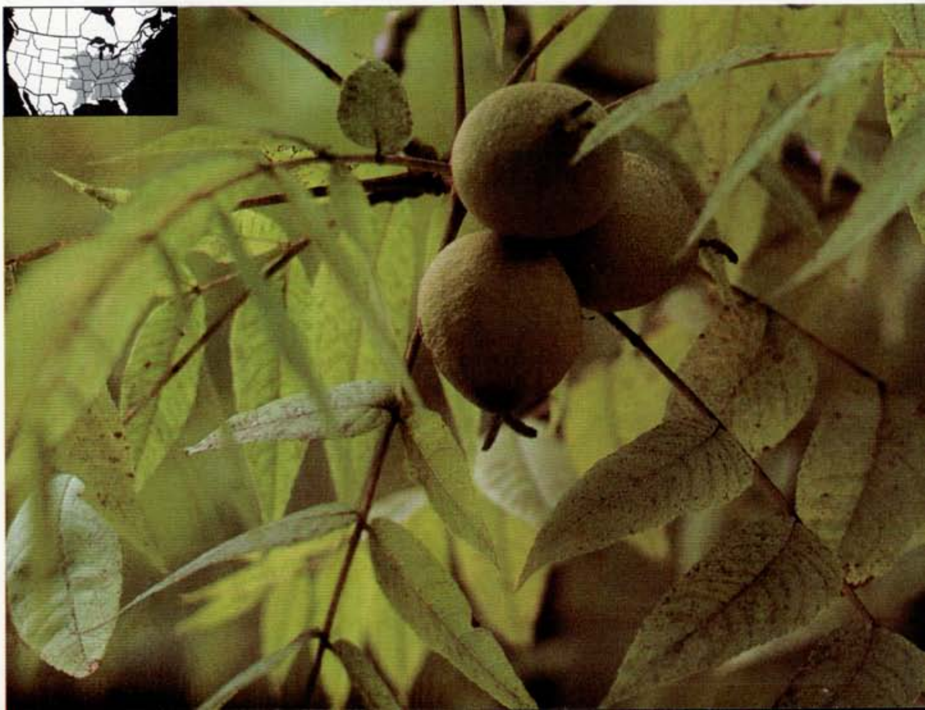

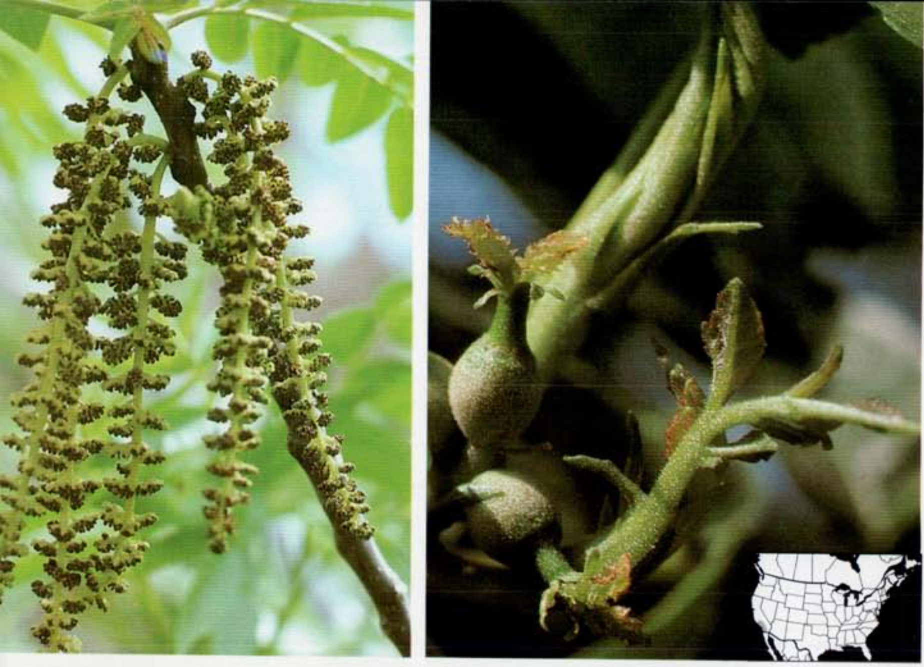

California walnut: male flowers and immature fruits (Shevock).

Butternut: nearly mature fruits (Elias).

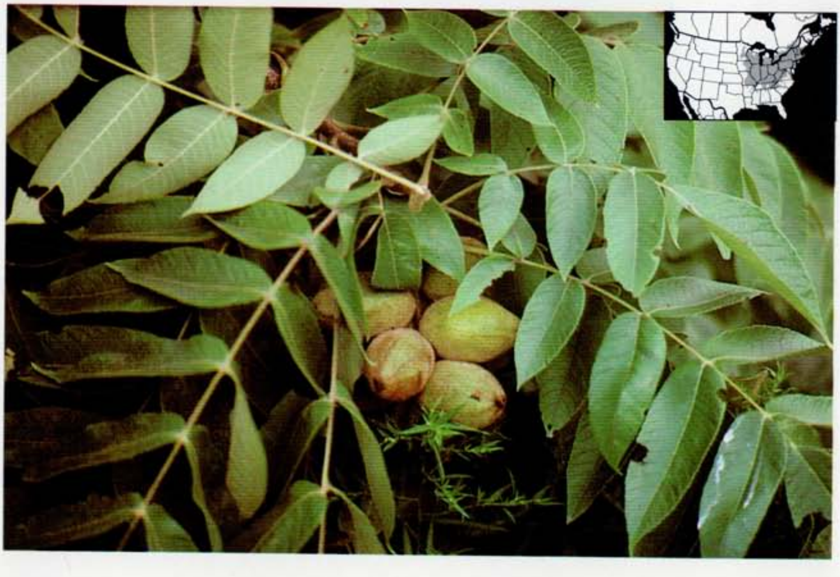

California walnut *Juglans californica*

Habitat: stream and river banks, bottomlands, often in gravelly soils at lower elevation, usually below 1,000 m (3,200 ft). **Identification:** small to medium-size tree with open rounded crown and thick deeply furrowed dark brown to almost black bark. ***Leaves*** alternate, deciduous, ***featherlike (pinnately) compound, 15–25 cm*** (6–10 in) ***long, normally with 9–15 leaflets;*** leaflets 2.5–7.5 cm (1–3 in) long, 1–2 cm (0.4–0.8 in) broad, lance-shaped to uniformly wide, with fine sharp-pointed teeth along margin. Male flowers in slender, hanging catkins; female flowers small, 1–4 at tips of new branches, both produced in early spring as leaves unfold. ***Fruits small, globe-shaped, 1–2 cm (0.4–0.8 in) in diameter, with thin husk surrounding nut; nuts rounded, with few shallow grooves,*** shell thin, nutmeat large, sweet. **Harvest:** Gather ripe nuts in autumn as they fall from tree. Remove brown-staining hulls immediately as described for BLACK WALNUT (preceding). Air dry before using. **Preparation:** Crack shells of dried nuts and remove meats with nutpick; easier to extract than some other walnuts. For Indian method, see BLACK WALNUT instructions. For uses, see other walnuts, hickories, and the book's introductory section. **Related edible species:** BLACK WALNUT. **Poisonous look-alikes:** none.

Butternut *(Also edible summer)* *Juglans cinerea*

Habitat: bottomlands, floodplains, mixed deciduous forests. **Identification:** medium-size tree with open, broadly rounded crown and thick, deeply furrowed, light gray to light brown bark. ***Leaves*** alternate, deciduous, ***featherlike*** (pinnate) ***compound,*** 30–60 cm (12–24 in) long, ***with 11–17 leaflets;*** leaflets 5–11 cm (2–4.3 in) long, 2–6 cm (0.8–2.4 in) wide, lance-shaped to widest above middle, finely toothed along margin. Male and female flowers separate, both appearing in early spring. ***Fruits large, egg-shaped, 5–8 cm*** (2–3.2 in) ***in diameter,*** often 4-sided, husk not splitting open at maturity. Nut egg-shaped, 3–6 cm (1.2–2.4 in) in diameter, 4-ribbed, shell deeply furrowed, thick, nutmeat sweet. **Harvest:** Pick partly grown nuts in summer for pickling when needle will penetrate husk. Gather ripe nuts in autumn as they fall from trees. Remove brown-staining hulls immediately as described for BLACK WALNUTS. Dry thoroughly before using. **Preparation:** Crack like BLACK WALNUTS or hold nut in vertical position and hammer on end until well cracked. Remove nutmeats with nutpick or use Indian method described under BLACK WALNUT to prepare oil and nut butter. For pickling, scald immature nut and remove all outer fuzz. Place nuts in kettle; cover with water and boil until water discolors. Change water and continue boiling. Repeat water changing and boiling until water remains clear. Pack nuts in canning jars with 1 dill flower, 3 walnut leaflets, 1 heaping tsp pickling spices, 1 tsp salt, ¼ tsp alum. Fill jar with boiling cider vinegar and seal. Age at least 1 month. For other uses see BLACK WALNUT, hickories, and book's introductory section. **Related edible species:** BLACK WALNUT, CALIFORNIA WALNUT (preceding), Arizona walnut *(J. major)*, Hinds walnut *(J. hindsii)*, and Texas black walnut *(J. microcarpa)*. **Poisonous look-alikes:** none.

Winter

Winter is hardly the season for wild plant foraging—especially in colder climates. Aboveground, edibles are basically limited to berries that persist into winter, twig bark for tea, and the inner bark of some trees. The most nutritious plant parts are underground; these are the starch-rich roots and tubers of perennials and biennials. But, in winter, roots and tubers are difficult to locate and identify, even if there's no snow cover. Besides, digging them in frozen ground would cost you more calories than the plants would return.

What about survival foods? You can survive many days without food, provided you stay warm and reasonably dry, and drink sufficient water to prevent dehydration. If you decide to stay put until help arrives, choose or fashion a shelter you can heat with a reflected campfire. In selecting a site, consider access to firewood, water, and an open area for distress signalling. Expend as little energy as possible. If you expect a long wait, consider passive means of obtaining meat: fishing with set lines or setting snares on small-game trails. If you have a firearm, you could

watch game trails from your shelter or attempt to call predators to you by imitating the squeal of an injured rabbit.

In winter, Indians sometimes raided the nut caches of squirrels and arrowhead tubers cached by muskrats. But such raids are strenuous. Besides, getting into a muskrat's house can be a wet, cold ordeal.

Some northern Indians made the inner bark of trees their major winter food staple. Since bark stripping kills trees, today it should be done only for survival.

You can also partake of wild edibles in winter by manipulating the seasons. That is, you can feast on wild preserves you harvested earlier. Or, if you are highly dedicated, you can in autumn dig up the whole roots of dandelion, chicory, dock, and pokeweed. Then plant the roots in a deep, soil-filled container until after a hard freeze. Bring the container into a dark cellar. Watered and kept at 13°C (55°F), the roots will produce several crops of blanched, tender, and mild leaves for salads or cooking.

The plant species shown in upcoming pages provide berries you can eat raw, berries and twigs for beverage flavoring, inner bark for gruel and flour, and sap for pure water or boiling down to syrup and sugar. These plants are shown as they look in winter, though most of them are also shown elsewhere in this book. Many other winter-edible plants are difficult to locate and identify in winter and so are not described in this winter section. In some regions, edible plants normally harvested in autumn may also be gathered in early winter.

(Dykeman)

Staghorn sumac *Rhus typhina*

Also edible summer, autumn

Habitat: common; woodland margins, fencerows, roadsides, and along streams. **Identification:** shrub or small tree to 10 m (33 ft) with thick, ***densely hairy branches and twigs with large orange to olive pith.*** Leaf scars C-shaped, nearly surrounding ***bluntly conical, hairy buds.*** No end bud. ***Fruits persist into winter in dense, cone-shaped clusters 10–20 cm (4–8 in) long; each fruit berrylike, rounded, 3–5 mm (0.1–0.2 in) in diameter, densely covered with dark red hairs.*** See also p. 186. **Harvest:** Fruits ripen in late summer to autumn and have strong lemony taste. Dense hairs on fruits prevent rain from penetrating cluster and washing out all flavor, so fruits are edible although less potent in winter. **Preparation:** For beverage, steep berries, with all twigs removed, in near boiling water for at least 15 min (at least 1 cup fruit to 1 qt water). Strain through cloth, dilute and sweeten to taste. Drink hot or cold but in moderation; some people show allergic reactions such as hives and cramps. To make jelly prepare extract as for beverage. Bring to boil 4 cups extract with 1 pkg powdered pectin. Add 5 cups sugar, boil hard 1 min, remove from heat, skim, pour into sterilized jars and seal with paraffin. **Related edible species:** SMOOTH SUMAC and SQUAWBUSH, and lemonade berry *(R. integrifolia)*. **Poisonous look-alikes:** Poison sumac *(R. vernix)* has white fruits and grows in swampy areas.

Highbush cranberry *Viburnum trilobum*

Also edible autumn

Habitat: along streams, wet thickets, moist woodlands. **Identification:** ***shrub,*** upright, to 5 m (16.5 ft) high; branches upright to spreading. Twigs light reddish-brown turning ash-gray with age. Buds opposite; no end bud. ***Fruits berrylike, in clusters of 10 or more, rounded to egg-shaped, 8–14 mm (0.3–0.5 in) long, bright red, translucent*** when ripe, juicy, sour, containing a single flattened stone. See also HIGHBUSH CRANBERRY on page 224. **Harvest:** Fruits ripen in late summer but persist on shrub and become less sour in winter. Make sure your shrub is highbush cranberry and not its bitter look-alike, the introduced guelder rose, *V. opulus.* Tasting will tell you. Best to pick in fall and winter. **Preparation:** much the same as CRANBERRY *(Vaccinium macrocarpon)*, except large seeds must be removed. While cooking add lemon or orange peel shavings to eliminate bad odor of berries. For sauce cover several quarts of berries with water in a kettle. Add outer peels of 2 lemons or oranges. Bring to boil and simmer 5 min. Mash thoroughly and simmer another minute or two. Force juice and pulp through coarse strainer to remove seeds. Add 1 pkg pectin to 4 cups strained fruit, bring to boil, and add 5 cups sugar. Boil again for 1 min and seal in sterile jars or refrigerate. Before first frost, pectin may not be needed. For juice and jelly, cook as for sauce above but strain through jelly bag. For juice, dilute and sweeten to taste. For jelly, proceed with 4 cups juice as for sauce. **Related edible species:** SQUASHBERRY (next), HOBBLEBUSH, NANNYBERRY, and the cranberry tree *(V. pauciflorum)*, of Pacific Northwest. **Poisonous look-alikes:** none, but the guelder rose *(V. opulus)* has bitter fruits.

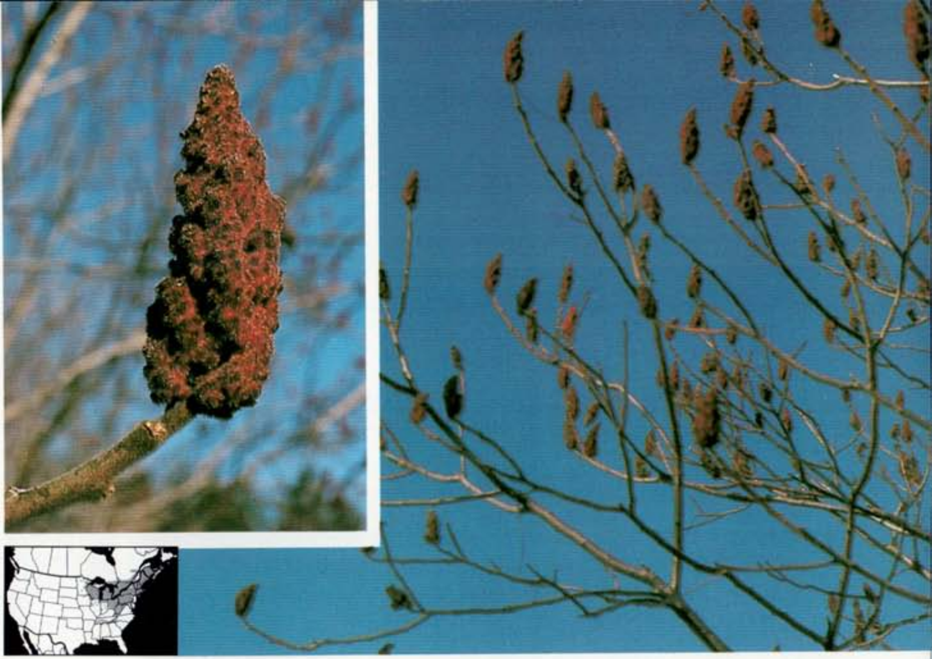

Staghorn sumac: winter fruit cluster and fruiting branches (Dykeman).

Highbush cranberry: early autumn branches (Elias). In winter berries look like this and are sweeter, though leaves will have fallen.

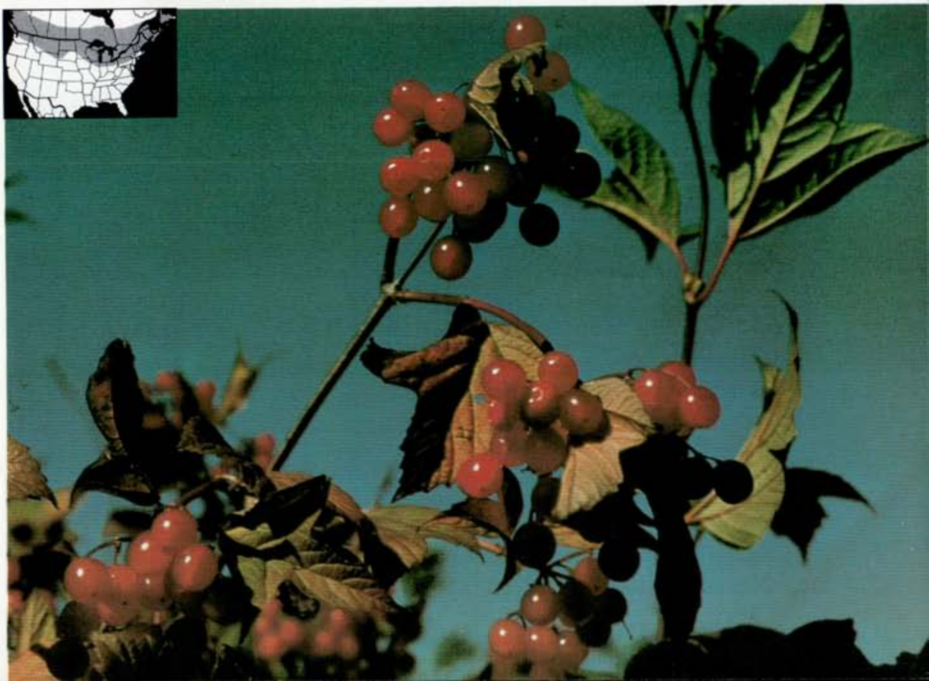

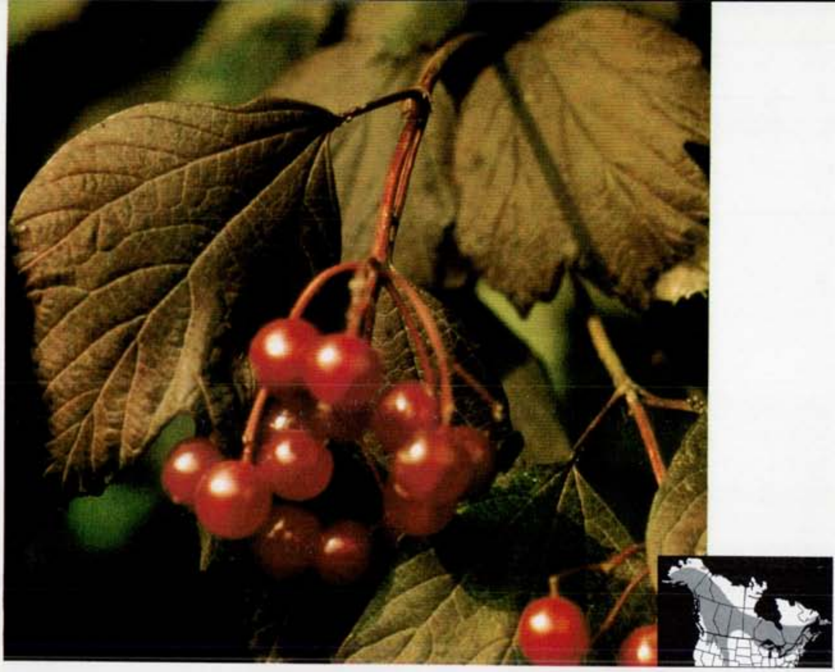

Squashberry: early autumn branch (Clawson). In winter, berries look like this and are sweeter, though leaves will have fallen.

Sweet birch: winter treetop, trunk bark, and immature male catkins (Dykeman).

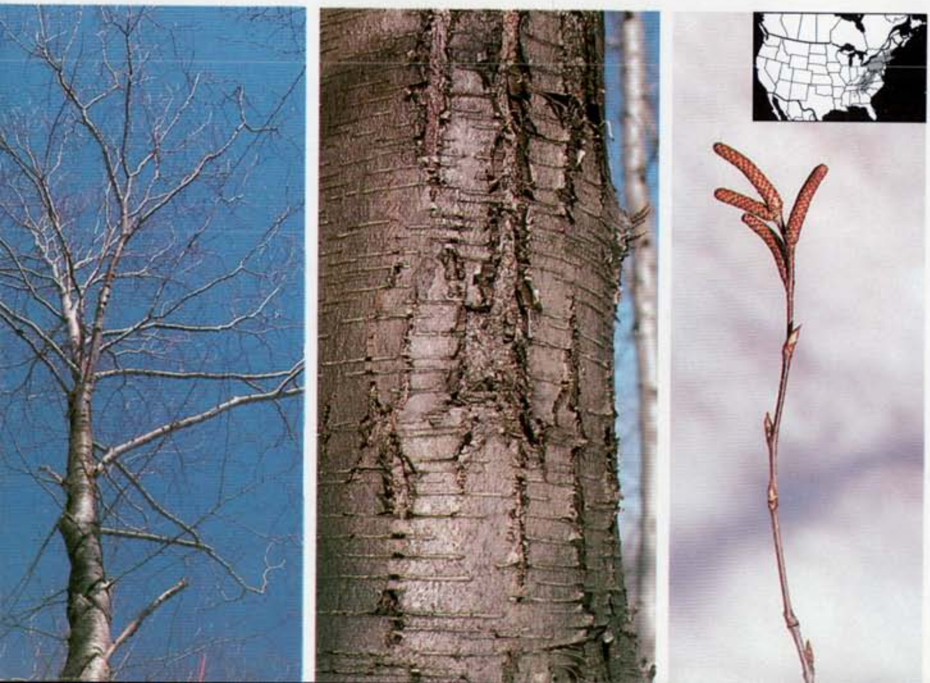

Squashberry *Viburnum edule*

Also edible summer, autumn

Habitat: along streams, wet thickets, margin of woodlands, moist low woodlands. **Identification:** ***shrub,*** often sprawling, to 2.5 m (8.1 ft) high; stems usually spreading, smooth. New branches reddish brown, older ones gray. ***Buds opposite, dark red, shiny, 2-scaled;*** both ***side and end buds present. Fruits in small clusters, berrylike, rounded,*** 6–10 mm (0.2–0.4 in) in diameter, ***red, containing a single flattened seed.*** See also SQUASHBERRY on page 226. **Harvest:** Fruits are similar to HIGHBUSH CRANBERRY but smaller and less sour. They ripen in August but persist through winter so are listed here. **Preparation:** See HIGHBUSH CRANBERRY (preceding), except juice does not require dilution for use as beverage. Makes excellent jelly. **Related edible species:** HIGHBUSH CRANBERRY. **Poisonous look-alikes:** none; the introduced guelder rose *(V. opulus)* is bitter but not toxic.

Sweet birch, Black birch *Betula lenta*

Also edible spring, summer, autumn

Habitat: forest or open woods, especially moist, north facing, protected slopes; in deep, rich, well-drained soils. **Identification:** medium-size tree with rounded crown and smooth, dark red to almost black bark. ***Broken twigs have wintergreen fragrance.*** Buds alternate, both side and end buds present, 5–7 mm (0.2–0.3 in) long, light brown, broadest near base and tapering to a point. Fruits in erect, ***brown cones, 2.5–3 cm (1–1.2 in) long, containing many tiny, winged seeds.*** Fruits mature in late summer and early fall. Cones persist into winter. ***New male flower catkins 2–3 cm (0.8–1.2 in) long at tips of twigs in winter.*** See also p. 122. **Harvest:** twigs, red inner bark, and bark of larger roots year round but best in late winter and spring. Sap in early spring, 3–4 weeks later than SUGAR MAPLE. **Preparation:** Eat inner bark fresh as emergency food, boiled like noodles, or dried and ground into flour. Dry inner bark at room temperature; store in sealed jars for later use. For tea, steep (do not boil) twigs or fresh or dried inner bark in water or, preferably, birch sap. Boiling removes volatile wintergreen oil. Sweeten to taste. For birch beer pour solution of 4 gal birch sap and 1 gal honey (or 5 gal sap and 3 lb sugar), which has been boiled 10 min, over 4 qt fine twigs in a crock. Cool, strain to remove twigs, add 1 cake yeast. Cover, ferment about 1 week, until cloudiness starts to settle. Bottle and cap tightly. For birch syrup, see instructions under YELLOW BIRCH (next). **Related edible species:** YELLOW BIRCH. **Poisonous look-alikes:** none.

Yellow birch *Betula alleghaniensis*

Also edible spring, autumn (synonym: *B. lutea*)

Habitat: rich woodlands, lower slopes and occasionally cool marshlands, usually below 1,000 m (3,300 ft) elevation. **Identification:** medium-size tree with rounded crown and peeling, ragged-edged, reddish-brown bark turning ***grayish dull yellow or yellowish-brown.*** Buds alternate, end bud absent, side buds 5–7 mm (0.2–0.3 in) long, brown, broadest near base and tapering to sharp point, somewhat sticky, with several scales. ***New male flower catkins 2–3 cm (0.8–1.2 in) long at tips of twigs.*** See also YELLOW BIRCH on page 122. **Harvest:** For syrup, tap as with SUGAR MAPLE beginning 3–4 weeks after maple sap flow begins. Drill 7/16-in hole (just over 11 mm) slightly upward about 7 cm (3 in) into a mature tree. Hammer in metal or wood spile only until firmly anchored; driving spile too far may split wood. Hang bucket and wait. Flow of sap copious but sugar content lower than from maple. For use of twigs and inner bark, see SWEET BIRCH (preceding); wintergreen flavor is milder in yellow birch. **Preparation:** Boil sap in open container, outdoors, adding more as volume decreases, until evaporation leaves a viscous, molasses flavored syrup with boiling temperature of about 104°C (220°F). Store in sterilized, completely filled, sealed jars. **Related edible species:** SWEET BIRCH. **Poisonous look-alikes:** none.

American mountain ash *Sorbus americana*

Also edible autumn

Habitat: rocky slopes, seepage areas along ridges at higher elevations. **Identification:** shrub or small tree to 9 m (30 ft) with open, rounded crown and thin, light-gray smooth bark. ***Leaf scars alternate, slightly raised on twig surface.*** Buds rather conical, ***end bud 6–12 mm (0.2–0.5 in) long, curved and gummy;*** side buds smaller, flattened and pressed against twig. ***Fruits in large, dense clusters, persisting into winter,*** each fruit 4–8 mm (0.2–0.3 in) in diameter, ***bright orange-red, shiny, slightly fleshy, containing 1 or 2 seeds.*** See also AMERICAN MOUNTAIN ASH on page 240. **Harvest and preparation:** Fruits become palatable in winter after one or more freezings and become easy to strip from twigs. Edible raw but better cooked. For sauce, stew like CRANBERRIES; bring to boil 4 cups berries and 2 cups sugar in 1 cup water (or berries plus 1 cup maple sugar and 1 cup cider). Reduce heat and simmer until berries mash easily and a drop of sauce gels on a cold plate. Pour into mold or storage jars. For pie, add to sauce (above) a rind of ½ lemon and ⅛ tsp cinnamon. Line pie plate with crust, put in sauce, cover with crisscross strips of crust leaving spaces between them. Bake at 230°C (450°F) for 20 min. For jelly, see the book's introductory section. For meat sauce substitute 1 cup vinegar for 1 cup water in jelly recipe. Berries keep well; but for prolonged storage, dry them to prevent mold. **Related edible species:** European mountain ash *(S. aucuparia)*, Greene mountain ash *(S. scopulina)*, and Sitka mountain ash *(S. sitchensis)*. **Poisonous look-alikes:** none.

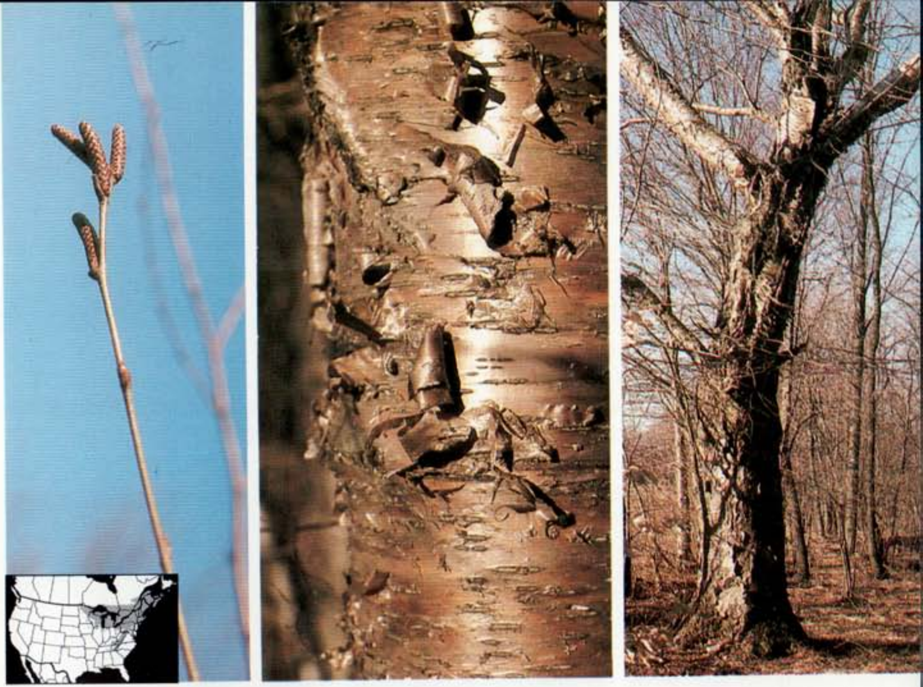

Yellow birch: winter immature male catkins, trunk bark, and tree (Dykeman).

American mountain ash: ripening autumn fruits (Elias). In winter, berries are brighter orange-red, and leaves will have fallen.

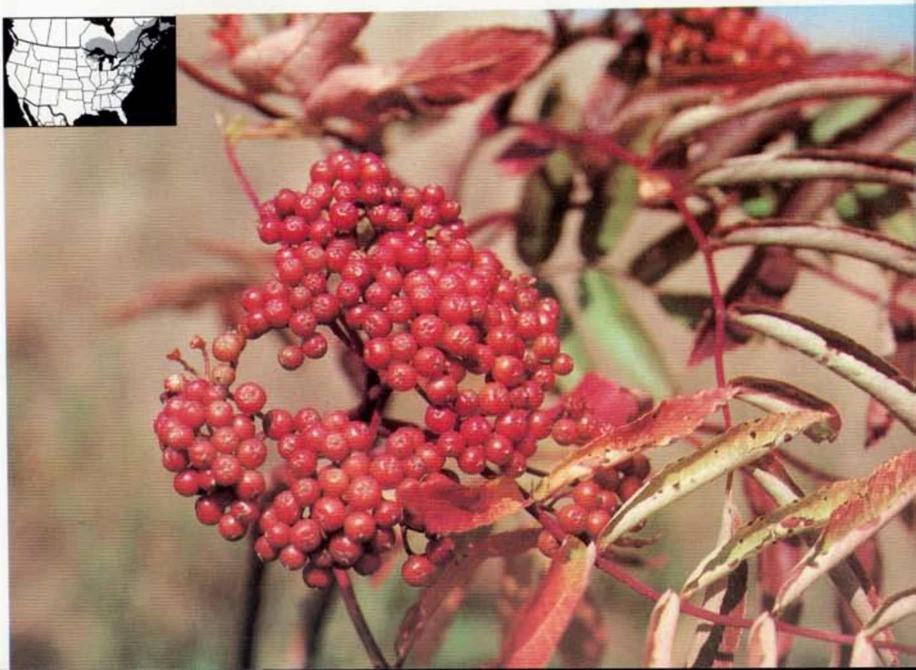

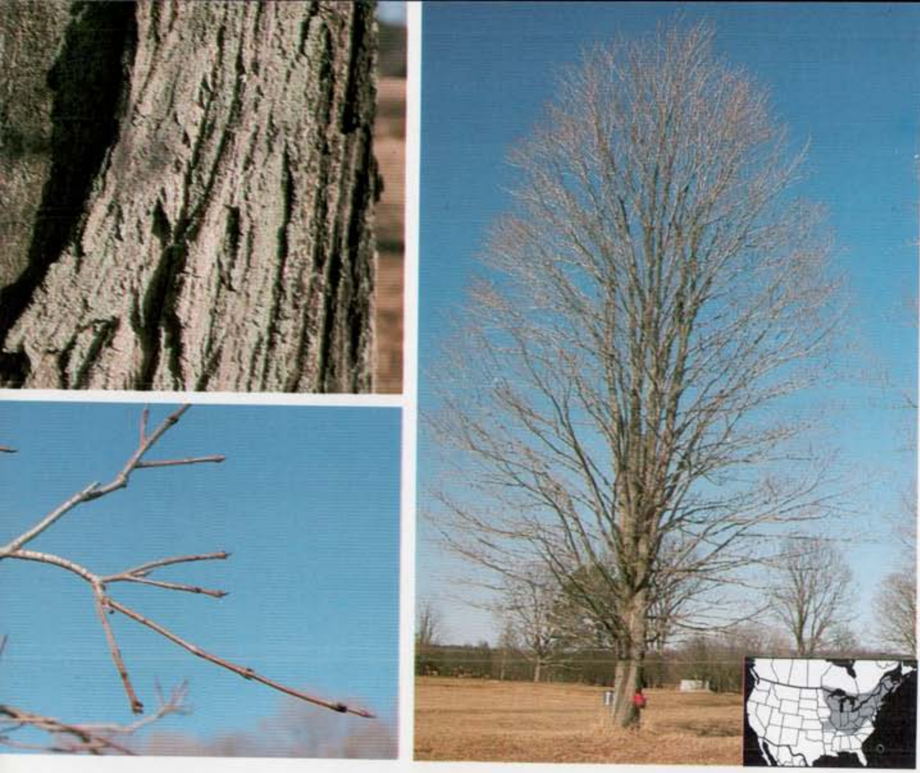

Sugar maple: trunk bark, winter twigs and tree. Metal spile with sap dripping into bucket. (Dykeman photos)

Sugar maple *Acer saccharum*

Also edible spring, summer

Habitat: eastern deciduous forest, common and widespread, especially at lower elevations. **Identification:** medium-size to tall ***trees*** to 30 m (98 ft) with a rounded crown, slightly ***fissured to furrowed dark-gray bark. Buds opposite,*** end and side buds present, ***light brown,*** scaly; ***end bud 6–12 mm (0.2–0.5 in) long,*** cone shaped; side buds smaller. See also SUGAR MAPLE on page 256. **Harvest:** Obtain sap from first spring flow until buds swell. Good sap flow requires freezing nights and warm days. Drill $^{7}/_{16}$-in hole (just over 11 mm) for commercial spile, slightly upward and 5–8 cm (2–3 in) into trunk. Drive spile just far enough to hold bucket, not so hard that you split wood. Collect sap and store cold until you have 25–30 gal. Collect winged seeds before fully ripe, usually from June to September. **Preparation:** Boil sap outdoors, indoors only if you like sticky walls. Use large surfaced, open pan, adding sap as water boils away. When 25 gal or so of sap has been added, continue to boil liquid until temperature is 4°C (7°F) above that of boiling water on that particular day. You may wish to boil for the last two degrees on a regulated stove. Filter syrup through milk filter into sterilized canning jars. Fill jars completely and seal. Yields about 3 qt. For maple sugar, boil 1 pt of syrup in saucepan with frequent stirring until temperature is at least 110°C (230°F). Remove from heat, cool, and stir until surface loses sheen. Pour quickly onto foil or waxed paper. When partially hardened, score into pieces with knife. Use sap fresh as a beverage, fermented to form a mild vinegar, or reduced by boiling to 25% its original volume as a base for teas. Soak seeds and remove wings. Boil until tender, drain, season, and roast for 10–15 min. **Related edible species:** Red maple *(A. rubrum)*; sap of all native maples may be used for syrup but sugar maple is best. **Poisonous look-alikes:** none; but avoid Norway maple *(A. platanoides)*, which has milky sap.

Poisonous plants

Plants that are inedible and even poisonous to varying degrees grow among the edible ones. So it's wise to learn to recognize poisonous plants, especially those that may resemble the edibles. In this section, you'll find full coverage of 20 plants that are particularly toxic, and you'll also find mention of many more related toxic species. To learn more about poisonous plants not fully covered here, consult a guidebook for your region.

Unfortunately, there are no general rules for recognition of poisonous plants. Even though birds or mammals eat a particular plant, that plant may still be poisonous to humans. For example, birds readily consume the fruits of poison ivy with no ill effects. But if you tried this, you'd be in serious trouble. Ironically, sometimes the most toxic plants are among the most beautiful. Some toxic beauties include blue flag, yellow flag, star of Bethlehem, and butterfly weed.

The more field experience you gain identifying plants, the easier you'll sort the edibles from the inedibles. Try to identify at least a few new poisonous plants each season.

Star of Bethlehem *Ornithogalum umbellatum*

Habitat: fields, grassy areas, roadsides, and open woodlands. **Identification:** *small perennial herb* to 35 cm (13.8 in) high, from an egg-shaped bulb 3–4 cm (1.2–1.6 in) long. ***Leaves mainly basal, long, narrow, 15–40 cm (5.9–15.7 in) long, 3–6 mm (0.1–0.2 in) wide, channeled, main vein almost white.*** Flowering stem erect, bearing several, short- to long-stalked flowers at the tip; ***each flower showy, bisexual, with 6 spreading petallike segments, white with a green stripe on lower side, each segment 1.5– 2.5 cm (0.6–1 in) long.*** Fruits are a 3-lobed, egg-shaped capsule 5–10 mm (0.2–0.4 in) long containing a few, nearly globe-shaped, black seeds. **Poisonous constituents:** Bulbs contain one or more alkaloids that have killed grazing animals. **Related poisonous species:** An introduced species, *O. nutans*, also has poisonous bulbs.

Death camass *Zigadenus venenosus*

Habitat: meadows, fields, scrubby woodlands along coast, in foothills, and coniferous forests. **Identification:** ***perennial herb from an egg-shaped bulb 1.2–2.5 cm (0.5–1 in) long, with dark outer scales;*** stems upright, 24–60 cm (9.4–24 in) high, slender, smooth. ***Leaves around base and on lower stem; basal leaves very narrow (linear), 15–30 cm (6–12 in) long, 5–10 mm (0.2–0.4 in) wide;*** stem leaves usually shorter and sheathing the stem. ***Stalked flowers numerous along an upright, unbranched, elongate cluster (lower-most flowers opening***

first), each flower with 6 petals or petallike structures, whitish, broadest near base, pointed at tip, bisexual. Fruit a small, egg-shaped capsule 1–1.5 cm (0.4–0.6 in) long, splitting open at maturity to release tiny, brown seeds. **Poisonous constituents:** All plant parts, especially the bulbs, contain alkaloids that can cause gastrointestinal distress, weakness, loss of motor function, and death. This plant and its relatives have killed many horses and cattle. **Related poisonous species:** All 12 native *Zigadenus* species should be considered *extremely* poisonous.

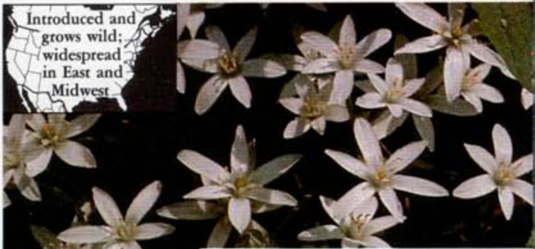

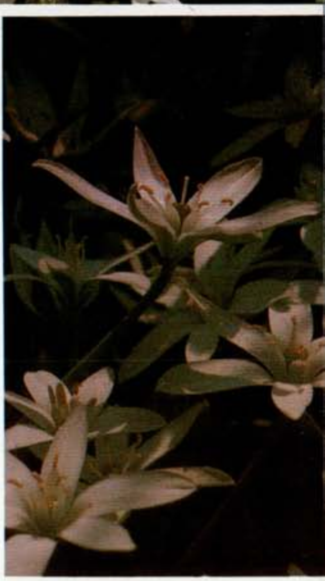

Star of Bethlehem: flowering plants (NYBG).

Death camass: flowering plant (NYBG).

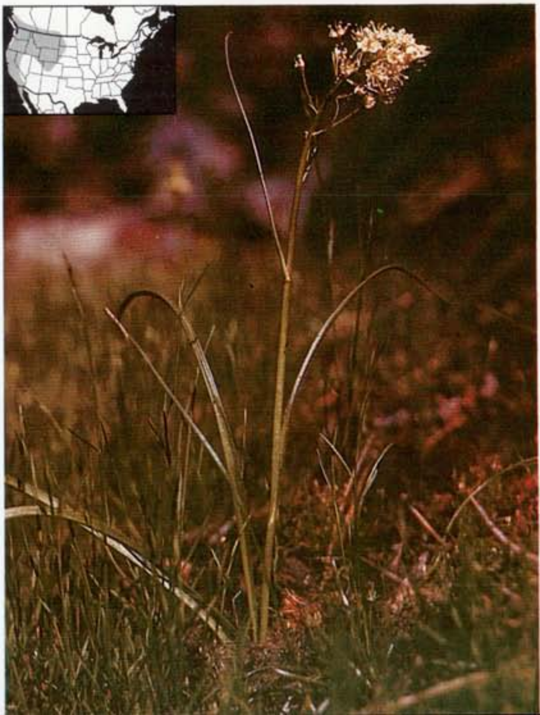

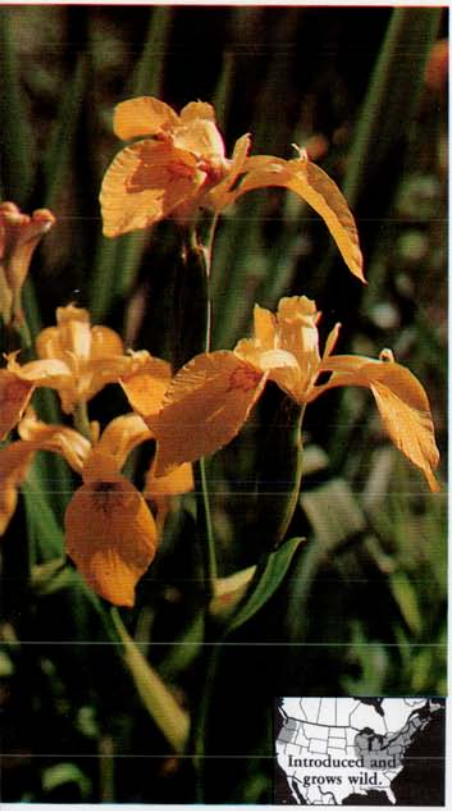
Introduced and grows wild.

Yellow flag: flowers (Elias).

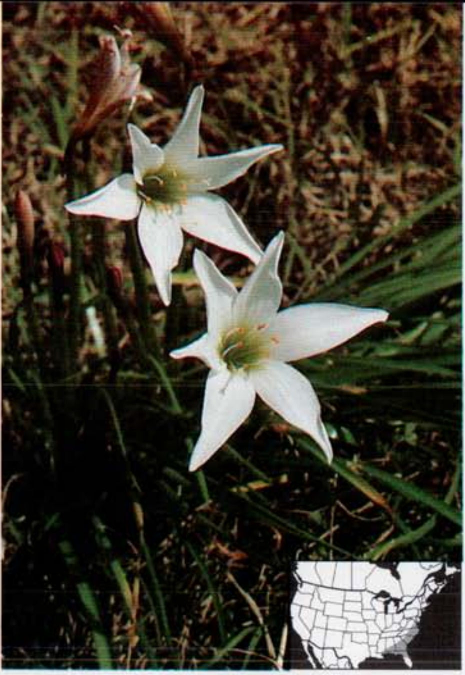

Atamasco lily: flowering plants (Speas).

Blue flag: flower (Elias).

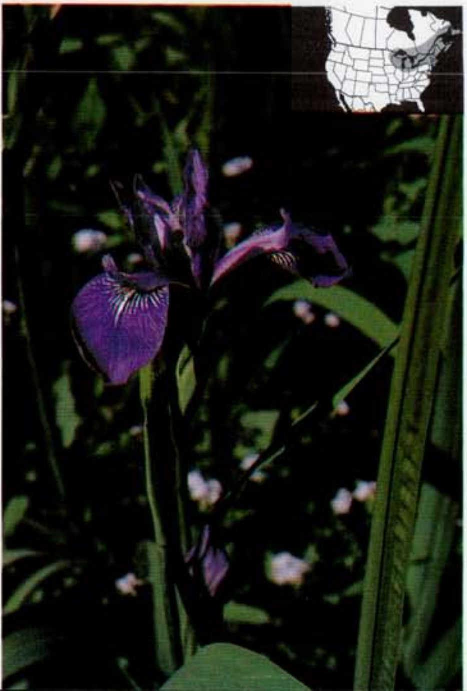

Atamasco lily *Zephyranthes atamasco*

Habitat: floodplain and low wet woodlands, wet fields and meadows, coastal plain and lower piedmont. **Identification:** perennial herb to 30 cm (12 in) high, from a small onionlike bulb 2–3 cm (0.8–1.2 in) in diameter. ***Leaves all basal, long, narrow (linear), 20–40 cm (8–16 in) long, 4–8 mm (0.15–0.3 in) wide,*** channeled, bright-green to bluish-green, shiny. ***Flowering stalk upright, to 30 cm (12 in) high, bearing a single flower at the tip; flowers white, rarely pink, showy, 6–10 cm (2.4–3.9 in) long, funnel-shaped with the 6 lobes spreading.*** Fruits are papery to leathery, nearly globe-shaped capsules, each 3-lobed and splitting open at maturity to release the shiny, black seeds. **Poisonous constituents:** Toxic compounds in the bulbs have produced staggering, collapse, and death in grazing animals. Thus, they should be regarded as *extremely* poisonous. **Related poisonous species:** All 12 native species of *Zephyranthes* should be considered extremely poisonous. ☠

Yellow flag *Iris pseudoacorus*

Habitat: swamps, ditches, borders of ponds, lakes, and streams; common, introduced from Europe. **Identification:** large perennial herb 0.6–1.2 m (2–3.9 ft) high, from spreading, underground stems (rhizomes). ***Leaves long,*** narrow, ***sword-shaped,*** 0.4–0.8 m (1.3–2.7 ft) long, 2–4 cm (0.8–1.6 in) wide, flattened, erect, pale green, sheathing the flowering stalks. Flowering stalks usually shorter than the leaves, bearing a ***large, showy flower;*** flowers usually ***bright yellow,*** with 3 spreading, petallike sepals each crested with brownish, irregular spots and 3 narrower, upright petals. Fruits are elongate, slightly angled capsules 5–10 cm (2–4 in) long, splitting open lengthwise to release the seeds. **Poisonous constituents:** leaves and roots; see BLUE FLAG (next). **Related poisonous species:** All native and introduced species of irises should be considered poisonous. ☠

Blue flag *Iris versicolor*

Habitat: wet meadows, ditches, swamps, marshes, along ponds and streams, native. **Identification:** ***large perennial herb*** to 1 m (3.3 ft) high, ***from thick, spreading, underground stems*** (rhizomes). ***Leaves long, narrow, sword-shaped,*** 0.4–1 m (1.4–3.3 ft) long, 1–3 cm (0.4–1.2 in) wide, flattened, erect, pale green to grayish-green, sheathing the stalks. Flowering stalks with 1 to 3 large, showy flowers; ***flowers bluish-purple to violet,*** with 3 broadly spreading, petallike sepals with conspicuous white veins and yellowish near base, petals 3, erect, narrow, 1/4 to 1/2 as long as sepals. ***Fruits are elongate, 3-angled capsules 3.4–5.6 cm*** (1.4–2.2 in) ***long.*** **Poisonous constituents:** Leaves and roots are toxic and can cause an inflammation of the mucous membrane of the stomach and intestine. Most grazing animals avoid wild irises, but calves have been fatally poisoned by them. **Related poisonous species:** All native and introduced species of irises should be considered poisonous. ☠

Common buttercup *Ranunculus acris*

Habitat: yards, fields, clearings, and other disturbed sites. **Identification:** ***slender perennial herb*** to 1 m (3.3 ft) high, from a short, thick underground stem (rhizome); stem upright, branched, usually with spreading hairs. ***Basal leaves rounded in outline, 4–10 cm (1.6–3.9 in) across, deeply 5–7 lobed,*** each lobe coarsely toothed or with narrow lobes, softly hairy, with long leafstalks; stem leaves similar to other leaves except smaller and gradually becoming stalkless. Flowers several in a branched, open, spreading cluster; ***each flower with 5 bright glossy, yellow to whitish petals*** 7–14 mm (0.25–0.5 in) long, broadest near the tip. Fruits are clusters of flattened, broad, beaked, thin-walled nuts about 2–3 mm (about 0.1 in) long. **Poisonous constituents:** Leaves and stems are bitter tasting, possibly due to oils. These oils can cause abdominal pains from an irritated stomach and intestines. Fresh buttercups have caused diarrhea and blindness in grazing animals. **Related poisonous species:** All native species of buttercups contain toxic or otherwise irritating oils and should not be eaten.

Jimson weed *Datura stramonium*

Habitat: disturbed sites and waste grounds, old fields, roadsides, barnyards. **Identification:** ***coarse annual herb*** to 1.5 m (5 ft) high, from a short taproot; stems upright, branched, usually smooth. ***Leaves broadest near the base, 8–16 cm (3.2–6.4 in) long, 4–12 cm (1.6–4.7 in) wide, coarsely and irregularly large-toothed along the margin. Flowers large, 5–8 cm (2–3.1 in) long, showy, white to light purple, upright,*** produced singly on upper stem; petals fused and narrowly funnel-shaped, the lobes spreading, with a heavy fragrance. ***Fruits upright, egg-shaped capsules 3–5 cm (1.2–2 in) long, usually with short spines,*** splitting open along 4 valves to release dark pitted seeds. **Poisonous constituents:** All plant parts, including seeds, are poisonous. Alkaloids will cause impaired vision, thirst, delirium, unpredictable movements, possibly coma and death. **Related poisonous species:** All *Datura* species.

May apple *Podophyllum peltatum*

Habitat: rich and open woodlands, wet fields and meadows, pastures, occasionally roadsides. **Identification:** attractive perennial herb to 50 cm (20 in) tall, from a fleshy, spreading, underground stem (rhizome); stem single, short, producing single or paired leaves and single blossom between. ***Leaves large, nearly circular in outline, 15–40 cm (5.9–15.7 in) in diameter, deeply 5–9 parted, margins with a few coarse teeth or lobes; leafstalk attached to center of blade.*** Flower somewhat showy, cup-shaped, with 6–9 white petals, each 3–5 cm (1.2–2 in) wide, produced on a nodding stalk. ***Fruit an egg-shaped, fleshy, yellow (rarely red) berry 2.5–5 cm (1–2 in) long,*** containing several seeds. **Poisonous constituents:** Leaves and particularly the roots contain a resinous compound known as podophyllin that can cause violent cathartic reactions. Consumption of small quantities will produce severe gastric upset and vomiting. Death may occur from larger quantities. The fleshy pulp of the fruit is edible, although the seeds should not be eaten. See MAY APPLE on page 140. **Related poisonous species:** none in North America.

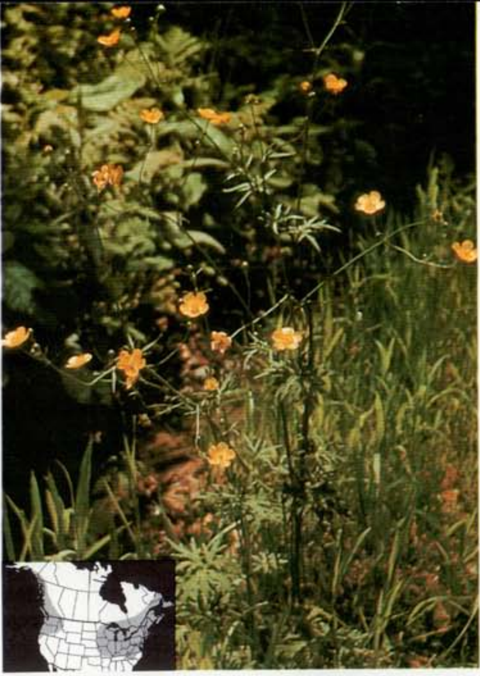

Common buttercup: flowering plants (NYBG).

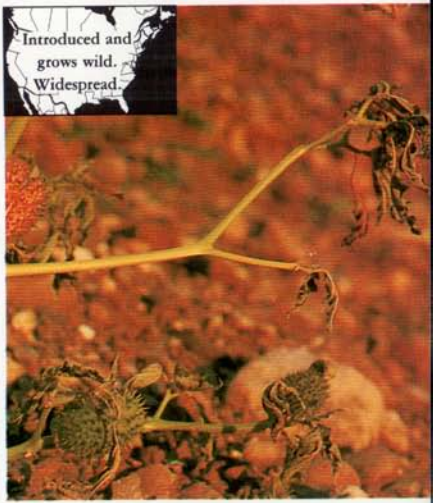
Introduced and grows wild. Widespread.

Jimson weed: fruiting branch after frost (Dykeman).

May apple: plants in early spring and flowering plant in May (NYBG).

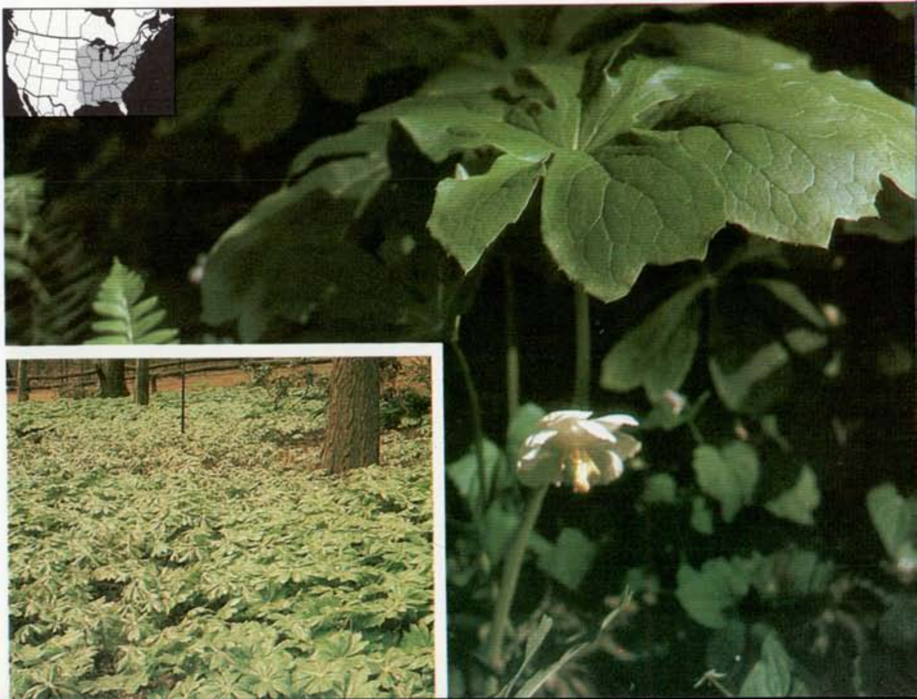

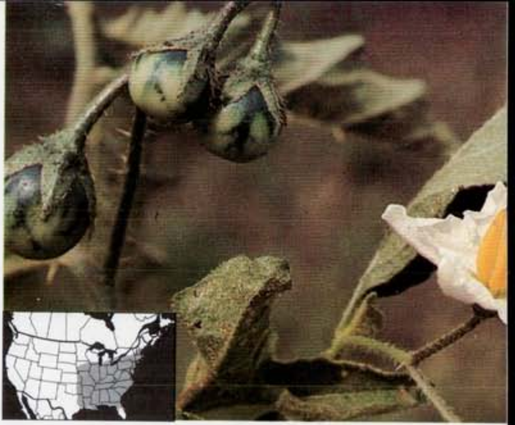

Horse nettle: flower and immature fruits, above (NYBG).

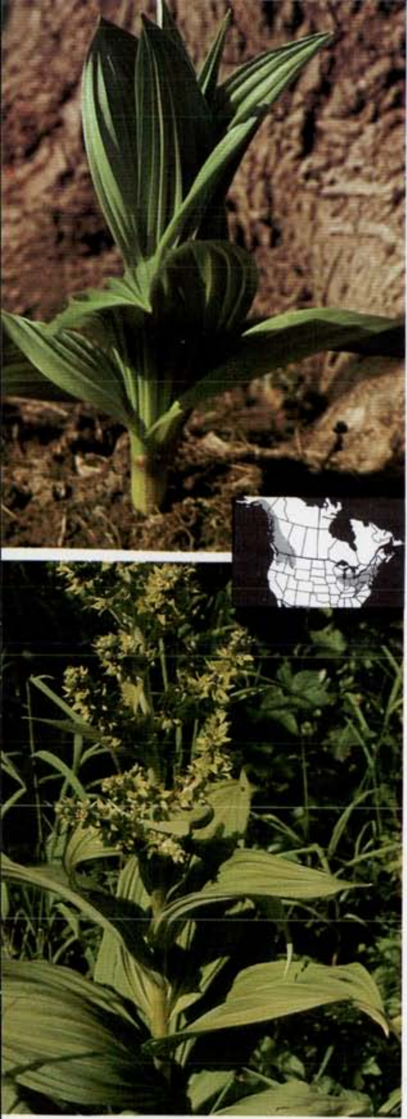

White hellebore: young plant, upper left (Elias). Top half of flowering plant, left (NYBG).

Yellow sweetclover: flower clusters, bottom left. Flower stalk, below. (NYBG photos)

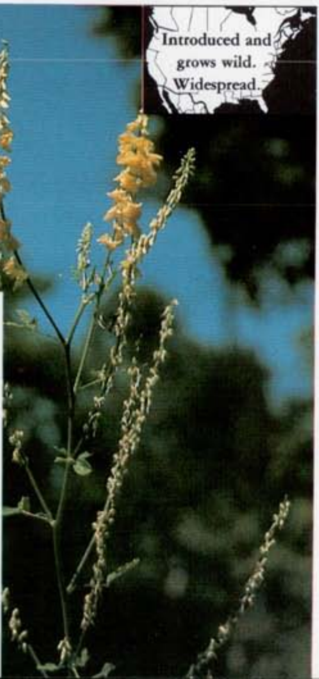
Introduced and grows wild. Widespread.

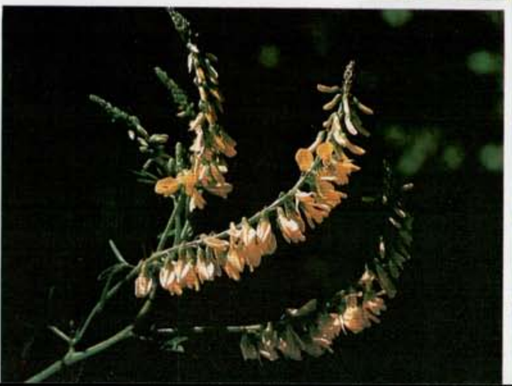

Horse nettle *Solanum carolinense*

Habitat: disturbed sites, fields, vacant lots, roadsides, and sandy waste areas. **Identification:** coarse perennial herb to 1 m (3.3 ft) high, from spreading underground stems (rhizomes); ***stem and leaves with branched hairs and slender spines. Leaves*** alternate, simple, broadest near base, 6–12 cm (2.4–4.7 in) long, 3–6 cm (1.2–2.4 in) wide, ***coarsely and irregularly large-toothed along margin, rough to touch.*** Flowers few on elongated terminal cluster; ***each flower white to light purple, 2–3 cm (0.8–1.2 in) across,*** five-parted petals spreading and even bending backward, broadest near base. ***Fruit a yellow fleshy berry*** 1–1.6 cm (0.4–0.6 in) in diameter, smooth. **Poisonous constituents:** Leaves and fruits contain the alkaloid solanine, which can cause vomiting, nausea, abdominal pains, and other gastrointestinal problems. **Related poisonous species:** Many species of the genus *Solanum* contain the solanine alkaloid in varying amounts. Among species to avoid are European nightshade *(S. dulcamara)*, black or deadly nightshade *(S. nigrum)*, and silverleaf nightshade *(S. elaeagnifolium)*. ☠

White hellebore, False hellebore *Veratrum viride*

Habitat: wetlands, swamps, floodplains, near streams and rivers, low wet sites in woodlands. **Identification:** ***large perennial herb*** to 2 m (6.6 ft) high, from thick, fibrous roots; stems upright, stout, unbranched. ***Leaves*** numerous along stem, ***broadest near base or middle, 15–32 cm (5.9–12.6 in) long, about half as wide,*** entire along margin and pointed at tip, nearly stalkless and almost clasping stem, with conspicuous, slightly sunken ribs. ***Flowers numerous in large, erect, branched clusters*** 20–50 cm (7.8–19.7 in) high, hairy; each flower yellowish-green, with 6 spreading, petallike segments. Fruits are egg-shaped capsules 1.8–2.6 cm (0.7–1 in) long, containing numerous seeds. **Poisonous constituents:** Several alkaloids from white and other hellebores have been used in medicines and insecticides. While all plant parts contain alkaloids, the roots concentrate them. Eating this plant can cause depressed heart activity, headaches, a burning sensation in the mouth and throat, and prostration. **Related poisonous species:** All 12 native *Veratrum* species should be considered poisonous. ☠

Yellow sweetclover *Melilotus officinalis*

Habitat: disturbed sites and waste areas, roadsides, fencerows, old fields; introduced weed from Europe and Asia. **Identification:** biennial herb to 2 m (6.6 ft) high, stems sparingly branched and weakly upright, usually smooth. ***Leaves compound, composed of three leaflets (trifoliolate);*** leaflets broadest near or above middle, 1.2–2.5 cm (0.5–1 in) long, 5–15 mm (0.2–0.6 in) wide, finely toothed along margin, greenish-yellow, usually smooth; leafstalks with conspicuous leaflike bract (stipule) at junction of stalk and stem. ***Flowers numerous on slender, elongated clusters 4–12 cm (1.6–4.7 in) long, each flower yellow, resembling tiny pea blossom.*** Fruits are egg-shaped pods 2–4 mm (0.1–0.2 in) long, smooth, stalked. **Poisonous constituents:** Improperly dried sweetclover will easily mold and in the process produce coumarin, an anticoagulant that can cause severe internal bleeding and death. Moldy sweetclover mixed in hay has killed many cattle. Thus, avoid this plant when gathering green leafy edibles. **Related** ☠

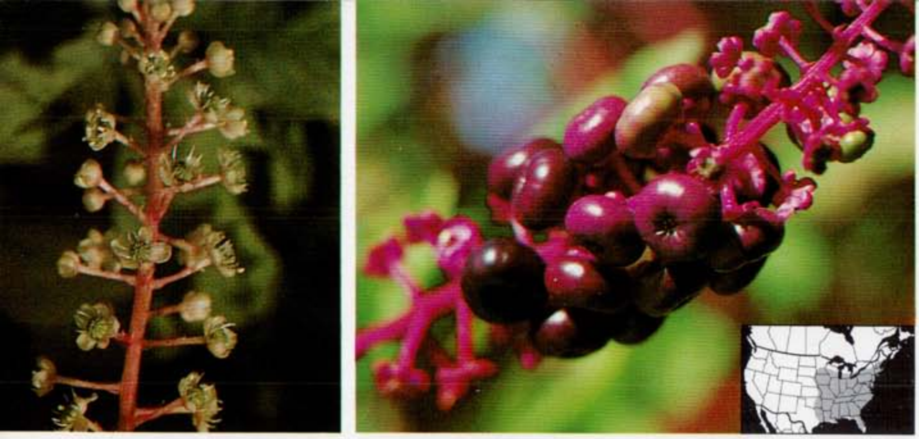

Pokeweed: flower cluster (NYBG). Fruit cluster with immature fruits at tip, bottom third; ripe fruits, middle; and stalks after fruits have fallen, upper third (Crow).

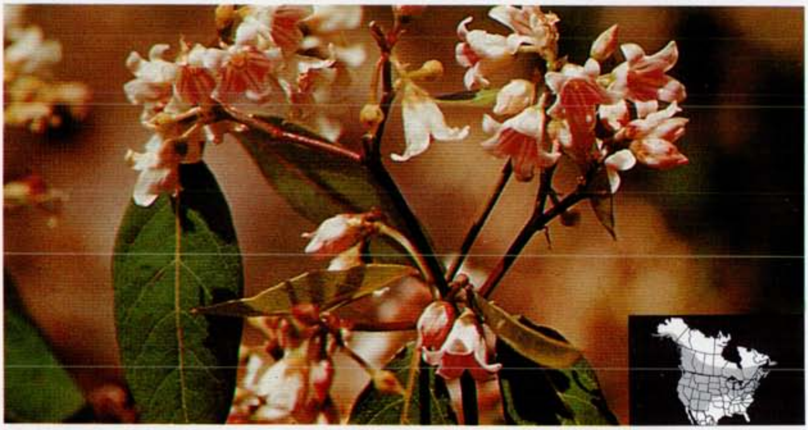

Dogbane: flowering branch (NYBG).

Butterfly weed: flowering plant top and fruit capsules (NYBG).

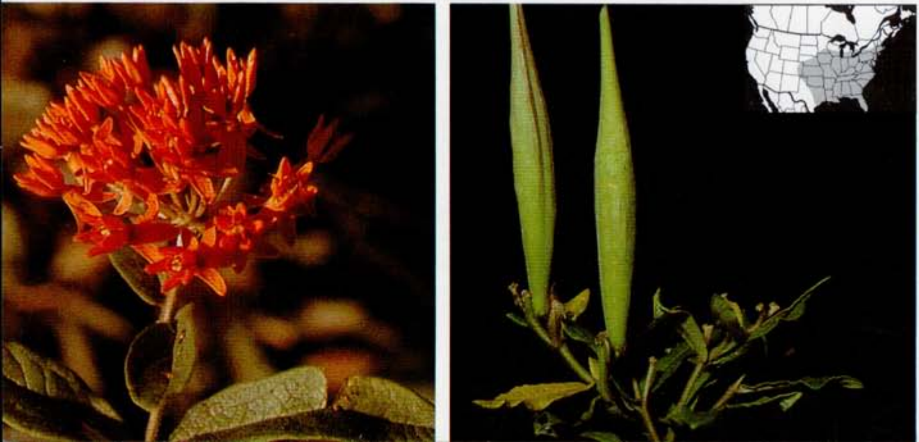

poisonous species: Also introduced from Europe, white sweetclover *(M. alba)* is equally dangerous.

Pokeweed *Phytolacca americana*

Habitat: woodland margins, disturbed sites, waste ground, roadsides, fencerows. **Identification:** ***large, perennial herb*** to 3 m (9.8 ft) tall with thick, fleshy roots; stems branched, upright, smooth, ***with disagreeable odor when broken.*** Leaves alternate, 9–30 cm (3.5–11.8 in) long, 3–12 cm (1.2–4.7 in) wide, broadest near base, pointed at tip, entire along margin; leafstalks to 5 cm (2 in) long. ***Flowers greenish to white, produced in narrow, elongate clusters*** (racemes); each flower 2–4 mm (0.1 in) long, petals absent. ***Fruits are 5–12-parted berries, wider than long, 6–10 mm (0.2–0.4 in) in diameter, green turning purplish-black at maturity.*** **Poisonous constituents:** Toxins are more prevalent in mature leaves, stems, and particularly in roots than in young growth and berries. Diarrhea, vomiting, cramps, sweating, reduced breathing capacity, or even death can occur from eating this plant. You can eat young cooked shoots if you discard the cooking water. See also POKEWEED on page 96. **Related poisonous species:** none. There is only one species of pokeweed in North America. ☠

Dogbane *Apocynum androsaemifolium*

Habitat: open woodlands, margins of woodlands, fields, roadsides, usually drier sites. **Identification:** ***perennial herb*** to 50 cm (19.7 in) high; stems upright, branching, ***with milky juice in all parts. Leaves opposite, broadest near base to almost uniformly wide, 4–8 cm (1.6–3.2 in) long, 2–4.5 cm (0.8–1.8 in) wide,*** entire along margin, pointed at tip, dark green above, hairy beneath, sometimes drooping, with slender leafstalk. Flowers several in branched, round-topped clusters at top or upper part of stems; each flower bell-shaped, 5–10 mm (0.2–0.4 in) long, white to pink, 5-parted, spreading to drooping. ***Fruits are narrow, cylindrical, capsulelike pods 6–18 cm (2.4–7 in) long, slender pointed at tip, containing numerous small seeds, each tipped with long silky hairs.*** **Poisonous constituents:** All plant parts contain resins and glycosides capable of affecting the cardiovascular system of mammals. **Related poisonous species:** All of the 6 or 7 native species of dogbane *(Apocynum)* contain milky sap and probably the glycosides. Thus, all should be considered poisonous. ☠

Butterfly weed *Asclepias tuberosa*

Habitat: fields, meadows, prairies, open woodlands, margins of woodlands. **Identification:** perennial herb, upright, 30–80 cm (11.8–31.5 in) tall; stems single or branched, stout, hairy. ***Sap not milky, leaves alternate on stems and opposite on branches,*** variable in shape but often very narrow and widest near base or tip, 5–10 cm (2–4 in) long, 0.4–2.5 cm (0.1–1 in) wide, pointed at tip, ***usually without leafstalk,*** hairy, especially beneath. ***Flowers produced in showy, branched, flat-topped clusters;*** each flower ***orange to red or yellow,*** 5-parted, petals (corolla) deeply lobed. Fruit a dry, narrowly egg-shaped capsule 8–14 cm (3.1–5.5 in) long, splitting open only along 1 side to release tiny, flattened seeds tipped with numerous, long, silky hairs. **Poisonous constituents:** Plant ☠

parts contain some glycosides, alkaloids, and resinoids that can cause weakness, staggering, and even seizures. The various species of *Asclepias* have killed sheep, cattle, horses, and goats. **Related poisonous species:** All 30 native species should be considered potentially poisonous.

Poison hemlock *Conium maculatum*

Habitat: disturbed sites such as fencerows, roadsides, stream and river banks, old fields and vacant lands; introduced from Europe. **Identification:** ***large, biennial herb*** to 3 m (9.9 ft) high, from large, white, carrotlike taproot; ***stems*** upright, branching, purple-spotted, hollow, ***smooth. Leaves basal,*** repeatedly branched, irregularly divided and highly dissected, ***resembling parsley leaves,*** broadly triangular in outline, smooth, dark green, ***with odor of parsnips when crushed.*** Tiny ***white flowers*** produced ***in*** compound, ***flat-topped clusters (umbels)*** 4–8 cm (1.6–3.1 in) wide; flower cluster stalks 4–10 cm (1.6–3.9 in) long. Fruits dry, egg-shaped, 3–4 mm (0.1 in) long, flattened on inner surface, conspicuously ribbed, grayish-green. **Poisonous constituents:** All plant parts, especially the stem, leaves, fruits, and root are extremely poisonous. The toxic alkaloids cause nervousness, trembling, reduced heartbeat, coma, and even respiratory failure. **Related poisonous species:** A related genus, *Cicuta,* contains several species, commonly called WATER HEMLOCK (next), which are also extremely poisonous. ☠

Water hemlock *Cicuta maculata*

Habitat: wet sites such as swamps, stream and river banks, ditches and bottomlands. **Identification:** ***large biennial or perennial herb*** to 2 m (6.6 ft) high, from one to a cluster of several, thick, fleshy, tuberlike roots; stems upright, branched, often purple spotted, smooth, exuding yellow liquid when cut. ***Leaves large,*** bi- or tripinnately compound on lower stem, upper stem leaves less dissected, leaf segments usually 4–8 cm (1.6–3.1 in) long, 0.5–3 cm (0.2–1.2 in) wide, toothed, smooth, ***with odor of raw parsnips when crushed. Small white flowers numerous in large, compound, flat-topped clusters (umbels).*** Fruits brown, dry, egg-shaped, 3–4 mm (0.15 in) long, with conspicuous ribs. **Poisonous constituents:** All parts of this plant are extremely poisonous. A resinlike cicutoxin causes severe abdominal pains, excessive salivation, vomiting within minutes of consumption, and can cause death. One of the most deadly poisonous North American plants! **Related poisonous species:** All 10 native species of *Cicuta* are extremely poisonous. Also see POISON HEMLOCK (preceding). ☠

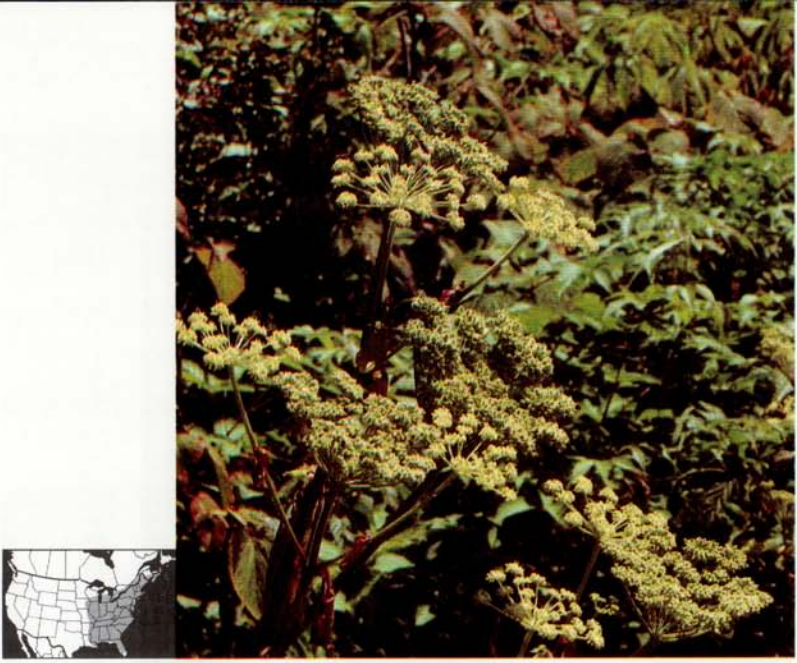

Poison hemlock: flowering stalks (Speas).

Water hemlock: flowering stalk (NYBG).

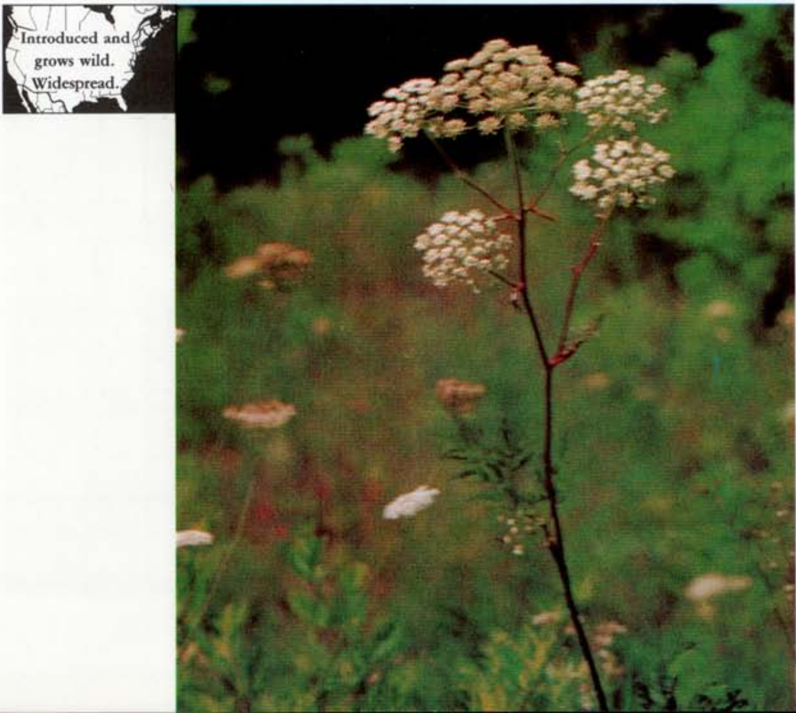
Introduced and grows wild. Widespread.

Southwestern coral bean: seeds and dried pods, flower cluster, and fruiting plant (Bernard).

American yew: mature fruits (Bogel). Fruiting branches (NYBG).

Southwestern coral bean *Erythrina flabelliformis*

Habitat: canyons, washes, desert grasslands, open oak woodlands. **Identification:** large spiny shrub or small tree to 5 m (16.4 ft); ***stems leafless except in summer,*** thick, brittle, armed with short spines. ***Leaves alternate, featherlike (pinnately) compound with 3 leaflets, the leaflets broadly triangular*** and tapering to a point, 2.5–7.5 cm (1–3 in) long, 4–8.7 cm (1.5–3.5 in) wide, grayish green; main leafstalk long, armed with several short, hooked spines. ***Flowers in large, showy clusters usually in spring, each narrow, elongated, pea-shaped, with 5 bright red to scarlet petals.*** Fruits are long, leathery pods 10–25 cm (4–10 in) long, constricted between the seeds; seeds hard, bright red, 1–2 cm (0.4–0.8 in) long. **Poisonous constituents:** Seed wall contains highly poisonous alkaloids that can cause death, even when consumed in small amounts. The seeds are sometimes used to make necklaces, which some wearers unfortunately have played with between their teeth. **Related Poisonous Species:** All species of *Erythrina* are poisonous. Eastern coral bean *(E. herbacea)* is native to the Coastal Plain from North Carolina to Texas.

American yew *Taxus canadensis*

Habitat: rich woodlands, pine forests, bogs, thickets. **Identification:** ***shrub, usually low, spreading and straggly,*** occasionally upright, up to 2 m (6.6 ft) high, branches turning reddish-brown with age. ***Leaves spirally arranged and spreading in 2 ranks along stems, narrow (linear), 1–2 cm (0.4–0.8 in) long, about 2 mm (0.1 in) wide, abruptly fine-pointed at tip, dark yellowish-green above, with 2 pale-green bands beneath,*** leafstalk short. Flowers tiny cones, either male or female. ***Fruits consist of a hard, dark, egg-shaped seed about 1 cm (0.4 in) long, enclosed in bright red to reddish-orange, fleshy disc.*** **Poisonous constituents:** Leaves and seeds contain one or more alkaloids called taxine, which can cause sudden death in people as well as horses and cattle. The fleshy red disc around the seed is edible but is better avoided because of the highly toxic seeds. **Related poisonous species:** Leaves and seeds of all species of yew *(Taxus)* are extremely poisonous. The introduced English yew *(T. baccata)* and the Japanese yew *(T. cuspidata)* are widely planted as ornamentals.

Poison ivy *Toxicodendron radicans*

(synonym: *Rhus radicans*)

Habitat: woodland margins, pastures, streams and river banks, fencerows, and disturbed sites. **Identification:** low shrub or vine, often climbing, with hairy, light-brown twigs. ***Leaves*** alternate, deciduous, ***compound of three leaflets*** (trifoliolate), leaflets broadest near base, 10–16 cm (3.9–6.3 in) long, 5–10 cm (2–3.9 in) wide, pointed at tip, ***entire or with a few coarse teeth along margin,*** yellowish-green, dull, often smooth, ***leafstalks reddish near junction with blade.*** Plants either male or female. Tiny male flowers produced in elongated, branched clusters 5–10 cm (2–3.9 in) long on new growth; small female flowers produced in smaller branched clusters 4–6 cm (1.6–2.4 in) long. ***Fruits are rounded,*** 4–6 mm (0.1 in) in diameter, ***creamy white,*** smooth, ***produced in clusters like grapes.*** **Poisonous constituents:** All parts of the plant have an oily resin containing urushiol. Contact with urushiol can cause minor to severe dermatitis, consisting of a rash and blisters. This affliction can be serious and most uncomfortable in the mouth, throat, and nasal passages as a result of eating berries or breathing smoke produced from burning plants. **Related poisonous species:** Poison oak *(Rhus toxicodendron)*, of sandy soils, pine forest, or barrens in the eastern U.S., and *Rhus diversiloba,* also called poison oak, of the Pacific coastal states, both contain oily resin capable of producing dermatitis like that caused by poison ivy.

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Ohio buckeye, Horsechestnut *Aesculus glabra*

Habitat: woodlands, hillsides, especially riverbottoms and stream banks. **Identification:** broad spreading tree with open, rounded crown and dark-brown, deeply furrowed bark. ***Leaves opposite,*** deciduous, ***hand-shaped compound*** (palmate) ***with 5 or 7 leaflets,*** leaflets usually widest near middle, 10–15 cm (4–6 in) long, 3.5–6 cm (1.4–2.4 in) wide, pointed at tip, finely toothed along margin, yellowish-green, leafstalks long. Flowers produced in large, erect clusters 12.5–15 cm (5–6 in) long, pale yellowish green, with 5-lobed calyx, 4 petals sometimes with red stripes. ***Fruits a leathery, 3-parted capsule 2.5–5 cm*** (1–2 in) ***long, with short blunt spines on outer surface*** of husk, ***containing 1 or 2 large, shiny, dark reddish-brown seeds.*** **Poisonous constituents:** All plant parts, especially the large seeds, contain aesculin, a glycoside. If ingested, this toxin can cause vomiting, stupor, twitching, paralysis, and possibly even death. Seeds of buckeyes or horsechestnuts resemble those of edible chestnuts. **Related poisonous species:** All native species of the buckeye genus *(Aesculus)* should be considered poisonous. Compounds from some species have been used medicinally. A coumarin glycoside, esculoside, obtained from the European horse chestnut *(A. hippcastanum)*, has been used to treat hemorrhoids.

☠

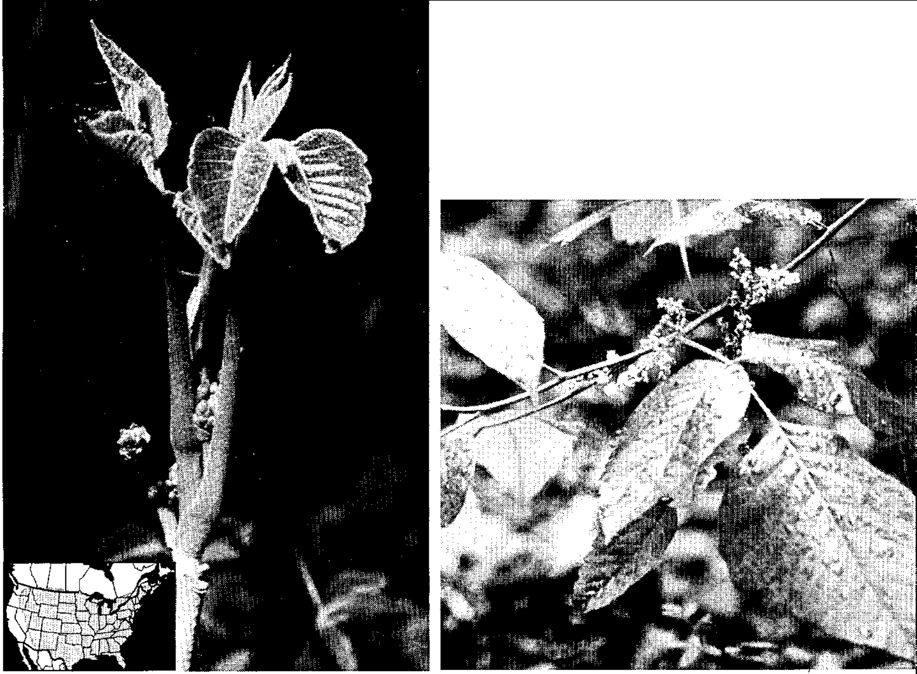

Poison ivy: immature plant with bronze leaves and fruiting branch with shiny green leaves and light-green female flower clusters (NYBG).

Ohio buckeye: Fruiting branch (Clawson).

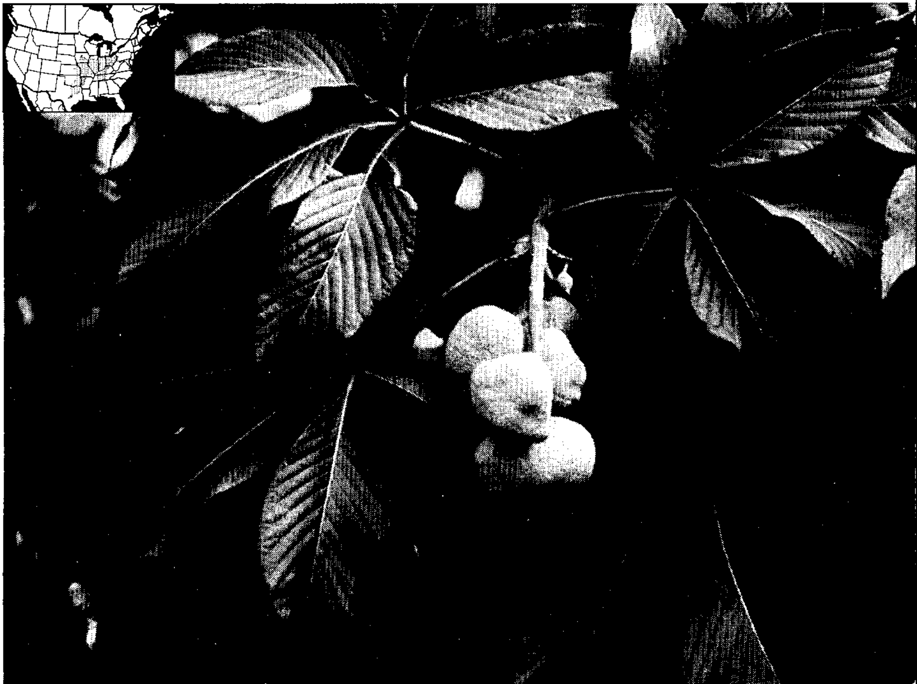

Picking Wild Foods

State and local regulations on picking wild plants vary, but mostly there are restrictions against taking plants or plant parts on public land. You should always check with park officials before foraging anywhere but on your own land.

In gathering plants, pick only on lands off non-posted access roads or from fields with owner's permission. Move from place to place, picking sparingly and only when there is several of any one plant. In addition: due to nature's changes and people's advances, many plants are now endangered. Even though this guide's plants are not endangered now, they may be in the future. Check your Local State library or Department of Agriculture for updates. Do not pick any endangered plants on private property.

FORAGING RULES

1. ***DO NOT*** collect plants closer than 200 feet from a road.
2. ***NEVER*** collect from areas sprayed with herbicides, pesticides, or other chemicals.
3. ***ALWAYS*** be familiar with all dangerous plants in the area.
4. ***POSITIVELY IDENTIFY*** all plants you intend to use for food or medicine. Check against three good field references with excellent illustrations.

If you are trying a plant for the first time, after checking your field guides, do the following:

1. Snip a piece of the plant and roll between your fingers and sniff. Discard if objectionable. If you like the smell, then rub the tiny piece on your GUMS, above your teeth.
2. Wait twenty minutes.
3. CHECK For burning, nausea, stinging, itching (all allergy results). Poisonous plants USUALLY produce one or more of these symptoms.
4. If no untoward reaction results, take another tiny bit of the plant and make a weak tea. (Place piece in teacup, pour boiling water over, cover, and steep for 10 minutes. Ingest a small amount.)

5. Wait another twenty minutes! Check for signs of irritation. If none, then reheat the tea and sip slowly.
6. Keep all samples away from children and pets. Keep edibles separate from samples to be identified—poisons will give their bad qualities to food through contamination. Bag foods, poisons, and samples separately.
7. Be aware that heating or boiling does not always destroy toxicity.

In general, it's a good idea to store all seeds and bulbs away from children and pets. Tape down the lids or use a locked closet for any questionable foods so children cannot reach them. Likewise, teach children to keep all plants away from their mouths. Do not let children chew on or suck nectar from unknown plants.

Avoid smoke from burning plants. Smoke may irritate the eyes or cause allergic reactions. Also, be aware of your neighbor's habits with regard to chemicals, pesticides, and herbicides. Ask questions! Call and report any chemical spills, contaminated areas, or other situations that may negatively affect your gathering safety.

Growing up with Wild Foods

"As a child, I always mashed and ate wild plants. This worried my Daddy. He began to teach us what not to eat and what good plants to enjoy. He showed us how to pick flowers from the top of ocotillo plants while on horseback. We sucked the honey from the bottom of each flower, much as Easterners used honeysuckle. The ocotillo flowers are just delicious. Our parents ran a cow ranch in Mohave County for fifty years, and we picked our ocotillo flowers often from horseback. A lovely life!"—Danielle Stephens, Kingman, Arizona.

Gathering

Decide which plant you will harvest on a particular day and take along a basket, a bag, or a sheet. Burlap is excellent if you are going to dry the plants, but biodegradable plastic bags generally are better for gathering because burlap gets heavy when wet.

Do any aquatic plant gathering in the morning, as the cool air and water will keep your collection fresher. Plastic bags are waterproof and lightweight, but remember to use biodegradable bags, and reuse them as often as possible. (Do not leave wild food in the sun, especially inside a plastic bag, because the food will wilt quickly; I have spoiled hundreds of milkweed buds this way!)

A flat, round tray also works well for gathering in tall grass, especially when gathering fireweed. It can be great fun wading through a field of these magenta flowers, snapping off the tips and tossing them onto a tray held above your head.

For most gathering, I use a clean sheet and a two-foot section of string. A small amount of wild food will fit in your basket or bag, while a winter's supply will fill a clean sheet. When the sheet is folded up and tied with a string, it can be hung up easily in a warm, airy spot to dry. The sheet method of collection also allows the bugs to crawl out of the food and provides an easy view of how much you have gathered.

When gathering wild foods, remember that certain plants snap off easily while others are better cut cleanly with a knife or scissors. If the plant gives you any resistance to a snap, give way to a tool immediately. A clean cut will help the plant recover quicker and you'll have greater gathering speed and accuracy.

Cutting a batch of leaves on the stem is simple when you hold the stem with one hand and with the other cut the stem with a sharp knife. When I gather with a penknife or scissors, I slide my fingers into the middle of the clump and go for inside growth. The plant then folds up around what I took and rejuvenates nicely. Goldenrod, asters, yarrow, and Queen Anne's lace work especially well this way.

If you're using the sheet method, you may want to strip the leaves off the stems while gathering for ease in drying. At this time you can also separate your favorite flowers for tea. Don't forget to save the stems, though, as they can be valuable, especially mint, spearmint, yarrow, and thyme.

When you've gathered enough, pull the corners of the sheet together, and use the twine to tie it closed. I often hang the bundle from a tree or other obvious spot and retrieve it later. This method also helps mark the trail. (I use a cactus in the desert since trees are sparse.)

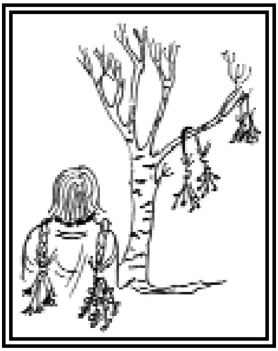

A Food Tree

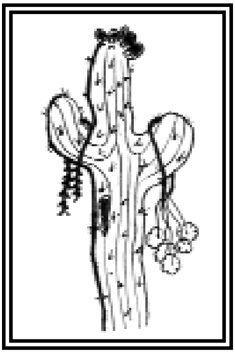

Saguaro as a food tree

Tie enough stems together to make a bunch, but be sure the leaves aren't packed too tight, lest you prevent air penetration. As a rule, when you swish the bundle in the air you should "feel" and hear the air moving through it.

Waists and belt loops also work well for carrying bundles of plants. You can also use burdock leaves or mullein to roll up several smaller items. Roll up nuts inside large leaves and put them in your pockets as you go. Fruits, twigs, nuts and flowers all wrap well in large leaves.

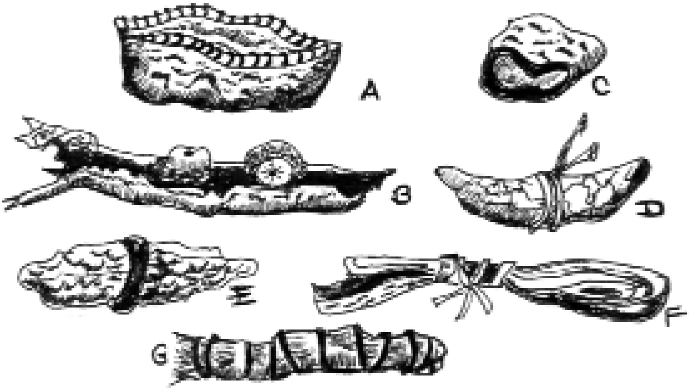

Leaf Bundles: A) White birch bark waterproof container, B) A bark tray, C) Hollow bark, D) Burdock leaf wrapping for small foods, E) Mullein leaf wrapping for small objects, F) Kit of white birch strings, and G) Bundle of foods, grasses or twigs.

In summary, here is a list of tools I generally use for gathering:
- A sheet
- Scissors
- 2-foot length of string
- Biodegradable plastic bags
- Penknife and Bowie knife
- Gloves
- Snake stick with fluorescent handle (in the West)
- Hand axe (in the East)
- Burlap bag

Washing the Foods

Certain plants attract aphids, ants, and "no-see-ums," as well as collect the usual dirt and dust. In the Adirondacks a nearby stream is always available, so washing large quantities of plants is always easy, no matter how dirty they are. But in Arizona, apartment living demands the use of a bathtub—it's the easiest way to wash a large quantity of food. Of course, it's always best to use a hose first, especially for roots, eliminating most of the soil before taking them into the house.

When cleaning small plants or bunches of leaves that aren't too dirty, it's a good idea to use a drainable container such as a colander. Some containers can be made to drain by poking holes in the bottom. Some plants may need more soaking, however, and may even need to soak overnight. In this case, soak in 1/4 cup vinegar to a tubful of water. In any case, it's best not to put too many types of plants in the same tub, since you may have difficulty separating them later.

Finally, here's a quick tip that will make it easier to clean your tub and prevent a clogged drain: Before filling the tub, place a piece of cheesecloth over a rubber stopper and use it as the plug. When you're ready to drain the tub, pull the stopper, but hold the cheesecloth in place. When the water is drained, just shake out the cheesecloth and save it for the next time!

Edible Wild Flowers

The following are common wild flowers I utilize often.

Birch catkins—unopened catkins eaten raw or brewed as tea. Dried or frozen for storage. Also cooked.

Blue Asters—All wild asters and flower buds may be eaten raw, cooked or dried and ground for flour.

Cattails—Flowers and flower buds are eaten raw, cooked, or dried and ground for flour. Used in tea.

Chamomile—White flowers and flower buds may be eaten raw, cooked, steeped for tea, or dried for storage.

Clover, Red or White—Flowers and flower buds are eaten raw, cooked, dried for tea, & frozen in ice cubes.

Dandelions—Whole flower and flower buds may be eaten raw in salads, stir-fried in garlic, frozen for use later. Used in tea.

Fireweed—Whole flower and flower buds are eaten raw, cooked, or dried for storage.

Goldenrod—Whole flower and flower buds are eaten raw as a tonic, and dried for tea. Frozen for storage; used in tea.

Maple—Flower buds are eaten raw, cooked, or dried for tea and storage. Can also be frozen.

Meadowsweet—Flowers and buds are eaten raw, cooked, or dried for a sugar substitute or tea.

Milkweed—Eastern flower is cooked as a vegetable, or frozen or dried for storage. Western varieties are caustic from desert sand.

Mint—Flowers and flower buds are eaten raw or cooked, or dried for storage; frozen in ice cubes; used in tea.

Mustard—Flowers and flower buds vary in intensity; may be cooked or eaten raw, and frozen.

Pine—Pine flowers or young cones are called catkins and are eaten raw, cooked, and dried for tea; also frozen.

Prickly Pear—Flowers are eaten raw in salads, and cooked; frozen for storage.

Queen Anne's Lace—Flowers and buds are eaten raw, cooked, frozen, and dried for storage.

Roses—Flowers and flower buds are eaten raw in salads, cooked, also frozen in cubes for storage.

Thyme—Flowers and buds are eaten raw, cooked, or dried for tea; also frozen.

Violets—Flowers and flower buds are eaten raw in salads, cooked, and dried or frozen for storage and tea.

Wintercress—Flowers and buds are eaten raw, cooked, and dried.

For information sections on drying and freezing flowers, see pages 33, 37, 39, 42 and 43 respectively.

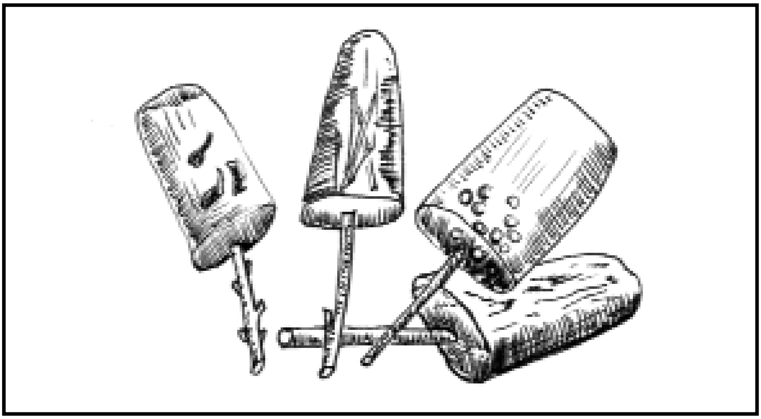

Wild Popsicles

Edible Roots

During my homesteading days I became interested in the many uses of plant roots. A particular experience gave me a lasting respect for the roots of wild plants.

In mid-winter, the ground was frozen and a snow-encrusted world was our environment. My son Todd had developed a bad cough. Soon Todd's condition worsened and he was coughing steadily. He needed more than the usual remedy of pine tea and honey. I knew about the antihistamine properties of mullein root. I could see the tall brown spikes of mullein poking above the snow like sentries standing beyond our camp. But the temperature was 20 degrees below zero and the ground was frozen solid.

The woodstove was filled with hardwood coals. I collected a pail of coals, put on my snowshoes, and went out to make a path to the closest mullein plant I could find. I scraped away as much snow as I could from around the plant and poured the hot coals on the icy crust at its base. (A very heavy pail is necessary for this, as coals will burn through a thin pail very quickly.) Sizzle, sizzle. The coals sunk quickly into the crusty ice. I returned to the house and fetched more coals. Pausing a few minutes between pailfuls, I scraped away each layer of slush until I reached mud. I placed a circle of dry wood around the base of the plant and made a large campfire inside the circle. With the wood concentrating the heat at the plant's base, the fire became hot in no time. I used birch bark to keep it very hot, adding a large sheet or two at a time. We were lucky to live next to a sawmill that cut white birch logs, and sheets of bark were plentiful. Never cut birch strips off a live tree.

After a long, cold hour, I scraped the remaining coals out from the circle and easily dug out a foot-long mullein root. It was partly decomposed, but there was more than enough root to brew a concentrated tea for Todd. He drank 2 tablespoons every hour, and his cough was calmed. Mullein root tea is an effective expectorant, helping Todd discharge mucus from his throat and bronchial tubes. This wintertime experience gave me untold security, knowing that mullein roots were out there if we needed them for medicine or food. This "underground farm" took on new meaning: it was available to us even through several feet of snow and in 20 below temperature.

The following edible roots are ones I use:
Amaranth—Used as a vegetable; dried & ground for flour.
Arrowhead—Tuber used as potatoes.
Balsam fir—Used for medicinal purposes (sedative), & tonic.
Burdock—Used as a vegetable, dried and ground for flour.
Cattail—Dried and ground for flour.
Chicory—Used as a coffee substitute.
Dandelion—Used as a vegetable and tonic.
Evening Primrose—Used as a vegetable flour.
Fireweed—Used as a medicine and a food.
Goldenrod—Used for a blood tonic tea.
Malva neglecta—Used as vegetable; dried & ground for flour.
Pine—Used for tonic and stimulant as well as rope making.
Plantain—Used for vegetable and as an antiseptic
Purslane—Used as a vegetable; dried and ground for flour.
Queen Anne's Lace—Used as a vegetable and dried food.
Strawberry—Used as a vegetable, a medicine and as an appetite stimulant.
Wild lettuce—Used as a vegetable.

Plant roots are greatly under utilized, and their magnificent properties barely understood. For example, many are aromatics.

Roses, for instance, have an aromatic root that can be reused many times, until the scent and color are gone. Scrub off any mold or black spots before use. Mullein root can be reused many times for tea, as can mint roots.

Clip newly gathered roots from the plant and scrub with a toothbrush. Then use fresh, or dry and store.

To use fresh, peel the root as you would a carrot or parsnip and slice crosswise or lengthwise. To dry the roots, place in a paper bag and label carefully with the name of the plant and the year you collected. Hang to dry. Reconstitute in boiling water or place in a grinder and grind to flour.

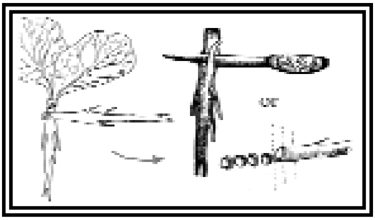

Harvesting roots: peel & slice either crosswise or lengthwise.

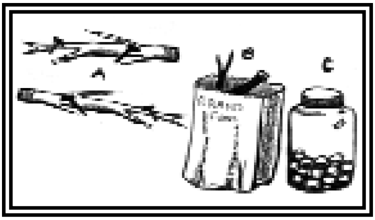

Storing roots: A) hang on wall B) dry & store in paper bag C) store dried slices in glass jars

Edible Parts of Trees and Shrubs

Many trees and shrubs have edible parts and can be a major source of food in the wilderness. The chemical content, vitamins and minerals are found in leaves and flowers, but in concentrated form in shrubs and tree bark. Inner bark, the layer underneath bark, is the “meat” of a tree. Twigs have both bark and inner bark. For example, pine or balsam fir bark strips, cut 1/3 inch to 1 inch wide, to fill a 2-quart glass container will yield a winter’s supply of tea. One small shrub, such as a rose bush, can yield a winter’s supply of tea.

In calculating your yield, figure one twig, 6 to 8 inches long, yields a moderately strong cup of tea. This tea could be used as a soup base. To prepare for cooking or tea, break the twig several times to release the flavor and steep or boil as intended. To store twigs and stems, place in dark paper bag. Or, place in glass jar and cap tightly. Wrap with opaque paper or foil to keep it dark. And, of course, label with the collection date.

The following diagram shows two different methods of peeling bark. Method A shows types of plants which will allow big pieces to be peeled. Method B makes smaller wispy pieces by first splitting along the length, then peeling small pieces around the girth from one side of the split to the other.

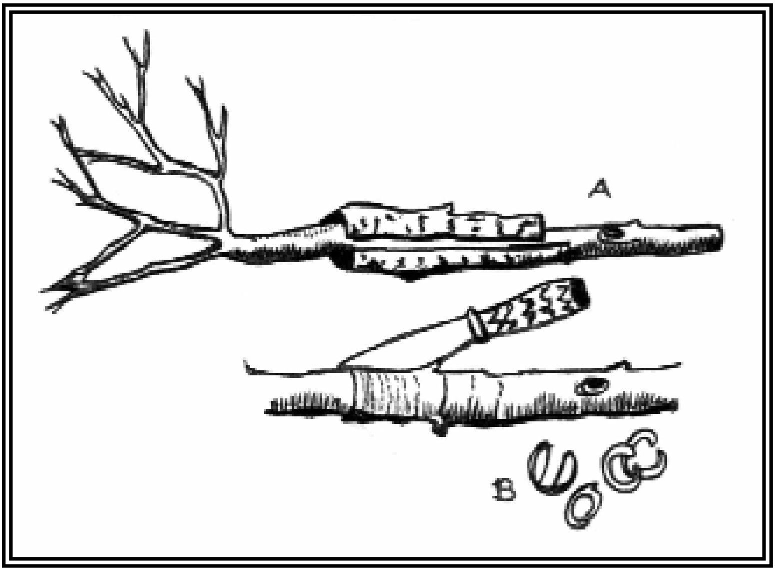

Peeling bark in strips.

The following are trees and shrubs and commonly harvested for their edible parts:

- Balsam fir—Parts of the entire tree are edible, especially the inner bark, sap, twigs, needles, and flower buds and seeds.
- Birch—Entire tree is high in mineral content and medicinal value; sap, buds, catkins and seeds are edible. Birch catkins, buds, twigs and bark, as well as inner bark, are all loaded with trace minerals, and beta-carotene.
- Blackberry—Inner bark, twigs, flowers, fruits and seeds are edible.
- Blueberry—The twigs, bark and roots are edible as well as fruits.
- Maple—Entire tree is edible, especially inner bark, sap, twigs, buds, young leaves, and seeds.
- Meadowsweet—Entire plant is high in minerals and medicinal value; inner bark, twigs, buds and flowers, leaves and seeds are not to be eaten in bulk.

- Pine—Entire tree is edible; inner bark, sap, twigs, needles, catkins, and in one species, Pinon pine nuts.
- Prickly pear—Buds, flowers, pads and fruits of plant are edible.
- Raspberry—Entire shrub is edible, including inner bark, sap, twigs, buds, flowers, fruits and seeds.
- Rose—Entire shrub is edible, especially inner bark, sap, twigs, buds and flowers, leaves and seeds (hips).
- Saguaro—Buds, flowers and fruits, and seeds are edible.
- Sumac—Flowers, fruits and seeds are edible.
- Tumbleweed—Twigs, buds, and leaves are edible.
- Willow—Entire tree has high mineral content or medicinal value and should not be eaten in bulk. Inner bark, sap, twigs, buds and catkins, leaves and seeds are eaten in moderation.

Teas from Wild Plants

Gathering and preparing teas from wild plants is simple and rewarding. For example, a large supply of thyme for tea can be harvested in just two minutes with scissors. Drying requires no more than a screen and takes but a few hours. Using the back shelf of my car, I can have it dried and ready for storage in a few hours. In a few days, the patch grows back and I can harvest it again. This is true for most tea plants.

Plants commonly gathered for tea include:

- balsam fir
- birch
- blackberry
- blueberry
- chamomile
- chicory
- clover
- dandelion
- fireweed
- goldenrod
- meadowsweet
- mint
- mullein
- raspberry
- strawberry
- thyme
- violet
- willow
- wintergreen.

(See Part II, the Field Guide, for information on individual plants.)

Picking Nettles

Do you want to try nettles but are afraid to pick them? Take your gloves, a pair of scissors, and a container and head for the nettle patch. Cut the leaves directly into the container, holding the plant with your gloves. Or, to take home the entire nettle plant, cut two individuals of a plant that is long and straight, such as goldenrod. Lay them on the ground parallel like railroad tracks. Cut the nettle, using your gloves and scissors, pile them across the top. Then pull the goldenrod stems up and fold over so you can carry your bundle home without getting pricked by stickers.

Storing Teas

You might enjoy fresh tea brewed from raw materials. Remember that raw material is a bit less effective and tastes weaker than dried.

Wild plants or leaves that have dried until crisp can easily be stripped clean for storage. Place a clean sheet on a counter and put bundles on top. Using gloved hands, pull the dried leaves, seeds, or flowers down gently, then scoop up and crumble by twisting the sheet and wringing it. This is what is known as a rough grind. In some cases you can obtain the same results by using your hands. Store rough ground teas in glass jars.

You may store twigs in “tea sizes”, such as six inch sections of willow equals approximately 2 aspirin. Six inches of a rose stem equals 1 cup of tea. Four inches of goldenrod stem equals one cup of tea. If you use a mayonnaise or quart size jar many cups of tea are easily stored.

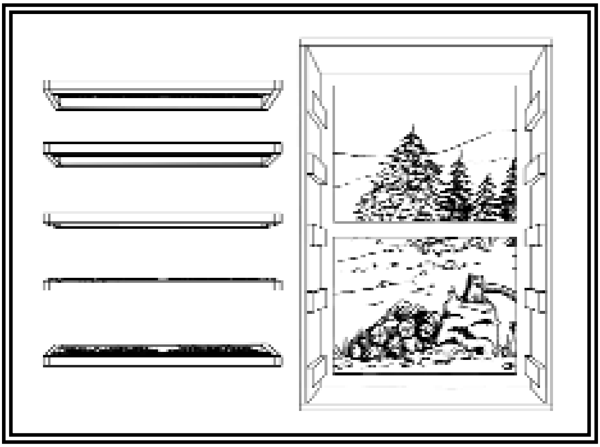

Window food dryer with removable racks.

Flour from Wild Grains

Bulrushes and phragmities grow prolifically in wet lands. They are a familiar sight to most of us, yet few people realize what a valuable food source they are. In both the East and West, I have gathered and ground bulrushes to make flour. The flour makes delicious muffins, cookies, and breads. What's more, there are common grasses growing in most people's lawns that can likewise be harvested for flour. My favorites are listed on page 35.

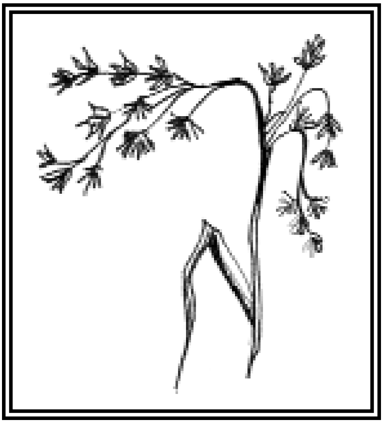
Bullrush

Gathering bulrush stalks is an easy task, so long as the water is clean. Know where the water comes from and look carefully at the stems as you cut them. It is a good idea to wear gloves until you are well used to spotting the stems of the rushes. Poison hemlock may be in the same marsh, so be careful! (see Part II, Field Guide, and Part V, Poisonous Look-Alikes).

Cut one of the two stems of a bulrush plant at a time, sliding your gloved finger down the stem, cutting, and placing the rush up and under your armpit. As you move along, the batch of plants under your arm will grow. When you have enough, stop and tie them into a bundle. Hang the bundle in a tree or make a yoke for around your shoulders. Pick from the centers of the bulrush clumps, so the plant will grow back quickly.

Dry bulrush in an attic, car, or other warm and dry area. Let dry thoroughly. They may appear to be dry, but check. The stems break, crack or snap easily when dry. Place in glass containers until you can grind the grain to flour.

When you are ready to grind to flour, check bulrushes for tiny black dots. These may represent ergot, a poisonous fungus. If present, discard the plants.

Each bulrush stem yields several teaspoons of flour, and a screen full of stems and flowers yields approximately 1 cup of finely ground flour. The color of the flour depends on the bulrush: it will be green if bulrushes are picked early in the season, tan if picked later.

> *"He causeth the grass to grow for the cattle, and the herbs for the service to man; that he may bring forth food out of the earth."*
>
> Psalm 104:14
>
> *"Also, to every beast of the earth, to every bird of the air, and to everything that creeps on the earth, in which there is life, I have given every green herb for food, and it was so."*
>
> Genesis 1:30

Harvesting Grasses

The following are common lawn grasses that make excellent flour. They are also known as Graminae, since they are in that family of plants. Since these plants are not described in Part II, check identification in several other reliable field guides. The grains may also be cooked whole for granola, cereal, and other uses.

Barnyard grass— *Echinochloa crus-galli, Graminae* Family
Barley grass— *Hordeum pusillum nott, Graminae* Family
Broomsedge— *Andropogon virginicus, Graminae* Family
Crabgrass— *Digitaria sanguinalis, Graminae* Family
Foxtail grass— *Setaria italica, Graminae* Family
Goosegrass— *Eleusine indica, Graminae* Family
Jungle grass— *Echinochloa colonum, Graminae* Family
Quackgrass— *Agropyron repens, Graminae* Family
Rye grass— *Lolium temulentum, Graminae* Family
Wild oats— *Avena fatua, A. barbara, Graminae* Family
Wild rice— *Zizania palustris, Graminae* Family
Wheat grass— *Triticum aestiuum, Graminae* Family
Yellow nutsedge—*Cyperus esculentus, Graminae* Family

Some grains are better sheared with scissors, such as crabgrass. Others are easily collected using a pillow case. If the seeds come off the stem easily, just put the pillow case over the tops, bend the grasses over, and wring the seeds off. This method is especially good for marsh grasses. I've happily spent many an evening gathering a quart or two of seed heads while watching the dragonflies in the setting sun.

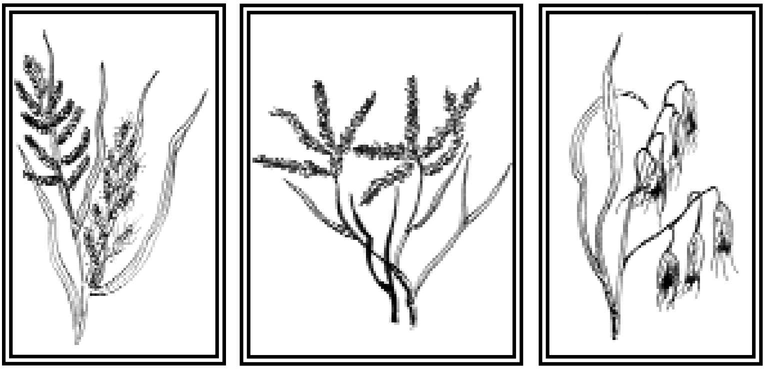

Barnyard Grass, Goose Grass & Wild Oats

After the grains are dried, they can be ground to flour. Use your own method; grinders, processors, and mortar and pestle are all successful.

I usually clip stems to six inches from the grain. Grinding a bit of the stem adds to the fiber content.

Grains contain protein, and protein is one of the building blocks of life. Unrefined grains are best because the natural elements have not been processed out. Much of wheat's protein and vitamins E and B^{6} are lost in the refining process. As a result we have "enriched" bread, which tries to make up for the loss. Isn't it a better idea to keep those nutrients to begin with? This is why whole wheat flour and whole natural grains are the wise nutritional choice today. Also, fiber is lost in the processing of wheat flour. Yet the higher the fiber content of our food, the better for our digestive system. Unrefined, natural grains are truly the only answer to better health.

Blend one-half cup of assorted wild grains putting them into a wide-mouth thermos and then pour boiling water over them. Cap tightly and let sit overnight to create an instant hot cereal for the morning or the ingredients for a rough bread dough or wild "pancake." Add a little vegetable flour such as amaranth or clover for a high-energy meal!

Preserving Nature's Bounty

Drying for tea or grinding to flour, as the preceding sections describe, are major ways to preserve and enjoy wild food, but there are other possibilities as well. You can collect roots, branches, needles, and flowers in season and either dry them or freeze them for later use in a variety of ways.

In the Adirondacks, my pantry was full of wild foods preserved for winter. The assortment varied from year to year, and when I moved West, there were many substitutes. Tumbleweed took the place of fireweed. Malva neglecta was used instead of arrowhead for flour. The caption to the illustration on the next page tells what wild foods I commonly had in my pantry, East and West.

Typical Pantry Storage

Eastern cupboards were always filled with certain staples. I did not own a freezer in those years. All staples were dried.

Plants hanging in storage pantry.

Car drying racks.

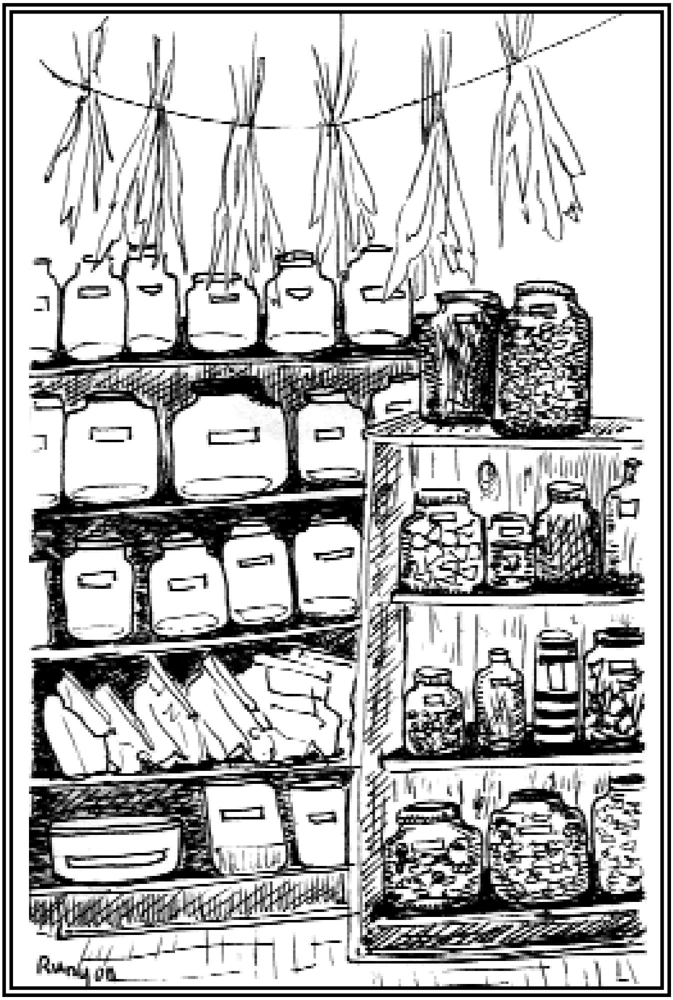

The Pantry

Gallon jars of leaves included: Amaranth, asters, lamb's quarter, strawberry, clover, red and white clover, chicory, daisy leaves, dandelion, dock & malva neglecta. Western jars also included tumbleweed, mesquite beans, palo verde beans & chaparral.

Gallon jars of twigs for teas included: Rose, meadowsweet, pine, balsam, birch, maple & willow, and, in the West, ephedra (Mormon tea).

Separate jars of dried flowers: Aster, clover, chamomile, chicory, dandelion and rose, both in the East and West.

My closets always had a few choice branches stored whole: pine, balsam, willow, and maple. Closets in both East and West are filled with paper cartons of grasses for future use as flour and, of course, the Christmas tree and wreath from year to year!

Preparing Food for Storage

Once you've gathered your bounty, shake off any soil and wash plants, leaves or roots gently under running water. Wash all foods except cattail pollen. Scrub roots with a toothbrush.

Trim off any dead leaves or parts. Remove and separate leaves, seeds, flowers, and roots for separate drying; or leave plant whole (as you might dry lamb's quarters or amaranth for flour). Cut stems to storage-container lengths.

Drying Methods

There are a few basic "don'ts" about drying food that you should know before you begin. Don't dry leaves in direct sunlight; find a warm, airy place out of the sun. Never dry foods near a road or garage, or you'll taste exhaust fumes. Lastly, don't dry pine needles in an oven or microwave. They are very volatile and may explode.

The best indoor drying apparatus I know is a window screen, convenient for either an apartment or a home. You simply bring home your favorite wild foods, wash them well, trim, and shake off excess water. Lay the foods on the screens, keeping any branches apart somewhat. Slide the screen into bracket and start the next screen. (See page 33 for an illustration of screen assembly.)

When you feel that food is as dry as it can be, preheat the oven to 300 degrees and turn off. Heat the foods for five minutes, then put in hot clean jars, or put the gatherings in the jar, without the lid and heat jar, foods, and all for five minutes at 300 degrees. Often I simply turn the oven to 300 for a while, put the food in, and turn off the oven, leaving it to cool slowly. I take the jar out when the oven is partly cool, then cap tightly for storage.

There is another method. Although you may feel odd driving around town with a rack of "weeds" in the back of your car, it is by far the most efficient drying rack! In July and August, one day on the back window shelf of your car will thoroughly dry most leaves. Just think, while spending money driving around town, you are performing an energy-saving task and making a step toward long-term food storage, ultimately saving dollars. The car doesn't have to be in the hot sun all the time. Park in the shade if you wish.

Caution: Don't dry foods in a car when the outside temperature is over 80 degrees—toxic fumes may arise from plastic or vinyl seats.

The Drying Roof

There are more ways to dry wild plants. Here's a simple method I used.

Looking around for a flat place to put the screens I used to dry plants on, I noticed that the roof seemed to take up a lot of space—space that didn't do much other than keep the rain out. So I climbed a ladder and began to place the screens on the roof. Since there were poplars surrounding the cabin, the shade was perfect for drying apples and berries. We even nailed on boards as scaffolding to create a large accessible drying space. You may not want to go this far, but with a little ingenuity you'll find almost any place can be used to dry fruits, berries, and such.

We dried several types of wild apples. We did this every year using the larger varieties, choosing about half the normal size apple. We also dried crabapples on the roof. We gathered the crabapples by spreading a sheet under the tree and shaking the limbs, making fruit fall. We cored the apples and then sliced them crosswise about 1/3 inch thick. We threaded these slices on old broom handles, then hoisted them up to the roof. After a few days, the crabapples had shriveled and became leathery. After a 5-minute baking in the oven to dry them completely (oven preheated to 300 F. then turned off), we stored them in glass jars. In winter we used them in everything from cereal to cobblers, pies, and snacks.

Linda says- You can also string the dried apple slices together with a needle and string. Not unlike the garlic and hot peppers in the Southwest, your wild foods can decorate your kitchen. I even string roots this way.

Label the jars with the date of drying before storing. The storage place is important. Closets work best. You need darkened spaces for dried foods, out of direct sunlight.

Store whole leaves and grind them into flour as you need it. For long-term storage, grind and place the flour in a shallow 1-inch pan and toast for five to ten minutes in a preheated 300 degree oven turned off. Store in glass for up to several weeks. Vegetable flour does not have a long life, so avoid storing for more than six months at a time.

Rinse dried branches to clean off any dust before you use them. Rose or raspberry vines, pine or balsam branches, and weeping willow can be stored for years, but will accumulate dust.

Containers for Dried Foods

Generally, I'll save just about any glass jar and use it to store dried foods. As long as they are in glass with a tight-fitting lid, wild foods can be stored for long periods of time. My friends bring me their glass jars: in fact, I have begun to consider myself a recycling center! Of course, brown glass is best because it lets in less light, but it is not readily available. You can find green jars with narrow screw tops, however, and these are ideal for storing seeds, nuts, and berries—things that pour well from a narrow top.

The best container for large amounts of stored leaves, twigs, branches, and such are the half-gallon glass containers that deviled eggs, pickles, and mayonnaise come in. Restaurants or convenience stores might save them for you.

Devices that seal plastic bags, removing the air, work almost as well for long-term storage. Roots store well in paper bags, as well as nuts, twigs, barks, and branches to a lesser degree. As long as food is as dry as possible, long-term storage is possible.

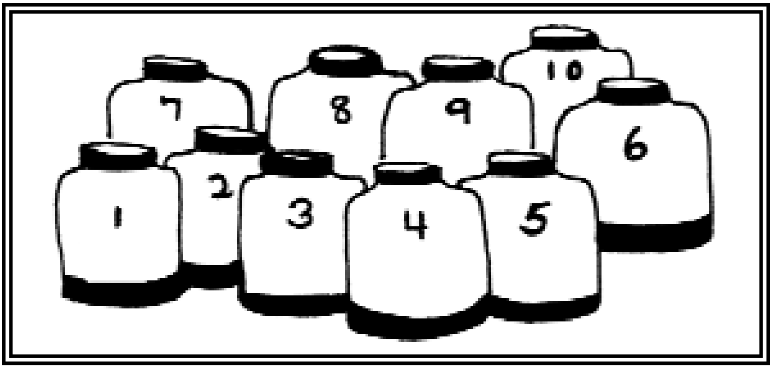

Storage Jars: #1 vegetables, #2 flowers, #3 twigs, #4 roots, #5 stems, #6 nuts, #7 corms, #8 buds, #10 flour

Storage Problems and Solutions

Problem: Pine needles that are stored in glass begin to display black spots or black mold.

This is known as ergot and develops on incompletely dried wild foods which are then sealed in airtight containers. Discard the contaminated foods as these molds are highly toxic. Similarly, grain that was incompletely dried also hosts this toxic black mold. Willow branches stored in a damp area outside develop black spots, also recognized as a poisonous mold.

Freezing Your Wild Foods

Freezer packages of vegetable matter have a life of six months. Roots, twigs and tubers last a bit longer as a rule. When I find freezer crystals throughout the freezer package, it's time for a massive green soup! Then you may re-freeze the soup.

The following are the wild foods successfully frozen. All must be steamed the indicated time before freezing.

Food	Steam Time	Food	Steam Time
Aloe Vera	raw	Plantain	1-2 minutes
Amaranth	1-2 minutes	Prickly pear	2-3 minutes
Arrowhead	1-2 minutes	Purslane	1-2 minutes
Aster	3 minutes	Malva	
Blackberry	2-3 minutes	neglecta leaf	1-2 minutes
Blueberries	1-2 minutes	Maple	2-3 minutes
Burdock	3 minutes	Milkweed	
Cattail	3 minutes	heads	3 minutes
Chamomile	1-2 minutes	leaves	2 minutes
Chickweed	1 minute	Mint	1-2 minutes
Chicory	3 minutes	Queen Anne's	1 minute
Clover	1-2 minutes	Raspberry	2-3 minutes
Daisy leaves	1-2 minutes	Rose	1 minute
Dandelion	3 minutes	Saguaro buds	3 minutes
Dock	3 minutes	Shep.'s purse	1-2 minutes
Evening		Strawberry	
primrose root	1 minute	leaves	2 minutes
Filarie	1-2 minutes	Thistles (all)	1-2 minutes
Fireweed	3 minutes	Thyme	1 minute
Goldenrod	1-2 minutes	Tumbleweed	1 minute
Grape	2 minutes	Violets	1 minute
Lamb's quarters	3 minutes	Wild lettuce	1 minute
Mustard	1-2 minutes	Wood sorrel	1 minute
Nettle leaves	2 minutes	Yarrow	1 minute

Some inexpensive freezing tools you'll need are:
- Plastic wrap
- Large plastic bags
- Labels or marker pen

To freeze vegetables, steam and drain the vegetable in a sieve; save the liquid for stock if desired. (See Soup Recipes starting on page 198.) Place one-foot-long piece of plastic wrap on the tray. Add 1/2 pieces of steamed vegetable and fold the edges in. Roll package tightly to seal. Any remaining liquid will seep out of package. Place the package in a large plastic bag and label with contents and date of freezing.

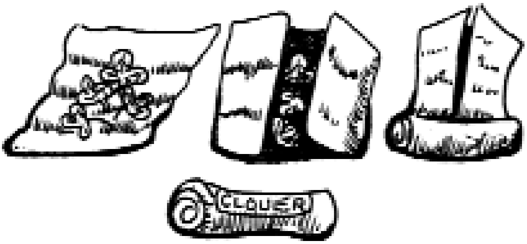

Vegetable Wraps

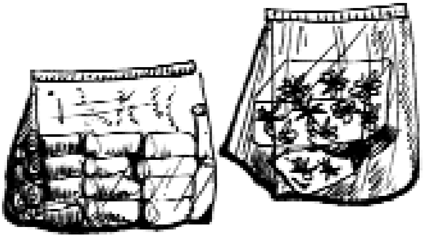

Freezing rolls of vegetables, flowers in blocks.

Freezing wildflowers is a simple matter of freezing whole flowers in solid blocks of ice. A frozen whole rose looks fantastic in a punch bowl. Use an ice cube with a rose inside instead of plain ice. As long as you use a container that will take freezing, you can create a bunch of frozen roses that looks like a crystal dream. My favorite luncheon surprise is layering a selection of flowers in different colors in a large, round bowl. I put in the bottom layer, add a little water, and freeze. A day later, I add another layer, add water, and freeze. And I repeat this until the display is to my liking.

To freeze whole roses, for instance, put a few inches of water in your containers, so that the flower does not float. Keep the pitcher of water handy so that you can reach it easily with one hand. Hold the stems in your other hand, and arrange the colors and shapes to suit you. (I cut the stems to uniform lengths first, making the job of holding them easier.) Then pour some water slowly around the sides, holding down the stems. Put on a lid or plate to hold the arrangement and freeze.

Whole heads of roses opened moderately and without the stems can be layered easily. The more roses in the container, the better. They won't remain in exactly the same position as you put them once you pour in the water, but if they don't float around a lot, the layers will be moderately undisturbed.

Pansies are relatively simple to freeze. Layer them in a sandwich bag and add a little water, then seal the bags. To freeze Queen Anne's lace flowers, spread plastic wrap or wax paper on a flat surface. Place the flowers face down on the wrap and roll up the wrap like a rug. If you have difficulty rolling a single piece of wrap with flowers, place cover sheet of wrap over the flowers and roll. Freeze the roll. Whenever you want some flowers, unroll the wrap take what you need, re-roll and return to the freezer. Queen Anne's lace flowers will turn brown when frozen, but they retain their delicious carrot taste and apparently their nutrition as well.

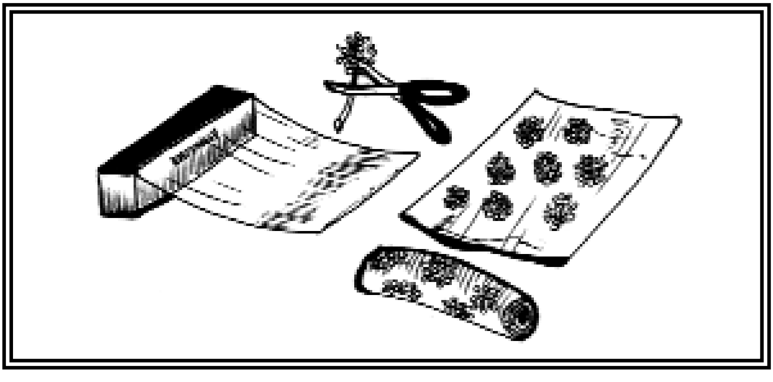

Freezing Queen Anne's Lace flowers.

Besides vegetables and fruits, you can successfully freeze vegetable stock and leftover fruits. Save all liquid from steaming or boiling vegetables or from leftover tea. The stock is best stored in freezer containers, ice cube trays, or heavy duty plastic bags. Soup stock can be frozen in layers until the container is full.

To freeze fruits, possibly for a mixed juice, layer the fruits in a large container as they are available. You might have a cup of raspberries—not quite enough to make jelly. Freeze in a large plastic container. Are there blueberries left over from making a pie? Add these to the fruit cache. When you have filled your container, you'll have the makings for a mixed fruit jelly or juice.

Decorations Can Be Edible Too

A blustery winter wind whistles outside the door, and my spirit needs a cup of hot rose tea—rose tea is filled with vitamin C, for muscle repair and vitality, nerve restoration, and a general feeling of well-being. From the rose-stem wreath on the north wall of my home, I break off a bunch of twigs, a few leaves, and one small dried flower. After rinsing and placing them in a tea pot, I cover the rose stems, leaves, and buds with boiling water. I let it steep for five minutes savoring the bouquet, and then serve myself tea from my old china teapot. Nature's bounty!

I had ventured out to a spot in the woods where wild roses grew. There they were, inviting me to make lush wreaths from the green shoots.

I took my loppers, and a big bag or length of twine, and began clipping off a few vines. I wound two vines together to make a circle, then added string to the overlapping ends to secure the wreath. I twisted more vines on the base, poking the ends through. When I finished, my decorative rose wreath was hung on the wall to provide a winter's supply of tea as well as to be a feast for my eyes and nose.

My home abounds with wild food wreaths. Circular, heart-shaped, sprays—all wreaths are either leaves or flowers for teas, grains for bread flour, vines or leaves for vegetables, and twig spices for herbal teas. I decorate every nook and cranny with food wreaths.

Wreaths made from wild grains are not only beautiful but practical. Since prehistoric days, people have twisted vines into coils and wreaths, combining craft with foraging. The Chippewa nation still does this today with wild rice hoops or wreaths.

What plants make the best food wreaths? Here's a list.

Food Wreaths
- Amaranth
- Aster
- Chicory
- Cholla
- Clover
- Daisy
- Dock
- Fireweed
- Grape
- Lamb's quarters
- Malva neglecta
- Queen Anne's Lace
- Rose

GrainWreaths
- Bulrush
- Crabgrass
- Phragmities
- Spice wreaths
- Catnip
- Chamomile
- Clover
- Mints
- Strawberry
- Thyme
- Wintergreen
- Yarrow

Tea Wreaths
- Balsam fir
- Birch
- Blackberry
- Maple
- Meadowsweet
- Pine
- Raspberry
- Rose
- Sumac
- Willow

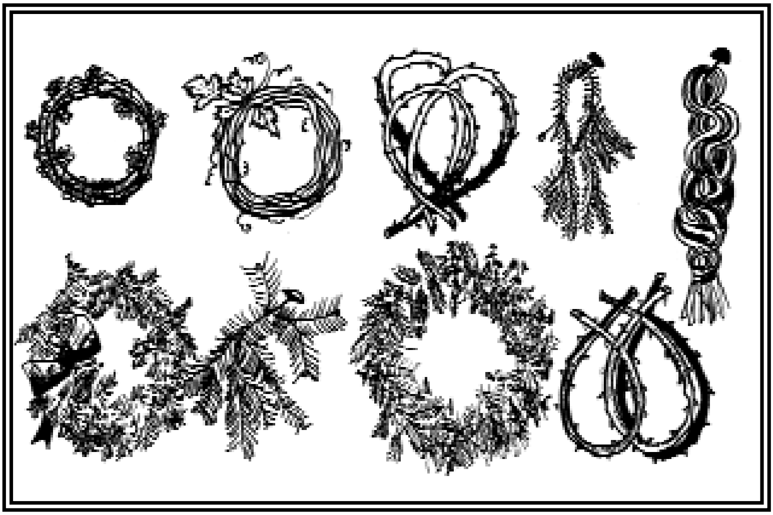

Food Wreaths (from left to right, top to bottom): Yarrow tea, Grape vine with tendrils for food, Raspberry canes for food and tea, Rosemary sprig for spice, Spice rope of thyme, mint & chamomile, (2nd row) Balsam fir & meadowsweet flowers for tea and food, Balsam sprig, Grasses, oats & dock seeds for food and flour, and Rose hoop for tea.

If you grow your own roses, treat them with a spray of mild soap and water instead of pesticides and herbicides to ensure their future edibility. Be sure your bush is at least 100 feet away from any busy street. And be aware of your neighbor's habits with sprays and wait a season to eat transplanted nursery stock.

When the time comes to buy your holiday tree, make sure it is organic. Christmas trees are often sprayed for insects and sometimes sprayed green to darken the needles. Find an organic dealer or cut your own tree. When the holidays are over and your tree is dry, spread a sheet around the base and shake off the dry needles. Place needles in a large oven container (a roaster, for example). Heat the oven to 300 degrees and then turn it off. Place the roaster with the pine needles in the oven and remove when the oven has cooled. Do not try to bake the needles! The resin is combustible. Put the completely dry needles into glass containers and enjoy five years more of your Christmas tree as tea.

The trimmings from your tree also make fantastic tea wreaths. Collect them before they are completely dry, rinsing and swishing any dust off the needles. Shape into wreaths and hang in your home for a source of fresh tea for weeks.

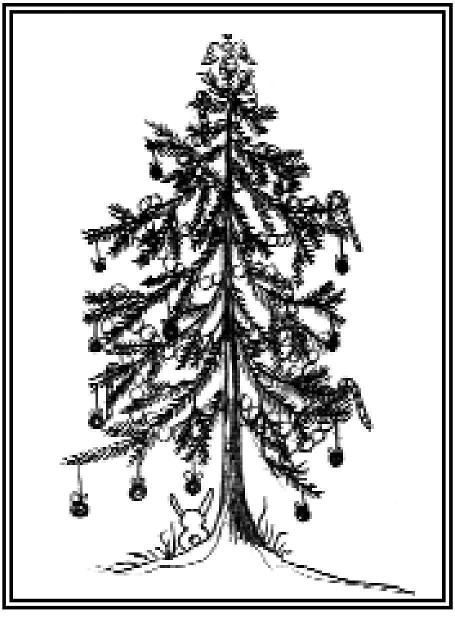

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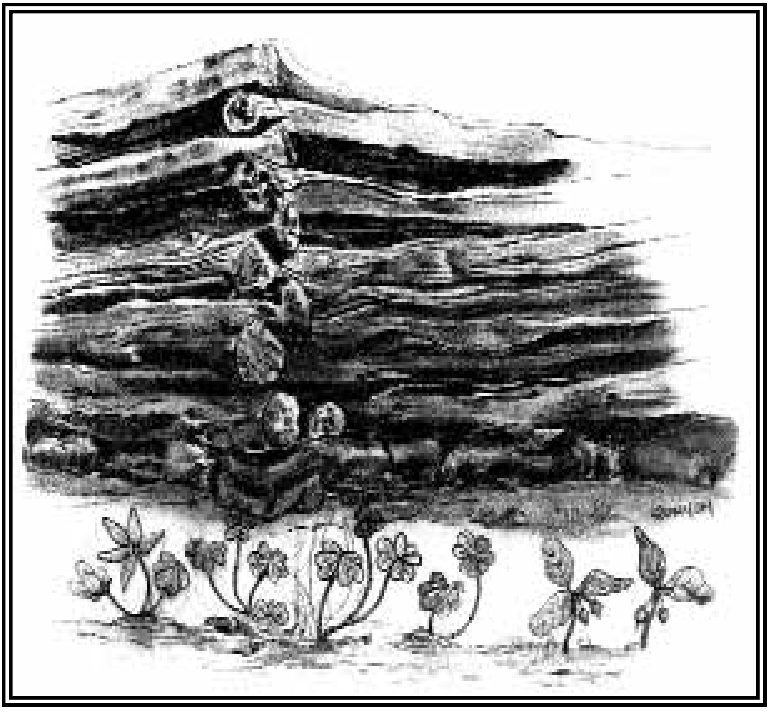

Left: garden sorrel Right: wintergreen

Part II: Field Guide to Wild Foods

Edible Plants

This Field Guide section provides illustrations and descriptions of the fifty-nine foods discussed in this book. It is not intended to substitute for a comprehensive field guide to wildflowers, trees, or plants. Rather, it should be used in conjunction with three well-illustrated, comprehensive guides to the plant life of your region. Also please note that plant sizes vary with environment, and measurements given here are intended as general guidelines only.

The material that follows is organized as following, information where applicable:

Common name.
Scientific (Latin) name of species, or genus, only if the entry describes a group of related plants.
Family to which the plant belongs.
Other Names: Other common names by which the plant is known; also, types are described if the entry deals with a group of plant rather than a species.
History: Brief background information on the origin of the plant and a notation if used by Native Americans.
Habitat: General growing requirements—where the plant is likely to be found.
Characteristics: Whether the plant is a tree, shrub, or herbaceous plant; whether annual, biennial, or perennial; major physical characteristics to help you identify it in the field.
Primary Uses: Whether used for food, medicine, or as a cosmetic; some mention of the uses the plant has been put to (not meant to be comprehensive).
Nutritional Value: When applicable, a general indication of the plant's value to human nutrition. See also the Nutritional Value tables at the end of Part II for further information on the nutritional value of these plants.
Medicinal Value: When applicable, information on medicinal uses of the plant. See the Appendix for explanations of these medical terms.
Cosmetic Value: When applicable, an indication of how the plant is used as external treatment or otherwise.
Collection and Storage: Tips on harvesting and preparation for immediate use or long-term storage.
Caution: There are some wild plants that can be mistaken for these edible plants. See the section on Poisonous Look-Alikes,

Part V. Note also that entries in the Field Guide include occasional cautions or warning notices about collecting and handling some plants. Be sure to heed these cautions.

Comments: Personal remarks and additional information on the plant and its uses for us all.

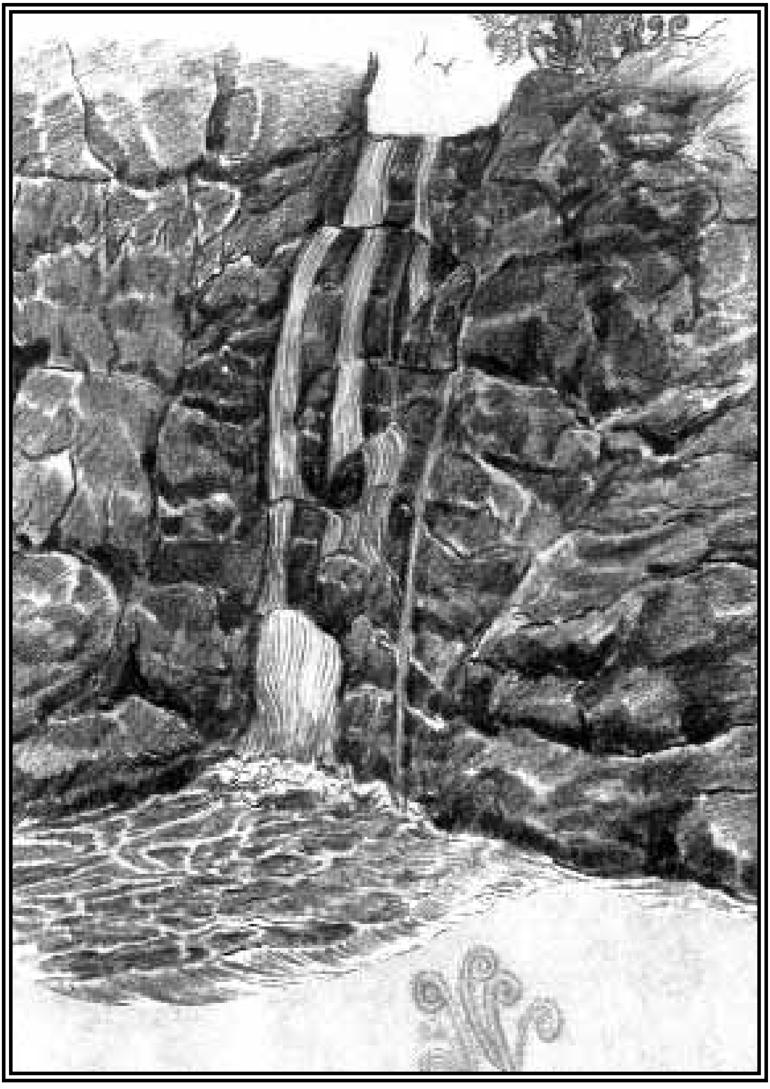

Foreground: fiddleheads

Legend to the Uses of Wild Foods

These symbols appear in the description of each wild food and indicate the main uses of that plant at a glance

Beverage

Bread

Casserole

Cereal

Flour

Jam

Medicine

Pickles 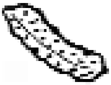

Salad

Soup

Sweets 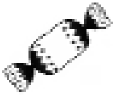

Tea

Toothpaste 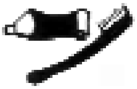

Vegetable

Wine

These symbols are used later in the poisonous look-alike section.

Edible

Poisonous

Aloe Vera

Aloe perfoliata vera
Family: *Liliaceae*

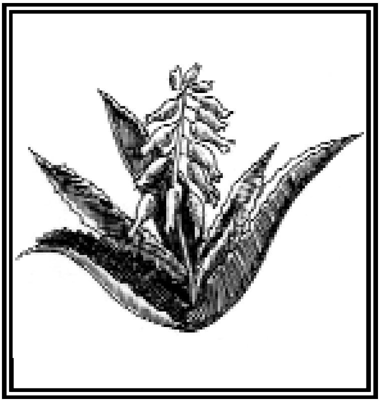

Other Names Medicinal aloe, Barbados aloe.
History: Probably native to Mediterranean. Used by Native Americans.
Habitat: Temperate zones, desert, arid regions.
Characteristics: Bushy succulent. Green fleshy leaves, called spikes, are filled with clear gelatinous liquid. Mature plant has spikes up to 3 feet high with dense, arrow-shaped clusters of yellow or orange flowers.
Primary Uses: Flowers, edible raw. Medicinal, cosmetic. In tea as an antispasmodic, antihistamine (asthma, colds, congestion), anodyne, or as tranquilizer or diuretic. Crushed leaves yield gel which is applied as poultice for burns or sores, promoting growth of new tissue.
Medicinal Value: An antibiotic, astringent (to accelerate wound healing), coagulating agent, biochemical bandage, pain inhibitor, growth stimulator, “wound hormone”, demulcent, antihistamine, mild laxative, burn healer.
Cosmetic Value: Skin conditioner, astringent. Also aloe has bacteria- inhibiting qualities that make it an excellent underarm deodorant.
Collection and Storage: Harvest in summer; buds, flowers, young leaves. For external use, slice leaf in half and place directly where needed. For internal use, remove gel and place in water. Refrigerate or freeze. Freezes well. Where aloe grows naturally, both young and old leaves are thick. Since old leaves are tough and the gel is bitter, harvest the new, thinner leaves.
Caution: Do not use as bulk food. Use sparingly for medicinal purposes only.

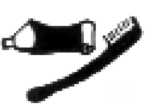

Linda Says- Aloe vera is the most important native plant in the West. Preparing aloe is fun. I take a leaf, turn the flat side down, and lay it on a flat surface. The skin comes off easily by slicing under the skin from tip to larger end. The gel scrapes off quickly with a spoon, Then I scoop the gel into a bowl, whip it thoroughly with an egg beater, and put it into an ice cube tray to freeze. I use one cube to a 6-ounce glass of orange juice for a tonic. One cube also works wonders for immediate application on sunburns.

While aloe is a Western plant, mullein in the East has many of the same properties.

Different Plants, Similar Uses

ALOE VERA	MULLEIN
Antihistamine	Antihistamine
Burn healer, pain reliever	Burn healer, pain reliever
Growth stimulator	Growth stimulator, reduces swelling
Wound hormone	Wound healer-promotes quick healing
Pain inhibitor	Pain inhibitor
Astringent, accelerated wound healing	Whole leaf bandage, antiseptic
Demulcent	Antispasmodic
Coagulating agent	Tranquilizer, biochemical bandage
Antibiotic	Mild sedative
Deodorant, inhibitor of bacteria	
Mild laxative	Anadyne, a medicine that relieves pain
Cosmetic, skin softener	Cosmetic, skin softener

Amaranth

Amaranthus retroflexus
Amaranth family, *Amaranthaceae*

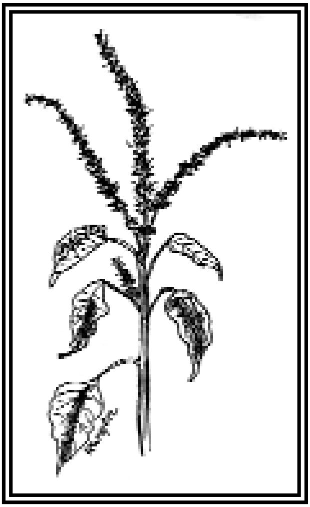

Common Amaranth (Western U.S.)

Other Names: Green amaranth, Pigweed, red root, carelessweed, choohugia (Pima name).

History: Native to tropical America; naturalized throughout the world. A staple food of the Zapotec Indians of Mexico. (Sturtevant 1972) Coastal Algonquins collected amaranth for a vegetable and used its ashes as salt. The plant is naturalized in Asian countries. It is cultivated in tropical Africa and Jamaica as a potherb. Seeds are used for flour in India and Nepal. Amaranth yields 8 ounces of seed from plants covering 1 square yard of ground.

Habitat: Cultivated soil.

Characteristics: Annual herb. Averages 2 foot, but may reach 6 feet or more. With bristly seed heads, clustered on multi-branch stems from a central stalk. Flower seeds are black and shiny; leaves are smooth and veined with slightly toothed margins. Eastern amaranth seed heads or "flowers" are denser and shorter than the Western species. Western varieties may have long, spindly, bristly seed heads, and white seed pods with black seeds inside.

Primary Uses: Culinary, cosmetic. Use leaves and stems like spinach, eaten raw, steamed, sautéed, cooking liquid is drunk. Leaves are also dried and ground for flour. They are used in soups and stews. Seeds are used raw or dried for baked goods, cereal, mush.

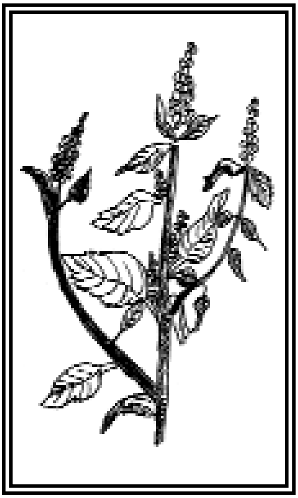

Common Amaranth (Eastern U.S.)

Nutritional Value: High in vegetable protein. High calcium and vitamin E.
Cosmetic Value: Astringent, wrinkle cream.
Collection and Storage: Use entire plant. Harvest lower leaves and branches in summer as vegetables. Refrigerate or freeze; dry. Wait until plant is full grown for large seed heads. Amaranth seeds are easily collected in autumn by tapping the seed head over a bowl, even in summer on the desert.

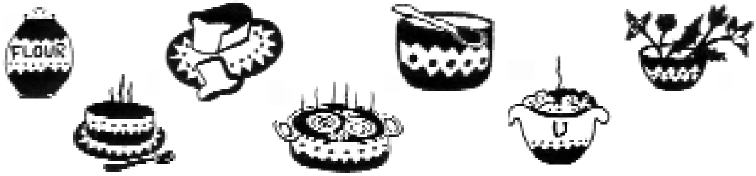

Linda Says- The first time I saw amaranth I couldn't believe my eyes! Tall, wondrous plants heavy with seeds bordering pasture and barn areas. There were hundreds of these "weeds" some bent over from the weight of their seeds. In less than 20 minutes I bundled enough amaranth for a week's supply of fresh vegetable and almost a winter's supply of flour. It did not take long to discover the wonders of amaranth in brownies, as a cooked green, or as a gruel.

Arrowhead

Sagittaria species, *S. chinensis*
Water Plantain Family, *Alismataceae*

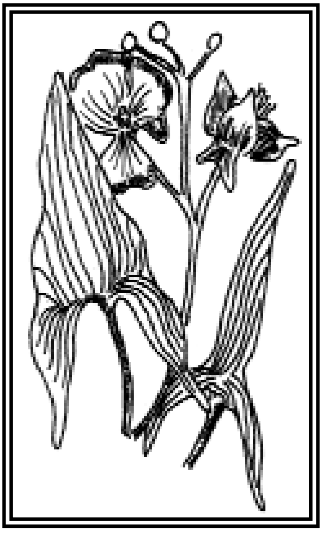

Other Names: Duck potato, wild potato, Wapatoo (Indian).
History: Native to North America. Lewis and Clark used Arrowhead for food, taught by Native Americans. The explorers wrote, “(they) can be ground fine. A flair for pudding, cakes, etc. They are nearly equal to Irish potatoes, and are a bread substitute.” Chinese sell it in marketplaces for food.

Habitat: Widely distributed. Marshes, wet bogs, mud flats.
Characteristics: Aquatic perennial with tubers. Grows in swamp water to a height of about 10 inches. Arrowhead-shaped leaves and filmy white-petal flowers. Roots have walnut-size tubers.
Primary Uses: Culinary. Root corms: Used as potatoes, sliced or whole, boiled, sautéed, or raw. Strung and dried then ground for flour.

Nutritional Value: Easily digestible; a nutritious food, especially for convalescents.
Collection and Storage: When harvesting arrowhead tubers, use a pitchfork and lift gently. The tubers tend to snap off in the mud and the pitchfork creates less tension. Freezes and dries well. Scrub the small tubers thoroughly and string with a needle and thread. Hang the strings to dry, then store in glass.
Caution: If water purity is in doubt, use purification tablet and soak tubers in water purifying solution.
Comments: There aren't too many arrowheads in my area of northern New York, but southern New York and areas of New Jersey have immense quantities in marshes and wetlands; they are also in wetlands in the West.

Linda Says- My marshes do have a few "secret" areas for Arrowheads. Misty, boggy, muddy, slimy, and mossy, the marsh's loam logs rot away to the richest, blackest soil I have ever seen. Mosquitoes are an inch long where the arrowheads poke up above the mud! I pray silently, dip my pitchfork under the plant, and lift slowly. I used a needle and thread to string the tubers in the cabin, drying them for the winter. Easily reconstituted in water, the tubers make delicious soups and stews.

Aster

Aster nemoralis
Composite Family, *Asteraceae*

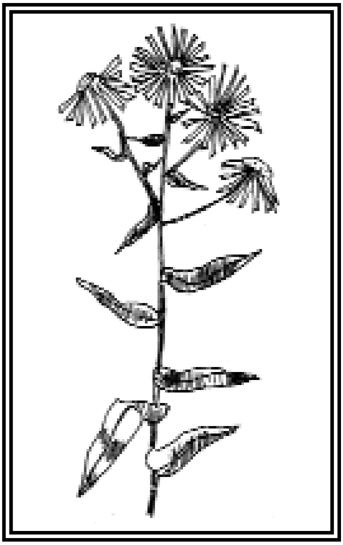

Other Names: Blue, pink, lavender, white & yellow aster.
History: Native to North America. Staple of the Iroquois Indians in the Northeast; food of tribes in the Midwest and West. Used in sweat lodges by Objibwa Indians to revive consciousness by putting on the hot rocks. Used as a food in South America.
Habitat: Fields and meadows, roadsides.
Characteristics: Perennial herb. Many varieties. Height varies, average 24 inches; may reach 40 inches. Numerous extensions jutting with multi-petaled flowers from a central stem. Petals are layered in flat, 1/2-inch-long sections. Colors vary from white to pink, yellow, blue, and purple.
Primary Uses: Culinary, Medicinal. Leaves eaten raw, steamed, boiled, sautéed, cooking liquid is drunk. Flowers stewed or steamed whole; chopped fine and stewed or steamed. Entire plant is dried, then stripped and ground for flour. Sprinkled on dishes, especially tomato-based dishes such as lasagna. The pith of the aster stem is edible, even in mid-winter. As emergency food, eat raw or cook in soup.
Medicinal Value: Dried stems and flowers are used as a wash for rheumatism; also excellent blood tonic tea. Roots of dwarf purple aster used for diarrhea control.
Collection and Storage: Snip the long stems at ground level and bundle together with string. I carry 2-foot lengths of string around my shoulders, and harvest the flowers until I have a bundle 10 to 15 stems thick. Stop bundling stems together when the flowers are too tight to be airy for drying. Take only a few plants from each

area (or 1 out of 4). Hang bundles upside down on a clothesline to dry. When dry, strip down onto sheet, crumble, and store. Also, leaves can be frozen.
Caution: Do not eat domestic asters.

Linda Says- Nature's abundance is particularly clear to me when I harvest the Iroquois staple, the wild aster. There are 250 varieties of wild aster in the United States: blue, lavender, yellow, and white prevail in the Adirondacks; blue, lavender and yellow in Western states. Field may have flowers as far as the eye can see. In less then 15 minutes I have enough to make a winter's supply of wild aster flour. I grind this bounty into flour for baking from dried storage food. The flour is particularly strong, nutritious. I recommend adding a small amount to regular recipes. This Iroquois staple remains one of my favorites.

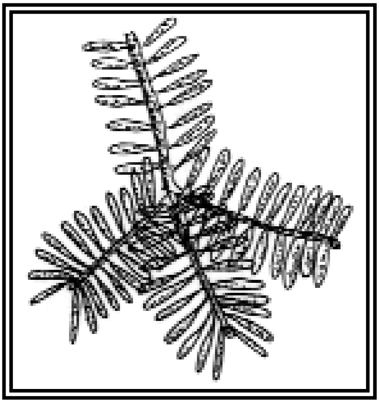

Balsam Fir

Abies balsamea
Pine Family, *Pinaceae*

Other Names: Christmas tree.
History: Native to North America. Soft inner bark was used as emergency food at Valley Forge. Native American usage.
Habitat: Grows in cool, moist, acidic soil along roadsides, woods, or lawns and in softwood forests.
Characteristics: Evergreen tree. Has small, short needles growing alternately from under stem, 1 to 1-1/2 inches long. Grows to height of 40 to 60 feet.
Primary Uses: Culinary, medicinal, cosmetic. Bark is chewed, ground or dried for flour. Sap is chewed as gum. Branches and

twigs are stripped and ground for flour. Needles are used raw for food; steeped raw or dried for tea. Used in wine. Ground raw or dried for emergency flour. Dried needles are used to fill balsam pillows and sachets. They lend a fresh scent to drawers and closets.
Nutritional Value: Good source of vitamin C.
Medicinal Value: Roots used as a poultice to soothe syphilitic sores and gonorrhea. Sap (pitch) is a “glue” for cuts, scratches, bites, and sores. Dried sap is chewed for colds, bronchitis, influenza, pneumonia, upper respiratory diseases.
Cosmetic Value: Oil used for flavoring, scents, perfumes, soaps.
Collection and Storage: One branch yields a winter’s supply. Balsam fir tips are a lighter green, indicating newer growth. I snip off needles here and there, filling a bag with dozens of twigs. Needles dry easily and quickly indoors in a sunny spot. For tea, simmer 1 cup needles until water is dark green. You may reuse needles or bark several times, adding water and simmering. Poke sap blister and gather liquid for emergency glue; store in glass if possible.

Linda Says- Rather than throw away your Christmas tree, use it for nutrition as well as a room refresher. For a wonderful aroma throughout the winter, simmer needles in water until they reach a thick, gummy state. Use twigs and parts of older branches as a fresh-smelling incense. To dry sap for medicine, make small flat cakes of sap and dry in a thin layer at the back of a wood stove or above the pilot light of a gas stove.

Birch

Betula species
Birch Family, *Betulaceae*

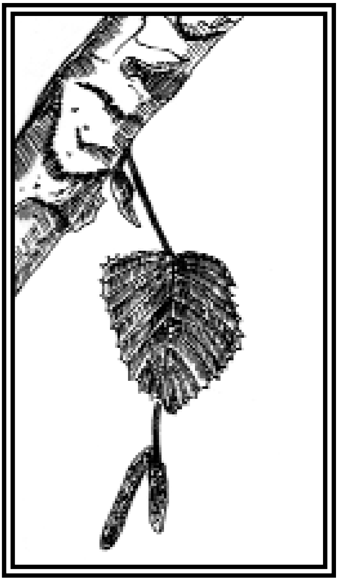

Other Names: White birch, paper birch, yellow birch, golden tree.
History: Native to North America. Scandinavians boiled, baked and added birch sawdust to their breads. Loggers say that their white birch sawdust used to be taken to American bread companies. Native Americans used birch dust for tea, and the strong inner bark was fashioned into many crafts. The Cree Indians folded birch bark and bit patterns into it, then unfolded it. Hundreds of Confederate soldiers were saved during their retreat to Monterey, Virginia, when they used birch bark as food[1] (Harris 1973).
Habitat: Woods, roadsides.
Characteristics: Deciduous tree. Alternate simple saw-toothed leaves. Papery bark of white and yellow birch peels in curls.
Primary Uses: Birch is an excellent cabinet-making wood; it makes strong hardwood furniture. Culinary, medicinal, cosmetic. Inner bark, sap, twigs, buds, and young leaves eaten raw as emergency food; dried and ground for flour. Sap is drunk raw for nutritious liquid. Twigs are used to make wines, dried for tea or crispy treat. Buds eaten raw. Young leaves steamed, sautéed, cooking liquid drunk.
Nutritional Value: High in minerals, calcium and phosphorous. High in potassium and beta carotene.

FLOUR 🍷 ☕

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[1] Ben Charles Harris, p. 444

Medicinal Value: Buds are a tonic, since birch bark contains salix, or acetylsalicylic acid. A strong tea made from the bark has been used as an aspirin substitute.

Cosmetic Value: Birch bark used for skin problems, eczema, skin eruptions, pimples, dandruff, and scalp disorders. Dried, powdered leaves used for chaffed skin; birch oil for hair tonic or body oil.

Collection and Storage: Use the bark of downed trees, or follow a logging trail and gather the sheets of bark left behind. You can also peel the bark off firewood in the spring. Strips of birch bark make a quick, sure fire. Four 5 1/2 inch strips = 2 cups fine flour (a winter's supply). One branch approximately 4 feet long = winter's supply for 4 people.

Tap the trunks in spring (April-June) like maple trees. One tree yields an average of 1 gallon of syrup in a few hours. Twigs, inner bark, and sap can be used all year. Buds and twigs have a wintergreen taste. The sap can be boiled down and used as a syrup or in birch beer. Boil down birch syrup further to make birch molasses. Store dried and ground inner bark in glass as an emergency food. The inner bark makes a delicious mineral tea; carry a chunk with you when doing hard physical work. The inner bark dries to a breakable sheet ready to be used as tea; store in glass containers.

Caution: People allergic to aspirin may have a reaction to salix wild foods such as birch.

Caution: Peeling the bark of a living birch will kill the tree. This is called girdling a tree. The bark is literally the skin of the tree, and without it the birch will die.

Linda Says- Birch bark is one of my most precious possessions. I use it in every season for tinder and generally keep sheets of it in quantity. In the middle of one winter I received an order for birch-bark baskets. Since I had no bark on hand, I got permission to go up a logging trail with Ken and Todd. What a day-20 degrees below zero, with 4 feet of snow and no snowshoes! As I peeled bark off stumps of white birch with my knife and hatchet, Todd played in the drifts. That night my back ached in remembrance of the work, but I had enough bark for hundreds of baskets, with plenty left over for Christmas cards and for starting fires.

Blackberry

Rubus villosus and other bramble berry species
Rose Family, *Rosaceae*

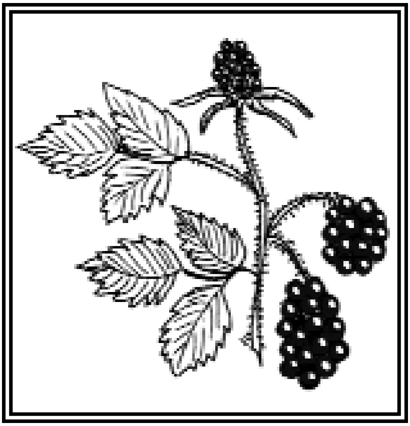

Other Names: Creeping blackberry, cloudberry, wine-berry, dewberry.
History: Native to North America and elsewhere. Used as a fruit in all countries where found
Habitat: Roadsides, fields, meadows.
Characteristics: Biennial trailing stems. Bush varies in size, up to 5 or 6 feet tall. Saw-toothed leaves in groups of 3 to 5; thorns on angular, arching stem; fruit pebbly and black when ripe. Canes produce fruit on second year's growth. Fruit does not separate from receptacle when picked.
Primary Uses: Culinary, medicinal, cosmetic. Young stems and shoots eaten raw or cooked; used fresh or dried for tea. Fruit is eaten raw, and cooked for jellies, jams, syrups; also juices and wines. Flowers entirely edible raw. Young leaves are edible as a cooked vegetable in the spring.
Nutritional Value: Young stems and fruit are good source of vitamin C.
Medicinal Value: Bark of stem helpful for intestinal problems. Tea made from blackberry root helps control diarrhea. This tea is also an astringent, a mouthwash for mouth sores. As a strong tea or eaten raw, all parts of this plant can be used to relieve diarrhea or as a blood cleanser.
Cosmetic Value: Leaves are good for facials, masks, lotions, and astringents. In an extract, clears blemishes, eases scalp itches, and heals scales.
Collection and Storage: Tie a lightweight receptacle around your waist and use both hands to pick berries. Hand-pick young leaves in early summer.

Picking Blackberries in Adirondack Bear Country

The dirt road next to the shanty led down to an old log bridge. The bridge spanned the Cedar River, and there was nothing but private wilderness for several miles. I crossed the river and climbed the wooded path for one mile. In another half-mile, I came to the largest blackberry patch I had ever seen. I was equipped with lightweight containers for the berries and fly repellent made of olive oil and pennyroyal.

I whistled a tune as I approached the patch, wary of the bears known to be in the area. I knew if I blended in too much, the bears might resent it. This philosophy had worked for me before-either I was allowed into their domain or I was not. Then I became aware of a very large body up ahead. I could hear and smell the bear shuffling slowly through the woods. I waited. Testing the wind for the bear smell and listening with my ears as I whistled, I knew the bear shuffled away.

I picked blackberries with both hands, dumping them into a plastic bottle and then into a large bucket. I worked my way around the path from left to right. Experience told me that I needed two hours to obtain eight quarts of juicy blackberries, and this particular day I picked eight quarts and then left the patch to the bears again.

When I worked with my son, Todd, we had our two coffee cans filled in moments and proceeded to dye our sweatshirts blue-black with the weight of the juicy fruit. With over a gallon of ripe blackberries we made jelly that night over an evening campfire. Breakfast was a treat!

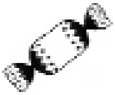

Blueberry

Vaccinium myrtillus
Heath Family, *Ericaceae*

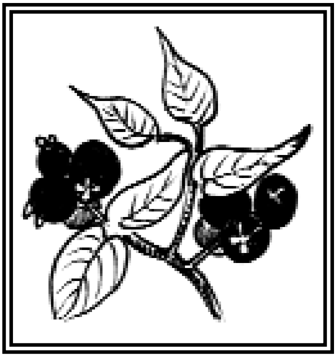

Other Names: Bilberry.
History: Native to North America. Used by Native American tribes.
Habitat: Acid soil, fields, roadsides, waste areas, bogs, marshes, woods.
Characteristics: Low spreading plant or woody shrub. Many varieties, from ground-hugging plants to high bushes. Fruit is in clusters in groups of 2 to 10. (Huckleberry often grows near blueberry; edible fruit looks similar, but huckleberry has stony pit and tart taste.) Wild blueberry looks like bilberry: both are edible, although true bilberry is not very tasty.
Primary Uses: Culinary, Medicinal. Fruit is eaten raw or cooked for jellies, jams, syrups; also wines.
Nutritional Value: High source of Vitamin C.
Medicinal Value: Blueberry leaves used medicinally in a tea. Because they contain myrtillin, an antispasmodic and relaxant, blueberries were used as a drink during childbirth to relax the mother. Leaves, fruit, and twigs can be made into an infusion and drunk for kidney problems. Dried berries are chewed slowly and thoroughly to aid control of diarrhea. Leaves and twigs can be used separately or together as teas, tisanes, and throat gargle.
Collection and Storage: Blueberries are best picked by first pulling sections with both hands rather roughly and letting berries fall on to a sheet spread around the bushes. After rough-picking a few bushes, rustle the branches for the many berries caught between the leaves. Gently gather up the sheet and pour the berries on a tray.

- 4 cups fresh berries = 8 jars jelly
- 4 cups fresh berries = 2 cups dried berries
- 4 cups fresh berries = 1 quart frozen berries

Twigs can be dried or dug up under the snow. Berries are placed in cold water. The immature berries and leaves float to the top for easy removal. To dry, spread on a tray; cover with a screen or cloth. For storage, berries can be dried until they rattle, or frozen.
Caution: Positively identify; crush fruit for characteristic blueber-

ry smell. Blueberries have a slight frill and an opening on the side away from the stem. A species of buckthorn, which is poisonous, has blue berries without a crown or frills.

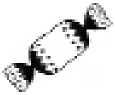

Linda Says- The fields behind the old McConnel place were filled with ripe berries, and became my favorite place to pick. I'd place a sheet around the bushes, and use both hands for picking. With a sheet you can become lightning fast, but it is still a challenge to pick enough berries for a pie before the blackflies find you. I usually made smudges before the clouds of flies found me if I wanted to take my time picking. Then I'd dry blueberries on screens covered with a cheese cloth. Those berries in my cereal on a winter's morning made it seem like spring.

Bulrush

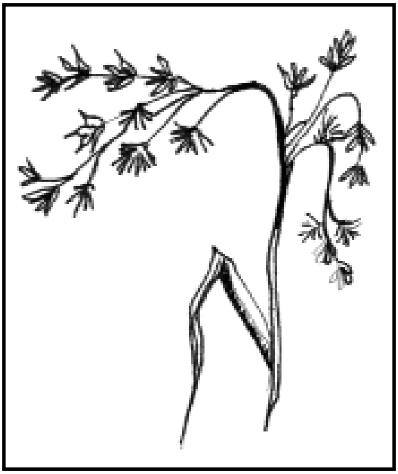

Scirpus validus and other sedge varieties
Sedge Family, *Juncaceae*

Other Names: Sedge, tule, great bulrush, nupiaskun (Crow Indian)
History: Found nearly throughout the world. Used as food from Moses' time including use by all Native Americans. The Crow made mats by sewing together bulrushes with basswood string and a bone needle.
Habitat: Wet areas, drainage spots, bogs, swamps; alongside waterways and ocean bays.

Characteristics: Grasslike herb. Many varieties with height to 24 inches or more. Stems smooth, round, with pith; head of flower spike full of seeds and pollen.
Primary Uses: Culinary, medicinal. Roots cooked as potato. Early shoots eaten raw, steamed, boiled, sautéed; cooking liquid drunk. Flower clusters dried and ground for flour. Bulrush flour is sweet and nutty—it has the most branlike taste of all the grains. Pollen used as flour. Seeds ground and roasted.
Nutritional Value: Highly nutritious, roots rich in complex carbohydrates.
Medicinal Value: A plaster or poultice for aches and pains.
Collection and Storage:

- 6-8 bulrush plants = up to 1 cup leaves
- 1 cup leaves = 1/2 cup bulrush flour
- 1 teaspoon powdered bulrush leaves = 1 cup tea

See page 34 for collection details.

Dry the bulrushes whole, bundle the long stems and hang them upside down in a warm, airy spot out of the sunshine. To ensure dryness, dry in a 300° F. oven for 5 minutes, then turn oven off and wait until cool. Follow this drying procedure even if using the bulrush strictly for decorative purposes.

Linda Says- I have spent many wonderful mornings watching dragonflies and frogs playing in the swamp while I gathered bulrushes. Swamping is not only fun, but profitable-I've fed many people on bulrush bread.

Insects love to lay tiny eggs in bulrush tops, so even if I am using the bulrushes for decoration, I leave them outside for 24 hours so the bugs can leave. After drying, I use them in lovely arrangements or grind them to a fine, delicious flour for baking.

Burdock

Arctium lappa
Sunflower Family, *Asteraceae*

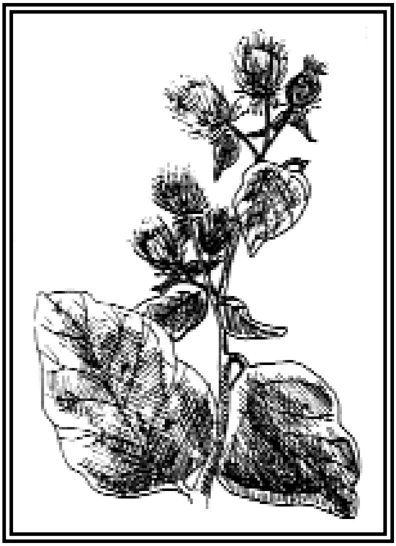

Other Names: Beggar's buttons, burs.
History: Native to Europe and Asia; widely naturalized in North America.
Habitat: Fields, roads, most waste areas.
Characteristics: Bush like, large green leaves over a foot wide, and many veined. Tubular, purple or white flowers followed by spherical burrs, 3/4" diameter. In the fall, burs dry to brown, sticky seed pods.
Primary Uses: Culinary, medicinal. Roots are boiled; dried and powdered for nutrient additive. Stem pith is baked, boiled; eaten as pickle, candy. Early leaves are eaten raw, steamed, boiled, sautéed; cooking liquid drunk. Large leaves are used as trays and receptacles for small plants. Burs when young and still pliable are steamed and eaten; when mature, broken in half and white pith eaten raw.
1 large leaf holds 2 cups green burs
1 8-inch root = enough raw root for 2 or 3 people
Nutritional Value: High in vegetable protein. Contains inulin, the chemical source of insulin.
Medicinal Value: Tea used to heal infections. Root is a diaphoretic; as wash infusion, for poultice, bruises, sore or tired feet.
Cosmetic Value: Seeds for skin problems, eczema, cleansing. For pet's fleas, simmer a small handful of brown burs, strain, and cool. Wash your pets with the decoction. Kills fleas quickly!
Collection and Storage: When you can, harvest the young roots before the flower stalk develops (usually the second year of

growth). When digging roots, slide the shovel thoroughly down one side, then another, until all 4 sides have been deeply cut. Keeping the shovel in one side, pry up the root without breaking it off. You will feel the pop when the root releases from the earth. If the tip remains, the plant will grow again. Steam and wrap burs individually to freeze. Slice and fry or simmer and then freeze roots. Gather burdock in any season. Similar in size to rhubarb leaves, the gigantic burdock leaf forms its own carrier. In spring, place tiny new burs on a leaf, roll the leaf, tuck in the ends, and put the leaf in your pocket. In winter the burs are brown. I take a few brown burs, stroke the bushes, and gather a ball in no time. I stick the burs together in a large ball and carry them on my shoulder, freeing both hands for further picking.

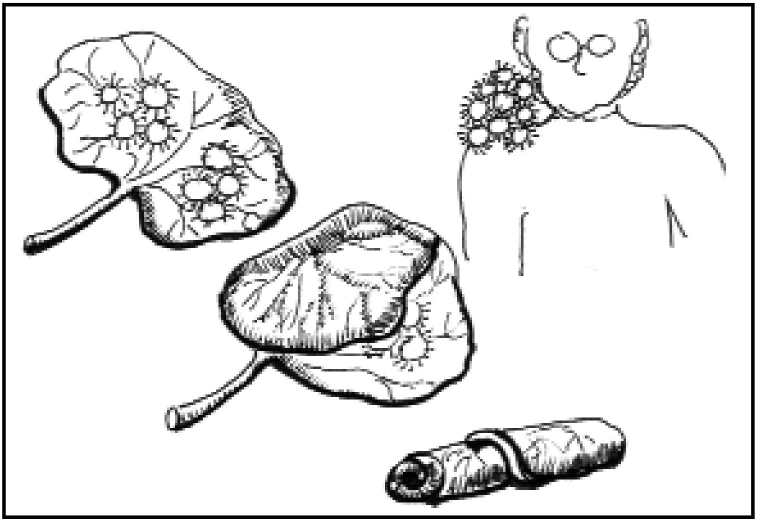

Carrying Burs

Linda Says- When harvesting, cut over the joint of the root where the stem begins. Scrub the root with a brush then peel root until you reach fiber. The fiber will turn from white to brown very quickly; this is normal oxidizing. You can peel the brown off again when serving, but I just steam the burdock pieces and freeze for a winter's meal. Drying the peels makes a crunchy, chewy root food.

Cattail

Typha latifolia
Cattail Family, *Typhacerae*

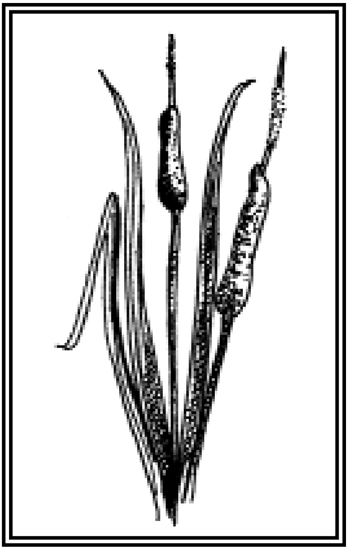

Other Names: Supermarket of the swamp, punk, upakiotipa (Crow Indian).
History: Native to North America, Europe, Asia. Cattail has been used for food throughout recorded history by people in all countries where it is found.
Habitat: Bogs, swamps, wet areas.
Characteristics: Perennial herb. Grows in wet areas to a height of 10 feet or more. Stalks have hot dog-shape heads, pollen flag in early spring. Very tall slender leaves with 1 vein.
Primary Uses: Culinary, medicinal. Roots are dried and ground for flour. Early shoots are eaten raw. Stem pith is eaten raw, boiled, and pickled. Early green heads are eaten raw, cut and cooked as ear of corn. Early brown heads are ground for flour. Pollen is used as nutrient additive. Leaves are used for basket weaving, mats, other crafts.
Nutritional Value: Plant holds about 30 percent complex carbohydrates; highly nutritious.
Medicinal Value: Flower heads used in tea for diarrhea control.
Collection and Storage: Pollen collected in spring; shake into a paper bag. Stems harvested before the cattail flowers, whenever possible. Roots dug from winter to early spring. Gather fluff from mature heads for excellent insulation or stuffing for jackets. The fluff floats and is waterproof, and serves as excellent tinder and torch. Can be used as cotton.
Caution: If water purity is in doubt, use purification tablet and soak plant in solution.
Caution: Pollen fluff may cause skin to break out in hives.

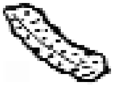

Cattailing Seasons

The morning is misty and cool. The Adirondack. ice has finally left the swamp and the crystals have melted along the edges of the mossy mats. The cattail shoots will soon be through. Water is beginning to show the spring signs of life. I saw bugs skating yesterday and heard a frog peep. Steam is rising from the invisible shield above the water. The old, dried stalks of cattails, left after winter's fury, lay bent and crooked, disheveled. The matted fuzz of the old tails looks pathetic as the new growth heads toward the surface of the shield.

There are blades-green shoots-poking up from the swamp. I take my trusty shears, long boots, plastic garbage bag, 4-foot board, and towel (should I fall in the boggy mud), to gather cattail shoots to can for winter. Laying the board from mat to mat, I gingerly move the length, clipping the shoots and dragging my filling bag behind me. Glancing back into the swamp, I can tell where I have harvested. The shoots will come again, reaching toward the sun of summer.

Later in spring, green plumes meet my eyes. The heads are like corn on the cob. I can taste and smell the meaty, nutritious flesh. My board goes down gingerly now. The swamp is dotted with thousands of green spikes. Gathering carefully, I pick only cattails with a full cob. Making piles of 8 to 10 stems, I bunch them in a pattern behind me, then I wrap each bundle with the leaves, winding them round.

Though the water is much warmer now, steam rises as dozens of insects zoom through. Mosquitoes glide by, legs tucked up underneath, looking like tiny planes with their landing gear drawn for a landing. Frogs and peepers croak and splash off their pads. I have cut the largest harvest ever. Now winding my way back I pick 10, 20, 30 tails at once. I'm coming back to camp with a supply of cobs to savor.

Summer is here and the murky mud is tough going. The cattails have filled the swamp with heavy bushy stems and blades rich with brown cobs. They are ready for harvest. Flour time! Bread time! Pancake time!

The cattail stems have swelled to 1 inch, sometimes 1 1/2 inches thick. Inside lies a creamy white pith that makes delicious pickles. Sweet and highly nutritious, they will supply a winter's fat. The cattail is heaviest now so I gather only a few, counting up to 10. I need 20 to 30 to make a loaf of bread. The mosquitoes are merciless, and the 90 degree August heat is causing the brackish water to make a stench. Under the cattails grow pennyroyal, mint, and other grasses. The harvest is half done for the winter. Another day and I will have seven or eight gallon containers filled with the pure starch piths.

Fall is here and my last trip for the year to the swamp is a sad one. Most mosquitoes have disappeared when the temperature dipped to 50 degrees. Ice crystals will form soon. Soon 40 mile per hour wind will swirl snow. Life will be in a dormant stage for many months now, but the precious cobs will be our insulation, our stuffing for pillows, blankets, and winter jackets. This collection is the easiest. As fast as I cut a cob, the pollen pops out and my bag fills with creamy fluff. The tough brown skin holds some heads together, awaiting a twist by both hands to rip open and fluff out the rich pollen.

The mud has an almost fishy odor, and it is full of algae and frogs. At this last harvest of the year, the rewards come in floods, and the swamp holds my deepest respect. I have reaped its finest fruit-the supermarket plant of the swamp: the aquatic cattail.

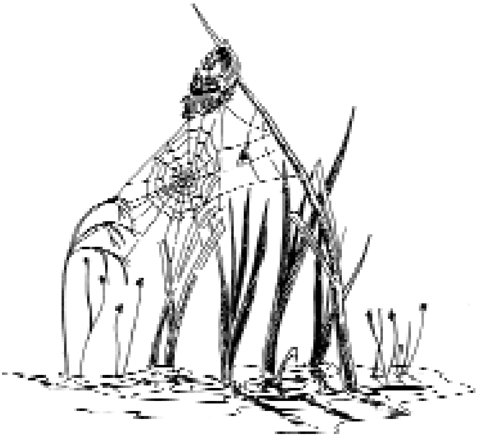

Cattails and Cobweb

Chamomile

Matricaria chamomilla
Composite Family,
Asteraceae

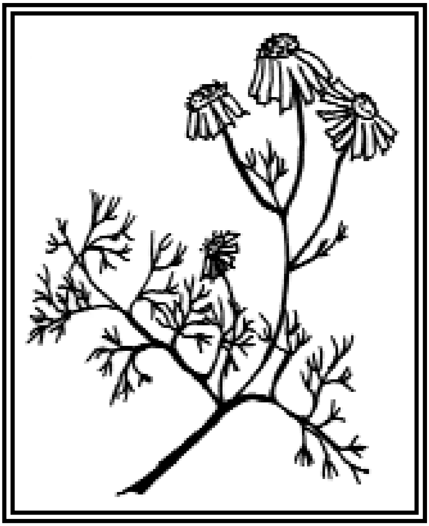

Other Names: Ground apple, Roman chamomile, mayweed, German chamomile, pineapple weed.
History: Some varieties native to North America; many naturalized from Europe. Used throughout Europe. Also cultivated for commercial use, such as in shampoos and teas. Oil is extracted for many products, including hair rinse and insect repellents. The fragrance is called mananilla in Spain. Used especially in Italy, England, and Germany.
Habitat: Roadsides, “people places,” walkways, gardens.
Characteristics: Biennial herb. Height average of 3 inches; may reach 12 inches or more. Tight-budded flowers, tiny yellow daisy; sweet, pineapple-like smell.
Primary Uses: Culinary, medicinal, cosmetic. Twigs are dried for crispy treat. Leaves are eaten raw; steamed; sautéed; cooking liquid drunk. Steeped raw or dried for tea. Flowers are eaten raw; steamed; sautéed; cooking liquid drunk. Entire plant is steamed; boiled; used in soups and stews. Steeped raw or dried for tea.
Nutritional Value: High in minerals; calcium, iron, potassium, and niacin.
Medicinal Value: Stomatic, diuretic, chapped skin ointment,. root used for toothache.
Cosmetic Value: Compress for eyes, shampoos, rinses for hair luster.
Collection and Storage: Grows near pathways, and a winter’s supply can be picked in a few minutes. Shear with scissors.

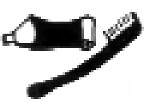

Linda Says- The smell of chamomile tea means fields, sunshine, and peace for me. I especially like to dry the flowers for tea, but any part of the plant will serve just as well. This lovely plant has more uses than tea, though. I eat the plant raw as a mild tranquilizer. The plant's parts make a delicious addition to salads. Chamomile flowers frozen in ice cubes bring a touch of spring to a drink on a cold winter's day.

To use as a hair rinse, simmer the entire plant -leaves, roots, and flowers-in water. Simmer until water is green, about 15 minutes. Cool the water, strain, and apply. Let this sit on your hair for a while, then rinse again. It will give your hair amazing vitality.

Try seeding chamomile in your garden or lawn and let it go wild.

Chickweed

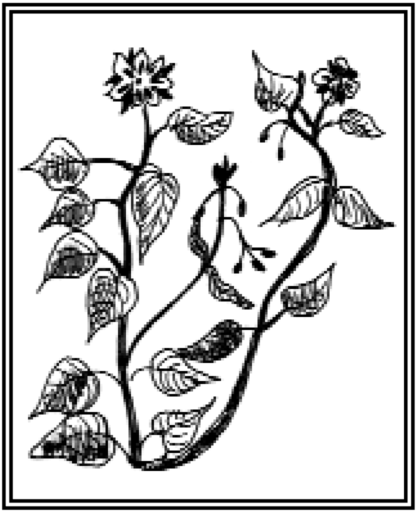

Stellaria media (common chickweed), *Cerastium* (mouse ear chickweed)
Pink Family, *Caryphyllea*

Other Names: Star flower, chickweed, stitchwort, starwort.
History: *Stellaria* native to Europe and Naturalized in North America; *Cerastium* native to North America. Widely distributed; used by Native Americans.
Habitat: Fields, lawns, roadsides, waste places.
Characteristics: Annual or perennial. Flowers petaled, 5 pairs, deeply cleft in half. Tiny and white above long stalk 4 to 6 inches. Leaves ovate and smooth. All types of chickweed are small ground plants with some parts erect but mostly prostrate. Prolific, seen year-round in some areas, even under the snow. Flowers

can be found most months of the year. Mouse-ear chickweed has minute hair on all leaves and stems.

Primary Uses: Culinary, medicinal. Whole plant is edible raw. Used as a vegetable or salad green. Also stewed, stir-fried, dried or frozen for later use. Mouse-ear chickweed is cooked to remove hairs.

Nutritional Value: High in calcium, potassium, and ascorbic acid; trace minerals.

Medicinal Value: Soothing effect; upper respiratory; externally for poultices on inflamed skin.

Collection and Storage: The tiny star-shaped flower petals have a tiny notch at the end. Leaves are easily twisted and picked from stems. Gather as you would dandelion leaves (see page 24). Young leaves are best. I have always identified them by this.

Linda Says- A bit of garlic and steaming hot chickweed make a nutritious meal for the forager because it is high in calcium, potassium, ascorbic acid, and trace minerals. I once found myself sitting on a hillside, pulling handfuls of chickweed and eating them with gusto! The most amazing feeling is the delicate leaves of chickweed. When I put my fingers down into the thick mat of tiny nourishing leaves to pull up a handful, my contact with this plant always is one of delicacy and gentleness. A little washing, oil and vinegar and the feeling is easily transferred to my mouth!!!

Chicory

Cichorium intybus
Composite Family, *Asteraceae*

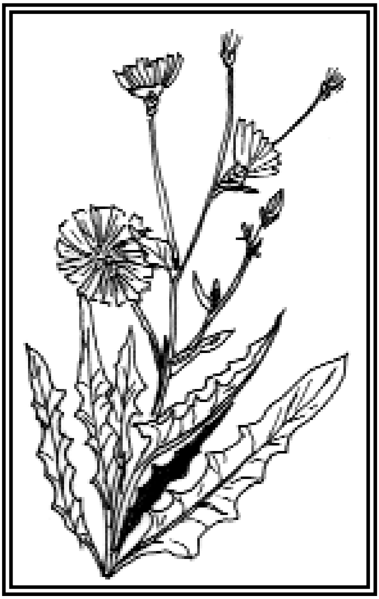

Other Names: Blue sailor, blue daisy, coffee weed, wild succory, Barbe de capuchin, whitloff, ragged sailor, wild bachelor button, blue dandelion, blue daisy.

History: Native to Europe, naturalized throughout much of North America. Used by Native Americans and a staple European food. Each year the United States imports tons of chicory root for use as a coffee substitute, coffee flavor, and coffee extender.

Habitat: Roadsides, fields, dry sandy areas.

Characteristics: Perennial herb. Grows to height of 2 feet but may reach 4 feet. Has deep taproot and milky juice. Red-veined, deep-cleft leaves are thicker than dandelion to touch. Stem has many star-blue ray flowers. When broken, root exudes a white milky sap, as do the stem and leaves. Plant begins in a lettuce-like whorl of leaves on the ground, heads up in a bunch, then shoots a stalk upwards from the center. Roadsides show bunches of deep green, deeply indented leaves; not unlike dandelion, but a bit more uniform in clusters before the stalk appears.

Primary Uses: Culinary and medicinal. Roots are dried and ground to coffee. Leaves are eaten raw in salads and sandwiches. May be steamed, stir-fried, boiled as a vegetable, sautéed; cooking liquid drunk. Stems are entirely edible as are the flowers and seeds.

Nutritional Value: Roots are rich in beta-carotene and niacin as well as carbohydrates.

Medicinal Value: For stomach and kidney disorders.

Collection and Storage: Gather roots in early spring. Roots may be stored in strips for easier grinding (see page 30 for illustration on stripping roots). Store whole roots in paper bags in a warm, dry area for future pulverizing or boiling.

- 1/2 paper grocery bag of dried leaves = 1 quart rough ground flour
- 1/2 paper grocery bag of dried chicory roots = 1 quart ground coffee substitute

To collect pull up entire plant by grasping stem as close to root as possible and pull straight up. Hack off the root (I use an ax), gather and wash the leaves, and scrub the root with a toothbrush. When the roots are clean, slice lengthwise into strings. These dry easily on a screen or may be strung over a wood stove to dry.

Linda Says- Chicory roots pull up easily from sandy soil. I put my bounty in a rain barrel to keep the entire plant fresh until I can work on it. All summer, Todd mows the lawn where there is chicory. The reddish vein makes it easy to identify the plant. To tell chicory from the common dandelion, just feel both leaves. Chicory leaves are thicker and not shiny. Dandelion is softer and shiny.

Cholla

Opuntia fulgida
Cactus Family, *Cactaceae*

Other Names: Jumping cactus.
History: Native to North America. Used by Hohokam, prehistoric desert people. Indian women used baskets, sticks, and wooden tongs made from saguaro ribs to gather the buds. A firepit was dug in the desert floor, and the buds and joints were placed in a mesquite fire, roasted, and split in two to eat the succulent insides.

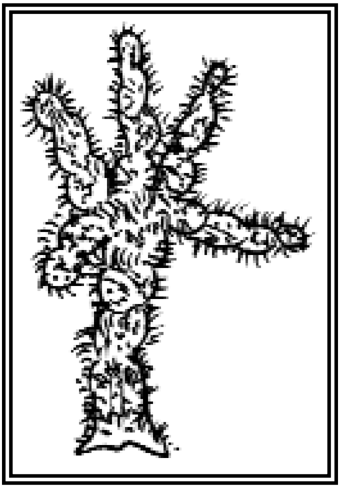

Habitat: Desert.
Characteristics: Treelike cactus with many branches. Cholla cactus has dozens of individual egg-shaped barbarous sections extending from tree-like stems reaching heights of 3 feet or more. Flower is light rose color, fruit is green and smooth.
Primary Uses: Culinary, medicinal, cosmetic. Edible flowers, seeds, fruits, and bud extensions. Fruits are eaten raw, boiled, or baked. Dried for long-term storage. Fruits used in soups, casserole.
Nutritional Value: High in calcium and iron.
Medicinal Value: Gel applied on skin burns.
Cosmetic Value: Gel used as skin softener.
Collection and Storage: Use tongs and paper bags to collect fruit, leaves, and flowers of cholla. Spines and glochids are removed in any of several methods. Indians used flash fire, holding a flame under the burr to remove the glochids, so that they could be opened easily and handled with the fingers. Another method is to place burrs in one paper bag and transfer to another several times. Dry cholla buds on screens in the sun. Cover with cheesecloth if birds pick at them. Dried buds are stored in paper bags until needed. When needed, reconstitute in water about 3 to 4 hours, then boil for one-half hour.

Evelyn Neithammer (1974) found that the easiest way to clean cholla buds is to fill each of 2 saucepans one-third full of clean gravel. The buds are added and the gravel and buds poured from one pan to the other four or five times, or until rid of spines and glochids. (Glochids are minuscule, dense pockets of small barbs which protrude from the pads of prickly pear cactus. They are small but mighty protection against antelope, deer, and cattle of the Western plains.)

Caution: Spines and glochids will penetrate skin with a voracious sting and burning sensation. Do not touch the cactus with bare skin.
Caution: All cholla, prickly pear, and saguaro cactus is “protected plant, by State of Arizona,” but it is legal to pick fruits and buds of the species in this field guide for food. The rare crested saguaro is completely protected, so NO fruits or parts may be taken. Be sure to check the regulations in your state.

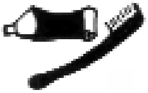

Teddy Bear Cholla

My first introduction to cholla is a painful, clear memory. My brother, Paul, and I were taking a first tour of the desert together. I was listening to him carefully. "Walk behind me, check your shoes carefully for the cholla burrs, and never step over the bushes here...walk around in the bare spaces." I was trying to listen, but the 100 degree temperature became a problem and I began doing my Adirondack way of walking. I stepped over a bush, but never put my other foot down. It was stuck to my rear with a thousand fire barbs. (The burrs were attached to my sneaker heel, which brushed my rear closely enough to get the burrs attached to my skin.) Screaming, I stood an embarrassed 20 minutes while Paul picked out the hundreds of minute hairs with tweezers. Needless to say, I remember the rules now and thank him for a lesson well learned!

Clover

Trifolium pratense (red clover)
Trefolium repens (white clover)
Legume Family, *Leguminosae*

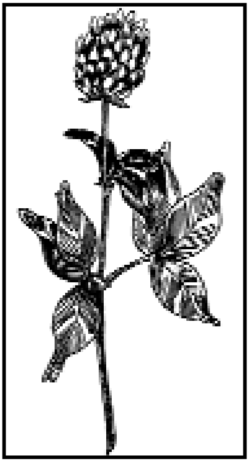

Red Clover

Other Names: Long stalk, strawberry clover (red clover); common, sweet, short stalk clover (white clover).
History: Naturalized from Europe. With over 300 species, clover has been used by all cultures throughout history. Native Americans used it widely as a vegetable or cure for chest congestion.
Habitat: Roadsides, fields, lawns.
Characteristics: Biennial or perennial herb. Red clover reaches height of 10 inches or more, with hairy stems. Red or purple blossom with oval nectar sections; elongated leaves form trefoil with white vein when mature. White clover reaches height of 2 inches or more. White blossoms have dozens of nectar filled sections; round leaves form trefoil at end of stem.
Primary Uses: Culinary, medicinal, cosmetic. Leaves are eaten raw; steamed; boiled; sautéed; cooking liquid drunk. Dried and

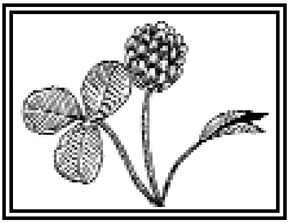
White Clover

ground for flour. Flowers eaten raw; steamed; sautéed; fried; cooking liquid drunk. Dried for tea; used for wines. Seeds crushed for cereal; sprouted. Entire plant is steamed or boiled and used in soups and stews; cooking liquid is drunk.

Nutritional Value: High in calcium, potassium, niacin and vegetable protein.

Medicinal Value: Red clover is used as tea for cough, whooping cough; blood tonic or purifier. Clover syrup used for chest congestion and bronchitis.

Cosmetic Value: Cosmetics, facial creams, rinses, shampoos, wash for pimples, poultices for athlete's foot fungus.

Collection and Storage: Plants are most succulent in spring and early summer. Gathering a winter's supply of clover takes only a few minutes. Clover can be frozen by placing it in a single layer on freezer wrap, folding over 2 sides to hold the clover in place, and freezing. After the clover is frozen, roll the paper to make a compact package, fasten, and label. Dry seed heads separately for an attractive potpourri.

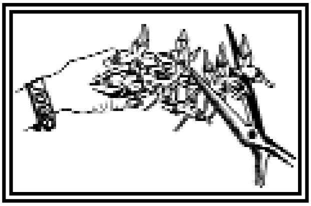
Sheering Clover

Linda Says - White clover has a particularly different flavor from red clover, with a smaller flower and leaf. The white clover leaves are easily sheared for food as they grow close to the ground in patches. One clover patch 3 feet wide will provide dozens of servings in one season. One summer I conducted an experiment. Shearing a 3-foot patch every morning for 3 weeks, I successfully fed 200 people several different dishes of clover: clover with rice or potatoes, clover casserole, breaded clover heads, clover tea, candied clover heads. The clover flowers went well in spaghetti sauce for meatballs too!

A Protection Powerhouse

Red clover borders almost every road edge. It appears to grow on all lawns, & is found in dozens of varieties throughout the world. When I discovered that the plant leaves were vegetable protein, I was ecstatic. I had been walking into town every two weeks for supplies, including cheese. My biggest nutritional concerns were protein and calcium,. & then I read that clover has tremendous amounts of protein. Indeed, five large clover leaves provided the same amount of vegetable protein as 1 ounce of cheese. That did it! I began to put clover leaves between two pieces of whole wheat bread, calling it cheese. Within three days I was eating the leaves raw, saying "I need energy." I would forage freely on a small amount of raw leaves.

A vegetable, a tea, a vegetable flour, clover has become one of my staples. I add clover to rice dishes, simmer clover soup, & steam casseroles with clover as an ingredient.

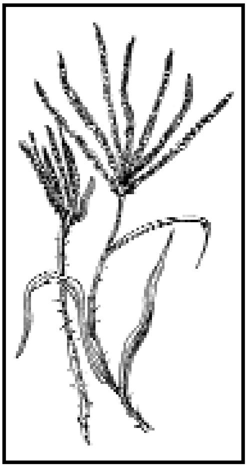

Crabgrass

Digitaria sanguinalis L.
Grass Family, *Gramineae*

Other Names: Finger grass (Horizontalis, ischaemun (smooth); serotina (creeping); longiflora; simpsoni; filiformis, and more.)
History: Native to North America, Asia, Mediterranean and North Atlantic coast as well as Europe. A drink called Mannagrit is a popular recipe. Used in most areas of the Mediterranean as flour for pita cake.
Habitat: Lawns, roadsides, waste places, edges of fields. The large crabgrass prefers moist soil, streams, ditch banks.
Characteristics: Grasslike, many varieties reaching heights from 3 to 24 inches or more. Summer annual and perennial, the bract or seed tips may vary in amounts and thickness, as well as smooth seeds or heavy bracts.

Primary Uses: Seed bracts as well as leaves are dried and ground to flour. Used raw, steamed, boiled, sautéed, and cooking liquid drunk. Pollen used as flour; seeds are sautéed; stir-fried, or ground and used as flour.
Nutritional Value: Highly nutritious; roots rich in complex carbs.
Medicinal Value: Used as a poultice for aches and pains.
Collection and Storage: Shear bracts and leaves, as if mowing lawn. Dry thoroughly, store whole in glass. Grind to flour when needed.

Linda Says- I'll never forget the feeling when I realized that a 2-foot section of crabgrass would yield a batch of muffins every 2 weeks or so. When I read that the Bedouins pulverized crabgrass to a rough flour and made a cake the same as I did, I knew then that my cakes were a universal recipe.

Daisy

Chrysanthemum leucanthemum
Composite Family, *Asteraceae*

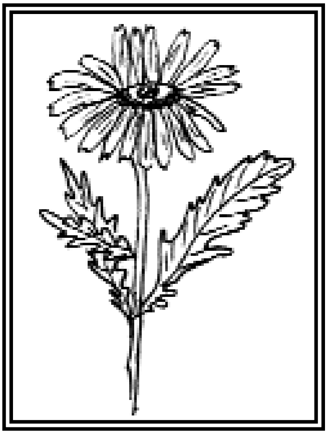

Other Names: She loves me, she loves me not; ox-eye daisy.
History: Native to Europe and Asia, widely naturalized throughout North America.
Habitat: Fields, roadsides, lawn, waste places.
Characteristics: Biennial herbs. White petaled flower about a long, erect stem 18 to 20 inches tall. Flower center has a yellow pebbly disk of seeds. Flower ranges from 1 1/2 to 2 inches in circumference. Petal number varies. Leaves are dark green and

irregularly lobed in a scalloped design. Smooth and succulent, they form a thick basal rosette the first year of growth, sending the stem up with flower the 2nd year.

Primary Uses: Culinary. Petals eaten raw; used as tea. Stem and leaves edible as a salad green, vegetable. Dried stems are added to soups or stews. Leaves eaten raw, put in sandwiches or soups.

Nutritional Value: Leaves very high in beta-carotene, riboflavin, niacin and potassium. Low in carbohydrates and calories. Petals are very high in beta-carotene and niacin.

Collection and Storage: Gather petals only, leaving yellow centers.

Caution: Do not eat the yellow center, as it may cause indigestion. Collect clumps of new spring leaves for salads. Chew leaves or stems while hiking for a taste treat. Dries and freezes well.

Daisy

"She loves me, she loves me not!" We all enjoy and play this game, but think of how much more fun if you popped the succulent white petals in your mouth! Why not make a treat of the petals in salad or gelatin, or even in chocolate ice cream. I have put them in popsicles for kids.

Using the petals for food became a real survival tool when I spent hours picking blueberries or raspberries. They usually grow nearby, and when I found the petals edible, I could vary my diet from fruit to flowers. Then I discovered that daisy leaves are fantastic. From that moment on, Todd and I ate them while walking, playing, and working in the mountains of the Adirondacks. I can never look at a daisy and not remember the freedom of this period of my life!

Dandelion

Taraxacum officinale
Composite Family, *Asteraceae*

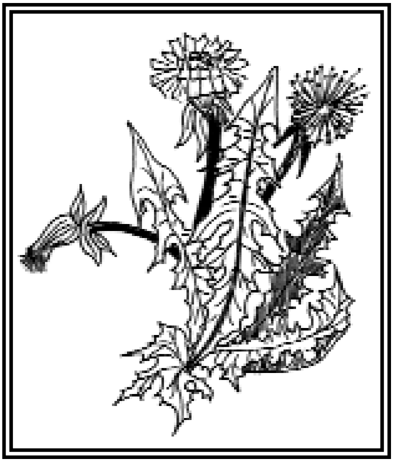

Other Names: Dent-de-lion, wild spinach, wild lettuce, red-seeded dandelion, wasanswak (Crow Indian).
History: Probably native to Europe, but widely distributed through the world. Used by many different cultures. Cultivated on the Mediterranean island of Minorca after locusts destroyed vegetation.
Habitat: Moist areas, lawns, roadsides, fields.
Characteristics: Perennial herb. Grows to height of 2 inches or more; clumped. Leaves saw-toothed; whorl from center. Yellow sectioned flowers mature to fluffy "pompoms" with seeds that blow in the wind.
Primary Uses: Culinary, medicinal. Early roots are eaten raw. Dried whole roots are pulverized or boiled. Leaves are eaten raw; steamed; boiled; sautéed; cooking liquid is drunk. Steeped for tea. Dried and ground for nutrient additive or flour. Flowers are eaten raw; sautéed; fried. Used for wine. Entire plant is steamed; boiled; sautéed; cooking liquid is drunk. Used in soups and stews.
Nutritional Value: High in protein, calcium, and vitamin A.
Medicinal Value: Use as tea for jaundice and other liver problems; a tonic, blood cleanser, purifier, stomatic, diuretic, laxative; for swellings, sores. Also effective for nervousness and hypochondria: an effective relaxant.

To reduce swelling and cleanse a wound, grind fresh leaves to a paste and spread over wound or fracture. Use dandelions as a bandage to bind wounds. Use as blood tonic by pulverizing either roots or leaves and mix 50-50 with whole wheat or rice flour. Make bread.

Cosmetic Value: Facials, wash for eczema; any external cosmetic skin treatments.

Collection and Storage: Gather flower heads in season. Yellow petals are very sweet. Twist the green base from the yellow flower petals and eat the petals raw. Roots can be dug year-round, even under the snow. Young leaves and stems are tastiest. Collect roots in early spring when most succulent and not bitter; dry and grind to coffee. Roots may be stored in strips (see page 30 for illustration on stripping roots). Store whole roots in paper bags in a warm, dry area.

Leaves
- 1/4 grocery-size bag = 8 cups leaves
- 8 cups raw leaves = 10 servings
- 8 cups steamed and frozen leaves = 4 servings
- 8 cups fresh leaves, dried on a screen = 1/2 cup flour

Flowers
- 1/4 grocery-size paper bag = 8 to 10 meals

Linda Says- Security—that is the only word I use for dandelion. Dandelion is always there, even frozen green under the snow, easily found, along edges of tree trunks or rocks. Ruth Spring taught me to core down the root, then peel the white succulent core for the first taste of a spring thaw. "As a tonic," she said, "the body will grab at it."

The former mayor of Vineland, New Jersey, started a large business growing and harvesting dandelions for the gourmet markets of Europe. The annual dandelion dinner he gave was nothing short of a gala feast.

Dock

Rumex crispus
Buckwheat Family, *Portulaceae*

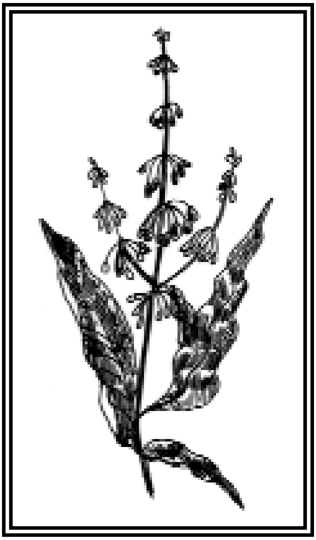

Other Names: Curly dock, yellow dock.
History: Native to Europe, widespread in North America. Pima Indians use roots, stems, and leaves.
Habitat: Fields, roadsides, rich soil.
Characteristics: Perennial herb. Grows to height of 14 inches, may reach 24 inches. Elongated leaves curl; seeds turn dark brown when dry.
Primary Uses: Culinary, medicinal, cosmetic. Roots cooked as carrot. Leaves eaten raw; steamed; boiled; sautéed; cooking liquid is drunk. Stems eaten raw or cooked. Seeds ground for flour. Entire plant makes excellent yellow dye. Seeds are a decorative craft material, useful in flower arranging.
Nutritional Value: High in vitamin A, minerals, and protein.
Medicinal Value: Roots used for skin infections or itches, and for healing wounds and sores. Stems and roots are laxative and tonic. Pulp of leaves used as a poultice for bruises, burns, and swellings. Boiled and mashed, bound on boils and swellings.
Collection and Storage: You can spot dock easily in a field by its deep chocolate-colored tops. Several stands of dock are often in a field; the dark brown tops stand out in peaked clusters, especially above a winter's snow. Gather seeds when rust brown. Leaves are collected in early spring or when young. Roots are gathered in early spring for medicinal storage. Dries and freezes well.

The Department of Agriculture suggests collecting roots in the late summer and splitting while green for drying and grinding.

Linda Says- I remember the summer Ruth Spring showed me dock. When I saw how many thick clusters of seeds there were on just one plant, I decided dock would be a main source of flour. I am constantly amazed at how many quarts of flour can be derived from one clump of dock. Because of the high vitamin A content of curly dock, this flour should be used sparingly only with another flour such as whole wheat. Curly dock seeds have 20,000 units of vitamin A per 1/2 cup. A few teaspoons in your recipe is adequate for vitamin content.

Evening Primrose

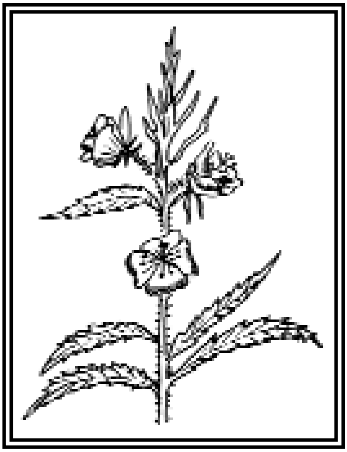

Oenothera biennis
Evening Primrose Family,
Onagraceae

Other Names: Meadow rose.
History: Native to North Americas. Used by Native Americans.
Habitat: Gravelly dry soil, roadsides, waste areas.
Characteristics: Biennial night-flowering herb. Has pinwheel rosette of leaves that are toothless with whitish midrib. Basal leaves brown in spring, hugging the ground. Stalk shoots upward, with 4-petaled flowers on top of multiple branches. With 4 petals, the flowers are not unlike a rose, exceptionally sweet smelling and waxy. Hairy stem. Between stalk bottom and root underground is a strip of red or pink to scarlet indicative of primrose. Single root with many hair-like extensions.
Primary Uses: Culinary, medicinal, cosmetic. Young leaves are eaten as a vegetable or salads. Dried and frozen for storage. Buds edible before flowering. Seeds edible. Roots look and taste like parsnip (peppery flavored), may be eaten raw or cooked.

Dried for long-term storage.
Medicinal Value: Evening primrose oil used for soothing the central nervous system as well as relieving stomach and gastrointestinal stress. See below.
Cosmetic Value: Creams, skin preparations.
Collection and Storage: Pick young leaves in early spring. Pinch flowers off stem. Dig roots and scrub. Roots can be dug in winter.

Linda Says- Rumor has it that oil from this delectable wildflower is one of the most expensive, as well as most beneficial for human beings. Its composition close to the constituents of mother's milk, evening primrose offers many medicinal remedies.

I began picking and eating the flowers in quantity. I use olive oil to make evening primrose oil, just press the flowers into a small jar and add boiling olive oil. (Be careful to avoid splatters.) Press the flowers down with a spoon and pour in oil until flowers are saturated and air has bubbled up. Cap tightly and shake every day or so for a week. Strain the oil and refrigerate. It's a potent tonic when added to your salads.

Filarie

Erodium circutarium
Cranesbill Family, *Geraniaceae*

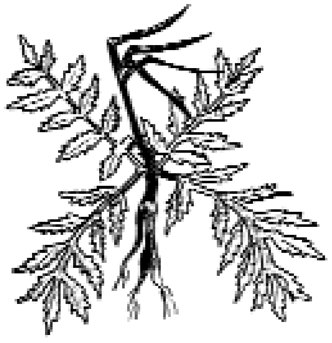

Other Names: alfilaree, alfilaria, redstem, stork's bill, pin clover.
History: Native to Europe and probably introduced to North America by the Spaniards; Native American use.

Habitat: Dry areas, desert areas with a little moisture, particularly clay soils.

Characteristics: Annual or biennial, reproducing via seeds at the base of stork's bill-shaped shoots. Flowers on long stalks shoot up from fern-like leaves lying in thick mats. Minute hair on stalks and stems. Stalks have purple flowers, then seed buds. Seed has a corkscrew tail, driving it into the soil for propagation.

Primary Uses: Culinary. Fern-like leaves are eaten raw like celery. Used in soups, stems, sandwiches. May be steamed and frozen for summer vegetable. Roots are like celery, delicious raw or in soups; steamed or pickled. Both roots and leaves are dried and ground to a flour.

Nutritional Value: Leaves are very high in calcium, potassium and beta carotene, niacin and vitamin C.

Collection and Storage: In the westI used a gloved hand, taking the most succulent leaves only up into your hand, pulling them upwards, and with a twist of your wrist, twist the leaves off the root. This leaves the root and flower stems.

Caution: Do not ingest flowers or stork's bill fruits, as they are known to be toxic. It is generally safe to ingest a large amount of filarie leaves if the vein in the center of the leaf is not pink or red. Filarie tends to pick up nitrates from the desert soil, turning the vein of the leaf as well as the stem of the flower red. Look carefully for healthy plants, green and luscious before eating.

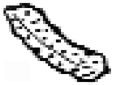

Linda Says- A winter's filarie sandwich has become a ritual. The greens appear after the rains on the Arizona desert. I clip them with scissors, wash them, and make a mild, nutritious raw vegetable served with a dip. Pickled in apple cider vinegar, they make a delicious salad ingredient.

Fireweed

Epilobium angustifolium
Evening-Primrose Family,
Onagraceae

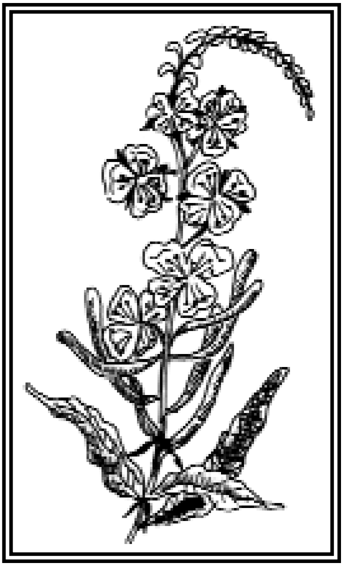

Other Names: Great willow herb, deerthorn, wild asparagus, wickup ocacadii (Potawatomi).
History: Native to North America. Staple food in Northern Asia and Iceland. First plant to re-seed itself after all wars of wasteland or defoliation. Grew on sides of Mt. St. Helen 3 weeks after volcano covered area in potash. Grows back first after fires. The Potawatomi Indians used its root as a soap by lathering it in water.
Habitat: Areas where there has been fire, waste areas, areas of regrowth, roadsides, fields.
Characteristics: Perennial herb with unbranched tall spikes up to 2-6 feet and willowlike. Spikes not unlike upside down asparagus. Stems hollow with white pith.
Primary Uses: Culinary. Pith is eaten raw or boiled; used in soups and stews; steeped for tea. Buds are eaten like asparagus; tips picked before they flower are eaten raw or used in soups and stews. Flowers may be eaten, but buds are more palatable. Young leaves eaten raw or prepared as spinach; dried for tea. The fluff makes excellent winter tinder; used as cotton.
Nutritional Value: Exceptionally high in beta carotene and potassium as well as most minerals.
Collection and Storage: Perennial herb. Reaches height of 2 feet or more. Spike of magenta or pink 4-petaled flowers; elongated top of buds.

Linda Says- The best way to see the old fireweed beds is when it is snowy. The plants' spiral top, tall and fuzzy, swirls with cotton fuzz. In season, fireweed shows a magenta top with flowers. Above the flowers are asparagus-like tips that I harvest as a delicious vegetable. They taste best fresh.

Goldenrod

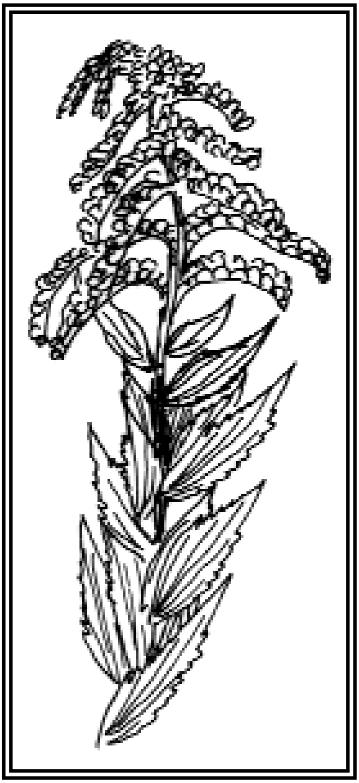

Solidago odora
Sunflower Family, *Compositae*

Other Names: Golden elixir, sweet goldenrod, asawush (Ojibive Indians). Poco moonshine is yet another species, *augustifolum*.
History: Native of North America. Used by pioneers. Ojibive Indians used it in tea as a carminative, antispasmodic, and intestinal astringent (Smith 1932).
Habitat: Dry, open fields, woods, road banks, pine barrens; acidic soil.
Characteristics: Perennial herb. Grows to height of 24 inches or more. Hundreds of tiny fluffy yellow flowers on top stalk. Flowers smell like anise.
Primary Uses: Culinary, medicinal, cosmetics.
Roots eaten raw; dried and pulverized for tonic powder. Stems dried for tonic nibble. Leaves picked and eaten fresh. Dried for tonic tea. Stems, buds, flowers, and seeds eaten or used as tea.
Medicinal Value: Energizer and tonic. As a tea, for diarrhea, bladder tone, colic. Mashed leaves for a poultice, raw flowers

chewed for sore throat. Leaves and roots are tonic for colds and upper respiratory problems. Powdered leaves are sprinkled in sores and wounds because goldenrod is an astringent. Helps stop internal hemorrhaging as a strong tea.

Cosmetic Value: Shampoo, astringent with diaphoretic qualities; aromatic and stimulating.

Collection and Storage: Gather the entire plant, bundle it, and hang it upside down until dry in a warm, airy place out of the sunlight. The bundles are dry when the stems snap easily. Place a clean sheet under the bundles. Hand strip and gather up the bounty. To store a winter's supply of tea, gather the stripped and dried goldenrod parts in a pillowcase or other cloth bag, then wring to crush the leaves. A handful of flowers and leaves will brew 6 to 8 cups of tea.

Caution: Do not use as bulk food. Use sparingly for medicinal purposes.

Linda Says- So easy to gather and bundle, the golden elixir grows thick and bountiful. Although its tonic qualities are present any time, the goodness is strongest just before the pollen forms in the flower head. If you choose to collect at this time, watch out for the bees! They love the flowers and frequently hide in the caps or rest in them.

For a perfect yellow tea, snip off the blossoms. Dry separately on a screen and store in glass bottles.

Grape

Vitis arizonica (Western)
Vitis labrusca (Eastern)
Vitis rotundifolia (South)
Vitis Family, *Vitacere*

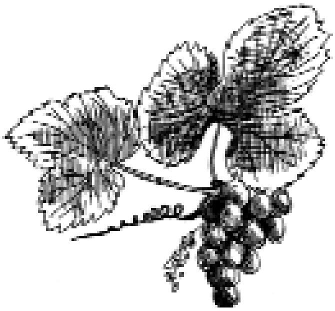

Other Names: Wild grape.
History: Native to North America.
Habitat: Thickets, edges of woods.
Characteristics: Deciduous vine. Forked tendrils at end and joints of high-climbing vines. Branches have a brown pith. Leaves tiny to large, coarse, saw-toothed, lobed, heart shaped. Fruit round, fleshy. One to 4 pear-shaped seeds in several colors from purple or black to amber.
Primary Uses: Culinary. Fruit cooked to make jellies, jams, juice, syrups, and flavorings. Leaves are used as a wrapper for main dishes. Leaves may be eaten raw, stir-fried, or steamed. Tendrils are pickled.
Nutritional Value: Fruit is high in vitamin C.
Collection and Storage: Pick tendrils all year; clip with scissors. Grapes in season may be gathered by hand. Young leaves are picked at any time. Freeze leaves for stuffing; laying between sheets of wax paper, folding paper after each layer.

Linda Says- I wandered the hills of Syracuse, New York, with a famous gourmet cook looking for grape tendrils. There they were, curling down from yards of grape vines. I rolled and sniffed them first for their characteristic grape smell, then used scissors to clip hundreds of tendrils into a bowl. Later, my friend and I stir-fried the tendrils into delicacies, as well as froze them for use later in the year. The tendrils make me pucker.

Lamb's Quarters

Chenopodium album
Goosefoot Family, *Chenopodiaceae*

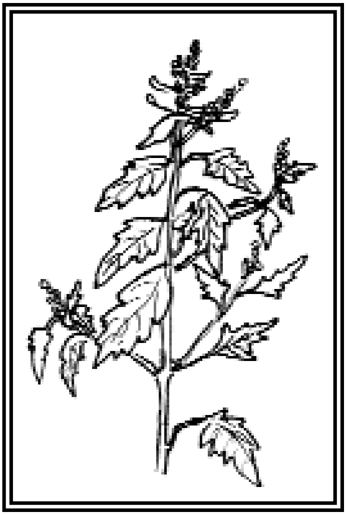

Other Names: Pigweed, goosefoot, wild spinach, chiciquelite, hwahai (Pima Indian). (Toakush Crow Indian).
History: Used in most countries and most civilizations. Recent archaeological findings in Denmark show it was an early food there. Now cultivated by Navaho and Mexicans. The Zapotec Indians use the flour as a staple food.
Habitat: Native to North America, Europe, Asia.
Characteristics: Annual herb. Grows to height of 18 inches or more. Leaf shaped like goose's foot, dark green with whitish underlay. New leaves have white or lavender-tinged powder near center whorl. Leaf beads with water when wet. Green seed-like flower clusters.
Primary Uses: Culinary, medicinal. Young shoots are boiled, cooking water is drunk. Leaves are spinach-like; eaten raw; steamed; boiled; sautéed; cooking liquid is drunk. Dried and ground for flour. Flower and seeds are ground for mush or cereal; sprouted, dried and ground for flour. Seed is excellent food for wild birds and canaries. Roots can be used as a soap substitute; wet hands and rub cleaned root. Young stems eaten raw or cooked.
Nutritional Value: High in nutrition, vitamins, calcium.
Medicinal Value: All parts used as a poultice for swelling, rheumatism, arthritis. Chewed raw for toothaches. Also, gelatin capsules filled with lamb's quarters are a potent vitamin.

Collection and Storage: Harvest large amounts with a long knife or small amounts with scissors and bag. Hang large bunches upside down to dry. When crispy dry store in glass for longevity or steam and freeze.

- 1 large bunch (stems bunched together to about 1 inch thickness) = 2 cups flour when dried and stripped.
- 1 large screen of leaves and seeds = 2 cups flour
- 1 large bunch chopped and steamed = approx. 12 to 14 sandwich sized plastic bags.

Caution: The lamb's quarters' leaf resembles poisonous, malodorous look-alike, nettleleaf goosefoot, which has a tough cardboard-like leaf. Crush and smell leaf. The rank odor will tell you immediately if you have this look-alike. Identify carefully. See page 294.

Comments: Chenopodium ambrosiodes; also known as Jerusalem oak, wormseed or Mexican goosefoot, is a type of lamb's quarters found in Arizona and other Western states. A sprig added to beans renders them anti-flatulent.

Lamb's Quarters

During World War II, the US government gave out information that garden weeds were good food. The top weeds included amaranth and lamb's quarters. Not only are these plants nutritious, but they are not bothered by cutworms or aphids.

Lamb's quarters grows phenomenally fast. In fact, just one plant yields all I need for a summer's meals for me! To gather, I pinch the tops and tips of each branch. I wait two or three days, then repeat; for each top taken, two or three will grow in its place. So just a few plants can yield an entire fall and winter supply.

Dried leaves make a delicious and nutritious flour. Mix it with a bit of water to make a tortilla, or combine with wheat flour to make an enriched pita bread or fry bread.

To make the flour, I pound the dried leaves with my favorite rock, but you can feed the leaves through a hand grinder for the same results. You can also place the crispy dried leaves in a pillow case and wring.

Malva

Malva Neglecta
Mallow family, *Malvaceae*

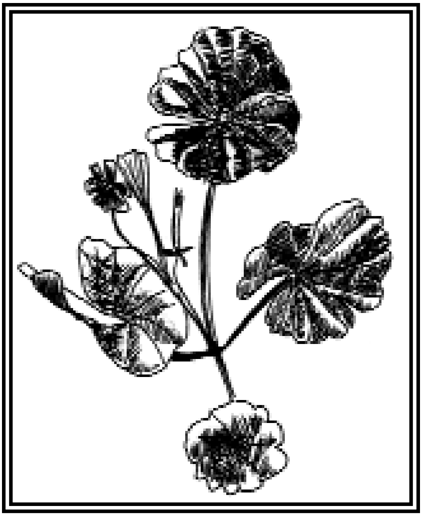

Other Names: Cheeseweed, button weed, cheeses, mallow.
History: Introduced from Europe; sold in the marketplaces of China and Japan.
Habitat: Fields, roadsides, waste areas.
Characteristics: Perennial or biennial herb. A stout, bushy plant branched and spreading from its base. Reaches height from 2 feet to 4 feet.
Primary Uses: Culinary, medicinal. Leaves used in soups, main dishes, stir-fried. Stems are vegetable stir-fried in garlic and olive oil. Flowers, buds and stems, and cheeses (seed cases) are all edible raw, steamed, sautéed, or dried and stored.
Nutritional Value: Very high in iron and calcium.
Medicinal Value: A mucilagenic, increasing the flow of saliva. Chewed for sore throats, upper respiratory problems.
Collection and Storage: Clip whole stems, pick off buds and leaves. Cut stems into sections for stir-fry or freezing. Cut leaves as large as you can for rolling around tofu, fried beans, potatoes, rice. Collect in bunches for abundance. Do not pick malva with red stems. Red stems may depict nitrate from the soil; pick fresh young plants when possible. Mince malva leaves and marinate in oil and vinegar before cooking.

Add 1 cup salsa to ice cube trays, a spoonful of fried beans, roll tightly in malva leaves and freeze. Easy to defrost and bake at a later date. (See recipe for Malva Rice Roll-Ups.)

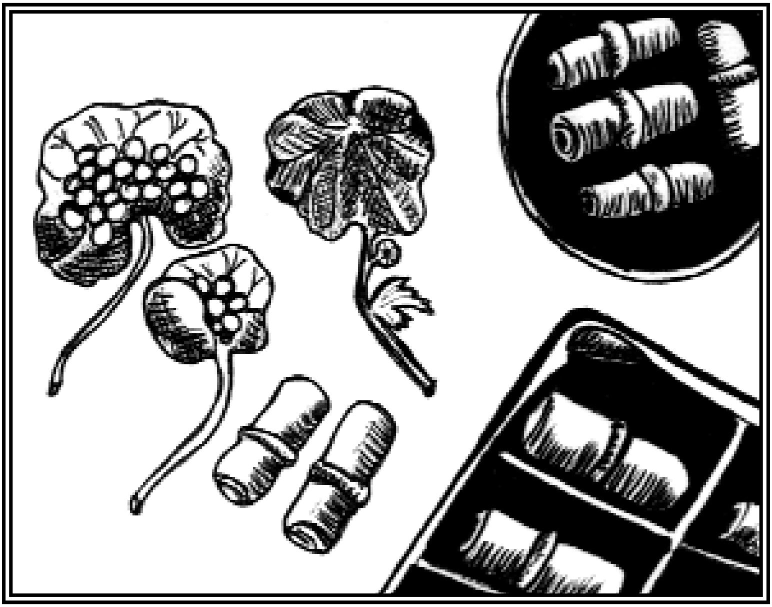

Stuffed Malva Leaves

Linda Says- Malva has cheese-wheel seeds. I love to gather them and dry them for potato salads, stir-fries, or eat them as they are.

Seeds are dried to use as "nuts" in winter. Large leaves used for wrapping foods. Stems are used for delicate sautéed vegetable, and younger leaves for salads and sandwiches. Once dried, all parts of malva can be ground for flour! I cook with malva flour a lot. As a general rule, I use 1 cup malva flour to 3 cups of wheat or other gluten flour.

Maple

Aceraceae Family

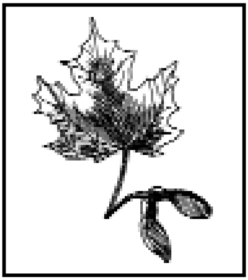

Other Names: Sugar, silver, soft, rock and red maple.
History: Many species native to United States. Native Americans were early users of the tree's products. Chippewa Indians pressed the seeds into cakes calling them maple cakes.
Habitat: All environments except lower Rocky Mountains and the Plains states; areas with rich, well drained soil.
Characteristics: Deciduous tree. Most leaves have 5 pointed lobes, are irregular toothed, and are opposite on branches. Leaves turn golden yellow to scarlet in early fall. Seeds have brown wings and occur in pairs. All have sweet sap to a varying degree.
Primary Uses: Culinary. Sap used for syrup, candy, flavorings. Seeds eaten raw or pressed into cakes. Twigs and young leaves used for tea and emergency food.
Nutritional Value: Leaves high in minerals, beta carotene and vegetable protein.
Collection and Storage: Cut the seed off the wing with scissors, dry on a screen, and put through the grinder. Twigs, inner bark, and sap can be collected and used in winter. Collections of twigs is simple because they snap off easily by hand. Syrup collection is through a tap drilled into tree using a collector pail. (Author used plastic milk bottles from a nearby dump.) Please refer to other references to details of syrup collection.

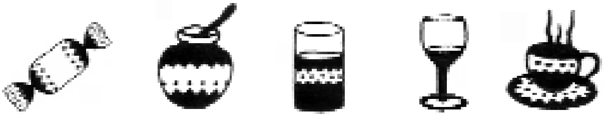

Maples in Winter

I was relaxing in front of a fire in the crispness of early morning when Crack! A sound like an explosion came from behind me in the woods. I scanned the trees and saw that a maple tree had "exploded." The explosion caused a big crack in the tree about three feet high. When a winter wind stirs the frozen trees, they sometimes appear to burst vertically. When it was 40 degrees below zero at night, I lay awake and listened to trees explode. That's a true wilderness thermometer!

Meadowsweet

Filipendula ulmaria
Rose Family, *Rosaceae*

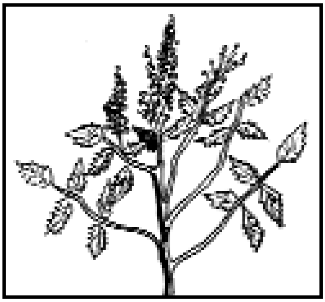

Other Names: Queen-of-the-meadow, meadow sweet.
History: Native to North America, used by native Americans.
Habitat: Meadows, old pastures from Nova Scotia and New Brunswick to North Carolina and west to Minnesota and Arkansas.
Characteristics: Perennial herb. Bush with symmetrical branches, 30 inches long or more. Flower spires, shaped like church steeples, are white and fluffy in spring. The steeples turn seedy and chocolate brown in the winter, giving it a characteristic look against the snow. Twigs have hundreds of tiny nodes between the branches and are characteristic of meadowsweet, not other hardhacks.
Primary Uses: Culinary. Twigs chewed or steeped as tea. Dried and stored for winter. Flowers are dried as a sugar substitute; sweet enough for teas & cereals, but flower must be dried. Used in wines. Seeds are also edible. Leaves used for tea.
Nutritional Value: High in vitamins and minerals. Also high in beta carotene, potassium, and niacin.
Medicinal Value: Mineral tonic. Flu and Rheumatic pains. (contains salicylates.) Twigs, inner bark and sap can be used in winter.
Collection and Storage: Collect twigs by breaking off when young and store in paper bag. Collect flowers by pinching off easily with fingers. Dry on screens.

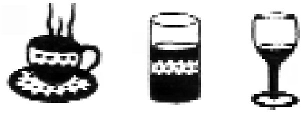

Linda Says- Shearing meadowsweet flowers with scissors is by far the quickest way to harvest them. Pick with both hands, breaking brittle twigs. Swing a handful from your right hand up under your left armpit. Hold tight and continue until bunch is cumbersome, then tie and set aside. Gather bunches and tie together.

Milk Thistle

Silybum marianum
Composite Family,
Compositae

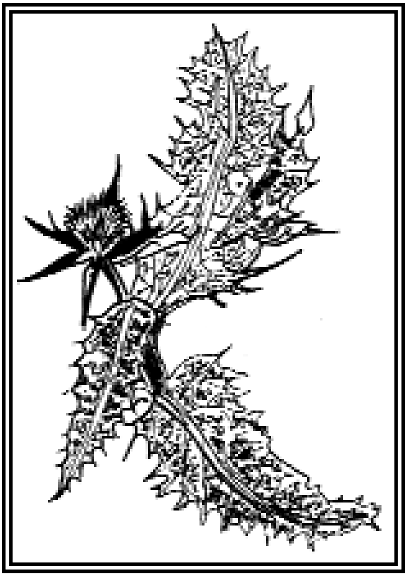

Other Names: Horse thistle, marian, holy thistle.
History: Native to the Mediterranean, also hot regions of North America, including Southern Arizona. Cultivated and dried in Europe. Used by Native Americans.
Habitat: In west, commonly found in ditches; waste places.
Characteristics: Annual herb. Grows 3 to 6 feet tall. White milk splotches on prickly leaves, named “Mother Mary’s milk.” Large prickly, fuzzy thistle flower with long prickers from central stem. Vigorous grower; 1 plant will quickly spread to a bed 3 feet around.
Primary Uses: Culinary, medicinal. Young leaves parboiled to remove prickers, for soup or stir-fry. Cooking liquid is drunk. Leaves dried and ground for extract.
Nutritional Value: High in vitamins and minerals. High in phosphorous, vitamin K, and thiamin and niacin.
Medicinal Value: For treatment of liver disease. A valuable source of the chemical silymarin. Mineral tonic, flu and rheumatic pains (contains salycylates).
Collection and Storage: Use a long blade or sharp machete to cut off prickly leaves. Extract young leaves from center of plant with long knife and tongs. Plant tends to pull up nitrates from the soil, so harvest young leaves. I dry the leaves by placing them face down on a screen. You can handle prickly leaf safely by pinching the back vein of the leaf.

Linda Says- The gigantic prickles on the milk thistle once scared me. I was aware of the multiple benefits of these ominous leaves, but how to gather them? Gloves did not help. The best tools are a long-handled tongs and a long kitchen knife. Slice the leaf off with the knife and pick it up with your tongs and bag it. Washing them becomes the next challenge, and cooking to a safe texture is yet another. The leaves fairly "melt" in cooking; even the barbs become tender if the leaf is simmered long enough. I cut off the barbs with scissors, then simmer a few minutes and drink the broth.

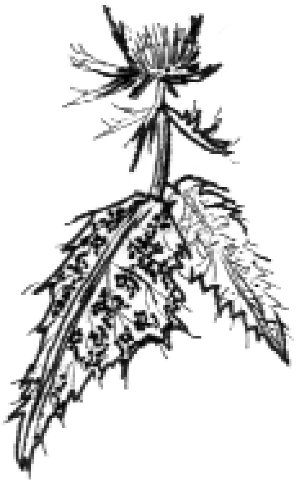

Milk Thistle

Milkweed

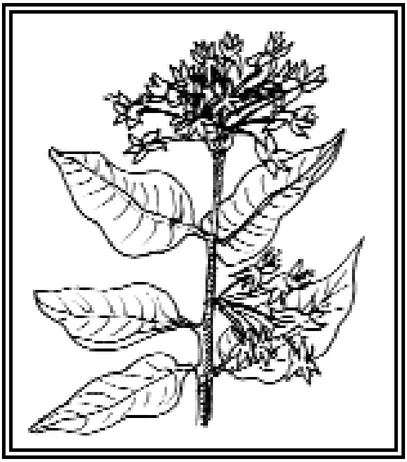

Asclepias species
Milkweed Family,
Aslepiadaceae

Other Names: Silkweed, butterfly weed, cotton tree, pleurisy root.
History: Native perennial with many species. Known since ancient times, used during World War II in rubber experiments, fluff considered for life preserver stuffing.
Habitat: Fields, roadsides, gardens.
Characteristics: Perennial herb. Single stem 2 to 5 feet high. Leaves opposite in pairs from 4 to 9 inches long. Heavily veined, smooth leaf with white milky sap throughout plant. Flowers are round clusters of pleasantly fragrant single stars at end of dozens of branches, making a round ball of blossoms. Flowers give rise to a green bristly pod, in which fluff-bearing seeds form. White sap exudes from all parts, including roots.
Primary Uses: Culinary and medicinal. Flowers and seeds are edible. New sprouts are used as vegetable, cooked. Young leaves and buds are cooked as vegetable. Stalks are peeled for strong fibers; used for fishing line, especially if braided. Bark is braided into ropes of varying thickness. Pods picked young are used in soups and stews.
Nutritional Value: Shoots high in niacin, potassium and vegetable protein.
Medicinal Value: Milky sap used in wart removal.
Collection and Storage: Break off buds, young leaves, and flowers by hand. Use a paper bag. The milk tends to turn the plant sour if kept in plastic bags. Strip stem fibers and braid for emergency fishing line or rope, as well as shoelaces (in the wild).

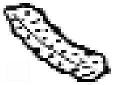

As a vegetable; young leaves and buds can be dried or frozen. Sprouts can be frozen. Buds should be simmered twice for 3 to 4 minutes, changing water in between. Roll any wide leaf with goodies and bake in salsa for a wild Mexican delight.

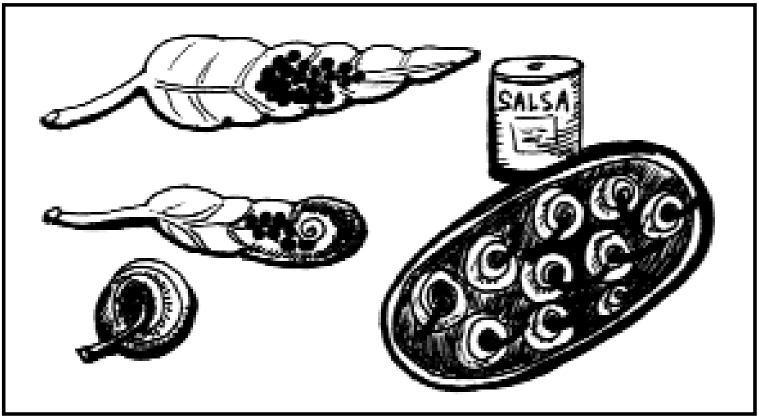

Wild Mexican delight!

Milkweed Abundance

Gathering milkweed is by far the easiest way to find food for my family. The abundant pebbly tops beckon to me. I move from every fourth plant or so with ease. I fill a large bag and then go to the Cedar River log bridge to wash them. The time spent swishing the milkweed buds in the cool water are some of the most precious moments of homesteading.

Mint

Mentha species
Labiatae family

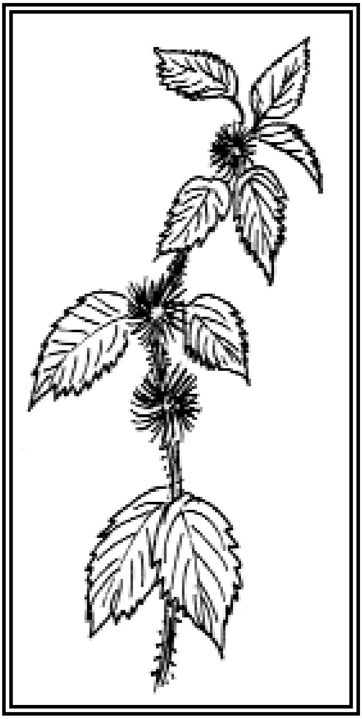

Other Names: Spearmint, peppermint, horehound, giant hyssop, wild bergamont, bee balm, oswego tea.
History: Mostly native to North America and widely distributed throughout the world. Used since ancient times in scents, cosmetics, flavorings, food and medicines.
Habitat: Found in most areas from swamps to fields, gardens to lawns.
Characteristics: Perennial herb. All mints are aromatic. Most mints have square stems; leaves are opposite with usual unevenly saw-toothed edge. Prominent veins; leaves may be smooth or coarse, sharply pointed in most species. Characteristic fuzzy leaves in wild varieties, especially swamp mints. Plants range from 5 inches to 2 feet high.
Primary Uses: Culinary, medicinal, cosmetic. Leaves, flowers, stems and roots eaten raw in salads, candies; leaves steeped for tea. Flowers dried for teas. Whole plant ground for aromatic tea.
Nutritional Value: High in vitamin C and iron.

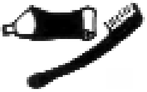
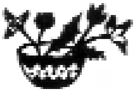
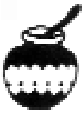
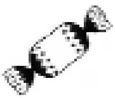

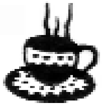
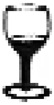

Medicinal Value: Well known as a stomachic, or stomach soother. Also used for insomnia, stomach ache, fevers and colds.
Cosmetic Value: Aromatic stimulant, astringent, restorative; used for scents, in soups and potpourris.
Collection and Storage: Cut stems where desired, as plant rejuvenates quickly. I used to pick and wind one plant into a bunch, then string bunches together for ease of harvesting as well as drying. Also, freeze flowers in ice for pretty edible cubes. Mints transplant easily and have characteristic prolific growth in an herb garden.

Linda Says- The camp always smelled good when the mint was drying for winter. Our family eats the leaves often. Since a leaf holds a whopping amount of iron, it is understandable why I eat at least 1/2 cupful every time I go out to pick it.

Mint Aromas

Lightning flashing all around me, I lay prostrate in a large patch of mint. The air was blue-black. Tired and clutching my bundle of freshly picked plants, I almost welcomed the respite, though I was a bit nervous.

Mint picking is always done around swamps, streams, and riverbeds, and this day I was able to gather a six-week supply before a typical Adirondack thunderstorm kept me waiting for 30 minutes.

Mullein

Verbascum thapsus
Snapdragon Family,
Scrophulariaceae

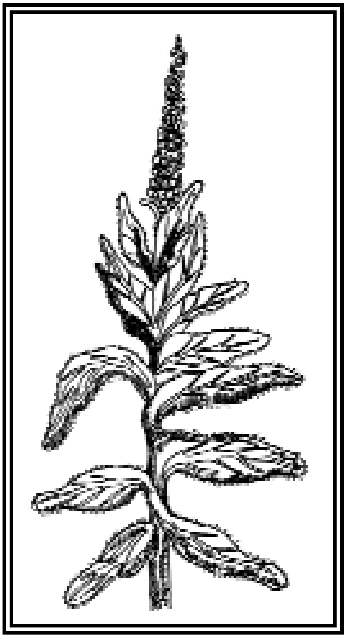

Other Names: Candlewick, flannel leaf, Aaron's rod, feltwort, hare's beard; velvet plant, velvet dock, blanket leaf.
History: Native to Europe, naturalized throughout pasture land of United States. Plant also known in Roman and Greek history; Quakers, Native Americans.
Habitat: Waste wet areas as well as roadsides, gravel-filled fields.
Characteristics: Biennial herb. Tall spikes with yellow flowers, velvety leaves whirl around spike. Grows up to 10 feet tall. Produces basal leaves in first year, then spike the second year. Leaves furry or velvety, ranging from 3 inches to 2 feet long. Flowers are succulent and sweet smelling, attracting bees.
Primary Uses: Culinary, medicinal, cosmetic. Root used for medicinal tea, leaves and flowers dried for tea and medicine. A normal root, up to 1 foot long, may be reused dozens of times. I put large leaves in my sneakers when walking long distances; they help soothe tired feet, and prevent blisters. Native Americans put leaves on cradle boards to heal elbows and shoulder blades. Antiseptic, mullein is invaluable for inflammation.
Medicinal Value: All parts of mullein, from single tap root to flowers have an antihistamine quality among other qualities. (See chart page 53 for comparing mullein to aloe vera.)
Cosmetic Value: Astringent and emollient properties, decoction of flowers for hair rinses to lighten hair color; flowers steeped in olive oil used as application for sores or massaging oils.

Collection and Storage: Second-year leaves may be harvested from the spike individually, flowers harvested individually, and root harvested at any time, any season. I harvest single leaves, roll them up, and dry them on a screen. These rolls may be kept in glass containers and taken along when hiking.

Floated in olive oil, mullein wicks will burn cleanly & clearly for 3 hours or more or until the olive oil is used up. Pour a tablespoon of olive oil on the top of a glass of water. (You must float the mullein by crossing 2 toothpicks, poking the ends of the toothpicks in a tiny piece of foam or buoyant material.) Place the wick in the center, letting a piece touch the oil you have poured on the top of the water.

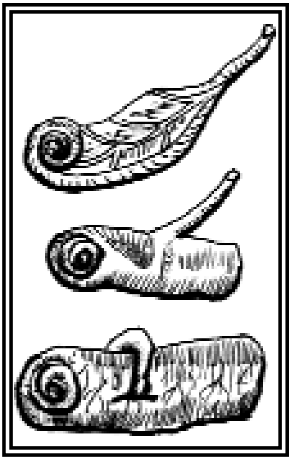

Figure 48 Rolling and Drying Mullein leaves.

Linda Says- I used mullein for lamp wicks when snowed in. A small piece of the flannel leaf cut to size, dried, and soaked in oil will burn for quite a while.

Mullein

I feel as if the 6-foot high plant were a person. I address the mullein and ask to pick its flannel leaves and flowers!

One summer, my Girl Scout Troop was horseback riding on a field trip in Indian Lake, New York. One of the horses moved too close to the one in front and the forward horse kicked, clipping the child on the ankle. It was obvious she had a bad injury. Removing her shoe, I shouted to get mullein, quick! The scouts came running with fresh mullein. "Roll the leaves and crush them quickly with a rock, girls." Poultices were made and applied on the swollen ankle. The mullein stalks became splints and the leaves became bandages until we could get the small scout to a hospital. Soon thereafter a doctor called to ask "What was that plant around the scout's ankle? She had a chip fracture but no swelling or pain!" Mullein, sir!

Mustard

Brassica species
Mustard Family, *Brassicerceae*

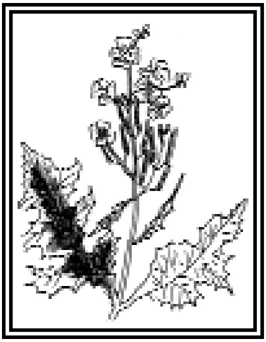

Other Names: Charlock mustard, field mustard, yellow mustard.
History: Native to Europe, pasture land in North America. Used medicinally in Greek, Anglo-Saxon history. A pot herb in English history.
Habitat: Fields, roadsides in cooler regions.
Characteristics: Annual herb. Grows to height of 10 feet or more. Leaves rounded, with extra protuberances of tiny leaves below main part of leaf. Crushed leaf yields herby pungent smell. Four-petaled yellow flower; petals in form of cross. Black seeds in pod.
Primary Uses: Culinary. Stems used raw as pungent spice. Leaves all eaten raw, used as pungent spice; steamed, boiled in soups, stews. Flowers are eaten raw; steamed. Seeds dried and used as spice; ground for mustard.
Nutritional Value: High in beta-carotene, minerals, vegetable protein.
Medical Value: Dried leaves and flowers used as a poultice, or mustard plaster for respiratory distress.
Collection and Storage: Collect young leaves by snipping off stalk with fingers. Collect pods separately in season when seeds are mature, pods almost dry.

Linda Says- When eating mustard greens boil in water for 15-20 minutes. Mustard is a very pungent vegetable.

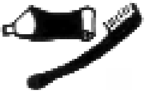

Mustard

As soon as the temperature rose to between 32 and 40 degrees, I would make a beeline to the back of Alice and Walt Sherman's barn. The mustard plants were always green, growing beneath the snow against the warm barn boards. There are no words to describe the taste of the first mustard leaves of the season. My body fairly roars with energy for days to follow!

Nettles

Urtica species
Urticaceae Family

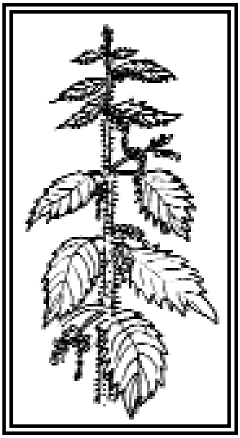

Other Names: Stinging, slender, great, dwarf, nettle.
History: Native to Europe, widely naturalized in North America. Used worldwide.
Habitat: Fields, fertile soil from Alaska throughout continental US.
Characteristics: Perennial herb. Leafy plant. Leaves opposite in pairs, coarsely veined, oblong tapered to tip with rough, sharp saw-toothed edges. Entire plant fuzzy with tiny stinging bristles or minute hairs. Flowers are tiny green seed-like clusters between stalk and branches.
Primary Uses: Culinary, medicinal, cosmetic. Leaves and flowers boiled for soups and stews, cooked in stir-fries. Seeds are used in herbal teas. Excellent tea!
Nutritional Value: High in protein, iron and vitamin C.
Medicinal Value: Tea well known as a nutritious restorative tonic.
Cosmetic Value: Commercial uses: nettle shampoo, herb wraps.
Collection and Storage: Use leather gloves when collecting nettles. When harvesting for vegetable, hold a bag or bowl under separate leaves and clip off with a pair of scissors. A few plants sustain a whole family, since several nettle leaves grow where pruned.

Clip seeds separately if desired, plant will continue to produce until mature. Place nettles in water to simmer away hair and leave a nutritious main dish.

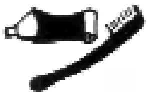

Linda says- I can still feel that prickly burn on my leg from each tiny hair as I approach the tall, stately plants. I learned my lesson. Blessing the "armored" leaves, I soon practiced safe collection. My young scout troop once gathered a bunch of nettles and presented a "bouquet" to Utica's city scouts; I'm sure their lesson became the same painful memory.

Phragmities

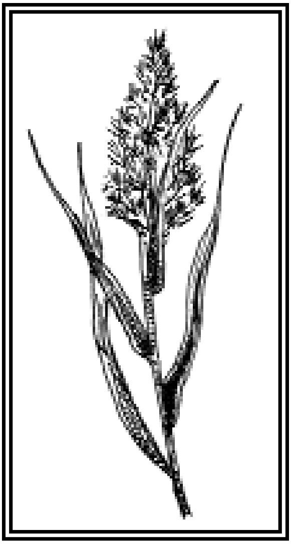

Phragmities communis
Grass Family, *Graminae*

Other Names: Reed, giant reed.
History: Native to Europe and North America. An ancient food, craft material, fiber. The Gosiute Indians gathered a sweet secretion formed on the leaves by aphids and used it as sugar (Chamberlain 1911). The Panamint Indians dried the entire reed, ground it, and sifted out the flour (Colville 1892). This moist and sticky substance was then set near a fire until it swelled and browned, when it would be eaten like taffy. The best time to gather the culms (stalks) was spring.
Habitat: Grows throughout the United States except inland areas of South Atlantic and south-central states; also Europe, Asia. Likes marshes, swamps, wet areas, roadsides.
Characteristics: Tall, reed-like stalks with feathery seed tips. Up to 6-8 feet tall.
Primary Uses: Culinary. Stalks are dried and ground to flour. Gummy substance in the stalk can be used as gum or in drinks. Stems woven for mats, bedding, thatching, grass huts. Excellent tinder. Fibers in stalk made into ropes by twisting together. Seed heads are made into a gruel, cereal, or flour. Used in cellulose, arrow shafts. If seeds are not present, chaff is ground into flour. Roots or rhizome (underground stems) are gathered and ground into flour. Eaten raw, roasted, or boiled into a sweet, gummy confection not unlike candy or marshmallow.
Collection and Storage: Study the cycle of head (seed) maturation. There is a 2-week period when seed head is full and ripe. Past that stage the seeds drop and blow away. Clip heads with scissors in the middle of summer, before seeds mature and fall out of seed head.
Caution: The water in which phragmities grows is often polluted, so test the water before eating the plant.

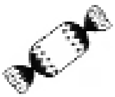

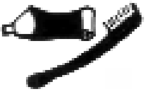

Linda says- Imagine my surprise when told that the waving reed was edible and could be ground to flour! It wasn't long before I began to experiment. The thought that such a tremendous proportions of the world was home to this plant, but few people were baking with it became another reason for this book. (The water in which phragmities grows is often polluted, so test the water before eating the plant.)

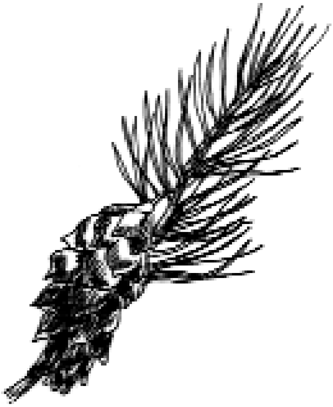

Pine

Pinus species
Pine Family, *Pinaceae*

Other Names: Too numerous to mention, but including white pine in East and pinyon in West.
History: Native to most parts of the world. Used by Native Americans.
Habitat: Woods, forests, landscaped area; soil varies from dry to moist.
Characteristics: Evergreen tree. Cone-bearing. Needles vary in length, usually long and slender occurring along the twigs. Bundles of 2 to 5 needles common. (White pine with 5 needles shown in picture.)
Primary Uses: Culinary, medicinal, cosmetic. Needles eaten raw or cooked as vegetable; tea, flour. Catkins eaten as candy; raw, dried for tea, salads. Cone and nuts (seeds) are eaten as snack; ingredient in baked goods. Bark is emergency food, roots are eaten raw, steeped for tea. Sap has medicinal application for small cuts, scrapes, blisters.
Nutritional Value: High in Vitamin C.
Medicinal Value: Colds, flu; as a tea, mixed with honey.
Cosmetic Value: Deodorant, air freshener; soaps, lotions, cleansing oils.
Collection and Storage: Gather needles, twigs, and bark. Using a knife, peel a section of bark lengthwise from a young branch; this may be chewed for a long time. (See “Peeling bark in strips” on page 31.) To harvest needles, let branches dry thoroughly

until needles fall. Gather needles in a sheet, then break up twigs into small sections. Place needles in glass jars. Preheat oven to 300 degrees, then turn off! Place jar with needles in oven and leave until the oven is cool. Cap immediately and store.
To do twigs, place them in a glass jar, leaving the cap off. Put in a turned off 300° F. oven, leaving until cool. Put in a sunny area for further drying, if needed (until they snap easily). Cap for storage.

Caution: Needles are volatile and catch fire easily.

Linda says- Many was the time I ploughed through snowdrifts looking for meadowsweet, maple and beech twigs, and succulent fresh pine needles. Pine provides the energy to go on! It is the taste and smell of the forest. Save every bit of your Christmas tree for pine tea if it has not been sprayed or dyed a darker green.

* * *

Plantain

Plantago major (common plantain)
P. Juncoides (Long-Leafed Plantain)
Plantain Family, *Plantaginaceae*

Other Names: Turnip leaf, cart-tract plant, cuckoo's bread, English plantain, goosetongue, Indian wheat, pale plantain, ribwort, rippleseed plantain, seaside plantain, seashore plantain, snake weed, soldiers herb, White man's footprint.

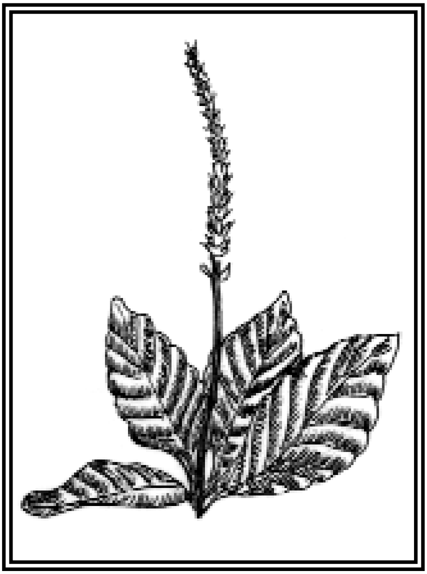

Common Plantain

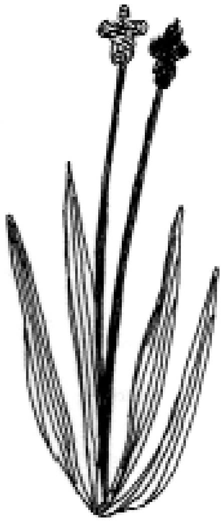

Long-leaf Plantain.

History: Many types native to Europe and naturalized in North America. Used as vegetable in France; cultivated in England. Some varieties native to Asia.
Habitat: Lawns, roadsides, fields, waste areas.
Characteristics: Biennial or annual herb. Turnip-like flat roundish leaves, with prominent parallel veins. Center stalk lined with seeds. Considered a pot herb in Europe, this plant has many species. Common plantain has spade-like flat leaves, whorling on the ground from a center point, with tall stalk in center with many seeds around stalk up to tip. Long-leafed plantain has long narrow leaves with heavy vein and similar texture, taste, and smell. Stalk has seeds at only top inch or so.

Primary Uses: Culinary, cosmetic. Young leaves are eaten raw or cooked. Stalks are dried for vegetable chewies. Seeds are eaten as sprouts. Entire plant is edible.
Collection and Storage: Turnip-like leaves are easily twisted from the ground by hand. The stalks are clipped and dried in a day or so. Use scissors. Leave stalks until the seeds are easily removed. Save stalks for a crispy stick food.

Linda says- The plantain leaf I eat is also a fantastic underarm deodorant! Prepare the leaves by placing 3 leaves together, then crush with a rock or hammer until the juices flow. Remove the inside leaf and wipe juice on underarm. Free supply abounds under my feet. Plantain has surrounded all the camps I have lived in throughout my homestead years.

Prickly Pear

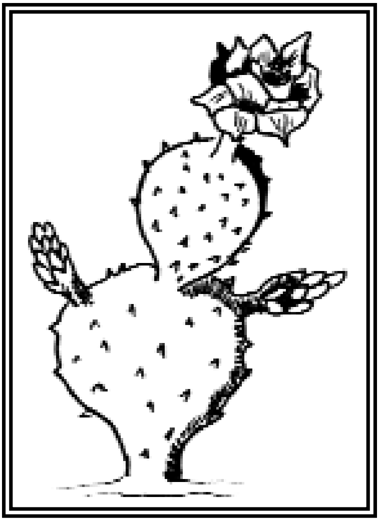

Opuntia megacantha and other species
Cactus Family, *Cactaceae*

Other Names: Devil's tongue, beavertail, Indian fig, tuna.
History: Native to North and South America. Used by Native Americans.
Habitat: Hot, dry, well drained soil.
Characteristics: Fleshy, low-spreading cactus. Has flat stems and pads with long needles. Thorny fruits are preceded by waxy flowers, yellow or red. Fruits ripe for harvesting are yellow-green to purplish black.
Primary Uses: Culinary, cosmetic. Pads are cut up for food; strips parboiled and french-fried; simmered for hair tonic and softener. Flowers eaten raw, cooked to candy, jelly; also frozen in cubes for drinks. Buds cooked for jellies, jams, syrups, deserts, candies; juices also made. Water from fruit and young pads may be used as a liquid in an emergency. Seeds may be dried and ground to flour; used as a soup thickener.
Nutritional Value: High in carbohydrates and calories.
Medicinal Value: Pads split open for soothing gel for burns, wounds, sunburn.
Cosmetic Value: Hair tonic, softener.
Collection and Storage: Handle pads only with leather gloves and tongs. To harvest, use a long stick, handle, or shovel to knock off each pad. With a deliberate touch-and-push movement, the pads break off and fall to the ground with ease. When you pick them up, slide a board underneath or use tongs, and put them in a container. One pad is a large filet, or 2 servings. It can be cut up and frozen in cubes for drinks.

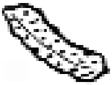

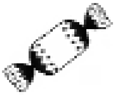

One hair rinse pad is good for several shampoos. Fruit and seed pulp also harvested with tongs. Flowers are easily removed by hand, petal at a time. Petals eaten raw, cooked to candy, jelly.

To prepare pads as poultice, hold gingerly with thumbs and forefinger. Using point of a knife, poke first, then slice carefully in half. Spread out and scrape off watery meat for use as a poultice.

Caution: Prickly pear is a protected plant. OK to harvest pads, flowers, buds as a survival food on the desert. Do not remove whole plants.

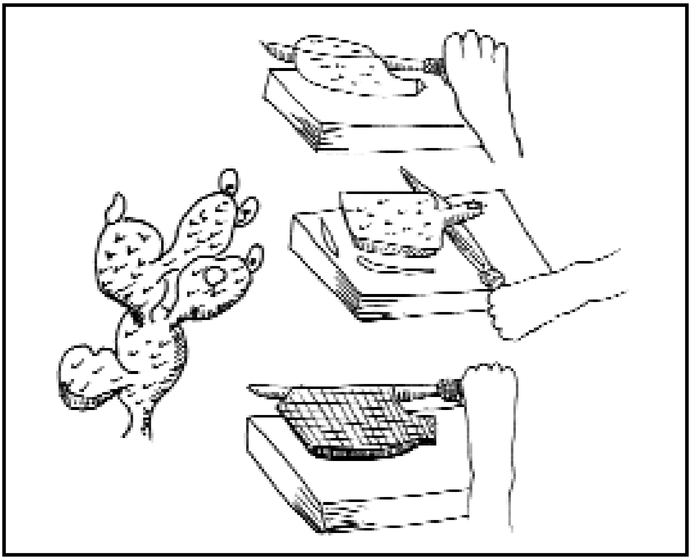

Preparing Prickly Pear.

Linda says- My personal attachment to this plant came in a way different from the usual. I led a wild food field trip to the desert in Black Canyon City. The temperature was only 90 degrees, but the sun was vicious to my fair, sensitive skin. I knew my sun block was not working so well. I scraped the needles off some prickly pear and cut the pad in half, applied the cactus meat to my sunburned face. The prickly pear and I became good friends from then on!

Purslane

Portulaca species
Purslane Family, *Portulacaceae*

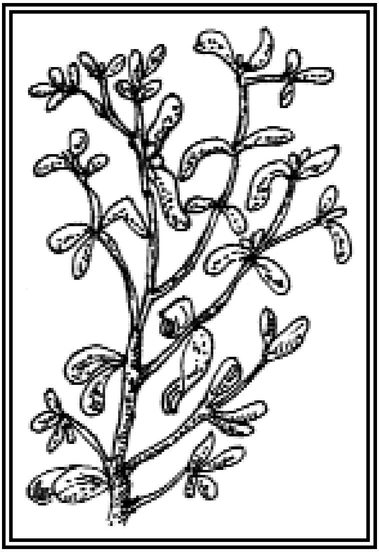

Other Names: Low pigweed, pusley.
History: Native to Europe, widely naturalized in United States.
Habitat: Fertile soil, topsoil.
Characteristics: Annual herb. Prostrate peddle-shaped succulent leaves on branching fleshy vines. Forms mats in masses of growth. Five to 7 petaled tiny yellow or red flowers are prolific. Multitudes of tiny black seeds produced on each plant.
Primary Uses: Culinary. All parts edible, raw or cooked. Purslane also pickled.
Nutritional Value: Shoots contain a balance of minerals for only l6 calories per half a cup.
Medical Value: A succulent that quenches thirst as well as puts a quantity of minerals in the body of an active person. Contains a high mineral content.
Collection and Storage: Gather mats, snapping off branches, and leave root for rejuvenation. Gather succulent young branches for raw treats. Also grows well indoors.

Linda says- My first harvest of purslane yielded 34 jars of pickles. Since then I have picked and pickled virtually hundreds of jars of purslane.

Queen Anne's Lace

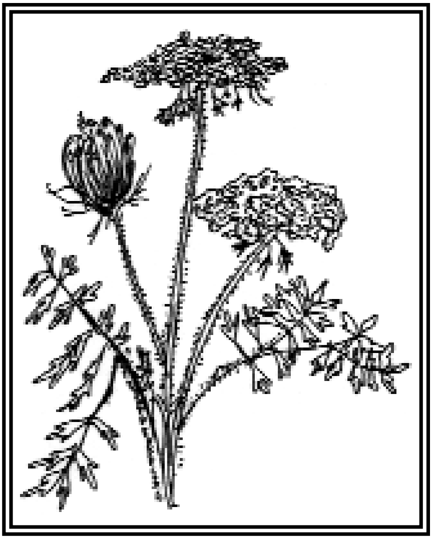

Daucus carota
Parsley Family,
Umbelliferae

Other Names: Wild Carrot.
History: Native to Europe, especially common in England; widespread in United States. Used by pioneers and Native Americans.
Habitat: Fields, waste areas.
Characteristics: Biennial herb. Reaches height of 2 feet or more. Carrot-like odor in stem and leaves as well as seeds. Flower clusters flat-topped, umbrella-like, lacy and often have single purple flower in the center. Old flowers "bird cage up" and turn brown. Leaves are parsley-like, feathery and smell like a carrot. All parts of stems have tiny fuzz, essential for proper identification.
Primary Uses: Culinary. Stems may be cut into sections and used for flavoring in stews & soups. Buds may be sautéed in oil.
Nutritional Value: Beta-carotene is exceptionally high, as is niacin.
Medicinal Value: The brown dried seeds are an excellent salt substitute.
Collection and Storage: Leaves are gathered in early spring and young leaves all season. Gather roots as carrots in early spring or fall; may be dug under leaves or hay even after winter snow. Gather flowers in summer. Collect seeds in fall.
Caution: Seeds of the wild carrot have a high content of vitamin A and shouldn't be eaten in excess.
Caution: Easily confused with Poison hemlock, resulting in severe burns of the fingers and hands as well as almost certain death if ingested. Check for the fuzz on the stem, as well as sandpaper-like feeling on dried stems from old dried fuzz. Use the foraging rule and crush, roll, and smell first; do not ingest. Determine the carrot smell and then look for the hair or fuzz.

Comments: In the fall, the flowers of wild carrot curl up; I call this "bird caging." At this time, I gather the seeds and a few seeds go a long way! I get a winter's supply of "salt" from a few flowers.

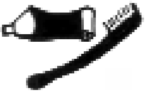

Queen Anne's Lace Chips

I will always remember my switch from potato chips to Queen Anne's lace flowers. In the wilderness, potato chips are a rare commodity, but Queen Anne's lace flowers crisp to a "chip" of carroty crispy flavor. I dip the flowers in hot oil and then put the brown crispy delights on hot rocks to cool. Todd loved to fly by and grab a few crispy flowers and pop them in his mouth using the stems as a handle.

Raspberry

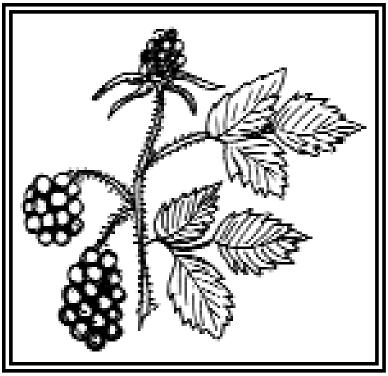

Species
Rose Family, *Rosaceae*

Types: Cloudberry, Thimbleberry, wild red.
History: Some varieties native to North America, others naturalized from Europe, Asia. Used as a fruit in all countries where raspberries are found, especially Europe.
Habitat: Roadsides, rocky fields, thickets.
Characteristics: Hardy shrub, biennial canes from perennial roots. Varies in size to average of 5 feet high. Saw-toothed leaves in groups of 3. Round, erect stem with short thorns. Stems have a white powder on them. Flower white; fruit pebbly and red or purple when ripe, pulls away from receptacle.
Primary Uses: Culinary, medicinal, cosmetics. Early leaves used fresh or dried for tea. Buds and flowers are edible. Frozen in ice for drinks. Fruit eaten raw, cooked for jellies, jams, syrups, fresh for juices, wines. Stem peeled and chewed, tea made from young twigs.

Nutritional Value: High in vitamin C.
Medicinal Value: Tea from leaves good for control of diarrhea. Relaxes muscles of the uterus, beneficial for menstrual cramps and strengthening the reproductive system.
Cosmetic Value: Stimulating astringent in herbal hair rinses and bath mixtures.
Collection and Storage: For quick, efficient berry harvesting, hang a container around your waist and pick using both hands. When drying berries, spread a fine cloth over trays of berries to keep flies and birds away. Harvest young leaves.

Caution: Reddish-tinged mature leaves may be toxic. Use only young green leaves.

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> ***Linda says-*** The Adirondacks are inundated with black bears during berry season. One time I came upon a huge mama bear lying on her back under a thicket of raspberry. She was stupefied from gorging on the fermented, overripe berries. As she rolled over, she hiccuped and burped, then waddled off. See page vii.

Rose

Rosa rugosa, R. Caroline
Rose Family, *Rosaceae*

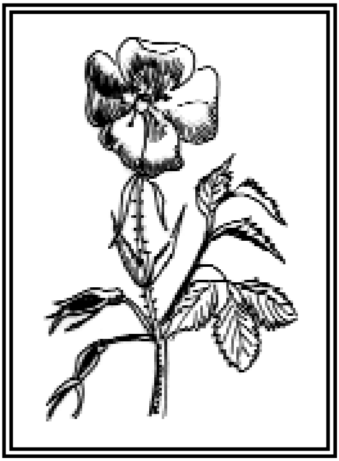

Other Names: Garden rose, wild rose.
History: R. Caroline native to North America; R. rugosa native to Asia but naturalized in United States. The symbol of love and beauty in ancient mythology. In Middle Ages, rose was symbol of secrecy (Subrosa). Also a heraldic symbol (War of Roses). Native Americans used all parts of plant. Europe and Asia (Sturtevant).
Habitat: Meadows, fields, woods, and coastal beaches.
Characteristics: Perennial or hardy shrub. Usually 5-petal flower,

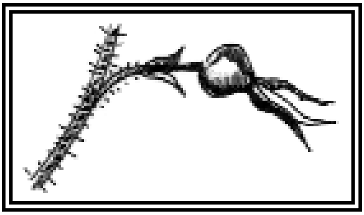
Rose Hip.

yellow, pink, red or purple. Thorny stems, particularly central stem. Fruit is called rose hip and has prominent calyx lobes.

Primary Uses: Culinary, medicinal, cosmetic. Petals eaten raw or cooked, in salads, as a garnish. Petals are used for teas for rose ice cubes or popsicles. Rosehips remain at end of stem after the petals fall off. This bulbous end is edible raw or cooked, sliced in salads. Leaves used raw in salads; dried for leaf tea. Stems peeled and brewed as tea; roots peeled and chewed; brewed as tea. Hips used in jam, jellies, tea, candy, or confections. Brewed as tea; dry and reuse, or store in glass jars. Also used in incense & lamp oil.

Nutritional Value: Rose hips are high in vitamin C.

Medicinal Value: Known to help with colds and coughs. All parts, including roots, pounded and powdered as snuff to clear sinuses. In the past, the bark was mashed and applied to boils, wounds, sores. Today, rose oil is used to soothe headaches and as a healing ointment.

Cosmetic Value: Soaps & perfumes.

Collection and Storage: Gather all parts. Early rose shoots are easily clipped with scissors. Save all parts. Leaves may be clipped at any time and wear gloves and use a canvas bag or paper bag, one for leaves, one for roses and hips. Full roses snip 1 inch below hip. Pull petals off and use hips later.

Sauté rose petals in light oil for delicious treat. Roll in confectioner's sugar and refrigerate for candy.

Make rose oil by adding 1 ounce of rose powder (ground petals) to 4 tablespoons olive oil and store for a few weeks.

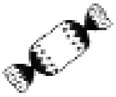

Linda says- Imagine what it's like to find yourself in a field of wild roses. Wandering among the bushes, I felt I was in the Garden of Eden. I wore gloves, dungarees and a long sleeve shirt for this experience. Nearby the Hudson River flowed past. Dragonflies and birds flew around me. When I tired of stuffing bags with petals for drying, I took a dip in the clean upper Hudson.

Saguaro

Carnegiea gigantea
Cactus Family, *Cactaceae*

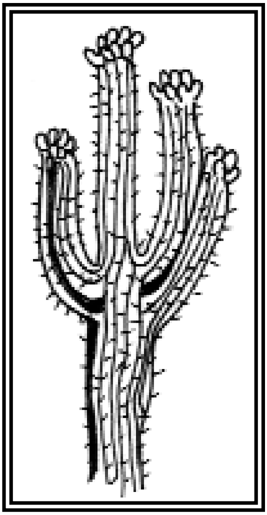

Other Names: Monument of the desert.
History: Native to North American desert. Used by desert dwellers, Native Americans. Papago Indians make heavy syrup and intoxicating wines.
Habitat: Rocky, gravel soil; hills, canyons, and dry washes.
Characteristics: Treelike cactus. Has one or more founded arms extending branch-like from a single, thick trunk. Shallow root system with small roots radiating out the height of the cactus and then some; no taproot. Long thick trunk can be 2 1/2 feet wide and 50 feet high. Large, thick grooves running laterally on all parts; glochids and thick fishhook barbs on all parts of the cactus. Circle of white flowers on top branch. Fruit is egg shaped, 2 to 3 inches long.
Primary Uses: Culinary. Flower buds and seeds are eaten. Flowers are seen first, then buds with seeds inside. Fruit is eaten raw; husks and seeds are boiled, baked; fruits, husks and seeds used for syrup or jam. Dehydrated pulp used for flour, also oil, soft drinks, wine, and vinegar.
Nutritional Value: Buds, or fruits are high in niacin, fiber, carbohydrates as well as ash.
Collection and Storage: Harvest fruit in July and monthly thereafter by using a long stick to knock off bulbs. The skin splits and bark curls back when fruit is mature. May be dried for storage or be cut in half and soaked in water for about 1 hour after removing seeds.
Caution: Saguaro is a protected cactus tree. The Department of Agriculture must give permission to remove cactus from the desert. Fruits, buds may be used for food in a survival way, but permission must be noted in larger quantities. No permission will be granted to remove a rare crested specie of saguaro.

Linda says- The saguaro is a monument to desert life, protecting myriads of insects, mice, fruit-eating bats, owls, and other creatures of the desert. During a field walk with Willie Whitefeather, my Cherokee friend, I saw the buds of the giant saguaro harvested correctly. Willie fashioned the dried ribs of an old saguaro hulk together, lashed a hook-like end on the tip. The tool was 16 feet long and bent like a giant fishing rod in the desert wind. Deftly, he pulled the saguaro buds to the waiting crowd below.

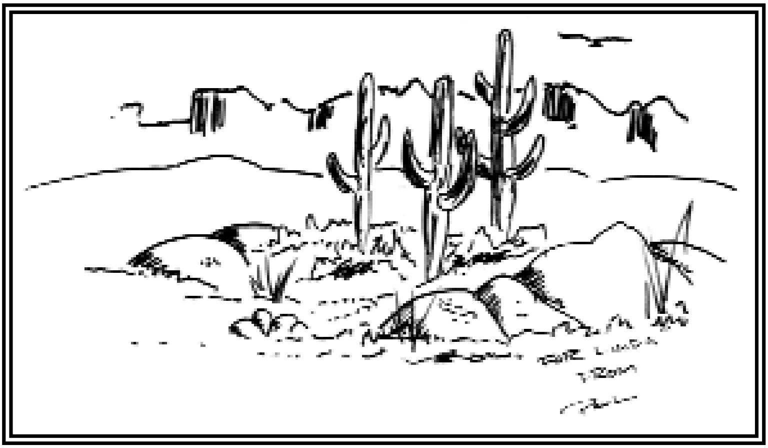

"Desert Saguaros" by Paul Runyon, Linda's brother.

Sheep Sorrel

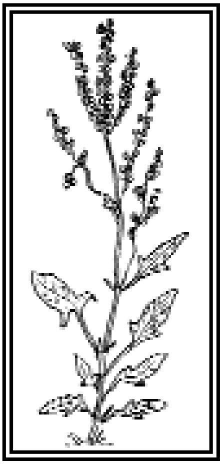

Rumex acetosella
Buckwheat Family *Polygonaceae*

Other Names: Garden sorrel, field sorrel, R. acetoea.
History: Native to Europe and Asia, naturalized throughout North America. Garden sorrel is cultivated for use as cooked green.
Habitat: Waste areas, roadsides.
Characteristics: Perennial herb. Reddish-tinged grassy tops. Mature seeds grow in spreading areas, standing out easily. The arrow shaped leaves are sour in taste.

Flowers are tiny and give way to seed quickly.
Primary Uses: Culinary. Leaves or stalks, eaten raw in salads or cooked as vegetable. Can be used in cold drinks.
Nutritional Value: High in vitamin C.
Medicinal Value: Juice has mild antiseptic effect (crush and place on wound as a poultice). Juice acts as laxative.
Collection and Storage: Use scissors and shear clumps of seeds easily, collecting in a bag or basket. Strip leaves off separately for soups, drinks. Seeds dried and stored in glass jar for use as spicy food additive.
Caution: All parts contain oxalic acid crystals. These may inhibit the absorption of calcium in the body. Place in boiling water for a minute or so to destroy the crystals.

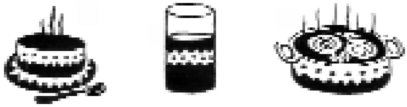

Linda says- I was amazed to taste the arrow head shaped leaves and find they were the same bitey, sour lemony taste as wood sorrel. (See page 137.)

Shepherd's Purse

Capsella bursa-pastoris
Mustard Family, *Brassicacae*

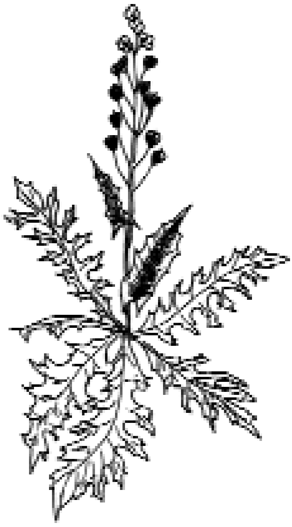

Other Names: Heart seed, field cabbage, purse seed, pick purse.
History: Native to Europe, widely naturalized in North America. Used by Native Americans.
Habitat: Waste areas, roadsides.
Characteristics: Annual herb. Erect plant from 3 inches to 1 1/2 feet high. Slender stem comes up from a spreading rosette of leaves formed flat on the ground. Deeply lobed leaves resemble wild lettuce or dandelion, but are more symmetrical. Has small white flower

with petals only 1/12 to 1/8 inch long, jutting out from the branches on a single stalk. Flowers give rise to seeds that resemble upside-down hearts.

Primary Uses: Culinary, medicinal. Basal leaves eaten in sandwiches, salads, soups, vegetable. Stalk is stir-fried, eaten raw. Buds and flowers eaten raw. Seeds are stir-fried and used as pepper, spice, seasoning. Roots are used fresh or dried as substitute for ginger or candied in syrup.

Nutritional Value: High in vitamin K, vegetable protein, potassium, calcium as well as beta-carotene and minerals.

Medicinal Value: Dried to use as blood-clotter and valuable taken in quantity for internal bleeding.[1]

Collection and Storage: Look for upside-down heart shaped seeds to distinguish plant from other wild mustards and pepper grasses. Gather leaves at any stage. Gather seeds when ripe. Entire plant may be gathered and chopped for vegetable, as well as dried for additive. Add seed pods to soups and stews for a pepper-like flavor.

[1] (Harrington 1967)

Linda says- In the East I ate the little heart-shaped seedpods with gusto, but in the West I seek them with a vengeance. Shepherd's purse is known to help relieve strong menses and internal bleeding. According to Peter Bigfoot in his book *Arizona Wild Herbs,* pick the mature, flowering plants in the Arizona Desert foothills in springtime. Dosage: 1 teaspoon dried herb per cup of hot water. Steep 15 minutes and drink the tea cool. Take 2 or more cups full per day as needed. Drink it quickly, do not sip for best effect with internal bleeding.

Sow Thistle

Sonchus oleraceus
Composite Family, *Compositae*

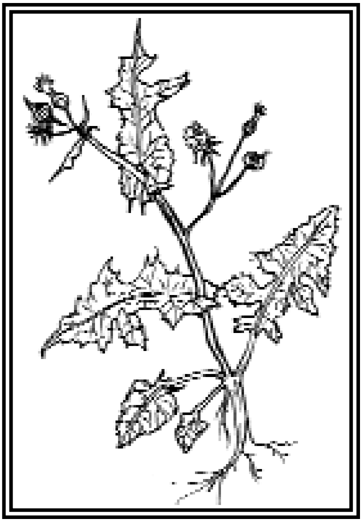

Other Names: Hoitgamivakhi (Pima Indian).
History: Native to North Africa, Europe, and western Asia; introduced to the United States and now found throughout most of Arizona. Used by Native Americans as greens.
Habitat: Roadsides, damp fields, waste areas.
Characteristics: Annual herb. Dandelion-type deeply lobed leaves begin from a central stem on the ground, clasping around stalk to a sharp point, like a sow's ear. Top of stalk bears branches, at the end of each grows a yellow flower that looks somewhat like a dandelion flower. After seeding, a white fuzz appears with single seeds on the end of the fluff.
Primary Uses: Culinary. Buds, flowers, and seeds edible raw or cooked. Stems may be cut into inch long pieces with scissors and stir fried or sautéed in oil as beans. Roots may be scrubbed and stewed in crock pot. Young leaves gathered and eaten as spring green, also eaten raw. Flowers stir-fried as vegetable or dried as well as frozen.
Nutritional Value: Very high in minerals.
Medical Uses: Milk reported to be somewhat diuretic.
Collection and Storage: One may trim leaves off long stems easily by leaving plant in ground and trimming off with a long knife. Use long handled knife or scissors, and wear gloves. Cut leaves over a basket or bag. To harvest large amounts, cut 2 long goldenrod or wild lettuce stalks and lay parallel to each other. Using a gloved hand, place the thistle plants across the parallel stalks. When a bundle is accumulated, pull golden rod stalks up and wrap around. Carry by holding both ends of the goldenrod together.

Linda says- My introduction to sow thistle was an experience. Early in the morning, when the dew was still on the grass, I wandered through a field of barley grass. The sow thistle was a succulent emerald green amid the grasses. Since I carry water with me; I rinsed off the leaves and munched on the sweetest breakfast I ever had in the West.

Strawberry

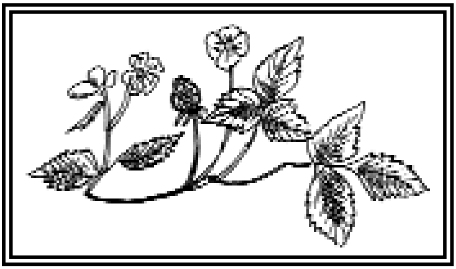

Fragaria virginiana
Rose Family, *Rosaceae*

Other Names:
Heartberry, wood strawberry.

History: Native to North America; Used in early European cultures, especially popular in France. Grows throughout Northern Hemisphere, excluding tropics. Native Americans steeped wild strawberries in warm water, then strained and cooled the liquid. The resulting lotion was a wash for irritations and skin ulcers.

Habitat: Fields, roadsides, meadows.

Characteristics: Low perennial, reaching height of 2 inches to 8 inches. Lobed saw-toothed basal leaves in groups of 3. Tiny, heart-shaped strawberry fruits. Small white flowers.

Primary Uses: Culinary, medicinal, cosmetic. Flowers are edible raw. Leaves eaten raw, dried for tea. Fruit eaten raw; cooked for jellies, jams, syrups; raw for juices, wines. Entire plant is steamed, boiled, used in soups and stews; cooking liquid is drunk.

Nutritional Value: Leaves and fruit high in vitamin C.

Medicinal Value: Leaves infused and used for sore throats. Juice is mixed with water for eye wash. Historically, roots are infused for gonorrhea remedy. Fruits are dried for stomach problems, diarrhea, dysentery, liver pain, jaundice. To juice, put a nylon stocking over a bowl. Place washed berries in stocking, then squeeze the juice into the bowl.

Cosmetic Value: Astringent and facial cleanser, useful for oily skin. Fruit is tartar remover for teeth; crush fruit, rub on, and rinse.

Collection and Storage: Pick fruits as you would cultivated strawberries With container around your waist, pick fruit and leaves easily using both hands.
Caution: Dry leaves thoroughly for tea. Partially dried leaves can cause a toxic reaction.

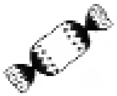

Linda says- Picking wild strawberries in the Adirondacks is difficult because the berries are very small and they ripen in blackfly season. The hardiest folk pick them in the wee morning hours or at night or in a rain. Snapping turtles eat the berries, as do other critters. I enjoy finding berries with chunks missing, and speculate what had breakfasted before me—insect, turtle, or mouse.

Sumac

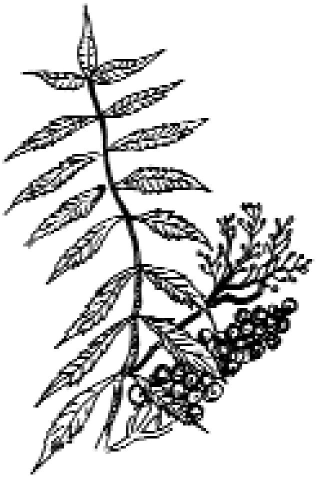

Rhus species
Cashew Family, *Anacardiaceae*

Other Names: Staghorn, smooth, scarlet, dwarf, shining, mountain, hairy, velvet, fragrant, virginian, and winged sumacs; lemonade tree.
History: Mostly native to North America. Used by Native Americans and colonists.
Habitat: Roadsides, field edges.
Characteristics: Deciduous tree or shrub. Bushes or shrubs with some varieties to height of 20 feet. Fern-like leaves 14 to 24 inches long. Flaming red fuzzy berry clusters, hairy and lemonade tasting. Stems and branches exude white milk when broken. Plants need heavy sunshine to produce berry clusters.

Primary Uses: Culinary. Flowers and seeds are the fruits. Fruits eaten raw or crushed in water as lemonade. Frozen in ice cube trays for popsicles.
Nutritional Value: High in vitamin C.
Collection and Storage: Collect fruit before completely mature, when spires turn dark red. Collect spires by breaking off stems. For tea, strain out hairs by overlapping balsam branches as a sieve or use cheesecloth. Look carefully at the whole tree to avoid accidental contact. I once pulled down a poison sumac branch growing in the midst of an edible sumac tree.

Caution: Poison sumac has white or greenish-brown clusters instead of red spires. When dried, a tan spire is evident. See Part V.

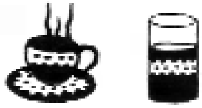

Linda says- There is nothing more beautiful than a glass decanter filled with sumac berries. Scarlet tea! Sumac lemonade is a year-round treat. Collect and rinse the heads early in the season. Do not wait until fall, when insects have made their nests in them! Summer seed heads may be dried and stored in glass, or bagged and frozen.

Sunflower

Helianthus species
Composite Family, *Compositae*

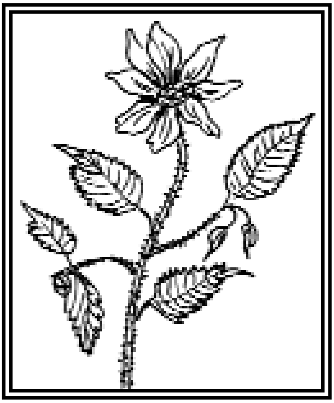

Types: Annual, wild, Western, common, tall, giant, weak, saw-toothed, swamp, little, aspen, showy, and woodland sunflower; Marigold of Peru.
History: Native to the Americas, probably originated in Peru. Used by Native Americans.
Habitat: Widespread but more common in West. Gardens, fields, sunny open areas.

Characteristic: Annual herb. Composite flowers on plants from 3 to 14 feet high. Yellow ray flowers with purplish red to brown disk flowers in center. Stems may be smooth or hairy. Leaves opposite or alternate, characteristically narrow, long, rough, and saw-toothed.
Primary Uses: Culinary, cosmetic. Seeds crushed and boiled; oil skimmed off top and eaten. Pith edible raw and cooked in soups. Used for paper making, organic fertilizer, oil, lubricants, candles. Petals used for yellow dye.
Nutritional Value: Seeds high in protein.
Cosmetic Value: Oil, soaps.
Collection and Storage: After flower matures and petals fall off, gather seeds. Snap off dried center and dry seeds on screen, then bottle. Large heads dried in a closed paper bag will mature eventually. Scrape the heads across a sieve with holes sized such that the seeds can drop through. Place seeds on cookie sheet and roast in dry, low oven. Bottle in glass for long-term storage. Pith is collected by peeling outer fresh stem when plant is dry and pulling out white pith.

Linda says- Snapping off the tiny dried heads of desert sunflowers is fun and very profitable for my table. A few crushed heads and a bit of water yielded a nutritious gruel with an obvious energy boost. Storage is simple: I put the dried sunflower heads in a glass jar.

Thistle

Circium species
Composite Family, *Compositae*

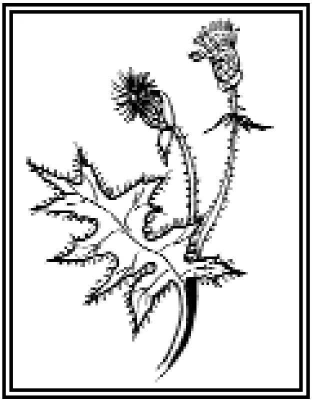

Other Names: Bull thistle, yellow thistle, plumed thistle, swamp thistle, field thistle.
History: Native to North America. Used since colonial times and by Native Americans.

Habitat: Roadside, fields, waste areas.
Characteristics: Biennial plant with dozens of varieties. Reaches height of 2 to 6 feet. Leaves and stems have sharp spines (bulbs) on all parts. One to 3 large, purplish flower heads with spines around base produced second year.
Primary Uses: Culinary. Flowers steamed and eaten raw much like an artichoke. Leaves dried and ground to a fine, green flour. Dried leaves also used for tea. Steamed leaves eaten as a vegetable. Stems peeled, sliced, and cooked as a vegetable. Roots boiled for tea.
Nutritional Value: High in potassium, phosphorus, and vegetable protein.
Medicinal Value: Roots are used for restorative tonic. Roots can be harvested year round, but early summer is best.
Collection and Storage: Early in the spring, use a penknife to cut beneath the basal leaves as you would a head of lettuce, being careful not to disturb the root. Cut leaves off central stem, holding a bag underneath. Use tongs and strainer to wash. Dries and freezes well.

Linda says- The beginnings of a thistle plant are succulent. Its thorny whorls are clear blue-green. The trick is to get as much of the core as possible, leaving the basal root. The thistle will grow again if you carefully take the upper part of the root along with the leaves, leaving the deeper root alone. The first time I did this I wondered if it was worth the effort. Now I use tongs and a strainer, and find the preparation time negligible while the taste is lasting!

Thyme

Thymus vulgaris
Mint Family, *Labiatae*

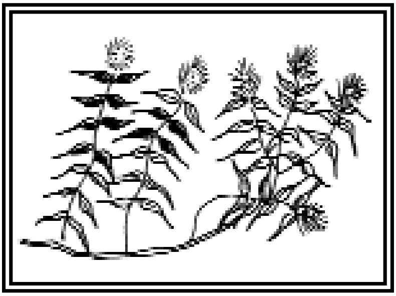

Other Names: Bee plant, wild thyme, mountain thyme, creeping thyme.
History: Native to Europe; in North America gardens vari-

ety has expanded to woods and fields. Adapted and used by Native Americans.

Habitat: Fields, roadsides, roadbanks, lawns.

Characteristics: Woody perennial. Prostrate herb growing to height of about 4 inches. Several varieties, all with pepper-like smell. Many spikes of leaves and lavender spike flowers. Grows in thick patches.

Primary Uses: Culinary, medicinal, cosmetic. All parts edible. Ground to powder; twigs, leaves, and flowers simmered for stimulant tea. Added as seasoning to soups, stews, fish, meat dishes.

Nutritional Value: Has a high count of vitamin C, iron and niacin.

Medicinal Value: For headaches, stimulant, antiseptic, aromatic, carminative, diuretic, diaphoretic, emenogogic, and antispasmodic. Treatment for sore throats.

Cosmetic Value: Oil is aromatic, antiseptic, diaphoretic, stimulant, disinfectant, and used in cosmetic lotions. An effective deodorant, mouthwash, aftershave lotion, and wash.

Collection and Storage: Easily sheared with scissors. Mow thyme patches regularly for a winter supply. For best results, rub dried thyme through a screen to remove stems and twigs.

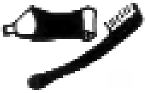

It's Thyme Time

Lying next to a patch of lavender thyme flowers and nibbling the pungent, peppery twigs and flowers soon became a favorite activity after a busy day. My favorite patch was near Cedar River Road in the Adirondacks. Those days were spent building structures, gathering large amounts of food, experimenting with storage and cooking methods, and just plain surviving. I would lay full length next to the bees working the thyme. The bees never minded, lifting off and moving as I raised my hand to pluck a stem to munch on. The thyme was a perfect stimulant. I returned to finish the evening renewed.

Tumbleweed

Salsola kali
Goosefoot Family,
Chenopodiaceae

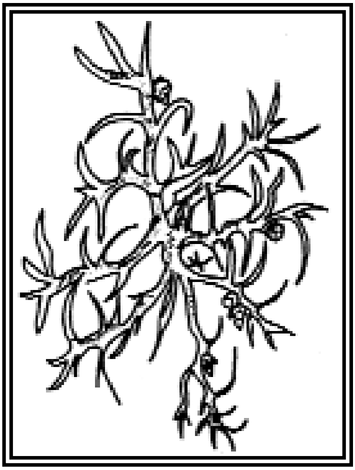

Other Names: Russian thistle.
History: Native to Russia, brought to United States in flaxseed 100 years ago.
Habitat: Open desert, fields, roadsides, hot dry country.
Characteristics: Annual herb. Reaches height of 2 feet in bushy and roundish intricately branched plant. Often reddish with ridged stems and many tiny ends. Late in season, plant breaks off at base and rolls around freely, dropping its many seeds.
Primary Uses: Culinary. Tips eaten cooked as vegetable or in soups and stir-fries.
Nutritional Value: High in calcium, vegetable protein, carbohydrates, fiber, potassium and *extremely* high in niacin.
Collection and Storage: Choose tumbleweed that does not have many buds and flowers, and harvest young seedlings whenever possible. If you don’t have time to stand and clip the bush, remove a few branches and let wilt naturally. Clip ends that wilt the most; this ensures getting the most succulent ends. Drop succulent ends in a bowl, wash well, or soak overnight in a large bowl of water and a teaspoon of vinegar. The more you clip the more the plant grows to maturation, producing many more branches.
Caution: Do not ingest raw except in extreme emergency, chewing thoroughly.

Linda says- Making tumbleweed soup is simple. I find a tumbleweed without prickly seeds and flowers, and shear the succulent ends into a basket. Wash the succulent tips well, quickly cook them in boiling water, then pack half-cup quantities into soup bags and freeze. You'll have a month's worth of delicious soup.

Violets

Viola species
Violet Family, *Violaceae*

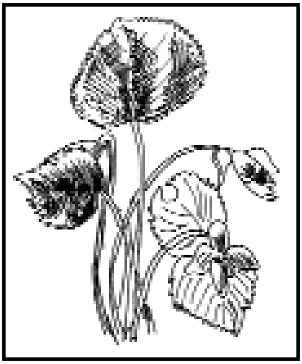

Other Names: Heart leaf, baby face, wild violet.
History: World wide distribution, including North America. Used by Native Americans.
Habitat: Rich, moist woods, swamp sides, stream banks, damp lawns.
Characteristics: Annual or perennial herb. Smooth, heart-shaped leaves with little scalloping on edges. Single stem. Flowers on single stem from leaf base; five-petaled, arising from a center spur, usually yellow. Lower petal has heavy veins and there is a bearded design. Colors vary from white or yellow to purple or blue.
Primary Uses: Culinary, medicinal, cosmetic. Flowers used as little "fruits", eaten raw and candied; also used in jam, jelly, wine. Buds, flowers, and leaves dried for tea. Leaves eaten raw in sandwiches or salads; cooked, as thickening agent. Roots of violets may be eaten raw or cooked in a crockpot. Stems may be snipped into 1 inch sections and added as "beans" to soups.
Nutritional Value: High in vitamins A and C.
Medicinal Value: Good for colds, flu. Eaten for dry, scratchy throat. Raw flowers eaten in quantity for varicose veins.
Cosmetic Value: An astringent; used in cold creams, oil lotions (infusion of flowers).
Collection and Storage: Clip violets easily with scissors, but use fingers when gathering leaves. Choose large leaves to wrap up tofu, rice, potatoes, beans.
Caution: Yellow wood violets may be cathartic; small, common lawn violets are not.

Linda says- Tiny faces peeping out of the dew-covered grass - violets are a favorite of mine, whether next to a stream in early spring or on the back lawn. The violet's face is a spring flag, heralding renewed life.

Todd loved the little faces in his ice cream. I would lightly stir a handful of violets into his vanilla ice cream.

Wild Lettuce

Lactuca canadensis
Composite Family, *Compositae*

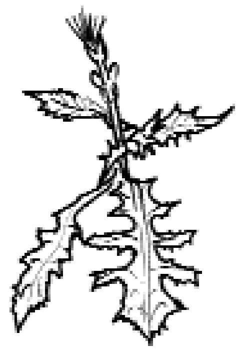

Other Names: Milk lettuce, chicory lettuce, horseweed.
History: Native to North America. Used by Native Americans; The Menominees use wild lettuce as a sedative.[2]
Habitat: Fields, waste ground, roadsides.
Characteristics: Biennial herb. Deeply serrated leaves, coming off a central stalk. Tiny buds and extensions off of top stalk. Dozens of yellow dandelion-like ray flowers. White milk in stem. Stem veins are characteristic.
Primary Uses: Leaves eaten in salads. Flowers and buds are stir-fried. Flowers and seeds are eaten raw or cooked, sautéed in oil and garlic. Stems (young) cut to bean size and cooked. Leaves dried and ground for seasoning. Roots have been used as a gum.
Nutritional Value: High in beta-carotene, ascorbic acid, (vitamin C)
Medicinal Value: Tea from milky leaves is sedative. Sap induces sweating and is used as a fever reducer. Decoctions of sap are known to ease irritability and insomnia.
Collection and Storage: Collect leaves, stems, flowers as you would lettuce, use raw.

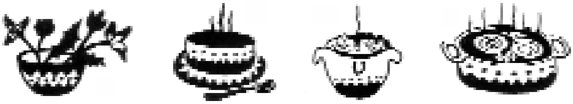

Linda says- The tops or buds of this great plant are delicious. Stir-fried with a little olive oil and garlic salt, wild lettuce makes a wild meal!

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[2] Densmore, Francis. *How the Indians Use Wild Plants for Food.* New York: Dover, 1974.

Willow

Salix species
Willow Family, *Salicaceae*

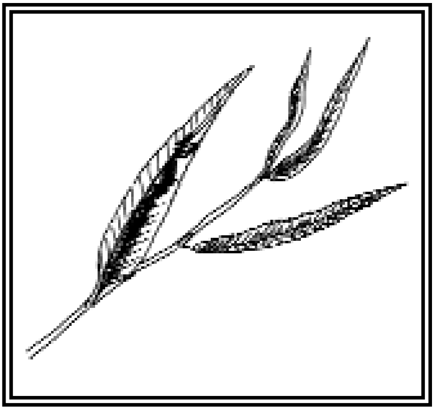

Types: Beaked, black, blue, Canada, coastal plain, crack, Drummond's, ward, weeping willow.
History: Grows throughout the world but abundant in cooler parts of Northern Hemisphere. In North America, used by Eskimos, Native Americans. Eskimos dry inner bark, strip, and cook like spaghetti; Inner bark layer called keeleeyuk in Eskimo, meaning "the scrape."
Habitat: Damp areas, stream sides, swamps.
Characteristics: Deciduous shrubby tree. Over 100 species, many with drooping branches alternate 2 inch leaves, sectioned twig tendril. Flowers (catkins) are furry, present before leaves. Roots seek water; have thousands of white hair-like extensions.
Primary Uses: Culinary, medicinal, cosmetic. Inner bark eaten raw; may be dried and pounded to flour. Buds, flowers or catkins, seeds are brewed as tea. Leaves are emergency food, tea, but use sparingly as they contain "aspirin". Willow sprouts provide early spring food.
Nutritional Value: Very high in beta-carotene.
Medicinal Value: All parts have acetylsalicylic acid, or salix, an aspirin source. Ten to 15 catkins or one 6 to 8 inch tendril, equal approximately 2 aspirins.
Cosmetic Value: Astringent; used in lotions, creams, facial washes.
Collection and Storage: Break tendrils into 6-inch pieces and dry. Store in glass container. Collect catkins or leaves by running hand down tendril. Dry and store. A supply of aspirin was easily kept through the year by stripping catkins in the spring, drying, and placing in glass.

Beneath the Weeping Willow

I sit under my favorite weeping willow tree. My fingers fly as I make a supple willow basket. At the same time, the tiny catkins hanging from the twigs are irresistible. I first munch only four or five, remembering that these catkins are like aspirin. But the catkins are so delicious. I quickly down about 1/2 cup of them while I make the basket. When I stand up, my ears ring and I wobble, almost faint. I sit down immediately and put my head between my knees to stop the dizziness. I curl up and go to sleep. Much later, I awake with a gigantic headache that lasts almost two days. A hard-learned lesson about the potency of willow catkins!

Wintergreen

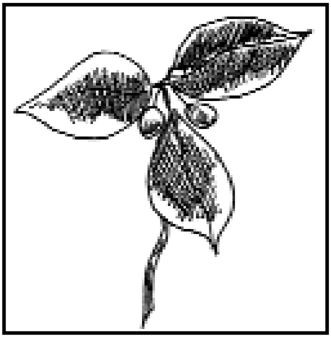

Gaultheria procumbens
Heath Family, *Ericaceae*

Other Names: Checkerberry.
History: Native to North America, especially East.
Habitat: Wooded areas, acid soils, under softwood trees.
Characteristics: Perennial herb. Drooping waxy white flowers hidden by flat shiny evergreen leaves. Has bright red berries.
Primary Uses: Culinary, medicinal, cosmetic. Leaves used fresh or dried, crush or steep for tea. Oils are distilled for flavorings. Buds, flowers, and seeds (berries) edible.
Nutritional Value: Fruit or berry, high in acetylsalicylic acid, or aspirin. Contains niacin.
Medicinal Value: Leaves contain acetylsalicylic acid (aspirin). Steeped for astringent. Boiled and applied to wounds or used as eyewash. Tea breaks a fever. Used as an anti-rheumatism gargle, to treat wounds or hemorrhages, as a poultice for insect bites and

bruises, or as vaginal douche (see page 138). Oils used for rheumatism or arthritis, sciatica.
Cosmetic Value: Aromatic oil used as flavoring for candies, toothpaste.
Collection and Storage: Snip leaves; dig roots, and collect berries. Wintergreen is known to grow under the snow; dig and eat during winter. Dried, powdered wintergreen leaves have more flavor than fresh leaves. Plant transplants easily, loves acid soil.
Caution: Contains acetylsalicylic acid (aspirin). Overdose of oil may produce drowsiness, congestion, and delirium.

Linda Says- Driving from Plainfield, New Jersey, to Indian Lake in upstate New York was a 17-hour drive in 1940. My frustration as a child was greatly relieved by chewing a wintergreen leaf I picked in the woods. I soon learned to recognize the flat, shiny, three-leafed plant growing close to the ground. If I was lucky enough to find a red wintergreen berry, I savored that berry for an hour of the drive!

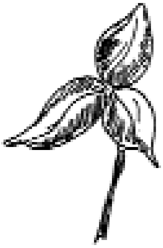

Winter Harvest

It was the first time I trooped through snowdrifts looking for food. I thought it would be hard work, but balsam and pine trees were always within reach of the trail. Bushes of meadowsweet poked above the snow. I would never starve if I ate twigs and bark. But I did not know then that the Iroquois Abanake (bark eaters) did just that for centuries. Following the deer trail, I located the wintergreen. Reaching deep into the snow opening, I pulled out a few plants. The shiny green aromatic leaf never tasted so good!

Wood Sorrel

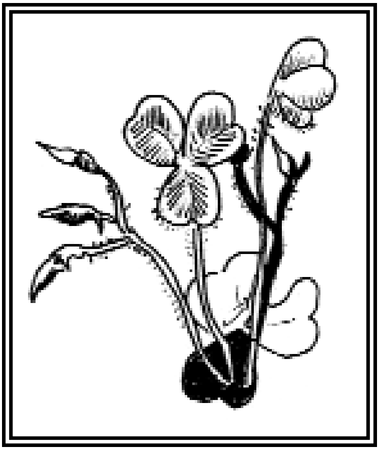

Oxalis species
Wood-Sorrel Family,
Oxalidaceae

Other Names: Clover sorrel, shamrock sorrel, lemon sorrel.
History: Eaten as spicy salad for centuries. Introduced to North America and used by Europeans and all Native American cultures except Crow and Menomini. George Washington Carver, of peanut fame, made pies and confections from wood sorrel; he even made a paint from sorrel.
Habitat: Fields, woods, moist places, under trees, or shrubs.
Characteristics: Low-growing perennial herb. Leaves alternate or basal, in 3 heart-shaped leaflets (a shamrock), sour lemon tasting. Grows from 2 inches to 8 inches in bunches or carpets. Flowers long, with 5 yellow, rarely green petals, sometimes red at the base. Leaves fold up sometimes when extremely warm or in sunshine.
Primary Uses: Culinary, cosmetic. Leaves cooked in soups, stews. Seeds cooked in soups, stews. Buds and flowers cooked in soups, stews. Many commercial uses. Stems are edible. Cut into inch pieces and add to soups, stews.
Nutritional Value: High in vitamin C. Because wood sorrel is high in oxalic acid, it hastens the elimination of calcium from the body and inhibits absorption of calcium. Therefore, limit intake of raw leaves to no more than 15 at most. Cook for safety. Drop entire plant in hot water. When color changes from bright emerald green to olive green, oxalic acid is neutralized.
Cosmetic Value: Antiseptic wash for skin and skin eruptions.
Collection and Storage: Gather seeds when they are red. Gather leaves year-round Collect flowers any time of year. Cut stems, leaves, and seeds to dry for soup or use as a salad ingredient.

Yarrow

Achillea millefolium
Composite Family, *Compositae*

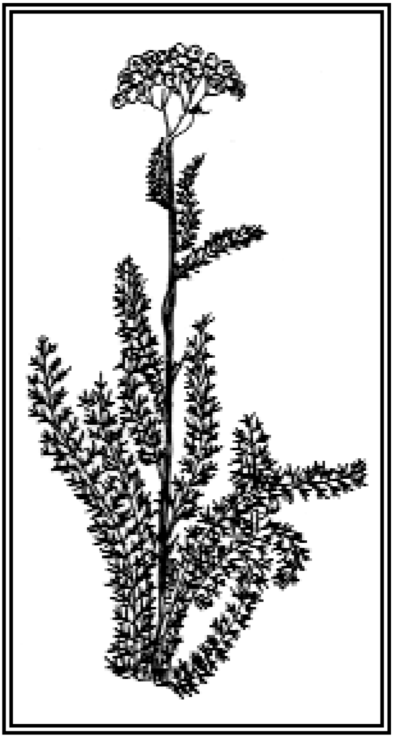

Other Names: Milfoil, field hop, old man's pepper.
History: Native to Europe. Naturalized in North America.
Habitat: Old fields, roadsides.
Characteristics: Perennial herb. Grown to height of 2 1/2 feet. Creeping rootstock; fern-like, lacy leaves, slightly hairy. Flowers typically white in wild, but occur in red, rosy, yellow, and magenta in ornamental gardens. Flowers have 5 petal-like rays, dozens in flat top clusters. Each flower is on its own stem, originating from one stem.
Primary Uses: Culinary, medicinal, cosmetic.
Stimulant tea. Boil any part of plant in small amounts. Leaves used raw in salads, or cooked for green. Seeds and flowers crumpled for seasoning. First-year roots peeled and cooked as vegetable.
Nutritional Value: High in calcium, and potassium.
Medicinal Value: Moves fluids in the body. Diaphoretic; cleanses the blood; tonic, stimulant, antiseptic; soothes burns. Strengthens immune system.
Cosmetic Value: Astringent; cleansing herb in facial mixtures, vaginal douches, shampoos; for dandruff and baldness treatments. Mouthwash for toothaches.
Collection and Storage: Clip flowers with scissors or break off with fingers. Pull leaves down stalk.

Yarrow for Teeth Cleansing

A dentist appointment loomed ahead. I hated to leave the forest and drive the old truck to Indian Lake, but having no phone, I could not cancel. I picked a yarrow stem and stripped off the leaves. I placed a leaf under my forefinger and scrubbed my teeth with the yarrow. Very astringent and satisfying. Using the stem, I picked here and there. Then I drove the pickup to town. In the dentist chair, the doctor exclaimed, "Linda, you've been in the yarrow again!" I did not realize that the yarrow had dyed the inside of my mouth green, especially my teeth—temporarily, of course.

The author begins her exploration of wild food.

Notes

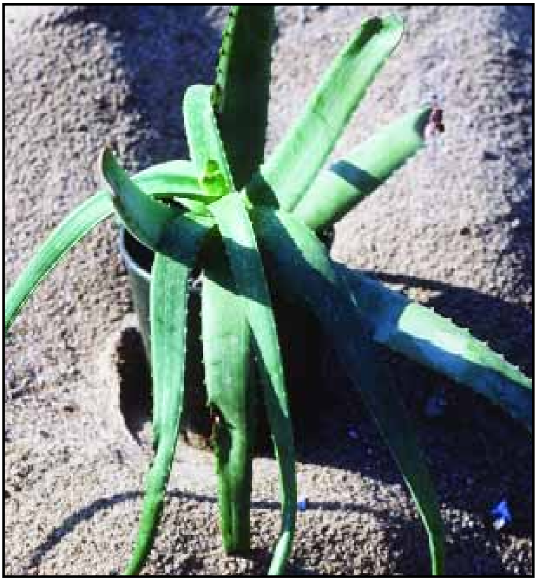

Aloe Vera
Aloe perfoliata vera *Cactus Family, Liliaceae*

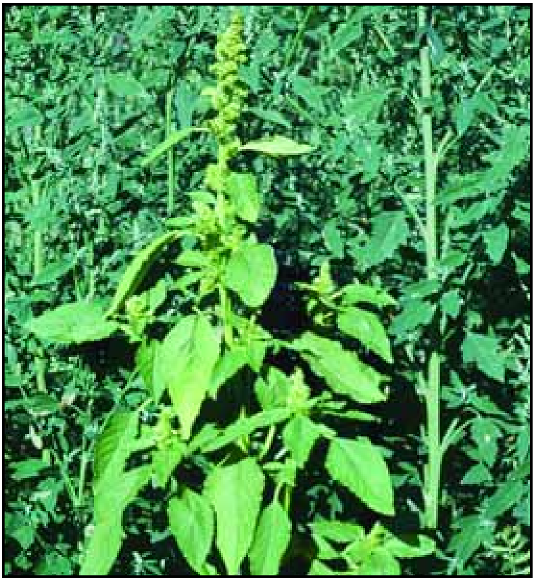

Amaranth
Amaranthus retroflexus *Amaranth Family, Amaranthaceae*

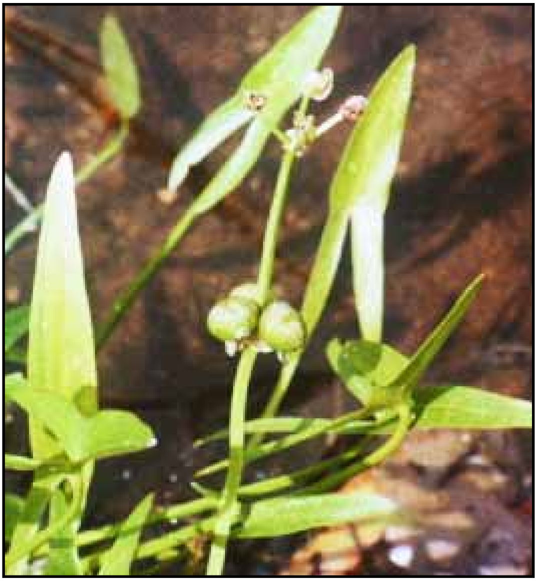

Arrowhead
Sagittaria species, S. chinensis *Water Plantain Family, Alismataceae*

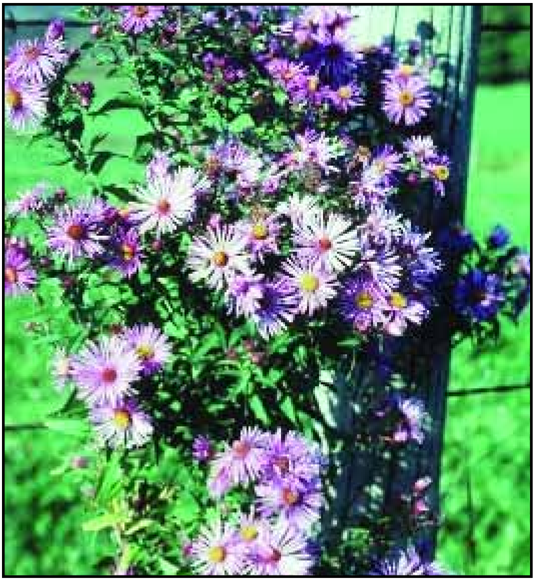

Aster
Aster nemoralis *Composite Family, Asteraceae*

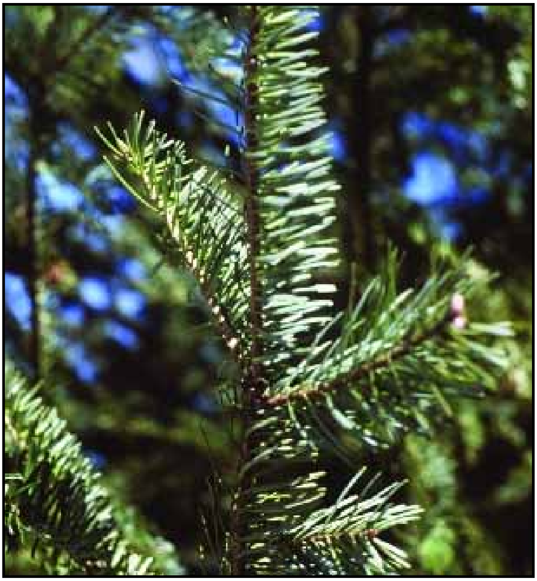

Balsam Fir
Abies balsamea *Pine Family, Pinaceae*

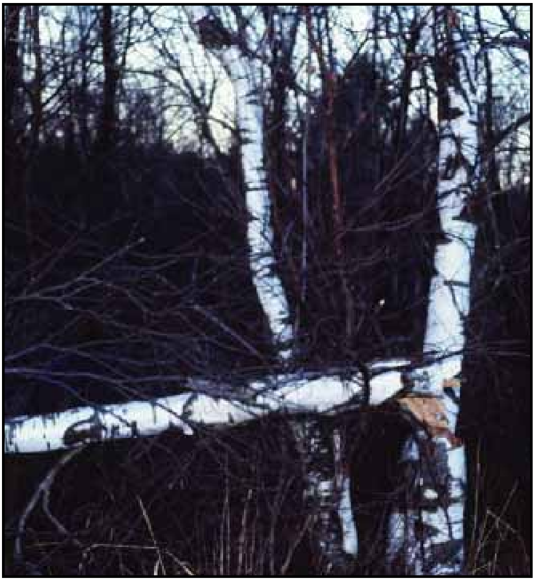

Birch
Betula species *Birch Family, Betulaceae*

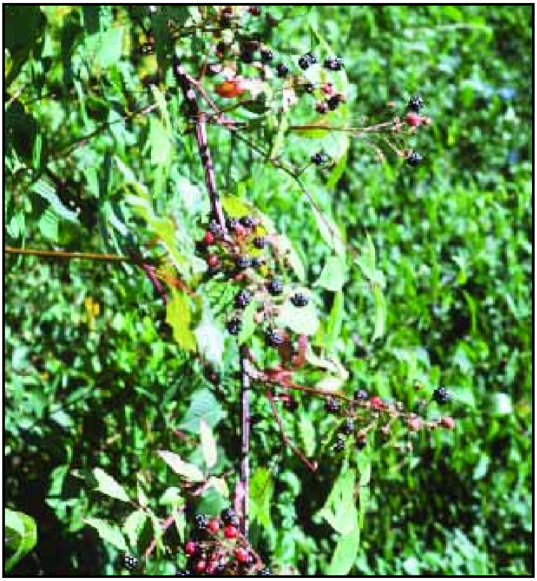

Blackberry

Rubus villosus and other bramble berry species *Rose Family, Rosaceae*

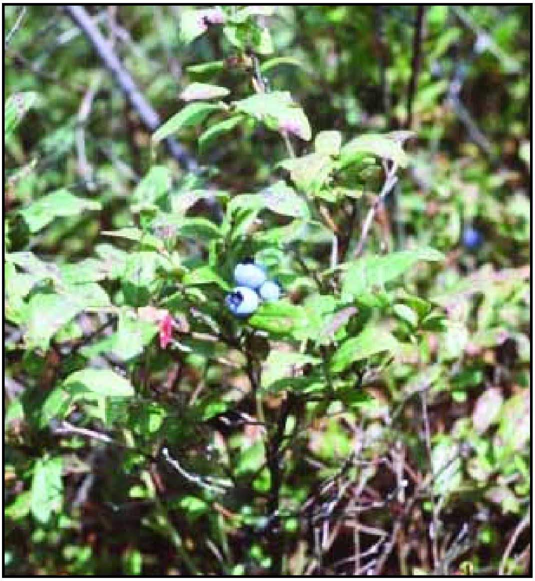

Blueberry

Vaccinium myrtillus *Heath Family, Erraceae*

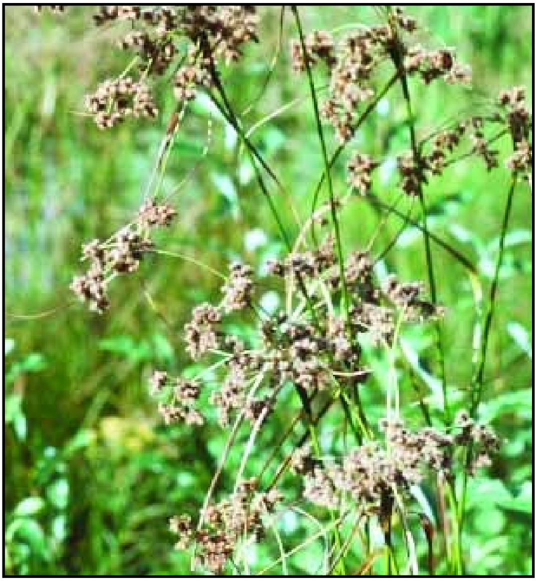

Bulrush
Scirpus validus *Sedge Family, Juncaceae*

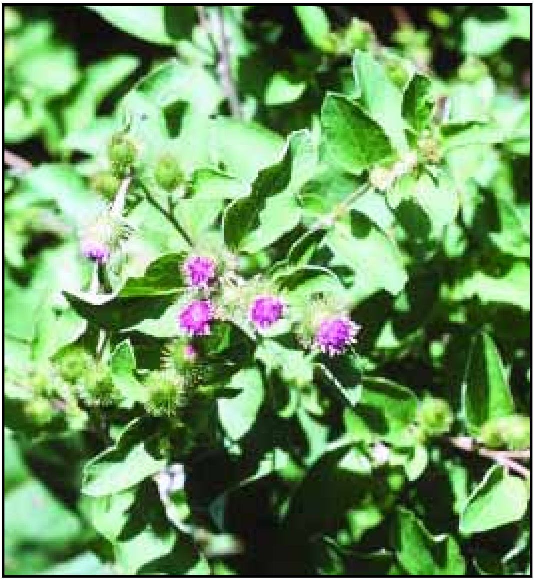

Burdock
Arctium lappa *Sunflower Family, Asteraceae*

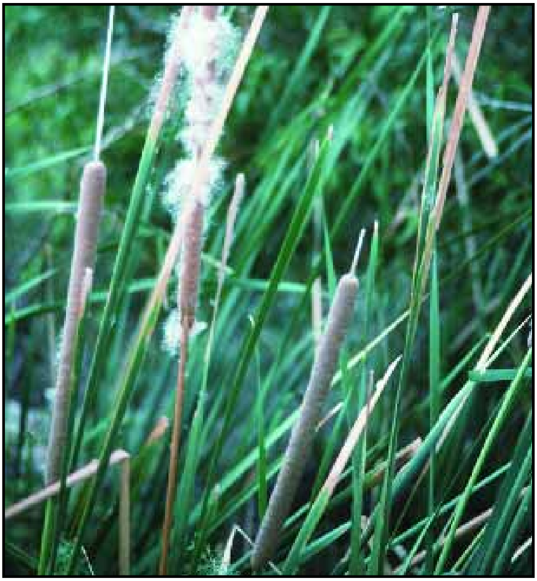

Cattail
Typha latifolia *Cattail Family, Typhacerae*

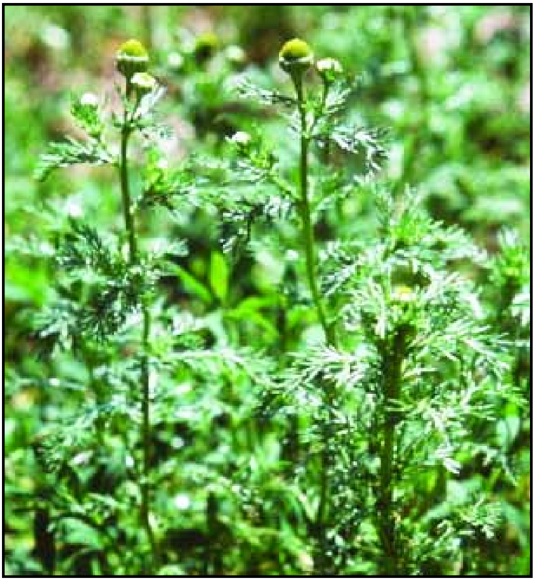

Chamomile
Matricaria chamomilla *Composite Family, Asteraceae*

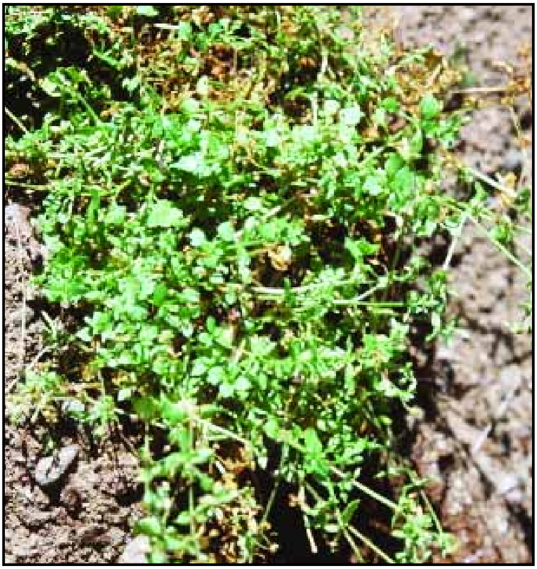

Chickweed
***Stellaria media* (common chickweed),** *Pink Family, Caryphyllea*

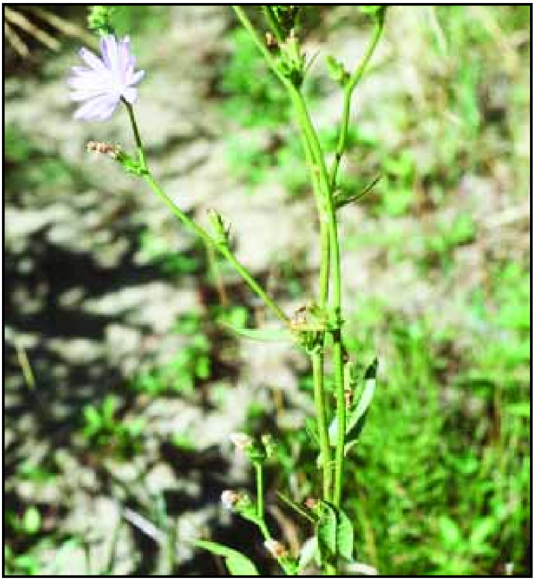

Chicory
Cichorium intybus *Composite Family, Asteraceae*

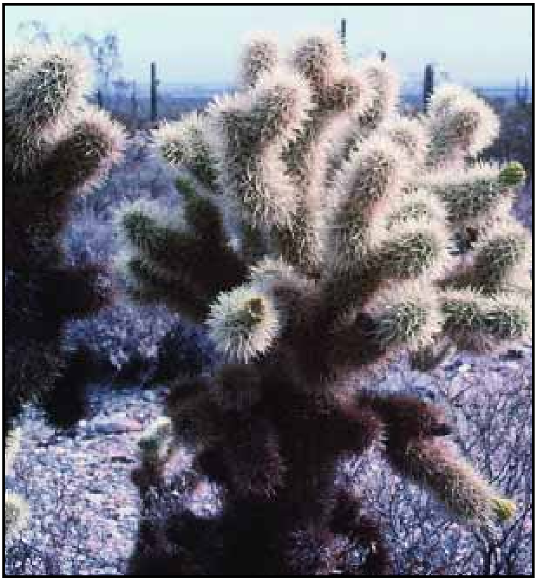

Cholla
Opuntia fulgida *Cactus Family, Cactaceae*

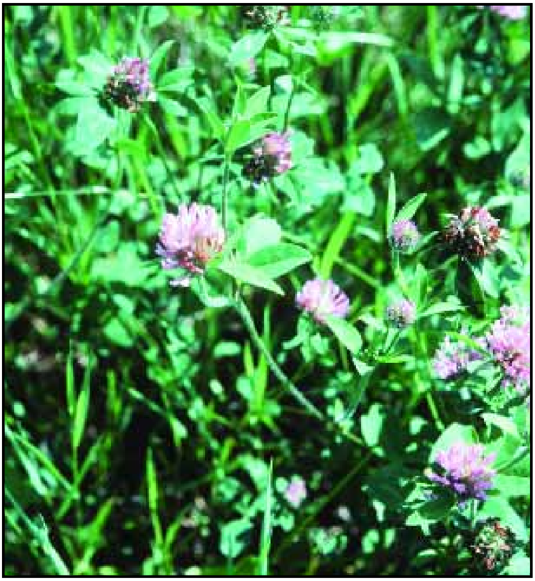

Clover, red
Trifolium pratense *Legume Family, Leguminosea*

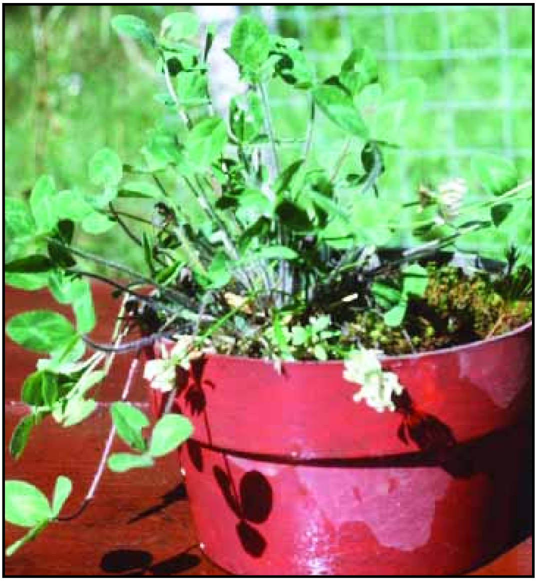

Clover, white
Trefolium Repens *Legume Family, Leguminosae*

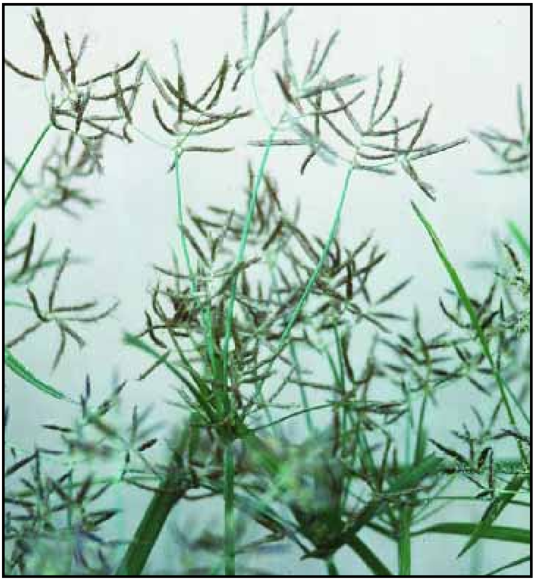

Crabgrass
Digitaria sanguinalis *Grass Family, Graminea*

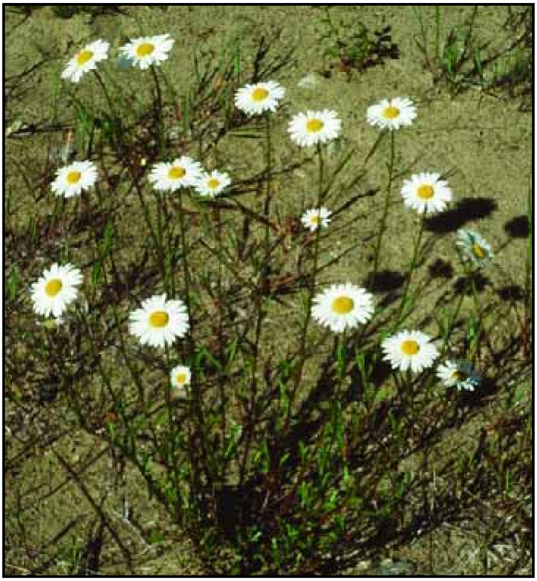

Daisy
Chrysanthemum leucanthemum *Composite Family, Asteraceae*

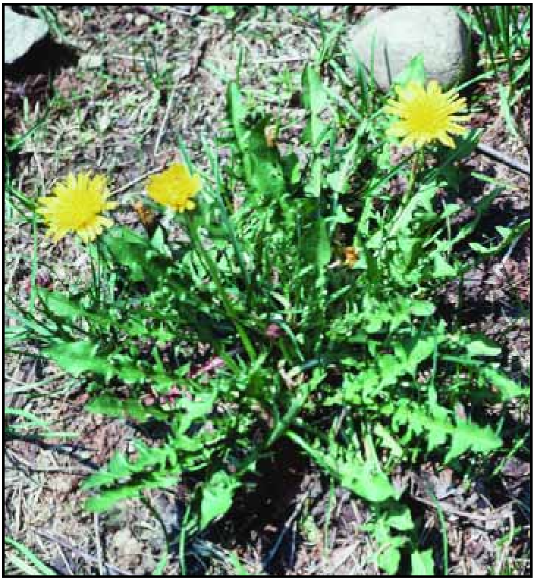

Dandelion
Taraxacum officinale *Composite Family, Asteraceae*

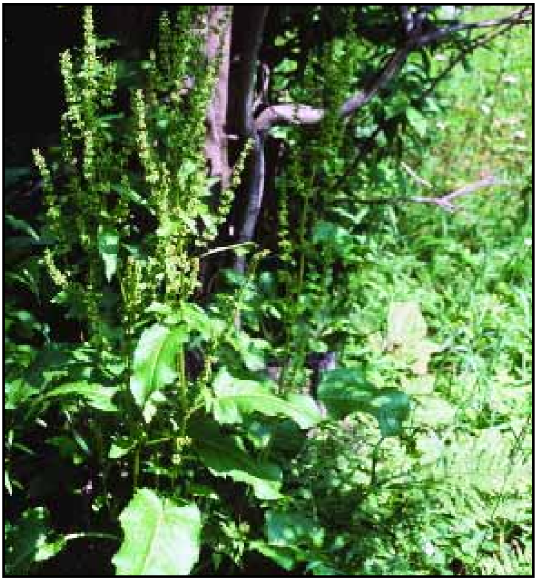

Dock
Rumex crispus *Buckwheat Family, Portulaceae*

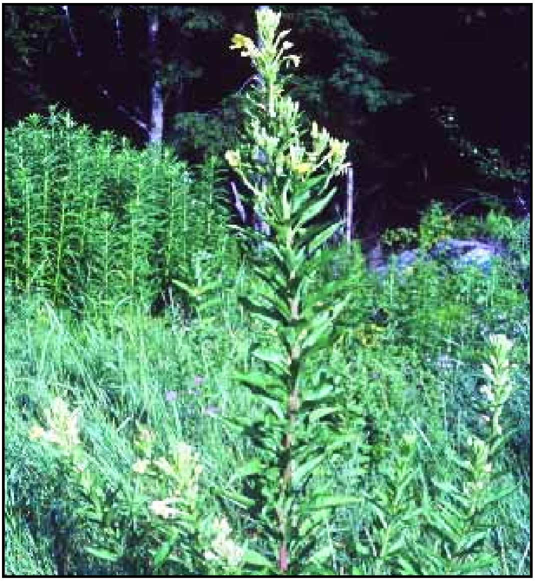

Evening Primrose
Oenothera biennis *Evening Primrose Family, Onagraceae*

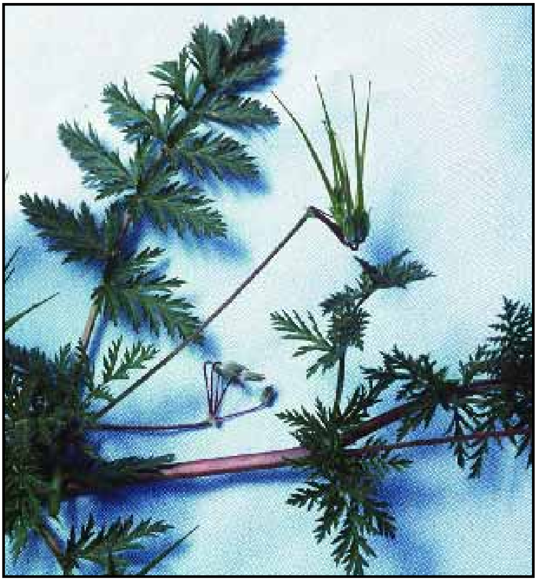

Filarie

Erodium circutarium *Cranesbill Family, Geraniaceae*

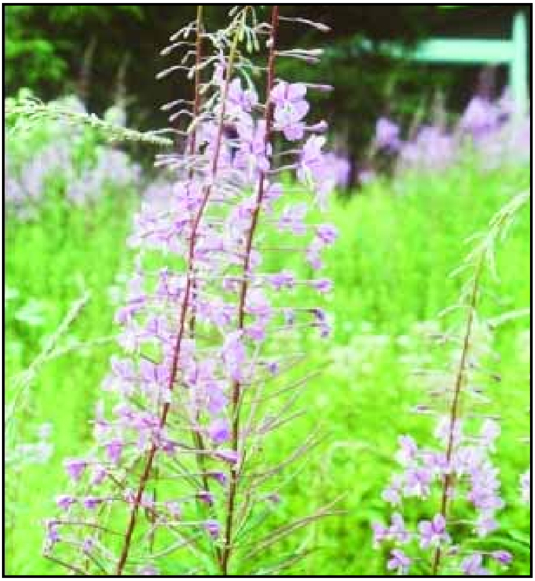

Fireweed

Epilobium angustifolium *Evening Primrose Family, Onagraceae*

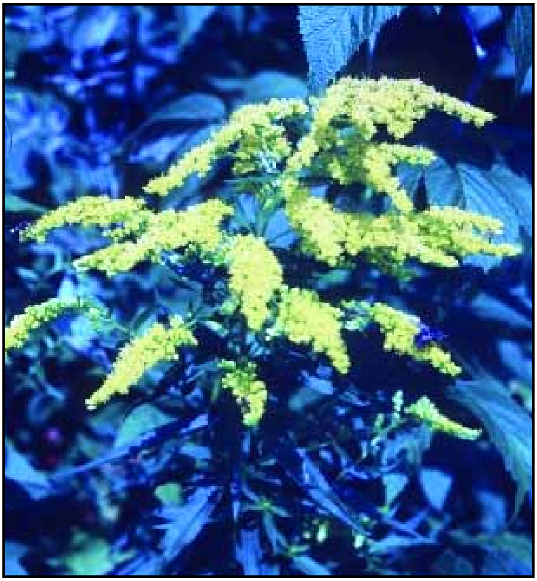

Goldenrod
Solidago odora *Sunflower Family, Compositae*

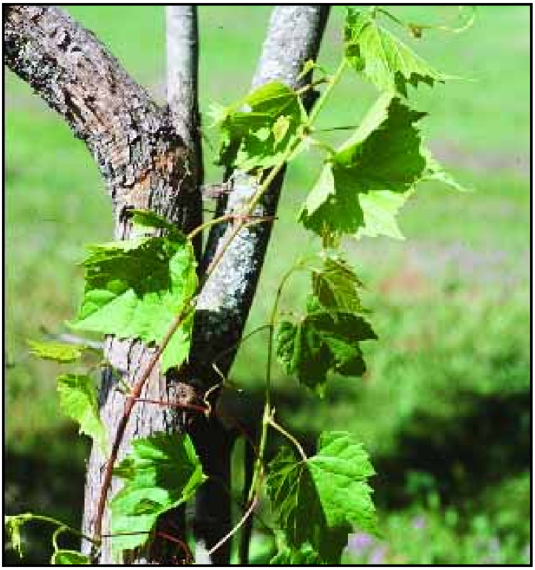

Grape
Vitis arizonica (Western) Vitis labrusca (Eastern) Vitis rotundifolia (South)
Vitis Family, Vitaceae

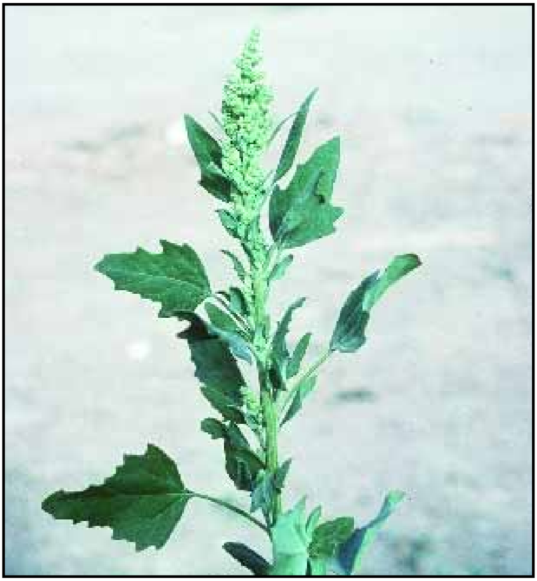

Lamb's Quarters
Chenopodium album *Goosefoot Family, Chenopodiaceae*

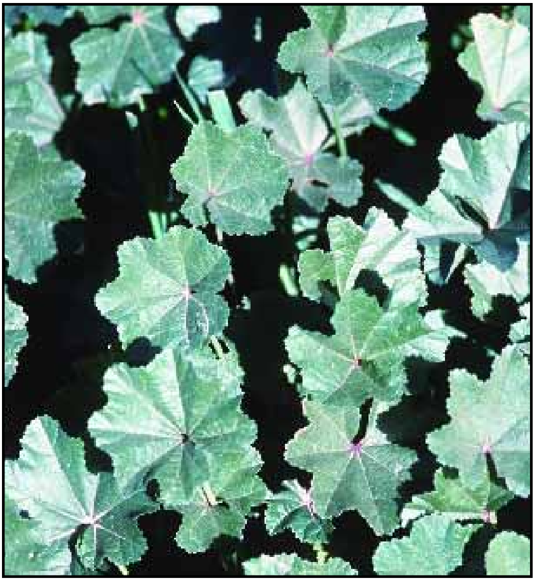

Malva
Malva Neglecta *Mallow Family, Malvaceae*

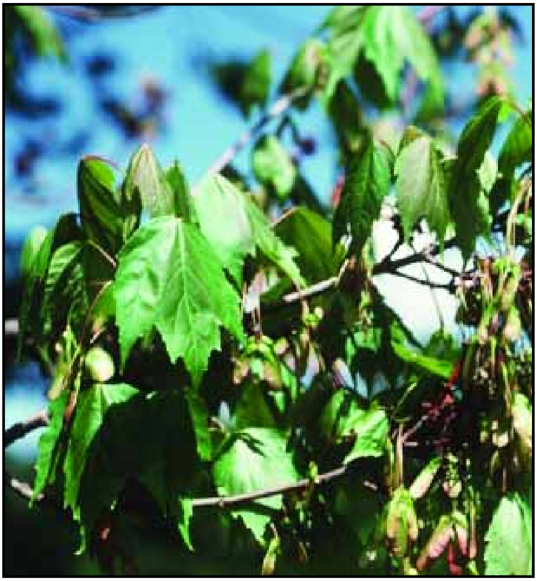

Maple
Aceraceae Family

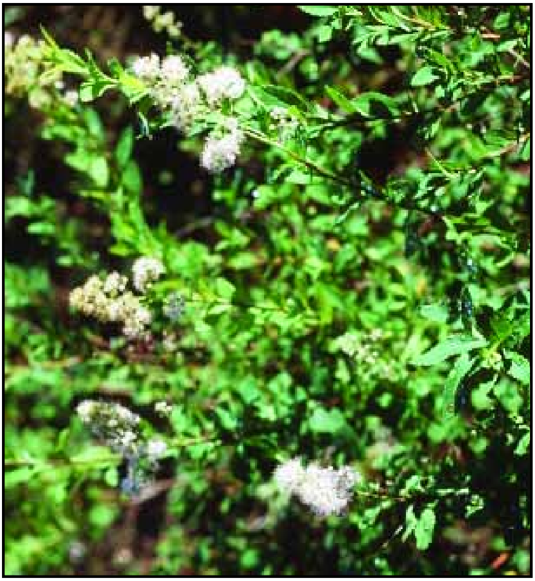

Meadowsweet
Filipendula ulmaria *Rose Family, Rosaceae*

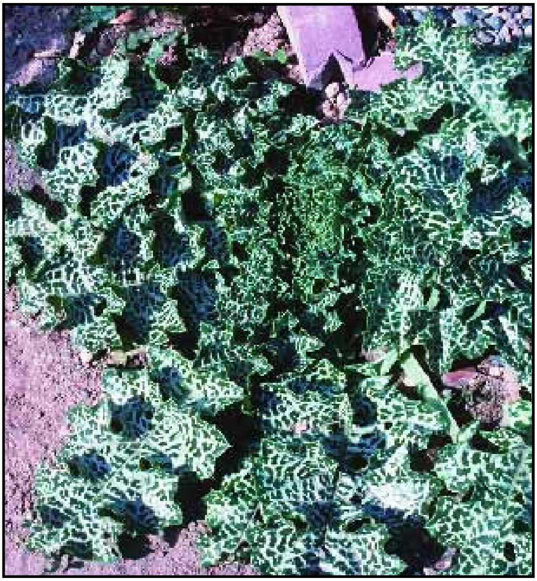

Milk Thistle
Silybum marianum *Composite Family, Compositae*

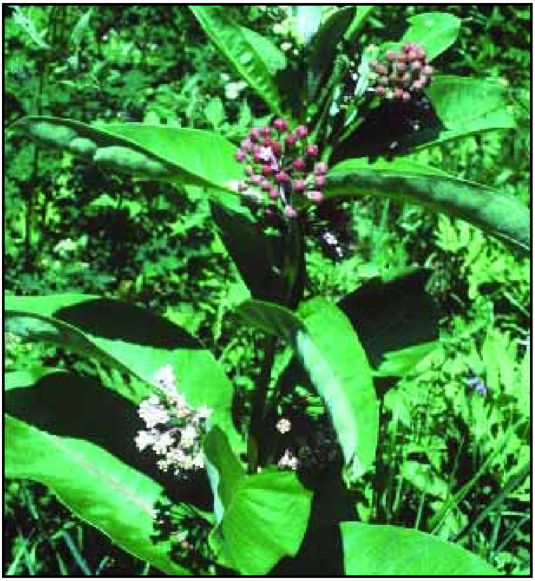

Milkweed
Asclepias species *Milkweed Family, Aslepiadaceae*

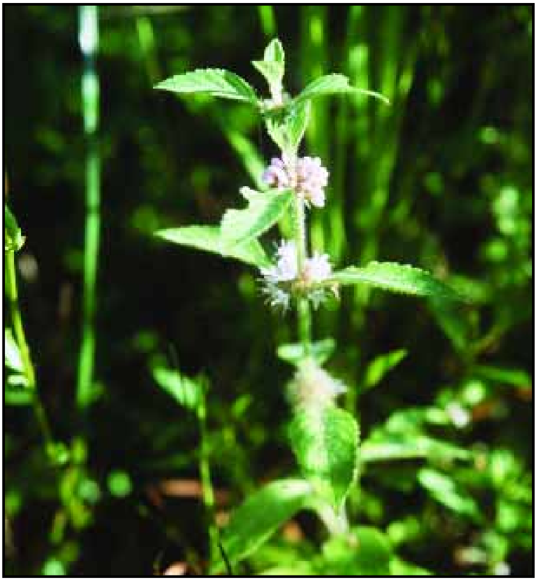

Mint
Mentha species *Labiatae Family*

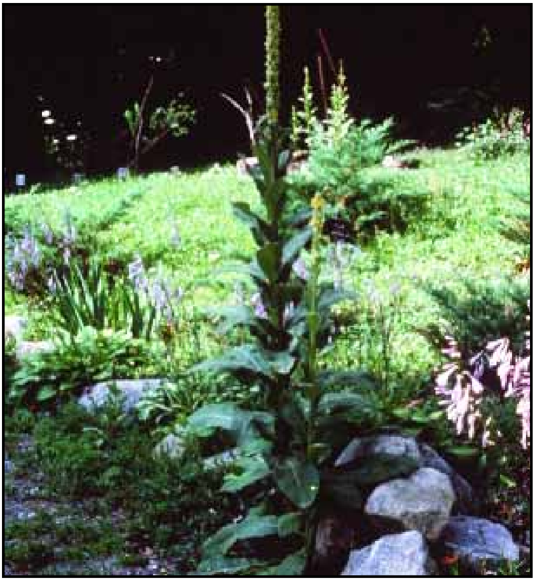

Mullein
Verbascum thapsus *Snapdragon Family, Scrophulariaceae*

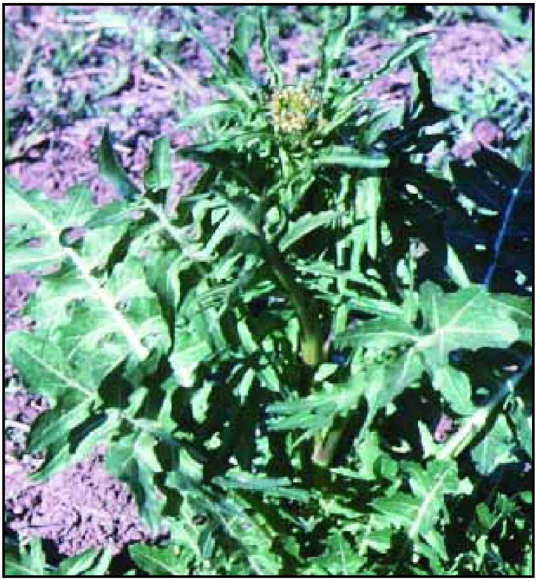

Mustard, yellow
Brassica species *Mustard Family, Brassiacaceae*

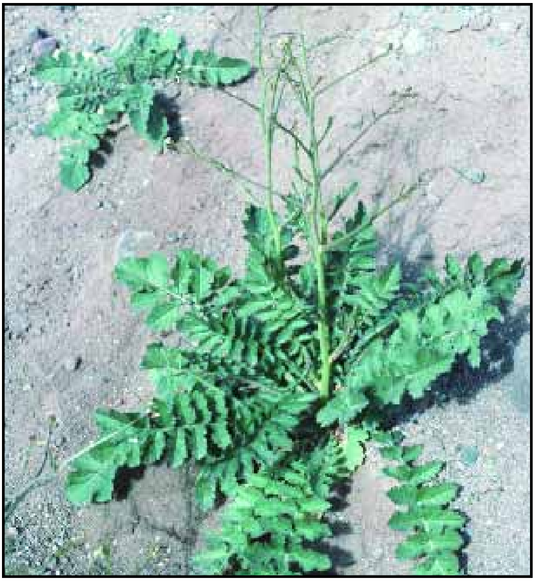

Mustard, black
Brassica species *Mustard Family, Brassicerceae*

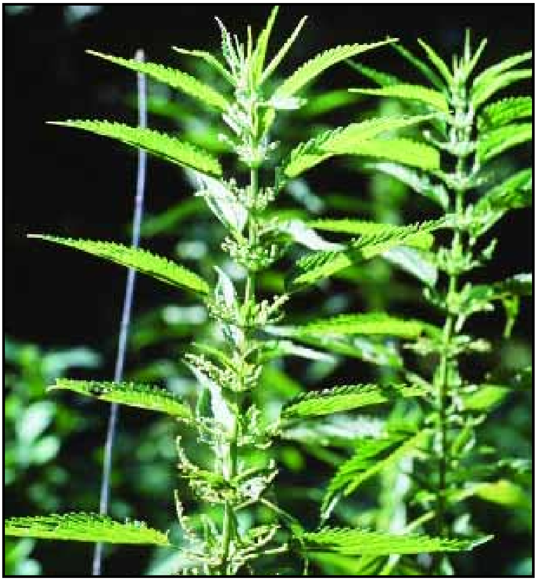

Nettles
Urtica species *Urticaceae Family*

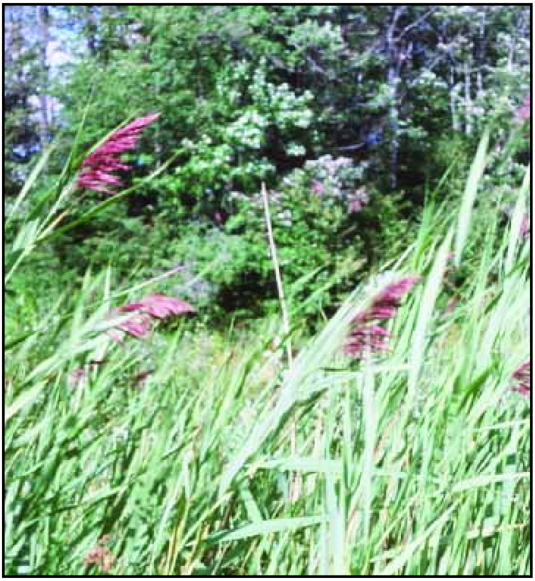

Phragmities
Phragmities communis *Grass Family, Graminae*

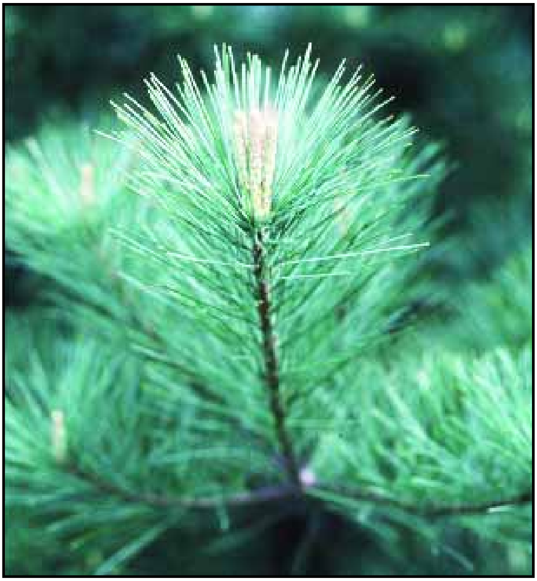

Pine
Pinus species *Pine Family, Pinaceae*

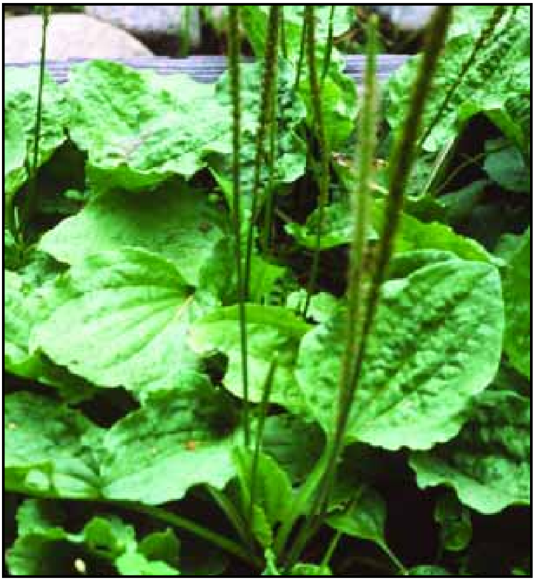

Plantain
Plantago major (common plantain) *Plantain Family, Plantaginaceae*

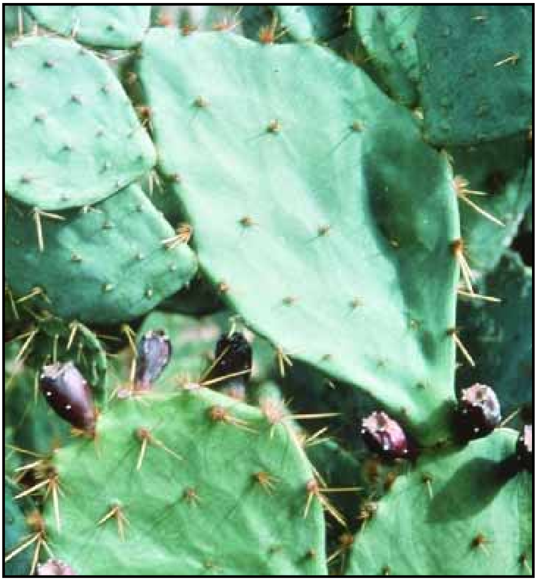

Prickly Pear
Opuntia megacantha *Cactus Family, Cactaceae*

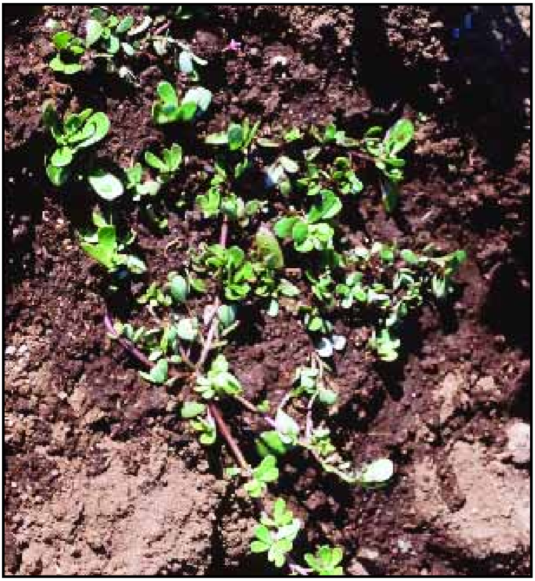

Purslane
Portulaca species *Purslane Family, Portulacaceae*

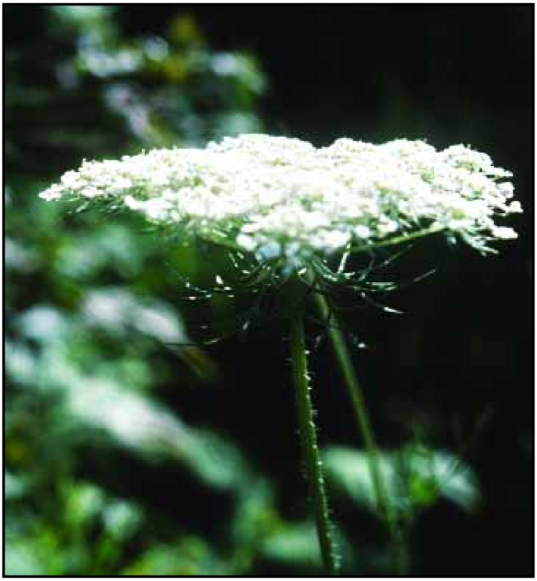

Queen Anne's Lace
Daucus carota *Parsley Family, Umbelliferae*

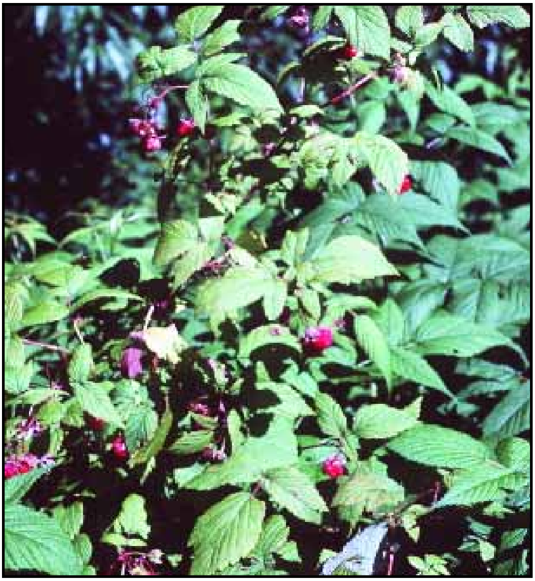

Raspberry
Species Rose *Family, Rosaceae*

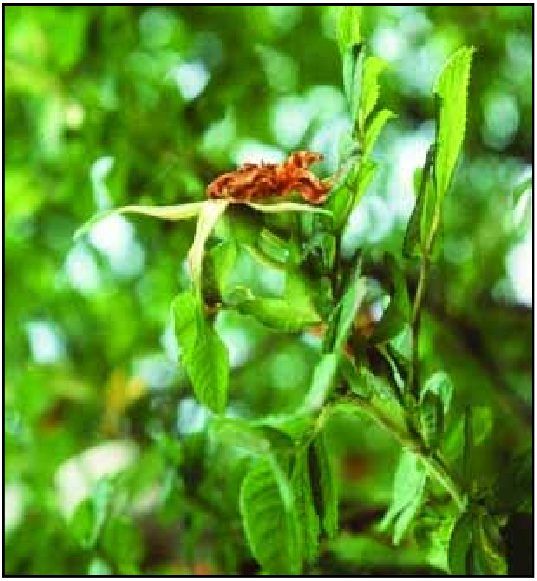

Rose
Rosa rugosa, R. Caroline *Rose Family, Rosaceae*

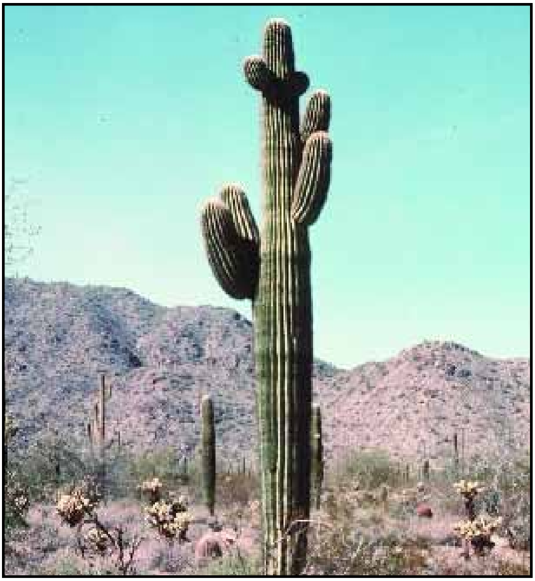

Saguaro
Carnegiea gigantea *Cactus Family, Cactaceae*

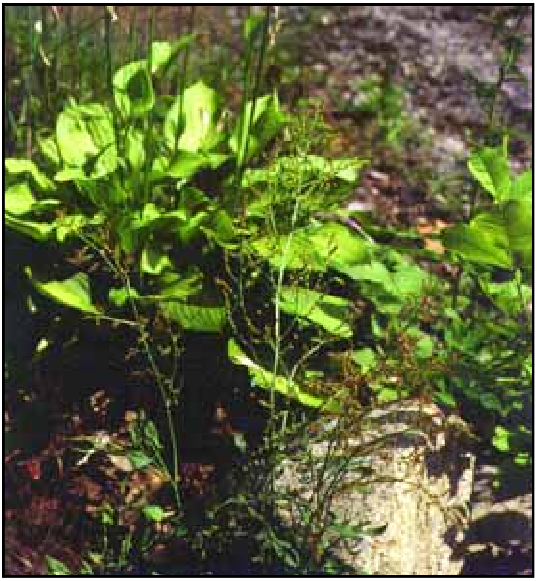

Sheep Sorrel
Rumex acetosella *Buckwheat Family, Polygonaceae*

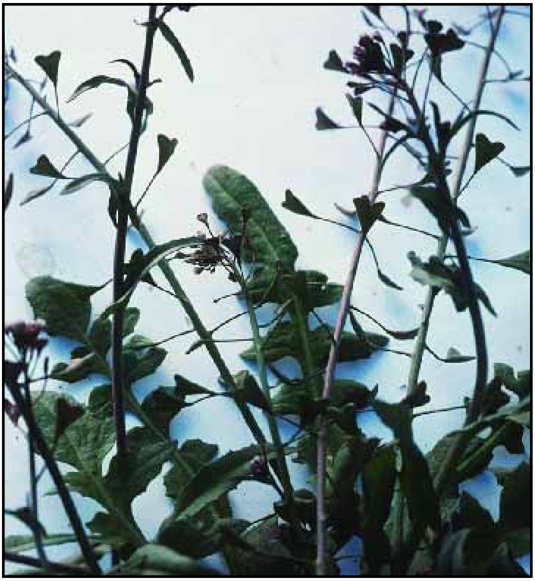

Shepherd's Purse
Capsella bursa-pastoris *Mustard Family, Brassicaceae*

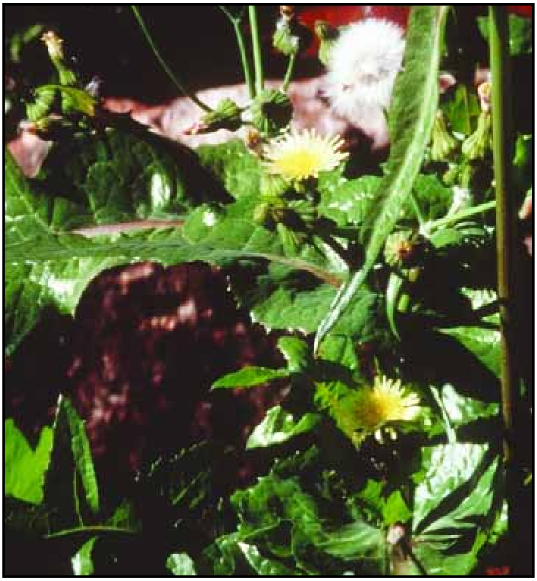

Sow Thistle
Sonchus oleraceus *Composite Family, Compositae*

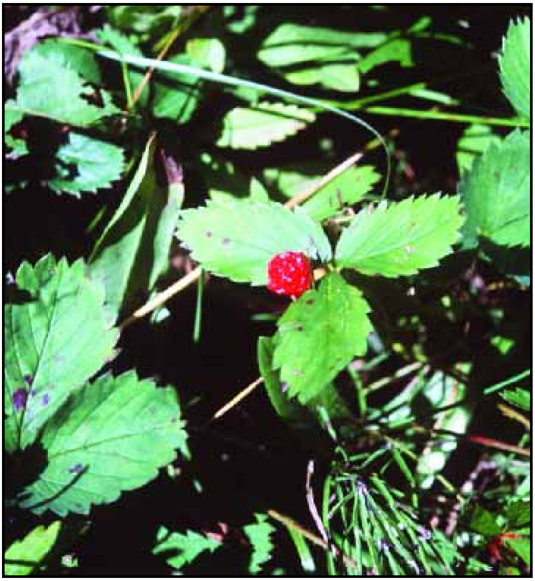

Strawberry
Fragaria virginiana *Rose Family, Rosaceae*

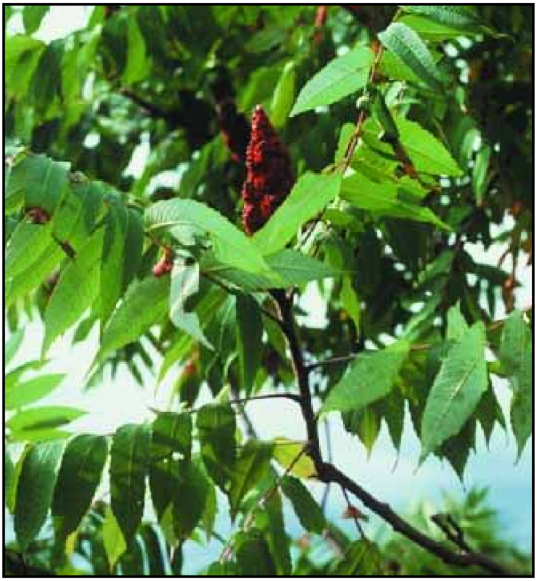

Sumac
Rhus species *Cashew Family, Anacardiaceae*

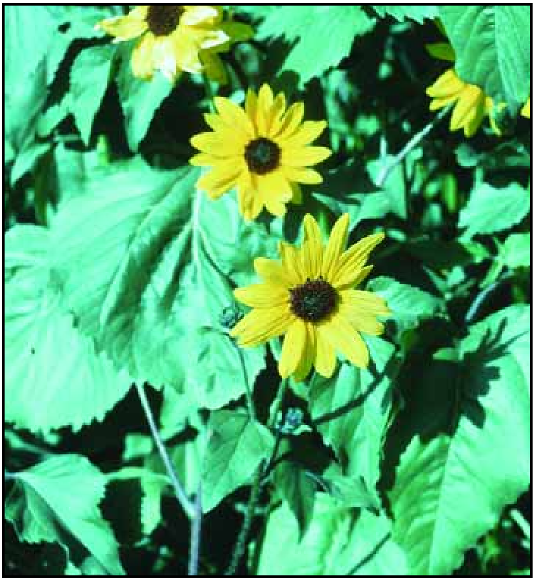

Sunflower
Helianthus species *Composite Family, Compositae*

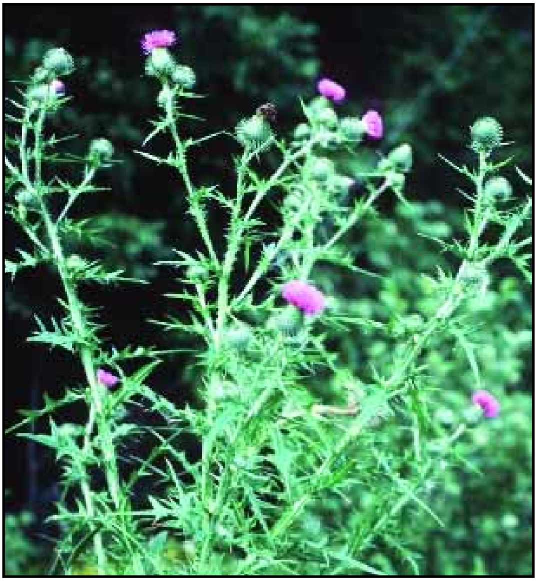

Thistle
Circium species *Composite Family, Compositae*

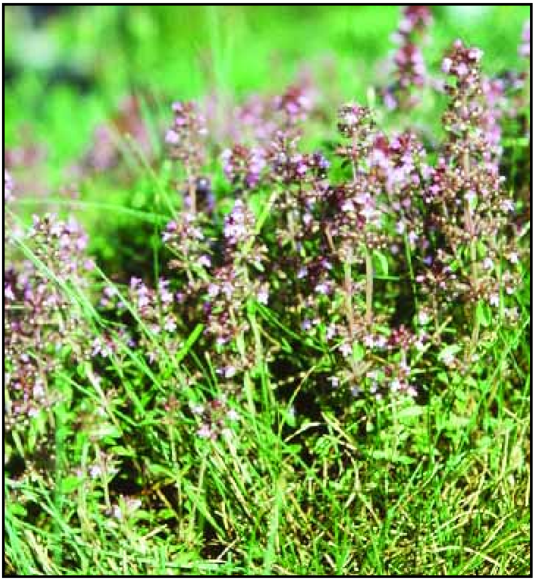

Thyme
Thymus vulgaris *Mint Family, Labiatae*

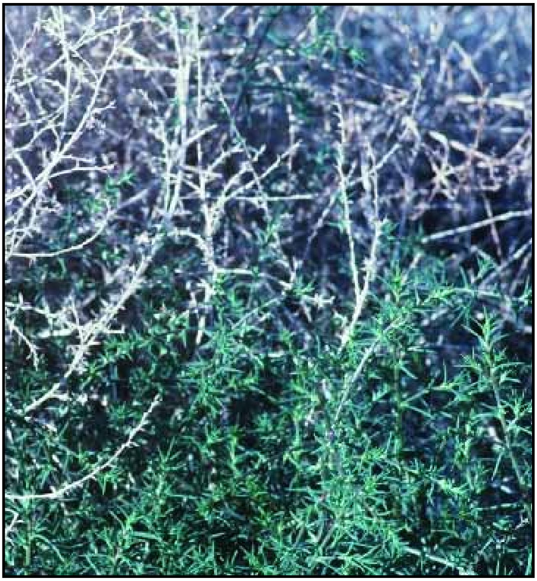

Tumbleweed
Salsola kali *Goosefoot Family, Chenopodiaceae*

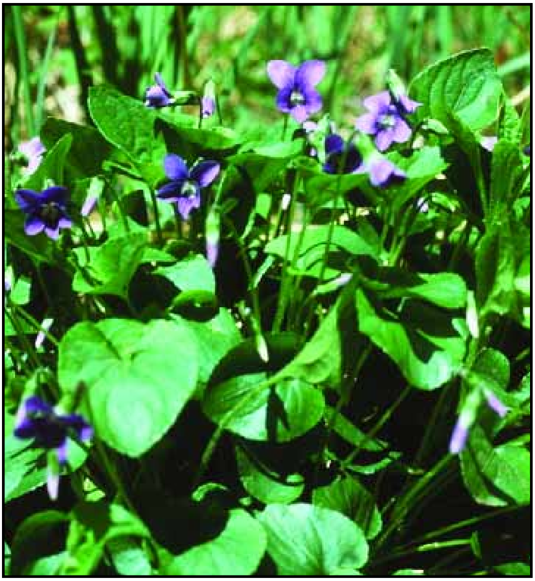

Violets
Viola species *Violet Family, Violaceae*

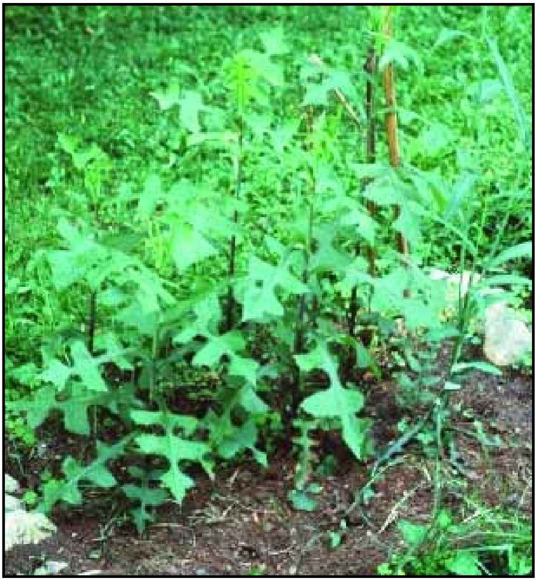

Wild Lettuce
Lactuca canadensis *Composite Family, Compositae*

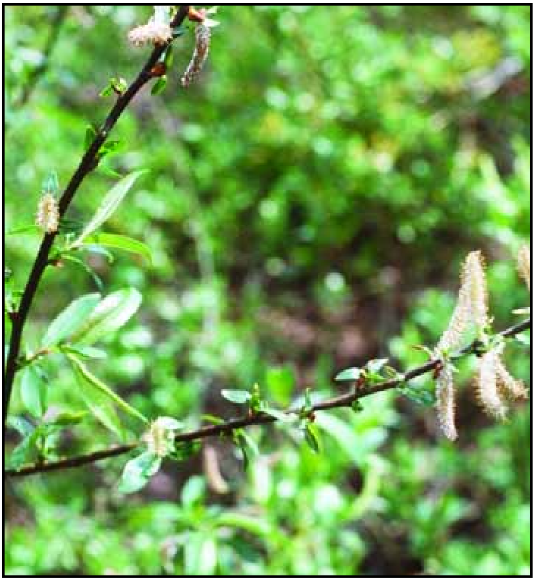

Willow
Salix species *Willow Family, Salicaceae*

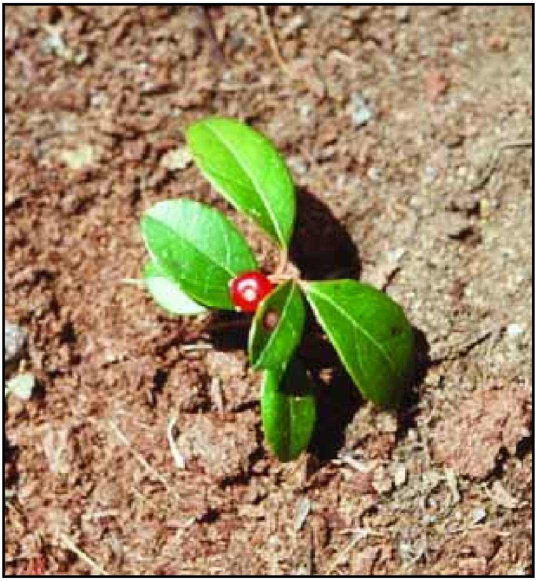

Wintergreen
Gaultheria procumbens *Heath Family, Ericaceae*

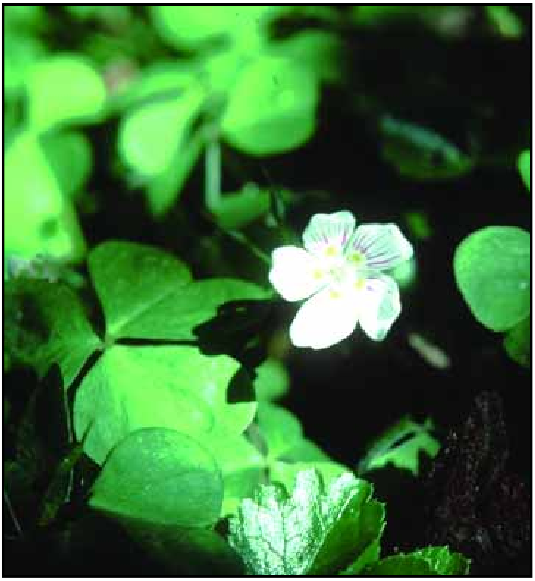

Wood Sorrel
Oxalis species *Wood Sorrel Family, Oxalidaceae*

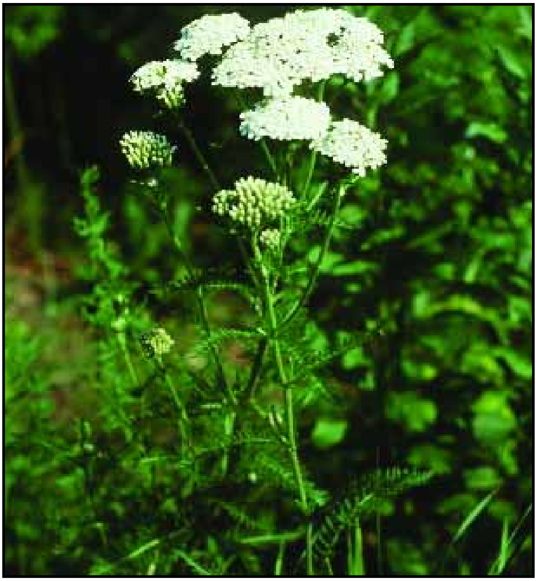

Yarrow

Achillea millefolium *Composite Family, Compositae*

Linda building a walk.

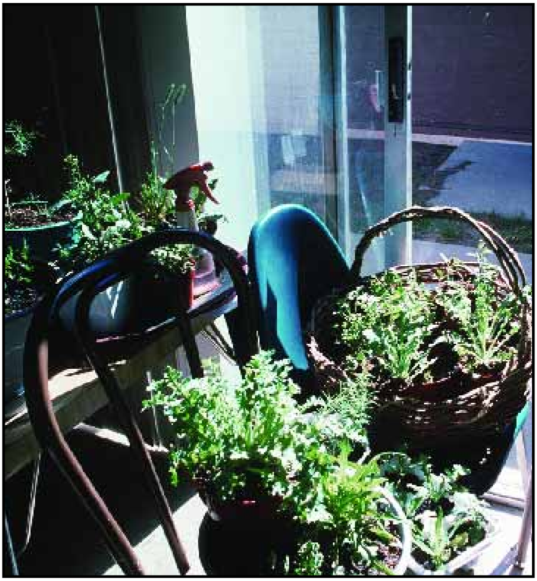

Field in Pots

Home Health Aides Provided Lunch for Linda

Nutrient Value of Wild Foods

I do not advocate giving up one's daily diet, but rather supplementing it with wild foods. My homesteading days taught me the value of a balanced vegetarian diet. Note the following dated 1997 - Some variations have been noted to date.

Some USDA recommended daily dietary allowances for adults are:

- Vitamin A—1,000 micrograms (males) and 800 micrograms (females)
- Vitamin C—60 milligrams
- Vitamin D—5 micrograms
- Vitamin B1 (thiamin)—1.4 milligrams (males) or 1.0 milligrams (females)
- Vitamin B2 (riboflavin)—1.6 milligrams (males) or 1.2 milligrams (females)
- Vitamin B3—20 milligrams
- Vitamin B6—2 milligrams
- Vitamin B12—3 micrograms
- Calcium—1,200 milligrams
- Iron—18 milligrams
- Phosphorous—800 milligrams
- Potassium—1,875 milligrams
- Protein—56 grams (males) or 44 grams (females)

So, you can see from the above how well wild foods can boost the nutritional value of your meal.

The listings that follow show the nutritional values for 1/2 cup quantities of uncooked plant matter.

As much as possible, the data was derived from Duke and Atchley, 1986 *CRC Handbook of Proximate Analyses*, CRC Press, 1986. Duke's FNF database; or from Joseph Laferriere's Nutricomp database. When no other data were available we used Mark Pedersen's Nutritional Herbology (Pedersen Publishing, 1987).

When available data was not specific to the plant or plant part we used data from a related species, or genus, or similar species in a different family. When absolutely no pertinent data was uncovered—as, for example, for violet flowers—averages for flowers such as those published by Duke and Atchley, were used. Occasionally it was necessary to estimate the water content, back-calculating from dried to a fresh basis. Adjustments were then made for carbohydrate and/or fiber content, ensuring that the figures were within a normal range for the plant.

How to read the Nutritional Listings

All quantities given are amounts per 1/2 cup raw food item (≈100 grams).

The figure for Calories is number of Calories per 1/2 cup (100 g) raw food.

Column 1: Measurements are in grams (g) per 100 g (1/2 cup). (Because of the mathematical coincidence, this could also be expressed as a percentage of the whole.)
Abbreviations:
- Carbos. = Carbohydrates
- Tr. = trace amount.

Column 2: Measurements are in milligrams (mg) per 100 g (1/2 cup).
Abbreviations:
- Phos. = Phosphorus
- Ascorbic. = Ascorbic acid
- Tr. = trace amount.

Column 3: Measurements are in micrograms (µg) per 100 g (1/2 cup).
Abbreviations:
- β Carotene = Beta-carotene
- Tr. = trace amount.

No. 1 Aloe Juice

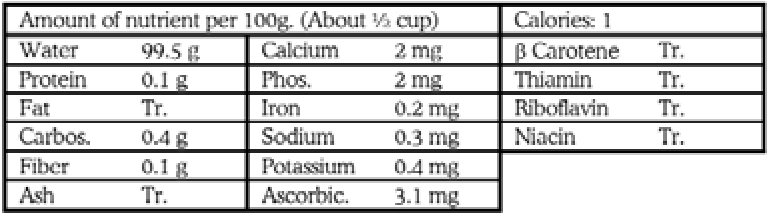

Amount of nutrient per 100g. (About ½ cup)				Calories: 1	
Water	99.5 g	Calcium	2 mg	β Carotene	Tr.
Protein	0.1 g	Phos.	2 mg	Thiamin	Tr.
Fat	Tr.	Iron	0.2 mg	Riboflavin	Tr.
Carbos.	0.4 g	Sodium	0.3 mg	Niacin	Tr.
Fiber	0.1 g	Potassium	0.4 mg		
Ash	Tr.	Ascorbic.	3.1 mg		

No. 2 Amaranth Leaves

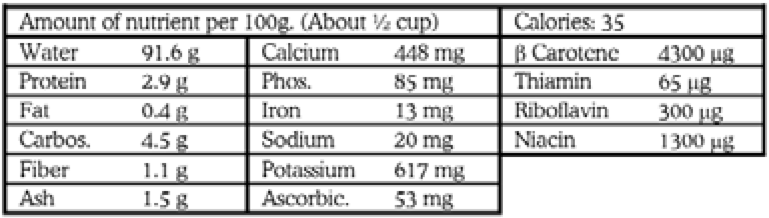

Amount of nutrient per 100g. (About ½ cup)				Calories: 35	
Water	91.6 g	Calcium	448 mg	β Carotene	4300 µg
Protein	2.9 g	Phos.	85 mg	Thiamin	65 µg
Fat	0.4 g	Iron	13 mg	Riboflavin	300 µg
Carbos.	4.5 g	Sodium	20 mg	Niacin	1300 µg
Fiber	1.1 g	Potassium	617 mg		
Ash	1.5 g	Ascorbic.	53 mg		

No. 3 Amaranth Seed

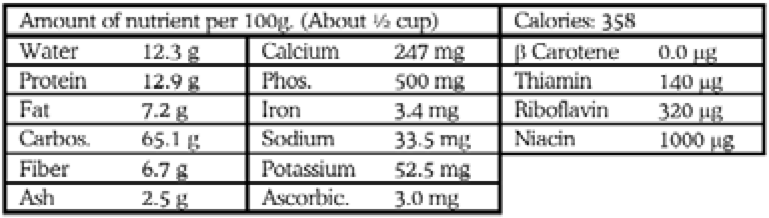

Amount of nutrient per 100g. (About ½ cup)				Calories: 358	
Water	12.3 g	Calcium	247 mg	β Carotene	0.0 µg
Protein	12.9 g	Phos.	500 mg	Thiamin	140 µg
Fat	7.2 g	Iron	3.4 mg	Riboflavin	320 µg
Carbos.	65.1 g	Sodium	33.5 mg	Niacin	1000 µg
Fiber	6.7 g	Potassium	52.5 mg		
Ash	2.5 g	Ascorbic.	3.0 mg		

No. 4 Arrowhead Tubers

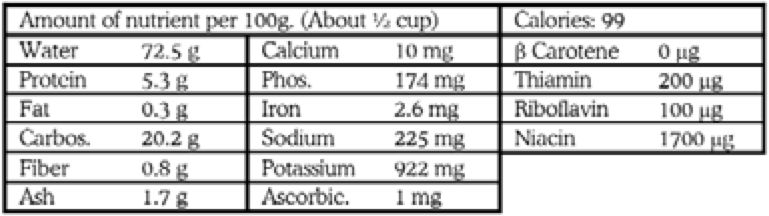

Amount of nutrient per 100g. (About ½ cup)				Calories: 99	
Water	72.5 g	Calcium	10 mg	β Carotene	0 µg
Protein	5.3 g	Phos.	174 mg	Thiamin	200 µg
Fat	0.3 g	Iron	2.6 mg	Riboflavin	100 µg
Carbos.	20.2 g	Sodium	225 mg	Niacin	1700 µg
Fiber	0.8 g	Potassium	922 mg		
Ash	1.7 g	Ascorbic.	1 mg		

DICTIONARY OF SELF-AFFIRMING POWERFUL QUOTATIONS

By Christian H. Godefroy
with the help of
Didier Penissard

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Introduction

What power do words have?

You surely remember fairy tales from your childhood where the wicked queen cast a spell on the hero. The spell usually consisted of some gesture, accompanied by a "Magic Formula" with powerful effects. Sometimes the spell was a curse or malediction (literally: words which convey a wish that harm come to someone).

During your childhood people around you cast all kinds of spells on you. Very often you were not aware of it, but Magic Formulas - transformed into so-called "killer sentences" - had their effect on your mind, and continued harming you in subtle ways.

Let's look at a few examples. Has anyone ever said something to you like:

- You're really good for nothing.
- You'll never make it.
- Blockhead!!!
- You're just a chip off the old block!
- You're even worse than your mother.
- You're not going to start crying again, are you!?!
- Stop trying to be so special...
- It never fails : you're incapable of being on time.
- What an idiot you are!
- You have absolutely no sense of humor.
- You're always sick.

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- You just don't have any talent.
- You should never...

Every time someone used the words "be" or "have" or "always" or "never" when referring to you, chances are they were casting a harmful spell on you.

How harmful spells affect your life

Because these kinds of sentences were stored in your subconscious at an age when you were not able to question their validity, they continued to affect you in subtle ways right into adulthood.

Of course they may be more specific:

- Beware of women.
- Beware of men.
- You'll never understand anything about math.
- Mechanics is a man's job.
- Never trust a Frenchman.
- Making love is dirty.

These kinds of thoughts may not prevent you from getting married, making love or repairing your car, but the causes for your lack of confidence, for the problems and failures you encounter in life, can very often be traced back to these negative seeds.

You are also casting spells on yourself

Do you sometimes talk to yourself? Of course you do, just like everyone else. And do you sometimes blame yourself for the way

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you behave? Are you ever negative about yourself? Of course you are.

- What an idiot I am!
- I'll never make it.
- I'm always so clumsy when I'm with other people.
- I'm just not lucky.
- I'm going to get shafted (taken for a ride) again.
- I'm not good enough.
- I'm so much less talented than...

You've taken up where the others have left off, and are casting spells on yourself! Ideally you would identify these kinds of negative reproaches and replace them with stimulating, positive thoughts which liberate you, make life easier, and affirm your worth instead of inhibiting and prohibiting you.

How to weed out these negative thoughts?

Using the Dictionary of Self-Affirming Powerful Quotations is an excellent way to discover where these seeds of failure, anxiety, health or relationship problems, etc. are hidden. It's as if, by consulting the dictionary, you are trying to defend yourself against them. Whenever a positive thought makes you uncomfortable, or bothers you without your knowing exactly why, or just seems stupid, take it as a sign. Continue working with that thought until it reveals its secret meaning to you.

You can also make a list of the difficulties you have to face, the problems you encounter, and then use a corresponding positive thought as an antidote.

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Try to remember what was said to you just before you started feeling “down on yourself” or depressed.

How to neutralize the power of negative spells

Many people before you have had to deal with these kinds of negative thoughts. That’s why therapists, doctors, and specialists in the art of suggestion have developed antidotes in the form of positive affirmations. The Dictionary of Self-Affirming Powerful Quotations offers you a selection of the best of these.

Better still, they’ve all been transcribed into the first person (I) so that you can use them to replace the negative spells you are casting on yourself. Here’s what to do:

1. Using the alphabetical headings and index, find a positive thought that can serve as an antidote. If you like you can copy the structure of existing affirmations to create your own new ones.

2. Read it carefully, out loud if possible. Then repeat it silently to yourself. Copy it on a pad or in a notebook that you carry around with you. Make it a theme of meditation: while driving, or riding on the train or bus, or lying the beach - any time your mind starts wandering - repeat the positive thought.

3. Use altered states of consciousness resulting from relaxation, meditation or self hypnosis to impregnate your subconscious more deeply. You can tape an hypnosis-inducing text on cassette, followed by your positive thought(s), and then a wake-up message.

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4. Discuss your situation with a friend or close relative. Exchange points of view with persons who do not have the same problem as you do, in order to understand how their minds work, and eventually to use them as models for your own behavior. Also try to read personal accounts of how others have successfully dealt with the same type of problem.

5. Allow at least 21 days for your inner transformation to take place. If you are trying to make some very drastic changes, persevere for at least 3 months.

A marvelous tool for personal development

The Dictionary of Self-Affirming Powerful Quotations is a constant companion, always ready to inspire you and guide you along the paths of life. It will help you learn to know yourself better, and exploit the formidable power of your subconscious to help you attain your goals.

You can also use it as an instrument of divination: just ask yourself a question, and then open the book at random. You'll be sure to find an answer, or at least its essential elements.

Copy the thoughts you find most inspiring. The simple act of writing out a thought helps make it your own.

If you're living through a difficult period in your life or feel that you're under a lot of stress, immerse yourself in the Dictionary of Self-Affirming Powerful Quotations and let it wash away all the negative influences and emotions you experience during the course of a day.

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And if you happen to be a therapist or teach some form of relaxation or meditation, or if you want to use positive suggestions to help your children, the dictionary will provide you with a constant source of counsel and guidance.

A valuable tool in your interpersonal relations

Does your child have a tummy ache? Does he or she have trouble concentrating? Is your sister in the process of rebuilding after a difficult divorce? Is your partner having business problems?

Open the Dictionary of Self-Affirming Powerful Quotations to the appropriate page. Select one or a number of sentences. A single positive thought can change your life. It can be the branch that saves a drowning person, the talisman, the blessing that breaks the evil spell.

Offer these thoughts to others as you would offer a bouquet of flowers. The Dictionary is like a jewel box, the positive thoughts it contains are like precious gems. Offer them as gifts to your friends and loved ones. And like jewels they will reflect the light of love and dispel the shadows of despair.

As you'll soon discover, this dictionary is an amazing collection of positive thoughts with almost magical powers. It's almost like an Aladdin's lamp, ready to grant all your wishes. All you have to do is keep reading it. In no time at all your life will become simpler and easier, free of all the obstacles which have been holding you back in the past.

Life gives you what you expect of it, on condition that you cultivate positive and creative thoughts. And the Dictionary of Self-Af-

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firming Powerful Quotations will help you change your way of thinking. You'll see opportunities where others see only obstacles, solutions where others see only problems, lessons to be learned where others see failure, and beauty where others see nothing at all.

Consider this dictionary as a great prayer of enthusiasm and confidence in life and in humanity, full of gratitude.

Christian H. Godefroy, mailto:webmaster@hypnotic-words.com

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ABUNDANCE

This great power, the power to choose, gives me the necessary hope and the necessary state of mind and the necessary courage to get everything I really want out of life.

J. Martin Kohe, Your Greatest Power, published by A Different Life Ltd., 1979

I believe in abundance, I desire abundance, I receive abundance.

Shakti Gawain, Reflections In The Light, New World Library, 1978

I allow this infinite abundance to pass freely through me and through all those who listen to me, just as I freely give up the money I possess, allowing it to flow through my hands, giving where it can do the most good.

Robert Collier, Riches At Your Doorstep, S.I.P. 1962

I am grateful, and I rejoice in a life full of abundance.

Dr. Joseph Murphy, The Miraculous Power To Attract Infinite Wealth, Godefroy Publications, 1979.

I lead a rich and abundant life, physically, spiritually, and on other levels.

Shad Helmstetter, The Power Of Inner Motivation, 1987.

The universe is a horn of plenty which everyone can draw from. My very nature is abundance, and I accept it fully. Abundance is what I really am. And I accept it fully and joyfully. The universe is pure abundance!

Shakti Gawain, Techniques Of Creative Visualization, Editions Soleil, 1978.

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ACCOMPLISHMENT (Also see Success)

By using my imagination I move towards accomplishment. I remove the debris caused by the wounds I have suffered, which deprive me of the inner security I deserve.

Dr. Maxwell Malts, Psychocybernetics and Self Accomplishment, published by A Different World Ltd. 1970.

I was conceived to accomplish, built for success, and gifted with the seeds of greatness.

Zig Ziglar, Rendezvous At The Summit, published by A Different World Ltd., 1975

I will do things that will make me live longer... live better.

J.V. Cerney, Stay Younger - Live Longer through the Magic of Mental Self-Conditioning,
Parker Publishing Company, Inc. 1968.

ACNE (See Urticaria, Eczema)

ACTION (Also see Opportunity)

From now on I will savor every one of my actions!

Shakti Gawain, Techniques Of Creative Visualization, Editions Soleil, 1978.

I will act immediately.

Og Mandino, The Greatest Secret In The World, published by A Different World, 1979.

I act constructively. I do what my conscience dictates.

W. Clement Stone, Napoleon Hill, Success Through Constructive Thinking, Godefroy Publications, 1978.

I flow with my energy - all the time.

Louis Proto, Self Healing, Piatkus Publications, 1990.

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I act in a positive way.

Subli Power - Subli Control, Edit Inter, 1989.

I act.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I cease all actions which work against me. Then the right actions are revealed to me.

Vernon Howard, Psycho- Pictography, S.I.P., 1965

I don't want to remain passive in the face of life any longer, nor allow myself to be carried along by circumstances. I want to act. I want to attain my goals.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I now know that to overcome fear I have to act without hesitation and my doubts will disappear. I now know that action transforms fear into serenity. I will live this day as if it were my last. Action is the bread and the wine that nourishes my success. Action is the spark that gives life to my dreams, my plans, my goals, and transforms them into reality.

Og Mandino, The Greatest Secret In The World, published by A Different World, 1979.

I am capable of action.

Jean Chartier, How To Acquire A Superior Personality, Published by Dangles, 1971.

I am in the process of changing my life through my actions. This is a choice that belongs to me.

Richard Corriere & Joseph Hart, Staying In Psychological Shape, Les Editions de l'Homme, 1979.

I am completely ready.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I simplify my life. I get rid of disorder and actions which are not fruitful. I continue asking myself questions, at least once a week:

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“What is it, above and beyond my daily routine, that constitutes the essence of my life, and what are the real activities to which I should be devoting my time?”

Denis Waitley, Seeds Of Greatness, Editions Pocket Books, 1984.

ADVERSITY

I face up to things courageously. I stay calm.

Alan Houel, How To Deal With Difficult People, Godefroy Publications, 1990.

I am happy to encounter a certain form of opposition. It offers me an opportunity to test my strength and my ideas.

Raymond Hull, Wanting Is Power, Les Editions de l’Homme, 1969.

Adversity always contains the seed of a new opportunity. I can do it, if I believe I can!

W. Clement Stone & Napoleon Hill, Success Through Constructive Thinking, Godefroy Publications, 1978.

Once I start playing a game I always do my best to hit the ball back and defeat my opponent.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

AEROPHAGY (Flatulence)

Although my stomach is swollen, I know the swelling will gradually disappear. Little by little my stomach will regain the strength and elasticity it lost, and as it regains this strength and elasticity it will return to its normal size, and carry out the functions of digesting food and sending it to the intestines more and more easily, until my stomach and intestines are in perfect form.

Emile CouÈ, Complete Works, Astra Publications, 1976.

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ADVICE

God will tell me what I should do.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

My subconscious becomes a more and more important part of myself... I can ask it questions... it answers... it advises me and guides me.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

AFFECTION

I am affectionate.

Dr. Wayne W. Dyer, Your Erogenous Zones, Tchou, 1976.

The positive emotions of love, affection and patience appear when I am in touch with my true self.

Vernon Howard, Psycho-Pictography, S.I.P., 1965

AFFIRMATION

I have the right to be myself. Affirmation is a measure of my success. I affirm myself more and more, in all areas of my existence.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

AGING

I avoid being inactive and doing nothing... I make sure not to let my movements slow down too much... I cultivate vivacity in order to keep myself alert.

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I am sure I will stay forever young... my mind will remain lucid... and I will not suffer the pains of aging until very late in life... my life is rich and productive.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I adapt to the ups and downs of life by maintaining my sense of humor. I keep the child alive and awake within me.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I may be aging, but I am also improving with age.

Emrika Padus, Encyclopedia of Emotions And Health, Edi Inter, 1991.

AGITATION

At the least sign of becoming over-excited I react and remain impassive.

Paul-Clement Jagot, How To Develop Your Personal Magnetism, published by Dangles, 1982.

AGREEMENT

I try to reach explicit agreements in the form of contracts.

Pierre Nicolas, Time Is Money - and Pleasure, Inter Editions, 1981.

AGGRESSION

The spirit in me is my shield. The spirit in me is my saviour. I have nothing to fear - the power of the spirit protects me.

Marcelle Auclair, The Book Of Happiness, Editions de Seuil, 1959.

The spirit in me is my refuge and my fortress.

Marcelle Auclair, The Book Of Happiness, Editions de Seuil, 1959.

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AIDS

My immune system is back to full strength again.

Louis Proto, Self Healing, Piatkus Publications, 1990.

ALCOHOLISM (Also see Sobriety)

Drinking is no longer important to me.
Drinking is no longer a necessity for me.
I forgive myself for past mistakes which led me to drink.
I am becoming a more relaxed person.
My self confidence is growing day by day.
I like people, and I feel they like me.
I think of myself as a positive person.
I like to think of myself as a person who doesn't drink.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec/Amerique Publications, 1874.

I like drinking water.

Subli Power, Sublihealth, Edi Inter, 1989.

I free myself of the habit of alcohol. I love myself, and I love life more every day. I am proud of myself.

Karl O. Stoeber, Psycho-training, Godefroy Publications, 1984.

I don't have to have a drink whenever I am upset or frustrated. I can survive life's frustrations without alcohol. And because I have proven to myself over and over again that I have never been able to handle alcohol intelligently, I am going to abstain altogether.

Frank S. Caprio, M.D. and Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc. 1974.

I have no trouble controlling my drinking habit. I now drink alcohol in moderation. I can easily go several days without having a drink. The less I drink the healthier I get. I am mastering my habits,

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and my general health is improving day by day. I like my body, and I want to keep it healthy for as long as possible. So I take care of it. I drink very moderately. There are many days I don't drink at all, and I'm perfectly happy.

I am giving up alcohol completely. I have no trouble not drinking at all, and I feel a lot better. My body and mind are completely free of the alcohol habit. I have more and more control over my emotions. I can stop drinking completely, starting right now. From now on I'll be sober and happy.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I couldn't care less about drinking, any place, any time, under any circumstances. Others can drink, but I'm really not interested.

Clement Auger, Transform Your Life Through Auto-suggestion, Heritage Press, 1979.

I feel as if all my problems were fading away.. I've solved them all... nothing can change my mind... I feel absolutely no desire for alcohol any more... drinking doesn't interest me... it turns me off... more and more... even the thought of alcohol turns me off... just looking at alcohol makes it even more repulsive.

From now on I won't drink any alcohol... nothing can make me change my mind... I'm happy to be improving my health, and I feel better every day... I'll never drink alcohol again. I find it more and more repulsive. Even the though of alcohol disgusts me.

If I drink a single glass, I'll get sick. My stomach can't take any alcohol... even a glass will make me very sick... I will try not to succumb to temptation.

I'll never drink alcohol again.

Just the sight of alcohol makes my disgust grow... I'm so happy to be free of it... nothing can make me change my mind. I can't drink any alcohol... and I won't!

Professor Kurt Tepperwein, Secret Techniques of Hypnosis, Godefroy Publications, 1981.

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I am capable of resolving my problems, and thus of freeing myself from the burden of alcoholism.

Professor Kurt Tepperwein, Think and Heal, Godefroy Publications, 1984.

I'm going to stop drinking not because others want me to, but because I really want to.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I'm a nice person when I don't drink. I look better when I don't drink. I work better when I don't drink. I lose weight when I don't drink. I'm healthier when I don't drink.

Editorial staff of Practical Health Guides: How To Activate Your Body's Natural Defences, Godefroy Publications, 1989.

ALLERGIES

I have more and more fun with cats. Cats are gentle, affectionate animals. My body reacts completely normally when I'm with them.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I'm a healthy normal person. My body functions normally, under any conditions. I function perfectly normally in the presence of animals. My body functions normally, whatever the surrounding odors are. I am free of past negative influences which have been causing my allergic reactions. Soon I'll be able to eat any food I like. Each day that goes by strengthens my conviction that I am in the process of resolving all past problems. I perceive of myself as a person who is not allergic to anything.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

ALLERGIES (Food)

I can now eat —— (name the food) easily and find it delicious. I

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am free of past negative influences. My body now reacts normally to all the foods I eat.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

ALTRUISM

To me loving means listening unconditionally and without prejudices, to the needs of another person, and fully appreciating his or her worth.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I have the right to be open with other people.

Christian. H. Godefroy & John Clark, How To Have More Time, Godefroy Publications, 1989.

I stop thinking only about myself, and think more about others. Every day I try to do something kind, something that brings a smile to a suffering face.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I always take other people's feelings into consideration. I am aware of their feelings, sensitive to their attitudes and opinions. I know how to listen. I show a sincere interest in the convictions, thoughts and ideas of others. And since my interest is sincere, other people recognize that and start counting on me.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

AMBITION
(Also see Vitality, Dynamism, Enthusiasm)

I maintain a victorious attitude towards life. I know there is no task a person cannot accomplish once he or she has made up his mind. I want to accomplish... (name the task). My ambition is completely

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legitimate. I want to make progress in my work, as well as in my intellectual and moral development. I will leave nothing to chance. Attaining the success I aspire to depends solely on me.

Professor Robert Tocquet, The powers Of The Will, Godefroy Publications, 1989.¥

I reconstruct myself with a brighter future.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I am not content with being less than I can become. I'm as capable as any other human being who has ever lived. I am not afraid of my own greatness.

I always remember that I can become anything I choose to be, and that greatness is there for the taking if I really want it.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

I am no longer satisfied with what I can get, but only with what I want to get.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I know I can obtain everything... gain access to the highest circles... I only have to want it... and have faith in my success, and I will succeed.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I am aware, conscious, and ready! I am overflowing with vitality and ambition. I exploit every opportunity with dynamism and enthusiasm.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am a CEO (or a lawyer, or any profession of your choice). Every day brings me closer to my goal. I know I am already there. It's fantastic. I accept my own amazing future.

Charles Baudouin, Psychology And Practice of Auto Suggestion, Idegraph Publications, 1990.

I am full of ambition, and there is nothing wrong with that. I want

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to succeed in my work, as well as in my personal development.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

ANAEMIA

My blood is getting richer and richer, more and more red, more and more nourishing. It is getting to be more and more like healthy blood. My anaemia is gradually disappearing, carrying away with it the host of problems that accompany being anaemic.

Emile Coue, Complete Works, Astra Publications, 1976.

My blood is rich, and is replenished daily.

Louis Proto, Self Healing, Piatkus Publications, 1990.

ANAESTHESIA (Also see Pain, Wounds)

With each pinch the anesthesia spreads. At first I pinch lightly, adding pressure each time. The fourth time I pinch, the anesthesia will be complete.

Leslie M. Le Cron, Liberate The Forces In You Through Self Hypnosis, Tchou/Ariston, 1964.

All right, now I'm going to count to three, and on the count of three my arm will become rigid, and the more I try to bend it, the more rigid it will get. During this time my right hand will grow more and more numb, more and more numb... more and more insensitive. Now even my left hand is becoming rigid, so the anesthesia in my right hand is getting stronger.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

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ANAESTHESIA - DENTAL

My cheek is numb, I can prick it with a needle, and not feel a thing... My lower gum is numb, I can prick it with a needle, and not feel a thing... My whole mouth including gums and teeth are totally numb, like a block of wood.

Giovanni Sciuto, Real Hypnosis, Dangles Press, 1975.

ANGER (Also see Migraines)

What other people think or say about me doesn't bother me. If my inner Guide is with me, if He (or She) approves of my thoughts and actions, then everything is all right. I am calm and strong!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

It's normal to get angry from time to time.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I take responsibility for my emotions. When I begin to get angry I acknowledge the fact that I own my emotions. I remove myself from any potentially hostile situations. When I talk about my anger or dissatisfaction I say: "I feel angry when I see that happening," instead of saying, "You make me angry when you do that." Only I can make myself angry.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I master my emotions. I never get angry for no reason, nor do I react violently to any situation whatsoever.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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I am very careful not to get angry. I have a good character, I demonstrate patience, and I always think before I act. I avoid complaining.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

When I get angry about not achieving the results I want in a situation, I move quickly from “stewing to doing.’ I ask, “What can I do to turn this situation around? Is there anything I can salvage from this situation? What can I learn from this situation? How can I prevent it from happening again?”

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

When I get angry I remind myself that everyone has the right to be what s/he chooses to be, and demanding that others be different will only result in prolonging my anger. I make sure to let other people make their own choices. After all, don’t I claim that right for myself?

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

When I feel myself getting angry I quickly give myself the suggestion that I can switch my thoughts to something else. If need be I can always walk away from the person who is provoking the anger reaction, or expend my energy in doing something that will divert my mind - finding some other outlet for my pent-up emotions. I am going to remind myself that people can make me angry only if I allow them to do so, and that getting angry is actually flattering the other person.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

ANGINA (Chest)

The attack is passing and my heart is beating normally.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

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ANSWERS

My Real Self knows all the answers I need.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

ANXIETY

From now on, whenever I feel anxious I will breathe deeply, relax, and feel a surge of energy rising through me.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I express the anxieties I have about myself, and then let go of them.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am completely calm... completely calm... A marvelous feeling of peace and harmony spreads through my body... I am happy... my circulation is regular and my digestion is perfect.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

I feel a hot current flowing through my solar plexus.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

In the past I would look anxiously outside, waiting nervously for something bad to happen. From now on I look inwards, full of confidence. I look to my Inner Guide.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I am learning to interpret my anxiety as a state of excitement instead of nervousness.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

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I stop anxiously fighting all the little complications of life. I simplify my affairs.

I have to work towards freeing myself of all forms of fear and anxiety.

I feel less tense and anxious.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I am in the process of becoming a much more self confident person.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I see my life and everything that happens from the calm, clear perspective of my conscience, and profound understanding.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

My tension can be an ally because if I feel any anxiety, I take it as a sign to call on the means at my disposal to deal with the situation.

I take a deep breath and relax. Everything's all right. I am in control of the situation, and of myself.

It's all over, I've succeeded.

It wasn't as bad as I thought it would be.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

Everything is fine.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

ANXIETY - SOCIAL

It does no good to worry. It's much better thinking about what I can do rather than becoming anxious. I have plenty of time to take a deep breath and relax before dealing with the situation.

I don't have to prove anything to anyone. If others accept me, all the better. If they don't, too bad. I'm not trying to make everyone

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love me.

I concentrate on the present moment. What do I have to do now?

I think mostly about the things I have to do, and about the positive results these actions will bring.

If I deal with the situation step by step, I won't have any trouble.

I can't expect people to always think as I do, and do what I want them to.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

APLOMB

In all situations where I used to be too impressionable, I am now protected by a suit of armor through which nothing can penetrate.

Charles Baudouin, Psychology And Practice of Self Suggestion, Idegraph Publications, 1990.

I develop my aplomb and my confidence.

SubliPower, Subli Confidence, Edi Inter, 1989.

I feel an imperturbable calm in the face of anything that happens.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I don't allow anyone to influence me.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

APPEARANCE (PHYSICAL)

I know that my appearance, my weight and my well being depend solely on me. I do everything necessary, every day and every instant, to create the "me" I really want to be.

I am in control of myself. Only I decide what my physical appearance is like, how much I weigh, and how I feel.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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APPETITE (Also see Digestion, Stool)

I'm hungry at mealtimes... I am attracted by natural, healthy foods.

Sublipower, Subli Health, Edi Inter, 1989.

APPREHENSION

I am calm, courageous and free! My inner Guide fills me with confidence, self assurance, love and harmony. I feel free, joyous and strong. I am free, and secure under Your wing. I am free!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

Negative suggestions, phobias, apprehensions, dark or sad thoughts all gradually disappear of their own accord, without my having to fight them. Even dark thoughts and feelings which are based on reality are gradually receding.

Charles Baudouin, Psychology And Practice of Self Suggestion, Idegraph Publications, 1990.

APPROVAL

I feel good because I want to, and my feeling good has nothing to do with you.

No one is unhappier than people who need (the approval of) other people. But those who want to love others become happy themselves.

I thank people who tell me things that can help me, even if what they say is difficult to accept. My feeling of gratitude replaces my need for approval.

I stop looking to my spouse, or to anyone else, for approval of what I say, by cutting out things like, "Isn't that true, dear?" or... "Don't you agree?" or... "Ask so and so, she'll tell you."

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I reprimand myself out loud every time I find myself seeking other people's approval. By doing so I become aware of this kind of behavior, so that I can stop it.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

It is completely normal that people forget to express or even feel gratitude; therefore, if I expect other people to reward me through a show of gratitude, I am only exposing myself to a flood of bitter disappointments.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

I'm sure the sales manager will notice my effort and my results.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

ARCHERY

I am perfectly relaxed when I practice archery.

My reflexes are getting faster and more efficient. I can hit the target more and more easily, shot after shot. I am improving all aspects of my archery. My vision and reflexes are working marvelously well. Archery is easy for me.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

ARTHRITIS

I relax the muscles around my joints. I feel a cascade of clear water flowing over my joints, washing them, purifying them, making them strong. The water carries away the pain. I see the cool clear water flowing over my fingers, my knees, my shoulders. It calms me, washing away the inflammation. I can already feel the water sooth-

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ing my joints, relaxing them, so that I can move with no pain at all.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

My joints are supple again, and feel smooth and comfortable.

Louis Proto, Self Healing, Piatkus Publications, 1990.

My energy circulates more and more freely through my whole body, which is becoming light and luminous. My pains completely disappear because the amazing power of my subconscious mind is healing me completely.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

ARRHYTHMIA

My heart beats slowly and calmly.
I am my heart.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

ASKING

I have the courage to ASK.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

ASSIDUITY (Also see Perseverance)

I'm interested in material things, and I do my work conscientiously.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

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Work that you're interested in is never difficult, and sure to succeed.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

ASSIMILATION

I'm getting stronger day by day. I assimilate information more and more rapidly and precisely, and my willpower is getting stronger.

Paul Clement Jagot, The Power Of The will, Dangles Press, 1950.

ASSISTANCE

The universe is always there to help me.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

ASSISTANCE - SPIRITUAL

I send you strength and courage. United with the forces of your inner Guide, I consciously direct our plenitude towards you, so that we can offer you assistance and stimulate the right conditions which will help your development.

I love you and send you energy, faith and courage. May a clear vision awaken in you of the right path to follow. Everything good you wish to accomplish will succeed.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

Right now divine love is doing its perfect work for the benefit of all.

From now on may divine love and light work through me.

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Divine love goes before me and prepares the way.
From now on God will show me the way.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

ASSOCIATES

My time and energy are precious. I choose to surround myself with positive associates who are focused on possibilities, learning, improving and taking responsibility for results. I guard my mental life against negative influences.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

ASSURANCE (Also see Self Confidence)

Every day I feel more and more sure of myself, and it's great. A beautiful, exciting life is awaiting me; it's wonderful to feel this sense of assurance growing in me, this confidence in myself that I feel getting stronger and stronger.

Charles Baudouin, Psychology And Practice of Auto Suggestion, Idegraph Publications, 1990.

I'm ready for action, I look more assured, more vibrant, more convincing. I speak with conviction and tread firmly.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

I feel strong and calm no matter what happens.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I always feel calm and self assured.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I can be whoever I want to be with total support. I can go fast or slow - it's my choice. I am protected.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

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I am calm and confident. I possess the tranquil assurance that my life will be a success.

Shad Helmsletter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am happy, self assured and strong.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I am confident.

Matthew McKay & Patrick Fanning, Self Esteem, New Harbinger Publications, 1990.

ASTHMA

Every day I feel more and more free and relaxed. I react normally to all situations. I fill my lungs fully when I breathe. And I can easily overcome any tension or anxiety I feel. I am in perfect control of my body in all situations.

My bronchial tubes and lungs are strong and relaxed. I breathe calmly and deeply in all situations. I always stay calm, and control my body's reactions. I feel more and more confident and relaxed all the time.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I send energy from my brain into my nostrils, which will remain open, sending air to my longs, for as long as I want.

My lungs are relaxing, air is entering, the attack is subsiding.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

I am completely relaxed, breathing deeply and freely.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I am convinced that my asthma problem is getting better every day.

I free myself of the causes of my asthma attacks.

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I am convinced that I don’t have to have these attacks.

I’m becoming a relaxed person.

I feel stronger and healthier every day.

I see myself as a healthy, normal person.

I always breathe easily and normally.

I don’t have to use an asthma attack to get other people’s attention.

I can now share my feelings with others more easily.

I have strong willpower, and I can easily control my physical reactions.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

My breathing is relaxed and effortless.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

My breathing is slow and regular; with each breath the muscles in my bronchial tubes and lungs relax more and more deeply; air enters my rib cage more and more freely, and my breathing becomes easier and easier.

After each session I see myself gradually improving. I breathe much more easily, the wheezing in my chest is disappearing, I am becoming much calmer, much more relaxed, and much less nervous.

As soon as I place my left hand on my chest, the muscles in my lungs and bronchial tubes relax; I feel them relaxing, I feel the air flowing more and more freely into my lungs, my breathing becomes easier and easier; with each breath my chest muscles relax more and more, and my breathing becomes calm, regular, calm, regular and easy.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

My breathing is completely normal, deep, regular and calm.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

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ASTHMA ATTACK

It's stopping, I'm already breathing easier.
I can feel myself breathing more easily. One more breath and it'll be over.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

AUDACITY (Also see Courage)

I will go where failures fear to tread.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I dare to do what I want. I act! I'm no longer afraid, and I will succeed.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I dare take the first step towards my rightful castle.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I can't always be reasonable and please everybody if I want to feel good about myself; I have to take risks, risks which develop a feeling of direction in me.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

I Can, I Want, I Dare, I Act.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I want to dare.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

To succeed I risk failure, and that is the proof of audacity.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

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If there's nothing to lose and a lot to gain, I'll go for it.

W. Clement Stone, Passport To Success, Godefroy Publications, 1962.

AUTOSUGGESTION (Also see Hypnosis)

I am going to follow the suggestions which I implant in my subconscious mind.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

AVAILABILITY

I am always available for people whom I consider important, and for things which I consider important.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

AWARENESS (See Self Awareness)

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B

BAD CHARACTER

I am acquiring a pleasant and joyous character.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I believe that my bad temper can be controlled, and I am not going to rationalize by thinking that I cannot help myself.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

BAD HABITS (See Habits - Negative)

BACKACHE

All the muscles in my back are relaxing. The tension in my dorsal region is dissolving completely. My whole back feels better and as this happens my confidence grows. My spine is relaxing. My back is getting stronger every day, and all tension is disappearing.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

BALANCE (Also see Peace, Strength, Wisdom, Health, Harmony)

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In the past I used to suffer from fears that almost made me physically sick, but I am gaining strength as I become more and more balanced, and the strong and healthy person I know myself to be.

Arthur Wassmer, The Art Of Making Friends And Being Happy, Belfond Publications, 1978.

I eat and sleep well.

I take care of my physical balance, since it plays such an important role in my ability to work well, and remain emotionally stable.

I know that the best thing is to maintain a constant and balanced relationship with my body, instead of getting preoccupied with it from time to time.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am well structured and balanced.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I am a balanced person.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am perfectly balanced.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

A sign of the presence of God in me is my feeling of peace and balance.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

My body is balanced, in perfect harmony with the universe. I am always deeply relaxed and balanced.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

BALDNESS

Now that I am no longer using my energy to work, I will channel

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it to my scalp; the energy flows more normally, replenishing my hair as it did in the past so that it grows quickly.

Like crabs who grow new legs I can regrow my hair.
I want my hair to look like... (add description).
My hair is growing... growing.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

BEAUTY (Also see Health)

Every day my beauty shows a little more clearly. Every day I move closer to this promise of beauty. I feel better and better.

Charles Baudouin, Psychology And Practice of Self Suggestion, Idegraph Publications, 1990.

I give thanks for ever increasing health, beauty and vitality.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

My body is pure and beautiful. I love nature and count my blessings. I see beauty in others, and experience it in myself.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

BEHAVIOR

The totality of my actions and behavior determines how others decide they should treat me.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

BEING

I am a strong, affectionate and creative being.

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I am a radiant expression of God. From now on my body and mind will express divine perfection.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

BELIEF

I allow myself to hold something sacred in life.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

BELONGING

I move forward with confidence and chances are I will experience a sense of belonging.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

BENEVOLENCE (Also see Sincerity)

I look at myself with benevolence and I can thus fend off my solitude indefinitely.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am more and more benevolent towards myself and towards others.

Sublipower, Subliconfidence, Edi Inter, 1989.

I am always serene and benevolent.

Alan Houel, How To Deal With Difficult People, Godefroy Publications, 1990.

Everyone wants the best for me.

Francoise and Michel Moine, Develop Your Psi Powers, Stock Editions, 1982.

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[I treat everyone with kindness. I treat everyone as a precious and passing gift.]

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

BEST

I accept and deserve the best, which is flowing to me now that I have become an open channel.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

BIRTHING

I prepare for giving birth every day, and make sure to practice the techniques I'm learning in my prenatal classes to make the birthing easier. I am a woman who is in full control of myself and my reactions.

Marcel Rouet, Mastering Your Subconscious, published by Dangles, 1982.

I feel very good, and I look forward to the birth impatiently... all this is engraved in my subconscious... As soon as I look at my right hand, I experience a state of deep relaxing sleepiness... pain does not exist... All I have to do is look at the palm of my hand and all the pain disappears... I feel completely fine.

Dr. Kurt Tepperwein, Secret Techniques of Hypnosis, Godefroy Publications, 1981.

BLAME

I don't expect anything from anybody, and I have no one and nothing to blame.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

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BLESSING

May God bless all my undertakings.
Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I accept the good that comes to me, here and now.
Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I love so that I see only what is good, give only what is good, and receive only what is good.
Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I count my blessings.
Og Mandino, The Greatest Secret In The World, A Different World Press, 1979.

I thank God for the gift of life.
Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

From this moment on I am a complete expression of love and gratitude for God. I realize that there is so much good in my life.
R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I am ready to receive all the blessings of this abundant universe.
Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I am grateful for the blessings I receive daily.
Louis Proto, Self Healing, Piatkus Publications, 1990.

I am thankful for everything that happens to me.
Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

BLISS

I feel the happiness and bliss of being alive.
Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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BLUSHING

My blood is descending into my feet. My feet are getting hot. My feet are burning!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

BODY

I have a body, but I am not my body. My body may be tired or rested, healthy or sick, but that has nothing to do with the real me. My body is a precious instrument which I use to experience and act on the outer world. But it is only an instrument. I treat it well, I try to keep it in good health, but it is not me. I have a body, but I am not my body.

Dr. Robert Assagioli, Psychosynthesis, Epi, 1965.

BOREDOM

Every day I try to overcome my boredom by working on achieving worthwhile goals.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I overcome boredom because I concentrate on the details and nuances of each new situation. Because I'm always interested in learning, I stay interested in my work.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

Boredom disappears for good when I observe the vastness of life.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

No matter what happens I will not allow boredom or obstacles on my path to deprive me of my peace of mind.

Orison Swett Marden, The Joy Of Living, J.H. Jeheber Publications.

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BOWLING

My bowling style is getting better every day. My approach is supple and relaxed. I release the ball with more and more precision. I am able to control the ball and put the effect I want on it. I can hit strikes with ease. My score is getting better every time I play. Bowling is easy for me.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

BRAGGING

I learn to control myself when I am about to brag or try to take advantage of someone.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

BRAVERY (Also see Strength, Courage)

I am in the process of becoming a brave person.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

BREAKING UP

I chose to love you. That was then, but now I've changed my mind.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

BREASTS

My breasts are developing... growing... at the same time they are

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becoming firmer and firmer... my breasts are becoming beautiful.

My breasts are becoming more beautiful every day... more and more beautiful... firmer and firmer... my breasts are becoming fantastic... I feel them swelling... pushing outward... growing... they grow larger every week.

I see myself with beautiful breasts... pushing against my sweater... attracting men's looks.

My chest will develop more and more... and I'll be proud of my breasts... which are becoming more and more beautiful... more and more attractive.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

BREATHING

My breathing is full, regular and deep; I am developing the habit of correct breathing even when I don't think about it, and I know that it is helping to keep my blood healthy.

Charles Baudouin, Psychology And Practise of Autosuggestion, Idegraph Publications, 1990.

My breathing is regular and calm.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

My breathing is completely calm and regular.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I am breathing a little more slowly.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

Every day I do deep breathing exercises... to maintain the elasticity of my lungs... increase their capacity... to purify my blood... and give my organism even more vitality.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

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BRIDGE

I defend myself very well at bridge.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

BUDGET

I allow myself a budget for personal expenses.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

BUSINESS (Also see Money)

All my money comes from God. He has sincerely given me enough to meet all the needs of my business, or if He hasn't given it to me yet, it won't be long in coming. If I need more, He will provide more. Therefore, I don't even want to think about easy ways of making money by taking advantage of others. God gives abundantly, and I'm going to manage this business as if He were always here, close to me.

Robert Collier, Riches At Your Doorstep, S.I.P., 1962

I am becoming a better businessman / woman.

Vernon Howard, Psycho-Pictography, S.I.P., 1965

My business affairs are the affairs of God - they are owned, operated and expanded by divine guidance.

R. Charles Barker, The Science Of Success, Dangles Publications, 1983.

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BUYING

I get the coat (house, car, etc.) that I want for a great price. Wearing it (or living in the house, or driving the car, etc.) gives me an enormous amount of pleasure.

Raymond Hull , Wanting Is Power, Les Editions de l'Homme, 1969.

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CALM (Also see Self Control)

I feel calm and in control of myself under all circumstances.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I use my resolute calm to combat the threatening attitudes of vain, excitable and impulsive people.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I cultivate calm.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I am becoming a calmer, more relaxed person.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I feel calm, rested and radiant.
I am becoming calm and balanced.
And as I become calm, I feel peaceful.
I am completely calm and reposed.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I stay calm, no matter what happens!

Alan Houel, How To Deal With Difficult People, Godefroy Publications, 1990.

I am calm and am comfortable being who I am.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am calm... calm... calm... calm... calm... calm...

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

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I am calm, tranquil, imperturbable.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

I am calm, very calm.

Francoise and Michel Moine, Develop Your Psi Powers, Stock Editions, 1982.

I am calmer and calmer in all situations.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I am imperturbable, calm. I am relaxed and peaceful.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

I am completely calm.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

My breathing is calm. My heart is beating peacefully. I am as tranquil as the depths of the sea.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I am cool, calm and collected.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

I control myself with the confidence of a master psychologist, and I stay cool under the most difficult circumstances.

Franck Rudolph Young, Cyclomancia, SIP, 1966.

I am cool, calm and lucid no matter how important the person I'm speaking to is.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

CANCER

I now imagine my tissues getting rid of this waste, becoming healthy again, clean and normal. My treatment is a success. I'm in

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good health. I'm getting stronger and stronger. I feel better and better. I smile a lot. I see myself as a smiling, happy, active, healthy person. Everything's fine. I am healed.

Now I imagine my cancer being defeated. My cancerous cells retreat, they are beaten, they disappear over the horizon, far, very far away, out of sight. My cancer disappears, melts into the distance, very far away, so far no one can ever find it.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

For me, the word 'incurable' simply means that the illness cannot be cured from the outside, but only from the inside ... Dissolving mental patterns dissolves disease.

Anything can be healed. So, I am realistic, and plan for a miracle!

The doctors are amazed at my total remission.

My body is healing itself totally.

Louis Proto, Self Healing, Piatkus Publications, 1990.

CARDIAC TROUBLE

My heart is beating calmly and regularly.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

CARE

The more I take care of myself, the more others take care of me.

Louis Proto, Self Healing, Piatkus Publications, 1990.

CAREER

God leads me forward in a career filled with success.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

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I know that I can earn a living in different ways, that I don't have to stick to the same job or even the same career just because I already have a lot of time invested in what I'm doing. I give myself permission to be whoever I want, and get into new areas which may have a bearing on my professional decisions.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

I find the ideal job that perfectly fulfils all my needs and desires.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I see every job change or career change as an opportunity to attain my objectives. I have a positive opinion of myself, and I feel good about myself. I am clear, calm, confident, and in control.

I never feel committed to work or a career that isn't totally beneficial.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

CHALLENGE

I look at every day as a challenge; and I try to give it the best shot I have. I start the day by making myself receptive to the outside world, and setting objectives which I try to define very clearly. I then decide what I can do to attain those objectives, and get right to work. I develop the habit of exploiting the opportunities that arise every day in order to attain my goals.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

Each victory strengthens me for the next challenge.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

At this moment, even as I express these truths about myself, I know that I can succeed and that I will succeed. If I think about the

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challenges awaiting me, whatever they are, I know I can win.

Just look what I can accomplish today! I am incredible... and today is the ideal day to prove it!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am eager to face new challenges!

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

Challenges are stimulating. I meet each challenge with determination and dynamism, and with the absolute certitude that I will get the best possible results.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

CHANGE (Also see Habit)

It is easy for me to reprogram the computer of my mind. All of life is change, and my mind is ever new.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I have the courage and strength to make the changes that need to be made.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I have the power to change myself the way I want.

Sublipower, Sublicontrol, Edi Inter, 1989.

I stop thinking that I have to change my situation before I can change myself. I change myself, and my situation changes naturally.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I start this day in a new and better way.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I will really begin a new life.

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The world will start to become better as soon as I choose to make it better. I won't wait for others to improve the world. I won't wait for my neighbor to improve him or herself. I'll be the one to start.

I can change my own small world, and that's what counts. I choose to believe that I can change it.

If I use my power to choose it is amazing how well things work out for me, even beyond my wildest expectations.

J. Martin Kohe, Your Greatest Power, A Different World Ltd., 1979.

I can change if I make the necessary effort.

I am going to be different.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I want to change this.

I want to change.

I want something different.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

CHARM (Also see Slimness, Health, Sincerity)

I am a radiant being, full of love and light.

From now on my perfect partner will find me divinely irresistible.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I am a warm, sincere, caring and affectionate person. And I see these qualities in others as well.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Other people appreciate me because I try to make them feel good. I'm attractive in many ways. I attract other people, their interest, their enthusiasm, their friendship and their confidence. I bring the best

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out in everyone, and that makes me attractive.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

My relations with men and women are more and more harmonious. I'm becoming more charming every day. I am capable of loving and of being loved.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

CHILL

I feel fine, I'm not cold, I'm not going to catch cold.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

CHOICE OF PROFESSION

Before making a choice that will determine the course of my entire existence I will spend weeks - months if necessary - gathering as much information and data as I can find concerning my future profession.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I completely abandon myself to You, my inner Guide. Lead me along the right path, and tell me what the right decision is. Enlighten me as to my vocation so that I can choose the profession that is best suited for me.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986

CIRCULATION (Also see Anemia)

My heart is beating normally and regularly; my circulation is regu-

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lar; I know how my heart and circulation are affected by emotions, thoughts and suggestions. Thus I can achieve perfect circulation; if an organ has a tendency to become congested and swollen, it will receive less blood and less nourishment from now on, so that it gradually shrinks back to its normal size. If an organ tends to become anemic it will receive more blood. This, plus the fact that the blood it receives will be of a better quality due to my improved digestion, will make it grow stronger.

Charles Baudouin, Psychology And Practice of Self Suggestion, Idegraph Publications, 1990.

My blood circulates freely, my heart beats calmly and strongly.

Sublipower, Sublihealth, Edi Inter, 1989.

CIRCUMSTANCE

I create my own future circumstances. I change myself today, and tomorrow's circumstances will be as I wish them to be.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

CLARITY

By cleaning and tidying up my physical environment, I clean and enlighten my whole life.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

CLIENTS

The people I call need my products and services.

I can't lose what I don't have. Any prospect I gain is one more than I have now.

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I'm widening the base of my contacts.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

COLD (Common)

It's getting better now. It's getting better.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I am getting rid of my tendency to catch colds.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I am breathing more and more easily now. My nose and sinuses are clearing up completely, and I feel myself breathing well. I feel wonderful. All my respiratory passages are opening.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

My sinuses are perfectly healthy. My head is completely clear, and my eyes are dry.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

COLIC (Biliary or Hepatic)

I am relaxing my biliary passages; the channels are dilating; the stone is moving down into my intestine.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

COMFORT (Feeling At Ease)

I feel completely comfortable when I'm with other people.

Shakti Gawain, Techniques of Creative Visualization, Editions Soleil, 1978.

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I feel at ease, sure of myself, and others appreciate me.

Claude Arpel, "I Have Confidence In Myself" - A Subliminal Method, Procauvi Publications, 1986

Every day I appreciate other people more, and find them fascinating. I feel more and more comfortable in the presence of strangers.

Paul-Clement Jagot, Education of the Word, Dangles Press, 1975.

COMMITMENT

I learn to say NO as if it means YES, I am already committed. One of the best ways to relieve stress is to schedule my time so that I can, comfortably, keep my commitments.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I don't commit myself halfway, but all the way in order to attain my objectives.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I honor my commitments.

Sublipower, Sublisuccess, Edi Inter, 1989.

Everything I do involves a price to pay.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

COMMUNICATION
(Also see Confidence, Tension)

It's easier and easier for me to see other people's points of view.

Christian H. Godefroy, Human Relations and Communication: The Subliminal Method, Godefroy Publications, 1987.

I have the right to be open with other people.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

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I communicate with ease and with joy.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I always communicate clearly and effectively.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

The first thing I do is show the respect I have for the other person.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I speak with ease, anywhere and to anyone.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I share my emotions.
I enjoy speaking in public.

Christian H. Godefroy, Human Relations and Communication: The Subliminal Method, Godefroy Publications, 1987.

I always think about saying what I feel.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

I am the best judge of my actions, thoughts and feelings, and I am the one who is responsible for their consequences.

In order to develop, learn and evolve I communicate with others about my limitations.

In my search for happiness, it is in my best interests to communicate with others about conditions that promote our mutual well being.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

I am in charge of what I say and how I say it. Realizing that nothing is learned while I talk, much of my communication is listening, observing and qualifying. When I communicate I am prepared to deliver a message that offers value and leads to mutual understanding on the part of the receiver.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

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There's no mystery about communicating. I know how to listen, and I always listen with a clear and receptive mind.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

People feel at ease with me. People feel good in the presence of someone who radiates relaxation.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

COMPANY

My company is there to serve me, and not vice versa.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

COMPASSION

I will not forget that my compassion can make me free.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I can't offer compassion to others unless I am compassionate with myself. I am not unfair with myself.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I know that others are equally worthy, equally imperfect. I have compassion for them because they are engaged in the same struggle for survival that I am. Since I know that everyone is doing his or her best, it's easy for me to feel sympathy and compassion for other people.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

COMPETENCE (Also see Money, Skill)

I have confidence in my competence.

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I am competent.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I'm always learning something new. I'm happy with the skills I already possess, and try to become even more competent in all my activities.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am becoming the best in my field, and money flows to me as if by magic.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I'm competent, hard-working, and really good at what I do.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I am open to learn new things every day, and that gives me the optimism, energy and inspiration to create a future full of success.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I am strong and competent.

Emrika Padus, Encyclopedia of Emotions And Health, Edi Inter, 1991.

I want to develop my skills to their highest level, and acquire superior competence and ability in my fields of expertise.

Paul Clement Jagot, Power Of The Will, Dangles Press, 1950.

My confidence is growing, and as my confidence grows so does my competence.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

COMPETITION

I have confidence in myself and in my subconscious mind. I can

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develop all the skills necessary for me to get ahead of the competition.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

I never compare myself to others in order to compete with them, because I can never become someone else, and therefore I cannot attain exactly what someone else attains. But what I can do that no one else can do is to be myself, fulfill my life's tasks, and reach the very summit of my own field of endeavour.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

COMPLEX

I embrace life openly... with no complexes... so that I can partake of the quintessential joy and pleasure of really being alive.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

COMPLEX - INFERIORITY

I have no complexes at all towards people I judge superior to myself.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I am no longer preoccupied with what other people think about me, since I know that all they're doing is wondering what I think about them.

I am totally indifferent to the opinions of others.

I thank my enemies for using their sharp eyes and tongues to point out the weaknesses in my life, and myself.

I thank everyone who has deceived me for making me more vigilant, and for having prevented me from becoming dishonest myself.

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I know they probably all enjoyed doing this for me, but that is small payment for the service they provided.

Clement Auger, Transform Your Life Through Autosuggestion, Heritage Publications, 1979.

I know that in certain respects I am superior to many people I am acquainted with.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

The best way not to feel inferior of others is to do something about my inferiority complex. Confidence follows accomplishment. Feeling sorry for myself will never cure me of my shyness. Working hard, making myself useful, doing something for someone else will give me the kind of inner satisfaction that brings with it a feeling of self confidence.

I must not use my sense of inferiority as an alibi for being too lazy to improve myself.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

When I am with another person I never consider myself inferior to that person, not even in my thoughts. I always see myself as an equal. Because my personality is unique, just like his or hers, and I am the only one who can do what I must do.

I don’t think about another person’s professional or financial standing, but only about the person in whom, like myself, there lives an inner Guide whose role it is to harmonize personal good with the general good, so that I have no reason to fear, but rather sufficient reason to love and see in the other person an accomplice to my evolution.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

COMPLEX - SEXUAL

I let Nature do its work; I let myself get carried away in (sensual)

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improvisations which arise spontaneously in my partner or myself, because I know that everything is normal and good about the ways men and women use to express their love for one another.

Clement Auger, Transform Your Life Through Autosuggestion, Heritage Publications, 1979.

I am free to express my sexuality as I choose.

Louis Proto, Self Healing, Piatkus Publications, 1990.

COMPLIMENTS

I always say “Thank you” when I am paid any compliment, by any one, for any reason. Neither do I try to play down or play up value that is bestowed. The ability to accept is the universal mark of an individual with solid self esteem.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

COMPOSURE

I cultivate composure... and stay calm under all circumstances.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I want to acquire constant composure, imperturbable self assurance and confidence that is worthy of who I am.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

COMPREHENSION

I make sure I understand the person I’m talking to correctly by reformulating his or her point of view, and asking if I’ve summed it up well.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

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CONCENTRATION (Also see Delegating)

I am learning to concentrate.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I concentrate all my energies on the challenge at hand, and my actions help me forget about everything else.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I'm in control of my thoughts and my imagination.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I believe I can concentrate. I am going to make concentrating a habit. I am going to reduce distractions to a minimum whenever I am reading or studying. I am going to visualize myself as a person having a good mind, the capacity to listen well, to become interested in everything, to concentrate better and achieve success in life.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I develop and improve my powers of concentration.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I master my powers of concentration perfectly. I can direct my attention and control my thoughts. My mental faculties are getting sharper every day, and I'm always looking for opportunities to make them even better, and to develop and improve my concentration. I practice concentrating my attention and my thoughts, so that I am the master of my own mind.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I concentrate on what I desire and prevent myself from thinking about what I don't want.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

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I can control my thoughts.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I can concentrate.

I can concentrate better and better.

I have a powerful ability to concentrate.

Nothing can distract me when I concentrate.

I do concentration exercises every day, I do them with pleasure, and they don't tire me out at all.

Marcel Rouet, Techniques And Practice Of Hypnotism, Paris Productions N.O.E., 1974.

I know I'm moving in the right direction; I look ahead, never backwards. Since I am able to concentrate on one thing at a time, I concentrate on the work at hand and finish it!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am calm. I feel good. I feel very good. Nothing can disturb my mind.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

My powers of concentration are improving day by day. I can therefore accomplish all my tasks more rapidly and effectively.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

The power of concentration has no limits, and I use it every time I speak or act.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

My mind does not wander.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

My mind can focus effectively on one thing at a time. The best use of my time and energy is to concentrate on the details of the task at hand and take things one step at a time.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

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Not now, I'm concentrating on something.

Professor Kurt Tepperwein, How To Learn The Painless Way, Godefroy Publications, 1983.

CONFIDENCE

The answer is Yes!

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

I trust in the process of life. I am safe.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I have confidence in — (name the person).

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

([I have a right to be here. I am a person too. I am okay.)

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

There are no weaknesses in my outlook... I always see the future serenely... with tranquil certitude and confidence.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

I leave yesterday behind and search for goals that will liberate my creative abilities.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I will not let this insignificant impression (or event) affect me.

Paul Clement Jagot, Power Of The Will, Dangles Press, 1950.

I can do everything I want.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

I can handle it.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

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I am capable.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I relax and trust the environment to support me. I place my trust in the Universe which helps me whenever I follow the dictates of my heart.

Louis Proto, Self Healing, Piatkus Publications, 1990.

People like me.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

The Real Me is completely confident, in any situation.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

No person and no thing has power over me.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I do nothing I cannot talk about, and I'm ready to talk about everything I do.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

If I confide in others, others will confide in me.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

CONFIDENCE IN THE FUTURE

My future is bright, healthy, loving, prosperous and SAFE. Being healthy, happy, loved and with no problems feels totally SAFE. My life gets better and better with every day that passes. With every day that passes I feel stronger and more alive. I look forward to the future with confidence and trust.

Louis Proto, Self Healing, Piatkus Publications, 1990.

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CONFIDENCE - SELF (See Self Confidence)

I think about my conflict situations. I try to find solutions. But I also now live joyously, as if my problems were already resolved. I live with this confidence, which never leaves me.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

If I'm in conflict with someone, I imagine that I am both myself and that other person.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

If I have to deal with a delicate or a conflict situation I make sure to create a positive atmosphere of respect for the persons opposing me at the moment.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

From this moment on all the difficulties between —— (name) and myself are erased and our relationship is marvelous.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

CONFORMING

I am infinitely more important than all these rules and social norms which are imposed on us for appearance's sake... talking in a certain way, never leaving the beaten path... that kind of repressive nonsense.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

CONGRATULATIONS

Tonight when I go to bed I will review my accomplishments of the day and reinforce my self image. I will think about them calmly and with pleasure; chances are I will have a very good sleep.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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I did my job perfectly today. I'm becoming more efficient every day.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I'm pleased with myself. My work was impeccable.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

CONSENSUS

I always look out for an agreement or some kind of consensus, even if certain things cannot be formulated officially.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

CONSIDERATION (Also see Respect)

I show others my consideration by making myself really available when I'm with someone, and through concrete actions that can help, rather than just empty words and wasted time.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I give myself the consideration and respect I deserve.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I treat myself as well as I would like others to treat me.

Sublipower, Sublicontrol, Edi Inter, 1989.

People see me as a good worthwhile person. Those who fail to see my worth have something on their screen that keeps them from seeing what a good person I am. When people really see me, they see me as a good person.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

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CONSTIPATION

From this moment on I will feel the need to go to the bathroom every morning after breakfast... every morning without fail I will feel the need to empty my bowels...

I will feel the need to go to the toilet... at night before going to bed, I will go to the toilet... where all my tensions will be released... my stool is normal... evacuation is easy... all my tension disappears... my digestion is perfect... I'm so happy not to have digestion problems any more.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

Using my own nervous energy I can provoke a bowel movement... I am trying.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

Every morning when I get up, or more precisely twenty minutes after breakfast, I have a bowel movement without having to take any medication, or depend on any artificial substances whatsoever.

Emile Coue, Complete Works, Astra Publications, 1976.

CONSTRAINT

I am now ready to give up control. I no longer hurt myself. I am strong, wonderful and free.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

CONTACT

Every person is a link in the golden chain of my own, as well as the universal well being.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

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I can choose the people I want to associate with.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

I touch others more often.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

CONTRACT

I make sure the contract is mutually profitable, i.e. that the sum of the gains for both parties present is as large as possible.

I also make sure the contract is equitable, i.e. that the sacrifices or losses (and not the gains) are equally spread among the parties present.

I then establish a contract with the other parties which precisely defines "who does what, how, and with what means."

And I always include a clause that allows for renegotiation.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

CONVERSATION

Whenever I'm involved in important or delicate discussions I take careful notes and eventually I offer a summary of the conversation to the other party and ask if he or she agrees with my interpretation.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

CONVICTION

I speak with conviction to everyone, and this influences them.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

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COOPERATION (Also see Help)

It is easier and easier for me to receive and give aid and cooperation.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

I commit myself to cooperate with others on constructive projects.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I meet my ideal business partner.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

COUGH

I don't cough anymore.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

COURAGE (Also see Dynamism, Resistance, Energy, Enthusiasm, Strength, Bravery)

Today is a magnificent day for courage.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

Everything important in life deserves fighting for.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I have the courage to aim higher.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I summon my courage.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

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I feel courageous, full of energy and enthusiasm.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I feel happy, joyous and courageous.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I try to enjoy everything I do. I feel courageous, energetic and enthusiastic; the things I have to do seem easy. Work distracts me, interests me and attracts me.

Professor Robert Tocquet, The powers Of The Will, Godefroy Publications, 1989.

I take hold of my courage with both hands; it's so easy to abandon everything, and so hard to keep your head held high.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I am brave, I am strong, I am courageous.

George Barbarin, How To Overcome Fears And Anxiety, Dangles Press, 1974.

When I work I am supple, relaxed and happy.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

Work distracts me, interests me and attracts me.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

The things I have to do seem easy.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

COURTESY

I am honest and sincere with everyone. I treat everyone I meet with courtesy and respect.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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COWARDICE (See Lying, Laziness)

CREATION (Also see Money)

From now on I have the firm intention of creating — (specify what) here and now!

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

CREATIVITY (Also see Sensitivity, Love)

In my own unique way, I am a genius.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

My aim is to understand an idea with maximum clarity.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I recognize and approach problems creatively. I view all problems as “situations needing improvement” or as “temporary inconveniences” and “opportunities to grow.”

I take time to ride my bike, build sand castles, fly a kite, smell a rose, walk in the woods or walk barefoot in the sand. I explore the wonderful creative world of children (and I’m going to do just that this weekend).

I know that ideas are expendable, and there’s always a new and better one. I challenge myself to make them work and get them into practical use.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I am becoming more and more creative every day. I realize that the only limits on my creativity are the ones I imposed on myself in the past. I now choose not to limit my creativity any longer.

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I'm not afraid of exploring new ground or looking for the best solutions to problems concerning every aspect of my life.

The more I make use of my creativity, the more creative I become. The more creative I am the more successful I am in my undertakings.

I use my creativity to explore the source (of universal energy) from which all ideas spring forth. I ask myself a question, and the answer appears in my mind. I define the problem, and my creative mind indicates a solution.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I never experience "writer's block" when I write a letter or memo.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I step beyond the limits of conventional ideas.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I will always be a part of the living spirit. The creative power of God is in me and acts through me.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I am more and more creative and inspired in all areas of my life. I find plenty of ideas and solutions to my problems because I am able to draw from the inexhaustible wealth of my subconscious mind.

I am more and more creative.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I feel more and more inspired every day. I feel more creative in dealing with life situations, full of new and original ideas.

Charles Baudouin, Psychology And Practice of Self Suggestion, Idegraph Publications, 1990.

From this moment on I am an open channel for creative energy.
I am the architect of my life.
From now on I will create my life exactly as I want.
I am an inexhaustible source of creative energy.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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I am the creative power in my world.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I am wise. I am intelligent and creative. I accept that a positive mental attitude is an important part of creating my reality.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

My subconscious provides me with answers for everything. I can always look to my subconscious for solutions to problems that arise. Now I feel creative, I feel inspired to get the best out of life, always.

Charles Baudouin, Psychology And Practice of Self Suggestion, Idegraph Publications, 1990.

If I try to get both hot and cold water out of the same tap at the same time, I only end up with water that is lukewarm. If I try to criticize and create at the same time, I can neither criticize objectively, nor create ideas with enthusiasm. I am therefore going to concentrate on creating new ideas, and leave the criticizing for later.

Virginia Godefroy and Thierry de Foichaings, How I Got Rid Of My Money Problems Once And For All, Godefroy Publications, 1985.

If the problem appears to be a new one requiring new solutions, I rely on the creative approach.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I do what is necessary to make each day a creative day.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

CREDIT

I am going to get my loan.
My bank manager will approve the loan.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

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CRISIS

It is entirely possible not to suffer the burdens of one crisis after another.

My Real Me can understand and resolve each crisis.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I never fail to take five minutes alone to get hold of myself (during a time of crisis).

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

CRITICISM

I want to judiciously examine all the ideas that come to me spontaneously, that I read about or hear about, before accepting them as valid.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

I do my best. Then I open my old umbrella and walk tranquilly through the storm of criticism, which no longer gets under my skin.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I laugh at critics... at bad reviews... which cannot disturb my serenity... nor destroy my confidence.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

I never forget that unjust criticism is often a compliment in disguise. I tell myself that criticism is often just a form of jealousy.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I never talk badly about anybody. I avoid criticizing, and even teasing people. I am only hard on myself. I try to notice other people's qualities in order to imitate them, and the bright side of situations in order to enjoy life.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

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I keep a scrupulous account of all my blunders and write my own criticism of each one. Since no one can hope to be perfect, I try to do what a little soap salesman once told me: “I seek out frank, useful and constructive criticism.”

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

Outside criticism doesn’t bother me as long as I stay calm and don’t react negatively. I have criticized others, it’s human nature, but I want to get rid of the habit. In future I won’t judge anyone on appearances. I’ll let my inner Guide be the judge, which means I can accept everything and everyone with benevolence instead of criticism. And this will immunize me against hostile remarks. I’ll take them with a smile, learn what I can and then continue on my way without being affected. My success is the best proof that the path I have chosen is the right one.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I thank my critics for spurring me on to ever greater achievements by offering criticism, which I may have misconstrued as a desire for vengeance, in the past.

Clement Auger, Transform Your Life Through Autosuggestion, Heritage Publications, 1979.

If I had to read all the criticism that is directed at me, never mind answer it all, I’d be better off closing down shop. I do my best with the capabilities I have, and try to see things through to the end. If it turns out that I’m right, then what was said against me is of no importance. And if I’m wrong, well ten angels could swear I’m right and it wouldn’t make any difference.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

CURIOSITY

I experience the world with excitement and curiosity so that every day is a great day for me.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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DANGER

In case of danger I don’t panic... I summon all my energy.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

There is a force in me that always makes me stronger than whatever is threatening me. I dominate the situation and come out a winner.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

DEAFNESS

I hear the truth. I know and love the truth. My ears are in tune with God’s perfect plan. That is why my hearing is good. Divine harmony is revealed to me through the perfection of its instruments.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

DEBT (Also see Money, Projects)

I obtain the sum of money I need to finance my project and repay my debts.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

My business is not encumbered with debts, and my cash flow is good.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

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DECISIONS

I forget about past mistakes; I stop torturing myself about them. Today is a day that will never return; I have to do everything I can to seize good opportunities when they occur.

I will not run around in circles any longer; I will set a direction for myself that will help me attain objectives which are really worthwhile.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I will always choose the correct course of action and accomplish it, because my Guide influences my thinking, inspires my words and directs my actions. With my Guide's help I can solve any problem and make positive decisions. I know what I want. I will succeed. I am succeeding!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I create a hierarchy of my priorities in order to develop clear criteria upon which to base my decisions.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I will not allow anyone to influence my decisions... to make me do what I don't want to do.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I will never make a hasty decision.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

I make judicious decisions.

When I learn to think with an open mind, the decisions I have to make on a daily basis become easy and profitable.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I make my decisions at the most opportune time.

I transform my decisions into actions that result in both profit

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and satisfaction.

I never go around in circles.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I will be able to define what would please me the most, and thus make decisions. I will feel that my decisions are the right ones. At the same time I will try to improve my life, by continuing with my studies, for example.

Charles de Liguori, Hypnotism, de Vecchi Publications, 1975.

I am certain that I've based my decisions on a solid foundation, one that would benefit both myself and those close to me.

I have no trouble making decisions.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

My subconscious mind guides me towards making the right decisions in all my undertakings.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

When I have an important decision to make I not only try to optimize the quality / price ratio, but also the quality / time-spent ratio.

I try to involve the people close to me in the decisions I make, and try to explain my way of thinking to them.

If I can't decide between two options, I look for new ways to approach the problem.

Before committing myself to a course of action I evaluate the impact my decision will have on the people concerned (and on my eventual public).

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I approve of myself and my decisions are always perfect for me.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

DEFEAT

I never talk about defeat.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

DEFEATISM

There is only goodness, and the manifestations of goodness.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

I never accept "no" as a satisfactory answer. I say "yes" to victory, I say "yes" to life!

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I never, never accept defeat.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

DEFENCE

I have the courage and strength to defend myself.

Louis Proto, Self Healing, Piatkus Publications, 1990.

DEFIANCE

I become more self confident, and this confidence gives me the certitude that I am capable not only of doing well, but of doing very well, of accomplishing anything I desire, within reason of course, and also of fulfilling my duty.

Emile Coue, Complete Works, Astra Publications, 1976.

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I am regaining confidence in myself.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

DELEGATING

I concentrate on what is essential, on where my efforts are profitable, and delegate the rest.

I only do one thing at a time, with variations in what I do.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am learning to organize, to delegate a portion of my powers, to direct and to survey.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I delegate as much as possible.

I know how to make other people work.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I delegate a portion of my reading to subordinates and then tell them to sum up the text orally, or in a memo.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

DEPENDENCE

I am convinced that my whole life depends on my relation with the Creator... I don’t rely on people, or on the conditions around me... I rely on the Infinite... on the Eternal.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

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DEPRESSION
(Also see Conditioning, Confidence, Happiness, Health, Abundance, Optimism)

Day by day I feel better and better... I feel more and more happy... more and more joyful... I feel completely comfortable with my life.

My self confidence is growing day by day... I feel more and more happy... more and more joyful... I feel absolutely wonderful.

My mind is clear, free of all dark thoughts. I feel joyful and happy.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

I try to consider depression as a passing feeling. I don't consider it a permanent part of myself.

I banish my depression.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I start and end each day with a smile. All day long I make a conscious effort to smile and to feel good about myself.

I only allow myself to get carried away by thoughts that can help me attain my most important goals. My thoughts are always clear, constructive and powerful.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I believe that life with all its complications and hardships is worth living. I am going to stop brooding because I'm depressed. I am going to remind myself that depressed spells quite often vanish - that they are transient and that everyone at times experiences the 'blues' or low moods.

If my depression is chronic or too deep-seated, I will contact my physician, have him check me physically, and will let him decide whether I should consult some specialist.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

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I am becoming a stronger person.
I am free of the negative conditioning of the past.
I like myself.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I allow my hidden feelings to surface. I study them and sort through them. I keep those I like and reject the others. It's normal to feel depressed from time to time. But then I free myself of these feelings of melancholy. I don't allow myself to become a prisoner. I am free because I am able to reject feelings that make me sad or depressed.

I feel strong, healthy and full of energy. Everything is working out in my life. I am liked by other people. I like what I do. My life is happy and serene. I know what peace is. I feel good about myself. I have confidence in the future.

I don't know what real depression is.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

Although I feel depressed for the moment, I know it won't last. And soon, when I've practiced more, these kinds of feelings won't affect me at all.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1982.

I will not allow myself to miss out on any more of the good things in life. I have no intention of falling back into a stupid feeling of depression which I know only too well.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I am abundance.

I am becoming a stronger and stronger person. I have confidence in life and I'm recovering my sense of joy. May this feeling of joy stay with me. I feel more and more happy. The current of life flows through me, bringing me an abundance of love and happiness.

I congratulate myself for handling the affair so well. And in future I will always handle myself just as well. I'm in great shape, and I'm completely positive. I'm in a very good mood. I congratulate myself.

Every day, and in all aspects, I am becoming stronger, more confident, happier and healthier.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I am relaxed, calm and happy. Everything is fine. I feel good. I await the future with confidence. Everything is fine, everything is calm.

Even if the weather is bad at the moment I know it won't last, and besides the weather isn't important.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I am happy, confident and strong.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I want my perceptions of things to be just as positive, and my feelings just as pleasant as they are negative and demoralizing when I'm depressed.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

Everything is going well, really well.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

DERMATOSIS

My blood is pure. My skin is beautiful.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

DESIRE

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I have desires, but I am not my desires. My desires are transitory and sometimes contradictory. Attraction alternates with repulsion. There are desires in me, but they are not me.

Dr. Robert Assagioli, Psychosynthesis, Epi, 1965.

I now have enough time, energy, wisdom and money to realize all my desires.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I know that by applying the principles of autosuggestion, any desire that I choose to go after will soon materialize, first through external signs, and then as the attainment of the goal itself.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

The power of Infinite Understanding is at work in my consciousness and will realize all the desires in my heart.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

Now I very much want what I desire. Now I have the strength, energy and courage to be myself.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

If I really desire something I can obtain it.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

DESIRE - SEXUAL (See Sexual Desire)

DESTINY

Thus, day by day I write my own destiny; for inexorably I become what I do.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

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I have the power to create the life I wish for.

Sublipower, Sublicontrol, Edi Inter, 1989.

I can create my life with my thoughts.
I am responsible for everything that happens to me.
Change my thoughts, and I change my life.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I can orient my thoughts accordingly and, this done, and by using the greatest power I have - the power of choice - I am indirectly in a position to control circumstances.

J. Martin Kohe, Your Greatest Power, A Different World Ltd., 1979.

I am the Master of my Destiny, I am the Captain of my Soul.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I am the master of circumstances.

Sublipower, Subliconfidence, Edi Inter, 1989.

Only I can decide what my destiny will be. I must do what I want to do, despite the obstacles.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

Above all I want, I want with all my strength, all the power lying dormant within me. I want to build a beautiful destiny.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

DETERMINATION (Also see Energy)

It is only by being relentless that I will succeed. I will therefore not be stingy with my efforts...

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

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I keep my head high. I look like the winner I am, and I act and think like a winner. Every time a problem starts wearing me down, I act immediately. I straighten up and attack my problems, and I solve them. Frustration and failure only make me stronger, more positive, better organized and more determined than ever!

I can imagine myself attaining my goals. I'm becoming more positive every day, and I'm more committed than ever!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I will never fail if my determination to succeed is strong enough.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I never let myself stray from the path I have chosen, nor allow anything or anyone to influence me in any way.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I can do what I please if I have enough determination and energy.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I have great determination. I know that nothing can stop me except myself. That's why I never stop moving forward.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I know that determination is the ultimate ingredient of all success, and I have a lot of it.

I am resolute, able to make decisions, constant, persevering and committed.

Each day I see how determined I am to attain all the goals I have established for myself, concerning both work and my personal life.

And because I accept and respect myself, I know that I really do deserve to be a winner in life. And that gives me the determination I need to be a winner, every day, in the most positive and beneficial sense of the word.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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I want to do the right thing at the right time, despite any obstacles or warnings which may try to prevent me.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

If I work assiduously enough and for long enough to attain what I believe in, I will make the dream a reality.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I don’t act with precipitation, but with determination.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I want to decide my own course of action and adhere inflexibly to the resolutions and decision I have made after proper deliberation.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

DIALOG

I always let other people express themselves freely and completely. I am attentive and reassuring when other people talk to me.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

DIET (Also see Hygiene, Negative Habits)

At each meal I eat half as much as usual.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

From now on I will no longer eat between meals.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

I like to eat the foods that are part of my diet. They are quite enough for me.

Raymond Hull, Wanting Is Power, Les Editions de l’Homme, 1969.

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Now I no longer want to eat what I crave at any given moment.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

My diet is doing me a world of good. I'm losing a pound and a half every week.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

DIFFERENCE

Please forgive me. I don't ask you to approve of what I did, or agree with me, but I do ask you to forgive me. I want to put our differences in the past, wipe the slate clean, and start fresh.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

DIFFICULT TASKS

This job looks so big that I'm avoiding doing anything. I'm going to break it down into smaller, manageable tasks and then get started on the first step.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

This task was destined for me. I can do it.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

DIFFICULTY (Also see Worry)

This is a tough situation. I'll have to dig deeper. Now is the time to really use my professional skills. I welcome the chance to test myself.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

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Each difficulty is a challenge which I accept.

Christian H. Godefroy, Positive Thinking: The Subliminal Method, Godefroy Publications, 1987.

I succeed in dominating all difficulties that arise.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1982.

The Spirit in me knows, the Spirit in me can.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

When a difficulty arises I don't ask, "Who's to blame?" Instead I ask, "What's to be done?"

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

Whatever happens I will react as calmly and intelligently as possible.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

DIGESTION (Also see Appetite, Stool)

I have a good appetite, I eat calmly, and I digest my food perfectly normally.

Professor Kurt Tepperwein, The Powers Of The Will, Godefroy Publications, 1989.

I feel no more pain, I have no weakness, my digestion is good, my circulation is very regular, all my bodily functions are normal.

Henry Durville, Course In Hypnosis and Suggestion, Durville Publications, 1938.

I transform the sunlight warming my skin into energy which I send to my lazy stomach to help it digest properly.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

My digestion and metabolism are functioning well. Every day at mealtime I tell myself that I am feeling very hungry; I eat with pleasure, but also with moderation; I get into the habit of chewing my

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food well so that digesting is easier. I also know how sensitive my stomach and intestines are to emotions and to cerebral activity, and therefore to suggestion. Thus I can make my stomach and intestines function normally through the power of suggestion. If I digest properly I will assimilate my food properly as well. This means my organism will be nourished as it should be. And finally, my bowel movements are completely normal.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

My digestion is fine.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I digest food freely and easily.

Sublipower, Sublirelax, Edi Inter, 1989.

My stomach is ready to do its work harmoniously. I'm happy to sit down at the table since the meals I eat will be perfectly assimilated by my body.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

My stomach is functioning normally again. It has all the energy it needs to do its work and assimilate all the foods I eat. I am now digesting more and more easily. I assimilate foods with ease. My digestion takes place normally and easily, and I am relaxed and in good spirits.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

Since my digestion is good I will also assimilate foods well; my body will benefit from all the foods I give it, using the nourishment to create blood, muscles, strength, energy - in short, life - so that each day I get stronger and more vigorous.

Emile Coue, Complete Works, Astra Publications, 1976.

Since I digest well, my intestinal functions are also normal. Every

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morning when I get up I feel the need to have a bowel movement, and without having to use any kind of medication or artificial stimulus whatsoever I perform the function normally and to my complete satisfaction.

Emile Coue, Complete Works, Astra Publications, 1976.

DIGNITY

I stop debasing myself.
I never neglect my human dignity.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I will by worthy of respect, confidence and esteem. I want to set a noble example. I will therefore overcome any faults I have, in order to live up to this esteem.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I am worthy.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

DIPLOMA

I will make sure to finish my program of studies since I want to obtain my —— (specify which) diploma.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I am a successful person. There is no way I won't get my doctoral degree (or any other diploma - specify which). I am certain to succeed, because I know my success is already a part of the order of things. A new and fascinating life is opening up for me.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

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DIRECTING OTHERS

I know how to be encouraging and understanding. I incite others to do their best and to fulfil themselves. I always seek out and find the best in the people who work for me, and instruct them in a positive way. Since I expect the best from others, I always get it. I assume complete responsibility for my person. And when I exercise my directorial functions, I let others assume their responsibilities as well.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

DISAGREEMENT (Also see Feud)

Tomorrow ——— (add name) will announce that s/he has changed his / her mind.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I don’t feel insulted by people who disagree with me.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

If, by chance, our opinions happen to coincide, all the better. If they don’t, we can’t do anything about it.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

My willpower is strong; I will calmly refrain from arguing.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1982.

DISAPPOINTMENT

I try to laugh at my little failures and disappointments.

I try to see the funny side of things. I tell myself that it’s not the end of the world, and that things will work out better next time. I

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overcome my disappointments by not making mountains out of molehills.

Emrika Padus, Encyclopedia of Emotions And Health, Edi Inter, 1991.

I'm disappointed with the results I'm getting so far. I'd better find out as much as I can about what is going wrong in this situation so I can improve it or at least get feedback to help me perform better in the future.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

DISAPPROVAL

When faced with someone's disapproval I react automatically by using sentences beginning with "you." I let anyone who is trying to make me feel guilty know that I am quite capable of surviving their disapproval.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

DISCIPLINE (Also see Laziness, Disorder)

I am teaching myself to be disciplined, and to listen with deference and goodwill to the people in charge of my education.

Professor Robert Tocquet, The powers Of The Will, Godefroy Publications, 1989.¥

DISCOMFORT

It won't be long before I feel better.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

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DISCOURAGEMENT

I will not let the hesitations and errors caused by my inexperience discourage me. I can always learn something very important.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

DISCUSSION

At the end of a discussion I make sure everyone involved has understood each other.

At the end of a discussion I specify the conclusions I have drawn, and ask the other parties to do the same.

I define, along with the other persons, the goals of the discussion and the points to be covered.

I make sure I am completely available for the entire duration of the discussions.

I try to terminate a discussion within the allotted time, even when I am talking to long-winded persons.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

When a difficult moment in a discussion arises I try to concentrate on what I like or appreciate about the other person(s).

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

DISOBEDIENCE

I am becoming more obedient and reasonable.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

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DISORDER (Also see Discipline, Laziness)

All areas of my life are becoming more and more orderly. I am becoming a disciplined and orderly person. I am more and more enthusiastic and I enjoy my work. I take pleasure in accomplishing all my day to day activities. I have all the energy I need to do what I have to do. Every morning I wake up overflowing with energy, and I attack the day with determination and discipline.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I am learning to organize my mind and my time more effectively, and to relax and free myself of worries about all kinds of things that are out of my control.

Arthur Wassmer, The Art Of Making Friends And Being Happy, Belfond Publications, 1978.

DISSATISFACTION

When I am dissatisfied I ask myself what I would like to be doing at that moment, and then I try to do it.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

DISTRACTION

I am going to keep myself busy and utilize my leisure time to advantage. I will always find something to do that will give me a lift, like seeing a good movie, reading an interesting book, listening to music or anything that will help me relax and make me forget my troubles.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

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DISTRESS

My inner Guide always advises me correctly, and shows me the right path to take. My Guide will rescue me from distress. S/He has the answers to all the questions that are tormenting me. S/He dissolves all my doubts. I have complete confidence in my Guide, and I know S/He is advising and assisting me at this very moment.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

DOUBT (Also see Self Confidence)

Here we are, with no doubts whatsoever.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

DREAMS (Also see Fear of the Unknown)

I let myself dream. I tell myself that I can have everything I want. With no taboos or prohibitions. That I have all the money I need to live out my fantasies for a period of fifteen days. I see that almost all my fantasies are realizable, that I don't desire the moon but simply things that I can obtain on condition that I get rid of my fear of the unknown and make the effort to stretch out my hand.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I want to remember one of my dreams, I can remember one of my dreams, and tomorrow morning I will have a clear recollection of that dream.

Christian Godefroy, Mental Dynamics, Robert Laffont Publications, 1976.

Tonight, as on all nights, I am going to live a new adventure, and tomorrow I will remember all of it!

Pierre Fluchaire, The Dream Revolution, Dangles Press, 1985.

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My dreams are becoming concrete reality more easily every day.

Sublipower, Sublisuccess, Edi Inter, 1989.

I have peaceful dreams, and my mind is at rest.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I can modify my dreams when I want to.

Christian Godefroy, Mental Dynamics, Robert Laffont Publications, 1976.

I can (I want to) remain conscious when I dream.

Christian Godefroy, Mental Dynamics, Robert Laffont Publications, 1976.

When I have a clear and lucid dream I feel perfectly rested.

Christian Godefroy, Mental Dynamics, Robert Laffont Publications, 1976.

DRIVING

I always stay calm when I'm driving. All my tension and nervousness disappears. I think before I react.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

I am a competent driver. I pass my test easily and effortlessly. Driving gives me pleasure. I find it easy and fun.

Vera Pfeiffer, Positive Thinking, Element Books, 1989.

DRUG ADDICTION

I feel more and more detached from my real life... I am free of my negative, annoying thoughts... Nothing is important... I abandon myself to this feeling of deliverance.

Everything around me becomes clear, clean and more and more beautiful... Colors and music blend into pleasant images... I abandon

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myself to the sounds and colors... nothing can disturb me.

I am indifferent to the noises from outside... I concentrate on myself... I am in a state which is much higher than any drug can take me... I can enter this state whenever I like... and be free of all worries, problems and negative influences.

No drug can do this for me... I don't need —— (specify the drug) which is ruining my health... and my health is improving every day.

I have confidence in my destiny, which I control through my desires... but nothing will make me go back to taking drugs... I don't see the point anymore.

Drugs disgust me... nothing on earth could make me start taking drugs again... if I feel the need to shut out reality, I will do some self hypnosis or meditation... things which regenerate my entire organism.

I do a few minutes of meditation every day... I concentrate on my future... I am overflowing with strength and energy... the solution to my problems becomes clearer every day... and I'm doing more and more to attain my goals.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

I'm proud of myself and my success.
People like me when I'm not on drugs.
I'm healthy when I'm not on drugs.
I work much more efficiently when I'm not on drugs.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

DRUGS

I will not forget that tobacco, coffee and alcohol are drugs. i.e. means of stimulating my body. They can be positive, but there is also a risk of becoming dependent.

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I avoid using one drug to compensate for the effects of another (for example drinking coffee when I've had too much alcohol).

I change my habits from time to time, especially those concerning drugs, to determine if I'm addicted or not.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

DUTY

I will do today's duty today.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

DYNAMISM (Mental - Also see Ambition, Enthusiasm, Vitality)

When I'm in the alpha state I condition my mind to become more open to the suggestions and directives I give it. I feel better every time I practice my alphagenic exercises.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

From this moment on I will always be ready and alert, strong and conscious of my goals. Nothing can distract me from attaining my objectives. I am untiring, opinionated and persevering. I take more and more pleasure in the joy of creation.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

From this moment on I am positive and I am going to keep moving forward!

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

I am a super dynamic person.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

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DYSFUNCTION (Organ)

Generally speaking, if I have one or a number of organs which are defective to a greater or lesser degree, I tell myself that these organs are starting to function better and better, so that they gradually return to normal and I am completely healed.

Emile Coue, Complete Works, Astra Publications, 1976.

My mind is in command. All my organs obey my mind.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

I make sure all my organs are functioning well; my heart beats normally and my blood circulates as it should; my lungs are working well; my stomach, intestines, liver, bladder and kidneys all perform their functions normally. If one of these organs happens to be malfunctioning at the moment, the problem will diminish day by day, so that in the very near future it will disappear completely, and the organ will resume its normal function.

Emile Coue, Complete Works, Astra Publications, 1976.

DYSPEPSIA

I send my stomach the order to contract.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

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E

EASE

It’s easier for me to do what is good for me.

Sublipower, Sublicontrol, Edi Inter, 1989.

I master X technique (specify) easily and pleasantly.

Raymond Hull, Wanting Is Power, Les Editions de l’Homme, 1969.

ECONOMIZING

I never spend my money stupidly. I know the value of wise spending. All my financial decisions are based on the principles of economy and moderation.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

ECZEMA (Also see Acne, Urticaria)

From now on I will stop thinking about my eczema, and think about my intestines instead; I have to get rid of the toxins that are being eliminated through my skin through the mucous membrane of my large intestine instead. As soon as I start doing this my eczema will disappear.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

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I am a healthy person, pure and perfect; my skin is healthy, and I am healed.

My skin is perfect.

Dr. Joseph Murphy, The Miracles Of Your Mind, Dangles Press, 1984.

My skin is becoming normal, my eczema is disappearing and my skin is becoming smooth, beautiful to the touch, and perfectly normal.

Clement Auger, Transform Your Life Through Autosuggestion, Heritage Publications, 1979.

EDUCATION

As a father of six children I know from experience that the greatest gifts a parent can give their children (and that managers can give their employees) are roots and wings. Roots of responsibility and wings of independence.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

It is my responsibility to teach my child, by example, what real love is and how to work out his problems intelligently, instead of emotionally, how he can live with the greatest amount of happiness in this society of ours.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I never resort to exaggerated threats or warnings which are forgotten in any case. I stick to my word.

I tend to give large or small rewards on all kinds of occasions.

For me each day is an opportunity to show, by setting an example, what the best way to live is.

I teach the values I believe in by setting a good example.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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I understand the difference between punishment, discipline and teaching, and I always try to consider these elements from their proper perspective.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

My children are my greatest joy. Their noisy games are a sign of their minds' vitality and vivacity. My spouse brings life into the home, and merits all my love. We smile at each other a lot and understand each other better each day.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

First, I am able to recognize my children's unique abilities and talents - to reinforce them, nurture them and help them recognize what is special about themselves.

Second, I am able to understand their behavior in the context of who they are - I don't misinterpret natural shyness as being unfriendly, or a need for privacy as rejection. Seen in context, even negative behavior is more understandable and predictable.

Third, seeing my children accurately helps me focus on changing only the behavior that is important to change - behavior that's harmful to them, behavior that isolates them socially, or behavior that is disruptive to the family.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

EFFICIENCY

Every day I am improving, I'm improving more and more in all ways.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I give the best of me in everything.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

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I am efficient in everything I do.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I use my time well. I do everything I have to do quickly and passionately.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I concentrate my time and energies on the 20% of my activities, contacts and concepts that have proven most productive to me in the past.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I do my best.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I do my work as well as possible, and I am no more incompetent than anyone else.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I always do my best according to my awareness at the moment.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I remind myself to only do one thing at a time.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am an organized and efficient person. I am mastering the art of doing more in less time.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I'm doing my job better. My performance is improving.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

EFFORT

Master of my body, master of my thoughts, I want my effort to also be others' salvation.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

Every effort also constitutes an investment.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

EGOISM

Attaining an objective implies sharing it with other people, and thus I move from isolation to happiness.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

By developing a love of humanity in myself I eliminate all hate, envy, jealousy, all egoism and all cynicism from my heart, because I know that harboring a negative attitude towards others can only result in disappointment.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

ELIMINATION (Bowel Movement)

I will assure better elimination of my body waste.

J.V. Cerney, Stay Younger, Live Longer Through The Magic Of Mental Self-Conditioning,
Parker Publishing Company Inc., 1968.

ELOCUTION

Every one of my words is spoken deliberately, fluently, and pro-

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nounced clearly.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I have all the tools I need for perfect elocution.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I dare speak out.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I pronounce my words strongly, clearly and fluidly.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I am determined to make my words become influential and dominating.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I'm going to think carefully before saying anything - being mindful of the effect my words may have on others. I am going to avoid being sarcastic, learn to become more diplomatic and develop the art of friendly and interesting conversation. I am going to be less argumentative. If I learn to control the impulse to say the wrong thing in haste, I will become a better person, one who will be loved and respected.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I make sure I have the language, with enough vocabulary and sufficiently varied examples, to best adapt what I'm saying to the person or people listening to me.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I'm becoming much more articulate and effective in my use of language.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

My elocution is becoming clear, harmonious and supple.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

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EMOTION

Today I will be the master of my emotions.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I have emotions, but I am not my emotions. These emotions are innumerable, changing, often conflicting, yet I always remain myself, through hope and despair, joy and pain, irritation and calm. I can observe, understand and judge my emotions; I can master them and channel them and use them in better and better ways. I have emotions, but I am not my emotions.

Dr. Robert Assagioli, Psychosynthesis, Epi, 1965.

I dominate my emotions.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I am able to control my emotions.

Claude Arpel, Self Confidence: The Subliminal Method, Procauvi Publications, 1986.

When a problem arises I avoid becoming emotional. I Stay Calm.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

EMOTION - NEGATIVE
(Also see Fear, Anxiety, Nervousness)

I cease being the victim of negative emotions. I realize that they have absolutely no power over me.

I know I am on the path towards dissolving all my negative emotions when I begin to consider what they really are.

I become my best friend by trying to understand my negative emotions.

The power of self awareness allows me to reject negative emo-

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tions whenever they try to influence me.

I destroy unhealthy thoughts and harmful emotions as soon as I start becoming aware of them.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I am able to control my emotions perfectly in all situations. I am gaining complete mastery of my reactions. I am more and more positive and fulfilled in all situations.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I am going to keep my negative emotions under control.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

EMOTIONAL SCARS

I erase the scars of my negative feelings.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

EMPHYSEMA (Also see Asthma Attacks)

I am calm, I am breathing, my lungs are relaxing, my kidneys are opening.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

ENCOURAGEMENT

I play a role in the lives of all the people I get close to. By treating someone like the person they should be, I offer a powerful encouragement for them to become that person.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

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ENDURANCE (Also see Dynamism, Courage)

Since I take good care of myself I have a lot of energy, endurance and vitality.

I now have more energy and endurance than I did before.

I love life, and I'm happy to be alive.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I have more and more endurance... more and more strength... I get stronger every day... I can make progress... and become stronger.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

I know that success isn't due to chance. Real and durable success requires a sum of intellectual and moral qualities. The principal physical quality is endurance. I must be healthy. Therefore I want to live in a healthy way.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I possess dynamism, courage and endurance. I have a very positive attitude towards myself and towards everything I do. I am practical and realistic, but I also believe in getting the best possible results from any situation.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I have more and more endurance, more and more strength.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

I have more endurance than X (specify).

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

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ENERGY (Also see Courage, Determination, Strength, Vitality, Health)

Each day I accumulate new energy in my solar plexus region.

Marcel Rouet, Techniques And Practice Of Hypnotism, Paris Productions N.O.E., 1974.

I have energy.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I inhale and I am inspired. I exhale and energy flows through me.

Christian H. Godefroy, The Seven Eternal Laws of Success, Godefroy Publications, 1980.

I am overflowing with more and more energy and strength.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I will destroy the negative images my enemies have tried to inject into my mind, and replace them with joyful images that encourage me and increase my energy.

Orison Swett Marden, The Joy Of Living, J.H. Jeheber Publications.

I feel very good today! I have more energy than ever.

I can do great things. And every task I accomplish gives me even more energy!

I have a lot of energy, which I nourish with my curiosity and enthusiasm.

I have more and more energy every day. I am full of life, in great shape, and in an exceptionally good mood.

When I do something that requires a surplus of energy I call on my reserves and find that I always have more than I need.

Every day I am becoming more and more aware of my energy and vitality. I create an unlimited reserve of energy in myself.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I do not waste my emotional energy.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

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I feel the life force flowing through my body.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

I am in excellent health, overflowing with energy.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I am bursting with energy.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

Energy flows freely through my body.

Sublipower, Sublirelax, Edi Inter, 1989.

My breathing is getting deeper and energy is circulating freely through my body.

Sublipower, Sublihealth, Edi Inter, 1989.

My most powerful energy for creating my life is present in me at this moment.

My energy is stimulated by my breathing, by love, and by life-giving thoughts and words.

I am bursting with energy and light.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

To be energetic I act energetically!

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

Every day and from all points of view I am more and more energetic.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I feel great! I'm full of energy! I'm so strong, I'm always going to feel healthy!

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I balance my energy.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

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I'm in good physical condition.

Francoise and Michel Moine, Develop Your Psi Powers, Stock Editions, 1982.

I'm in great shape.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

ENERGY - CREATIVE

I am overflowing with divine light and creative energy.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

ENERGY - VITAL

I absorb the energy scattered throughout the atmosphere, and store it in me. I exhale air, but I retain the energy which is carried into my body by the air I breathe, and which I make my own.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1982.

ENJOYMENT

I relish each golden day.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

All the obstacles to my total expression in life and my complete enjoyment of existence are now dissolved.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

ENLIGHTENED MIND

My mind is clear, alert and ready to meet any challenge.

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I enthusiastically wait for opportunities to put my mind to the test and improve it. Instead of considering problems as difficulties to avoid, I see them as opportunities to sharpen my mental faculties.

I am awake and fully conscious. My senses are sharp, my mind is clear. I am aware of everything around me, and I am in control of my life.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Divine light and divine love are flowing through me.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

ENTERITIS

If I am suffering from enteritis I imagine the enteritis is clearing up; the intestinal inflammation is gradually disappearing, and the phlegm and other secretions are becoming less and less abundant until they disappear and I am completely cured.

Emile Coue, Complete Works, Astra Publications, 1976.

ENTERPRISING SPIRIT

The search for the best in myself is my greatest enterprise. It is a creative adventure, because it leads me towards self acceptance.

With an enterprising spirit I can combat all negative feelings which belittle me and destroy my true identity.

With an enterprising spirit I increase the power of my personality as I find new horizons, and fully accept what I have already discovered.

With an enterprising spirit I progress towards a world of pure dynamic energy.

My enterprising spirit is the creative effort I make to resolve the

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enigma which is in me, to try and understand my complexities and problems in order to overcome them.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

ENTHUSIASM (Also see Ambition, Dynamism, Vitality, Energy, Courage)

Today is the first day of the rest of my life.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

Thunder and lightning! Life electrifies me!

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I am naturally enthusiastic.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I am enthusiastic about my goals; I develop this quality which is so essential to my success.

I apply myself with gusto to creative endeavors. I understand that life can be enjoyable and fun.

Every day I see myself in top form.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I have an iron will... nothing can discourage me... on the contrary, problems only give me more energy... the energy I need to overcome them... nothing can stifle my enthusiasm... absolutely nothing.

I cultivate my enthusiasm... my passion for everything I do.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I give myself a chance to become spontaneously enthusiastic about what I'm doing.

I am enthusiastic about everything I choose to undertake.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

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I stimulate my enthusiasm by maintaining a high level of interest. The more my activities interest me, the more enthusiastic I am. The more enthusiastic I am, the more energy I have.

I regularly program my mind with positive instructions designed to keep me in shape, full of youthful enthusiasm.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am enthusiastic about life and filled with energy and enthusiasm.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

Life interests me.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

My day starts when I wake up in the morning and shake off the numbness of sleep, overcome my negative impulses and promise to make this day exciting.

I will not spend my day doing nothing; I have exciting goals and I'm full of enthusiasm.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am enthusiastic about my life.

Christian H. Godefroy, Positive Thinking: The Subliminal Method, Godefroy Publications, 1987.

Oh, this is a great day for getting out there and conquering the world!

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

To be enthusiastic I act enthusiastically!

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

Every day, in all ways, I am becoming more and more enthusiastic.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

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ENURESIS (Bedwetting)

From now on I will stop wetting my bed, and I won't get angry when I have to go to bed. My bed won't be wet when I wake up in the morning.

I like going to bed at night.

If I have to go to the bathroom at night I get up and use the toilet. As soon as I get back into bed I fall asleep and my bed stays dry.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

From now on I will have a very strong desire to overcome this shameful habit, which is really a feeling of inferiority. A moment will come when my desire to control my bedwetting will be stronger than anything else.

I can now control myself much better than before.

Every night before falling asleep I order myself to wake up as soon as I feel the need to go to the bathroom. If It happens I will wake up.

I can control myself. I will not wet my bed. I am capable of controlling my bladder no matter what. Even if bedwetting has some hidden meaning for me, even if I want to be obstinate, I can still overcome my enuresis.

And even if I have a relapse, it doesn't mean anything. I will look for the cause of the relapse. I no longer suffer from enuresis. I can control it, and I will succeed in controlling it.

Charles de Liguori, Hypnotism, de Vecchi Publications, 1975.

I always call my mummy, and my bed is always clean.

Emile Coue, Complete Works, Astra Publications, 1976.

I always ask my mummy when I have to go to the toilet, and I always stay clean when I sleep. It's easy for me to stay dry and clean the whole night long.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

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I can restrain myself all night long and my bed is always clean and dry.

Emile Coue, Complete Works, Astra Publications, 1976.

I am a pretty little girl and people like me a lot. Everyone likes me because I'm so likable, so happy and gay. People like me because I only sleep in a clean, dry bed. I always sleep in a warm, dry bed. If I have to go to the bathroom, I always wake up in time.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

My bed is clean and dry, and I always wake up when I have to.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

If I concentrate on what I feel as I urinate during the day, I will feel the same sensation at night when I'm asleep, and after I've gone to the bathroom I'll get back in bed and fall asleep instantly.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

ENVY

This is so wonderful! I rejoice in that person's prosperity, and wish him/her more and more good fortune.

Dr. Joseph Murphy, The Miracles Of Your Mind, Dangles Press, 1984.

EQUILIBRIUM (See Balance)

EQUANIMITY

I maintain my tranquillity and equanimity.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

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ERRORS (See Mistakes)

ESTEEM (Also see Self Esteem)

I accord myself this elementary form of respect. I do not deny who I am. I'm worth more than that. I am in no way obliged to lead a monotonous existence.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I esteem myself. I know I am a good person.

Claude Arpel, Self Confidence: The Subliminal Method, Procauvi Publications, 1986.

I never belittle myself to myself.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

EVOLUTION

I am a directly linked representative of the ever-evolving, ever-expanding consciousness of the Creator. I am spirit expressing through a physical structure. I am patient with myself.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

EVOLVING

I have the right to develop, to learn and to evolve.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

EXAMS

(Say this to yourself on the night before an exam): I will not waste

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a single minute more on this stupid activity, and I really don't care if I pass or not.

Dr. Maxwell Maltz, Psychocybernetics, Godefroy Publications, 1978.

From now on I always concentrate only on what I'm doing, and any noises only serve to reinforce my concentration.

I prepare very carefully for all my exams.

I am calm and relaxed. I can always remember what I learned when I need to, and therefore all my answers are clear and precise.

I channel all my attention towards my goal.

My marks are improving daily.

I am in complete control in all situations, and I attain the goals I set for myself within their prescribed time limits.

Professor Kurt Tepperwein, How To Learn The Painless Way, Godefroy Publications, 1983.

I study hard. I am certain to be ready on exam day.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I will pass my exam.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I am going to pass the exam. I am calm and my mind is clear.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

I am secure in the knowledge that I have prepared well for my exam. My thorough revision is now paying off. Everything I have revised is ready in my mind to be recalled easily and effortlessly during the exam.

Vera Pfeiffer, Positive Thinking, Element Books, 1989.

EXCHANGE

I like to give and I like to receive.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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I give and I receive.

Sublipower, Sublisuccess, Edi Inter, 1989.

EXCUSES

Once and for all, and from this moment on, I will get rid of these excuses.

I will not excuse myself all the time, especially when I'm really not sorry for what I said or did.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I can decide not to start acting in such and such a way again, I can realize that I'm wrong to adopt such and such a behavior, but excusing myself all the time is a sickness which makes me feel responsible for the emotions of others.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

EXERCISE (Also see Obesity, Nutrition)

I have to exercise every day so that I won't get sick... and stay in top shape.

By exercising every day... never missing a single day... even if only for a few minutes if I'm pressed for time... I will live at least ten healthy years longer.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

Every time I exercise I have a better opinion of myself. I'm really proud of the extraordinary work I'm accomplishing.

I always get the exercise I need. I don't stop until I have attained my objective, every time I exercise.

I never force myself too much or hurt myself physically or other-

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wise. I do exactly the amount of exercise I need.

I couldn't live without exercise. It helps keep my healthy. It makes me alert, makes me feel better, and allows me to give the best of myself!

I set objectives for myself and then I achieve them. I'm on a regular exercise program, I eat healthy food and I get enough sleep. I spend a part of each day staying in shape.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I like doing exercise.
I feel like moving, walking...

Sublipower, Sublihealth, Edi Inter, 1989.

I can't wait to do some exercise today.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I will do a moderate amount of exercise every day, and I'll have fun doing it.

J.V. Cerney, Stay Younger, Live Longer Through The Magic Of Mental Self-Conditioning,
Parker Publishing Company Inc., 1968.

I am going to engage in some form of moderate daily exercise.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

Any amount of exercise (running, jumping rope, aerobic dancing, bicycle riding, etc.) gets my mind and body working much better. Exercise makes joy!

Exercising brings me joy.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

EXPERIENCE

I have learned from my experiences, even if sometimes they were

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painful.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I listen for the secret messages hidden in my experiences. I let these help me develop positive and useful habits.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

To get into a specialty I first have to learn the basics.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

EXPRESSING ONESELF (See Self Expression)

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FAILURE

From this moment on I will very calmly devote all my energy to finding ways likely to reduce the impact of the consequences which I have already mentally accepted.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

This is NOT a catastrophe! This is not horrible, humiliating, or the end of the world! It's inconvenient. I'm disappointed. Now I'm going to learn something and start again. So let's get going!

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I am learning that failure, no matter how serious, can be a trampoline to success and not a chopping block.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

At least once a week I review my goals and find out what I truly want now. I am willing to risk giving up all I have been for what I can become.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I'll do better next time.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

I transform failure into success.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

Next time I will succeed.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

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FAILURE (In School)

I can, therefore I must. I could have avoided this mistake, I should have been able to avoid it. I could have learned the lesson better and more quickly, so I should have done it. I could have done better, so I should have.

Professor Robert Tocquet, The powers Of The Will, Godefroy Publications, 1989.

FAITH (Also see Fear)

Belief helps me follow the way.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I have faith, faith in my ideas, in my destiny, and faith in God.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I am free of all fear, I am firm in my faith.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

Faith is invincible.
I believe, I really believe.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

Well directed faith adds amazing power to all of my thoughts.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

FALSE BELIEFS

I never let my convictions trap me into passivity. Becoming attached to a belief based on past experience is like trying to escape reality. Only the present exists, and what is true in the present may

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not necessarily be true of the past. I do not base my behavior on what I believe but on what is, what I experience in the present. By opening myself to the present experience instead of clouding reality with my beliefs, I realize that the unknown is a vast and fascinating domain.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I am ready to clear up any beliefs that hold me back from the good I want in life.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

FAMILY LIFE

My professional life and my family life are mutually enriching.

My family life is rich and creative.

I am there for my loved ones, giving them both time and my full attention.

My family understands and appreciates my professional activities.

I don’t feel guilty about being absent from home when I work.

I make sure that my family life plays an important role in my balance as a human being and my personal fulfillment.

I always make a note of any meetings with my spouse or children in my agenda, in the same way that I keep track of meetings with my boss, or clients.

I ask myself if there is anything positive in my family life that can also be applied to my professional life (and vice versa).

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

FASCINATION

Others find me fascinating and terrific.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

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FATIGUE

I like my work, but I also make sure to take time out to have fun: in this way I rarely feel tired.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I am not in the least tired.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

I am never lazy... physically or mentally.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

I'm in great shape.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

The sensations of fatigue and weakness that I sometimes feel will gradually disappear and be replaced by sensations of strength and vigor which will become stronger every day.

Emile Coue, Complete Works, Astra Publications, 1976.

FAULTS

Every day I am going to improve and eventually I will succeed in eliminating the faults I have discovered in myself.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

I accept the helpful criticism of my friends, and I use self hypnosis to purge myself of whatever personality shortcomings I possess.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I accept my weaknesses and my faults so that I feel all right even when I fail.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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I use my faults as inspiration to motivate me to improve and save more time.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

FEAR (Also see Emotional Paralysis, Anxiety, Nervousness, Guilt, Rejection)

I confront my fears with a positive state of mind and positive behavior.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I do what frightens me.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I have nothing to fear, the Spirit in me is watching, I have everything to hope for.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

I fear nothing since my faith in the Mystery is great.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I know that the love of goodness fills my soul and dissolves all fears. I now live in the joyous expectation of goodness.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

Simply because I am aware of it, and because I abhor it, because I absolutely don't want this to happen - it will not happen!

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

Nothing can harm me since I am united with my inner Guide!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

The Real Me knows no fear.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

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No matter what threatens me I will face up to it and meet the challenge!

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

If I find myself in a situation that frightens me, for example, I think about something that will calm me down.

Franck Rudolph Young, Cyclomancia, SIP, 1966.

What cannot defeat me only makes me stronger.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

Every day I overcome my fears, worries and any other destructive thoughts.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

[To overcome fear I use my mind.]

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I confront my fears and I accept them.

Sublipower, Sublicontrol, Edi Inter, 1989.

I free myself of my fear of what other people think.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

Only I can free myself from my fears. I start by becoming aware of what I fear, and stop myself whenever I find that I'm thinking or talking about it. I become aware of the 'fear-talk' around me, and stop listening to it.

I specify my fears. As long as they remain unclear they continue to have power over me.

I ask myself what the worst that could happen is. Not only is the worst hardly likely to occur, the answers often make me laugh!

I don't suppress fear. I feel it, talk about it objectively.

I am as safe as I allow myself to be. Only good comes to me. I

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have nothing to fear.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I allow myself to be, without the need to prove myself to anyone. I live my power without fear of defeat or rejection. I control my dreams, my life.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I am not afraid of being afraid.

Knowing myself helps free me from fear.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I reject useless fears.

I understand my fears and I can explain them rationally.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I smile and my fears evaporate. I am strong. I am powerful. I have confidence in myself.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I am calm and relaxed.

Fears may come and go, but it doesn't matter; I can control them as long as I stay relaxed.

When I can control my thoughts, I can control my fears.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

I am inviolable, I am invulnerable.

George Barbarin, How To Overcome Fears And Anxiety, Dangles Press, 1974.

The Eternal is my refuge, and I make the Highest of the high my home.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

The Real Me cannot be afraid of anyone.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

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FEAR OF ANIMALS

From now on I am no longer afraid of —— (name the animal). I find them tranquil, calm animals. When I see them I identify as much as possible with them.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I love all animals.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

FEAR OF DEATH

I meditate on death every day in order to give my life more meaning.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

FEAR OF ELEVATORS

I have no trouble taking the elevator. I now feel perfectly relaxed whenever I enter an elevator. I am able to control my reactions and emotions completely. I am able to master the situation completely, remaining calm and relaxed.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

FEAR OF EXAMS (Also see Stagefright)

I know I can pass my exam. I know the material perfectly. I'm ready. I have no reason to worry.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

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FEAR OF FAILURE (Also see Disapproval)

I'm making a common mistake. I'm thinking of failure as the enemy of success. But it isn't at all. Failure is a teacher - a harsh one perhaps, but the best. I can be discouraged by failure - or I can learn from it.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I remind myself that fear of failure is really often a fear of disapproval or ridicule, and I tell myself that everyone has a right to their own opinion, but that other people's opinions don't concern me.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I do not fear failure. I am responsible for my actions. I acquire the necessary knowledge and skills to succeed, and I move forward.

I am never afraid to try.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

FEAR OF FLYING

I like airplanes, I am fascinated by them, they are a wonderful way to travel, and I am fortunate to be living in an age where this mode of travel is available to me. I am sharing the benefits of modern progress with many thousands of other people.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

FEAR OF REALITY

I remind myself that nothing human is foreign to me. I can be what I choose to be. I engrave this sentence in my mind, and I recall this aphorism every time I fall into the familiar habit of trying to es-

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cape reality.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

FEAR OF REJECTION

It's better to ask for what I wish to obtain and get "no" for an answer than never to ask for anything, and never get anything.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

FEAR OF THE DARK

From now on I am no longer afraid of the dark. Nothing changes when it gets dark. There is no reason to be afraid. On the contrary, I know that darkness is my friend because it helps me rest.

The darkness is my friend, it helps me get a good night's rest.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

FEAR OF THE FUTURE

Starting today I am no longer afraid of the future. I feel strong. I am in control of my destiny. I have absolutely no reason to be afraid. The future belongs to me. I am happy, loved and respected.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

(From now on only beautiful things will happen in my life.

I rejoice at the thought of the beautiful moments I am going to experience.)

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I am very happy... I feel good about who I am... I look confidently

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into the future... and I know: my destiny is full of wonderful events.

Day by day, in all ways, things are getting better.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

Life is for me.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

Guide me, celestial light, guide me on the right path; I don’t ask to see what the distant future holds in store for me. Just the next step is enough.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

FEAR OF THE OPPOSITE SEX

I feel better and better in my relations with the opposite sex. I feel more and more comfortable with men / women. My relationships are harmonious. I am completely at ease, and men / women find me attractive. I am more and more confident and sure of myself with men / women.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

FEAR OF THE UNKNOWN

If I really believe in myself, everything is possible. The totality of human experience is at my disposal from the moment I decide to adventure into unknown territory, without asking for guarantees of any kind. Just because it’s different, and I’ll have fun doing it.

If I see myself shrinking back from the unknown, I ask myself: “What is the most terrible thing that can happen?”

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

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FEAR OF VEGETABLES

From now on I am no longer afraid of — (name the vegetable). I know I am stronger. I see them as friends. They are beautiful plants, basking in the same sunshine as we do. We share the planet with them.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

FEAR OF WATER

From now on I am no longer afraid of water. I know there is nothing to fear because water is an element of nature. I am confident, I am happy, I feel good in the water.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses , Godefroy Publications, 1989.

FEELINGS

To attain emotional maturity each of us must learn to develop two critical capacities: the ability to live with uncertainty and the ability to delay immediate gratification in favor of long range goals.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I accept all my feelings as forming a part of myself.

From now on I will try to live all my feelings.

It's good to express my feelings, and from now on I will allow myself to do so.

I like myself when I express my feelings.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I have the right to express my feelings.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

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I am in control of my feelings.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I can assume responsibility for my own feelings.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I can control my feelings.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I know how to communicate my feelings to other people. I understand them and they understand me. I am not afraid of approaching people and telling them what I feel.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

If there's no feeling in it I don't want it any more.

Louis Proto, Self Healing, Piatkus Publications, 1990.

FEELINGS - NEGATIVE

I refuse to allow images of disaster and of a terrible future to take root in my mind and dominate my personality with feelings of failure.

I refuse to allow distorted, rambling thoughts to occupy any space in my mind.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

Trying to rise above my negative feelings means that I am making progress.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

FEELINGS - POSITIVE

I am working to continue my past successes and create entirely

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new ones. As a constructive observer of the mind, I make sure my feelings of success are constantly growing in my imagination.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

FERMENTATION (Intestinal)

Under my hand my intestine is contracting and pushing the gas upwards.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

FEUDING

I want my problems with —— (name the person) to stop.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

To cut the thread of my negative thoughts towards someone I cut the knot attached to my own mind.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

Your inner Guide is allied with my own. Together they can bring us peace. I understand you, and you understand me. Our inner Guide is our only guide.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

FEVER

My temperature is going down.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

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FIBROMA

The contractions of my uterine muscles strangle the blood vessels which nourish my fibroma; lacking blood, it atrophies and disappears.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

FIGHTING SPIRIT

I know that I have the fighting spirit to attain my objectives; that means I try, and when I try I succeed. If I fail I try again.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I develop the habit of reacting positively and with a fighting spirit to threats and problems. I do this by adopting a positive, fighting attitude towards all day to day problems, as well as the problems in my mind.

Dr. Maxwell Maltz, Psychocybernetics, Godefroy Publications, 1978.

FILING

I equip myself with the necessary material (office furniture) to set up an efficient filing system.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

FINANCE

I find it easy to organize my finances.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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[I attain my financial objectives.]

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

My finances are prospering more every day.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

FIRMNESS

I can achieve goals in this situation with firmness. I don't need to be this angry. I can assert myself and be firm without being so angry or demanding.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I have the right to say no to someone without losing that person's love or respect.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I am learning to say no.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I never cave in to pressures or demands imposed by others... except if I have personal reasons for doing so.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I know how to say 'No' without being aggressive or timid.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I want to maintain a firm and dignified attitude, without becoming arrogant or cynical, without violence and without fear.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

Other people can say 'No' to me without my being affected.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

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FLAB

I am aware of the weight I've put on around the waist and stomach... my waist is going to get a little smaller every day... and my kidneys will purge my body of fat.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

FORCE OF NATURE

No force of nature is bad - it all depends on how it is used.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

FOREIGN LANGUAGES

Studying this language gives me more pleasure every day... I await each class with impatience. I concentrate exclusively on learning this new language... nothing can distract me. Every new word I learn is engraved forever in my subconscious... I don't forget anything that I've learned.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

I learn the —— (specify) language easily. My memory absorbs new words more and more easily. I understand the language better and better, and I'm also speaking much more fluently. My memory for this new language is improving day by day. Learning —— is easy for me.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

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FORGIVENESS (Also see Resentment)

It is over, I can forgive myself.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

Every night I forgive all my enemies for everything.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I forgive my father with a sincere heart. He acted as he thought best. I accept what he did. I wish him peace, joy and harmony. I am sincere. I say what I think.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I forgive all those who have offended me.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

I forgive others, they are only human. I forgive myself, I'm human also. If I harbor resentment I may be able to hurt other people, but I am sure to hurt myself with the poison my resentment builds up in me. A person who can't forgive is not really alive.

When I forgive others I take a giant step towards maximum relaxation; and when I forgive myself, I attain it.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I forgive —— (name the persons who offended you). I will radiate love, peace, benevolence and all good things under heaven towards them. They are free and I am free. I know I am free of them because I can think about them without any pain, but rather with a gentle feeling of peace and a blessing that springs from my heart.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

I am willing to forgive anyone who ever hurt me, and wish them well.

Louis Proto, Self Healing, Piatkus Publications, 1990.

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I fully and freely forgive you. I loose you and let you go. I do not wish to hurt you. I am free and you are free and all is well again between us. I feel love toward you and I glory in your success, prosperity and complete good.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I now forgive you and liberate you all.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I may not be able to overcome my human weakness and actually love my enemies, but for the sake of my own health and happiness I forgive them and forget about them.

Please open your heart to me. Understand, accept and forgive.

I wish this hadn't happened, but I was trying to meet my needs.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

FORESIGHT

I never undertake something without having a contingency solution, just in case.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I consider what I will do in case of success as well as in case of momentary failure.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

FORTUNE

My happiness? My fortune? They are within me.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

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FOUNTAIN OF YOUTH

I feel and think as if I had a magic charm, as if I were much younger than I am. I NEVER consider myself older than twenty-eight to thirty-five years old.

Franck Rudolph Young, Cyclomancia, SIP, 1966.

FRANKNESS (Candor)

I am always frank about everything I do. I never lie out of self interest, negligence or even for amusement. Everything my conscience finds reprehensible I refrain from doing.

Professor Robert Tocquet, The powers Of The Will, Godefroy Publications, 1989.

I force myself to play the game frankly and openly.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

If I realize I've made a mistake I admit it; I try to learn from the experience in order to change my line of action.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

FRATERNITY

My activities and my life, in fact my entire being finds meaning in the spirit of human generosity and fraternity with all people.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

FREEDOM

I am not resistant to new truths. They can free me. I am not bound

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to a sad past except by my own mental chains. I break them apart. I can be totally free of negative feelings linked to the past. And this freedom makes everything in the present seem fresh and new.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I plan ahead and free my energy in order to benefit others. I breath in goodness, which liberates me.

I breath the desire to give into my heart, instead of just taking all the time, and I feel free and full of power.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I know that there are infinite forces at work within me. I want to free them, and make them grow constantly.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

(I am limitless. I know no boundaries as I live unconditional love and creativity. I recognize my true identity.)

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I use my power to choose wisely.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I choose what happens in my life instead of leaving things to chance.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am now at peace with my past. It's finished, and I am free!

From now on I will forgive everyone whom I come in contact with. We are all happy and free. I don't have to try and please others. I am worthy of being loved and appreciated, whatever I do!

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I am free to act as I wish.

Francoise and Michel Moine, Develop Your Psi Powers, Stock Editions, 1982.

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I am free to live in any way I choose.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I want to be free; free of myself as well as of others.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

When my mind is really free I won't be imprisoned by my emotions. A man who is freed from prison doesn't have to think about freedom or imprisonment any longer.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

In harmony with the whole universe I find my individual freedom.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

FREE TIME

I never miss an opportunity to do nothing, and give myself the time to do so regularly.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

FRIENDSHIP

I need friends, I need to be surrounded with people who will help me as I help them.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

I like others and I like myself. I find it easy to make new friends.

Vera Pfeiffer, Positive Thinking, Element Books, 1989.

I create close links of friendship around me, in which the principle attractions are not problems or needs, but values and goals.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

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I cultivate friendships which are important to me. I allow myself to have confidential relationships with certain people.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

I keep making new friends.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

I make friends easily, and I have a lot of respect for them. My friends can count on me.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I only have friends.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

I never neglect my friendship with others.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am funny and adorable, and I have some very, very good friends.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I am surrounded by friends.

Francoise and Michel Moine, Develop Your Psi Powers, Stock Publications, 1982.

I appeal to You, my Inner Guide, to give me the power to radiate love and sympathy all around me, so that I can attract others to me. Help me find those with whom I can forge real and lasting friendships. Let these people cross my path, and help us recognize immediately that we are on the same wavelength, that we belong to each other. I thank You for your help and guidance.

K.O. Schmidt, Success At Your Doorstep, Astra Publications, 1986.

FRIGIDITY

I have gained a better understanding of my problem. I know that

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I am not really frigid, that I am a warm person and that the sex act is an expression of love.

I am not frigid and I can achieve an orgasm.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I love my body and I have the right to be sexually satisfied. I find it easier and easier to have an orgasm. I love orgasms, and abandon myself completely, with complete confidence. I am becoming a sexually fulfilled woman, vibrant with sensuality. I find it easy to attain orgasm, and to satisfy my partner. I love my body, and my partner's body, and I am becoming a more and more desirable woman.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I like my body and I like myself. I reach orgasm with ease. I awaken my partner's desire and I know how to satisfy him. I am a sensual woman and I can abandon myself to my desire.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I am a normal woman who functions normally.

I can be perfectly relaxed and enjoy a sexual encounter.

I know that having an orgasm is completely normal.

I am a healthy woman; I relax completely and open myself to my partner.

I accept my orgasm without forcing it or wanting it too much.

I am convinced that making love is a beautiful and pleasant experience.

I see myself as a woman who can always have an orgasm.

My body and mind are free of past sexual failures.

I am a woman, a feminine being, and I love to make love with my companion.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

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FRUGALITY

Whether I'm out or at home I enjoy eating small portions.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I found health by living in moderation and eating frugally, simply in order to assure my survival.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I like leaving the table still feeling a little hungry.

Sublipower, Sublihealth, Edi Inter, 1989.

I will only eat healthy foods, and never to excess.

J.V. Cerney, Stay Younger, Live Longer Through The Magic Of Mental Self-Conditioning, Parker Publishing Company Inc., 1968.

When I sit down to eat I always tell myself: "I live better when I eat less."

I like eating less. Although I am always well nourished, I really like eating small portions and staying a bit hungry.

I never eat more than I should. I know how much food I need, and I'm proud of myself because I eat well, I am reasonable, and I've never looked better!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

FRUSTRATION

I stop brooding about the best way to do things and simply start doing them.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I remind myself that frustration is a waste of time.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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I can always reap an advantage of some kind from a negative experience. I no longer react to frustration as I did at one time, for I know that I can profit from whatever happens, good or bad, in one way or another.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

FULFILLMENT

I am burning to discover the best part of myself, that confident, companionable and responsible person I sometimes am. I avidly search for occasions to fulfill myself and refuse to get frustrated and boxed into a dead end.

I never neglect the responsibility I have to myself to open the doors of my real personality and live my life to the fullest.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

[I am excited to be alive. I am glad to be here. I am a bright shiny star that glows every day and night.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

In future everything I say will tend to magnify my life. I want to live a noble and full life, spreading good to those around me, in an atmosphere of clarity and serene joy.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I want to live fully.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

I feel fulfilled.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

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FUTURE

I try to be as conscious and as positive as possible when making decisions that affect my life and my future.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

This is a great opportunity. I am constructive and positive, and I am starting to work on my future.

Vera Pfeiffer, Positive Thinking, Element Books, 1989.

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GAMBLING (Games Of Chance)

I am incredibly smart. I know which (card, horse, number, etc.) is going to win.

Win, win, win.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

I never play.

NEVER.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

GASTRITIS (Inflammatory)

Blood flows into my stomach and intestines, repairing my mucous membranes, which are red and inflamed; my white blood cells close up the sores, and my mucous membrane is healed.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

GENEROSITY

[I am gentle and generous with the people I like.]

Louis Proto, Self Healing, Piatkus Publications, 1990.

I am a generous and loving person.

Emrika Padus, Encyclopedia of Emotions And Health, Edi Inter, 1991.

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The more I share my possessions the more is given to me in return.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

GIFTS (Talents)

Every day I develop the gifts that have been bestowed upon me. I cultivate them assiduously, and with more and more noticeable success. Once again I let my inner Guide act through and for me. His will is my own.

I am united with my inner Guide. It activates my inner aptitudes, especially my gift for.... (specify). Every day this gift gets stronger.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

GOALS (Aims)

Every time I want to do something or change something about my life I write it down, I develop a plan for attaining my goal, and set myself a deadline. In this way all my goals are transformed into action.

Whenever I want to change something about myself, or get something in life, I set myself a goal, I write it down, I read it over every day, and I take the necessary steps to attain my objectives.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I find my goals and decide now to go after them (intense desire makes things happen!).

I write my goals down. (Writing goals has magic. I have a plan, rather than a wish or daydream. Writing is a commitment).

I read my goals every day (I reinforce my commitment, and in-

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spire action).

I visualize myself reaching my goal (just after awakening and just before falling asleep).

I make an affirmation for my goal and affirm myself. (Affirmations are the fuel for motion. I affirm my objective(s) many times each day. I keep building my confidence. I repeat each day's words aloud 10 times, 3 times daily).

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I will not waste my strength on idle pleasure or useless work. All my actions will lead towards my goal.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I don't get all worried about results. I take pleasure in the journey towards my goal. I know exactly what I want.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I always set new and higher goals once the old ones have been attained.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I know what I want.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I know I am capable of attaining the goal I set for myself; therefore I demand continued and indefatigable action from myself, directed towards my goal.

I have a clear written description of the precise goals I set for myself, and I will not stop trying to attain them.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

I am strong. I am courageous. I pursue my choices with focus and confidence.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

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Once I set goals for myself, I find it easy to attain them.

Sublipower, Subli Success, Edi Inter, 1989.

My desires lead to positive goals which direct my life.

Sublipower, Subli Success, Edi Inter, 1989.

My prayers are powerful, and I know they will help me attain my goal.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

One of the keys to my success is knowing precisely what I want to do.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

GOLF

My golf swing is improving day by day. I hit the ball with power and precision, no matter what the situation. My swing is becoming elegant and effective. I hit my irons as well as my woods. And I'm doing very well with my putter too. Golf is becoming easy for me. My score is improving all the time.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

GOOD HUMOR

At the center of every human being there lives an inner Guide. May my Guide awaken and transform the sullen side of my personality into a friendly, joyous and harmonious disposition.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I try to maintain my good humor and enthusiasm.
Every morning I try to wake up in a good mood, ready for action!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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GOODNESS

I try to see the good in others, but first I look for what is good in myself.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I put my best self out there.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I am good.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

If I want to find happiness I have to stop thinking about the gratitude or ingratitude of others, and give solely for the joy of giving.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

If man is good, the world is good.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

GRATITUDE

I now give thanks for all the good things I have and all that is still to come.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

If I want my children to be grateful I have to show them how myself, by being grateful to others.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I give thanks for having been allowed to discover the divine aspect of my mind and body, and for the help I received in settling my business affairs and personal relations.

Now I give thanks for this life full of health, wealth, happiness,

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and perfect self expression.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

GREED

I have more material wealth than I need, because I am not greedy and desire only what I can use constructively in my life. It took a lot of effort to get where I am, and I have always observed the laws of nature by developing positive habits to which I adhere.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

GRIEF (Also see Forgiveness)

I free myself of my grief, and the incessant flow of negative thoughts.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

GRIEVANCES

I agree to let bygones be bygones, and bury my grievances in the past.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

GROWTH

I'm open to new ideas. The best in me surges forward, never stopping, never ending, filling me with joy and freedom. That is the law of growth working within me, leading me towards what is good.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

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My world is opening and expanding.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

GROWTH - PHYSICAL

I have a good appetite, I am digesting my food better, my lungs are getting stronger, I'm becoming robust, and developing normally.

Emile Coue, Complete Works, Astra Publications, 1976.

GUILT (Also see Fear, Rejection)

Feeling guilty won't change the past and won't make me a better person.

I tell myself that the past can never be changed, no matter how unpleasant it may be. What's done is done. I can feel as guilty as I like, but that won't change anything.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I have the right not to feel responsible for other people's feelings.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I stop feeling needlessly guilty. I try to find the reason for a mistake, without blaming myself.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I give myself the right to make mistakes.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I pardon and absolve myself of all guilt, here, now and forever!

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I forgive all those who tried to make me feel guilty about sex and

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my body.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I thank God every day for what life brings me. I an thankful for my luck and for my joys, and also for the obstacles and deceptions. I ask forgiveness for my prejudices against others, and thus free myself of guilt.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

Everybody makes mistakes, it's only human.

I accept the consequences of my actions without embarrassing myself by blaming myself for past errors.

However bad a decision I made, it doesn't matter. I accept myself as a person who, like everyone else, is just trying to survive.

I can learn from my mistakes without guilt or worry.

I am not responsible for others.

Everyone's awareness is different, so comparisons are worthless.

Matthew McKay & Patrick Fanning, Self Esteem, New Harbinger Publications, 1990.

I shake off all my erroneous thoughts, as well as those of the people around me. My mind is perfectly clear and free.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

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HABIT

I reject my negative habits, those which don’t do me any good; I cultivate my positive habits, those which work to help me.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I know that habits can be changed. I have already altered old habits and acquired new ones, whether in sales, bowling, or thinking. I have done it (1) when I became aware of the habit; (2) when I became convinced it was blocking me from reaching my goals; (3) when I worked at substituting a new, more useful habit.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I am completely free of this habit. Harmony and peace of mind reign over me.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

HABITS - NEGATIVE
(Also see Diet, Habit, Hygiene)

No negative habit can dominate or influence me. I am in control of myself and my actions. I always do what is best for me and for my future.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I have decided not to have any unhealthy habits.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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I do not identify with undesirable habits. They are only acquired traits, and are not part of my real Self.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I am free of this habit, I have peace of mind.

Dr. Joseph Murphy, The Miracles Of Your Mind, Dangles Press, 1984.

My bad habits disappear easily and are replaced by positive ones, especially concerning my diet and hygiene. And this naturally contributes to improving my general state of physical health.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

It is easy for me to replace one habit with another.

Sublipower, Sublicontrol, Edi Inter, 1989.

HABITS - POSITIVE

I will develop good habits and become their slave.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I have good working and living habits.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am going to develop habits that are going to make me think better and feel better.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

HAIR

I can improve the condition of my hair... help it grow back... through mental action... I feel my hair revitalizing... getting stronger and more vigorous every day.

I'm not afraid my hair will fall out... losing my hair is no longer a

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problem... because I know I can keep my hair.

I think about caring for my hair every day... helping to give it strength and vitality.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

HAIR LOSS

I'm not at all worried about going bald one day... I know I will keep my hair... I don't think about losing it any more... on the contrary I'm certain I have the power to keep my hair... I am free of the fear of losing my hair... I actually feel it getting stronger and thicker.... growing more and more...

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

HALITOSIS

My breath smells fresh.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

HANDICAP

I can be greater than anything that happens to me.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

HAPPINESS
(Also see Love of Self, Confidence, Intimacy)

None of my past sufferings, nothing unpleasant or tragic that

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happened to me will enter my mind. I will only allow positive thoughts, thoughts of joy and of the friends with whom I shared happy times, thoughts of peace and success, to enter my mind today.

I will not allow anything to disturb my happiness: I have the right not only to exist today, but to really live.

I don't want to be unhappy today, whatever happens. I want to live and rejoice to the fullest on this day. I won't let anything make me angry.

Orison Swett Marden, The Joy Of Living, J.H. Jeheber Publications.

Today is the best day ever.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

God wants me to be happy.

The happier I am, the happier the people around me are.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I assert my permanent good health, my happiness, the perfect creative expression of myself.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I have the right to be happy. I work on getting better at being happy.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

I have the right to try to be as happy as possible as long as I respect others.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

I always have what I need to be happy here and now.

I am rich, I feel good about myself, I am happy.

I do, however, also accept responsibility for trying to make the world an oasis of happiness and abundance for everyone.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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I believe that happiness comes from the ability to enjoy life and an unselfish desire to comfort and help others.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I make an effort to be happy.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I deserve to be happy, healthy and wealthy. My mind's natural state is happiness.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I am immersed in happiness.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I think of happiness as a state of inner freedom.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I know how to savor each instant of happiness. I live intensely, in the present moment.

Christian Godefroy, 1987.

I will be happy.

Og Mandino, The Greatest Secret In The World, Different World Press, 1979.

I am happy to be alive and to be building my success.

Charles Baudouin, Psychology And Practice of Self Suggestion, Idegraph Publications, 1990.

The spirit in me is the artisan of my happiness.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

My mind and my soul are a haven of happiness, joy and confidence.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

To be happy I make others happy!
I have found happiness by helping others find it.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

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For me, true happiness never comes alone...

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

HARMONY

I accept the divine balance between male and female. I experience this male / female relationship with love and understanding. I allow this relationship to expand and strengthen me every day.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I am in perfect harmony with the universe.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

HARMONY - CONJUGAL

Each day I shall remind myself to be less sensitive. Love frustrations are often the result of over sensitivity. We all know couples who truly love each other, yet constantly bicker over trivialities, each oversensitive and on the defensive. Their love is like a duet, played on a discordant note.

I must give my wife companionship.

I must not expect my wife to conform to my way of thinking about everything.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I like being married and I take advantage of the numerous benefits it offers.

My marriage is a success because I do my part. I don't take my success for granted, and I make a conscious effort to make my marriage a success, and help it grow.

My marriage is proof of the effectiveness of teamwork. I am never

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alone in life, because I am part of a loving, attentive and successful team.

I respect my marriage and my partner, and I always try to resolve our differences in as positive a way as possible.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I begin and end each day with a declaration of love for my spouse, and during the day, if possible, I devote three minutes of telephone time just to chat with him / her and express my love.

I'm a good listener. I care about my spouse's life, about the thousand and one details and little incidents that occur every day. I remind myself that things done out of duty may be done well, but things done out of love are done with grace. I see how something begun as a duty can be transformed into a work of love. It's actually amazing how fascinating the 'little things' in life can be.

I do not force my spouse to compete with the children for my attention. I make sure to spend time alone with my spouse.

When we disagree about something I think that it is possible to have different opinions without arguing. However, we never go to sleep before resolving our differences.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I know and believe that there is a man out there who will love and take care of me. I also know that I can contribute to his happiness and peace. He will accept me the way I am. He won't want to re-educate me, and I don't want to be re-educated. It won't be necessary, because our relationship will be based on love, freedom and mutual respect.

I can picture very clearly the qualities I'd like to see in my husband. I think about these qualities, so that they also become my own.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I am you and you are me. We are one, nothing can separate us.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

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Every day our relationship is becoming more and more harmonious. We are happy to live together, we compliment each other and our love for each other is growing.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

We always solve our differences with understanding and consideration.

I respect the unique character of my spouse. I admire the numerous qualities in her / him which makes this relationship unique.

I am honest and sincere, and I express my thoughts and opinions openly, while taking what my partner has to say into account.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Our relationship is going very well.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

HARMONY - FAMILIAL

(I invest in the well being of my children. And I must make my wife feel like a woman and not a mother substitute.)

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

HARVEST

I ask God to bless each furrow of ploughed earth. Every seed that is put into the seeder is blessed, and I have a clear image in my mind of the abundant harvest that will come later, God willing.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

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HATE (Also see Love)

Whenever I feel an impulse of hate or anger arising in me I replace it with a loving thought and act as if I feel love instead of aversion.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I celebrate a general amnesty, freeing all those who have hurt me. I wish them all peace, health and happiness, and send them my blessings.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

HEALING

My healing powers are developing and getting stronger.

Sublipower, Sublihealth, Edi Inter, 1989.

What the mind causes the mind can cure.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

My thoughts are becoming more positive every day, healing me, assuring my success and bringing me happiness.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

I love my body. I have the power to heal myself.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I believe and know that divine love is in the process of healing me.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I direct all the energy in me towards God and His powers of healing. And the seed of this attitude sprouts and grows in the fertile soil

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of my subconscious mind.

I know that the infinite power of healing is healing me right now. It can heal me despite any logical proofs to the contrary. I feel it, I believe it, and I'm ready to attain my objective, which is my complete recovery.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I will recover.

Emile Coue, Complete Works, Astra Publications, 1976.

I rejoice in this new body and give thanks.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I am getting better.
I want to get better.

Professor Robert Tocquet, The powers Of The Will, Godefroy Publications, 1989.¥

The love of God saturates my entire being. The peace that comes from God fills my soul, and I give thanks for the marvelous healing that is taking place in me at this very moment.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

The power of my subconscious heals my body and makes it perfectly healthy.
I have the power to heal myself.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

The doctors are amazed at my progress.

Louis Proto, Self Healing, Piatkus Publications, 1990.

My state if health is improving.

Dr. Joseph Murphy, The Miracles Of Your Mind, Dangles Press, 1984.

If one of my organs is functioning badly the natural power of healing will work on curing the anomaly day by day.

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My healing powers are strong and protect me against all disease.

Sublipower, Sublihealth, Edi Inter, 1989.

The power of suggestion accompanied by effective treatment will assure my recovery.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

Every day, and in all ways, I am feeling better and better.

Emile Coue, Complete Works, Astra Publications, 1976.

Everything is fine.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

HEALTH - GENERAL (Also see Beauty, Vitality, Confidence, Happiness, Looking Good, Slimness, Charm, Balance, Harmony, Self Expression, Peace, Success, Prosperity, Love of Life, Energy)

As my essential functions of digestion, circulation, breathing and sleep get better and better, so does my general health.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

From today on I will develop my body and mind. I will remain in good health. I am solid and strong because I have decided to be so.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

Calm and relaxed, I regain my strength and health.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

Every cell of my body breathes harmony and health. My whole body radiates health. I feel wonderful. I'm in great shape. The way I

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look and move expresses health and harmony. I radiate well being.

Every day my positive thoughts keep me healthy. My thoughts create harmony in my body and in my relations with people. These harmonious thoughts give me strength and health.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

Every day I get more beautiful and healthy!

Everything I do promotes my health and beauty.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

The prototype of my body in all its perfection can be found in my subconscious mind.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I can feel my body more healthy now. I visualize, think and speak well of my health. I use positive self-talk on a regular basis.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I am acquiring good health. I make sure to keep all the parts of my body healthy.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I have an increasingly positive mental attitude in a perfectly healthy body.

I am constantly creating positive images and thoughts which keep me healthy and in top shape.

Christian Godefroy, Mental Dynamics Seminar, 1978.

I listen to my inner voice which always tells me the truth about my physical condition. I always listen to its warnings and advice.

My mind takes good care of me. By giving it clear inner instructions, I consciously condition it to keep my body bursting with health, energy and vitality. My mind always obeys my commands.

I am very healthy, but I don't take my health for granted. I am

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proud of the efforts I make to stay healthy.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I use the power of my mind to control my thoughts, and keep my body and mind healthy.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I will consult my dentist and physician for periodic checkups. I am going to devote a portion of each day to improving my health.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

(I feel good, I look good, I am good.)

Louis Proto, Self Healing, Piatkus Publications, 1990.

I feel very healthy! I feel happy! I am in great shape!

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

(I am a friend to my body. I always let my body guide me in perfect equilibrium. I have confidence in my body.)

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I feel good.
I am in perfect health.

George Barbarin, How To Overcome Fears And Anxiety, Dangles Press, 1974.

I feel fine... I'm healthy... I have confidence in my subconscious... which watches over me and keeps my sympathetic nervous system in balance... my sympathetic nervous system which regulates all my bodily functions... and which keeps me in perfect health...

Nothing can affect me... nothing can harm me... my health can withstand anything... my vital forces are inexhaustible... I am in perfect health... in great shape.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

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I am now in perfect health.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

I am very healthy. God is my health.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

I will always live with a positive frame of mind, and that will keep my body healthy.

Day by day my health is improving.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

My body's natural state is exuberant health! I see myself perfectly healthy, radiant and strong. I focus on health.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

The idea of perfect health now fills my mind.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

Every cell, every tissue of my body is regaining its health and harmony.

My health is improving day by day, I am glowing with health. My strength is growing and my health is improving daily.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

The life of God penetrates every fiber of my being. I AM well and whole in every part of my body. I am composed of billions of cells all containing intelligent life, and this intelligence guides me towards health, happiness and prosperity.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

My body is my friend.

The power of life is in me and regenerates me.

Sublipower, Sublihealth, Edi Inter, 1989.

My body is perfect.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

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Everything about me is an affirmation of balance and health.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

HEART

I feel each heart beat. My heart is strong. It is doing its work perfectly. I can count on it. It is strong, healthy and vigorous. It is beating regularly, calmly. It is strong.

My heart is vigorous. The blood it circulates is pure.

My cardiovascular system is purified. My arteries are free of all obstructions. My arteries are healthy. I feel good. I feel fine.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

My heartbeat is slow and regular.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

My heart is beating slowly and regularly.

My heart is beating regularly, calmly, and strongly. It is working completely normally.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

My heart is strong again, and functioning normally.

Louis Proto, Self Healing, Piatkus Publications, 1990.

My heart is getting stronger and stronger, more and more calm, more and more rested. It is beating slowly and regularly, easily sending fresh blood full of oxygen to all parts of my body. My heart is getting stronger day by day, becoming more and more calm and powerful.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

My heart feels fine.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

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I'm feeling better and better.
My heart is beating normally and regularly.
My heart is perfectly calm.
My heart is perfectly healthy.
My heart is doing fine.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

HEART ATTACK (See Tachycardia)

HELP (Also see Cooperation)

God is with me, God helps me, He cannot abandon me.

Marcel Baugin, Hypnotism, Suggestion and Telepsychic Phenomena, Scientific Distribution, 1956.

I accept the help others give me.

Subli Power, Sublicontrol, Edi Inter, 1989.

I have the courage to ask for help.

Shakti Gawain, Reflections In The Light, New world Library, 1978.

I make use of everything that can or could help me.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I am supported by life.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

May God give me the patience to accept what I cannot change, the courage to change what I can, and the wisdom to know the difference.

W. Clement Stone & Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978

Everybody loves me and supports me wherever I go.

Louis Proto, Self Healing, Piatkus Publications, 1990.

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HESITATION

As soon as I decide something... I do it, after having considered all the advantages... I do it right away... enthusiastically... and I resolutely eliminate all doubt and hesitation from my mind.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

HINDRANCES

I now get rid of all the feelings of guilt, fear, resentment, disappointment and hate I may have accumulated. I am free of all hindrances!

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I free myself of the hindrances that are no longer useful.

SubliPower, SubliControl, Edi Inter, 1989.

HOMEWORK (Also see Studies)

When I'm at home I concentrate on my homework. I finish all of it carefully. I don't let myself get distracted. I'm not going to be tempted to do anything else until my homework is completed and my courses for tomorrow are prepared.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

HOMOSEXUALITY

I am a man.
A boy's penis smells bad. It's horrible, disgusting.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

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HOME

I find my dream home. It's exactly what I've been looking for, and corresponds to all my needs. My subconscious is an infallible guide.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

HONESTY (Also see Frankness, Sincerity)

Honesty demands that I rid myself of the need to evaluate my own worth in terms of exterior values, instead of looking at myself as objectively as possible, with an eye towards an even better life than the one I am living today - in other words, instead of being more or less faithful to 'the way it's always been.'

Being honest with myself requires that I realistically evaluate my strong points and my weak points so that I can identify and separate all the defence mechanisms I've built up around me from my valid inner messages, and eliminate them.

I can decide to continue listening to false inner signals, trying to hide my real self from others, but even if I do, from now on I will be totally honest with myself.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

HONOR

I would be ashamed not to live up to my responsibilities and delude myself; therefore I must live up to my responsibilities to others, and not try to delude them.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

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HOPE

I build my hope, and never destroy it.
I choose to believe that something good can happen.

J. Martin Kohe, Your Greatest Power, A Different World Ltd., 1979.

Everything is tranquil around me. I feel good. I am confident. My life unfolds under the sign of hope. I am proud of what I have accomplished up to now. And I will continue being proud. My life is calm, pleasant and full of hope.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

HUMILIATION

No one can humiliate or upset me. I won't allow it.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

Humor

I am going to convince myself that a sense of humor is an antidote to worry. It will help me develop a balanced personality, and is as essential to intelligent living as food is for survival.

I need to laugh for the maintenance of good health, for the relaxation of my mind and body. I am going to remind myself not to take either myself or my troubles too seriously. Laughter will help me make life more bearable. Laughter is a habit. I am capable of cultivating it by simply repeating each day that I will find something to laugh about.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I have a kindly sense of humor about myself.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

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HURT

Only the False Me can hurt me.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

No one can hurt me unless I authorize them to do so.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I eliminate the hurt of a negative emotion by refusing to identify with it; this means that I don't see it as a permanent part of myself, but rather as a feeling that is just passing through me.

I try to put a definitive end to my inner hurt instead of seeking temporary solutions.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

HYGIENE (Also see Negative Habits, Dieting)

I give my body the best.
I love my body and I admire my beauty.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I will keep my body and mind clean because I want to live longer and stay young.

J.V. Cerney, Stay Younger, Live Longer Through The Magic Of Mental Self-Conditioning, Parker Publishing Company Inc., 1968.

I am good to my body and my body is good to me.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I am going to develop habits that are conducive to making me think and feel better. I am going to cultivate healthy living habits.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

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HYPERTENSION

My blood pressure is always normal, and my heart beats regularly.

Christian Godefroy, Mental Dynamics Seminar, Godefroy Publications, 1978.

HYPNOSIS

I am certain I can put anyone under, at any time.

Marcel Rouet, Techniques And Practice Of Hypnotism, Paris Productions N.O.E., 1974.

I am going to use the technique of self hypnosis to develop a will to improve, a desire to study, learn and make progress in every aspect of my life.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

My hypnotic powers are developing day by day.

Pr. Lawrence Powers, The Ten Secrets Of Hypnotic Power, Godefroy Publications, 1982.

I am influencing your mind. I am going to put you to sleep. You cannot resist me.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

My hypnotic power is developing day by day.

Dr. Lawrence Powers, Ten Secrets Of Hypnotic Power, Godefroy Publications, 1982.

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I

IDEALS

I intend to become.... (specify).

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

I will become great.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I can be one of the cogs in a great cause. I strive to attain my highest ideals, which always include excellent physical and mental health.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

My role is to try to acquire the intellectual and moral qualities of the person I wish to imitate. I therefore observe my ideal model closely. I am aware of the value of each word I speak.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

My ideal is my guide. It is easier and easier for me to attain the goals I set for myself.

Christian H. Godefroy, The Seven Eternal Laws of Success, Godefroy Publications, 1980.

IDEAS

I don't forget the ideas that enter my mind.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

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I make a conscious effort to think of new and better ideas, which are the subconscious keys to the vault of my mind.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I try to put an idea to practical use in my business or job, at home, and in my social relations.

I often review the immensely beneficial ideas I have concerning my Real Self and my False Self.

I take all these ideas and store them in my mental filing cabinet.

If an idea is really effective, it will prove itself sooner or later. I want to give my ideas a chance to prove their worth.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

The idea that will enable me to succeed is already in my mind. I just have to think to get it out.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I am part of the vital flow of divine ideas. I gather them and rejoice in them.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

The exact idea I need today will appear in my mind. Coming from the Divine Intelligence, it also contains all the subsidiary ideas I need. I allow this right idea to govern my thoughts.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

IDEAS - LUCRATIVE

I find the idea I need to double my revenue in one year.

My subconscious comes up with ideas for rapidly earning $50,000 (or the amount you need).

My subconscious comes up with ideas for rapidly earning

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$100,000.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

My mind is always creating new and lucrative ideas.

Christian H. Godefroy, Prosperity: The Subliminal Method, Godefroy Publications, 1987.

IDEAS - NEGATIVE

I let go of any mental pattern which is creating negative effects in my life.

Louis Proto, Self Healing, Piatkus Publications, 1990.

IDEAS - PRECONCEIVED

I have a conversation with someone whom I've avoided up to now. I soon notice that my preconceived ideas, when re-evaluated, paralyze me and nourish my indifference.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

IDENTITY

I master the principles of perception. I learn to know myself. I discover my real identity.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I am —— (specify what kind) of person.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

I am happy being me right now.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

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I am ME.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences the same way as I give , Godefroy Publications, 1989.

IGNORANCE (Also see Sickness)

As I give myself the right to make mistakes, I also give myself the right to be ignorant.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

Divine force is manifesting itself in me, I am positive, positive, positive. I have the power to destroy sickness and ignorance.

Richard Ingalese, The Power Of The Mind, Dangles Publications, 1981.

ILLNESS (Also see Pain, Ignorance)

In the final analysis I must love in order not to fall ill.

I have learned the lesson(s) I needed to learn and no longer need to be ill.

I intend to enjoy myself in spite of my illness, rather than brooding over it and bringing myself down with worry.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I have now transcended all preconceived ideas about illness. I am free and healthy!

Shakti Gawain, Reflections In The Light, New World Library, 1978.

I forget about illness.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I feel better.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

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I know I can resist all diseases... whatever they are... I cannot be sick... I feel full of vitality... no discomfort whatsoever... no illness can catch my subconscious off guard.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

Illness begins in the mind. I will never allow my mind to fall prey to thoughts which are likely to result in disease.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

You couldn't get the better of me, you will never get the better of me again.

Emile Coue, Complete Works, Astra Publications, 1976.

I am in good health, and my body no longer has any trace of disease. I look in the mirror and I feel happy. My skin is clear, my eyes shine with health. I feel good. I have energy. Life interests me. Everything is fine. My body is healthy, perfectly healthy.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

ILLUSION

If I accept myself I choose reality and its accompanying roles: happiness, confidence and success. I don't have to live in a world of illusion any longer, because I'm very happy to be who I am.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I get rid of outdated attitudes and acquired convictions. My life will be free of illusions.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

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IMAGINATION

I use my imagination in a constructive way.

My imagination is a friend, responsible for my past successes. I construct my present based on these positive images of the past, and make progress towards building a good and pleasant life for myself.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

The power of my imagination is my greatest strength.

Even if I haven't had a lot of success, what I have accomplished remains in my imagination, where it really counts.

I use my imagination to help establish goals for myself; it provides me with realistic objectives, unclouded by fantasies, which will make me a happier person.

I allow my imagination to work creatively for me and for others, by planning sensible and attainable goals.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

My imagination is a powerful tool for creation.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

My imagination always helps me find new ways to succeed... new and enriching paths to follow.

I have confidence in my imagination, which shows me the best ways to overcome obstacles.

My imagination is becoming more and more fertile. I am constantly discovering things I had no idea about... things that enrich and diversify my mind... so that I have a definite advantage over those whose horizons are limited.

I know I can count on my imagination.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

All the strokes of luck I have benefited from in life already ex-

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isted in my imagination.

Imagination is my mind's workshop. It is where I convert my mental energy into action and wealth.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

IMMUNITY

(I am convinced that unconditional love is the most powerful stimulant for the immune system.)

Louis Proto, Self Healing, Piatkus Publications, 1990.

IMPASSE

When faced with an insurmountable obstacle I try to see things on a higher level.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

IMPATIENCE

I will no longer feel impatient or angry; on the contrary I will always be patient, always in control of myself. And from now on the things that used to bother or irritate me won't affect me any more.

Emile Coue, Complete Works, Astra Publications, 1976.

IMPOTENCE (Also see Premature Ejaculation)

Tonight when I am alone with my partner I will feel exactly as I do now. I will be completely confident, sure of myself, I'll feel vigor-

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ous and healthy, exactly as I do now.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

It's easy for me to get a strong and long lasting erection. And I have no trouble satisfying my sexual partner. I only ejaculate when I want to - I have perfect control. I like making love more and more, and I'm more and more skillful and loving with my partner. I am becoming more and more virile, and I satisfy my partner completely.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I have perfect control of my erections. I love to make love, and I know how to satisfy my partner. Day by day I am becoming more and more virile and loving.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I am a normal man, with normal functions.

I feel confident with the woman I have chosen as my sexual partner.

Just as I am able to stay erect when I masturbate, I can do the same when I am making love.

I am a normal man, with normal sexual habits.

I only think about my successful sexual encounters.

I know that my sexual functions are normal.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

IMPULSE - NEGATIVE

I want to control my physical and emotional impulses and refuse to act on those which run counter to goals, principles and which disturb my vital balance. Next time I'm going to think before I act. I am absolutely determined to control my impulses.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

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I am always calm... and I control all my impulses. I never act before deliberating... but once I've made a decision I see it through.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

INCOME

I now have a satisfactory income of $—— per month.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I'm doing what I really like. I therefore excel at what I do and my income is constantly increasing.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

My abilities are improving and helping to increase my income.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

INDECISION

I am no longer undecided, I make no more mistakes or errors of judgment. My conscience is a perfect center of Intelligence of the universal Understanding which is God.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

INDEPENDENCE

As an independent and positive observer of the mind, I do my best to be a complete and independent person. I refuse to let others dominate and control my thoughts.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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I don’t need to be accompanied by a friend to do what I want to do.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

I have the right to live my own life, as long as I don’t harm myself or others.

I live my own life. It belongs to me.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I will never allow others to think for me. I must remain the master of my thoughts and actions. I am capable of steering my boat the way I want.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body’s Natural Defenses, Godefroy Publications, 1989.

I am the sole creator of my universe and day and night I watch over my thoughts and feelings in order to guarantee my independence from others.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

INDEPENDENCE - FINANCIAL

I make a good living! I am heading for even greater success and financial independence.

I appreciate the financial independence which allows me to attain my financial objectives. The more precise and detailed my financial plan is, the more rapidly I will attain my objectives, and the more financially independent I will be.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I aim for financial independence and I make sure I don’t owe anyone anything. If I have to beg for money I become its slave. In cases where I can’t borrow money I find a creative way to earn it.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

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INDIGESTION

My digestive system is calming down.

Emrika Padus, Encyclopedia of Emotions And Health, Edi Inter, 1991.

INDIVIDUALITY

I am a unique creature.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

INFARCTUS

After each session I feel the pain in my chest diminishing. I will not feel my heart laboring. It now beats regularly and much more strongly.

The fear I feel about my heart is disappearing, and I will stop thinking about it all the time. My heart is now healthy and strong enough, and I am recovering.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

INFERIORITY (See Complex)

INFLUENCE

I have a positive influence on other people.

Sublipower, Subliconfidence, Edi Inter, 1989.

I influence the people around me at will.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

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I will tell X that ——— (specify) and my words will have a powerful effect.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I am sure of myself, no one can resist my influence.

Marcel Rouet, Techniques And Practice Of Hypnotism, Paris Productions N.O.E., 1974.

I intimidate you, and you can do nothing to resist me.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

The fact of understanding another person gives me power and influence over that person.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

The acts and words of others have no power or authority over me.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

X! During our meeting on — (specify) your opinions will change when I tell you that —— (specify).

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

INFORMATION

I try to promote the exchange of a maximum of information, considering that other people are, in a sense, really strangers, and that I am also a stranger to myself.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I make sure I'm well informed about new developments in my field.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

Other people (superiors, subordinates and colleagues) know what

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I'm doing, as well as why and how.

I am well informed about everything that has to do with my work and with my business.

I make sure there are no misunderstandings about the information I circulate.

I consider that a part of my work consists of circulating information.

If I'm in doubt about whether or not to divulge a piece of information, I go ahead and do it.

I make sure to always reformulate the information I receive in order to verify that I've understood it correctly.

I do not hesitate to be redundant, i.e. to repeat the same information two or three times in slightly different forms, to make sure that I have been understood correctly.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

INNER DIALOG

I stop focusing my thoughts on the negative. I just let them go! Being realistic doesn't demand focusing on a problem continuously.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I turn all negative 'self-talk' into positive 'self-talk.'

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

INNER GUIDE

I learn to take charge of myself.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I learn to take orders from my inner headquarters - the Real Me.

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It is always a sure guide.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I listen to my inner guide for everything that is good, honest and positive.

Sublipower, Sublicontrol, Edi Inter, 1989.

The law of love guides me.

The inner force which guides me shows me how I can best serve humanity. In my dealings with friends and clients I am conscious of the fact that God resides in them, and I work with them for the triumph of happiness, prosperity and peace.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

My true Self guides me in all my actions.

Divine love guides me and always takes care of me.

It is now my inner wisdom that is my guide.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

INNER PEACE

I often practice mental relaxation. When I want to relax completely, even if only for a moment, I use my imagination to project myself to a place where I know I will immediately feel inner peace.

I possess inner peace. I live in a positive and interesting way. I have a reason for being here. I like what I am, and that gives me even greater assurance and inner peace.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

The secret place where I find refuge is found deep in my own mind.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

INNER STRENGTH (See Strength - Inner)

INSOMNIA

Every night from the moment I want to go to sleep to the moment I want to wake up the next morning, I will fall into a deep, calm, tranquil sleep during which I will have no nightmares. When I awaken I will be completely refreshed and feel great.

Emile Coue, Complete Works, Astra Publications, 1976.

As soon as I go to bed I fall asleep.

As soon as I go to bed I fall into a deep sleep. I sleep all night long, and wake up refreshed and full of energy.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

Being physically and mentally relaxed will enable me to sleep well again... a deep, restorative sleep... This sleep will make me feel completely rested when I wake up.

I will never be nervous again... always relaxed... I know how to relax and fall asleep when I want to.

I will sleep deeply all night long... nothing can bother me. And in the morning when I wake up I'll feel happy, lucid, completely rested... and full of joyous and well channeled energy.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I always get enough sleep; my body makes sure to get all the rest that it needs!

I love sleeping. I get tired, and sleep comes. I am going to have a deep sleep.

My body craves sleep. I will sleep well right through the night, and I'll wake up happy and full of new energy!

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I feel the peaceful calm of the night making me drowsy; I am completely relaxed; I am in a state of repose, peace and harmony. I am calm, I feel I am a part of the rhythm of the night... I am weary and relaxed... I feel free and in tune with the natural rhythm of nature, which sleeps at night... my thoughts are getting fuzzy... I'm so tired... I'm falling asleep... sleep.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I sleep deeply and calmly.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I sleep better and better.

Emile Coue, Complete Works, Astra Publications, 1976.

I fall asleep easily, I will sleep deeply all night long and wake up refreshed and full of energy and good humor.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I fall asleep easily. I savor my sleep. Every night when I go to bed I forget my worries, fears and anxieties. I am happy, relaxed, calm, and ready for a great night's sleep.

I don't wake up during the night. Everything is fine. Everything is calm. I sleep deeply right through to the morning. I am calm and I don't think about anything. I sleep deeply.

Everything around me is calm. I do not wake up. I sleep deeply. I am relaxed and happy. Everything is fine.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I couldn't care less about whether I'm going to sleep or not. Even if I stay up till tomorrow morning it wouldn't bother me.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I am calm... my muscles are loose... my nerves relaxed. I am calm...

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and I am falling asleep.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

I am a normal person and I can fall asleep naturally.

The noise in my room helps me sleep.

The noise outside my room helps me sleep.

I can sleep the whole night through, without waking up, as I have done many times.

When I go to bed I leave my worries and preoccupations behind.

I am relaxed, free of all the negative influences that troubled my sleep in the past.

I don't have to try to sleep any more - I just let myself fall asleep.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I am going to use self hypnosis and practice relaxing my body and my mind. I am going to sleep soundly and awaken in the morning feeling refreshed and invigorated.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

A wonderful feeling of quiet and harmony spreads through my body... I feel happy... Every night when I go to bed this feeling overcomes me.

I fall asleep immediately... my sleep is healthy and natural... when I wake up I feel rested and refreshed... I can feel the peace and harmony spreading through me... I'll be happy when I wake up... day by day things are getting better and better.

Every night when I go to bed I eliminate all negative or annoying thoughts... I fall asleep right away... and sleep all night long until the next morning... When I awaken this marvelous feeling of peace and harmony is still there... I feel happy... day by day my condition is improving.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

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INSOMNIA - CHILDREN

I love to go beddy-by because it feels so good.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

INSPIRATION (Also see Creativity, Optimism)

Every day ideas and creative inspiration come to me.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

Something good is waiting for me. And God sends me love. God is the light of my life, the source of all my knowledge and inspiration. God, who is at the heart of my being, knows all. He provides the nourishment for my thoughts, ideas which serve me well, and clear divine intelligence.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I am now guided by God. His love fills my soul. God inspires me and enlightens my life. I am full of goodwill and love for all. Every instant of my life I submit to the will of God.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I am optimistic and inspired.

Sublipower, Subliconfidence, Edi Inter, 1989.

The inspiration I need will come to me while I sleep. Tomorrow I will resolve all my problems easily.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

My subconscious helps me discover the solution I am looking for. The answer I seek comes to me with ease. What is the best way to —— (specify)?

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

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If I am stymied or at a dead end with a problem, I change the scenery and my mood. I try relaxing and reflecting by getting away for a day at the ocean or in the country. I remember that the right brain creative problem solver in my mind is always available for review when my left brain logic slows down.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

INTELLECT

I have an intellect, but I am not my intellect. It is fairly developed and active; it lacks discipline but it can be controlled and channeled; it is an instrument for gaining knowledge, both of the exterior world and the inner world, but it is not me. I have an intellect, but I am not my intellect.

Dr. Robert Assagioli, Psychosynthesis, Epi, 1965.

INTELLIGENCE (Also see Self Confidence)

The self image I choose depends only on me. I can choose to consider myself intelligent by applying my own criteria. For me, the happier I am the more intelligent I am.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I am intelligent.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

I am wise. I am intelligent and creative. I accept that a positive mental attitude is an important part of creating my reality.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I am an intelligent person.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

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INTIMACY

I have the right to be intimate with someone.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I am capable of being intimate. I like having someone close to me. I am not afraid of intimacy. I'm ready to commit myself to an enriching relationship. I am happy to love someone.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I am completely happy. My intimate relations are deeply satisfying and enriching.

I look at my being and my intimacy with enthusiasm and hope. I believe that I deserve the best. I am worthy of the very best, and I obtain it.

I am aware of my most intimate feelings and desires. I possess a fabulous treasure - my magnificent intimacy with another human being.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

INTRANSIGENCE

I will never convince anyone by using force. The feelings this would create are very negative and the results are short lived.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

INTRODUCTIONS

I always greet the people I meet with a smile. When introducing myself in any new association I take the initiative to volunteer my own name first, clearly; I always extend my hand first, looking the

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person in the eyes when I speak.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

INTUITION

By listening to my intuition I can hear the voice of God.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

I am intuitive... my intuition is the voice of my inner Guide. S/He leads me and I obey.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

My intuition is getting better and better... and this intuition comes from my subconscious, which protects me... which knows what I should do... to stay healthy... to be loved... to succeed in my affairs... to earn money.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I develop my intuition and heed its advice.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I recognize my own intuitive ability.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I know what I need to know each moment. My consciousness is forever expanding and deepening.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I am receptive to the counsel of my inner self.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

The Universal Understanding which is in me knows things that I don't. I let this great force of understanding and the power of action do what has to be done. All the wisdom, all the spirit and all the

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intelligence of God are now working through me to accomplish my goals.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

The spirit in me knows.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

Intuition is not merely a hunch, but is an irresistible light which must be followed.

I never ignore my inner messages.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

My intuition is perfect, my perception of things is also perfect.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

INVESTMENT

I resolve to get my money working instead of me.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

INVOLVEMENT

I insist on my right to be a constructive member of the great human family.

No one can force me to isolate myself.

I live in the present, even in moments of tension, pain or grief.

I voluntarily strive to attain new and inspiring objectives.

I make sure I am open towards people.

I get involved in constructive projects.

Today is another day during which I can become wholeheartedly involved with other people.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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IRRITATION

I am starting to free myself from anger, resentment and irritation as I recognize that the causes of my anger are mostly in my mind, and disappear as soon as I modify my mental attitude.

If I get into a bad mood I sit or lie down, I close my eyes, I rest, breathing deeply a number of times and concentrating on an image of tranquility I repeat, ‘I am at peace. I am at peace. I am calm, I am strong.”

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I don’t get irritated every time a problem arises.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

ISOLATION

I reject whatever can separate me from others.

If I neglect my self esteem I will find myself isolated.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am overcoming my feeling of isolation from others.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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JEALOUSY

I have complete confidence in my husband / wife.
I am no longer afraid that s/he will leave me.
I won’t try to eavesdrop on his / her telephone conversations any more.
I know s/he loves me as much as I love him / her.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body’s Natural Defenses, Godefroy Publications, 1989.

I love him / her as s/he loves me - unselfishly.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

I am ready to allow Love to flow through me, working for the benefit of all. I free myself of all hate, all unpleasant thoughts, and all jealousy.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

May my confidence shine through all my actions and attitudes. I show my love for my spouse by doing special little things for him / her, and I do everything I can to fulfil his / her needs and desires. I don’t ask for anything s/he is not willing to give voluntarily; I firmly believe in our love, and I see how the magic power of love and mutual confidence changes both of us for the better.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

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JOBS (Also see Remuneration)

From now on I have a perfectly satisfying and well paying job.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I now have a good job.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I will find the ideal job.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I am keeping my job.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I easily find a well paid and pleasant job such as ——— (specify).

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

The ideal job for me does exist. But I have to start by believing it if I want to find it.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

Infinite Spirit, give me the possibility of having a job (or a house, or abundance, or anything else you desire) which pleases me, a job that keeps me busy, a job where I am needed, and which no one else can do as well as I. May I meet the right people so that I find a job where I can offer good service and get well paid for it. Lead me to where I can make the right contacts. I leave it up to You, and I know that all will be well.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I accept the inevitable.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

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JOIE DE VIVRE (See Love Of Life)

JOY

I smile a lot. I feel happy inside, and I show it.

I'm a happy person by nature. I try to look at life with warmth and joy, and I believe that life is worth living.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Today is a great day. And I have everything I need. So I choose to live wonderfully, in joy and love!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Each day I prepare myself to be receptive to joy.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

Every day my mind is filled with joy, love and peace.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I now choose harmonious thoughts and let the joy flow freely through me.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I let go of the past and now live totally in the present.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I think and act joyously, and so I am joyous.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I smile because I want to share my joy.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

I am as joyous as possible.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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(I am excited to be alive.)

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I am always joyous, active and energetic. Eternal joy is my strength. I am always in a good mood, free and full of happiness.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

Because my morale is getting stronger and stronger, I feel more and more in control of all situations, however difficult they are. Instead of all those negative and depressing thoughts, I will concentrate my mind on thoughts of health, courage, confidence in life and in myself, certitude and joy.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

JUDGMENT (Also see Action, Memory)

Moderation, common sense, good judgment and balance are all important elements of the way I live.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I channel my thoughts and take the time to exercise judgment concerning all my activities.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I never act contrary to my own better judgment.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

My thoughts are ordered and clear.
My judgment is rapid and sure, my memory is accurate.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

In order to clarify my judgment I try to understand other people's opinions about my behavior, my ideas and my emotions.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

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JUSTICE

To be just, I act justly.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

JUSTIFICATION

I refuse to justify everything I do. If someone asks why I do such and such a thing, I reply that I have no reasonable explanation. I do what I do simply because I feel like it.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

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KLEPTOMANIA (Also see Honesty)

I no longer feel the need to steal. I am in perfect control of my reactions and my impulses. In stores I always pay for the merchandise I take. I can easily master my impulses. I take pleasure in spending money for objects I desire. I am a perfectly honest person, and happy about it.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

KNOW-HOW

I trust myself to acquire the knowledge and skills I need if this plan or approach does not lead to the results I want.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

KNOWLEDGE

I seek knowledge in order to make wiser choices.

My daily job is to broaden my knowledge.

I can do whatever I want, but what I want is determined by what I know.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I raise my consciousness, my level of understanding.

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I raise my level of knowledge.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I make harmonious and confident use of the knowledge I acquire in my life.

Professor Kurt Tepperwein, How To Learn The Painless Way, Godefroy Publications, 1983.

I collect all the information I can.

I replace the effort of thinking with a tranquil understanding of everything that is going on.

I transform my acquired knowledge into personal knowledge. And then I experience the miracle of peace, every day.

The supreme secret for breaking out of the vicious circle of problems is knowledge.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I invest in my own knowledge. I enroll in an extension or seminar class in some aspect of personal or professional development. I make the bookstores and fitness centers my new haunts for 'happy hour.'

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

(Each person's knowledge is different, therefore no comparison is of any value.)

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

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LACK

People give to me freely: I do not have to beg or fight.

Louis Proto, Self Healing, Piatkus Publications, 1990.

LAUGHTER

From now on I will cultivate laughter. I will smile, and my digestion will improve; I will rejoice and my burden will grow lighter; I will laugh, and my life will be prolonged, because that is the secret of long life, and it is now mine.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

My scale of values changes as my inner self develops. So now I laugh about things that caused me to suffer in the past.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

LAZINESS (Also see Cowardice, Lying, Disorder, Discipline)

Tomorrow I will wake up at — (specify) o'clock. I will feel rested and eager; I will not waste a minute lying around in bed; I will jump out of bed and joyously greet the day that awaits me. I will maintain my enthusiasm throughout the day, and I will work with joy and

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presence of mind, certain that my efforts will lead to the desired results.

Starting today I will not allow myself to waste time on insignificant things, in order to prevent the bacteria of laziness from taking over my mind and my body. I walk straight and stand tall, not bent over like a crescent moon.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I am becoming a good worker, committed, courageous, and more and more frank and sincere.

Emile Coue, Complete Works, Astra Publications, 1976.

I will react against laziness and I will work with courage and regularity (dedication).

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

I'm starting to like what I do again.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I can now get up on time every morning, feeling great.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I am rested and full of drive. I rejoice in the things I have to do. Today is a lucky day for me. I am calm and serene, and I can handle any situation!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

LEARNING (Also see Knowledge)

Learning is like depositing gold in the bank of your mind. I invest in myself every day. I can learn whatever I want.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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I love to learn. I find the time to learn new things, and constantly develop my mind.

Christian H. Godefroy, The Seven Eternal Laws of Success, Godefroy Publications, 1980.

I am constantly learning!

W. Clement Stone, Passport To Success, Godefroy Publications, 1962.

After you have gained general knowledge in a field or subject, concentrate on learning one aspect of it well. Succeed in specializing, before you diversify. Doing one thing well, until you have mastered it, brings confidence and a reputation for excellence.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I take great joy in learning.

I am completely relaxed, and assimilate the text perfectly.

I can easily remember everything I learn when I wish, and I am satisfied with my progress.

I will stick to the program I set up for myself right to the end, and I will not let myself get distracted.

I am very happy to learn so quickly and easily in this way, and I feel great.

I listen enthusiastically to the information I want to acquire, and assimilate it as if it were the easiest thing in the world to do.

I always concentrate on what I am doing, at the moment I'm doing it.

Learning brings me more joy every day.

I feel free of all obstacles, and learn with enthusiasm.

Each time I make progress I get more pleasure from my work.

Each day brings me a greater and greater understanding of the deeper meaning of what I learn.

Professor Kurt Tepperwein, How To Learn The Painless Way, Godefroy Publications, 1983.

I believe I can learn anything.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

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LEARNING WHILE ASLEEP

Soon I will be deeply asleep. And yet I will easily be able to hear what I taped, and memorize it without waking up. I will learn the text on the tape easily, while I am completely calm and relaxed.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

In a few minutes, when I fall asleep, and even if I sleep very deeply, I will be able to hear the tape recorder; it will be easy to learn and memorize everything I hear.

Valery Sanfo, Practical Guide To Self Hypnosis, de Vecchi Publications, 1987.

LEISURE

I engage in inspirational recreation. I get out the kites, grab the Frisbees, dust off the picnic basket, share a project with the children, attend little theatre productions, musicals, and concentrate most of my television and movie viewing on shows that warm my heart.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

My leisure time is full.

I am aware that I can take an active part in managing my leisure time, just as I manage my professional life, or anything else I want to do.

I don’t consider leisure time as wasted, or just time to kill. On the contrary it is an opportunity to develop myself and to relax.

Every now and then I review how I make use of my leisure time, and plan various ways to use it better (theatre, vacations, etc.).

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

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LESIONS

If there are lesions in one or another of my organs, these will heal up day by day, and will rapidly disappear.

Emile Coue, Complete Works, Astra Publications, 1976.

LEVEL HEADEDNESS

I am always level headed, calm and serene. God's peace permeates my mind and my soul, my entire being. I am full of goodwill, and sincerely wish all people peace and happiness.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

LIFE

Life is an amusing game which I want to play.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I now dedicate my entire mind to the Divine Plan of creative life. I refuse to be a mediocre person achieving mediocre results in my life. God has given me the genius of the Spirit.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

Now is the best time to be alive.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

LIKABILITY

I am likable and affectionate, and I have a lot to share with others.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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I am likable.

Dr. Wayne W. Dyer, Your Erogenous Zones, Tchou Press, 1976.

I am always relaxed, never irritable, and therefore always smiling and likable.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

LIMITATION

I never allow the obtuse thoughts of others to limit me; instead I open myself to limitless possibilities.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

There is no limit to how good I can feel.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I am limitless. I know no boundaries as I live unconditional love and creativity. I recognize my true identity.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I am free, nothing frightens me, nothing can limit me. The realm of the mind has no boundaries.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

(I am a limitless being.)

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

All thoughts of limitation and poverty are now erased from my mind.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

No task is impossible if I know and understand my limits.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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My only limit is my mental image.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

LISTENING

I listen to what other people are saying instead of preparing my answers, and I make sure they have finished expressing their point of view before responding.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I listen to everything the people I'm talking to have to say, not only a part of it. To me listening doesn't mean waiting for my turn to speak. When I listen, I really listen.

I am an attentive listener. I don't listen just for the sake of listening, but to understand.

I listen to other people's thoughts, but I also listen to my inner voice, the voice of my best friend and advisor. I listen to the advice I receive.

Every day I become more and more skilled in the art of positive listening. I like to use my listening skills every time I have an opportunity to do so, no matter who it is I'm talking to, what the occasion is, or where I am.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

LOGIC

I am a rational person.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

My thoughts are coherent and organized in an orderly way.

Sublipower, Sublimemory, Edi Inter, 1989.

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LOOKING GOOD
(Also see Weight, Losing Weight, Health)

I am gradually reaching my ideal weight. Every day I am closer to having the figure I dream about. I'm looking better every day. My body is firm, and I feel light. Life is nourished by life: I feel like eating living nourishing food, rich in vitamins. I love the life-giving taste of fresh raw fruits and vegetables, which enhance my beauty and energy.

Each day I feel my body becoming more beautiful and I rejoice in the life flowing through me.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

When I take an honest look at myself in the mirror I like what I see. I'm proud of the efforts I make to look and feel good!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

(I know I have to look good as good as I can to please my husband / wife.)

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I vibrate with immense happiness, in a magnificent body sculpted by the immense power of my subconscious.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

LOSING WEIGHT
(Also see Strength, Body Fitness)

I'll soon reach my ideal weight. I feel happy, and my body is looking better and better every day. I don't have to deprive myself of anything. I like my body, I like myself. My subconscious mind is my most

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powerful ally. Through the power of my subconscious I can completely master my eating habits. I am free and happy. As I lose weight I feel more fulfilled, I am more active, more considerate of others, and prouder of my image.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

Every time I start eating I rapidly lose my hunger. I will not eat any more foods that make me gain weight, and I won't eat between meals. My body will function on a strict minimum of food and, by perspiring, will eliminate all toxic substances.

Valery Sanfo, Practical Guide To Self Hypnosis, de Vecchi Publications, 1987.

I lose a couple of pounds every week, and I feel fine.

Professor Kurt Tepperwein, Secret Techniques of Hypnosis, Godefroy Publications, 1981.

From now on I will be slim, strong and in perfect condition, whatever I do.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I find it pleasant and easy to lose X number of pounds.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I love this new beautiful body my subconscious is sculpting day after day. I'm losing weight. I'm looking better. I feel good. Every breath I take is filled with health and energy. Every time I exhale I get rid of toxins and excess fat.

My fat is melting. I'm looking better and better every day. I have less and less desire for useless foods that do nothing for my health. I am free of all that. I feel light, so light. I'm in great shape. And I feel great.

I feel so much better being myself in a slim body, free of all those false cravings and superficial pleasures.

Charles Baudouin, Psychology And Practice of Auto Suggestion, Idegraph Publications, 1990.

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I am gradually reaching my ideal weight, and can maintain it easily. My health is improving. My appearance is also getting better and better, and people like to be with me more. I'm looking better every day. I only eat healthy foods, which help me lose weight without feeling hungry. I am becoming more and more attractive and healthy, thanks to the power of my subconscious mind. I can easily reach my ideal weight, and stick to it with no effort. I like my body, and the new self image my subconscious is helping me create. I am in perfect control of my eating habits. I love my body, and I have the power to lose weight.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I have no trouble maintaining my ideal weight.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am always slim and healthy.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

Whenever I sit down to eat I never let anyone else influence me, tempt me, or discourage me in a negative way. I am learning to say no to food and yes to success.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Losing weight the self hypnosis way will definitely improve my appearance.

Losing weight the self hypnosis way will change my personality, giving me greater self confidence, a sense of pride, a feeling of accomplishment.

Losing weight the self hypnosis way will make me less tired and sluggish.

Losing weight the self hypnosis way will improve my sex life by making me more attractive.

Losing weight the self hypnosis way will prolong my life.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

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LOST OBJECTS

You know all things; therefore You know where my ring is and You will reveal where it is to me.

Dr. Joseph Murphy, The Miracles Of Your Mind, Dangles Press, 1984.

LOVE (Also see Success, Happiness)

To love is to look beyond other people's faults and failings. I concentrate on the good in other people.

I love, and I never hesitate to go that extra mile, or spend that extra time to show someone my love.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

Every time my partner is affectionate, I forget all my worries, and feel full of love and tenderness.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

My life is an experience of love and warmth.

Christian H. Godefroy, Positive Thinking: The Subliminal Method, Godefroy Publications, 1987.

Giving and accepting love makes me strong. I always treat love as the most prized gift. The natural state of my heart is love.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I accept appreciation for my loving actions. As I give freely, I also receive freely. I appreciate myself as a male and female.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I greet this day with my heart full of love.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I love to love and be loved.

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The more I love, the more love I have to give to others.

From now on I will love and receive love without any reservations.

All the love I seek is already in my heart.

The more I love myself, the more I love ———.

I love ——— and ——— loves me.

I now invoke the quality of love.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I love life, and life loves me in return.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I love.

Jean Chartier, How To Acquire A Superior Personality , Dangles Press, 1971.

I learn to think in terms of love in my mind, and I feel love in my heart.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I give and receive love freely.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I don’t hate anyone, I don’t envy anyone, but I love and respect the whole of humanity.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I could stop loving you, but for the time being I prefer to continue.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I radiate love through my thoughts, words and actions. Love brings harmony and happiness to my life, and to my relations with others.

Dr. Joseph Murphy, Triumph Over Yourself And Others, Le Jour Publications, 1988.

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I am always in love with the universe, with life, and with myself.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

I am a person worthy of love and affection.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I live in a cosmic universe, and I can hate no person, nation or race.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I live according to the law of love.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I love you.

Marcelle Auclair, The Book Of Happiness, Seuil Publications, 1959.

The emotions of love exists in me when I can be with other people and not want anything from them.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

The Spirit in me loves the Spirit in you.

Marcelle Auclair, The Book Of Happiness, Seuil Publications, 1959.

Harmony surrounds me. I listen with love to the pleasant and the good. I am a centre for love.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I fill myself with love and always expect the best.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

LOVE - FILIAL (Also see Creativity, Sensitivity, Optimism, Peace, Joy, Tenderness)

I love and respect my father because he is good for me.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

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I love my mother, but I'm not responsible for her happiness.

Louis Proto, Self Healing, Piatkus Publications, 1990.

LOVE LIFE

I respect myself and assume the responsibility of being myself in my love life.

I am loving and caring both towards my partner and myself.

I don't consider marriage an institution where one partner dominates the other. I have faith in love, in the support and opinions of my partner, but I am the only one who is in control of my life.

I like the way my partner looks at me, and I know that this look is a reflection of my approval and appreciation for him / her.

I feel sincere admiration for my partner, and I show it. I often express my admiration and approval, both in public and at home.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

LOVE OF LIFE (Also see Prosperity, Happiness, Self Confidence, Courage, Peace, Love)

I am going to regain my zest for life.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

Life is fantastic. That's right, fantastic.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

[I am going to make a positive effort to enjoy life, based on the principle that happiness is an attitude that can be cultivated.]

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I am excited to be alive. I'm glad to be here. I am a bright, shiny

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star that glows every day and night.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I rejoice in life, and I am happy to be alive at this point in history. I contemplate the bounty and richness of life all around me.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I profit from life.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

I am full of life. I love life and I'm happy to be alive. I am a very special person, living an extraordinary life.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Life is fun and pleasurable.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

LOVE OF SELF
(Also see Self Confidence, Self Esteem)

(The more responsibilities I accept, the more energy and self love I have.)

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I love the body I was given. It is a part of me, and I love who I am.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I love and appreciate myself as I am.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I love myself without condition or judgment. I am an energy pattern like no other before or after me. I am comfortable in my individuality.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

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I love myself the way I am.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I respect and love myself.

Sublipower, Sublisuccess, Edi Inter, 1989.

I feel warm and loving towards myself.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

LOYALTY

I invest my sincerity and loyalty in others. This brings me closer to people.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

LUCIDITY (Also see Self Control)

By acquiring a lucid and constructive mind I become my own judge; not a judge who condemns with impunity, but a compassionate judge who does everything to plead my cause.

The lucidity of my mind is my laboratory.

My lucidity helps me develop positive habits.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I think clearly and judiciously.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I want to be perfectly lucid under all circumstances, remain in control of myself whatever happens, and feel perfectly at ease with everyone I meet.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

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My mind is always clear and lucid, and the results I obtain are the proof.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

LUCK (Also see Money)

I am lucky.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

I am getting luckier and luckier.

Christian H. Godefroy, Positive Thinking: The Subliminal Method, Godefroy Publications, 1987.

I have the right to be lucky and rich.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I go through life smiling.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

I am a magnet for everything good.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

Love, that divine magnet, attracts everything that is good.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

Everything comes to me easily and effortlessly.

From now on everything will contribute to make my life beautiful.

Everything good comes to me easily and effortlessly.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

LUNG DISEASE

My lungs are getting stronger.

Sublipower, Sublihealth, Edi Inter, 1989.

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My lungs are clean and strong. I can breathe deeply.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

LYING (Also see Cowardice, Laziness)

I always tell the truth.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

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MAGNETISM (Also see Influence)

I am accumulating great magnetic power.
I accumulate all ambient magnetic energy in my solar plexus.
My magnetism is becoming more radiant every day.
The magnetic power I emit makes my suggestions irresistible.
I can easily concentrate the magnetism in me, and project it where and how I want.

Marcel Rouet, Techniques And Practice Of Hypnotism, Paris Productions N.O.E., 1974.

I am projecting my magnetic force. I am saturating this person with the flow of my magnetic energy.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

The people who enter my life are attracted by my own personal level of magnetism.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I have magnetism because I am in control of my mind and body... this gives me great inner strength... this force... each day... I feel it developing in me.

I control and channel my thoughts at will... and this cohesion of my personality has a positive influence on those around me.

Such thoughts attract similar forces... of love and benevolence... which reinforce my personal magnetism.

I feel myself radiating a powerful magnetic force... which helps me succeed in life... which makes me attractive... to both men and

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women... I always try to be friendly, hoping to benefit them in some way... with my magnetic force.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I now exert an irresistible attraction on people.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I project my personal magnetism.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

I feel attractive, bursting with all the power in my soul.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I feel more and more attractive, more and more powerful and magnetic. I have a positive influence on everyone around me. More and more people are attracted to me. Yes, day by day I feel my magnetism getting stronger.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

Other people love to have me around.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

My personality is becoming more and more magnetic. I can influence the people around me at will.

People are attracted to me more and more. I'm liked by everyone I meet.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I'm working on my facial expression: I want it to be frank, full of light and strength, ready to spread my power wherever necessary.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

No one can resist the power of my eyes.

Professor Lawrence Powers, The Ten Secrets Of Hypnotic Power, Godefroy Publications, 1982.

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Nothing can resist my gaze.

Marcel Rouet, Techniques And Practise Of Hypnotism, Paris Productions N.O.E., 1974.

MAIL

I answer my mail, or throw it away, or delegate it every day, so that it doesn't pile up.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

The mail I send projects a positive image of my service and of myself.

Taking care of my correspondence doesn't take a lot of time.

I use empty blocks of time to take care of my mail.

I write creatively.

I am learning (through practice) to write clean copy on the first draft.

I am learning (through practice) to dictate a clean copy to my secretary on the first draft.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

MANAGEMENT

I build other winners too.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

MANAGEMENT - MONEY

I enjoy managing money carefully and successfully.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

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I know how to manage my money. I have a healthy respect for what I earn and what I know, and I put them to the best possible use.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I know where I stand financially.

My spending is in line with my resources, with a sufficient margin for maneuvering.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

MANAGEMENT - TIME

I dedicate about twenty minutes a day to managing my time: ten minutes in the morning going over the list of things I have to do, and one minute per hour throughout the day.

I regularly ask myself what I can do to save time.

I allow myself sufficient time alone to think about how I'm organizing my time.

I know how to say 'no' and avoid time wasting activities.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I make a list of my daily tasks, in order of importance.

I know how important it is to remain in control of my time and my priorities.

Since I establish my own priorities and since I am aware of the importance of each of my actions, I give them exactly the amount of time and degree of attention they merit.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

(I manage my time well.)

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I take time for sunsets and flowers.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

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MARRIAGE

I am wanted by someone. I am happily married to a good and loving man / woman who is interested in things of the mind. I am secure.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

MATURITY

I am becoming more mature every day.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

MEDICAL TREATMENT

This treatment is totally successful and feels very comfortable. My pills are working wonders - and with no side effects.

Louis Proto, Self Healing, Piatkus Publications, 1990.

MEDITATION

I bow before the power that is in me.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I remain awake in a passive way.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

MEETING PEOPLE

I like to meet people and I focus on their good qualities. My goal

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is to make each person glad they talked with me.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I take great pleasure in meeting other people, and I always see their good side. I am in no way unconsciously fearful of people, I know that the Spirit in all people is one of warmth and loving friendship. I give thanks for all the people I know, and for those I will meet in the future.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I approach people with heartfelt friendship.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I can't select all the people I'd like to work with and be with; but I control whom I spend most of my time with, and I can meet new people. I can change my environment and seek out successful role models to learn from and share with.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

Now I meet exactly the type of people I want to know.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

The more I meet different people, the more opportunity I have to realize that my fears were all a waste of time. With this in mind the unknown becomes something that I want to explore instead of something I want to shy away from.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

You are you and I am me.
I am not in this world to meet your expectations.
You are not in this world to meet mine.
I am here to do my thing.
You are here to do your thing.
Sometimes we will meet - and that's beautiful.

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Sometimes we won't. Too bad.

Louis Proto, Self Healing, Piatkus Publications, 1990.

MEETINGS

I always get to my meetings slightly ahead of time, and I make sure I never miss a plane or train.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

Each time I am called upon to make a presentation to my department I prepare carefully and arrive at the meeting feeling completely sure that I know my material and that I will be in control of the meeting.

Each time I meet with our financial advisors I feel very much a part of the family. Being young only emphasizes my capabilities. Sitting with my colleagues I feel calm and serene, one member of a team all collaborating to achieve the same objectives. Because my mind is concerned with the decisions that we will soon have to make, I am oblivious to my body, and I am calm, concentrated and completely without tension.

Arthur Wassmer, The Art Of Making Friends And Being Happy, Belfond Publications, The 1978.

I prepare for my meetings.

I make sure that the person chairing the meeting does his or her job properly.

Only the people who are required to make the meeting more effective are allowed to participate.

The meetings I chair always result in explicit decisions being made and understood by all participants.

When I'm not chairing a meeting that I find is going badly I try to exert a positive influence by getting myself appointed secretary, or by suggesting that we take time out to evaluate the proceedings.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

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Whenever I am asked a point-blank question in a group meeting I am usually able to respond because I always pay attention to the discussion. I feel calm. I don't worry about coming up with the "right" answer because after all, I am the expert.

Arthur Wassmer, The Art Of Making Friends And Being Happy, Belfond Publications, 1978.

MELANCHOLY

I am never melancholy.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

When I am in one of my melancholy moods I will make sure not to project my disturbed feelings of gloomy disposition onto others.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

MEMORY
(Also see Concentration, Judgment, Willpower)

Starting today all aspects of my memory are improving. It is getting better and better. I retain everything I need to know more and more easily. I have confidence in my memory. It is more and more accurate. It is becoming more and more effective.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

What I record in my memory is written in indelible ink, and stays there forever.

Professor Kurt Tepperwein, How To Learn The Painless Way, Godefroy Publications, 1983.

Whenever I repeat the word X three times in a row my memory becomes perfectly active. It is ready to assimilate data, and I learn everything I have to with ease. Whenever I read or listen to some-

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thing my mind will be more open and will store as much information as possible. My memory is improving, and it is much easier to concentrate on the subject at hand.

Valery Sanfo, Practical Guide To Self Hypnosis, de Vecchi Publications, 1987.

I have a good memory... a faultless memory... I can retain whatever I want.

My memory is powerful... and improving every day... as I organize my thoughts.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I like going to classes more and more as my memory improves.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

My memory is improving daily. My memory is getting better day by day, so that I can remember everything I need for my work.

All aspects of my memory are improving. From now on I can easily remember everything I have to, under any circumstances and in any place. My memory is more and more precise and faithful. I absorb all the information I need in my day to day life more and more easily. My memory is improving daily, and will soon be completely effective. I control my memory under any circumstances.

I congratulate myself. I really have a fantastic memory. I should be proud to have such a good memory. I can easily remember all the dates, events, statistics, thoughts, words, reading and work-related information I need to know. I really have an effective memory. Once again, bravo! I congratulate myself!

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I train my memory in order to make it more powerful, and I use it to advance in my chosen profession.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I imagine my memory as a fruit (any fruit). It is healthy, perfectly

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smooth, free of imperfections. It is perfect. That is my memory.

I am relaxed. Everything is going well, everything is calm. My memory is improving day by day. I have a good memory, a faithful memory. I can count on my memory because it is becoming more and more accurate.

My memory is faithful. I can count on it. It is becoming more faithful every day. I am happy about the progress it is making.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I always remember my conversations with others clearly. I can repeat important parts word for word. This helps in my work, and in all other areas of my life.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am going to devote a part of each day to improving my memory.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I want to make my memory fast and accurate, my assimilation (of information) clear and correct, and my willpower faultless.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

My mind stores information with ease.

All I have to do is give myself a mental command to retrieve any information I want from my memory.

Every day I work on developing my concentration and memory.

My memory is getting better every day.

I have confidence in my memory, as it becomes more and more accurate.

My memory is getting stronger every day.

My thoughts transform into images, which are engraved on my mind.

I can easily recall any information I need, when I need it.

I have the power to remember everything I see, hear or read.

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My memory is my friend, and I can count on it.

If I want to forget an event, a thought, a person or an object, my memory obeys.

The more I use my memory, the more accurate and faithful it becomes.

Sublipower, Sublimemory, Edi Inter, 1989.

I now have complete confidence in my memory. It is now fully effective. I can control it under any circumstances. It absorbs everything I need to know, and provides me with the information I need, when I need it.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

MENOPAUSE

I am not at all worried about my life as a woman... because I can stay young... stay young for a very long time.

I feel good... I am relaxed... I am not worried... I am resolutely optimistic... at this age where women reach their full potential... A great life lies ahead... full of promise... and I feel good, wonderfully good.

I am going to manage my menopause and make it another, even more enriching stage in my life as a woman.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

MENSTRUATION

I know that the menstrual cycle should occur regularly every twenty-eight days, and not every thirty days as many people believe. It will last for four days, no more, no less, and the flow will be neither

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too abundant or too sparse, both before and during the period; I should not suffer from kidney or lower back pains, headaches or any other kind of pain, since this natural function should take its course naturally, without my having to suffer in any way at all.

Emile Coue, Complete Works, Astra Publications, 1976.

I am balanced and peaceful in all changes of cycles, and I bless my body with love.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

My uterus is tightening, emptying itself.
My uterus is becoming empty; I want it to be empty.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

MENTAL CONTROL

I take charge of my thoughts. I can do what I will with them.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I am responsible for the thoughts in my head.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

MENTAL FACULTIES (Also see Concentration)

My faculties are developing day by day.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

MENTAL FATIGUE

My thoughts are clear and precise, my mind is fresh and alert.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

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I do not hesitate to take a break from my work if I'm tired... to relax my muscles... to breathe deeply and restore my energy... or to relax my brain by emptying my mind.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

MENTAL PROJECTION

I develop my faculties of concentration and mental projection. I learn to project my mind and all my senses in the desired direction, to any place and any level in the universe.

Christian Godefroy, Mental Dynamics, Robert Laffont Publications, 1976.

I am learning to develop my five senses, my concentration, and to project my mind to any place and any level in the universe.

Christian Godefroy, Mental Dynamics, Robert Laffont Publications, 1976.

MENTAL RETREAT

In my place of retreat I am free, and I am in control of my subconscious.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

MERIT

I merit the best, and from now on only the best will come to me.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I was just talking about luck, but luck had nothing to do with it. I got that good grade because I deserved it.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

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I want to imitate the examples of those who succeed, of those who fear no obstacles. I want to merit and obtain success, joy, power and love.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

MIGRAINE (Also see Emotion)

I can relax at any time. My head feels cool... my head feels light... my neck and shoulders are supple and relaxed.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

In a few moments my mind will become clearer. The excess blood congesting my head is flowing back down to other parts of my body. Soon my headache will be gone.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I feel my head getting calm.
I feel my head relaxing, getting lighter.
I feel free of all mental stress.
I feel my head is normal, clear.
I am in control of my emotions.
I feel free of the past events which caused my migraines.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I will feel good today, my head will be clear and lucid.

Leslie M. Le Cron, Liberate The Forces In You Through Self Hypnosis, Tchou/Ariston, 1964.

I am going to free myself of migraines.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

My head is opening, becoming calm and light. Energy is once again circulating normally though my head, eliminating all fatigue and all tension. My blood is irrigating every part of my brain fully,

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bathing it in a soft light. My head is completely relaxed.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

My forehead feels pleasantly cool.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

My headache has disappeared.

Emrika Padus, Encyclopedia of Emotions And Health, Edi Inter, 1991.

Go away! Go away!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

MIND (Also see Memory, Concentration)

I use the vast power of my mind.
I concentrate my mind on one thing at a time.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I want to be mindful of everything because whatever I am aware of can inspire new ideas and opportunities.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

All the functions of my mind, like memory, attention, etc. are improving.

Charles Baudouin, Psychology And Practice of Self Suggestion, Idegraph Publications, 1990.

Like an eagle my mind was created to rise to great heights.
I rely on my aptitude for developing maximum mental power.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I affirm the existence of the Real Me.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

I will never use the power of my mind to do harm to others.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

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I rejoice in this Life which exists for me. I am an incarnation of the Mind of all life.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I AM everything of substance that is.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

[I am going to think with my mind and not my emotions. I am learning to think love in my mind, so that I will feel love in my heart.]

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

My mind is a divine center of operations.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

Everything is the Mind. When the Mind is well, everything is well.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

MIND PROJECTION

I want X (specify who) to be forced to reveal —— (specify what).

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

MIRACLES

The light in me is accomplishing miracles in my life, here and now.

The light in me is accomplishing miracles in my body, in my mind, and in my affairs, here and now.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I am the greatest miracle in nature.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

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Divine love is working in me here and now in order to create something.

The Christ in me is accomplishing miracles in my life, here and now.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

My own words create miracles in my life.

I expect a miracle.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

MISOGYNY

I will make an attempt to understand and appreciate feminine psychology so as to better comprehend the underlying motivations for my wife's behavior.

I cannot expect love and respect from my wife if I belittle or abuse her.

I must also remind myself that little courtesies, tender attentions and acts of kindness are as important to her as material gifts.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

MISTAKES

I collect my mistakes with pleasure. I consider them as tools for learning.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I have the right to make a mistake.

To err is human. I am a human being.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

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I nourish my conviction to rise above my mistakes.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I learn from my mistakes.

Sublipower, Sublisuccess, Edi Inter, 1989.

(My father thought that it is important not to make mistakes. But I have to learn how to do this work. I can only learn by trying. If I worry about mistakes I will stagnate, I won't learn anything.)

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I know that I am free to make mistakes, it is fine to make mistakes. I do the best I can. I always do the best I can within the limits of my awareness. Within the limits of what I know at any given time I do the best I can. I love myself, mistakes and all. I am a good person. I learn from my mistakes, and I am free to make them.

I am free to make mistakes. I can learn from my mistakes without guilt or worry. The past is over and there is nothing I can do about it.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

When I make a mistake or get ridiculed or rejected, I look at mistakes as learning experiences, and ridicule as ignorance. After a rejection, I take a look at my BAG - Blessings, Accomplishments, Goals. I look at rejection as part of one performance, not as a turndown of the performer.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

Here's a mistake I promise myself I'll never make again, with the help of God!

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

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MISTRUST

I believe everything —— (name the person) tells me about his / her activities.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

MISUNDERSTANDING

I make sure not to mistake a misunderstanding for a real disagreement.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

MODERATION (Also see Discernment)

I am happy to possess this or that object. I promise to use it wisely and in moderation, so that I get as much pleasure as I can from it.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

When I reprimand someone or express my unhappiness I try to do so after the urge to fight or become upset has subsided. The best way to get my feelings across is when I can speak in a normal voice, without all of the warlike body language. When I am upset I try a substitute physical exercise such as running, tennis, racquetball, or handball, in which there is impact involved to release the built-up adrenaline in my system. I do speak my mind, but I criticize the behavior without attacking the other person.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

Everything has its just measure, and I respect it.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

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I am going to observe moderation in everything I do.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

MONEY (Also see Business, Luck, Competence, Creation, Projects, Debts, Vocations)

From now on I have more money at my disposal than I need.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I earn more money than I spend.

Christian Godefroy Collection, Magic Formulas For Being Happier And More Successful, Godefroy Publications.

I manage my affairs wisely and confidently. I earn enough money to satisfy my needs.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I don't dislike money... it gives me security... and I know that I can make money if I want to.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

I can do anything I want to extremely well, including making money.

J. Martin Kohe, Your Greatest Power, A Different World Ltd., 1979.

I am receiving plenty of money for doing exactly what I want to do.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

I am mentally and spiritually connected to the money I gave ——— (name) and it will come back to me multiplied and magnified in the Divine Scheme.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

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I bless you so that you can bless others in turn. May you enrich everyone you touch. I thank God on your behalf, but I thank Him even more for the thousands of others like you. I bless this infinite abundance. I thank God for it, and receive it with an ever more open mind.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I find the money I require to buy the car I need.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

Money is energy, and I control its flow.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

Money makes me, and the people close to me, happy.
Money allows me to help others.
Money comes to me without effort.

Christian H. Godefroy, Prosperity: The Subliminal Method, Godefroy Publications, 1987.

Money comes to me freely.

Louis Proto, Self Healing, Piatkus Publications, 1990.

Life places people on my path who can help me progress financially.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

On the first of —— (month), 19— (five years from now) I will have $50,000, accumulated gradually over a 5 year period. In exchange, I will do my best to provide excellent service as a (describe the service or merchandise) salesman.

I firmly believe that I will have that money. My conviction is so strong that I can already see it in front of me. I can touch it... it's there waiting for me to take it. I instruct my subconscious mind to come up with a plan that will get me that money, and as soon as my subconscious mind forms a plan I will put it into action.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

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I become more financially comfortable every day.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

MOODS

From now on I will be in a good mood more and more often. Joy, happiness and serenity will become my normal states of mind.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I am going to devote time to studying the reasons for my mood swings.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

MOROSITY

I greet this day with a heart full of love.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I no longer think there is no point to life. I use the principles of truth to discover goals in life.

Life is worth living when I understand the value of the richness of life.

My life becomes richer and fuller when I can free myself from my negative self and the errors that part of me commits.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

Oh, what a wonderful day for going out and enjoying what the world has to offer!

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

This is the day God has made; I will rejoice and be happy on this day. I thank God for the abundance of life, I thank God for lasting love. I thank God for joy. I thank God for magnificent health, I thank

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God for infinite abundance.

I have awakened to a new day. I feel at one with the birds and with all living creatures, celebrating this new day with a burst of song and thanksgiving. God, I thank You for the abundance that is mine.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

MOTIVATION

I like ——— (specify an activity which you like but which you haven't had the courage to undertake.)

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I feel rich! I feel happy! I feel great!

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I enjoy my professional activities.

I am enjoying the new project I'm working on.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I show my self respect through this inner motivation which keeps me on the path of achieving my goals, on the path of success, even if I fail now and then.

I am my goal.

I am success, even before I attain it, since I am already on the path of full realization.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

If I want to achieve permanent, sustaining success, the motivation that will drive me toward that goal must come from within. It must be personal, deep-rooted and a part of my innermost thoughts. All other motivation, the excitement of a crowd, the stimulation of a pep-talk, the exhilaration of a passing circumstance is external and

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temporary. It will not last.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

MOTIVATION - SCHOOL

After I finish this lesson I can go and watch the football game.
I'll do three more chapters, and then I can watch the movie on TV.

Professor Kurt Tepperwein, How To Learn The Painless Way, Godefroy Publications, 1983.

MOVING

I'm soon moving to a really nice apartment that will make my life more stimulating.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

MUSCLES

Every muscle in my body is controlled by my Muscle Coordination Center.

Franck Rudolph Young, Cyclomancia, SIP, 1966.

My muscles are relaxed and warm.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

My muscles are strong and supple.
My muscles are supple and healthy.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

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MUTUAL AID

Every day I find occasions to help my peers and accomplish constructive things.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

MYOPIA (See Nearsightedness)

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NAIL BITING

Every time I bring my nails to my mouth to bite them, as soon as I put my nails in my mouth, I will experience an extremely bitter taste, and the taste will get more and more bitter, more and more unbearable to the point where I will feel sick and want to vomit.

Gradually, as I grow up, I will become more and more attractive. So I don't want to harm my appearance by having ugly hands; beautiful hands with well trimmed nails will make me even more attractive, and for this reason I will make a determined effort to stop biting my nails.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

I no longer feel any need to bite my nails. I find it easy to break the habit, and my hands are becoming beautiful and elegant.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

NATURAL

I am natural and confident.
I act as naturally as I feel inside.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

NEARSIGHTEDNESS

The lens of my eye, too rounded (too convex) ... is relaxing.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

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NEED

I have legitimate needs and wants. I can choose what I need and want without having to justify it to anybody. I make choices, and I take responsibility for them.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

It's all right to meet my needs as I see fit.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I express my needs honestly, listen to the needs of others, and look for the deepest truth.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

I first understand my own needs, and then the needs of others.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I can invent new ways to satisfy a need and wisely choose the best option.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I am secure enough to grow. I ask for what I need. All my needs will be fulfilled.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

The universe always provides for my needs.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

What I say, I get.
And I always have everything I need.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

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NEGOTIATING

I know how to break off negotiations if I have to.

My negotiations always result in clear, explicit and concrete agreements.

Before negotiating I clearly define my objective(s) in order to know exactly what I want and what I don't want to happen.

Before negotiating I clearly define my bottom line (without necessarily telling the other party) in order to use dissuasive strategies without being forced to walk away from the table.

When I negotiate I try to remember that any business relationship is comprised of one part cooperation and one part competition, each of which may predominate according to the time and circumstances.

I am careful not to get boxed into an undesirable choice: friend or enemy, trust or mistrust, cooperation or competition.

I make clear pronouncements of the points of agreement as they occur.

I know how to break down my negotiations, so that the discussion about one clause does not systematically bring into question all the clauses already agreed to.

Breaking down the negotiating agenda allows me to remain firmly opposed to the other party on certain points.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

If I negotiate without having the power of decision, I make sure the scope of my delegated authority is clear in my mind, and in the minds of everyone involved.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

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NERVOUS BREAKDOWN
(Also see Nervousness)

From now on I will no longer be taken by surprise as I was in the past; every time I feel a nervous attack coming on I will be warned by certain symptoms; but these symptoms will no longer frighten me at all, because at the same time as I feel them I will hear a voice inside me saying, as quick as lightning, "No... no... I will not allow this breakdown to happen. My nervousness is disappearing... it has disappeared."

Emile Coue, Complete Works, Astra Publications, 1976.

NERVOUSNESS (Also see Agitation, Anxiety, Fear, Nervous Breakdown)

I always act calmly... without making needless gestures... and I never swear in moments of impatience.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I don't have to be nervous and tense. I am capable of relaxing. I have learned how to relax my mind and body.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I want to dominate my anxiety, fear, nervousness and any other paralyzing emotions.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

When I find my Real Self, nervousness disappears forever.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

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NERVOUS SYSTEM

My nervous system is making amazing progress. I am affecting it in two ways, which makes my influence doubly effective. Firstly I influence it directly through suggestion, since the nervous system is directly related to the brain; secondly I influence it indirectly by improving my general state of health, since the nervous system is also affected by the body's general state. My nervous system is becoming more and more sensitive and vibrant, as it should be, and at the same time it is becoming more and more calm, strong and resistant, as it also should be.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

NEW BEGINNING

I am making a new beginning towards a new and better life, and I will get involved with other people.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

NOISE

Noise doesn't bother me... I know how to adapt to any situation... without becoming nervous.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

NOSTALGIA

I should not be nostalgic about the past. I should think about today.

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Today is the day I should be living.

I am doing all I can to love this day.

I will use this day to express my positive qualities freely.

I am ready for a day of confidence and accomplishment.

I combat negative emotions which will destroy my having a good day.

I call on my positive qualities: life is lived in the present.

I nourish my enthusiasm for the present moment.

I will use this day to try and express the best of myself.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

The good old days are here and now!

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

NOVELTY

I like to invite people with very diverse opinions about things. I seek out novelty instead of limiting myself to conventionality, where the unpredictable is excluded.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

NUMBNESS

I want (specify which part of your body) to become numb. I impose my will.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

My hand feels dead, completely numb... and this numbness will soon move up into my wrist, my forearm, my upper arm, right up to

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my shoulder... I can feel it moving upwards... my whole arm is becoming numb... there is no feeling at all... it is becoming more and more numb... my whole arm is dead... numb... completely numb.

Marcel Rouet, Techniques And Practise Of Hypnotism, Paris Productions N.O.E., 1974.

NUTRITION

I only eat foods which are good for me.

I only eat foods which are healthy and which help me maintain my ideal weight.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I put only the best fuel into my body.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

[I am constantly fulfilled in my life. Since I know life, I nourish myself with joy. I construct my body in a balanced way.]

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I am going to eat good wholesome food and not overeat, or overindulge in foods that are not good for my health.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

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OBESITY (Also see Nutrition, Physical Exercise)

I respect my body, I care for my body, I need my body to live.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

I am gradually reaching my ideal weight.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I maintain my ideal weight. It's easy to do because I exercise and eat in a balanced and healthy way.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I never eat between meals.
I chew my food very slowly.
I don't eat food that contains wheat.
I don't eat food that contains sugar.
I don't eat standing up.
I visualize the body I want.
I eat smaller portions.
I don't need to be encouraged not to overeat.
I like myself and I want to be the best I can be.
I persevere until I attain my goal.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

Losing weight through self hypnosis will keep me from developing health complications associated with obesity, such as hardening

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of the arteries, coronary disease, diabetes, etc.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I stay at my ideal weight no matter what I eat.

Sublipower, Sublihealth, Edi Inter, 1989.

OBJECTIVES (Also see Goals, Self Control)

Every day I make progress towards attaining my objectives.

Every day I continue moving forward by trying as much as possible to avoid the hazards of life. To do this I summon my inner resources to lead my to my objectives.

I learn to attain my objectives by mastering my fears and rejecting my negative emotions.

I choose realistic objectives and then work on attaining them.

I concentrate on my objectives.

I try to attain my objectives every day. I break out of the prison I have created for myself and strive to reach my objectives.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

It is easier and easier for me to realize all my dreams.

Christian H. Godefroy, Prosperity: The Subliminal Method, Godefroy Publications, 1987.

I have clear objectives which guide me in determining my priorities.

I often review my priorities in life, my professional and personal priorities, in order to discern convergencies or contradictions, and any lack of coherence.

I define my priorities in order to make them concrete, stimulating, and attainable.

I am make sure to explain my objectives to superiors and subor-

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dinates.

I work on my objectives.

For each objective I strive for harmony between the objective itself, the results it yields and the methods used to attain it.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I easily attain all the objectives I set for myself.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I make a list of goals that I hope to achieve for the day. I visualize myself accomplishing each goal in the best way. I write a note of thanks that I've reached my goals.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I establish my objectives and then use the resources I possess with devotion and perseverance in order to obtain the desired results.

When I keep my mind fixed on an objective I increase my chances of attaining it immeasurably.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I make sure my objectives are clear to myself.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

I set precise objectives and deadlines for myself.

Sublipower, Sublisuccess, Edi Inter, 1989.

I set my objectives, write them down, and review them often.

My objectives are a clear illustration of my future!

I spend a few minutes every day reading over the file of objectives I've written for myself. I read over my objectives every morning after I get up, and every evening before going to sleep.

My objectives are very precise. The more detailed and precise they are the better I can visualize them and make them a concrete part of my life.

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I set myself an objective. I don’t hesitate, but start striving to attain it. I know the universe is overflowing with opportunity. Look at what I can do! Where I can go! Look at what I can accomplish, simply by saying “Yes!” to myself.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I never lose sight of my long term objectives.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I’m in my car driving towards my destination. I’m in the driver’s seat, and I don’t let anyone else drive my car. I am the driver. If I get to a dead end I back up, turn around and continue my journey towards my objective.

I remind myself to concentrate on my objective all day long.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I eliminate this objective for such and such reasons. I realize I no longer need it, or no longer want it. My initial idea is now only a memory of a desire. It has no more power or effect on me. It no longer interests me. I am now concentrating all my interest and all my energy on a new and better objective.

Raymond Hull, Wanting Is Power, Les Editions de l’Homme, 1969.

My objectives in this situation are important. If I don’t achieve them, I’ll be disappointed and it will be inconvenient, but it will not be a catastrophe or a horrible event. By thinking about negative results as a catastrophe, I’m creating tension and fear that actually reduce my chance of success.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

OBJECTIVES - FINANCIAL

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In one year I will find the $———— I need to buy a house.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

OBLIGATION

I always respect the obligations I accept. I never accept obligations which I cannot respect.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

OBSESSION

I am now calmly and confidently concentrating my mind on another subject.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

If I cannot meet such and such a deadline, I won't let it become an obsession. I am satisfied knowing I've done my best.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

OBSTACLES

I eliminate the word impossible from my vocabulary!
I possess the means to overcome all obstacles.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I can overcome obstacles by mentally flying over them.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I will take care of all kinds of obstacles as I encounter them. I will go as far as I can, and when I get there I'll be able to see even farther.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

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I was born to win, to succeed. I am very prosperous, and through the power of God I overcome all obstacles and all problems. I am happy, joyous and free.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

I can overcome anything, and see everything through to the end.

George Barbarin, How To Overcome Fears And Anxiety, Dangles Press, 1974.

Up to now no problem has been able to get the better of me: I'll overcome this one as well.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

Now everything will work out.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

The greatest obstacle to my success lies within me. What prevents me from doing what I want to do is my belief that I cannot do it.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

OFFERING

The more I give the more I receive and the happier I feel.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

OPINIONS

I don't have to give up my opinions for those of another person just because that person seems sure of him/herself.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I can refuse to discuss my opinions or try to convince someone of the logic of my position, and simply believe that I am right.

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When I buy clothes or other personal objects I have confidence in my taste, and I don't start by asking advice from someone whose opinions I deem to be more valuable than my own.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

Other people can disagree with me without it affecting me.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

OPPORTUNITY

I take action! I seize opportunities!

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I readjust my objectives according to circumstances, in order to exploit opportunities to their fullest.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am always at the right place at the right time, doing the right and successful thing.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I take advantage of every opportunity.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

A favorable opportunity will give me a sign if I am meant to see it; I am on the lookout for opportunities, and I always try to take advantage of them.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

OPTIMIZING

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I always try to make the next hour better and more productive than the one that has just past.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

OPTIMISM (Also see Depression, Inspiration, Positive Thinking)

Whenever my attention strays from what is constructive and positive I immediately concentrate on things that are good and beautiful.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I love life... it's wonderful... full of all kinds of surprises and sudden developments... I never get morose... I'm never bored... because I only see the good side of things.

I stay away from pessimistic people... people who criticize and complain all the time... who are never satisfied with anything... instead I seek out spiritual people, people who radiate health, and whose inner life is calm and serene.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I listen to upbeat, inspiring music. When I am getting ready for work or school I turn the radio on to a good FM station. I stay away from the morning TV news. I can brief myself by scanning the news on the front page of the Wall Street Journal. I resist the temptation to waste time reading the sordid details of someone else's tragedies. I listen to music or cassette tapes in my car. If possible I have breakfast and lunch with an optimist. Instead of sitting in front of the TV at night, I spend time listening to and being involved with those I love.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I use positive words. Never negative words. I use the RIGHT WORDS!

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

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I inject myself with optimism.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I always expect the very best for myself.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I feel good, very good, my life is going wonderfully well. I have no reason to be afraid. I never get depressed. I'm an optimist. I have confidence in the future, the people close to me love me, my colleagues respect me. I do my work well. I have no fears about the future.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

One of the best ways to make other people happy is to spread optimism and good humor. Every one of my words and actions can contribute to that.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

OPULENCE

I am ever thankful for God's riches, present as always, unchanged and abundant.

Dr. Joseph Murphy, Miraculous Power Attracts Infinite Riches, Godefroy Publications, 1978.

ORDER

Order which is the Spirit is, from this moment on, a part of all my affairs, a part of the way I use my time, a part of my body, my thoughts, my mind and the world.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

Now I put my life in order as I prepare to accept all the good that awaits me.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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ORGANIZATION (Also see Efficiency)

I accomplish my tasks in order of importance.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I am well organized in my work.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I possess an organized and orderly mind, and that shows in the way I live.

I am very organized. Every night I draw up a list of tomorrow's activities. I establish my priorities and I stick to them.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I take time out to think about the problem at hand, and then I act scientifically.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I get the best out of my time.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

ORIENTATION (See Choice of Profession)

ORIGINALITY

I will find the original me when I eliminate all acquired perceptions concerning myself. I am eliminating them.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

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OUT OF BODY EXPERIENCE

I know that I can condense my identity and appear in a distant place.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

OVERWORK

I have the right to take my time.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I have the right to live in the present.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I have the time I need to do what I want to do.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I keep my Workaholic firmly under control.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I can stay relaxed and focused on my timetable.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I am relaxed and balanced. I have all the time I need to do all the things I have to do.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

My days unfold tranquilly, at the pace I like. I am satisfied with my accomplishments, and with my life. I am affectionate with the people close to me, and greatly appreciated by those around me. I react positively.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

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P

PACE

I adapt my pace to the activity I am engaged in. I make sure to work at the right pace.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

PAIN (Also see Hepatic Colic, Illness, Wounds, Anesthesia)

Soon the pain will pass. I will feel fine.

Leslie M. Le Cron, Liberate The Power In You Through Self Hypnosis, Tchou/Ariston, Forces

As soon as I press the nail of my thumb against the inside of my little finger I will block all the nerves conducting the pain.

A wonderful feeling of calm and security will pervade my body... as long as I keep pressing my thumb nail against the inside of my little finger I will feel no pain... I will feel completely fine.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

I eliminate the pain.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

I relax my entire body and forget about the pain.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

I concentrate on calming my body down. I am completely relaxed,

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and feel this sense of relaxation throughout my whole body. I don't think about the pain at all. Instead I savor this beneficial sensation of total relaxation.

As I count down from five the sensation of pain will diminish. Each number eases the pain even more. When I reach the number one the pain will be completely gone. Now I'm counting down... five... four... three... the pain is disappearing... two... one...

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

Energy circulates harmoniously in me. A wonderful wave of heat and well being spreads throughout my body, which is becoming light, very light and pure, full of light and life. My pain dissolves and disappears completely in this wave of light and heat. The power of life flows and spreads through my regenerated body. I am completely healed.

Charles Baudouin, Psychology And Practise of Autosuggestion, Idegraph Publications, 1990.

Pain is sometimes caused by, and always amplified and aggravated by nervous tension and anxiety... Therefore as soon as I relax I start feeling better. And gradually, as I become more relaxed, the pain gets less and less intense. And now I feel so totally and completely relaxed that the pain is gone.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

My pain is disappearing. Soon I won't feel it at all, it will be completely gone. I'm already suffering a lot less, less and less... In an hour (or in a few minutes - set a time limit) I will not be suffering at all.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

PARALYSIS

God has not given me a fearful mind, but a mind full of power,

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love and health. My faith is in the curative powers of God, my creator. I am relaxed and peaceful. Each one of my nerves is also one of God's ideas, and I feel revitalized, energized and healed. I give thanks to God.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

PARTNERSHIP

I find the partner I need to help with my work. Our association will be mutually profitable.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

PASSION

The only way to be happy and make a lot of money is to do what I really like to do.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

PATIENCE (Also see Understanding)

It's easy for me to be patient, understanding and just.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

When I have to wait I do so without getting impatient... by using the time to relax.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

Nothing can stop me today. If I need some extra determination, I'll find it! If I need extra energy and drive, well I've got it! Whatever task or problem awaits me, I have the power and the patience to over-

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come it.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

PEACE (Also see Joy, Love, Wisdom, Prosperity, Health, Success)

God, my Father, all my thoughts are of You. My body, my heart, my intelligence, my soul, my mind, depend on You. In You I find refuge, light and life.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

I inhale the peace of God, and exhale the peace of God for all.

Dr. Joseph Murphy, Miraculous Power Attracts Infinite Riches, Godefroy Publications, 1978.

I am completely relaxed physically and intellectually. I am free. I believe in the wisdom of God and I feel my mind filling with His peace. I feel it right to the bottom of my heart and my being.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I am at peace with myself and with others.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

Peace is in me... peace reigns in this home.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

The current of God’s peace flows freely through my whole being, and I am immersed in the peaceful river of God at this moment.

I am relaxed and calm. I am at peace. A peace which goes beyond understanding fills my mind. Peace is in my home, in my heart, and in all my affairs.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

Joy now flows freely through me, and I am at peace with life.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

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I raise my soul towards you, Lord.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

PEACE OF MIND

I am at peace with myself.
My mind is at peace.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

PERFECTION

I am whole and complete unto myself.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

My life unfolds in total perfection.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I am perfect.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I always try to improve myself, eliminate my faults, resist my negative impulses and become a better and more perfect person each day.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

PERFECTIONISM

It doesn't bother me to be imperfect.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

I stop trying to attain perfection in myself.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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I stop making it an obligation for me or my children to succeed at everything we undertake.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

I always do my best. Each thought and action is the best I am capable of at the time. Because I'm human, I make mistakes. I accept my mistakes without blame or judgment. When I make a mistake I learn from it. I am imperfect, and I forgive myself for my mistakes.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

PERFORMANCE (Also see Self Image)

My concentration always improves when I make an effort... concentrating allows me to unite all my energies into one effort... and thus improve my performance.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I maintain and develop my image of technical performance.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

One of the best, quickest and most effective ways to improve my image and my performance is to be part of an organization which has useful goals.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

PERFORMANCE - SPORTS

In a short time I will regain my superiority.

I'm sleeping more and more deeply... more and more deeply... I take pleasure in competition because I know my performance is improving day by day... day by day my performance is improving... I

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feel very good.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

PERSEVERANCE

It is still too soon to abandon everything, and I won't give up.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I keep trying.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I'll go that extra mile.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I tell myself to persevere and attain my objective; I refuse to be swayed by doubt and fear.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I never forget that my life belongs to me. I continue trying. If I can't make it on my own, someone else will probably help. But I keep trying and I persist.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I persevere until I succeed.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I will persevere until I succeed.
As long as there is a breath left in me I will persist. Because I now know one of the most important elements of success - if I persevere long enough I will win.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I persist with my dreams; they'll become real.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

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I will stay healthy and generate new strength which will help me want to act with perseverance.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I am strong... I succeed at everything I do because I persevere... I see things through to the end... I am conscious of my power!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I want to play an active role and dedicate all my strength to attaining my goals. I will persevere despite all obstacles because I am certain that properly directed willpower can overcome anything, if the goal is just and honorable.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

Once I make a decision I persevere in carrying it out for as long as I believe I am right.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

If I don't succeed on the first attempt I try again and again.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

PERSONAL AFFAIRS

I am very efficient at taking care of my personal and/or family affairs.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Editions, 1981.

PERSONAL DEVELOPMENT

I am changing my life. I experience a deeper connection with my true self. I am excited about my growth.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

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PERSONALITY

I am asserting my real personality more and more every day.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I do what I have to do, and you do what you have to do.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

I don't try to do better; I try to be different.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I don't imitate others. I try to understand my personality fully, and be myself.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I don't compare myself to others.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I am not inferior. I am not superior. I am simply me.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I'm not going to let myself imitate the undesirable personality traits of other people.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I'm not here to live the way you want me to.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

I make a firm decision to be myself and not an imitation of somebody else.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am me and you are you.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

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I am me.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I am a unique being and I express my self fully, aiming for success and wealth.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I am unique and I like it that way.

Sublipower, Subliconfidence, Edi Inter, 1989.

I am unique, from head to toe. I may resemble other persons, acting and speaking like them, but I am not them, I am me.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I want to acquire constant calm, imperturbable self assurance, and justified confidence in myself.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1973.

My personality is who I think I am.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

The more I express myself, the happier I feel.

Louis Proto, Self Healing, Piatkus Publications, 1990.

You are not alive to live the way I want you to live.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

PERSUASION

The most persuasive influence I have over others is my mature personality.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

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PESSIMISM

I forgive myself for holding on to negativity, and now let go of it.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I will not allow my personal opinions to distort the facts in a negative and pessimistic way.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

PHOBIAS (Also see Fear, Negative Thoughts)

I am in harmony with God, and I have nothing to fear.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

My phobia is afraid of me because it knows I am much stronger than it is. I am at ease, perfectly relaxed and confident of my strength. I smile because my phobia has no more power over me. It is unimportant.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

Little by little I see these fears, these ideas, these phobias appearing less and less frequently in my mind; they are getting weaker and weaker, less and less tenacious; they have less and less influence on me; I am eliminating them right now by repeating the formulation: "It's over, it's all over..."

Emile Coue, Complete Works, Astra Publications, 1976.

PHYSICAL STRENGTH (See Strength - Physical)

PLANNING (Also see Money)

Above all it is essential I obtain such and such results, which will

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bring me closer to my ultimate goal, whether materially, or by increasing my worth or my power.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

I have finally come up with a working plan, and I intend to stick to it.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

Every day I draw up a list of things to do.
I determine the time required for each activity.
I allot some time for pauses, unexpected events, and a margin of error.
I draw up my list of things to do every day.
I make plans.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I study, I think, I take the time to make plans!

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I do high priority work first. I set my priorities on a must-do-now, should-do-soon, and would-like-to-do-when-possible basis.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I gave myself orders and I carried them out.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I never waste my time because I plan. And since I always stick to my schedule, I have enough time to accomplish what I choose to do.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am in control of my time. My time is the very essence of my life, and I take control of it.
I create as much free time as I like, and I know how to delegate.

Christian Godefroy, The Creativity Method, Godefroy Publications, 1992.

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Planning builds self confidence. I know beforehand what I am going to do each day. This enables me to develop self discipline, which is so essential to success.

Planning gives my life direction. I must know where I am going, the goals I wish to attain, and how not to dissipate my time. As my plans materialize I become inspired by a sense of achievement.

Planning enables me to get more fun out of life. The habit of day to day planning should include time for enjoyment of life whether it is reading an interesting book, listening to soothing music, playing golf or other sports, seeing a good movie or play or anything else that will relax my mind. To be happy I must make plans for happier living.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

When I plan, I don't just plan FOR the future, I plan so that I will HAVE a future.

This task needs to be done but I can't do it right now. I'm going to schedule a time when I know I'll be able to do it and stick to that schedule. If I don't there's a good chance I won't get to it. Now that I've scheduled it I can forget about it and concentrate on the job at hand.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I choose which Concepts, Contacts and Commitments warrant the most attention and effort. I am responsible for which of them become contractual, with priorities and deadlines. I create my own track to run on - slow, medium, or fast - in my commitments.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I finish each task before moving on to the next one.

Sublipower, Sublisuccess, Edi Inter, 1989.

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PLANS

I am open to new points of view, perspectives and plans.

God as Understanding knows what I should know, and I am united with this universal Understanding so that I know everything I need to know.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

From now on I live in harmony with the divine plan assigned to my life.

From now on I recognize, accept and conform to the divine plan of my life, as it is revealed to me step by step.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

Talking about ideas and plans needs to be balanced by trying them out. Theory and practice converge into wholeness. I field-test my ideas.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

Starting today I will become the architect of my life.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

PLAY

(I am free to enjoy myself any way I want.)

Louis Proto, Self Healing, Piatkus Publications, 1990.

I take time to play like a child.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

PLEASING OTHERS

I please everyone I meet. I have confidence in life because I have

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confidence in myself. I know I can count on this immense reservoir of energy that is within me, and which attracts others. I radiate the energy that is mine.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

I want to please everyone.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

PLEASURE

I begin the day with pleasure!

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

PLEASURE - SEXUAL

I deserve love and sexual pleasure.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

PLEURISY

I call on the forces of nature to help heal me. I absorb the curative forces of nature and unite them with my own. I eliminate the gas and other waste products which are making me ill.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

POSITIVE MENTAL ATTITUDE

I like people and people like me.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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I am learning to love instead of suffer! I am learning to love what I hated, and transform negative forces into positive energy. I am forging a path towards happiness. I react positively, even if it takes a great effort at first. And I remain positive even if an adversary is not as positive as I am. I notice the changes this is producing in my life and in the way people see me.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

Whatever the situation, I always adopt a positive mental attitude. And I succeed thanks to my positive mental attitude.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

Every morning I am going to condition my mind and instill a positive mental attitude for the rest of the day.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I am developing a positive mental attitude.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

POSSESSION

I can have anything I want!

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

POSSIBILITY

I always exceed my possibilities.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

POTENTIAL

I awaken the giant within me!

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

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I nourish my real potential.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

POVERTY

I will buy it! I'll get it!

J. Martin Kohe, Your Greatest Power, A Different World Ltd., 1979.

My inner Guide is the spirit of plenitude and will preserve me from all misery. I will lack nothing.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

POWER (Also see Self Confidence)

I can do anything.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I can.
I can do it if I believe I can!
I can make it if I believe I can!

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I possess a great and marvelous power.

J. Martin Kohe, Your Greatest Power, A Different World Ltd., 1979.

I could do it.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

When I want to do something within reason, or when I have to do something that is my duty to do, I always imagine that whatever I do is easy. May words like difficult, impossible, I can't, it's too much for me, I can't help myself... and so on, disappear from my vocabu-

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lary. They are not English. I don't understand them. What I do understand is: it's easy, and I can do it.

Emile Coue, Complete Works, Astra Publications, 1976.

Each day brings me more strength and power.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

Day by day, in all ways, I am becoming more powerful and confident.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I possess vast power which I have not yet realized.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I am united through my inner Guide with an inexhaustible source of health, courage, abundance and prosperity. It fills me with strength and spirit. It provides me with everything I need to move forward ceaselessly. I am confident in its power; it is my strength and my wisdom. It makes me strong and independent of things and people. I am persevering, strong and courageous. I am strong!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

My constant contact with God gives me the power of an eagle soaring above the clouds and the humility of a gentle dove.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

POWER - PSYCHIC

I am learning how to use my mind in extraordinary ways, like mastering my psychic powers, and I am becoming a different person.

Franck Rudolph Young, Cyclomancia, SIP, 1966.

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POWER - SPIRITUAL

I can touch the sky. I can be big. I can fly if I want to - I can do anything.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

POWER - SUBCONSCIOUS

I have unshakable faith in the power of my subconscious... unshakable faith.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

PRAISE

S/he worked hard to get the promotion s/he wanted. I wish him/her well.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I allow others to love me and praise me.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

PRAYER

God has received my request.

Richard Ingalese, The Power Of The Mind, Dangles Publications, 1981.

May my comings and goings be done in all honesty, and in the full light of day; not in disorder and drunkenness, not in licentiousness, not in anger or envy. I place my faith in our Lord Jesus Christ, I care nothing for the needs of my body, or for my frivolous desires.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

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I pray, I really pray.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

PRECAUTIONS

I care for myself enough not to expose myself to physical risks or emotional damage.

Louis Proto, Self Healing, Piatkus Publications, 1990.

PREGNANCY

I await my pregnancy with pleasure.
I will be happy to be pregnant.
I want to get pregnant.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I feel marvelous... I know the birth will be easy.

I'm enthusiastic about the prospect of having a wonderful child.

My thoughts have a positive influence on the health of my child... on his development. If I am assailed by negative thoughts I always remember that they can hurt my child... and I immediately replace them with joyous, optimistic thoughts of a radiant future.

Everything is going fine... I am firmly optimistic... firmly optimistic. My pregnancy is progressing normally... and will continue to do so right up to the birth, which will be easy... very easy.

I know that my child is developing perfectly. I am sure to have a beautiful baby... a superb, magnificent child.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I will not suffer from morning sickness.
I'll get my figure back after giving birth.

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I am thrilled at the idea of waiting for my baby.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

PREJUDICE

I am now dissolving all my negative and limiting prejudices. They no longer have any power over me.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

PREMATURE EJACULATION (Also see Impotence)

I control my ejaculation.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

PREOCCUPATION

Everything is going very well.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

PRESSURE

I choose not to spend my life trying to live up to other people's expectations. I don't let others pressure me with their beliefs unless I accept them.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

When external pressures become too strong I call on my inner strength to combat them; to do this I mentally review the successes I

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have already achieved.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

PRIDE

(I am proud of my accomplishments and goals.)

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

PRIORITIES

I have enough time for my priorities: 80% of the time, every day, I work on two out of three priorities.

I set deadlines and time limits for myself, and I ask others to do the same.

I regularly sit down and review my priorities.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I re-evaluate my priorities.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I am a person who is responsible and I act in timely manner to reach my goals and priorities.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

PROBLEMS

Before attacking a problem I try to formulate it in terms of "How to do what for whom?"

Before attacking a problem I ask myself, "Am I really determined to resolve this problem?"

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If the problem consists of choosing between a relatively small number of clearly defined options, I use the “Pros and Cons” method.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

All right, here’s the problem. I look at it calmly and carefully study its elements. I consider its implications. I take time out for careful reflection. And above all... no emotions!

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

This is my problem. I can do anything I want about it. I know the answer to everything. I will find the solution.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

It works!
My subconscious knows the answer to all my problems.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

Tonight my subconscious mind will resolve the problem of — (specify). When I wake up tomorrow morning I will remember the solution, either as a dream, or as a flash of inspiration during the day.

Christian Godefroy, Mental Dynamics, Robert Laffont Publications, 1976.

In quietness I find the answer to every problem. Everything I need to know is inside me.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I am learning to see problems on a higher level of understanding. They seem to solve themselves under my very eyes. I try to approach a problem as if I had no connection to it whatsoever. This prevents me from clinging to prejudices and ideas which are impossible to realize, and allows me to access a higher level of understanding. In fact a problem can only be solved when it is completely understood.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I seek an end to all problems.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

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I know that the resolution of my problem depends on me: the answer is in me because God is in me. I now feel calm and relaxed. I am at peace. I know that confusion never comes from God. I am now in harmony with the infinite. I believe and know that infinite wisdom will reveal the correct solution to me.

I know that all problems can be solved when the mind is calm. I confide in God because He knows the answer. I am at peace.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I attack the problems of life without being afraid to make mistakes, and thus I break free of my chains.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I'm not afraid of problems, I solve them. I don't try to ignore them, I confront them. I don't avoid them, I conquer them!

I know that every problem's solution has a key. Therefore the clearer the problem is, the better I can determine its solution.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I can easily resolve — (specify the problem).

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

I look at each problem as an opportunity.

Christian H. Godefroy, Self Confidence: The Subliminal Method, Godefroy Publications, 1987.

I overcome any problems easily. My life is enjoyable and positive.

Vera Pfeiffer, Positive Thinking, Element Books, 1989.

I know my victory over my problems is certain because I know that my intelligence is a part of God.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

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I know you have the answer to this question and I know you will give it to me when you are ready. I will wait patiently, in complete confidence.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I see you with the eyes of love. There is a harmonious solution, and I accept it now.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

Easy is right.

Louis Proto, Self Healing, Piatkus Publications, 1990.

Only living beings have problems. The more problems I have, the more alive I am. I am happy to have these problems.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I relax and let divine wisdom and the divinely accurate action of my subconscious mind resolve this problem. I disassociate myself from the problem and let things take their course.

Dr. Joseph Murphy, Miraculous Power Attracts Infinite Riches, Godefroy Publications, 1978.

I offer thanks to my Father for His Divine solution.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

PROCRASTINATION

Today I will do my work without wasting time.

I have finally decided to correct my habit of putting things off for later.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

Right now is the best time.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

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This task is important and it's the kind I might procrastinate on or forget to do at all. I'm going to do it now and get it out of the way. It won't be hanging over my head and I'll be mentally free to concentrate on my other work or just relax.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I act immediately.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

It is my duty to finish what I begin.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I stop worrying about what I can't do now, and do what I can do with all my heart and soul.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I always do what I have to do on time.

I immediately transform all indecisiveness into ACTION, and so I stop stalling.

I don't let chance decide for me. Since I can make decisions rapidly, stick to my convictions and act in consequence, I have no time to stall around.

I have learned to recognize all the arguments that tend to drag me down, and I avoid them instead of avoiding the tasks I encounter in the course of doing my work.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I do everything I have to do at the right time.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I do it now!

John Clark, Do It Now, Godefroy Publications.

I'll do it without wasting a minute.

W. Clement Stone, Passport To Success, Godefroy Publications, 1962.

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I'll do it right away... I'll do it immediately!

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I set to work immediately and passionately.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I will not neglect today's tasks by putting them off for tomorrow, because I know that tomorrow never comes.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I profit from each day: I don't put off what I have to do, and I do it with joy.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

When I'm faced with a problem I solve it right away if I have all the facts. I don't put off making decisions.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

If I want to succeed I have to start this very day.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I do everything I undertake with care, and I complete it before moving on to some other occupation. I never put off for later what I should and can do now.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

PRODUCTION

I am satisfied with the results produced by my working time.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

PRODUCTIVITY

Whenever I make a change in my life, from the current way I am

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doing something, I anticipate a temporary drop in productivity and efficiency. I don't worry if a change I made in profession or lifestyle isn't bearing fruit right away. It takes time for a change to be assimilated. As familiarity and confidence rebuild, productivity will increase again. I don't stew, I let it simmer for awhile.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

PROFESSION (Also see Wealth)

I deserve to have a profession that satisfies me 100%, and which gives me the opportunity to develop and enrich myself beyond my expectations.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

There are experts and professionals in my field who will help me learn, improve and excel. They will respond to my sincere, thought-out questions and concerns.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

PROFIT

I profit from the present moment.

Sublipower, Sublisuccess, Edi Inter, 1978.

PROGRESS

I have everything I need to make profitable progress under the present circumstances.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

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I move forward with all my strength.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

I develop affirmative statements, about five words in length, describing my correct performance, in the present tense. I relax and listen to myself state the affirmation, and visualize the accompanying action or feeling.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I am pleased with the progress I am making. I'm going to tell my best friend about it.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

I move forward!

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I want to do better.
I want to do more.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

PROJECTS (Also see Debt, Money)

I set a deadline for every project.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

This project does not have to succeed, and if it fails the world won't come to an end. But I want it to succeed, and so I'm going put all my energy and enthusiasm into it. What do I risk by doing that?

John Clark, Do It Now, Godefroy Publications.

Creative wisdom is at work through me to bring all my projects and plans to fruition.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

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PROMISES

Every time I promise something I keep my word faithfully and exactly.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

PROMOTION

I am qualified for the promotion to (specify the job you wish to get) because everyone appreciates me and because I always demonstrate goodwill towards my employer and my colleagues.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I have a right to my place under the sun. I carve out this place through my work, through the contacts I make, through the dignity of my life, through friends and the help I give to others.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

PROSPERITY (Also see Happiness, Budget, Love Of Life, Health, Peace, Success)

Every day I am acquiring better health, a greater love of life and more and more prosperity.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

My interests are prospering day and night.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I accept and believe in prosperity for myself.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

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I organize my budget well, and my affairs prosper.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I believe with all my heart that health, peace, success and prosperity in my affairs are mine to enjoy. I see myself under the spiritual sign of peace, harmony and inner development, an image which is completely oriented towards success and prosperity.

I impregnate my subconscious mind with ideal images of prosperity and success. I rely on the infinite source from which everything I need flows. I listen to the voice of God in me. His voice guides and directs me in everything I undertake. I feel linked to the wealth and generosity of God. I believe and I know that there are new and better opportunities in store for me. God will reveal them to me.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I deserve prosperity and happiness. From now on I will be prosperous and happy.

I am now ready to accept all the joy and prosperity that life offers me.

I am blessed with financial prosperity. Each day makes me more prosperous.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I have divine guidance all day long, and everything I do prospers. Divine justice and the law of divine order govern all my undertakings, and everything I do succeeds.

I know that prosperity means spiritual growth from all points of view. God helps me succeed in mind, body, and in the things I do. God's will is constantly at work in me, bringing me health and wealth, and making me an expression of divine perfection.

Dr. Joseph Murphy, Miraculous Power Attracts Infinite Riches, Godefroy Publications, 1978.

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PROTECTION

I remain under the protection of the Most High.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I am never afraid because I know that the Divine Presence which is in me is my saviour.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I am safe and secure at all times. Love surrounds me and protects me. All is well.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I am guarded, I am protected.

George Barbarin, How To Overcome Fears And Anxiety, Dangles Press, 1974.

The Spirit walks ahead of me, showing me the path... I have absolutely nothing to fear, the Spirit protects me... the wisdom of the Spirit guides me in all my actions.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

PSYCHIC SHIELD

I will completely reject and ignore all negative and pessimistic “facts” which I can do nothing to change.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

PUBLIC SPEAKING

I like talking to people. When I address a group I feel self confident and relaxed.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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As soon as I begin speaking... I feel transported... I speak with conviction and warmth.

I could speak for hours... ideas keep coming to me one after the other.

At a meeting or conference... I am more and more likely to get up and express my ideas.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I have the energy, assurance and complete self control I need to speak in public. I speak easily and eloquently.

I feel relaxed in public. I feel at ease in any situation. I have complete confidence in myself and in what I have to transmit to others. Everything will be fine.

I am the most important thing I have to transmit to others. I am perfectly at ease. I am in perfect control of myself. I know exactly what I have to say. I am perfectly at ease in public.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

I have nothing to fear. I'm going to concentrate on the message I wish to pass on to my audience and not on myself - I have confidence in the power of my own mind.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I feel comfortable in public. I feel at ease under any circumstances. I have complete confidence in myself, and in what I have to transmit to others. Everything will be fine.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

I am the most important thing I have to transmit to others. I am perfectly at ease. I am in perfect control of myself. I know exactly what I have to say. I am perfectly at ease in public.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

PUBLISHING

Infinite Intelligence paves the way for the acceptance and publication of my writing.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

PULMONARY DISEASE (See Lung Disease)

PUNCTUALITY

I arrive on time for my meetings.
I arrive at the prescribed time.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am always punctual.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I rarely hurry, and I feel good about myself.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

PURIFICATION

Every breath I take cleanses my body totally. With every out breath I rid my body of toxins.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I eliminate gasses and all other waste products from my body.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1973.

I clean my mind with the waters of love and life.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 198

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QUALIFICATIONS

I have the necessary qualifications, and everything else I need to succeed.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

QUALITY

It is my —— (specify which quality) that people appreciate in me.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

I have the potential to develop all the qualities I admire in others.

Sublipower, Sublicontrol, Edi Inter, 1989.

I cultivate and develop my qualities.

Sublipower, Sublicontrol, Edi Inter, 1989.

I acknowledge my qualities, as well as those of others.

Christian H. Godefroy, Positive Thinking: The Subliminal Method, Godefroy Publications, 1987.

QUALITY OF LIFE

The quality of my life improves day by day.

Louis Proto, Self Healing, Piatkus Publications, 1990.

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RADIANT

I am a being of light. I am energy. I am whole as a spirit, mind, and body.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

The more radiant I am the more I attract good things.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

REACTION

I am perfectly capable of reacting in a happy and healthy way, no matter what happens to me.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

READING

I look at books as working tools.

Sometimes I read very quickly, sometimes very slowly, depending on what my objective is.

I have an alarm system that goes off every time I find myself getting distracted, reading a sentence over and over without really taking it in because I'm thinking about something else.

When I finish reading something I ask myself what I got out of

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the book or article, and how I can put this information to good use.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

Realization

All my thoughts tend to materialize in my life.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

What the mind can conceive and believe, it can also realize!

W. Clement Stone, Success Through Constructive Thinking, Godefroy Publications, 1978.

I have the right to realize my desires.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I can do anything I believe I can.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I'll do it!

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I can do anything through the power of my subconscious mind.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I realize what I want to do.

Christian Godefroy, Mental Dynamics Seminar, Godefroy Publications, 1978.

The universe is now paying me to do what I really love.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

Everything I have to do is simple and easy.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

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REALIZATION - SELF

Every day I take a small step towards self realization.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

REALISM

I take care to always remain in contact with reality.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I am practical and realistic, and I keep my feet planted firmly on the ground. But I also give myself the freedom to live according to my ideals.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am a realist.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

REBIRTH

Today I start a new life.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

Just as the pain of childbirth is forgotten, I experience each aspect of my life as a manifestation of peace and joy. The past is dead. I am free of all suffocating prejudices. I am reborn every instant, I triumph in my rebirth and my new and happy being.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

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RECEPTIVITY

I am receptive to healthy ideas and techniques.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

REFLECTION

I determine the time a task will take before starting it.

I sit down from time to time to reflect on things that are important to me.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

I always find a solution if I take the time to reflect.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I give myself the time to reflect on subjects that are important to me.

I write these subjects down in my agenda so I won't forget about them.

I know that reflection takes time, and that this time is not necessarily directly connected to solving my problems: a time of reflection can also be a time of maturing.

Whenever possible I either write down or record the fruit of my reflections.

Whenever possible I allow myself time for reflection before making a decision.

As I reflect I establish "satisfaction criteria" concerning the results I hope to achieve from the decision I make.

I use my time of reflection to gather ideas which I would then note down in my agenda.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

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I want to think about things, because every profound idea contains information that is only revealed through reflection.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

REFUSAL

I always say no when it's the right thing to do.

By not giving in to the demands or influence of others I become more aware of my freedom and my self control.

I am able to say no easily. I am self confident, and always in control of my life.

I never feel obliged to do something I honestly haven't chosen to do. I say what I think. I am frank, direct and honest. I know what I want and where I am, and I express my opinions clearly and without hesitation.

I allow no one to sell me anything against my will. I live according to my own decisions, without ever giving in to pressures from salespersons or anyone else.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

REGULARITY - ABDOMINAL

My solar plexus radiates heat.

I feel a source of heat in my abdomen.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

REGULARITY - RESPIRATORY

I am all breathing, there is something breathing inside me, I feel my rib cage rising and falling like a boat on the ocean, my breathing

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is calm, I listen to my breathing. I am breathing gently.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

REJECTION

(I confront my fear, rejection and guilt and let go of them. I am going to discover and overcome these feelings which are obscuring my real light.)

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I allow myself to be, without the need to prove myself to anyone. I live my power without fear of defeat or rejection. I control my dreams, my life.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

REJOICING

It's good for me to have fun and rejoice, and that's what I do!

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

The more I enjoy myself, the more alive I feel.

Louis Proto, Self Healing, Piatkus Publications, 1990.

RELATIONS - COMMERCIAL

I can never control another person; I can only influence him. If I expect to be able to control him I'll probably be angry and frustrated. If I accept that I can influence his free choices I'll be calmer, learn more about him, and be much more effective.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

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RELATIONS - FAMILY

I love my family.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

My relations with my family are improving.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

RELATIONS - HARMONIOUS

I have the right to be happy with my chosen love.

My relationship with X is becoming more and more harmonious, happy and enriching every day. We are evolving together. We always compliment each other perfectly. I give love and receive abundance in return. I live in the abundance of love and life. X is abundance, I am abundance.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I am now ready to get involved in a fulfilling and happy relationship.

I am ready to have harmonious relations with everyone.

Divine love is now working through me to establish a perfect relationship with ——.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

The spirit in me speaks to the spirit in —— so that there is only harmony, peace, love and understanding between us.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

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RELATIONS - HUMAN

To improve my human relations I accept people as they really are and not as I would like them to be.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I choose my relations. I deliberately seek out people with high moral values who see the beauty in life.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I am not interested in relating to anybody who does not respect me as much as I respect myself.

Louis Proto, Self Healing, Piatkus Publications, 1990.

My relations with people are becoming happier and more fulfilling every day.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

When I change my inner self, I also change all my external relations.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

From now on my relations with others will be happy, satisfying and full of love.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I have confidence in myself and I like being with other people.

Alan Houel, How To Deal With Difficult People, Godefroy Publications, 1990.

I have fruitful and pleasant relations with the people I see (both professionally and socially).

If I am with someone, I give them all my attention.

I try to discern what other people are feeling.

I may take a calculated risk of breaking off a relation if that is the

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only way I can work things out.

I am careful to concern myself with only one pole of the relation at a time: me, the other person, or the situation.

I periodically review my personal relations and evaluate them, dividing the people I spend time with into positive and negative categories. I then determine those with whom I'd like to try and improve my relations, and those with whom I'd like to establish a relation, but haven't done so as yet.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I have very easy-going human relations.

I understand the natural laws governing relationships, and I work in harmony with them.

When I am in touch with my Real self, all my relations are cordial and effective.

Any sincere effort to improve my human relations will be rewarding.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I like people a lot, and I like to be nice to them.

Arthur Wassmer, The Art Of Making Friends And Being Happy, Belfond Publications, 1978.

I like to thank others.

The more I like myself, the easier it is for me to like others.

I am available for other people.

I know how to listen. I encourage people to talk about themselves.

I listen to them, and they confide in me.

I find it easy to meet new people.

I accept people the way they are.

I like to demonstrate my care and thoughtfulness.

I am sincerely interested in other people.

I wish others only positive things.

Christian H. Godefroy, Human Relations and Communication: The Subliminal Method, Godefroy Publications, 1987.

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I will try to be a little more friendly towards others.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I will do all I can to understand and maintain good relations with —— (specify such and such member of the family, colleague, etc.).

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I imagine myself at my best and I project that image to others in order to improve my relations and become a happier person.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am going to practice the technique of self-relaxation whenever I find myself in a situation that may precipitate an argument.

Whenever I find myself baited into a heated argument I will change the subject or will remind myself to remain calm and realize that the other person may have reasons for feeling as he does.

I am going to give myself the daily suggestion that I will talk more to people, act more friendly and initiate the kind of conversation that will enlist the interest of the other person.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I seek and find the essential quality of each person I meet.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am in harmony with others.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

I treat others as I would have them treat me.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

I want to maintain the friendly and harmonious relations I have created with the people around me, my family, friends and colleagues.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

The only kind of relation I can have with anyone, no matter who

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that person is, is one of love, understanding and peace. I am a free expression of God.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

RELATIONS - PERSONAL

People are important to me. I like the people who are a part of my life, and I know they like me.

I naturally attract honest and sincere people who respect my opinions, as I respect theirs.

My personal relations are warm, meaningful and enriching. I am always honest and sincere with the people I meet, whatever the situation, and whatever kind of relation we have.

I am worthy of confidence, I am responsible, and other people greatly appreciate these qualities in me.

I am always ready to give someone the benefit of the doubt, whatever the situation. When I'm uncertain, I always imagine the best possible scenario.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

RELATIONS - PROFESSIONAL

The basis of all the thoughts, words and actions I use to address my superiors and colleagues is my ever present good will.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

My relations with associates are governed by the law of harmony.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

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RELAXATION

Every time I take a breath, and every time I exhale, I relax more and more deeply.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

Each inhalation and exhalation relaxes me even more.

Each new movement makes me a little more relaxed. I breathe in deeply and hold the air for the time it takes to count to five. I exhale very slowly. My body is feeling more and more rested, making me even more relaxed. And the more I relax, the better I feel. The feeling of being completely relaxed is very pleasant and reassuring.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I feel more and more relaxed.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I know how to relax and let go. I can flow with the current.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I know how to organize spaces of relaxation, even during very intense activity.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am relaxing now. I am at peace.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I am going to take time each day for some form of recreational relaxation to balance my day with work and play.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

My body is loose and relaxed.

Emrika Padus, Encyclopedia of Emotions And Health, Edi Inter, 1991.

Every time I do my alphagenic induction exercises I relax quickly

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and deeply.

I do relaxation exercises every day.

I feel completely numb and insensitive to the position of my body. I am cut off from the people around me. I feel secure and in control of the situation.

My body is relaxing more and more. I am becoming numb to all sensation.

I feel relaxed from head to foot. Every part of my body is relaxed, and I stop analyzing my feelings. I am not thinking about anything except relaxing as I watch the indicator continuing to descend. Soon I will be completely impervious to everything around me.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

With each breath I become more relaxed, with each breath my body becomes looser, heavier and more numb.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

I am falling asleep. My whole body is resting. I will awaken in half an hour, at exactly —— (specify the time), rested and full of energy. I am so light I feel as if I'm floating!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I relax every night.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I can relax.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I feel good, very relaxed.
A feeling of well being gently spreads through my body.
My scalp is relaxing little by little.
My forehead and face are relaxing.
My tongue is loose in my mouth.
I relax my throat, my tonsils, my vocal chords.

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The muscles around my eyes are relaxing.
My neck and back are loosening up.
My tension is dissolving day by day.
My breathing is unobstructed and is getting fuller all the time.
My diaphragm massages my internal organs.
My solar plexus is relaxing.

Sublipower, Sublirelaxation, Edi Inter, 1989.

(I am going to practice relaxation as a way of life. I am going to practice relaxing each part of my body (progressive relaxation) until I have learned to master the technique of relaxing my entire body (complete relaxation). When my body is relaxed my mind will relax. Relaxation is the best antidote for worry. I am going to make good use of my new habit of hypnotic self-induced relaxation.)

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

Relaxing is important to me, and I always make sure to get my required dose. I use my time not only to pursue my goals, but also to appreciate the beauty of life.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Everything is relaxing... everything is opening... becoming peaceful and relaxed... my head is heavy, my jaws are loose... my body becomes calmer and calmer every minute.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

RELAXATION - DIGESTIVE

My solar plexus radiates warmth.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

RELAXATION - MENTAL (See Inner Peace)

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REMUNERATION (Also see Job)

I have a wonderful job and I am very well paid. I offer a valuable service and do my work admirably.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

REPARTEE

I can answer any question at all without hesitating.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

REPRESSION

As I count to ten I start becoming conscious of these emotions. I feel them more and more strongly. I will feel them intensely, in every fiber of my being.

Charles de Liguori, Hypnotism, de Vecchi Publications, 1975.

REPROACH

I remind myself that my relatives, my spouse, my friends, my boss, my children and all kinds of other people I come in contact with will often disagree with my behavior, but their reproaches have absolutely nothing to do with my inner self.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I start accepting certain attitudes which I have chosen to adopt but which others may disapprove of. Therefore, if a relative or my boss or a neighbor or even my spouse reproaches me for such and

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such behavior, I find it completely natural that they do so.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

No more blaming!

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

RESENTMENT (Also see Forgiveness)

No feelings of resentment can enter my mind because I have a spiritual understanding of all beings. I contemplate the love of God in people, which blesses me and fills me with goodness.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I give up all my resentment; this done I find I can be honest with myself.

I reject my feelings of resentment; I use my intelligence to find ways to spend my days fruitfully. I forget the day's setbacks and, above all, I stop being obsessed with the numerous injustices I suffered in the past.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I forgive you. I may not approve or agree, but I can forgive. I can let go of the past and wipe the slate clean. I know better than to expect atonement. I let go of revenge and resentment. Our differences are in the past. I am in control of the present and I can forgive you in the present. I can leave my anger behind.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I want to get rid of all my bad memories, eliminate all hate and resentment from my heart and retain nothing which can degrade or belittle me.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

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RESOURCES

God is the infallible and unlimited source of all my resources.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

My mind is strong and its resources allow me to control my body, my emotions and my thoughts.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

RESPECT (Also see Consideration)

I earn the respect of others.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I am respectful and listen to people who have experience.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

First I respect myself, then I respect others.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I respect myself enough to say ‘yes’ only when I mean it.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I respect myself. I respect my values, my thoughts, my ideas and acts. And I respect myself the most when I stick to the path I have chosen.

I have a healthy attitude towards myself. I really like myself. I cultivate a very positive self image, and a deep respect for who I am.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I respect others and they respect me. Every person I meet is important to me. I can easily create a feeling of respect and confidence between myself and others.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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Above all I respect myself.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

RESPONSIBILITY

(I am completely responsible for my thoughts, feelings and actions.)

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I consider everything that happens to me as being my fault.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

I have to accept my responsibilities with joy in order to relax my Real Self.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I will leave nothing to chance because chance does not exist, and the success I aspire to depends solely on myself.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I assume responsibility for my strength, my happiness, and for my positive and healthy attitude; I am responsible for my past, present and future.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am grabbing hold of my life.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I am happy to realize that I am not a victim of life's circumstances.

I am creating the happy life I lead. I am the author of my own life story.

I don't need to make up excuses, and no one is obliged to assume my responsibilities for me. I carry my burden with pride and joy.

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Every day I recognize and assume responsibility not only for my actions, but also for my emotions, my thoughts, and even my beliefs.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am in control of myself and my environment. I take charge of myself!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am responsible for what happens to me.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

I am responsible for my life.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I am responsible for myself because I have chosen to be so.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I am responsible.

Sublipower, Sublicontrol, Edi Inter, 1989.

I want more responsibilities.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

REST (Also see Sleep)

I always allot myself sufficient time for rest and relaxation. I get enough sleep, and my sleep is deep and regenerating.

I give both my mind and body enough rest, but I don't depend solely on rest to recharge my energy.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am resting peacefully.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

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As long as I don't move and don't get upset I am in perfect repose.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

REST - MENTAL

When one minute has passed I will count from one to seven. When I reach the number 7 I will emerge from my state of mental rest and feel as if I had slept deeply for two hours.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

RESULTS (Also see Work)

I get more done because I work harder. I like to make that extra effort and obtain better results.

I feel great satisfaction in knowing that I work hard and well. I try to be more efficient and get better results every day.

I improve my results by concentrating my energy and attention on what I am doing. When I have a task to accomplish, it is the only thing I think about.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Infinite Intelligence shows me the best ways to get better results.

Dr. Joseph Murphy, Miraculous Power Attracts Infinite Riches, Godefroy Publications, 1978.

I am getting better results at work every day. I find my work more and more fulfilling.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I let the results come naturally and effortlessly.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

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From now on the divine light within me produces perfect results in all aspects of my life.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

RESULTS - SCHOLASTIC

My interest is growing day by day and my scholastic results are improving. I am doing everything in my power to attain my goal.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

RETIREMENT

I am going to make my golden years interesting and meaningful. I'm not going to be a stay-at-home just because I am past 60 or even 70. Growing old graciously means practising being kind, unselfish and understanding.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

REVENUE (See Income)

REWARD

I reward myself with gifts!

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I give myself what I want; I feel I deserve it.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I reward myself when I bring a project in on time.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

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(I deserve this reward.)

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I will spend this Saturday doing something I really want to do. I don't mean next month. I mean this Saturday. I will enjoy being alive and being able to do it. I deserve it. There will never be another me. I will spend at least one day a week on ME!

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

When this project is finished I'll buy myself the new suit I've been wanting.

John Clark, Do It Now, Godefroy Publications.

When this job is finished I'll relax and have something to eat.

John Clark, Do It Now, Godefroy Publications.

When I complete this assignment I'm going to reward myself with my favorite —— (specify which food, item of clothing, TV show, movie, sports or leisure activity).

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

If I finish all this today I'll go to a movie tonight.

John Clark, Do It Now, Godefroy Publications.

RICHES (See Wealth)

RISK

I accept responsibility for some of the risks involved in the decisions I make, because taking calculated risks is the only way to acquire experience. Therefore I always ask myself this question: 'If this fails, am I ready to assume responsibility for the consequences?'

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

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I risk nothing if I fear nothing.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I take risks that may complicate my life, but which could prove to be extremely profitable.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

My path is a luminous one of sunshine and promise. I follow it with joyous anticipation. When I take a necessary risk, I look ahead, anticipating the best, and never turn back.

I reduce the risk of running risks by informing myself as much as possible in advance. Then, once my decision is made, I accomplish each stage with the determination to succeed.

I take positive risks which always bring the desired reward, and contribute to my health and well being.

I only take risks which provide me with even more positive energy, and which contribute to my well being, as well as to the well being of those close to me.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

RIVALRY

I no longer feel any rivalry with my neighbors.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

ROUTINE

I take risks to break the routine. For example, I take unplanned vacations, with no reservations, no maps, telling myself that whatever happens I am capable of dealing with any situation. I apply for a new job, or talk to someone I've avoided in the past because I was

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afraid of what might happen. I take a different route to get to work, or I eat at midnight instead of at six. Why? Because it's different, and because I feel like it.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

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SADNESS

If I sometimes got sad or bored, moody or overcome by dark thoughts, I know that this will no longer happen, and instead of being sad, instead of feeling melancholic and dark I will be joyful, joyful for no reason perhaps, but joyful all the same, just like I got sad for no reason in the past. And what's more, even if I have reason to be sad, real reasons that cause me to feel dark and melancholic, I will not do so.

Emile Coue, Complete Works, Astra Publications, 1976.

I will fill this day with my laughter; I will fill this night with song. I will never have to work to be happy; instead I'll keep myself too busy to be sad. Today's happiness must be enjoyed today.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

SALARY (Also see Work, Value)

My salary is in accordance with my integrity and honesty. I exploit my talents to their fullest. I am appreciated and sought after, and I am indispensable. It's wonderful!

My salary is in line with my spiritual values. My revenue corresponds to my faith and my expectations. My wealth depends on the Universal Substance, and the degree to which people accept me determines the amount of my salary. I accept all the good that comes

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my way, here and now.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

SALES

I am learning about the marketplace. I'm widening my base of contacts. The people I call need my products and services.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

Starting today my sales will increase every day.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I will develop my understanding of people, of myself and of the merchandise I am selling in order to multiply my sales.

I will become the top salesman in my department because I am unique.

I will be the greatest salesperson the world has ever known.

I will work harder than ever, pushing my body to its limit, and then I'll do even more. I'll make more contacts than ever, more sales than ever, and I'll make more money than ever.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I'm not just any salesperson. I am an experienced salesperson. I am a champion salesperson.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I am a spiritual magnet, attracting clients who are interested by what I have to offer. The service I give is improving day by day. I am highly successful in everything I undertake. I bless everyone who comes into my store, and treat them well. All these thoughts are now filtering down into the deepest part of my subconscious mind, transforming my life into one of abundance, security and peace of mind.

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It’s wonderful.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

I am an excellent salesperson. I like to sell and I appreciate the numerous rewards my profession offers me.

I always put in the time required to find new clients. It is natural and easy for me to generate new business.

I always take care of details related to my work. I like everything that has to do with sales, and I always have the time to pay attention to details.

I have a great talent for sales. I am a professional salesperson, and it shows.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am going to start out every morning with the idea that this is going to be a good day for me, that I am going to experience an inner feeling of confidence, a feeling that I can sell almost anything to anyone, that I can make more sales than I ever have before.

I believe in the usefulness and value of what I am selling.

I am going to train myself not to do all the talking, but to listen well, ask questions so that my client is made to feel comfortable and not high-pressured into buying something against his better judgment.

I am going to read and study as many books as I can, pertaining to the psychology of selling and apply whatever knowledge I acquire.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

Phone calls lead to appointments; appointments lead to sales; sales lead to referrals.

Each person I contact has the potential of opening up a world of new customers and referrals.

I am taking charge of my inner life by choosing my self-talk. I warm up mentally by focusing on effective self-talk and I prepare

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thoroughly for every sales interaction.

I am thankful to have this opportunity to present myself and my product.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

My sales are increasing every day.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

Despite all the people who have come before me, if I constantly try to surpass my own record I will constantly make progress, more sales and lots of money.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

SALES - REAL ESTATE

Infinite intelligence will bring me the right buyer for this house, someone who needs it and will benefit from it. The person will be attracted to me through the creative intelligence of my subconscious mind, which commits no errors.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

SATISFACTION

I always get what I need when I need it.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I tell myself that I did the best thing at the best time.
I am satisfied with myself at the end of the day.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I feel good about myself, and all aspects of my life provide me with great satisfaction.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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SAVINGS

I am fully insured (or protected by my savings).

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

Because I know how to manage my money I am always able to save a part of it. I set myself monthly and annual savings goals, and I respect them.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

SCHOOLWORK

From now on I will concentrate totally on what my professors are saying.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

From now on I will concentrate on what my teachers at school are saying... I will not let myself get distracted... I will raise my hand whenever I know the answer to a question... I will participate enthusiastically in all my classes.

I will do my homework conscientiously. I will concentrate on my lessons.

I won't let myself get distracted. I won't do anything else until I've finished my homework, and prepared for the next day's courses.

I'm doing much better in school... I'm happy with my results.

Day by day I am improving my performance at school... I work with joy... and my work is improving day by day... day by day my schoolwork is improving.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

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SECURITY

Security is found in myself.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

Intimately united with you, my inner Guide, I am stronger and stronger in all situations. I feel secure under your protection and guidance. I am independent of exterior circumstances, things and people. You help me and thanks to you all obstacles become incentives. Your strength is my strength. Your supremacy creates my superiority. You make everything succeed for me, and transform all things to my advantage.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

(I have what I need. I will always have what I need.)

Louis Proto, Self Healing, Piatkus Publications, 1990.

I am at home. I am comfortable as I move into a deeper connection with my true self. I am flexible and secure in my life.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I try as much as possible to eliminate external explanations from my behavior, and external circumstances from my life, my thoughts or my feelings.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

SEDUCTION

I am responsible for keeping myself physically attractive, clean and desirable for my husband.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I am becoming more seductive every day.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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I am seductive.

Charles Baudouin, Psychology And Practise of Autosuggestion, Idegraph Publications, 1990.

I want to make a favorable impression on ——.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

SELF ACCEPTANCE
(Also see Self Confidence, Self Expression)

I continue searching for the best in myself. I accept myself the way I am, and at the same time I do what is required in order to improve myself and gain ever greater satisfaction.

Dr. Maxwell Maltz, Psychocybernetics and Self Accomplishment, published by A Different World Ltd. 1970.

I accept my situation and I feel perfectly good about it.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

I accept all my feeling as part of myself.
I like myself and accept myself the way I am.
I don't have to try and please anyone, I please myself and that's what counts.
I like myself the way I am, and I feel better and better.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I have the right to be myself.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I like who I am, and live each day in the freedom of self acceptance and self confidence, and with the joy of expressing myself fully.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I like and accept both my body and my spirit.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

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I exercise my right to self acceptance.

I am learning to accept myself.

I accept myself for who I am, and I don't try to imitate anyone else.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I stop concerning myself with social popularity. I am working on accepting myself.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I accept myself and I accept others.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

(I stand tall and shine brightly. I appreciate myself and respect myself.)

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I'd make a bad somebody else, but I'm the best 'me' there is.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

SELF AFFIRMATION

Here I am. I have as much right to be here as anyone else. I matter.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I have the absolute right to be who I am, to think what I think, to feel what I feel, and to want what I want.

Arthur Wassmer, The Art Of Making Friends And Being Happy, Belfond Publications, 1978.

I have the right to say 'NO' to someone without losing their love or friendship.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

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I have the right to affirm myself, and it is to my advantage to communicate. I have the right to ask for what I want. I give others the freedom to say ‘yes’ or ‘no.’ If I don’t express what I want, no one will know and I’ll always be dissatisfied.

I have the right to have needs, and to fulfill them, as long as it doesn’t harm anyone.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

SELF AWARENESS

I know that I never waste time asking myself what other people think about me. If I want to know, I simply ask them! In this way I obtain the information I need, and I also feel I know myself better.

Wayne. W, Dyer, The Sky’s The Limit, Mortagne Publications, 1988.

Self awareness helps me see that unhappiness is not a part of the Real Me, and is therefore not necessary to endure. Relaxation and tranquility are the result of self understanding. I make self understanding my goal each day.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

The more I know myself the more I love myself.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I am convinced that I am a center of pure self awareness; I am a center of willpower, capable of dominating and influencing, using all my psychological and bodily functions.

Dr. Robert Assagioli, Psychosynthesis, Epi, 1965.

I am MYSELF, a Center of pure consciousness.

Dr. Robert Assagioli, Psychosynthesis, Epi, 1965.

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SELF CONFIDENCE (Also see Self Esteem, Self Control, Competence, Depression)

My self confidence grows stronger every day.
I have confidence in myself.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I'm more confident of myself every day. I'm getting stronger. I AM ME. I love who I am. I can handle any situation.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I have more and more confidence in myself every day.
I often tell myself: "It's easy, you can do it."
I speak clearly and articulately.
I decide what I really want, and act accordingly.
I can now depend on myself.

Suplipower, Subliconfidence, Edi Inter, 1989.

I have confidence in my abilities.
I trust in myself and believe in my innate wisdom.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I have confidence in my inner powers.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I have confidence in myself and in the future.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I am confident in myself, in others and in life.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

I have confidence in you.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

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I have faith in myself.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I have everything I need to be happy, here and now.
Everything I need is already within me.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I have absolute confidence in myself... and I feel at ease under any circumstances... even in public I feel no apprehension... all my faculties remain intact... because I am sure of myself.

Marcel Rouet, Motivating Your Subconscious, Dangles Press, 1982.

I like who I am.
I feel good about myself.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I will reach the highest summits through the power of this newfound confidence in myself.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

I trust my inner knowing in all situations.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

I believe in myself.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I develop my self confidence and have faith in my clear conscience, letting it guide me without fear as my confidence grows.

I avoid negativity. I help myself live more fully in the present moment, by keeping in mind the confidence I felt when I succeeded in the past.

I have confidence in my abilities.

The more I am myself, the more I believe in myself.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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I am gradually gaining more and more self confidence.

Alan Houel, How To Deal With Difficult People, Godefroy Publications, 1990.

I congratulate myself on each new success.

Christian H. Godefroy, Self Confidence: The Subliminal Method, Godefroy Publications, 1987.

I feel calm and sure of myself.
I am confident.
I build up my confidence.
My approach is relaxed, calm, tranquil and confident.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I prefer not to be a chronic worrier. I am going to manifest faith in everything I do - faith in the thought that nothing will happen. My faith in a Higher Power will always come to my rescue and provide me with peace of mind.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I am the greatest miracle in the world!

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I am a positive person and I have confidence in myself. I emit positive vibrations. If you look closely you can even see a halo around my head.

If I have suffered from a lack of self confidence in the past I don’t anymore. Today is an ideal day for getting rid of all those false beliefs which have paralyzed me up to now.

It doesn’t matter what I demand of myself, I can do it, I know I can.

Today, right now, I am capable of offering myself the gift of solid, unshakable self confidence.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Others appreciate my company. I have self confidence and self

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esteem. I like myself, and others find that irresistible.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Now I am very sure of myself. I have complete confidence in myself, and confidence in life. I know my life will be very beautiful, because it is a pleasure to use this newfound confidence to work on myself, and to give to others.

Charles Baudouin, Psychology And Practice of Self Suggestion, Idegraph Publications, 1990.

I trust and follow my 'gut feelings' at all times.

Louis Proto, Self Healing, Piatkus Publications, 1990.

SELF CONTROL (Also see Objectives, Calm, Self Confidence, Willpower)

I'm in control of my body, now.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I am in complete control of my thoughts and faculties. I use them to attain my objectives.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

I command and then I obey my own command.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

Every day I am in better control of my habits.

Sublipower, Sublicontrol, Edi Inter, 1989.

I become a mental magician when I control not only what I want to do, but also what I don't want to do.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

All my thoughts lead to acts.

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I control my thoughts, and I control my world.
My thoughts make things happen.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I am in perfect control of my mental impressions.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

Every day I expect to gain greater control of my feelings and my thoughts.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

I am in control of my thoughts, ideas and feelings.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

From this moment on I am ready to control the personality which awakens in me each morning. I will control my emotions by acting in a positive way, and it is by controlling my emotions that I can control my destiny.

I become my own master.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I feel in complete control of myself.

Francoise and Michel Moine, Develop Your Psi Powers, Stock Editions, 1982.

I take full control of my mind and my emotions.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I am the master of my life and my own authority.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I am in control of my gestures, my thoughts, my emotions. I am free of the things I inherited, free of my impulses which I have brought to heel. I am free of all restraints. I follow my chosen path calmly and firmly.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

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SELF CRITICISM

I can calmly review and critique my performance and then make improvements without calling myself names or blaming my performance on someone else.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I try to be myself as much as possible. I don't criticize myself that much. After all, you have to live a little.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

When I make a mistake I don't scold or berate myself with left-brain criticism. I develop an affirmative statement, about 5 words in length, describing my correct performance, in the present tense. I relax, and listen to myself stating the affirmation, and I visualize the accompanying action and feeling.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

SELF ESTEEM
(Also see Self Confidence, Self Love)

Increase my self esteem and I will be better respected by everyone.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I esteem myself and recognize that I am capable of exploiting the potential of every aspect of my being.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

(I have enough self esteem to accept what I think is the best.)

Louis Proto, Self Healing, Piatkus Publications, 1990.

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I speak about myself in a positive way.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I am capable of handling a position of authority. But to do that I must start by improving my self esteem.

Charles de Liguori, Hypnotism, de Vecchi Publications, 1975.

I am a human being. I am worthwhile just because I exist and try to survive. I take care of myself. I take myself seriously. I correctly take myself into consideration first in all matters. No one is any more or less worthy than I.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I'm a wonderful person just the way I am.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I am really unique. I like who I am and I feel good about myself.

I always wanted to be someone, and now I know that I am.

I prefer being me to any other person in the world.

I like what I feel, I like the way I think and act.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I reject thoughts of "I'm this way..." or "I'm like that..." as much as possible.

I let the people close to me know that I intend to try to get rid of certain labels which are attached to me. I choose the labels I want to eliminate first, and ask them to tell me whenever I continue using them.

I make a decision to act differently than I did in the past. I set myself the task of eliminating one label per day.

I tell someone I can confide in about my decision.

I ask him / her to tell me every time I seem to fall back and start hiding behind a negative image or label.

I try to get rid of all these labels day by day.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

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The farther I get away from my old habit of underestimating myself and my abilities, the more excited I become about the prospect of living my life in a really fulfilling way.

Arthur Wassmer, The Art Of Making Friends And Being Happy, Belfond Publications, 1978.

I sometimes fail on purpose. If I lose a tennis match or a game of cards, does that in any way impair my integrity? Or do I remain an estimable individual who is simply participating in an activity for the fun of it?

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

SELF EVALUATION

I cease evaluating myself according to other people's standards. I use my own personal standards.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

SELF EXPRESSION (Also see Self Acceptance, Self Confidence, Health, Happiness)

Every time I express my personal opinion I do it as precisely as possible, speaking in the first person. I explain my expectations clearly, and I encourage others to do the same.

I express my opinions frankly, making sure not to be aggressive towards others, and I do not hesitate to express emotions like satisfaction or disappointment when I feel it is necessary.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I speak with gentleness and love. I exhale only the good.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

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I know how to express myself in a dynamic way.
I express myself freely, fully and easily.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I am capable of expressing everything I feel, even if I don't know ahead of time what these feelings will be.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

I am conscious of myself. I believe in my ability to express myself fully on a physical, spiritual or emotional level.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I want to express my feelings.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

When I express myself I pay attention to other people's reactions (verbal or non-verbal) in order to make sure that I am being understood.

If necessary I know how to talk in very simple language, using images, gestures and illustrations to get the point across.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

SELF FORGIVENESS

I am a human being, worthy but imperfect. I am like you. We are both just trying to survive. When I hurt you I was just trying to do what seemed best for me at the time. If I had then the awareness I do now, I would have chosen differently. But at the time, I could only do what I did. I understand that I hurt you, and I want you to know that hurting you was not my goal.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

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SELF HEALING

I trust that I have the power to heal myself.

Louis Proto, Self Healing, Piatkus Publications, 1990.

My healing power is getting stronger day by day.

Sublipower, Subli Health, Edi Inter, 1989.

SELF HYPNOSIS

I feel fine, perfectly fine. This session is over, and I'm going to resume my normal activities. I am in full possession of all my faculties.

Francoise and Michel Moine, Develop Your Psi Powers, Stock Editions, 1982.

Now I am sleeping. So calm, so serene! Everything is tranquil. My mind is free, calm. This feeling of calm encompasses everything. I feel it in my legs right up to my chest, in my arms and in my head.

Charles de Liguori, Hypnotism, de Vecchi Publications, 1975.

My ability to practise self hypnosis is improving from session to session. My eyelids are heavy... they're getting heavier and heavier... They are so heavy that soon I will have to close them, and when I do I will enter a state of self hypnosis.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

SELF IMAGE

As much as possible I am going to think: ‘Success is inevitable, and I am already the kind of person I want to be.” I am going to feel and act like that new person.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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I have a positive self image.

Claude Arpel, Self Confidence: The Subliminal Method, Procauvi Publications, 1986.

I encourage myself to choose and stick to the path that gives me a healthy self image.

To improve my self image I learn from the school of successful failures.

Now that I like myself the way I am I consolidate my self image every day.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I allot myself some free time each day to work on a better me.

This decision to improve myself each day gives me the strength to improve the image I have of myself. This is going to be a good day, and my self image will be even more positive.

I concentrate on strengthening my self image.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I know that my dominating thoughts have to go through a number of stages before they become reality; that's why I devote 30 minutes every day to thinking about the man I intend to become, creating a precise image of that person.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

When I visualize myself "in the present" as if I were already accomplishing one of my goals, I make certain my visual image is as I would see it out of my own eyes, not "watching me do it" through the eyes of a spectator.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

All the negative images and attitudes I have about myself are now dissolved. I love and appreciate myself.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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SELF IMPROVEMENT

I believe that I am capable if improving my life by improving my way of thinking.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I dedicate a little time each day to improving myself as a human being.

I make a daily resolution to improve myself.

Progressing towards my goals implies a powerful desire to improve myself. In other words I want to become better, I want to strengthen the image I have of myself. I search for new horizons, I want to give my life a deeper meaning.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I love and approve of myself totally, every moment.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I stand tall and shine brightly. I appreciate myself. I respect others

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I'd rather be me than anyone else in the world.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I am a unique and valuable human being. I always do the best I can. I love (like) myself, mistakes and all.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I see what is positive in me and I appreciate it.

Sublipower, Subliconfidence, Edi Inter, 1989.

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SELF LOVE (See Love Of Self)

SELF PUNISHMENT

I reward myself, never punish myself.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

SELF REJECTION

I am trying to feel better about myself.
I offer myself my own friendship.
I will never abandon my sense of self.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

SELF RESPECT

I respect myself and appreciate myself.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

SELF SUFFICIENCY

I do not have to try so hard. I have enough. I am enough.

Louis Proto, Self Healing, Piatkus Publications, 1990.

SENSATION

I accept and experience all my feelings. (wrong section!)

Shakti Gawain, Reflections In The Light, New World Library, 1978.

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I am in control of my way of sensing things.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

SENSE OF SMELL

My sense of smell is improving fantastically... I am able to perceive odors with amazing accuracy... over unusual distances... I am surprised at the number of different odors I can smell... and their intensity... My sense of smell is developing... I can sense even the most subtle odors... my sense of smell is becoming very developed.

Marcel Rouet, Techniques And Practice Of Hypnotism, Paris Productions N.O.E., 1974.

SENSES

All my senses are sharpened. My vision, sense of smell, hearing, and even my sense of touch are more awake than ever.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

SENSITIVITY

I concentrate my mental energy, my time and emotions on what concerns me.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I am a magnificent, sensitive, likable, creative and valuable being.

Louis Proto, Self Healing, Piatkus Publications, 1990.

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SENSUALITY

I express my love and my sensuality in many ways.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

SERENITY

I love the tranquility and peace I create in my mind.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

From now on I will feel deep inner peace and serenity.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I am calm, tranquil and serene.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I always remain in a state of serene and peaceful balance because I know that God will always provide the right solution to any problem I encounter.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

Nothing can disturb my serenity.

Marcel Rouet, Techniques And Practice Of Hypnotism, Paris Productions N.O.E., 1974.

SERVICE

I try to be useful, pleasant, set a good example and help others on all occasions.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

I can get everything I want out of life if I help other people get what they want.

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If I do something for someone who can't help me in return, I still get more than I give.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

SETBACKS

I never allow a setback to make me physically ill.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am coming back stronger day by day!

Now life is starting to look like a friend instead of the enemy it appeared to be before. The more I get into the habit of not expecting any help from anyone, except from my inner Guide, the closer I get to realizing my hopes and fulfilling my desires, while my fears of powerful adversaries and those who wish me harm disappear.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

SEXUAL BLOCKS

Women (or men) like and accept me the way I am.

Whether or not my sexual activities always work out is of no importance.

My sexual life is enjoyable, and does not cause me any tension or anxiety.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

SEXUAL DESIRE

I feel more and more sexually aroused. My whole body vibrates with desire and love. I am more and more desirable, and I find my partner —— (name) more and more desirable. I am irresistibly at-

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tracted to him / her. I find my partner charming and sensual. My desire grows stronger day by day, and all aspects of my sexual life are improving.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

SEXUALITY

I give my fantasies the freedom to live in my mind and strengthen the joy and beauty of my love life.

I take the time to let my partner know about my needs and thus allow him / her to participate in my sexual fulfillment.

The intimate sexual expression of my being constitutes one of the greatest joys of my life. I give myself the freedom to experience pleasure with my whole being.

I love touching. I have no trouble expressing myself physically with the person of my choice.

I know it is good for me to express my sexuality, which constitutes a positive and important part of my overall well being.

I am a GREAT lover! I know how to relax and satisfy both myself AND MY PARTNER, simply by being myself.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I know that the sexual act is an expression of love on a physical level; I know that it is natural for me to be a warm, sensual woman, and there is absolutely nothing wrong with that.

I know that sexual pleasure is a right given to us by nature; I know that the union of two beings is creative in ALL senses of the word; it is the earthly expression of oneness with the total BEING through union with another.

I am constantly more enthusiastic, both actively and passively, when I make love with my husband; it's easy for me to close my eyes

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and savor all the pleasant sensations associated with the act of love; I am relaxed and not in a hurry; I abandon myself to the tide of pleasure without even trying to think about having an orgasm.

Clement Auger, Transform Your Life Through Autosuggestion, Heritage Publications, 1979.

I am comfortable with my sexuality.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I am free to express my sexuality as I choose. I enjoy my sexuality tremendously.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I am going to enjoy the sex act; I can and will have complete sexual fulfillment whenever I have sexual relations with my spouse.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

When I take my partner in my arms an irresistible desire overcomes me... I feel ready to move on to the act of love... physical love is completely natural... and when I make love I am relaxed and free of complexes.

I am happy with my partner... just thinking about it awakens my physical desire... I am ready for love.

*Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.^*

My body is alive.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

SHARING

I give to others. Doing so makes me feel good. I practice my ability to share with others.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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I give and I share.

Sublipower, Sublisuccess, Edi Inter, 1989.

I don't ask favors from anyone, but I have the privilege of sharing the blessings I have received with those who want to partake of them.

I share a part of the good and desirable things I possess with others.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

The more I have the more I want to give.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

The richer I get, the more I have to share with others. The more I receive, the more I have to give.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

As I give to myself, it is fun to give to others.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

SHORTNESS OF BREATH (Also see Breathing, Smoking)

I am catching my breath.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

My breathing is regular and calm.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

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SINCERITY
(Also see Benevolence, Warmth, Honesty)

I will be sincere with myself, and not create any more illusions or overestimate my qualifications or possibilities. I will also be sincere with other people.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

I am warm, sincere, honest and authentic. I am all this and much more. All these qualities are a part of me! I love who I am, and I'm happy to be me.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

My attitude towards friends is sincere, and my sincerity is real. Since I like, appreciate and accept others, benevolence and sincerity are a part of my personality.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

SKIN

My skin is becoming more and more beautiful and radiant. My face is glowing with health. My skin is improving day by day, becoming as fresh as a rose. My skin looks younger every day as it regains its freshness, elasticity and radiance.

My skin is getting softer and smoother.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

SLANDER

The storm will soon blow over, and in any case slanderous words

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cannot hurt me.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I never talk about anyone except to express my esteem. I never slander anyone.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

SLAVERY

I flee from servitude; instead I look for ways to become involved. In this way I move from isolation towards happiness.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

SLEEP (Also see Rest)

Every night brings me deep restorative sleep. I sleep, I sleep (inhale), I am deeply asleep, I am deeply asleep (exhale).

I I fall deeper and deeper into sleep.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

Tonight, tomorrow night, and on all nights to come, as soon as I wish to sleep I will fall asleep, and sleep right through the night until the next morning, until the hour I set for myself to wake up. I will sleep deeply, calmly, tranquilly, and when I awaken I will feel completely refreshed, happy and ready to greet the day.

Emile Coue, Complete Works, Astra Publications, 1976.

I sleep perfectly every night, and wake up fully rested.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

I slide gently into a tranquil sleep.

Tonight I will feel calm and relaxed.

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I will fall asleep with a calm body and mind.
My sleep will be deep and calm.
My sleep is calm and restful.
Every night I will sleep more and more deeply.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I am falling asleep in harmony and plenitude.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

I feel good and I am secure when I sleep.
I love sleeping in a natural, normal way.
I never resist sleep, whatever time of day it is.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I will soon fall calmly asleep... my muscles are relaxing... my mind is calm... just one minute more and I'll be asleep... the thought of sleep fills my mind... I am going to sleep.

Henry Durville, Hypnotism and Suggestion, Durville Publications, 1938.

I will get into the habit of going to bed at approximately the same hour each night.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

Just before falling asleep I flex and then relax every muscle in my body, starting with my feet and moving progressively upwards. I rid each muscle of tension.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

When I wake up I will feel full of energy. I'll be ready to do a thousand and one things, because I will have slept wonderfully well. I'll be in a good mood, happy, enthusiastic. I'm sleeping better every night. I'm sleeping better and better. Everything is fine. I sleep deeply. All is tranquil.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

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Now I will fall deeply asleep until tomorrow morning... I am deeply asleep... deep deep sleep.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

My sleep is calm, deep, restful, restorative. It lasts right through until morning, from the time I want to go to sleep to the time I want to wake up, and I wake up exactly on time. I must do this.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

I sleep deeply... As soon as I get into bed I forget about all my problems... I fall asleep right away. My sleep is healthy, natural and restorative... In the morning I feel rested and happy to face the new day.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

When I wake up I shall feel totally refreshed, energized and well.

Louis Proto, Self Healing, Piatkus Publications, 1990.

Every night, from the moment I want to go to sleep to the moment I wake up, I sleep deeply, calmly and tranquilly.

Sublipower, Sublihealth, Edi Inter, 1989.

SLIMNESS (Also see Charm, Looking Good, Health, Weight Loss)

Female goal: I enjoy weighing — (specify your ideal weight) pounds and looking slim in my new bathing suit.

Male goal: I weigh a trim, athletic —— (specify your ideal weight) pounds and enjoy exercising every day.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I know that my weight depends solely on the way I see myself, and what I tell myself. I am learning to see myself as slim, in shape,

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healthy and very happy.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am now slim.
I'm getting slimmer every day.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

Everything I eat makes me more beautiful, healthy, slim and charming.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

SMILING

I belong to the compliment and smile club. When I smile at someone and the person smiles back I automatically feel better.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I remind myself to laugh a little every day.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I smile at life.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I am going to smile at least three times a day.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

SNACK

I have the willpower and assurance to control myself. I decide what I eat, and when I eat!

I will not eat between meals out of habit any longer, nor replace meals with impulsive snacking. From now on I will eat regular meals

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of just enough healthy and nourishing food.

I never eat between meals to soothe my anxiety, my nervousness, my tension or solitude. I solve my problems by facing up to them and working on them. But I never replace a solution with a snack.

I no longer eat just to pass the time, or while I'm reading, working, talking or watching TV.

Every day I manage to eat less and less between meals. I am developing the healthy habit of keeping my weight down. I am a winner, and I am proving it every day!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

SOBRIETY (Also see Alcoholism)

I will not drink today.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am acquiring the habit of sobriety, and I can control myself.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I will never allow drinking to become a problem; I will use discretion as to how many drinks I can have or handle.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I don't drink any more and I feel better both mentally and physically every day.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I am sober. I don't drink alcohol. I'm making a success out of my life. I am happy and serene.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses , Godefroy Publications, 1989.

I will surmount life's frustrations without drinking. I am sober and happy.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

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Sobriety and peace of mind are now mine to enjoy, and I am thankful.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I am affirming my sobriety more and more strongly every day. I am becoming completely sober. My Guide is helping me faithfully, removing temptation from my path until I have completely vanquished this harmful habit. I am strong, I am joyous, I am free! I am strong, I am joyous, I am free!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

SOLITUDE

I like myself and I naturally attract loving relationships.

My relations with people are solid and affectionate.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I treat others with benevolence.

The fact of not criticizing myself so much any more means that I am being fair with myself, and that I am overcoming my solitude.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I find a partner who likes me, and who is cultivated, sincere, spiritual, faithful, happy, and at peace with him / herself. We feel an irresistible attraction for each other. In my life only things which are the result of love and truth can occur. I gratefully accept the fact that there is someone out there who is the ideal partner for me.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I am a center of creative intelligence, love and good grace. I am no longer alone, because Divine Love is flowing through me, making all people feel affection for me. I attract those who are in the same

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state of mind as I am.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I want to be loved.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

If I am always myself I will be sure to meet people who love and respect me.

Dr. Martin Shephard, How To Overcome Your Cares, Marabout Publications, 1973.

SOLUTIONS

I now see this point in a completely new light.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

There is a solution, and I'm going to find it.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I gather as much information as possible concerning my problem. Knowing the problem is the key to finding the right solution.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I dare to be aware of myself! I am completely capable of finding the solution I need.

I stop running around looking for solutions. I simply remain calmly receptive to my Real Self; it always provides a solution to my problem.

Solution, solution, solution...

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I am now being guided towards the perfect solution to this problem.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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At night I ask my subconscious to find a solution for a problem I cannot solve, using the 'blackboard' technique. The next day when I wake up, or sometime during the day, the solution appears in my mind.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

Dear God, I know that You have the answer, and so I submit my question. It is in Your hands, and I will patiently await the solution.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

SORROW

Today I start a new life. I will forget everything that has caused me pain, sorrow or shame in the past.

Orison Swett Marden, The Joy Of Living, J.H. Jeheber Publications.

SOULMATE

From now on I won't be afraid to approach a person who attracts me. I am strong. I am ready to love and be loved.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I will attract a man who is honest, sincere, loyal, good, faithful and prosperous. He is peaceful and happy. These qualities are now engraved on my subconscious, and as I assimilate them, they become a part of me. I know that the law of attraction is irresistible, and that I will attract the man who corresponds to my subconscious convictions, and deepest feelings.

Dr. Joseph Murphy, The Miracles Of Your Mind, Dangles Press, 1984.

I will meet my ideal partner, someone whom I love deeply, and

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who loves me deeply in return.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

My ideal partner is waiting for me, and I will meet him (or her) in the right place, at the right time.

Vera Pfeiffer, Positive Thinking, Element Books, 1989.

SPEECH MAKING

My voice will be strong enough for this speech, and my positive thoughts are now helping me systematically improve my speech.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

When I speak my voice is clear, firm and distinct. I breathe deeply and regularly. My body is perfectly calm. When I look up from my notes I look at my audience, making sure to make eye contact with as many people as possible.

Arthur Wassmer, The Art Of Making Friends And Being Happy, Belfond Publications, 1978.

SPENDING

Every dollar I spend comes back to me multiplied.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

I deserve to spend money on things I desire.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

I earn more money than I spend.

Christian H. Godefroy, Prosperity: The Subliminal Method, Godefroy Publications, 1987.

I never spend impulsively, nor do I feel obliged to spend simply for the pleasure of spending.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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SPIRITUALITY

God is always good.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

He's got the whole world in his hands - and that includes ME. I surrender to the will of God.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I believe in the existence of a Higher Power, A Force of Love, that is eternal, that puts meaning into our lives.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I am one with my supreme nature and my creative power is infinite.

God is in me and manifests in the world through me.

Divine light and divine love flow through me and radiate from me, lighting up everything around me.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I am the king's son.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

SPORT

I weigh a trim, athletic —— pounds, and enjoy exercising every day.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I do a lot of sports.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am capable of taking part in sports.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

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Taking take three deep breaths through my mouth gives me the strength to perform great sporting feats.

My performance in sports is improving day by day.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

STAGEFRIGHT (Also see Fear Of Exams)

Starting today I will no longer experience stage fright.

I have overcome it once and for all.

I am confident, I know my strong points.

I feel relaxed, calm and serene, just like when I —— (describe a personal and pleasant event).

From now on whenever I have to write an exam I will feel as comfortable as on the day I —— (insert your personal and pleasant experience).

My stage fright is disappearing gradually.

I have overcome it, and I am a stronger person.

I have confidence in myself. I know I am going to succeed.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I have the ability to concentrate on what I am going to accomplish before the fact... I think of nothing else... and I concentrate my energy... also... I never feel any anxiety... even at the idea of speaking in public... I am never afraid... I am never anxious... I am sure of myself.

So I speak and act with vitality... knowing that my stage fright has disappeared... my mind is perfectly clear.

I am not afraid to speak out.... whether I'm with friends... or in front of a group of people I don't know.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

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I sing wonderfully well.
I an tranquil, serene, calm and full of confidence.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I am calm and relaxed.
I can deal with any situation.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I am strong! I will triumph! I will succeed!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

(I'm ready. I have already succeeded in the past.)

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

STAYING IN SHAPE

I'm in great shape.

Charles Baudouin, Psychology And Practise of Autosuggestion, Idegraph Publications, 1990.

I am conscious of my body and its importance vis-a-vis my overall well being. I always to what is necessary to stay in top shape.

I do everything I have to do to stay healthy and in shape, and maintain my well being.

I enjoy the challenge of getting and staying in shape. I accept the challenge, and nothing can prevent me from succeeding.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

STOMACH ACHE

Rays of healing energy flow through my stomach. Everything is fine and my stomach is functioning normally.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

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STOOL (See Digestion, Appetite)

STRENGTH (Also see Courage)

I decided I was strong.
I dare to be healthy and strong.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I have faith. Strength will come. It lies sleeping in me. I make an effort, I struggle. My hidden strength will surge to the surface. I persevere, knowing that my strength is growing, is transforming me. Weak as I am now, I will become strong and robust. I stop my crying and hold my head high. I reject negative thoughts. I don't believe my strength will abandon me.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I seek out and use my personal strength.

The greatest contribution I can make to others is to be strong within myself. People need my strength.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I feel stronger with every moment that passes.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I am strong.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

I am very strong. Stronger than I've ever been in my life. Stronger, much much stronger. I am surprised at how strong I am.

Dr. Maxwell Maltz, Psychocybernetics, Godefroy Publications, 1978.

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STRENGTH - INNER

I feel a more and more irresistible strength growing within me.

Marcel Rouet, Techniques And Practice Of Hypnotism, Paris Productions N.O.E., 1974.

STRENGTH - PHYSICAL (Also see Losing Weight, Staying In Shape)

Every time I say the word X (choose a word) three times the strength of my muscles will immediately double. My muscles will be perfectly nourished by my blood, giving me perfect muscle tone.

Valery Sanfo, Practical Guide To Self Hypnosis, de Vecchi Publications, 1987.

STRESS

As soon as I lie down I feel completely calm. My problems disappear. My body and nerves relax.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

I approach life in a relaxed way.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

Stress slides of me like water off a duck's back. I relax with each breath I take. If a stressful event occurs I take a deep breath and regain my inner calm.

Christian H. Godefroy, The Creativity Method, Godefroy Publications, 1992.

I create pressure in any situation by what I focus on and what I say to myself. I can remove pressure by concentrating on doing the best job I can right now and learning all I can.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

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I release any thought that subjects me to any stress whatsoever.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I never allow destructive tension to accumulate in me. I overcome stress by attacking its causes. I make a conscious effort to guard myself against stress and tension by maintaining a long-term perspective, by establishing simple goals for myself, and by taking appropriate measures such as exercise and relaxation.

I feel the peace that comes from relaxation and contentment. Every time I repeat these words to myself I become more confident and more relaxed, and I free myself from all the stress inherent in all areas of my life.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am happy because my attitude is making my life more joyous and serene. I am free of stress.

I am a totally individual being, with my joys and heartaches. I am healthy and good. Every time I feel some tension building up inside me I take refuge behind my mental shield. Stress cannot break through my shield. I feel protected, night and day. I see all kinds of tension smashing into my mental shield without being able to break through it.

Tension cannot affect me. I am protected against stress. Other people may become upset, but I do not. I go about my life tranquilly, at my own pace. Everything is fine.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I am completely calm... relaxed... I will concentrate on everything I do, and I will remain calm and relaxed inside... I do my work calmly... nothing can upset me... I know I can deal with any situation... and this certitude fills me with strength and energy.

I am sure of myself... It is a marvelous feeling to be able to say: 'I will triumph! I will realize all my projects while remaining calm and

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relaxed.'

Day by day my sense of inner calm and self assurance grows stronger.

I am more and more calm... I feel completely comfortable with my situation. My heart beats calmly, regularly... My circulation is regular... any effort only makes me stronger... my health is improving day by day. I feel completely good about my situation... Day by day, and in all ways, things are improving. I feel better and better.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

STUBBORNNESS

I am learning to be mentally supple in all situations.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

The universe is running its course to perfection. I have no need to be stubborn.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

STUDIES

Today I learn things easily. My memory is functioning perfectly. If I have an exam I will remain calm and relaxed, and find the right answers. My marks will improve day by day, and I will take pleasure in learning.

Professor Kurt Tepperwein, How To Learn The Painless Way, Godefroy Publications, 1983.

May God show help me complete my —— (specify which) year of university, in harmony with divine law and order.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

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I do my homework and learn my course material.
I participate in courses whenever I can.
Learning interests me.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I know I can do this work since I am studious... may I also be wise.

Professor Robert Tocquet, The powers Of The Will, Godefroy Publications, 1989.

When I study I do nothing else! I concentrate my mind and energy on the object of my study.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

When my homework is done I prepare for the next day's courses.

Everything I undertake I do conscientiously. So I also do a good job preparing for tomorrow's courses.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

My thoughts are organized, and my comprehension is growing.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

If I draw a blank on a certain subject, like algebra for example, it's just a natural result of the choices I made up to now. If I decided to make an effort to study these subjects by putting in the necessary time, I would certainly make progress.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

STUTTERING

Every time I say the word —— in my mind I will feel calm and relaxed, the muscles in my windpipe will remain completely relaxed and I will speak very well, with confidence and ease. It will be easy for me to communicate with others.

Valery Sanfo, Practical Guide To Self Hypnosis, de Vecchi Publications, 1987.

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I can now express myself correctly... correctly... with no problem whatsoever.... correctly.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

SUBCONSCIOUS MIND

I am united with the infinite wealth of my subconscious mind.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

SUBCONSCIOUS PROGRAMMING

I program my subconscious in order to realize my desires... my projects... my subconscious gives my imagination the means to attain my goals.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

SUBMISSIVENESS

I remind myself that habit is not a reason for doing something. Just because I've always had a submissive attitude doesn't mean I have to continue being submissive.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

SUCCEEDING

I have the right to succeed and get the best out of life.

Sublipower, Sublisuccess, Edi Inter, 1989.

I have everything I need to succeed.

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

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I do everything in my power to succeed at such and such an endeavor.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

I am determined to succeed.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

I am succeeding.

I know I will continue to succeed, as I have done up to now. I am more determined than ever to reject anything that can become an obstacle to my success, anything that is unhealthy in my life.

Everything I do succeeds.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I am happy and successful because I have decided to succeed.

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

Today I am going to succeed wonderfully well in everything I do.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I want to be happy and succeed.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I want to succeed.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

The greatest secret in the world is that I just have to be a little better than mediocre... that's all I need to succeed.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I succeed at everything I do.

Christian H. Godefroy, Prosperity: The Subliminal Method, Godefroy Publications, 1987.

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SUCCESS (Also see Wealth, Happiness, Self Love, Peace, Prosperity, Health)

Stocks may go up or down on the exchange, but in life my abilities are constantly helping me reach new heights of success.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am now willing to be happy and successful.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I have the certitude that I am making the best use of what I have. With this in mind, and armed with the desire and determination to see things through, chances are very good that I will attain success.

I believe I was put on earth to succeed, to be happy and healthy, and to attain useful goals.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I know that my future is one of progress, creative endeavor and financial security. This in no way depends on external factors. It depends on my mind, and I am grateful only to God, in the present as well as in the future.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I make my dreams a reality.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I make sure to take advantage of events.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

I am attaining a higher level of existence as I become more receptive to superior powers.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I turn to you, my inner Guide, with my prayer. I am confident

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you will assist me in everything that has to do with my inner progress and my exterior success, both today and all the days to come.

You are helping me attain the goal I so ardently desire. I thank you for your support. You are the power that makes my desires a reality. I am one with my desires and I attain success. With your help I always attain success.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I will succeed by attracting the forces necessary for my success, by always being the first to be of service, and by instilling in my peers a desire to help me.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

I will succeed because I am able to handle any situation.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I am succeeding more and more easily at everything I do.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I succeed very well in certain areas.
I am in the process of becoming a successful person.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I am strong, I feel better every day, and I will succeed at what I do.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

Life is beautiful. I am succeeding! I am succeeding!

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

My mind is constantly opening to new ideas. I use all the means at my disposal to achieve success. I am open to new ideas which lead to my success.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

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Today is God’s day. I choose to let harmony, success, prosperity, abundance, security, and divine justice guide my actions.

Dr. Joseph Murphy, Miraculous Power Attracts Infinite Riches, Godefroy Publications, 1978.

I accept the responsibility of being alive. I concentrate my thoughts on what I want to do and who I want to be. I know I can obtain all the good things I can imagine. I rid my subconscious of all negative thoughts which can prevent me from achieving what I desire. They do not exist. God’s power over me is now complete, and I progress on the path of right thinking. I await the results of my actions, and I give thanks.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I grant myself success, happiness, love of self and love of others.

Sublipower, Subliconfidence, Edi Inter, 1989.

I look to my past successes.

I invite success and not failure.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I only envisage the possibility of success... and so I succeed.

W. Clement Stone, Passport To Success, Godefroy Publications, 1962.

I persevere until I attain success.

I am more and more successful in everything I do. I am able to attain all my objectives more and more easily. I am becoming a successful person. Life smiles on me. Everything I do succeeds. I move from one success to another, more and more easily.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I am the personification of success. I do my work, allowing God to guide me in all my undertakings.

The divine wisdom in me will reveal the solutions and means I need to attain professional success.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

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I succeed when I attain my objectives, but I also succeed each day, on the voyage of life. I know that success does not only exist at my final destination, but at every step along the way.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am aware of my worth. I know I merit success in everything I undertake, and that I also merit the rewards my success will bring.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am on the road to success.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

All the powers of my subconscious are working for my success.

Negative thoughts and doubts are erased and replaced by new ideas and positive thoughts of success.

I have all the qualities I need to succeed.

The creative power of the universe is at my disposal to help me succeed.

I like having a goal and persevering until I succeed.

Each day I take a step closer to success.

I have confidence in my intuition, which is guiding me towards success.

Sublipower, Sublisuccess, Edi Inter, 1989.

SUCCESS - FINANCIAL (Also see Marketing, Happiness)

Financial success comes to me easily and effortlessly.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

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SUFFERING

It’s going away, it’s going away...

Emile Coue, Complete Works, Astra Publications, 1976.

(I choose to ignore death. I live my life based on what I think and feel.)

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

When I face up to my suffering and treat it, my present suffering frees me from future suffering. It must be confronted.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

SUGGESTION - POSITIVE

I have a positive attitude towards each one of these suggestions, and I am convinced that they will make me a happier person.

The suggestions I am receiving will help me and I will listen to them. These suggestion will influence me every day of my life.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

SUPERIORITY

The person opposing me is no trouble at all. S/he knows nothing about my expertise or experience on the subject, and so I have every advantage over him / her. I am strong! Much stronger that s/he imagines.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

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SUPPLENESS

Every breath I take makes me more supple.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

My bones must always stay healthy, and my joints, especially those in my spine, should move freely and easily.

I make sure that my muscles are healthy, able to respond rapidly, and always ready to function.

Christian Godefroy, Mental Dynamics Seminar, Godefroy Publications, 1978.

SUPPORT

Everyone around me helps me to grow.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

SURGERY

The operation is a total success. Everything is healing as it should.

Louis Proto, Self Healing, Piatkus Publications, 1990.

Nothing is going to disturb my recovery. I'll have no complications, and I will feel good because I know it's all over.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

SURPASSING

Today I will surpass everything I did yesterday.

It isn't important to surpass others; the only important thing is to surpass myself.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

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SWEETS

I don't eat sweets. I imagine life without sweets. I imagine that I (specify a daily activity) without feeling the need to eat sweets. I don't like sweets. But I do like to be healthy. I am in great shape and full of energy. I don't eat sweets.

I now reject my tendency to eat sweets. I don't like sweets. I reject them because they harm my body. They are bad for my teeth. They make me gain weight. I don't like them. Sweets disgust me.

Because I have always succeeded at what I tried in the past, I will also succeed in getting rid of this harmful habit. I don't eat sweets. They're bad for my health. I want to be healthy, slim and full of energy.

Without sweets my skin looks fresh and pure.

Without sweets I do not gain weight.

Without sweets I don't run the risk of becoming diabetic.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I give up candy, chocolate and sweets.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

Sweets disgust me... and day by day this feeling of disgust grows stronger... From this moment on I won't eat any more sweets. I will lose two pounds every week... I feel a lot better... I have lost this voracious craving... I eat two meals a day... and I don't snack between meals.

My health is improving day by day... my digestive functions are working wonderfully well... Eating doesn't interest me... I feel great.

I don't eat a lot at mealtimes... and I don't snack on sweets between meals... day by day I find sweets more and more disgusting.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

I make sure I don't overeat.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

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SYMPATHY

I feel more and more sympathetic towards people. People like me and spontaneously seek me out.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

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TACHYCARDIA

I want my heart to slow down now.
My heartbeat is becoming regular.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

My heart is beating regularly and normally.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

TACT

I am adept at treating people tactfully.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

TALENT (Also see Gift, Salary, Service)

I have talent, I am intelligent and creative.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I have a number of talents which are just waiting to be awakened and used to carry me right to the top.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

(I change everything. I share my creative talents in my daily life. I am a ray of sunshine.)

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

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I possess numerous qualities and numerous talents. I even have aptitudes which I'm still not aware of. I'm always discovering new ones.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I take what I have and use it, and my talent grows, which brings me more profit.

Since I possess the only me there is, I am precious. So I take myself and my talent and I exploit them.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I proclaim my uniqueness.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I find a job which exploits my talents and qualities to the fullest.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

TELEMARKETING

I can improve my phone technique.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

TELEPATHY

I will make ..... (specify who) think about me... s/he won't be able to resist thinking about me.... my image is forcing its way into his / her mind.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1950.

I perceive each of your sensations, all your states of mind, your emotions, everything that enters your mind.

From this moment on our minds are very close, our minds inter-

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penetrate and fuse with each other, transforming us into a single mind.

From this moment on I will have no trouble reading your thoughts; all your thoughts will appear to me as clear and precise mental sensations.

I find myself in your body; your body has become my own, your mind is my mind. I see through your eyes, I hear with your ears, I think with your brain.

Your thoughts are present in me; I perceive them very clearly, they are my thoughts.

I am perfectly capable of reading your mind...

Valery Sanfo, Practical Guide To Telepathy, de Vecchi Publications, 1984.

I am going to read your mind... I can read your thoughts... but first I will empty my own mind... I am not thinking about anything... then when I tell myself to... your thoughts will appear in my mind like writing on a blackboard, and they will be easy to read... I will see them clearly... and I will tell you what they are.

Marcel Rouet, Techniques And Practice Of Hypnotism, Paris Productions N.O.E., 1974.

TELEPHONE

In my telephone communications at work or at home I answer the telephone pleasantly, immediately giving my own name to the caller, before I ask who's calling.

Whenever I initiate a call to any residence or place of business where someone new may answer, I always give my own name up front, before I ask for the party I want and before I state my business. By leading with my own name I underscore my value.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

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TEMPTATION

I have mastered the blind force which caused me to submit to temptation and I have subjugated it to my will; I will consciously make use of this force for positive ends.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

I keep the force that is pushing me to give in to this temptation to myself. ???

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

TENACITY

What others call defeat or failure never stops me. I know that so-called failure is nothing more than a detour. So I get over it and continue on my way.

Whenever I set a precise goal for myself, whatever it is, and develop a specific plan to attain it, I never let it out of my sight, and pursue it tenaciously.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

Each step brings me closer to victory. Each obstacle contains the seed of a blessing and of even greater opportunity.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I never stop trying; I will make it through. I will stick with it. Everything will work out in the end.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I persist in a positive and flexible manner until I get things done.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I keep at it and I will succeed.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

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One last effort may be all that is keeping me from success. I'm going to do it, right now!

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

TENDERNESS (See Love)

TENNIS

I find it easier and easier to play tennis. And I'm making more and more of my shots. Tennis is becoming easy for me. I'm improving day by day, and I'm winning more and more matches.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

TENSION (Also see Confidence, Communication)

With each exhalation I get rid of my worries and tension.

Sublipower, Sublirelax, Edi Inter, 1989.

As I breathe in deeply I am able to overcome my tension.
It is easy for me to relax.
I avoid situations that create tension.
The image I project is of a relaxed person.
I like being a relaxed person.
I perceive myself as a relaxed person.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I let my benevolent mind support me in moments of tension; it gives me confidence in my ability to overcome any kind of tension.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

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I feel calm and relaxed.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

A good part of my tension disappears because I feel secure and good about myself, and because I put all the little things that irritate me into their proper perspective.

In short, little things don't annoy me any more.

My bank account of confidence is growing, the communication barriers in my life are falling by the wayside, and my family life is benefiting as well.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

(I will no longer live in a state of constant tension, afraid to relax, not allowing myself to smile and spending too much time reliving unhappy memories from the past. I'm going to make every single day a pleasure.

In order to prevent nervous tension from developing, I try to keep my mind relaxed and free of unpleasant thoughts that tense me up. I nourish myself with pleasant thoughts.

I use the technique of self hypnosis to relax my muscles. Relaxing my body relaxes my mind.)

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

All my tension is disappearing.

Emrika Padus, Encyclopedia of Emotions And Health, Edi Inter, 1991.

TEST

I am very well prepared for —— (specify the situation).

Raymond Hull, Wanting Is Power, Les Editions de l'Homme, 1969.

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THOUGHTS

I choose my thoughts... I can do it... I change my thoughts... I can do it.

J. Martin Kohe, Your Greatest Power, A Different World Ltd., 1979.

THOUGHTS - NEGATIVE

Every day I create new positive and harmonious thoughts and emotions. They transform my life, bringing me happiness and health.

Christian Godefroy Collection, Magic Formulas For Success And Happiness, Godefroy Publications.

I prohibit myself from thinking negative thoughts. Everything that happens to me has a positive side.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I drop negative thoughts like hot pans!

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I reject and rid my subconscious of all acquired negative thoughts. I am the Spirit, and thus I am in no way affected by disease, death, unhappiness, poverty or frustration. All these things no longer exist in my subconscious mind.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I recognize my wealth and material energy. I get rid of negative thoughts which sap my strength.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

THOUGHTS - POSITIVE

I am going to discover for myself that I have the power within me

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to control and influence my mind at will, that I can quickly convert negative thinking into positive thinking.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I have positive thoughts.

Claude Arpel, Self Confidence: The Subliminal Method, Procauvi Publications, 1986.

(I avoid other people's negativity. (I am strong. I do not share in the failures that stem from the minds of others.)

I do not get mired down by depression, fear, anger, poverty, disease, lack of energy, struggle, conflicts or bad relationships.)

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I change my mental diet and refuse to ingest negativity.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I concentrate on good thoughts. I retain thoughts which are likely to help me, and reject the others.

J. Martin Kohe, Your Greatest Power, A Different World Ltd., 1979.

I think positively.

Sublipower, Subliconfidence, Edi Inter, 1989.

I saturate my subconscious with well directed positive thoughts which help get me what I expect out of life.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

I am confident of my power to forge the future through the thoughts of today. That is why I take care to formulate them in accordance with my most sincere wishes.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

My thoughts are positive.

Francoise and Michel Moine, Develop Your Psi Powers, Stock Editions, 1982.

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YES.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

My thoughts are more and more positive.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

TIME

I have all the time in the world for what I want to do.

Louis Proto, Self Healing, Piatkus Publications, 1990.

TIMIDITY
(Also see Inferiority Complex, Self Confidence)

I find it easy to talk to individuals and groups of people.
I am at ease in the company of members of the opposite sex.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

Each time I mentally repeat the word X at least three times I will feel perfectly relaxed; I am sure of myself, and talk to people with a strong sense of confidence and serenity.

Valery Sanfo, Practical Guide To Self Hypnosis, de Vecchi Publications, 1987.

I confront the unknown, and triumph over it.

Claude Arpel, Self Confidence: The Subliminal Method, Procauvi Publications, 1986.

I take great pleasure in meeting impressive, well-known people.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

I dare to speak out.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

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I no longer attach much importance to what other people think about me... and this frees me from my shyness.

I never waste an opportunity to fight my timidity... I often approach people I don't know and engage them in conversation.

I like to get involved in group discussions... in the street I don't hesitate to find some pretext or other to talk to people.

When I talk to people I look them right in the eye... naturally and openly... without trying to avoid eye contact... without being shy... with absolutely no timidity whatsoever.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I must not consider shyness as something to be ashamed of. Shyness is merely a symptom of a lack of self confidence, feelings of insecurity, inferiority and a fear of people.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I will not be shy; I won't be nervous when I talk to people, no matter who they are.

I will be perfectly at ease in all situations.

Paul Clement Jagot, Education Of The Word, Dangles Press, 1975.

If my inner Guide approves of me, which is always the case when I feel His presence, then whatever other people think or say about me doesn't matter. It doesn't affect me. I see my goal, and let my inner Guide lead me to it.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

TOBACCO ADDICTION
(Also see Shortness Of Breath, Cough)

I can easily stop smoking. I completely renounce the smoking habit. At the same time my health and general state will improve. I

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can control my reaction to cigarettes. I have absolutely no desire to smoke. I am becoming a new person with absolutely no need to smoke. My subconscious is helping me to stop smoking easily, completely and forever, without gaining weight.

I don't smoke any more. I stopped smoking completely and definitively. My health is great. I'm breathing better and I feel wonderful.

I congratulate myself for having stopped smoking. I really look a lot better. I'm in great shape. This is fantastic. I have stopped smoking.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I feel less and less like smoking, and I have less and less need for cigarettes. I feel good. I feel better every day. I'm smoking less and less. I already feel a lot better.

I'm smoking less. I feel better. I feel full of energy, and I have the courage to continue. I know I'm going to stop smoking once and for all. I already smoke less and less, and I feel great.

I don't smoke any more. I don't need tobacco. I'm breathing better. I fill my lungs with pure air. Each breath fills me with pure oxygen and vitality, recharging my body with energy and doing me a world of good.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

I have an image of myself without cigarettes. I imagine myself as a non smoker. I give up tobacco, I reject the habit. My body rejects it, my mind rejects it. I don't smoke and I feel great.

I reject cigarettes because I know they are harming me. I do it for myself, for my health and well being. And since my life is a success, I will continue to succeed as a non smoker. I choose to be a non smoker.

I'm breathing better and better, and I have more and more energy. I feel wonderful. I breathe easily, I have more endurance. The

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people around me are happy at my success. I feel marvelous without cigarettes. I am a non smoker!

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I'm learning to do without cigarettes... I don't want to smoke any more... it doesn't interest me... smoking doesn't interest me at all... Even the idea disgusts me... Whenever I smell smoke I feel this disgust.

Now I don't smoke anymore... Nothing can make me change my mind.

I'm happy to be able to improve my health by not smoking.

My health is improving day by day... I don't smoke anymore.

Day by day it's getting easier not to smoke.

I have absolutely no interest in smoking... even the idea of smoking is enough to make me feel disgusted with cigarettes... The smell of cigarette smoke disgusts me more and more.

I'm very happy not to smoke anymore... Nothing can make me change my mind... I'll never smoke again.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

I will smoke less or not at all.

J.V. Cerney, Stay Younger, Live Longer Through The Magic Of Mental Self-Conditioning,
Parker Publishing Company Inc., 1968.

I don't feel like smoking anymore. My health is already better, I'm breathing better, I'm becoming a new person. Not smoking is an expression of my freedom. My subconscious is my most powerful ally, and it is helping me to stop smoking, to build a new self image which is more free and more fulfilled.

Karl O. Stoeber, Psychotraining, Godefroy Publications, 1984.

I don't smoke and I'm proud of myself.

When I see a cigarette or think about smoking, the words 'I Do

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Not Smoke' automatically enter my mind and I abstain.

I really like breathing fresh clean air, I like being healthy and in complete control of my mind and body.

My lungs are healthy. I can breathe deeply.

It's easy for me to be a non smoker. After all, I was born that way, so the state is completely natural for me. I am a non smoker! I do not smoke.

I let myself relax, breathe deeply and feel good. I appreciate being healthy and a non smoker no matter what the circumstances.

I do not in any way see cigarettes as a symbol of power, of intelligence or of prestige. I see cigarettes for what they are, and refuse to allow them any place in my life.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am breathing deeply... and this purifying breath eliminates my need to smoke... with each purifying breath my need to smoke diminishes... I need to smoke less and less...

I am breathing deeply... and each exhalation gets rid of the toxins which tobacco has deposited in my lungs... I am cleaning my body of these poisons which have been contaminating my blood... weakening my organism... and ruining my health.

Not smoking will give me new vitality... make me more dynamic... more active... I will feel better from all points of view... and I will be victorious in gaining mastery over myself.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I know I am going to get more satisfaction from not smoking than I did from smoking.

I know that I am indifferent to cigarettes, anywhere, anytime, under any circumstances; other people may smoke but as for me, I don't care about cigarettes.

Clement Auger, Transform Your Life Through Autosuggestion, Heritage Publications, 1979.

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I have decided to make life as pleasant as possible by becoming a non smoker. I have made a deliberate choice not to smoke, and I feel great. I am a non smoker. I've found the way to get rid of my bad habits.

The next time I need to relax I'll do a few breathing exercises and drink a glass of water or juice instead of lighting up a cigarette.

The next time I go to a restaurant or take a plane I'll sit in the non smoking section.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defenses, Godefroy Publications, 1989.

I'm intelligent, I've got common sense. I need my body to live, and cigarettes are poison.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

I am free of the habit of smoking.

Jack Ensign Addington, How To Set Goals And Attain Them, A Different World Publications Ltd., 1977.

I absolutely want to stop smoking.

The taste of tobacco is disgusting.

I don't need to smoke anymore.

I am aware that it is much better not to smoke.

I want my breath to smell good, without the after odor of tobacco.

I respect my body.

I am in good health.

I am gradually freeing myself of my dependence on tobacco.

I substitute the harmful habit of smoking with beneficial habits of nutrition.

As I stop smoking I watch what I eat so I won't gain weight.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

Freedom and peace of mind are now mine. I know that believing and affirming these truths will allow them to penetrate deeply into my subconscious, which will in turn force me to give up cigarettes,

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because smoking is harmful and breaks the laws of my subconscious mind.

Dr. Joseph Murphy, Miraculous Power Attracts Infinite Riches, Godefroy Publications, 1978.

My voice is normal again.
I don't cough anymore.
My mouth is fresh tasting and I feel better and better every day.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

If I light up a cigarette I won't get any pleasure out of it. On the contrary the taste will disgust me, to the point where I'll have to put the cigarette out. It will be impossible for me to smoke.

Valery Sanfo, Practical Guide To Self Hypnosis, de Vecchi Publications, 1987.

If I must smoke I will smoke in moderation.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

TOLERANCE

From now on I will think, feel and act justly. I will do what is right, and never deviate from the path of justice. I think, speak and write without taking sides or being prejudiced. From now on I will not react like an ignorant fanatic, but base all my actions on the divine spirit that resides in me. I wish from the bottom of my heart that all men may live in liberty, and rejoice fully in their right to life and happiness. I obey the golden rule and the law of love.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I accept and respect the right of each person to choose.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

(I use self hypnosis techniques to strengthen my potential for tolerance, and I never have any problems.)

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Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I cease imposing temporary conditions in order to organize and program other people's lives.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

I never force others to share my points of view.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am full of tolerance for myself and for others.

Christian H. Godefroy, Self Confidence: The Subliminal Method, Godefroy Publications, 1987.

(I am a warm, open and tolerant person.)

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I am going to criticize less and be a little more tolerant of others, of their faults, their failures and errors. I will interpret their actions in the best light possible.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

TOOTHACHE (Also see Pain)

I just have to touch my —— (name the part of the body) for it to become numb.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

TORMENT

I calmly try to reduce the impact of extreme circumstances.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

This too will pass.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

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I am learning to mentally detach myself from external turmoil.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I calmly determine what worst case scenario is that I may have to deal with.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I prepare myself to accept the irremediable if necessary.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

I never abandon myself; I support myself when things go badly or start getting difficult.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

TOXINS

With every out breath I rid my body of toxins.

Louis Proto, Self Healing, Piatkus Publications, 1990.

TRANQUILLITY

My mind and body are tranquil.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I am completely tranquil.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

When I repeat the word X just once, my mind enters a state of rest.

Valery Sanfo, Practical Guide To Self Hypnosis, de Vecchi Publications, 1987.

TRANSACTIONS

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God is always present in my transactions, and I never finish a day without accomplishing something valuable.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

Infinite intelligence governs and protects all my financial transactions.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

TRANSFORMATION

Today I am starting a new life.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I find it easy to transform myself.

Sublipower, Sublicontrol, Edi Inter, 1989.

I am transformed.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I am a new person every minute.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I want everyone around me to notice my transformation. I have an improved attitude. I am straightening up: my muscles are firmer and stronger. I feel new life flowing through me.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

TRAVEL TIME

Before going somewhere I make sure I am using the means of transportation that is going to save me the most time, not necessarily

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the one which is fastest.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I try to organize my traveling time so that my mind is clear, and I can use it to work or think.

I avoid encumbrances, and only move around when I have to.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

TROUBLE

I try not to bother too much about my troubles.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I avoid blaming myself for things I cannot change.

They aren't really important.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

I assign a lot less time for worrying about things.

I give myself ten minutes in the morning and ten minutes in the afternoon to vent my anxiety and reassess all the catastrophes I can think of during those time periods.

Then I use my ability to control my thoughts and stop troubling myself until the next worry period.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

Everything is fine the way it is.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I am going to auto condition my mind every morning with a positive attitude toward each new day.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

TRUTH

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I have the courage to look truth in the eye.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I seek the truth.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I am full of desire to unlearn false ideas and learn new truths.

I don't need to fall into any traps. Desire without hope dissolves. I have nothing to fear. There is enough of everything to satisfy my real needs. I place Truth above all else, and everything else comes to me. The mental struggle is useless. I just have to relax. I am aware, and I let Truth liberate me.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I have to confront myself and search for truth within myself, with my own means, because I consider it important.

Whether I am aware of it or not my mind is functioning in a unique and natural way, based on the fundamental principle of showing me the truth about any situation I encounter.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

TUBERCULOSIS

Every cell, every nerve and every muscle in my lungs is now being purified, strengthened and perfected. My whole body is healthy and harmonious.

Dr. Joseph Murphy, The Miracles Of Your Mind, Dangles Press, 1984.

TUMOUR

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I want my little tumor to go away.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

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ULCERS (Also see Digestion)

My body is building a protective barrier of tissue around the wound; the wound stops bleeding and heals up.

My wound is no longer painful; all the reflexive reactions disappear; my stomach is calm and digests normally.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

My stomach digests better and better.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

UNCERTAINTY

(When I'm not very sure about what I'm doing I examine the consequences of each possible course of action.)

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

UNDERTAKINGS

I have a clear conscience; it will surely guide me in all my endeavors.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I undertake things which I have always avoided under the pretext that I didn't understand enough about them.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

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UNEMPLOYMENT

All right. I haven't got a job. I have to react immediately. I'm going to find work this week. In any case, it's not serious. It'll do me good to see different things, meet different people. Because in fact, I didn't really like the job I had. I was starting to get really bored.

I am competent. I have experience. I'm due for some luck. I am convinced that somewhere out there, right at this very moment, is my ideal job. And I'm going to find it.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

In the universal harmony where all human beings have their place, I have the useful and well paying job I deserve. Thank you!

Marcel Auclair, The Book Of Happiness, Seuil Publications, 1959.

The god in me knows what kind of work suits me best, where it is, and what I must do to carry it out. May this knowledge in me become a living revelation to my conscious mind, so that I may know where my real work lies, and the steps I must take to find it.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

UNEXPECTED EVENTS

I schedule the time I need to deal with unexpected events.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

I never let myself get flustered.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

UNHAPPINESS

I stop trying to be happy. I try to understand the causes of my

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unhappiness.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I believe I have the mind-power to survive all life's frustrations, disappointments and misfortunes.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

UNIFORMITY

I remind myself that uniformity and death are the opposite of fulfillment.

Wayne Dyer, Your Erogenous Zones, Tchou Press, 1976.

UNION

I know that an irresistible law of attraction exists and that I will attract a man / woman who is in harmony with my subconscious beliefs. I attract what my subconscious believes to be true.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I know that the intelligence of my subconscious mind has united us in accordance with the divine order of things.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I am in union with Life, Love and Truth, because I live with God. I am united with all beings because the image and reflection of perfect Life resides in everyone.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

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URINE RETENTION (Uremia)

In a minute I am going to empty my bladder completely.

Dr. G.R. Rager, Hypnosis, Sophrology and Medicine, Fayard Publications, 1973.

I will urinate tonight, and then more tomorrow.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

URTICARIA (See Eczema, Acne)

USED CARS

I will find the used car I am looking for. At a good price. It is in excellent condition. It corresponds exactly to my needs. My subconscious mind is infallibly guiding me towards this car.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

UTERINE BLEEDING

My uterus is tightening; the blood vessels are closing; the flow of blood is stopping.

I feel my uterus getting tighter as I tighten my fist.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

UTERINE SPASMS

My uterus is relaxing, the pain is going away, and I feel fine.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

VACATION

(This is good, I'll be able to relax, I'll take a vacation.)

Louis Proto, Self Healing, Piatkus Publications, 1990.

I try to take short vacations instead of extended ones which would probably exceed my real need for physical and emotional relaxation.

I remind myself that other people have the same need for relaxation as I do.

I plan my vacations, and discuss them with my spouse and children.

I know that I am not obliged to spend all my vacations with my family (relatives, spouse, children, etc.).

I make sure I get a lot of free time when I'm on vacation.

Pierre Nicolas, Time Is Money... And Pleasure!, Inter Publications, 1981.

VENGEANCE

I never try to do the same to my enemies as they have done to me because by seeking revenge I hurt myself more than the people I want to hurt. I follow General Eisenhower's example: I never waste even a minute thinking about the people I don't like.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

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VERTIGO (Dizziness)

Starting today I won't suffer from vertigo anymore. Every time I feel dizzy I will think that I feel as good as on the day I (insert a pleasant experience). I am serene, happy and confident. I can go wherever I like. I am in control of my sensations.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

VICE

I am free of the vice that has been sapping my strength. No negative impulses can make me renounce my freedom. They no longer have any power over me. I see my goal clearly, and nothing can distract me.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

VICTORY

I am the greatest of nature's miracles. And nature knows no failure. It always wins, as will I starting today. And thanks to my victories the struggles to come will be less severe.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

I embark on the path of life with a new ideal. I embark with a victorious attitude, and a generous and beautiful soul. I know I will be victorious. And I want to be worthy of my victory.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I am a victory.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

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I want to be victorious.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

I want to be victorious, and to do so I must start by triumphing over myself.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

VIGILANCE

(I always expect the unexpected.)

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I am always vigilant for opportunities.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I concentrate on performing with a smooth, relaxed alertness.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

VIGOR

I see myself as a vigorous person in the best of health.

Dr. Anthony and Mary Zaffuto, Alphagenics, Quebec - Amerique Publications, 1974.

A guaranteed way to stay young and vigorous is to first change my inner self. The energy will follow.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

VISION

I relax the muscles in my eyes, in both eyes, and my vision is improving.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

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I can see better and better; I have excellent vision, in an intellectual, spiritual and physical sense.

The divine spirit, which has the infinite power of healing, is now opening my eyes and recreating my visual faculties. My eyes are the instruments of perfection desired by God, and allow me to see both inside myself and out into the exterior world. The magnificence of God is revealed to me through my eyes.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

My vision is becoming clear again... I can see better and better.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

VISION - POSITIVE

I see with love and joy.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

Visualization

Who I see in my imagination will always rule my world.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I increase my receptivity to mental images. I make them work for me more and more.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I use my senses on all mental levels as I experience the external world.

Christian Godefroy, Mental Dynamics Seminar, Godefroy Publications, 1978.

I can obtain what I want by visualizing it.

Sublipower, Sublisuccess, Edi Inter, 1989.

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VITALITY (Also see Ambition, Dynamism, Enthusiasm, Beauty, Health)

Every breath I take increases my aliveness.
Every day that passes I feel stronger and more alive.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I am overflowing with more and more energy and strength.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I am overflowing with vitality and enthusiasm!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I am regaining my balance and vitality.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I am energetic and overflowing with vitality.
I give thanks for my ever increasing health, beauty and vitality.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I am strong and vital.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

My natural state is to have radiant health, boundless energy and vitality throughout my life.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

VIVACITY

I have a pleasant and lively mind, and I find that people appreciate it because I use it a little more each day.

Arthur Wassmer, The Art Of Making Friends And Being Happy, Belfond Publications, 1978.

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I am intelligent, my mind is lively, alert, brilliant and amusing. Since my thoughts are positive, my mind creates harmonious situations in my life.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

VOCATION (Also see Money)

I trust my preferences to show me where my true vocation lies.

Louis Proto, Self Healing, Piatkus Publications, 1990.

My subconscious mind will infallibly guide me to the vocation where I will succeed best, and which will bring me all the money I need.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

Subconscious Mind, help me discover the vocation that pleases me the most.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

VOICE

I am certain I won’t lose my voice, not even for a moment.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I want my voice to be more confident; I want it to express my decisions not as commands, but rather as well thought out advice.

Henry Durville, I Want To Succeed, Durville Publications, 1968.

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WAKING UP

I wake up every morning full of joy and confidence.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

All I have to do is concentrate on a given time in order to wake up at that time feeling refreshed and ready to face the world.

Christian Godefroy, Mental Dynamics, Robert Laffont Publications, 1976.

When I wake up I feel great and full of energy.

Sublipower, Sublihealth, Edi Inter, 1989.

Whenever I use my mental clock and sincerely want it to work, I wake up at the exact time I choose.

Christian Godefroy, Mental Dynamics, Robert Laffont Publications, 1976.

Tomorrow at precisely —— o'clock I will wake up feeling refreshed, and get out of bed immediately.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I want to wake up at —— o'clock.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

WARTS

The blood vessels in my wart are contracting; the wart is no longer being nourished with blood, and is drying up.

Dr. Gaston Durville and Dr. Andre Durville, Mental Cure, Naturist Institute Publications, 1923.

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WEAKNESS

I give up being helpless.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I have the right not to be strong.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

WEALTH (Also see Profession, Success, Value)

This year I will double my income to $———, and in six years from now, that is on —— (specify the date) I will be a millionaire.

Marc Fisher, The Instant Millionaire, Golden Publications Ltd. and Godefroy Publications, 1986.

Each day I am getting wealthier in all things.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

Each day brings me closer to wealth.
I desire to be rich.
I am capable of being rich.
I want to be rich.
My subconscious is guiding me infallibly towards wealth.

Christian H. Godefroy, Prosperity: The Subliminal Method, Godefroy Publications, 1987.

Every day, in all ways, I am becoming more and more wealthy.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

Every day I am more and more wealthy in everything.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

There is no logical reason which can prevent me from becoming wealthy.

I am getting more and more wealthy.

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I am becoming wealthy.
I am getting wealthier day by day.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I have confidence in you, my inner Guide, and from now on everything will be fine. I feel my mental distress and the obstacles separating me from enjoying wealth disappearing. I feel I am flowing with the current of abundance, and I am moving forward with it. I know that with your help my wishes will be granted.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I have the right to be rich, healthy and prosperous.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

I opt for the richness of life here and now. Wealth is already uppermost in my thoughts. Yes, I am grateful for all the wealth of my mind and my life. I feel wealthy. I am wealthy. I am becoming wealthier every day.

All the riches of the world circulate joyously and freely in my life, and I am very grateful. I know that all my needs are satisfied because I accept wealth. The world is there for me to enjoy, and I am rich. I am rich because I accept being rich. I can feel all my wealth now. I feel it with gratitude.

Charles Baudouin, Psychology And Practise of Autosuggestion, Idegraph Publications, 1990.

I am becoming more and more wealthy.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I am becoming wealthy.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I enrich myself day by day.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

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I do not believe that wealth is the private domain of a selected few, but rather that the abundance of life offers wealth to everyone who creates it.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I do things that are likely to bring me good fortune... I don't bargain with God... I don't set an amount that I'd like to reach... I conduct my business by submitting to His impulses, knowing that He will give me what I firmly desire.

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

I reflect with a positive mental attitude, and I become rich!

The more I share what I possess with others the more my wealth increases.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I am now a mental millionaire.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I am rich.

Charles Baudouin, Psychology And Practice of Autosuggestion, Idegraph Publications, 1990.

I am a child of infinity, and wealth flows through me freely, joyously and eternally. I am enriched with happiness, peace, wealth, success and extraordinary sales. I seek wealth in the deepest recesses of my mind, and abundance is the result.

Dr. Joseph Murphy, Miraculous Power Attracts Infinite Riches, Godefroy Publications, 1978.

The power of 'collective consciousness' helps make my fortune and my money grow.

I think and become rich because nothing, absolutely nothing can stand in my way.

Napoleon Hill, Think And Get Rich, Tchou / Ariston, 1966.

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My connection to infinite being and infinite intelligence is quite enough for me to amass a considerable personal fortune.

Christian H. Godefroy, Mental Techniques For Financial Independence, Godefroy Publications, 1983.

My life is a free flow of infinite wealth.
This universe is bursting with riches for every one of us.
Infinite wealth appears easily in my life.
I am wealthy within and without.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

My affairs are improving every day. I am making progress, moving forward, and I am richer every day.

Dr. Joseph Murphy, The Miracles Of Your Mind, Dangles Press, 1984.

One day I will be a millionaire.

J. Martin Kohe, Your Greatest Power, A Different World Ltd., 1979.

WEIGHT

Now that I weigh — pounds I feel fine, I look great and my physical condition is excellent.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

WELL BEING

I am responsible for creating my life.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

There is no limit to how good I can feel.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I have the power to feel good.

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

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I love my body and accept it totally.
I love doing what makes me feel good.
It is good to be alive on this earth.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I experience continual well being.

Professor Robert Tocquet, The powers Of The Will, Godefroy Publications, 1989.¥

I am at home in my body.

Louise L. Hay, You Can Heal Your Life, Hay House, 1984.

I'm doing fine, intellectually, physically and financially. I feel fine, day and night.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I feel good about myself.

Claude Arpel, Self Confidence: The Subliminal Method, Procauvi Publications, 1986.

I feel good, really good.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I feel fine.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

I feel better and better.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

I feel relaxed and happy. I feel good about myself.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

I am completely calm... I experience a marvelous sensation of calm and harmony spreading through me... a feeling of indescribable joy flows from my heart.

Professor Kurt Tepperwein, Think And Heal, Godefroy Publications, 1984.

My persevering quest for the principles of truth will be sure to

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produce an inner change which, in turn, will produce a warm feeling of well being.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I refrain from doing anything that may inadvertently cause me harm.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

WILLPOWER
(Also see Self Control, Self Confidence)

I have confidence in myself. My willpower is already very strong, and it is getting stronger and stronger. I want to succeed. I want to follow the examples of those who have attained the goals they set for themselves. I will persevere because I know with certitude that properly directed willpower will succeed when it is working for a just and honorable goal.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

I have willpower... I never give in to outside influences... I don't care what people may think.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

I have the willpower to act.

Jean Chartier, How To Acquire A Superior Personality, Dangles Press, 1971.

I desire —— (specify) and I am in the process of obtaining it.

Emile Coue, Complete Works, Astra Publications, 1976.

I do not let circumstance defeat me. I control them psychologically.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

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I can act according to my reason, and that is how I want to act.

Paul Clement Jagot, How To Develop Your Personal Magnetism, Dangles Press, 1982.

I can encourage my mind to think in a certain way, and direct my actions towards accomplishing a certain project.

When my willpower is intensified to the point where I can defy circumstances and realize the project I envisage, I will achieve results in my life which will astonish everyone.

Franck Rudolph Young, Cyclomancia, SIP, 1966.

I can have or be anything I want as long as I have enough energy and willpower.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

I can do it and I want to do it.

Leon Kendal, Personal Magnetism, Godefroy Publications, 1911.

I can do it! It's easy. I can do this task better than anyone else. Thanks to the power of my inner Guide no obstacle can stop me. I succeed at everything I do!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I know what I want and I believe I can get it.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

I know exactly what I want and I authorize my subconscious to act according to the law so that it becomes immediately manifest.

All paths are free, all doors are open. At this very moment all my actions are perfect, and I will get what I want.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I feel my willpower getting stronger and stronger.

Professor Lawrence Powers, Ten Secrets Of Hypnotic Power, Godefroy Publications, 1982.

I am in control of my actions, my thoughts and my emotions. I

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am free of all restraints. My willpower is getting stronger and stronger. I have confidence in myself and in the future.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

I am a centre of conscious willpower.

Isabelle Capanio, The Powers Of the Will, De Vecchi Publications, 1987.

(I am going to develop the technique of self hypnosis in order to develop my willpower to improve, my desire to study, to learn and to make progress in all aspects of my life.)

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

I want to train my willpower until it is strong enough to change my life.

Paul Clement Jagot, The Power Of The Will, Dangles Press, 1973.

I want, I can, and I am sure of myself.

Professor Lawrence Powers, The Ten Secrets Of Hypnotic Power, Godefroy Publications, 1982.

I want, therefore I can.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

I want... I want... I want...

Claude M. Bristol, Harold Sherman, Your Inner Power = TNT, A Different World Publications, 1954.

Playing my role means trying to acquire the intellectual and moral qualities of a man of willpower. I want it with all my strength, with all the power I have. I want to create a beautiful future.

My willpower is getting stronger and stronger.

To play my role faithfully, I first develop the attitude of a person who is strong and who wants to succeed.

Professor Robert Tocquet, The Powers Of The Will, Godefroy Publications, 1989.

My willpower is getting stronger and stronger, more and more powerful.

Marcel Rouet, Techniques And Practice Of Hypnotism, Paris Productions N.O.E., 1974.

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My willpower is consolidating.

Marcel Baugin, Hypnotism, Suggestion and Telepsyche, Scientific Distribution, 1956.

When I want to, I can.

Norman Vincent Peale, When You Want, You Can!, A Different World Press, 1974.

WINNING

I now win all the time.

Louis Proto, Self Healing, Piatkus Publications, 1990.

I won! I won! I won!

Richard Corriere, Joseph Hart, Getting Into Psychological Shape, Les Editions de l'Homme, 1979.

I have the right to win.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I know that everything depends on me, and nothing but me. Everything will depend on the way I see things, and on what I do. That's what success is all about, and that's why I always win.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

I play to win.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I'm a winner. I'm a winner.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

I'm a winner. I'm a likable person, I'm enthusiastic, warm and honest, the type of person people like to be with.

Every day my personality becomes stronger and more radiant, revealing ever more clearly the positive, optimistic spirit that animates all my actions.

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

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My ability to become a full time winner depends entirely on my determination to want to think like a winner, and erase all self images of being a loser that I may have accumulated in the past. My capacity for being a person with No Limits, and reaching beyond even my own wildest dreams is entirely in my own hands.

Wayne. W, Dyer, The Sky's The Limit, Mortagne Publications, 1988.

I am a winner in my life. I am not a victim, I'm a winner!

Shad Helmstetter, The Power Of Inner Motivation, Published by Le Jour, 1987.

WISDOM

Now joy, wisdom and the peace of God are uppermost in my mind.

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

With God everything is possible. All powerful God is the spirit living in me, and the source of all wisdom and enlightenment.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

I trust myself and believe in my innate wisdom.

Liah Kraft-Macoy, 30 Days To Happiness, Stillpoint, 1987.

I pray every day, not to amass more wealth, but to become wiser so that I can recognize and benefit from the abundance of goods which are always in my possession, and take pleasure in them.

W. Clement Stone and Napoleon Hill, Success Through Positive Thinking, Godefroy Publications, 1978.

I am wiser than I think. When I rid my mind of false notions, wisdom surges upward like an underground spring.

Vernon Howard, Psycho-Pictography, S.I.P., 1965.

I am full of the wisdom of divine life.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

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I am a balanced being of love. Creation is my playground. I open to my inner wisdom and live it every day.

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

My heart contains perfect wisdom.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

WISDOM - SUBCONSCIOUS

My subconscious knows exactly what is good for me, and what can help me in life.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

WISH

It's okay to ask for what I want - and get it.

Louis Proto, Self Healing, Piatkus Publications, 1990.

——— (specify your wish) will come to me easily and without effort.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

Life is a self fulfilling prophesy; I won't necessarily get what I want in life, but in the long run I will usually get what I expect.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

WIFE

My wife wishes to be loved and respected as a person.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

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WONDER

I never lose my sense of wonder about life.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

WORK (Also see Reward, Salary, Worth)

Today I'll finish all the work I have joyously and easily. Everything I have to do interests me. My mind is constantly present and alert; I am ready to use the opportunities this work, or any other week provide, to do my best to succeed.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

In my life work and play are the same.

Shakti Gawain, Reflections In The Light, New World Library, 1978.

I like my job, my colleagues and my responsibilities. Through them I add value to life, and thus I become useful to God.

R. Charles Barker, The Science Of Success, Dangles Press, 1983.

I like my work, therefore my work likes me.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I like my work. It fulfils me on both a creative and financial level.

Shakti Gawain, Creative Visualization Techniques, Soleil Publications, 1978.

I choose to do this because it is in my best interests, based on the current realities and my current goals. No one is forcing me to do this, and I don't 'have to' do it. I've assessed the consequences and alternatives and on that basis I choose to do this.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

I make my work an exercise in concentration: I do it consciously,

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with interest, and I apply myself body and soul. In no time at all my work becomes a pleasure. Instead of being bored, I discover new sources of interest and opportunities for success in my work that I had no idea existed until now.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I find my work more and more fulfilling.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

I'm happy in my work.

Emrika Padus, Encyclopedia of Emotions And Health, Edi Inter, 1991.

I work well.

Editorial Staff, Practical Health Guides, How To Stimulate Your Body's Natural Defences, Godefroy Publications, 1989.

My work is interesting and easy, and I do it with pleasure. Problems are made to be overcome. I will see things through. And I have the strength to do even better. Not only does my work provide me with real benefits, it also enriches my mind.

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

My work is a joy and a pleasure.

Louis Proto, Self Healing, Piatkus Publications, 1990.

When I think about my business and the office I am filled with love and joy, inner peace and harmony.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

All my work bears fruit in accordance with the divine order of things.

Dr. Joseph Murphy, Exploit The Power Of Your Subconscious, Tchou / Ariston, 1962.

All work becomes simple and pleasant for me.

R.L. Charpentier, Autosuggestion And Its Practical Application, Champs Elysees Publications, 1958.

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WORRY

Instead of worrying about being afraid, I am going to do something about it. I am going to read various books explaining the psychology of fear. I am going to learn the difference between normal and abnormal fears. If I understand the facts about various fears I will be more successful in overcoming them.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

God is watching over me, and that's wonderful!

Dr. Joseph Murphy, These Truths Will Change Your Life, Published by Le Jour, 1982.

I describe the things around me to myself. While I do that I stop thinking about my worries.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

I am getting stronger day by day. At the same time all my worries and fears, all my inner problems are dissolving. I am strong and free. I have all the energy of my Guide at my disposal, and S/He will surely lead me to my goal. My goal is near, and I will succeed!

K.O. Schmidt, Success At Your Service, Astra Publications, 1986.

I don't want to worry about that now; I'll worry about it tomorrow.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

Stop! Fear and worrying are a waste of time and energy, and they block me from using my skills.

Dr. Marty Seldman, Super Selling Through Self Talk, Price Stern Sloan, 1986.

God is the light shining on my path; I am no longer groping, trembling with vain hopes, I see no seeds of worry or struggle on my path, but only seeds of joy and love of life.

Robert Collier, Wealth At Your Doorstep, S.I.P., 1959.

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I eliminate worrying, the major consumer of wasted time, as much as possible.

Christian H. Godefroy and John Clark, How To Have More Time, Godefroy Publications, 1989.

I count my reasons for being happy instead of unhappy.

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

Worries and negative thoughts slide off me like water off a duck's back.

Christian H. Godefroy, Positive Thinking: The Subliminal Method, Godefroy Publications, 1987.

My mind is free of all worry.

Francoise and Michel Moine, Develop Your Psi Powers, Stock Editions, 1982.

My mind is free of doubt and worry.

Since these words come from my soul, they erase all my negative thoughts and negative feelings.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

No matter what happens or doesn't happen to me today there is one thing I am sure of: I want to get the most I can out of this day.

Orison Swett Marden, The Joy Of Living, J.H. Jeheber Publications.

Two months from now I will have completely forgotten this setback, so why should I worry about it today?

Why not assume the attitude I'll probably have in two months right now?

Dale Carnegie, Overcome Your Worries, Flammarion, 1944.

From now on the setbacks in life no longer affect me. If I am assailed by doubt, fear and worry, I know that my faith will overcome them.

Dr. Joseph Murphy, Mastering Yourself And Others, Published by Le Jour, 1988.

If I am sometimes assailed, pursued, haunted by harmful and

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unhealthy thoughts, by fears, phobias, temptations or resentment, I know they will fade away gradually, seeming to melt from my mind, growing faint like a distant cloud which will soon disappear completely.

As dreams disappear when I awaken, so will all these vain images disappear as well.

Emile Coue, Complete Works, Astra Publications, 1976.

WORTH (Also see Wealth, Work, Salary)

Today I will multiply my worth a thousand times.

Og Mandino, The Greatest Secret In The World, A different World Press, 1979.

Every day I multiply my worth a hundred times, and my success grows as a result.

Day by day, in all ways, I am becoming better and better. All areas of my life are enriched, because I multiply my worth a hundredfold.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

I am aware of my worth.

Claude Arpel, Self Confidence: The Subliminal Method, Procauvi Publications, 1986.

I have worth because I struggle to survive.

Matthew McKay and Patrick Fanning, Self Esteem, New Harbinger Publications Inc., 1990.

I evaluate my real worth by asking how good I feel about myself.

Recognizing my own worth is the beginning of a mature acceptance of myself and others.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I believe I am unique and special.

Denis Waitley, Seeds Of Greatness, Pocket Books Press, 1984.

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I am a rare, exclusive, different, unique individual on this earth. These attributes give me enormous worth.

Zig Ziglar, Rendez-vous At The Top, A Different World Publications, 1975.

I am a worthy person.

Alan Houel, How To Deal With Difficult People, Godefroy Publications, 1990.

I am unique and unlimited.

Jean-Marie Boisvert and Madeline Beaudry, Self Affirmation and Communication, Godefroy Publications, 1979.

I am unique. My worth is multiplying, allowing me to do a job which I like and which pays very well.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

(I deserve to be who I am.)

Shakti Gawain, Reflections In The Light, New World Library, 1978.

The best way to increase my worth is to improve my self image.

Charles Albert Poissant & Christian Godefroy, The Secret Of Being A Millionaire, Godefroy Publications, 1987.

The more I realize my true worth, the more everybody respects me.

Louis Proto, Self Healing, Piatkus Publications, 1990.

Whatever anyone says or does to me, I remain a worthy person.

Alan Houel, How To Deal With Difficult People, Godefroy Publications, 1990.

WOUNDS (Also see Pain, Numbness)

Now the pain is disappearing from my —— (name the part of the body) and my blood is coagulating rapidly. The pain is diminishing rapidly. I won't feel any more pain for half an hour. It will disappear completely. Now I'm going to count to five. And on the count of five my pain will disappear completely for half an hour (or substitute the

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desired period). One, two, three, four, five!

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

WRINKLES

I am relaxing the muscles in my face... in my forehead... I feel a cool wave of relaxation...

Every time I feel myself getting tense or upset... I will think of the word serenity... and immediately all the muscles in my face will relax.

My face will look younger... it is going to look younger... releasing... relaxing all my features will prevent wrinkles from forming... smooth over those that are already there... and chase away my worries.

Marcel Rouet, Mastering Your Subconscious, Dangles Press, 1982.

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YOUTH

I do not accept the passive lifestyle of many elderly persons. I live an active life.

I refuse to always think about the past, as too many elderly persons do. I am alive today; I live in he present moment.

Dr. Maxwell Maltz, Psychocybernetics and Self Realization, A Different World Ltd. Publications, 1970.

I am going to remain young in mind and heart by finding new pleasures, new interests and new friends.

Frank S. Caprio, M.D. & Joseph R. Berger, Helping Yourself With Self Hypnosis, Prentice Hall Inc., 1974.

My body is getting younger and more vigorous. I am regaining (or maintaining) optimum use of my bodily functions. My hearing, my vision and my memory are becoming more and more efficient and healthy. I am in excellent health. My face looks younger every day, and I'm looking better and better. I feel more and more young, more and more relaxed, more and more healthy. I am regaining my youthful enthusiasm and sense of curiosity. Youth. Youth. Youth. I am more and more energetic, creative, and young in body and mind.

Christian H. Godefroy, Helping Yourself Through Self Hypnosis, Godefroy Publications, 1985.

(I can be whoever I want to be with total support. I can go fast or slow - it's my choice.)

Barbara J. Gress, Personal Power Cards, Aslan Publishing, 1991.

I'm losing weight... I am happy to feel so good about myself...

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day by day everything is getting better... my skin is supple... I feel younger and younger... slimmer and slimmer... full of newfound energy.

Professor Kurt Tepperwein, Secret Techniques Of Hypnosis, Godefroy Publications, 1981.

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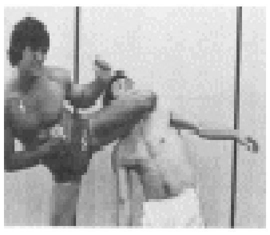

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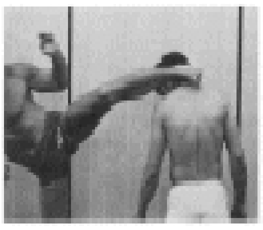

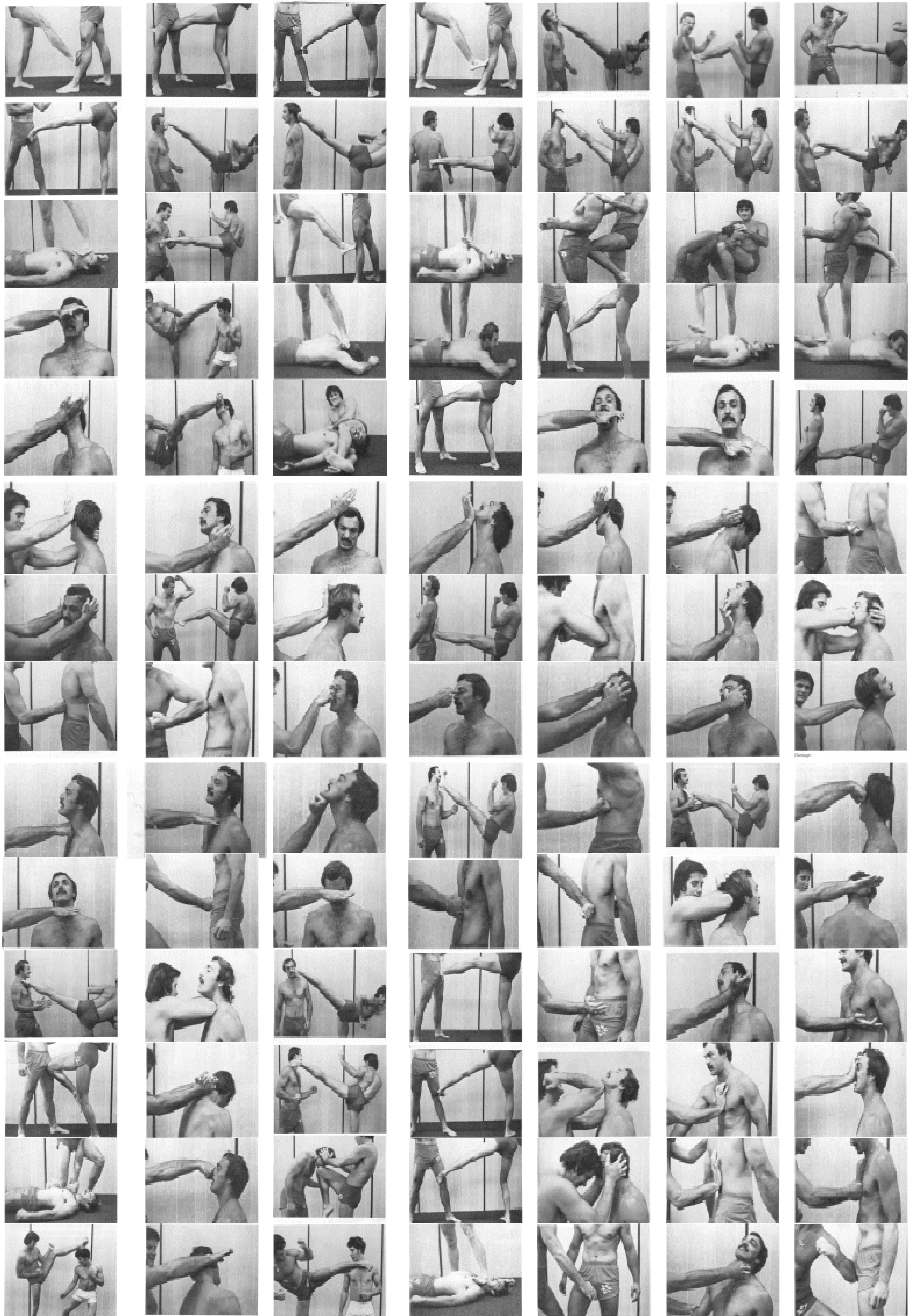

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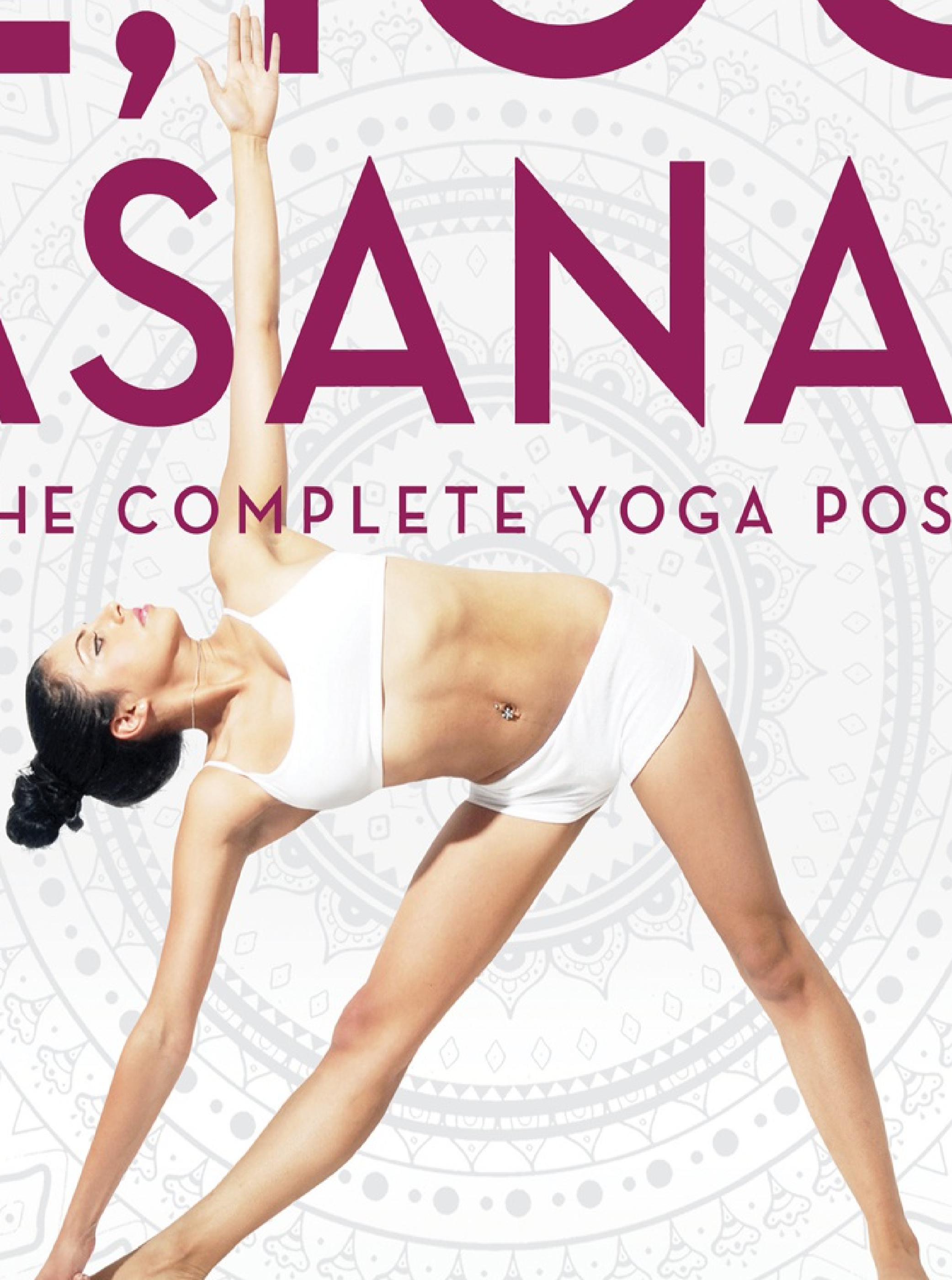

DANIEL LACERDA

FOUNDER OF MR. YOGA, INC.

2,100 ASANAS

The Complete Yoga Poses

Daniel Lacerda

FOUNDER OF MR. YOGA, INC.

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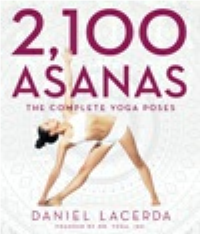

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Opening Prayer

Om

For the peaceful resolution
From the illusionary nature of dualistic existence,
I ground myself before the lotus feet of the gurus,
Who remind me that the light I search for is within me
Bringing stillness to the whirling of the cascading ego mind
I behold the awakened joy of my own Soul
Realizing the truth of pure radiance
That we are in fact the same
To the self-awakened gurus of the past, present, and future,
I salute

Om

Daniel Lacerda, Mr. Yoga

A MESSAGE FROM MR. YOGA

The ultimate goal of yoga is self-realization. You do not need to go to the mountaintop to find it or pay a teacher to show you the way. There are currencies that we exchange with one another that are much more valuable than money: kindness, selflessness, being one part of the greater good. Nor do you need to look outside yourself. If you have an open mind, a sincere desire to learn and to apply that knowledge on a daily basis, and the commitment to follow through on what you've begun, you can achieve self-realization.

Self-realization is the knowledge that we sentient beings are interconnected and that what we think, say, and do affects those around us. Burdened by the pressures and demands that exist outside of ourselves—of our jobs, bills, desire for status and for material possessions—we forget this. Self-realization is the ability to achieve freedom from these demands and to know that true happiness comes from fulfilling our own potential and from lifting up those around us without the thought of self-gain. Dedicating yourself to the regular practice of yoga can help bring you back to this place.

Yoga is, indeed, an excellent form of exercise that carries with it many immediate and long-term physical benefits from improved flexibility to stronger muscles and bones. However, yoga is not just about moving through the poses. Mindfulness plays an essential part in any dedicated yoga practice. If performed properly, yoga quiets the mind of all distracting thoughts from the outside world (*chittavritti*, meaning mind chatter), bringing you to a place of peace within. In turn, being mindful of your thoughts will allow you to be mindful of, and truly connected with, your body, thus completing the cycle of mental and physical health that will allow you to enjoy all the wonderful things that life has to offer.

For the past eleven years, I have dedicated my life to yoga, teaching an average of twenty-five classes seven days a week. I have done this to make a difference in the lives of my students. Now it's my pleasure to share this passion and dedication with you.

Namaste!

A HISTORY OF YOGA

Most of us know yoga as a set of poses performed in a gym or yoga studio setting. The majority of yoga styles practiced today were invented in the last quarter of the 20th century and are either a far cry from yoga's roots or have no authentic lineage.

If we really want to examine the roots of yoga, we need to go back to the Harrapan culture, dating back 3,500 years, when yoga was a meditative practice. According to some, around 1500 BCE, Harrapan culture was diminished due to Aryan invasion. Barbarians from Normandy introduced the caste system and enforced a set of religious rituals that involved blood sacrifice practices. Along with these religious practices came sacred scriptures called the Vedas, a large body of spiritual texts originating in India. The word "yoga" was first mentioned in the oldest of the Vedas, *Rig Veda*. It referred to the concept of discipline.

Fast forward to 800 BCE. The Upanishads, a collection of texts that contain some of the earliest concepts of Hinduism, prescribed the method of achieving enlightenment by studying under a teacher and dedicating one's life to a yoga practice. The Upanishads outlined two paths to enlightenment: Karma Yoga (selfless dedication to the service of others) and Jnana Yoga (intense study of spiritual writings). Around the 3rd century BCE, the *Maitrayaniya Upanishad* prescribed a six-step process to enlightenment, which included mastering *pranayama* (breath control), *pratyaharia* (sense withdrawal), *dhyana* (meditation), *dharana* (one-pointed concentration), *tarka* (self-reflection), and *samadhi* (absolute absorption) in order to unite the Atman (individual's spirit) and Brahman (universal spirit or source of creation). The sacred syllable *om* appeared in this particular Upanishad as a symbol of union between mind and breath.

At around the same time that *Maitrayaniya Upanishad* was introduced, *Bhagavad Gita* gained prominence. This scripture combined and mythological tales that later made their way into a celebrated collection of tales, *Mahabharata*. Three methods of devotion were outlined in *Bhagavad Gita*: Karma Yoga, Jnana Yoga, and Bhakti Yoga (devotion).

Compiled around 400 CE by Patanjali, *The Yoga Sutras* introduced the eight-fold path to yoga practice, which is considered to be the classical yoga manual and the foundation of many of today's yoga practices, particularly Ashtanga Yoga. We will hear more about this eight-fold path in The Eight Limbs of Yoga (here), which include *yama* (self-restraint) *niyama* (self-purification by self-restraint and discipline), *asana* (seat or posture), *pranayama* (control of breath), *pratyahara* (sense withdrawal), *dharana* (one-pointed concentration), *dhyana* (meditation), and *samadhi* (total absorption).

Around the 4th century CE, Tantra Yoga emerged. This new form of yoga celebrated the physical body as a vehicle to enlightenment. The philosophy behind Tantra Yoga can be summarized by the idea of uniting all the dualities within a human body (e.g., male and female; good and evil), which gave

Tantra a very sexual reputation. This is, however, a common misunderstanding, since Tantra practices extend far beyond sexuality.

Hatha Yoga was introduced in the 10th century CE. It combined the physicality and conscious intent of using bodily postures, or *asana* practice, and *pranayama* breath control for the goal of self-realization.

In 14th century CE, the Yoga Upanishads were introduced. One of these sacred texts, *Tejo Bindu Upanishad*, added seven more important parts of yoga practice on top of Patanjali’s eight. They were as follows: *mula bandha* (root lock), balance, undisturbed vision, *tyaga* (abandonment), *mauua* (quiet), *desha* (space), and *kala* (time).

It was not until the 20th century that yoga gained any kind of popularity in Western Europe and North America. Swami Sivananda Saraswati was one of the first yogis to travel outside of India to spread the teachings of yoga to the West. He established yoga centers in North America at the time Swami Satchidananda also delivered an opening speech at the Woodstock Festival in 1969. However, T. Krishnamacharya is arguably the father of the yoga practice with which Westerners are familiar today. In the 1930s, he began teaching his students the Mysore vigorous sequences of yoga poses that emphasize strength and athletic ability. Students were only allowed to learn the next and more challenging pose after they had grasped the previous one. His three most prominent and influential students are Pattabhi Jois, Iyengar, and Indra Devi. Pattabhi Jois established Ashtanga yoga. It is one of the most popular types of yoga practiced in the West. Iyengar became successful by creating his own sequences of yoga poses, which were characterized by a focus on the alignment of the body and the use of various props. Indra Devi is considered the first famous yogini (female yoga master). Krishnamacharya also educated his son Desikachar in yoga. An engineer by training, Desikachar saw great value in studying yoga only when he was already a college graduate. Desikachar developed Vinyoga, which is a more therapeutic and less intense approach to physical practice, as compared to Ashtanga.

The 21st century presents us with an endless variety of yoga “styles” or “brands,” such as Bikram Yoga, Power Yoga, Kundalini Yoga, and countless more. It is important to be open-minded, try as many styles and approaches as possible, and figure out what gives you the best results in terms of achieving both your physical and spiritual goals. There is no wrong way to achieve self-realization. Just make sure you are mindful, patient, practical, and consistent in your practice.

A Note on the Naming of Poses:

One of the ways that the distance from yoga’s roots expresses itself in Western culture is in the naming of the poses. “Seated forward bend,” “eagle pose,” and “dolphin pose,” for example, are all imprecise translations of the original Sanskrit name. *Garudasana*, for example, is widely known as eagle pose, but traditionally this pose was named in dedication to Garuda, who is a Hindu deity, portrayed as half-man and half-eagle. He is the charioteer of Lord Vishnu, who is part of the Holy Trinity in Hinduism. Knowing this history adds a whole new dimension to our understanding of the significance, philosophical depth, and essence of the pose, and can in turn enrich our practice.

The poses throughout this book are identified by both their English and Sanskrit names. The English name is a direct translation of the Sanskrit, which sometimes differs from the more common Western name, also provided in the notes. For a literal translation of each part of the Sanskrit name, you may consult the glossary at the back of the book. The intention is to provide you with as much information about the name of the pose and its history as possible, so no matter what style of yoga you practice, you will have the most complete understanding of the names of the poses.

THE EIGHT LIMBS OF YOGA

The Yoga Sutras, also known as *The Eight Limbs (Ashtanga) of Raja (King) Yoga*, was the first fully developed and recorded system of yoga. Created by Patanjali around 400 CE, this system influences much of the yoga that is practiced today. Although most of the sutras were originally focused on mindfulness, the yoga practiced in the West today seems to focus more on the body. Somewhere along the way, it seems, we began to practice the movement of yoga in isolation from its original philosophies.

For those interested in truly integrating the mindfulness of yoga with its movement, I recommend that you read *The Eight Limbs of Yoga* in its entirety and digest it very slowly. Take time to reflect on it piece by piece so you can implement it into both your practice and your daily life. Wisdom is in the doing. The following, however, is a useful summary of *The Eight Limbs of Yoga*, which will introduce you to the basic concepts of the philosophy. A deep understanding of yoga philosophy and history will greatly enhance the benefits of your practice and put you on the path to mindfulness and self-realization.

There is a wonderful lesson in Buddhism that applies here:

Once, a very old king went to see an old hermit who lived in a bird's nest in the top of a tree. He asked the hermit, "What is the most important Buddhist teaching?" The hermit answered, "Do no evil do only good. Purify your heart." The king expected to hear a long and detailed explanation. He protested, "Even a five-year-old child can understand that!" "Yes," replied the wise sage, "but even an eighty-year-old man cannot do it."

Your biggest obstacle to self-realization is you. As it says in the *Bhagavad Gita*, "The mind is restless and hard to control, but it can be trained by constant practice (*abhyasa*) and freedom from desire (*vairagya*). A man who cannot control his mind will find it difficult to attain this divine communion; but the self-controlled man can attain it if he tries hard and directs his energy by the right means."

Pantanjali's *Eight Limbs of Yoga* will help you form the necessary groundwork to get on the right track, but you must decide to confront your problems at their roots. Reading and intellectualizing is not enough. If you want to reap the full benefits of the yoga experience, implement the Eight Limbs into every aspect of your life. You must live it, breathe it, and engage this planet and its inhabitants with the lessons below.

The first and second limbs, ***Yama*** and ***Niyama***, form your foundation. Here, awareness and realization is established. *Yama* and *Niyama* lay the footing for everything to come. A serious student should be mindful of every limb, as each of these limbs need constant reflection. As you commit yourself to their study and practice, your depth of understanding for each limb will get deeper over time. In our world that perpetuates instant gratification, many people will take shortcuts and go straight to the yoga poses. Others will go straight to meditation and neglect physical health. I highly recommend starting with Pantanjali's first two limbs. Your practice will be at its deepest and most fulfilling if the first two limbs are practiced at a high level. If the first two limbs are not practiced at a proficient level, the rest of the limbs will be performed at a more superficial and less effective level.

FIRST LIMB **Yama** (Self-Restraint)

The focus of the first limb is on being an ethical and moral person, and on improving your relationship with the outer world. These values are as important today as they were centuries ago. The *Yamas*, as they are referred to, are not meant to be a moral straitjacket, but instead are meant to help develop a greater awareness of one's place in the world. It is not a coincidence that this is the first limb of the practice. When taking steps to transform our inner world, our outer world becomes a total reflection of this effort. There are five *Yamas*:

1. *Ahimsa:* **Non-violence**
   Replace harmful thoughts, speech, and actions with that of loving kindness toward yourself and others.
2. *Satya:* **Truth to be expressed in thought, word, and action**
   Be honest in your thoughts, words, and actions toward yourself and others.
3. *Asteya:* **Non-stealing and non-covetousness**
   Curb desires for things that are not your own. Share the beauty of your thoughts, speech, actions, and material belongings to uplift others instead of stealing and hoarding them for yourself.
4. *Brahmacharya:* **Abstinence from sexual intercourse when not married, practicing monogamy and not having sexual thoughts about another person who is not your spouse**
   It is believed that a life built on celibacy and spiritual studies done by free will increases energy and zest for life. Celibacy may sound like an unrealistic goal today, but it may help to remember that brahmacharya is also about monogamy. When brahmacharya is fully realized in marriage, the sex lives of both partners improve because the level of trust and devotion deepens their connection. It is important that the sexual activity is an expression based on the highest level of mutual respect, love, selflessness, and wisdom.
5. *Aparigraha:* **Non-possessiveness or non-greediness**
   Replace the habit of hoarding with sharing. Do not take without giving back. If you want something, work for it. This builds appreciation for what you have. This will help minimize the insatiable desire to constantly consume. An appetite that is not wisely disciplined leads to personal ill health, financial debt or poor credit, and destruction of the planet's natural resources. The Greek god Apollo's motto, "Nothing in excess. All things in moderation," is a great way to describe *aparigraha*.

SECOND LIMB **Niyama** (Self-Purification by Self-Restraint and Discipline)

The second limb helps refine your spiritual path. Discipline and self-restraint lead to a more orderly and productive life. From the perspective of ancient yoga texts, life is extremely short and we need to make the most of it while we can. This limb gives us guidance. There are five Niyamas:

1. *Shaucha:* **Purity of body and mind**
   When you develop *shaucha* (cleanliness), unwholesome thoughts that lead to foul speech and a sick body are cleared. Purity starts with your mind. Speech and action follow. So, the second limb directs you to make a habit of consuming both food and mental stimuli that support well-being for yourself and the environment (humanity and the planet). This will allow destructive habits (hatred, greed, and delusion) to dissolve.
2. *Santosha:* **Contentment with what one has**
   When you achieve *santosha* (contentment), bonds to the material world are broken and authentic peace and happiness are established within. A lack of contentment is often based on a distorted perception of what one has versus what others have. You advance on the path to self-realization when you can be content with your lot, whether you sit on a throne of dirt or gold.
3. *Tapas:* **Self-discipline, sometimes associated with austerity, and being able to conquer the body and mind through mental control**
   Tapas literally means “heat” or “glow.” This refers to a burning desire to accomplish one’s goal despite what obstacles may appear. The commitment to achieving a goal, no matter how challenging it becomes, builds character. However, note that the highest level of *tapas* is to complete one’s goal without a selfish motivation. When *tapas* is attained, laziness is overcome and willpower is developed for future use.
4. *Svadhyaya:* **Self-study that leads to introspection and a greater awakening of the soul and the source of creation; traditionally studied through Vedic scriptures**
   Svadhyaya (self-study) leads to a greater awakening of your true potential, the root of one’s place in this world and how to live in harmony with the Earth and all its inhabitants.
5. *Ishvara pranidhana:* **The surrender to God**
   When you accept that all things come from a higher power, pride and egocentric behavior are turned into humility and devotion. This strengthens your practice of all the limbs leading up to *samadhi* (the eighth limb).

Asana and *Pranayama* are the third and fourth limbs, and they relate to health and longevity, which allow us more time to achieve the ultimate goal of yoga, Self-Realization or Enlightenment. The third and fourth limbs are important, as they prepare the body for meditation, which will be the key to calming your mind and discovering your true potential.

THIRD LIMB Asana (Seat or Posture)

Here is a question: If Gandhi is one of the greatest yogis of our time, does that mean he can touch his toes or bring his foot behind his head? The answer is that it doesn’t matter. Gandhi’s ability to perform the *asanas* had very little to do with what he contributed to the world as a great yogi. The same applies to you. The practice of *asanas* is as much about training the mind as it is the body. How you approach your *asana* practice is often a reflection of how you approach life. Do you keep a sense of peace and calm when a challenge presents itself? Do you break down the impossible into smaller tasks, making the whole possible through commitment to and reflection on each of the parts? Do you overcome self-perceived limitations on your own or do you accept support from others?

Your practice of yoga poses should be characterized by two components: steadiness (*sthira*) and ease (*sukha*). Concentrating on the sound of your breath (*ujjayi*, the most commonly practiced breathing technique in yoga, see here), can provide the steadiness. If you lose your breath, it is most likely because you are pushing too hard; ease off the pose and let the pose cater to the breath.

There is no such thing as a perfect pose; let the poses come like the steps of a dance. Just like in dance, when we focus too much on the mechanics, we let go of the ability to enjoy the music. While the mechanics of alignment are important to prevent injury, never forget the final goal. Feel the music of life flow through you as you do each pose and your body will learn the moves naturally. There are more than enough postures to keep you busy for the rest of your life, so allow yourself to let go of ambition and enjoy the journey. Incorporating a combination of forward bends, backbends, twists, and inversions in your yoga session is optimal for health.

Remember, too, that *asanas* help prepare the mind and body for meditation, relieving tension and protecting the body from disturbances by purifying the nervous system.

FOURTH LIMB **Pranayama** (Control of Breath)

The English word “spirit” comes from the Latin *spiritus*, meaning “breath.”

The breath and the mind are interconnected. Deep, rhythmic, and fluid breathing will energize yet calm the mind and body. Rapid, irregular, and strained breathing produces a chaotic and disturbed mind. A calm mind will give you the mental space to make better decisions and a life in which you take control instead of feeling like a victim of circumstances.

Breathing properly is fundamental to our very existence. Your brain feeds on oxygenated blood, which is supplied with every inhalation. If you are unable to draw oxygen into your body, you will become brain dead after a few minutes. On the other hand, proper exhaling helps expel carbon dioxide. If your ability to exhale were impaired, you would most likely die due to the toxic buildup of carbon dioxide and poison. Stress tends to negatively affect breathing patterns, which contributes to a chain of effects that cause wear and tear on both your body’s nervous and immune systems. In fact, 90 percent of illness is stress-related and, for this reason, attention to breathing properly is, indeed, a matter of life and death.

FIFTH LIMB **Pratyahara** (Sense Withdrawal)

Our perception of reality is predominantly influenced by our sensory experience—what we see, feel, hear, touch, and taste. *Pratyahara* refers to the withdrawal of the senses from external objects and our modern-day need for constant gratification from sensory stimuli. Our minds are constantly being pulled outward to evaluate all the information the senses bring in. Evaluation involves categorizing what has been perceived; often, we hold on to what we believe is desirable, push away what we believe is undesirable, and ignore what we believe to be neutral. *Pratyahara* gives our minds a moment to rest and teaches us to be free of the grasping and clinging to the things we enjoy and avoiding the undesirable.

When you throw a pebble into a pond, your reflection becomes distorted by the resulting ripples. Your mind works in very much the same way: Every thought creates a ripple that distorts the ability to see your true self clearly. Constantly disrupted by these ripples, you begin to believe that the distorted reflection is who you really are. Practicing *pratyahar*a calms the mind, allowing you to see yourself clearly.

SIXTH LIMB **Dharana** (One-Pointed Concentration)

Asanas, *pranayamas*, and *pratyahara* help prepare us for meditation.

When the mind moves from experiencing random scattered thoughts to single one-pointed concentration, it can then find complete absorption in the present moment. By practicing one-pointed concentration, we clear the mind of all distracting thoughts. This can be achieved by focusing on your breath, counting, reciting mantras, or observing a candle flame or an image. Because we are constantly entangled in reliving past memories or living in anticipation of what is to come, it is very seldom that we live in the present moment. It is even less common to be mindful of the present moment with a calm and focused mind. However, this is crucial when trying to achieve self-realization. The power is in the now!

SEVENTH LIMB **Dhyana** (Meditation)

Just as there are many different types of yoga poses, there are many ways of meditating. Meditation is a form of inner contemplation that allows you to access a state of mind that has transcended the ego. This is a state of pure awareness of the present moment that is free of judgment. All meditation leads to a state of full awareness that does not discriminate or categorize things in a dualistic manner, which is to say the perception of what is good versus what is bad, beautiful versus ugly, pleasant versus unpleasant, etc. When we examine reasons behind such judgments, we find many of these beliefs are based on learned behavior, may vary from one culture to another, and have no fixed or concrete reality. With consistent reflection and an open mind, we can correct our biased perceptions. You will develop that part of you called “the Observer.” Once grounded in a regular seated mediation, it is important to take it into a moving mediation throughout your daily life.

EIGHTH LIMB **Samadhi** (Total Absorption)

Samadhi occurs when the analytical mind becomes absent and at one with the object of meditation. The object of meditation can be whatever you are focusing on in your meditation that is used to achieve one-pointed concentration. The word *om*, a deity, or a candle flame are all examples of objects of meditation. Total absorption involves the feeling of oneness with all creation, dissolving all lines between the act of meditation and the object being meditated upon.

It is the absorption in the present moment (*amanaska*) where dualistic thinking is transcended. Many are mistaken in believing *samadhi* is the final goal of yoga. It is but a temporary state of mind that we enter based on the conditions that we have nurtured to support it.

It's useful to remember that every moment in your life gives you an opportunity to practice the eight limbs. Learn at your own pace, but stay focused, be consistent, and enjoy the journey!

THE *UJJAYI* BREATH

Breath is an essential staple of every yoga practice. By focusing on the breath, a yogi is able to stay in the present moment. Since the breath is neutral, a yogi neither seeks to avoid it, nor is she eager to chase it. Proper and continuous breath helps clear the mind of distracting thoughts and to remain in the present moment with one-pointed concentration.

Deep, conscious breathing also slows down the heartbeat and activates the parasympathetic nervous response, which soothes the nervous system, and allows the muscles to relax into the stretches and stay strong in the strength-based yoga poses. Maintaining deep, fluid breathing will help transform your yoga practice into a moving meditation.

Ujjayi pranayama is one of the most commonly used breathing techniques in every yoga practice. *Ujjayi* means “victorious” in Sanskrit. When practicing this breathing technique, a yogi creates what can be described as the “ocean sound” in the back of the throat by gently squeezing the glottis (the opening between the vocal cords in the throat). You’re aiming to create a breathy and whispery sound at the back of the throat. The sound is often compared to the sound Darth Vader makes when breathing! In order to practice *ujjayi* breath, first sit in a comfortable position. Inhale through the nose and, as you exhale, imagine you are trying to fog up a glass. Try to inhale with the same sound. Once you feel like you have an understanding of the *ujjayi* breath technique, seal your lips in order to prevent the throat from drying out. (A dry throat usually leads to coughing and drinking water, which distracts you from your yoga practice.) Inhale and exhale through the nose, while still maintaining the sensation in the throat of trying to fog up a glass.

Using breath to facilitate poses:

- Keep your breath deep and rhythmic.
- If your breathing becomes restricted or choppy, there is a good chance that you are pushing yourself unnecessarily. In this case, you should ease off the pose and return to a place that promotes smooth and fluid breathing.
- The body lifts up and lengthens on the inhale. For example, lift up from a forward bend into a mountain pose on the inhale, using the inhale to lengthen the limbs of the body and the spine. Use the exhales to go deeper into the pose.

THE *BANDHAS*

Bandha means "lock." *Bandhas* were traditionally believed to regulate the flow of life energy (*prana*) throughout the body. In contemporary yoga practice, *bandhas* serve a more practical purpose. They are contractions, or "body locks," that you can implement to help correct your posture or aid you in proper alignment.

There are three major *bandhas*: *mula bandha*, *uddiyana bandha,* and *jalandhara bandha*. The combination of all three *bandhas* is called *maha bandha*, or "the great lock."

Mula bandha refers to the triggering of the perineum muscle that is located between the genitals and the anus. *Mula* means "root," therefore *mula bandha* translates as "root lock." When this *bandha* is engaged, you will feel a slight pull on the inside of the thighs, similar to what you feel when trying to stop the flow of urine.

Uddiyana bandha means "flying/moving up." To engage this *bandha*, place three fingers below the belly button and pull your lower abdominal muscles slightly in and up. This will cause your pelvis to tilt forward slightly with an upward action, protecting the lower back and strengthening the lower abdominals.

Mula and *uddiyana bandhas* should be engaged throughout the yoga practice. Together they help correct the posture and create proper alignment, which will reduce the chance of injury.

Jalandara bandha is a chin lock. To practice this lock, bring the chin toward the clavicle bone while keeping your spine upright and moving your shoulder blades down the back. This *bandha* is rarely used, but can be found when engaged in *Dandasana*, Staff Pose.

THE *DRISHTIS*

Drishtis are the meditation gazing points to focus on while performing the poses. They are designed to aid with proper alignment, as well as to strengthen the focus on the present moment. While practicing we tend to look around, compare ourselves to others in the room, or look at the clock. This takes away from the focus on the internal aspects of the practice. *Drishtis* are meant help you look inward.

They are as follows:

1. *Nasagrai* or *Nasagre* (nose)
2. *Bhrumadhye* or *Ajna Chakra* (third eye, between the eyebrows)
3. *Nabhi, Nabhicakre,* or *Nabi Chakra* (belly button)
4. *Hastagrai* or *Hastagre* (hands)
5. *Padayoragrai* or *Padayoragre* (toes/feet)
6. *Parshva Drishti* (to the right)
7. *Parshva Drishti* (to the left)
8. *Angushtamadhye* or *Angushta Ma Dyai* (thumbs)
9. *Urdhva* or *Antara Drishti* (up to the sky)

Drishtis can be complicated to grasp at first. However, there are general guidelines for the gaze. It comes down to letting your eyes follow the direction of the stretch. For example, in backbends we look at our third eye in order to let the head roll back and deepen the backbend. Similarly, in seated forward bends, such as *Paschimottanasana* (Western Intense Stretch Pose), we gaze at the toes to lengthen the spine. The purpose of *drishtis* is not for you to become cross-eyed; they are a way to softly focus without intensely staring.

HOW TO APPROACH YOGA POSES

Yoga poses provide much more than a physical workout. Performing them builds character. Facing your fears and challenges that extend beyond your comfort zone with a sense of peace, calmness, and psychological equanimity will help you overcome your self-perceived limitations.

I find it helpful to think of every yoga pose as a prayer you do with your body. While you perform the pose, focus on what is good in your life with a feeling of gratitude. Being at one with your mind and body in this place of grace helps you transcend the ego, which helps you get closer to the ultimate goal of yoga, which is enlightenment.

Universal Alignment Cues

- Engage *mula* and *uddhiyana bandhas*.
- Engage the *ujjayi* breath and maintain deep conscious breathing all throughout the yoga session. If your breath is suffering, then back off a bit.
- Keep the chest open and shoulder blades down the back.
- Lengthen the body and limbs on the inhale, deepen the pose on the exhale.
- Avoid jerky and uncontrolled movements during the poses that are based on flexibility.
- Square your hips.
- Don’t let your knee go past your ankle when doing any kind of lunge.
- In Plank and the majority of arm balances, shoulders should be just over the fingertips.
- Even if you are intermediate or advanced, start with the beginner modifications in order to ensure proper form and get the blood into the targeted muscle as a warm-up.

Universal Flexibility Cues

- Hold flexibility for a minimum of 30 to 90 seconds.
- Stretch to the edge of comfort and stimulation without straining.
- Don’t overstretch to the point of pain; your muscles will tighten up in order to protect themselves and your flexibility will decrease.

RELAXATION AND MEDITATION

Relaxation

Corpse Pose (Shavasana)

(Shava in Sanskrit means "corpse")

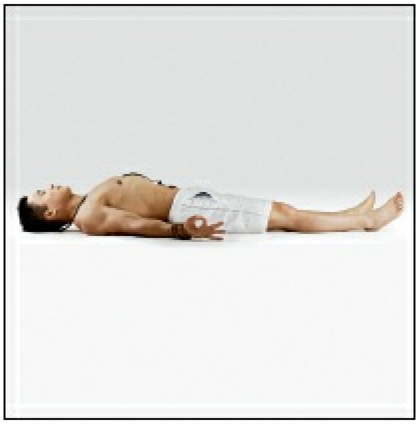

After an intensive *asana* practice, the final resting yoga pose, Corpse Pose or *Shavasana,* helps deepen the connection between our physical body and mind and helps prepare both for meditation. *Shavasana* can be thought of as an awakening, giving us the time to contemplate the question "If I died today, would I be fully satisfied and content with what I accomplished in this lifetime?" Have you lived up to your full potential? Have you fully acknowledged the people in your life that are of great importance to you? Would you be able to pass on with no regrets?

1. Lie down on your back, shoulder blades tucked in, legs apart. Relax your arms and let your palms face the ceiling. Let your fingers naturally curl. Relax your body into a neutral, comfortable position.
2. Close your eyes. Let your jaw naturally separate as you relax your whole body as if it were sinking down to the floor. Release all tension from your body.
3. Without letting the mind wander, concentrate on your breathing to reach a deep state of conscious relaxation, both physically and mentally.

Meditation

Easy Pose (Sukhasana), Seated Lotus Pose (Padmasana)

1. Start in Staff Pose (*Dandasana*), both legs extended in front of you. Grab onto your sitting bones and pull back the flesh to lengthen your legs and spine.
2. Sit in a cross-legged position that is comfortable. You can sit on a chair, in Easy Pose (*Sukhasana*), in Half Lotus (*Ardha Padmasana*), or Full Lotus (*Padmasana*). Press your sitting bones into the ground as you extend up through the spine. Lift the crown of your head up to the sky. Place one hand on top of the other and have the thumbs lightly touch. Gently close your eyes. Perform the 1:4:2 Healing Breath Zen Meditation as follows:

   Inhale for a count of 4 and feel your lower abdomen expand as you push it out. Hold and retain the air in your lungs for the count of 16. Exhale for a count of 8 as you squeeze the belly button back to the spine. Visualize the numbers as you count throughout the set. This will help develop what is called “one-pointed concentration.” Your breathing must be so fine that it would not ruffle a feather. Each count should be one second long.

   After 10 breath cycles are performed, the exercise is finished. In an authentic yoga practice, the ego may not be permitted to intrude into the process. Don’t “perform” the exercises as if you had an appreciative audience. This is your personal journey. Explore and express yourself while you gain the wonderful physical and mental benefits. This breathing technique is called Abdominal Breathing and should be maintained during the entire yoga practice.

A BRIEF SUMMARY OF *CHAKRAS*

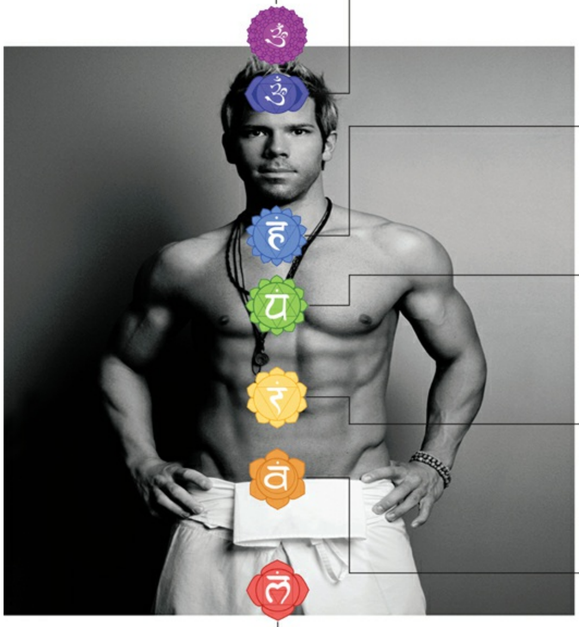

7th **Crown Chakra**/Thousand Petal or Spoked Wheel/*Sahasrara Chakra*
Location: just above the crown of the head
Color: encompasses all colors
Mantra Seed Syllable: encompasses all sounds

Element: the ultimate reality of all truth
Number of Petals: 1000 (symbolic for unlimited)
Focus: detachment from ego and illusory nature of the material world, attaining the goal of yoga (self-realization).

6th **Third Eye Chakra/**Rule or Command Wheel/*Ajna Chakra*
Location: in the middle of the forehead, between the eyebrows
Color: indigo
Mantra Seed Syllable: *om*

Element: the universal mind
Number of Petals: 12
Focus: intuition, decision-making, and the surrendering of egocentric intellect in favor of attaining nondualistic wisdom

5th **Throat Chakra**/Especially Pure Wheel/*Vishuddha Chakra*
Location: throat
Color: turquoise or blue
Mantra Seed Syllable: *ham*

Element: ether/space
Number of Petals: 16
Focus: self-expression and communication

4th **Heart Chakra**/Wheel of the Unstruck or Singular Sound/*Anahata Chakra*
Location: within the center of the chest
Color: green
Mantra Seed Syllable: *yam*

Element: air
Number of Petals: 12
Focus: peace, love, and empathy

3rd **Solar Plexus or Navel Chakra/**Wheel of the Jewel City/*Manipura Chakra*
Location: solar plexus
Color: yellow
Mantra Seed Syllable: *ram*

Element: fire
Number of Petals: 10
Focus: power, will, and self-esteem

2nd **Sacral Chakra/**One's Own Self-Based Wheel/*Svadhisthana Chakra*
Location: sacrum
Color: orange
Mantra Seed Syllable: *vam*

Element: water
Number of Petals: 6
Focus: emotions, desires, and creativity

1st **Root Chakra or Root Wheel/***Muladhara Chakra*
Location: base of the spine
Color: crimson
Mantra Seed Syllable: *lam*

Element: earth
Number of Petals: 4
Focus: physical survival, self-preservation, and security

In Sanskrit the word *chakra* can be translated into “wheel” or “turning.” In the yogic interpretation, the *chakras* are based on the concept of a vortex and are visually portrayed as a lotus flower.

According to various Eastern yogic spiritual practices such as Hinduism and Tantric Buddhism, *chakras* are described as wheels or rings of energy found in the subtle (non-physical) body; the culmination of the mind, intelligence, and ego, which influences the gross physical body. Within this subtle body there are energy channels called *nadis* that carry the life force or vital energy (*prana*). The main *nadi* that runs through the *chakras* is called the *sushumna* (*brahma*) *nadi*. The *sushumna* joins two other important *nadis* (*ida* and *pingala*) together at the first and seventh *chakras*. The diameter of a singular *nadi* is believed to be no thicker than a thousandth of a hair’s width and is located along the spine.

There are various opinions on how many *chakras* there are, but it is generally agreed that *chakras* spin in a “wheel-like” motion to draw in vital energy that creates a balance between the spiritual and physical body.

The earliest known recording of *chakras* dates back to the ancient Vedas (1700 BCE). The most popular *chakra* model used today is based on two Indian texts: *Shat-Cakra-Nirupana*, written by a Bengali yogi named Purnananda Swami in 1577, and the *Padaka-Panchaka*, written in the 10th century.

Chakras are activated in the following ways:
By stretching open the area where the *chakra* is located. For example, the throat *chakra* can be activated in Camel Pose (*Ushtrasana*). The head is rolled back so there is a stretch in the front of the throat.

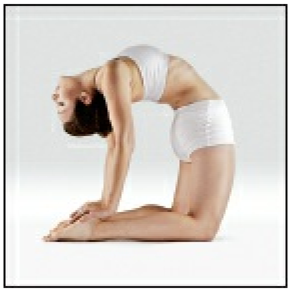

By applying physical pressure on the area where the *chakra* is located. Throat *chakra*, for example, can be activated in Staff Pose (*Dandasana*). The Chin Lock (*Jaladhara Bandha*) is engaged by bringing the chin to the clavicle bone, therefore applying pressure to the throat area.

By combining the two methods above, throat *chakra* is activated in full version of Inverted Locust Pose (*Viparita Shalabhasana*). The head is rolling back, creating a stretch in the front of the throat. At the same time, the throat area is pressed to the floor, so there is physical pressure on that area.

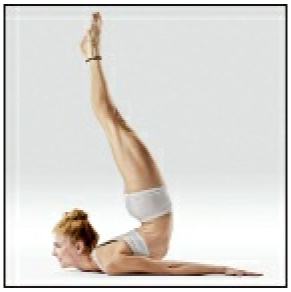

BENEFITS AND CAUTIONS FOR 8 CONDITIONS

CONDITION

1. Headache & Migraine

Many headaches are caused by tension and stress. In yoga we breathe deeply and relax. The yoga practice stretches the tight muscles in the upper body, releases endorphins (a “feel good” hormone) and relaxes the mind. It helps release tension by increasing blood flow to the muscles, making the nervous system less agitated and reducing a chance of a headache or migraine.

Poses that put weight or pressure on the head and neck should be avoided. If you suffer from migraines, avoid poses that dramatically increase blood flow to the head. If your migraines are severe, avoid practicing yoga poses and lie down in a dark room.

BENEFICIAL POSES

Seated forward bends–Ex. Both Hands to Ankle Head to Knee Pose (*Dwi Hasta Kulpa Janu Shirshasana*) here. Seated forward bends release tension in the hamstrings and lower back and help prevent headaches caused by tension in the legs and lower back.

Seated twists–Ex. Half Root Lord of the Fishes Pose (*Ardha Mula Matsyendrasana*) here. Seated twisting poses can help prevent headaches caused by tension in the upper and lower back.

Hand position of the pose dedicated to Garuda–Ex. Hand Position of the Pose Dedicated to Garuda in Child’s Pose (*Hasta Garudasana in Balasana*) here. Any pose with this hand position helps stretch the upper back and back shoulder heads and can help prevent headaches caused by tension in the muscles of the upper back.

Hand position of Cow Face Pose–Ex. Hand Position of Cow Face Pose in Bound Angle Pose (*Hasta Garudasana in Baddha Konasana*) here. Any pose with this hand position helps stretch the triceps, front shoulder heads, and rotator cuffs and can help prevent headaches caused by tension in the arms and shoulder muscles.

POSES TO APPROACH WITH CAUTION

Inversions–Ex. Peacock Feather Pose (*Picha Mayurasana*) here, Leg Position of One-Legged King Pigeon 1 Version B in Headstand 5 (*Pada Eka Pada Raja Kapotasana 1 B in Shirshasana 5*) here, and Leg Position of the Pose Dedicated to Garuda in Hands Bound Supported Whole Bod Pose (*Pada Garudasana in Baddha Hasta Salamba Sarvangasana*), also known as Shoulderstand here. Avoid any intense inversions that require a lot of strength, as they increase the heart rate and blood flow to the head and may trigger headaches or migraines.

Backbends with feet and head on the floor–Ex. Bridge Pose (*Setu Bandhasana*) here. Avoid poses that put pressure on the head and neck, as they may trigger headaches or migraines.

CONDITION

2. Carpal Tunnel

To help prevent or alleviate carpal tunnel syndrome with yoga, you'll need to practice poses that strengthen and stretch the flexor muscles of the forearm, which are the muscles on the palm side of the forearm. Depending on the severity of your condition, you may want to start with poses that bear less weight on the wrist joint.

BENEFICIAL POSES

Poses that strengthen the wrist without straining it–Ex. Staff Pose (*Dandasana*) here. Stretching and gently strengthening the wrist and muscles of the forearm can help prevent or reduce carpal tunnel syndrome.

Poses with hands in the reverse prayer position–Ex. Hidden Lotus Pose (*Gupta Padmasana*) here and Reverse Prayer Mountain Pose (*Viparita Namaskar Tadasana*) here. These poses help stretch out the wrists, forearms, front shoulder heads, chest, and rotator cuffs. Releasing tension from these areas is helpful because muscles in the upper body are interconnected and carpal tunnel can be caused or worsened by a chain reaction of tense muscles.

Poses that have hands in prayer (Anjali Mudra)–Ex. Revolved Prayer Standing Rising Winc Relieving Pose (*Parivritta Namaskar Stiti Utthita Vayu Muktyasana*) here. Stretching the wrists and forearm muscles can promote blood flow and lessen tension in the area.

Poses with bound hands, palms facing out–Ex. Mountain Pose—Raised Bound Hands (*Tadasana Urdhva Baddha Hastasana*) here These poses help stretch the forearm muscles that are strained and tight in most people who have carpal tunnel syndrome.

POSES TO APPROACH WITH CAUTION

Arm balances with both feet off the floor–Ex. Crane Pose (*Bakasana*) here. These poses have the entire body weight resting on the wrists, which puts a great amount of strain on the carpal tunnel and may drastically worsen its symptoms.

Backbends with hands and feet on the floor–Ex. Upward Bow Pose (*Urdhva Dhanurasana*) here and Wild Thing Pose (*Chamatkarasana*) here. These poses are very hard on the wrists.

Backbends with straight arms–Ex. Upward Facing Dog (*Urdhva Mukha Shvanasana*) here. These poses put strain on the wrist joints because most of the upper body weight rests on the hands.

ADDITIONAL NOTES: There are some options to avoid pressure on the wrist while practicin Upward Facing Dog Pose (*Urdhva Mukha Shvanasana*) here or Downward Facing Dog (*Adho Mukha Shvanasana*) here. If you feel that these poses irritate the carpal tunnel, drop the knees to the floor and rotate the hands 45 degrees to the outside to take the pressure off the nerve. You may also experiment with placing props (rolled-up yoga mat, thin book, or slant board) under the heels of the palms to shift the weight to the knuckles and fingers to reduce the compression of the wrist.

CONDITION

3. Asthma

Yoga can help bring awareness to your breathing patterns and release tension from the neck, upper back, chest, and shoulders. Focus on developing full and complete breaths through seated mediation sitting in Easy Pose (*Sukhasana*) here. Since a symptom of asthma is short shallow breaths, developing control of the breath will help the body obtain the oxygen needed and help calm the body, preventing future attacks.

Some yoga poses may be strenuous to the respiratory system and could cause asthma attacks. It's recommended that you pace yourself, gradually raising your body temperature and gradually cooling down. Cold air can cause bronchi to contract and cause an asthma attack. Hot and humid air can cause dehydration and can also cause an asthma attack. Find a room with a comfortable temperature.

BENEFICIAL POSES

Poses on hands and knees–Ex. Going from Tiger Pose (*Vyaghrasana*) here to Unsupported Tiger Pose (*Niralamba Vyaghrasana*) here. Many people who suffer from asthma have tension in the upper back and chest from coughing during asthma attacks. Combining mild backbends with mild forward bends gently stretches the chest, upper back, and the neck, which can help reduce the symptoms of asthma worsened by tension in those areas.

Mild backbends–Ex. Fish Pose (*Matsyasana*) here. Mild backbends help open the chest and front shoulder heads and improve the quality of breathing.

Lion's Pose variations–Ex. Lion Pose Dedicated to an Avatar of Lord Vishnu in Garland Pose (*Narasimhasana in Malasana*) here. Lion's Pose variations can help release tension in the throat, neck, and jaw because you "roar" like a lion in these poses. They also can help push the stale air out of your lungs.

Seated meditation focusing on breathing–Ex. Lotus Pose (*Padmasana*) here. Bringing awareness to your breath and developing control can be useful during an asthma attack. It can also help prevent an attack from happening.

Inversions–Ex. Headstand 5 (*Shirshasana 5*), also known as Tripod Headstand here. Inversions help promote proper movement of the diaphragm during an exhalation. Since the majority of the body is upside down, gravity works with the exhalation, not against it.

POSES TO APPROACH WITH CAUTION

Inversions on the shoulders–Ex. Ear Pressure Pose (*Karnapidasana*) here. Inversions on the shoulders compress the neck and chest, especially when the knees are bent toward the head. This compression restricts your breathing and may cause an asthma attack.

Backbends on the chin and chest–Ex. Inverted Locust Pose (*Viparita Shalabhasana*) here. These poses compress the throat and restrict your breathing, and may cause an asthma attack.

Seated forward bends–Ex. Western Intense Stretch Pose (*Paschimottanasana*) here. These poses compress the lungs and restrict your breathing, and may cause an asthma attack.

Cardio-intense poses–Ex. Crocodile Pose (*Nakrasana*) here. Poses that require a lot of strength and that are demanding on the cardiovascular system can cause shortness and shallowness of breath, and may cause an asthma attack.

Intense backbends–Ex. Little Thunderbolt Pose (*Laghuvajrasana*) here. These poses can be stimulating and cause shortness of breath if you have asthma. It is recommended to start with mild backbends and progress into deeper ones slowly, according to how your body feels.

Arm balances with both feet off the floor–Ex. Uneven Half Repose Pose Dedicated to Ashtavakra (*Vishama Ardha Shayana Ashtavakrasana*) here. These types of poses require a lot of strength and endurance and may cause shortness of breath.

CONDITION

4. Neck Pain

Yoga practice can help prevent and relieve neck pain. The combination of gentle stretches and strengthening movements can open up tight muscles in the body, increasing neck flexibility and rebalancing postural muscles. Simple and slow movements will lubricate the neck and increase its range of movement. Hold each pose for 30 to 90 seconds.

While it’s important to strengthen and stretch the neck muscles in order to help prevent neck injury, if you already have a neck concern it’s best not to aggravate it. Poses that are most strenuous for the neck are the ones that bear the majority of the body’s weight on the head or neck.

BENEFICIAL POSES

Seated neck stretches–Ex. Easy Pose with Neck Stretch (*Sukhasana*) here. Neck pain can be caused by tension in the neck muscles. Stretching these muscles can help prevent or reduce neck pain.

Seated twists–Ex. Pose Dedicated to Bharadvaja 1 (*Bharadvajasana 1*) here. Muscles in the neck are connected to the muscles in the upper back. Seated twists increase the range of motion in the upper back and neck and can help prevent or reduce neck pain caused by tension in these areas.

Poses on hands and knees–Ex. Going from Tiger Pose (*Vyaghrasana*), modification knee to the forehead, here to Tiger Pose (*Vyaghrasana*), also known as Cat Tilt here, top. Rounding the back and then going into a mild backbend can help strengthen the neck muscles and stretch the front of the neck (in Dog Tilt) and the back of the neck (in Cat Tilt).

Hand position of the pose dedicated to Garuda–Ex. Hand Position of the Pose Dedicated to Garuda in Hero Pose (*Hasta Garudasana in Virasana*) here. Any pose with this hand position helps stretch the upper back and back shoulder heads and can help prevent neck pain caused by tension in the muscles of the upper back.

POSES TO APPROACH WITH CAUTION

Full inversions–Ex. Revolved Leg Position of One-Legged King Pigeon 1 Version B in Headstan 5 (*Parivritta Pada Eka Pada Raja Kapotasana 1 B in Shirshasana 5*) here, One-Legged Unsupported Whole Body Pose (*Eka Pada Niralamba Sarvangasana*), also known as Shoulderstand here Full inversions with the head on the floor put strain on the neck since the majority of the body weight tends to rest on the head or neck. If you have a neck injury, it's best to avoid these.

Backbends with feet and head on the floor–Ex. Inverted Tip Toe Bow Pose (*Viparita Prapada Dhanurasana*), also known as Headstand Bow Pose (*Shirsha Dhanurasana*) here. Backbends with head and feet on the floor require a lot of neck strength and should be avoided if you have a neck concern.

CONDITION

5. High Blood Pressure

If you think you may be at risk or have already been diagnosed with high blood pressure, it is advisable to speak with your health care provider. Practicing yoga may help with blood pressure management since it combines the benefits of meditation, muscle relaxation, and strength training exercise. When practicing yoga poses, ensure that you are able to breathe comfortably and deeply. If you have any difficulty breathing, come out of the pose and rest or perform an easier version of the pose. If difficulty breathing persists, then consult your health care provider immediately.

BENEFICIAL POSES

Seated backbends–Ex. Hands Bound Lotus Pose (*Baddha Hasta Padmasana*) here. Seated backbends gently open the chest and improve the flow of oxygen to the lungs. They release tension in the chest and front shoulder heads often caused by stress and hunching over a computer on a daily basis. This can help lower high blood pressure that is a result of stress.

Seated twists–Ex. Revolved Easy Pose (*Parivritta Sukhasana*) here. Seated twists help release tension from the upper back and detoxify the body. This can help lower high blood pressure that is a result of tension in the upper back.

Supine forward bends–Ex. Reclining Both Hands to the Leg Pose (*Supta Dwi Hasta Padasana*) here. Supine forward bends stretch the hamstrings without increasing blood pressure, as opposed to standing forward bends where the head is below the heart. This can help lower high blood pressure that is a result of muscle tension of the lower back and legs.

POSES TO APPROACH WITH CAUTION

Inversions–Ex. Feet Spread Out Intense Stretch Pose 2 (*Prasarita Padottanasana 2*) here and Crane Pose in Headstand 5 Prep. (*Bakasana in Shirshasana 5 Prep.*) here. Inversions should be avoided if you have high blood pressure that is not controlled. They are very stimulating postures since the head is below the heart, which causes an increased demand for oxygen. These increase blood flow and heart rate, generating pressure to the blood vessels of the brain, and may cause blood pressure to rise dramatically.

Lunges with back knee off the floor–Ex. Revolved Son of Anjani (Lord Hanuman) Lunge Pose with Hands in Prayer (*Parivritta Anjaneyasana Namaskar*) here. These poses can require a lot of lower body strength if you are not used to practicing them. They can raise the heart rate and increase blood pressure.

Arm balances with both feet off the floor–Ex. Leg Position of Cow Face Pose in Pendant Pos (*Pada Gomukhasana in Lolasana*) here. These poses are demanding on the upper body and may increase heart rate, which can increase blood pressure.

Backbends with hands and feet on the floor–Ex. Elevated Both Legs Inverted Staff Pose (*Utthita Dwi Pada Viparita Dandasana*) here. Poses such as these can be demanding on the upper body and can elevate blood pressure by increasing heart rate.

CONDITION

6. Menstruation

During a period, uterine contractions can cause painful cramps in the lower abdomen and lower back. Yoga can help release endorphins to relax the body. Stretch out the lower body and back to help release the pain. Forward bends, inside hip openers, and gentle twists can help relieve the symptoms of menstruation.

Some are of the opinion that inversions can cause engorgement in the blood vessels of the uterus, which may increase blood flow, and should be avoided during a period. On the other hand, B.K.S. Iyengar's book *The Path to Holistic Health* recommends inversions during a period to reduce blood flow. You should listen to your own body and judge accordingly. If you are not feeling strong, engage in a slower-paced yoga pose practice.

BENEFICIAL POSES

Supine hip openers–Ex. Universal All-Encompassing Diamond Pose (*Vishvavajrasana*) here. Poses such as this open up the hips and groin and allow the lumbar spine to rest, which can help relieve the menstrual discomfort.

Low squats–Ex. One Leg Bound Garland Pose (*Eka Pada Baddha Malasana*) here. Practice poses such as this to stretch out the groin, the chest, and front shoulders. Releasing tension from those areas can help relieve menstrual discomfort.

Seated hip openers–Ex. One Legged King Pigeon Pose 1 Prep. (*Eka Pada Raja Kapotasana 1 Prep.*) here. Poses such as this help open up the hip and stretch the lower abdomen, which can help relieve menstrual discomfort due to tension in that area.

Backbends on the knees–Ex. Camel Pose (*Ushtrasana*) here. Poses such as this can help stretch out the lower abdomen and release tension from that region, which can help relieve menstrual discomfort.

Gentle seated twists–Ex. Easy Lord of The Fishes Pose Prep. (*Sukha Matsyendrasana Prep.*) here. Seated twists stimulate internal organs and can help relieve the symptoms of menstruation by gently encouraging the natural blood flow during menstruation.

POSES TO APPROACH WITH CAUTION

Arm balances with hands and feet on the floor–Ex. Four Limbed Staff Pose (*Chaturanga Dandasana*) here. Poses such as this are very demanding on the upper body and core, and may worsen the symptoms of menstruation due to overstraining.

Arm balances with both feet off the floor–Ex. Pose Dedicated to Galava, One-Legged Variatio (*Eka Pada Galavasana*) here. These poses demand a lot of strength and may worsen the symptoms of menstruation due to overstraining.

High squats–Ex. Tip Toe Fierce Pose (*Prapada Utkatasana*) here. Poses such as this are demanding on the legs and core, and may worsen the symptoms of menstruation due to overstraining.

Backbends on hands and feet–Ex. Partridge Pose (*Kapinjalasana*) here. Intense backbends put a lot of strain on the body, because they engage the entire body. They may worsen the symptoms of menstruation due to overstraining.

CONDITION

7. Pregnancy

Don't engage in a vigorous yoga practice with jump-through and jump-back *Vinyasas*. Jumping is dangerous during pregnancy. Avoid hot yoga classes that can dangerously elevate your core temperature or cause dehydration. After giving birth, be mindful when going into deep stretches. The levels of relaxin (the hormone that loosens the muscles and joints to accommodate birth) in the body may still be high, increasing the danger of injury due to overstretching. If you had a C-section, make sure the wound heals properly. Avoid doing any intense twists or backbends, as they may interfere with healing of the wound.

BENEFICIAL POSES

Seated inner hip openers–Ex. Knees Spread Wide Hero Pose (*Prasarita Janu Virasana*) here. Poses such as this stretch out the inner hips without compressing the abdomen.

Wide-legged squats–Ex. Lotus Hand Seal in Upward Hands Pose Dedicated to Goddess Kal (*Padma Mudra Urdhva Hasta Kalyasana*) here. Wide-legged squats strengthen quadriceps (front of the thighs), hamstrings (back of the thighs), and glutes (buttocks) without putting pressure onto the abdomen.

Standing side bends–Ex. Extended Side Angle Pose (*Utthita Parshva Konasana*) here. Standing side bends stretch out the side of the torso and lower back while strengthening the legs without putting pressure onto the abdomen.

Poses on hands and knees–Ex. Tiger Pose (*Vyaghrasana*) here. Poses on hands and knees can be done during pregnancy because they do not compress the abdomen.

Mild backbends on the knees–Ex. Half Camel Pose (*Ardha Ushtrasana*) here. Mild backbends can be practiced during pregnancy since they don't compress the abdomen.

POSES TO APPROACH WITH CAUTION

Inversions–Ex. Repose Pose (*Shayanasana*) here. Don't do any inversions where your heart is above your head beyond the first trimester. Turning your body upside down creates pressure on your internal organs and may be damaging to the developing fetus.

Forward bend twists–Ex. Two Hands Revolved Western Intense Stretch Pose (*Dwi Hasta Parivritta Paschimottanasana*) here. Don't do any forward bends or twists that compress the abdomen and squeeze the fetus and placenta.

Core poses–Ex. Revolved Boat Pose (*Parivritta Navasana*) here. Don't do strenuous core poses that compress the abdomen.

Prone poses–Ex. One-Legged Pose Dedicated to Siddhar Konganar (*Eka Pada Konganarasana*) here. Avoid prone poses since they put a lot of pressure on the abdomen.

Supine poses where the back is flat on the floor–Ex. Reclined Leg Position of Cow Face Pose (*Supta Pada Gomukhasana*) here. Supine poses with the back flat on the floor take out the natural curve in the lumbar spine that is present during pregnancy and can compress the fetus and placenta.

Intense backbends–Ex. One-Legged Pigeon Pose (*Eka Pada Kapotasana*) here. Intense backbends create too much stretch in the abdomen and should be avoided during pregnancy.

CONDITION

8. Menopause

Common symptoms of menopause such as hot flashes and mood swings can be alleviated with regular yoga pose practice. Focus on poses that open up the pelvic area as well as mediation to help control stress.

Avoid practicing hot yoga and avoid overexertion. Both can trigger menopause symptoms. It is recommended to avoid vigorous Sun Salutes, as they can increase body temperature and cause hot flashes.

BENEFICIAL POSES

Mild supine backbends–Ex. Bridge Whole Body Pose (*Setu Bandha Sarvangasana*) here. Mild backbends open up the chest and heart area. They can help balance blood pressure and hormonal secretions as well as help relieve mood swings and hot flashes.

Supine hip openers–Ex. Reclined Bound Angle Pose *(Supta Baddha Konasana*) here. These poses open up the chest, heart and pelvic areas. Blood flow is increased into the pelvic area and reproductive organs and that can help balance hormonal functions. These poses can help relieve high blood pressure, headaches, and breathing problems.

Supine thigh openers–Ex. Reclined Hero Pose (*Supta Virasana*) here. Poses such as this can help improve blood circulation in the ovarian region and stimulate the pelvic organs, which can help balance hormonal functions and relieve the symptoms of menopause.

POSES TO APPROACH WITH CAUTION

Backbends on hands and feet–Ex. Tip Toe One Hand Upward Bow Pose (*Prapada Eka Hasta Urdhva Dhanurasana*) here. Poses such as these can be too strenuous on the upper body (arms and shoulders). They can raise the body temperature and cause hot flashes.

Core poses–Ex. Boat Pose (*Navasana*) here. Avoid any vigorous core yoga poses, as it creates too much tension around the abdominal organs and may worsen the menopause symptoms.

Standing twists–Ex. Revolved Side Angle (*Parivritta Parshva konasana*) here. Avoid any intense twists, as it creates too much compression around the internal organs of the torso, which may worsen the menopause symptoms.

Inversions–Ex. Headstand 1 (*Shirshasana 1*) here. Avoid any full inversions, as they increase blood flow to the internal organs of the torso and raise heart rate which may cause hot flashes.

Standing Poses

MOUNTAIN POSE

SIDE BENDS

STANDING BACKBENDS

ONE LEG STANDING BALANCE

STANDING FORWARD BENDS

LEGS WIDE

DOWNWARD DOG

INTENSE SIDE STRETCH

TRIANGLE POSE

WARRIOR AND SIDE ANGLE POSES

LUNGES AND KNEELING POSES

SQUATS

Mountain Pose

Tadasana

(tuh-DAHS-uh-nuh)

Also Known As: Equal Steady Standing, State of Balance (Samasthiti)
Modification: palms rotated forward
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

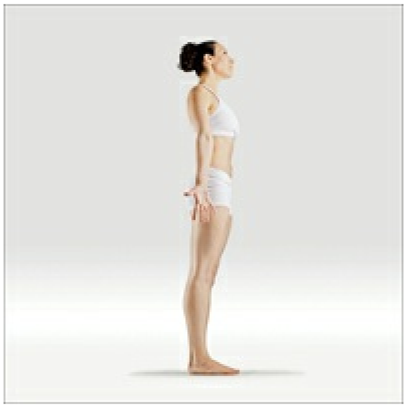

Mountain Pose with Hands in Prayer

Tadasana Namaskar

(tuh-DAHS-uh-nuh nuh-muhs-KAHR)

Modification: hands in Anjali Mudra (Hands in Prayer); feet to the front, toes lifted
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

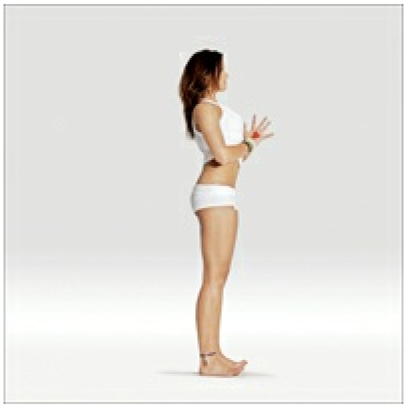

Reverse Prayer Mountain Pose

Viparita Namaskar Tadasana

(vi-puh-REE-tuh nuh-muhs-KAR tuh-DAHS-uh-nuh)

Also Known As: Penguin Pose, Back of the Body Prayer Mountain Pose (Paschima Namaskara Tadasana)
Modification: feet rotated out
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

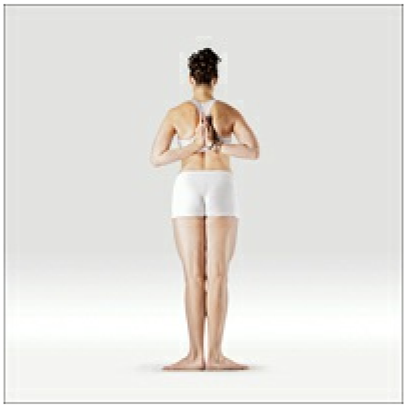

Hands Bound Mountain Pose

Baddha Hasta Tadasana

(BUH-duh HUH-stuh tuh-DAHS-uh-nuh)

Pose Type: standing
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

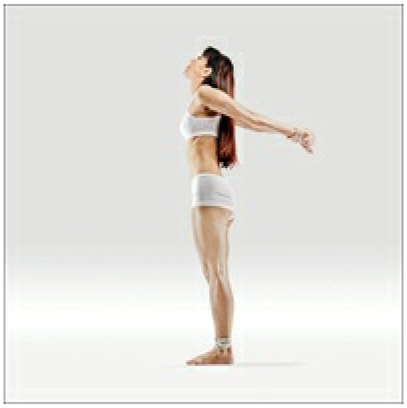

MOUNTAIN POSE: HANDS ABOVE THE HEAD & TANDAVA AND LASYA DANCE MODIFICATIONS

Upward Salute Pose

Urdhva Hastasana

(OORD-vuh huh-STAHS-uh-nuh)

Also Known As: Volcano Pose
Modification: arms shoulder width apart
Pose Type: standing, mild backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

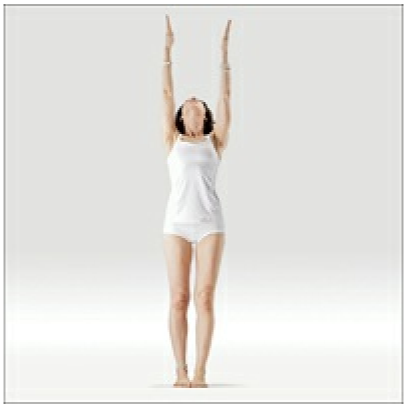

Upward Salute Pose

Urdhva Hastasana

(OORD-vuh huh-STAHS-uh-nuh)

Also Known As: Volcano Pose
Modification: palms pressed together
Pose Type: standing, mild backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

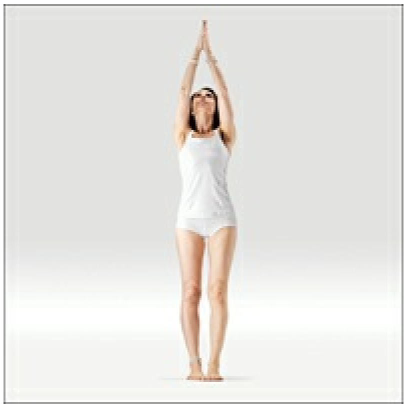

Mountain Pose—Raised Bound Hands

Tadasana Urdhva Baddha Hastasana

(tuh-DAHS-uh-nuh OORD-vuh BUH-duh huh-STAHS-uh-nuh)

Also Known As: Mountain Pose (Parvatasana)
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)
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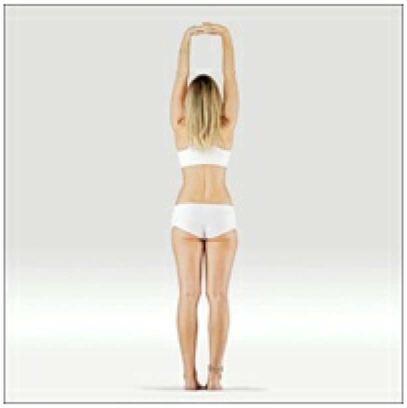

Mountain Pose

Tadasana

(tuh-DAHS-uh-nuh)

Modification: shoulder opener, intense version
Pose Type: standing
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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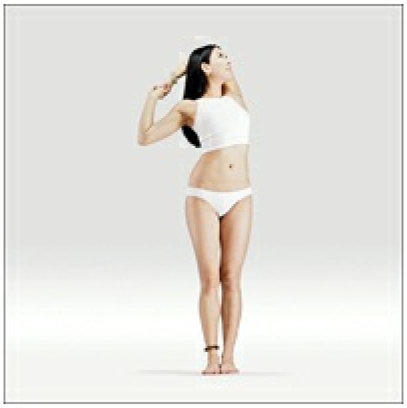

Pose Inspired by Parvati's Graceful Dance

Lasyasana

(lahs-YAHS-uh-nuh)

Modification: both legs straight; one leg extended to the front, heel up; one arm up over the head reaching to the floor, other arm reaching up to the sky; deep backbend
Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

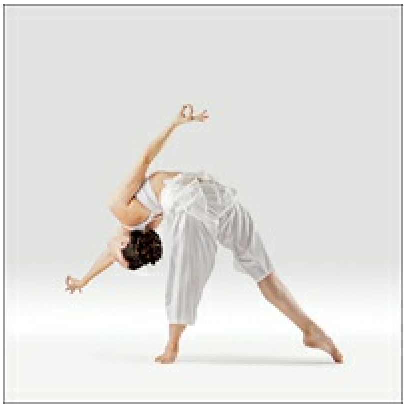

SIDE BENDS: FEET TOGETHER, ARMS UP OVER THE HEAD & TANDAVA AND LASYA DANCE MODIFICATIONS

Standing Crescent Pose

Indudalasana

(in-doo-duh-LAHS-uh-nuh)

Modification: grabbing onto the wrist of the top hand
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

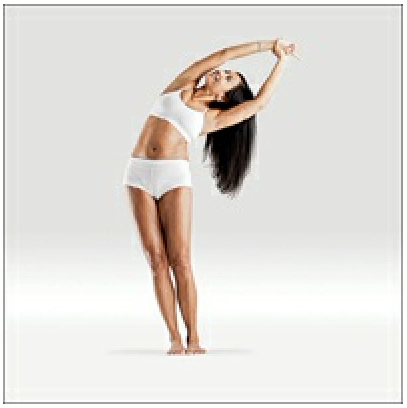

Sideways Mountain Pose—Raised Bound Hands

Parshva Tadasana Urdhva Baddha Hastasana

(PAHRSH-vuh tuh-DAHS-uh-nuh OORD-vuh BUH-duh HUH-STAHS-uh-nuh)

Also Known As: Side Bending Pose (Parshva Bhangi)
Pose Type: standing, side bend

Drishti Point: Nasagrai or Nasagre (nose)
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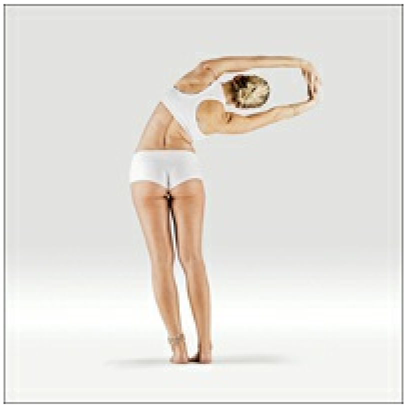

Revolved Upward Mountain Pose—Raised Bound Hands

Parivritta Urdhva Tadasana Urdhva Baddha Hastasana

(puh-ri-VRIT-tuh OORD-vuh tuh-DAHS-uh-nuh OORD-vuh BUH-duh HUH-STAHS-uh-nuh)

Also Known As: Side Bending Pose (Parshva Bhangi)
Pose Type: standing, side bend, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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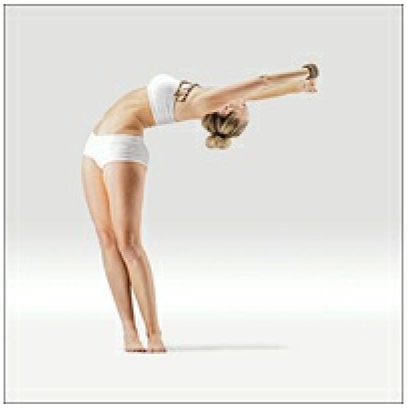

One-Legged Standing Crescent Pose

Eka Pada Indudalasana

(EY-kuh PUH-duh in-doo-LAHS-uh-nuh)

Modification: grabbing onto the wrist
Pose Type: standing one-legged balance, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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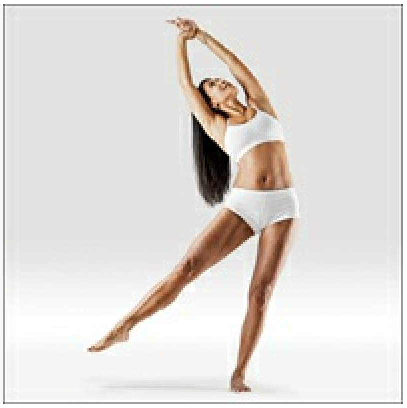

Side Stretch Pose

Parshvasana

(pahrsh-VAH-suh-nuh)

Modification: fingers interlocked, palms pressed together
Pose Type: standing, side bend
Drishti Point: Nasagrai or Nasagre (nose), Urdhva or Antara Drishti (up to the sky)
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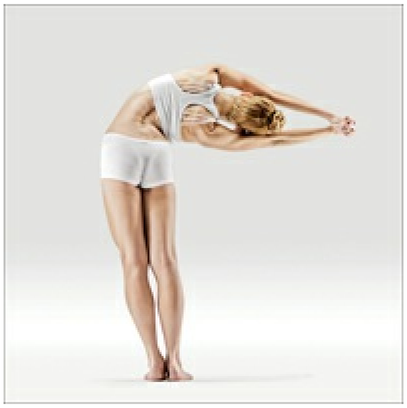

Pose Inspired by Shiva’s Vigorous Cycle of Life Dance

Tandavasana

(tahn-duh-VAHS-suh-nuh)

Modification: heels down, legs crossed, arms up over the head
Pose Type: standing, side bend, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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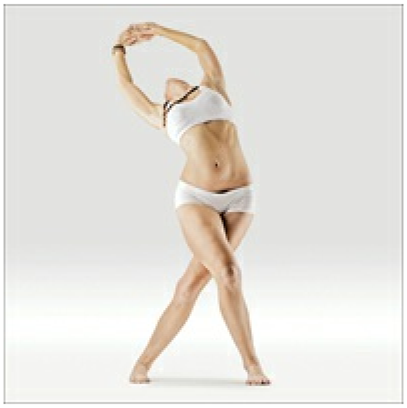

TANDAVA AND LASYA DANCE MODIFICATIONS

Pose Inspired by Parvati’s Graceful Dance

Lasyasana

(lahs-YAHS-uh-nuh)

Modification: legs crossed, knees bent; one hand on the hip, one arm over the head
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

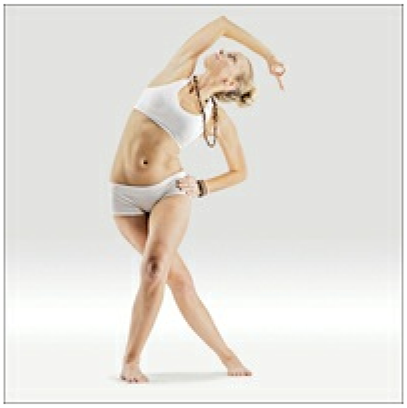

Pose Inspired by Parvati’s Graceful Dance

Lasyasana

(lahs-YAHS-uh-nuh)

Modification: front leg ankle stretch, both knees bent, legs crossed, one arm toward the opposite knee, other arm up over the head
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

SIDE BENDS: ONE ARM UP OVER THE HEAD, OTHER ARM ALONG THE SIDE OF TORSO

One Hand Side Stretch Pose

Eka Hasta Parshvasana

(EY-kuh HUH-stuh pahrsh-VAH-suh-nuh)

Modification: one arm up over the head, other hand sliding down the leg
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

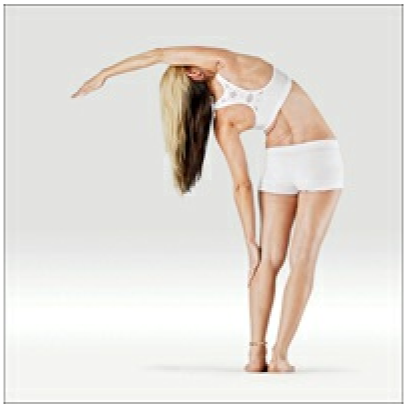

Swaying Palm Tree Pose

Tiryak Tala-Vrikshasana

(TIR-yuhk TAHL-uh-vrik-SHAHS-uh-nuh)

Pose Type: standing, side bend

Drishti Point: Hastagrai or Hastagre (hands)

How to Perform the Pose:

1. Begin by standing in Mountain Pose (*Tadasana*). Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Inhale; step your feet slightly wider than shoulder-distance apart with toes facing forward and feet parallel to each other. Expand your chest and hold your arms straight out to the sides, parallel to the floor.
3. Exhale as you side bend to the left, dropping your left hand either to the side of the left thigh or the left shin. (Avoid putting pressure on the knee joint.) Bring your right arm over head and bend it at the elbow.
4. Inhale as you rotate your chest up to the sky; do not collapse it forward. Feel the deep stretch on the right side of your torso as you look toward your right hand (Pose #1).
5. On your next exhale, try to reach your right arm over your head with fingertips pointing toward the floor (Pose #2).
6. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch. Exhale as you release the pose. Inhale as you press strongly into both feet to come up.
7. Exhale, come back to Mountain Pose (*Tadasana*), and repeat on the left side.

Modification: elbow of the top arm bent
1. mild version
2. intense version

tiryak = horizontally, sideways, obliquely, across

tala-vrikshasana = palm tree

1.

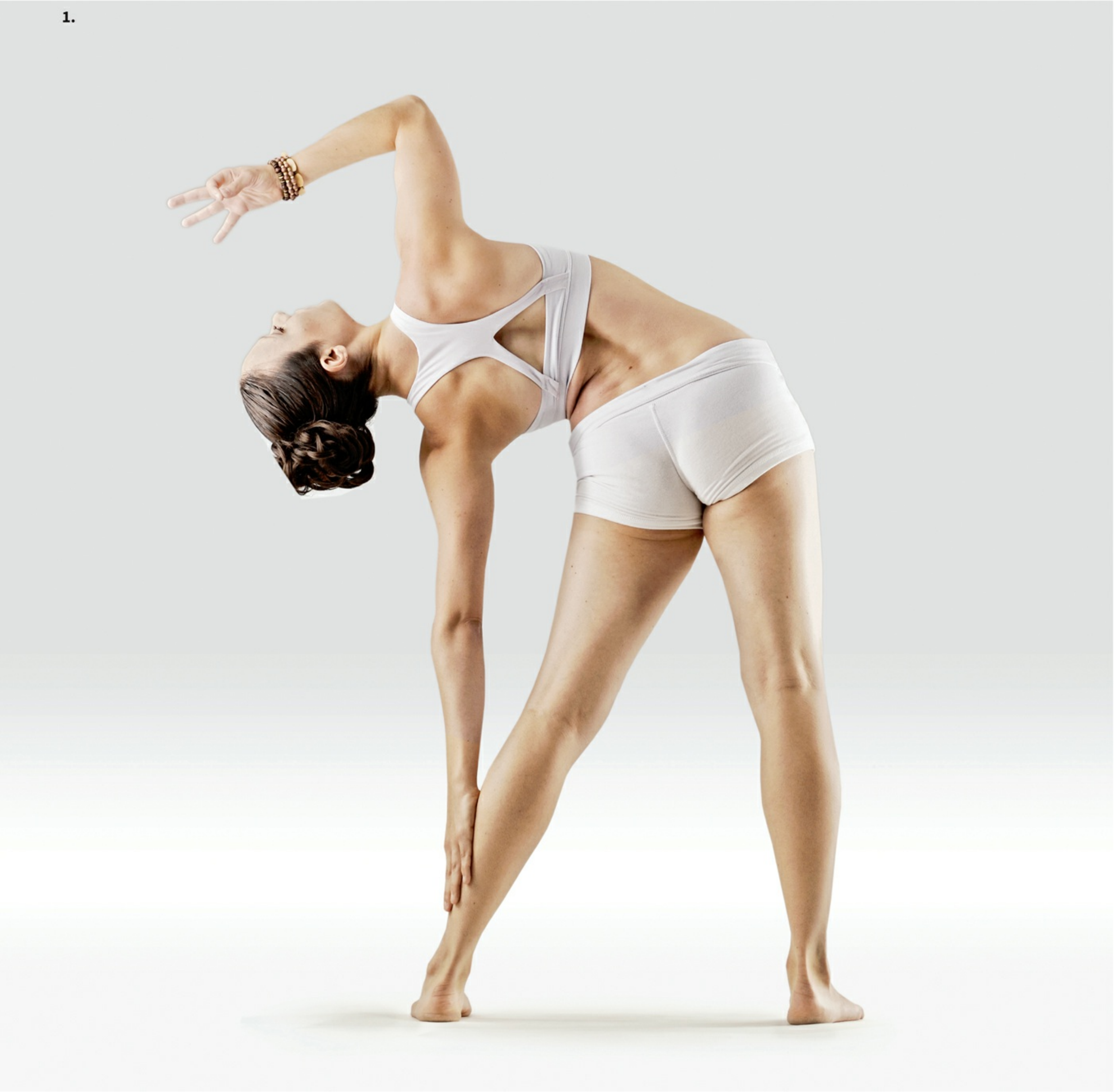

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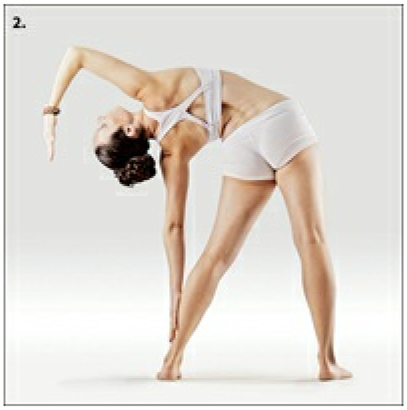

Hands Bound Rising Standing Locust Pose

Baddha Hasta Utthita Stiti Shalabhasana

(BUH-duh HUH-stuh UT-ti-tuh STI-ti shuh-luh-BAHS-uh-nuh)

Also Known As: Baddha Hasta Utthita Nindra Shalabhasana
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

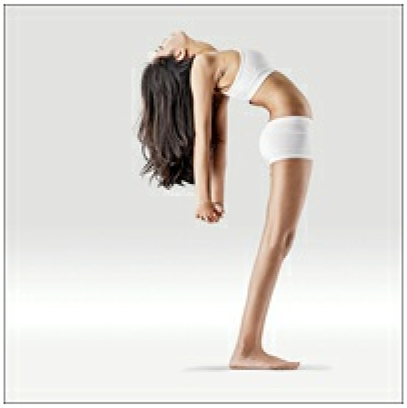

Sun Salutation Pose—Raised Bound Hands

Surya Namaskarasana Urdhva Baddha Hastasana

SOOR-yuh nuh-muhs-kahr-AHS-uh-nuh OORD-vuh BUH-duh huh-STAHS-uh-nuh)

Pose Type: standing, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

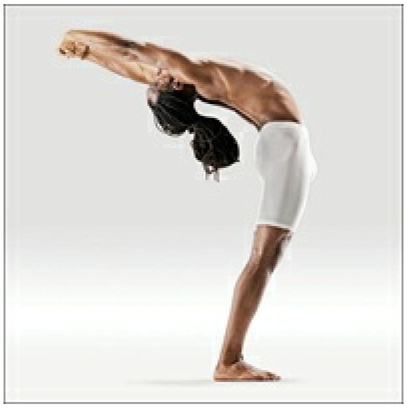

Rising Standing Cobra Pose

Utthita Stiti Bhujangasana

(UT-ti-tuh STI-ti bu-juhng-AHS-uh-nuh)

Also Known As: Utthita Nindra Bhujangasana

Modification: toes down, hands on the front of the knees

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

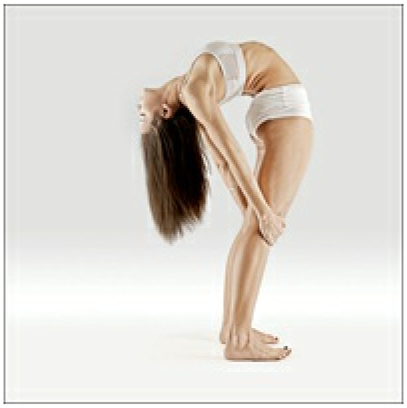

Sun Salutation Pose

Surya Namaskarasana

(SOOR-yuh nuh-muhs-kahr-AHS-uh-nuh)

Modification: palms facing up

Pose Type: standing, backbend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

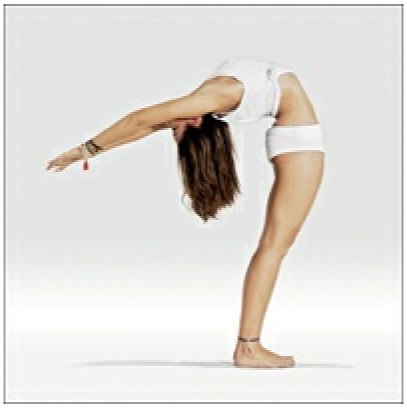

Sun Salutation Pose

Surya Namaskarasana

(SOOR-yuh nuh-muhs-kahr-AHS-uh-nuh-uh-nuh)

Modification: fingers interlocked, pointer fingers out
Pose Type: standing, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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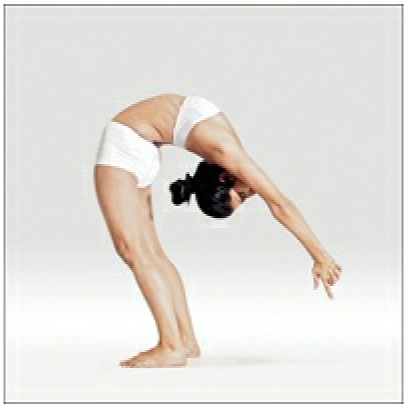

Reverse Facing Intense Stretch Pose

Tiryang Mukhottanasana

(TEER-yuhng mu-ko-tahn-AHS-uh-nuh)
Also Known As: Full Wheel Pose (Purna Chakrasana)
Modification: grabbing onto the shins
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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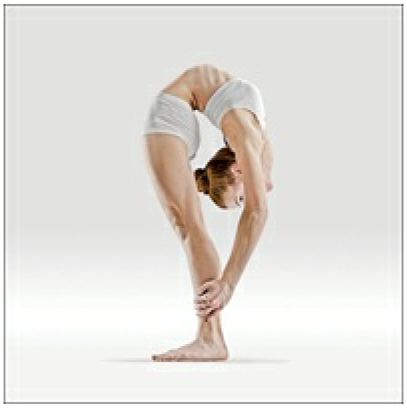

Reverse Facing Intense Stretch Pose

Tiryang Mukhottanasana

(TEER-yuhng mu-ko-tahn-AHS-uh-nuh)
Modification: grabbing onto the front of the knees
Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

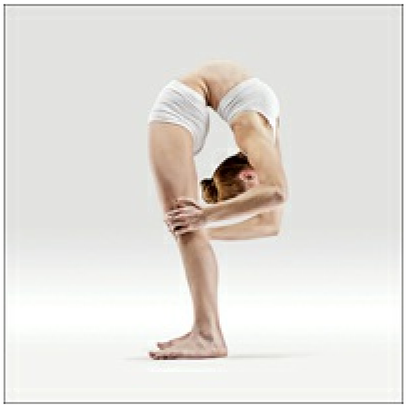

STANDING BACKBENDS: KNEES BENT

Standing Upward Facing Intense Ankle Stretch Bow Pose

Stiti Urdhva Mukgattana Kulpa Dhanurasana

(STI-ti OORD-vuh mu-ko-TAH-nuh KUL-puh duh-nur-AHS-uh-nuh)

Also Known As: Nindra Urdhva Mukgattana Kulpa Dhanurasana
Modification: hands to the heels
Pose Type: standing, backbend, balance
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

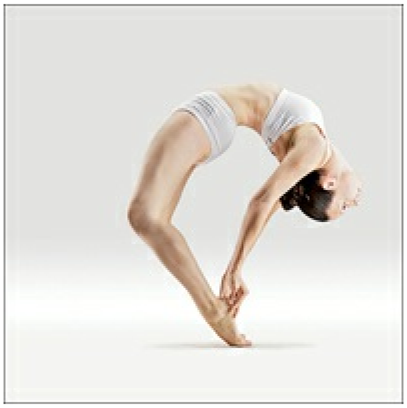

ONE LEG STANDING BALANCE: KNEE BENT—HEEL TO THE SITTING BONES

One Hand to Foot Rising Standing One-Legged Frog Pose

Eka Hasta Pada Utthita Stiti Eka Pada Bhekasana

(EY-kuh HUH-stuh PUH-duh UT-ti-tuh STI-ti EY-kuh PUH-duh bey-KAHS-uh-nuh)

Also Known As: Eka Hasta Pada Utthita Nindra Eka Pada Bhekasana

Modification: grabbing onto the foot, arm crossed in front; foot toward the glutes

Pose Type: standing one-legged balance, binding

Drishti Point: Hastagrai or Hastagre (hands)

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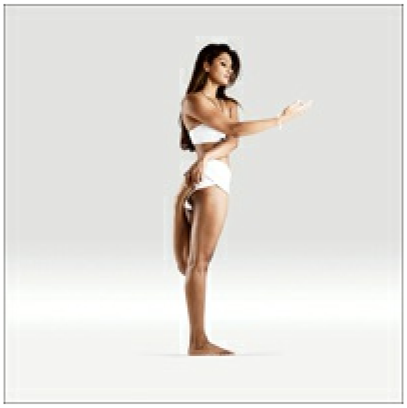

Lord of the Dance Pose

Natarajasana

(NAH-tuh-rahj-AHS-uh-nuh)

Modification: one hand to foot, foot toward the glutes

Pose Type: standing one-legged balance, backbend

Drishti Point: Hastagrai or Hastagre (hands)

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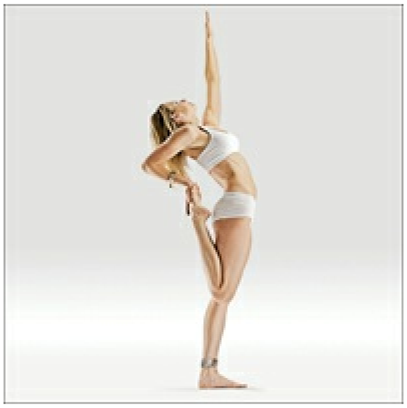

Both Hands to Foot Rising Standing One-Legged Frog Pose

Dwi Hasta Pada Utthita Stiti Eka Pada Bhekasana

(dwi-huh-stuh PUH-duh UT-ti-tuh STI-ti EY-kuh PUH-duh bey-KAHS uh-nuh)

Also Known As: Dwi Hasta Pada Utthita Nindra Eka Pada Bhekasana

Pose Type: standing one-legged balance

Drishti Point: Nasagrai or Nasagre (nose)
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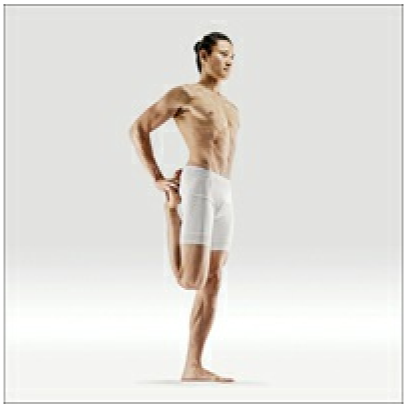

ONE LEG STANDING BALANCE: KNEE BENT—HEEL TO THE SITTING BONES—HALF FORWARD BEND

Bowing with Respect Lord of the Dance Pose

Nantum Natarajasana

(NUHN-tum NAH-tuh-rahj-AHS-uh-nuh)

Modification: half forward bend, both hands to the back foot, foot toward the glutes
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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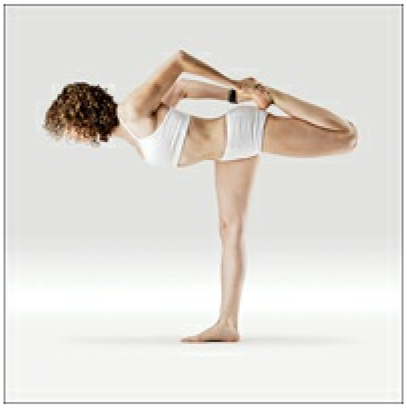

Half Bound Bowing with Respect Lord of the Dance Pose

Ardha Baddha Nantum Natarajasana

(UHR-duh BUH-duh NUHN-tum NAH-tuh-rahj-AHS-uh-nuh)

Modification: grabbing onto the back foot with opposite hand
Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

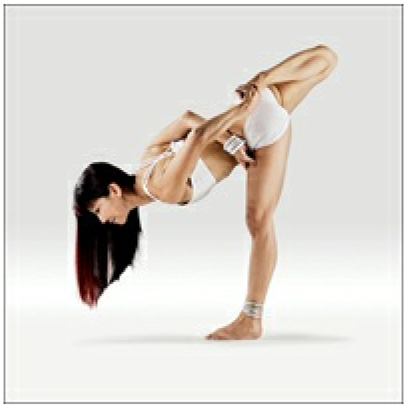

Half Moon Bow Pose Prep.

Ardha Chandrachapasana Prep.

(UHR-duh CHUHN-druh-chahp-AHS-uh-nuh)

Modification: grabbing onto the back foot with the hand on the same side
Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

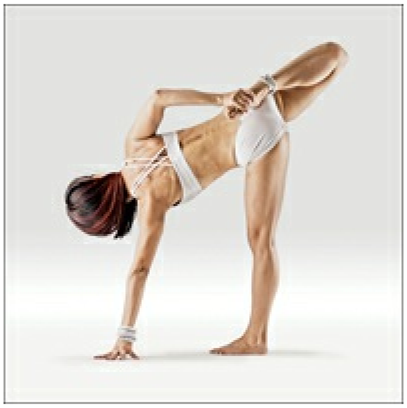

Hand to Foot Revolved Half Moon Bow Pose

Hasta Pada Parivritta Ardha Chandrachapasana

(HUH-stuh PUH-duh puh-ri-VRIT-tuh UHR-duh CHUHN-druh-chahp-AHS-uh-nuh)

Also Known As: Lord of the Dance Pose Modification (Natarajasana)
Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

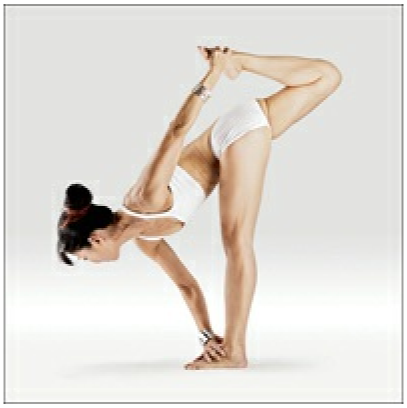

Half Bound Unsupported Bound One-Legged Intense Stretch Pose Prep.

Ardha Baddha Niralamba Baddha Eka Pada Uttanasana Prep.

(UHR-duh BUH-duh nir-ah-LUHM-buh BUH-duh EY-kuh PUH-duh ut-tahn-AHS-uh-nuh)

Also Known As: Lord of the Dance Pose Prep. Modification (Natarajasana Prep.) and Half Bound Unsupported Bound One-Legged Forward Bend Prep.
Modification: one hand to the floor
Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Hastagrai or Hastagre (hands), Nasagrai or Nasagre (nose)
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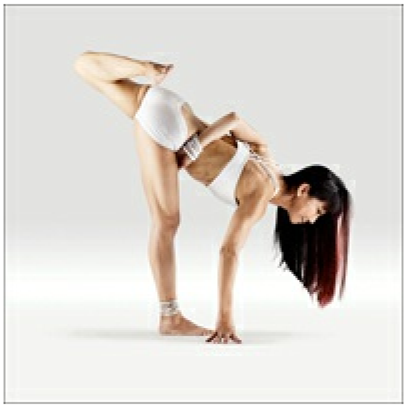

ONE LEG STANDING BALANCE: KNEE BENT—HEEL TO THE SITTING BONES—FORWARD BEND

One Leg Stretched Upward Pose Prep.

Urdhva Prasarita Ekapadasana Prep.

(OORD-vuh pruh-SAH-ri-tuh EY-kuh-puh-DAHS-uh-nuh)

Modification: top leg bent, heel toward the glutes; both palms to the floor
Pose Type: standing one-legged balance, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)

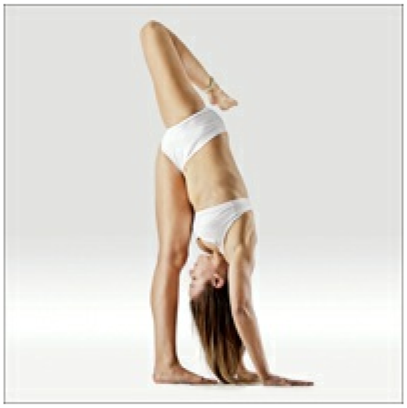

Unsupported Bound One Foot Intense Stretch Pose

Niralamba Baddha Eka Pada Uttanasana

(nir-ah-LUHM-buh BUH-duh EY-kuh PUH-duh ut-TAHS-uh-nuh)

Also Known As: Unsupported Bound One Foot Full Forward Bend
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

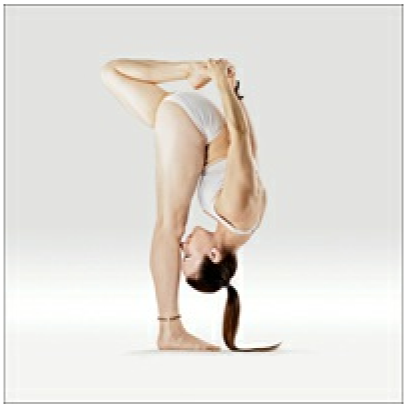

ONE LEG STANDING BALANCE: KNEE BENT—HALF FORWARD BEND

Revolved Half Moon Bow Pose

Parivritta Ardha Chandrachapasana

(puh-ri-VRIT-tuh UHR-duh CHUHN-druh-chahp-AHS-uh-nuh)

Pose Type: standing one-legged balance, backbend, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky), Padhayoragrai or Padayoragre (toes/feet), Hastagrai or Hastagre (hands)

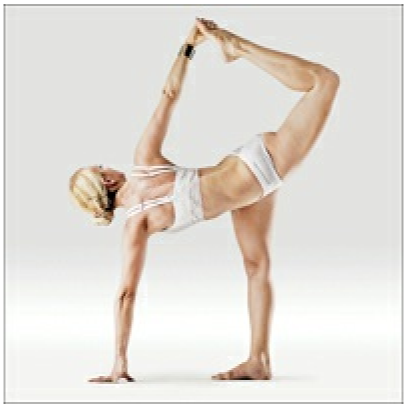

Pose Dedicated to Yogi Gitananda

Gitanandasana

(geet-ah-nuhn-DAHS-uh-nuh)

Also Known As: Lord of the Dance Pose Modification (Natarajasana)
Modification: foot away from the head
Pose Type: standing one-legged balance, backbend, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

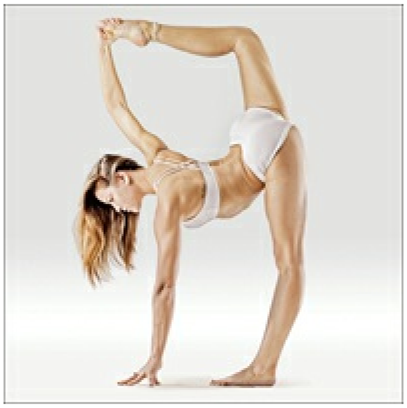

Pose Dedicated to Yogi Gitananda

Gitanandasana

(geet-ah-nuhn-DAHS-uh-nuh)

Also Known As: Lord of the Dance Pose Modification (Natarajasana)
Modification: foot to the head
Pose Type: standing one-legged balance, backbend, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

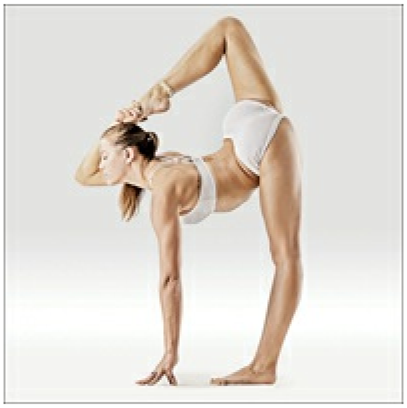

ONE LEG STANDING BALANCE: HANDS BOUND BEHIND THE BACK

Toppling Tree Pose

Patan Vrikshasana

(PUH-tuhn vrik-SHAHS-uh-nuh)

Modification: both knees bent
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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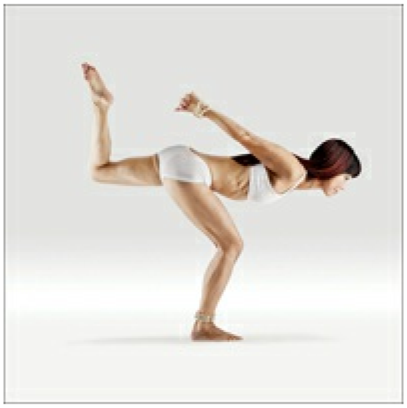

Toppling Tree Pose

Patan Vrikshasana

(PUH-tuhn vrik-SHAHS-uh-nuh)

Modification: both legs straight
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

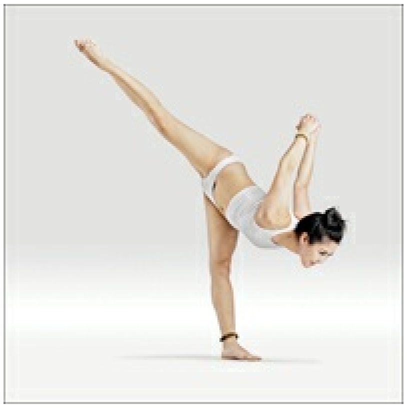

ONE LEG STANDING BALANCE: KNEE BENT—FOOT TO THE ELBOW CREASE

Lord of the Dance Pose Prep.

Natarajasana Prep.

(NAH-tuh-rahj-AHS-uh-nuh)

Modification: foot to the elbow crease, arms open to the sides, elbows bent
Pose Type: standing one-legged balance, backbend
Drishti Point: Hastagrai or Hastagre (hands)

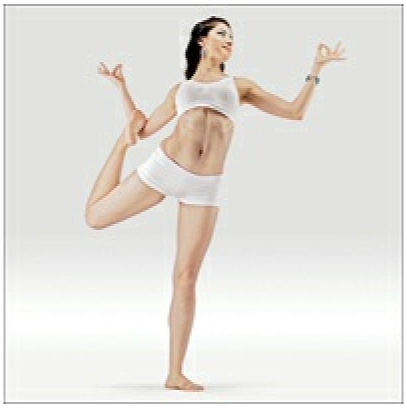

Prayer Lord of the Dance Pose

Namaskar Natarajasana

(nuh-muhs-KAHR NAH-tuh-rahj-AHS-uh-nuh)

Modification: foot to the elbow crease
Pose Type: standing one-legged balance, backbend
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

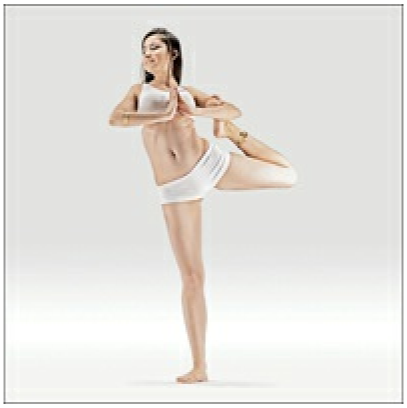

Half Moon Bow Pose Prep.

Ardha Chandrachapasana Prep.

(URH-duh chuhn-druh-chahp-AHS-uh-nuh)

Modification: foot to the elbow crease
Pose Type: standing one-legged balance, backbend, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

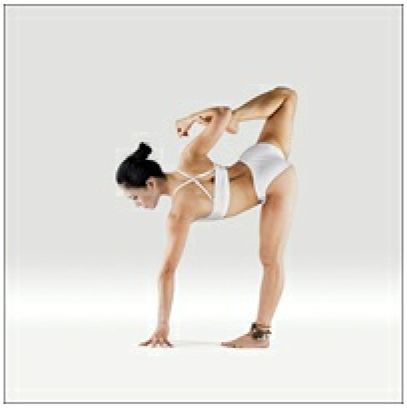

ONE LEG STANDING BALANCE: KNEE BENT BEHIND

Lord of the Dance Pose

Natarajasana

(NAH-tuh-rahj-AHS-uh-nuh)

Also Known As: Baby Dancer’s Pose (Bala Natarajasana)
Modification: hand to the foot on the same side using an under-head grip, back knee bent
1. thigh parallel to the floor
2. thigh 45 degrees to the floor, half forward bend

Pose Type: standing one-legged balance, backbend

Drishti Point: Hastagrai or Hastagre (hands)

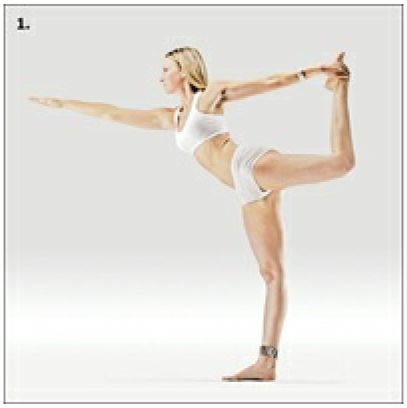

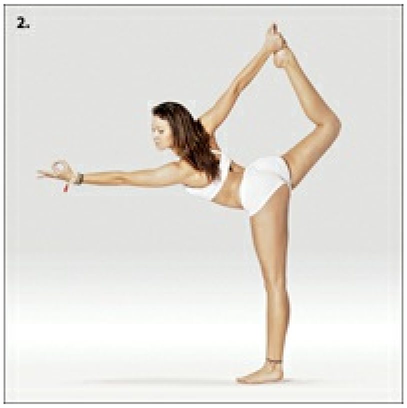

Hand Position of Mermaid Pose in Bowing With Respect

Lord of the Dance Pose

Hasta Naginyasana in Nantum Natarajasana

(HUH-stuh nuh-gin-YAHS-uh-nuh in nan-toom NAH-tuh-rahj-AHS-uh-nuh)

Pose Type: standing one legged balance, backbend, forward bend

Drishti Point: Nasagrai or Nasagre (nose) or Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

How to Perform the Pose:

1. Begin by standing in Mountain Pose (*Tadasana*). Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Inhale and bring your weight onto the left foot. Exhale as you bend your right knee, grab onto the right foot with your right hand, and bring your right heel to your right sitting bone. Keep your standing leg strong and straight by pulling the knee cap up and engaging the front thigh muscles (quadriceps). Keep your knees together.
3. On the next exhale, start pushing your right foot back and up to the sky, while tipping your torso forward.
4. Exhale as you bring the right foot to the right elbow crease and bend your right arm to keep the foot in place.
5. Inhale as you reach your left arm out in front of you. Exhale, bend the left elbow, and grab onto the right hand with your left hand (Pose #2). This is the arm position of Mermaid Pose (*Hasta Naginyasana*).
6. To deepen the shoulder stretch, on the next exhale start walking your left hand down your left forearm. Grab first onto the left elbow and then to your left tricep (Pose #1).
7. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch. Exhale as you release the pose, come back to Mountain Pose (*Tadasana*), and repeat on the right side.

hasta = hand

naga = great mythological snake

nantum = to bow with respect

Nataraj = name of Shiva as a cosmic dancer

1.

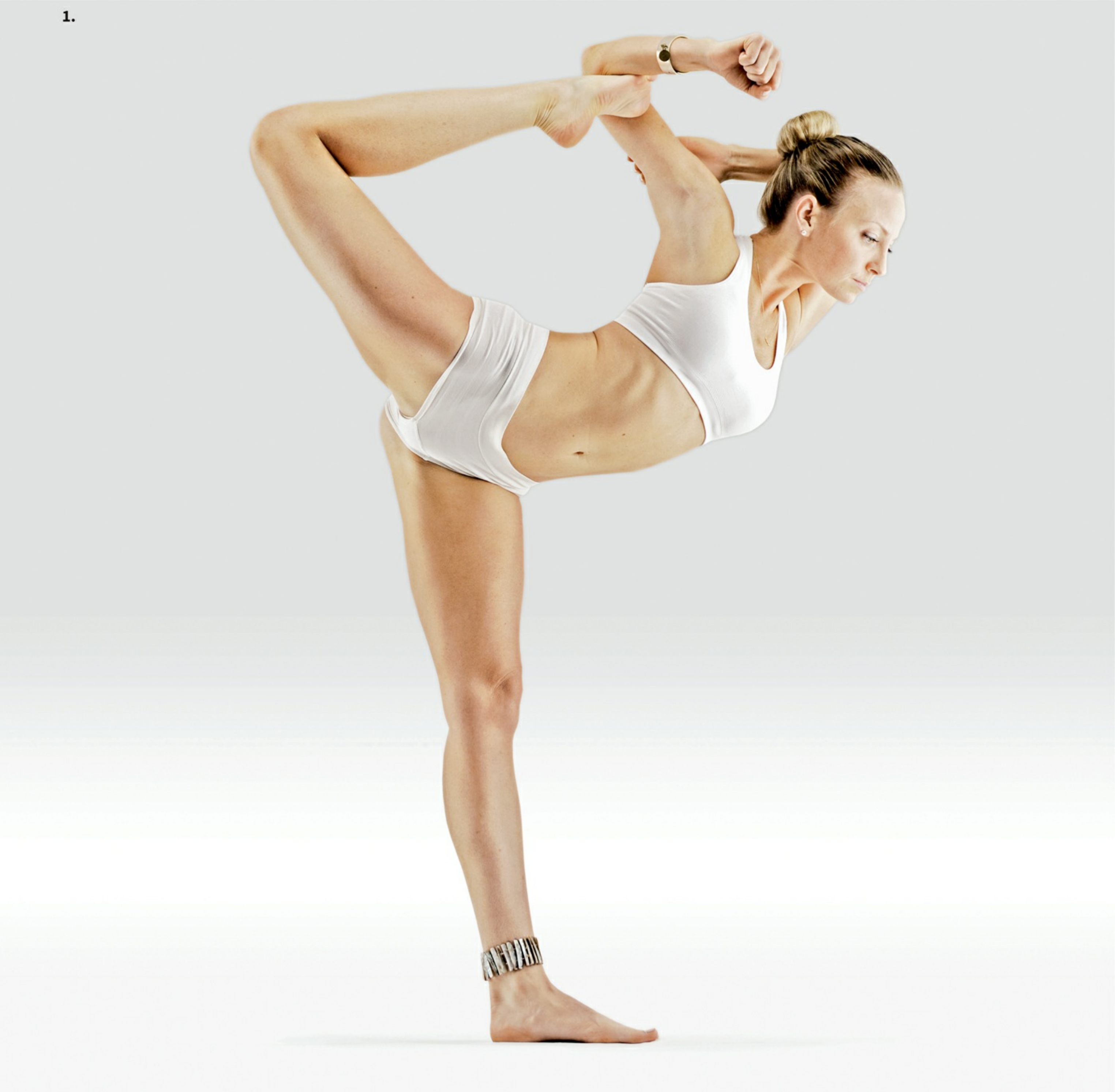

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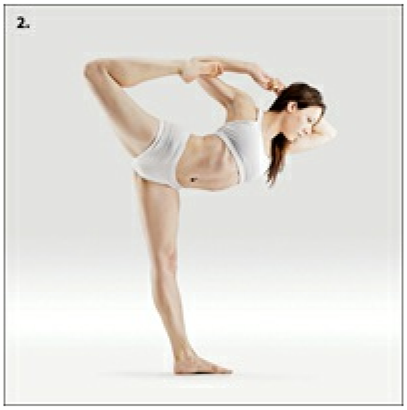

Open Heart Lord of the Dance Pose

Anahata Chakra Natarajasana

(uhn-AH-huh-tuh CHUHK-ruh NAH-tuh-rahj-AHS-uh-nuh)

Modification: back knee bent, arms open to the sides, foot working toward the head
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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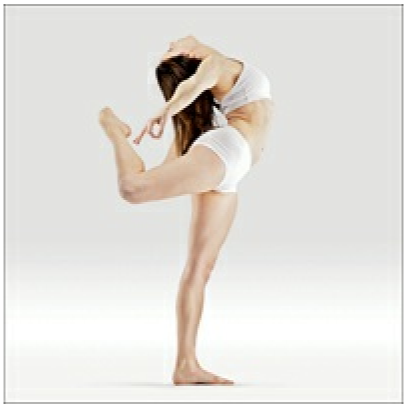

Lord of the Dance Pose

Natarajasana

(NAH-tuh-rahj-AHS-uh-nuh)

Modification: hand to opposite foot using an under-head grip, back knee bent
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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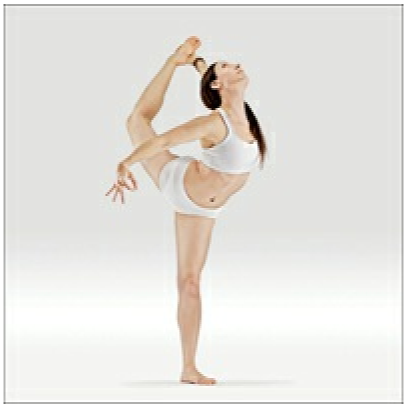

Lord of the Dance Pose

Natarajasana

(NAH-tuh-rahj-AHS-uh-nuh)

Modification: standing leg bent, heel to the floor; hand to the foot on the same side using an overhead grip, foot to the shoulder

Pose Type: standing one-legged balance, backbend

Drishti Point: Hastagrai or Hastagre (hands)

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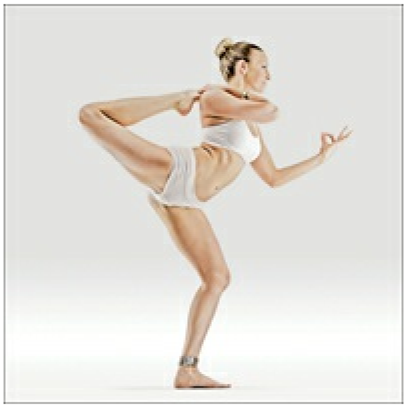

Lord of the Dance Pose

Natarajasana

(NAH-tuh-rahj-AHS-uh-nuh)

Also Known As: Lord of the Dance Pose 1 (Natarajasana 1)

Modification: both hands grabbing onto the back foot with overhead grip, foot away from the head

Pose Type: standing one-legged balance, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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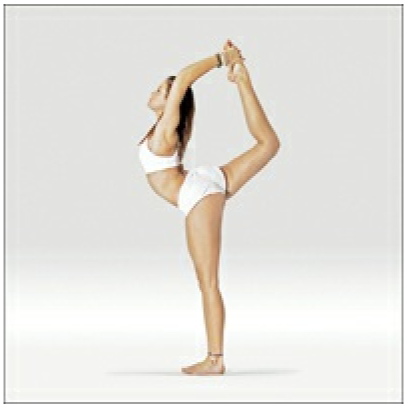

ONE LEG STANDING BALANCE: GRABBING ONTO THE BACK KNEE

Bound Lord of the Dance Pose

Baddha Natarajasana

(BUH-duh NAH-tuh-rahj-AHS-uh-nuh)

Also Known As: Yogi Yogananda Pose (Yoganandasana)
Modification: hand binding to the knee on the same side of the body; back foot away from the head
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

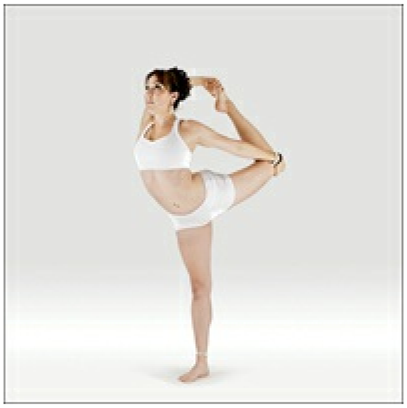

Bound Lord of the Dance Pose

Baddha Natarajasana

(BUH-duh NAH-tuh-rahj-AHS-uh-nuh)

Modification: one hand binding to the knee on the same side of the body, other arm crossed in front of the neck
1. left side view
2. right side view
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

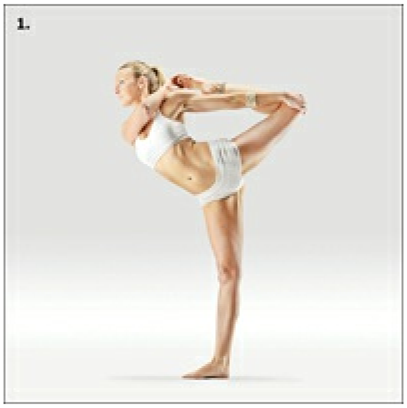

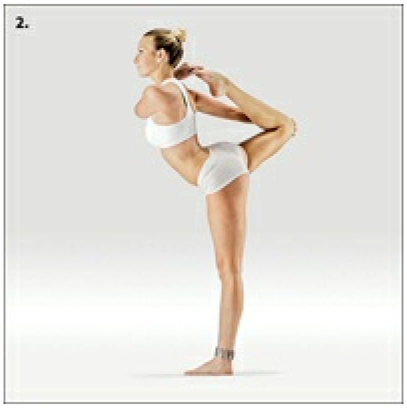

Bound Lord of the Dance Pose

Baddha Natarajasana

(BUH-duh NAH-tuh-rahj-AHS-uh-nuh)

Also Known As: Yogi Yogananda Pose (Yoganandasana)
Modification: hand binding to the inside of the thigh on the same side of the body, back foot away from the head
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

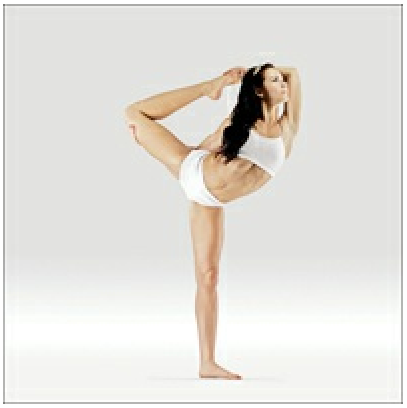

Supported Sideways Hand to Knee Lord of the Dance Pose

Salamba Parshva Hasta Janu Natarajasana

(sah-LUHM--buh PAHRSH-vuh HUH-stuh JAH-nu NAH-tuh-rahj-AHS-uh-nuh)

Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

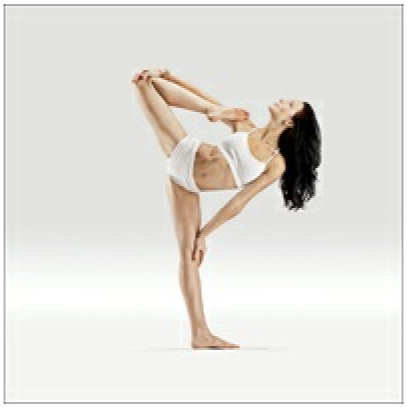

Unsupported Sideways Hand to Knee Lord of the Dance Pose

Niralamba Parshva Hasta Janu Natarajasana

(nir-ah-LUHM-buh-nuh PAHRSH-vuh HUH-stuh JAH-nu NAH-tuh-rahj-AHS-uh-nuh)

Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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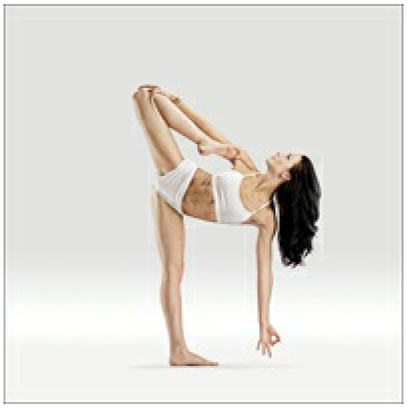

ONE LEG STANDING BALANCE: KNEE BENT IN FRONT

Hand Bound Rising Standing Wind Relieving Pose Prep.

Baddha Hasta Utthita Stiti Vayu Muktyasana Prep.

(BUH-duh HUH-stuh UT-ti-tuh STI-ti VAH-yu muk-TYAHS-uh-nuh)

Also Known As: Baddha Hasta Utthita Nindra Vayu Muktyasana Prep.
Modification: knee of the standing leg bent; fingertips to elbows, arms parallel to the floor, knee of the lifted leg to the forearm
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)
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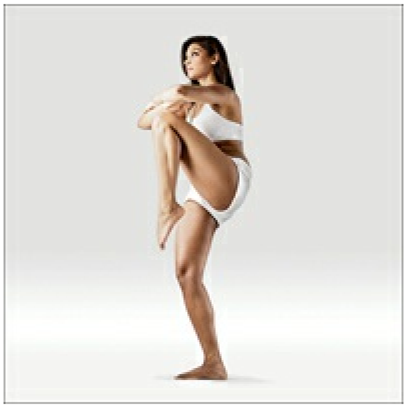

Standing Rising One-Legged Chin to Knee Pose Prep.

Stiti Utthita Eka Pada Chibi Janu Shirshasana Prep.

(STI-ti UT-ti-tuh EY-kuh PUH-duh CHI-bi JAH-nu sheer-SHAHS-uh-nuh)

Also Known As: Nindra Utthita Eka Pada Chibi Janu Shirshasana Prep.

Modification: 1. arms wrapped around the shin 2. fingers interlocked over the shin

Pose Type: standing one-legged balance, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

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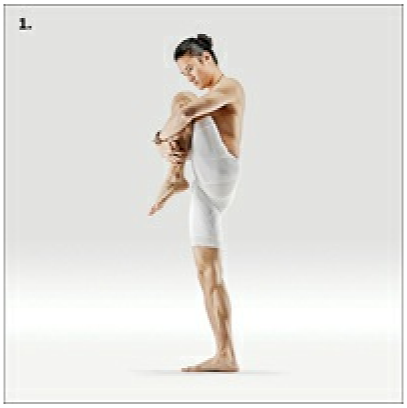

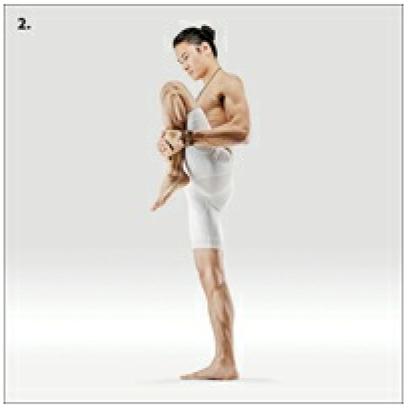

Standing Rising Wind Relieving Pose

Stiti Utthita Vayu Muktyasana

(STI-ti UT-ti-tuh VAH-yu muk-TYAHS-uh-nuh)

Also Known As: Nindra Utthita Vayu Muktyasana; Standing Pose Dedicated to Marichi (Nindra Marichyasana)
Modification: standing up straight
Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

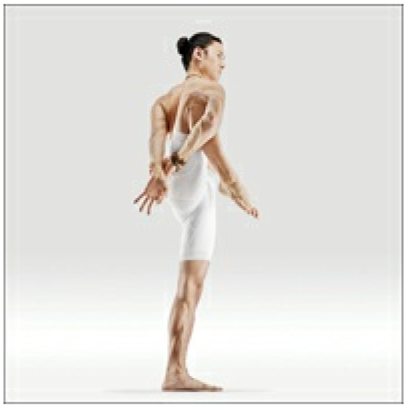

Revolved Prayer Standing Rising Wind Relieving Pose

Parivritta Namaskar Stiti Utthita Vayu Muktyasana

(puh-ri-VRIT-tuh nuh-muhs-KAHR STI-ti UT-ti-tuh VAH-yu mukTYAHS-uh-nuh)

Also Known As: Parivritta Namaskar Nindra Utthita Vayu Muktyasana
Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

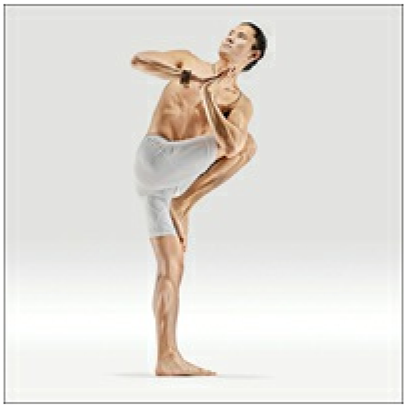

Revolved Bound Standing Rising Wind Relieving Pose

Parivritta Baddha Stiti Utthita Vayu Muktyasana

(puh-ri-VRIT-tuh BUH-duh STI-ti UT-ti-tuh VAH-yu muk-TYAHS-uh-nuh)

Also Known As: Parivritta Baddha Nindra Utthita Vayu Muktyasana
Modification: binding around the back of the thigh
1. foot on the knee
2. foot away from the knee
Pose Type: standing one-legged balance, forward bend, twist, binding
Drishti Point: Nasagrai or Nasagre (nose)

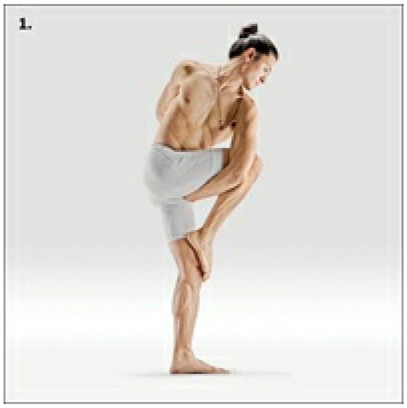

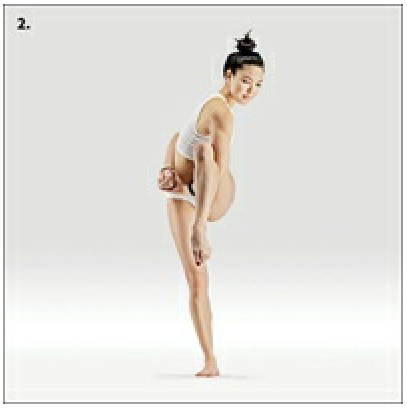

Revolved Bound Standing Rising Wind Relieving Pose

Parivritta Baddha Stiti Utthita Vayu Muktyasana

(puh-ri-VRIT-tuh BUH-duh STI-ti UT-ti-tuh VAH-yu muk-TYAHS-uh-nuh)

Also Known As: Parivritta Baddha Nindra Utthita Vayu Muktyasana
Modification: binding around the shin
Pose Type: standing one-legged balance, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

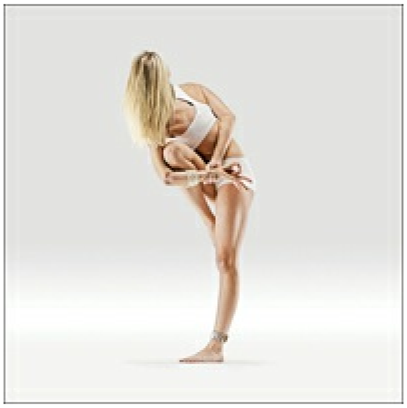

ONE LEG STANDING BALANCE: BOTH KNEES BENT—BINDING & TWISTS

Revolved Bound Standing Rising Wind Relieving Pose Prep.

Parivritta Baddha Stiti Utthita Vayu Muktyasana Prep.

(puh-ri-VRIT-tuh BUH-duh STI-ti UT-ti-tuh VAH-yu muk-TYAHS-uh-nuh)

Also Known As: Parivritta Baddha Nindra Utthita Vayu Muktyasana Prep.
Modification: foot resting on the knee, standing leg bent
Pose Type: standing one-legged balance, forward bend, twist, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

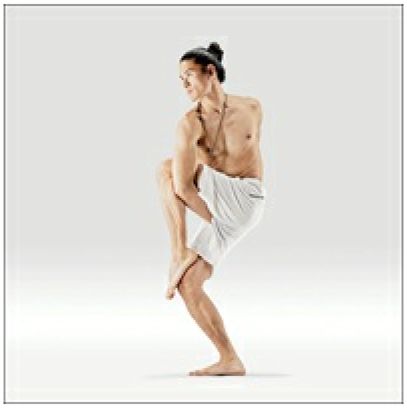

Pose Inspired by Shiva’s Vigorous Cycle of Life Dance

Tandavasana

(tahn-duh-VAHS-uh-nuh)

Modification: knee to the opposite elbow, foot resting on the knee, standing leg bent, heel down
Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

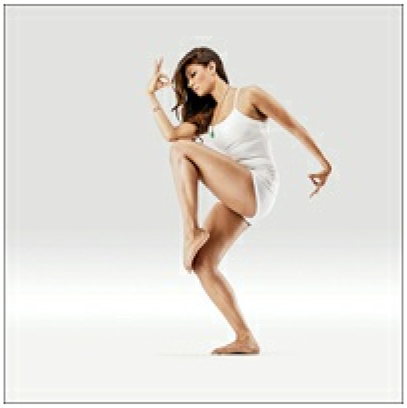

Pose Inspired by Shiva’s Vigorous Cycle of Life Dance

Tandavasana

(tahn-duh-VAHS-uh-nuh)

Modification: both arms straight, one forearm to the opposite knee, other arm straight up to the sky, both knees bent
Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)
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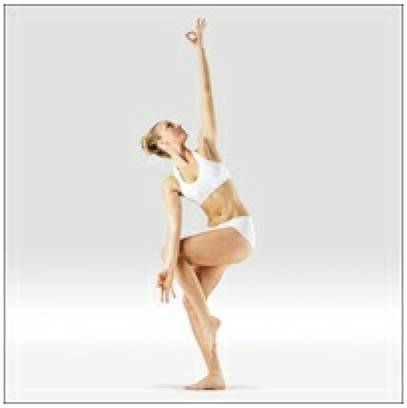

ONE LEG STANDING BALANCE: HEEL UP

Tip Toe Pose Inspired by Shiva’s Vigorous Cycle of Life Dance

Prapada Tandavasana

(PRUH-puh-duh tahn-duh-VAHS-uh-nuh)

Modification: knee to the opposite elbow, foot resting on the knee, standing leg bent
Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)
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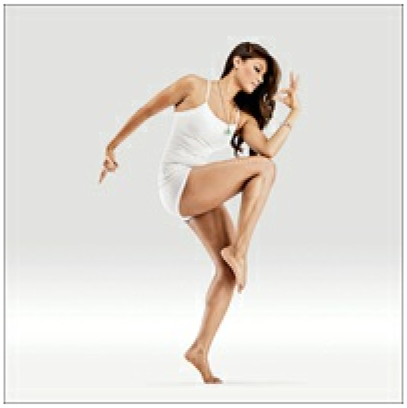

Tip Toe Pose Inspired by Parvati’s Graceful Dance

Prapada Lasyasana

(PRUH-puh-duh lahs-YAHS-uh-nuh)

Modification: deep backbend, one arm reaching up to the sky, other arm reaching down to the floor; standing leg straight, other knee bent; foot to the inside of the knee of the opposite leg
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)

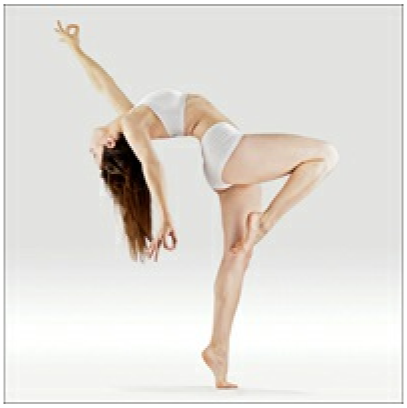

Intense Ankle Stretch Tip Toe Lord of the Dance Pose

Uttana Kulpa Prapada Natarajasana

(ut-TAHN-uh KUL-puh PRUH-puh-duh NAH-tuh-rahj-AHS-uh-nuh)

Also Known As: Tip Toe Pose Inspired by Parvati’s Graceful Dance (Prapada Lasyasana)
Modification: standing leg bent, toes curled under, overhead grip, foot to the shoulder
Pose Type: standing one-legged balance, backbend
Drishti Point: Hastagrai or Hastagre (hands)

ONE LEG STANDING BALANCE: KNEE BENT IN FRONT, BINDING, FORWARD BENDS

Half Standing Wind Relieving Intense Stretch Pose 1 & 2 Prep.

Ardha Stiti Vayu Muktyuttonasana 1 & 2 Prep.

(UHR-duh STI-ti VAH-yu muk-tew-ton-AHS-uh-nuh)

Also Known As: Ardha Nindra Vayu Muktyuttonasana; Standing Wind Relieving Half Forward Bend
Modification: fingers interlocked on the knee, half forward bend
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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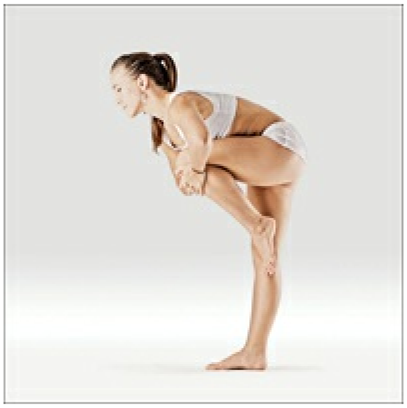

One Hand Bound Half Standing Wind Relieving Intense Stretch Pose

Eka Hasta Baddha Ardha Stiti Vayu Muktyuttonasana

(EY-kuh HUH-stuh BUH-duh UHR-duh STI-ti VAH-yu muk-tew-ton-AHS-uh-nuh)

Also Known As: Eka Hasta Baddha Ardha Nindra Vayu Muktyuttonasana; One Hand Bound Standing Wind Relieving Half Forward Bend
Modification: binding around the shin, palm to the rib cage, foot resting on the thigh of the standing leg
Pose Type: standing one-legged balance, forward bend, binding

Drishti Point: Hastagrai or Hastagre (hands)
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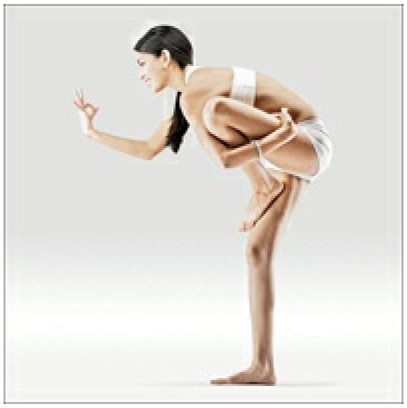

Standing Wind Relieving Intense Stretch Pose 1

Stiti Vayu Muktyuttonasana 1

(STI-ti VAH-yu muk-tew-ton-AHS-uh-nuh)

Also Known As: Nindra Vayu Muktyuttonasana; Standing Wind Relieving Half Forward Bend 1
Modification: chin away from the shin, binding on the inside of the thigh
Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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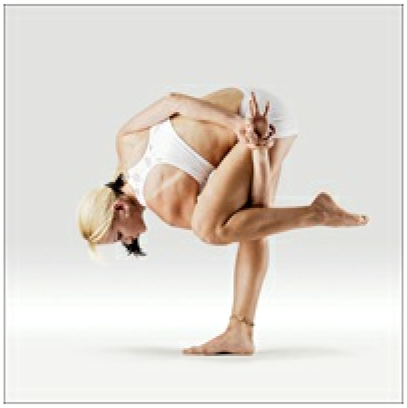

ONE LEG STANDING BALANCE: KNEE BENT IN FRONT, BINDING, TWIST FORWARD BENDS

Standing Wind Relieving Intense Stretch Pose 2

Stiti Vayu Muktyuttonasana 2

(STI-ti VAH-yu muk-tew-ton-AHS-uh-nuh)

Also Known As: Nindra Vayu Muktyuttonasana; Standing Pose Dedicated to Sage Marichi (Nindra Marichyasana) and Standing Wind Relieving Full Forward Bend

Modification: chin away from the shin, binding around the shin
Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)
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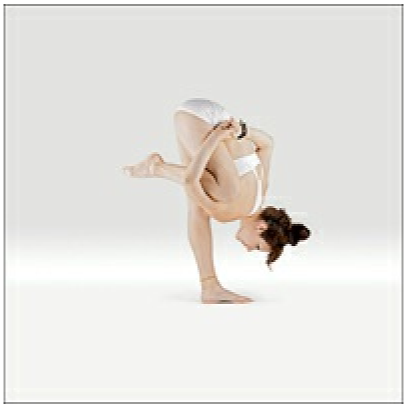

Revolved Half Standing Wind Relieving Intense Stretch Pose

Parivritta Ardha Stiti Vayu Muktyuttonasana

(puh-ri-VRIT-tuh UHR-duh STI-ti VAH-yu muk-tew-ton-AHS-uh-nuh)

Also Known As: Parivritta Ardha Nindra Vayu Muktyuttonasana; Revolved Standing Wind Relieving Half Forward Bend
Pose Type: standing one-legged balance, forward bend, twist, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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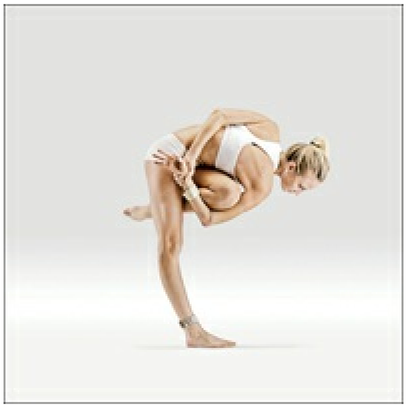

ONE LEG STANDING BALANCE: KNEE BENT IN FRONT—BACKBENDS

Hand to Knee Pose Inspired by Parvati’s Graceful Dance

Hasta Janu Lasyasana

(HUH-stuh JAH-nu lahs-YAHS-uh-nuh)

Modification: arm up over the head and parallel to the floor
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)

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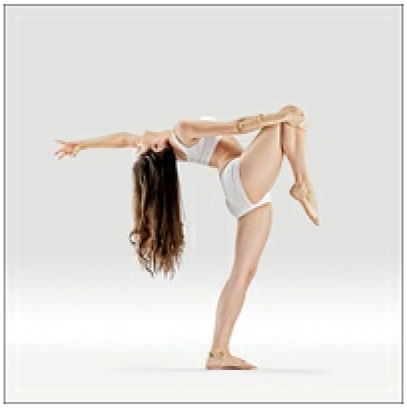

ONE LEG STANDING BALANCE: KNEE BENT IN FRONT—BACKBENDS—GRABBING ONTO THE ANKLE

Standing One-Legged Hero Pose

Stiti Eka Pada Virasana

(STI-ti EY-kuh PUH-duh veer-AHS-uh-nuh)

Also Known As: Nindra Eka Pada Virasana; Standing One-Legged Thunderbolt Pose (Nindra Eka Pada Vajrasana)
Modification: hand grabbing onto the foot, heel toward the glutes, shin parallel to the floor, other arm up to the sky
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)

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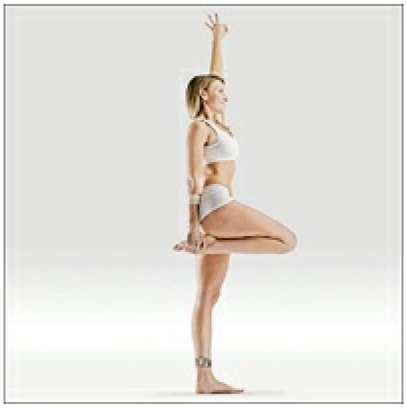

Hand to Foot Pose Inspired by Parvati’s Graceful Dance

Hasta Pada Lasyasana

(HUH-stuh PUH-duh lahs-YAHS-uh-nuh)

Modification: arm up over the head reaching to the sky
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)

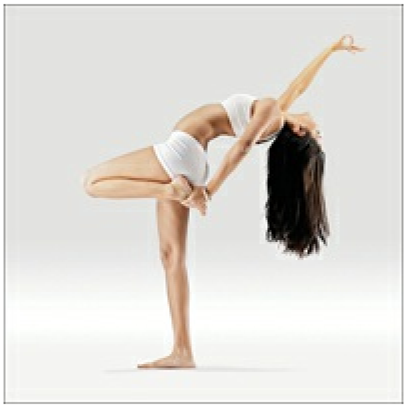

ONE LEG STANDING BALANCE: KNEE BENT, KNEES IN LINE, FORWARD BENDS

Hand to Ankle Half Standing Wind Relieving Intense Stretch Pose

Hasta Kulpha Ardha Stiti Vayu Muktyuttonasana

(HUH-stuh kul-puh UHR-duh STI-ti VAH-yu muk-tew-ton-AHS-uh-nuh)

Also Known As: Hasta Kulpha Ardha Nindra Vayu Muktyuttonasana; Knee to Ear Half Standing Wind Relieving Intense Stretch Pose (Janu Karna Ardha Nindra Vayu Muktyuttonasana) and Hand to Ankle Standing Wind Relieving Half For-ward Bend
Modification: one hand grabbing onto the ankle, knee to the temple; other arm up to the sky, elbow bent
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

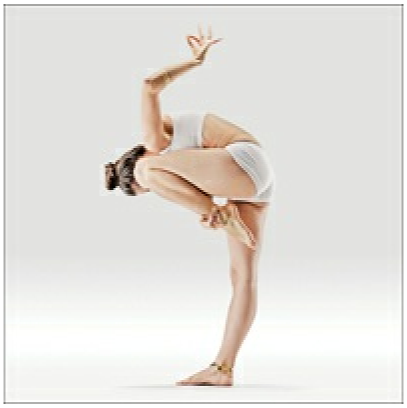

Hand to Foot One-Legged Half Intense Stretch Pose

Hasta Pada Eka Pada Ardha Uttanasana

(HUH-stuh PUH-duh EY-kuh PUH-duh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Hand to Foot One-Legged Half Forward Bend
Modification: hand to the foot from the same side, heel to the sitting bone, other palm to the floor
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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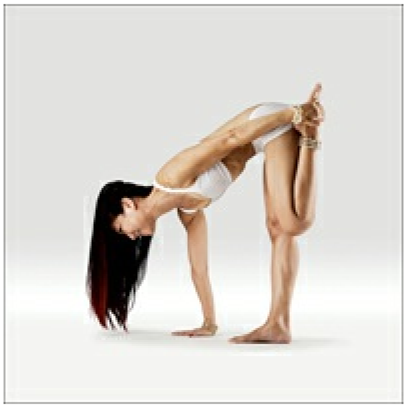

Hand to Foot One-Legged Intense Stretch Pose

Hasta Pada Eka Pada Uttanasana

(HUH-stuh PUH-duh EY-kuh PUH-duh ut-tahn-AHS-uh-nuh)

Also Known As: Hand to Foot One-Legged Full Forward Bend
Modification: hand to the foot on the same side, heel to the sitting bone; other palm to the floor
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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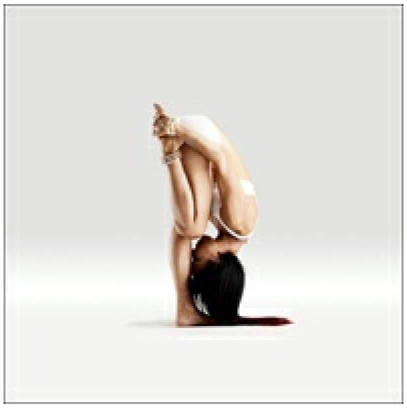

One-Legged Intense Stretch Pose 1

Eka Pada Uttanasana 1

(EY-kuh PUH-du ut-tahn-AHS-uh-nuh)

Also Known As: One-Legged Full Forward Bend 1
Modification: leg bent, heel to the sitting bone, knees together; fingertips to the floor, arms extended behind the foot
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

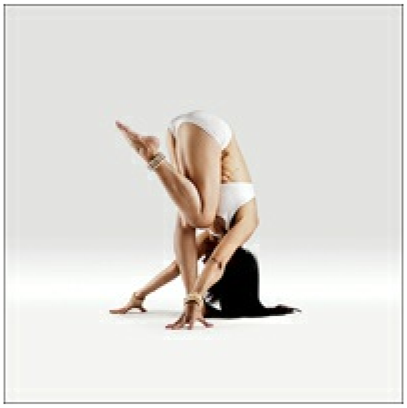

One-Legged Intense Stretch Pose 2

Eka Pada Uttanasana 2

(EY-kuh PUH-du ut-tahn-AHS-uh-nuh)

Also Known As: One-Legged Full Forward Bend 2
Modification: leg bent, heel to the sitting bone, knees together; fingertips to the floor, arms extended behind the foot
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

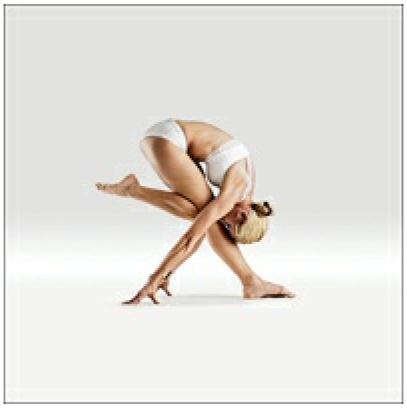

Pose Inspired by Shiva’s Vigorous Cycle of Life Dance

Tandavasana

(tahn-duh-VAHS-uh-nuh)

Modification: both knees bent, both elbows bent
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)

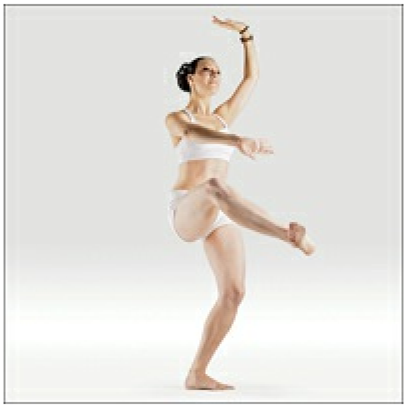

Pose Inspired by Shiva’s Vigorous Cycle of Life Dance

Tandavasana

(tahn-duh-VAHS-uh-nuh)

Modification: standing leg straight; other knee bent, foot to the inside of the knee; one forearm to the opposite knee, other arm extended up to the sky
Pose Type: standing one-legged balance, twist
Drishti Point: Hastagrai or Hastagre (hands)

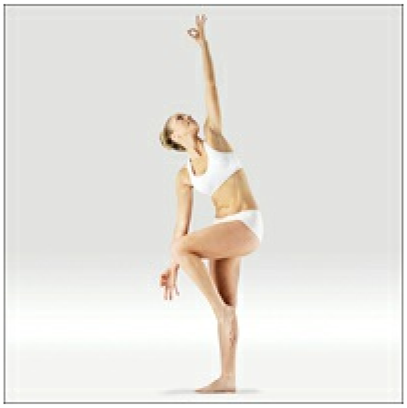

Pose Inspired by Shiva’s Vigorous Cycle of Life Dance

Tandavasana

(tahn-duh-VAHS-uh-nuh)

Modification: standing leg straight, other knee bent at 90 degrees; both elbows bent, fingertips reaching to the sky; twisting to the outside of the body
Pose Type: standing one-legged balance, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

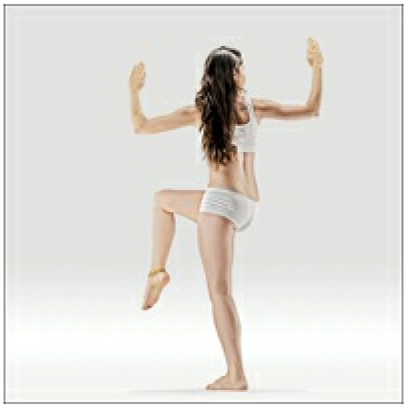

ONE LEG STANDING BALANCE: KNEE BENT TO THE SIDE

Pose Inspired by Shiva’s Vigorous Cycle of Life Dance

Tandavasana

(tahn-duh-VAHS-uh-nuh)

Modification: knee to the tricep on the same side; both elbows bent, one arm up over the head
Pose Type: standing one-legged balance, side bend
Drishti Point: Hastagrai or Hastagre (hands)

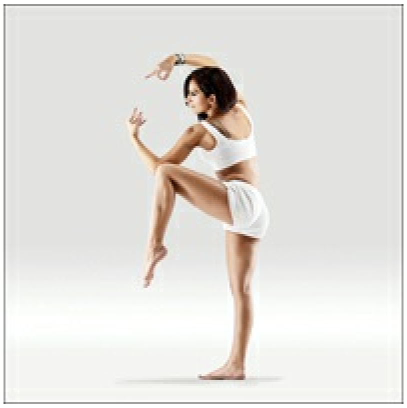

Pose Inspired by Shiva’s Vigorous Cycle of Life Dance

Tandavasana

(tahn-duh-VAHS-uh-nuh)

Modification: standing leg straight, other knee bent, toes pointing away from the head; fingertips to the temples

Pose Type: standing one-legged balance

Drishti Point: Nasagrai or Nasagre (nose)

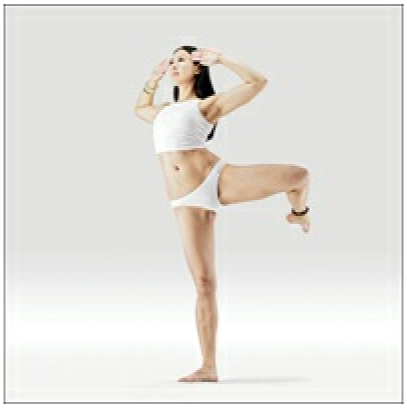

Extended Hand to Big Toe Pose 2 Prep.

Utthita Hasta Padangushtasana 2 Prep.

(UT-ti-tuh HUH-stuh puh-DAHNG-goosh-tahn-AHS-uh-nuh)

Also Known As: Extended Hand to Big Toe Pose B Prep. (Utthita Hasta Padangushtasana B Prep.)

Modification: knee bent

Pose Type: standing one-legged balance

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

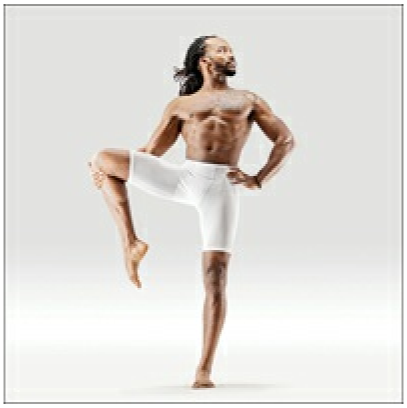

Easy Tree Pose Modification

Sukha Vrikshasana

(SOOK-uh vrik-SHAHS-uh-nuh)

Modification: hands on the hips
1. toes to the floor
2. foot to the calf muscle

Pose Type: standing one-legged balance

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

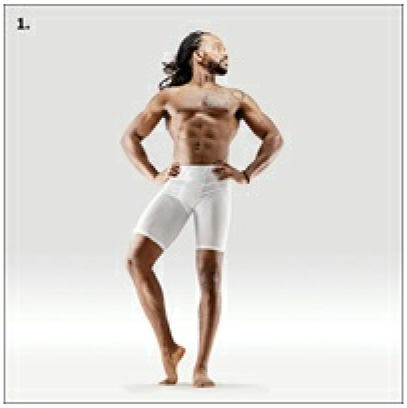

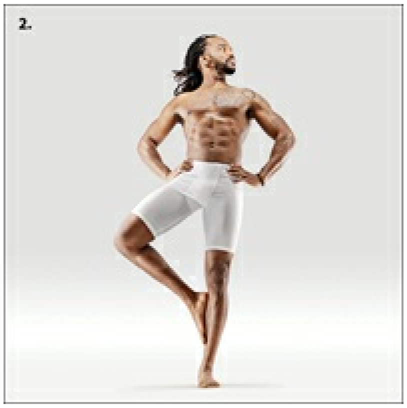

Tree Pose with Hands in Prayer

Vrikshasana Namaskar

(vrik-SHAHS-uh-nuh nuh-muhs-KAHR)

Pose Type: standing one-legged balance

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

Reverse Prayer Tree Pose

Viparita Namaskar Vrikshasana

(vi-puh-REE-tuh nuh-muhs-KAHR vrik-SHAHS-uh-nuh)

Also Known As: Back of the Body Prayer Tree Pose (Paschima Namaskara Vrikshasana)
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)

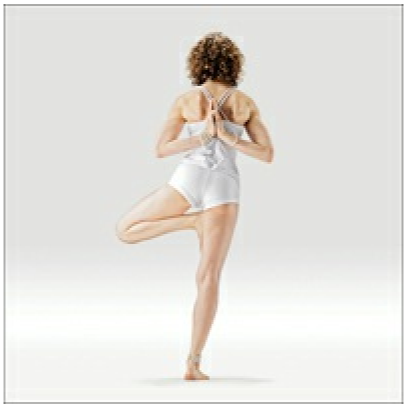

Revolved Half Bound Tree Pose

Parivritta Ardha Baddha Vrikshasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh vrik-SHAHS-uh-nuh)

Pose Type: standing one-legged balance, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

Tree Pose with Hands in Prayer

Vrikshasana Namaskar

(vrik-SHAHS-uh-nuh nuh-muhs-KAHR)

Modification: backbend
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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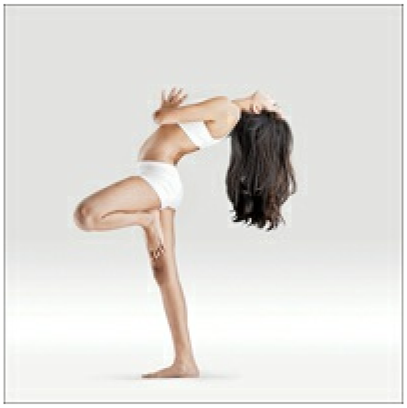

Tree Pose

Vrikshasana

(vrik-SHAHS-uh-nuh)

Also Known As: Upward Hands Tree Pose (Urdhva Hasta Vrikshasana) or Pose Dedicated to Royal Sage Bhagiratha (Bhagirathasana)

Pose Type: standing one-legged balance, mild backbend

Drishti Point: Angusthamadhye or Angustha Ma Dyai (thumbs)

How to Perform the Pose:

1. Begin by standing in Mountain Pose (*Tadasana*). Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing. Find a still point on the floor to keep your gaze on. This will help you find and keep your balance.
2. Inhale and bring your weight onto the right foot. Exhale as you bend your left knee, and bring it out to the left side, opening the inside of your left hip. Keep your hips leveled and parallel to the floor (don’t let your left hip go higher than your right). Keep the lower abdomen engaged to take out the compression (the arch) in the lower back.
3. Exhale as you place the sole of your left foot to the left calf muscle. Make sure the toes of your left foot are pointing to the floor.
4. On the next exhale, grab onto the left ankle with your left hand and slide the left foot up to the inside of your left thigh, keeping the toes of the left foot pointing to the floor. Avoid putting pressure on your right knee. Make sure to keep the left knee out to the side as you open the inside of your left hip.
5. Inhale as you reach both arms up over your head, fingertips pointing up to the sky. Keep them straight and shoulder-width apart. Make sure to lengthen your neck and keep your shoulder blades down your back.
6. Exhale and bring your gaze to your thumbs (Pose #1). You can experiment with rolling your head all the way back, feeling the stretch in the front of your neck (Pose #2).
7. If your shoulders are open, the neck is long, and your breathing is not constricted, you can bring your palms together on the exhale and look at your thumbs (Pose #3). With your palms pressed together, you can also experiment with rolling your head all the way back, feeling the stretch in the front of your neck (Pose #4).
8. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch. Exhale as you release the pose, come back to Mountain Pose (*Tadasana*), and repeat on the other side.

Modification: arms extended up over the head
1. arms shoulder width
2. arms shoulder width, head rolling back
3. palms together
4. palms together, head rolling back

vriksha = tree

1.

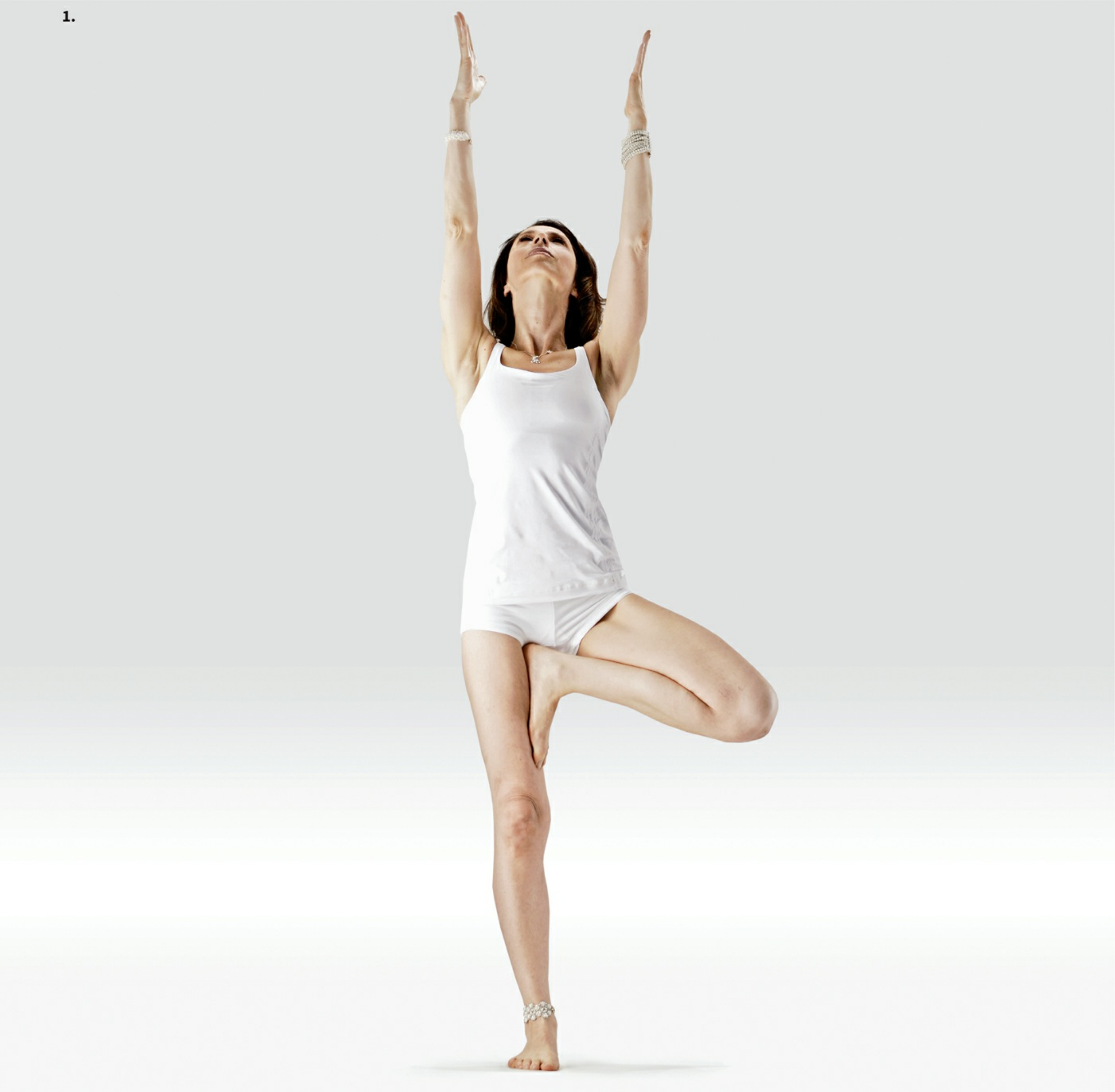

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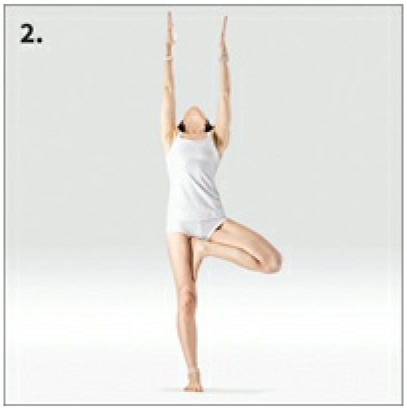

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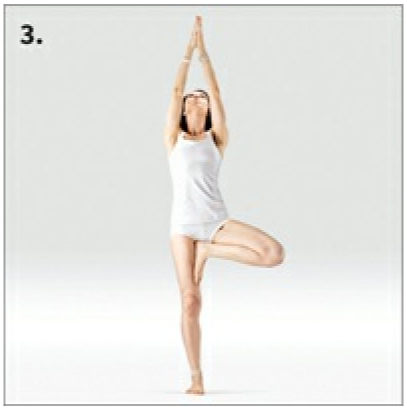

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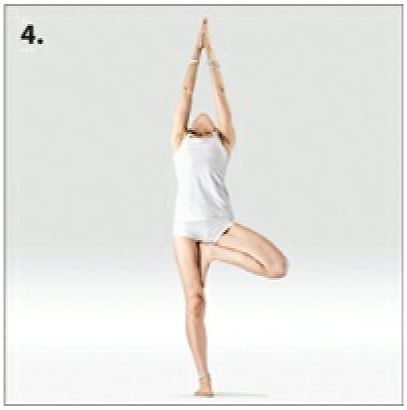

Hand Position of Cow Face Pose in Tree Pose

Hasta Gomukhasana in Vrikshasana

(HUH-stuh go-muk-AHS-uh-nuh in vrik-SHAHS-uh-nuh)

Modification: Gomukhasana arms
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)

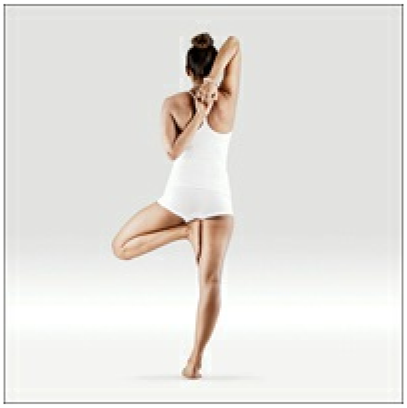

Hand Position of the Pose Dedicated to Garuda in Tree Pose

Hasta Garudasana in Vrikshasana

(HUH-stuh GUH-ru-duh-AHS-uh-nuh in vrik-SHAHS-uh-nuh)

Pose Type: standing one-legged balance
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

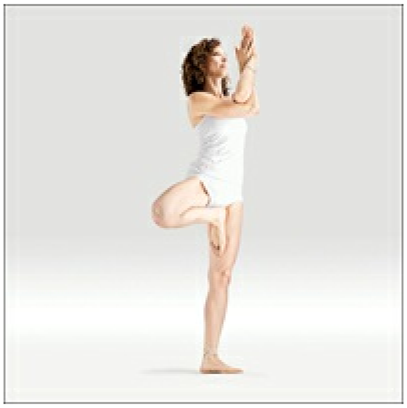

Sideways Tree Pose

Parshva Vrikshasana

(PAHRSH-vuh vrik-SHAHS-uh-nuh)

Modification: side bend toward the bent knee
Pose Type: standing one-legged balance, side bend
Drishti Point: Hastagrai or Hastagre (hands)

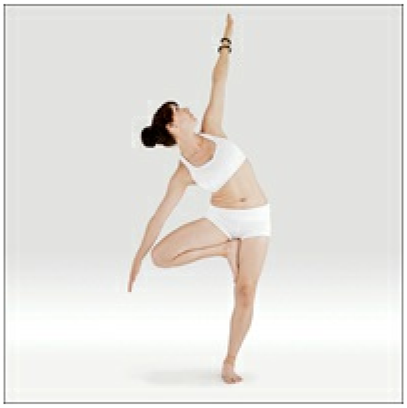

Upward One Hand Half Bound Lotus Tree Pose

Urdhva Eka Hasta Ardha Baddha Padma Vrikshasana

(OORD-vuh EY-kuh HUH-stuh UHR-duh BUH-duh PUHD-muh vrik-SHAHS-uh-nuh)

Pose Type: standing one-legged balance, binding
Drishti Point: Nasagrai or Nasagre (nose)

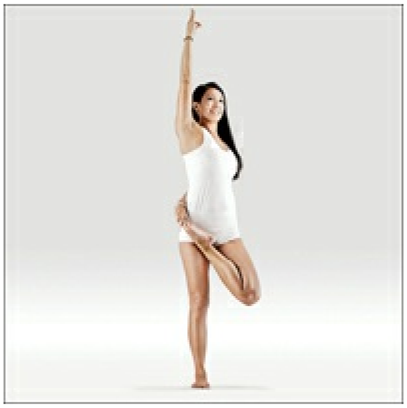

Revolved Half Bound Lotus Tree Pose

Parivritta Ardha Baddha Padma Vrikshasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh PUHD-muh vrik-SHAHS-uh-nuh)

Pose Type: standing one-legged balance, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

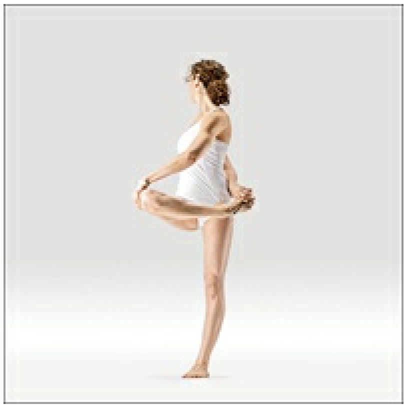

Hand to Foot Hand to Knee Tree Pose

Hasta Pada Hasta Janu Vrikshasana

(HUH-stuh PUH-duh HUH-stuh JAH-nu vrik-SHAHS-uh-nuh)

Modification: grabbing onto the foot and the knee, knee to the outside
Pose Type: standing one-legged balance
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
ल व य

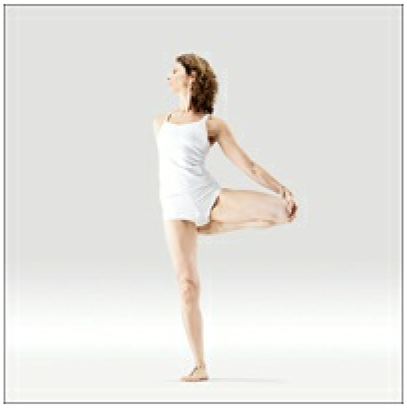

Hand to Foot Hand to Knee Tree Pose

Hasta Pada Hasta Janu Vrikshasana

(HUH-stuh PUH-duh HUH-stuh JAH-nu vrik-SHAHS-uh-nuh)

Modification: backbend, grabbing onto the foot and the knee, knee to the outside, looking straight ahead
Pose Type: standing one-legged balance, backbend
Drishti Point: Nasagrai or Nasagre (nose)
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Hand to Foot Hand to Knee Toppling Tree Pose

Hasta Pada Hasta Janu Patan Vrikshasana

(HUH-stuh PUH-duh HUH-stuh JAH-nu PUH-tuhn vrik-SHAHS-uh-nuh)

Modification: grabbing onto the foot and the shin, knee to the outside
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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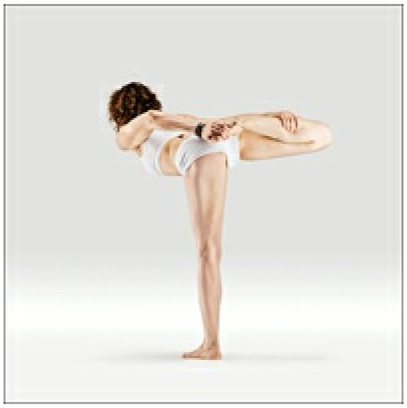

ONE LEG STANDING BALANCE: LEG STRAIGHT IN FRONT

Both Hands to Foot Pose

Dwi Hasta Padasana

(dwi-huh-stuh puh-DAHS-uh-nuh)

Also Known As: Raised Up Leg and Back Stretch Pose (Utthita Eka Pada Paschimottanasana), Standing Head to Knee Pose (Dandayamana-Janushirasana)
Modification: chin to the shin
Pose Type: standing one-legged balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

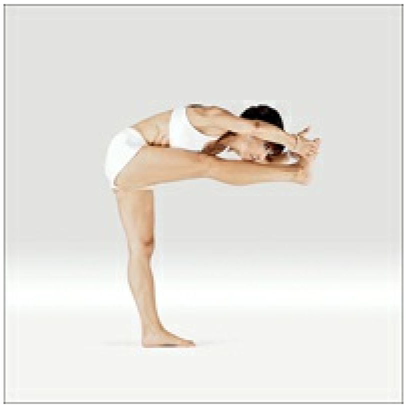

Extended One Foot Pose

Utthita Ekapadasana

(UT-ti-tuh EY-kuh-puh-DAHS-uh-nuh)

Also Known As: Extended Hand to Big Toe Pose D (Utthita Hasta Padangushtasana D; found in Ashtanga Yoga System)
Modification: hands on the hips
Pose Type: standing one-legged balance
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

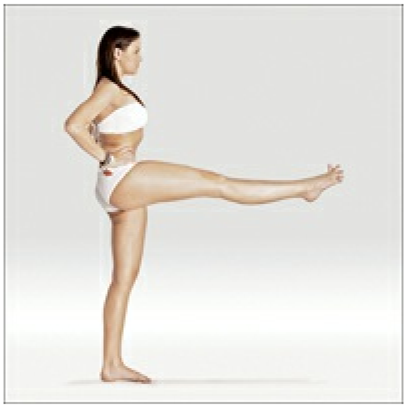

Extended Hand to Big Toe Pose 1

Utthita Hasta Padangushtasana 1

(UT-ti-tuh HUH-stuh puhd-ahng-goosh-TAHS-uh-nuh)

Also Known As: Extended Hand to Big Toe Pose A (Utthita Hasta Padangushtasana A)
Modification: lifted leg in front of the body
Pose Type: standing one-legged balance
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

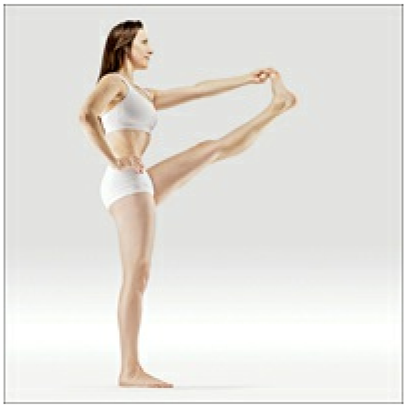

Extended Pose Dedicated to Trivikrama—Conqueror of the Three Worlds (Vishnu)

Utthita Trivikramasana

(UT-ti-tuh tri-vi-kruh-MAHS-uh-nuh)

Also Known As: Extended Hand to Foot Stretch Pose (Utthita Hastha Pada Uttanasana)
Modification: knee away from the shoulder
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)

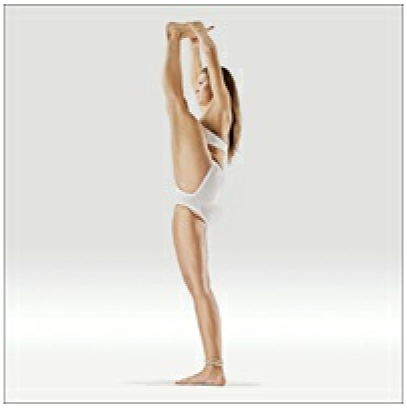

ONE LEG STANDING BALANCE: LEG STRAIGHT TO THE SIDE

Pose Dedicated to Trivikrama—Conqueror of the Three Worlds (Vishnu)

Trivikramasana

(tri-vi-kruh-MAHS-uh-nuh)

Also Known As: Leg to the Side Pose Dedicated to Trivikrama—Conqueror of the Three Worlds (Vishnu) (Parshva Pada Trivikramasana)
Modification: arm wrapping around the leg on the same side
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)
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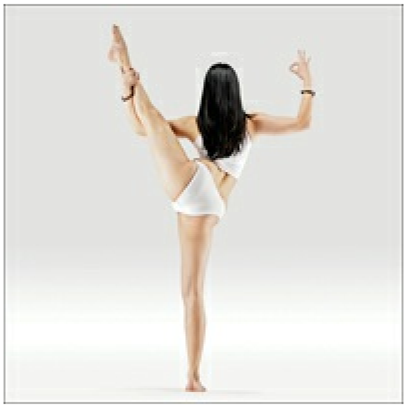

Rising Standing Sundial Pose

Utthita Stiti Surya Yantrasana

(UT-ti-tuh STI-ti SOOR-yuh yuhn-TRAHS-uh-nuh)

Also Known As: Utthita Nindra Surya Yantrasana
Modification: side bend
Pose Type: standing one-legged balance, side bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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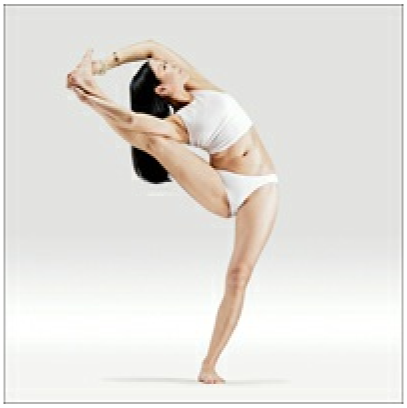

Pose Dedicated to Trivikrama—Conqueror of the Three Worlds (Vishnu)

Trivikramasana

(tri-vi-kruh-MAHS-uh-nuh)

Also Known As: Leg to the Side Pose Dedicated to Trivikrama—Conqueror of the Three Worlds (Vishnu) (Parshva Pada Trivikramasana)
Modification: both hands grabbing onto the leg, shoulder to the back of the knee, looking to the side
Pose Type: standing one-legged balance, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

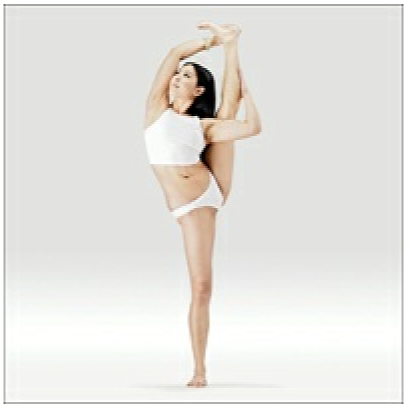

Pose Dedicated to Trivikrama—Conqueror of the Three Worlds (Vishnu)

Trivikramasana

(tri-vi-kruh-MAHS-uh-nuh)

Also Known As: Leg to the Side Pose Dedicated to Trivikrama—Conqueror of the Three Worlds (Vishnu) (Parshva Pada Trivikramasana)
Modification: one hand grabbing onto the opposite foot, shoulder to the front of the knee, other arm straight out to the side, looking straight ahead
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)

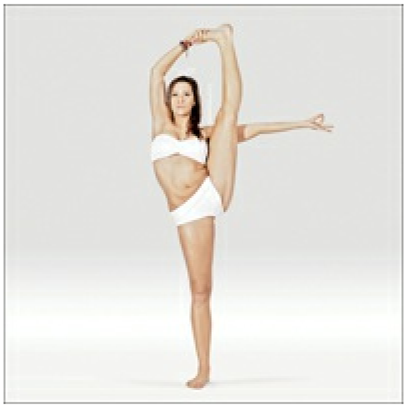

Extended Hand to Big Toe Pose 2

Utthita Hasta Padangushtasana 2

(UT-ti-tuh HUH-stuh puhd-ahng-goosh-TAHS-uh-nuh)

Also Known As: Extended Hand to Big Toe Pose B (Utthita Hasta Padangushtasana B), Standing Leg Going to the Side Pose Prep. (Utthita Parshvasahita Prep.)
Pose Type: standing one-legged balance
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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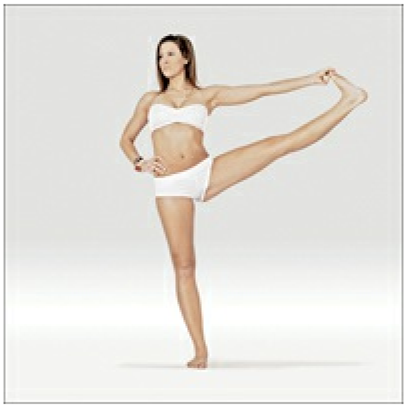

Half Bound Pose Dedicated to Trivikrama—Conqueror of the Three Worlds (Vishnu)

Ardha Baddha Trivikramasana *(UHR-duh BUH-duh tri-vi-kruh-MAHS-uh-nuh)*
Also Known As: Leg to the Side Half Bound Pose Dedicated to Trivikrama—Conqueror of the Three Worlds (Vishnu) (Parshva Pada Ardha Baddha Trivikramasana)
Modification: one arm wrapping around the leg on the same side, other arm behind the back, hand to the inside of the thigh
Pose Type: standing one-legged balance, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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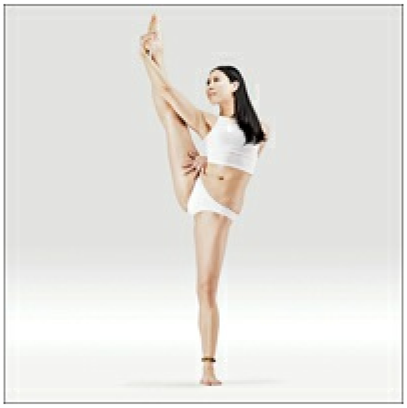

Bird of Paradise Pose

Svarga Dvijasana

(SVUHR-guh dwij-AHS-uh-nuh)

Pose Type: standing one-legged balance, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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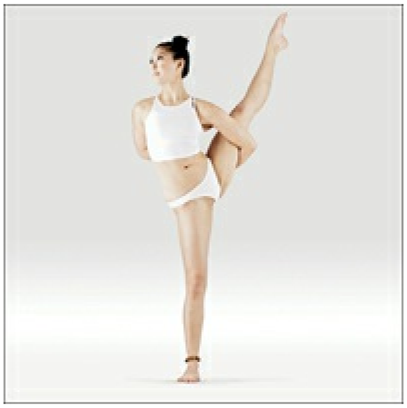

Revolved Extended Hand to Foot Pose

Parivritta Utthita Pada Hastasana

(puh-ri-VRIT-tuh UT-ti-tuh PUH-duh huh-STAHS-uh-nuh)

Also Known As: Revolved Hand to Big Toe Pose (Parivritta Hasta Padangushtasana)
Pose Type: standing one-legged balance, twist
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
ल व

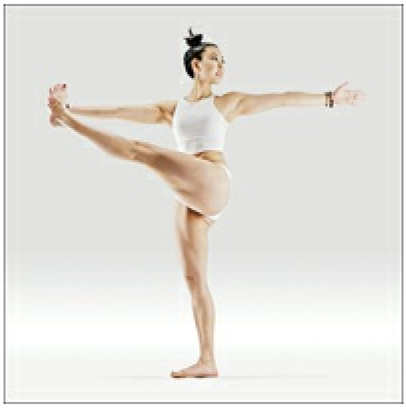

Revolved Bird of Paradise Pose

Parivritta Svarga Dvijasana

(puh-ri-VRIT-tuh SVUHR-guh dwij-AHS-uh-nuh)

Also Known As: Raised and Revolved Bound Leg Pose (Utthita Parivritta Baddha Padasana)
Pose Type: standing one-legged balance, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
ल व

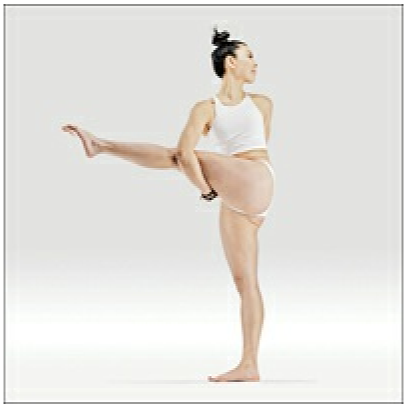

ONE LEG STANDING BALANCE: BOTH LEGS STRAIGHT—BACKBEND

Lord of the Dance Pose

Natarajasana

(NAH-tuh-rahj-AHS-uh-nuh)

Modification: under-head grip with one hand on the same side; both legs straight
Pose Type: standing one-legged balance, backbend
Drishti Point: Hastagrai or Hastagre (hands)
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Pose Dedicated to Yogi Yogananda

Yoganandasana

(yo-gah-nuhn-DAHS-uh-nuh)

Also Known As: Pose Dedicated to Vishnu Devananda (Vishnu Devanandasana)
Modification: both legs straight, grabbing onto the back leg with an under-head grip
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

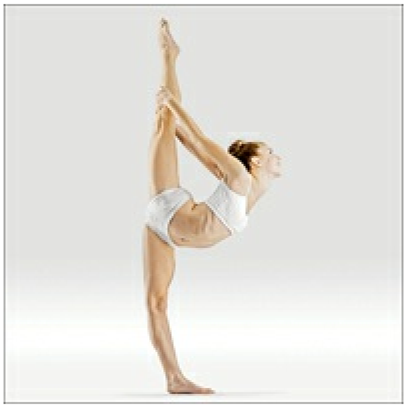

Yogi Sivananda’s Pose

Sivanandasana

(shiv-ah-nuhn-DAHS-uh-nuh)

Modification: grabbing onto the shin
Pose Type: standing one-legged balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

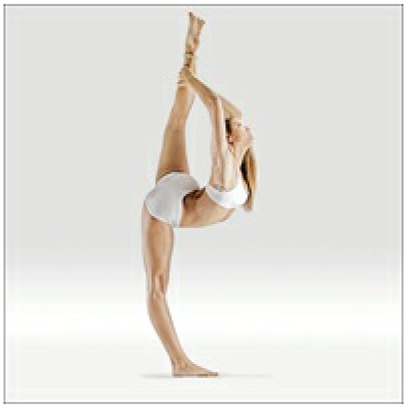

ONE LEG STANDING BALANCE: BOTH LEGS STRAIGHT—FORWARD BEND

Pose Dedicated to Sage Sundaranandar

Sundaranandarasana

(sun-duh-RAH-nuhn-duh-RAHS-uh-nuh)

Modification: palms to the floor, forehead to the shin
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

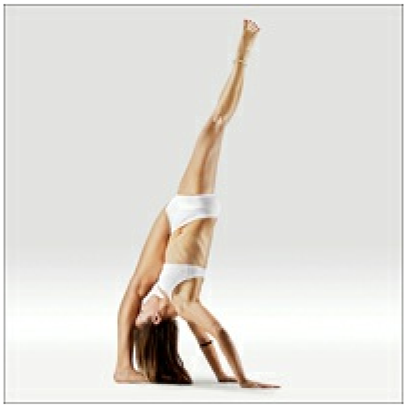

One Leg Stretched Upward Pose

Urdhva Prasarita Ekapadasana

(OORD-vuh pruh-SAH-ri-tuh ey-kuh-puhd-AHS-uh-nuh)

Modification: one hand grabbing onto the ankle on the same side, palm of the other hand to the floor, head away from the shin
Pose Type: standing one-legged balance, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet) or Nasagrai or Nasagre (nose)

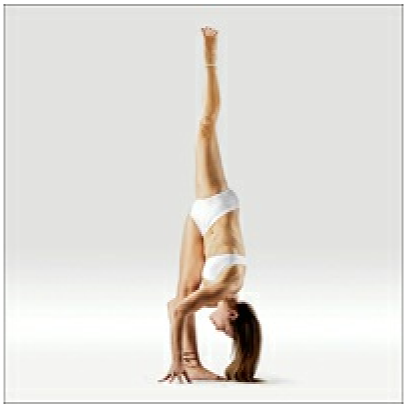

One Leg Stretched Upward Pose

Urdhva Prasarita Ekapadasana

(OORD-vuh pruh-SAH-ri-tuh ey-kuh-puhd-AHS-uh-nuh)

Modification: both hands grabbing onto the ankle, forehead to the shin
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose) if chin touches the shin
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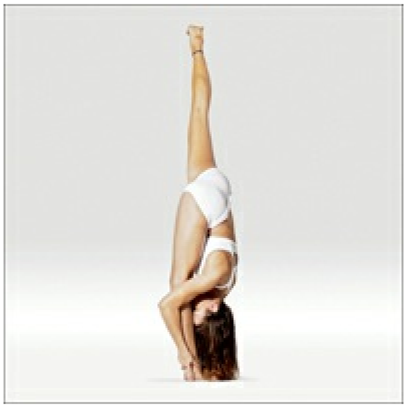

Unsupported One Leg Stretched Upward Pose

Niralamba Urdhva Prasarita Ekapadasana

(nir-AH-luhm-buh OORD-vuh pruh-SAH-ri-tuh ey-kuh-puhd-AHS-uh-nuh)

Modification: arms straight along the sides of the torso, fingertips to the sky
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Padayoragrai or Padayoragre (toes/feet), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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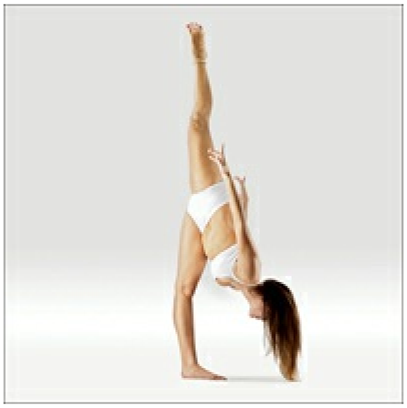

Bound Unsupported One Leg Stretched Upward Pose

Baddha Niralamba Urdhva Prasarita Ekapadasana

(BUH-duh nir-AH-luhm-buh OORD-vuh pruh-SAH-ri-tuh ey-kuh-puhd-AHS-uh-nuh-uh-nuh)

Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose), Padayoragrai or Padayoragre (toes/feet), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

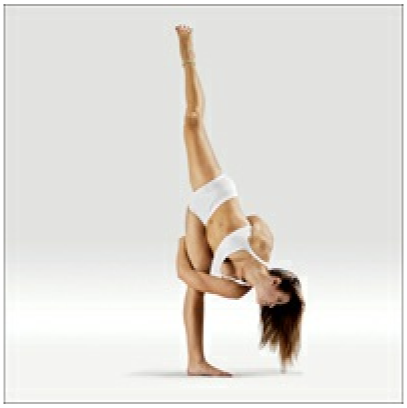

ONE LEG STANDING BALANCE: LEG STRAIGHT TO THE SIDE—HALF FORWARD BEND

Bowing with Respect Extended Hand to Big Toe Pose 2

Nantum Utthita Hasta Padangushtasana 2

(NUHN-tum UT-ti-tuh HUH-stuh puhd-ahng-goosh-TAHS-uh-nuh)

Modification: forward bend, grabbing onto the big toe of the lifted leg; other arm extended to the side parallel to the floor
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

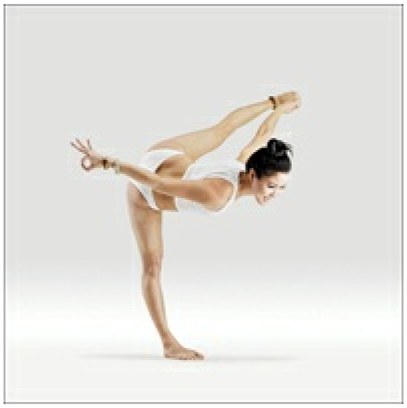

Bowing with Respect Both Hands Extended to Big Toes Pose 2

Nantum Utthita Dwi Hasta Padangushtasana 2

(NUHN-tum UT-ti-tuh DWI-huh-stuh puhd-ahng-goosh-TAHS-uh-nuh-uh-nuh)

Modification: forward bend, grabbing onto the big toes with both hands, leg lifted higher than the hip
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

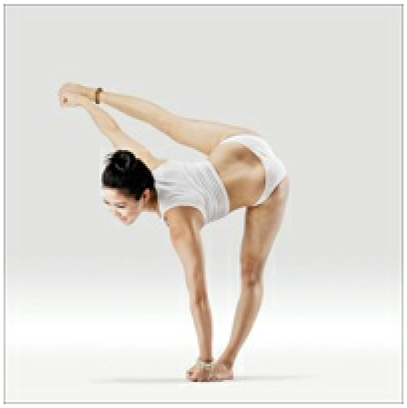

Bowing with Respect Half Bound Hand to Leg Pose

Nantum Ardha Baddha Hasta Padasana

(NUHN-tum UHR-duh BUH-duh HUH-stuh puhd-AHS-uh-nuh)

Modification: half forward bend
Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

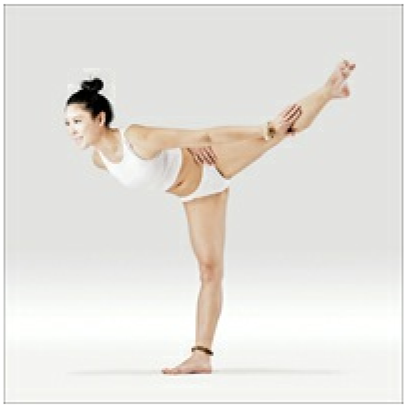

ONE LEG STANDING BALANCE: STANDING KNEE BENT & STRAIGHT—FORWARD BEND

Bowing with Respect Bird of Paradise Pose Prep.

Nantum Svarga Dvijasana Prep.

(NUHN-tum SVUHR-guh dwij-AHS-uh-nuh)

Modification: 1. standing leg bent; other knee to the back of the shoulder, leg bent
2. standing leg bent; other knee to the back of the shoulder, leg straight
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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1.

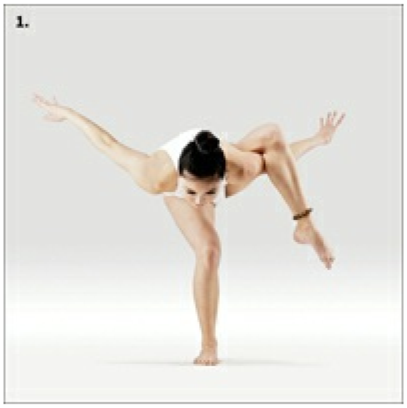

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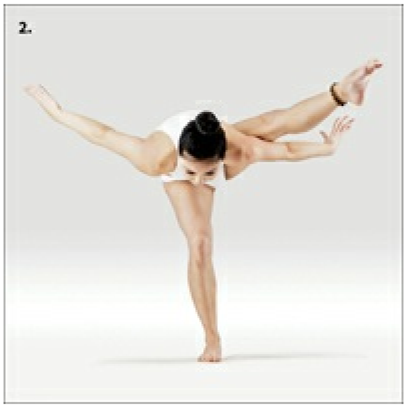

Bowing with Respect Bird of Paradise Pose

Nantum Svarga Dvijasana

(NUHN-tum SVUHR-guh dwij-AHS-uh-nuh)

Modification: half forward bend
Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

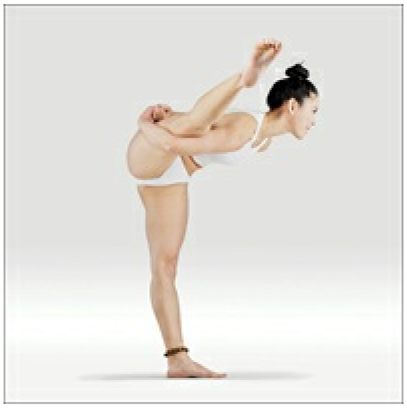

Benu Bird Pose 2

Benvasana 2

(ben-VAHS-uh-nuh)

Modification: both knees bent, chest toward the quadriceps, arms open to the sides
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

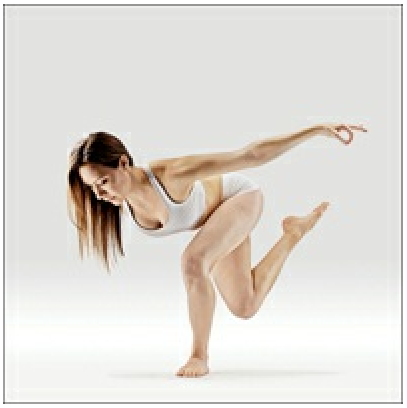

ONE LEG STANDING BALANCE: ONE LEG STRAIGHT TO THE BACK, HANDS TO THE FLOOR

Half One Leg Stretched Upward Pose

Ardha Urdhva Prasarita Ekapadasana

(UHR-duh OORD-vuh pruh-SAH-ri-tuh ey-kuh-puh-DAHS-uh-nuh)

Also Known As: One Leg Stretched Upwards Pose Prep. (Urdhva Prasarita Ekapadasana Prep.), Warrior 3 Prep. (Virabhadrasana 3 Prep.)
Modification: fingertips to the floor
Pose Type: standing, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

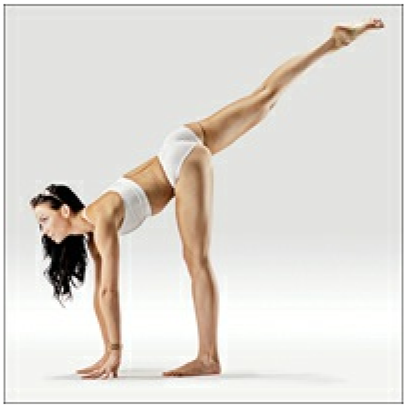

One Leg Stretched Upward Pose Prep.

Urdhva Prasarita Ekapadasana Prep.

(OORD-vuh pruh-SAH-ri-tuh ey-kuh-puh-DAHS-uh-nuh)

Modification: standing leg bent, shoulder to the back of the knee, arms extended to the back
Pose Type: standing, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

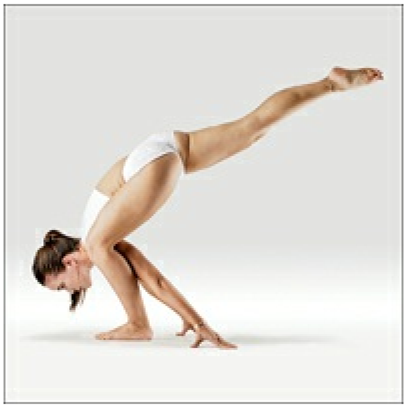

Half Moon Pose Prep.

Ardha Chandrasana Prep.

(UHR-duh chuhn-DRAHS-uh-nuh)

Modification: with yoga block prop, hand on the hip
Pose Type: standing one-legged balance, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

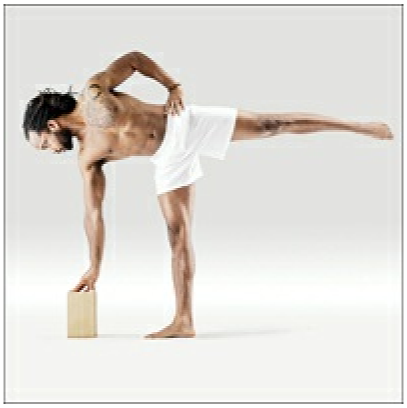

Half Moon Pose

Ardha Chandrasana

(UHR-duh chuhn-DRAHS-uh-nuh)

Pose Type: standing one-legged balance, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

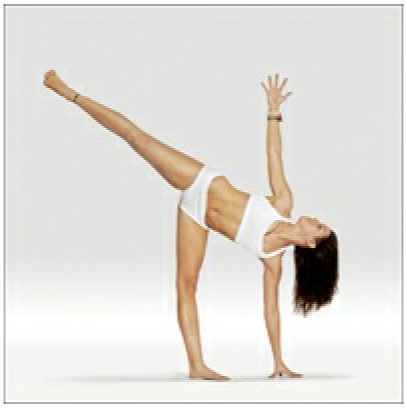

ONE LEG STANDING BALANCE: ONE LEG STRAIGHT TO THE BACK—HANDS OFF THE FLOOR

Warrior 3

Virabhadrasana 3

(VEER-uh buh-DRAHS-uh-nuh)

Also Known As: Bird Pose A (Dikasana A)

Pose Type: standing one-legged balance, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

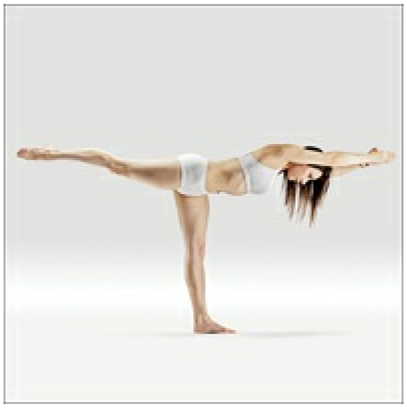

Warrior 3

Virabhadrasana 3

(VEER-uh buh-DRAHS-uh-nuh)

Also Known As: Bird Pose B (Dikasana B)

Modification: arms extended to the back and parallel to the floor

Pose Type: standing one-legged balance, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

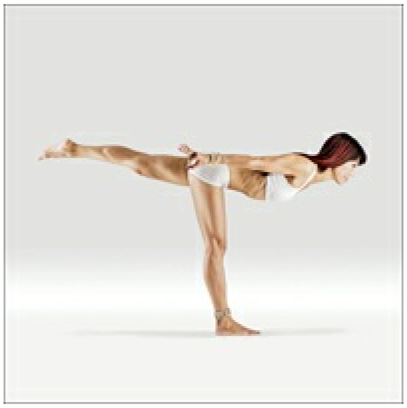

Reverse Prayer Warrior 3

Viparita Namaskar Virabhadrasana 3

(vi-puh-REE-tuh nuh-muhs-KAHR VEER-uh buh-DRAHS-uh-nuh)

Also Known As: Back of the Body Prayer Warrior 3 (Paschima Namaskara Virabhadrasana 3)
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

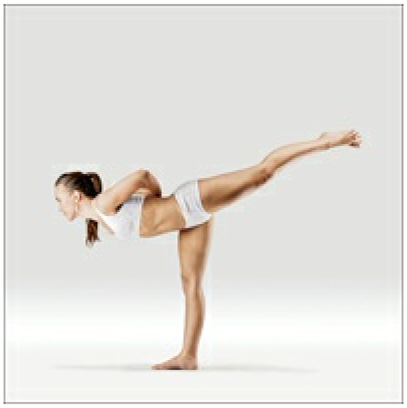

Hand Position of the Pose Dedicated to Garuda in Warrior 3

Hasta Garudasana in Virabhadrasana 3

(HUH-stuh guh-ru-DAHS-uh-nuh in VEER-uh-buh-DRAHS-uh-nuh)

Pose Type: standing one-legged balance, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

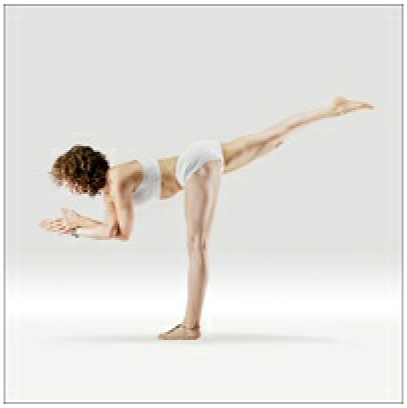

Half Lotus Warrior 3

Ardha Padma Virabhadrasana 3

(UHR-duh PUHD-muh VEER-uh-buh-DRAHS-uh-nuh-uh-nuh)

Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

Half Moon Pose

with Hands in Prayer

Ardha Chandrasana Namaskar

(UHR-duh chuhn-DRAHS-uh-nuh nuh-muhs-KAHR)

Pose Type: standing one-legged balance, forward bend

Drishti Point: 1. Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) 2. Urdhva or Antara Drishti (up to the sky)

How to Perform the Pose:

1. Begin by doing Extended Triangle Pose (*Utthita Trikonasana*) with the left foot in front and your left hand to the floor outside the left foot (either on the fingertips or with the palm flat on the floor). Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale as you slide your left palm out to the front while bending your left knee. Experiment with the distance to find your balance.
3. Inhale and lift your right foot off the floor until your right leg is parallel to the floor. Keep it straight and reaching away from your head. Straighten your standing left leg.
4. Exhale and rotate your chest to the side so that your shoulders stack one on top of the other.
5. On your next exhale, lift your left arm up off the floor and bring your hands into prayer at the center of your chest.
6. You can either find a gazing point on the floor that is not moving to help keep your balance (Pose #1) or challenge yourself by looking up to the sky (Pose #2).
7. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch. Exhale, lower your right foot to the floor, coming back into Extended Triangle Pose (*Utthita Trikonasana*), and repeat on the other side.

Modification:

1. looking down
2. looking up to the sky

ardha = half

chandra = moon

namaskar = greeting with hands in Anjali Mudra (hands in prayer)

1.

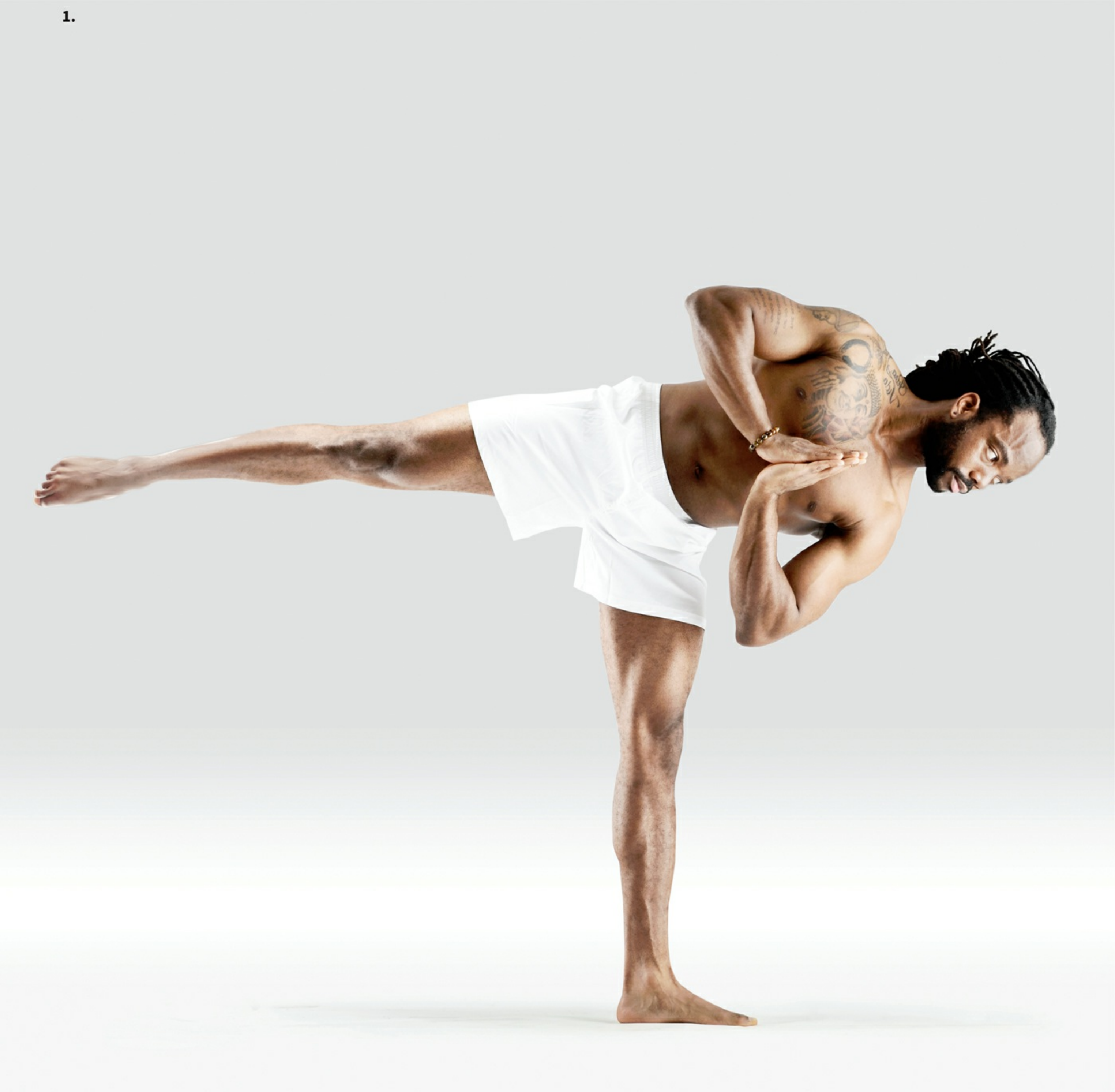

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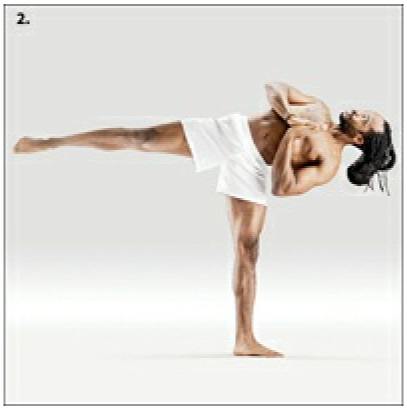

Reverse Prayer Half Moon Pose

Viparita Namaskar Ardha Chandrasana

(vi-puh-REE-tuh nuh-muhs-KAHR UHR-duh chuhn-DRAHS-uh-nuh)

Also Known As: Back of the Body Prayer Half Moon Pose (Paschima Namaskara Ardha Chandrasana)
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

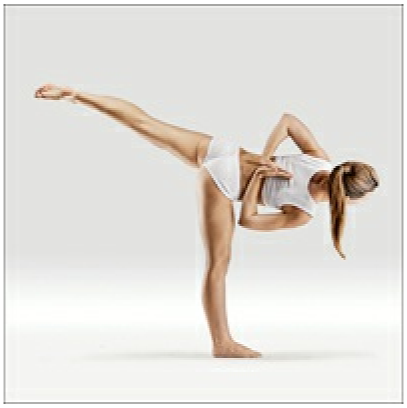

Bound Half Moon Pose

Baddha Ardha Chandrasana

(BUH-duh UHR-duh chuhn-DRAHS-uh-nuh)

Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose) or Padayoragrai or Padayoragre (toes/feet)

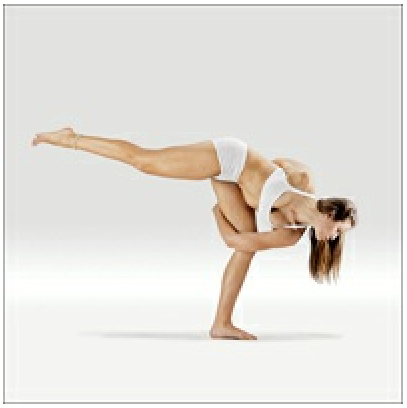

Revolved Bound Half Moon Pose

Parivritta Baddha Ardha Chandrasana

(vi-puh-REE-tuh BUH-duh UHR-duh chuhn-DRAHS-uh-nuh)

Modification: looking up to the sky
Pose Type: standing one-legged balance, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

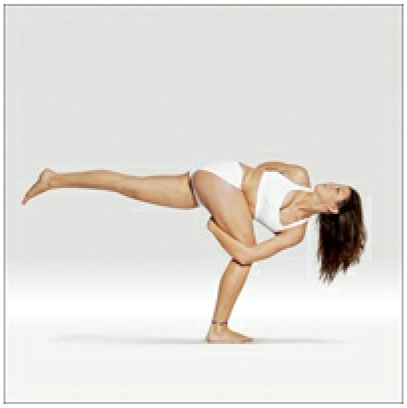

Half Firelog Pose in Half Moon Pose Prep.

Ardha Agnistambhasana in Ardha Chandrasana Prep.

(UHR-duh uhg-ni-stuhm-BAHS-uh-nuh in UHR-duh chuhn-DRAHS-uh-nuh)

Modification: foot on top of the knee, palm to the lower back
Pose Type: standing one-legged balance, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

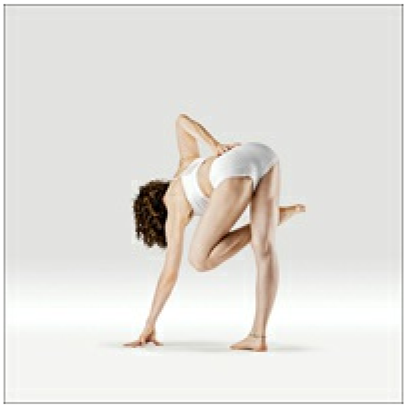

Half Bound Lotus Half Moon Pose Prep.

Ardha Baddha Padma Ardha Chandrasana Prep.

(UHR-duh BUH-duh PUHD-muh UHR-duh chuhn-DRAHS-uh-nuh)

Modification: arm behind the back, binding to the inside of the thigh of the leg in Half Lotus

Pose Type: standing one-legged balance, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

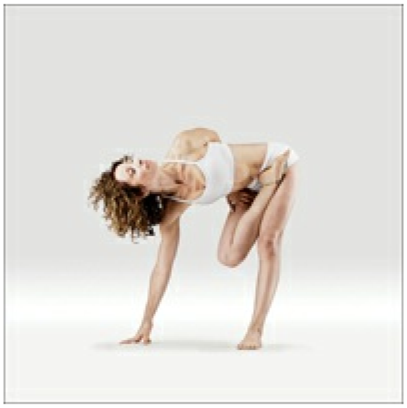

Leg Position of Half Cow Face Pose in Half Moon Pose Prep.

Pada Ardha Gomukhasana in Ardha Chandrasana Prep.

(PUH-duh UHR-duh go-muk-AHS-uh-nuh in UHR-duh chuhn-DRAHS-uh-nuh)
Also Known As: One-Legged Cow Face Pose in Half Moon Pose Prep. (Eka Pada Gomukhasana in Ardha Chandrasana Prep.)
Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

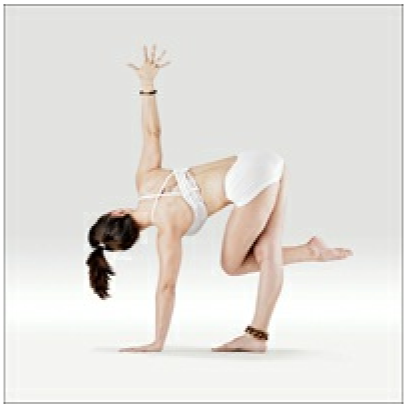

ONE-LEGGED STANDING BALANCE: HALF LOTUS

Half Bound Lotus Intense Stretch Pose Prep.

Ardha Baddha Padmottanasana Prep.

(UHR-duh BUH-duh puhd-mo-tahn-AHS-uh-nuh)
Also Known As: Half Bound Lotus Half Forward Bend Prep., Half Lotus Half Intense Stretch Pose

(Ardha Padma Ardha Uttanasana), Half Lotus Half Forward Bend
Modification: half forward bend, fingertips of both hands to the floor
Pose Type: standing, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

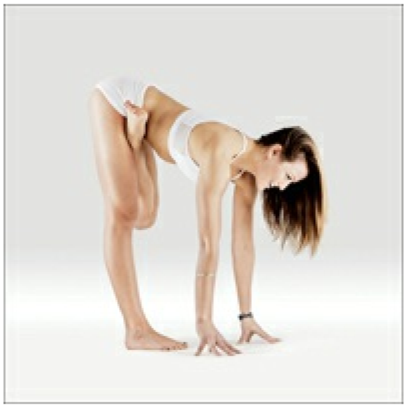

Half Bound Lotus Intense Stretch Pose Prep.

Ardha Baddha Padmottanasana Prep.

(UHR-duh BUH-duh puhd-mo-tahn-AHS-uh-nuh)
Also Known As: Half Bound Lotus Half Forward Bend
Modification: half forward bend
Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

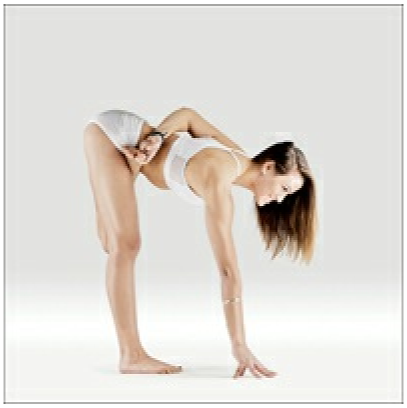

Half Bound Lotus Intense Stretch Pose

Ardha Baddha Padmottanasana

(UHR-duh BUH-duh puhd-mo-tahn-AHS-uh-nuh)

Also Known As: Half Bound Lotus Full Forward Bend
Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)
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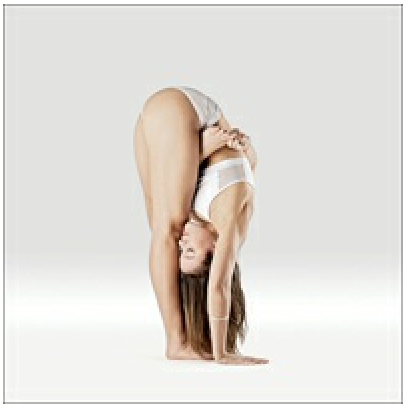

GARUDA LEGS

Pose Dedicated to Garuda

Garudasana

(guh-ru-DAHS-uh-nuh)
Also Known As: Eagle Pose
Modification: hands intertwined in front, low stance
Pose Type: standing one-legged balance
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
ल व

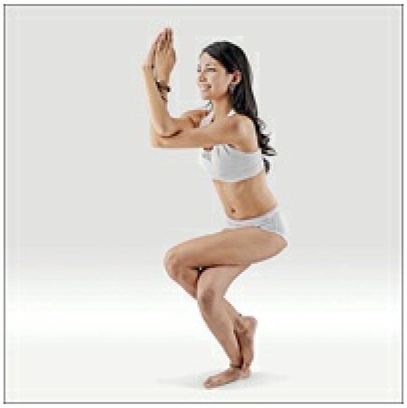

Reverse Heart Chakra Seal in Leg Position of the Pose Dedicated to Garuda

Viparita Anahata Chakra Mudra in Pada Garudasana

(vi-puh-REE-tuh un-AH-huh-tuh chuh-kruh MU-druh in PUH-duh guh-ru-DAHS-uh-nuh)

Also Known As: Reverse Heart Chakra Seal in Leg Position of the Eagle Pose
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)
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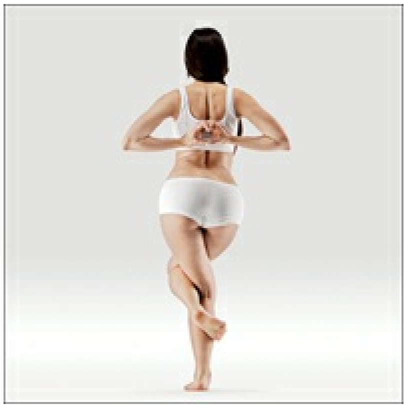

Pose Dedicated to Garuda

Garudasana

(guh-ru-DAHS-uh-nuh)

Also Known As: Eagle Pose
Modification: elbows to the knees
Pose Type: standing one-legged balance, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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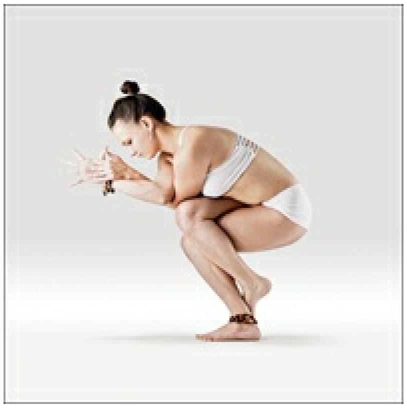

Leg Position of the Pose Dedicated to Garuda

Pada Garudasana

(PUH-duh guh-ru-DAHS-uh-nuh)

Also Known As: Leg Position of the Eagle Pose
Modification: arms straight out to the sides behind the back
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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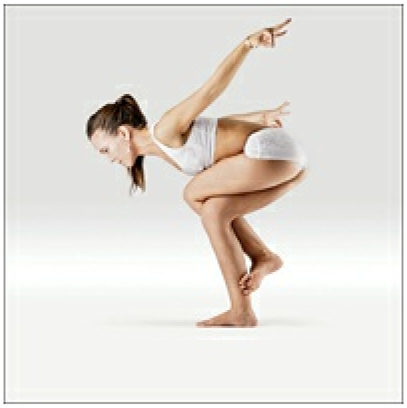

Revolved Bound Leg Position of the Pose Dedicated to Garuda

Parivritta Baddha Pada Garudasana

(puh-ri-VRIT-tuh BUH-duh PUH-duh guh-ru-DAHS-uh-nuh)
Also Known As: Revolved Bound Leg Position of the Eagle Pose
Pose Type: standing one-legged balance, forward bend, binding, twist
Drishti Point: Nasagrai or Nasagre (nose)
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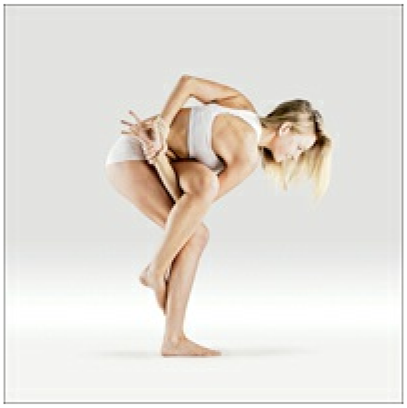

Hands Bound Leg Position of the Pose Dedicated to Garuda

Baddha Hasta Pada Garudasana

(BUH-duh HUH-stuh PUH-duh guh-ru-DAHS-uh-nuh)
Also Known As: Hands Bound Leg Position of the Eagle Pose
Pose Type: standing one-legged balance, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

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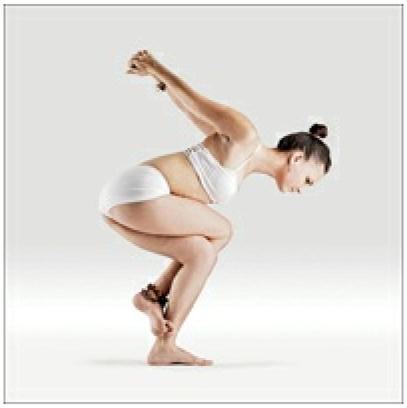

ONE-LEGGED SQUATS: TWISTS

Revolved Half Standing Wind Relieving Intense Stretch Pose

Parivritta Ardha Stiti Vayu Muktyuttonasana

(puh-ri-VRIT-tuh UHR-duh STI-ti VAH-yu muk-tew-to-NAHS-uh-nuh)

Also Known As: Parivritta Ardha Nindra Vayu Muktyuttonasana; Revolved Standing Wind Relieving Half Forward Bend

Modification: knees together; elbow to the opposite knee, other arm extended to the back

Pose Type: standing one-legged balance, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

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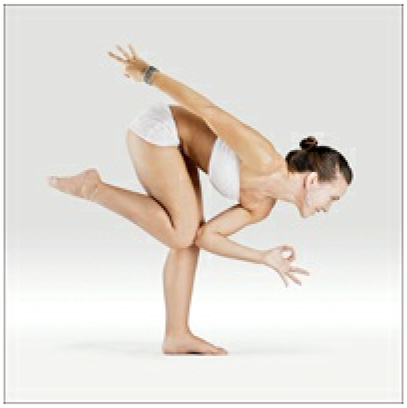

Revolved Half Standing Wind Relieving Intense Stretch Pose with Hands in Prayer

Parivritta Ardha Stiti Vayu Muktyuttonasana Namaskar

(puh-ri-VRIT-tuh UHR-duh STI-ti VAH-yu muk-tew-to-NAHS-uh-nuh nuh-muhs-KAHR)

Also Known As: Parivritta Ardha Nindra Vayu Muktyuttonasana Namaskar; Revolved Standing Wind Relieving Half Forward Bend with Hands in Prayer

Modification: back leg crossed under the front leg

Pose Type: standing one-legged balance, forward bend, twist

Drishti Point: Nasagrai or Nasagre (nose)

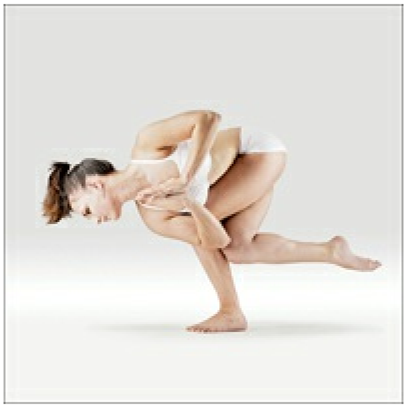

Bound Revolved Half Standing Wind Relieving Intense Stretch Pose

Baddha Parivritta Ardha Stiti Vayu Muktyuttonasana

(BUH-duh puh-ri-VRIT-tuh UHR-duh STI-ti VAH-yu muk-tew-to-NAHS-uh-nuh)

Also Known As: Baddha Parivritta Ardha Nindra Vayu Muktyuttonasana; Bound Revolved Standing Wind Relieving Half Forward Bend

Pose Type: standing one-legged balance, forward bend, twist, binding

Drishti Point: Urdhva or Antara Drishti (up to the sky)

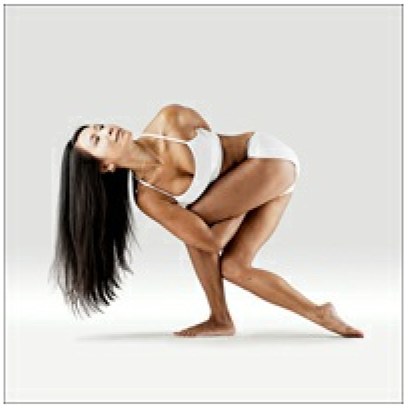

ONE-LEGGED SQUATS: KNEES IN LINE—HEEL TO THE SITTING BONES—GRABBING ONTO THE ANKLE

Revolved One Hand to Foot Half Standing Wind Relieving Intense Stretch Pose

Parivritta Eka Hasta Pada Ardha Stiti Vayu Muktyuttonasana

(puh-ri-VRIT-tuh EY-kuh HUH-stuh PUH-duh UHR-duh STI-ti VAH-yu muk-tew-to-NAHS-uh-nuh)

Also Known As: Parivritta Eka Hasta Pada Ardha Nindra Vayu Muktyuttonasana; Revolved One Hand to Foot Standing Wind Relieving Half Forward Bend
Modification: knees together; elbow to the opposite knee, other hand grabbing onto the ankle
Pose Type: standing one-legged balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

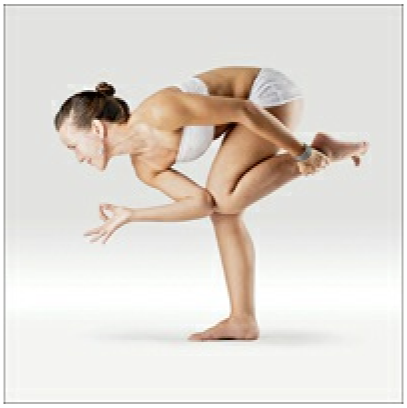

Both Hands to Foot Half Standing Wind Relieving Intense Stretch Pose

Dwi Hasta Pada Ardha Stiti Vayu Muktyuttonasana

(DWI-huh-stuh PUH-duh UHR-duh STI-ti VAH-yu muk-to-NAHS-uh-nuh)

Also Known As: Dwi Hasta Pada Ardha Nindra Vayu Muktyuttonasana
Pose Type: standing one-legged balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

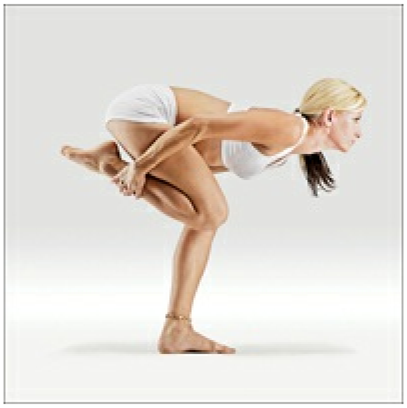

One Hand to Foot Tip Toe Half Standing Wind Relieving Intense Stretch Pose

Eka Hasta Pada Prapada Ardha Stiti Vayu Muktyuttonasana

(EY-kuh HUH-stuh PUH-duh PRUH-puh-duh UHR-duh STI-ti VAH-yu muk-to-NAHS-uh-nuh)

Also Known As: Eka Hasta Pada Prapada Ardha Nindra Vayu Muktyuttonasana
Pose Type: standing one-legged balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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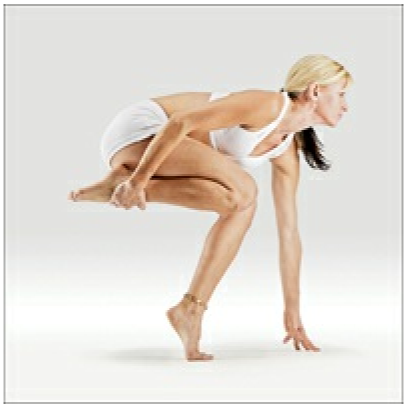

Both Hands to Foot Tip Toe Half Standing Wind Relieving Intense Stretch Pose

Dwi Hasta Pada Prapada Ardha Stiti Vayu Muktyuttonasana

(DWI-huh-stuh PUH-duh PRUH-puh-duh UHR-duh STI-ti VAH-yu muk-to-NAHS-uh-nuh)

Also Known As: Dwi Hasta Pada Prapada Ardha Nindra Vayu Muktyuttonasana
Pose Type: standing one-legged balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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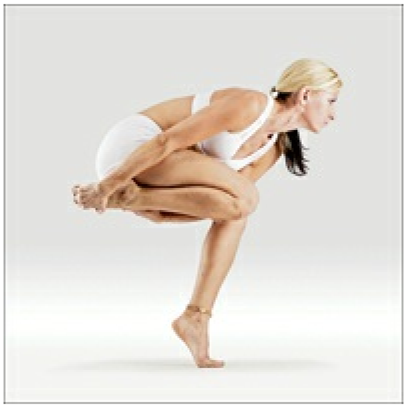

ONE-LEGGED SQUATS: TWISTS—GRABBING ONTO THE FOOT, LEG STRAIGHT IN FRONT

One-Legged Pose Dedicated to Yogi Shankara

Eka Pada Shankarasana

(EY-kuh PUH-duh shunk-uhr-AHS-uh-nuh)

Modification: forehead to the shin

Pose Type: standing one-legged balance, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

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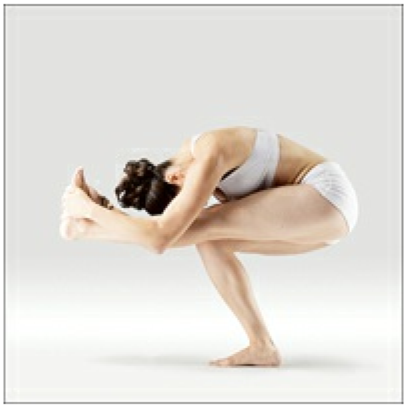

Revolved One-Legged Pose Dedicated to Yogi Shankara

Parivritta Eka Pada Shankarasana

(puh-ri-VRIT-tuh EY-kuh PUH-duh shunk-uhr-AHS-uh-nuh)

Modification: twisting to the inside of the leg

Pose Type: standing one-legged balance, forward bend, twist, side bend

Drishti Point: Urdhva or Antara Drishti (up to the sky)

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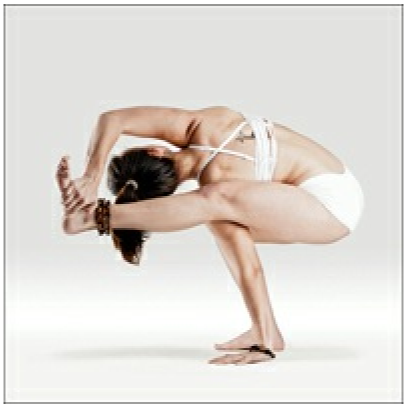

Revolved One-Legged Pose Dedicated to Yogi Shankara

Parivritta Eka Pada Shankarasana

(puh-ri-VRIT-tuh EY-kuh PUH-duh shunk-uhr-AHS-uh-nuh)

Modification: twisting to the outside of the leg
Pose Type: standing one-legged balance, forward bend, twist, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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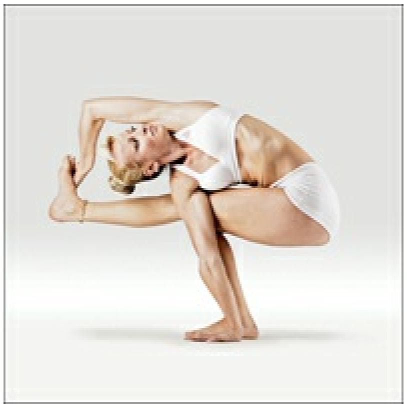

ONE-LEGGED SQUATS: FOOT ON TOP OF THE KNEE

One-Legged Fierce Pose 1

Eka Pada Utkatasana 1

(EY-kuh PUH-duh ut-kuh-TAHS-uh-nuh)

Also Known As: One-Legged Prayer Fierce Pose (Eka Pada Namaskar Utkatasana)
Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing one-legged balance
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

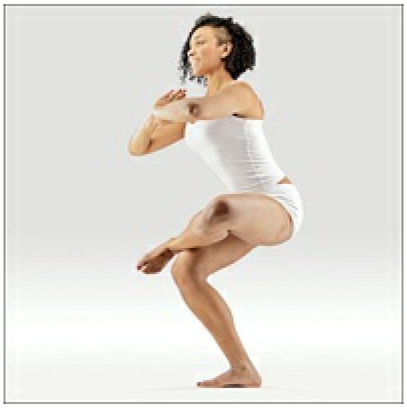

One-Legged Fierce Pose 2

Eka Pada Utkatasana 2

(EY-kuh PUH-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Both Hands to Ankle One-Legged Fierce Pose (Dwi Hasta Kulpa Eka Pada Utkatasana)
Modification: both hands to the ankle
Pose Type: standing one-legged balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

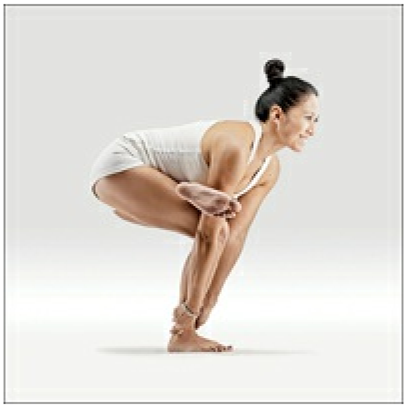

One-Legged Fierce Pose 3

Eka Pada Utkatasana 3

(EY-kuh PUH-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Arms Spread One-Legged Fierce Pose (Prasarita Hasta Eka Pada Utkatasana)
Modification: arms straight out to the sides, forward bend
Pose Type: standing one-legged balance, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

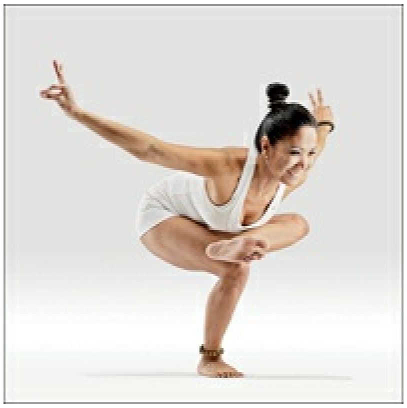

One-Legged Fierce Pose 4

Eka Pada Utkatasana 4

(EY-kuh PUH-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Hands Bound One-Legged Fierce Pose (Baddha Hasta Eka Pada Utkatasana)
Modification: hands bound behind the back, forward bend
Pose Type: standing one-legged balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

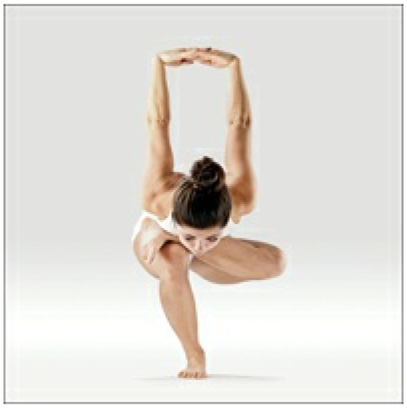

ONE-LEGGED SQUATS: HALF LOTUS

Half Bound Lotus Fierce Pose

Ardha Baddha Padma Utkatasana

(UHR-duh BUH-duh PUHD-muh ut-kuh-TAHS-uh-nuh)

Modification: hips low
Pose Type: standing one-legged balance, binding
Drishti Point: Hastagrai or Hastagre (hands)

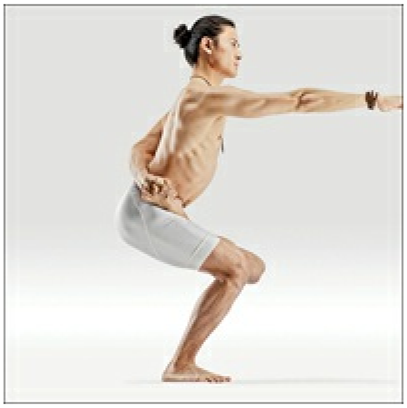

STANDING: FORWARD BEND—FOOT TO KNEE & FOOT TO ARMPIT

Baby Cradle Pose in Intense Stretch Pose

Hindolasana in Uttanasana

(hin-do-LAHS-uh-nuh in ut-tahn-AHS-uh-nuh)

Also Known As: Baby Cradle Pose in Full Forward Bend
Modification: foot behind the knee of the standing leg
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

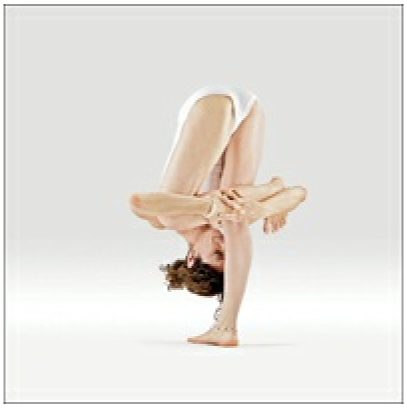

Standing Bound Yogic Staff Pose

Stiti Baddha Yoganandasana

(STI-ti BUH-duh yo-gah-nuhn-DAHS-uh-nuh)

Also Known As: Nindra Baddha Yoganandasana
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

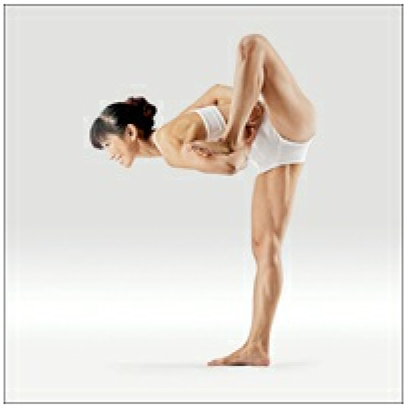

Yogic Staff Intense Stretch Pose

Yogadananda Uttanasana

(yo-gah-nuhn-duh ut-tahn-AHS-uh-nuh)
Also Known As: Yogic Staff Full Forward Bend
Pose Type: standing one-legged balance, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)

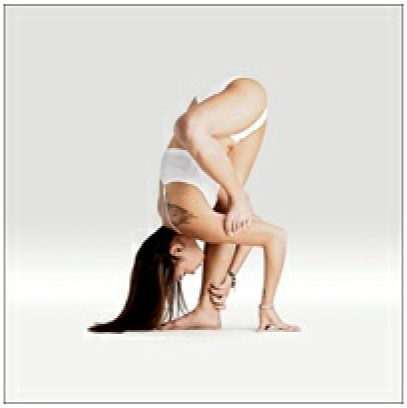

STANDING HALF FORWARD BEND: LEGS CROSSED

Hand Position of the Pose Dedicated to Garuda in Sideways Half Intense Stretch Pose

Hasta Garudasana in Parshva Ardha Uttanasana

(HUH-stuh guh-ru-DAHS-uh-nuh in PAHRSH-vuh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Hand Position of the Pose Dedicated to Garuda in Sideways Legs Crossed Half Forward Bend

Modification: legs crossed

Pose Type: standing, forward bend, twist

Drishti Point: Hastagrai or Hastagre (hands)

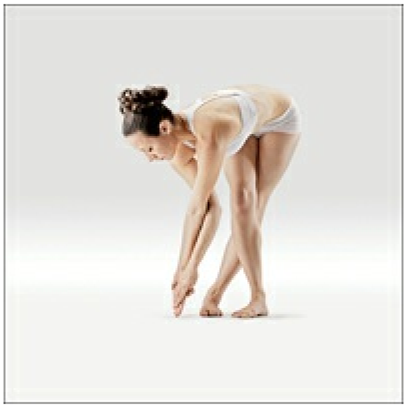

STANDING HALF FORWARD BEND: ONE KNEE BENT

Reverse Prayer Uneven Legs Half Intense Stretch Pose

Viparita Namaskar Vishama Pada Ardha Uttanasana

(vi-puh-REE-tuh nuh-muhs-KAHR VISH-uh-muh PUH-duh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Back of the Body Prayer Uneven Legs Half Intense Stretch Pose (Paschima Namaskara Vishama Pada Ardha Uttanasana), Reverse Prayer Uneven Legs Half Forward Bend

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

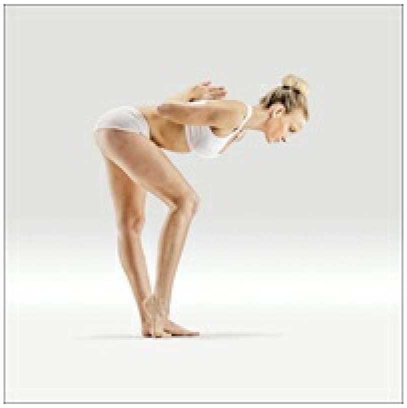

Bound Uneven Legs Half Intense Stretch Pose

Baddha Vishama Pada Ardha Uttanasana

(BUH-duh VISH-uh-muh PUH-duh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Bound Uneven Legs Half Forward Bend

Pose Type: standing, forward bend, binding

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

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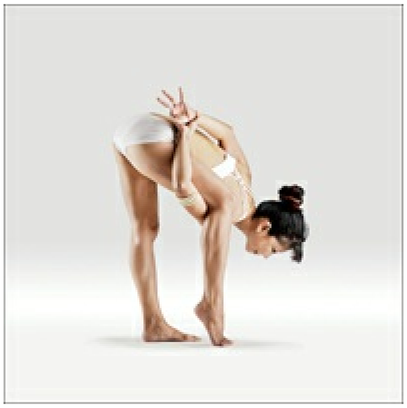

STANDING HALF FORWARD BEND: ONE KNEE BENT—TWISTS & BINDING

Revolved Uneven Legs Half Intense Stretch Pose

Parivritta Vishama Pada Ardha Uttanasana

(puh-ri-VRIT-tuh VISH-uh-muh PUH-duh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Revolved Uneven Legs Half Forward Bend

Modification: one hand to the floor, other hand up to the sky; looking down

Pose Type: standing, forward bend, twist

Drishti Point: Hastagrai or Hastagre (hands)

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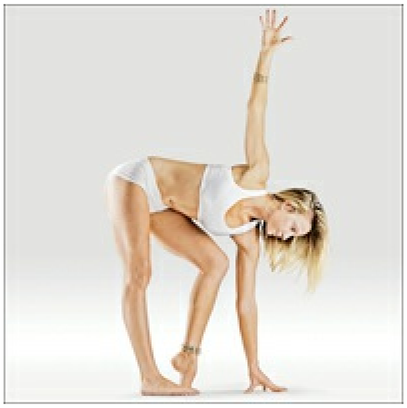

Reverse Prayer Revolved Uneven Legs Half Intense Stretch Pose

Viparita Namaskar Parivritta Vishama Pada Ardha Uttanasana

(vi-puh-REE-tuh nuh-muhs-KAHR puh-ri-VRIT-tuh VISH-uh-muh PUH-duh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Back of the Body Prayer Revolved Uneven Legs Half Intense Stretch Pose (Paschima Namaskara Ardha Parivritta Uttanasana), Reverse Prayer Revolved Uneven Legs Half Forward Bend
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

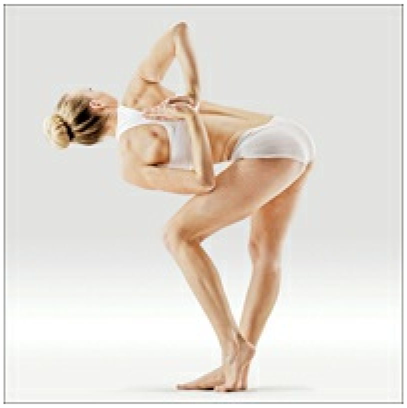

Hands Bound Revolved Uneven Legs Half Intense Stretch Pose

Baddha Hasta Parivritta Vishama Pada Ardha Uttanasana

(BUH-duh HUH-stuh puh-ri-VRIT-tuh VISH-uh-muh PUH-duh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Hands Bound Revolved Uneven Legs Half Forward Bend
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

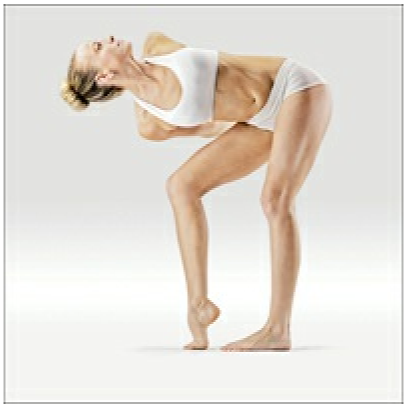

Bound Revolved Half Intense Stretch Pose

Baddha Parivritta Ardha Uttanasana

(BUH-duh puh-ri-VRIT-tuh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Bound Revolved Half Forward Bend

Pose Type: standing, forward bend, twist, binding

Drishti Point: Urdhva or Antara Drishti (up to the sky)

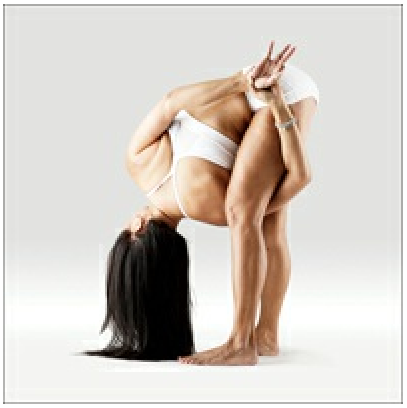

STANDING HALF FORWARD BEND: HANDS OFF THE FLOOR

Arms Extended Half Intense Stretch Pose

Utthita Hasta Ardha Uttanasana

(UT-ti-tuh HUH-stuh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Arms Extended Half Forward Bend

Modification: palms pressed together

Pose Type: standing, forward bend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

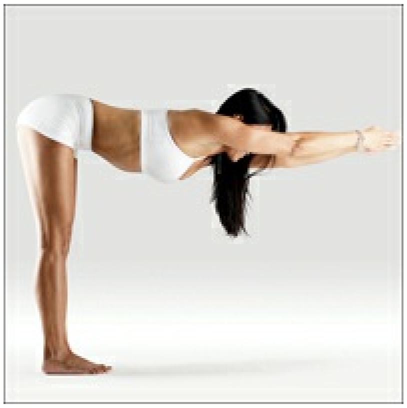

STANDING HALF FORWARD BEND: HANDS ON THE FLOOR

Half Foot Big Toe Pose

Ardha Padangushtasana

(UHR-duh puhd-ahng-goosh-TAHS-uh-nuh)

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

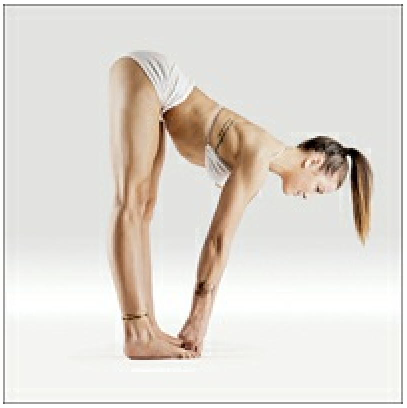

Sideways Half Intense Stretch Pose

Parshva Ardha Uttanasana

(PAHRSH-vuh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Sideways Half Forward Bend

Modification: fingers interlocked, palms to the floor on the outside edge of the foot

Pose Type: standing, forward bend, side bend, twist

Drishti Point: Hastagrai or Hastagre (hands)

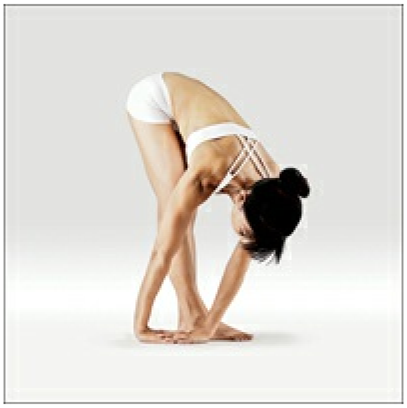

STANDING HALF FORWARD BEND: HANDS ON THE FLOOR—HEELS UP

Tip Toe Half Intense Stretch Pose

Prapada Ardha Uttanasana

(PRUH-puh-duh UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Tip Toe Half Forward Bend and Downward Facing Tree Pose Prep. (Adho Mukha Vrikshasana Prep.)
Pose Type: standing, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

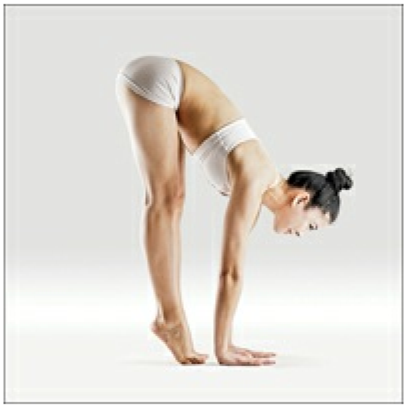

Tip Toe Intense Stretch Pose

Prapada Uttanasana

(PRUH-puh-duh ut-tahn-AHS-uh-nuh)

Also Known As: Tip Toe Full Forward Bend
Modification: arms straight and pointing to the back, both arms on the inside of the legs
1. head up
2. forehead toward the shins
Pose Type: standing, forward bend
Drishti Point: 1. Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) 2. Nasagrai or Nasagre (nose)

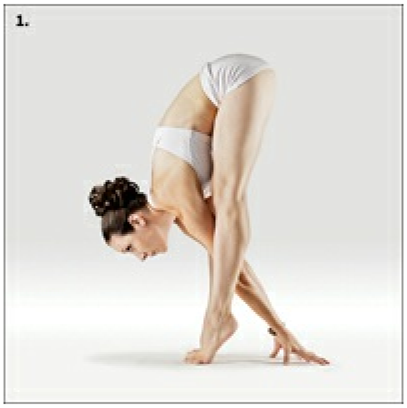

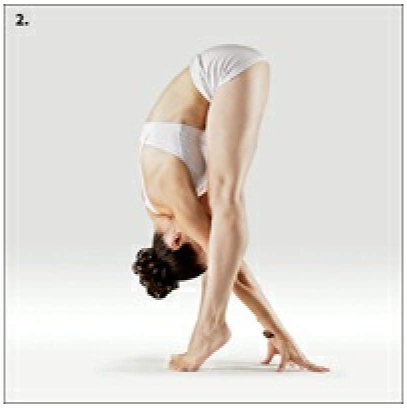

STANDING FULL FORWARD BEND: BALLET TOES

Intense Ankle Stretch Intense Stretch Pose 1

Uttana Kulpa Uttanasana 1

(ut-TAHN-uh KUL-puh ut-tahn-AHS-uh-nuh)

Also Known As: Intense Ankle Stretch Forward Bend
Modification: legs together
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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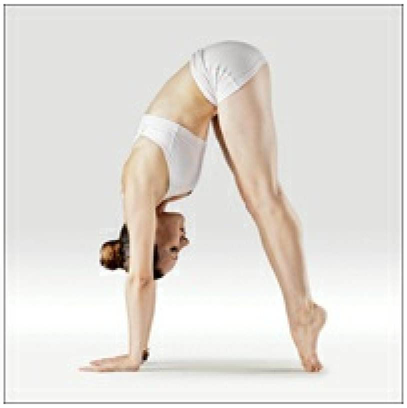

Intense Ankle Stretch Intense Stretch Pose 2

Uttana Kulpa Uttanasana 2

(ut-TAHN-uh KUL-puh ut-tahn-AHS-uh-nuh)

Also Known As: Intense Ankle Stretch Forward Bend
Modification: scissor legs
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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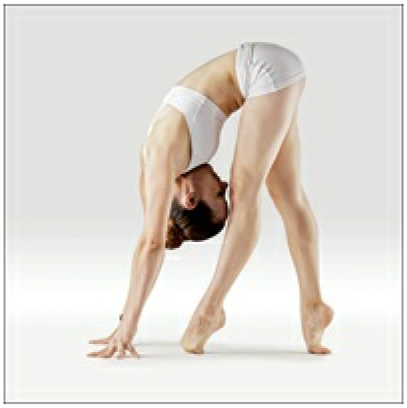

STANDING FULL FORWARD BEND: ONE-LEGGED

Extended One Hand to Foot Intense Stretch Pose 1

Utthita Eka Hasta Pada Uttanasana 1

(UT-ti-tuh EY-kuh HUH-stuh PUH-duh ut-tahn-AHS-uh-nuh)

Also Known As: Extended One Hand to Foot Full Forward Bend 1
Modification: hand grabbing the foot on the same side
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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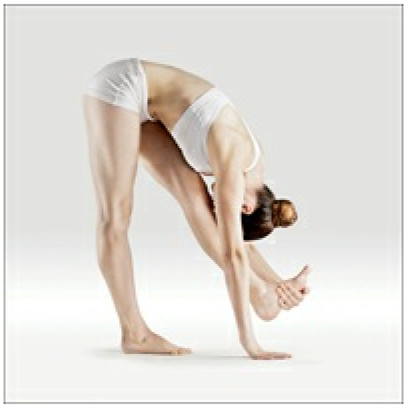

Extended One Hand to Foot Intense Stretch Pose 2

Utthita Eka Hasta Pada Uttanasana 2

(UT-ti-tuh EY-kuh HUH-stuh PUH-duh ut-tahn-AHS-uh-nuh)

Also Known As: Extended One Hand to Foot Full Forward Bend 2
Modification: hand grabbing the foot on the opposite side
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

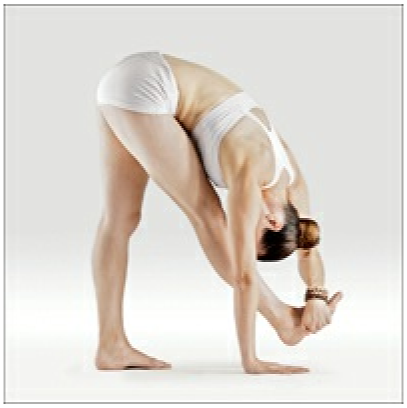

STANDING FULL FORWARD BEND: HANDS TO THE FLOOR & HANDS TO THE BACK OF THE LEGS

Intense Stretch Pose

Uttanasana

(ut-tahn-AHS-uh-nuh)

Also Known As: Full Forward Bend
Modification: palms to the floor, fingers pointing to the back
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

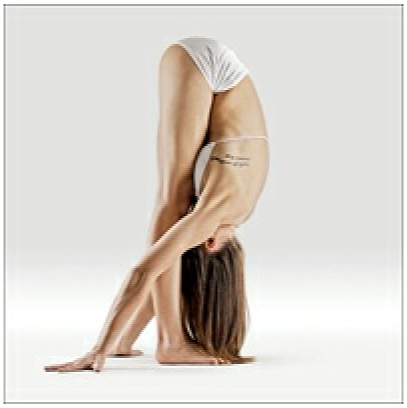

Intense Stretch Pose

Uttanasana

(ut-tahn-AHS-uh-nuh)

Also Known As: Full Forward Bend and Standing Turtle Pose (Nindra Kurmasana)
Modification: feet hip width apart, grabbing onto the calves, elbows bent
Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)
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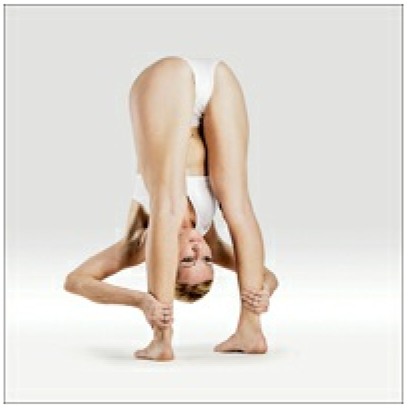

Intense Stretch Pose

Uttanasana

(ut-tahn-AHS-uh-nuh)

Also Known As: Full Forward Bend and Locked Elbows Standing Intense Stretch Pose (Baddha Padahastasana)
Modification: grabbing onto triceps behind the calves
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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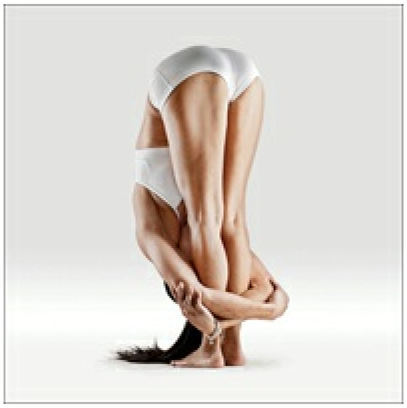

STANDING FULL FORWARD BEND: GRABBING ONTO THE FEET

Foot Big Toe Pose

Padangushtasana

(puh-ahng-goosh-TAHS-uh-nuh)

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

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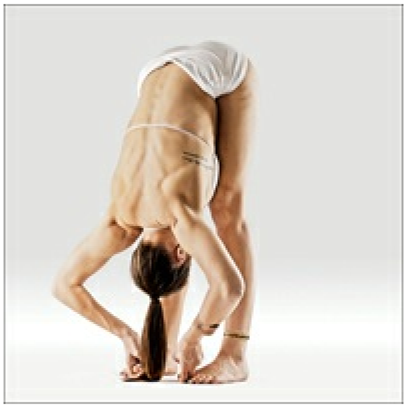

Hand Under Foot Pose

Pada Hastasana

(PUH-duh huh-STAHS-uh-nuh)

Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

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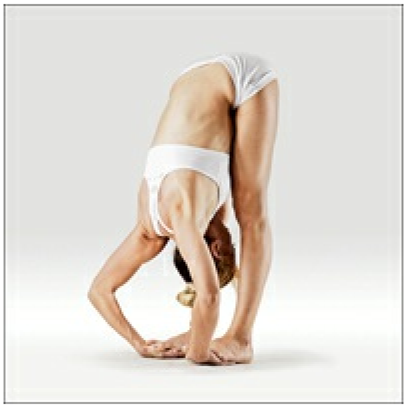

Intense Stretch Pose

Uttanasana *(ut-tahn-AHS-uh-nuh)*
Also Known As: Full Forward Bend
Modification: arms crossed, grabbing onto the outside edges of the feet, half forward bend
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet) or Nasagrai or Nasagre (nose)

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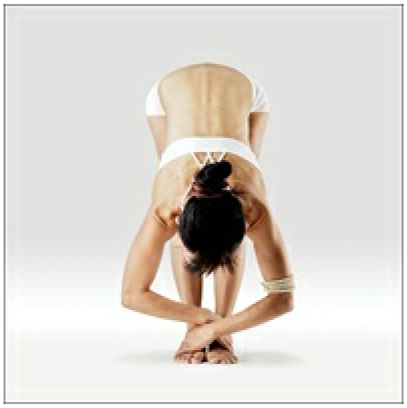

Forward Bend

Uttanasana

(ut-tahn-AHS-uh-nuh)

Also Known As: Full Forward Bend and Hands to Feet Pose Modification (Pada Hastasana)
Modification: feet hip width apart, arms crossed, grabbing onto the outside edges of the feet, elbows moving toward the feet
1. half forward bend
2. full forward bend
Pose Type: standing, forward bend
Drishti Point: 1. Padayoragrai or Padayoragre (toes/feet) 2. Nasagrai or Nasagre (nose)

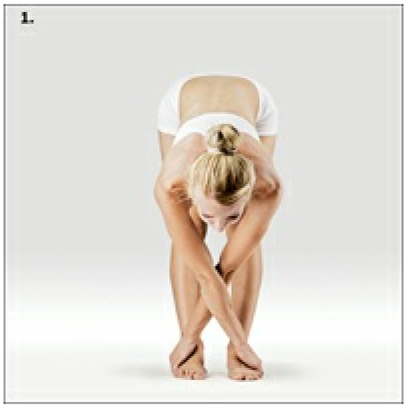

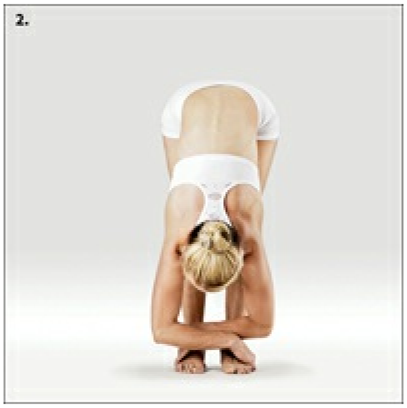

STANDING FULL FORWARD BEND: UNSUPPORTED

Intense Stretch Pose
Uttanasana
(ut-tahn-AHS-uh-nuh)
Also Known As: Full Forward Bend
Modification: grabbing onto the triceps, swaying from side to side
Pose Type: standing, forward bend, side bend
Drishti Point: Nasagrai or Nasagre (nose)

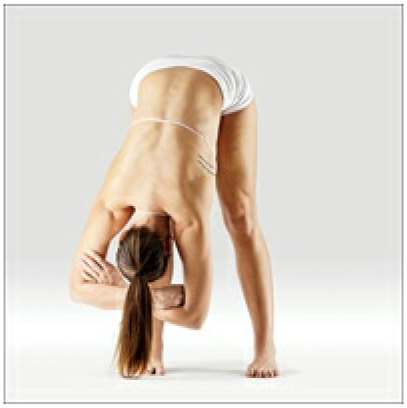

Intense Stretch Pose

Uttanasana

(ut-tahn-AHS-uh-nuh)
Also Known As: Full Forward Bend and Unsupported Forward Stretch Pose (Niralamba Uttanasana)
Modification: arms straight out to the sides behind the back, forehead to the shins
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

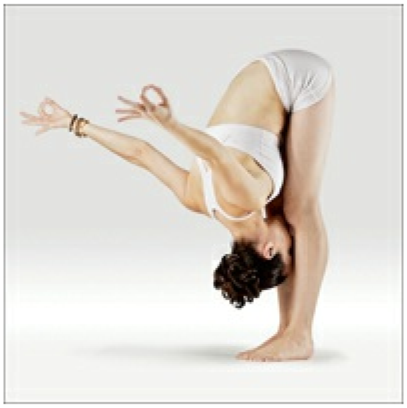

Hands Bound Forward Bend Modification

Baddha Hasta Uttanasana

(BUH-duh HUH-stuh ut-tahn-AHS-uh-nuh)

Also Known As: Hands Bound Full Forward Bend and Unsupported Forward Stretch Pose (Niralamba Uttanasana)

Modification: knees bent, chest to the quadriceps

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

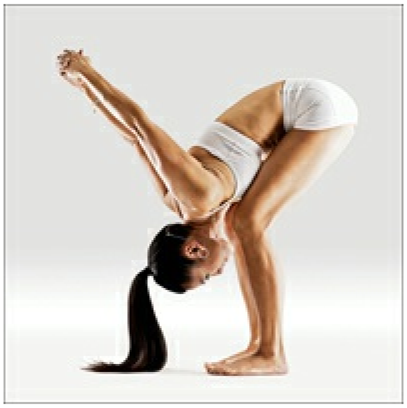

STANDING FULL FORWARD BEND: HANDS TO THE FLOOR—ARMS OPEN WIDE

Intense Stretch Pose

Uttanasana

(ut-tahn-AHS-uh-nuh)

Also Known As: Legs Crossed Full Forward Bend

Modification: legs crossed, forehead to the shins, hands to the floor in line with the feet, elbows bent

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

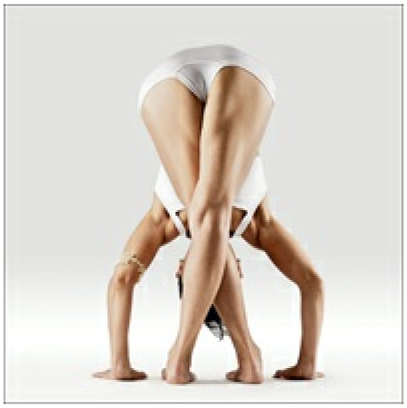

Sideways Intense Stretch

Parshva Uttanasana

(PAHRSH-vuh ut-tahn-AHS-uh-nuh)

Also Known As: Sideways Full Forward Bend
Modification: one hand grabbing onto the opposite ankle, fingertips of the other hand to the floor
Pose Type: standing, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

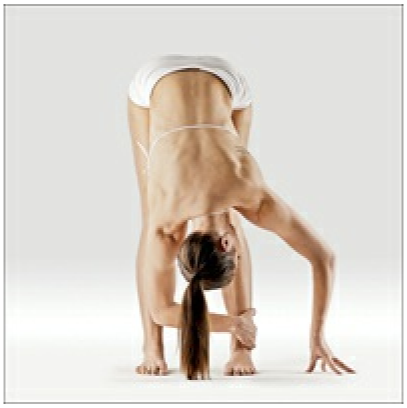

Sideways Intense Stretch

Parshva Uttanasana

(PAHRSH-vuhut-tahn-AHS-uh-nuh)

Also Known As: Sideways Full Forward Bend and Sideward Forward Stretch (Parshva Bhaga Uttanasana)
Modification: fingers interlocked, palms to the floor on the outside edge of the foot
Pose Type: standing, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose)

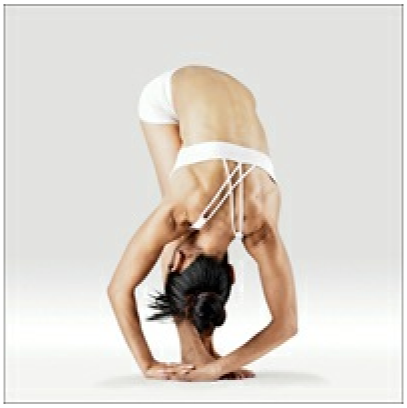

Revolved Intense Stretch Prayer Pose

Parivritta Uttana Anjalyiasana

(puh-ri-VRIT-uh ut-TAHN-uh uhn-juhl-YAHS-uh-nuh)

Also Known As: Revolved Full Forward Bend Prayer Pose
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

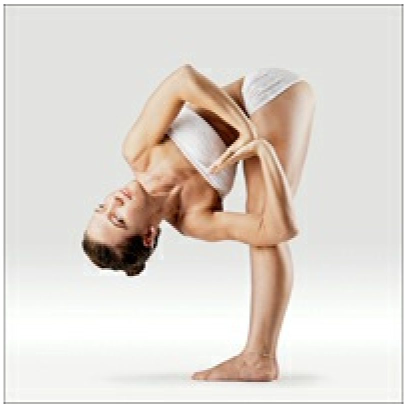

Revolved Intense Stretch

Parivritta Uttanasana

(puh-ri-VRIT-tuh ut-tahn-AHS-uh-nuh)

Also Known As: Revolved Full Forward Bend
Modification: grabbing the outside edge of the feet, feet hip width apart
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

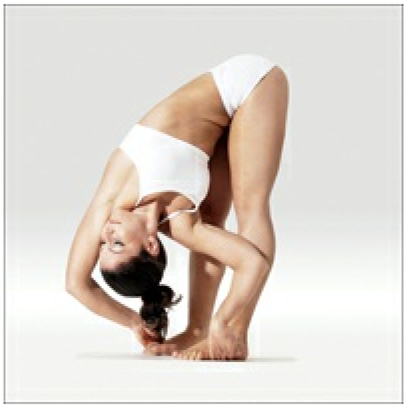

STANDING FULL FORWARD BEND: TWISTS—FEET SLIGHTLY WIDER THAN HIPS

Revolved Intense Stretch

Parivritta Uttanasana

(puh-ri-VRIT-tuh ut-tahn-AHS-uh-nuh)

Also Known As: Revolved Full Forward Bend

Modification: feet wide; one hand grabbing onto the ankle, back of the other hand to the floor in front of the opposite foot

Pose Type: standing, forward bend, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky)

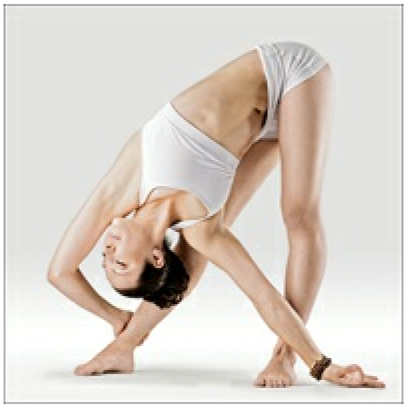

Revolved Intense Stretch

Parivritta Uttanasana

(puh-ri-VRIT-tuh ut-tahn-AHS-uh-nuh)

Also Known As: Revolved Legs Crossed Full Forward Bend

Modification: feet wide, legs crossed, feet flat on the floor

Pose Type: standing, forward bend, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky)

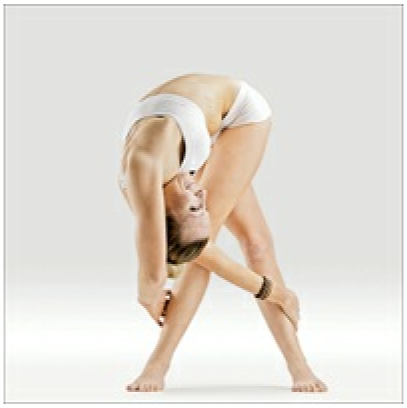

Firefly Pose 2 A

Tittibhasana 2 A

(ti-ti-BAHS-uh-nuh)

Also Known As: Intense Stretch Pose Stork Modification (Uttanasana), Standing Bound Arms Head Between Knees Pose (Utthita Baddha Hasta Janu Shirshasana)
Modification: arms wrapped around the legs, fingers interlocked behind the head
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)
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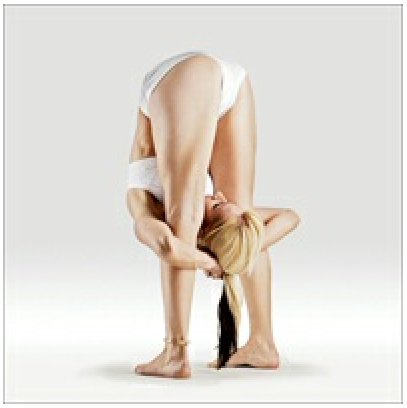

Firefly Pose 2 B

Tittibhasana 2 B

(ti-ti-BAHS-uh-nuh)

Also Known As: Inverted Firefly Prayer Pose (Viparita Tittibha Anjali Asana)
Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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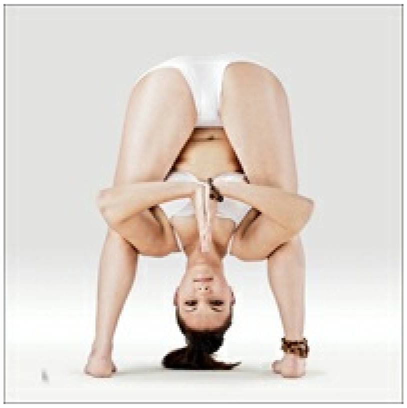

Complete Firefly Pose 2

Paripurna Tittibhasana 2

(puh-ri-POOR-nuh ti-ti-BAHS-uh-nuh)

Also Known As: Firefly Pose B (Tittibhasana B), Inverted Firefly Pose (Viparita Tittibhasana), Standing Firefly Pose Modification (Utthita Tittibhasana), Bound Firefly Pose, Standing Tortoise Pose (Nindra Kurmasana)
Modification: hands bound
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

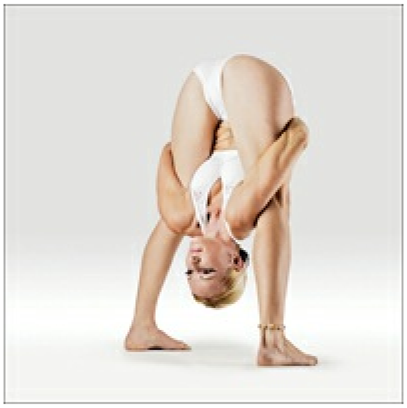

Firefly Pose 3 A Prep.

Tittibhasana 3 A Prep.

(ti-ti-BAHS-uh-nuh)

Modification: hands on the ankles, heels up
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

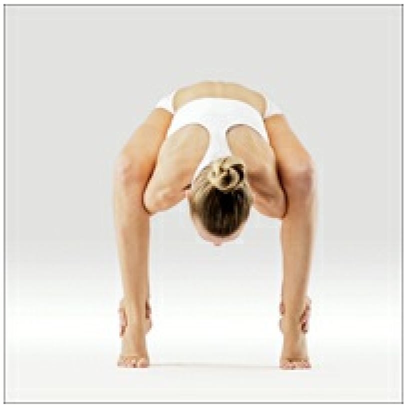

Firefly Pose 3 A

Tittibhasana 3 A

(ti-ti-BAHS-uh-nuh)

Also Known As: Firefly Pose C Prep. (Tittibhasana C Prep.)
Modification: hands on the ankles, one foot lifted
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

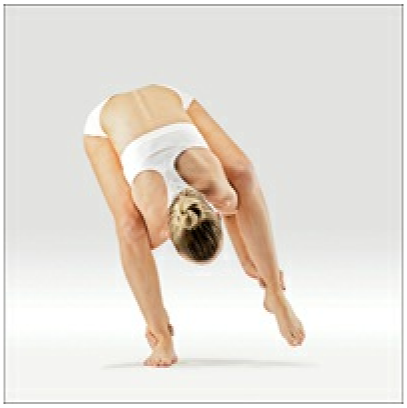

Firefly Pose 4 A

Tittibhasana 4 A

(ti-ti-BAHS-uh-nuh)

Also Known As: Firefly Pose D (Tittibhasana D), Standing Firefly Pose (Utthita Tittibhasana)
Modification: fingers interlocked in front of the ankles
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

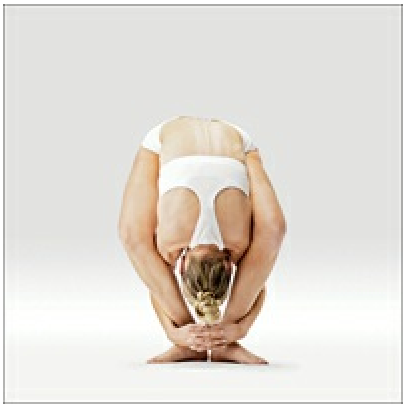

Firefly Pose 4 B

Tittibhasana 4 B

(ti-ti-BAHS-uh-nuh)

Also Known As: Inverted Both Legs Prayer Pose (Viparita DwiPada Anjaliasana)
Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

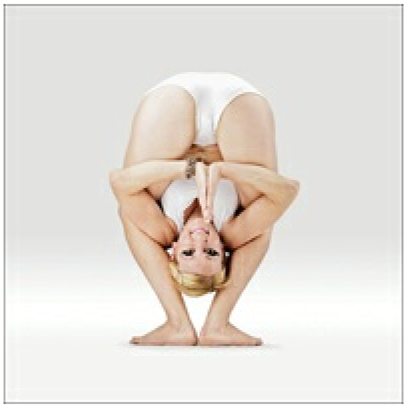

Complete Firefly Pose 4

Paripurna Tittibhasana 4

(puh-ri-POOR-nuh ti-ti-BAHS-uh-nuh)

Also Known As: Inverted Bound Legs Pose (Viparita DwiPada Baddhasana)
Modification: hands bound
Pose Type: standing, forward bend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

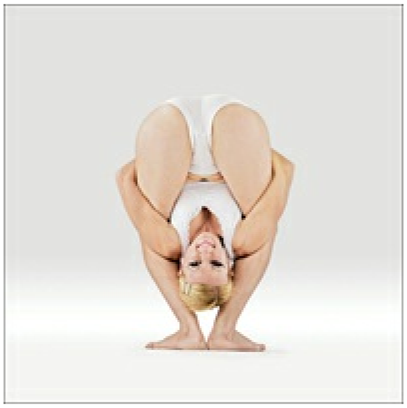

Book Stand Pose

Grantadara

(gruhn-tah-DAH-ruh)

Also Known As: Chikkyasana
Modification: hands to the head, palms facing up, looking to the side
Pose Type: standing, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

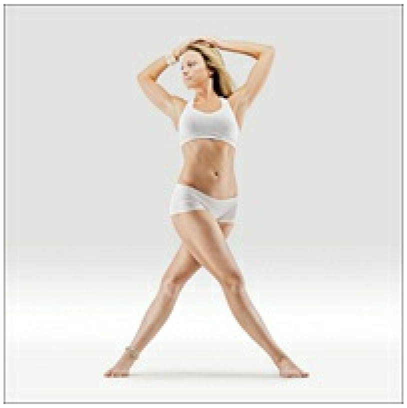

Revolved Feet Spread Mountain Pose

Parivritta Prasarita Pada Tadasana

(puh-ri-VRIT-tuh pruh-SAH-ri-tuh PUH-duh tuh-DAHS-uh-nuh)

Modification: arms straight out to the sides
Pose Type: standing, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

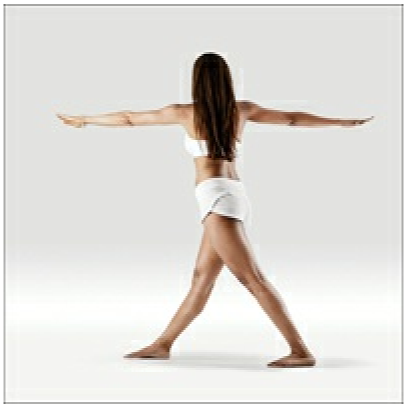

Feet Spread Mountain Pose in Hero Succession Series

Prasarita Pada Tadasana in Vira Parampara

(pruh-SAH-ri-tuh PUH-duh tuh-DAHS-uh-nuh in VEER-uh puh-ruhm-puh-RAH)

Modification: backbend, hands on the calf muscles

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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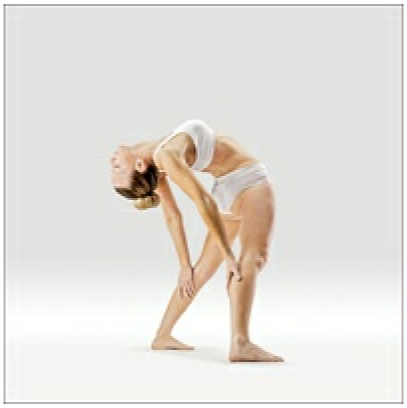

LEGS WIDE: ARMS UP OVER THE HEAD

Easy Feet Spread Upward Hands Pose

Sukha Prasarita Pada Urdhva Hastasana

(SUK-kuh pruh-SAH-ri-tuh PUH-duh OORD-vuh huh-STAHS-uh-nuh)

Also Known As: Part of Hero Succession Series (Vira Parampara)

Modification: palms together, looking up

Pose Type: standing, mild backbend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

ल व य ह ॐ

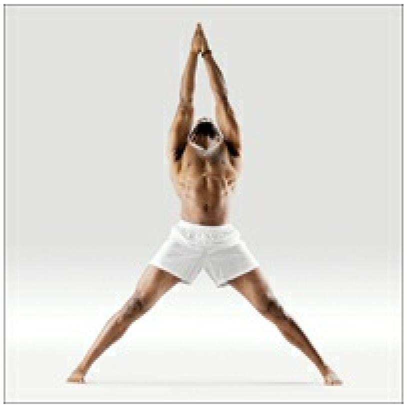

Feet Spread Upward Hands Pose

Prasarita Pada Urdhva Hastasana

(pruh-SAH-ri-tuh PUH-duh OORD-vuh huh-STAHS-uh-nuh)

Also Known As: Equal Angle Pose (Sama Konasana)
Modification: legs open extremely wide; palms together, looking straight ahead
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)
ल व य ह

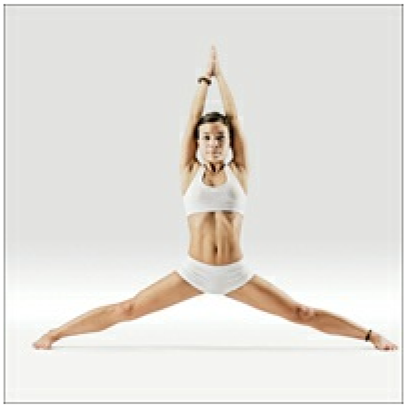

Angle Pose

Konasana

(ko-NAHS-uh-nuh)

Also Known As: Triangle Pose (Konasana)
Modification: fingers interlocked, palms together; side bend
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky), Nasagrai or Nasagre (nose)
ल व

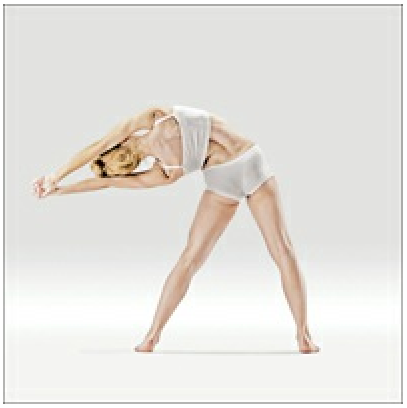

Book Stand Pose with Upward Bound Hands

Grantadara Urdhva Baddha Hastasana

(gruhn-tah-DAH-ruh OORD-vuh BUH-duh HUH-STAHS-uh-nuh)

Also Known As: Chikkiasana Urdhva Baddha Hastasana
Modification: fingers interlocked, palms facing up, looking up
Pose Type: standing
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

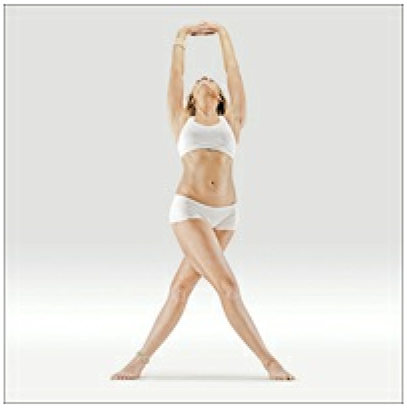

KALI SQUAT: HEELS DOWN—ARMS UP OVER THE HEAD

Lotus Hand Seal in Upward Hands Pose Dedicated to Goddess Kali

Padma Mudra Urdhva Hasta Kalyasana

(PUHD-muh MU-druh OORD-vuh HUH-stuh kahl-YAHS-uh-nuh)

Modification: heels down; arms extended to the sky, fingertips open
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

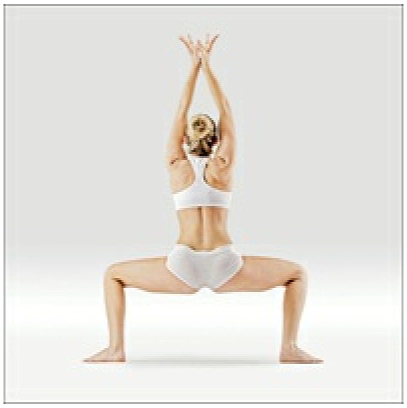

Sideways Hands Bound Pose Dedicated to Goddess Kali

Parshva Baddha Hasta Kalyasana

(PAHRSH-vuh BUH-duh HUH-stuh kahl-YAHS-uh-nuh)

Modification: side bend, fingers interlocked
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)
ल व य

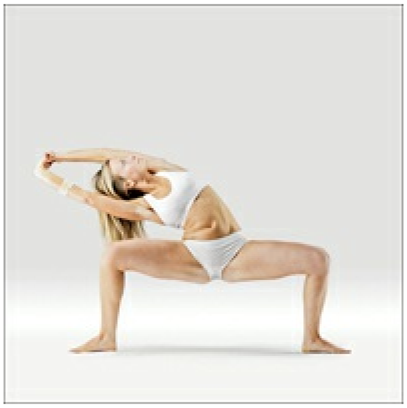

KALI SQUAT: HEELS DOWN—ARMS AT HEAD HEIGHT

Pose Dedicated to Goddess Kali

Kalyasana

(kahl-YAHS-uh-nuh)

Modification: elbows bent, palms facing the sky, heels down
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)
ल व

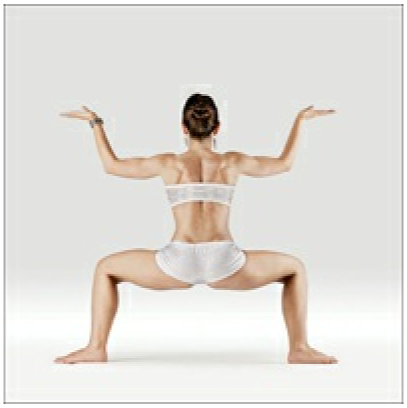

Hand Position of the Pose Dedicated to Garuda in Pose Dedicated to Goddess Kali

Hasta Garudasana in Kalyasana

(HUH-stuh guh-ru-DAHS-uh-nuh in kahl-YAHS-uh-nuh)

Pose Type: standing

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

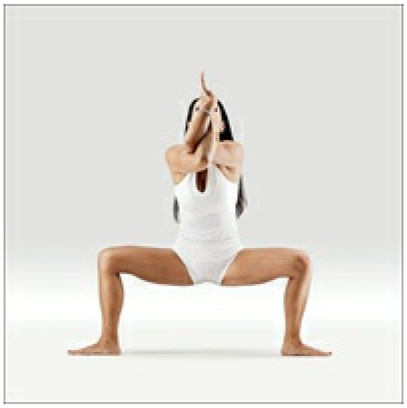

KALI SQUAT: HEELS DOWN—ARMS BEHIND

Hands Bound Pose Dedicated to Goddess Kali

Baddha Hasta Kalyasana

(BUH-duh HUH-stuh kahl-YAHS-uh-nuh)

Modification: head rolling back, heels down

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

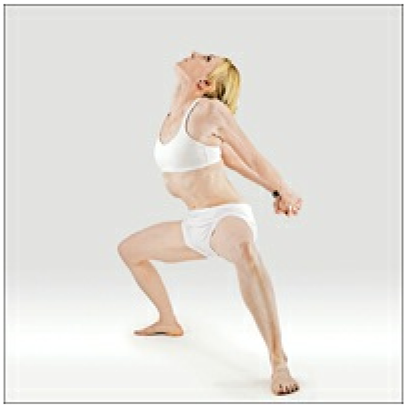

Bound Pose Dedicated to Goddess Kali

Baddha Kalyasana

(BUH-duh kahl-YAHS-uh-nuh)

Pose Type: standing, binding

Drishti Point: Nasagrai or Nasagre (nose)

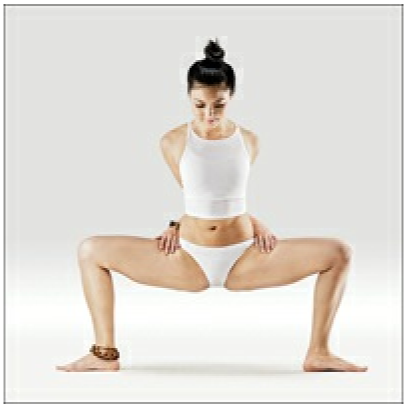

KALI SQUAT: HEELS DOWN—ONE ARM SIDE BENDS

Pose Dedicated to Goddess Kali

Kalyasana

(kahl-YAHS-uh-nuh)

Modification: one hand to the forehead, arm to the knee on the same side

Pose Type: standing

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

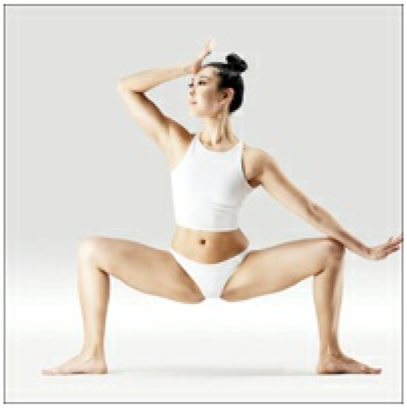

Pose Dedicated to Goddess Kali

Kalyasana

(kahl-YAHS-uh-nuh)

Modification: one arm straight and parallel to the floor, other arm bent, palm facing up
Pose Type: standing
Drishti Point: Hastagrai or Hastagre (hands)

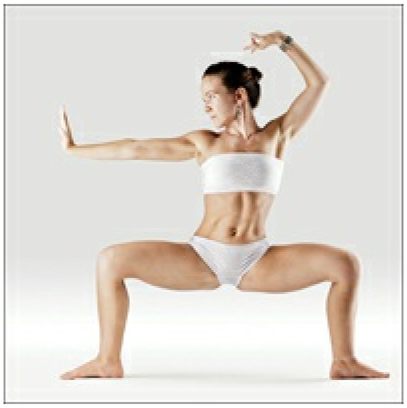

Sideways Pose Dedicated to Goddess Kali

Parshva Kalyasana

(PAHRSH-vuh kahl-YAHS-uh-nuh)

Modification: leaning to one side, one arm out to the side—elbow slightly bent, palm facing up, other hand to the face—palm down
Pose Type: standing, side bend
Drishti Point: Hastagrai or Hastagre (hands)

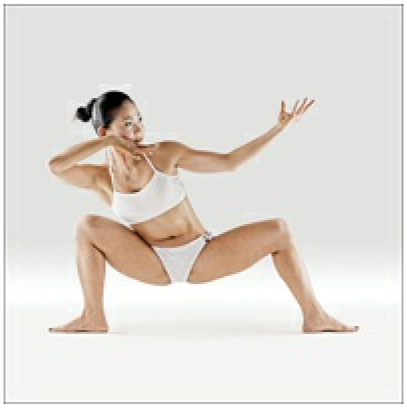

Sideways Half Bound Pose Dedicated to Goddess Kali

Parshva Ardha Baddha Kalyasana

(PAHRSH-vuh UHR-duh BUH-duh kahl-YAHS-uh-nuh)

Modification: forearm to the knee on the same side
Pose Type: standing, side bend, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

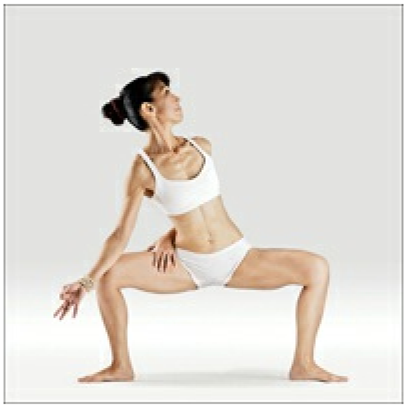

Sideways Pose Dedicated to Goddess Kali

Parshva Kalyasana

(PAHRSH-vuh kahl-YAHS-uh-nuh)

Modification: one hand to the floor, other arm up to the sky
Pose Type: standing, side bend
Drishti Point: Hastagrai or Hastagre (hands)

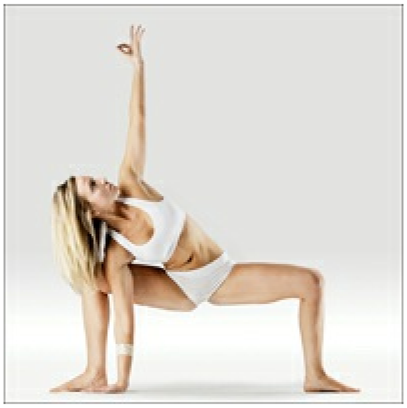

KALI SQUAT: HEELS DOWN—FORWARD BEND

Bound Pose Dedicated to Goddess Kali

Baddha Kalyasana

(BUH-duh kahl-YAHS-uh-nuh)

Modification: forward bend

Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

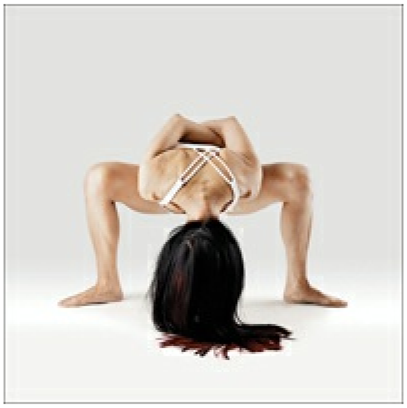

Pose Dedicated to Goddess Kali

Kalyasana

(kahl-YAHS-uh-nuh)
Modification: forward bend, arms straight and parallel to the floor, palms together
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

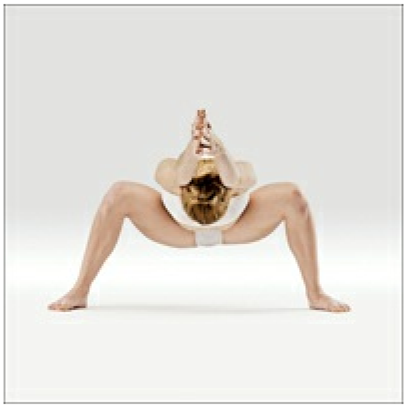

Pose Dedicated to Goddess Kali

Kalyasana

(kahl-YAHS-uh-nuh)
Modification: forward bend, arms crossed, hands to the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

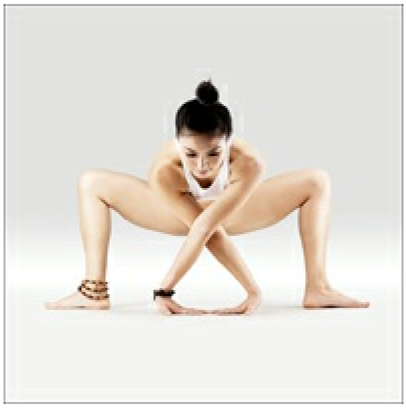

KALI SQUAT: HEELS DOWN—FORWARD BEND & FORWARD BEND TWISTS

Revolved Half Bound Pose Dedicated to Goddess Kali

Parivritta Ardha Baddha Kalyasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh kahl-YAHS-uh-nuh)

Modification: arm under the opposite leg
Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

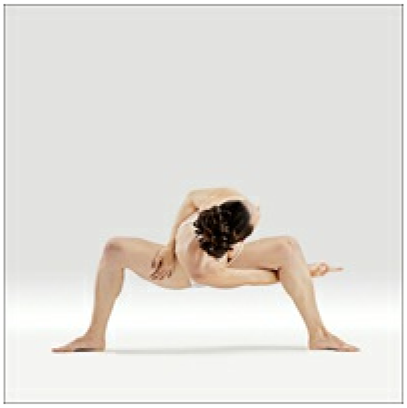

Revolved Pose Dedicated to Goddess Kali

Parivritta Kalyasana

(puh-ri-VRIT-tuh kahl-YAHS-uh-nuh)

Modification: hands to the knees
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

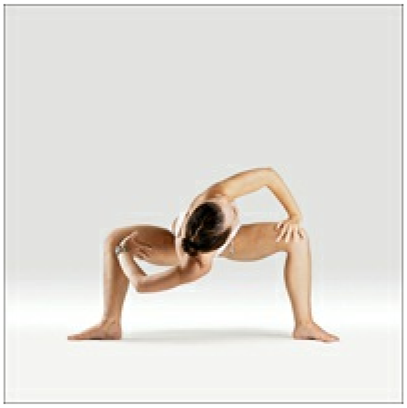

KALI SQUAT: HEELS UP—ARM POSITIONS

Tip Toe Pose Dedicated to Goddess Kali

Prapada Kalyasana

(PRUH-puh-duh kahl-YAHS-uh-nuh)

Modification: head down, elbows bent, back of the hands on the knees
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

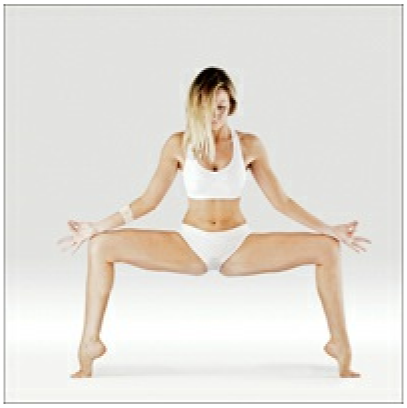

Lotus Hand Seal in Upward Hands Tip Toe Pose Dedicated to Goddess Kali

Padma Mudra in Urdhva Hasta Prapada Kalyasana

(PUHD-muh MU-druh in OORD-vuh HUH-stuh PRUH-puh-duh kahl-YAHS-uh-nuh)

Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

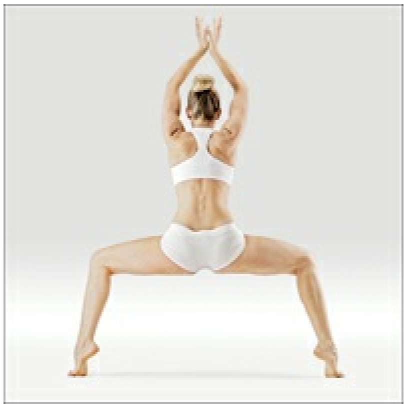

Tip Toe Pose Dedicated to Goddess Kali

Prapada Kalyasana

(PRUH-puh-duh kahl-YAHS-uh-nuh)

Modification: one hand behind the back in reverse prayer, one elbow on the knee
Pose Type: standing
Drishti Point: Hastagrai or Hastagre (hands)

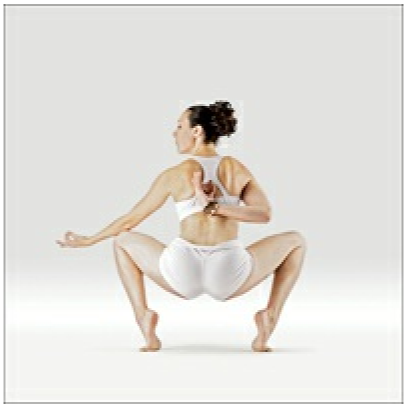

Reverse Prayer Tip Toe Pose Dedicated to Goddess Kali

Viparita Namaskar Prapada Kalyasana

(vi-puh-REE-tuh nuh-muhs-KAHR PRUH-puh-duh kahl-YAHS-uh-nuh)

Also Known As: Back of the Body Prayer Tip Toe Pose Dedicated to Goddess Kali (Paschima Namaskar Prapada Kalyasana)
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

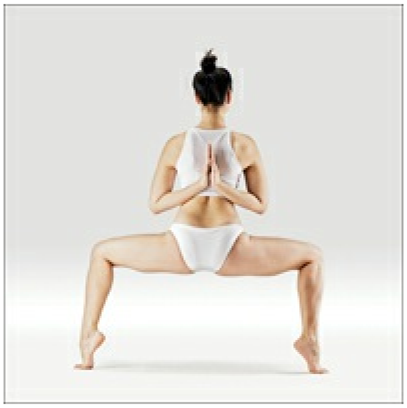

KALI SQUAT: HEELS UP—SIDE BENDS

Sideways Tip Toe Pose Dedicated to Goddess Kali

Parshva Prapada Kalyasana

(PAHRSH-vuh PRUH-puh-duh kahl-YAHS-uh-nuh)

Modification: one palm to the forehead, fingertips of the other hand to the floor
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

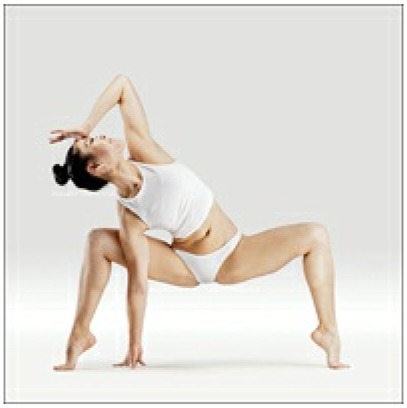

KALI SQUAT: ONE HEEL UP, ONE HEEL DOWN

Sideways Uneven Tip Toe Pose Dedicated to Goddess Kali

Parshva Vishama Prapada Kalyasana

(PAHRSH-vuh VISH-uh-muh PRUH-puh-duh kahl-YAHS-uh-nuh)

Modification: side bend
Pose Type: standing, side bend
Dristhi Point: Padhayoragrai or Padayoragre (toes/feet)

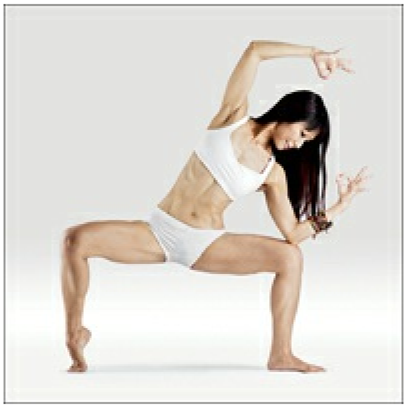

KALI SQUAT: HEELS UP—FORWARD BENDS

Tip Toe Pose Dedicated to Goddess Kali

Prapada Kalyasana

(PRUH-puh-duh kahl-YAHS-uh-nuh)

Modification: forward bend, arms crossed, hands to the floor, fingertips pointing toward each other
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

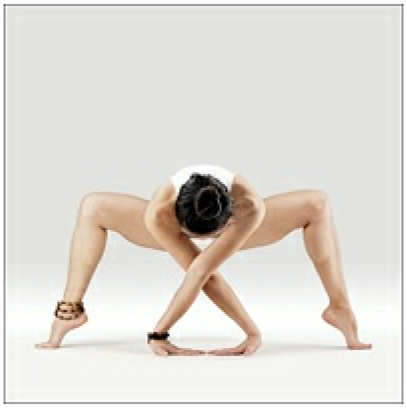

Tip Toe Pose Dedicated to Goddess Kali

Prapada Kalyasana

(PRUH-puh-duh kahl-YAHS-uh-nuh)

Modification: forward bend, arms crossed, hands to the floor, fingertips pointing away from each other
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

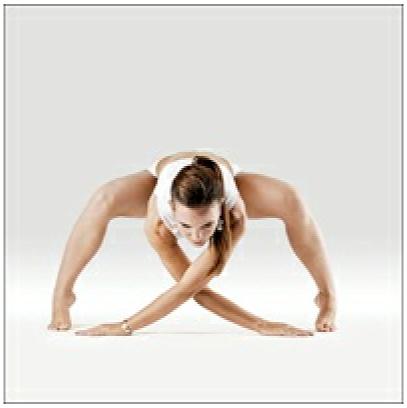

Tip Toe Pose Dedicated to Goddess Kali

Prapada Kalyasana

(PRUH-puh-duh kahl-YAHS-uh-nuh)

Modification: forward bend, hands to the floor, fingertips to the floor facing away from each other
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

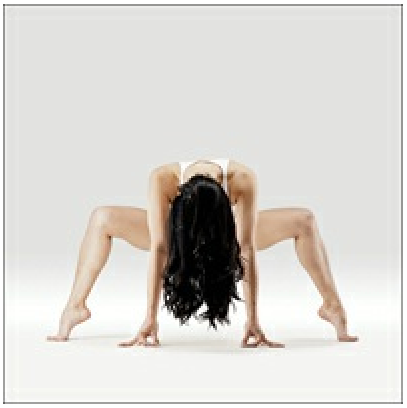

Tip Toe Pose Dedicated to Goddess Kali

Prapada Kalyasana

(PRUH-puh-duh kahl-YAHS-uh-nuh)

Modification: forward bend, arms open wide
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

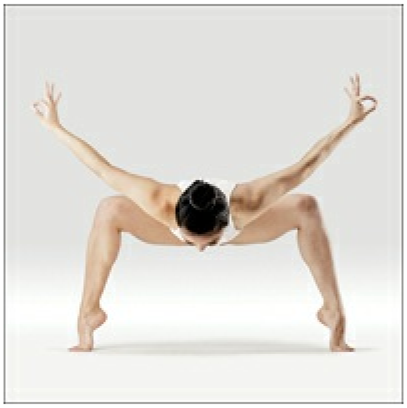

KALI SQUAT: HEELS UP—BINDING

Extended Side Revolved Hands Bound Half Pose Dedicated to Goddess Kali

Utthita Parshva Parivritta Baddha Hasta Ardha Kalyasana

(UT-ti-tuh PAHRSH-vuh puh-ri-VRIT-tuh BUH-duh HUH-stuh UHR-duh kahl-YAHS-uh-nuh)

Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
ल व य

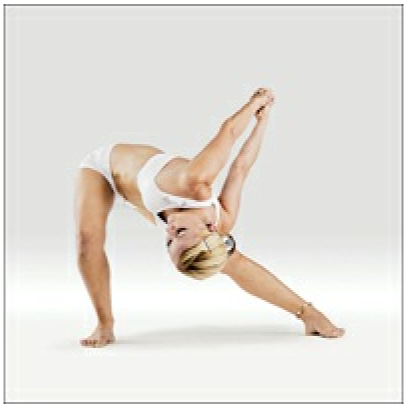

Hands Bound Pose Dedicated to Goddess Kali

Baddha Hasta Kalyasana

(BUH-duh HUH-stuh kahl-YAHS-uh-nuh)

Modification: hands bound under the leg, heels down
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)
ल व य

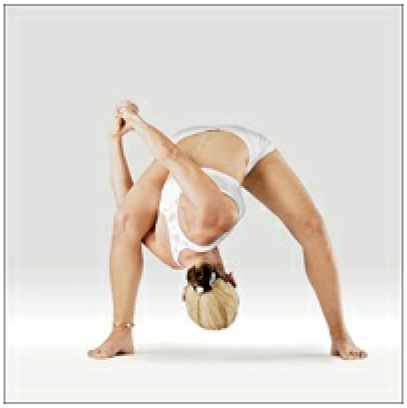

KALI SQUAT: HEELS UP—BINDING

Tip Toe Hands Bound Pose Dedicated to Goddess Kali

Prapada Baddha Hasta Kalyasana

(PRUH-puh-duh kahl-YAHS-uh-nuh)

Modification: hands bound under the leg
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)
ल व य

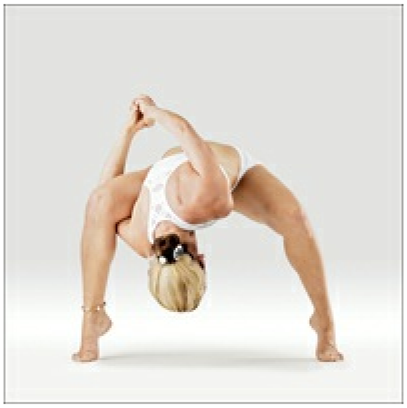

Tip Toe Half Bound Pose Dedicated to Goddess Kali

Prapada Ardha Baddha Kalyasana

(PRUH-puh-duh UHR-duh BUH-duh kahl-YAHS-uh-nuh)

Modification: one arm bound under the leg, palm to the rib cage, other forearm to the floor
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose), Angushtamadhye or Angushta Ma Dyai (thumbs)
ल व

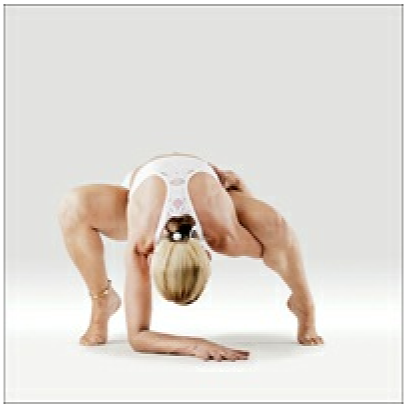

LEGS WIDE: HALF FORWARD BEND

Half Feet Spread Out Intense Stretch Pose

Ardha Prasarita Padottanasana

(UHR-duh pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Feet Spread Out Half Forward Bend
Modification: legs straight, hands on the shins
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व ह

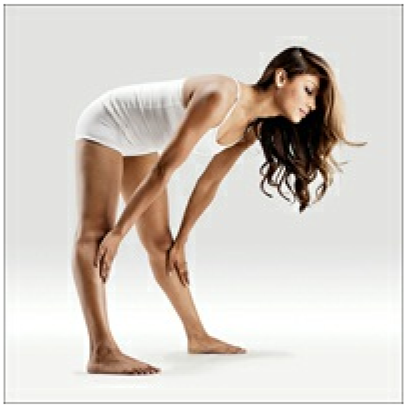

LEGS WIDE: HALF FORWARD BEND, HANDS TO THE FLOOR—HEELS DOWN & HEELS UP

Half Feet Spread Out Intense Stretch Pose

Ardha Prasarita Padottanasana

(UHR-duh pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Feet Spread Out Half Forward Bend
Modification: 1. toes pointing straight ahead, palms flat on the floor 2. toes pointing slightly outward,

back of the hands to the floor, fingertips pointing toward each other
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)
लं वं हं

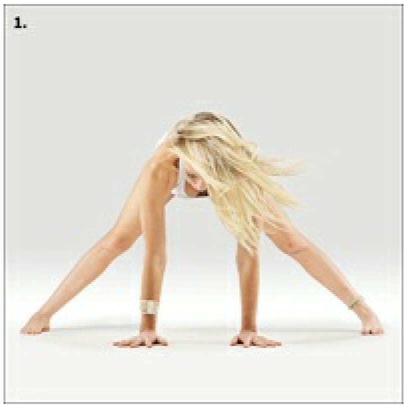

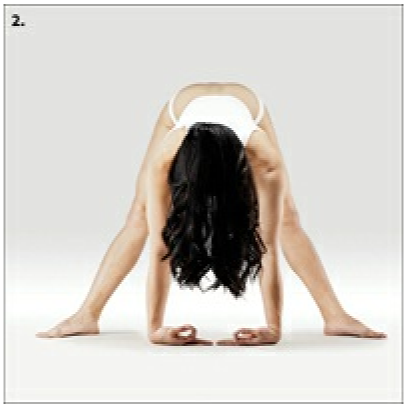

Tip Toe Half Feet Spread Out Intense Stretch Pose

Prapada Ardha Prasarita Padottanasana

(PRUH-puh-duh UHR-duh pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)
Also Known As: Tip Toe Feet Spread Out Half Forward Bend
Modification: toes pointing straight ahead, heels up, palms flat on the floor
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)
लं वं हं

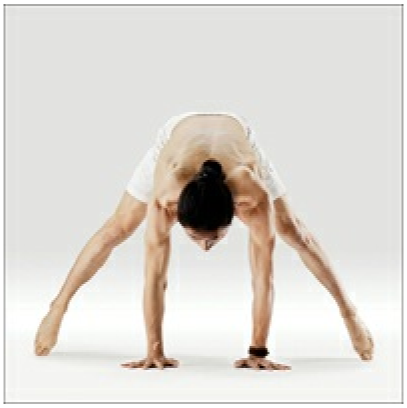

LEGS WIDE: FULL FORWARD BEND—HANDS TO THE FLOOR

Feet Spread Out Intense Stretch Pose 1

Prasarita Padottanasana 1

(pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Feet Spread Out Intense Stretch Pose A (Prasarita Padottanasana A), Feet Spread Out Full Forward Bend A
Modification: palms to the floor, elbows bent at 90 degrees
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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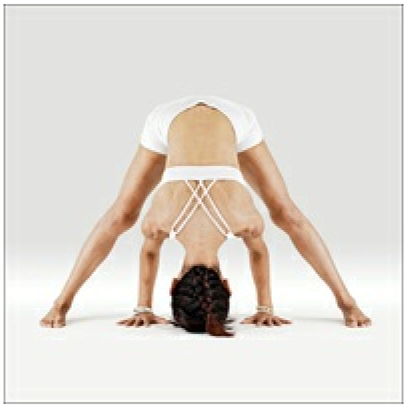

Feet Spread Out Intense Stretch Pose 1

Prasarita Padottanasana 1

(pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Feet Spread Out Intense Stretch Pose A (Prasarita Padottanasana A), Feet Spread Out Full Forward Bend A
Modification: arms straight, palms to the floor, fingertips pointing away from the head
Pose Type: standing, forward bend

Drishti Point: Hastagrai or Hastagre (hands)

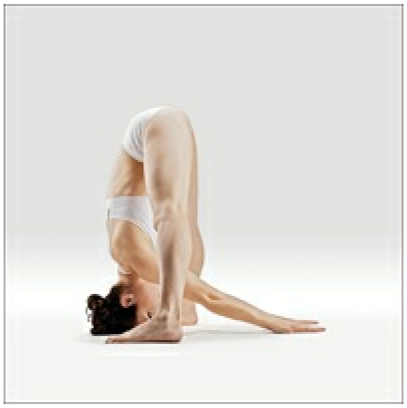

Feet Spread Out Intense Stretch Pose 4

Prasarita Padottanasana 4

(pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Feet Spread Out Intense Stretch Pose D (Prasarita Padottanasana D), Hands to Big Toes Feet Spread Out Full Forward Bend (Hasta Padangushta Prasarita Padottanasana)

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

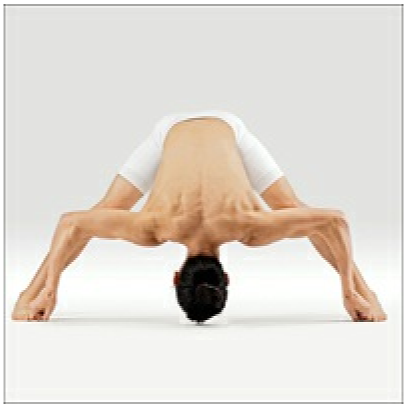

LEGS WIDE: FULL FORWARD BEND—ARMS BEHIND THE BACK

Feet Spread Out Intense Stretch Pose 2

Prasarita Padottanasana 2

(pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Feet Spread Out Intense Stretch Pose B (Prasarita Padottanasana B), Feet Spread Out Full Forward Bend

Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

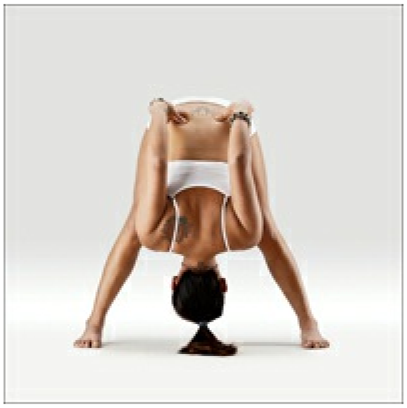

Feet Spread Out Intense Stretch Pose 5

Prasarita Padottanasana 5

(pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Reverse Prayer Feet Spread Out Full Forward Bend (Viparita Namaskar Prasarita Padottanasana)
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

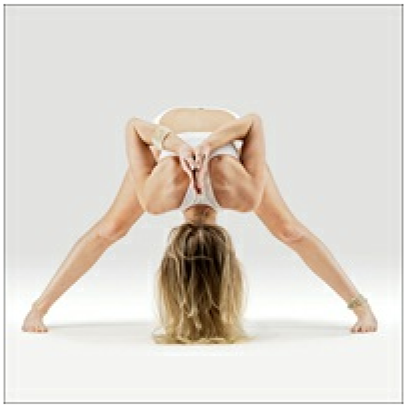

Feet Spread Out Intense Stretch Pose 3

Prasarita Padottanasana 3

(pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Feet Spread Out Intense Stretch Pose C (Prasarita Padottanasana C), Feet Spread Out Full Forward Bend, Hands Bound Wide Legs Forward Fold (Baddha Hasta Prasarita Padottanasana)

Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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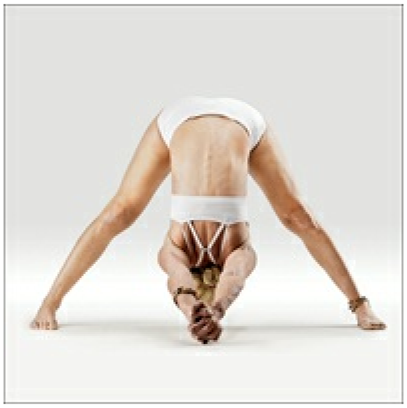

LEGS WIDE: FULL FORWARD BEND—ARMS OPEN WIDE

Feet Spread Out Intense Stretch Pose 6

Prasarita Padottanasana 6

(pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)
Also Known As: Feet Spread Out Full Forward Bend 6
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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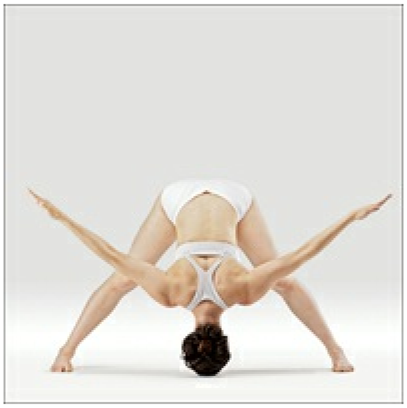

Feet Spread Out Intense Stretch Pose 7

Prasarita Padottanasana 7

(pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)
Also Known As: Feet Spread Out Full Forward Bend 7
Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

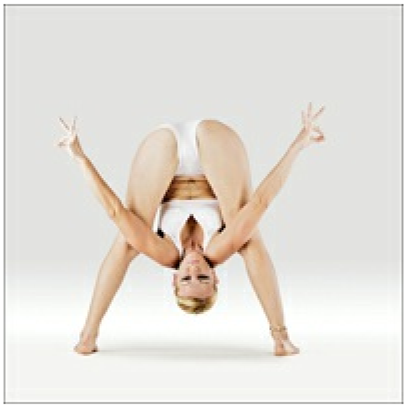

LEGS WIDE: FULL FORWARD BEND—TWISTS

Revolved Half Feet Spread Out Intense Stretch Pose

Parivritta Ardha Prasarita Padottanasana

(puh-ri-VRIT-tuh UHR-duh pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Revolved Feet Spread Out Half Forward Bend
Modification: palm to the floor
Pose Type: standing, forward bend, twist
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

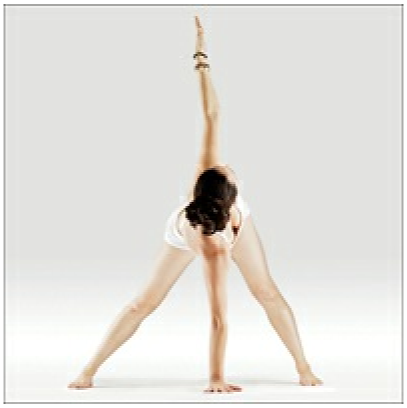

Revolved Half Feet Spread Out Intense Stretch Pose

Parivritta Ardha Prasarita Padottanasana

(puh-ri-VRIT-tuh UHR-duh pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Revolved Feet Spread Out Half Forward Bend
Modification: forearm to the floor

Pose Type: standing, forward bend, twist
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

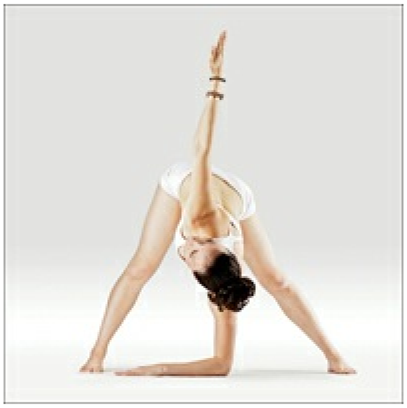

Revolved Paying Homage Feet Spread Out Intense Stretch Pose

Parivritta Namasya Prasarita Padottanasana

(puh-ri-VRIT-tuh nuh-MUHS-ya pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Revolved Paying Homage Feet Spread Out Forward Bend
Modification: legs crossed, hand to the back foot, other arm extended to the sky
Pose Type: standing, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

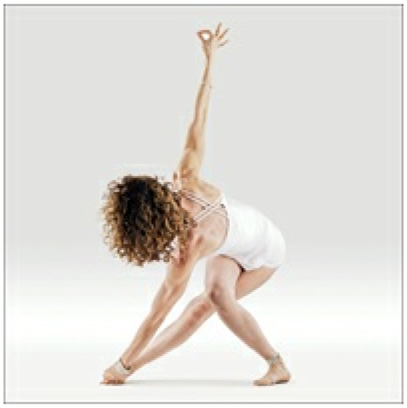

Bound Revolved Feet Spread Out Intense Stretch Pose

Baddha Parivritta Prasarita Padottanasana

(BUH-duh puh-ri-VRIT-tuh pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Bound Revolved Feet Spread Out Full Forward Bend
Modification: arm straight, looking up
Pose Type: standing, forward bend, twist, binding

Drishti Point: Urdhva or Antara Drishti (up to the sky)
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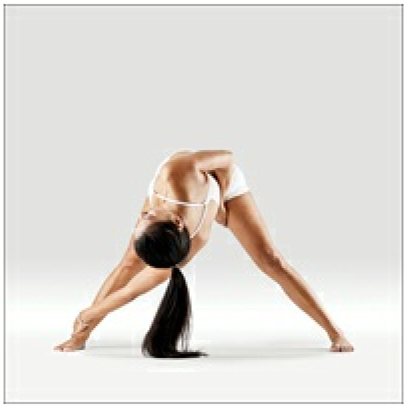

Hands Bound Revolved Feet Spread Out Intense Stretch Pose

Baddha Hasta Parivritta Prasarita Padottanasana

(BUH-duh HUH-stuh puh-ri-VRIT-tuh pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Hands Bound Revolved Feet Spread Out Full Forward Bend
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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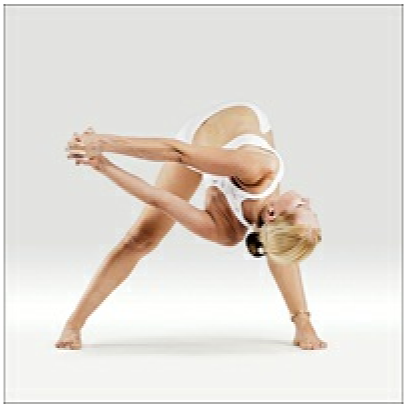

Revolved Paying Homage Feet Spread Out Intense Stretch Pose

Parivritta Namasya Prasarita Padottanasana

(puh-ri-VRIT-tuh nuh-MUHS-ya pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Modification: outside edges of the feet to the floor, legs crossed, forward bend, both hands on the back foot
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
ल व

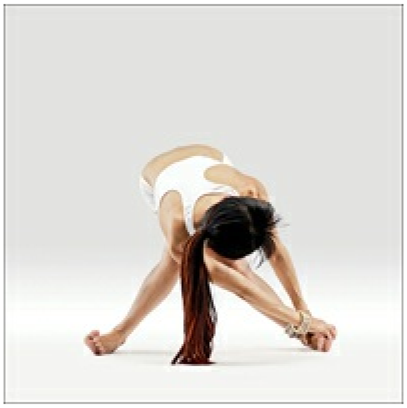

Revolved Feet Spread Out Intense Stretch Pose

Parivritta Prasarita Padottanasana

(puh-ri-VRIT-tuh pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Revolved Feet Spread Out Full Forward Bend
Modification: grabbing onto the knee and the foot
Pose Type: standing, forward bend, side bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

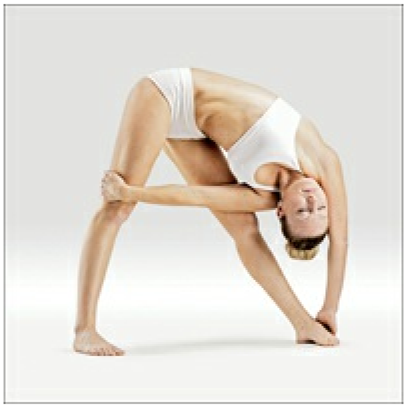

Revolved Feet Spread Out Intense Stretch Pose

Parivritta Prasarita Padottanasana

(puh-ri-VRIT-tuh pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Revolved Feet Spread Out Full Forward Bend
Modification: grabbing onto the ankles
Pose Type: standing, forward bend, side bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

Revolved to the Side Feet Spread Out Intense Stretch Pose

Parivritta Parshva Prasarita Padottanasana

(puh-ri-VRIT-tuh PAHRSH-vuh pruh-SAH-ri-tuh puhd-o-tahn-AHS-uh-nuh)

Also Known As: Revolved to the Side Feet Spread Out Full Forward Bend)
Modification: grabbing onto the foot with both hands
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

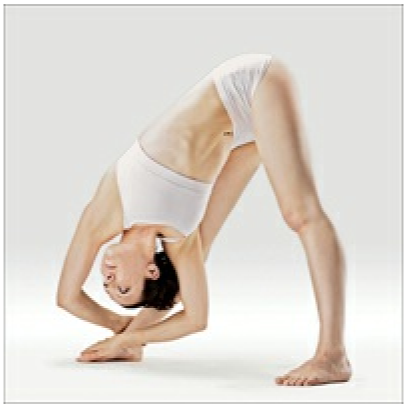

Downward Facing Dog Pose

Adho Mukha Shvanasana

(uh-DO MUK-uh shwa-NAHS-uh-nuh)

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

How to Perform the Pose:

1. Start by lying on your stomach with your whole body flat on the floor. Place your palms on the floor at the bottom of your ribs with fingertips facing forward and elbows tucked in. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale as you engage your core and lift your torso off the floor, and straighten your arms, coming into a distinct upside-down V shape with your sitting bones up to the sky. Your feet should be in line with your sitting bones and your hands should be shoulder width apart.
3. Try to keep your legs as straight as possible while pressing the heels to the floor. You should feel a deep stretch in the back of your thighs (the hamstrings) and your calf muscles.
4. Inhale as you lengthen your spine, keeping your neck long and your shoulder blades down your back. Try not to round your lower back, keeping it long. Exhale as you press through your chest, moving it toward your thighs. You should feel a deep stretch in the back of your shoulders.
5. You can either keep your head off the floor (Pose #1) or bring your forehead to the floor (Pose #2) if your shoulders are open.
6. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
7. To come out of the pose, inhale as you rock into Plank Pose, and exhale as you bend your elbows into Four Limbed Staff Pose (*Chaturanga Dandasana*) and lower all the way down to the floor into the starting position.

Modification:

1. head off the floor
2. forehead to the floor

adho = downward

mukha = face

shvana = dog

1.

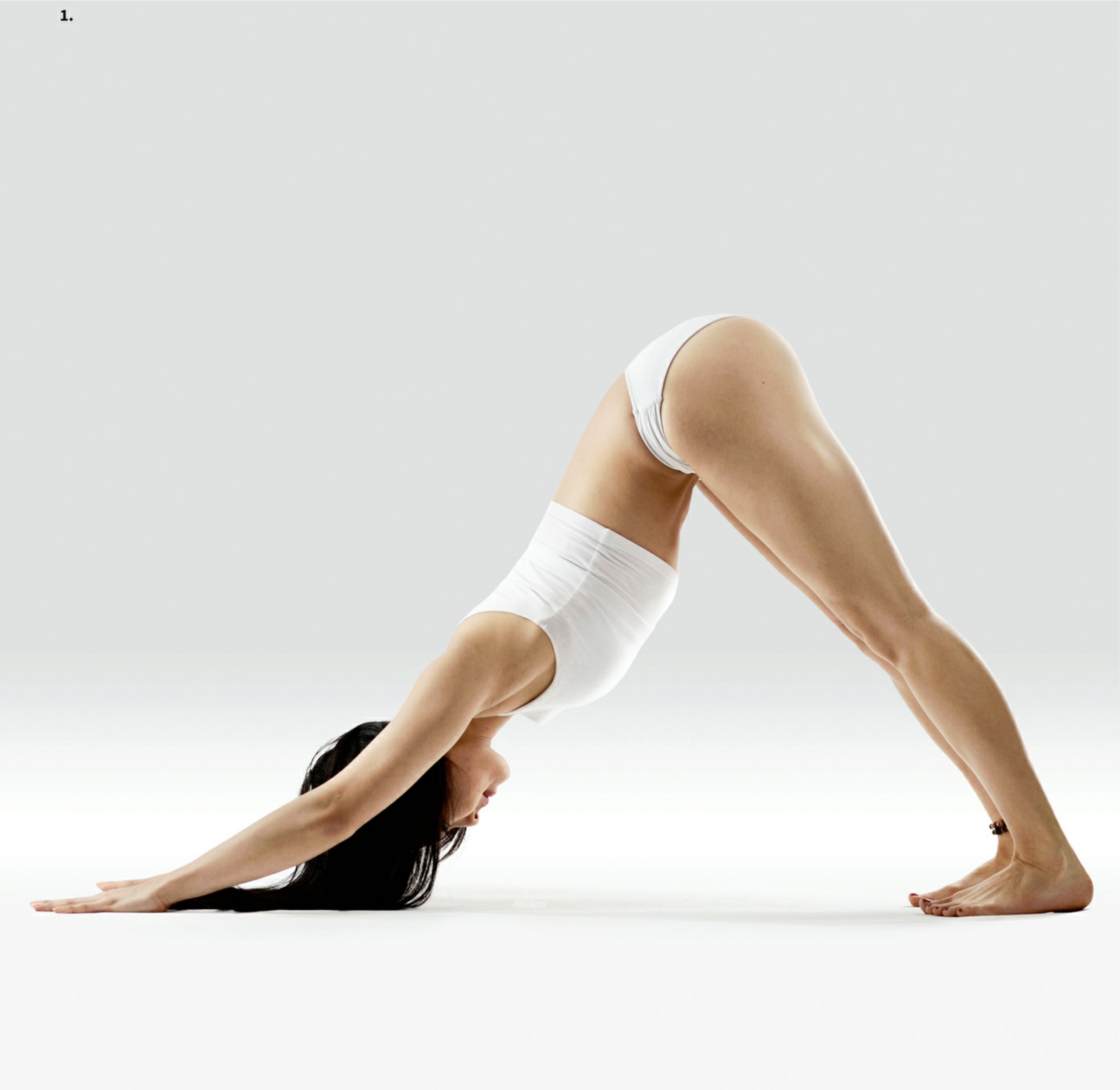

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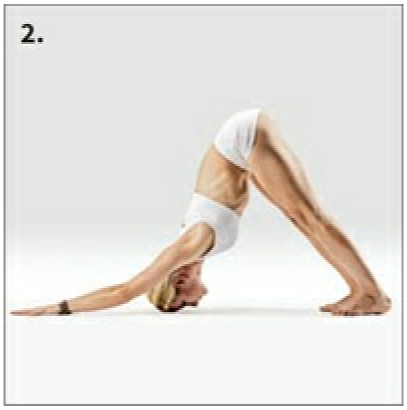

DOWNWARD DOG: FOREARMS AND HEAD ON THE FLOOR

Downward Facing Pose Dedicated to Makara on the Head

Adho Mukha Shirsha Makarasana

(uh-DO MUK-uh SHEER-shuh muh-kuh-RAHS-uh-nuh)

Pose Type: forward bend, inversion, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

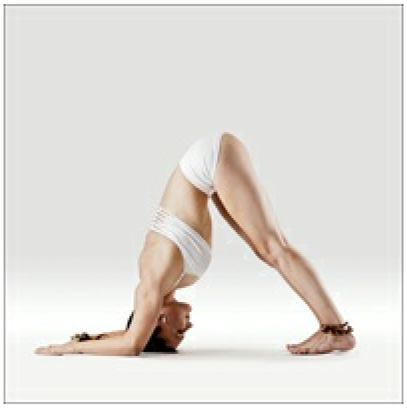

DOWNWARD DOG: KNEES BENT

Downward Facing Dog Pose

Adho Mukha Shvanasana

(uh-DO MUK-uh shwa-NAHS-uh-nuh)

Modification: knees bent, heels up
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

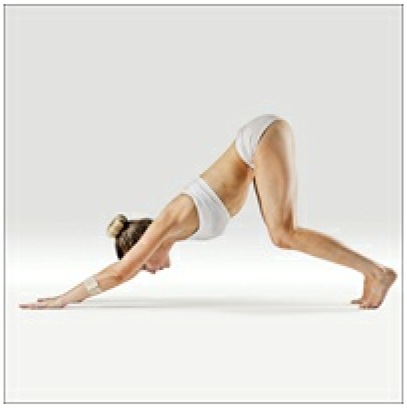

Downward Facing Dog Pose

Adho Mukha Shvanasana

(uh-DO MUK-uh shwa-NAHS-uh-nuh)

Modification: knees bent, heels up, spine in Cat Tilt, forehead toward the knees
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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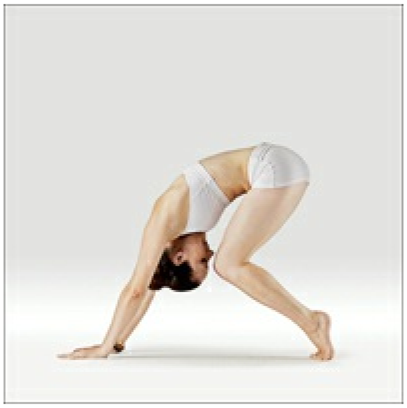

DOWNWARD DOG: WIDE-LEGGED

Feet Spread Downward Facing Dog Pose

Prasarita Pada Adho Mukha Shvanasana

(pruh-SAH-ri-tuh PUH-duh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Modification: heels down, palms down
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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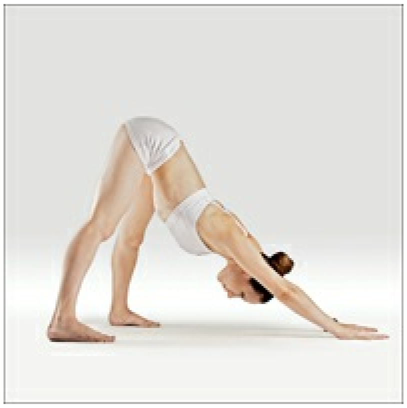

Tip Toe Feet Spread Downward Facing Dog Pose

Prapada Prasarita Pada Adho Mukha Shvanasana

(PRUH-puh-duh pruh-SAH-ri-tuh PUH-duh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Modification: one palm on top of the other, fingertips to the floor, head above the arms
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands), Nasagrai or Nasagre (nose)
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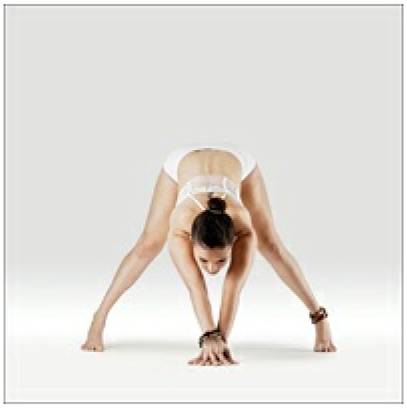

DOWNWARD DOG: ONE-LEGGED—KNEES TOGETHER

One-Legged Downward Facing Dog Pose

Eka Pada Adho Mukha Shvanasana

(EY-kuh PUH-duh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Modification: back leg bent, knees together
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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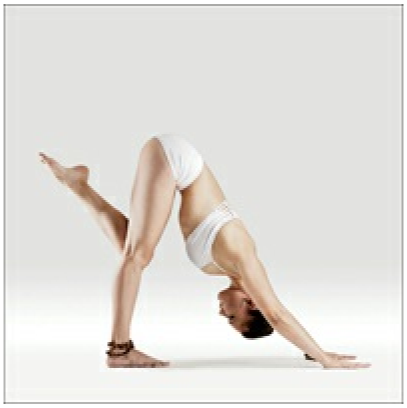

Leg Position of the Half Cow Face Pose in Downward Facing Dog Pose

Pada Ardha Gomukhasana in Adho Mukha Shvanasana

(PUH-duh URH-duh go-muk-AHS-uh-nuh in uh-DO MUK-uh shwa-NAHS-uh-nuh)

Also Known As: Leg Position of the One-Legged Cow Face Pose in Downward Facing Dog Pose (Eka Pada Gomukhasana in Adho Mukha Shvanasana)
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

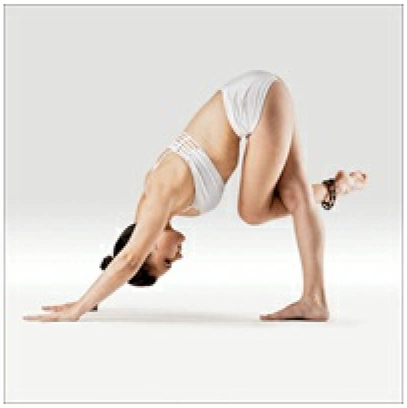

DOWNWARD DOG: ONE-ARMED

Revolved Downward Facing Dog Pose

Parivritta Adho Mukha Shvanasana

(puh-ri-VRIT-tuh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

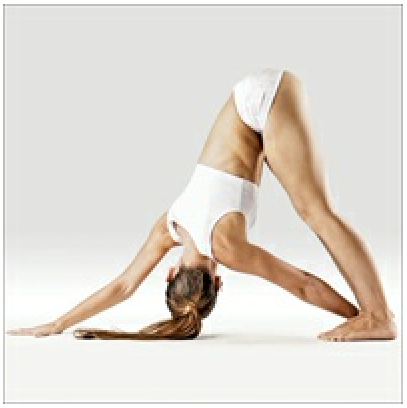

Hand to Knee One-Legged Downward Facing Dog Pose

Hasta Janu Eka Pada Adho Mukha Shvanasana

(HUH-stuh JAH-nu EY-kuh PUH-duh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Modification: hand grabbing onto the opposite knee
Pose Type: standing one-legged balance, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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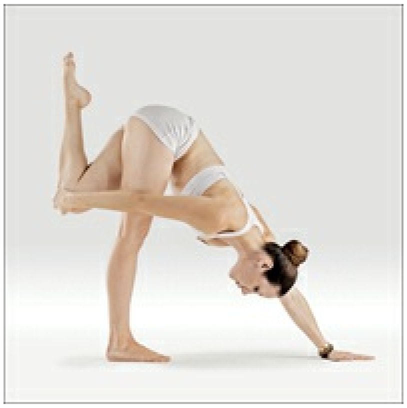

Hand to Ankle One-Legged Downward Facing Dog Pose 1

Hasta Kulpa Eka Pada Adho Mukha Shvanasana 1

(HUH-stuh KUL-puh EY-kuh PUH-duh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Modification: grabbing onto the ankle on the same side; back leg bent, knees together
Pose Type: standing one-legged balance, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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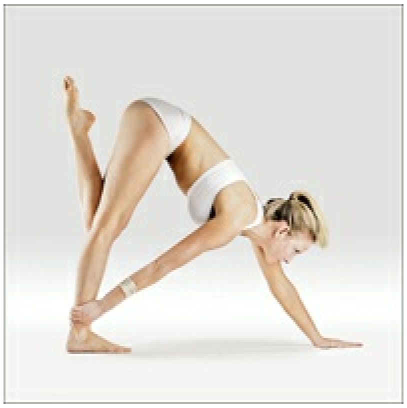

Hand to Ankle One-Legged Downward Facing Dog Pose 2

Hasta Kulpa Eka Pada Adho Mukha Shvanasana 2

(HUH-stuh KUL-puh EY-kuh PUH-duh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Modification: grabbing onto the ankle on the opposite side; back leg bent, knees together

Pose Type: standing one-legged balance, forward bend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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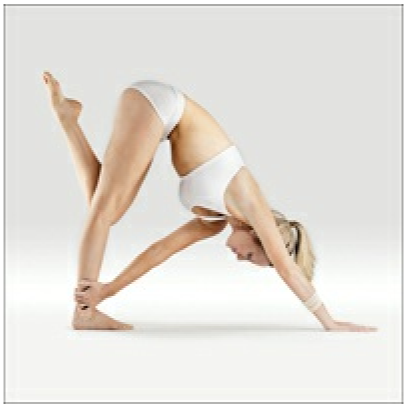

DOWNWARD DOG: ONE-LEGGED

One-Legged Downward Facing Dog Pose

Eka Pada Adho Mukha Shvanasana

(EY-kuh PUH-duh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Modification: knee bent

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

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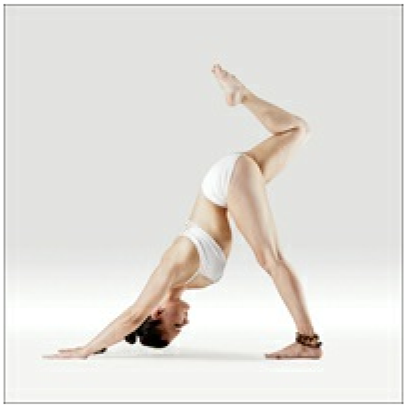

One Leg to the Side Downward Facing Dog Pose

Parshva Eka Pada Adho Mukha Shvanasana

(PAHRSH-vuh EY-kuh PUH-duh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

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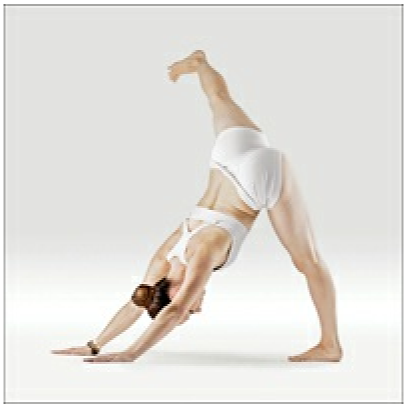

One-Legged Downward Facing Dog Pose

Eka Pada Adho Mukha Shvanasana

(EY-kuh PUH-duh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Also Known As: One-Legged Downward Facing Dog Shoulder Press

Modification: bottom knee bent; elbows bent, fingertips to the floor

Pose Type: standing, forward bend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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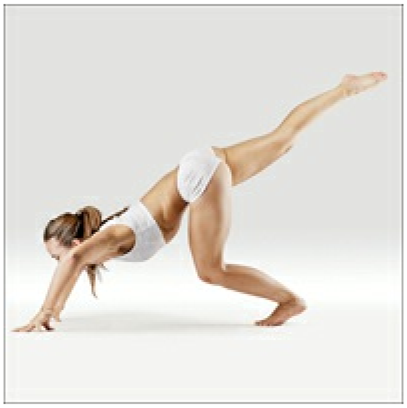

One-Legged Downward Facing Dog Pose

Eka Pada Adho Mukha Shvanasana

(EY-kuh PUH-duh uh-DO MUK-uh shwa-NAHS-uh-nuh)

Also Known As: One Leg Raised Up Downward Facing Dog Pose (Utthita Eka Pada Adho Mukha Shvanasana)

Modification: back leg straight and extended up to the sky
Pose Type: standing, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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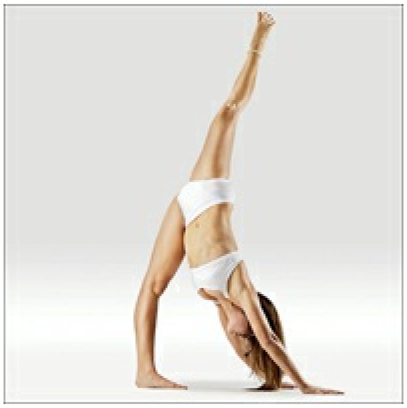

DOWNWARD DOG: TWISTS

Uneven Legs Revolved Downward Facing Dog Pose 1

Vishama Pada Parivritta Adho Mukha Shvanasana 1

(VISH-uh-muh PUH-duh puh-ri-VRIT-tuh uh-DO MUK-uh shwa-NAHS-uh-nuh)
Modification: one knee bent, foot crossed over
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
ल व ह

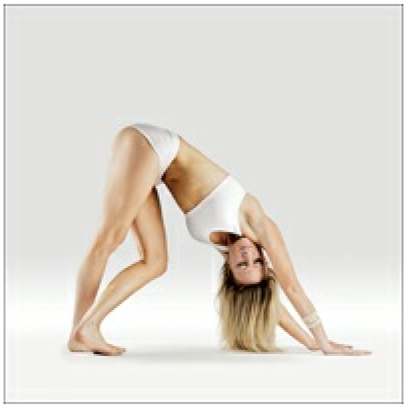

Uneven Legs Revolved Downward Facing Dog Pose 2

Vishama Pada Parivritta Adho Mukha Shvanasana 2

(VISH-uh-muh PUH-duh puh-ri-VRIT-tuh uh-DO MUK-uh shwa-NAHS-uh-nuh)
Modification: both legs straight, one leg crossed over

Pose Type: standing, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

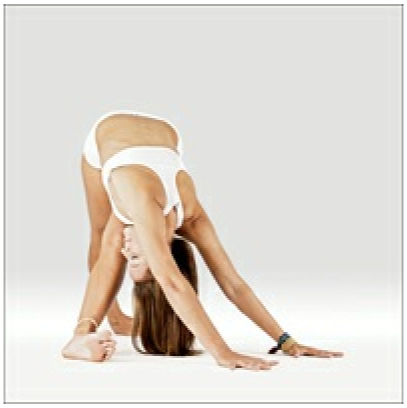

[INTENSE SIDE STRETCH: STRAIGHT SPINE TO BACKBEND](#)

Upward Bound Hands Pose in Hero Succession Series

Urdhva Baddha Hastasana in Vira Parampara

(OORD-vuh BUH-duh huh-STAHS-uh-nuh in VEER-uh puh-ruhm-puh-RAH)
Modification: arms up to the sky, fingers interlocked, spine straight
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

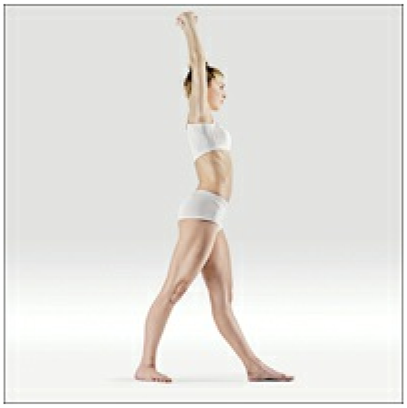

Hands Bound Pose in Hero Succession Series

Baddha Hastasana in Vira Parampara

(BUH-duh huh-STAHS-uh-nuh in VEER-uh puh-ruhm-puh-RAH)
Modification: grabbing onto the triceps behind the back
Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
ल व र य ह ॐ

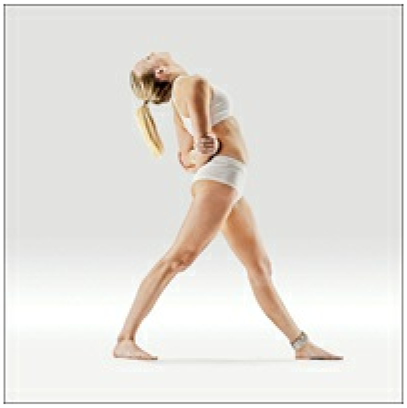

Reverse Prayer Pose in Hero Succession Series

Viparita Namaskarasana in Vira Parampara

(vi-puh-REET-tuh nuh-muhs-kahr-AHS-uh-nuh in VEER-uh puh-ruhm-puh-RAH)

Also Known As: Back of the Body Prayer in Hero Succession Series (Paschima Namaskara in Vira Parampara)
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
ल व र य ह ॐ

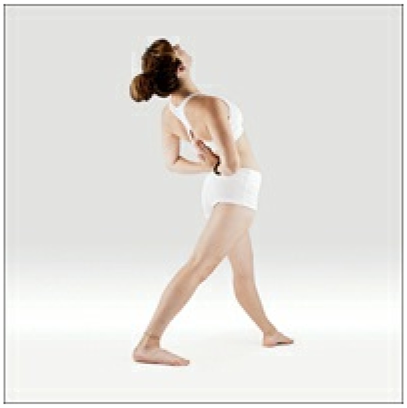

Upward Bound Hands Pose in Hero Succession Series

Urdhva Baddha Hastasana in Vira Parampara

(OORD-vuh BUH-duh huh-STAHS-uh-nuh in VEER-uh puh-ruhm-puh-RAH)

Modification: deep backbend
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angusthamadhye or Angustha Ma Dyai (thumbs)

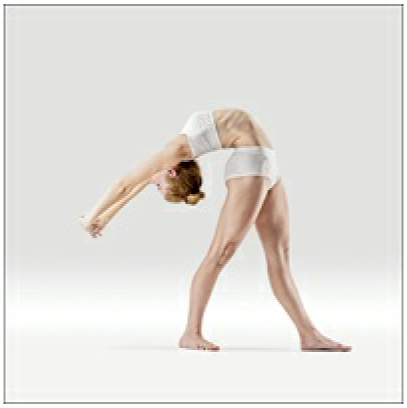

INTENSE SIDE STRETCH: HALF FORWARD BEND

Intense Side Stretch Pose Prep.

Parshvottanasana Prep.

(pahrsh-vo-tahn-AHS-uh-nuh)

Modification: arms straight out in front, palms pressed together
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

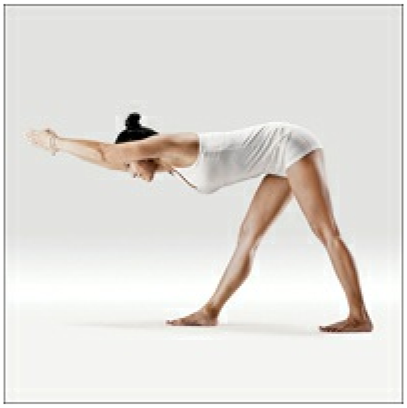

Intense Side Stretch Pose Prep.

Parshvottanasana Prep.

(pahrsh-vo-tahn-AHS-uh-nuh)

Modification: one hand to the lower back, one arm extended out in front and parallel to the floor
Pose Type: standing, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)

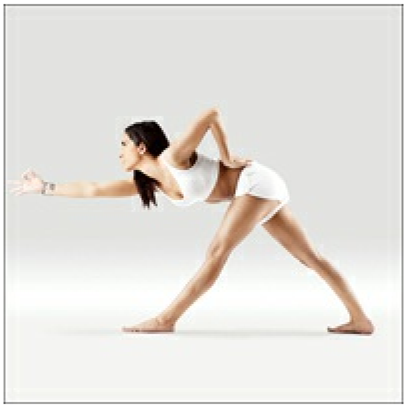

Intense Side Stretch Pose Prep.

Parshvottanasana Prep.

(pahrsh-vo-tahn-AHS-uh-nuh)

Modification: grabbing onto the triceps behind the back
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

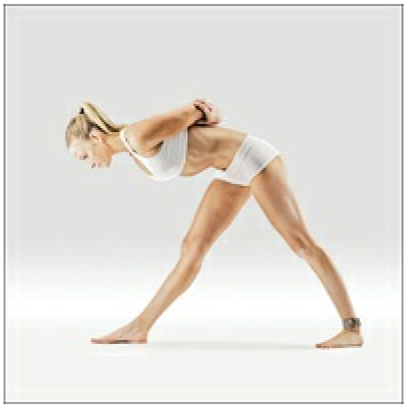

Intense Side Stretch Pose Prep.

Parshvottanasana Prep.

(pahrsh-vo-tahn-AHS-uh-nuh)

Modification: arms open to the sides
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

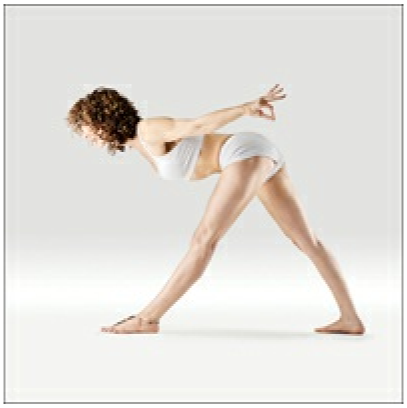

INTENSE SIDE STRETCH: HALF FORWARD BEND—GRABBING ONTO ONE LEG

Intense Side Stretch Pose Prep.

Parshvottanasana Prep.

(pahrsh-vo-tahn-AHS-uh-nuh)

Modification: both hands on the shin on the front leg
Pose Type: standing, forward bend
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)

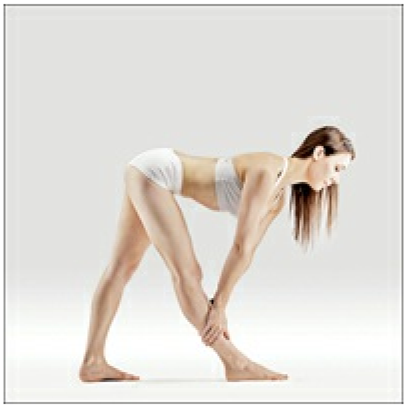

Extended Both Hands to Foot Intense Side Stretch Pose

Utthita Dwi Hasta Pada Parshvottanasana

(UT-ti-tuh DWI-huh-stuh PUH-duh pahrsh-vo-tahn-AHS-uh-nuh)

Modification: toes of the front foot flexed in and lifted off the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

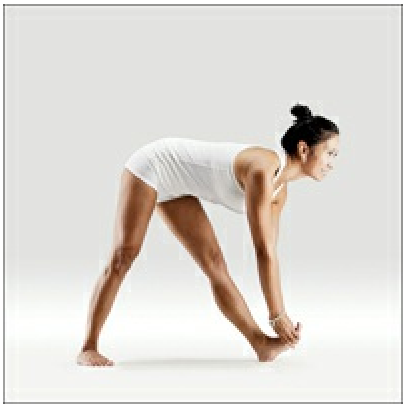

Intense Side Stretch Pose

Parshvottanasana

(pahrsh-vo-tahn-AHS-uh-nuh)

Modification: both hands grabbing onto the calf of the back leg

Pose Type: standing, forward bend

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

ल व ह

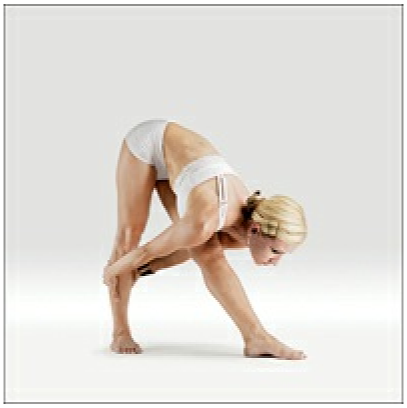

INTENSE SIDE STRETCH: FULL FORWARD BEND—ARMS IN FRONT AND ARMS POINTING TO THE BACK

Intense Side Stretch Pose Prep.

Parshvottanasana Prep.

(pahrsh-vo-tahn-AHS-uh-nuh)

Modification: palms to the floor on either side of the front foot

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

ल व र य

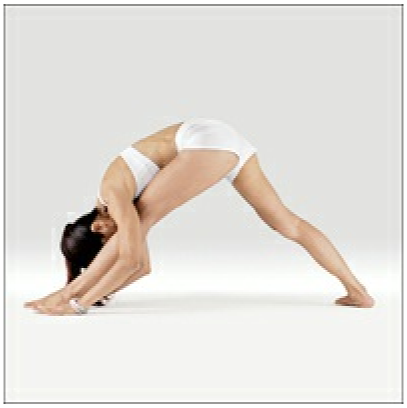

Intense Side Stretch Pose Prep.

Parshvottanasana Prep.

(pahrsh-vo-tahn-AHS-uh-nuh)

Also Known As: Hero Succession Series (Vira Parampara)
Modification: arms reaching to the back, fingertips to the floor
1. chin to the shin
2. forehead to the shin
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)
ल व र य ह ॐ

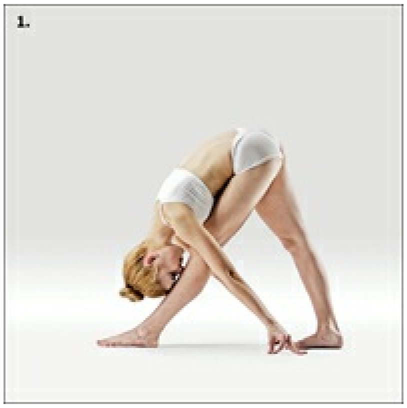

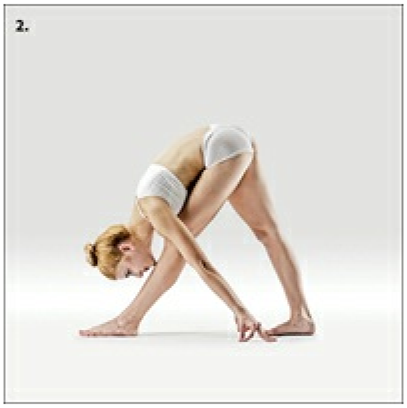

Intense Side Stretch Pose Prep.

Parshvottanasana Prep.

(pahrsh-vo-tahn-AHS-uh-nuh)

Modification: hands in Anjali Mudra (Hands in Prayer), arms wrapped around the front leg
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व र य ॐ

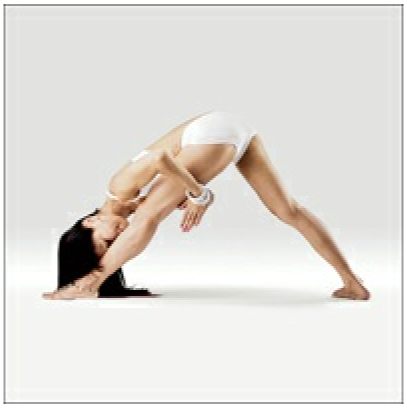

Revolved Intense Side Stretch Pose

Parivritta Parshvottanasana

(puh-ri-VRIT-tuh pahrsh-vo-tahn-AHS-uh-nuh)

Modification: hands in Anjali Mudra (Hands in Prayer), arms wrapped around the front leg, twist
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
ल व र य

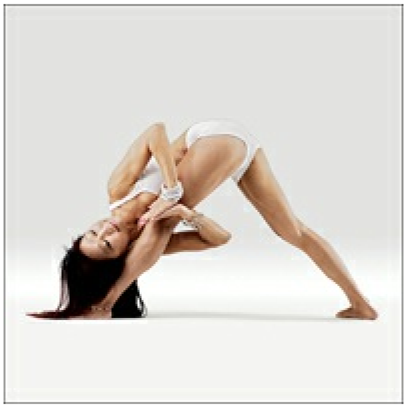

Intense Side Stretch Pose

Parshvottanasana

(pahrsh-vo-tahn-AHS-uh-nuh)

Also Known As: Reverse Prayer Intense Side Stretch Pose (Viparita Namaskar Parsvottanasana), Back of the Body Prayer Intense Side Stretch Pose (Paschima Namaskara Parshvottanasana)
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व र य

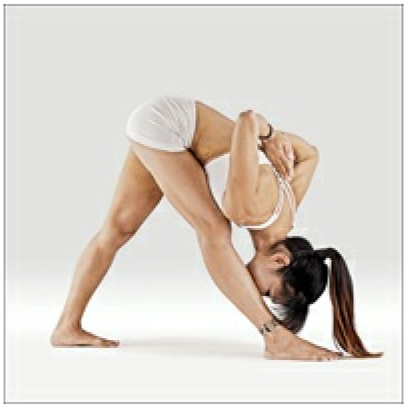

Hands Bound Intense Side Stretch Pose

Baddha Hasta Parshvottanasana

(BUH-duh HUH-stuh pahrsh-vo-tahn-AHS-uh-nuh)

Modification: both legs straight
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)
ल व र य ह

1.

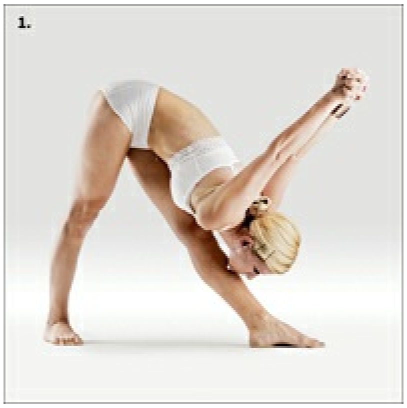

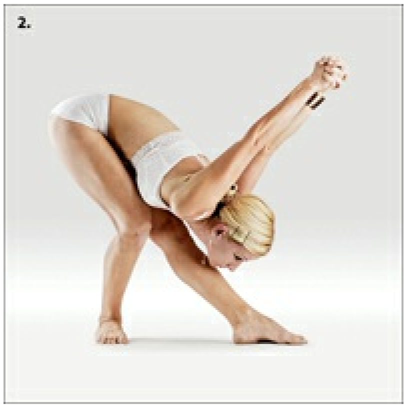
2.

INTENSE SIDE STRETCH: FULL FORWARD BEND—ONE ARM IN FRONT—ONE ARM BEHIND

Uneven Legs Tip Toe Intense Side Stretch Pose

Vishama Pada Prapada Parshvottanasana

(VISH-uh-muh PUH-duh PRUH-puh-duh pahrsh-vo-tahn-AHS-uh-nuh)

Modification: 1. one arm stretched out to the back and up to the sky; other arm stretched out to the front, fingertips to the floor 2. both arms stretched out in front, fingertips to the floor
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
ल व र य ह

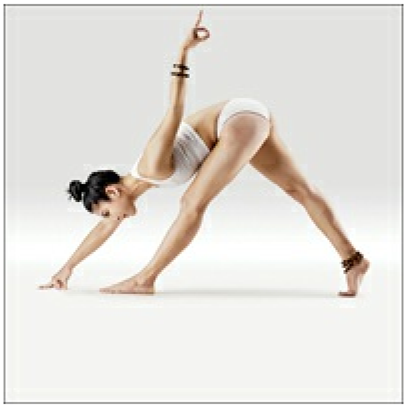

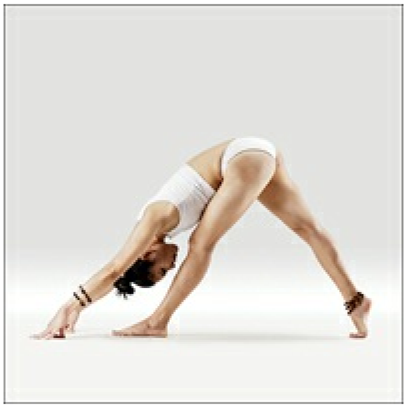

Intense Side Stretch Pose Prep.

Parshvottanasana Prep.

(pahrsh-vo-tahn-AHS-uh-nuh)

Modification: opposite arm wrapped around the front calf, chin to the shin
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
ल व र य ह

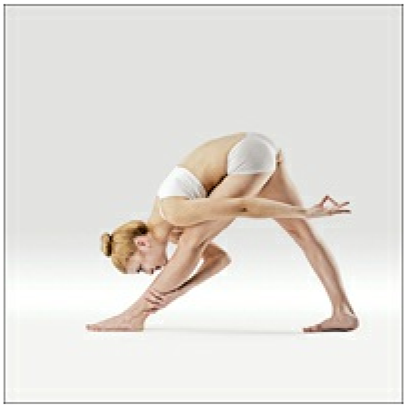

[TRIANGLE POSE]

Extended Side Triangle Pose

Utthita Parshva Trikonasana

(UT-ti-tuh PAHRSH-vuh tri-ko-NAHS-uh-nuh)

Modification: top arm parallel to the floor
Pose Type: standing, forward bend, side bend
Drishti Point: Hastagrai or Hastagre (hands)
ल व र य

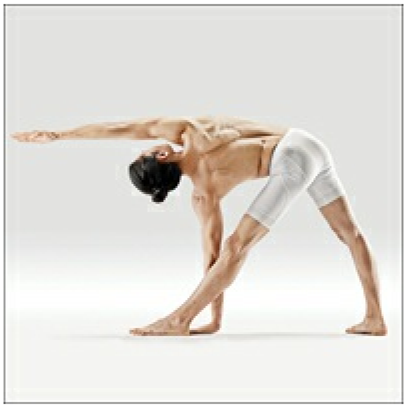

Extended Triangle Pose

Utthita Trikonasana

(UT-ti-tuh tri-ko-NAHS-uh-nuh)

Pose Type: standing, forward bend, side bend

Drishti Point: Angusthamadhye or Angustha Ma Dyai (thumbs)

How to Perform the Pose:

1. Begin by standing in Mountain Pose (*Tadasana*). Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Inhale and step your feet about elbow distance apart with toes facing forward and feet parallel to each other. Expand your chest and hold your arms straight out to the sides, parallel to the floor.
3. Keep your legs strong and straight by engaging your quadriceps and pulling the kneecaps up. Turn your left foot 90 degrees to the left. Turn your right foot as close to 45 degrees to the left as possible.
4. On your next exhale, reach over to the left as far as you can with good form and drop your left hand toward the left shin (or left foot or to the floor either on the inside or the outside of the left foot).
5. Reach your right arm up to the sky and look at your right thumb (the *drishti* point). Make sure that your chest is not collapsing down toward the floor by lengthening both arms, grabbing onto the big toe of your left foot with pointer finger and middle finger and thumb locked on top, and leaning back far enough so that your shoulders are stacked one on top of the other.
6. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch. Exhale as you release the pose. Inhale as you press strongly into both feet to come up.
7. Exhale, come back to Mountain Pose (*Tadasana*) and repeat on the other side.

Modification:

1. front view
2. back view

utittha = extended

tri = three

kona = angle

1.

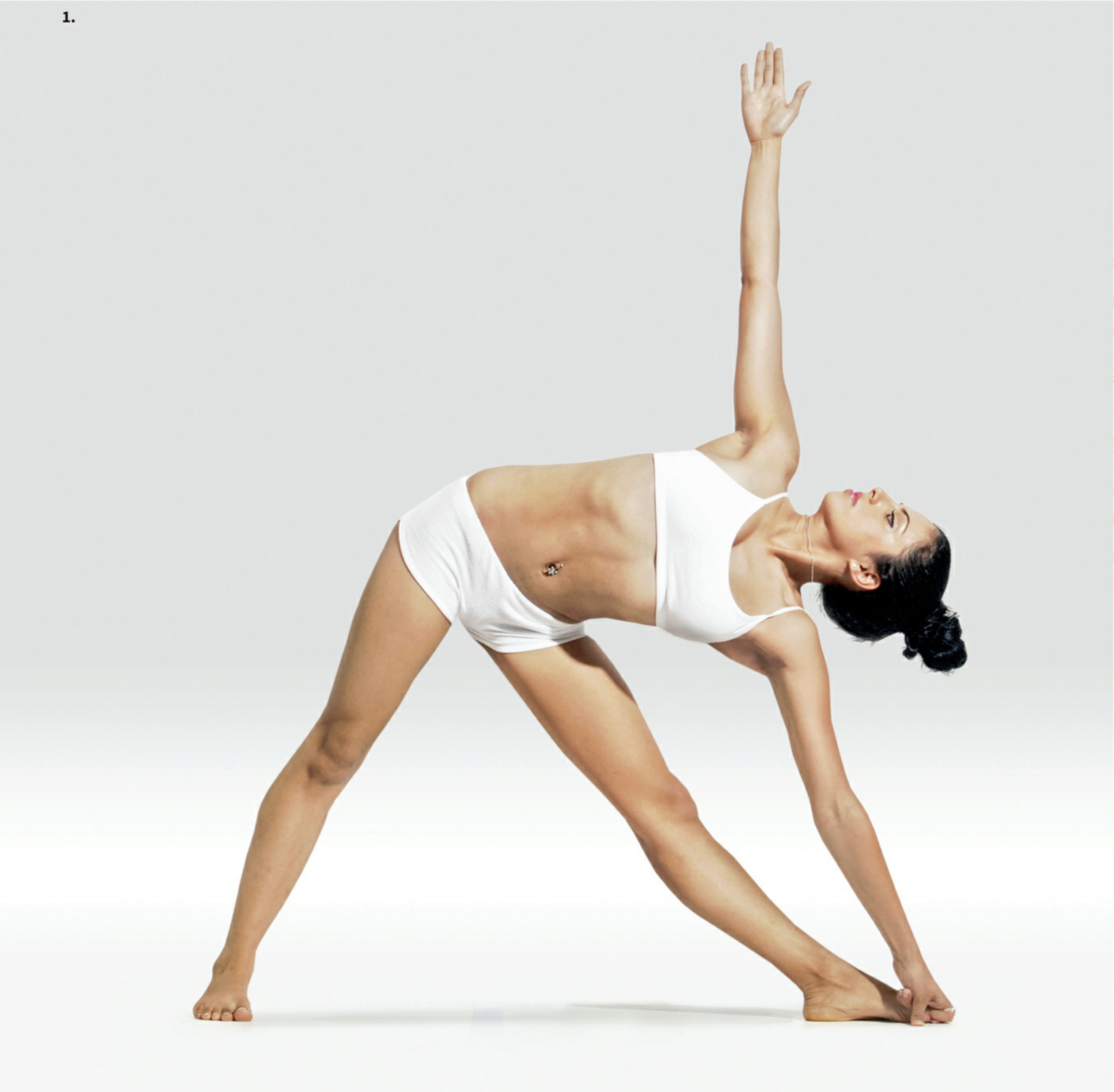

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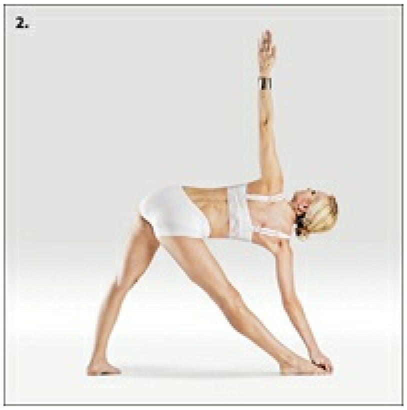

Half Bound Extended Triangle Pose

Ardha Baddha Utthita Trikonasana

(UHR-duh BUH-duh UT-ti-tuh tri-ko-NAHS-uh-nuh)

Pose Type: standing, forward bend, side bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

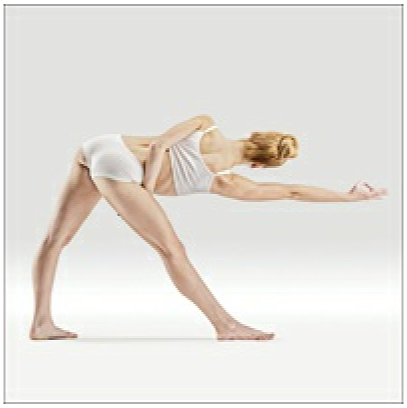

Bound Extended Triangle Pose

Baddha Utthita Trikonasana

(BUH-duh UT-ti-tuh tri-ko-NAHS-uh-nuh)

Modification: fingers interlocked on the inside of the thigh
Pose Type: standing, forward bend, side bend, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

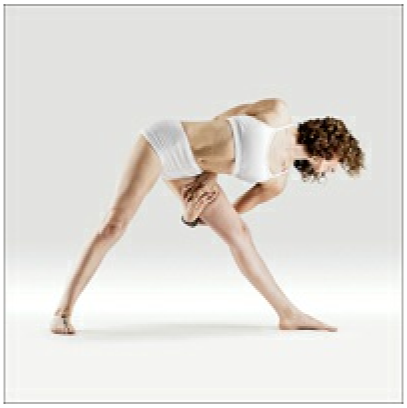

Bound Extended Triangle Pose

Baddha Utthita Trikonasana

(BUH-duh UT-ti-tuh tri-ko-NAHS-uh-nuh)

Pose Type: standing, forward bend, side bend, binding, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky)

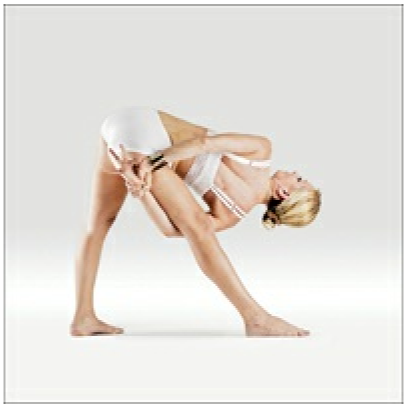

Revolved Sideways Extended Triangle Pose

Parivritta Parshva Utthita Trikonasana

(puh-ri-VRIT-tuh PAHRSH-vuh UT-ti-tuh tri-ko-NAHS-uh-nuh)

Modification: grabbing onto both shins

Pose Type: standing, forward bend, side bend, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky)

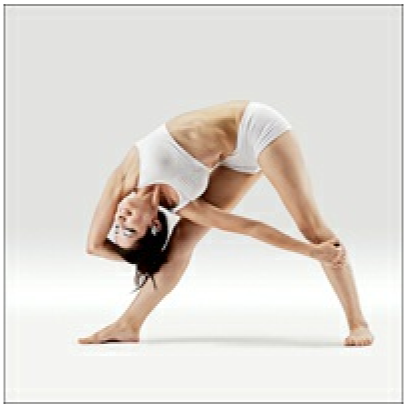

TRIANGLE POSE: REVOLVED & BINDING

Revolved Triangle Pose

Parivritta Trikonasana

(puh-ri-VRIT-tuh tri-ko-NAHS-uh-nuh)

Also Known As: Revolved Intense Side Stretch Pose (Parivritta Parshvottanasana)
Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

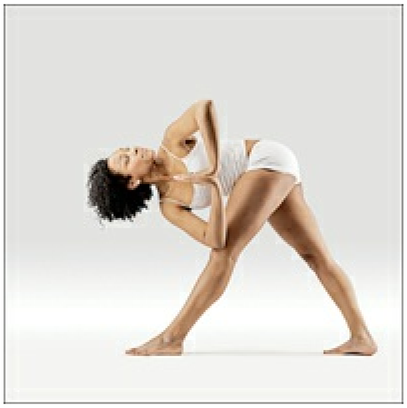

Revolved Triangle Pose

Parivritta Trikonasana

(puh-ri-VRIT-tuh tri-ko-NAHS-uh-nuh)

Pose Type: standing, forward bend, twist
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

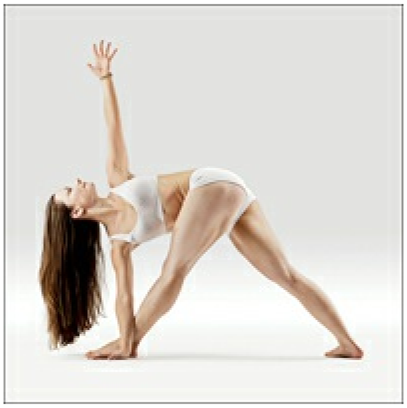

Revolved Bound Triangle Pose

Parivritta Baddha Trikonasana

(puh-ri-VRIT-tuh BUH-duh tri-ko-NAHS-uh-nuh)

Also Known As: Bound Leg Twisted Angle Pose (Baddha Pada Parivritta Konasana)
Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

Extended Side Angle Pose

Utthita Parshva Konasana

(UT-ti-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Pose Type: standing, side bend

Drishti Point: Hastagrai or Hastagrahe (hands)

How to Perform the Pose:

1. Begin by standing in Mountain Pose (*Tadasana*). Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Inhale and step your feet about wrist-distance apart with toes facing forward and feet parallel to each other. Expand your chest and hold your arms straight out to the sides parallel to the floor.
3. Keep your legs strong and straight by engaging your quadriceps and pulling the kneecaps up. Turn your left foot 90 degrees to the left. Turn your right foot 45 degrees to the left as much as possible.
4. Exhale and bend your left knee until your left thigh is parallel to the floor, coming into Warrior 2 Pose (Virabhadrasana 2).
5. On the exhale, bend to the left and drop your left elbow to the left thigh. Reach your right arm over your head and rotate your chest to the side until your right shoulder is on top of your left shoulder.
6. You can experiment with bringing your left palm to the floor on the inside of your left thigh or the outside of your thigh.
7. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch. Exhale as you release the pose. Inhale as you press strongly into both feet to come up.
8. Exhale, come back to Mountain Pose (*Tadasana*) and repeat on the right side.

Modification:

1. arm to the inside of the thigh
2. elbow on the thigh
3. arm to the outside of the thigh

utthita = extended, rising, risen

parsva = side

kona = angle

1.

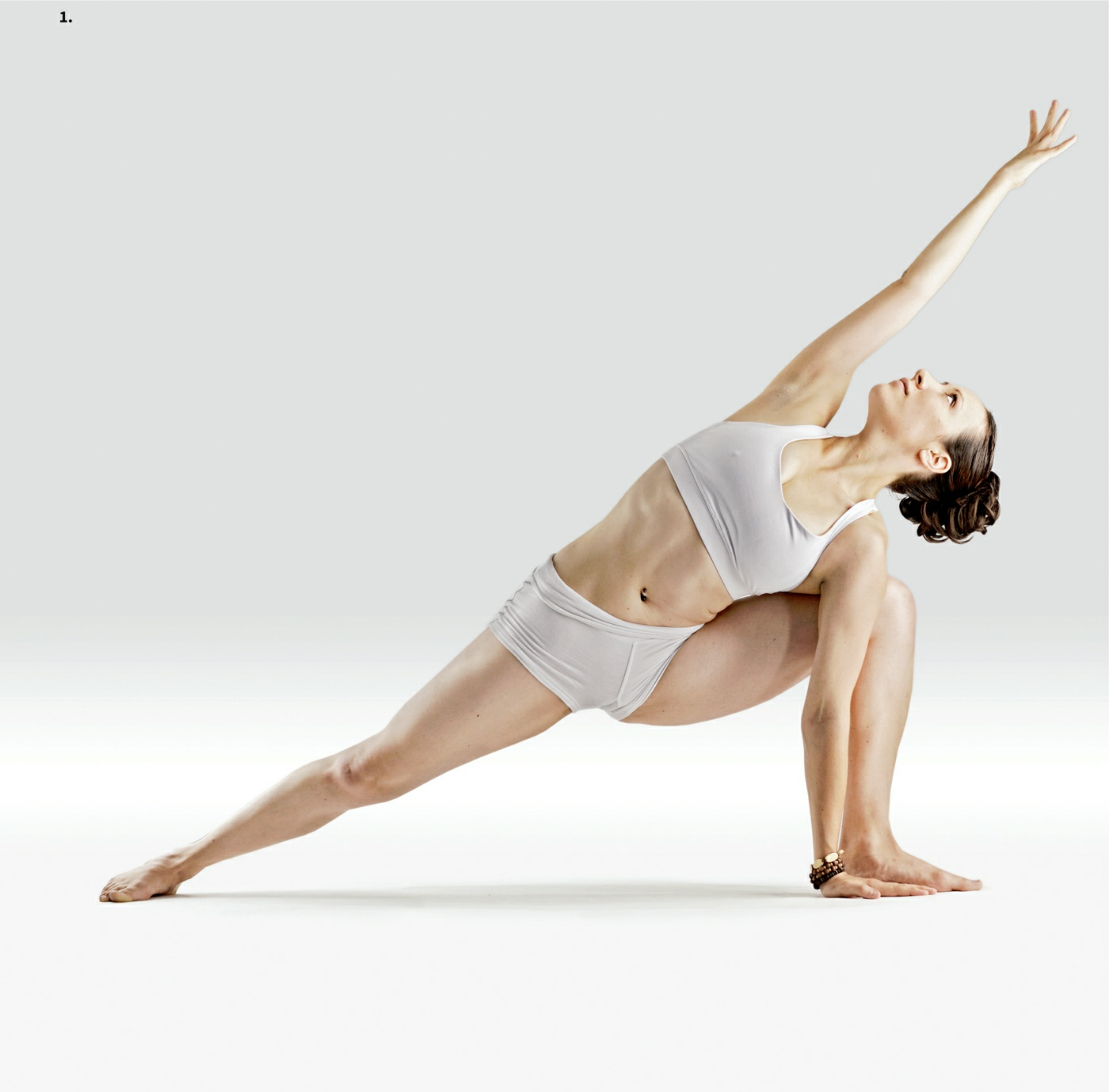

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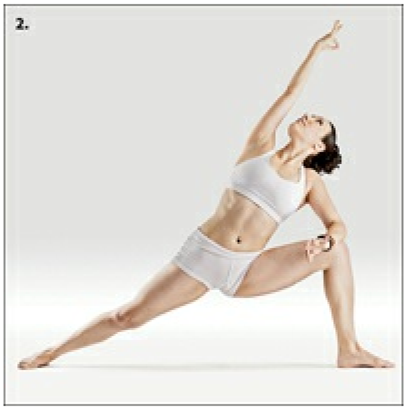

3.

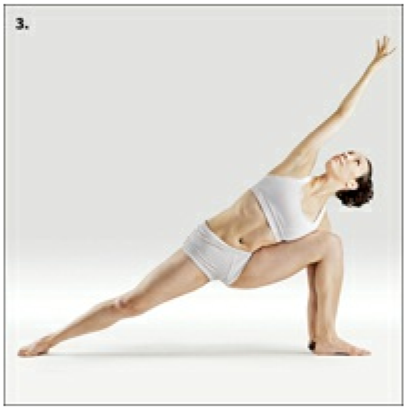

Warrior 2

Virabhadrasana 2

(veer-uh-buh-DRAHS-uh-nuh)

Also Known As: Half Side Angle Pose (Ardha Parshva Konasana)
Pose Type: standing
Drishti Point: Hastagrai or Hastagre (hands)

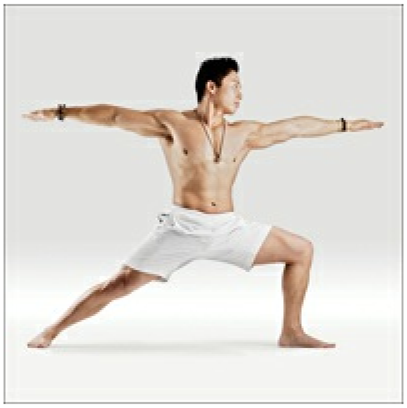

SIDE ANGLE POSE

Extended Side Angle Pose Prep.

Utthita Parshva Konasana Prep.

(UT-ti-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: back knee on the floor, palm to the floor on the inside of the front leg
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

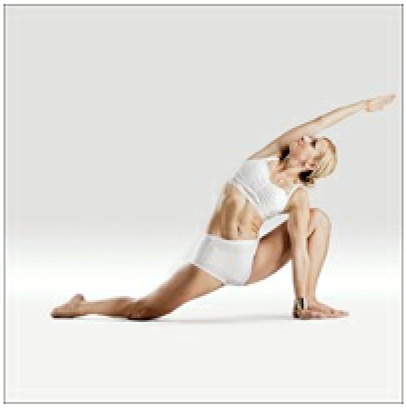

Both Arms Extended Side Angle Pose Prep.

Dwi Hasta Utthita Parshva Konasana Prep.

(DWI-huh-stuh UT-ti-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: back knee on the floor
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

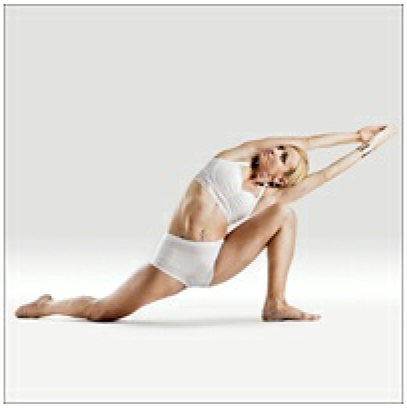

Both Arms Extended Side Angle Pose

Dwi Hasta Utthita Parshva Konasana

(DWI-huh-stuh UT-ti-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: back knee off the floor
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

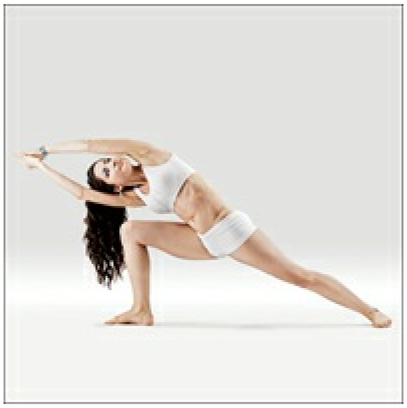

Tip Toe Extended Side Angle Pose Prep.

Prapada Utthita Parshva Konasana Prep.

(PRUH-puh-duh UT-ti-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: front heel lifted, fingertips to the floor on the inside of the leg, other arm resting on the side of the torso

Pose Type: standing, side bend

Drishti Point: Urdhva or Antara Drishti (up to the sky)

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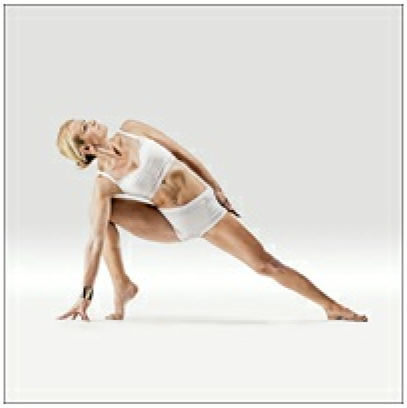

Tip Toe Both Arms Extended Side Angle Pose

Prapada Dwi Hasta Utthita Parshva Konasana

(PRUH-puh-duh DWI-huh-stuh UT-ti-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: back knee off the floor

Pose Type: standing, side bend

Drishti Point: Urdhva or Antara Drishti (up to the sky)

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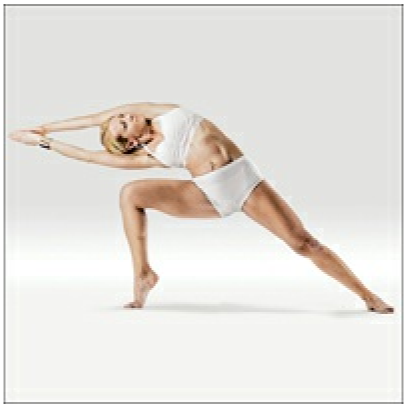

SIDE ANGLE POSE: BINDING

Half Bound Extended Side Angle Pose

Ardha Baddha Utthita Parshva Konasana

(UHR-duh BUH-duh UT-ti-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: hand to the floor on the inside of the front leg
Pose Type: standing, side bend, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

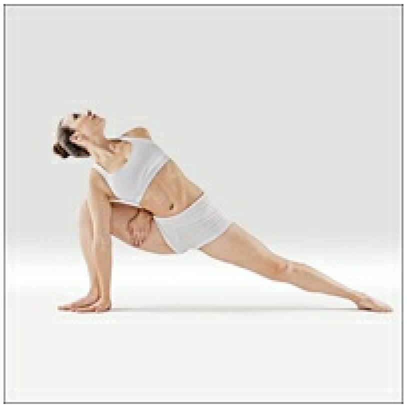

Bound Extended Side Angle Pose

Baddha Utthita Parshva Konasana

(BUH-duh UT-ti-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: fingers interlocked on the inside of the front thigh
Pose Type: standing, side bend, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

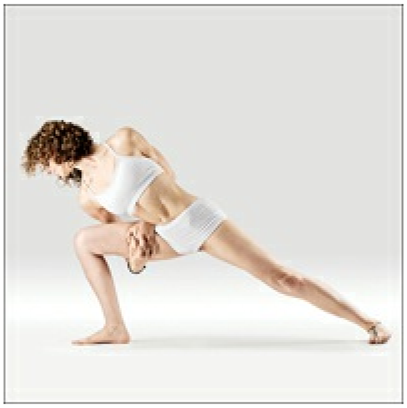

Bound Extended Side Angle Pose

Baddha Utthita Parshva Konasana

(BUH-duh UT-ti-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Also Known As: Bound Arms Side Angle Pose (Baddha Hasta Parshva Konasana)

Pose Type: standing, side bend, binding, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

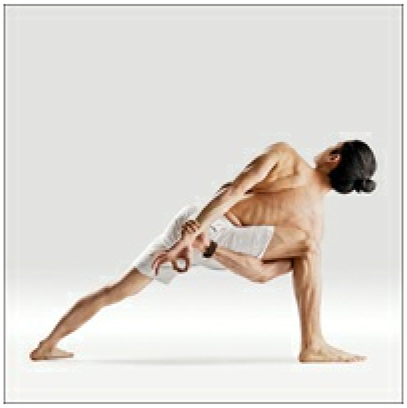

Pose Dedicated to Vishvamitra Prep.

Vishvamitrasana Prep.

(VISH-vah-mi-TRAHS-uh-nuh)
Modification: knee bent wrapped around the tricep, grabbing onto the foot
Pose Type: standing, arm balance
Drishti Point: Urdhva or Antara Drishti (up to the sky)

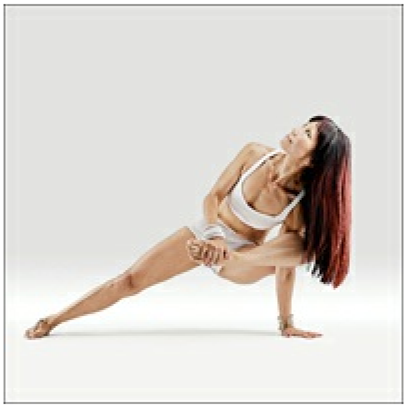

Pose Dedicated to Vishvamitra Prep.

Vishvamitrasana Prep.

(vish-vah-mi-TRAHS-uh-nuh)
Modification: knee bent, shin to the tricep
Pose Type: standing, arm balance
Drishti Point: Hastagrai or Hastagre (hands), Padayoragrai or Padayoragre (toes/feet)

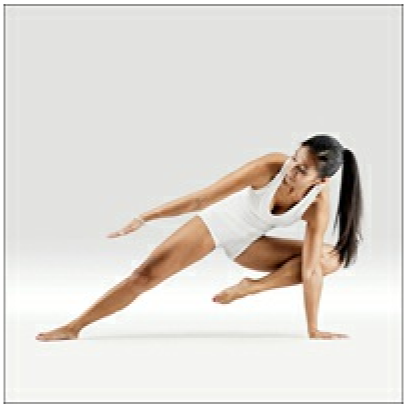

SIDE ANGLE POSE: REVOLVED

Revolved Side Angle Pose Prep.

Parivritta Parshva Konasana Prep.

(puh-ri-VRIT-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: one arm under the leg, hands in Anjali Mudra (Hands in Prayer),
1. back knee on the floor, looking up to the sky 2. back knee off the floor, looking down
Pose Type: standing, twist
Drishti Point: 1. Urdhva or Antara Drishti (up to the sky)
2. Padayoragrai or Padayoragre (toes/feet)

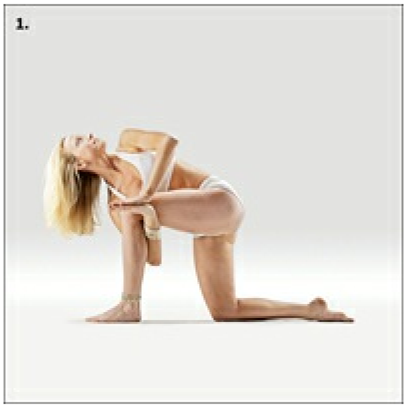

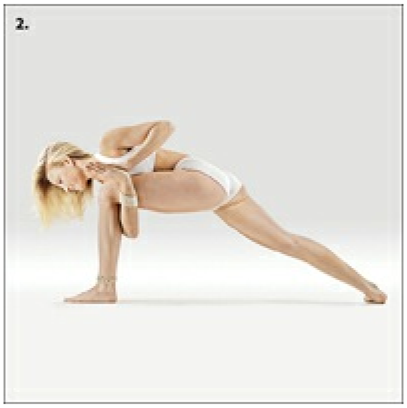

Revolved Side Angle Pose Prep.

Parivritta Parshva Konasana Prep.

(puh-ri-VRIT-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: hands in Anjali Mudra (Hands in Prayer)
1. back knee on the floor, looking up to the sky
2. back knee off the floor, looking up to the sky
Pose Type: standing, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

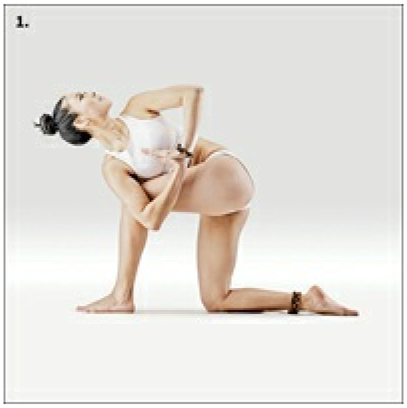

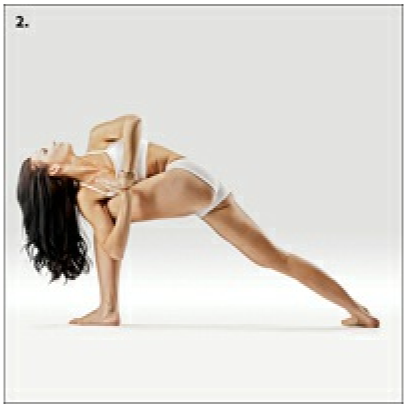

Both Hands Free Revolved Side Angle Pose

Dwi Mukta Hasta Parivritta Parshva Konasana

(DWI muk-tuh HUH-stuh puh-ri-VRIT-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: bottom hand off the floor, fingertips pointing in opposite directions
1. back knee on the floor
2. back knee off the floor
Pose Type: standing, twist, side bend
Drishti Point: Hastagrai or Hastagre (hands)

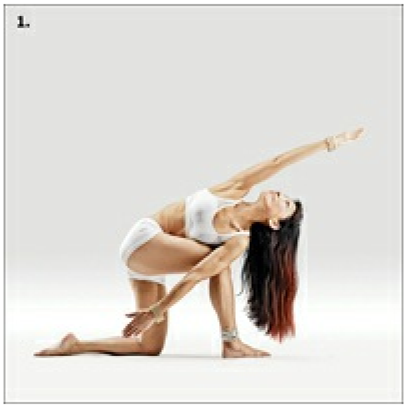
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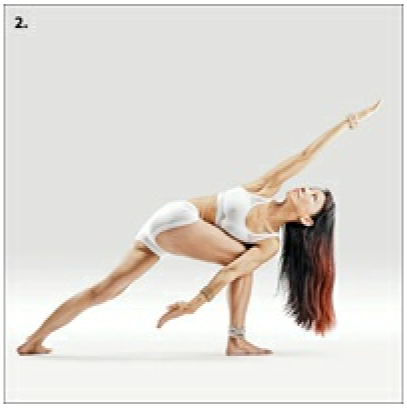
2.

Revolved Side Angle Pose Prep.

Parivritta Parshva Konasana Prep.

(puh-ri-VRIT-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: palm to the floor, other palm to lower back

Pose Type: standing, twist, side bend

Drishti Point: Hastagrai or Hastagre (hands) or Padhayoragrai or Padayoragre (toes/feet)

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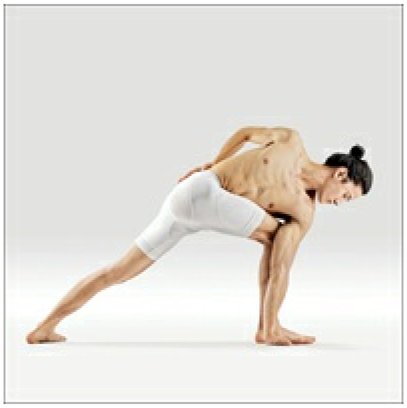

SIDE ANGLE POSE: REVOLVED BOUND

Revolved Side Angle Pose

Parivritta Parshva Konasana

(puh-ri-VRIT-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: 1. palm to the floor, back knee on the floor 2. palm to the floor, back knee off the floor
Pose Type: standing, twist, side bend
Drishti Point: Hastagrai or Hastagre (hands)
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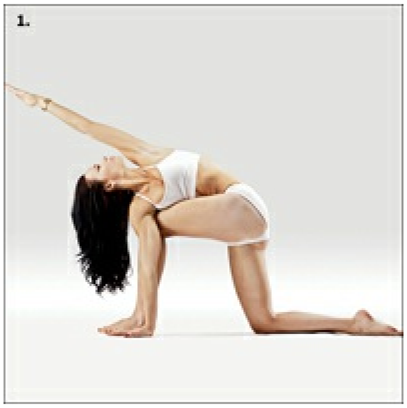

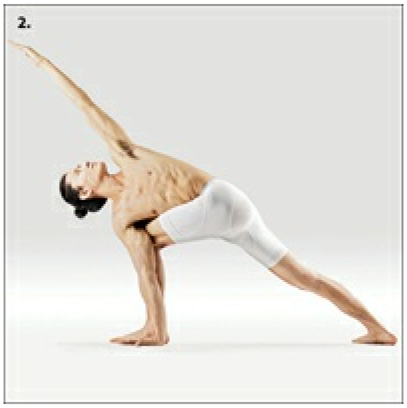

Bound Revolved Side Angle Pose

Baddha Parivritta Parshva Konasana

(BUH-duh puh-ri-VRIT-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Also Known As: Hands Bound Revolved Side Angle Pose Prep. (Baddha Hasta Parivritta Parshva Konasana Prep.)
Modification: 1. back knee on the floor 2. back knee off the floor
Pose Type: standing, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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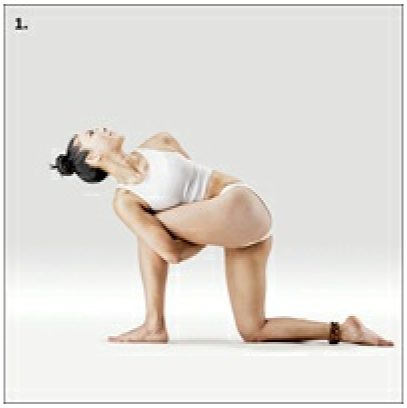
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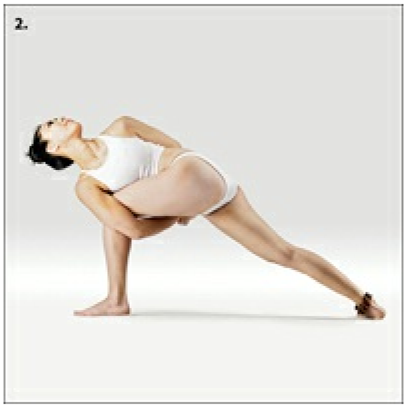
2.

REVERSE WARRIOR

Both Arms Extended Reverse Warrior Pose Prep.

Dwi Hasta Utthita Viparita Virabhadrasana Prep.

(DWI-huh-stuh UT-ti-tuh vi-puh-REE-tuh vee-ruh-buh-DRAHS-uh-nuh)

Modification: back knee on the floor, arms straight, palms together
Pose Type: standing, backbend, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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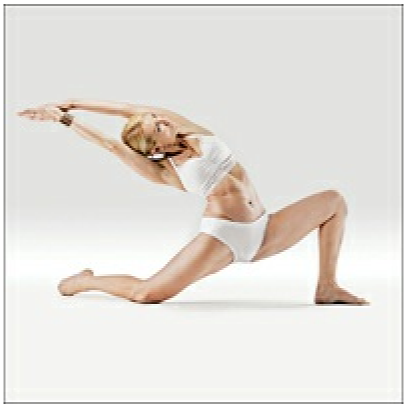

Tip Toe Both Arms Extended Reverse Warrior Pose

Prapada Dwi Hasta Utthita Viparita Virabhadrasana

(PRUH-puh-duh DWI-huh-stuh UT-ti-tuh vi-puh-REE-tuh vee-ruh-buh-DRAHS-uh-nuh)

Modification: arms straight, palms together

Pose Type: standing, backbend, side bend

Drishti Point: Bhrumadhye (third eye, between the eyebrows) or Hastagrai or Hastagre (hands)

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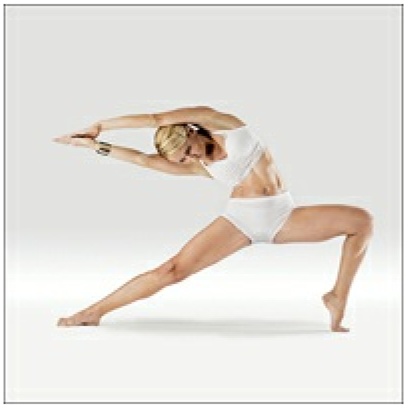

Revolved Sideways Tip Toe Reverse Warrior Pose

Parivritta Parshva Prapada Viparita Virabhadrasana

(puh-ri-VRIT-tuh PAHRSH-vuh PRUH-puh-duh vi-puh-REE-tuh vee-ruh-buh-DRAHS-uh-nuh)

Modification: front heel up, one arm in front and parallel to the floor; other elbow bent, palm facing up, hand to the crown of the head

Pose Type: standing, backbend, twist, side bend

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

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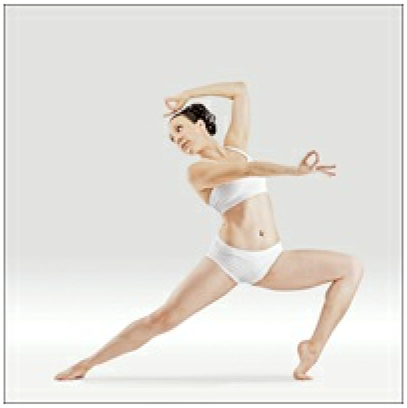

Tip Toe Reverse Warrior Pose

Prapada Viparita Virabhadrasana

(PRUH-puh-duh vi-puh-REE-tuh vee-ruh-buh-DRAHS-uh-nuh)

Modification: front heel up, both elbows bent, one arm up over the head, other arm in front of the torso
Pose Type: standing, backbend
Drishti Point: Hastagrai or Hastagre (hands)
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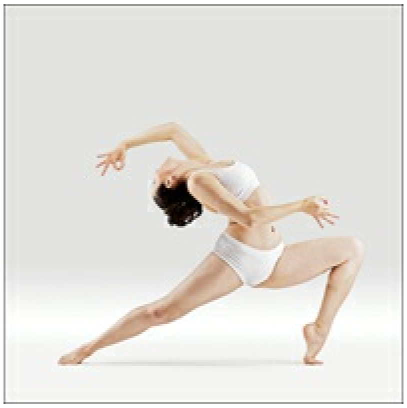

Half Bound Reverse Warrior Pose

Ardha Baddha Viparita Virabhadrasana

(UHR-duh BUH-duh vi-puh-REE-tuh vee-ruh-buh-DRAHS-uh-nuh)

Pose Type: standing, backbend, binding
Drishti Point: Hastagrai or Hastagre (hands)
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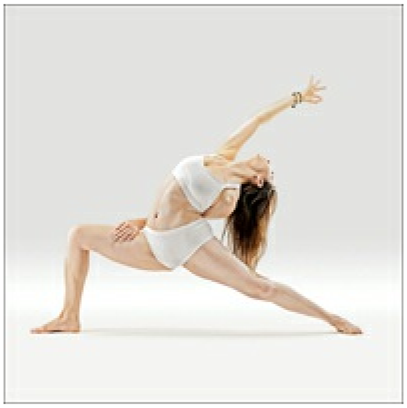

Reverse Warrior Pose

Viparita Virabhadrasana

(vi-puh-REE-tuh vee-ruh-buh-DRAHS-uh-nuh)

Also Known As: Reverse Warrior Pose 2 (Viparita Virabhadrasana 2)

Modification: hand to the calf of the back leg; low lunge, low stance
Pose Type: standing, backbend
Drishti Point: Hastagrai or Hastagre (hands)
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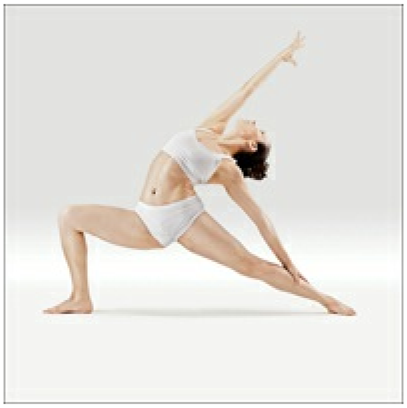

WARRIOR 1

Warrior 1 Prep.

Virabhadrasana 1 Prep.

(vee-ruh-buh-DRAHS-uh-nuh)
Modification: both legs straight, palms pressed together
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)
ल व

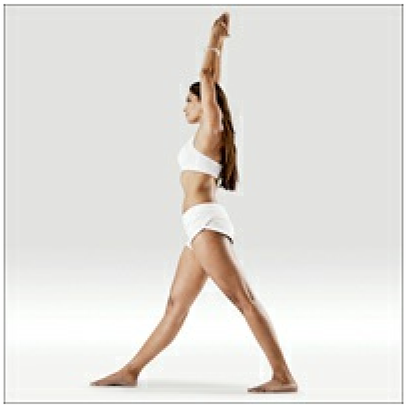

Warrior 1

Virabhadrasana 1

(vee-ruh-buh-DRAHS-uh-nuh)
Also Known As: Raised Arms Warrior Pose (Urdhva Hasta Veerasana), Hero Succession Series

(Vira Parampara)
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

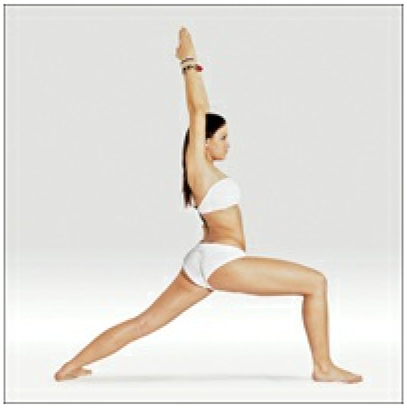

Warrior 1

Virabhadrasana 1

(vee-ruh-buh-DRAHS-uh-nuh)
Modification: arms out in front and parallel to the floor, palms facing the sky
Pose Type: standing
Drishti Point: Hastagrai or Hastagre (hands)

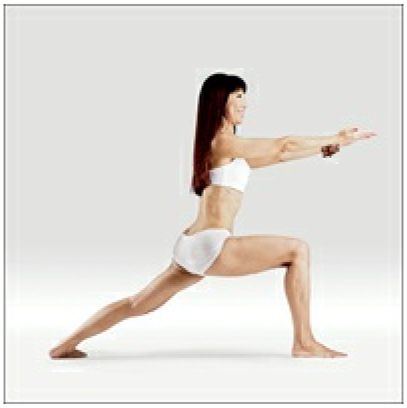

Bound Warrior 1

Baddha Virabhadrasana 1

(BUH-duh vee-ruh-buh-DRAHS-uh-nuh)
Modification: fingers interlocked on the inside of the front thigh
Pose Type: standing, binding
Drishti Point: Nasagrai or Nasagre (nose)

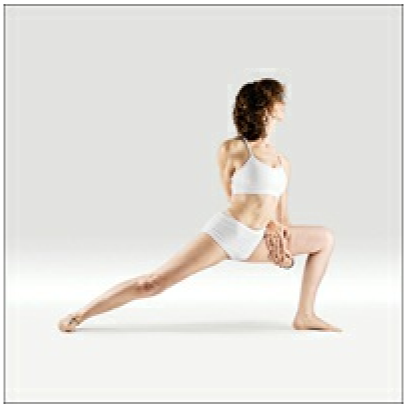

Warrior 1

Virabhadrasana 1

(vee-ruh-buh-DRAHS-uh-nuh)

Modification: arms up over the head and open to the sides; front leg, toes rotated out; deep backbend

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

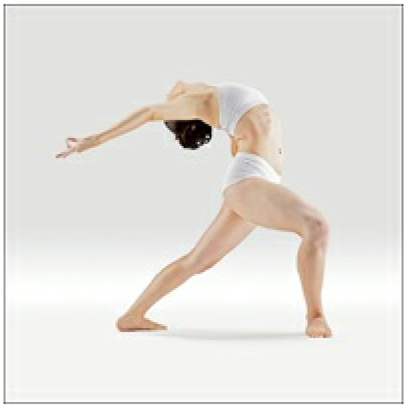

Open Heart Chakra Hands Bound Warrior

Anahata Chakra Baddha Hasta Virabhadrasana

(uh-NAH-huh-tuh CHUHK-ruh BUH-duh HUH-suh vee-ruh-buh-DRAHS-uh-nuh)

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

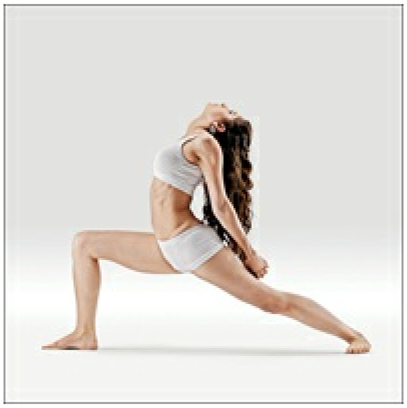

Raised Bound Hands in Warrior 1

Urdhva Baddha Hastasana in Virabhadrasana 1

(OORD-vuh BUH-duh huh-STAHS-uh-nuh in vee-ruh-buh-DRAHS-uh-nuh)

Modification: fingers interlocked deep backbend
Pose Type: standing, backbend
Drishti Point: Hastagrai or Hastagre (hands)
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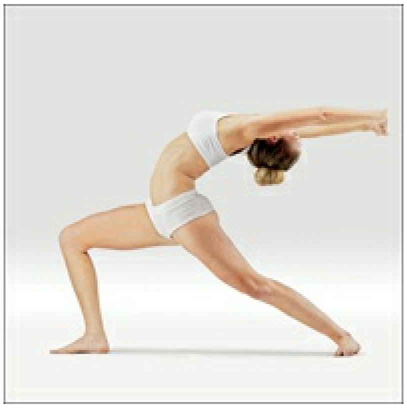

WARRIOR 1: FORWARD BEND—TO THE SIDE

Spread Out Hands Side Angle Pose

Prasarita Hasta Parshva Konasana

(pruh-SAH-ri-tuh HUH-stuh pahrsh-vuh-ko-NAHS-uh-nuh)

Also Known As: Down Dog Lunge Pose
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व ह

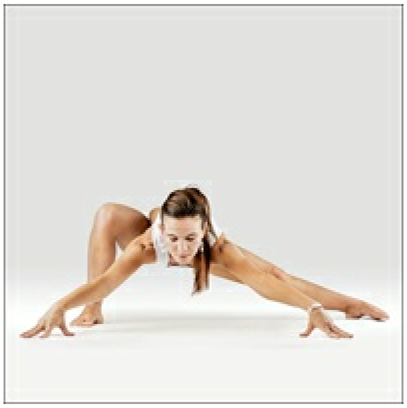

Hand Position of the Pose Dedicated to Garuda in Side Angle Pose

Hasta Garudasana in Parshva Konasana

(HUH-stuh guh-ru-DAHS-uh-nuh in pahrsh-vuh-ko-NAHS-uh-nuh)

Pose Type: standing, forward bend

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

● ●

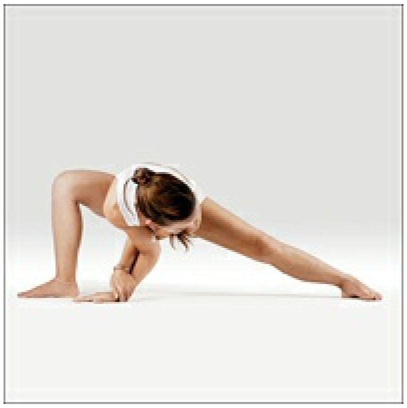

Hand Position of Cow Face Pose in Side Angle Pose

Hasta Gomukhasana in Parshva Konasana

(HUH-stuh go-muk-AHS-uh-nuh in pahrsh-vuh-ko-NAHS-uh-nuh)

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

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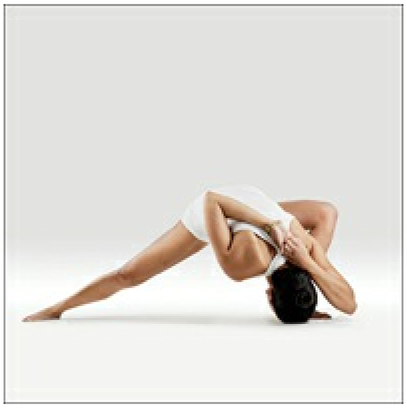

WARRIOR 1: FORWARD BEND—ARMS BEHIND

Bowing Warrior with Hands in Prayer

Nama Virabhadrasana Namaskar

(NUH-muh vee-ruh-buh-DRAHS-uh-nuh nuh-muhs-KAHR)

Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व ह

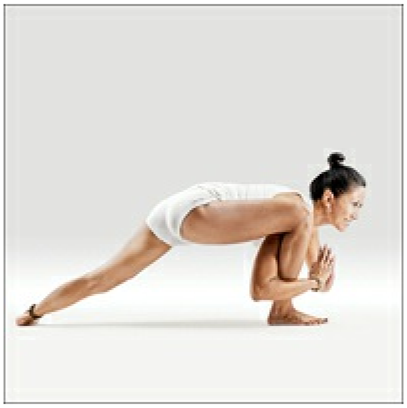

Bowing Hands Bound Warrior

Nama Baddha Hasta Virabhadrasana

(NUH-muh BUH-duh HUH-stuh vee-ruh-buh-DRAHS-uh-nuh)

Modification: grabbing onto the triceps behind the back
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व ह

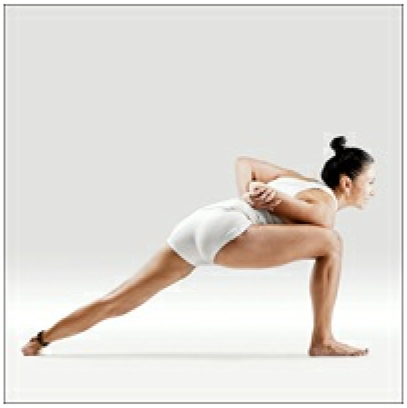

Bowing Reverse Prayer Warrior

Nama Viparita Namaskar Virabhadrasana

(NUH-muh vi-puh-REE-tuh nuh-muhs-KAHR vee-ruh-buh-DRAHS-uh-nuh)

Also Known As: Bowing Back of the Body Prayer Warrior (Nama Paschima Namaskara Virabhadrasana)
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

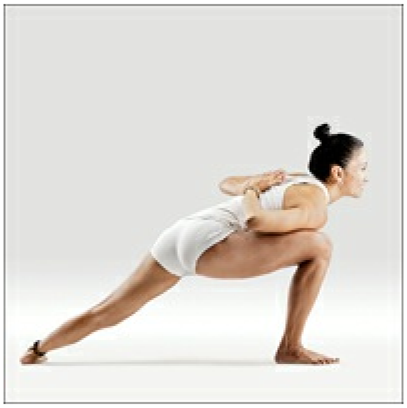

Bowing Hands Bound Warrior Pose

Nama Baddha Hasta Virabhadrasana

(NUH-muh BUH-duh HUH-stuh vee-ruh-buh-DRAHS-uh-nuh)

Also Known As: Warrior Veerastambana Pose (Veerastambanasana), Bound Hands Side Angle Pose (Baddha Hasta Parshva Konasana)
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

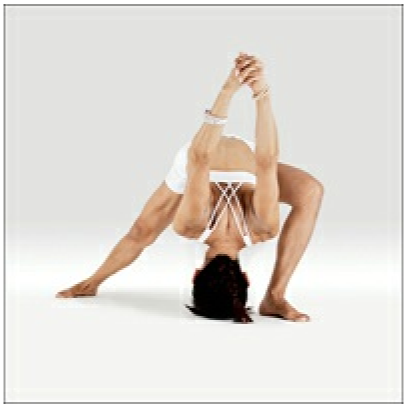

Bowing Hands Bound Warrior Pose

Nama Baddha Hasta Virabhadrasana

(NUH-muh BUH-duh HUH-stuh vee-ruh-buh-DRAHS-uh-nuh)

Also Known As: Bound Hands Side Angle Pose (Baddha Hasta Parshva Konasana)
Modification: arms bound around the front leg
Pose Type: standing, forward bend, binding
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)
ल व य ह

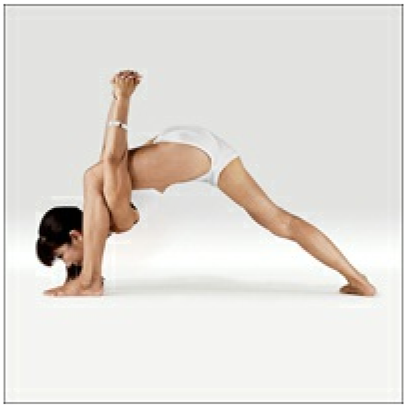

SIDE ANGLE POSE: HEAD BEHIND LEG

One Foot Behind the Head Side Angle Pose

Eka Pada Shirsha Parshva Konasana

(EY-kuh PUH-duh SHEER-shuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: arms crossed in front of the chest
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व

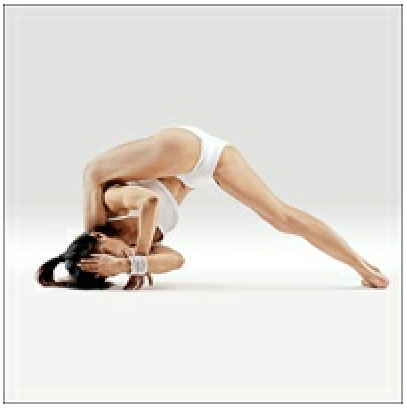

One Foot Behind the Head Side Angle Pose

Eka Pada Shirsha Parshva Konasana

(EY-kuh PUH-duh SHEER-shuh pahrsh-vuh-ko-NAHS-uh-nuh)

Modification: palms together, arms straight on the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

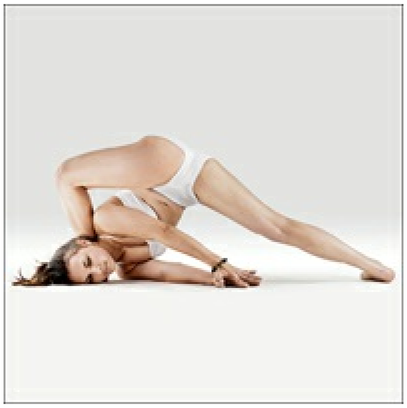

One Foot Behind the Head Bound Side Angle Pose

Eka Pada Shirsha Baddha Parshva Konasana

(EY-kuh PUH-duh SHEER-shuh BUH-duh pahrsh-vuh-ko-NAHS-uh-nuh)

Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

LUNGE: BACK KNEE ON THE FLOOR

Equestrian Riding Horse Lunge Pose

Ashva Sanchalanasana

(UHSH-vuh suhn-chuh-luh-NAHS-uh-nuh)

Modification: back knee on the floor, hands to the floor on either side of the front foot, looking up to the sky
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

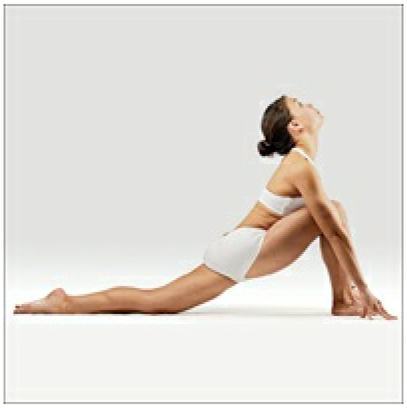

Equestrian Riding Horse Lunge Pose Prep.

Ashva Sanchalanasana Prep.

(UHSH-vuh suhn-chuh-luh-NAHS-uh-nuh)

Also Known As: Son of Anjani (Lord Hanuman) Lunge Pose Prep. (Anjaneyasana Prep.)
Modification: back knee on the floor, both hands on the front knee
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

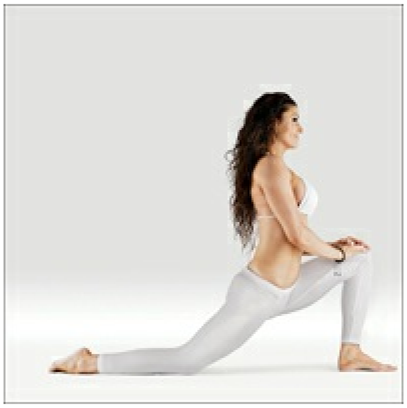

LUNGE: BACK KNEE ON THE FLOOR—FORWARD BEND

Hands Bound Extended Lizard Tail Lunge Pose

Baddha Hasta Uttana Pristhasana

(BUH-duh HUH-stuh ut-TAHN-uh prish-TAHS-uh-nuh)

Also Known As: Bowing Warrior Pose Prep. (Nama Virabhadrasana Prep.)
Modification: back knee on the floor, forehead to the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

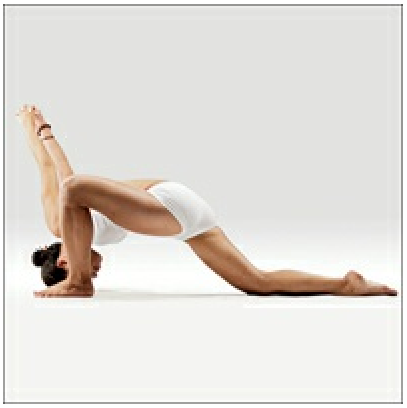

Tip Toe Extended Lizard Tail Lunge Pose

Prapada Uttana Pristhasana

(PRUH-puh-duh ut-TAHN-uh prish-TAHS-uh-nuh)

Modification: back knee on the floor, shoulder to the back of the knee, one arm straight out in front, other arm straight to the back, forehead to the floor
Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

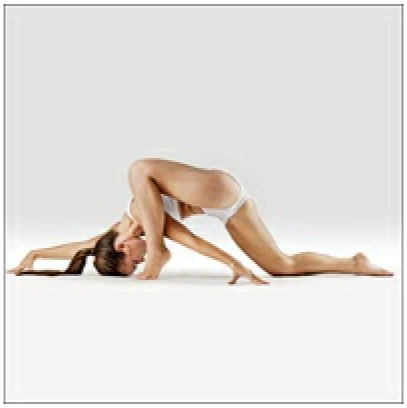

Extended Lizard Tail Lunge Pose

Uttana Pristhasana

(ut-TAHN-uh prish-TAHS-uh-nuh)

Modification: back knee on the floor
1. forearms to the floor on the inside of the foot
2. forearms to the floor on either side of the foot
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

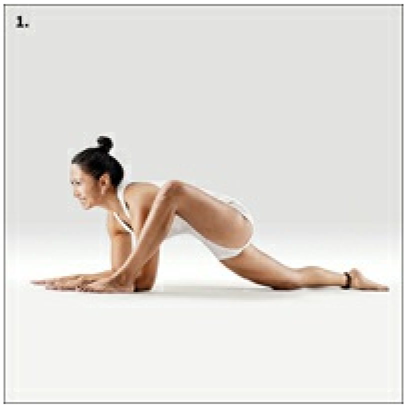

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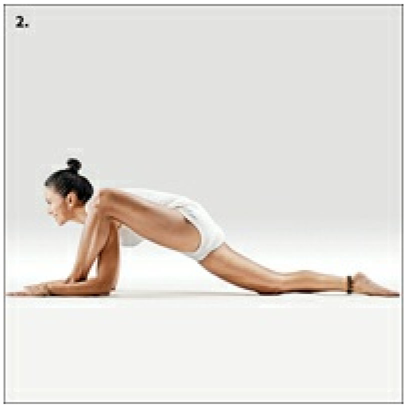

2.

Unsupported Extended Lizard Tail Lunge Pose

Niralamba Uttana Pristhasana

(nir-AH-luhm-buh ut-TAHN-uh prish-TAHS-uh-nuh)

Also Known As: God Favour Seeking Sacrifice Ritual Pose (Yajnasana), Christ's Cross Pose
Modification: arms straight out to the sides
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

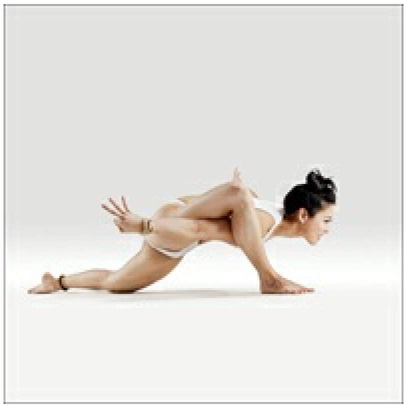

Bound Extended Lizard Tail Lunge Pose

Baddha Uttana Pristhasana

(BUH-duh ut-TAHN-uh prish-TAHS-uh-nuh)

Also Known As: Bound God Favor Seeking Sacrifice Ritual Pose (Baddha Yajnasana), Bound Christ's Cross Pose)
Modification: back knee on the floor
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

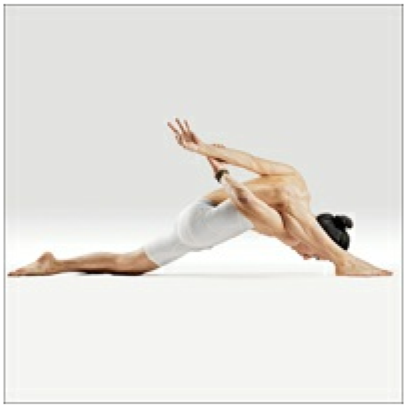

Hands Spread Out Extended Lizard Tail Lunge Pose

Prasarita Hasta Uttana Pristhasana

(pruh-SAH-ri-tuh HUH-stuh ut-TAHN-uh prish-TAHS-uh-nuh)

Also Known As: God Favour Seeking Sacrifice Ritual Pose (Yajnasana), Christ’s Cross Pose
Modification: back knee on the floor, shin to the tricep
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

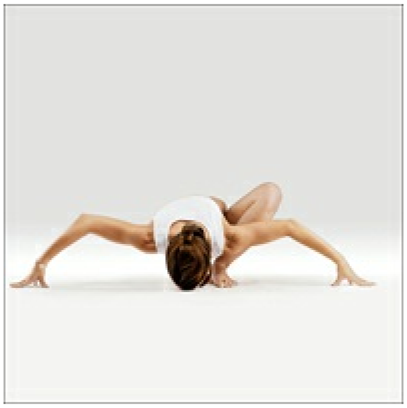

LUNGE: BACK KNEE ON THE FLOOR—BACKBEND—ARMS BEHIND THE BACK

Bound Hands Son of Anjani (Lord Hanuman) Lunge Pose

Baddha Hasta Anjaneyasana *(BUH-duh HUH-stuh uhn-juh-ney-AHS-uh-nuh)*

Also Known As: Open Heart Chakra Hands Bound Equestrian Riding Horse Pose (Anahata Chakra Baddha Hasta Ashva Sanchalanasana)
Modification: back knee on the floor, backbend, hands to the floor on the inside of the back knee
Pose Type: standing, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

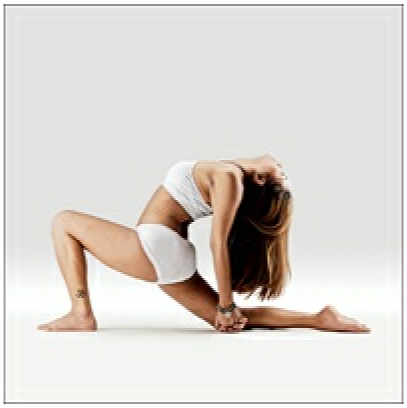

Son of Anjani (Lord Hanuman) Lunge Pose

Anjaneyasana *(uhn-juh-ney-AHS-uh-nuh)*
Also Known As: Open Heart Chakra Equestrian Riding Horse Pose (Anahata Chakra Ashva Sanchalanasana)
Modification: back knee on the floor, backbend, fingertips to the floor on either side of the back knee
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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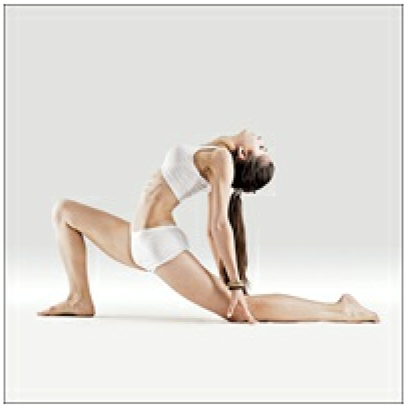

One Hand Son of Anjani (Lord Hanuman) Lunge Pose

Eka Hasta Anjaneyasana *(EY-kuh HUH-stuh uhn-juh-ney-AHS-uh-nuh)*
Also Known As: Equestrian Riding Horse Pose (Ashva Sanchalanasana)
Modification: back knee on the floor, one arm extended up over the head, other hand to the floor
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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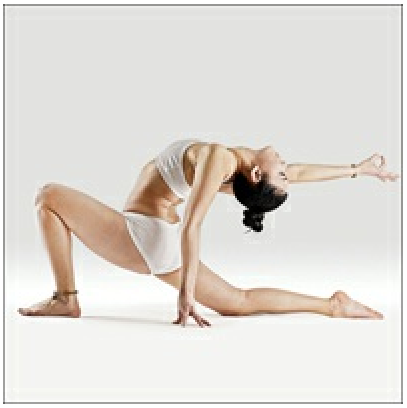

LUNGE: BACK KNEE ON THE FLOOR—BACKBEND—ARMS UP OVER THE HEAD

Son of Anjani (Lord Hanuman) Lunge Pose

Anjaneyasana *(uhn-juh-ney-AHS-uh-nuh)*
Also Known As: Crescent Lunge Pose
Modification: front heel on the floor, back knee down, back toes curled in; arms shoulder width apart, fingertips up to the sky
Pose Type: standing, mild backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

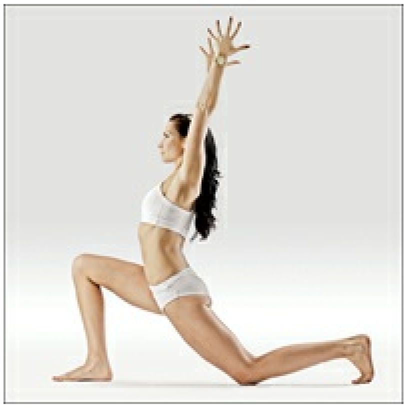

Tip Toe Son of Anjani (Lord Hanuman) Lunge Pose

Prapada Anjaneyasana *(PRUH-puh-duh uhn-juh-ney-AHS-uh-nuh)*
Also Known As: Tip Toe Crescent Lunge Pose
Modification: front heel off the floor, back knee down, back toes curled in; arms shoulder width apart, fingertips up to the sky
Pose Type: standing, mild backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

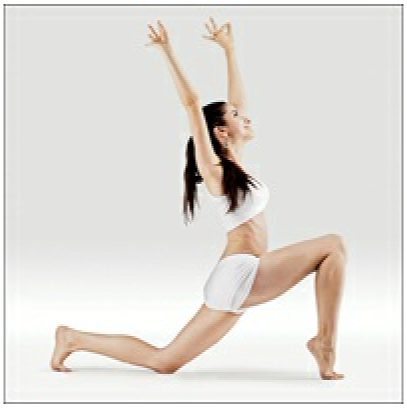

Son of Anjani (Lord Hanuman) Lunge Pose

Anjaneyasana *(uhn-juh-ney-AHS-uh-nuh)*
Also Known As: Monkey Pose (Kapyasana), Crescent Lunge Pose
Modification: arms up over the head, back knee on the floor, palms pressed together
Pose Type: standing, mild backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angusthamadhye or Angustha Ma Dyai (thumbs)

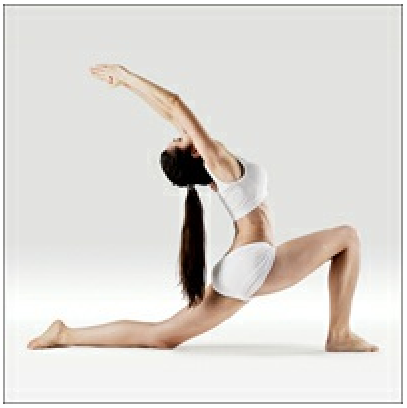

Standing Pose of the Heavenly Spirits Prep.

Stiti Valakhilyasana Prep. *(STI-ti VAH-luh-kil-YAHS-uh-nuh)*
Also Known As: Nindra Valakhilyasana; Son of Anjani (Lord Hanuman) Lunge Pose (Anjaneyasana), Crescent Lunge Pose)
Modification: back knee on the floor, arms up over the head, palms open to the sky, arms parallel to the floor
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

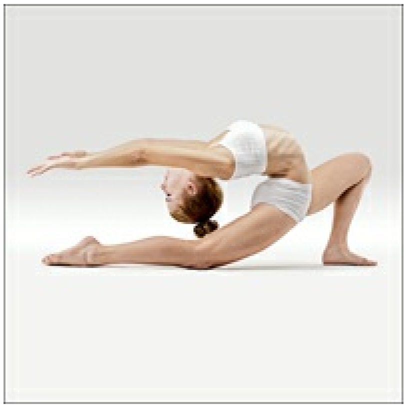

Standing Pose of the Heavenly Spirits

Stiti Valakhilyasana *(STI-ti VAH-luh-kil-YAHS-uh-nuh)*
Also Known As: Nindra Valakhilyasana
Modification: back knee to the floor, grabbing the back heel with overhead grip
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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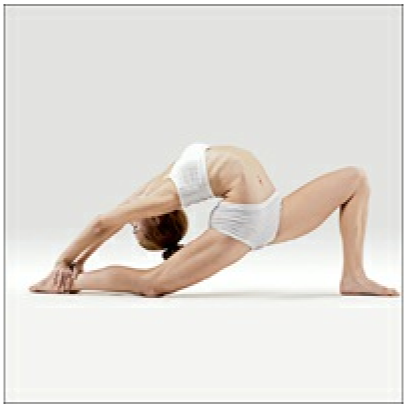

LUNGE: BACK KNEE ON THE FLOOR—TWISTS AND SIDE BENDS

Sideways Son of Anjani (Lord Hanuman) Lunge Pose

Parshva Anjaneyasana
(PAHRSH-vuh uhn-juh-ney-AHS-uh-nuh)
Modification: back knee on the floor; one hand to the inside of the opposite knee, other arm up over the head
Pose Type: standing, side bend, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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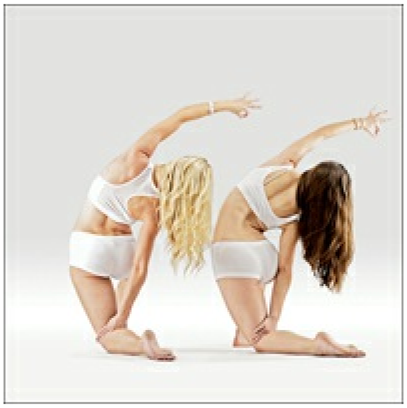

Revolved Paying Homage Lunge Pose

Parivritta Namasyasana

(puh-ri-VRIT-tuh nuh-muh-SYAHS-uh-nuh)

Also Known As: Curtsey Lunge
Modification: front leg crossed over to the side, opposite elbow over the front knee, back knee on the floor
Pose Type: standing, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

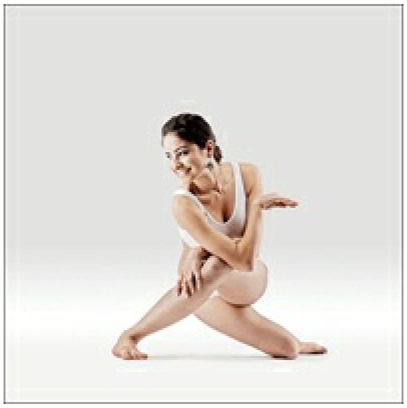

Revolved Son of Anjani (Lord Hanuman) Lunge Pose

Parivritta Anjaneyasana

(puh-ri-VRIT-tuh uhn-juh-ney-AHS-uh-nuh)

Modification: back knee on the floor, toes curled in; one hand to the floor, other arm up in the sky; twisting to the inside of the front knee
Pose Type: standing, twist
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

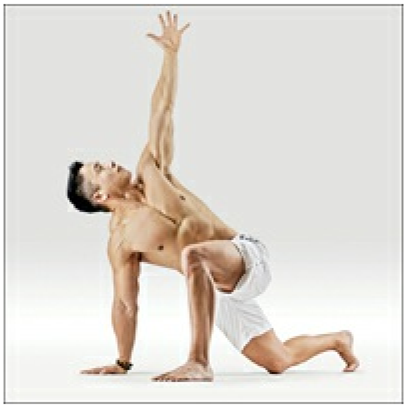

Tip Toe Sideways Son of Anjani (Lord Hanuman) Lunge Pose

Prapada Parshva Anjaneyasana

(PRUH-puh-duh PAHRSH-vuh uhn-juh-ney-AHS-uh-nuh)

Modification: back knee on the floor, toes pointed to the back, one hand to the floor, other arm up in the sky, twisting to the outside of the front knee
Pose Type: standing, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

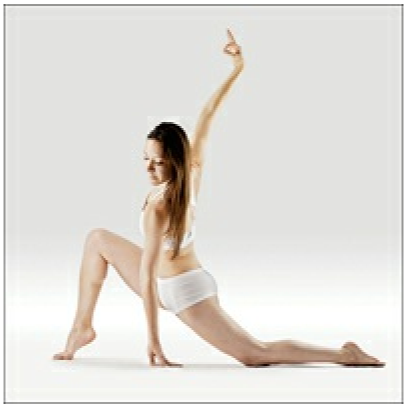

Revolved Son of Anjani (Lord Hanuman) Lunge Pose

Parivritta Anjaneyasana

(puh-ri-VRIT-tuh uhn-juh-ney-AHS-uh-nuh)

Also Known As: Revolved Monkey Pose (Parivritta Anjaneyasana)
Modification: back knee on the floor
Pose Type: standing, twist
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)

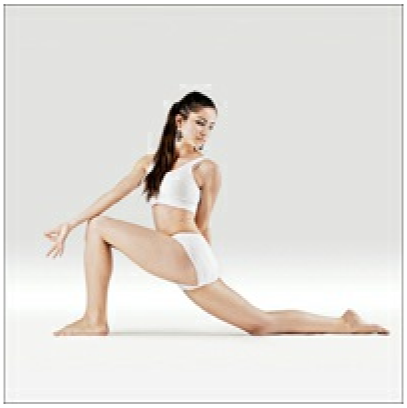

Tip Toe Revolved Son of Anjani (Lord Hanuman) Lunge Pose

Prapada Parivritta Anjaneyasana

(PRUH-puh-duh puh-ri-VRIT-tuh uhn-juh-ney-AHS-uh-nuh)

Pose Type: standing, twist

Drishti Point: Nasagrai or Nasagre (nose)

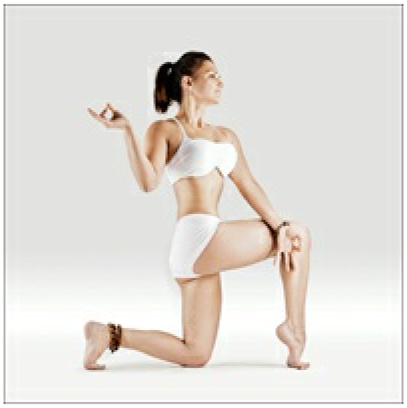

Horse Pose Prep.

Vatayanasana Prep.

(vah-tah-yuh-NAHS-uh-nuh)

Modification: back knee and foot on the floor

Pose Type: standing

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

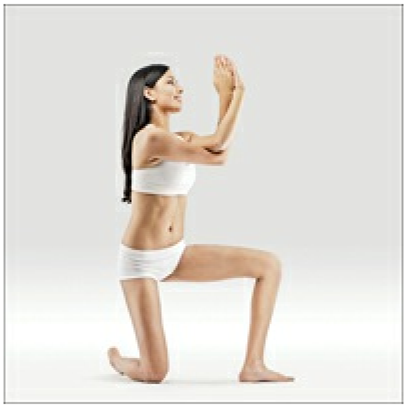

Fighting Warrior Pose 1

Yudhasana 1

(yu-DAHS-uh-nuh)

Pose Type: standing

Drishti Point: Hastagrai or Hastagre (hands)

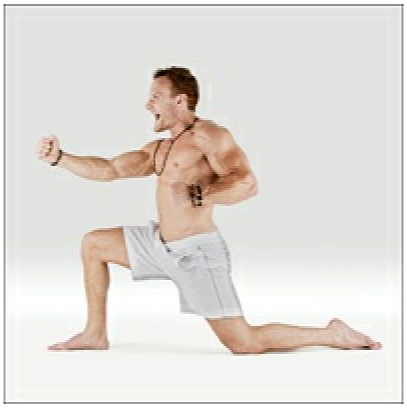

Fighting Warrior Pose 2

Yudhasana 2

(yu-DAHS-uh-nuh)

Modification: back knee on the floor

Pose Type: standing

Drishti Point: Hastagrai or Hastagre (hands)

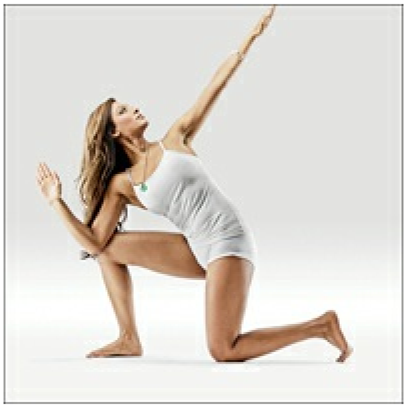

LUNGE: BACK KNEE ON THE FLOOR UNDER THE HIP SOCKET—FORWARD BEND

Half Equestrian Riding Horse Lunge Pose

Ardha Ashva Sanchalanasana

(UHR-duh UHSH-vuh suhn-chuh-luh-NAHS-uh-nuh)

Modification: spine in Cat Tilt, back knee down, toes pointing away from the head
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

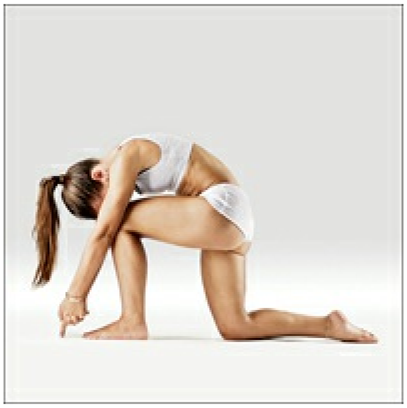

Tip Toe Bound Son of Anjani (Lord Hanuman) Lunge Pose

Prapada Baddha Anjaneyasana

(PRUH-puh-duh BUH-duh uhn-juh-ney-AHS-uh-nuh)
Modification: front leg bound, back knee on the floor, toes pointing away from the head
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

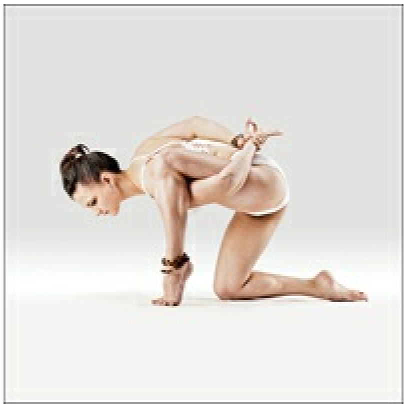

One Foot Behind the Head Extended Lizard Tail Lunge Pose

Eka Pada Shirsha Uttana Pristhasana

(EY-kuh PUH-duh SHEER-shuh ut-TAHN-uh prish-TAHS-uh-nuh)
Modification: back knee under the hip, toes pointing away from the head
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

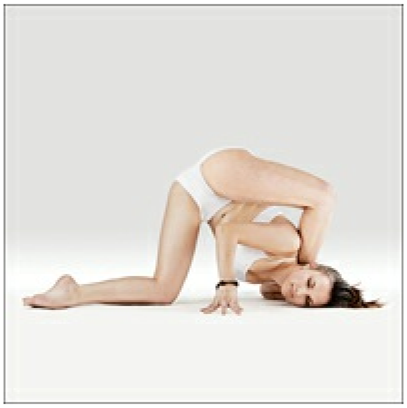

One Foot Behind the Head Extended Lizard Tail Lunge Pose

Eka Pada Shirsha Uttana Pristhasana

(EY-kuh PUH-duh SHEER-shuh ut-TAHN-uh prish-TAHS-uh-nuh)

Modification: legs working toward full vertical splits, toes of the back leg curled in
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

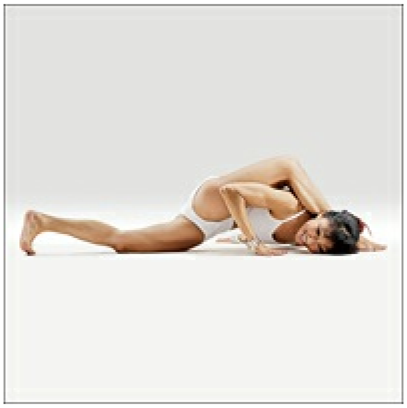

LUNGE: BACK KNEE ON THE FLOOR UNDER THE HIP SOCKET—BACKBEND

Son of Anjani (Lord Hanuman) Lunge Pose

Anjaneyasana

(uhn-juh-ney-AHS-uh-nuh)

Modification: deep backbend; chest open, arms to the side, elbows bent; back knee on the floor, toes pointing away from the head
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

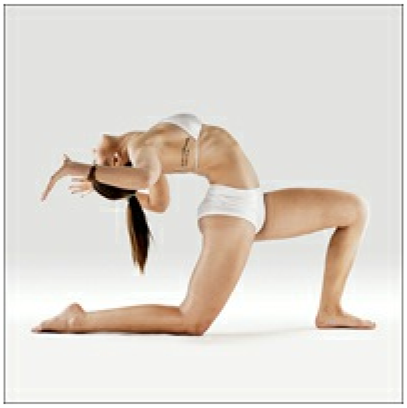

Tip Toe One Hand to Foot Son of Anjani (Lord Hanuman) Lunge Pose

Prapada Eka Hasta Pada Anjaneyasana

(PRUH-puh-duh EY-kuh HUH-stuh PUH-duh uhn-juh-ney-AHS-uh-nuh)

Modification: deep backbend; hand to the ankle on the same side
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

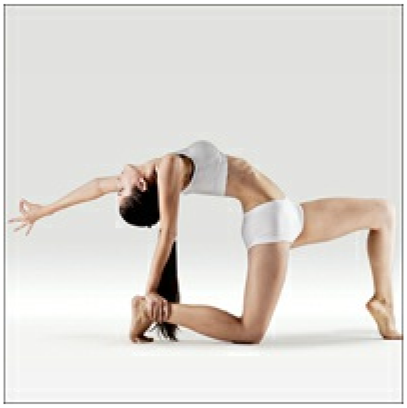

Both Hands to Foot Son of Anjani (Lord Hanuman) Lunge Pose

Dwi Hasta Pada Anjaneyasana

(DWI-huh-stuh PUH-duh uhn-juh-ney-AHS-uh-nuh)

Modification: backbend
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

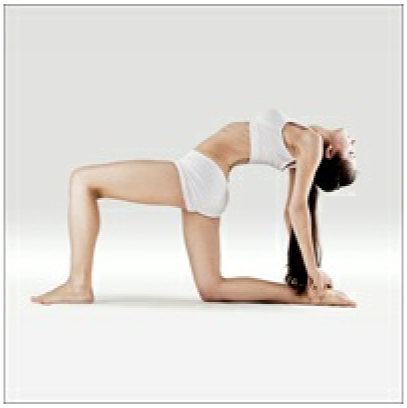

Tip Toe Both Hands to Foot Son of Anjani (Lord Hanuman) Lunge Pose

Prapada Dwi Hasta Pada Anjaneyasana

(PRUH-puh-duh DWI-huh-stuh PUH-duh uhn-juh-ney-AHS-uh-nuh)

Modification: deep backbend, back knee on the floor, back toes curled in

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

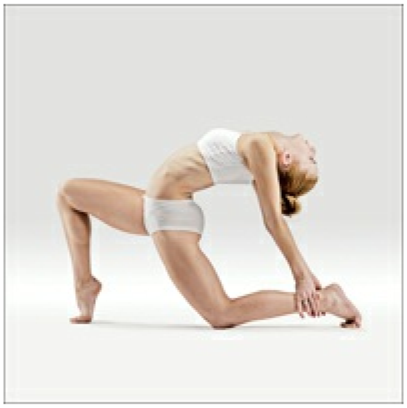

LUNGE: BACK KNEE ON THE FLOOR—FOOT OFF THE FLOOR

One-Legged King Pigeon Pose 2 Prep.

Eka Pada Raja Kapotasana 2 Prep.

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: arms open wide and raised

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

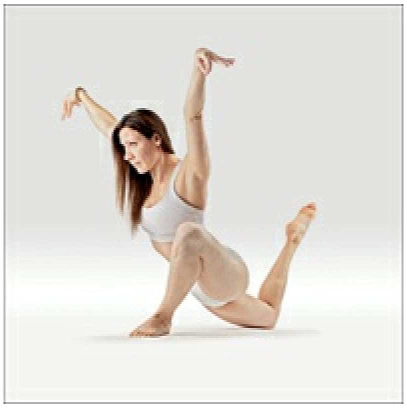

Half Bound Revolved One-Legged King Pigeon Pose 2 Prep.

Ardha Baddha Parivritta Eka Pada Raja Kapotasana 2 Prep.

(UHR-duh BUH-duh puh-ri-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Pose Type: standing, twist, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
ल व

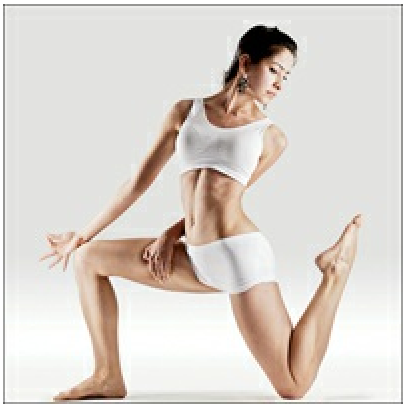

Tip Toe Extended Lizard Tail Lunge Pose Prep.

Prapada Uttana Pristhasana Prep.

(PRUH-puh-duh ut-TAHN-uh prish-TAHS-uh-nuh)

Modification: arms straight to semi-straight, back foot lifted off the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
ल व ह ॐ

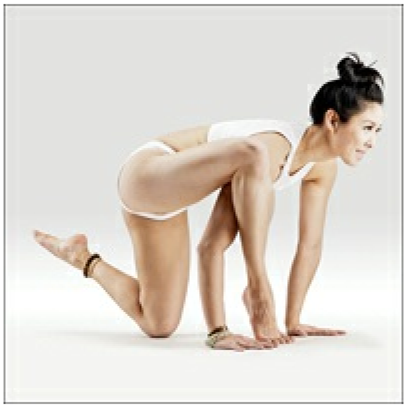

Bound Revolved Side Angle Pose Prep.

Baddha Parivritta Parshva Konasana Prep.

(BUH-duh puh-ri-VRIT-tuh pahrsh-vuh-ko-NAHS-uh-nuh)

Also Known As: Bound Revolved Son of Anjani (Lord Hanuman) Lunge Pose Prep. (Anjaneyasana Prep.)
Modification: back knee bent, heel toward the sitting bone
Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

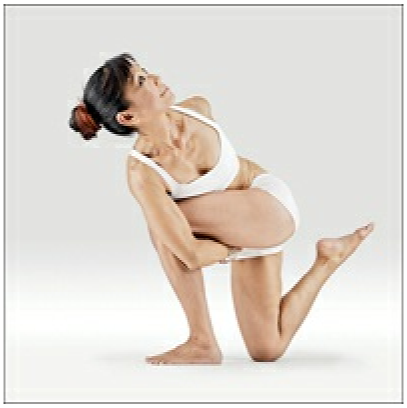

Foot to Knee Revolved Son of Anjani (Lord Hanuman) Lunge Pose with Hands in Prayer

Janu Pada Parivritta Anjaneyasana Namaskar

(JAH-nu PUH-duh puh-ri-VRIT-tuh uhn-juh-ney-AHS-uh-nuh nuh-muhs-KAHR)

Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

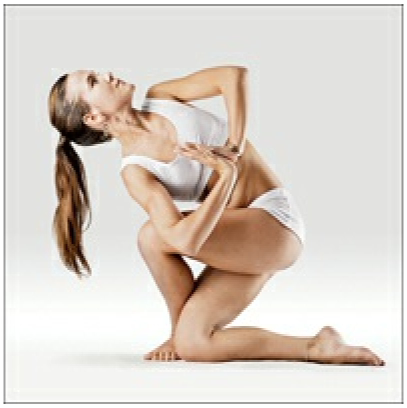

LUNGE: BACK KNEE ON THE FLOOR—GRABBING ONTO THE BACK FOOT

Tip Toe One-Legged King Pigeon Pose 2 Prep.

Prapada Eka Pada Raja Kapotasana 2 Prep.

(PRUH-puh-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: both hands grabbing onto the back foot with under-head grip
Pose Type: standing, mild backbend
Drishti Point: Nasagrai or Nasagre (nose)

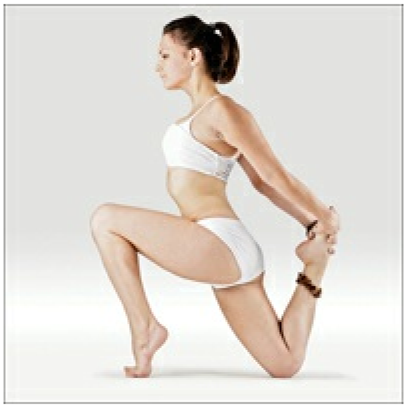

Revolved One-Legged King Pigeon Pose 2 Prep.

Parivritta Eka Pada Raja Kapotasana 2 Prep.

(puh-ri-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: grabbing onto the back foot with the opposite hand using an under-head grip, twisting toward the front knee
Pose Type: standing, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

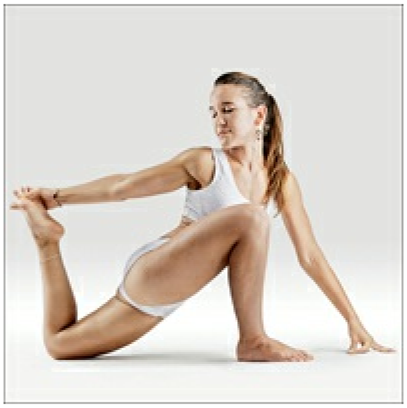

One Hand in Prayer Revolved One-Legged King Pigeon Pose 2 Prep.

Eka Hasta Namaskar Parivritta Eka Pada Raja Kapotasana 2 Prep.

(EY-kuh HUH-stuh nuh-muhs-KAHR puh-ri-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: opposite hand to the back foot, other hand to the heart

Pose Type: standing, forward bend, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky)

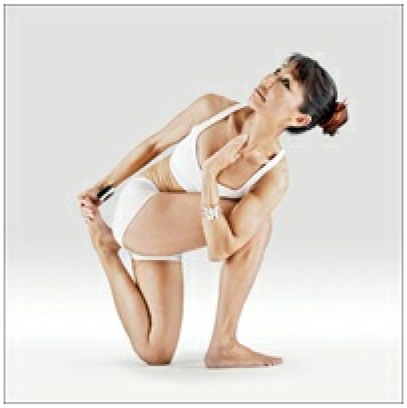

One Hand to Foot Extended Lizard Tail Lunge Pose

Eka Hasta Pada Uttana Pristhasana

(EY-kuh HUH-stuh PUH-duh ut-TAHN-uh prish-TAHS-uh-nuh)

Modification: forward bend, elbow to the floor, grabbing onto the back foot with opposite hand, heel to the glutes

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

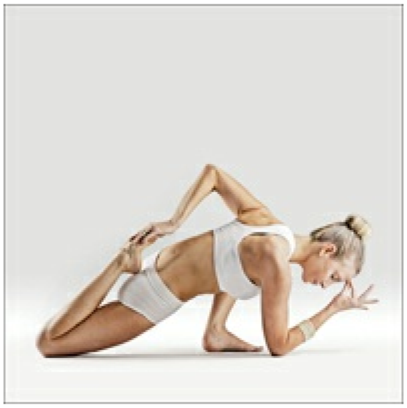

LUNGE: BACK KNEE ON THE FLOOR—FOOT TO THE HIP SOCKET

Spear Pose Prep.

Kuntasana Prep.

(kun-TAHS-uh-nuh)

Modification: grabbing onto the foot with one hand, arm crossed over in front, other arm parallel to the floor, foot away from the hip
Pose Type: standing, twist
Drishti Point: Hastagrai or Hastagre (hands)
ल व य

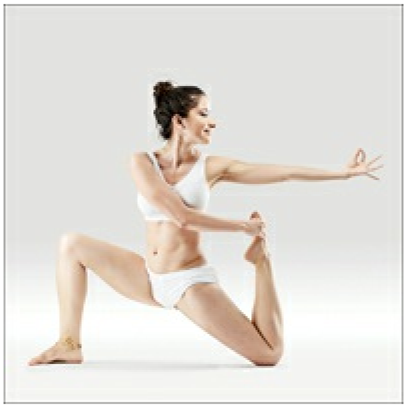

Spear Pose

Kuntasana

(kun-TAHS-uh-nuh)

Modification: grabbing onto the foot with one hand, arm crossed over in front, other hand to the knee, foot close to the hip
Pose Type: standing, twist
Drishti Point: Hastagrai or Hastagre (hands)

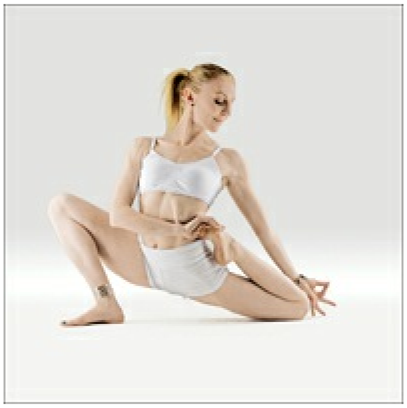

Both Hands Bound Revolved Spear Pose Prep.

Dwi Hasta Baddha Parivritta Kuntasana Prep.

(dwi HUH-stuh BUH-duh puh-ri-VRIT-tuh kun-TAHS-uh-nuh)

Pose Type: standing, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

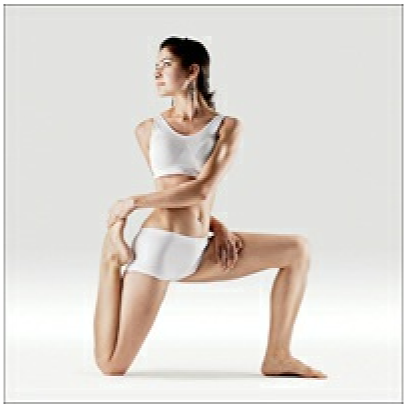

Spear Pose with Hands in Prayer

Kuntasana Namaskar

(kun-TAHS-uh-nuh nuh-muhs-KAHR)

Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

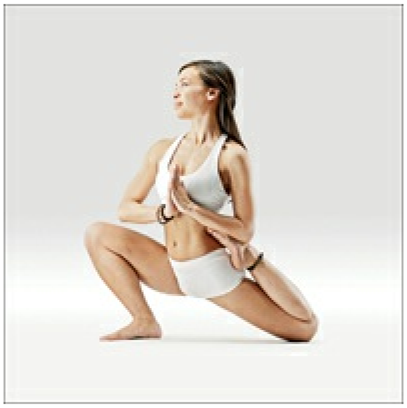

Half Bound Revolved Spear Pose Prep.

Ardha Baddha Parivritta Kuntasana Prep.

(UHR-duh-BUH-duh puh-ri-VRIT-tuh kun-TAHS-uh-nuh)

Modification: foot to the inside of the elbow
Pose Type: standing, twist, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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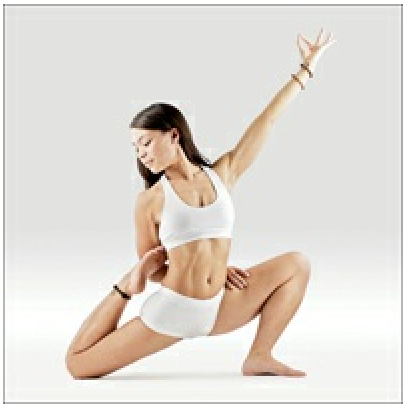

Spear Pose

Kuntasana

(kun-TAHS-uh-nuh)

Pose Type: standing
Drishti Point: Hastagrai or Hastagre (hands)
● ● ●

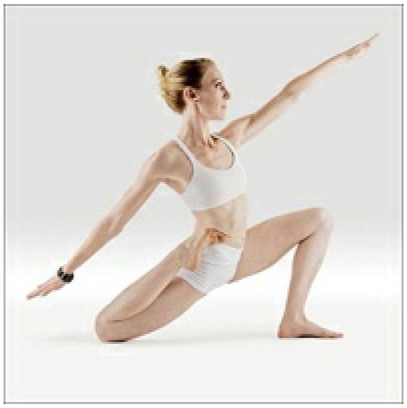

Hands Bound Ankle Stretch Pose

Baddha Hasta Kulpasana

(BUH-duh HUH-stuh kul-PAHS-uh-nuh)

Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

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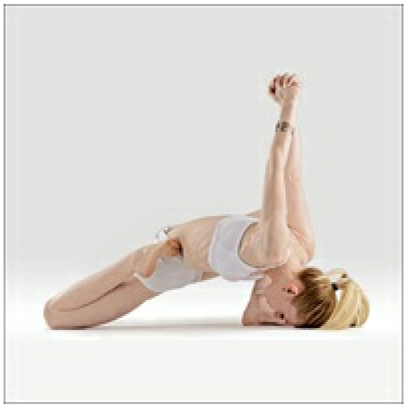

LUNGE: BACK KNEE ON THE FLOOR—HEAD BEHIND THE FRONT LEG, GRABBING ONTO THE BACK FOOT

One Foot Behind the Head Extended Lizard Tail Lunge Pose

Eka Pada Shirsha Uttana Pristhasana

(EY-kuh PUH-duh SHEER-shuh ut-TAHN-uh prish-TAHS-uh-nuh)

Modification: grabbing onto the foot with the opposite hand, back knee under the hips
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

● ●

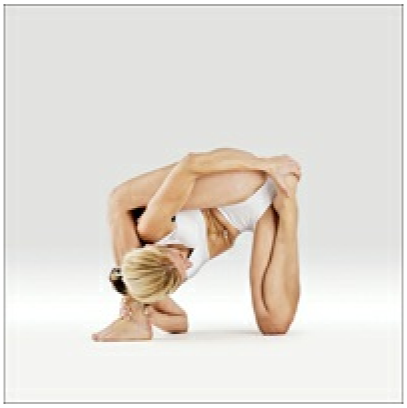

One Foot Behind the Head Extended Lizard Tail Lunge Pose

Eka Pada Shirsha Uttana Pristhasana

(EY-kuh PUH-duh SHEER-shuh ut-TAHN-uh prish-TAHS-uh-nuh)

Modification: grabbing onto the foot with the opposite hand, chest and quadriceps on the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

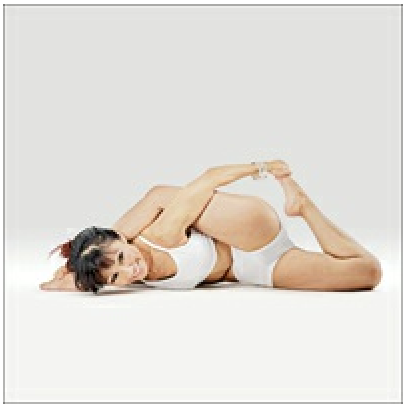

LUNGE: BACK KNEE ON FLOOR—ONE-LEGGED KING PIGEON 2

One-Legged King Pigeon Pose 2 Prep.

Eka Pada Raja Kapotasana 2 Prep.

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: back knee bent toward the glutes, front heel down; arms on the sides, spine straight
Pose Type: standing
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

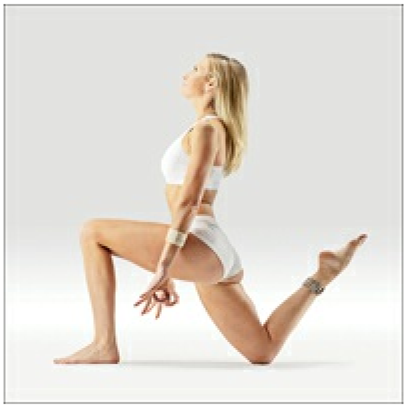

Tip Toe One-Legged King Pigeon Pose 2 Prep.

Prapada Eka Pada Raja Kapotasana 2 Prep.

(PRUH-puh-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: back knee bent toward the glutes, heel of the top foot up; hands on the hips, backbend
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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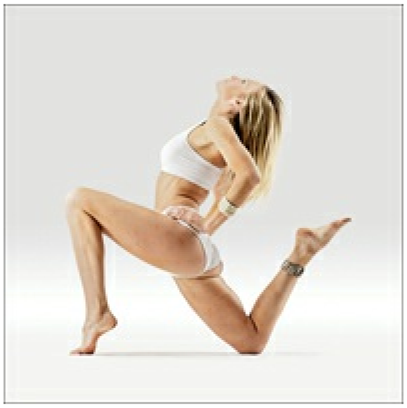

One-Legged King Pigeon Pose 2

Eka Pada Raja Kapotasana 2

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: prep.—arms up over the head, back knee bent toward the glutes
Pose Type: standing, mild backbend
Drishti Point: Nasagrai or Nasagre (nose)
लं वं यं

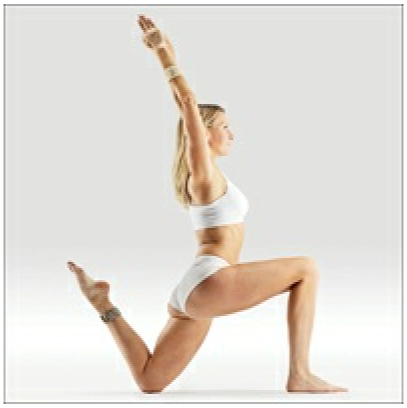

Tip Toe One-Legged King Pigeon Pose 2 Prep.

Prapada Eka Pada Raja Kapotasana 2 Prep.

(PRUH-puh-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: fingertips to the floor, front heel lifted

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

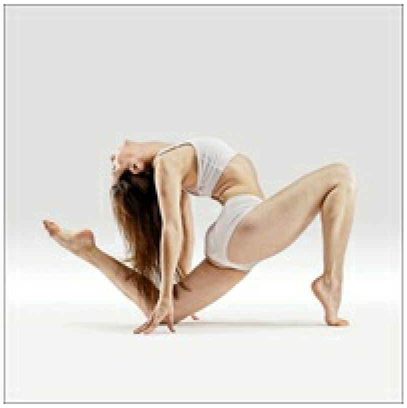

Intense Ankle Stretch One-Legged King Pigeon Pose 2

Uttana Kulpa Eka Pada Raja Kapotasana 2

(ut-TAH-nuh kul-puh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: prep.—fingertips to the floor, front toes curled under

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

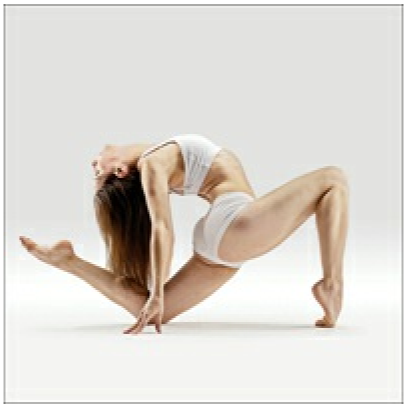

LUNGE: BACK KNEE ON FLOOR—ONE-LEGGED KING PIGEON 2

One-Legged King Pigeon Pose 2 Prep.

Eka Pada Raja Kapotasana 2 Prep.

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: 1. grabbing onto the foot on the same side
2. grabbing onto the foot with the hand on the same side, foot toward the hip
3. grabbing onto the foot with the opposite hand, foot twisted toward the opposite glute
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

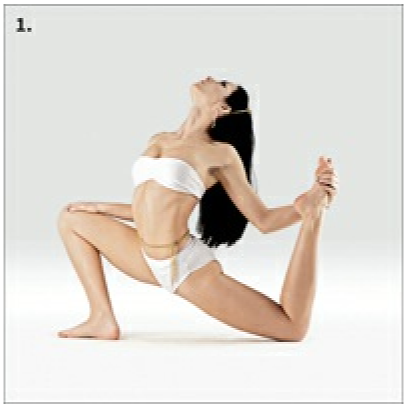

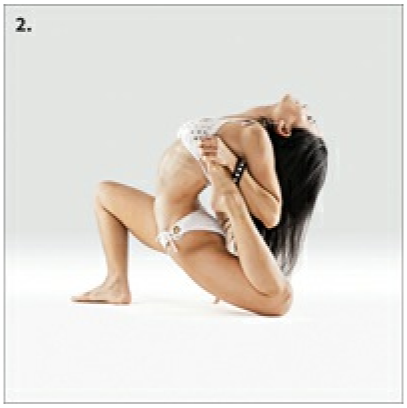

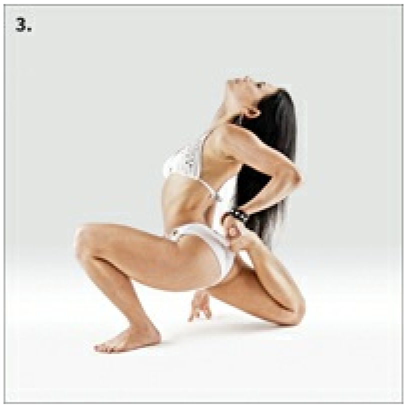

Revolved One-Legged King Pigeon Pose 2

Parivritta Eka Pada Raja Kapotasana 2

(puh-ree-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Pose Type: standing, forward bend, twist

Drishti Point: Parsva Drishti (to the right), Parsva Drishti (to the left)

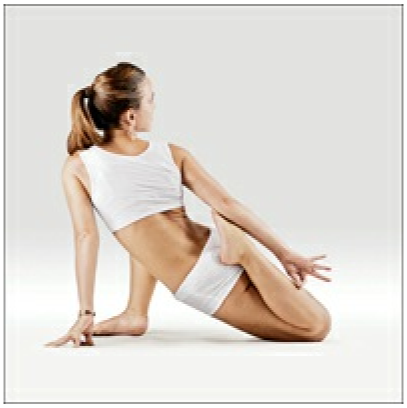

Mermaid Pose 2

Naginyasana 2

(nuh-gin-YAHS-uh-nuh)

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

LUNGE: BACK KNEE ON FLOOR—ONE-LEGGED KING PIGEON 2—OVERHEAD GRIP

One-Legged King Pigeon Pose 2

Eka Pada Raja Kapotasana 2

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: grabbing onto the foot with the opposite hand, palm of the other hand to the floor on the side
1. foot to the head
2. heel to the forehead
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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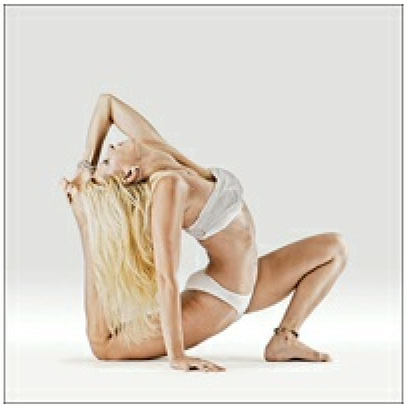

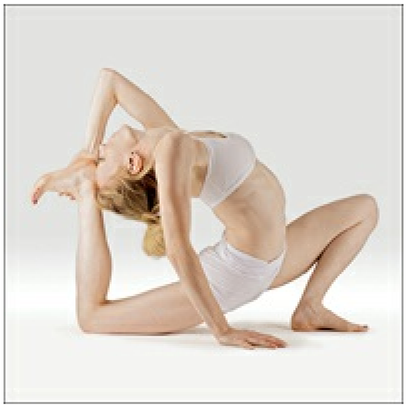

One-Legged King Pigeon Pose 2

Eka Pada Raja Kapotasana 2

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: both hands grabbing onto the foot
1. foot to the head
2. heel to the forehead

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

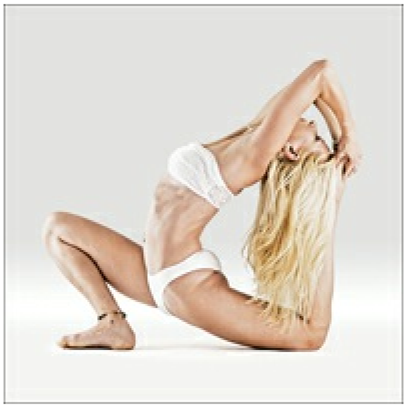

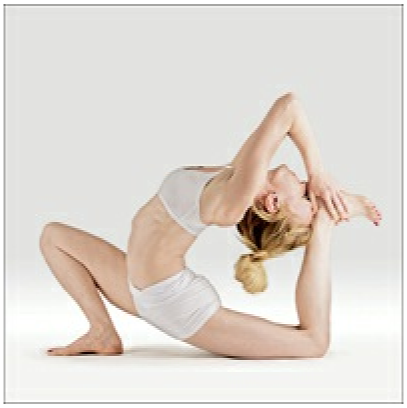

Half Bound One-Legged King Pigeon Pose 2

Ardha Baddha Eka Pada Raja Kapotasana 2

(UHR-duh BUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Pose Type: standing, backbend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

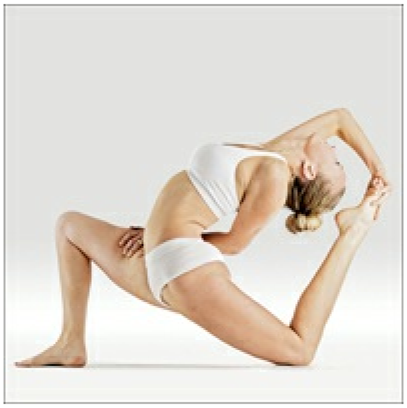

LUNGE: BACK KNEE ON FLOOR—ONE-LEGGED KING PIGEON 2—FOOT TO THE BACK OF THE HEAD

Necklace Pose Prep.

Graivasana Prep.

(gr-eye-VAHS-uh-nuh)
Also Known As: Chain Pose (Gaivasana)
Modification: back foot to the back of the head, hands to the floor
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

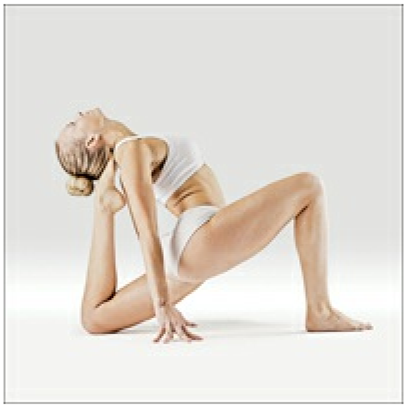

Necklace Pose Prep.

Graivasana Prep.

(gr-eye-VAHS-uh-nuh)
Also Known As: Chain Pose (Gaivasana)
Modification: back foot to the back of the head, hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

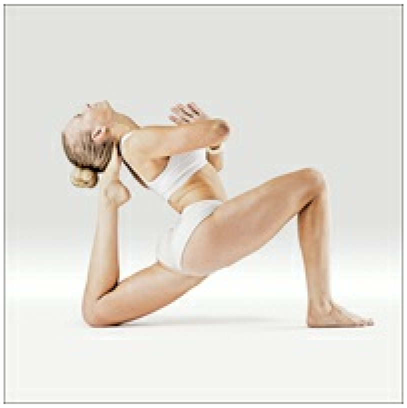

LUNGE: BACK KNEE ON FLOOR—ONE-LEGGED KING PIGEON 2—ARM CROSSED OVER IN FRONT

Bound Hand to Foot Supported One-Legged King Pigeon Pose 2

Baddha Hasta Pada Salamba Eka Pada Raja Kapotasana 2

(BUH-duh HUH-stuh PUH-duh SAH-luhm-buh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: arm crossed in front of the neck, other hand to the floor
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

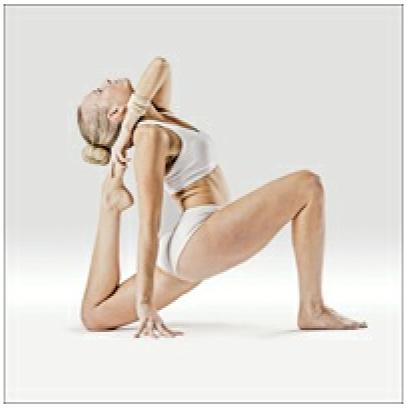

Bound Hand to Foot Unsupported One-Legged King Pigeon Pose 2

Baddha Hasta Pada Niralamba Eka Pada Raja Kapotasana 2

(BUH-duh HUH-stuh PUH-duh nir-AH-luhm-buh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: arm crossed in front of the neck, other arm straight out in front
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

LUNGE: FRONT LEG STRAIGHT—BACKBEND

Both Hands to Foot Son of Anjani (Lord Hanuman) Lunge Pose

Dwi Hasta Pada Anjaneyasana

(DWI-huh-stuh PUH-duh uhn-juh-ney-AHS-uh-nuh)

Modification: front leg straight
1. back knee on the floor
2. back knee off the floor

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

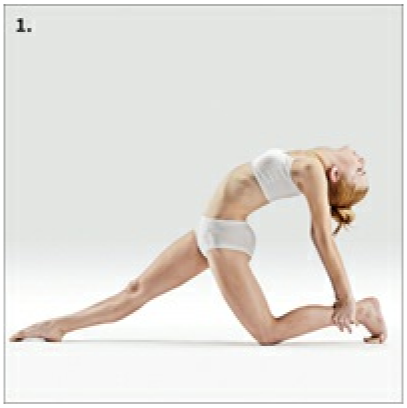

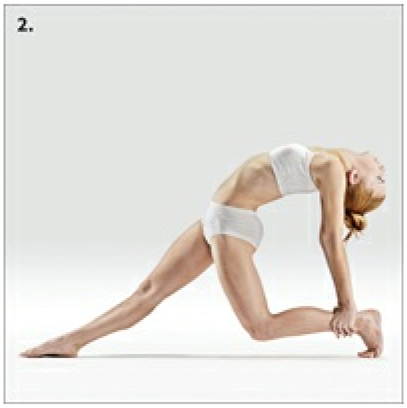

2.

Gate Pose

Parighasana

(puh-ri-GAHS-uh-nuh)

Pose Type: standing, side bend

Drishti Point: Hastagrai or Hastagrahe (hands)

How to Perform the Pose:

1. Begin by standing on your knees with sitting bones lifted off the feet. (Make sure your knees are comfortable by rolling up the yoga mat a couple of times.) Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale and extend your right leg straight out to the side with the right foot on the floor. You can either point the toes to the right (Pose #1) or point your toes straight ahead, lifting the arch and pressing the outside edge of the right foot to the floor (Pose #2).
3. Inhale as you expand your chest and hold your arms straight out to the sides, parallel to the floor.
4. On your next exhale, side bend to the right and bring your right hand onto your right shin (Pose #2), while extending your left arm over your head to the right with the palm facing down. Make sure your chest is rotated to face forward and not collapsing toward the floor. Look toward your right hand. You can also experiment with dropping your right palm to the floor on the inside of your right leg (Pose #1).
5. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch. Inhale as you come up and bring your right knee back to the floor by your left knee. Repeat on the other side.

Modification: bending to the opposite side of the bent knee on the floor
1. palm to the floor, toes of the straight leg pointing to the side
2. hand on the shin, toes of the straight leg pointing straight ahead

parigha = iron bar used for locking a gate

1.

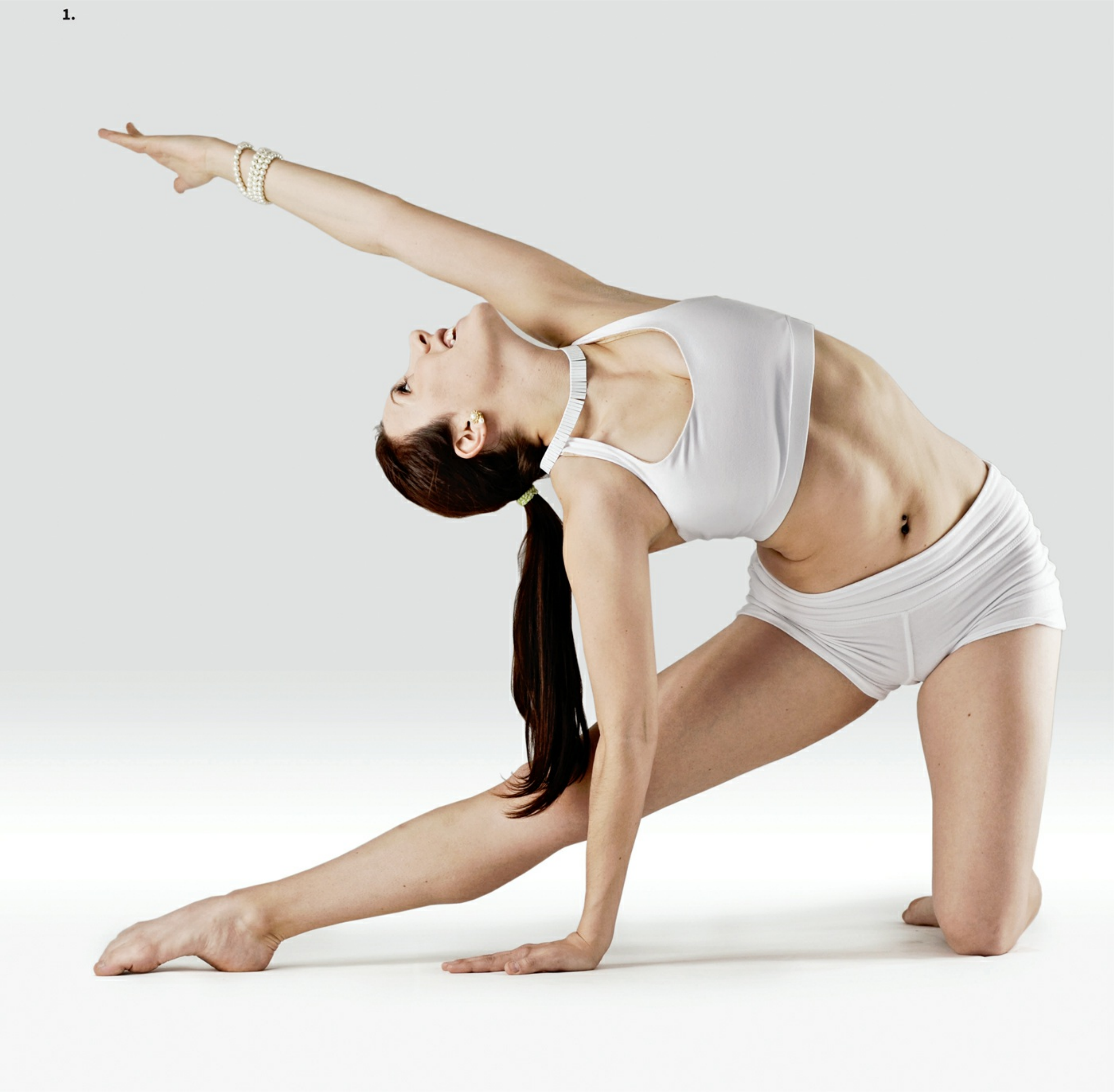

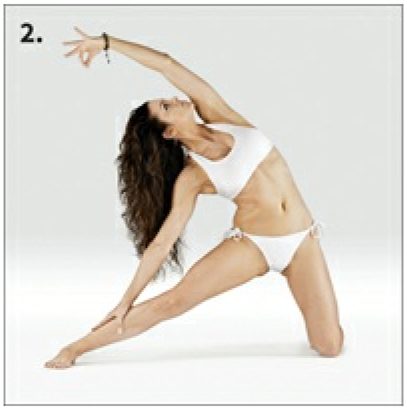

2.

Gate Pose

Parighasana

(puh-ri-GAHS-uh-nuh)

Modification: bending to the side of the bent knee on the floor, hand to the floor on the outside of the bent leg, toes of the straight leg pointing straight ahead
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)
● ●

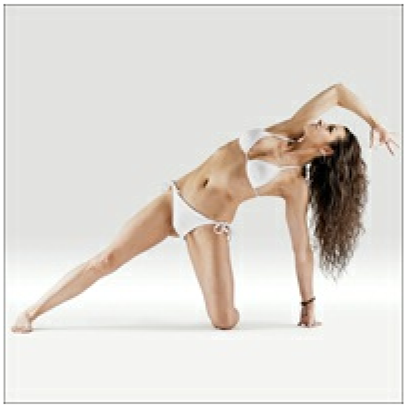

Half Bound Gate Pose

Ardha Baddha Parighasana

(UHR-duh BUH-duh puh-ri-GAHS-uh-nuh)

Modification: bending to the side of the bent knee on the floor, forearm to the floor on the side of the bent leg, toes of the straight leg pointing straight ahead
Pose Type: standing, side bend, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)
● ● ●

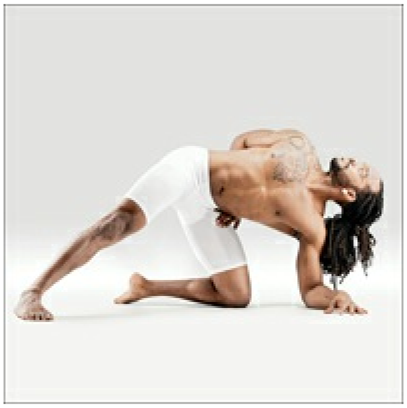

Gate Pose

Parighasana

(puh-ri-GAHS-uh-nuh)

Modification: bending to the opposite side of the bent knee on the floor, forearm to the floor, toes of the straight leg pointing to the side

Pose Type: standing, forward bend, side bend

Drishti Point: Hastagrai or Hastagre (hands)

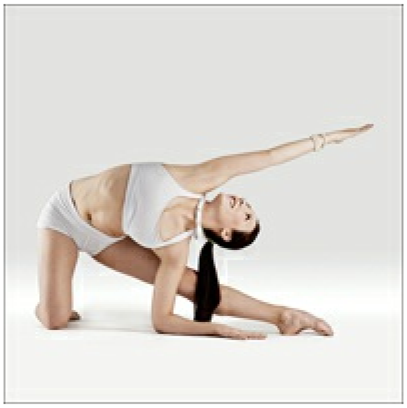

ONE LEG STRAIGHT OTHER KNEE ON THE FLOOR: SIDE BEND & BINDING

Gate Pose

Parighasana

(puh-ri-GAHS-uh-nuh)

Modification: bending to the opposite side of the bent knee on the floor, palm to the top of the foot of the straight leg, toes of the straight leg pointing to the side

Pose Type: standing, forward bend, side bend

Drishti Point: Hastagrai or Hastagre (hands)

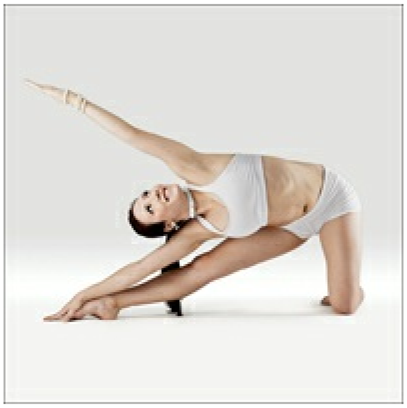

Gate Pose

Parighasana

(puh-ri-GAHS-uh-nuh)

Modification: bending to the opposite side of the bent knee on the floor, both hands to the top of the foot of the straight leg, toes of the straight leg pointing to the side
Pose Type: standing, forward bend, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)
ल व

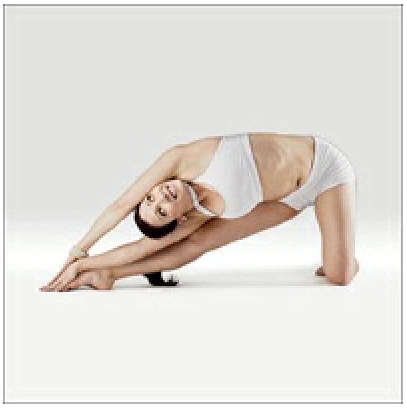

Revolved Half Bound Gate Pose

Parivritta Ardha Baddha Parighasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh puh-ri-GAHS-uh-nuh)

Modification: hand to the floor on the outside of the straight leg, rotating the chest to the sky, toes of the straight leg pointing to the side
Pose Type: standing, side bend, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)
ल व य

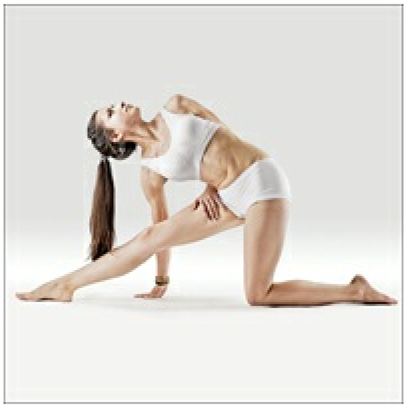

Revolved Bound Gate Pose

Parivritta Baddha Parighasana

(puh-ri-VRIT-tuh BUH-duh puh-ri-GAHS-uh-nuh)

Modification: toes of the straight leg flexed in, toes of the bent leg pointing away from the head
Pose Type: standing, forward bend, side bend, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

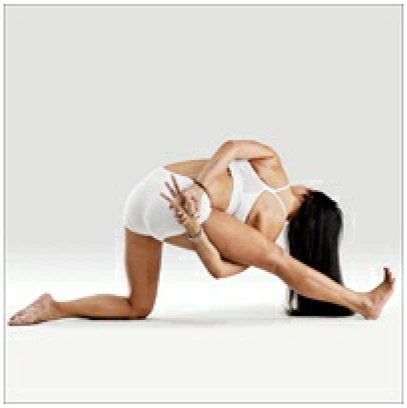

Revolved Bound Half Lotus Gate Pose

Parivritta Baddha Ardha Padma Parighasana

(puh-ri-VRIT-tuh BUH-duh UHR-duh PUHD-muh puh-ri-GAHS-uh-nuh)

Modification: toes of the straight leg pointing to the side
Pose Type: standing, side bend, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

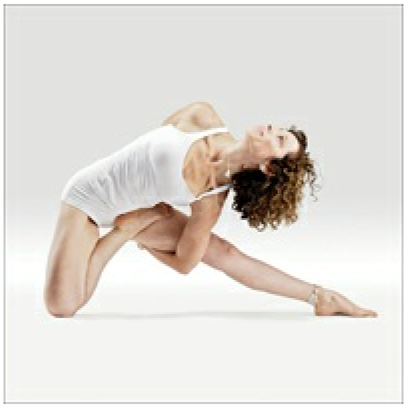

ONE LEG STRAIGHT OTHER KNEE ON THE FLOOR: TWISTS

Revolved Gate Pose

Parivritta Parighasana

(puh-ri-VRIT-tuh puh-ri-GAHS-uh-nuh)

Modification: forearm to the floor, hand grabbing onto the opposite foot, other arm straight up to the sky, toes of the straight leg pointed to the side, toes of the bent leg pointing away from the head
Pose Type: standing, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

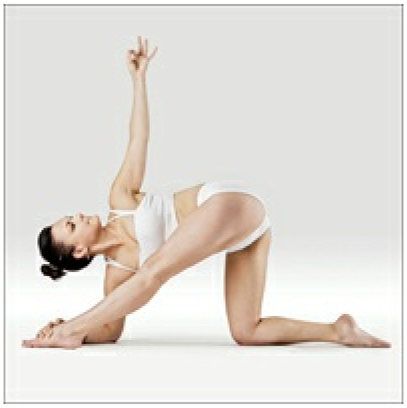

Revolved Half Bound Gate Pose

Parivritta Ardha Baddha Parighasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh puh-ri-GAHS-uh-nuh)

Modification: forearm to the floor, twisting toward the straight leg, toes of the straight leg pointing to the side
Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

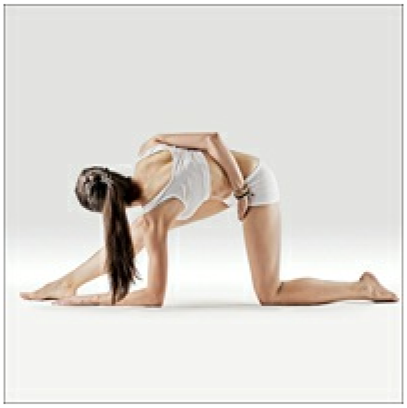

Half Pose Dedicated to Lord Hanuman

Ardha Hanumanasana

(UHR-duh huh-nu-mahn-AHS-uh-nuh)

Also Known As: Pose Dedicated to Lord Hanuman Prep. (Hanumanasana Prep.)
Modification: back toes pointed away from the head, fingertips to the floor on the outsides of the straight leg
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

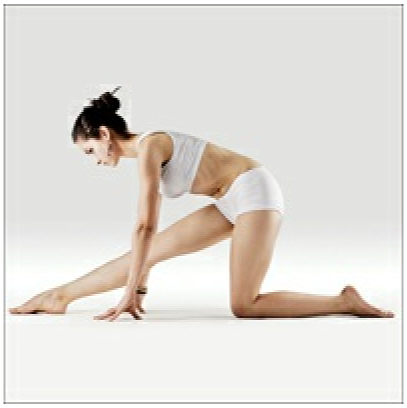

Half Pose Dedicated to Lord Hanuman

Ardha Hanumanasana

(UHR-duh huh-nu-mahn-AHS-uh-nuh)

Also Known As: Pose Dedicated to Lord Hanuman Prep. (Hanumanasana Prep.)
Modification: back toes curled in, toes of the straight leg flexed in, arms extended to the front, fingertips to the floor
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

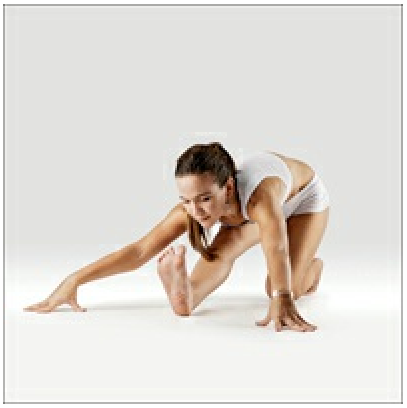

Half Bound Half Pose Dedicated to Lord Hanuman

Ardha Baddha Ardha Hanumanasana

(UHR-duh BUH-duh UHR-duh huh-nu-mahn-AHS-uh-nuh)

Also Known As: Pose Dedicated to Lord Hanuman Prep. (Hanumanasana Prep.)
Modification: toes of the bent leg pointed away from the head
Pose Type: standing, forward bend, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

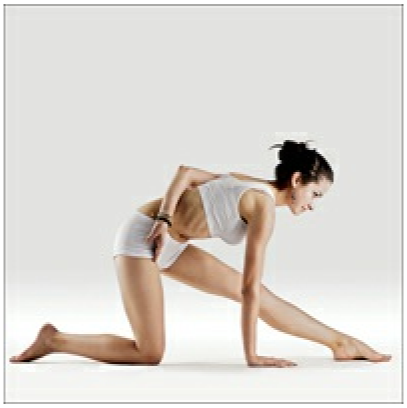

Half Pose Dedicated to Lord Hanuman

Ardha Hanumanasana

(UHR-duh huh-nu-mahn-AHS-uh-nuh)

Also Known As: Pose Dedicated to Lord Hanuman Prep. (Hanumanasana Prep.)
Modification: toes of the straight leg flexed in; hand grabbing onto the back foot on the same side, heel to the sitting bone
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

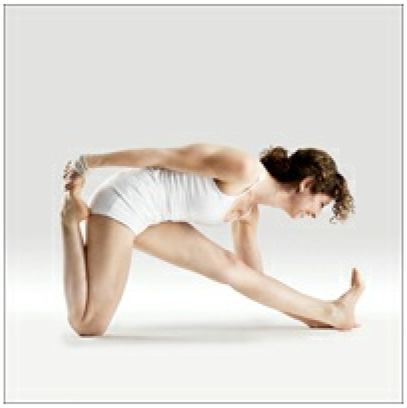

Half Lotus Half Pose Dedicated to Lord Hanuman

Ardha Padma Ardha Hanumanasana

(UHR-duh PUHD-muh UHR-duh huh-nu-mahn-AHS-uh-nuh)

Also Known As: Pose Dedicated to Lord Hanuman Prep. (Hanumanasana Prep.)
Modification: fingertips of both hands on the sides of the straight leg
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

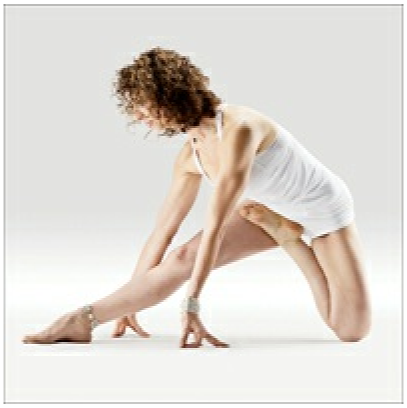

HORSE POSE: FORWARD BEND, BINDING & TWIST

Revolved Leg Position of Horse Pose with Hands in Prayer

Parivritta Pada Vatayanasana Namaskar

(puh-ri-VRIT-tuh PUH-duh vah-tah-yuh-NAHS-uh-nuh nuh-muhs-KAHR)

Pose Type: standing, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

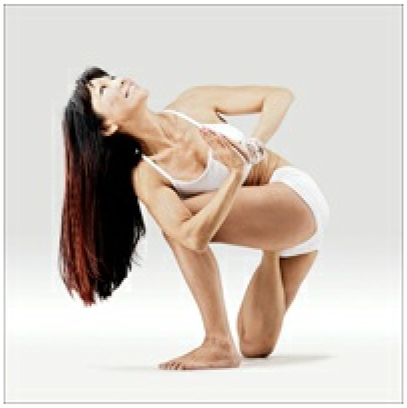

Half Lotus Extended Lizard Tail Lunge Pose

Ardha Padma Uttana Pristhasana

(UHR-duh PUHD-muh ut-TAHN-uh prish-TAHS-uh-nuh)

Modification: 1. palms to the floor, elbows bent 90 degrees
2. forearms to the floor
3. one forearm to the floor; other elbow to the floor, hand to the face
Pose Type: standing, forward bend
Drishti Point: 1 & 3. Nasagrai or Nasagre (nose)
2. Padhayoragrai or Padayoragre (toes/feet) and Angusthamadhye or Angushta Ma Dyai (thumbs)

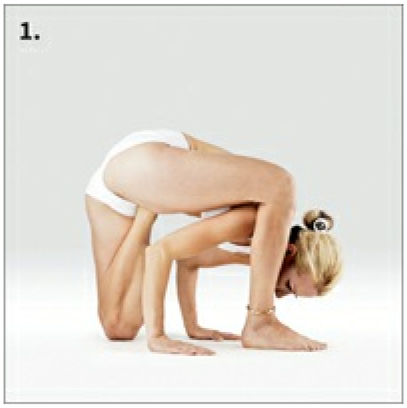

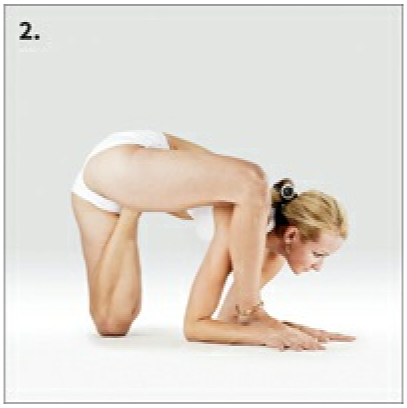

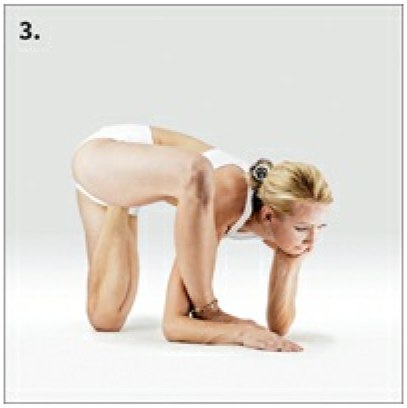

Bound Half Lotus Extended Lizard Tail Lunge Pose

Baddha Ardha Padma Uttana Pristhasana

(BUH-duh UHR-duh PUHD-muh ut-TAHN-uh prish-TAHS-uh-nuh)

Pose Type: standing, forward bend, binding

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

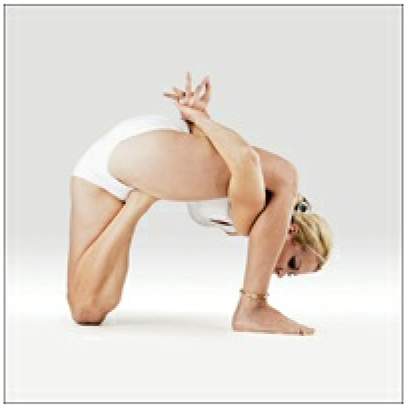

One Foot Behind the Head Bound Half Lotus Extended Lizard Tail Lunge Pose

Eka Pada Shirsha Baddha Ardha Padma Uttan Pristhasana

(EY-kuh PUH-duh SHEER-shuh BUH-duh UHR-duh PUHD-muh ut-TAHN-uh prish-TAHS-uh-nuh)

Pose Type: standing, forward bend, binding

Drishti Point: Urdhva or Antara Drishti (up to the sky)

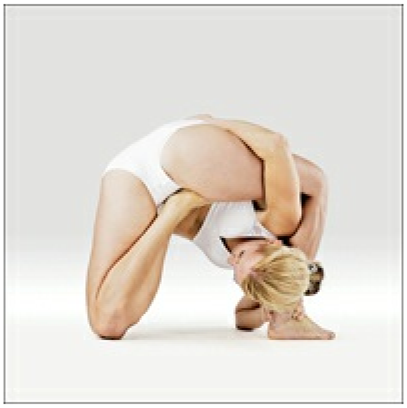

HORSE POSE: SPINE STRAIGHT

Half Bound Revolved Leg Position of Horse Pose

Ardha Baddha Parivritta Pada Vatayanasana

(UHR-duh BUH-duh puh-ri-VRIT-tuh PUH-duh vah-tah-yuh-NAHS-uh-nuh)

Modification: wrist to the knee of the front leg
Pose Type: standing, binding
Drishti Point: Hastagrai or Hastagre (hands)

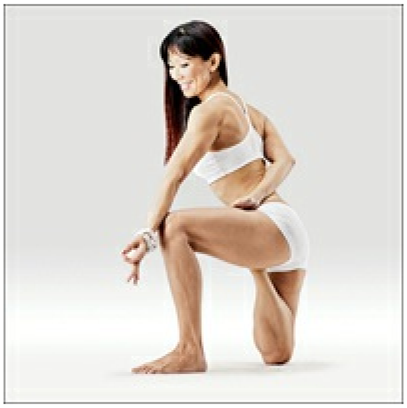

Horse Pose

Vatayanasana

(vah-tah-yuh-NAHS-uh-nuh)

Also Known As: Sea Horse Pose
Modification: 1. Front View
2. Side View
Pose Type: standing
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

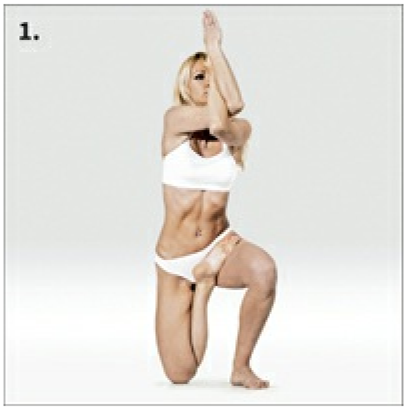
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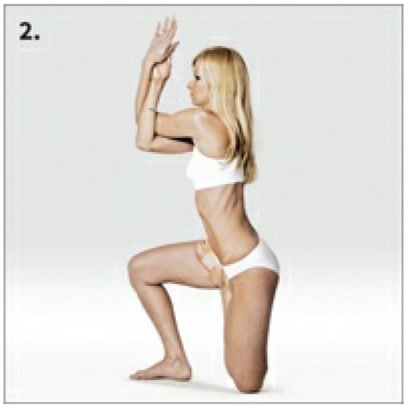
2.

ONE KNEE BENT TOWARD THE HIP: SPINE STRAIGHT

One-Legged Frog Pose in Camel Pose

Eka Pada Bhekasana in Ushtrasana

(EY-kuh PUH-duh bey-KAHS-uh-nuh in oosh-TRAHS-uh-nuh)

Modification: spine straight

Pose Type: standing (on the knees)

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

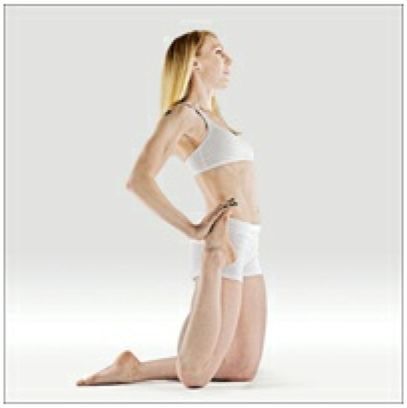

Mermaid Arm Position in Half Camel Pose

Hasta Naginyasana in Ardha Ushtrasana

(HUH-stuh nuh-gin-YAHS-uh-nuh in UHR-duh oosh-TRAHS-uhna)

Modification: spine straight
Pose Type: standing (on the knees), mild backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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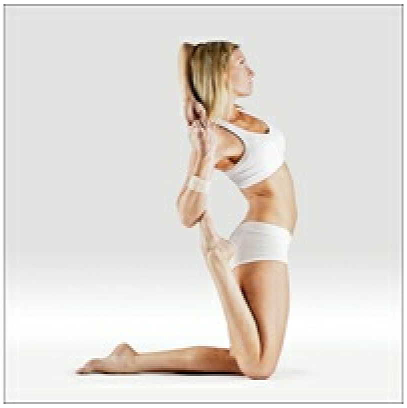

Revolved One-Legged Frog Pose in One-Legged King Pigeon 1 Version B

Parivritta Eka Pada Bhekasana in Eka Pada Raja Kapotasana 1 B

(puh-ri-VRIT-tuh EY-kuh PUH-duh bey-KAHS-uh-nuh in EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: fingertips to the floor in front
Pose Type: standing (on the knees), twist, binding
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)

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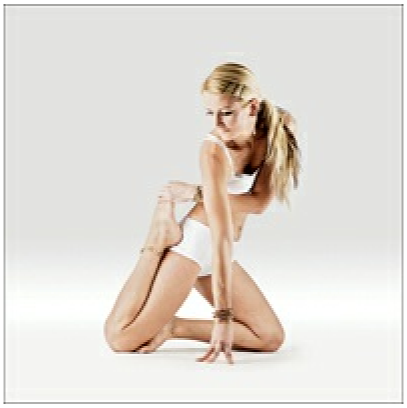

Half Bound Revolved One-Legged Frog Pose in One-Legged King

Pigeon 1 Version B

Ardha Baddha Parivritta Eka Pada Bhekasana in Eka Pada Raja Kapotasana 1 B

(UHR-duh BUH-duh puh-ri-VRIT-tuh EY-kuh PUH-duh bey-KAHS-uh-nuh in EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Pose Type: standing (on the knees), twist, binding

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

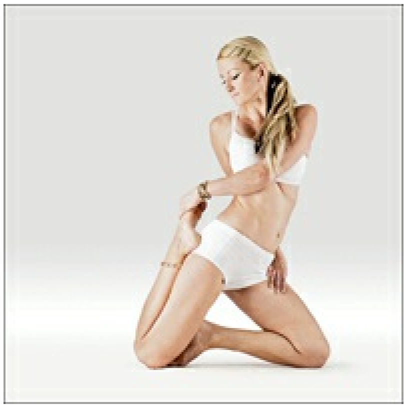

COW FACE POSE AND GARUDA ON THE KNEES

Leg Position of Cow Face Pose on the Knees

Janu Pada Gomukhasana

(JAH-nu PUH-duh go-moo-KAHS-uh-nuh)

Modification: hands on the hips

Pose Type: standing (on the knees)

Drishti Point: Nasagrai or Nasagre (nose)

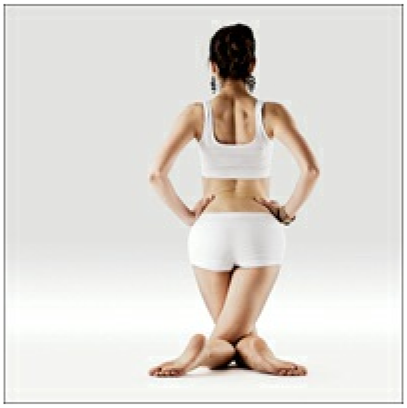

Leg Position of Cow Face Pose on the Knees

Janu Pada Gomukhasana

(JAH-nu PUH-duh go-moo-KAHS-uh-nuh)

Modification: 1. one hand on the hip, other arm straight over the head, side bend
2. one arm crossed in front of the body, other arm over the head, elbow bent, side bend
Pose Type: 1. standing (on the knees)
2. standing (on the knees), side bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Hastagrai or Hastagre (hands)
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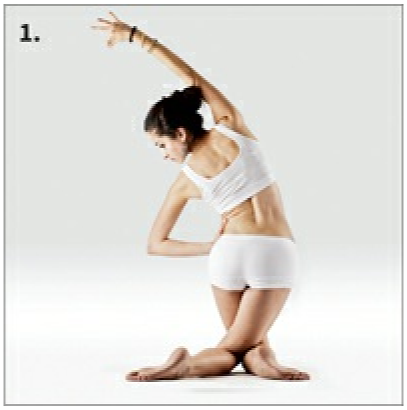

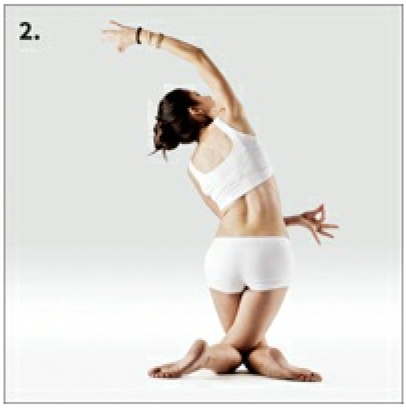

KNEES ON THE FLOOR: LOTUS POSE

Half Pose Dedicated to Sage Goraksha

Ardha Gorakshasana

(UHR-duh go-rak-SHAHS-uh-nuh)

Modification: spine straight, one hand to the heart, other hand to the side of the thigh
Pose Type: standing (on the knees), balance
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)
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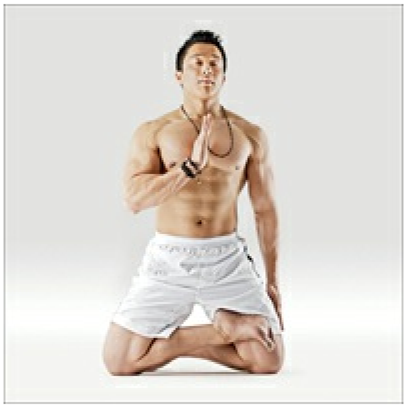

Pose Dedicated to Sage Goraksha

Gorakshasana

(go-ruhk-SHAHS-uh-nuh)

Also Known As: Yogic Seat Pose A (Yogapithasana A)
Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing (on the knees), balance
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

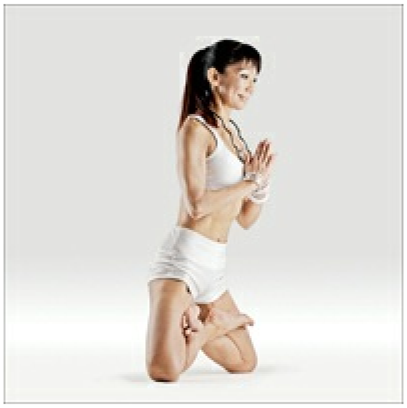

LUNGE: BACK KNEE OFF THE FLOOR

Fighting Warrior Pose 2

Yudhasana 2

(yu-DAHS-uh-nuh)

Modification: back knee off the floor
Pose Type: standing
Drishti Point: Hastagrai or Hastagre (hands)

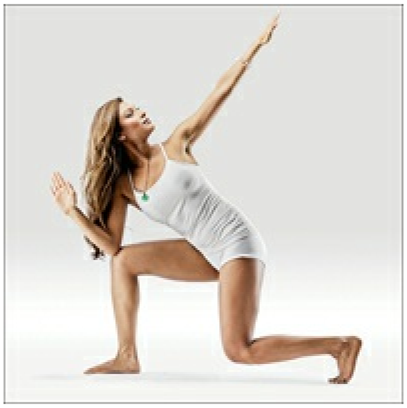

Son of Anjani (Lord Hanuman) Lunge Pose

Anjaneyasana

(uhn-juh-ney-AHS-uh-nuh)

Modification: arms open wide, forward bend, back knee bent and off the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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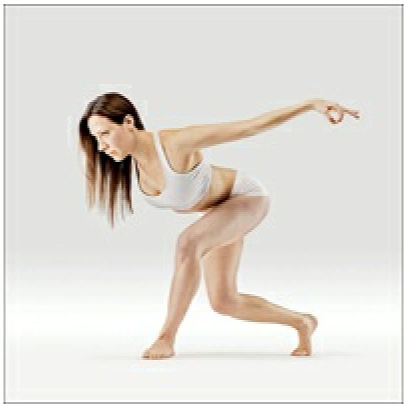

Son of Anjani (Lord Hanuman) Lunge Pose

Anjaneyasana

(uhn-juh-ney-AHS-uh-nuh)

Also Known As: Warrior 1 Modification (Virabhadrasana 1 Modification)
Modification: hands on the hips, back knee off the floor
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)
लं वं

LUNGE: BACK KNEE OFF THE FLOOR

Equestrian Riding Horse Pose

Ashva Sanchalanasana

(UHSH-vuh suhn-chuh-luh-NAHS-un-nuh)

Pose Type: standing, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Padhayoragrai or Padayoragre (toes/feet)

How to Perform the Pose:

1. Begin in Intense Stretch Pose (*Uttanasana*), also known as Full Forward Bend Pose. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Inhale and bend your knees enough for your fingertips to touch the floor on the sides of the feet.
3. Exhale as you step your left foot to the back, keeping your toes curled in, your left knee off the floor and keep your left leg strong and straight. Make sure your right knee is on top of your right ankle to prevent wear and tear on your knee joint.
4. Rest your torso on your right thigh. Inhale as you lengthen your spine, stretching your body in two opposing directions: crown of the head moving to the front and the heel of the right foot pushing to the back. You can look at the toes of the right foot.
5. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
6. Exhale as you step your left foot to the front in line with your right foot, and repeat on the other side.

Modification: back knee off the floor, fingertips off the floor on either side of the front foot

ashva sanchala = horse, riding posture

Reverse Prayer Son of Anjani (Lord Hanuman) Lunge Pose

Viparita Namaskar Anjaneyasana

(vi-puh-REE-tuh nuh-muhs-KAHR uhn-juh-ney-AHS-uh-nuh)

Also Known As: Back of the Body Prayer Son of Anjani (Lord Hanuman) Lunge Pose (Paschima Namaskara Anjaneyasana)
Modification: back knee off the floor
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

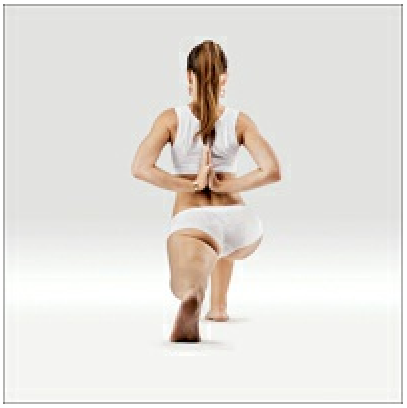

Son of Anjani (Lord Hanuman) Lunge Pose

Anjaneyasana

(uhn-juh-ney-AHS-uh-nuh)

Modification: palms together, thumbs to upper back, back knee off the floor
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

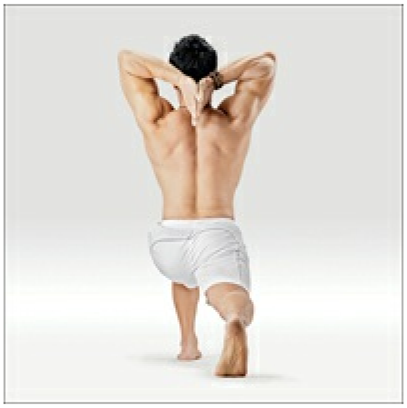

Tip Toe One Hand Son of Anjani (Lord Hanuman) Lunge Pose

Prapada Eka Hasta Anjaneyasana

(PRUH-puh-duh EY-kuh HUH-stuh uhn-juh-ney-AHS-uh-nuh)

Modification: deep backbend, one arm up over the head; fingertips of the other hand to the floor, back knee off the floor
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

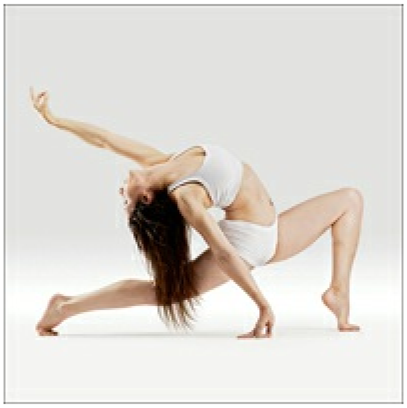

Son of Anjani (Lord Hanuman) Lunge Pose

Anjaneyasana

(uhn-juh-ney-AHS-uh-nuh)

Also Known As: Warrior 1 Modification (Virabhadrasana 1 Modification), Crescent Lunge Pose
Modification: hands up over the head and shoulder width apart, back knee off the floor
Pose Type: standing, mild backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

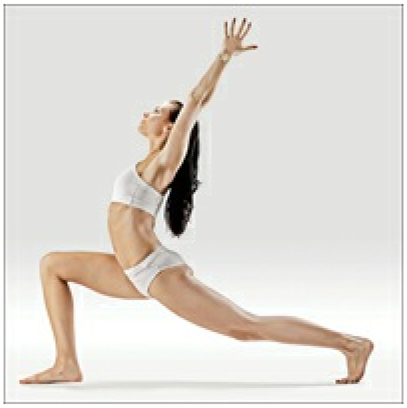

One Hand Rising Standing Pose of the Heavenly Spirits

Eka Hasta Utthita Stiti Valakhilyasana

(EY-kuh HUH-stuh UT-ti-tuh STI-ti vah-luh-khil-YAHS-uh-nuh)

Also Known As: Eka Hasta Utthita Nindra Valakhilyasana; Son of Anjani (Lord Hanuman) Lunge Pose (Anjaneyasana)
Modification: grabbing the back ankle overhead on the same side, other hand to the floor, back knee off the floor
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

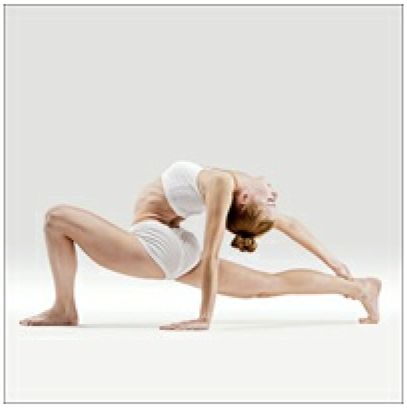

Rising Standing Pose of the Heavenly Spirits

Utthita Stiti Valakhilyasana

(UT-ti-tuh STI-ti vah-luh-khil-YAHS-uh-nuh)

Also Known As: Utthita Nindra Valakhilyasana; Son of Anjani (Lord Hanuman) Lunge Pose (Anjaneyasana)
Modification: grabbing the back ankle overhead with both hands, back knee off the floor
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

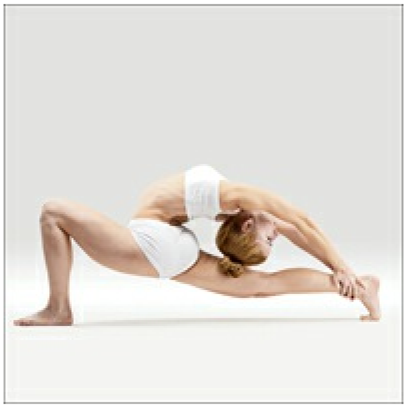

Extended Lizard Tail Lunge Pose

Uttana Pristhasana

(ut-TAH-nuh prish-TAHS-uh-nuh)

Modification: elbows to the floor on the inside of the front leg, back knee off the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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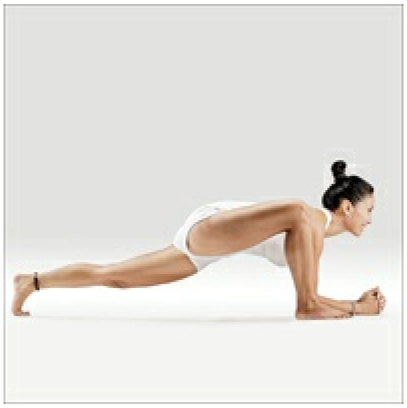

Pose Dedicated to Sage Punnakeesar Lunge

Punnakeesarasana

(pu-nuh-kee-suh-RAHS-uh-nuh)

Also Known As: Bound God Favor Seeking Sacrifice Ritual Pose (Baddha Yajnasana), Bound Christ's Cross Pose
Modification: back knee off the floor
Pose Type: standing, forward bend, binding
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)
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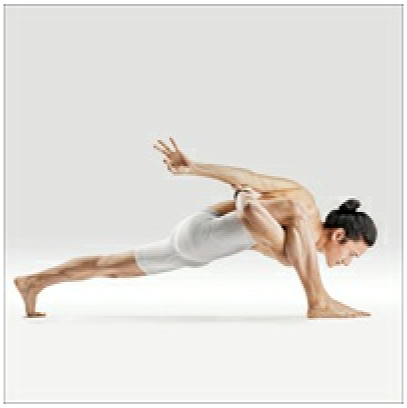

Extended Lizard Tail Lunge Pose

Uttana Pristhasana

(ut-TAH-nuh prish-TAHS-uh-nuh)

Modification: elbows bent at 90 degrees, palms to the floor, back knee off the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

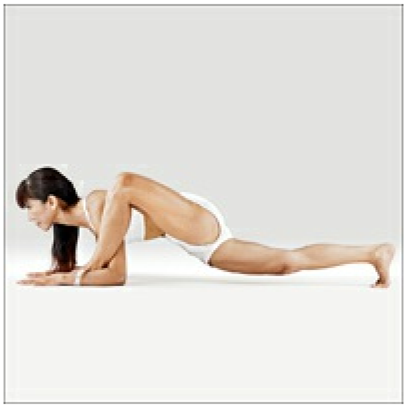

Extended Lizard Tail Lunge Pose

Uttana Pristhasana

(ut-TAH-nuh prish-TAHS-uh-nuh)

Modification: forearms to the floor on either side of the front foot, back knee off the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

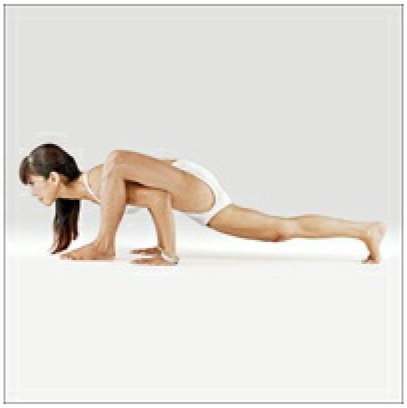

Tip Toe Extended Lizard Tail Lunge Pose

Prapada Uttana Pristhasana

(PRUH-puh-duh ut-TAH-nuh prish-TAHS-uh-nuh)

Modification: arms straight and reaching in the opposite directions, heel of the front leg up, top of the back foot to the floor, back knee off the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व

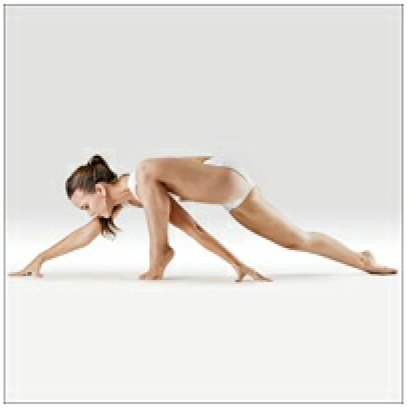

LUNGE: BACK KNEE OFF THE FLOOR, BACK LEG STRAIGHT—TWISTS

Sideways Son of Anjani (Lord Hanuman) Lunge Pose

Parshva Anjaneyasana

(PAHRSH-vuh uhn-juh-ney-AHS-uh-nuh)

Modification: top of the back foot on the floor, back knee off the floor
Pose Type: standing, side bend, backbend
Drishti Point: Hastagrai or Hastagre (hands)
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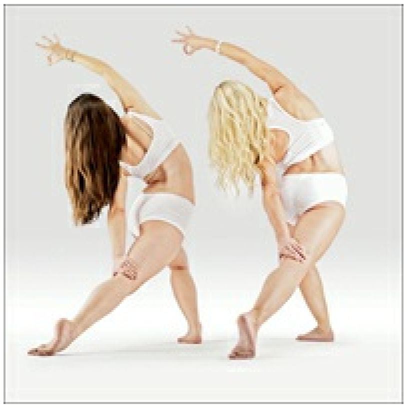

Revolved Son of Anjani (Lord Hanuman) Lunge Pose with Hands in Prayer

Parivritta Anjaneyasana Namaskar

(puh-ri-VRIT-tuh uhn-juh-ney-AHS-uh-nuh nuh-muhs-KAHR)

Modification: elbow over knee, back knee off the floor
Pose Type: standing, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

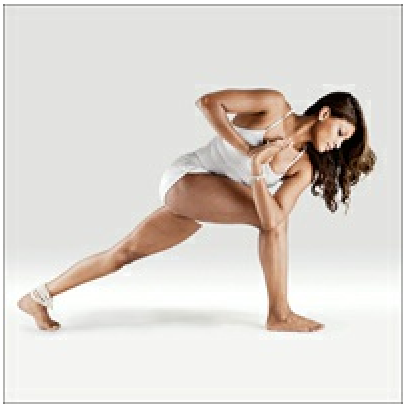

Revolved Son of Anjani (Lord Hanuman) Lunge Pose with Hands in Prayer

Parivritta Anjaneyasana Namaskar

(puh-ri-VRIT-tuh uhn-juh-ney-AHS-uh-nuh nuh-muhs-KAHR)

Modification: arm under the knee, back knee off the floor
Pose Type: standing, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

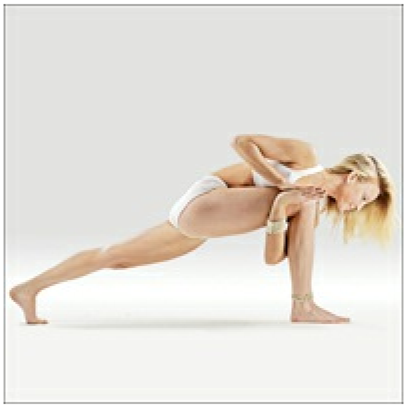

Bound Revolved Son of Anjani (Lord Hanuman) Lunge Pose

Baddha Parivritta Anjaneyasana

(BUH-duh puh-ri-VRIT-tuh uhn-juh-ney-AHS-uh-nuh)

Modification: back knee off the floor
Pose Type: standing, twist, binding
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)
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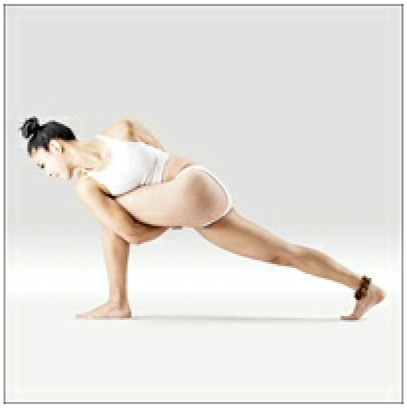

Revolved Son of Anjani (Lord Hanuman) Lunge Pose

Parivritta Anjaneyasana

(puh-ri-VRIT-tuh uhn-juh-ney-AHS-uh-nuh)

Modification: one hand to the floor, other arm up in the sky, twisting to the inside of the front knee, back knee off the floor
Pose Type: standing, twist
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
ल व य

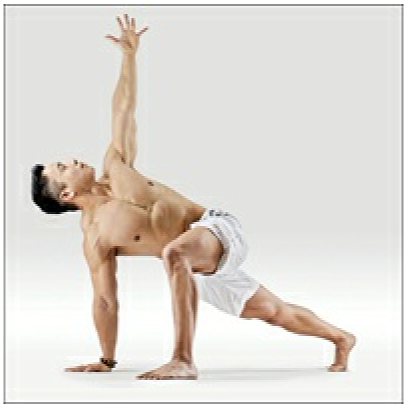

Tip Toe Sideways Son of Anjani (Lord Hanuman) Lunge Pose

Prapada Parshva Anjaneyasana

(PRUH-puh-duh PAHRSH-vuh uhn-juh-ney-AHS-uh-nuh)

Modification: one hand to the floor, other arm up in the sky, twisting to the outside of the front knee, back knee off the floor

Pose Type: standing, twist

Drishti Point: Hastagrai or Hastagre (hands)

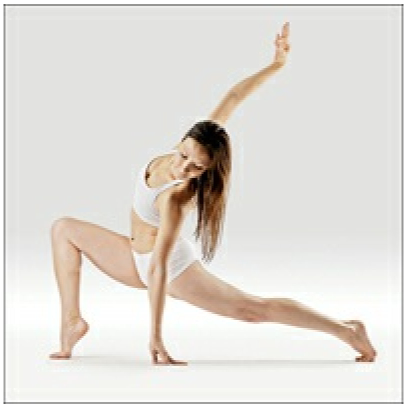

Revolved Paying Homage Lunge Pose

Parivritta Namasyasana

(puh-ri-VRIT-tuh nuh-muhs-YAHS-uh-muh)

Also Known As: Curtsey Lunge

Modification: front leg crossed over to the side, opposite elbow over the front knee, back knee off the floor

Pose Type: standing, twist

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

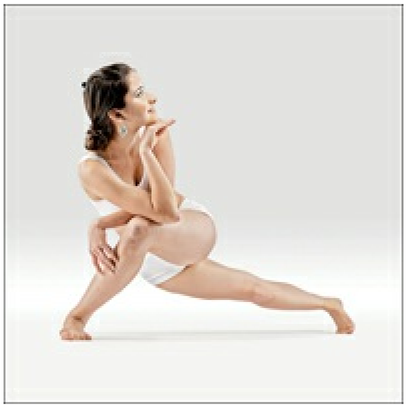

SIDE LUNGE: SITTING BONES LIFTED—ARMS BELOW HEAD

Extended Leg to the Side Squat Pose

Utthita Parshva Pada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Also Known As: Plyo Side Lunge
Modification: high stance, fingers interlocked in front of the chest
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

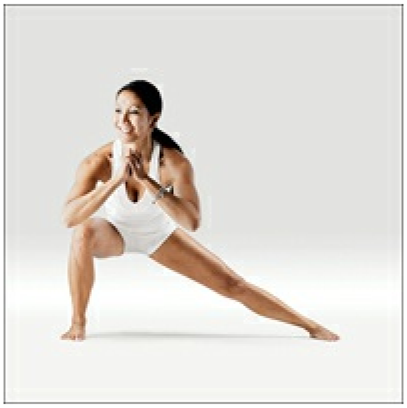

Tip Toe Extended Leg to the Side Squat Pose

Prapada Utthita Parshva Pada Upaveshasana

(PRUH-puh-duh UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: high stance; arms straight out to the sides, toes of the straight leg flexed in
Pose Type: standing
Drishti Point: Hastagrai or Hastagre (hands)

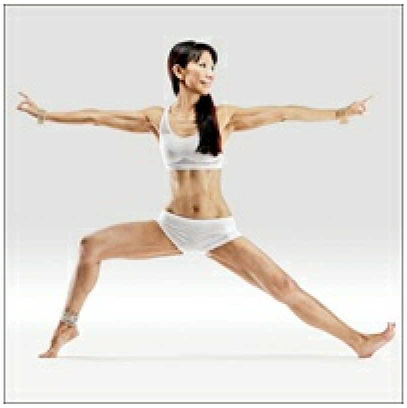

Extended Leg to the Side Squat Pose

Utthita Parshva Pada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: arms crossed in front of the chest, forward bend
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

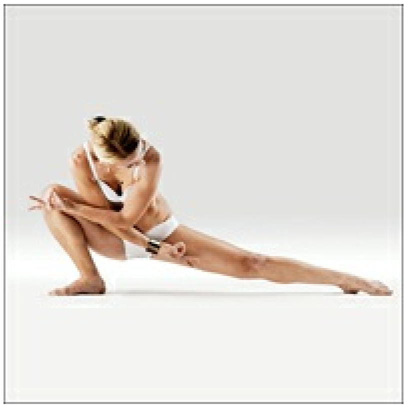

Extended Leg to the Side Squat Pose

Utthita Parshva Pada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: leaning toward the bent leg, one arm straight to the side, fingertips flexed in; other elbow to the side, fingertips to the back of the head
Pose Type: standing, side bend
Drishti Point: Hastagrai or Hastagre (hands)

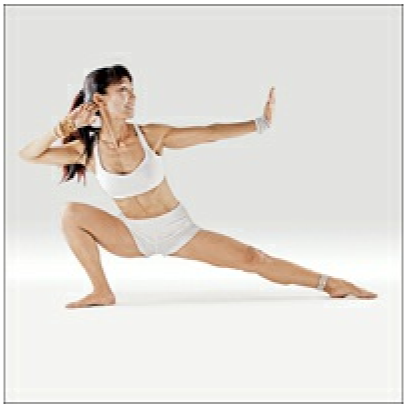

SIDE LUNGE: SITTING BONES LIFTED—ARMS ABOVE THE HEAD

Extended Leg to the Side Squat Pose

Utthita Parshva Pada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: side bend toward the straight leg, one arm parallel to the floor, other arm extended to the sky

Pose Type: standing

Drishti Point: Hastagrai or Hastagre (hands)

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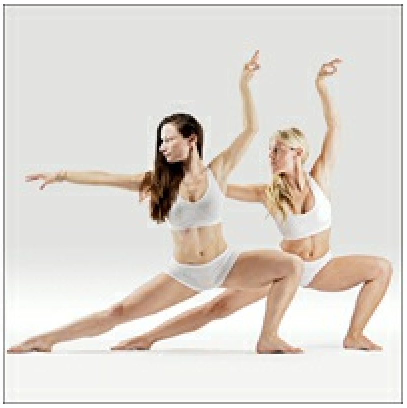

SIDE LUNGE: SITTING BONES LIFTED—HANDS TO THE FLOOR

Tip Toe Extended Leg to the Side Squat Pose

Prapada Utthita Parshva Pada Upaveshasana

(PRUH-puh-duh UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: one palm to the floor

Pose Type: standing, forward bend

Drishti Point: Hastagrai or Hastagre (hands)

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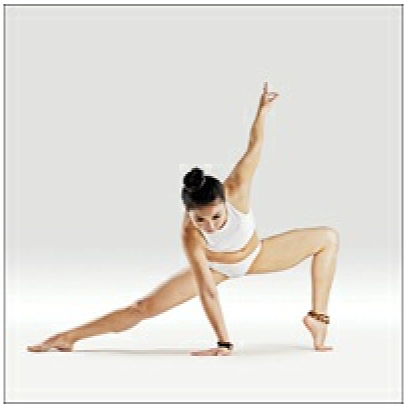

Extended Leg to the Side Squat Pose

Utthita Parshva Pada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: both hands to the floor, side bending toward the straight leg

Pose Type: standing, forward bend, side bend

Drishti Point: Hastagrai or Hastagre (hands)

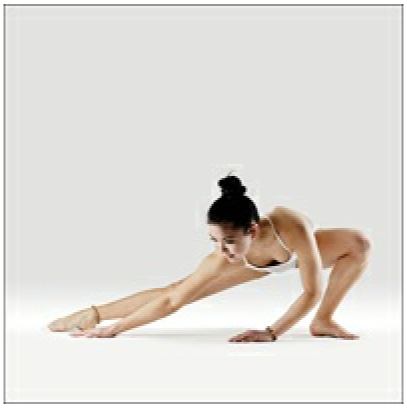

Intense Ankle Stretch Extended Leg to the Side Squat Pose

Uttana Kulpa Utthita Parshva Pada Upaveshasana

(ut-TAH-nuh kul-puh UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: both palms to the floor, arms crossed

Pose Type: standing, forward bend, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky)

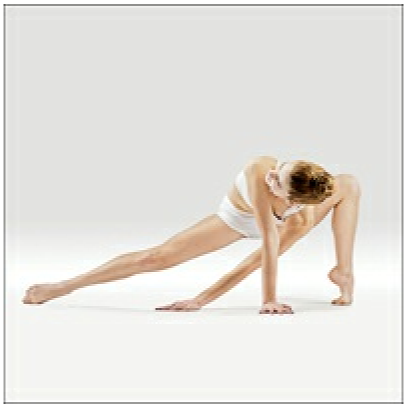

SIDE LUNGE: SITTING BONES ON THE FLOOR

Lotus Hand Seal Extended Leg to the Side Squat Pose

Padma Mudra Utthita Parshva Pada Upaveshasana

(PUHD-muh MU-druh UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: forward bend, forehead to the floor, arms extended in front

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

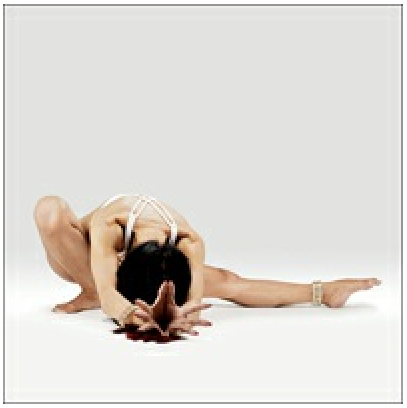

Uneven Arms Extended Leg to the Side Squat Pose

Vishama Hasta Utthita Parshva Pada Upaveshasana

(VISH-uh-muh HUH-stuh UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: forward bend, one forearm to the floor, other hand to the face

Pose Type: standing, seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

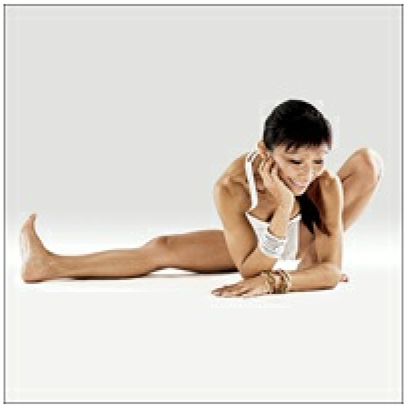

Revolved Extended Leg to the Side Squat Pose 1

Parivritta Utthita Parshva Pada Upaveshasana 1

(puh-ri-VRIT-tuh UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: both hands to the foot of the straight leg

Pose Type: standing, seated, forward bend, side bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

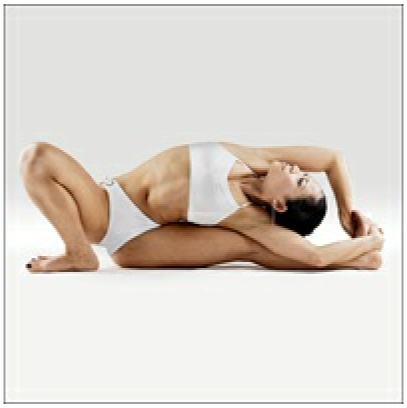

Revolved Extended Leg to the Side Squat Pose 2

Parivritta Utthita Parshva Pada Upaveshasana 2

(puh-ri-VRIT-tuh UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)
Modification: grabbing onto both feet
Pose Type: standing, seated, forward bend, side bend, twist
Drishti Point: Hastagrai or Hastagre (hands), Padayoragrai or Padayoragre (toes/feet)

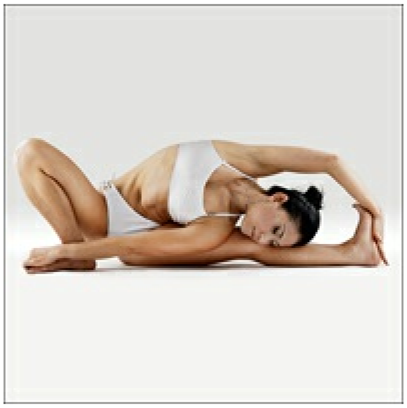

SIDE LUNGE: SITTING BONES LIFTED—TWISTS AND BINDING

Extended Leg to the Side Squat Pose

Utthita Parshva Pada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)
Modification: fingertips to the floor, toes of the straight leg flexed in
Pose Type: standing, forward bend

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

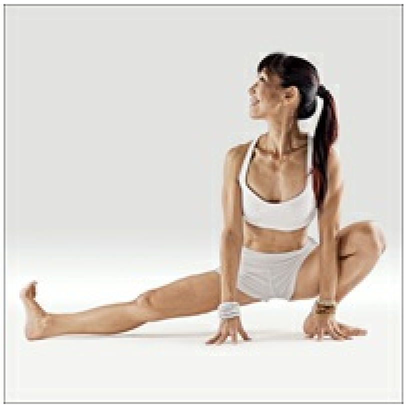

Knee to Shoulder Extended Leg to the Side Squat Pose

Janu Bhuja Utthita Parshva Pada Upaveshasana

(JAH-nu BHU-juh UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: toes of the straight leg pointed
Pose Type: standing, forward bend, side bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

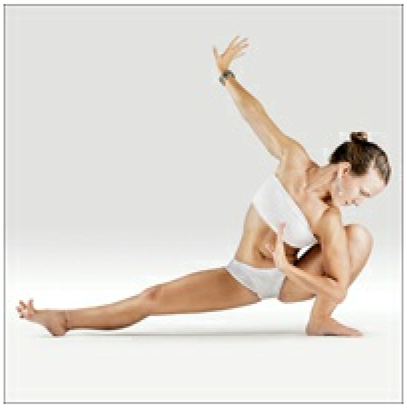

Bound Extended Leg to the Side Squat Pose

Baddha Utthita Parshva Pada Upaveshasana

(BUH-duh UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: binding around the shin of the bent leg, toes of the straight leg flexed in
Pose Type: standing, side bend, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

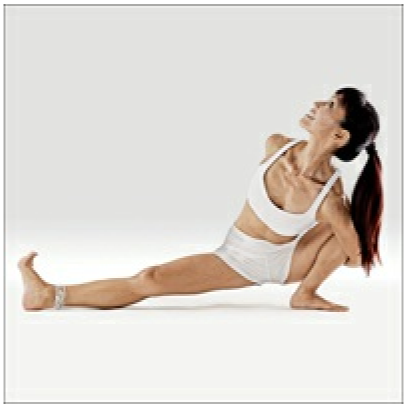

Revolved Half Bound Extended Leg to the Side Squat Pose

Parivritta Ardha Baddha Utthita Parshva Pada Upaveshasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh UT-ti-tuh PAHRSH-vuh PUH-duh u-puh-vey-SHAHS-uh-nuh)

Modification: toes of the straight leg pointed
Pose Type: standing, side bend, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

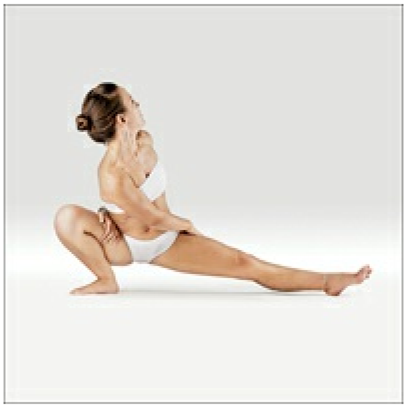

SIDE LUNGE: SITTING BONE TO THE HEEL—ARMS HIGHER THAN HEAD LEVEL

Extended Leg to the Side Tip Toe Squat Pose

Utthita Parshva Pada Prapada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh)

Modification: toes of the straight leg to the floor
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

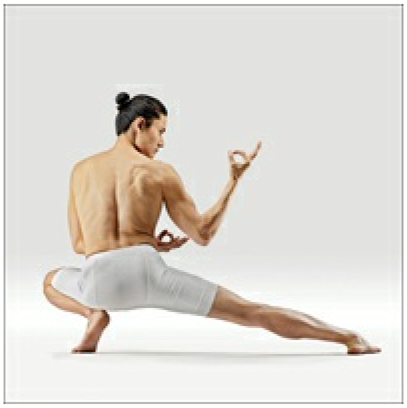

Extended Leg to the Side Tip Toe Squat Pose

Utthita Parshva Pada Prapada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh)

Modification: elbow to the knee of the bent leg, toes of the straight leg to the floor
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)
लं वं

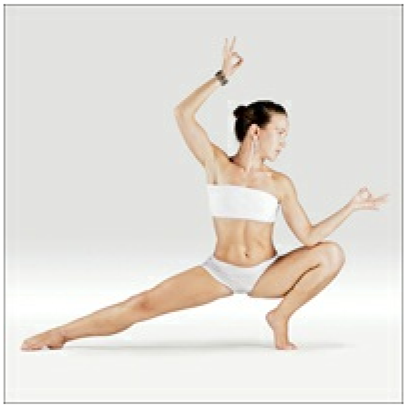

Extended Leg to the Side Tip Toe Squat Pose

Utthita Parshva Pada Prapada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh)

Modification: side bend toward the straight leg, one arm parallel to the floor, other arm extended to the sky, toes of the straight leg pointed
Pose Type: standing, side bend
Drishti Point: Hastagrai or Hastagre (hands)
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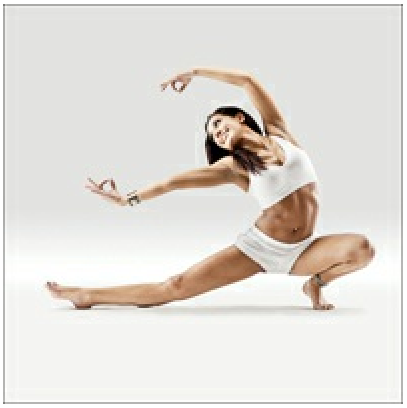

Extended Leg to the Side Tip Toe Squat Pose

Utthita Parshva Pada Prapada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh)

Modification: side bend toward the straight leg, arms extended to the side and straight, toes of the straight leg to the floor
Pose Type: standing, side bend
Drishti Point: Hastagrai or Hastagre (hands), Padayoragrai or Padayoragre (toes/feet)

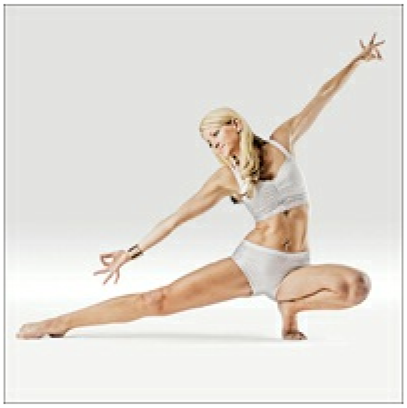

Both Arms Extended Leg to the Side Tip Toe Squat Pose

Dwi Hasta Utthita Parshva Pada Prapada Upaveshasana

(DWI-huh-stuh UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh)

Modification: side bend toward the bent leg, toes of the straight leg to the floor
Pose Type: standing, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

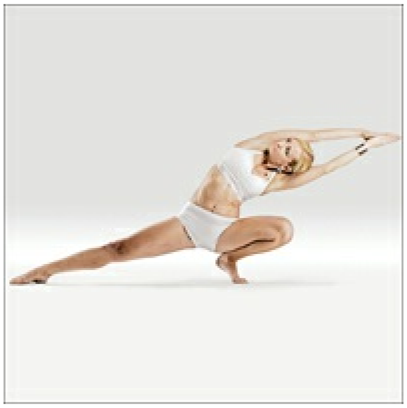

SIDE LUNGE: SITTING BONE TO THE HEEL—HAND TO THE FLOOR

Extended Leg to the Side Tip Toe Squat Pose

Utthita Parshva Pada Prapada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh)

Modification: one hand on the knee, other hand to the floor, toes of the straight leg pointed
Pose Type: standing, forward bend
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

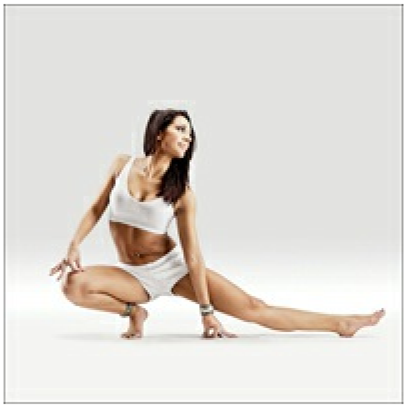

Extended Leg to the Side Tip Toe Squat Pose

Utthita Parshva Pada Prapada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh)

Modification: one palm to the floor, other arm straight and parallel to the straight leg, toes of the straight leg to the floor
Pose Type: standing
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Hastagrai or Hastagre (hands)

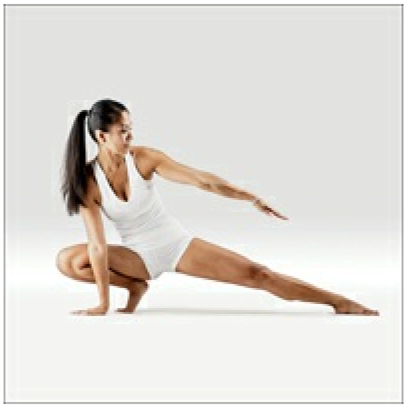

SIDE LUNGE: SITTING BONE TO THE HEEL—1 ARM OVERHEAD, OTHER HAND TO THE FLOOR

Extended Leg to the Side Tip Toe Squat Pose

Utthita Parshva Pada Prapada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh)

Modification: side bending toward the bent knee, one hand to the floor, other arm extended up over the head, toes of the straight leg to the floor
Pose Type: standing, side bend
Drishti Point: Hastagrai or Hastagre (hands)
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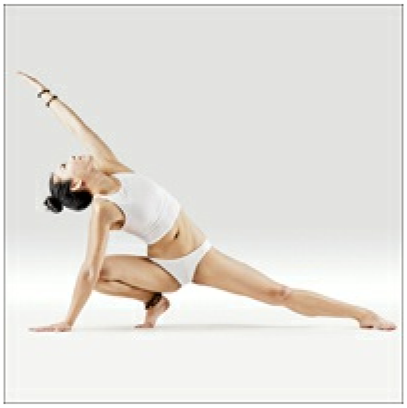

Extended Leg to the Side Tip Toe Squat Pose

Utthita Parshva Pada Prapada Upaveshasana

(UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh)

Modification: side bending toward the straight leg, one hand to the floor, other arm extended up over the head, toes of the straight leg to the floor
Pose Type: standing, side bend
Drishti Point: Hastagrai or Hastagre (hands)

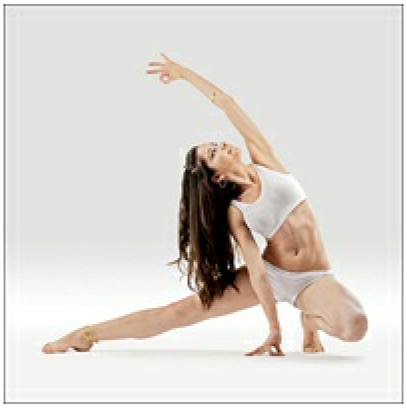

SIDE LUNGE: SITTING BONE TO THE HEEL—TWISTS & BINDING

Revolved Extended Leg to the Side Tip Toe Squat Pose with Hands in Prayer

Parivritta Utthita Parshva Pada Prapada Upaveshasana Namaskar

(puh-ri-VRIT-tuh UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh nuh-muhs-KAHR)

Modification: toes of the straight leg to the floor
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

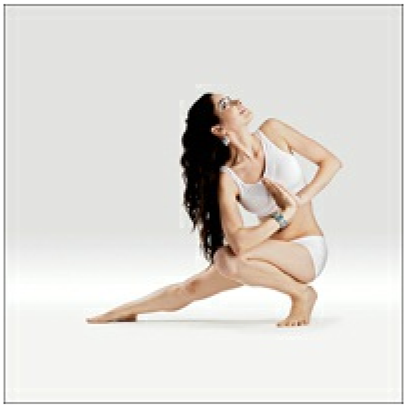

Revolved Bound Extended Leg to the Side Tip Toe Squat Pose

Parivritta Baddha Utthita Parshva Pada Prapada Upaveshasana

(puh-ri-VRIT-tuh BUH-duh UT-ti-tuh PAHRSH-vuh PUH-duh PRUH-puh-duh u-puh-vey-SHAHS-uh-nuh)

Modification: toes of the straight leg to the floor
1. knee on the floor

2. knee off the floor

Pose Type: standing, twist, binding

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

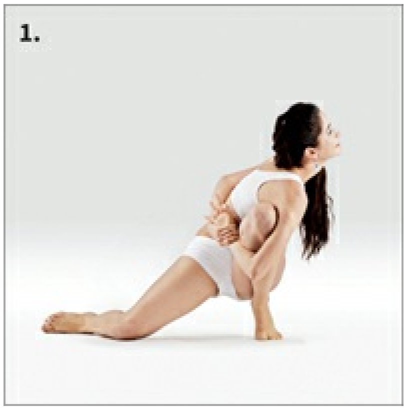
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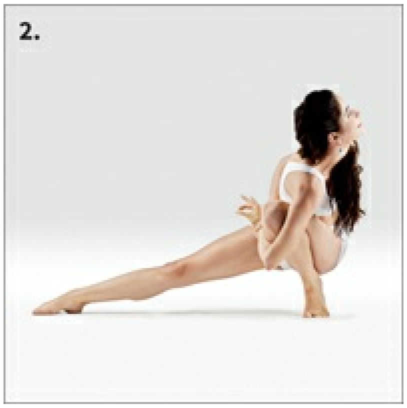
2.

CHAIR SQUAT: HIGH STANCE

Fierce Pose

Utkatasana

(OOT-kuh-TAHS-uh-nuh)

Also Known As: Chair Pose

Modification: palms pressed together, high squat

Pose Type: standing, mild backbend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

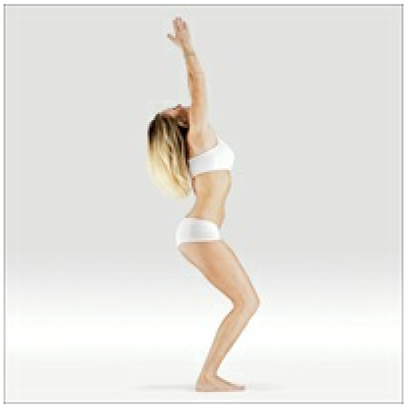

Fierce Pose

Utkatasana

(OOT-kuh-TAHS-uh-nuh)

Also Known As: Chair Pose
Modification: hands shoulder width apart, low squat
Pose Type: standing
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

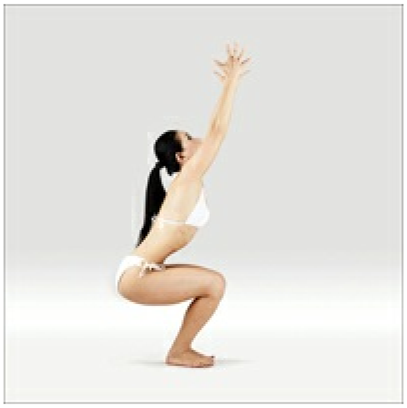

CHAIR SQUAT: HIGH STANCE—HANDS TO THE FLOOR

Wagtail Bird Pose Prep.

Khanjanasana Prep.

(kuhn-juh-NAHS-uh-nuh)

Modification: hands to the floor, palms facing up, feet together
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye/Ajna Chakra (third eye, between the eyebrows)

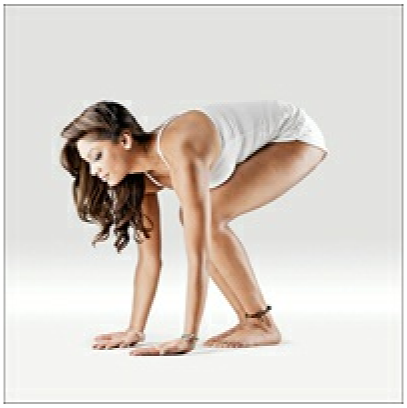

Intense Wrist Stretch Fierce Pose

Uttana Manibandha Utkatasana

(ut-TAH-nuh muh-ni-BUHN-duh OOT-kuh-TAHS-uh-nuh)

Also Known As: Intense Wrist Stretch Chair Pose
Modification: palms to the floor, fingertips facing the toes
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

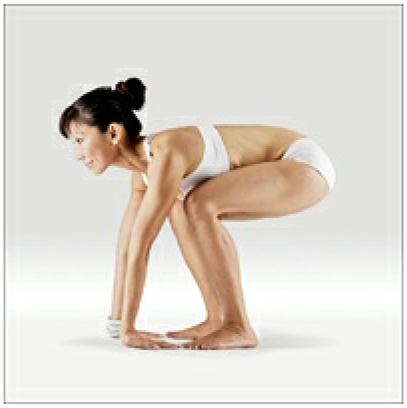

Wagtail Bird Pose

Khanjanasana

(kuhn-juh-NAHS-uh-nuh)

Also Known As: Shoulder Pressure Pose Prep. (Bhujapidasana Prep.)
Modification: shoulders to the back of the knees, fingertips to the heel
Pose Type: standing, forward bend
Drishti Point: Bhrumadhye/Ajna Chakra (third eye, between the eyebrows)

Intense Wrist Stretch Half Bound

Fierce Pose

Uttana Manibandha Ardha Baddha Utkatasana

(ut-TAH-nuh muh-ni-BUHN-duh UHR-duh OOT-kuh-TAHS-uh-nuh)

Also Known As: Intense Wrist Stretch Half Bound Chair Pose

Pose Type: standing, forward bend, binding

Drishti Point: Hastagrai or Hastagrahe (hands)

How to Perform the Pose:

1. Begin by standing in Mountain Pose (*Tadasana*). Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale, bend your knees until your thighs are parallel to the floor, and drop both your hands to the floor. Rest your torso on top of your thighs.
3. Inhale as you externally rotate your right arm to point the fingertips of your right hand toward your feet.
4. On your next inhale, bring your left arm behind your back and your left hand to the inside of your right thigh. Try to seal the gap between your ribcage and your elbow.
5. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
6. Exhale as you release your left arm and bring your left hand to the floor. Repeat on the right side.

Modification: hand to the floor, fingertips pointing toward the toes

ut = intense

tan = to stretch, to extend

manibandha = wrist

ardha = half

baddha = bound

utkata = fierce

Elephant Old Form

Gaja Vadivu

(GUH-juh vah-dee-vuh)

Pose Type: standing, forward bend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

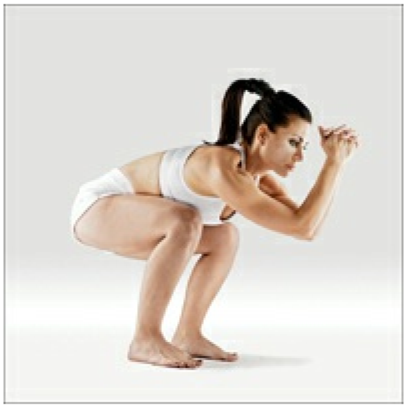

Hand Position of the Pose Dedicated to Garuda in Half Intense Stretch Pose

Hasta Garudasana in Ardha Uttanasana

(HUH-stuh guh-ru-DAHS-uh-nuh in UHR-duh ut-tahn-AHS-uh-nuh)

Also Known As: Hand Position of the Pose Dedicated to Garuda in Half Forward Bend

Modification: knees bent, feet hip width apart

Pose Type: standing, forward bend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

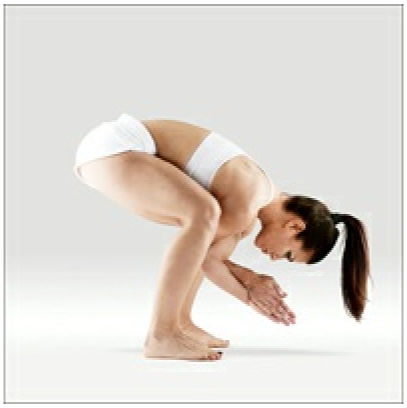

Hands Bound Ear Pressure Fierce Pose

Baddha Hasta Karnapida Utkatasana

(BUH-duh HUH-stuh kahr-nuh-PEE-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Hands Bound Ear Pressure Chair Pose

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

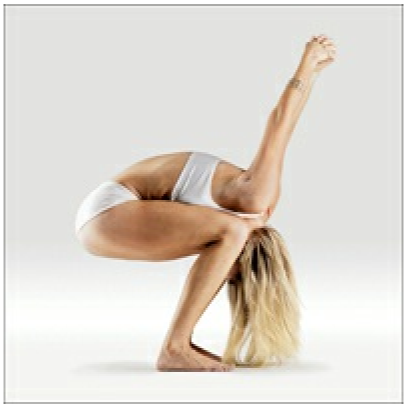

Hands Bound Revolved Fierce Pose

Baddha Hasta Parivritta Utkatasana

(Buh-duh HUH-stuh puh-ri-VRIT-tuh ut-kuh-TAHS-uh-nuh)

Also Known As: Hands Bound Revolved Chair Pose

Pose Type: standing, forward bend, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky)

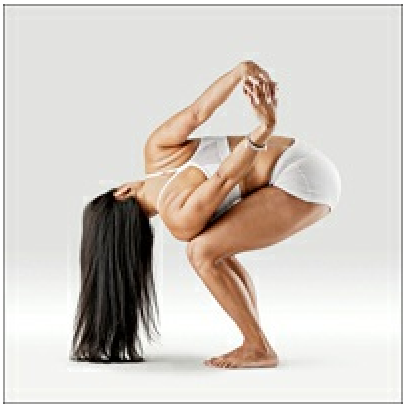

CHAIR SQUAT: HIGH STANCE—TWIST, ONE HAND TO THE FLOOR

Intense Wrist Stretch Revolved Half Bound Pose Dedicated to Yogi Shankara

Uttana Manibandha Parivritta Ardha Baddha Shankarasana

(ut-TAHN-uh muh-ni-BUHN-duh puh-ri-VRIT-tuh UHR-duh BUH-duh shuhng-kuhr-AHS-uh-nuh)

Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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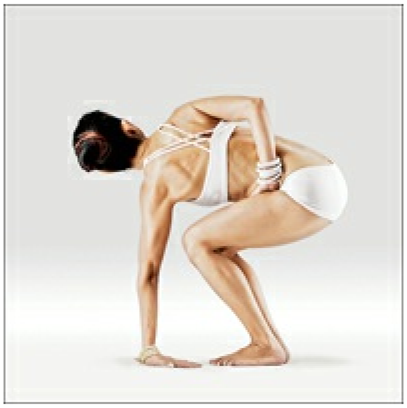

Revolved Pose Dedicated to Yogi Shankara

Parivritta Sankarasana

(puh-ri-VRIT-tuh shuhng-kuhr-AHS-uh-nuh)

Pose Type: standing, forward bend, side bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
🔴 🟡

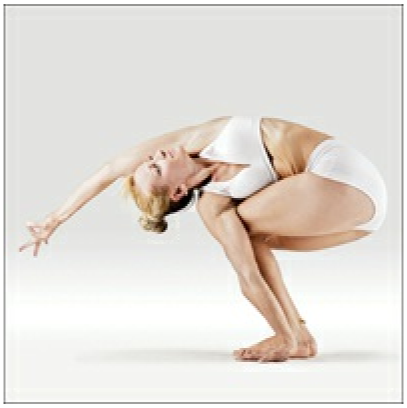

CHAIR SQUAT: HIGH STANCE—TWIST AND ELBOW OVER THE KNEE

Revolved Fierce Pose

Parivritta Utkatasana

(puh-ri-VRIT-tuh ut-kuh-TAHS-uh-nuh)

Also Known As: Revolved Chair Pose
Modification: feet wide apart, hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

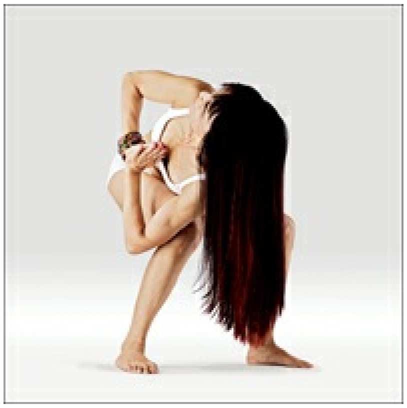

Revolved Fierce Pose

Parivritta Utkatasana

(puh-ri-VRIT-tuh ut-kuh-TAHS-uh-nuh)

Also Known As: Revolved Chair Pose
Modification: feet together, hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

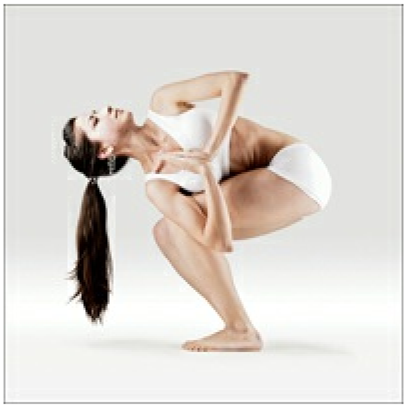

Revolved Fierce Pose

Parivritta Utkatasana

(puh-ri-VRIT-tuh ut-kuh-TAHS-uh-nuh)

Also Known As: Revolved Chair Pose
Modification: hands behind the head
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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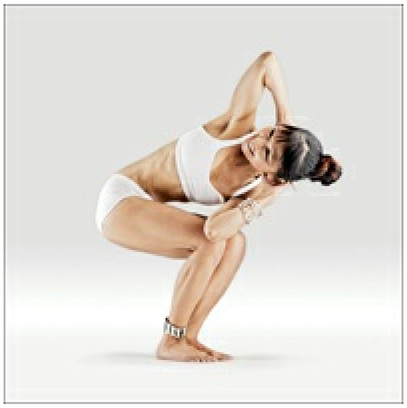

Revolved Fierce Pose

Parivritta Utkatasana

(puh-ri-VRIT-tuh ut-kuh-TAHS-uh-nuh)

Also Known As: Revolved Chair Pose
Modification: arm wrapped under the knee, hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
● ●

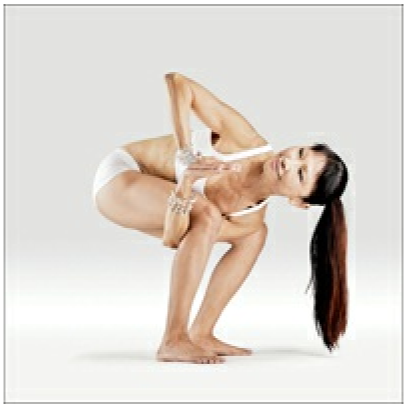

One Hand Bound Revolved Fierce Pose

Eka Hasta Baddha Parivritta Utkatasana

(EY-kuh HUH-stuh BUH-duh puh-ri-VRIT-tuh ut-kuh-TAHS-uh-nuh)

Also Known As: One Hand Bound Revolved Chair Pose
Modification: 1. one hand to the heart
2. hand grabbing onto the biceps, other elbow over the opposite knee
Pose Type: standing, forward bend, twist, binding
Drishti Point: 1. Urdhva or Antara Drishti (up to the sky)
2. Padhayoragrai or Padayoragre (toes/feet)

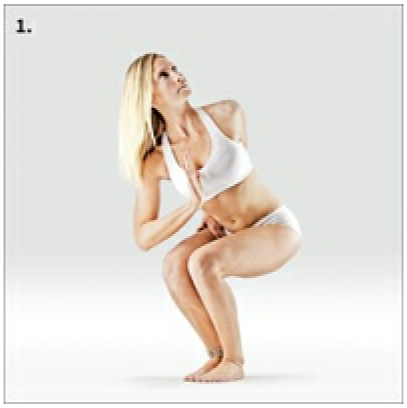
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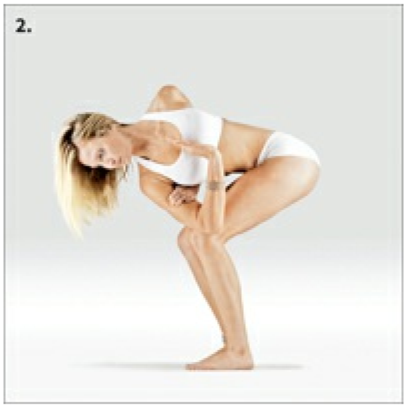
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Revolved One Leg Bound Fierce Pose

Parivritta Eka Pada Baddha Utkatasana

(puh-ri-VRIT-tuh EY-kuh PUH-duh BUH-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Revolved One Leg Bound Chair Pose
Pose Type: standing, forward bend, twist, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

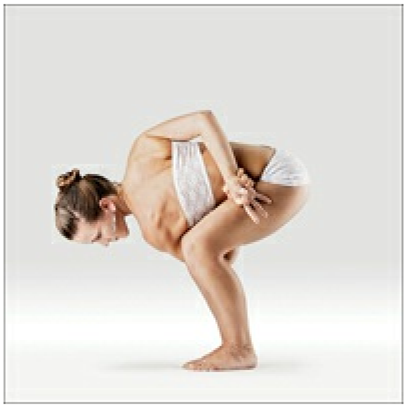

Revolved One Leg Bound Fierce Pose

Parivritta Eka Pada Baddha Utkatasana

(puh-ri-VRIT-tuh EY-kuh PUH-duh BUH-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Revolved One Leg Bound Chair Pose
Modification: binding around one leg, hands bound overhead
Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

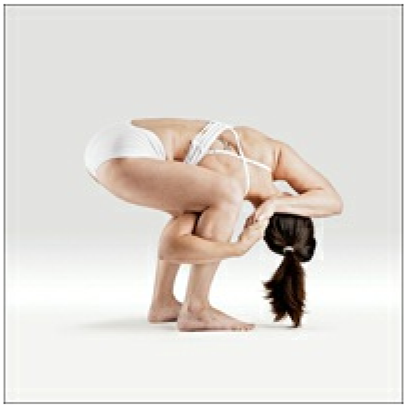

Revolved Both Legs Bound Fierce Pose

Parivritta Dwi Pada Baddha Utkatasana

(puh-ri-VRIT-tuh DWI-puh-duh BUH-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Revolved Both Legs Bound Chair Pose
Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

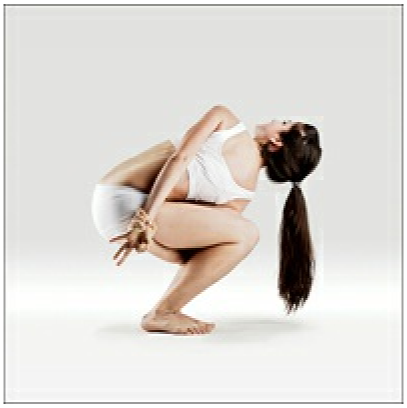

CHAIR SQUAT: HIGH STANCE HEELS UP—CHEST AWAY FROM QUADRICEPS

Tip Toe Fierce Pose 1

Prapada Utkatasana 1

(PRUH-puh-duh ut-kuh-TAHSuh-nuh)

Also Known As: Tip Toe Chair Pose 1
Modification: arms up over the head, fingers interlocked
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

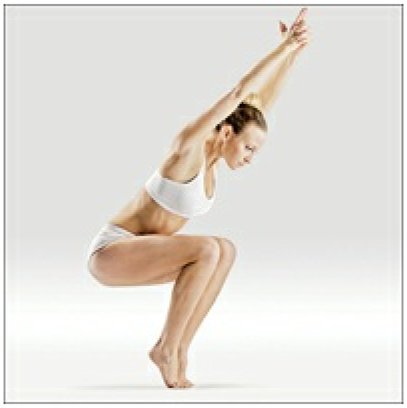

Tip Toe Fierce Pose 3

Prapada Utkatasana 3

(PRUH-puh-duh ut-kuh-TAHSuh-nuh)

Also Known As: Tip Toe Chair Pose 3
Modification: both elbows bent, one arm up in front, one arm down to the back
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

CHAIR SQUAT: HIGH STANCE HEELS UP—KNEES TO THE ARMPITS, VARIOUS HAND POSITIONS TO THE FLOOR

Crane Pose Prep.

Bakasana Prep.

(buhk-AHS-uh-nuh)

Modification: hands to the floor in front of the feet
1. fingertips to the floor
2. palms flat to the floor, arms shoulder width apart, fingertips pointing away from the head
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands), Nasagrai or Nasagre (nose)

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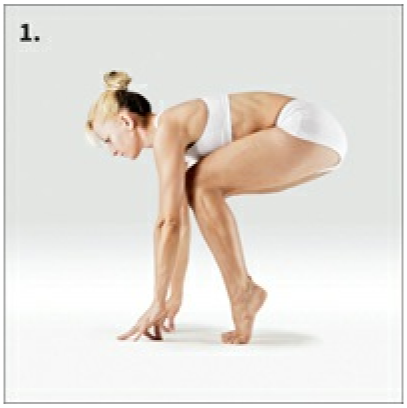

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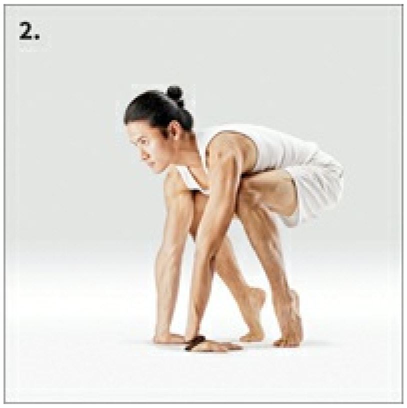

Tip Toe Fierce Pose

Prapada Utkatasana

(PRUH-puh-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Awkward Pose (Utkatasana)
Modification: arms out in front and parallel to the floor, sitting bones lifted off the heels
Pose Type: standing
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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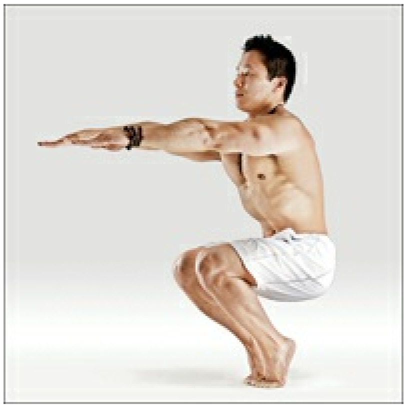

Tip Toe Fierce Pose 2

Prapada Utkatasana 2

(PRUH-puh-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Tip Toe Chair Pose 2 and Tip Toe Diver’s Pose
Modification: arms extended to the back, chest to the quadriceps, palms facing down
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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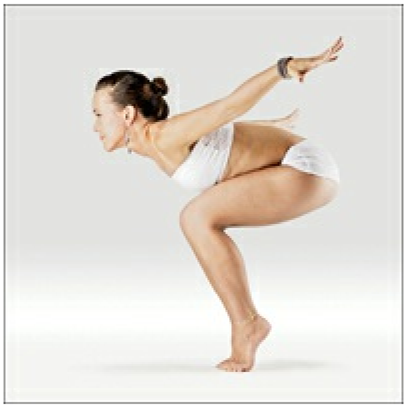

Head to Knees Tip Toe Fierce Pose 2

Janu Shirsha Prapada Utkatasana 2

(JAH-nu SHEER-shuh PRUH-puh-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Head to Knees Tip Toe Chair Pose 2 and Head to Knees Tip Toe Diver’s Pose
Modification: knees together, arms straight out to the sides, forehead to the knees
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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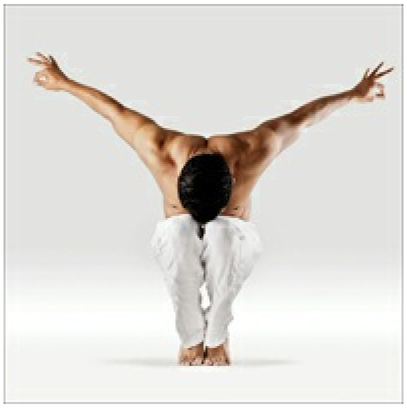

CHAIR SQUAT: HIGH STANCE HEELS UP—BACK OF THE KNEE OVER THE SHOULDER

Unsupported Tip Toe Wagtail Pose 1

Niralamba Prapada Khanjanasana 1

(nir-ah-LUHM-buh PRUH-puh-duh kuhn-juh-NAHS-uh-nuh)

Modification: elbows bent, hands reaching to the front
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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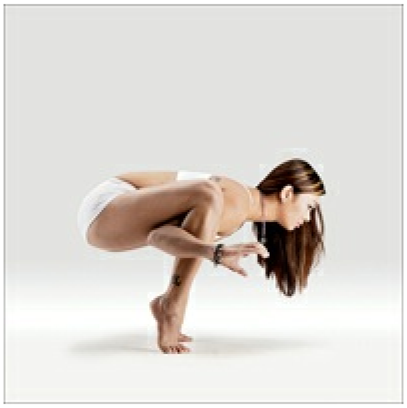

Unsupported Bound Tip Toe Wagtail Pose

Niralamba Baddha Prapada Khanjanasana

(nir-ah-LUHM-buh BUH-duh PRUH-puh-duh kuhn-juh-NAHS-uh-nuh)

Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)
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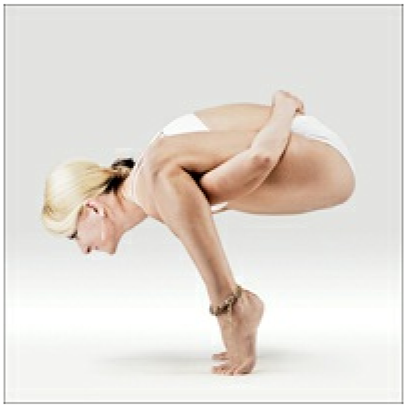

Supported Tip Toe Wagtail Pose

Salamba Prapada Khanjanasana

(sah-LUHM-buh PRUH-puh-duh kuhn-juh-NAHS-uh-nuh)

Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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Unsupported Tip Toe Wagtail Pose 2

Niralamba Prapada Khanjanasana 2

(nirsah-LUHM-buh PRUH-puh-duh kuhn-juh-NAHS-uh-nuh)

Modification: fingertips reaching away from the head, palms pressed together, high stance
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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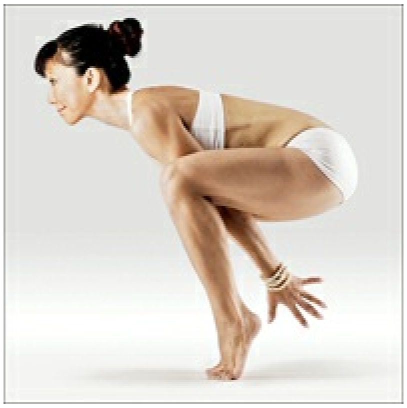

Intense Ankle Stretch Tip Toe Fierce Pose 3

Uttana Kulpa Prapada Utkatasana 3

(ut-TAH-nuh KUL-puh PRUH-puh-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Intense Ankle Stretch Tip Toe Chair Pose 3
Modification: both elbows bent, one arm up in front, one arm down to the back
Pose Type: standing, balance
Drishti Point: Hastagrai or Hastagre (hands)

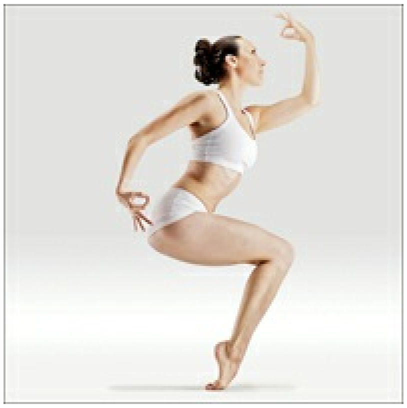

Revolved Intense Ankle Stretch Tip Toe Uneven Legs Half Intense Stretch Pose

Parivritta Uttana Kulpa Prapada Vishama Pada Ardha Uttanasana

(puh-ri-VRIT-tuh ut-TAH-nuh KUL-puh PRUH-puh-duh VISH-uh-muh PUH-duh UHR_duh ut-tahn-AHS-uh-nuh)

Also Known As: Revolved Intense Ankle Stretch Tip Toe Uneven Legs Half Forward Bend
Modification: fingertips off the floor
Pose Type: standing, balance, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

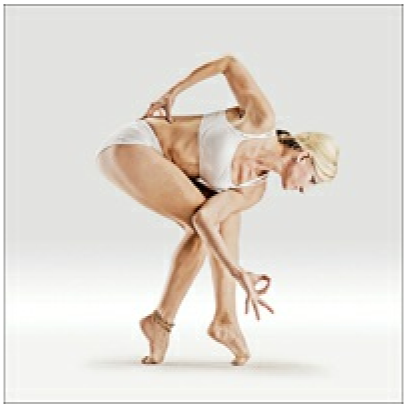

Intense Ankle Stretch Tip Toe Fierce Pose Prep.

Uttana Kulpa Prapada Utkatasana Prep.

(ut-TAH-nuh KUL-puh PRUH-puh-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Intense Ankle Stretch Tip Toe Chair Pose Prep.
Modification: fingertips to the floor
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)
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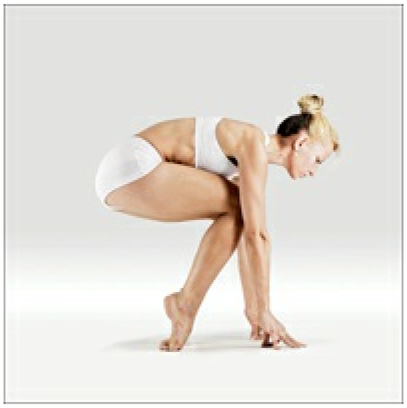

Intense Ankle Stretch Tip Toe Fierce Pose 2

Uttana Kulpa Prapada Utkatasana 2

(ut-TAH-nuh KUL-puh PRUH-puh-duh ut-kuh-TAHS-uh-nuh)

Also Known As: Intense Ankle Stretch Tip Toe Chair Pose 2 and Intense Ankle Stretch Tip Toe Diver’s Pose
Modification: arms extended to the back, chest to the quadriceps
Pose Type: standing, balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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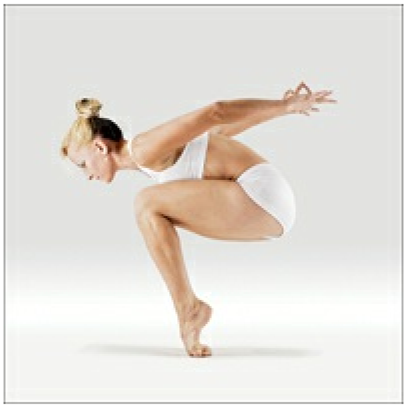

CHAIR SQUAT: HIGH STANCE HEELS UP—ANKLES CROSSED, HANDS TO THE FLOOR

Revolved Tip Toe Pose

Parivritta Prapadasana

(puh-ri-VRIT-tuh pruh-puh-DAHS-uh-nuh)

Modification: ankles crossed, one arm to the back, other hand toward the floor in front of the feet
Pose Type: standing, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

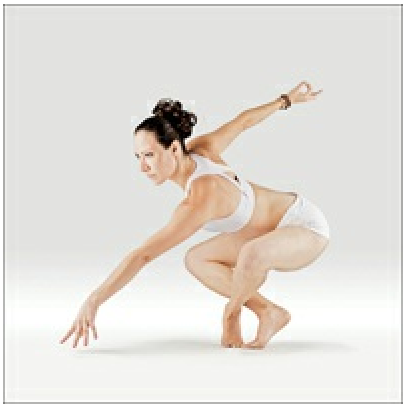

Tip Toe Pose

Prapadasana

(pruh-puh-DAHS-uh-nuh)

Modification: ankles crossed, arms crossed, fingertips to the floor in front of the feet
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

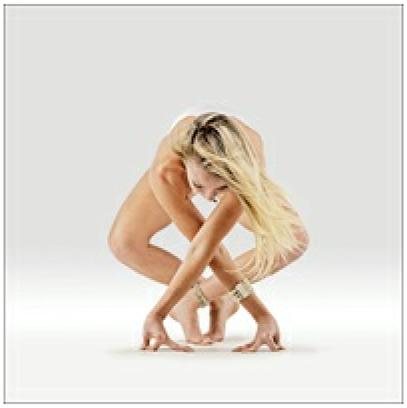

Pendant Pose Prep.

Lolasana Prep.

(lo-LAHS-uh-nuh)

Modification: ankles crossed
Pose Type: standing, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

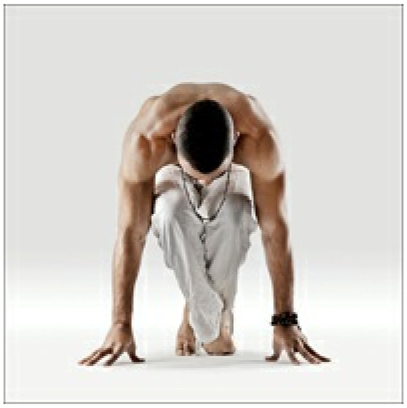

SQUAT: HEELS UP—LEGS CROSSED

Easy Leg Position of the Pose Dedicated to Garuda in Yoga Squat with Hands in Prayer

Sukha Pada Garudasana in Upaveshasana Namaskar

(SUK-kuh PUH-duh guh-ru-DAHS-uh-nuh in u-puh-veysh-AHS-uh-nuh nuh-muhs-KAHR)

Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagrahe (hands)

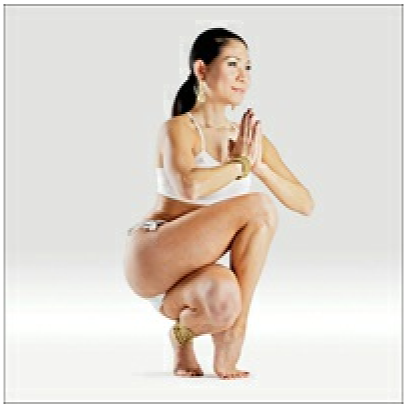

Easy Leg Position and Complete Arm Position of the Pose Dedicated to Garuda in Yoga Squat

Sukha Pada Paripurna Hasta Garudasana in Upaveshasana

(SUK-kuh PUH-duh puh-ri-POOR-nuh HUH-stuh guh-ru-DAHS-uh-nuh in u-puh-veysh-AHS-uh-nuh)

Pose Type: standing, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

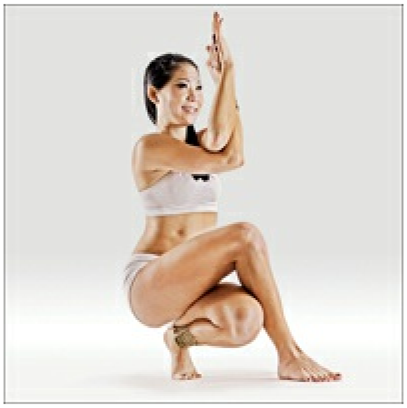

Revolved Easy Leg Position of the Pose Dedicated to Garuda in Yoga Squat

Parivritta Sukha Pada Garudasana in Upaveshasana

(puh-ri-VRIT-tuh SUK-kuh PUH-duh guh-ru-DAHS-uh-nuh in u-puh-veysh-AHS-uh-nuh)

Modification: both knees off the floor, arms open wide and straight
Pose Type: standing, forward bend, twist
Drishti Point: Hastagrai or Hastagrahe (hands)

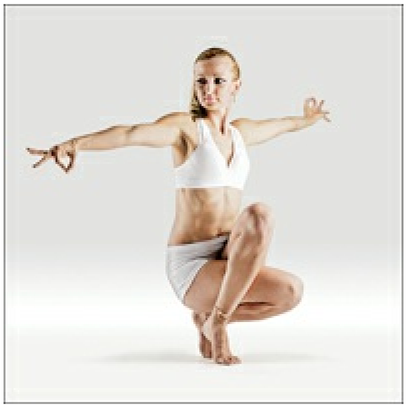

Revolved Easy Leg Position of the Pose Dedicated to Garuda in Yoga Squat

Parivritta Sukha Pada Garudasana in Upaveshasana

(puh-ri-VRIT-tuh SUK-kuh PUH-duh guh-ru-DAHS-uh-nuh in u-puh-veysh-AHS-uh-nuh)

Modification: bottom knee on the floor, arms open wide and straight
Pose Type: standing, forward bend, twist
Drishti Point: Hastagrai or Hastagrahe (hands)
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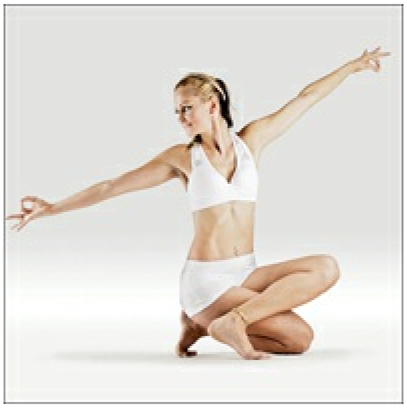

Revolved Easy Leg Position of the Pose Dedicated to Garuda in Yoga Squat

Parivritta Sukha Pada Garudasana in Upaveshasana

(puh-ri-VRIT-tuh SUK-kuh PUH-duh guh-ru-DAHS-uh-nuh in u-puh-veysh-AHS-uh-nuh)

Modification: elbow over the opposite knee, other arm straight out to the side
Pose Type: standing, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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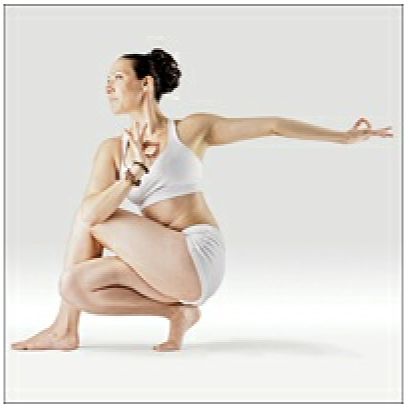

SQUAT: HEELS UP—KNEES APART

Hand Position of the Pose Dedicated to Garuda in Half Tip Toe Hero Pose

Hasta Garudasana in Ardha Prapada Virasana

(HUH-stuh guh-ru-DAHS-uh-nuh in UHR-duh PRUH-puh-duh veer-AHS-uh-nuh)

Modification: one knee on the floor, one foot to the floor on the inside of the knee
Pose Type: standing, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

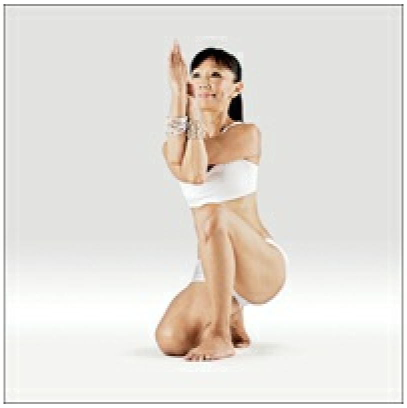

Half Bound Hand to Foot Uneven Tip Toe Pose

Ardha Baddha Hasta Pada Vishama Prapadasana

(UHR-duh BUH-duh HUH-stuh PUH-duh VISH-uh-muh pruh-puh-DAHS-uh-nuh)

Modification: one hand crossed in front, grabbing onto the heel; other hand to the inner thigh on the opposite side
Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

Hand Position of the Pose Dedicated to Garuda in Half Lotus Tip Toe Pose

Hasta Garudasana in Ardha Padma Prapadasana

(HUH-stuh guh-ru-DAHS-uh-nuh in UHR-duh PUHD-muh pruh-puh-DAHS-uh-nuh)

Modification: 1. Both knees on the floor
2. One knee on the floor
Pose Type: standing
Drishti Point: 1. Angusthamadhye or Angustha Ma Dyai (thumbs)
2. Nasagrai or Nasagre (nose)

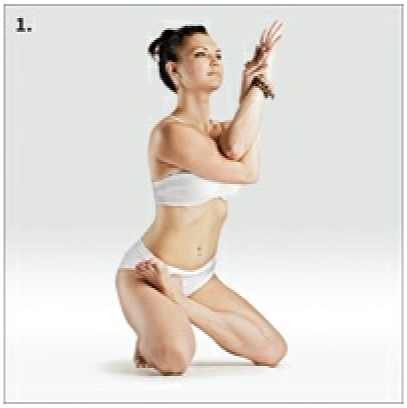
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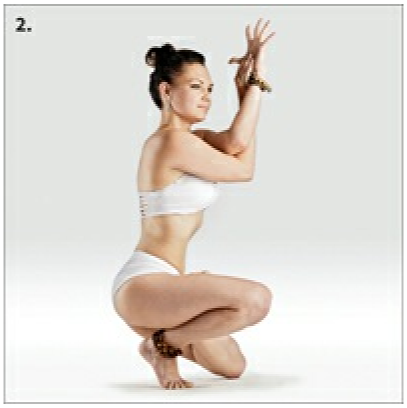
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Tip Toe Pose

Prapadasana

(pruh-puh-DAHS-uh-nuh)

Also Known As: Noose Pose Prep. (Pasasana Prep.)
Modification: 1. fingertips to the floor on the outside of the knees
2. one hand to the heart, other hand to the floor
3. hands on the hips
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

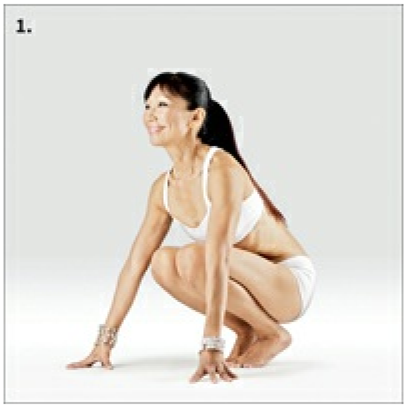

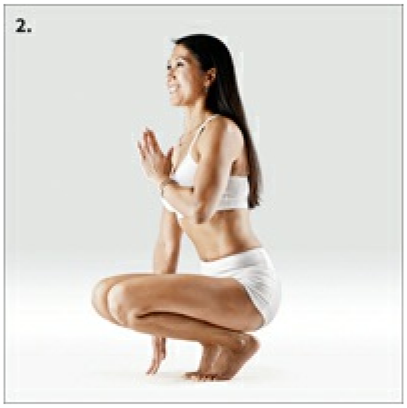

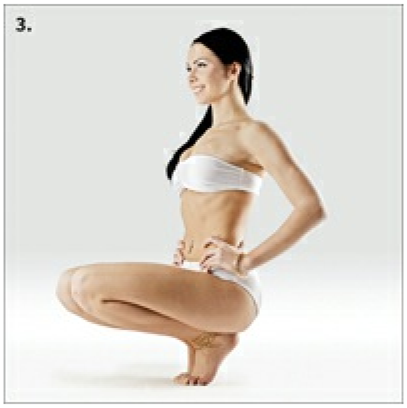

Hands Bound Tip Toe Pose

Baddha Hasta Prapadasana

(BUH-duh HUH-stuh pruh-puh-DAHS-uh-nuh)

Modification: arms straight out in front, palms facing out, chest to the quadriceps
Pose Type: standing, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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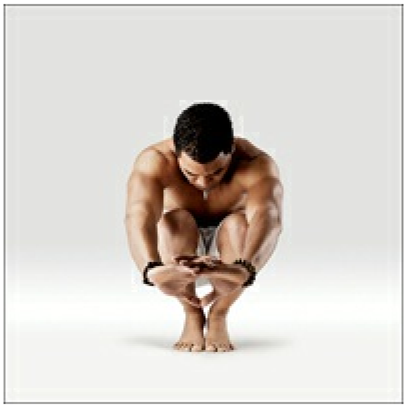

Tip Toe Pose with Hands in Prayer

Prapadasana Namaskar

(pruh-puh-DAHS-uh-nuh nuh-muhs-KAHR)

Modification: knees together, chest to the quadriceps
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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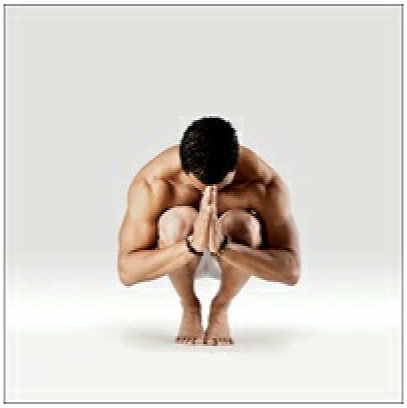

SQUAT: HEELS UP—KNEES TOGETHER—ARMS HEAD LEVEL OR ABOVE HEAD

Tip Toe Pose

Prapadasana

(pruh-puh-DAHS-uh-nuh)

Also Known As: Garland Pose Prep. (Malasana Prep.), Full Squat Pose (Purna Utkatasana)
Modification: 1. arms straight out in front and parallel to the floor
2. arms up over the head, palms pressed together, elbows bent
Pose Type: standing
Drishti Point: Hastagrai or Hastagre (hands)
Drishti Point: 1. Hastagrai or Hastagrahe (hands)
2. Nasagrai or Nasagre (nose)

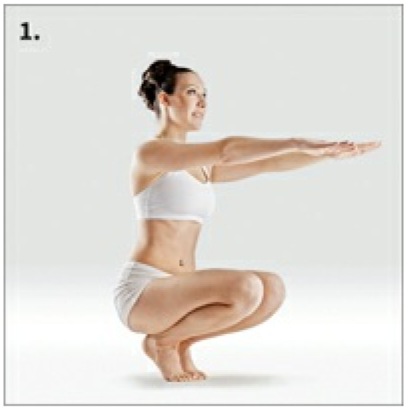

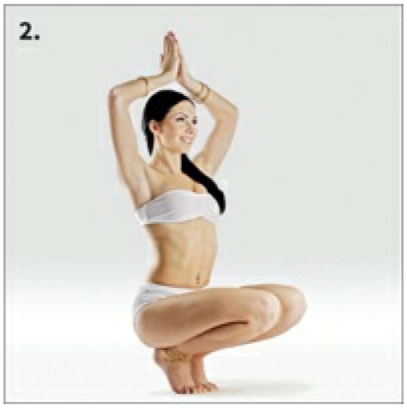

Half Bound Tip Toe Pose

Ardha Baddha Prapadasana

(UHR-duh BUH-duh pruh-puh-DAHS-uh-nuh)

Modification: one hand binding to the opposite hip behind the back, other arm straight and extended out to the side
Pose Type: standing, binding
Drishti Point: Nasagrai or Nasagre (nose)

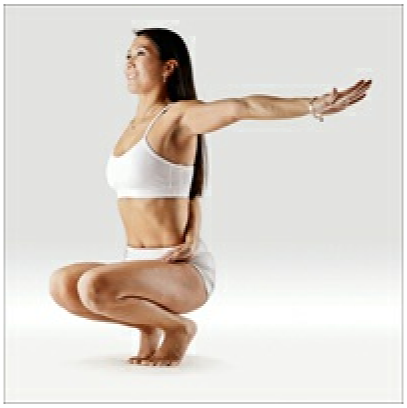

SQUAT: HEELS UP—KNEES TOGETHER—KNEES SHOULDER LEVEL

Seated Tip Toe Pose

Upavishta Prapadasana

(u-puh-VISH-tuh pruh-puh-DAHS-uh-nuh)

Also Known As: Crouching Tip Toe Pose; Upavistha Prapadasana
Modification: elbows resting on the knees, fingers interlocked in front of the face
Pose Type: standing, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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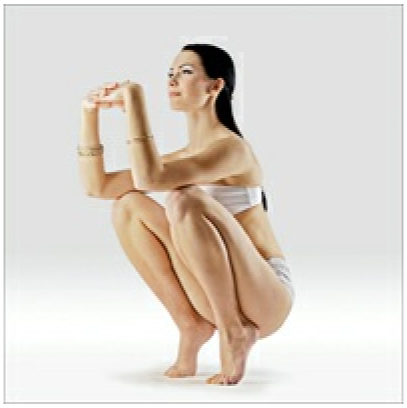

Hands Bound Seated Tip Toe Pose

Baddha Hasta Upavishta Prapadasana

(BUH-duh HUH-stuh u-puh-VISH-tuh pruh-puh-DAHS-uh-nuh)

Also Known As: Hands Bound Crouching Tip Toe Pose; Baddha Hasta Upavistha Prapadasana
Modification: arms away from the body
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

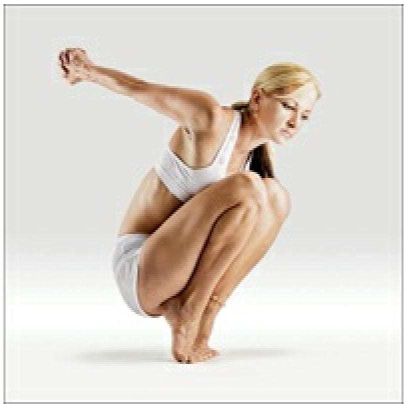

Knees to the Shoulders Seated Tip Toe Pose

Janu Bhuja Upavishta Prapadasana

(JAH-nu BHU-juh u-puh-VISH-tuh pruh-puh-DAHS-uh-nuh)

Also Known As: Knees to the Shoulders Crouching Tip Toe Pose; Janu Bhuja Upavistha Prapadasana
Modification: 1. palms together to the floor
2. palms apart and to the floor, elbows bent
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

1.

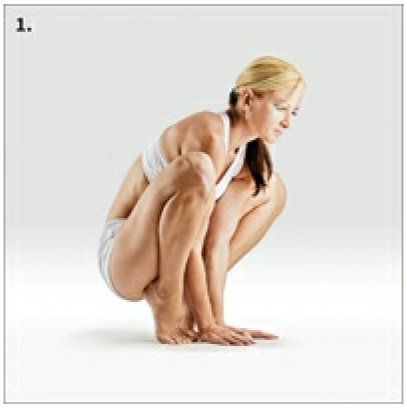

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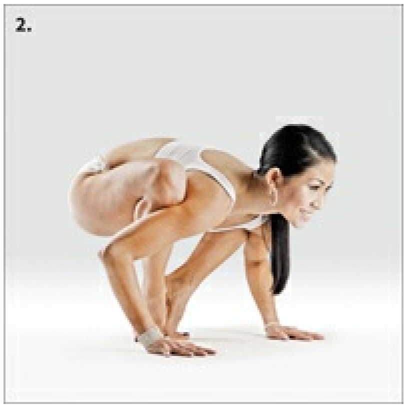

Supported Seated Tip Toe Pose

Salamba Upavishta Prapadasana

(sah-LUHM-buh u-puh-VISH-tuh pruh-puh-DAHS-uh-nuh)

Also Known As: Supported Crouching Tip Toe Pose; Salamba Upavistha Prapadasana
Modification: fingertips to the floor in front of the feet
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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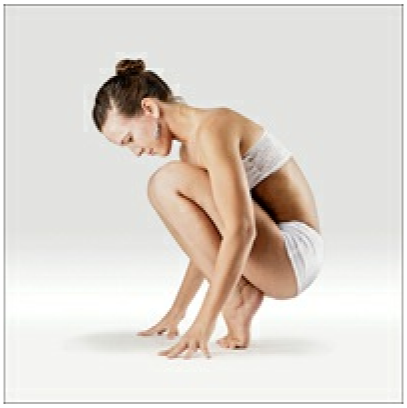

Supported/Unsupported Intense Ankle Stretch Seated Tip Toe Pose

Salamba/Niralamba Uttana Kulpa Upavishta Prapadasana

(sah-LUHM-buh-/nir-ah-LUHM-buh ut-TAHN-uh KUL-puh u-puh-VISH-tuh pruh-puh-DAHS-uh-nuh)

Also Known As: Supported/Unsupported Intense Ankle Stretch Crouching Tip Toe Pose; Salamba/Niralamba Uttana Kulpa Upavistha Prapadasana
Modification: 1. hands to the floor by the hips
2. arms wrapped around the shins, grabbing onto the triceps
Pose Type: 1. standing, forward bend
2. standing, balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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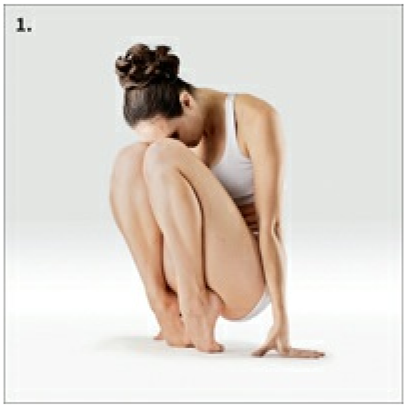

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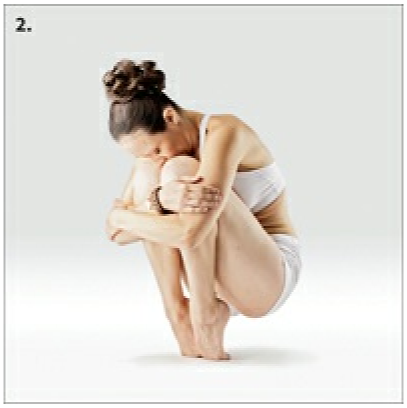

SQUAT: HEELS UP—TWISTS

Tip Toe Easy Noose Pose Prep.

Prapada Sukha Pashasana Prep.

(PRUH-puh-duh SUK-kuh puh-SHAHS-uh-nuh)

Modification: elbow on the inside of the thigh, arms open wide
Pose Type: standing, twist
Drishti Point: Hastagrai or Hastagre (hands)
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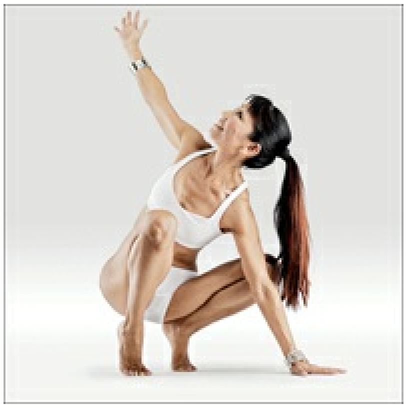

Uneven Legs One Hand to Foot Noose Pose

Vishama Pada Eka Hasta Pada Pashasana

(VISH-uh-muh PUH-duh EY-kuh HUH-stuh PUH-duh puh-SHAS-uh-nuh)

Modification: one heel up, one heel down
Pose Type: standing, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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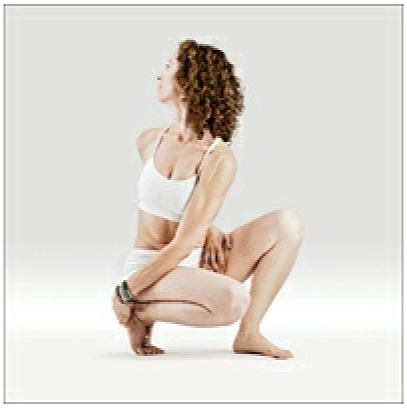

Extended Side Tip Toe Noose Pose

Utthita Parshva Prapada Pashasana

(UT-ti-tuh PAHRSH-vuh PRUH-puh-duh puh-SHAHS-uh-nuh)

Modification: one hand to the floor, other arm extended up over the head
Pose Type: standing, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

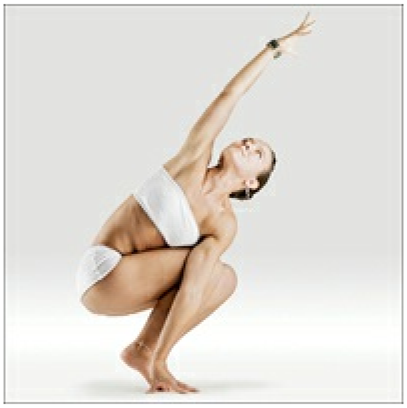

Tip Toe Noose Pose with Hands in Prayer

Prapada Pashasana Namaskar

(PRUH-puh-duh puh-SHAHS-uh-nuh nuh-muhs-KAHR)

Pose Type: standing, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

One Hand to the Foot Tip Toe Noose Pose

Eka Hasta Pada Prapada Pashasana

(EY-kuh HUH-stuh PUH-duh PRUH-puh-duh puh-SHAHS-uh-nuh)

Modification: one hand to the opposite heel, other hand binding to the opposite hip behind the back
1. right side view
2. left side view

Pose Type: standing, twist, binding

Drishti Point: Urdhva or Antara Drishti (up to the sky)

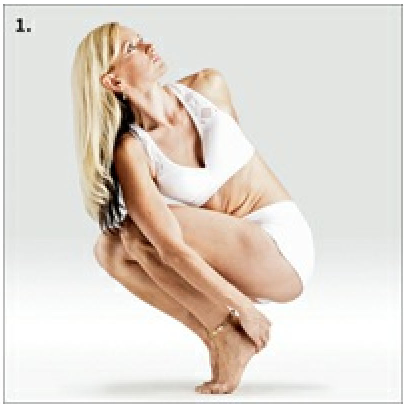
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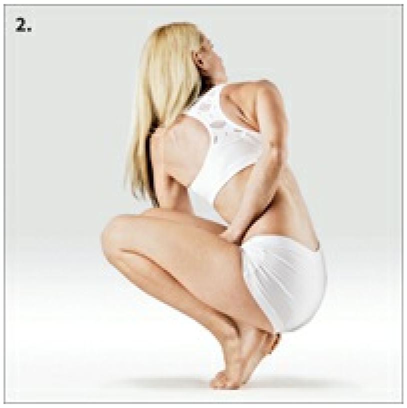
2.

Tip Toe Noose Pose Prep.

Prapada Pashasana Prep.

(PRUH-puh-duh puh-SHAHS-uh-nuh)

Modification: 1. binding around one leg with a strap
2. binding around one leg without a strap
Pose Type: standing, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

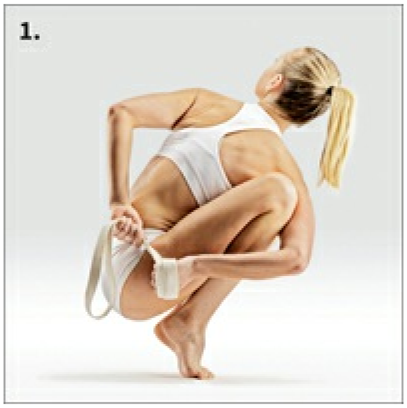

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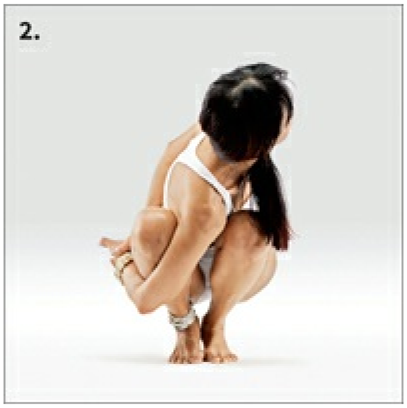

2.

Tip Toe Noose Pose

Prapada Pashasana

(PRUH-puh-duh puh-SHAHS-uh-nuh)

Modification: binding around both legs
Pose Type: standing, forward bend, twist, binding
Drishti Point: Nasagrai or Nasagre (nose)

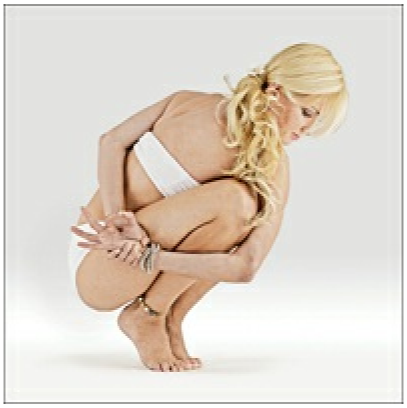

SQUAT: HEELS DOWN—ARMS BELOW HEAD

Intense Wrist Stretch Garland Pose Prep.

Uttana Manibandha Malasana Prep.

(ut-TAH-nuh muh-ni-BUHN-duh mah-LAHS-uh-nuh)

Modification: heels down, knees together, palms to the floor, fingers facing the toes, chest to the quadriceps
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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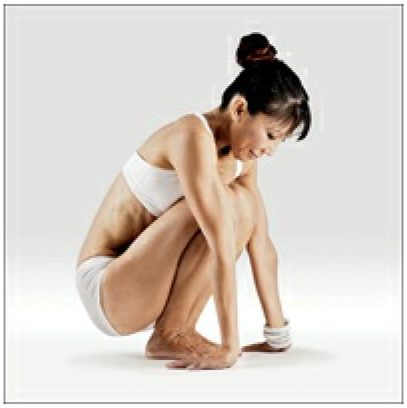

Garland Pose with Hands in Prayer Prep.

Malasana Namaskar Prep.

(mah-LAHS-uh-nuh nuh-muhs-KAHR)

Modification: heels down
Pose Type: standing, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

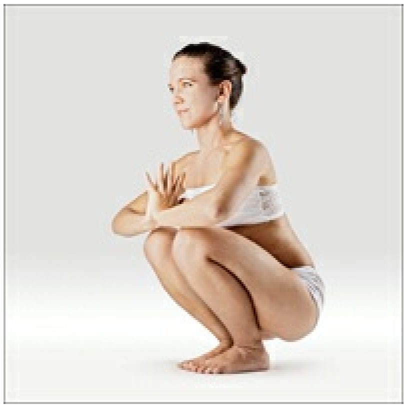

Garland Pose Prep.

Malasana Prep.

(mah-LAHS-uh-nuh)

Also Known As: Full Squat Pose (Purna Utkatasana)
Modification: knees together, heels down; arms straight out to the front, palms down
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

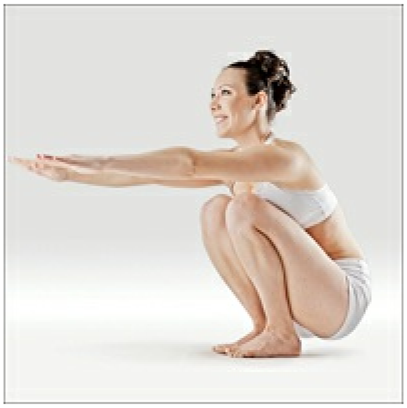

Arms Spread Out Garland Pose Prep.

Prasarita Hasta Malasana Prep.

(pruh-SAH-ri-tuh HUH-stuh mah-LAHS-uh-nuh)

Also Known As: Full Squat Pose (Purna Utkatasana), Flying Bird Pose (Khagasana)
Modification: knees together, heels down, arms straight out to the side
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

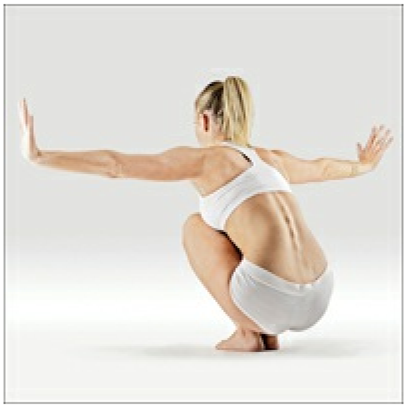

SQUAT: HEELS DOWN—ARMS ABOVE HEAD

Upward Hands Garland Pose Prep.

Urdhva Hasta Malasana Prep.

(OORD-vuh HUH-stuh mah-LAHS-uh-nuh)

Also Known As: Full Squat Pose (Purna Utkatasana)
Modification: knees together, hands to the sky
Pose Type: standing, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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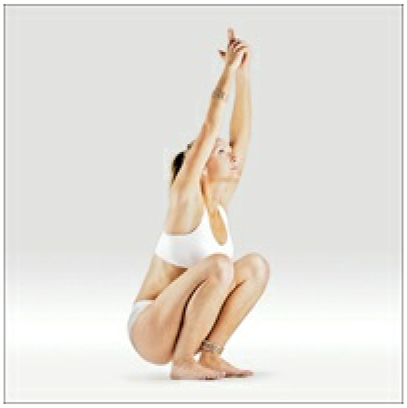

Easy Noose Pose

Sukha Pashasana

(SUK-kuh puh-SHAHS-uh-nuh)

Also Known As: Revolved Yoga Squat (Parivritta Upaveshasana)
Modification: heels down, shoulder between the knees, one palm flat on the floor, other arm straight out to the back
Pose Type: standing, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

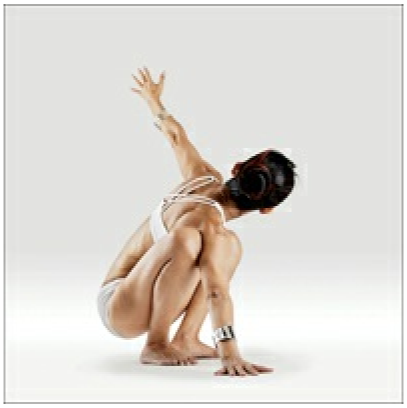

Extended Side Noose Pose

Utthita Parshva Pashasana

(UT-ti-tuh PAHRSH-vuh puh-SHAHS-uh-nuh)

Modification: heels down, one hand to the floor, other arm extended up over the head
Pose Type: standing, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

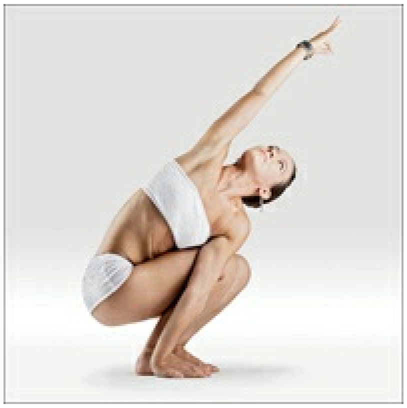

SQUAT: HEELS DOWN—TWISTS

Noose Pose with Hands in Prayer

Pashasana Namaskar

(puh-SHAHS-uh-nuh nuh-muhs-KAHR)

Modification: heels down
Pose Type: standing, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

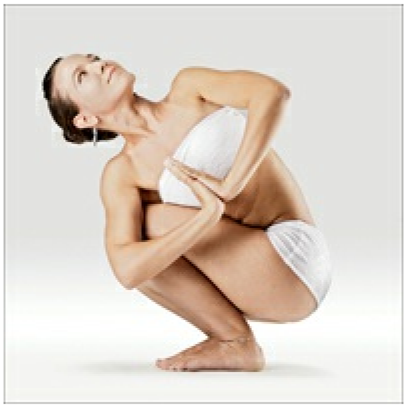

Half Bound Noose Pose

Ardha Baddha Pashasana

(UHR-duh BUH-duh puh-SHAHS-uh-nuh)

Modification: heels down
Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

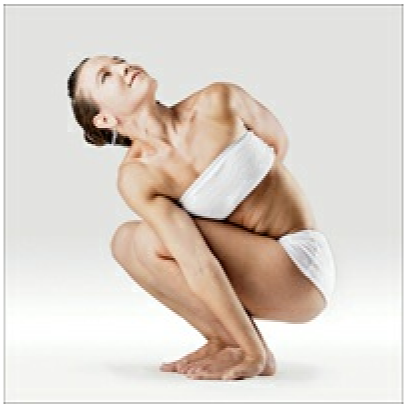

Noose Pose

Pashasana

(puh-SHAHS-uh-nuh)

Modification: heels down, binding with a strap
1. binding around one leg
2. binding around both legs
Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

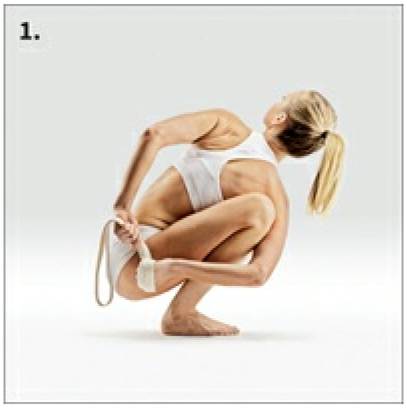

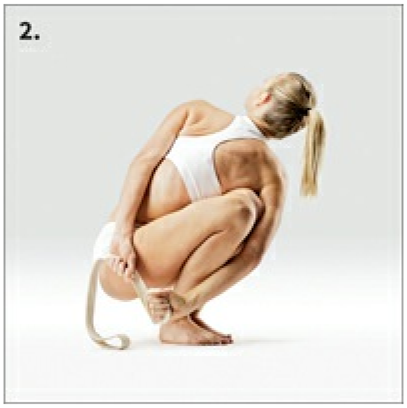

Noose Pose

Pashasana

(puh-SHAHS-uh-nuh)

Modification: heels down, binding around both legs
1. side view
2. front view
Pose Type: standing, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

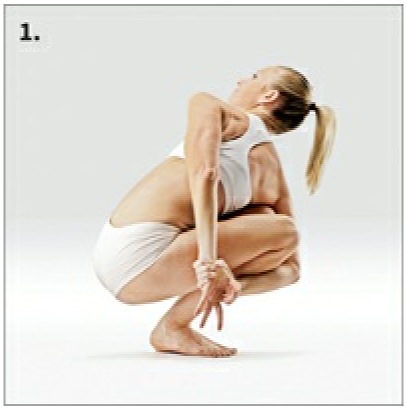

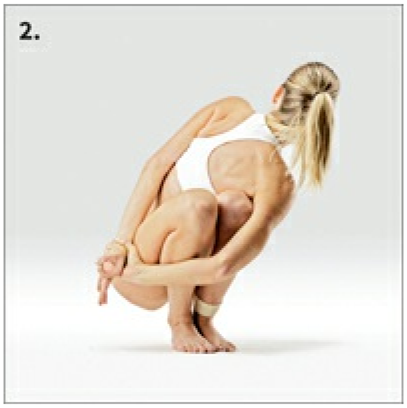

ONE-LEGGED SQUAT: FOOT TO KNEE

One-Legged Tip Toe Pose

Eka Pada Prapadasana

(EY-kuh PUH-duh pruh-puh-DAHS-uh-nuh)

Also Known As: Half Bound Lotus Tip Toe Pose Prep. (Ardha Baddha Padma Padangushtasana Prep.)
Modification: 1. both hands to the floor on the sides
2. hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)

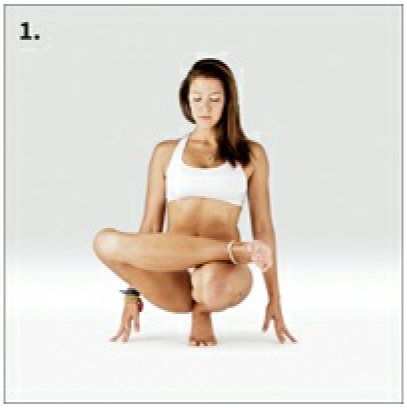

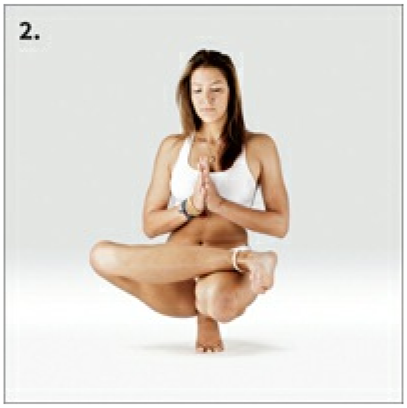

One-Legged Tip Toe Pose

Eka Pada Prapadasana

(EY-kuh PUH-duh pruh-puh-DAHS-uh-nuh)

Also Known As: Half Bound Lotus Tip Toe Pose Prep. (Ardha Baddha Padma Padangushtasana Prep.)
Modification: 1. one hand on the hip, other hand to the floor
2. one hand on the hip, one arm up over the head
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)
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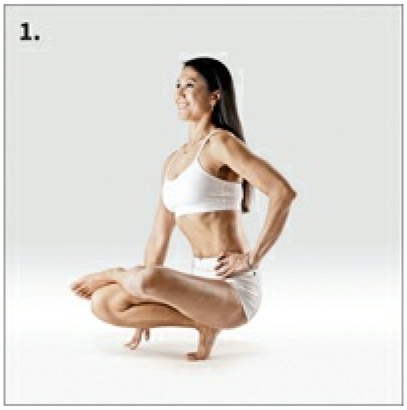

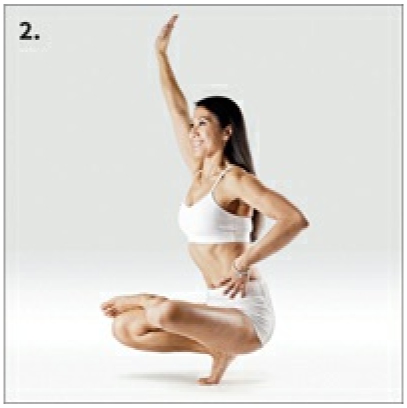

Baby Cradle Pose with Hands in Prayer in One-Legged Garland Pose

Hindolasana Namaskar in Eka Pada Malasana

(hin-do-LAHS-uh-nuh EY-kuh PUH-duh mah-LAHS-uh-nuh)

Also Known As: Baby Cradle Pose with Hands in Prayer in One-Legged Yoga Squat (Hindolasana Namaskar in Eka Pada Upavesashana)
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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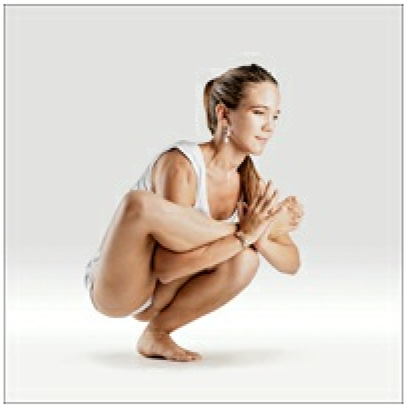

Baby Cradle Pose in One-Legged Tip Toe Pose 1

Hindolasana in Eka Pada Prapadasana 1

(hin-do-LAHS-uh-nuh in EY-kuh PUH-duh pruh-puh-DAHS-uh-nuh)

Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

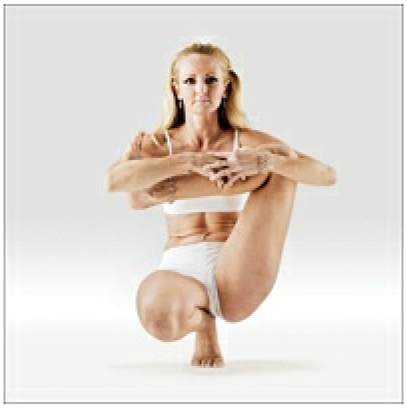

Half Yogic Staff Pose Prep. in One-Legged Tip Toe Pose

Ardha Yogadandasana Prep. in Eka Pada Prapadasana

(UHR-duh yo-guh-duhn-DAHS-uh-nuh in EY-kuh PUH-duh pruh-puh-DAHS-uh-nuh)

Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

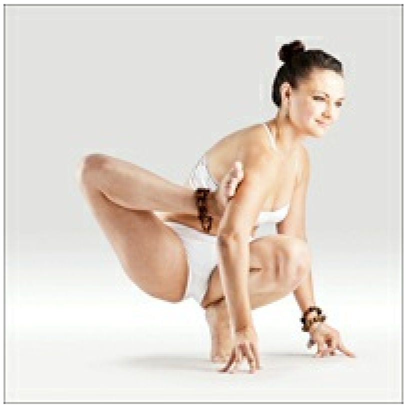

ONE-LEGGED SQUAT: FOOT UNDER THE KNEE

Baby Cradle Pose in One-Legged Tip Toe Pose 2

Hindolasana in Eka Pada Prapadasana 2

(hin-do-LAHS-uh-nuh in EY-kuh PUH-duh pruh-puh-DAHS-uh-nuh)

Pose Type: standing one-legged balance, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

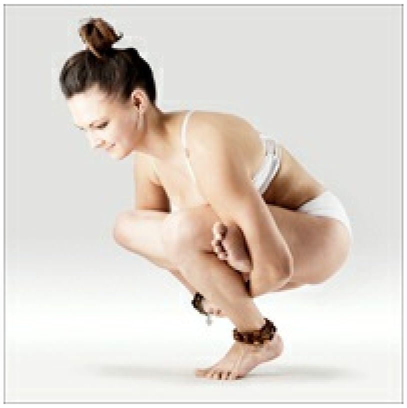

Supported Revolved One-Legged Tip Toe Pose

Salamba Parivritta Eka Pada Prapadasana

(sah-LUHM-buh puh-ri-VRIT-tuh EY-kuh PUH-duh pruh-puh-DAHS-uh-nuh)

Modification: foot under the knee

Pose Type: standing one-legged balance, forward bend, twist

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

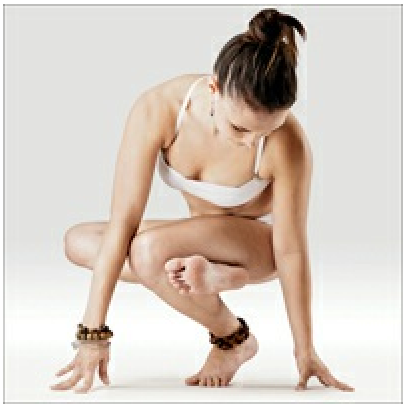

ONE-LEGGED SQUAT: FOOT TO KNEE & ONE KNEE OVER THE SHOULDER

Tip Toe Lord of the Fishes Pose

Prapada Matsyendrasana

(PRUH-puh-duh muhts-y-eyn-DRAHS-uh-nuh)

Pose Type: standing one-legged balance, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

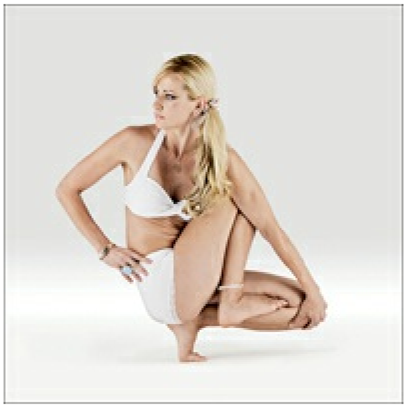

Supported One-Legged Tip Toe Pose

Salamba Eka Pada Prapadasana

(sah-LUHM-buh EY-kuh PUH-duh pruh-puh-DAHS-uh-nuh)

Modification: leg wrapped around the tricep, fingertips to the floor
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)

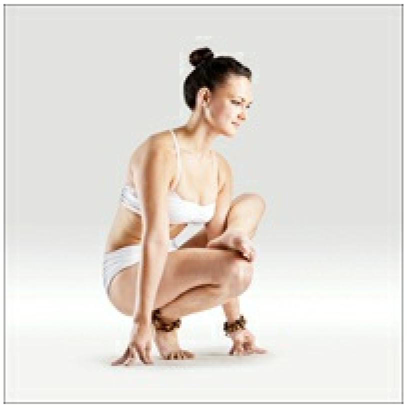

Supported One-Legged Tip Toe Pose

Salamba Eka Pada Prapadasana

(sah-LUHM-buh EY-kuh PUH-duh pruh-puh-DAHS-uh-nuh)

Modification: hands to the floor, shoulder to the back of the knee, other foot wrapped around the forearm
Pose Type: standing one-legged balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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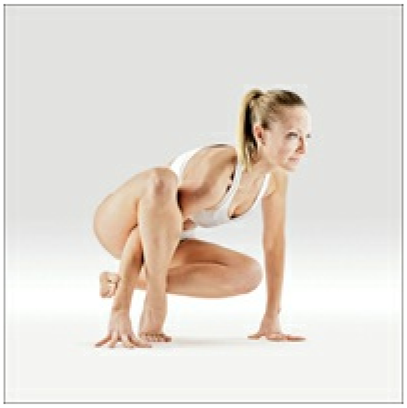

ONE-LEGGED SQUAT: HALF LOTUS

Half Bound Lotus Tip Toe Pose

Ardha Baddha Padma Prapadasana

(UHR-duh BUH-duh PUHD-muh pruh-puh-DAHS-uh-nuh)

Also Known As: Half Bound Lotus Tip Toe Pose (Ardha Baddha Padma Padangushtasana)
Modification: 1. fingertips to the floor, other hand to the heart
2. binding, other hand to the heart
3. binding, other arm out to the side, parallel to the floor
Pose Type: 1. standing one-legged balance

2 & 3. standing one-legged balance, binding

Drishti Point: Nasagrai or Nasagre (nose)

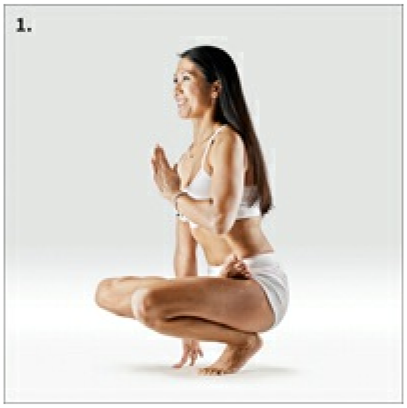

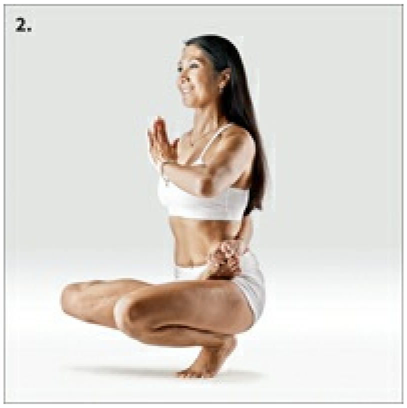

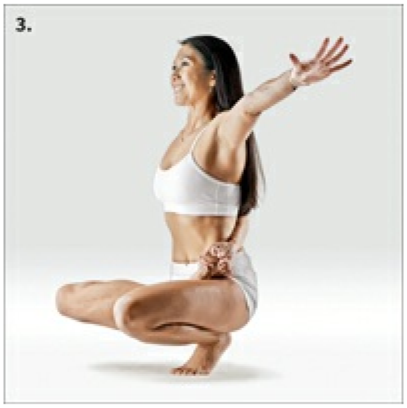

Hand Position of the Pose Dedicated to Garuda in Half Lotus Tip Toe Pose

Hasta Garudasana in Ardha Padma Prapadasana

(HUH-stuh guh-ru-DAHS-uh-nuh in UHR-duh-PUHD-muh pruh-puh-DAHS-uh-nuh)

Modification: knee on the floor, forward bend

Pose Type: standing one-legged balance, forward bend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

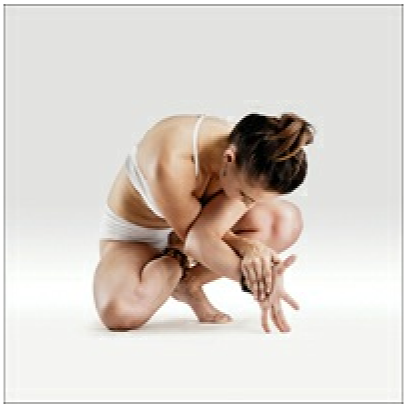

ONE-LEGGED SQUAT: HALF LOTUS—HEEL DOWN

Half Lotus One-Legged Garland Pose

Ardha Padma Eka Pada Malasana

(UHR-duh PUHD-muh EY-kuh PUH-duh mah-LAHS-uh-nuh)

Also Known As: Half Lotus One-Legged Yoga Squat (Ardha Padma Eka Pada Upaveshasana)
Modification: arms parallel to the floor
Pose Type: standing one-legged balance
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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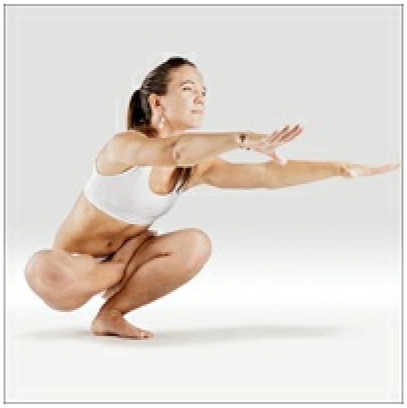

Half Lotus Bound One-Legged Garland Pose

Ardha Padma Baddha Eka Pada Malasana

(UHR-duh PUHD-muh BUH-duh EY-kuh PUH-duh mah-LAHS-uh-nuh)

Also Known As: Half Lotus Bound One-Legged Yoga Squat (Ardha Padma Baddha Eka Pada Upavesasana)
Pose Type: standing one-legged balance, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

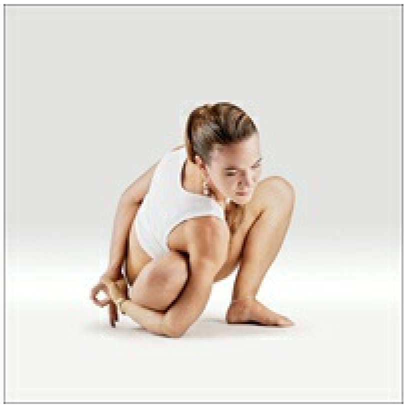

ONE-LEGGED SQUAT: ONE LEG STRAIGHT—HEEL UP & DOWN

Hand to Foot Pose Squatting Prep.

Hasta Padasana Prep.

(HUH-stuh puh-DAHS-uh-nuh)

Modification: leg straight and lifted off the floor, arms parallel to the floor
Pose Type: standing one-legged balance
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

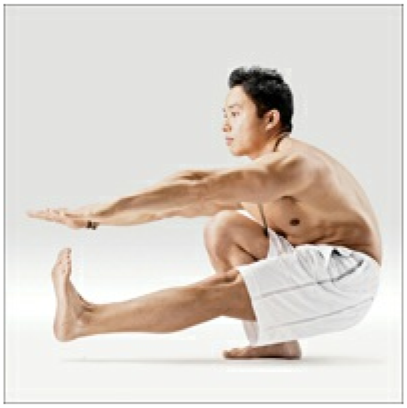

Hands to Foot Squatting Pose 1

Hasta Padasana 1

(HUH-stuh puh-DAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi Modification (Marichyasana Modification)
Modification: both hands to the foot, heel down
Pose Type: standing one-legged balance
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

Drishti Point: Nasagrai or Nasagre (nose) or Padhayoragrai or Padayoragre (toes/feet)

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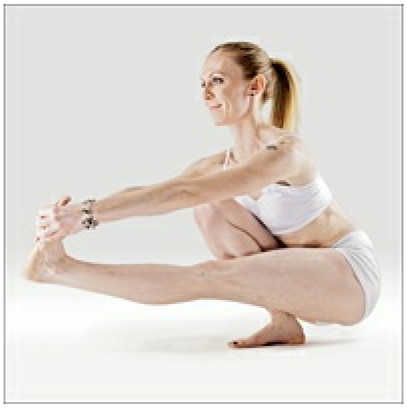

Revolved Supported Hand to Foot Pose Squatting

Parivritta Salamba Hasta Padasana

(puh-ri-VRIT-tuh SAH-luhm-buh HUH-stuh puh-DAHS-uh-nuh)

Modification: one hand to the floor

Pose Type: standing one-legged balance, twist

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

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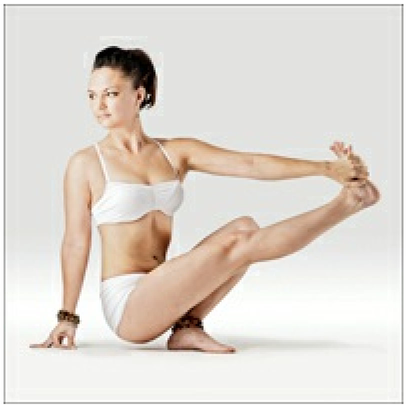

Hand to Foot to the Side Tip Toe Pose

Hasta Pada Parshva Prapadasana

(HUH-stuh PUH-duh PAHRSH-vuh pruh-puh-DAHS-uh-nuh)

Pose Type: standing one-legged balance

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

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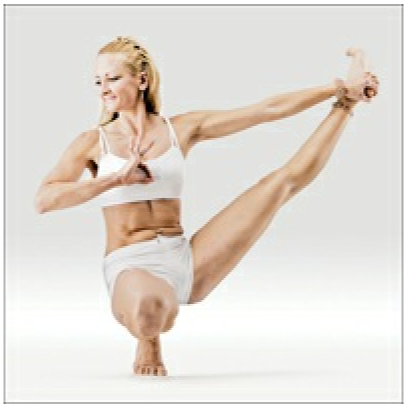

Sundial Pose in One-Legged Garland Pose

Surya Yantrasana in Eka Pada Malasana

(SOOR-yuh yuhn-TRAHS-uh-nuh in EY-kuh PUH-duh mah-LAHS-uh-nuh)

Also Known As: Sundial Pose in One-Legged Yoga Squat (Surya Yantrasana in Eka Pada Upavesasana)
Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

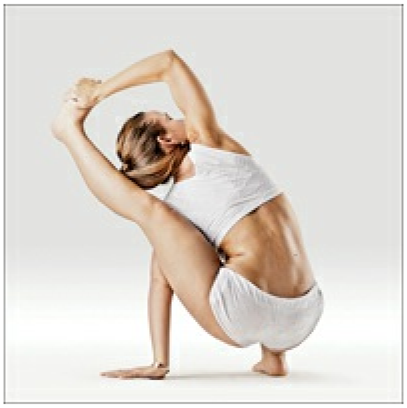

Extended Hand to Big Toe Pose in Half Tip Toe Hero Pose

Utthita Hasta Padangushtasana in Ardha Prapada Virasana

(UT-ti-tuh HUH-stuh puhd-ahng-goosh-TAHS-uh-nuh in UHR-duh PRUH-puh-duh veer-AHS-uh-nuh)

Pose Type: standing one-legged balance, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

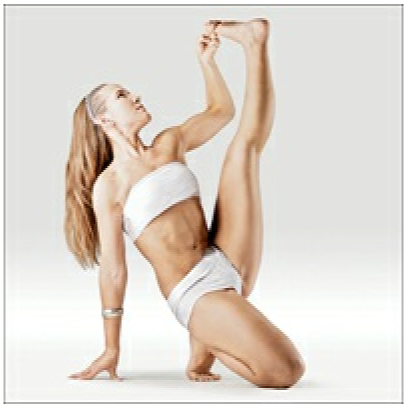

ONE-LEGGED SQUAT: ONE LEG STRAIGHT—HEEL DOWN

Baby Grasshopper Pose

Bala Shalabhasana

(BUH-luh shuh-luh-BAHS-uh-nuh)

Also Known As: Baby Locust Pose
Modification: chest facing the floor, forearm on the floor
Pose Type: standing one-legged balance, forward bend, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

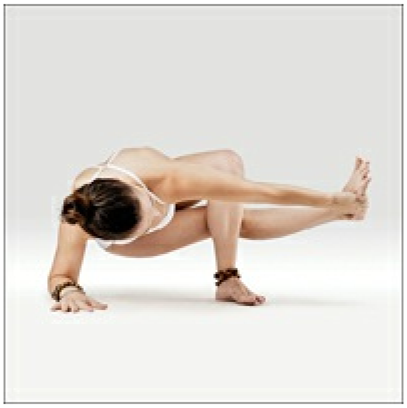

Hand to Foot Pose 2

Hasta Padasana 2

(HUH-stuh puh-DAHS-uh-nuh)

Modification: leg crossed over, one hand to the foot, other hand to the heart
Pose Type: standing one-legged balance, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Angushtamadhye or Angushta Ma Dyai (thumbs)

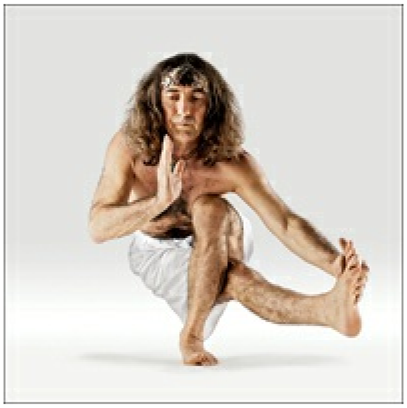

ONE-LEGGED SQUAT: LEG BEHIND THE HEAD

Supported One Foot Behind the Head Tip Toe Pose Prep. 1

Salamba Eka Pada Shirsha Prapadasana Prep. 1

(SAH-luhm-buh EY-kuh PUH-duh SHEER-shuh pruh-puh-DAHS-uh-nuh)

Modification: heel up, sitting bones lifted
Pose Type: standing one-legged balance, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

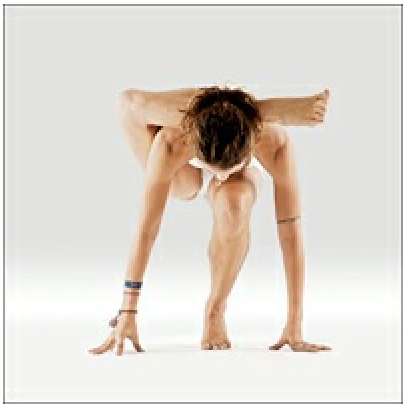

Supported One Foot Behind the Head Tip Toe Pose Prep. 2

Salamba Eka Pada Shirsha Prapadasana Prep. 2

(SAH-luhm-buh EY-kuh PUH-duh SHEER-shuh pruh-puh-DAHS-uh-nuh)

Modification: hands to the floor
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)

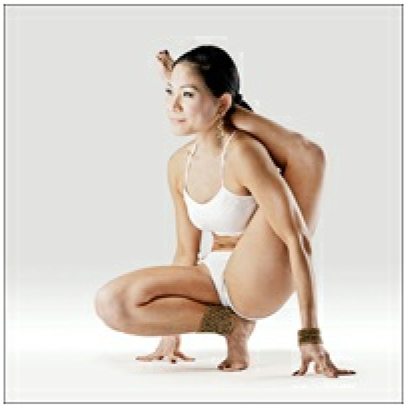

One Foot Behind the Head Tip Toe Pose

Eka Pada Shirsha Prapadasana

(EY-kuh PUH-duh SHEER-shuh pruh-puh-DAHS-uh-nuh)

Also Known As: Tip Toe Balance Foot Behind The Head Pose (Padangushta Eka Pada Shirshasana), One Foot Behind the Head Tip Toe Pose (Eka Pada Shirsha Padangushtasana)
Pose Type: standing one-legged balance
Drishti Point: Nasagrai or Nasagre (nose)

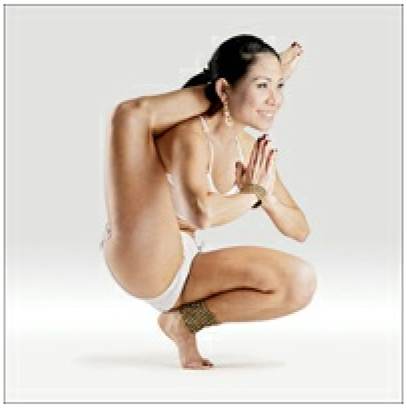

SQUAT: HEELS DOWN—KNEES WIDE

Hand Position of the Pose Dedicated to Garuda in Garland Pose

Hasta Garudasana in Malasana

(HUH-stuh guh-ru-DAHS-uh-nuh in mah-LAHS-uh-nuh)

Also Known As: Hand Position of the Pose Dedicated to Garuda in Yoga Squat (Hasta Garudasana in Upaveshasana)
Pose Type: standing, forward bend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

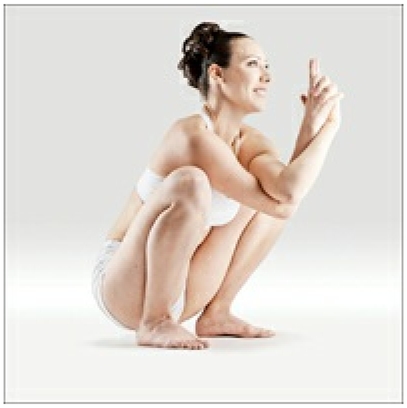

Lion Pose Dedicated to an Avatar of Lord Vishnu in Garland Pose

Narasimhasana in Malasana

(nuh-ruh-sim-HAHS-uh-nuh in mah-LAHS-uh-nuh)

Also Known As: Lion Pose in Yoga Squat (Simhasana in Upaveshasana)
Modification: heels down
Pose Type: standing, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

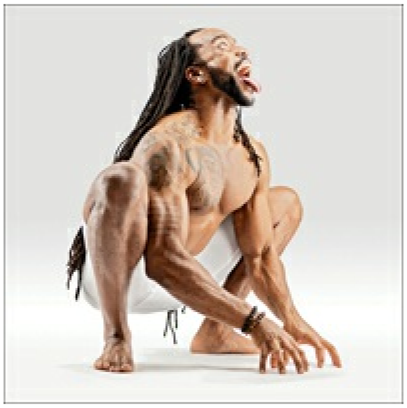

Half Bound Revolved Garland Pose

Ardha Baddha Parivritta Malasana

(UHR-duh BUH-duh puh-ri-VRIT-tuh mah-LAHS-uh-nuh)

Also Known As: Half Bound Revolved Yoga Squat (Ardha Baddha Parivritta Upaveshasana)
Modification: forearm on the knee
Pose Type: standing, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

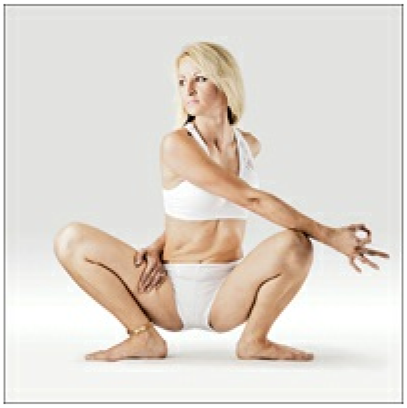

Bound Garland Pose

Baddha Malasana

(BUH-duh mah-LAHS-uh-nuh)

Also Known As: Bound Yoga Squat (Baddha Upaveshasana)
Pose Type: standing, binding
Drishti Point: Nasagrai or Nasagre (nose)

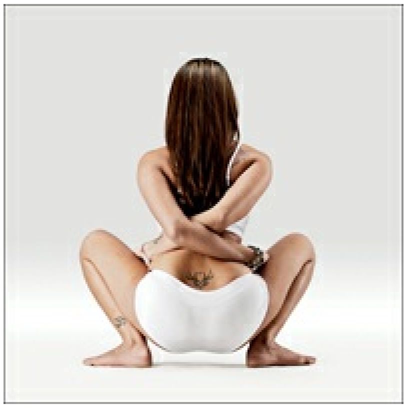

One Leg Bound Garland Pose

Eka Pada Baddha Malasana

(EY-kuh PUH-duh BUH-duh mah-LAHS-uh-nuh)

Also Known As: One Leg Bound Yoga Squat (Eka Pada Baddha Upaveshasana)
Modification: heels down, binding around one of the legs, knees open wide
Pose Type: standing, binding, forward bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

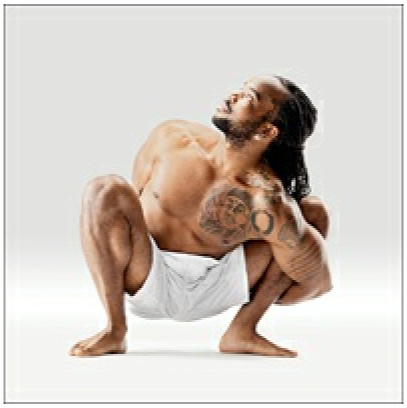

SQUAT: ONE HEEL UP, ONE HEEL DOWN—KNEES WIDE

Uneven Legs Garland Pose

Vishama Pada Malasana

(VISH-uh-muh PUH-duh mah-LAHS-uh-nuh)

Also Known As: Uneven Legs Yoga Squat (Vishama Pada Upaveshasana)
Modification: one knee higher than the other; fingertips of one hand to the floor, other elbow on the knee
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

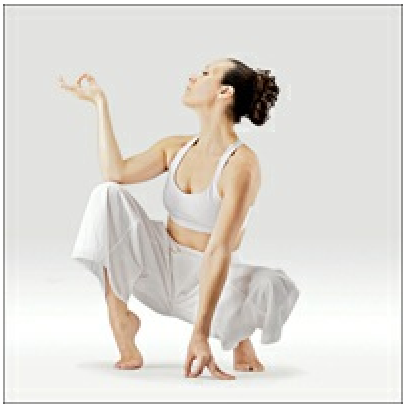

Sideways Uneven Legs Garland Pose

Parshva Vishama Pada Malasana

(PAHRSH-vuh VISH-uh-muh PUH-duh mah-LAHS-uh-nuh)

Also Known As: Sideways Uneven Legs Yoga Squat (Parshva Vishama Pada Upaveshasana)
Modification: one heel up, one heel down, one arm up over the head into a side bend, back of the other hand on the floor
Pose Type: standing, forward bend, side bend

Drishti Point: Hastagrai or Hastagre (hands)

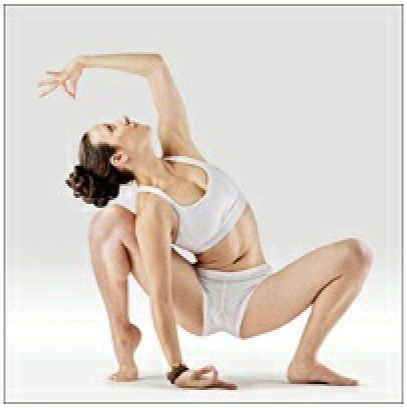

SQUAT: HEELS DOWN—KNEES WIDE, FORWARD BENDS

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Also Known As: Yoga Squat (Upaveshasana)
Modification: 1. hands in Anjali Mudra (Hands in Prayer)
2. arms straight out in front; palms down, head up
3. arms straight out in front; palms down, head down
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

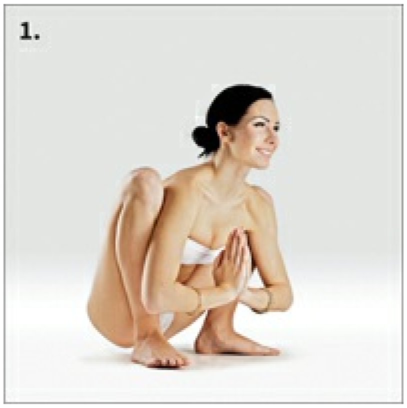

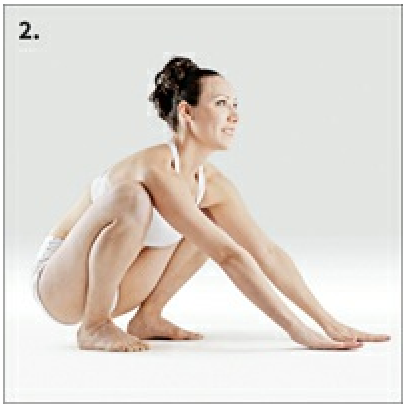
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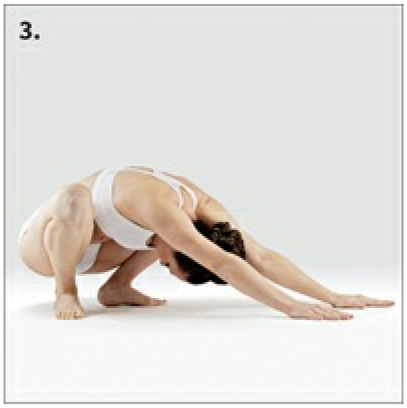
3.

Hands Bound Garland Pose

Baddha Hasta Malasana

(BUH-duh HUH-stuh mah-LAHS-uh-nuh)

Also Known As: Hands Bound Yoga Squat (Baddha Hasta Upaveshasana)
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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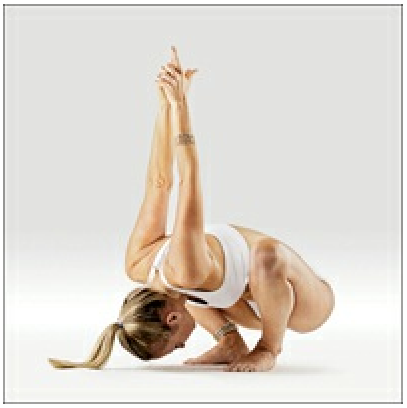

SQUAT: HEELS DOWN—KNEES WIDE, FORWARD BENDS—BINDING

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Also Known As: Tortoise Pose Squat (Kurmasana Modification)
Modification: grabbing onto heels
1. head off the floor
2. forehead to the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

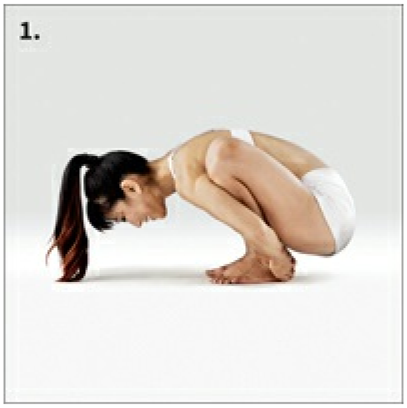

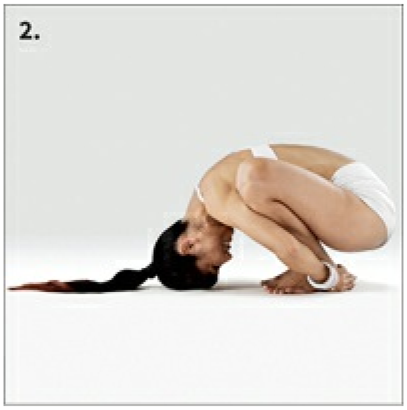

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Also Known As: Golden Belt Pose (Kanchyasana)
Modification: hands bound, heels down
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

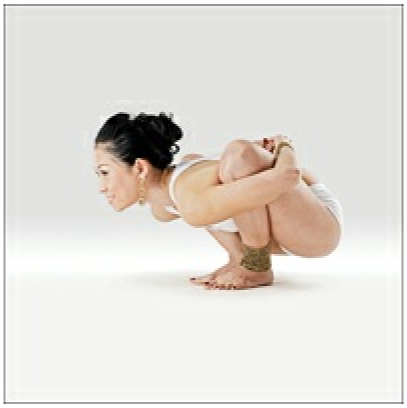

SQUAT: HEELS UP—KNEES WIDE, FORWARD BENDS—BINDING

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Modification: heels up, arms stretched out to the back, palms facing up, forehead to the floor
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

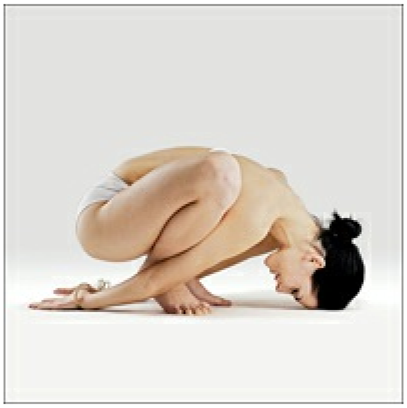

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Also Known As: Golden Belt Pose (Kanchyasana)
Modification: heels up, hands bound
1. front view
2. side view
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

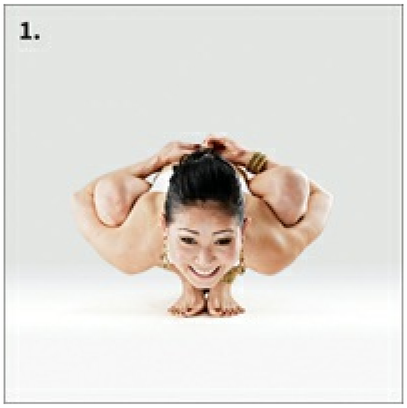

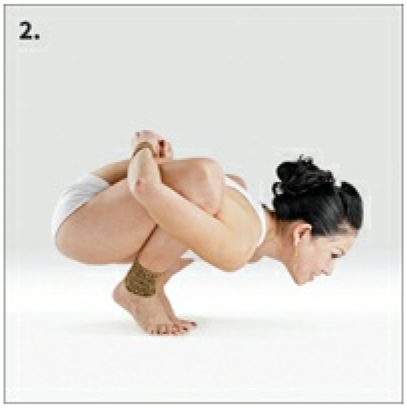

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Modification: heels up, arms binding around the shins, hands between thighs and rib cage
Pose Type: standing, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

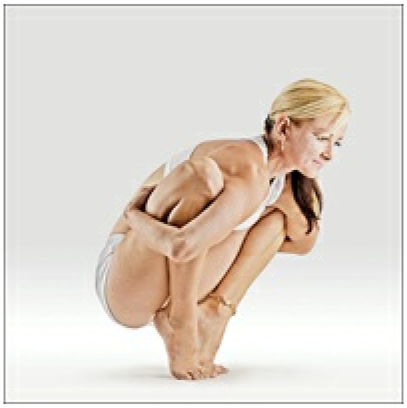

SQUAT: HEELS UP—KNEES WIDE, FORWARD BENDS—FOREARMS & ELBOWS ON THE FLOOR

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Modification: forehead to the floor, thumbs to the upper back
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

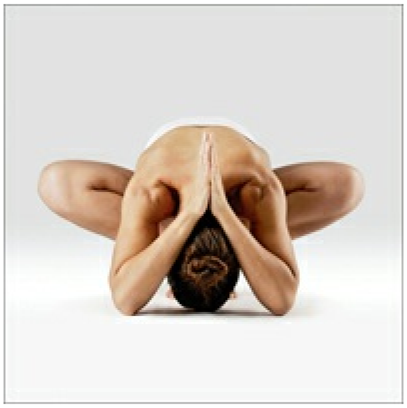

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Modification: forearms to the floor
1. grabbing onto the triceps
2. forearms on the floor, palms pressed together
Pose Type: standing, forward bend
Drishti Point: 1. Nasagrai or Nasagre (nose)
2. Angusthamadhye or Angustha Ma Dyai (thumbs)

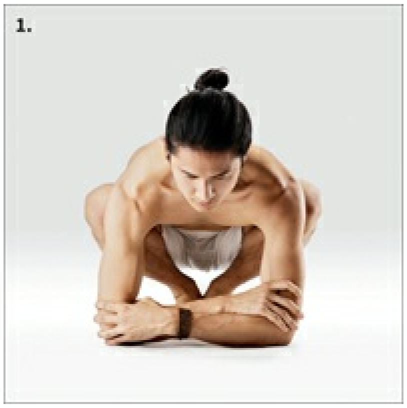

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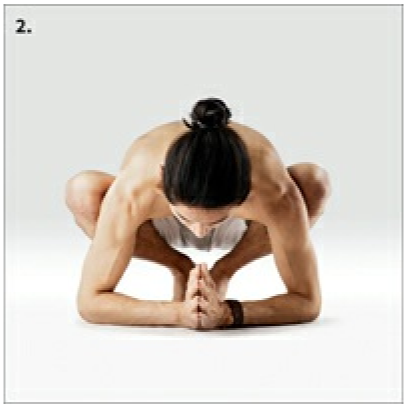

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Pose Type: standing, forward bend

Drishti Point: 1 & 2. Angusthamadhye or Angustha Ma Dyai (thumbs) 3 & 4. Nasagrai or Nasagre (nose)

How to Perform the Pose:

1. Begin by standing in Mountain Pose (*Tadasana*). Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale as you bend your knees, lift your heels, and drop your sitting bones to your heels.
3. Inhale as you open your knees out to the sides. Exhale as you drop your chest between your knees and lower your forearms to the floor. Your knees should end up on the outsides of your shoulders.
4. You can experiment with various arm positions. Start with your palms flat on the floor (Pose #1), then bring either one hand to your face (Pose #2) or both hands to your face (Pose #3) and then spread your fingers out (Pose #4).
5. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
6. To come out of the pose, inhale as you lift your chest and bring your knees together. Exhale as you press into your feet, straighten your legs, and come back to Mountain Pose (*Tadasana*).

Modification:

1. forearms and palms to the floor
2. one forearm and palm to the floor, other elbow to the floor hand to the face
3. both hands to the face, elbows on the floor
4. both hands to the face, fingers spread open in a Padma Mudra - Lotus Hand Seal elbows, on the floor

1.

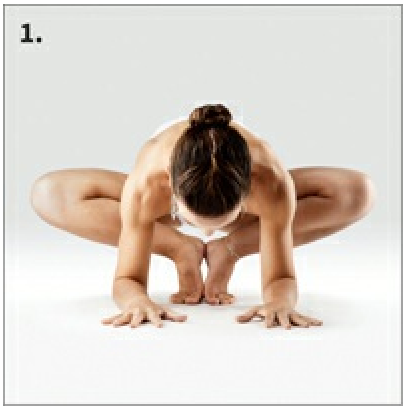

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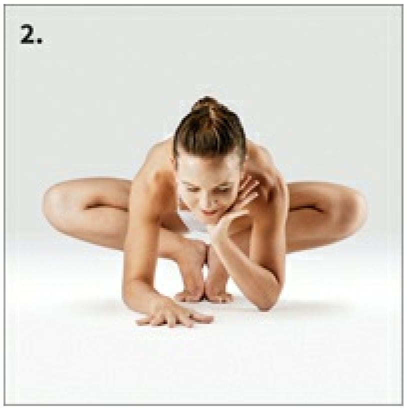

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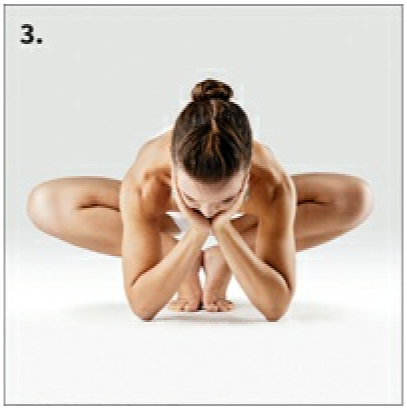

4.

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Also Known As: Full Squat Pose (Kunthasana)

Modification: hands wide, knees on top of the triceps

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

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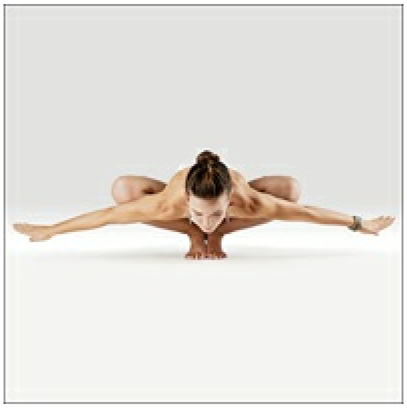

Garland Pose

Malasana

(mah-LAHS-uh-nuh)

Modification: heels up

1. knees to the armpits; hands out to the sides, fingertips to the floor
2. forehead to the floor; elbows bent at 90 degrees, fingertips to the floor
3. forehead to the floor; hands off the floor, arms out to the sides

Pose Type: standing, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

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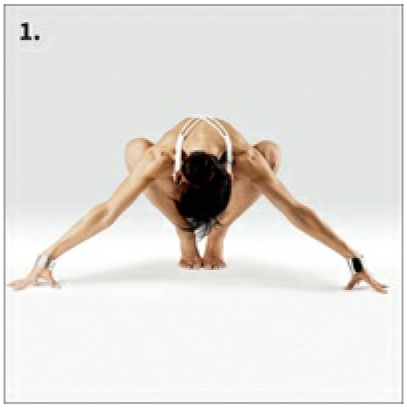

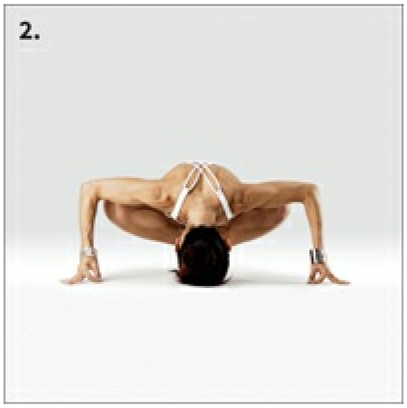

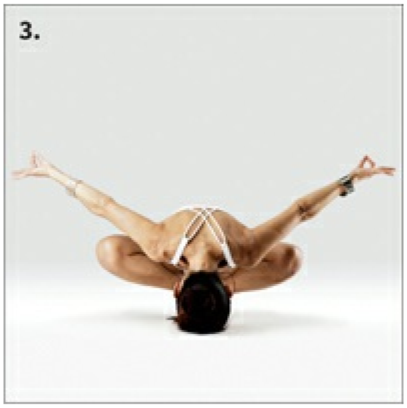

SQUAT: HEELS UP—KNEES WIDE, ARMS TO THE FLOOR & BALLET TOES

Supported Tip Toe Pose

Salamba Prapadasana

(SAH-luhm-buh pruh-puh-DAHS-uh-nuh)

Modification: knees open, elbows and wrists together, fingertips touching the floor in front of the feet
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व र य

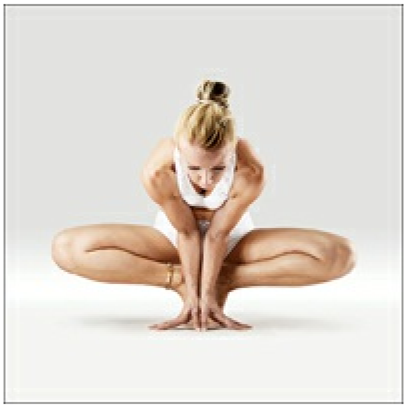

Intense Wrist Stretch Supported Tip Toe Pose

Uttana Manibandha Salamba Prapadasana

(ut-TAH-nuh muh-ni-BUHN-duh SAH-luhm-buh pruh-puh-DAHS-uh-nuh)

Modification: knees open wide; palms on the floor, fingertips toward the feet
Pose Type: standing, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

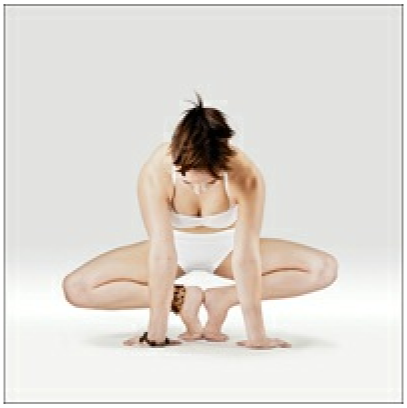

Lion Pose Dedicated to an Avatar of Lord Vishnu in Tip Toe Pose

Narasimhasana in Prapadasana

(nuh-ruh-sim-HAHS-uh-nuh in pruh-puh-DAHS-uh-nuh)

Also Known As: Lion Pose in Tip Toe Pose (Simhasana in Prapadasana)
Modification: feet wide apart
Pose Type: standing, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

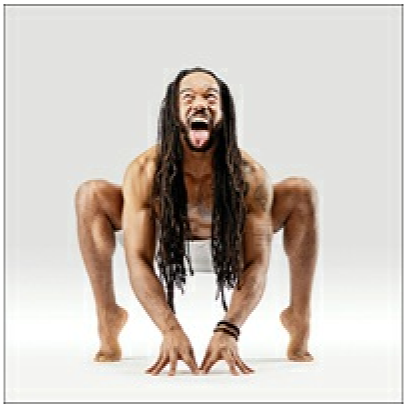

Unsupported Intense Ankle Stretch Tip Toe Pose

Niralamba Uttana Kulpa Prapadasana

(nir-AH-luhm-buh ut-TAH-nuh KUL-puh pruh-puh-DAHS-uh-nuh)

Modification: hands on the knees
Pose Type: standing, balance
Drishti Point: Nasagrai or Nasagre (nose)

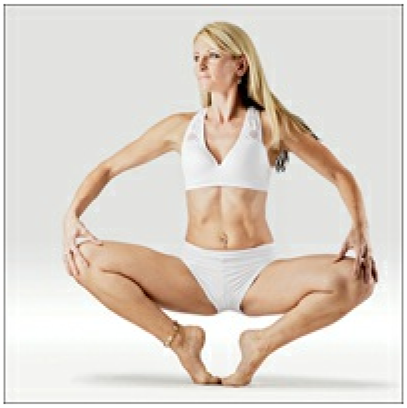

Supported Intense Ankle Stretch Tip Toe Pose

Salamba Uttana Kulpa Prapadasana

(SAH-luhm-buh ut-TAH-nuh KUL-puh pruh-puh-DAHS-uh-nuh)

Modification: fingertips to the floor
Pose Type: standing, balance
Drishti Point: Nasagrai or Nasagre (nose)

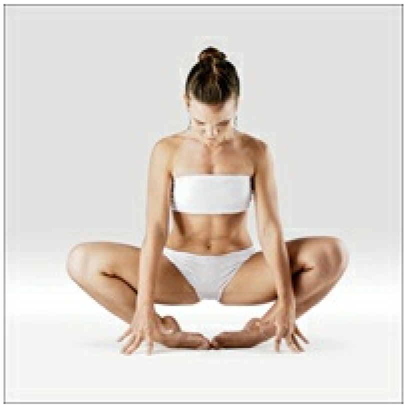

SQUAT: HEELS UP—KNEES WIDE, ARM MODIFICATIONS

Tip Toe Pose

Prapadasana

(pruh-puh-DAHS-uh-nuh)

Modification: knees open wide; palms together, elbows together
Pose Type: standing
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

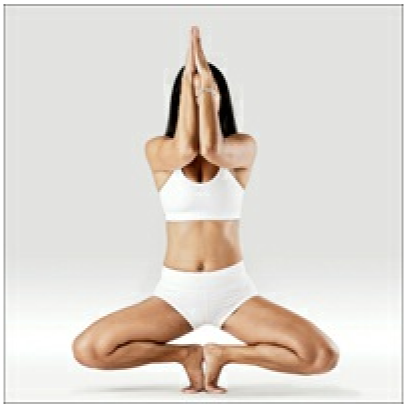

Tip Toe Pose

Prapadasana

(pruh-puh-DAHS-uh-nuh)

Modification: knees open wide, hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

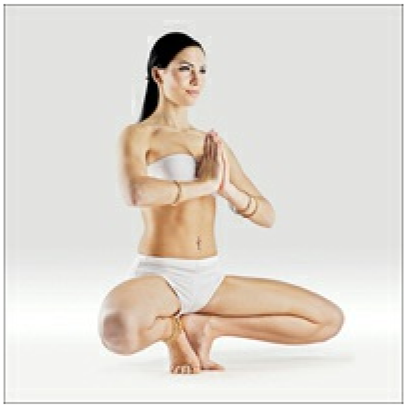

One Hand in Reverse Prayer Tip Toe Pose

Eka Hasta Viparita Namaskar Prapadasana

(EY-kuh HUH-stuh vi-puh-REE-tuh nuh-muhs-KAHR pruh-puh-DAHS-uh-nuh)

Modification: knees open wide; one hand to the knee
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)
ल व

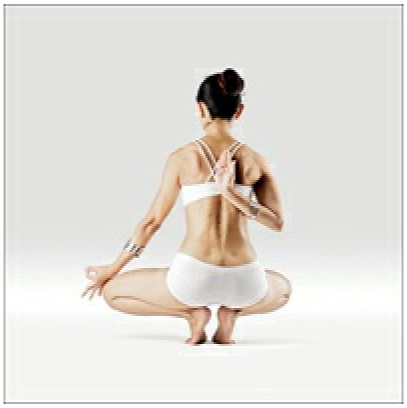

Upward Hands Tip Toe Pose

Urdhva Hasta Prapadasana

(OORD-vuh HUH-stuh pruh-puh-DAHS-uh-nuh)

Modification: knees open wide; arms extended up to the sky, head rolling back
Pose Type: standing, mild backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
ल व य

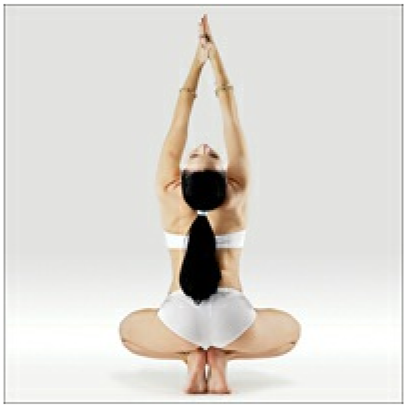

SQUAT: HEELS UP—KNEES WIDE, KNEES ON THE FLOOR—ARM MODIFICATIONS

Reverse Prayer Root Lock Pose Prep.

Viparita Namaskar Mulabhandasana Prep.

(vi-puh-REE-tuh nuh-muhs-KAHR moo-luh-buhn-DAHS-uh-nuh)

Also Known As: Back of the Body Prayer Tip Toe Pose (Paschima Namaskara Prapadasana)
Modification: knees open wide; knees to the floor
Pose Type: standing
Drishti Point: Nasagrai or Nasagre (nose)

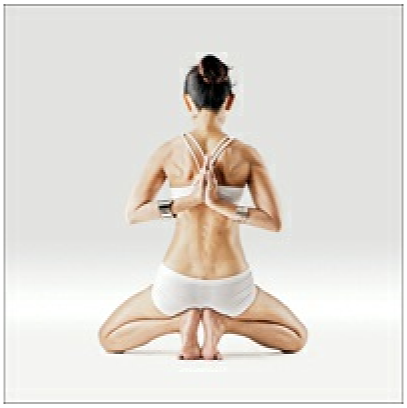

Root Lock Pose Prep.

Mulabhandasana Prep.

(moo-luh-buhn-DAHS-uh-nuh)

Also Known As: Tip Toe Pose Modification (Prapadasana Modification)
Modification: knees open wide; palms and elbows together; knees to the floor
Pose Type: standing
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

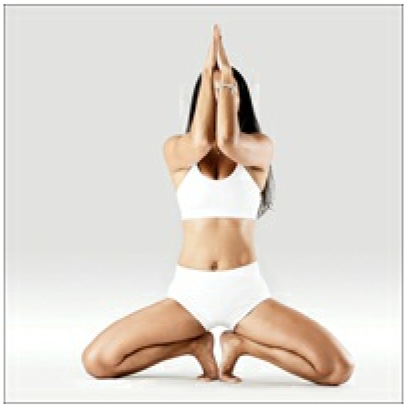

Root Lock Pose Prep.

Mulabhandasana Prep.

(moo-luh-buhn-DAHS-uh-nuh)

Also Known As: Tip Toe Pose Modification (Prapadasana Modification)
Modification: knees open wide; elbows and ankles crossed; knees to the floor, fingertips to the floor
Pose Type: standing, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

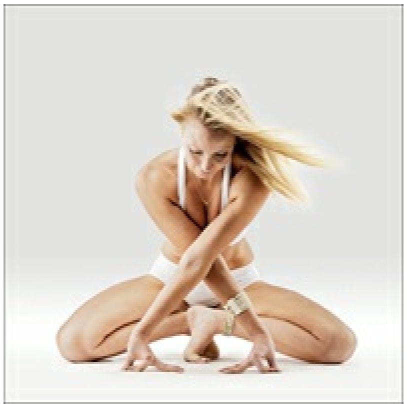

ROOT LOCK POSE

Root Lock Pose Prep.

Mulabhandasana Prep.

(moo-luh-buhn-DAHS-uh-nuh)

Also Known As: Twisted Feet Bound Angle Pose (Parivritta Pada Baddha Konasana)
Modification: fingertips to the floor behind the hips, sitting bones off the floor
Pose Type: standing, mild backbend

Drishti Point: Urdhva or Antara Drishti (up to the sky)
लं वं हं

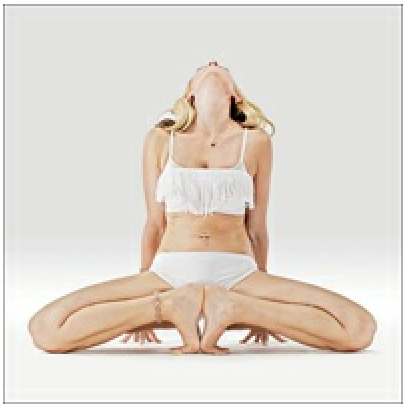

Womb Staff Pose

Yoni Dandasana

(YO-ni duhn-DAHS-uh-nuh)
Also Known As: Root Lock Pose Modification (Mulabandhasana Modification)
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)
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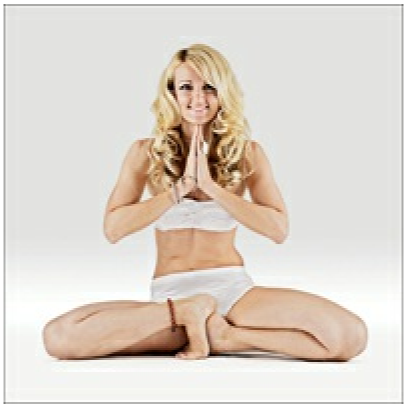

Root Lock Pose

Mulabhandasana

(moo-luh-buhn-DAHS-uh-nuh)
Also Known As: Perineal Contraction Pose (Mula Bandhasana)
Modification: palms up on the knees, head rolled back
Pose Type: seated, mild backbend
Drishti Point: Urdhva or Antara Drishti (up to the sky)
लं वं हं

Pose Dedicated to Sage Vamadeva 1

Vamadevasana 1

(vah-muh-dey-VAHS-uh-nuh)

Modification: both hands binding to the top foot
Pose Type: seated, twist, binding
Drishti Point: Parsva Drishti (to the right), Parsva Drishti (to the left)
ल व

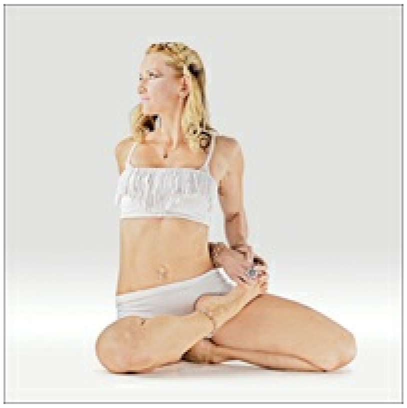

Seated Poses

EASY POSE
ACCOMPLISHED ONE POSE
FIRE LOG POSE
HALF LOTUS AND LOTUS POSE
BOTH KNEES BENT
BOUND ANGLE POSE
STAR POSE
LEGS IN FRONT
HORIZONTAL SPLITS
LEGS STRAIGHT IN FRONT
GARUDA LEGS
LEG CRADLE
HEAD TO KNEE
HERO POSE
THUNDERBOLT POSE
ONE KNEE BENT (VARIATIONS)
COW FACE POSE
SAGE VAMADEVA’S POSE
ONE-LEGGED KING PIGEON POSE
VERTICAL SPLITS

Easy Pose

Sukhasana

(suk-AHS-uh-nuh)

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

How to Perform the Pose:

1. Begin by sitting on the floor with both your legs straight out in front of you. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale as you bring your feet toward you and cross them at the ankles. Keep the soles of your feet flat on the floor and your knees in line with your shoulders.
3. Inhale, stretch your arms up to the sky to lengthen your spine, and exhale as you bring your elbows together on the inside of your knees.
4. Inhale as you open your palms up to sky with your fingertips pointing to the outsides. Exhale as you bring you thumbs and pointer fingers together.
5. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
6. Exhale as you release the pose, coming back to starting position with both your legs straight out.

Modification: knees in line with the shoulders, elbows to the inside of the knees

sukha = easy, lightness

Easy Pose

Sukhasana

(suk-AHS-uh-nuh)

Modification: knees to the chest, elbows to the outside of the knees, palms covering the face
Pose Type: seated, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

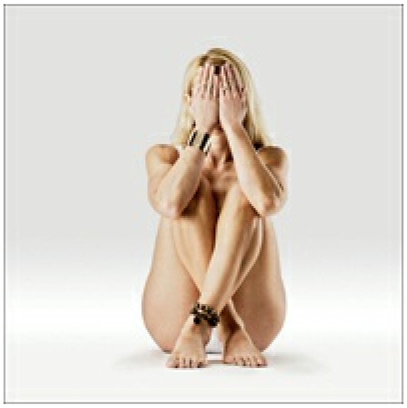

Easy Pose

Sukhasana

(suk-AHS-uh-nuh)

Modification: knees high, forearms to the shins
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

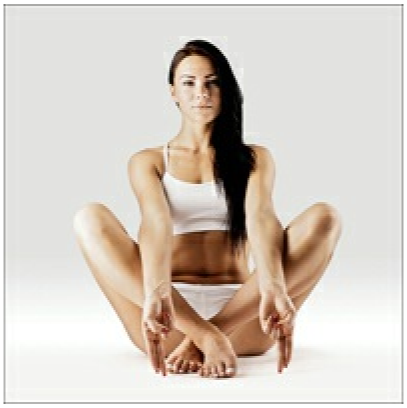

Easy Pose

Sukhasana

(suk-AHS-uh-nuh)

Modification: elbows crossed, backs of both hands to the knees

Pose Type: seated, mild backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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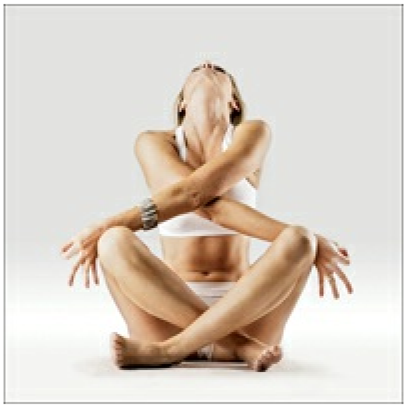

EASY POSE: SPINE STRAIGHT

Easy Pose

Sukhasana

(suk-AHS-uh-nuh)

Modification: on the yoga block

Pose Type: seated

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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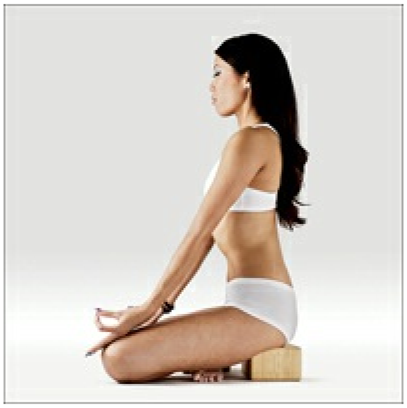

Easy Pose

Sukhasana

(suk-AHS-uh-nuh)

Pose Type: seated

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

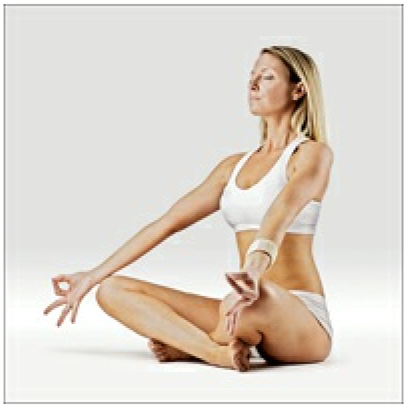

Bound Hands Easy Pose

Baddha Hasta Sukhasana

(BUH-duh HUH-stuh suk-AHS-uh-nuh)

Modification: arms in front, arms straight

Pose Type: seated

Drishti Point: Hastagrai or Hastagre (hands), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

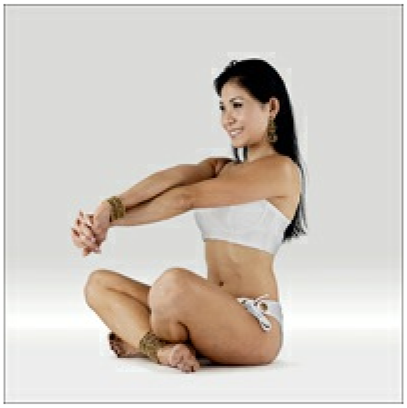

Embryo in the Womb Pose in Easy Pose

Garbha Pindasana in Sukhasana

(GUHR-buh pin-DAHS-uh-nuh in suk-AHS-uh-nuh)

Modification: grabbing onto the outside edges of the feet

Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

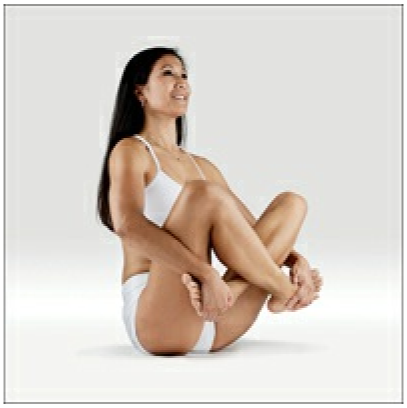

EASY POSE: TWISTS & SIDE BENDS

Easy Pose

Sukhasana

(suk-AHS-uh-nuh)
Modification: neck stretch
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)

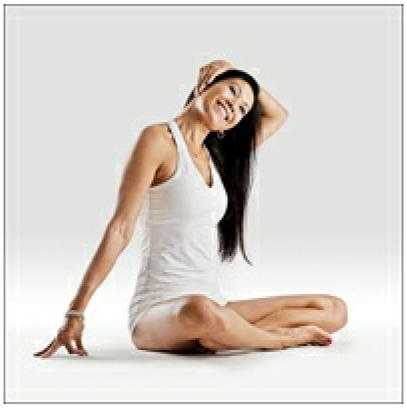

Revolved Easy Pose

Parivritta Sukhasana

(puh-ri-VRIT-tuh suk-AHS-uh-nuh)
Pose Type: seated, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

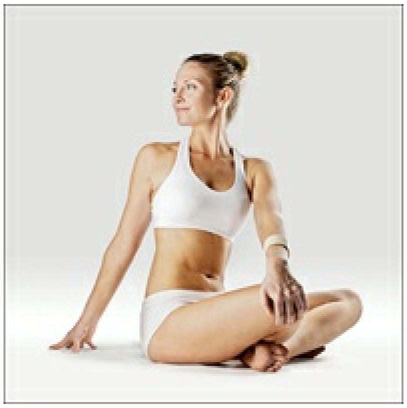

Sideways Easy Pose

Parshva Sukhasana

(PAHRSH-vuh suk-AHS-uh-nuh)

Modification: one forearm to the floor, other arm extended up over the head
Pose Type: seated, side bend
Drishti Point: Hastagrai or Hastagre (hands)

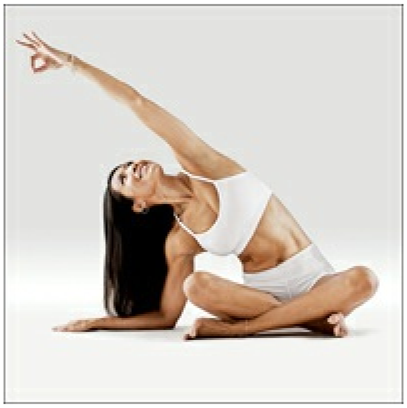

Revolved Bound Easy Pose

Parivritta Baddha Sukhasana

(puh-ri-VRIT-tuh BUH-duh suk-AHS-uh-nuh)

Modification: elbow to the floor
Pose Type: seated, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

ACCOMPLISHED ONE POSE

Accomplished One Pose

Siddhasana

(sid-DAHS-anna)

Modification: 1. one heel in front of the other
2. one foot tucked between the hamstring and the calf
Pose Type: seated
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

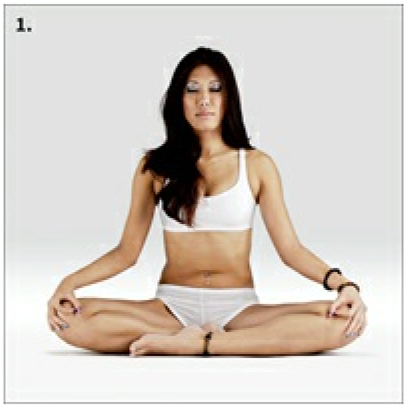

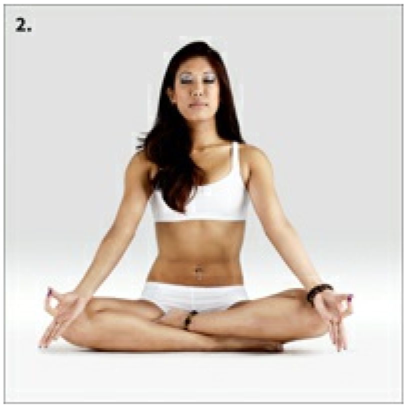

Fire Log Pose

Agnistambhasana

(uhg-ni-stuhm-BAHS-anna)

Modification: 1. spine straight, fingertips to the floor behind the hips
2. leaning forward, palms on the floor by the thighs
Pose Type: 1. seated
2. seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

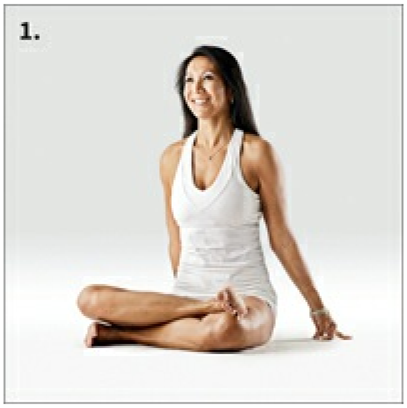

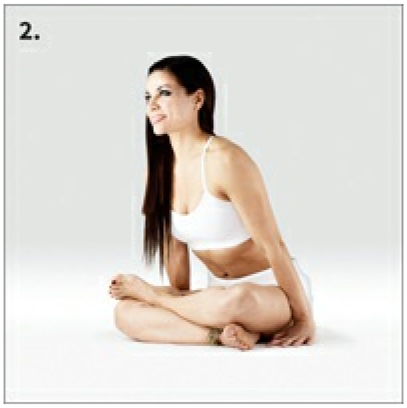

Revolved Fire Log Pose

Parivritta Agnistambhasana

(puh-ri-VRIT-tuh uhg-ni-stuhm-BAHS-uh-nuh)

Modification: hands in Anjali Mudra (Hands in Prayer)
1. elbow to the knee
2. elbow to the foot
Pose Type: seated, forward bend, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky); Parshva Drishti (to the right), Parshva Drishti (to the left)

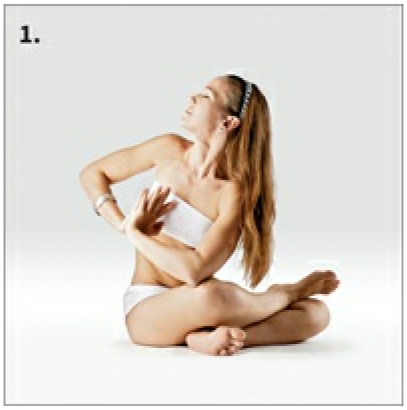
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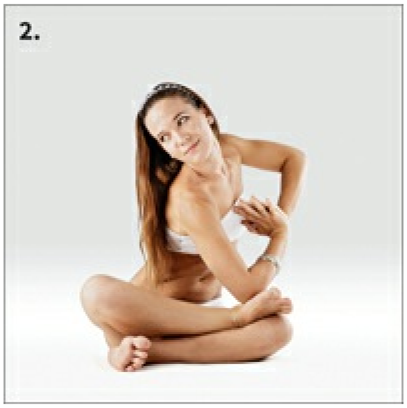
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Revolved Bound Fire Log Pose

Parivritta Baddha Agnistambhasana

(puh-ri-VRIT-tuh BUH-duh uhg-ni-stuhm-BAHS-uh-nuh)

Modification: one elbow to the sole of the top foot, other arm behind the back, hand to the inside of the thigh
Pose Type: seated, forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

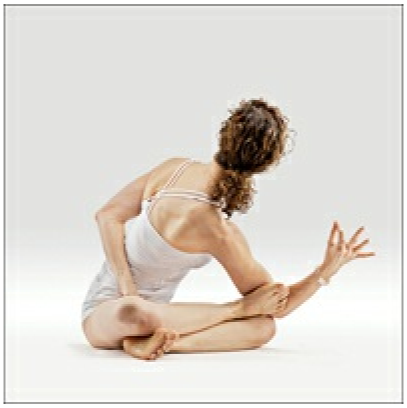

Revolved Fire Log Pose

Parivritta Agnistambhasana

(puh-ri-VRIT-tuh uhg-ni-stuhm-BAHS-uh-nuh)

Modification: forearms to the floor
Pose Type: seated, forward bend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

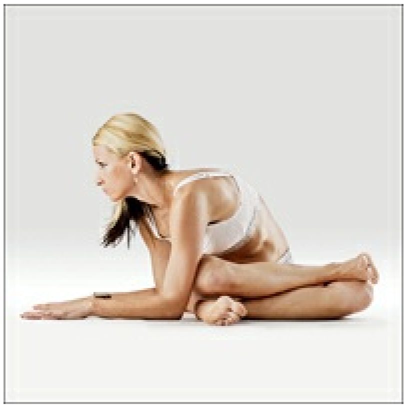

Fire Log Pose

Agnistambhasana

(uhg-ni-stuhm-BAHS-uh-nuh)

Modification: forward bend, palms together, fingers spread wide; elbows and forehead on the floor
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

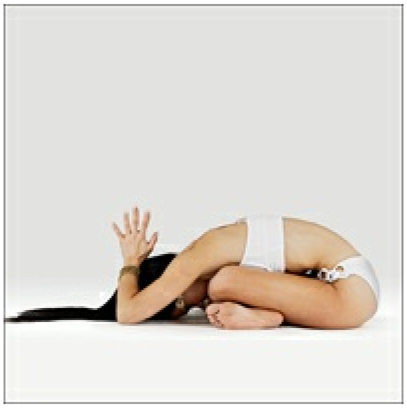

HALF LOTUS POSE

Half Lotus Pose

Ardha Padmasana

(UHR-duh puhd-MAHS-uh-nuh)

Modification: back of the hands on the knees

Pose Type: seated

Drishti Point: Nasagrai or Nasagre (nose)

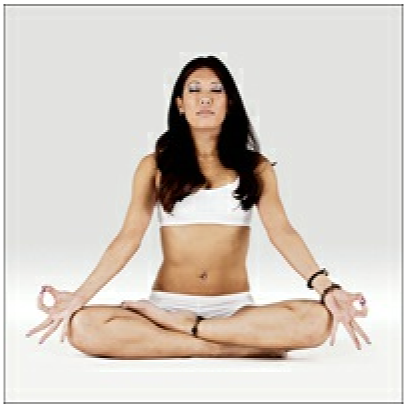

Half Lotus Pose

Ardha Padmasana

(UHR-duh puhd-MAHS-uh-nuh)

Modification: Salute to the Buddha Mudra Hand Position: one palm facing up, fingertips of the other hand to the floor

Pose Type: seated

Drishti Point: Nasagrai or Nasagre (nose)

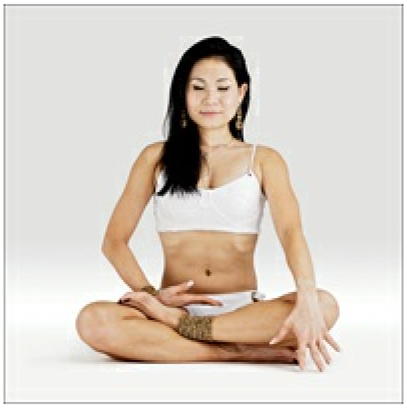

Reverse Prayer Revolved Half Lotus Pose

Viparita Namaskar Parivrtta Ardha Padmasana

(vi-puh-REE-tuh nuh-muhs-KAHR puh-ri-VRIT-tuh UHR-duh puhd-MAHS-uh-nuh)

Also Known As: Back of the Body Prayer Revolved Half Lotus Pose (Paschima Namaskara Parivrtta Ardha Padmasana)
Modification: top foot resting on the bottom knee
Pose Type: seated, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

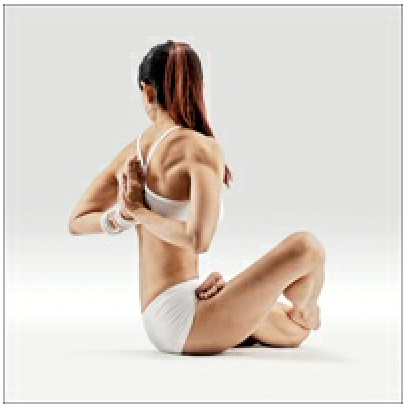

Embryo in the Womb Pose in Half Lotus Pose

Garbha Pindasana in Ardha Padmasana

(guhr-buh-pin-DAHS-uh-nuh in UHR-duh puhd-MAHS-uh-nuh)

Modification: knees lifted toward the chest
Pose Type: seated, forward bend, core
Drishti Point: Nasagrai or Nasagre (nose)

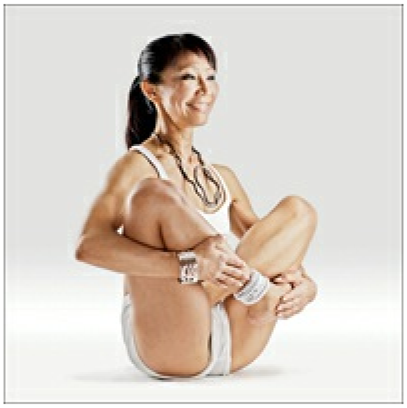

LOTUS POSE: ARMS IN FRONT

Lotus Pose

Padmasana

(puhd-MAHS-uh-nuh)

Modification: back of the hands on the knees

Pose Type: seated

Drishti Point: Nasagrai or Nasagre (nose)

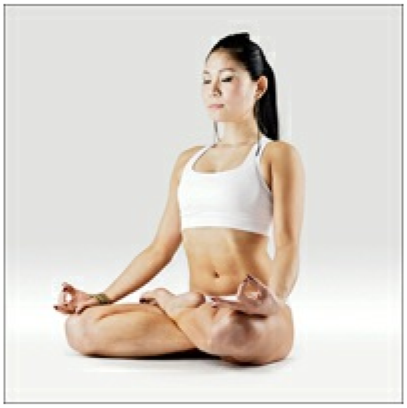

Lotus Pose

Padmasana

(puhd-MAHS-uh-nuh)

Modification: fingers interlocked, hands resting on the lap

Pose Type: seated

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

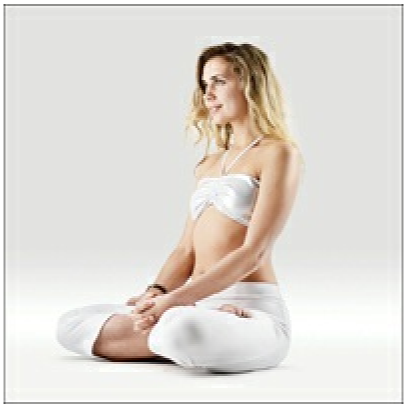

LOTUS POSE: ARMS BEHIND

Reverse Prayer Lotus Pose

Viparita Namaskar Padmasana

(vi-puh-REE-tuh nuh-muhs-KAHR puhd-MAHS-uh-nuh)

Also Known As: Back of the Body Prayer Lotus Pose (Paschima Namaskara Padmasana)
Modification: 1. fingertips pointing down
2. fingertips pointing up
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)
● ●

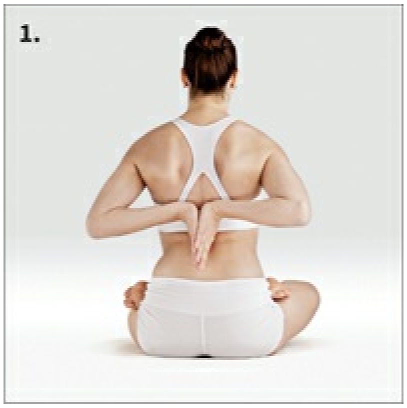

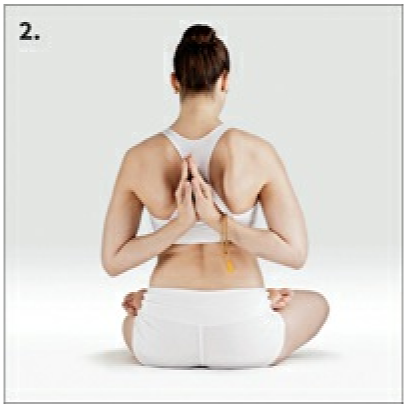

Bound Lotus Pose

Baddha Padmasana

(BUH-duh puhd-MAHS-uh-nuh)

Modification: both hands to one foot, one arm behind the back
Pose Type: seated, mild backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
● ● ● ● ●

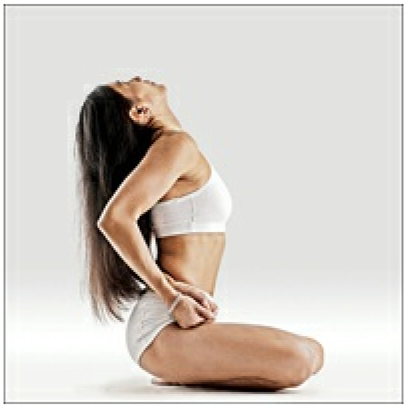

Bound Lotus Pose

Baddha Padmasana

(BUH-duh puhd-MAHS-uh-nuh)

Modification: both arms behind the back

Pose Type: seated, mild backbend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

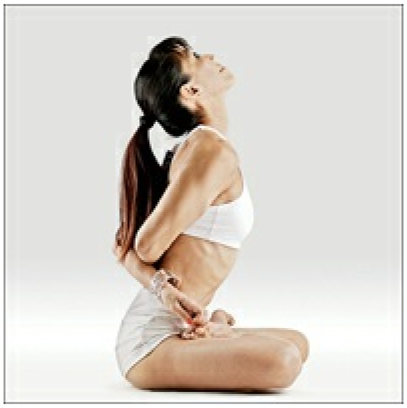

Hands Bound Lotus Pose

Baddha Hasta Padmasana

(BUH-duh HUH-stuh puhd-MAHS-uh-nuh)

Modification: backbend

Pose Type: seated, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

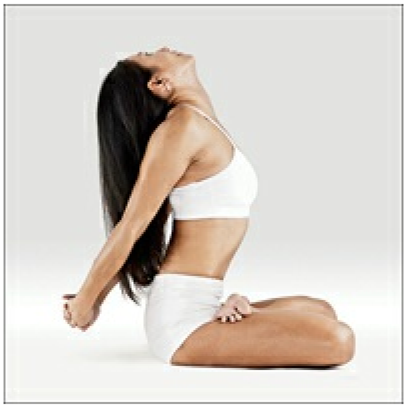

Lotus Pose

Padmasana

(puhd-MAHS-uh-nuh)

Modification: palms to the floor behind the hips; fingertips facing forward, backbend
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
लं वं रं यं हं ॐ

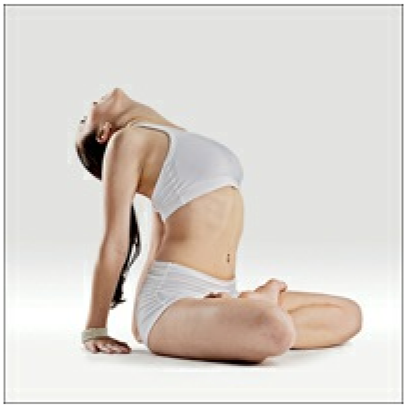

LOTUS POSE: FINGERS BOUND - BICEPS BY THE EARS

Raised Bound Hands Lotus Pose

Urdhva Baddha Hasta Padmasana

(OORD-vuh BUH-duh HUH-stuh puhd-MAHS-uh-nuh)

Also Known As: Seated Mountain Pose A (Parvatasana A)
Pose Type: seated, mild backbend
Drishti Point: Angushtamadhye (Thumbs)
लं वं हं

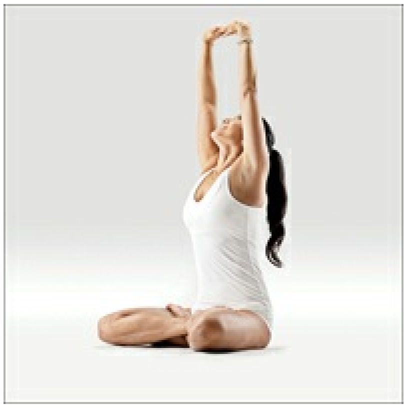

Simple Yoga Seal

Laghu Yoga Mudra

(LUH-gu YO-guh MU-druh)

Also Known As: Seated Mountain Pose B (Parvatasana B)
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व र य

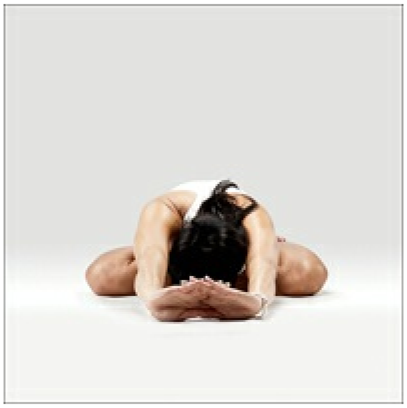

Sideways Simple Yoga Seal

Parshva Laghu Yoga Mudra

(PAHRSH-vuh LUH-gu YO-guh MU-druh)

Modification: fingers interlocked, palms facing out; arms straight to the side, forward bend
Pose Type: seated, forward bend, side bend
Drishti Point: Nasagrai or Nasagre (nose)
ल व र य ह

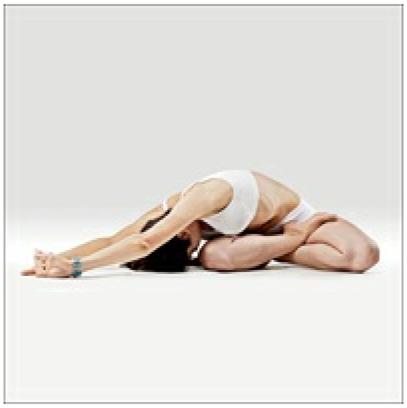

LOTUS POSE: TWISTS

Pose Dedicated to Siddhar Vaasamuni—Easy Version

Sukha Vaasamunvasana

(SUK-uh vah-sah-moo-NYAHS-uh-nuh)

Pose Type: seated, side bend, forward bend, twist

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

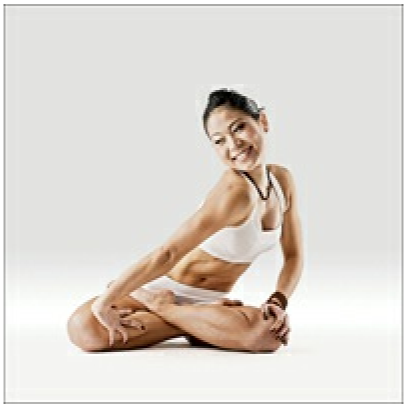

Arms of Twist Dedicated to Sage Bharadvaja 2 in Revolved Lotus Pose

Hasta Bharadvajasana 2 in Parivritta Padmasana

(HUH-stuh buh-ruhd-vuhj-AHS-uh-nuh in puh-ri-VRIT-uh puhd-MAHS-uh-nuh)

Pose Type: seated, twist, binding

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

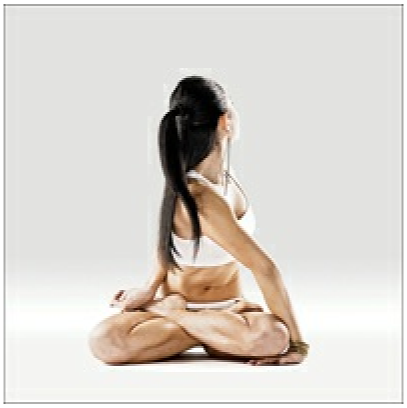

Revolved Lotus Pose

Parivritta Padmasana

(puh-ri-VRIT-uh puhd-MAHS-uh-nuh)

Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

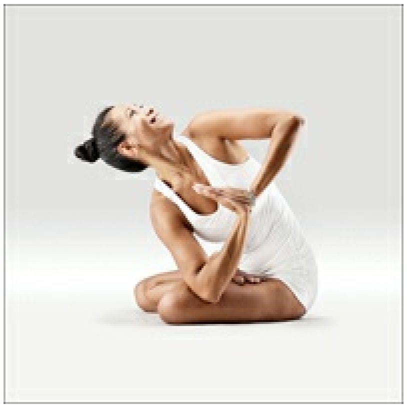

LOTUS POSE: SIDE BEND & TWISTS

Sideways Lotus Pose

Parshva Padmasana

(PAHRSH-vuh puhd-MAHS-uh-nuh)

Modification: forearm to the floor
Pose Type: seated, side bend
Drishti Point: Hastagrai or Hastagre (hands)

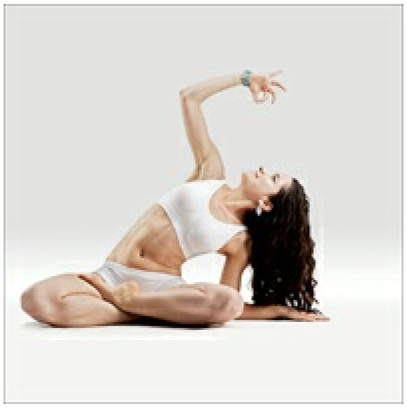

Revolved Western Intense Stretch Pose Lotus Pose

Parivritta Paschimottana Padmasana

(puh-ri-VRIT-uh puhsh-chi-mo-TAHN-nuh puhd-MAHS-uh-nuh)

Also Known As: Revolved Forward Bend Lotus Pose
Modification: shoulder to the floor, other arm extended to the sky
Pose Type: seated, forward bend, twist
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
लं वं

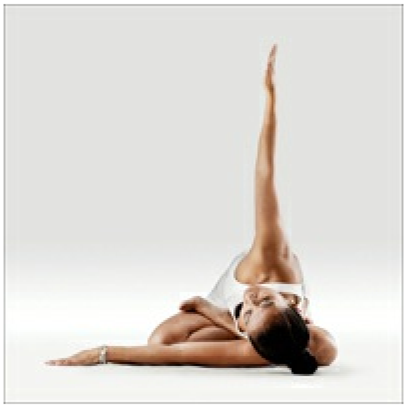

Pose Dedicated to Siddhar Vaasamuni—One Hand Modification

Eka Hasta Vaasamunvasana

(EY-kuh HUH-stuh [vah-sah-moo]-NYAHS-uh-nuh)

Pose Type: seated, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
लं वं हं

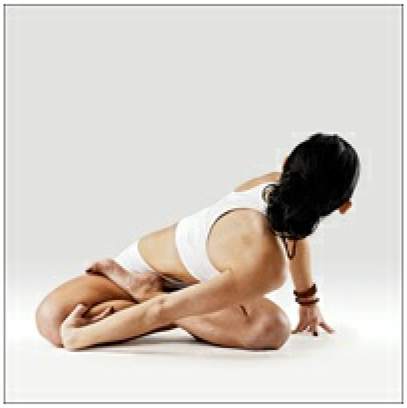

Pose Dedicated to Siddhar Vaasamuni

Vaasamunvasana

([vah-sah-moo-NYAHS-uh-nuh)

Pose Type: seated, forward bend, twist, binding

Drishti Point: Urdhva or Antara Drishti (up to the sky)

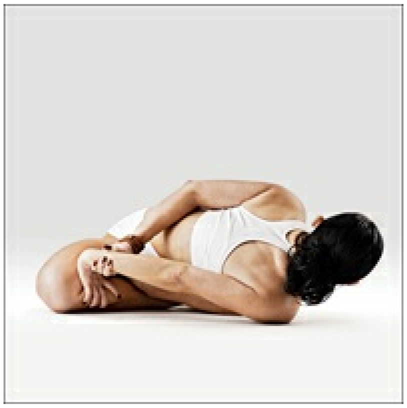

LOTUS POSE: FORWARD BEND

Yogic Seal Pose

Yoga Mudrasana

(YO-guh mu-DRAHS-uh-nuh)

Also Known As: Yoga Pose (Yogasana)

Modification: grabbing onto the wrist behind the back

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose) or Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

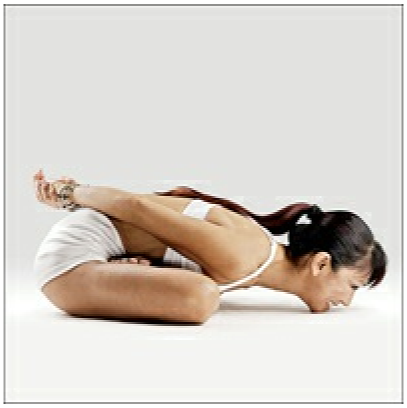

Hands Bound Lotus Pose

Baddha Hasta Padmasana

(BUH-duh HUH-stuh puhd-MAHS-uh-nuh)

Also Known As: Yoga Seal (Yoga Mudra)
Modification: chin to the floor, forward bend
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose) or Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
लं वं रं यं हं ॐ

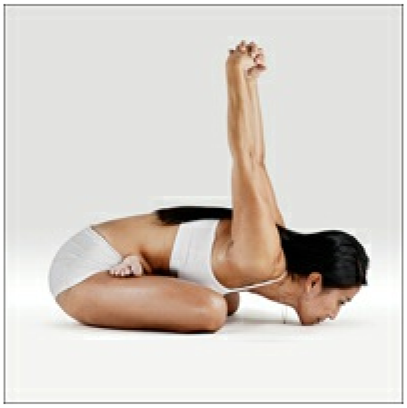

Reverse Prayer Yogic Seal Pose

Viparita Namaskar Yoga Mudrasana

(vi-puh-REE-tuh nuh-muhs-KAHR YO-guh mu-DRAHS-uh-nuh)

Also Known As: Back of the Body Prayer Yogic Seal Pose (Paschima Namaskara Yoga Mudrasana)
Modification: forehead to the floor
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
लं वं रं

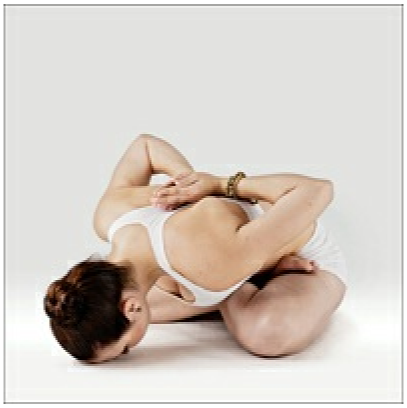

Yogic Seal Pose Prep.

Yoga Mudrasana Prep.

(YO-guh mu-DRAHS-uh-nuh)

Modification: 1. using a yoga strap
2. wrists crossed behind the back, reaching toward the feet
Pose Type: seated, forward bend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
ल व य ह ॐ

1.

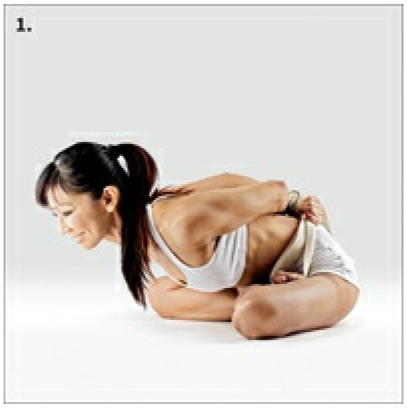

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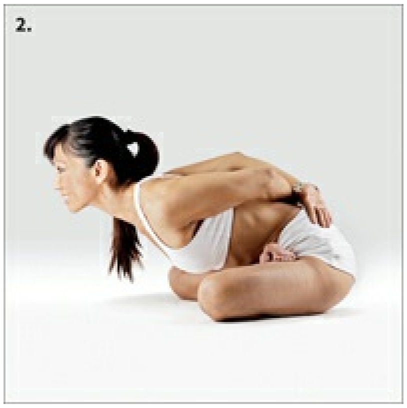

Sideways Yogic Seal Pose

Parshva Yoga Mudrasana

(PARHSH-vuh YO-guh mu-DRAHS-uh-nuh)

Also Known As: Sideways Bound Lotus Pose (Parshva Baddha Padmasana)
Modification: chin to the knee
Pose Type: seated, forward bend, binding, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
ल व र य

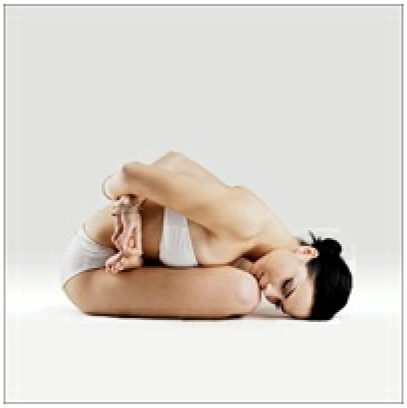

Yogic Seal Pose

Yoga Mudrasana

(YO-guh mu-DRAHS-uh-nuh)

Also Known As: Bound Lotus Pose (Baddha Padmasana)
Modification: 1. side view
2. front view
Pose Type: seated, forward bend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
ल व र य ह ॐ

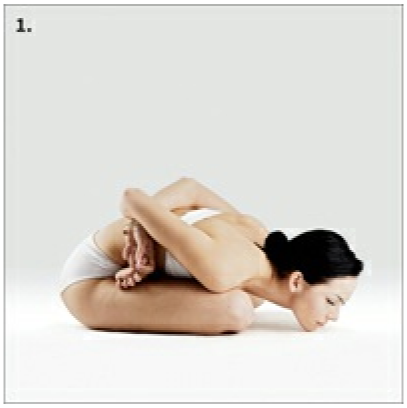

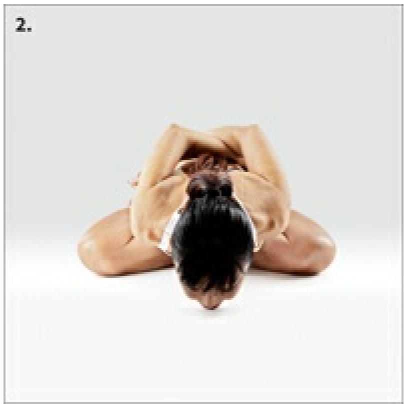

2.

LOTUS POSE: EMBRYO IN THE WOMB POSE

Embryo in the Womb Pose

Garbha Pindasana

(guhr-buh pin-DAHS-uh-nuh)

Modification: arms wrapped around the legs
Pose Type: seated, forward bend, core
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
ल व र य

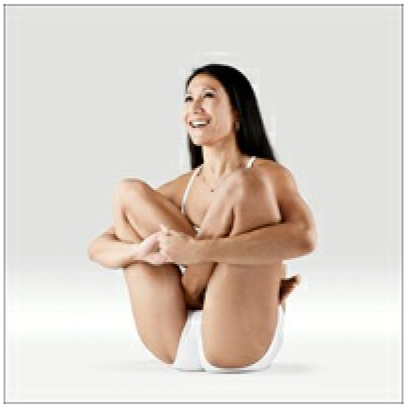

Hand Position of the Pose Dedicated to Garuda in Yoga Pose A

Hasta Garudasana in Yogasana A

(HUH-stuh guh-ru-DAHS-uh-nuh in yo-GAHS-uh-nuh)

Pose Type: seated, forward bend, core
Drishti Point: Angushtamadhye or Angustha Ma Dyai (thumbs)
ल व र य ह

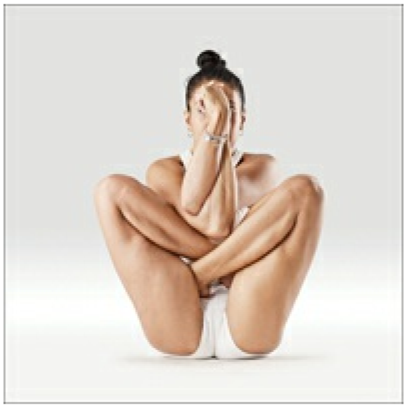

Embryo in the Womb Pose

Garbha Pindasana

(guhr-buh pin-DAHS-uh-nuh)

Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Nasagrai or Nasagre (nose)

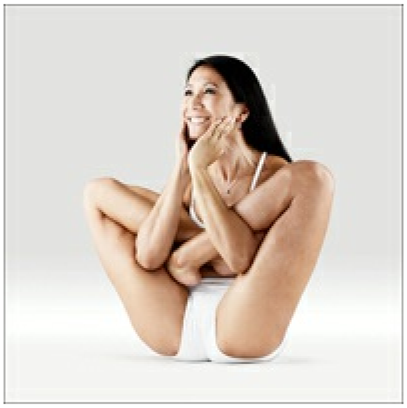

BOTH KNEES BENT: BINDING & TWISTS

Bound Sundial Pose

Baddha Surya Yantrasana

(BUH-duh SOOR-yuh yuhn-TRAHS-uh-nuh)

Modification: both knees bent
Pose Type: seated, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

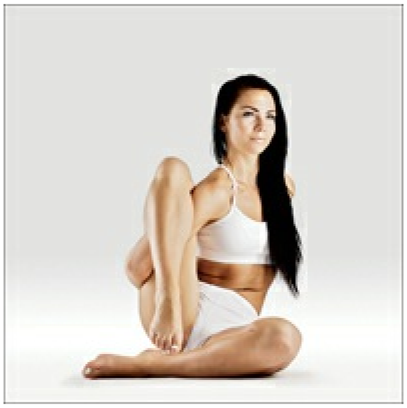

Revolved Pose Dedicated to Sage Marichi

Parivritta Marichyasana

(puh-ri-VRIT-tuh muh-ree-CHYAHS-uh-nuh)

Modification: twisting to the inside, foot to the thigh, binding under the leg
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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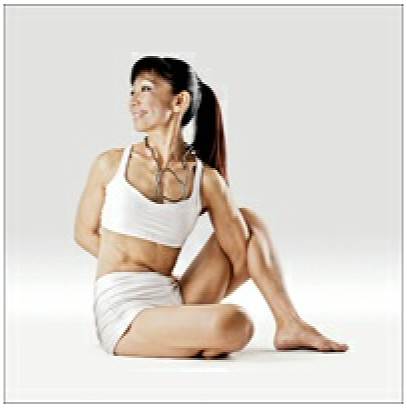

Half Lord of the Fishes Pose 3

Ardha Matsyendrasana 3

(UH-ruh muhts-yeyn-DRAHS-uh-nuh)

Modification: looking to the back
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
ल व य

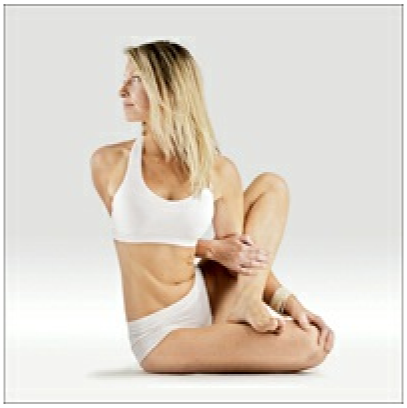

Pose Dedicated to Sage Marichi 4

Marichyasana 4

(muh-ree-CHYAHS-uh-nuh)

Modification: binding under the knee
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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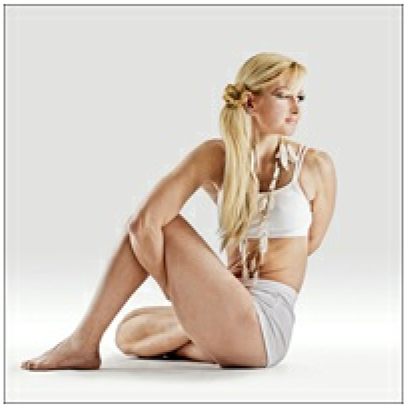

BOTH KNEES BENT: BINDING & TWISTS—ARM THREADED UNDER

Half Pose Dedicated to Sage Agasthiyar

Ardha Agasthiyarasana

(UHR-duh uh-guhs-ti-yahr-AH-suh-nuh)

Modification: 1. one arm threaded through
2. full expression of the pose
Pose Type: 1. seated, forward bend, twist, binding
2. seated, forward bend, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky), Nasagrai or Nasagre (nose), or Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

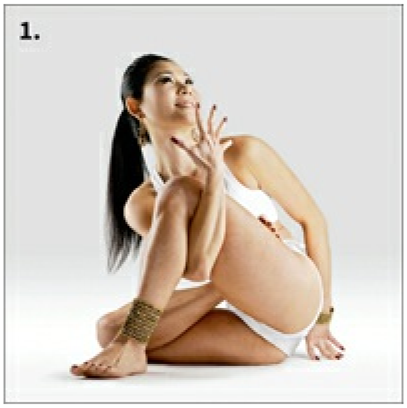

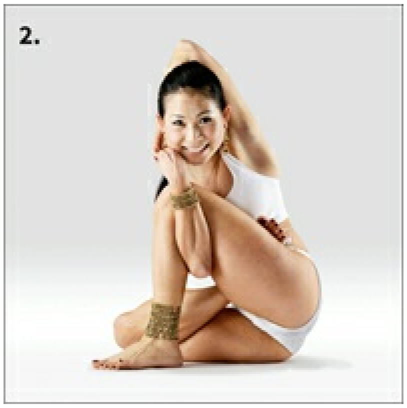

Revolved Half Pose Dedicated to Sage Agasthiyar

Parivritta Ardha Agasthiyarasana

(puh-ri-VRIT-tuh UHR-duh uh-guhs-ti-yahr-AH-suh-nuh)

Pose Type: seated, forward bend, binding, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky)

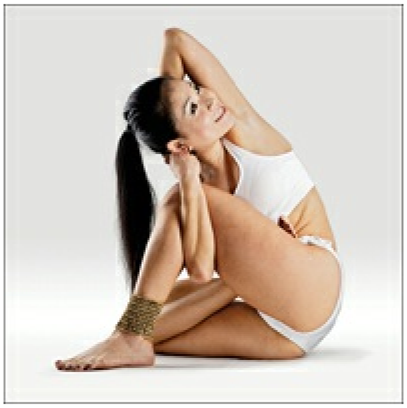

Pose Dedicated to Sage Agasthiyar

Agasthiyarasana

(uh-guhs-ti-yahr-AH-suh-nuh)

Modification: 1. prep. one arm threaded under the knee, fingertips of the other hand to the floor
2. full expression of the pose

Pose Type: seated, forward bend, binding

Drishti Point: 1. Hastagrai or Hastagre (hands)
2. Nasagrai or Nasagre (nose)

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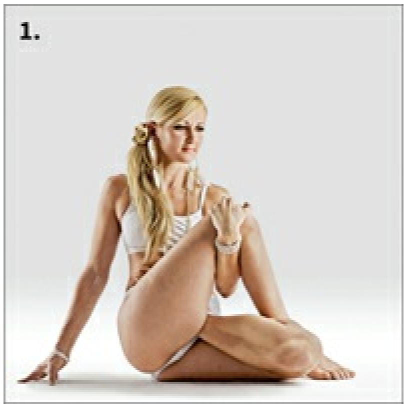
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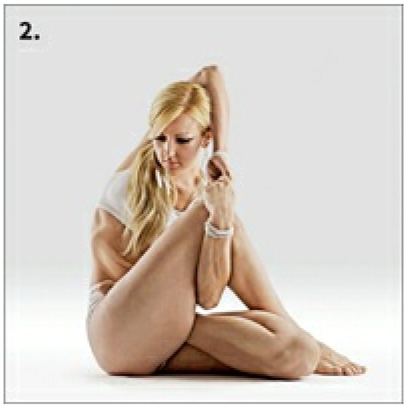
2.

BOTH KNEES BENT: BINDING & TWISTS—KNEES TOGETHER

Seated Noose Pose Prep.

Upavishta Pashasana

(u-puh-VISH-tuh puh-SHAHS-uh-nuh)

Also Known As: Half Noose Pose (Ardha Pashasana), Upavistha Pashasana

Modification: 1. grabbing onto the knees
2. elbow over the opposite knee

Pose Type: seated, forward bend, twist

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

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1.

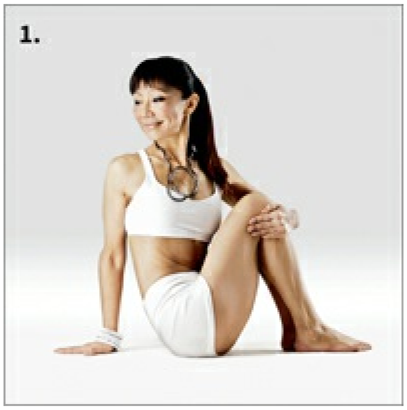

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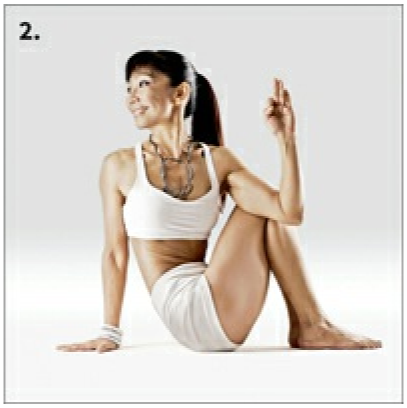

Seated Noose Pose Prep.

Upavishta Pashasana

(u-puh-VISH-tuh puh-SHAHS-uh-nuh)

Also Known As: Upavistha Pashasana
Modification: heels lifted; elbow over the opposite knee, hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated, forward bend, twist, core
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

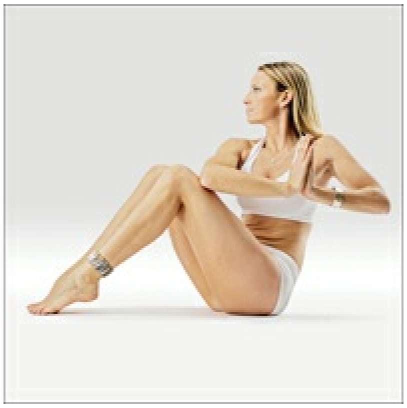

Seated Noose Pose

Upavishta Pashasana

(u-puh-VISH-tuh puh-SHAHS-uh-nuh)

Also Known As: Upavistha Pashasana

Modification: binding around both legs under the knees

Pose Type: seated, forward bend, twist, binding

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

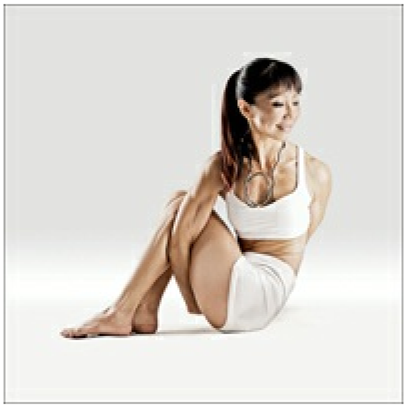

Seated Noose Pose

Upavishta Pashasana

(u-puh-VISH-tuh puh-SHAHS-uh-nuh)

Also Known As: Upavistha Pashasana

Modification: binding around both shins

Pose Type: seated, forward bend, twist, binding

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

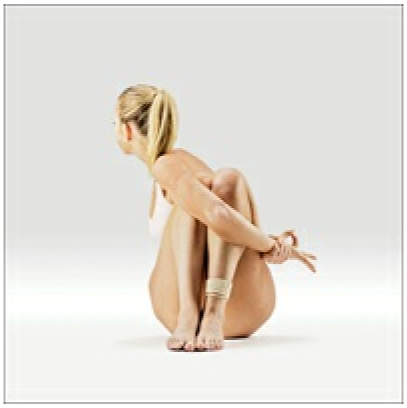

Half Lord of the Fishes Pose

Ardha Matsyendrasana

UHR-duh muhts-yeyn-DRAHS-uh-nuh

Pose Type: seated, forward bend, side bend, twist

Drishti Point: Padhayoragrai or Padayoragre (toes/feet)

How to Perform the Pose:

1. Begin by sitting on the floor with both your legs straight out in front of you. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale as you bend the right knee toward your right shoulder and then bring it over your left leg so that your right foot is flat on the floor on the outside of your left shin.
3. Exhale and bend your left knee, bringing your left heel toward your right sitting bone. Keep the left knee and both your sitting bones evenly on the floor.
4. Exhale as you bring your right elbow to your right knee. Inhale as you bring your left arm up over your head and look towards your left foot (Pose #1).
5. To execute pose #2, exhale as you bring your left elbow over the right knee. Inhale as you bring your right arm up and exhale as you bend your right elbow and look over toward your right foot.
6. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
7. Inhale as you release the twist and exhale as you bring both your legs out in front of you. Repeat on the other side.

Modification: side bend twist:
1. elbow to the knee on the same side
2. elbow to the opposite knee

ardha = half

Matsyendra = a Hindu sage and one of the first teachers of Hatha yoga, a legend, king of the fish

1.

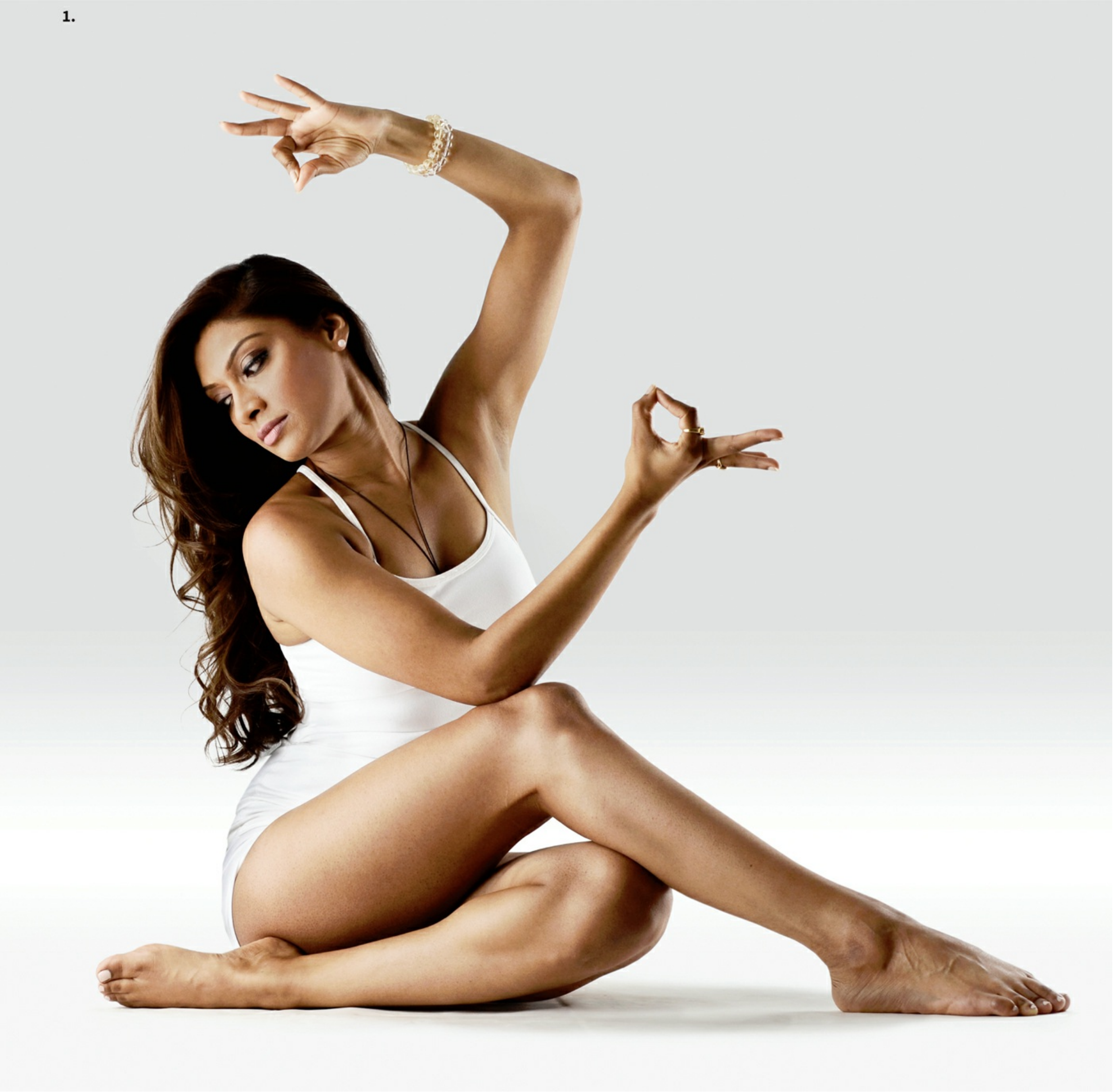

2.

Half Lord of the Fishes Pose

Ardha Matsyendrasana

(UHR-duh muhts-yeyn-DRAHS-uh-nuh)

Modification: backbend
Pose Type: seated, backbend, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

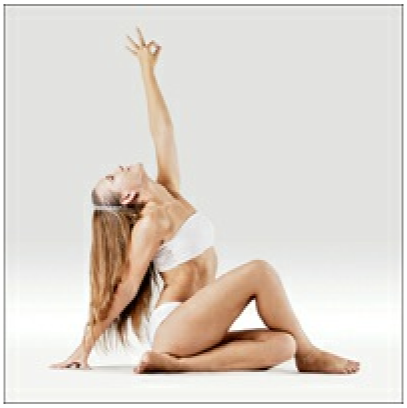

Half Lord of the Fishes Pose

Ardha Matsyendrasana

(UHR-duh muhts-yeyn-DRAHS-uh-nuh)

Modification: twisting to the inside
1. grabbing onto the ankle
2. elbow over the knee
Pose Type: seated, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

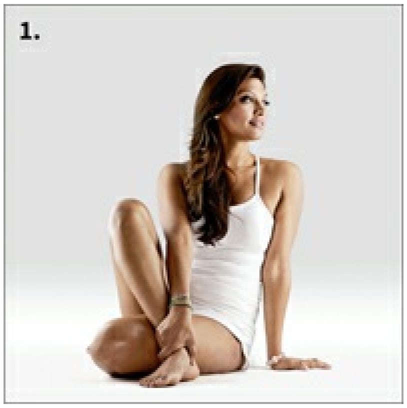

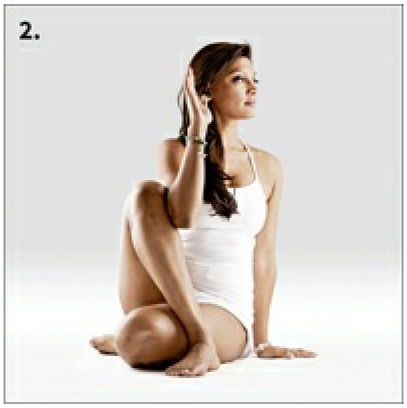

Half Lord of the Fishes Pose

Ardha Matsyendrasana

(UHR-duh muhts-yeyn-DRAHS-uh-nuh)

Modification: twisting to the outside, elbow over the knee; palm of the other hand to the floor
Pose Type: seated, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

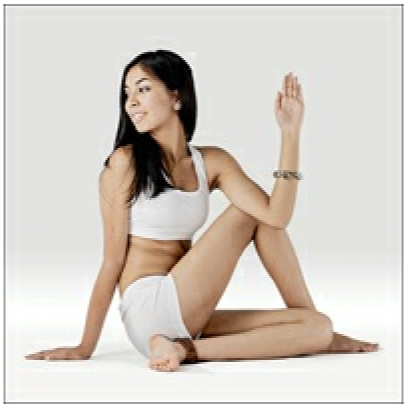

Half Lord of the Fishes Pose 1

Ardha Matsyendrasana 1

(UHR-duh muhts-yeyn-DRAHS-uh-nuh)

Modification: grabbing onto the ankle, other arm behind the back, hand to the inside of the thigh
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

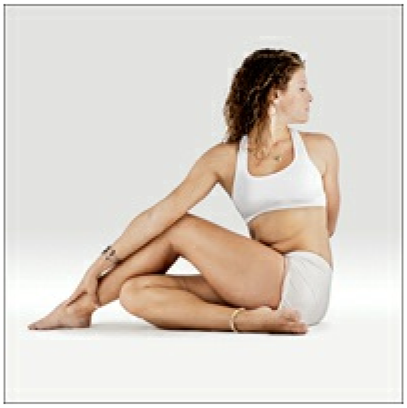

BOTH KNEES BENT: BINDING FORWARD BEND & TWIST

Pose Dedicated to Sage Marichi 3 Prep.

Marichyasana 3 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi B (Marichyasana B)
Modification: top foot to the bottom thigh, binding around the shin, nose to the knee
Pose Type: seated, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

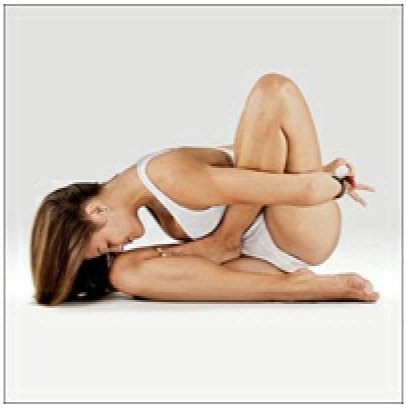

Pose Dedicated to Sage Marichi 4 Prep.

Marichyasana 4 Prep.

(muh-ree-CHYAHS-uh-nuh)

Modification: sitting in a cross-legged position, one knee dropped to the side, foot by the sitting bones; other knee bent toward the shoulder, binding around the shin on the outside of the leg
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

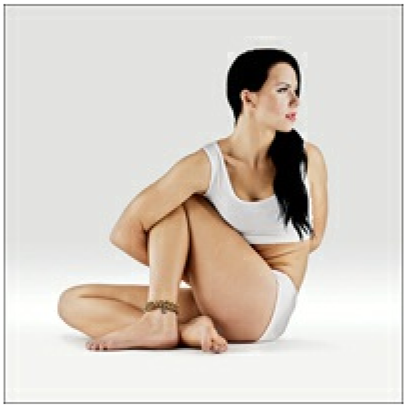

BOTH KNEES BENT: BINDING & TWIST

Pose Dedicated to Sage Marichi 3 Prep.

Marichyasana 3 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi B (Marichyasana B)
Modification: spine straight, bottom knee wrapped around the foot, fingers interlocked on the shin
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

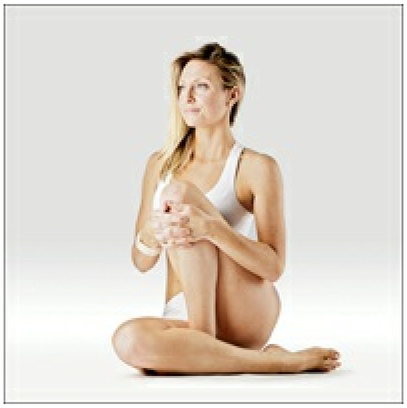

Pose Dedicated to Sage Marichi 3 Prep.

Marichyasana 3 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi B Modification (Marichyasana B Modification)
Modification: bottom knee wrapped around the foot, binding under the thigh

Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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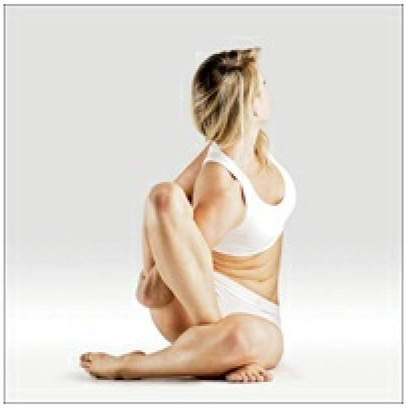

Pose Dedicated to Sage Marichi 3 Prep.

Marichyasana 3 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi B Modification (Marichyasana B Modification)
Modification: knee wrapped around the foot, binding over the shin
Pose Type: 1. seated, forward bend, binding
2. seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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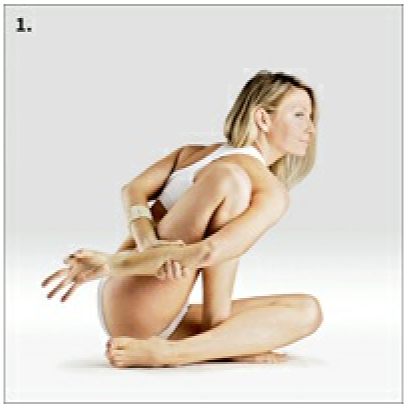

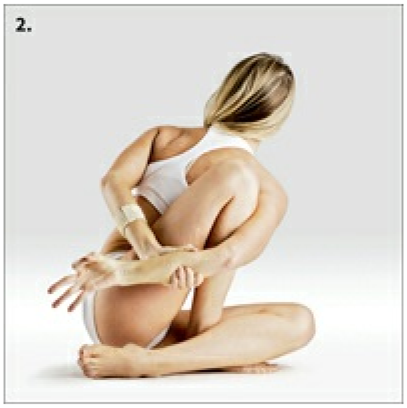

Half Lord of the Fishes Pose 1 Prep.

Ardha Matsyendrasana 1

(UHR-duh muhts-yeyn-DRAHS-uh-nuh)

Modification: foot under the knee, twisting to the outside
Pose Type: seated, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

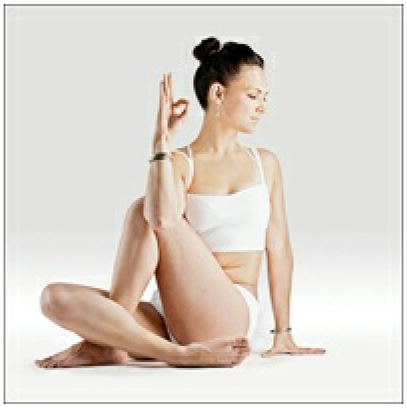

HALF LOTUS POSE: KNEE BENT TOWARD THE CHEST

Pose Dedicated to Sage Marichi Prep.

Marichyasana Prep.

(muh-ree-CHYAHS-uh-nuh)

Modification: prep.-—elbow to the knee on the same side, palm to the floor behind the hips
Pose Type: seated, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

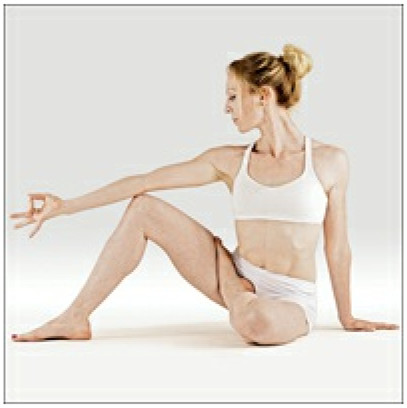

Pose Dedicated to Sage Marichi Prep.

Marichyasana Prep.

(muh-ree-CHYAHS-uh-nuh)

Modification: prep.—arms wrapping around the leg
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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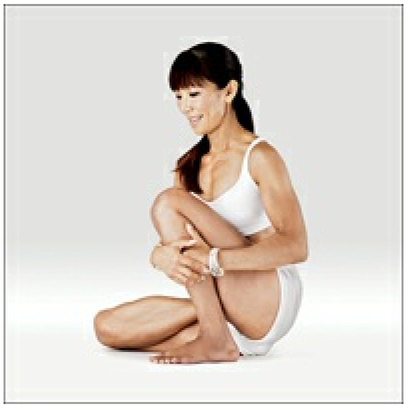

HALF LOTUS POSE: BINDING & TWISTS—KNEE BENT TOWARD THE CHEST

Pose Dedicated to Sage Marichi 3

Marichyasana 3

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi B (Marichyasana B)
Modification: sitting up straight
Pose Type: seated, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)
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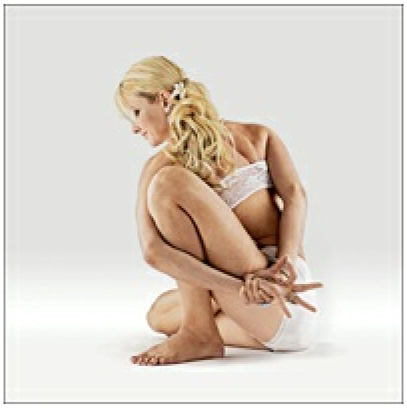

Pose Dedicated to Sage Marichi 3

Marichyasana 3

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi B (Marichyasana B)
Modification: full forward bend
Pose Type: seated, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

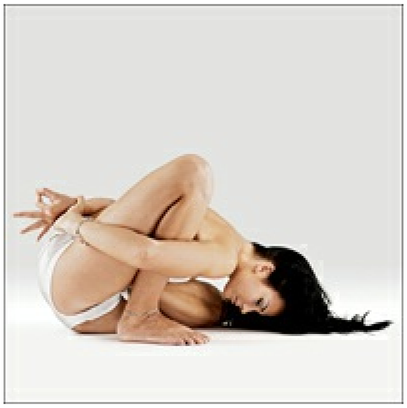

Pose Dedicated to Sage Marichi 4

Marichyasana 4

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi D (Marichyasana D)
Modification: sitting bones on the floor
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

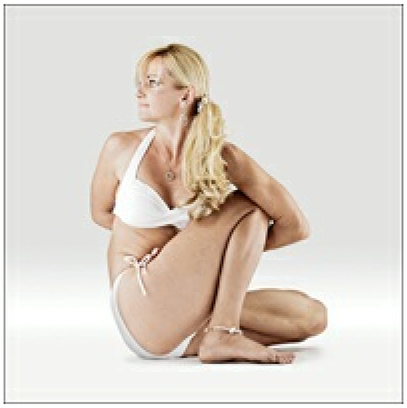

LOTUS POSE: BINDING & TWISTS—KNEE BENT TOWARD THE CHEST

Full Lord of the Fishes Pose Prep.

Paripurna Matsyendrasana Prep.

(puh-ri-POOR-nuh muhts-yeyn-DRAHS-uh-nuh)

Modification: one palm to the floor behind the hips, grabbing onto the knee with the opposite hand
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

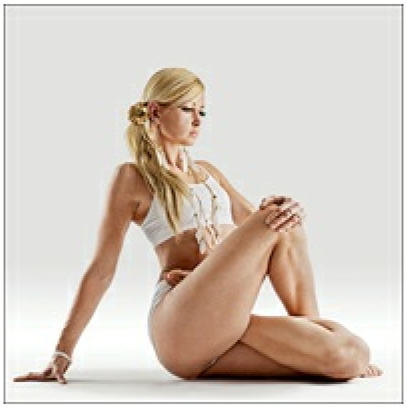

Full Lord of the Fishes Pose

Paripurna Matsyendrasana

(puh-ri-POOR-nuh muhts-yeyn-DRAHS-uh-nuh)

Also Known As: Full Lord of the Fishes Pose (Poorna Matsyendrasana)
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

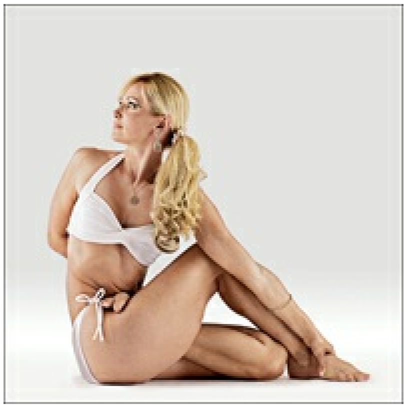

FOOT TO THE BACK: TWISTS—KNEE BENT TOWARD THE CHEST

Root Lord of the Fishes Pose Prep.

Mula Matsyendrasana Prep.

(MOOL-uh muhts-yeyn-DRAHS-uh-nuh)

Modification: heel to the perineum, other foot resting on the knee, fingertips to the floor by the hips
Pose Type: seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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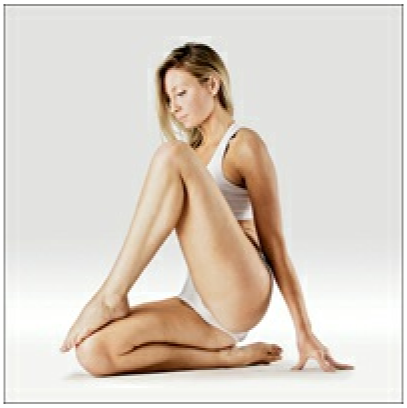

Half Root Lord of the Fishes Pose

Ardha Mula Matsyendrasana

(UHR-duh MOOL-uh muhts-yeyn-DRAHS-uh-nuh)

Modification: heel to the perineum, other foot resting on the knee, fingertips of one hand to the floor by the hips, other hand grabbing onto the opposite knee
Pose Type: seated, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
● ●

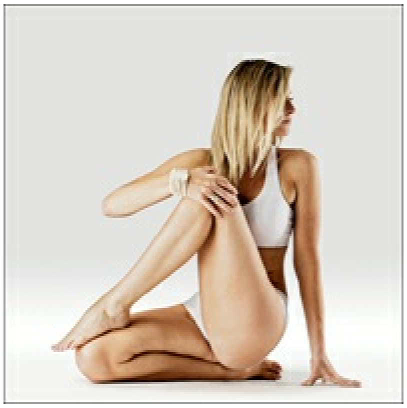

Root Lord of the Fishes Pose Prep.

Mula Matsyendrasana Prep.

(MOOL-uh muhts-yeyn-DRAHS-uh-nuh)

Modification: backbend, heel to the perineum, other foot resting on the knee, fingertips to the floor behind the hips
Pose Type: seated, backbend, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

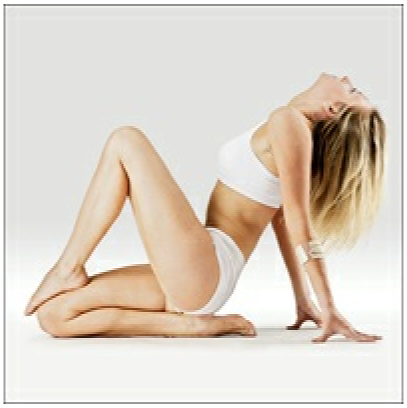

Pose Dedicated to Sage Marichi 6 Prep.

Marichyasana 6 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi F (Marichyasana F)
Modification: opposite hand grabbing onto the foot, heel resting on the knee, other arm behind the back to the inside of the thigh, looking over the shoulder to the back
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

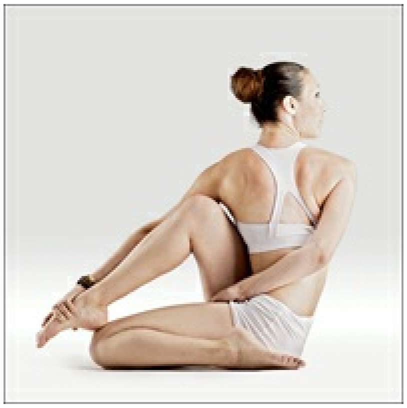

Pose Dedicated to Sage Marichi 6 Prep.

Marichyasana 6 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi F (Marichyasana F)
Modification: opposite hand grabbing onto the foot, foot flat to the floor, other arm behind the back to the inside of the thigh, looking toward the foot
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

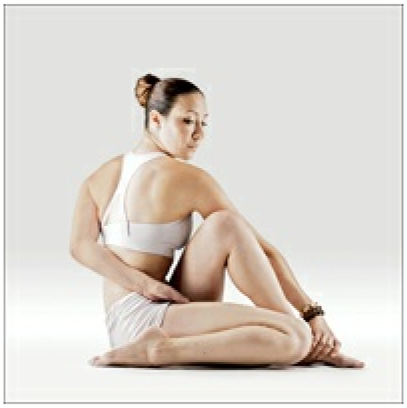

BOUND ANGLE POSE: ARMS IN FRONT

Bound Angle Pose with Hands in Prayer

Baddha Konasana Namaskar

(BUH-duh ko-NAHS-uh-nuh nuh-muhs-KAHR)

Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose) or Hastagrai or Hastagre (hands)

Bound Angle Pose

Baddha Konasana

(BUH-duh ko-NAHS-uh-nuh)

Modification: fingertips touching the floor
Pose Type: seated
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

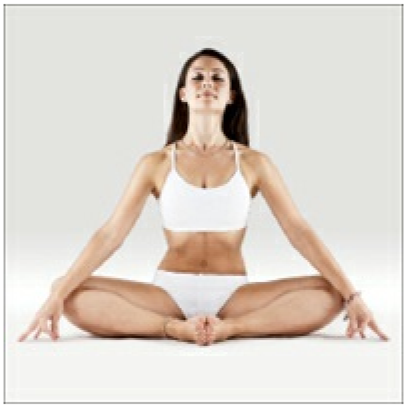

Bound Angle Pose

Baddha Konasana

(BUH-duh ko-NAHS-uh-nuh)

Modification: half forward bend, opening the soles of the feet up to the sky
Pose Type: seated, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

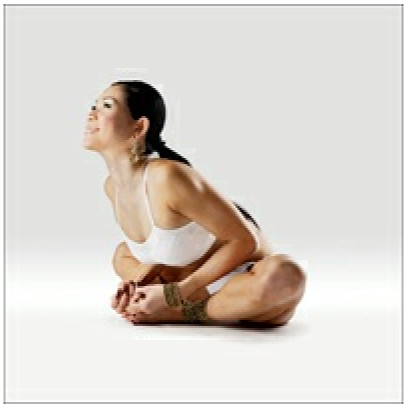

BOUND ANGLE POSE: ARMS BEHIND

Bound Angle Pose

Baddha Konasana

(BUH-duh ko-NAHS-uh-nuh)

Modification: one hand to the knee; other hand behind, grabbing onto the bicep
Pose Type: seated, binding
Drishti Point: Nasagrai or Nasagre (nose)

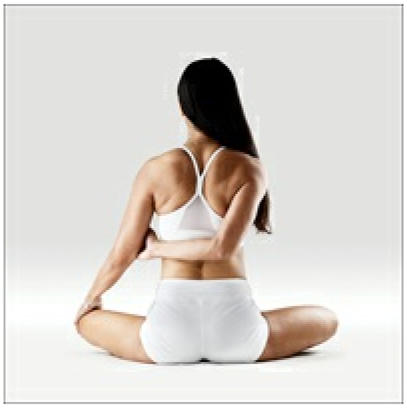

Bound Hands Bound Angle Pose

Baddha Hasta Baddha Konasana

(BUH-duh HUH-stuh BUH-duh ko-NAHS-uh-nuh)

Modification: arms behind, grabbing onto the elbows
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)

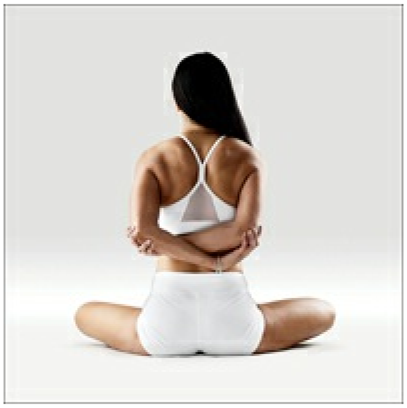

Reverse Prayer Bound Angle Pose

Viparita Namaskar Baddha Konasana

(vi-puh-REE-tuh nuh-muhs-KAHR BUH-duh ko-NAHS-uh-nuh)

Also Known As: Back of the Body Prayer Bound Angle Pose (Paschima Namaskara Baddha Konasana)
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)
ल व

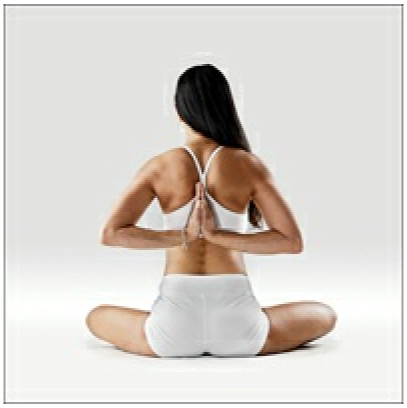

Hand Position of Cow Face Pose in Bound Angle Pose

Hasta Gomukhasana in Baddha Konasana

(HUH-stuh go-muk-AHS-uh-nuh in BUH-duh ko-NAHS-uh-nuh)

Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)
ल व

BOUND ANGLE POSE: SIDE BEND & BINDING

Sideways Bound Angle Pose

Parshva Baddha Konasana

(PAHRSH-vuh BUH-duh ko-NAHS-uh-nuh)

Pose Type: seated, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

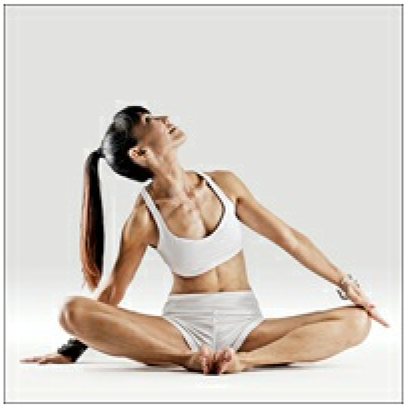

Sideways Star Pose

Parshva Tarasana

(PAHRSH-vuh tahr-AHS-uh-nuh)

Pose Type: seated, side bend
Drishti Point: Hastagrai or Hastagre (hands)

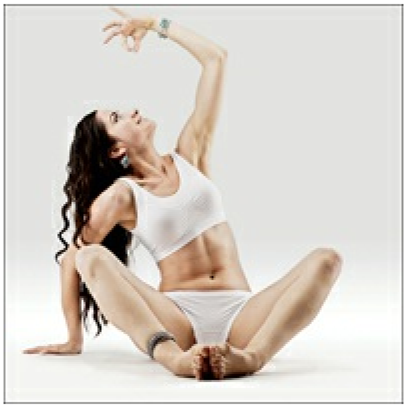

Sideways Bound Leg Bound Angle Pose

Parshva Baddha Pada Baddha Konasana

(PAHRSH-vuh BUH-duh PUH-duh BUH-duh ko-NAHS-uh-nuh)

Modification: binding around one leg, arm wrapped around the shin
Pose Type: seated, forward bend, side bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)
ल व य

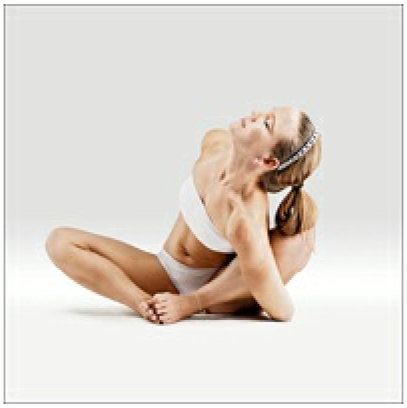

BOUND ANGLE POSE: HEELS CLOSE, FEET LIFTED, SITTING BONES LIFTED AND FORWARD BEND

Pose Dedicated to Sage Goraksha

Gorakshasana

(go-rahk-SHAHS-uh-nuh)

Modification: feet in Bound Angle Pose (Baddha Konasana), sitting on the heels
1. one hand to the centre of the chest, other hand to the floor behind the hips
2. hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated, balance
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

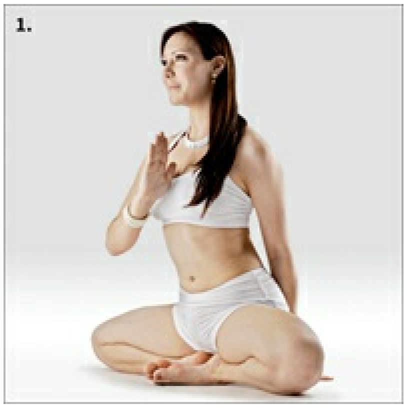

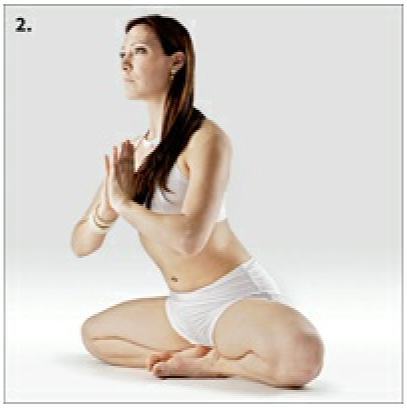

Equilibrium Bound Angle Pose 1

Tulya Baddha Konasana 1

(TUL-yuh BUH-duh ko-NAHS-uh-nuh)

Modification: feet lifted off the floor
Pose Type: seated, forward bend, core
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

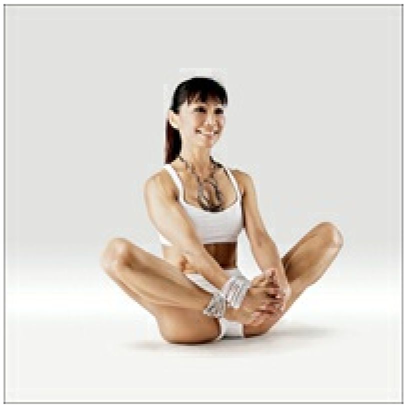

Equilibrium Bound Angle Pose 2

Tulya Baddha Konasana 2

(TUL-yuh BUH-duh ko-NAHS-uh-nuh)

Modification: sitting bones lifted off the floor
Pose Type: seated, forward bend, core
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

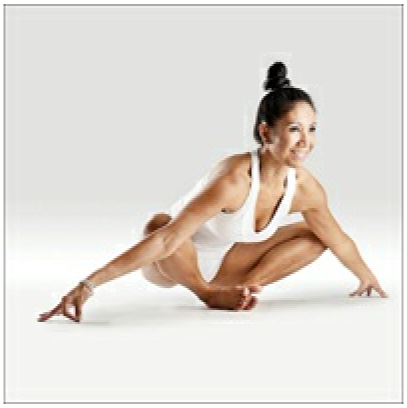

Bound Angle Pose

Baddha Konasana

(BUH-duh ko-NAHS-uh-nuh)

Modification: forward bend; arms straight to the front, palms down
Pose Type: seated, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs) or Nasagrai or Nasagre (nose)

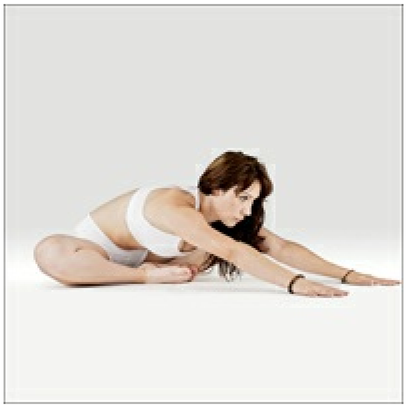

BOUND ANGLE POSE: FORWARD BEND

Bound Angle Pose

Baddha Konasana

(BUH-duh ko-NAHS-uh-nuh)

Modification: 1. half forward bend
2. full forward bend, chin to the floor
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose) or Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

1.

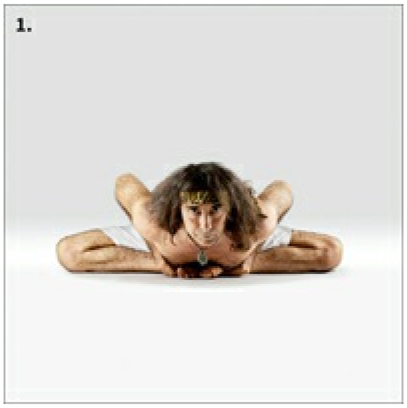

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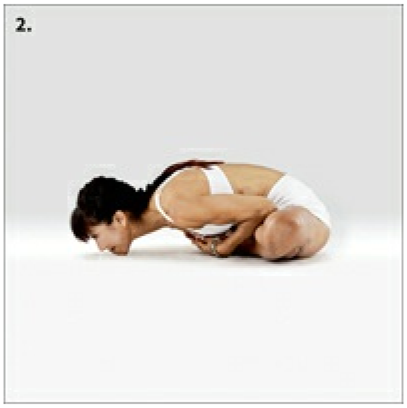

Bound Angle Pose

Baddha Konasana

(BUH-duh ko-NAHS-uh-nuh)

Modification: elbows bent and to the floor, forehead to the floor, palms together, fingers spread wide
Pose Type: seated, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Nasagrai or Nasagre (nose)

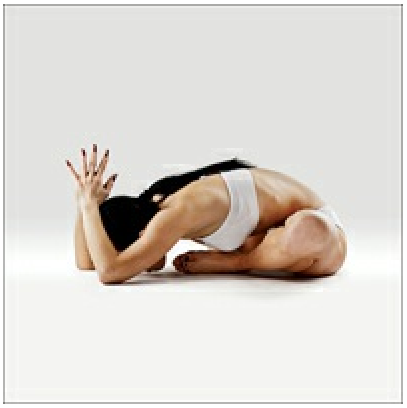

STAR POSE

Easy Embryo in the Womb Pose

Sukha Garbha Pindasana

(SUK-uh GUHR-buh pin-DAHS-uh-nuh)

Modification: arms under the legs
1. hands to the feet
2. fingertips to the temples
3. hands to the sides; heels touching, feet to the sides
Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

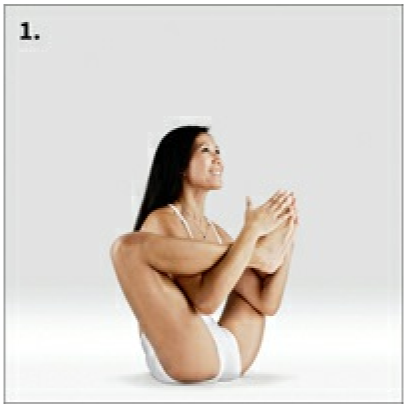

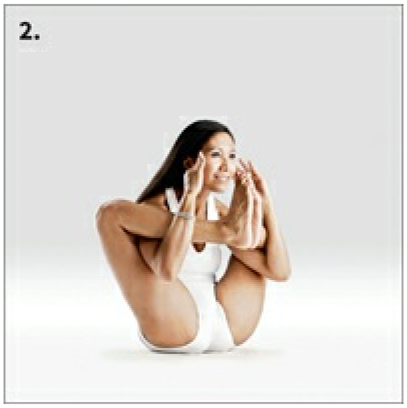

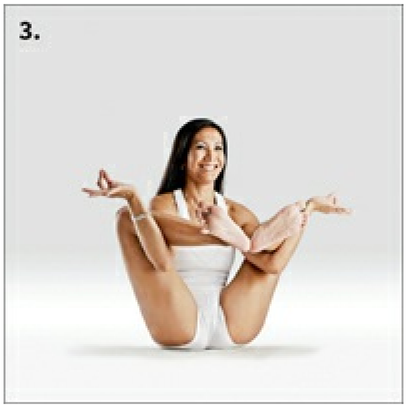

Easy Embryo in the Womb Pose

Sukha Garbha Pindasana

(SUK-uh GUHR-buh pin-DAHS-uh-nuh)

Also Known As: Yoga Pose A Prep. (Yogasana A Prep.)
Modification: shins into armpits, hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

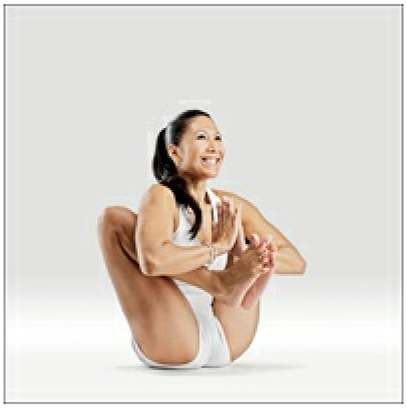

Star Pose

Tarasana

(tahr-AHS-uh-nuh)

Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

Upward Star Pose

Urdhva Tarasana

(OORD-vuh tahr-AHS-uh-nuh)

Pose Type: seated, forward bend, core
Drishti Point: Padhayoragrai or Padayoragre (toes/feet) or Nasagrai or Nasagre (nose)

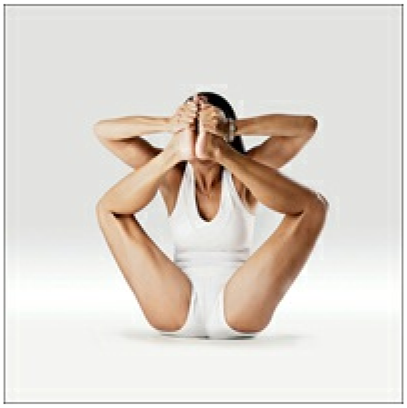

LEGS IN FRONT: KNEES BENT

Seated Eastern Intense Stretch Pose

Upavishta Purvottanasana

(u-puh-VISH-tuh poor-vo-TAHS-uh-nuh)

Also Known As: Reverse Plank Prep.; Upavistha Purvottanasana
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

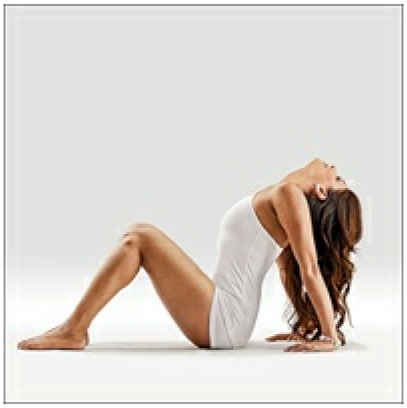

One Hand Seated Eastern Intense Stretch Pose

Eka Hasta Upavishta Purvottanasana

(EY-kuh HUH-stuh u-puh-VISH-tuh poor-vo-TAHS-uh-nuh)

Also Known As: One Hand Reverse Plank Prep.; Eka Hasta Upavistha Purvottanasana
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)

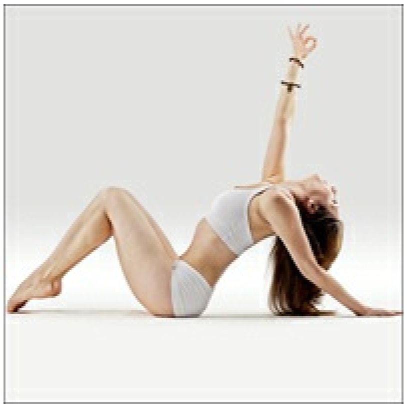

LEGS IN FRONT: KNEES BENT—LEGS OUTSIDE OF THE SHOULDERS

Seated Knee to Shoulder Pose

Upavishta Janu Bhujasana

(u-puh-VISH-tuh JAH-nu buj-AHS-uh-nuh)

Also Known As: Upavistha Janu Bhujasana
Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

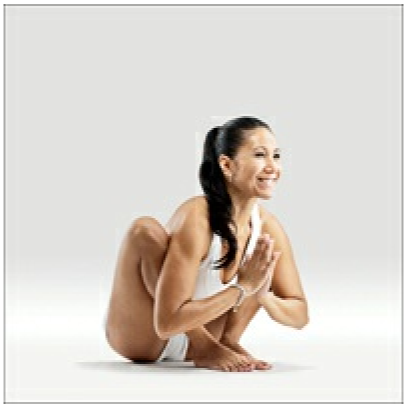

Broken Wing Pose

Avabhinna Pakshakasana

(uh-vuh-BIN-uh puhk-shuh-KAHS-uh-nuh)

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

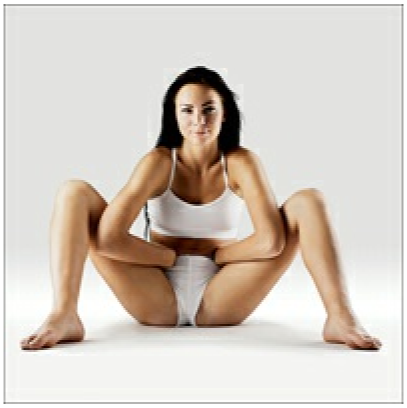

Tortoise Pose Prep.

Kurmasana Prep.

(koor-MAHS-uh-nuh)

Modification: grabbing onto the ankles

Pose Type: seated, forward bend

Drishti Point: Padhayoragrai or Padayoragre (toes/feet) or Nasagrai or Nasagre (nose)

Tortoise Pose Prep.

Kurmasana Prep.

(koor-MAHS-uh-nuh)

Modification: 1. arms straight
2. elbows bent
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose,) Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

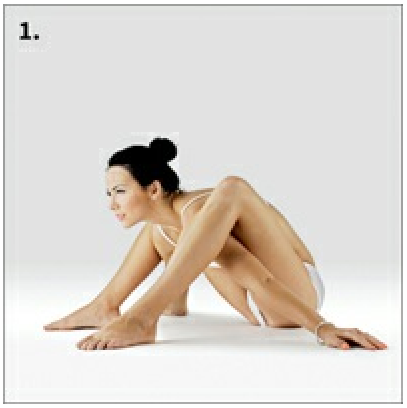
1.

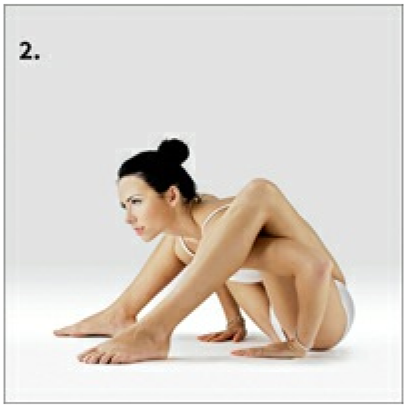
2.

Sleeping Tortoise Pose Prep.

Supta Kurmasana Prep.

(SUP-tuh koor-MAHS-uh-nuh)

Modification: feet unhooked

Pose Type: seated, forward bend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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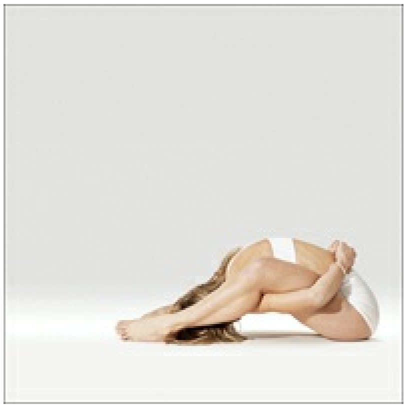

Sleeping Tortoise Pose

Supta Kurmasana

(SUP-tuh koor-MAHS-uh-nuh)

Pose Type: seated, forward bend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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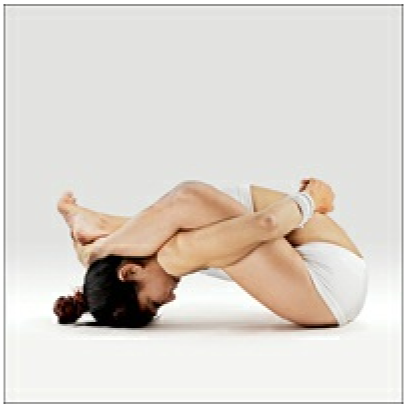

HORIZONTAL SPLITS: LEGS LIFTED—KNEES BENT

Half Upward Seated Angle Pose Prep.

Ardha Urdhva Upavistha Konasana Prep.

(UHR-duh OORD-vuh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Modification: shoulders to the back of the knees, palms to the floor, knees bent
Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

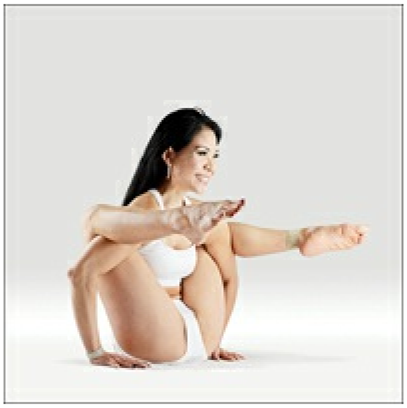

Bound Legs in Half Pose Dedicated to Sage Koormamuni

Baddha Pada Ardha Koormamunyasana

(BUH-duh PUH-duh UHR-duh koor-muh-mun-YAHS-uh-nuh)

Pose Type: seated, forward bend, core, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

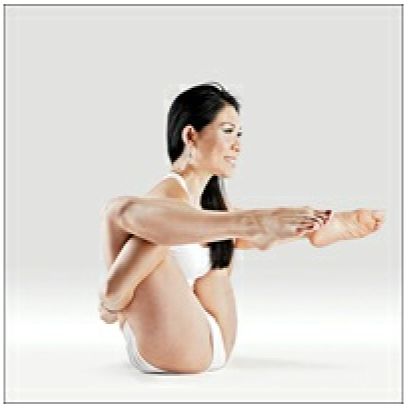

HORIZONTAL SPLITS: LEGS LIFTED

Half Upward Seated Angle Pose Prep. in One Hand to Foot Boat Pose

Ardha Urdhva Upavishta Konasana Prep. in Eka Hasta Pada Navasana

(UHR-duh OORD-vuh u-puh-VISH-tuh ko-NAHS-uh-nuh in EY-kuh HUH-stuh PUH-duh nuh-VAHS-uh-nuh)

Also Known As: Ardha Urdhva Upavistha Konasana Prep. in Eka Hasta Pada Navasana
Modification: one leg straight, back of the other knee to the shoulder
Pose Type: seated, forward bend, core
Drishti Point: Hastagrai or Hastagre (hands) or Padhayoragrai or Padayoragre (toes/feet)

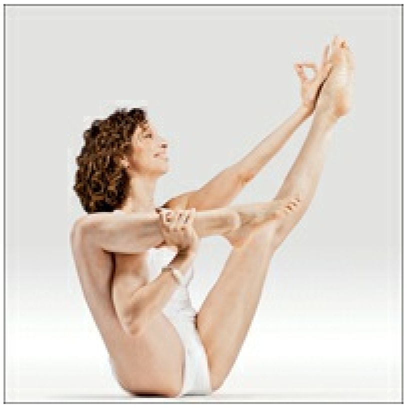

Half Upward Seated Angle Pose

Ardha Urdhva Upavishta Konasana

(UHR-duh OORD-vuh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Ardha Urdhva Upavistha Konasana
Modification: palms to the floor, one leg straight up to the sky; other foot to the floor, knee to the chest
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

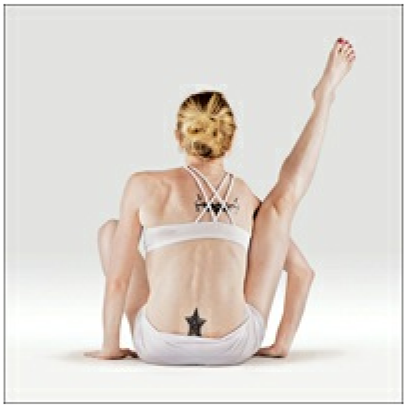

Upward Seated Angle Pose

Urdhva Upavishta Konasana

(UHR-duh OORD-vuh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Urdhva Upavistha Konasana
Modification: arms open to the sides, triceps to the back of the knees
Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

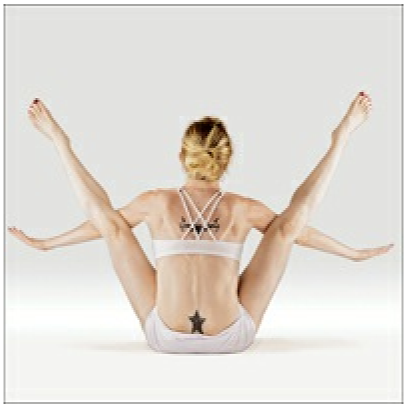

HORIZONTAL SPLITS: LEGS LIFTED & STRAIGHT

Seated Firefly Pose

Upavishta Tittibhasana

(u-puh-VISH-tuh ti-ti-BAHS-uh-nuh)

Also Known As: Upward Seated Angle Pose Prep. (Urdhva Upavishta Konasana Prep.), Pose Dedicated to Sage Koormamuni Prep. (Koormamunyasana Prep.), Upavistha Tittibhasana
Modification: palms to the floor, shoulders to the back of the knees
Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

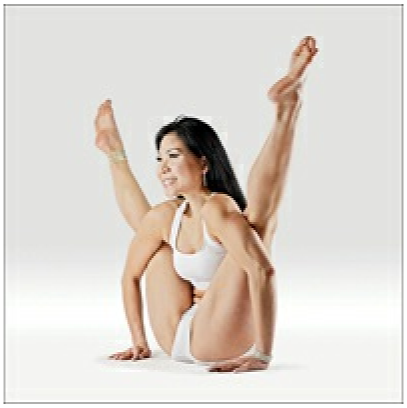

Pose Dedicated to Sage Koormamuni

Koormamunyasana

(koor-muh-mun-YAHS-uh-nuh)

Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

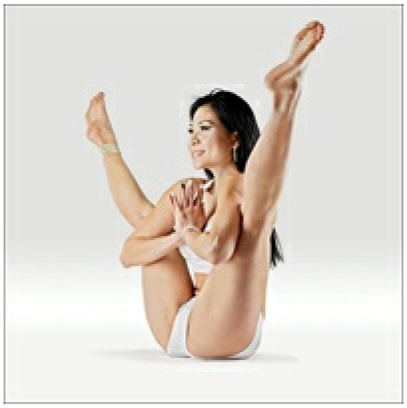

Pose Dedicated to Sage Koormamuni—Bound Legs

Baddha Pada Koormamunyasana

(BUH-duh PUH-duh koor-muh-mun-YAHS-uh-nuh)

Modification: legs straight
Pose Type: seated, forward bend, core, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

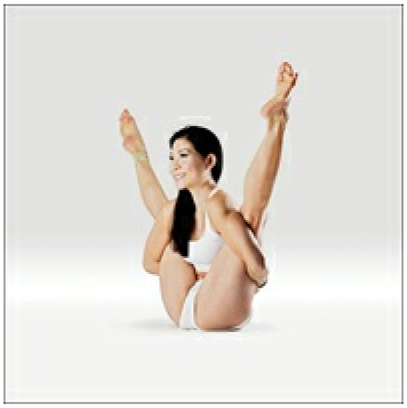

Hands to Feet Upward Seated Angle Pose

Pada Hasta Urdhva Upavishta Konasana

(PUH-duh HUH-stuh OORD-vuh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Pada Hasta Urdhva Upavistha Konasana
Modification: grabbing onto the outside edges of the feet
Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Urdhva or Antara Drishti (up to the sky)
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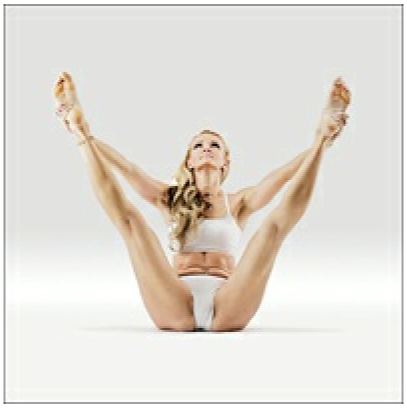

Big Toe Upward Seated Angle Pose

Padangushta Urdhva Upavishta Konasana

(puhd-ahng-GOOSH-tuh OORD-vuh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Padangushta Urdhva Upavistha Konasana
Modification: grabbing onto the big toes, arms parallel to the floor
Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Urdhva or Antara Drishti (up to the sky)
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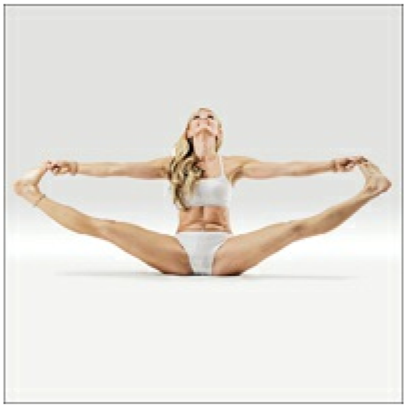

Upward Seated Angle Pose

Urdhva Upavishta Konasana

(OORD-vuh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Urdhva Upavistha Konasana

Modification: palms to the floor, heels of the palms touching, fingertips pointing to the sides; feet lifted, toes pointed

Pose Type: seated, forward bend, core

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Urdhva or Antara Drishti (up to the sky)

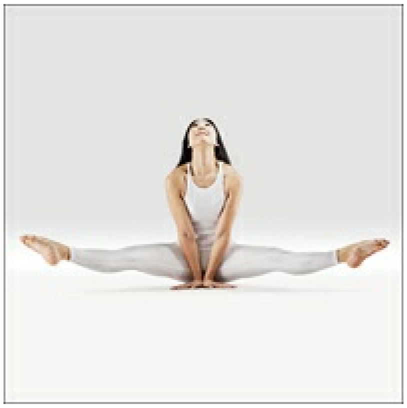

HORIZONTAL SPLITS: FORWARD BEND

Tortoise Pose

Kurmasana

(koor-MAHS-uh-nuh)

Modification: 1. knees bent

2. legs straight

Pose Type: seated, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

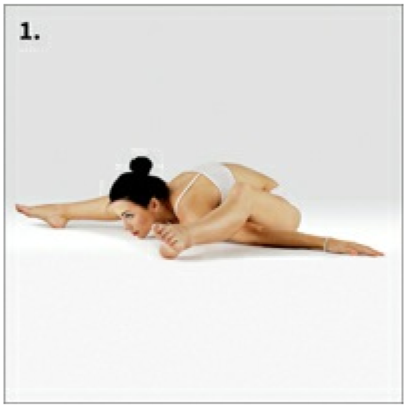

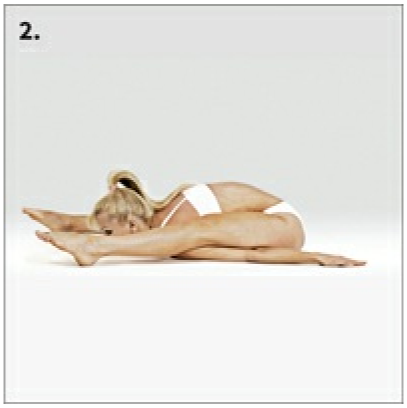

Equal Angle Pose

Samakonasana

(suh-muh-ko-NAHS-uh-nuh)

Modification: forward bend, forearms to the floor
Pose Type: seated, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

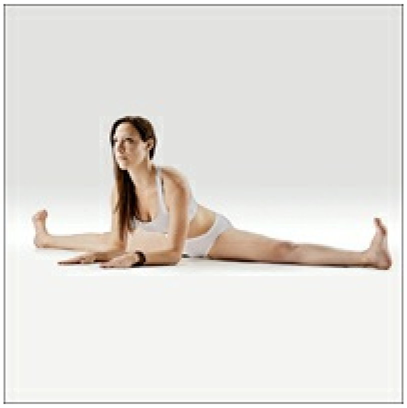

Big Toe Seated Angle Pose

Padangushta Upavishta Konasana

(puhd-ahng-GOOSH-tuh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Padangushta Upavistha Konasana

Modification: forward bend, chin to the floor

Pose Type: seated, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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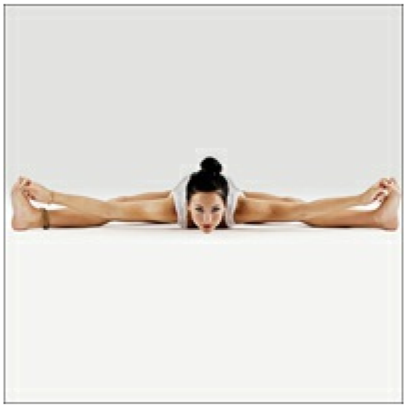

Equal Angle Pose

Samakonasana

(suh-muh-ko-NAHS-uh-nuh)

Modification: forward bend, arms crossed in front

Pose Type: seated, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

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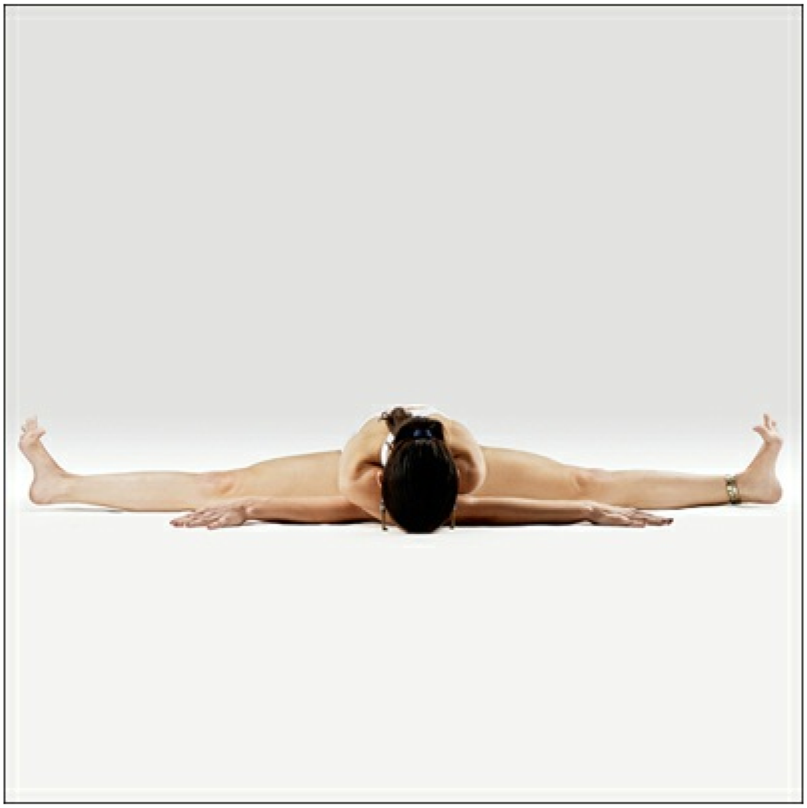

Equal Angle Pose

Samakonasana

(suh-muh-ko-NAHS-uh-nuh)

Modification: forward bend, arms extended to the front
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

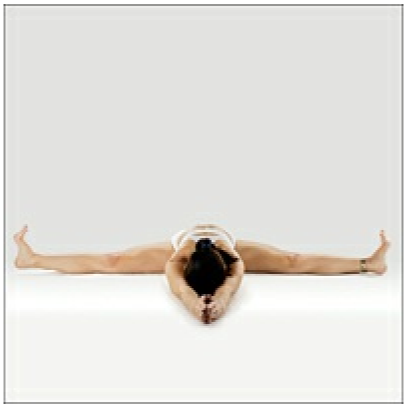

Reverse Prayer Equal Angle Pose

Viparita Namaskar Samakonasana

(vi-puh-REE-tuh nuh-muhs-KAHR suh-muh-ko-NAHS-uh-nuh)

Also Known As: Back of the Body Prayer Equal Angle Pose (Paschima Namaskara Samakonasana)
Pose Type: seated, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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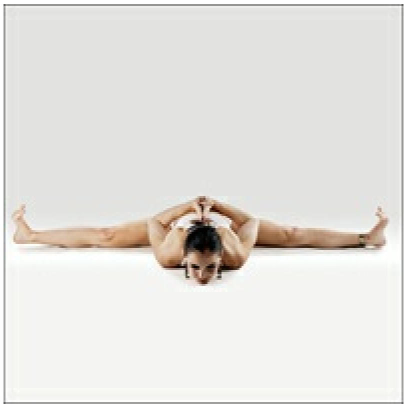

Hands Bound Equal Angle Pose

Baddha Hasta Samakonasana

(BUH-duh HUH-stuh suh-muh-ko-NAHS-uh-nuh)
Modification: forward bend
Pose Type: seated, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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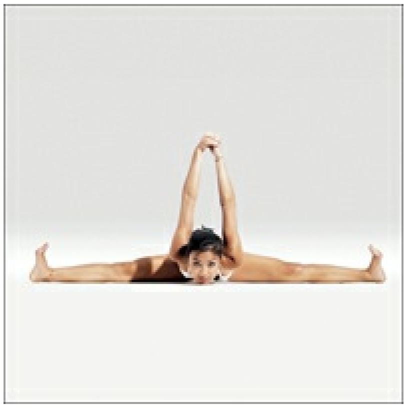

HORIZONTAL SPLITS: SPINE STRAIGHT

Seated Angle Pose

Upavishta Konasana

(u-puh-VISH-tuh ko-NAHS-uh-nuh)
Also Known As: Upavistha Konasana

Modification: mild version, backbend
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

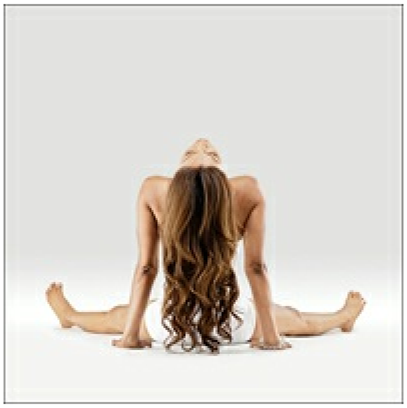

Seated Angle Pose

Upavishta Konasana

(u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Upavistha Konasana
Modification: 1. hands in Anjali Mudra (Hands in Prayer), toes flexed in
2. hands in reverse prayer, toes flexed in
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose) or Hastagrai or Hastagre (hands)

1.

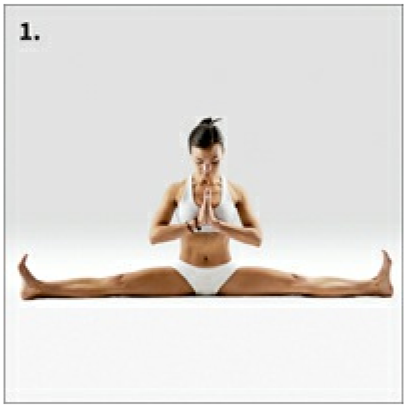

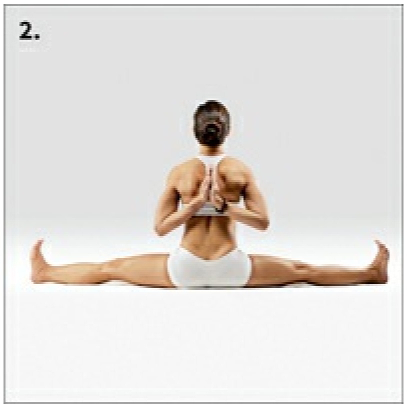

Seated Angle Pose

Upavishta Konasana

(u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Upavistha Konasana
Modification: palms to the floor in front of the hips, heels of the palms touching, fingertips pointing to the side, straight spine, toes pointed
Pose Type: seated
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

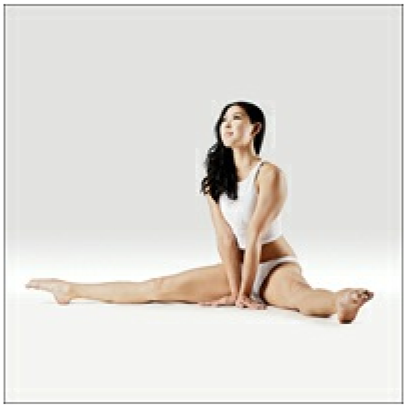

Equal Angle Pose

Samakonasana

(su-muh-ko-NAHS-uh-nuh)

Modification: hands on the knees, spine straight
Pose Type: seated
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

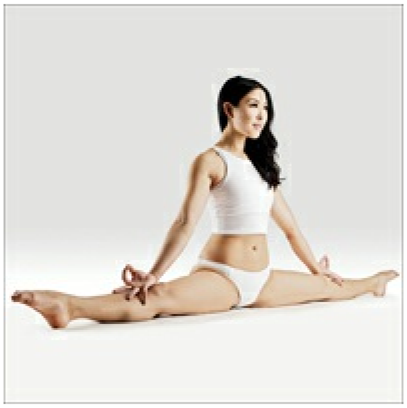

Bound Equal Angle Pose

Baddha Samakonasana

(BUH-duh su-muh-ko-NAHS-uh-nuh)

Pose Type: seated, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

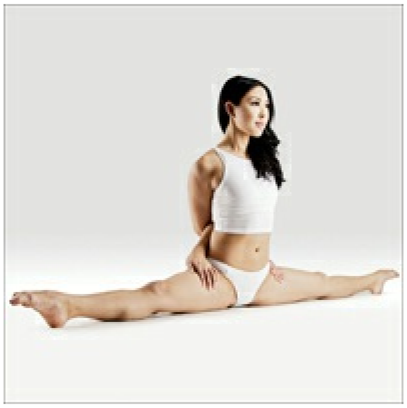

HORIZONTAL SPLITS: TWISTS

Half Bound Seated Angle Pose

Ardha Baddha Upavishta Konasana

(UHR-duh BUH-duh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Ardha Baddha Upavistha Konasana
Modification: toes pointed, one hand binding behind the back, fingertips of the other hand to the floor in front of the hips
Pose Type: seated, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

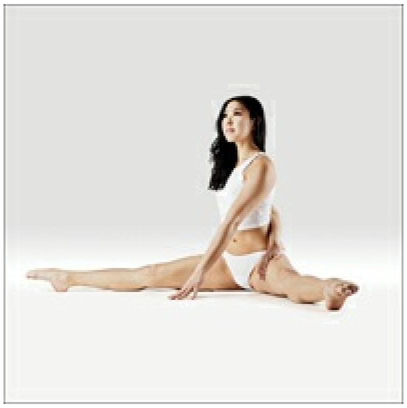

Revolved Half Bound Equal Angle Pose

Parivritta Samakonasana

(puh-ri-VRIT-tuh suh-muh-ko-NAHS-uh-nuh)

Modification: 1. toes pointed, both hands on one leg
2. toes flexed in, one hand to the leg, other hand to the floor
Pose Type: seated, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

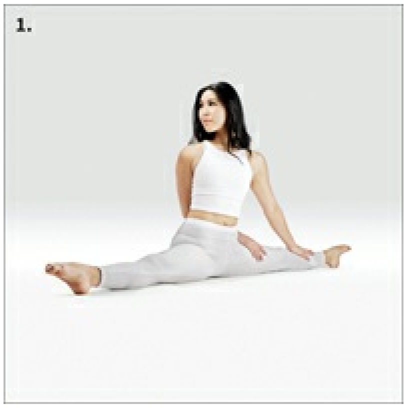

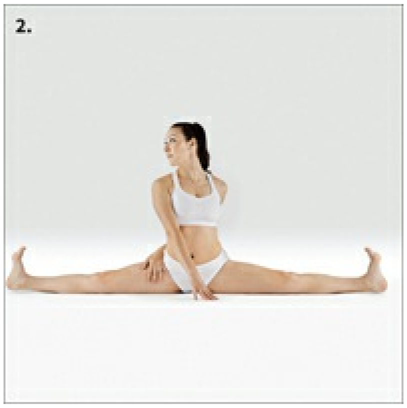

Revolved Bound Equal Angle Pose

Parivritta Baddha Samakonasana

(puh-ri-VRIT-tuh BUH-duh suh-muh-ko-NAHS-uh-nuh)

Modification: 1. toes pointed
2. toes flexed in
Pose Type: seated, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

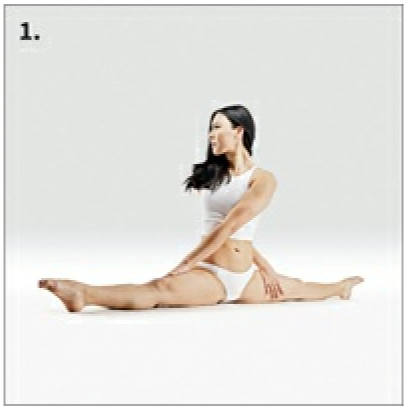

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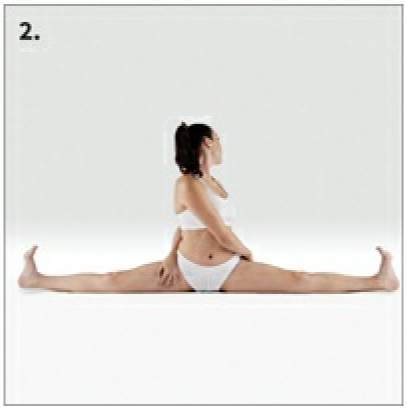

2.

HORIZONTAL SPLITS: SIDE BENDS

Sideways Equal Angle Pose

Parshva Samakonasana

(PAHRSH-vuh suh-muh-ko-NAHS-uh-nuh)

Modification: side bend, fingertips to the back of the head; elbow to the floor
Pose Type: seated, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

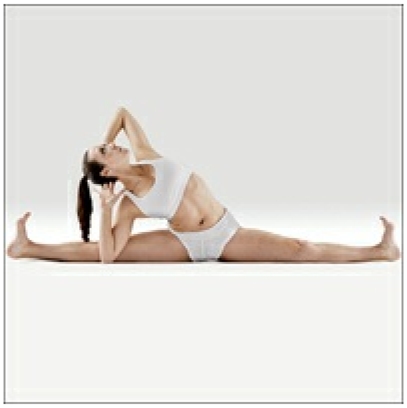

Both Hands to Foot Revolved Seated Angle Pose

Dwi Hasta Pada Parivritta Upavishta Konasana

(DWI-huh-stuh PUH-duh puh-ri-VRIT-tuh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Dwi Hasta Pada Parivritta Upavistha Konasana
Pose Type: seated, side bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

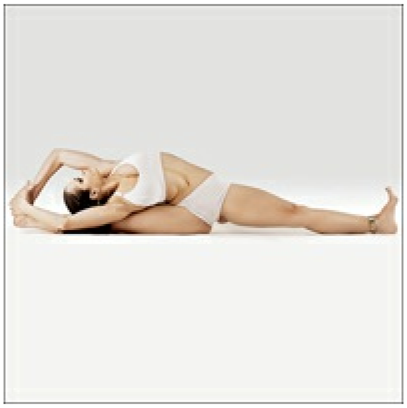

LEGS STRAIGHT IN FRONT: SPINE STRAIGHT & BACKBEND

Staff Pose

Dandasana

(duhn-DAHS-uh-nuh)

Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose), Padhayoragrai or Padayoragre (toes/feet)

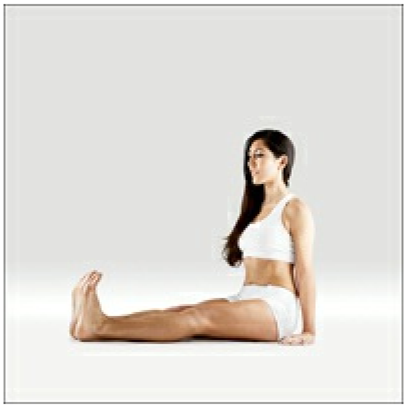

Reverse Prayer Staff Pose

Viparita Namaskar Dandasana

(vi-puh-REE-tuh nuh-muhs-KAHR duhn-DAHS-uh-nuh)

Also Known As: Back of the Body Prayer Staff Pose (Paschima Namaskara Dandasana)
Pose Type: seated
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)
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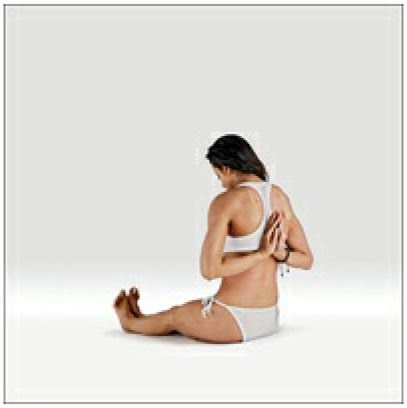

Staff Pose

Dandasana

(duhn-DAHS-uh-nuh)

Modification: 1. fingertips pointing to the heels
2. fingertips pointing away from the heels, head rolling back
Pose Type: seated, mild backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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1.

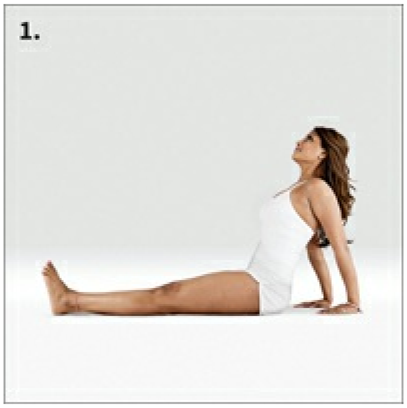

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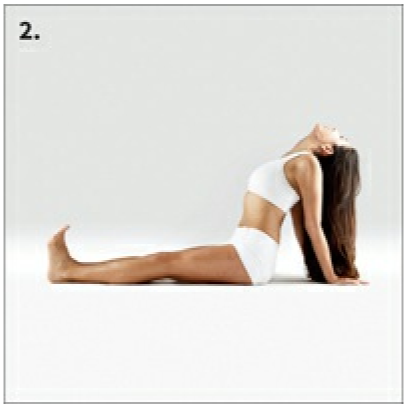

LEGS STRAIGHT IN FRONT: FORWARD BEND

Western Intense Stretch Pose

Paschimottanasana

(puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Seated Forward Bend
Modification: grabbing onto the big toes
Pose Type: seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)
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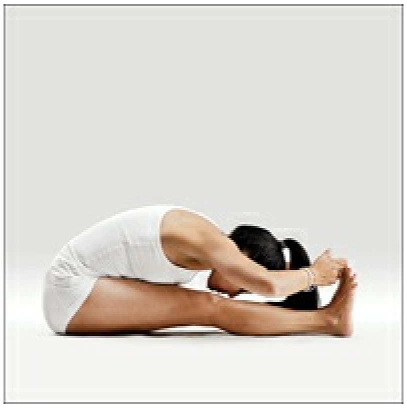

Western Intense Stretch Pose

Paschimottanasana

(puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Seated Forward Bend
Modification: grabbing onto the balls of the feet
Pose Type: seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)

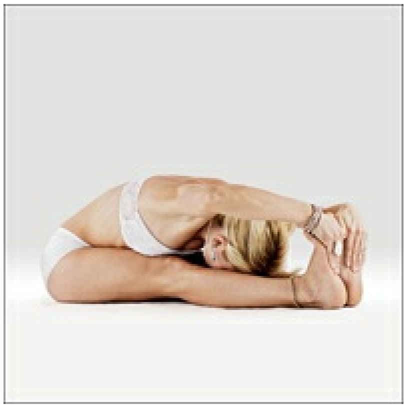

Western Intense Stretch Pose

Paschimottanasana

(puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Seated Forward Bend
Modification: grabbing onto the wrist
Pose Type: seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)

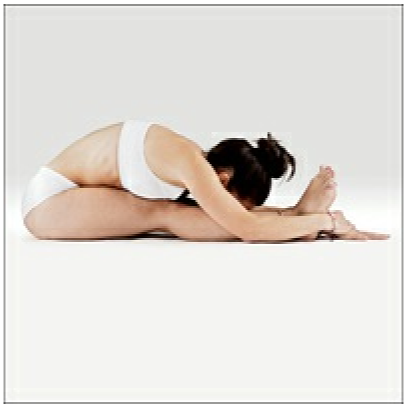

Western Intense Stretch Pose

Paschimottanasana

(puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Seated Forward Bend
Modification: palms down
Pose Type: seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)
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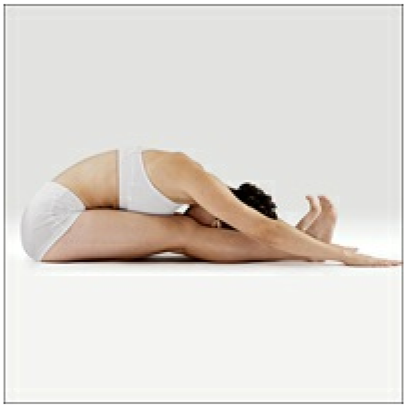

Bound Hands Western Intense Stretch Pose

Baddha Hasta Paschimottanasana

(BUH-duh HUH-stuh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Seated Forward Bend
Pose Type: seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)
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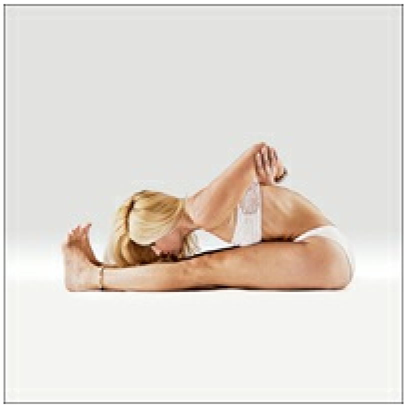

Reverse Prayer Western Intense Stretch Pose

Viparita Namaskar Paschimottanasana

(vi-puh-REE-tuh nuh-muhs-KAHR puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Back of the Body Prayer Western Intense Stretch Pose (Paschima Namaskara Paschimottanasana), Reverse Prayer Forward Bend

Pose Type: seated, forward bend

Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)

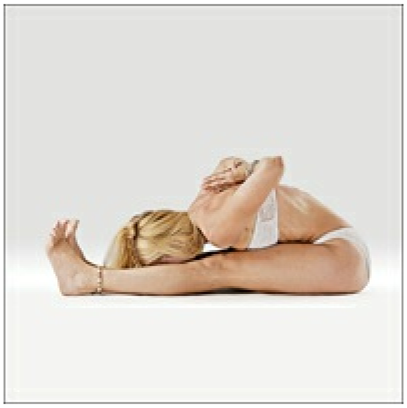

LEGS STRAIGHT IN FRONT: TWISTS

Revolved Staff Pose

Parivritta Dandasana

(puh-ri-VRIT-tuh duhn-DAHS-uh-nuh)

Pose Type: seated, twist

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

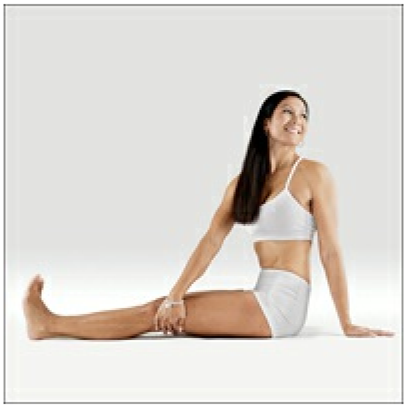

Revolved Upward One Arm Extended Hand to Foot Staff Pose

Parivritta Urdhva Eka Hasta Utthita Hasta Pada Dandasana

(puh-ri-VRIT-tuh OORD-vuh EY-kuh HUH-stuh UT-tu-tuh HUH-stuh PUH-duh duhn-DAHS-uh-nuh)

Pose Type: seated, forward bend, twist

Drishti Point: Hastagrai or Hastagre (hands)

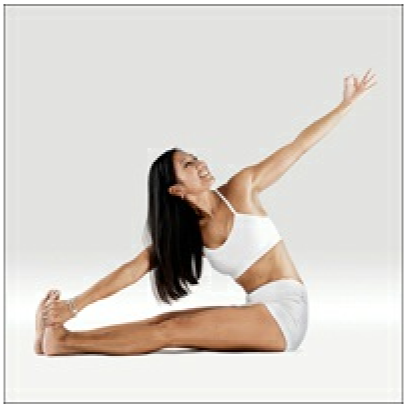

One Hand Revolved Western Intense Stretch Pose

Eka Hasta Parivritta Paschimottanasana

(EY-kuh HUH-stuh puh-ri-VRIT-tuh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: One Hand Revolved Seated Forward Bend

Modification: one hand to the foot

Pose Type: seated, forward bend, side bend, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky)

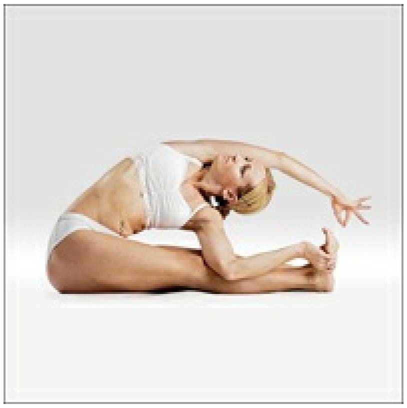

Two Hands Revolved Western Intense Stretch Pose

Dwi Hasta Parivritta Paschimottanasana

(DWI-huh-stuh puh-ri-VRIT-tuh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Two Hands Revolved Forward Bend

Pose Type: seated, forward bend, side bend, twist

Drishti Point: Urdhva or Antara Drishti (up to the sky)

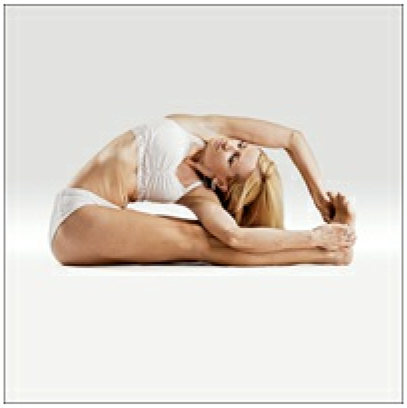

LEGS STRAIGHT: ON THE SIDE & SCISSOR LEGS

Upward Side Infinity Pose

Urdhva Parshva Anantasana

(OORD-vuh PARSH-vuh uh-nuhn-TAHS-uh-nuh)

Pose Type: seated, side bend

Drishti Point: Urdhva or Antara Drishti (up to the sky)

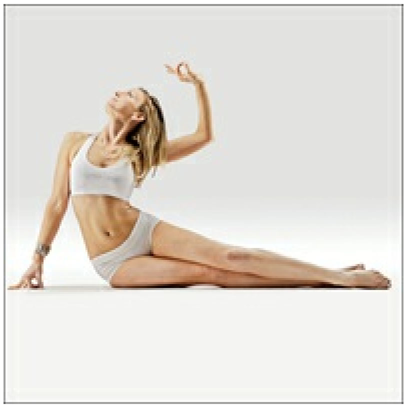

One Leg Upward Hand to Knee Revolved Staff Pose

Urdhva Eka Pada Janu Hasta Parivritta Dandasana

(OORD-vuh EY-kuh PUH-duh JAH-nu HUH-stuh puh-ri-VRIT-tuh duhn-DAHS-uh-nuh)

Pose Type: seated, forward bend, twist

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

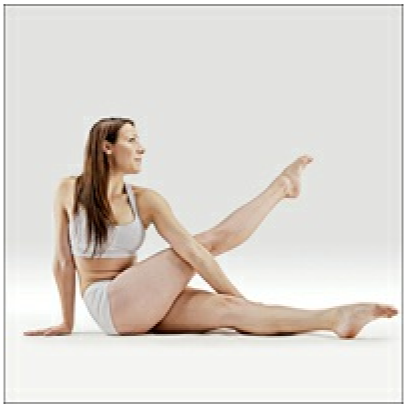

One Leg Upward Hand to Foot Revolved Staff Pose

Urdhva Eka Pada Hasta Pada Parivritta Dandasana

(OORD-vuh EY-kuh PUH-duh HUH-stuh PUH-duh puh-ri-VRIT-tuh duhn-DAHS-uh-nuh)

Pose Type: seated, forward bend, twist
Drishti Point: Parsva Drishti (to the right), Parsva Drishti (to the left)
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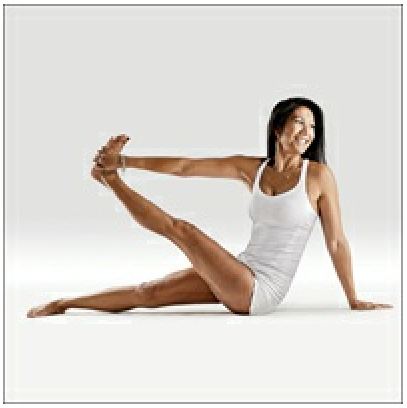

One Hand to Foot Archer's Pose

Eka Hasta Pada Akarna Dhanurasana

(EY-kuh HUH-stuh PUH-duh AH-kuhr-nuh duh-nur-AHS-uh-nuh)

Modification: both legs straight, knee behind the shoulder, other palm to the floor
Pose Type: seated, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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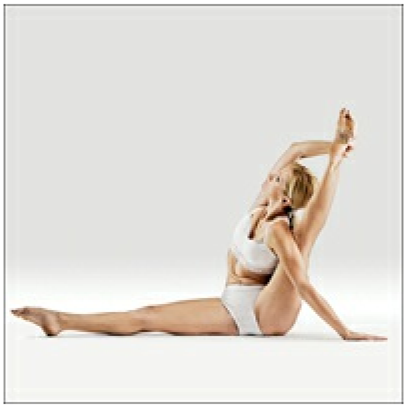

Bound Leg Archer’s Pose

Baddha Pada Akarna Dhanurasana

(BUH-duh PUH-duh AH-kuhr-nuh duh-nur-AHS-uh-nuh)

Pose Type: seated, twist, binding

Drishti Point: Urdhva or Antara Drishti (up to the sky)

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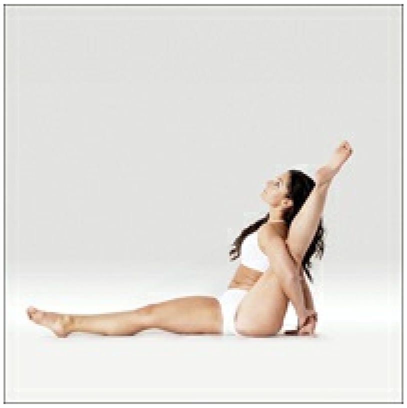

ONE LEG STRAIGHT, ONE LEG BENT

Archer’s Pose Prep.

Akarna Dhanurasana Prep.

(AH-kuhr-nuh duh-nur-AHS-uh-nuh)

Modification: knee wrapping around the arm

Pose Type: seated, mild backbend

Drishti Point: Urdhva or Antara Drishti (up to the sky)

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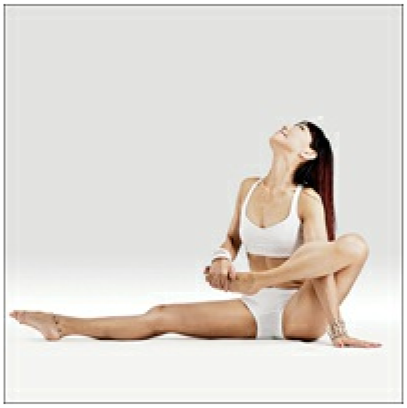

Archer’s Pose

Akarna Dhanurasana

(AH-kuhr-nuh duh-nur-AHS-uh-nuh)

Modification: foot to the ear
Pose Type: seated, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

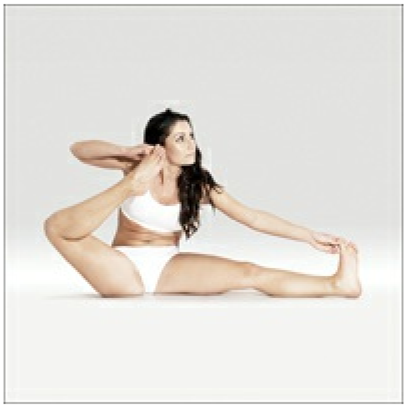

Foot Behind the Head Pose

Eka Pada Shirshasana

(EY-kuh PUH-duh sheer-SHAHS-uh-nuh)

Also Known As: Foot Behind the Head Pose A (Eka Pada Shirshasana A)
Modification: leg straight
1. palms to the floor by the hips
2. hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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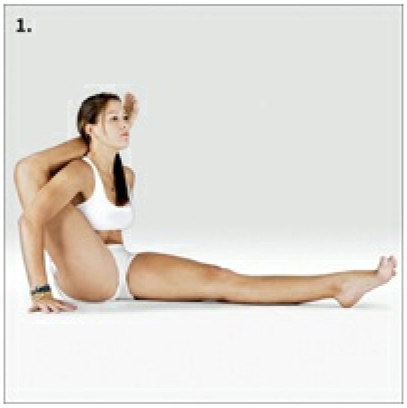

2.

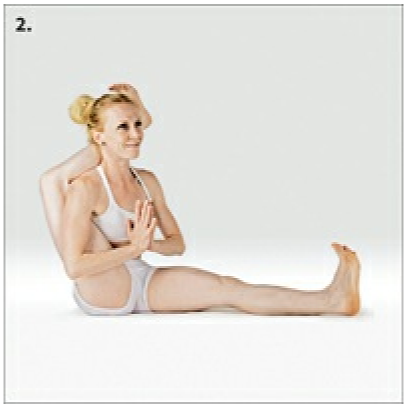

Pose Dedicated to Skanda

Skandasana

(skuhn-DAHS-uh-nuh)

Also Known As: Foot Behind the Head Pose B (Eka Pada Shirshasana B)
Pose Type: seated, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

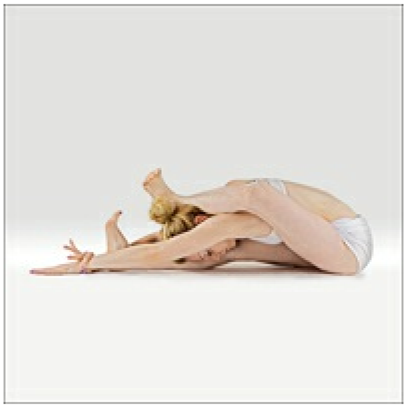

ONE LEG STRAIGHT, ONE LEG BENT: TWISTS

Easy Lord of the Fishes Pose Prep.

Sukha Matsyendrasana Prep.

(SUK-uh muhts-yeyn-DRAHS-uh-nuh)

Modification: one leg straight, arm wrapped around the bent knee

Pose Type: seated, forward bend, twist

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

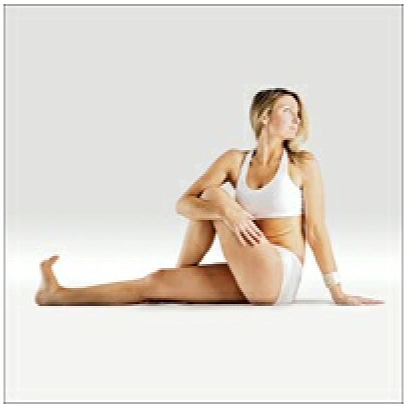

Easy Lord of the Fishes Pose

Sukha Matsyendrasana

(SUK-uh muhts-yeyn-DRAHS-uh-nuh)

Pose Type: seated, forward bend, twist, binding

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

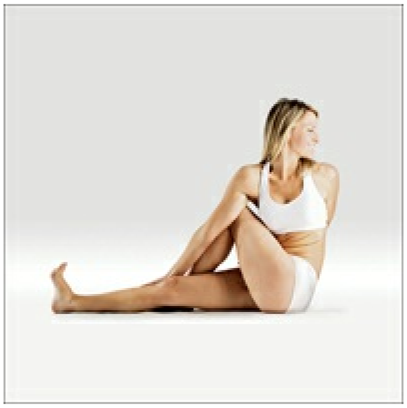

ONE LEG STRAIGHT, ONE LEG BENT: KNEE TO THE CHEST

Pose Dedicated to Sage Marichi 1 & 2 Prep.

Marichyasana 1 & 2 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi A & C Prep. (Marichyasana A & C Prep.)
Modification: arms parallel to the floor in front of the chest
Pose Type: seated, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

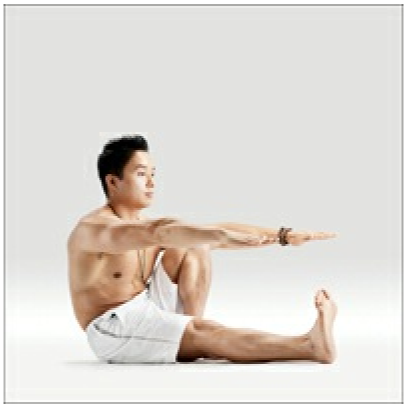

Pose Dedicated to Sage Marichi 1 & 2 Prep.

Marichyasana 1 & 2 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi A & C Prep. (Marichyasana A & C Prep.)
Modification: both hands grabbing onto the foot of the straight leg
Pose Type: seated, forward bend
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)

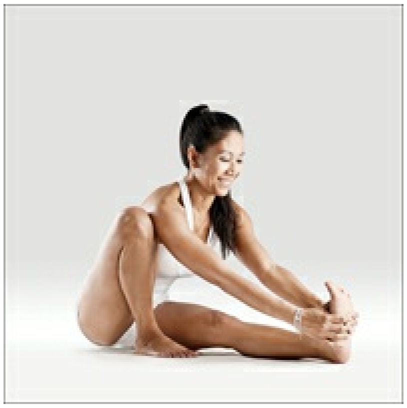

Revolved Pose Dedicated to Sage Marichi 1 Prep.

Parivritta Marichyasana 1 Prep.

(puh-ri-VRIT-tuh muh-ree-CHYAHS-uh-nuh)

Modification: twisting to the inside of the bent knee, elbow to the knee

Pose Type: seated, forward bend, twist

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

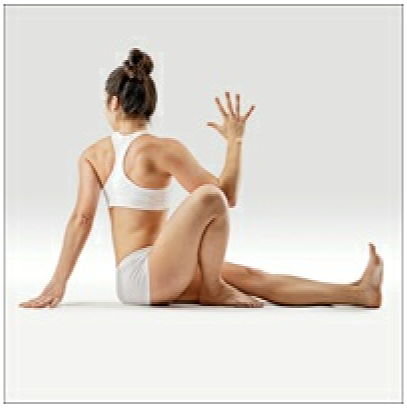

ONE LEG STRAIGHT, ONE LEG BENT: KNEE TO THE CHEST—BINDING & TWIST

Pose Dedicated to Sage Marichi 1

Marichyasana 1

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi A (Marichyasana A)

Modification: 1. spine straight
2. half forward bend
3. full forward bend, nose to the shin

Pose Type: seated, forward bend, binding

Drishti Point: 1. Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
2 & 3. Padhayoragrai or Padayoragre (toes/feet) or Nasagrai or Nasagre (nose)

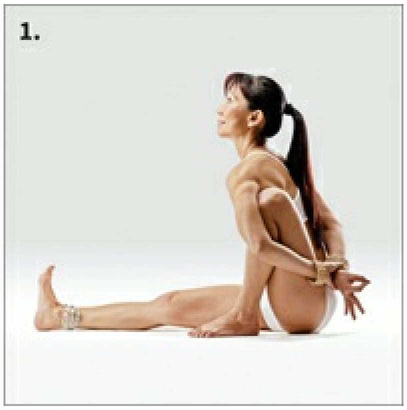

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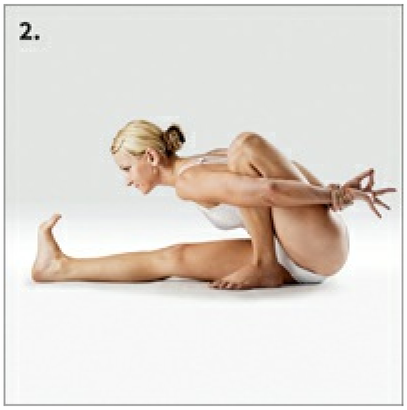

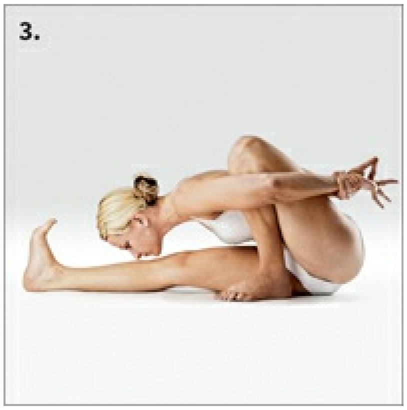

Pose Dedicated to Sage Marichi 2 Prep.

Marichyasana 2 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi C (Marichyasana C)
Modification: elbow over the bent knee
Pose Type: seated, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

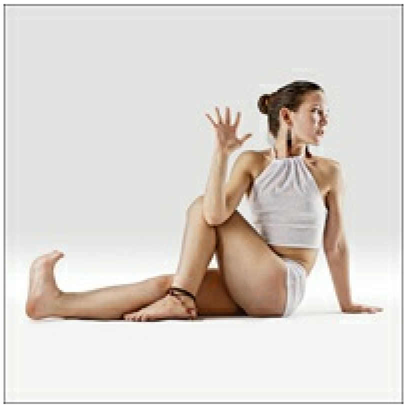

Pose Dedicated to Sage Marichi 2 Prep.

Marichyasana 2 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi C (Marichyasana C)
Modification: grabbing onto the knee of the straight leg
Pose Type: seated, forward bend, twist, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Padhayoragrai or Padayoragre (toes/feet)

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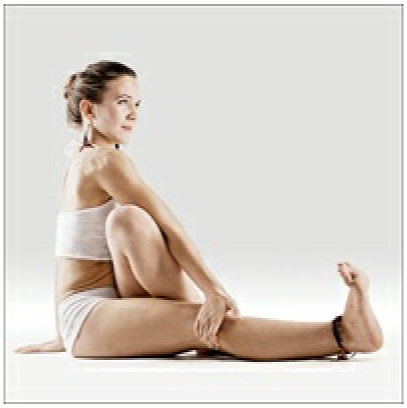

Pose dedicated to Sage Marichi 2

Marichyasana 2

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi C (Marichyasana C)
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

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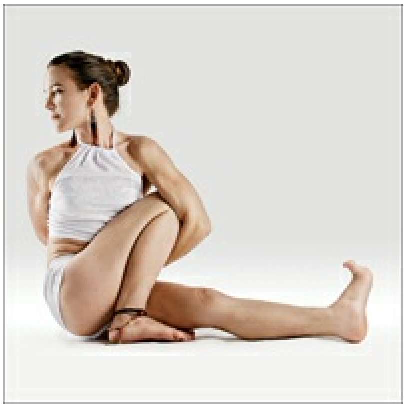

ONE LEG STRAIGHT & LIFTED, ONE LEG BENT

Seated Revolved Upward One Hand to Foot Pose

Upavishta Parivritta Urdhva Eka Pada Hastasana

(u-puh-VISH-tuh puh-ri-VRIT-tuh OORD-vuh EY-kuh PUH-duh huh-STAHS-uh-nuh)

Also Known As: Upavistha Parivritta Urdhva Eka Pada Hastasana
Modification: straight leg lifted, grabbing the foot with the opposite arm, other forearm on the floor
Pose Type: seated, forward bend
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)

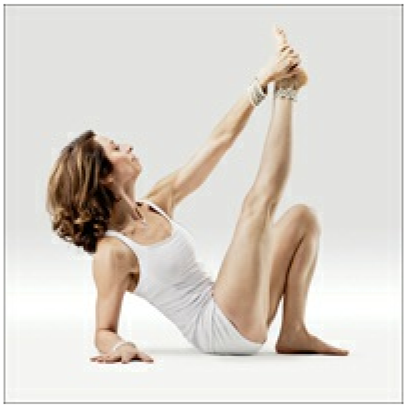

One Leg Extended Full Lord of the Fishes Pose

Utthita Eka Pada Paripurna Matsyendrasana

(UT-ti-tuh EY-kuh PUH-duh puh-ri-POOR-nuh muhts-yeyn-DRAHS-uh-nuh)

Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

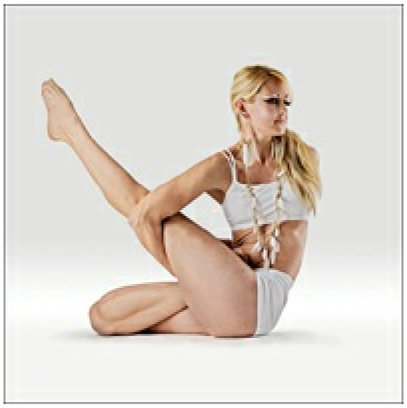

ONE LEG STRAIGHT, OTHER LEG CROSSED OVER: FOREARM & ELBOW TO THE FLOOR

Revolved Western Intense Stretch Pose Hand to Foot Side Infinity Pose

Parivritta Paschimottana Hasta Pada Parshva Anantasana

(puh-ri-VRIT-tuh puhsh-chi-mo-TAHN-uh HUH-stuh PUH-duh PAHRSH-vuh uh-nuhn-TAHS-uh-nuh)

Also Known As: Revolved Seated Forward Bend Hand to Foot Side Infinity Pose
Pose Type: seated, forward bend, twist
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

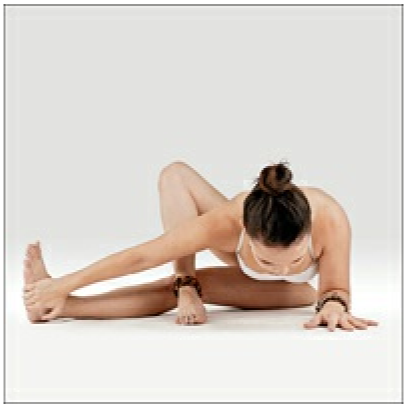

Revolved Western Intense Stretch Pose Uneven Arms Upward Side Infinity Pose

Parivritta Paschimottana Vishama Hasta Urdhva Parshva Anantasana

(puh-ri-VRIT-tuh puhsh-chi-mo-TAHN-uh VI-shuh-muh HUH-stuh OORD-vuh PAHRSH-vuh uh-nuhn-TAHS-uh-nuh)

Also Known As: Revolved Seated Forward Bend Uneven Arms Side Infinity Pose
Pose Type: seated, forward bend, twist
Drishti Point: Angushtamadhye or Angustha Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

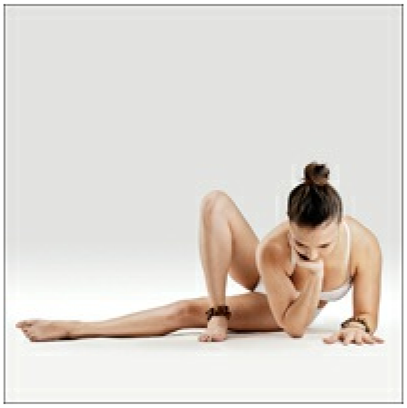

Revolved Western Intense Stretch Pose Bound Arms Upward Side

Infinity Pose

Parivritta Paschimottana Baddha Hasta Urdhva Parshva Anantasana

(puh-ri-VRIT-tuh puhsh-chi-mo-TAHN-uh BUH-duh HUH-stuh OORD-vuh PAHRSH-vuh uh-nuhn-TAHS-uh-nuh)

Also Known As: Revolved Seated Forward Bend Bound Arms Upward Side Infinity Pose
Modification: arms wrapped around the foot, elbows toward the floor
Pose Type: seated, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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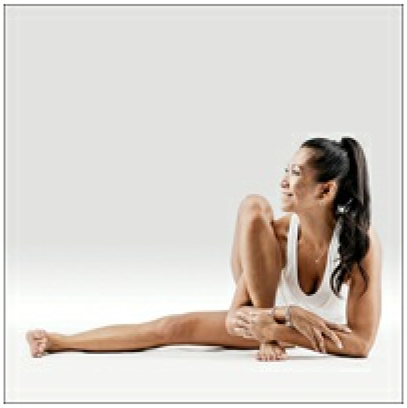

ONE LEG STRAIGHT, OTHER LEG CROSSED OVER: SIDE & BACKBEND

Upward Side Infinity Pose

Urdhva Parshva Anantasana

(OORD-vuh PAHRSH-vuh uh-nuhn-TAHS-uh-nuh)

Modification: top leg crossed over, outside edge of the foot to the floor
1. looking to the side
2. head rolling back
Pose Type: 1. seated, side bend, twist
2. seated, side bend, twist, backbend
Drishti Point: 1. Hastagrai or Hastagre (hands), Padhayoragrai or Padayoragre (toes/feet)
2. Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
1. लं वं हं
2. लं वं हं ॐ

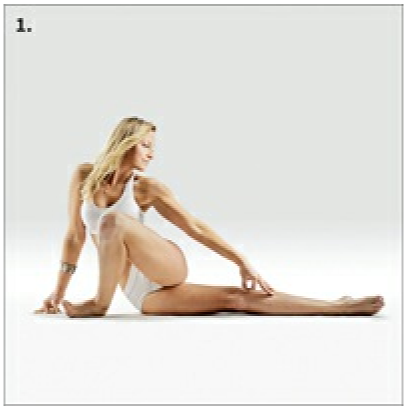

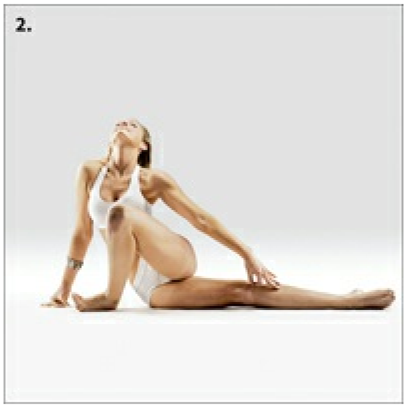

HALF COW FACE POSE: FORWARD BEND & SIDE BEND

Half Cow Face Western Intense Stretch Pose Prep.

Ardha Gomukha Paschimottanasana Prep.

(UHR-duh GO-muk-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: One-Legged Cow Face Western Intense Stretch Pose (Eka Pada Gomukha Paschimottanasana), Half Cow Face Seated Forward Bend
Modification: half forward bend
Pose Type: seated, forward bend
Drishti Point: Padhayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)

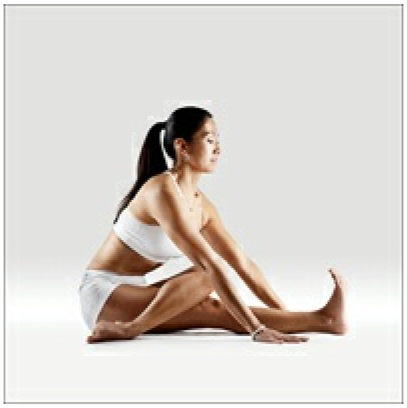

Half Cow Face Western Intense Stretch Pose

Ardha Gomukha Paschimottanasana

(UHR-duh GO-muk-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: One-Legged Cow Face Western Intense Stretch Pose (Eka Pada Gomukha Paschimottanasana), Half Cow Face Seated Forward Bend
Modification: 1. grabbing onto the wrist, chin to the knee
2. chin to the knee, arms straight, palms down in front of the foot
Pose Type: seated, forward bend
Drishti Point: Padhayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)
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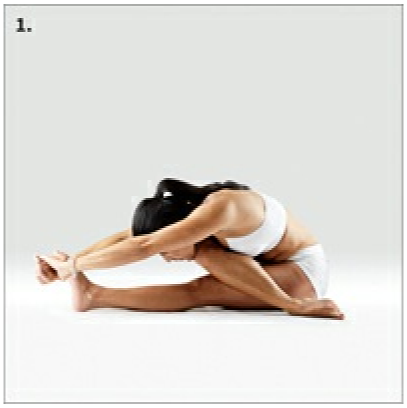

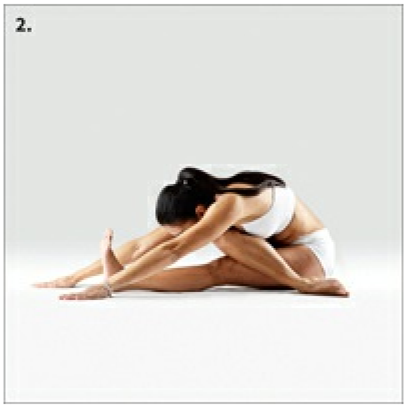

Revolved Sideways Half Cow Face Western Intense Stretch Pose

Parivritta Parshva Ardha Gomukha Paschimottanasana

(puh-ri-VRIT-tuh PAHRSH-vuh EY-kuh PUH-duh GO-muk-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Revolved Sideways One-Legged Cow Face Western Intense Stretch Pose (Parivritta Parshva Eka Pada Gomukha Paschimottanasana), Revolved Sideways Half Cow Face Seated Forward Bend
Modification: top leg straight
Pose Type: seated, forward bend, side bend, twist
Drishti Point: Padhayoragrai or Padayoragre (toes/feet), Hastagrai or Hastagre (hands), Parshva

Drishti (to the right), Parshva Drishti (to the left)

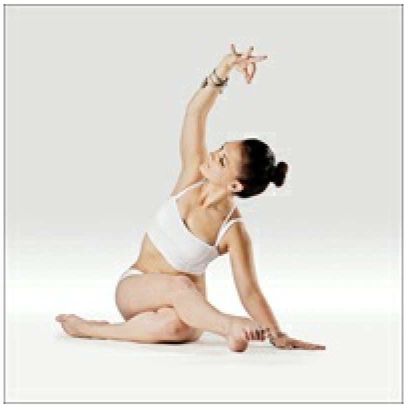

Revolved Hand to Foot Sideways Half Cow Face Western Intense Stretch Pose

Parivritta Hasta Pada Parshva Ardha Gomukha Paschimottanasana

(puh-ri-VRIT-tuh HUH-stuh PUH-duh PAHRSH-vuh UHR-duh GO-muk-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Revolved Hand to Foot Sideways One-Legged Cow Face Western Intense Stretch Pose (Parivritta Hasta Pada Parshva Eka Pada Gomukha Paschimottanasana), Revolved Hand to Foot Sideways Half Cow Face Seated Forward Bend
Modification: bottom leg straight, looking up to the sky
Pose Type: seated, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

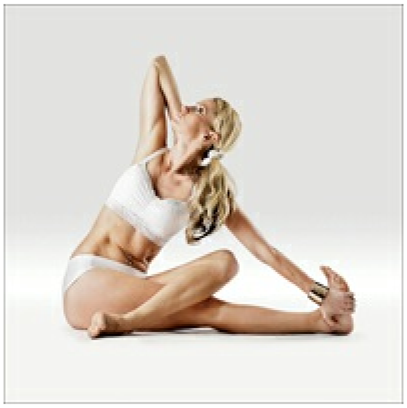

HALF COW FACE POSE: LEG LIFTED

Upward Half Cow Face Western Intense Stretch Pose

Urdhva Ardha Gomukha Paschimottanasana

(OORD-vuh UHR-duh GO-muk-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward One-Legged Cow Face Western Intense Stretch Pose (Urdhva Eka Pada Gomukha Paschimottanasana), Upward Half Cow Face Seated Forward Bend
Modification: bottom leg straight, grabbing onto the foot
Pose Type: seated, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Urdhva or Antara Drishti (up to the sky)

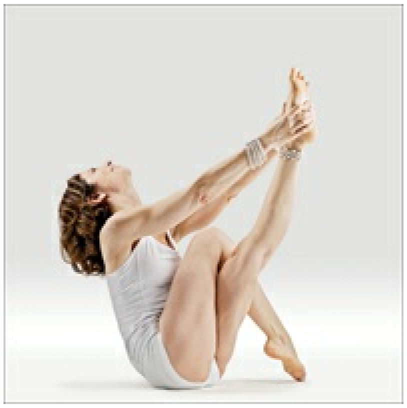

Upward Half Cow Face Western Intense Stretch Pose

Urdhva Ardha Gomukha Paschimottanasana

(OORD-vuh UHR-duh GO-muk-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward One-Legged Cow Face Western Intense Stretch Pose (Urdhva Eka Pada Gomukha Paschimottanasana), Upward Half Cow Face Seated Forward Bend
Modification: top leg straight, grabbing onto both feet
Pose Type: seated, forward bend, core
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)

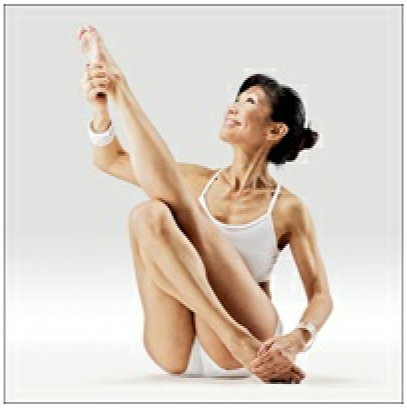

Sundial Pose 2

Surya Yantrasana 2

(SOOR-yuh yuhn-trahn-AHS-uh-nuh)

Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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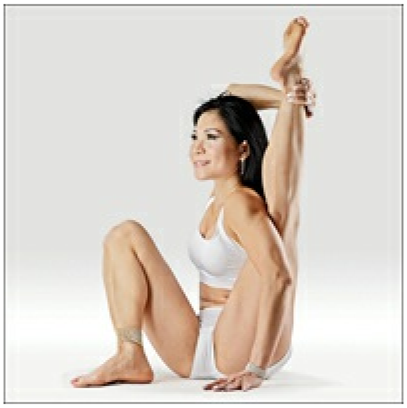

Sundial Pose 1

Surya Yantrasana 1

(SOOR-yuh yuhn-trahn-AHS-uh-nuh)

Pose Type: seated, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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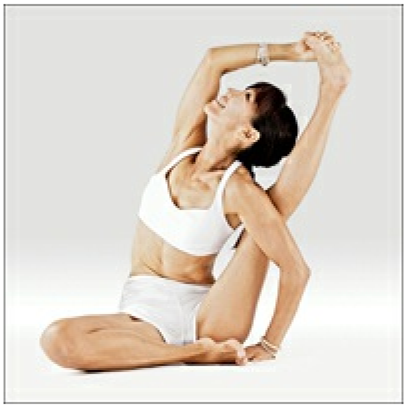

Upward Bound Hands Sundial Pose 1

Urdhva Baddha Hasta Surya Yantrasana 1

(OORD-vuh BUH-duh HUH-stuh SOOR-yuh yuhn-trahn-AHS-uh-nuh)

Pose Type: seated, twist, binding

Drishti Point: Urdhva or Antara Drishti (up to the sky)

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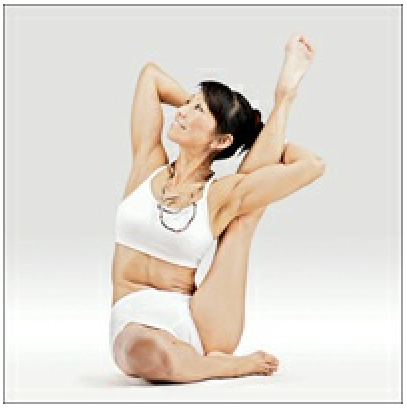

Downward Bound Hands Sundial Pose 1

Adho Baddha Hasta Surya Yantrasana 1

(uh-DO BUH-duh HUH-stuh SOOR-yuh yuhn-trahn-AHS-uh-nuh)

Pose Type: seated, forward bend, binding

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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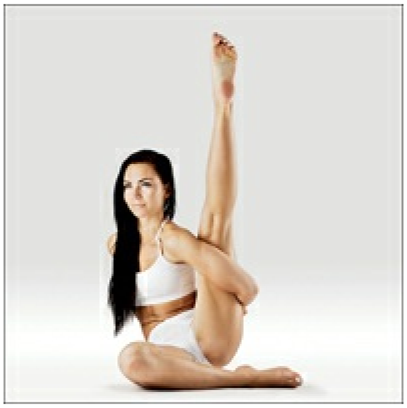

ONE LEG STRAIGHT, ONE LEG BENT: HALF LOTUS & BINDING

Half Bound Lotus Western Intense Stretch Pose Prep.

Ardha Baddha Padma Paschimottanasana Prep.

(UHR-duh BUH-duh PUHD-muh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Half Bound Lotus Seated Forward Bend Prep.
Modification: arm extended to the sky
Pose Type: seated, binding
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

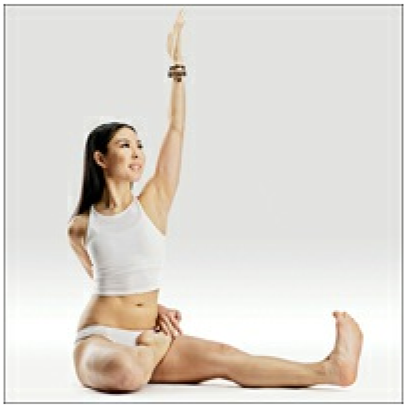

Half Bound Lotus Western Intense Stretch Pose

Ardha Baddha Padma Paschimottanasana

(UHR-duh BUH-duh PUHD-muh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Half Bound Lotus Seated Forward Bend
Modification: 1. half forward bend
2. full forward bend
Pose Type: seated, forward bend, binding
Drishti Point: Padhayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

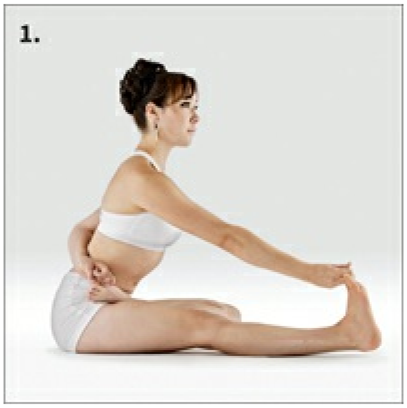

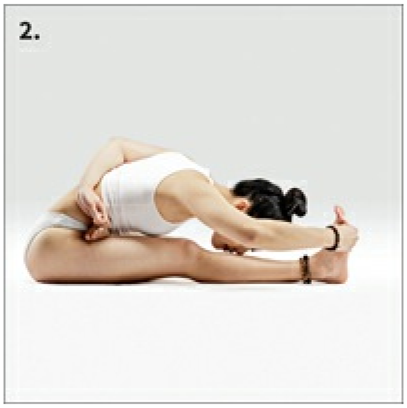

ONE LEG STRAIGHT, ONE LEG BENT: HALF LOTUS, TWISTS & BINDING

Revolved Half Bound Lotus Western Intense Stretch Pose

Parivritta Ardha Baddha Padma Paschimottanasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh PUHD-muh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Revolved Half Bound Lotus Seated Forward Bend and Half Lord of the Fishes Pose (Ardha Matsyendrasana)
Modification: grabbing onto the big toe
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

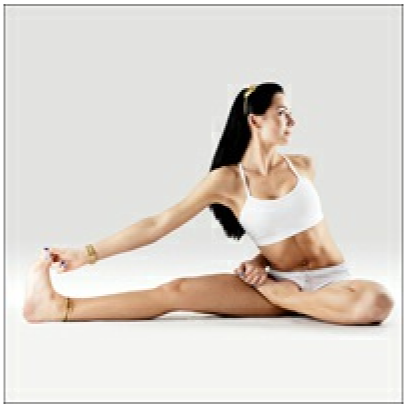

Half Lord of The Fishes Pose 2

Ardha Matsyendrasana 2

(UHR-duh muhts-yeyn-DRAHS-uh-nuh)

Also Known As: Sage Warrior Bharadvaja Prep. (Bharadvajasana Prep.)
Modification: 1. looking toward the foot
2. looking over the shoulder
Pose Type: seated, forward bend, twist, binding

Drishti Point: 1. Padhayoragrai or Padayoragre (toes/feet)
2. Parshva Drishti (to the right), Parshva Drishti (to the left)

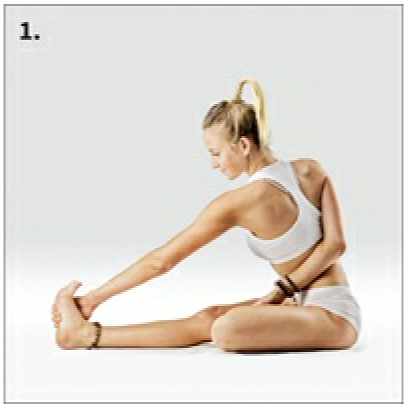

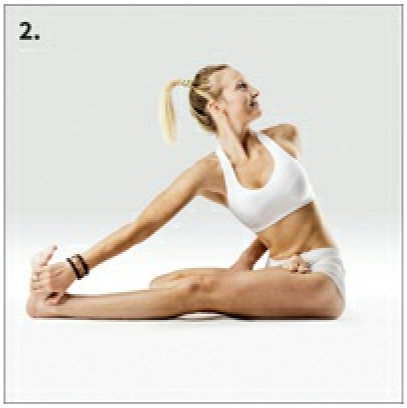

ONE LEG STRAIGHT, ONE LEG BENT: HALF LOTUS—LEG LIFTED

Half Lotus Extended Hand to Big Toe Pose in Infinity Pose

Ardha Padma Utthita Hasta Padangusthasana in Anantasana

(UHR-duh PUHD-muh UT-ti-tuh HUH-stuh puhd-ahng-goosh-TAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Pose Type: seated, mild backbend
Drishti Point: Urdhva or Antara Drishti (up to the sky), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

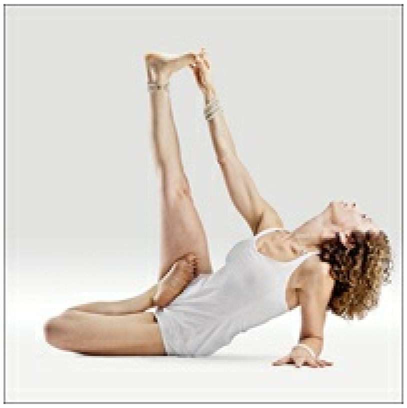

Half Lotus Extended Revolved Hand to Foot Pose in Infinity Pose

Ardha Padma Utthita Parivritta Pada Hastasana in Anantasana

(UHR-duh PUHD-muh UT-ti-tuh puh-ri-VRIT-tuh PUH-duh huh-STAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Modification: grabbing onto the foot on the opposite side
Pose Type: seated, mild backbend, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

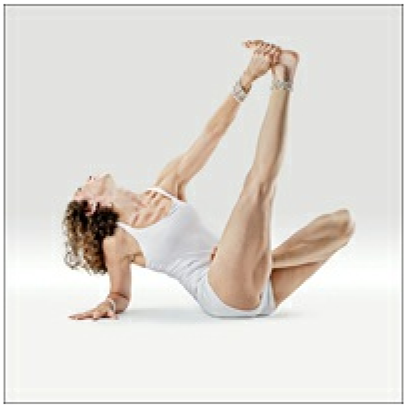

ONE LEG STRAIGHT, ONE LEG BENT: HALF LOTUS & BACKBEND—BINDING

Half Lotus Upward Infinity Pose

Ardha Padma Urdhva Anantasana

(UHR-duh PUHD-muh OORD-vuh uhn-uhnt-AHS-uh-nuh)

Pose Type: seated
Drishti Point: Urdhva or Antara Drishti (up to the sky), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

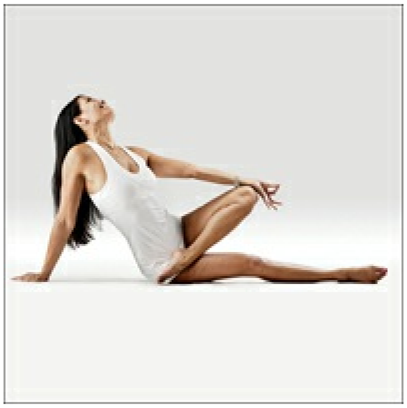

Half Bound Lotus Infinity Pose

Ardha Baddha Padma Anantasana

(UHR-duh BUH-duh PUHD-muh uhn-uhnt-AHS-uh-nuh)

Modification: Arm 1: forearm to the floor
Arm 2: grabbing onto the foot
Pose Type: seated, mild backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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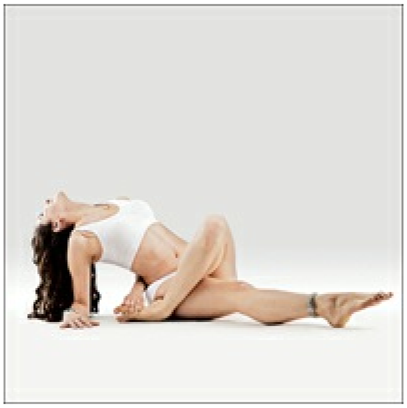

Half Bound Lotus Infinity Pose

Ardha Baddha Padma Anantasana

(UHR-duh BUH-duh PUHD-muh uhn-uhnt-AHS-uh-nuh)

Modification: Arm 1: elbow to the floor
Arm 2: hand to the hip socket
Pose Type: seated, mild backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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ONE LEG STRAIGHT, ONE KNEE BENT TO THE BACK: FORWARD BEND & TWIST

Three Limbed Face to Foot Western Intense Stretch Pose

Trianga Mukhaikapada Paschimottanasana

(tri-UHNG-uh muk-EYE-kuh-puh-duh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Three Limbed Face to Foot Seated Forward Bend
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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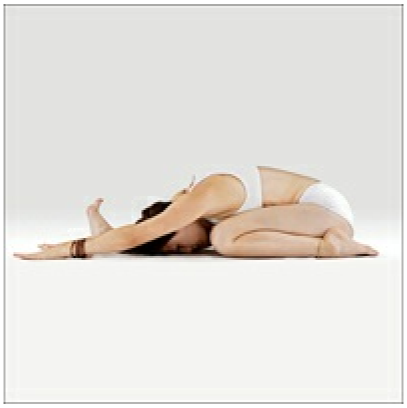

Churning Pose

Chalanasana

(chuh-luh-NAHS-uh-nuh)

Pose Type: seated, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)
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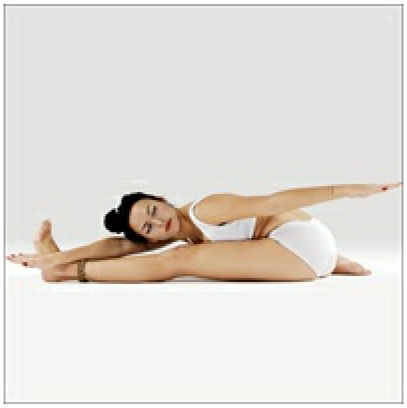

ONE LEG STRAIGHT, ONE KNEE BENT TO THE BACK: TWIST, SIDE BEND & FORWARD BEND

Revolved Half Bound Half Hero Half Seated Angle Pose

Parivritta Ardha Baddha Ardha Vira Ardha Upavishta Konasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh UHR-duh VEER-uh UHR-duh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Parivritta Ardha Baddha Ardha Vira Ardha Upavistha Konasana
Konasana Modification: spine straight
Pose Type: seated, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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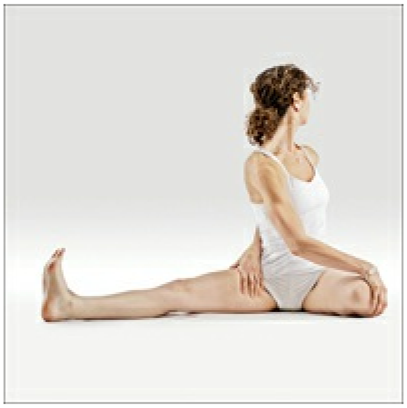

Gate Pose

Parighasana

(puh-ri-GAHS-uh-nuh)

Modification: side bend toward the straight leg; grabbing onto the heel of the bent leg with both hands
Pose Type: seated, side bend, forward bend, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

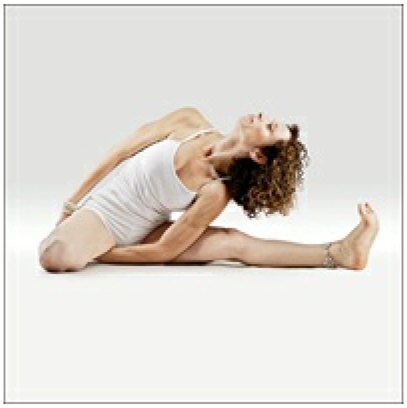

Gate Pose

Parighasana

(puh-ri-GAHS-uh-nuh)

Modification: seated: 1. palm to the floor by the ankle, other arm up over the head
2. elbow to the floor by the knee
3. both hands grabbing onto the foot, chest rotated up to the sky
Pose Type: 1 & 2. seated, side bend
3. seated, side bend, twist
Drishti Point: 1. Hastagrai or Hastagre (hands)
2 & 3. Urdhva or Antara Drishti (up to the sky)

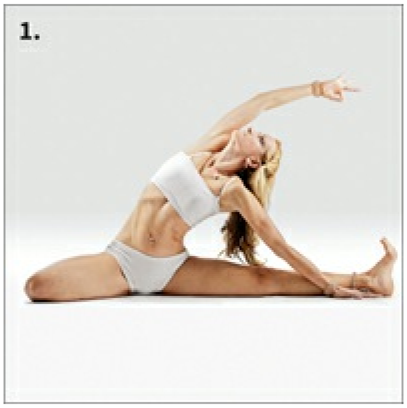

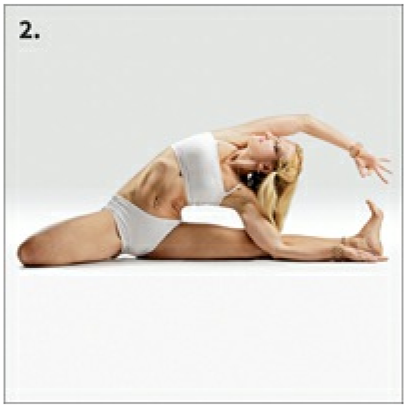

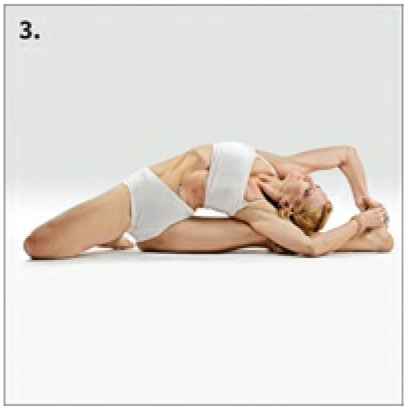

Benu Bird Pose 1

Benvasana 1

(ben-VAHS-uh-nuh)

Modification: seated; sitting bone on the heel, forward bend; arms to the side and to the back
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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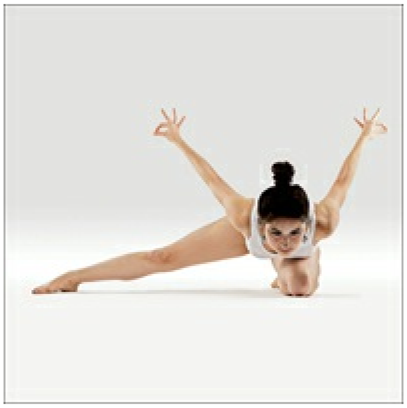

ONE LEG STRAIGHT, ONE KNEE BENT TO THE BACK: LEG LIFTED—BACKBEND

Reclined Half Hero Extended Hand to Foot Pose

Supta Ardha Vira Utthita Hasta Padasana

(SUP-tuh UHR-duh VEER-uh UT-ti-tuh HUH-stuh PUH-duhs-uh-nuh)

Modification: 1. right side view
2. left side view
Pose Type: seated, mild backbend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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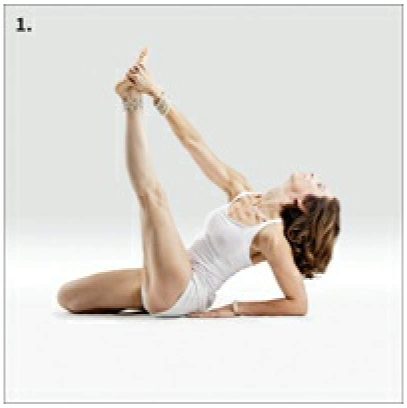

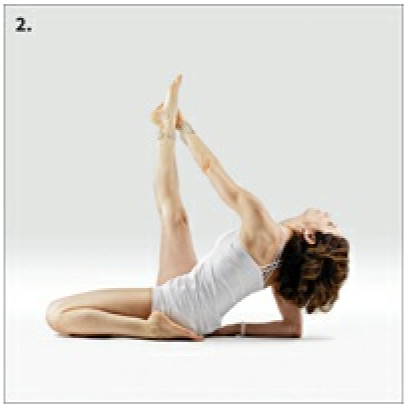

ONE LEG STRAIGHT, ONE KNEE BENT TO THE BACK: LEG LIFTED

Heron Pose

Krounchasana

(crown-CHAHS-uh-nuh)

Modification: grabbing onto the wrist, toes pointed
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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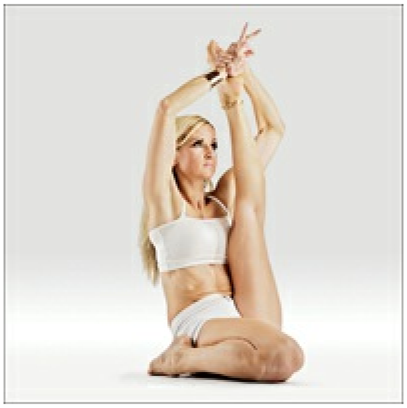

Sundial Pose 3

Surya Yantrasana 3

(SOOR-yuh yuhn-TRAHS-uh-nuh)

Modification: foot turned to the back
Pose Type: seated, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

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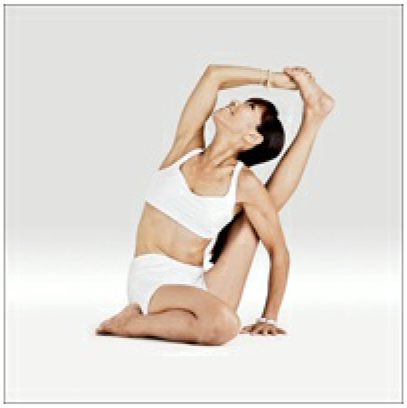

Revolved Heron Pose

Parivritta Krounchasana

(puh-ri-VRIT-tuh crown-CHAHS-uh-nuh)

Also Known As: Revolved Sundial Pose 3 (Parivritta Surya Yantrasana 3)
Pose Type: seated, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

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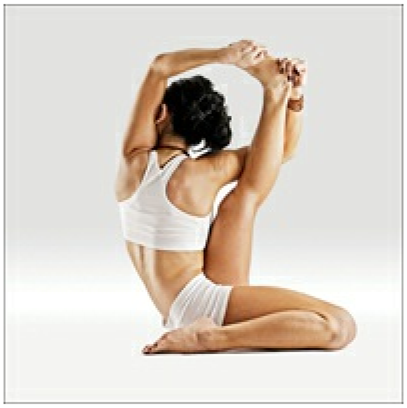

GARUDA LEGS: BACKBEND, TWIST, FORWARD BEND & BINDING

Seated Leg Position of the Pose Dedicated to Garuda

Upavishta Pada Garudasana

(u-puh-VISH-tuh PUH-duh guh-ru-DAHS-uh-nuh)

Also Known As: Upavistha Pada Garudasana
Modification: backbend, one hand to the sky
Pose Type: seated, backbend
Drishti Point: Hastagrai or Hastagre (hands)
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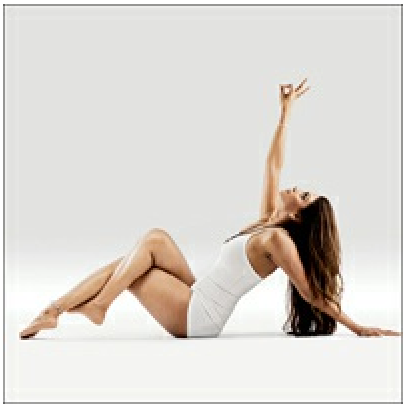

Revolved Hand to Foot Seated Leg Position of the Pose Dedicated to Garuda

Parivritta Hasta Pada Upavishta Pada Garudasana

(puh-ri-VRIT-tuh HUH-stuh PUH-duh u-puh-VISH-tuh PUH-duh guh-ru-DAHS-uh-nuh)

Also Known As: Parivritta Hasta Pada Upavistha Pada Garudasana
Pose Type: seated, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

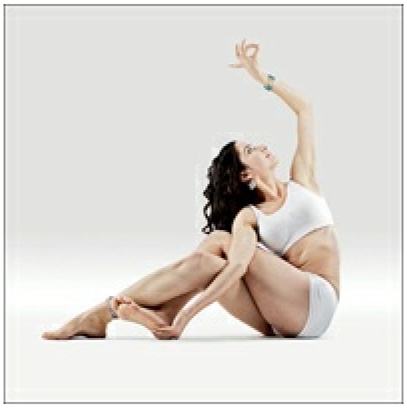

Seated Leg Position of the Pose Dedicated to Garuda

Upavishta Pada Garudasana

(u-puh-VISH-tuh PUH-duh guh-ru-DAHS-uh-nuh)

Also Known As: Upavistha Pada Garudasana
Modification: forehead to the knee
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

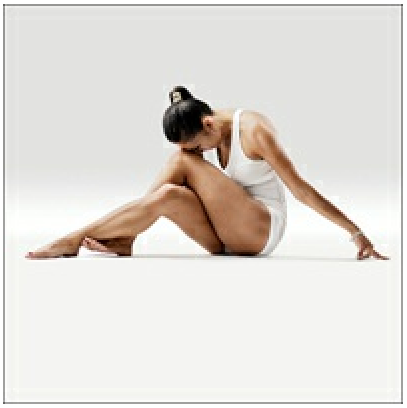

Revolved Seated Leg Position of the Pose Dedicated to Garuda

Parivritta Upavishta Pada Garudasana

(puh-ri-VRIT-tuh u-puh-VISH-tuh PUH-duh guh-ru-DAHS-uh-nuh)

Also Known As: Parivritta Upavistha Pada Garudasana
Modification: hands in Anjali Mudra (Hands in Prayer), one arm threaded through the legs
Pose Type: seated, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

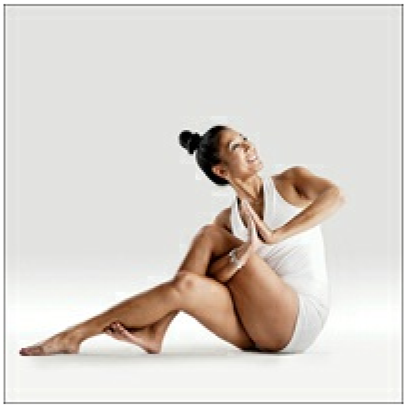

Bound Revolved Seated Leg Position of the Pose Dedicated to Garuda

Baddha Parivritta Upavishta Pada Garudasana

(BUH-duh puh-ri-VRIT-tuh u-puh-VISH-tuh PUH-duh guh-ru-DAHS-uh-nuh)

Also Known As: Baddha Parivritta Upavistha Pada Garudasana
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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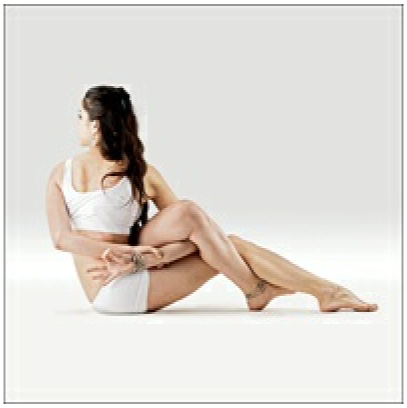

GARUDA LEGS: KNEES TO THE FLOOR ON THE SIDE

Seated Leg Position of the Pose Dedicated to Garuda in Upward Side Infinity Pose

Upavishta Pada Garudasana in Urdhva Parshva Anantasana

(u-puh-VISH-tuh PUH-duh guh-ru-DAHS-uh-nuh in OORD-vuh PAHRSH-vuh uhn-uhnt-AHS-uh-nuh)

Also Known As: Upavistha Pada Garudasana in Urdhva Parshva Anantasana
Modification: one hand to the floor, one arm extended out
Pose Type: seated, side bend
Drishti Point: Hastagrai or Hastagre (hands)

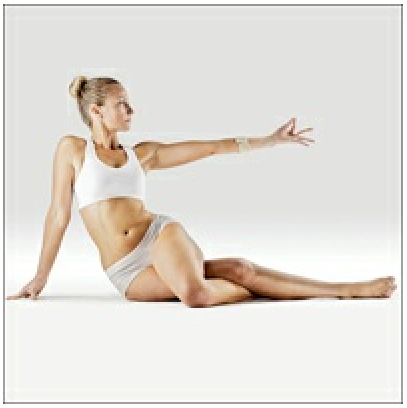

Seated Leg Position of the Pose Dedicated to Garuda in Upward Side Infinity Pose

Upavishta Pada Garudasana in Urdhva Parshva Anantasana

(u-puh-VISH-tuh PUH-duh guh-ru-DAHS-uh-nuh in OORD-vuh PAHRSH-vuh uhn-uhnt-AHS-uh-nuh)

Modification: palms flat on the floor, fingertips pointing away from the heels, backbend
Pose Type: seated, side bend, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

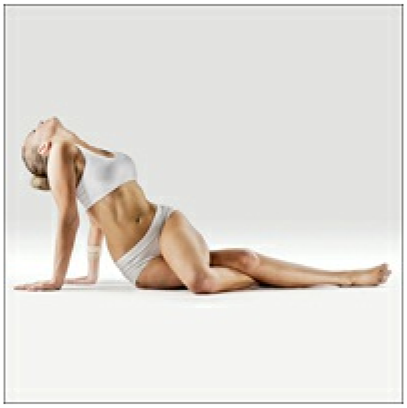

BOTH KNEES BENT: ANKLES HOOKED—TWIST & SIDE BEND

Twist Dedicated to Sage Bharadvaja 3

Bharadvajasana 3

(buh-ruhd-vahj-AHS-uh-nuh)

Pose Type: seated, forward bend, twist
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)

Sideways Twist Dedicated to Sage Bharadvaja 3

Parshva Bharadvajasana 3

(PAHRSH-vuh buh-ruhd-vahj-AHS-uh-nuh)

Modification: forearm to the floor
Pose Type: seated, mild backbend, side bend
Drishti Point: Hastagrai or Hastagre (hands)

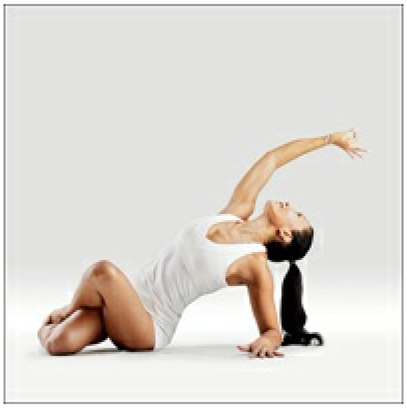

LEG CRADLE: ONE LEG STRAIGHT

Baby Cradle Pose

Hindolasana

(hin-do-LAHS-uh-nuh)

Also Known As: One Foot Behind the Head Pose A & B Prep. (Eka Pada Shirshasana A & B Prep.)
Modification: leg straight
1. spine straight, front view
2. half forward bend, side view

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose), Padhayoragrai or Padayoragre (toes/feet), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

1.

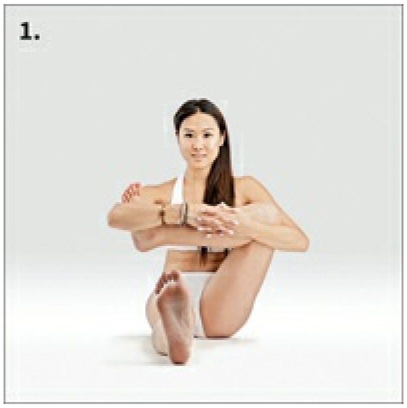

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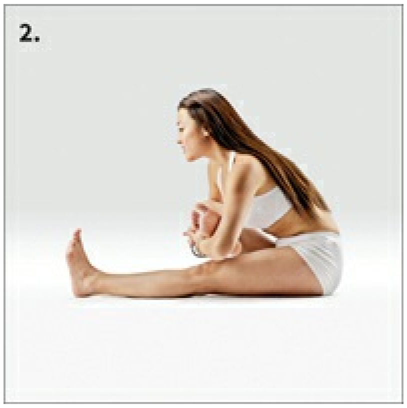

Baby Cradle Pose

Hindolasana

(hin-do-LAHS-uh-nuh)

Also Known As: One Foot Behind the Head Pose A Prep. (Eka Pada Shirshasana A Prep.)

Modification: leg straight, hands to the face

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

HEAD TO KNEE POSE: FORWARD BEND

Head to Knee Pose Prep.

Janu Shirshasana Prep.

(JAH-nu sheer-SHAHS-uh-nuh)

Modification: palms to the floor by the hips, spine straight
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose), Padhayoragrai or Padayoragre (toes/feet)

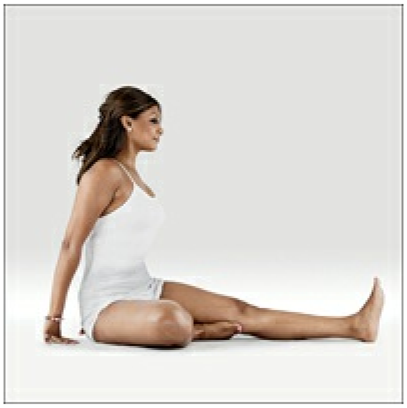

Both Hands to Ankle Head to Knee Pose

Dwi Hasta Kulpa Janu Shirshasana

(DWI-huh-stuh KUL-puh JAH-nu sheer-SHAHS-uh-nuh)

Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Padhayoragrai or Padayoragre (toes/feet)

Both Hands to Foot Head to Knee Pose

Dwi Hasta Pada Janu Shirshasana

(DWI-huh-stuh PUH-duh JAH-nu sheer-SHAHS-uh-nuh)

Modification: 1. grabbing onto the foot; fingers interlocked, half forward bend
2. grabbing onto the wrist, half forward bend
Pose Type: seated, forward bend
Drishti Point: Padhayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)

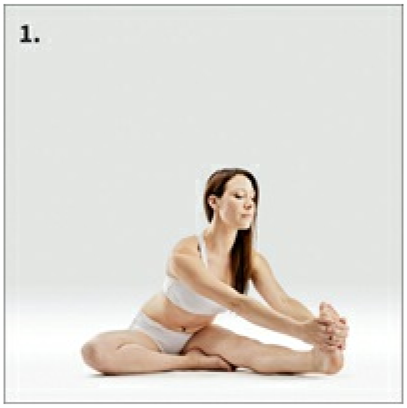

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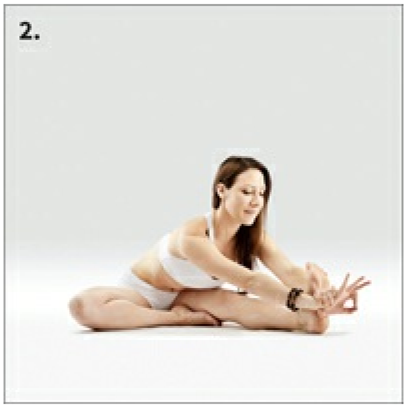

2.

HEAD TO KNEE POSE: HEEL UP—FORWARD BEND

Head to Knee Pose C Prep.

Janu Shirshasana C Prep.

(JAH-nu sheer-SHAHS-uh-nuh)

Also Known As: Half Root Lock Pose (Ardha Mula Bandhasana)

Pose Type: seated

Drishti Point: Nasagrai or Nasagre (nose), Padhayoragrai or Padayoragre (toes/feet), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

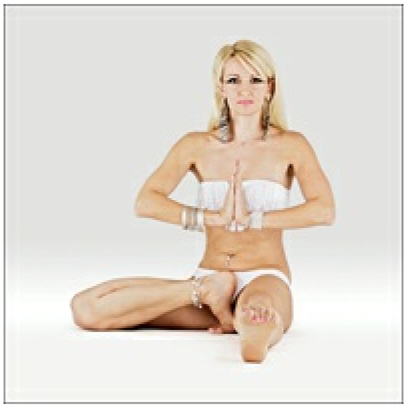

Head to Knee Pose C

Janu Shirshasana C

(JAH-nu sheer-SHAHS-uh-nuh)

Modification: 1. half forward bend

2. full forward bend

Pose Type: seated, forward bend

Drishti Point: Padhayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)

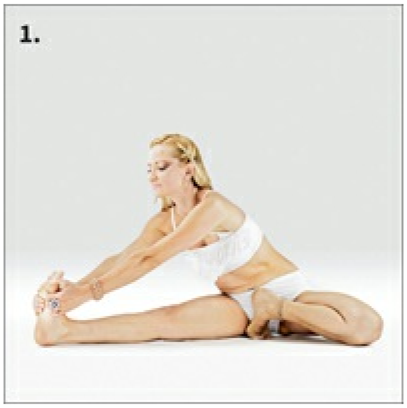

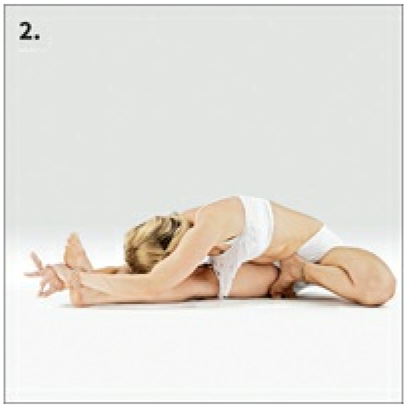

HEAD TO KNEE POSE: TWISTS

Revolved Half Bound Angle Pose

Parivritta Ardha Baddha Konasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh ko-NAHS-uh-nuh)

Modification: hand to the knee, other hand to the floor behind the hips for support
Pose Type: seated, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
● ●

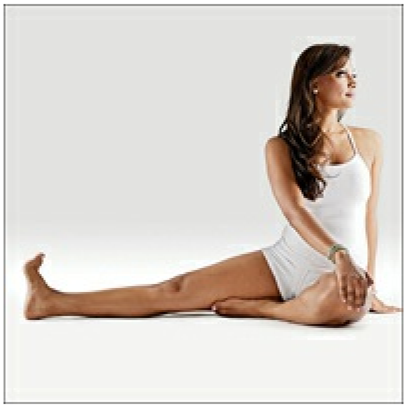

Revolved Half Bound Angle Pose

Parivritta Ardha Baddha Konasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh ko-NAHS-uh-nuh)

Pose Type: seated, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
● ●

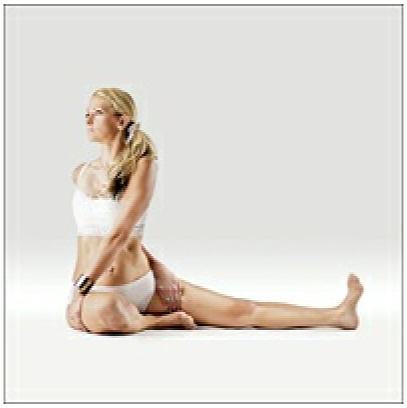

Revolved Sideways Half Bound Angle Pose

Parivritta Parshva Ardha Baddha Konasana

(puh-ri-VRIT-tuh PAHRSH-vuh UHR-duh BUH-duh ko-NAHS-uh-nuh)

Modification: grabbing onto the big toe of the bent leg
Pose Type: seated, twist, side bend, binding
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)
ल व

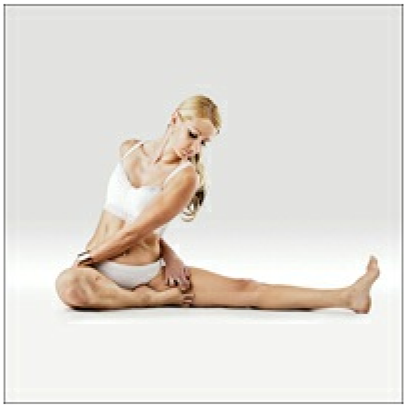

Revolved Half Bound Angle Pose

Parivritta Ardha Baddha Konasana

(puh-ri-VRIT-tuh UHR-duh BUH-duh ko-NAHS-uh-nuh)

Modification: looking back Arm 1: grabbing onto the outside edge of the opposite foot
Arm 2: grabbing onto the shin of the opposite leg behind the back
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
ल व

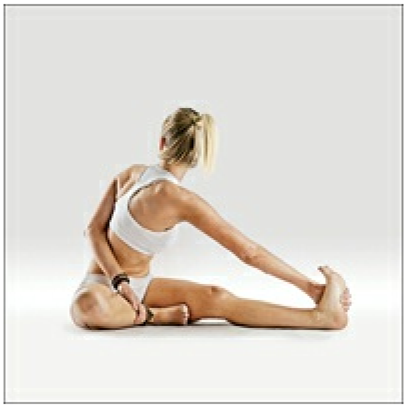

HEAD TO KNEE POSE—SIDE BENDS

Half Bound Angle Pose in Infinity Pose

Ardha Baddha Konasana in Anantasana

(UHR-duh BUH-duh ko-NAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Modification: elbow to the floor, head rolling back
Pose Type: seated, mild backbend, side bend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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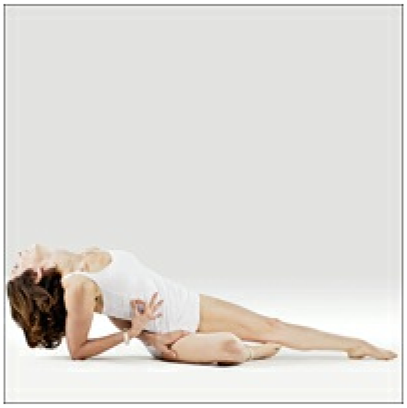

Revolved Head to Knee Pose Prep.

Parivritta Janu Shirshasana Prep.

(puh-ri-VRIT-tuh JAH-nu sheer-SHAHS-uh-nuh)

Modification: grabbing onto the foot, other hand to the knee
Pose Type: seated, forward bend
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)
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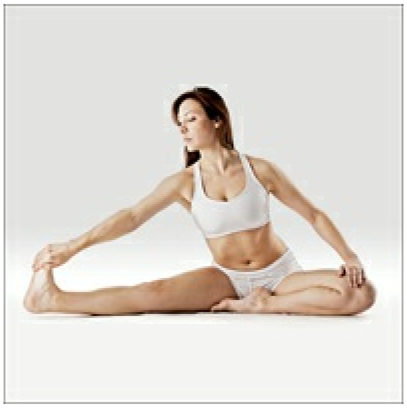

Sideways Head to Knee Pose

Parshva Janu Shirshasana

(PAHRSH-vuh JAH-nu sheer-SHAHS-uh-nuh)

Also Known As: Sideways Half Bound Angle Pose (Parshva Ardha Baddha Konasana)
Pose Type: seated, side bend
Drishti Point: Hastagrai or Hastagre (hands)

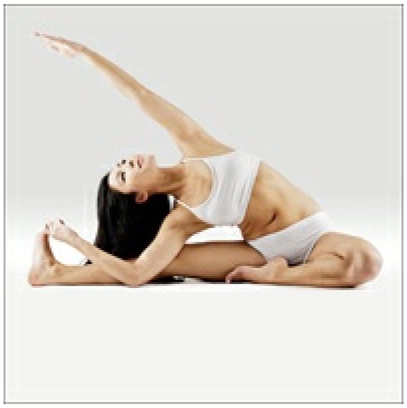

Sideways Head to Knee Pose

Parshva Janu Shirshasana

(PAHRSH-vuh JAH-nu sheer-SHAHS-uh-nuh)

Also Known As: Sideways Half Bound Angle Pose (Parshva Ardha Baddha Konasana)
Modification: elbow to the floor on the inside of the leg, other hand on the hip
Pose Type: seated, forward bend, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

Half Bound

Half Seated Angle Pose

Ardha Baddha Ardha Upavishta Konasana

(UHR-duh BUH-duh UHR-duh u-puh-VISH-tuh ko-NAHS-uh-nuh)

Also Known As: Ardha Baddha Ardha Upavistha Konasana

Pose Type: seated, side bend, binding

Drishti Point: Nasagrai or Nasagre (nose)

How to Perform the Pose:

1. Begin by sitting on the floor with both your legs straight out in front of you. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale as you bend your left knee and bring the sole of your left foot toward your right thigh.
3. On the next exhale, bring your right leg out to the right side, keeping it strong and straight by pulling up the kneecap and engaging the thigh muscles (quadriceps). Press your right toes and your right heel to the floor, lifting the right leg slightly on off the floor.
4. Inhale as you expand your chest and hold your arms straight out to the sides, parallel to the floor.
5. Exhale as you bend your left arm and reach your left hand behind the back to the inside of your right thigh to bind.
6. Inhale as you reach your right arm up to the sky. Exhale as you bend your right elbow and look toward your left knee.
7. Hold the pose for at least 30, and up to 90, seconds in order to receive full benefits of the stretch.
8. Inhale as you release the bind. Exhale as you bring both your legs straight out in front of you. Repeat on the other side.

Modification: side bend toward the bent knee

ardha = half

baddha = bound

ardha = half

upavishta = seated

kona = angle

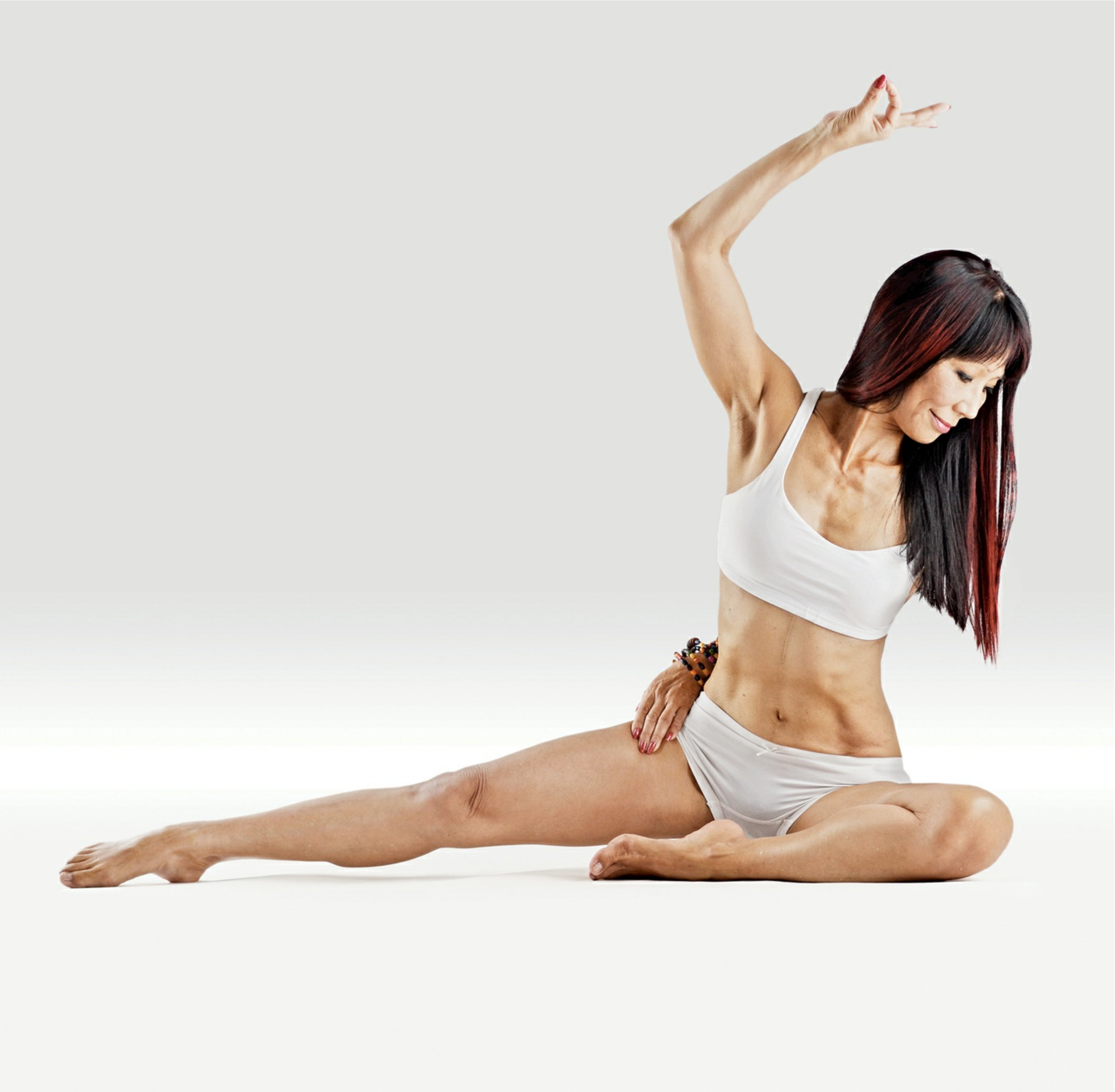

Half Bound Sideways Head to Knee Pose

Ardha Baddha Parshva Janu Shirshasana

(UHR-duh BUH-duh PAHRSH-vuh JAH-nu sheer-SHAHS-uh-nuh)

Also Known As: Sideways Half Bound Angle Pose (Parshva Ardha Baddha Konasana)
Modification: 1. toes pointed
2. toes flexed in
Pose Type: seated, forward bend, side bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)
ल व

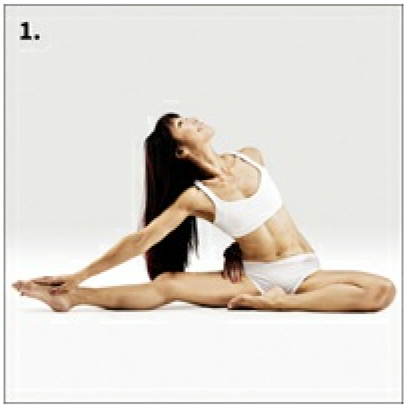
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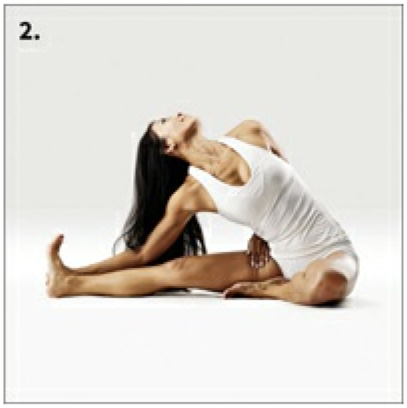
2.

Revolved Head to Knee Pose

Parivritta Janu Shirshasana

(puh-ri-VRIT-tuh JAH-nu sheer-SHAHS-uh-nuh)

Modification: elbow to the floor
1. forearm to the floor, chest to the side
2. head on the knee, chest to the sky
Pose Type: seated, side bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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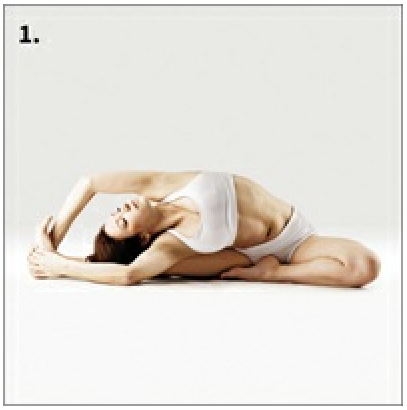

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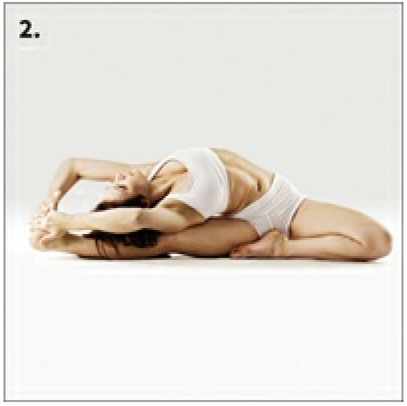

Both Hands to the Head Sideways Head to Knee Pose

Dwi Hasta Shirsha Parshva Janu Shirshasana

(DWI-huh-stuh SHEER-shuh PAHRSH-vuh JAH-nu sheer-SHAHS-uh-nuh)

Also Known As: Sideways Half Bound Angle Pose (Parshva Ardha Baddha Konasana)
Modification: 1. slight side bend
2. elbow to the knee
3. elbow to the floor
Pose Type: seated, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

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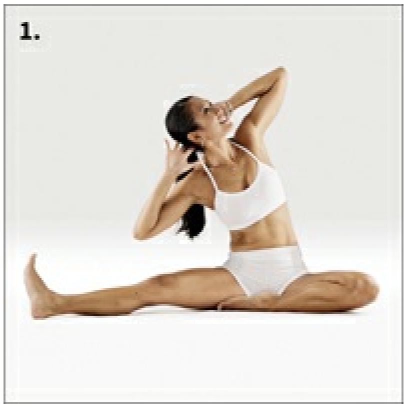

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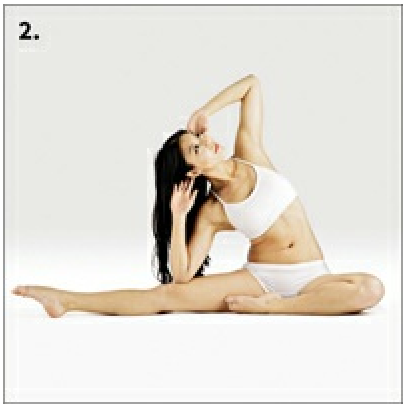

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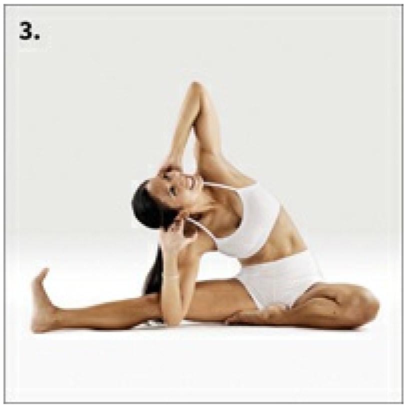

HEAD TO KNEE POSE: LEG LIFTED

Hands Free Sundial Pose 1

Mukta Hasta Surya Yantrasana 1

(MUK-tuh HUH-stuh SOOR-yuh yuhn-TRAHS-uh-nuh)

Modification: foot to thigh, fingertips of both hands to the floor
Pose Type: seated, forward bend, side bend, core
Drishti Point: Hastagrai or Hastagre (hands)

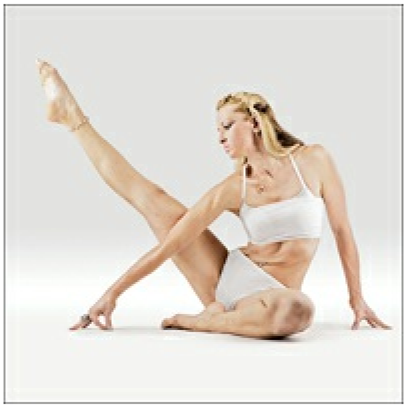

Sundial Pose 1

Surya Yantrasana 1

(SOOR-yuh yuhn-TRAHS-uh-nuh)

Modification: foot to thigh, grabbing onto the foot on the same side
Pose Type: seated, forward bend, side bend
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
ल व

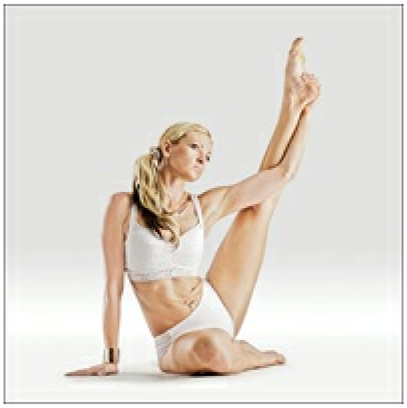

Unsupported Seated Revolved Upward One Hand to Foot Pose

Niralamba Upavishta Parivritta Urdhva Eka Pada Hastasana

(nir-AH-luhm-buh u-puh-VISH-tuh puh-ri-VRIT-tuh OORD-vuh EY-kuh PUH-duh huh-STAHS-uh-nuh)

Pose Type: seated, forward bend, twist, core
Drishti Point: Hastagrai or Hastagre (hands)
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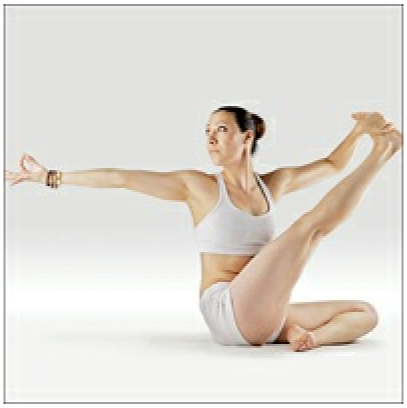

HERO POSE: TOES CURLED IN

Tip Toe Hero Pose

Prapada Virasana

(PRUH-puh-duh veer-AHS-uh-nuh)

Also Known As: Thunderbolt Pose (Vajrasana)
Modification: toes curled in, hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated
Drishti Point: Hastagrai or Hastagre (hands) or Nasagrai or Nasagre (nose)

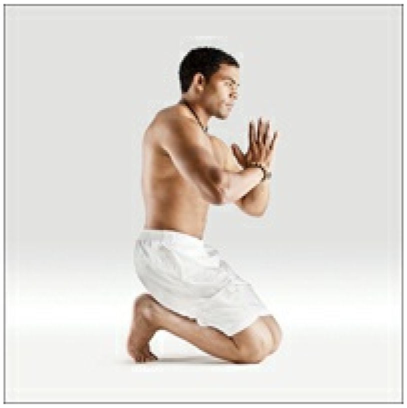

Tip Toe Hero Pose

Prapada Virasana

(PRUH-puh-duh veer-AHS-uh-nuh)

Also Known As: Thunderbolt Pose (Vajrasana)
Modification: head down, arms open wide
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

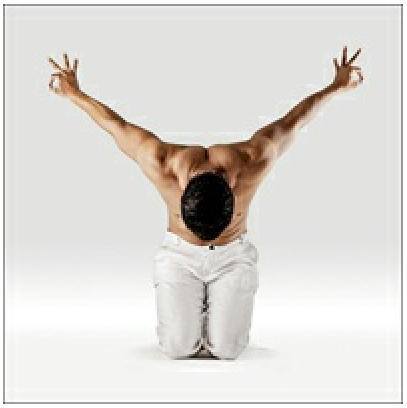

HERO POSE: SITTING ON THE HEELS

Hero Pose

Virasana

(veer-AHS-uh-nuh)

Also Known As: Thunderbolt Pose (Vajrasana)

Modification: arms to the sides; modified version for tight ankles

Pose Type: seated

Drishti Point: Nasagrai or Nasagre (nose)

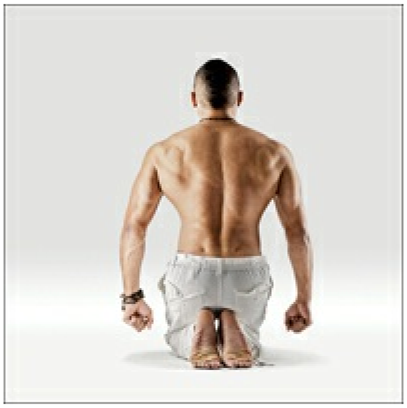

HERO POSE: SITTING ON THE HEELS—HANDS ON THE KNEES

Hero Pose

Virasana

(veer-AHS-uh-nuh)

Also Known As: Thunderbolt Pose (Vajrasana)

Modification: hands on the knees, palms up

Pose Type: seated

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

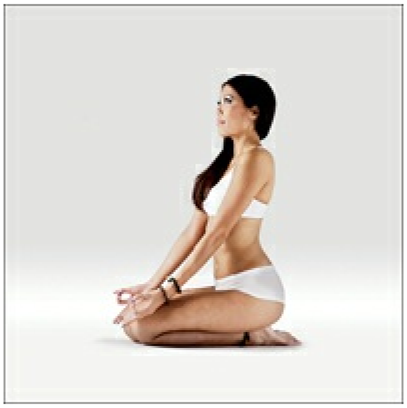

Lion Pose Dedicated to an Avatar of Lord Vishnu in Hero Pose

Narasimhasana in Virasana

(nuh-ruh-sim-HAHS-uh-nuh in veer-AHS-uh-nuh)

Also Known As: Lion Pose in Thunderbolt Pose (Simhasana in Vajrasana)
Modification: sitting on the heels
1. Cat Tilt
2. Dog Tilt
Pose Type: seated
1. forward bend
2. mild backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

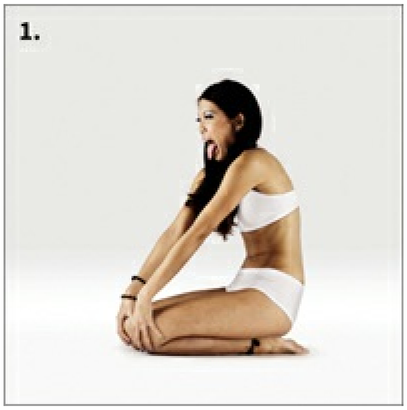

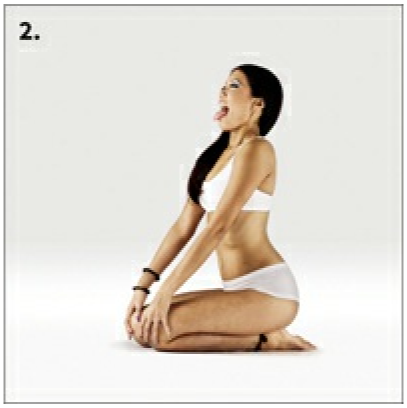

HERO POSE: SITTING ON THE HEELS—ARMS UP & FORWARD BEND

Hero Pose—Raised Bound Hands

Virasana Urdhva Baddha Hastasana

(veer-AHS-uh-nuh OORD-vuh BUH-duh huh-STAHS-uh-nuh)

Also Known As: Thunderbolt Pose Raised Bound Hands (Vajrasana Urdhva Baddha Hastasana)

Modification: palms facing up
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)

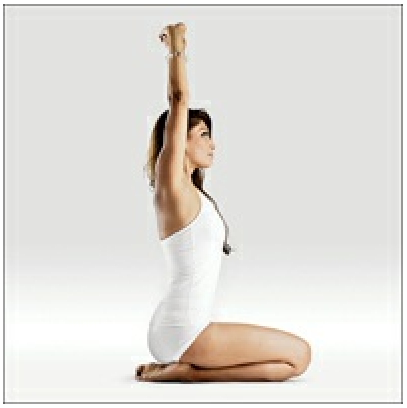

Hero Pose

Virasana

(veer-AHS-uh-nuh)
Also Known As: Thunderbolt Pose (Vajrasana)
Modification: forward bending, ankles crossed, palms to the floor by the knees
Pose Type: seated, forward bend
Drishti Point: Angushtamadhye or Angustha Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

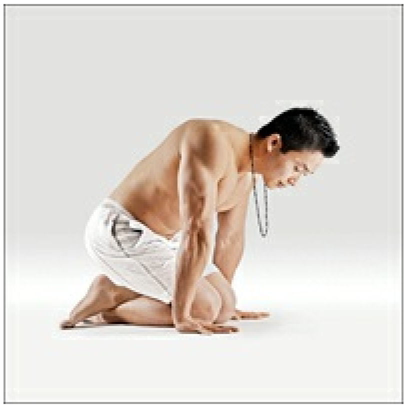

Hand Position of the Pose Dedicated to Garuda in Hero Pose

Hasta Garudasana in Virasana

(HUH-stuh guh-ru-DAHS-uh-nuh in veer-AHS-uh-nuh)
Also Known As: Hand Position of the Pose Dedicated to Garuda in Thunderbolt Pose (Hasta Garudasana in Vajrasana)
Modification: 1. half forward bend

2. spine straight
Pose Type: 1. seated, forward bend
2. seated
Drishti Point: Angushtamadhye or Angustha Ma Dyai (thumbs)
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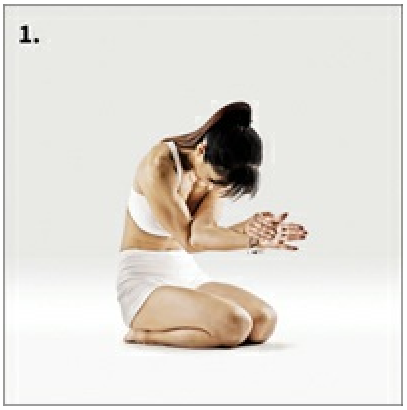
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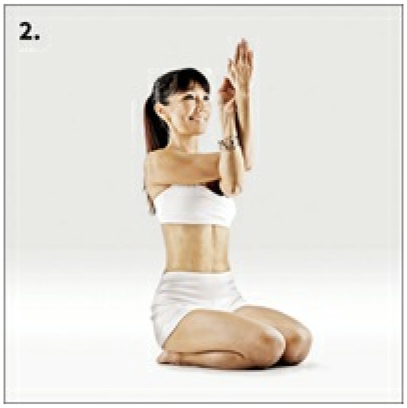
2.

HERO POSE: SITTING ON THE HEELS—KNEES OFF THE FLOOR

Hero Scale Pose with Hands in Prayer

Vira Tolasana Namaskar

(VEER-uh to-LAHS-uh-nuh nuh-muhs-KAHR)
Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated, balance, core
Drishti Point: Nasagrai or Nasagre (nose) or Hastagrai or Hastagre (hands)
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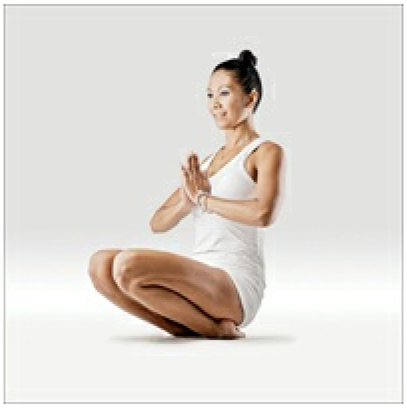

Hero Scale Pose

Vira Tolasana

(VEER-uh to-LAHS-uh-nuh)

Modification: grabbing onto the knees, Cat Tilt
Pose Type: seated, balance, core
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

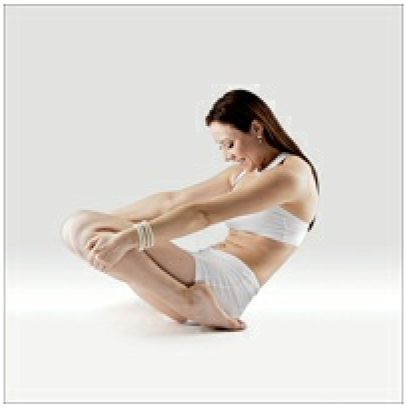

THUNDERBOLT POSE: SITTING BONES ON THE FLOOR—VARIOUS ARM POSITIONS

Hero Pose

Virasana

(veer-AHS-uh-nuh)

Also Known As: Thunderbolt Pose (Vajrasana)
Modification: sitting bones to the floor
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)

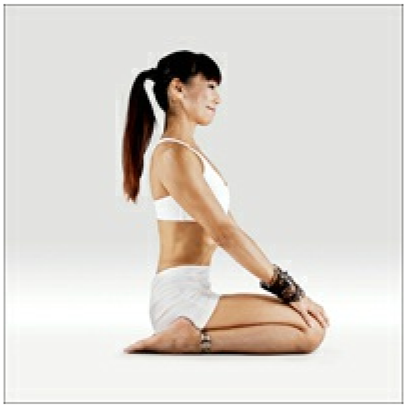

Both Hands to Feet Hero Pose

Dwi Hasta Pada Virasana

(DWI-huh-stuh PUH-duh veer-AHS-uh-nuh)

Also Known As: Both Hands to Feet Thunderbolt Pose (Dwi Hasta Pada Vajrasana)
Modification: sitting bones to the floor, arms crossed behind the back
1. back view
2. front view, mild backbend
Pose Type: 1. seated, binding
2. seated, mild backbend, binding
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

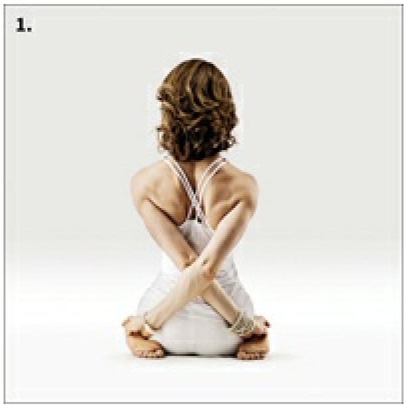

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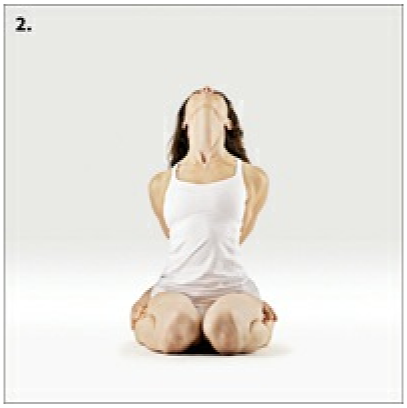

2.

One Arm Upward Hero Pose

Eka Urdhva Hasta Virasana

(EY-kuh OORD-vuh HUH-stuh veer-AHS-uh-nuh)

Also Known As: One Arm Upward Thunderbolt Pose (Eka Urdhva Hasta Vajrasana)
Pose Type: seated
Drishti Point: Hastagrai or Hastagre (hands)

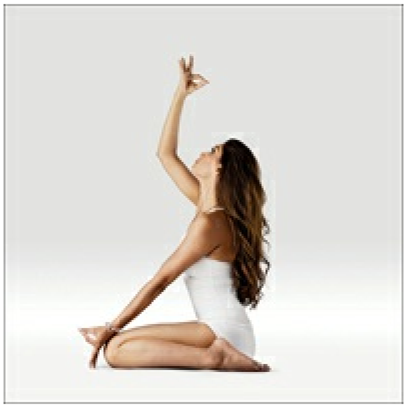

Hero Pose—Raised Bound Hands

Virasana Urdhva Baddha Hastasana

(veer-AHS-uh-nuh OORD-vuh BUH-duh huh-STAHS-uh-nuh)

Also Known As: Thunderbolt Pose Raised Bound Hands (Vajrasana Urdhva Baddha Hastasana)
Modification: palms facing up
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)

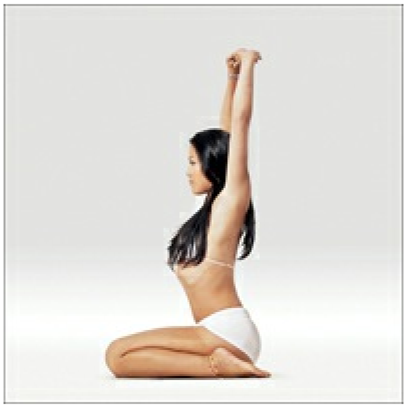

THUNDERBOLT POSE: SITTING BONES ON THE FLOOR—TWISTS & SIDE BEND

Revolved Hero Pose

Parivritta Virasana

(puh-ri-VRIT-tuh veer-AHS-uh-nuh)

Also Known As: Revolved Thunderbolt Pose (Parivritta Vajrasana)
Pose Type: seated, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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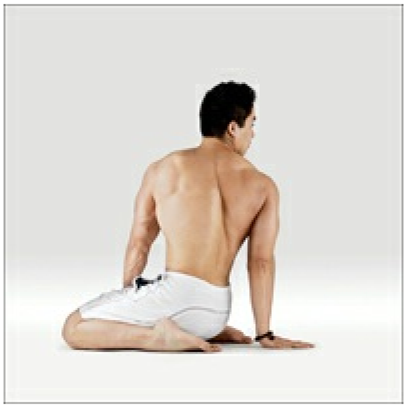

Pose Dedicated to Sage Bharadvaja 1

Bharadvajasana 1

(buh-ruhd-vuhj-AHS-uh-nuh)

Modification: ankles crossed, grabbing onto the bicep
Pose Type: seated, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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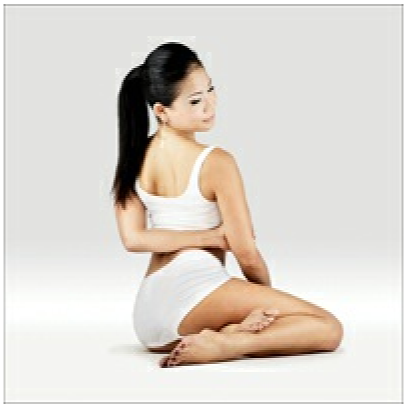

Sideways Pose Dedicated to Sage Bharadvaja 1

Parshva Bharadvajasana 1

(PAHRSH-vuh buh-ruhd-vuhj-AHS-uh-nuh)

Modification: one arm crossed in front; other arm over the head, elbow bent
Pose Type: seated, side bend
Drishti Point: Hastagrai or Hastagre (hands)
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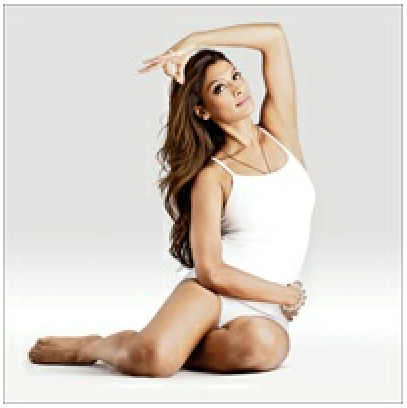

Pose Dedicated to Bharadvaja 1

Bharadvajasana 1

(buh-ruhd-vuhj-AHS-uh-nuh)

Modification: 1. grabbing onto the inside of the hip with opposite hand, other hand on the knee, looking over the shoulder
2. grabbing onto the tricep of the opposite arm, looking over the shoulder
Pose Type: seated, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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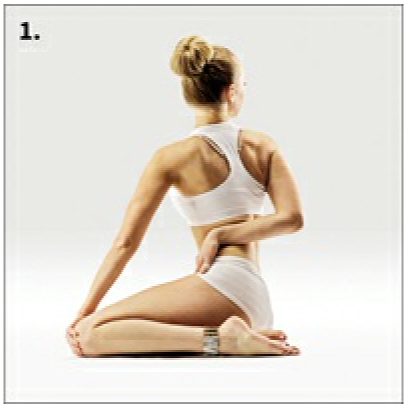

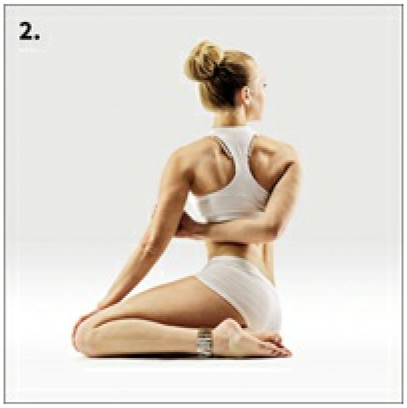

THUNDERBOLT POSE: SITTING BONES ON THE FLOOR—KNEES OPEN WIDE

Lion Pose Dedicated to an Avatar of Lord Vishnu in Knees Spread Wide Hero Pose

Narasimhasana in Prasarita Janu Virasana

(nuh-ruh-sim-HAHS-uh-nuh in pruh-SAH-ri-tuh JAH-nu veer-AHS-uh-nuh)

Also Known As: Lion Pose (Simhasana)
Modification: sitting bones on the floor
Pose Type: seated, mild backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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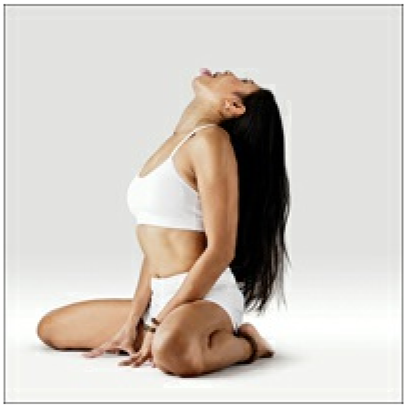

Knees Spread Wide Hero Pose

Prasarita Janu Virasana

(pruh-SAH-ri-tuh JAH-nu veer-AHS-uh-nuh)

Also Known As: Frog Pose (Mandukasana)
Modification: sitting bones off the floor
Pose Type: seated

Drishti Point: Nasagrai or Nasagre (nose)

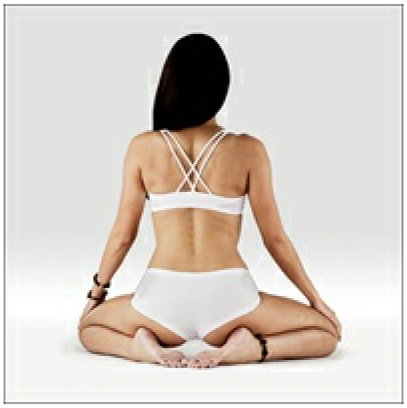

Half Bound Revolved Knees Spread Wide Hero Pose

Ardha Baddha Parivritta Prasarita Janu Virasana

(UHR-duh BUH-duh puh-ri-VRIT-tuh pruh-SAH-ri-tuh JAH-nu veer-AHS-uh-nuh)

Pose Type: seated, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

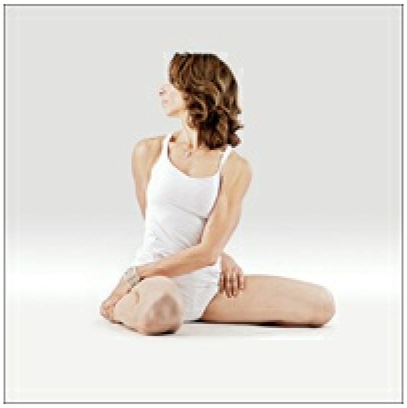

THUNDERBOLT POSE: SITTING BONES ON THE FLOOR—FEET TURNED OUT

Complete Thunderbolt Pose

Paripurna Vajrasana

(puh-ri-POOR-nuh vuhj-RAHS-uh-nuh)

Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)

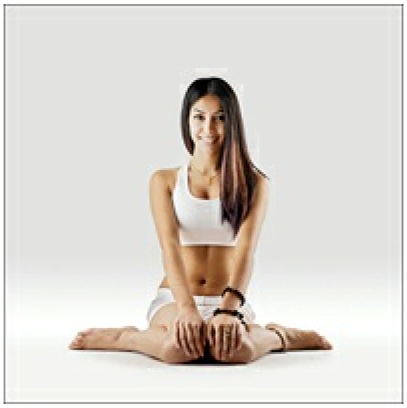

Revolved Complete Thunderbolt Pose

Parivritta Paripurna Vajrasana

(puh-ri-VRIT-uh puh-ri-POOR-nuh vuhj-RAHS-uh-nuh)

Pose Type: seated, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

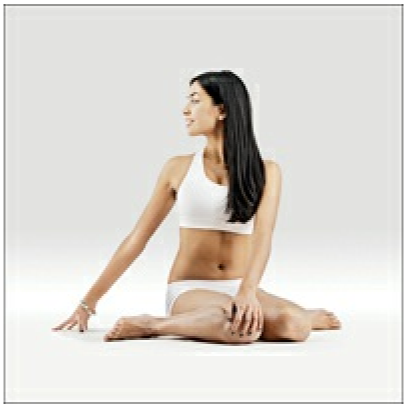

Western Intense Stretch Pose in Complete Thunderbolt Pose

Paschimottanasana in Paripurna Vajrasana

(puhsh-chi-mo-tahn-AHS-uh-nuh in puh-ri-POOR-nuh vuhj-RAHS-uh-nuh)

Also Known As: Seated Forward Bend in Complete Thunderbolt Pose
Modification: forward bend, toes turned out
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

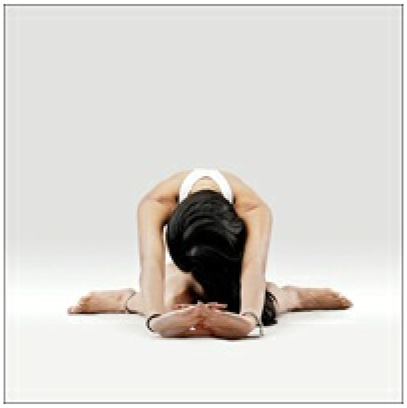

Half Pose Dedicated to Sage Marichi in Revolved Half Thunderbolt Pose

Ardha Marichyasana in Parivritta Ardha Vajrasana

(UHR-duh muh-ree-CHYAHS-uh-nuh in puh-ri-VRIT-uh UHR-duh vuhj-RAHS-uh-nuh)

Modification: 1. looking straight ahead
2. looking over the shoulder
Pose Type: seated, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)
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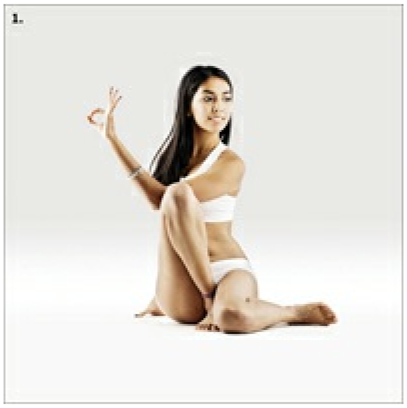

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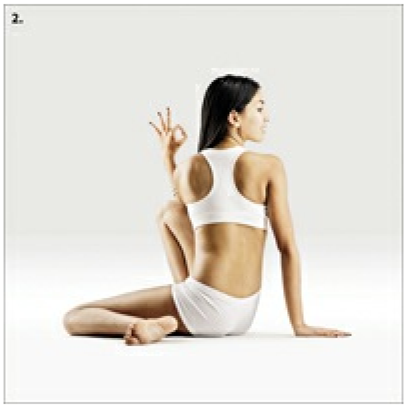

2.

Half Bound Pose Dedicated to Sage Marichi in Half Thunderbolt Pose

Ardha Baddha Marichyasana in Ardha Vajrasana

(UHR-duh BUH-duh muh-ree-CHYAHS-uh-nuh in UHR-duh vuhj-RAHS-uh-nuh)

Pose Type: seated, forward bend, twist, binding

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

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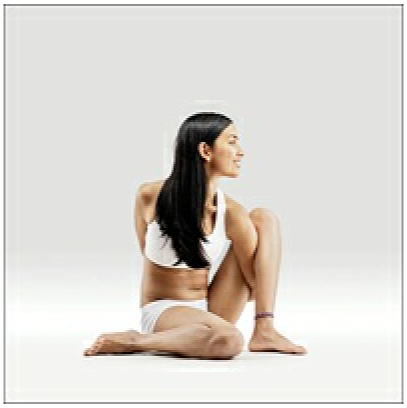

THUNDERBOLT POSE: SITTING BONES ON THE FLOOR—FEET TURNED OUT—ARMS UP OVER THE HEAD

Complete Thunderbolt Pose—Raised Bound Hands

Paripurna Vajrasana—Urdhva Baddha Hastasana

(puh-ri-POOR-nuh vuhj-RAHS-uh-nuh OORD-vuh BUH-duh huh-STAHS-uh-nuh)

Modification: 1. looking straight ahead
2. head rolling back

Pose Type: 1. seated
2. seated, mild backbend

Drishti Point: 1. Nasagrai or Nasagre (nose)
2. Angushtamadhye (thumbs)

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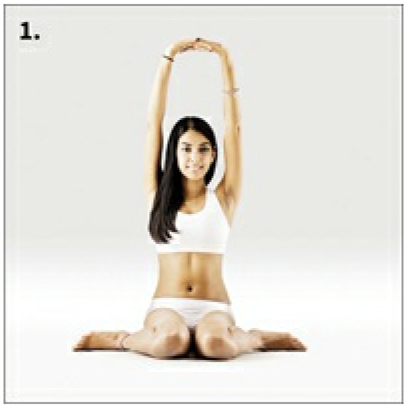

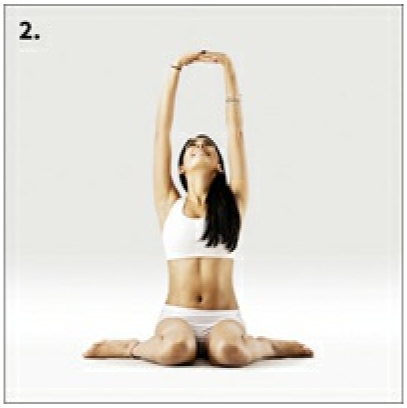

Revolved Complete Thunderbolt Pose—Raised Bound Hands

Parivritta Paripurna Vajrasana—Urdhva Baddha Hastasana

(puh-ri-VRIT-tuh puh-ri-POOR-nuh vuhj-RAHS-uh-nuh OORD-vuh BUH-duh huh-STAHS-uh-nuh)

Pose Type: seated, twist

Drishti Point: Angushtamadhye (thumbs)

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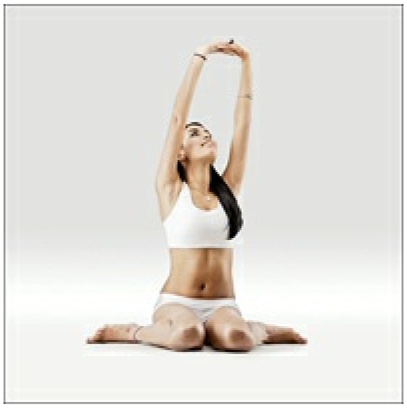

Sideways Complete Thunderbolt Pose—Raised Bound Hands

Parshva Paripurna Vajrasana—Urdhva Baddha Hastasana

(PAHRSH-vuh puh-ri-POOR-nuh vuhj-RAHS-uh-nuh OORD-vuh BUH-duh huh-STAHS-uh-nuh)

Pose Type: seated, side bend

Drishti Point: Angushtamadhye (thumbs)

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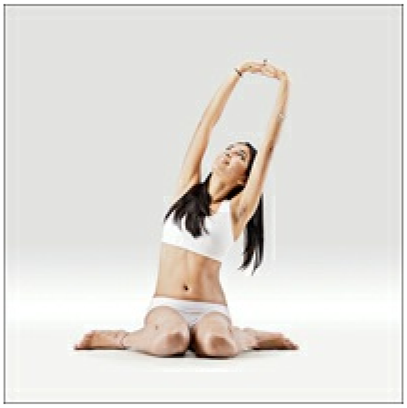

One Hand Sideways Complete Thunderbolt Pose

Eka Hasta Parshva Paripurna Vajrasana

(EY-kuh HUH-stuh PAHRSH-vuh puh-ri-POOR-nuh vuhj-RAHS-uh-nuh)

Pose Type: seated, side bend
Drishti Point: Hastagrai or Hastagre (hands)
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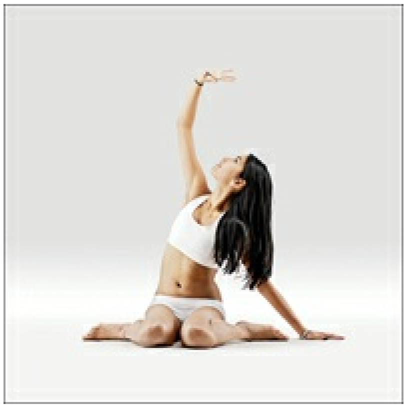

THUNDERBOLT POSE: SITTING BONES ON THE FLOOR—FEET TURNED OUT—ONE-LEGGED & FORWARD BENDS

Half Pose Dedicated to Sage Marichi in Half Thunderbolt Pose

Ardha Marichyasana in Ardha Vajrasana

(UHR-duh muh-ree-CHYAHS-uh-nuh in UHR-duh vuhj-RAHS-uh-nuh)

Modification: grabbing onto the knee with both hands
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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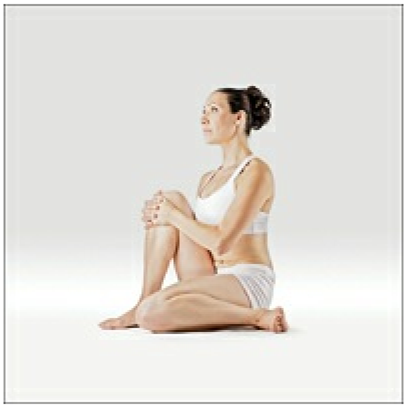

Half Pose Dedicated to Sage Marichi in Half Thunderbolt Pose

Ardha Marichyasana in Ardha Vajrasana

(UHR-duh muh-ree-CHYAHS-uh-nuh in UHR-duh vuhj-RAHS-uh-nuh)

Modification: palms to the floor in front of the hips
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

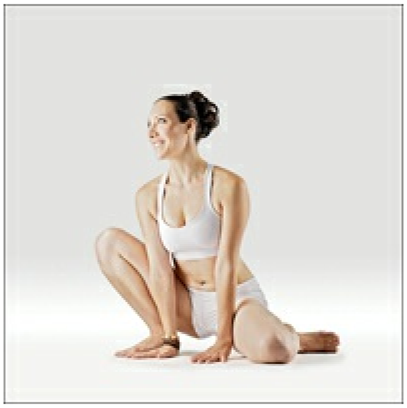

Half Star Pose in Half Frog Pose

Ardha Tarasana in Ardha Mandukasana

(UHR-duh tahr-AHS-uh-nuh in UHR-duh muhn-doo-KAHS-uh-nuh)

Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

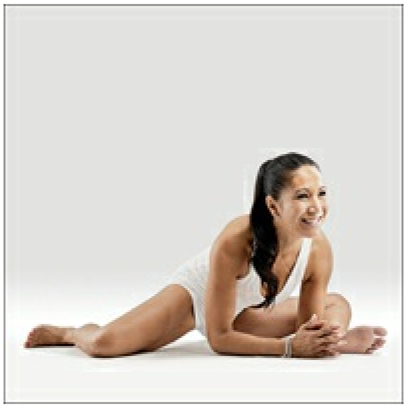

Pose Dedicated to Virancha (Brahma) 1 Prep.

Viranchyasana 1 Prep.

(vir-uhn-CHYAHS-uh-nuh)

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

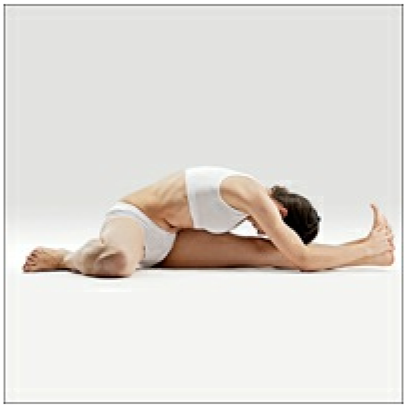

ONE KNEE BENT TO THE BACK: OTHER FOOT TO THE THIGH—SPINE STRAIGHT, TWIST & SIDE BEND

Easy Pose Dedicated to Sage Bharadvaja 2 Prep.

Sukha Bharadvajasana 2 Prep.

(SUK-uh buh-ruhd-vuhj-AHS-uh-nuh)

Modification: neutral spine, back of the hands on the knees

Pose Type: seated

Drishti Point: Nasagrai or Nasagre (nose)

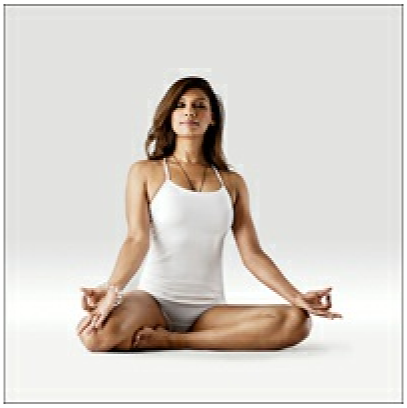

Easy Pose Dedicated to Sage Bharadvaja 2

Sukha Bharadvajasana 2

(SUK-uh buh-ruhd-vuhj-AHS-uh-nuh)

Modification: foot to the inside of the thigh
Pose Type: seated, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

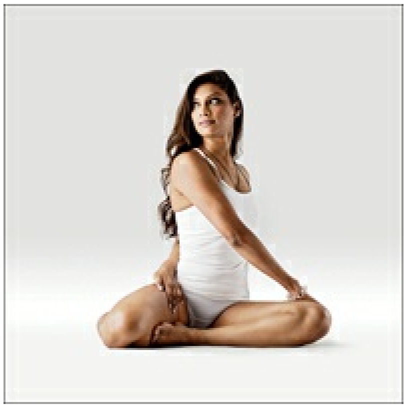

Sideways Easy Pose Dedicated to Sage Bharadvaja 2

Parshva Sukha Bharadvajasana 2

(PAHRSH-vuh SUK-uh buh-ruhd-vuhj-AHS-uh-nuh)

Modification: foot to the inside of the thigh, side bend
Pose Type: seated, side bend
Drishti Point: Hastagrai or Hastagre (hands)

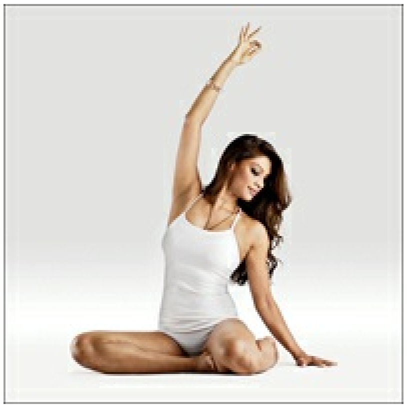

ONE KNEE BENT TO THE BACK: OTHER FOOT TO THE THIGH—SIDE BEND

Easy One-Legged King Pigeon Pose 1

Sukha Eka Pada Raja Kapotasana 1

(SUK-uh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Pose Type: seated, side bend

Drishti Point: Hastagrai or Hastagre (hands)

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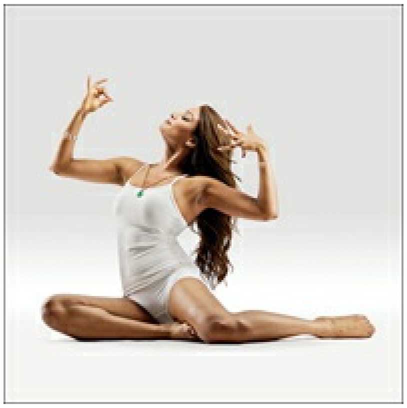

Sideways Half Hero Half Bound Angle Pose

Parshva Ardha Vira Ardha Baddha Konasana

(PAHRSH-vuh UHR-duh VEER-uh UHR-duh BUH-duh ko-NAHS-uh-nuh)

Modification: forearm to the floor

Pose Type: seated, side bend

Drishti Point: Hastagrai or Hastagre (hands)

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Half Hero Half Bound Angle Pose

Ardha Vira Ardha Baddha Konasana

(UHR-duh VEER-uh UHR-duh BUH-duh ko-NAHS-uh-nuh)

Modification: arm behind the back, hand to the hip; backbend
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

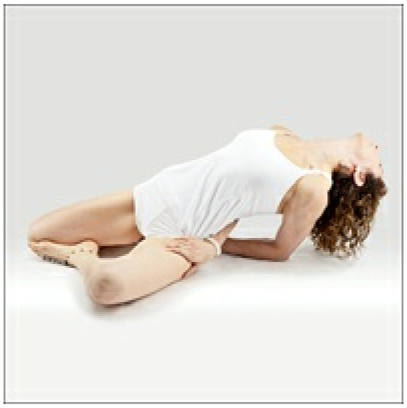

Twist Dedicated to Sage Bharadvaja 2

Bharadvajasana 2

(buh-ruhd-vuhj-AHS-uh-nuh)

Pose Type: seated, twist, binding

Drishti Point: Parsva Drishti (to the right), Parsva Drishti (to the left)

How to Perform the Pose:

1. Begin by sitting on the floor with both your legs straight out in front of you. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Inhale as you lean over to the left side, bending your right knee and bringing your right knee, shin, and ankle to the floor. Your right heel should be close to your right hip to protect the knee and your right knee should be open slightly to the side.
3. Exhale as you bend your left knee and bring your left foot to your right hip socket in the Half Lotus (*Ardha Padmasana*), rotating the sole of your left foot up to the sky. Try to keep both knees on the floor.
4. Inhale as you expand your chest and hold your arms straight out to the sides, parallel to the floor.
5. Exhale as you twist to the left, bringing your left arm behind your back and grabbing your left foot with your left hand to bind. Grab onto the left knee with your right hand and look over your left shoulder (Pose #2).
6. Inhale as you lengthen your spine. Exhale as you bring the back of your left hand under your right knee (Pose #1). On the next exhale, look over your right shoulder to deepen the twist (Pose #3).
7. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
8. Inhale as you release the bind and look forward. Exhale as you bring both your legs straight out in front of you. Repeat on the other side.

Modification:

1. palm under the knee, twisting to the inside of the body
2. hand on the knee, twisting to the inside of the body
3. palm under the knee, twisting to the outside of the body

Bharadvaja = Pindola Bharadvaja was one of four Arhats asked by Buddha to stay on earth to propagate Buddhist law or Dharma

1.

2.

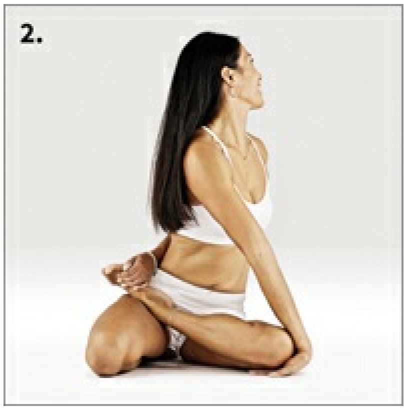

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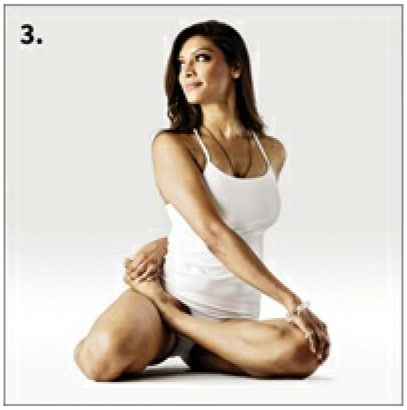

Half Fire Log Pose in Half Bound Hero Pose

Ardha Agnistambhasana in Ardha Baddha Virasana

(UHR-duh uhg-ni-stuhm-BAHS-uh-nuh in UHR-duh BUH-duh veer-AHS-uh-nuh)

Modification: 1. grabbing onto the hip
2. grabbing onto the heel
Pose Type: seated, binding
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

1.

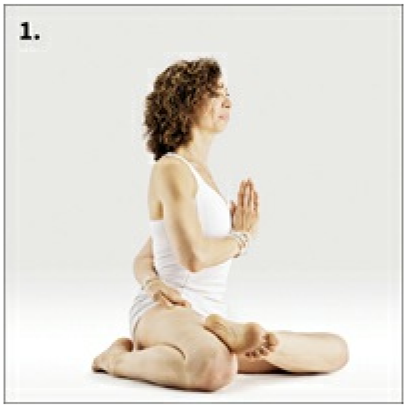

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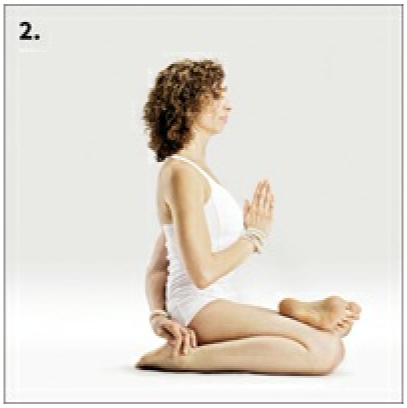

Pose Dedicated to Sage Bharadvaja 2 Prep.

Bharadvajasana 2 Prep.

(buh-ruhd-vuhj-AHS-uh-nuh)

Modification: palms together, heels of the palms resting on the crown of the head, neutral spine
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

Pose Dedicated to Sage Bharadvaja 2 Prep.

Bharadvajasana 2 Prep.

(buh-ruhd-vuhj-AHS-uh-nuh)

Also Known As: Root Lock Pose (Mula Bandhasana)
Modification: sitting on the heel, both hands grabbing onto the foot, neutral spine
Pose Type: seated, binding
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

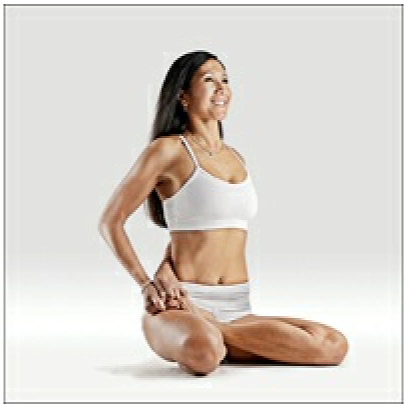

ONE KNEE BENT TO THE BACK: KNEE TO THE CHEST, BINDING, TWIST & BACKBEND

Pose Dedicated to Sage Marichi 5 & 6 Prep.

Marichyasana 5 & 6 Prep.

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi E & F Prep. (Marichyasana E & F Prep.)
Modification: spine straight
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

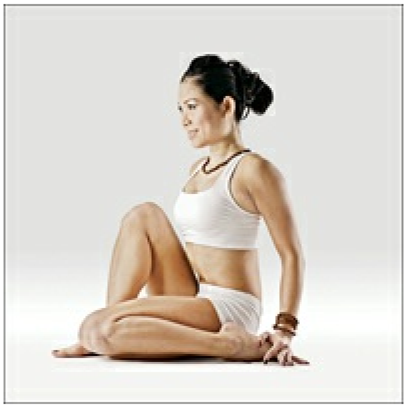

Pose Dedicated to Sage Marichi 5

Marichyasana 5

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi E (Marichyasana E)
Pose Type: seated, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

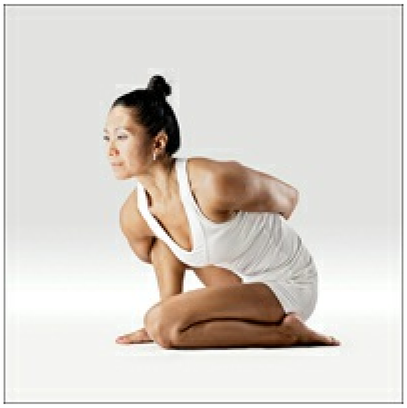

Pose Dedicated to Sage Marichi 6

Marichyasana 6

(muh-ree-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Sage Marichi F (Marichyasana F)
Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

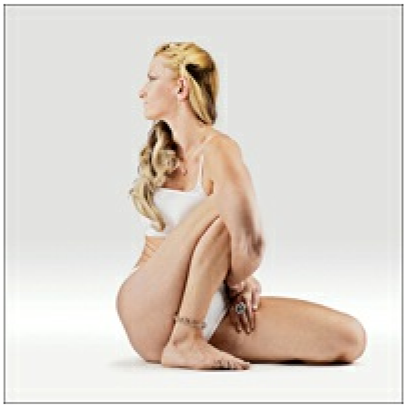

One-Legged King Pigeon Pose 3

Eka Pada Raja Kapotasana 3

(EY-kuh PUH-duh RAHJ-uh kuh-po-TAHS-uh-nuh)

Pose Type: seated, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

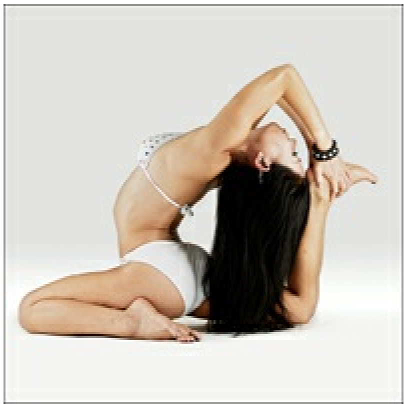

LEG CRADLE & FOOT TO THE KNEE

Baby Cradle Pose in Half Hero Pose

Hindolasana in Ardha Virasana

(hin-do-LAHS-uh-nuh in UHR-duh veer-AHS-uh-nuh)

Also Known As: Baby Cradle Pose in Half Thunderbolt Pose (Hindolasana in Ardha Vajrasana)

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

Baby Cradle Pose Prep.

Hindolasana Prep.

(hin-do-LAHS-uh-nuh)

Modification: palms to the floor behind the hips, heel of the bottom foot to the sitting bone
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

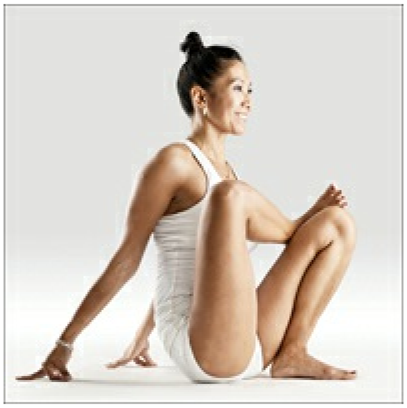

Half Fire Log Pose in Half Yogic Staff Pose Prep.

Ardha Agnistambhasana in Ardha Yogadandasana Prep.

(UHR-duh uhg-ni-stuhm-BAHS-uh-nuh in UHR-duh yo-guh-duhn-DAHS-uh-nuh)

Pose Type: seated, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

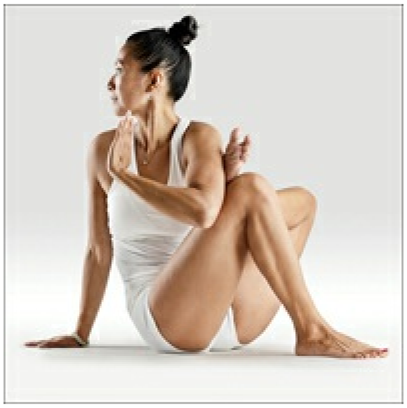

Yogic Staff Pose Prep.

Yogadandasana Prep.

(yo-guh-duhn-DAHS-uh-nuh)

Modification: grabbing onto the foot with one hand
Pose Type: seated, forward bend
Drishti Point: Hastagrai or Hastagre (hands)
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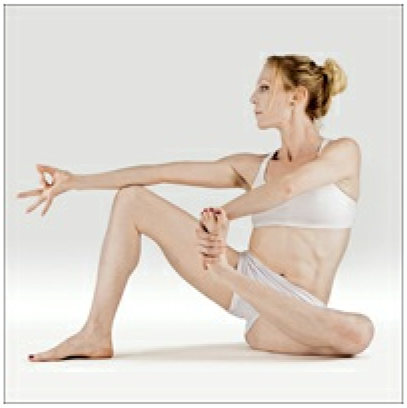

Yogic Staff Pose Prep.

Yogadandasana Prep.

(yo-guh-duhn-DAHS-uh-nuh)

Modification: grabbing onto the foot with both hands, foot to the chest
Pose Type: seated, forward bend
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)
ल व य

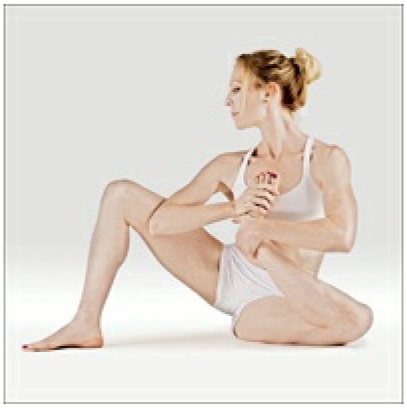

LEG CRADLE: FOOT TO THE HIP & HALF LOTUS

Baby Cradle Pose Prep.

Hindolasana Prep.

(hin-do-LAHS-uh-nuh)

Modification: both hands grabbing onto the foot, fingers interlocked
Pose Type: seated, forward bend
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)

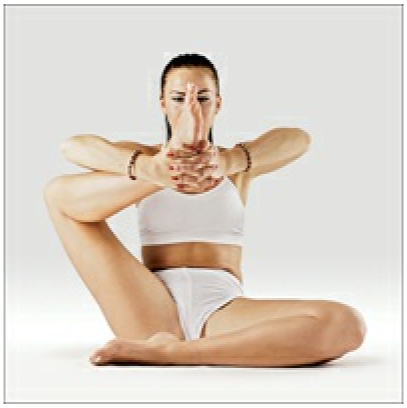

Baby Cradle Pose

Hindolasana

(hin-do-LAHS-uh-nuh)

Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

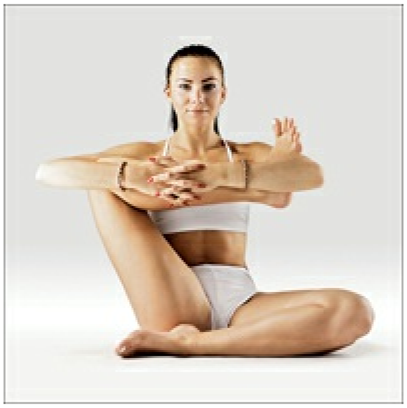

Four Corner Pose

Chatushkonasana

(chuh-tush-ko-NAHS-uh-nuh)

Pose Type: seated, forward bend, binding
Drishti Point: Nasagrai or Nasagre (nose)

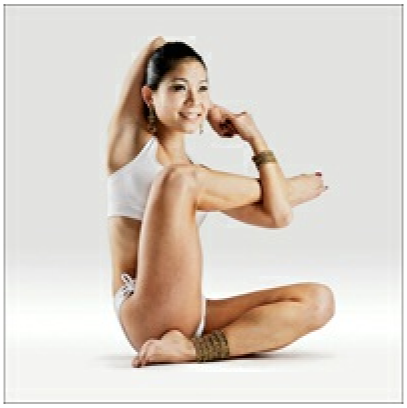

Half Lotus Baby Cradle Pose

Ardha Padma Hindolasana

(UHR-duh PUHD-muh hin-do-LAHS-uh-nuh)

Also Known As: Pose Dedicated to Virancha (Brahma) 1 or A Prep. (Viranchyasana 1 or A Prep.)
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

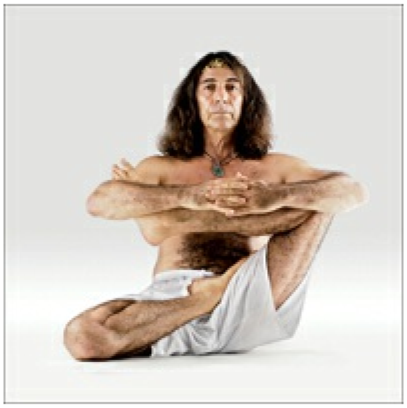

FOOT TO THE ARMPIT: BOTH KNEES BENT

Yogic Staff Pose with Hands in Prayer

Yogadandasana Namaskar

(yo-guh-duhn-DAHS-uh-nuh nuh-muhs-KAHR)

Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

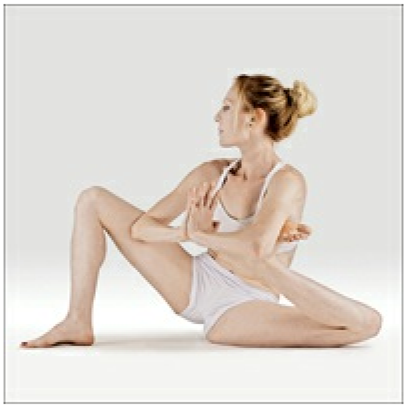

Yogic Staff Pose

Yogadandasana

(yo-guh-duhn-DAHS-uh-nuh)

Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

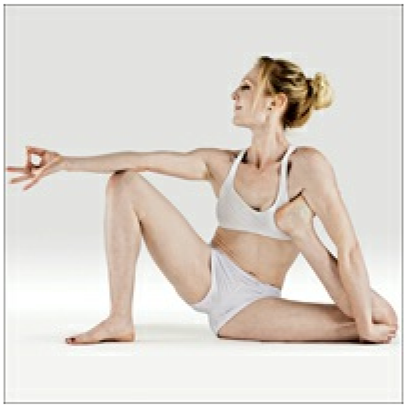

Half Bound Fire Log Pose in Half Yogic Staff Pose Prep.

Ardha Baddha Agnistambhasana in Ardha Yogadandasana Prep.

(UHR-duh BUH-duh uhg-ni-stuhm-BAHS-uh-nuh in UHR-duh yo-guh-duhn-DAHS-uh-nuh)

Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

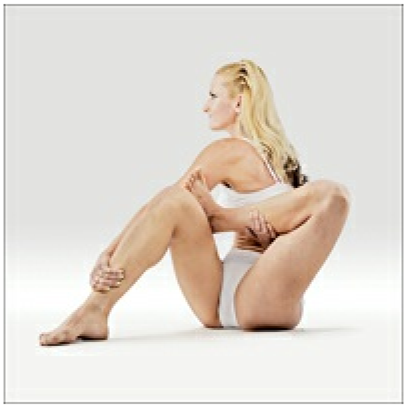

Bound Fire Log Pose in Half Yogic Staff Pose Prep.

Baddha Agnistambhasana in Ardha Yogadandasana Prep.

(BUH-duh uhg-ni-stuhm-BAHS-uh-nuh in UHR-duh yo-guh-duhn-DAHS-uh-nuh)

Pose Type: seated, forward bend, twist, binding
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

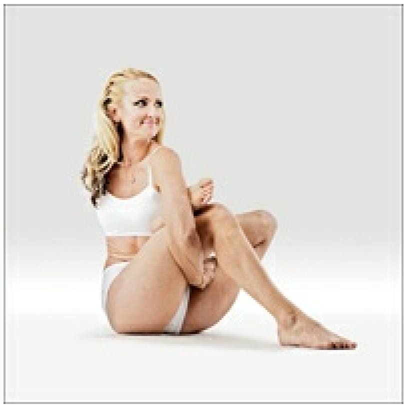

Hands Bound Half Lotus Pose in Half Yogic Staff Pose Prep.

Baddha Hasta Ardha Padmasana in Ardha Yogadandasana Prep.

(BUH-duh HUH-stuh UHR-duh puhd-MAHS-uh-nuh in UHR-duh yo-guh-duhn-DAHS-uh-nuh)

Pose Type: seated, twist, binding

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

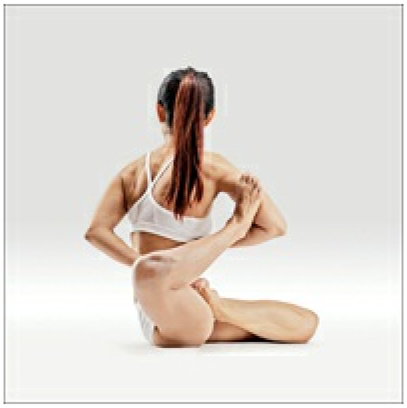

Hands Bound Half Hero Pose in Half Yogic Staff Pose Prep.

Baddha Hasta Ardha Virasana in Ardha Yogadandasana Prep.

(BUH-duh HUH-stuh UHR-duh veer-AHS-uh-nuh in UHR-duh yo-guh-duhn-DAHS-uh-nuh)

Pose Type: seated, twist, binding

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

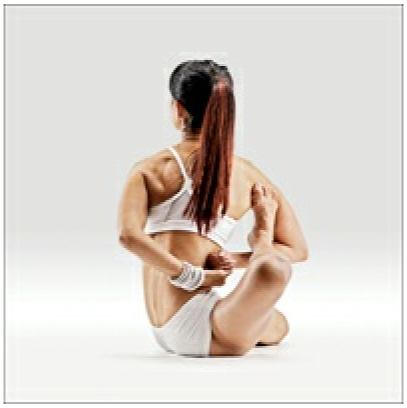

ONE LEG OVER THE SHOULDER: BOTH KNEES BENT

Sundial Pose 2 Prep.

Surya Yantrasana 2 Prep.

(SOOR-yuh yuhn-TRAHS-uh-nuh)

Modification: shoulder to the back of the knee, knee bent
Pose Type: seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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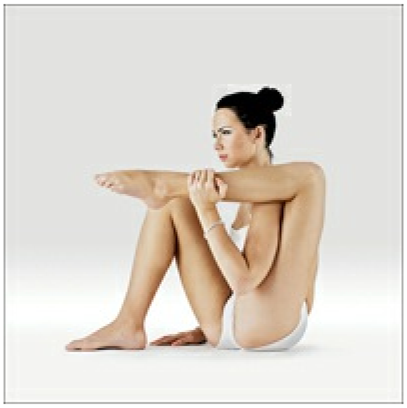

FOOT BEHIND THE HEAD

Pose Dedicated to Virancha (Brahma) 1

Viranchyasana 1

(vir-uhn-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Virancha (Brahma) A (Viranchyasana A)
Pose Type: seated, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

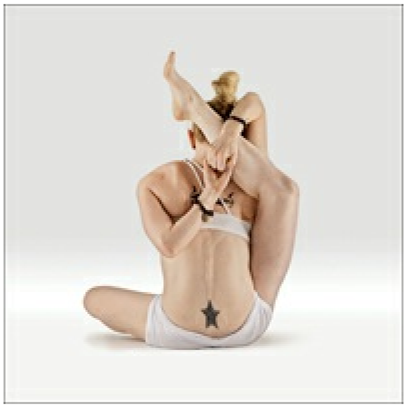

Seated Moonbird Pose

Upavishta Chakorasana

(u-puh-VISH-tuh chuh-kor-AHS-uh-nuh)

Also Known As: Upavistha Chakorasana
Pose Type: seated, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

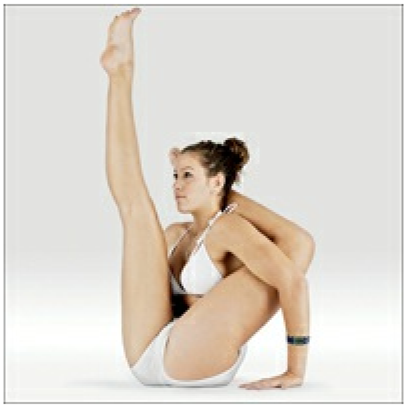

One Foot Behind the Head Pose

Eka Pada Shirshasana

(EY-kuh PUH-duh sheer-SHAHS-uh-nuh)

Modification: palms on the floor by the hips, knee bent toward the chest
Pose Type: seated, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

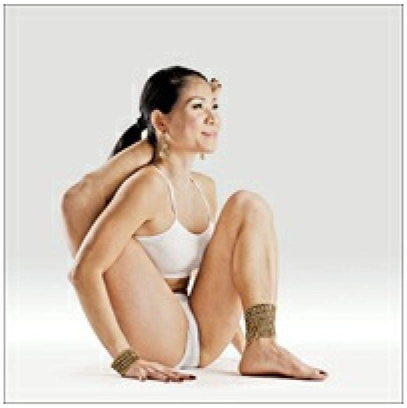

Pose Dedicated to Virancha (Brahma) 1

Viranchyasana 1

(vir-uhn-CHYAHS-uh-nuh)

Also Known As: Pose Dedicated to Virancha (Brahma) A (Viranchyasana A)
Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: seated
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

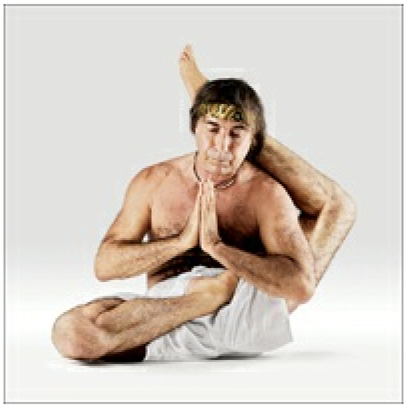

COW FACE POSE: SPINE STRAIGHT

Leg Position of Cow Face Pose

Pada Gomukhasana

(PUH-duh go-muk-AHS-uh-nuh)

Modification: hands on the top knee, one palm on top of the other
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)

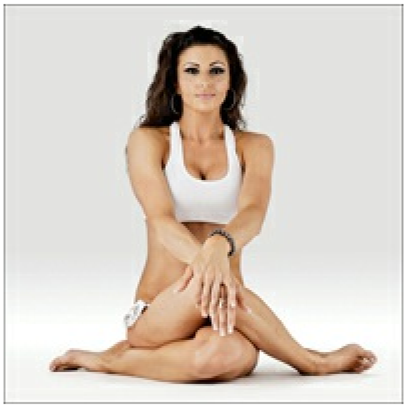

Ganesh Seal in Leg Position of Cow Face Pose

Ganesh Mudra in Pada Gomukhasana

(guh-NEYSH MU-druh in PUH-duh go-muk-AHS-uh-nuh)

Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)
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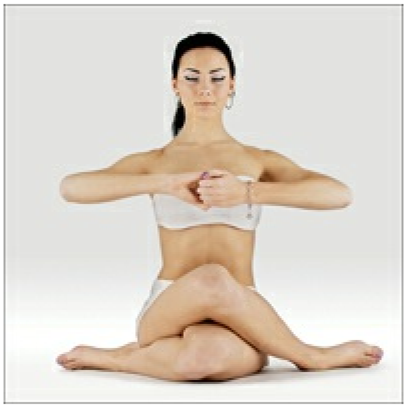

Both Hands to Feet Leg Position of Cow Face Pose

Dwi Hasta Pada Gomukhasana

(DWI-huh-stuh PUH-duh go-mu-KAHS-uh-nuh)

Modification: arms crossed behind the back, grabbing onto the feet
1. back view
2. front view
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
● ● ● ● ● ●

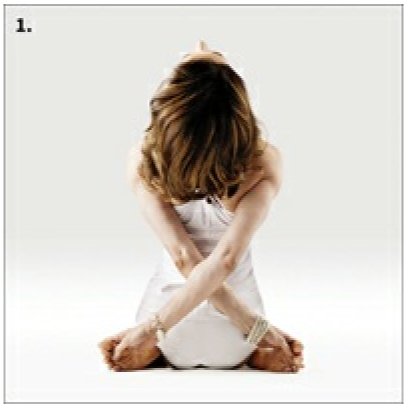

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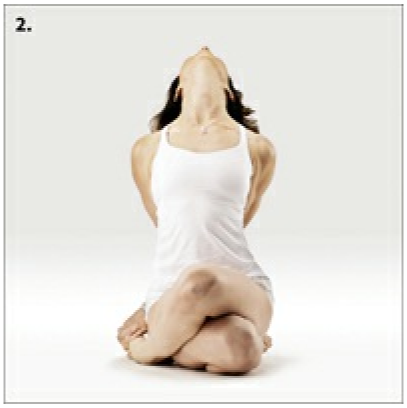

2.

Cow Face Pose

Gomukhasana

(go-mu-KAHS-uh-nuh)

Pose Type: seated

Drishti Point: Nasagrai or Nasagre (nose)

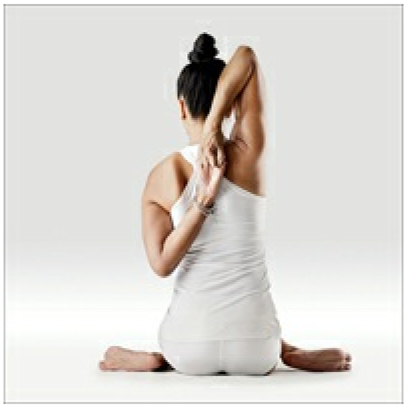

Leg Position of Cow Face Pose

Pada Gomukhasana

(PUH-duh go-mu-KAHS-uh-nuh)

Modification: elbows touching behind the head
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose)

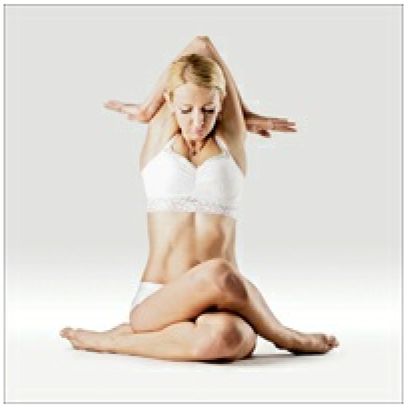

COW FACE POSE: FORWARD BEND

Leg Position of Cow Face Pose

Pada Gomukhasana

(PUH-duh go-mu-KAHS-uh-nuh)

Modification: hands in Anjali Mudra (Hands in Prayer), thumbs to third eye; elbows together
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose) or Angushtamadhye or Angustha Ma Dyai (thumbs)

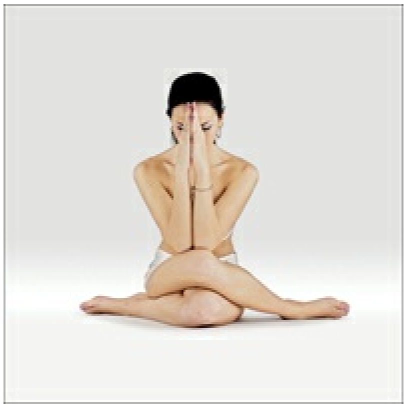

Western Intense Stretch Pose in Leg Position of Cow Face Pose

Paschimottanasana in Pada Gomukhasana

(puhsh-chi-mo-TAHS-uh-nuh in PUH-duh go-mu-KAHS-uh-nuh)

Also Known As: Seated Forward Bend in Leg Position of Cow Face Pose and Long Horn Pose

(Dighasrngasana)

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

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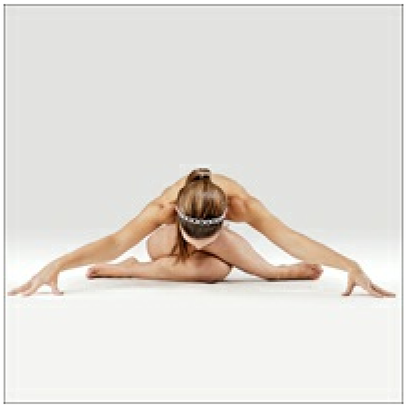

Hand Position of the Pose Dedicated to Garuda in Leg Position of Cow Face Pose

Hasta Garudasana in Pada Gomukhasana

(HUH-stuh guh-ru-DAHS-uh-nuh in PUH-duh go-mu-KAHS-uh-nuh)

Modification: forward bend

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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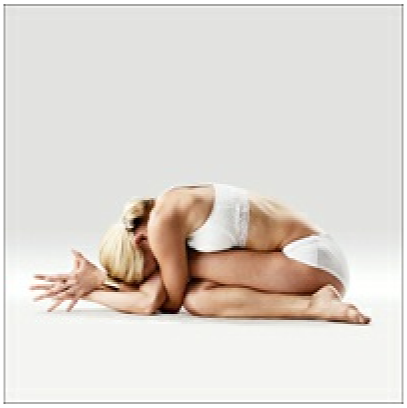

COW FACE POSE: SIDE BEND

Sideways Leg Position of Cow Face Pose

Parshva Pada Gomukhasana

(PAHRSH-vuh PUH-duh go-mu-KAHS-uh-nuh)

Pose Type: seated, side bend

Drishti Point: Hastagrai or Hastagre (hands)

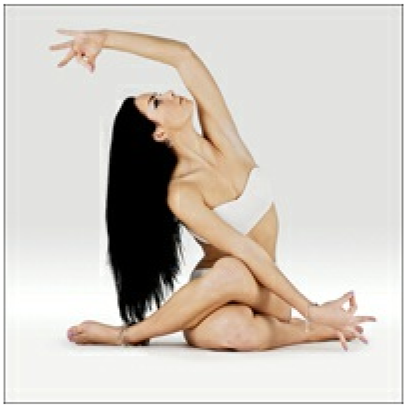

Hand to Foot Sideways Leg Position of Cow Face Pose

Hasta Pada Parshva Pada Gomukhasana

(HUH-stuh PUH-duh PAHRSH-vuh PUH-duh go-mu-KAHS-uh-nuh)

Pose Type: seated, side bend

Drishti Point: Hastagrai or Hastagre (hands)

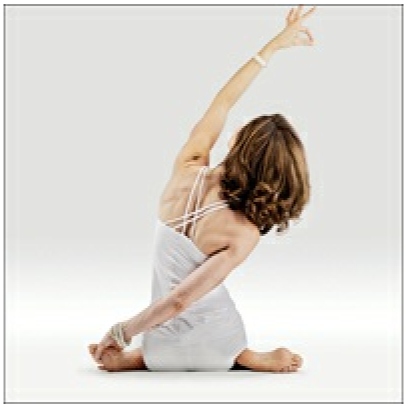

Sideways Leg Position of Cow Face Pose

Parshva Pada Gomukhasana

(PAHRSH-vuh PUH-duh go-mu-KAHS-uh-nuh)

Modification: intense shoulder stretch

Pose Type: seated, side bend

Drishti Point: Urdhva or Antara Drishti (up to the sky)

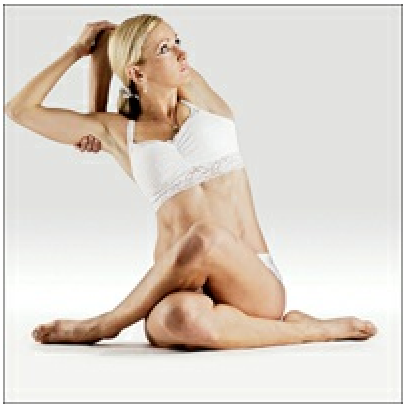

Hand to Foot Revolved Leg Position of Cow Face Pose

Hasta Pada Parivritta Pada Gomukhasana

(HUH-stuh PUH-duh puh-ri-VRIT-tuh PUH-duh go-mu-KAHS-uh-nuh)

Modification: grabbing onto the big toe, arm behind the back; other arm in front of the body, hand on the hip
Pose Type: seated, twist, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

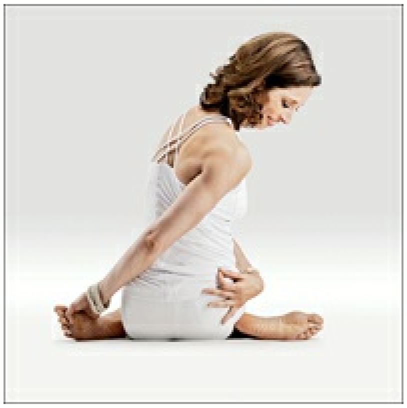

COW FACE POSE: KNEES LIFTED TO THE CHEST

Upward Leg Position of Cow Face Pose

Urdhva Pada Gomukhasana

(OORD-vuh PUH-duh go-mu-KAHS-uh-nuh)

Modification: arms under the legs, knees lifted to the chest
Pose Type: seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Hastagrai or Hastagre (hands)

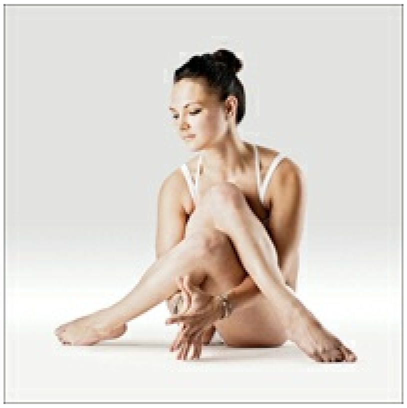

Upward Hands Upward Leg Position of Cow Face Pose

Urdhva Hasta Urdhva Pada Gomukhasana

(OORD-vuh HUH-stuh OORD-vuh PUH-duh go-mu-KAHS-uh-nuh)

Pose Type: seated, forward bend, core

Drishti Point: Hastagrai or Hastagre (hands), Nasagrai or Nasagre (nose)

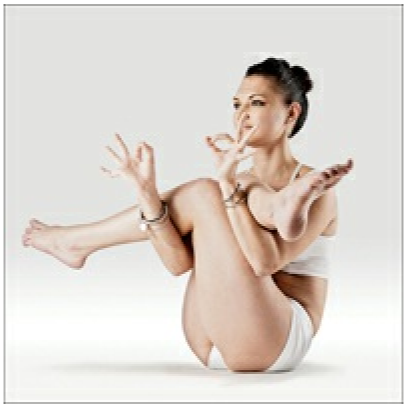

Both Hands to Feet Upward Leg Position of Cow Face Pose

Dwi Hasta Pada Urdhva Pada Gomukhasana

(DWI-huh-stuh PUH-duh OORD-vuh PUH-duh go-mu-KAHS-uh-nuh)

Modification: grabbing the outside edges of both feet

Pose Type: seated, forward bend, core

Drishti Point: Nasagrai or Nasagre (nose)

COW FACE POSE: ELBOW & FOREARM ON THE FLOOR

Half Bound Sideways Easy Leg Position of Cow Face Pose

Ardha Baddha Parshva Sukha Pada Gomukhasana

(UHR-duh BUH-duh PAHRSH-vuh SUK-uh PUH-duh go-mu-KAHS-uh-nuh)

Modification: forearm to the floor, sitting on the bottom heel
1. front view
2. back view
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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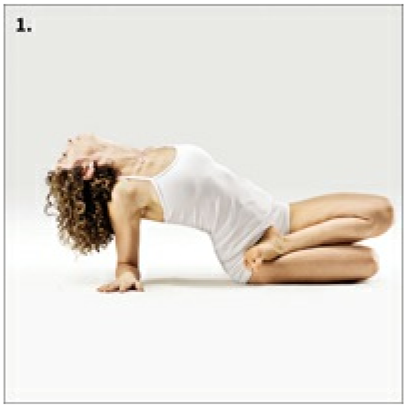
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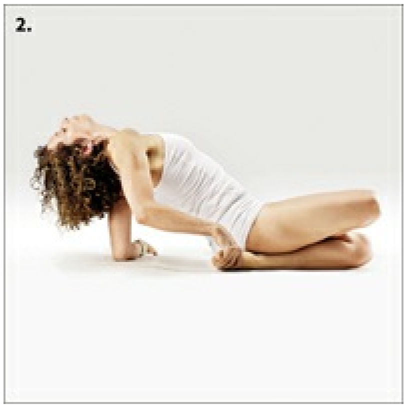
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Half Bound Sideways Easy Leg Position of Cow Face Pose

Ardha Baddha Parshva Sukha Pada Gomukhasana

(UHR-duh BUH-duh PAHRSH-vuh SUK-uh PUH-duh go-mu-KAHS-uh-nuh)

Modification: elbow to the floor
Pose Type: seated, backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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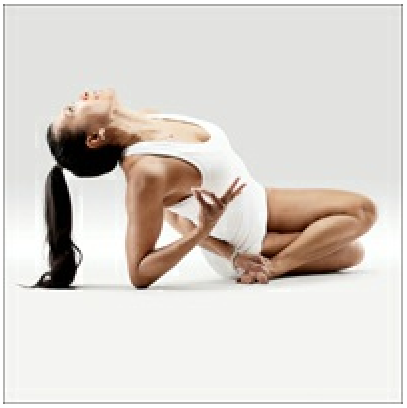

[SAGE VAMADEVA’S POSE: LEANING TO THE SIDE](#)

Pose Dedicated to Sage Vamadeva Prep.

Vamadevasana Prep.

(vahm-uh-dey-VAHS-uh-nuh)

Modification: 1. palm flat on the floor, chest rotating up
2. one arm crossed over in front, hand grabbing onto the back foot; top hand to the head
Pose Type: seated, side bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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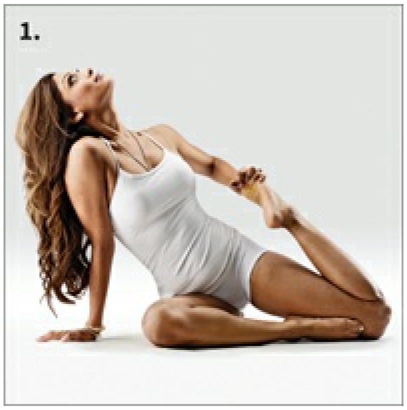

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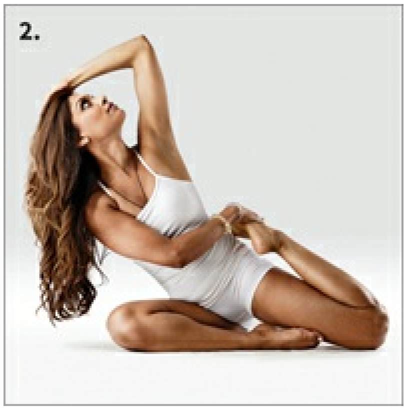

Pose Dedicated to Sage Vamadeva

Vamadevasana

(vahm-uh-dey-VAHS-uh-nuh)

Modification: binding:
1. hand to the hip socket
2. hand to the knee

Pose Type: seated, side bend, twist, binding

Drishti Point: 1. Urdhva or Antara Drishti (up to the sky)
2. Padayoragrai or Padayoragre (toes/feet)

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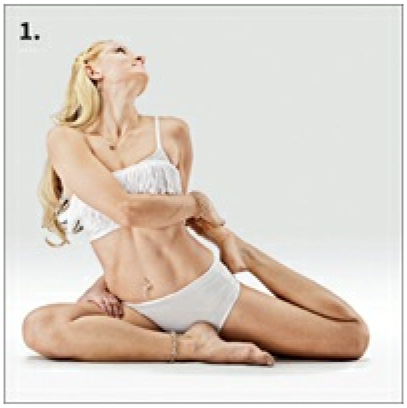

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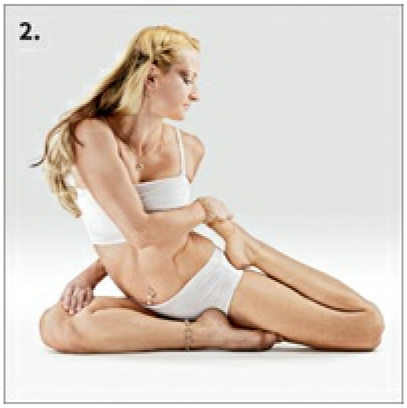

Revolved One-Legged King Pigeon Pose 1 Prep.

Parivritta Eka Pada Raja Kapotasana 1 Prep.

(puh-ri-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: grabbing onto the back foot
1. one arm crossed over, other arm to the side, elbow bent
2. arms crossed in front of the body, free hand to the opposite knee
Pose Type: seated, side bend, twist
Drishti Point: Hastagrai or Hastagre (hands), Parshva Drishti (to the right), Parshva Drishti (to the left)

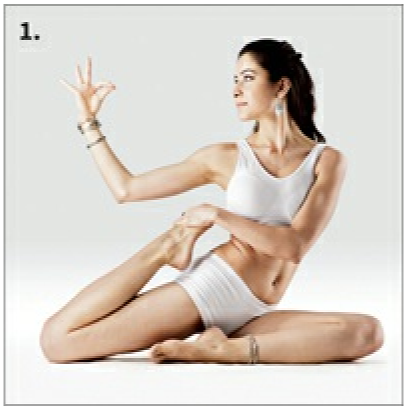
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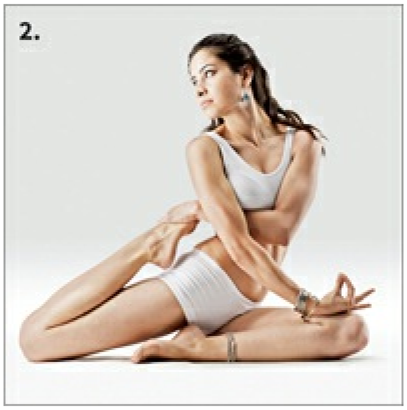
2.

Pose Dedicated to Sage Vamadeva 2

Vamadevasana 2

(vahm-uh-dey-VAHS-uh-nuh)

Pose Type: seated, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

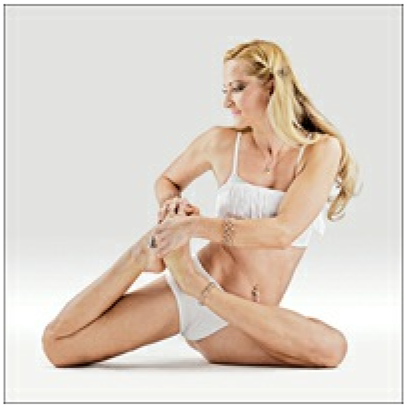

ONE-LEGGED KING PIGEON: HIPS OFF THE FLOOR

One-Legged King Pigeon Pose 1 Version B

Eka Pada Raja Kapotasana 1 B

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Pose Type: standing (on the knees), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

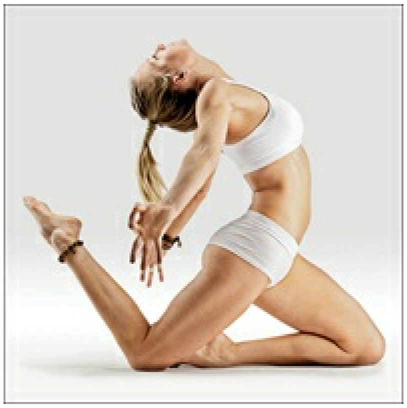

Easy One-Legged King Pigeon Pose 1

Sukha Eka Pada Raja Kapotasana 1

(SUK-uh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: hips lifted off the floor, grabbing onto the foot on the opposite side with overhead grip
1. free arm extended to the front
2. free hand to the floor by the opposite knee
Pose Type: standing (on the knees), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

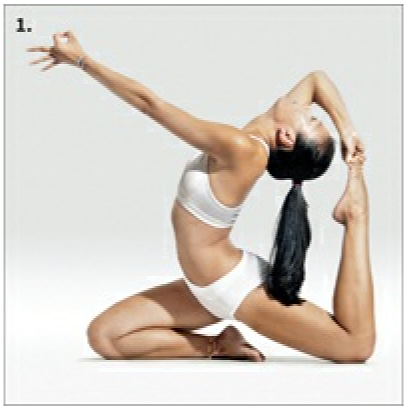

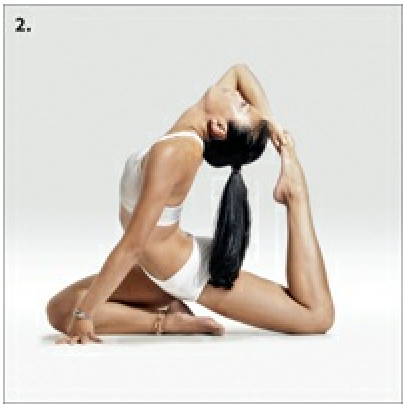

Easy One-Legged King Pigeon Pose 1

Sukha Eka Pada Raja Kapotasana 1

(SUK-uh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: hips off the floor; fingertips to the floor by the hips, foot touching the head
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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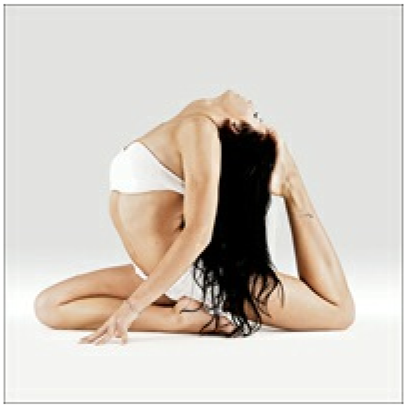

ONE-LEGGED KING PIGEON: UNDER-HEAD GRIP

One-Legged King Pigeon Pose 1 Prep.

Eka Pada Raja Kapotasana 1 Prep.

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: 1. back knee bent
2. grabbing onto the back foot with one arm on the same side
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

1.

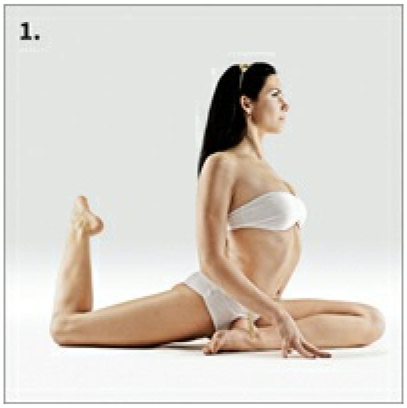

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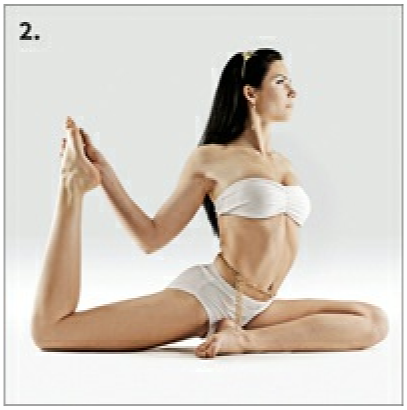

One-Legged King Pigeon Pose 1

Eka Pada Raja Kapotasana 1

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: one hand on the front knee on the same side, other hand pressing the back foot toward the hip
Pose Type: seated, backbend
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

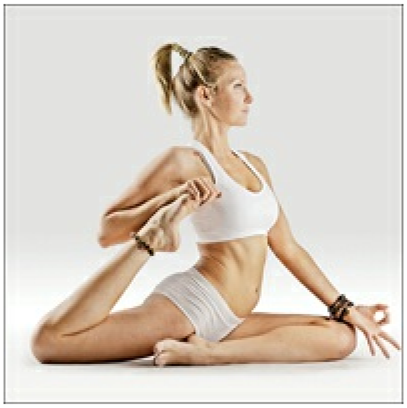

One-Legged King Pigeon Pose 1

Eka Pada Raja Kapotasana 1

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: one hand on the back knee, one hand on the front knee; foot to the back of the head
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

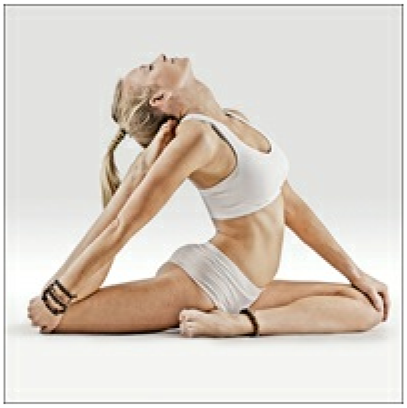

One-Legged King Pigeon Pose 1

Eka Pada Raja Kapotasana 1

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: foot to the opposite armpit
Pose Type: seated, backbend, twist
Drishti Point: Nasagrai or Nasagre (nose) or Hastagrai or Hastagre (hands)

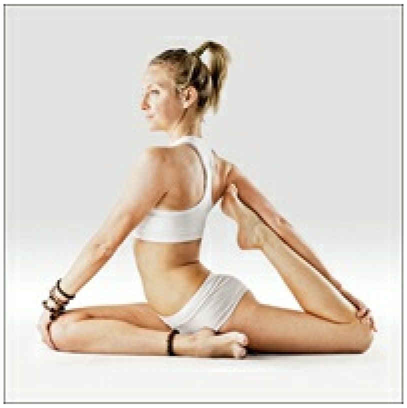

Revolved One-Legged King Pigeon Pose 1

Parivritta Eka Pada Raja Kapotasana 1

(puh-ri-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: foot to the armpit on the same side

Pose Type: seated, backbend, twist

Drishti Point: Hastagrai or Hastagre (hands)

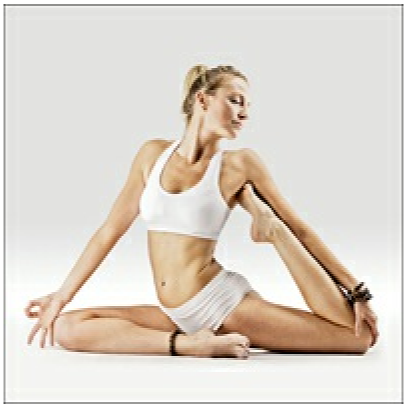

Revolved One-Legged King Pigeon Pose 1

Parivritta Eka Pada Raja Kapotasana 1

(puh-ri-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: foot under the chin

Pose Type: seated, backbend, twist

Drishti Point: Hastagrai or Hastagre (hands)

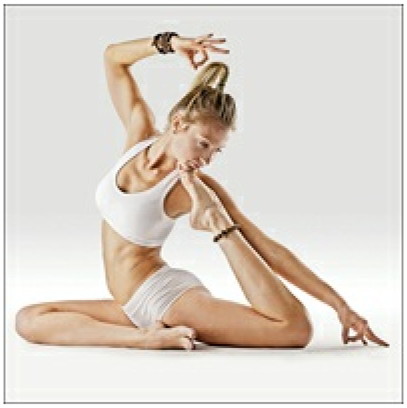

Pose of the Heavenly Spirits Prep.

Valakhilyasana Prep.

(vah-luh-kil-YAHS-uh-nuh)

Modification: under-head grip
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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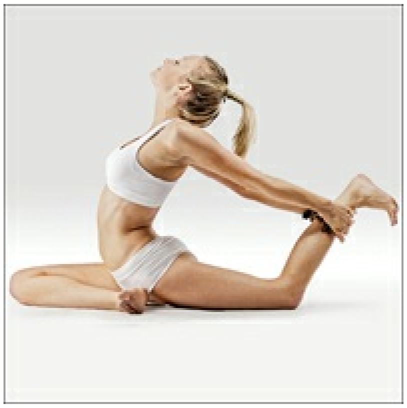

ONE-LEGGED KING PIGEON: OVERHEAD GRIP

One-Legged King Pigeon Pose 1

Eka Pada Raja Kapotasana 1

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: grabbing onto the foot with one hand on the same side, overhead grip; other hand resting on the front knee
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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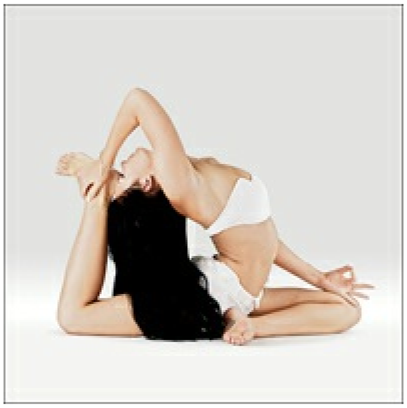

One-Legged King Pigeon Pose 1

Eka Pada Raja Kapotasana 1

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: grabbing onto the foot with both hands, overhead grip; heel of the back foot to the forehead

Pose Type: seated, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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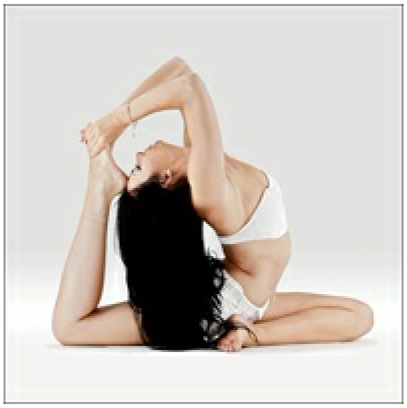

ONE-LEGGED KING PIGEON: ASYMMETRICAL ARMS—CROSS OVER & UNDER-HEAD/OVERHEAD GRIP

One Hand to Foot Bound One-Legged King Pigeon Pose 1

Eka Hasta Pada Baddha Eka Pada Raja Kapotasana 1

(EY-kuh HUH-stuh PUH-duh BUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: arm crossed over in front of the neck, other hand on the knee

Pose Type: seated, backbend

Drishti Point: Nasagrai or Nasagre (nose)

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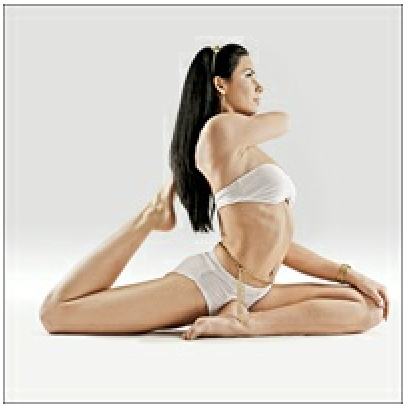

Both Hands to Feet Bound One-Legged King Pigeon Pose 1

Dwi Hasta Pada Baddha Eka Pada Raja Kapotasana 1

(DWI-huh-stuh PUH-duh BUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: arm crossed over in front of the neck
Pose Type: seated, backbend, binding
Drishti Point: Nasagrai or Nasagre (nose)
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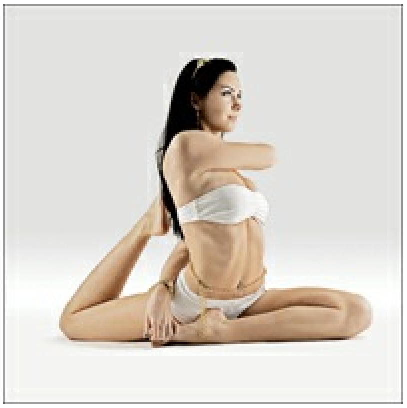

Mermaid Pose 1

Naginyasana 1

(nah-gin-YAHS-uh-nuh)

Pose Type: seated, backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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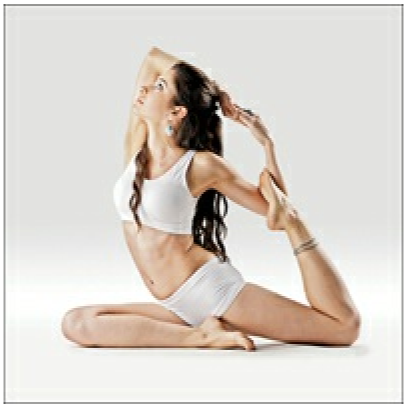

ONE-LEGGED KING PIGEON: ASYMMETRICAL ARMS—CROSS OVER & UNDER-HEAD/OVERHEAD GRIP

Both Hands to Feet Bound One-Legged King Pigeon Pose 1

Dwi Hasta Pada Baddha Eka Pada Raja Kapotasana 1

(DWI-huh-stuh PUH-duh BUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: grabbing onto the opposite foot with overhead grip
Pose Type: seated, backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

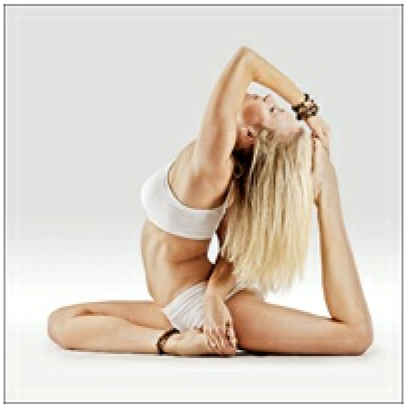

One-Legged King Pigeon Pose 1

Eka Pada Raja Kapotasana 1

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: one hand on the back knee, one hand grabbing onto the opposite foot with overhead grip
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

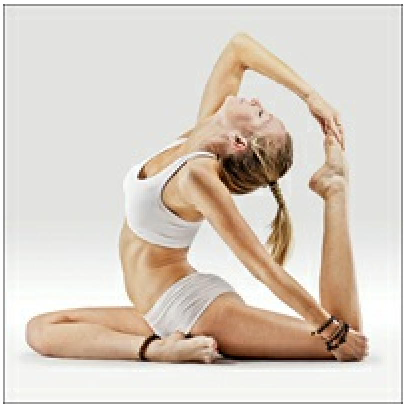

ONE-LEGGED KING PIGEON: FOOT TO THE BACK OF THE HEAD

One-Legged King Pigeon Pose 1

Eka Pada Raja Kapotasana 1

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: grabbing onto the back knee with both hands under-head grip; foot to the back of the head
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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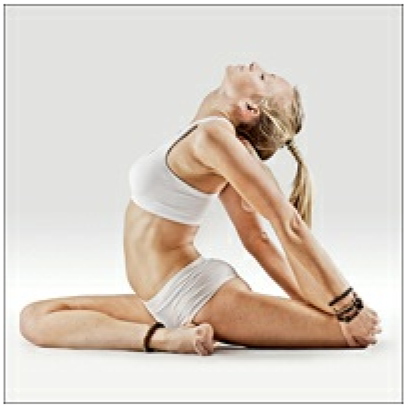

One Legged King Pigeon Pose 1

Eka Pada Raja Kapotasana 1

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Pose Type: seated, backbend

Drishti Point: Angusthamadhye or Angustha Ma Dyai (thumbs)

How to Perform the Pose:

1. Begin by sitting on the floor with both your legs straight out in front of you. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale and bend your left knee, keeping the knee on the floor, and slide the left heel toward the inside of your right thigh.
3. Inhale as you lean forward. Exhale, extend the right leg straight out behind you with your right thigh, knee, shin, and front of the right foot on the floor. Square your hips by pulling the left hip to the back and right hip to the front.
4. Inhale as you lengthen the spine, pressing both hands to the floor by your hips for support. Exhale as you let your head roll back into a backbend.
5. Exhale as you bend your right knee, bringing your right foot toward your head. Once your right foot touches your head, slide your right foot under the back of your head and fix it in place.
6. Inhale as you stretch both arms up over your head. Exhale as you bring your palms together, keeping your arms straight and strong (Pose #1). Push through your chest. You can experiment with interlocking your fingers and letting your pointer fingers and thumbs be straight. You can also bring your foot to the side of your head (Pose #2).
7. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
8. Exhale as you release the right foot from under your head and lower it to the floor. Inhale and straighten your spine. Exhale as you bring both your legs straight out in front of you. Repeat on the other side.

Modification: both arms extended to the sky
1. foot to the back of the head, palms together
2. foot to the side of the head, fingers interlocked, pointer fingers free

eka = one

pada = foot or leg

raja = king, royal

kapota = pigeon

1.

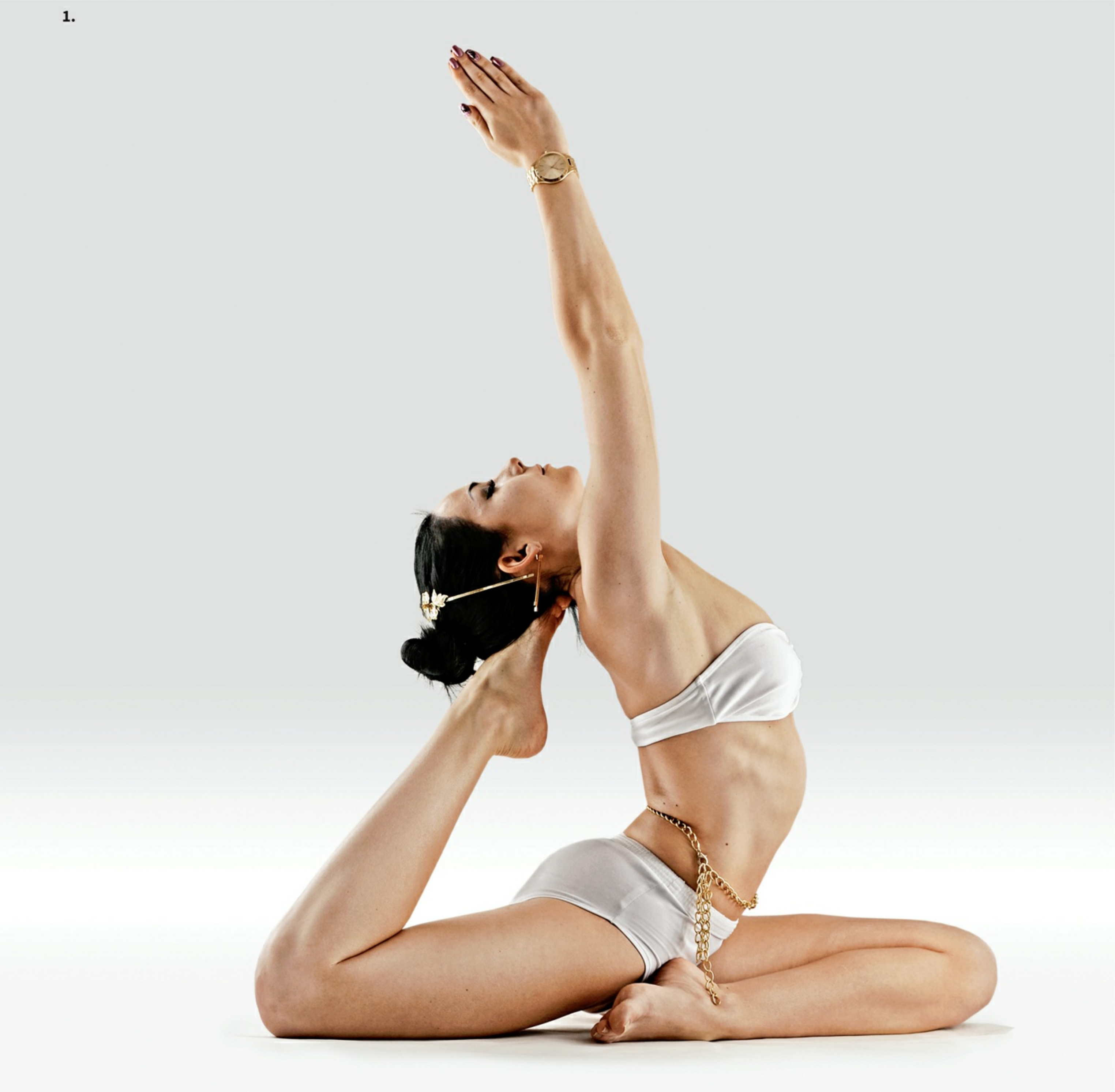

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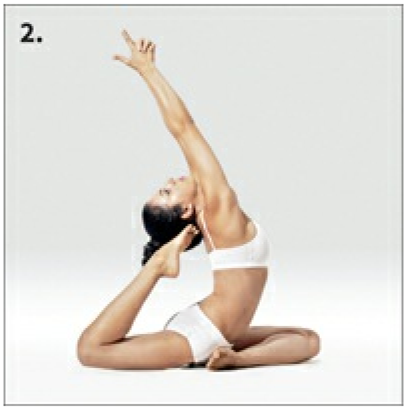

Easy One-Legged King Pigeon Pose 1

Sukha Eka Pada Raja Kapotasana 1

(SUK-uh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: hips lifted, back leg straight, arms open wide

Pose Type: standing (on the knees), backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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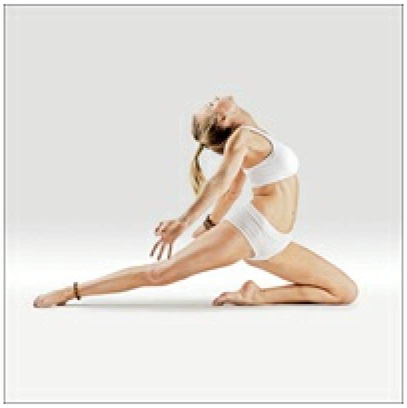

One-Legged King Pigeon Pose 1 Prep.

Eka Pada Raja Kapotasana 1 Prep.

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: hips off the floor, back leg straight; hands on the hips

Pose Type: seated, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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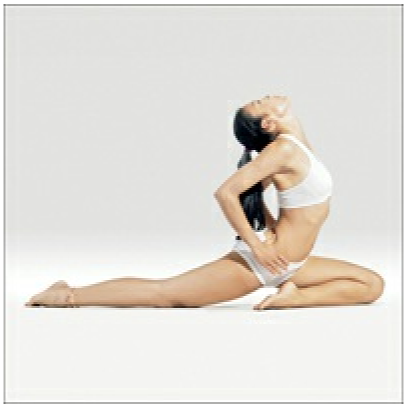

Upward Hands One-Legged King Pigeon Pose 1

Urdhva Hasta Eka Pada Raja Kapotasana 1

(OORD-vuh HUH-stuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: hips off the floor, back leg straight; arms extended to the sky

Pose Type: seated, backbend

Drishti Point: Angushtamadhye or Angustha Ma Dyai (thumbs)

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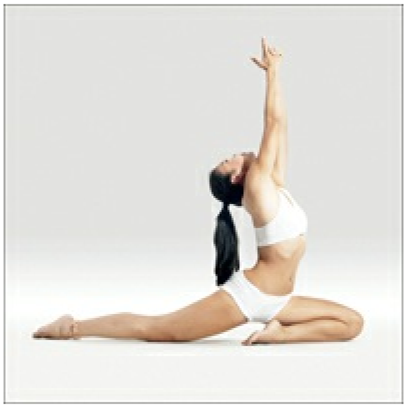

One-Legged King Pigeon Pose 1 Prep.

Eka Pada Raja Kapotasana 1 Prep.

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: back leg straight; palms facing up, back of the hand on the foot and the knee

Pose Type: seated, backbend

Drishti Point: Nasagrai or Nasagre (nose)

ल व र य

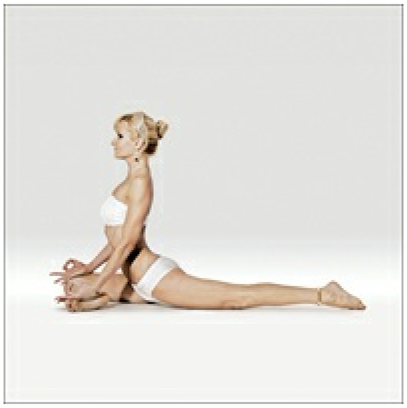

ONE-LEGGED KING PIGEON: BACK LEG STRAIGHT—FORWARD BEND & TWIST

One-Legged King Pigeon Pose 1

Eka Pada Raja Kapotasana 1

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: back leg straight; forward bend, forearms to the floor, foot and knee to the elbow creases

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

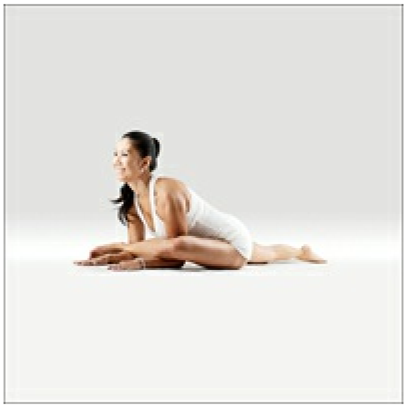

One-Legged King Pigeon Pose 1

Eka Pada Raja Kapotasana 1

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: back leg straight; forehead to the floor, palms to the floor, elbows on top of the wrists

Pose Type: seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

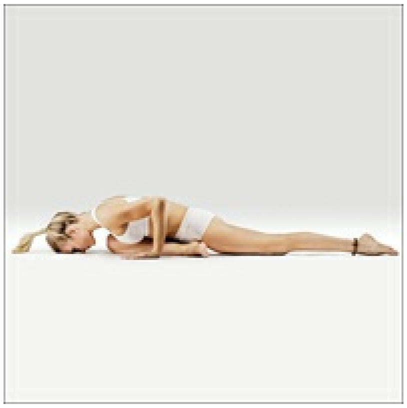

Hand Position of Cow Face Pose in One-Legged King Pigeon Pose 1

Hasta Gomukhasana in Eka Pada Raja Kapotasana 1

(HUH-stuh go-muk-AHS-uh-nuh in EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: back leg straight, forward bend with Gomukhasana Arms
Pose Type: seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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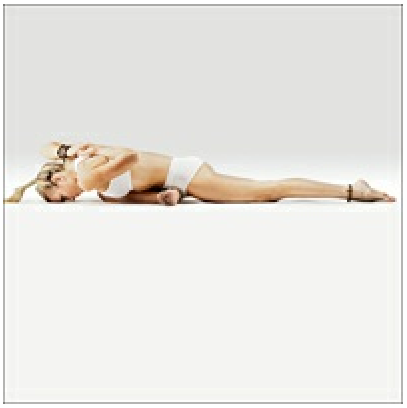

Revolved One-Legged King Pigeon Pose 1

Parivritta Eka Pada Raja Kapotasana 1

(puh-ri-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)
Modification: twisting to the inside of the body, back leg straight; foot to the armpit
Pose Type: seated, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
ल व

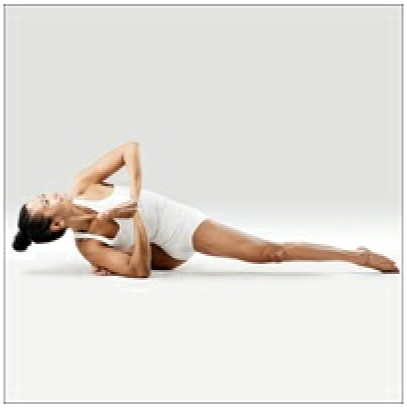

Revolved One-Legged King Pigeon Pose 1

Parivritta Eka Pada Raja Kapotasana 1

(puh-ri-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)
Modification: twisting to the outside of the body, back leg straight; knee to the armpit
Pose Type: seated, forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

VERTICAL SPLITS: SPINE STRAIGHT

Pose Dedicated to Hanuman

Hanumanasana

(huh-nu-mahn-AHS-uh-nuh)

Also Known As: Pose Dedicated to Hanuman A (Hanumanasana A)
Modification: hands in Anjali Mudra (Hands in Prayer)
1. side view
2. front view
Pose Type: seated
Drishti Point: Nasagrai or Nasagre (nose) or Hastagrai or Hastagre (hands)

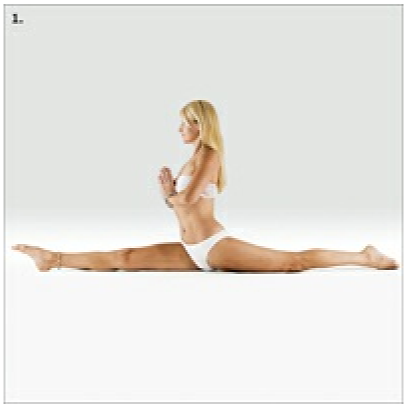

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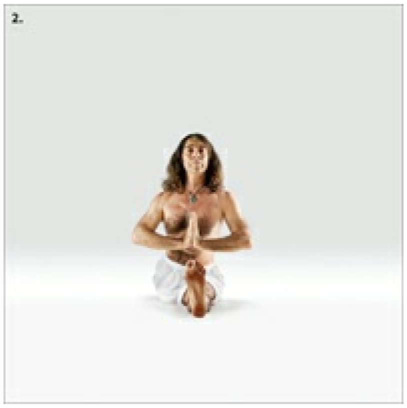

Upward Hands in

Pose Dedicated to Hanuman

Urdhva Hasta Hanumanasana

(OORD-vuh HUH-stuh huh-nu-mahn-AHS-uh-nuh)

Also Known As: Pose Dedicated to Hanuman B (Hanumanasana B)

Pose Type: seated, backbend

Drishti Point: Angusthamadhye or Angustha Ma Dyai (thumbs)

How to Perform the Pose:

1. Begin by standing on your knees with sitting bones lifted off the heels. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale, step your left foot to the front into a lunge. Keep your left knee on top of your left ankle and your right knee under your right hip.
3. Inhale as you slide your left foot out to the front, lifting your left toes off the floor until your left leg is straight.
4. Inhale and stretch your arms up to lengthen your spine. Exhale as you hinge forward from your hips, bringing your hands to the floor on either side of the left leg.
5. On your next exhale, start sliding your left foot out to the front and your right knee to the back, reaching your legs in two opposite directions, coming into a full vertical split. Keep your hips square by pulling your left hip back and your right hip forward.
6. Inhale and reach both your arms up to the sky. Exhale as you deepen the backbend by letting your head roll back and your arms reach in the direction of your back foot.
7. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
8. Inhale as you come out of the backbend. Exhale and place both your palms to the floor on the inside of the left leg. Inhale. As you exhale, swing your left leg back and bring your left knee to the floor by your right knee. Inhale and come up to the starting position with both knees on the floor. Repeat on the other side.

Modification: deep backbend

urdhva = upward

hasta = hand

Hanuman = Hindu Deity, Lord of the Monkeys

Hands Bound Pose Dedicated to Hanuman

Baddha Hasta Hanumanasana

(BUH-duh HUH-stuh huh-nu-mahn-AHS-uh-nuh)

Modification: forward bend

1. side view
2. front view

Pose Type: seated, forward bend

Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)

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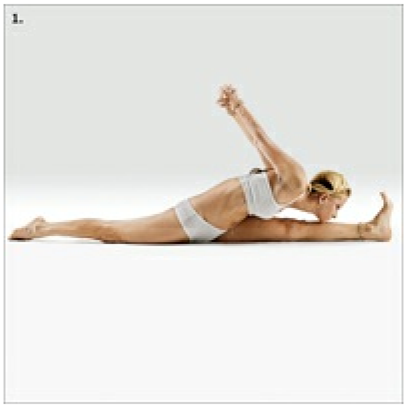

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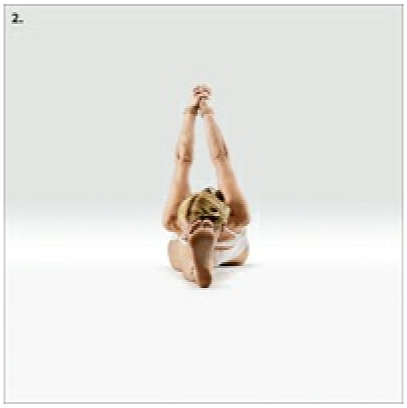

2.

VERTICAL SPLITS: TWISTS & SIDE BENDS

Revolved Pose Dedicated to Hanuman

Parivritta Hanumanasana

(puh-ri-VRIT-uh huh-nu-mahn-AHS-uh-nuh)

Pose Type: seated, twist

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

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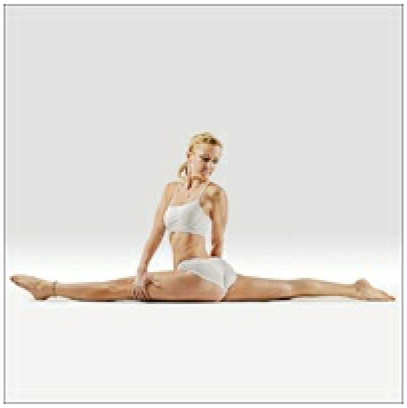

Revolved Sideways Pose Dedicated to Hanuman

Parivritta Parshva Hanumanasana

(puh-ri-VRIT-uh PAHRSH-vuh huh-nu-mahn-AHS-uh-nuh)

Modification: twisting to the inside of the body
Pose Type: seated, forward bend, twist, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

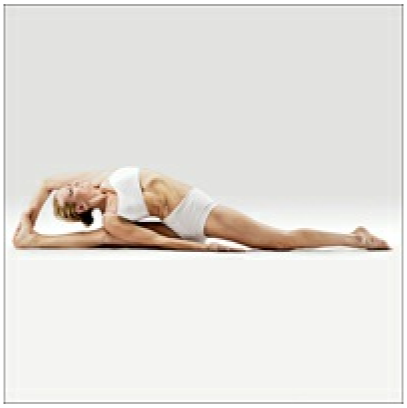

Revolved Sideways Pose Dedicated to Hanuman

Parivritta Parshva Hanumanasana

(puh-ri-VRIT-uh PAHRSH-vuh huh-nu-mahn-AHS-uh-nuh)

Modification: twisting to the outside of the body
Pose Type: seated, forward bend, twist, side bend
Drishti Point: Urdhva or Antara Drishti (up to the sky)

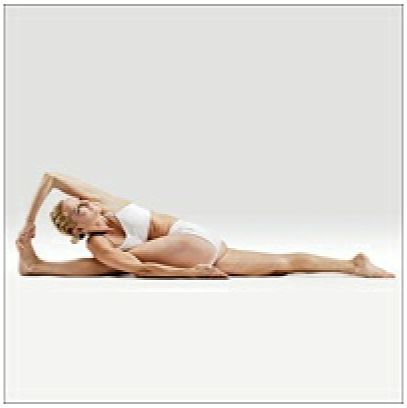

VERTICAL SPLITS: BACK FOOT TOWARD THE HIP & MERMAID POSE

Revolved One-Legged King Pigeon Pose 4 Prep.

Parivritta Eka Pada Raja Kapotasana 4 Prep.

(puh-ri-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: 1. hand to the floor by the hip, other hand pressing the foot toward the hip
2. grabbing onto the big toe of the front foot on the same side, other hand pressing the back foot toward the hip
Pose Type: seated, backbend, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Parshva Drishti (to the right), Parshva Drishti (to the left)

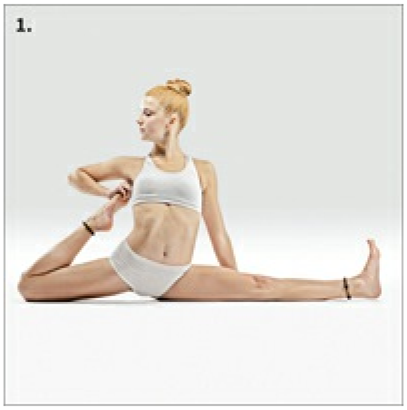

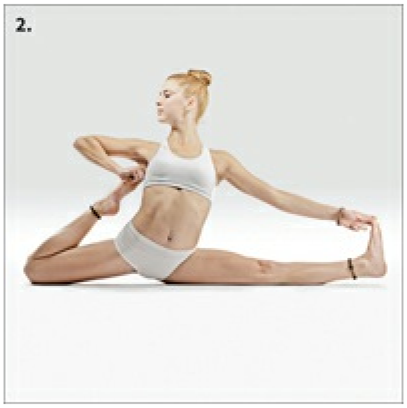

Mermaid Pose 4

Naginyasana 4

(nuh-gin-YAHS-uh-nuh)

Pose Type: seated, backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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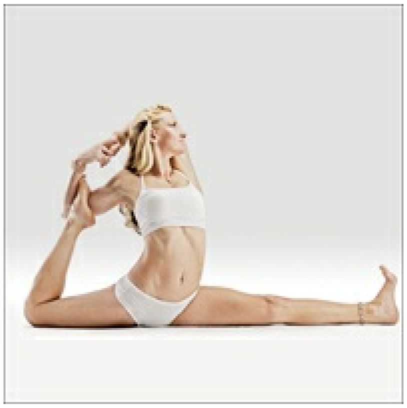

VERTICAL SPLITS: BACK KNEE BENT—OVERHEAD GRIP & FOOT TO THE BACK OF THE HEAD

One-Legged King Pigeon Pose 4

Eka Pada Raja Kapotasana 4

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: one hand grabbing onto the back foot on the same side with overhead grip
Pose Type: seated, backbend
Drishti Point: Hastagrai or Hastagre (hands)
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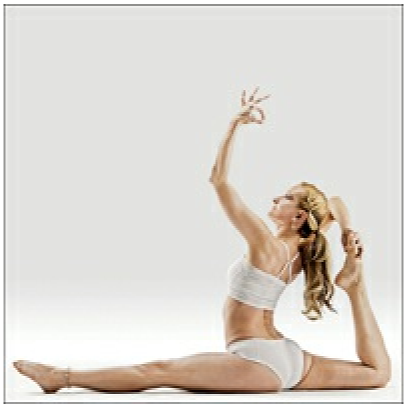

One-Legged King Pigeon Pose 4

Eka Pada Raja Kapotasana 4

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: one hand grabbing onto the back foot on the opposite side with overhead grip, foot reaching toward the head; other hand on the knee of the front leg
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

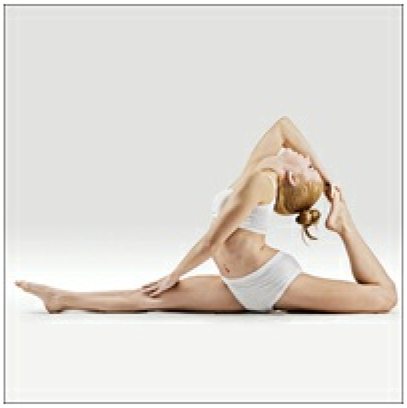

One-Legged King Pigeon Pose 4

Eka Pada Raja Kapotasana 4

(EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Also Known As: One-Legged Stretched Out King Pigeon Pose (Prasarita Pada Raja Kapotasana), Pose of the Lord Kailasha (Kailashasana), Saw Pose A (Kroukachasana A)
Modification: both hands grabbing onto the back foot with overhead grip
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

Foot to the Head One-Legged King Pigeon Pose 4

Shirsha Pada Eka Pada Raja Kapotasana 4

(SHEER-shuh PUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)

Also Known As: Hanuman Salutation Pose (Hanumana Namaskara)
Modification: both arms extended to the sky, back foot to the back of the head
Pose Type: seated, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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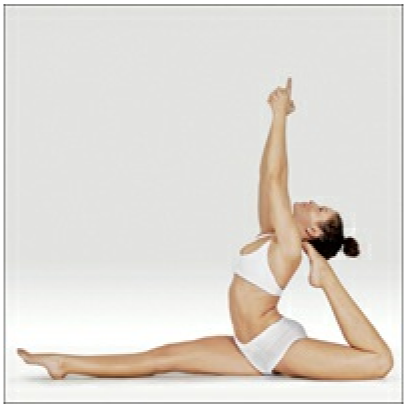

Core Poses

- BOAT POSE
- SIX TRIANGLES POSE
- SUPINE POSES

Easy Boat Pose

Sukha Navasana

(SUK-uh nah-VAHS-uh-nuh)

Modification: knees bent, arms wrapped around the shins
Pose Type: core, seated
Drishti Point: Nasagrai or Nasagre (nose)

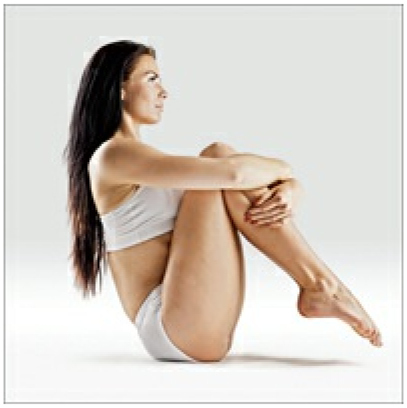

Easy Boat Pose

Sukha Navasana

(SUK-uh nah-VAHS-uh-nuh)

Modification: knees bent, grabbing the back of the thighs, toes touching the floor
Pose Type: core, seated
Drishti Point: Nasagrai or Nasagre (nose)

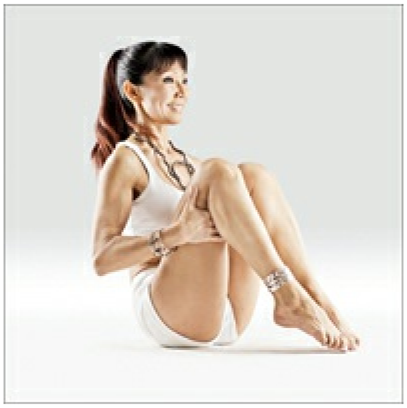

Easy Boat Pose

Sukha Navasana

(SUK-uh nah-VAHS-uh-nuh)

Modification: knees bent, arms wrapped around the back of the thighs, shins parallel to the floor

Pose Type: core, seated

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

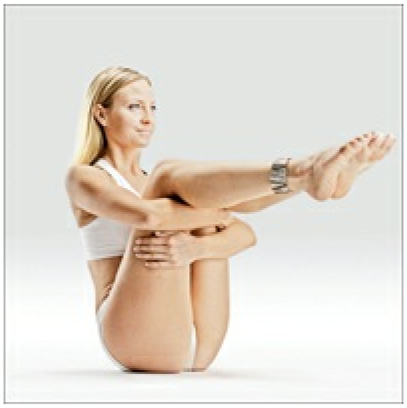

Easy Boat Pose

Sukha Navasana

(SUK-uh nah-VAHS-uh-nuh)

Modification: grabbing onto the heels, toes touching the floor

Pose Type: core, seated

Drishti Point: Nasagrai or Nasagre (nose)

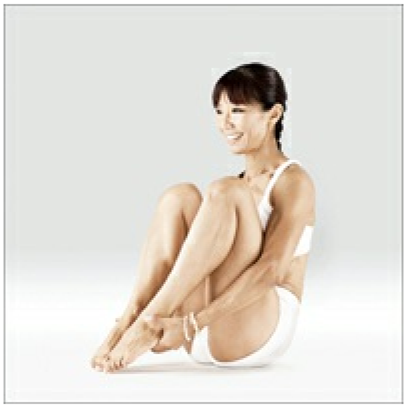

Easy Boat Pose

Sukha Navasana

(SUK-uh nah-VAHS-uh-nuh)

Modification: grabbing onto the outside edges of the feet, shins parallel to the floor

Pose Type: core, seated
Drishti Point: Nasagrai or Nasagre (nose)

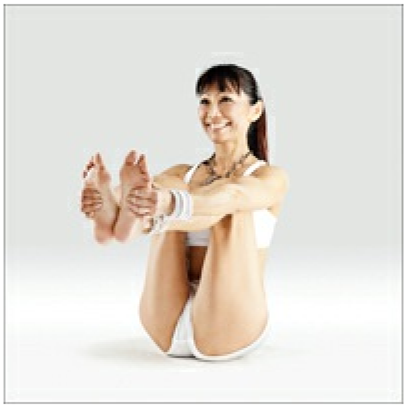

Pendant Pose

Lolasana

(lo-LAHS-uh-nuh)
Modification: knees in front of chest, ankles crossed
Pose Type: core, arm balance
Drishti Point: Nasagrai or Nasagre (nose)

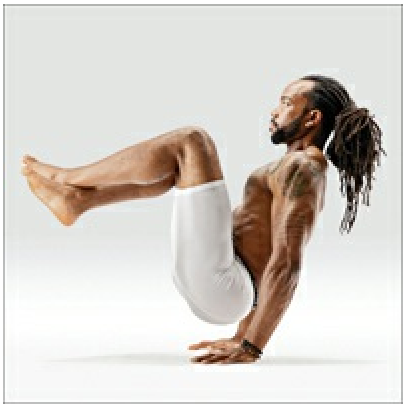

Boat Pose

Navasana

(nah-VAHS-uh-nuh)

Pose Type: core, seated

Drishti Point: Padhayoragrai or Padayoragre (toes/feet)

How to Perform the Pose:

1. Begin by sitting on the floor with both your legs straight out in front of you. Keep your hands on the floor at the sides of your hips for support. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale, bend your knees, and slide your feet toward your sitting bones. Keep your feet and knees together.
3. Inhale as you lengthen your spine. Engage your core and lean back. Make sure your spine is straight and your lower back is off the floor.
4. Exhale and lift your feet off the floor until your shins are parallel to the floor.
5. Once you have your balance, exhale and lift your arms off the floor, keeping them parallel to the floor.
6. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of pose.
7. Inhale as you release the pose by lowering your hands and feet to the floor. Exhale and slide your feet out in front until your legs are straight to come back to the starting position.

Variation: arms straight and parallel to the floor, knees bent, shins parallel to the floor

nava = boat

Easy Boat Pose

Sukha Navasana

(SUK-uh nah-VAHS-uh-nuh)

Modification: knees bent, ankles crossed, arms straight and parallel to the floor
Pose Type: core, seated
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

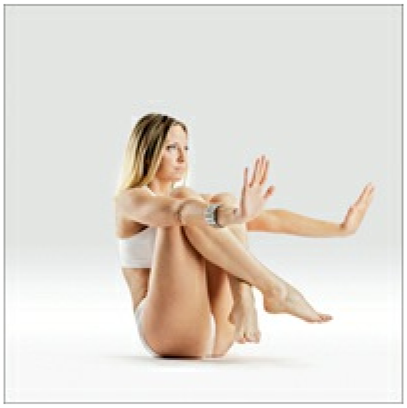

Easy Boat Pose

Sukha Navasana

(SUK-uh nah-VAHS-uh-nuh)

Modification: knees bent, fingertips to the floor, toes touching the floor
Pose Type: core, seated
Drishti Point: Nasagrai or Nasagre (nose)

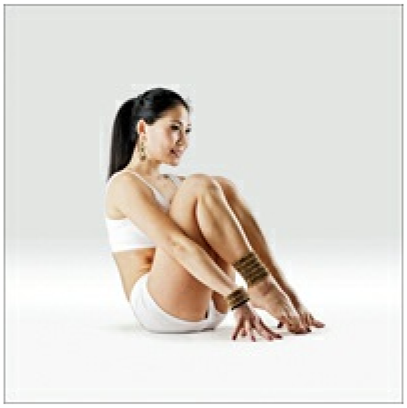

Easy Boat Pose

Sukha Navasana

(SUK-uh nah-VAHS-uh-nuh)

Modification: knees bent, fingertips to the floor, shins parallel to the floor

Pose Type: core, seated

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

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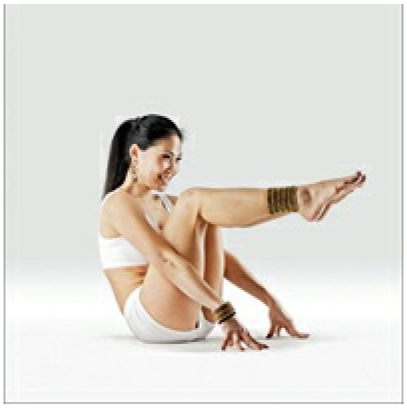

BOAT POSE: BOTH LEGS STRAIGHT

Supported Boat Pose

Salamba Navasana

(SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: palms to the floor behind the hips

1. both legs straight, fingertips pointing toward the hips
2. both legs straight, both arms straight, fingertips pointing to the back

Pose Type: core, seated

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

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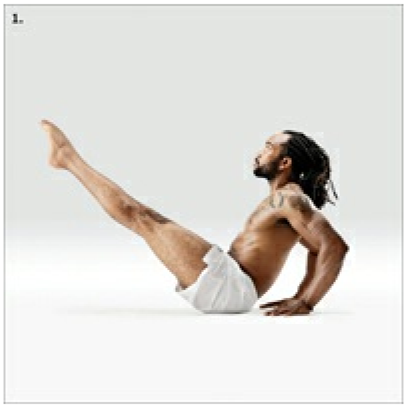

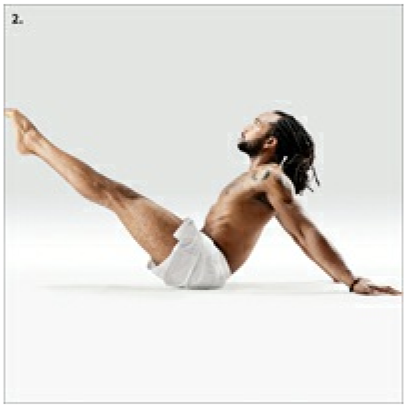

Supported Boat Pose

Salamba Navasana

(SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: both arms wrapped around both legs, legs straight
Pose Type: core, seated
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

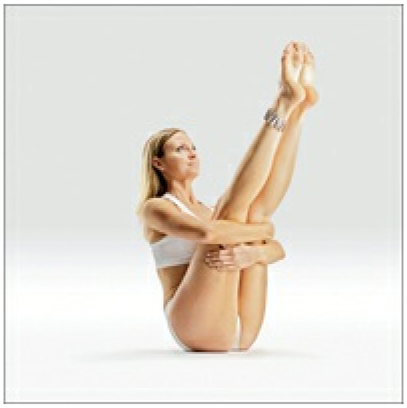

Supported Boat Pose—One-Handed

Eka Hasta Salamba Navasana

(EY-kuh HUH-stuh SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: both legs straight; one arm straight, fingertips to the sky; other arm wrapping behind the ankles of both legs
Pose Type: core, seated
Drishti Point: Urdhva or Antara Drishti (up to the sky) or Hastagrai or Hastagre (hands)

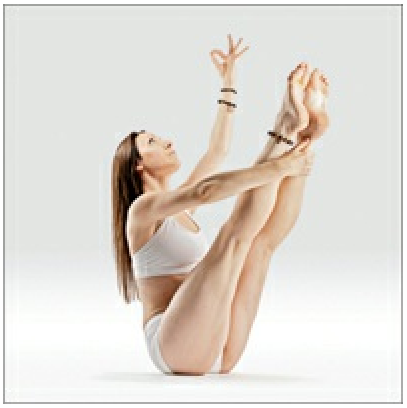

Supported Boat Pose

Salamba Navasana

(SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: fingertips on the floor, pointing to the front
Pose Type: core, seated
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

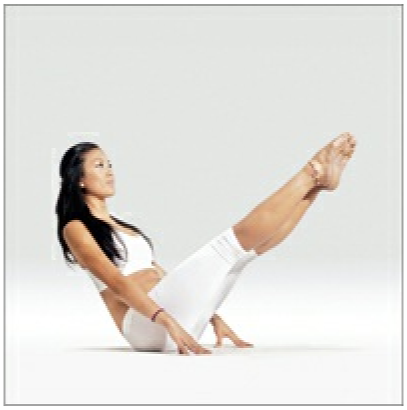

Supported Boat Pose

Salamba Navasana

(SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: grabbing behind the knees, legs straight
Pose Type: core, seated
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

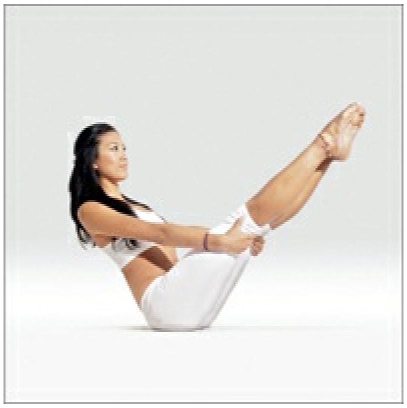

Complete Boat Pose

Paripurna Navasana

(puh-ri-POOR-nuh nah-VAHS-uh-nuh)

Modification: arms straight and parallel to the floor, legs straight
Pose Type: core, seated
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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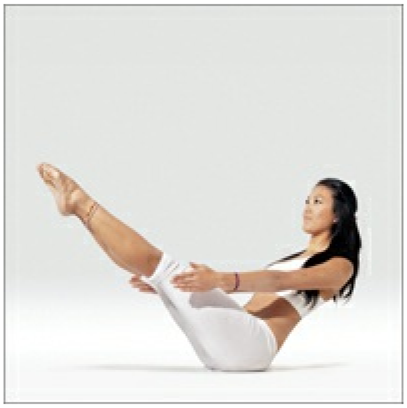

Half Boat Pose

Ardha Navasana

(UHR-duh nah-VAHS-uh-nuh)

Modification: fingers interlocked behind the head
Pose Type: core, seated
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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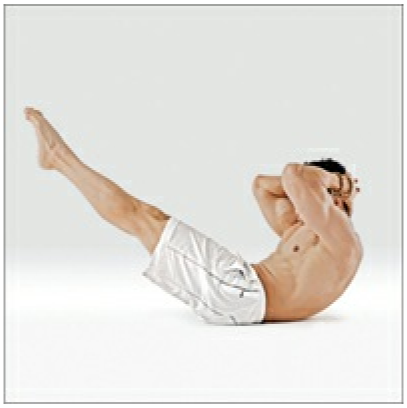

Boat Pose

Navasana

(nah-VAHS-uh-nuh)

Modification: palms and elbows together, elbows bent
Pose Type: core, seated
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

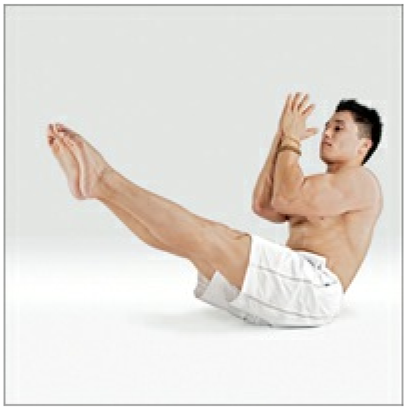

Unsupported Boat Pose

Niralamba Navasana

(nir-AH-luhm-buh nah-VAHS-uh-nuh)

Modification: arms shoulder width apart
Pose Type: core, seated
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

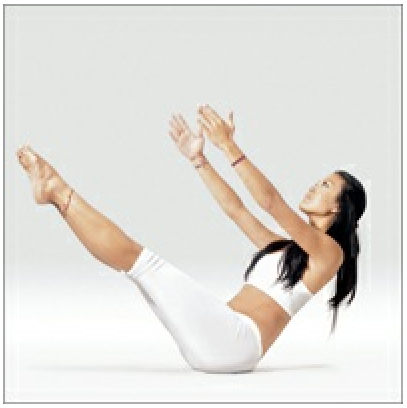

BOAT POSE: TWIST

Revolved Boat Pose with Hands in Prayer

Parivritta Navasana Namaskar

(puh-ri-VRIT-tuh nah-VAHS-uh-nuh nuh-muhs-KAHR)

Pose Type: core, seated, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

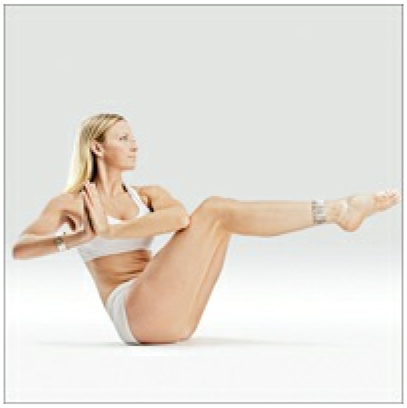

Supported Boat Pose—One-Handed

Eka Hasta Salamba Navasana

(EY-kuh HUH-stuh SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: both legs straight, ankles crossed; one arm straight, palm to the floor behind the hips; other arm wrapping behind the ankles of both legs
Pose Type: core, seated
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

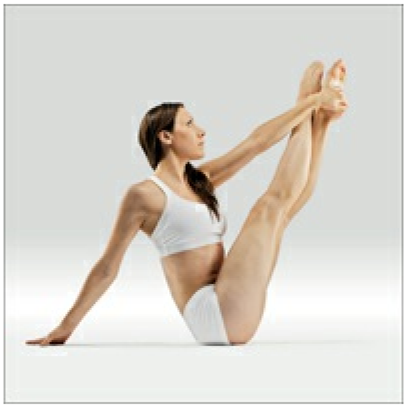

Revolved Supported Boat Pose—One-Handed

Parivritta Eka Hasta Salamba Navasana

(puh-ri-VRIT-tuh EY-kuh HUH-stuh SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: both legs straight, ankles crossed; arms straight, fingertips to the floor behind the hips, one hand grabbing onto the heel
Pose Type: core, seated, twist
Drishti Point: Hastagrai or Hastagre (hands)

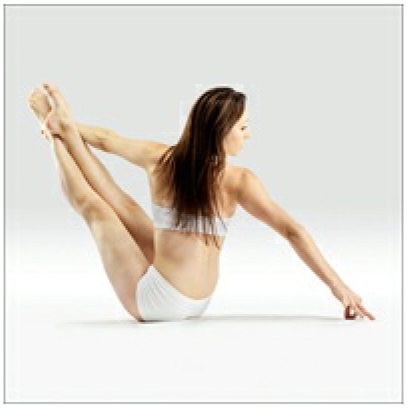

Revolved Supported Boat Pose—One-Handed

Parivritta Eka Hasta Salamba Navasana

(puh-ri-VRIT-tuh EY-kuh HUH-stuh SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: one foot under the knee, other leg straight; one arm threaded under the bent leg, fingertips of the other hand on the floor
Pose Type: core, seated, twist
Drishti Point: Hastagrai or Hastagre (hands)

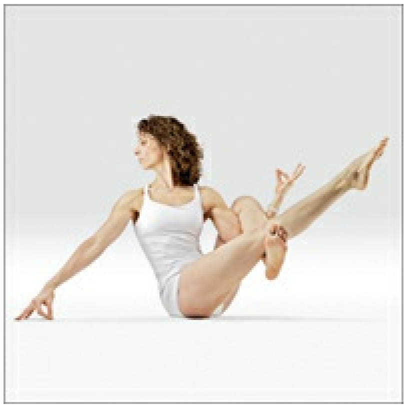

Revolved Supported Boat Pose

Parivritta Salamba Navasana

(puh-ri-VRIT-tuh SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: ankles crossed, legs wrapped around the forearm
Pose Type: core, seated, twist
Drishti Point: Parshva (far to the right), Parshva (far to the left)

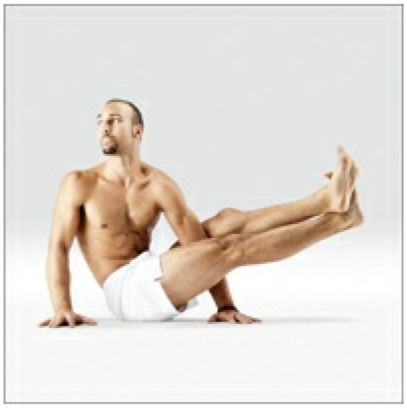

BOAT POSE: TWIST, SCISSOR LEGS

Revolved Boat Pose

Parivritta Navasana

(puh-ri-VRIT-tuh nah-VAHS-uh-nuh)

Modification: one leg over the shoulder, toes of the other leg to the floor
1. front view
2. back view
Pose Type: core, seated, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

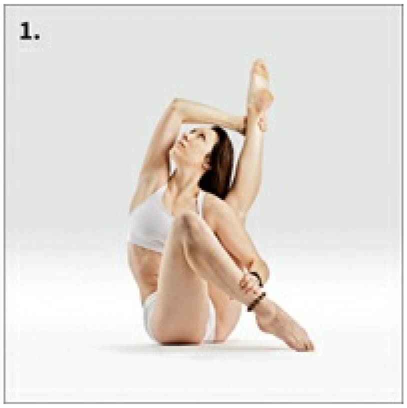

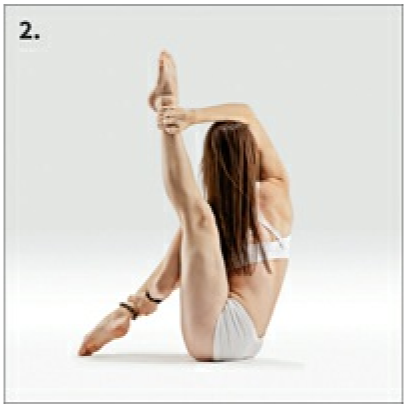

Revolved Boat Pose

Parivritta Navasana

(puh-ri-VRIT-tuh nah-VAHS-uh-nuh)

Modification: one leg over the shoulder, both legs straight
1. front view
2. back view
Pose Type: core, seated, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

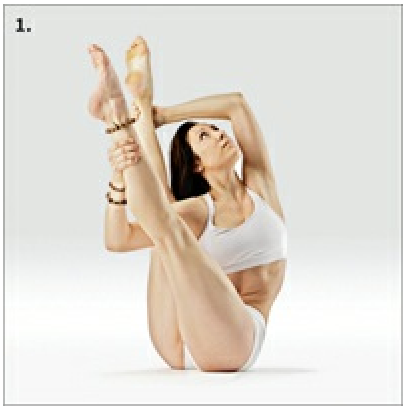

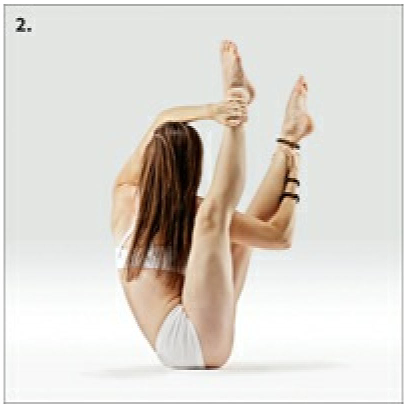

BOAT POSE: ONE LEG STRAIGHT, ONE LEG BENT

One-Legged Supported Boat Pose

Eka Pada Salamba Navasana

(EY-kuh PUH-duh SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: one leg straight, one knee bent and dropped to the side for support
Pose Type: core, seated
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Padayoragrai or Padayoragre (toes/feet)

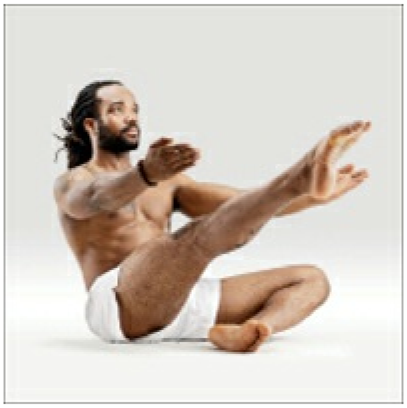

One-Legged Supported Boat Pose

Eka Pada Salamba Navasana

(EY-kuh PUH-duh SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: grabbing onto the back of the thighs for support; one leg straight, one leg bent—toes touching the floor
Pose Type: core, seated
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

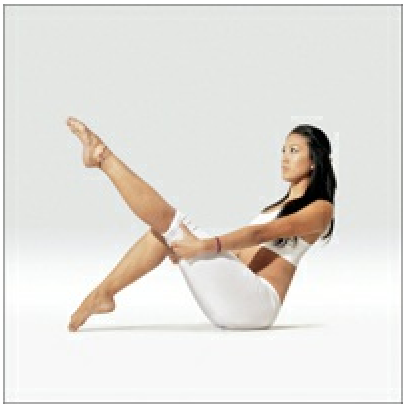

One-Legged Unsupported Boat Pose

Eka Pada Niralamba Navasana

(EY-kuh PUH-duh nir-AH-luhm-buh nah-VAHS-uh-nuh)

Modification: one leg straight; one knee bent toward the chest, foot off the floor
Pose Type: core, seated
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

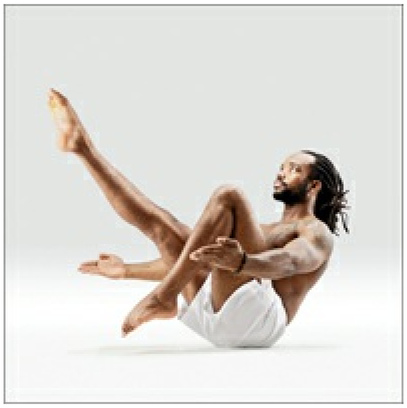

BOAT POSE: SCISSOR LEGS

One-Legged Supported Boat Pose—One-Handed

Eka Pada Eka Hasta Salamba Navasana

(EY-kuh PUH-duh EY-kuh HUH-stuh SAH-luhm-buh nah-VAHS-uh-nuh)

Modification: grabbing the outside edge of the foot with the opposite hand for support, leg straight, other arm up to the sky
1. other leg bent, toes touching the floor
2. other leg straight, foot off the floor
Pose Type: core, seated
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or

Padayoragre (toes/feet)

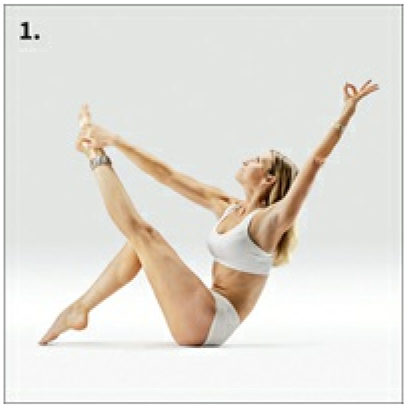

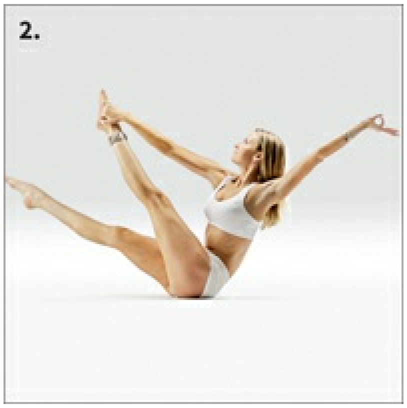

BOAT POSE: ONE FOOT TO KNEE

Upward Half Firelog Western Intense Stretch Pose

Urdhva Ardha Agnistambha Paschimottanasana

(OORD-vuh UHR-duh uhg-ni-STUHM-buh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward Half Firelog Seated Forward Bend

Modification: 1. forehead to the shin
2. forehead away from the shin

Pose Type: core, seated, forward bend

Drishti Point: Nasagrai or Nasagre (nose), Padayoragrai or Padayoragre (toes/feet)

1.

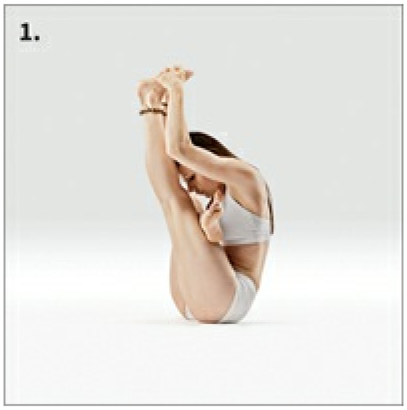

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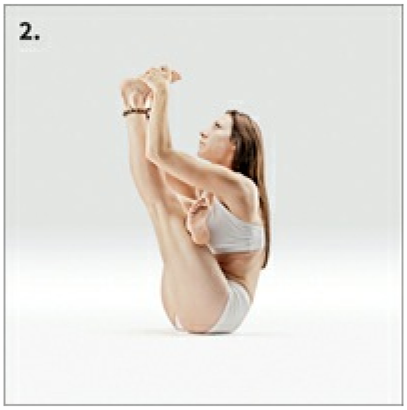

Baby Cradle Pose in Boat Pose

Hindolasana in Navasana

(hin-do-LAHS-uh-nuh in nah-VAHS-uh-nuh)

Modification: foot of the bent leg to the back of the knee of the straight leg
Pose Type: core, seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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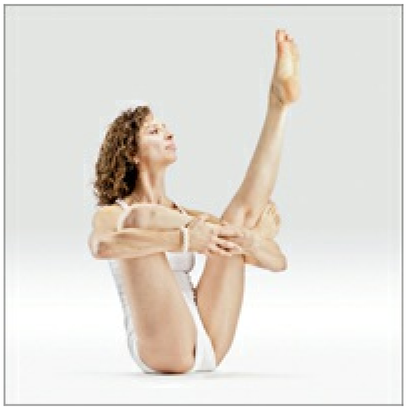

Revolved Yogic Staff Boat Pose

Parivritta Yogadanda Navasana

(puh-ri-VRIT-tuh yo-guh-DUHN-duh nah-VAHS-uh-nuh)

Modification: both knees bent; one arm behind the back, grabbing onto the ankle; other arm grabbing the outside edge of the foot

Pose Type: core, seated, twist, binding

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

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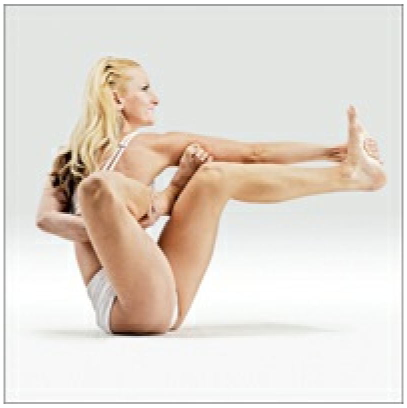

Revolved Bound Yogic Staff Boat Pose

Parivritta Baddha Yogadanda Navasana

(puh-ri-VRIT-tuh BUH-duh yo-guh-DUHN-duh nah-VAHS-uh-nuh)

Modification: binding around the straight leg

Pose Type: core, seated, twist, binding

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

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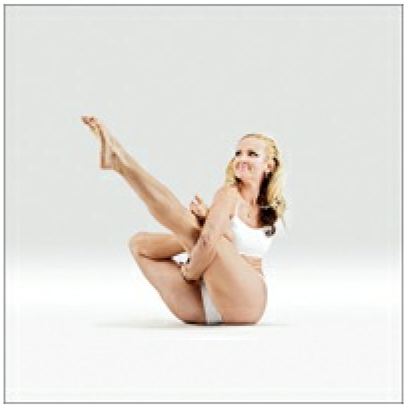

Revolved Yogic Staff Boat Pose

Parivritta Yogadanda Navasana

(puh-ri-VRIT-tuh yo-guh-DUHN-duh nah-VAHS-uh-nuh)

Modification: foot to the triceps; one arm grabbing onto the heel of the straight leg, other arm open to

the side
Pose Type: core, seated, twist
Drishti Point: Hastagrai or Hastagre (hands)

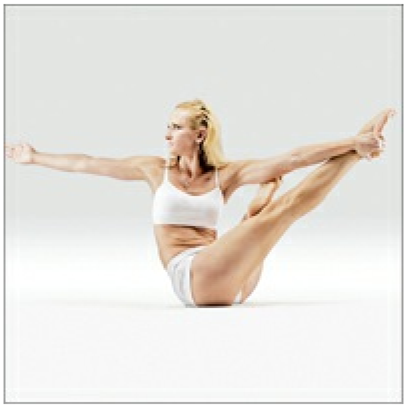

BOAT POSE: ONE FOOT TO HIP SOCKET

Upward One-Legged Half Lotus Western Intense Stretch Pose

Urdhva Eka Pada Ardha Padma Paschimottanasana

(OORD-vuh EY-kuh PUH-duh UHR-duh PUHD-muh puhsh-chi-mo-tahn-AHS-uh-nuh)
Also Known As: Upward One-Legged Half Lotus Seated Forward Bend
Modification: one hand grabbing onto the big toe, one hand on the hip
Pose Type: core, seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

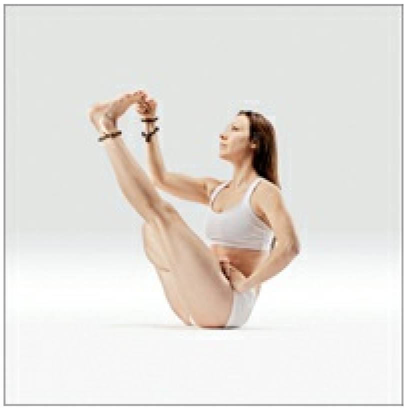

Upward One-Legged Half Bound Lotus Western Intense Stretch Pose

Urdhva Eka Pada Ardha Baddha Padma Paschimottanasana

(OORD-vuh EY-kuh PUH-duh UHR-duh BUH-duh PUHD-muh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward One-Legged Half Bound Lotus Seated Forward Bend
Pose Type: core, seated, forward bend, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

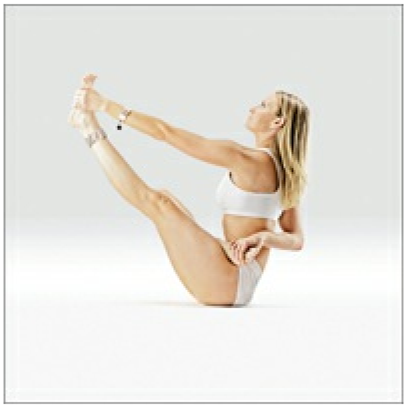

Upward One-Legged Half Bound Lotus Western Intense Stretch Pose

Urdhva Eka Pada Ardha Baddha Padma Paschimottanasana

(OORD-vuh EY-kuh PUH-duh UHR-duh BUH-duh PUHD-muh puhsh-chi-mo-tahn-AHS-uh-nuh)
Also Known As: Upward One-Legged Half Bound Lotus Seated Forward Bend
Modification: grabbing onto the foot, hand between the calf muscle and the hamstring
Pose Type: core, seated, forward bend, binding
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

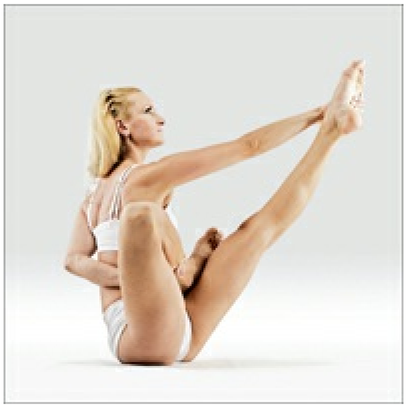

Upward One-Legged Half Lotus Western Intense Stretch Pose

Urdhva Eka Pada Ardha Padma Paschimottanasana

(OORD-vuh EY-kuh PUH-duh UHR-duh PUHD-muh puhsh-chi-mo-tahn-AHS-uh-nuh)
Also Known As: Upward One-Legged Half Lotus Seated Forward Bend
Modification: 1. grabbing onto the wrist, hands over the foot

2. grabbing onto the foot, nose to the shin
Pose Type: core, seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet) or Nasagrai or Nasagre (nose)

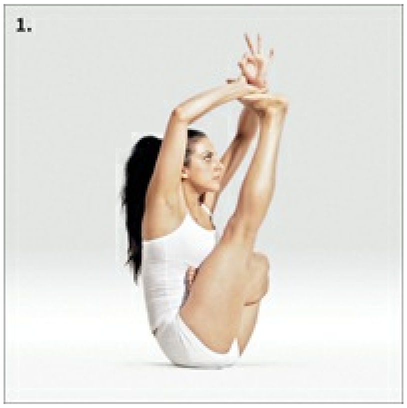

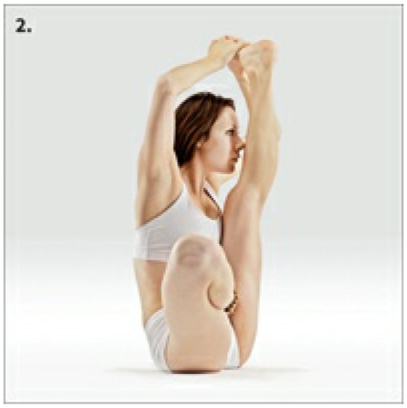

BOAT POSE: GRABBING ONTO FEET/TOES

Big Toes Pose

Ubhaya Padangusthasana

(u-beye-uh puhd-ahng-goosh-TAHS-uh-nuh)
Modification: grabbing onto the big toes, toes flexed in
Pose Type: core, seated
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

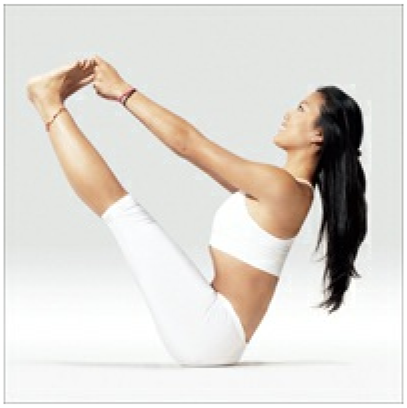

Upward Facing Western Intense Stretch

Urdhva Mukha Paschimottanasana

(OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward Facing Seated Forward Bend
Modification: grabbing onto the heels, arms straight
Pose Type: core, seated, forward bend, quadriceps to the chest
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

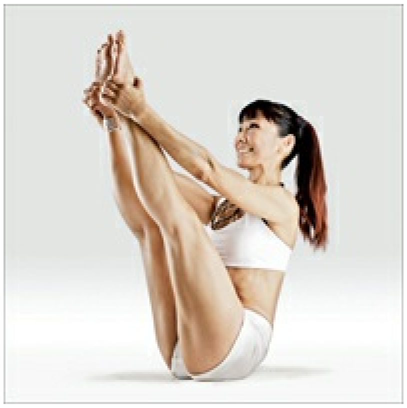

Upward Facing Western Intense Stretch

Urdhva Mukha Paschimottanasana

(OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward Facing Seated Forward Bend
Modification: grabbing onto the heels
1. forehead away from the shins
2. forehead to the shins
Pose Type: core, seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

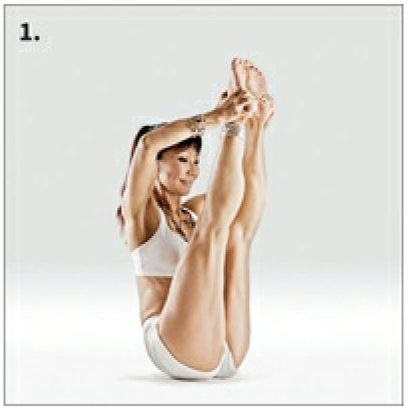
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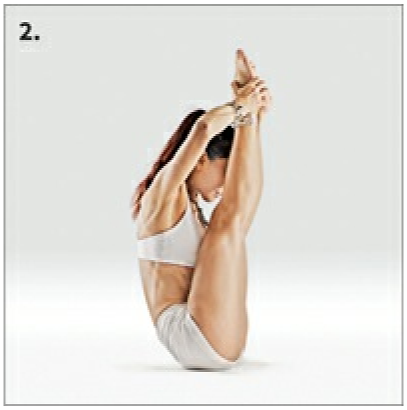
2.

Upward Facing Supported Western Intense Stretch

Urdhva Mukha Salamba Paschimottanasana

(OORD-vuh MUK-uh SAH-luhm-buh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward Facing Seated Forward Bend

Modification: arms reaching to the front, fingertips to the floor, 1. forehead away from the shins 2. forehead to the shins

Pose Type: core, seated, forward bend

Drishti Point: Padayoragrai or Padayoragre (toes/feet) or Nasagrai or Nasagre (nose)

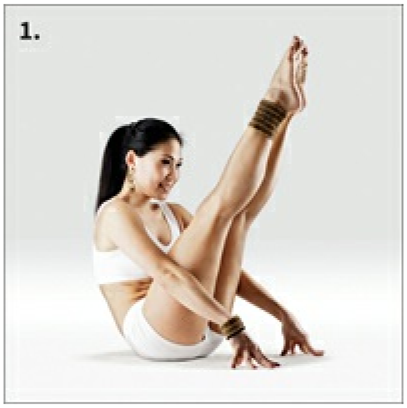
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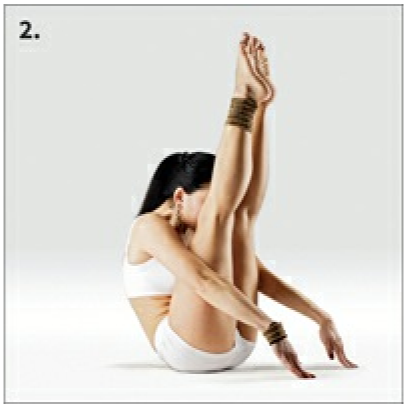

Bound Hands Upward Facing Western Intense Stretch

Baddha Hasta Urdhva Mukha Paschimottanasana

(BUH-duh HUH-stuh OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Bound Hands Upward Facing Seated Forward Bend
Pose Type: core, seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

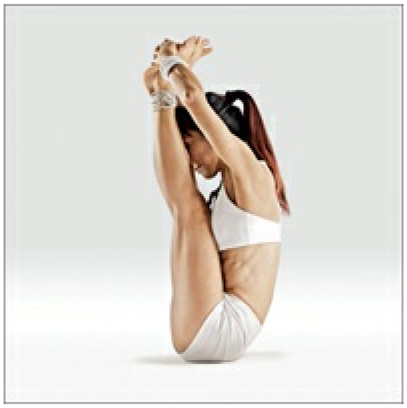

Upward Facing Western Intense Stretch

Urdhva Mukha Paschimottanasana

(OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward Facing Seated Forward Bend
Modification: grabbing onto the ankles, forehead to the shins
Pose Type: core, seated, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

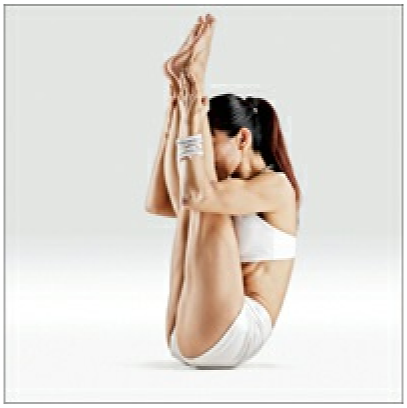

Upward Facing Western Intense Stretch

Urdhva Mukha Paschimottanasana

(OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward Facing Seated Forward Bend
Modification: grabbing onto the outside edges of the feet, feet hip distance apart, toes pointed
Pose Type: core, seated, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

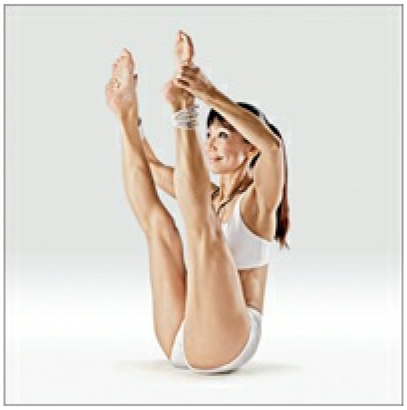

ARM BALANCE: SITTING BONES & FEET OFF THE FLOOR

Celibate Pose

Brahmacharyasana

(bruh-muh-chahr-YAHS-uh-nuh)

Also Known As: Lifted Up Staff Pose (Dandasana Utpluti)
Modification: fingers to the floor, thumbs pointing to the back
Pose Type: core, arm balance
Drishti Point: Nasagrai or Nasagre (nose)

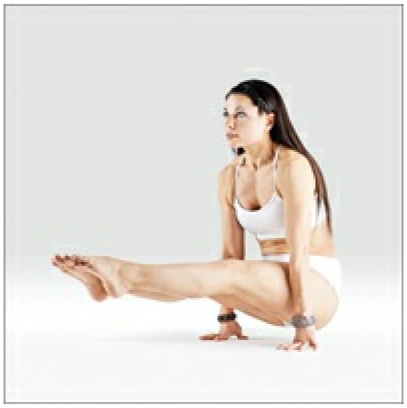

SIX TRIANGLES POSE

Six Triangles Pose

Shatkonasana

(shuht-ko-NAHS-uh-nuh)

Modification: top foot on the bottom knee
1. fingertips to the temples
2. one forearm to the floor, other arm wrapped around the top knee
3. fingertips to the temples, elbow toward the top knee
4. one elbow to the floor, other elbow to the top knee on the same side

Pose Type: core, seated, twist

Drishti Point: 1. Urdhva or Antara Drishti (up to the sky)
2. Nasagrai or Nasagre (nose)
3. Nasagrai or Nasagre (nose)
4. Hastagrai or Hastagre (hands)

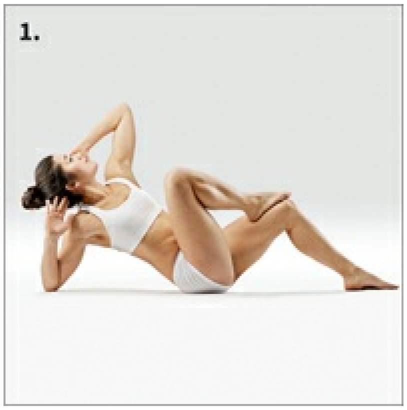

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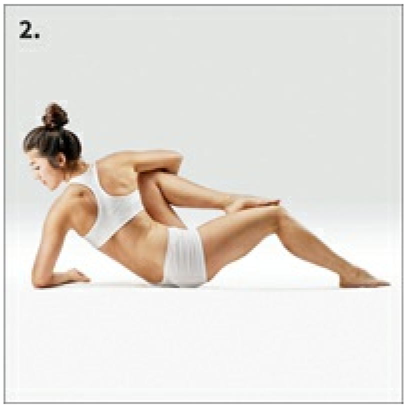

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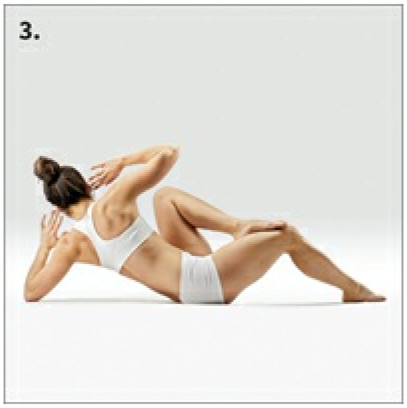

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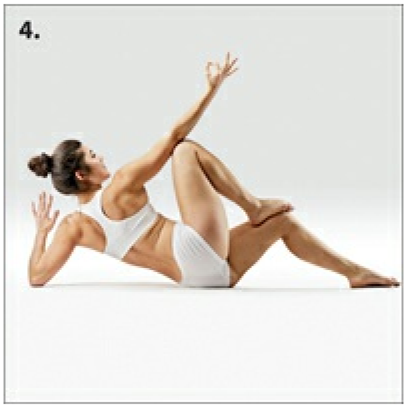

[SUPINE: ONE LEG STRAIGHT, ONE LEG BENT](#)

Half Wind Relieving Pose

Ardha Vayu Muktyasana

(UHR-duh VAH-yu muk-TYAHS-uh-nuh)

Also Known As: Wind-Relieving Pose (Pavana Muktasana)
Pose Type: core, supine
Drishti Point: Nasagrai or Nasagre (nose)
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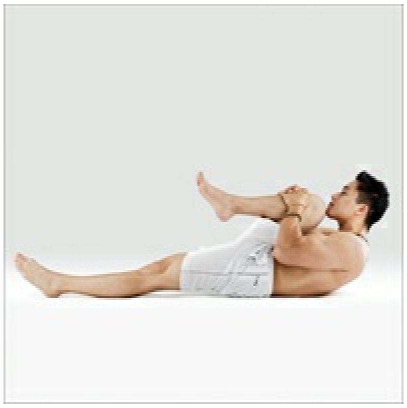

Revolved Half Wind Relieving Pose

Parivritta Ardha Vayu Muktyasana

(puh-ri-VRIT-tuh UHR-duh VAH-yu muk-TYAHS-uh-nuh)

Modification: one knee bent, one leg straight
Pose Type: core, supine, twist
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye (third eye, between the eyebrows)

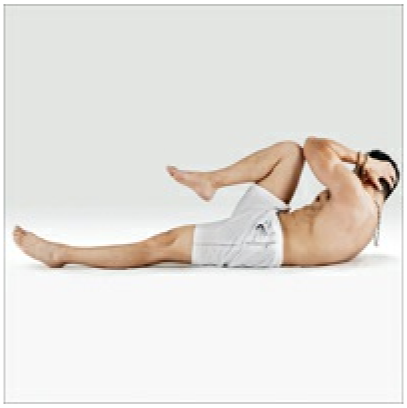

SUPINE: BOTH LEGS STRAIGHT "SCISSORS"

One-Legged Upward Extended Legs Pose

Eka Pada Urdhva Prasarita Padasana

(EY-kuh PUH-duh OORD-vuh pruh-SAH-ri-tuh puh-DAHS-uh-nuh)

Modification: 1. one arm extended to sky, other palm to the floor, head on the floor
2. one arm extended to sky, other palm to the floor, head and shoulders off the floor
3. fingers interlocked behind the back of the head, head and shoulders off the floor
Pose Type: core, supine
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

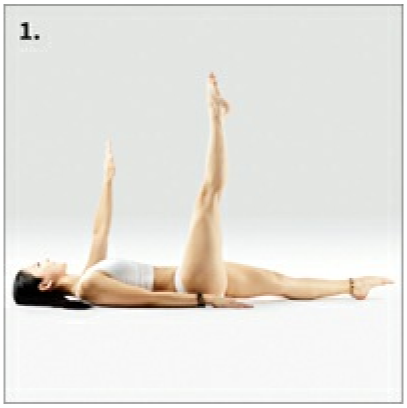
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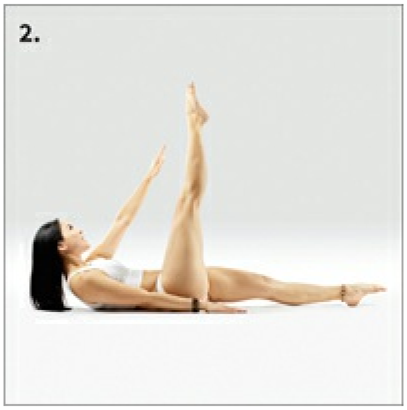
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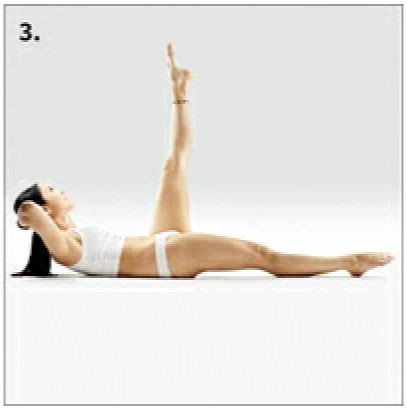
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SUPINE: BOTH LEGS STRAIGHT

Abdominal Lift Pose

Jatharasana

(jah-tuh-RAHS-uh-nuh)

Modification: head on the floor, palms down by the hips
Pose Type: core, supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

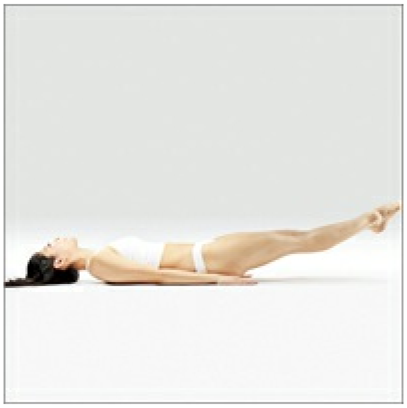

Upward Extended Legs Pose

Urdhva Prasarita Padasana

(OORD-vuh pruh-SAH-ri-tuh puh-DAHS-uh-nuh)

Pose Type: core, supine

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

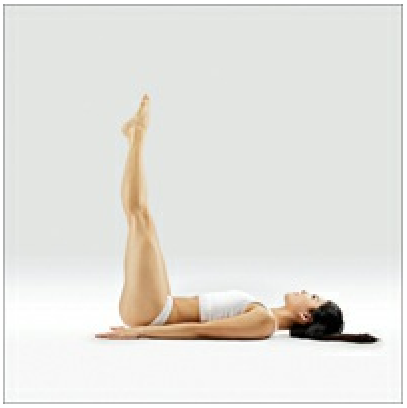

Abdominal Lift Pose

Jatharasana

(jah-tuh-RAHS-uh-nuh)

Modification: head and shoulders off the floor, feet off the floor

Pose Type: core, supine

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

SUPINE: BOTH LEGS STRAIGHT

Two-Legged Abdominal Lift Upward Extended Legs Pose

Dwi Pada Jathara Urdhva Prasarita Padasana

(DWI-puh-duh JAH-tuh-ruh OORD-vuh pruh-SAH-ri-tuh puh-DAHS-uh-nuh)

Modification: with a yoga block

Pose Type: core, supine

Drishti Point: Urdhva or Antara Drishti (up to the sky), Padayoragrai or Padayoragre (toes/feet)

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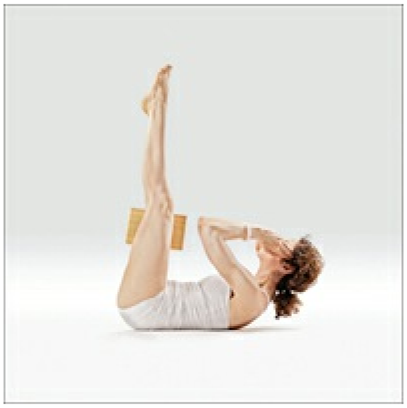

Abdominal Lift Upward Facing Western Intense Stretch

Jathara Urdhva Mukha Paschimottanasana

(JAH-tuh-ruh OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Abdominal Lift Upward Forward Bend

Modification: head lifted off the floor, forehead to the shins

Pose Type: core, supine

Drishti Point: Nasagrai or Nasagre (nose)

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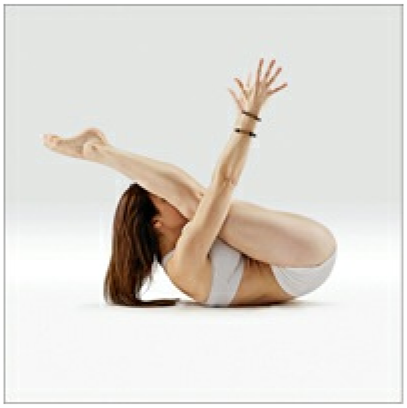

Abdominal Lift Upward Facing Western Intense Stretch

Jathara Urdhva Mukha Paschimottanasana

(JAH-tuh-ruh OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Abdominal Lift Upward Forward Bend
Modification: head lifted off the floor, legs crossed modification
Pose Type: core, supine
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

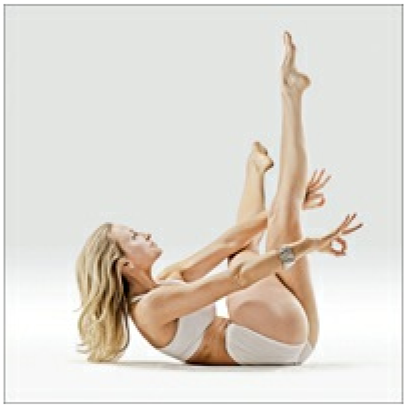

SUPINE: ONE LEG STRAIGHT, ONE KNEE BENT

Revolved Stomach One Leg Extended Pose

Parivritta Jathara Utthita Eka Padasana

(puh-ri-VRIT-tuh JAH-tuh-tuh UT-ti-tuh EY-kuh puh-DAHS-uh-nuh)

Modification: foot to the elbow
Pose Type: core, supine, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

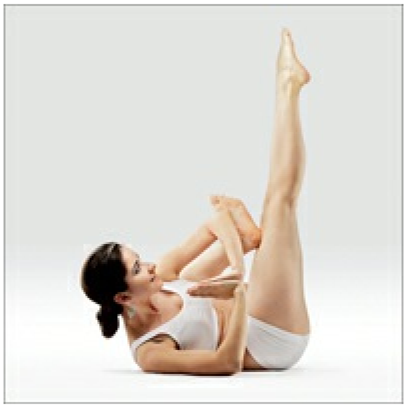

SUPINE: GARUDA LEGS ON THE BACK

Reclining Abdominal Lift Pose Dedicated to Garuda

Supta Jathara Garudasana

(SUP-tuh JAH-tuh-ruh guh-ru-DAHS-uh-nuh)

Pose Type: core, supine

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

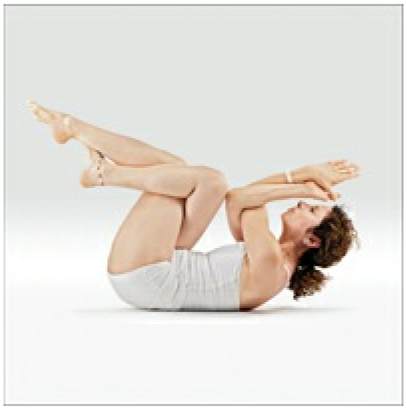

Reclining Abdominal Lift Pose Dedicated to Garuda

Supta Jathara Garudasana

(SUP-tuh JAH-tuh-ruh guh-ru-DAHS-uh-nuh)

Modification: fingers to the temples, elbows to the knees

Pose Type: core, supine

Drishti Point: Urdhva or Antara Drishti (up to the sky), Padayoragrai or Padayoragre (toes/feet)

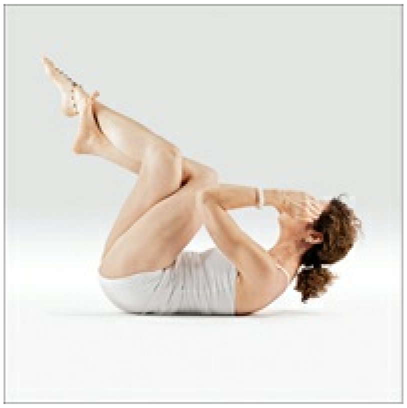

Abdominal Lift Pose Dedicated to Garuda

Jathara Garudasana

(JAH-tuh-ruh guh-ru-DAHS-uh-nuh)

Modification: palms to the floor, arms straight, sitting bones lifted off the floor
Pose Type: core, supine
Drishti Point: Urdhva or Antara Drishti (up to the sky), Padayoragrai or Padayoragre (toes/feet)

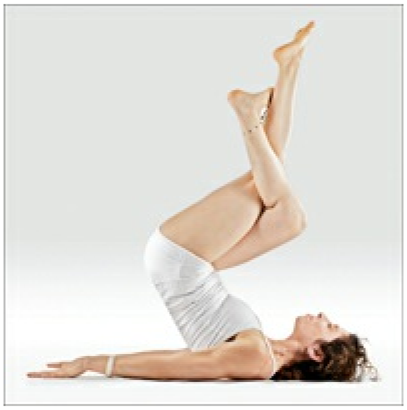

Revolved Stomach Reclining Pose Dedicated to Garuda

Parivritta Jathara Supta Garudasana

(puh-ri-VRIT-tuh JAH-tuh-ruh SUP-tuh guh-ru-DAHS-uh-nuh)

Modification: fingers to the temples, elbows out to the sides
Pose Type: core, supine, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

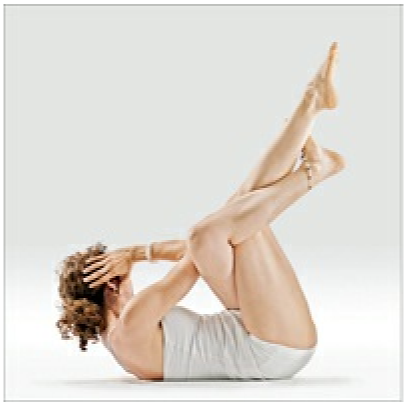

SUPINE: FULL LOTUS

Reclining Abdominal Lift Lotus Pose

Supta Jathara Padmasana

(SUP-tuh JAH-tuh-ruh puhd-MAHS-uh-nuh)

Modification: fingers to the temples, knees up to the sky
Pose Type: core, supine
Drishti Point: Nasagrai or Nasagre (nose)
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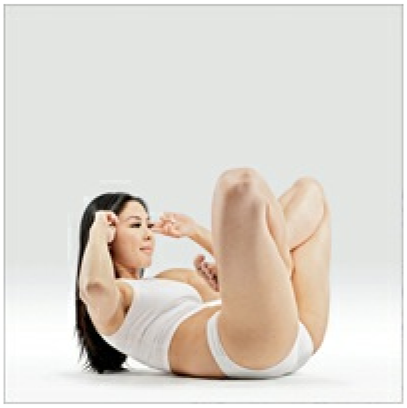

Revolved Stomach Reclining Lotus Pose

Parivritta Jathara Supta Padmasana

(puh-ri-VRIT-tuh JAH-tuh-ruh SUP-tuh puhd-MAHS-uh-nuh)

Modification: fingers to the temples, elbows out to the sides
1. back view
2. front view
Pose Type: core, supine, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

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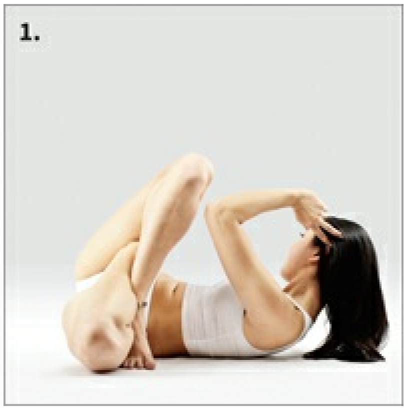

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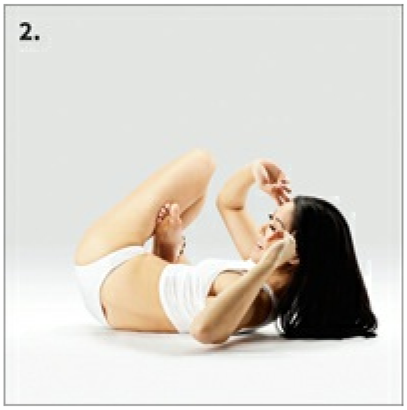

Abdominal Lift Lotus Pose

Jathara Padmasana

(JAH-tuh-tuh puhd-MAHS-uh-nuh)

Modification: palms on the floor, arms straight, sitting bones lifted off the floor
Pose Type: core, supine
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

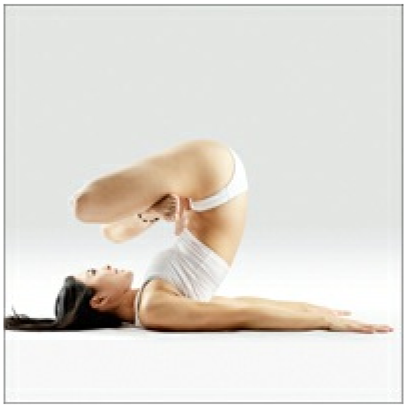

Unsupported Abdominal Lift Lotus Pose

Niralamba Jathara Padmasana

(nir-AH-luhm-buh JAH-tuh-tuh puhd-MAHS-uh-nuh)

Modification: arms extended in front, knees to the forearms

Pose Type: core, supine

Drishti Point: Nasagrai or Nasagre (nose)

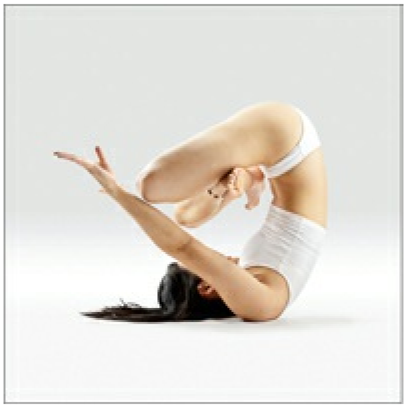

Quadruped Poses

CHILD’S POSE

RABBIT POSE

COW POSE

ALL FOURS (VARIATIONS)

PLANK POSE

PLANK ON FOREARMS

FOUR LIMBED STAFF POSE

SIDE PLANK

CHILD’S POSE

Child’s Pose

Balasana

(bah-LAHS-uh-nuh)

Also Known As: Child’s Pose (Garbhasana)
Modification: arms extended to the back, palms up; toes pointed to the back
Pose Type: forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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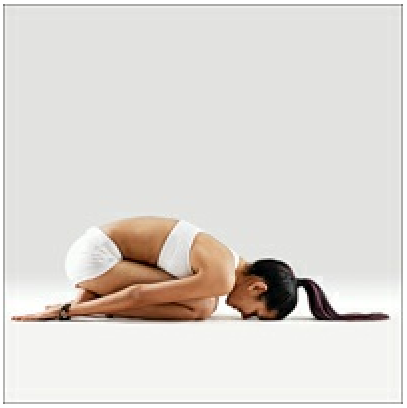

Child’s Pose

Balasana

(bah-LAHS-uh-nuh)

Also Known As: Child’s Pose (Garbhasana)
Modification: arms extended to the front, palms down; toes pointed to the back
Pose Type: forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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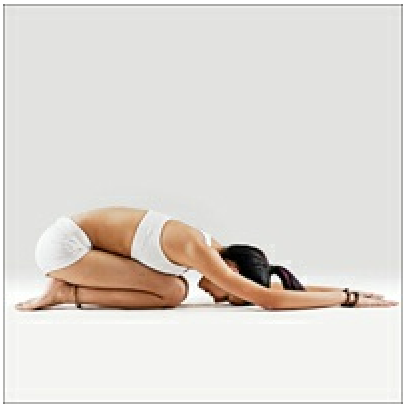

Child’s Pose

Balasana

(bah-LAHS-uh-nuh)

Modification: arms extended to the front, palms down; toes curled in
Pose Type: forward bend
Drishti Point: Nasagrai or Nasagre (nose)

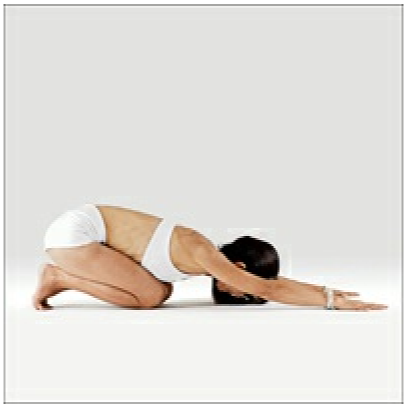

Hands to the Side Child’s Pose

Parshva Hasta Balasana

(PAHRSH-vuh HUH-stuh bah-LAHS-uh-nuh)

Pose Type: forward bend, side bend
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

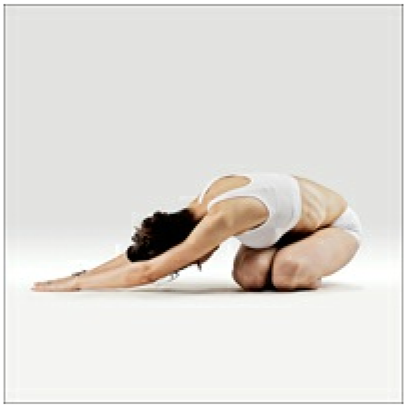

Hand Position of the Pose Dedicated to Garuda in Child’s Pose

Hasta Garudasana in Balasana

(HUH-stuh guh-ru-DAHS-uh-nuh in bah-LAHS-uh-nuh)

Pose Type: forward bend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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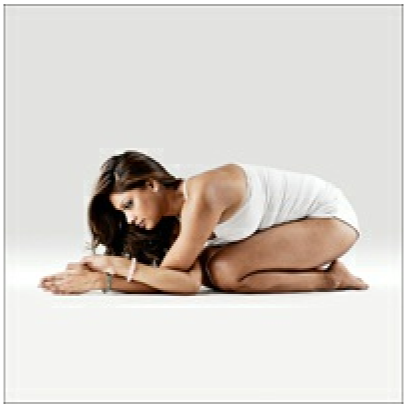

Child’s Pose

Balasana

(bah-LAHS-uh-nuh)

Modification: knees open wide; palms pressed together, fingers spread wide, thumbs to the upper back

Pose Type: forward bend, mild backbend

Drishti Point: Nasagrai or Nasagre (nose)

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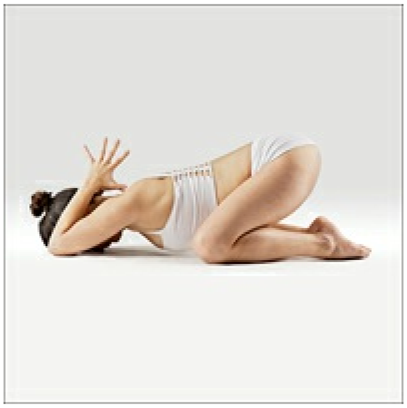

CHILD’S POSE: TWISTS

Revolved Side Child’s Pose

Parivritta Parshva Balasana

(puh-ri-VRIT-tuh PAHRSH-vuh bah-LAHS-uh-nuh)

Pose Type: forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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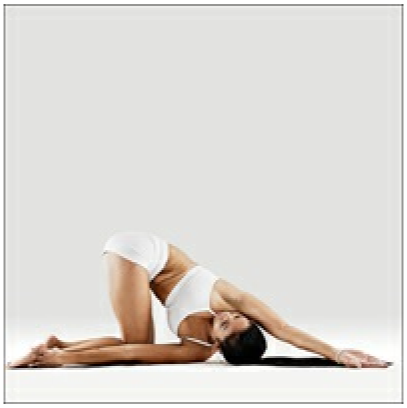

Both Hands to Legs Bound Revolved Child’s Pose

Dwi Hasta Pada Baddha Parivritta Balasana

(DWI-huh-stuh PUH-duh BUH-duh puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Pose Type: forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)
● ●

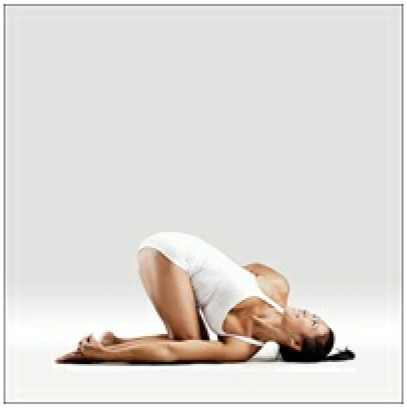

Leg Position of the Pose Dedicated to Garuda in Revolved Child’s Pose

Pada Garudasana in Parivritta Balasana

(PUH-duh guh-ru-DAHS-uh-nuh in puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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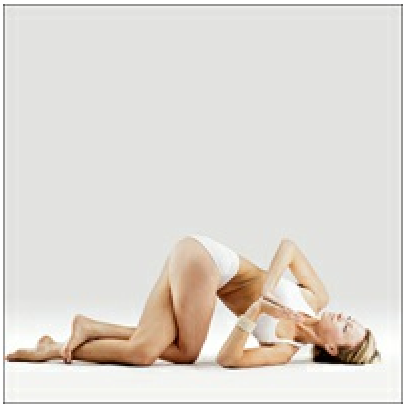

Revolved Child’s Pose

Parivritta Balasana

(puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Also Known As: Turned Child’s Pose (Parshva Balasana)
Modification: bottom arm straight out to the side; top arm bent at 90 degrees, palm to the floor overhead
Pose Type: forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

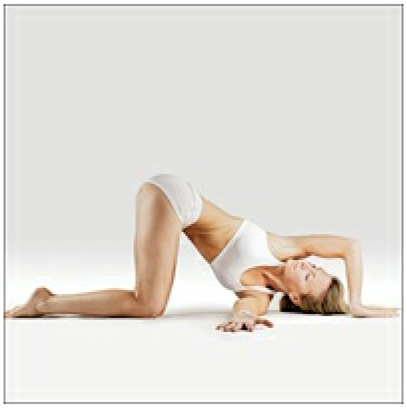

One Hand Bound Revolved Child’s Pose

Eka Hasta Baddha Parivritta Balasana

(EY-kuh HUH-stuh BUH-duh puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Modification: grabbing onto the quadricep
Pose Type: forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

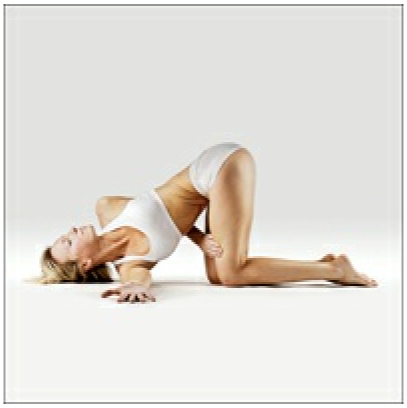

CHILD’S POSE: TWISTS & HALF LOTUS BINDING

Hand to Foot Revolved Side Child’s Pose

Hasta Pada Parivritta Parshva Balasana

(HUH-stuh PUH-duh puh-ri-VRIT-tuh PAHRSH-vuh bah-LAHS-uh-nuh)

Modification: foot resting on the back of the knee
Pose Type: forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

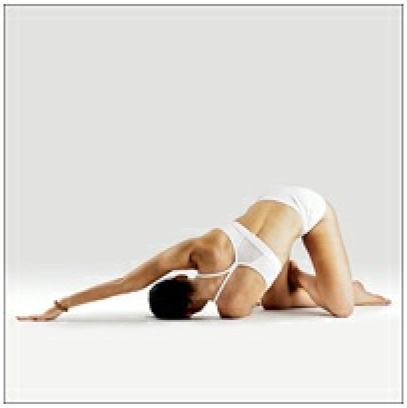

Both Hands to Feet Half Bound Lotus Revolved Child’s Pose

Dwi Hasta Pada Ardha Baddha Padma Parivritta Balasana

(DWI-huh-stuh PUH-duh UHR-duh BUH-duh PUHD-muh puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Pose Type: forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

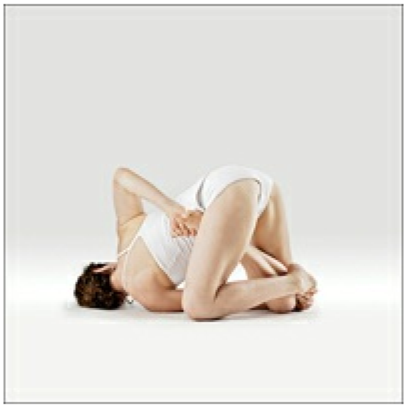

Half Bound Lotus Revolved Child’s Pose

Ardha Baddha Padma Parivritta Balasana

(UHR-duh BUH-duh PUHD-muh puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Modification: torso twisting to the outside of the body, hand binding to the foot
Pose Type: forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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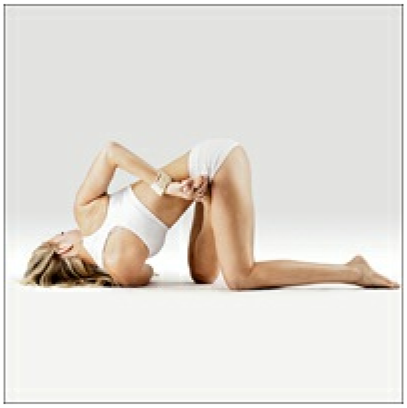

Half Bound Lotus Revolved Child’s Pose

Ardha Baddha Padma Parivritta Balasana

(UHR-duh BUH-duh PUHD-muh puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Modification: torso twisting to the inside of the body, hand binding to the shin
Pose Type: forward bend, twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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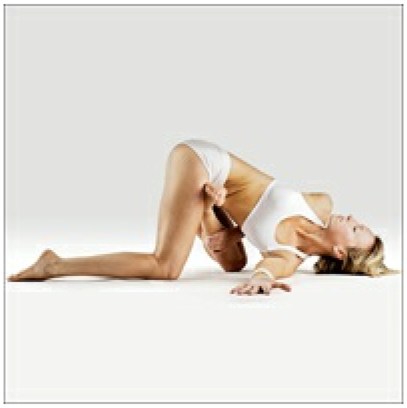

CHILD'S POSE: TWISTS—ONE-LEGGED—BACK FOOT IN THE AIR

Equilibrium One-Legged Revolved Child's Pose with Hands in Prayer

Tulya Eka Pada Parivritta Balasana Namaskar

(TUL-yuh EY-kuh PUH-duh puh-ri-VRIT-tuh bah-LAHS-uh-nuh nuh-muhs-KAHR)

Modification: knee of the top leg bent
Pose Type: forward bend, twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

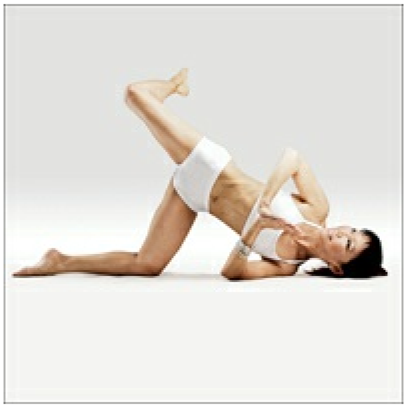

Half Bow Pose in Equilibrium One-Legged Revolved Child's Pose

Ardha Dhanurasana in Tulya Eka Pada Parivritta Balasana

(UHR-duh duh-nur-AHS-uh-nuh in TUL-yuh EY-kuh PUH-duh puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Pose Type: forward bend, twist, backbend
Drishti Point: Hastagrai or Hastagre (hands)

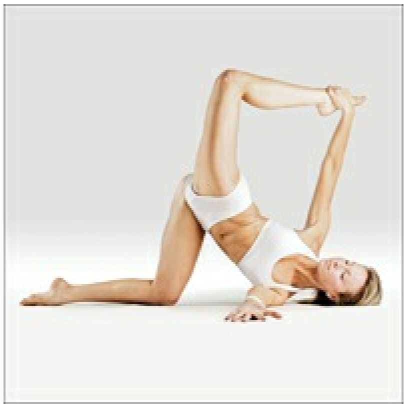

Revolved Half Bow Pose in Equilibrium One-Legged Revolved Child’s Pose

Parivritta Ardha Dhanurasana in Tulya Eka Pada Parivritta Balasana

(puh-ri-VRIT-tuh UHR-duh duh-nur-AHS-uh-nuh in TUL-yuh EY-kuh PUH-duh puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Pose Type: forward bend, twist, backbend

Drishti Point: Hastagrai or Hastagre (hands)

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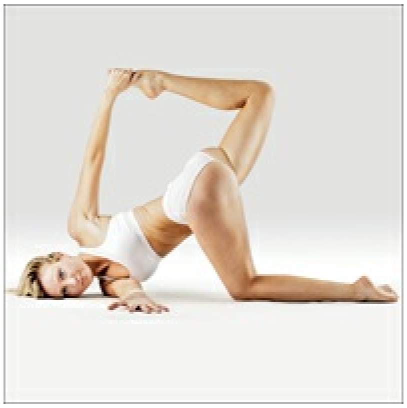

Half Bow Pose in Equilibrium One-Legged Revolved Child’s Pose

Ardha Dhanurasana in Tulya Eka Pada Parivritta Balasana

(UHR-duh duh-nur-AHS-uh-nuh in TUL-yuh EY-kuh PUH-duh puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Modification: back heel toward the sitting bone

Pose Type: forward bend, twist, backbend

Drishti Point: Hastagrai or Hastagre (hands)

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Equilibrium One-Legged Revolved Child’s Pose

Tulya Eka Pada Parivritta Balasana

(TUL-yuh EY-kuh PUH-duh puh-ri-VRIT-tuh bah-LAHS-uh-nuh)

Modification: one leg straight, other knee bent, heel toward the sitting bone
Pose Type: forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

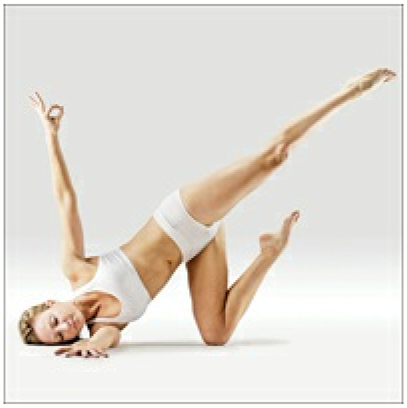

Hands Bound

Rabbit Pose

Baddha Hasta Sasangasana

(BUH-duh HUH-stuh shuh-shahng-AHS-uh-nuh)

Pose Type: forward bend

Drishti Point: Nasagrai or Nasagre (nose) or Nabhi, Nabhicakre, or Nabi Chakra (belly button)

How to Perform the Pose:

1. Begin by sitting on your heels in Hero Pose (*Virasana*). Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale and bend forward, letting the crown of your head touch the floor, and lift your sitting bones off your heels. Grab onto your heels with both your hands, keeping your arms on the outsides of your shins.
3. Exhale as you rock forward, bringing your forehead toward your knees. Feel the stretch in the upper back between your shoulder blades.
4. Inhale as you lift your hands off your heels and interlock your fingers behind your back. Try to press your palms together. Exhale and stretch your arms up to the sky behind your back. Feel the stretch in your front shoulder heads and your chest (Pose #1). You can experiment by leaving your sitting bones on the heels and moving your forehead away from your knees (Pose #2).
5. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
6. Inhale as you release the arms. Exhale as you straighten your spine, coming back to Hero Pose (*Virasana*).

Modification:

1. forehead to the knees, sitting bones lifted
2. forehead away from the knees, sitting bones to the heels

baddha = bound

hasta = hand

sasanga = rabbit

1.

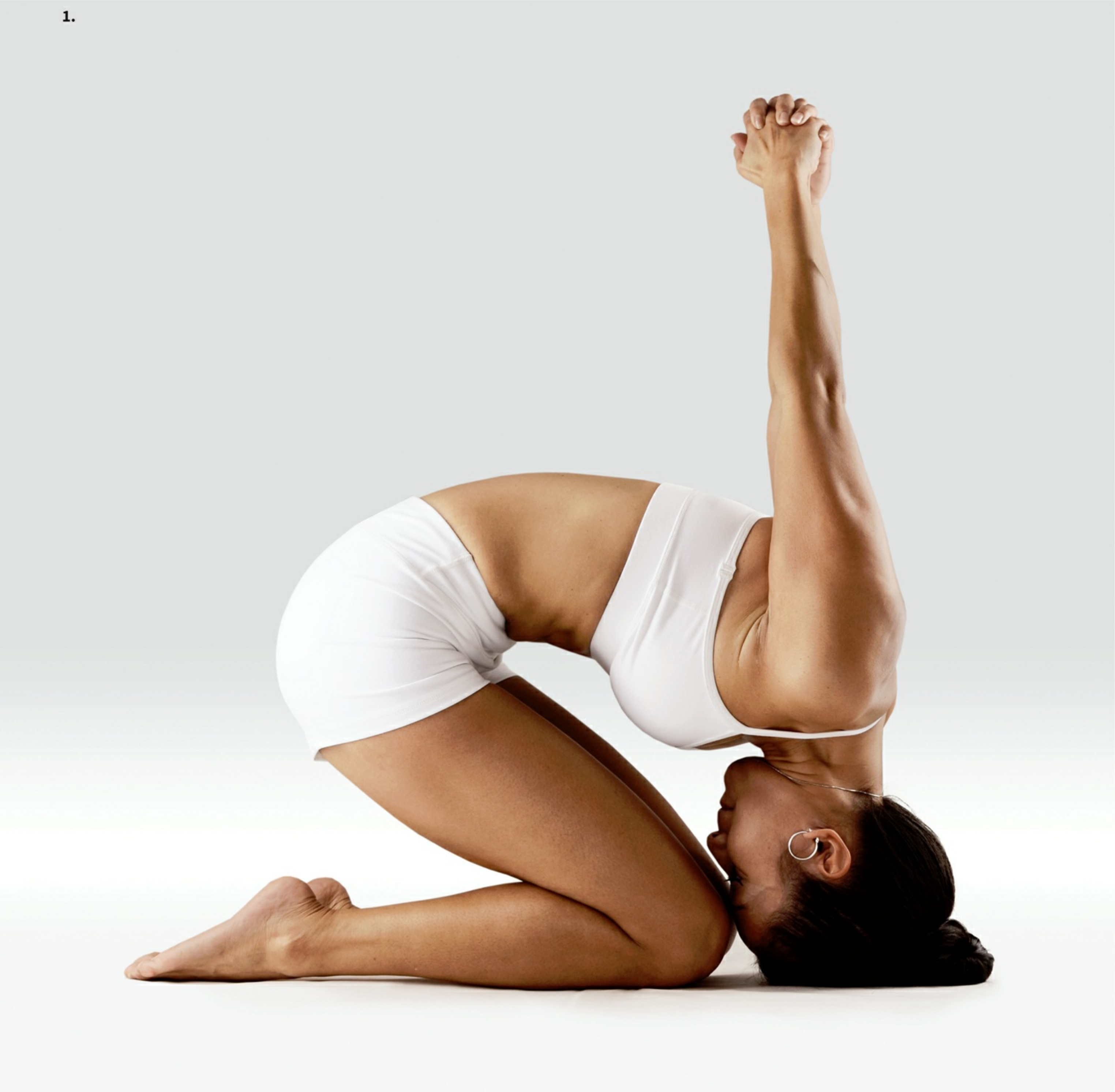

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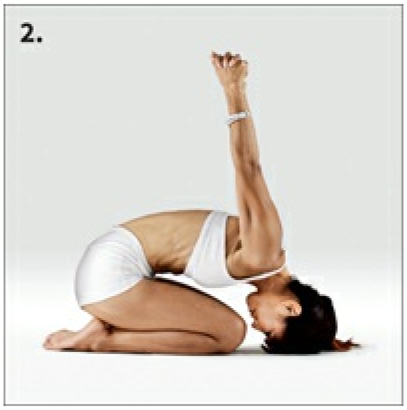

Rabbit Pose

Sasangasana

(shuh-shahn-GAHS-uh-nuh)

Also Known As: Rabbit Foot Pose
Pose Type: forward bend, inversion
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)
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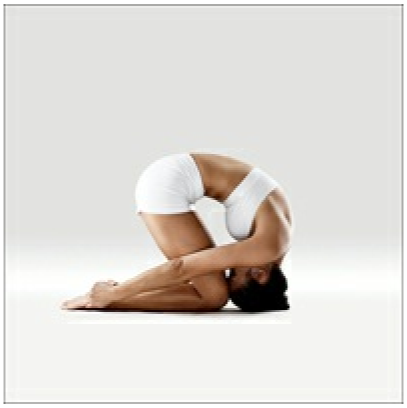

COW POSE ON THE HEAD: HALF LOTUS & GARUDA LEGS

Half Bound Lotus Cow Pose on the Head

Ardha Baddha Padma Shirsha Bitilasana

(UHR-duh BUH-duh PUHD-muh SHEER-shuh bee-til-AHS-uh-nuh)

Also Known As: Ardha Baddha Padma Shirsha Gavasana*
Modification: crown of the head to the floor
Pose Type: forward bend, inversion, binding
Drishti Point: Nasagrai or Nasagre (nose), Nabhi, Nabhicakre, or Nabi Chakra (belly button)
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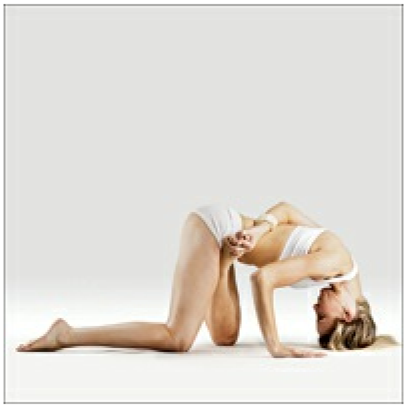

Reverse Prayer in Leg Position of the Pose Dedicated to Garuda in Cow Pose on the Head

Viparita Namaskar in Pada Garudasana in Shirsha Bitilasana

(vi-puh-REE-tuh nuh-muhs-KAHR in PUH-duh guh-ru-DAHS-uh-nuh in SHEER-shuh bee-til-AHS-uh-nuh)

Also Known As: Back of the Body Prayer Leg Position of the Pose Dedicated to Garuda in Cow Pose on the Head (Paschima Namaskara Pada Garudasana in Shirsha Bitilasana)
Pose Type: forward bend, inversion
Drishti Point: Nasagrai or Nasagre (nose), Nabhi, Nabhicakre, or Nabi Chakra (belly button)
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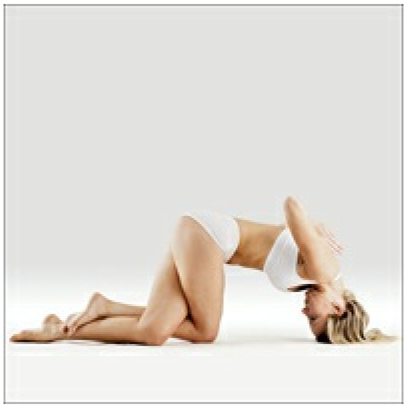

COW POSE ON THE HEAD: HEELS TO THE SITTING BONES & HEELS TO THE OUTSIDE OF THE HIPS

Both Hands to the Legs Cow Pose on the Head

Dwi Hasta Pada Shirsha Bitilasana

(DWI-huh-stuh PUH-duh SHEER-shuh bee-til-AHS-uh-nuh)

Modification: heels toward the sitting bones
Pose Type: forward bend, inversion
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)
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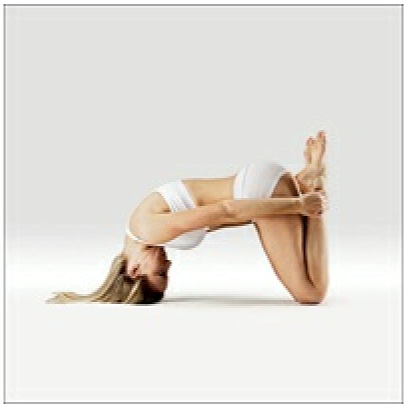

Both Hands to the Feet Cow Pose on the Head

Dwi Hasta Pada Shirsha Bitilasana

(DWI-huh-stuh PUH-duh SHEER-shuh bee-til-AHS-uh-nuh)

Modification: heels to the outside of the hips
Pose Type: forward bend, inversion
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

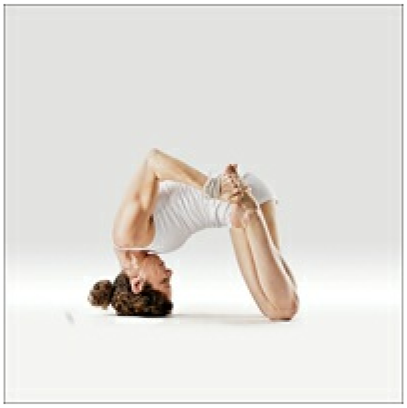

ALL FOURS: NEUTRAL SPINE

Cow Pose

Bitilasana

(bee-til-AHS-uh-nuh)

Also Known As: Table Pose (Bharmanasana)
Pose Type: standing (hands and knees)
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

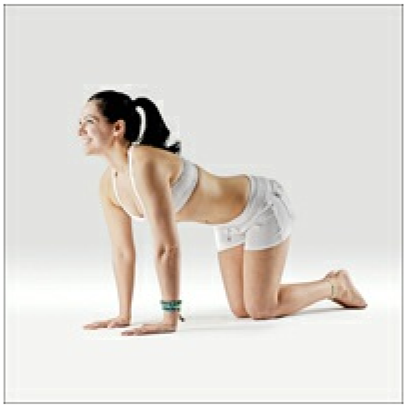

Intense Wrist Stretch Cow Pose

Uttana Manibandha Bitilasana

(ut-TAHN-uh muh-ni-BUHN-duh bee-til-AHS-uh-nuh)

Also Known As: Table Pose Modification (Bharmanasana)
Pose Type: standing (hands and knees)
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

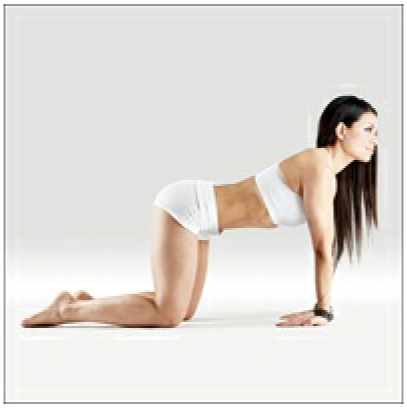

One Hand Cow Pose

Eka Hasta Bitilasana

(EY-kuh HUH-stuh bee-til-AHS-uh-nuh)

Also Known As: Table Pose (Bharmanasana)
Pose Type: standing (hands and knees)
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

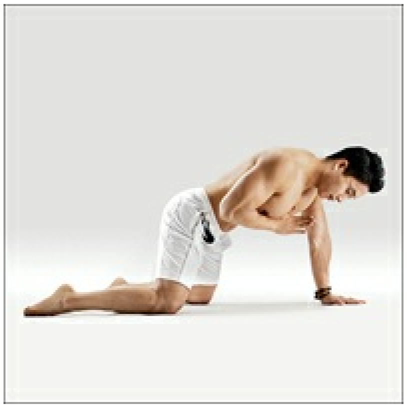

Leg Position of the Pose Dedicated to Garuda in Cow Pose

Pada Garudasana in Bitilasana

(PUH-duh guh-ru-DAHS-uh-nuh in bee-til-AHS-uh-nuh)

Also Known As: Table Pose Modification (Bharmanasana)
Pose Type: standing (on hands and knees)
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

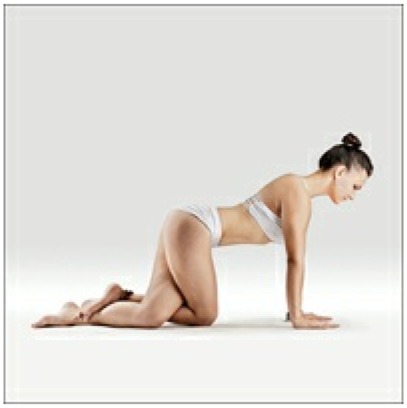

Lotus Pose in Cow Pose

Padmasana in Bitilasana

(puhd-MAHS-uh-nuh in bee-til-AHS-uh-nuh)

Also Known As: Table Pose Modification (Bharmanasana)
Pose Type: standing (on hands and knees)
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

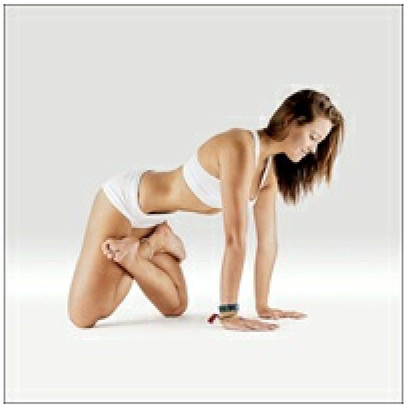

ALL FOURS: NEUTRAL SPINE—ONE LEG EXTENDED TO THE BACK

Tiger Pose

Vyaghrasana

(vyah-GRAHS-uh-nuh)

Also Known As: Table Pose Modification (Bharmanasana)
Modification: neutral spine
Pose Type: standing (hands and knees)
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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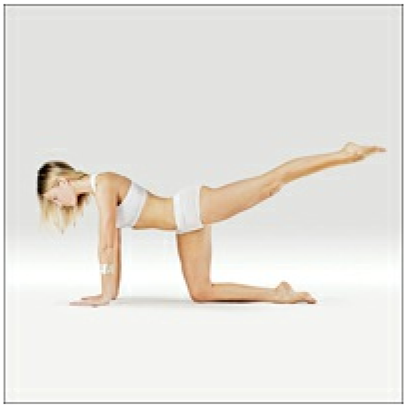

One Hand One-Legged Cow Pose

Eka Hasta Eka Pada Bitilasana

(EY-kuh HUH-stuh EY-kuh PUH-duh bee-til-AHS-uh-nuh)

Also Known As: Cat Pose (Marjarasana), Balancing Table Pose Modification (Dandayamana Bharmanasana)
Modification: neutral spine
1. arm reaching to the front, opposite leg reaching to the back
2. arm reaching to the back, opposite leg reaching to the back

3. arm reaching to the back, leg reaching to the back on the same side

Pose Type: standing (hands and knees)

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

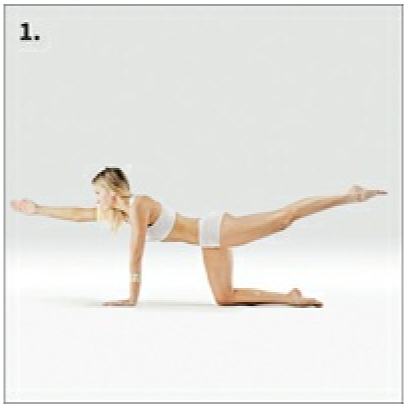

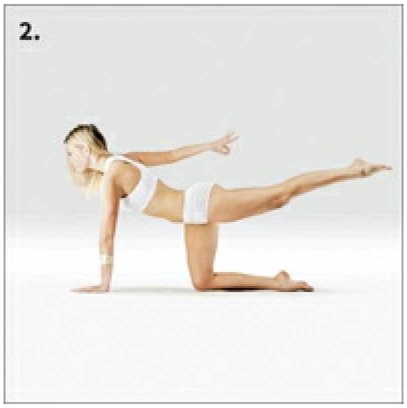

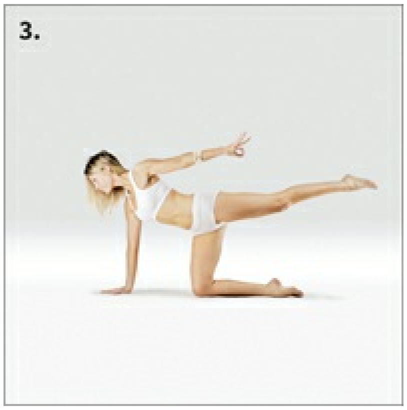

One Knee Cow Pose

Eka Janu Bitilasana

(EY-kuh JAH-nu bee-til-AHS-uh-nuh)

Also Known As: Unsupported Balancing Table Pose Modification (Niralamba Dandayamana Bharmanasana)

Pose Type: standing (on the knee), balance

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

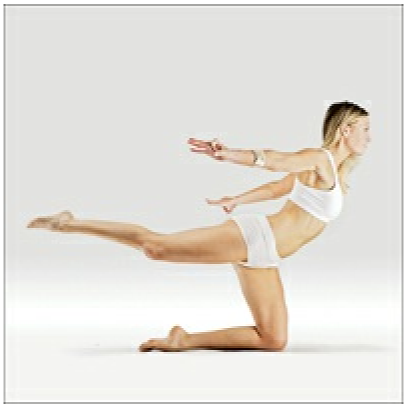

ALL FOURS: NEUTRAL SPINE—ONE LEG EXTENDED TO THE BACK—HALF LOTUS

Downward Facing Pose Dedicated to Kashyapa

Adho Mukha Kashyapasana

(uh-DO MUK-uh kah-shyuh-PAHS-uh-nuh)

Modification: Leg 1: knee on the floor Leg 2: foot on the floor
Pose Type: arm balance, binding
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

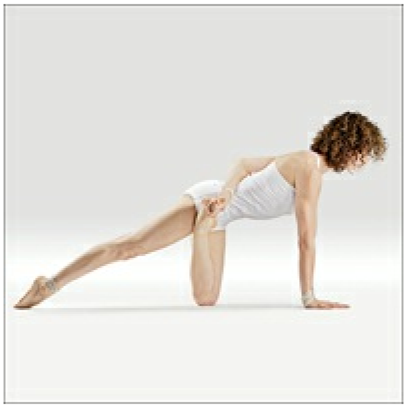

Downward Facing Pose Dedicated to Kasyapa

Adho Mukha Kasyapasana

(uh-DO MUK-uh kah-shyuh-PAHS-uh-nuh)

Modification: Leg 1: knee on the floor Leg 2: foot off the floor
Pose Type: arm balance, binding
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

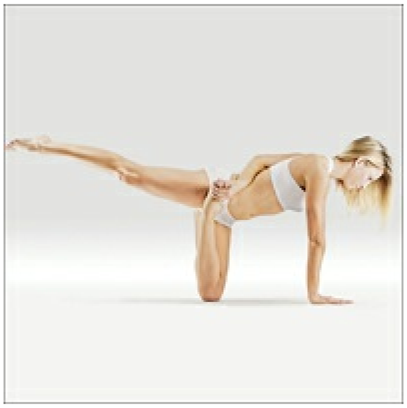

ALL FOURS: CAT TILT

Downward Facing Cat Pose

Adho Mukha Marjarasana

(uh-DO MUK-uh mahr-jah-RAHS-uh-nuh)

Modification: toes pointing away from the head
Pose Type: standing (on hands and knees), forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

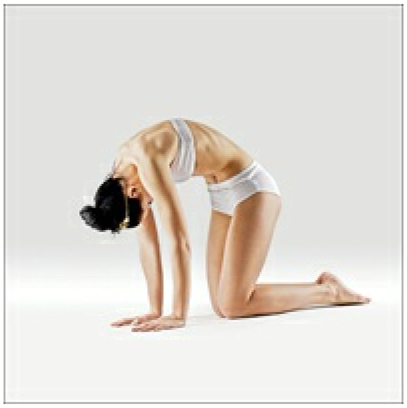

Downward Facing Cat Pose

Adho Mukha Marjarasana

(uh-DO MUK-uh mahr-jah-RAHS-uh-nuh)

Modification: arms straight to the front, fingertips to the floor; rocking back, toes curled in
Pose Type: standing (on hands and knees), forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

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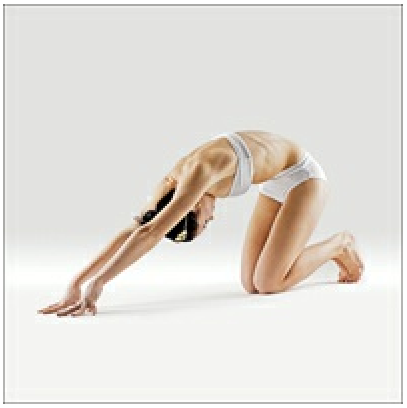

Tiger Pose

Vyaghrasana

(vyah-GRAHS-uh-nuh)

Also Known As: Cow Pose Modification (Bitilasana)
Modification: knee to the forehead
Pose Type: standing (on hands and knees), forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

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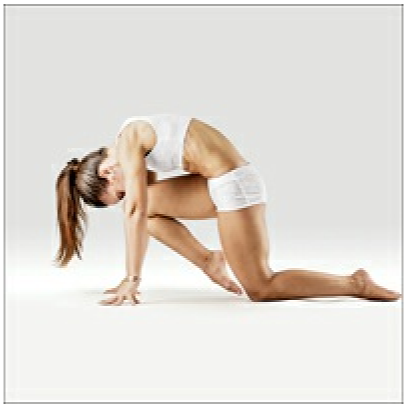

Tiger Pose

Vyaghrasana

(vyah-GRAHS-uh-nuh)

Also Known As: Cow Pose Modification (Bitilasana)
Modification: knee to the shoulder on the same side
Pose Type: standing (on hands and knees), forward bend
Drishti Point: Nasagrai or Nasagre (nose)

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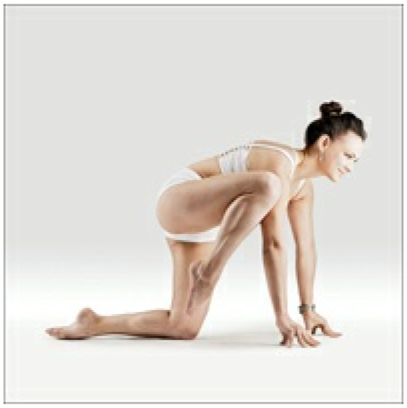

Tiger Pose

Vyaghrasana

(vyah-GRAHS-uh-nuh)

Also Known As: Cow Pose Modification (Bitilasana)
Modification: knee to the opposite tricep
Pose Type: standing (on hands and knees), forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose)

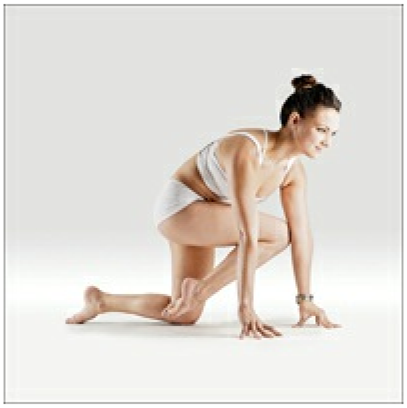

Tiger Pose

Vyaghrasana

(vyah-GRAHS-uh-nuh)

Also Known As: Cow Pose Modification (Bitilasana)
Modification: shoulder to the back of the knee; back leg, toes curled in
Pose Type: standing (on hands and knees), forward bend
Drishti Point: Nasagrai or Nasagre (nose), Padayoragrai or Padayoragre (toes/feet)

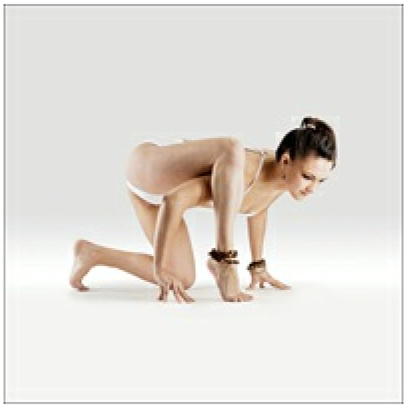

Tiger Pose

Vyaghrasana

(vyah-GRAHS-uh-nuh)

Also Known As: Cow Pose Modification (Bitilasana)
Modification: one hand to the heart
1. back of the knee to the shoulder, leg bent
2. back of the knee to the shoulder, leg straight
Pose Type: standing (on hands and knees), forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

1.

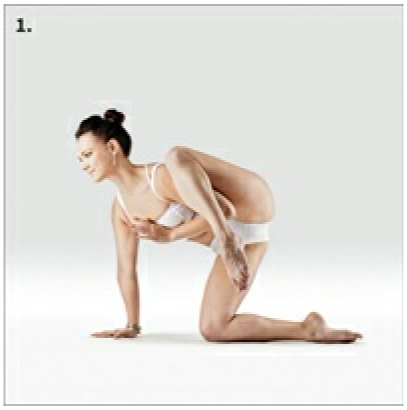

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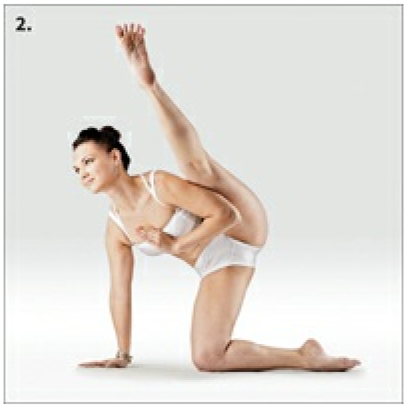

Upward Facing Dog Pose Tilt

Urdhva Mukha Shvanasana Tilt

(OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Pose Type: standing (on hands and knees), backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows

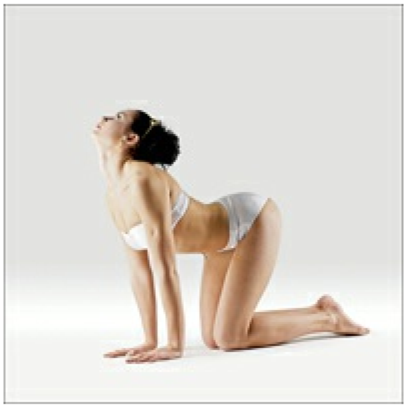

Tiger Pose

Vyaghrasana

(vyah-GRAHS-uh-nuh)

Also Known As: Balancing Table Pose Modification (Niralamba Dandayamana Bharmanasana)

Modification: one leg straight out, toes pointing away from the head

Pose Type: standing (on hands and knees), backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

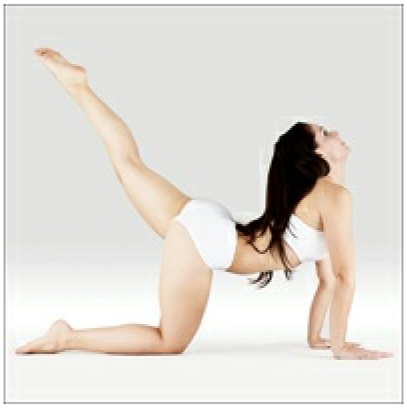

Unsupported Tiger Pose

Niralamba Vyaghrasana

(nir-AH-luhm-buh vyah-GRAHS-uh-nuh)

Also Known As: One-Legged Bow Pose from All Fours (Eka Pada Dhanurasana), Balancing Table Pose Modification (Dandayamana Bharmanasana)
Modification: grabbing onto the foot with under-head grip on the same side
Pose Type: standing (on hands and knees), backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

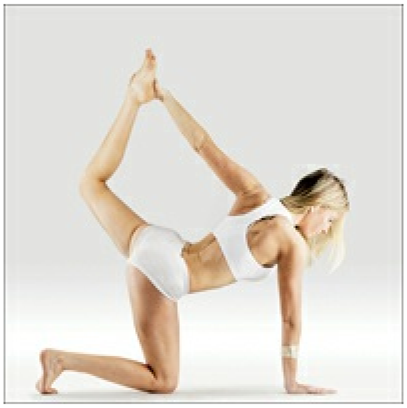

Unsupported Tiger Pose

Niralamba Vyaghrasana

(nir-AH-luhm-buh vyah-GRAHS-uh-nuh)

Also Known As: One-Legged Bow Pose from All Fours (Eka Pada Dhanurasana), Balancing Table Pose Modification (Dandayamana Bharmanasana)
Modification: grabbing onto the shin with under-head grip on the opposite side
Pose Type: standing (on hands and knees), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

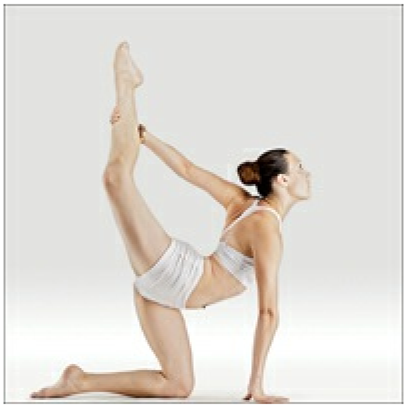

Unsupported Tiger Pose

Niralamba Vyaghrasana

(nir-AH-luhm-buh vyah-GRAHS-uh-nuh)

Also Known As: Balancing Table Pose Modification (Dandayamana Bharmanasana)

Modification: grabbing onto the foot with overhead grip on the same side, foot toward the head

1. toes pointing away from the head
2. toes curled in

Pose Type: standing (on hands and knees), backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

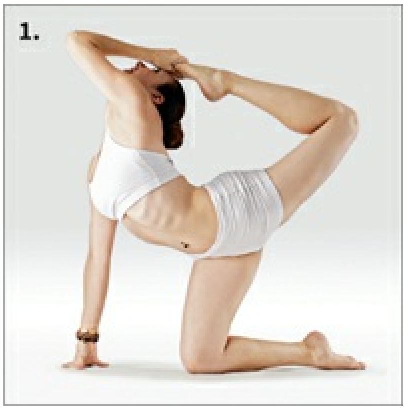

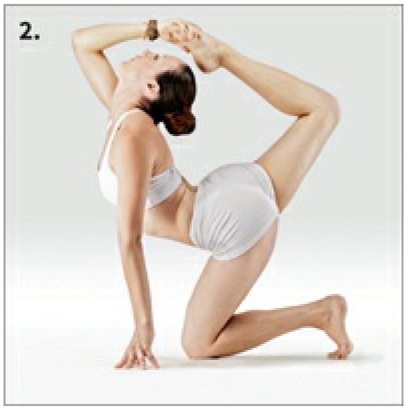

Unsupported Tiger Pose

Niralamba Vyaghrasana

(nir-AH-luhm-buh vyah-GRAHS-uh-nuh)

Also Known As: Balancing Table Pose Modification (Dandayamana Bharmanasana)

Modification: grabbing onto the foot with overhead grip on the opposite side, foot away from the head, toes curled in

Pose Type: standing (on hands and knees), backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

ALL FOURS: FOREARMS

Cow Pose

Bitilasana

(bee-til-AHS-uh-nuh)

Also Known As: Table Pose Modification (Bharmanasana)
Modification: forearms to the floor
Pose Type: standing (on forearms and knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

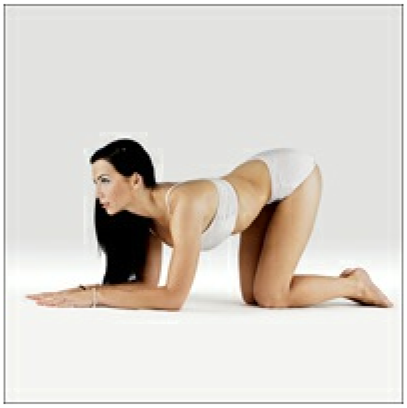

Frog Pose in Cow Pose

Mandukasana in Bitilasana

(muhn-doo-KAHS-uh-nuh in bee-til-AHS-uh-nuh)

Also Known As: Frog Pose in Table Pose Modification (Mandukasana in Bharmanasana)
Modification: forearms to the floor, knees open wider than hips
Pose Type: standing (on forearms and knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

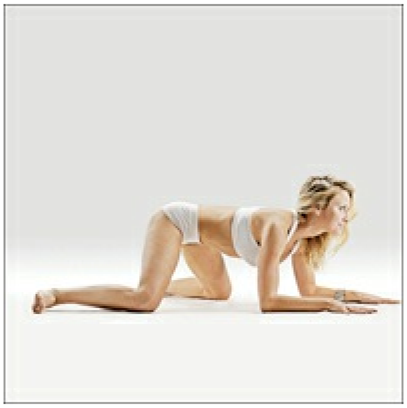

Uneven Wounded Duck Pose Prep.

Vishama Pungu Karandavasana Prep.

(VISH-uh-muh pung-u kahr-uhn-duh-VAHS-uh-nuh)

Modification: one forearm to the floor, toes of both feet on the floor
Pose Type: standing (on forearms and feet), forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

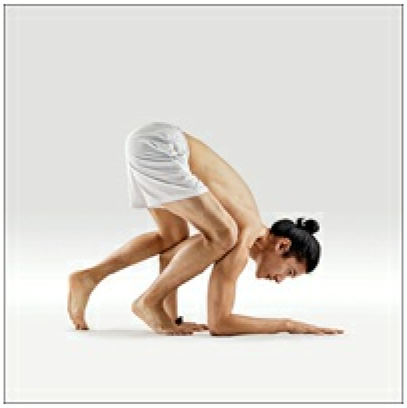

Supported Tiger Pose

Salamba Vyaghrasana *(SAH-luhm-buh vyah-GRAHS-uh-nuh)*
Also Known As: Cow Pose Modification (Bitilasana)
Modification: forearm on the floor, one hand to the heart; back of the knee to the shoulder, leg straight
Pose Type: standing (on forearms and knees), forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

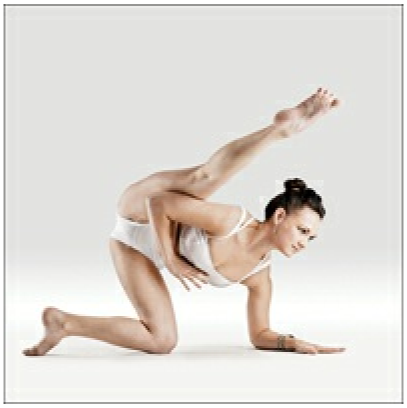

Supported Tiger Pose

Salamba Vyaghrasana *(SAH-luhm-buh-nuh vyah-GRAHS-uh-nuh)*
Also Known As: Cow Pose Modification (Bitilasana)
Modification: forearm on the floor, grabbing onto the foot with under-head grip on the opposite side
Pose Type: standing (on forearms and knees), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

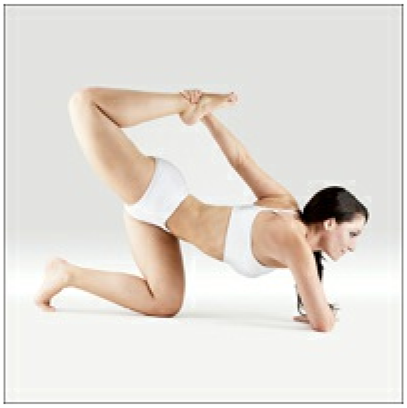

ALL FOURS: FOREARMS—TWISTS

Hand to Leg Sideways Leg Position of Cow Face Pose in Cow Pose

Hasta Pada Parshva Pada Gomukhasana in Bitilasana
(HUH-stuh PUH-duh PAHRSH-vuh PUH-duh go-mu-KAHS-uh-nuh in bee-til-AHS-uh-nuh)
Modification: forearm to the floor
Pose Type: standing (on forearms and knees), twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

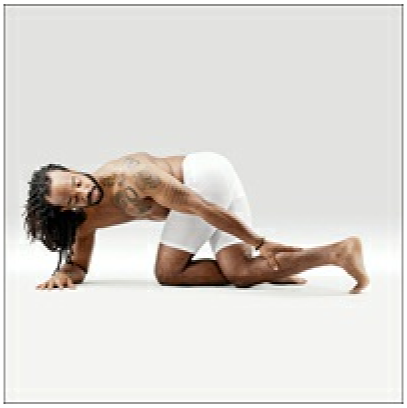

Half Bound Sideways Leg Position of Cow Face Pose in Cow Pose

Ardha Baddha Parshva Pada Gomukhasana in Bitilasana

(UHR-duh BUH-duh PAHRSH-vuh PUH-duh go-mu-KAHS-uh-nuh in bee-til-AHS-uh-nuh)

Modification: forearm to the floor
Pose Type: standing (on forearms and knees), twist, binding
Drishti Point: Urdhva or Antara Drishti (up to the sky)

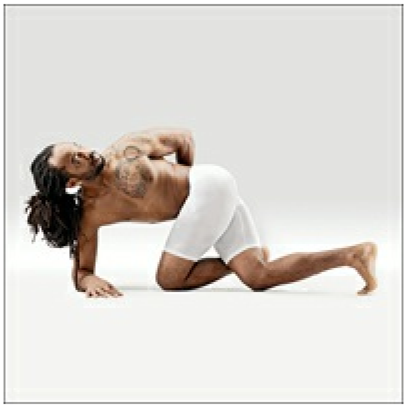

ALL FOURS: FOREARMS—HALF LOTUS

Half Lotus Cow Pose

Ardha Padma Bitilasana

(UHR-duh PUHD-muh bee-til-AHS-uh-nuh)

Also Known As: Half Lotus Table Pose Modification (Ardha Padma Bharmanasana)
Modification: forearms to the floor
Pose Type: standing (on forearms and knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

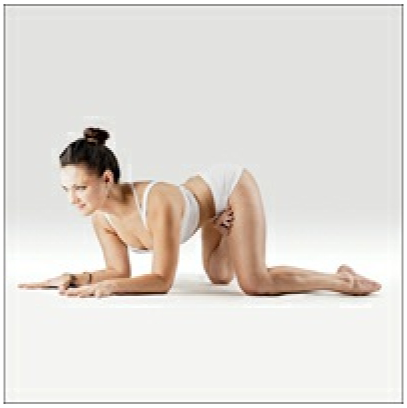

Revolved Half Lotus Cow Pose

Parivritta Ardha Padma Bitilasana

(puh-ri-VRIT-uh UHR-duh PUHD-muh bee-til-AHS-uh-nuh)

Also Known As: Revolved Half Lotus Table Pose Modification (Parivritta Ardha Padma Bharmanasana)
Modification: forearm on the floor, other hand behind the back
Pose Type: standing (on forearms and knees), twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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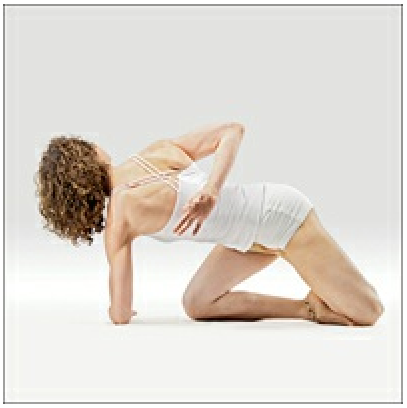

Half Bound Lotus Cow Pose

Ardha Baddha Padma Bitilasana

(UHR-duh PUHD-muh bee-til-AHS-uh-nuh)

Also Known As: Half Bound Lotus Table Pose Modification (Ardha Baddha Padma Bharmanasana)
Modification: forearm to the floor
Pose Type: standing (on forearms and knees), binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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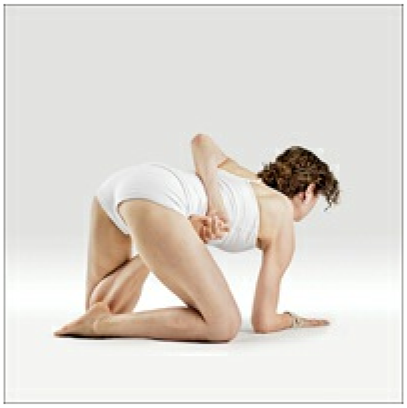

Revolved Half Lotus Cow Pose

Parivritta Ardha Padma Bitilasana

(puh-ri-VRIT-uh UHR-duh PUHD-muh bee-til-AHS-uh-nuh)

Also Known As: Revolved Half Lotus Table Pose Modification (Parivritta Ardha Padma Bharmanasana)
Modification: forearm on the floor, top arm up to the sky
1. back view
2. front view
Pose Type: standing (on forearms and knees), twist
Drishti Point: Hastagrai or Hastagre (hands)

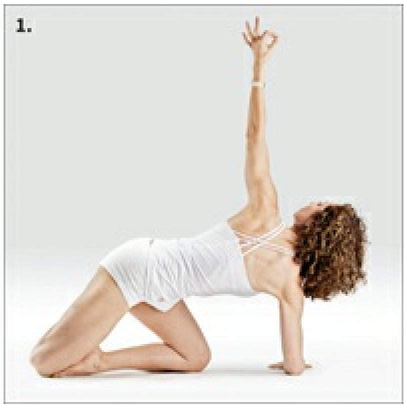

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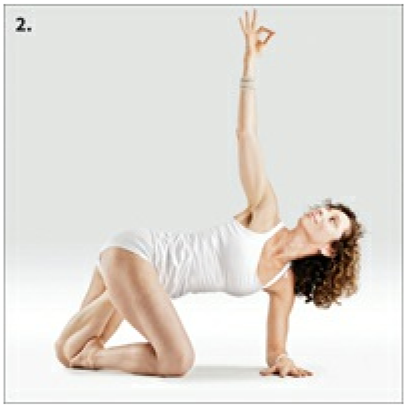

2.

PLANK POSE: ON THE FINGERTIPS & ARMS CROSSED

Extended Four Limbs Staff Pose

Utthita Chaturanga Dandasana

(UT-ti-tuh chuh-tur-UHNG-guh-uh duhn-DAHS-uh-nuh)

Also Known As: High Plank
Modification: on the fingertips
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

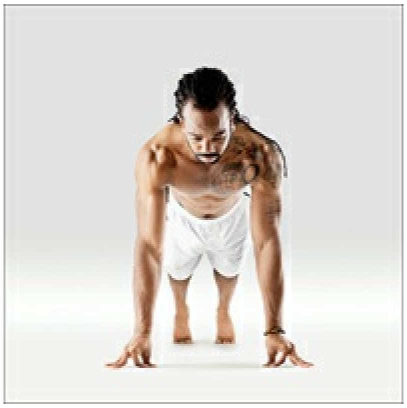

Extended Four Limbs Staff Pose

Utthita Chaturanga Dandasana

(UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: High Plank
Modification: arms crossed
1. knees on the floor
2. knees off the floor
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

1.

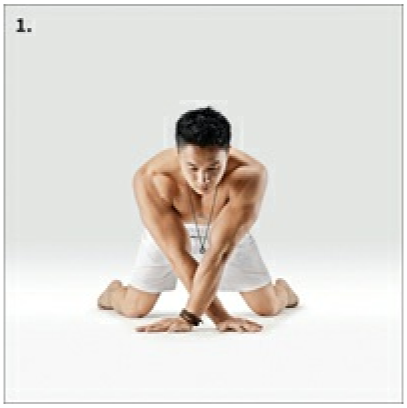

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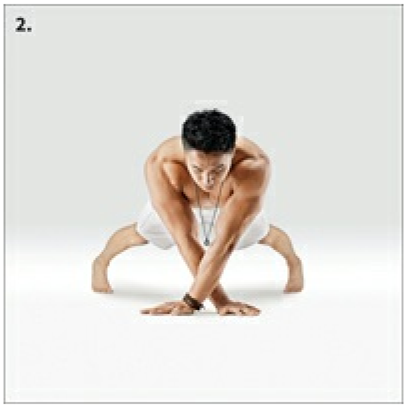

PLANK POSE: LEG MODIFICATIONS

Extended Four Limbs Staff Pose

Utthita Chaturanga Dandasana

(UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: High Plank Modification
Modification: 1. knees on the floor
2. knees off the floor
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

1.

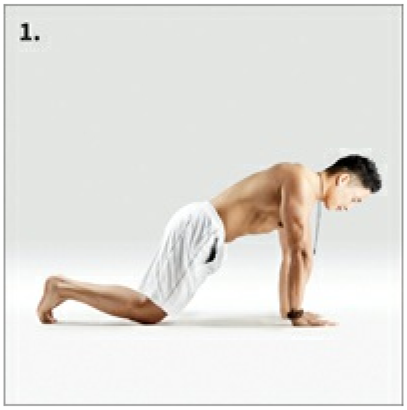

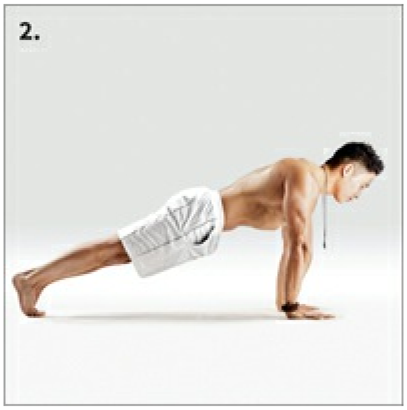

One-Legged Extended Four Limbs Staff Pose

Eka Pada Utthita Chaturanga Dandasana

(EY-kuh PUH-duh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: One-Legged High Plank Modification
Modification: knee to the nose
Pose Type: arm balance, forward bend, core
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

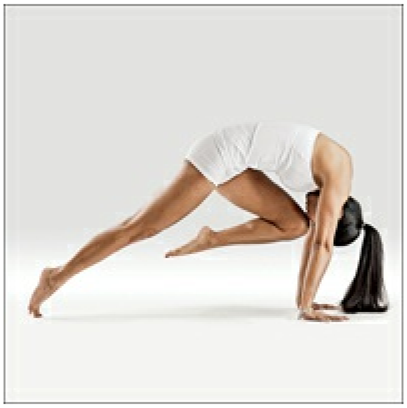

One-Legged Extended Four Limbs Staff Pose

Eka Pada Utthita Chaturanga Dandasana

(EY-kuh PUH-duh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: One-Legged High Plank Modification
Modification: knee to the shoulder on the same side
Pose Type: arm balance, forward bend, core
Drishti Point: Nasagrai or Nasagre (nose)

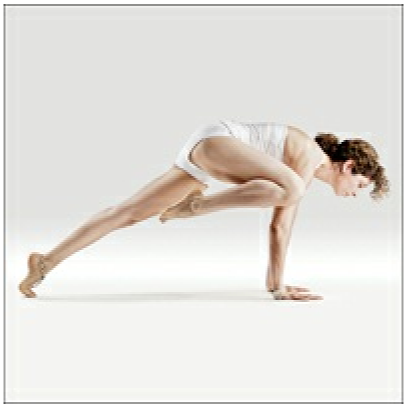

One-Legged Extended Four Limbs Staff Pose

Eka Pada Utthita Chaturanga Dandasana

(EY-kuh PUH-duh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: One-Legged High Plank Modification
Modification: foot wrapping around the calf muscle
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

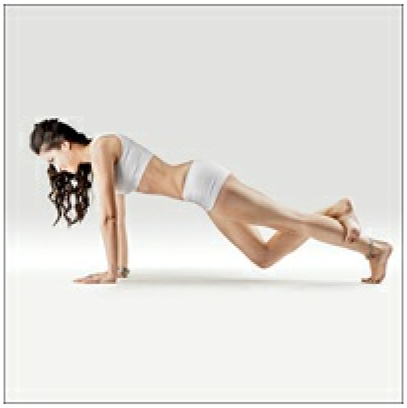

Revolved Extended Four Limbs Staff Pose

Parivritta Utthita Chaturanga Dandasana

(puh-ri-VRIT-tuh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: Revolved High Plank Modification
Pose Type: arm balance, twist, core
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

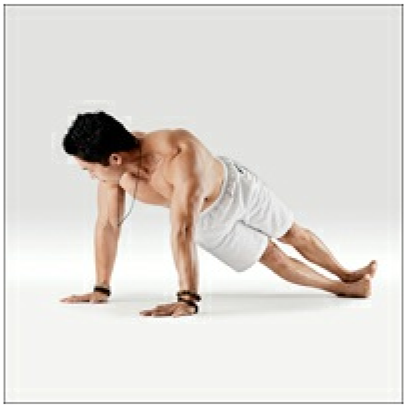

PLANK POSE: ARM AND LEG MODIFICATIONS

One-Legged Extended Four Limbs Staff Pose

Eka Pada Utthita Chaturanga Dandasana

(EY-kuh PUH-duh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: One-Legged High Plank Modification
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

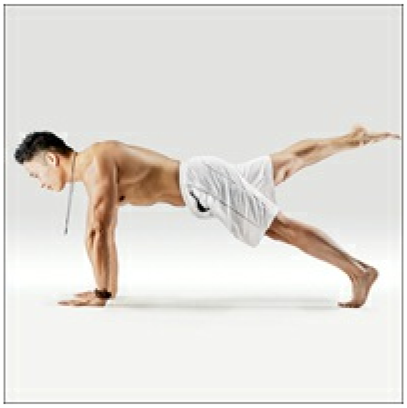

One Hand Extended Four Limbs Staff Pose

Eka Hasta Utthita Chaturanga Dandasana

(EY-kuh HUH-stuh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: One Hand High Plank Modification
Pose Type: arm balance, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

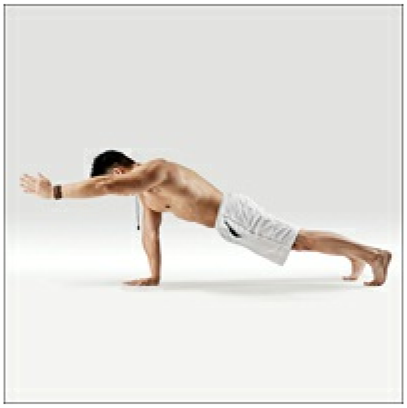

One Hand Extended Four Limbs Staff Pose

Eka Hasta Utthita Chaturanga Dandasana

(EY-kuh HUH-stuh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)
Also Known As: One Hand High Plank Modification
Modification: hand to the heart
Pose Type: arm balance, core
Drishti Point: Angushtamadhye or Angushtha Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

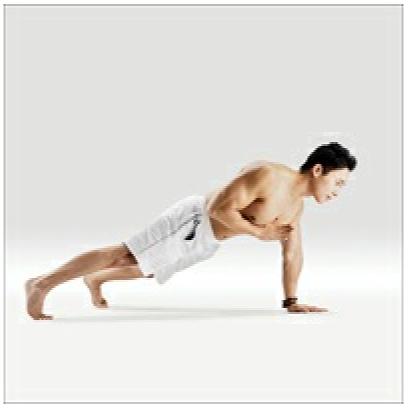

One Leg One Hand Extended Four Limbs Staff Pose

Eka Pada Eka Hasta Utthita Chaturanga Dandasana

(EY-kuh PUH-duh EY-kuh HUH-stuh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)
Also Known As: One Hand High Plank Modification
Pose Type: arm balance, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Nasagrai or Nasagre (nose)

Tree Pose in One-Legged Extended Four Limbs Staff Pose

Vrikshasana in Eka Pada Utthita Chaturanga Dandasana

(vrik-SHAHS-uh-nuh in EY-kuh PUH-duh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: Tree Pose in One-Legged High Plank Modification
Modification: 1. knees on the floor
2. knees off the floor
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

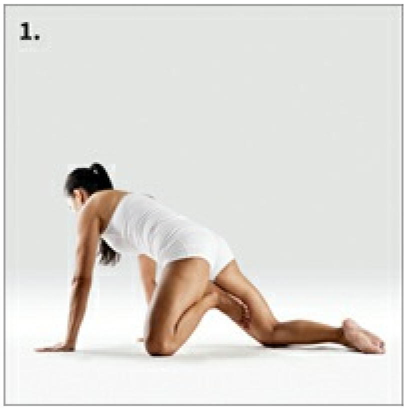

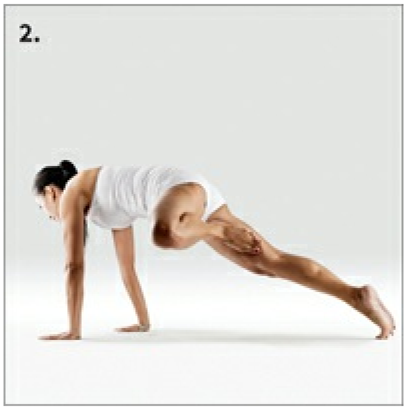

Extended Four Limbs Staff Pose

Utthita Chaturanga Dandasana

(UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: High Plank Modification
Modification: arms extended to the front, tops of the feet on the floor
1. knees on the floor
2. knees off the floor
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

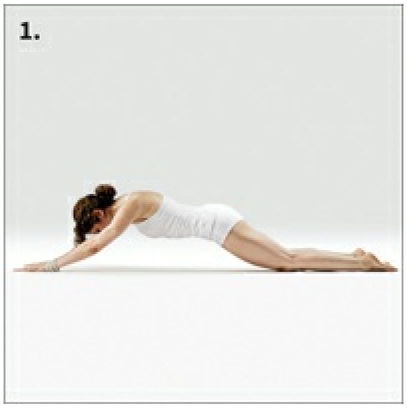

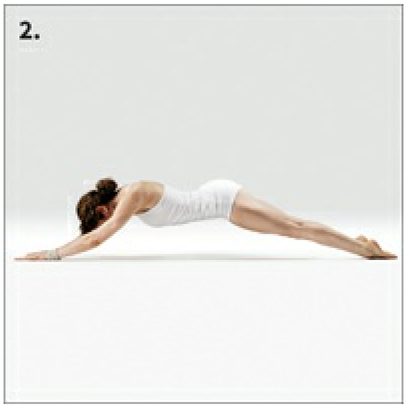

PLANK POSE: TWISTS

Leg to the Side Revolved One Hand Extended Four Limbs Staff Pose

Parshva Pada Parivritta Eka Hasta Utthita Chaturanga Dandasana

(PAHRSH-vuh PUH-duh puh-ri-VRIT-tuh EY-kuh HUH-stuh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: Leg to the Side Revolved One Hand High Plank Modification
Modification: 1. back knee on the floor
2. back knee off the floor, knee bent
3. back knee off the floor, both legs straight
4. back knee off the floor, knee bent, toes of the straight leg pointed
Pose Type: arm balance, twist, core

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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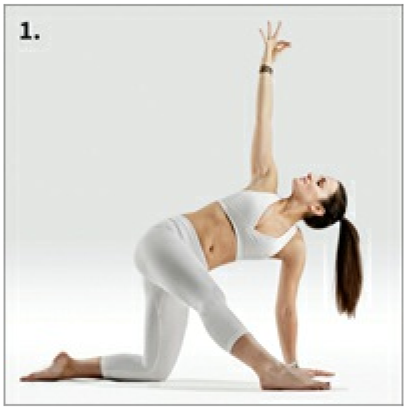
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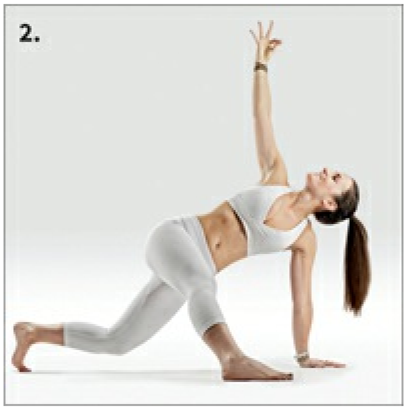
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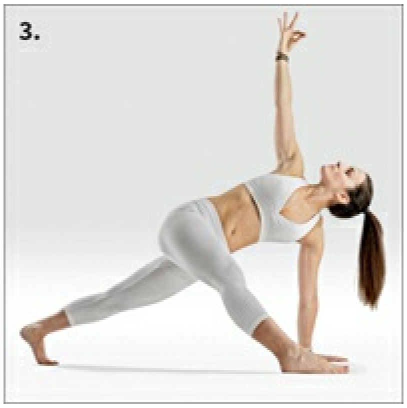
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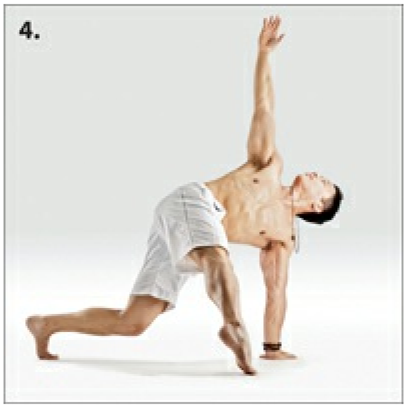
4.

Revolved One Hand Extended Four Limbs Staff Pose

Parivritta Eka Hasta Utthita Chaturanga Dandasana

(puh-ri-VRIT-tuh EY-kuh HUH-stuh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: Revolved One Hand High Plank Modification
Modification: 1. knees on the floor
2. knees off the floor
Pose Type: arm balance, twist, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

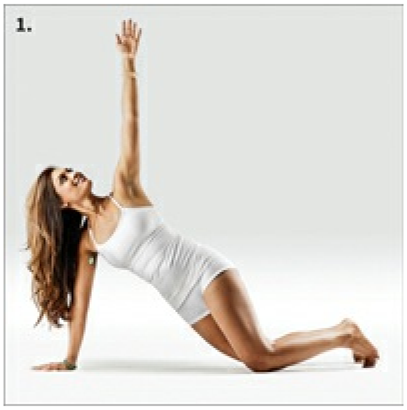

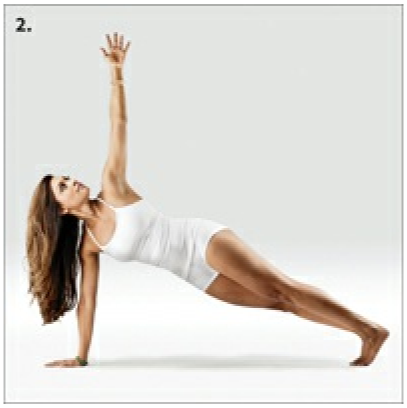

Revolved Leg to the Side Extended Four Limbs Staff Pose

Parivritta Parshva Pada Utthita Chaturanga Dandasana

(puh-ri-VRIT-tuh PAHRSH-vuh PUH-duh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: Revolved Leg to the Side High Plank Modification
Modification: leg sweeping under the torso
Pose Type: arm balance, twist, core
Drishti Point: Nasagrai or Nasagre (nose)

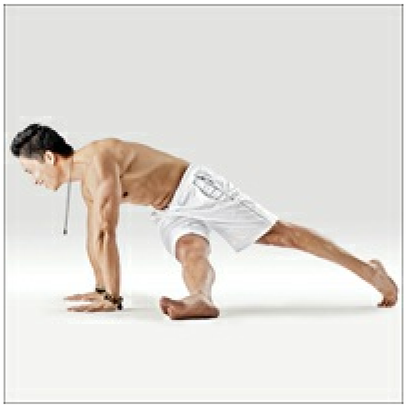

PLANK POSE: ONE LEG TO THE SIDE

Leg to the Side Extended Four Limbs Staff Pose

Parshva Pada Utthita Chaturanga Dandasana

(PAHRSH-vuh PUH-duh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: Leg to the Side High Plank Modification

Modification: 1. back knee on the floor

2. back knee off the floor

Pose Type: arm balance, core

Drishti Point: Nasagrai or Nasagre (nose)

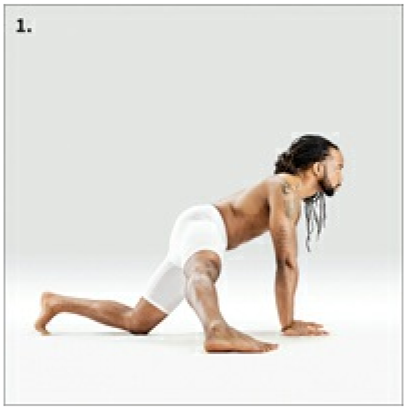

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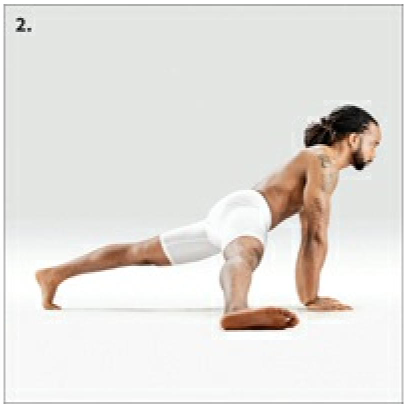

2.

Upward One Leg to the Side Extended Four Limbs Staff Pose

Urdhva Parshva Eka Pada Utthita Chaturanga Dandasana

(OORD-vuh PAHRSH-vuh EY-kuh PUH-duh UT-ti-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: Leg to the Side One-Legged High Plank Modification
Modification: back knee off the floor, other leg off the floor
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

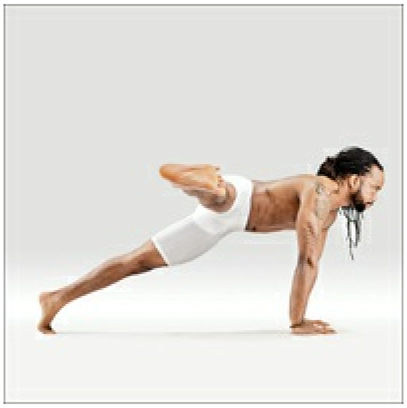

PLANK ON FOREARMS

Staff Pose Dedicated to Makara

Makara Dandasana

(MUH-kuh-ruh duhn-DAHS-uh-nuh)

Also Known As: Dolphin Plank Modification
Pose Type: forearm balance, core
Drishti Point: Nasagrai or Nasagre (nose), Angushtamadhye or Angushta Ma Dyai (thumbs)

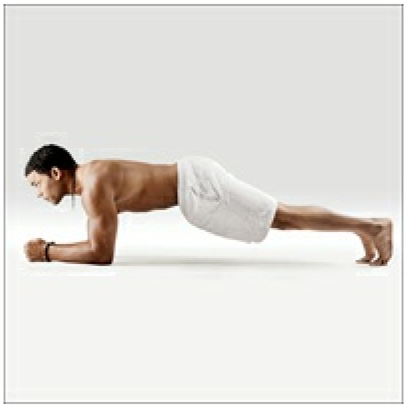

One Hand Staff Pose Dedicated to Makara

Eka Hasta Makara Dandasana

(EY-kuh HUH-stuh MUH-kuh-ruh duhn-DAHS-uh-nuh)

Also Known As: One Hand Dolphin Plank Modification
Pose Type: forearm balance, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

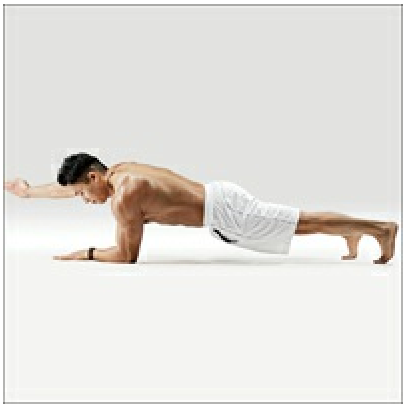

One-Legged Staff Pose Dedicated to Makara

Eka Pada Makara Dandasana

(EY-kuh PUH-duh MUH-kuh-ruh duhn-DAHS-uh-nuh)

Also Known As: One-Legged Dolphin Plank Modification
Pose Type: forearm balance, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

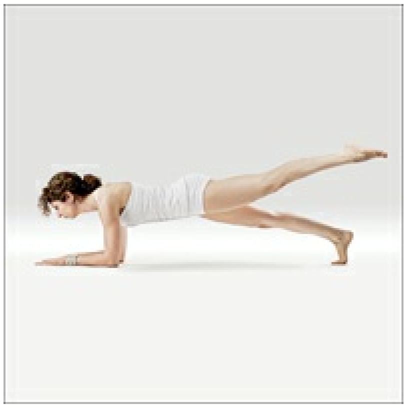

PLANK ON ELBOW

Uneven Repose Staff Pose

Vishama Sayana Dandasana

(VISH-uh-muh SHUH-yuh-nuh duhn-DAHS-uh-nuh)

Also Known As: Uneven Elbow Plank Pose Modification
Modification: one hand to the face, one forearm to the floor
Pose Type: forearm/elbow balance, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

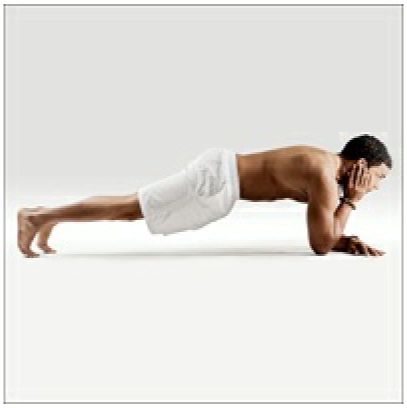

Repose Staff Pose

Sayana Dandasana

(SHUH-yuh-nuh duhn-DAHS-uh-nuh)

Also Known As: Elbow Plank
Pose Type: elbow balance, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

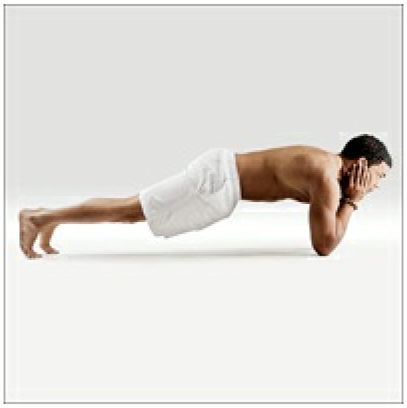

Leg Position of One-Legged King Pigeon 1 Version B in Repose Staff

Pose

Pada Eka Pada Raja Kapotasana 1B in Sayana Dandasana

(PUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh in SHUH-yuh-nuh duhn-DAHS-uh-nuh)

Pose Type: elbow balance, mild backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

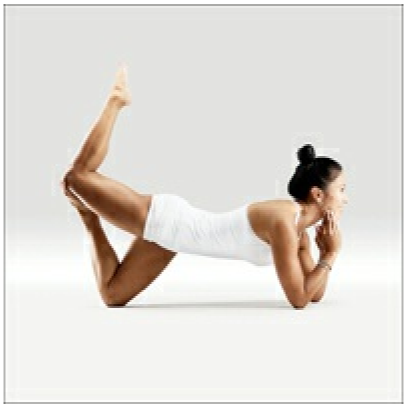

PLANK ON FOREARMS: TWIST

Revolved One Hand Staff Pose Dedicated to Makara

Parivritta Eka Hasta Makara Dandasana

(puh-ri-VRIT-tuh EY-kuh HUH-stuh MUH-kuh-ruh duhn-DAHS-uh-nuh)

Also Known As: Revolved Dolphin Plank Modification

Modification: 1 & 2. knees on the floor, front and back view

3 & 4. knees off the floor, front and back view

Pose Type: forearm balance, twist, core

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

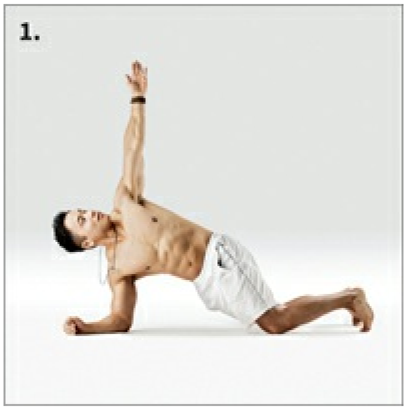

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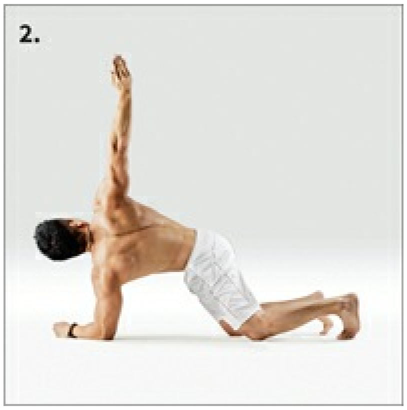

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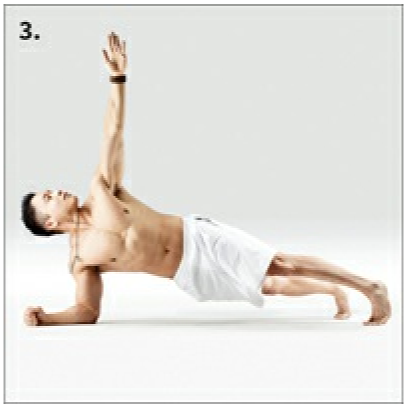

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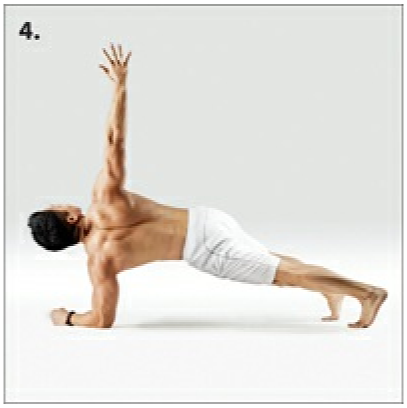

PLANK ON FOREARMS: UNEVEN LEG AND ARM POSITIONS

Uneven Staff Pose Dedicated to Makara

Vishama Makara Dandasana

(VISH-uh-muh MUH-kuh-ruh duhn-DAHS-uh-nuh)

Also Known As: Uneven Dolphin Plank Modification
Modification: one elbow bent at 90 degrees, other forearm to the floor, knees on the floor
Pose Type: arm/forearm balance, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

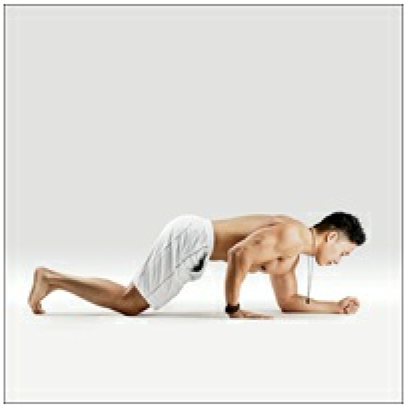

Hand to the Leg Sideways Uneven Legs Staff Pose Dedicated to Makara

Hasta Pada Parshva Vishama Pada Makara Dandasana

(HUH-stuh PUH-duh PAHRSH-vuh VISH-uh-muh PUH-duh MUH-kuh-ruh duhn-DAHS-uh-nuh)

Also Known As: Hand to the Leg Sideways Dolphin Plank Modification
Pose Type: forearm balance, twist, core
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

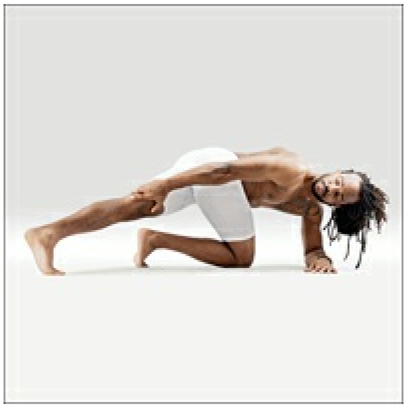

Uneven Staff Pose Dedicated to Makara

Vishama Makara Dandasana

(VISH-uh-muh MUH-kuh-ruh duhn-DAHS-uh-nuh)

Also Known As: Uneven Dolphin Plank Modification
Modification: one elbow bent at 90 degrees, other forearm to the floor, knees off the floor 1. left forearm on the floor, right arm at 90 degrees
2. right forearm on the floor, left arm at 90 degrees
Pose Type: arm/forearm balance, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

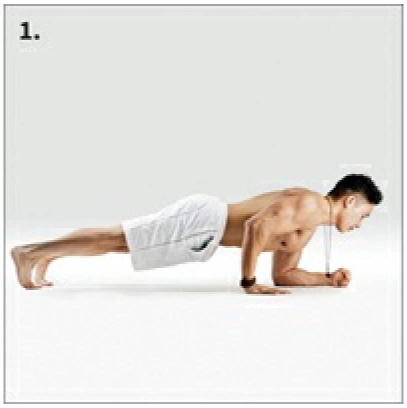

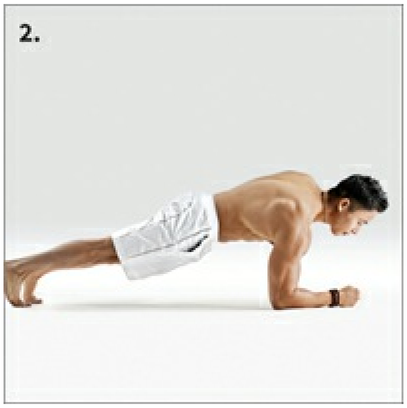

FOUR LIMBED STAFF POSE: KNEES ON THE FLOOR

Four Limbed Staff Pose

Chaturanga Dandasana

(chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: knees on the floor
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

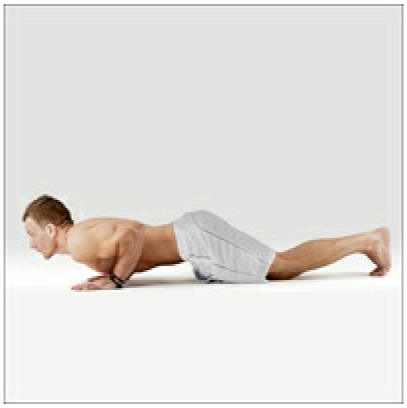

One Hand Four Limbed Staff Pose

Eka Hasta Chaturanga Dandasana

(EY-kuh HUH-stuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: knees on the floor
1. starting position
2. end position
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

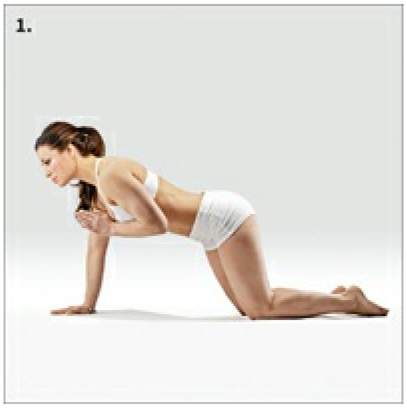

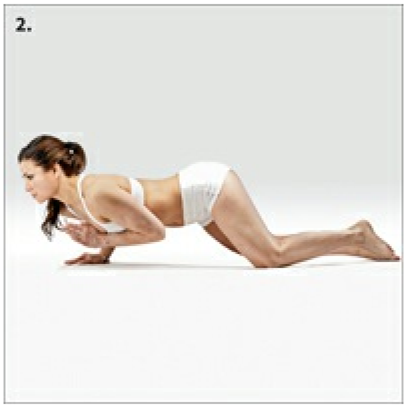

Lion Pose Dedicated to an Avatar of Lord Vishnu in Four Limbed Staff Pose

Narasimhasana in Chaturanga Dandasana

(nuh-ruh-sim-HAHS-uh-nuh in chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Also Known As: Lion Pose (Simhasana)
Modification: 1. on the fingertips
2. on the fists
Pose Type: arm balance, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

1.

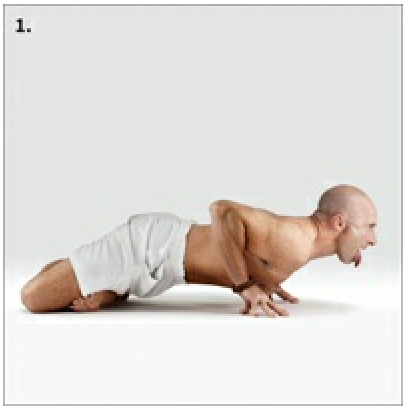

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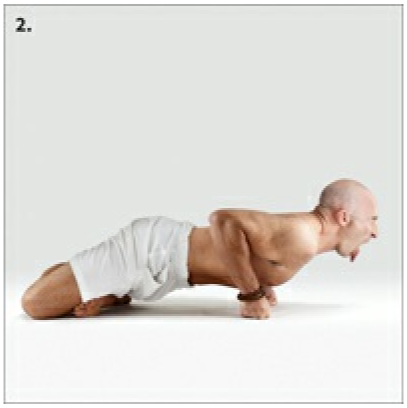

Leg Position of One-Legged King Pigeon 1 Version B in Four Limbed Staff Pose

Pada Eka Pada Raja Kapotasana 1 B in Chaturanga Dandasana

(PUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh in chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: bottom knee bent and on the floor; top leg straight—knee resting on the sole of the bottom foot
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

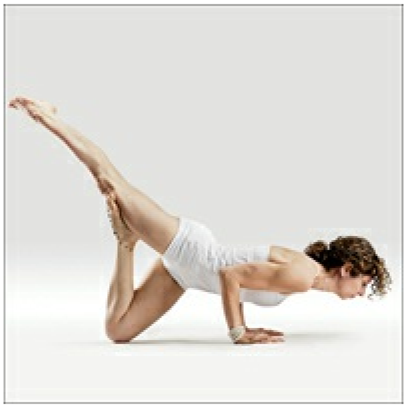

Four Limbed Staff Pose

Chaturanga Dandasana

(chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

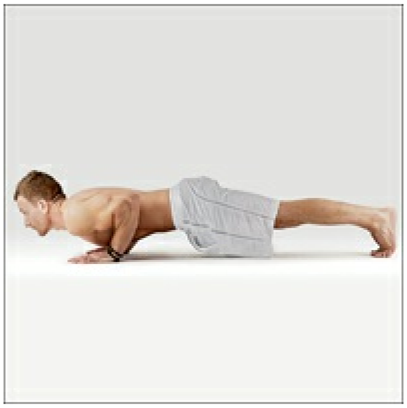

Crocodile Pose

Nakrasana

(nuh-KRAHS-uh-nuh)

Modification: feet and hands off the floor and up in the air
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

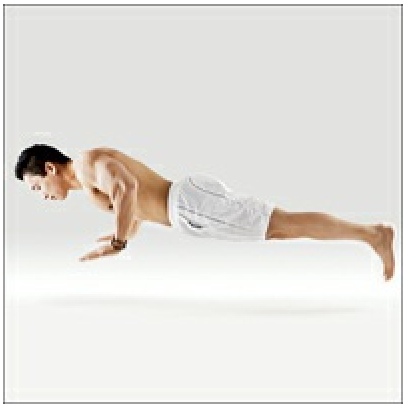

Revolved Four Limbed Staff Pose

Parivritta Chaturanga Dandasana

(puh-ri-VRIT-tuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Pose Type: arm balance, twist, core

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

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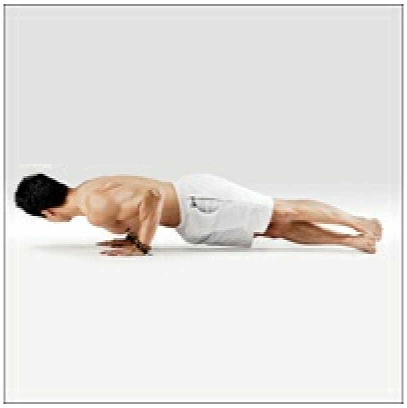

One-Legged Four Limbed Staff Pose

Eka Pada Chaturanga Dandasana

(EY-kuh PUH-duh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Pose Type: arm balance, core

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

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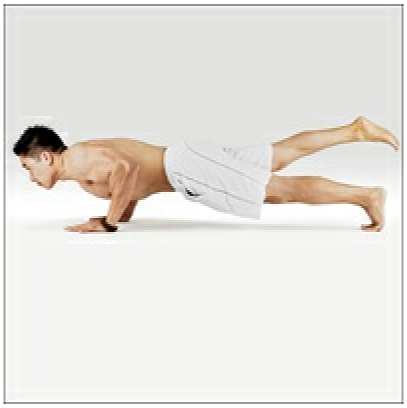

Upward One Leg to the Side Four Limbed Staff Pose

Urdhva Parshva Eka Pada Chaturanga Dandasana

(OORD-vuh PAHRSH-vuh EY-kuh PUH-duh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Pose Type: arm balance, core

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

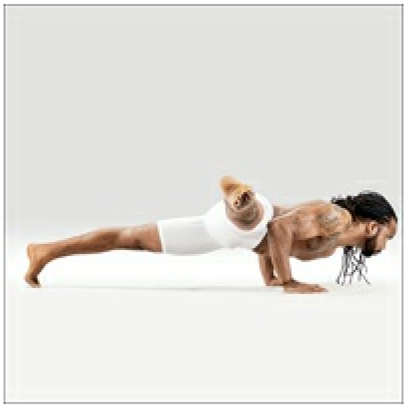

FOUR LIMBED STAFF POSE: KNEE TO THE ARM

One-Legged Four Limbed Staff Pose

Eka Pada Chaturanga Dandasana

(EY-kuh PUH-duh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: knee to the forearm
Pose Type: arm balance, forward bend, core
Drishti Point: Nasagrai or Nasagre (nose)

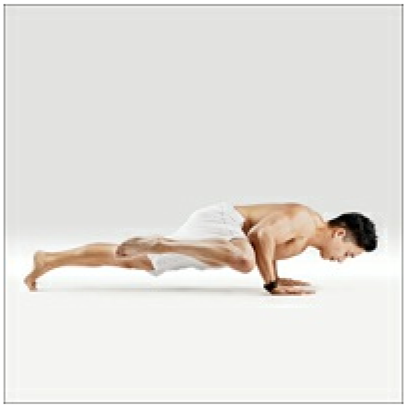

One-Legged Four Limbed Staff Pose

Eka Pada Chaturanga Dandasana

(EY-kuh PUH-duh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: knee on top of the tricep
Pose Type: arm balance, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

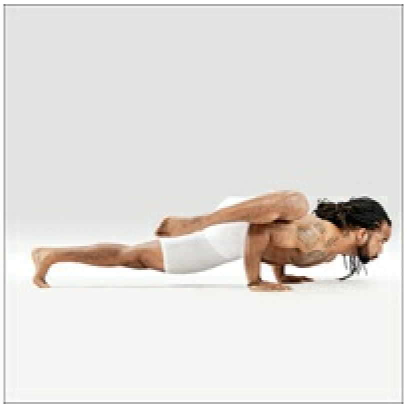

FOUR LIMBED STAFF POSE: ONE ARMED

One Hand Four Limbed Staff Pose

Eka Hasta Chaturanga Dandasana

(EY-kuh HUH-stuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: hand to the heart
Pose Type: arm balance, core
Drishti Point: Hastagrai or Hastagre (hands) or Nasagrai or Nasagre (nose)

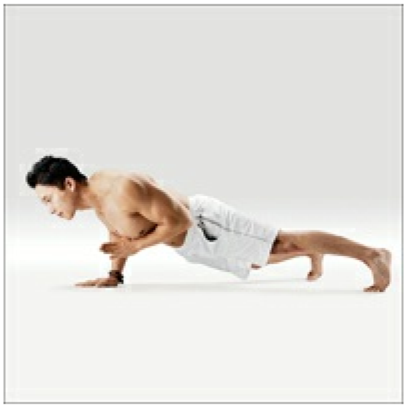

Hand to the Side Four Limbed Staff Pose

Parshva Hasta Chaturanga Dandasana

(PAHRSH-vuh HUH-stuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: 1. knees on the floor
2. knees off the floor
Pose Type: arm balance, core
Drishti Point: Hastagrai or Hastagre (hands) or Nasagrai or Nasagre (nose)

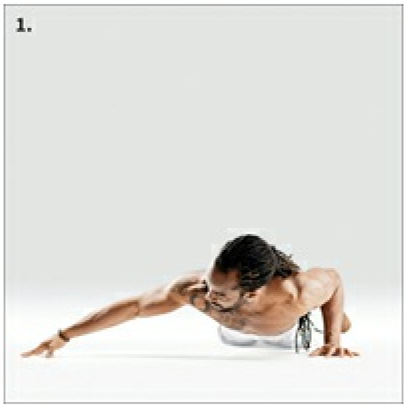

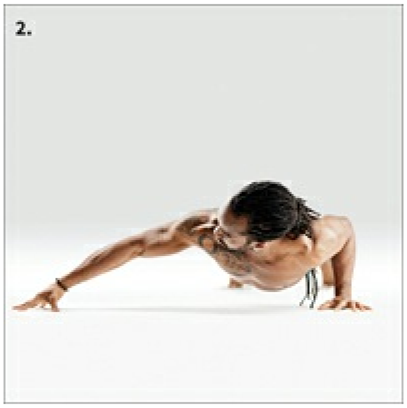

One Hand to the Side Four Limbed Staff Pose

Parshva Eka Hasta Chaturanga Dandasana

(PAHRSH-vuh EY-kuh HUH-stuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: one knee on the floor, other knee off the floor

Pose Type: arm balance, core

Drishti Point: Nasagrai or Nasagre (nose)

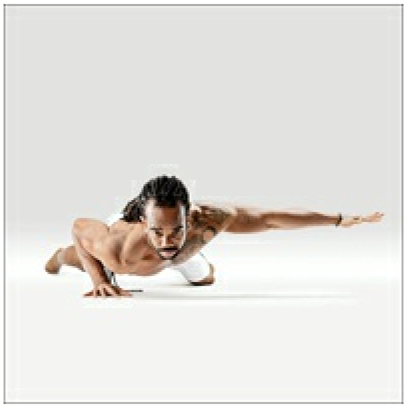

One Hand to the Side Four Limbed Staff Pose

Parshva Eka Hasta Chaturanga Dandasana

(PAHRSH-vuh EY-kuh HUH-stuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: knees off the floor

Pose Type: arm balance, core

Drishti Point: Nasagrai or Nasagre (nose)

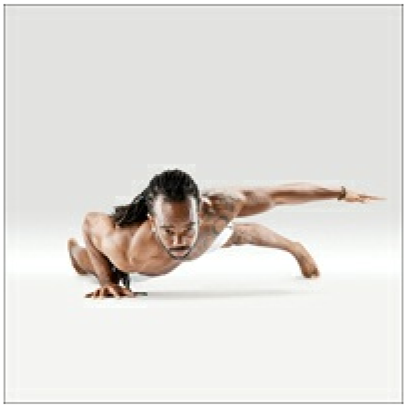

One Hand to the Side One-Legged Four Limbed Staff Pose

Parshva Eka Hasta Eka Pada Chaturanga Dandasana

(PAHRSH-vuh EY-kuh HUH-stuh EY-kuh PUH-duh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: one knee on the floor

Pose Type: arm balance, core

Drishti Point: Hastagrai or Hastagre (hands)

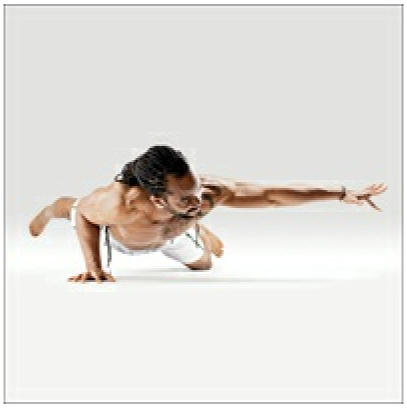

FOUR LIMBED STAFF POSE: PUSH UPS

Diamond Four Limbed Staff Pose

Vajra Chaturanga Dandasana

(VAHJ-ruh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: knees on the floor

1. start position
2. end position

Pose Type: arm balance, core

Drishti Point: Nasagrai or Nasagre (nose)

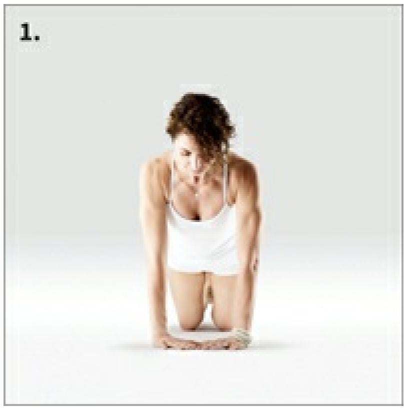

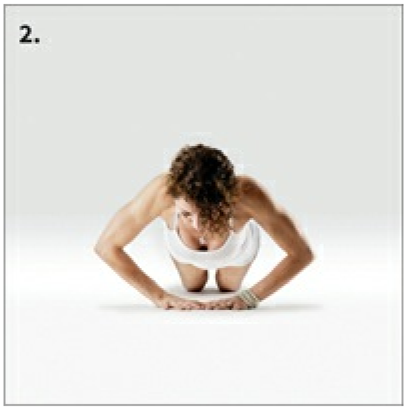

Diamond Four Limbed Staff Pose

Vajra Chaturanga Dandasana

(VAHJ-ruh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: knees off the floor

1. start position
2. end position

Pose Type: arm balance, core

Drishti Point: Nasagrai or Nasagre (nose)

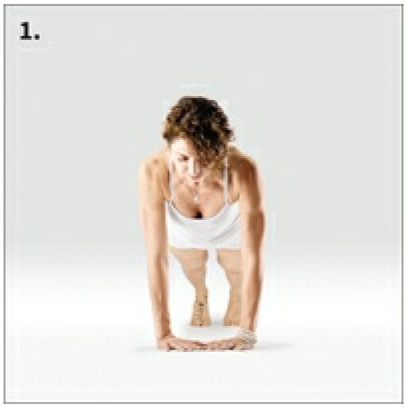

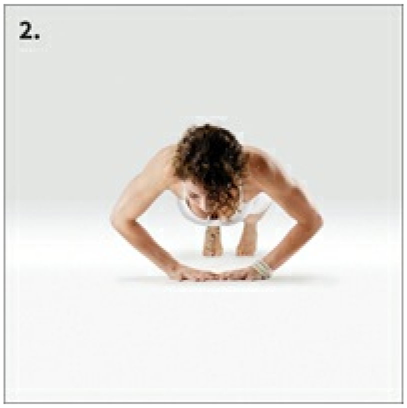

Hands Spread Wide Four Limbed Staff Pose

Prasarita Hasta Chaturanga Dandasana

(pruh-SAH-ri-tuh HUH-stuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: knees on the floor
1. start position
2. end position
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose)

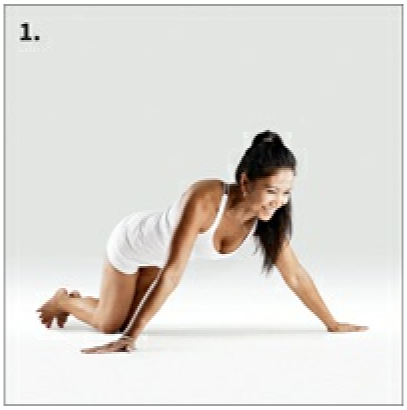

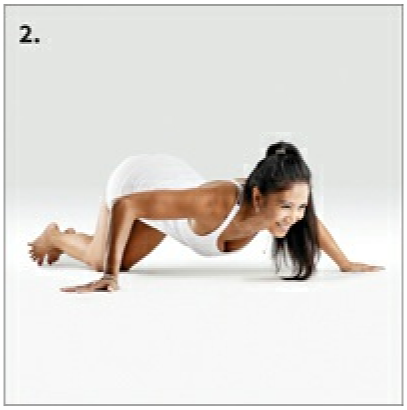

Hands Spread Wide Four Limbed Staff Pose

Prasarita Hasta Chaturanga Dandasana

(pruh-SAH-ri-tuh HUH-stuh chuh-tur-UHNG-guh duhn-DAHS-uh-nuh)

Modification: knees off the floor

1. start position
2. end position

Pose Type: arm balance, core

Drishti Point: Nasagrai or Nasagre (nose)

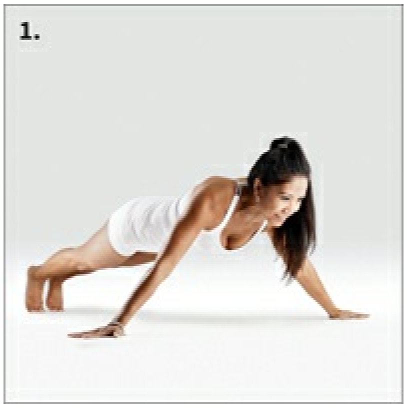

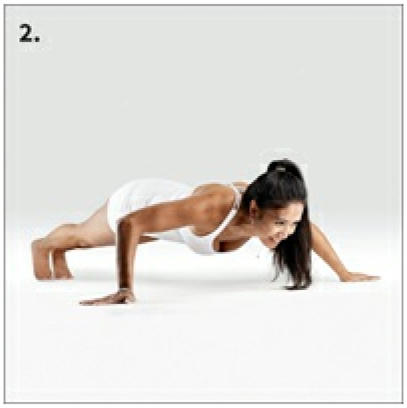

SIDE PLANK: TOP LEG CROSSED OVER

Pose Dedicated to Sage Vasistha

Vasisthasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Side Plank Modification
Modification: top leg crossing over
1. arm alongside of the torso
2. arm extended up
Pose Type: arm balance, core
Drishti Point: Nasagrai or Nasagre (nose), Angushtamadhye or Angushta Ma Dyai (thumbs)

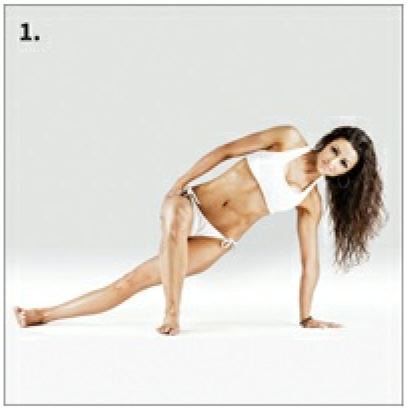

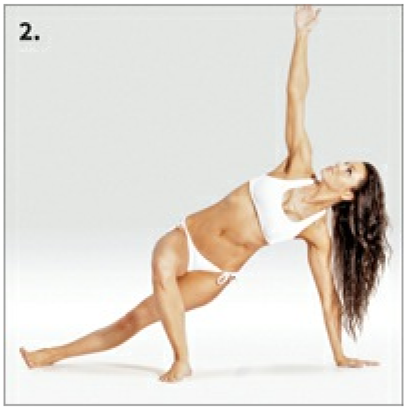

Pose Dedicated to Sage Vasistha

Vasisthasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Side Plank Modification
Modification: bottom knee to the floor
1. arm alongside of the torso
2. arm extended up
Pose Type: arm balance, core
Drishti Point: Angushtamadhye or Angushtha Ma Dyai (thumbs)

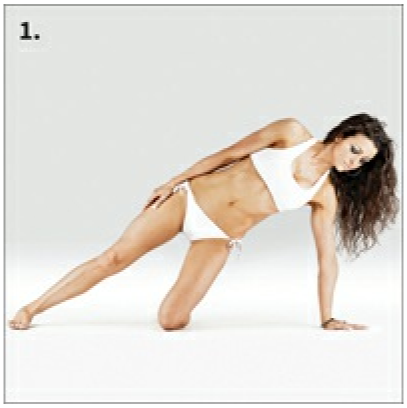

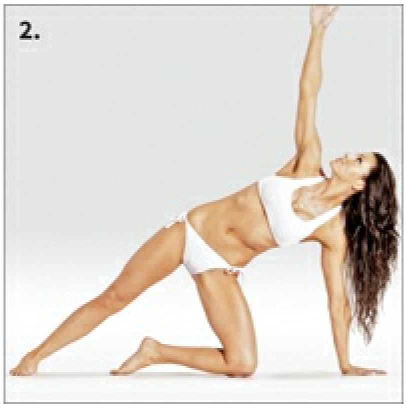

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Side Plank Modification

Modification: both knees bent, shin of the top leg on the inside of the knee of the bottom leg

1. bottom leg bent at 90 degrees
2. bottom leg slightly bent

Pose Type: arm balance, core

Drishti Point: Urdhva or Antara Drishti (up to the sky)

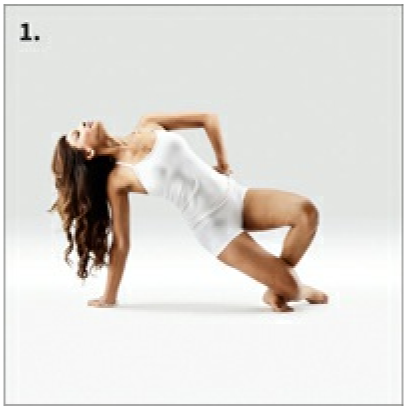

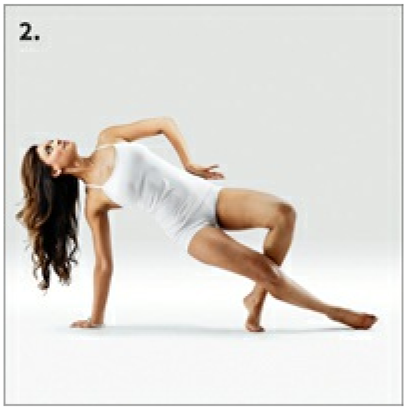

SIDE PLANK: LEGS STRAIGHT

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Side Plank Modification
Modification: both legs straight
1. arm alongside of the torso
2. arm extended up
Pose Type: arm balance, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

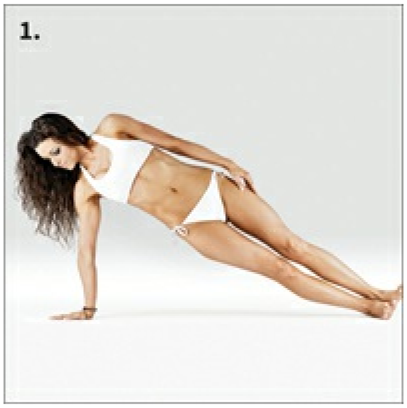

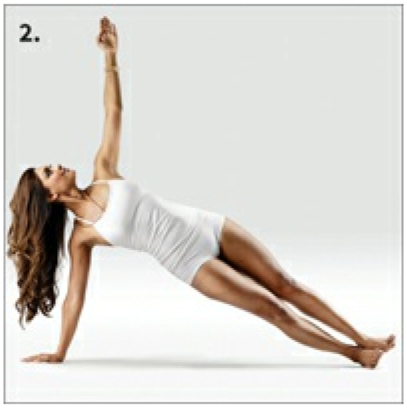

SIDE PLANK: BOTTOM LEG OFF THE FLOOR

Revolved Pose Dedicated to Sage Vasistha

Parivritta Vasisthasana

(puh-ri-VRIT-tuh vuh-sish-TAHS-uh-nuh)

Also Known As: Revolved Side Plank Modification

Modification: bottom knee bent, foot resting on the thigh of the top leg; the wrist of the top arm to the knee of the bottom leg

Pose Type: arm balance, twist, forward bend, core

Drishti Point: Hastagrai or Hastagre (hands)

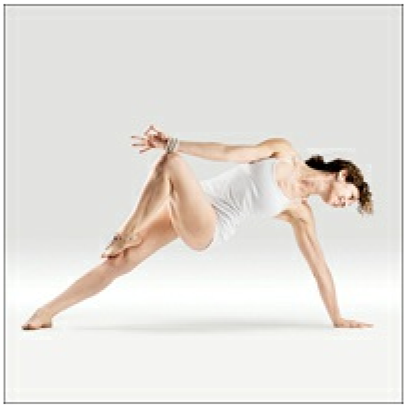

Revolved Leg to the Side Pose Dedicated to Sage Vasistha

Parivritta Parshva Pada Vasisthasana

(puh-ri-VRIT-tuh PAHRSH-vuh PUH-duh vuh-sish-TAHS-uh-nuh)

Also Known As: Revolved Leg to the Side Plank Modification

Modification: both legs straight, bottom foot lifted off the floor, leg crossing over in front of the body

Pose Type: arm balance, twist, core

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Padayoragrai or Padayoragre

(toes/feet)

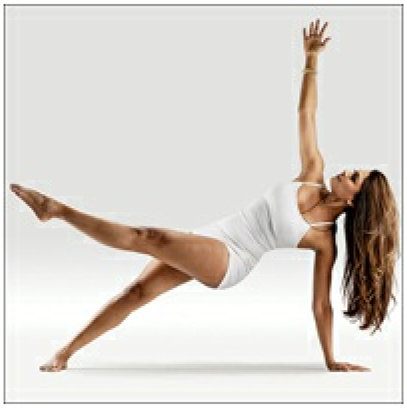

Hand to Foot Pose Dedicated to Sage Vasistha

Hasta Pada Vasisthasana

(HUH-stuh PUH-duh vuh-sish-TAHS-uh-nuh)

Also Known As: Hand to Foot Side Plank Modification

Modification: both legs straight; bottom leg crossing over in front of the body, foot in line with the center of the chest

Pose Type: arm balance, forward bend, core

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

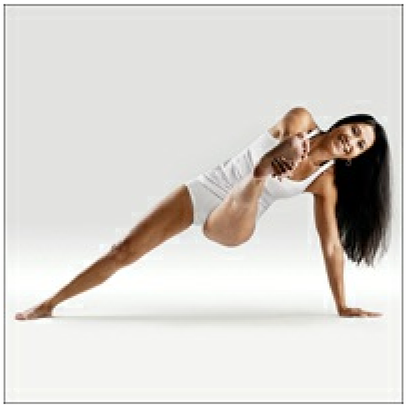

SIDE PLANK: FOOT TO THE THIGH & HALF LOTUS

Tree Pose in Pose Dedicated to Sage Vasista

Vrikshasana in Vasishtasana

(vrik-SHAHS-uh-nuh in vuh-sish-TAHS-uh-nuh)

Also Known As: Tree Pose in Side Plank Modification

Modification: top foot to the inner thigh
Pose Type: arm balance, core
Drishti Point: Urdhva or Antara Drishti (up to the sky)

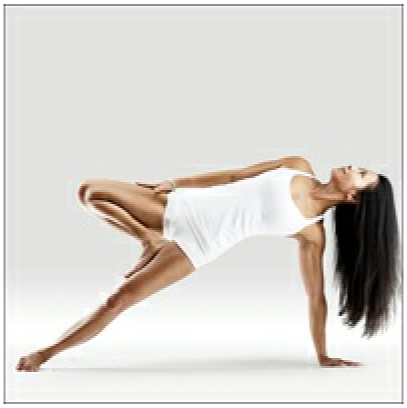

Half Lotus Pose in Pose Dedicated to Sage Vasishta

Ardha Padmasana in Vasishtasana

(UHR-duh puhd-MAHS-uh-nuh in vuh-sish-TAHS-uh-nuh)

Also Known As: Half Lotus Pose in Side Plank Modification
Modification: bottom knee on the floor
Pose Type: arm balance, core
Drishti Point: Hastagrai or Hastagre (hands)

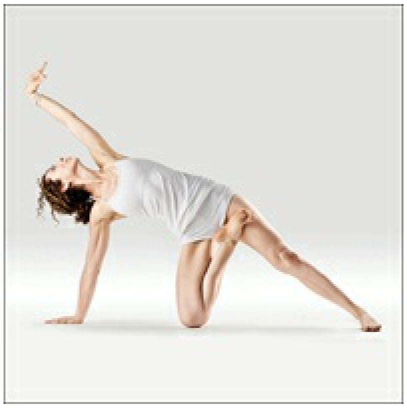

SIDE PLANK: TOP LEG OFF THE FLOOR

One Big Toe Pose Dedicated to Sage Vasishta

Eka Padangushta Vasisthasana

(EY-kuh puhd-ahng-GOOSH-tuh vuh-sish-TAHS-uh-nuh)

Also Known As: Big Toe Side Plank Modification
Modification: 1. bottom knee on the floor—leg bent, toes pointing to the back; on the fingertips
2. bottom knee off the floor; palm flat to the floor
Pose Type: arm balance, forward bend, core
Drishti Point: Urdhva or Antara Drishti (up to the sky), Padayoragrai or Padayoragre (toes/feet)
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1.

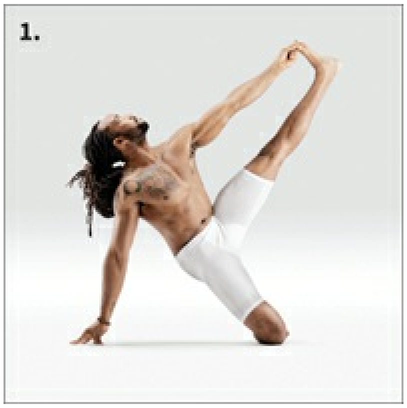

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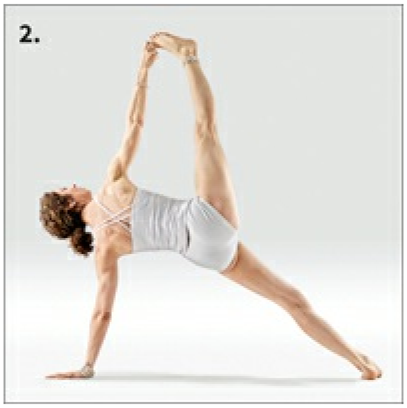

VISHVAMITRA’S POSE

Pose Dedicated to Vishvamitra

Vishvamitrasana

(vish-vuh-mi-TRAHS-uh-nuh)
Modification: knee on the floor, grabbing onto the outside edge of the foot
Pose Type: arm balance, side bend, twist, core
Drishti Point: Urdhva or Antara Drishti (up to the sky)
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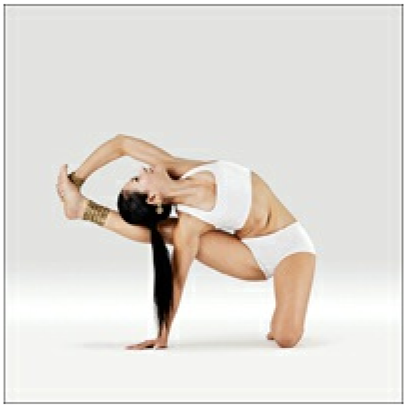

Pose Dedicated to Vishvamitra

Vishvamitrasana

(vish-vuh-mi-TRAHS-uh-nuh)

Modification: arm alongside of the torso
Pose Type: arm balance, core
Drishti Point: Urdhva or Antara Drishti (up to the sky)

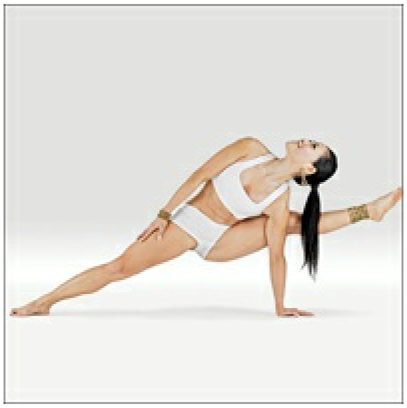

Pose Dedicated to Vishvamitra

Vishvamitrasana

(vish-vuh-mi-TRAHS-uh-nuh)

Modification: knee off the floor, top arm straight and extended up to the sky
Pose Type: arm balance, side bend, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

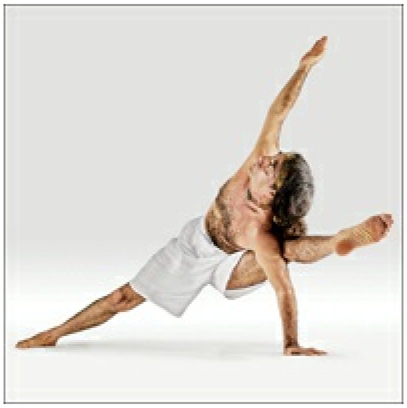

Pose Dedicated to Vishvamitra

Vishvamitrasana

(vish-vuh-mi-TRAHS-uh-nuh)

Modification: knee off the floor
1. grabbing onto the outside edge of the top foot
2. grabbing onto the ankle of the top leg
Pose Type: arm balance, side bend, twist, core
Drishti Point: Urdhva or Antara Drishti (up to the sky)

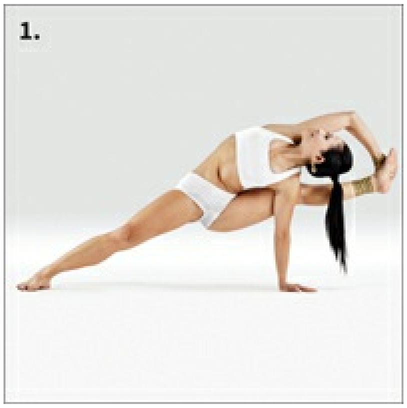
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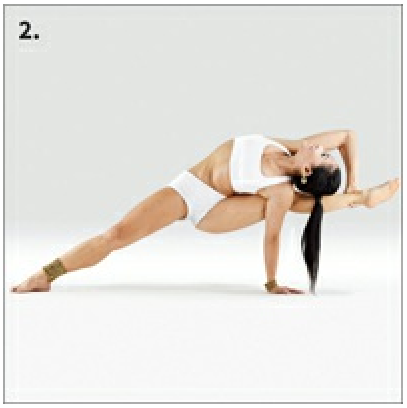
2.

KALA BHAIRAVA’S POSE

Pose Dedicated to Shiva the Destroyer

Kala Bhairavasana

(KAH-luh beye-ruh-VAHS-uh-nuh)

Modification: 1. arm extended up
2. top hand to the inside of the bottom thigh

Pose Type: arm balance, core

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Padayoragrai or Padayoragre (toes/feet)

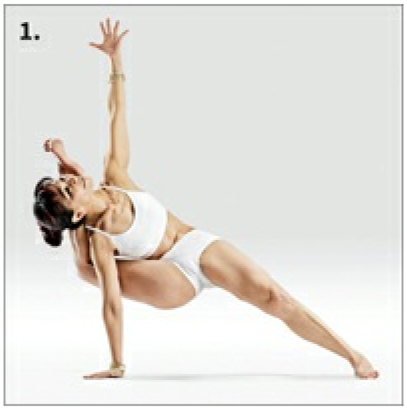

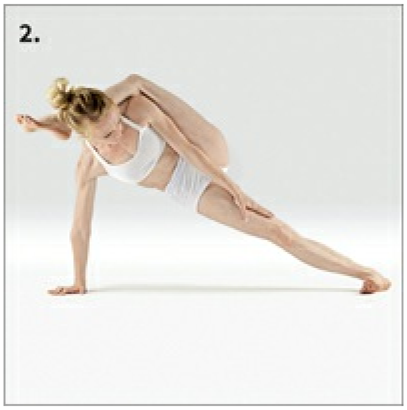

SIDE PLANK: TOP LEG OVERHEAD GRIP

Partridge Pose

Kapinjalasana

(kuh-pinj-uh-LAHS-uh-nuh)

Modification: overhead grip
1. bottom knee on the floor
2. bottom knee off the floor

Pose Type: arm balance, backbend, core

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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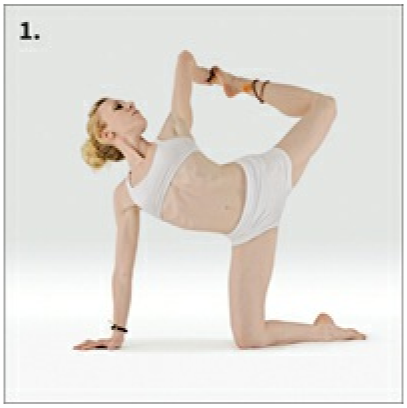
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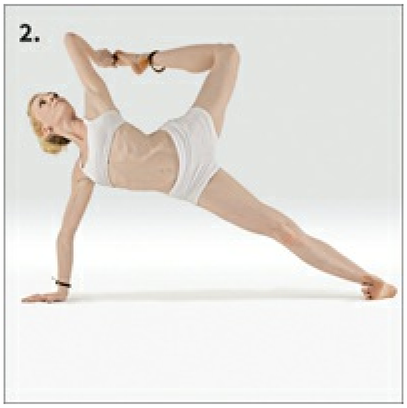
2.

SIDE PLANK ON FOREARMS: KNEES ON THE FLOOR

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Dolphin Side Plank Modification

Modification: forearm on the floor, both knees to the floor

1. arm up to the sky
2. arm alongside the torso

Pose Type: forearm balance, core

Drishti Point: 1. Angushtamadhye or Angushta Ma Dyai (thumbs)
2. Nasagrai or Nasagre (nose)

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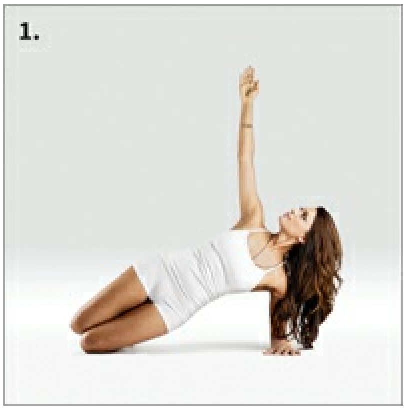

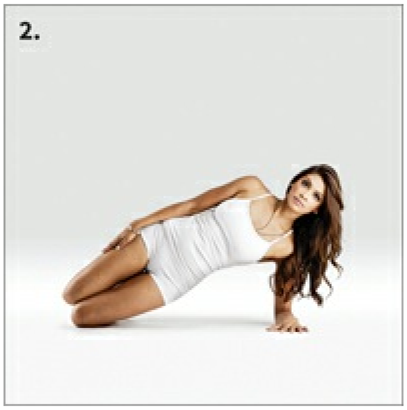

SIDE PLANK ON FOREARMS: KNEES OFF THE FLOOR

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Dolphin Side Plank Modification
Modification: forearm on the floor, arm crossed over in front of the chest, looking down
Pose Type: forearm balance, twist, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

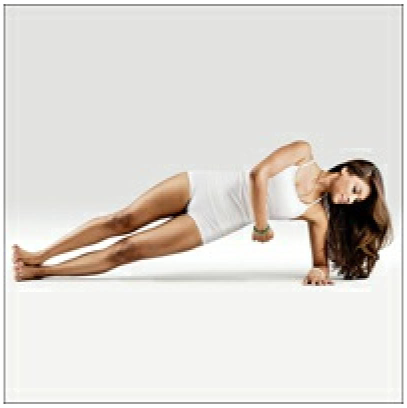

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Dolphin Side Plank Modification

Modification: forearm on the floor, top hand on the hip

Pose Type: forearm balance, core

Drishti Point: Nasagrai or Nasagre (nose)

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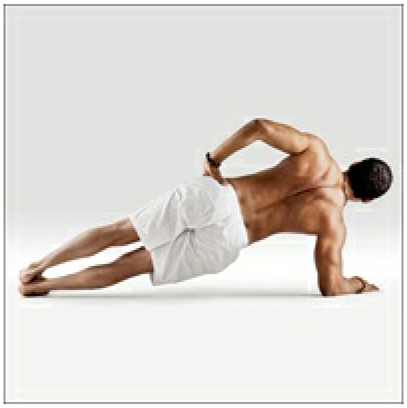

Pose Dedicated to Sage Vasistha

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Dolphin Side Plank Modification

Modification: forearm on the floor, top arm up to the sky

Pose Type: forearm balance, core

Drishti Point: Hastagrai or Hastagre (hands)

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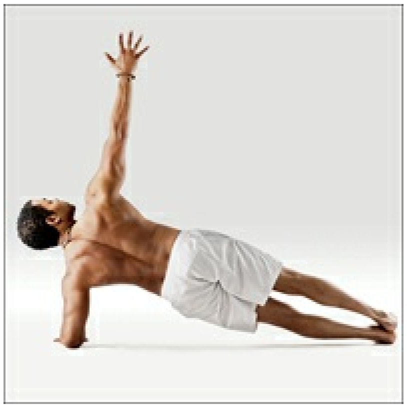

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Dolphin Side Plank Modification

Modification: forearm on the floor, top hand to the back of the head

Pose Type: forearm balance, core

Drishti Point: Nasagrai or Nasagre (nose)

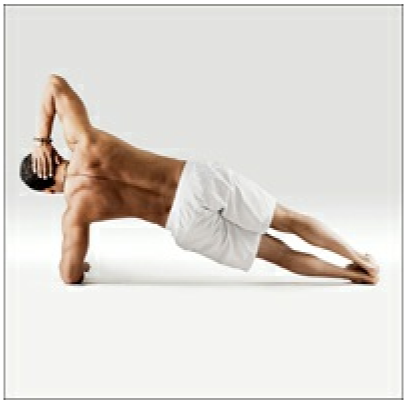

SIDE PLANK ON FOREARMS: ONE LEG CROSSED OVER

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Dolphin Side Plank Modification

Modification: forearm on the floor; top leg crossed over, foot flat on the floor; top hand by the bottom hip socket

Pose Type: forearm balance, core

Drishti Point: Urdhva or Antara Drishti (up to the sky)

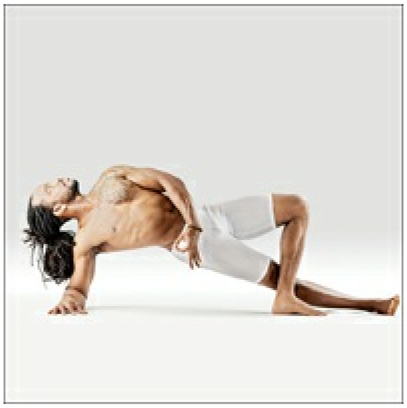

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Dolphin Side Plank Modification
Modification: forearm on the floor; top leg crossed over, heel lifted; top arm extended up to the sky
Pose Type: forearm balance, core
Drishti Point: Hastagrai or Hastagre (hands)

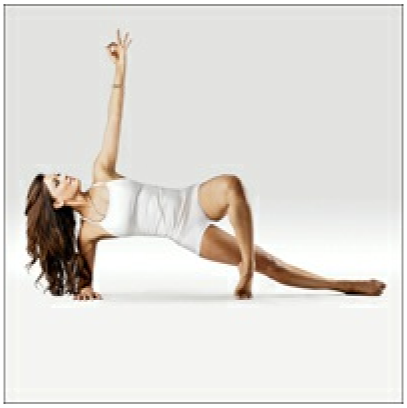

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Dolphin Side Plank Modification
Modification: forearm on the floor; top leg crossed over, foot flat on the floor, bottom leg lifted off the floor, top hand on the hip
Pose Type: forearm balance, core
Drishti Point: Urdhva or Antara Drishti (up to the sky)

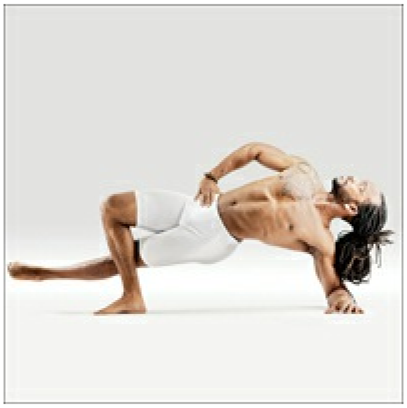

Half Lotus Pose in Pose Dedicated to Sage Vasishta

Ardha Padmasana in Vasishtasana

(UHR-duh puhd-MAHS-uh-nuh in vuh-sish-TAHS-uh-nuh)

Also Known As: Half Lotus Pose in Dolphin Side Plank Modification
Modification: forearm on the floor, top arm extended up to the sky
Pose Type: forearm balance, core
Drishti Point: Hastagrai or Hastagre (hands)
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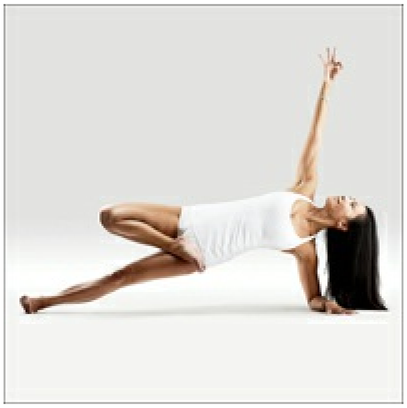

SIDE PLANK ON FOREARMS: TOP LEG LIFTED

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Dolphin Side Plank Modification
Modification: forearm on the floor; top knee toward the top elbow, bottom knee on the floor; leg bent, toes pointing to the back
Pose Type: forearm balance, forward bend, core
Drishti Point: Hastagrai or Hastagre (hands)
ल व

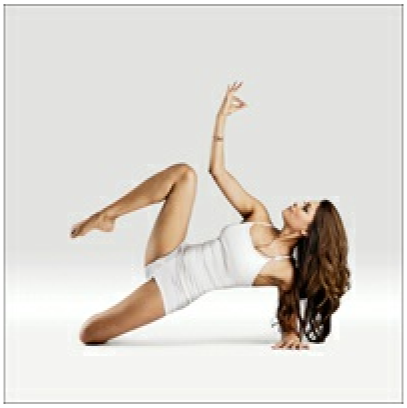

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Dolphin Side Plank Modification
Modification: forearm on the floor; top knee toward the top elbow; bottom leg straight, knee off floor
Pose Type: forearm balance, forward bend, core
Drishti Point: Hastagrai or Hastagre (hands)

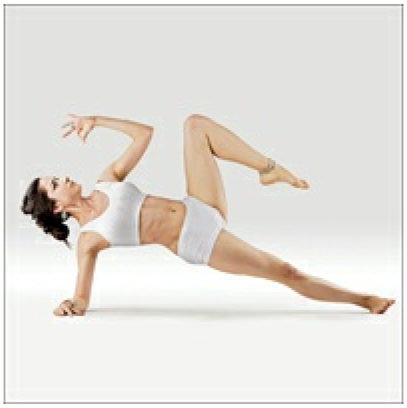

One Big Toe Pose Dedicated to Sage Vasishta

Eka Padangushta Vasishtasana

(EY-kuh puhd-ahng-GOOSH-tuh vuh-sish-TAHS-uh-nuh)

Also Known As: Big Toe Dolphin Side Plank Modification
Modification: forearm on the floor
1. knee bent
2. leg straight
Pose Type: forearm balance, forward bend, core
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

1.

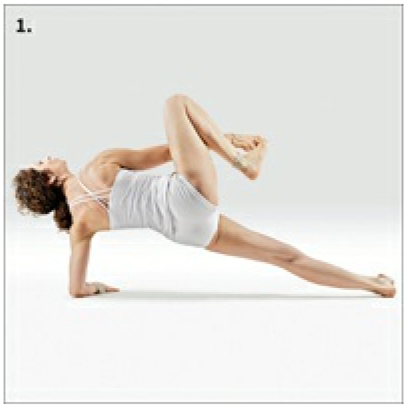

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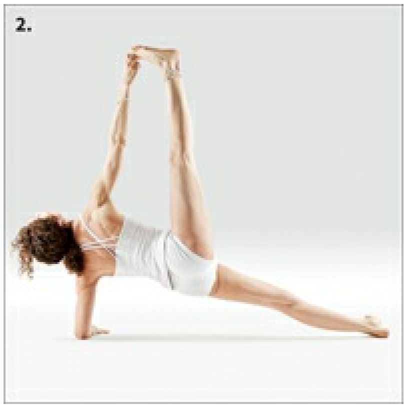

SIDE PLANK ON FOREARMS: BOTTOM LEG LIFTED

Revolved Leg to the Side Pose Dedicated to Sage Vasishta

Parivritta Parshva Pada Vasishtasana

(puh-ri-VRIT-tuh PAHRSH-vuh PUH-duh vuh-sish-TAHS-uh-nuh)

Also Known As: Revolved Leg to the Side Dolphin Side Plank Modification
Modification: forearm on the floor; both legs straight, bottom leg lifted in front of the body
Pose Type: forearm balance, twist, core
Drishti Point: Hastagrai or Hastagre (hands)
ल व य

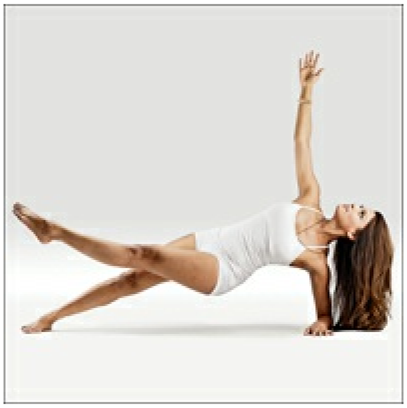

Revolved Pose Dedicated to Sage Vasishta

Parivritta Vasishtasana

(puh-ri-VRIT-tuh vuh-sish-TAHS-uh-nuh)

Also Known As: Revolved Dolphin Side Plank Modification

Modification: forearm on the floor; bottom knee bent, foot resting on the thigh of the top leg; the elbow of the top arm to the knee of the bottom leg

Pose Type: forearm balance, forward bend, twist, core

Drishti Point: Urdhva or Antara Drishti (up to the sky)

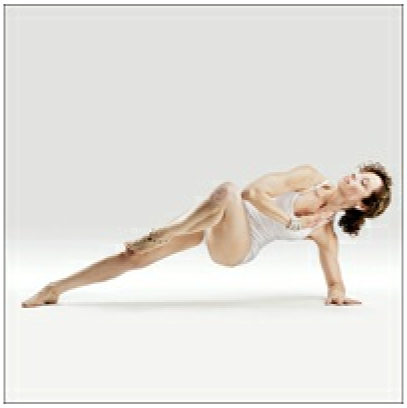

SIDE PLANK ON FOREARMS: TOP LEG UNDER-HEAD GRIP

Partridge Pose

Kapinjalasana

(kuh-pinj-uh-LAHS-uh-nuh)

Modification: forearm on the floor, under-head grip:

1. knee on the floor
2. knee off the floor

Pose Type: forearm balance, backbend, core

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

1.

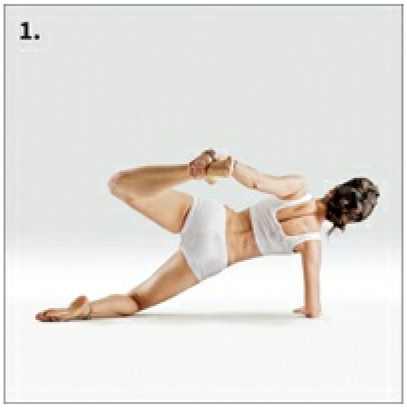

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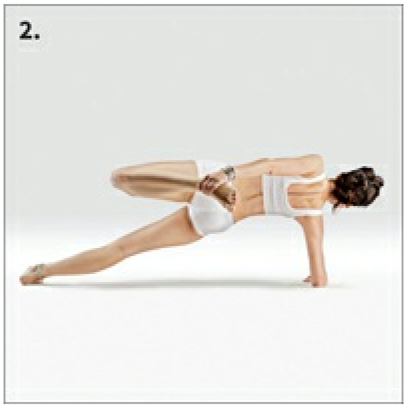

SIDE PLANK ON FOREARMS: HALF LOTUS & LOTUS

Half Lotus Pose in Pose Dedicated to Sage Vasistha

Ardha Padmasana in Vasishtasana

(UHR-duh puhd-MAHS-uh-nuh in vuh-sish-TAHS-uh-nuh)

Also Known As: Half Lotus Dolphin Side Plank Modification

Modification: forearm on the floor, bottom leg in half lotus, top knee bent, toes to the floor

Pose Type: forearm balance, core

Drishti Point: Hastagrai or Hastagre (hands)

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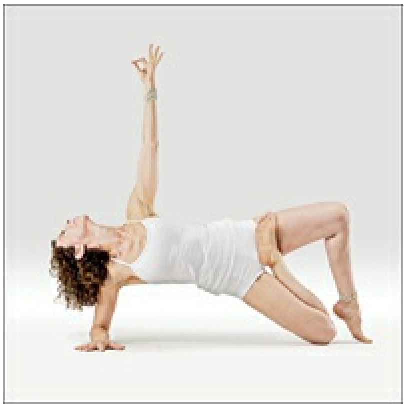

Half Lotus One Big Toe Pose Dedicated to Sage Vasistha

Ardha Padma Eka Padangushta Vasisthasana

(UHR-duh PUHD-muh EY-kuh puhd-ahng-GOOSH-tuh vuh-sish-TAHS-uh-nuh)

Also Known As: Half Lotus Big Toe Dolphin Side Plank Modification
Modification: forearm on the floor
Pose Type: forearm balance, forward bend, core
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Urdhva or Antara Drishti (up to the sky)
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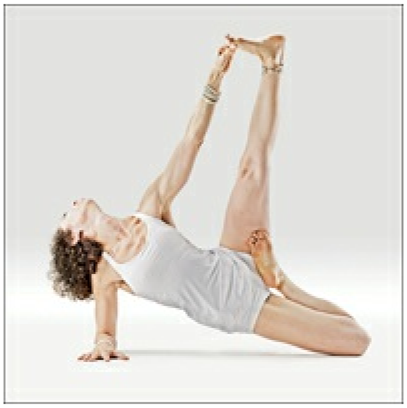

Half Lotus Half Bow Pose in Pose Dedicated to Sage Vasishta

Ardha Padma Dhanurasana in Vasishtasana

(UHR-duh PUHD-muh duh-nur-AHS-uh-nuh in vuh-sish-TAHS-uh-nuh)

Also Known As: Half Lotus Half Bow Pose in Dolphin Side Plank Modification
Modification: forearm on the floor, bottom leg in half lotus, grabbing onto the top foot with underhead grip
Pose Type: forearm balance, backbend, core
Drishti Point: Hastagrai or Hastagre (hands)
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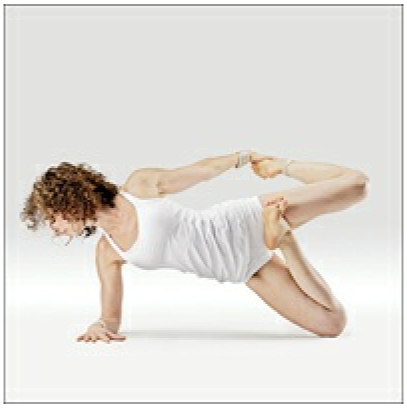

Lotus Pose in Pose Dedicated to Sage Vasishta

Padmasana in Vasisthasana

(puhd-MAHS-uh-nuh in vuh-sish-TAHS-uh-nuh)

Also Known As: Lotus Pose in Dolphin Side Plank Modification
Modification: forearm on the floor
Pose Type: forearm balance, core
Drishti Point: Hastagrai or Hastagre (hands)

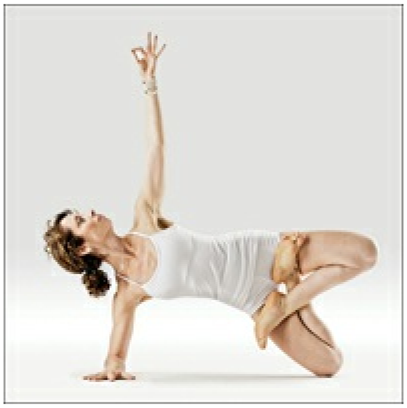

SIDE PLANK ON THE ELBOWS

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Elbow Side Plank Modification
Modification: on the elbow; both legs straight, ankles crossed
Pose Type: elbow balance, core
Drishti Point: Urdhva or Antara Drishti (up to the sky)

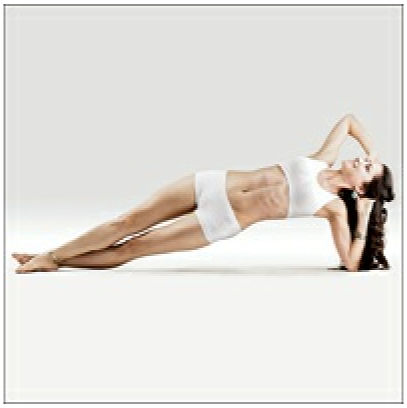

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Elbow Side Plank Modification

Modification: on the elbow; bottom leg straight; top leg crossed over, foot flat on the floor; fingertips of the top arm to the floor in front of the body

Pose Type: elbow balance, core

Drishti Point: Urdhva or Antara Drishti (up to the sky)

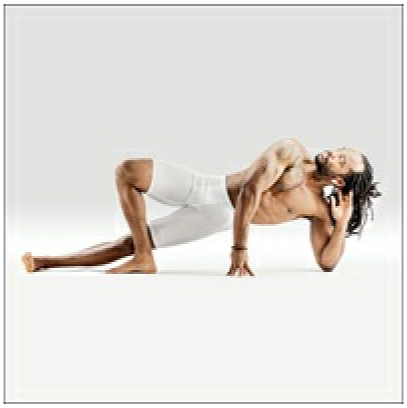

Pose Dedicated to Sage Vasishta

Vasishtasana

(vuh-sish-TAHS-uh-nuh)

Also Known As: Elbow Side Plank Modification

Modification: on the elbow, top foot to the side of the bottom leg

Pose Type: elbow balance, core

Drishti Point: Nasagrai or Nasagre (nose)

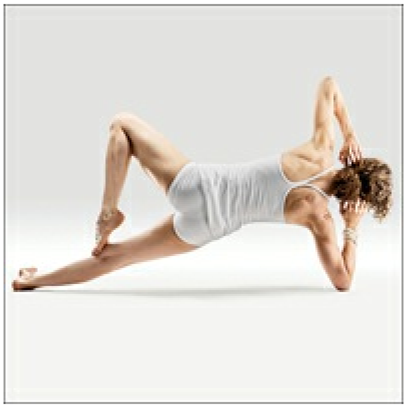

Half Lotus Pose in Pose Dedicated to Sage Vasistha

Ardha Padmasana in Vasisthasana

(UHR-duh puhd-MAHS-uh-nuh in vuh-sish-TAHS-uh-nuh)

Also Known As: Half Lotus Pose in Elbow Side Plank Modification
Modification: on the elbow
Pose Type: elbow balance, core
Drishti Point: Hastagrai or Hastagre (hands)

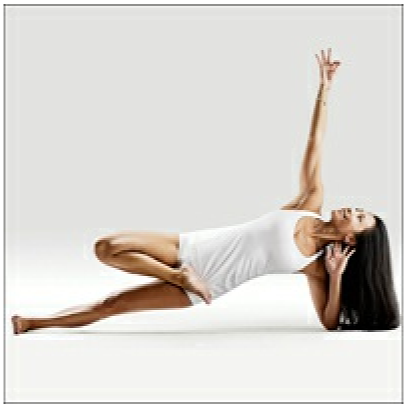

Backbends

COW FACE POSE AND GARUDA ON KNEES

KNEES ON THE FLOOR

BACKBEND ON THE KNEES

BACKBEND

UPWARD BOW POSE

WILD THING POSE

Pose Dedicated to Garuda on the Knees

Janu Garudasana

(JAH-nu guh-ru-DAHS-uh-nuh)

Pose Type: standing (on the knees), backbend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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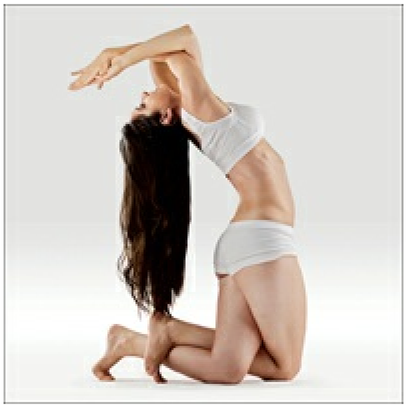

Leg Position of Cow Face Pose in Camel Pose

Pada Gomukhasana in Ushtrasana[*]

(PUH-duh go-moo-KAHS-uh-nuh in oosh-TRAHS-uh-nuh)

Modification: Gomukhasana legs modification

Pose Type: backbend, standing (on the knees)

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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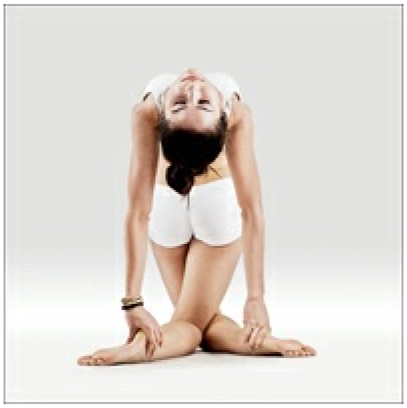

KNEES ON THE FLOOR: LOTUS POSE

Half Pose Dedicated to Siddhar Kamalamuni

Ardha Kamalamunyasana

(UHR-duh KUH-muh-luhmoo-nyAHS-uh-nuh)

Also Known As: Upward Facing Lotus Pose (Urdhva Mukha Padmasana)
Modification: fingertips pointing to the back, thumbs pointing to the front, knees close to the hands
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

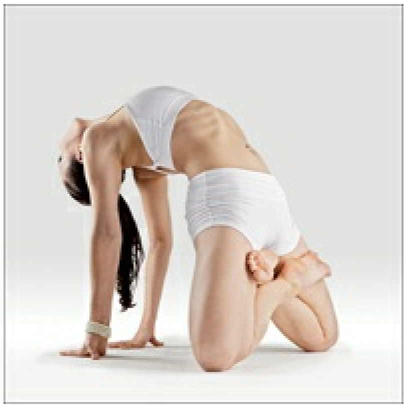

ONE KNEE TO THE FLOOR: ONE LEG BENT & ONE LEG STRAIGHT UP TO THE SKY

One-Legged Camel Pose

Eka Pada Ushtrasana

(EY-kuh PUH-duh oosh-TRAHS-uh-nuh)

Modification: Leg 1: knee to the floor Leg 2: foot to the floor in semi-lunge position
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

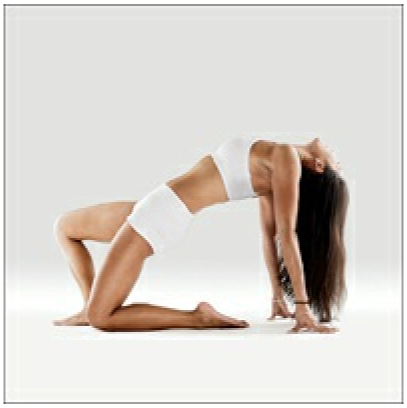

One-Legged Camel Pose

Eka Pada Ushtrasana

(EY-kuh PUH-duh oosh-TRAHS-uh-nuh)

Modification: Leg 1: knee to the floor
Leg 2: sole of the foot to the quadricep
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

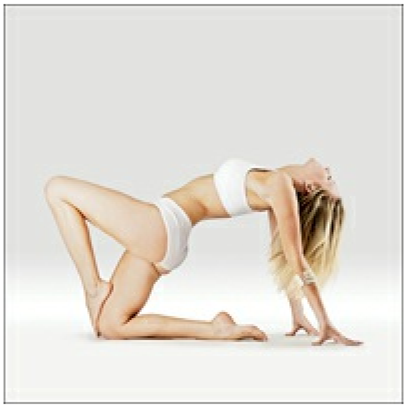

Extended Hand to Big Toe Pose in Half Camel Pose

Utthita Hasta Padangushtasana in Ardha Ushtrasana

(UT-ti-tuh HUH-stuh puhd-AHNG-goosh-TAHS-uh-nuh in UHR-duh oosh-TRAHS-uh-nuh)

Modification: 1. toes pointed to the back
2. toes curled in
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

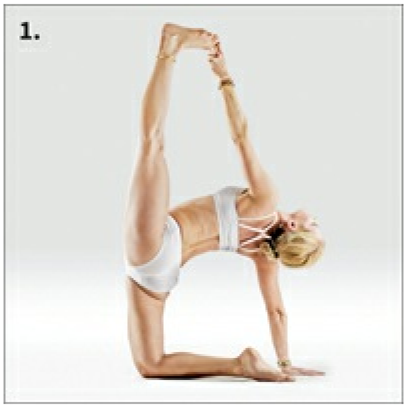

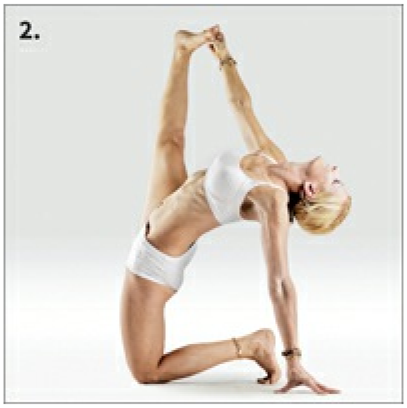

KNEES TO THE FLOOR: BACKBEND

Camel Pose Prep.

Ushtrasana Prep.

(oosh-TRAHS-uh-nuh)

Modification: 1. hands to the lower back
2. hands in Anjali Mudra (Hands in Prayer)
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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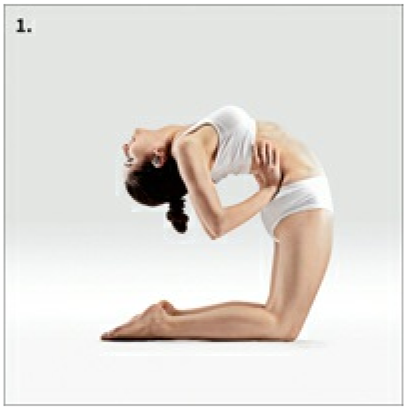

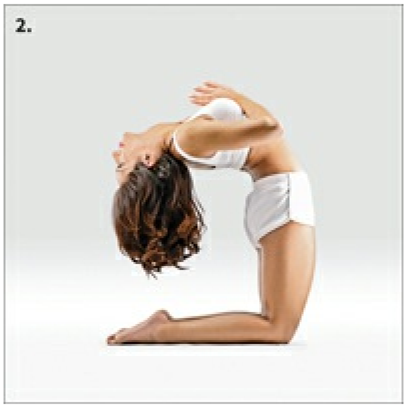

Upward Salute Pose in Camel Pose

Urdhva Hastasana in Ushtrasana

(OORD-vuh huh-STAHS-uh-nuh in oosh-TRAHS-uh-nuh)

Also Known As: Pigeon Pose Prep. (Kapotasana Prep.)
Modification: palms together
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angushtamadhye or Angushta Ma Dyai (thumbs)

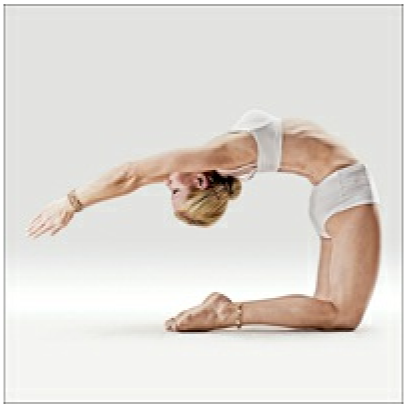

Raised Bound Hands in Camel Pose

Urdhva Baddha Hastasana in Ushtrasana

(OORD-vuh BUH-duh huh-STAHS-uh-nuh in oosh-TRAHS-uh-nuh)

Modification: 1. hips pushed back
2. hips pushed forward
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

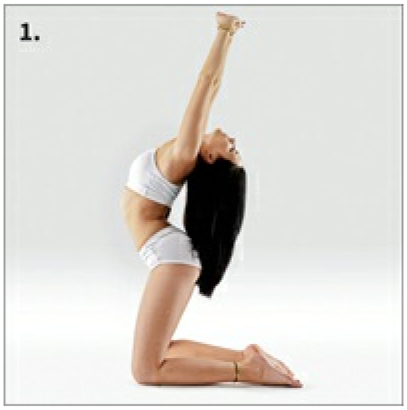

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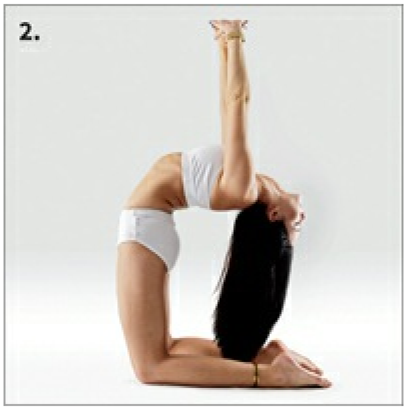

KNEES ON THE FLOOR: BACKBEND—HANDS TO THE HEELS AND TO THE FLOOR

Camel Pose

Ushtrasana

(oosh-TRAHS-uh-nuh)

Modification: 1. grabbing onto both ankles
2. palms to the heels, fingertips pointing to the back
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

1.

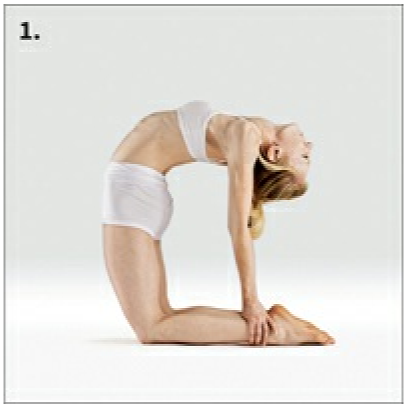

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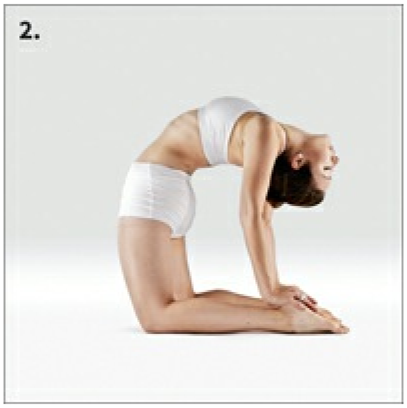

Pose Dedicated to King Nahusha

Nahushasana

(nuh-hu-SHAHS-uh-nuh)

Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

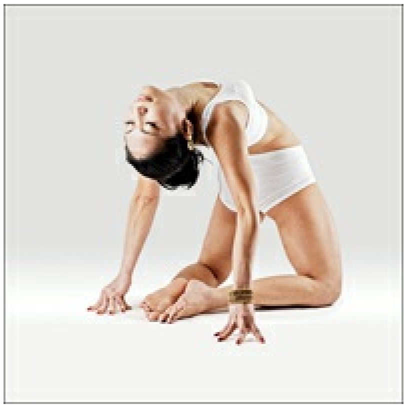

One Hand Graceful Thunderbolt Pose

Eka Hasta Laghuvajrasana

(EY-kuh huh-stuh luh-gu-vuhj-RAHS-uh-nuh)

Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

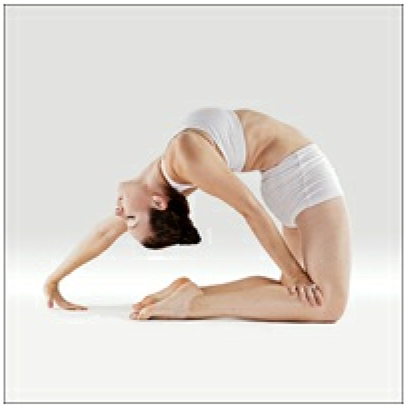

Pigeon Pose

Kapotasana

(kuh-po-TAHS-uh-nuh)

Also Known As: Sage Korakar Pose (Korakarasana), Graceful Thunderbolt Pose (Laghuvajrasana)
Modification: arms over the head, palms to the floor, feet toward the head
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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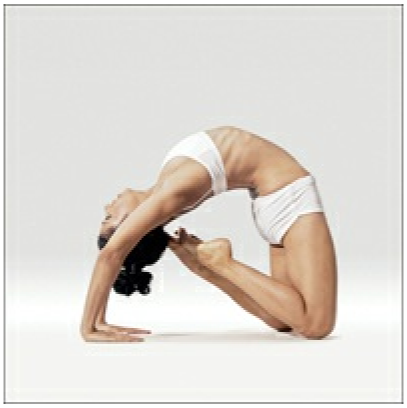

KNEES ON THE FLOOR: ONE ARM EXTENDED

Half Camel Pose

Ardha Ushtrasana

(UHR-duh oosh-TRAHS-uh-nuh)
Also Known As: One Arm Camel Pose (Eka Hasta Ustrasana)
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)
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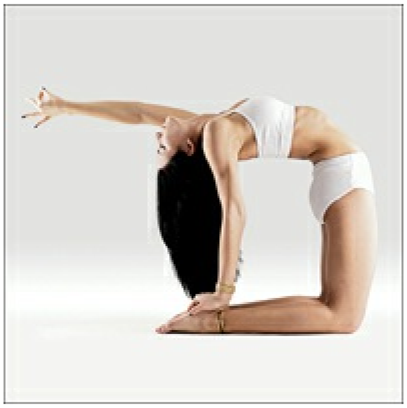

Half Camel Pose

Ardha Ushtrasana

(UHR-duh oosh-TRAHS-uh-nuh)

Modification: arm crossed behind the back to the opposite leg
1. hand to the outside of the hip
2. hand to the inside of the knee

Pose Type: backbend, standing (on the knees)

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)

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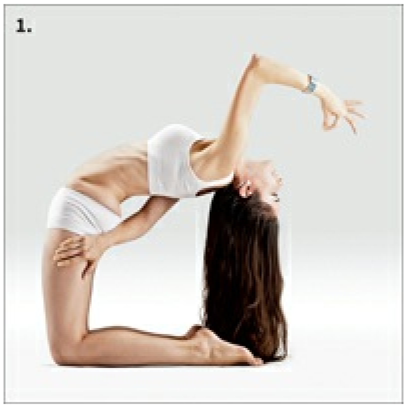

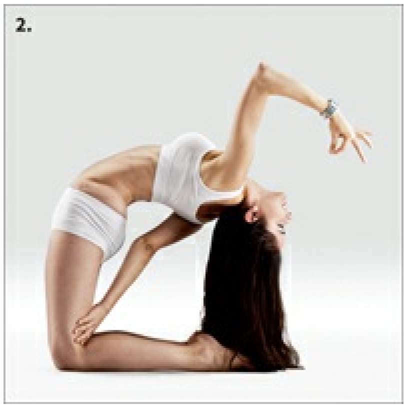

Leg Position of the Pose Dedicated to Garuda in Half Camel Pose

Pada Garudasana in Ardha Ushtrasana

(PUH-duh guh-ru-DAHS-uh-nuh in UHR-duh oosh-TRAHS-uh-nuh}

Modification: one hand to the floor; other arm up, elbow bent

Pose Type: backbend, standing (on the knees)

Drishti Point: Hastagrai or Hastagre (hands), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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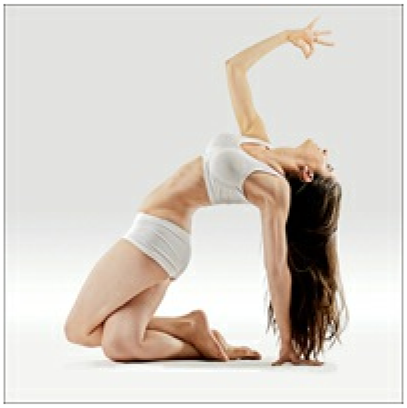

Half Camel Pose

Ardha Ushtrasana

(UHR-duh-oosh-TRAHS-uh-nuh)

Modification: one foot to the armpit on the same side; opposite arm straight up over the head
Pose Type: backbend, standing (on the knees)
Drishti Point: Hastagrai or Hastagre (hands), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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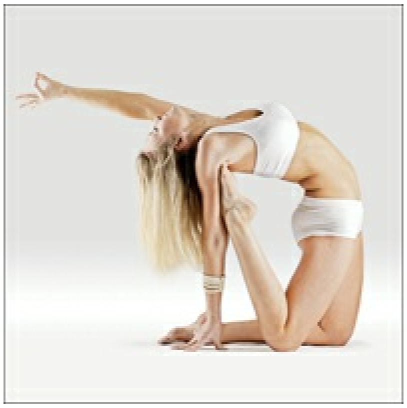

Half Bound Lotus Camel Pose

Ardha Baddha Padma Ushtrasana

(UHR-duh BUH-duh PUHD-muh oosh-TRAHS-uh-nuh)

Modification: free arm straight up over the head
Pose Type: backbend, standing (on the knees), binding
Drishti Point: Hastagrai or Hastagre (hands) or Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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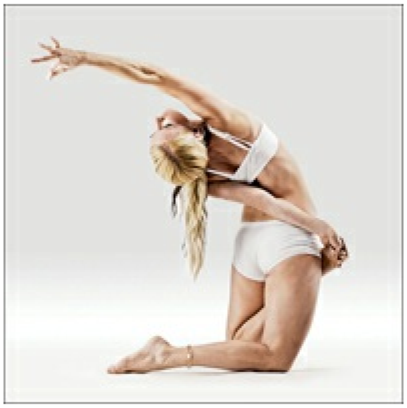

ONE KNEE BENT TOWARD THE HIP: BACKBEND

One-Legged Frog Pose in Camel Pose

Eka Pada Bhekasana in Ushtrasana

(EY-kuh PUH-duh bey-KAHS-uh-nuh in oosh-TRAHS-uh-nuh)

Pose Type: backbend, standing (on the knees)

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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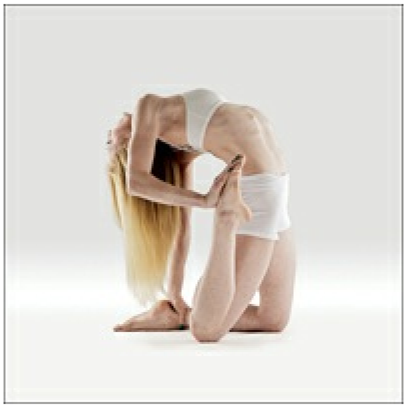

Mermaid Arm Position in Camel Pose

Hasta Naginyasana in Ushtrasana

(HUH-stuh nuh-gin-YAHS-uh-nuh in oosh-TRAHS-uh-nuh)

Pose Type: backbend, standing (on the knees)

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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[**BACKBEND ON THE KNEES, HEAD AND SITTING BONES: BED POSE**]

Bed Pose

Paryankasana

(puhr-yuhng-KAHS-uh-nuh)

Also Known As: Reclined Thunderbolt Pose (Supta Vajrasana)
Modification: 1. head off the floor
2. crown of the head on the floor
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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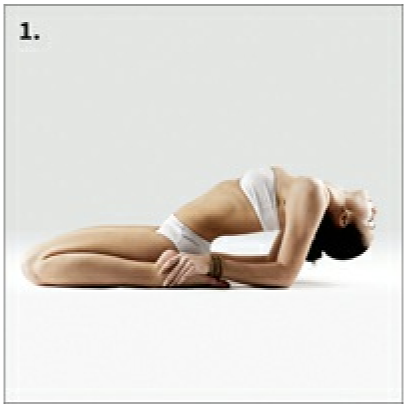
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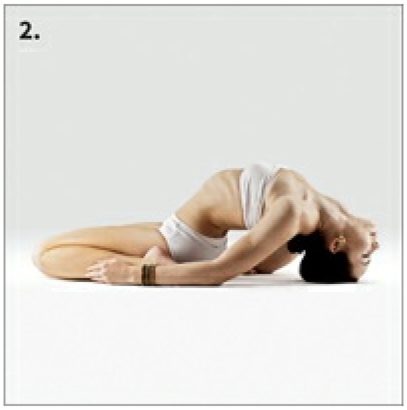
2.

Bed Pose

Paryankasana

(puhr-yuhng-KAHS-uh-nuh)

Also Known As: Reclined Thunderbolt Pose (Supta Vajrasana)
Modification: 1. hands in Anjali Mudra (Hands in Prayer), fingertips pointing to the sky
2. grabbing onto the forearms, arms to the floor up over the head
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

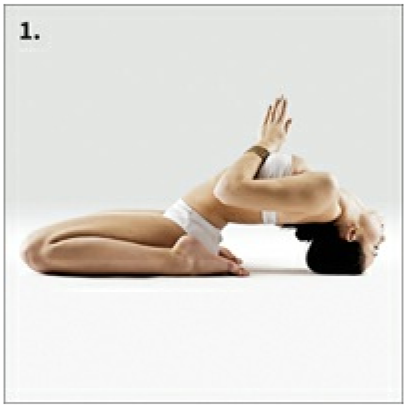

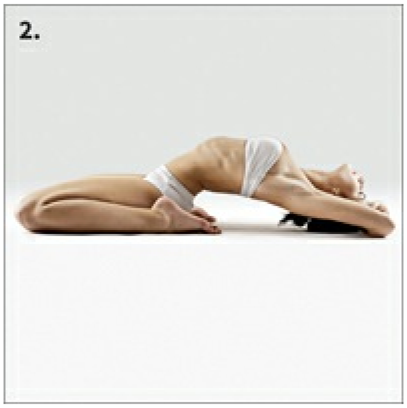

BACKBEND ON THE KNEES AND HEAD: LITTLE THUNDERBOLT POSE

Little Thunderbolt Pose

Laghuvajrasana

(lluh-goo-vuhj-RAHS-uh-nuh)

Modification: 1. grabbing onto the knees, head off the floor
2. forehead to the floor, hands on the quadriceps
3. head to feet, grabbing onto the knees
Pose Type: backbend, standing (on the knees)

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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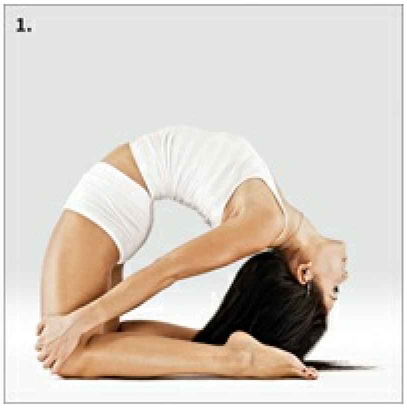

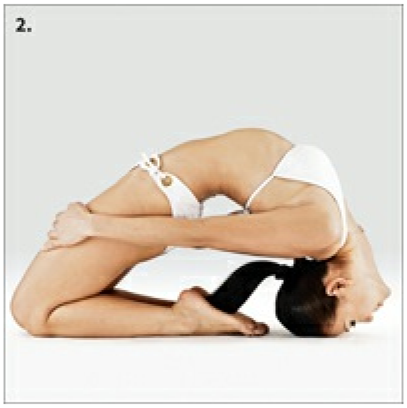

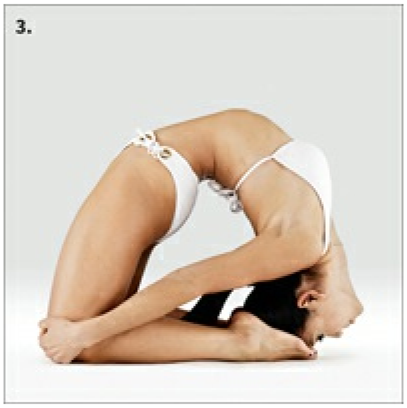

Little Thunderbolt Pose

Laghuvajrasana

(luh-goo-vuhj-RAHS-uh-nuh)

Modification: back of the head on the floor, grabbing onto the knees
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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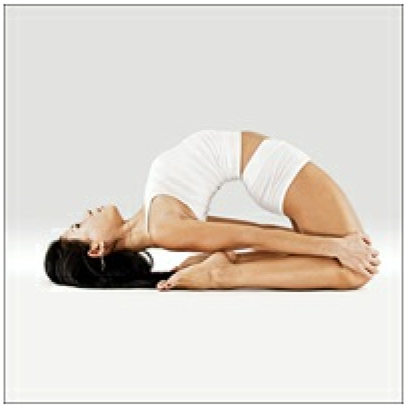

BACKBEND ON THE KNEES AND HEAD: PIGEON POSE

Little Thunderbolt Pose Prep.

Laghuvajrasana Prep.

(luh-goo-vuhj-RAHS-uh-nuh)

Modification: crown of the head to the floor, arms in Headstand 5 (see here) position
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

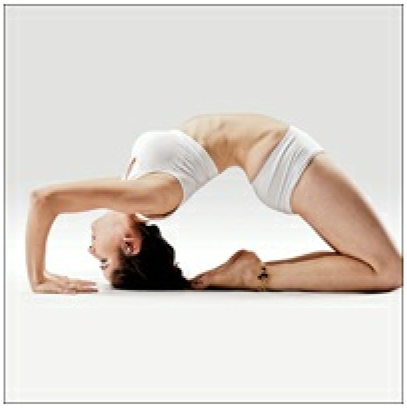

One Hand Pigeon Pose

Eka Hasta Kapotasana

(EY-kuh HUH-stuh kuh-po-TAHS-uh-nuh)

Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

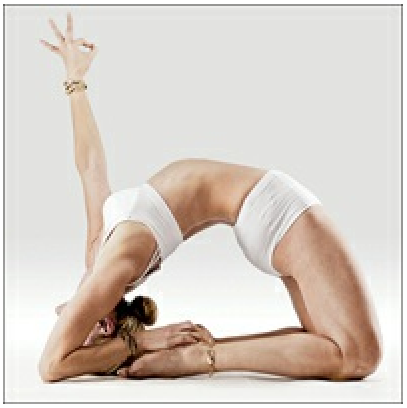

Pigeon Pose

Kapotasana

(kuh-po-TAHS-uh-nuh)

Modification: grabbing onto the ankles
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

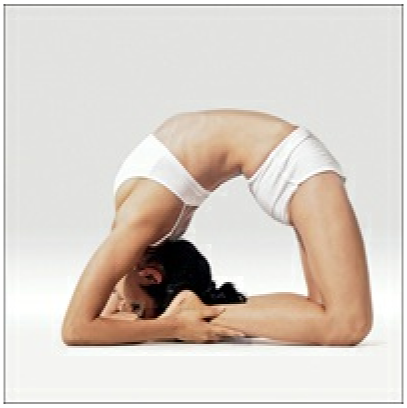

Pigeon Pose

Kapotasana

(kuh-po-TAHS-uh-nuh)

Modification: fingertips toward the knees, palms flat down
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

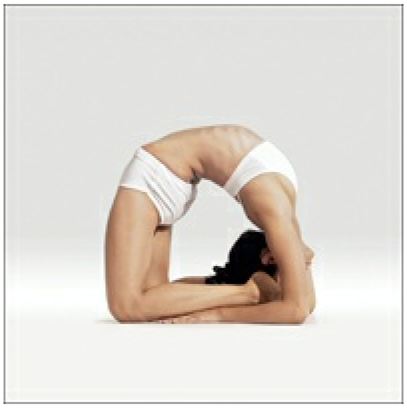

PIGEON POSE: ONE-LEGGED

One-Legged Pigeon Pose Prep.

Eka Pada Kapotasana Prep.

(EY-kuh PUH-duh kuh-po-TAHS-uh-nuh)

Modification: arms over the head palms to the floor, head away from the foot
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
ल व य ह ॐ

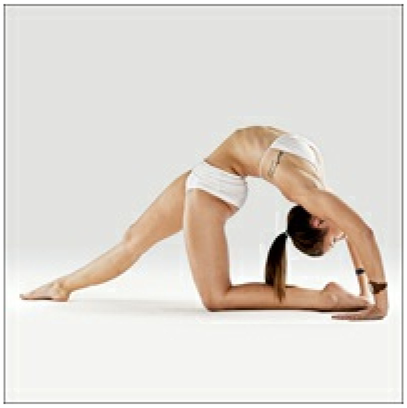

One-Legged Pigeon Pose Prep.

Eka Pada Kapotasana Prep.

(EY-kuh PUH-duh kuh-po-TAHS-uh-nuh)

Modification: 1. knee bent, foot to the floor
2. leg straight, foot to the floor
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
ल व र य ह ॐ ॐ

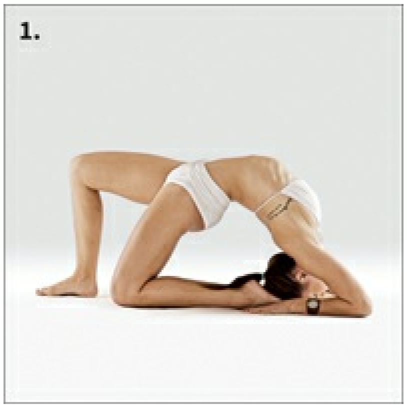
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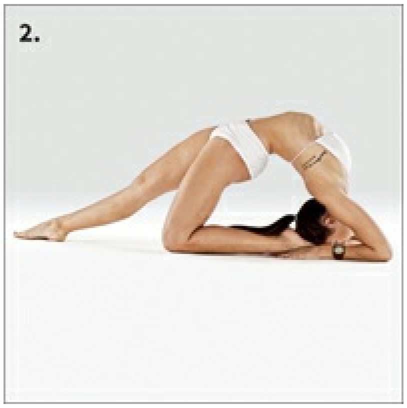
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One-Legged Pigeon Pose

Eka Pada Kapotasana

(EY-kuh PUH-duh kuh-po-TAHS-uh-nuh)

Modification: foot to the quadriceps
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

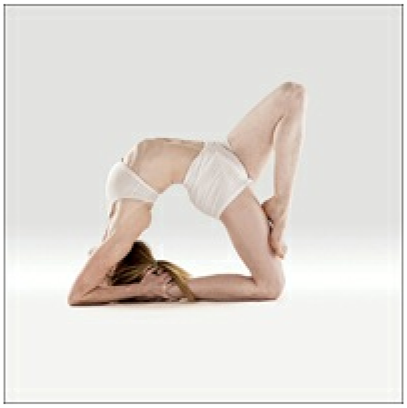

One-Legged Pigeon Pose

Eka Pada Kapotasana

(EY-kuh PUH-duh kuh-po-TAHS-uh-nuh)

Modification: leg straight

Pose Type: backbend, standing (on the knees)

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

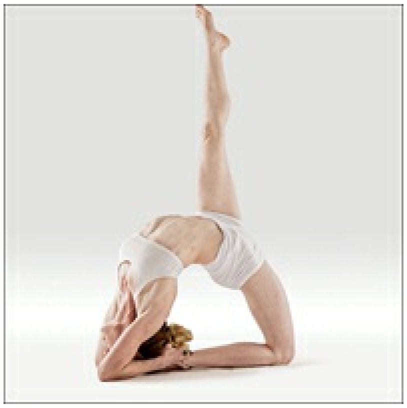

TOES CURLED IN: BACKBEND—SHOULDERS ON THE FLOOR & HEAD ON THE FLOOR

One-Legged Tip Toe Bridge Pose

Eka Pada Prapada Setu Bandhasana

(EY-kuh PUH-duh PRUH-puh-duh SEY-too buhn-DAHS-uh-nuh)

Modification: back of the head on the floor, arms up to the sky

1. knee bent, foot resting on the knee
2. leg straight and extended to the sky

Pose Type: supine, backbend

Drishti Point: Angushtamadhye or Angustha Ma Dyai (thumbs)

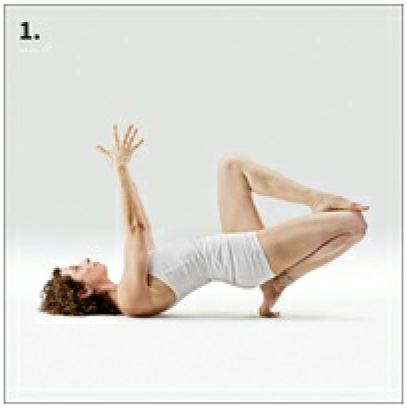

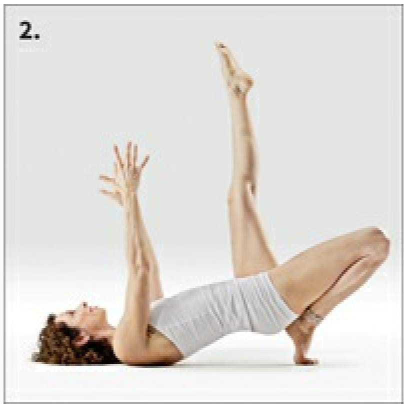
2.

Tip Toe Bridge Pose

Prapada Setu Bandhasana

(PRUH-puh-duh SEY-too buhn-DAHS-uh-nuh)

Also Known As: Tip Toe Bed Pose (Prapada Paryankasana), Big Toe Bridge Pose (Padangushta Setu Bandhasana)
Modification: 1. grabbing onto the shins, elbows to the floor
2. grabbing onto the shins, arms straight
3. hands on the quadriceps, arms straight
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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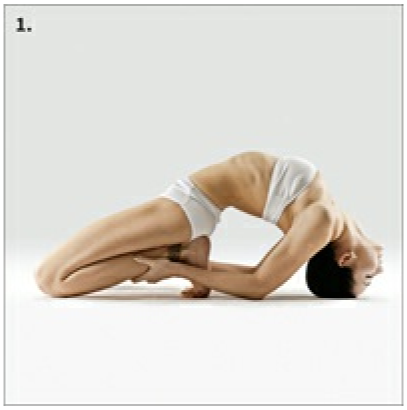
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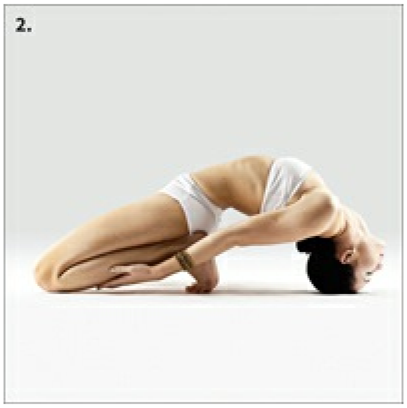
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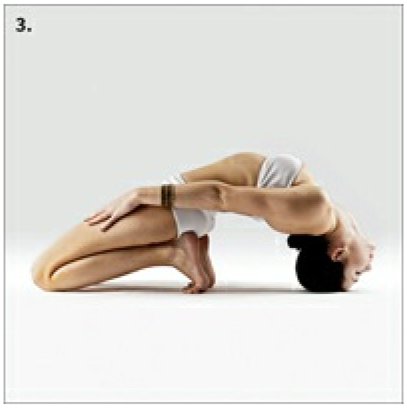
3.

TOES CURLED IN: BACKBEND—HANDS TO THE FLOOR & TOE BALANCE

Thunderbolt Pose

Vajrasana

(vuhj-RAHS-uh-nuh)

Also Known As: Tip Toe Bed Pose Prep. (Prapada Paryankasana Prep.)
Modification: toes curled in, fingertips pointing away from the feet, intense backbend
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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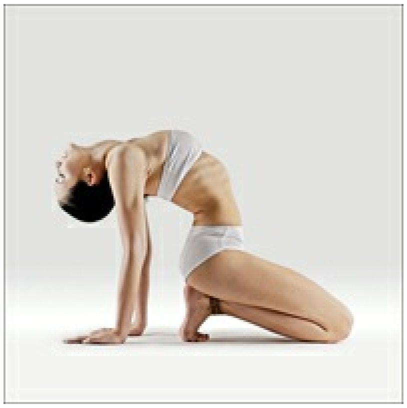

Tip Toe Camel Pose

Prapada Ushtrasana

(PRUH-puh-duh oosh-TRAHS-uh-nuh)

Modification: palms flat to the floor, fingertips pointing to the front
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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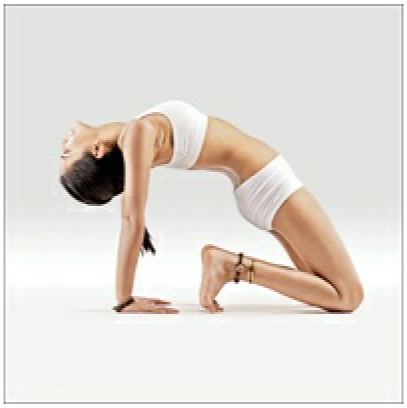

Unsupported Tip Toe Camel Pose

Niralamba Prapada Ushtrasana

(neer-AH-luhm-buh PRUH-puh-duh oosh-TRAHS-uh-nuh)

Modification: knees lifted off the floor, hands in Anjali Mudra (Hands in Prayer)
Pose Type: standing, balance, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

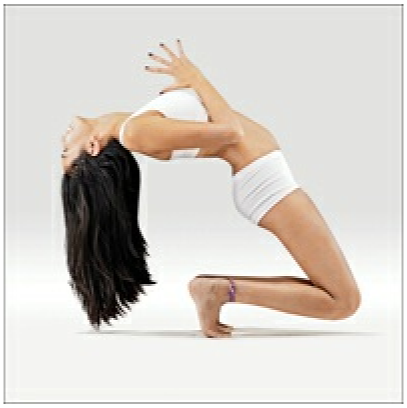

TOES CURLED IN: BACKBEND—GRABBING ONTO THE HEELS & KNEES, HANDS ON THE FLOOR & HEAD TO THE HEELS

Tip Toe Camel Pose

Prapada Ushtrasana

(PRUH-puh-duh oosh-TRAHS-uh-nuh)

Modification: hands in Anjali Mudra (Hands in Prayer)
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

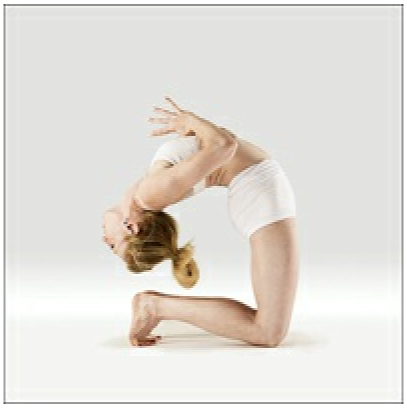

Half Tip Toe Camel Pose

Ardha Prapada Ushtrasana

(UHR-duh PRUH-puh-duh oosh-TRAHS-uh-nuh)

Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)
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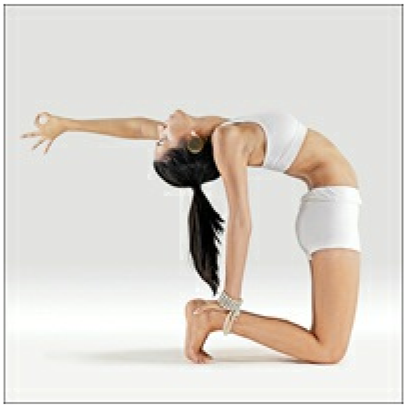

Tip Toe Camel Pose

Prapada Ushtrasana

(PRUH-puh-duh oosh-TRAHS-uh-nuh)

Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
ल र य ह ॐ

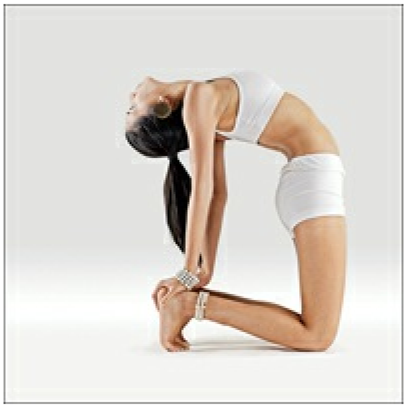

Tip Toe Camel Pose

Prapada Ushtrasana

(PRUH-puh-duh oosh-TRAHS-uh-nuh)

Modification: hands on the knees
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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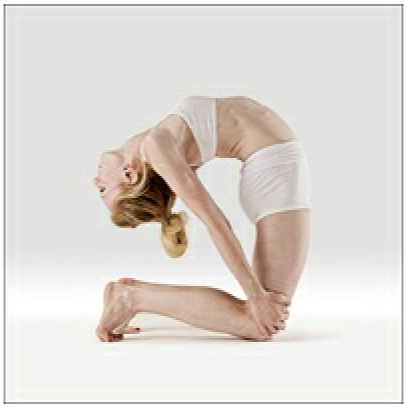

Tip Toe Pigeon Pose

Prapada Kapotasana

(PRUH-puh-duh kuh-po-TAHS-uh-nuh)

Also Known As: Big Toe Pigeon Pose (Padangushta Kapotasana)
Modification: arms straight up over the head, palms to the floor
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)
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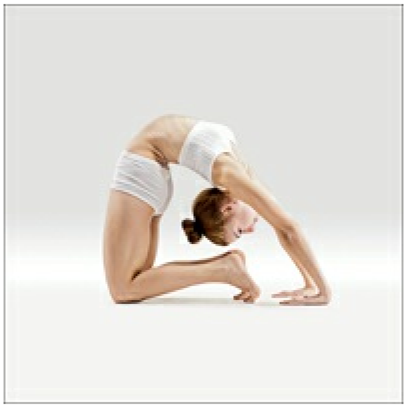

Tip Toe Pigeon Pose

Prapada Kapotasana

(PRUH-puh-duh kuh-po-TAHS-uh-nuh)

Also Known As: Big Toe Pigeon Pose (Padangustha Kapotasana), Little Wheel Pose (Laghu Chakrasana)
Modification: arms up over the head, elbows bent, palms to the floor, forehead to the heels
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

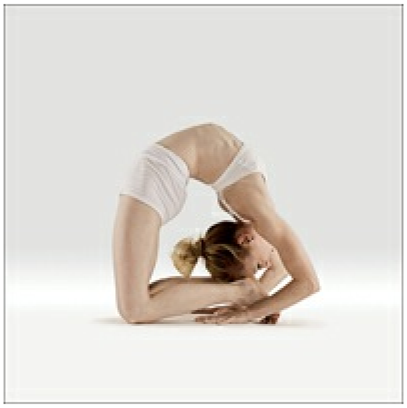

TOES CURLED IN: BACKBEND—ARMS STRAIGHT, PALMS TOGETHER

Raised Bound Hands in Tip Toe Camel Pose

Urdhva Baddha Hastasana in Prapada Ushtrasana

(OORD-vuh BUH-duh huh-STAHS-uh-nuh in PRUH-puh-duh oosh-TRAHS-uh-nuh)

Modification: hips pushing back
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angushtamadhye or Angushta Ma Dyai (thumbs)

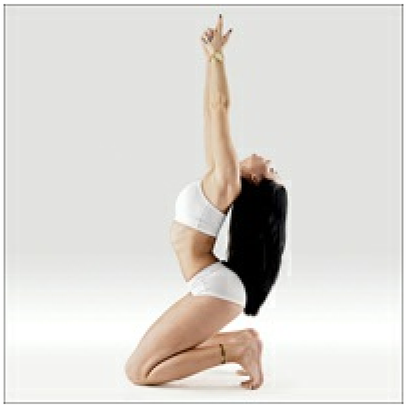

Tip Toe Pigeon Pose

Prapada Kapotasana

(PRUH-puh-duh kuh-po-TAHS-uh-nuh)

Also Known As: Big Toe Pigeon Pose (Padangushta Kapotasana), Full Camel Pose (Purna Ushtrasana), or Little Wheel Pose (Laghu Chakrasana)
Modification: 1. arms extended to the sky
2. arms parallel to the floor
Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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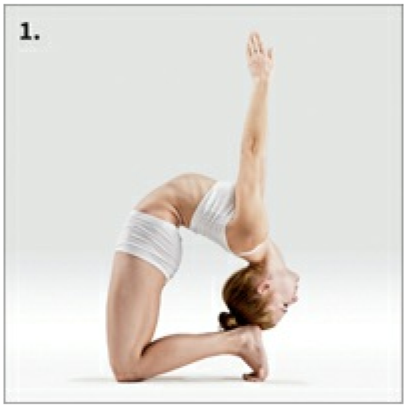

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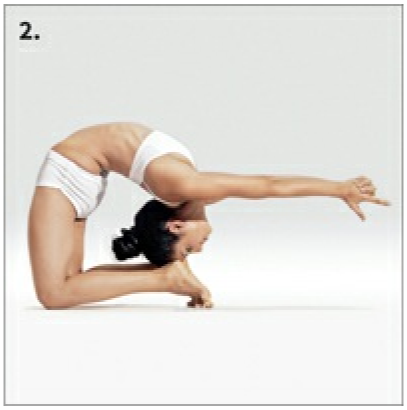

BACKBEND: HEADSTAND 5 ARM POSITION

Upward Bow Pose in Headstand 5

Urdhva Dhanurasana in Shirshasana 5

(OORD-vuh duh-nur-AHS-uh-nuh in sheer-SHAS-uh-nuh)

Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

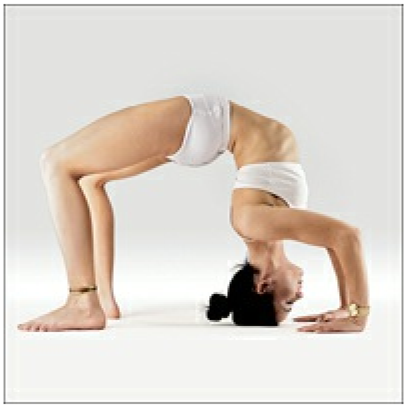

Upward Bow Pose with Leg Position of the Pose Dedicated to Garuda in Headstand 5

Urdhva Dhanurasana Pada Garudasana in Shirshasana 5

(OORD-vuh duh-nur-AHS-uh-nuh PUH-duh guh-ru-DAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

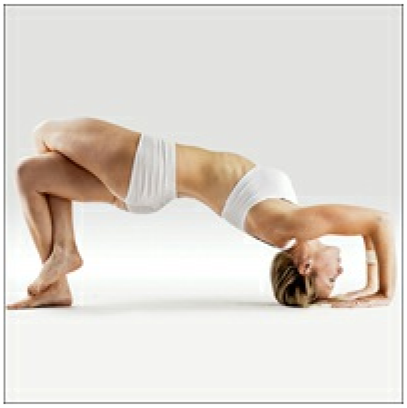

Upward Tip Toe Bow Pose in One Hand Headstand 5

Urdhva Prapada Dhanurasana in Eka Hasta Shirshasana 5

(OORD-vuh PRUH-puh-duh duh-nur-AHS-uh-nuh in EY-kuh HUH-stuh sheer-SHAHS-uh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

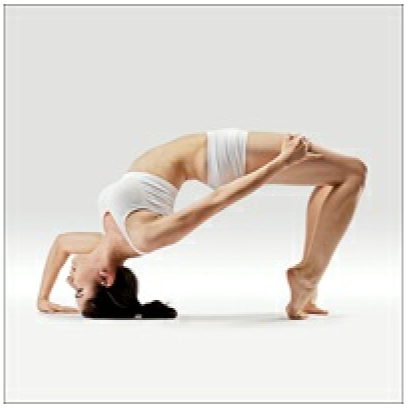

Inverted Tip Toe Bow Pose

Viparita Prapada Dhanurasana

(vi-puh-REE-tuh PRUH-puh-duh duh-nur-AHS-uh-nuh)

Also Known As: Headstand Bow Pose (Shirsha Dhanurasana)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

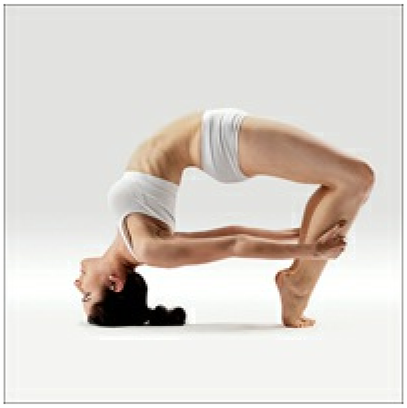

BACKBEND: HEADSTAND 1 ARM POSITION—KNEE/KNEES BENT

Upward Bow Pose in Headstand 1

Urdhva Dhanurasana in Shirshasana 1

(OORD-vuh duh-nur-AHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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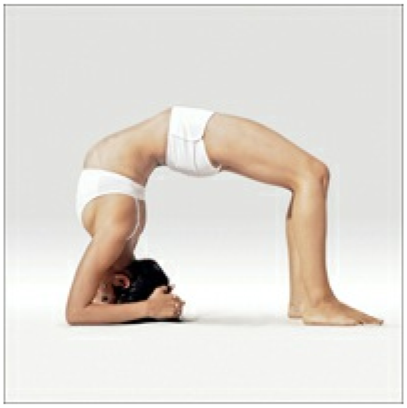

Upward Tip Toe Bow Pose in Headstand 1

Urdhva Prapada Dhanurasana in Shirshasana 1

(OORD-vuh PRUH-puh-duh duh-noor-AHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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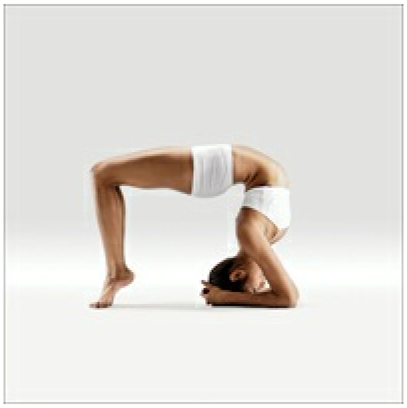

One-Legged Inverted Staff Pose

Eka Pada Viparita Dandasana

(EY-kuh PUH-duh vi-puh-REE-tuh duhn-DAHS-uh-nuh)

Modification: knee of the bottom leg bent

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

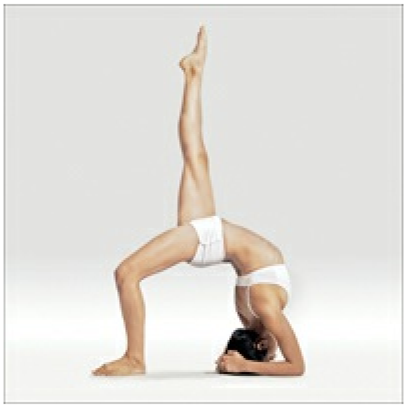

BACKBEND: HEADSTAND 1 ARM POSITION—LEGS STRAIGHT

One-Legged Inverted Staff Pose

Eka Pada Viparita Dandasana

(EY-kuh PUH-duh vi-puh-REE-tuh duhn-DAHS-uh-nuh)

Also Known As: Inverted Staff Pose B (Viparita Dandasana B)
Modification: both legs straight
Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

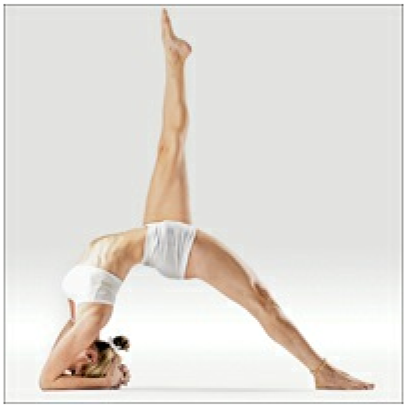

Two-Legged Inverted Staff Pose

Dwi Pada Viparita Dandasana

(DWI-puh-duh vi-puh-REE-tuh duhn-DAHS-uh-nuh)

Also Known As: Inverted Staff Pose A (Viparita Dandasana A)
Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

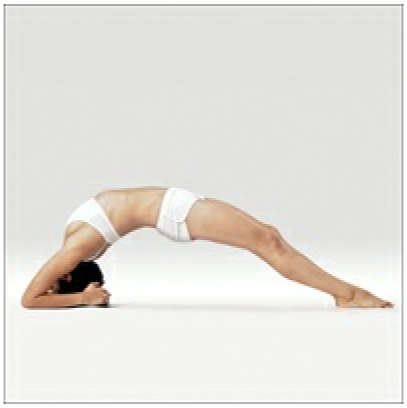

BACKBEND: FOREARMS ON THE FLOOR, BOUND HANDS

Bound Arms Tip Toe Bound Wheel Pose

Baddha Hasta Prapada Chakra Bandhasana

(BUH-duh HUH-stuh PRUH-puh-duh CHUHK-ruh buhn-DAHS-uh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

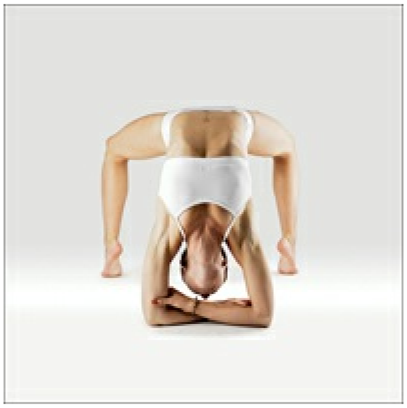

Bound Arms Both Legs Inverted Staff Pose

Baddha Hasta Dwi Pada Viparita Dandasana

(BUH-duh HUH-stuh DWI-puh-duh vi-puh-REE-tuh duhn-DAH-suh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

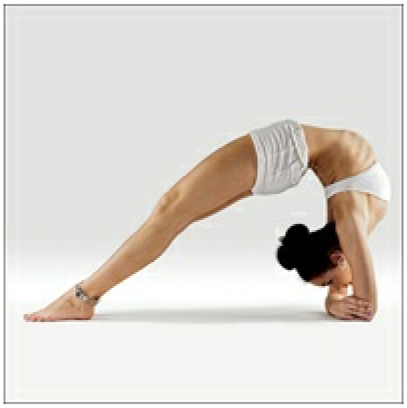

BACKBEND: FOREARMS ON THE FLOOR, HEELS DOWN

Bound Wheel Pose

Chakra Bandhasana

(CHUHK-ruh buhn-DAHS-uh-nuh)

Modification: forearms to the floor, heels down, fingertips touching the heels
Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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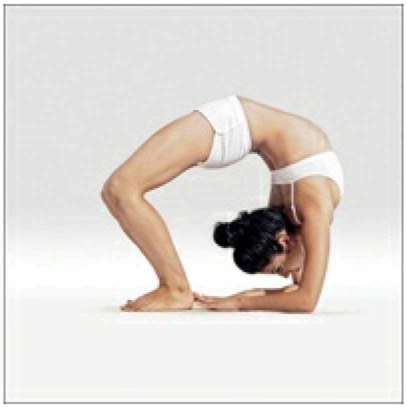

Bound Wheel Pose

Chakra Bandhasana

(CHUHK-ruh buhn-DAHS-uh-nuh)

Also Known As: Bound Wheel Pose (Bandha Chakrasana)
Modification: grabbing onto ankles
1. looking straight ahead
2. head rolling back
Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

1.

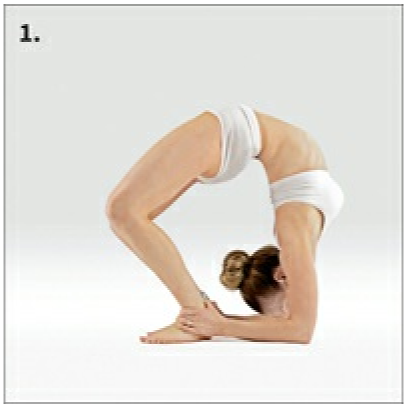

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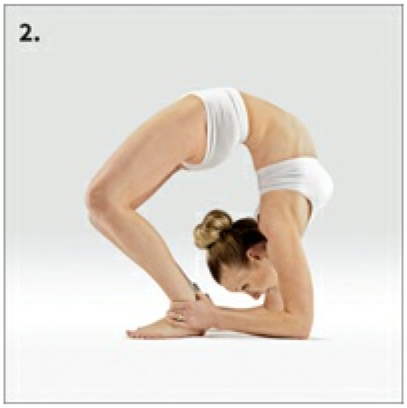

BACKBEND: FOREARMS ON THE FLOOR, HEELS LIFTED

Tip Toe Bound Wheel Pose

Prapada Chakra Bandhasana

(PRUH-puh-duh CHUCK-ruh buhn-DAHS-uh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

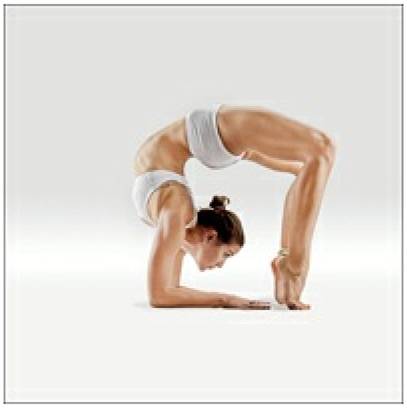

Uneven Tip Toe Bound Wheel Pose

Vishama Prapada Chakra Bandhasana

(VI-shuh-muh PRUH-puh-duh CHUCK-ruh buhn-DAHS-uh-nuh)

Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

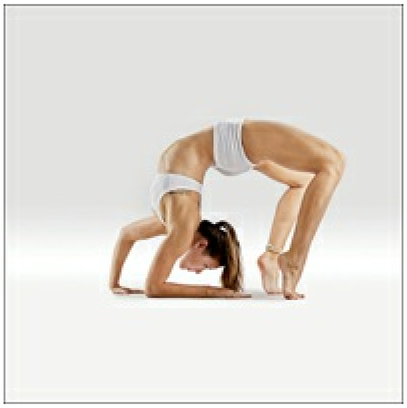

BACKBEND: FOREARMS ON THE FLOOR, ONE-LEGGED

One-Legged Inverted Staff Pose

Eka Pada Viparita Dandasana

(EY-kuh PUH-duh vi-puh-REE-tuh duhn-DAHS-uh-nuh)

Modification: forearms to the floor, head off the floor
Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

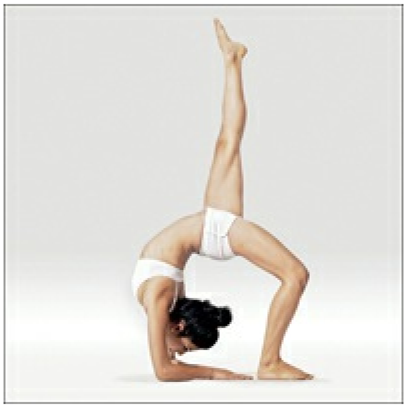

Bound Foot One-Legged Inverted Staff Pose

Baddha Pada Eka Pada Viparita Dandasana

(BUH-duh PUH-duh EY-kuh PUH-duh vi-puh-REE-tuh duhn-DAHS-uh-nuh)

Modification: forearms to the floor, head off the floor

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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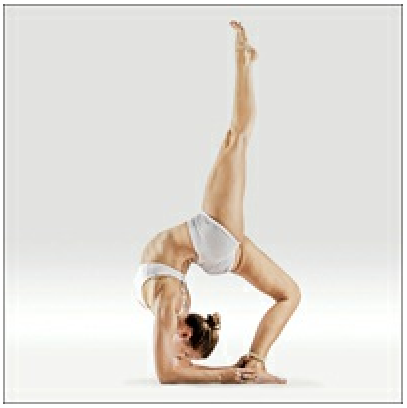

Tip Toe Bound Foot One-Legged Inverted Staff Pose

Prapada Baddha Pada Eka Pada Viparita Dandasana

(PRUH-puh-duh BUH-duh PUH-duh EY-kuh PUH-duh vi-puh-REE-tuh duhn-DAHS-uh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

How to Perform the Pose:

1. Begin by lying flat on your back. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing. Inhale and bring your hands under your shoulders with elbows bent and close to your head, with the fingertips pointing away from your head.
2. Exhale and bend your knees, keep your feet flat on the floor and slide your heels toward your sitting bones. Keep your feet in line with your sitting bones and parallel to each other with your toes pointing straight ahead.
3. Exhale as you lift your sitting bones and your back off the floor. Place the crown of your head onto the floor, balancing on your hands, head, and feet.
4. Exhale as you slide your right palm in the direction of your feet until your forearm is flat on the floor. On the next exhale, slide your left palm to meet your right. Interlock your fingers at the back of your head.
5. Exhale and lift your head off the floor.
6. On the next exhale, walk your feet toward your hands. Grab onto your left ankle with both hands.
7. Exhale as you lift your right foot off the floor, keeping your right leg strong and straight with toes pointing up to the sky.
8. Inhale and lift your left heel, coming onto the toes of the left foot, while holding onto the left toes with both hands. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch on the right side.
9. Inhale and lower the left heel to the floor, followed by the right foot. Exhale and grab onto the right ankle with both hands. On the following exhale, lift your left foot off the floor, keeping your left leg strong and straight with toes pointing up to the sky.
10. Inhale and lift your right heel, coming onto the toes of the right foot while holding onto the right toes with both hands. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch on the left side.
11. Inhale and lower your right heel to the floor, followed by your left foot. Exhale and lower your head to the floor. Exhale and tuck your chin to your chest and lower your spine to the floor, coming

out of the pose.

Modification: forearms to the floor, head off the floor

prapada = tip of the feet

baddha = bound

pada = foot or leg

eka = one

pada = foot or leg

viparita = inverted

danda = stick or staff

Foot to the Head One-Legged Inverted Staff Pose

Shirsha Pada Eka Pada Viparita Dandasana

(SHEER-shuh PUH-duh EY-kuh PUH-duh vi-puh-REE-tuh duhn-DAHS-uh-nuh)

Modification: forearms to the floor, head off the floor
Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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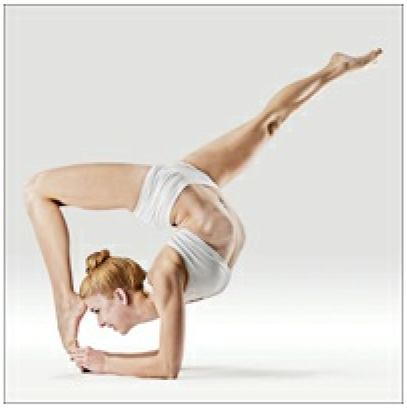

UPWARD BOW POSE

Upward Bow Pose

Urdhva Dhanurasana

(OORD-vuh duh-nur-AHS-uh-nuh)

Modification: heels down
Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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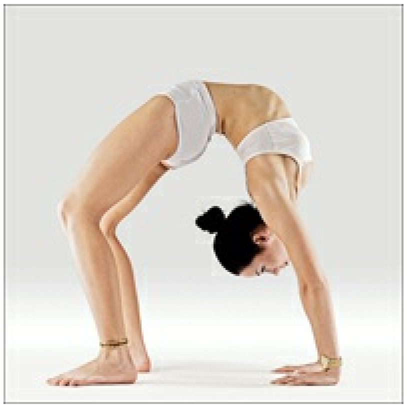

Tip Toe Upward Bow Pose

Prapada Urdhva Dhanurasana

(PRUH-puh-duh OORD-vuh duh-nur-AHS-uh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

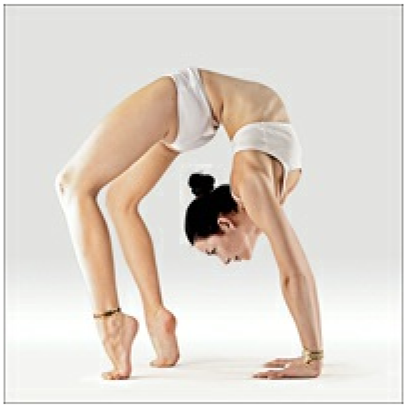

Elevated Both Legs Inverted Staff Pose

Utthita Dwi Pada Viparita Dandasana

(UT-ti-tuh DWI-puh-duh vi-puh-REE-tuh duhn-DAHS-uh-nuh)

Also Known As: Upward Bow Pose (Urdhva Dhanurasana)

Modification: head rolling back

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

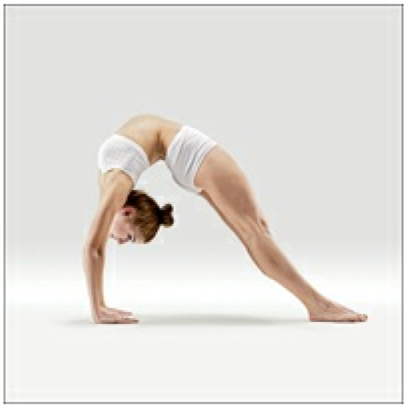

Tip Toe One-Legged Upward Bow Pose

Prapada Eka Pada Urdhva Dhanurasana

(PRUH-puh-duh EY-kuh PUH-duh OORD-vuh duh-nur-AHS-uh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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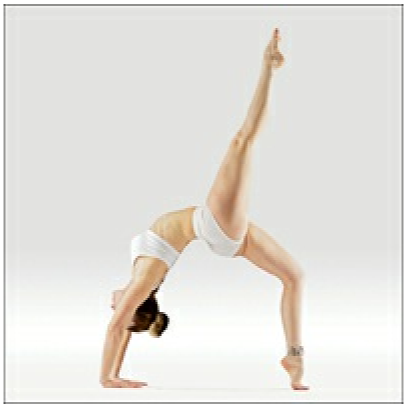

One-Legged Upward Bow Pose

Eka Pada Urdhva Dhanurasana

(EY-kuh PUH-duh OORD-vuh duh-nur-AHS-uh-nuh)

Also Known As: Two Limb Upward Bow Pose (Dwi Anga Urdhva Dhanurasana)

Modification: one hand to the thigh

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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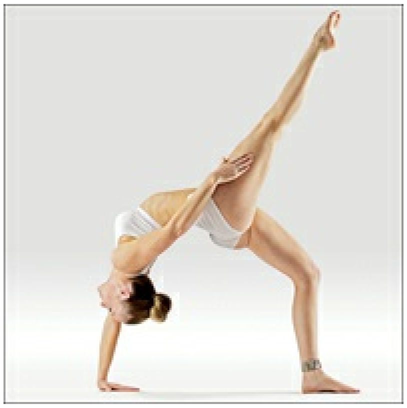

Tip Toe One Hand Upward Bow Pose

Prapada Eka Hasta Urdhva Dhanurasana

(PRUH-puh-duh EY-kuh HUH-stuh OORD-vuh duh-nur-AHS-uh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

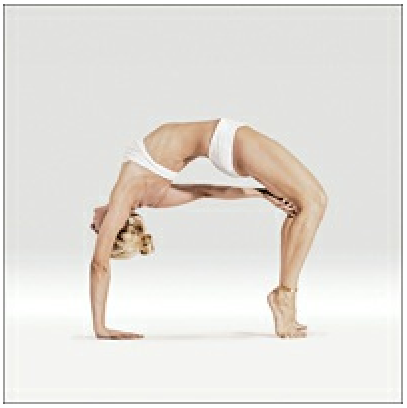

WILD THING POSE

Wild Thing Pose

Chamatkarasana

(kuh-muht-kar-AHS-uh-nuh)

Modification: forearm to the floor
Pose Type: backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Hastagrai or Hastagre (hands)
See the glossary for a more precise translation of chamatkarasana.

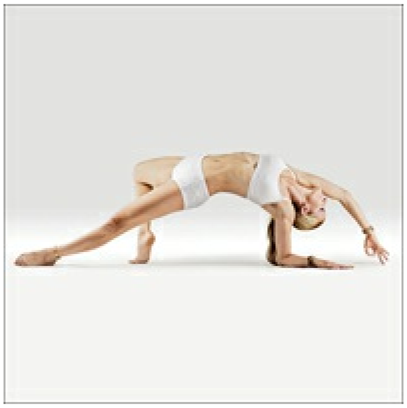

Wild Thing Pose

Chamatkarasana

(kuh-muht-kar-AHS-uh-nuh)

Pose Type: backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Hastagrai or Hastagre (hands)

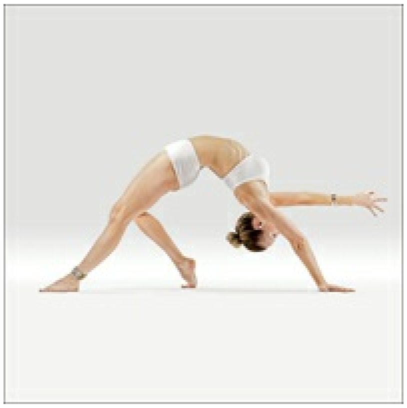

Wild Thing Pose

Chamatkarasana

(kuh-muht-kar-AHS-uh-nuh)

Modification: foot to inside of the thigh
Pose Type: backbend
Drishti Point: Hastagrai or Hastagre (hands)

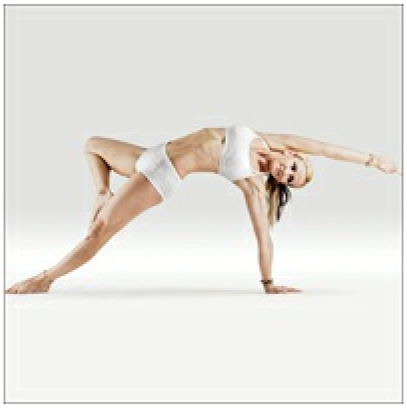

Wild Thing Pose

Chamatkarasana

(kuh-muht-kar-AHS-uh-nuh)

Modification: grabbing the ankle with overhead grip on the same side
Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Hastagrai or Hastagre (hands)

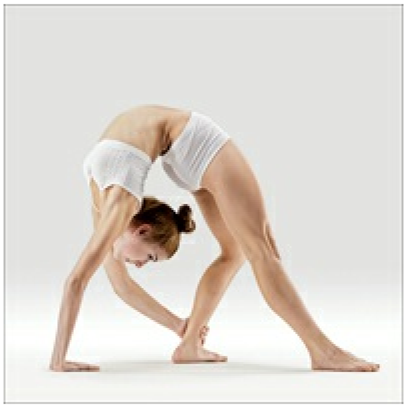

Wild Thing Pose

Chamatkarasana

(kuh-muht-kar-AHS-uh-nuh)

Modification: grabbing the ankle with overhead grip on the same side; other foot off the floor—knee bent
Pose Type: backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Hastagrai or

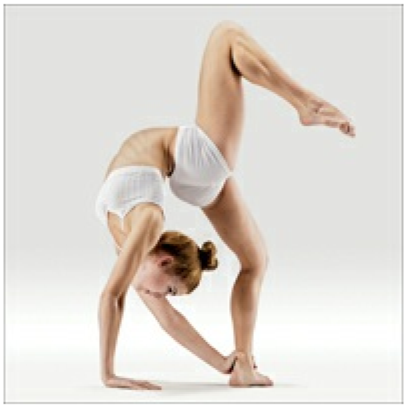

Arm Balances

LOTUS POSE

PENDANT POSE

ONE LEG OVER THE SHOULDER

CRANE POSE

FIREFLY POSE

SCISSOR LEGS

GARUDA LEGS

PEACOCK AND SWAN POSES

Half Fire Log Celibate Pose

Ardha Agnistambha Brahmacharyasana

(UHR_duh uhg-ni-STUHM-buh bruh-muh-chahr-YAHS-uh-nuh)

Pose Type: core, arm balance
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

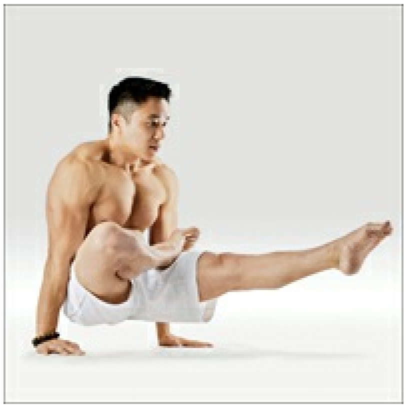

One Leg Over Shoulder Pose

Eka Hasta Bhujasana

(EY-kuh HUH-stuh buj-AHS-uh-nuh)

Also Known As: Comfortable Bird Pose (Sukha Chakorasana)
Pose Type: core, arm balance
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

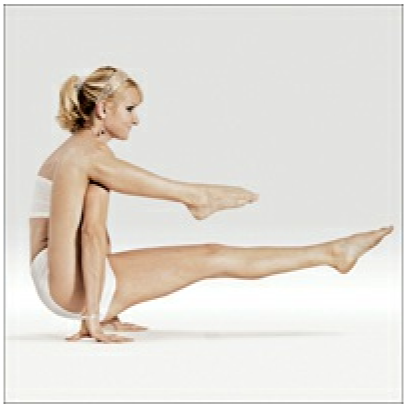

Moonbird Pose

Chakorasana

(chuh-kor-AHS-uh-nuh)

Pose Type: core, arm balance

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

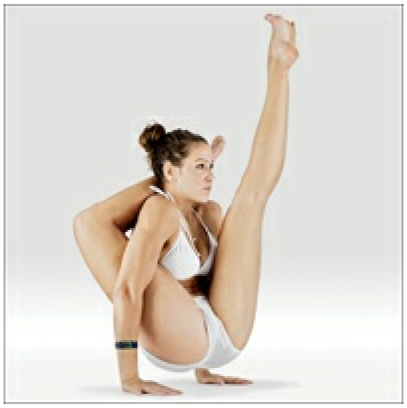

ARM BALANCE: LOTUS

Rooster Pose

Kukkutasana

(ku-ku-TAHS-uh-nuh)

Pose Type: arm balance, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

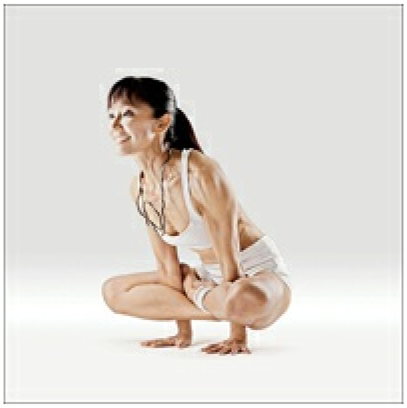

Scales Pose

Tolasana

(to-LAHS-uh-nuh)

Modification: 1. fingertips pointing to the back, thumbs pointing to the front
2. palms flat on the floor, fingertips pointing to the front
Pose Type: arm balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

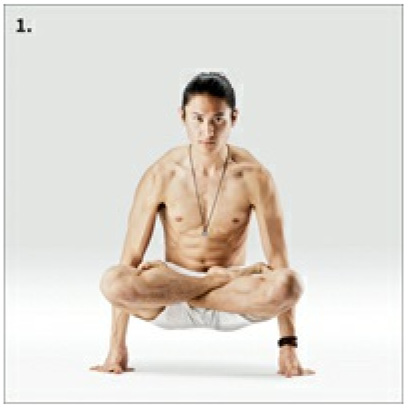

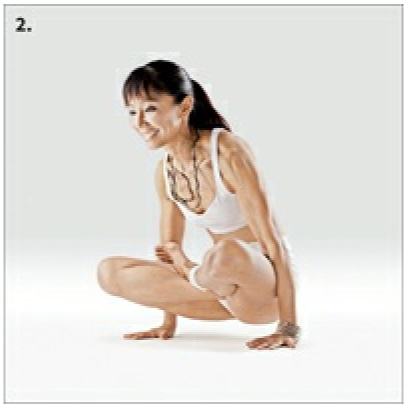

Pose Dedicated to Sage Galava

Galavasana

(gah-luh-VAHS-uh-nuh)
Modification: 1. hips low
2. hips high
Pose Type: arm balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

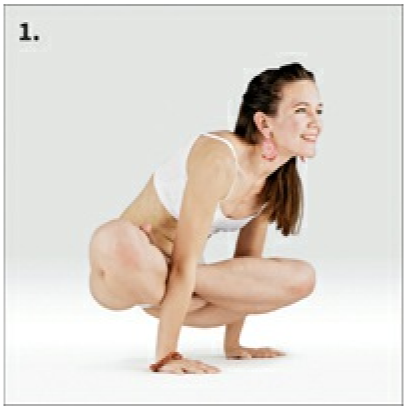

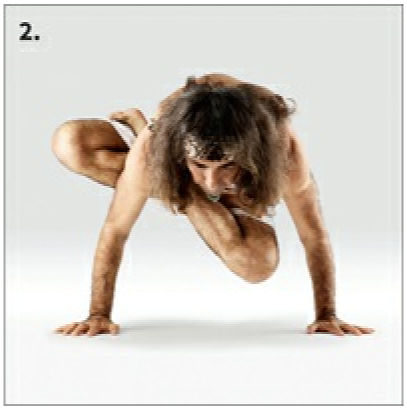

Upward Rooster Pose

Urdhva Kukkutasana

(OORD-vuh ku-ku-TAHS-uh-nuh)

Modification: 1. hips at shoulder height
2. hips higher than the shoulders
Pose Type: arm balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angushtamadhye or Angushta Ma Dyai (thumbs)

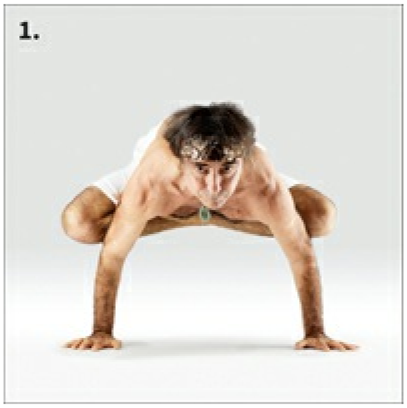

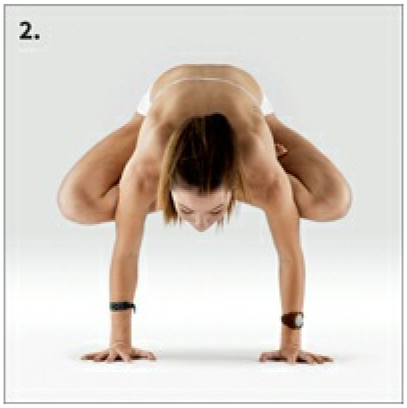
2.

Side Rooster Pose

Parshva Kukkutasana

(PAHRSH-vuh ku-ku-TAHS-uh-nuh)

Also Known As: Revolved Rooster Pose (Parivritta Kukkutasana), Wounded Rooster Pose (Pungu Kukkutasana)
Modification: 1. elbows bent
2. arms straight
Pose Type: arm balance, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose)
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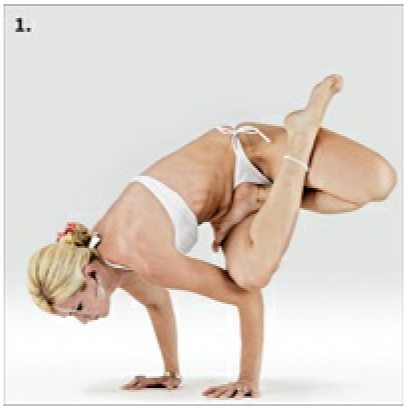
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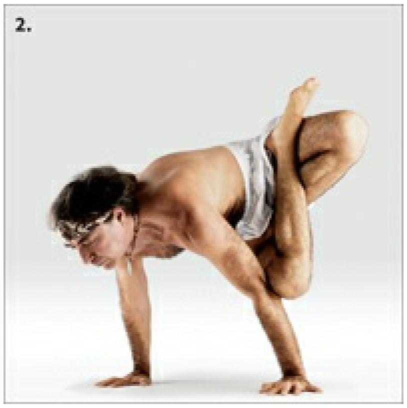
2.

Pendant Pose

Lolasana

(lo-LAHS-uh-nuh)

Modification: ankles crossed
Pose Type: arm balance, forward bend, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs) or Nasagrai or Nasagre (nose)

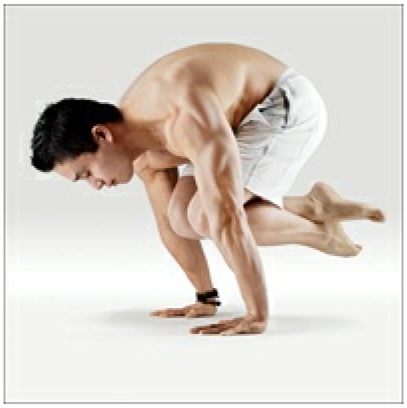

Pendant Pose

Lolasana

(lo-LAHS-uh-nuh)

Pose Type: arm balance, forward bend, core

Drishti Point: Angusthamadhye or Angustha Ma Dyai (thumbs) or Nasagrai or Nasagre (nose)

How to Perform the Pose:

1. Begin by sitting on the floor with both your legs straight out in front of you. Keep your fingertips on the floor on the sides of your hips. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale and lean forward, lifting your sitting bones off the floor. Bend your right knee, sliding your foot back. On the next exhale, bend your left knee, sliding your left foot back to meet your right. Your left shin should end up on top of your right calf muscle. Sit on your heels with ankles crossed under your sitting bones.
3. Inhale and rock forward. Exhale, engage your core, pull your quadriceps toward your chest, and lift your knees and feet off the floor, balancing on your fingertips. Make sure your arms are strong and straight and your shoulders are on top of your fingertips.
4. Aim to hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the pose.
5. Inhale and lower your feet and knees to the floor. Exhale and bring both legs straight out in front of you. Repeat on the opposite side.

Modification: on the fingertips; ankles crossed

lola = pendant

Pendant Pose

Lolasana

(lo-LAHS-uh-nuh)

Modification: fingertips pointing to the back, thumbs pointing to the front
Pose Type: arm balance, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

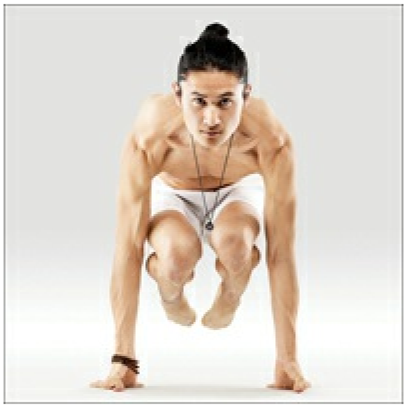

Leg Position of Cow Face Pose in Pendant Pose

Pada Gomukhasana in Lolasana

(PUH-duh go-muk-AHS-uh-nuh in lo-LAHS-uh-nuh)

Modification: fingertips pointing to the back, thumbs pointing to the front
Pose Type: arm balance, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

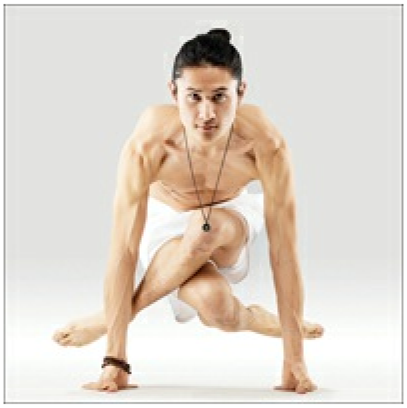

ARM BALANCE: ONE LEG OVER THE SHOULDER

Pose Dedicated to Viranchi (Brahma) 1 Prep.

Viranchyasana 1 Prep.

(vir-uhn-CHYAHS-uh-nuh)

Modification: back of the knee toward the shoulder
Pose Type: arm balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

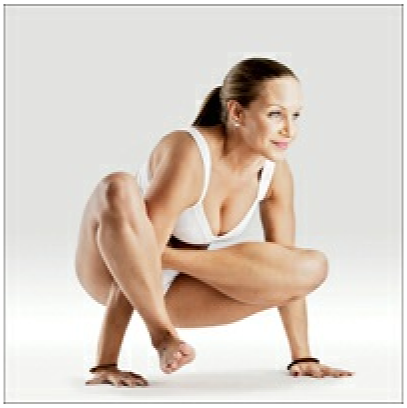

One-Legged Crane 2 Prep.

Eka Pada Bakasana 2 Prep.

(EY-kuh PUH-duh buh-KAHS-uh-nuh)

Modification: both knees bent, back of one knee over the shoulder, other knee toward the chest
Pose Type: arm balance, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

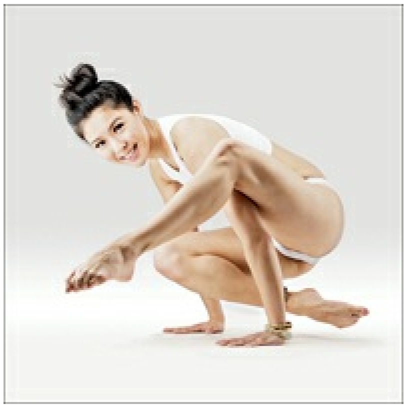

One Foot Behind Head Crane Pose

Eka Pada Shirsha Bakasana

(EY-kuh PUH-duh SHEER-shuh buh-KAHS-uh-nuh)

Modification: 1. hips at shoulder height
2. hips at elbow height, head lifted
Pose Type: arm balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

1.

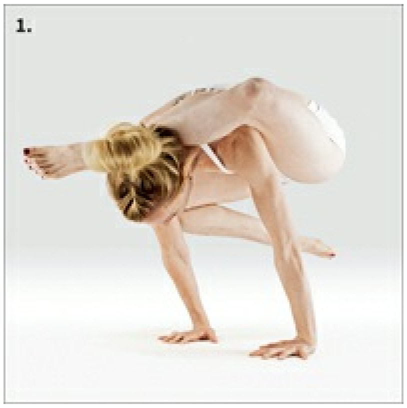

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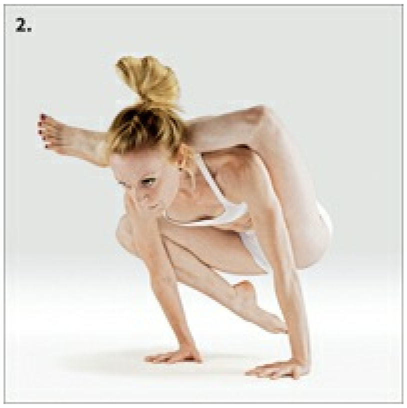

ARM BALANCE: CRANE POSE

Crane Pose

Bakasana

(buh-KAHS-uh-nuh)

Also Known As: Crow Pose (Kakasana)
Modification: elbows bent
Pose Type: arm balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

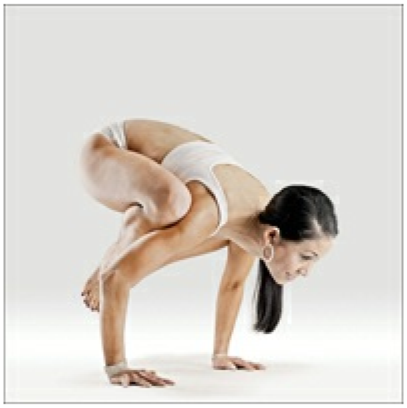

Crane Pose

Bakasana

(buh-KAHS-uh-nuh)

Modification: 1. knees off the triceps
2. knees on the triceps
Pose Type: arm balance, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Nasagrai or Nasagre (nose)
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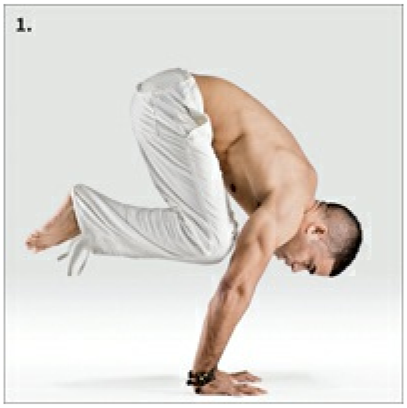

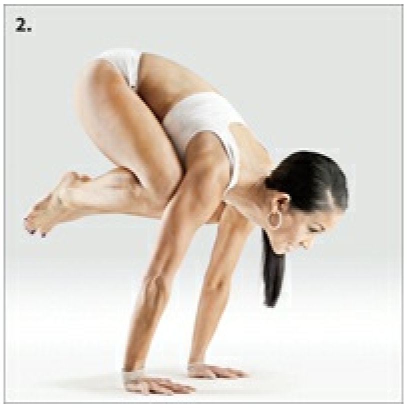

ARM BALANCE: SHOULDER PRESSURE POSE & FIREFLY POSE

Two-Handed Arm Balance

Dwi Hasta Bhujasana

(DWI-huh-stuh buj-AHS-uh-nuh)

Modification: 1. feet off the floor
2. toes touching the floor
Pose Type: arm balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Padayoragrai or Padayoragre (toes/feet)

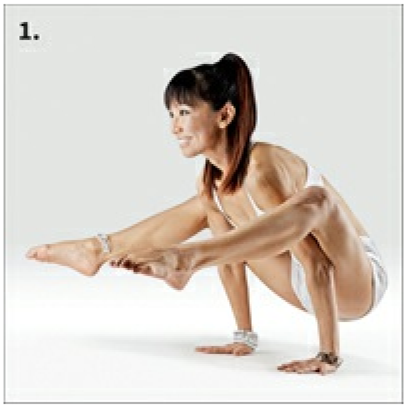

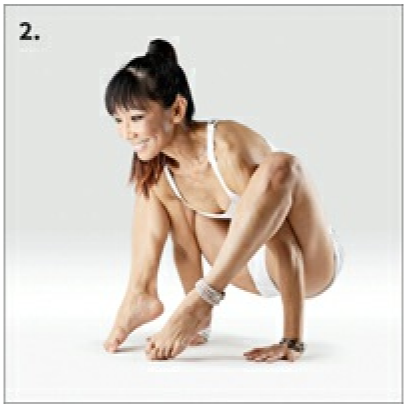

Shoulder Pressure Pose

Bhujapidasana

(buj-uh-peed-AHS-uh-nuh)

Also Known As: Shoulder Pressure Pose (Bhujapidasana A)
Modification: head off the floor
Pose Type: arm balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Padayoragrai or Padayoragre (toes/feet)

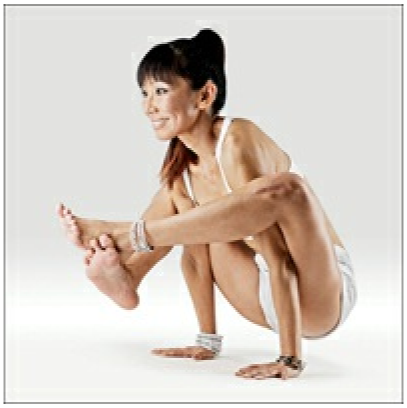

Firefly Pose 1

Tittibhasana 1

(ti-ti-BAHS-uh-nuh)

Also Known As: Firefly Pose A (Tittibhasana A)
Modification: elbows bent, legs on top of the shoulders
Pose Type: arm balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), or Nasagrai or Nasagre (nose)

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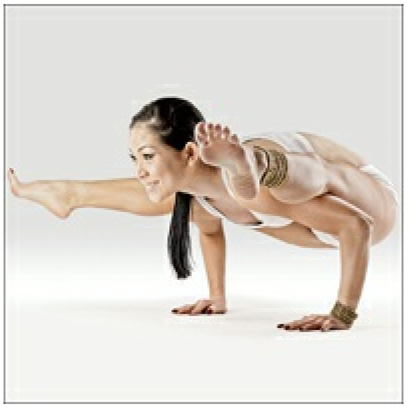

Firefly Pose 1

Tittibhasana 1

(ti-ti-BAHS-uh-nuh)

Also Known As: Firefly Pose A (Tittibhasana A)
Modification: arms straight, feet extended to the sky
Pose Type: arm balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Nasagrai or Nasagre (nose)

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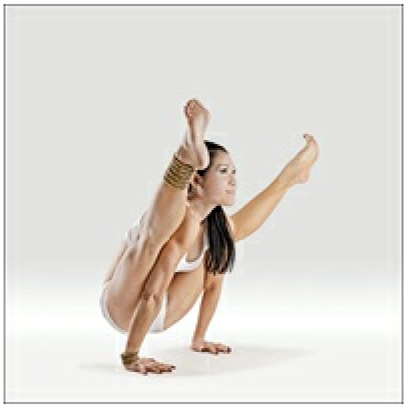

Firefly Pose 1

Tittibhasana 1

(ti-ti-BAHS-uh-nuh)

Also Known As: Firefly Pose A (Tittibhasana A), Raised Tortoise Pose (Utthita Kurmasana)
Modification: arms straight, legs parallel to the floor
Pose Type: arm balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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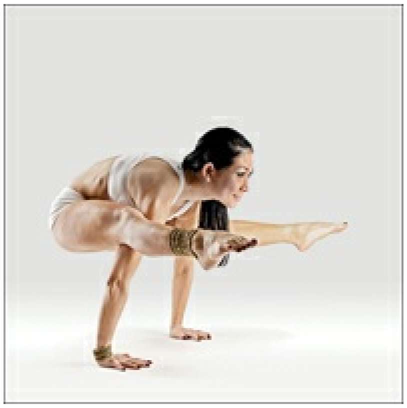

ARM BALANCE: FIREFLY POSE

Firefly Pose

Tittibhasana

(ti-ti-BAHS-uh-nuh)

Also Known As: Raised Up Feet Spread Out Resting on the Arms Pose (Utthita Dwi Pada Vrishtasana)
Modification: elbows bent, legs on triceps, wide legged
1. side view
2. front view

Pose Type: arm balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

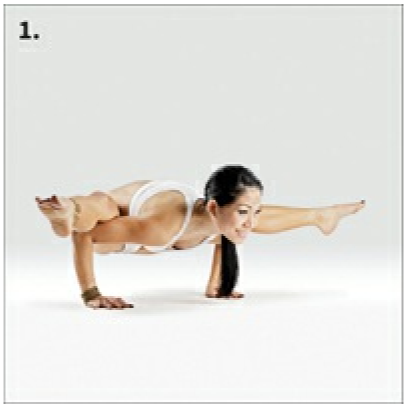
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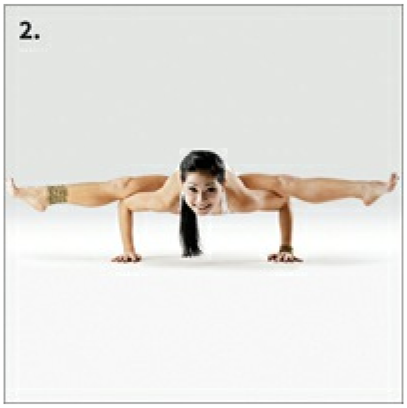
2.

Lifted Feet Spread Out Pose

Utthita Dwi Pada Vrishtasana

(UT-ti-tuh DWI-puh-duh vrish-TAHS-uh-nuh)

Modification: arms straight, heels of the palms touching, fingertips pointing to the sides
Pose Type: arm balance, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

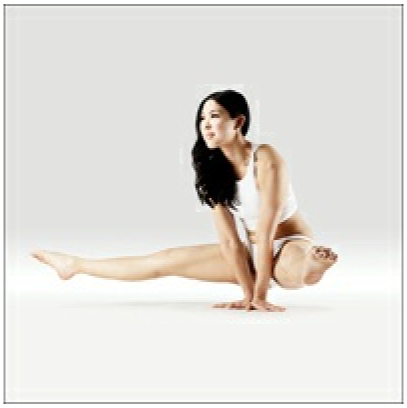

One-Legged Crane 1

Eka Pada Bakasana 1

(EY-kuh PUH-duh buh-KAHS-uh-nuh)

Modification: knee to the tricep
Pose Type: arm balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

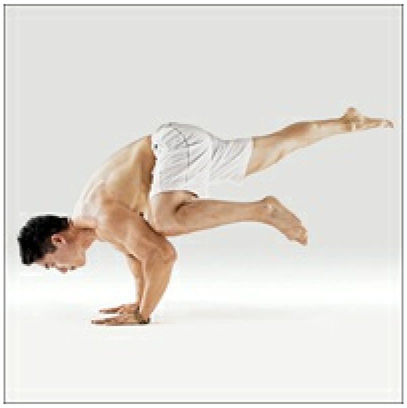

One-Legged Crane 1

Eka Pada Bakasana 1

(EY-kuh PUH-duh buh-KAHS-uh-nuh)

Modification: knee to the outside of the shoulder
Pose Type: arm balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

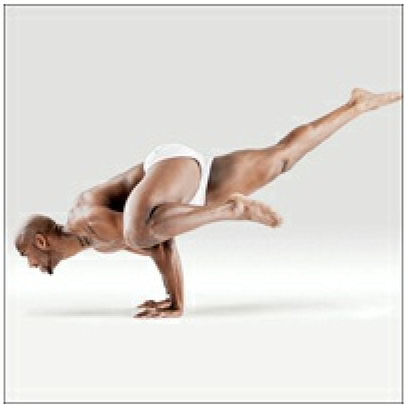

One-Legged Crane 2

Eka Pada Bakasana 2

(EY-kuh PUH-duh buh-KAHS-uh-nuh)

Modification: shin of the bent leg to the tricep

Pose Type: arm balance, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Nasagrai or Nasagre (nose)

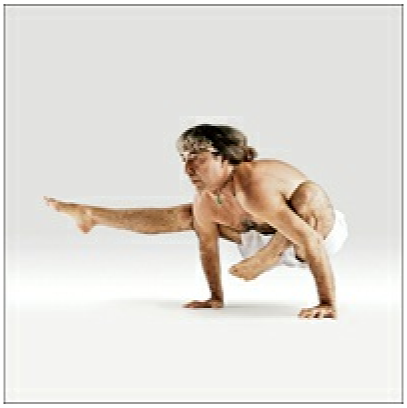

Pose Dedicated to Galava, One-Legged Modification

Eka Pada Galavasana

(EY-kuh PUH-duh gah-luh-VAHS-uh-nuh)

Pose Type: arm balance, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

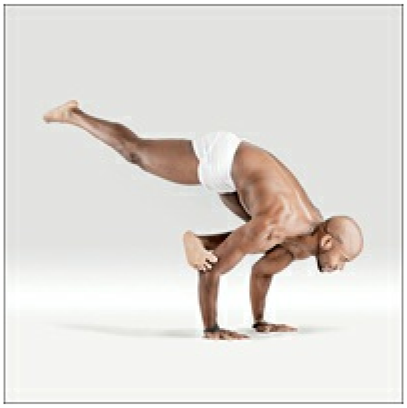

Dragonfly Pose 1

Maksikanagasana 1

(muhk-shi-kah-nah-GAHS-uh-nuh)

Also Known As: Stick Arm to the Side Grasshopper Pose (Parshva Bhuja Danda Salabhasana)
Pose Type: arm balance, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose)
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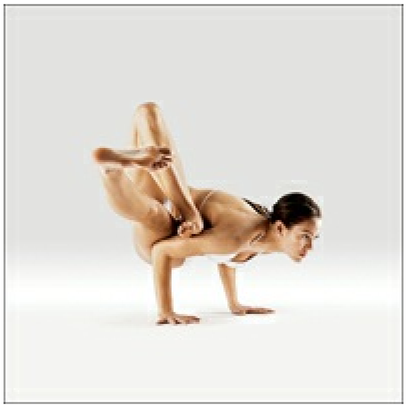

Moonbird Pose

Chakorasana

(chuh-kor-AHS-uh-nuh)

Pose Type: arm balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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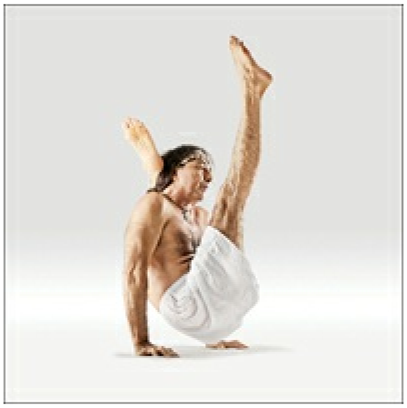

Uneven One-Legged Crane 1

Vishama Eka Pada Bakasana 1

(VISH-uh-muh EY-kuh PUH-duh buh-KAHS-uh-nuh)

Modification: one forearm to the floor, other elbow bent at 90 degrees
Pose Type: arm/forearm balance, forward bend, inversion

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

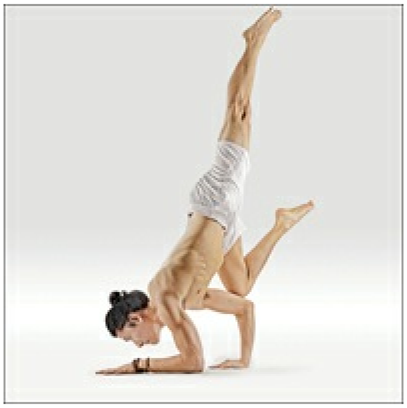

Arm to the Side Pose Dedicated to Sage Koundinya One-Legged Version 1

Parshva Hasta Eka Pada Koundinyasana 1

(PAHRSH-vuh HUH-stuh EY-kuh PUH-duh kown-din-YAHS-uh-nuh)

Modification: bottom knee bent
Pose Type: arm balance, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

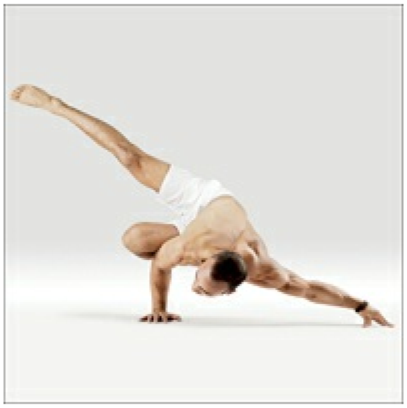

ARM BALANCE: SCISSOR LEGS

Pose Dedicated to Sage Koundinya One-Legged Version 1 Prep.

Eka Pada Koundinyasana 1 Prep.

(EY-kuh PUH-duh kown-din-YAHS-uh-nuh)

Modification: ear to the floor, bottom knee bent

Pose Type: arm balance, forward bend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

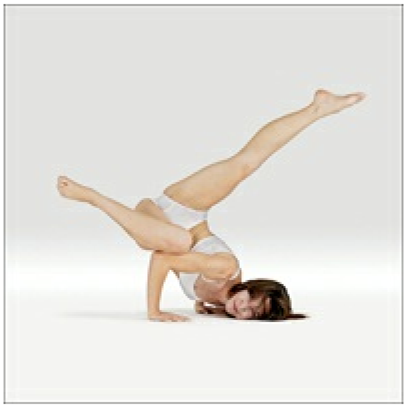

Pose Dedicated to Sage Koundinya One-Legged Version 1 Prep.

Eka Pada Koundinyasana 1 Prep.

(EY-kuh PUH-duh kown-din-YAHS-uh-nuh)
Modification: head on the floor
Pose Type: arm balance, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose)

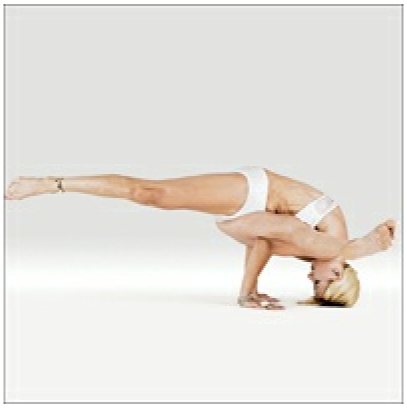

Pose Dedicated to Sage Koundinya One-Legged Version 2

Eka Pada Koundinyasana 2

(EY-kuh PUH-duh kown-din-YAHS-uh-nuh)
Modification: 1. prep. back foot on the floor, toes curled in
2. back foot lifted
Pose Type: arm balance, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre

(nose)

1.

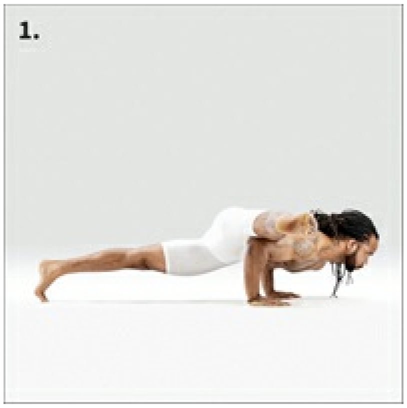

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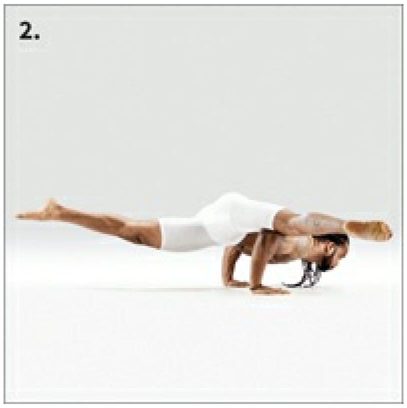

ARM BALANCE: GARUDA LEGS

Revolved Leg Position of the Pose Dedicated to Garuda in Swan Pose

Parivritta Pada Garudasana in Hamsasana

(puh-ri-VRIT-tuh PUH-duh guh-ru-DAHS-uh-nuh in huhms-AHS-uh-nuh)

Pose Type: arm balance, forward bend, twist

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

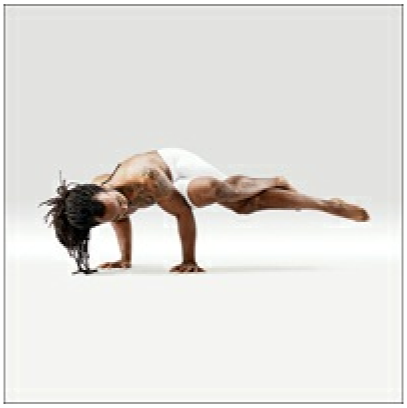

Revolved Leg Position of the Pose Dedicated to Garuda in Uneven Swan Pose

Parivritta Pada Garudasana in Vishama Hamsasana

(puh-ri-VRIT-tuh PUH-duh guh-ru-DAHS-uh-nuh in VISH-uh-muh huhms-AHS-uh-nuh)

Modification: forearm to the floor
Pose Type: arm balance, forward bend, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

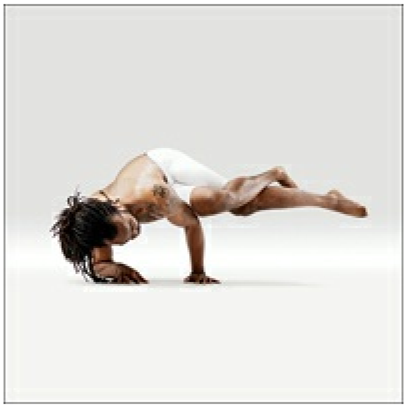

Revolved Leg Position of the Pose Dedicated to Garuda in Uneven Swan Pose

Parivritta Pada Garudasana in Vishama Hamsasana

(puh-ri-VRIT-tuh PUH-duh guh-ru-DAHS-uh-nuh in VISH-uh-muh huhms-AHS-uh-nuh)

Modification: elbow to the floor
Pose Type: arm balance, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose) or Padayoragrai or Padayoragre (toes/feet)

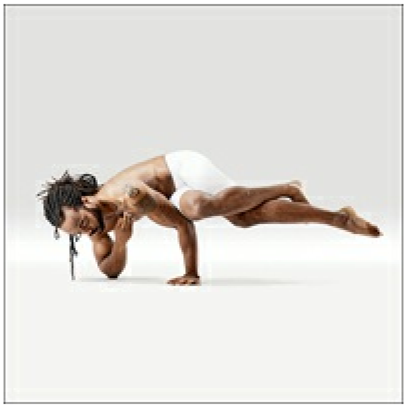

Two-Legged Pose Dedicated to Koundinya

Dwi Pada Koundinyasana

(DWI-puh-duh kown-din-YAHS-uh-nuh)

Pose Type: arm balance, forward bend, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

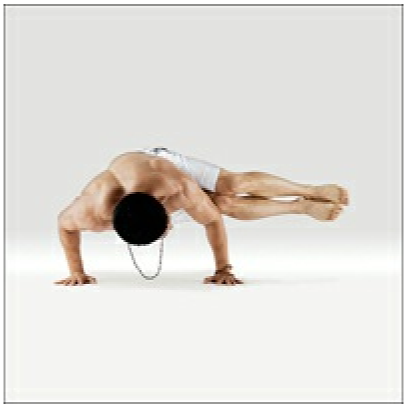

Uneven Two-Legged Pose Dedicated to Koundinya

Vishama Dwi Pada Koundinyasana

(VISH-uh-muh DWI-puh-duh kown-din-YAHS-uh-nuh)

Modification: one forearm to the floor, knees bent
Pose Type: arm balance, forward bend, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

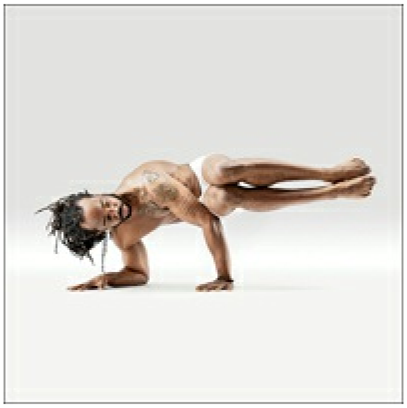

Pose Dedicated to Ashtavakra Prep.

Ashtavakrasana Prep.

(uh-shtuh-vuh-KRAHS-uh-nuh)

Also Known As: Eight Angle Pose Prep.
Modification: feet unhooked
Pose Type: arm balance, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose)

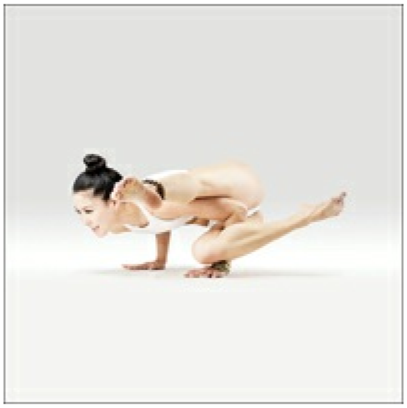

ARM BALANCE: BOTH LEGS TO THE SIDE—ASHTAVAKRA’S POSE

Pose Dedicated to Ashtavakra

Ashtavakrasana

(uh-shtuh-vuh-KRAHS-uh-nuh)

Also Known As: Eight Angle Pose
Pose Type: arm balance, forward bend, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

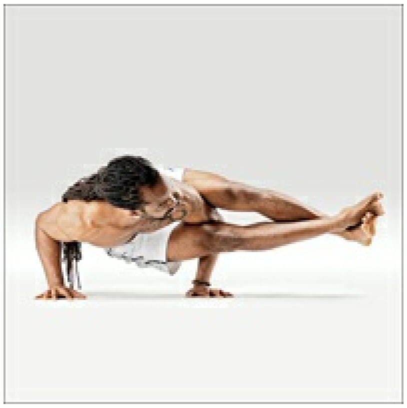

Uneven Pose Dedicated to Ashtavakra

Vishama Ashtavakrasana

(VISH-uh-muh uh-shtuh-vuh-KRAHS-uh-nuh)

Also Known As: Uneven Eight Angle Pose
Modification: one forearm to the floor
Pose Type: arm/forearm balance, forward bend, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

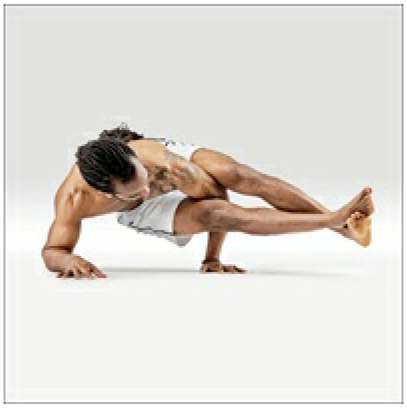

Uneven Half Repose Pose Dedicated to Ashtavakra

Vishama Ardha Shayana Ashtavakrasana

(VISH-uh-muh UHR-duh shuh-yuh-nuh uh-shtuh-vuh-KRAHS-uh-nuh)

Also Known As: Uneven Half Repose Eight Angle Pose
Modification: one elbow to the floor, hand to the face
Pose Type: arm/elbow balance, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose)

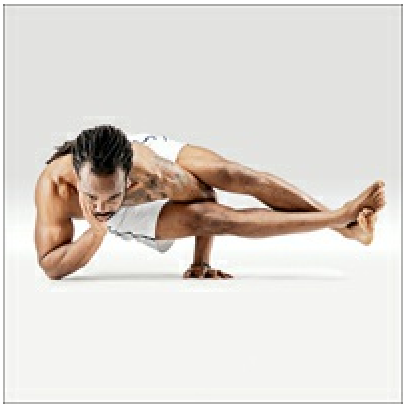

ARM BALANCE: BOTH LEGS TO THE SIDE—KNEES BENT AND TOGETHER

Side Crane Pose

Parshva Bakasana

(PAHRSH-vuh buh-KAHS-uh-nuh)

Also Known As: Revolved Crane Pose (Parivritta Bakasana), Sideways Crow Pose (Parshva Kakasana)
Modification: 1. elbows bent
2. arms straight
Pose Type: arm balance, forward bend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

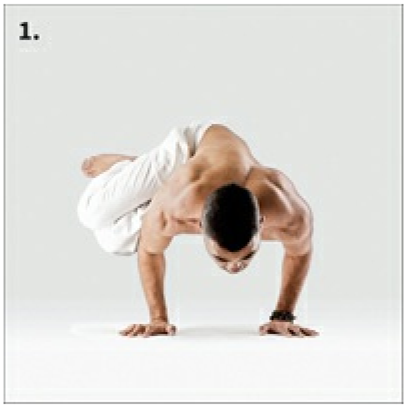

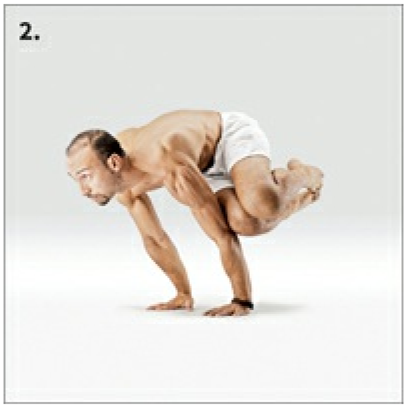

Two-Legged Pose Dedicated to Koundinya Modification on the Fists

Mushti Dwi Pada Koundinyasana

(mush-ti DWI-puh-duh kown-din-YAHS-uh-nuh)

Modification: ankles crossed
Pose Type: arm balance, forward bend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

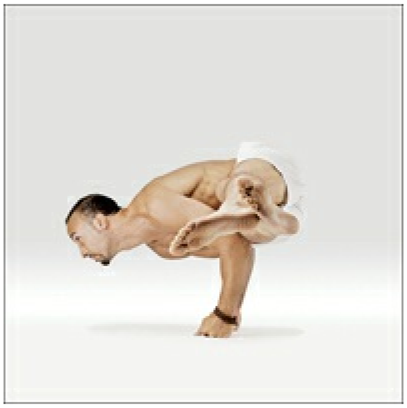

Uneven Arms Side Crane Pose

Vishama Hasta Parshva Bakasana

(VISH-uh-muh HUH-stuh PAHRSH-vuh buh-KAHS-uh-nuh)

Pose Type: arm balance, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose)

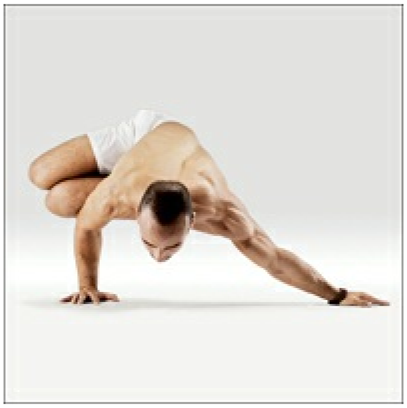

ARM BALANCE: LOTUS PEACOCK

Bound Angle Pose in Peacock Pose

Baddha Konasana in Mayurasana

(BUH-duh ko-NAHS-uh-nuh in muh-yoor-AHS-uh-nuh)

Pose Type: arm balance
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

Lotus Pose in Peacock Pose

Padmasana in Mayurasana

(puhd-MAHS-uh-nuh in muh-yoor-AHS-uh-nuh)

Pose Type: arm balance, hip opener

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

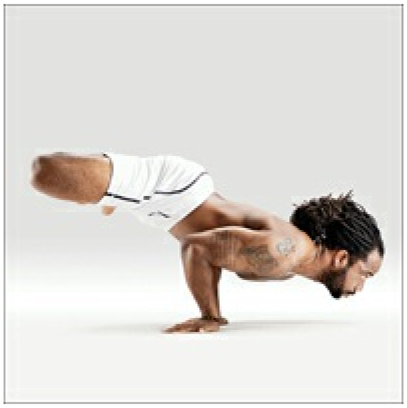

Fist Lotus Peacock Pose

Mushti Padma Mayurasana

(mush-ti PUHD-muh muh-yoor-AHS-uh-nuh)

Pose Type: arm balance

Drishti Point: Nasagrai or Nasagre (nose)

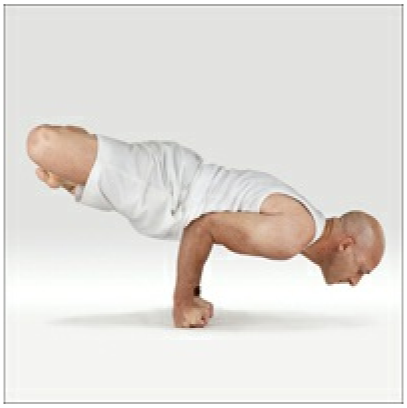

ARM BALANCE: PEACOCK AND SWAN

Peacock Pose

Mayurasana

(muh-yoor-AHS-uh-nuh)

Modification: 1. feet lifted higher than the hip level
2. body parallel to the floor
Pose Type: arm balance
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

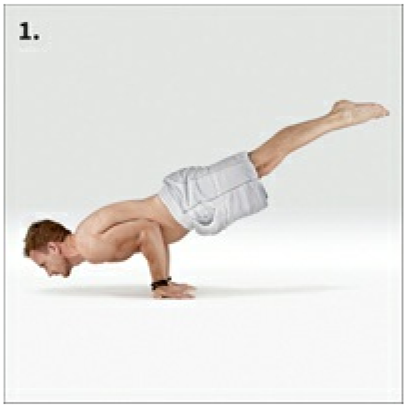

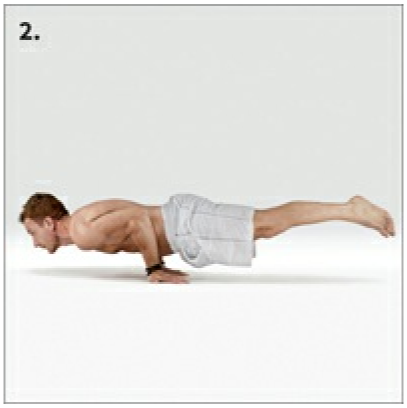

Swan Pose

Hamsasana

(huhms-AHS-uh-nuh)

Also Known As: Swan Pose (Hansasana)
Pose Type: arm balance
Drishti Point: Nasagrai or Nasagre (nose)

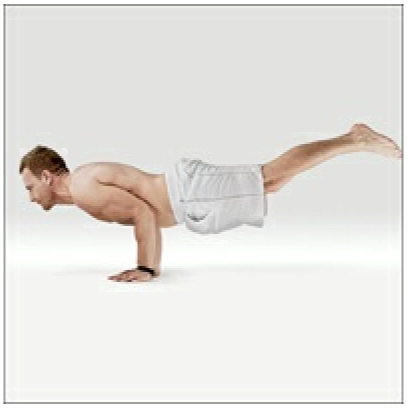

One Hand Peacock Pose

Eka Hasta Mayurasana

(EY-kuh HUH-stuh muh-yoor-AHS-uh-nuh)

Also Known As: Wounded Peacock Pose (Pungu Mayurasana)
Pose Type: arm balance
Drishti Point: Nasagrai or Nasagre (nose)

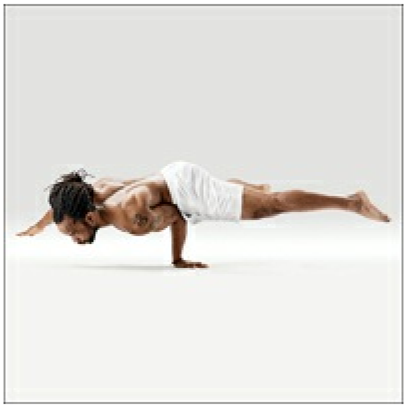

Inversion Poses

DUCK POSE

DOLPHIN POSE

PEACOCK FEATHER POSE

BACKBENDS ON FOREARMS

HANDSTANDS (VARIATIONS)

HEADSTANDS (VARIATIONS)

SHOULDERSTAND (VARIATIONS)

PLOW POSE

Duck Pose

Karandavasana

(kahr-uhn-duh-VAHS-uh-nuh)

Also Known As: Baby Duck Pose

Modification: thumbs grabbing onto the biceps, fingers grabbing onto the triceps; knees to the armpits, feet together

Pose Type: forearm balance, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

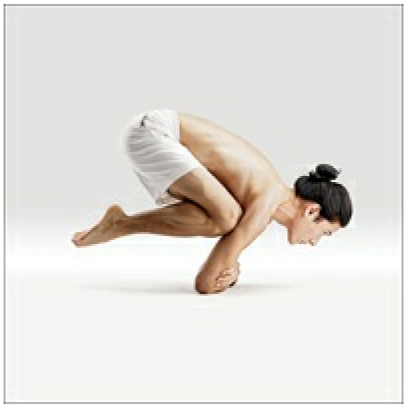

Duck Pose

Karandavasana

(kahr-uhn-duh-VAHS-uh-nuh)

Also Known As: Baby Duck Pose

Modification: forearms to the floor, knees to the armpits, feet together

Pose Type: forearm balance, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

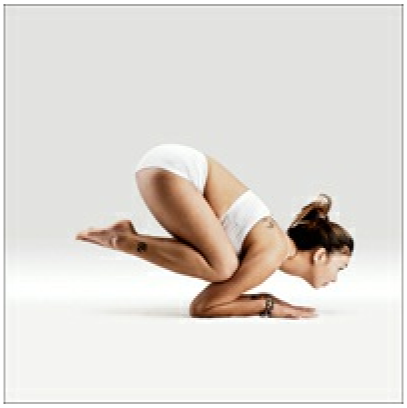

DOLPHIN POSE

Downward Facing Pose Dedicated to Makara

Adho Mukha Makarasana

(uh-DO MUK-uh muh-kuh-RAHS-uh-nuh)

Also Known As: Dolphin Pose
Pose Type: forward bend, inversion, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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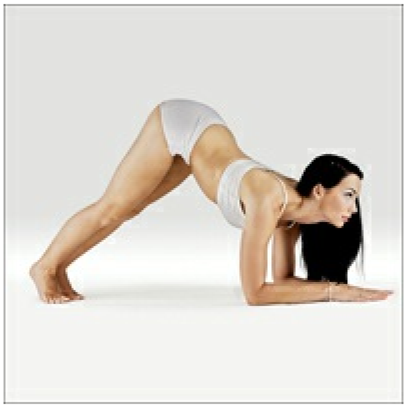

One-Legged Uneven Peacock Feather Pose

Eka Pada Vishama Picha Mayurasana

(EY-kuh PUH-duh VISH-uh-muh pich-chuh muh-yoor-AHS-uh-nuh)

Also Known As: Eka Pada Vishama Pincha Mayurasana
Pose Type: forearm balance, inversion, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
ल व ह

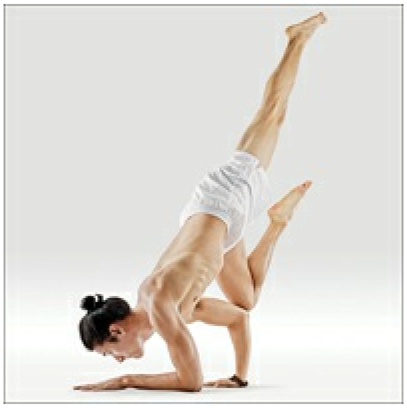

Half Lotus Downward Facing Pose Dedicated to Makara

Ardha Padma Adho Mukha Makarasana

(UHR-duh PUHD-muh uh-DO MUK-uh muh-kuh-RAHS-uh-nuh)

Also Known As: Half Lotus Dolphin Pose
Modification: heel down
Pose Type: forward bend, inversion, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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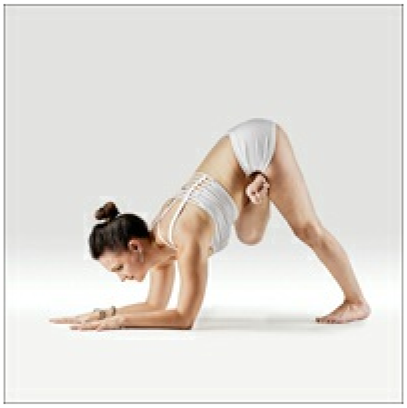

Leg Position of the Pose Dedicated to Garuda in Downward Facing Pose Dedicated to Makara

Pada Garudasana in Adho Mukha Makarasana

(PUH-duh guh-ru-DAHS-uh-nuh in uh-DO MUK-uh muh-kuh-RAHS-uh-nuh)

Also Known As: Leg Position of the Pose Dedicated to Garuda in Dolphin Pose
Pose Type: forward bend, inversion, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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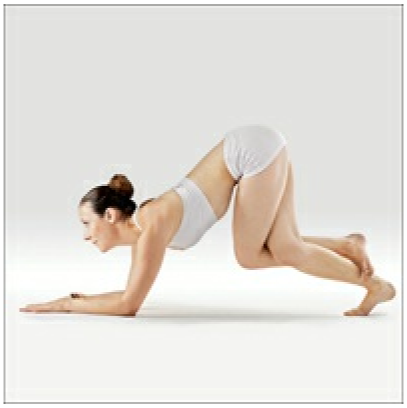

PEACOCK FEATHER POSE

Peacock Feather Pose

Picha Mayurasana

(pich-chuh muh-yoor-AHS-uh-nuh)

Also Known As: Upright Scorpion Pose (Avakra Vrishchikasana), Pincha Mayurasana

Pose Type: forearm balance, inversion

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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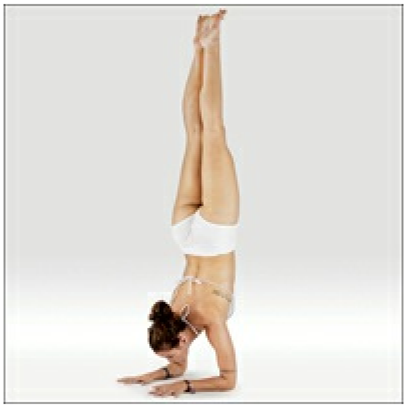

One-Legged Peacock Feather Pose

Eka Pada Picha Mayurasana

(EY-kuh PUH-duh pich-chuh muh-yoor-AHS-uh-nuh)

Also Known As: Eka Pada Pincha Mayurasana

Pose Type: forearm balance, inversion, forward bend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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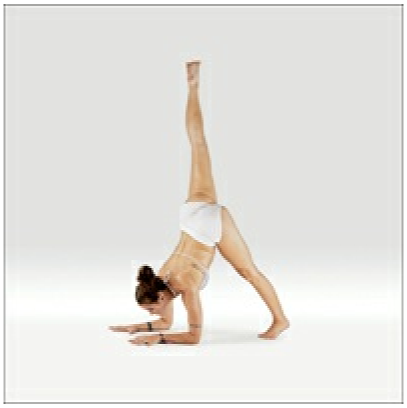

One-Legged Scorpion Pose

Eka Pada Vrishchikasana

(EY-kuh PUH-duh vrish-chi-KAHS-uh-nuh)

Modification: biceps in line with the ears

Pose Type: forearm balance, inversion, backbend
Drishti Point: Nasagrai or Nasagre (nose)
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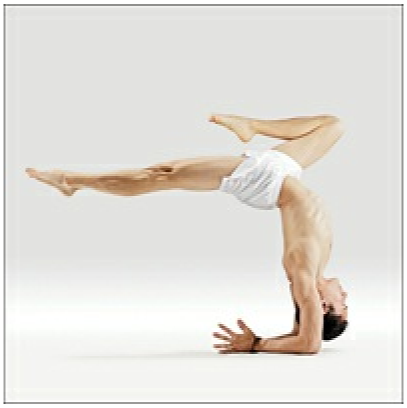

Pose Dedicated to Lord Hanuman in Peacock Feather Pose

Hanumanasana in Picha Mayurasana

(huh-nu-mahn-AHS-uh-nuh in pich-chuh muh-yoor-AHS-uh-nuh)
Also Known As: Hanumanasana in Pincha Mayurasana
Pose Type: forearm balance, inversion, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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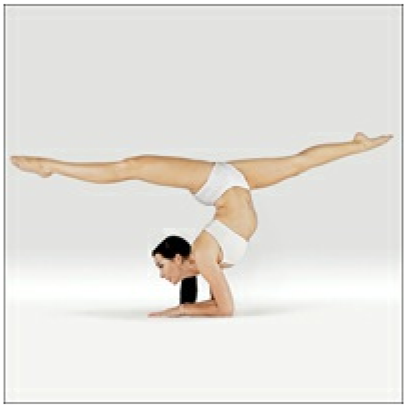

One-Legged Stretched Out Scorpion Pose

Eka Pada Paripurna Vrishchikasana

(EY-kuh PUH-duh puh-ri-POOR-nuh vrish-chi-KAHS-uh-nuh)
Pose Type: forearm balance, inversion, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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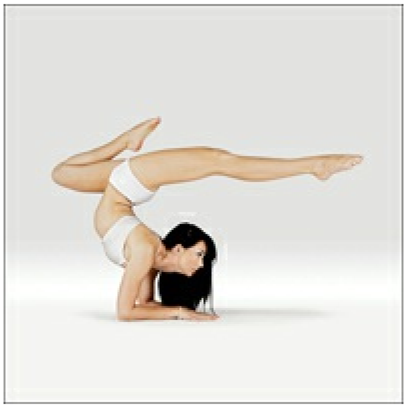

One-Legged Scorpion Pose

Eka Pada Vrishchikasana

(EY-kuh PUH-duh vrish-chi-KAHS-uh-nuh)

Modification: forearms to the floor, foot away from the head
Pose Type: forearm balance, inversion, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

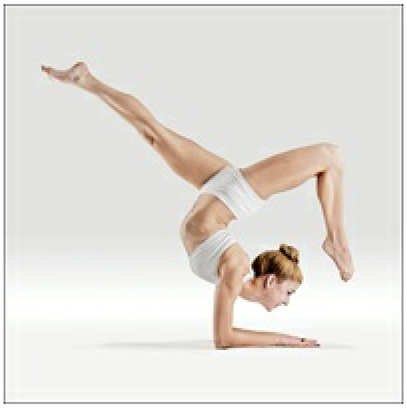

BACKBENDS ON FOREARMS, LOTUS ON FOREARMS, AND ELBOW BALANCES

Inverted Puppy Dog Pose in Peacock Feather Pose

Viparita Shvanakasana in Picha Mayurasana

(vi-puh-REE-tuh shvuh-nuh-KAHS-uh-nuh in pich-chuh muh-yoor-AHS-uh-nuh)

Also Known As: Viparita Shvanakasana in Pincha Mayurasana
Modification: knees bent, backbend
Pose Type: forearm balance, inversion, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

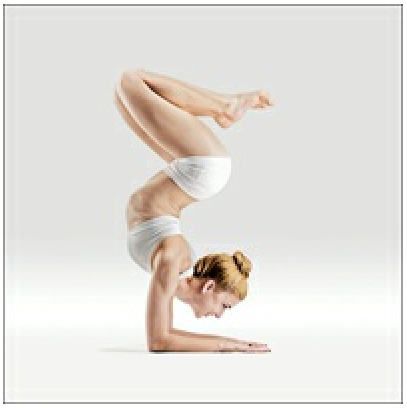

Scorpion Pose

Vrishchikasana

(vrish-chi-KAHS-uh-nuh)

Modification: forearms to the floor, feet to the head
Pose Type: forearm balance, inversion, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

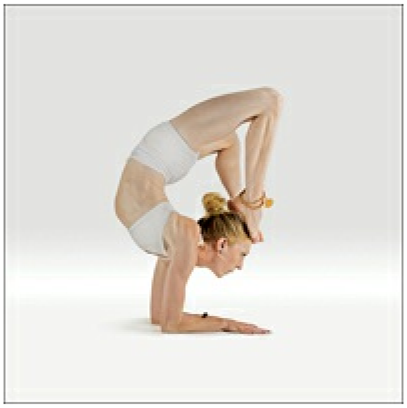

One-Legged Scorpion Pose

Eka Pada Vrishchikasana

(EY-kuh PUH-duh vrish-chi-KAHS-uh-nuh)

Modification: forearms to the floor, foot to the head, other leg parallel to the floor
Pose Type: forearm balance, inversion, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

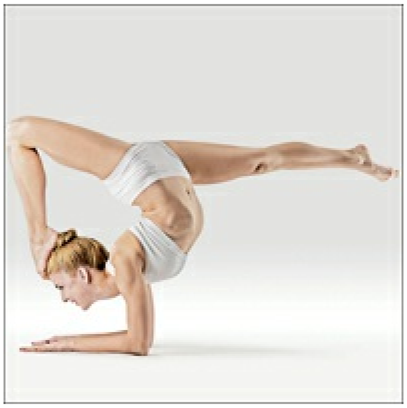

Upward Lotus Pose in Peacock Feather Pose

Urdhva Padmasana in Picha Mayurasana

(OORD-vuh puhd-MAHS-uh-nuh in pich-chuh muh-yoor-AHS-uh-nuh)

Also Known As: Raised Lotus Scorpion Pose (Urdhva Padma Vrishchikasana), Duck Pose (Karandavasana)
Pose Type: forearm balance, inversion
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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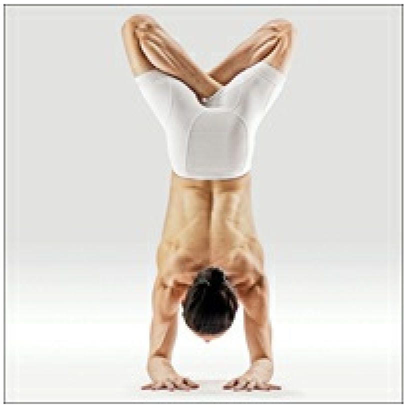

Uneven Repose Pose

Vishama Shayanasana

(VISH-uh-muh shuh-yuh-NAHS-uh-nuh)

Modification: both knees bent
Pose Type: forearm/elbow balance, inversion, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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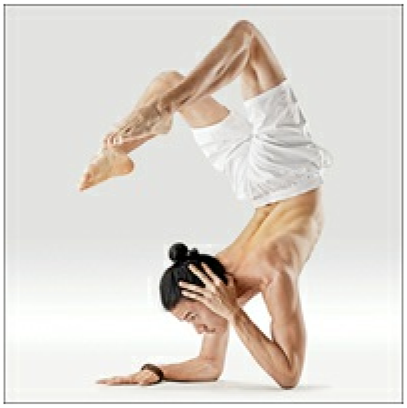

Repose Pose

Shayanasana

(shuh-yuh-NAHS-uh-nuh)

Modification: both knees bent
Pose Type: elbow balance, inversion, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

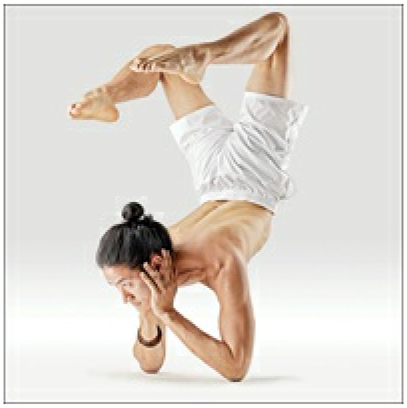

HANDSTANDS: BOTH LEGS STRAIGHT

Feet Spread Intense Stretch Pose in Downward Facing Tree Pose

Prasarita Padottanasana in Adho Mukha Vrikshasana

(pruh-SAH-ri-tuh puh-do-tahn-AHS-uh-nuh in uh-DO MUK-uh vriks-SHAHS-anna)

Also Known As: Feet Spread Full Forward Bend Pose in Downward Facing Tree Pose, Prasarita Padottanasana in Adho Mukha Vrksasana
Pose Type: inversion, arm balance, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

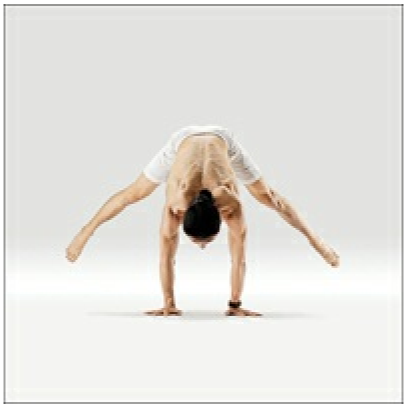

One-Legged Downward Facing Tree Pose

Eka Pada Adho Mukha Vrikshasana

(EY-kuh PUH-duh uh-DO MUK-uh vrik-SHAHS-uh-nuh)

Also Known As: Eka Pada Adho Mukha Vrksasana
Pose Type: inversion, arm balance, forward bend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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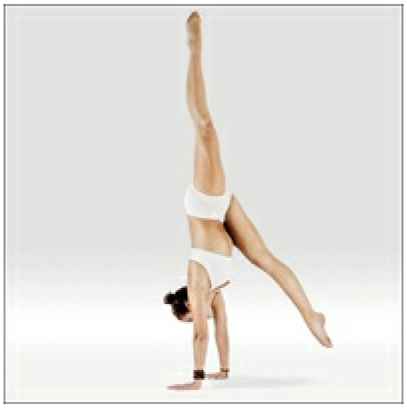

Downward Facing Tree Pose

Adho Mukha Vrikshasana

(uh-DO MUK-uh vrik-SHAHS-uh-nuh)

Also Known As: Adho Mukha Vrksasana
Modification: legs crossed
Pose Type: inversion, arm balance
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
लं वं यं हं

Seated Angle Pose in Downward Facing Tree Pose

Upavishta Konasana in Adho Mukha Vrikshasana

(u-puh-VISH-tuh ko-NAHS-uh-nuh in uh-DO MUK-uh vrik-SHAHS-uh-nuh)

Also Known As: Upward Spread Feet Pose A (Urdhva Prasarita Padasana A), Upavista Konasana in Adho Mukha Vrikshasana
Pose Type: inversion, arm balance
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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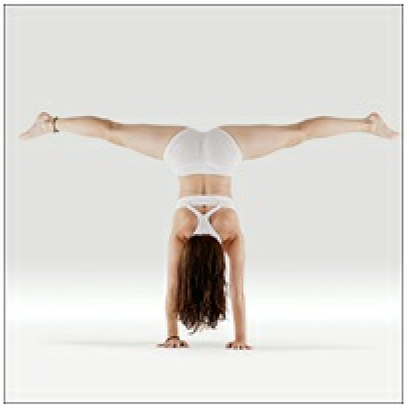

Leg Position of the Pose Dedicated to Garuda in

Downward Facing Tree Pose

Pada Garudasana in Adho Mukha Vrikshasana

(PUH-duh guh-ru-DAHS-uh-nuh in uh-DO MUK-uh vrik-SHAHS-uh-nuh)

Also Known As: Pada Garudasana in Adho Mukha Vrksasana

Pose Type: inversion, arm balance

Drishti Point: Angusthamadhye or Angustha Ma Dyai (thumbs)

How to Perform the Pose:

1. Begin by standing in Mountain Pose (*Tadasana*). Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale and hinge from the hips, coming into a forward bend, placing the palms on the floor on the outsides of your feet. Your hands should be shoulder width apart or slightly wider. Make sure your arms are straight and your shoulders are on top of your fingertips.
3. There are many ways to come into a handstand. When you start practicing handstands, make sure you can balance on your hands against the wall for at least 60 seconds. Then you can experiment with jumping into a handstand or lifting your legs using your core. Press strongly into your hands.
4. Once you find your balance in a Downward Facing Tree Pose (*Adho Mukha Vrikshasana*), also known as Handstand, exhale and bend your knees; cross your right leg over your left leg, hooking your right foot around your left calf muscle. Hold for 30, and up to 90, seconds to receive the full benefits of the stretch.
5. Inhale and bring your legs back to the straight position. Exhale and switch legs as you bend your knees and cross your left leg over your right leg, hooking your left foot around your right calf muscle. Hold for 30, and up to 90, seconds to receive the full benefits of the stretch.
6. Inhale and bring your legs back to the straight position. On the following inhale, lower your feet to the floor. Inhale as you come back to Mountain Pose (*Tadasana*).

pada = foot or leg

Garuda = Hindu Deity, half-man half-eagle, carrier of Lord Vishnu

adho = downward

mukha = facing

vriksha = tree

Frog Pose in Downward Facing Tree Pose

Mandukasana in Adho Mukha Vrikshasana

(muhn-doo-KAHS-uh-nuh in uh-DO MUK-uh vrik-SHAHS-uh-nuh)

Also Known As: Mandukasana in Adho Mukha Vrksasana
Pose Type: inversion, arm balance
Drishti Point: Nasagrai or Nasagre (nose) or Angusthamadhye or Angustha Ma Dyai (thumbs)

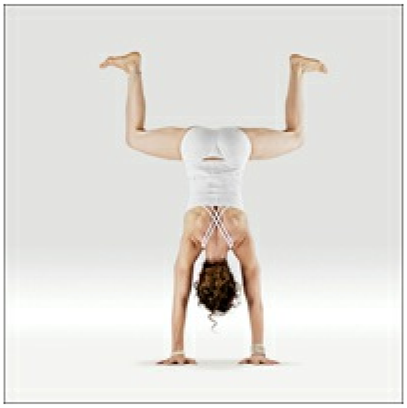

Bound Angle Pose in Downward Facing Tree Pose

Baddha Konasana in Adho Mukha Vrikshasana

(BUH-duh ko-NAHS-uh-nuh in uh-DO MUK-uh vrik-SHAHS-uh-nuh)

Also Known As: Baddha Konasana in Adho Mukha Vrksasana
Pose Type: inversion, arm balance
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

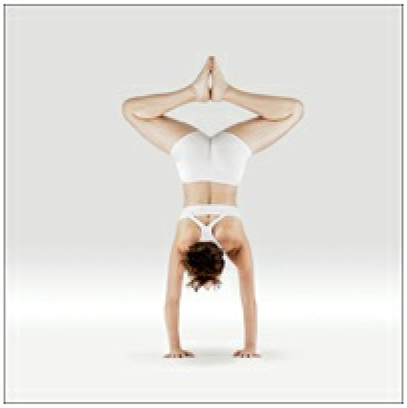

Svastika Legs in Downward Facing Tree Pose

Pada Svastikasana in Adho Mukha Vrikshasana

(PUH-duh svuh-sti-KAHS-uh-nuh in uh-DO MUK-uh vrik-SHAHS-uh-nuh)

Also Known As: Pada Svastikasana in Adho Mukha Vrksasana

Modification: both knees bent, one knee bent toward the chest, other foot pointing to the back

Pose Type: inversion, arm balance, mild backbend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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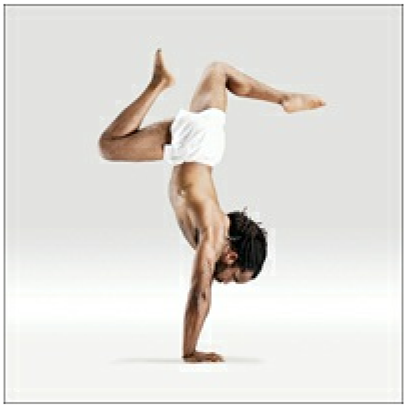

Scorpion Pose Prep.

Vrishchikasana Prep.

(vrish-chi-KAHS-uh-nuh)

Also Known As: Pose Dedicated to the Demon Taraka A (Tarakasana A)

Modification: knees bent, feet away from the head

Pose Type: inversion, arm balance, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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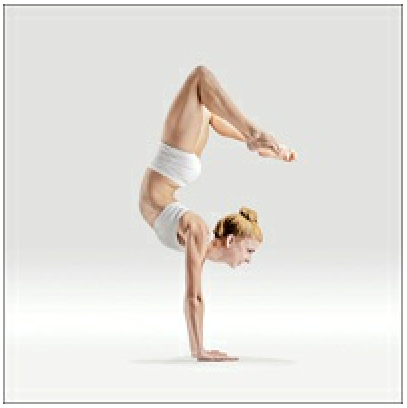

Half Lotus Pose in Downward Facing Tree Pose

Ardha Padmasana in Adho Mukha Vrikshasana

(UHR-duh puhd-MAHS-uh-nuh in uh-DO MUK-uh vrik-SHAHS-uh-nuh)

Also Known As: Ardha Padmasana in Adho Mukha Vrksasana
Pose Type: inversion, arm balance
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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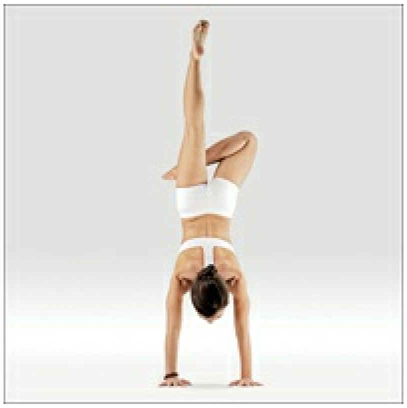

HANDSTAND, LEGS CROSSED: GARUDA LEGS & LOTUS

Leg Position of the Pose Dedicated to Garuda in Downward Facing Tree Pose

Pada Garudasana in Adho Mukha Vrikshasana

(PUH-duh guh-ru-DAHS-uh-nuh in uh-DO MUK-uh vrik-SHAHS-uh-nuh)

Also Known As: Pada Garudasana in Adho Mukha Vrksasana
Modification: arms bent at 90 degrees
Pose Type: inversion, arm balance
Drishti Point: Nasagrai or Nasagre (nose)
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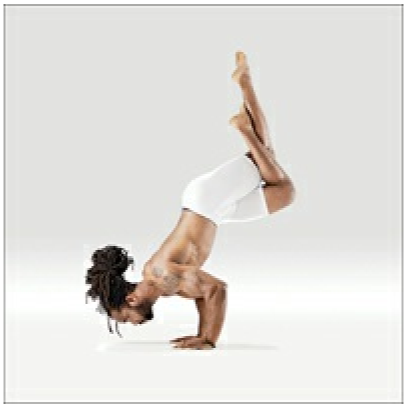

Upward Lotus Pose in Downward Facing Tree Pose

Urdhva Padmasana in Adho Mukha Vrikshasana

(OORD-vuh puhd-MAHS-uh-nuh in uh-DO MUK-uh vrik-SHAHS-uh-nuh)

Also Known As: Urdhva Padmasana in Adho Mukha Vrksasana
Pose Type: inversion, arm balance
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

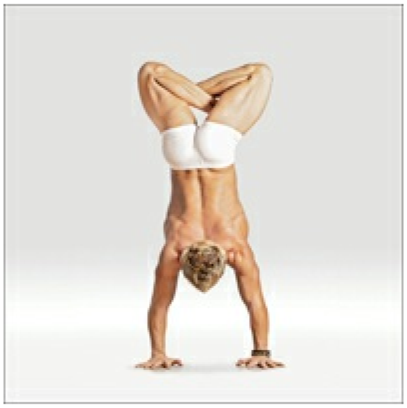

HEADSTAND 1 ARM POSITION: LEG MODIFICATIONS

Headstand 1

Shirshasana 1

(sheer-SHAHS-uh-nuh)

Also Known As: Supported Headstand (Salamba Shirshasana[*]), Bound Hands Headstand A (Baddha Hasta Shirshasana A)
Modification: 1. back view
2. side view
Pose Type: inversion
Drishti Point: Nasagrai or Nasagre (nose)

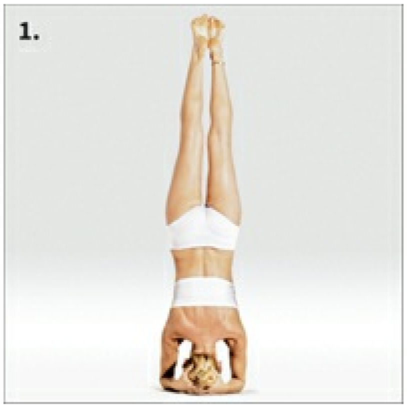

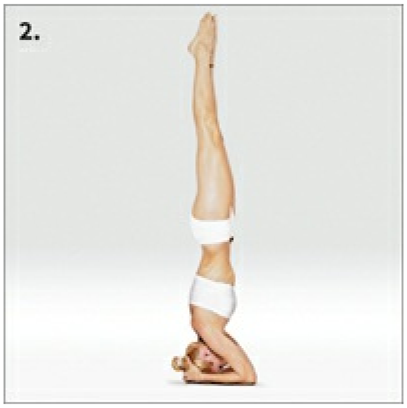

One-Legged Headstand 1

Eka Pada Shirshasana 1

(EY-kuh PUH-duh sheer-SHAHS-uh-nuh)

Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Padayoragrai or Padayoragre (toes/feet)

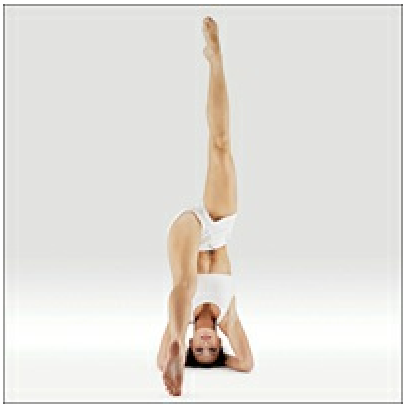

Leg Contraction Knee Bend Pose in Headstand 1

Pada Akunchanasana in Shirshasana 1

(PUH-duh uh-kunch-uh-NAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: one knee bent toward the chest
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

Upward Staff Pose in Headstand 1

Urdhva Dandasana in Shirshasana 1

(OORD-vuh duhn-DAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Also Known As: Half Headstand Pose (Ardha Shirshasana), Headstand B (Shirshana B)
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

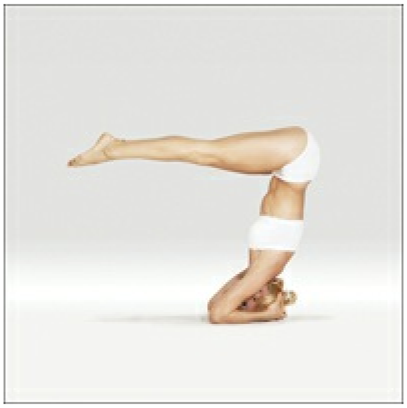

HEADSTAND 1 ARM POSITION: VARIOUS LEG POSITIONS

Svastika Legs in Headstand 1

Pada Svastikasana in Shirshasana 1

(PUH-duh svuh-sti-KAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: inversion, mild backbend
Drishti Point: Nasagrai or Nasagre (nose)

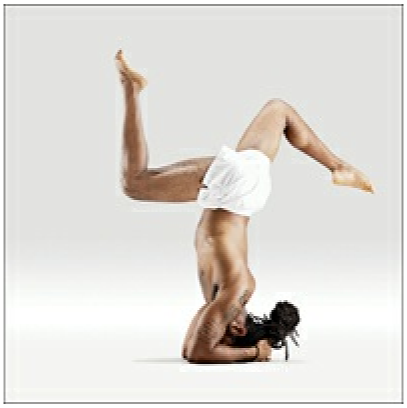

Leg Position of One-Legged King Pigeon 1 Version B in Headstand 1

Pada Eka Pada Raja Kapotasana 1 B in Shirshasana 1

(PUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: both knees bent, one knee to the sky, other foot to the knee

Pose Type: inversion, mild backbend

Drishti Point: Nasagrai or Nasagre (nose)

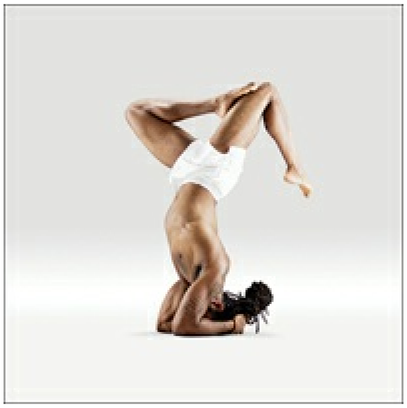

Feet to Head Pose

Shirsha Padasana

(SHEER-shuh puh-DAHS-uh-nuh)

Pose Type: inversion, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

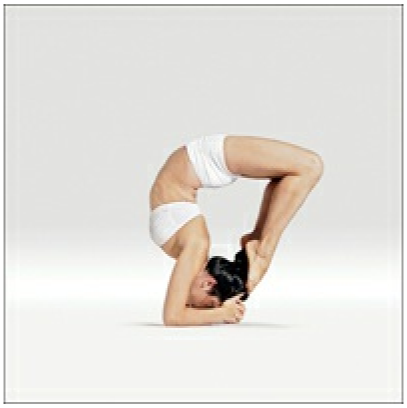

Bound Angle Pose in Headstand 1

Baddha Konasana in Shirshasana 1

(BUH-duh ko-NAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: inversion

Drishti Point: Nasagrai or Nasagre (nose)

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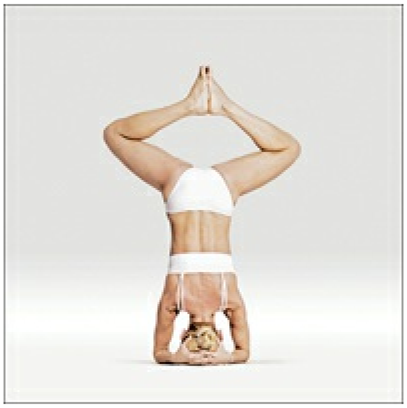

Sideways Bound Angle Pose in Headstand 1

Parshva Baddha Konasana in Shirshasana 1

(PAHRSH-vuh BUH-duh ko-NAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: inversion, side bend

Drishti Point: Nasagrai or Nasagre (nose)

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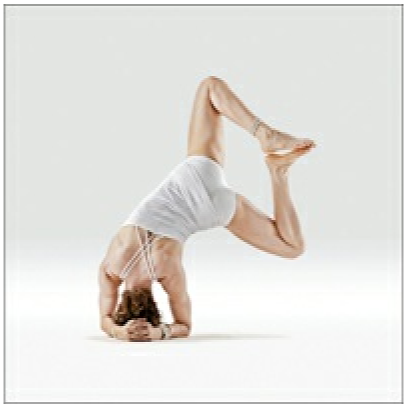

Pose Dedicated to Hanuman in Headstand 1

Hanumanasana in Shirshasana 1

(huh-nu-mahn-AHS-uh-nuh in sheer-SHAH-suh-nuh)

Pose Type: inversion
Drishti Point: Nasagrai or Nasagre (nose)

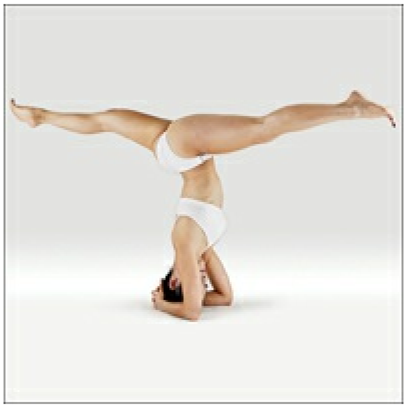

Seated Angle Pose in Headstand 1

Upavishta Konasana in Shirshasana 1

(u-puh-VISH-tuh ko-NAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Also Known As: Upavista Konasana in Adho Mukha Vrikshasana, Upavista Konasana in Adho Mukha Vrksasana
Pose Type: inversion
Drishti Point: Nasagrai or Nasagre (nose)

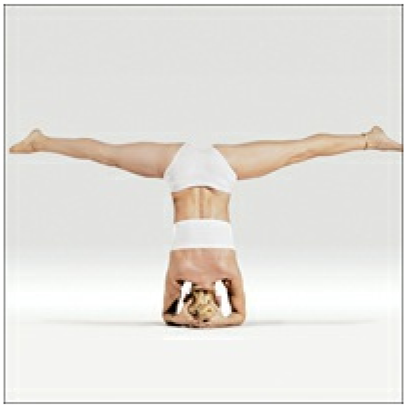

Leg Position of the Pose Dedicated to Garuda in Headstand 1

Pada Garudasana in Shirshasana 1

(PUH-duh guh-ru-DAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: inversion
Drishti Point: Nasagrai or Nasagre (nose)

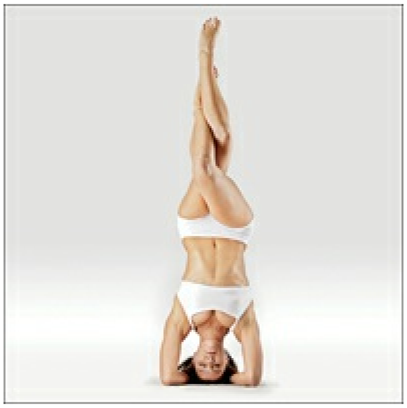

HEADSTAND 1 ARM POSITION: LOTUS LEG POSITION

Upward Lotus in Headstand 1

Urdhva Padmasana in Shirshasana 1

(OORD-vuh puhd-MAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: 1. back view
2. side view
Pose Type: inversion
Drishti Point: Nasagrai or Nasagre (nose)

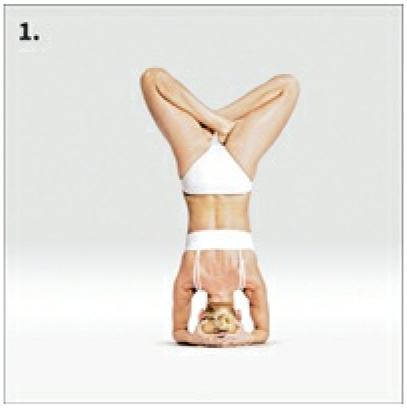

1.

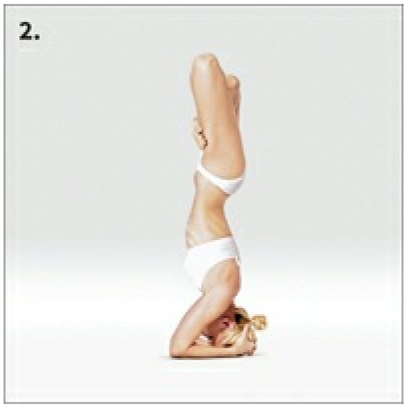

2.

Sideways Upward Lotus in Headstand 1

Parshva Urdhva Padmasana in Shirshasana 1

(PAHRSH-vuh OORD-vuh puhd-MAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: inversion, twist
Drishti Point: Nasagrai or Nasagre (nose)

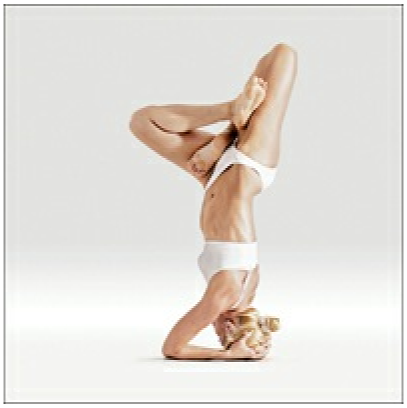

Embryo Pose in Headstand 1 Prep.

Pindasana in Shirshasana 1 Prep.

(pin-DAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: thighs parallel to the floor
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
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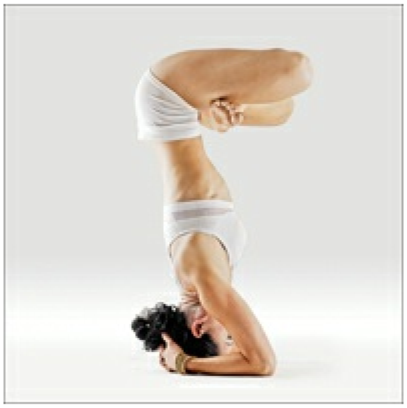

Embryo Pose in Headstand 1

Pindasana in Shirshasana 1

(pin-DAHS-uh-nuh in sheer-SHAHS-uh-nuh)
Modification: 1. knees to the triceps
2. knees to the chest
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)
● ● ● ● ●

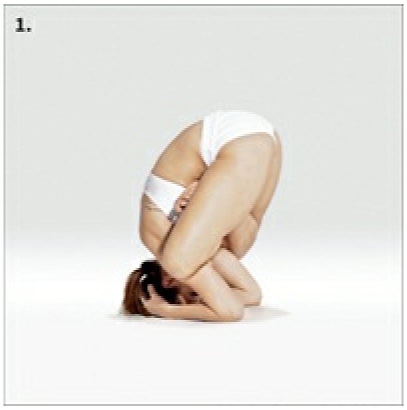

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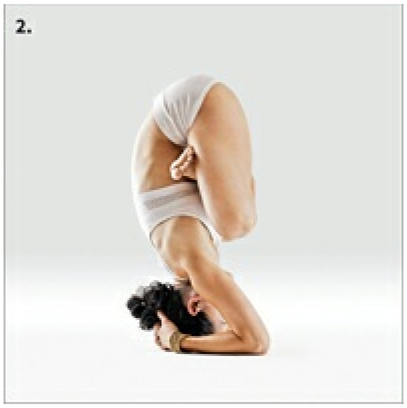

HEADSTAND 1 & 3 ARM POSITIONS: VARIOUS ARM AND LEG POSITIONS

One Hand Headstand 1

Eka Hasta Shirshasana 1

(EY-kuh HUH-stuh sheer-SHAHS-uh-nuh)

Modification: both knees bent toward the chest, one forearm on the floor

1. other arm straight, fingertips to the sky
2. other arm behind the back, fingertips pointing to the upper back

Pose Type: inversion, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

● ●

1.

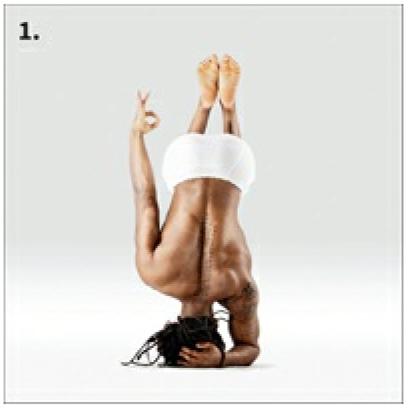

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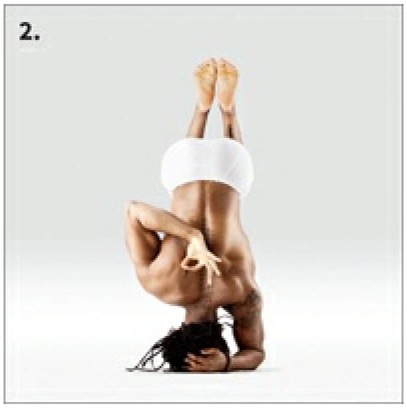

Sideways Uneven Upward Staff Pose

Parshva Vishama Urdhva Dandasana

(PAHRSH-vuh VISH-uh-muh OORD-vuh duhn-DAHS-uh-nuh)

Modification: forearm to the floor in front of the face, palm down; legs parallel to the floor
Pose Type: inversion, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

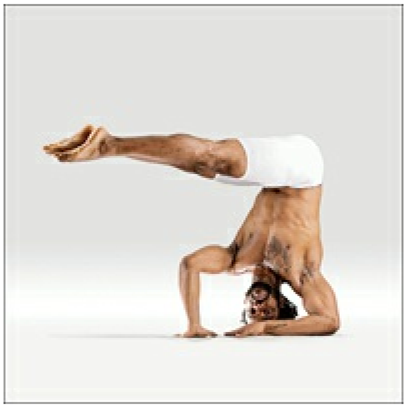

Leg Contraction Pose in Headstand 3

Pada Akunchanasana in Shirshasana 3

(PUH-duh uh-kunch-AHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: one leg straight and out to the side, other knee to the chest
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

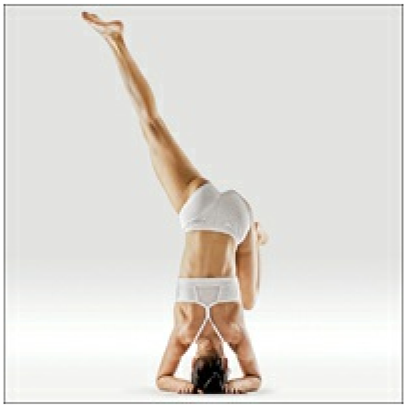

Leg Contraction Pose in Uneven Headstand (Fusion of Headstand 5 and Headstand 3 Arm Position)

Pada Akunchanasana in Vishama Shirshasana

(PUH-duh uh-kunch-AHS-uh-nuh in VISH-uh-muh sheer-SHAHS-uh-nuh)

Modification: one forearm to the floor, other elbow on top of the wrist, knee to the tricep on the same side

Pose Type: inversion, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

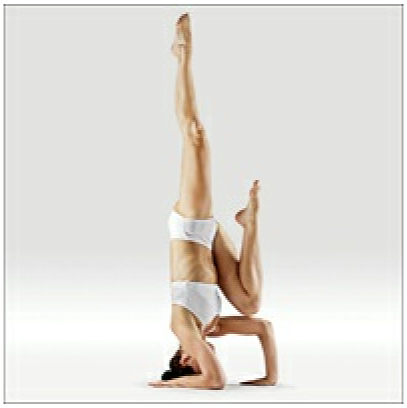

HEADSTAND 5 ARM POSITION: VARIOUS LEG POSITIONS

Leg Position of the Pose Dedicated to Garuda in Headstand 5

Pada Garudasana in Shirshasana 5

(PUH-duh guh-ru-AHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: inversion

Drishti Point: Nasagrai or Nasagre (nose)

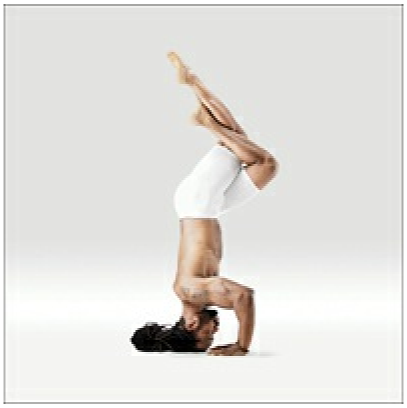

Leg Position of Cow Face Pose in Headstand 5

Pada Gomukhasana in Shirshasana 5

(PUH-duh go-muk-AHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: bottom knee to the opposite tricep

Pose Type: inversion, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

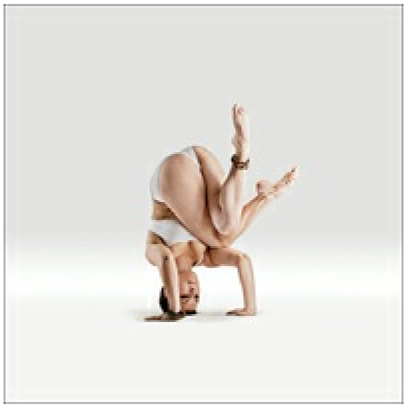

Headstand 5

Shirshasana 5

(sheer-SHAHS-uh-nuh)

Also Known As: Tripod Headstand

Pose Type: inversion

Drishti Point: Nasagrai or Nasagre (nose)

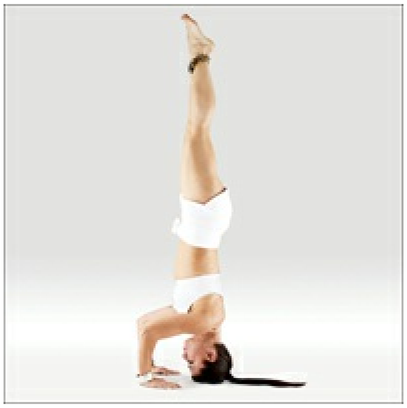

Frog Pose in Headstand 5

Mandukasana in Shirshasana 5

(muhn-doo-KAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: inversion

Drishti Point: Nasagrai or Nasagre (nose)

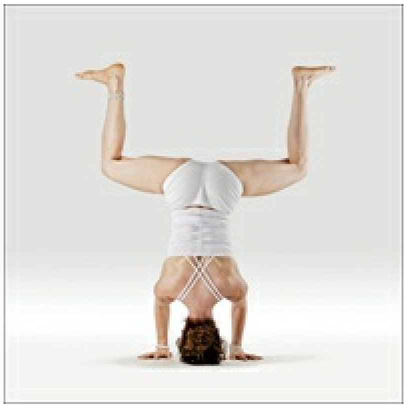

Seated Angle Pose in Headstand 5

Upavishta Konasana in Shirshasana 5

(u-puh-VISH-tuh ko-NAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Also Known As: Tripod Headstand Same Angle Pose (Utripada Shirsha Samakonasana), Upavista Konasana in Shirshasana
Pose Type: inversion
Drishti Point: Nasagrai or Nasagre (nose)

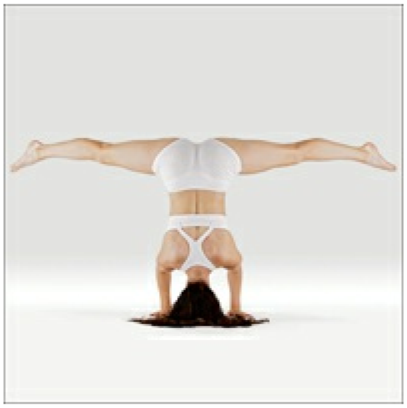

Leg Position of One-Legged King Pigeon 1 Version B in Headstand 5

Pada Eka Pada Raja Kapotasana 1 B in Shirshasana 5

(PUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: knee to the tricep on the same side, other knee resting on the foot
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

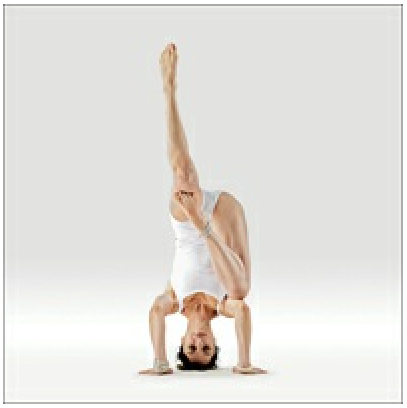

Revolved Leg Position of One-Legged King Pigeon 1 Version B in Headstand 5

Parivritta Pada Eka Pada Raja Kapotasana 1 B in Shirshasana 5

(puh-ri-VRIT-tuh PUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: knee resting on the foot
1. top leg straight
2. top knee bent at 90 degrees

Pose Type: inversion, forward bend, twist

Drishti Point: Nasagrai or Nasagre (nose)

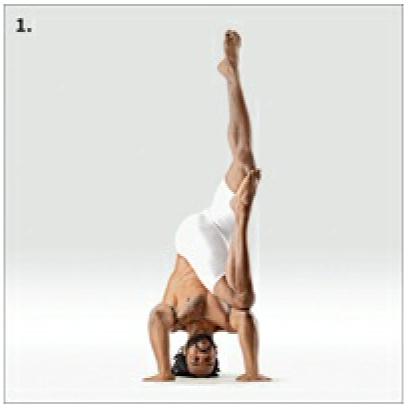

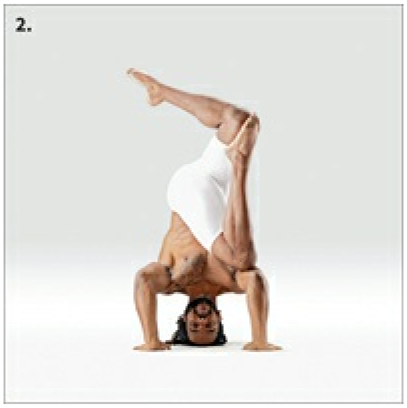

Headstand 5 Prep.

Shirshasana 5 Prep.

(sheer-SHAHS-uh-nuh)

Modification: one knee to the tricep, other foot to the floor on the side
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

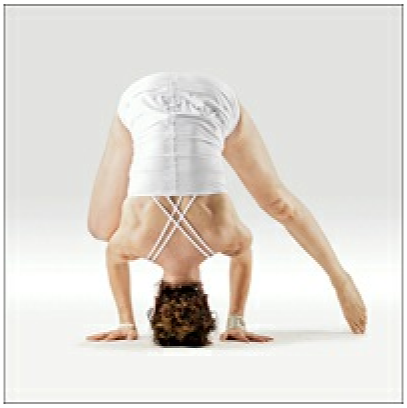

Crane Pose in Headstand 5 Prep.

Bakasana in Shirshasana 5 Prep.

(buh-KAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: knees on the triceps
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

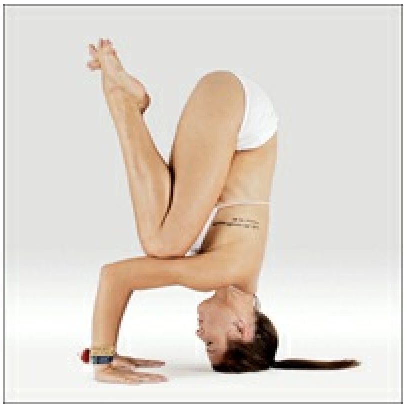

Side Crane Pose in Headstand 5

Parshva Bakasana in Shirshasana 5

(PAHRSH-vuh buh-KAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: knees together, knee to the opposite tricep

Pose Type: inversion, forward bend, twist

Drishti Point: Nasagrai or Nasagre (nose)

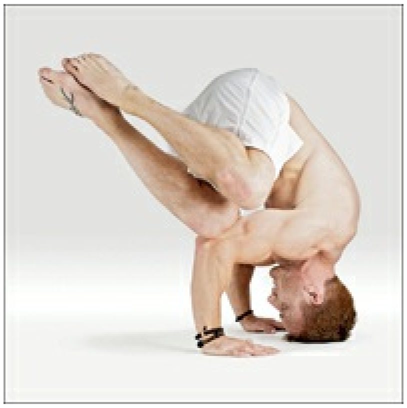

Embryo in the Womb Pose in Headstand 5

Garba Pindasana in Shirshasana 5

(guhr-buh-pin-DAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Pose Type: inversion, forward bend

Drishti Point: Nasagrai or Nasagre (nose)

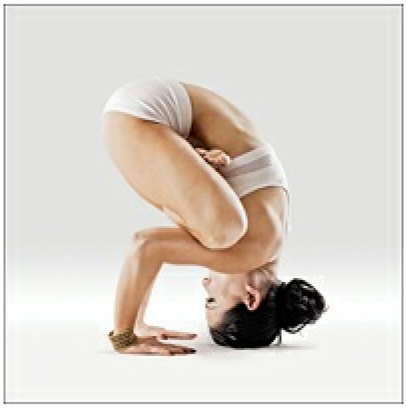

Side Rooster Pose in Headstand 5 Prep.

Parshva Kukkutasana in Shirshasana 5 Prep.

(PAHRSH-vuh ku-ku TAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: crown of the head on the floor

Pose Type: inversion, forward bend, twist

Drishti Point: Nasagrai or Nasagre (nose)

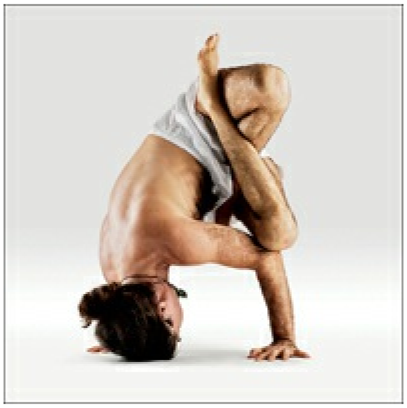

HEADSTAND 5 ARM POSITION: VARIOUS ARM POSITIONS BASED ON HEADSTAND 5 & VARIOUS LEG POSITIONS

Baby Cradle Pose in Headstand 5

Hindolasana in Shirshasana 5

(hin-do-LAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: Side 1: ankle to the inside of the elbow joint of the opposite arm, knee bent to the inside of the same arm, toes touching the floor.
Side 2: other knee bent to the side, heel toward the sitting bone
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

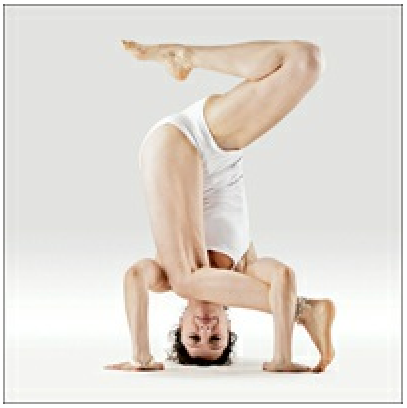

Baby Cradle Pose in Headstand 5

Hindolasana in Shirshasana 5

(hin-do-LAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: Side 1: arm bent at 90 degrees, fingertips to the floor, knee to the elbow on the same side.
Side 2: arm bent at 90 degrees, palm flat on the floor, ankle to the inside of the elbow joint, toes lifted off the floor
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

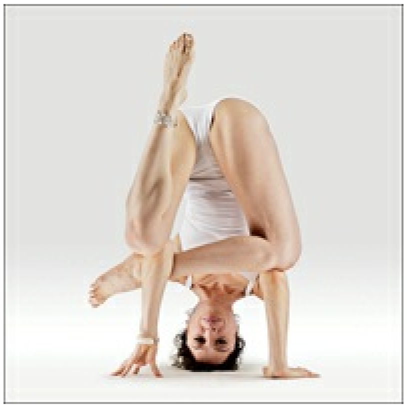

Extended Hand to Big Toe Pose in One Hand Headstand 5

Utthita Hasta Padangushtasana in Eka Hasta Shirshasana 5

(UT-ti-tuh HUH-stuh puhd-ahng-goosh-TAHS-uh-nuh in EY-kuh HUH-stuh sheer-SHAHS-uh-nuh)

Modification: Side 1: arm and leg straight out, grabbing onto the big toe.
Side 2: arm bent 90 degrees, knee resting on the tricep on the same side
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

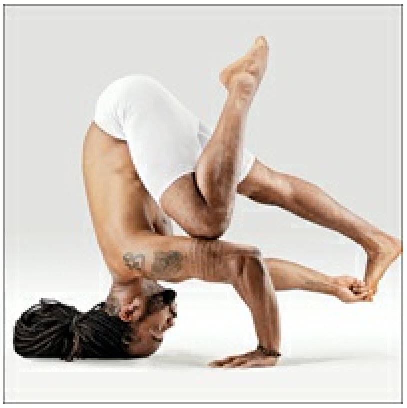

One-Legged Crane Pose 1 in One Hand Headstand 5

Eka Pada Bakasana 1 in Eka Hasta Shirshasana 5

(EY-kuh PUH-duh buh-KAHS-uh-nuh in EY-kuh HUH-stuh sheer-SHAHS-uh-nuh)

Modification: Side 1: arm and leg straight out.
Side 2: arm bent 90 degrees, knee resting on the tricep on the same side
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

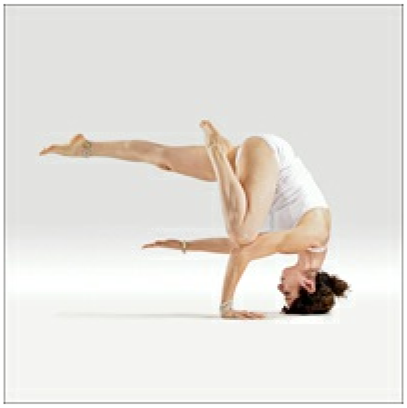

HEADSTAND 6 ARM POSITION: VARIOUS ARM POSITIONS BASED OFF HEADSTAND 6 & VARIOUS LEG POSITIONS

Extended Hand to Big Toe Pose in Uneven Headstand (Fusion of Headstand 5 and Headstand 6 Arm Position)

Utthita Hasta Padangushtasana in Vishama Shirshasana 5 & 6

(UT-ti-tuh HUH-stuh puhd-ahng-goosh-TAHS-uh-nuh in VISH-uh-muh sheer-SHAHS-uh-nuh)

Modification: Side 1: arm and leg straight out, grabbing onto the big toe
Side 2: arm bent 90 degrees, knee bent to the tricep on the same side
Pose Type: inversion, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Hastagrai or Hastagre (hands)

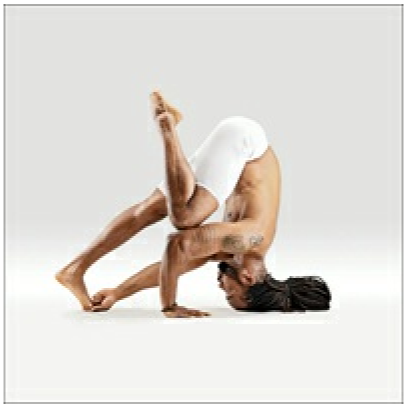

Crane Pose in Uneven Headstand (Fusion of Headstand 5 and Headstand 6 Arm Position)

Bakasana in Vishama Shirshasana 5 & 6

(buh-KAHS-uh-nuh in VISH-uh-muh sheer-SHAHS-uh-nuh)

Modification: Side 1: arm straight out, fingertips to the floor, knee to the tricep. Side 2: arm bent 90 degrees, knee bent to the tricep on the same side
Pose Type: inversion, forward bend
Drishti Point: Hastagrai or Hastagre (hands)

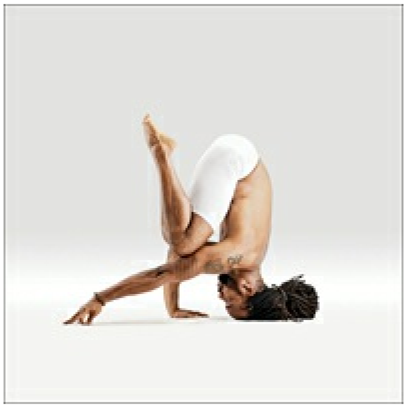

Headstand 6

Shirshasana 6

(sheer-SHAHS-uh-nuh)

Also Known As: Hands Free Headstand (Mukta Hasta Shirshasana)
Pose Type: inversion
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

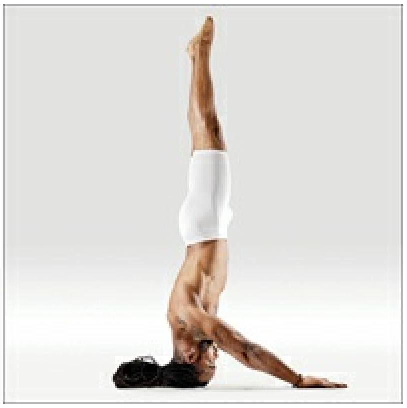

Upward Staff Pose in Headstand 6

Urdhva Dandasana in Shirshasana 6

(OORD-vuh duhn-DAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Modification: on the fingertips
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

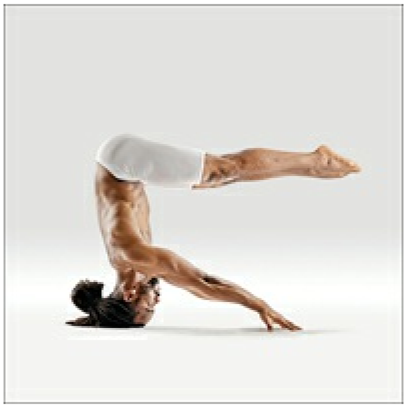

HEADSTAND 7 ARM POSITION: VARIOUS ARM POSITIONS BASED OFF HEADSTAND 7 & VARIOUS LEG POSITIONS

Headstand 7A

Shirshasana 7A

(sheer-SHAHS-uh-nuh)

Also Known As: Spread Hands Headstand (Prasarita Hasta Shirshasana), Hands Free Headstand C (Mukta Hasta Shirshasana C)
Pose Type: inversion
Drishti Point: Nasagrai or Nasagre (nose)

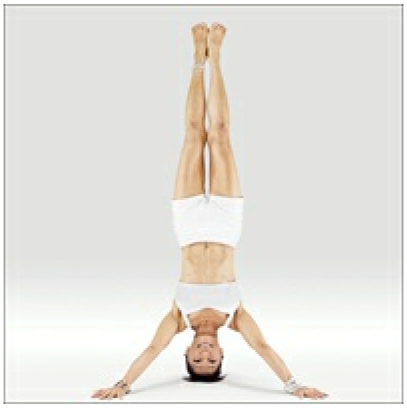

Bound Angle Pose in Headstand 7B

Baddha Konasana in Shirshasana 7B

(BUH-duh ko-NAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Also Known As: Bound Angle Pose in Free Hands Headstand (Baddha Konasana in Mukta Hasta Shirshasana)

Pose Type: inversion

Drishti Point: Nasagrai or Nasagre (nose)

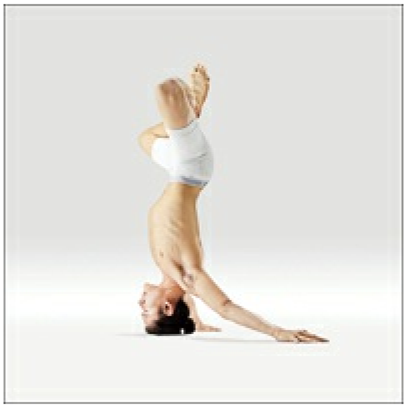

Leg Position of the Pose Dedicated to Garuda in Uneven Headstand (Fusion of Headstand 5 and Headstand 7 Arm Positions)

Pada Garudasana in Vishama Shirshasana 5 & 7A

(PUH-duh guh-ru-DAHS-uh-nuh in VISH-uh-muh sheer-SHAHS-uh-nuh)

Pose Type: inversion

Drishti Point: Nasagrai or Nasagre (nose)

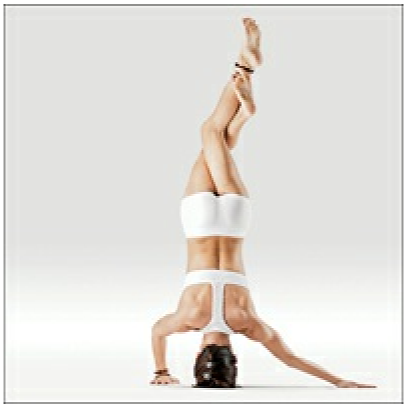

Upward Lotus Pose in Headstand 7B

Urdhva Padmasana in Shirshasana 7B

(OORD-vuh puhd-MAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Also Known As: Supported Lotus Headstand Pose (Salamba Padma Shirshasana), Upward Lotus Pose in Spread Hands Headstand (Urdhva Padmasana in Prasarita Hasta Shirshasana), Upward Lotus in Hands Free Headstand (Urdhva Padmasana in Mukta Hasta Shirshasana)

Modification: 1. neutral spine
2. backbend

Pose Type: 1. inversion
2. inversion, backbend

Drishti Point: Nasagrai or Nasagre (nose)

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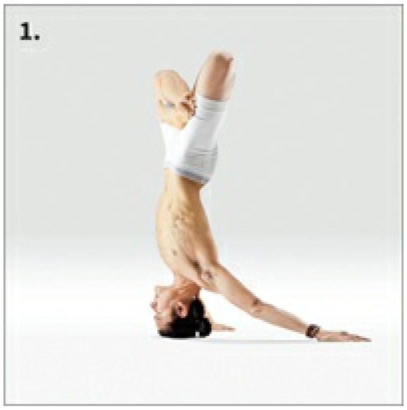

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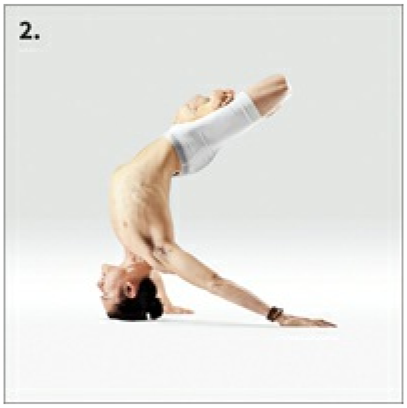

2.

HEADSTAND 8 & 5 ARM POSITIONS: LEG STRAIGHT OUT TO THE SIDE

Leg to the Side Revolved Uneven Headstand (Fusion of Headstand 5 and Headstand 8 Arm Positions)

Parshva Pada Parivritta Vishama Shirshasana 5 & 8

(PAHRSH-vuh PUH-duh puh-ri-VRIT-tuh VISH-uh-muh sheer-SHAHS-uh-nuh)

Modification: Side 1: arm bent at 90 degrees, palm flat on the floor, knee resting on the opposite elbow
Side 2: arm bent at 90 degrees, fingertips to the floor, leg straight out to the side

Pose Type: inversion, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

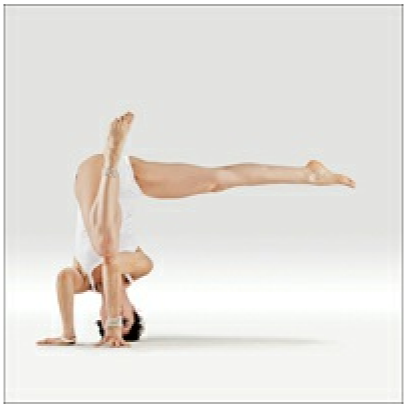

Leg to the Side One Hand Headstand 5

Parshva Pada Eka Hasta Shirshasana 5

(PAHRSH-vuh PUH-duh EY-kuh HUH-stuh sheer-SHAHS-uh-nuh)

Modification: Side 1: arm bent at 90 degrees, palm flat on the floor, knee resting on the same elbow
Side 2: arm straight, grabbing onto the shin of the leg, leg straight out to the side
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

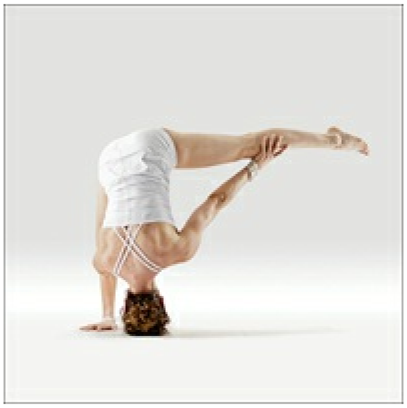

Leg to the Side Revolved One Hand Headstand 5

Parshva Pada Parivritta Eka Hasta Shirshasana 5

(PAHRSH-vuh PUH-duh puh-ri-VRIT-tuh EY-kuh HUH-stuh sheer-SHAHS-uh-nuh)

Modification: Side 1: arm bent at 90 degrees, palm flat to the floor, leg straight out to the side
Side 2: arm straight up to the sky, knee resting on the opposite tricep
Pose Type: inversion, forward bend, twist

Drishti Point: Hastagrai or Hastagre (hands), Nasagrai or Nasagre (nose)

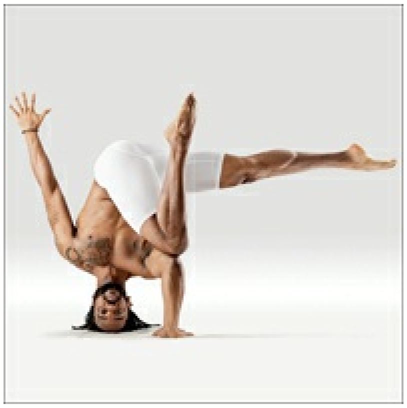

Leg to the Side Revolved One Hand Headstand 8

Parshva Pada Parivritta Eka Hasta Shirshasana 8

(PAHRSH-vuh PUH-duh puh-ri-VRIT-tuh EY-kuh HUH-stuh sheer-SHAHS-uh-nuh)

Modification: Side 1: arm bent at 90 degrees, fingertips to the floor, leg straight out to the side
Side 2: arm straight out to the side, knee resting on the opposite tricep
Pose Type: inversion, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands), Nasagrai or Nasagre (nose)

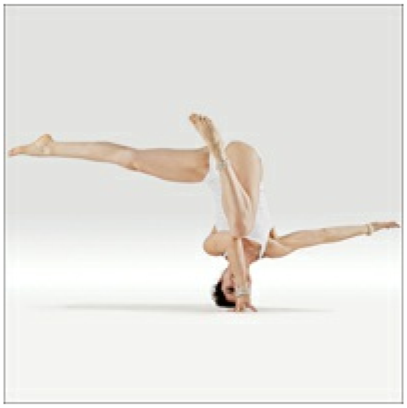

HEADSTAND 8 ARM POSITION: VARIOUS LEG POSITIONS

Feet Spread Intense Stretch Pose in Headstand 8

Prasarita Padottanasana in Shirshasana 8

(pruh-SAH-ri-tuh puh-do-tahn-AHS-uh-nuh in sheer-SHAHS-uh-nuh)

Also Known As: Feet Spread Full Forward Bend in Headstand 8
Modification: fingertips on the floor

Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

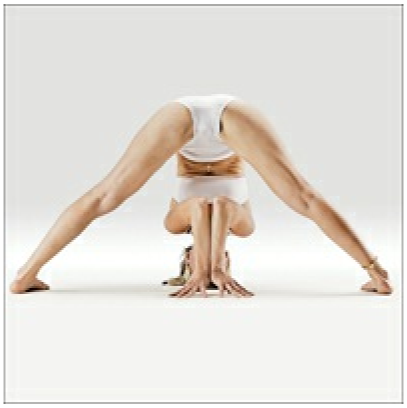

Revolved Leg Position of One-Legged King Pigeon 1 Version B in Headstand 8

Parivritta Pada Eka Pada Raja Kapotasana 1 B in Shirshasana 8

(puh-ri-VRIT-tuh PUH-duh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh in sheer-SHAHS-uh-nuh)
Modification: palms flat on the floor
Pose Type: inversion, forward bend, twist
Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

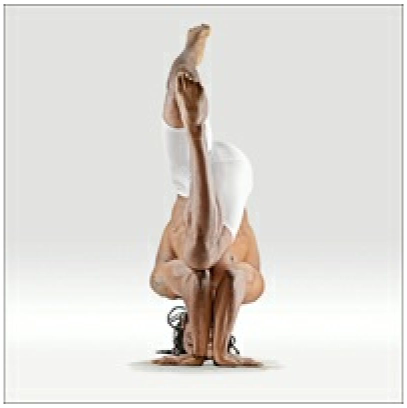

Headstand 8

Shirshasana 8

(sheer-SHAHS-uh-nuh)
Modification: knees resting on the triceps, ankles crossed
1. hands apart, elbows touching, fingertips to the floor
2. hands together, elbows together, palms flat on the floor

Pose Type: inversion, forward bend

Drishti Point: Nasagrai or Nasagre (nose), Hastagrai or Hastagre (hands)

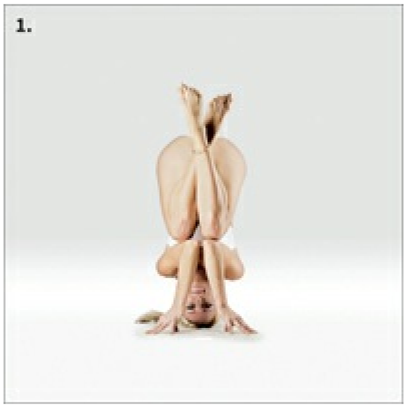
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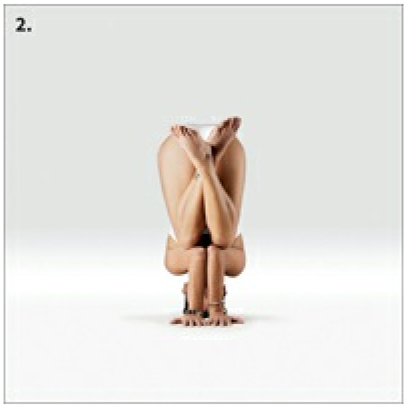
2.

HEADSTAND 2 ARM POSITION: LOTUS

Upward Lotus Pose in Headstand 2

Urdhva Padmasana in Shirshasana 2

(OORD-vuh puhd-MAHS-uh-nuh in sheer-SHAHS-uh-nuh)

Also Known As: Upward Lotus in Hands Bound Headstand (Urdhva Padmasana in Baddha Hasta Shirshasana)

Pose Type: inversion

Drishti Point: Nasagrai or Nasagre (nose)

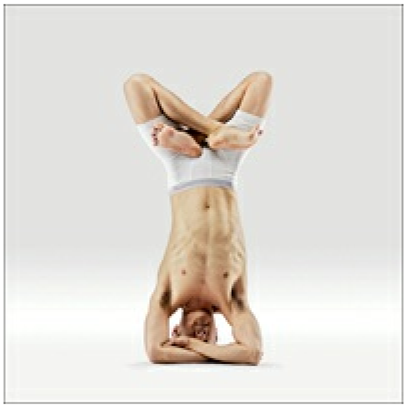

SHOULDERSTAND: BOTH LEGS STRAIGHT—DIFFERENT ARM POSITIONS

Inverted Pose Dedicated to Mythological Khimi Karani Pond

Viparita Khimi Karanyasana

(vi-puh-REE-tuh kuh-HEE-mee kuh-ruh-NEE-uhs-uh-nuh)

Also Known As: Inverted Lake Seal (Viparita Karani Mudra), Half Whole Body Pose (Ardha Sarvangasana)
Pose Type: inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

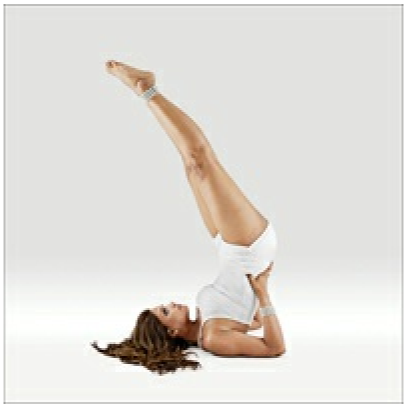

Supported Whole Body Pose

Salamba Sarvangasana

(SAH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Pose Type: inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

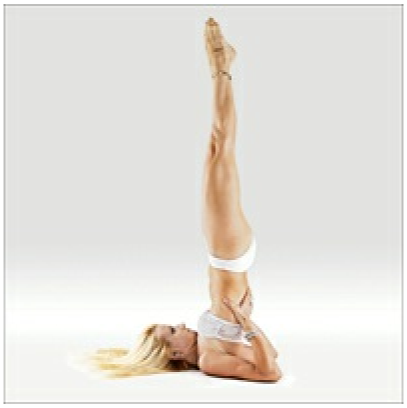

Hands Bound Supported Whole Body Pose

Baddha Hasta Salamba Sarvangasana

(BUH-duh HUH-stuh SAH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Pose Type: inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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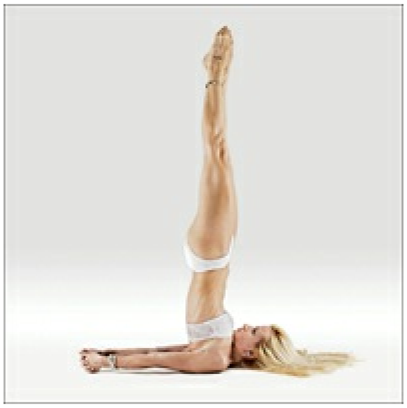

Unsupported Whole Body Pose

Niralamba Sarvangasana

(nir-AH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Pose Type: inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nabhi, Nabhicakre, or Nabi Chakra (belly button)
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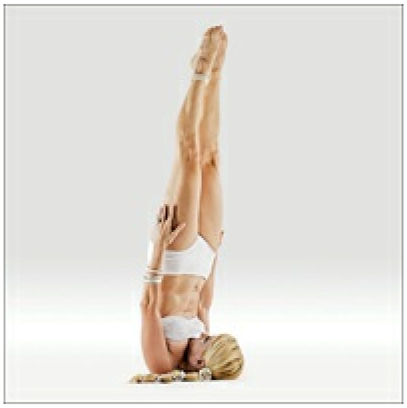

SHOULDERSTAND: ONE LEG UP, ONE LEG DOWN

Leg Contraction Pose in Supported Whole Body Pose

Pada Akunchanasana in Salamba Sarvangasana

(PUH-duh uh-kunch-AHS-uh-nuh in SAH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Modification: one knee bent toward the forehead
Pose Type: inversion, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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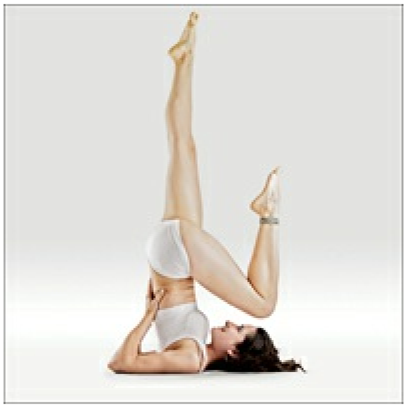

One-Legged Supported Whole Body Pose

Eka Pada Salamba Sarvangasana

(EY-kuh PUH-duh SAH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: One-Legged Plow Pose (Eka Pada Halasana), Shoulderstand
Pose Type: inversion, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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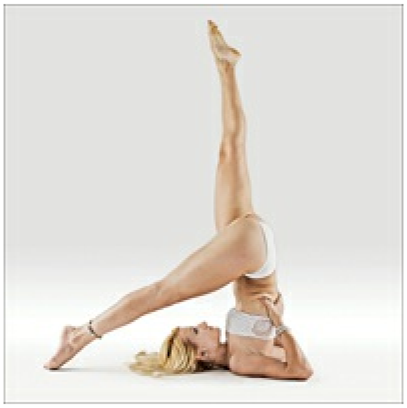

One-Legged Sideways Supported Whole Body Pose

Parshva Eka Pada Salamba Sarvangasana

(PAHRSH-vuh EY-kuh PUH-duh SAH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Pose Type: inversion, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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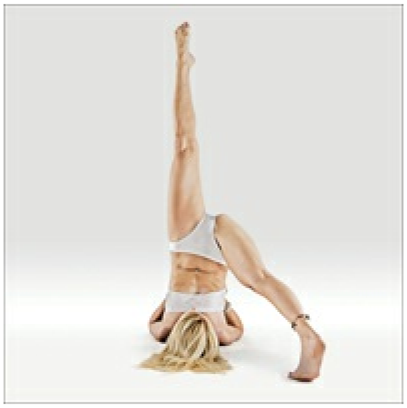

SHOULDERSTAND: ONE LEG UP, ONE LEG DOWN—DIFFERENT ARM POSITIONS

One-Legged Unsupported Whole Body Pose

Eka Pada Niralamba Sarvangasana

(EY-kuh PUH-duh nir-AH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Modification: both hands to the calf of the bottom leg
Pose Type: inversion, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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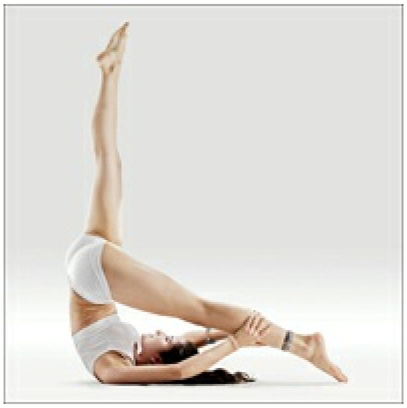

Extended Hand to Big Toe Pose in Unsupported Whole Body Pose

Utthita Hasta Padangushtasana in Niralamba Sarvangasana

(UT-ti-tuh HUH-stuh puhd-ahng-goosh-tahn-AHS-uh-nuh in nir-AH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Pose Type: inversion, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

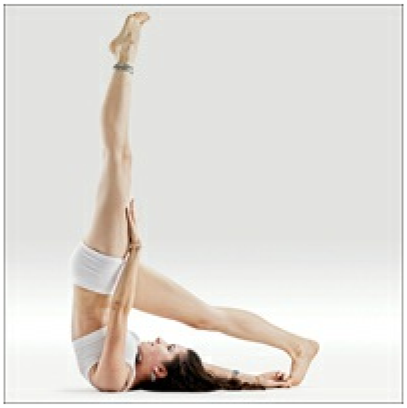

One-Legged Unsupported Whole Body Pose

Eka Pada Niralamba Sarvangasana

(EY-kuh PUH-duh nir-AH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Modification: both arms along the sides of the torso
Pose Type: inversion, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

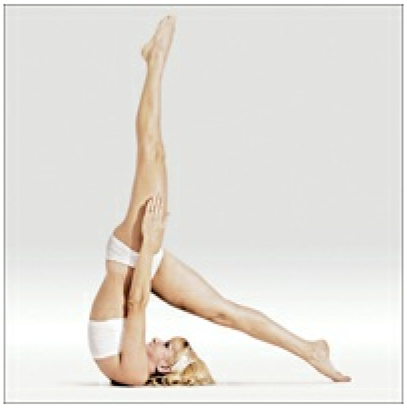

Half Bound Inverted Tortoise Pose

Ardha Baddha Viparita Kurmasana

(UHR-duh BUH-duh vi-puh-REE-tuh koor-MAHS-uh-nuh)

Pose Type: inversion, forward bend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

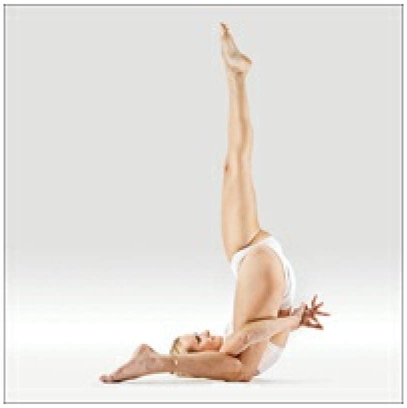

SHOULDERSTAND: GARUDA LEGS

Leg Position of the Pose Dedicated to Garuda in Hands Bound Supported Whole Body Pose

Pada Garudasana in Baddha Hasta Salamba Sarvangasana

(PUH-duh guh-ru-DAHS-uh-nuh in BUH-duh HUH-stuh SAH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Modification: knees toward the forehead
Pose Type: inversion, forward bend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

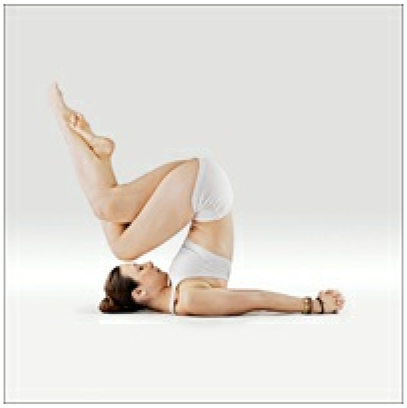

Leg Position of the Pose Dedicated to Garuda in Hands Bound Supported Whole Body Pose

Pada Garudasana in Baddha Hasta Salamba Sarvangasana

(PUH-duh guh-ru-DAHS-uh-nuh in BUH-duh HUH-stuh SAH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand

Modification: legs extended toward the sky

Pose Type: inversion, forward bend

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

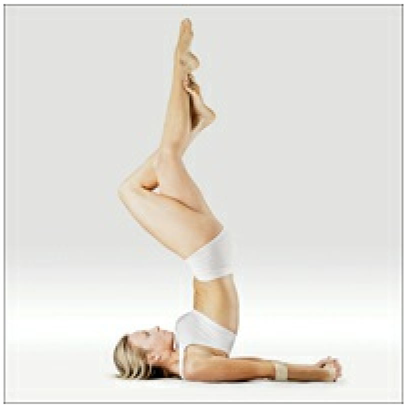

Leg Position of the Pose Dedicated to Garuda in Supported Whole Body Pose

Pada Garudasana in Salamba Sarvangasana

(PUH-duh guh-ru-DAHS-uh-nuh in SAH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand

Pose Type: inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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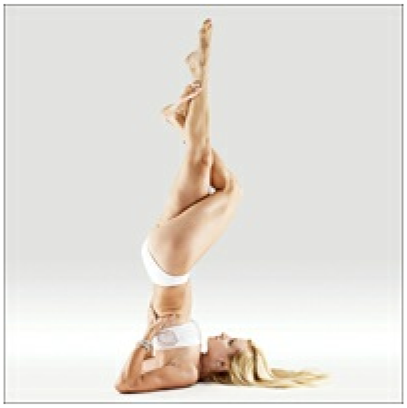

SHOULDERSTAND: BOUND ANGLE & LOTUS

Bound Angle Pose in Whole Body Pose

Baddha Konasana in Sarvangasana

(BUH-duh ko-NAHS-uh-nuh in suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand

Pose Type: inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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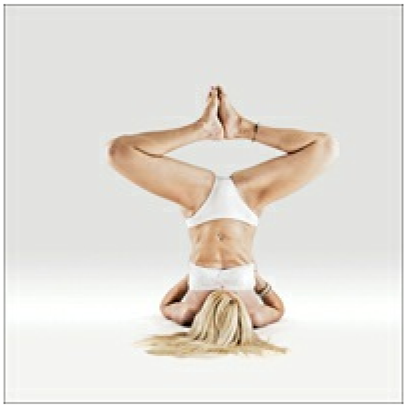

Upward Lotus in Whole Body Pose

Urdhva Padmasana in Salamba Sarvangasana

(OORD-vuh puhd-MAHS-uh-nuh in SAH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand

Pose Type: inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

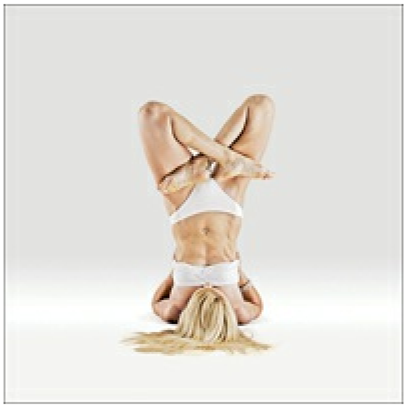

Upward Lotus in Whole Body Pose

Urdhva Padmasana in Salamba Sarvangasana

(OORD-vuh puhd-MAHS-uh-nuh in SAH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Modification: arms straight to the back, palms on the floor
Pose Type: inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

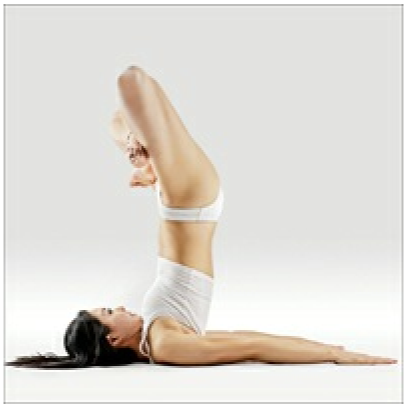

Upward Lotus in Unsupported Whole Body Pose

Urdhva Padmasana in Niralamba Sarvangasana

(OORD-vuh puhd-MAHS-uh-nuh in nir-AH-luhm-buh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Pose Type: inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

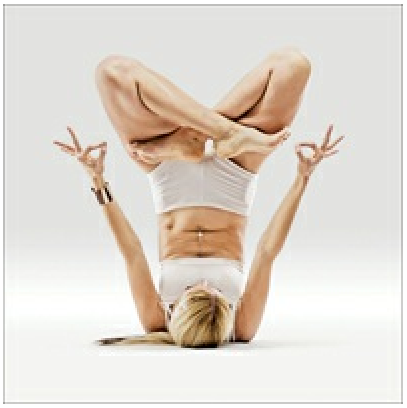

Inverted Ear Pressure Raised Up Lotus Pose

Viparita Karnapida Urdhva Padmasana

(vi-puh-REE-tuh kuhr-nah-PEED-uh OORD-vuh puhd-MAHS-uh-nuh)

Pose Type: inversion
Drishti Point: Nasagrai or Nasagre (nose)

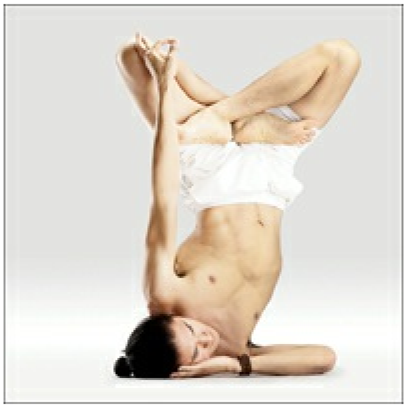

SHOULDERSTAND: LOTUS—BACKBEND & FORWARD BEND

Intense Lotus Peacock Prep.

Uttana Padma Mayurasana Prep.

(ut-TAHN-uh PUHD-muh muh-yoor-AHS-uh-nuh)

Also Known As: Intense Front Body Stretching and Rejuvenating Lotus Pose (Purvottana Padma Sarvangasana)
Modification: knees off the floor, fists to the lower back
Pose Type: inversion, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

Upward Lotus Pose in Whole Body Pose

Urdhva Padmasana in Sarvangasana

(OORD-vuh puhd-MAHS-uh-nuh in suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulderstand
Modification: 1. thighs parallel to the floor, elbows bent
2. arms straight
Pose Type: inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

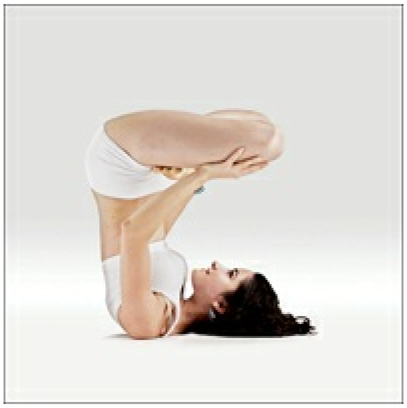

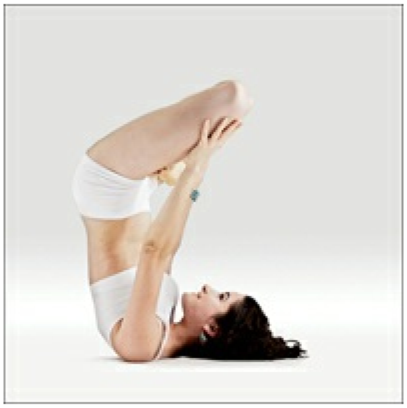

Embryo Pose in Whole Body Pose

Pindasana in Sarvangasana

(pin-DAHS-uh-nuh in suhr-vuhng-GAHS-uh-nuh)

Also Known As: Inverted Embryo Pose (Viparita Pindasana), Embryo Pose in Plow Pose (Pindasana in Halasana), Shoulderstand

Pose Type: inversion, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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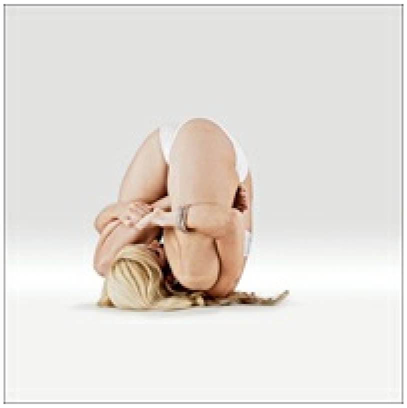

SHOULDERSTAND: LOTUS—KNEES ON THE FLOOR

Lotus Pose in Plow Pose

Padmasana in Halasana

(puhd-MAHS-uh-nuh in hul-AHS-uh-nuh)

Pose Type: inversion, forward bend

Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

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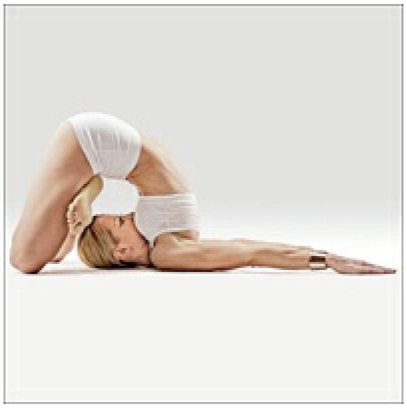

Sideways Embryo Pose in Whole Body Pose

Parshva Pindasana in Sarvangasana

(PAHRSH-vuh pin-DAHS-uh-nuh in suhr-vuhng-GAHS-uh-nuh)

Also Known As: Side Embryo Pose (Parshva Pindasana), Embryo Pose in Plow Pose (Pindasana in Halasana), Shoulderstand

Pose Type: inversion, forward bend, twist

Drishti Point: Nasagrai or Nasagre (nose)

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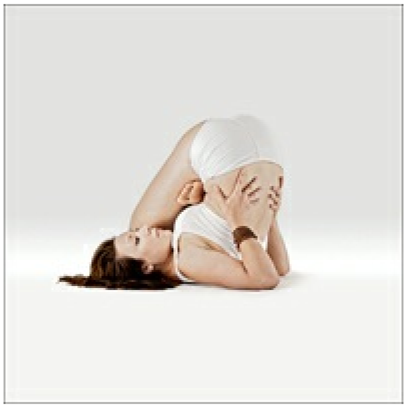

SHOULDERSTAND: EAR PRESSURE POSE—FEET ON THE FLOOR

Inverted Tortoise Pose

Viparita Kurmasana

(vi-puh-REE-tuh koor-MAHS-uh-nuh)

Modification: 1. grabbing onto the feet

2. palms to the floor, fingertips facing to the back

Pose Type: inversion, forward bend

Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

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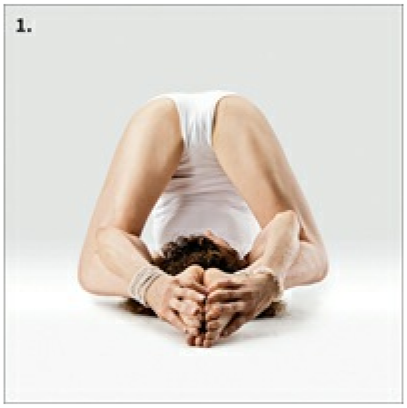

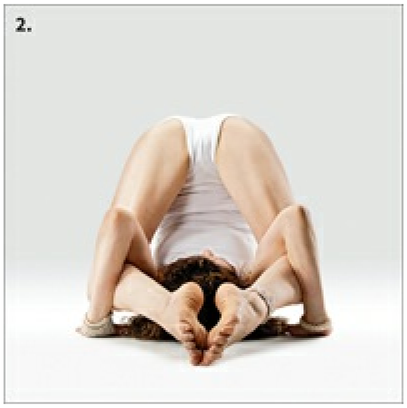

Bound Inverted Tortoise Pose

Baddha Viparita Kurmasana

(BUH-duh vi-puh-REE-tuh koor-MAHS-uh-nuh)

Pose Type: inversion, forward bend, binding

Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

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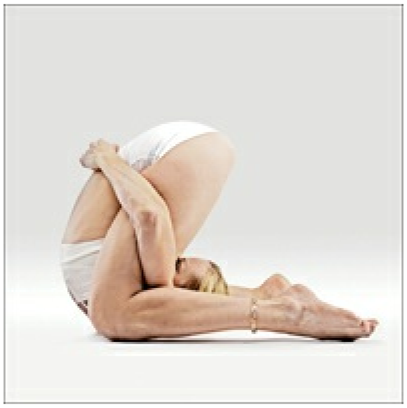

SHOULDERSTAND: EAR PRESSURE POSE—FEET OFF THE FLOOR

Ear Pressure Pose Prep.

Karnapidasana Prep.

(kuhr-nah-pee-DAHS-uh-nuh)

Modification: knees to the temples, palms to the lower back

Pose Type: inversion, forward bend

Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

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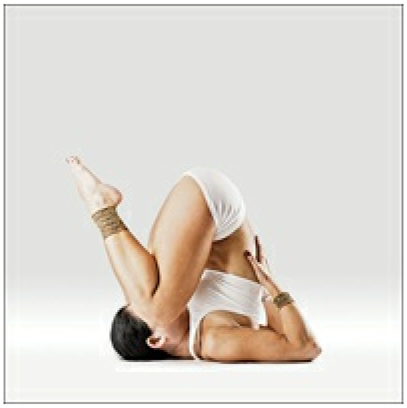

Ear Pressure Pose Prep.

Karnapidasana Prep.

(kuhr-nah-pee-DAHS-uh-nuh)

Modification: one hand to the lower back; other arm up over the head, elbow bent, fingertips to the floor; both knees bent, one knee to the elbow of the front arm, heel of the other foot toward the sitting bone
Pose Type: inversion, forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

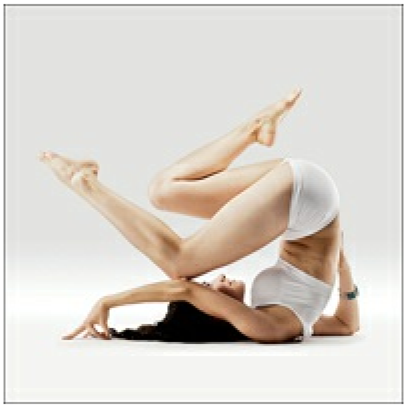

Ear Pressure Pose

Karnapidasana

(kuhr-nah-pee-DAHS-uh-nuh)

Modification: both knees bent, feet off the floor; arms straight behind the back and off the floor, palms up
Pose Type: inversion, forward bend, balance
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

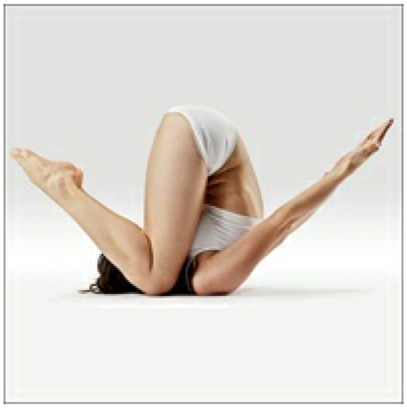

SHOULDERSTAND: EAR PRESSURE POSE—HEELS TO THE SITTING BONES, GRABBING ONTO THE SHINS

Ear Pressure Pose

Karnapidasana

(kuhr-nah-pee-DAHS-uh-nuh)

Modification: both heels to the sitting bones, grabbing onto the ankles, elbows bent
Pose Type: inversion, forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

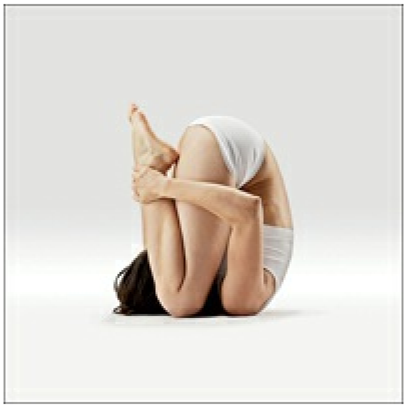

SHOULDERSTAND: EAR PRESSURE POSE—KNEES ON THE FLOOR—DIFFERENT ARM POSITIONS

Ear Pressure Pose

Karnapidasana

(kuhr-nah-pee-DAHS-uh-nuh)

Modification: palms to the lower back
Pose Type: inversion, forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

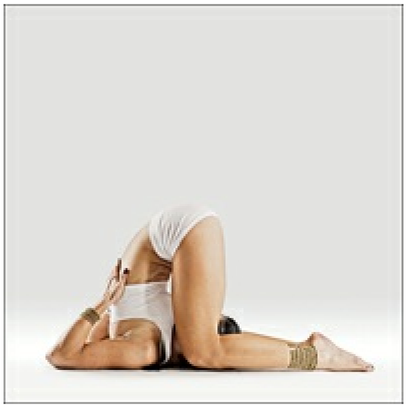

Sideways Ear Pressure Pose

Parshva Karnapidasana

(PAHRSH-vuh kuhr-nah-pee-DAHS-uh-nuh)

Also Known As: Side Contraction Pose (Parshva Akunchanasana)
Modification: palms to the lower back
Pose Type: inversion, forward bend, twist
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

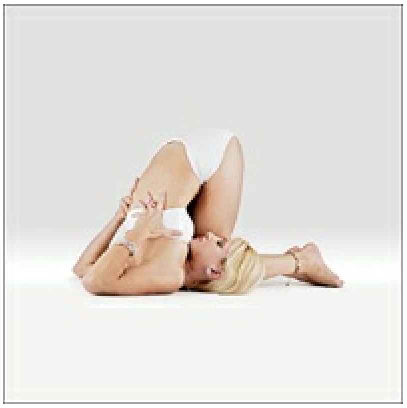

Hands Bound Ear Pressure Pose

Baddha Hasta Karnapidasana

(BUH-duh HUH-stuh kuhr-nah-pee-DAHS-uh-nuh)

Modification: fingers interlocked
Pose Type: inversion, forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

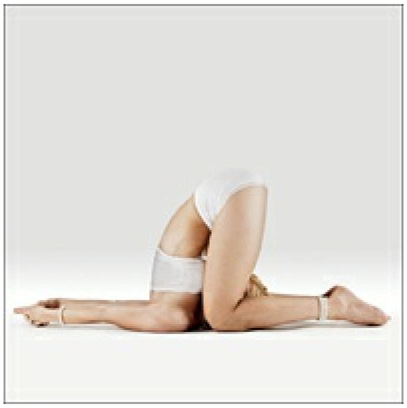

Shivalinga Pose

Lingasana

(ling-GAHS-uh-nuh)

Also Known As: Ear Pressure Pose (Karnapidasana)
Pose Type: inversion, forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

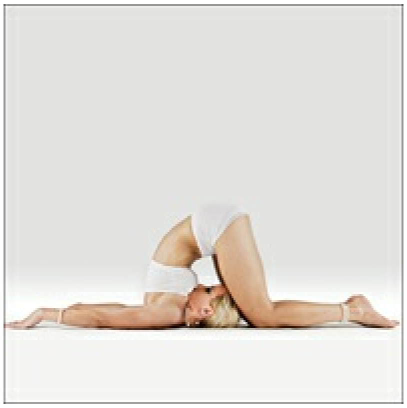

Bound Hands Shivalinga Pose

Baddha Hasta Lingasana

(BUH-duh HUH-stuh ling-GAHS-uh-nuh)

Also Known As: Ear Pressure Pose (Karna Pidasana)
Pose Type: inversion, forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

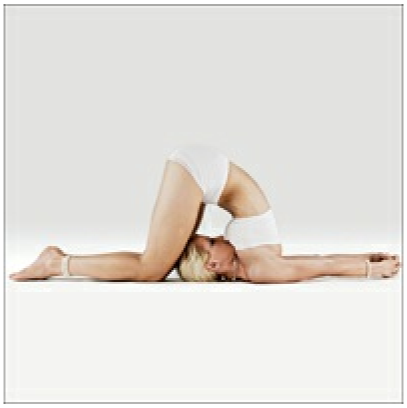

Ear Pressure Pose

Karnapidasana

(kuhr-nah-pee-DAHS-uh-nuh)

Modification: grabbing onto the heels
Pose Type: inversion, forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

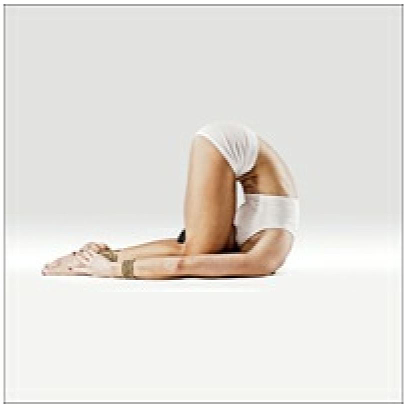

PLOW POSE: LEGS STRAIGHT AND TOGETHER—DIFFERENT ARM POSITIONS

Plow Pose

Halasana

(huh-LAHS-uh-nuh)

Modification: palms to the lower back, toes pointed to the front
Pose Type: inversion, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

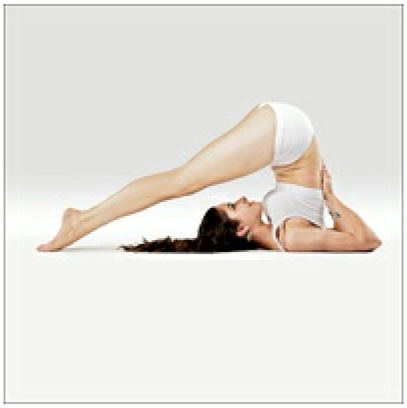

Plow Pose

Halasana

(huh-LAHS-uh-nuh)

Modification: fingers to the toes, palms up
Pose Type: inversion, forward bend
Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)
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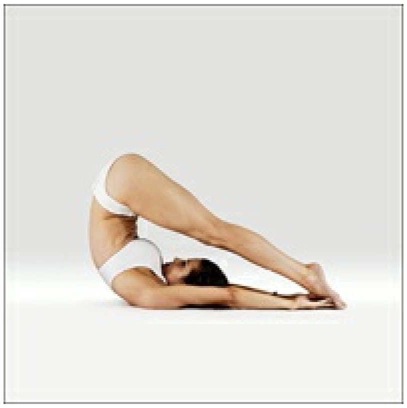

Plow Pose

Halasana

(huh-LAHS-uh-nuh)

Modification: arms straight to the back, palms on the floor
Pose Type: inversion, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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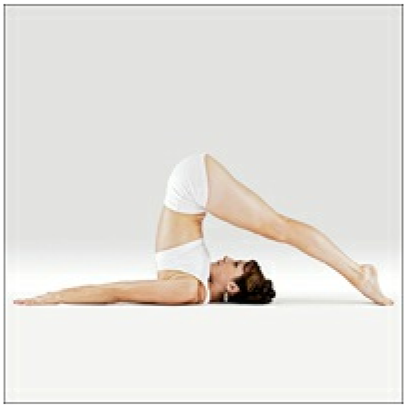

Bound Hands Plow Pose

Baddha Hasta Halasana

(BUH-duh HUH-stuh huh-LAHS-uh-nuh)

Pose Type: inversion, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

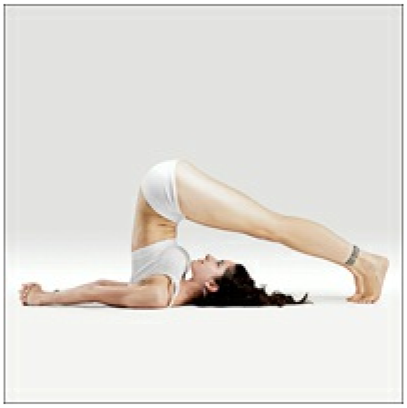

PLOW POSE: LEGS TO THE SIDE & LEGS WIDE APART

Sideways Plow Pose

Parshva Halasana

(PAHRSH-vuh huh-LAHS-uh-nuh)

Modification: palms to the lower back

Pose Type: inversion, forward bend, twist

Drishti Point: Nabhi, Nabhicakre, or Nabi Chakra (belly button)

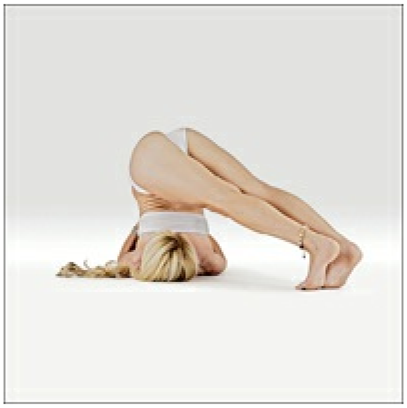

Hands Bound Feet Spread Wide Intense Stretch Pose in Plow Pose

Baddha Hasta Prasarita Padottanasana in Halasana

(BUH-duh HUH-stuh pruh-SAH-ri-tuh puh-do-tahn-AHS-uh-nuh in huh-LAHS-uh-nuh)

Also Known As: Hands Bound Feet Spread Wide Full Forward Bend in Plow Pose
Pose Type: inversion, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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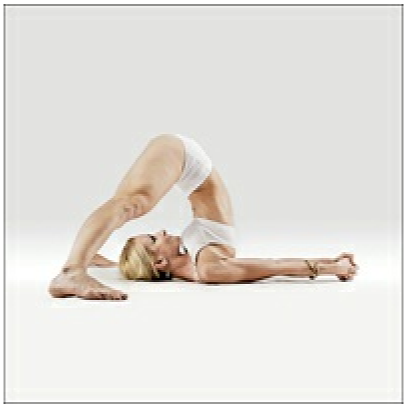

PLOW POSE: ONE LEG STRAIGHT, ONE LEG BENT

One-Legged Elbow to Knee Plow Pose

Eka Pada Kurpara Janu Halasana

(EY-kuh PUH-duh kuhr-PAH-ruh JAH-nu hul-AHS-uh-nuh)

Modification: one hand to the lower back; other arm up over the head, elbow bent, fingertips to the floor; knees together, one leg straight; knee to the elbow, other knee bent, heel to the sitting bone
Pose Type: inversion, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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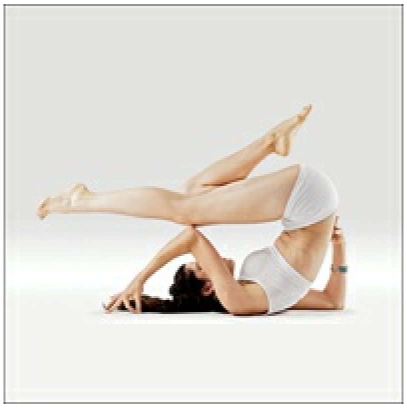

Reclined Upward Foot Thunderbolt Pose

Supta Urdhva Pada Vajrasana

(SUP-tuh OORD-vuh PUH-duh vuhj-RAHS-uh-nuh)

Also Known As: Half Bound Lotus Pose in Whole Body Pose (Ardha Baddha Padmasana in Sarvangasana), Shoulderstand

Modification: 1. front side view

2. back side view

Pose Type: inversion, forward bend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

1.

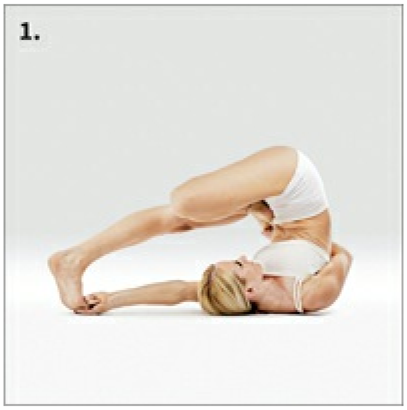

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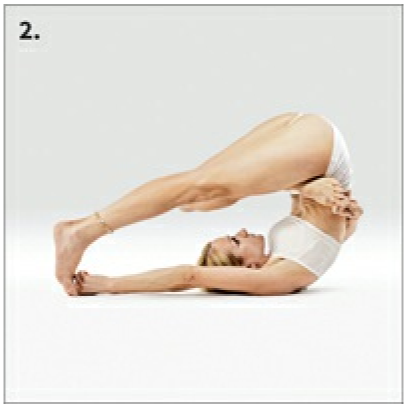

Prone Poses

STOMACH ON THE FLOOR

CHEST FACING THE FLOOR

LOCUST POSE

SPHINX POSE

COBRA POSE

KING PIGEON POSE

UPWARD DOG POSE

COBRA POSE 2

BOW POSE

HALF LOTUS AND LOTUS BACKBENDS

SAGE GHERANDA’S POSE

BACKBENDS

CHIN AND CHEST ON THE FLOOR

CHEST AND KNEES ON THE FLOOR

Pose Dedicated to Makara—Prone Modification

Makarasana

(muh-kuh-RAHS-uh-nuh)

Also Known As: Crocodile Pose
Modification: whole body flat on the floor; arms straight out in front, palms together
Pose Type: prone
Drishti Point: Nasagrai or Nasagre (nose)

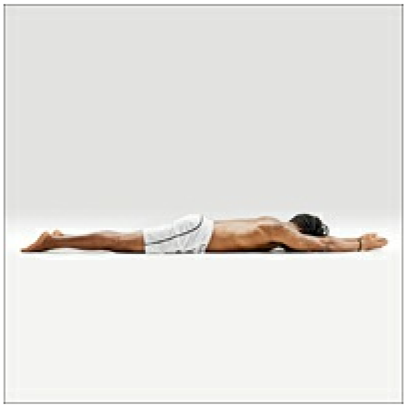

Side Corpse Pose

Parshva Shavasana

(PAHRSH-vuh shuh-VAHS-uh-nuh)

Pose Type: prone
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

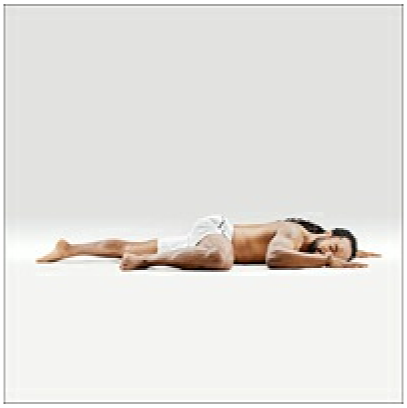

Downward Facing One Leg to the Side Pose

Adho Mukha Parshva Eka Padasana

(uh-DO MUK-uh PAHRSH-vuh EY-kuh puh-DAHS-uh-nuh)

Pose Type: prone

Drishti Point: Nasagrai or Nasagre (nose)

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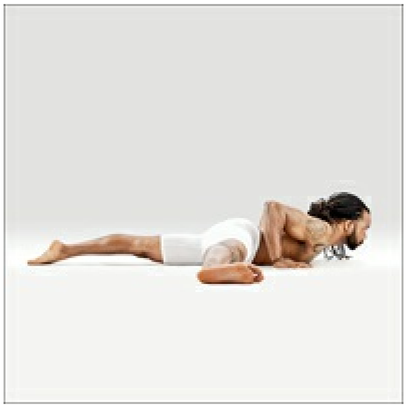

STOMACH ON THE FLOOR: ONE LEG STRAIGHT, ONE KNEE BENT—FOOT TO THE FLOOR ON THE SIDE

Intense Stretch Slithering Lizard Lunge Pose

Utthana Sarpa Godhasana

(ut-TAHN-uh SUHR-puh go-DAHS-uh-nuh)

Also Known As: Extended Lizard Tail Lunge Pose (Uttana Pristhasana)

Modification: foot to the elbow crease

Pose Type: prone

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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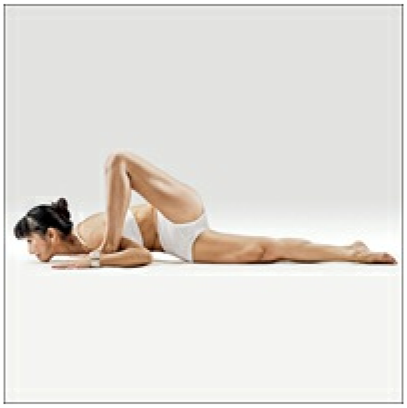

Intense Stretch Slithering Lizard Lunge Pose

Utthan Sarpa Godhasana

(ut-TAHN-uh SUHR-puh go-DAHS-uh-nuh)

Also Known As: Extended Lizard Tail Lunge Pose (Uttana Pristhasana)

Modification: foot to the outside of the rib cage, arm binds around the leg

Pose Type: prone

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

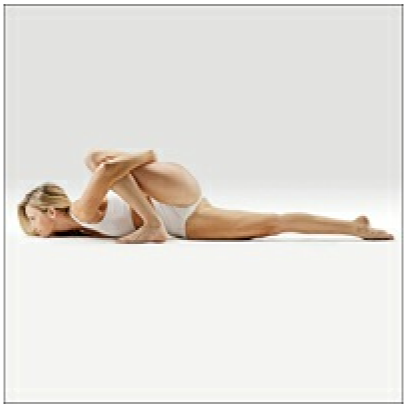

STOMACH ON THE FLOOR: FROG POSE & LOTUS POSE

Frog Pose

Mandukasana

(muhn-doo-KAHS-uh-nuh)

Also Known As: Thavaliasana

Pose Type: prone

Drishti Point: Nasagrai or Nasagre (nose)

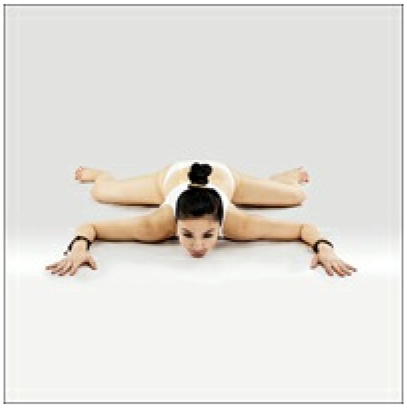

Lotus Staff Surrender Salutation Pose

Padma Danda Namaskarasana

(PUHD-muh DUHN-duh nuh-muhs-kahr-AHS-uh-nuh)

Modification: arms straight in front, palms down to the floor
Pose Type: prone
Drishti Point: Nasagrai or Nasagre (nose)

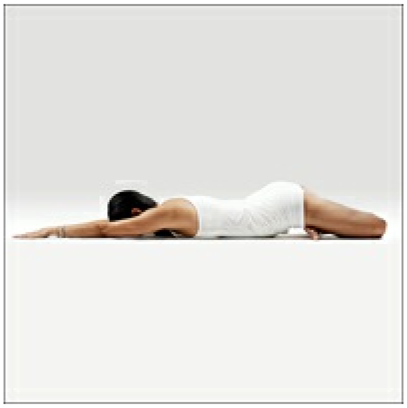

Hidden Lotus Pose

Gupta Padmasana

(GUP-tuh puhd-MAHS-uh-nuh)

Pose Type: prone, mild backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

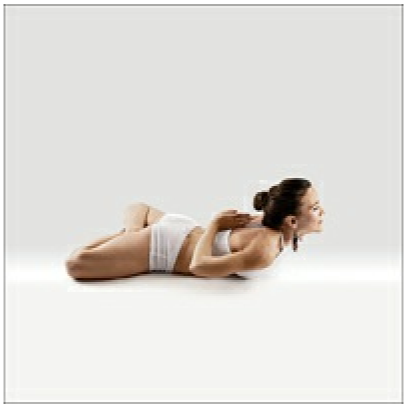

CHEST FACING THE FLOOR: TWISTS

Downward Facing Twisted Stomach Pose

Adho Mukha Jatara Parivartanasana

(uh-DO MUK-uh JAHT-uh-ruh puh-ri-vuhr-tuh-NAHS-uh-nuh)

Modification: knees together, legs bent
Pose Type: prone, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

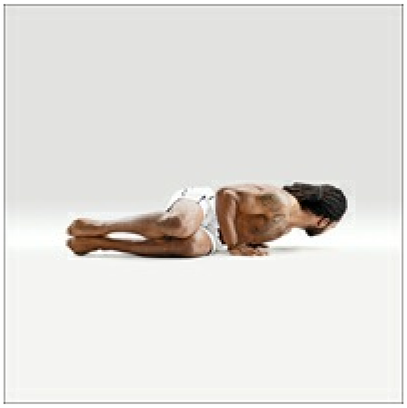

Downward Facing Twisted Stomach Pose

Adho Mukha Jatara Parivartanasana

(uh-DO MUK-uh JAHT-uh-ruh puh-ri-vuhr-tuh-NAHS-uh-nuh)

Modification: top leg straight, bottom knee bent
Pose Type: prone, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

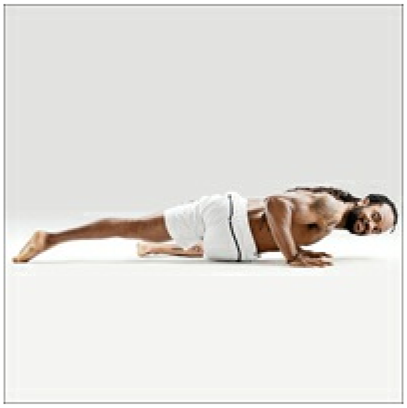

Downward Facing Twisted Stomach Pose

Adho Mukha Jatara Parivartanasana

(uh-DO MUK-uh JAHT-uh-ruh puh-ri-vuhr-tuh-NAHS-uh-nuh)

Modification: legs straight
Pose Type: prone, twist

Drishti Point: Nasagrai or Nasagre (nose)

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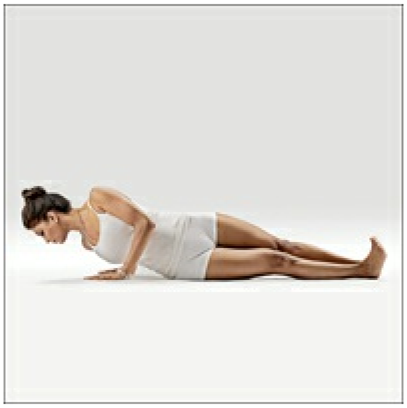

Pose Dedicated to St. Brighid of Kildare

Brighidasana

(bree-gid-AHS-uh-nuh)

Modification: bottom leg crossed under, looking straight ahead
Pose Type: prone, twist
Drishti Point: Nasagrai or Nasagre (nose)

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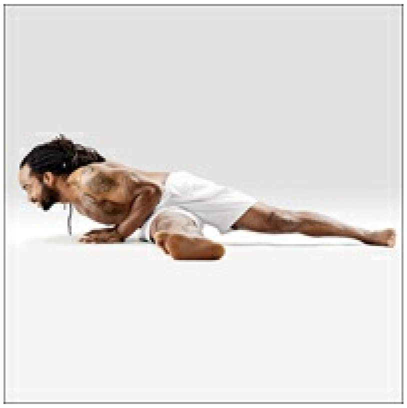

CHEST FACING THE FLOOR: TWISTS—LEGS TO THE SIDE

Pose Dedicated to Sage Koundinya One-Legged Version 1—Prone Modification

Eka Pada Koundinyasana 1

(EY-kuh PUH-duh kown-din-YAHS-uh-nuh)

Modification: one arm straight to the side, bottom knee bent

Pose Type: arm balance, forward bend, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

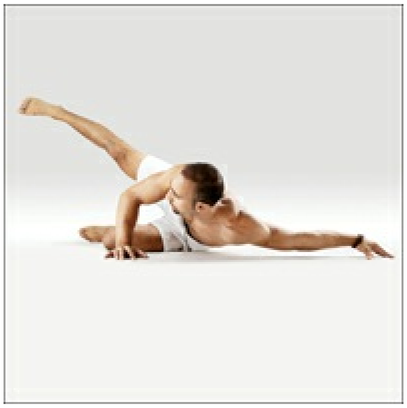

Pose Dedicated to Ashtavakra—Prone Modification

Ashtavakrasana

(uh-shtuh-vuh-KRAHS-uh-nuh)

Also Known As: Eight Angle Pose—Prone Modification
Modification: legs unhooked, bottom knee wrapped around the opposite forearm, top leg straight
Pose Type: arm balance, forward bend, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

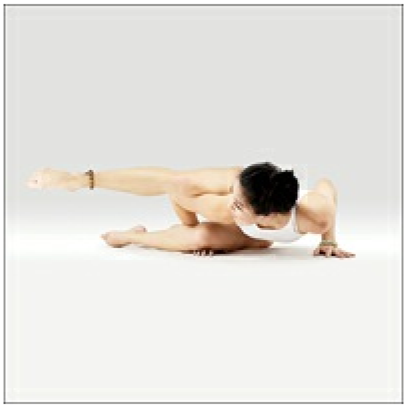

Pose Dedicated to Ashtavakra—Prone Modification

Ashtavakrasana

(uh-shtuh-vuh-KRAHS-uh-nuh)

Also Known As: Eight Angle Pose—Prone Modification
Pose Type: arm balance, forward bend, twist
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

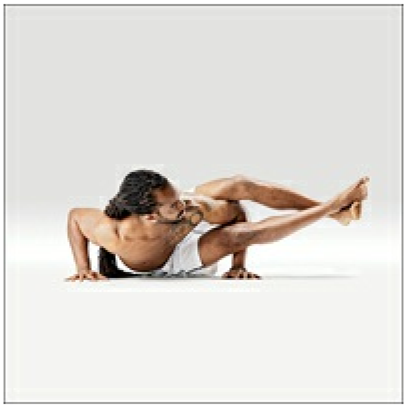

CHEST FACING THE FLOOR: TWIST & VERTICAL SPLITS

Svastika Legs in Downward Facing Twisted Stomach Pose

Pada Svastikasana in Adho Mukha Jatara Parivartanasana

(PUH-duh svuh-sti-KAHS-uh-nuh in uh-DO MUK-uh JAHT-uh-ruh puh-ri-vuhr-tuh-NAHS-uh-nuh)

Modification: one arm straight out in front, palm down to the floor; other elbow bent, temple resting on the forearm of the bent arm

Pose Type: prone, twist

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

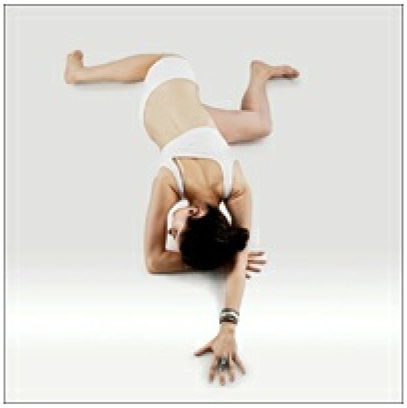

Downward Facing Pose Dedicated to Trivikrama—Prone Modification

Adho Mukha Trivikramasana

(uh-DO MUK-uh tri-vi-kruhm-AHS-uh-nuh)

Pose Type: prone

Drishti Point: Hastagrai or Hastagre (hands)

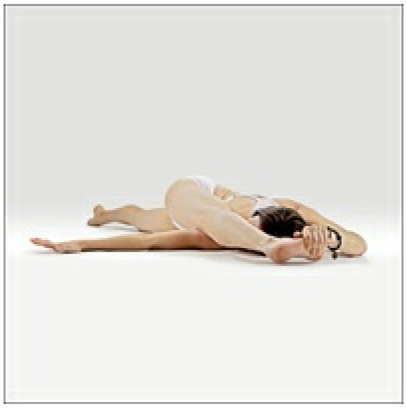

Bound Downward Facing Pose Dedicated to Trivikrama—Prone Modification

Baddha Adho Mukha Trivikramasana

(BUH-duh uh-DO MUK-uh tri-vi-kruhm-AHS-uh-nuh)

Modification: back leg bent—toes pointing to the sky
Pose Type: prone, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

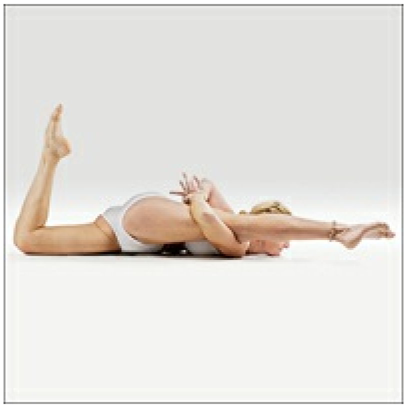

[LOCUST POSE: LEGS ON THE FLOOR, ARMS BEHIND](#)

Cobra Pose 1

Bhujangasana 1

(buj-uhng-GAHS-uh-nuh)

Modification: palms lifted off the floor, elbows bent
Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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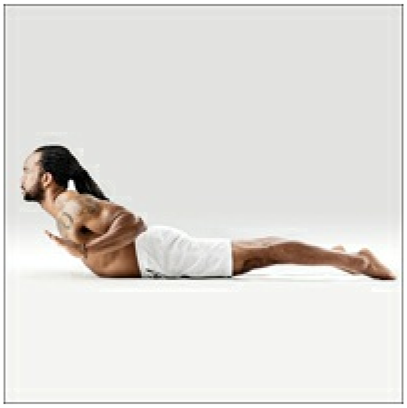

Locust Pose

Shalabhasana

(shuh-luh-BAHS-uh-nuh)

Modification: arms straight, palms facing up by the hips; feet on the floor
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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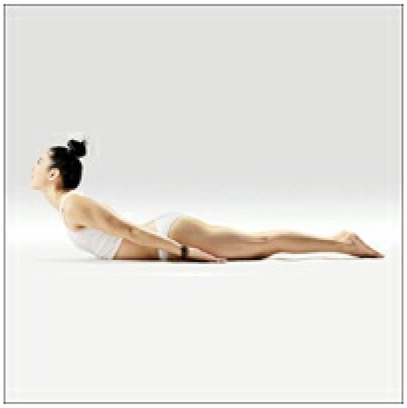

LOCUST POSE: LEGS AND CHEST OFF THE FLOOR—ARMS BEHIND ON THE FLOOR

Locust Pose

Shalabhasana

(shuh-luh-BAHS-uh-nuh)

Also Known As: Locust Pose B (Shalabhasana B)

Modification: palms to the floor by the bottom of the ribs, elbows bent at 90 degrees

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

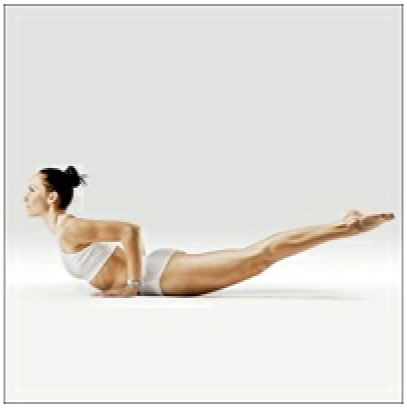

Locust Pose

Shalabhasana

(shuh-luh-BAHS-uh-nuh)

Also Known As: Locust Pose A (Salabhasana A)
Modification: palms to the floor by the hips, arms straight, legs and chest lifted
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

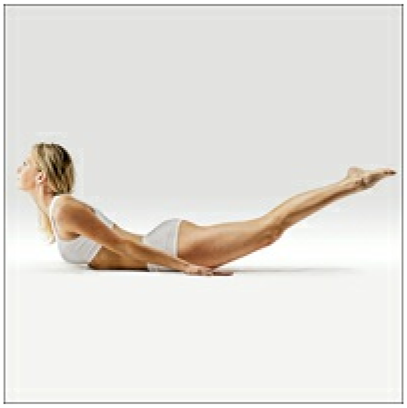

LOCUST POSE: LEGS AND CHEST OFF THE FLOOR—ARMS BEHIND

Fingers to Head Reverse Prayer Locust Pose

Anguli Shirsha Viparita Namaskar Shalabhasana

(UHNG-goo-lee SHEER-shuh vi-puh-REE-tuh nuh-muhs-KAHR shuh-luh-BAHS-uh-nuh)

Also Known As: Back of the Body Prayer Fingers to Head Locust Pose (Paschima Namaskara Anguli Shirsha Shalabhasana)

Modification: feet on the floor
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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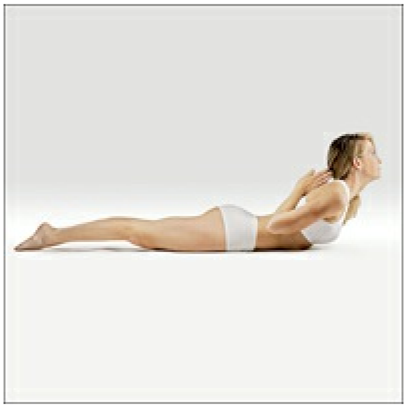

Pose Dedicated to Makara

Makarasana

(muh-kuh-RAHS-uh-nuh)
Also Known As: Crocodile Pose
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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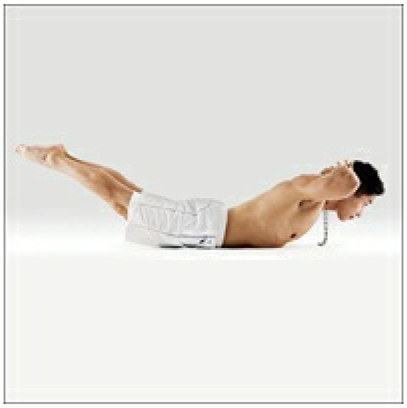

Locust Pose

Shalabhasana

(shuh-luh-BAHS-uh-nuh)
Modification: arms open wide, fingertips pointing to the toes
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

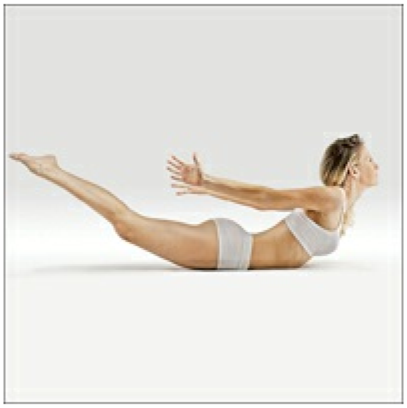

Hands Bound Locust Pose

Baddha Hasta Shalabhasana

(BUH-duh HUH-stuh shuh-luh-BAHS-uh-nuh)

Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

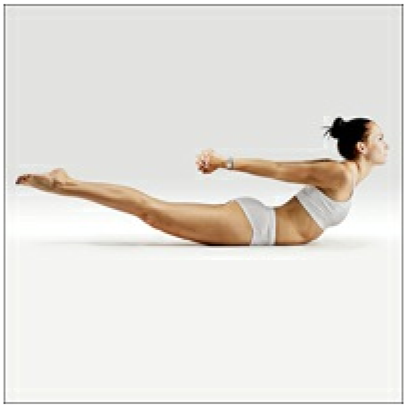

LOCUST POSE: LEGS AND CHEST OFF THE FLOOR—ARMS IN FRONT

Locust Pose

Shalabhasana

(shuh-luh-BAHS-uh-nuh)

Also Known As: Crocodile Pose (Makarasana), Boat Pose (Navasana)
Modification: both arms straight in front, palms facing down
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Angushtamadhye or Angushta Ma Dyai (thumbs)

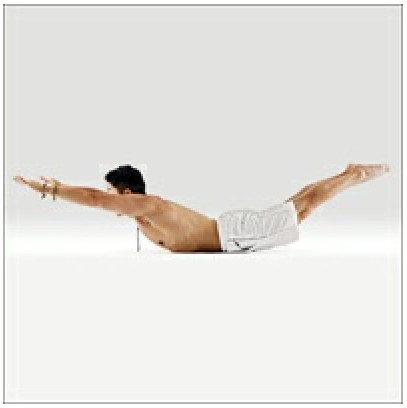

Hand Position of the Pose Dedicated to Garuda in Locust Pose

Hasta Garudasana in Shalabhasana

(HUH-stuh guh-ru-DAHS-uh-nuh in shuh-luh-BAHS-uh-nuh)

Pose Type: prone, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

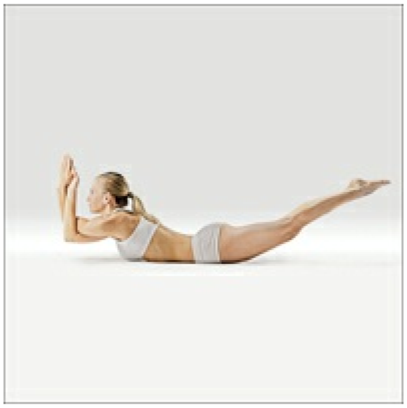

Inverted Locust Pose

Viparita Shalabhasana

(vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Modification: chin to the floor, legs lifted
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

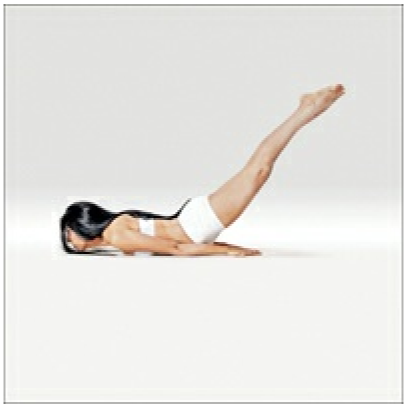

LOCUST POSE: ONE LEG

Half Locust Pose

Ardha Shalabhasana

(UHR-duh shuh-luh-BAHS-uh-nuh)

Modification: hands to the floor by the hips, palms facing up, arms straight

Pose Type: prone, backbend

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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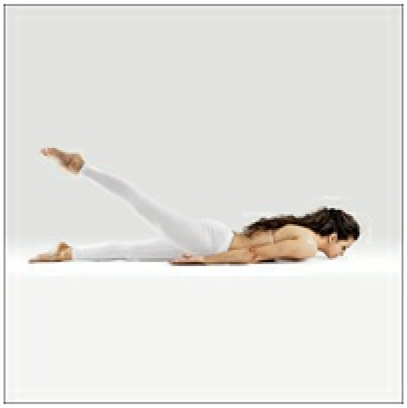

Hand Position of the Pose Dedicated to Garuda in Half Locust Pose

Hasta Garudasana in Ardha Shalabhasana

(HUH-stuh guh-ruh-DAHS-uh-nuh in UHR-duh shuh-luh-BAHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

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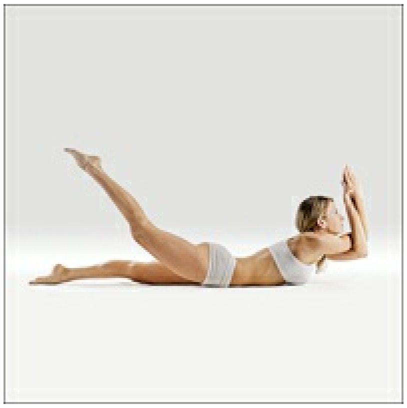

Half Locust Pose

Ardha Shalabhasana

(UHR-duh shuh-luh-BAHS-uh-nuh)

Also Known As: Crocodile Pose (Makarasana)
Modification: one arm straight to the front—palm facing down, other hand to the floor by the hip—palm down
Pose Type: prone, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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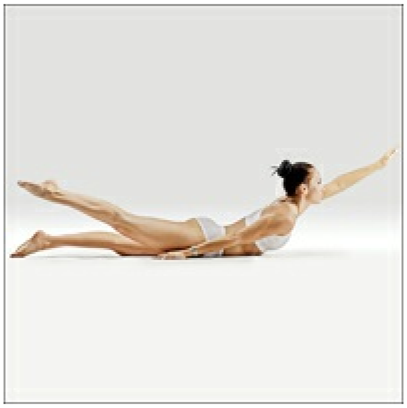

One-Legged Frog Pose in Locust Pose

Eka Pada Bhekasana in Shalabhasana

(EY-kuh PUH-duh bey-KAHS-uh-nuh in shuh-luh-BAHS-uh-nuh)

Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Hastagrai or Hastagre (hands)
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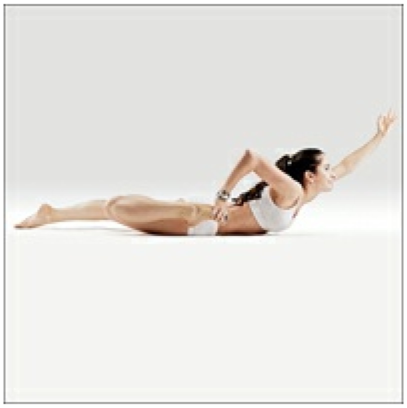

Mermaid Pose in Locust Pose

Naginyasana in Shalabhasana

(nuh-gin-YAHS-uh-nuh in shuh-luh-BAHS-uh-nuh)

Pose Type: prone, backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

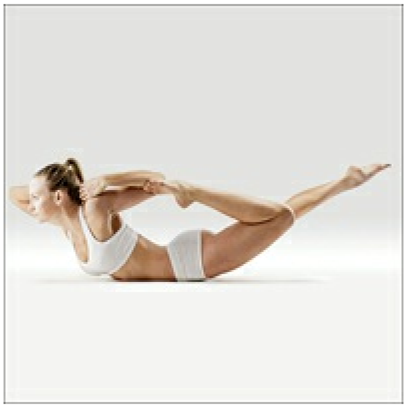

SPHINX POSE: BOTH AND ONE LEG STRAIGHT

Supported Cobra Pose

Salamba Bhujangasana

(SAH-luhm-buh buj-uhng-GAHS-uh-nuh)

Also Known As: Sphinx Pose or Crocodile Pose (Makarasana)
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

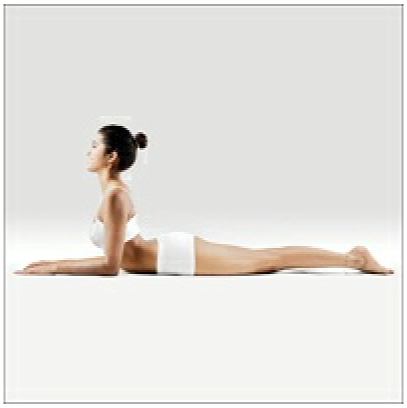

One-Legged Frog Pose

Eka Pada Bhekasana

(EY-kuh PUH-duh bey-KAHS-uh-nuh)

Modification: open ankles modification, heel to the floor by the hip socket
Pose Type: prone, backbend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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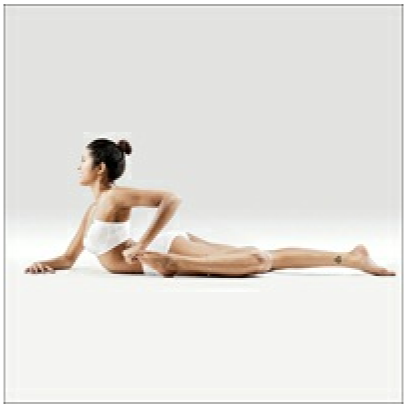

Leg Extended Uneven Supported Cobra Pose

Utthita Pada Vishama Salamba Bhujangasana

(UT-ti-tuh PUH-duh VISH-uh-muh SAH-luhm-buh buj-ung-GAHS-uh-nuh)

Also Known As: Uneven Sphinx Pose
Modification: 1. knee bent 2. leg straight
Pose Type: prone
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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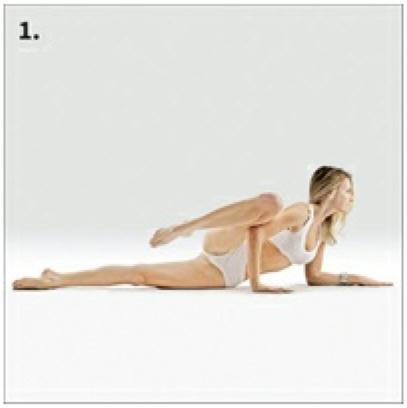

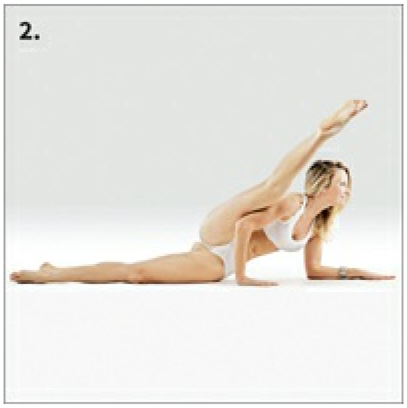

SPHINX POSE: BOTH KNEES BENT

Supported Cobra Pose

Salamba Bhujangasana

(SAH-luhm-buh buj-uhng-GAHS-uh-nuh)

Also Known As: Sphinx Pose or Crocodile Pose (Makarasana)
Modification: knees bent
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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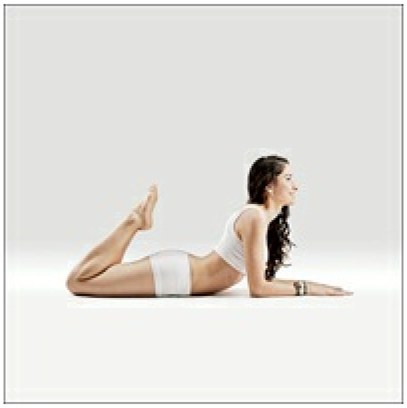

Feet to the Head Supported Cobra Pose

Shirsha Pada Salamba Bhujangasana

(SHEER-shuh PUH-duh SAH-luhm-buh buj-uhng-GAHS-uh-nuh)

Also Known As: Feet to the Head Sphinx Pose
Modification: toes to the forehead
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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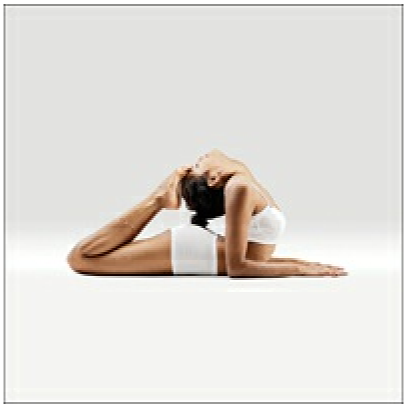

Feet to the Face Supported Cobra Pose

Mukha Pada Salamba Bhujangasana

(MUK-uh PUH-duh SAH-luhm-buh buj-uhng-GAHS-uh-nuh)

Also Known As: Feet to the Face Sphinx Pose
Modification: heels to the forehead
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)
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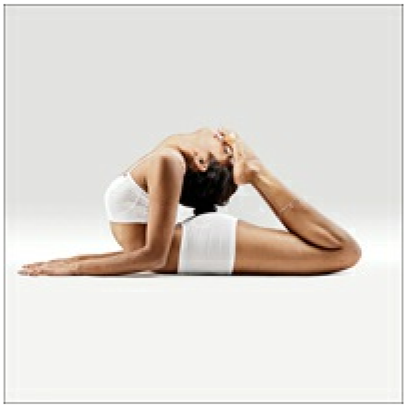

Downward Facing Bound Angle Pose

Adho Mukha Baddha Konasana

(uh-DO MUK-uh BUH-duh ko-NAHS-uh-nuh)

Modification: forearms to the floor

1. top view
2. side view

Pose Type: prone, backbend

Drishti Point: Nasagrai or Nasagre (nose)

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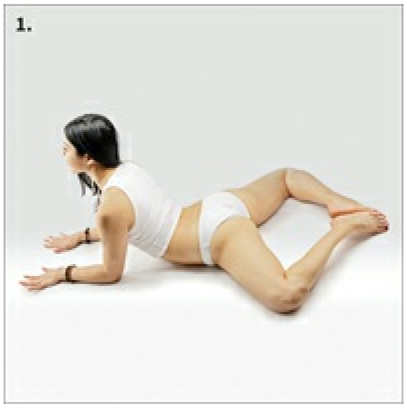

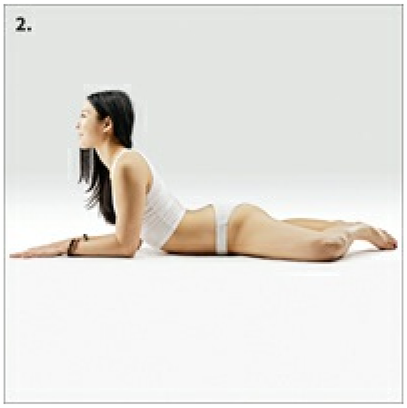

Hidden Lotus Pose

Gupta Padmasana

(GUP-tuh puhd-MAHS-uh-nuh)

Modification: hands to the face on the elbows

Pose Type: prone, backbend

Drishti Point: Nasagrai or Nasagre (nose)

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COBRA POSE

Cobra Pose

Bhujangasana

(buj-uhng-GAHS-uh-nuh)

Modification: palms on the floor, elbows bent
1. mild backbend
2. intense backbend

Pose Type: prone, backbend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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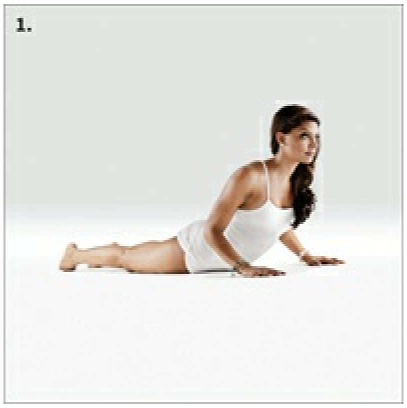

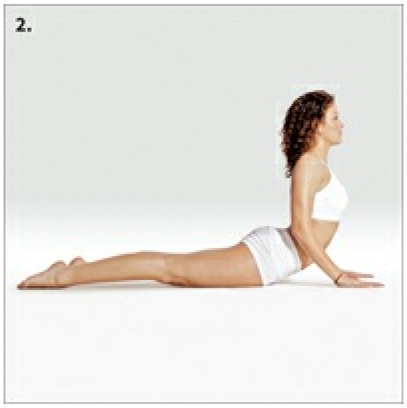

Cobra Pose

Bhujangasana

(buj-uhng-GAHS-uh-nuh)

Modification: 1. elbows bent, fingertips to the floor 2. arms straight, palms to the floor
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)

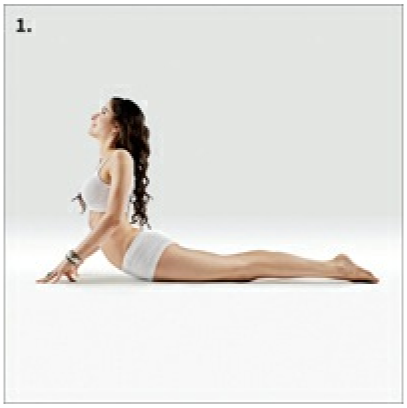
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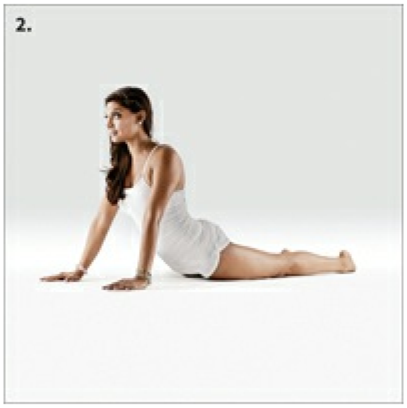
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Cobra Pose

Bhujangasana

(buj-uhng-GAHS-uh-nuh)

Modification: palms on the floor, arms straight, head to the glutes
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

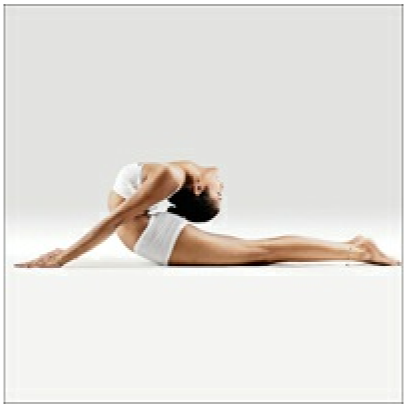

KING PIGEON POSE: HANDS TO THE FLOOR

Half King Pigeon Pose

Ardha Raja Kapotasana

(UHR-duh RAH-juh kuh-po-TAHS-uh-nuh)

Modification: palms to the floor, one foot to the head
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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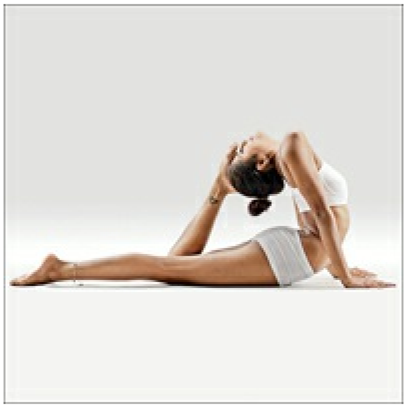

One-Legged One Hand King Pigeon Pose

Eka Pada Eka Hasta Raja Kapotasana

(EY-kuh PUH-duh EY-kuh HUH-stuh RAH-juh kuh-po-TAHS-uh-nuh)

Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)
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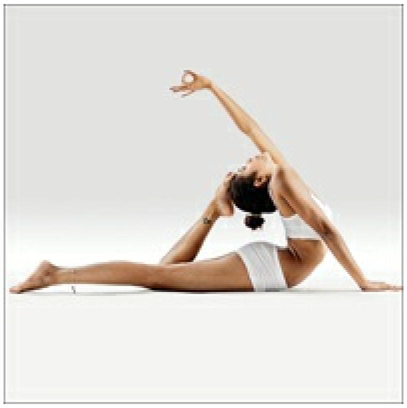

King Pigeon Pose

Raja Kapotasana

(RAH-juh kuh-po-TAHS-uh-nuh)

Modification: palms to the floor, feet away from the head
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

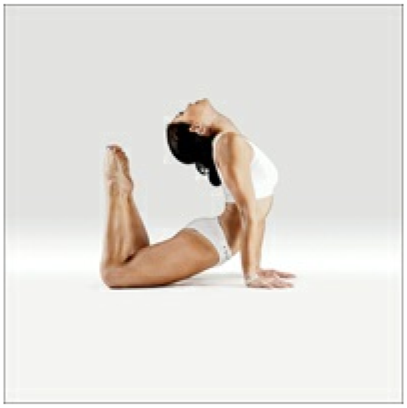

King Pigeon Pose

Raja Kapotasana

(RAH-juh kuh-po-TAHS-uh-nuh)

Modification: head touching the glutes, knees bent, feet away from the head
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

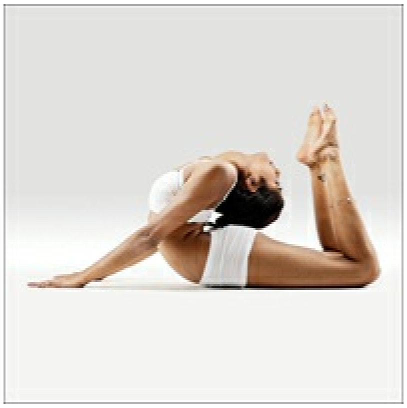

King Pigeon Pose

Raja Kapotasana

(RAH-juh kuh-po-TAHS-uh-nuh)

Modification: palms to the floor, feet to the head
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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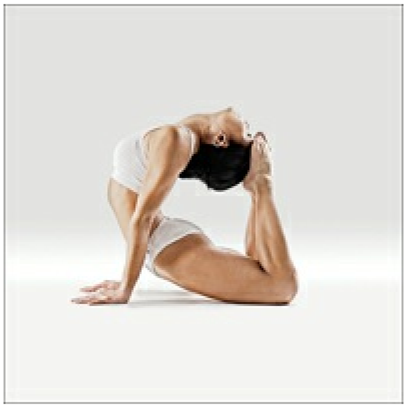

King Pigeon Pose

Raja Kapotasana

(RAH-juh kuh-po-TAHS-uh-nuh)

Modification: palms to the floor, feet to the shoulders
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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King Pigeon Pose

Raja Kapotasana

(RAH-juh kuh-po-TAHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

How to Perform the Pose:

1. Begin by lying flat on your stomach with your legs straight out behind you. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale and bring your forearms to the floor with your shoulders on top of your elbows. Inhale, lengthen your neck, roll your shoulder blades down, and feel the backbend in your upper back.
3. On the next exhale, press strongly into your hands and straighten your arms. Walk your hands as close as you can toward you.
4. Exhale and bend both your knees, reaching your feet toward your head.
5. Inhale and shift your weight to your left hand. Exhale, bring your right arm behind you, and grab onto your right knee. On the next exhale, bring your left arm behind you and grab onto your left knee.
6. Exhale as you push through your chest, keeping the backbend in the upper back and pressing your feet to the crown of your head (Pose #1).
7. To deepen the pose, exhale and bring your feet to your shoulders (Pose #2).
8. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
9. Inhale as you release the pose, letting go of your knees. Bring your hands to the front and lower your chest and feet to the floor.

Modification: grabbing onto the knees
1. feet to the head
2. feet to the shoulders

raja = king, royal

kapota = pigeon

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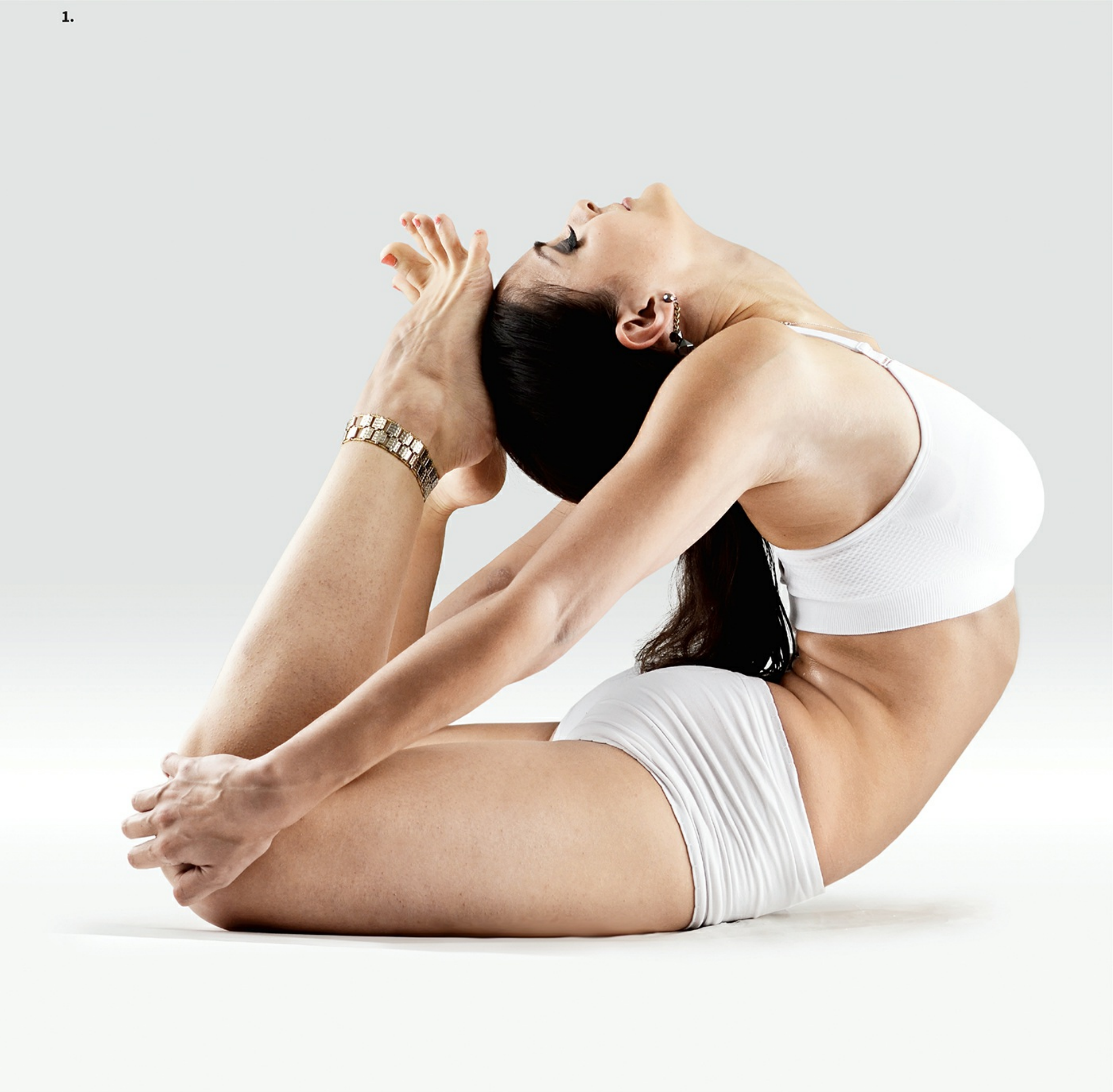

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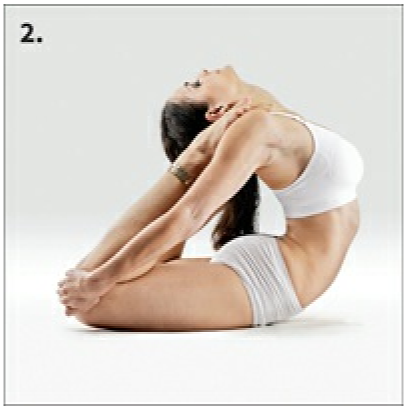

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King Pigeon Pose Prep.

Raja Kapotasana Prep.

(RAH-juh kuh-po-TAHS-uh-nuh)

Modification: one hand to the floor, other hand grabbing onto the knee

Pose Type: prone, backbend

Drishti Point: Nasagrai or Nasagre (nose)

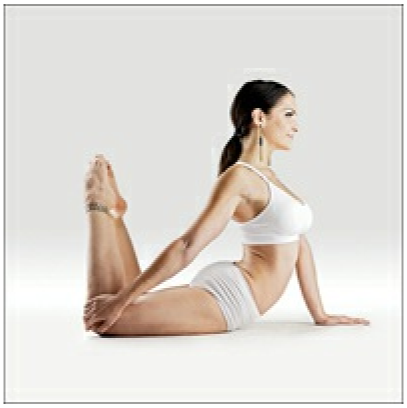

King Pigeon Pose Prep.

Raja Kapotasana Prep.

(RAH-juh kuh-po-TAHS-uh-nuh)

Modification: both hands grabbing onto the knees

1. looking straight ahead
2. head rolling back

Pose Type: prone, backbend

Drishti Point: 1. Nasagrai or Nasagre (nose)

2. Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

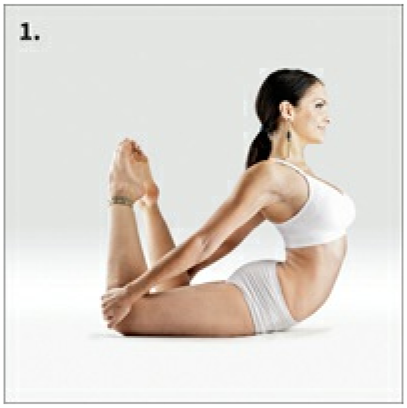

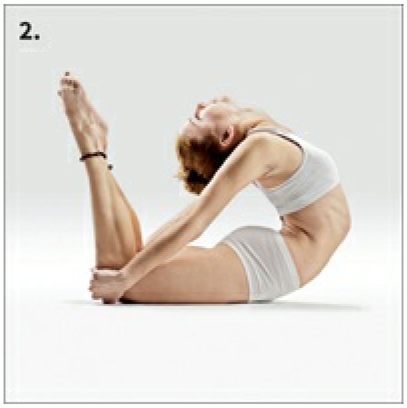

Feet to the Back King Pigeon Pose

Pada Paschima Raja Kapotasana

(PUH-duh PUHSH-chi-muh RAH-juh kuh-po-TAHS-uh-nuh)

Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

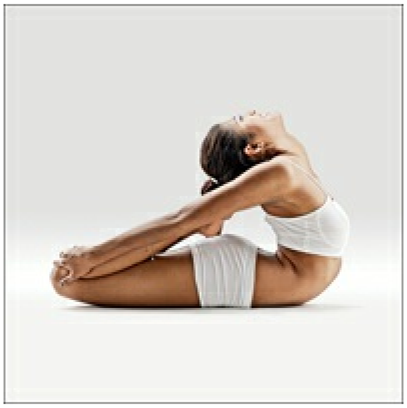

UPWARD DOG POSE: BOTH LEGS STRAIGHT

Upward Facing Dog Pose

Urdhva Mukha Shvanasana

(OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: toes pointed to the back, knees on the floor
1. looking straight ahead
2. head rolling back
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

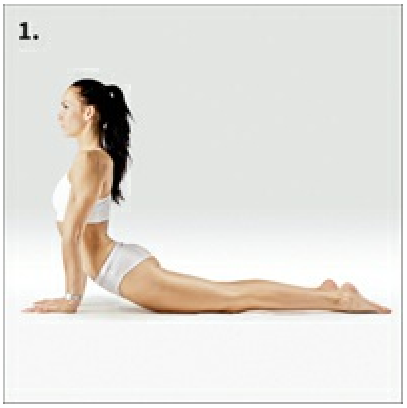

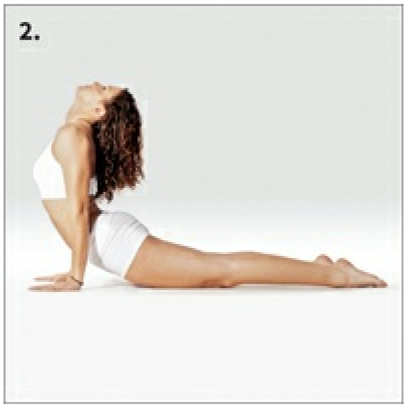

Upward Facing Dog Pose

Urdhva Mukha Shvanasana

(OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: toes pointed to the back, knees off the floor
1. looking straight ahead
2. head rolling back
Pose Type: prone, backbend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

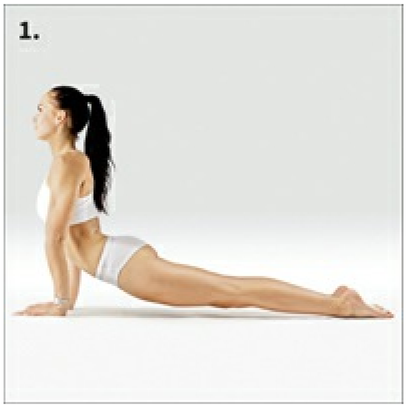

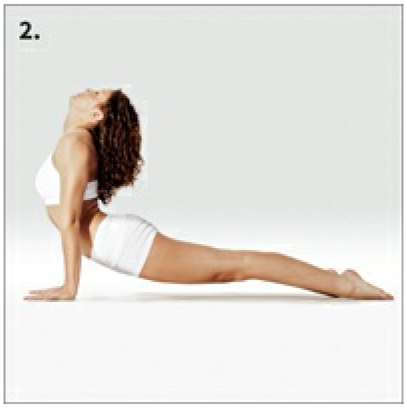
2.

UPWARD DOG POSE: BOTH LEGS STRAIGHT—ONE LEG, ONE ARM, & TO THE SIDE

Uneven One-Legged Upward Facing Dog Pose

Vishama Eka Pada Urdhva Mukha Shvanasana

(VISH-uh-muh EY-kuh PUH-duh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: both toes pointed

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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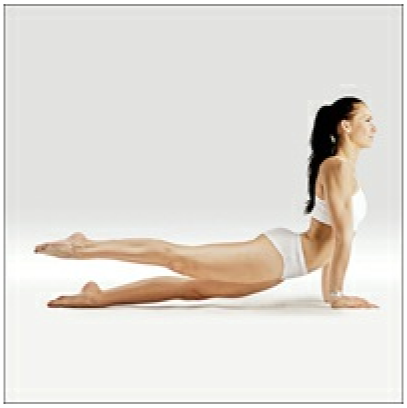

Sideways Upward Facing Dog Pose

Parshva Urdhva Mukha Shvanasana

(PAHRSH-vuh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Pose Type: prone, backbend, side bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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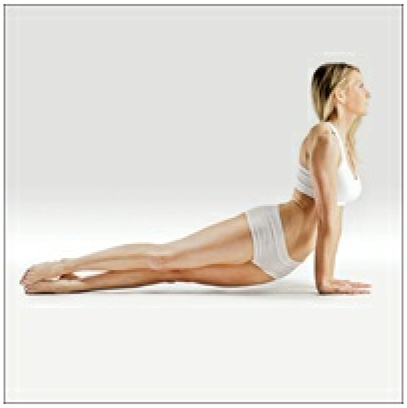

One Hand Upward Facing Dog Pose

Eka Hasta Urdhva Mukha Shvanasana

(EY-kuh HUH-stuh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: toes pointed to the back
1. knees on the floor
2. knees off the floor

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

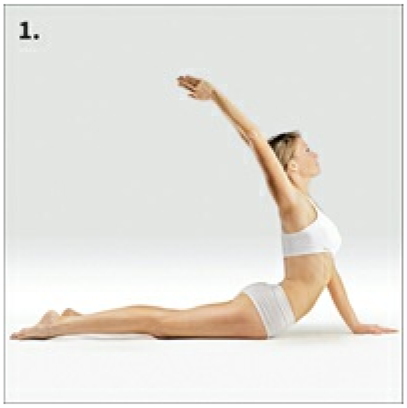

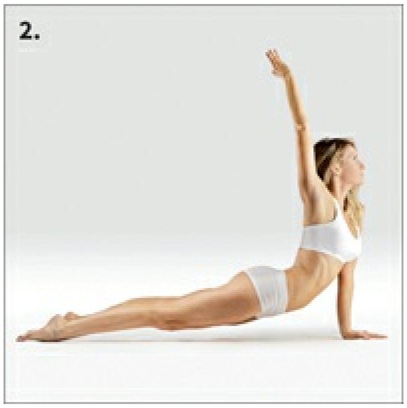

UPWARD DOG POSE: TOES CURLED IN

Upward Facing Dog Pose

Urdhva Mukha Shvanasana

(OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: toes curled in
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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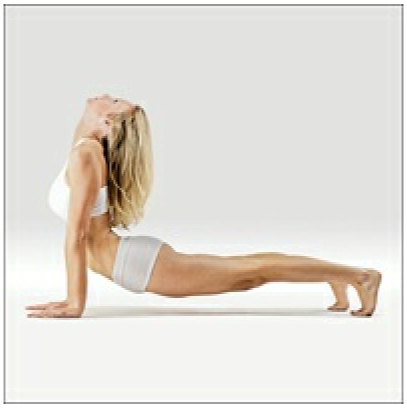

Sideways One-Legged Upward Facing Dog Pose

Parshva Eka Pada Urdhva Mukha Shvanasana

(PAHRSH-vuh EY-kuh PUH-duh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: toes curled in
Pose Type: prone, backbend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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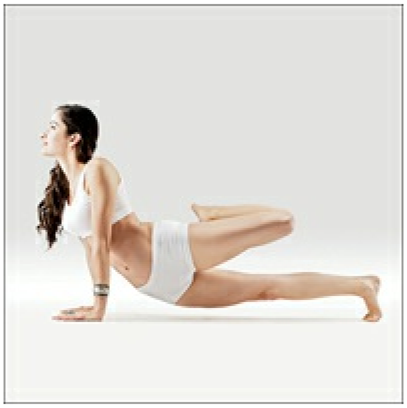

One-Legged Upward Facing Dog Pose

Eka Pada Urdhva Mukha Shvanasana

(EY-kuh PUH-duh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: toes of the straight leg curled in; knee of the other leg bent, toes pointing up to the sky

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

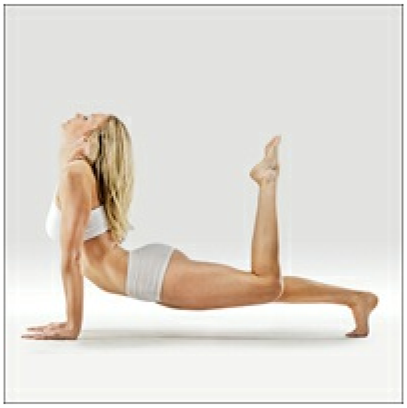

Half Big Toe Bow Pose in One-Legged Upward Facing Dog Pose

Ardha Padangushta Dhanurasana in Eka Pada Urdhva Mukha Shvanasana

(UHR-duh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh in EY-kuh PUH-duh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: grabbing onto the foot with overhead grip on the same side

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

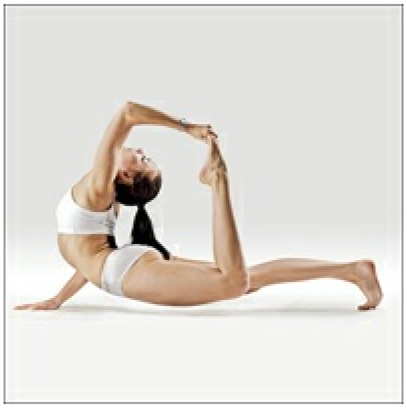

UPWARD DOG POSE: TOES CURLED IN—LEGS CROSSED

Upward Facing Dog Pose

Urdhva Mukha Shvanasana

(OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: toes curled in, ankles crossed
1. knees on the floor
2. knees off the floor, looking straight ahead
3. knees off the floor, head rolling back

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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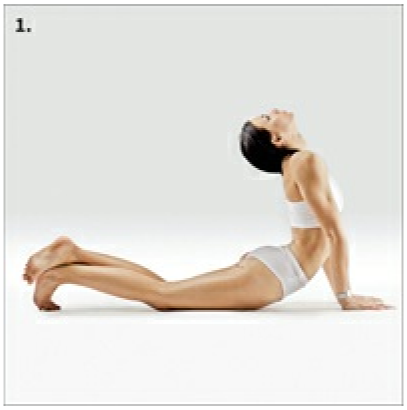

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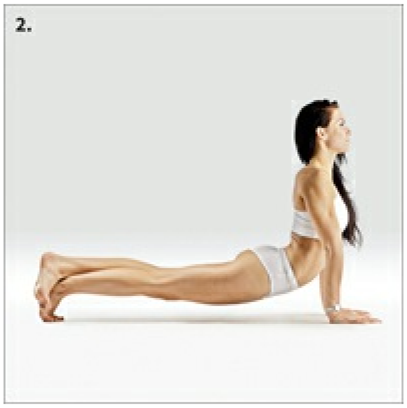

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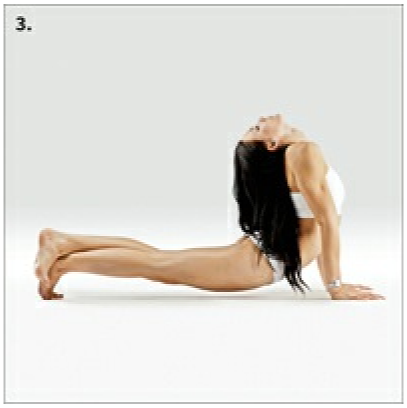

One-Legged Upward Facing Dog Pose

Eka Pada Urdhva Mukha Shvanasana

(EY-kuh PUH-duh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: toes curled in, foot of the bent leg to the inside of the knee of the straight leg
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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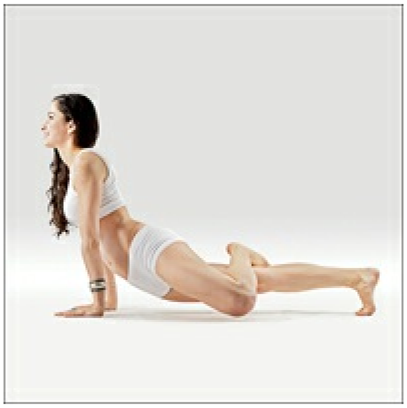

UPWARD DOG POSE: ONE LEG BENT

Uneven One-Legged Upward Facing Dog Pose

Vishama Eka Pada Urdhva Mukha Shvanasana

(VISH-uh-muh EY-kuh PUH-duh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: Leg 1: knee bent and on the floor, toes pointed to the sky Leg 2: straight and off the floor, toes pointed away
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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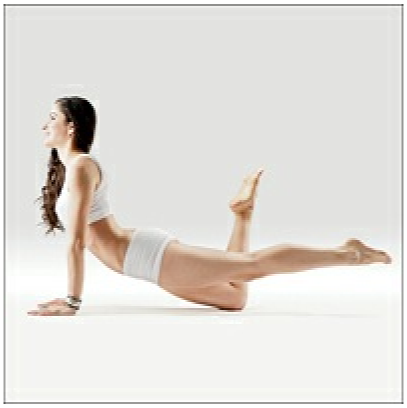

Half Bow Pose in One-Legged Upward Facing Dog Pose

Ardha Dhanurasana in Eka Pada Urdhva Mukha Shvanasana

(UHR-duh duh-nur-AHS-uh-nuh in EY-kuh PUH-duh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: grabbing onto the opposite foot with under-head grip
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

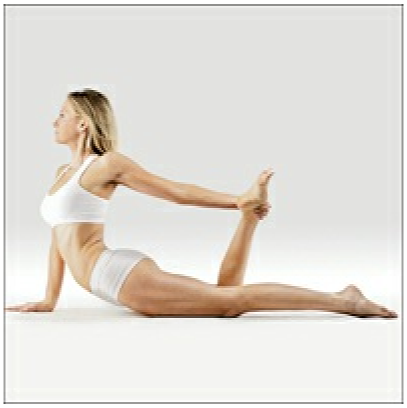

Half Bow Pose in One-Legged Upward Facing Dog Pose

Ardha Dhanurasana in Eka Pada Urdhva Mukha Shvanasana

(UHR-duh duh-nur-AHS-uh-nuh in EY-kuh PUH-duh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: under-head grip on the same side
Pose Type: prone, backbend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

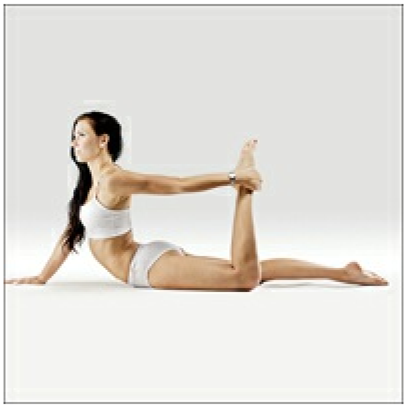

Half Pose Dedicated to Siddhar Konganar in One-Legged Upward Facing Dog Pose

Ardha Konganarasana in Eka Pada Urdhva Mukha Shvanasana

(UHR-duh kong-guh-nuh-RAHS-uh-nuh in EY-kuh PUH-duh OORD-vuh MUK-uh shvuh-NAHS-uh-nuh)

Modification: grabbing onto the knee with under-head grip on the same side—foot to the armpit

Pose Type: prone, backbend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

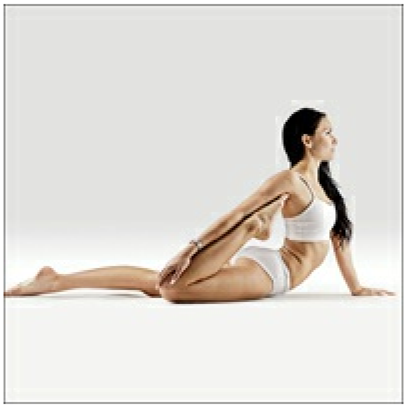

COBRA POSE: UNDER-HEAD GRIP

Half King Pigeon Pose in One-Legged Big Toe Bow Pose

Ardha Raja Kapotasana in Eka Pada Padangushta Dhanurasana

(UHR-duh RAH-juh kuh-po-TAHS-uh-nuh in EY-kuh PUH-duh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: Hand 1: grabbing onto the knee on the same side.
Hand 2: grabbing onto the big toe of the opposite foot with overhead grip
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

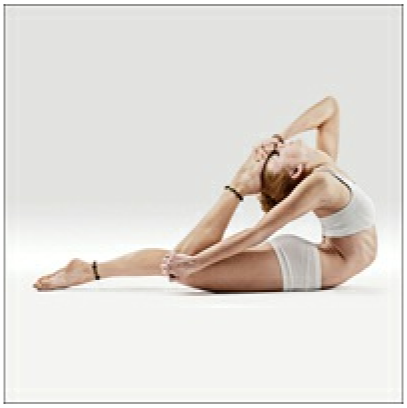

Cobra Pose

Bhujangasana

(buj-uhng-GAHS-uh-nuh)

Also Known As: Supported Cobra Pose (Alamba Bhujangasana), King Pigeon Pose Prep. (Raja Kapotasana Prep.)
Modification: grabbing onto the knees with under-head grip
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

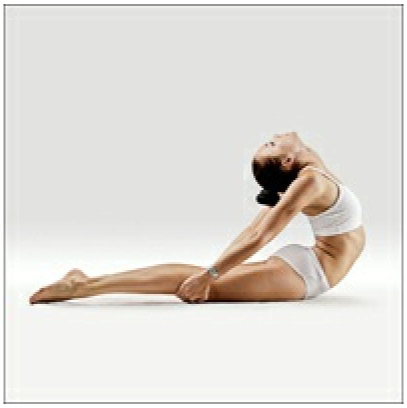

COBRA POSE: OVERHEAD GRIP

Upward Facing Unsupported Cobra Pose

Urdhva Mukha Niralamba Bhujangasana

(OORD-vuh MUK-uh nir-AH-luhm-buh buj-uhng-GAHS-uh-nuh)

Pose Type: prone, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

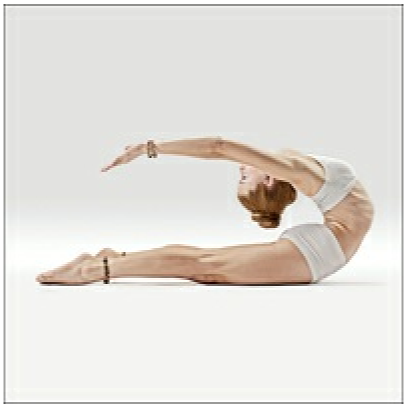

Unsupported Complete Cobra Pose

Niralamba Paripurna Bhujangasana

(nir-AH-luhm-buh puh-ri-POOR-nuh buj-uhng-GAHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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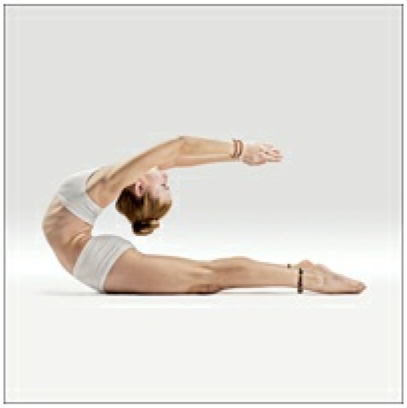

Complete Cobra Pose

Paripurna Bhujangasana

(puh-ri-POOR-nuh buj-uhng-GAHS-uh-nuh)

Modification: 1. grabbing onto the shins with overhead grip
2. grabbing onto the knees with overhead grip
3. grabbing onto the shins with overhead grip, toes curled in

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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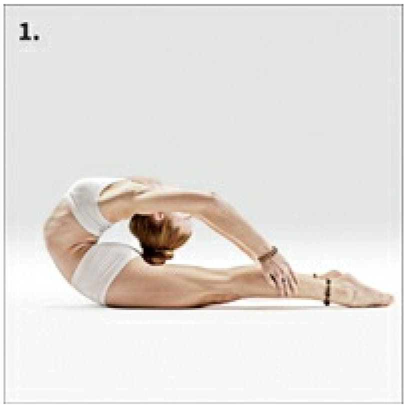

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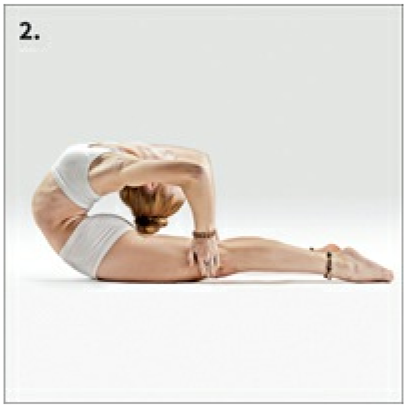

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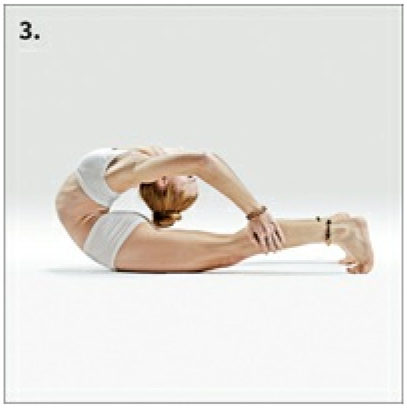

BOW POSE: UNDER-HEAD GRIP—BOTH KNEES BENT

Bow Pose

Dhanurasana

(duh-nur-AHS-uh-nuh)

Modification: hands grabbing onto the ankles
1. on the inside of the ankles
2. on the outside of the ankles

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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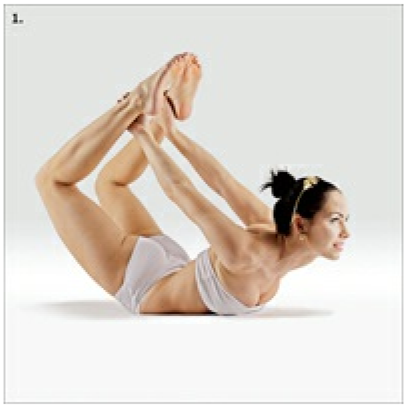

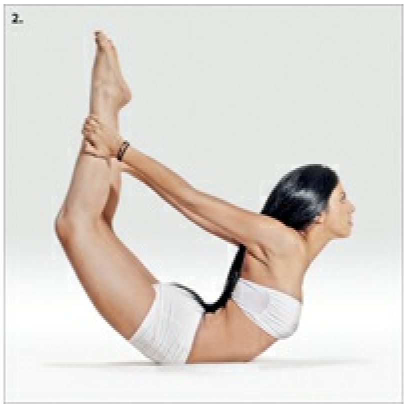

Bow Pose

Dhanurasana

(duh-nur-AHS-uh-nuh)

Modification: legs bent at 90 degrees; ankles and knees together, toes pointed to the sky
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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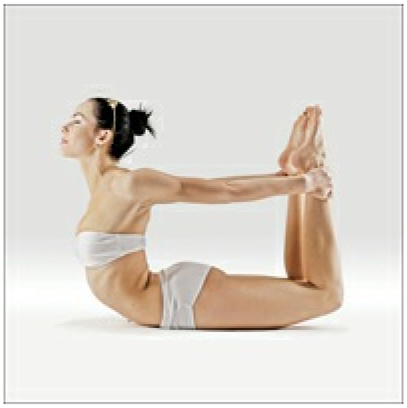

Bow Pose

Dhanurasana

(duh-nur-AHS-uh-nuh)

Modification: legs bent at 90 degrees; ankles and knees together, toes flexed away from the head
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)
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Sideways Bow Pose

Parshva Dhanurasana

(PAHRSH-vuh duh-nur-AHS-uh-nuh)

Pose Type: supine, prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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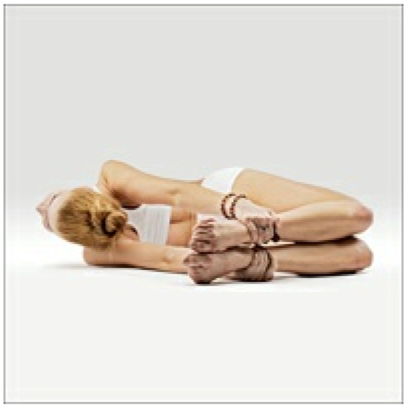

One-Legged

Pose Dedicated to Siddhar Konganar

Eka Pada Konganarasana

(EY-kuh PUH-duh kong-guh-nuh-RAHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Nasagrai or Nasagre (nose) or Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

How to Perform the Pose:

1. Begin by lying flat on your stomach with your legs straight out behind you. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale and bring your forearms to the floor with your shoulders on top of your elbows. Inhale, lengthen your neck, roll your shoulder blades down, and feel the backbend in your upper back.
3. On the next exhale, press strongly into your hands and straighten your arms.
4. Exhale and bend both your knees, reaching your feet toward your head.
5. On the next exhale, reach your right hand behind you and grab onto your right shin. Keep sliding your right hand until your right foot reaches your right armpit and your right hand rests on your right knee.
6. Inhale and reach your left arm up and over your head. Exhale and grab onto your left foot with your left hand, keeping your left elbow close to your ear.
7. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
8. Inhale, let go of your legs one by one, and lower your chest and feet to the floor to come back to the starting position. Repeat on the opposite side.

eka = one

pada = foot or leg

Konganar = one of the Siddhars

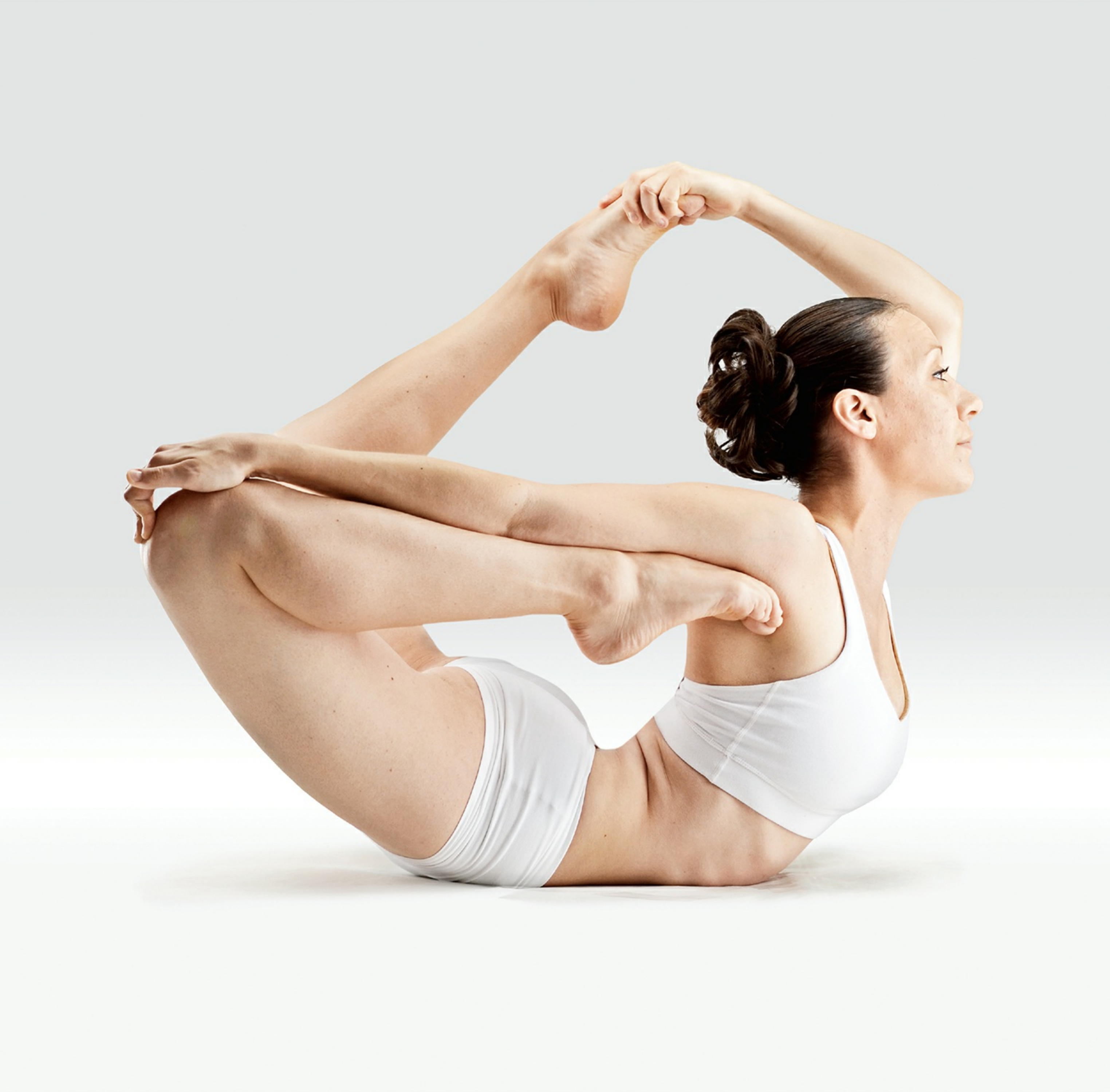

Little Bow Pose

Laghu Dhanurasana

(LUH-gu duh-nur-AHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

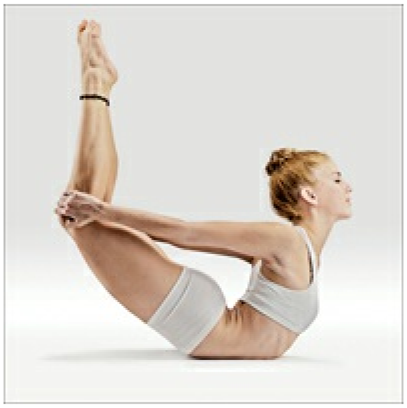

Feet to the Head Little Bow Pose

Shirsha Pada Laghu Dhanurasana

(SHEER-suh PUH-duh LUH-gu duh-nur-AHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

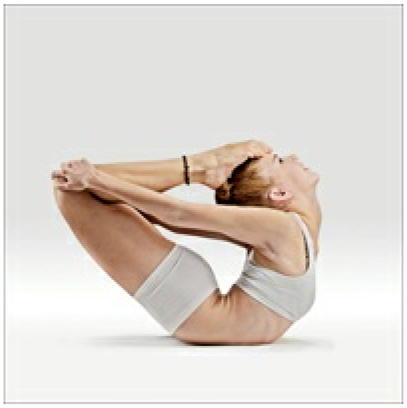

Pose Dedicated to Siddhar Konganar

Konganarasana

(kong-guh-nuh-RAHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

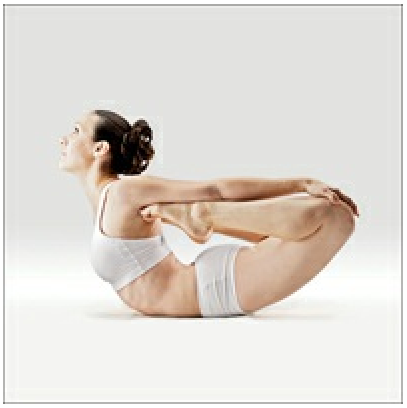

BOW POSE: OVERHEAD GRIP—BOTH KNEES BENT

One Hand Both Feet Big Toe Bow Pose

Eka Hasta Dwi Pada Padangushta Dhanurasana

(EY-kuh HUH-stuh DWI-puh-duh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: grabbing onto the toes of both feet with one hand, other palm to the floor

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

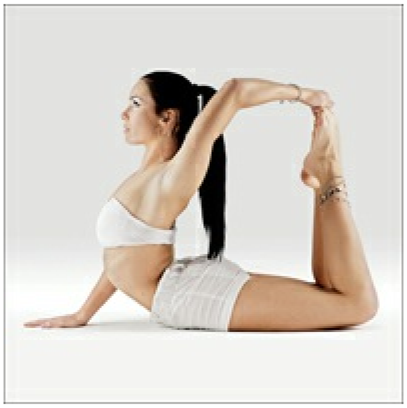

Big Toe Bow Pose

Padangushta Dhanurasana

(puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: head rolling back

Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

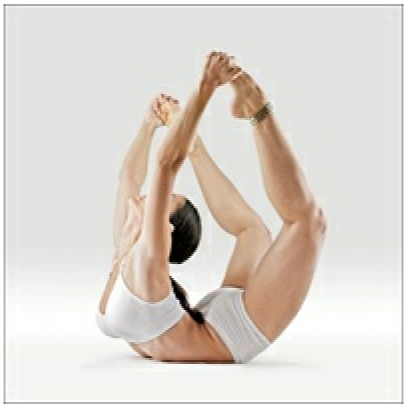

Big Toe Bow Pose

Padangushta Dhanurasana

(puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: 1. feet to the face
2. heels to the forehead
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

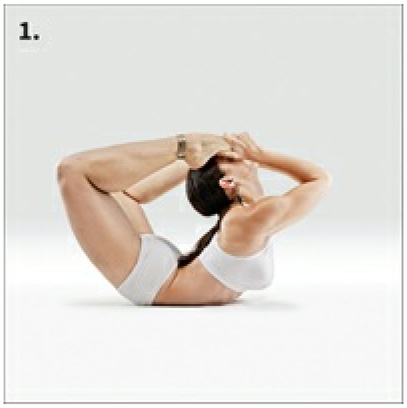
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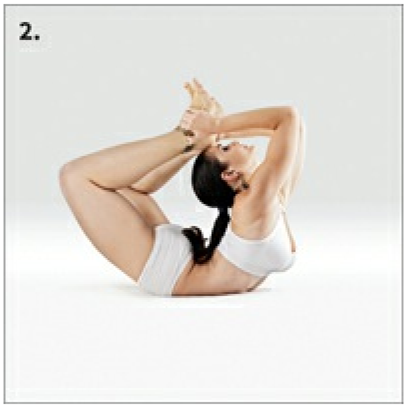
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One Hand One-Legged Big Toe Bow Pose

Eka Hasta Eka Pada Padangushta Dhanurasana

(EY-kuh HUH-stuh EY-kuh PUH-duh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: 1. one hand grabbing onto the foot on the opposite side with overhead grip
2. with backbend

Pose Type: prone, backbend

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

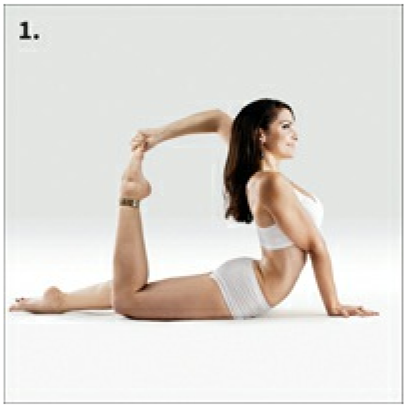

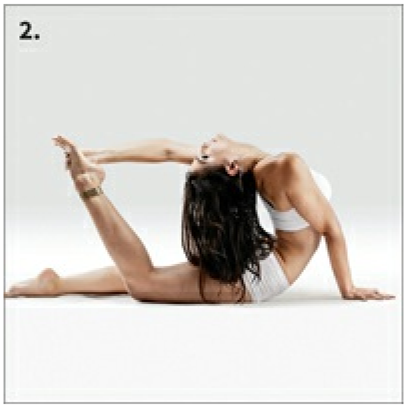

One Hand One-Legged Big Toe Bow Pose

Eka Hasta Eka Pada Padangushta Dhanurasana

(EY-kuh HUH-stuh PUH-duh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: one hand grabbing onto the foot on the same side with overhead grip

Pose Type: prone, backbend

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

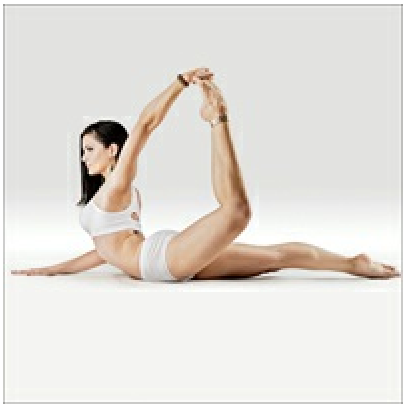

Both Hand One-Legged Big Toe Bow Pose

Dwi Hasta Eka Pada Padangushta Dhanurasana

(DWI-huh-stuh EY-kuh PUH-duh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: both hands grabbing onto the foot with overhead grip
Pose Type: prone, backbend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

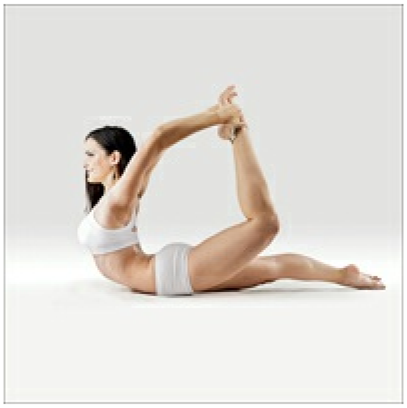

BOW POSE: OVERHEAD GRIP—ONE KNEE BENT, ONE LEG STRAIGHT AND OFF THE FLOOR

Pose Dedicated to Goddess Kamala

Kamalasana

(kuh-muh-LAHS-uh-nuh)

Also Known As: Upward Facing One-Handed Big Toe Boat Pose (Urdhva Mukha Eka Hasta Padangushta Navasana)
Modification: 1: grabbing onto the ankle

2. foot to the shoulder

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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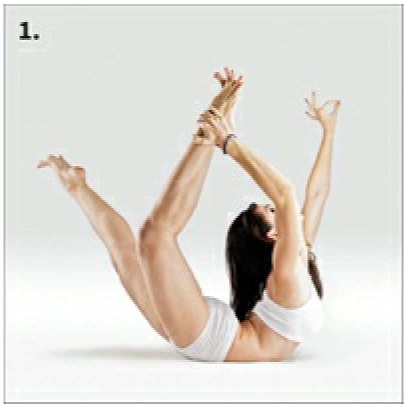

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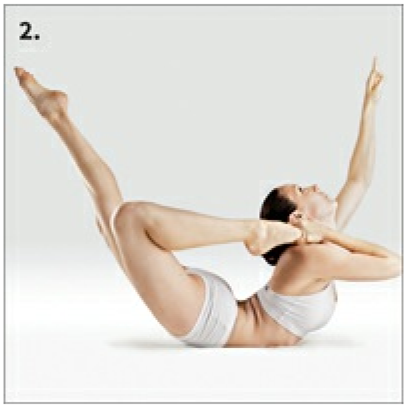

BOW POSE: CRISS-CROSS LEGS AND ARMS

Revolved Bow Pose

Parivritta Dhanurasana

(puh-ri-VRIT-tuh duh-nur-AHS-uh-nuh)

Pose Type: prone, backbend, twist

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padhayoragrai or Padayoragre (toes/feet)

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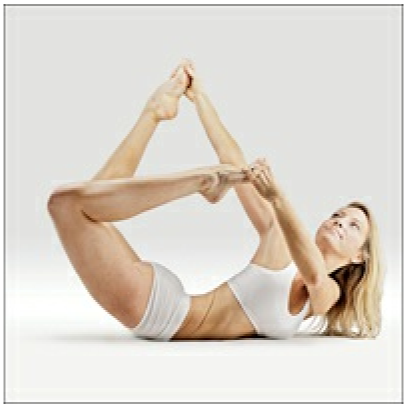

Bow Pose

Dhanurasana

(duh-nur-AHS-uh-nuh)

Modification: legs crossed
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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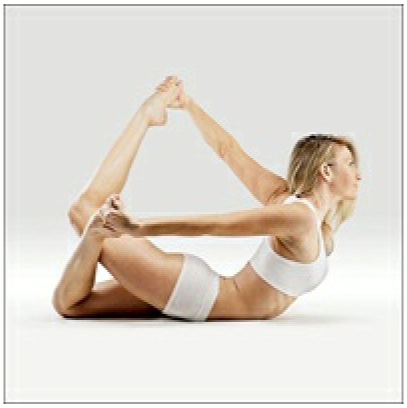

Big Toe Bow Pose

Padangushta Dhanurasana

(puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Also Known As: Difficult Bow Pose (Dur Dhanurasana)
Modification: one hand grabbing opposite ankle with under-head grip, other hand grabbing the opposite foot with overhead grip
1. one knee on the floor
2. both knees off the floor
Pose Type: prone, backbend
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

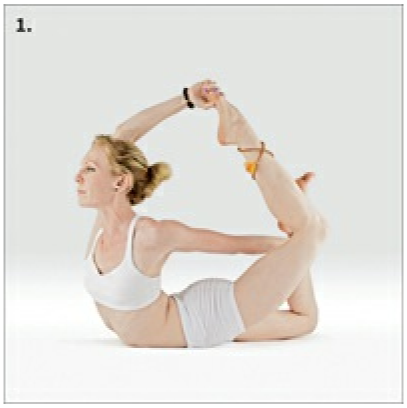

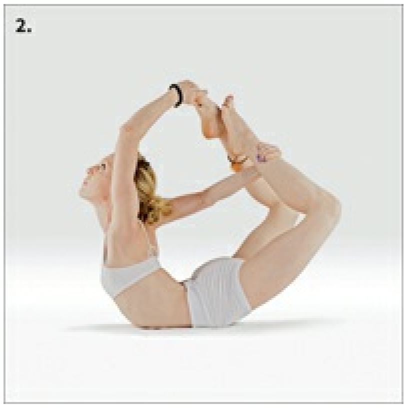

Big Toe Bow Pose

Padangushta Dhanurasana

(puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)
Modification: one foot toward the shoulder
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

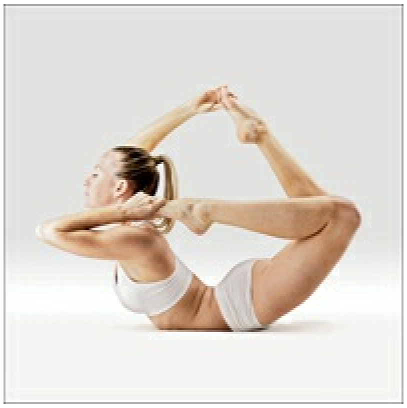

HALF LOTUS BACKBENDS

Half Lotus Frog Pose

Ardha Padma Bhekasana

(UHR-duh PUHD-muh bey-KAHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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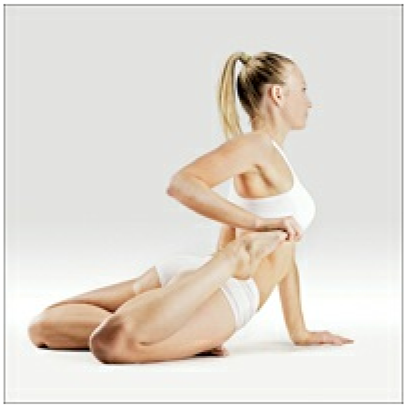

Half Lotus Bow Pose

Ardha Padma Dhanurasana

(UHR-duh PUHD-muh duh-nur-AHS-uh-nuh)

Modification: both hands grabbing onto the ankle with under-head grip

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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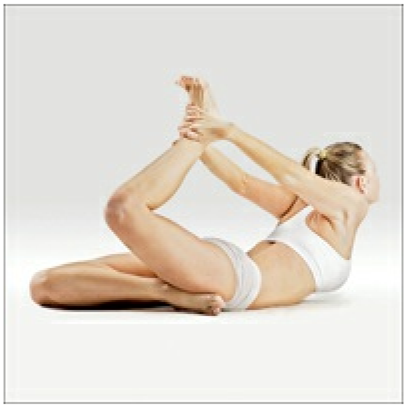

Half Lotus One Hand One-Legged Big Toe Bow Pose

Ardha Padma Eka Hasta Eka Pada Padangushta Dhanurasana

(UHR-duh PUHD-muh EY-kuh HUH-stuh EY-kuh PUH-duh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: grabbing onto the foot with overhead grip on the same side, other hand to the floor
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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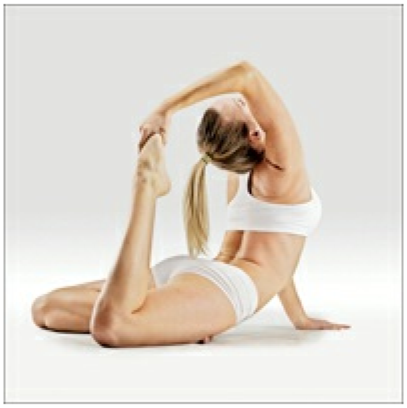

LOTUS BACKBENDS

Lotus Cobra Pose

Padma Bhujangasana

(PUHD-muh buj-uhng-GAHS-uh-nuh)

Modification: both hands to the floor, hips off the floor, arms straight
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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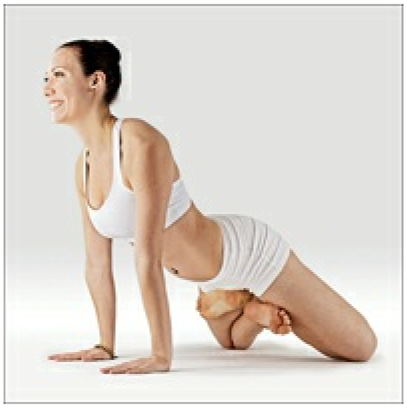

Lion Pose Dedicated to an Avatar of Lord Vishnu

Narasimhasana

(nuh-ruh-sim-HAHS-uh-nuh)

Also Known As: Lion Pose (Simhasana)
Modification: full lotus leg position
1. elbows bent, fingers in lion claw
2. arms straight, palms flat on the floor
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

1.

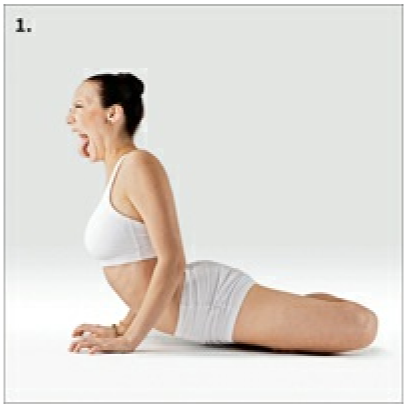

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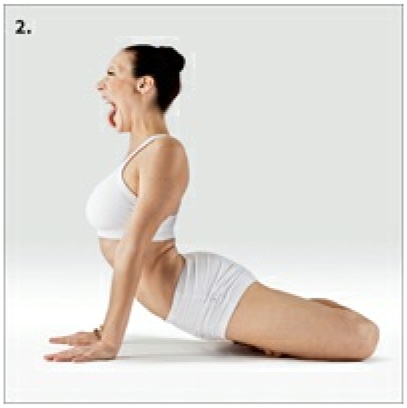

One Hand Lotus Cobra Pose

Eka Hasta Padma Bhujangasana

(EY-kuh HUH-stuh PUHD-muh buj-uhng-GAHS-uh-nuh)

Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

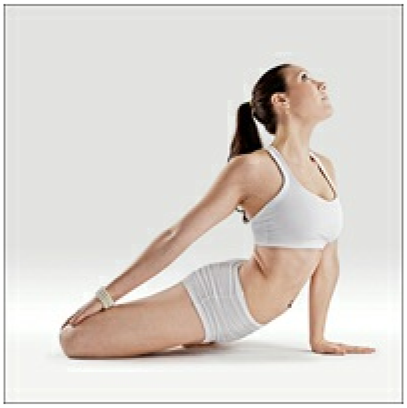

Lotus Cobra Pose

Padma Bhujangasana

(PUHD-muh buj-uhng-GAHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

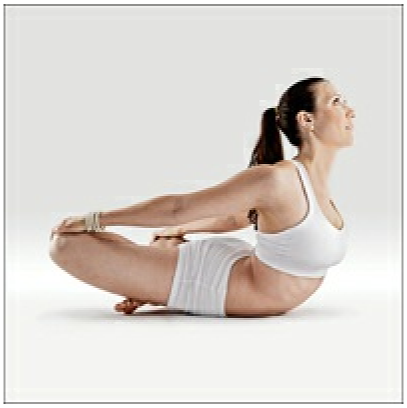

SAGE GHERANDA’S POSE: UNDER-HEAD GRIP

Revolved Pose Dedicated to Sage Gheranda 1

Parivritta Ardha Gherandasana 1

(puh-ri-VRIT-tuh UHR-duh gey-ruhn-DAHS-uh-nuh)

Pose Type: prone, backbend, twist

Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

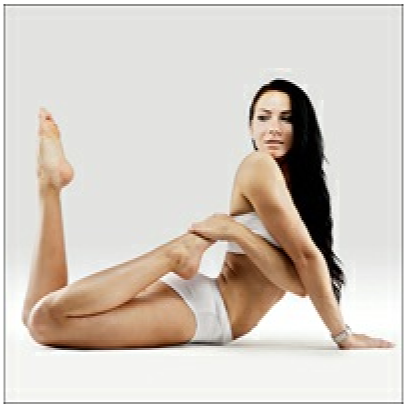

Half Pose Dedicated to Sage Gheranda 1

Ardha Gherandasana 1

(UHR-duh gey-ruhn-DAHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Nasagrai or Nasagre (nose)

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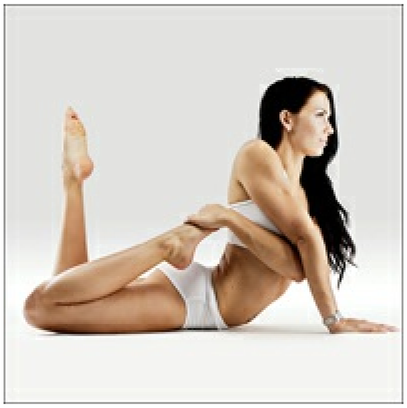

Pose Dedicated to Sage Gheranda 5B

Gherandasana 5 B

(gey-ruhn-DAHS-uh-nuh)

Modification: under-head grip, grabbing onto the ankle, elbow on the floor instead of the forearm

Pose Type: prone, backbend, twist

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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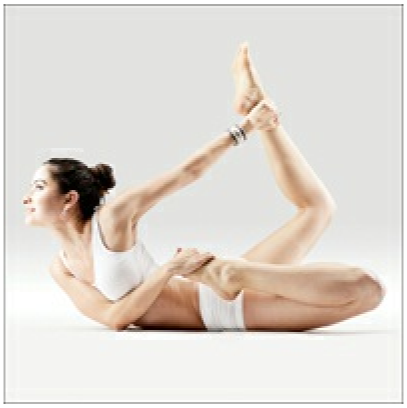

Pose Dedicated to Sage Gheranda 1B

Gherandasana 1 B

(gey-ruhn-DAHS-uh-nuh)

Modification: under-head grip
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

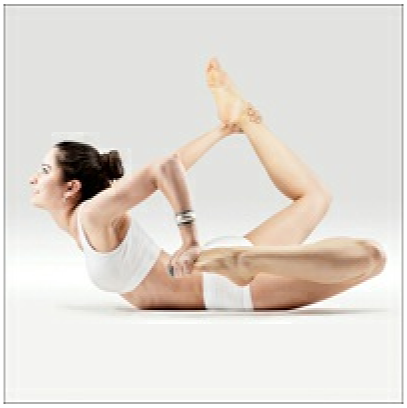

Pose Dedicated to Sage Gheranda 6

Gherandasana 6

(gey-ruhn-DAHS-uh-nuh)

Modification: under-head grip
Pose Type: prone, backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

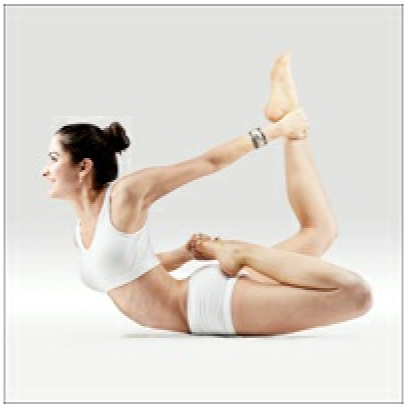

SAGE GHERANDA’S POSE: OVERHEAD GRIP

Pose Dedicated to Sage Gheranda 5

Gherandasana 5

(gey-ruhn-DAHS-uh-nuh)

Pose Type: prone, backbend, binding

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

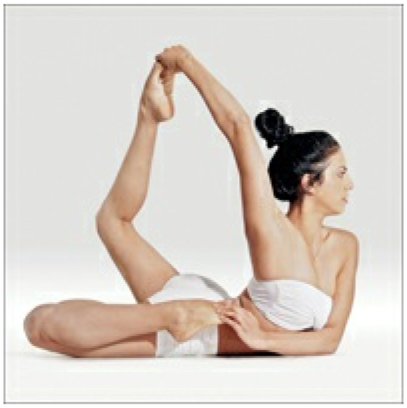

Pose Dedicated to Sage Gheranda 1

Gherandasana 1

(gey-ruhn-DAHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

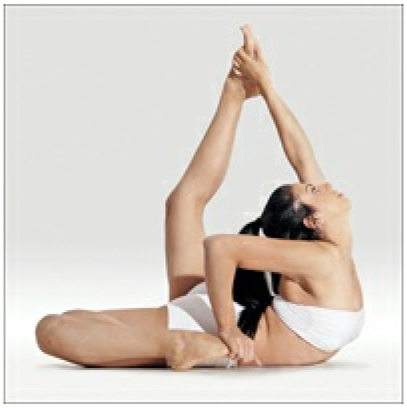

Pose Dedicated to Sage Gheranda 2

Gherandasana 2

(gey-ruhn-DAHS-uh-nuh)

Pose Type: prone, backbend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

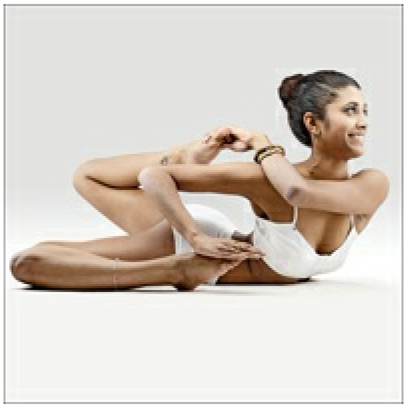

Pose Dedicated to Sage Gheranda 3

Gherandasana 3

(gey-ruhn-DAHS-uh-nuh)

Pose Type: prone, backbend, binding

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

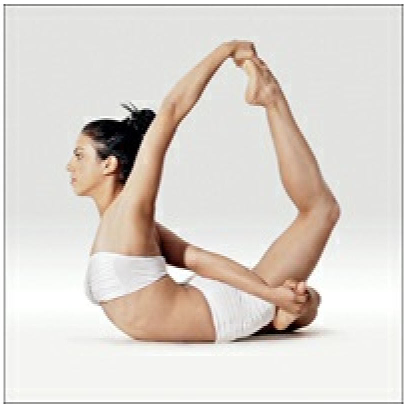

Pose Dedicated to Sage Gheranda 4

Gherandasana 4

(gey-ruhn-DAHS-uh-nuh)

Modification: 1. back view
2. front view
Pose Type: prone, backbend, binding, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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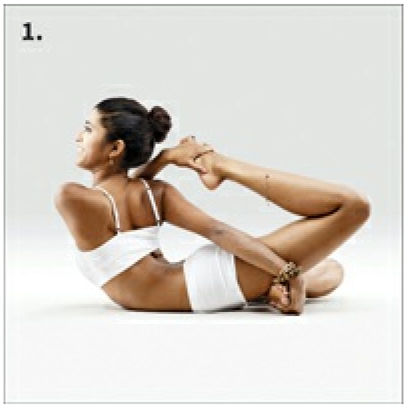

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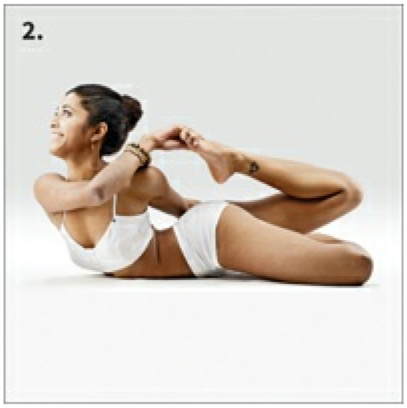

BACKBENDS: GARUDA LEGS: UNDER-HEAD GRIP

Twined Legs Cobra Pose

Parivitta Pada Bhujangasana

(puh-ri-VRIT-tuh PUH-duh buj-uhng-GAHS-uh-nuh)

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

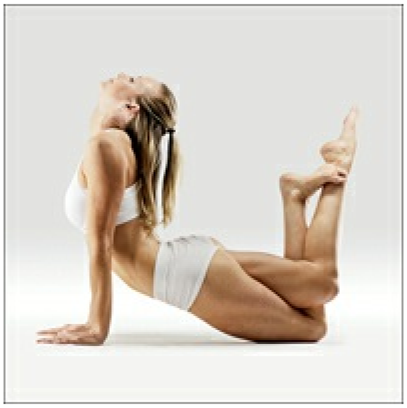

Supported Twined Legs Cobra Pose

Salamba Parivid Pada Bhujangasana

(SAH-luhm-buh PUH-ri-vid PUH-duh buj-uhng-GAHS-uh-nuh)

Also Known As: Supported Twined Legs Sphinx Pose

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

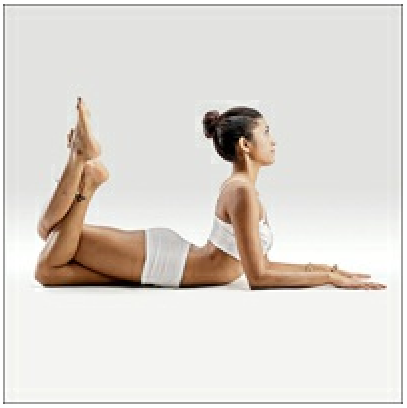

Leg Position of the Pose Dedicated to Garuda in One Hand Bow Pose

Pada Garudasana in Eka Hasta Dhanurasana

(PUH-duh guh-ru-DAHS-uh-nuh in EY-kuh HUH-stuh duh-nur-AHS-uh-nuh)

Modification: one forearm to the floor, one hand to the ankle, under-head grip

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

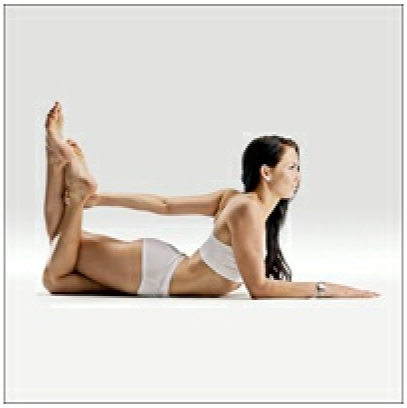

BACKBENDS: GARUDA LEGS: OVERHEAD GRIP

Leg Position of the Pose Dedicated to Garuda in One Hand Big Toe Bow Pose

Pada Garudasana in Eka Hasta Padangushta Dhanurasana

(PUH-duh guh-ru-DAHS-uh-nuh in EY-kuh HUH-stuh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: forearm to the floor

1. grabbing onto the top foot
2. grabbing onto the bottom foot

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

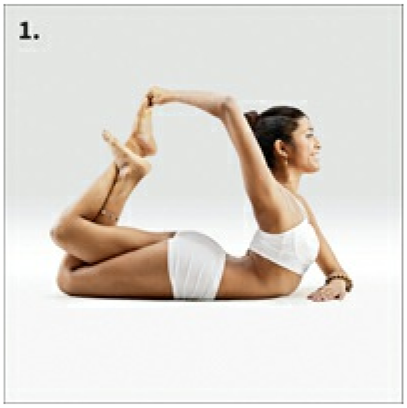

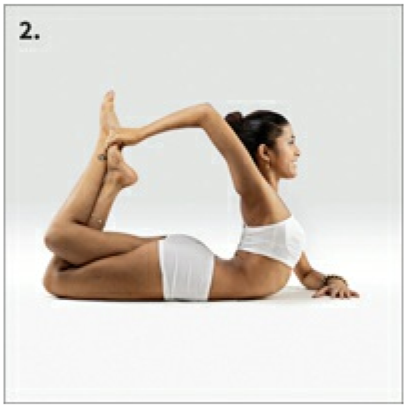
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Unsupported Leg Position of the Pose Dedicated to Garuda in One Hand Big Toe Bow Pose

Niralamba Pada Garudasana in Eka Hasta Padangushta Dhanurasana

(nir-AH-luhm-buh puh-ri-vid-PUH-duh guh-ru-DAHS-uh-nuh in EY-kuh HUH-tuh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Also Known As: One Handed Twined Legs Bow Pose (Eka Hasta Parivid Pada Dhanurasana)
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

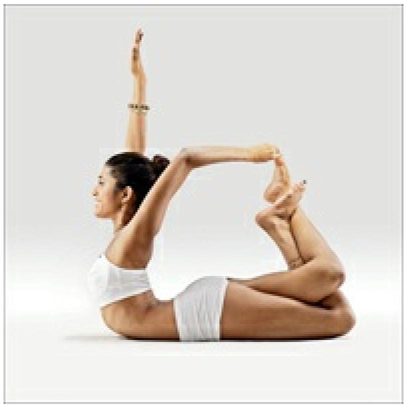

Leg Position of the Pose Dedicated to Garuda in Big Toe Bow Pose

Pada Garudasana in Padangushta Dhanurasana

(PUH-duh guh-ru-DAHS-uh-nuh in puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Also Known As: Difficult Bow Pose (Dur Dhanurasana)
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

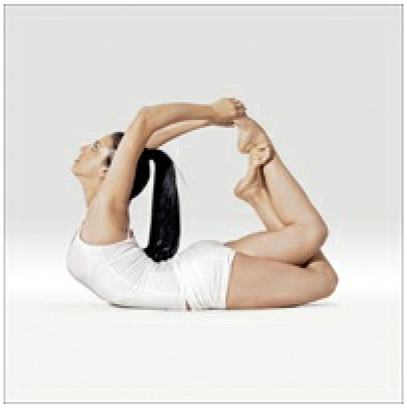

CHIN ON THE FLOOR & EAR ON THE FLOOR

One-Legged Inverted Locust Pose

Eka Pada Viparita Shalabhasana

(EY-kuh PUH-duh vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Pose Type: prone, backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

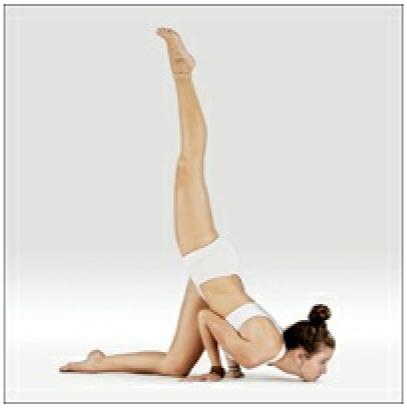

Ear Pressure Staff Formidable Face Pose

Karnapida Danda Ganda Bherundasana

(kuhr-nah-PEED-uh DUHN-duh GUHN-duh bey-run-DAHS-uh-nuh)

Pose Type: prone, backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

CHEST ON THE FLOOR: BOTH LEGS STRAIGHT

Inverted Locust Pose

Viparita Shalabhasana

(vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Modification: 1. chin to the floor
2. chest to the floor, chin lifted off the floor
Pose Type: prone, backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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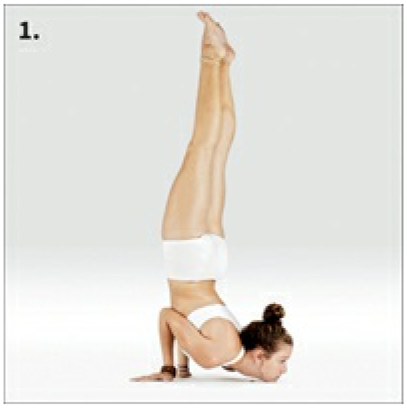

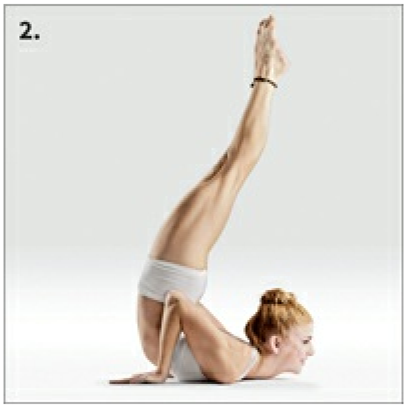

Formidable Face Staff Pose

Danda Ganda Bherundasana

(DUHN-duh GUHN-duh bey-run-DAHS-uh-nuh)

Also Known As: Intense Stretch Locust Pose A (Uttana Shalabhasana A)
Pose Type: prone, backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

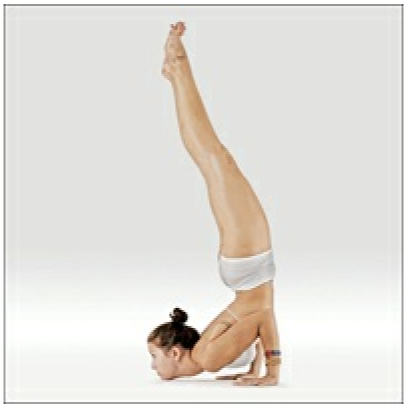

Inverted Locust Pose

Viparita Shalabhasana

(vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Also Known As: Raised Locust Pose—Urdhva Shalabhasana)
Modification: arms straight on the floor, palms down, chin lifted off the floor
Pose Type: prone, backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

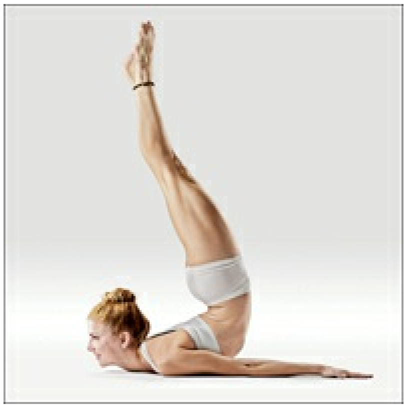

CHEST ON THE FLOOR: BOTH FEET TO HEAD

Formidable Face Pose

Ganda Bherundasana

(GUHN-duh bey-run-DAHS-uh-nuh)

Also Known As: Full Locust Pose (Purna Shalabhasana), Intense Stretch Locust Pose B (Uttana Shalabhasana B)

Modification: fingers pointing to the front of the body, feet to the head, chest on the floor 1. side view 2. front view

Pose Type: prone, backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

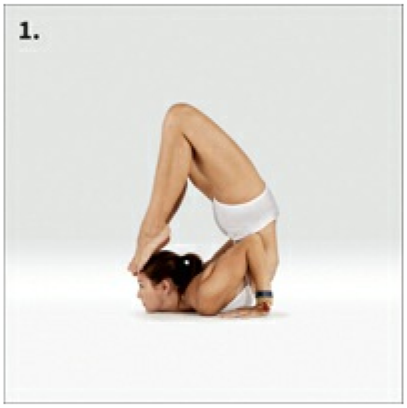

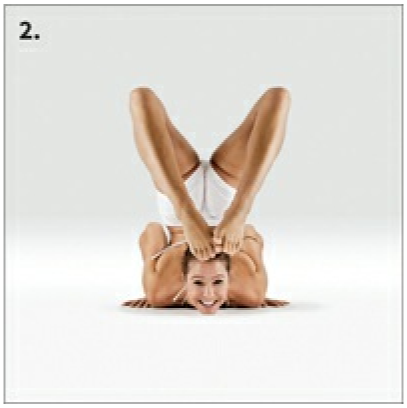

Formidable Face Pose

Ganda Bherundasana

(GUHN-duh bey-run-DAHS-uh-nuh)

Modification: fingers pointing to the back

1. knees apart

2. knees together, chin lifted off the floor

Pose Type: prone, backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

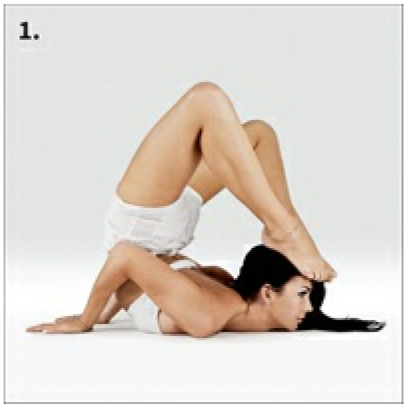
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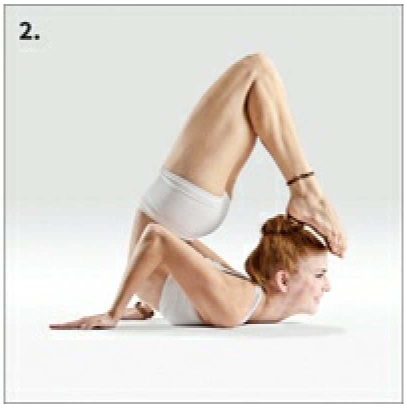
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Inverted Locust Pose

Viparita Shalabhasana

(vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Also Known As: Full Locust Pose (Purna Shalabhasana)
Modification: arms straight on the floor, palms down; feet to the head
Pose Type: prone, backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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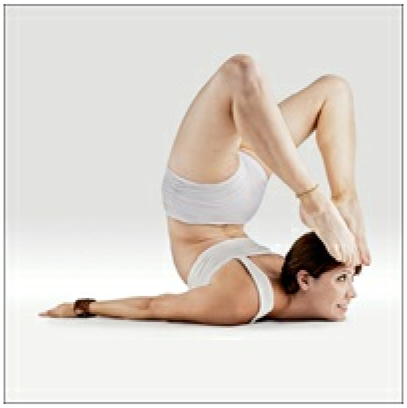

Formidable Face Pose

Ganda Bherundasana

(GUHN-duh bey-run-DAHS-uh-nuh)

Modification: feet to the head, grabbing onto both feet, chin off the floor

Pose Type: prone, backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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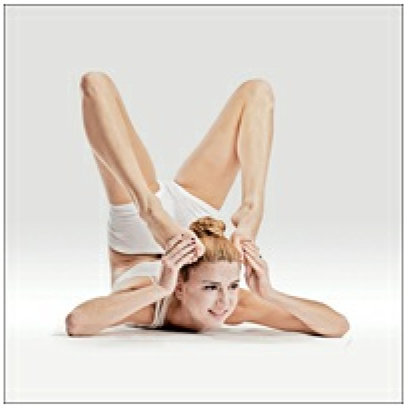

CHIN ON THE FLOOR: FULL LOTUS

Inverted Lotus Peacock Pose

Viparita Padma Mayurasana

(vi-puh-REE-tuh PUHD-muh muh-yoor-AHS-uh-nuh)

Pose Type: prone, backbend, inversion

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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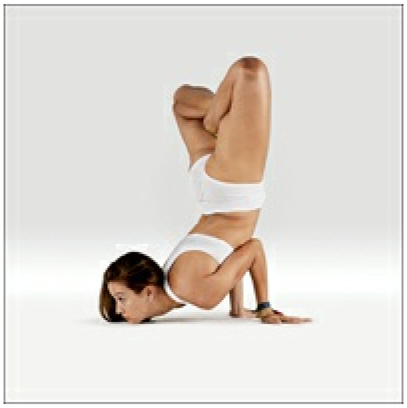

Inverted Locust Pose with Lotus Legs

Padma Viparita Shalabhasana

(PUHD-muh vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Pose Type: prone, backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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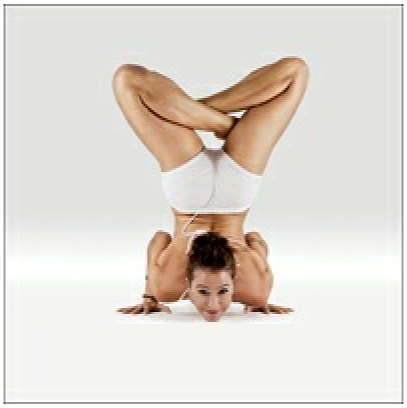

CHEST ON THE FLOOR: FEET TO THE FLOOR

Inverted Locust Pose

Viparita Shalabhasana

(vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)
Modification: arms straight on the floor, palms down; feet toward the floor over the head, legs bent
1. heels up
2. heels down
Pose Type: prone, backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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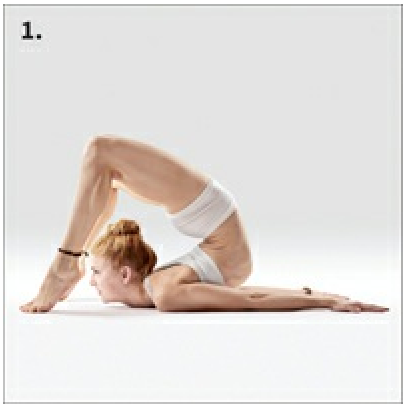

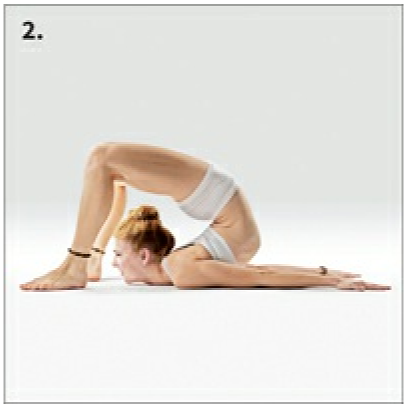

2.

Formidable Face Pose

Ganda Bherundasana

(GUHN-duh bey-run-DAHS-uh-nuh)

Modification: feet on the floor, grabbing onto both ankles, chin off the floor
Pose Type: prone, backbend, inversion
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

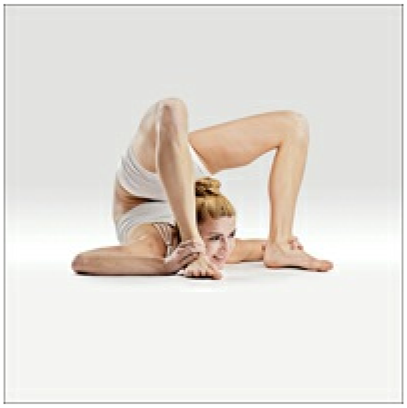

CHEST AND KNEES ON THE FLOOR: KNEES UNDER THE HIPS

Intense Extended Puppy Dog Pose

Uttana Shvanakasana

(ut-TAHN-uh shvuh-nuh-KAHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification), Extended Dog Pose (Utthita Shvanasana)
Modification: 1. palms down to the floor 2. grabbing onto the heels
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

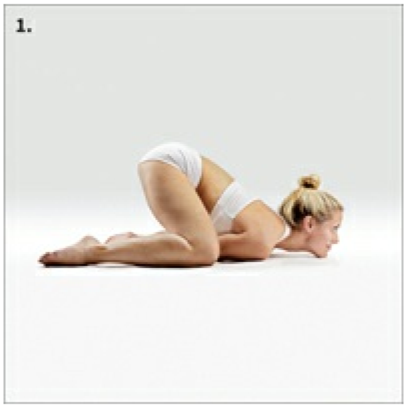
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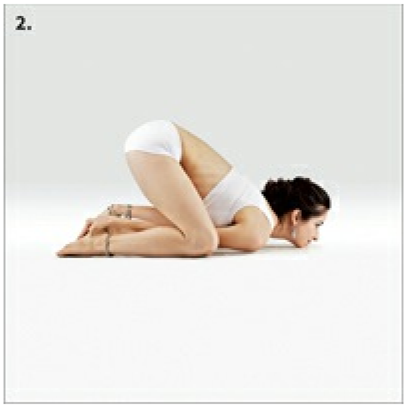
2.

Intense Extended Puppy Dog Pose

Uttana Shvanakasana

(ut-TAHN-uh shvuh-nuh-KAHS-uh-nuh)

Also Known As: Prayer Heart Pose (Namaskar Anahatasana), Extended Dog Pose (Utthita Shvanasana)
Modification: thumbs to the upper back
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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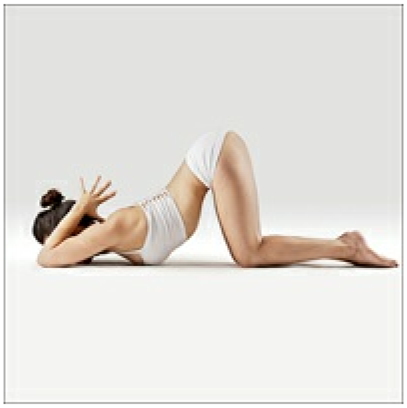

Water Grove Pose

Nirakunjasana

(neer-uh--kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)

Modification: arms in front, elbows bent; palms together; chin off the floor; heels toward the sitting bones

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angushtamadhye or Angushta Ma Dyai (thumbs)

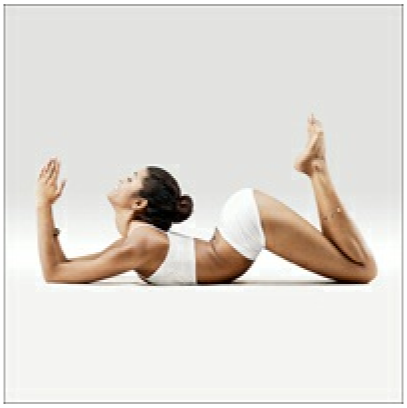

Hands Bound Water Grove Pose

Baddha Hasta Nirakunjasana

(BUH-duh HUH-stuh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)

Modification: heels toward the sitting bones

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

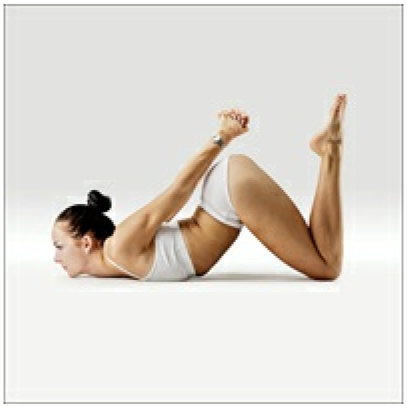

Pose Dedicated to Goddess Arani Prep.

Aranyasana Prep.

(uh-rah-NYAHS-uh-nuh)

Also Known As: Dragon Pose

Modification: 1. hands underneath the shoulders, elbows tucked in
2. arms reaching toward the knees, palms up

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

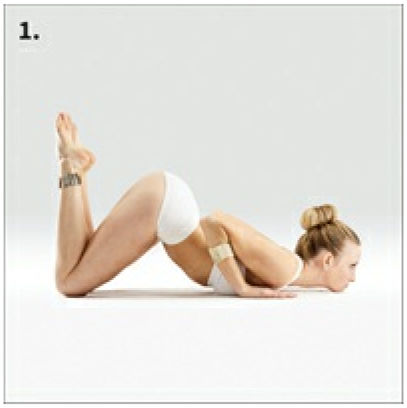

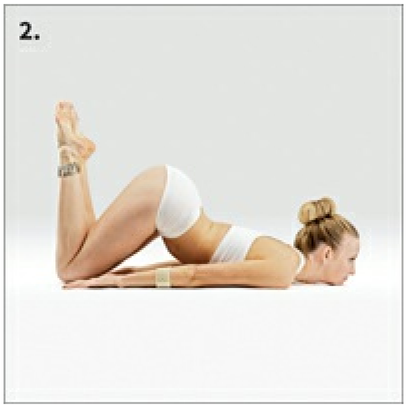

Pose Dedicated to Goddess Arani

Aranyasana

(uh-rah-NYAHS-uh-nuh)

Also Known As: Dragon Pose

Modification: 1. grabbing onto the shins
2. grabbing onto the hamstrings

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

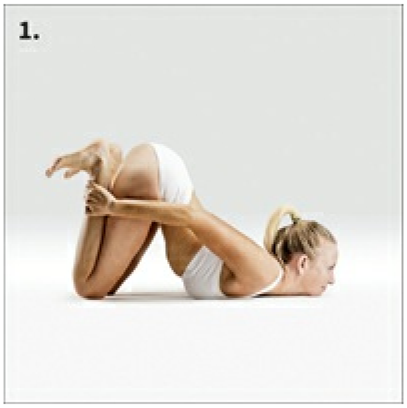

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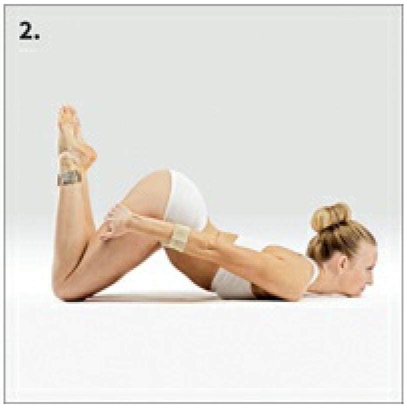

2.

CHEST AND KNEES ON THE FLOOR: KNEES UNDER THE HIPS—HALF LOTUS

Intense Extended Puppy Dog Pose

Uttana Shvanakasana

(ut-TAHN-uh shvuh-nuh-KAHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification), Extended Dog Pose (Utthita Shvanasana)
Modification: arms extended to the front
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angushtamadhye or Angushta Ma Dyai (thumbs)

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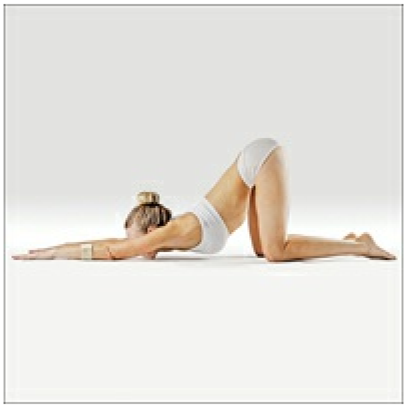

Half Lotus Intense Extended Puppy Dog Pose

Ardha Padma Uttana Shvanakasana

(UHR-duh PUHD-muh ut-TAHN-uh shvuh-nuh-KAHS-uh-nuh)

Also Known As: Half Lotus Heart Pose (Ardha Padma Anahatasana), Half Lotus Extended Dog Pose (Ardha Padma Utthita Shvanasana)
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angushtamadhye or Angushta Ma Dyai (thumbs)

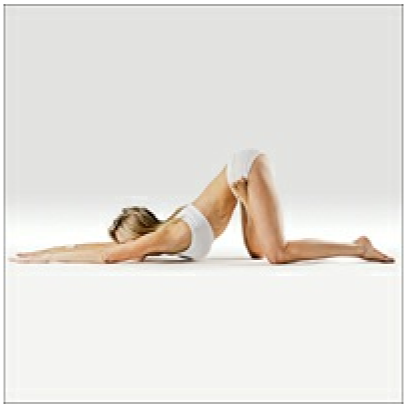

Half Bound Lotus Intense Extended Puppy Dog Pose

Ardha Baddha Padma Uttana Shvanakasana

(UHR-duh BUH-duh PUHD-muh ut-TAHN-uh shvuh-nuh-KAHS-uh-nuh)

Also Known As: Half Bound Lotus Heart Pose (Ardha Baddha Padma Anahatasana), Half Bound Lotus Extended Dog Pose (Ardha Baddha Padma Utthita Shvanasana)
Pose Type: prone, backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angushtamadhye or Angushta Ma Dyai (thumbs)

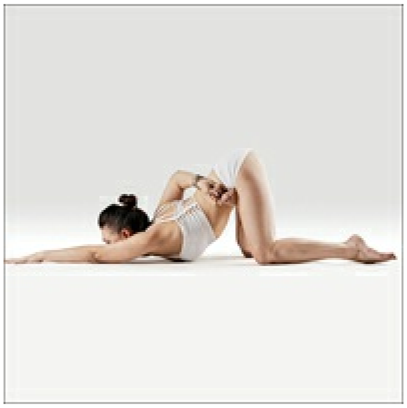

Lotus Intense Extended Puppy Dog Pose

Padma Uttana Shvanakasana

(PUHD-muh ut-TAHN-uh shvuh-nuh-KAHS-uh-nuh)

Also Known As: Lotus Heart Pose (Padma Anahatasana), Lotus Extended Dog Pose (Padma Utthita Shvanasana)
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angushtamadhye or Angushta Ma Dyai (thumbs)
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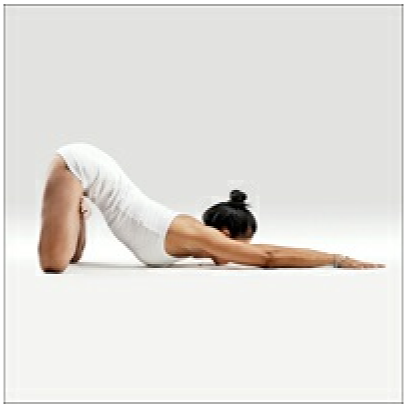

Upward Hands Bound Lotus Pose in Pose Dedicated to Goddess Arani

Urdhva Baddha Hasta Padmasana in Aranyasana

(OORD-vuh BUH-duh HUH-stuh puhd-MAHS-uh-nuh in uh-rah-NYAHS-uh-nuh)

Also Known As: Dragon Pose, Upward Bound Hand Lotus Heart Pose (Urdhva Baddha Hasta Padma Anahatasana)
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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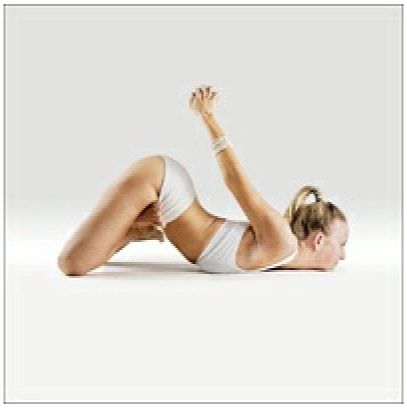

Feet Spread Wide Pose in Inverted Locust Pose

Prasarita Padottanasana in Viparita Shalabhasana

(pruh-SAH-ri-tuh puh-do-tahn-AHS-uh-nuh in vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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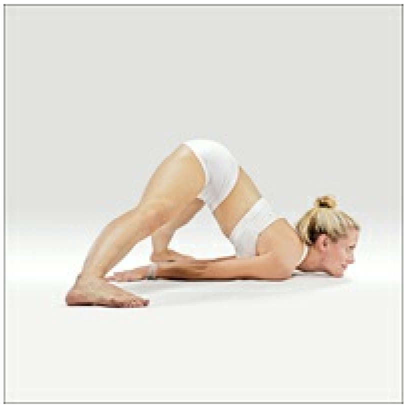

CHEST AND KNEES ON THE FLOOR: KNEES BEHIND HIPS—ARMS IN FRONT AND BEHIND THE BACK

Water Grove Pose

Nirakunjasana

(neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)
Modification: arms straight and crossed in front
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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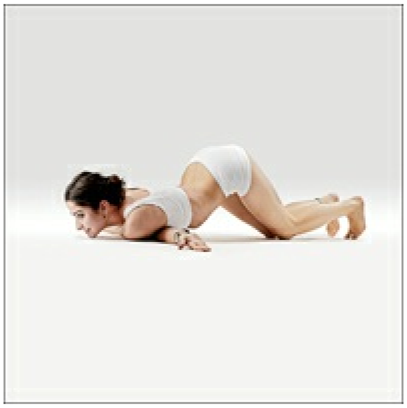

Water Grove Pose

Nirakunjasana

(neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)
Modification: chin and feet on the floor
1. knees on the floor
2. knees off the floor
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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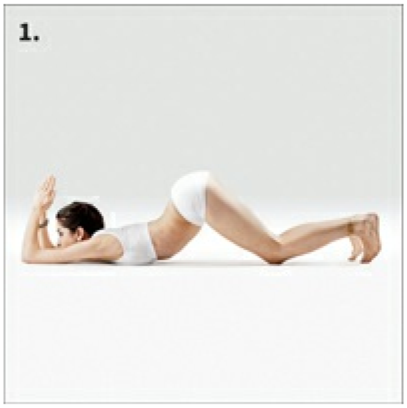

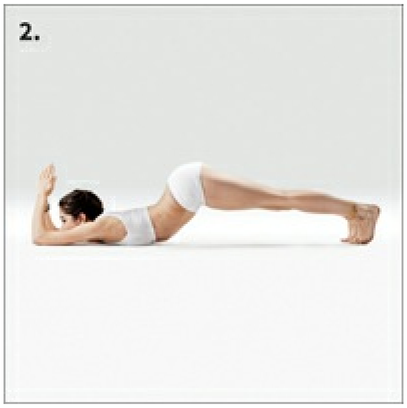

Eight Limbs Pose

Ashtangasana

(uhsh-tahng-AHS-uh-nuh)

Also Known As: Eight Point Bow Pose (Ashtanga Namaskara)
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

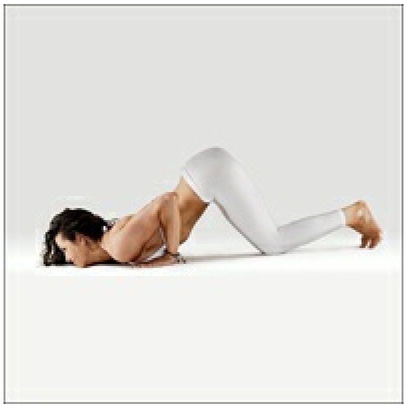

Reverse Prayer Water Grove Pose

Viparita Namaskar Nirakunjasana

(vi-puh-REE-tuh nuh-muhs-KAHR neer-uh-kunj-AHS-uh-nuh)

Also Known As: Back of the Body Prayer Water Grove Pose (Paschima Namaskara Nirakunjasana), Heart Pose Modification
Modification: toes curled in
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

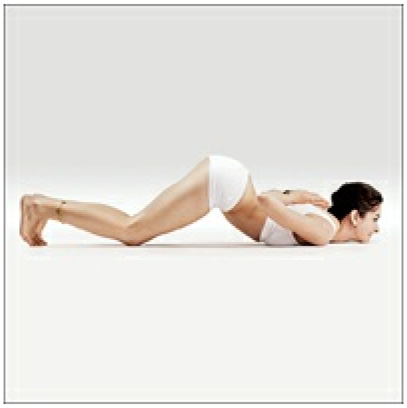

Hands Bound Water Grove Pose

Baddha Hasta Nirakunjasana

(BUH-duh HUH-stuh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)
Modification: 1. knees on the floor, toes pointed to the back
2. knees on the floor, toes curled in
3. knees off the floor
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

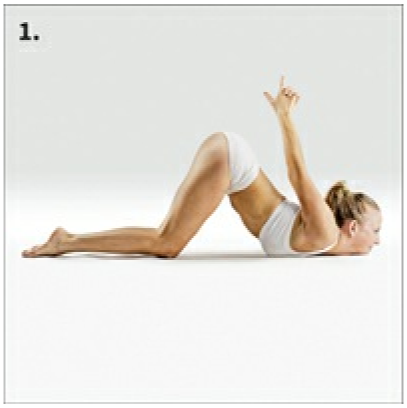

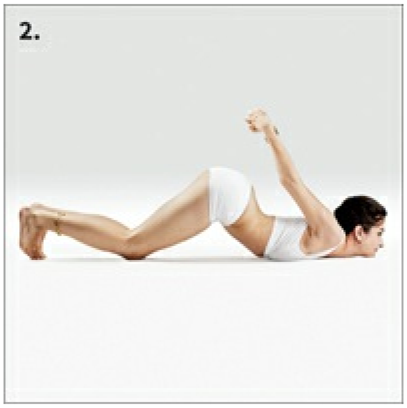

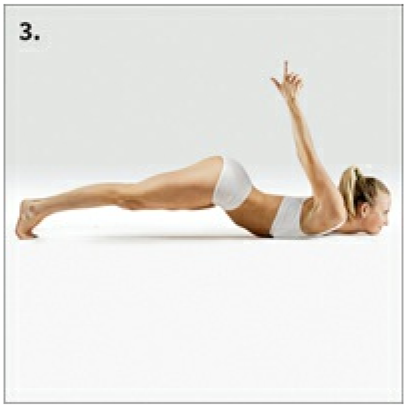

One-Legged Water Grove Pose

Eka Pada Nirakunjasana

(EY-kuh PUH-duh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)

Modification: 1. forearms on the floor, toes pointed

2. palms to the floor by the rib cage, elbows bent, toes curled in

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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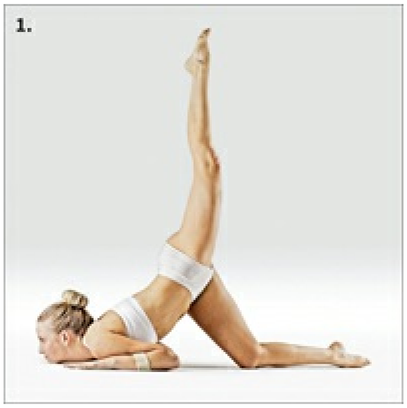

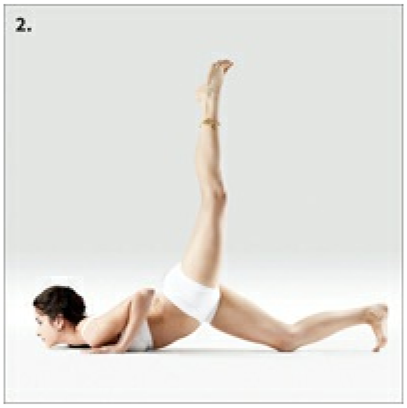

Hands Bound One-Legged Water Grove Pose

Baddha Hasta Eka Pada Nirakunjasana

(BUH-duh HUH-stuh EY-kuh PUHD-uh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

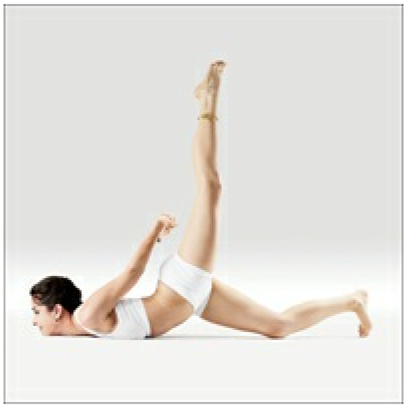

Reverse Prayer One-Legged Water Grove Pose

Viparita Namaskar Eka Pada Nirakunjasana

(vi-puh-REE-tuh nuh-muhs-KAHR EY-kuh PUH-duh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Back of the Body Prayer One-Legged Water Grove Pose (Paschima Namaskara Eka Pada Nirakunjasana), Heart Pose

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

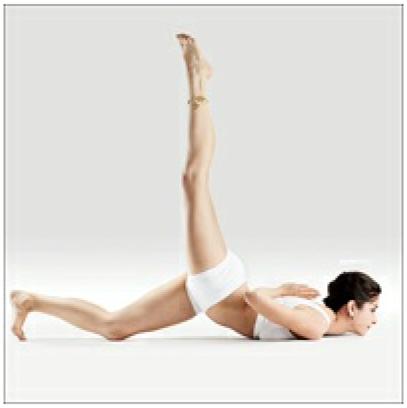

CHEST AND KNEES ON THE FLOOR: KNEES BEHIND HIPS—ONE LEG STRAIGHT AND LIFTED—BOTTOM KNEE BENT

One-Legged Inverted Locust Pose Prep.

Eka Pada Viparita Shalabhasana Prep.

(EY-kuh PUH-duh vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Modification: forearms on the floor, knee of straight leg resting on the foot of the bottom leg

Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

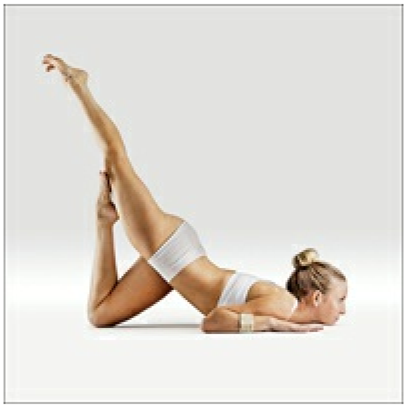

Revolved One-Legged Inverted Locust Pose Prep.

Parivritta Eka Pada Viparita Shalabhasana Prep.

(puh-ri-VRIT-tuh EY-kuh PUH-duh vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Modification: bottom leg bent, top leg straight, top knee resting on the sole of the bottom foot
Pose Type: forward bend, twist
Drishti Point: 1. Urdhva or Antara Drishti (up to the sky)
2. Hastagrai or Hastagre (hands)

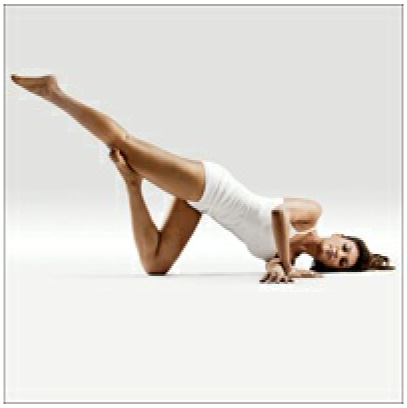

Upward Bound Hands One-Legged Inverted Locust Pose

Urdhva Baddha Hasta Eka Pada Viparita Shalabhasana

(OORD-vuh BUH-duh HUH-stuh EY-kuh PUH-duh vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Also Known As: Flying Locust Pose (Uddayate Shalabhasana)
Modification: 1. knee of the straight leg resting on the foot of the bottom leg
2. bottom foot away from the top leg
Pose Type: prone, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

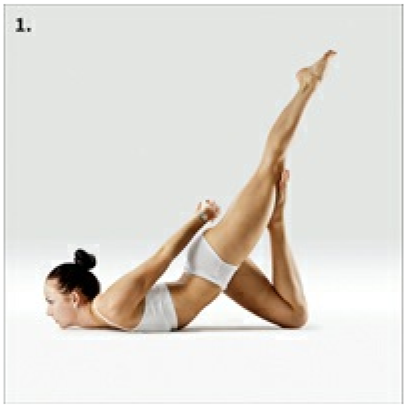
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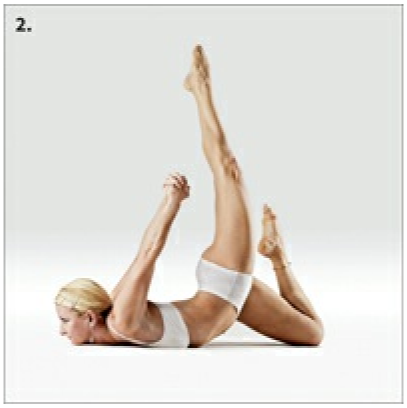
2.

CHEST AND KNEES ON THE FLOOR: KNEES BEHIND HIPS—BOTH LEGS BENT—ARMS IN FRONT

One-Legged Water Grove Pose

Eka Pada Nirakunjasana

(EY-kuh PUH-duh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)
Modification: both knees bent; arms straight out in front, palms down
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angushtamadhye or Angushta Ma Dyai (thumbs)

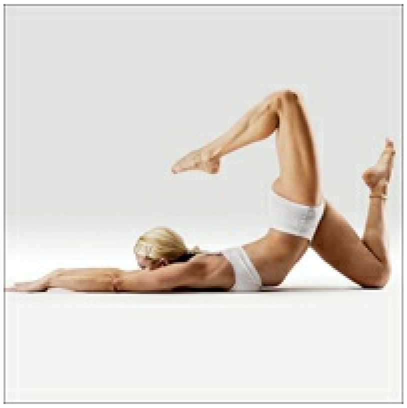

Half Bow Pose in One-Legged Water Grove Pose

Ardha Dhanurasana in Eka Pada Nirakunjasana

(IUHR-duh duh-nur-AHS-uh-nuh in EY-kuh PUH-duh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)
Modification: 1. right front side view
2. right back side view
Pose Type: backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Angushtamadhye or Angushta Ma Dyai (thumbs)
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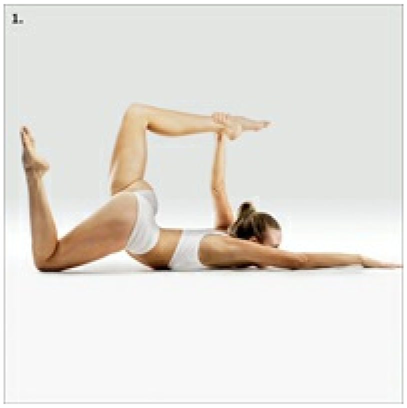

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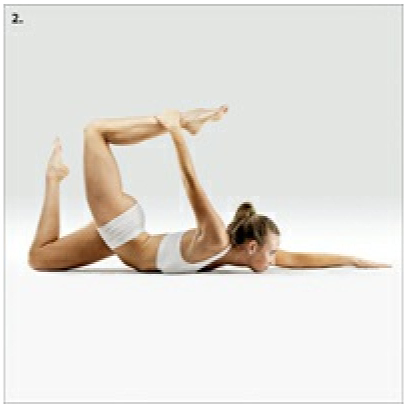

One-Legged Water Grove Pose

Eka Pada Nirakunjasana

(EY-kuh PUH-duh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)
Modification: both knees bent
1. arms straight to the back, palms down
2. arms lifted off the floor
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

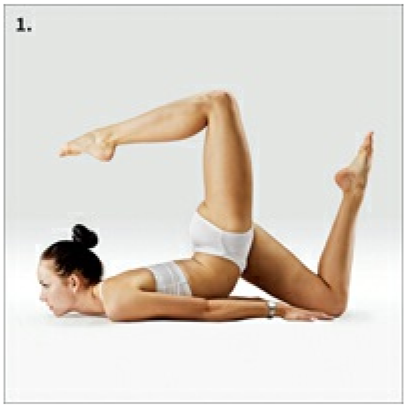

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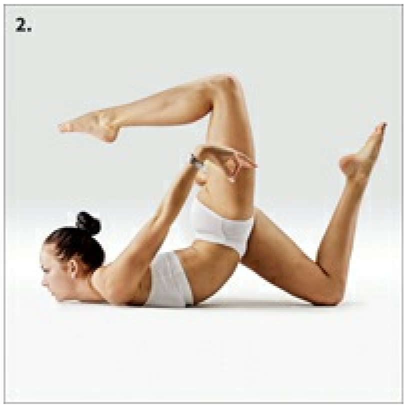

2.

Bow Pose in One-Legged Water Grove Pose

Dhanurasana in Eka Pada Nirakunjasana

(duh-nur-AHS-uh-nuh in EY-kuh PUH-duh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)
Modification: both hands grabbing the top foot with under-head grip; the knee of the bottom leg on the floor, toes pointing to the sky
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

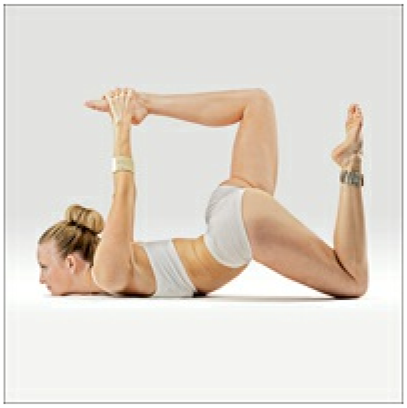

Half Bow Pose in One-Legged Water Grove Pose

Ardha Dhanurasana in Eka Pada Nirakunjasana

(UHR-duh duh-nur-AHS-uh-nuh in EY-kuh PUH-duh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)

Modification: grabbing onto the foot on the opposite side, under-head grip; other hand to the lower back, palm up

Pose Type: prone, backbend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

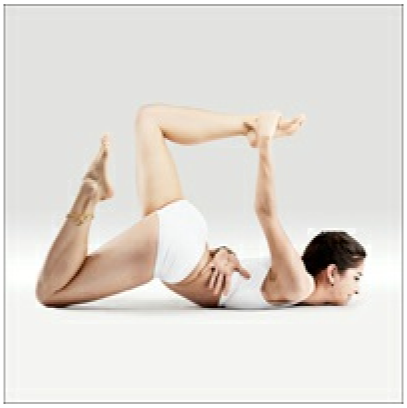

CHEST AND KNEES ON THE FLOOR: KNEES BEHIND HIPS—BOTTOM KNEE BENT—OVERHEAD GRIP

Big Toe Bow Pose in One-Legged Water Grove Pose

Padangushta Dhanurasana in Eka Pada Nirakunjasana

(puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh in EY-kuh PUH-duh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)

Pose Type: prone, backbend

Drishti Point: Padayoragrai or Padayoragre (toes/feet), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

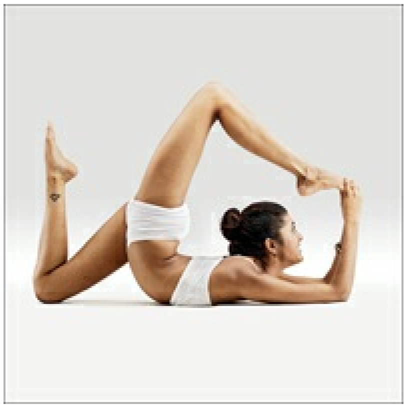

One Leg to the Head Water Grove Pose

Eka Pada Shirsha Nirakunjasana

(EY-kuh PUH-duh SHEER-shuh neer-uh-kunj-AHS-uh-nuh)

Also Known As: Heart Pose (Anahatasana Modification)
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

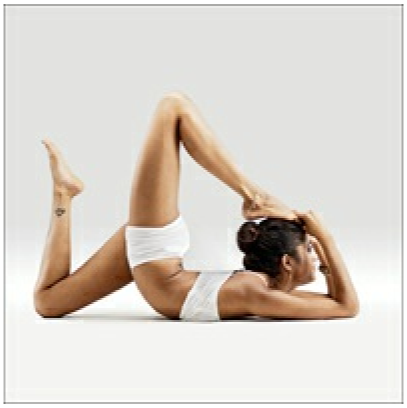

CHEST AND KNEES ON THE FLOOR: KNEES BEHIND HIPS—BOTTOM KNEE BENT—UNDER-HEAD & OVERHEAD GRIP

One-Legged Inverted Locust Pose

Eka Pada Viparita Shalabhasana

(EY-kuh PUH-duh vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Modification: one palm to the floor at the bottom of the ribs, other arm straight, palm down; both

knees bent, knee of the top leg resting on the foot of the bottom leg
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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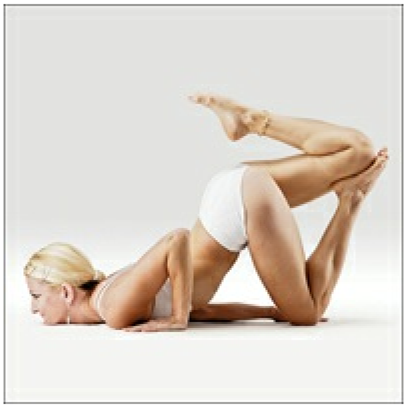

One Hand to Foot Inverted Locust Pose

Eka Hasta Pada Viparita Shalabhasana

(EY-kuh HUH-stuh PUH-duh vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Modification: grabbing onto the top foot with the opposite hand; other arm straight, palm down to the floor; both knees bent, knee of the top leg resting on the foot of the bottom leg
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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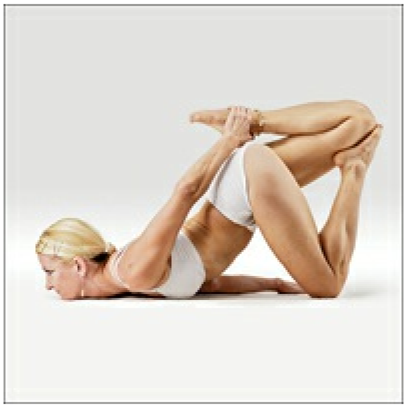

Both Hands to One Foot Inverted Locust Pose

Dwi Hasta Eka Pada Viparita Shalabhasana

(DWI-huh-stuh EY-kuh PUH-duh vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Modification: both hands grabbing the top foot with under-head grip; top knee resting on the sole of the bottom foot

Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

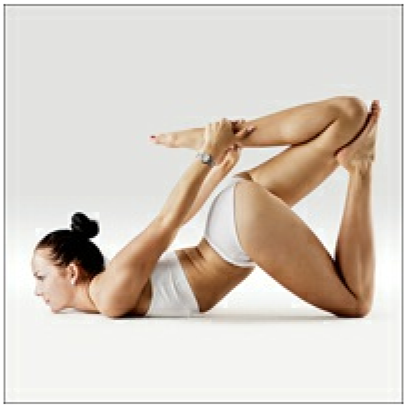

One Foot to the Shoulder Inverted Locust Pose

Eka Pada Bhuja Viparita Shalabhasana

(EY-kuh PUH-duh buj-uh vi-puh-REE-tuh shuh-luh-BAHS-uh-nuh)

Modification: grabbing onto the toes of the top foot; the quadriceps of the top leg resting on the sole of the bottom foot
Pose Type: prone, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

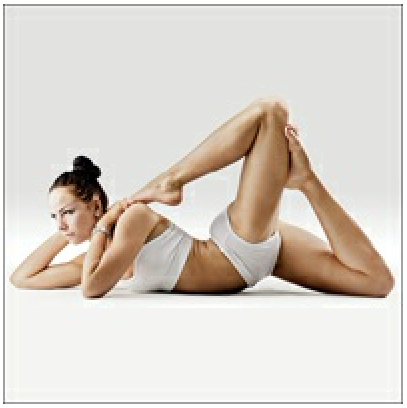

Supine Poses

SHOULDER ON THE FLOOR

TRICEPS ON THE FLOOR

ELBOW ON THE FLOOR

FOREARM ON THE FLOOR

EASTERN INTENSE STRETCH

BRIDGE POSES

HEAD AND SITTING BONES ON THE FLOOR

BOUND ANGLE POSE

KNEES BENT

HAPPY BABY POSE

ONE AND BOTH FEET BEHIND HEAD

HORIZONTAL SPLITS

ONE KNEE BENT TO THE BACK (VARIATIONS)

VERTICAL SPLITS

BOTH LEGS STRAIGHT AND TOGETHER

SUPINE LOTUS AND CORPSE POSE

Sideways Wind Relieving Pose

Parshva Vayu Muktyasana

(PAHRSH-vuh VAH-yu muk-TYAHS-uh-nuh)

Modification: palms together in front of the face, knees together
Pose Type: supine (on the side)
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

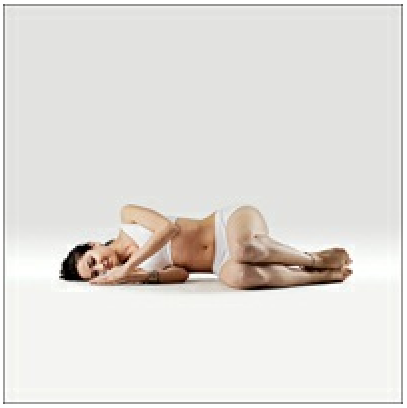

Arms Raised Sideways Wind Relieving Pose

Urdhva Hasta Parshva Vayu Muktyasana

(OORD-vuh HUH-stuh PAHRSH-vuh VAH-yu muk-TYAHS-uh-nuh)

Pose Type: supine (on the side)
Drishti Point: Urdhva or Antara Drishti (up to the sky)

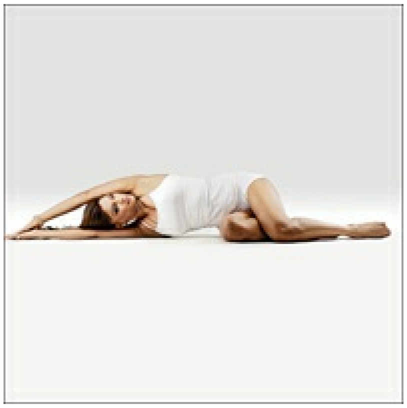

Sideways Wind Relieving Pose

Parshva Vayu Muktyasana

(PAHRSH-vuh VAH-yu muk-TYAHS-uh-nuh)

Modification: bottom leg straight; top knee bent, foot to the knee of the straight leg

Pose Type: supine (on the side)

Drishti Point: Nasagrai or Nasagre (nose)

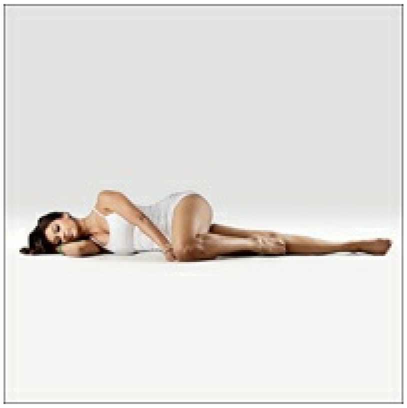

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose

Modification: top leg lifted in front of the body, bottom leg straight

Pose Type: supine (on the side), forward bend

Drishti Point: Nasagrai or Nasagre (nose), Padayoragrai or Padayoragre (toes/feet)

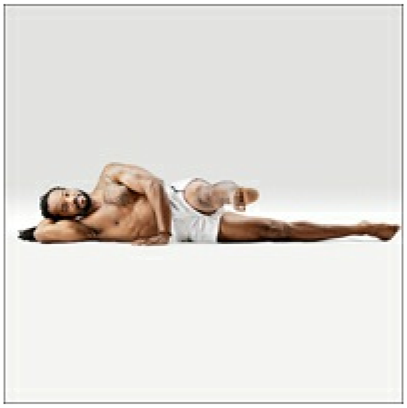

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose

Modification: top leg straight and lifted; bottom leg bent, toes pointing to the back
Pose Type: supine (on the side)
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

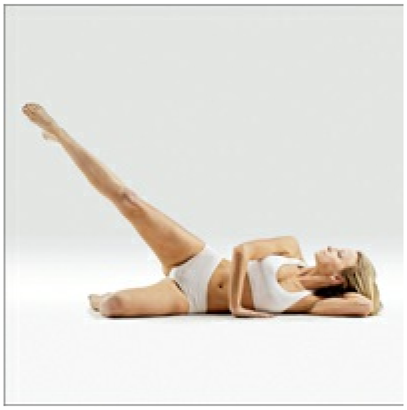

SHOULDER ON THE FLOOR: TWISTS AND BINDING

Svastika Legs in Twisted Stomach Pose

Pada Svastikasana in Jatara Parivartanasana

(PUH-duh svuh-sti-KAHS-uh-nuh in JAH-tuh-ruh puh-ri-vuhrt-ahn-AHS-uh-nuh)
Modification: grabbing onto the back foot, heel toward the glutes
Pose Type: supine (on the side), twist
Drishti Point: Hastagrai or Hastagre (hands)

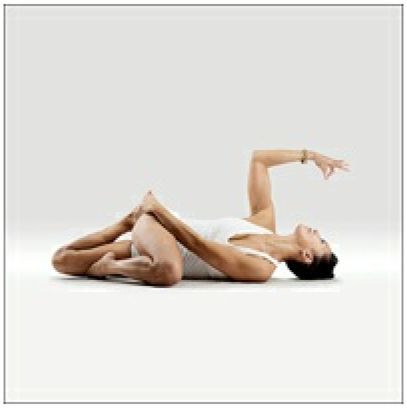

Revolved One-Legged King Pigeon Pose 1

Parivritta Eka Pada Raja Kapotasana 1

(puh-ri-VRIT-tuh EY-kuh PUH-duh RAH-juh kuh-po-TAHS-uh-nuh)
Modification: back knee bent, both hands to the back foot; front foot to hip socket

Pose Type: supine (on the side), twist
Drishti Point: Urdhva or Antara Drishti (up to the sky)

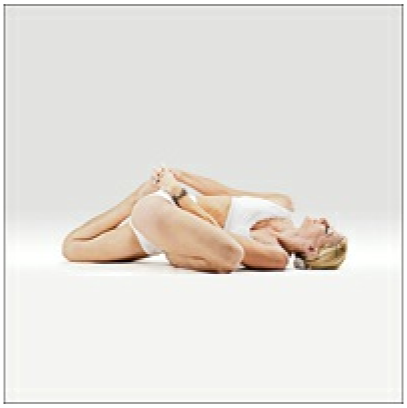

One-Legged Bound Infinity Pose

Eka Pada Baddha Anantasana

(EY-kuh PUH-duh BUH-duh uhn-uhnt-AHS-uh-nuh)

Also Known As: One-Legged Bound Sleeping Vishnu Pose
Modification: bottom leg bent, heel toward the glutes; top leg bent
Pose Type: supine (on the side), twist, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

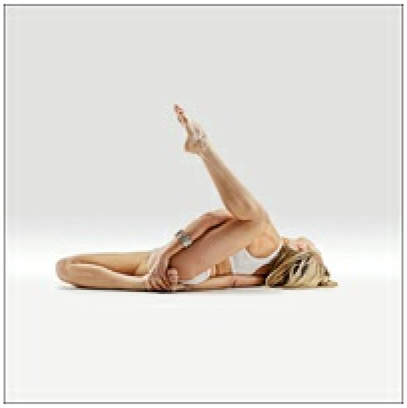

SHOULDER ON THE FLOOR: HALF LOTUS BACKBEND—UNDER-HEAD & OVERHEAD GRIP

Sideways Half Lotus Bow Pose

Parshva Ardha Padma Dhanurasana

(PAHRSH-vuh UHR-duh PUHD-muh duh-nur-AHS-uh-nuh)

Modification: grabbing onto the bottom foot with both hands with under-head grip

Pose Type: supine (on the side), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

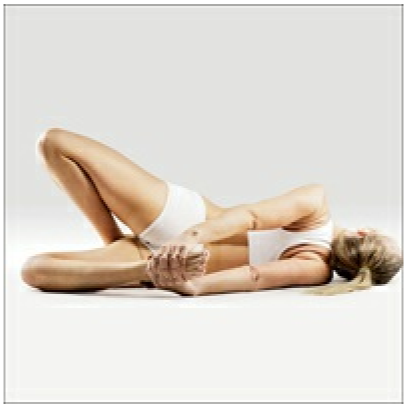

Sideways Half Lotus One-Handed Big Toe Bow Pose

Parshva Ardha Padma Eka Hasta Padangushta Dhanurasana

(PAHRSH-vuh UHR-duh PUHD-muh EY-kuh HUH-stuh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: grabbing onto the bottom foot with overhead grip on the same side, top arm straight, fingertips to the sky
Pose Type: supine (on the side), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

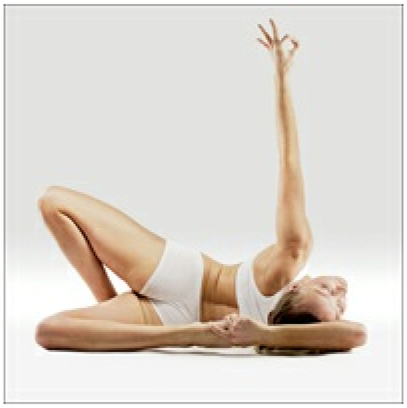

Sideways Half Lotus Two-Handed Big Toe Bow Pose

Parshva Ardha Padma Dwi Hasta Padangushta Dhanurasana

(PAHRSH-vuh UHR-duh PUHD-muh DWI-huh-stuh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh)

Modification: overhead grip, both hands grabbing onto the foot
Pose Type: supine (on the side), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

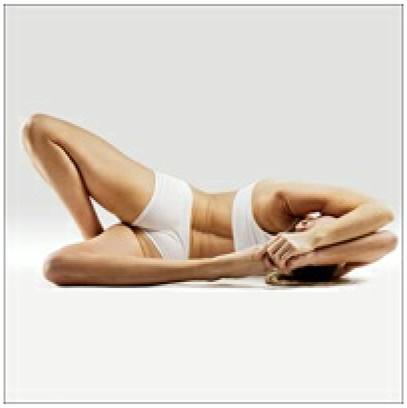

SHOULDER ON THE FLOOR: FOOT TO THE THIGH, HALF LOTUS & LOTUS

Mermaid Pose in Infinity Pose

Naginyasana in Anantasana

(nuh-gin-YAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Mermaid Pose in Sleeping Vishnu Pose
Pose Type: supine (on the side), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

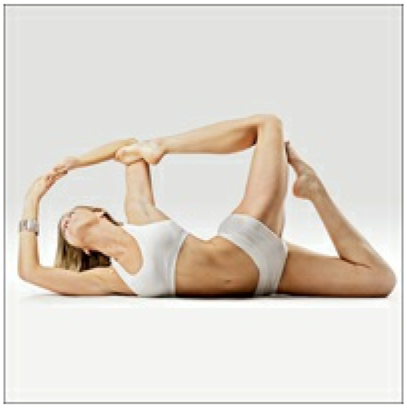

Sideways Half Lotus Bow Pose

Parshva Ardha Padma Dhanurasana

(PAHRSH-vuh UHR-duh PUHD-muh duh-nur-AHS-uh-nuh)

Modification: grabbing onto the top foot with the bottom hand; grabbing onto the bottom foot with top hand
1. front view
2. back view

Pose Type: supine (on the side), backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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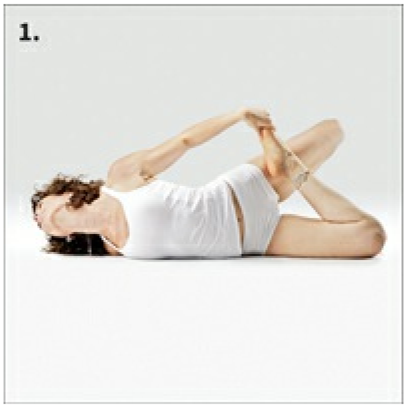

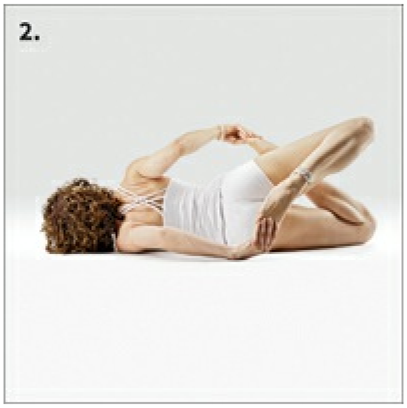

Hands Bound Lotus Pose in Infinity Pose

Baddha Hasta Padmasana in Anantasana

(BUH-duh HUH-stuh puhd-MAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Hands Bound Lotus Pose in Sleeping Vishnu Pose

Pose Type: supine (on the side), mild backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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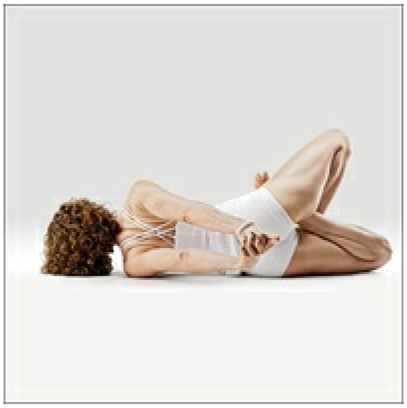

Hands Bound Infinity Pose

Baddha Hasta Anantasana

(BUH-duh HUH-stuh uhn-uhnt-AHS-uh-nuh)

Also Known As: Hands Bound Sleeping Vishnu Pose

Modification: 1. bottom leg bent, top leg straight and lifted; resting on the arms and the bent knee for support
2. bottom leg straight, top leg straight and lifted; arms lifted off the floor

Pose Type: supine (on the side), backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

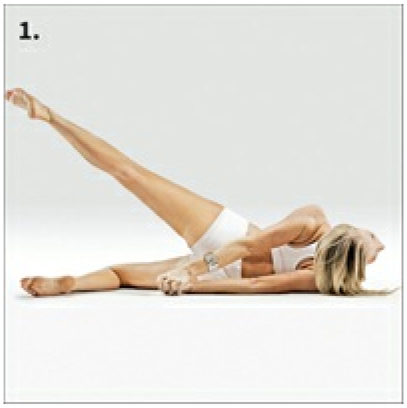

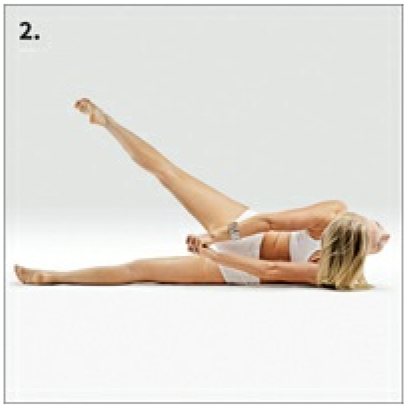

Hands Bound Half Lotus Pose in Infinity Pose

Baddha Hasta Ardha Padmasana in Anantasana

(BUH-duh HUH-stuh UHR-duh puhd-MAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Hands Bound Half Lotus Pose in Sleeping Vishnu Pose

Modification: 1. front view
2. back view

Pose Type: supine (on the side), backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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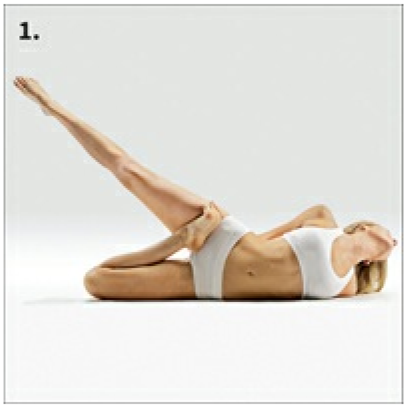

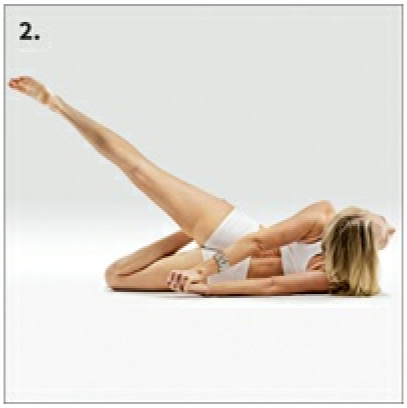

TRICEPS ON THE FLOOR: HAND TO THE HEAD—LEGS TOGETHER & LEGS APART

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose
Modification: both legs straight and together; bottom leg on the floor
Pose Type: supine (on the side), side bend
Drishti Point: Padhayoragrai or Padayoragre (toes/feet)
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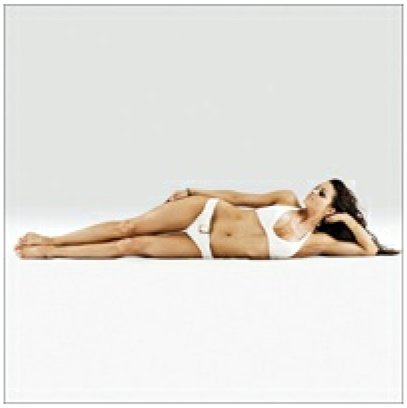

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose
Modification: legs straight, together and lifted off the floor
Pose Type: supine (on the side), core, side bend
Drishti Point: Nasagrai or Nasagre (nose)

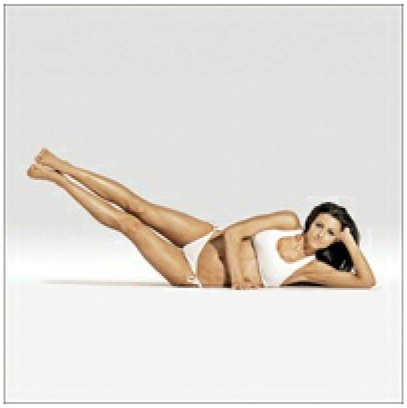

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose
Modification: both legs straight, top leg lifted, bottom leg on the floor
Pose Type: supine (on the side), core, side bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Urdhva or Antara Drishti (up to the sky)

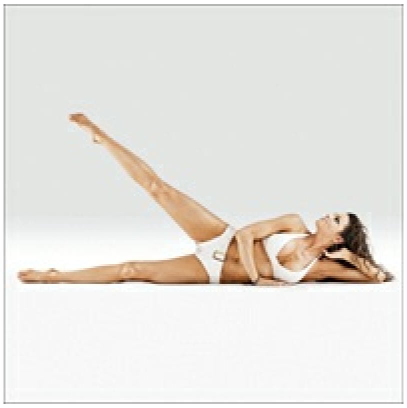

Extended Hand to Big Toe Pose in Infinity Pose

Utthita Hasta Padangushtasana in Anantasana

(UT-ti-tuh HUH-stuh puhd-ahng-goosh-TAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Extended Hand to Big Toe Pose in Sleeping Vishnu Pose
Pose Type: supine (on the side), forward bend, side bend
Drishti Point: Nasagrai or Nasagre (nose)

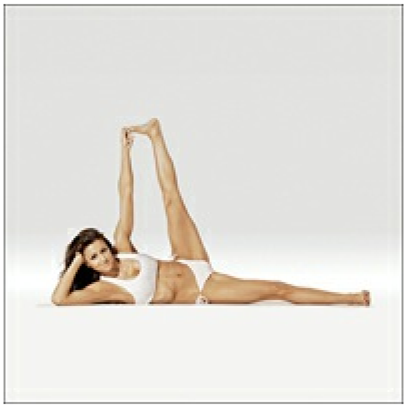

Sundial Pose in Infinity Pose

Surya Yantrasana in Anantasana

(SOOR-yuh yuhn-TRAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Sundial Pose in Sleeping Vishnu Pose
Modification: 1. grabbing onto the heel on the outside of the calf
2. grabbing onto the heel on the inside of the calf
Pose Type: supine (on the side), forward bend, side bend
Drishti Point: Nasagrai or Nasagre (nose)

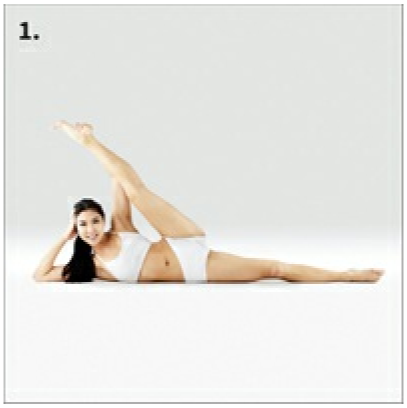

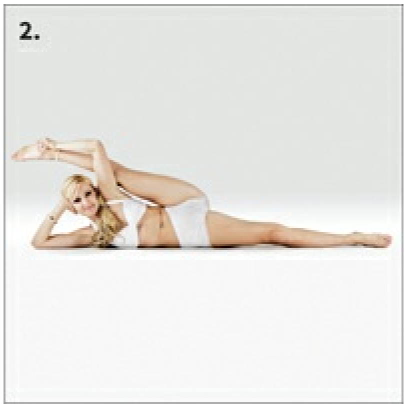

TRICEPS ON THE FLOOR: BOTH KNEES BENT

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose
Modification: top knee to the top shoulder; both knees bent
Pose Type: supine (on the side), forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Padhayoragrai or Padayoragre (toes/feet)
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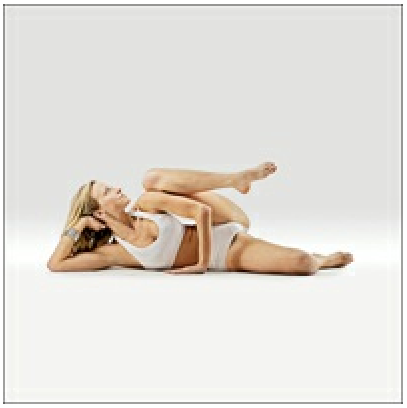

Bound Angle Pose in Infinity Pose

Baddha Konasana in Anantasana

(BUH-duh ko-NAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Bound Angle Pose in Sleeping Vishnu Pose
Modification: 1. top wrist on the top knee
2. top hand grabbing onto the top foot
Pose Type: supine (on the side), side bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Hastagrai or Hastagre (hands)
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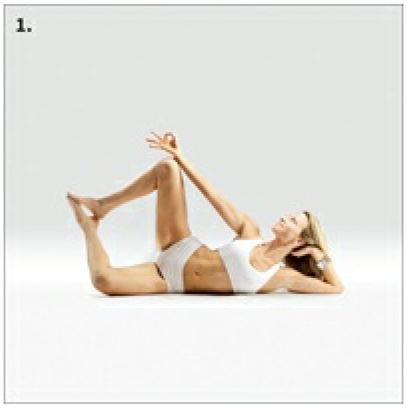

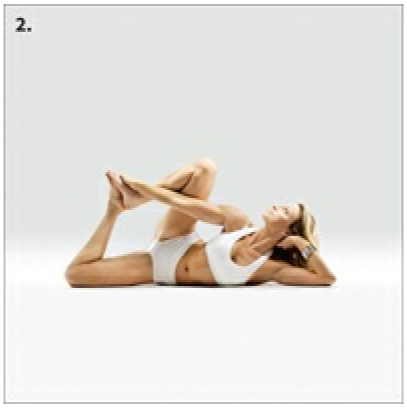

TRICEPS ON THE FLOOR: BOTTOM LEG STRAIGHT—BACKBENDS

Half Frog Pose Prep. in Infinity Pose

Ardha Bhekasana in Anantasana

(UHR-duh bey-KAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Half Frog Pose Prep. in Sleeping Vishnu Pose
Modification: hand in beginner modification; neutral spine, top leg moving into a half-frog leg position

Pose Type: supine (on the side), mild backbend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)
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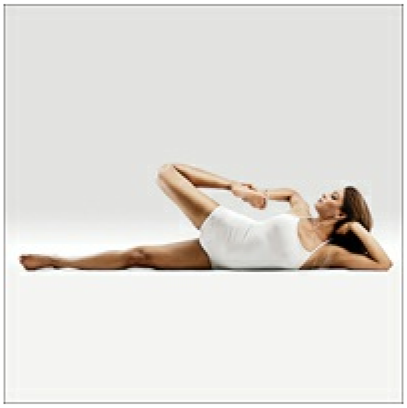

Half Bow Pose in Infinity Pose

Ardha Dhanurasana in Anantasana

(UHR-duh duh-nur-AHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)
Also Known As: Half Bow Pose in Sleeping Vishnu Pose
Pose Type: supine (on the side), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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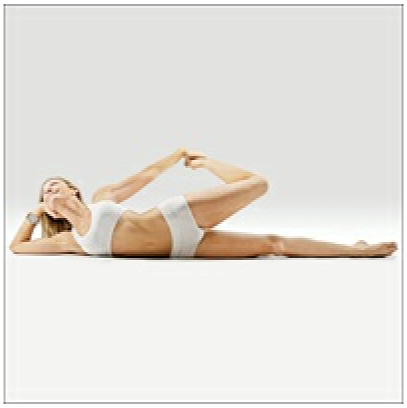

Half Big Toe Bow Pose in Infinity Pose

Ardha Padangushta Dhanurasana in Anantasana

(UHR-duh puhd-ahng-GOOSH-tuh duh-nur-AHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)
Also Known As: Half Big Toe Bow Pose in Sleeping Vishnu Pose
Pose Type: supine (on the side), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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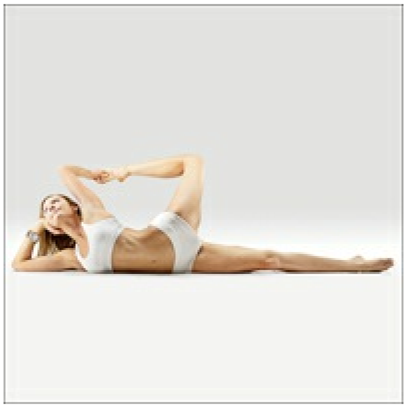

TRICEPS ON THE FLOOR: ONE LEG STRAIGHT, OTHER FOOT TO THE HIP SOCKET

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose
Modification: top foot to the hip socket, toes touching the floor; bottom leg straight on the floor
Pose Type: supine (on the side), side bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

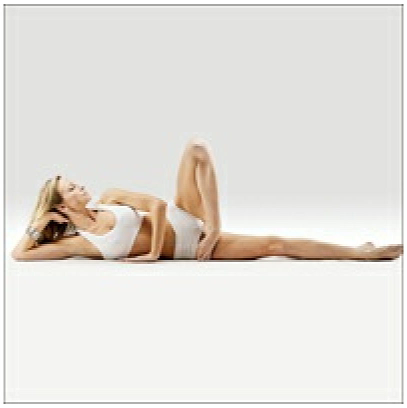

Half Lotus Pose in Infinity Pose

Ardha Padmasana in Anantasana

(UHR-duh puhd-MAHS-uh-nuh in anan-TAHS-annauhn-uhnt-AHS-uh-nuh)

Also Known As: Half Lotus Pose in Sleeping Vishnu Pose
Modification: bottom foot in half lotus, top leg lifted and straight
Pose Type: supine (on the side), side bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

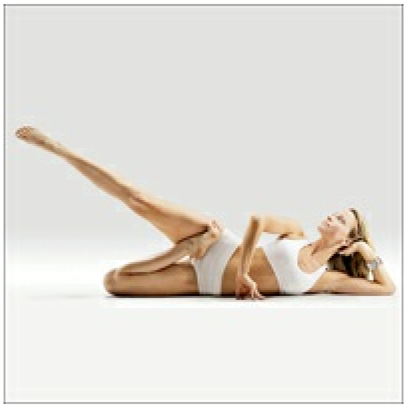

TRICEPS ON THE FLOOR: HALF LOTUS & FULL LOTUS

Half Lotus Mermaid Pose in Infinity Pose

Ardha Padma Naginyasana in Anantasana

(UHR-duh PUHD-muh nuh-gin-YAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Half Lotus Mermaid Pose in Sleeping Vishnu Pose
Pose Type: supine (on the side), backbend, side bend
Drishti Point: Hastagrai or Hastagre (hands)

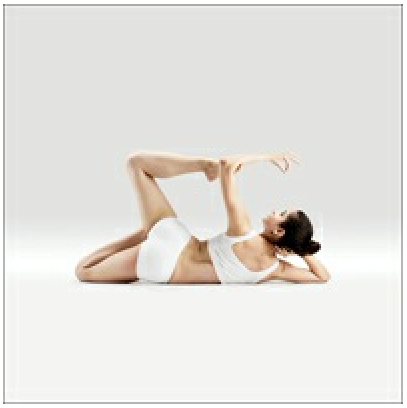

Lotus Pose in Infinity Pose

Padmasana in Anantasana

(puhd-MAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Lotus Pose in Sleeping Vishnu Pose
Pose Type: supine (on the side), side bend, knee, ankle opener
Drishti Point: Hastagrai or Hastagre (hands)

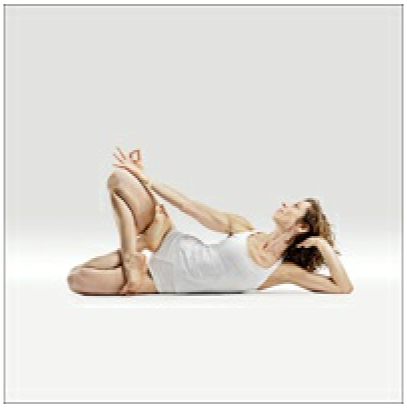

ELBOW ON THE FLOOR: BOTTOM LEG STRAIGHT, TOP LEG CROSSED OVER

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose
Modification: elbow to the floor, top knee bent, leg crossed over in front of the body; bottom leg straight
1. palm of the top hand on the floor
2. top hand on the top knee
Drishti Point: Urdhva or Antara Drishti (up to the sky)

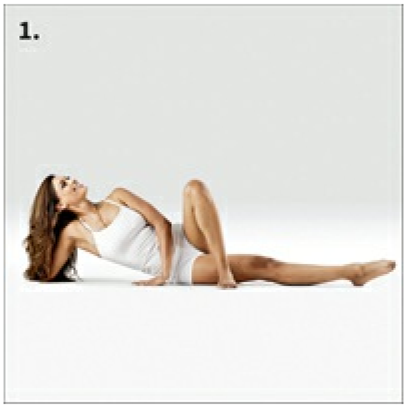

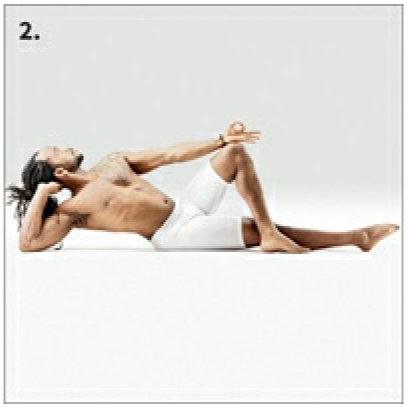

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose
Modification: elbow to the floor, hands in Anjali Mudra (Hands in Prayer); top knee bent, foot by the hip, bottom leg straight
1. bottom leg on the floor
2. bottom leg lifted off the floor
Pose Type: 1. supine (on the side), side bend
2. supine (on the side), side bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

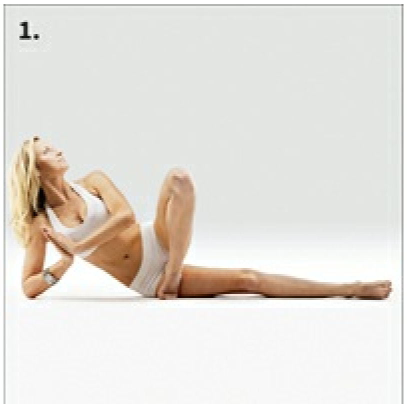

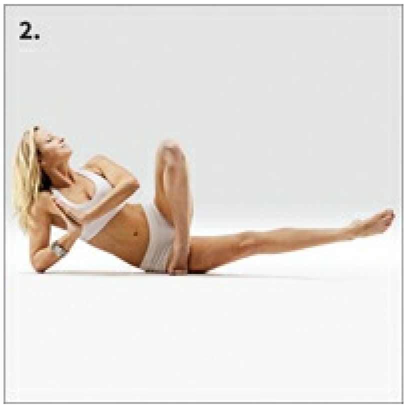

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose

Modification: top leg crossed over in front, toes on the floor; bottom leg bent, toes to the back; elbow to the floor, other arm straight fingertips to the sky

Pose Type: supine (on the side)

Drishti Point: Hastagrai or Hastagre (hands)

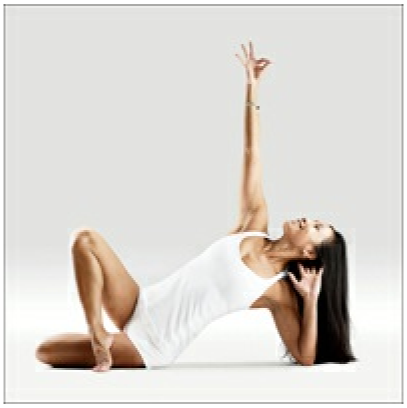

Half Lotus Pose in Infinity Pose

Ardha Padmasana in Anantasana

(UHR-duh puhd-MAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Half Lotus Pose in Sleeping Vishnu Pose

Modification: top leg in half lotus; bottom leg bent, heel to the sitting bone; elbow to the floor, other arm straight fingertips to the sky

Pose Type: supine (on the side)

Drishti Point: Hastagrai or Hastagre (hands)

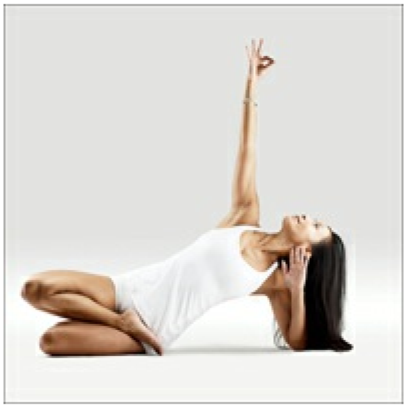

Leg Position of the Pose Dedicated to Garuda in Infinity Pose

Pada Garudasana in Anantasana

(PUH-duh guh-ru-DAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Leg Position of the Pose Dedicated to Garuda in Sleeping Vishnu Pose
Modification: elbow to the floor, hands behind the head
Pose Type: supine (on the side)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

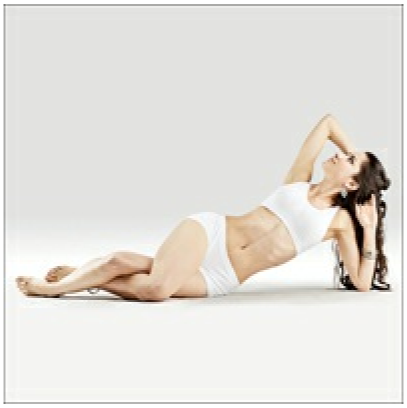

FOREARM ON THE FLOOR: ONE LEG CROSSED OVER & HALF LOTUS

Infinity Pose

Anantasana

(uhn-uhnt-AHS-uh-nuh)

Also Known As: Sleeping Vishnu Pose
Modification: top leg crossed over; forearm to the floor, top elbow resting on the top knee
Pose Type: supine (on the side)
Drishti Point: Hastagrai or Hastagre (hands)

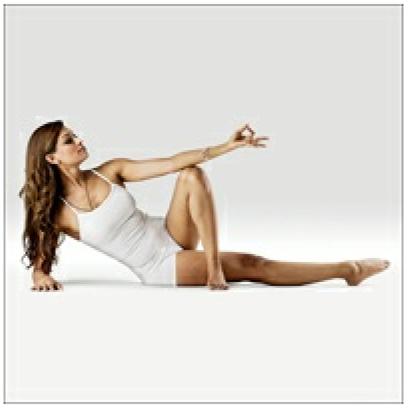

Extended Hand to Big Toe Half Cow Face Western Intense Stretch in Infinity Pose

Utthita Hasta Padangushta Ardha Gomukha Paschimottanasana in Anantasana

(UT-ti-tuh HUH-stuh puhd-ahng-GOOSH-tuh UHR-duh go-MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Extended Hand to Big Toe Half Cow Face Forward Bend in Infinity Pose, Extended Hand to Big Toe Half Cow Face Western Intense Stretch in Sleeping Vishnu Pose
Modification: forearm to the floor; top leg crossed over; grabbing onto the big toe of the bottom foot, leg off the floor
Pose Type: supine (on the side), forward bend
Drishti Point: Hastagrai or Hastagre (hands)

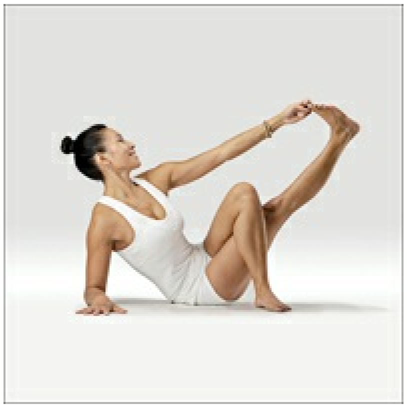

Half Lotus Pose in Infinity Pose

Ardha Padmasana in Anantasana

(UHR-duh puhd-MAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Also Known As: Half Lotus Pose in Sleeping Vishnu Pose
Modification: top foot to the bottom knee; top forearm to the top knee

Pose Type: supine (on the side), mild backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

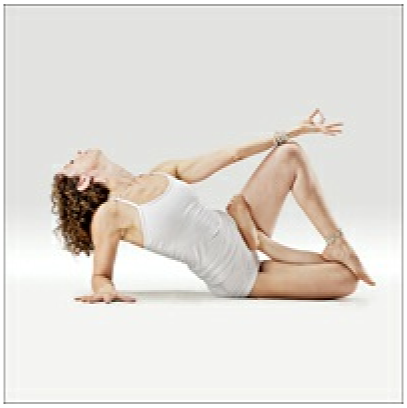

Half Lotus Extended Hand to Leg Pose in Infinity Pose

Ardha Padma Utthita Pada Hastasana in Anantasana

(UHR-duh PUHD-muh UT-ti-tuh PUH-duh huh-STAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)
Also Known As: Half Lotus Extended Hand to Leg Pose in Sleeping Vishnu Pose
Pose Type: supine (on the side), forward bend, mild backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

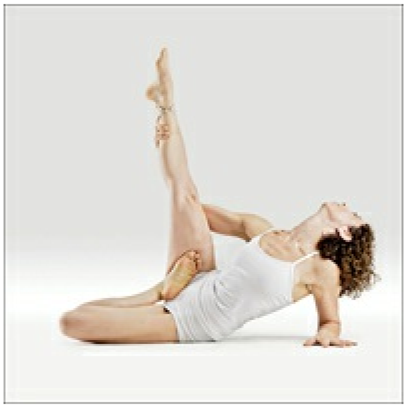

FOREARM ON THE FLOOR: TOP LEG STRAIGHT, BOTTOM FOOT TO THE THIGH

Half Bound Angle Pose in Infinity Pose

Ardha Baddha Konasana in Anantasana

(UHR-duh BUH-duh ko-NAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)
Also Known As: Half Bound Angle Pose in Sleeping Vishnu Pose
Modification: forearm to the floor

1. finger tips of the top arm to the floor in front of the abdomen, elbow bent
2. top arm straight and parallel to the top leg

Pose Type: supine (on the side), side bend

Drishti Point: Padayoragrai or Padayoragre (toes/feet), Hastagrai or Hastagre (hands)

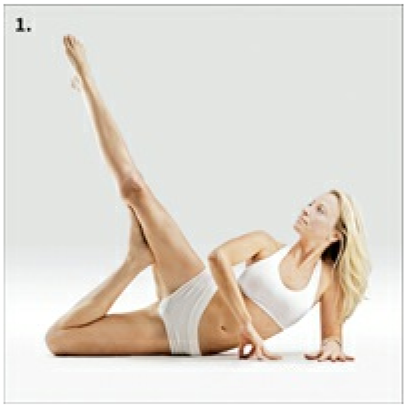

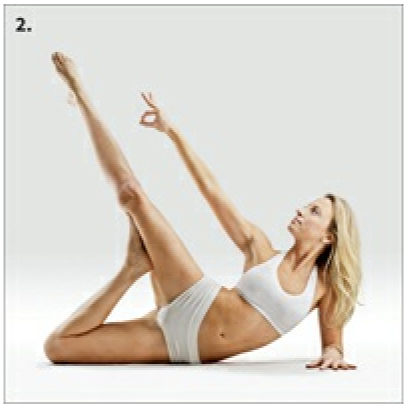

EASTERN INTENSE STRETCH: SITTING BONES BELOW KNEES—ONE LEG OFF FLOOR & TWISTS

Tip Toe Half Eastern Intense Stretch Pose

Prapada Ardha Purvottanasana

(PRUH-puh-duh UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Tip Toe Half Reverse Plank Pose

Modification: prep—sitting bones below the knee level, on the fingertips

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

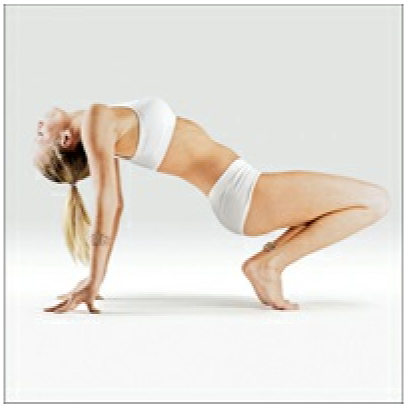

Half Eastern Intense Stretch Pose

Ardha Purvottanasana

(UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Half Reverse Plank

Modification: mild prep—sitting bones slightly off the floor, feet flat on the floor; palms flat on the floor, fingertips pointing to the heels

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

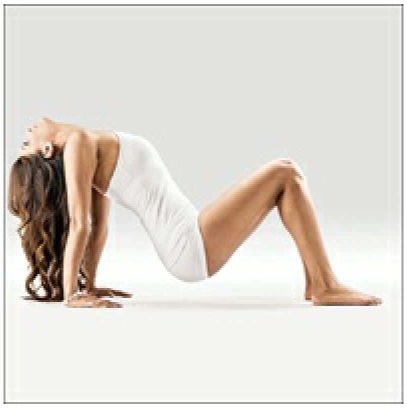

Half Fire Log Pose in Half Eastern Intense Stretch Pose

Ardha Agnistambhasana in Ardha Purvottanasana

(UHR-duh uhg-ni-stuhm-BAHS-uh-nuh in UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Half Firelog Pose in Half Reverse Plank

Modification: prep—sitting bones slightly off the floor; elbows bent, fingertips pointing to the heels

Pose Type: standing, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

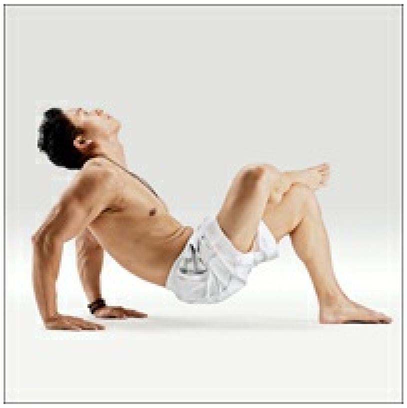

Intense Ankle Stretch Pose in One-Legged Half Eastern Intense Stretch Pose

Uttana Kulpasana in Eka Pada Ardha Purvottanasana

(ut-TAHN-uh kul-PAHS-uh-nuh in EY-kuh PUH-duh UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Intense Ankle Stretch Pose in One-Legged Half Reverse Plank
Modification: knee bent toward the chest, fingertips pointing away from the heels
Pose Type: standing, forward bend
Drishti Point: Padayoragrai or Padayoragre (toes/feet)

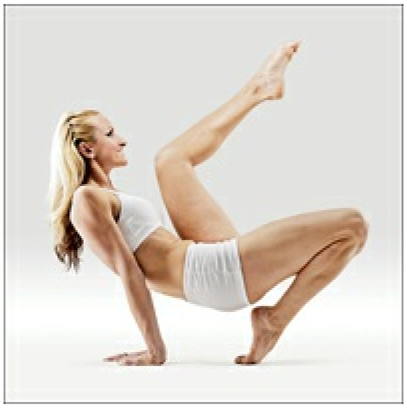

Revolved Half Eastern Intense Stretch Pose

Parivritta Ardha Purvottanasana

(puh-ri-VRIT-tuh UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Revolved Half Reverse Plank Pose
Modification: opposite elbow to knee of the straight leg
Pose Type: arm balance, forward bend, twist
Drishti Point: Hastagrai or Hastagre (hands)

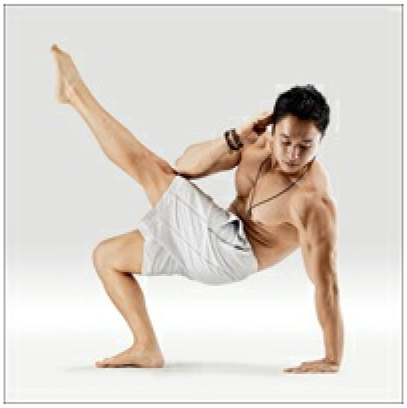

EASTERN INTENSE STRETCH: KNEES BENT

Half Eastern Intense Stretch Pose

Ardha Purvottanasana

(UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Reverse Table Top and Half Reverse Plank Pose
Modification: prep—knees bent and on top of the ankles, fingertips pointing away from the heels
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

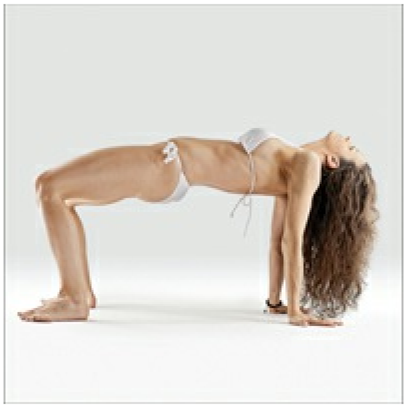

Uneven Leg Position of Cow Face Pose in Half Eastern Intense Stretch Pose

Vishama Pada Gomukhasana in Ardha Purvottanasana

(VISH-uh-muh PUH-duh go-muk-AHS-uh-nuh in UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Uneven Leg Position of Cow Face Pose in Reverse Table Top and Uneven Leg Position of Cow Face Pose in Half Reverse Plank
Modification: knees bent, fingertips pointing to the heels

Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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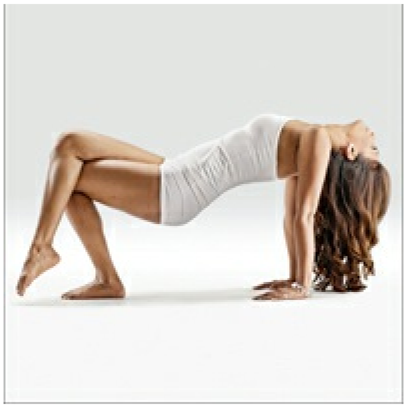

One-Legged Half Eastern Intense Stretch Pose

Eka Pada Ardha Purvottanasana

(EY-kuh PUH-duh UHR-duh poor-vo-tahn-AHS-uh-nuh)
Also Known As: One-Legged Reverse Table Top and One-Legged Half Reverse Plank Pose
Modification: prep—one knee bent, foot on the floor; other leg straight; knees in line, fingertips pointing to the heels
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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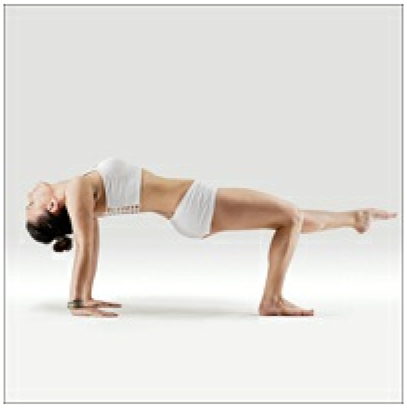

One-Legged Half Eastern Intense Stretch Pose

Eka Pada Ardha Purvottanasana

(EY-kuh PUH-duh UHR-duh poor-vo-tahn-AHS-uh-nuh)
Also Known As: One-Legged Reverse Table Top and One-Legged Half Reverse Plank
Modification: prep—both knees bent, top foot to the knee, fingertips pointing to the heels

Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

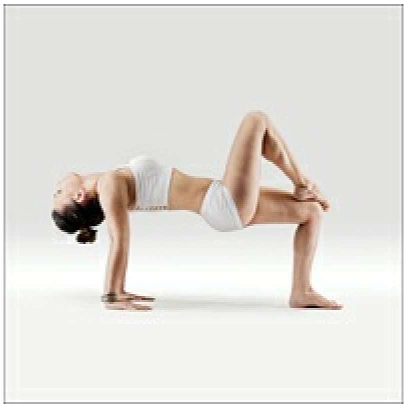

One-Legged Half Eastern Intense Stretch Pose in Pose Dedicated to Sage Vasistha on the Forearm

Eka Pada Ardha Purvottanasana in Vasishtasana

(EY-kuh PUH-duh UHR-duh poor-vo-tahn-AHS-uh-nuh in vuh-sish-TAHS-uh-nuh)

Also Known As: One-Legged Reverse Table Top in Pose Dedicated to Sage Vasistha on the Forearm, One-Legged Half Reverse Plank Top in Pose Dedicated to Sage Vasistha on the Forearm
Modification: both knees bent, foot to the knee
Pose Type: standing (on the forearm and the foot)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

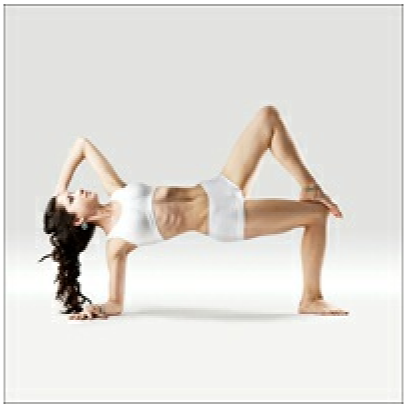

One Hand Half Eastern Intense Stretch Pose

Eka Hasta Ardha Purvottanasana

(EY-kuh HUH-stuh UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: One Hand Reverse Table Top or One Hand Half Reverse Plank

Modification: knees bent, fingertips pointing away from the heels
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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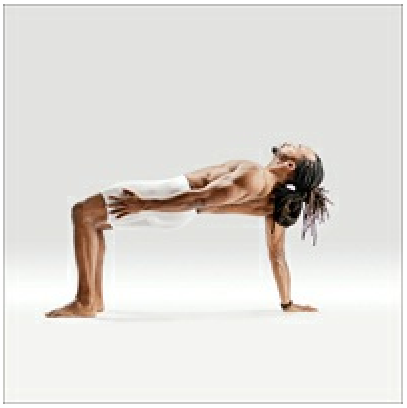

EASTERN INTENSE STRETCH: LEGS STRAIGHT

Eastern Intense Stretch Pose

Purvottanasana

(poor-vo-tahn-AHS-uh-nuh)
Also Known As: Reverse Plank and Upward Plank Pose
Modification: legs straight, fingertips pointing to the heels
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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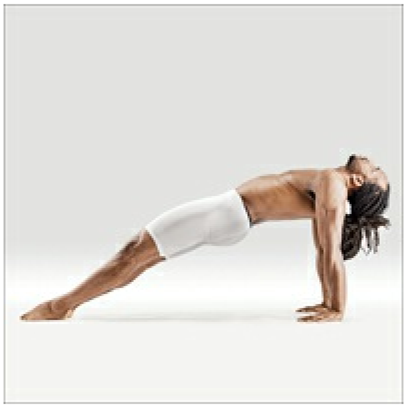

Foot to the Side

Half Eastern Intense Stretch Pose

Parshva Eka Pada Ardha Purvottanasana

(PAHRSH-vuh EY-kuh PUH-duh UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Foot to the Side Reverse Table Top, Foot to the Side Half Reverse Plank and Foot to the Side Half Upward Plank Pose

Pose Type: standing, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

How to Perform the Pose:

1. Begin by sitting on the floor with both your legs straight out in front of you. Keep your hands on the floor on the sides of your hips with fingertips pointing toward your feet. Engage your *mula bandha*, *uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale, bend your knees, and slide your feet toward your sitting bones. Keep your feet and knees hip-width apart.
3. On the next exhale, press into your hands and feet and lift your sitting bones off the floor. Your shoulders should be on top of your wrists, your knees on top of your ankles, and your torso and thighs parallel to the floor.
4. Exhale, straighten your right leg, and bring it out to the side, flexing the toes of your right foot out to the side. Hold the pose for at least 30, and up to 90, seconds in order to receive full benefits.
5. Inhale and bring your right leg back to the center in line with your left leg. Repeat on the other side. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch.
6. Inhale and lower your hips to the floor, coming back to the starting position.

Modification: one knee bent, other leg straight out to the side, fingertips pointing to the heels

parshva = side

eka = one

pada = foot or leg

ardha = half

purva = east, the front of the body

ut = intense

tan = to stretch, to extend

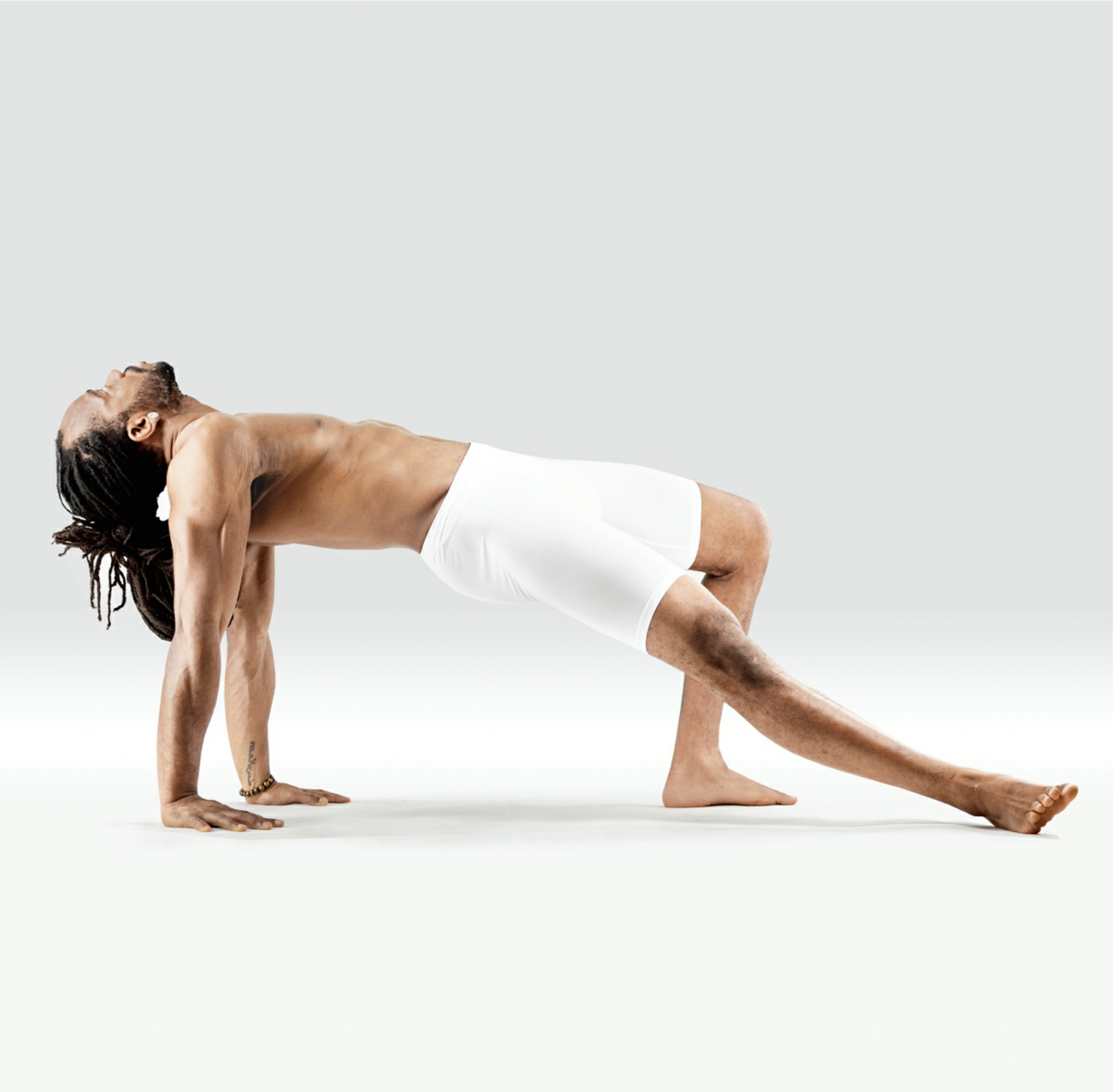

Feet Wide Eastern Intense Stretch Pose

Prasarita Pada Purvottanasana

(pruh-SAH-ri-tuh PUH-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Feet Wide Reverse Plank and Feet Wide Upward Plank Pose
Modification: legs straight, toes flexed in, fingertips pointing to the heels
1. side view
2. front view
Pose Type: standing, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

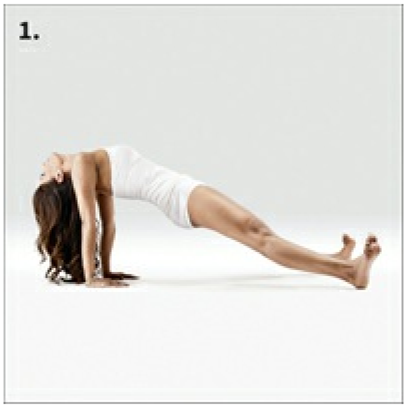

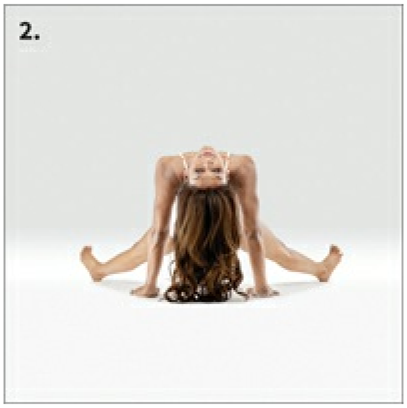

EASTERN INTENSE STRETCH: FOREARMS ON THE FLOOR

Easy Fish Pose

Sukha Matsyasana

(SUK-uh muhts-YAHS-uh-nuh)

Also Known As: Eastern Intense Stretch Pose Prep. (Purvottanasana Prep.), Reverse Plank Prep.
Modification: head off the floor, forearms on the floor, legs straight
Pose Type: seated, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

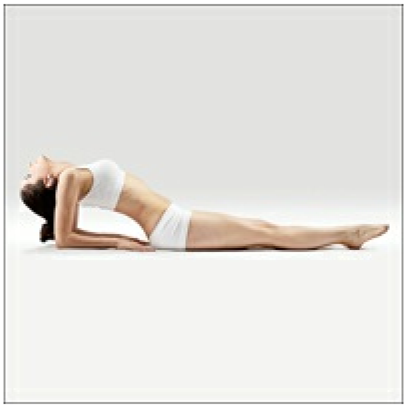

Eastern Intense Stretch Pose

Purvottanasana

(poor-vo-tahn-AHS-uh-nuh)

Also Known As: Reverse Plank on the Forearms and Upward Plank Pose on the Forearms
Modification: legs straight, forearms on the floor
Pose Type: standing (on the forearms), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

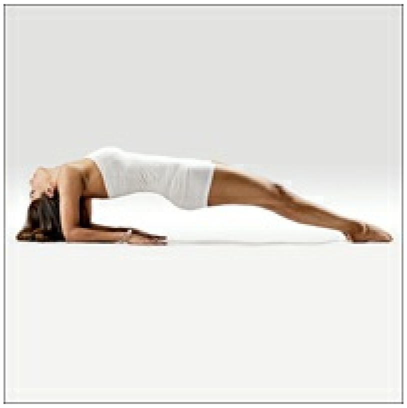

Easy Fish Pose

Sukha Matsyasana

(SUK-uh muhts-YAHS-uh-nuh)

Also Known As: Eastern Intense Stretch Pose Prep. (Purvottanasana Prep.), Reverse Plank Prep.
Modification: head off the floor, forearms to the floor; one leg straight, other knee bent, foot flat on the floor
1. straight leg on the floor

2. straight leg off the floor, toes flexed in

Pose Type: seated, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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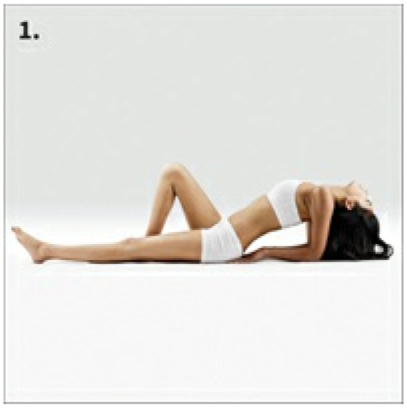

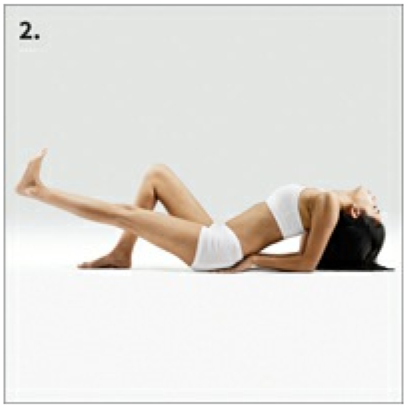

EASTERN INTENSE STRETCH: FOREARMS TO FLOOR—ONE LEG OFF FLOOR

Half Fire Log Pose in Easy Fish Pose

Ardha Agnistambhasana in Sukha Matsyasana

(UHR-duh uhg-ni-stuhm-BAHS-uh-nuh in SUK-uh muhts-YAHS-uh-nuh)

Also Known As: Eastern Intense Stretch Pose Prep. (Purvottanasana Prep.), Reverse Plank Prep.

Modification: forearms to the floor, head off the floor

Pose Type: seated, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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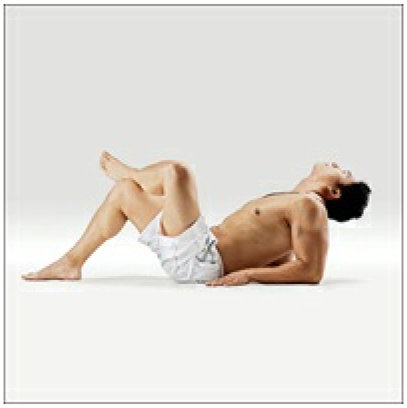

Easy Fish Pose

Sukha Matsyasana

(SUK-uh muhts-YAHS-uh-nuh)

Also Known As: Eastern Intense Stretch Pose Prep. (Purvottanasana Prep.), Reverse Plank Prep.
Modification: forearms to the floor, head off the floor, sole of the foot to the opposite knee
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

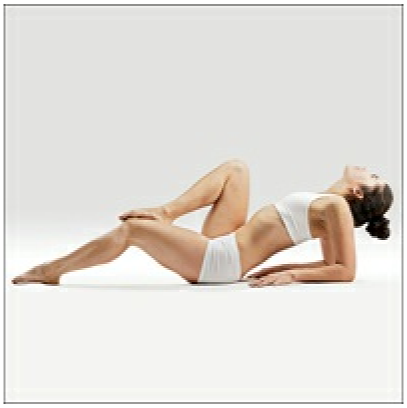

Revolved Hand to Foot Pose in Half Eastern Intense Stretch Pose on the Forearm

Parivritta Hasta Padasana in Ardha Purvottanasana

(puh-ri-VRIT-tuh HUH-stuh puh-DAHS-uh-nuh in UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Revolved Hand to Foot Pose in Reverse Table Top, Revolved Hand to Foot Pose in Half Reverse Plank
Modification: forearm on the floor; grabbing onto the outside edge of the foot, leg straight
Pose Type: standing (on the forearm and the foot), twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

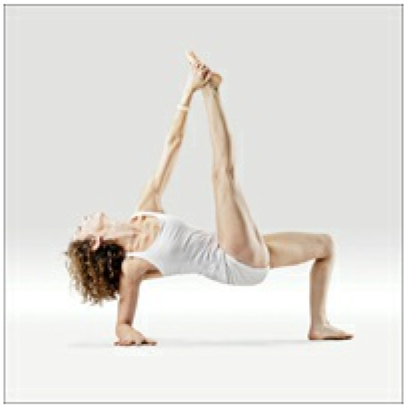

EASTERN INTENSE STRETCH: FOREARMS TO FLOOR—GRABBING ONTO TRICEPS—KNEES BENT

Hands Bound Easy Fish Pose

Baddha Hasta Sukha Matsyasana

(BUH-duh HUH-stuh SUK-uh muhts-YAHS-uh-nuh)

Modification: knees bent, feet to the floor
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

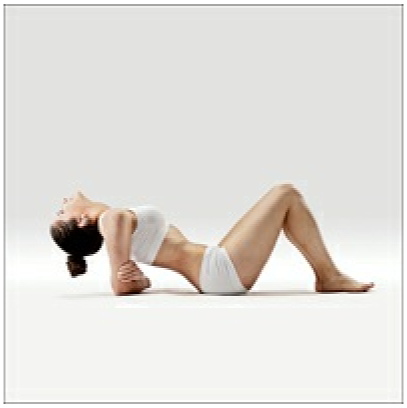

Hands Bound Half Eastern Intense Stretch Pose

Baddha Hasta Ardha Purvottanasana

(BUH-duh HUH-stuh UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Hands Bound Reverse Table Top, Hands Bound Half Reverse Plank
Pose Type: standing (on the forearms), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

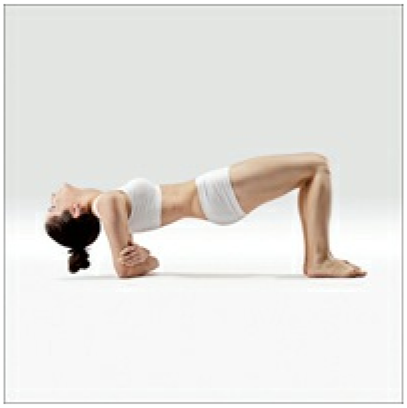

Reverse Prayer One-Legged Easy Fish Pose

Viparita Namaskar Eka Pada Sukha Matsyasana

(vi-puh-REE-tuh nuh-muhs-KAHR EY-kuh PUH-duh SUK-uh muhts-YAHS-uh-nuh)

Also Known As: Back of the Body Prayer One-Legged Easy Fish Pose (Paschima Namaskara Eka Pada Sukha Matsyasana)
Modification: both knees bent, heel to the knee
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

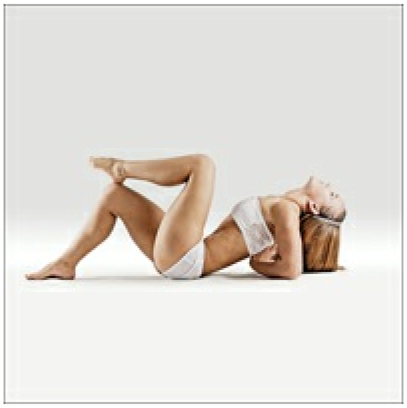

Hands Bound One-Legged Half Eastern Intense Stretch Pose

Baddha Hasta Eka Pada Ardha Purvottanasana

(BUH-duh HUH-stuh EY-kuh PUH-duh UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Hands Bound One-Legged Reverse Table Top, Hands Bound One-Legged Half Reverse Plank
Modification: heel to the knee; grabbing onto the triceps
Pose Type: standing (on the forearms), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

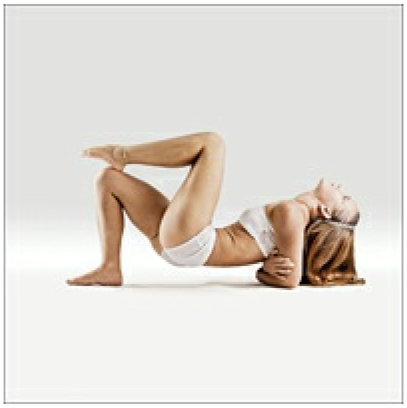

EASTERN INTENSE STRETCH: FOREARMS TO FLOOR—GRABBING ONTO THE TRICEPS

Hands Bound Easy Fish Pose

Baddha Hasta Sukha Matsyasana

(BUH-duh HUH-stuh SUK-uh muhts-YAHS-uh-nuh)

Modification: one leg straight to the floor; other knee bent, foot to the floor
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

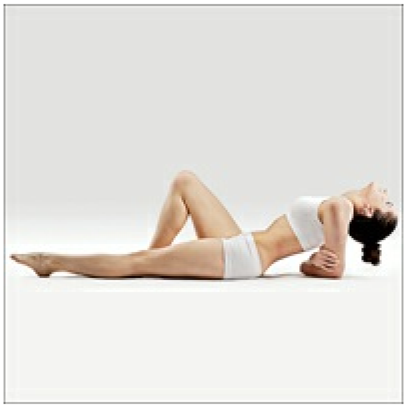

Hands Bound Easy Intense Leg Stretch

Baddha Hasta Sukha Uttana Padasana

(BUH-duh HUH-stuh SUK-uh ut-TAHN-uh puh-DAHS-uh-nuh)

Modification: knees bent at 90 degrees, feet off the floor
Pose Type: seated, backbend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

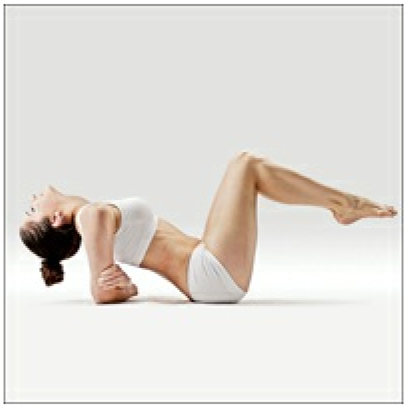

EASTERN INTENSE STRETCH: ELBOWS ON THE FLOOR—HALF LOTUS

Half Lotus Easy Fish Pose

Ardha Padma Sukha Matsyasana

(UHR-duh PUHD-muh SUK-uh muhts-YAHS-uh-nuh)

Also Known As: Eastern Intense Stretch Pose Prep. (Purvottanasana Prep.), Reverse Plank Prep.
Modification: elbows to the floor, palms to the lower back; one leg in half lotus, other knee bent; heel up
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

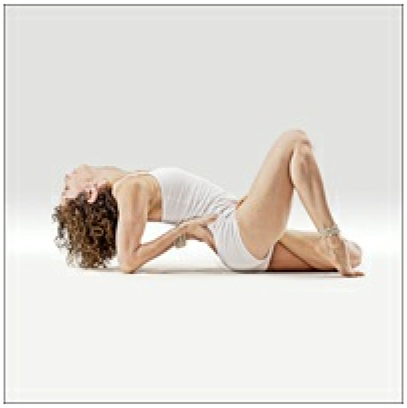

Half Lotus Half Eastern Intense Stretch Pose

Ardha Padma Ardha Purvottanasana

(UHR-duh PUHD-muh UHR-duh poor-vo-tahn-AHS-uh-nuh)

Also Known As: Half Lotus Reverse Table Top, Half Lotus Half Reverse Plank
Modification: elbows to the floor, palms to the lower back; one leg in half lotus, other knee bent; heel up
1. right side view

2. left side view
Pose Type: standing (on the elbows, knee and foot), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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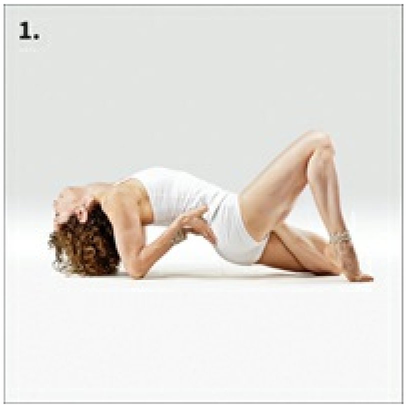

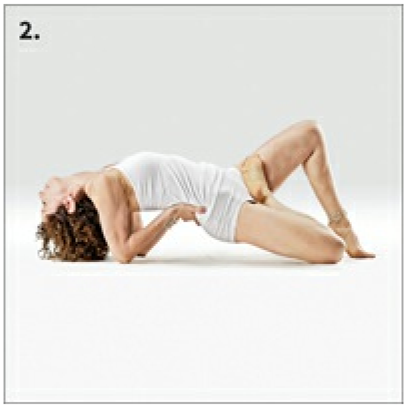

BRIDGE: HEELS DOWN, SPINE ON THE FLOOR

Bridge Whole Body Pose Prep.

Setu Bandha Sarvangasana Prep.

(SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)
Modification: spine flat on the floor, palms down by the hips, heels down
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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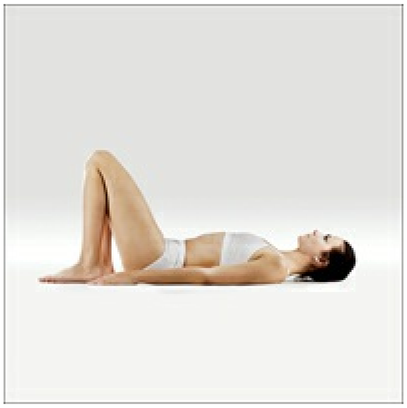

Reclined Hands Bound Twisted Stomach Pose in Bridge Whole Body Pose Prep.

Supta Baddha Hasta Jatara Parivartanasana in Setu Bandha Sarvangasana Prep.

(SUP-tuh BUH-duh HUH-stuh JAH-tuh-ruh puh-ri-vuhrt-uhn-AHS-uh-nuh in SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: ear resting on a yoga block
Pose Type: supine, twist
Drishti Point: Parshva Drishti (to the right), Parshva Drishti (to the left)

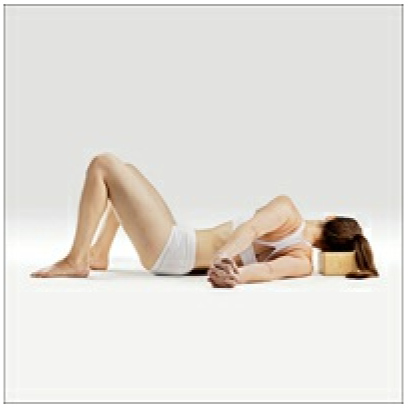

Reclined Hands Bound One Leg Extended Pose in Bridge Whole Body Pose Prep.

Supta Baddha Hasta Utthita Eka Padasana in Setu Bandha Sarvangasana Prep.

(SUP-tuh BUH-duh HUH-stuh UT-ti-tuh EY-kuh puh-DAHS-uh-nuh in SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: arms straight in front, palms facing up
Pose Type: supine
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

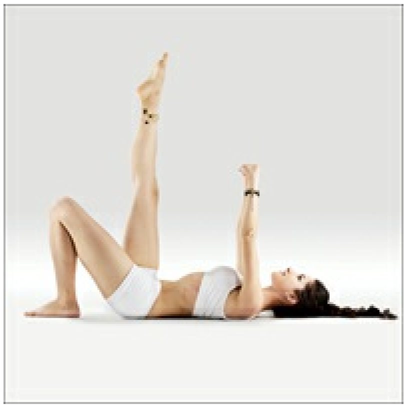

Reclined Half Bound Lotus Pose in Bridge Whole Body Pose Prep.

Supta Ardha Baddha Padmasana in Setu Bandha Sarvangasana Prep.

(SUP-tuh UHR-duh BUH-duh puhd-MAHS-uh-nuh in SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: grabbing onto the ankle
Pose Type: supine, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

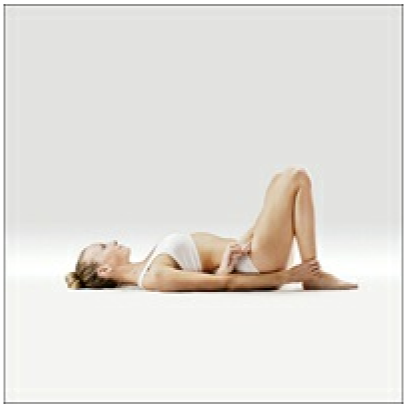

BRIDGE: HEELS DOWN, ARMS BEHIND THE BACK

Bridge Whole Body Pose

Setu Bandha Sarvangasana

(SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms to the floor, arms straight; feet in front of the knees
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

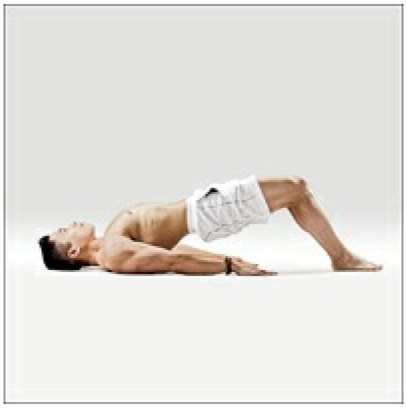

Uneven Bridge Whole Body Pose

Vishama Setu Bandha Sarvangasana

(VISH-uh-muh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Desk Pose Modification (Dwipadapitam)
Modification: palms down by the heel of the bent leg, other leg straight
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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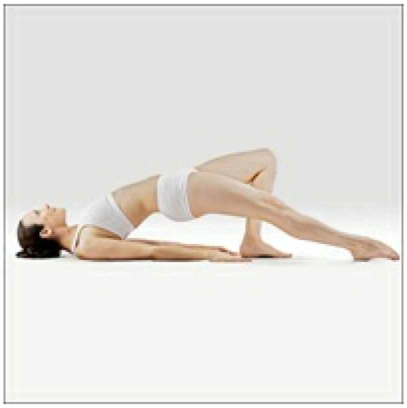

Bridge Whole Body Pose

Setu Bandha Sarvangasana

(SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Shoulder Pose (Kandharasana)
Modification: palms down by the heels
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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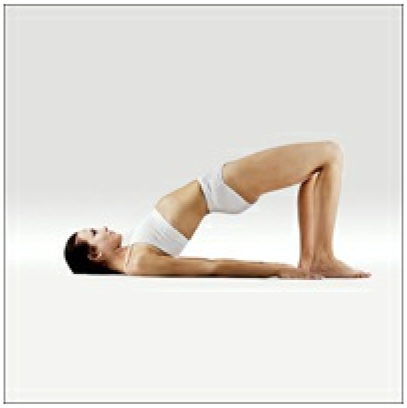

Bridge Whole Body Pose

Setu Bandha Sarvangasana

(SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms to the lower back
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

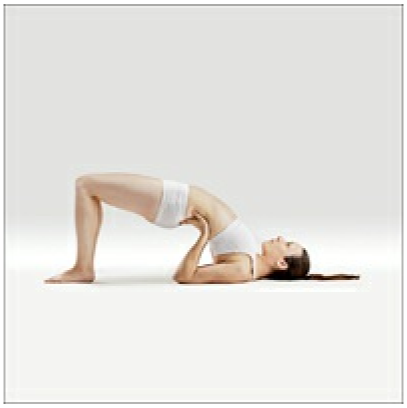

BRIDGE: HEELS DOWN, ARMS OVERHEAD & BEHIND THE BACK

Bridge Whole Body Pose

Setu Bandha Sarvangasana

(SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Desk Pose Modification (Dwipadapitam)
Modification: arms straight to the floor over the head, palms facing up
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

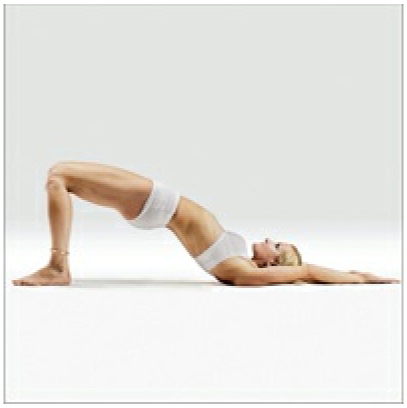

Bridge Whole Body Pose

Setu Bandha Sarvangasana

(SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Upward Bow Pose Prep. (Urdhva Dhanurasana Prep.)
Modification: palms under the shoulders, fingertips pointing to the heels
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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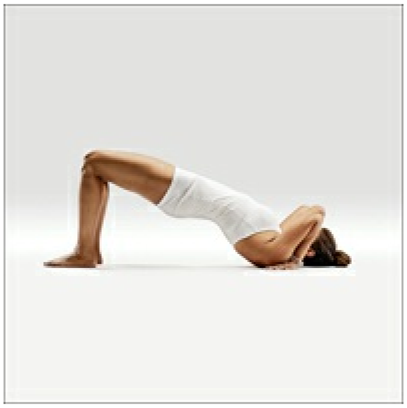

Upward Hands Bound Bridge Whole Body Pose

Urdhva Baddha Hasta Setu Bandha Sarvangasana

(OORD-vuh BUH-duh HUH-stuh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Desk Pose Modification (Dwipadapitam)
Pose Type: supine, backbend
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)
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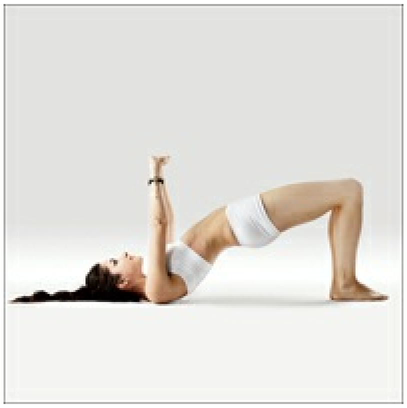

Hands Bound Bridge Whole Body Pose

Baddha Hasta Setu Bandha Sarvangasana

(BUH-duh HUH-stuh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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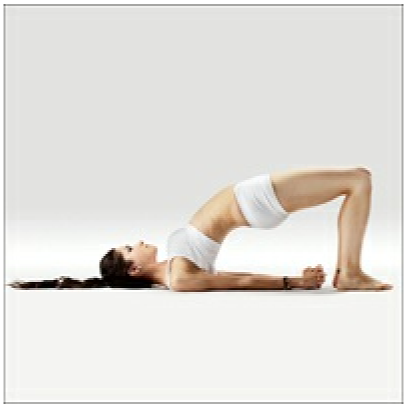

BRIDGE: HEELS DOWN, GRABBING ONTO THE ANKLES

Hand to Ankle Bridge Whole Body Pose

Hasta Kulpa Setu Bandha Sarvangasana

(HUH-stuh KUL-puh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Desk Pose Modification (Dwipadapitam)

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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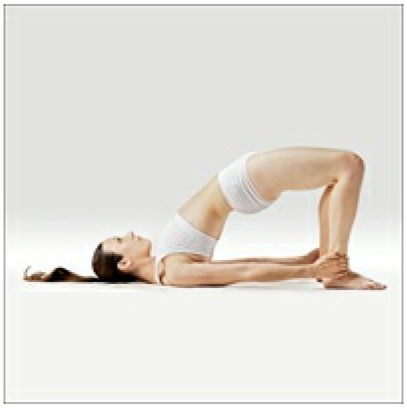

Hand to Ankle Bridge Whole Body Pose

Hasta Kulpa Setu Bandha Sarvangasana

(HUH-stuh KUL-puh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Desk Pose Modification (Dwipadapitam)
Modification: arms crossed
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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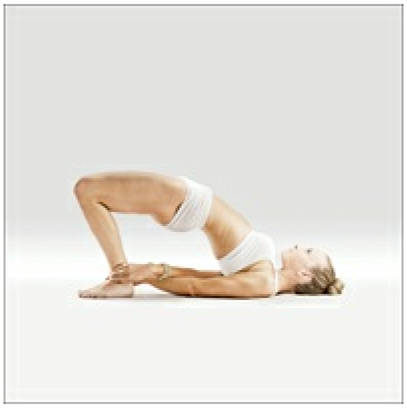

BRIDGE: HEELS DOWN—ONE FOOT OFF THE FLOOR

One Hand to Ankle Bridge Whole Body Pose

Eka Hasta Kulpa Setu Bandha Sarvangasana

(EY-kuh HUH-stuh KUL-puh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: yoga block under the sitting bones; grabbing onto the ankle on the same side, top of the foot to the floor
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

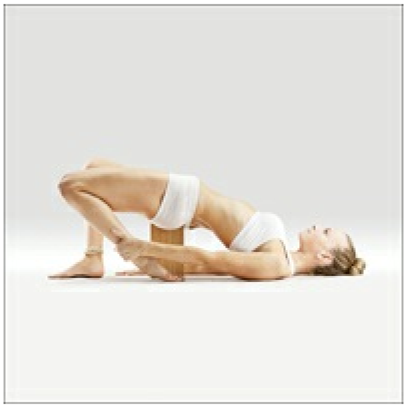

One Hand to Ankle Bridge Whole Body Pose

Eka Hasta Kulpa Setu Bandha Sarvangasana

(EY-kuh HUH-stuh KUL-puh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: Arm 1: grabbing onto the ankle of the opposite leg Arm 2: grabbing onto the opposite arm

Pose Type: supine, backbend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

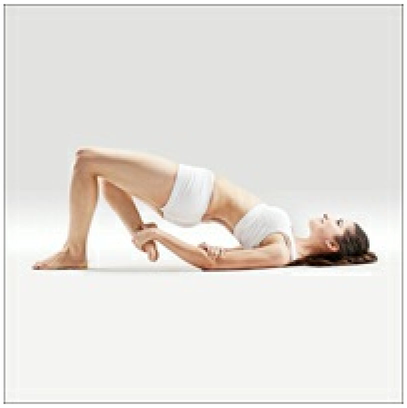

Half Fire Log Pose in One-Legged Hands Bound Bridge Whole Body Pose

Ardha Agnistambhasana in Eka Pada Baddha Hasta Setu Bandha Sarvangasana

(UHR-duh uhg-ni-stuhm-BAHS-uh-nuh in EY-kuh PUH-duh BUH-duh HUH-stuh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: ankle on top of the knee heel down, toes of the top foot pointed

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

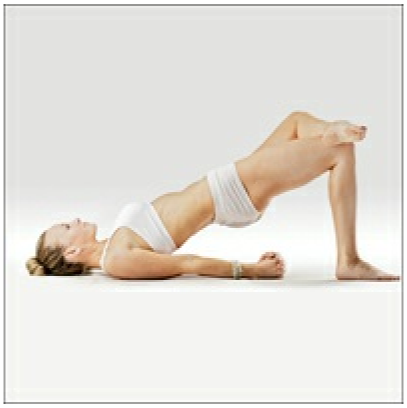

Half Bound Lotus One Hand to Ankle Bridge Whole Body Pose

Ardha Baddha Padma Eka Hasta Kulpa Setu Bandha Sarvangasana

(UHR-duh BUH-duh PUHD-muh EY-kuh HUH-stuh KUL-puh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Desk Pose Modification (Dwipadapitam)
Modification: heel down
Pose Type: supine, backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

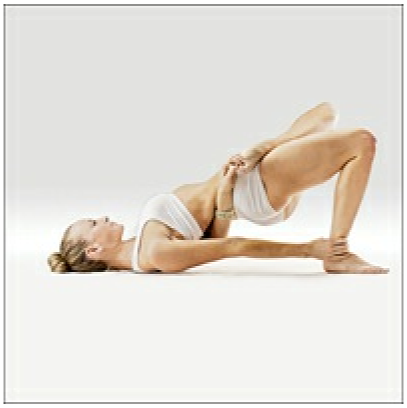

BRIDGE: HEELS DOWN—ONE LEG TO THE SKY

One-Legged Bridge Whole Body Pose

Eka Pada Setu Bandha Sarvangasana

(EY-kuh PUH-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms down, arms straight on the floor; both knees bent
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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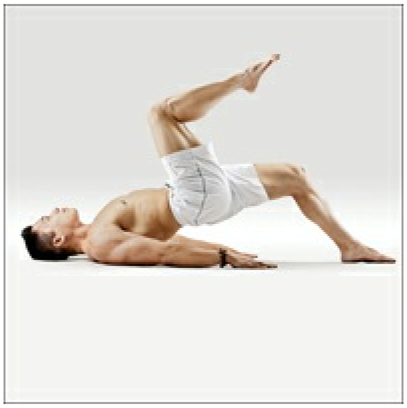

One-Legged Bridge Whole Body Pose

Eka Pada Setu Bandha Sarvangasana

(EY-kuh PUH-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms down, arms straight on the floor; one leg up and straight, knees toward each other

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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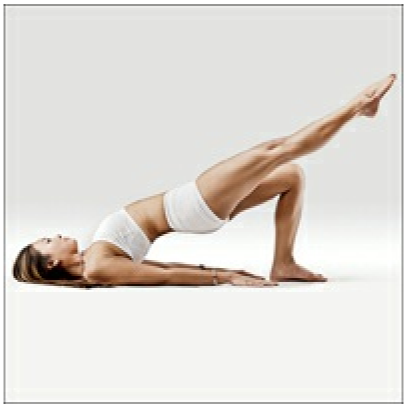

One-Legged Bridge Whole Body Pose

Eka Pada Setu Bandha Sarvangasana

(EY-kuh PUH-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Desk Pose Modification (Dwipadapitam)

Modification: palms down by the heel

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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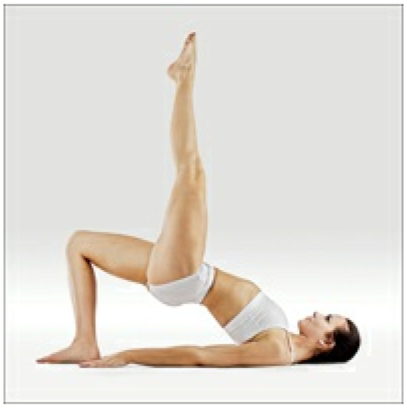

One-Legged Bridge Whole Body Pose

Eka Pada Setu Bandha Sarvangasana

(EY-kuh PUH-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Also Known As: Peacock Stretch Pose (Uttana Mayurasana)
Modification: palms to the lower back
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

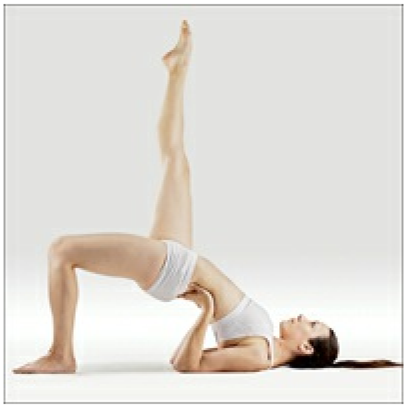

Both Hands to Ankle One-Legged Bridge Whole Body Pose

Dwi Hasta Kulpa Eka Pada Setu Bandha Sarvangasana

(DWI-huh-stuh KUL-puh EY-kuh PUH-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: grabbing onto the ankle with both hands
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

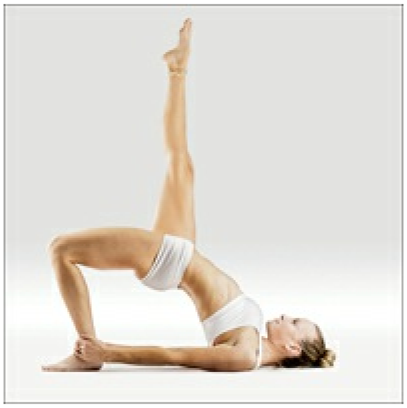

One-Legged Upward Hands Bound Tip Toe

Bridge Whole Body Pose

Eka Pada Urdhva Baddha Hasta Prapada Setu Bandha Sarvangasana

(EY-kuh PUH-duh OORD-vuh BUH-duh HUH-stuh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Pose Type: supine, backbend

Drishti Point: Angusthamadhye or Angustha Ma Dyai(thumbs)

How to Perform the Pose:

1. Begin by lying with your back flat on the floor. Keep your arms by the sides of your torso, hands by the sides of the hips, palms facing down. Engage your *mula bandha, uddhiyana bandha*, and *ujjayi* breathing.
2. Exhale, bend your knees, and slide your feet toward your sitting bones. Keep your feet flat on the floor, parallel to each other and in line with your sitting bones.
3. On the next exhale, push into your arms and feet and lift your hips off the floor until your thighs are parallel to the floor.
4. Inhale, interlock your fingers behind your back, and press your palms together. Exhale as you push through your chest and straighten the arms.
5. Exhale, bring your ankles and feet together. On the next exhale, lift your right leg, pointing your right toes up to the sky (Pose #2).
6. Exhale, bring your left heel up. Inhale, release your arms and bring them out in front of your chest. Exhale as you interlock your fingers, rotate your palms up to the sky and straighten the arms (Pose #1).
7. Hold the pose for at least 30, and up to 90, seconds in order to receive the full benefits of the stretch. Inhale, lower your right leg, and repeat on the opposite side.
8. On the next inhale, lower your spine to the floor and stretch the legs out in front of you, coming back to the starting position.

Modification: arms extended up to the sky, fingers interlocked, palms facing up, heel up

eka = one

pada = foot or leg

urdhva = upward

baddha = bound

hasta = hand

prapada = tip of the feet

setu = bridge, dam or dike

bandha = lock

sarvanga = the whole body

1.

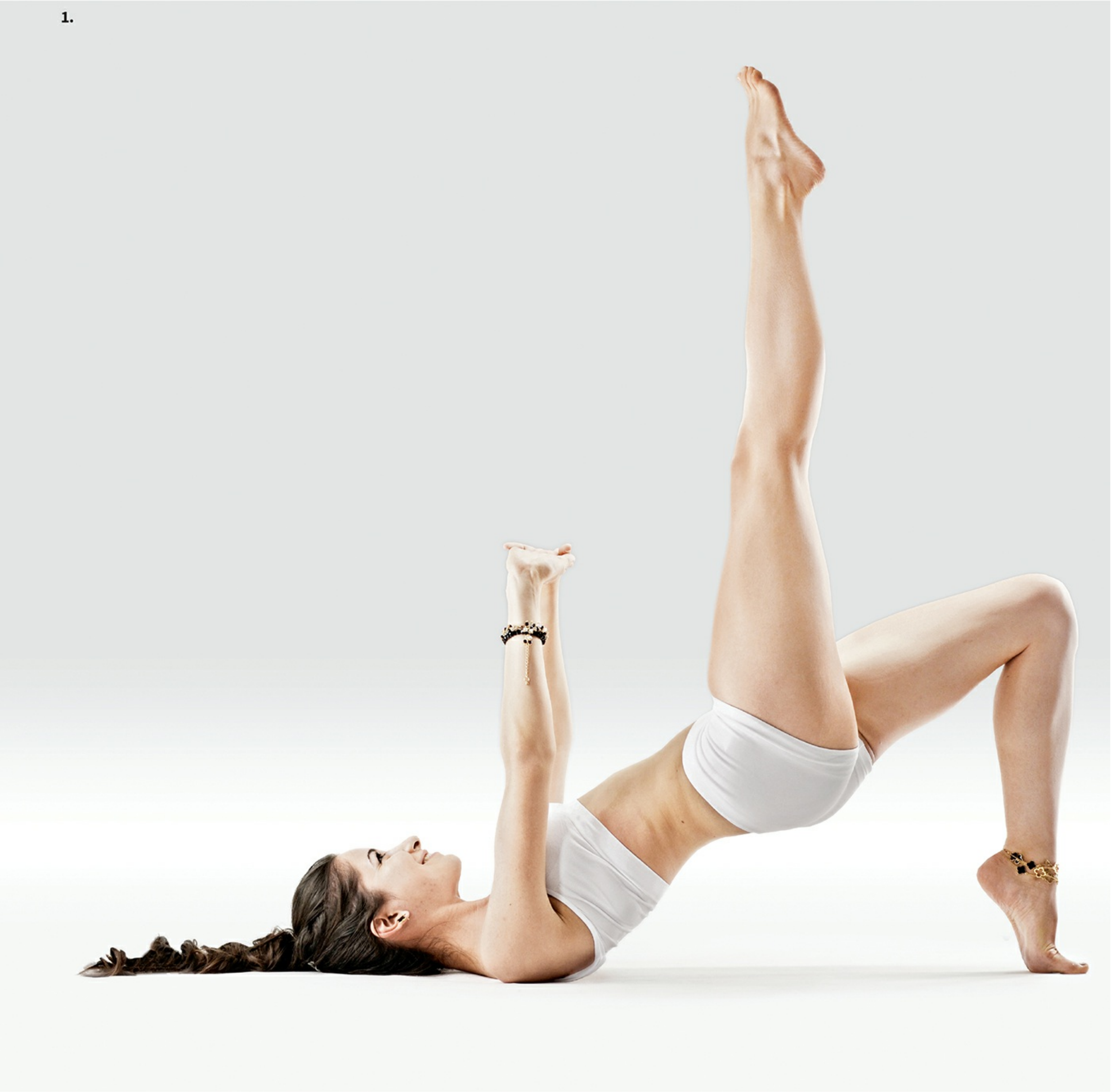

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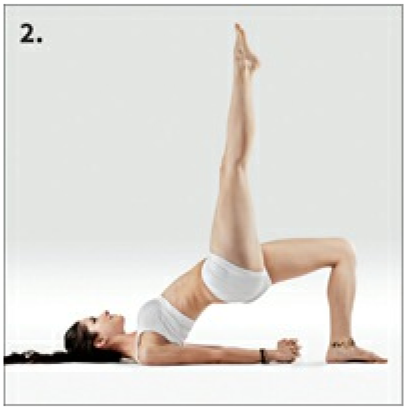

Tip Toe Bridge Whole Body Pose Prep.

Prapada Setu Bandha Sarvangasana Prep.

(PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: spine flat on the floor, palms down by the hips, heels up

Pose Type: supine

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

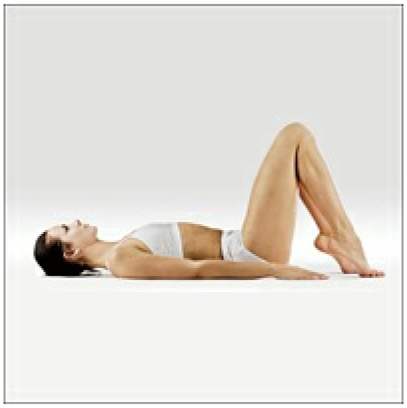

Tip Toe Bridge Whole Body Pose

Prapada Setu Bandha Sarvangasana

(PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms down

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

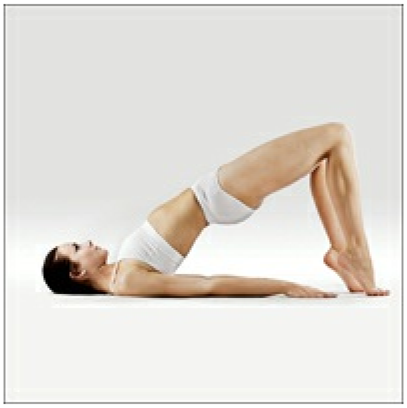

Tip Toe Bridge Whole Body Pose

Prapada Setu Bandha Sarvangasana

(PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms to the lower back

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

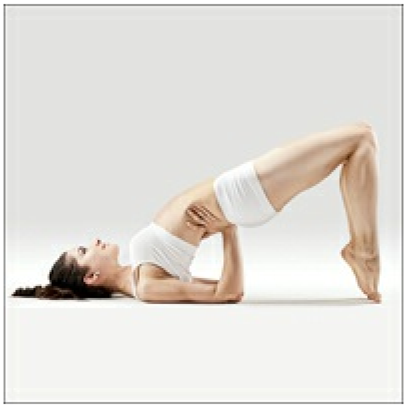

Hands Bound Tip Toe Bridge Whole Body Pose

Baddha Hasta Prapada Setu Bandha Sarvangasana

(BUH-duh HUH-stuh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

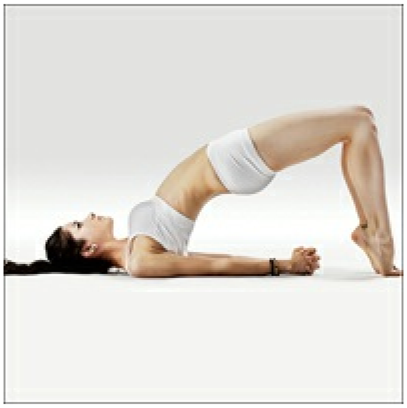

Upward Hands Bound Tip Toe Bridge Whole Body Pose

Urdhva Baddha Hasta Prapada Setu Bandha Sarvangasana

(OORD-vuh BUH-duh HUH-stuh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Pose Type: supine, backbend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

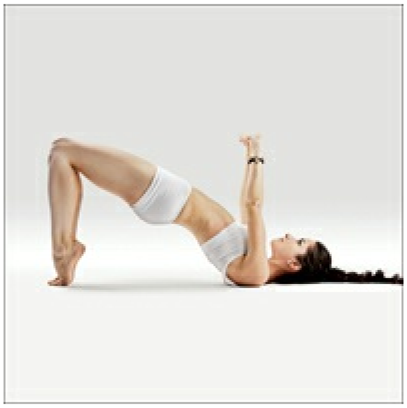

BRIDGE: HEELS UP—ONE LEG CROSSED OVER

Half Fire Log Pose in One-Legged Hands Bound Tip Toe Bridge Whole Body Pose

Ardha Agnistambhasana in Eka Pada Baddha Hasta Prapada Setu Bandha Sarvangasana

(UHR-duh uhg-ni-stuhm-BAHS-uh-nuh in EY-kuh PUH-duh BUH-duh HUH-stuh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: heel up; ankle on top of the knee, toes flexed in
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

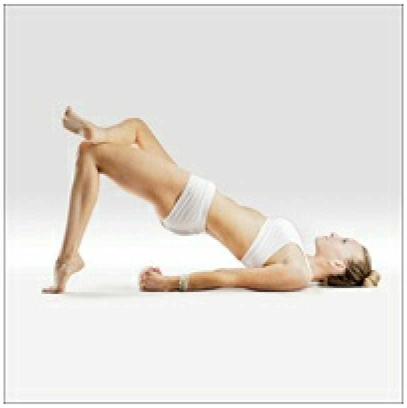

Uneven Leg Position of Cow Face Pose in One-Legged Tip Toe Bridge Whole Body Pose

Vishama Pada Gomukhasana in Eka Pada Prapada Setu Bandha Sarvangasana

(VISH-uh-muh PUH-duh go-muk-AHS-uh-nuh in EY-kuh PUH-duh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: Arm 1: grabbing onto the foot of the opposite leg Arm 2: grabbing onto the opposite arm

Pose Type: supine, backbend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

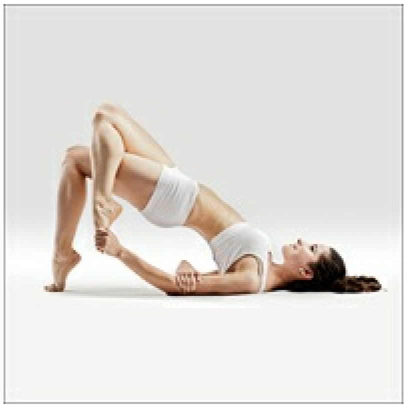

Half Bound Lotus One Hand to Ankle Tip Toe Bridge Whole Body Pose

Ardha Baddha Padma Eka Hasta Kulpa Prapada Setu Bandha Sarvangasana

(UHR-duh BUH-duh PUHD-muh EY-kuh HUH-stuh KUL-puh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: heel up

Pose Type: supine, backbend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

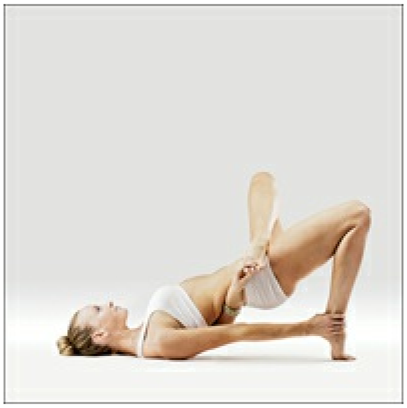

BRIDGE: HEELS UP—ONE LEG EXTENDED TO THE SKY

One-Legged Tip Toe Bridge Whole Body Pose

Eka Pada Prapada Setu Bandha Sarvangasana

(EY-kuh PUH-duh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms down
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

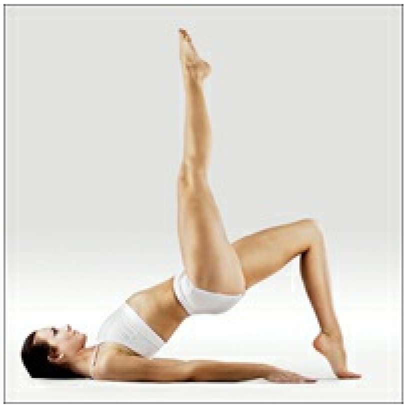

One-Legged Tip Toe Bridge Whole Body Pose

Eka Pada Prapada Setu Bandha Sarvangasana

(EY-kuh PUH-duh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms to the lower back
1. fingertips pointing to the heel
2. fingertips pointing to the head
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

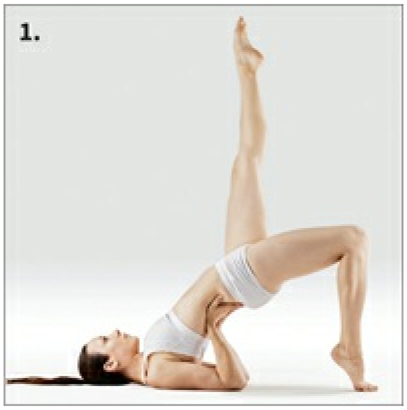

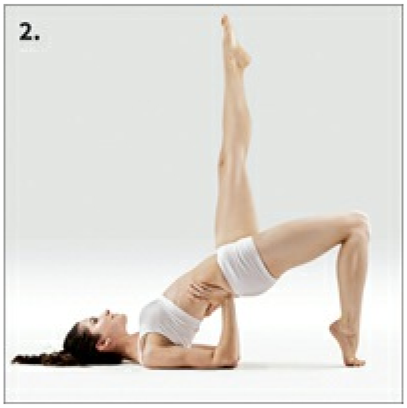

One-Legged Hands Bound Tip Toe Bridge Whole Body Pose

Eka Pada Baddha Hasta Prapada Setu Bandha Sarvangasana

(EY-kuh PUH-duh BUH-duh HUH-stuh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: leg straight and extended to the sky, heel up

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

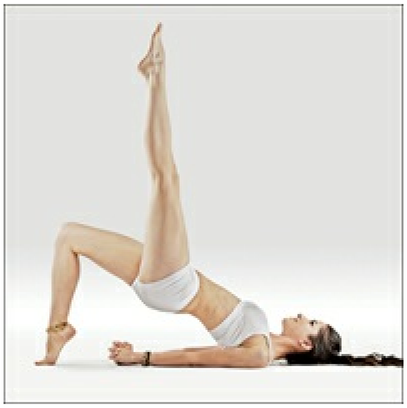

BRIDGE: HEELS UP—ONE LEG EXTENDED TO THE SKY—“BALLET TOES”

Intense Ankle Stretch One-Legged Bridge Whole Body Pose

Uttana Kulpa Eka Pada Setu Bandha Sarvangasana

(ut-TAHN-uh KUL-puh EY-kuh PUH-duh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms to the lower back; both knees bent

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

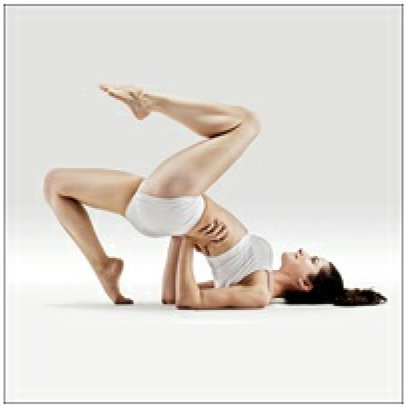

Intense Ankle Stretch One-Legged Bridge Whole Body Pose

Uttana Kulpa Eka Pada Setu Bandha Sarvangasana

(ut-TAHN-uh KUL-puh EY-kuh PUH-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms to the lower back; top leg straight

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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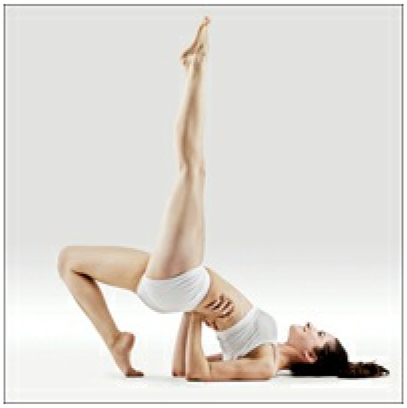

One Hand One-Legged Tip Toe Bridge Whole Body Pose

Eka Hasta Eka Pada Prapada Setu Bandha Sarvangasana

(EY-kuh HUH-stuh EY-kuh PUH-duh PRUH-puh-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: lifted leg bent; palm to the lower back, heel up

Pose Type: supine, backbend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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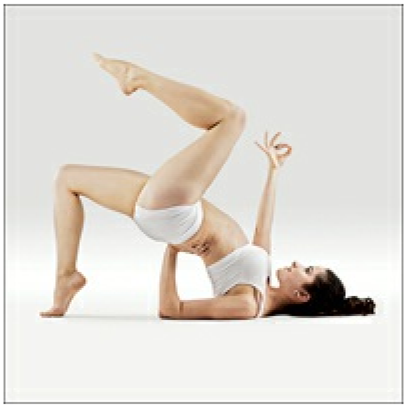

BRIDGE: LEGS STRAIGHT—BACK OF THE HEAD TO THE FLOOR

Extended Hand to Big Toe Pose Intense Ankle Stretch One-Legged Bridge Whole Body Pose

Utthita Hasta Padangushtasana in Uttana Kulpa Eka Pada Setu Bandha Sarvangasana

(UT-ti-tuh HUH-stuh puhd-ahng-goosh-TAHS-uh-nuh in ut-TAHN-uh KUL-puh EY-kuh PUH-duh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Pose Type: supine, backbend, forward bend

Drishti Point: Padayoragrai or Padayoragre (toes/feet)

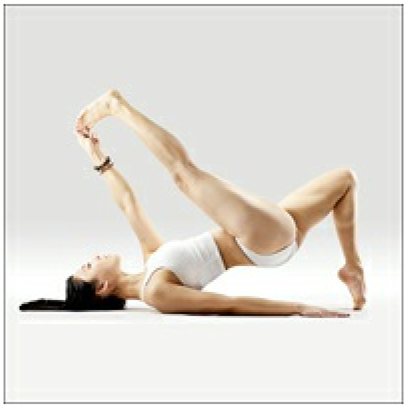

BRIDGE: LEGS STRAIGHT—BACK OF THE HEAD TO THE FLOOR

Complete Bridge Whole Body Pose

Paripurna Setu Bandha Sarvangasana

(puh-ri-POOR-nuh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms to the lower back
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

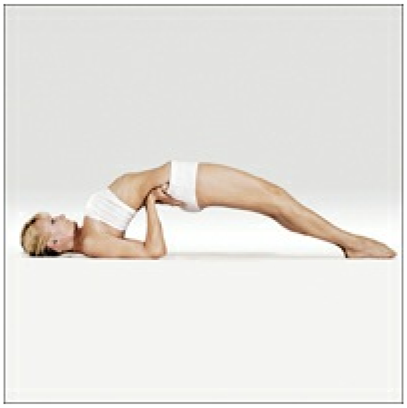

One-Legged Complete Bridge Whole Body Pose

Eka Pada Paripurna Setu Bandha Sarvangasana

(EY-kuh PUH-duh puh-ri-POOR-nuh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)
Modification: palms to the lower back
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

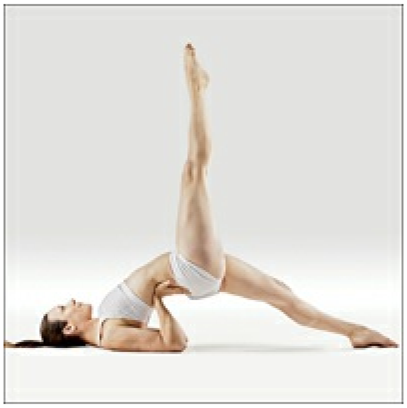

HEAD AND SITTING BONES ON THE FLOOR: KNEES BENT

Half Fish Pose

Ardha Matsyasana

(UHR-duh muhts-YAHS-uh-nuh)
Modification: knees bent; feet flat on the floor, heels toward the sitting bones; palms down to the

floor by the heels, elbows to the floor
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

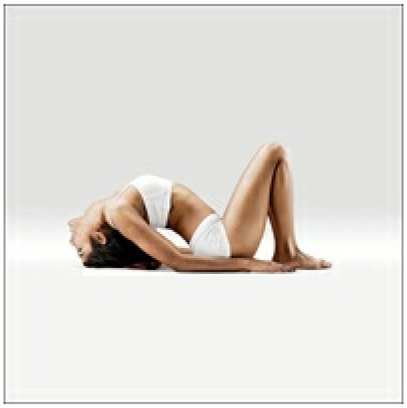

Half Fish Pose

Ardha Matsyasana

(UHR-duh muhts-YAHS-uh-nuh)

Modification: knees bent
1. arms over the head, feet flat on the floor
2. hands by the navel, palms pressed together, fingertips pointing up, both feet in the tip toe position
3. hands by the navel, palms pressed together, fingertips pointing up; one foot in the tip toe position, other leg raised
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

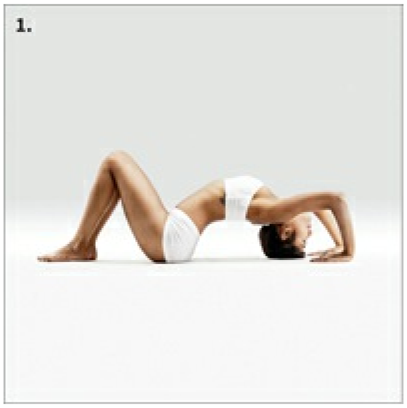

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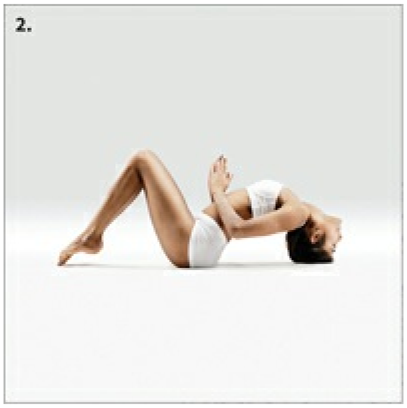

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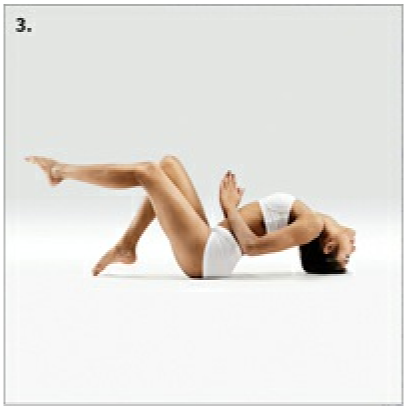

HEAD AND SITTING BONES ON THE FLOOR: LEGS STRAIGHT

Fish Pose

Matsyasana

(muhts-YAHS-uh-nuh)

Modification: legs straight on the floor, elbows to the floor, palms down to the floor by the hips
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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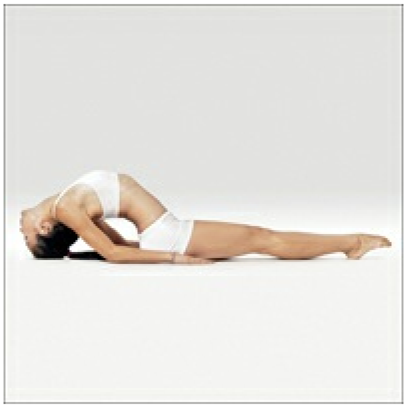

Reverse Prayer Fish Pose

Viparita Namaskar Matsyasana

(vi-puh-REE-tuh nuh-muhs-KAHR muhts-YAHS-uh-nuh)

Also Known As: Back of the Body Prayer Fish Pose (Paschima Namaskara Matsyasana)
Modification: legs straight to the floor
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

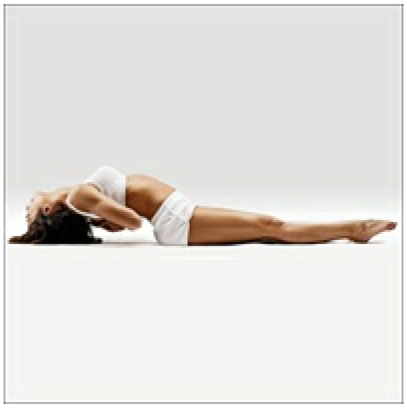

Intense Leg Stretch

Uttana Padasana

(ut-TAHN-uh puh-DAHS-uh-nuh)

Modification: legs straight on the floor, arms straight in front of the chest, palms pressed together
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

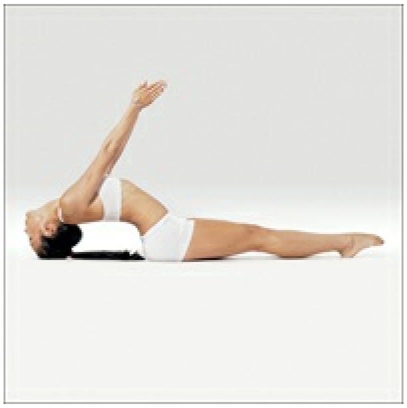

HEAD AND SITTING BONES ON THE FLOOR: ONE LEG STRAIGHT, ONE KNEE BENT

Fish Pose

Matsyasana

(muhts-YAHS-uh-nuh)

Modification: 1. one leg straight, other knee bent
2. one leg straight, other knee bent, bent leg crossed over
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

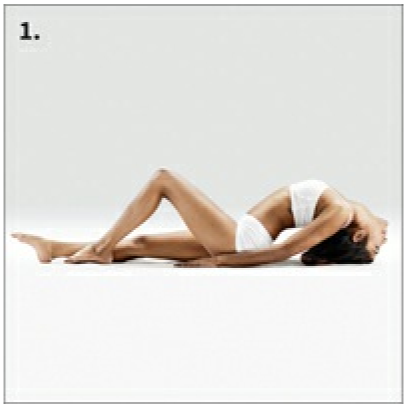

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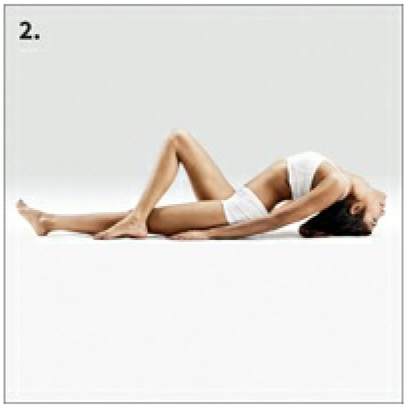

2.

Half Bound Lotus Fish Pose

Ardha Baddha Padma Matsyasana

(UHR-duh BUH-duh PUHD-muh muhts-YAHS-uh-nuh)

Modification: sitting bones on the floor, palm to the floor by the hip
Pose Type: seated, backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

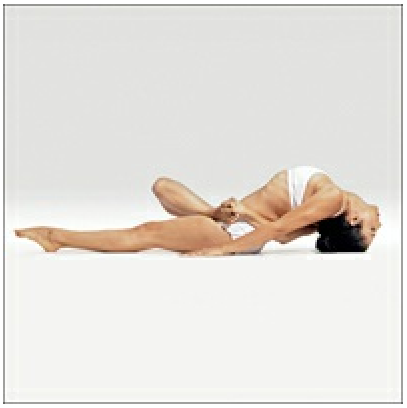

Half Bound Lotus Fish Pose

Ardha Baddha Padma Matsyasana

(UHR-duh BUH-duh PUHD-muh muhts-YAHS-uh-nuh)

Modification: one arm straight up to the sky, other arm grabbing onto the inside of the thigh behind the back; leg straight
Pose Type: seated, backbend, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

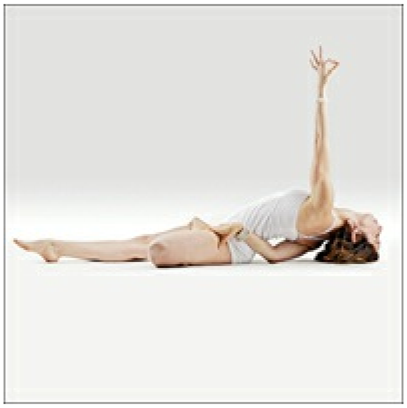

HEAD AND SITTING BONES ON THE FLOOR: HANDS AND FEET ON FLOOR—BINDING & GARUDA ARMS AND LEGS

Half Bound Lotus Half Fish Pose

Ardha Baddha Padma Ardha Matsyasana

(UHR-duh BUH-duh PUHD-muh UHR-duh muhts-YAHS-uh-nuh)

Modification: grabbing onto the foot with arm behind the back, fingertips of the other arm touching the floor overhead, elbow bent; knee of the free leg bent

1. heel down
2. heel up

Pose Type: seated, backbend, binding

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)

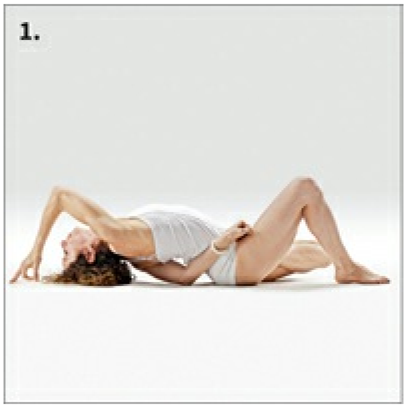
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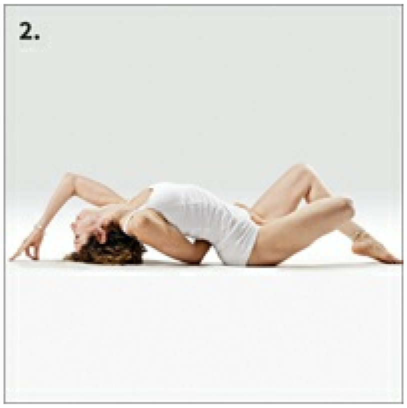
2.

Intense Leg Stretch Pose Dedicated to Garuda

Uttana Pada Garudasana

(ut-TAHN-uh PUH-duh guh-ru-DAHS-uh-nuh)

Modification: fingertips and bottom foot to the floor

Pose Type: seated, backbend

Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

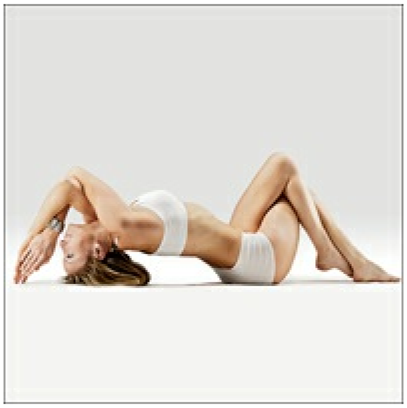

RECLINED BOUND ANGLE POSE & FISH POSE

Reclined Bound Angle Pose

Supta Baddha Konasana

(SUP-tuh BUH-duh ko-NAHS-uh-nuh)

Modification: hands to the inner thighs, palms up
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

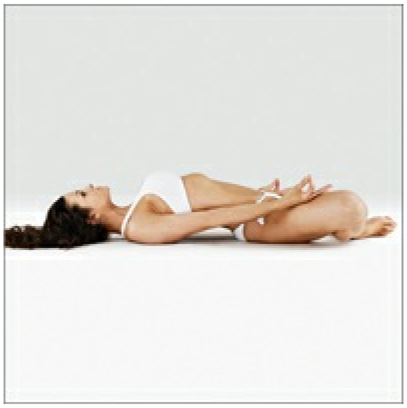

Reclined Bound Angle Pose

Supta Baddha Konasana

(SUP-tuh BUH-duh ko-NAHS-uh-nuh)

Also Known As: Bound Legs Fish Pose (Baddha Pada Matsyasana)
Modification: crown of the head to the floor, grabbing onto the shins, arms on top of the legs
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

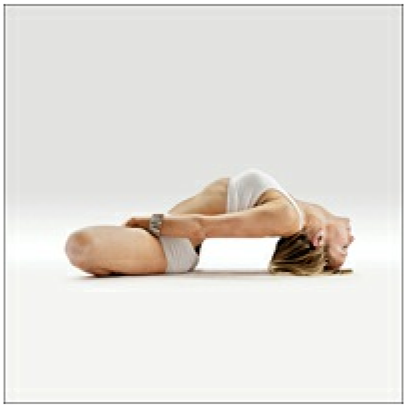

Fish Pose

Matsyasana

(muhts-YAHS-uh-nuh)

Modification: 1. palms up on the inside of the thighs
2. grabbing onto the big toes, elbows to the floor
3. grabbing onto the forearms, arms up over the head
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

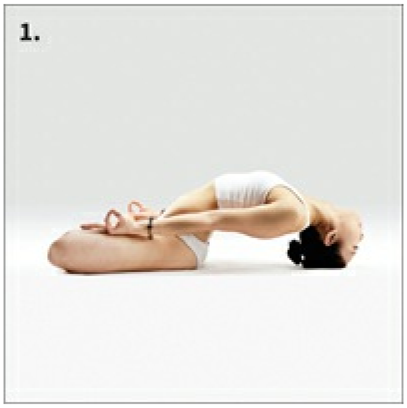

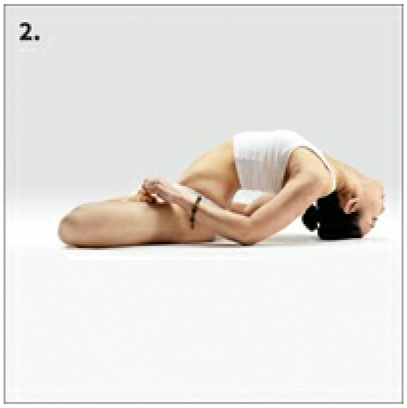

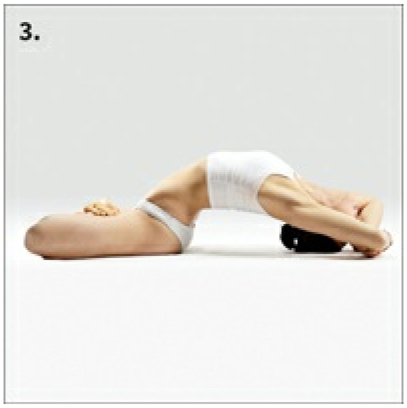

HEAD AND SITTING BONES ON THE FLOOR: LEGS AND ARMS OFF THE FLOOR

Reverse Prayer Intense Leg Stretch

Viparita Namaskar Uttana Padasana

(vi-puh-REE-tuh nuh-muhs-KAHR ut-TAHN-uh puh-DAHS-uh-nuh)

Also Known As: Back of the Body Prayer Intense Leg Stretch (Paschima Namaskara Uttana Padasana)
Modification: legs straight and off the floor, ankles crossed
Pose Type: seated, backbend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

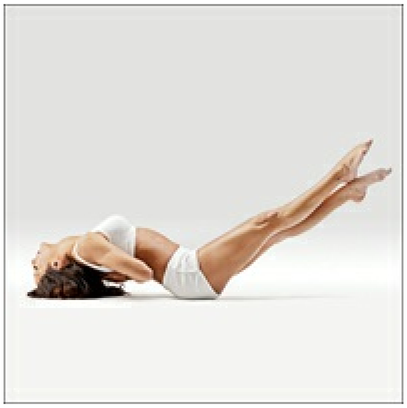

Intense Leg Stretch

Uttana Padasana

(ut-TAHN-uh puh-DAHS-uh-nuh)

Modification: legs straight and off the floor; arms straight in front of the chest, palms pressed together
Pose Type: seated, backbend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

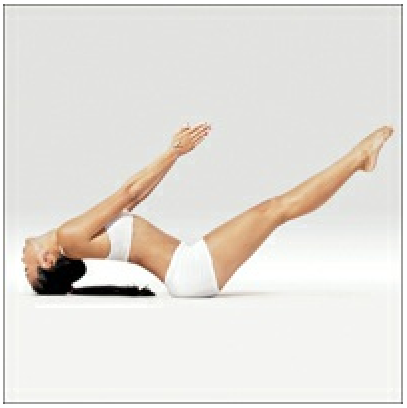

Intense Leg Stretch Pose Dedicated to Garuda

Uttana Pada Garudasana

(ut-TAHN-uh PUH-duh guh-ru-DAHS-uh-nuh)

Modification: legs and arms lifted off the floor
Pose Type: seated, backbend, core
Drishti Point: Angushtamadhye or Angushta Ma Dyai (thumbs)

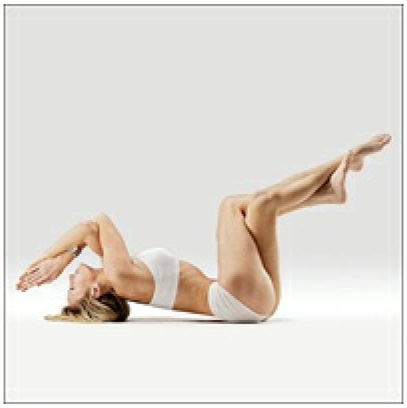

BRIDGE POSE

Complete Bridge Whole Body Pose

Paripurna Setu Bandha Sarvangasana

(puh-ri-POOR-nuh SEY-tu BUHN-duh suhr-vuhng-GAHS-uh-nuh)

Modification: palms to the floor under the shoulders, fingertips pointing to the heels; elbows tucked in, shoulder width apart
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

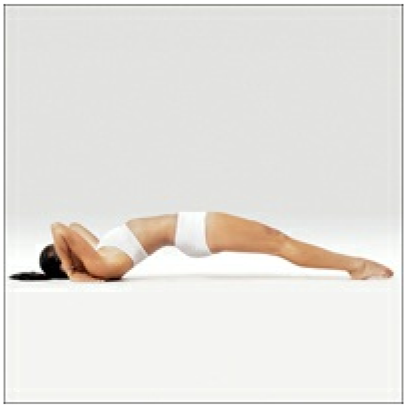

Vajra Cutter Sutra Bridge Pose

Vajracchedika Prajnaparamita Sutra Setu Bandhasana

(vahj-ruh-CHEY-di-kuh pruhj-NAH-puh-ruh-mi-TAH SU-truh SEY-tu buhn-DAHS-uh-nuh)

Modification: forehead to the floor, elbows splaying to the side, arms in "diamond" shape
Pose Type: standing (on the head and feet), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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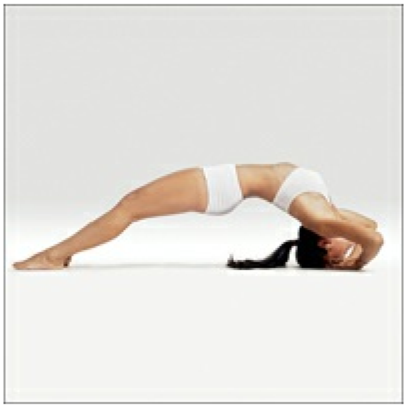

Bridge Pose

Setu Bandhasana

(SEY-tu buhn-DAHS-uh-nuh)

Modification: fingertips to the floor and pointing toward the heels
Pose Type: standing (on the head and feet), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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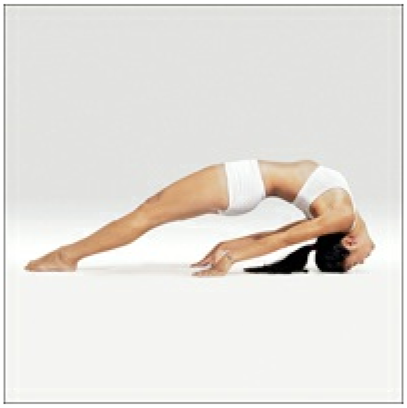

Bridge Pose

Setu Bandhasana

(SEY-tu buhn-DAHS-uh-nuh)

Modification: arms crossed in front of the chest, hands to the shoulders

Pose Type: standing (on the head and feet), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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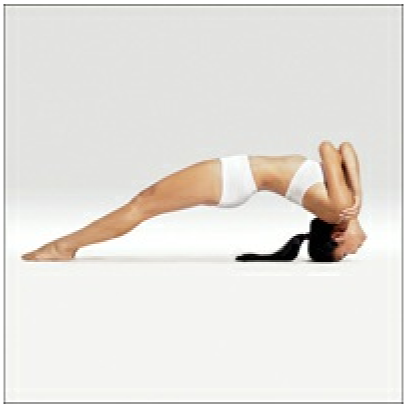

One-Legged Bridge Pose

Eka Pada Setu Bandhasana

(EY-kuh PUH-duh SEY-tu buhn-DAHS-uh-nuh)
Modification: fingertips pointing toward the heels, palms flat on the floor
Pose Type: standing (on the head and feet), backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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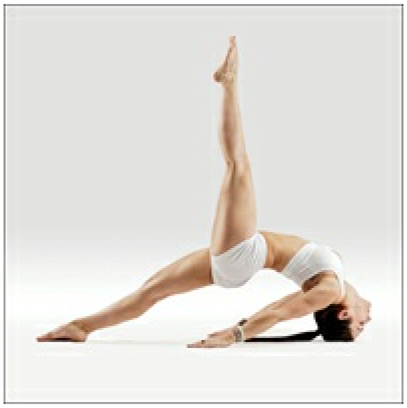

BOUND ANGLE POSE & LOTUS: BACKBEND

Reclined Bound Angle Pose

Supta Baddha Konasana

(SUP-tuh BUH-duh ko-NAHS-uh-nuh)
Also Known As: Bound Legs Fish Pose (Baddha Pada Matsyasana)
Modification: crown of the head to the floor, grabbing onto the shins under the legs

1. elbows to the floor
2. arms straight, elbows off the floor

Pose Type: backbend, standing (on the knees)
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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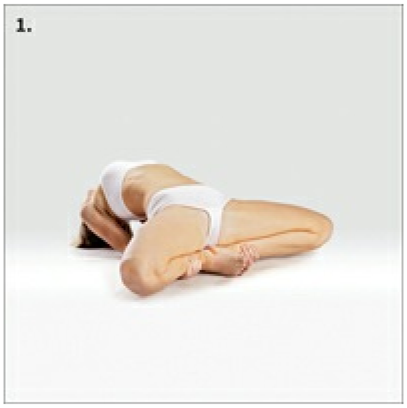

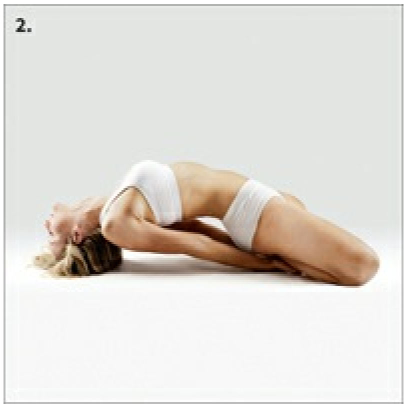

Intense Lotus Peacock

Uttana Padma Mayurasana

(ut-TAHN-uh PUHD-muh muh-yoor-AHS-uh-nuh)

Also Known As: Intense Front Body Stretching and Rejuvenating Lotus Pose (Purvottana Padma Sarvangasana), All Body Parts Lotus Pose (Sarvangasana Padmasana)
Modification: knees on the floor
Pose Type: supine, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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BOTH KNEES BENT: ONE LEG CROSSED OVER

Eye of the Needle Pose

Sucirandrasana

(soo-chi-ruhn-DRAHS-uh-nuh)

Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

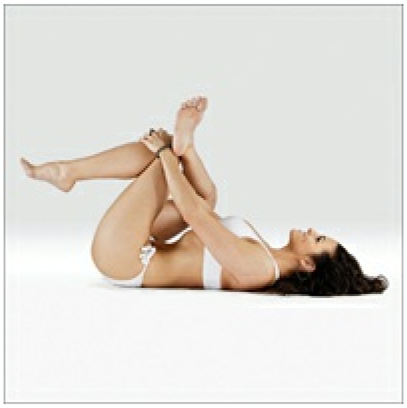

Reclined Leg Position of Cow Face Pose

Supta Pada Gomukhasana

(SUP-tuh PUH-duh go-muk-AHS-uh-nuh)

Modification: knees to the chest, grabbing onto both feet
1. front view
2. side view
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

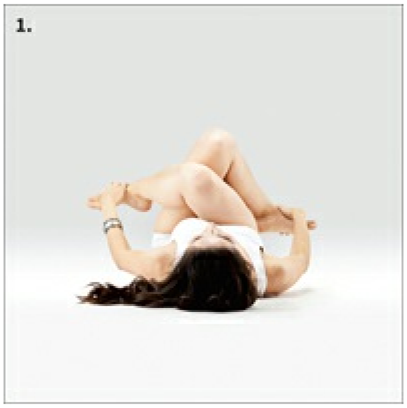

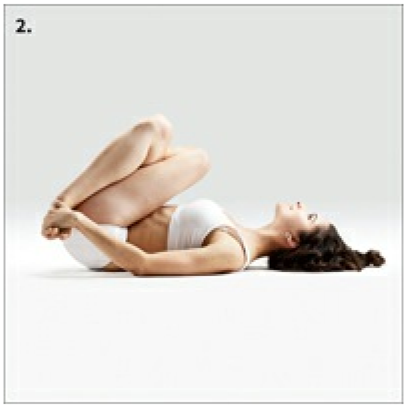

Reclined Twisting Fire Log Pose

Supta Parshva Agnistambhasana

(SUP-tuh PAHRSH-vuh uhg-ni-stuhm-BAHS-uh-nuh)

Pose Type: supine, forward bend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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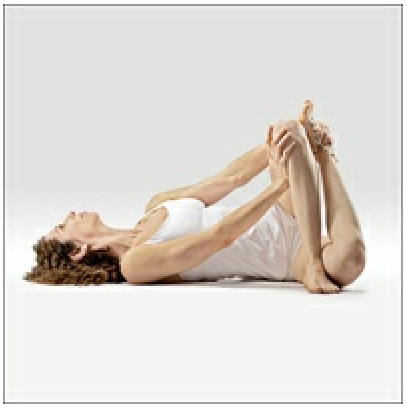

Reclined Leg Position of Half Cow Face Pose

Supta Pada Ardha Gomukhasana

(SUP-tuh PUH-duh UHR-duh go-muk-AHS-uh-nuh)

Modification: knees apart, top foot on the floor
1. one hand to the forehead, other hand on the top knee
2. grabbing onto the shoulders, arms crossed in front of the neck
3. one hand to the top ankle, other hand to the bottom foot

Pose Type: supine, forward bend, twist

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

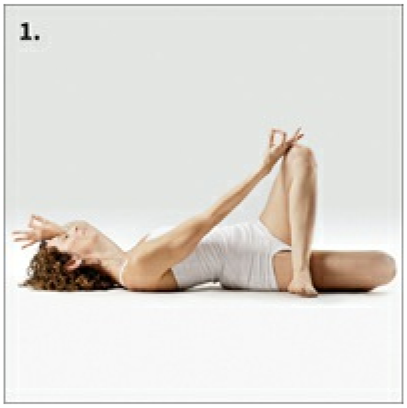
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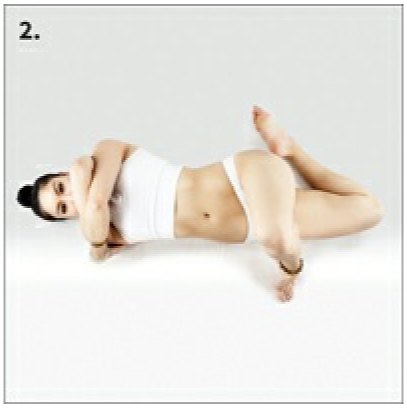
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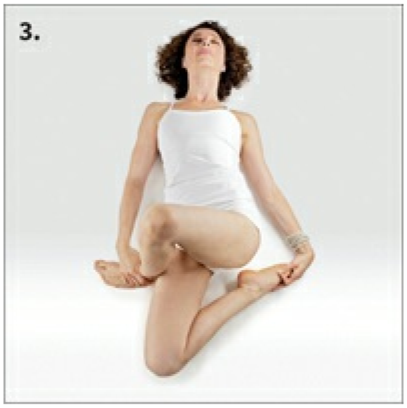
3.

BOTH KNEES BENT: ONE LEG CROSSED OVER—KNEES TO THE FLOOR

Reclined Leg Position of Cow Face Pose

Supta Pada Gomukhasana

(SUP-tuh PUH-duh go-muk-AHS-uh-nuh)

Modification: knees to the floor

Pose Type: supine

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

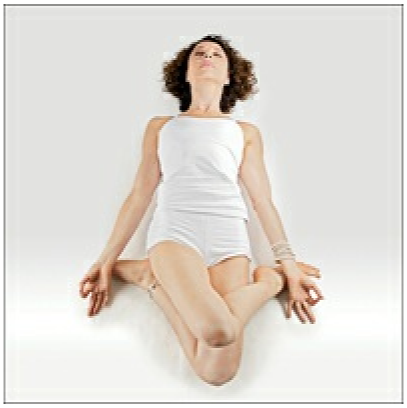

Universal All-Encompassing Diamond Pose

Vishvavajrasana

(vish-vuh-vuhj-RAHS-uh-nuh)

Also Known As: Double Diamond Pose

Modification: foot on top of the knee; hand to the sole of the back foot, other hand resting on the thigh of the front leg, looking straight ahead

Pose Type: supine, twist

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

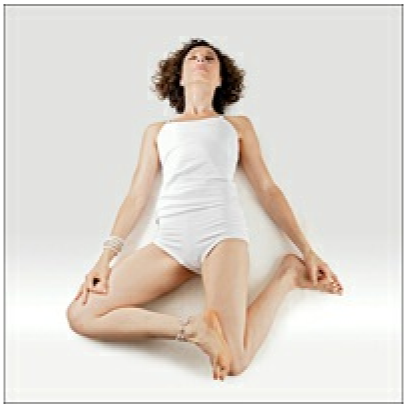

Revolved Universal All-Encompassing Diamond Pose

Parivritta Vishvavajrasana *(puh-ri-VRIT-tuh vish-vuh-vuhj-RAHS-uh-nuh)*

Also Known As: Revolved Double Diamond Pose

Modification: hand grabbing onto the foot; other hand grabbing onto the opposite knee, looking up to the sky
Pose Type: supine, forward bend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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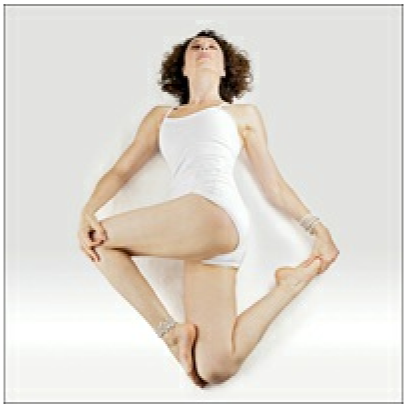

Revolved Universal All-Encompassing Diamond Pose

Parivritta Vishvavajrasana *(puh-ri-VRIT-tuh vish-vuh-vuhj-RAHS-uh-nuh)*
Also Known As: Revolved Double Diamond Pose
Modification: hand grabbing onto the ankle, arm under the thigh; other hand grabbing onto the ankle of the bottom leg, looking straight ahead
Pose Type: supine, forward bend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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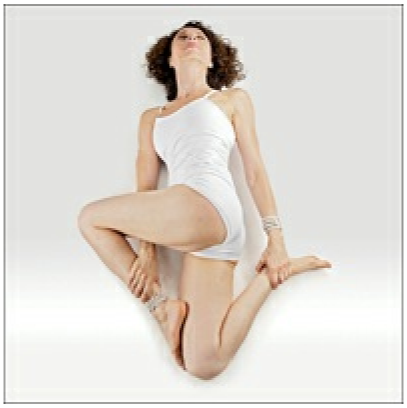

BOTH KNEES BENT: KNEES TOGETHER

Reclined Child’s Pose

Supta Balasana

(SUP-tuh bah-LAHS-uh-nuh)

Also Known As: Pelvic Pose (Apanasana)
Modification: binding arms, grabbing onto the triceps
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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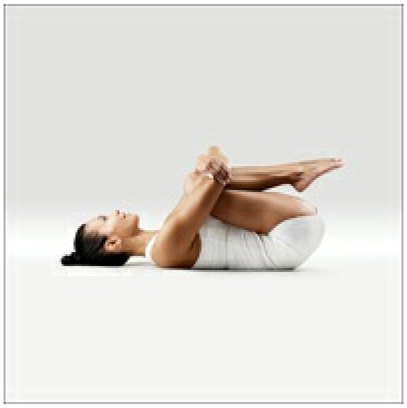

Wind-Relieving Pose

Vayu Muktyasana

(VAH-yuh muk-TYAHS-uh-nuh)

Also Known As: Wind Releaser Pose (Pavana Muktasana)
Modification: fingers interlocked on top of the shins
Pose Type: supine, forward bend, core
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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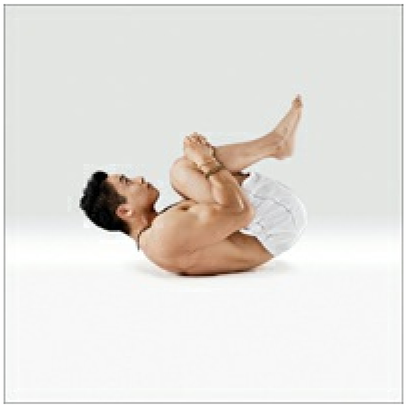

Twisted Stomach Pose

Jatara Parivartanasana

(JAH-tuh-ruh puh-ri-vuhrt-uhn-AHS-uh-nuh)

Also Known As: Reclining Waist Pose Prep.(Supta Madhyasana), Sideways Wind Releaser Pose (Pavana Muktasana)
Modification: knees bent, arms straight out to the sides
Pose Type: supine, forward bend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

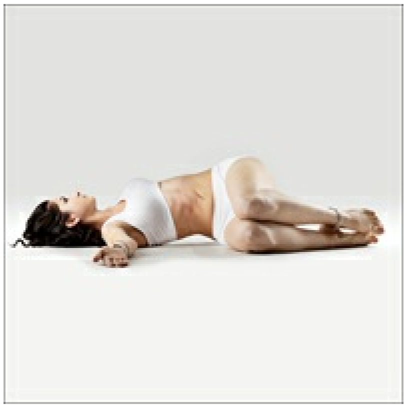

ONE LEG STRAIGHT, ONE KNEE BENT

One-Legged Wind Relieving Pose

Eka Pada Pavana Muktasana

(EY-kuh PUH-duh puh-vuh-nuh muk-TAHS-uh-nuh)
Also Known As: Reclined Big Toe Pose A Prep. (Supta Padangushtasana A Prep.)
Modification: head on the floor, fingers interlocked on top of the shin
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

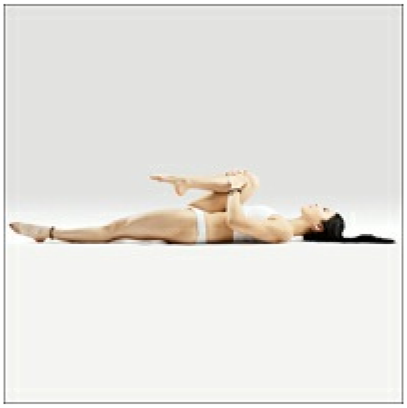

Reclining Tree Pose

Supta Vrikshasana

(SUP-tuh vrik-SHAHS-uh-nuh)

Also Known As: Reclined Big Toe Pose B Prep. (Supta Padangushtasana B Prep.)

Modification: hand to the bent knee, other hand along side of the torso, toes flexed in

Pose Type: supine

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

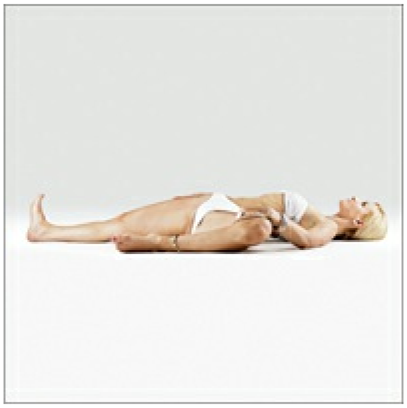

BOTH LEGS STRAIGHT: ONE LEG TO THE SIDE

Revolved Reclining Hand to Foot Pose

Parivritta Supta Hasta Padasana

(puh-ri-VRIT-tuh SUP-tuh HUH-stuh puh-DAHS-uh-nuh)

Modification: legs straight, grabbing onto the inside arch of the foot

Pose Type: supine, forward bend, twist

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

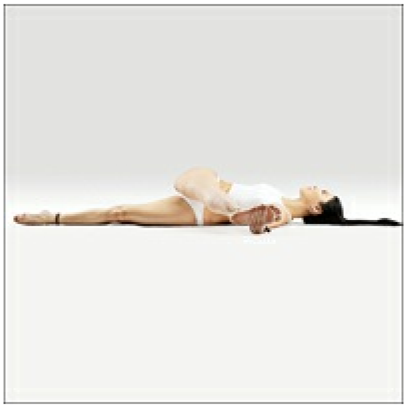

Reclining Big Toe Pose 2

Supta Padangushtasana 2

(SUP-tuh puhd-ahng-goosh-TAHS-uh-nuh)

Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

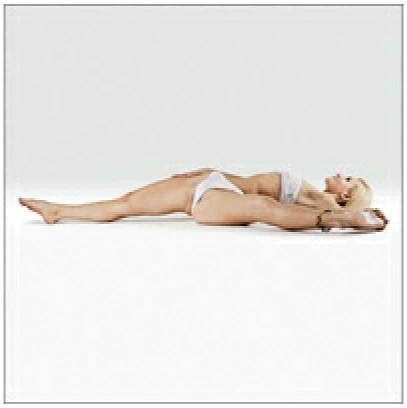

ONE LEG STRAIGHT, ONE KNEE BENT: TWIST

Reclined Lord of the Fishes Pose

Supta Matsyendrasana

(SUP-tuh muhts-yeyn-DRAHS-uh-nuh)

Also Known As: Revolving Reclined Big Toe Pose Prep. (Parivritta Supta Padangushtasana Prep.), Revolved Reclining Tree Pose (Parivritta Supta Vrikshasana)
Modification: knee bent at 90 degrees
Pose Type: supine, forward bend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

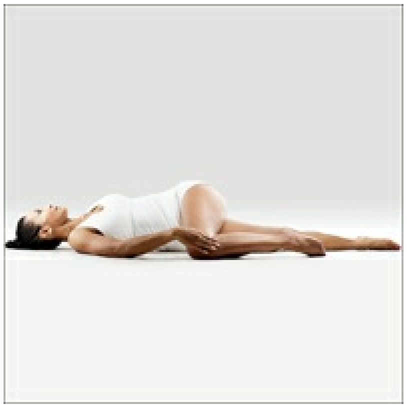

GARUDA LEGS: TWISTS

Sideways Reclining Leg Position of the Pose Dedicated to Garuda

Parshva Supta Pada Garudasana

(PAHRSH-vuh SUP-tuh PUH-duh guh-ru-DAHS-uh-nuh)

Modification: hand resting on the top knee, other arm to the floor along side the torso, looking to the side; arms straight out to the side, looking straight ahead

Pose Type: supine, twist

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre (hands)

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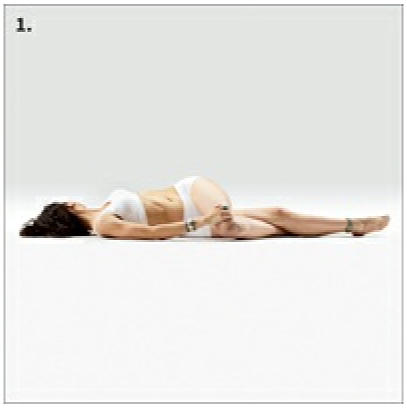

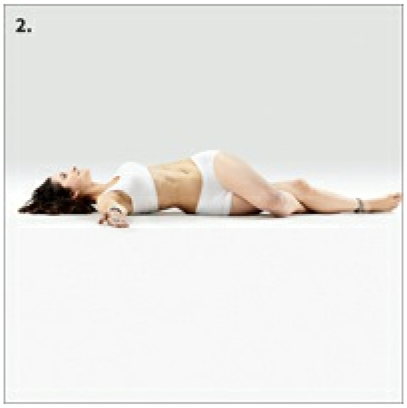

BOTH LEGS STRAIGHT AND TOGETHER: TWIST

Twisted Stomach Pose

Jathara Parivartanasana

(JAH-tuh-ruh puh-ri-vuhrt-uhn-AHS-uh-nuh)

Also Known As: Reclining Waist Pose (Supta Madhyasana)

Modification: legs and arms straight

Pose Type: supine, forward bend, twist

Drishti Point: Hastagrai or Hastagre (hands)

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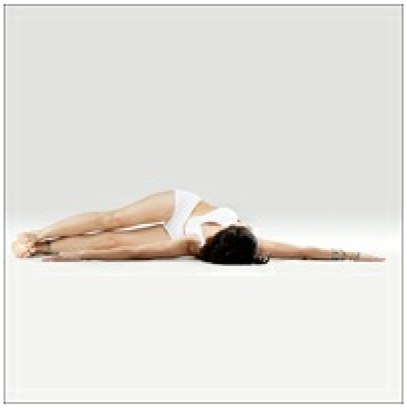

ONE LEG STRAIGHT, ONE KNEE BENT: LEG CRADLE & HALF HAPPY BABY POSE

Reclined Baby Cradle Pose

Supta Hindolasana

(SUP-tuh hin-do-LAHS-uh-nuh)

Modification: back leg straight
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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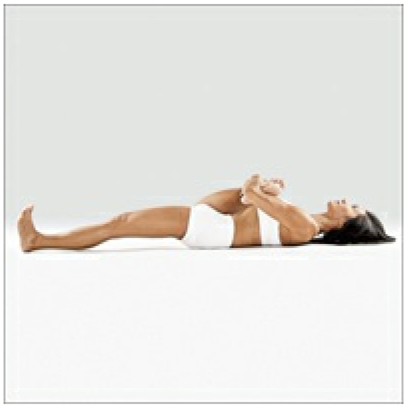

Reclined One Hand to Foot Pose

Supta Eka Hasta Padasana

(SUP-tuh EY-kuh HUH-stuh puh-DAHS-uh-nuh)

Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

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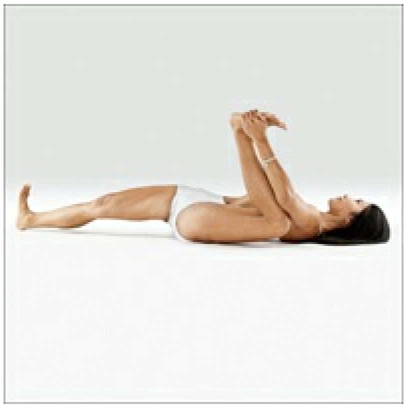

HAPPY BABY POSE & ONE FOOT BEHIND THE HEAD

Happy Baby Pose

Sukha Balasana

(SUK-uh bahl-AHS-uh-nuh)
Also Known As: Happy Baby Pose (Ananda Balasana)
Modification: grabbing onto the big toes of the feet
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

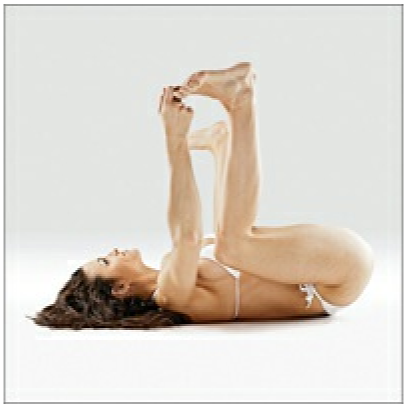

Reclined Star Pose

Supta Tarasana

(SUP-tuh tah-RAHS-uh-nuh)
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

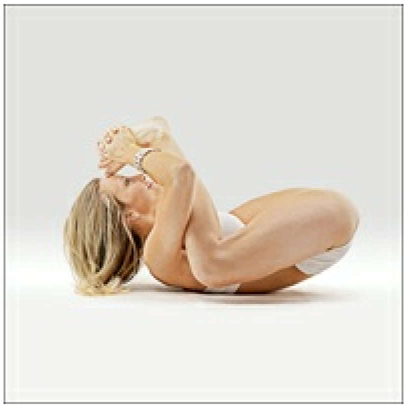

Happy Baby Pose

Sukha Balasana

(SUK-uh bahl-AHS-uh-nuh)

Also Known As: Happy Baby Pose (Ananda Balasana)
Modification: arms crossed, grabbing onto the outside edges of the feet
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

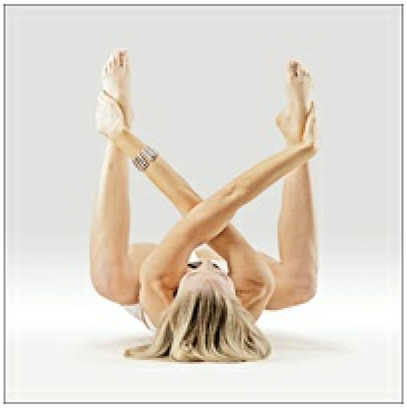

Reclined One Hand to Foot Pose

Supta Eka Hasta Padasana

(SUP-tuh EY-kuh HUH-stuh puh-DAHS-uh-nuh)

Modification: grabbing onto the back foot, heel to the sitting bone, toes pointed to the floor
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

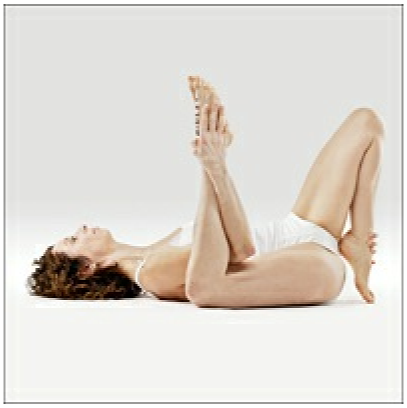

Reclined One Hand to Foot One Leg Behind the Head Pose in Infinity Pose

Supta Eka Hasta Pada Eka Pada Shirshasana in Anantasana

(SUP-tuh EY-kuh-HUH-stuh PUH-duh EY-kuh PUH-duh sheer-SHAS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Modification: bottom knee to the floor, toes pointing up to the sky
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

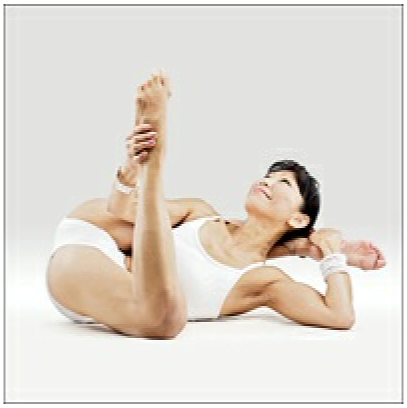

One Leg Behind the Head in Infinity Pose

Eka Pada Shirshasana in Anantasana

(EY-kuh PUH-duh sheer-SHAHS-uh-nuh in uhn-uhnt-AHS-uh-nuh)

Modification: bottom heel toward the hip
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

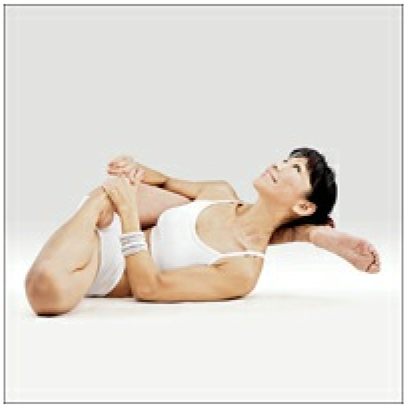

ONE AND BOTH FEET BEHIND THE HEAD

Pose Dedicated to Bhairava in Half Upward Facing Western Intense Stretch 2

Bhairavasana in Ardha Urdhva Mukha Paschimottanasana 2

(b-eye-ruh-VAHS-uh-nuh in UHR-duh OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Pose Dedicated to Bhairava in Half Upward Facing Forward Bend 2
Modification: 1. front view
2. back view
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

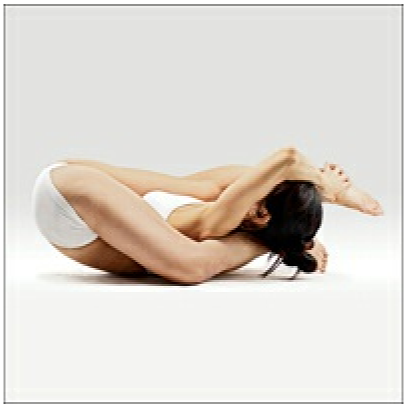

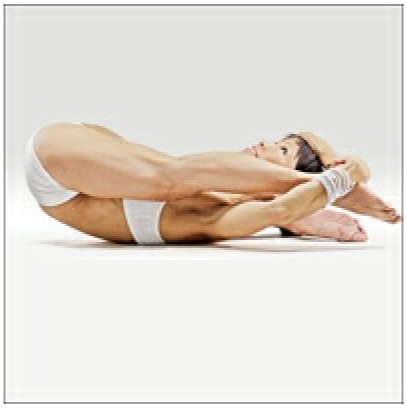

Hands Bound Yogic Sleep Pose

Baddha Hasta Yoganidrasana

(BUH-duh HUH-stuh yo-guh-ni-DRAHS-uh-nuh)

Modification: hands bound
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

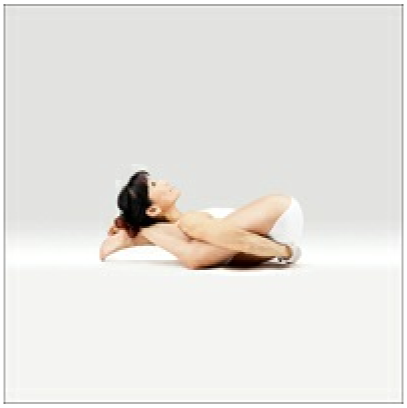

HORIZONTAL SPLITS

Reclined Angle Pose

Supta Konasana

(SUP-tuh ko-NAHS-uh-nuh)

Modification: back flat on the floor, feet lifted off the floor, grabbing onto the big toes
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

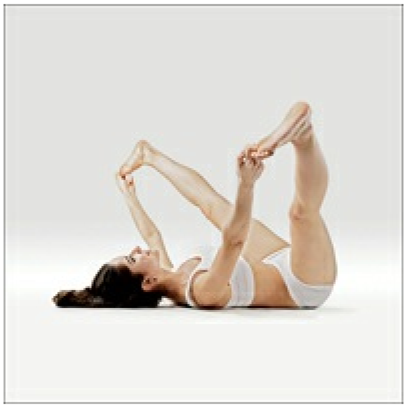

Reclined Angle Pose

Supta Konasana

(SUP-tuh ko-NAHS-uh-nuh)

Modification: back flat on the floor, toes to the floor, grabbing onto the outside edges of the feet
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

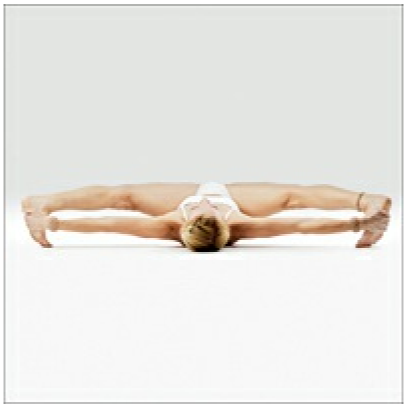

Reclined Angle Pose

Supta Konasana

(SUP-tuh ko-NAHS-uh-nuh)

Modification: back flat on the floor, feet lifted off the floor, arms straight out to the sides, palms down to the floor
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

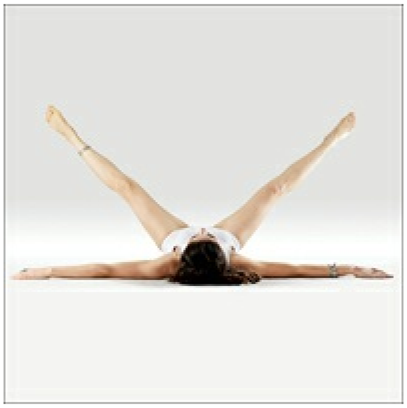

Sideways Reclined Angle Pose

Parshva Supta Konasana

(PAHRSH-vuh SUP-tuh ko-NAHS-uh-nuh)

Modification: back flat on the floor, head turning to side Side 1: leg in the air; arm straight on the floor, palm facing up
Side 2: leg on the floor, grabbing onto the big toe
Pose Type: supine, twist
Drishti Point: Hastagrai or Hastagre (hands)

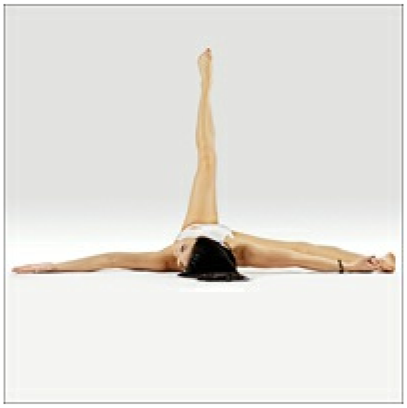

Revolved Half Bound Reclined Angle Pose

Parivritta Ardha Baddha Supta Konasana

(puh-ri-VRIT-uh UHR-duh BUH-duh SUP-tuh ko-NAHS-uh-nuh)

Modification: both legs straight Side 1: leg pointing to the sky; arm wrapping around the back, hand to the inside of the hip on the opposite side
Side 2: leg on the floor, opposite hand grabbing onto the foot
Pose Type: supine, twist, binding
Drishti Point: Hastagrai or Hastagre (hands), Padayoragrai or Padayoragre (toes/feet)

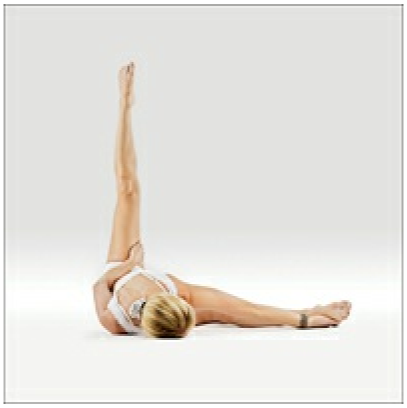

ONE LEG STRAIGHT TO THE SKY, ONE LEG CROSSED OVER

Upward Facing Western Intense Stretch

Urdhva Mukha Paschimottanasana

(OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward Facing Forward Bend
Modification: legs crossed, one arm threaded through the legs, other hand to the center of the chest
Pose Type: supine, forward bend, twist
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

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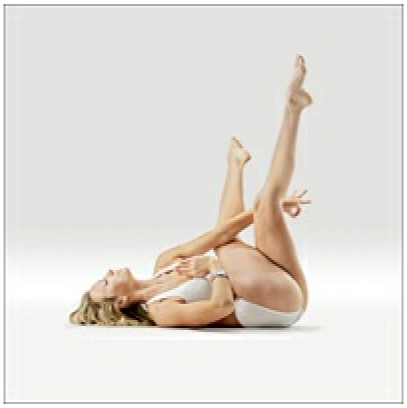

Reclined Hands Bound Pose Dedicated to Astavakra

Supta Baddha Hasta Ashtavakrasana

(SUP-tuh BUH-duh HUH-stuh uhsh-tuh-vuh-KRAHS-uh-nuh)

Also Known As: Reclined Hands Bound Eight Angle Pose
Modification: ankles crossed
Pose Type: supine, forward bend, twist, binding
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

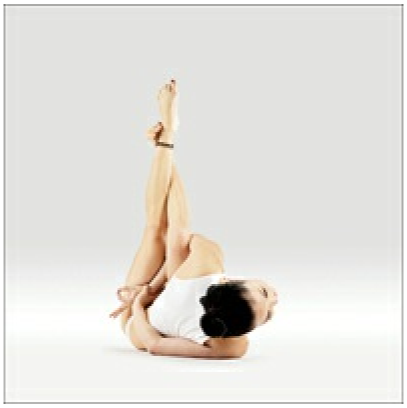

ONE KNEE BENT TO THE BACK, OTHER LEG STRAIGHT

One-Legged Reclined Hero Pose

Eka Pada Supta Virasana

(EY-kuh PUH-duh SUP-tuh veer-AHS-uh-nuh)

Modification: straight leg lifted, fingers interlocked on the back of the thigh
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

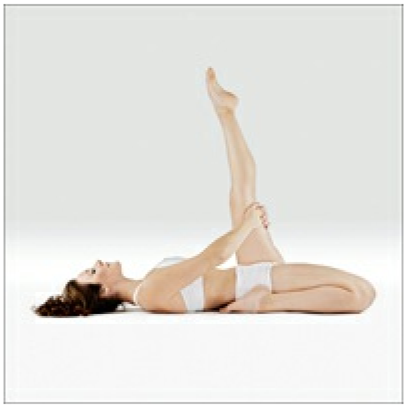

One-Legged Reclined Hero Pose

Eka Pada Supta Virasana

(EY-kuh PUH-duh SUP-tuh veer-AHS-uh-nuh)

Modification: leg straight out to the side, grabbing onto the outside edge of the foot
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

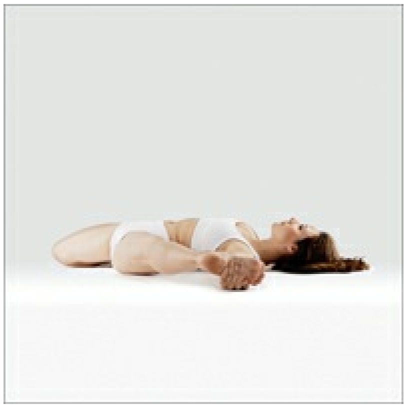

One-Legged Reclined Hero Pose

Eka Pada Supta Virasana

(EY-kuh PUH-duh SUP-tuh veer-AHS-uh-nuh)

Modification: leg straight on the floor, toes flexed in; arms straight out to the sides, palms facing up
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

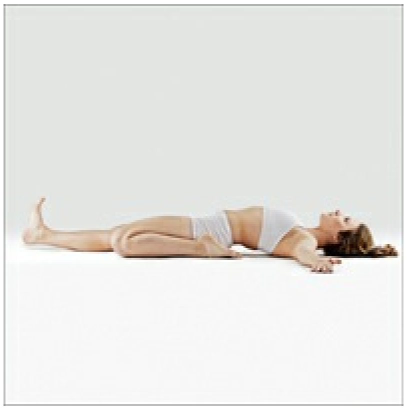

ONE KNEE BENT TO THE BACK, OTHER LEG BENT

One-Legged Reclined Hero Pose

Eka Pada Supta Virasana

(EY-kuh PUH-duh SUP-tuh veer-AHS-uh-nuh)

Modification: Leg 1: in Hero Pose (Virasana)
Leg 2: knee up to the sky, heel to the sitting bones; arms up over the head, palms facing up
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

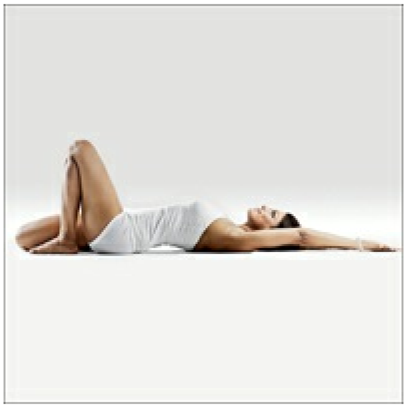

One-Legged Reclined Hero Pose

Eka Pada Supta Virasana

(EY-kuh PUH-duh SUP-tuh veer-AHS-uh-nuh)

Modification: Leg 1: in Hero Pose (Virasana)
Leg 2: knee toward the chest, toes flexed in; fingertips interlocked on top of the knee
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

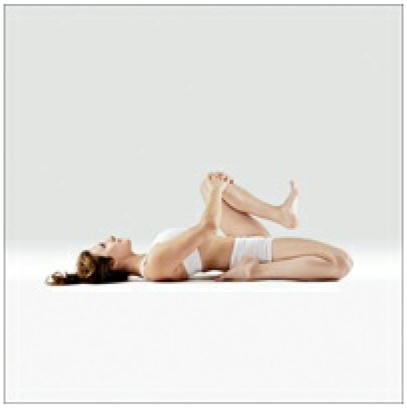

Half Bound Angle Pose in One-Legged Reclined Hero Pose

Ardha Baddha Konasana in Eka Pada Supta Virasana

(UHR-duh BUH-duh ko-NAHS-uh-nuh in EY-kuh PUH-duh SUP-tuh veer-AHS-uh-nuh)

Modification: arms up over the head, palms facing upward
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

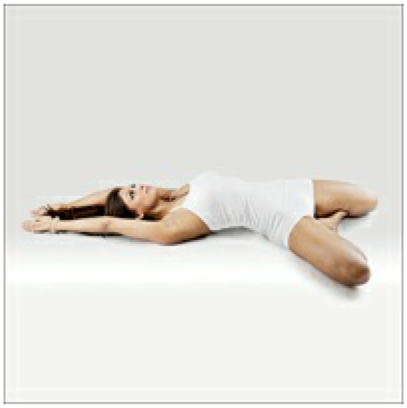

Reclined Hero Pose

Supta Virasana

(SUP-tuh veer-AHS-uh-nuh)

Also Known As: Bed Pose B (Paryankasana B)
Modification: arms up over the head, palms facing upward
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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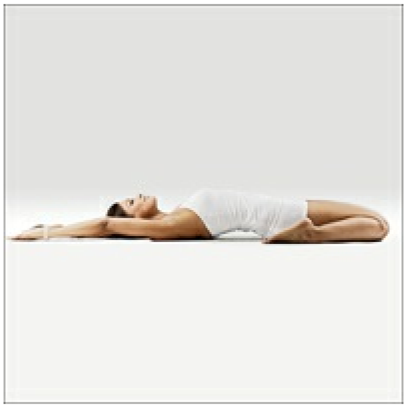

TOES TURNED OUT TO THE SIDE: ONE KNEE BENT TO THE BACK, OTHER LEG BENT

Reclined One-Legged Thunderbolt Pose

Supta Eka Pada Vajrasana

(SUP-tuh EY-kuh PUH-duh vuhj-RAHS-uh-nuh)

Modification: Leg 1: in Thunderbolt Pose (Vajrasana)
Leg 2: knee up to the sky, heel to the sitting bones; arms up over the head, fingers interlocked, palms facing out
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

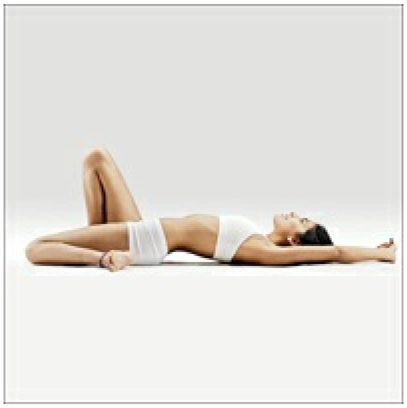

Reclined One-Legged Thunderbolt Pose

Supta Eka Pada Vajrasana

(SUP-tuh EY-kuh PUH-duh vuhj-RAHS-uh-nuh)

Modification: Leg 1: in Thunderbolt Pose (Vajrasana)
Leg 2: knee up to the sky, sole of the foot to the thigh; arms up over the head, fingers interlocked, palms facing out
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

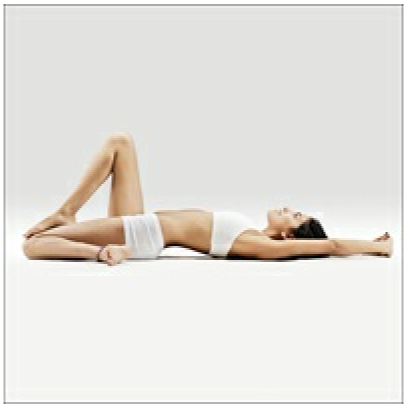

Reclined One-Legged Thunderbolt Pose

Supta Eka Pada Vajrasana

(SUP-tuh EY-kuh PUH-duh vuhj-RAHS-uh-nuh)

Modification: Leg 1: in Thunderbolt Pose (Vajrasana)
Leg 2: knee bent at 90 degrees, heel off the floor; arms up over the head, fingers interlocked, palms facing out
Pose Type: supine

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

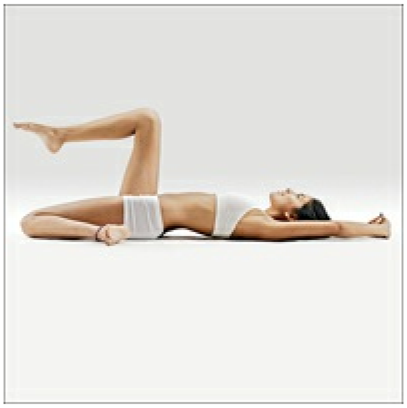

Reclined Complete Thunderbolt Pose

Supta Paripurna Vajrasana

(SUP-tuh puh-ri-POOR-nuh vuhj-RAHS-uh-nuh)

Modification: arms up over the head, fingers interlocked, palms facing out
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

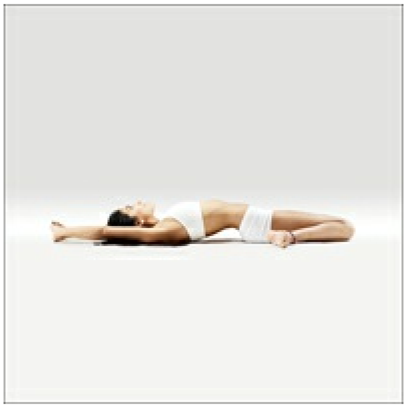

TOES TURNED OUT TO THE SIDE: ONE KNEE BENT TO THE BACK, OTHER LEG STRAIGHT & FOREARM POSES

Reclined One-Legged Thunderbolt Pose

Supta Eka Pada Vajrasana

(SUP-tuh EY-kuh PUH-duh vuhj-RAHS-uh-nuh)

Modification: leg straight to the floor, toes flexed in; arms up over the head, fingers interlocked, palms facing out

Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

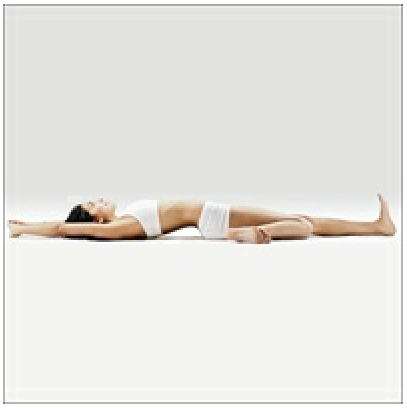

Reclined One-Legged Thunderbolt Pose

Supta Eka Pada Vajrasana

(SUP-tuh EY-kuh PUH-duh vuhj-RAHS-uh-nuh)
Modification: leg straight and lifted off the floor by using a Yoga strap
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

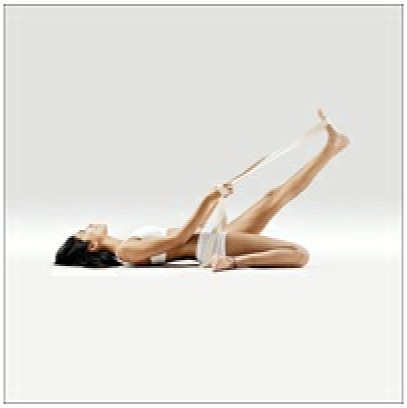

Reclined One-Legged Thunderbolt Pose

Supta Eka Pada Vajrasana

(SUP-tuh EY-kuh PUH-duh vuhj-RAHS-uh-nuh)
Modification: forearms to the floor in a backbend, one leg straight to the floor, toes flexed in, other leg in Thunderbolt Pose (Vajrasana)
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

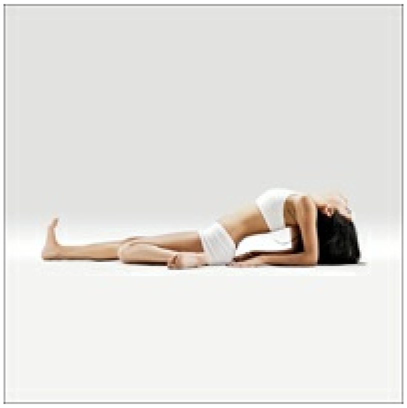

Reclined Complete Thunderbolt Pose

Supta Paripurna Vajrasana

(SUP-tuh puh-ri-POOR-nuh vuhj-RAHS-uh-nuh)

Modification: forearms to the floor in a backbend
Pose Type: seated, backbend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

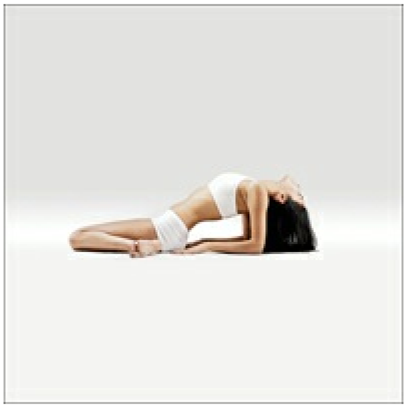

VERTICAL SPLITS: SCISSOR LEGS—BOTH KNEES BENT & ONE KNEE BENT, ONE LEG STRAIGHT

Reclining Both Hands to the Leg Pose

Supta Dwi Hasta Padasana

(SUP-tuh DWI-huh-stuh puh-DAHS-uh-nuh)

Modification: elbows bent, triceps on the floor, fingers interlocked behind the back of the thigh Leg 1: slight knee bend, foot flat on the floor Leg 2: knee bent at 90 degrees, knee toward the chest
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows) or Padayoragrai or

Padayoragre (toes/feet)

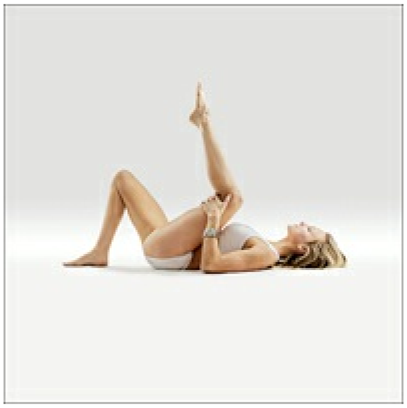

Reclining Half One Leg Extended Pose

Supta Ardha Utthita Eka Padasana

(SUP-tuh UHR-duh UT-ti-tuh EY-kuh puh-DAHS-uh-nuh)

Modification: palms flat to the floor on the sides.

Leg 1: straight up to the sky Leg 2: knee bent, foot flat to the floor, heel to the sitting bones

Pose Type: supine, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

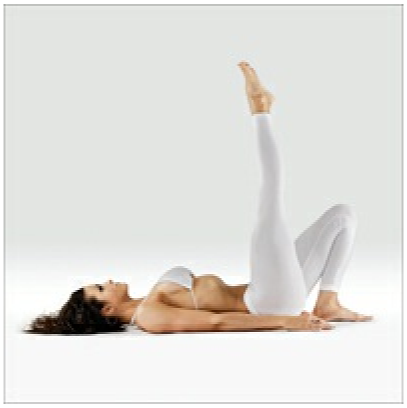

Reclining Both Hands to the Leg Pose

Supta Dwi Hasta Padasana

(SUP-tuh DWi-huh-stuh puh-DAHS-uh-nuh)

Modification: grabbing onto the calf muscle, elbows bent Leg 1: straight and toward the chest Leg 2: knee bent, foot flat to the floor

Pose Type: supine, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

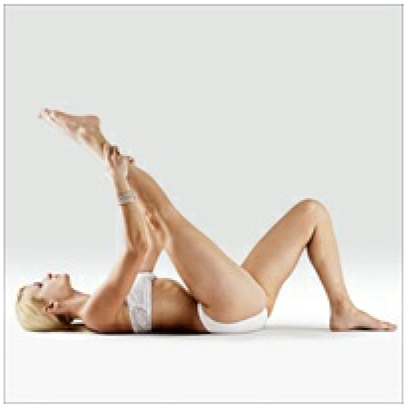

Reclining Both Hands to the Leg Pose

Supta Dwi Hasta Padasana

(SUP-tuh DWI-huh-stuh puh-DAHS-uh-nuh)

Modification: grabbing onto the calf muscle, elbows bent at 90 degrees, nose toward the shin Leg 1: straight and toward the chest Leg 2: knee bent, foot flat to the floor
Pose Type: supine, forward bend, core
Drishti Point: Padayoragrai or Padayoragre (toes/feet), Nasagrai or Nasagre (nose)

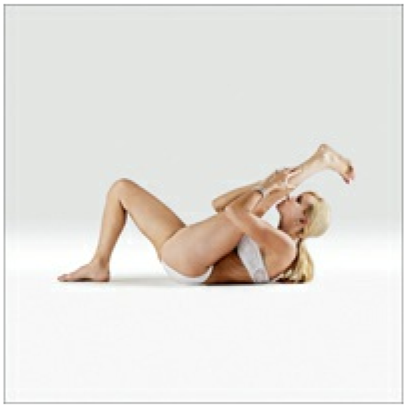

VERTICAL SPLITS: SCISSOR LEGS—BOTH LEGS STRAIGHT

Reclining One Leg Extended Pose

Supta Utthita Eka Padasana

(SUP-tuh UT-ti-tuh EY-kuh puh-DAHS-uh-nuh)

Modification: palms flat to the floor on the sides Leg 1: straight up to the sky Leg 2: straight out on the floor, toes flexed in

Pose Type: supine, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

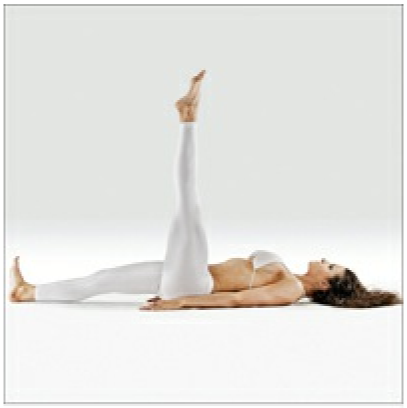

Reclining Big Toe Pose 1

Supta Padangushtasana 1

(SUP-tuh puhd-uhng-goosh-TAHS-uh-nuh)

Modification: back flat on the floor

Pose Type: supine, forward bend

Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

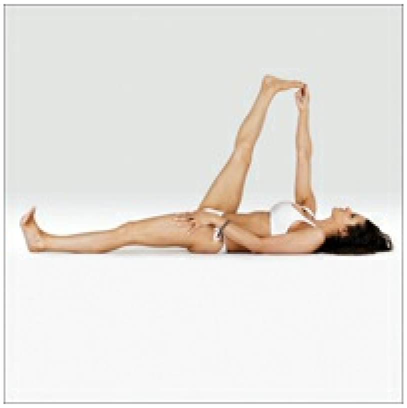

Reclining Big Toe Pose 1

Supta Padangushtasana 1

(SUP-tuh puhd-uhng-goosh-TAHS-uh-nuh)

Modification: head and shoulders off the floor, nose to the shin

Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Nasagrai or Nasagre (nose)
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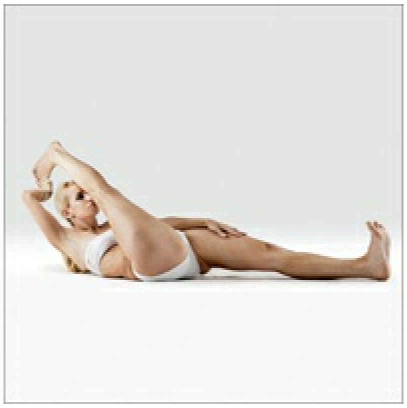

Reclining Both Hands to the Leg Pose

Supta Dwi Hasta Padasana

(SUP-tuh DWI-huh-stuh puh-DAHS-uh-nuh)
Modification: head and shoulders off the floor, nose to the shin, toes pointed
Pose Type: supine, forward bend, core
Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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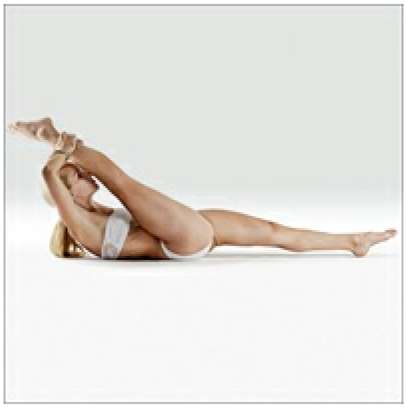

Reclining One Hand to the Leg Pose

Supta Eka Hasta Padasana

(SUP-tuh EY-kuh HUH-stuh puh-DAHS-uh-nuh)
Modification: hand to opposite leg, head and shoulders off the floor, nose to the shin, toes flexed in
Pose Type: supine, forward bend, core

Drishti Point: Nasagrai or Nasagre (nose), Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

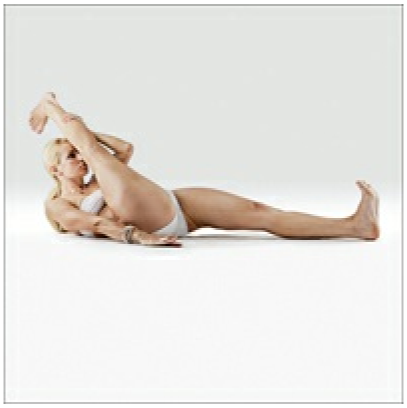

Reclining One Leg Extended Pose

Supta Utthita Eka Padasana

(SUP-tuh UT-ti-tuh EY-kuh puh-DAHS-uh-nuh)

Modification: palms flat to the floor on the sides, head and shoulders off the floor, nose to the knee, bottom toes flexed in
Pose Type: supine, forward bend
Drishti Point: Nasagrai or Nasagre (nose)

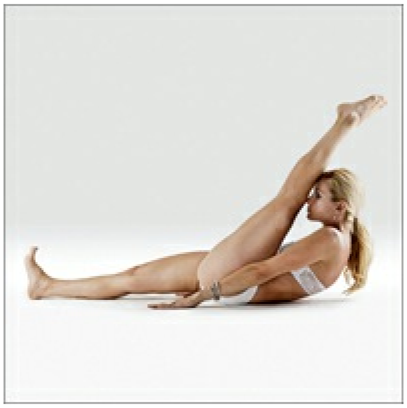

BOTH LEGS STRAIGHT AND TOGETHER

Reclining Legs Extended Pose

Supta Utthita Padasana

(SUP-tuh UT-ti-tuh puh-DAHS-uh-nuh)

Modification: arms crossed in front of the chest

Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

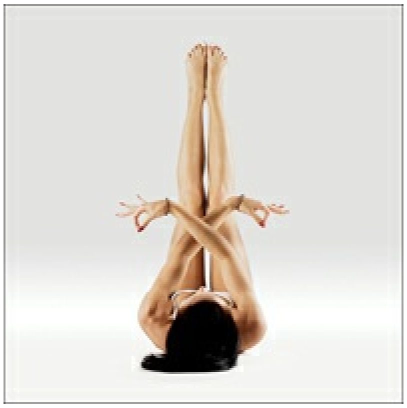

Reclining Legs Extended Pose

Supta Utthita Padasana

(SUP-tuh UT-ti-tuh puh-DAHS-uh-nuh)

Modification: arms straight up to the sky
1. arms and legs perpendicular to the floor
2. arms and legs slightly lowered toward the floor
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet), Hastagrai or Hastagre (hands)

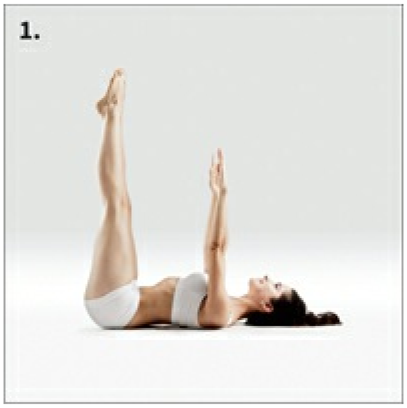

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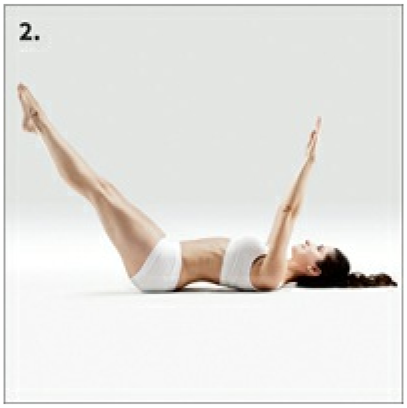

Half Upward Facing Western Intense Stretch 2

Ardha Urdhva Mukha Paschimottanasana 2

(UHR-duh OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Half Upward Facing Forward Bend, Upward Facing Western Intense Stretch Pose 2 Prep. (Urdhva Mukha Paschimottanasana 2 Prep.)
Modification: grabbing onto the calf muscles
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

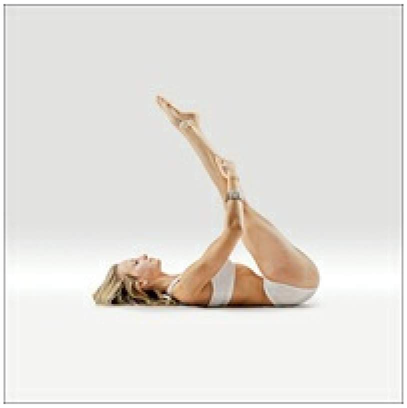

Upward Facing Western Intense Stretch 2

Urdhva Mukha Paschimottanasana 2

(OORD-vuh MUK-uh puhsh-chi-mo-tahn-AHS-uh-nuh)

Also Known As: Upward Facing Forward Bend 2
Pose Type: supine, forward bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Padayoragrai or Padayoragre (toes/feet)

[SUPINE LOTUS & CORPSE POSE]

Reclining Lotus Pose

Supta Padmasana

(SUP-tuh puhd-MAHS-uh-nuh)

Also Known As: Fish Pose (Matsyasana)
Modification: back flat on the floor; arms up over the head, palms facing up
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)
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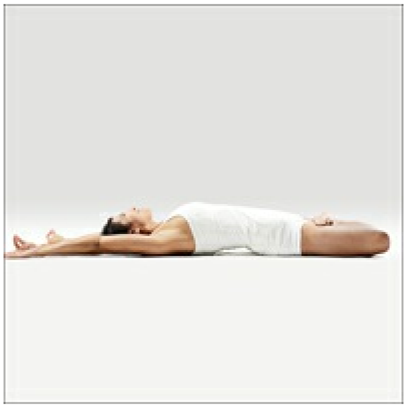

Side Corpse Pose

Parshva Shavasana

(PAHRSH-vuh shuh-VAHS-uh-nuh)

Also Known As: Belly Twist (Jataraparivritti)
Modification: 1. head turned to the opposite side of feet
2. looking straight ahead
Pose Type: supine, side bend
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows), Hastagrai or Hastagre

(hands)

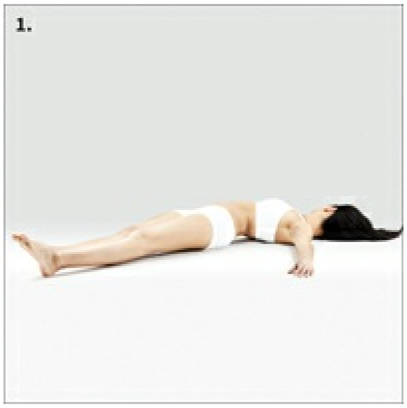

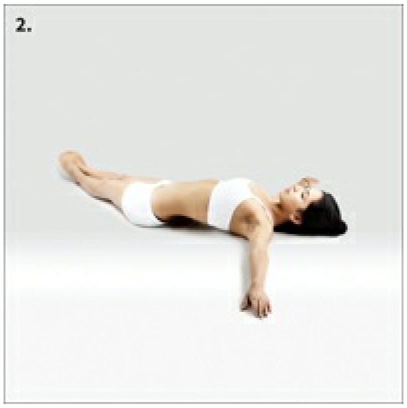

Corpse Pose

Shavasana

(shuh-VAHS-uh-nuh)

Also Known As: Dead Pose (Mrtasana)
Pose Type: supine
Drishti Point: Bhrumadhye or Ajna Chakra (third eye, between the eyebrows)

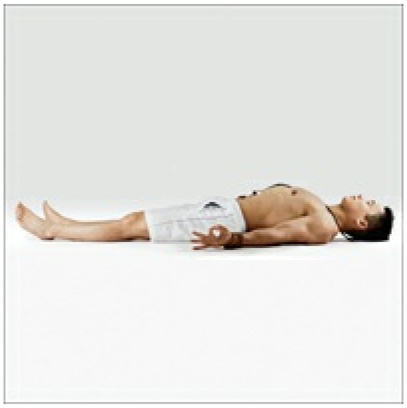

ACKNOWLEDGMENTS

Meet the talented people of Mr. Yoga, Inc. who have contributed their energy, passion, and skills to this project.

Mr. Yoga

Victoria B.

Tatiana U.

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Olga Q. B.

Laura Lisa

Vanessa D. S.

Snow W.

Paul M.

Kat D.

Paula O.

Venessa S.

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Welcome to the Mr. Yoga, Inc. global family. All of the models selected to appear in this book are students of Daniel Lacerda, aka Mr. Yoga.

Frances L.

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Tatiana U.

Elena B.

Stephanie M. & Iva M.

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Hue N.

Deanna D.

Aggie M.

Corrado R. M.

Taylor K.

Susan M.

Neil F.

Justin L.

Thank you to special guest, Danny Paradise.

GLOSSARY

A

adho mukha = having the face downward
agni = fire
ahimsa = nonviolence; the word has not merely the negative and restrictive meaning of “nonkilling or nonviolence,” but the positive and comprehensive meaning of “love embracing all creation”; one of the *yamas*
ajna = to command
ajna chakra = energy or command *chakra*, energy center/the nerve plexus located between the eyebrows, the third eye, the seat of command, the sixth *chakra*
akarna = near the ear
akuncha = contraction or bend
alamba = a prop or support
anahata = unstruck
anahata chakra = spiritual heart *chakra*, energy center situated near the heart, the nervous plexus situated in the cardiac region, the fourth *chakra*
ananda = joy, happiness, bliss, ecstasy
ananta = infinite, without end; a name of Vishnu and also of Vishnu’s couch, the serpent Sesa
anga = limb, points, step, the body; a limb or a part of the body; a constituent part
angushta (angula) = finger or digit, the thumb
anjali = hands held together as in prayer
anjali-mudra = the gesture of *anjali*
Anjaneya = son of Anjani (Hanuman’s mother’s maiden name is Anjani)
antara = within, interior
apanasana = pelvic floor yoga pose
aparigraha = non-greediness, freedom from greed, desire, hoarding or collecting; one of the *yamas*
Arani = Hindu Goddess of Fire
aranya = wild animal
asana = a physical posture, the third limb or stage of yoga, originally this meant “meditation posture” or “seat”
ashta (asta, astau) = eight
Ashtavakra = one having eight bends (crooked in eight places), in reference to a Hindu Sage who was born with eight physical deformities in his body, and went on to become a spiritual preceptor of King Janaka of Mitila
ashva (asva) = horse
ashva sanchala = horse, riding posture
asteya = nonstealing, freedom from avarice; one of the *yamas*
atman = individual soul, the true self, consciousness; the term Vedanta uses instead of *purusha*
avabhinna = broken

avatara = divine manifestation, descent, advent or incarnation of God. There are ten avataras of Vishnu: Matsya (the Fish), Kurma (the Tortoise), Varaha (the Boar), Narasimha (the Man-Lion) Vamana (the Dwarf), Parasurama, Rama (hero of the epic *Ramayana*), Krishna (hero of the epic *Mahabharata*, who related the *Bhagavad Gita*), Balarama, and Kalki

B

baddha = bound

baka = crane, heron, a wading bird

bala = young, childish, not fully grown

bandha = a bond, tying, energetic lock, contraction, bondage, or fetter; a posture in which certain organs or body parts are contracted and controlled

Benu = the mythological bird of ancient Egypt symbolic of rebirth and creation, also associated with the Sun

bhaga = strength

Bhagavad Gita = one of India’s most beloved and sacred texts, the divine song of the Lord, the most influential of all *shastras*; the epic story of Arjuna, a warrior prince who confronts moral dilemmas through sacred dialogues with Krishna (one of Lord Vishnu’s Avatars) and is led to a better understanding of reality by learning the teachings of Samkhya, Yoga, and Vedanta

Bhagavata Purana = also called Shrimad Bhagavatam, a *purana* that deals with devotion to the Supreme Being in the form of Lord Vishnu and describes some of the avatars of Vishnu, including Krishna

bhairava = terrible, gruesome, formidable; one of the fierce manifestations of Shiva

bhakti = devotion, worship or love; from *bhaj*, (to divide), the belief that there is an eternal divide between the Supreme Being and the world that cannot be overcome through knowledge, hence the Supreme Being must be met with an attitude of devotion

bhangi = position

Bharadvaja (Bharadwaja) = a Vedic *rishi*, great warrior described in the *Mahabharata*, Pindola Bharadvaja was one of four *arhats* asked by Buddha to stay on earth to propagate Buddhist law, or *dharma*

bharman = load, nourishment, care, burden, maintenance load

bheka = a frog

bherunda = terrible, frightful; it also means a species of a bird or a name of a yogi

bhuja = arm or shoulder

bhujanga (bhujagga) = serpent, snake

bhuja-pida = pressure on the arm or shoulder

bidala = cat

bija-mantra = a mystical syllable with a sacred prayer repeated mentally during *pranayama*, and the seed thus planted in the mind germinates into one-pointedness

bindu (bindhu) = seed, point, dot, the creative potency of anything where all energies are focused, the third eye

bitila = cow

Brahma = a five-headed first deity of the Hindu Trinity; the Supreme Being, the creator; responsible

for the creation of the world, he is the first being to appear at the dawn of each universe to create it based on its subconscious conditioning: the Brahma of the present universe is called Prajapati (progenitor), the predecessor of humankind
brahmachari = a religious student vowed to celibacy and abstinence; one who is constantly moving (*charin*) in *brahman* (The Supreme Spirit); one who sees divinity in all
brahmacharya = chastity or teacher of the soul, abstinence, a life of celibacy, religious study and self-restraint, recognition of Brahma in everything; one of the *yamas*
Brahman = the absolute, or divinity itself, infinite consciousness, universal soul, deep reality, the reality that cannot be reduced to a deeper layer; the Supreme Being, the cause of the Universe, the all-pervading spirit of the Universe
Buddha = enlightened one

C

chakora = a type of bird like a partridge (Greek partridge), moonbeam bird, said to feed on moonbeams
chakra = literally, a wheel or circle, the wheel of a wagon; metaphorically, psycho-energetic subtle centers of the subtle body in which energy flows, located along the spine, believed to transform cosmic energy into spiritual energy when activated. Energy (*prana*) is said to flow in the human body through three main channels (*nadis*), namely, *sushumna*, *pingala,* and *ida*; *sushumna* is situated inside the spinal column. *Pingala* and *ida* start respectively from the right and the left nostrils, move up to the crown of the head, and course downward to the base of the spine. These two *nadis* intersect with each other and also the *sushumna*. These junctions of the *nadis* are known as *chakras* of the flywheels, which regulate the body mechanism. The important *chakras* are: (a) *muladhara* (*mula* = root, source; *adhara* = support, vital part) situated in the pelvis, above the anus; (b) *svadhishtana* (*sva* = vital force, soul; *adhishtana* = seat of abode) situated above the organs of gestation; (c) *manipuraka* (*manipura* = navel) situated in the navel; (d) *manas* (mind) and (e) *surya* (the sun) which are situated between the navel and the heart; (f) *anahata* (= unbeaten) situated in the cardiac area; (g) *vishuddha* (= pure) situated in the pharyngeal region; (h) *ajna* (= command) situated between the eyebrows; (i) *sahasrara* (= a thousand) which is called a thousand-petaled lotus in the cerebral cavity; and (j) *lalata* (= forehead) which is at the top of the forehead.
chalana = to churn
chamatkara = delight or savoring; the refined pleasure that a connoisseur takes in a lovely poem, painting, or fine wine. Chamatkarasana is translated as “Wild Thing Pose” probably because the posture looks like someone who has just seen something so amazing and beautiful that they are “bowled over” or “blown away.”
chandra (candra) = moon
chapa = bow, rainbow, arc
chatur (chatuari, chatura) = four
chatush = four times
chatushpada = quadruped
chikitsa = therapy

chitta = consciousness that comprises mind, intellect, the restraint of consciousness; a mind in its total or collective sense, being composed of three categories: (a) mind, having the faculty of attention, selection, and rejection; (b) reason, the decisive state which determines the distinction between things; and (c) ego, the I-maker, the aggregate of intellect (*buddhi*), egoity (*ahamkara*) and thinking agent (*manas*)
chittavritti (chitta-vritti, chitta vritti) = an imbalance of the mental state, fluctuations of the mind, movement of the consciousness; a course of behavior, mode of being, condition, or mental state
cibi = chin

D

dakshina = the right side
danda = stick, staff (refers to the spine)
dasha = ten
dhanu (dhanura) = bow
dharana = concentration, sixth limb of Ashtanga yoga, orienting the mind toward a single point
dhyana = generally translated as meditation, freedom from attachments, an ongoing stream of awareness from the meditator toward the object of meditation, and of information from the object toward the meditator; the seventh limb of Ashtanga yoga
dhyana-yoga = yoga of meditation
Diti = the mother of the demons, also called Daityas
drishti = focal point, perception or looking place, “view” or “sight”: yogic gazing, such as at the tip of the nose or the spot between the eyebrows
dur = difficult
Durvasa = a very irascible, notoriously angry sage
dvija = twice-born
dwi (dve) = two
dwihasta = two hands
dwipada = two feet or legs

E

eka (ekam) = one
eka-pada (ekapada) = one leg, one-legged, one-footed

G

gaja = elephant
Galava = the pupil or son of Viswamitra
ganda = the cheek or side of the face including the temple
gandha = subtle earth element; quantum of (*tanmatra*) earth; smell
gandha-bherunda = a species of bird, also a two-headed mythological bird that embodies immense powers and destructive forces
garbha = an infant, womb, fetus

garbha kosha = uterus
garbha pinda (garbha-pinda) = fetus, embryo in the womb
Garuda = Hindu deity, half-man half-eagle, fierce bird of prey, vehicle (*vahana*) of Lord Vishnu, king of birds; Garuda is represented as a vehicle of Vishnu and as having a white face, an aquiline beak, red wings, and a golden body
gava = cow
Gheranda = author of *Gheranda Samhita*, an important text on Hatha Yoga which he taught to Chanda Kapali
Gheranda Samhita = a Tantric treatise describing Hatha Yoga written by the sage Gheranda in the 15th century
Gitananda = a well-known *yogi*, living in the 20th century CE
go = cow
godha = iguana
gomukha = cow face, face resembling a cow, cow head; it is also a kind of musical instrument, narrow at one end and broad at the other, like the face of a cow
Goraksha (Goraksha, Gorakshanath) = an 11th to 12th Century Hindu Nath*yogi*, one of Matsyendranath's two most important disciples; tending to or breeding cattle, cowherd
graiva = a chain worn around the neck of an elephant; necklace or collar
guru = "he who is heavy, weighty," a spiritual teacher or preceptor, one who illuminates the darkness of spiritual doubt, one who hands down a system of knowledge to a disciple; heavy one or dark/light, dispeller of darkness, one who helps to gain knowledge
guru-shishya parampara = the tradition of teaching dating back centuries, where a guru imparts his knowledge to his students

H

ha = first syllable of the word *hatha*, which is composed of the syllables *ha* (= sun) and *tha* (= moon); the object of Hatha Yoga is to balance the flow of solar and lunar energy in the human system
hala = plow
hamsa (hansa) = a swan; a metaphor for the soul; a vehicle of Lord Brahma; the name of the mantra by which *prakriti* permeates the universe; also refers to the breath as it moves within the body
Hanuman = a powerful monkey chief, a mythological entity, of extraordinary strength and prowess, whose exploits are celebrated in the epic *Ramayana*; he was the son of Anjana and Vayu, the god of wind, monkey-god, hero of *Ramayana*, egoless superhero and perfect devotee, who resembles a monkey leaping
hasta = hand
hastasana = forward stretch of the arms
hatha = force; the word *hatha* is used adverbially in the sense of "forcibly" or "against one's will"; Hatha Yoga is so called because it prescribes rigorous discipline in order to find union with the Supreme
hatha-vidya = the science of Hatha Yoga
Hatha Yoga = "Forceful Yoga," a major branch of yoga, developed by Goraksha and other adepts c.

1000–1100 CE, emphasizing the physical aspects of the transformative path, notably postures (*asana*), cleansing techniques (*shodhana*) and breath (*pranayama*); literally, sun/moon yoga (*ha* = sun, *tha* = moon), it emphasizes balancing the solar and lunar energy channels in the body. Hatha Yoga shifted the focus away from the mysticism and philosophy of the older Upanishadic types of yoga toward using the body as a tool; combines opposing forces to achieve balance, sighting the soul through the restraint of energy, yoga concerned with mastering control over the physical body as a path to enlightenment (self-realization)

Hatha Yoga Pradipika = a celebrated treatise on yoga compiled in the 12th century by the sage Svatmarama

himsa = violence, killing

Hindola = cradle or swing; also Hindu Religious Festival associated with baby Krishna being rocked in a decorated swing

I

ida = a *nadi*, a channel through which *prana* moves, starting from the left nostril, then moving to the crown of the head and then descending to the base of the spine on the left side; in its course it conveys lunar energy and so is called *chandra nadi,* “channel of the lunar energy”; associated with pale or blue (left/feminine)

Indra = ruler, lord of thunder, king of the heavens

indudala = crescent moon

Ishvara = God, the Supreme Being, Brahman, with form

ishvara pranidhana = one of the *niyamas*; centering on the divine, devotion or surrender to God, dedication to the Lord of one’s actions and one’s will

J

jalandhara bandha (jalandharabandha) = a *bandha* that locks the throat, chin lock; straightening the back of the neck by keeping your head straight while slightly receding your chin; a yoga pose where the neck and throat are contracted and the chin is rested in the notch between the collarbones at the top of the breast-bone

janu = knee

jatara = stomach, belly, or the interior of anything

jatara-parivartana = an action of an *asana* (yoga pose) in which the abdomen is made to move to and fro

Jnana Yoga = the emphasis is on questioning, contemplation, and meditation as a path to enlightenment, yoga that seeks to teach the identity of the individual self (*atman*) and the infinite consciousness (*brahman*)

K

kaka = crow

Kala Bhairava = Shiva in his terrible or gruesome form as Destroyer of the Universe

Kali = Hindu Goddess of Time and Change

Kamala = Hindu Goddess of Wealth, “One of the Lotus”

Kamalamuni = one of the 18 Siddhars believed to be over 4,000 years old

kanda = a bulbous root, a knot, egg, stem, stalk, trunk; the *kanda* is a round shape of about four inches situated twelve inches above the anus and near the navel, where the three main *nadis* (*sushumna*, *ida*, and *pingala*) unite and separate; it is covered as if with a soft white piece of cloth

kapala = skull

kapalabhati = bellow-like breathing technique with sharp, quick inhalations and exhalations; a cleansing ritual for the respiratory tract, lungs, and sinuses; skull shining

kapila = a sage or *rishi*, the founder of the Samkhya system, one of the six orthodox systems of Hindu philosophy, noted in the *Bhagavad Gita* and *Bhagavata Purana* as a manifestation of the Supreme Being

kapinjala = a kind of partridge, the *chataka* bird, which is supposed to drink only raindrops

kapota = dove, pigeon

kapya = monkey

karanda = duck

karani = making, doing

karma (karma law) = action, activity of any kind, including ritual acts; said to be binding only so long as engaged in a self-centered way; the law of cause and effect, or the movement toward balanced consciousness: everything that you do, say, or think has an immediate effect on the universe that will reverberate back to you in some way

karma yoga (karma-yoga) = yoga of action, path to enlightenment is through selfless acts and service to others, the achievement of union with the Supreme Universal Soul through action; in its original Vedic sense, Karma Yoga is any yoga that employs ritualistic action, such as *asana*, meditation, or *mantra*, to produce spiritual gain. The term excludes Jnana Yoga and Bhakti Yoga, which are thought to operate beyond spiritual gain

karna = the ear; also one of the heroes in the *Mahabharata*

karna-pida = pressure around the ear, blocked ears

Kashyapa = an ancient Hindu sage, husband of Aditi and Diti; he is one of the lords or progenitors of living things

khaga = bird

khanjana = a wagtail bird

Khimi Karani = mythological pond of milk in which Garuda drowned a snake to give birth to the Shami Tree

kona = angle

Konganar = one of the Siddhars, student of Siddhar Bogar

Koormamuni = Hindu Sage

Korakar = one of the 18 Siddhars, a well-known sage, author of works on philosophy, medicine, and alchemy

Koundinya (Kaundinya) = Hindu sage, Vedic scholar, and a descendant of Vasishta

kriya = act, action, cleansing

kriya yoga = the yoga of action and participation in life, preliminary yoga consisting of simplicity (*tapas*), the reading of sacred texts (*svadhyaya*), and acceptance of the existence of a Supreme Being (*ishvarapranidhana*); also, a Tantric mode of yoga using breath, *mantra*, and visualization.

krakacha = a saw

krounch (krouncha, krauncha) = heron

kukkuta = rooster, cock

kulpa = ankle

kundalini = a coiled female serpent; the divine cosmic energy, the obstacle that closes the mouth of *sushumna*; the rising of *shakti* in the *sushumna*; this force or energy is symbolized as a coiled and sleeping serpent lying dormant in the lowest nerve center at the base of the spinal column, the *muladhara-chakra*. This latent energy has to be aroused and made to ascend the main spinal channel, the *sushumna* piercing all the *chakras* right up to the *sahasrata*, the thousand-petaled lotus in the head. Then the *yogi* is in union with the Supreme Universal Soul.

Kundalini Yoga = a mode of yoga that focuses on the raising of the life force

kunja = grove, alcove

kunta = spear, lance

kurma (koorma) = a tortoise, it is also the name of one of the subsidiary vital airs whose function is to control the movements of the eyelids to prevent foreign matter or light that is too bright going into the eyes

L

laghu = little, small, simple; it also means “handsome”

lasya = beauty, happiness, and grace; also a dance performed by Goddess Parvati in response to her husband Shiva’s *tandava*

Linga (Lingam, Shivalinga) = symbol of union and origin of all life associated with Lord Shiva and Goddess Shakti

lola = tremulous, dangling, pendant; charm, swing; swinging like a pendulum, moving to and fro

M

madhya (madya) = middle of the body, central

maha = great, mighty, powerful, lofty, noble

maha bandha = the great lock

maha mudra = the great seal

Mahabharata = the celebrated epic, the largest piece of literature created by humankind, authored by Rishi Vyasa and containing the *Bhagavad Gita*, dating to the first century BCE; *dharma shastra* (scripture dealing with right action), which comes to the conclusion that however hard you try, you can never be completely right

makara = a mythological sea creature, who is the vehicle of the river Goddess Ganga; a crocodile

makshika = fly

mala = a garland or a wreath, often of prayer beads or flowers

manas-chakra = nervous plexus situated between the navel and the heart

mandala = a circle ambulation, a circular drawing or design that exemplifies sacred geometry that draws your eye to the center and is used as a focal point while meditating; it also means a “collection,” a division of Rig Veda

manduka = frog

manipuraka = a nervous plexus situated in the region of the navel; the third *chakra*, the navel *chakra*, the fire energy center, site of the sense of fear and apprehension

mantra = a mystical syllable designed to create and alter reality by influencing the vibrational patterns that make up creation; a sacred sound or phrase that has a transformative effect

Marichi = a sage, son of Brahma, the great-grandfather of Manu, the Vedic Adam and the father of humanity, the creator of the universe, and the father of Kasyapa

marjarai = cat

matsya = fish

Matsyendra = a Hindu sage and one of the first teachers of Hatha Yoga; a legend, king or lord of the fish

mayura = peacock

moksha (moksha) = liberation from bondage, final emancipation of the soul from recurring births

mrita (mrta, mritra) = dead, corpse

mudra = a seal; a pleasant hand gesture or seal posture; directs the life current (life energy) through the human body, usually a combination of *asana*, *pranayama*, and *bandha*

mukha = face

mukta = free, unbound, liberated

mukti = release, liberation, final absolution of the soul from the chain of birth and death

mula = root, foundation, bottom; a yoga pose where the body from the anus to the navel is contracted and lifted toward the spine

mula bandha (mula-bandha) = rectal lock, root lock; contraction of the pubococcygeus, a yoga pose where the body from the anus to the navel is contracted and lifted up and toward the spine

muladhara = root foundation, the name of the first *chakra*

muladhara chakra = the first *chakra*, the base *chakra*, the earth energy center situated at the root of the spine, nervous plexus situated in the pelvis above the anus at the base or root of the spine, the main support of the body that controls sexual energy

mushti = fist

mutra kosa = bladder

N

nabi = navel

nadi = river; nerve or conduit, channels that distribute energy from the *chakras* throughout the body, a tubular organ of the subtle body through which energy flows, subtle vibratory passages of psychospiritual energy; it consists of three layers, one inside the other, like insulation of an electric wire. The innermost layer is called the *sira* and the middle layer, *damani*. The entire organ as well as the outer layer is called *nadi*; they connect at special points of intensity (*chakras*).

naga = great mythological snake; one of the subsidiary vital airs that relieves abdominal pressure, causing one to belch

Nahusha = Hindu King of Aila Dynasty

nakra = crocodile

namaskar = greeting, worship, salutation with hands in prayer

namaste mudra = a *mudra* in which the hands are placed together in a prayerlike fashion to honor the inner light

nantum = to bow with respect

nara = a man

Narasimha = an avatar of the Hindu god Vishnu in his fourth incarnation, often visualized as half-man, half-lion

nasika = nose

nata = actor, dancer, mime

Nataraj = name of Shiva as a cosmic dancer, the lord of the dancers

natya = dancing

nauka = boat

nava = boat

nava = nine

nidra = deep, dreamless sleep; the third state listed in the *Mandukya Upanishad*. The others are waking state (*jagrat*), dream (*susupt*), and consciousness (*turiya*); also the fourth fluctuation of the mind listed by Patanjali in *Yoga Sutra* I.6 (the others are correct cognition, wrong cognition, perceptualization, and memory).

nindra (nantra) = sage, praise, wonder

nindra (nitara) = standing firm, standing

nir = without

nira = water

niralamba = self-supported, independent, without support

niyama = self-restraint, personal observances, self-purification by discipline, the Vedic system of logic; the second stage or limb of Ashtanga Yoga mentioned by Patanjali; five personal disciplines, as defined by Patanjali in his *Yoga Sutras*: *shaucha, santosha, tapas, svadhyaya,* and ishvarapranidhana

O

om (aum) = the original *mantra* symbolizing the ultimate reality, the sacred syllable emitted by the Supreme Being, the sound that produces all other sounds and into which all other sounds return. Like the Latin word *omne*, the Sanskrit work *aum* means “all” and conveys concepts of Omnipotence, Omnipresence, and Omniscience.

P

pada = foot or leg; also a part of a book or text

pada-hasta = hand(s)-to-feet

padangushta = big toe

padma = lotus

pakshaka = wing

pakshi = bird

pancha = five

parampara = tradition, uninterrupted series, convention, a succession

parigha = iron bar used for locking, bolting, or shutting a gate

parigraha = hoarding, possessiveness
paripurna = full, entire, complete
parivartana = turning around, revolving
parivartana-pada = with one leg turned around
parivid = twined, twisted around
parivritta = revolved, turned around
parivritti = crossed or with a twist, turning, rolling
parshva = the side, flank, lateral
parshvaika = *parsva* (side) + *eka* (one)
parshvaika-pada = with one leg turned sideways
parvata = mountain
paryanka = a bed, a couch
pasa (pasha) = snare, trap, noose, fetter
paschima = the back of the whole body from head to heels, west side, western
paschimatana = intense stretch of the back side of the body from the nape to the heels
pakshya = being in or belonging to the wings
patan = to collapse
Patanjali = a sage, the author of the *Yoga Sutras*, a treatises on Sanskrit and *Ayurveda*; the founder of yoga, most likely lived between 200 BCE and 300 CE; a manifestation of the serpent of infinity
pavanamuktasana = wind release pose
perineum = the area between the thighs, behind the genitals, and in front of the anus
pichamayura = peacock with stretched feathers
pid = squeeze
pida = pain, discomfort, pressure
pincha = a feather of a tail, the chin
pinda = a fetus, an embryo in an early stage of gestation, ball, the body
pingala = a channel on the right side of the spine through which *prana* moves, associated with reddish color, a *nadi* or channel of masculine energy starting from the right nostril, then moving to the crown of the head and then downward to the base of the spine; as the solar energy flows through it, it is also called *surya-nadi*
pitam = stool, chair
plavana = jump through
pliha = the spleen
poorna = full
prana = breath, life, vitality, wind, energy, strength; connotes the soul, life force or inner breath; sometimes refers to anatomical or outer breath; vital upward energy current
pranayama = breath control, energy control through breathing, consisting of conscious inhalation (*puraka*), retention (*kumbhaka*), and exhalation (*rechaka*), breath extension, breathing exercises to harmonize the flow of life force; the fourth stage or limb of Ashtanga Yoga
prapada = tip of the feet
prasarita = spread, stretched out
pratyahara = internalization of the senses, independence from sensory stimuli; the fifth stage or limb of Ashtanga Yoga, withdrawal and emancipation of the mind from the domination of the senses and

sensual objects; withdrawal of the mind, mental detachment from the external world

prishta = back

Punakeesar (Punnakeesar) = one of the Siddhars, a *guru* of Machamuni (also referred to as Matsyendra)

pungu = Telugu word for “wounded”

purna = complete

purva = eastern

purvottana = intense stretch of the front side of the body

R

raja = king, royal

raja yoga (raja-yoga) = royal yoga; a term generally applied to the three higher limbs of Ashtanga Yoga, that is *dharana, dhyana,* and *samadhi*; the royal road to self-realization through the control of the mind. The achievement of union with the Supreme Universal Spirit by becoming the ruler of one’s own mind by defeating its enemies, sighting the soul through a restraint of consciousness

raja-kapota (rajakapota) = king pigeon

Ramayana = literally, Rama’s way; a famous ancient epic (*itihasa*) authored by Sage Valmiki that describes the life of Rama, an *avatar* of Lord Vishnu

Rig Veda = literally “Knowledge of Praise,” it consists of 1,028 hymns and is the oldest known reference to *yoga* and possibly the oldest known text in the world

rishi = a Vedic seer, a liberated sage or saint, one who through suspension of the mind can see to the bottom of his heart

Ruchika (Richika, Ruschika) = name of a Hindu sage, dedicated to the grandfather of an incarnation of Vishnu

S

sa = with

sahaja = easy, natural

sahasrara chakra = energy center situated at the crown of the head, the thousand-petaled lotus in the cerebral cavity, the most important seventh *chakra* which, when uncoiled, brings the seeker to freedom

St. Brighid = known for establishing numerous monasteries

sakti = power

salamba = with support

sama = same, equal, even, upright

samadhi = “putting together”: the ecstatic or state in which the mediator becomes one with the object of meditation, forgetting him/herself completely (the Supreme Spirit pervading the universe) where there is a feeling of unutterable joy and peace, absorption, ecstasy, enlightenment, self-realization; the state of meditation in which ego disappears and all becomes one; a state of absolute bliss; the eighth limb or stage of Ashtanga Yoga

samadhi yoga = yoga of absorption

samastiti = a state of balance

Sankarar = yogi from the eighth century BC

Sanskrit = the programming language used to write the operating system of the subtle body; the language of the gods

santosha (santosa) = contentment; one of the *niyamas*

sapta = seven

sarpa = serpent, snake

sarva = all, whole

sarvanga = all parts, the whole body

sasanga = rabbit

satya = truth; one of the yamas

Shesha = a celebrated serpent, said to have a thousand heads; Sesa is represented as the couch of Vishnu, floating on the cosmic ocean, or as supporting the world on his hoods; other names of Shesha are Ananta and Vasuki

setu = a bridge, dam, dike

setu-bandha = the construction of a bridge; name of an *asana* in which the body is arched

shalabha = grasshopper, locust

Shankara, Adi = world teacher, yoga master, propounder of Jnana Yoga and Advaita Vedanta; author of commentaries on the *Brahma Sutra*, the *Upanishads*, the *Bhagavad Gita* and thirty other texts; founder of ten monk orders and four large monasteries whose abbots today still carry the title Shankaracharya. His dates are disputed. Western academics often place him at 800 CE. Tradition places him at 1800 BCE. Also known as Shankaracharya or Shankara Bhagavatpada

shanti = peace

shat = six

shaucha = purity or inner and outer cleanliness; one of the *niyamas*

shava (shava) = corpse

shayana = bed, couch, sleeping

shirsha = head

Shiva (Siva) = the most Powerful God in Hinduism, the Destroyer, a name of the Supreme Being pure consciousness, Brahman with form

shvana (swana) = dog; inspiration

shvnaka = puppy dog

siddha = accomplished, fulfilled, perfected; a sage, seer, or prophet; also a semi-divine being of great purity and holiness, a perfected being, a yoga master who has become an immortal, ethereal being

siddhi = divine attribute, perfection, supernatural power, proof

simha = lion

Skanda = a name of Kartikeya, the god of war, general of the celestial army, Lord of War, second son of Lord Shiva and Godmother Uma Parvat

stamba = transition

steya = theft, robbery

sucirandra = threading the needle

sukha = ease, lightness, comfort, happiness, delight, joy, pleasure; literally, agreeable mental space

Sundaranandar = one of the eighteen Siddhars, author of numerous works on medicine

supta = lying down or sleeping, reclining, supine
surya = sun
surya yantra = sun dial
surya-chakra = nervous plexus situated between the navel and the heart
surya-nadi = the *nadi* of the Sun; another name for *pingala-nadi*
sushumna = the main *nadi* channel situated inside the spinal column, a hollow passageway between *pingala nadi* and *ida nadi* that runs through the spinal cord, and through which *kundalini* can travel once it is awakened
sutra = thread: a work consisting of aphoristic statements such as Patanjali's *Yoga Sutra*
sva = one's own, innate, vital force; soul, self
svadhyaya = education of self by study of divine literature, self-study, to study one's body, mind, intellect, and ego; one of the *niyamas*
svarga = heaven
svastika = good fortune
Svatmarama = the author of *Hatha-yoga-pradipika*, a classical textbook on Hatha Yoga
swadhishtana chakra = site of worldly desires, energy center located above the organ of generation
Swami Sivananda = a well-known *yogi* of the 20th century, founder of Sivananda Yoga
Swami Vishnu Devananda = a close disciple of Swami Sivananda

T

taal-vrksa = palm tree
tada = mountain, straight tree
tadasana-samasthiti = a state of balance; an even distribution of weight while standing
tan = stretch, lengthen out or extend
tana = to stretch out, extend
Tandava (Thandava) = sacred frantic dance representing the cosmic cycles of creation and destruction performed by the Hindu Deity Lord Shiva
tantra = thread on the loom
Tantra (Tantric) Yoga = this yoga is characterized by certain rituals designed to awaken the *kundalini*
tap = to burn, to blaze, to shine, to suffer pain, to be consumed by heat
tapa = austerity
tapas = a burning effort, glow, heat; austerity gained through the committed practice of yoga, self-discipline; practice with discipline, devotion and religiosity; one of the *niyamas*
tara = star
Taraka = a demon slain by Kartikeya, the god of war
tha = the second syllable of the word *hatha*; the first syllable *ha* stands for the sun, while the second syllable *tha* stands for the moon; the union of these two is represented in Hatha Yoga
thavali = frog in Tamil
tirieng = horizontal, oblique, transverse, reverse, upside down
tiryak= horizontally, sideways, obliquely, across
tiryang-mukha = backward facing
tittibha = a small bird living along the coastline; firefly; or insect

tola = balance, scale
tolana = weighing
tri (tri, tra) = three
tryanga = three limbs
trikona = three angle or triangle
Trivikrama = Vishnu in his fifth incarnation, The Dwarf *avatar* of Lord Vishnu, who with his three steps (*krama*) filled the earth, heaven and hell, the conqueror of three worlds
tulya = equilibrium, balance

U

ubhaya = both
uddayate = fly, soar, fly up
uddiyana = a fetter or bondage, a yogic abdominal lock; here the diaphragm is lifted high up the thorax and the abdominal organs by tilting your pelvic floor up and pulling your belly button back toward your spine; the *uddiyana-bandha,* the great bird *prana* (life), is forced to fly up through the *shushumna-nadi*; to fly up
ujjayi = a *pranayama* that produces sound in the throat with the inhalation, literally meaning "extended victory"; the lungs are fully expanded and the chest is puffed out, slow throat breathing
Upanishad = the word is derived from the prefixes *upa* (near) and *ni* (down) added to the root *shad* (to sit); it means sitting down near a *guru* to receive spiritual instruction. The *Upanishad* scriptures of ancient Hindu philosophy are the philosophical portion of the Vedas, the most ancient sacred literature of the Hindus, dealing with the nature of man and the universe and the union of the individual or self with the Universal Soul
upavishta (upavistha) = seated, sitting, with legs spread
urdhva (urdhwa) = upward, raised, elevated, inverted
urdhva-mukha = face upward
ushtra (ustra) = camel
ut = intense, a particle denoting intensity
utkata = fierce, powerful, exceeding the usual measure, excessive, squat
utpluti = lifting or pumping up
utripada = upright tripod
uttana = an intense stretch, upright
utthita = extended, risen or rising, raised up, stretched

V

Vaasamuni Siddhar = a disciple of Shiva
vadivu = old form; Gaja Vadivu is an animal posture from Kalari Yoga, a mystical tantric form of *yoga*, which stems from Kalarippayat
vajra = thunderbolt, Indra's weapon
Vajracchedika Prajnaparamita Sutra = Diamond Cutter Sutra, one of the *sutras* of Mahayana Buddhism focusing on non-attachment
vakra = bent, curved, crooked

Valakhilya = flying wise and virtuous companions, celestial beings; a class of divine personages of the size of a thumb, produced from the Creator’s body, and said to precede the chariot of the sun
Valmiki = known as the father of Sanskrit classical poetry
vama = left side
Vamadeva = the name of the preserving aspect of the God Shiva
vamana = Vishnu in his fifth incarnation, when he was born as a dwarf to humble the demon king Bali
Vasishta = a celebrated sage, author of Yoga Vasistha; several Vedic hymns, most excellent, best, richest
vatayana = horse
vayu = air, vital force, wind, vital air
Vedas = the sacred scriptures of the Hindus, revealed by the Supreme Being
vibhuti = might, power, greatness
vimshati = twenty
vini = single movement
vinyasa = a steady flow of connected yoga *asanas* linked with breath, work in a continuous movement, going progressively, variation
viparita = reversed, inverted, turned
vira = a brave or eminent man, heroic, chief, hero
virabhadra = a legendary warrior, a powerful hero created out of Shiva’s matted hair
Virancha (Viranchi) = one of the names of Lord Brahma
vishama = uneven, unequal
Vishnu (Vishnu, Narayana, Hari) = the second deity of the Hindu Trinity, All-Pervading essence of all beings, one who supports, Preserver God
vishuddhi chakra = seat of intellectual awareness, energy center situated behind the throat, the nervous plexus in the pharyngeal region
vishva = entire, whole
Vishvamitra = a celebrated Hindu Sage, ruler so impressed with Vasistha’s knowledge and contentment that he became his disciple
vrischika = scorpion
vriksha = tree
vrishta = fallen or dropped as rain
vyaghra = tiger

Y

yajna = Hindu Sacrificial Ceremony
yama = ethical codes for daily life, self-restraint
Yama = the god of death; Yama is also the first of the eight limbs or means of attaining yoga. Yamas are universal ethical codes for daily life, self-restraint, and moral commandments or ethical disciplines transcending creeds, countries, age, and time. The five mentioned by Patanjali are: non-violence, truth, non-stealing, continence, and non-coveting
yantra = to sustain
yoga = union, communion, the path which integrates the body, senses, mind, and the intelligence with

the self, derived from "yuj", meaning to join or to yoke, to concentrate one's attention on. It is the union of our will to the will of God, a poise of the soul which enables one to look evenly at life in all its aspects. The chief aim of yoga is to teach the means by which the human soul may be completely united with the Supreme Spirit pervading the universe and thus secure absolution

yoga-mudra = a posture, a seal

yoga-nidra = the sleep of yoga, where the body is at rest as if in sleep while the mind remains fully conscious, though all its movements are stilled; *yoga-nidra* is also the name of an *asana*

Yogananda = a great yogi of the twentieth century

yogasana = yogic posture

Yoga Sutra (yoga-sutra) = a classical collection of aphorisms on the practice of yoga, attributed to the sage Patanjli. It consists of 185 terse aphorisms on yoga and it is divided into four parts dealing respectively with *samadhi*, the means by which yoga is attained, the powers the seeker comes across in his quest, and the state of absolution

yogi or yogini = one who follows the path of *yoga*, a student, a seeker of truth

yogic = an adjective describing things that are associated with *yoga*

yoni = the womb

yoni-mudra = womb or female seal or awakened *kundalini*, the sealing; the breeding place, and *mudra* is a seal; *yoni-mudra* is a sealing posture where the apertures of the head are closed and the aspirant's senses are directed within to enable him to find out the source of his being

yudha = from Yudhisthira, a legendary warrior mentioned in the ancient Hindu epic *Mahabharata*

yuj = to join, to yoke, to use, to concentrate one's attention on

yukti = union

* “Bitilisana” may also be translated as “Gavasana” in the following cow poses.

[*] "Ushtrasana" may also be spelled as "Ustrasana" in the following camel poses.

[*] “Shirshasana” may also be spelled as “Sirsasana” in the following headstand poses.

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THE COMPLETE YOGA POSES

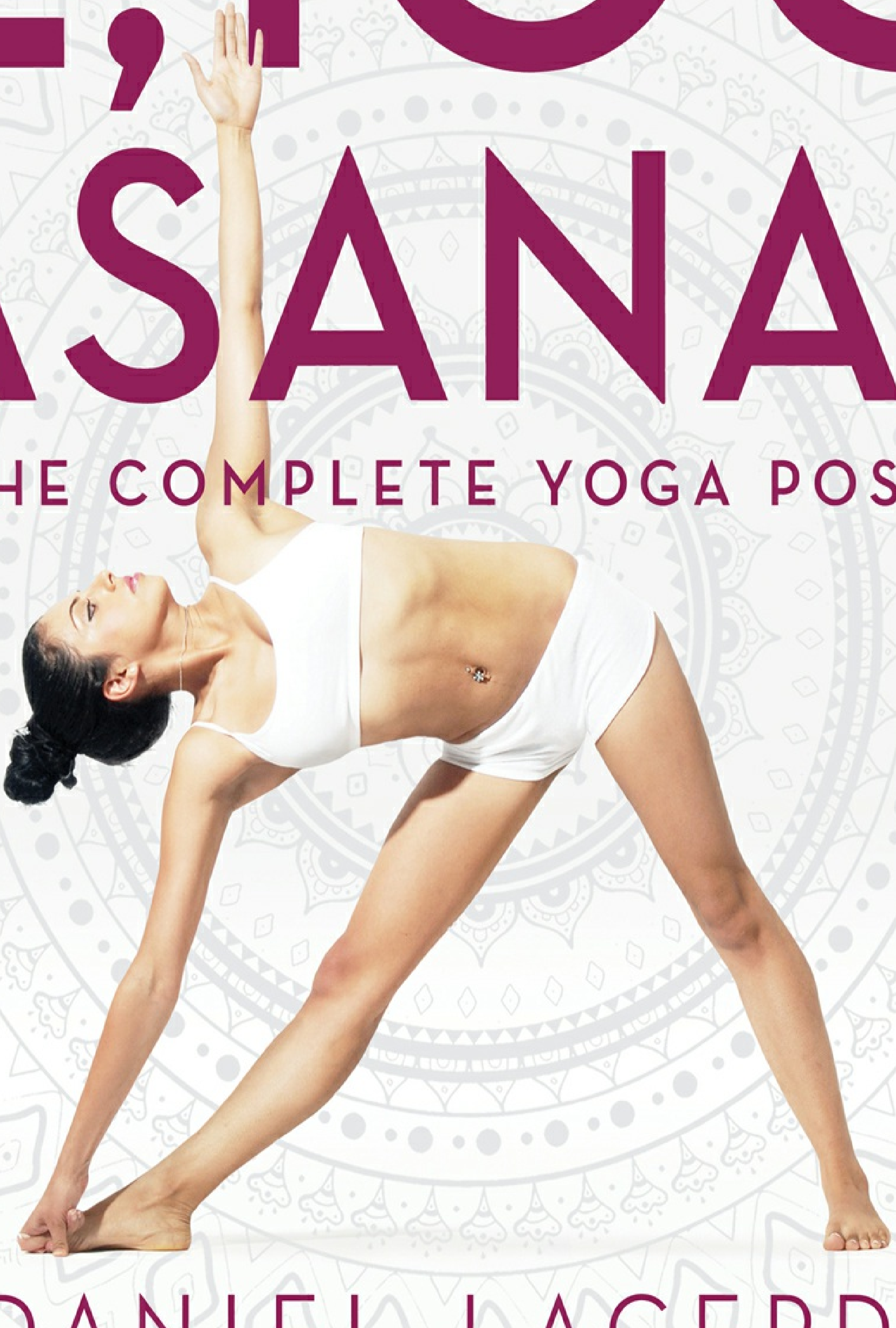

DANIEL LACERDA

FOUNDER OF MR. YOGA, INC.

Fighting the pollution by public radio broadcast antennas

Un texte en français :	La pollution radio par les émetteurs FM
Een tekst in het Nederlands:	De radiovervuiling door FM-stralen
A petition:	www.petition-electrosmog.be

The electromagnetic pollution has now reached such a level that not only hypersensitive persons are being harmed. The debate most often focuses on cell phones, their relay antennas, Wi-Fi routers and similar technologies. It is often pointed out that domestic appliances like power saving lamps and cheap electronic devices, are harmful too. Recently, I came to the conclusion that I too had problems with electromagnetic radiations. Yet after a few months investigating, I was surprised to find out that far out the main cause of my problems was nothing I had heard about. A 100 MHz FM public radio broadcast antenna is located atop a local hospital and burns the whole city with an astounding force of 2 V/m (pike value).

I found other persons that are harmed. For example people who develop severe headaches or tiredness after a few hours working in a given place. They have no problems in other places, that are less exposed to the FM radio waves. It seems to me that people who live in strongly exposed habitations often develop psychiatric problems. My guess is that probably several thousand persons in the city are severely affected. Maybe tens of thousands are affected but without getting obviously sick.

Most puzzling is the fact that this hammering by radio waves is completely useless. It wouldn't change anything to the quality of the reception by the listeners in the city, if the force of the radio waves was divided by 100 or preferably 1,000. The purpose of those antennas is to emit far away in the countryside. That's why they are located atop hills or tall buildings and they have a huge power. But, due to their rudimentary construction, quite much of that power is wasted and hits the nearby city.

It is legal to hit the ground with such force. Whether I measure in rooms or in the open, it is at worst a little below the norms. Hence the problem is with the norms. They keep being too high, despite the efforts of many scholars and health organizations. The situation is catastrophic. If the people did understand the harm that is done to their children, revolts would break open.

Below is a picture of a cheap calculator that I transformed. It contains no more battery nor solar power cell. Instead it draws its energy from a 1 meter long antenna. Anyplace in the city center, in direct view of the emitter, the power of the radio waves is strong enough to feed the device. I made this because nobody was frightened by the figures I was reporting, except some friends that are into electronics. Everybody knows that a car can kill even at 30 km/h speed but almost nobody has any knowledge about radio waves figures. When I showed the calculator, everybody understood and some whitened. (The calculator also works in some classrooms where I tried it out. The emitter was visible through the windows... Should I warn the parents of the students that failed their exams?)

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This didn't help anyway, so I invented another device: the "snake". The picture below shows six of them, an early version.

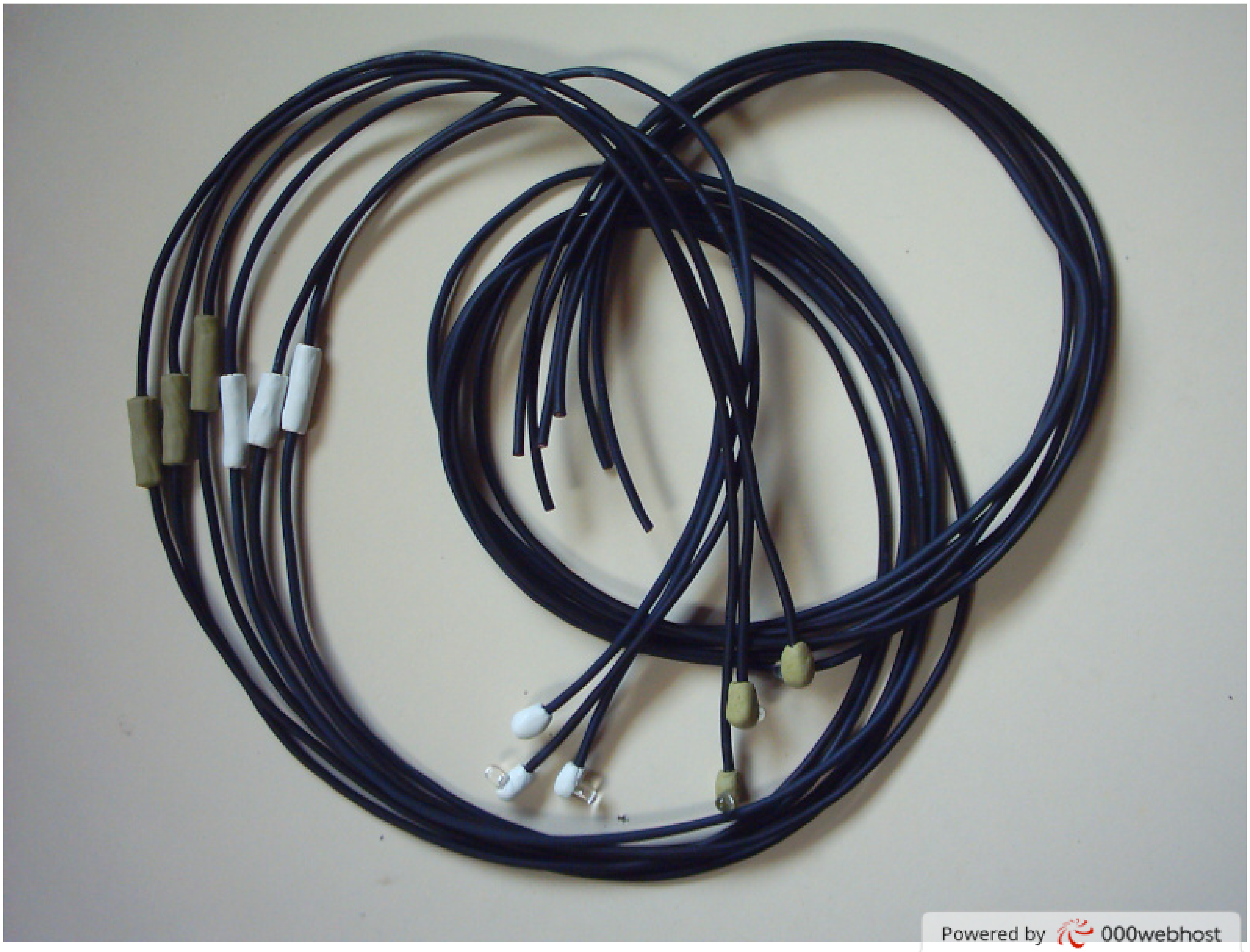

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You just hang the snake in the flux of radio waves and the LED lamp at one end will bright up, clearly visible in daytime and enough to light and read a text at night.

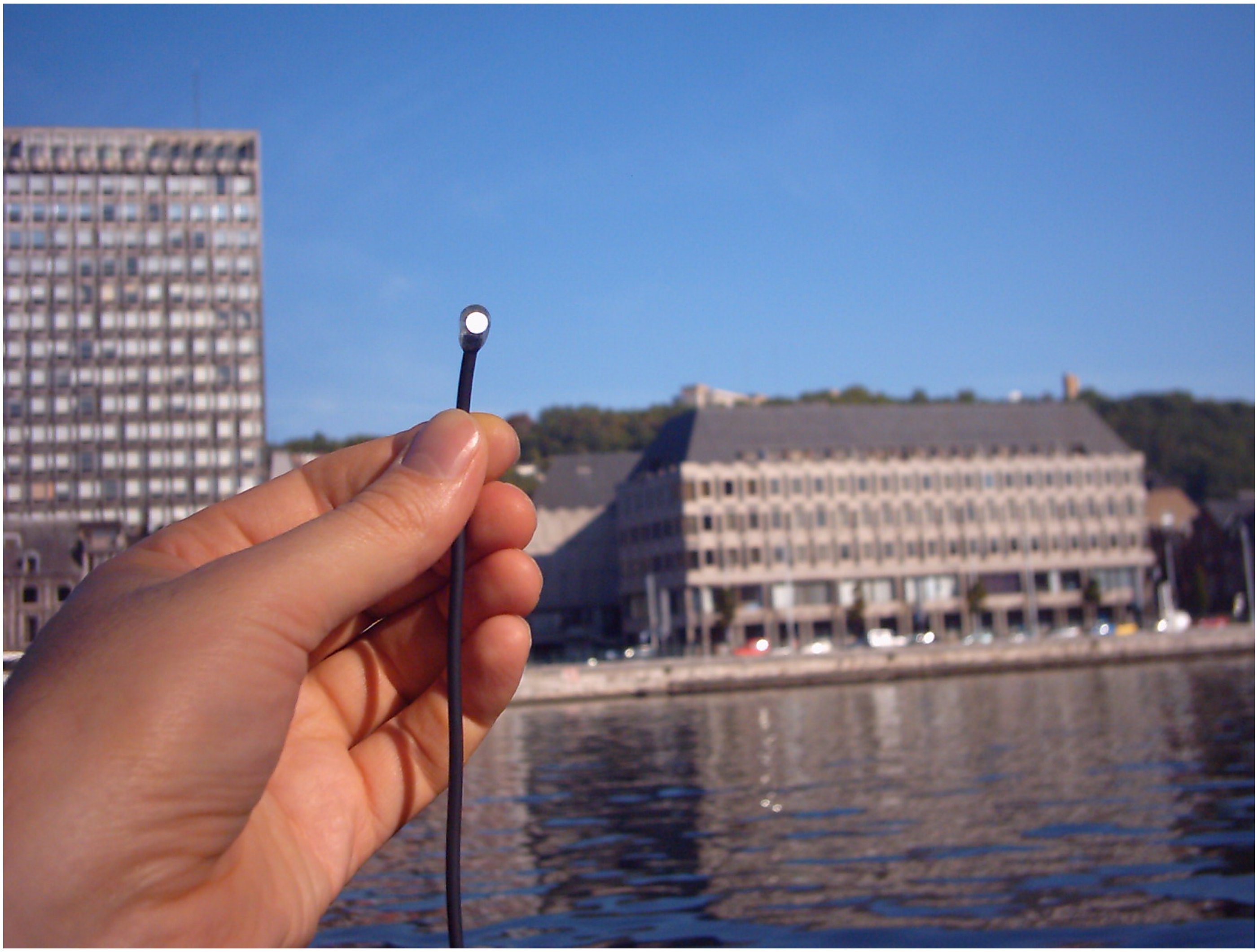

The snake is less impressive than the calculator but it is much cheaper and easier to make and it can be sent in an envelope. I made tens of them and sent them to politicians, newspapers, universities... I gave some to local people, together with a user guide on a sheet of paper. Just like the calculator, the snake contains no battery. The lamp lights up solely on the power of the radio waves. The picture below shows a later version, that can be rolled up in an envelope that fits the conditions to be sent with only one stamp.

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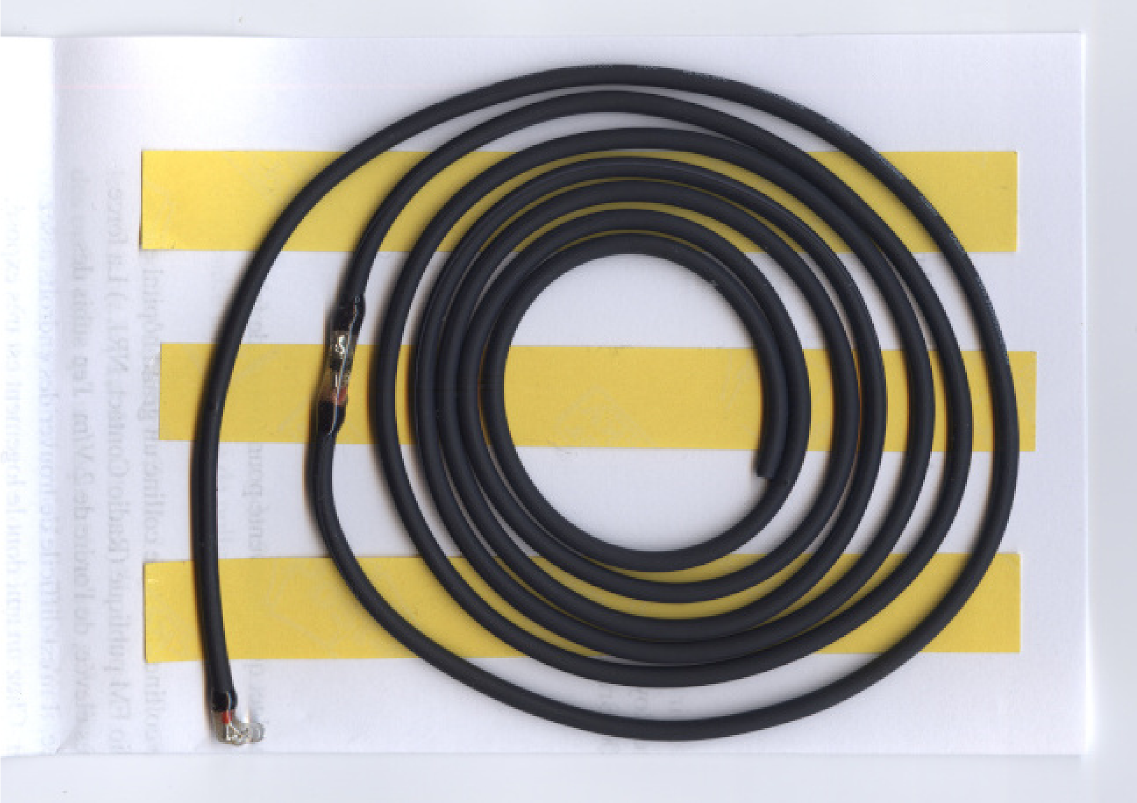

However mad it is to send such power on a city, nothing has been done yet against this. It's like an 19th century chemical plant sending its pollutants all around. Some complain but others argue that closing the factory would mean people laid off. Some then reply that being employed to feed children that die from ugly sicknesses may be nonsense... And so on, except for the fact that the chemical factory indeed had a purpose while the strength of the radio waves we're talking about, has no serious purpose at all.

Something common to all heavy sources of electromagnetic pollution is that it wouldn't cost much to make them harmless. For example, high tension power lines can be made harmless by feeding them DC current instead of AC current. This requires some more heavy electronics at the input and the output but the price of it is a detail in the whole. I studied the schematics of power saving lamps and simply noticed that they were conceived by people who do not understand the propagation of radio waves. Adding the necessary components to make the lamps radio-silent would almost not increase their prices. Enforcing proper norms will not change our way of life, it will just stop to favor the sociopathics amongst the industrials and lobbyists.

So, what can I do to help people understand the situation? They need to appropriate the scientific knowledge involved. Most assume that the necessary studies will be made by labs and then the governments will adapt the laws accordingly... That would be OK if it wasn't for the trillions of money involved. A minister in Belgium tried to prevent sugar dispensers in schools, she immediately got a made-up scandal on her shoulders. All she ultimately managed to get was to have some health advice notices glued on the sacred dispensers...

Flows of observations are now available, showing the effects of radio waves that match the norms: brains of rats destroyed, people unable to work, eggs that don't hatch, quarreling birds, increased risk of cancer, cows aging abnormally... I myself had seeds germinate and saw them die quicker when closer to a power saving lamp. Their strategy to cope with this is simple: "OK, there does exist scientific evidence of some danger... but there also does exist evidence that there is no danger at all! So let's balance the whole..." The norms are lowered but kept above what cell phone operators need for the current systems. The fact in itself of making a balance between scientific evidence is nonsense. Either a study proves a given danger and it can be verified, or bust. But anyway, what are those studies that tend to prove that there would be no danger? Lots of them are simply payed for by the cell phone industry... Yet some are perfectly serious, for example those concluding that radiations within the norms will not heat the brain or the body abnormally. This is perfectly true. There is no problem of scientific fairness involved with these studies. But, is a bullet harmless because it only very slightly heats your bones? A more sophisticated approach is to pick out studies that have borderline conclusions: "there may be a problem but it is not clear..." The study will be assumed to conclude that there is no problem at all, while it just was an inconclusive experiment like many are in science.

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(When I'm exposed, I tend to compulsively perform simple tasks. What if a study examines if being exposed hampers the ability to perform that kind of tasks?)

Then, there is the problem that I'm going to make people sick. Indeed, electromagnetic hypersensitivity has a psychological component. Once people understand that they are victim to the radio waves and what symptoms the radio waves cause, they can overreact and become very sick when they start feeling the symptoms or just when they know there is a strong radiation force around. The radio waves induce a physiological stress, that hampers the proper functioning of the brain. When you add a psychological stress, due to the awareness of the problem, the summation of the two multiplies... Therapies for hypersensitive persons imply to dislearn them to overreact. Some friends of mine just refuse to start talking about electromagnetic sensitivity because they don't want to embark in the sickness. They do so with everything, meanwhile they eat very good food and have lots of pleasure in life. It works... with people with a strong health and a tad of selfishness.

When you are in a cold wind and you feel a pain in the neck, you know it is due to the wind and you take cover. Almost nobody can do this with the symptoms of an exposition to strong radio waves. You feel tired, some brain fog, like if your head was in a clamp, a headache, or simply you make stupid errors... You will blame yourself or the location, possibly the noisy people around... while in fact you are mainly undergoing electromagnetic sensitivity. The home of a friend is strongly exposed. After about twenty minutes I can nor more find my words and speak correctly, unless I wrap my head in aluminum foil. There is a fair chance that a while ago, I would have blamed my friend for being annoying (he is) to the point of making me speechless. There also is a fair chance that my friend is annoying because he hangs in that electromagnetic pollution everyday. Since he lives there, he became an alcoholic, lost his job, manages to keep no girlfriend... (Everything I mention here can have other causes. Quite often, such causes just add up. For example, the person blaming the noisy people around, would maybe have felt nothing if the noisy people weren't there. Like you don't feel your bad knee when you carry no bag.)

The impact of the electromagnetic pollution is severe. It is a far too heavy, and pointless, contribution to our burdens and losses. But how do you establish, scientifically, be it as an amateur, that there indeed is a problem? My initial approach can be an illustration of this. As my home is uninhabitable, I spend most of the day working in local libraries. I noticed that I could work quite well at some places and not at all at other places. Then I saw an article taped on a board, about the effects of cell phone and Wi-Fi radiations. Okay... I made a spreadsheet, with a row for each location and a note from 0 to 10 according to my ability to work there. Although I knew it was a weak approach, I then filled in each row the strength of the closest Wi-Fi router, as listed by my laptop. There was no correlation... but this proved not at all that the Wi-Fi was innocent. Weeks later I made a nonsensical but working little assembly that made the variability of the radio waves hearable. This time I got a correlation. Mild, but obvious. The ability to work is horizontally while the intensity of the radio signals is vertically:

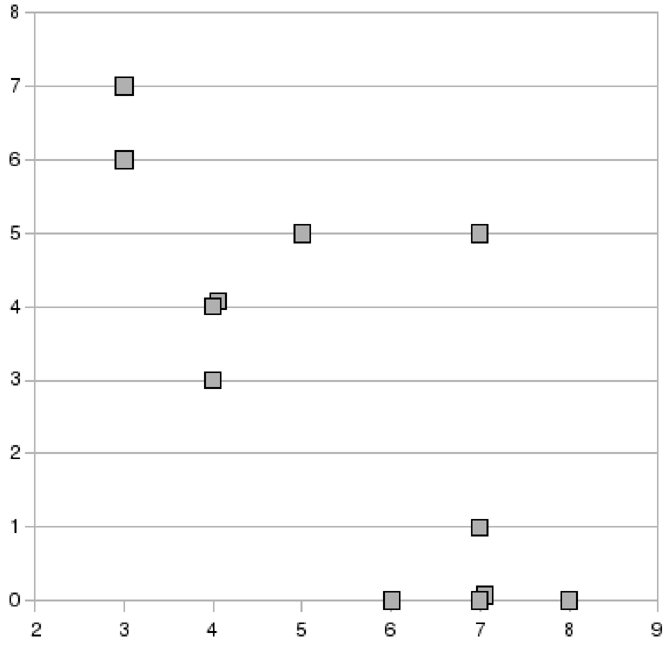

It quickly became obvious that I was measuring no strong signal in the GHz bands. I had no doubt that there were cell phone and Wi-Fi emissions coming from all directions and echoing all around but their strength was obviously

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weak. The problem was with lower frequencies. I accused the fluorescent lamps for a while, till I finally understood that there was only one strong source, hitting me everywhere; those 100 MHz public radio broadcasts. The picture below shows the final correlation. Only one dot disagrees with the theory:

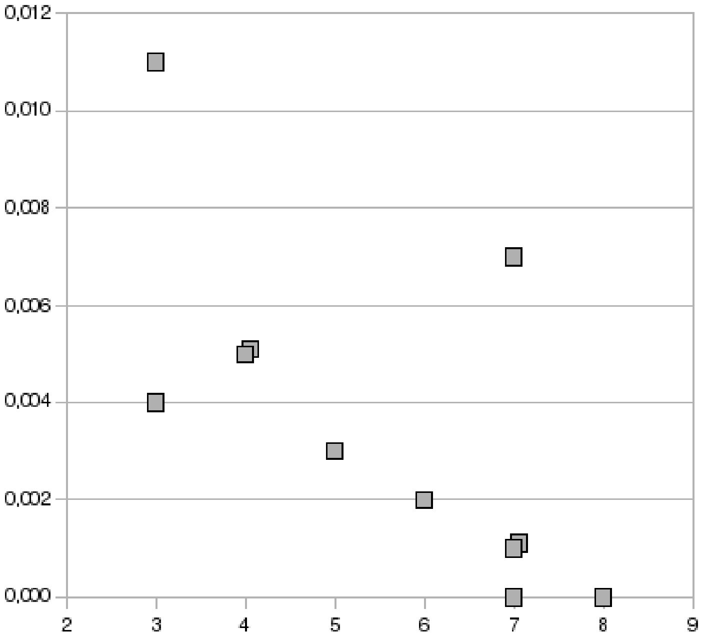

I was heavily disturbed by the radio waves, simply unable to work, long before I started puzzling on the subject. This is a strong proof that the matter is not just psychological. Reciprocally, once I understood the psychological component, I tried to use it positively, to counterbalance the effects of the electrosmog. I did get some results but I was never able to work correctly in the most exposed places. It is by no means "just psychological". It is useless "to be willing to make a small effort". I did efforts that frightened other people. One thing that does clearly help is eating a lot of sugar (Organic jam on rice bread...) (by the way, is that why sugar dispensers are placed everywhere kids are supposed to think and learn, to counterbalance the effects of the nearby cell phone relay antennas?) Alcohol does also help and I'm afraid this is why people seem to become alcoholics in exposed habitations.

Also, it does sometimes happen that I feel like undergoing strong radio waves but when I pop out my measuring device, I measure nothing serious. I have a natural tendency to be knocked-out... The radio waves are far out my heaviest problem but they are not always responsible.

I started studying other sources of radio pollution. I had an obvious benefit of removing every power saving lamp in my home. I put ferrite cores on most power chords. On one power chord that I sometimes use to feed my laptop inside my shielded tent, I had to put ten ferrites till I felt no more direct effect. Something very interesting is that till then I had no problem when using my cell phone. You guessed correctly: I started having problems, to the point that I never more hold it against my ear. I always use an earplug linked to the cell phone by a wire with two ferrite cores. I suppose that since I started avoiding the exposure to strong radio waves (which significantly improved my life and ability to work), my brains are no more constantly knocked out. So they get knocked out if I hold my cell phone against my head. And I feel it. This is one more synergy between the public broadcasts emitters and the cell phone industry: one hides the other away. 'Want to prove that inhabitants close to a relay antenna are no worse than those further away? Do the experiment in a city that is strongly exposed to public broadcasts...

So: buy a measuring tool or have a friend assemble one for you. And start comparing your problems and those of the people around you, with the level of electromagnetic pollution. If you can, make large-scale experiments with tens of persons, under advice of somebody with knowledge in statistics (to build an expressive statistic yet completely false, is *easy*). We need many such experiments, till it becomes unbearable for local interlocutors to negate the problem and not to dim the emissions. Step by step, we need to conquer our world back. Some enterprises and some countries have already set their norms at responsible levels.

One very important parameter is the rate at which the problems build up and then disappear, when exposed. Some people claim that they instantly feel when their cell phone is going to ring. I never could verify this. A friend claims that his cat reacts when he is going to get a text message on his cell phone. I tried several times to see the cat change

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behavior while making my cell phone emit close to him but I got nothing. So I suppose that the cat reacts to the tone of the cell phone and my friend brain-confuses the timing. (I don't pretend nobody can feel a text message arriving, I'm just saying that I never could verify.) What I'm sure about is that my problems need minutes to build up, most often some ten or twenty minutes, the problem possibly becoming really painful after an hour. Once the problem built up, it needs much more time to diminish, maybe four times more. I often had to sleep a whole night on it. One day I "burned" my brains by holding a very polluting power saving lamp about 3 decimeters away from my head. I only noticed the problem after half an hour. But then it was horrible, like if a flame had been sweeping inside my head. Really just like the ache of a burn wound. I had a strong nausea and headache, that calmed down only hours later. I identified a few persons whose problems are obviously due to the electromagnetic pollution, in all cases the same applies: it needs time to build up. This means you cannot simply walk in and out of an exposed zone and claim you feel no difference. Also, you cannot get into a safe zone and claim you feel no better. If you were already poisoned, you will stay that way a long while. The only sure approach is to stay really long in a safe zone, preferably spend the night there, then go working in a polluted area. Try to be aware of what happens to you. The next day go working in a safe zone and try to see the difference. (This is a goldmine to build inconclusive studies.)

Everybody is sensitive to electromagnetic waves. The question is about the level of the sensibility. That's why people who get seriously sick with the current levels of exposition are called "hypersensitive". They are more sensitive than the average, sometimes with very painful and debilitating consequences.

There is a whole ladder of symptoms. This is roughly the ladder for me, exposed to the 100 MHz FM broadcasts:

0.01	V/m	No problem
0.1	V/m	No more able to concentrate and work
1	V/m	head in a clamp, maybe difficulties to talk
10	V/m	Tried it once for 2 hours, had to stay the whole next day in bed with an awful headache.

The serious problems begin for me at 0.1 V/m. Yet I know some people that wouldn't be called hypersensitive and that get problems similar to mine at about 0.3 V/m. A friend spent with me the two hours under the 10 V/m radiation and claimed he endured no problem... but he made surprising errors on the way back. It is very difficult for me, in my city, to find locations where the force is around 0.01 V/m. Values between 0.1 and 0.3 are common. It is easy to find building with rooms reaching 1 V/m. The force is quite predictable, according to the location and the orientation of the building, how much it emerges out of other buildings... So, because many people are being affected and because the radiation is reasonably easy to measure or to estimate, making statistics linking common health problems with the level of exposition is quite doable.

Hypersensitive persons would be 1% of the population. The need to protect this minority is enough to stop those powerful broadcasts from reaching the ground. I don't understand why I have to add that everybody is being harmed, be it to a lesser degree. I met official people whose job is to help hypersensitive persons. They've seen their pain and anguish by themselves... but they feel clueless as to how to stop the emissions. It's a very strange situation, when even the people close to the steer and convinced of a problem, can't do anything to stop it.

It has been claimed that the hypersensitivity of some persons is caused by an accumulation of toxic metals or organic pollutants. In such cases, antioxidants can be of immediate help and detoxifications would greatly help. (Note that common medical analysis like looking for mercury and the like in samples of blood, urine or hair, will reveal nothing even under severe intoxication, because blood and hair renew constantly. Only a sudden intoxication can be revealed by such analysis. The toxics slowly accumulated in standing body cells like the brain... Best method seem to be to take a well-tuned quantity of chelating molecules and then perform an analysis of the blood or urine.)

Cell phone and Wi-Fi radiations are different, for several reasons: they don't spread the same way in the body, they are pulsated and their frequency make they will not target the same macromolecules in the body. It would seem that you need 3 times more force of FM broadcast waves than cell phone or Wi-Fi waves, to have a same global impact...

I was frightened when I understood that under those 2 V/m force of radiation, an electric current in the order of 1 mA oscillates through the body. Such a current at a high frequency of 100 MHz will interact with the body quite differently than a DC or low frequency AC current. You cannot make direct comparisons... Anyway, 100 mA of DC current can be enough to kill a person by electrocution. 1 mA of low frequency current is enough to feel the current as a tickle. What are the consequences of such a current on the chemical reactions in the liver, on the production of

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hormones by glands everywhere in the body? What if the person being exposed is a pregnant woman, with the baby just at the worst place in the flux of current? The length of an "antenna" matters much to allow it to build up current. Teenagers have the "optimal" length for 100 MHz radio waves... One thing I'm sure about is that if the government decided that from now on the school kids will be latched electrodes on the body and a current of 1 mA send through several hours a day, whatever the frequency, the parents will not accept. But this *is* happening, through radio waves, and I could feel the neuroleptic-like effect of it. (By the way, this implies that those experiments that show brains of rats destroyed by cell phones waves within the norms, apply only to a lesser degree to human brains, because of the difference in size. Rats are close to the optimal length to be harmed by cell phone waves... The optimal wavelength to dammage teenagers is that of those 100 MHz public broadcasts...)

The radiations harm me more inside buildings than outside. I may get more sick under 0.2 V/m in a room than under 2 V/m directly exposed to an antenna. I don't know exactly why. Here are four possibilities:

- The roofs atop buildings act like prisms and send the waves towards the inhabitants beneath. Radio waves coming from above would be more harmful than when coming from aside.
- The radio waves resonate and echo inside the building and build up in metallic structures. This creates halos of proximity that will inject more power inside nearby living bodies. For example, while simply wrapping aluminum foil around my head, it is obvious that some designs of shielding will make me even more sick than using no aluminum at all. The same way, when some parts of the shielding of my tent wear off and stop to be conducting, I can get serious problems till I replace or complement the faulty area.
- Buildings contain their own sources of electromagnetic pollution. They add their effects to those of the pollution from the outside...
- Close to metallic structures, the electromagnetic field can become rotating. This because waves with equivalent strength come from different directions with different phase shifts.

Again, the four possibilities mentioned above are potentially very suitable to build experiments that demonstrate there is no problem. Perform the experiment in an anechoic place with the waves coming from aside and no other radiation than the one from the experiment... Just the opposite from real world situations but you can claim to be serious at avoiding parasitic variables...

If you want to find the FM emitters somewhere, fmscan.org is the reference I used till now.

This is the schematic of the "snake":

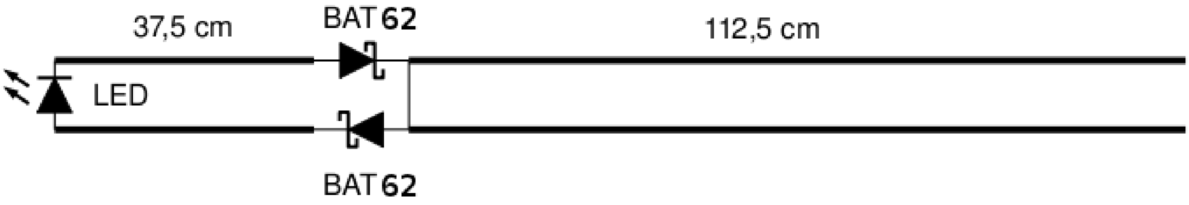

BAT62 detection diodes are no more produced. **BAT15** diodes work fine but they wear out; after a few months they stop functioning. **SMS7630** diodes are great but very little and mechanically fragile. **MMSD701T1G** diodes are sturdy and powerful; an excellent choice for a beginner. Such SMD diodes do also work for cell phone frequencies, which allows to test out a snake with a calling cell phone pushed against it. But any detection diodes that can manage 100 MHz will do.

The LED I'm currently using is the **L-7113SEC-H** . It lights up with a low tension and a very low current (the bluer a LED, the more tension it needs). Its color is red yet close to orange hence it is easily seen by the human eye (the eye is most sensitive to green, yellow and orange). The beam is quite narrow so when the LED is directed towards somebody's eyes it will appear quite bright.

For the lengths of 37.5 and 112.5 centimeters, any electric wire with two copper conductors will do. Audio signal wire is a practical solution. Use the shielding as one of the two conductors. The lengths of the two segments must not be precise. What matters is that the total length of the snake be 1.5 meters. Do not hesitate to try out if a little

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longer or shorter snake gives better results.

A schematic of my current probes, that I connect to a standard multimeter, measuring Volts DC. The measure displayed by the multimeter must be multiplied by 10. When using a 200.0 mV scale, just read while forgetting the dot:

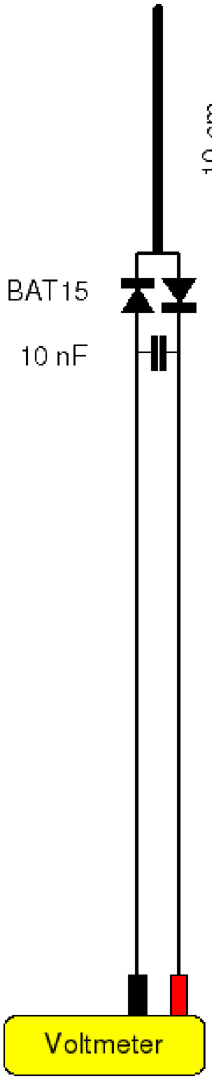

This is a picture of a device that tries to pack the whole in a neat gadget. The electronic circuit is a €7 digital Volts display with a scale of 200.0 mV. I soldered away the jumper that makes the dot be displayed. The antenna is only 7 cm long, so an RMS value is displayed (for roughly steady radio waves). The whole cost about €12. Hold the antenna perpendicular to the direction the waves come from and try to hold the device away from conducting objects like your body or metallic objects. You cannot closely trust such simple device yet it is very handy and adequate to compare the radiation level in different places:

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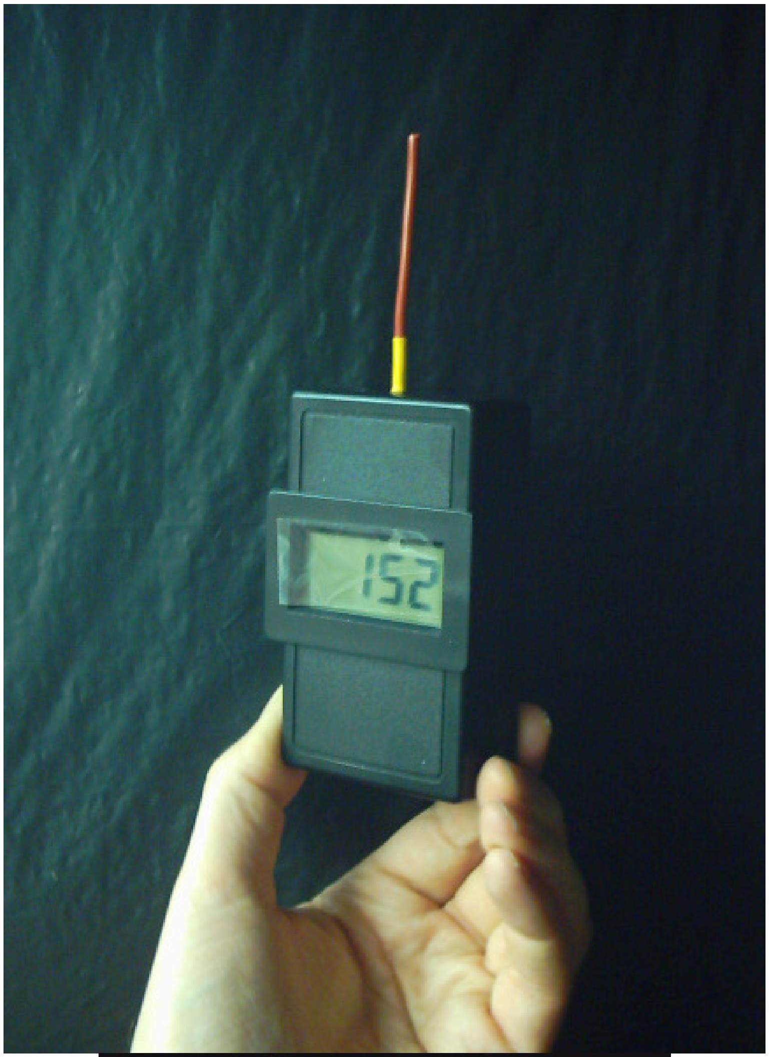

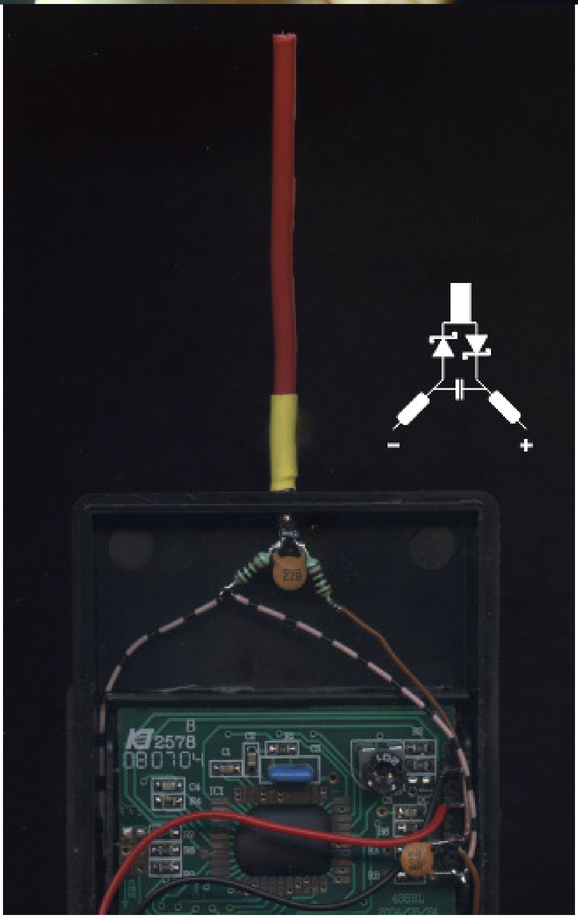

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Those probes and device, quite easily allow to know the direction some 100 MHz radiation come from. Hold the thing at some decimeters from your body, roughly at the height of the belly. Your body and the device form a directional antenna... When the device is towards the emitter, it will display up to twice the value, while when it is hidden from the emitter by your body, the measure will be very low.

If you measure something strong, yet by turning in different directions the device always shows approximately the same value, then you are probably undergoing low-frequency radio waves like short wave broadcasts.

If the emitter is close, like a power saving lamp or a wrongly build power supply, converge towards it simply using the fact that the closer you get, the stronger the measure.

Such measuring tools are handy to find out power chords and appliances that pollute, yet then the measure displayed doesn't mean much. Once you are really close to an emitter, the measuring device and the emitter interact and the power flowing through the measuring device can be tremendous even though the device is only weakly polluting. You are in the "halo of proximity" of the device... Best example is most quality laptops, which emit almost no radio waves. I never could notice a problem while using my laptop when it is plugged to nothing... Yet if I hold a measuring tool against the screen I get frightening data... A few decimeters further, where my head can be, the measuring tool tells there is nothing... So, the high figures close to the laptop indeed tell that strong currents flow through it, but competent people made things such that those currents harm nobody...

If you want a global measure, away from the effects of your body, hold the device above your head. Or place it on some plastic or cardboard box and walk some distance away.

The windows are a common entry point of radio waves and electric wires can be awfull ducts, yet in some cases I noticed that metallic structures unrelated with electricity, like the copper tubes of water heating radiators, were the main ducts of radio pollution towards a room.

Below is a device I assembled to focus on 1.8 GHz cell phone radio waves. Close to the nearby cell phone relay antenna, in direct view of it, I could not measure much more than 0.1 V/m (pike value). While this is still too much, it is by no means comparable to the frightening 2 V/m intensity of the FM broadcasts. I also went measuring in places where people complain about problems similar to mine. They thought the reason was the nearby cell phone relay antennas. But I could measure no significant intensity of cell phone radio waves at all, while the force of the FM broadcasts was above 0.2 V/m...

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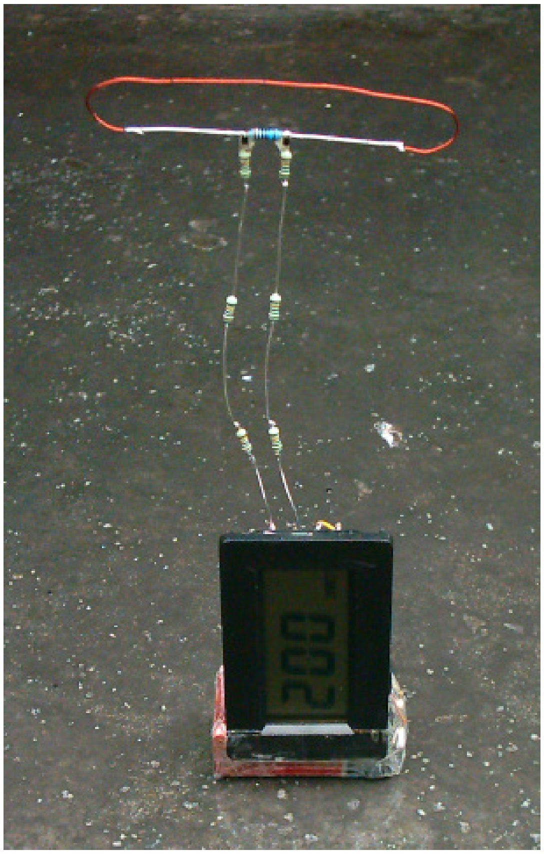

After about a year experimenting, the most simple protection I could come up with against 100 MHz broadcasts is a headband of aluminum, much the shape and size of a sweatband. I hide it inside a bonnet. I have no idea as to how and why it helps, aside from the general fact that any conducting structure will change something to the propagation of high frequency currents. Don't make it too high, a 3 to 4 centimeters height is OK. To try this out, you can just fold in a circle a 1 meter long wrap of aluminum and compress it to a flattened ring that fits your head. If you intent to re-use it, then you must strengthen it with lengths of tape before (inside) and after (outside) the ring is constituted. Make sure the tape does not hamper a perfect electric contact all around the ring. This protection is not perfect but it really helps.
When the field strength is above 0.1 V/m, I need a complementary vertical band in order to be able to work.
This also is a cheap way to make statistics. Compare days with the headband to days without the headband. In order to be scientific, you must ask somebody else to put the headband inside your bonnet every morning, at random. Every morning, the other person writes down if there was a conducting headband inside the bonnet or not. Every evening, you write a comment down to how your day was (headache? brain fog? errors? doomed day?) Then after a while you compare the two. At worst, if you have to do it alone, buy two identical bonnets, push a plastic headband inside one and an aluminum headband inside the other, and spend each day without knowing which one you picked. At the end of the day, write your appreciation down before checking and writing down which bonnet you picked.

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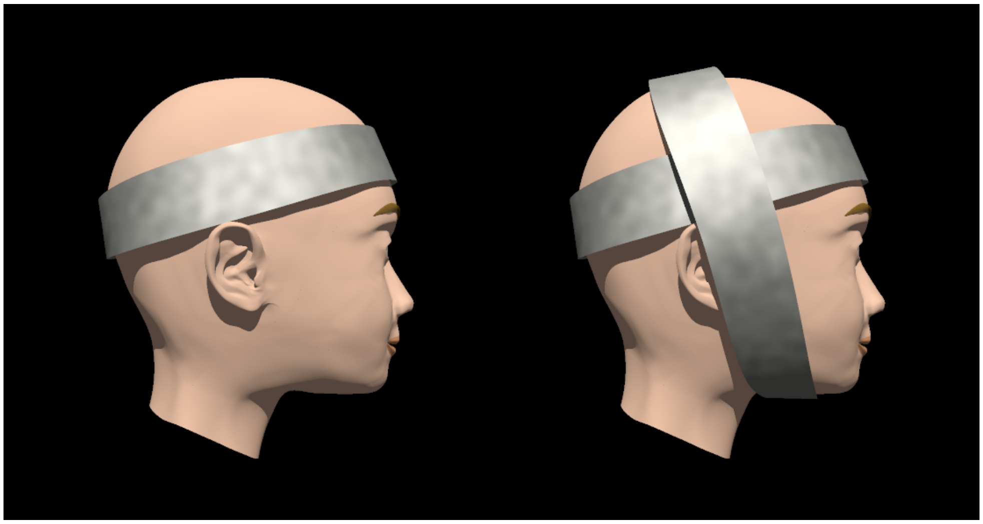

A friend who is a physician points out that in many administrations, be they public or private, the employees are being persecuted. (That often happens when the work done by the administration is mostly useless and only serves to justify the social position and the salaries of a few people.) A statistic about the health impact of radio waves in such administrations could be of few significance, because the people have all kinds of health problems due to the harassment. The addition to this by the radio waves may be comparatively negligible. (Yet another way to build a statistic that shows few or no impact of the radio waves: perform it in a place where people bow under humilations...)

I was quite frightened to discover that the symptoms caused by radio waves, as I see them around me, are very close to those of "radiation poisoning". This is part of nuclear medicine. When a victim is exposed to a short and strong burst of radioactivity or any other ionizing radiation, its body will quickly react like if it had been poisoned. A "low" poisoning by radiations yields headaches, tiredness, difficulties to think... while stronger poisoning can lead to the person die in a few days like if it was heavily burn. The exposure to ionizing radiations is measured in "Gray". 1 Gy leads to a low poisoning. So I computed out how much energy a person gets from the local FM emitter, like the person I know that get sick at their desk. The result is 0.01 Gy for 8 hours of exposition, which is quite close.

Radio waves can induce all the typical problems caused by that ionisinig radiations but the energy levels involved can be quite different. For example, ionizing radiations cause burns without increasing the temperature of the body, while radio waves can only burn if they are powerful enough to heat the body. Radio waves can induce cancer but again the energy required is ways higher, like spending ten years using a cell phone against the head, several hours a day.

Body cells can be attacked by all kinds of means. Ionizing radiations lead to direct damage of the cell membrane. Radio waves disturb the molecular cell gates operate. The cell will always react the same way, as for poisoning: it will close the cell gates, to try to shun itself from the outside world and from the harm. This has many consequences. The cell is less able to fulfill its purpose inside the body. It uses resources to try to protect its internal parts. It will accumulate waste. That's why people get tired, less efficient or even sick. When the aggression made to the cell is deemed too strong, the cell will auto-destruct. That's the way radiations and chemicals can be used against cancer, making the cancer cell suicide.

The cells can be helped to better recover from the state of shock. Also they can be made to go less likely into the state of shock. Medication and health advice can be helpful for this.

A link has been proposed between autism and radio pollution. The growth of the human brain is very complex, with cells traveling from one side of the brain towards the other to find their place. This involves a tremendous amount of communication and coordination between the cells. What if those cells are too often put into a state of shock?

These are two scientific publications about the link between autism and radio waves :

http://www.ncbi.nlm.nih.gov/pubmed/16530334

http://www.ncbi.nlm.nih.gov/pubmed/14962625

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Publications about how radio waves disturb cells :

http://www.ncbi.nlm.nih.gov/pubmed/10860806

http://www.ncbi.nlm.nih.gov/pubmed/12379225

Links

http://www.teslabel.be
http://www.clag.be
http://www.001.be.cx
http://www.criirem.org
http://www.next-up.org
http://www.robindestoits.org
http://www.beperkdestraling.org
http://www.stopumts.nl

A petition: www.petition-electrosmog.be

Eric Brasseur - October 3 2009 till October 16 2015

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3 CRYSTAL SETS

The simplest type of radio receiver consists of an aerial, a tuned circuit and a detector–plus headphones to listen to the signals received by the tuned circuit. It is generally called a *crystal set* because it works on the same principle as the very earliest radio sets, using a lead-galena crystal and a 'cat's whisker' as a detector. The only real difference is that the crystal and cat's whisker have been replaced by the much more efficient point-contact *diode*.

A simple *tuned circuit* can be made by winding a coil of wire of specific diameter and length (number of turns) to match the capacitance range of a variable capacitor. The combination of coil (inductance) and capacitance can then be adjusted by turning the variable capacitor spindle to be resonant, or tune in to various broadcast frequencies. The signal which is tuned in is then passed to the diode which blocks the RF content, and rectifies and passes on the AF content to the headphones, which transform these signals into audible sounds.

The tuned circuit can be combined with the aerial by winding the coil on a *ferrite rod.* This increases the inductance of the coil (reducing the length of wire required), whilst the rod itself also acts as an aerial to pick up the radio signals. This is the type of aerial employed in most domestic radio receivers. However, with very simple sets working with very weak signals, an external aerial may also be required.

The performance of all simple, low-powered receivers is, in fact, very much dependent on the efficiency of the aerial and tuned circuit, which can be regarded as the critical part of the system. Performance can perhaps be improved by experimenting with different aerial/tuned-circuit systems, and by the addition of further circuitry, as explained in later chapters.

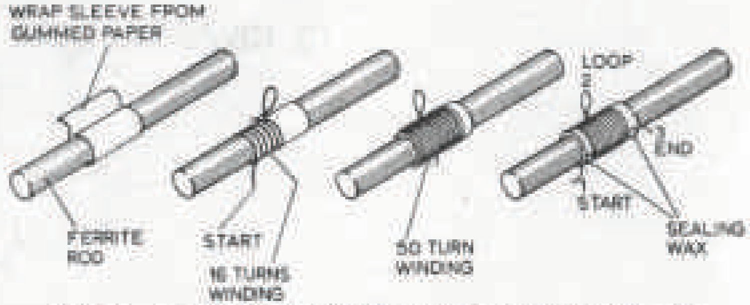

Fig. 3.1 Aerial tuning coil wound from 38-s.w.g. wire on a $\frac{3}{8}$-in. diameter ferrite rod.

Fig. 3.1 details the construction of a suitable coil for a tuned circuit, matched to a ferrite rod of $\frac{3}{8}$ in. diameter and about 4 in. long (see Chapter 4 for alternative coil windings on different rod sizes). If a rod is purchased longer than 4 in., it can be used as it is, or cut down by marking around with a file and then breaking off the surplus length.

Cut seven 1-in. lengths of gumstrip. Moisten one and wrap around the rod gummed side up. Now add about another half a dozen wrappings of similar length over the first, this time with gummed side *down* to form a reasonably rigid tube. Make sure that the paper tube is a *sliding* fit on the ferrite rod and leave to dry thoroughly (preferably removed from the rod so that it cannot become stuck to it).

When the paper tube is quite dry it should be rigid, when the coil windings can be applied. The wire to be used is 38-s.w.g. enamelled copper wire, the number 38 referring to the actual diameter of the wire according to the standard wire gauge (s.w.g.).*

Starting about $\frac{1}{4}$ in. in from one end of the paper tube, wind the wire carefully round the tube, with each turn tight against the one before it, until sixteen full turns have been completed. Then make a loop in the wire, as shown, and carry on winding, with succeeding turns touching, until fifty turns in all have been completed. The two loose ends of the coil (the start and finish) can be secured with a dab of sealing wax whilst the projecting loop can be twisted together (e.g. by putting a pencil through the loop and twisting up). Cut off the loop, leaving about $\frac{3}{4}$ in. protruding from the main coil, bare the wire ends and solder together. This forms point 2 on the coil; the start is point 1, and the end point 3–see Fig. 3.1. It will be easy to remember these

---

* American wire gauge (AWG) is about two sizes smaller than the British standard wire gauge (s.w.g.). For example, 38 s.w.g. is approximately the same as 36 AWG.

without marking since the loop or tapping point (2) comes much closer one end (1) than the other (3).

Cut a panel of *Paxolin sheet* to about the size shown in Fig. 3.2, using a hacksaw.* On this secure a *tag strip*, as shown, and drill a hole to mount a miniature or small-size 500 pF *variable capacitor*.

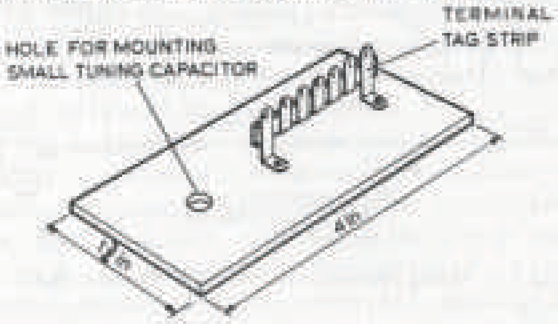

Fig. 3.2 Paxolin panel and tag strip for crystal set circuits.

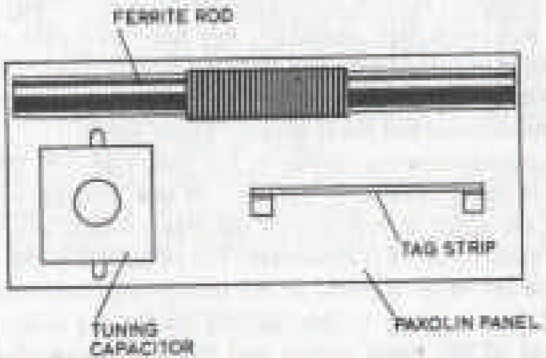

Fig. 3.3 Layout of components on Paxolin panel.

The aerial coil is then mounted on the panel as shown in Fig. 3.3, gluing the coil on to the Paxolin with two or three dabs of sealing wax, or some other suitable adhesive. *Note:* the ferrite rod must be free to slide in the paper tube for 'tuning' adjustments.

Virtually any miniature germanium or silicon diode will be suitable for the detector. Recommended types, which are readily available, are 1N34 and 1N914.

Earphones must be of *high-impedance* type, which need not be expensive to buy, and the higher the impedance the better the reception.

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* A phenolic or fiberglass sheet may also be used.

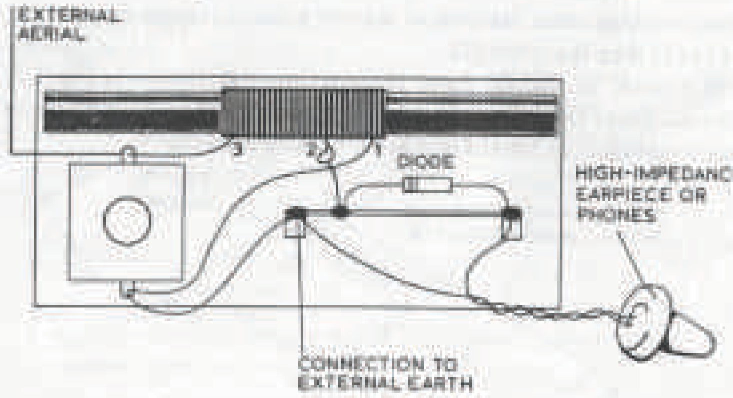
EXTERNAL AERIAL
3
2
1
DIODE
HIGH-IMPEDANCE EARPIECE OR PHONES
CONNECTION TO EXTERNAL EARTH

Fig. 3.4 Wiring connections to complete the crystal set.

Alternatively a deaf-aid type earpiece can be used; this will not give the same volume or quality of reproduction as headphones, but is a less expensive component. This should preferably be of the *high-impedance magnetic* type, with high sensitivity. Any high-impedance earpiece will suffice, but if of crystal type will require a resistor, connected across it, to complete the circuit. This will reduce the amount of current flowing through the earpiece and lower the strength of signal.

Wiring connections are shown in Fig. 3.4. End 3 of the aerial coil (the end of the 50-turn coil) connects to one terminal of the tuning capacitor, the aerial or 'hot' end of the tuned circuit, and the point to which an external aerial is connected. The other end of the coil (end 1) connects to the other terminal of the tuning capacitor, from which an additional wire is taken to the first tag on the tag strip. This is the 'earthy' end of the tuned circuit, and the point to which an external earth is connected. Leave plenty of slack wire between the coil and tuning capacitor.

The other connections are then as follows:

(i) Tapping point of the coil wire bared and connected to the second tag.
(ii) The diode also soldered to this same tag, and to any other free tag.
(iii) Headphone (or earpiece) leads to the 'earthing' tag, and to the 'free' tag to which the above diode has been connected. All connections should be made with *soldered* joints.

The wiring-up can be checked against the *circuit diagram* shown in Fig. 3.5 (ignoring the components shown with broken lines). The set should now be 'working'.

In areas of strong signal strength, no external aerial or earth connections should be necessary. Performance will, however, be improved in any area by attaching an aerial wire (which can be any thin wire, e.g. using the same wire as for the coil winding), of up to 160 feet. The longer the aerial the better the reception, provided it is led away from the receiver to as *high* a point as possible.

An earth connection may further improve aerial performance; by this we mean a connection to some conductor positively in contact with the ground (preferably buried), an excellent example being a metal water-pipe. Thus, if an earth connection is found to be necessary (or you want to try one to see how performance is affected), connect a wire from the 'earthing' tag on the receiver to a convenient water-pipe.

This question of obtaining a *good* aerial and earth is a most important one in areas of poor signal strength. Linking up to a television aerial is often a good plan, since TV aerials are also usually mounted as high as possible. If bare wire is used, it is also important that the upper (free) end of the aerial is not made fast to something which could produce an earth connection (e.g. a damp tree), or at least is suitably insulated from such a support. String is not an efficient insulator; that, too, can conduct when wet.

Quite good results are often obtained by using the springs of a bed as an aerial, in which case an earth connection is usually not necessary. Sometimes, too, when other attempts to yield a good signal strength in

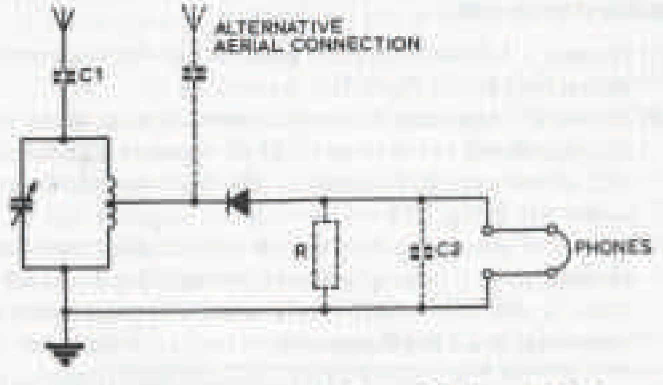

Fig. 3.5 *Circuit 1.* Circuit diagram of basic crystal set.

the aerial have failed, connecting the *aerial* side of the tuning coil to a *good earth* (a water-pipe) can produce better results, the normal earth connection being left off.

Tuning

The receiver is adjusted as follows. Turn the tuning capacitor to fully close the vanes, then open about half a turn on the spindle or knob. (If you are using a trimmer as a tuning capacitor, screw right down and then open half a turn.)

The tuning coil should now be slid up and down the ferrite rod (the coil leads were left a fairly long time to give the necessary freedom of movement) until BBC Radio 3 is heard.*

It may be necessary to slightly alter the adjustment of the variable condenser to tune in to this programme. Also, because of the ferrite-rod aerial the set will be directional, that is, the signal strength received will depend to some extent on the direction in which the aerial rod is pointing, so position the set to pick up the maximum volume.

Having established the best position of the tuning coil on the rod to receive BBC Radio 3, fix permanently with a dab of sealing wax. You should then find it possible to tune in to further stations by altering the setting of the variable capacitor—e.g. typically Radio 4 in about the middle of the capacitor travel and Radio 1 towards the other end.

Any reception you get will almost certainly be very weak and (unless you live close to a broadcast station) you can really feel satisfied if you get any station at all at audible strength. But it is surprising how, sometimes, even quite distant stations can be heard. Also you can often improve the reception and listening strength by quite simple modifications. Try these in order:

(i) Connect a 1,000-pF capacitor across the headphone (earpiece) connections (C2 in Fig. 3.5).

(ii) Instead of connecting the external aerial directly to the tuned circuit, connect one lead to a 220-pF capacitor, and the other end of the capacitor circuit to the 'hot' end of the tuned circuit (C1 in Fig. 3.5).

(iii) Instead of connecting the external aerial to the tuned circuit, connect to the tapping point of the coil (tag to which the diode is also connected). Try a direct connection, and also connecting in a 220-pF capacitor.

---

* Tune to an AM broadcast station near the lower end of the dial—close to 550 kHz.

(iv) Try connecting a 1.2-k resistor (or higher value) across the phone connection (R in Fig. 3.5). You may be using the wrong type of phones or earpiece, which do not provide a proper load or complete the circuit.

If there is a complete lack of response, check for faulty wiring-up. A more likely cause, however, is lack of an external aerial or earth connection in an area where these are strictly necessary for adequate reception; or an inefficient aerial (too short) or poor earth connection (bad electrical contact to a good earth point, or connection to a bad earth point).

Another possible cause of apparent failure may be too much outside noise entering the ear so that it is impossible to detect the very weak radio signal as it is being tuned in. Headphones are better than a single deaf-aid type of earpiece in this respect but, in any case, a really quiet room is virtually essential for initial setting up and tuning adjustments. Also, if your adjustment of the tuning control is too coarse, you may completely miss the setting for the station you are looking for, without realizing it.

Reception will also tend to vary with weather conditions. Some days it may be so poor that what was normally a strong station is hardly heard at all. The simple basic receiver has many limitations but, since it costs very little to construct and nothing at all to operate, this must be regarded as inevitable.

Providing you can hear something—even if too weak a signal to distinguish properly—you can certainly improve the performance of your basic set by further experimentation with tuned circuits (see Chapter 4) and/or the addition of amplification to the circuit. You can also try other types of basic crystal set, as described in the following projects.

Circuit 2 (Fig. 3.6) is identical to *Circuit 1* except that, instead of a diode, a transistor is used as a detector. Only two of the transistor leads are connected—the emitter (*e*) connection to the tapping part of the coil, and the base (*b*) to the 'earthy' end of the circuit. The collector lead of the transistor is ignored (bend it out of the way so that it cannot accidentally short out the other leads).

You can try almost any type of low-cost AF transistor; recommended types are OC42 2N370, 2N2925, 2N5088.

With the addition of two more components, Circuit 2 can be modified to work the transistor both as a detector and an amplifier, to give stronger signals through the headphones. Using the same transistor type

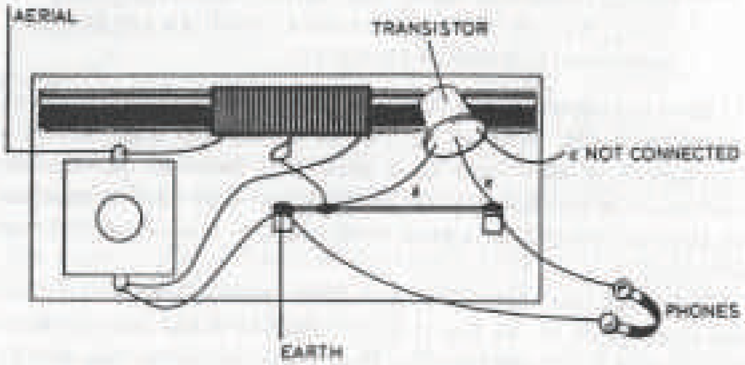
AERIAL
TRANSISTOR
e NOT CONNECTED
PHONES
EARTH

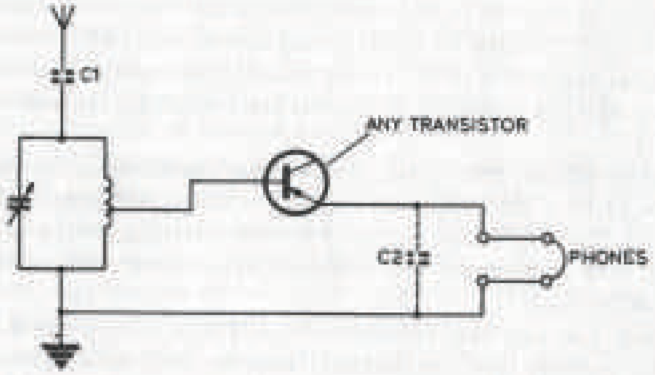
C1
ANY TRANSISTOR
C2
PHONES

Fig. 3.6 *Circuit 2.* Crystal set using transistor instead of a diode.

as above (or near-equivalent) resistor R should be 15 k and capacitor C3 1 µF or higher.

This time a battery is also required to supply power for the transistor to work as an amplifier. This can be from 1.5 V up to 9 V. Remember the rules for polarity of connection: those shown in Fig. 3.7 are for a p-n-p transistor; an n-p-n transistor would need the battery connected the opposite way round. Battery polarity also affects the connections of capacitor C3 (if an electrolytic or polarized type).

Experiment further by trying the effect of using additional capacitors in the circuit, e.g. C1, 220 pF; C2, 0.001 µF (try other values as well); C4, 0.001 µF (try other values as well).

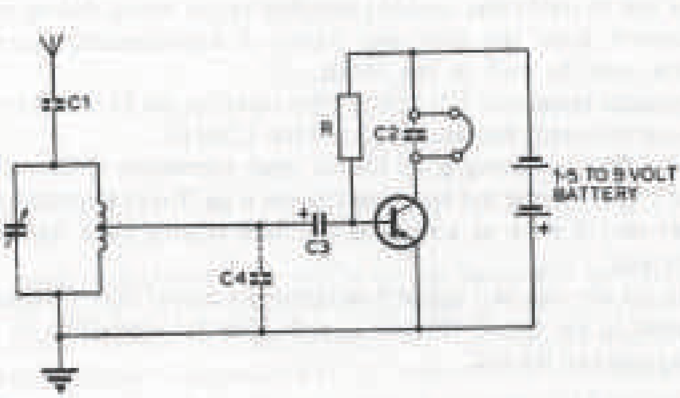
C1
R
C2
1·5 TO 9 VOLT BATTERY
C3
C4

Fig. 3.7 *Circuit 3.* Crystal set with amplification.

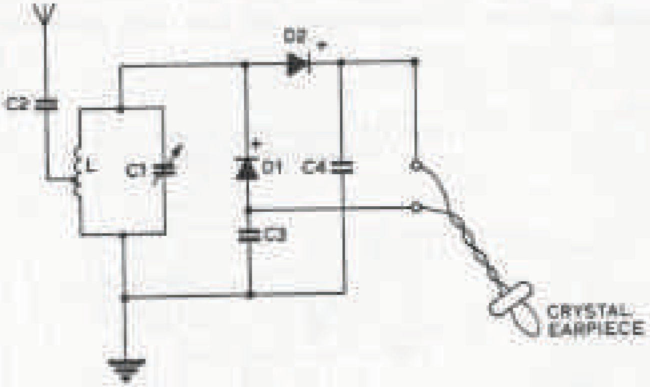
D2
C2
L
C1
D1
C4
C3
CRYSTAL EARPIECE

Fig. 3.8 *Circuit 4.* Double diode crystal set.

This circuit incorporates 'voltage doubling' to improve the signal volume and should give better performance than a single diode circuit. L and C1 are the usual tuned circuit, but an unusual feature is that the *aerial* is connected to the coil tapping point. Any type of germanium diodes can be used (they should preferably be the same), making sure to connect them the right way round. A high-impedance *crystal* earpiece must be used in this circuit.

Capacitor values are: C2, 220 pF (this capacitor can be omitted–try with and without in the circuit); C3 and C4, 1,000 pF.

The optimum tapping point for the aerial connection to the coil L is best found by trial and error (see Chapter 4 on 'Tuned Circuits'), but the set should work at a nominal one-third tapping point from the 'earthy' end.

This set can also be tried with conventional tuned-circuit coupling–i.e. aerial to the top of the coil L, and diode D2 connection to the tapping point on the coil.

4 MORE ABOUT TUNED CIRCUITS

The basic combination of a coil of certain *inductance* connected in parallel with a *variable capacitor* is the form of tuned circuit used in most radio receivers, from simple crystal sets upwards. The *tuning range* of such a circuit is determined by the respective values of inductance and capacitance used. At the same time, the *resistance* of the coil can have a significant effect on the *selectivity* of the circuit, so that a particular broadcast frequency is tuned into sharply, with other nearby frequencies rejected.

In the simple tuned circuit used for the crystal set of Chapter 3, the aerial is connected to the upper or 'hot' end of the coil, the other end of the coil being earthed; the diode is connected to a tapping point on the coil. Performance may well be improved by adjusting both the aerial-connecting point and the diode-connecting point, as shown in Fig. 4.1.

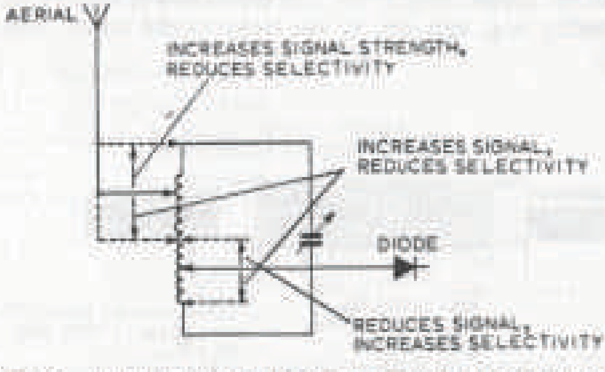
AERIAL
INCREASES SIGNAL STRENGTH, REDUCES SELECTIVITY
INCREASES SIGNAL, REDUCES SELECTIVITY
DIODE
REDUCES SIGNAL, INCREASES SELECTIVITY

Fig. 4.1 The effect of varying the tapping points on the aerial coil.

Connecting the aerial to the 'hot' end should give the loudest signal, but the *selectivity* of the circuit may be poor because of the coil *resistance* involved in the actual circuit to earth. Connecting the aerial to a tapping point lower down the coil (towards the 'earthy' end) should improve selectivity, but reduce signal strength. Experimentation will produce the optimum aerial-connecting point. There will also be an optimum tapping point for the diode.

Finding optimum tapping points for the aerial and diode connections is a bit tricky on a close-wound coil since each tapping point tried has to be bared by scraping off the enamel insulation, with the risk of producing shorted turns. The same *effect* can be provided by removing, or adding, turns at each end of the coil, using the original tapping point for the diode connection–e.g. see Fig. 4.2. Unless the *total* number of turns on the coil remain the same, however, the inductance of the complete coil will be altered, and thus the tuning range of the tuned circuit (see later). Then the *diode* tapping point will be shifted.

For this type of experiment an air-cored coil of relatively large diameter is easier to use, wound on a card or paper tube to which two $\frac{1}{4}$ in.^{2} lengths of hardwood or balsa strip have been cemented. The windings can be bared by scraping or sandpapering over this raised section, and individual wires carefully separated to avoid shorting–Fig. 4.3. Optimum tapping points can be established by pushing bared ends on the aerial- and diode-connecting wires into the raised section of the coil, soldering in place very carefully once they have been found. This should not result in shorting out more than a few turns at these points; which will not greatly modify the coil inductance if allowed for in the initial winding (e.g. add five or six turns to the design number of windings).

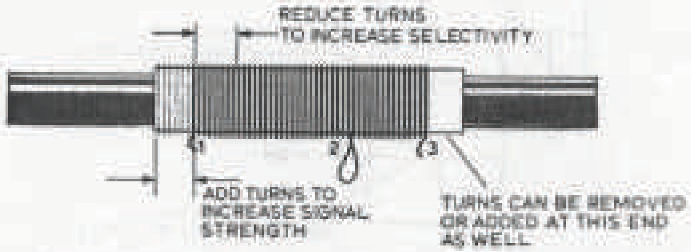
REDUCE TURNS TO INCREASE SELECTIVITY
1
2
3
ADD TURNS TO INCREASE SIGNAL STRENGTH
TURNS CAN BE REMOVED OR ADDED AT THIS END AS WELL

Fig. 4.2 The effective tapping point on a simple coil can also be varied by adding or removing turns on each end of the winding.

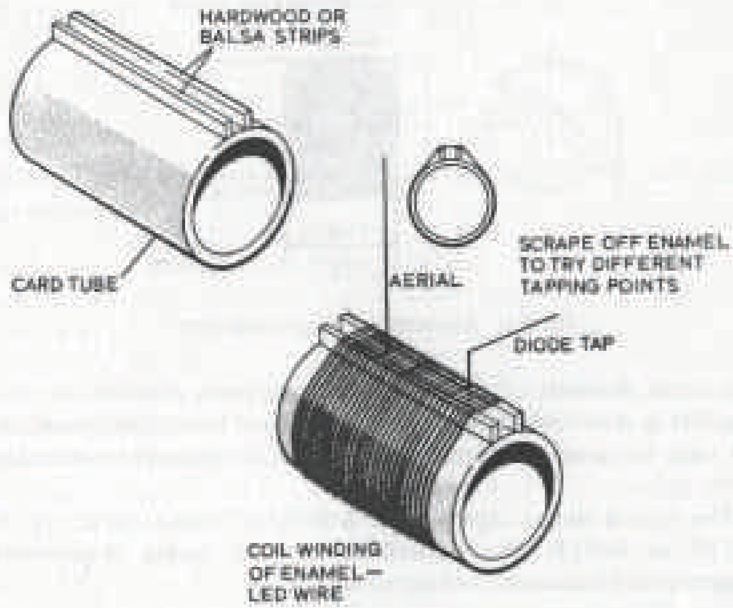
HARDWOOD OR BALSA STRIPS
CARD TUBE
AERIAL
SCRAPE OFF ENAMEL TO TRY DIFFERENT TAPPING POINTS
DIODE TAP
COIL WINDING OF ENAMEL-LED WIRE

Fig. 4.3 Construction of an air-cored aerial coil.

In air-cored coils, the inductance can be calculated with reasonable accuracy from the diameter and number of turns (see also Fig. 4.4):

$$\text{L. inductance, microhenries} = \frac{R^2 \times N^2}{9R + 10l}$$

where R = coil radius in inches,
l = coil length in inches,
N = number of turns.

The more usual form of this formula is:

$$N = \sqrt{\left(\frac{(9R + 10l) \times L}{R^2}\right)}$$

(A worked-out example using this formula is given later.) This is based on the turns of the coil being close-wound, in enamelled copper wire.

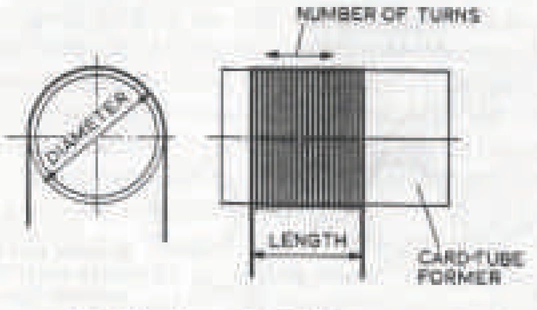

Fig. 4.4 Air-cored coil design parameters.

The actual diameter of the wire is not significant, provided the coil diameter is reasonably large (e.g. greater than 1 inch). The formula is not valid for smaller-diameter air-cored coils, or for coils wound on a ferrite rod.

The typical tuning capacitor has a rating of (about) 50 pF up to 350 pF or 500 pF. The relationship between tuning or *resonant frequency* and inductance and capacitance is:

$$\text{resonant frequency } (f) = \frac{1}{6.28\sqrt{(LC)}} \times 10^6 = \frac{0.16}{\sqrt{(LC)}} \times 10^6$$

where L = inductance in microhenries (μH),
C = capacitance in picofarads (pF).

This is more conveniently written as a solution for the *product* of inductance and capacitance required, i.e.

$$LC = \frac{0.025}{f^2} \times 10^{12}$$

For the medium waveband the range of frequencies to be covered is 500 to 1,500 kHz.* Thus, to encompass this range, the products of LC required are:

at 500 kHz

$$LC = \frac{0.025}{(500)^2} \times 10^{12}$$

$$= 0.001 \times 10^8 \text{ (approx.)}$$

---

* In the U.S.A. the AM broadcast band is from 530 to 1600 kHz.

at 1,500 kHz

$$LC = \frac{0.025}{(1{,}500)^2} \times 10^{12}$$

$$= 0.0001 \times 10^8 \text{ (approx.)}$$

At one end of the capacitor tuning range where $C = 50$ pF, inductance L required is:

$$\frac{0.001 \times 10^8}{\cancel{50}\ 500}$$

$$= 200\ \mu\text{H}$$

At the other end of the capacitor tuning range where $C = 500$ pF, inductance L required is:

$$\frac{0.0001 \times 10^8}{\cancel{500}\ 50}$$

$$= 200\ \mu\text{H}$$

Using a 1-in. coil diameter (0.5-in. radius) and a coil length of 1.5 in.

$$N = \sqrt{\left(\frac{(4.5 + 15) \times 200}{0.5^2}\right)}$$

$$= \sqrt{15{,}600}$$

$$= 125$$

In other words, a 125-turn air-cored coil of this size should be about right for covering the medium waveband, matching a 50–500 pF variable capacitor. Tapping point (or diode connection) would nominally be one-third of the coil length from the 'earthy' end.

Air-cored coils can also be designed in this way for long-wave coverage (more turns); or short-wave reception (less turns), which is not likely to be so good because of the low efficiency of the coils. Also, at higher frequencies the resistance of the *capacitor* is also significant, and so simple calculation of coil size is no longer valid.

The efficiency of a tuning coil can be expressed in terms of the magnification of the original signal received, when tuned to resonance, and decreases with increasing coil resistance. The magnification produced in a resonant circuit is referred to as the 'Q'; a high-Q coil is thus desirable for maximum performance and selectivity, and is essentially a low-resistance one. For this reason larger diameter air-cored coils, using thicker wire, are more effective than smaller diameter coils wound from thinner wire (since wire resistance increases with decreasing diameter).

Equally, the inductance of a wound coil can be increased by winding it over a magnetic-iron core, such as a ferrite rod. Much smaller diameter coils can be used, requiring less turns, to produce the inductance required—both reducing the length of wire and its resistance.

Because the actual inductance produced is dependent on the size and characteristics of the core material, windings for ferrite-rod aerials cannot be calculated, and are based on empirical results, or optimum windings established by trial and error.

Common sizes of ferrite rod available are:

$\frac{1}{4}$-in. diameter	length $3\frac{1}{2}$ in.
$\frac{5}{16}$-in. diameter	lengths 4, 5, 6 and 8 in.
$\frac{3}{8}$-in. diameter	lengths 4, 5, 6, 8 and 10 in.

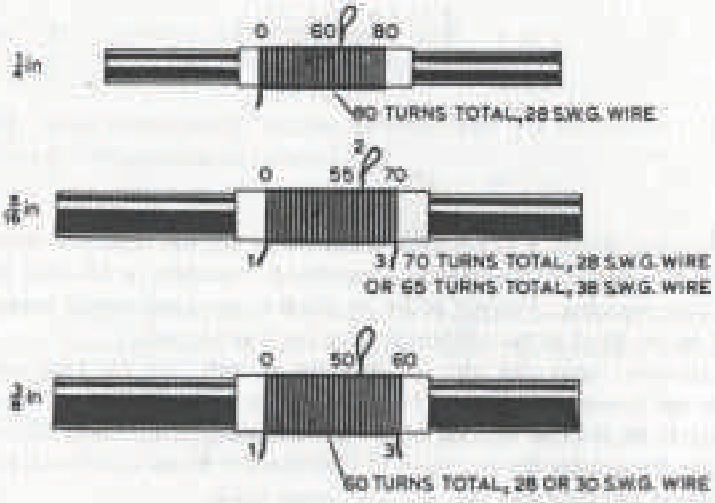
0
60
80
$\frac{1}{4}$in
80 TURNS TOTAL, 28 S.W.G. WIRE
2
0
55
70
$\frac{5}{16}$in
1
3
70 TURNS TOTAL, 28 S.W.G. WIRE
OR 65 TURNS TOTAL, 38 S.W.G. WIRE
0
50
60
$\frac{3}{8}$in
1
3
60 TURNS TOTAL, 28 OR 30 S.W.G. WIRE

Fig. 4.5 Medium-wave aerial coil windings on three sizes of ferrite rod.

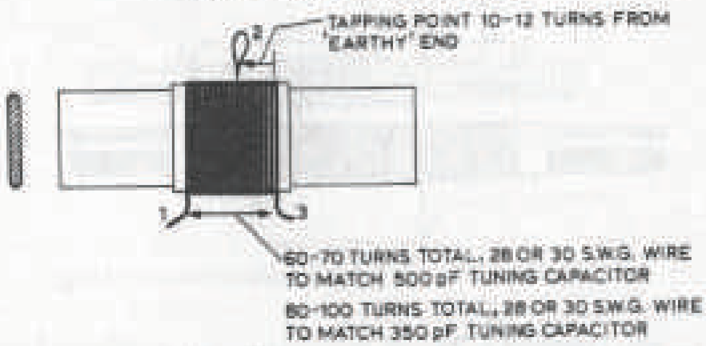
2
TAPPING POINT 10–12 TURNS FROM 'EARTHY' END
1
3
60–70 TURNS TOTAL, 28 OR 30 S.W.G. WIRE TO MATCH 500 pF TUNING CAPACITOR
80–100 TURNS TOTAL, 28 OR 30 S.W.G. WIRE TO MATCH 350 pF TUNING CAPACITOR

Fig. 4.6 Medium-wave winding for a ferrite slab.

A long length enables maximum adjustment of coil position (a way of 'trimming' the aerial) and, also, additional coils to be incorporated on the same rod, if the circuit needs them (e.g. for multi-waveband coils). But it is the diameter which really determines the winding specification.

Recommendations for medium-wave coil windings for these three standard ferrite-rod diameters are given in Fig. 4.5, all windings being enamelled copper wire. Normal tapping points are one-third from the 'earthy' end. It is a simple matter to experiment with different windings—e.g. adding more turns to extend the *wavelength* upwards (i.e. lower frequencies), or reducing the number of turns to extend the *wavelength* coverage downwards (i.e. for higher-frequency transmissions).

Ferrite-core material is also available in slab form, which is often easier to accommodate in a small receiver case. A typical ferrite-slab size is $2\frac{1}{2}$ in. long by $\frac{3}{4}$ in. wide, with a thickness of $\frac{1}{8}$ in. or less. A typical winding specification is shown in Fig. 4.6.

Generally, the long waveband should be covered by *doubling* the number of turns used for the medium waveband. *Reducing* the number of turns shifts the coverage out of the medium waveband down into the trawler band (80 m) and 'top-band' (160 m). For short-wave coverage very few turns indeed will be needed—perhaps less than half a dozen—and the optimum number can only be determined by careful experiment.

Separate coils for the various wavebands to be covered can be accommodated on the same ferrite rod and connected to a common tuning capacitor via a waveband switch—Fig. 4.7. This is the usual

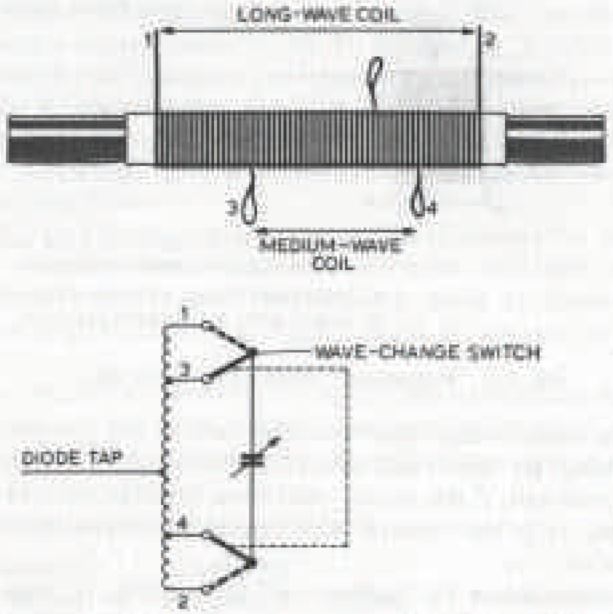
LONG-WAVE COIL
1
2
3
4
MEDIUM-WAVE COIL
1
WAVE-CHANGE SWITCH
3
DIODE TAP
4
2

Fig. 4.7 Long- and medium-wave aerial coil connected to wave-change switch.

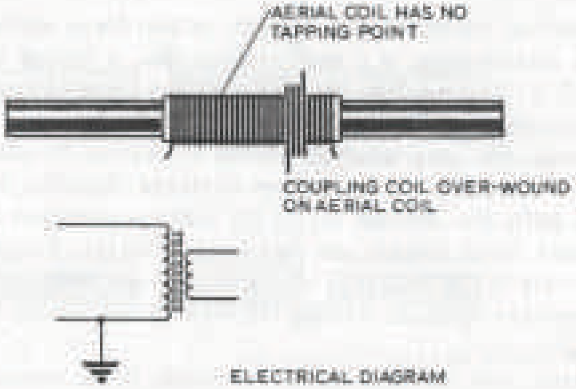
AERIAL COIL HAS NO TAPPING POINT
COUPLING COIL OVER-WOUND ON AERIAL COIL
ELECTRICAL DIAGRAM

Fig. 4.8 Inductively-coupled aerial coil.

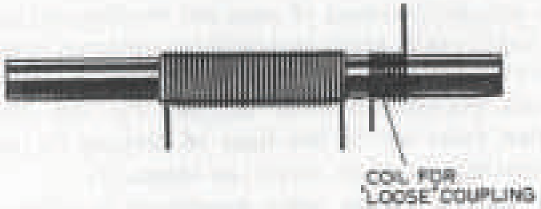
COIL FOR 'LOOSE' COUPLING

Fig. 4.9 'Loose' inductive coupling with separate coupling coil.

procedure with an elaborate receiver circuit and domestic radios, but is seldom satisfactory with the simpler circuits because of the tuned-circuit characteristics (i.e. the need for meticulous adjustment to get optimum results for any single waveband coverage).

All the coil constructions so far described are based on single windings (covering a specific waveband) with a tapping point for the output (diode connection in the case of simple receivers). The alternative form is to provide *inductive coupling* for the output in the form of an overwinding, which can comprise five or more turns of the same gauge wire used for the main winding–Fig. 4.8. The optimum number of turns for the overwinding depends on the degree of coupling required, which in turn is influenced by the characteristics of the following circuit. The position of the coupling coil can also affect the performance, although usually it is best positioned over the 'earthy' end

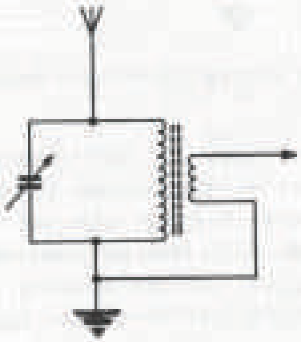

Fig. 4.10 Transformer coupling between tuned circuit and next stage of receiver.

of the main coil. Both number of turns and coupling-coil position are subjects for experimental adjustment to obtain optimum results.

Sometimes a coupling coil is wound on the ferrite rod, separate from the aerial coil, providing a 'loose' coupling–Fig. 4.9. Regenerative receivers often make use of this form of coupling for introducing 'feedback' into the front of the circuit (see Chapter 9).

Inductive coupling is also called *transformer* coupling, since the principle of passing current generated in one coil into another coil is the same. With transformer coupling (Fig. 4.10) the aerial coil has no tapping point, and is an alternative to direct coupling, where the next stage of the circuit is connected directly to a tapping point on the coil.

There is a third method of coupling which may be used between stages in a radio circuit–*capacity coupling*. Here, connection between the stages (e.g. to the tapping point on the aerial coil) is made through a capacitor, which isolates the two stages as far as d.c. flow is concerned (only a.c. will pass through the capacitor)–Fig. 4.11.

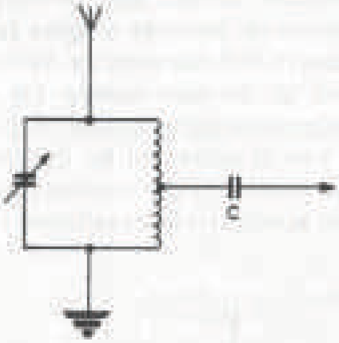

Fig. 4.11 Capacity coupling between tuned circuit and next stage of receiver.

Again the optimum value for the capacitor depends on the characteristics of the circuits being coupled. To couple an aerial coil to the next stage in a receiver, optimum values can vary from 200 pF to 10 μF. In general, though, a high value gives best results.

Direct, transformer, and capacity coupling are alternatives for connecting any two stages in receivers–not just the tuned circuit to the next stage.

5 AMPLIFIERS

It is a characteristic of a transistor that it works as an *amplifier* of signals. In the most widely used mode of connection of transistors for such duties with input and output circuits both connected to the emitter (common-emitter mode), the degree of amplification or current gain is called the 'beta' (β) of the transistor. This is given as h_{FE} (or static forward current ratio) in transistor characteristics data (see also Chapter 7).

A basic transistor amplifier circuit is very simple–and is identical for a p-n-p or n-p-n transistor, except for the battery polarity–see Fig. 5.1. Virtually any low-power AF transistor can be used in this circuit. The *bias resistor* (R) must have a value providing a collector current not exceeding the maximum specified rating for the transistor used, the actual current flowing in the collector circuit also being influenced by the voltage of the battery.

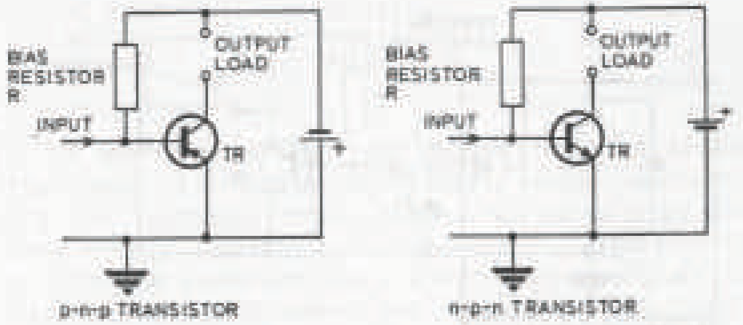

p-n-p TRANSISTOR n-p-n TRANSISTOR

Fig. 5.1 Basic amplifier circuits with simple current biasing via a single resistor.

Knowing the transistor characteristics, a suitable value for R can be calculated as follows:

$$R = \text{gain} \times \frac{\text{battery voltage}}{\text{collector current}}$$
$$= h_{FE} \times \frac{\text{battery voltage}}{I_c}$$

where I_c is equal to, or preferably less than, the specification figure for I_c max.

Assuming that an OC72 transistor is being used, and the battery voltage is 9 V, specified figures are:

$$I_c \text{ max} = 250 \text{ mA}$$
$$h_{FE} = 30 \text{ to } 90$$

Taking the maximum gain, and 2.5 mA as a 'safe' working figure for the collector current:

$$R = 90 \times \frac{9}{0.0025}$$
$$= 324\text{k}\Omega$$

A suitable (preferred-value) resistor would thus be 330k.

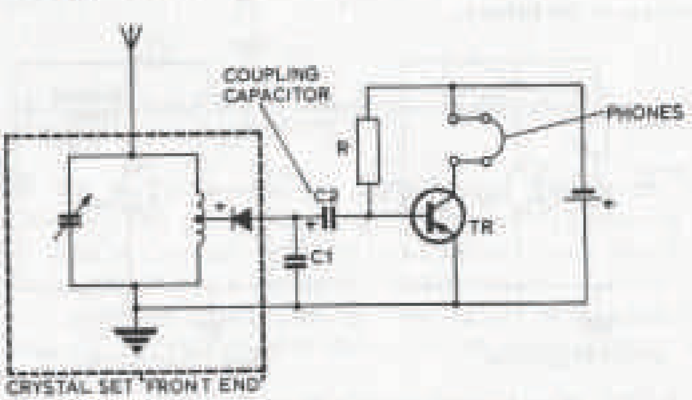

Fig. 5.2 *Circuit 5.* Crystal set with single stage of amplification. Any ~~RF~~ transistor can be used for TR.
AF

Fig. 5.2 shows the complete circuit for a simple AF amplifier of this type, coupled to the 'front end' of a basic crystal set. The detector (output) is coupled to the amplifier via capacitor C2, a suitable value for which would be 10 µF or higher (e.g. 20, 25, 30, 40 or 50 µF); capacitor C1 (0.001 µF) may not be necessary. The output load in the collector circuit is formed by high-impedance phones.

Note that the *polarity* of the battery used to power this circuit is important (as far as the transistor connection is concerned); also the connections to the *diode* and C2 (which will normally need to be an electrolytic type to provide the high-capacity value required). With an n-p-n transistor the battery polarity would be reversed; and also the diode and electrolytic capacitor connections.

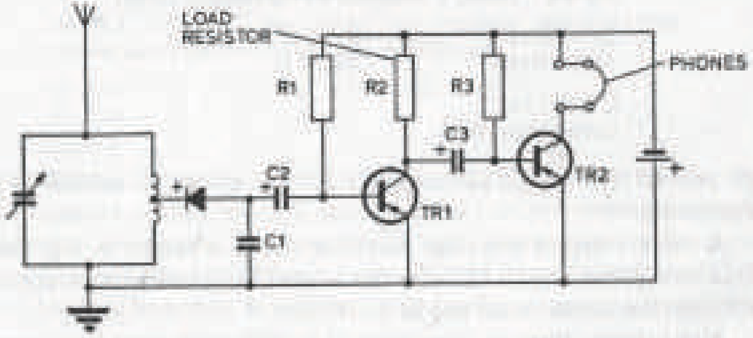

Fig. 5.3 *Circuit 6.* Crystal set with two stages of amplification. Component values matching OC71, OC72 or near equivalent for TR1 and TR2:

R1, 470 k	C1, 0.001 µF
R2, 4.7 k	C2, 8 or 10 µF
R3, 470 k	C3, 8 or 10 µF

Battery voltage 6 to 9 V.

The same type of circuit can be used to provide additional amplification, if required, simply by adding another amplifier stage (Fig. 5.3). The second amplifier stage can be identical to the first or based on a higher-power transistor taking the higher output present and providing even greater gain. The load in the output (collector) of the first amplifier stage is provided by a resistor (R2) (which should be about the same value as the phone resistance, 3.3 to 4.7 k), and the two stages coupled by a capacitor (C3). Value of R3 depends on the second transistor used, and may be anything from 47 Ω to 470 kΩ; capacitors

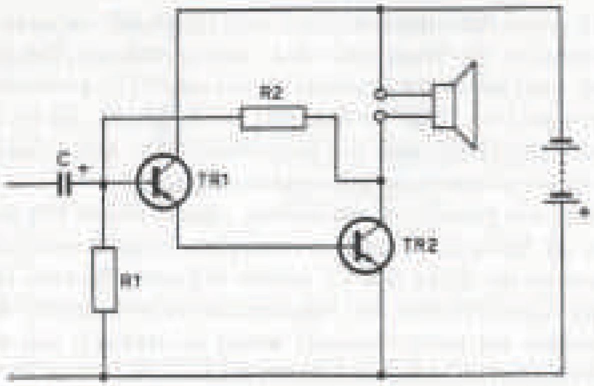

Fig. 5.4 *Circuit 7.* Amplifier for loudspeaker output

TR1, OC72 R1, 6.8 k
TR2, AD140 R2, 33 k
C, 8 or 10 μF
Loudspeaker, 80 Ω

C2 and C3 can be 10 μF or larger (20 μF up to 50 or 100 μF), electrolytic.

A more compact two-stage amplifier circuit is shown in Fig. 5.4. This may prove capable of operating a small 80 Ω loudspeaker direct, although the current drain will be quite high.

Alternatively, three or four stages of amplification using low-power transistors, following a basic 'front end' crystal set, should provide enough power to drive a small loudspeaker at the final output, through a suitable step-down transformer, to provide an impedance match (see Chapter 6).

Simple amplifier circuits of this type have the important limitation that performance of the transistor(s) will tend to vary with temperature. There is also the possibility of 'thermal runaway' developing, which can destroy the transistor(s), because as the external temperature increases the collector current also tends to increase, which in turn causes a further increase in junction temperature, so the effect is cumulative and goes from bad to worse, even to the point of ruining the transistor completely. It is possible to overcome this trouble by arranging for the circuit to be self-biasing or d.c. stabilized so that a constant operating collector current is provided, regardless of transistor type or temperature variations. In other words, the working point of the collector circuit is stabilized.

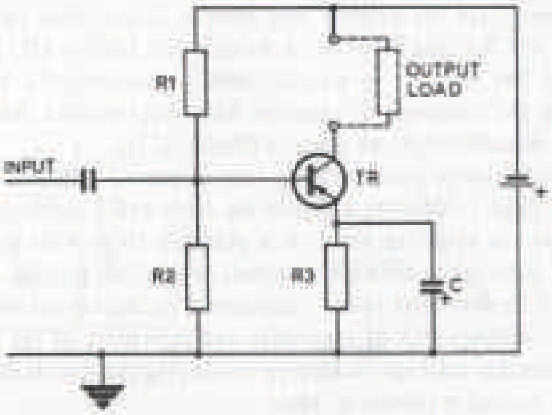

Fig. 5.5 Stabilized bias circuit for transistor amplifier stage. Typical values for low/medium-power transistors

R1, 22 k C, 8 or 10 μF
R2, 10 k
R3, 1 k

A further advantage of a stabilized circuit is that it makes the performance of the amplifier less dependent on the characteristics of individual transistors, which can differ appreciably even for the same type. Capacity coupling between stages should be used since this makes each stage independent as regards working, rather than inter-dependent.

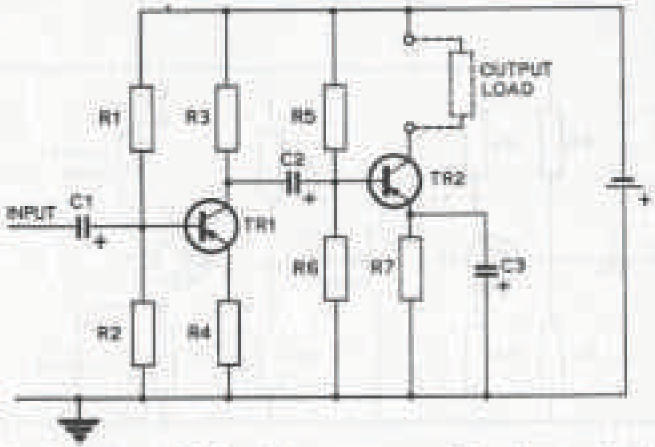

Fig. 5.6 *Circuit 8.* Practical two-stage amplifier using two low/medium-power AF transistors. (See Chapter 7 for determination of matching component values.)

To achieve this the original bias resistor is split into two separate values R1 and R2 (see Fig. 5.5). A further bias resistor (R3) is applied directly to the emitter, in parallel with a capacitor (C) to act as a by-pass for AF currents. (Transistor bias requirements, and data on transistor characteristics, are given in Chapter 7.)

A receiver design incorporating two stages of amplification with stabilized circuits following a crystal set front end is shown in Fig. 5.6. This, in fact, is about as far as it is practical to go with such a basic circuit as, although additional complete stages will provide more gain and greater final output power, deficiency in the circuit will also be aggravated–notably lack of sensitivity and selectivity in the front end. Such deficiencies are best tackled by modifying the circuit design from the simple 'crystal set detector' basis.

The amplifier stage(s) also provides a convenient point to insert a *volume control* into the receiver circuit. This takes the form of a potentiometer which can replace one of the bias resistors, or be placed in series with the flow of the current after the first stage of amplification–Fig. 5.7. This will introduce minimum distortion over the volume control range.

On low-power receivers which give satisfactory reception without an external aerial, a volume control can be an unnecessary refinement. Since the ferrite aerial has directional characteristics, merely turning the set one way and the other will produce changes in signal strength.

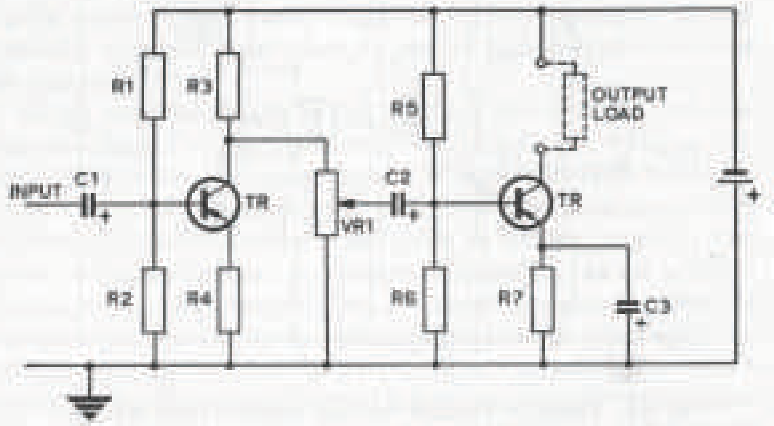

Fig. 5.7 *Circuit 9.* Two-stage amplifier with volume control.

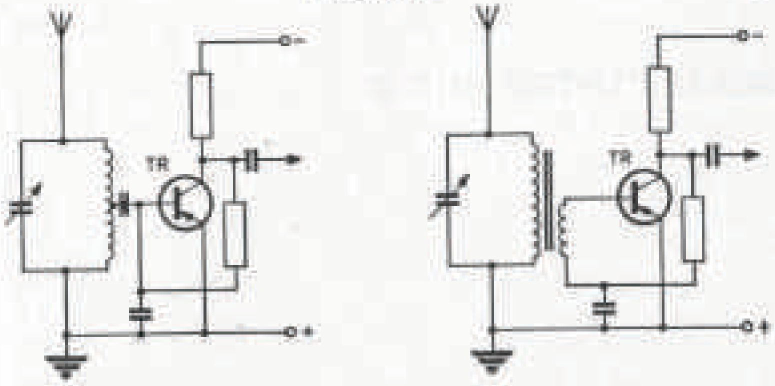

Fig. 5.8 Basic pre-amplifier circuits. The transistor (TR) must be an RF type; p-n-p transistors shown in these diagrams. If n-p-n transistors are used, the battery polarity must be reversed.

Pre-amplifiers

A pre-amplifier is designed to amplify signals between the tuned circuit and detector stages. The main difference is that the transistor(s) selected must be an RF type since it is handling RF signals at this stage. Otherwise the basic circuit is similar to that of an AF amplifier–see Fig. 5.8.

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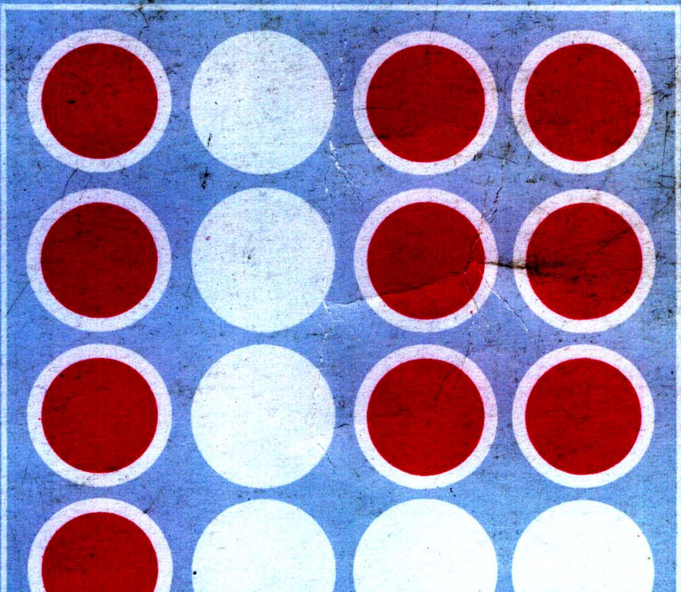

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SECTION I
"NO SOLDERING" PROJECTS

With these, connections are generally made with small terminals, or nuts and bolts. By this means components are connected together, and fixed to an insulated board or panel.

A project can be built using one size of bolt and nut throughout, but it will be found convenient to have two or three sizes. Small nuts and bolts can then be used for connections between components, while larger bolts with extra nuts, or terminals, can be used to connect external items, such as headphones.

For one size throughout, 6ba screws or bolts will be satisfactory, about ½ inch long. Only a few are needed for each project, but they are quite inexpensive in 50 or 100 packs. Some extra nuts will prove useful, and also a quantity of 6ba washers. If the insulated board or panel is not too thick, the ½ inch bolts with an extra nut each will do as terminals for connecting external items.

A 4ba bolt is *larger* than 6ba, and a few of these, ½ inch or more long, also with washers and nuts, can be used for terminals, if preferred. It is also possible to obtain terminal heads, so that bolts with nuts can be used as terminals.

The 8ba size is *smaller* than 6ba. These can be of advantage in a project where size is to be kept down, or for positions where several leads come close together (as at a transistor). Bolts, nuts and washers (8ba throughout) can be obtained together.

Naturally all sorts of nuts and bolts, to hand or obtained from constructional toys or old electronic equipment, can be used. Results are not going to depend on the sizes used, which are more a matter of convenience and appearance

There is also considerable latitude in the insulated panels or boards used to carry the components. Some projects need only a few holes in a small board. Here, it is convenient to use 1/16 inch thick or similar paxolin sheet, cutting a piece of the wanted size and drilling holes for the bolts or terminals. A small hand drill is satisfactory for this purpose. The drills used can be 3/32 inch for 8ba bolts, 1/8 inch for 6ba, and 5/32 inch for 4ba, or any similar sizes giving clearance.

Where drilling is inconvenient, a ready-perforated board must be used. For projects where size is not important, perforated 1/8 inch thick hardboard is suitable – holes are generally at 1 inch intervals, but this is not important. For this type of board, the size of the holes will generally mean that 4ba nuts and bolts will be beeded.

Plain perforated board (that is, without any conductor foil) can be obtained with holes at 0.1 inch or 0.15 inch spacing but these holes are too small and too close together. However, such boards can be used instead of plain unperforated paxolin sheet by drilling the holes larger in just those places where bolts must be placed.

There is also a type of eyelet board, with holes at 5mm spacing and just large enough to take 8ba bolts. This is handy for small projects.

It is also relatively easy to prepare a fully perforated board or panel, which can be used for a number of projects in turn.

For a board up to about 4 x 6 inch paxolin 1/16 inch thick is adequate, with 1/8 inch sheet for larger boards. It is also possible to use 1/8 inch or similar PVC or other transparent sheet, which allows connections to be seen on both sides. Plain hardboard, or thin plywood, is also satisfactory. Hardboard or wood should be given a coat of shellac or similar varnish, before use, to keep out damp.

Where size is not important, the board can be drilled with holes spaced 1 inch from each other throughout. Do *not* mark off a grid with pencil lines, as this may cause leakage between adjacent terminals. An easy method is to mark such a grid on paper, secure this over the board or panel with tape, and drill all the holes. Make these of an appropriate size for the terminals or bolts.

For small items, the board will need to be prepared to suit.

But where a board is going to be a general purpose support for several projects in turn, it can be much larger. It is also handy to support it on two strips of wood, about 1 inch high, so that there is clearance underneath for bolts and connections.

It will be found that neat and efficient projects can be assembled on such boards, and that it is easy to check connections or components, or to make changes for experimental or other purposes.

Theoretical Circuits

A theoretical circuits shows an electronic device in simple form. Capacitors, resistors, transistors and other items are shown by their own symbols. Lines representing connections are drawn from symbol to symbol. The layout of actual components in the device may not be the same as the positions of the symbols in the theoretical circuit.

It will be found that it soon becomes easy to follow a theoretical circuit. An understanding of such circuits develops when they are compared with an actual layout which shows components and the connections.

The Signal Tracer in Fig. 1 is an example of this. The main item here is the transistor, which has emitter (E), base (B) and collector (C) wires. For the transistors shown, these wires come from the base as in the diagram, which is of the underside of the transistor. (Emitter, base and collector wires may be in different positions in other transistors.) It will be seen that the emitter E is connected to negative at the battery, and to a clip on a lentth of flexible wire.

The headphones – or single earpiece – go between collector C and battery positive. A headphone jack, marked P, is used to take a plug for the phones. Generally, an on-off switch would be present in one battery connection, but this is not necessary here as the circuit can be interrupted (to switch "off") by unplugging the phones. Exactly the same results would be obtained if two separate sockets were used, to take two plugs from the headphones.

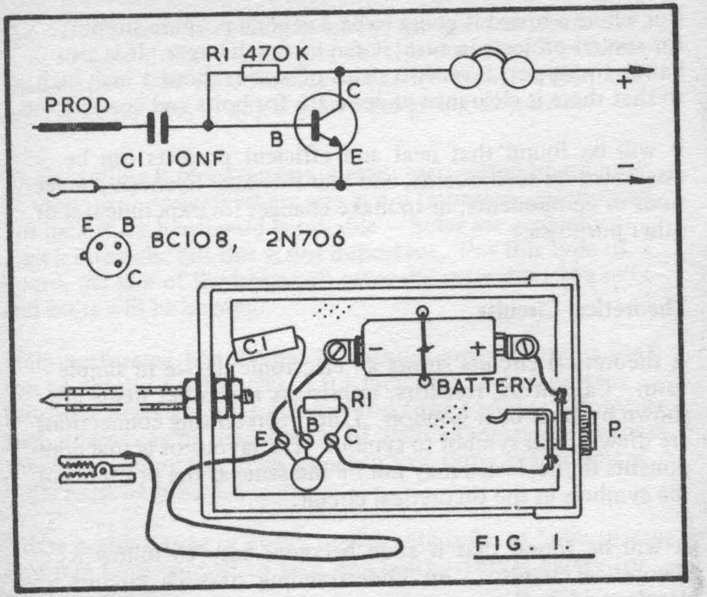

FIG. 1.

Resistor R1 is connected from collector C to base B, and it supplies a base current for the transistor, so that the latter can operate as an amplifier.

The signal to be amplified is obtained through capacitor C1. A capacitor has plates or foils separated from each other by an insulator. There is no direct current circuit through the capacitor, so placing the test prod on various points of a circuit being tested does not upset direct current working conditions.

It is clear, from Fig. 1, how the theoretical circuit is made up as a practical piece of equipment, with C1, R1, transistor, phones and battery connected together in the way required.

With later projects, the theoretical circuit and practical wiring diagram may be shown together in this way, or may appear as separate diagrams when they are larger. If the theoretical circuit and wiring diagram are compared, so that capacitors, resistors and other items on one are also found on the other, it will soon be found that a theoretical circuit is readily followed and understood. It will be noted that the theoretical circuit could be built up in numerous ways, all equally satisfactory.

Signal Tracer

This locates and amplifies audio (sound) signals which may be present in a circuit. Construction is most easily carried out in a small plastic case (Fig. 1). An insulated board about 1¼ x 2 inch (or to suit the case) has three small bolts to secure emitter, base and collector leads of the transistor. Bolts also hold two small brackets, which press on the negative and positive ends of the 9v battery. String or elastic through holes in the board helps to secure the battery.

The prod is a long 6ba or 4ba bolt, or length of screwed rod. Lock one end of C1 lead with nuts, or loop it under the bolt head. Thread the clip flex through a hole in the case, and pass the prod through another hole, as shown. A washer and nut then fix the prod, with the board inside the case. The case lid can then be fitted, and the securing nut can be screwed on the phone outlet. Connections here can be tightly twisted round the outlet tags, and compressed with pliers. A piece of insulating sleeving is put on the test prod, and a clip with fixing screw is attached to the flexible lead.

Making Connections

For all the projects in this book, any thin insulated connecting wire can be used; or bare wire with insulated sleeving. It is handy to have two or more colours – such as red for positive, and black for negative circuits.

A loop is made at the bare end of the wire, and is put under the screw head, or under a washer. Where two or more leads go to the same bolt, it is convenient in some cases to have a washer or two extra, to go between loops. Each connection must be reasonably tight, and short circuits must not be allowed between wires or loops which are shown separated from each other.

Battery and external leads are generally of flexible wire. Positive and negative battery clips, with leads already attached, are available for transistor radio and similar batteries. Elsewhere it may be convenient to arrange contacts as in Fig. 1, or to twist wires to the battery tags.

The battery polarity (positive and negative) *must* always be correct, as shown.

When dealing with transistors, it will be found that some types have long wire leads, more than adequate for easy screwed connections. Others, such as the BC108 and similar types, have rather short wires, but can be held satisfactorily with 8ba bolts fairly near eath other. (With other transistor types not used in this section, soldering may be essential for proper connections to be made.)

Circuit Tracing

To use the signal tracer, connect the clip to the earth return line of the receiver or amplifier. The prod is then touched one by one on points where the audio signal should be present, working systematically through the audio amplifier, or from the first point where the signal can be heard. Take in each capacitor, joint, or stage in turn. When signals cease to be heard, the fault lies between this point and the previous point, where signals were heard.

Do not test any mains operated or high voltage equipment, as this is a job for an engineer who will follow the necessary and essential precautions for safety.

Medium or high impedance phones are most suitable for this tracer. A 600 ohm DC headset will be ideal. The tracer can be utilised as an amplifier for a crystal diode radio receiver

Multivibrator

You will be able to use this as an audio oscillator for numerous test purposes, or for Morse Code practice, or as a signal device in place of a bell or buzzer.

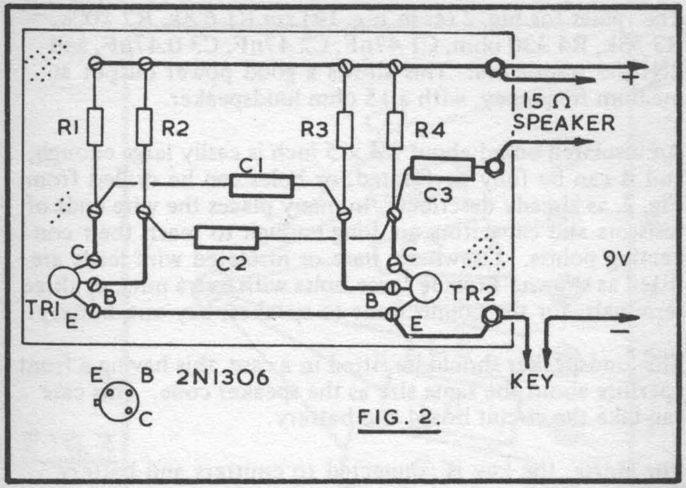

FIG. 2.

Fig. 2 shows the practical assembly of the device on an insulated board. A theoretical circuit is given in Fig. 14, and is not repeated here, so Figs. 2 and 14 should be looked at together.

R1 is the collector load resistor for transistor TR1. Collector current passes through this resistor, and an audio signal voltage is developed across it. Resistor R2 supplies base current for TR1.

TR2 has a similar collector resistor R4, and base resistor R3. Capacitor C1 couples the signal at the collector C of TR1 to the base B of TR2, while C2 similarly couples TR2 collector to TR1 base. Amplification in the transistors and feedback by the capacitors in this way result in the circuit oscillating. That is, each transistor goes rapidly in and out of conduction in turn, so that a voltage at audio frequency is produced across the collector load resistors. C3 is a coupling capacitor, allowing the signal voltage at the collector of TR2 to be taken to a loudspeaker or headphones.

With a circuit of this type, the component values, transistors, and battery voltage will not be critical. However, resistor values, capacitor values, battery voltage, transistors, and the loudspeaker or other sound-reproducing device will all have an influence on the frequency of oscillation, or tone produced.

The values for Fig. 2 (as in Fig. 14) are R1 6.8k, R2 100k, R3 33k, R4 330 ohm, C1 47nF, C2 47nF, C3 0.47μF, and 2N1306 transistors. This allows a good power output at medium frequency, with a 15 ohm loudspeaker.

An insulated board about 2½ x 5 inch is easily large enough, and it can be fully perforated, or holes can be drilled from Fig. 2, as already described. In many places the wire ends of resistors and capacitors are long enough to reach their connecting points. Elsewhere, bare or insulated wire leads are fitted as shown. Provide three bolts with extra nuts, or three terminals, for the connections to speaker, key and battery.

The loudspeaker should be fitted in a case, this having a front aperture about the same size as the speaker cone. This case can take the circuit board and battery.

For Morse, the key is connected to emitters and battery negative as shown, with flexible leads of convenient length. If the multivibrator is to be used as a warning device then these leads can instead go to a door bell push, or to a relay or SCR, used to complete the circuit, as with some later projects. In this way the multivibrator, with its speaker, can replace a buzzer or bell.

If the frequency of the multivibrator is to be changed, this can readily be done by altering the values of capacitors C1 and C2 in particular. The two capacitors need not be of the same value. Larger values reduce the frequency (lower the tone) while smaller capacitors increase the frequency. C3 also has some effect, due to loading from the speaker.

Such a circuit can be used with a battery voltage as low as 1.5v, for headphones. Transistor types are very uncritical. But if PNP transistors are fitted, the battery polarity must be reversed. The transistors shown are NPN.

"C" Substitution Box

When experimenting with circuits or checking a suspected capacitor, a box bringing into circuit a range of capacitor values may be used. In many circuit positions an exactly correct value is not required for testing by substitute, so that a very large number of capacitors need not be provided.

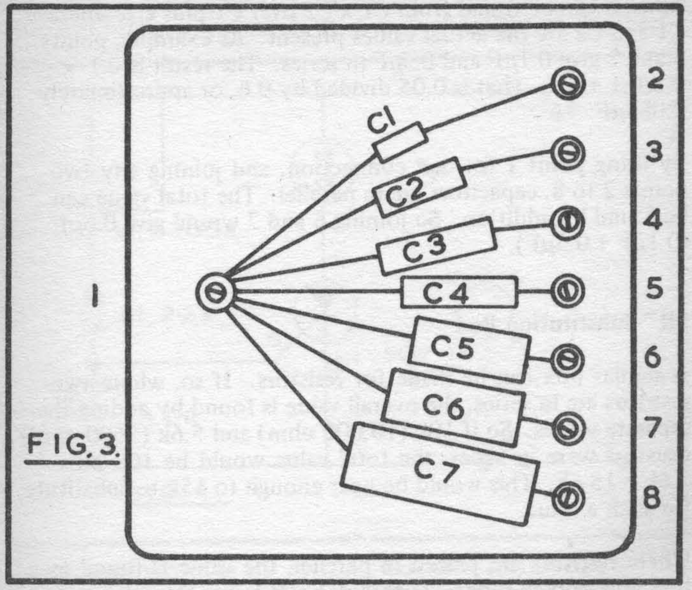

FIG. 3.

Such a box is easily made as in Fig. 3, using a plastic or other insulated case. Here, point 1 is common to all the capacitors, and any capacitor can be selected by connecting to points 2 to 8. Connections can be taken to 6ba bolts, using extra nuts. An alternative is to have eight sockets, with a pair of test leads equipped with plugs.

Suggested values are C1 100pF, C2 470pF, C2 1nF (1000pF or 0.001μF), C4 10nF (0.01μF), C5 0.1μF, C6 0.5μF, and C7 8μF. As the last capacitor will be polarised, mark its terminal to agree.

These values will be found sufficiently near for use in many coupling, decoupling, by-pass and similar circuit positions. The substitution box can be used in place of C1 or C2 in Fig. 2. But where a defective capacitor is found in a tuned circuit, it should be replaced by the exact value.

By ignoring terminal 1 and connecting leads to any pair of the terminals 2 to 8, two capacitors can be used in series. For those who like to work out the value of such combinations, it can be found from C1 x C2 over C1 plus C2, where C1 and C2 are the actual values present. As example, points 6 and 7 give 0.1μF and 0.5μF in series. The result is 0.1 x 0.5/0.1 + 0.5. That is 0.05 divided by 0.6, or approximately 0.083μF.

By using point 1 for one connection, and joining any two points 2 to 8, capacitors are in parallel. The total value can be found by addition. So joining 6 and 7 would give 0.6μF (0.1μF + 0.5μF).

"R" Substitution Box

A similar box can be made for resistors. If so, where two resistors are in series, the overall value is found by adding the separate values. So if 10k (10,000 ohm) and 5.6k (5600 ohm) resistors were in series, the total value would be 10k plus 5.6k = 15.6k. This would be near enough to 15k to substitute for such a value.

Where resistors are placed in parallel, the value is found as for capacitors in series. That is, R1 x R2 over R1 + R2. So for the 10k and 5.6k resistors, this would be approximately 3.6k.

Naturally each resistor may be selected alone, as for the capacitors. If sufficient terminals are provided, a large number of resistors could be fitted. For most transistor circuits, values from about 150 ohm to 270k will fill most needs.

SCR Controlled Light

This device will switch on a light, when the level of general illumination falls below that for which triggering is set. It can thus be used for an automatic night light. Operation can be from a battery; or from a mains power supply, as described later.

Fig. 4 is the circuit, and introduces two new devices. One is the light-dependent resistor LDR. The resistance of this component depends on the strength of the light falling on it. The

resistance is low (some hundreds of ohms) with bright light, but rises to many thousands of ohms in dim light, or darkness.

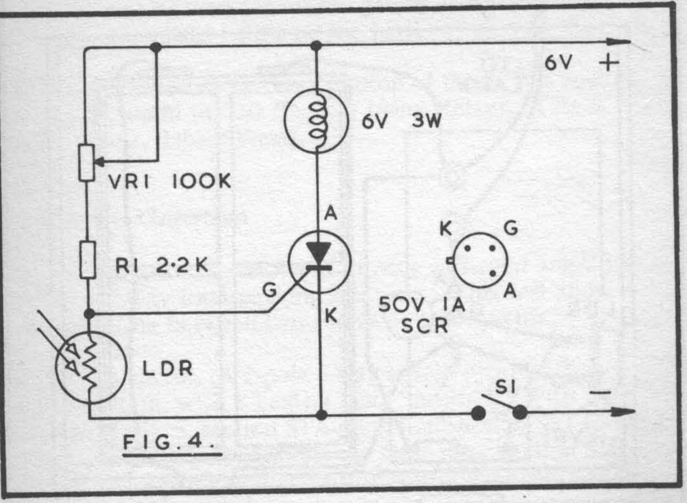

FIG. 4.

The second device is the silicon controlled rectifier SCR. Normally, this does not allow current to pass from its cathode K to its anode A. However, a small current applied to its gate G will trigger it so that it conducts from cathode to anode. It remains in this state even when gate current is removed. It is restored to the non-conducting state by removing the voltage from its cathode, by opening switch S1.

In this device the SCR is controlled by the LDR. With illumination present the resistance from gate to cathode is low, so that when S1 is closed, current does not flow from the anode circuit through the 6 volt 3 watt lamp. As illumination falls, the resistance of the LDR rises. This continues until a sufficient gate potential is present to operate the SCR, which moves into its avalanche or conducting state, lighting the lamp. The potentiometer VR1 enables the resistance from positive to gate to be adjusted, to set the illumination level at which the circuit operates.

A 50v 1 amp SCR is more than adequate for this circuit, and it resembles a large transistor externally, and can be mounted by its wire ends.

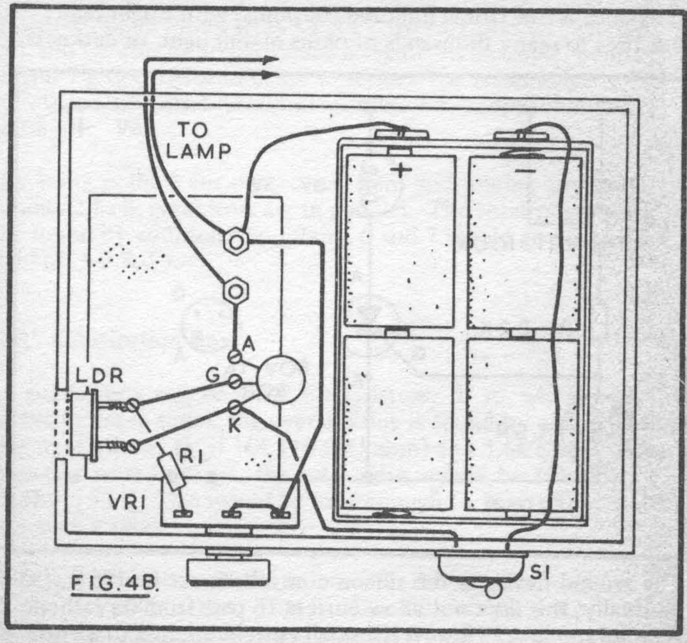

FIG.4B.

Fig. 4B shows constructional and wiring details. The SCR is mounted on a small insulated board. Clear bared wires are twisted tightly to the LDR, so that this also can be fitted by small bolts and nuts, as shown. The connections to VR1 are also tightly twisted and pressed together with pliers.

A battery holder for four 1.5v cells is shown, and connections to this can be by means of clips which have leads attached. The switch S1 is the small, low-voltage type having small screws, as used for toy lighting circuits and similar purposes.

A hole is cut in the box level with the LDR, which may be directed towards the window of the room, or positioned as found to give the results wanted. The bulb, in holder, can be positioned on top of the case. If light from it reaches the LDR this will not stop the circuit working, as the SCR can only be returned to the non-conducting state by opening the switch S1,

For an automatic night light or similar device, a case can be made from thin wood, with opening back or bottom. The device can also be used for various games, where momentarily interrupting the light falling on the LDR switches on the bulb.

If a detailed reference to the operation of the SCR is wanted, this can be found in "50 Projects Using Relays, SCRs & Triacs" (BP37, Babani Press).

One Transistor Intercom

A single high gain transistor will provide sufficient amplification for a 2-way loudspeaking intercom. This will allow communication between two rooms or other points.

Fig. 5 is the circuit. A 2-pole 3-way switch provides 2-way communication, with a central "Off" position. With the switch as in Fig. 5, section S1A takes loudspeaker SP1 to the base coupling capacitor C1. At the same time, section S1B connects the battery and transistor collector circuit to the

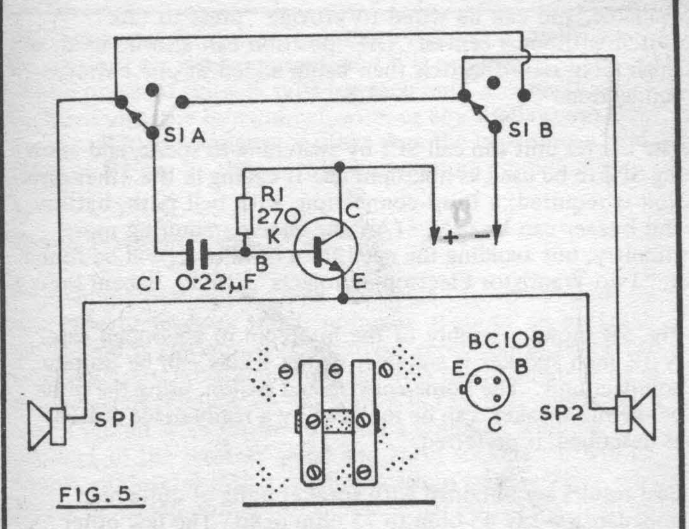

FIG. 5.

speaker SP2. SP1 then acts as a microphone, and sounds are reproduced in SP2.

With the switch in the opposite position, S1A selects SP2 as microphone, and amplified signals pass via S1B to SP1, so that speech can be in the other direction.

The switch, amplifier, battery and SP2 are assembled as the master control unit, and twin leads run to SP1. The person at SP1 should say "Over" so that the other person can operate the switch, and he in turn should say "Over" to signify that SP1 is again acting as microphone.

A simplified home-made change over switch is shown in Fig. 5. This is two strips of metal, pivoted so that they can be swung from side to side, and bearing on two of the three round-headed screws. A strip of insulating material is fitted so that both strips move together. In Fig. 5, this switch is in its "Off" position.

Ready made 2-pole 2-way switches can be obtained and used instead (see Fig. 49). Spring-loaded push switches are also available, and can be wired to provide "press to talk". A switch without a central "Off" position can also be used, a single pole on-off switch then being added in one battery connection.

The master unit can call SP1 by switching to speak, and allowing SP2 to be used as microphone. If calling in the other direction is required, a third connection, with bell push, battery and buzzer can be used. (An alternative, requiring more circuitry, but avoiding the need for a third wire, will be found in "Two Transistor Electronic Projects", (BP30, Babani Press.)

Fig. 5B shows assembly of the intercom in a wooden case. A 3½ inch speaker is suitable, so the whole can be quite a compact unit. The home-constructed switch, using the bolts below the speaker, can be replaced by a ready-made switch, as described, if preferred.

Best results are obtained with speaker units of quite high impedance – say 45 ohm to 75 ohm or so. The few other components are assembled on a small insulated board, as for earlier circuits.

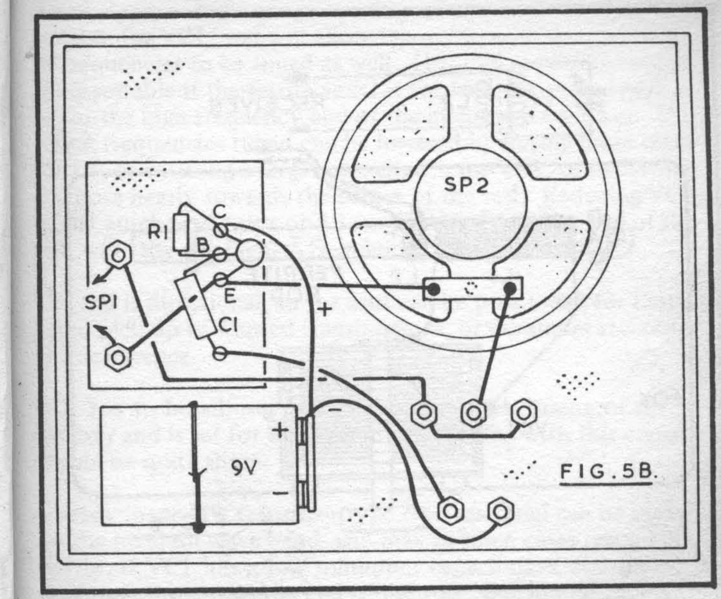

FIG. 5B.

The speaker at the remote point also requires a small case. Dimensions are not important, and it is possible to utilise plastic boxes of suitable type for each unit. Connections between units are by twin bell wire, or any similar twin conductor. With a transistor of other than the type shown, the value of R1 can be chosen to give maximum amplification.

Tuned Ferrite Aerial

This simple device will allow "portable" reception with the old type of receiver which normally requires an external aerial, and it can also give improved reception in terms of freedom from interference on the 160 metre amateur band and adjacent frequencies. As shown in Fig. 6, it consists of a tuned circuit with ferrite rod, and a coupling winding to connect to the receiver aerial and earth sockets. It will be found very useful with a communications type receiver, where a long extended outdoor or similar aerial results in a high level of noise and interference.

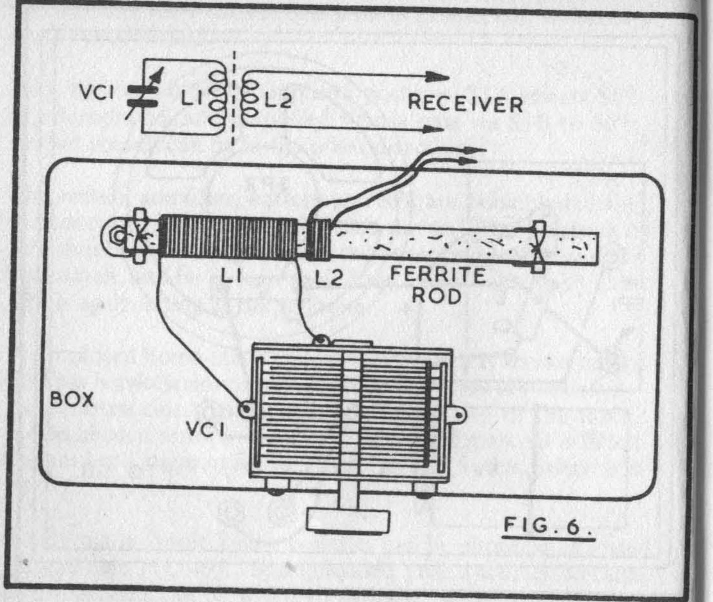

FIG. 6.

The device is constructed in a plastic lunch box about 6 x 4 x 4 inch or other *insulated* case. Some boxes of this kind, though strong, are of brittle material. These must be drilled without too much pressure, or they may crack. Drill points should also be sharp.

The rod is 6 inch long and 3/8 inch in diameter, and it is supported by two strips of insulating material, which are fixed with brackets. Each strip has a V-shaped notch, so that the rod can be held with thin string. L1 is the tuned winding, and it had sixty turns of 24 swg enamelled wire, side by side. Connections can be made to the frame (moving plates) and fixed plates of the capacitor VC1 by means of small bolts, or may be lightly twisted.

L2 is the coupling winding. Many communications type receivers have a low impedance input circuit, and twelve turns will be adequate for L2. The same wire can be used as for L1. With other receivers it may be worth while to experiment with the number of turns on L2, for best reception.

An air-spaced single gang capacitor of about 315pF is most suitable for VC1, and will allow the usual medium wave band of frequencies to be tuned as well. However, a smaller capacitor is suitable if the ferrite aerial is for 160m reception only, or for the high frequency end of the medium wave band. The actual frequencies tuned can be lowered by having more turns for L1, or by using a larger capacitance for VC1, or by having L1 more nearly towards the centre of the rod. Reducing VC1, or the number of turns on L1, or moving L1 to the end of the rod, will raise the highest frequency tuned.

The rod is directional, so the unit can be positioned for best signal pick up of wanted transmissions, or minimum reception of interference.

VC1 has to be adjusted in conjunction with tuning of the receiver and is set for best reception. Tuning with this control should be quite sharp.

A ready made MW transistor type receiver aerial can be useful for the medium wave band, and may in some cases reach 160 metres, if VC1 has a low minimum capacitance, and the winding is quite near the end of the rod. But should tuning not reach a high enough frequency, some turns will have to be removed.

Diode Radio

A lot of interest can be obtained from a diode radio receiver. It requires few components, no battery or other supply, and can give good headphone reception of a few of the more powerful transmitters. It can also be used as a tuner, as shown later, and will provide excellent audio quality for local station reception.

The circuit in Fig. 7 is intended for medium wave reception. That is, from about 200 metres to 500 metres, or 1500 kilohertz to 600 kilohertz.

The coil L1 is tuned by the variable capacitor VC1. At resonance with the wanted transmission, a signal voltage is developed across the coil. Detection or demodulation by the diode D1 allows the audio component of the signal to be recovered, and taken to the phones or to an amplifier. Such "crystal sets" were used in very many homes, in the early days of radio.

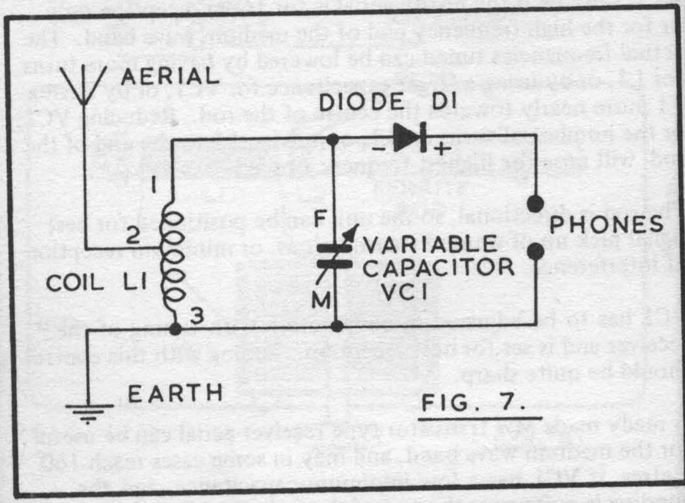

FIG. 7.

Fig. 7B shows the practical layout. It is convenient to use an insulated board larger than necessary, so that a transistor amplifier can be added later. A board about 5 x 8 inch is suggested, and it can be supported on 1 inch high runners (strips of wood) so that there is clearance for screws or terminals.

Coil L1 is wound with 26swg or similar wire, and has seventy turns, side by side. Secure the wire by passing it through two small holes, wind on about thirty five turns, and form a loop. Continue to wind in the same direction for a further thirty five turns, cut off the wire, and secure the end through two holes. The tube used can be 1½ inch to 2 inch in diameter, and can be paxolin, or can be made by winding thin card round a suitable object, smearing a little adhesive on to form a tube.

Point 1, the beginning of the coil, is taken to the fixed plates tag F of the variable capacitor, which is also connected to diode D1. The tapping 2 goes to the aerial terminal. End 3 is taken to the moving plates connection or metal frame of the capacitor. Ends 1 and 2, and loop 3, are left long enough to reach these points, and the insulation is carefully scraped off the wire where connections are to be made. The capacitor VC1 can best be about 500pF, but this exact value is not essential.

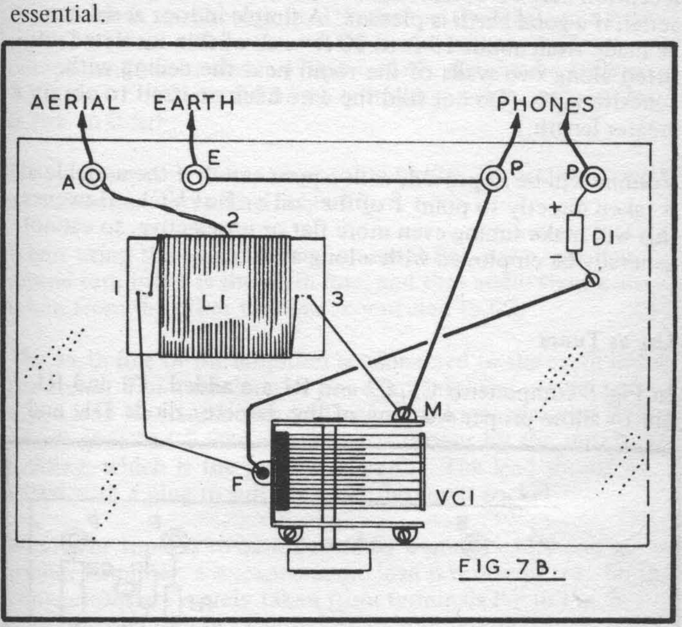

FIG. 7B.

Four terminals, for Aerial, Earth, and Phones, will complete the receiver. Best results will be had by connecting a good headset, of about 500 ohm to 2,000 ohm. Very low impedance earpieces, such as are employed with some transistor receivers, are not suitable here.

With a simple receiver of this kind it is necessary to employ a reasonably effective aerial and earth. Only in some circumstances will volume be great enough with no earth, or with a short aerial. The earth connection can be taken to a metal spike in the ground, or to a metal object buried in soil, or to any other available earth other than a mains circuit earth. (No connection must be made to any mains plug or other mains circuit.) A cold water pipe may provide a good earth. Gas pipes should not be used.

For the aerial, a length of aerial wire some 30 ft to 75 ft or so in all may form the aerial itself and lead-in. If this can be suspended quite high, and clear of buildings or earthed objects, signal strength will be improved. However, satisfactory reception may be obtained from an indoor aerial, or shorter aerial, if a good earth is present. A simple indoor aerial can be made from about 15 ft to 20 ft or so of thin insulated wire, fitted along two walls of the room near the ceiling with adhesive tape. (Do not fold the wire back on itself to obtain a greater length.)

Volume will be improved, with a poor aerial, if the aerial lead is taken directly to point 1 of the coil or F at VC1. However, this will make tuning even more flat or unselective, so cannot generally be employed with a long aerial.

Use as Tuner

In Fig. 8 components C1, C2 and R1 are added. C1 and R1 are to allow proper working of the detector diode D1, and may be considered as replacing the headphones. C2 is a coupling capacitor passing audio signals to the following amplifier.

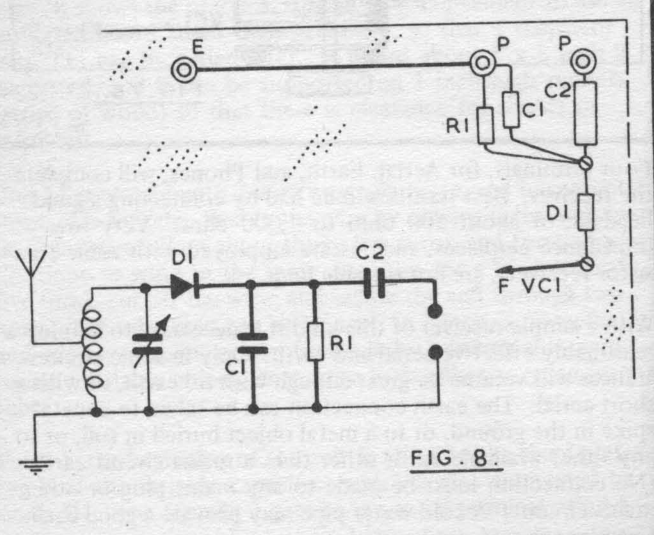

FIG. 8.

As with the previous circuit, any general purpose detection type diode is satisfactory for D1, such as the OA91 and many similar devices. The value of C1 is not critical, and this component can be about 470pF or 1nF. R1 can be 100k to 220k or so. C2 should be of quite large value, and can be $0.1\mu F$ to $0.5\mu F$.

D1 can be moved from the position in Fig. 7B, and the few extra components added, as in Fig. 8.

When using the tuner to feed an amplifier, note that one phone terminal P is the earth line, and that audio signals are taken from the other terminal, connected to C2.

The earth line of the amplifier is connected to the earth line of the tuner. For a sensitive or powerful amplifier, a screened audio lead is recommended. This has an inner screened lead, which goes to C2, and a conductor former by the outer brading, which is the ground or earth. The lead should be fitted with a plug to suit the amplifier input socket.

Where the tuner is to be followed by a small headphone or similar amplifier, a screened audio lead is not required. So then connections are merely taken from terminals P-P in Fig. 8, remembering to join amplifier earth and tuner earth circuits as explained.

Medium and Long Wave

The addition of long wave coverage is worthwhile in some areas, and the coil can be modified as in Fig. 9 so that both MW and LW can be tuned.

A tube about 3 inch long and approximately 1½ inch in diameter will be necessary. The section L1 is wound as before. L2 consists of about two hundred turns of 34swg or 36swg wire, in two compact piles of one hundred turns each. All turns throughout are in the same direction. The junction of L1 and L2 goes to the waveband switch S1. The second switch terminal goes to 4 and earth line. MW tuning is obtained with S1 closed, and LW tuning with S1 open.

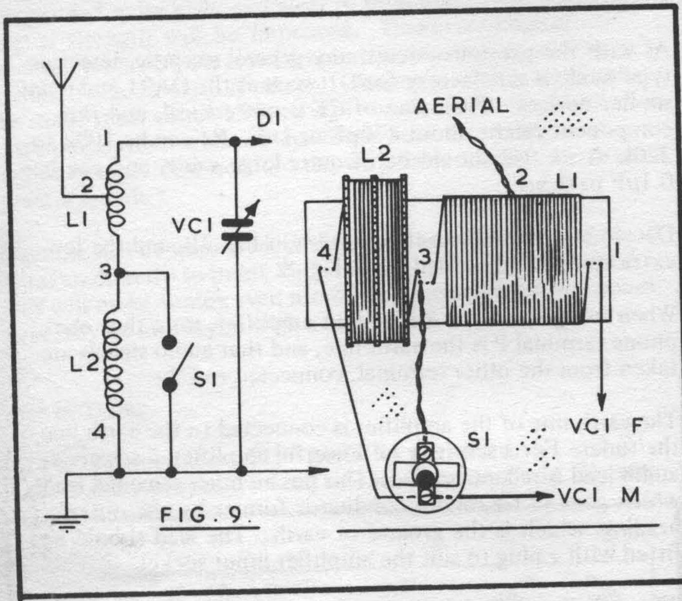

FIG. 9.

For accurate coverage of the usual MW and LW bands, and using a 1¼ inch diameter tube, L1 can be eighty-four turns of 32swg enamelled wire, with tapping 2 sixty turns from point 1. Leave a space of 5/8 inch and glue on a card disc cut to fit the tube. Also glue on two further discs, leaving spaces of ¼ inch between them. L2 is wound with 32swg double cotton covered wire, with one hundred and twenty turns in each slot (making 240 in all for L2). The coil can be fixed with two screws or small bolts, with spacers or extra nuts to hold it a little clear of the board. The windings should not be varnished, covered with adhesive, or wax.

With circuits of this kind there is no ganged tuning, or need for exact tuning of a particular frequency band. This means that coil winding details (wire gauge and covering, and diameter, or number of turns) can be varied to suit materials to hand. Ready-made coils can also be tried. Some commercially made coils with cores can give a slightly better

performance than the air-cored home made type of coil. Coils can also be wound in a similar way to that in Fig. 6.

One Transistor Amplifier

Headphone volume obtained from the crystal diode receiver can be considerably boosted by adding a single transistor audio amplifier. Space for this can be found on the circuit board.

In Fig. 10, resistor R2 and the transistor have been added, with a switch S2 for on-off switching of the battery. R1, C1, D1 and C2 are already present, as shown in Fig. 8.

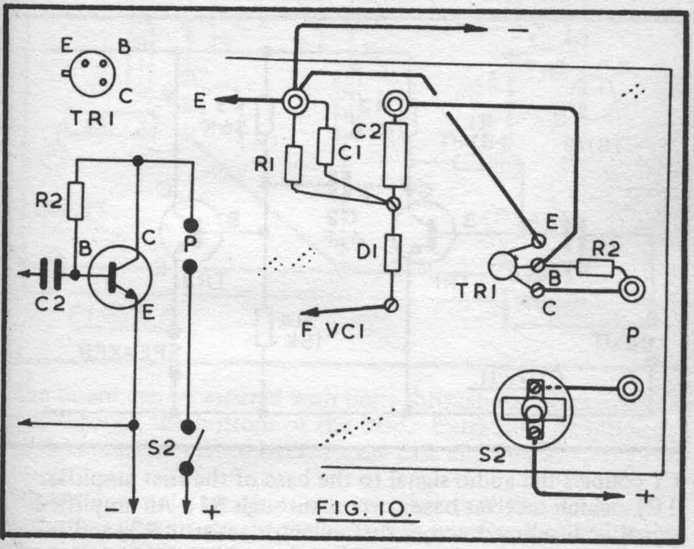

FIG. 10.

TR1, R2 and S2 are connected as shown. For TR1, a BC108, 2N706, or similar general purpose NPN transistor will be satisfactory. R2 can generally be 1 megohm with satisfactory results, but it can be worth while trying values from about 100k to 2.2 megohm here, as performance depends on the transistor, phones, and battery voltage.

Medium and high impedance phones, such as a 600 ohm DC headset, will be most suitable. The battery can be 4.5v to 9v.

If the phones are first connected to terminals P-P in Fig. 8, then taken to terminals P in Fig. 10, a very considerable increase in volume should be obtained.

If a PNP transistor is to be tried in this circuit, the polarity of the battery *must* be reversed.

Two Transistor Amplifier

Fig. 11 is the circuit for an easily made 2-transistor amplifier which can provide reasonable loudspeaker volume. The audio signal is taken to the input terminals, battery negative being the grounded side of this circuit.

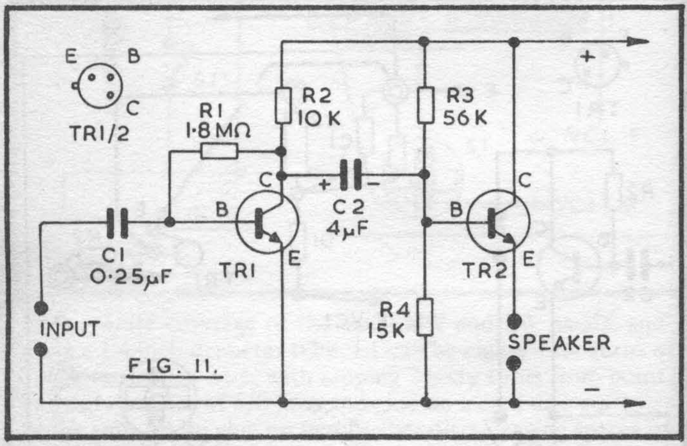

FIG. 11.

C1 couples the audio signal to the base of the first amplifier TR1, which receives base current through R1. An amplified signal is developed across the collector resistor R2, and is coupled to the base of the following amplifier TR2 by means of C2.

The two resistors R3 and R4 set the base operating conditions for TR2, and the output is taken from TR2 emitter.

Fig. 11B shows assembly of the components on a small insulated board. If preferred, connections between components can be on the underside of the board, in the way shown for later circuits. Fit red and black flexible leads for battery connections. The amplifier, with its battery, can be fixed in an insulated box or metal case. Sockets can then be used for input and output circuits, and an on-off switch can be placed in one battery lead.

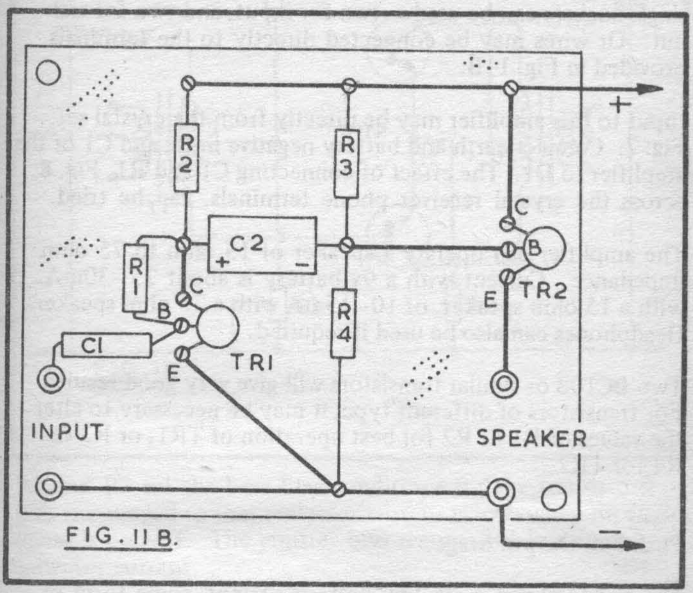

FIG. 11 B.

The board can be secured with bolts through its fixing holes, and through the bottom of the case. Extra nuts or other spacers must be placed between the case and board.

Whenever a metal box is used, remember that all connections and other circuits except the earth line must be insulated from the metal. The metal case itself is normally connected to the earth line, and a lead can be put under one of the fixing screws for this purpose. In Fig. 11, both input and speaker are returned to the earth line. So 3.5mm jack sockets of the type in which the outer or sleeve contact is common to the fixing bush could be used, as these points will be connected to battery negative and the earth line and metal box. But with some circuits it is necessary to use an insulated jack socket, or to insulate this from the metal. An example of this would arise if the speaker were placed in the collector circuit of TR2, as the outer or sleeve circuit would then need to go to battery positive.

Instead of the type of socket which takes a jack plug, ordinary single sockets can be used – two for input, and two for output. Or wires may be connected directly to the terminals provided in Fig. 11B.

Input to this amplifier may be directly from the crystal set, Fig. 7. Connect earth and battery negative lines; and C1 of the amplifier to D1. The effect of connecting C1 and R1, Fig. 8, across the crystal receiver phone terminals, can be tried.

The amplifier can operate a speaker of 15 ohm to 75 ohm impedance. Current with a 9v battery is about 25–30mA with a 15 ohm speaker, or 10–15mA with a 75 ohm speaker. Headphones can also be used if required.

Two BC108 or similar transistors will give very good results. For transistors of different type, it may be necessary to alter the values of R1 or R2 for best operation of TR1, or R3 or R4 for TR2.

Push-Pull Output Stage

For good volume, with low battery current, some form of push-pull output stage is generally used. This has two transistors, and each amplifies one half of the audio signal. Base bias conditions of the two transistors are so arranged that only a low current flows during silent intervals. Overall battery drain is thus much lower than if a single transistor were used to obtain a similar level of volume.

Fig. 12 is a typical push-pull output stage. T1 is the input or driver transformer, and an audio signal is taken to its primary P. The secondary S is centre tapped. So for one half of the audio cycle one transistor base is driven positive and the other transistor base is driven negative, this being reversed for the remaining half cycle. Thus each transistor conducts alternately, and the centre-tapped output transformer T2 combines the collector currents, to operate the speaker connected to the secondary S.

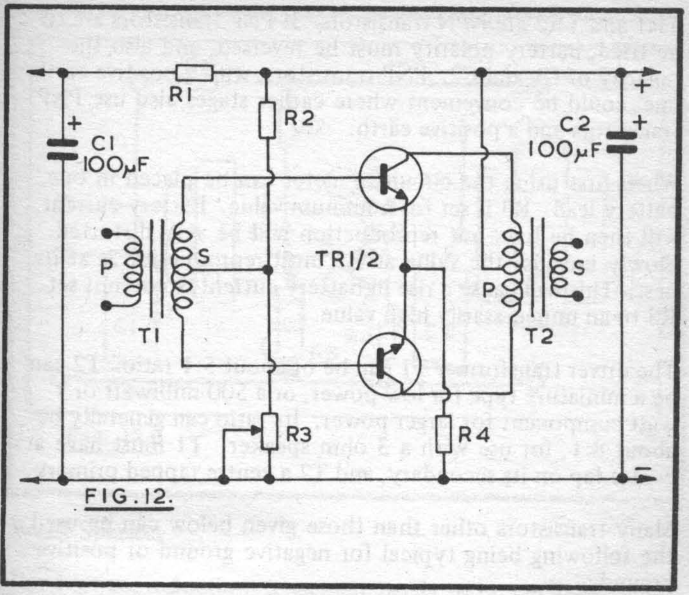

FIG. 12.

R2 and R3 set the base bias conditions for the transistors. Bias is arranged so that collector current is low, when no audio signal is present. The emitter bias resistor R4 limits peak collector current.

If R3 is a pre-set resistor, as in Fig. 12, operating conditions can be arranged to suit the transistors fitted. For best results TR1 and TR2 should be a matched pair. This means that they will have similar gain and current characteristics. However, two transistors of the same type number will generally be satisfactory.

It is assumed that the same battery will supply earlier stages of the amplifier, and current for this purpose is taken from C1 and R1. R1 and C1 prevent audio signals present in the positive line passing back to earlier amplifier stages. The by-pass capacitor C2 also helps in this respect. With simple circuits not giving much overall amplification, or small power outputs, R1, C1 and C2 might all be omitted.

TR1 and TR2 are NPN transistors. If PNP transistors are to be tried, battery polarity must be reversed, and also the polarity of C1 and C2. PNP transistors, with a positive earth line, could be convenient where earlier stages also use PNP transistors and a positive earth.

When first using the circuit, a meter can be placed in one battery lead. R3 is set for minimum value. Battery current will then be low, but reproduction will be very distorted. Slowly increase the value at R3 until reproduction is at its best. This will cause a rise in battery current, so do not set R3 to an unnecessarily high value.

The driver transformer T1 can be of about 5:1 ratio. T2 can be a miniature type for low power, or a 500 milliwatt or 1 watt component for larger power. Its ratio can generally be about 8:1, for use with a 3 ohm speaker. T1 must have a centre tap on its secondary, and T2 a centre tapped primary.

Many transistors other than those given below can be used, the following being typical for negative ground or positive ground.

Negative earth (NPN transistors). 2 x BC108. R1 1.2k. R3 100 ohm fixed or 250 ohm pre-set. R4 4.7 ohm.

Positive earth (PNP transistors). 2 x AC128 or 2 x AC142. R2 4.7k. R3 82 ohm or 250 ohm pre-set. R4 4.7 ohm.

R1 will generally be 1k to 2.2k, depending on the earlier amplifier. The primary of T1 can be connected to terminals P in Fig. 10; or alternatively to any audio source where a reasonably strong signal is present.

Where signals are too strong, an audio gain control needs to be fitted. In Fig. 8 this can be done by omitting R1, and disconnecting C2 from D1. Connect the outer tags of a 100k volume control or log pot from D1 to earth line. Take C2 to the centre tag or slider of the potentiometer. Any required audio level can then be taken off by adjusting the control knob.

Fig. 12B shows the board layout.

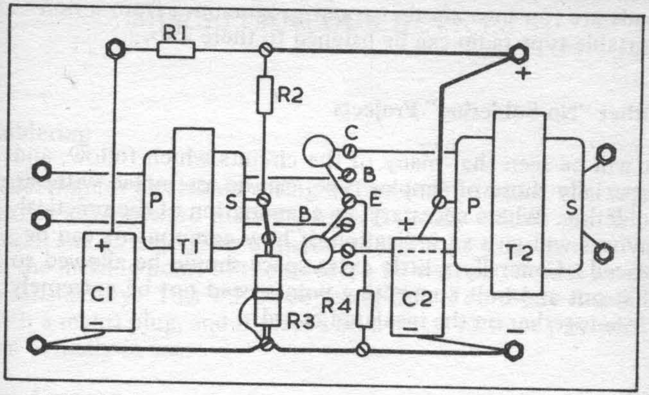

FIG. 12 B.

Boost Speaker

For best reproduction, a speaker needs to be enclosed in a cabinet or fitted to a baffle board. A cabinet can be made from wood, and can be about 6 x 10 inch and 4 inch deep, or as required for the speaker unit. Cut an aperture in the cabinet front to match the cone diameter, and glue thin fabric behind this opening. The speaker can be fixed with nuts and bolts, or short woodscrews driven in from behind.

Connect flexible leads, with separate plugs or a jack plug, to suit the equipment.

Small pocket receivers, which have a miniature speaker, can give much improved volume and reproduction when used with a larger speaker. If a headphone socket, operated from the receiver output stage, is present, it is only necessary to plug the speaker into this. A fairly large speaker, of sensitive type, will give best results. A unit 5 inch to 6 inch in diameter, or about 4 x 7 inch, will be convenient. The speaker has to be of approximately the correct impedance, which should be found in the receiver operating instructions. Where the speaker impedance is wrong, a matching transformer has to be employed between receiver and speaker.

Extension speakers are less frequently used today, but if two leads are run into another room programmes from a non-portable type radio can be listened to there also.

Other "No Soldering" Projects

It will be seen that many of the circuits which follow, and especially those of simpler type, can be assembled without soldering. Where necessary, an examination of the practical layouts will give an indication of how components can be placed. Generally a little extra space should be allowed so that nut and bolt connecting points need not be extremely close together on the insulated board.

SECTION 2
MISCELLANEOUS DEVICES

Soldering

Soldering for electronic wiring will be found to be a very easy and straightforward matter. An electrically heated iron is usual, and as large areas of metal do not have to be raised to the melting point of the solder, a 20 watt to 25 watt iron is satisfactory. This will be perfectly safe if correctly fitted with a mains plug, and if placed on a metal plate or tray when not actually in use.

It is best to use cored solder, as made for electronic wiring.

Leads, tags and other items to be joined should be clean and bright. They have to be raised in temperature to the melting point of the solder at the actual points where a joint is to be made, and the active core of the solder, or flux, must be present here when the joint is being made.

The iron should be tinned – that is, have melted solder on its tip – and have reached its correct temperature. Leads can be hooked or looped into position. The joint is then heated with the iron, and the solder is simultaneously applied to the joint, so that it melts and flows over the surfaces to be soldered. This usually takes place in a second or two. The solder and iron should be removed at once, as excessive heating may damage some components, and especially transistors or other semiconductors. The joint cools in a few seconds, and should be rigid, and solder having flown onto the items to be joined.

A probable cause of poor joints is insufficient heating of items to be soldered, or carrying solder to the joint on the iron, so that the activity of the flux is wasted.

Electronic items such as tags and the wire ends of components are generally designed for easy soldering. They will be copper, tinned copper, and similar metals and alloys which solder readily. For this reason, difficulties are unusual.

Some metals do not solder readily, or need special methods. Aluminium is one of these, and it is not used where popular cored solders intended for copper or general wiring are employed.

Make sure that heat from the iron does not damage furniture or other items, and keep the flexible cord away from the heated tip. Always switch the iron off at once when the work in progress is to be left.

One Transistor Audio Oscillator

This can be used instead of a bell or buzzer warning, or for code practice and similar purposes. It needs very few components, Fig. 13, and can be made to work satisfactorily with a wide range of transistors.

In Fig. 13, an NPN transistor is shown in the theoretical circuit, so battery polarity is as indicated, with negative to emitter. If a PNP transistor is fitted, battery polarity must be reversed.

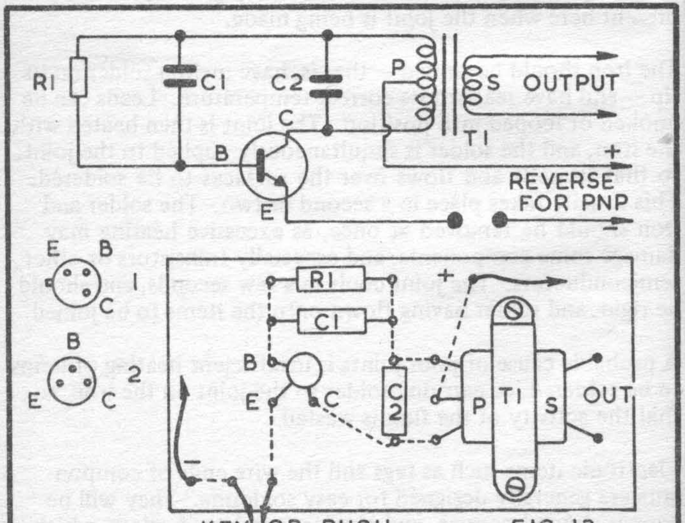

FIG.13.

(1) shows leads from a typical NPN transistor, such as the BC108, 2N706, and similar types. (2) is the base of the PNP AC128 transistor.

T1 can be a small speaker matching transformer, as used for push-pull stages. A centre tapped primary is necessary. The secondary S can be taken to a loudspeaker or headphones.

The values of R1, C1 and C2 can be varied considerably. C1 can be 0.1μF or so. R1 determines to some extent the power obtained, and can be about 22k, increased to 47k or 100k for lower power. The value of C2 has considerable influence on the note, or frequency of oscillation. Increasing the value of C2 lowers the pitch. C2 can be about 47nF to 4.7nF or thereabouts. A 9v battery can be used. Changes to the supply voltage will influence the note produced.

Fig. 13 also shows a layout for components, using either a fully perforated board, or a panel drilled to suit. Transformer T1 is fixed by screws. Small transformers of this type are usually wire ended, or have pins which pass down through holes in the board.

The wire ends of the resistors and capacitors are passed down through suitable holes, and bent over. The board is then turned so that the underside wiring can be carried out. In most places the wire ends of the components will be long enough to reach connecting points. Elsewhere, 24swg tinned copper wire, or similar connecting wire, will be used. Make the soldered joints as described, and snip off unwanted ends of wire. It is as well to leave the transistor to last, as this avoids heating it unnecessarily when soldering other items. Lengths of flex, anchored at holes in the board, are used for battery, key (or push) and speaker connections.

Multivibrator

Fig. 14 is the circuit of the multivibrator assembled in Fig. 2. Reference to Fig. 14B will show how this can also be prepared on a tag board.

The tag board has two rows of tags fitted to an insulated board, and it is five tags long in Fig. 14B. Boards of this type can be obtained in many sizes. It is also easy to cut a section from a long tag board, to suit the needs of the item to be assembled. Such boards are very handy indeed for electronic assemblies, as the tags support resistors, capacitors and other items, and a neat layout is readily achieved.

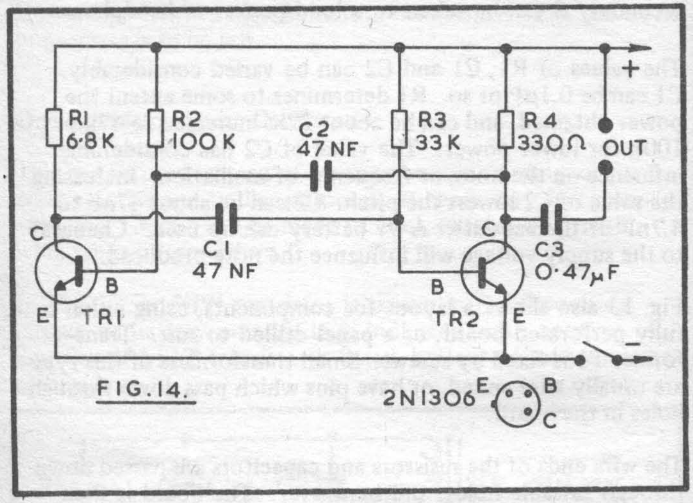

FIG.14.

Tag strips are also useful for projects, and may have any number of tags required. Long tag strips can be cut down as necessary. Short tag strips have one tag for mounting the strip, longer strips having two tags formed as brackets for this purpose.

Place the components approximately as in Fig. 14B, and solder the wires to the tags. If any component values may be changed, do not twist the leads tightly round the tags before soldering, or removal will be difficult.

Wires which cross can be kept clear of each other, and then no insulated sleeving will be necessary. The transistors can be soldered on last, and can readily be changed without disturbing other parts.

The same layout can be used for the next project, though the component values are different.

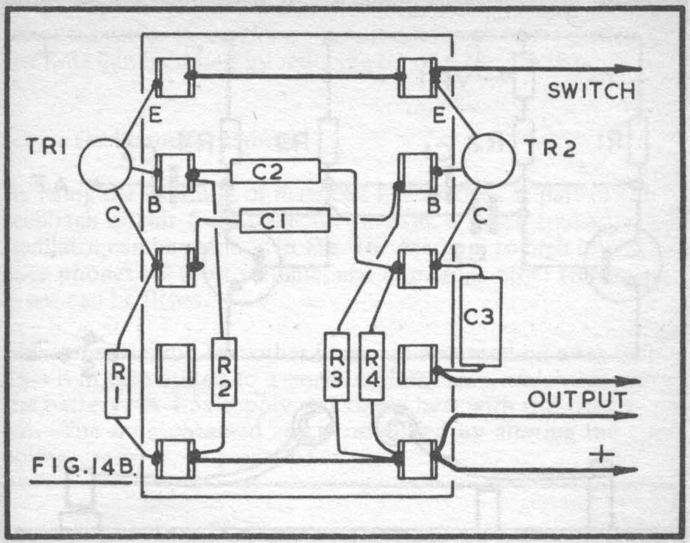

FIG.14B.

Glissade

This device will produce swooping, rising and falling tones, for "effects" purposes, or can with additional skill be used to obtain musical notes through several octaves. The circuit is shown in Fig. 15, and reference can be made to Fig. 14B for a practical layout on a tag board.

In Fig. 15, suitable component values are:

R1	10k	C1	22nF
R2	12k	C2	22nF
R3	100k	C3	22nF
R4	10k	VR1	100k linear pot.

Transistors: 2 x BC108 or similar types.

The circuit is a wide frequency audio oscillator, in which the pitch can be controlled by VR1, and "on" switching is obtained by S. The oscillator is placed in a box, so that switch S and VR1 can be mounted on the top. The switch is a strip of springy metal, fitted with a spacer and bolt, so that it is just clear of a further bolt. A small downwards movement of the arm or knob completes the circuit.

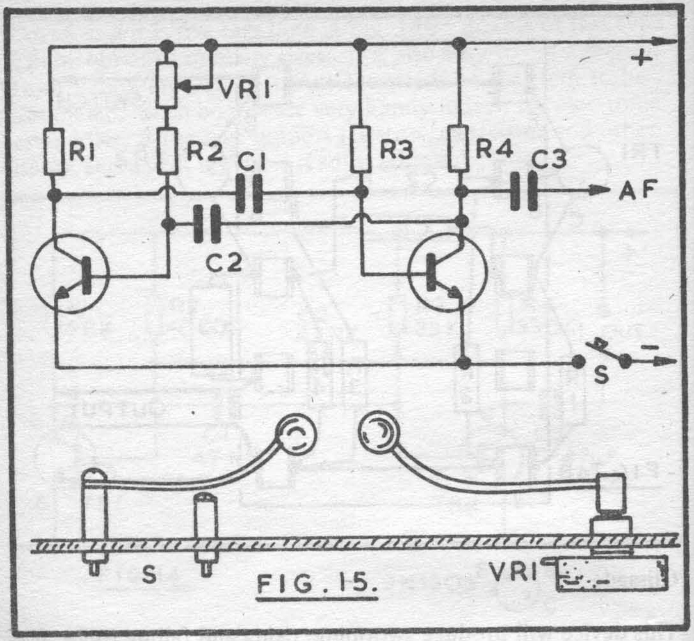

FIG. 15.

VR1 has a ¼ inch shaft coupler, into which is screwed a length of 4ba threaded rod. A knob is also fitted to the end of this rod. It can be swung backwards or forwards, to change the resistance of VR1. Connect VR1 so that movement of the knob towards the right raises the pitch.

Output from C3 can go to high resistance headphones, for amusement, but should be taken to an audio amplifier. Gain of the amplifier will have to be turned back somewhat, as the output from the glissade is at a quite high level.

Swooping tones are produced by holding down the switch S and swinging the control knob attached to VR1 from side to side. For notes which do not swoop to frequency, switch S must be released while VR1 is rotated. A slight quivering motion of the hand controlling VR1 will produce a vibrate effect. It is useful to have an ordinary switch in parallel with the knob control S, and to have the amplifier audio gain control near the left hand, so that fading effects can be produced as well.

About 4.5v to 9v can be used, this influencing volume. Should other transistor types give an unsuitable range of frequencies, the note can be raised by reducing C1 or C2 (or both).

Morse Oscillator for Phones

By using the windings of magnetic headphones as part of the feedback circuit from collector to base, a single transistor oscillator can be made as in Fig. 16. Medium to high impedance phones are most suitable, and numerous other transistor types can be fitted.

The transistor and few other items are mounted on a tag strip. This is in turn bolted to a small insulated box, which can carry the battery. A 4.5v supply was found best with this oscillator. The note obtained can be modified by altering the voltage, resistor, or capacitor values.

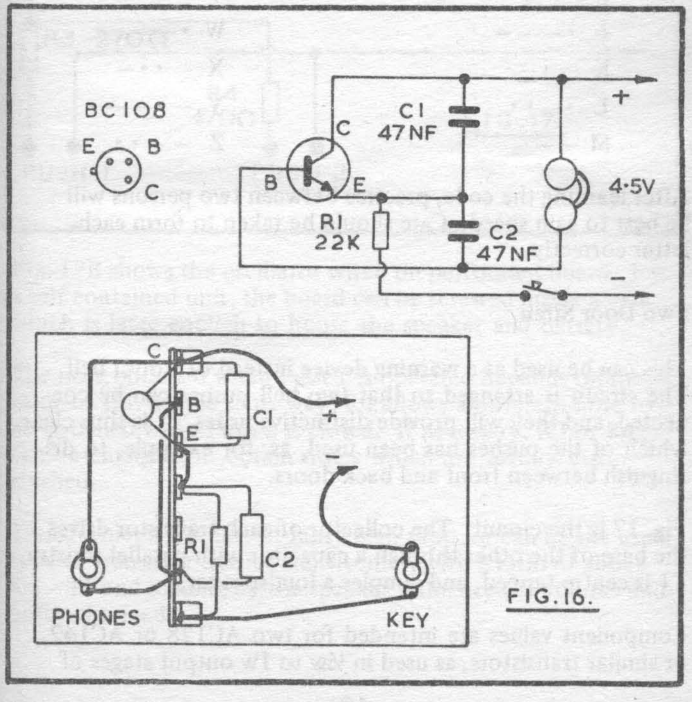

FIG. 16.

For serious code practice a good Morse key is required. It is adjusted so that only a small movement of the wrist is needed to operate it. Each letter consists of short and long sounds, shown as (•) and (–). The (–) has three times the length of the (•)

A •–
B –•••
C –•–•
D –••
E •
F ••–•
G ––•
H ••••
I ••
J •–––
K –•–
L •–••
M ––
N –•
O –––
P •––•
Q ––•–
R •–•
S •••
T –
U ••–
V •••–
W •––
X –••–
Y –•––
Z ––••

After learning the code, practice between two persons will be best to gain speed. Care should be taken to form each letter correctly.

Two Door Siren

This can be used as a warning device instead of a door bell. The circuit is arranged so that two bell pushes can be connected, and they will provide distinctive notes. It is thus clear which of the pushes has been used, as, for example, to distinguish between front and back doors.

Fig. 17 is the circuit. The collector of each transistor drives the base of the other through a capacitor with parallel resistor. T1 is centre tapped, and couples a loudspeaker.

Component values are intended for two AC128 or AC142, or similar transistors, as used in ½w to 1w output stages of receivers and small amplifiers. Other transistors will of course operate in this circuit. The pitch obtained can be modified by changing C3. The circuit shown is for PNP transistors, and battery polarity has to be reversed for NPN transistors.

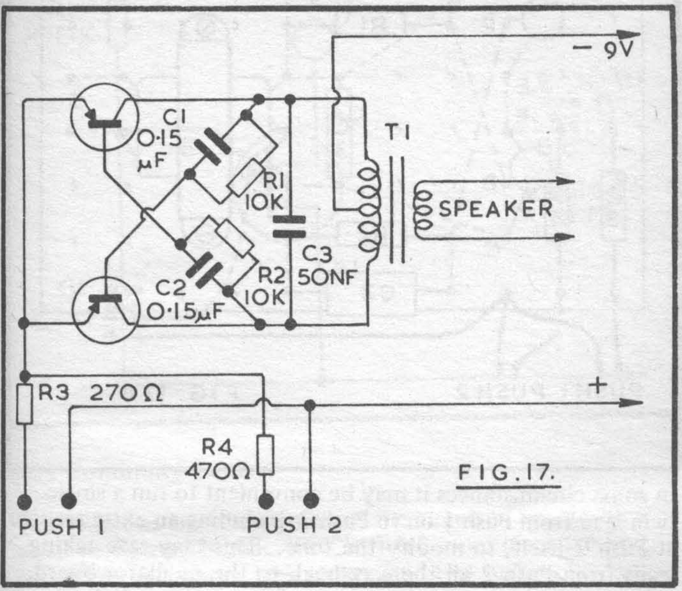

FIG.17.

Fig. 17B shows the oscillator wired on perforated board. For a self contained unit, the board can be screwed inside a case which is large enough to house the speaker and battery.

The note obtained when Push 1 is operated depends on the value of R3. In the same way, R4 allows a different note to be obtained when Push 2 is closed. If necessary, R3 or R4 can be changed, to obtain notes which are readily distinguished.

Transformer T1 is best of fairly high ratio, or can be the usual type of transistor output transformer, with a ratio of about 8:1. T1 and loading by the speaker influence the volume and notes obtained.

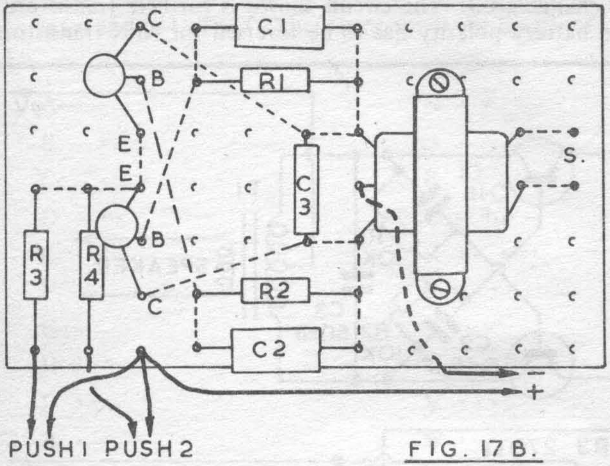

FIG. 17B.

In some circumstances it may be convenient to run a single twin lead from Push 1 on to Push 2, including an extra resistor at Push 2 itself, to modify the tone. This may save taking leads from Push 2 all the way back to the oscillator board.

UJT Oscillator

The uni-junction transistor is a device having emitter, Base 1, and Base 2, Fig. 18. B2 receives positive bias, in this case through the headphones. When forward bias on the emitter E is reached the UJT conducts.

In Fig. 18, the emitter potential rises as C1 charges through the resistor R1. When the UJT conducts, C1 is discharged, and the process is repeated. This can take place over a very wide range of frequencies, depending on the values used for R1 and C1. Here, these are chosen to produce an audio tone.

A battery supply of 3v to 9v will be convenient. For use of the UJT oscillator during code practice, place the key in one battery lead.

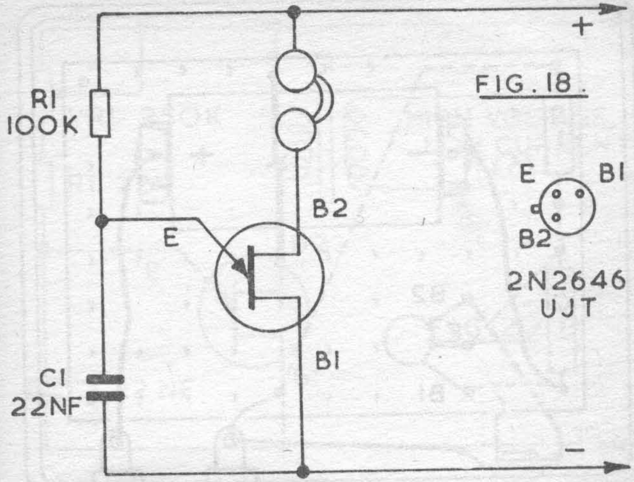

FIG. 18.

UJT Continuity Tester

Fig. 19 shows actual assembly of the circuit in Fig. 18 on a small perforated board. This is fitted in an insulated box, which carries a phone jack socket, and two sockets for Morse key or test leads. A 9v battery is used, secured with string or elastic.

For continuity tests, take prods or clips on the test leads to the suspected item. If the circuit is in order, the UJT oscillator will produce an audio tone. Oscillation will be obtained with a series resistance between the prods of up to 20k or more, so various components can also be tested, and some idea of the resistance in circuit can be gained from the sound obtained. The tester can also be used to check bulbs, lamps, fuses, extension and other leads, and similar items – these must of course be removed or disconnected from the equipment, before being tested.

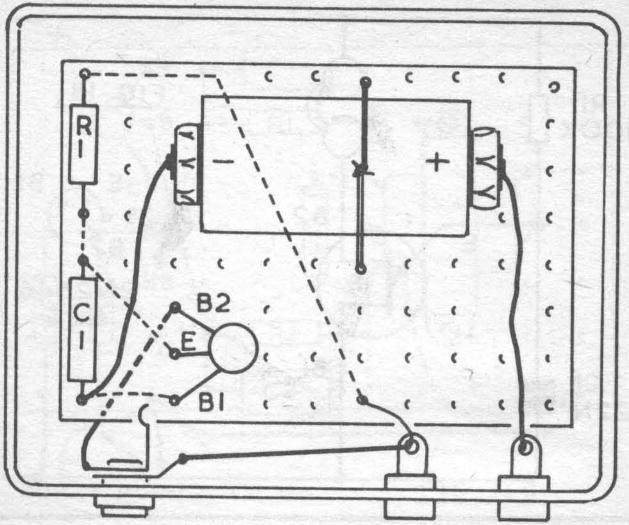

FIG. 19.

UJT High Voltage Producer

The UJT oscillator can be used to produce a high voltage, at very low current, by connecting a transformer as in Fig. 20. A loudspeaker transformer, as would be used in valve equipment, is suitable, and will have a ratio of about 45:1 or so. The usual secondary, or low-resistance winding, is connected to B2 and positive, so that a step-up of voltage is obtained. This should be found to light a small neon lamp.

VR1 is fitted to allow some adjustment, to find the most suitable frequency of oscillation. For maximum possible high voltage output, if required, operating voltage and current should be raised. No rating of the UJT must be exceeded. For the 2N2646, the supply should not exceed 30v, emitter current should not be over 50mA, and dissipation of power in the device should not be more than 300 milliwatts. (Dissipation can be found from Voltage x Current.)

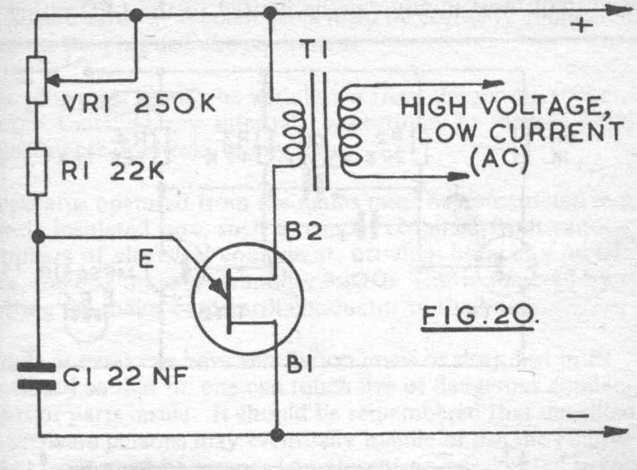

FIG.20.

A small mains transformer can be used for T1, with a low voltage winding, such as that for a 6.3v heater circuit, as primary, and the 200/250v winding as secondary. The high voltage output is alternating current.

Signal Blinker

Fig. 21 is a multivibrator in which the feedback capacitors C1 and C2 are of high value, so that conduction alternates between TR1 and TR2 at a low rate. A light emitting diode is placed in the collector circuit of TR2, and so flashes on and off.

This device can be used for various instruments and other equipment, and a flashing indicator draws attention to a greater extent than does one continuously illuminated. The LED can be located at any required point, with leads running to it.

Transistors other than the types shown can be utilised. R4 can usually be about 150 ohm for a 3v supply, 470 ohm to 1.2k for 6v, or 680 ohm to 1.5k for 9v. This depends to some extent on the amount of light required when the indicator is operating. Lower resistor values at R4 will increase light, but current must in any case be limited to the LED rating.

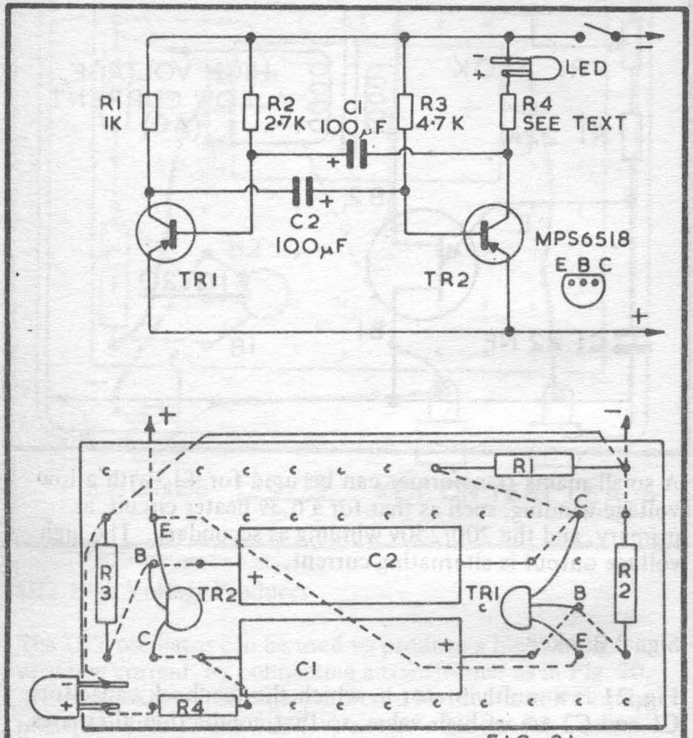

FIG. 21.

C1 and C2 need only be 6.4v working, and the device can be assembled on a very small perforated board. See p.61 for LED polarity.

Mains Wiring

All the devices described so far have operated from low voltage batteries, so than no shock hazard exists with them. However, it is necessary to employ mains power for some units, and proper care must then be taken to avoid any danger.

Power should be drawn from a 3-pin plug, and this should have a 3A or other low rating fuse installed. The live or L, neutral or N, and earth or E conductors must be correctly connected, both at the plug and the equipment.

The plug must always be withdrawn from the supply socket, before touching any internal connections, or making any adjustments or checks of any kind.

Apparatus operated from the mains must be constructed in a strong insulated box, such as can be obtained from various suppliers of electrical equipment; or when built in a metal box, the box must be soundly earthed. This is achieved by bolting the mains cord earth conductor to the box.

Boxes or cases can have ventilation holes or slots, but must be closed so that no one can touch live or dangerous connections or parts inside. It should be remembered that unskilled or unaware persons may eventually handle or use the equipment, so it must be arranged to present no unexpected hazards such as live terminals or parts, or openings for the fingers.

If these points are remembered, mains operated equipment can be safe to use and handle. No switch or other means of interrupting the circuit is put in the earth conductor, and any switch or equivalent device is placed in the live or L conductor. This leaves both earth and neutral permanently connected, for maximum safety.

Dimmer/Heat Control

It is often convenient to dim a filament lamp, or reduce the heat of a soldering iron to be left on for long periods, or the power of a low wattage heater. The silicon controlled rectifier circuit in Fig. 22 can be used for these purposes.

When the switch marked "Full" is closed, current for the load passes through this, so that full power is obtained.

When this switch is opened, current passes through the SCR. This device conducts only when the gate has been triggered, and the instantaneous point in the alternating current cycle where this arises is determined by the setting of the potentiometer VR1. Triggering is advanced as the wiper of VR1 is moved towards R1. The average power supplied to the load can thus be adjusted between wide limits. Since the device is operating as a half wave controller, full power is not obtained with VR1 at maximum, so the switch is closed as described.

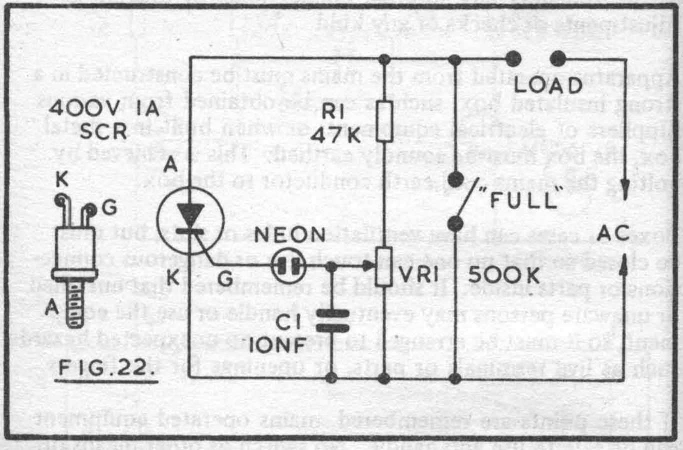

FIG.22.

Fig. 22B shows construction of the SCR controller in a metal box. The front of this carries a socket outlet, and the mains cord has a 3-pin plug, wired as explained earlier. It is thus easy to plug the controller into an outlet, and insert the plug of the lamp or other item to be used in the new outlet.

The mains cord is secured with a clamp, and passes through an insulated grommet. The tag strip supporting the small items is mounted by an unused tag. A strip of metal is cut to clamp round the body of the SCR, and is soldered to one tag, as shown. Run earth and neutral leads from the cord up through a hole, and connect them to the E and N terminals of the socket outlet. Also earth the case, at E. A well insulated wire runs from the L terminal of the outlet, to the "Full" switch. The outlet can be secured with bolts and nuts.

R1 should be 1 watt, and C1 is a 500v capacitor. The neon is a small type as used for indicators, etc.

After checking that the controller operates correctly, the back of the box should be screwed in place. A suitable size is about 4 x 5 x 2 inch deep.

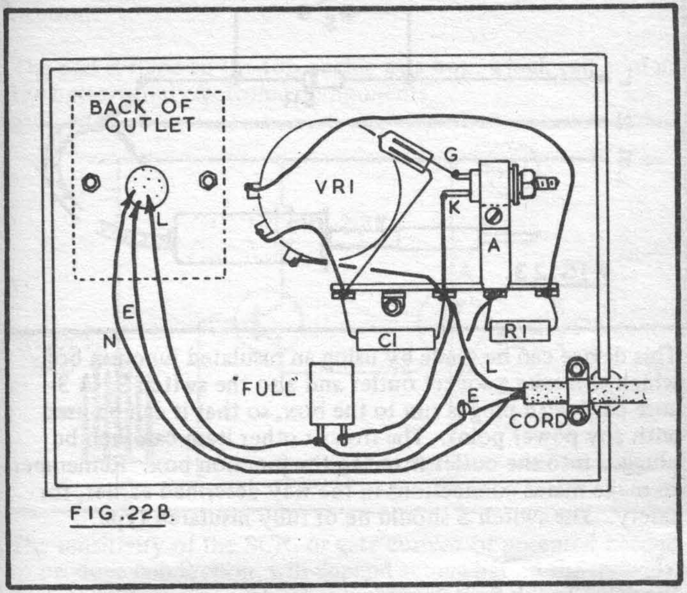

FIG.22B.

If a fully insulated box is used instead, then the bush of VR1 and of the switch should both be earthed by wires, except when these items are constructed wholly with insulated material. (This precaution is necessary to avoid any chance of metal parts outside the box becoming "live".)

Two Power

A circuit which will allow half or full power can be useful to reduce the heat of a soldering iron, or for dimming a filament lamp.

Fig. 23 is an easy circuit of this type. Full power is obtained when the switch S is closed. With S open, the silicon rectifier allows current to flow in one direction only, so that power is approximately halved. A 600v 1A or 1000v 1A rectifier is suitable.

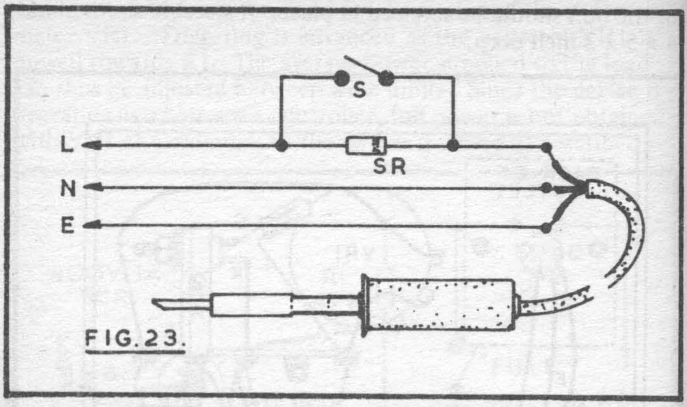

FIG.23.

This device can be made by using an insulated junction box which will take a socket outlet and also the switch S. A 3-core cord with plug is run to the box, so that it can be used with any power point. The iron or other item can then be plugged into the outlet fitted to the junction box. Remember to make mains connections in the way described earlier, for safety. The switch S should be of fully insulated type.

Sensitive Touch Switch

In Fig. 24, finger contact with the touch pad switches on a low voltage bulb. This circuit is suitable for a battery operated portable bedside light, and for some other devices.

Normally the silicon controlled rectifier is not conducting, so the lamp is extinguished. Finger contact with the pad provides positive base bias for the transistor so that it conducts. This moves the transistor emitter and SCR gate positive, triggering the SCR. Current then flows from cathode K to anode A, and through the bulb. The SCR remains in the conducting condition until the battery circuit is interrupted by opening the switch. A push switch, normally closed, is most suitable here. Pressing it then switches off the bulb.

This touch pad is easily made from a piece of circuit board with foil strips. It can be about 2 x 1 inch, or of any convenient size. Join together alternate foils – e.g., 1, 3, 5 and 7 – by soldering a connecting wire through the holes. This will provide one connection to the pad. The other foils – 2, 4 and 6 – are similarly joined together for the other pad connection.

The pad is fixed to the top or side of a box, which can contain the battery and electronic components.

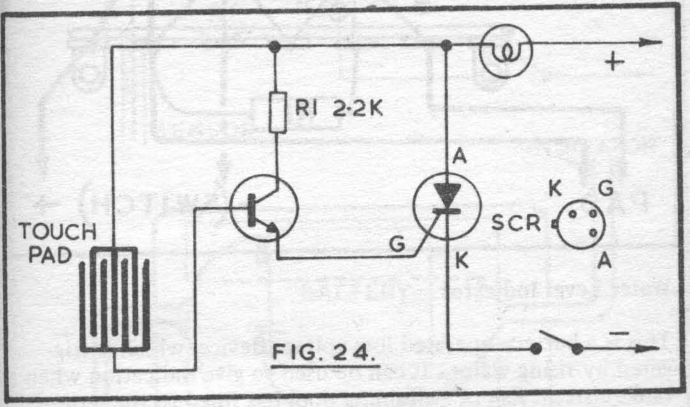

FIG. 24.

The sensitivity of the SCR, or gate current or potential needed to produce conduction, will depend somewhat on the individual device, while the gain of individual transistors will also be different. Numerous NPN types are suitable. If it is found that the switch is too sensitive, this can be corrected by placing a resistor from transistor base to SCR cathode or negative line. This resistor can be about 470k to 1 megohm or so. Excessive sensitivity will be apparent if the circuit is switched on by dust, damp air, or similar effects. The pad should be kept clean by wiping it with a dry cloth.

Fig. 24B shows assembly of the components on a tag strip. A small 50v 1A SCR is more than adequate. The bulb can be a screw in type, and can be 6.3v 0.15A, or 6.3v 0.3A. A 6v 3W (0.5A) bulb is also suitable, provided the battery is fairly large.

It is convenient to make a wooden box which will take the battery, and leave a little space for the tag strip assembly.

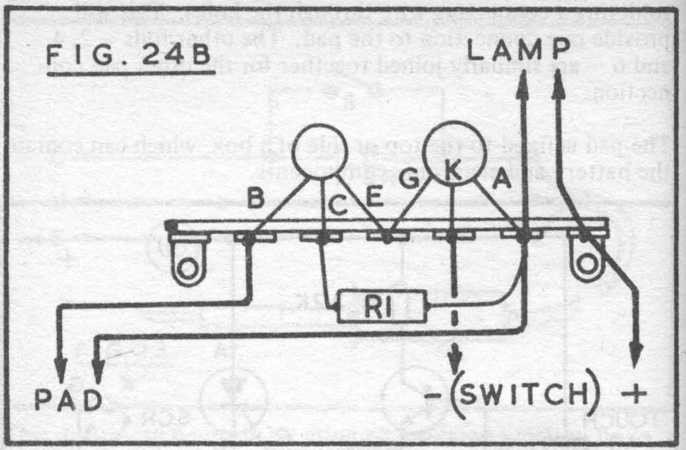

FIG. 24B

Water Level Indicator

This is a battery operated low voltage device, which is triggered by rising water. It can be used to give indication when a tank, cistern, fish or swimming pool has filled to the required level.

Fig. 25 shows the circuit, and also assembly on an insulated board. This also carries the battery, and it is fitted in a metal or plastic box.

In use, the base normally has no positive bias, as the sensor passes no current. When water reaches the sensor, it conducts, and the transistor passes collector current, to operate the indicator. R1 limits base current.

This circuit will operate satisfactorily with a wide range of PNP or NPN transistors, but battery polarity must be reversed for the PNP types.

The indicating or warning device can be one of the multivibrator or other audio oscillators shown earlier. These will give an audible warning, and will draw only a small current, so that a large transistor is not required.

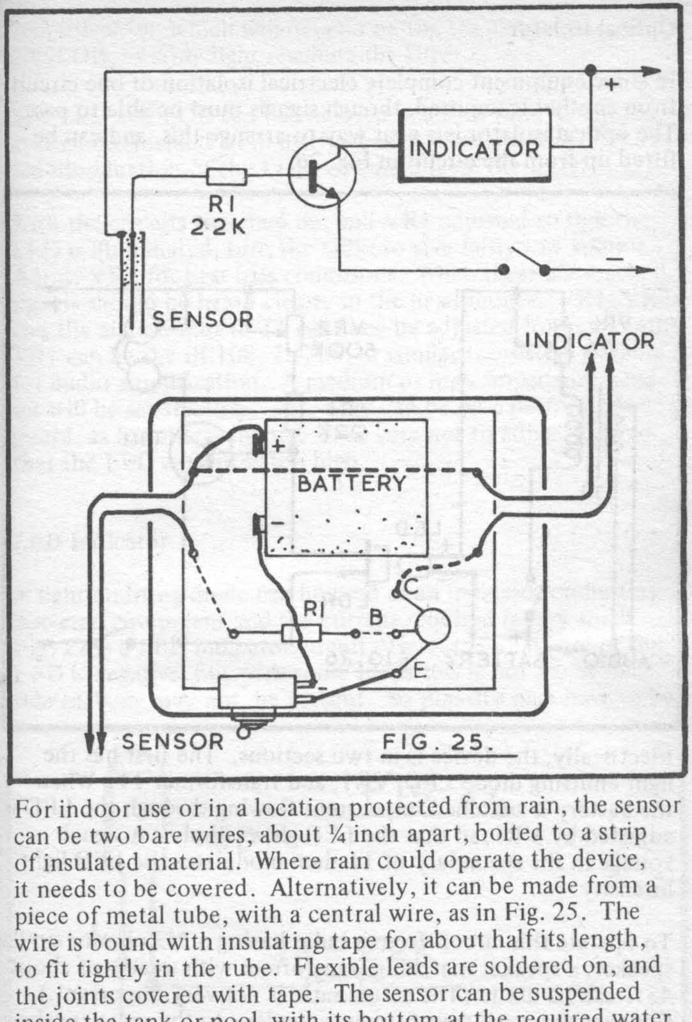

FIG. 25.

For indoor use or in a location protected from rain, the sensor can be two bare wires, about ¼ inch apart, bolted to a strip of insulated material. Where rain could operate the device, it needs to be covered. Alternatively, it can be made from a piece of metal tube, with a central wire, as in Fig. 25. The wire is bound with insulating tape for about half its length, to fit tightly in the tube. Flexible leads are soldered on, and the joints covered with tape. The sensor can be suspended inside the tank or pool, with its bottom at the required water level.

If the transistor is a high gain one, so that damp operates the indicator, sensitivity can be reduced by connecting a 100k resistor from base to emitter.

Optical Isolator

In some equipment complete electrical isolation of one circuit from another is required, though signals must be able to pass. The optical isolator is a neat way to arrange this, and can be fitted up from the circuit in Fig. 26.

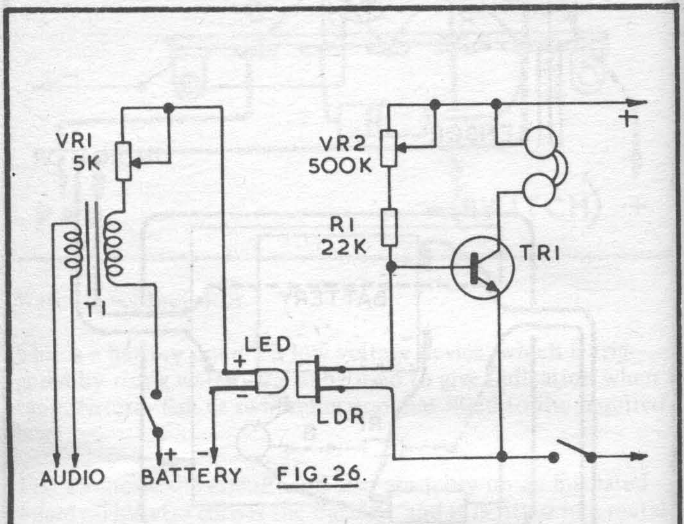

FIG. 26.

Electrically, the device is in two sections. The first has the light emitting diode LED, VR1, and transformer T1. When the battery is switched on, current flowing through the LED is adjusted by VR1, so that the LED glows dimly. A signal voltage in the secondary of T1 then modulates the LED light intensity.

To operate this circuit from a radio having a 2/3 ohm or similar speaker, a speaker matching transformer with a ratio of about 45:1 can be used. (The actual ratio is not very important.) Connect the usual transformer secondary to the radio speaker, so that T1 provides a step up effect.

The second part of the equipment has the light dependent resistor LDR, forming part of the network providing TR1 with base bias. VR2 allows adjustment of conditions for best amplification, which will depend on the transistor, and also the LDR, or stray light reaching the latter.

The LED and LDR can be enclosed in a card tube, or should at least be shielded from light, which will swamp the modulated illumination of the LDR, obtained from the LED.

With the circuits switched on, and VR1 adjusted so that the LED is illuminated, turn the radio to give fairly low volume. Adjust VR2 for best bias conditions. When these are reached, signals should be heard clearly in the headphones. VR1, VR2 and the audio input to T1 can then be adjusted for best results. TR1 can be the BC108, 2N706, or similar transistors suitable for audio amplification. A medium or high impedance headset will be satisfactory. Assembly can be on a perforated board, as for other circuits. Take care not to adjust VR1 so that the LED current is too high.

LED Indicator

A light emitting diode can be used as an indicator on battery powered equipment and the current required is very small. Fig. 27 is a LED indicator circuit. Here, the long wire of the LED is negative, but with some LEDs this is not so. A flat side may, or may not, be present. So polarity may have to be

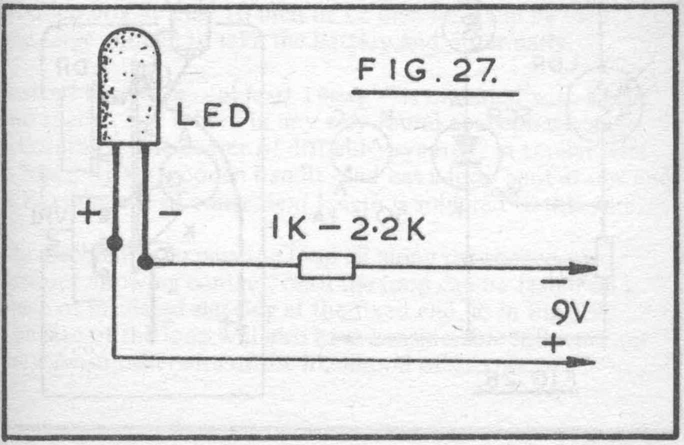

FIG. 27.

found by trial – the correct connections are those allowing the LED to light. The series resistor may be about 150 ohm to 1k or more, depending on the actual voltage, and brightness required. Current drawn varies with different LEDs, and with voltage and series resistance, but can be about 5mA or less, without reducing the brightness too far.

The LED indicator with resistor is connected to the circuit where voltage is present when the equipment is on. LEDs are available in red, yellow, green and other colours, with grommets or clips for panel mounting. Different circuits may be identified by a range of colours.

"Magic Candle"

The triggering of a silicon controlled rectifier can be used for slave photoflash and similar purposes. In Fig. 28 it is employed to switch on a light when a match or lighter is brought near. Sensitivity is best in somewhat subdued light, and it will then be found that striking a match at some distance can bring on the light.

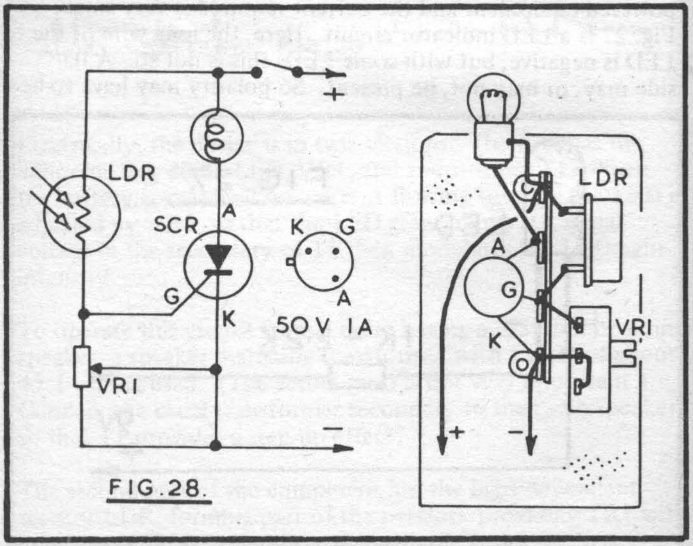

FIG.28.

The LDR has a high resistance when in darkness or subdued light, so that the gate potential of the SCR is not sufficiently high to trigger this device. When light reaches the LDR, its resistance falls, and the SCR gate voltage rises. The SCR then moves into its conducting condition, so that current flows through the bulb. The sensitivity of the circuit, or level of illumination needed to trigger the SCR, is set by VR1.

Components can be assembled on a small tag strip. This, with a battery, can occupy a tubular case, with the lamp on top. An opening is necessary opposite the LDR, and a hole is also made so that VR1 can be adjusted with a screwdriver. Here, a miniature pre-set 50k or 100k linear potentiometer is most suitable. It is necessary to have a small push switch to interrupt the battery current, as the SCR remains in the conducting condition until the circuit is momentarily broken. A 6V battery and bulb can be used. SCRs may fail to operate at all if attempts are made to use them with extremely low voltages, such as a single 1.5v cell.

"Nerve Tester"

This device tests the nerve, concentration, and steadiness of hand, and always provides amusement.

Connections and construction will be seen from Fig. 29. A wooden box at least 10 inch or 12 inch long will be used, and large enough to take the battery and other parts.

A stout bare wire – at least 14swg – is mounted with a bolt and spacer, and is bent in any way found appropriate, and according to the degree of difficulty wanted. A similar wire is fitted with a wooden handle, and has a loop bent at one end. A flexible lead of convenient length is soldered to this wire.

The problem is to pass the loop all along the shaped wire, without allowing contact, until the loop can be rested on a piece of insulated sleeving at the fixed end, as in Fig. 29. The size of the loop will also have considerable influence on the ease or otherwise of the likelihood of success.

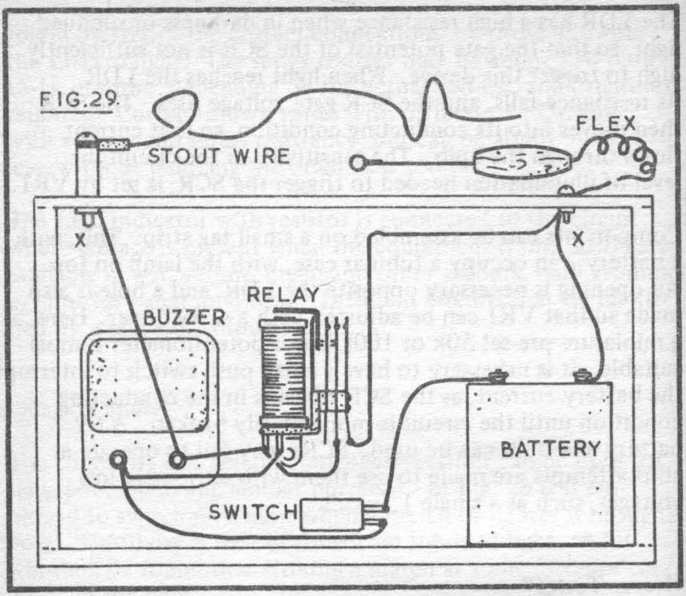
FIG.29.

If loop and wire touch, current flows from the battery to the buzzer, which sounds. Current also flows to the relay winding, so that the relay contacts close. Even a momentary contact between loop and wire will thus cause the buzzer to sound until the switch is used to break the circuit.

Any 4.5v, 6v or similar battery and buzzer will be satisfactory, with a relay which operates on a similar voltage. Connections are to the relay contacts which remain open until the relay is energised.

In use, the device can stand upright. A back is attached with small screws.

Burglar Alarm

The same circuit arrangement as in Fig. 29 will provide a burglar alarm operated by pressure mats. The latter are available in various sizes, and consist of a thin pad which can be placed under a carpet or ordinary mat.

Leads from the mat or mats will run to the terminals at X–X. The buzzer should be changed for a bell, which need not be fitted in the box, but can be situated where it is best heard. Momentary weight on any of the mats will then switch on the bell, which will be locked on by the relay as described, and will ring until the unit is switched off.

Transistor Tester

A very useful check of transistors can be made with the aid of a multi-range test meter, with a selection of base resistors to provide base current, as in Fig. 30. This method does not give an exact indication of transistor gain, but it does allow defective transistors to be eliminated, and provides a good idea of the performance to be obtained from surplus or other unknown transistors.

A 6-way switch allows the base to be open circuit, or to receive current through one of the resistors R1 to R5. These values are R1 330k, R2 110k, R3 33k, R4 11k and R5 3.3k. After allowing for the base-emitter potential, switch positions and corresponding base currents are near the following: 1, zero; 2, 10μA; 3, 30μA; 4, 100μA; 5, 0.3mA, and 6, 1mA.

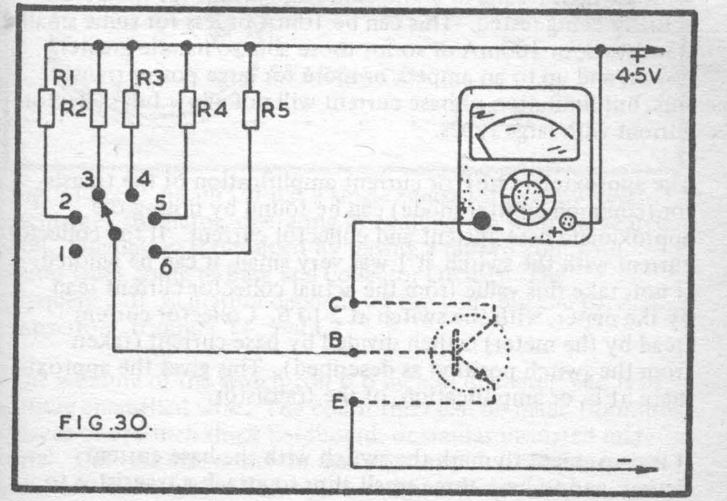
FIG.30.

Polarity is shown for NPN transistors. Reverse polarity of both meter and battery for PNP transistors.

For all tests, initially set the switch to 1, and the meter to its highest range (say 1 ampere). Afterwards, switch the meter to a lower range, after adjustment of the 6-way switch, as may prove to be necessary to obtain an easy reading.

With the switch at 1, a high reading on the meter shows that the transistor has a short circuit from emitter to collector, and is defective.

With germanium transistors, collector current (with the switch at 1) may be 0.1mA or so up to perhaps 0.5mA for small types, and up to some milliamperes for larger types. This small leakage current does not show that the transistor is defective.

In the case of silicon transistors, the leakage current (with switch at 1) will be zero or extremely small, if the device is in good condition.

The switch is then turned to one of the positions 2 to 6. If collector current does not rise, the transistor is defective. If current rises at each step, do not go beyond the switch setting which results in a safe collector current for the device actually being tested. This can be 10mA or less for some small transistors, or 100mA or so for those able to handle greater power, and up to an ampere or more for large power transistors, but limitation of base current will not allow full collector current with large types.

The approximate hFE or current amplification of the transistor (common emitter mode) can be found by noting the approximate base current and collector current. If the collector current with the switch at 1 was very small, it can be ignored. If not, take this value from the actual collector current read by the meter, with the switch at 2 to 6. Collector current (read by the meter) is then divided by base current (taken from the switch position as described). This gives the approximate hFE, or amplification, of the transistor.

It is convenient to mark the switch with the base current figures, and to have three small clips to attach a transistor to the circuit. Switch, clips, and battery can all be fitted to a small box. A development of the circuit would be to include a current meter, with switch and shunts, to replace the external general purpose test instrument.

Treasure Locator

This locator is among the simplest that can be constructed, as it uses an ordinary small portable radio as part of the detection circuitry. No modifications or connections to the radio are needed.

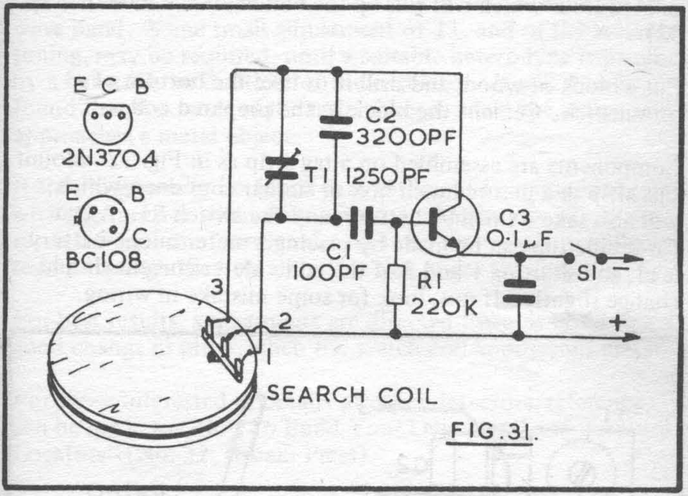

FIG.31.

Fig. 31 is the circuit. It has a single transistor as a low radio-frequency oscillator, operating in conjunction with the search coil. Oscillation is obtained by having a tapped coil, with outer leads going to base and collector circuits. The frequency of oscillation depends on the coil, and the parallel capacitors, trimmer T1, and C2.

The winding of the search coil is 6 inch in diameter, and is of 34swg enamelled wire. The coil former can be made from three pieces of 1/8 inch thick hardboard, or similar insulated material. Cut one disc 6 inch in diameter, and two others about 6½ inch in diameter. Smooth the edges with glasspaper, and cement them securely together, with the small disc between the larger discs. This provides a former with a channel to take the winding. The adhesive should be allowed to dry with the discs under pressure, so that there is no gap into which turns can fall. The former should also be varnished, and allowed to dry, before winding.

The wire is passed up through a small hole, this being point 1. Wind on fifteen turns. Make a loop and pass this up through a hole, for point 2. Wind a further twenty-five turns in the same direction, finishing off at point 3. These leads are scraped and soldered to a small tag strip. This is an anchor point for insulated leads which will run up the handle of the locator (Fig. 32).

Cut a block of wood, and drill it to take the bottom of a broomstick. Cement the block to the prepared coil.

Components are assembled on a tag strip as in Fig. 32. Mount this strip in a plastic lunch box or similar container, which will also take a small 9v battery, and the switch S1. A test for oscillation can be made by placing a meter in one battery lead, and shorting 1 and 3 of the coil. Meter current should change slightly. If not, look for some mistake in wiring.

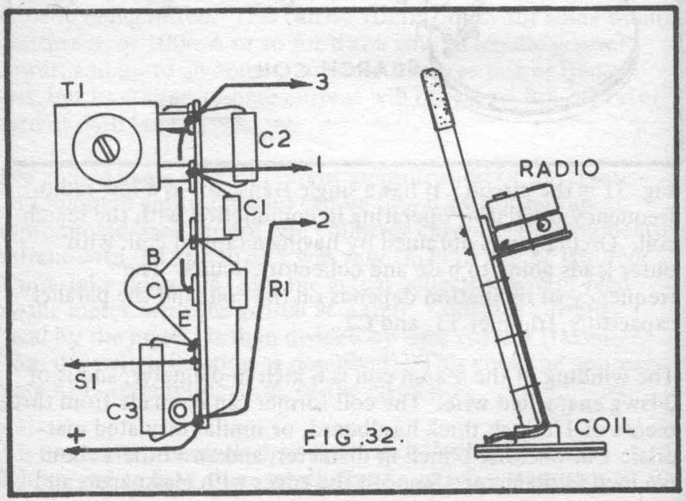

FIG.32.

A shelf is bolted to the handle, and the detector rests on this, with connections passing down to the search coil. A few loops of tape or string will secure these to the handle.

Operation in Great Britain can be on frequencies under 100kHz. Initially tune the radio receiver to 200kHz on long wave, and place it near the coil. Adjust T1 until a strong whistle is heard in the receiver speaker. This is the 2nd harmonic of the oscillator. T1 is then screwed down very slightly from this position.

The small portable radio is placed on top of the locator box, and can be held here with elastic. It is tuned to the medium wave band. Some small adjustment of T1, and of the receiver tuning, may be required, until a suitable heterodyne is produced by a harmonic or multiple of the oscillator. It will then be found that the pitch of the note changes when the search coil approaches a metal object.

It should generally be found that sufficient coupling is obtained with the receiver when they are situated as in Fig. 32. If not, run a few inches of insulated wire from the transistor collector tag up through the box and place this under the receiver.

For best results, adjustments are directed towards obtaining a good change in pitch, when the search coil approaches metal.

For those interested in details of other detectors, reference can be made to "How to Build Your Own Metal and Treasure Locators" (No. 32, Babani Press).

[illegible]

[illegible]

The small portable radio is placed on top of the search loop and can be held here with a strip [illegible], tuned to the medium wave band. Some small adjustment of T1, and of the receiver tuning, may be required, until a suitable heterodyne is produced by a harmonic or multiple of the oscillators. It will then be found that the pitch of the note changes when the search coil approaches a metal object.

It should generally be found that [illegible] with the search coil [illegible] as in Fig. 32. [illegible] a few inches of lead [illegible] from the [illegible] tag up through the box [illegible].

For best results, adjustments are directed towards obtaining a good change in pitch, when the search coil approaches metal.

For those interested in details of metal detection, reference can be made to "How to Build Your Own Metal and Treasure Locators" (No. 32, Babani Press).

SECTION 3
RADIO AND AUDIO FREQUENCY

MW Booster

This unit can be employed in conjunction with any ordinary portable having a ferrite rod aerial, and will provide a considerable increase in range and sensitivity to weak signals. It has two functions – to allow the use of an external aerial and earth, and to amplify and couple signals to the portable receiver.

Tuning coverage is for medium waves. That is, about 200–550 metres, or 1500–550kHz. Many overseas and other stations can be picked up on this band, and distant reception can be particularly common on the higher frequencies, during the hours of darkness.

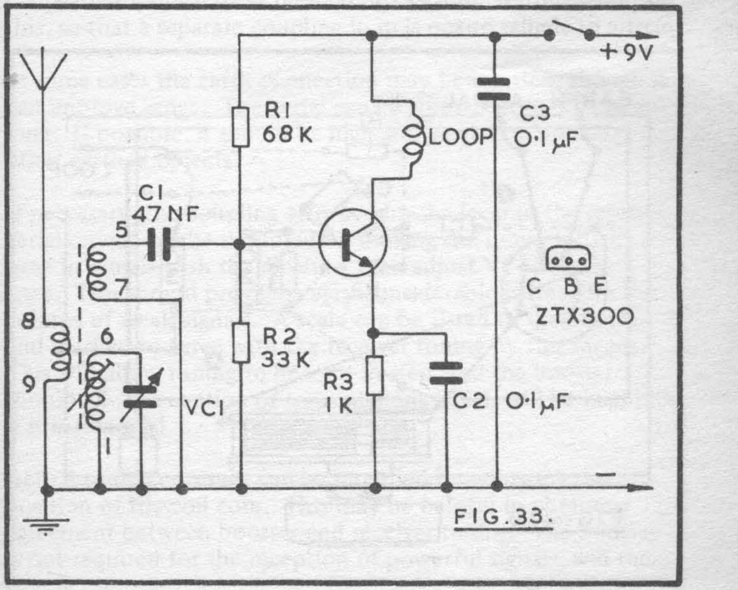

FIG.33.

Fig. 33 is the circuit, and it uses a cored tuning coil with aerial coupling winding 8–9, tuned winding 6–1, and base coupling coil 5–7. These numbers are for the pins of the Denco (Clacton) "Blue" Range 2 component. It will be apparent that other coils, or surplus or home-wound inductors, can be substituted.

For the coil mentioned, VC1 is 315pF. However, this value is not too critical, provided the capacitor fitted allows tuning the wanted frequencies. A solid dielectric capacitor can be used, though the air spaced type is likely to be a little more efficient.

Coupling to the base is by C1, and resistors R1 and R2 set the base bias conditions, with R3 for emitter bias. These values will suit numerous RF transistors.

Fig. 33B shows assembly of the components on an insulated board. The coil is mounted by its threaded bush. When the board has been wired, it can be mounted by means of bolts with extra nuts. The case is preferably metal, for screening purposes, but the booster can be used satisfactorily with a plastic or similar box.

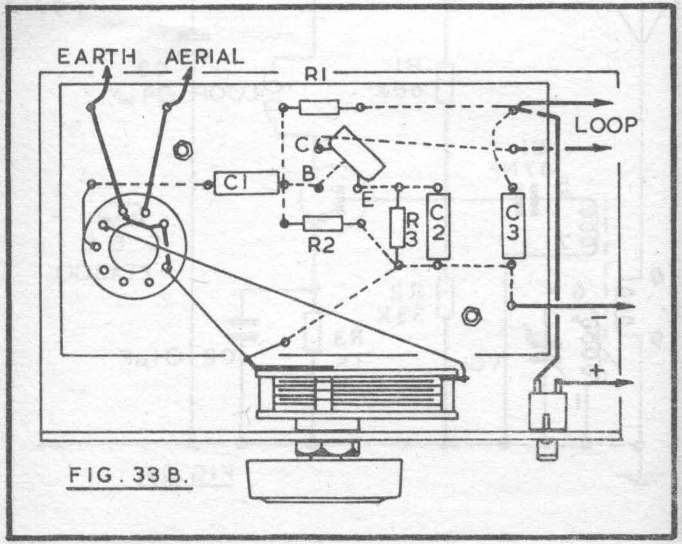

FIG. 33 B.

Fit a small slide switch to the box front, and aerial and earth sockets to the back, near the coil. A 9v battery is accommodated in the case.

Coupling to the transistor receiver is by means of a loop which is placed on the receiver ferrite rod, or near the rod. The loop can be about twenty turns of thin insulated wire, about ½ inch in diameter, and bound with cotton to keep the turns together The ends can be left long enough to reach the two connecting points in Fig. 33B.

If the case is metal, the booster and receiver can be near each other, so the loop leads will only need to be a few inches long. But when an insulated case is used, coupling from the receiver ferrite aerial or other circuits, to the booster coil, may cause instability. This will become apparent as whistles accompanying most signals. If this arises, the booster and receiver should be moved some inches apart. The aerial lead must not run near the loop connections.

Some receivers have an internal winding which is intended to couple an external aerial, and it may be possible to connect to this, so that a separate coupling loop is not required.

In some cases the earth connection may be omitted, though it can improve range. The aerial can be some 20ft to 40ft or so long. If possible, it should be high and clear of walls and other earthed objects.

If necessary, the coupling afforded by the loop to the receiver aerial circuit can be modified by moving the loop. Initially, tune in signals with the receiver, then adjust VC1 for resonance. This should provide a very considerable increase in the volume of weak signals. A scale can be fitted to the booster, and marked to agree with the receiver tuning by this means. This will allow tuning to be kept in step, and the booster should allow reception of transmissions which will be inaudible if it is removed.

Actual tuning coverage can be modified by adjusting the position of the coil core. This may be helpful in obtaining agreement between booster and receiver tuning. The booster is not required for the reception of powerful signals, and the receiver automatic gain control circuit will tend to mask any increase in signal strength obtained with such transmissions.

Midget MW Diode Radio/Tuner

A small, compact tuner can be of utility in allowing radio reception through an amplifier, and a diode receiver can give excellent quality of reception. Such a unit can also be employed alone, with headphones, for personal listening.

Fig. 34 is a receiver/tuner which can be built in a very small plastic or other insulated box. VC1 is a compression type trimmer, fitted with a small knob for adjustment by hand. To do this, it is necessary to remove the short screw (generally 6ba) and replace this with a longer one, which projects to take the knob. The latter can be a terminal head, or the cap from an empty tube of adhesive, secured with lock nuts.

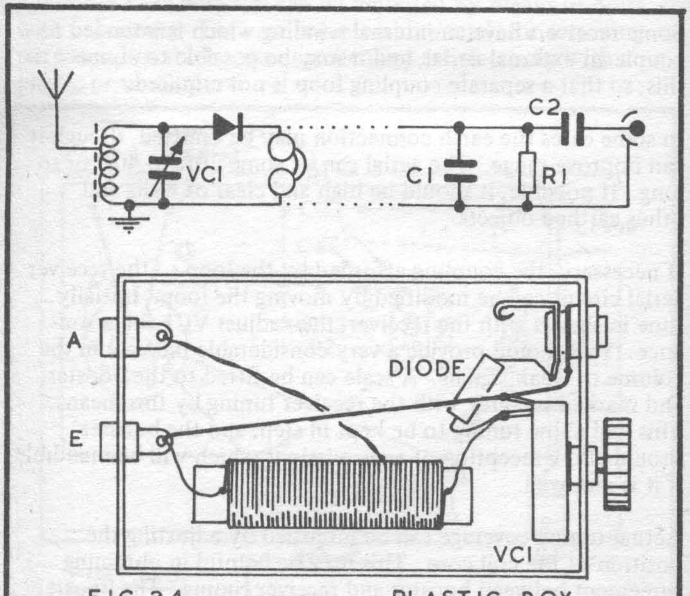

FIG.34.

For best efficiency and small size, the tuning coil is wound on a piece of ferrite rod. It consists of seventy turns of 24swg or similar enamelled wire, on a rod about 1½ inch long and 3/8 inch in diameter. Actual details will not be critical. A piece can be obtained from a longer rod by cutting a notch round the rod with a file and snapping at this point with the fingers. A few touches of adhesive will hold the ends of the winding secure. The loop for the aerial connection is about one-third the total number of turns from the diode end of the coil. (Moving this tapping towards the earthed end of the coil will increase selectivity or sharpness of tuning, but reduce volume.)

Aerial and earth sockets, and a 3.5mm jack outlet, complete the receiver. Headphones can be plugged directly in here.

The aerial and earth can be provided as explained for the diode radio in Fig. 7.

To use the radio as a tuner, C1, R1 and C2 may be added. Suitable values are C1 470pF, R1 220k, and C2 0.25μF. A screened lead with jack plug should be made up to connect the tuner to the amplifier input socket.

One Transistor VHF Receiver/Converter

The super-regenerative receiver is well known for its great sensitivity, which equals that of a multi-stage superhet. It has no alignment difficulties, and few components, so is an interesting project. Its main disadvantages are its background hiss, but this ceases when a signal is tuned in, and its lack of selectivity. The latter is however relatively unimportant on the VHF bands. The circuit here is particularly intended for 2m reception, but is easily modified. It is not intended for FM signals.

In Fig. 35 the detector is a VHF FET, and the field effect transistor will be found very satisfactory in circuits of this kind. T1 is the pre-set tuning capacitor, which allows adjustment over a fairly wide band of frequencies. Tuning is by VC1, which does not require a reduction drive.

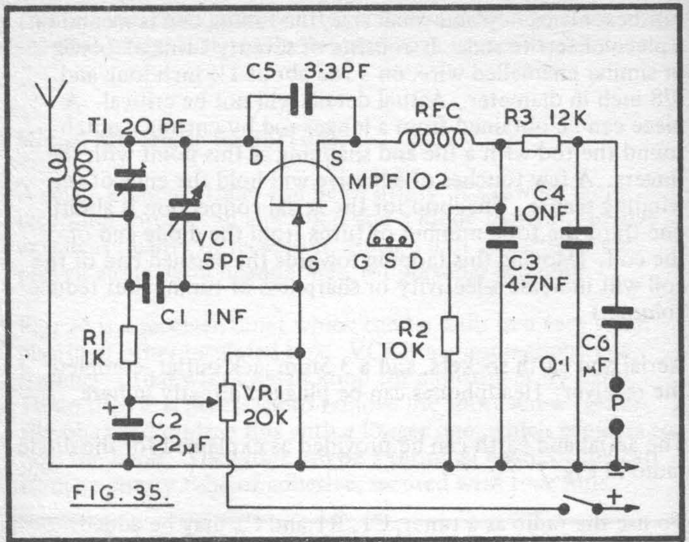

FIG. 35.

Control of super-regeneration is by means of the potentiometer VR1, which adjusts the FET drain potential. The value of VR1 is not very important, but a linear potentiometer is necessary.

C5 provides feedback from source to drain, for regeneration. R3 and the associated components form the quench network, with C6 feeding headphones, or an audio amplifier.

For best results, VR1 should enable the transistor to go smoothly into super-regeneration, which is shown by the hiss mentioned. Achieving this depends somewhat on the transistor, value of C5, adjustment of T1, and aerial loading. However, matters are not too critical.

Transistors unsuitable for VHF cannot be used. Individual FETs of the same type will also differ somewhat, so that in some cases it might be necessary to omit C5, or change the value. Alternatively, a small pre-set (not over 10pF) may be fitted. It will be found that a very small capacitance is required.

Another cause of failing to obtain super-regeneration is too tight aerial coupling, and this is easily corrected by moving the aerial coupling winding a little further from the larger winding.

The RF choke can be a VHF type, or can consist of seventy five turns of 36swg enamelled wire, side by side on a ¼ inch diameter insulated rod. Touches of adhesive may hold the end turns only.

Short leads are essential, and assembly on a tag board is shown in Fig. 35B. The variable capacitor is fitted first, and it can later attach the finished board to a panel, by means of an extra nut.

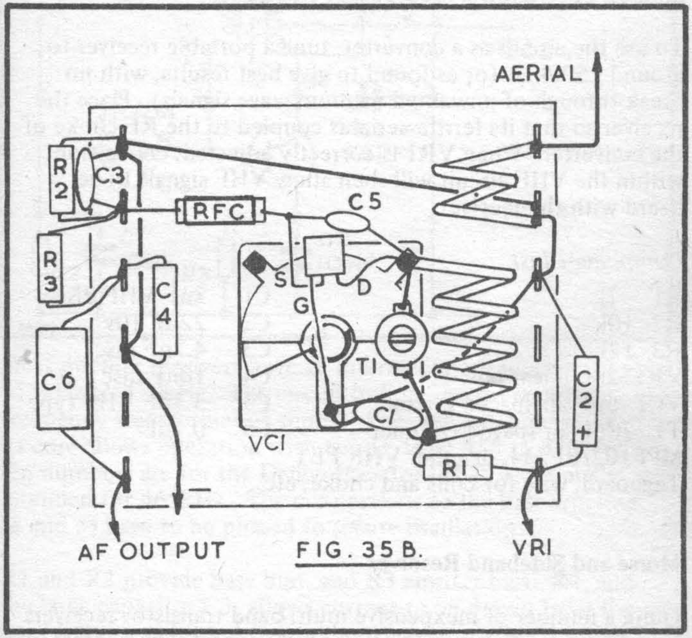

FIG. 35 B.

The larger coil has five turns of 18swg wire, and is ½ inch in diameter and ¾ inch long. The smaller coil has two turns. Wiring to VC1, T1, C5, the coil and C1 must be as short as can be arranged. Connections elsewhere are reasonably direct. A ceramic disc capacitor may be used at C1. T1 should be a low loss trimmer.

The board can be fitted in a case which will carry VR1, and large enough for the battery and on-off switch. The case can be used to support a telescopic aerial, some 30 inch or so when extended.

Frequencies tuned by VC1 can be raised by unscrewing T1, or by stretching the larger coil to separate the turns more, or by using a coil with fewer turns, or of smaller diameter. The receiver is most suitable for use over the 70MHz to 200MHz range.

For the single transistor alone, a sensitive pair of medium or high resistance phones will be needed. Audio ouptut from C6 can be taken to an amplifier, for more powerful reception with phones, or to allow a loudspeaker to be used.

To use the circuit as a converter, tune a portable receiver to around 1500kHz (or as found to give best results, with no break through of unwanted medium wave signals). Place the receiver so that its ferrite aerial is coupled to the RF choke of the converter. When VR1 is correctly adjusted, conversion within the VHF circuit will then allow VHF signals to be heard with the receiver.

Component List

R1	1k	C1	1nF VHF disc
R2	10k	C2	22μF 10v
R3	12k	C3	4.7nF disc
VR1	20k linear pot.	C4	10nF disc
VC1	5pF air-spaced variable	C5	3.3pF VHF type
T1	20pF air spaced trimmer	C5	0.1μF

MPF102/BF244, or other VHF FET
Tagboard, wire for coils and choke, etc.

Morse and Sideband Resolver

Quite a number of inexpensive multi-band transistor receivers have frequency coverage which includes one or more Amateur bands. That is, 1.8, 3.5, 7, 14, 21, or 28MHz. On these bands transmissions are often in Morse code or CW, or single sideband. CW or SSB can be resolved by the specialised Amateur receivers and transceivers, but not with the general purpose home receiver. To receive CW or SSB with the latter type of radio, it is necessary to add an oscillator. This either generates a heterodyne or beat note for code reception, or replaces the carrier which was eliminated from the single sideband transmission.

The circuit in Fig. 36 may be used for these purposes. It generates a carrier of about the same frequency as that used in the intermediate frequency stages of the receiver, exact adjustment of frequency being by VC1,

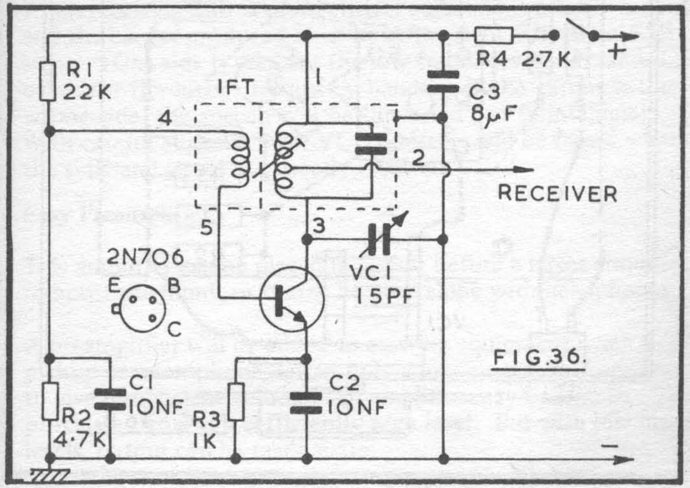

FIG.36.

Most popular receivers have an intermediate frequency of about 455kHz to 470kHz. The circuit in Fig. 36 uses an intermediate frequency transformer of similar type, and adjustment of its core allows operation with any IF from 455 to 470kHz. Pin numbers are for the Denco (Clacton) IFT13, normally intended for 465kHz. The connections to the base winding (4 and 5) have to be phased to secure oscillation.

R1 and R2 provide base bias, and R3 emitter bias. R4, and the large capacitor C3, allows current to be drawn from the same battery as is used to run the receiver, if wished. Alternatively, a separate 9v battery may be employed here.

Fig. 36B shows the practical layout of components, and wiring to them, using a perforated board. Connections and joints are kept close against the underside of the board. When wiring is finished, the board is mounted in a metal box, using ½ inch bolts with extra nuts for clearance.

VC1 can best have a dial with a central zero mark, this showing when the plates are half meshed.

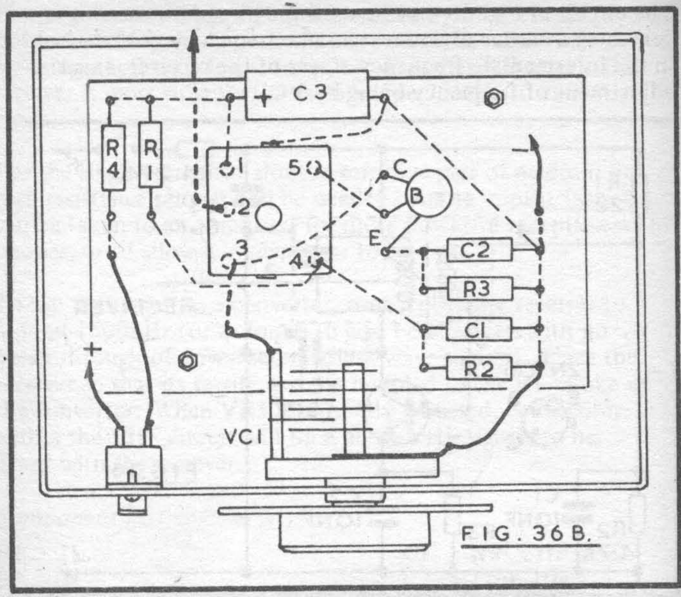

FIG. 36B.

An insulated lead is run from 2 on the IFT, and is placed near the receiver. This lead may be so positioned as to give best coupling into the IF stages of the receiver. If coupling is too weak, the signal from the CW/SSB Resolver will be inadequate. On the other hand, tight coupling will allow the carrier to swamp weak signals tuned in on the receiver. Fortunately the degree of coupling is not at all critical.

To set up the oscillator, first of all tune in any normal broadcast with the receiver. Set VC1 half closed and switch on. The core of the IFT should now be slowly adjusted until a loud heterodyne or beat note is heard accompanying the signal received. Set the core so that this note falls to about zero, or to a low pitch. It will then be possible to rotate VC1 either way from this central zero beat position, in each case producing a note which rises in frequency as VC1 is rotated.

To receive CW or Morse code, it is only necessary to tune in the code signal with the receiver, and then to adjust VC1 to obtain a note of the most suitable pitch. VC1 can be rotated either way from its central or zero beat position, to obtain best freedom from interference.

When receiving SSB, a more critical adjustment of VC1 is needed and the carrier produced must be at the right side of the SSB signal. (One side is used for the low frequency bands, and the other for the higher frequency bands.) If the carrier is the wrong side, the speech will be "inverted" or unintelligible. With careful adjustment of VC1, a setting will be found where the sideband signal is correctly resolved.

Easy Preamplifier

This amplifier can be placed in circuit before a larger amplifier, to boost the input, or it may be used alone with headphones.

A preamplifier will be added to existing equipment when a pickup or microphone having only a low output has been found to give insufficient volume. An amplifier may be able to provide a signal at a sufficiently high level. But with low input levels, output can be inadequate.

The stage in Fig. 37 can provide considerable gain. Audio input is to C1, and R1 provides base current for the transistor. Amplified signals are obtained across R2, and pass to the main amplifier (or phones) via the isolating capacitor C2.

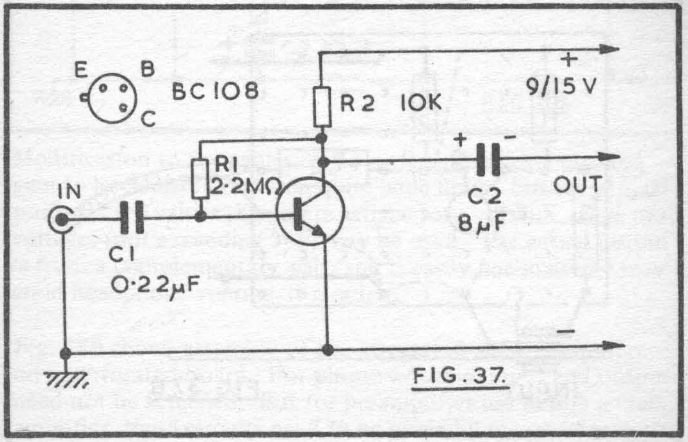

FIG.37.

With a BC108 or similar transistor, the supply can be about 9v to 15v. Numerous NPN transistors, intended for preamplifier use and of low noise type, will perform well. Current may be from a separate battery. Or it may in many cases be drawn from the main amplifier. To avoid instability or similar troubles, the positive supply should be from a well decoupled and smoothed point in the main amplifier. If this is not available, connect a 220μF capacitor from positive to negative in Fig. 37, and draw the positive supply through a 1k resistor. Negative is returned to the negative line of the main amplifier.

Should the main amplifier have a positive earth line, then the transistor can be a PNP type, R1 and R2 being changed to suit.

Fig. 37B shows assembly on a perforated board. When the circuit provides input to a main amplifier, it should generally be in a metal case. Input is by a screened lead, and a screened lead is also fitted for the audio circuit to the main amplifier. The case should be earthed to the negative line. This can be by means of one of the bolts securing the board.

Screening to avoid hum or instability will generally prove to be unnecessary when using the stage to operate headphones. So two sockets, or a jack socket, will be more convenient for the phone circuit.

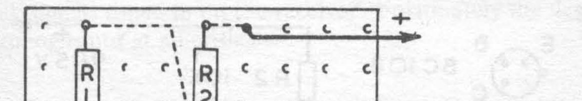

FIG.37 B.

741 Preamplifier

Integrated circuits have several stages of amplification, formed as a single chip and enclosed in a small case. The 741 is an easily obtained audio IC which can be used in many circuits. The uA741CE or metal can 741 is convenient, as its leads may be spaced to suit any ready perforated board. The dual in line 741 is electrically similar.

Fig. 38 shows a preamplifier using the metal can 741. Input is via C1 to 3. As shown, 7 and 4 are positive and negative, while output is from 6. Negative feedback is applied to 2, via R4. C3 is an isolating capacitor.

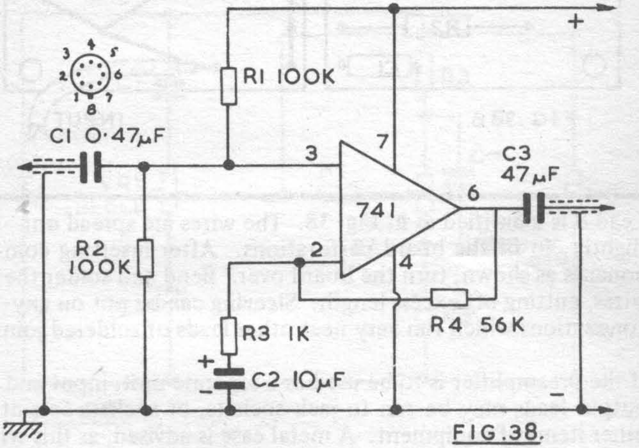

F1G.38.

Modification to the values of R3 or R4 allow feedback and gain to be adjusted between quite wide limits, but for general purposes the values shown are satisfactory. A wide range of voltages (not exceeding 36v) may be used. The actual output is from a complementary pair, and is easily adequate for very good headphone volume, if required.

Fig. 38B shows assembly of the integrated circuit amplifier on a perforated board. For phone working, input and output need not be screened. But for preamplifier use before a main amplifier, these circuits need to be made by means of screened leads.

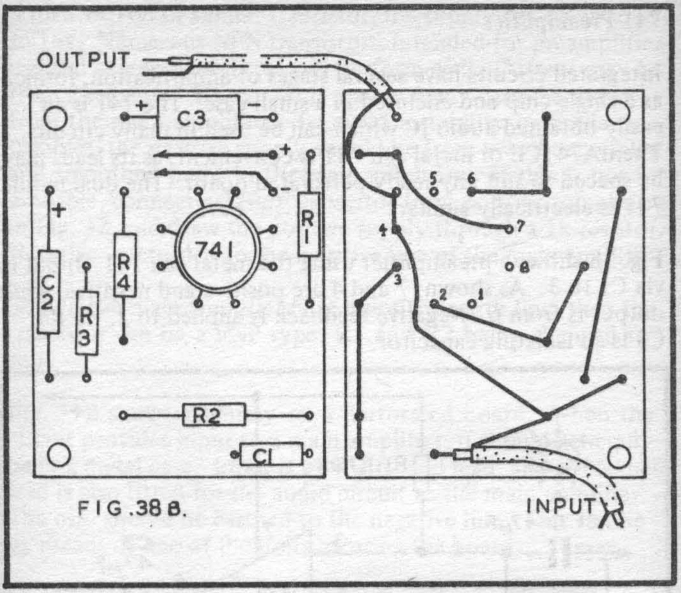

FIG.38B.

Lead 8 is identified as in Fig. 38. The wires are spread out slightly, to fit the board perforations. After inserting components as shown, turn the board over. Bend and solder the wires, cutting off excess length. Sleeving can be put on any connections which run very near other leads or soldered joints.

If the preamplifier is to be used as a separate unit, input and output leads may be run to jack sockets, or sockets to suit other items of equipment. A metal case is advised, as this will help to avoid any pick up of hum, or other troubles due to coupling to the board wiring. The board can be secured to the metal box or case with ½ inch 6ba bolts, and extra nuts to give a little clearance.

The amplifier may be run from its own battery; or from a supply used with a main amplifier. For the latter, it is wise to provide a decoupled point, in a similar manner to that described for the transistor preamplifier. This consists of a quite large capacitor (say 220μF to 470μF) from positive to negative across the preamplifier supply circuit, and a resistor of 1k to 2.2k or so from preamplifier positive to positive on the main amplifier.

Tone Control for Your Discs Etc.

The preamplifiers shown have a substantially flat response. That is, they do not purposely emphasize bass or treble, or have similar effects in modifying the audio frequencies present. In some circumstances it is necessary to boost treble or bass, or reduce the emphasis of these frequencies, in order to obtain the most satisfactory reproduction.

This may be achieved by making a fully adjustable tone control, and Fig. 39 is a suitable circuit. A volume control is also incorporated, as this has not been present in the preamplifiers.

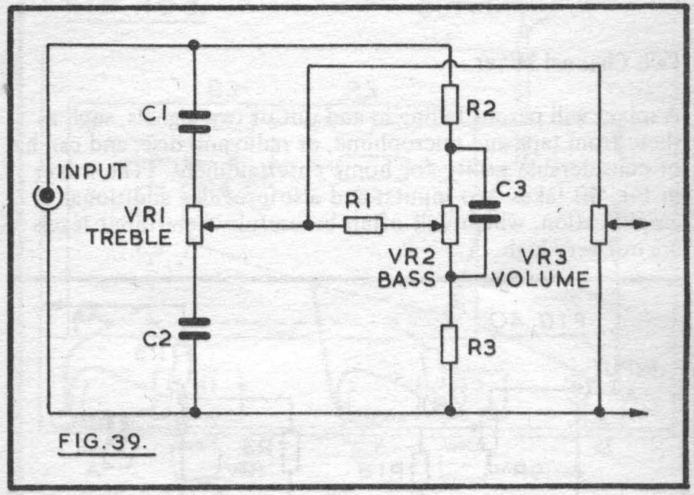

FIG.39.

The tone control is a passive circuit, needing no battery, and it can be placed between the source of audio signals (generally a microphone, pick-up, or radio tuner) and the amplifier or preamplifier. It may also be located between preamplifier and main amplifier, if wished.

Results are substantially flat with the treble control VR1 and base control VR2 in their central positions. Adjustment of VR1 and VR2 will provide separate boost or cut of treble, or boost or cut of bass frequencies. VR3 is the volume control.

The degree of control afforded by circuits of this type may be adjusted by alterations to the component values. In practice, it will be found that there is little point in having extreme levels of adjustment, which will never be required. The following values may be used: C1 and C2, 270pF; R1, 390k; R2 and R3, 100k; C3 680pF; VR1 and VR2, 2 megohm linear potentiometers; VR3, 2 megohm log potentiometer.

Components should be assembled in a metal case, for screening. The case is grounded to the earth line. Input and output sockets can be near the ends of the case, with VR1, VR2 and VR3 between. Components can be soldered directly to the potentiometer tags.

Two Channel Mixer

A mixer will permit fading in and out of two signals, such as these from tape and microphone, or radio and disc, and can be of considerable utility for home entertainment. The mixer in Fig. 40 takes two inputs, and also provides additional amplification, which will often be useful where input levels are not very high.

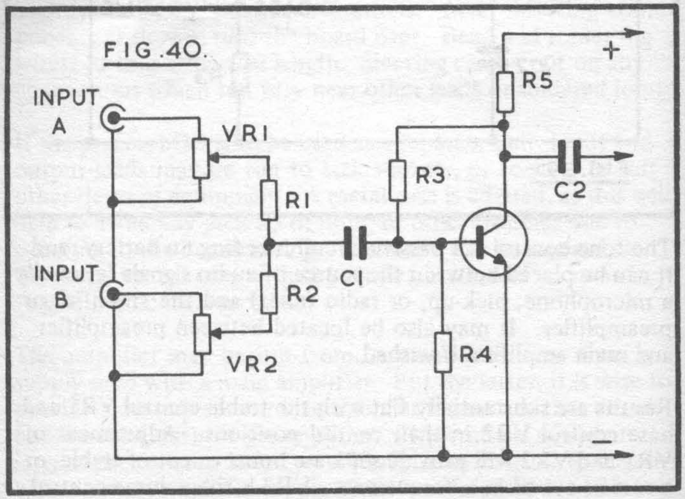
FIG.40.

Input A has its individual volume control VR1, and Input B is similarly provided with VR2. Resistors R1 and R2 prevent short circuiting one input when the other potentiometer is set at zero. Coupling to the transistor base is by C1. R3 and R4 set base bias conditions, with R5 as the collector load and audio output from C2.

Component values are not very critical, though R3, R4 and R5 need to be selected to suit the transistor fitted. The mixer is connected and used in a similar way to that explained for the preamplifiers.

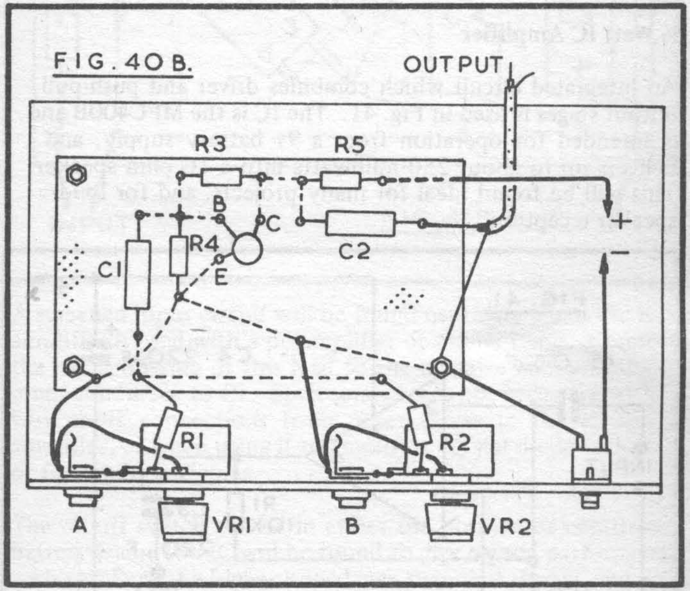
FIG. 40B.

Fig. 40B is the layout, using a metal case or box. A screened output lead is provided. Input sockets A and B may be chosen to suit the type of plugs on existing equipment. The on-off switch is separate from the potentiometers, so that these can be left at pre-set levels if wished.

Component values may be chosen to suit low or high impedance inputs, if wished. Or the following may be used for general purposes:

Components List:

VR1, VR2, 1 megohm log potentiometers.
R1, R2, 200k
C1 0.5µF
R3 330k
R4 22k
R5 10k
C2 0.5µF
BC109

This is when using a 9v supply.

¼ Watt IC Amplifier

An integrated circuit which combines driver and push-pull output stages is used in Fig. 41. The IC is the MFC400B and is intended for operation from a 9v battery supply, and delivers up to about 250 milliwatts into a 16 ohm speaker. This will be found ideal for many projects, and for loudspeaker reception.

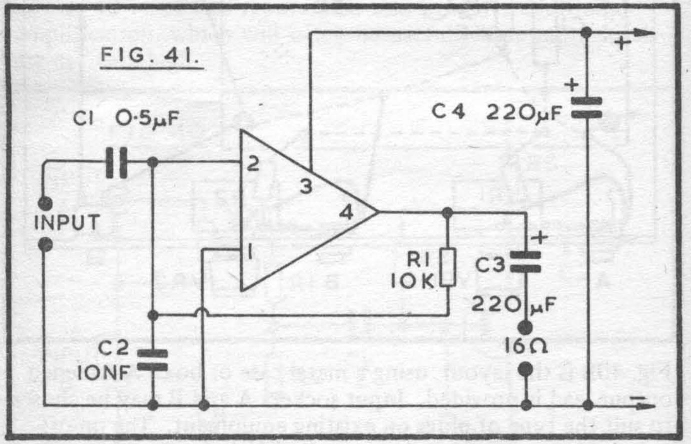
FIG. 41.

Audio input is to 2 of the IC, from the isolating capacitor C1. C2 is a by-pass capacitor to maintain stability. The IC has only four connections, 1 going to the negative line, and 3 to the positive supply. Audio output is from 4, and to the loudspeaker via C3. R1 provides negative feedback and bias to point 2.

The assembly of this amplifier on 0.15 inch matrix board is shown in Fig. 41B. Pin numbering is when looking at the top of the IC and the component side of the board.

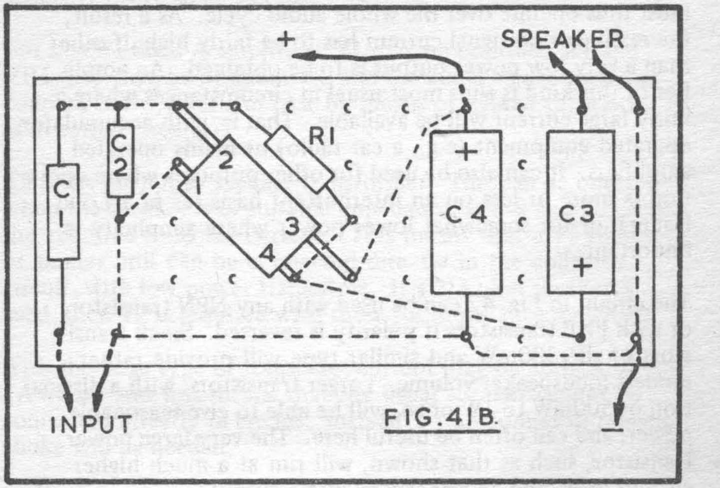
FIG.41B.

A screened input circuit will be found necessary when the IC amplifier is used with a preamplifier or similar items. Connect the outer brading of this lead to the negative line, and the inner conductor to C1. Such screening is not necessary with very short connections from other stages to the IC amplifier, or when using it to amplify a crystal diode radio, or for similar purposes.

The on-off switch can be in either the positive or negative battery lead. The IC will be found to give a good performance with speakers of a higher impedance than that shown, and up to 75 ohm may be used (with some small loss in output). Units of lower impedance than 16 ohms should not be fitted.

The small size of this IC and the few extra components needed make is very suitable for miniature apparatus, probably with a 2½ inch speaker. It will also operate a large speaker well (see "Boost Speaker") and at a volume level adequate for many purposes.

Class A Amplifier

A Class A amplifier uses a single transistor, Fig. 42, which must thus operate over the whole audio cycle. As a result, the resting or no-signal current has to be fairly high, if other than a very low power output is to be obtained. An amplifier of this kind is thus most usual in circumstances where a fairly large current will be available. That is, with accumulator operated equipment (e.g., a car radio) or mains operated amplifiers. It can also be used for other purposes where operation is more or less on an intermittent basis (as in a Loud Hailer), or for somewhat lower power where simplicity is important.

The circuit in Fig. 42 can be used with any NPN transistor, or with PNP transistors if polarity is reversed. Small transistors of the 300mW and similar type will provide rather modest loudspeaker volume. Larger transistors, with a dissipation of 500mW to 1W or so, will be able to give reasonable power, and can often be useful here. The very large power transistor, such as that shown, will run at a much higher current level, and deliver several watts output.

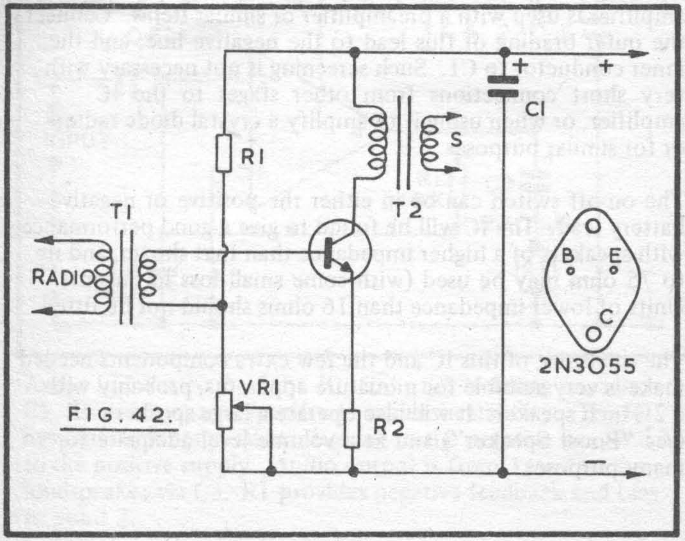

FIG. 42.

T1 is the coupling or driver transformer, which may receive audio signals from a radio receiver, smaller amplifier, or other equipment. A step down ratio of about 5:1 to 10:1 will generally prove to be suitable.

For smaller Class A amplifiers, T1 may be omitted. R1 and VR1 may then be of about 1k, and the audio signal can be coupled to the transistor base by means of a fixed capacitor, as in earlier circuits.

T2 is the output or speaker transformer. This can be omitted when the speaker is of suitable impedance, and is able to carry the required collector current. This means that a 75 ohm or similar unit can be connected directly in the collector circuit, with low power transistors. If a 2/3 ohm speaker is used, then T2 is required with these for impedance matching.

With the large type of transistor, current may be 500mA to 1A or so, and this means that the usual speaker cannot be connected directly in circuit. Instead, a transformer or tapped choke will be needed.

The circuit is often operated from 12v (a vehicle supply) but can be used with 9v, or more than 12v.

R1 and VR1 set bias conditions, and R2 limits peak collector current. For the 2N3055, R2 may be 1 ohm. R1 can be 100 ohm, and VR1 25 ohm. T2 can be 2:1 for a 3.5 ohm speaker. C1 is 3200μF. Begin with VR1 at minimum value, slowly increasing this until reproduction is satisfactory. (This will set collector current at about ½ ampere.)

With other transistors, adjustment can be made in the same way, by slowly increasing the base bias until best results are secured. Raising the value of VR1 in Fig. 42, or reducing the value of R1, will increase collector current, and thus raise the power which can be handled. However, current is limited by the power handling capacity of the transistor, so a meter should be put in one battery lead, and a check made that the power dissipation of the transistor is not exceeded. With small transistors, current can be limited to 50mA or so.

Fig. 42B shows assembly of the circuit in Fig. 42. The power transistor is mounted on an aluminium plate, which acts as a heat sink to carry away heat from the transistor itself. Note that this plate is common to the collector. Base and Emitter pins pass through clearance holes. Smooth off any burr round the fixing and clearance holes, so that the transistor can rest flat on the metal. Where it is awkward to have the plate or case common to the collector, the usual insulation set can be fitted. This consists of bushes for the fixing bolts, and a thin mica washer to go under the transistor, so that electrical isolation is obtained.

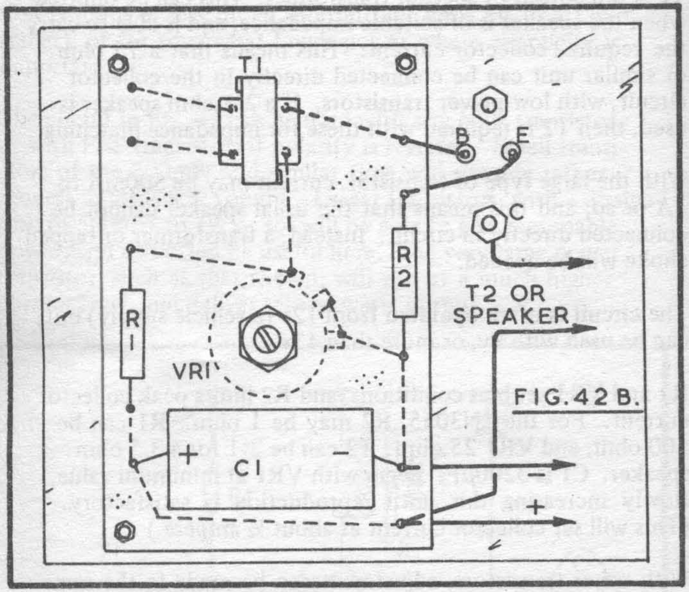

FIG. 42 B.

The insulated board carrying the other components is mounted by long bolts with extra nuts. A large Class A stage transistor of this type will grow very warm to the touch, if run at anything like maximum power rating. This does not indicate any defect.

Two Stage Amplifier

The circuit of a 2-stage amplifier is shown in Fig. 43, and this can be used for loudspeaker reproduction. Input to the driver stage is by the isolating capacitor C1. Operating conditions in this stage depend largely on the values of R2, R3, and the emitter bias resistor R5.

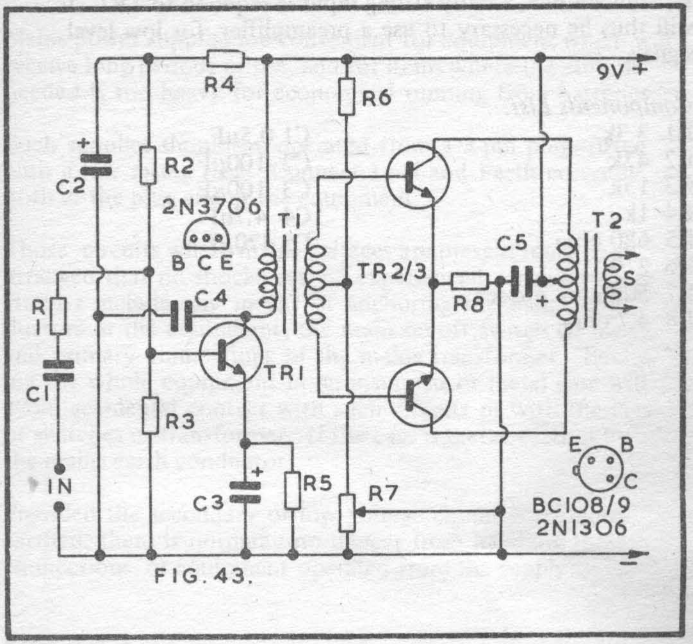

FIG. 43.

T1 is the driver transformer, with centre tapped secondary, so that TR2/3 may be operated in push-pull (see Fig. 12). T2 couples output to a 2/3 ohm speaker.

With the values shown, a BC109 will give very good results in the TR1 position, with 2 x BC108s for the output stage. R7 is set so that battery current is around 10mA, with no signal present. Current rises from 20mA to 60mA or so, according to volume, when the amplifier is driven.

A pair of 2N1306 transistors may be used for the output stage. Other transistors are also possible here, as operating conditions can be adjusted by R7.

The 2N3706 will operate in the TR1 position, though with lower gain than the BC109. Numerous other small audio transistors can also be used here.

For full volume, a fairly strong input is required to TR1. It will thus be necessary to use a preamplifier, for low level signals.

Components List:

R1 3.3k
R2 47k
R3 15k
R4 1k
R5 680 ohm
R6 2.7k
R7 500 ohm pre-set
R8 4.7 ohm

C1 0.5μF
C2 100μF
C3 100μF
C4 4.7nF
C5 470μF

SECTION 4
POWER SUPPLIES

Mains power supplies are convenient for equipment which will receive long periods of use, and for items where the current needed is too heavy for economical running from batteries.

Such supplies should be operated from a 3-pin plug, fitted with a low rating fuse. Connect L, N and Earth correctly, both at the plug and at the equipment.

Those circuits where mains voltages are present must be so arranged that no shocks can be experienced. Mains voltage circuits include any means of anchoring the mains conductors in the equipment, the main on-off switch (if used), and primary connections of the mains transformer. Enclosing the whole equipment in an insulated or metal case will avoid accidental contact with such circuits or with the tags of switches or transformer. If the case is metal, earth it by the mains earth conductor.

Provided the secondary or low voltage circuit is correctly earthed, there is normally no danger from handling these connections, or equipment operated from the supply.

Easy PSU

A useful power supply suitable for many purposes can use the circuit in Fig. 44. Mains L (live) and N (neutral) conductors go to the primary P of the transforer. A switch is placed in the L circuit.

The secondary S can delivery any wanted low voltage, and also give isolation from the mains.

Almost all equipment will need direct current. The four separate rectifiers, or an equivalent single device, produce pulsating DC. The reservoir capacitor C1 smoothes this. Resistor R1, with the second capacitor C2, gives additional smoothing. Output from the supply is then substantially smooth DC, as would be obtained from a battery.

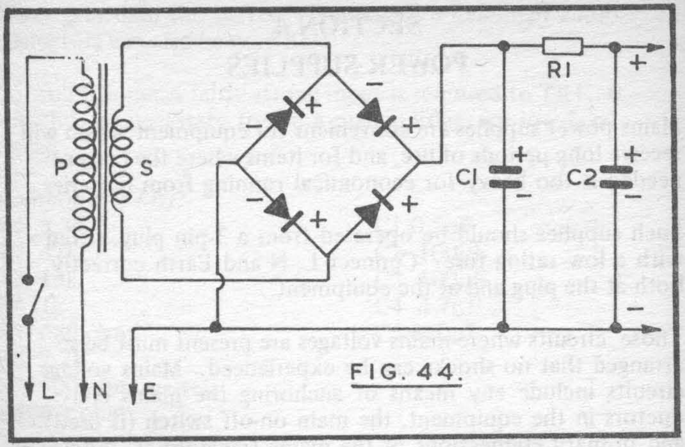

FIG. 44.

Sometimes R1 and C2 are omitted. Should hum accompany reproduction from an amplifier, this shows that smoothing is probably inadequate, and if so the cure is to add R1 and C2.

Any wanted voltage can be obtained by using a transformer with an appropriate secondary, with rectifiers and capacitors to suit.

C1 may charge up to approximately 1.4 times the RMS or usual voltage rating of the secondary S. Thus, if S were a 6.3v winding, about 8.8v would be expected across C1. But should R1 be present, a voltage drop will arise in it, the figure depending on the resistance value of R1, and current flowing.

For these reasons, the actual output may not be exactly the figure expected. This will often be unimportant, and such power supplies are largely used for all sorts of equipment.

For apparatus generally operated from a 9v or similar battery, a bell transformer with 3v, 5v and 8v output tappings is suitable. If R1 is 22 ohm, this will give around 9v at 100mA, with the 8v tap in use.

It is convenient to use 50v or 100v rectifiers, and the rating can be 1 ampere, with a 1 ampere transformer secondary. Four individual wire ended rectifiers can be mounted on a

tag strip, and connected as in Fig. 44. A combined rectifier will have AC, positive, and negative tags (see Fig. 45) and can be fitted instead.

The capacitors need to be of large value, and have a voltage rating higher than the actual voltage which will be present. The 12v capacitors could be fitted in the circuit described. C1 can be 2500μF or larger, and C2 can be of similar value.

Easy Regulated PSU

With the circuit in Fig. 44, the exact voltage will depend on the current drawn, rising when current is low. To avoid this, some means of regulation may be employed.

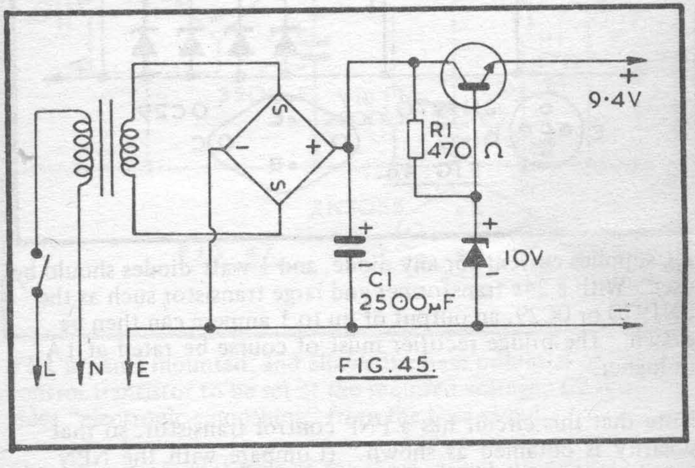

FIG.45.

Fig. 45 shows a typical regulation circuit, giving an output of approximately 9.4v. The output from the rectifier needs to be of somewhat higher voltage than required at the output, and a transformer with a 10v secondary is suitable. Current through R1 supplies the Zener diode, which holds the base of the transistor at virtually the same voltage for all current loads. Some voltage is lost in the transistor, so the output is nearly the same, for any current load. For up to about 200mA, a BFY51 or equivalent transistor is adequate, so this will do well for many purposes.

Multi-Voltage Regulated PSU

Fig. 46 is a somewhat similar circuit, but it has a switch, to select any one of the four Zener diodes. These may be chosen so that 6v, 9v, 12v and 15v will be available.

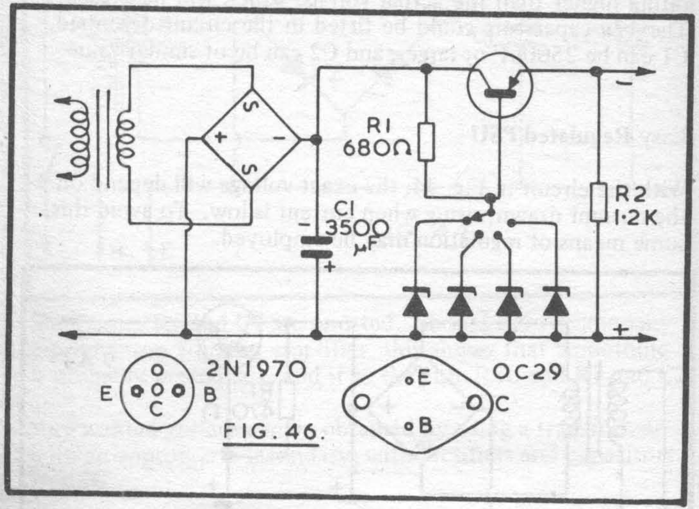

FIG. 46.

R1 supplies current for any diode, and 1 watt diodes should be used. With a 24v transformer and large transistor such as the 2N1970 or 0C29, an output of up to 1 ampere can then be drawn. The bridge rectifier must of course be rated at 1A or higher.

Note that this circuit has a PNP control transistor, so that polarity is obtained as shown. (Compare with the NPN transistor in the previous circuit.) However, either positive or negative can be grounded, and a separate earth terminal can be provided to allow this. A flying lead is placed between earth terminal and positive, or earth and negative, as required. The permanent negative earth connection shown in Fig. 45 must of course then be omitted.

More details of actual construction will be found later.

One Transistor Adjustable PSU

Fig. 47 is the circuit of a simple power supply unit which can be set to provide any output from zero to 12 volts. The transformer has a 17v secondary, rated at 1 ampere or higher. After rectification, DC is obtained from the reservoir capacitor C1.

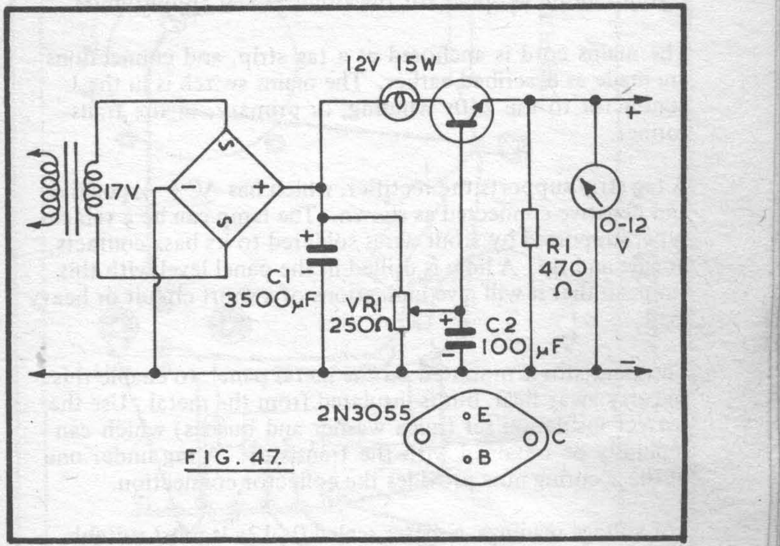

FIG. 47.

VR1 is panel mounted, and allows the base potential of the control transistor to be set at the required voltage. C2 provides "electronic smoothing" from the base circuit.

The 12 volt 15 watt bulb is for short circuit protection. With relatively low currents, little voltage is lost here. But if a short circuit arises in the output circuit, current is limited to a little over 1A by the bulb. This reduces the chances of any damage due to temporary shorts in leads or equipment.

R1 is a bleeder resistor, drawing some current even when no external load is connected. The meter is the usual high resistance type, scaled from zero to 12v. VR1 is adjusted until this instrument shows the wanted voltage.

The regulation of this supply is not so good as that of supplies using a number of transistors. But it will be found suitable for all ordinary purposes, and to supply power for circuits in this book, as only a small change in voltage arises, with changes to the load, or current drawn.

Fig. 47B shows practical construction of this PSU. A similar layout can be adopted for the other power supply units.

The mains cord is anchored at a tag strip, and connections are made as described earlier. The mains switch is in the L conductor to the 240v winding, or primary, of the transformer.

A tag strip supports the rectifier, which has AC (~), positive and negative connected as shown. The lamp can be a vehicle type, supported by stout wires soldered to its base contacts, or side and tip. A hole is drilled in the panel level with this lamp, so that it will give indications of a short circuit or heavy load.

The transistor is mounted on the metal panel, to enable this to carry away heat, but is insulated from the metal. Use the correct insulation set (mica washer and bushes) which can generally be obtained with the transistor. A tag under one of the securing nuts provides the collector connection.

For voltage readings, a meter scaled 0–12v is most suitable. Or a 1mA meter, with 12k 1% series resistor, may be used. If so, a new scale, marked 0–12, can be drawn for it.

A 3 watt linear potentiometer is used. Earth and negative are connected to the metal panel, for equipment with a negative ground line. The positive output terminal or socket is insulated from the metal.

The case can be metal, or wood. It should have a few ventilation holes. The transistor can be expected to run quite warm, at maximum current. Heating here rises as the output voltage is reduced by VR1, as in these circumstances more voltage is dropped in the transistor.

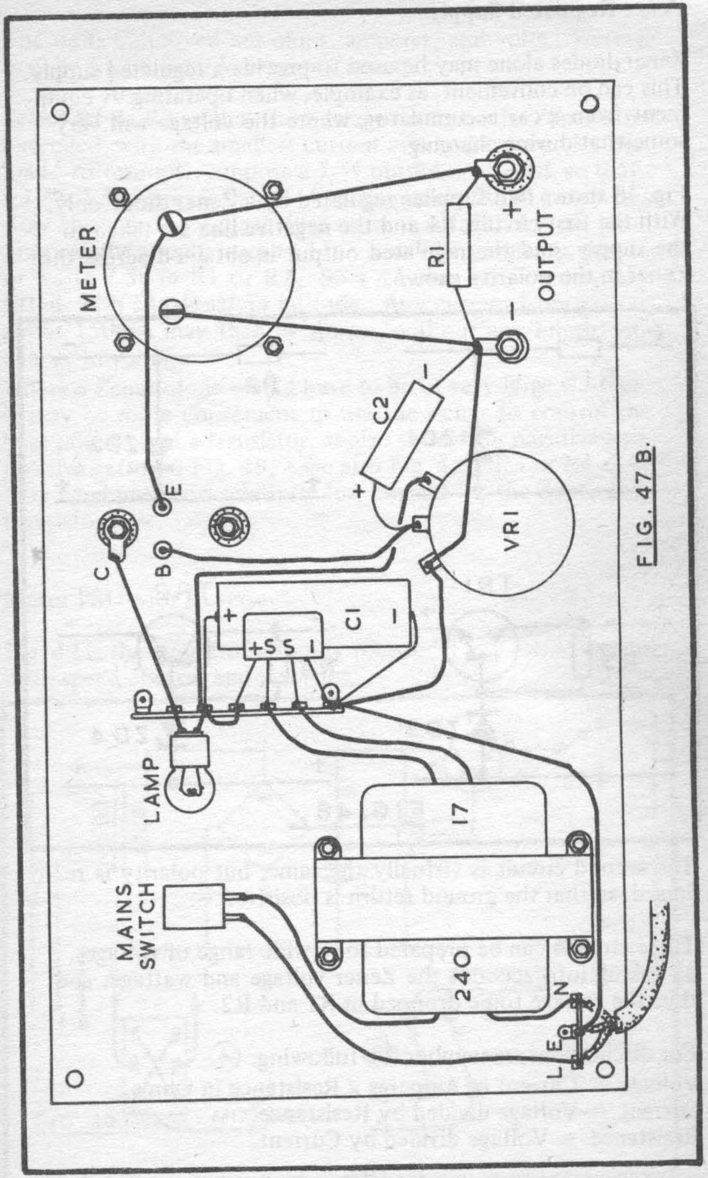

FIG. 47B.

Zener Regulated Supply

Zener diodes alone may be used to provide a regulated supply. This can be convenient, as example, when operating 9v equipment from a car accumulator, where the voltage will vary somewhat during charging.

Fig. 48 shows two supplies regulated by a Zener diode only. With the first circuit, R1 and the negative line are taken to the supply, and the regulated output is obtained across the Zener in the polarity shown.

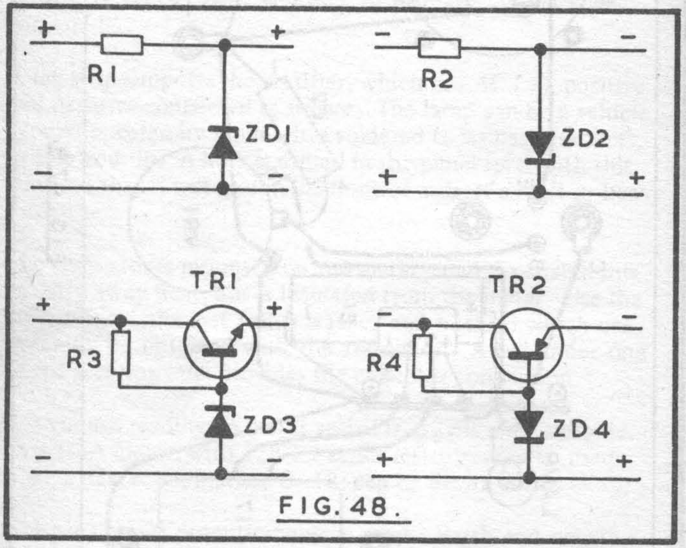

FIG. 48.

The second circuit is virtually the same, but polarity is reversed, so that the ground return is positive.

These circuits can be prepared for a wide range of voltages, by taking into account the Zener voltage and wattage, and thus the voltage to be dropped in R1 and R2.

For calculations, remember the following:
Voltage = Current in Amperes x Resistance in Ohms.
Current = Voltage divided by Resistance.
Resistance = Voltage divided by Current.

The units employed are ohms, amperes, and volts. Wattage may be found from Voltage x Current.

Select R1 or R2 so that the wattage rating of the Zener is not exceeded, with the smallest current ever to be drawn by the load. As example, suppose a 7.5v output is wanted, so that a 1½w 7.5v Zener is fitted. Approximately 200mA may thus flow through the Zener, if no current is taken by the load. Suppose the supply is up to 15v. It will be necessary to drop or waste 7.5v in R1 or R2. So a 42 ohm resistor may be fitted, with a little safety latitude. Any current from zero to about 150mA may then be drawn, without any important change in voltage.

Where a Zener diode would have to be of very large wattage, it may be more convenient to use the Zener to control the base potential of a transistor, as also shown for negative and positive earths in Fig. 48. (See also Fig. 45.) R3 or R4 then only need provide a relatively low current for the Zener and transistor base.

Motor PSU with Reverse

Fig. 49 is the circuit of a supply for model motors, and giving both speed control and reversing.

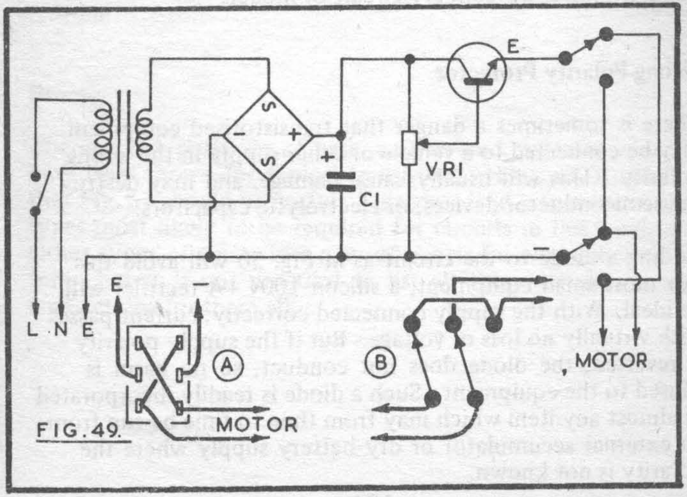

FIG.49.

A transformer with a 12v secondary will be suitable for the usual model requiring up to 12v. The circuit is similar to that of the supply in Fig. 47. The potentiometer VR1 gives speed control. C1 can be around 2,000μF.

"A" is one type of ready-made switch, and it can be obtained with a central off position. "B" shows a home-built switch, similar to that described in Fig. 5. The switch must not short circuit the supply when changing over polarity, and one with central off is recommended.

Motors reversed in this way must be of the permanent magnet type, in which a change of polarity causes the armature to run in the opposite direction. Train and many other model motors are of this construction. Motors with a wound field will not be reversed by changing the polarity of supply.

A controller of this kind should be constructed as shown earlier, so that it is safe to use, and so that no joints in the mains circuits can be touched.

Earthing can only be omitted when a double-insulated transformer, of the type specifically made to avoid any need for earthing, has been used. The whole controller should be so constructed that, even if a fault develops, mains voltages cannot reach the secondary circuit or model.

Wrong Polarity Protector

There is sometimes a danger that transistorised equipment may be connected to a vehicle or other supply in the wrong polarity. This will usually cause damage, and may destroy the semiconductor devices, or electrolytic capacitors.

Adding a diode to the circuit as in Fig. 50 will avoid this. For most small equipment, a silicon 100v 1A rectifier will be ideal. With the supply connected correctly, current passes with virtually no loss of voltage. But if the supply polarity is reversed, the diode does not conduct, so no harm is caused to the equipment. Such a diode is readily incorporated in almost any item which may from time to time be run from an external accumulator or dry battery supply where the polarity is not known.

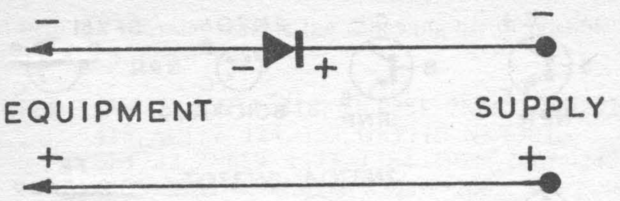

FIG. 50.

Component Tolerances

For circuits in this book, exact component values are generally not too important. Capacitor values such as 47nF (0.047μF) and 0.05μF may be regarded as interchangeable. In the same way, a 125μF capacitor may replace 100μF, or 200μF can be used instead of 220μF, and so on.

Resistors will generally be the standard 5% tolerance types. In some circuits exact resistor values are not at all critical. In others, and especially base, emitter and collector circuits, the values which provide best results can have much less latitude.

Bases

The lead-out positions of base, emitter and collector wires have been shown for typical transistors. However, it is felt that Fig. 51 should be useful. This gives lead information for types most likely to be required for circuits in this book. Other types of transistors may of course be used successfully, but it is not practical to list all these, or show connections for them all.

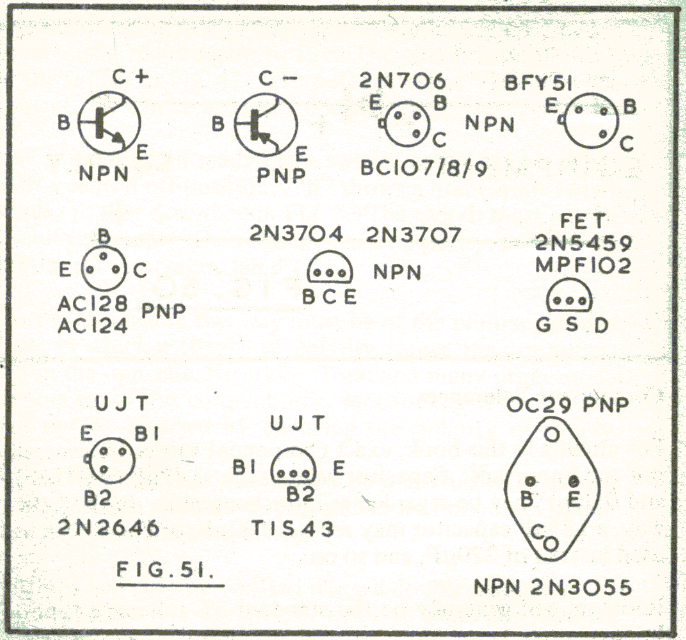
C +
B
E
NPN
C −
B
E
PNP
2N706
E
B
C
BC107/8/9
NPN
BFY51
E
B
C
B
E
C
AC128
AC124
PNP
2N3704 2N3707
B C E
NPN
FET
2N5459
MPF102
G S D
UJT
E
B1
B2
2N2646
UJT
B1
B2
E
TIS43
OC29 PNP
B
E
C
NPN 2N3055

FIG. 51.

EQUIVALENT SEMICONDUCTORS

To help our overseas readers the following list of possible equivalents is shown below: –

AC128	CV9778, OC74–318, NKT281, 2N467, 2SB222–415, AC117–124–153, GET110, NKT302, SFT232, 2N659–1373–1384–1926–2001–2431–4106, 2SB370, SK3004, RS276–2005.
ACY39	CV9475, NKT243, ACZ10, 2N652–2303–2801.
AF117	2N642, 2SA155, AF102–105–127–133–137, BFX48, BSW19–73, GM1213B, NKT603F, SFT354, SK3006, 2N2273–2635–3324–4916–5354, RS276–2003.
BC107	CV9780, AM251, BC147–167–207–317, MPS6566, SK3020–3122, ZTX107, TT107, RS276–2009.
BC108	CV10541, AM252, BC148–168–208–318, MPS6520, SK3020, ZTX108, TT108, RS276–2009.
BC109	CV10769–10806, AM253, BC149–169–209–319, MPS6521, SK3020, ZTX109, TT109, RS276–2009.
BC147	BC171–182/L–207–317, MPS6566, SK3020, RS276–2013,
BC148	BC172–183/L–208–318, MPS6520, SK3020, BS276–2009.
BC149	BC184/L–209–173–319, MPS6521, SK3020, RS276–2009.
BF200	BF162–173–225–271–311–314, SE5020/1/2/3/4, SK3018, 2N616–2708–3288–3693, RS276–2011.
BFY51	CV7723–7726–10827–11238, BFX51–68A, BFR19, BSX45/X, BSY46–85, SK3024, 40347, 2SC708, ME6102 2N2193/4–2218–2410–3053–3252–4046, RS276–2009.
BSY95A	CV7648–9379, BC108A, BSX51–73–91, BFX96, BSY20–58–62, ME9022, SK3122, 2SC321, 2N744–914–1708–2218–2369–5187, RS276–2011.
MPF102	E305, SK3116.
OA81	AA117–118–132–144, AAZ15, OA91–95–161, SD38, 1N38–56–476–618, 1S33.
OC26	CV8560, NKT452, 2N257–297–458–553–1021, 2SB3, AD130–131–138–140–149, OC28, SK3009, TF80, T1156–3027, 2N174–1073–2870–RS276–2006.

OC29	CV7083–8356, NKT402, 2N457, 2SB86–425, AD150, ASZ16, AUY21, OC28–35–36, SK3009, T13028, 2N174–1073–2870, RS276–2006.
OC44	CV5710–7003, OC170–171–410–613, 2N1303, 2SA15, AF101–117–126, ASY55, AC191, BC126, NKT211, SKT358, SK3005, 2N36–1191/2–1352–1373–1384, RS276–2003.
OC70	CV5457, OC303–602, NKT214, 2N279–1305, 2SB75, AC122–125–151–163, ACY27–34, ASY27, BC213–206A, BSX36, SK3003, 2N1193–1352–1375–2429, RS276–2004.
OC71	CV5712–7005–8344, OC70–304–604, NKT214, 2N280–1305, 2SB77, AC122–125–151–163, ACY35, BSX36, OC3041, SK3003, 2N1193–1352–1375–1384–2429, RS276–2004.
OC72	AC122/3–125/6–131–151 IV–152–162–191, BC126–213–206A, NKT211, SFT353, 2N282–1190–1352–1371–1384–1991–2431, CV5713–7006–8440, RS276–2005.
OC76	CV8314, OC307–6025, 2N284–1305, NKT212, 2SB89, AC128–131–151–152, ACY28, ASY58–76, BC126–213–260A, SK3004, 2N394–1191–1352–1371–1384–1991, RS276–2004.
ORP12	RS276–116, LDR03, RPY25.
1N4001	BY127, EM502, RS276–1101/1135, 1S100.
1N4002	BY127, EM502, RS276–1102/1136, 1S100.
2N1306	CV7350–10686, NKT736, 2N634–635–636–1891–1993–1994–1995, ASY26–29, BSX19–20, RS276–2001.
2N1613	CV7440–8843, BFY33–34–67, BSY44, 2N698–699–717–1711–1889–1890–1893, BFY41, BSX45/6, BSY53, MPS6530, 2SC708, 2N2101.

N.B.: Although equivalent semiconductors may have similar electrical properties, physical dimensions may be different and this must be born in mind if space is tight and for mounting details.

Remember polarities if replacing PNP with NPN types and vice versa. If in doubt always be advised by your dealer for suitable equivalent semiconductors.

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OLEG D. JEFIMENKO
West Virginia University

Electrostatic Motors

Their History, Types, and Principles of Operation —

With many illustrations, of which 57 are
by
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of
Waynesburg College

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This book is dedicated to an accomplished
farmer, craftsman, musician,
educator, and lawyer
MY FATHER

PREFACE

The fascinating science of electrostatics was developed mainly in the 18th century at a time when the technology and industry were too primitive to put this science to practical uses. As a result, serious research in electrostatics soon lost its momentum and, except for a few isolated efforts, was practically nonexistent during the entire 19th century. Only very recently practical aspects of electrostatics began to make their impact on the industry and economy, and the once glamorous but long forgotten science has again appeared at the focal point of serious scientific investigations.

A peculiar obstacle stands, however, in the way of many such investigations: because of the one and one half century of neglect of electrostatic explorations there is a singular lack of easily available quantitative and qualitative information on even the most basic electrostatic phenomena, techniques, and devices. Whereas experimental and theoretical data pertaining to most modern sciences are well documented and are easily retrievable from numerous reference sources, many data in the field of electrostatics must be extracted through thorough and laborious firsthand studies of old books and magazines, the very existence of which is not generally known, and which are not readily available in any of the present-day libraries or repositories.

It is precisely this kind of obstacle that the author encountered, when several years ago he started his research on electrostatic motors. Luckily, however, the obstacle soon transformed itself into a highly rewarding experience of studying various "ancient" books and periodicals and searching through electrostatic inventories of various European and American science museums. In the course of these studies he found numerous forgotten publications on electrostatic motors and found that several old electrostatic motors can actually be seen in some of the museums. (It is interesting to note that the latter motors are usually not on public display, apparently because of a lack of adequate information about their purpose and mode of operation available to museum personnel. It is also interesting to note that certain types of electrostatic motors were frequently employed in various animated toys during the second half of the 18th century, and that, although some of these toys are shown in museums, they are usually shown without an explanation of what made them move or how they were supposed to function.)

The purpose of this book is to describe the various types of electrostatic motors reported in the scientific literature between 1700 and the present, and to discuss in general terms their various design features and principles of operation. The book is written for a wide circle of readers, and care has been taken to avoid technical details that would be useful only to a small group of specialists. The readers interested in additional scientific and technical data on the various motors are referred to appropriate original publications cited in this book.

The material is presented in several chapters, each chapter describing a particular class of motors. The sequence of the chapters corresponds to the chronological order in which the earliest motor belonging to each particular chapter was invented. The sequence of material in each chapter is normally arranged also in a chronological order. The last chapter describes some of the most recent research results on electrostatic motors and extrapolates these results into the immediate future.

The author is grateful to his wife Valentina for typing the manuscript and for otherwise helping him to make the book ready for publication. He is also grateful to Dr. David K. Walker for reading the manuscript and for drawing the illustrations for the book.

Oleg D. Jefimenko

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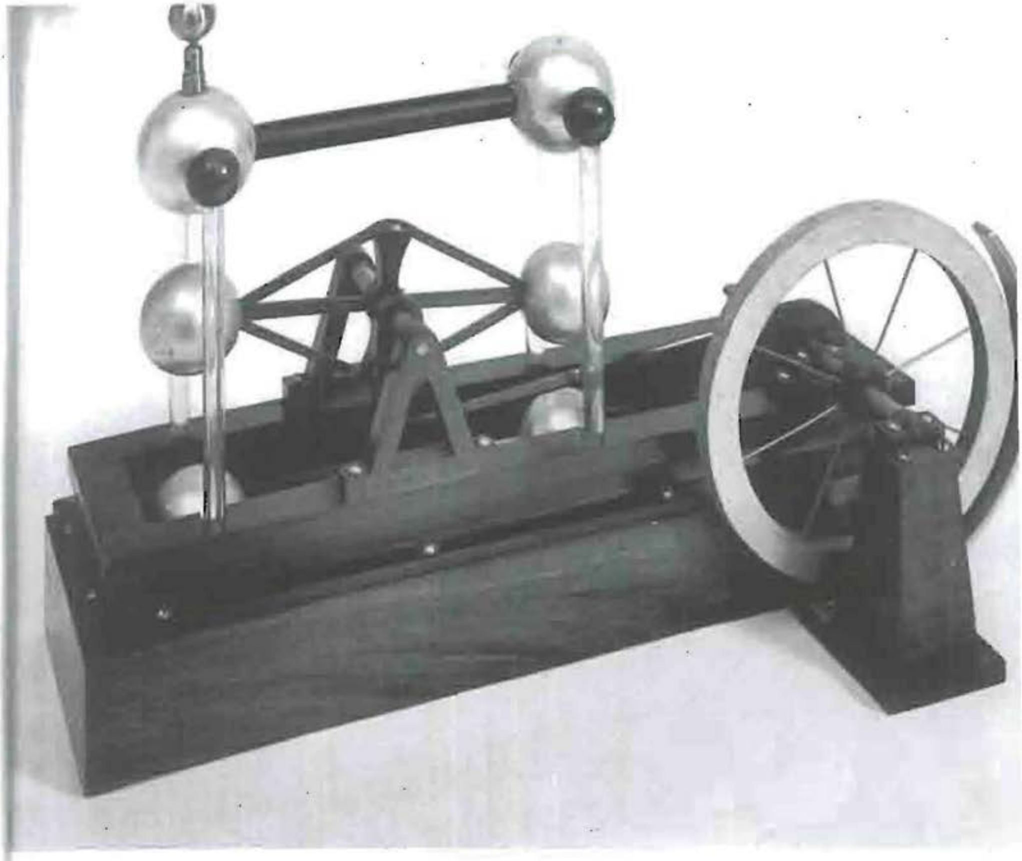

PLATE 1

Here is what H. B. Dailey wrote about this electrostatic motor which he and his father built in 1880: "Whether or not there is about the instrument and its history that which would ever give it a claim to any measure or serious interest, it is at least an electric motor most unique. A motor without magnetism, wiring, or any iron in its make up. A motor that runs by the action of the direct push and pull of the pure unconverted electricity itself".

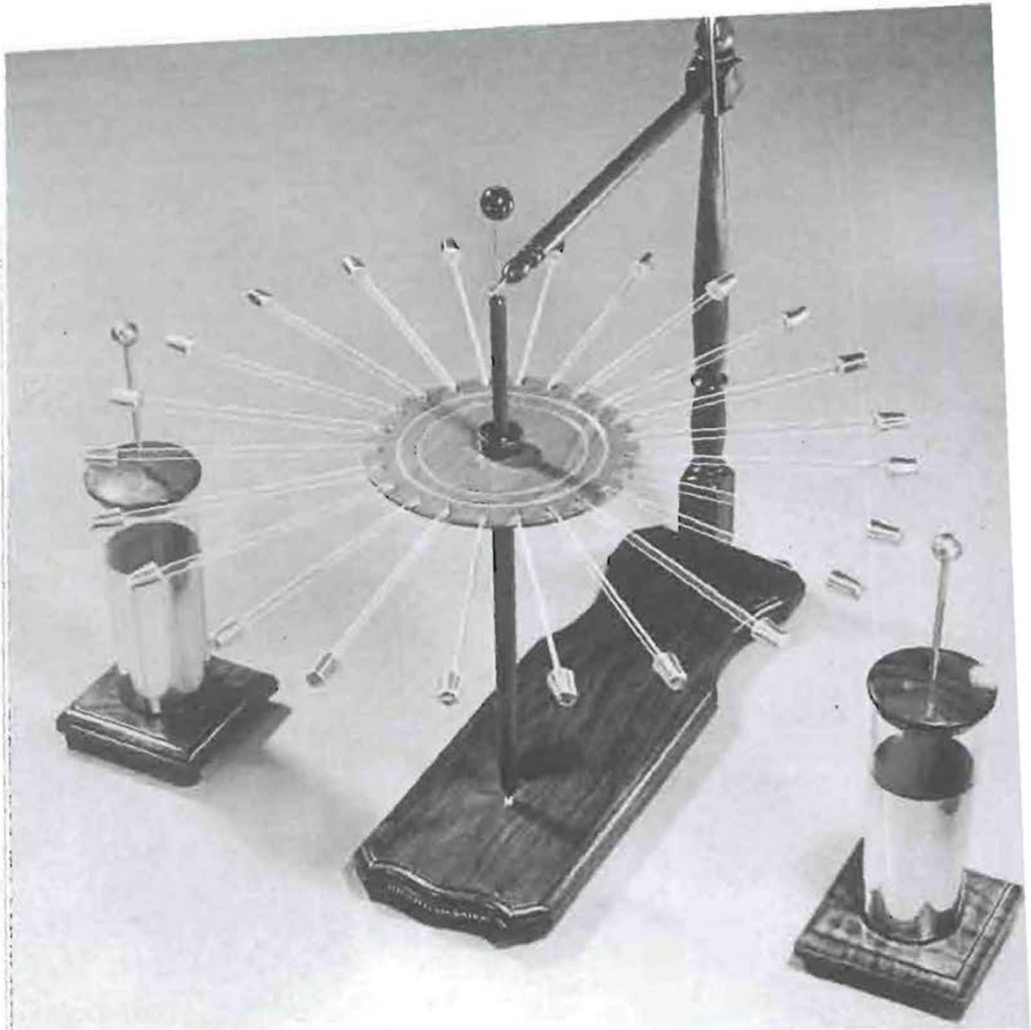

PLATE 2

It was Benjamin Franklin who in 1748 constructed the first electrostatic motors. No original drawings or models of his motors are known to exist, but his first motor must have looked very similar to this replica designed by the author for the Electret Scientific Company.

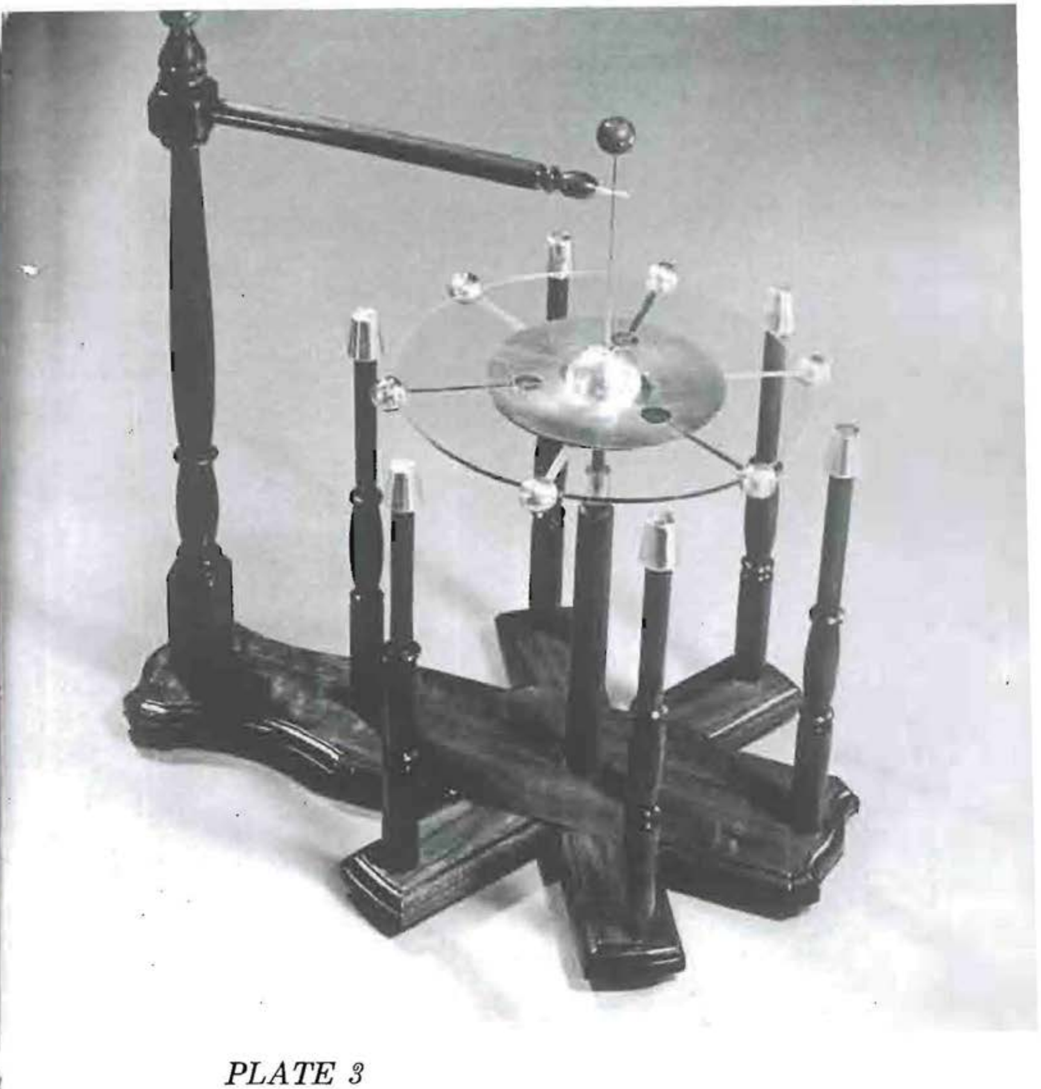

PLATE 3

Franklin's second motor probably looked very much like this replica also designed by the author for the Electret Scientific Company. Whereas the first motor operated from the electricity stored in Leyden jars, this motor operated from the electricity stored in the motor itself.

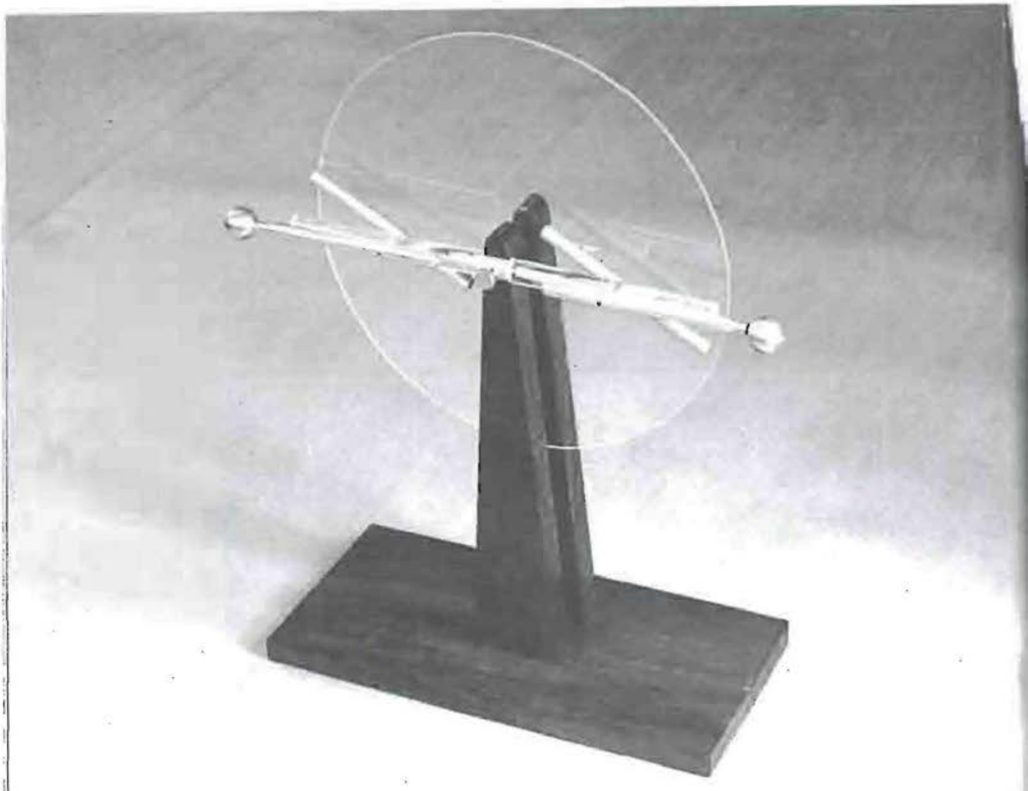

PLATE 4

The first corona motor was designed around 1869 by the German physicist Poggendorff. Poggendorff made a thorough study of the motor, but failed to appreciate its possibilities in the mistaken belief that no sources of electricity could supply enough power to any electric motor to make it do useful work. This simplified version of Poggendorff's motor was built by the author.

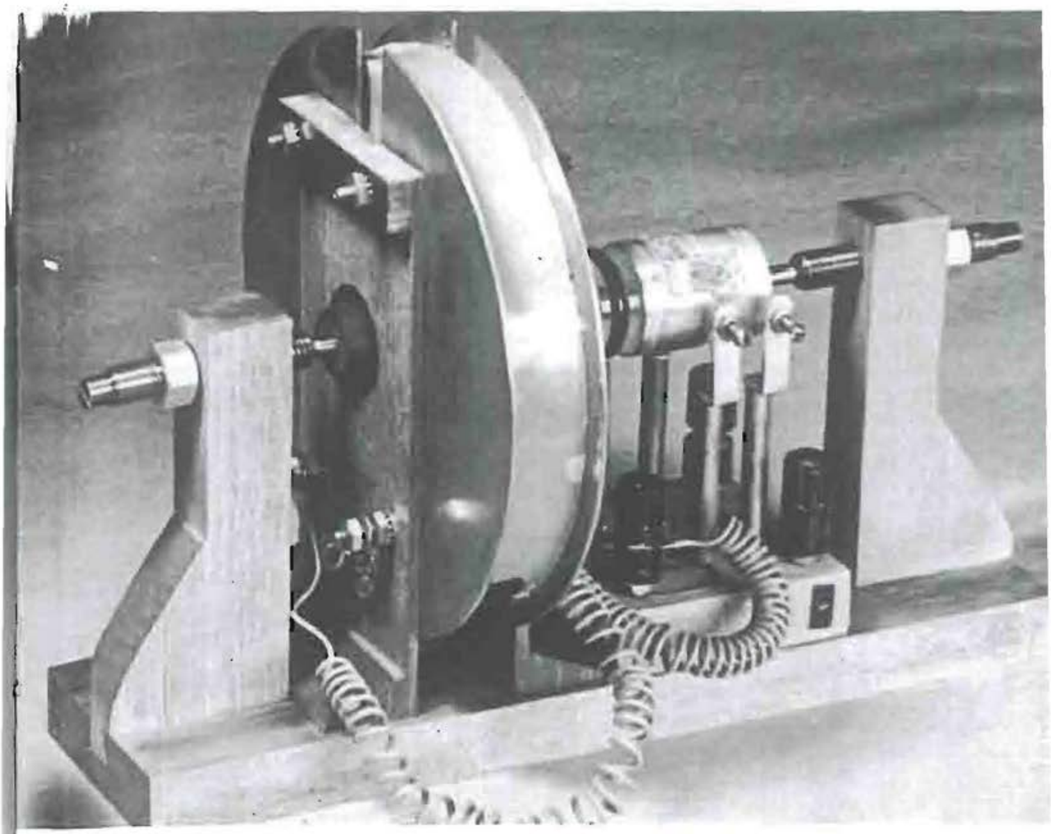

PLATE 5

The electret—a permanently electrized dielectric—is essentially a product of the 20th century. When an electret is placed between slotted electrodes to which a voltage is applied, the electret experiences a force. This motor designed by the author utilizes the slot effect. The rotor of the motor is a carnauba wax electret made of two oppositely polarized half-disks. The motor was built in 1966.

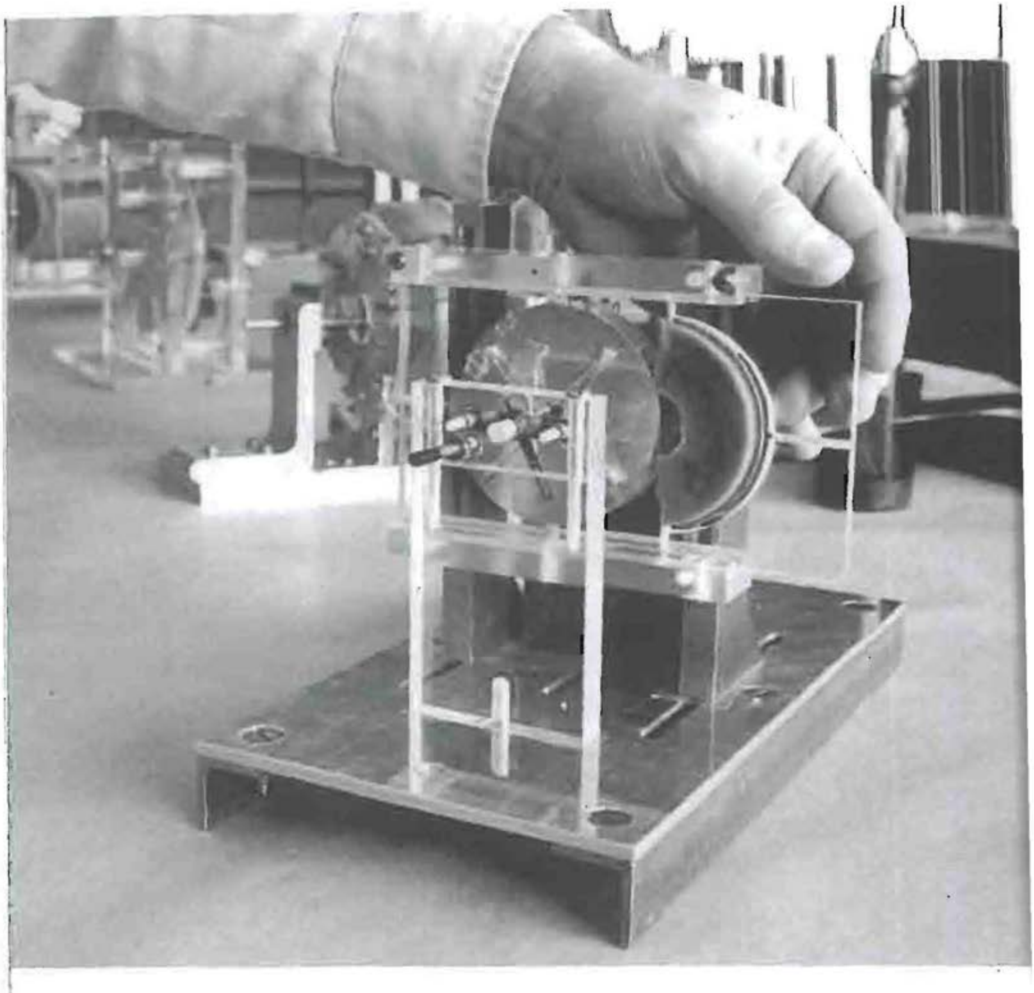

PLATE 6

A more practical design of an electret motor incorporates stationary electrets and rotating electrodes. The electrets can be easily withdrawn from the motor for servicing or replacement. The motor operates from approximately 60 volts dc. This particular motor was the first ever operated from atmospheric electricity.

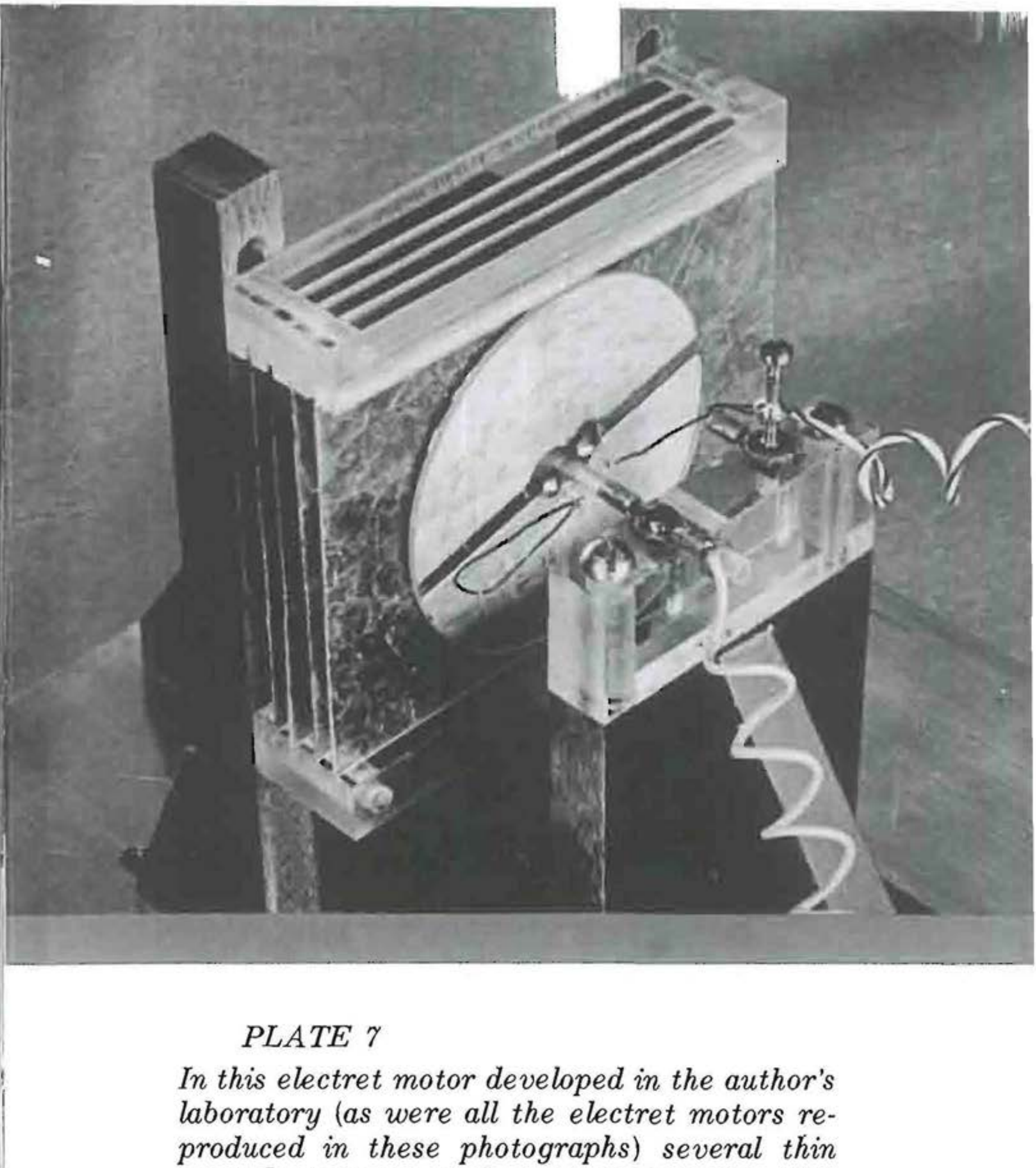

PLATE 7

In this electret motor developed in the author's laboratory (as were all the electret motors reproduced in these photographs) several thin mica electrets are used as active elements. This arrangement of electrets makes good use of the available space and allows one to construct relatively powerful electret motors.

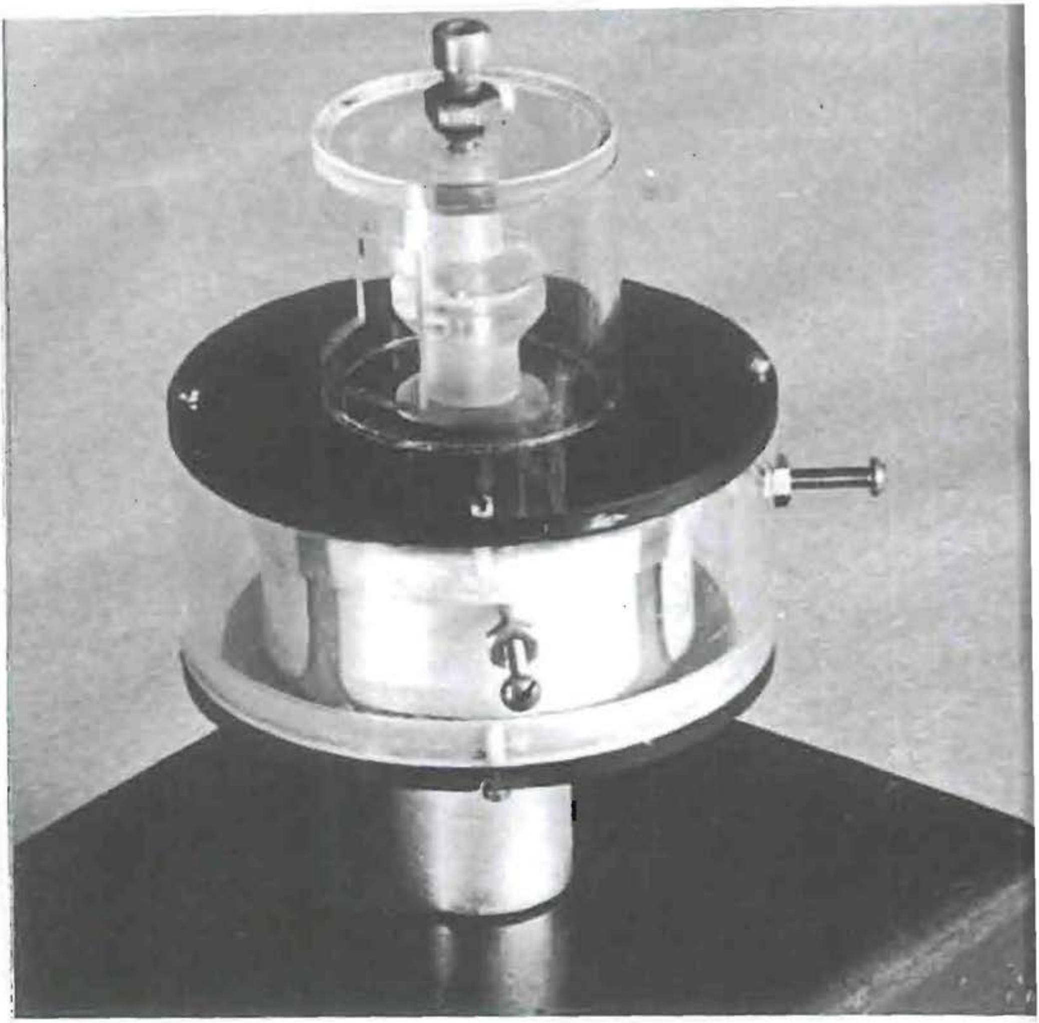

PLATE 8

This "hoop" electret motor built in 1967 by D. K. Walker has a stationary cylindrical electret. The rotor is made of four pairs of bent aluminum plates enclosing the electret. The motor requires no commutator. The motor has been operated for several years without any servicing.

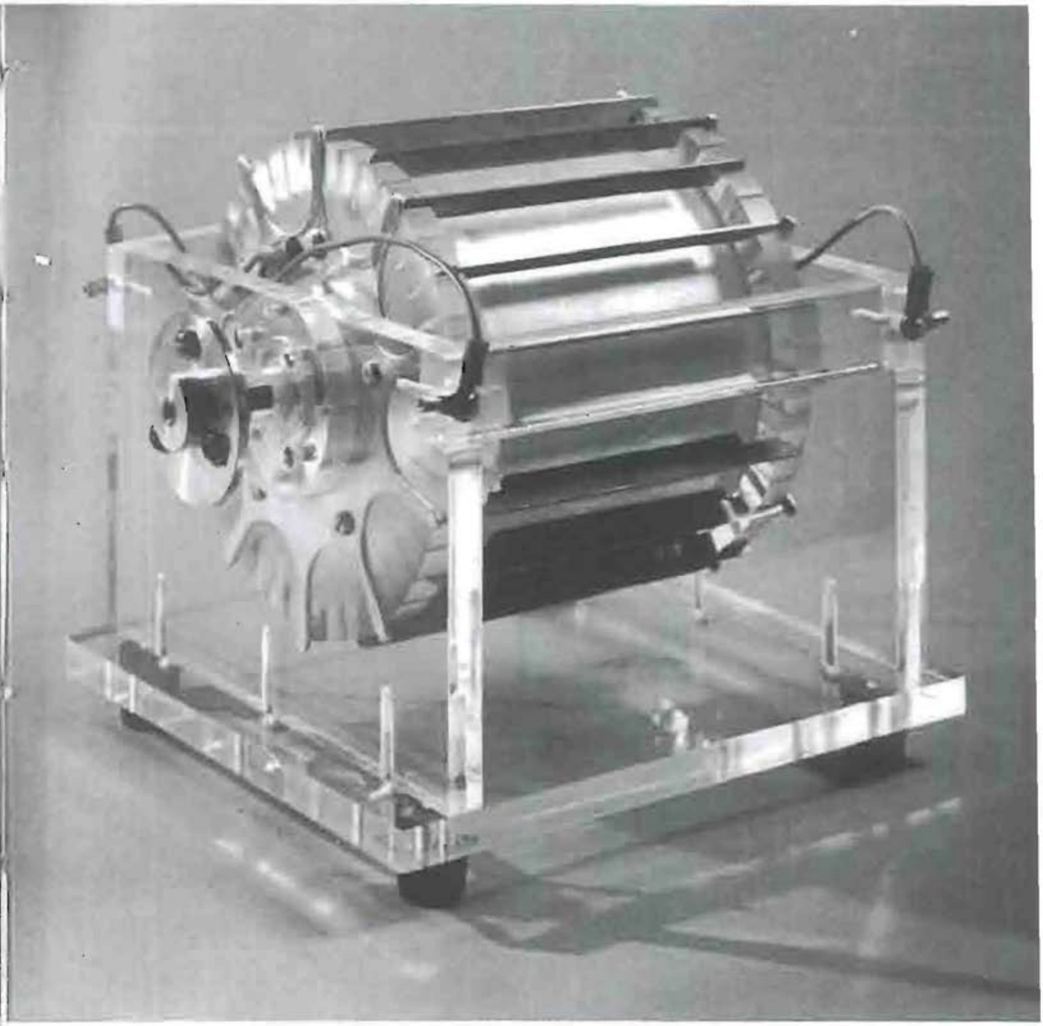

PLATE 9

Corona motors are probably the most promising electrostatic motors. This 0.1-hp modern version of the Poggendorff motor has a cylindrical rotor instead of a disk. The motor operates from a 6000-volt power supply as well as from an earth field antenna.

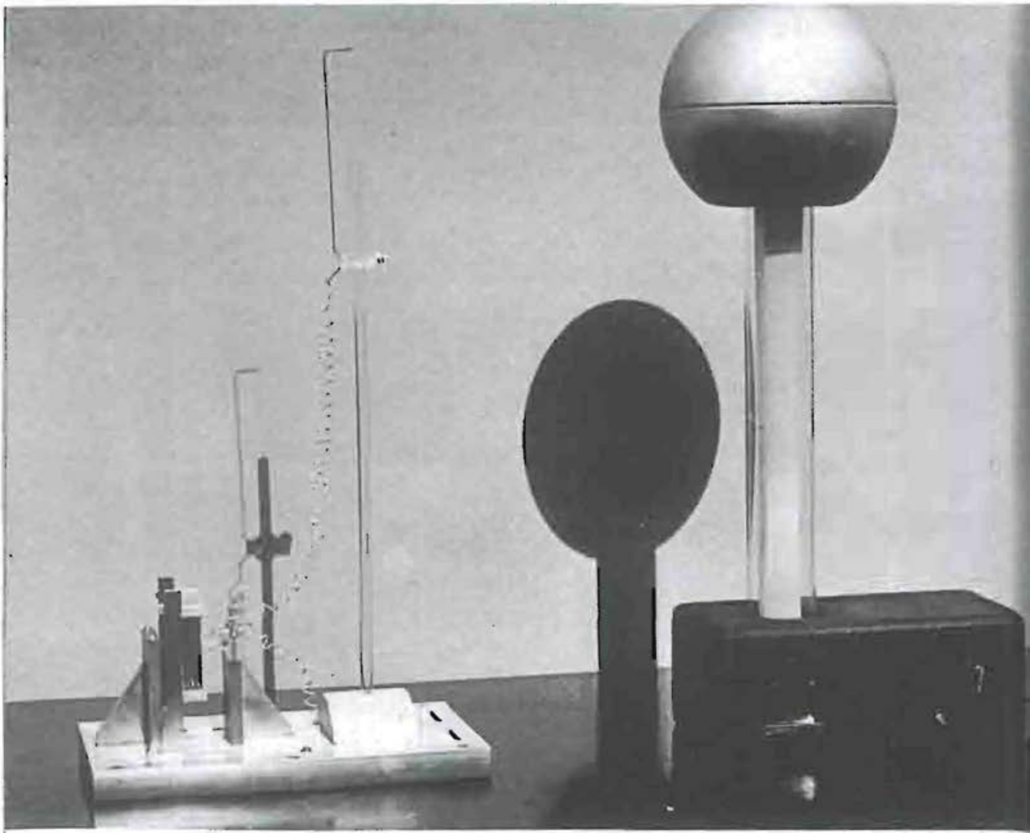

PLATE 10

The operation of electrostatic motors from antennas can be demonstrated with this lecture-room apparatus. The Van de Graaff generator produces electric charges in the air. The sharp-point antenna collects the charges from the air and delivers them to one terminal of an electrostatic motor whose other terminal is grounded.

PLATE 11

The author and D. K. Walker attempt to operate an electret motor from a 20-foot pole antenna in front of the Physics Building of the West Virginia University. The tall building screened the atmospheric field, and the motor did not run, although it operated very well from the same antenna in the nearby unobstructed parking lot.

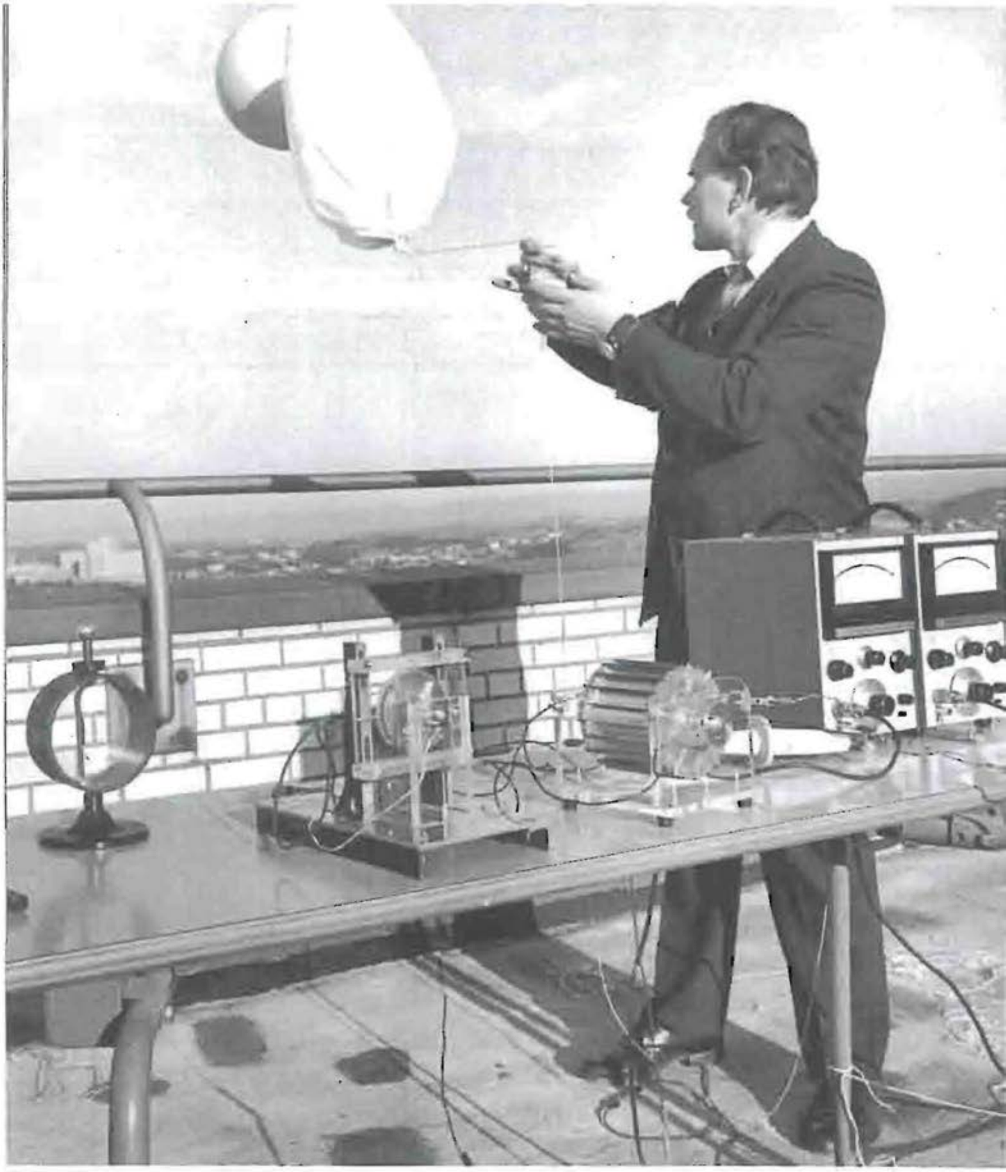

PLATE 12

The author operates electrostatic motors by means of an airborne antenna.

1

WHAT ARE ELECTROSTATIC MOTORS?

Conventional electric motors create mechanical motion as a result of magnetic forces acting upon electric currents. These motors are properly called *electromagnetic motors*. There is, however, another type of electric motor, in which the motion is created as a result of electric, or "electrostatic", forces acting between electric charges. Motors of this type are called *electrostatic motors*.

It is interesting to note that in nature the electrostatic forces are much stronger than the magnetic ones. There are many ways in which this can be demonstrated. For example, although a considerable effort may be needed to separate a magnet from an object attracted by it, a much greater effort is needed to break the magnet; this is because the magnet and the object are held together by magnetic forces, while the molecules of matter in the magnet (as well as in any other body) are held together by electrostatic forces.

Why, then, do we not use the electrostatic forces in our electric devices, and in motors in particular, at least on as wide a scale as we use the "inferior" magnetic forces? There are two main reasons for that. First, it is difficult to establish appreciable concentrations of electric charges without causing an electric breakdown in the medium surrounding or supporting the charges (although with modern insulating materials and techniques this difficulty becomes progressively less serious). Second, powerful electrostatic devices require voltages of many kilovolts for their operation, and until recently such voltages could not be produced conveniently and economically.

Motors of great power, however, are not the only ones needed. Equally important are low-power motors capable of performing various special tasks. In this respect electrostatic motors may compete successfully with their electromagnetic cousins even now.

Although electrostatic motors are not yet widely known or used, they already hold at least five very impressive records as compared with the electromagnetic motors:

1. The first electric motor ever invented was an electrostatic one. It was built about 100 years before the first electromagnetic motor was conceived.

2. The electric motor that operated without interruption longer than any other electric motor was an electrostatic one. This was a pendulum-type motor, known as the "electric perpetuum mobile", installed at the University of Insbruck, Austria, in 1823. Since then it operated continuously at least until 1909, powered by a Zamboni pile (an early high-voltage battery).

3. Electrostatic motors have been operated from voltages in excess of 10^5 volts, which is much higher than the voltages suitable for operating electromagnetic motors.

4. Electrostatic motors have been operated by using currents smaller than 10^{-9}amp, which is much less than the currents needed to operate electromagnetic motors.

5. The first electric motor that operated directly from the atmospheric electricity was an electrostatic motor. None of the presently available electromagnetic motors can operate directly from this source.

Even this short list reflecting some of the more obvious peculiarities of electrostatic motors shows quite clearly that electrostatic motors possess a number of unique properties. These properties undoubtedly will make electrostatic motors increasingly more important for the science, engineering, and technology of the future.

Many different types and designs of electrostatic motors are possible. It is customary to classify electrostatic motors in accordance with some prominent feature of their mode of operation or some prominent feature of their design. Thus, in reference to the techniques used for delivering electric charges to the active part of a motor one speaks of *contact motors*, *spark motors*, *corona motors*, *induction motors*, and *electret motors*. In reference to the medium in which the active part of a motor is located one speaks of *liquid-* or *gas-immersed motors*. In reference to the material and design of the active part of a motor one speaks of *dielectric motors* (the active part is made mainly of dielectric material) and *conducting-plate*, or *capacitor*, *motors* (the active part is made mainly of metal and resembles a variable capacitor). Finally, in reference to the rate of rotation of a motor relative to the period of the applied voltage (for ac operated motors) one speaks of *synchronous motors* and *asynchronous motors*.

This classification of electrostatic motors does not make it possible, however, to specify uniquely each individual motor. Also, two or more different operation modes are usually possible for most electrostatic motors (for example, certain motors can be operated at will as contact, spark, or corona motors). Therefore an assignment of a particular motor to one or another of the above types or categories is frequently more or less arbitrary. This applies, of course, also to the present book, where certain motors described in the chapters that follow could be equally well discussed under different chapter headings, and where the inclusion of certain motors in a particular chapter was occasionally dictated by the fact that such an inclusion resulted in a more coherent development of the subject matter.

2

ELECTRIC PENDULUM MOTORS; CONTACT MOTORS

If "electric motor" is understood to be a device converting electric energy into a continuous mechanical motion, then the first two electric motors were invented in the early 1740's by Andrew Gordon, a Scottish Benedictine monk and professor of philosophy at Erfurt, Germany.[1] Gordon's first motor was a device known as the "electric bells" (his second motor will be described in the next chapter). The device and its operation were as follows. A metallic clapper (pendulum) was suspended by a silk thread between two oppositely charged bells (Fig. 1). From an initial contact with one of the bells the clapper acquired a charge of the same polarity as that of the bell. Due to repulsion of like charges and attraction of opposite charges the clapper was then repelled by this bell and attracted by the second bell. As the clapper struck the second bell, it gave off its initial charge and acquired a charge of the same polarity as that of the second bell. Then the clapper was repelled by the latter and attracted by the first bell, which it struck again, and so on.

Numerous variations of Gordon's bells have been described by later authors, mostly as devices for lecture-room demonstrations of electrostatic forces. Such devices are widely used for this purpose even now.

An ingenious application of Gordon's bells was made by Benjamin Franklin in 1752. He connected the bells to an insulated lightning rod as a warning device "to give notice when the rod should be electrified".[2] (It appears that at that time neither Franklin nor any other scientist suspected how dangerous this "warning" device could be. The extreme danger of experiments with insulated lightning rods became clear a year later, when in 1753 the Russian physicist George Wilhelm Richmann was killed by lightning that entered his laboratory through such a rod, as he approached it in order to measure its electrification with a specially constructed electrometer.)

In a later modification of Gordon's invention one of the two bells was mounted on a Leyden jar (Fig. 2); the bells would then ring for as long as there was enough electric energy stored in the jar to move the clapper. (Franklin described the operation of an electric pendulum powered by a Leyden jar in 1747; see Ref. 2, p. 189.)

Sometimes Gordon's bells were made as a set

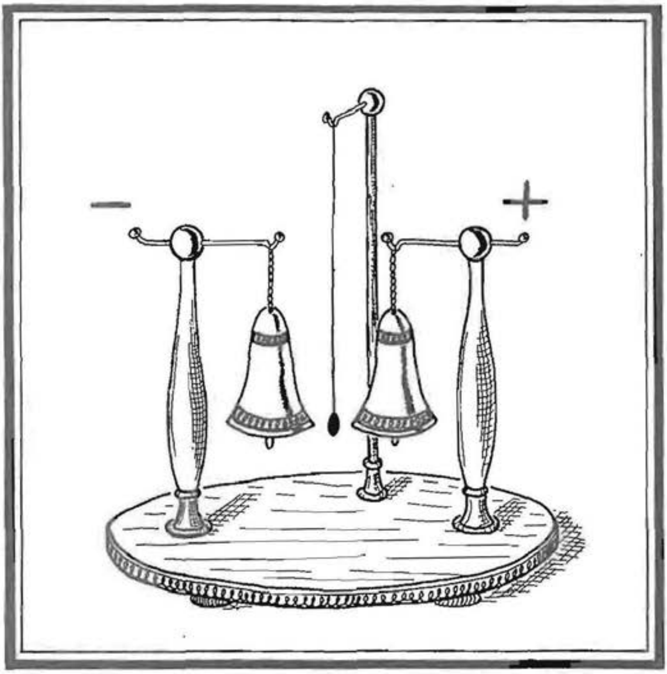

FIGURE 1

The so-called "electric bells" constituted the first device that converted electrical energy into a continuous mechanical motion. They were invented in about 1742 by Andrew Gordon, a professor of philosophy at Erfurt, Germany.

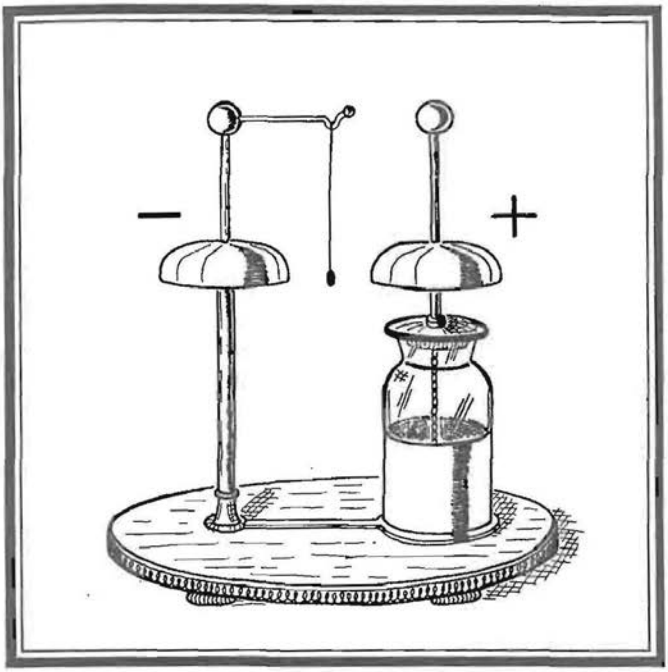

FIGURE 2

In a later modification of Gordon's invention one of the two bells was mounted on a Leyden jar. The bells would then ring for as long as there was enough electrical energy stored in the jar to move the clapper.

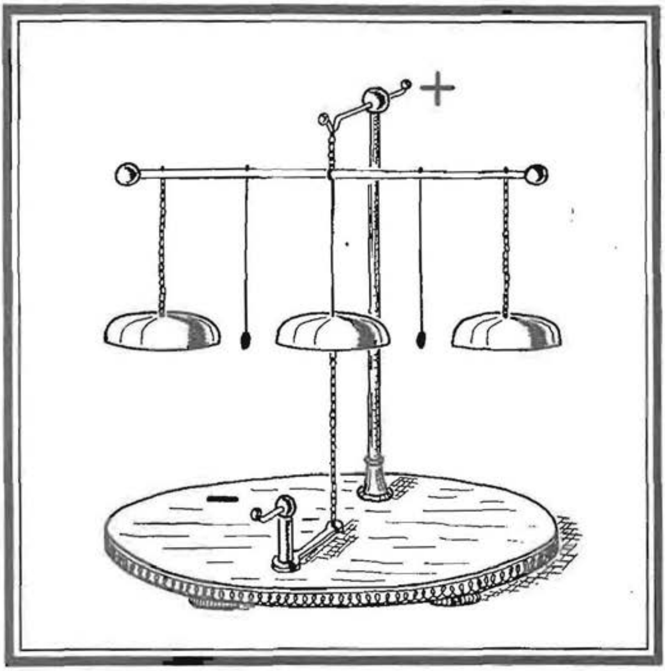

FIGURE 3

Sometimes Gordon's bells were made as a set of three bells and two clappers, all suspended from a horizontal bar, the central bell being insulated from the bar and grounded by means of a light chain.

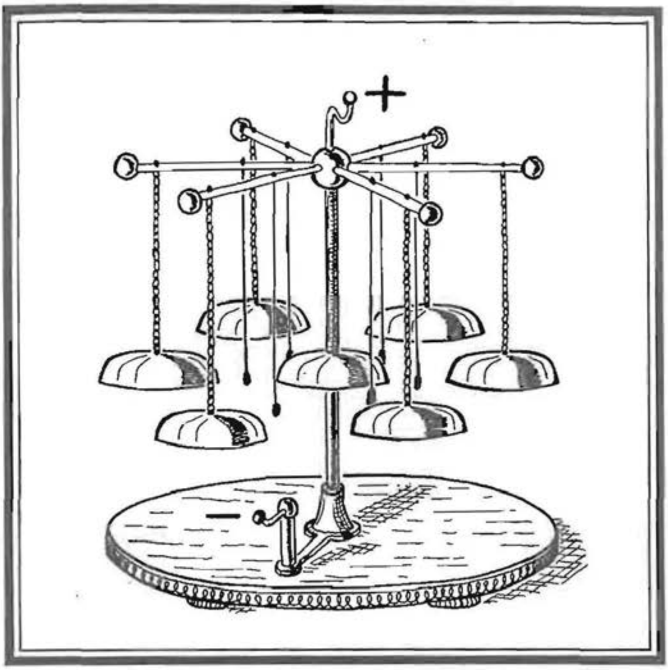

FIGURE 4

Another modification of Gordon's bells was a set of bell chimes arranged on a wooden base in a circular formation around the central bell. A separate clapper was then present for each of the outside bells.

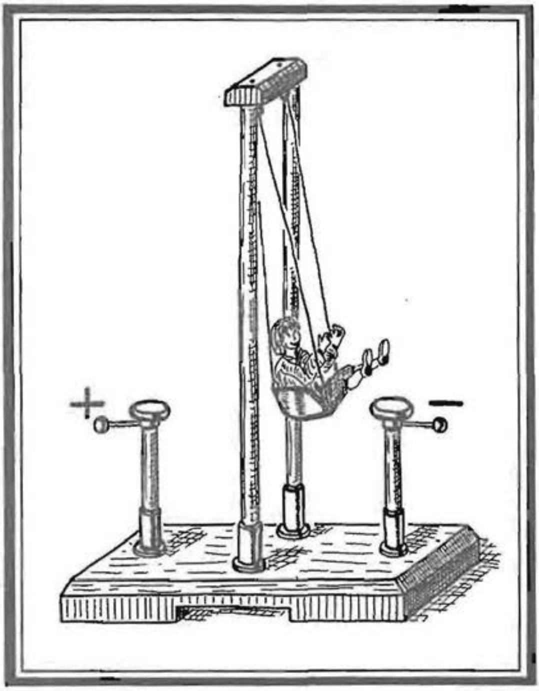

FIGURE 5

The electrical and mechanical principle of Gordon's invention could be used not only for ringing bells but for creating a mechanical motion in general. In this "electric swing" this principle was used to operate an animated toy.

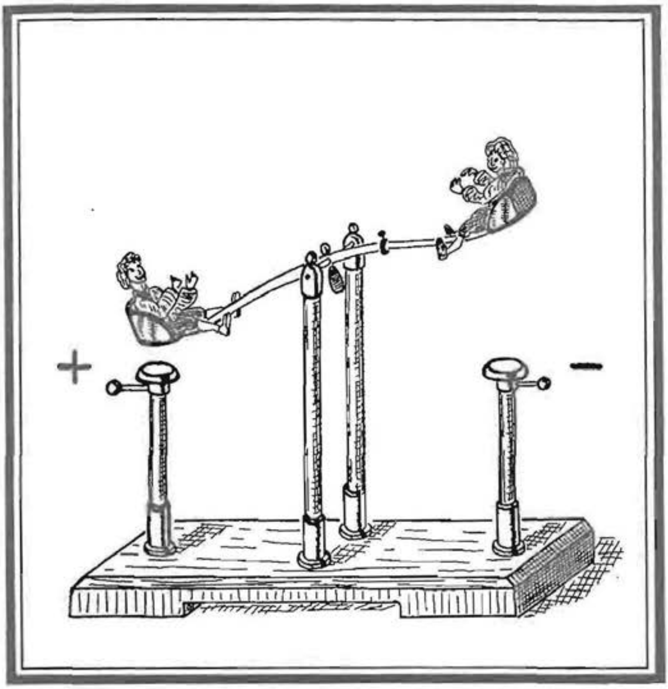

FIGURE 6

Various electrostatically operated toys were invented in the 18th and 19th centuries. This "electric seesaw" was basically a conducting bar oscillating about a horizontal axis on the same principle as the clapper of Gordon's bells.

of three bells and two clappers, all suspended from a horizontal bar, the central bell being insulated from the bar and grounded by means of a light chain (Fig. 3). Another modification of Gordon's bells was a set of bell chimes arranged in a circular formation around the central bell (Fig. 4); a separate clapper was then present for each of the outside bells, each clapper moving between one of the latter and the central bell (the central bell was usually grounded, the outside bells were connected to an electrostatic generator).

The electrical and mechanical principle of Gordon's invention could be used, of course, not only for ringing bells but also for a variety of other purposes. In particular, this principle was later used in two electrically operated toys: the "electric swing" and the "electric seesaw", which utilized, respectively, an insulated pendulum made as a swing (Fig. 5) and an insulated conducting swing bar capable of oscillating about a horizontal axis (Fig. 6).[3,4]

Except for Franklin's bells, all of the above devices were designed for operation from an electrostatic generator or from Leyden jars charged by such a generator. However, in 1806 a high-voltage chemical battery ("dry pile", later known as the "Zamboni pile") was invented by Georg Behrens, and in 1810 this pile was adapted by Giuseppe Zamboni to operate primitive electrostatic motors.[5] Inasmuch as a Zamboni pile could remain active for many years, the little motors that operated from it were known as the "electric perpetuum mobile". An example of such a perpetuum mobile is shown in Fig. 7 (see Chapter 4 for another design). The apparatus consisted of a light rigid insulated pendulum, pivoted just above the center of gravity, with a light conducting ring at the top. The ring was located between the two knobs of a Zamboni pile. When the ring contacted one of the knobs, it acquired a charge from the knob and was repelled from this knob and attracted to the second knob, and so on, just like the clapper in Gordon's bells. One such perpetuum mobile is reported to have operated without interruption for at least 86 years.[6]

The most sophisticated device derivable from Gordon's electric bells was probably the reciprocating electrostatic motor (Fig. 8 and Plate 1) built in 1880 by Howard B. Dailey and Elijah M. Dailey.[7] The motor, which is now at the Museum of History and Technology of the Smithsonian Institution, was described by one of its builders as follows:

"This machine operates by the direct action of static electric attractions and repulsions. It is constructed entirely of fine wood, glass and hard rubber, there being no magnetic materials used. The flywheel is of laminated, soft wood and runs in journal bearings of very small diameter. The moving balls, mounted on the walking beam of vulcanite, are made of wood, hollowed out so that the walls are about 2 millimeters thick.

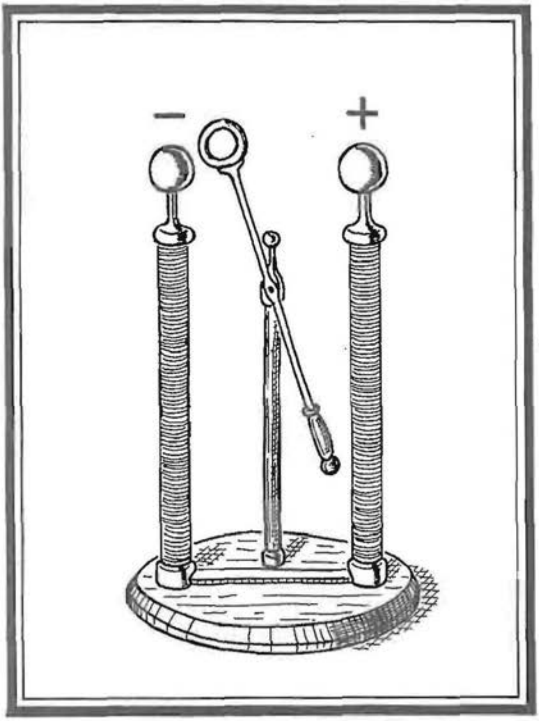

FIGURE 7

This electric pendulum operated from a Zamboni pile, an early high-voltage battery. Since the pile remained active for years, the pendulum was known as an "electric perpetuum mobile".

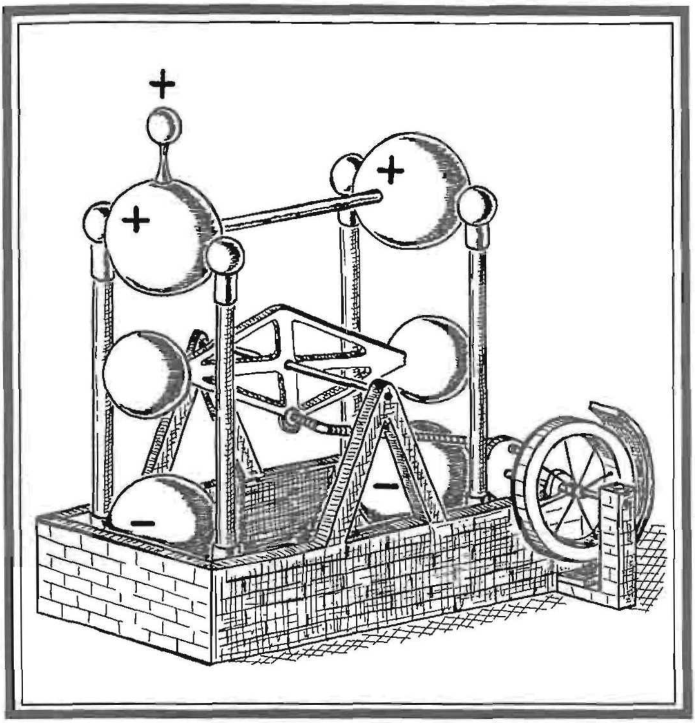

FIGURE 8

The most sophisticated device derivable from Gordon's bells was probably this reciprocating electrostatic motor built in 1880 by H. B. Dailey and E. M. Dailey.

They are covered with aluminum foil for static conductivity. The stationary balls are of solid wood.

"To operate the engine the stationary balls are charged with electricity from a static electric generator, such as a Holtz machine, the upper balls being connected through the brass ball to one pole of the machine while the lower stationary balls are connected through the binding post on the bed frame to the opposite pole of the machine. Under proper conditions, when charged, the engine will make about 375 revolutions per minute.

"The walnut base upon which the engine is mounted is 14" long, 4" wide and 1¾" thick. The movable balls are about 1½" in diameter; the upper stationary balls are 1¾" in diameter; and the lower stationary balls, 1½". The four glass rods, mounted vertically, are about 6" high and spaced 6" apart along the bed. The diameter of the flywheel is 5¾". It is gilded and has small wire spokes. The connecting rod is 7" in length."*

The electric principle of Gordon's bells could be used also for producing a continuous unidirectional motion. A fascinating device of this type was the "electric racing ball", or the "electric planetarium", an excellent description of

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*The author is grateful to Mr. Elliot N. Sivowitch, Smithsonian Institution Museum Specialist, for kindly providing this description and the photograph of Dailey's motor.

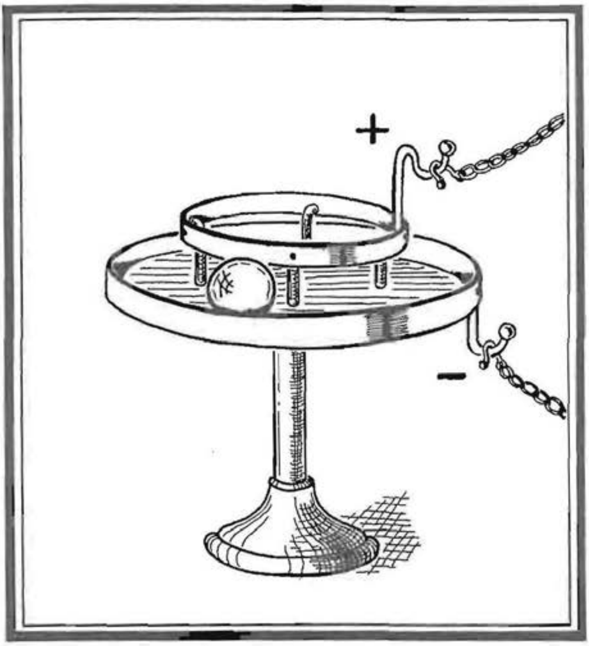

FIGURE 9

The electric principle of Gordon's bells could be used also for producing a continuous unidirectional motion. This "electric racing ball" was propelled along a conducting hoop by the same mechanism that moved the clapper in Gordon's bells.

which has been provided by M. Guyot.[8] The apparatus consisted of an insulated horizontal conducting hoop positioned above a conducting disk having a vertical rim concentric with the hoop (Fig. 9). The arrangement constituted a track for a light sphere of glass placed on the disk between the hoop and the rim. When the hoop and the disk were connected to an electrostatic generator, the sphere ran along this track due to attraction and repulsion exerted by the hoop and the disk upon the points of the sphere that acquired charges from contact with the disk and the hoop (the rolling of the sphere usually had to be initiated with a light push by hand, but once the sphere had started to run, it continued running for as long as the electrostatic generator was in operation).

Since the moving elements in the above described motors were charged by contact, the motors may be classified as "contact motors". This method of charging, however, is neither the only possible nor the most expedient one. Therefore contact motors will probably always be subordinate to most of the motors described in the following chapters. In this connection it may be useful to note that, upon a closer examination of the operation of Gordon's bells and other similar devices, one recognizes that the charging of the moving elements in these devices usually occurs by means of a spark that jumps from a stationary electrode (bell) to a moving element (clapper) as soon as the latter comes close enough to the former. Thus the actual physical contact between the moving and stationary components in these devices is not at all necessary for their operation. In fact, such a contact is harmful insofar as it results in energy losses from impact and friction.

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4. A. Neuburger, *Ergötzliches Experimentierbuch*, Ullstein & Co., Berlin, 1920, pp. 434-436.
5. Gilbert, *Annalen der Physik*, Ser. 1, Vol. 49, pp. 35-46, (1815).
6. Müller-Pouillet, *Lehrbuch der Physik und Meteorologie*, Friedrich Vieweg und Sohn, Braunschweig, 1909, 10th edn., Vol. 4, p. 338.
7. H. B. Dailey, *Modern Electrics*, Vol. 5, pp. 916-917 (1912).
8. M. Guyot, *Nouvelles Recreations Physiques et Mathematiques*, Gueffier, Paris, 1786, Vol. 1, pp. 272-274 and Plate 27.

3

ELECTRIC WIND MOTORS

As already mentioned in the preceding chapter, Andrew Gordon invented two electric motors. His second motor was the "electric fly",[1,2] also known as the "electric whirl", "electric pinwheel", or "electric reaction wheel" (Fig. 10). The electric fly consisted of one or more light metal arms with sharp-point ends bent at right angles to each arm and in the same circumferential direction. The fly was pivoted at its center on an insulated needle. When the needle was connected to an electrostatic generator, a corona discharge* took place from the sharp points of the fly. The air near these points became charged with charges of the same polarity as that of the fly and was then repelled from the points due to repulsion of like charges (the resulting motion of the air is known as the "electric wind"). Similarly, the points themselves were repelled from the charges in the air, and the fly rotated therefore in the opposite sense to that in which the points were directed.

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*Corona discharge is a spontaneous electric conduction in a gas (air) originating from sharp conducting bodies whose electrostatic potential relative to the ground is 3000 volts or higher.

Also the electric fly was used for ringing bells or chimes. This was accomplished by suspending from the fly a clapper, which, as the fly rotated, struck in turn several bells positioned in a circular formation underneath the fly (Fig. 11).[3]

In 1760, Hamilton, professor of philosophy at Dublin, suggested to use a similar device as an electrometer.[4] In this electrometer small weights were suspended from the fly. As the fly turned, the weights were deflected from the vertical direction by centrifugal forces. This deflection was a measure of the fly's speed and, hence, of the strength of the source to which the fly was connected. A more sophisticated electrometer utilizing the electric fly was described by Jakob Langenbucher,[5] a silversmith at Augsburg, Germany, who spent a large part of his time and fortune on improving electrostatic generators and studying electrostatic phenomena. In this electrometer the fly was mounted on a thin vertical cylinder. A fine string was fastened to the cylinder. The string passed over a small pulley and had a light pan attached to its free end. A small weight was placed on the pan. As the fly turned, the string

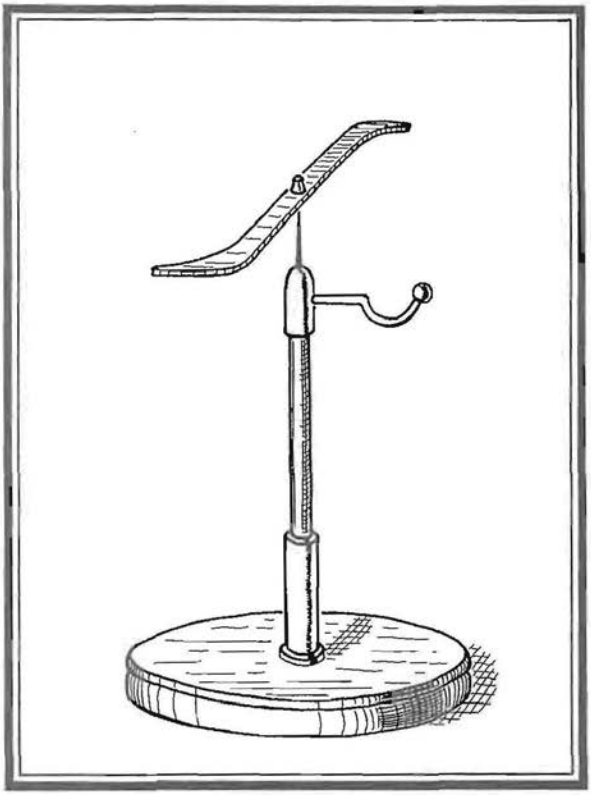

FIGURE 10

Andrew Gordon invented two electric motors. His second motor was the so-called "electric fly".

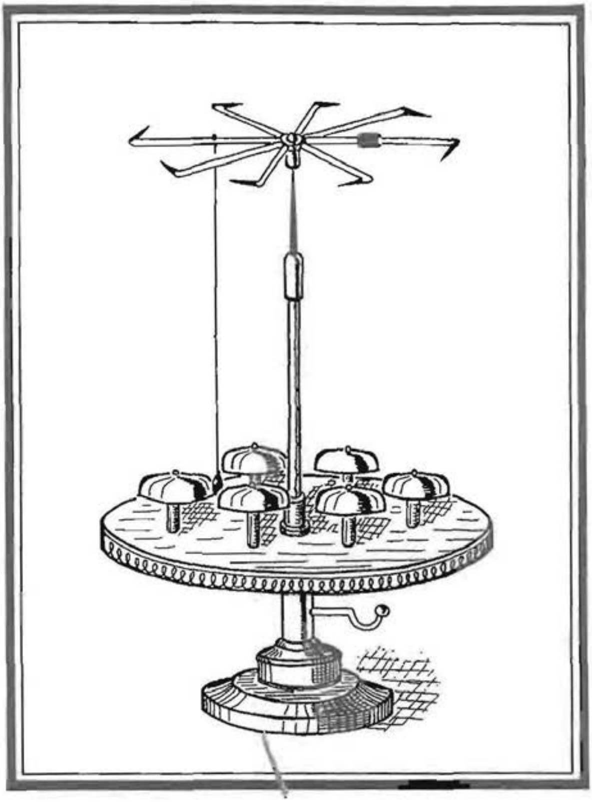

FIGURE 11

Also the electric fly was used for ringing bells with the aid of a clapper suspended from it.

wound itself on the cylinder lifting the pan and the weight. The maximum weight that could be lifted by this electrometer was a measure of the strength of the source from which the fly was operated.

The principle of the electric fly was later used to operate an orrery depicting the orbital motions of the Sun, the Moon, and the Earth (Fig. 12).[6] In such an orrery, also known as the "electrical tellurium", the longer bent arm carried a large sphere at one end, while at the other end it carried a similar but smaller bent arm, each end of which also carried a small sphere. The three spheres represented the Sun, the Moon, and the Earth. The arms were pivoted on sharp points, and each arm had a perpendicular sharp point in the horizontal plane. When the instrument was connected to an electrostatic generator, the two systems rotated about their points of support, the smaller system, being lighter, rotated more rapidly than the larger one. The relative masses of the spheres were adjusted to make the Earth-Moon system rotate twelve times for every single rotation of the Sun.

An interesting variation of the electric fly was constructed in 1761 by Ebenezer Kinnersley, a Philadelphia school teacher and close friend of Benjamin Franklin. Kinnersley called his device the "electrical horse-race".[7] This was a cross formed by two pieces of wood of equal length (probably about 18 inches long) supported horizontally on a central pin. A light figure of horse

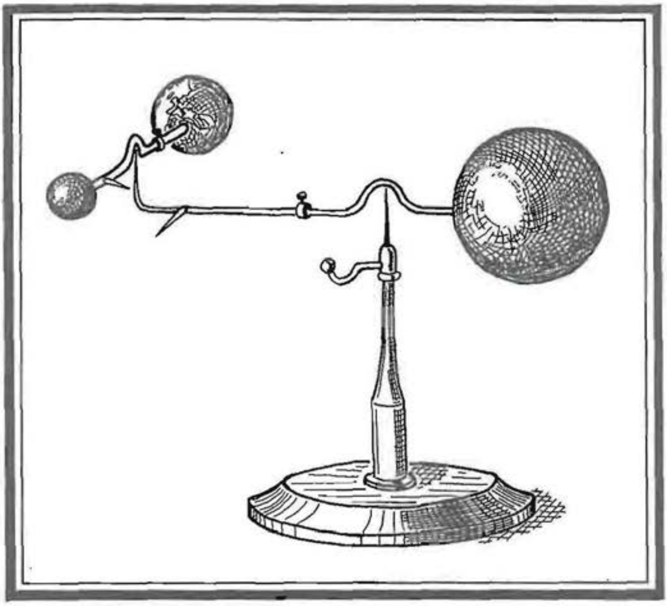

FIGURE 12

The principle of the electric fly was later used to operate an orrery depicting the orbital motions of the Sun, the Moon, and the Earth. The masses of the spheres were adjusted to make the Earth-Moon system rotate twelve times for every single rotation of the Sun.

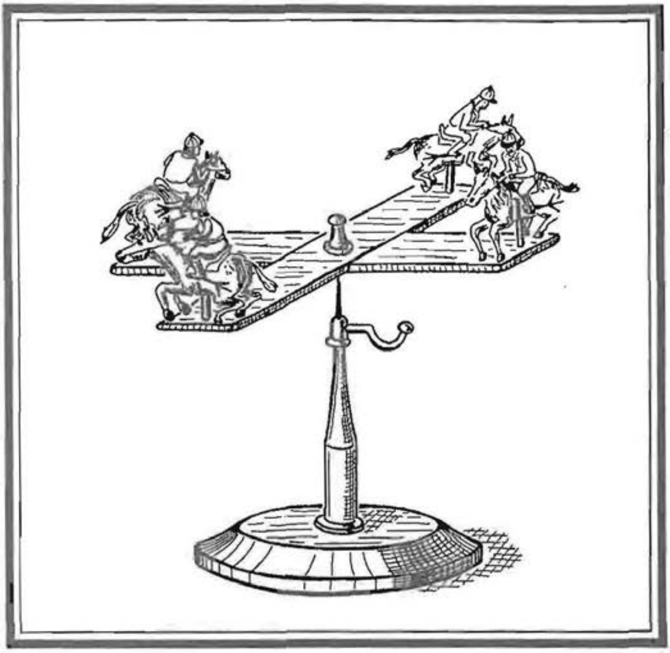

FIGURE 13

An interesting variation of the electric fly was constructed in 1761 by Ebenezer Kinnersley, a friend of Benjamin Franklin. Kinnersley called his device the "electrical horse-race". The electrical horse-race was a popular toy in the latter part of the 18th century.

with his rider was placed upon each extremity of the cross. The motion was produced by corona discharge from the spurs of the riders (Fig. 13). The electrical horse-race was a popular toy in the latter part of the 18th century. Interesting descriptions of this toy have been provided by Langenbucher (Ref. 5, p. 206 and Plate 8), and by Guyot.[8]

To show more convincingly that the electric fly converted electrical energy into mechanical energy, electric flies were placed on horizontal axes and were arranged to lift small weights (Fig. 14) or to climb inclined rails (Fig. 15).[9]

Operation of the electric fly in liquids was investigated by Aimé.[10] A historical account of electric fly studies was presented by Tomlinson.[11] The mechanism of the fly was discussed at some length by Mascart.[12] A quantitative study of the forces acting upon the electric fly was performed by Kämpfer.[13]

A more efficient modification of the electric fly was proposed in 1887 by Bichat.[14] Bichat's electric "tourniquet" consisted of a light vertical frame capable of turning about a vertical axis and supporting two thin vertical wires producing a corona discharge along their entire length. The vertical sides of the frame acted as "spoilers" preventing a corona discharge from the "back side" of the wires. A simple motor based on Bichat's device is shown in Fig. 16.

In recent years the principle of the electric fly (reaction force experienced by a sharp point as a

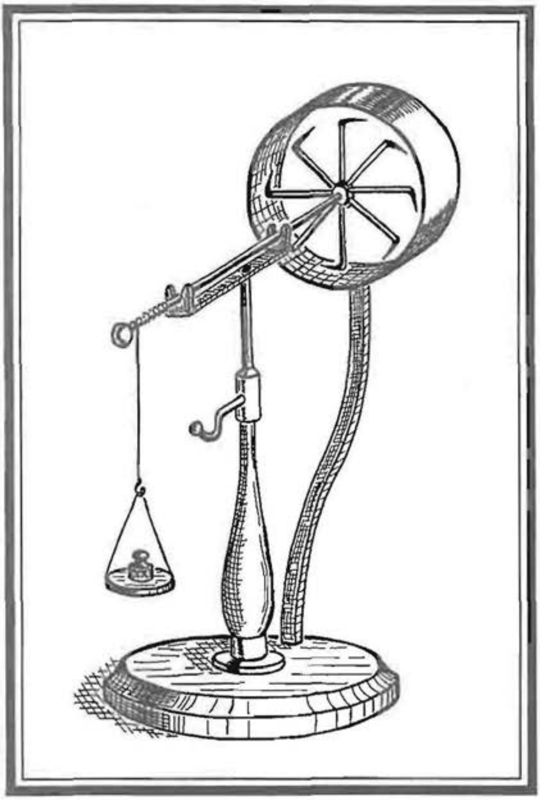

FIGURE 14
Electric fly converted electrical energy into mechanical energy and could lift small weights.

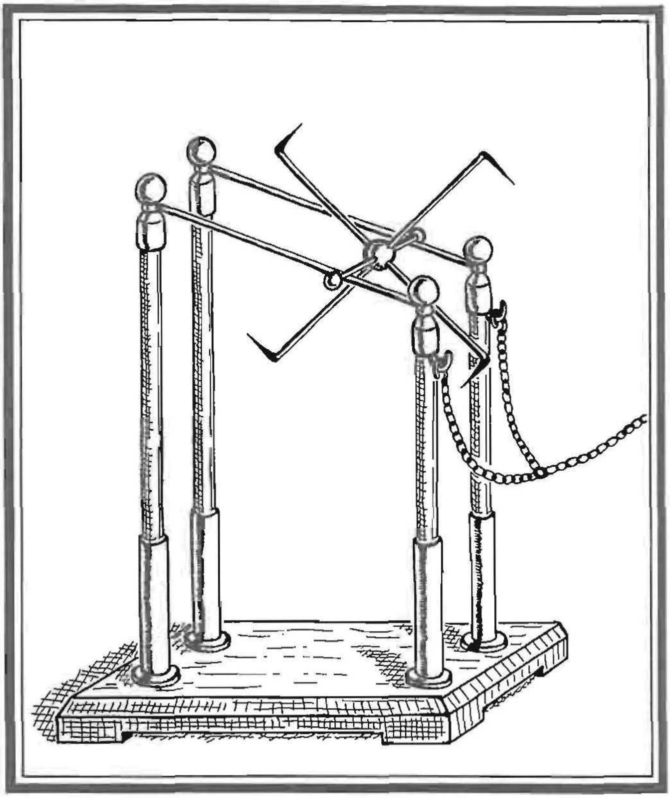

FIGURE 15

Electric fly developed enough mechanical energy for climbing inclined rails.

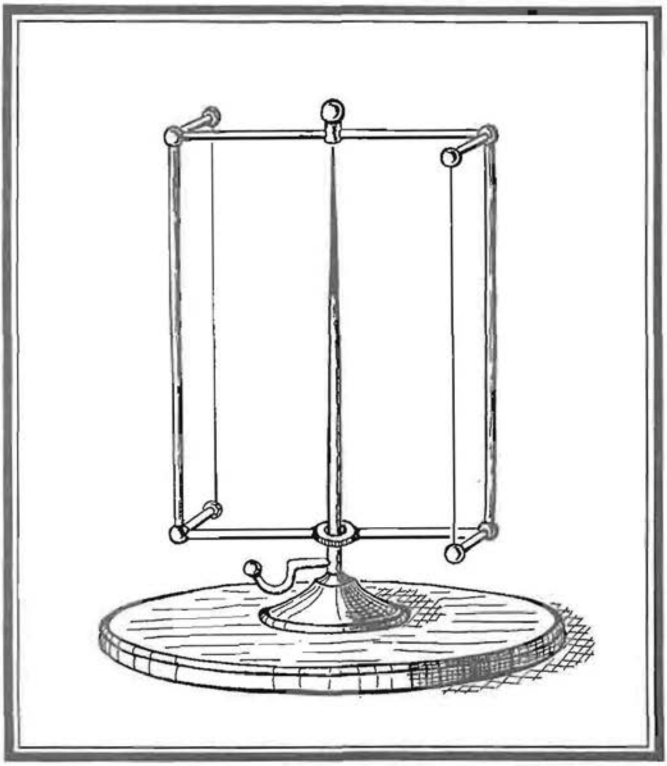

FIGURE 16

A more efficient modification of the electric fly was proposed in 1887 by Bichat, who called his device the "electric tourniquet".

result of a corona discharge from it) has been suggested for a flying machine ("corona-kraft levitation").[15] The lift realizable from such a machine does not, however, appear to be of practical significance.[16]

Closely related to the electric fly were the "electric wind wheels" and the "electric wind turbines". Like the electric fly, they were invented in the 1740's and utilized a corona discharge from sharp points for their operation. Benjamin Franklin studied these devices in 1747 (he first learned of them from his friend Philip Syng). According to Franklin (Ref. 7, p. 184) they were "light windmill-wheels made of stiff paper vanes; also...little wheels, of the same matter, but formed like water-wheels". Their probable appearance was as shown in Figs. 17 and 18. Later versions of these devices have been described by Guyot (Ref. 8, pp. 274, 275 and Plate 27), by Langenbucher (Ref. 5, pp. 75, 76 and Plate 3), by Gale,[17] and by Neuburger.[18]

A delightful electric toy using the electric wind for its propulsion was made by W. R. King, an associate of James Wimshurst (the designer of the electrostatic machine carrying his name). This toy, which may be called an "electrical rabbit hunt", now at the Science Museum in London, is shown in a simplified form in Fig. 19. It consists of a small electric wind turbine mounted on a vertical shaft carrying five light metal arms on its upper end; the arms support

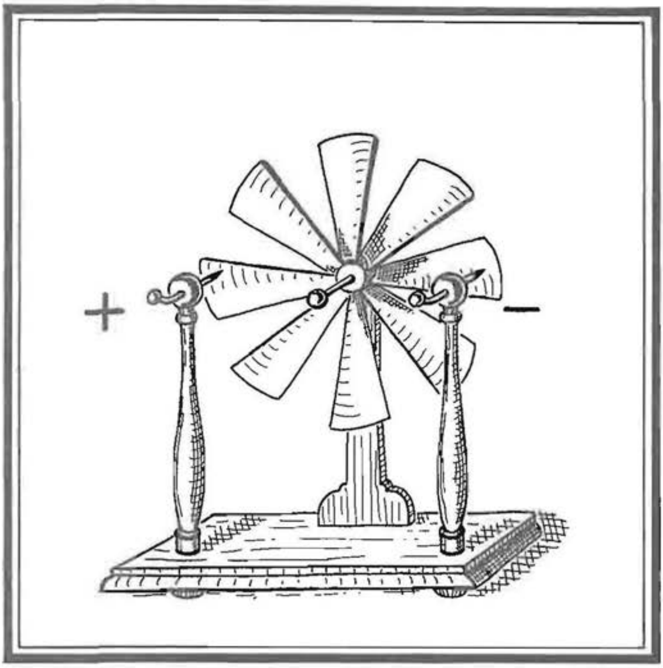

FIGURE 17

Closely related to Gordon's electric fly was the "electric wind wheel". Like the electric fly, it was invented in the 1740's and utilized a corona discharge from two sharp points for its operation.

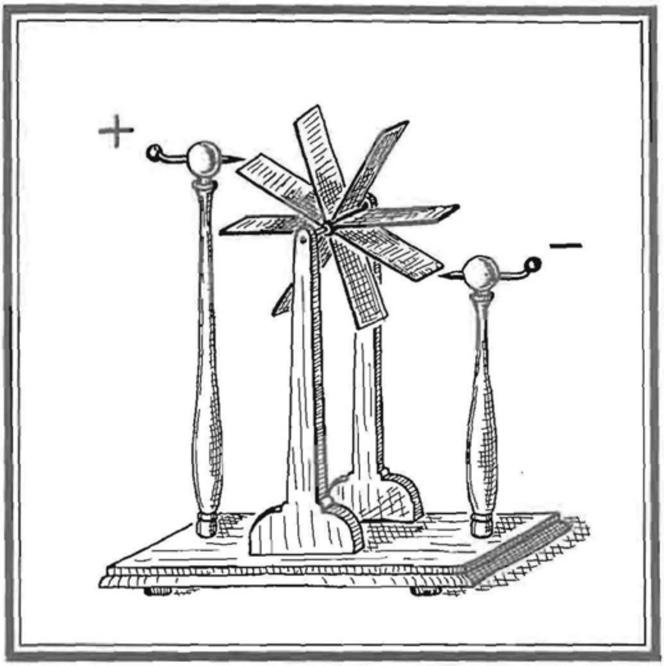

FIGURE 18

Benjamin Franklin studied this "electric wind turbine" in 1747. He concluded that its action depended not as much on the electric wind as on the forces between the charges present on its moving and stationary parts.

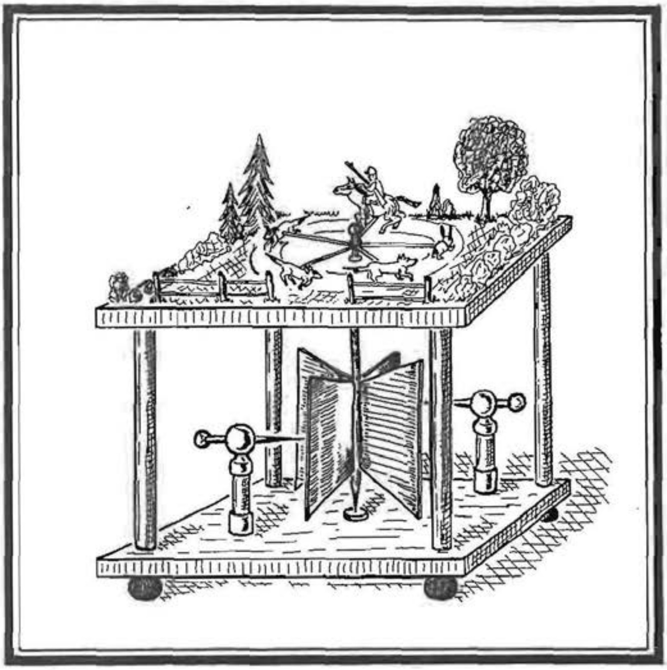

FIGURE 19

A delightful electric toy utilizing the electric wind for its propulsion was made by E. R. King, an associate of James Wimshurst. This toy, which may be called an "electrical rabbit hunt", is now at the Science Museum in London.

figurines of a rabbit, three dogs, and a horseman, who chase each other in a beautiful little garden, as the arms turn powered by the turbine below.

In studying the electric wind motors, Benjamin Franklin concluded that their action depended not as much on the electric wind as such, but on the repulsion and attraction of electric charges present on the moving and stationary parts of the motors (Ref. 7, p. 184). It is very probable that this conclusion led him to the invention of his big electric motors, the famous "electrical wheels", which are described in the next chapter.

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4

FRANKLIN'S SPARK MOTORS AND THEIR DESCENDANTS

If one defines the "electric motor" as a machine capable of converting substantial amounts of electrical energy into mechanical energy, then it was Benjamin Franklin who invented the electric motor, for he was the first person to design and to construct a machine capable of accomplishing such a conversion.

Franklin built two electric motors, which he called "electrical wheels". He described them in a letter to Peter Collinson, Fellow of the Royal Society of London, written in Philadelphia in 1748.[1]

His first motor was a big machine, about 40 inches in diameter. The main part of this motor was a wooden disk mounted horizontally on a vertical wooden axle and carrying 30 glass spokes with brass thimbles on their ends (Fig. 20 and Plate 2). The axle turned on a sharp point of

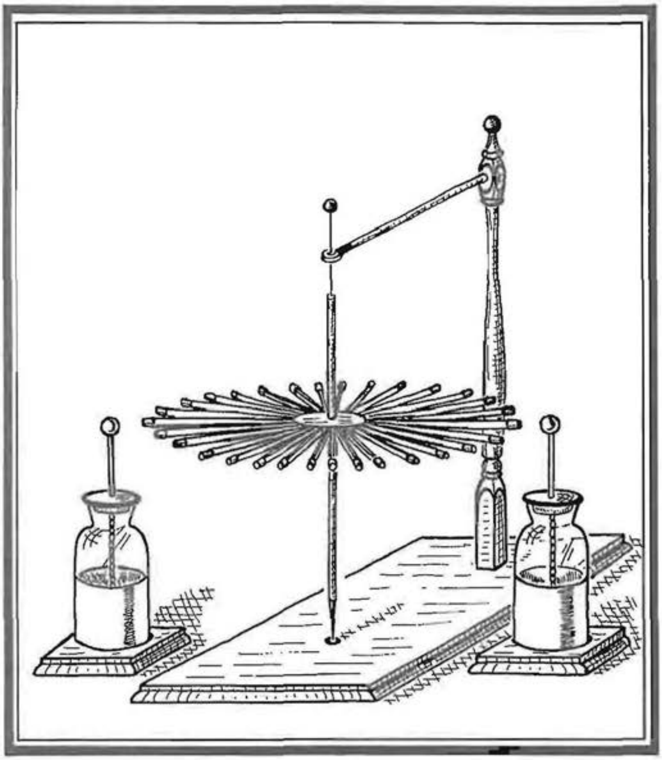

FIGURE 20

Franklin's first "electrical wheel" was the earliest device converting substantial amounts of electrical energy into mechanical energy.

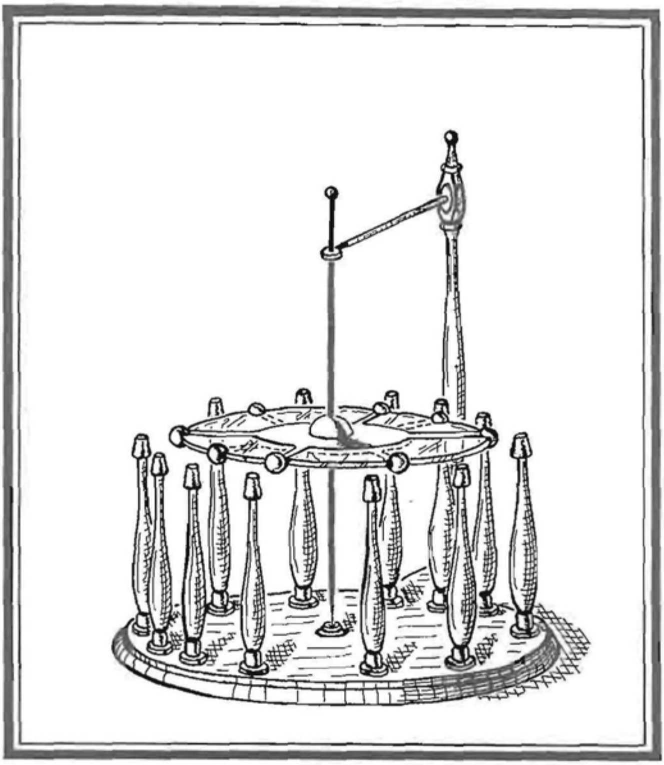

FIGURE 21

Franklin's second "electrical wheel" was more efficient than the first. It was powered by the electric charge stored in its capacitor-rotor.

iron fixed in its lower end and was kept in the vertical position by a strong wire mounted in its upper end and passing through a small hole in a thin stationary brass plate. Two oppositely charged Leyden jars (bottles) were placed in close proximity to the thimbles on the spokes, so that when the wheel turned, the thimbles barely missed the knobs of the jars.

As the thimbles moved past the Leyden jars, a spark jumped between a jar knob and the passing thimble, charging the latter with a charge of the same polarity as that of the knob. Therefore each knob attracted the oncoming thimbles ("opposite charges attract") and repelled the departing thimbles ("like charges repel"), causing the motor to turn. The motor, being perfectly symmetric, could turn in either direction, and usually required a starting push by hand to initiate the charging of the thimbles.

Here is how Franklin himself described the operation of his motor:[1]

"If now the wire of a bottle, electrified in the common way, be brought near the circumference of this wheel, it will attract the nearest thimble, and so put the wheel in motion; that thimble, in passing by, receives a spark, and thereby being electrified, is repelled, and so driven forwards; while a second being attracted, approaches the wire, receives a spark, and is driven after the first, and so on till the wheel has gone once round, when the thimbles before electrified approaching the wire, instead of being attracted as they were at first, are repelled, and the motion presently ceases. But if another bottle, which had been charged through the coating (e.i. charged oppositely to the first, O. J.), be placed near the same wheel, its wire will attract the thimble repelled by the first, and thereby double the force that carries the wheel round; and, not only taking out the fire (electric charge, O. J.) that had been communicated to the thimbles by the first bottle, but even robbing them of their natural quantity, instead of being repelled when they come again towards the first bottle, they are more strongly attracted, so that the wheel mends its pace, till it goes with a great rapidity, twelve or fifteen rounds in a minute, and with such strength, as that the weight of one hundred Spanish dollars, with which we once loaded it, did not seem in the least to retard its motion".

Franklin was not quite pleased with this motor, however, because it required "a foreign force, to wit, that of the bottles" for its operation. He constructed therefore a second, "self-moving", motor, which itself contained the electrical energy to be converted into the mechanical motion.

The second motor was made as follows (Fig. 21 and Plate 3). A disk of window glass, 17 inches in diameter, was gilded on each side, except for narrow areas next to the edge. Several lead spheres (bullets) were fixed to the edge of the disk and were connected in alternation to the two gold layers. The disk was mounted on a vertical axle consisting of two pieces of strong wire, each about 9 inches long; the upper wire being in contact with the top layer of gold, the lower wire being in contact with the bottom layer. The lower wire terminated in a sharp point resting on a piece of brass cemented within a glass salt-cellar. The upper wire passed through a hole in a thin brass plate cemented on a long strong piece of glass. This wire carried a small ball on its upper end for preventing a corona discharge from it. Several glass pillars with thimbles on their tops were positioned in a circle around the disk, so that the spheres on the edge of the disk barely missed the thimbles when the disk was in motion. The motor was powered by electricity stored in the disk itself, which, due to the two layers of gold, constituted a capacitor capable of storing an appreciable quantity of charge (to charge the rotor, the two layers of gold were temporarily connected to an electrostatic friction generator).

The motor operated on the same principle as Franklin's first motor, except that now the thimbles were stationary and received positive or negative charges from the passing spheres, rather than the other way around. As in the first motor, the rotation persisted as long as there was enough charge stored in the capacitor (rotor) to produce sparks between the spheres and the thimbles.

Franklin reported that his second motor

(which was more powerful than the first one) could make 50 turns in a minute and could run for up to 30 minutes on a single charging of the rotor.[1] Experiments with replicas of Franklin's motors performed by the author indicate that the original motors developed a power of the order of 0.1 watt,[2,3] which was a very impressive achievement for that very early period in the history of electric science.

Several authors have described simplified versions of Franklin's motors.[4,5] Miniature Franklin-type motors have been constructed and described by A. D. Moore[6] (Fig. 22). One such motor consists of a Plexiglas disk about 4 inches in diameter with small conducting balls embedded in the rim. The disk turns on a horizontal axis supported by a base behind the disk. The motor runs when placed between two conductors connected to an electrostatic generator. To make the motor self-starting and one-way running, the conductors may be provided with short auxiliary rods tangential to the disk; since the rods dispatch sparks predominantly in the direction of their free ends, the disk also turns in this direction. Another little motor of the same type designed by Moore is shown in Fig. 23.

An obvious improvement of Franklin's motors would be to use a cylindrical rotor with electrodes in the shape of long strips. Such electrodes would accept more charge than thimbles or spheres, and the power of the motor would be increased considerably. Motors of this type

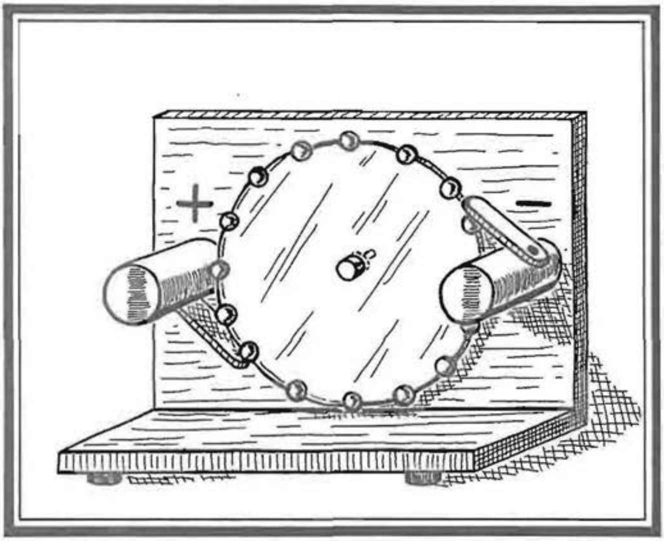

FIGURE 22

Several authors have described simplified versions of Franklin's motors. One such motor consists of a Plexiglas disk about 4 inches in diameter with small conducting balls embedded in the rim. The disk turns on a horizontal axis supported by a base behind the disk.

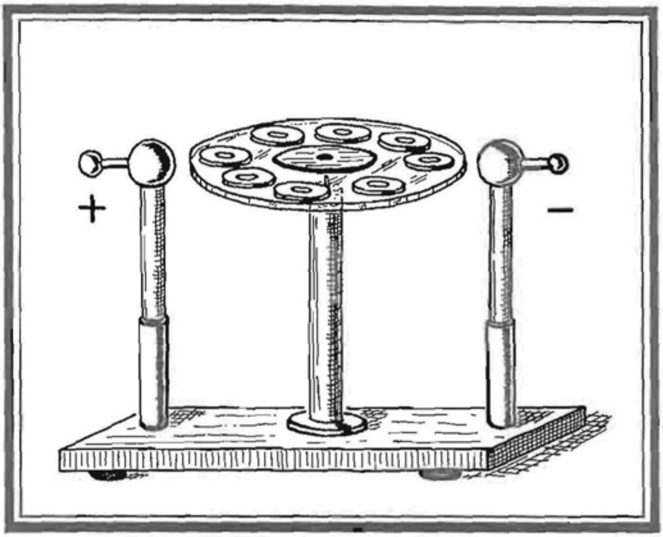

FIGURE 23

This inexpensive miniature Franklin-type motor of recent design can be used for lecture-room demonstrations of electrostatic forces. The rotor disk can be made from cardboard, wood, or plastic. For the rotor electrodes one can use thumbtacks or small aluminum foil disks.

have indeed been constructed. Here is a description of a "bell jar" motor taken from a book published in 1847 (Fig. 24):

"On a pivot, *a*, suspend a bell jar having four pieces of tinfoil pasted on its sides, *b*, *c*, *d*; connect the jar, by means of the insulated wire, *y*, with the prime conductor (high-voltage terminal of an electrostatic friction generator, O. J.) so that the pieces of tinfoil may receive sparks. On the opposite side arrange a conductor, *x*, in connection with the ground by a chain. On putting the machine into activity, the jar will commence rotating on its pivot."[7]

Small motors closely related to both Franklin's first motor and to pendulum motors were used in the rotary-type "perpetuum mobile" (see Chapter 2) operated from a Zamboni pile.[8] The main part of these motors (Fig. 25) was a light insulated arm pivoted on a sharp point and carrying a piece of tinsel on each end. The tinsels could just touch the knobs of the pile when the arm was moving on its pivot. The device functioned in the same manner as Franklin's first motor, the two tinsels corresponding to the thimbles of the latter.

An analogous design has recently been described as a "millifleapower motor" operating from a nuclear battery.[9] In this motor a light aluminum vane with pointed ends (Fig. 26) bent so as to form an inverted V is mounted at its midpoint on the tip of a sharp needle protruding from the positive terminal of the battery. As the

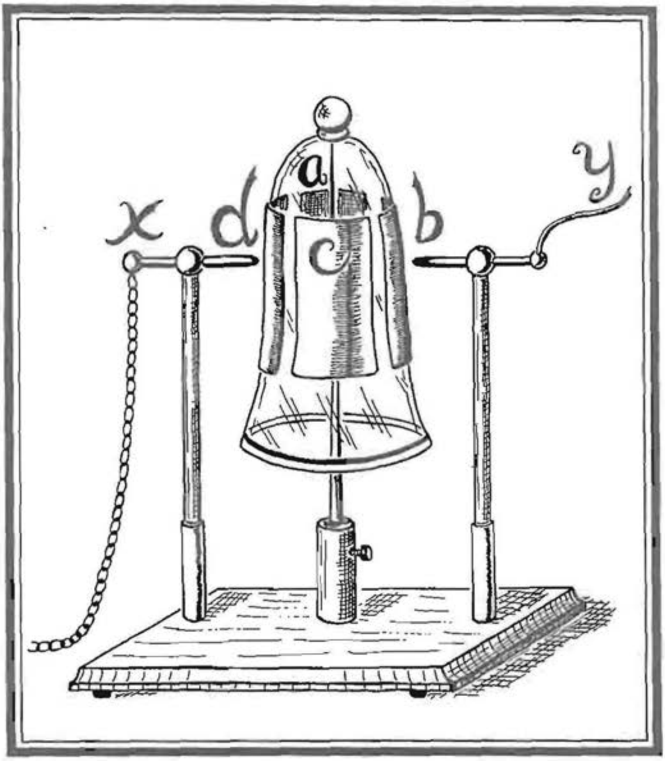

FIGURE 24

This "bell jar" Franklin-type motor had a cylindrical rotor with tinfoil electrodes in the shape of long strips.

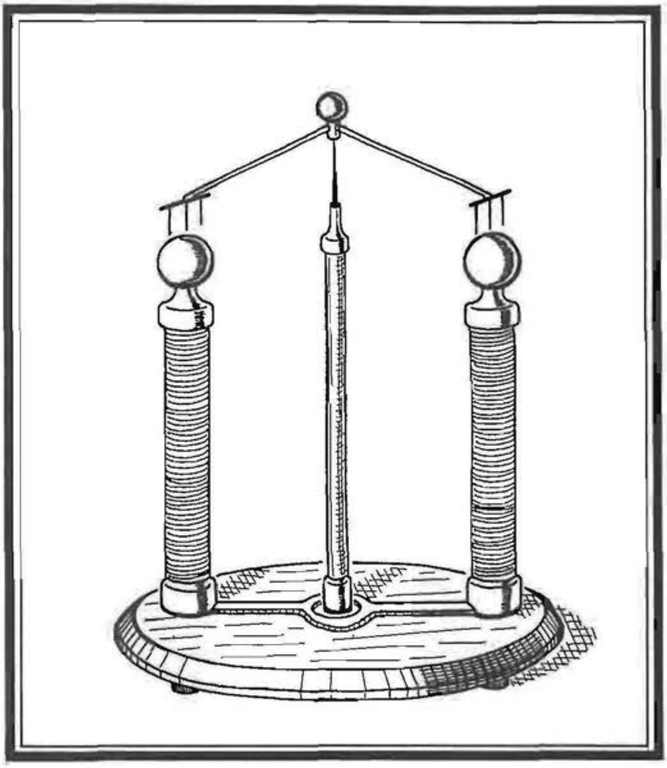

FIGURE 25

This small motor was used as a rotary-type "perpetuum mobile" operating from a Zamboni pile. Such motors turned for years without stopping.

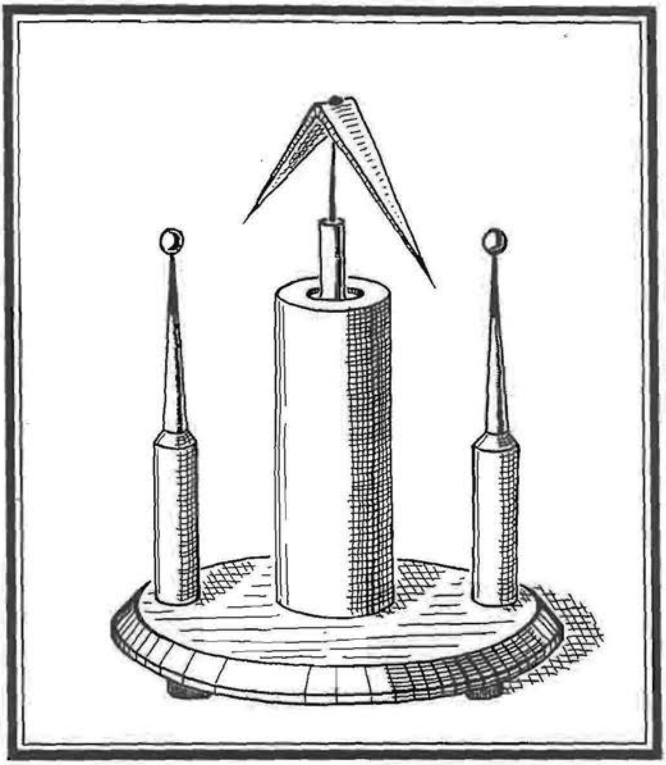

FIGURE 26

An analogous design has recently been described as a "millifleapower motor" operating from a nuclear battery.

vane turns, its ends come close to two spheres connected with the ground through a high resistance and become attracted by them. A discharge from the ends of the vane charges the two spheres, and the spheres then repel the ends of the vane. During the time it takes the vane to complete one half of its revolution, the charges of the spheres leak off to the ground, so that the spheres can again attract the ends of the vane, accept new charges from them, and then again repel them. The motor is expected to run for many years.

An interesting motor derivable from Franklin's first motor and from pendulum motors was suggested for operation from an electrophorus.[10] The main part of this motor (Fig. 27) was a light conducting ring supported in a vertical plane on an insulated needle. In front of the ring there were two insulated spheres, which were so positioned that the ring just missed them as it turned on its needle. The spheres were either charged oppositely by the electrophorus, or only one sphere was charged, in which case the second sphere was grounded. The device operated on the same principle as Franklin's first motor.

Of all the motors discussed above, Franklin's original motors and the bell jar motor were the most powerful ones. One can make such motors even more powerful by increasing the number of moving and stationary electrodes. But this can be done only up to a limit, because if the electrodes are too close to one another, sparks will

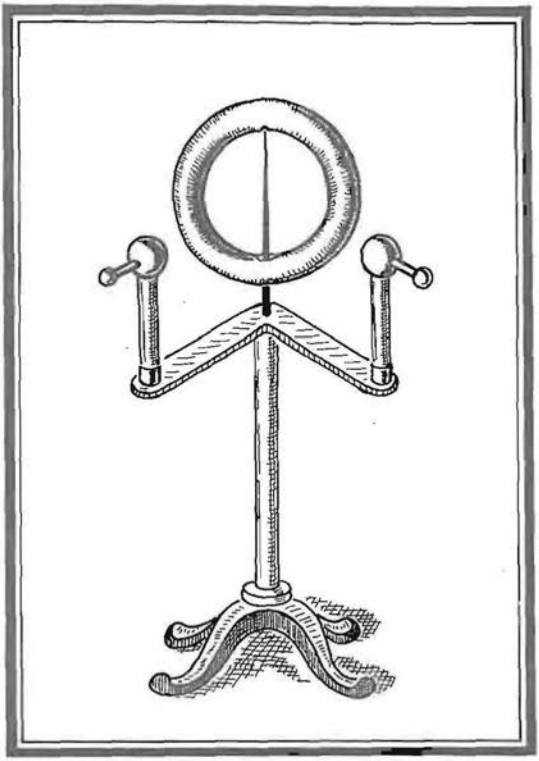

FIGURE 27

This motor derivable from Franklin's first motor and from pendulum motors was suggested for operation from an electrophorus.

jump all around from one electrode to the next, thus short-circuiting the motor. The motor will then not work at all, unless the operating voltage is lowered. But by lowering the voltage one also lowers the power, so that the gain obtained by increasing the number of electrodes becomes offset by the decrease in the operating voltage. Franklin type motors have therefore an inherent limitation in their power characteristics, and the fact that they depend for their operation on the presence of many metallic electrodes is one of their disadvantages.

Since in Franklin's motors and in other motors described in this chapter the rotor is charged by means of electric sparks, these motors may be classified as "spark motors". Toward the end of the 19th century a way was found to construct electrostatic motors based on the same mechanism of attraction and repulsion between electric charges as in Franklin's motors, but with rotors (or stators) charged more efficiently than it is possible to do by means of the sparks. These motors are described in the next chapter.

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5

CORONA MOTORS AND MOTORS SIMILAR TO THEM

In 1867, W. Holtz, the inventor of the electrostatic "influence" machine (generator) carrying his name, discovered that this machine could function as a motor when powered by another similar machine.[1] In order to study this effect in some detail, the famous German physicist J. C. Poggendorff ordered the construction of a special device, analogous to Holtz's machine, but designed to operate only as a motor and provided with numerous adjustable components so as to operate under a wide range of conditions.[2]

The basic part of this motor was a vertical glass-disk rotor placed between two ebonite crosses carrying metallic sharp-needle "combs" (Fig. 28 and Plate 4). The sharp points of the combs almost touched the surface of the disk, so that the disk could be charged by means of a corona discharge from the combs when they were connected in alternation to an electrostatic generator. Each comb could be oriented so as to make an arbitrary angle with respect to a radial direction.

Just like the sparks in Franklin's motors, the corona discharge from a comb deposited on the rotor a charge of the same polarity as that of the comb. Each comb repelled therefore the segment of the rotor carrying charges which it sprayed onto the rotor and attracted the segment carrying charges sprayed onto the rotor by the preceding comb. Because of a continuous discharge between the combs and the rotor, almost the entire surface of the rotor was sprayed with electric charges. The repulsion and attraction between the combs and the rotor, were therefore not only much stronger than in Franklin's motors, (where only the electrodes were charged) but were also much steadier, since the distances between the combs and the charges on the rotor were always the same. As a result, the torque and power obtainable with this motor were far greater than those obtainable with Franklin's motors of similar dimensions.

Poggendorff made a thorough study of his motor, varying all its important parameters (his article comprises 32 pages). He used several rotors of different thickness and surface characteristics, whose weight ranged from 2.5 to 4.5 pounds (all rotors were 15 inches in diameter). He varied the number, the orientation, and the polarity of the combs.

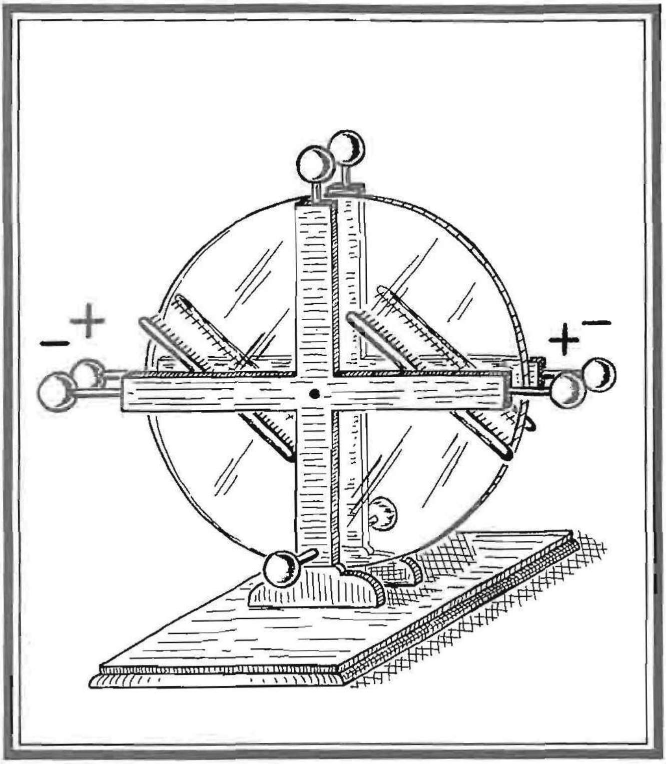

FIGURE 28

Poggendorff's corona motor had a glass-disk rotor placed between two ebonite crosses carrying metallic sharp-needle "combs".

He found that a motor with combs arranged along the radii of the rotor could rotate equally well in either direction but was not self-starting, since such combs sprayed charges onto the rotor in a perfectly symmetric fashion. However, if the combs were slanted relative to the radii, the motor became self-starting and unidirectional, because such combs sprayed charges predominantly in one direction. He also fould that the performance of the motor could be improved by placing pieces of glass, cardboard, or metal close to the surface of the rotor (this is the principle of the modern "backing plate" or "lining"; see Chapter 10). When properly adjusted, the motor could run at better than 300 rpm.

Poggendorff had fully appreciated the superiority of his motor in comparison fo Franklin's motors, and had stated so at the end of his article. In fact, he had indicated that his motor used from 1200 to 1800 times as much current as Franklin's motors, in which case, assuming that the operating voltage of his motor was the same as that of Franklin's motors (approximately 100 kilovolts), the power of his motor must have been close to 100 watts.

At the time when Poggendorff's article was written, however, it was considered unscientific to expect that electricity (*any* electricity) could ever become a significant source of motive power. This may be the reason why Poggendorff, speaking of the rotation phenomenon that he investigated, declared at the end of his article: "...it would be a sanguine hope if one wanted to believe that any useful mechanical effect could be achieved with it. That this is not possible, follows already from the consideration of how small is the quantity of electricity that is here put into play in comparison to that developed by a voltaic battery, with which one nevertheless, even with the help of the magnetismus produced by it, has so far achieved nothing substantial ("Erkleckliches")". The argument was obviously weak, but taking into account Poggendorff's reputation as an eminent scientist, it was probably sufficient to discourage further serious investigations of the corona-induced rotation for many years to come.

Since Poggendorff's motor depended on a corona discharge for its operation, the motor may be classified as a "corona motor".

Holtz's rotation phenomenon was also studied by the Danish physicist C. Christiansen (whose interest in the phenomenon had been aroused by a preliminary report of Poggendorff's investigations published in 1867).[3] Christiansen described two motors based on Holtz's discovery. His first motor consisted of a horizontal disk rotor and two stationary corona-producing combs. His second motor was similar to the first except that in it the glass disk was stationary and the combs constituted the rotor. The rotor combs in this second motor were located below the glass disk and were charged by means of two foil strips hanging from them and sliding along

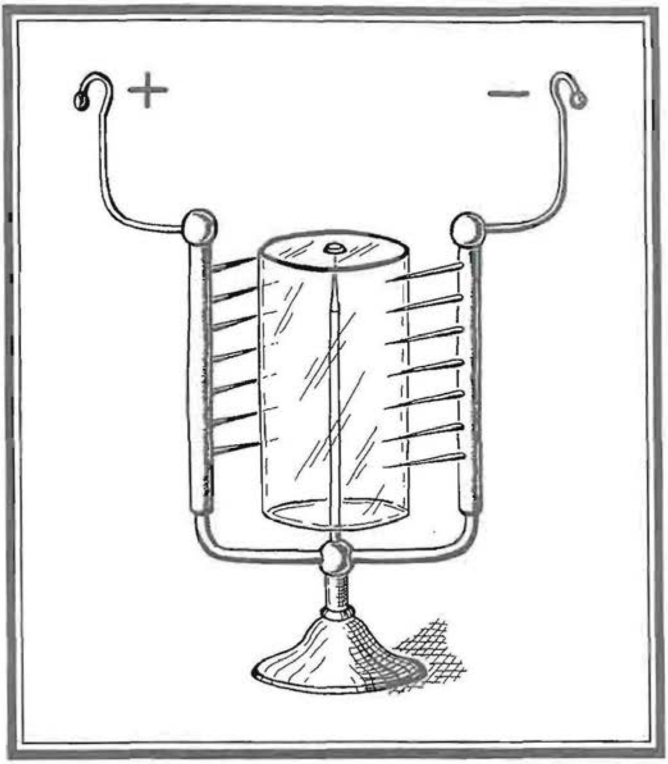

FIGURE 29

This self-starting corona motor with a cylindrical rotor was described in 1871 under the name of "electric tourbillion".

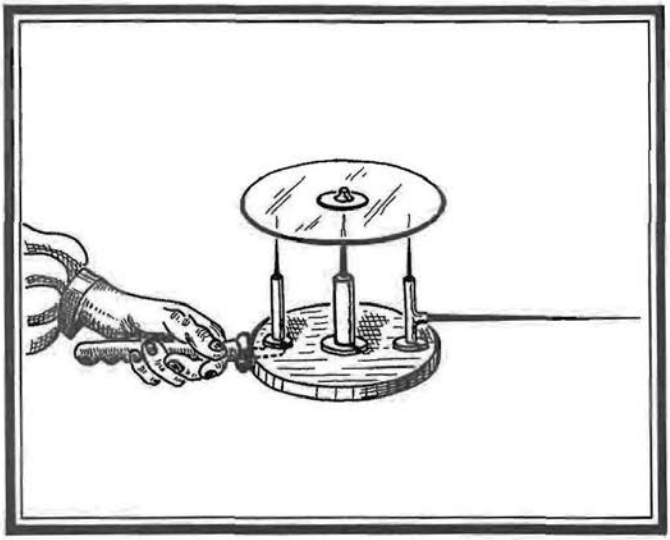

FIGURE 30

In this hand-held corona motor (attributed to Ruhmkorff) the horizontal wire, by a corona discharge, extracted charges from the power source, and the vertical needle connected to this wire, also by a corona discharge, sprayed these charges onto the rotor.

two horizontal concentric contact rings mounted on the base of the motor.

Cylindrical and spherical motors operating on the same principle as Poggendorff's motor were described in 1871 by W. Gruel (Fig. 29), who called them the "electric tourbillions".[4] Gruel pointed out that these motors could be made self-starting and unidirectional by inclining the combs in the same rotational direction with respect to the surface of the rotor. He also suggested that by providing the rotors with a series of holes, the motors could be used as sirens.

A disk motor not noticeably different from Poggendorff's motor was patented in the U.S.A. in 1891 by J. W. Davis and J. B. Farrington.[5]

An interesting hand-held corona motor (attributed to Ruhmkorff) was described in 1876 by M. E. Mascart.[6] The motor had a horizontal mica disk rotor (Fig. 30) supported on a vertical needle by a jewel bearing, such as are used for supporting compass needles. Below the disk there were two vertical corona-producing needles mounted on a hard rubber base. One of the latter needles was connected to a metal handle, the other was connected to a long, stiff, horizontal wire terminating in a sharp point. To set the motor in motion, the operator held the motor so that the sharp point of the horizontal wire was in the proximity of a charged conductor. By a corona discharge, the horizontal wire then extracted charges from the conductor, and the ver-

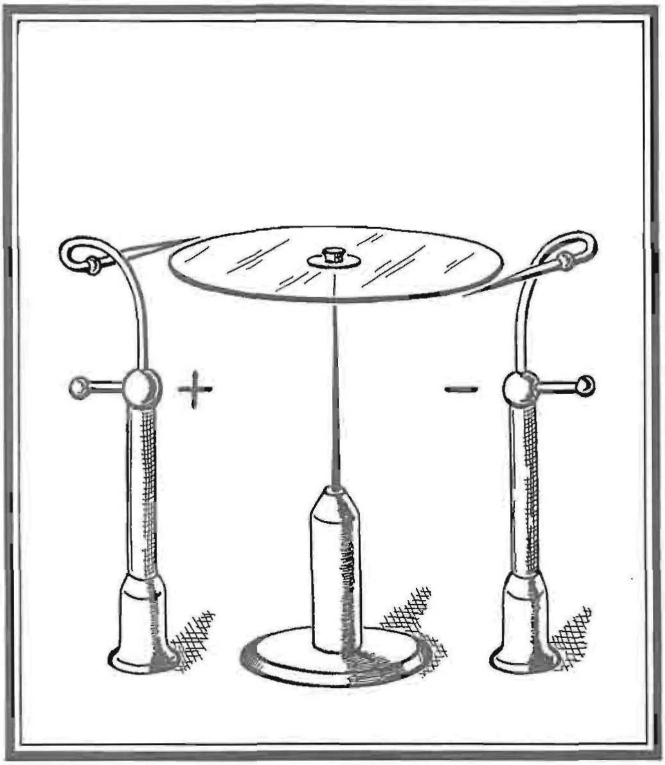

FIGURE 31

This motor had two insulated corona-producing points tangential to the rotor disk and oriented in the same rotational direction.

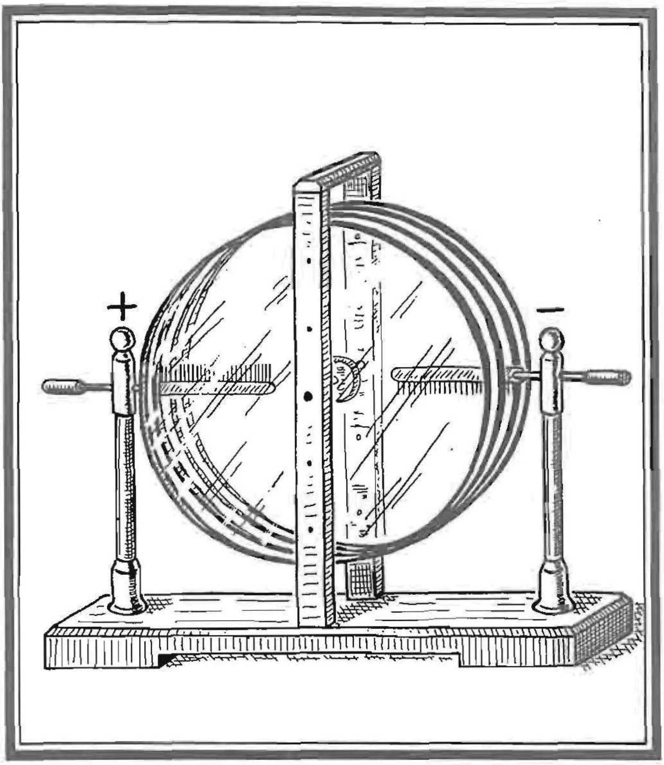

FIGURE 32

This corona motor with a compound glass rotor could run at about 2000 rpm and had a power of about 90 watts.

tical needle connected to this wire, also by a corona discharge, sprayed these charges onto the rotor. The second vertical needle discharged the rotor and conducted its charges to the ground through the hand and body of the operator.

A number of experiments with Poggendorff type corona motors were reported in 1921 by V. E. Johnson.[7] One of his motors was similar to Ruhmkorff's motor (Fig. 31). This was a horizontal mica disk, about 6 inches in diameter, supported on a vertical needle point. At the edge of the disk there were two insulated corona-producing points tangential to the disk and oriented in the same rotational direction. Another of Johnson's motors was a big machine consisting of two stationary glass disks and a three-piece glass rotor that could rotate on ball bearings between the stationary disks. The rotor was made of two large glass disks separated by a smaller disk so as to have a deep slot along its edge. Two flat sharp-point combs were inserted diametrically opposite to one another into the slot of the rotor (Fig. 32). Johnson estimated that his motor could run at about 2000 rpm and had a power of about 90 watts.

Just as Poggendorff's motor was derived from Holtz's electrostatic machine, a series of electrostatic motors were similarly derived from Wimshurst's electrostatic machine.

In 1891 five such motors were constructed by William McVay of New York City.[8] McVay's first motor (Fig. 33) consisted of two horizontal glass disks, about 12 inches in diameter, one stationary and the other rotating on the vertical axis just above the first. The lower disk had two quadrants of tinfoil, and the upper disk had 16 tinfoil sectors, as shown in the figure. The power (from a Wimshurst machine) was delivered to the motor by means of two insulated arms, each of which terminated in two brushes, one touching continually one of the lower quadrants, the other charging a sector on the upper disk just clear of the edge of the quadrant. Charges of the same polarity were thus deposited on the quadrant and on the sector, causing them to repel each other. An "equalizer" reduced the charge of the sectors before they passed over the further edge of an oppositely charged quadrant, thus reducing the back torque on the rotating disk. An important new feature of this motor was the simultaneous charging of the stationary quadrants and of the moving sectors, which assured a relatively strong starting torque and, together with the neutralizing system, assured a reliable unidirectional operation. McVay also constructed motors of cylindrical geometry, one of which is shown in Fig. 34. In this motor the quadrants were located on the inner cylinder, while the charging and neutralizing brushes were on the neck of the outside cylinder.

McVay's first motor was later modified for charging by combs, rather than by brushes (Fig. 35). The motor then operated essentially as

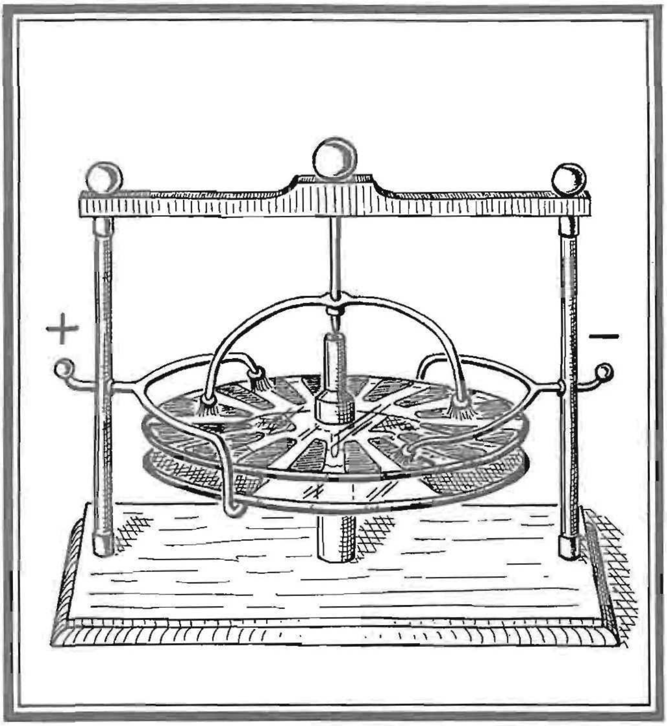

FIGURE 33

McVay's first motor consisted of two horizontal glass disks, about 12 inches in diameter, one stationary and the other rotating on the vertical axis just above the first.

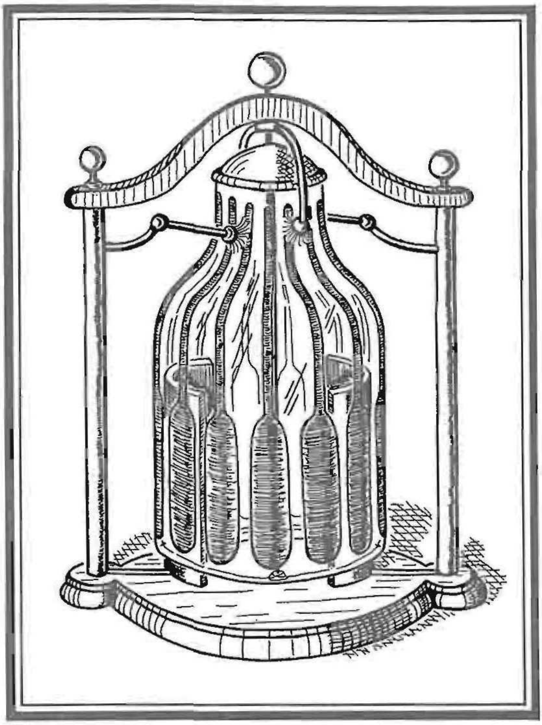

FIGURE 34
In this McVay's motor the quadrants were located on the inner cylinder (shown as two segments), while the charging and neutralizing brushes were on the neck of the outside cylinder.

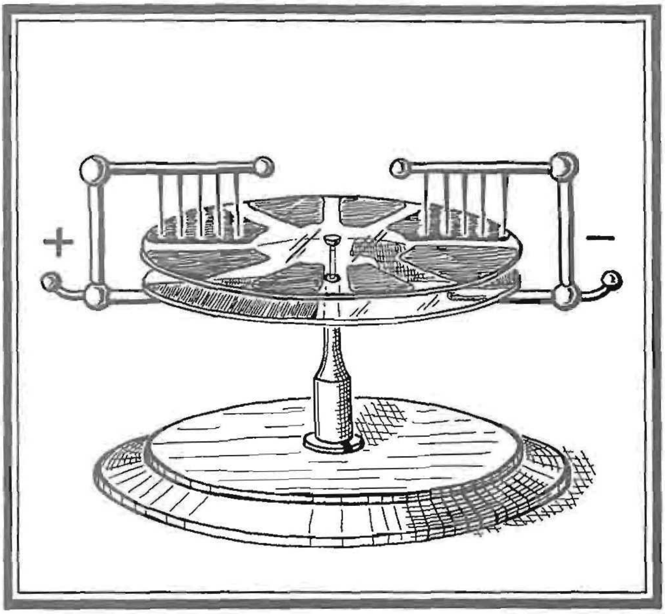

FIGURE 35

McVay's first motor was later modified for charging by combs, rather than by brushes. The motor then operated essentially as Poggendorff's corona motor, retaining, however, its self-starting and unidirectional qualities.

Poggendorff's corona motor, retaining, however, its self-starting and unidirectional qualities.

Instructions for building a Poggendorff motor may be found in the May 1971 issue of Popular Science.[9] Instructions for building a simple McVay motor may be found in the January 1914 issue of Electrical Experimenter[10] (the author is grateful to Mr. Thorn L. Mayes for this information).

Since a corona discharge in air at atmospheric pressure requires a minimum voltage of about 3000 volts, ordinary corona motors can operate only from sources capable of supplying a voltage of this magnitude. Such voltages are, of course, easily attainable at the present time, and since the corona motors are very simple and efficient devices, they have been further developed and studied in recent years. We shall return to them in the last chapter of this book.

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6

CAPACITOR MOTORS

In 1889, Karl Zipernowsky, a Hungarian engineer (co-inventor of practical electrical transformers), constructed a new type of electrostatic motor,[1] which was derived from Thomson's quadrant electrometer.[2] The rotor of this motor (Fig. 36) consisted of two pairs of aluminum sectors insulated from each other and from the rest of the apparatus. The stator consisted of four double (hollow) sectors of brass enclosing the rotor. The rotor was fitted with a commutator in four parts, by means of which the sectors of the rotor were charged oppositely to those sectors of the stator into which they were entering and identically to those sectors of the stator which they were leaving. An interesting property of this motor was that it could operate from high-voltage dc as well as from high-voltage ac sources.

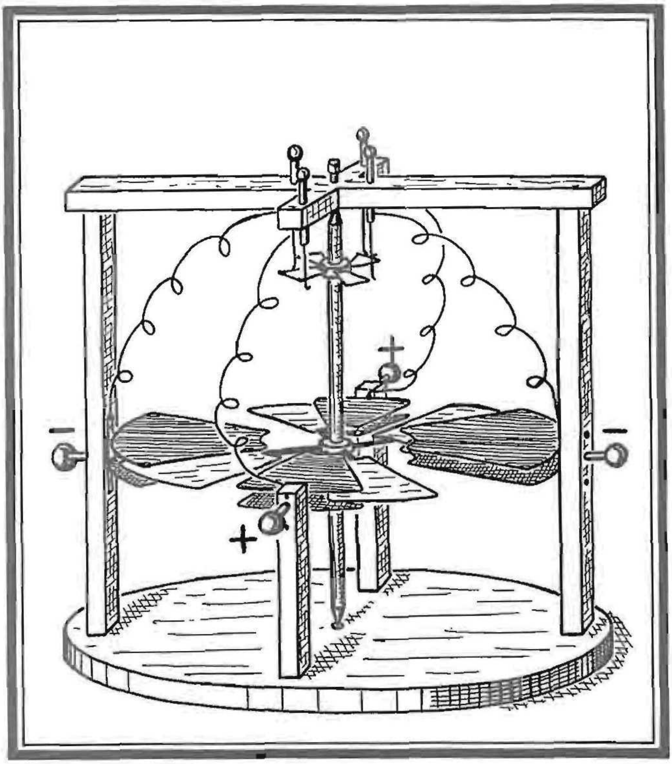

FIGURE 36

This motor was built in 1889 by Karl Zipernowsky, a Hungarian engineer. It operated from dc as well as from ac sources.

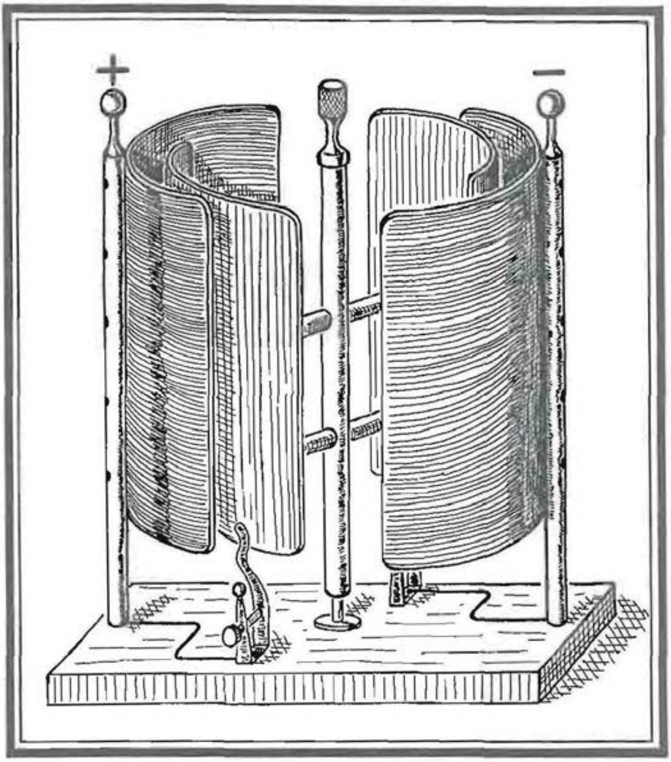

FIGURE 37

This capacitor motor was described in 1904 by van Huffel. Its rotor could be charged by contact or by sparks.

Inasmuch as Zipernowsky's motor operated as a result of the electric forces exerted by one charged conducting plate upon a second charged conducting plate (which are the same forces that act upon the two plates of a capacitor) it constituted what is now called an electrostatic "capacitor motor".

A simpler version of a capacitor motor was described in 1904 by van Huffel.[3] This motor was based on the so-called Thomson's replenisher.[4] The motor had an essentially cylindrical geometry (Fig. 37) and consisted of a rotor with two insulated bent brass plates mounted on a vertical axle and located between two similar, but slightly larger, plates of the stator. The rotor plates (which were not quite coaxial) were charged by means of two metallic tongues connected to the stator plates; the tongues touched the rotor plates just as the latter began to clear the stator plates. The charging of the rotor plates could occur by a direct contact as well as through a spark, depending on the adjustment of the tongues.

Since capacitor motors do not require sparks or a corona discharge for their operation, they can operate, at least in principle, from as low a voltage as one desires to use. This is one of their important advantages and is one of the reasons that such motors have been given considerable attention in recent years. Furthermore, as already indicated, capacitor motors can operate not only from dc sources, but also from ac sources. Finally, when powered by an ac source, they can operate both as synchronous and asynchronous motors (Zipernowsky's original motor operated from ac as an asynchronous motor).

A synchronous capacitor-type electrostatic motor is merely a multi-electrode capacitor motor without a commutator, the proper charging of the rotor being accomplished by continuously supplying an ac voltage of proper frequency between the stator and the rotor (Fig. 38). It is easy to see that if the rotor moves by one electrode in one period of the supply voltage, then the ac voltage accomplishes the same effect as that accomplished by a dc voltage with a commutator. The synchronous velocity is therefore $2\pi f/N$, where f is the frequency of the supply voltage and N is the number of the electrodes.

Several precision-made synchronous motors were described in 1969 by B. Bollée.[5] One of these motors ran on sapphire bearings and had a cylindrical aluminum rotor 1 centimeter long and 0.45 centimeters in diameter; the rotor and the stator had 60 electrodes each, with a 0.001 centimeter gap between stator and rotor electrodes. The maximum power of this motor was about 100 microwatts at 220 volts and 50 hertz. Another motor (for an electric clock) had a dielectric disk rotor, with four rows of 100 electrodes on each side, located between two bearing covers, each with five rows of 100 elec-

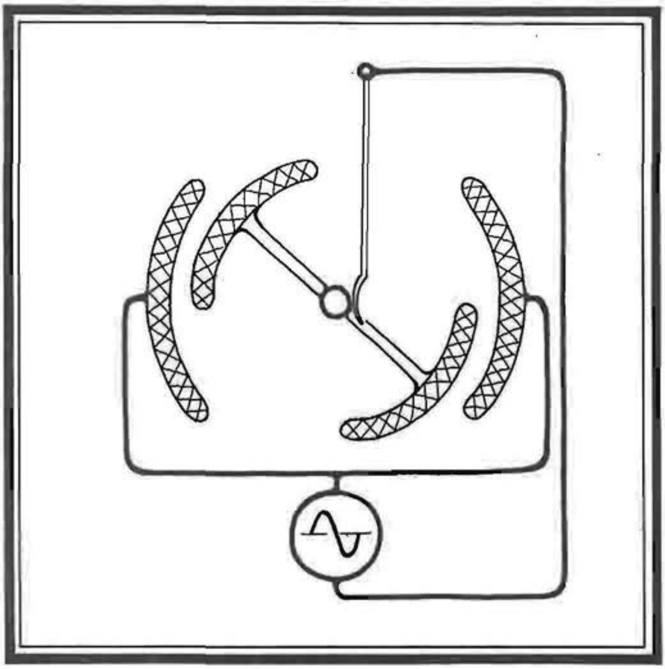

FIGURE 38

In a synchronous capacitor-type electrostatic motor the proper charging of the rotor is accomplished by continuously supplying an ac voltage of proper frequency between the stator and the rotor.

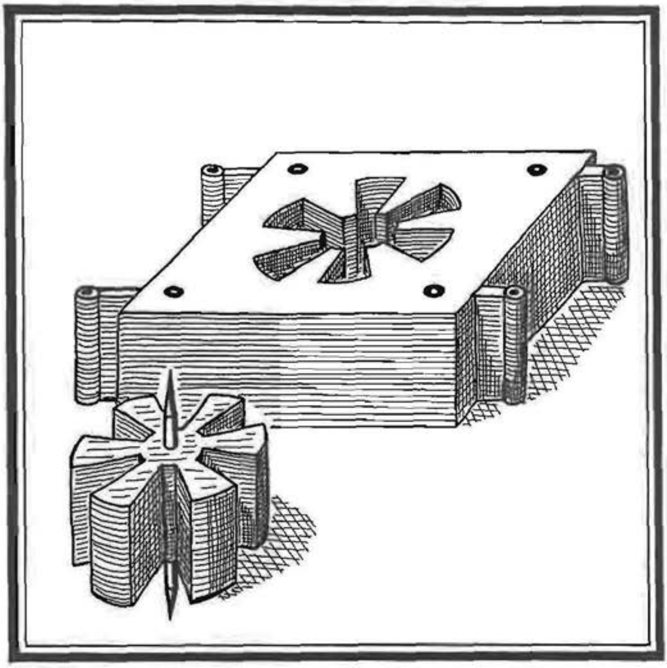

FIGURE 39

This synchronous electrostatic motor is essentially a variable capacitor with a rotatable shaft. The design of this motor is similar to the design of an electrostatic variable-capacitance generator.

trodes; the gap width in the axial direction was 0.01 centimeter. At 200 volts this motor had a maximum output of 600 microwatts. An interesting feature of this motor was that it had no slip ring on the rotor shaft, and that the rotor was therefore not connected to the power source. Instead, the stator was divided into two mutually insulated halves. This arrangement reduced the friction of the rotor and improved the performance of the motor. Still another motor was essentially a variable capacitor with a rotatable shaft. It had 15 plates in the stator and 14 in the rotor, each 0.03 centimeters thick; the gaps between stator and rotor plates were 0.015 centimeters (Fig. 39). The design of this motor is similar to the design of the electrostatic variable-capacitance generator described by N. J. Felici.[6]

According to Bollée, the maximum average torque on the rotor in a capacitor-type electrostatic motor is $T_{\max} = kNV^2$, where k is a geometrical constant, and V is the peak voltage applied. A motor with many electrodes is therefore slow but produces greater torque. The power of the motor is proportional to the square of the applied voltage and to the frequency but does not depend on the number of electrodes.

An important parameter in capacitor-type electrostatic motors is the capacitance difference $C_{\max} - C_{\min}$, where $C_{\max}$ is the greatest capacitance between the rotor and the stator and $C_{\min}$ is the smallest capacitance as they oc-

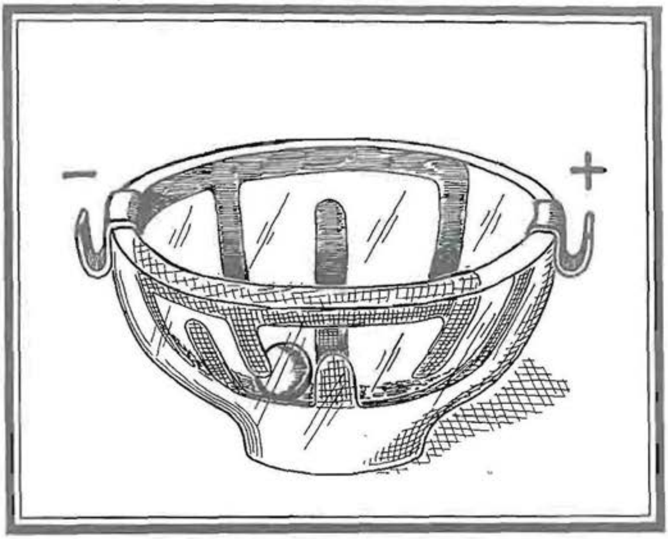

FIGURE 40

This interesting motor has been described by Moore, who calls it the "Interdigital Motor". The stator consists of a glass bowl with strips of aluminum foil glued to it. The rotor is a single conducting ball inside the bowl.

cur when the rotor turns. The larger this parameter is, the better are both the torque and the power. The main objective in the design of such motors is therefore to obtain the greatest possible variation of the capacitance.

An interesting motor which can be classified either as a modified Franklin's second motor or as a modified capacitor-type motor has been described by Moore,[7] who calls it the Interdigital Motor. The stator consists of a glass bowl with strips of aluminum foil glued to it (Fig. 40). The rotor is a single conducting ball inside the bowl; the ball runs along the sloping side when the strips are connected to an electrostatic generator (positive and negative strips are connected in alternation). Several balls can be placed into the bowl at the same time, and all of them will then run.

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7

INDUCTION MOTORS

In 1892-1893, electrostatic motors of a fundametally new kind were described by Riccardo Arno[1,2] and by W. Weiler.[3] Their motors operated on the principle that the polarization of a dielectric in a variable electric field lags behind the field inducing the polarization. Therefore if a dielectric body is placed into a rotating electric field, the polarization charges* induced on the body will experience a force causing the body to follow the rotation of the field.

Arno's motor (Fig. 41) had a cylindrical stator formed by four insulated copper segments enclosing the space in which the rotating field was to be produced. The rotor was a hollow closed ebonite cylinder supported on two steel points turning in holes in glass; the cylinder weighed 40.33 grams, was 18 centimeters long and 8 centimeters in diameter. The rotating field was produced by means of a high-voltage transformer (3800 volts output), an RC-circuit, and a mercury commutator. The rotor attained a speed of about 250 rpm and developed a torque of 176 $\text{centimeter}^2 \times \text{gram} \times \text{second}^{-2}$.

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*See, for example, O. Jefimenko "Electricity and Magnetism", Appleton-Century-Crofts, Inc. (1966), pp. 245-249.

Weiler used a hand-operated double commutator for his motors. The commutator delivered high voltage from an electrostatic generator in sequence to the four segments of a stator, thus producing the needed rotating electric field. Weiler described four different motors utilizing rotating fields. One of his motors was similar to Arno's motor. The operation of this motor (and that of Arno's motor) can be explained with the aid of Fig. 42, representing the top view of the motor. When segment A of the stator is positive, and segment B is negative, the electric field of the stator induces in the dielectric rotor (assumed to be at rest) polarization charges as shown in the figure. After the commutator has completed ¼ revolution, segment C is positive and segment D is negative. Thus the field has rotated by 90°, and now it polarizes the rotor in a new direction (at 90° with respect to the first). However, since it takes a certain time for the polarization charges to relax to zero, some of the initial polarization charges are still on the rotor, so that the distribution of the polarization charges on the rotor is not symmetrical relative

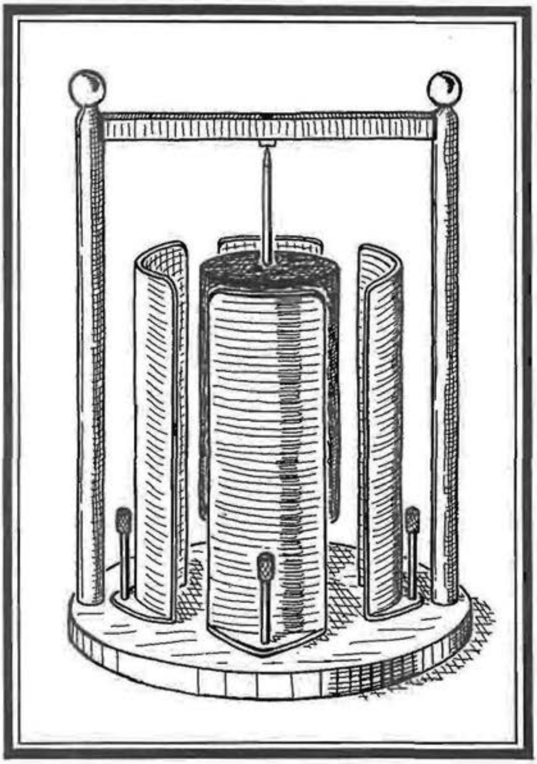

FIGURE 41

Arno's induction motor operated on the principle that the polarization of a dielectric in a variable electric field lags behind the field.

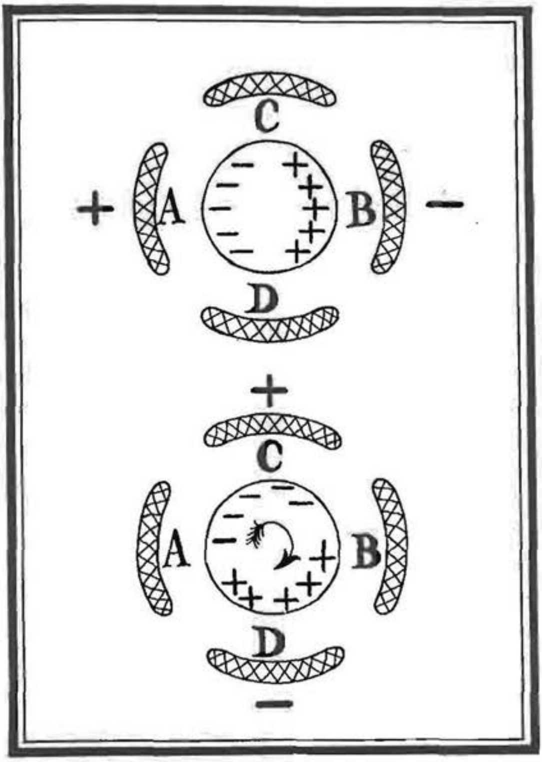

FIGURE 42

The operation of Arno's and Weiler's induction motors can be explained with the aid of this diagram.

to the charges on the stator. The rotor experiences therefore a torque due to attraction and repulsion between the rotor charges and stator charges, and the rotor turns.

Weiler also experimented with motors having noncylindrical rotors. One such motor is shown in Fig. 43. Rotating field electrostatic motors with disk-shaped rotors were built and studied between 1894 and 1901 in Japan by Hiderato Ho.[4]

Since Arno's and Weilers motors depend for their operation on induced polarization charges, they may be called "induction motors".

Induction motors, too, have a number of appealing features which attracted considerable interest to such motors in recent years: the motors can operate from both dc and ac; the motors can operate from low-voltage sources; since the motors require no brushes or slip rings, friction losses in these motors are very small.

Several carefully designed induction motors (both cylindrical and flat) were described in 1969 by Bollée.[5] One such motor of cylindrical geometry operated from a three-phase power supply at 220 volts and 50 hertz. The stator had 12 electrodes, which surrounded a rotor 15 centimeters in diameter. A disk-type induction motor operating from a three-phase power supply had a rotor consisting of 10 glass disks, each 6 centimeters in diameter, coated with a thin layer of slightly conductive material and mounted on a common axle. The rotor turned inside a ring

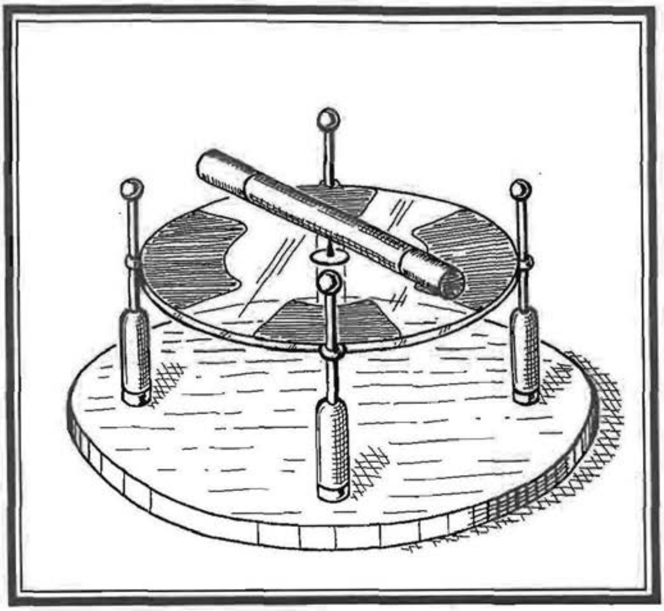

FIGURE 43

In 1892-1893, Weiler also experimented with induction motors having noncylindrical rotors, such as the motor shown in this drawing. Induction motors have a number of appealing features which attracted considerable interest to such motors in recent years.

formed by 60 comb-shaped stator electrodes. The maximum torque was 2000 centimeter^2 × gram × second $^{-2}$ at 220 volts and 50 hertz.

Another interesting motor described by Bollée was a linear induction motor, which "may be regarded as a segment of rotating-field motor bent straight".[5]

An extensive mathematical analysis of the induction motors was published in 1970 by Soon Dal Choi and D. A. Dunn.[6] They tested their theoretical results on a cylindrical motor with 72 electrodes. The motor was 14 inches wide, 14 inches high, and 19¼ inches long. It had a Plexiglas rotor that turned at a maximum rate of about 1000 rpm when powered by a 10-kilovolt source.

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8

LIQUID-IMMERSED MOTORS

In 1893, W. Weiler discovered that a glass cylinder placed in a poorly conducting liquid between two spherical electrodes began to rotate when the electrodes were connected to an electrostatic generator.[1] He then constructed a small motor based on this discovery (Fig. 44). The principle of the operation of this motor was essentially the same as that of a cylindrical corona motor, except that the charges were now deposited on the rotor not by a corona discharge, but by the conduction current in the liquid.

In 1896, G. Quincke reported the same phenomenon and published a very comprehensive experimental study of it.[2] His device is shown in a simplified form in Fig. 45. It is interesting to note that Quincke, rather than Weiler, has been credited by subsequent investigators with the discovery of the rotation of dielectric bodies in

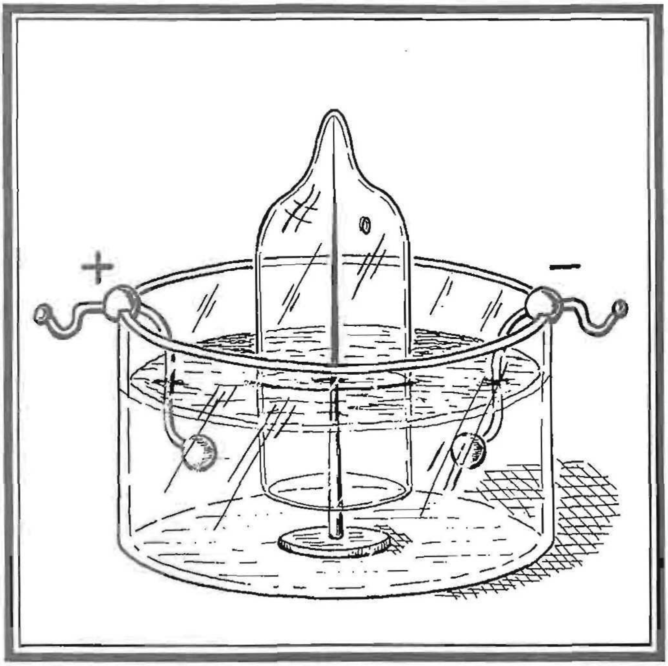

FIGURE 44

In 1893, W. Weiler discovered that a glass cylinder placed in poorly conducting liquid between two spherical electrodes began to rotate when the electrodes were connected to an electrostatic generator.

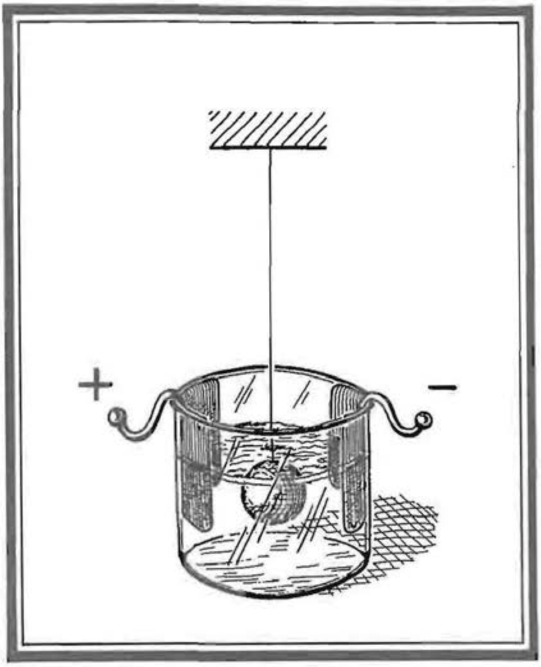

FIGURE 45

In 1896, G. Quincke reported the same phenomenon of rotation and published a very comprehensive experimental study of it. His liquid-immersed motor is shown in a simplified form in the above drawing.

poorly conducting liquids.

Weiler-type liquid-immersed dielectric motors were recently studied in considerable detail by P. E. Secker and his co-workers.[3,4] Their motors operated in various semi-insulating liquids such as hexane, hexane doped with amyl alcohol or ethyl alcohol, and isoamyl alcohol.

In one of their motors the electrodes were stainless steel squares 1.8 centimeters on a side. Their separation was varied from 1 to 2.5 centimeters. The rotor, of ebonite or Perspex, was 0.95 centimeters in diameter and 2.2 centimeters long. The operating voltage was from 3 to 30 kilovolts. The speed of the motor was found to be a linear function of the applied voltage, with the maximum recorded speed of about 2500 rpm.

In another motor, a stator with six electrodes was used (Fig. 46). The rotor was made of Perspex and was 7/8 inches in diameter and 2 inches long; it had a layer of high-permittivity material on its surface (titanium ceramic in polystyrene). Powered by a 30-kilovolt source, the motor turned at 1700 rpm, and the total power input amounted to 5.4 watts, of which 2.7 watts appeared at the rotor shaft.

A discussion of electrohydrodynamic effects that may take place during an operation of liquid-immersed motors has been presented by J. R. Melcher and G. I. Taylor.[5]

Because of considerable hydrodynamical losses, the motors of this type will apparently always have a relatively low output torque.

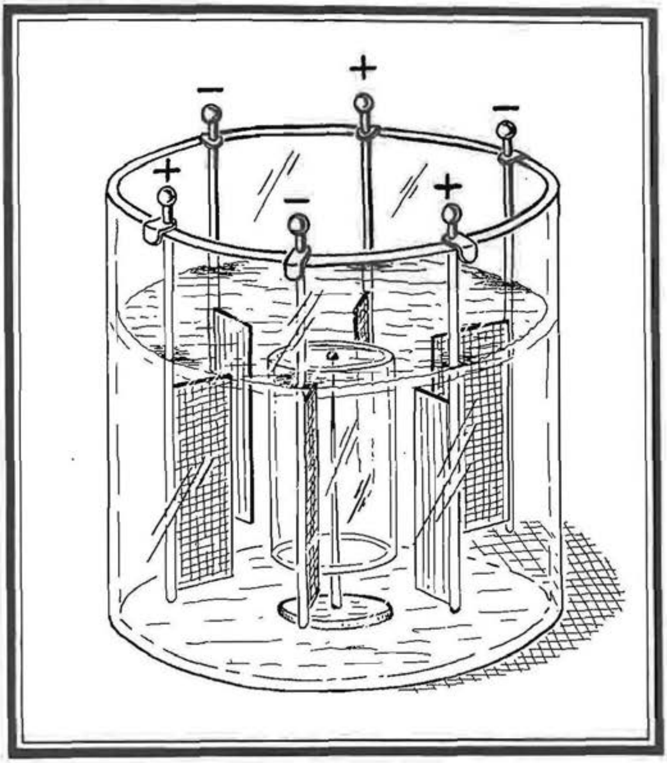

FIGURE 46

This liquid-immersed dielectric motor was recently studied in considerable detail by P. E. Secker and his co-workers.

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9

ELECTRET MOTORS

In general, an electret is a permanently charged dielectric body. In a more restricted sense of the word, an electret is a permanently polarized dielectric body and may be considered to constitute the electrical counterpart of a permanent magnet. It is this latter type of electret that has been used for constructing electrostatic motors.

In 1961, the Russian physicist A. N. Gubkin described an electret motor[1] shown schematically in Fig. 47. The motor consisted of a stator formed by two horizontal, axially symmetric, parallel-plate capacitors and a rotor formed by two flat, axially symmetric, oppositely polarized electrets mounted on a vertical axle and capable of passing between the plates of the capacitors. The motor operated as follows. When a voltage was applied to the two capacitors, so that

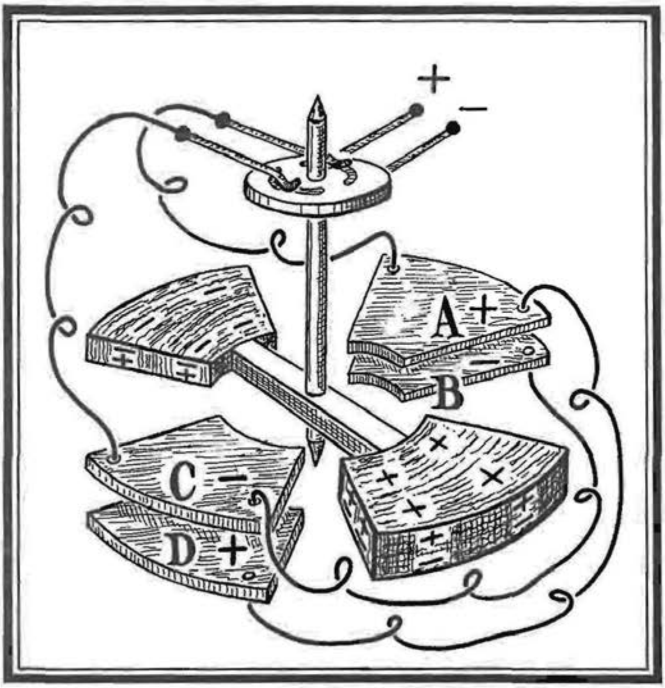

FIGURE 47

In 1961, the Russian physicist A. N. Gubkin described this motor with two electrets in the rotor and two parallel-plate capacitors in the stator. A commutator was used to change the polarity of the capacitors.

plates A and D were positive and plates B and C were negative, the capacitors attracted the electrets as soon as the latter came close to the plates, and the electrets were pulled into the capacitors. A commutator changed the polarity of the plates just as the electrets were coming out from the capacitors, and the electrets were then repelled from them, and so on. Thus the rotor was set in a continuous rotation.

A well-known property of electrets is that they lose their polarization in the absence of adequate shielding. Electret motors with almost perfect shielding were described by this author and by D. K. Walker in 1970.[2] These motors were based on the so-called "electret slot effect".[3] The slot effect works as follows (Fig. 48). An electret is placed between two pairs of electrodes, each pair forming a slot. If a voltage is applied to one or both electrode pairs, the electret (or the electrodes) experiences a force in a direction perpendicular to the slot and parallel to the plates. This arrangement insures both a nearly perfect shielding and a relatively large force.

A simple electret motor utilizing the slot effect is shown in Fig. 49 and Plate 5.* It uses a disk-shaped carnauba wax electret rotor consisting of two oppositely polarized half-disks. The stator has two pairs of electrodes connected to a

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*The motor was designed by the author and built by one of his students, Charles Lynn Walls, in 1966.

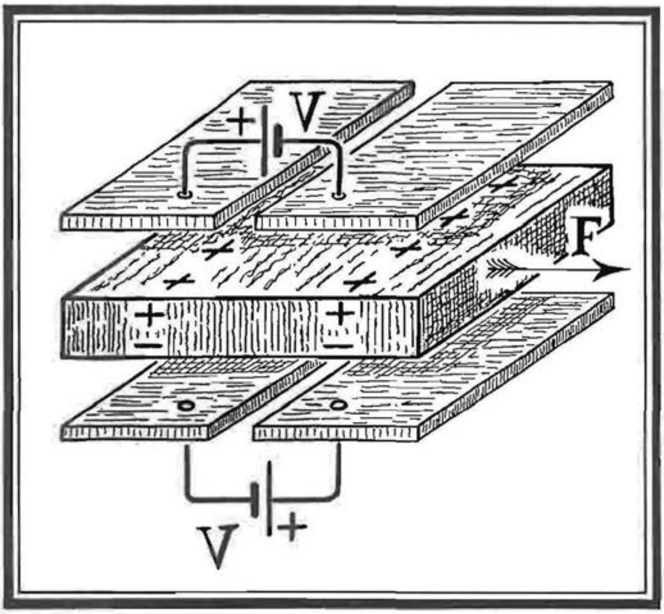

FIGURE 48

The slot effect works as follows. An electret is placed between two pairs of electrodes, each pair forming a slot. If a voltage is applied to one or both electrode pairs, the electret experiences a force in a direction perpendicular to the slot and parallel to the plates.

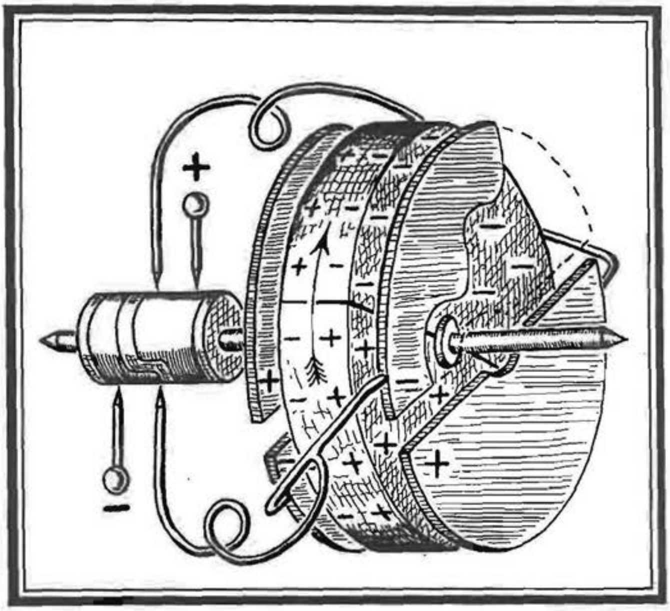

FIGURE 49

This simple electret motor utilizes the slot effect. The rotor is made of a disk-shaped electret consisting of two oppositely polarized half-disks. The stator has two pairs of slotted electrodes connected to a cylindrical commutator, which is charged by contact or by sparks.

cylindrical commutator. The thickness of the rotor is ½ inch, the diameter is 5 inches. The motor operates from an 8-kilovolt power supply and rotates at 1500 rpm.

Similar motors with stationary electrets and rotating electrodes are shown in Plates 6 and 7.

A more sophisticated slot-effect motor[2] uses a cylindrical electret (Fig. 50 and Plate 8). The electret is stationary; it is shaped as a hollow cylinder and has four sections of opposite radial polarization. The rotor is made of four internal and four external aluminum electrodes forming two cylinders with four slots in each. The inner electrodes are cross-connected with the outer ones, and all electrodes are supported by a Plexiglas disk mounted on a steel axle. This motor uses no commutator. The power is delivered to two adjacent external electrodes by means of two sharp points which charge the rotor through a corona discharge. The overall diameter of this motor is 3 inches, the operating voltage is 6 kilovolts, the speed is up to 5000 rpm, the power is about 20 milliwatts.

Synchronous electret motors for electric clocks have been recently announced by the General Time Corporation. The motors are about 1¼ inches in diameter and ¼ inch thick. In these motors (Fig. 51) a thin plastic electret disk with 15 active sectors and 15 equally large cut-outs is the rotor. The rotor is placed between two stator plates fabricated as printed circuit boards. Each stator plate has 30 elec-

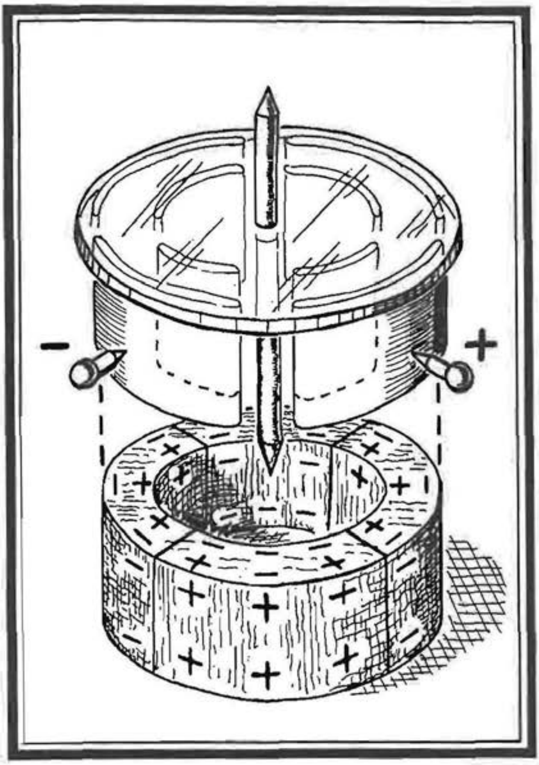

FIGURE 50

This more advanced slot-effect motor uses a stationary cylindrical electret and works without a commutator. The rotor has 8 slots.

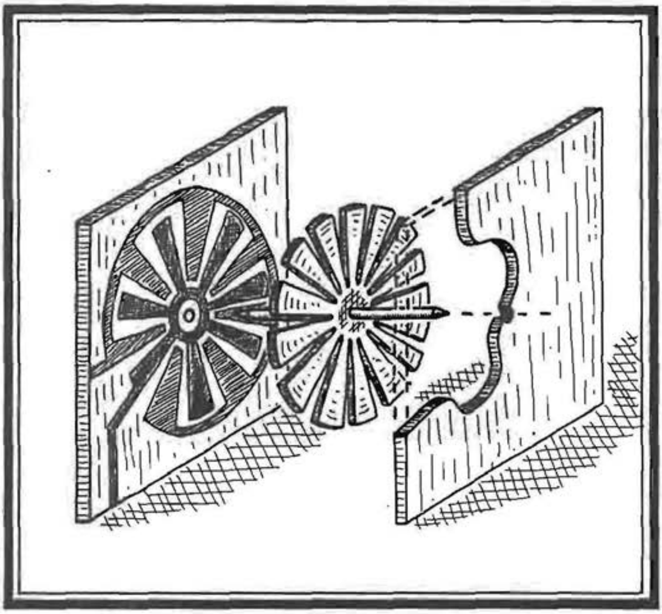

FIGURE 51

In this simplified version of a synchronous electret motor for electric clocks a thin plastic electret disk with several active sectors and several cut-outs is used as the rotor.

trodes connected in alternation to the two input terminals. The operation of this motor is similar to that of the first slot-effect motor described above (Fig. 49) except that the reversal of polarity of the electrodes is accomplished directly by the applied ac voltage rather than by a commutator.

Of all presently known types of electrostatic motors, electret motors are the newest and (together with corona motors) the most highly promising ones. We shall return to them once again in the next chapter.

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10

WHAT TO EXPECT FROM ELECTROSTATIC MOTORS

Having described the various types of electrostatic motors we shall now present a brief discussion of the current aims in the electrostatic motor research and a brief discussion of the most probable future uses and applications of these motors.

It has been pointed out by Bollée[1] that electromagnetic motors rapidly lose their efficiency in scaled-down versions (which is due to the relative increase in energy dissipation in the magnet coils) and that very small capacitor-type and induction-type electrostatic motors may be a better choice for miniaturized systems. Therefore one may expect that miniature electrostatic motors of these types will find applications in various sensor and control devices where only very small torques and power are needed.

Experiments with electret motors conducted in the author's laboratory[2] indicate that these motors may be very useful in systems where powers of up to 1 watt are needed.

The most promising electrostatic motors appear to be, however, the corona motors. These motors possess a number of highly desirable features. Here are some of them: the motors are extremely simple in design; they require no expensive materials; their maintenance is very simple; having only few metal parts they possess a very good power-to-weight ratio; they are fully capable of developing appreciable amounts of power; and they can attain very high speeds.

Our present-day awareness of the many attractive properties of corona motors is to a great extent due to the work of the Russian engineers Yu. Karpov, V. Krasnoperov, and Yu. Okunev published in 1958 and 1960.[3,4] They described a 6-watt cylindrical corona motor of improved design (Fig. 52) operating from a 7-kilovolt power supply and turning at a rate of 6000 rpm. This motor had a hollow Plexiglas rotor 10.5 centimeters in diameter and 17 centimeters long with a conducting lining on its inner surface. The stator supported 16 knife-like electrodes inclined relative to the surface of the rotor in the direction of the desired rotation. The lining of the rotor served to increase the electric field in the gap between the electrodes and the surface of the rotor and thus to enhance the corona discharge from the electrodes.

A high-speed corona motor with a disk rotor

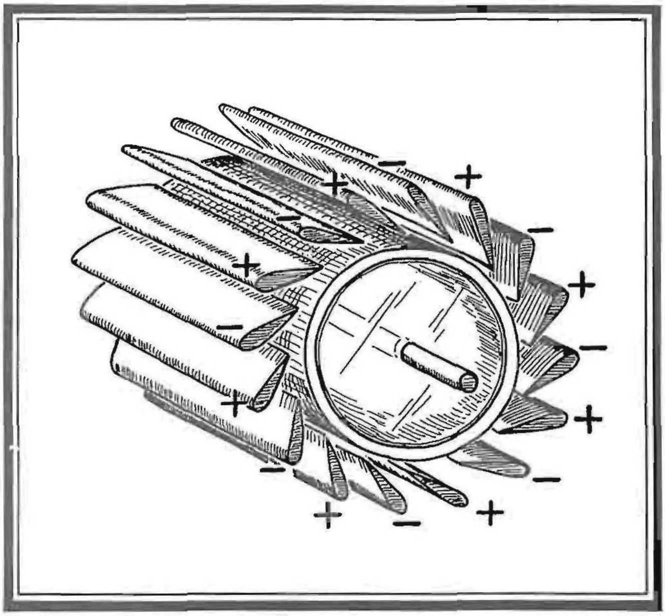

FIGURE 52

In 1958, the Russian engineers Yu. Karpov, V. Krasnoperov, and Yu. Okunev described a 6-watt cylindrical corona motor of an improved design operating from a 7-kilovolt power supply and turning at a rate of 6000 rpm. This motor had a Plexiglas rotor.

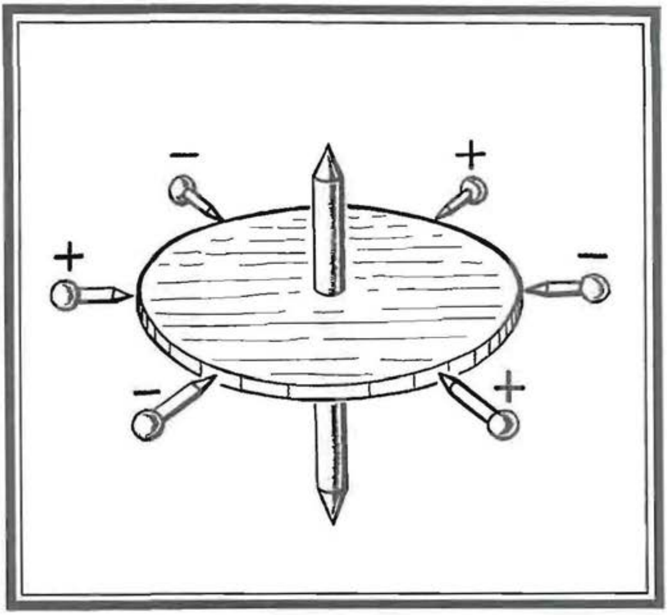

FIGURE 53

This corona motor with a disk rotor and circumferential electrodes was described by J. D. N. Van Wyck and G. J. Kühn of South Africa in 1961. It had a rotor 1.5 inches in diameter turning in jewel bearings. Operating from 13 kilovolts, the motor ran at 12000 rpm.

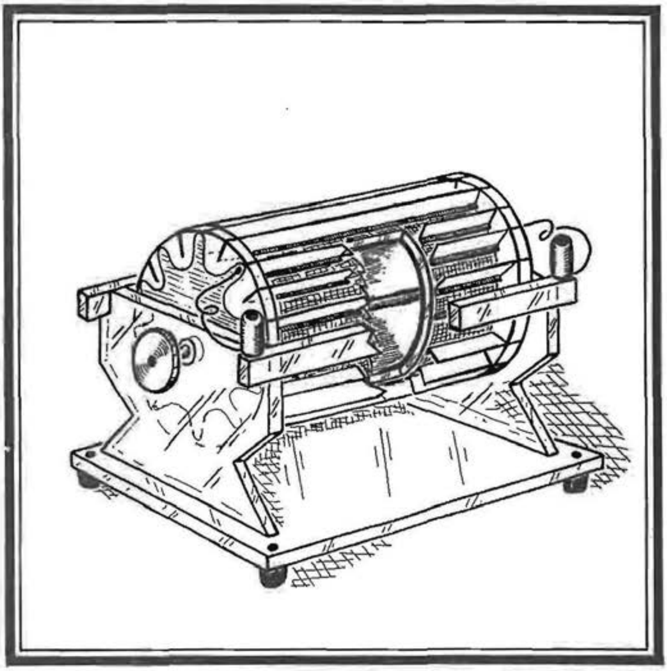

FIGURE 54

The performance of a corona motor depends on the shape and arrangement of electrodes and the structure of the rotor. The curved electrodes of this motor produce an especially large torque. The lining of the rotor increases the power.

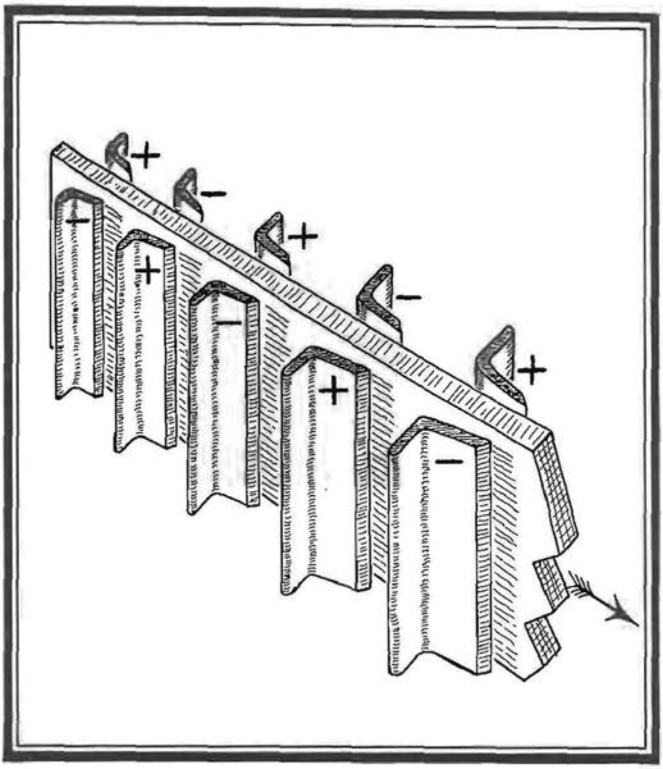

FIGURE 55

The mechanism of electric interaction producing rotational motion in corona motors can be used to achieve a translational motion as well. This drawing shows the principle of a linear corona motor with multiple electrodes.

and circumferential electrodes was described by J. D. N. Van Wyck and G. J. Kühn of South Africa in 1961.[5] The motor (Fig. 53) had a rotor 1.5 inches in diameter turning in jewel bearings. The stator supported 6 sharp-point electrodes. Operating from 8-13 kilovolts, the motor developed speeds of up to 12000 rpm.

A similar motor was studied in Poland by B. Sujak and W. Heffner in 1963.[6]

A number of advanced corona motors were studied in the author's laboratory;[7] an example of these motors is given in Fig. 54 and Plate 9. A diagram of a linear corona motor designed by the author is shown in Fig. 55. Instructions for building the corona motors of the author's design may be found in the May 1971 issue of Popular Science.[8]

It appears that corona motors with input power of 100 to 1000 watts and efficiency of at least 60% can be constructed without any difficulty. There seems to be no reason why even more powerful corona motors could not be built. It is likely that the motors can be further improved by using rotors immersed in a gas other than the air at atmospheric pressure.

Performance characteristics of corona motors strongly depend on the design and geometrical configuration of the electrodes spraying charges onto the rotor. Several typical electrode types and electrode configurations for corona motors are shown in Fig. 56. Especially interesting is the electrode arrangement shown in Fig. 56c.

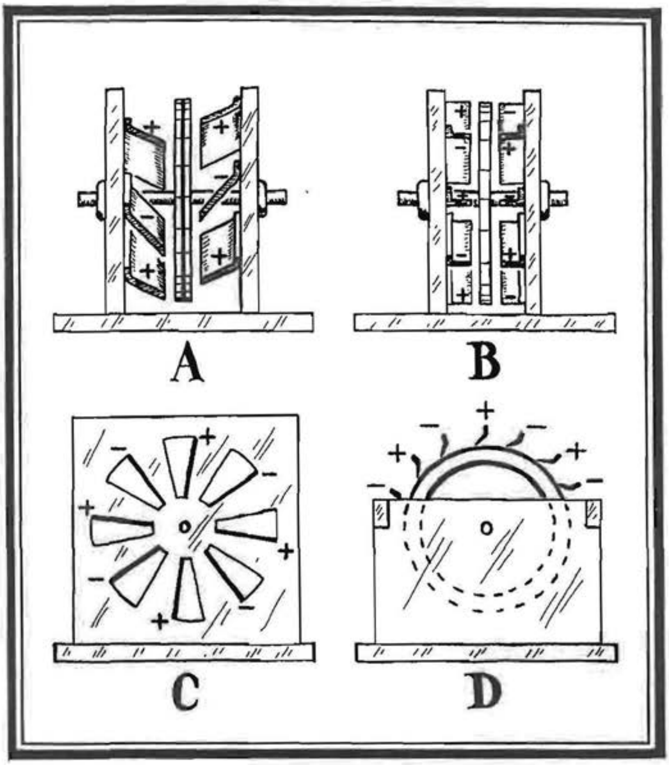

FIGURE 56

(a) Slanted electrodes and disk rotor with a conducting lining in the middle; (b) Straight electrodes; (c) Foil electrodes shielded on one side; (d) Curved electrodes and cylindrical rotor with a conducting lining.

This arrangement is used in conjunction with thin disk-shaped rotors "sandwiched" between two insulating stator plates. An even number of windows is cut in each stator plate, and metal foil electrodes are glued to the walls of the holes, as shown by heavy lines in Fig. 56c. In this arrangement there is a dielectric medium on one side of each electrode, and there is air on the other side. Therefore the electrodes spray charges predominantly in the direction of the side facing the air. Thus a motor with electrodes of this type is unidirectional and self-starting. Furthermore, the entire "sandwich" comprising the rotor and the two stator plates may be very thin. Therefore many such "sandwiches" can be placed on a single axle thus forming a compound motor in which good use is made of the entire volume occupied by the motor. There are indications that compound motors of this type can develop up to 1000 horsepower for each cubic meter of their volume.

An important property of electrostatic motors is that they can operate from a much greater variety of sources than the electromagnetic motors. It is, of course, obvious that any sources used for operating conventional electromagnetic motors can be used to operate the electrostatic motors. However, the electrostatic motors can operate also from sources from which no other motors can operate. The reason for this is that the electrostatic motors are extra-high impedence devices and thus require extremely small currents for their operation.

One very interesting source of electricity for electrostatic motors is the ordinary capacitor. It is true that capacitors, as we know them now, do not store appreciable amounts of electric energy. However, if high-permittivity low-loss dielectric materials were developed, then the capacitor would become a very useful device for storage of electric energy, and possibly could be used in place of the chemical batteries for operating electrostatic motors.

Another possible source of power for electrostatic motors are high-impedance high-voltage batteries of the type of Zamboni pile.

A potentially very important source of electricity for powering electrostatic motors are electrostatic generators. Considerable advances in the development of such generators have been made in recent years[9,10] and it is conceivable that electrostatic motor-generators will be used to convert the high-voltage dc produced by such generators into the conventional low-voltage dc or ac.

Finally, a very interesting source for powering electrostatic motors is the atmospheric electric field. In fact, it appears possible to extract the energy contained in this field by means of electrostatic motors. Experiments on such an energy extraction have been conducted by the author.[11,12] In these experiments an electret motor and a corona motor were powered by simple earth-field antennas (Fig. 57; Plates 10 to

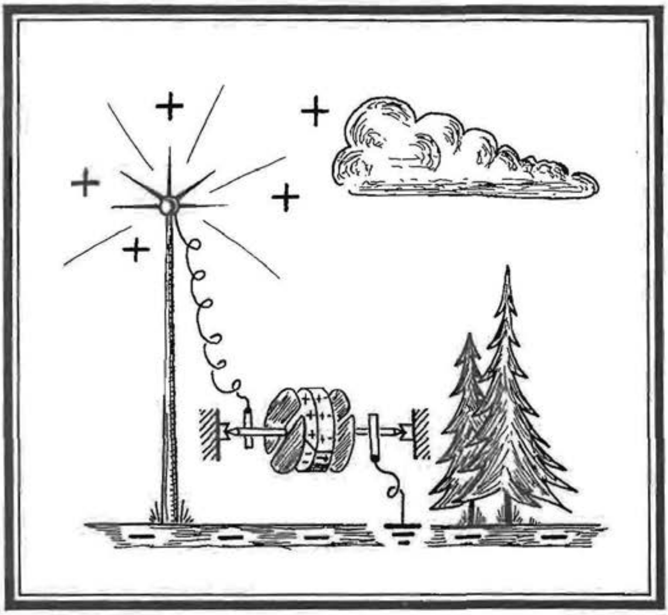

FIGURE 57

Small electrostatic motors can be powered from atmospheric electricity by means of simple earth-field antennas. Whether or not it will be possible to operate large motors in this manner will depend on how successful we are in designing antennas capable of extracting appreciable power from the earth electric field.

12). The corona motor was the one shown in Plate 9. The electret motor was similar to that shown in Fig. 49, but with the electret stationary and the electrodes rotating (Plate 6). These experiments indicate that it is entirely possible to operate small electrostatic motors from atmospheric electricity. Whether or not it will be possible to operate large motors in this manner will depend on how successful we will be in designing and building earth-field antennas capable of extracting appreciable power from the earth electric field.

In conclusion it may be useful to mention that a quantitative electrostatic motor research is now only in its very rudimentary stage. Almost all papers on electrostatic motors published thus far deal with the qualitative aspects of the performance of the various types of motors. Only very few papers deal with the optimization of design and with the quantitative aspects of the operation of the motors, likewise only very few papers present a theoretical analysis of the electrostatic motors. It is clear therefore that the electrostatic motors still constitute an essentially unexplored area of physics and engineering, and that the electrostatic motor research is presently one of the potentially most rewarding research fields in modern electrostatics.

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Plates 4, 5, 7, 8, and 10: author's photographs.

M0DAD RADIO WEBSITE

Basic Crystal Radio Set

I have been very interested in crystal radios for many years, I can remember building my first set back in my schooldays in the early 1980s. It was the first and still is the most basic of all radio receivers , If you are new to radio and have never seen one of these sets you will be very amazed at how easy it is to build a working radio needing so few components. What also may surprise a newcomer is that it does not need any battery or power to work, The only power it uses is taken from the transmitter of the station you are listening to, In other words it pulls the power from the radio wave.

The biggest craze of building and listening to crystal sets was at its peak in the 1920s. The old style sets used a real mineral crystal for the detector, The most popular being the galena and a fine bit of wire called a cats whisker which you would have to touch the crystal in the correct place to find the best reception where the radio station would come in. During world war II the underground people of Europe used crystal sets to listen to prohibited broadcast stations, Because of there simplicity to build. It is now getting harder to obtain all the original parts like the high impedance headphones, But I will show you how to build the modern day circuit using readily available parts.

My basic crystal radio project is aimed at the absolute beginner or younger generation, to try and interest them in the radio hobby as many amateur radio operators began there interest in radio with building the crystal set. The circuit can be soldered or built using chock block connectors for safety if a young person is doing this project.

CIRCUIT

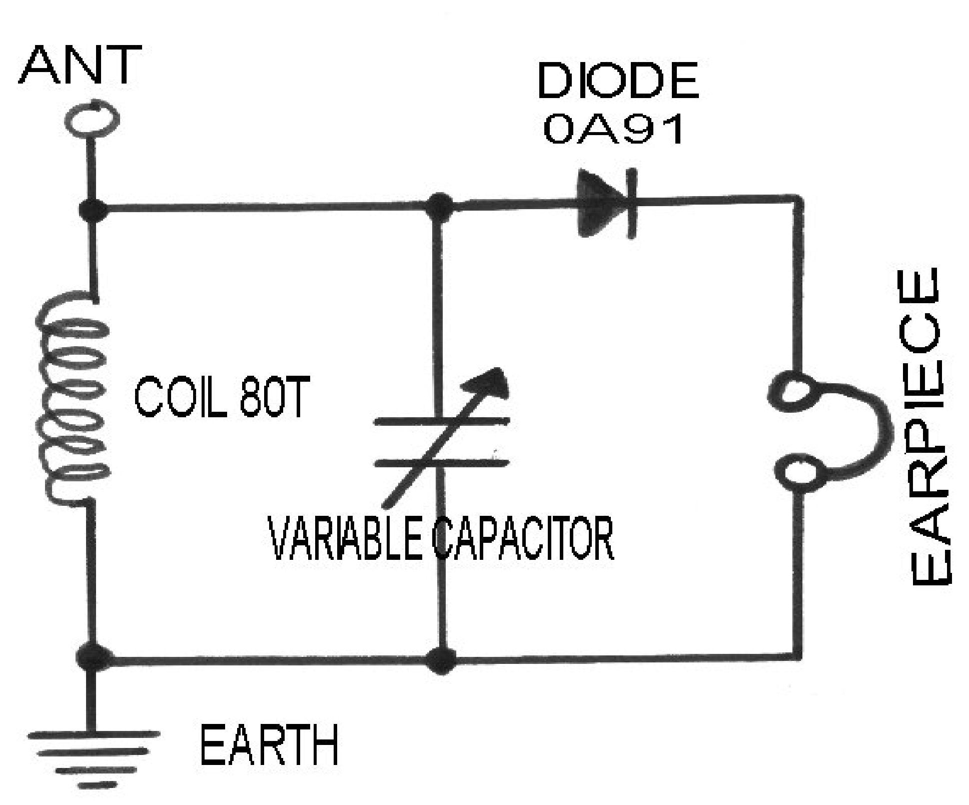
ANT
DIODE
0A91
COIL 80T
VARIABLE CAPACITOR
EARPIECE
EARTH

HOW THE CIRCUIT WORKS

First of all there are many different signals from stations which will be traveling down the long wire antenna, The coil and capacitor together form a tuned circuit, And because the capacitor is a variable type you can change the resonant frequency of the tuned circuit by rotating the tuning knob on the capacitor. Only signals from stations on or near the resonant frequency can pass through the tuned circuit, The other remaining frequencies are bypassed to earth. The passed signals then go through the germanium diode (detector) which rectifies the positive half cycles changing it to DC current and then sending it to the crystal earpiece or high impedance headphones.

BOARD LAYOUT

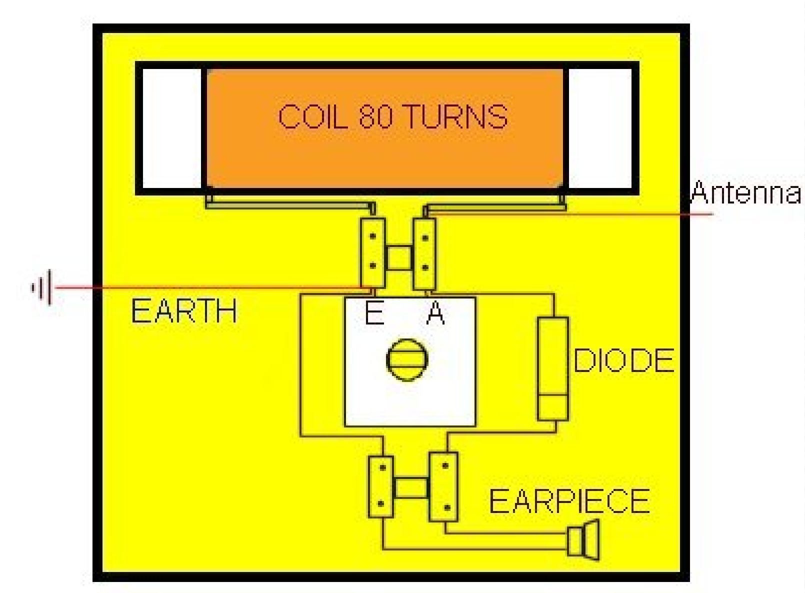
COIL 80 TURNS
Antenna
EARTH
E
A
DIODE
EARPIECE

PARTS

I personally find it a lot more fun to salvage all the parts from an old radio as it will cost you nothing, But just for this project I have listed all the parts that you will need and where to buy them from.

Variable capacitor, available from Maplin Electronics (UK) Code FT78K

Diode: Maplin Electronics 0A91, Code QH72ZP, 0A90 Code QH71N or any germanium point contact diode such as an OA70,OA71, or 1N34.

Chock block connectors Maplin Electronics (UK).

Crystal earplug, avail able from Maplin Electronics (UK) Code LB25C

26 s.w.g. Enameled copper wire.

Coil former: An empty card board toilet roll or an off cut piece of plastic waste pipe.

Base: Any piece of soft scrap wood about 4"x 5"

PVC coated wire for links.

A roll of any kind of wire PVC coated or copper wire for antenna and an earth connection.

CONSTRUCTION

Start the construction with the coil by securing the former (toilet roll, or PVC pipe) and then winding 80 turns of 26 s.w.g enameled copper wire around. When finished secure the windings with sticky tape or glue, Then scrape the wire enamel off both ends of the coil with a knife or sand paper until you can see a shiny tip. The coil can be secured to the wood base with two drawing pins.

Now the most difficult part is over , you can secure a couple of chock block connectors in front of the coil and the two behind the capacitor then wire the circuit as in the board layout, It is straight forward, but make sure you get the capacitor the correct way, the earth and antenna pins are marked e and a on the bottom, There is no connection to the pin marked o. The diode has a glass body with a band on to show the flow of the conducting current. Strip the plastic coating off the end of the crystal earpiece leads and insert them into the two rear chock blocks.

You are now ready to connect the antenna, Just string up the longest length of wire you can, run it from the set through a window and secure it to an insulated pole, tree or fence as high and as long as you possibly can to achieve the best results. If it is impossible for you to have an outdoor wire, String a wire several times around a room ceiling or an attic, It will still receive some stations but at reduced volume.

You will need an earth, run a wire from the set to a cold water pipe, connect it to the pipe or to a water tap with a crocodile clip, Or if you want a more permanent arrangement you can run a wire outside and connect it to an earth rod driven into the ground, This can be a length of copper pipe or brass rod as long and deep into the ground as you can. It is said that you must have a good earth for a crystal set to work, In practice I found it works slightly better but have also achieved good results without any earth.

OPERATING THE SET

This is the best part, When you are finished building the circuit connect the earth and antenna wires, pick up the earpiece and have a listen, You should be able to hear noise, turn the screw on the variable capacitor until you tune into a station, You should be able to hear several stations on the MW band, Depending on your location, length and how high the wire antenna is, Because this is a basic circuit you will soon notice that the set has poor selectivity, This means that sometimes you can hear two or more stations coming in together and may find it difficult to separate the one you want to listen to, That is if you can at all. If you can only receive one or two stations and the screw on the variable capacitor is fully turned, try unwinding about 4 or 5 turns off the coil. One of the most difficult requirements is having the patience, Some stations will come in loud and then may fade out altogether after a wile, If you leave it on the same frequency they can sometimes return as the propagation changes.

FAULT FINDING

If it does not work, Check your wiring with that of the board layout, And make sure all leads are not slack.

You must make sure you have a germanium point contact diode, other diodes will not work.

Make sure you have a proper crystal earpiece or high impedance headphones, Do not be confused with the standard white coloured magnetic earpiece, Unlike the standard 8 or 16 ohm earphones of today crystal earpieces are into the mega ohms, So if you used the wrong type it would be like trying to run your washing machine on a PP3 9 volt battery.

EXPERIMENTING

When I built this crystal set for the web site I hooked a wire to a radiator for an earth, strung a 60 FT length of PVC coated wire through a window down to the rear garden fence, The first station I heard was quite a surprise, Radio Korea, Other stations where Virgin Radio - 1215 KHz, Talk Sport 1071 KHz, Magic 1152 KHz, BBC Radio 5 Live 693 KHz, BBC Radio 4 - 603 KHz, So it had a good range through the medium wave broadcast band.

Do not be afraid to experiment, Due to the simplicity of the set you wont break it, You can try changing the diode around, Try other coils with different number of windings, The more turns should take you lower in frequency, and the smaller number higher, try a ferrite rod as a former or salvage a ready made coil from an old broken radio. Experiment with different lengths of antenna wire. I also find these sets work better with a higher quality air spaced variable capacitor which you can buy from a radio rally or you could try J. Birkett suppliers of electronic components who always stocks them at reasonable prices, TEL NO. +44 (0)1522 520767. The company is UK based and may not export, but I am sure that you will know of local electronics suppliers for such parts.

I hope you have enjoyed reading about the crystal set and if you have built the one from this page e mail me and let me know how it went. If this page has interested you and you would like to build more sets check out my other web pages or web links page.

BACK TO M0DAD HOMEPAGE

A Simple Crystal Radio Set

Whether you are a beginner or a seasoned expert, you would probably agree that there is nothing quite like using this simple design to make a crystal radio and enjoying it, listening to stations both near and far. Add to this the "something for nothing" advantage of not having to power this set with batteries or AC line and you can see why this simple design will be used and enjoyed for a long time to come. Almost like magic... Let' build one!

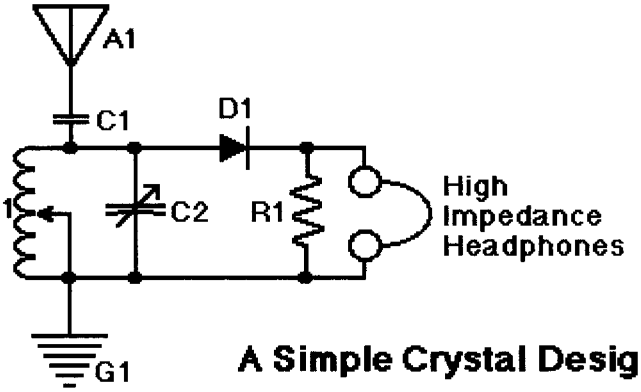
A1
C1
D1
L1
C2
R1
High
Impedance
Headphones
G1

A Simple Crystal Design

Components:

- **A1- 50-100 foot longwire antenna**
- **C1 - 50 pf ceramic capacitor OSE p/n CD-5**
- **C2 - 365 pf variable capacitor OSE p/n BC14400**
- **D1 - 1N34A diode OSE p/n 1N34A**
- **G1 - Ground (see instructions below)**
- **L1 - 100 turns of #20 AWG enamel coated copper wire OSE p/n MW20, adjustable tap (see instrctions below)**
- **R1 - a 100k ohm resistor OSE p/n RQ100K**
- **Crystal Earphones OSE p/n CE748**
- **Fahnestock clips OSE p/n 2090**

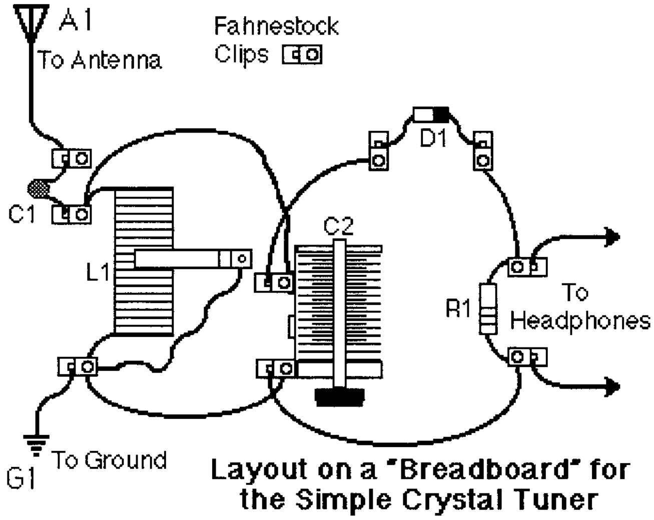
A1
To Antenna
Fahnestock
Clips
D1
C1
C2
L1
R1
To
Headphones
G1
To Ground

Layout on a "Breadboard" for the Simple Crystal Tuner

all about
CRYSTAL SETS

by
Charles Green

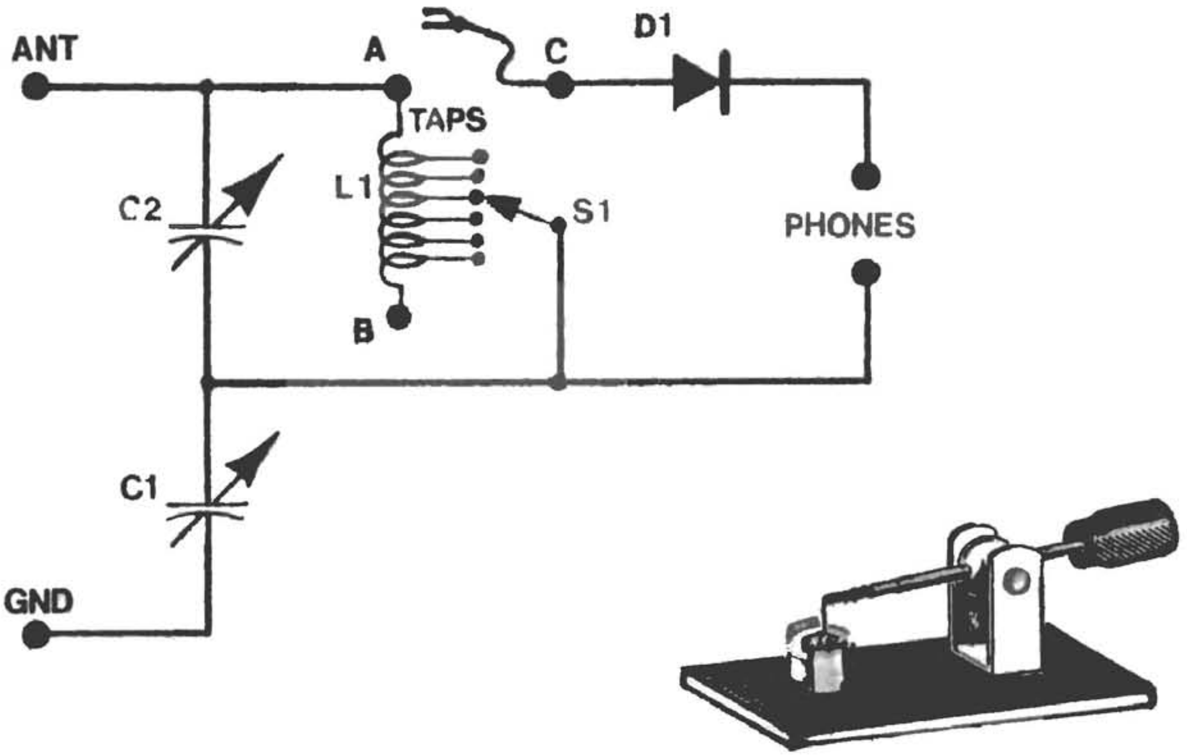
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How-To-Build Simple Crystal Set Radios

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all about CRYSTAL SETS

by

Charles Green

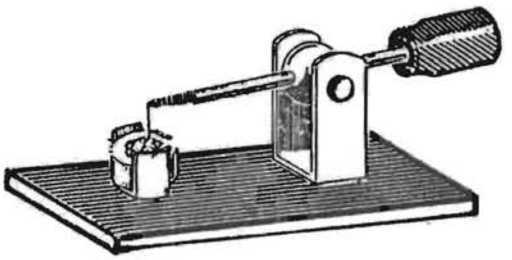

How - To - Build Simple Crystal Set Radios

FIRST EDITION

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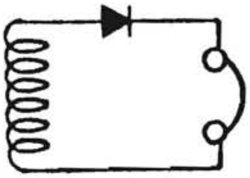

PREFACE

In the beginning of this century, when radio was called "Wireless", most of the early experimenters used a crystal set to receive radio signals.

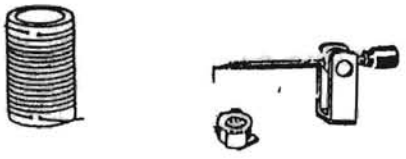

The crystal set is still the simplest type of radio receiver. A catwhisker (made from a thin wire) touching a sensitive spot on a piece of galena or silicon mineral crystal and a tuning coil, form the basic parts of this radio.

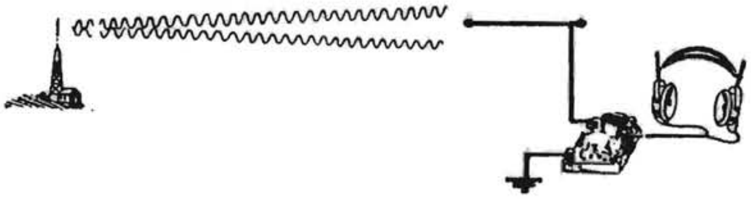

Radio signals from a nearby station are picked up via antenna and ground connections to the crystal set. The galena or silicon crystal detects the signals and the resultant audio is heard with headphones. No battery or electrical power is required.

This book tells you about crystal sets and shows you how to build them.

Charles Green

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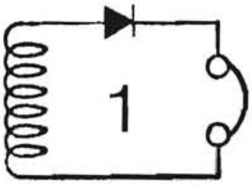

1

THE CRYSTAL DETECTOR

A crystal detector of radio waves can be either a traditional catwhisker and natural mineral crystal, or a modern semiconductor diode.

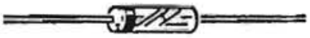

SEMICONDUCTOR DIODE

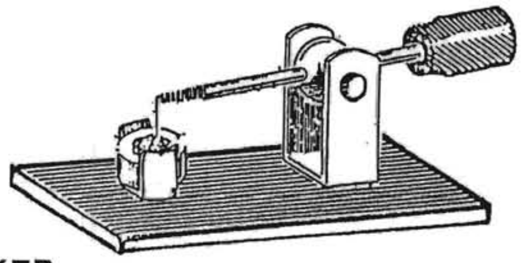

CATWHISKER DETECTOR

Certain natural minerals such as galena (lead sulphide) and silicon have electrically sensitive surface spots. In the beginning of this century, experimenters discovered that electrical current would flow into the sensitive spot on a mineral crystal from a catwhisker, but would not pass readily (high resistance) from the crystal to the catwhisker. This unique feature was used to detect (rectify) radio waves and extract the audio modulation.

HOW-IT-WORKS

There are two general types of crystal detctors;

. Point contact diode
. Junction diode

Both types use semiconductor material such as silicon, germanium, or galena. The basic semiconductor junction diode is made of two portions of the material "doped" in manufacturing by adding controlled amounts of chemicals. The doped portions have opposite electrical properties:

"P" TYPE, with an excess of positive electrical charges (holes).
"N" TYPE, with an excess of negative electrical charges (electrons).

Junction Diode

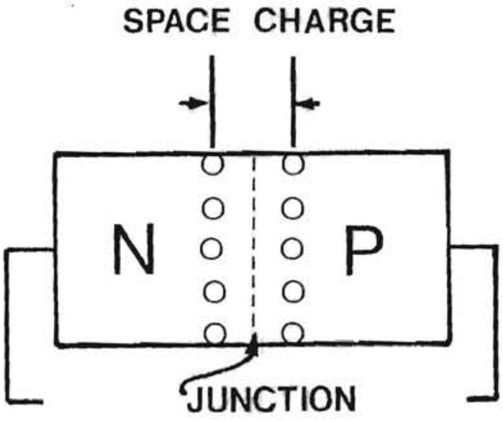

The boundary between the two doped portions is called a PN junction. The area on both sides of the PN junction is called the space charge region. When a positive voltage is applied to the "P" material (and negative voltage to the "N" material), the space charge region becomes narrow and electron current flows through the PN junction.

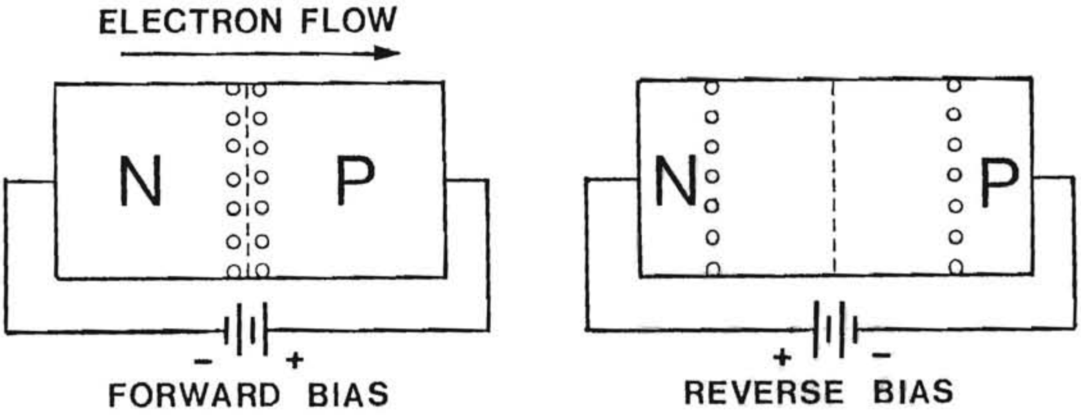

When the voltage polarities are reversed, negative to "P" and positive to "N", the space charge region widens (increasing the effective resistance of the PN junction) and the electron flow is very small (back current). If an ac voltage is applied to the PN junction, it will act as a rectifier (or radio wave detector).

Point Contact Diode

The point contact diode uses a "catwhisker" of thin wire contacting the surface of doped "N" semiconductor material. The pointed end of the wire produces a high intensity electric field in the area of the semiconductor surrounding the wire. When an electric current flows from the wire to the semiconductor material, a small region of "P" material forms around the area of the point contact. Thus a PN junction is formed which operates in the same way as the junction diode.

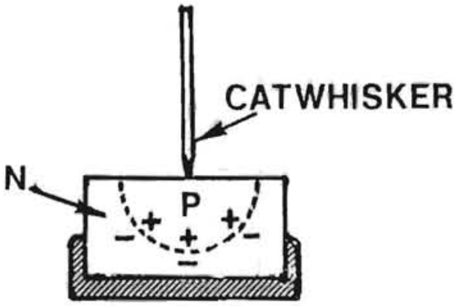

The sensitive spots of galena and silicon crystals used in traditional catwhisker detectors have naturally doped areas of semiconductor material, and operate in the same way as the point contact detector.

DETECTION OF RADIO WAVES

At the transmitting radio station, a microphone converts sound waves into electrical audio signals. The audio signals then modulate the transmitted radio waves.

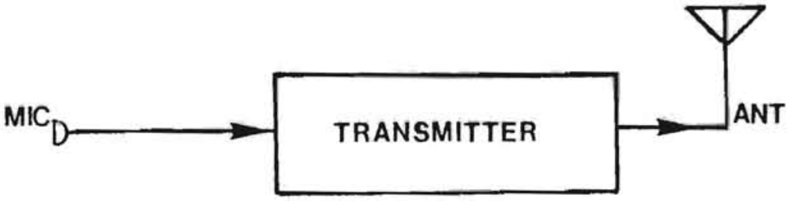

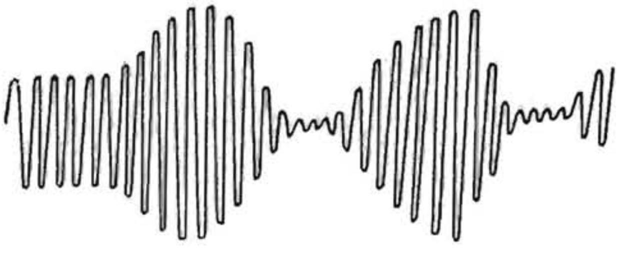

MODULATED RADIO WAVES ⟶

the crystal detector

The transmitted radio waves are intercepted by the receiving antenna and small rf currents are induced in the antenna wire. The rf currents (high frequency ac) flow through the detector to ground. As previously explained, the crystal detector will pass current in only one direction, therefore, pulsating dc voltages (detected audio signals) are developed by the crystal equivalent to the audio modulation of the transmitted radio waves.

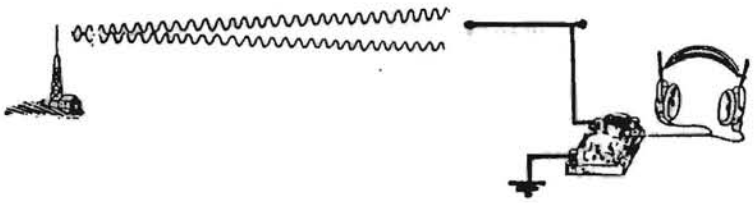

The detected audio signals flow through the headphone coils and affect the intensity of a magnetic field. This causes the steel discs of the headphones to vibrate and produce audible sound waves.

TUNING THE CRYSTAL SET

The antenna intercepts all radio waves in the area, and the signals will be heard jumbled up in the earphones. A nearby radio station may be received with the other stations heard in the background.

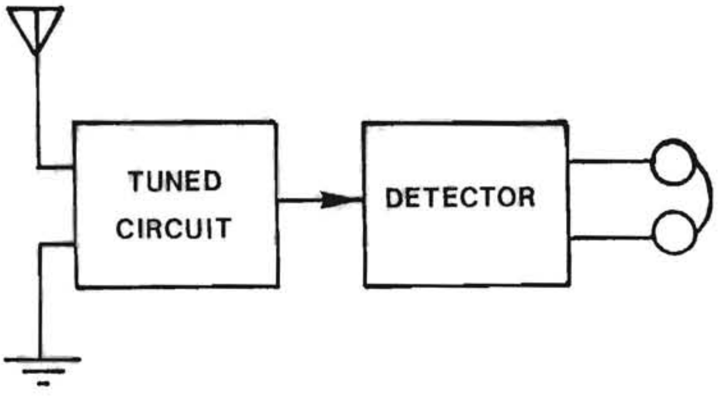

In order to receive a radio station properly, the crystal set must be tuned to the frequency of the transmitter. A tuned circuit composed of an rf coil (inductance) and a capacitor, is connected between the antenna/ground circuit and the detector.

Capacitor

The modern capacitor is evolved from the old Leyden jar. It consists of two or more metal sections separated by a dielectric (air, paper, or plastic). The capacitor stores energy in the form of an electrostatic charge in its dielectric. A variable capacitor (used in a tuned circuit) has movable metal sections that adjust the amount of capacity.

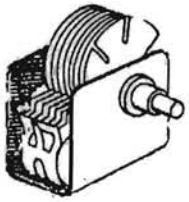

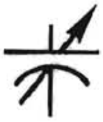

A capacitor will allow pulsating dc current or ac current to flow through it, but will block steady dc current. A capacitor has an oppositon or "reactance" to ac that varies with frequency. The higher the frequency, the lower the reactance of a given value of capacity. Capacity is measured in micro-farads (uF) or micro-micro-farads (picofarads) (uuF or pF).

RF Coil

An rf coil is made of insulated copper wire wound on a plastic or cardboard tube. When electric current flows through the coil, a magnetic field is created. This magnetic field resists any change in electric current flow. This opposition or "reactance" to ac varies with frequency. The higher the frequency, the higher the reactance of a given value of rf coil inductance. Inductance is measured in millihenrys (mH) and microhenrys (uH).

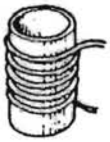

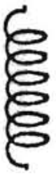

Tuned Circuit

A tuned circuit is composed of a capacitor and an rf coil. As previously described, the reactances of a capacitor and an rf coil change with frequency (but in opposite ways). At a particular frequency, the two reactances will cancel each other out. This condition is called "resonance". The impedance of a parallel tuned circuit is at its highest at resonance. Radio signals at the resonant frequency will be greatly magnified, while signals at other frequencies will be shunted to ground (rejected).

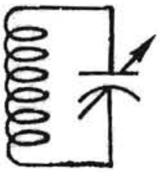

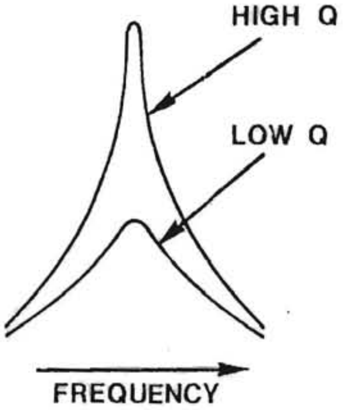

The resonant frequency of a tuned circuit can be changed by adjusting the capacitance (using a variable capacitor), or by varying the inductance (using a slider or taps on the rf coil). A ferrite core can also be used to change the inductance of a coil. The selectivity of a tuned circuit is dependent upon the quality (Q) of the components and the inductance /capacity ratio (L/C ratio). A high-Q tuned circuit is more selective than a low-Q circuit. A tuned circuit with a high L/C ratio (large inductance and small capacity) is more selective than a low L/C ratio circuit.

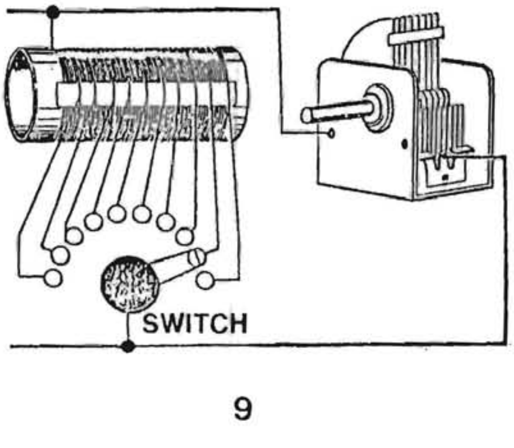

ANTENNA AND GROUND

A simple crystal set depends upon the strength of the radio waves received by the antenna to produce audio in the earphones. If you live in a strong signal area (a nearby radio transmitter), a crystal set can produce loud audio in earphones with only an inside antenna. But in lower signal areas, a good outside antenna with a ground connection is required.

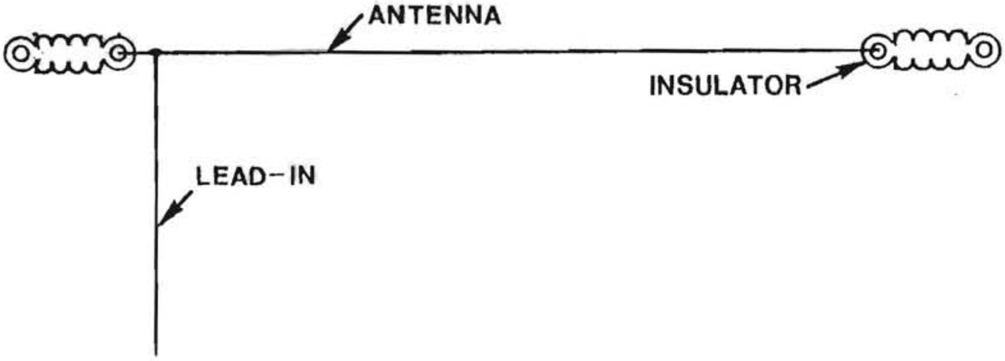

If you are fortunate enough to be able to put up an outside antenna, the basic rule of thumb is the higher, the better reception. Check your local electronics store for an antenna kit. You can construct an antenna using a glass or plastic insulator at each end of a length of copper wire (insulated or bare). Make the antenna as long as possible. It does not have to be in a straight line to work.

CAUTION

ANTENNA INSTALLATION
NEAR ELECTRICAL POWER
LINES IS DANGEROUS.

Make sure that your antenna
is far enough away from any
power line, so that it will
not touch a wire if it falls.

Connect a length of insulated wire between the end of the antenna and your crystal set antenna terminal. This antenna lead-in wire can be fed into your house through a window.

If you can not erect an outside antenna, run a length of insulated wire as long and high as possible through your house or apartment. It will work, but not as well as an outside antenna because of the shielding affect of the house walls.

Connect a ground lead to a cold water pipe. Make sure that it is a metal pipe. Or, you can buy a ground rod from your local electrical supply store and drive it into the ground near your house. Then connect your crystal set ground lead to the rod. For safety install a lightening arrestor between the antenna lead and ground (see the instructions with the device).

HEADPHONES

Headphones (also called earphones, or headset) are required to hear the received audio from a crystal set. The standard headphones are made with dual coils of fine wire connected in series in each phone. Horseshoe magnets are built into each phone case to provide a magnetic field. A disk of thin sheet iron (diaphragm) is mounted near the top of the coils. The phones are connected in series with a set of flexible leads terminated in metal "phone tips".

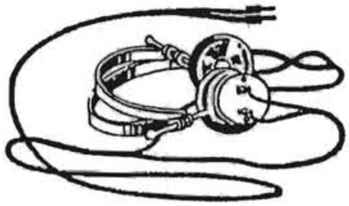

Detected audio signals flow through the coils and affect the intensity of the magnetic field from the horseshoe magnet. This changes the magnetic attraction of the diaphragm, and causes it to vibrate and produce audible sounds.

The total resistance of the series headphone coils is used as a measure of audio sensitivity. A resistance of 2000 ohms is sufficient. More sensitive headphones have a resistance of over 5000 ohms and are used to hear very weak signals.

The 2000 ohm headphones can be obtained at electronic parts mail order houses.

2

SIMPLE RECEIVER PROJECTS

SIMPLE CRYSTAL SET

Look at the schematic diagram. The crystal set uses a tunable ferrite coil L1, and a crystal diode D1. This type of tuning coil is called a "loopstick". The ferrite core is screwed into the coil form and increases the inductance of L1, thus tuning the receiver to a lower frequency.

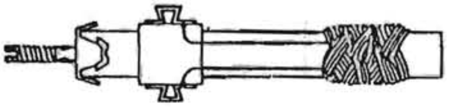

CONSTRUCTION

As shown in the illustration, the crystal set components are mounted on a 5 1/2-inch by 2 1/2-inch by 3/4-inch wood base. Layout and install the crystal set parts in the locations shown. The loopstick L1, is mounted with a metal strip supplied with it. Push the snap-in end of L1 into the large hole of the metal strip. Then bend 1/2-inch of the other end of the strip to form a bracket and mount it on the base with a wood screw. If the metal strip is not available, make one out of sheet metal approximately 2-inches long by 1/2-inch wide. Then drill a hole to fit L1 at one end, and a small hole to fit a wood screw at the other end.

Mount the four fahnestock clips and solder lugs with wood screws in the locations shown in the illustration.

WIRING

Use hookup wire to connect the crystal set components as shown in the schematic and illustration. The loopstick L1 may have three terminals. One of the terminals is a tap, which is not used in this circuit. Make sure that you connect only to the terminals at the start and end of the loopstick coil.

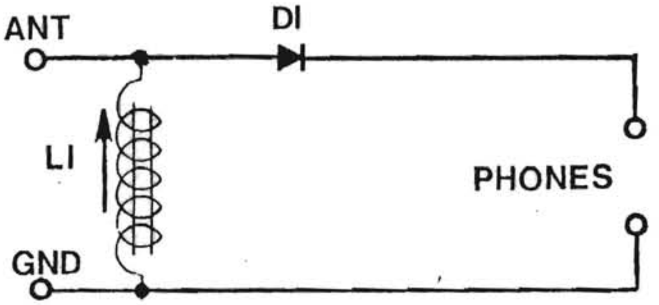
ANT
DI
LI
GND
PHONES

SIMPLE CRYSTAL SET

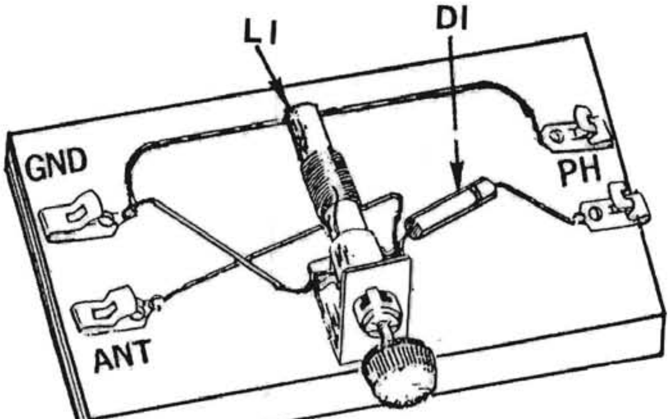
LI
DI
GND
PH
ANT

List of Materials

D1 - Germanium diode
(1N34A or equiv.)
L1 - Loopstick
(see text)
4 - Fahnestock clips
BASE - 5 1/2 X 2 1/2 X
3/4-inch wood section
PHONES - 2000-ohm headphones
MISC. - Solder lugs, wood screws,
knob and bracket to fit L1,
hook-up wire.

Install a small knob on the end of the L1 adjustment screw. Make sure that the screw turns freely with the knob. Position the 1N34A diode as shown before soldering the leads.

Experiment 1

Connect the antenna, ground, and 2000-ohm headphones to the crystal set terminals. Rotate the L1 knob counter-clockwise as far as it will go. Do not turn past this point, or you may break the ferrite rod inside the coil form. The ferrite is now outside of the coil winding. This is the highest frequency point of the tuning range of L1.

Slowly turn the L1 knob clockwise and listen for received radio stations. When the L1 knob is turned fully clockwise, the ferrite will be completly inside the coil (increasing the inductance) and it will be at the lowest frequency point of the tuning range.

Experiment 2

Connect capacitors, with values from 50 mmf to 300 mmf, in parallel with L1. Then tune L1 and note how the frequency range has changed.

AMPLIFIER CONNECTION

The simple Crystal Set (and the other receiver projects) can be connected to an amplifier in place of earphones. This amplifier can be a single channel input of your home stereo.

Parts values are not critical; C1 is approximately .005 mfd, and the volume control R1 can be any value from 1000 ohms to 10,000 ohms. Use shielded wire between R1 and the amplifier input jack.

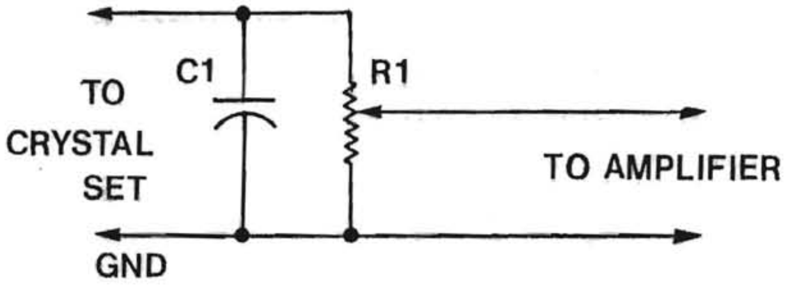
TO
CRYSTAL
SET
C1
R1
TO AMPLIFIER
GND

Amplifier Connection

Schematic Symbols

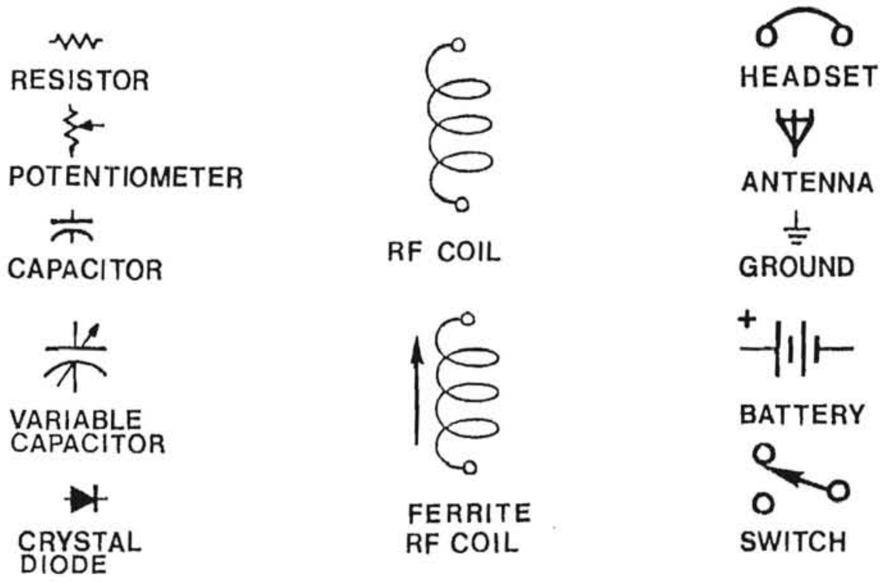
RESISTOR
POTENTIOMETER
CAPACITOR
VARIABLE CAPACITOR
CRYSTAL DIODE
RF COIL
FERRITE RF COIL
HEADSET
ANTENNA
GROUND
+
BATTERY
SWITCH

List of Materials

D1 - Germanium diode, type 1N34A, 1N60, 1N82A, or equiv.
L1 - Slider-tuned coil (see text)
4 - Fahnestock clips (terminals)
BASE - 6 x 3 x 1/2-inch section of wood (see text)
PHONES - 2000 ohms headphones
MISC. - Coil form (see text), No. 24 enameled copper wire, 3/32 inch dia. brass rod, brass ball slider (see text), solder lugs, two small brackets, hook-up wire, wood screws, machine screws and nuts.

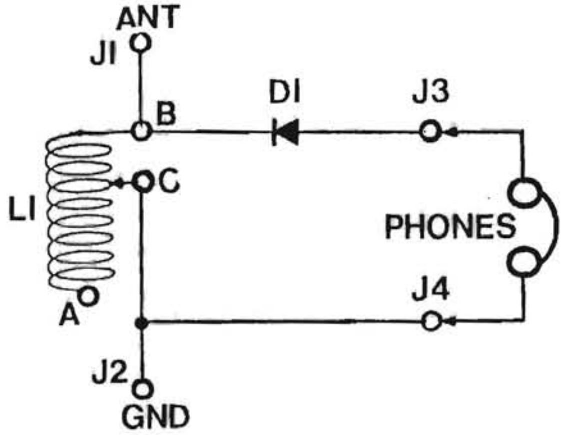
ANT
J1
B
D1
J3
C
L1
PHONES
J4
A
J2
GND

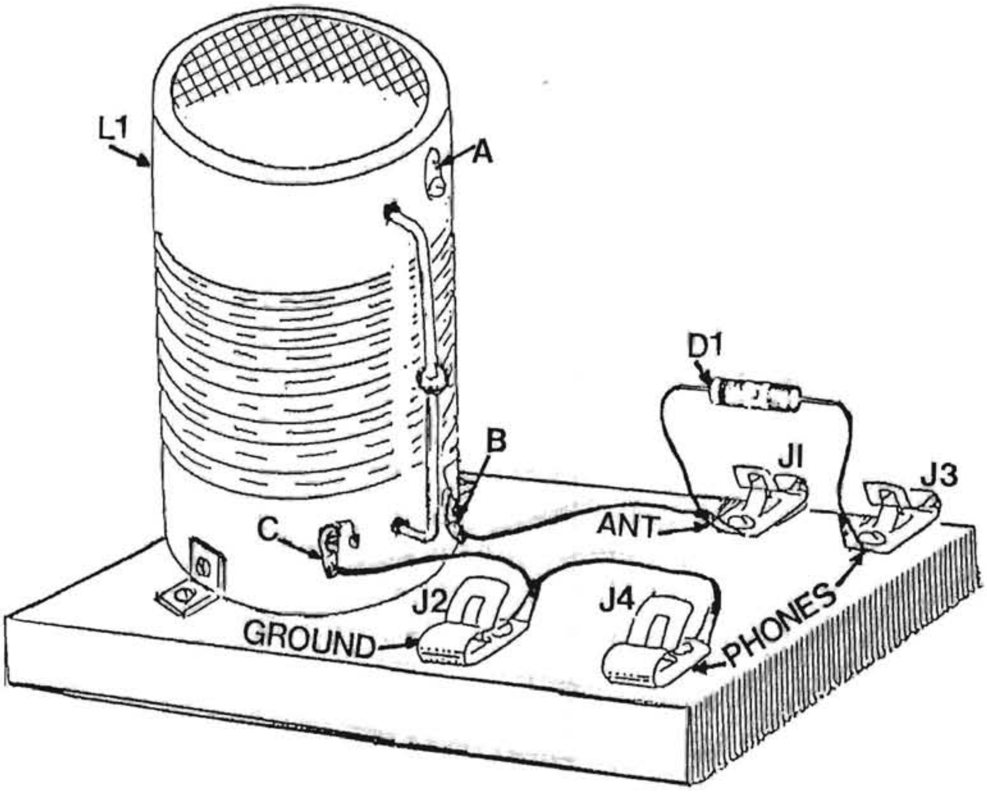
L1
A
D1
B
J1
J3
C
ANT
J2
J4
GROUND
PHONES

SLIDER TUNED CRYSTAL SET

SLIDER TUNED CRYSTAL SET

In the early days of radio, slider tuned coils were used in crystal sets. This method of tuning the inductance uses an adjustable metal contact (slider) that moves over the coil. The slider makes contact with individual coil wires to tune in the radio stations.

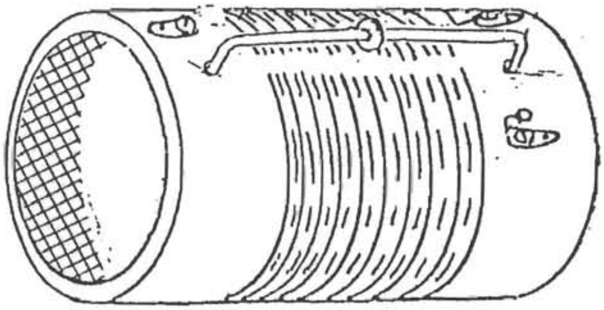

The enamel insulation of the coil wires in the slider path is removed for good electrical contact.

You can experiment with a slider tuned coil by building this crystal set. As shown in the illustration, the coil is mounted upright on a 6-inch by 3 1/2-inch by 1/2-inch wood base. A semiconductor diode is used for a detector.

TUNING COIL CONSTRUCTION

Look at the drawing of the tuning coil L1 construction details on the next page. The tuning coil is wound on a cardboard or plastic mailing tube section, 2 5/8-inches in diameter and 5-inches long. Make sure that you select a rigid, thick-walled tube for a coil form. The tube used in our model has a 3/16-inch wall. The coil form must be rigid to hold the slider ball and rod assembly.

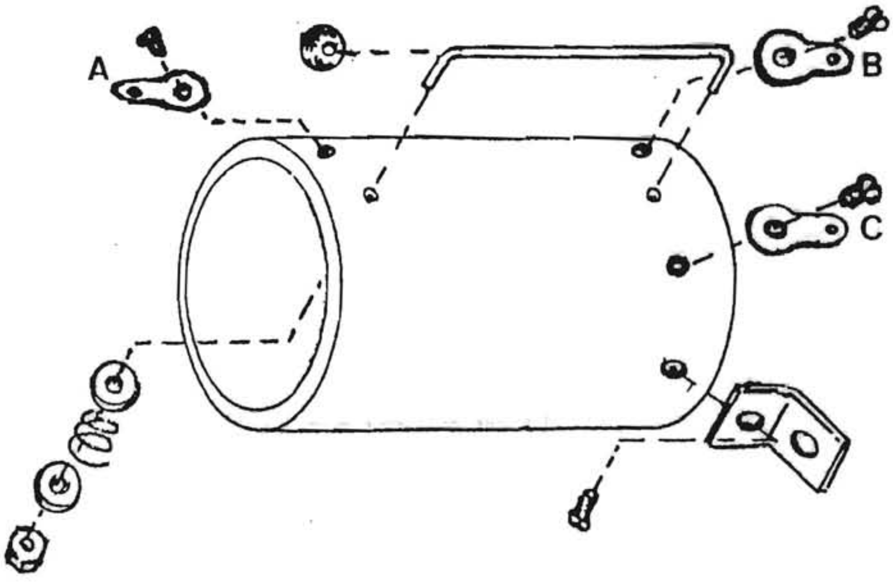

Before winding the coil, drill all the holes in the form as shown in the drawing, and then install the solder lugs. Position the solder lug ends toward the coil form edges.

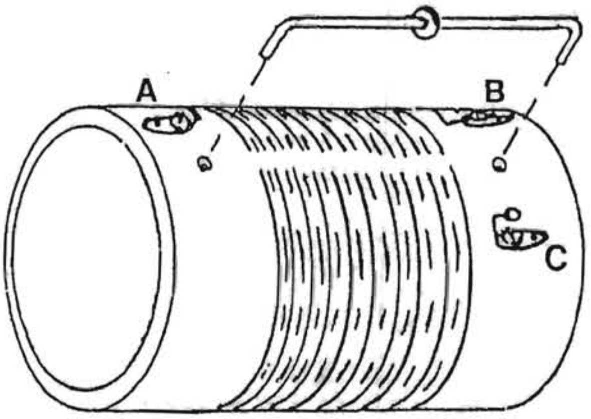

The coil is wound with No. 24 enameled copper wire. Remove the enamel from the wire end with sandpaper and then solder the wire to the lug. Start winding the coil, keeping the turns as tight and close together as possible. Wind the wire to the front of the bottom solder lug B. Remove the enamel and solder the wire end to the lug.

A brass ball approximately 3/8-inches in diameter is used as the moving contact slider. This brass ball can be found at your local electrical supply store. It is a type of ball that is used as a top nut for small table lamps. Drill a hole through the ball so that it will slide over a length of 3/32-inch diameter brass rod. Bend the brass rod at each end (after placing the ball in the center of the rod), to fit through the holes in the coil form as shown in the drawing. Cut the rod 1-inch down from the bend at each end.

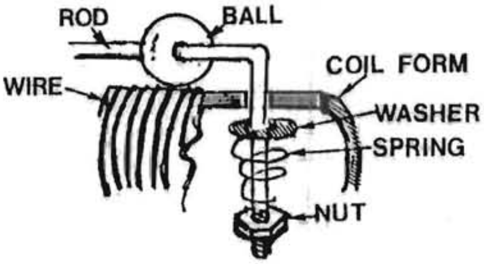

Insert the brass rod with the slider ball into the coil form holes. Then place a small washer and spring on one end of the rod (inside the coil form). Solder a nut on the end of the rod to hold the spring in place. Do the same to the other end of the rod. After soldering, slide the ball over the wires and check that it slides smoothly. Use sandpaper to remove the enamel insulation of the wires in the path of the ball slider. Connect a wire between the soldered nut on the bottom end of the brass rod and the solder lug near the rod.

BASEBOARD

All of the crystal set components are mounted on a wood baseboard as shown in the drawings. Cut the baseboard to size; a 6-inch by 3 1/2-inch section of 1/2-inch thick wood (maple is used in our model). Sand the edges after cutting. It is not necessary to paint or stain the baseboard.

Mount the four terminals and solder lugs as shown in the drawing. Label the four terminals with either rub-on lettering or cemented paper tags. Install two brackets on opposite sides of the bottom of the coil, and mount it on the baseboard with the lugs toward the terminals.

WIRING

Bare No.22 wire was used to wire our model, but any kind of hookup wire can be used. Connect the wires between the solder lugs as shown in the drawing, except do not connect the antenna terminal lug wire to the coil terminal at this time. Connect the crystal diode between the solder lugs as shown.

Experiment 1

This experiment will show how an untuned crystal detector functions.

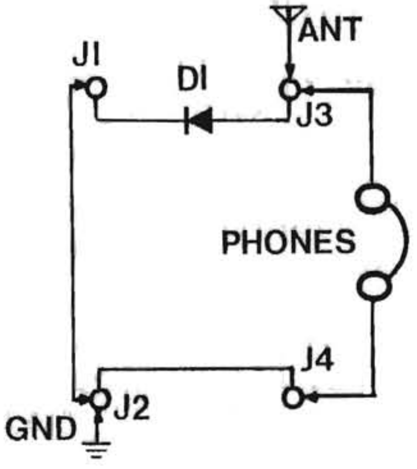

Connect the untuned detector circuit as shown in the drawing, and then hook-up your antenna and ground leads. Connect 2000-ohm headphones to the circuit and listen to the detected radio waves.

You will probably hear a strong local radio station, with other, weaker radio station transmissions all jumbled together.

Experiment 2

Reconnect the baseboard wires to the circuit of the Slider-Tuned Crystal Set as shown in the drawing. Listen to the detected radio waves as you tune the coil by sliding the brass ball over the sanded wire path. You should be able to receive the radio stations much better than the untuned detector circuit of Experiment 1.

LOADING COIL

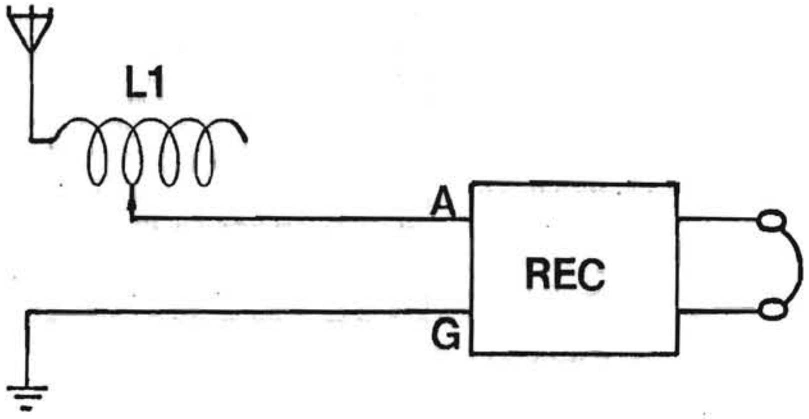

An additional slider tuned coil, L1, can be used as a Loading Coil to increase the electrical length of your antenna. This may allow better reception of the lower broadcast band frequencies. Connect L1 in series with the antenna lead to the receiver, and tune it for best reception.

WAVE TRAP

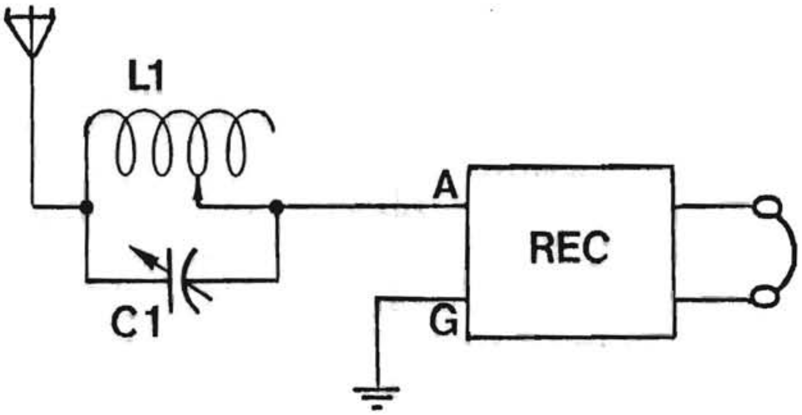

L1 can also be used in a Wave Trap circuit to tune out a strong local signal, and allow easier tuning of weaker stations. C1 is a 365 mmf variable capacitor connected in parallel with L1. Adjust L1 and C1 so that the interfering station is at minimum.

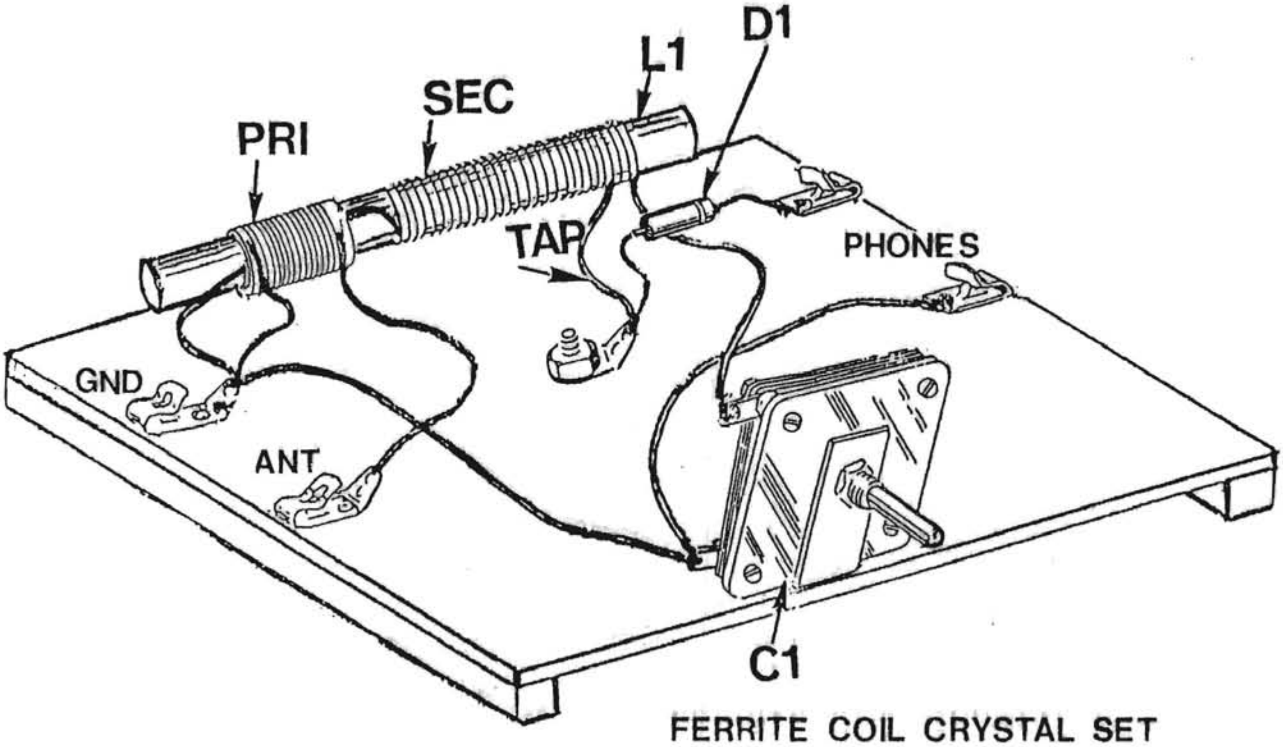
D1
L1
SEC
PRI
TAP
PHONES
GND
ANT
C1

FERRITE COIL CRYSTAL SET

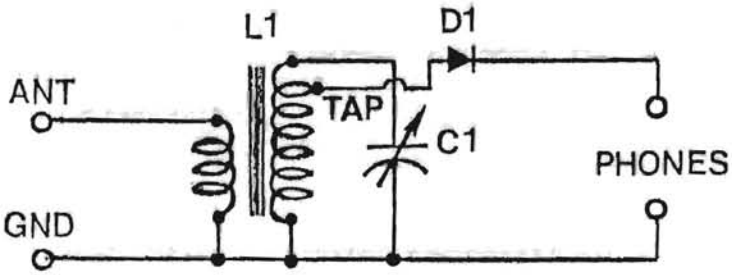
L1
D1
ANT
TAP
C1
PHONES
GND

List of Materials

C1 - 365 mmf variable capacitor.
D1 - Germanium diode (1N34A or equiv.).
L1 - Ferrite coil (see text).
4 - Fahnestock clips.
2 - wood sections; 6 X 1/2-inch square (see text).
BASE - 8 1/2 X 6-inch sheet plastic (see text).
PHONES - 2000-ohm headphones
MISC. - plastic tube section for L1 primary winding (see text), solder lugs, machine screws and nuts, wood screws, bracket for C1 (see text), knob for C1, hookup wire.

FERRITE COIL CRYSTAL SET

This crystal set has a large ferrite core coil L1 of a type that is normally used for a built-in antenna in portable radios. This type of coil has a very high "Q" and may be more selective than an air-core coil. As you can see in the schematic, a primary coil is wound around the ferrite coil. The original winding is used as the secondary.

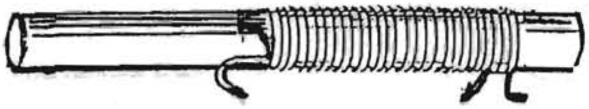

The primary coil (connected to the antenna and ground) can be moved close to, or away from, the secondary (original winding connected to D1). This variable coupling is used to control the selectivity of the crystal set.

PRIMARY COIL

The primary coil is wound on a 1-inch section of plastic tube that can fit loosely over the ferrite rod. A 1/2-inch diameter plastic tube is used on the receiver shown in the illustration. Wind 12-turns of hookup wire evenly over the tube and twist the ends together to prevent movement. Leave 4-inch leads from the primary coil winding. Slide the primary coil over the center of L1.

BASEBOARD

The crystal set components are mounted on a 8 1/2-inch by 6-inch section of sheet plastic. The thickness of the plastic is not critical, but it must be rigid enough to hold the parts without bending. A 6-inch long 1/2-inch square wood section is installed under each end of the baseboard. A section of wood can be used for the baseboard with wood screws to mount the parts, in place of machine screws and nuts.

The model shown uses a plastic variable tuning capacitor, but an air type capacitor can be used for C1 instead. Make a metal bracket approximately 1-inch wide by 1 1/4-inch high and a 1/2-inch right angle mounting foot from sheet aluminum. Drill a hole in the top of the bracket to fit C1 and two holes in the mounting foot to fit small machine screws. Locate the components on the baseboard as shown in the illustration and then drill mounting holes. If you have a cardboard or plastic mounting supplied with ferrite coil L1, you can mount it on the baseboard. If not, L1 can be taped loosely on top of the baseboard. Th ferrite coil L1 in our crystal set was obtained from an old radio. Install the components on the board with solder lugs, machine screws, and nuts.

WIRING

Connect the parts with hookup wire as shown in the illustration. Use the schematic diagram as a guide. Make sure that the ground lead from L1 secondary passes inside the primary coil. Also check that the primary coil slides freely over the L1 winding. Install a knob on the C1 shaft, and mark the terminal designations on the baseboard.

Experiment 1

Hookup the antenna, ground and 2000-ohm headphones to the crystal set terminals. Slide the primary coil over the center of the L1 winding. Tune C1 for radio stations. Then slide the primary coil towards the ground end of L1 while tuning C1. Note the difference in selectivity.

Experiment 2

Change the number of turns of the primary winding and repeat Experiment 1.

Operating Tips

After operating a crystal set for some time, you may notice a difference between day, evening, and night reception of radio stations. This is due to the two ways that radio signals travel between the transmitting antenna and a receiving antenna.

(a) The ground wave; which moves along the surface of the earth.
(b) The sky wave; which travels upward and is reflected by the ionosphere.

The reception of broadcast stations is dependent upon the time of day. During daylight hours, stations are received primarily by ground wave transmission. At night, the broadcast stations will be received via sky wave transmission. Also, some radio stations change to a lower power at night. Reception in the evening may be more difficult as the fading ground wave is interfered with by reflected waves. But later, it may be possible to hear far-away stations transmitted by sky wave.

Your geographical location to radio stations is very important for reception, as a crystal set receiver does not amplifiy signals. It is entirely dependent upon the strength of the radio waves. If you are in a deep valley surrounded by high mountains, reception will be difficult. If you live in a flat plain, with no obstacles to radio transmission, reception may be very good.

An outside antenna is necessary for for best reception. If possible, try erecting an extra antenna at a right angle to the original one, and switch it in to provide a directional effect for increased signal strength. Keeping a log of received stations for a week may be helpful in determining the radio reception conditions in your area.

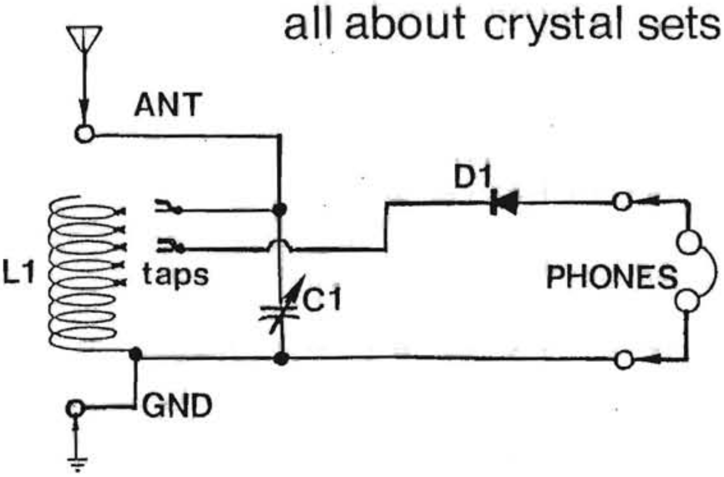
ANT
D1
L1
taps
C1
PHONES
GND

List of Materials

C1 - 365 mmf variable capacitor.
D1 - Catwhisker crystal detector (or 1N34A or equiv. diode).
L1 - Spiderweb coil (see text).
4 - Fahnestock clips.
2 - small alligator clips
BASE - 8 X 6 X 1/2-inch section of wood (see text).
MTG. POST - 5 x 3/4 x 3/8-inch wood section (see text).
PHONES - 2000 ohms headphones.
MISC. - Coil form (see text), No. 22 enameled copper wire, solder lugs, hook-up wire, wood screws, machine screws, and nuts.

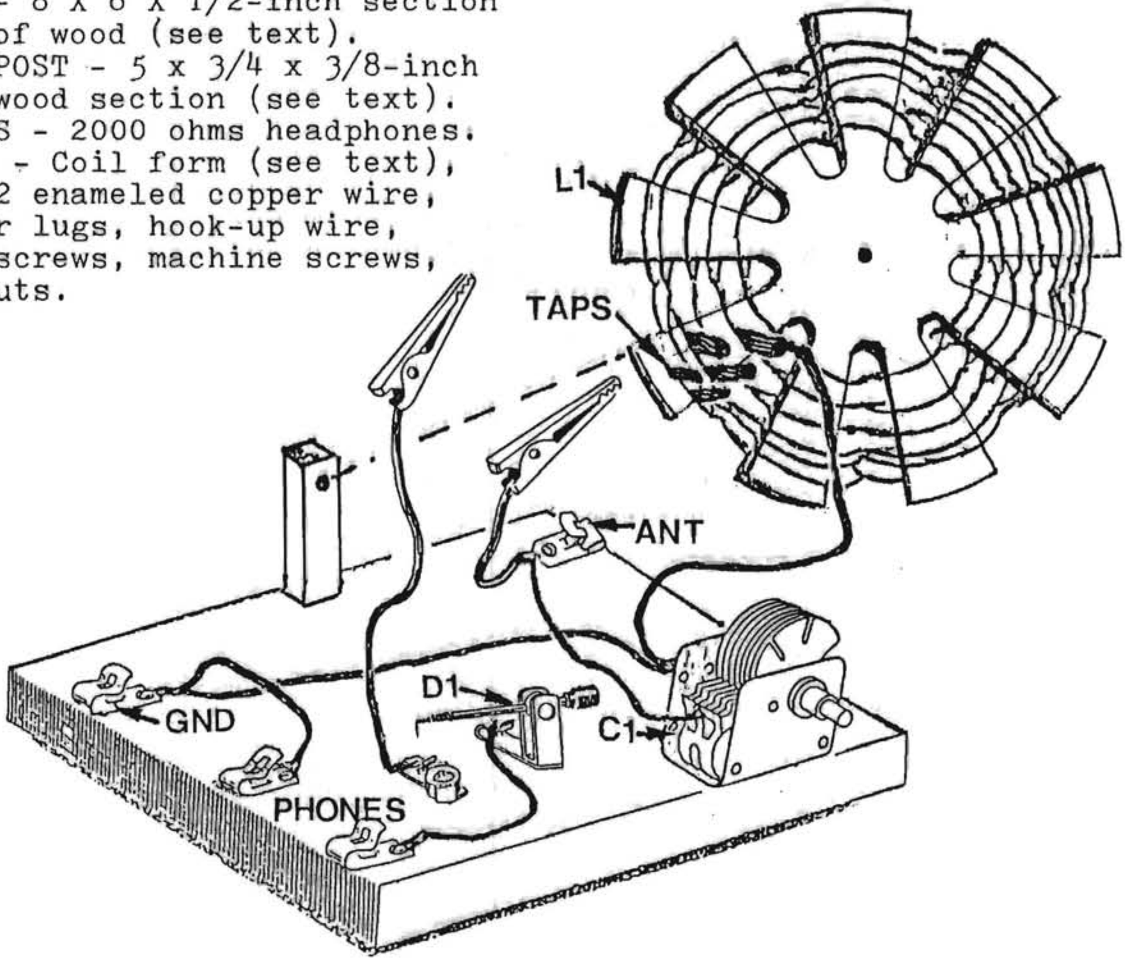
L1
TAPS
ANT
D1
C1
GND
PHONES

SPIDERWEB COIL CRYSTAL SET

SPIDERWEB COIL CRYSTAL SET

The spiderweb coil is a tuning coil that is wound on a flat wheel form that has an uneven amount of spokes. This type of coil was also used as a loop antenna in early radios.

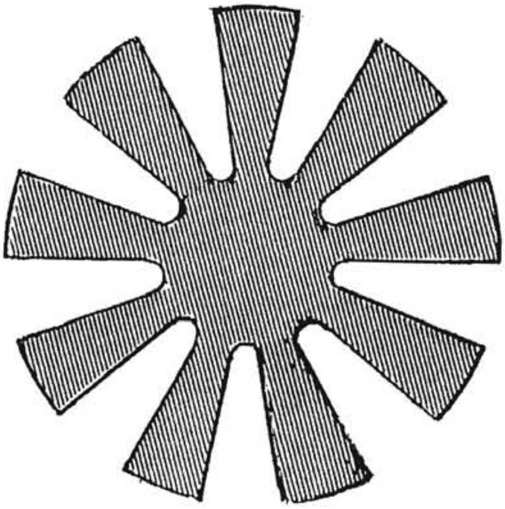

Our receiver uses a tapped spiderweb coil that is tuned by a variable capacitor. As shown in the illustration, the spiderweb coil is mounted at the rear of a 8-inch by 6-inch by 3/4-inch wood base. A catwhisker crystal detector and a variable capacitor are mounted near the front of the wood base.

SPIDERWEB

The spiderweb coil is wound on a 6-inch diameter flat form that has nine vanes. Make a tracing of the spiderweb coil form template on the next page. Then use carbon paper to transfer the tracing to a section of 1/8-inch fibreboard or sheet plastic. Cut the coil form out with a jeweler's saw, and drill a center hole to fit a small wood screw.

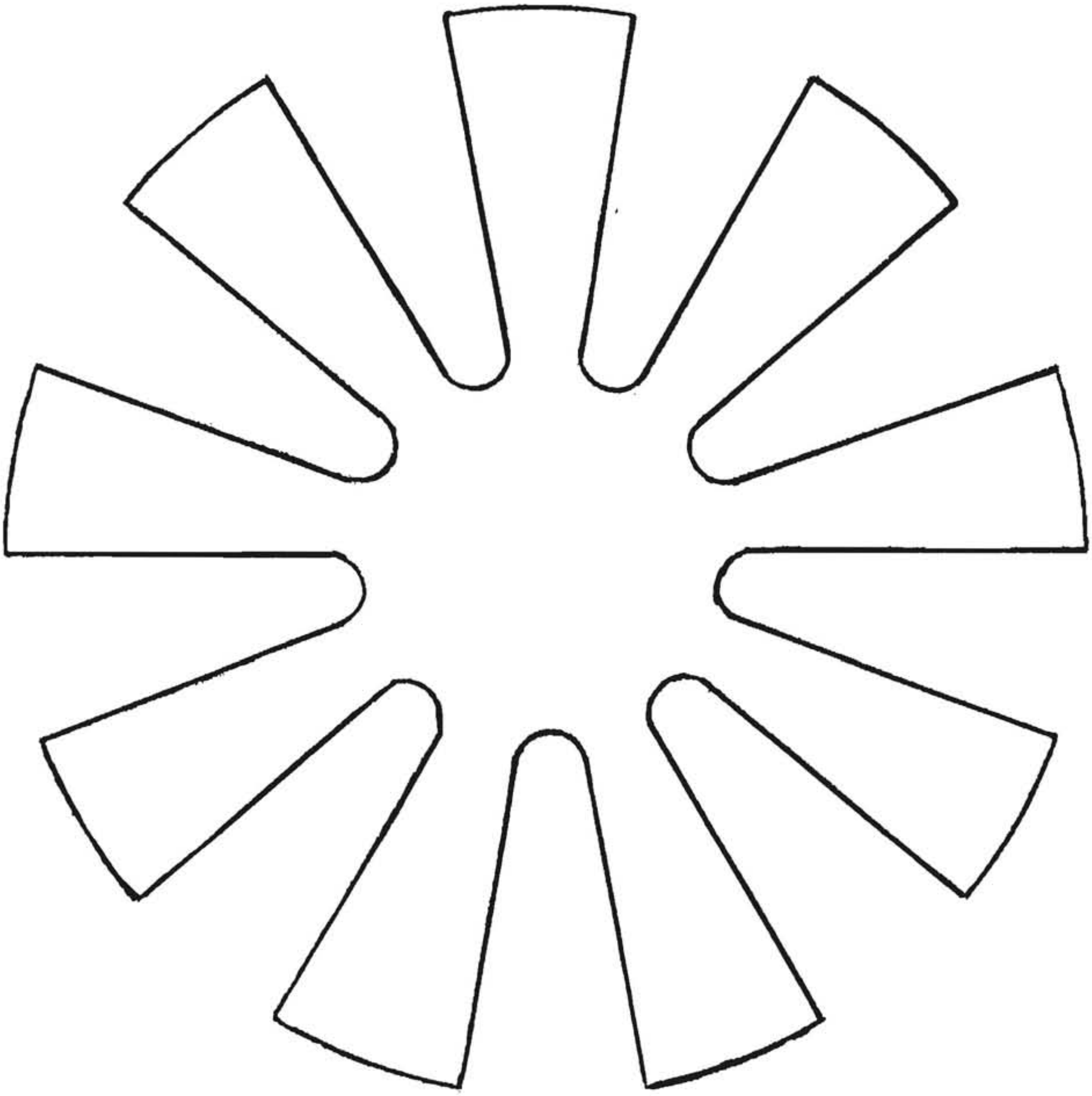

Spiderweb Coil Form Template

Wind the coil with No. 22 enameled copper wire, starting from the center and winding outward. Leave about 5-inches of the starting end of the wire free. It will be used as a connecting lead. Feed the wire behind a vane and over the front of the next vane as you wind. Wind the wire closely and evenly on the form. It is not necessary to count the turns. Wind the wire to about 1/4-inch from the end of a form vane. Then drill a small hole near the vane end, and bend a solder lug through it. Solder the wire end to the lug.

On one of the vanes, count down five wires and then carefully lift it outward. Remove about 1/4-inch of the enamel with a section of sandpaper and then bend the end of a solder lug aound the bared wire. Solder the lug to the wire, then cut off remaining portion of the lug (away from the bentover end). Repeat this every five turns until you have a total of six lug taps on the coil. Stagger the lugs away from each other to keep them from shorting.

BASEBOARD

As shown in the illustration, the Spiderweb Coil Crystal Set parts are mounted on a wood baseboard. Cut the 8-inch by 6-inch baseboard from a section of 1/2-inch thick wood. White pine was used in our model. Sand the surface of the wood after cutting.

Make the spiderweb coil mounting post by cutting out a 5-inch by 3/4-inch by 3/8-inch wood section. Then cut a notch in the center of the rear of the baseboard to fit the wood section. Install the wood section in the notch with small wood screws.

Mount the parts on the baseboard as shown in the illustration with small wood screws. If the mounting holes of the tuning capacitor C1 are on the bottom, drill matching holes in the baseboard and use flathead machine screws to hold the capacitor.

Install solder lugs with the four terminals, and mount the spiderweb coil to the mounting post with a wood screw through a center hole in the coil form. The coil should be positioned with the lugs facing forward (on the left side of the coil form).

WIRING

Connect the crystal set components with hookup wire as shown in the illustration. Use 6-inch lengths of insulated stranded wire to the two small alligator clips.

Experiment 1

Connect antenna, ground, and 2000-ohm headphones to the crystal set. Then connect the D1 alligater clip lead to the antenna terminal. Set the tuning capacitor C1 to minimum capacity (rotor blades all the way out). Connect the antenna clip lead to the tap on L1 near the center of the form.

Adjust the crystal detector D1 catwhisker to a sensitive spot and tune C1 for a radio station. It may be easier to tune for stations if you temporarily connect a crystal diode (1N34A or equiv.) in place of the catwhisker crystal detector.

After a station is heard, you can disconnect the diode and probe for a sensistive spot on the crystal with the catwhisker. Change the antenna clip lead to other L1 taps and continue tuning C1 for radio stations.

Experiment 2

Disconnect the D1 clip lead and reconnect it to a tap on L1 close to the center of the coil. This will load L1 more lightly than if the detector was connected to the top of the coil. Repeat the tuning procedure of Experiment 1 and note the difference in selectivity and volume of the received radio stations. Then tune in a radio station and move the D1 clip lead to other taps on L1. There will be a particular tap point for optimum selectivity and volume for each received station.

STATION LOG

DATE	TIME	DIAL	STATION	NOTES

3 ADVANCED RECEIVER PROJECTS

DUAL TUNED CRYSTAL SET

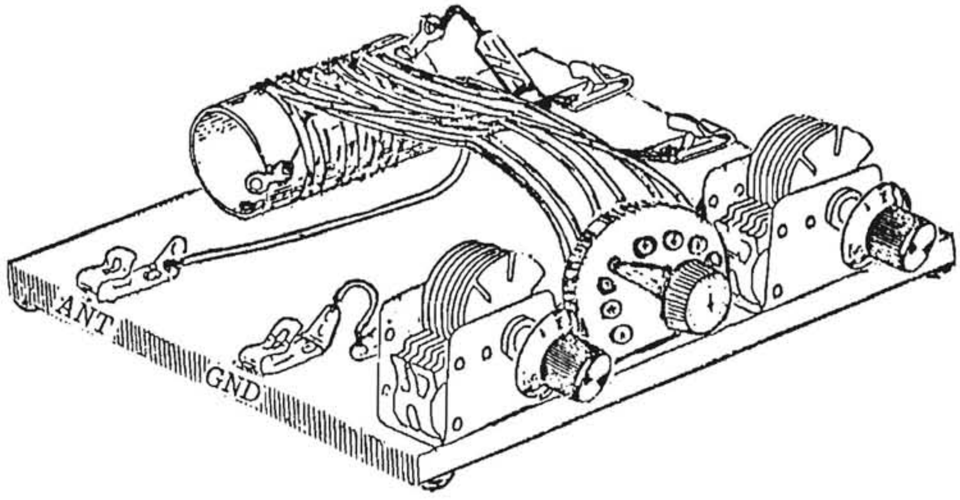

This crystal set circuit uses two variable capacitors C1 and C2. As you can see in the schematic drawing, C1 tunes the ground circuit, and C2 tunes a tapped coil L1. The taps of L1 are connected via the rotary switch S1.

TUNING COIL

Look at the drawing of the coil form construction details on page 34. The tuning coil L1 is wound on a section of 1/8-inch wall plastic tube, 2-inches in diameter, and approximately 4-inches long.

Drill holes in the form and install three solder lugs with machine screws and nuts. Position the solder lug ends towards the coil form ends as shown.

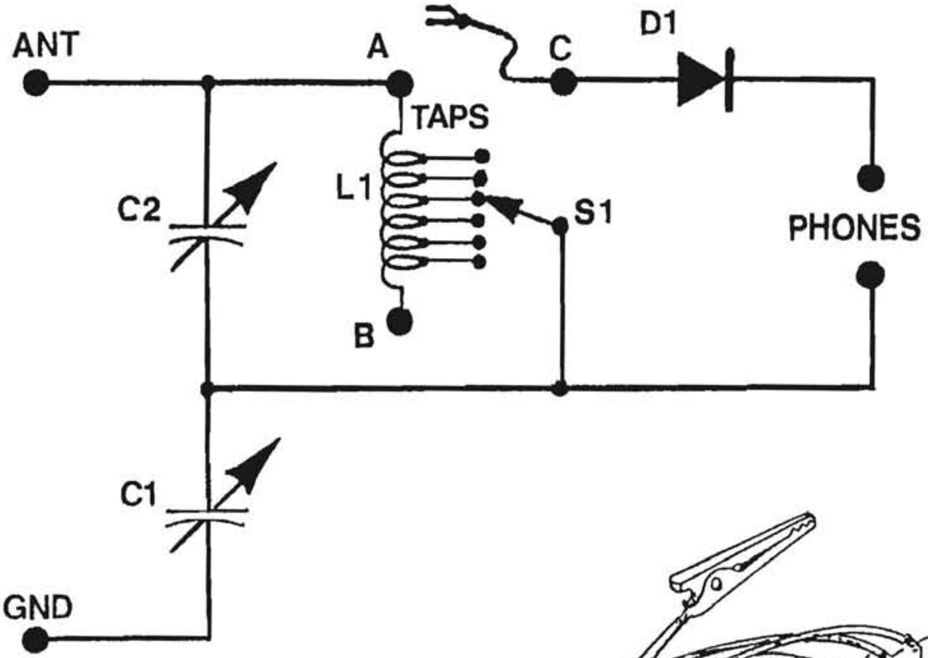
ANT
A
C
D1
TAPS
L1
C2
S1
PHONES
B
C1
GND

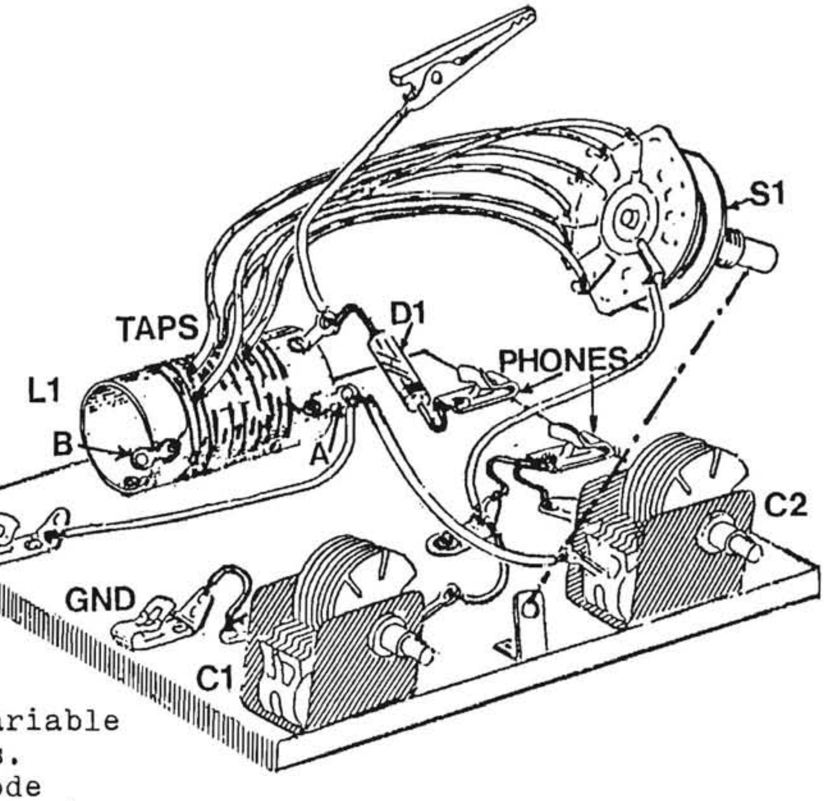
S1
TAPS
D1
L1
PHONES
B
A
C2
ANT
GND
C1

List of Materials

C1,C2 - 365 mmf variable capacitors.
D1 - Germanium diode (1N34A or equiv.).
L1 - Tuning coil (see text).
S1 - 1-pole, 10-position rotary switch (see text).
4 - Fahnestock clips.
1 - Small alligator clip.
BASEBOARD - 5 x 8 x 3/8-inch wood section (see text).
PHONES - 2000-ohm headphones.
MISC. - Coil form (see text), No. 24 enameled copper wire, solder lugs, hook-up wire, wood screws and nuts, knobs, bracket for S1.

DUAL TUNED CRYSTAL SET

The coil L1 is wound with No. 24 enameled copper wire, and is tapped every five turns for a total winding of 75 turns.

Drill a small hole in the coil form approximately 1 1/4-inch from the "A" lug. Remove the enamel from the end of the No. 24 wire and then feed the wire end through the hole. Solder the wire to lug "A".

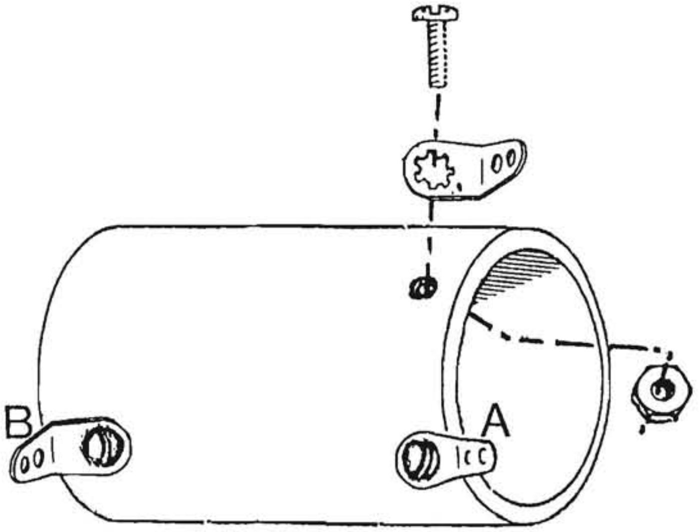

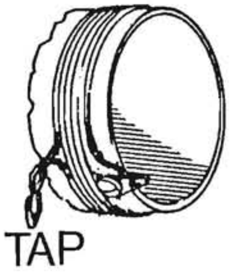

Wind five closely spaced tight turns around the coil form. Then bend back and twist together 1/2-inch of the wire to make a tap. Position the tap outward and then continue winding the coil, keeping the turns as tight and close together as possible. Make a tap every five turns and then drill a small hole in the coil form after the 75th turn. Feed the wire through the hole, remove enamel, and solder the end to lug "B".

BASEBOARD

The Dual-Tuned Crystal Set is built on a wood baseboard as shown in the illustration. Cut the 5-inch by 8-inch baseboard from a section of 1/4-inch thick plywood. Sand the edges and surface of the baseboard to remove any splinters. Drill holes in the baseboard and install the parts with small machine screws and nuts in the locations shown in the illustration. Drill mounting holes at each end of the tuning coil L1 and position it on the rear of the baseboard with the coil taps toward the front. The illustration shows a commercial rotary switch, but a wooden rotary switch can be used for S1 instead. (See page 53 for construction details.)

Install the four fahnestock clips (used as antenna, ground and headphone terminals) with solder lugs. Mount an additional solder lug on the baseboard midway between S1 and L1.

WIRING

Connect the crystal set parts with hookup wire as shown in the pictorial illustration and the schematic diagram. Use the center solder lug as a junction point for leads from C1, C2 and S1 as shown in the illustration. Connect the leads from S1 to the taps on L1 in numerical sequence; every 5 turns for 7 taps. Then connect the last three leads every 10 taps. Insert the lead ends into the taps and hold them with a drop of solder. This will make it easier to move leads to other L1 taps. Use a 5-inch length of stranded hookup wire for the alligator clip lead connected to D1 at solder lug C.

Experiment 1

Connect 2000-ohm headphones, antenna and ground leads, to the crystal set terminals. Then connect the D1 clip lead to the L1 "A" solder lug.

Set S1 to each tap position in turn and tune C1 and C2 for received radio stations. If all of the local stations can not be heard, experiment with different connections to the L1 taps. More turns may have to be added to L1 (with additional five-turn taps) to receive stations at the lower frequency end of the broadcast band.

Experiment 2

Remove the D1 clip lead from "A" and then connect it to the "B" solder lug on L1. Repeat the tuning method of Experiment 1 and note if the crystal set is more selective. This is possible, because L1 is now connected as an rf transformer. You can also connect the D1 clip lead to each of the S1 taps and note if there has been any improvement in reception.

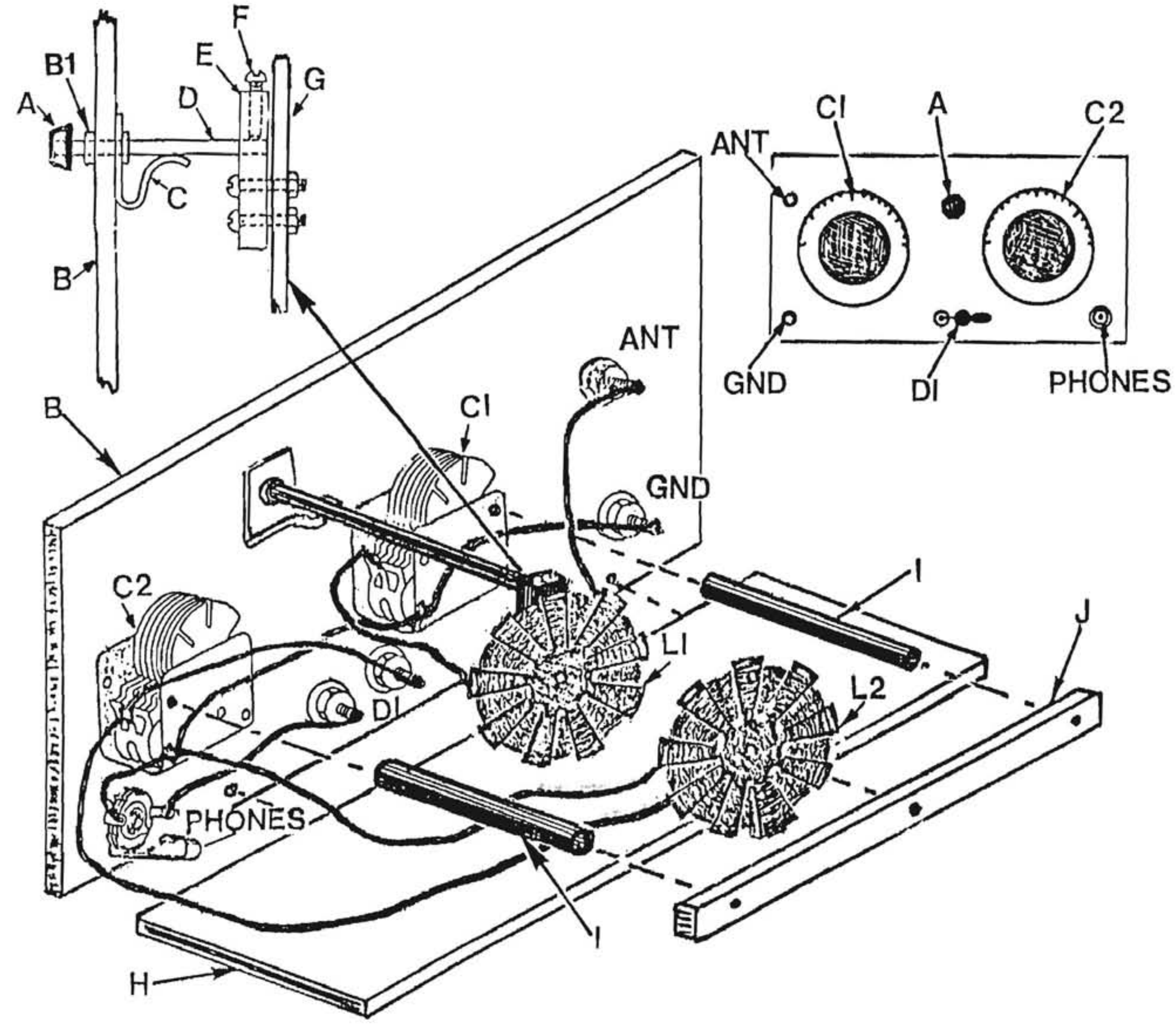
F
B1
E
G
A
D
C
B
ANT
C1
A
C2
GND
D1
PHONES
ANT
B
C1
GND
C2
I
J
L1
L2
D1
PHONES
I
H

SELECTIVE CRYSTAL SET

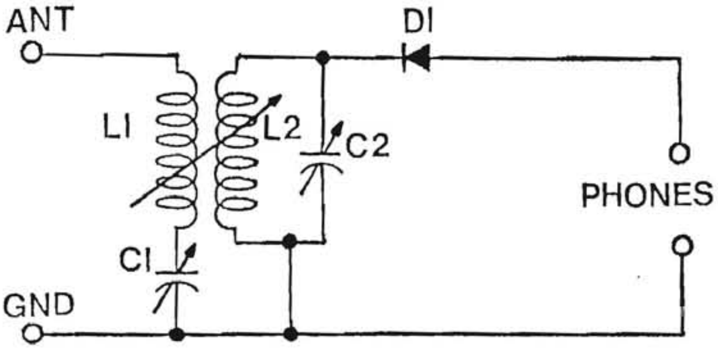
ANT
D1
L1
L2
C2
PHONES
C1
GND

SELECTIVE CRYSTAL SET

This receiver uses two spiderweb coils in a two-circuit tuner for good selectivity and sensitivity. As you can see in the schematic diagram, the antenna-ground rf input circuit is tuned by L1-C1 for maximum signal gain. L1 acts as the primary winding of an rf transformer, with L2-C2 as the tuned secondary. Coupling between L1 and L2 is variable for best selectivity. L2 is connected to a catwhisker crystal detector and the audio signals are fed through the phone jack to 2000-ohm headphones.

As shown in the illustration, the crystal set parts are mounted on the rear of a black plastic panel. This type of layout is similar to the type of construction of the old-time crystal sets.

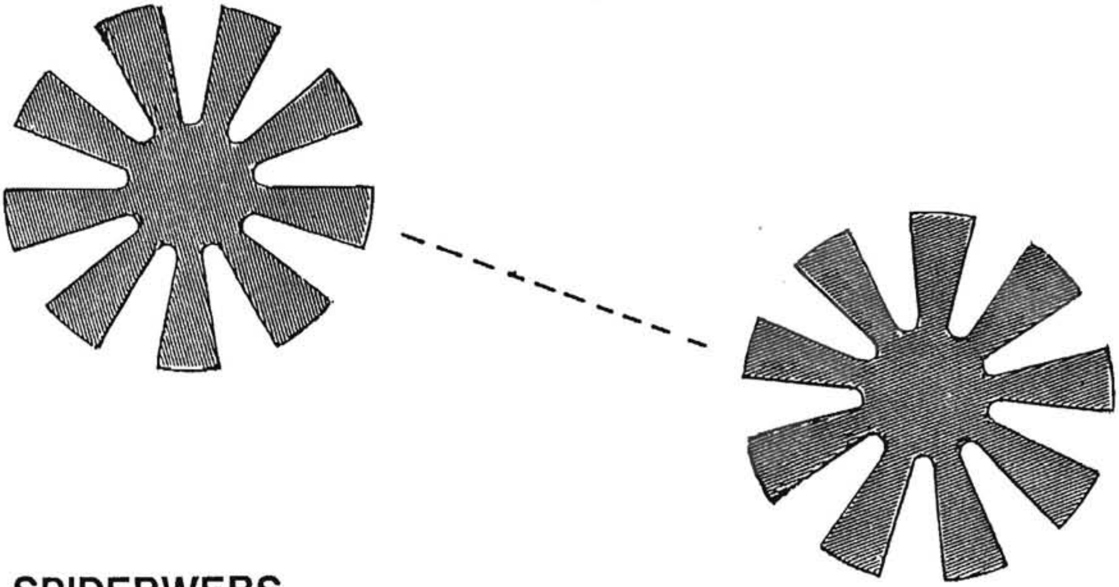

SPIDERWEBS

Both L1 and L2 spiderweb coils are made exactly the same way. L1 and L2 are wound on 17-vane coil forms 3 5/8-inches in diameter. The coil forms in our receiver are made from 1/16-inch sheet plastic of the same type used for printed circuit boards (but without the copper foil). Any kind of rigid sheet plastic should be suitable for the coil forms.

Make a tracing of the spiderweb coil template. Then use carbon paper to transfer the tracing on a section of 1/16-inch thick sheet plastic. Cut out the vanes with a jeweler's saw. Drill two holes as shown, and install the two solder lugs.

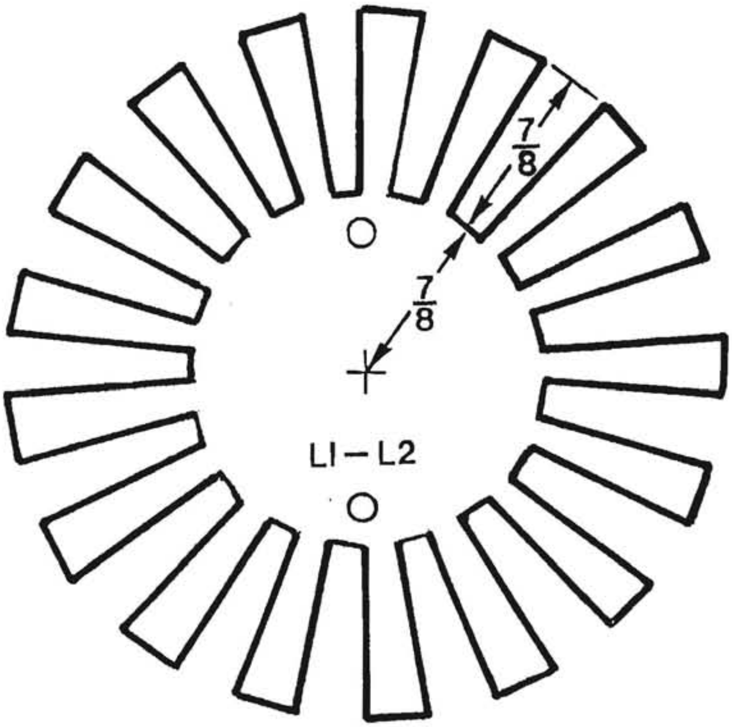

COIL FORM TEMPLATE FOR L1–L2

Wind as much No.22 enameled wire as possible on each coil form. Solder the wire to a solder lug before winding a coil. Then wind the wire over a vane and under the next vane. Wind the wire closely and evenly on the form. It is not necessary to count the turns. Solder the wire end to the remaining solder lug

CONSTRUCTION

The panel used in our receiver is a 7 3/4-inch by 4 1/2-inch section of 1/4-inch thick black acrylic plastic. The size is not critical, but it should be large enough to mount all of the parts as shown in the illustration.

Layout and drill the mounting holes of the components on the panel. Make sure that C1 and C2 are positioned so that the edges of the tuning knob dials are more than 1/2-inch apart. Install the catwhisker crystal detector assembly, antenna and ground terminals, and the phone jack in the locations shown.

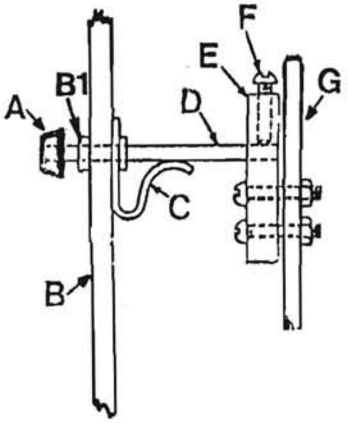

As you can see in the illustration, L1 is installed on the end of a variable coupling metal rod. This 1/4-inch diameter rod is 3-inches long with a flat side. Drill and tap a small hole close to the end of the rod. The rod used in our model came from a discarded volume control. Cut a 2-inch long by 1/2-inch wide by 3/8-inch thick wood section and drill holes to fit the rod, two mounting screws, and a hole for the rod set screw. Locate and mount the wood section in the center of a spiderweb coil L1 so that the rod will be 3/4-inch down from the edge of the top vane.

Hold L1 behind the panel and using the free end of the rod, locate the panel hole. Position L1 midway between C1 and C2, and make sure that the top edge of the coil is below the top of the panel. Drill a hole to fit the rod bushing in the panel hole location. The panel bushing in our model was removed from a discarded volume control.

Drill a hole to fit the bushing in one end of a 2-inch by 1/2-inch section of sheet aluminum. Bend the other end of the section to fit against the flat side of the rod. Install the metal section and the bushing in the panel hole.

Insert the rod into the bushing and make sure that the metal section end fits close to the flat side to prevent rotation of the rod. Install a knob on the rod end and make sure that the rod can be pushed in and out easily. If necessary, put a small amount of grease on the flat side of the rod.

Install the remaining spiderweb coil L2 on a wood section that is mounted on the rear of the panel with two spacers. The spacers should be long enough for L2 to be located 1/4-inch behind L1 with the rod pushed all the way in. The 5 1/2-inch by 1-inch by 1/4-inch wood section in our model is supported with screws installed through 1 1/2-inch metal spacers into tapped holes in the rear of C1 and C2. The screws and bushings can be made longer and mount into panel holes in your receiver.

Install a wood section on the bottom rear of the panel to keep the receiver upright. A 5-inch by 3-inch section of 1/4-inch thick wood is used in our receiver.

SET WIRING

Connect the receiver components with hookup wire as shown in the illustration and schematic diagram. Use flexible stranded wire for connections to L1. Make sure that the L1 leads do not touch any component as the variable coupling rod is moved in and out.

Install knobs on C1, C2, and the variable coupling rod. Then place the crystal in the detector assembly.

OPERATION

Connect antenna and ground leads to the receiver terminals. Plug in a set of 2000-ohm headphones into the panel phone jack. For easier initial operation of the receiver, temporarily connect a germanium diode (1N34A or equivalent) across the D1 connecting lugs. Make sure that the catwhisker is not touching the crystal at this time.

Push the variable coupling rod half way in and tune C1 and C2 for a station. Adjust the variable coupling rod and retune C1-C2 for best reception. Check operation over the entire broadcast band. It may be necessary to add or subtract turns of wire on L1-L2 for complete coverage. After checking operation with the germanium diode, remove it and try using the catwhisker crystal detector.

List of Materials

C1,C2 - 365 mmf variable capacitor.
D1 - Catwhisker crystal detector assembly.
L1,L2 - Spiderweb coils (see text).
2 - Terminals.
1 - Phone jack.
PHONES - 2000-ohm headphones.
MISC.- Plastic sheet for spiderweb coils, solder lugs, machine screws and nuts, wood screws, hookup wire.
CONSTRUCTION MATERIALS (See Text).
A - knob
B - Panel
B1- Bushing
C - Aluminum section
D - Rod
E - Wood section
F - Setscrew
G - L1 coil form
H - Wood section
I - Spacers (2)
J - Wood section

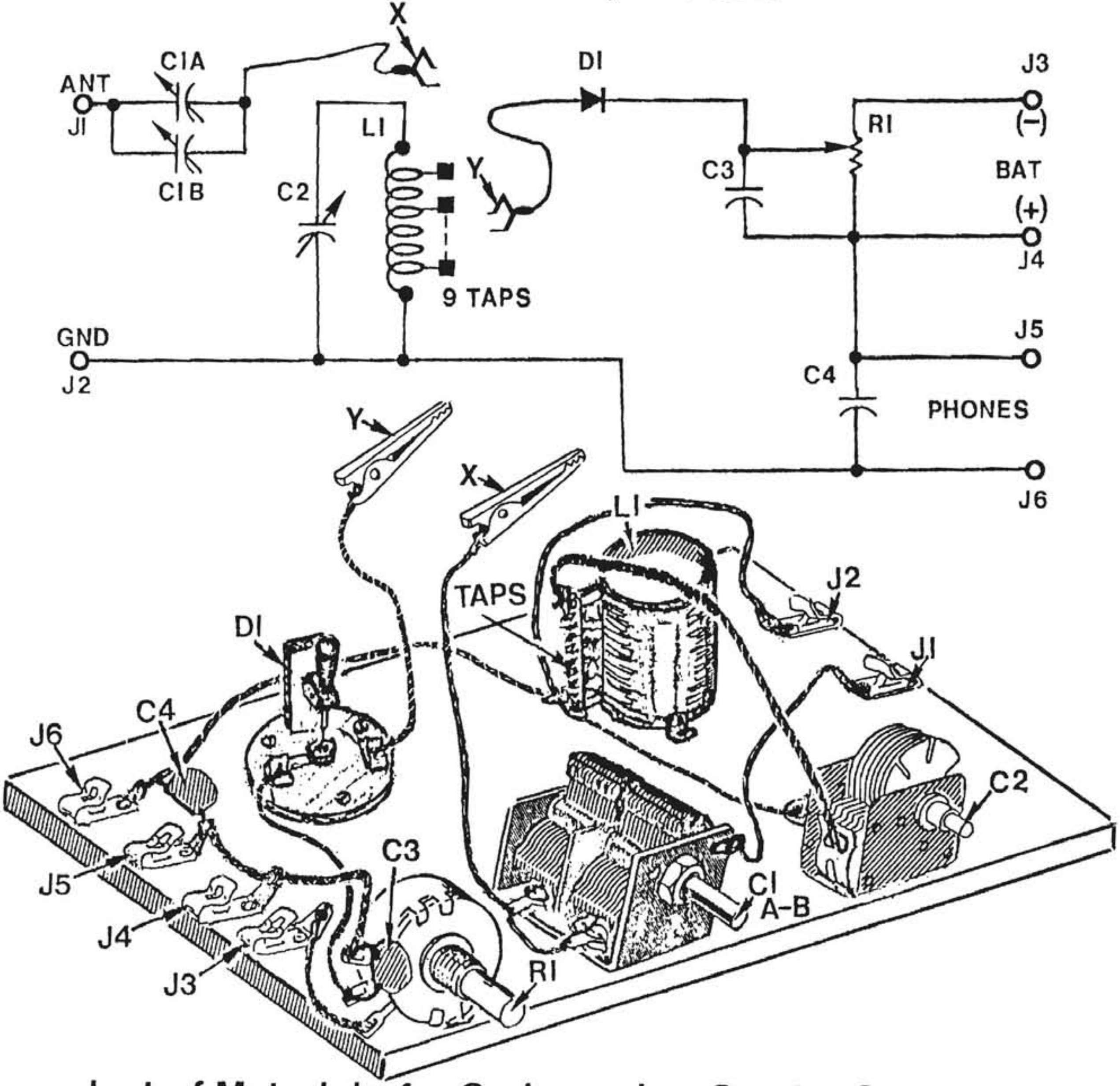
X
C1A
D1
J3
ANT
J1
L1
R1
(−)
C1B
C2
Y
C3
BAT
(+)
J4
9 TAPS
GND
J2
J5
C4
PHONES
J6
Y
X
L1
TAPS
J2
D1
J1
C4
J6
C2
C3
J5
C1
A-B
J4
R1
J3

List of Materials for Carborundum Crystal Set

C1A-C1B - Dual 365 mmf variable capacitor.
C2 - 365 mmf variable capacitor.
C3 - 0.1 mf capacitor.
C4 - 1000 mmf capacitor.
D1 - Carborundum crystal and catwhisker detector assembly (see text).
J1 to J6 - Fahnestock clips.
L1 - Tuning coil (see text).
R1 - 5,000-ohm potentiometer (linear taper).
BAT - 6-volt battery
PHONES - 2000-ohm headphones.
MISC. Coil form (see text), No.24 enameled copper wire, 1/2-inch long spacers, perfboard strip (see text), push-in clips, solder lugs, knobs, hook-up wire, 1N34A diode (or equiv.), wood for base and D1 detector assembly (see text), wood screws, machine screws and nuts, alligator clips X-Y, brackets for L1 and R1.

CARBORUNDUM CRYSTAL SET

Materials other than galena, silicon or germanium have the property of detection. In the beginning of radio, carborundum (the name given to a compound of silicon carbide) was also used as a detector. The required heavy catwhisker pressure made it suitable for the early radio stations on ships, as it did not fall out of adjustment. It would also handle the strong signal energy from nearby spark transmitters without burning out. But what makes this type of crystal detector different, is the necessity for a bias battery.

A crystal detector has a high current flow with voltage applied so that it conducts in the forward direction (catwhisker to crystal), and a very low current flow in the reverse direction. The amount of current flow in the forward direction depends upon the characteristics of the crystal material and the applied forward voltage.

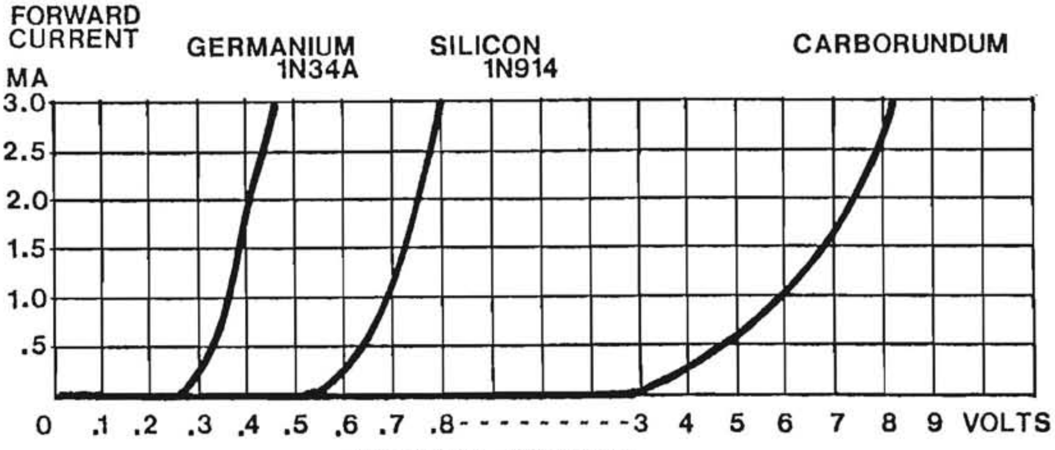

TYPICAL CRYSTAL DIODE CURRENT

The graph compares carborundum with germanium and silicon crystal detectors. Germanium minimum conduction voltage is about 0.3 V. Silicon is 0.6 V, and carborundum is 3 V. The high carborundum minimum conduction voltage is the reason a bias battery is used to move the threshold down so that weak radio signal voltages can be detected.

TUNING COIL

As shown in the illustration, the tuning coil L1 is wound on a cardboard (or plastic) mailing tube section 2-inches in diameter and 2 3/4-inches long.

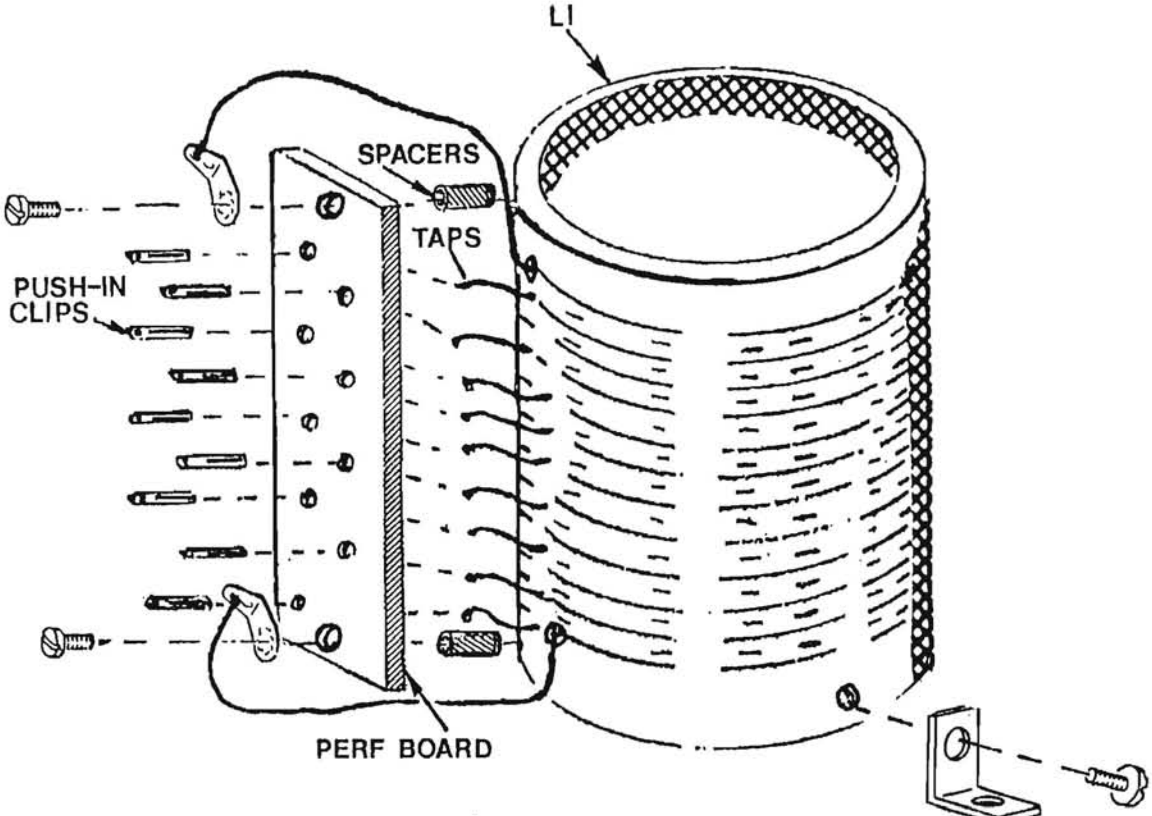

TUNING COIL ASSEMBLY

Locate and drill a hole 1/4-inch from each coil form end for machine screws to fit the two spacers. Also drill holes for two mounting brackets at one end. Then drill a small hole near each spacer hole to feed the wire on the form before you start winding.

Wind the coil with No. 24 enameled copper wire. Tap the coil every 10 turns for a total of 9 taps. An easy way to make the taps is to twist the wire together for a half inch and position the free end out. Make all the coil taps in the area between the two spacer holes. Thread the free end of the wire through the small hole at the end of the form near the spacer hole. Make sure that all of the turns are tightly wound and close together. Use a section of sandpaper to remove the enamel from the tap wire ends. Then tin the ends.

Mount 9 push-in clips in a 1/2-inch by 2 1/4-inch perf board section. Locate and drill holes on the board and install it on the coil form with two solder lugs, 1/2-inch spacers, machine screws, and nuts. Solder the coil taps to the ends of the push-in clips. Connect the coil leads to the solder lugs and mount the two 1/2-inch brackets on the coil form.

DETECTOR

The crystal detector assembly is vertical, (as shown in the illustration) instead of horizontal as in most catwhisker detectors. Begin construction by cutting the 2 1/2-inch diameter base and 2-inch by 4-inch vertical section from 1/4-inch thick wood.

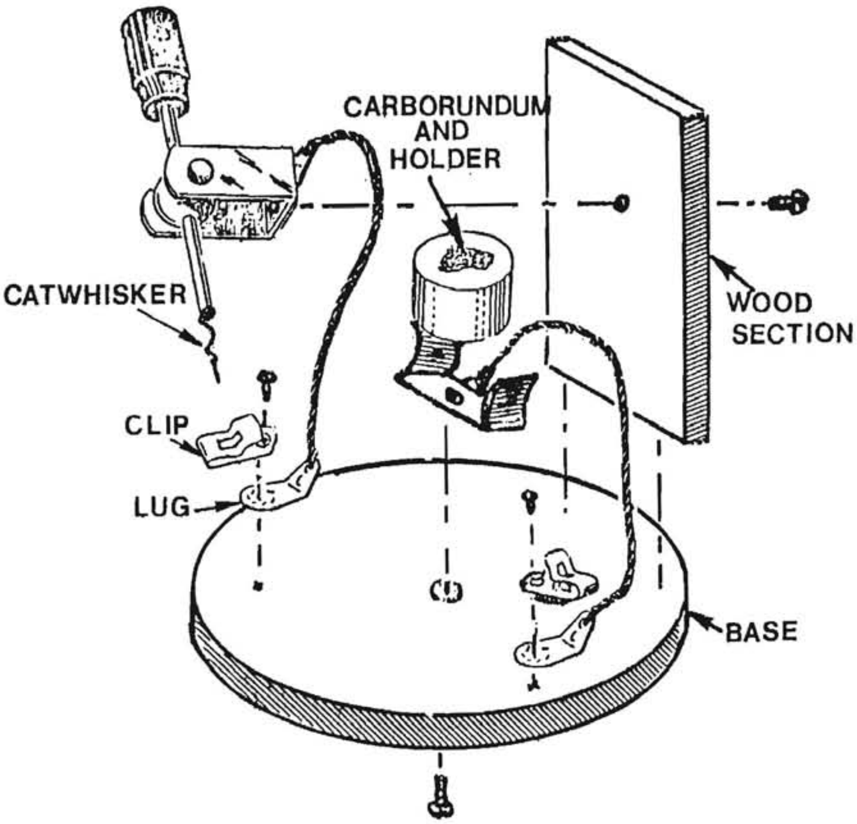

DETECTOR ASSEMBLY

Locate and install the two fahnestock clips on the base with solder lugs and small wood screws. Mount the vertical section on the edge of the base with wood screws (or cement). Locate and install the catwhisker holder with a solder lug, machine screw and nut near the top of the vertical section.

Temporarily position the crystal holder on the base so that the catwhisker will touch the center of the crystal. Locate and mount the crystal holder in this position with a solder lug and machine screw and nut. Connect the detector assembly with hookup wire as shown in the illustration. Solder a short section of coiled steel spring wire to the end of the positioning rod to serve as a catwhisker. Cut the end of the wire diagonally to give it a sharp point.

BASEBOARD

The receiver parts are installed on a 8-inch by 7-inch by 3/4-inch wood base. Wherever poossible, small wood screws are used to hold the components on the base.

Begin construction by laying out and installing the parts in the positions shown in the illustration. It will be necessary to make a metal mounting bracket to fit R1. C1A-B and C2 are mounted with machine screws in the tuning capacitor frames through countersunk holes in the base. Install solder lugs in the rear frame of both tuning capacitors. Also mount solder lugs with all of the terminals. Install knobs on the tuning capacitors and R1.

WIRING

Use hookup wire to connect the crystal set parts as shown in the schematic and illustration. Connect 5-inch leads of flexible stranded insulated wire to each alligator clip. Solder one lead to the stator lugs of C1A-B and connect the other lead to D1. Connect C3 and C4 as shown and keep their leads as short and direct as possible.

Experiment 1

Connect your antenna to J1, ground to J2, and 2000-ohm headphones to J5 and J6. Temporarily connect a germanium diode (1N34A or equiv.) in place of the carborundum crystal detector D1. The diode will make it easier to check out the receiver.

Do not attach the battery
to J3-J4 at this time, or
the diode may be damaged.

Connect **X** C1A-B clip lead to the top tap of L1, and **Y** D1 clip lead to the second tap from the top. Tune in a radio station with C2 and then adjust C1A-B for best volume. Change the position of the clip leads and retune C1A-B and C2 for best reception. Check operation of the receiver over the entire broadcast band.

Experiment 2

Tune the receiver to a radio station and then disconnect the germanium diode. Do not disturb the receiver tuning. Install a carborundum crystal into the D1 assembly. Set R1 to mid range, and connect a 6-volt battery to the receiver; negative lead to J3, positive lead to J4.

Adjust the D1 catwhisker for a sensitive spot on the carborundum crystal. Then set R1 for best volume of received signal. Retune C1A-B and C2 and change the clip leads on the L1 taps as necessary for reception of radio stations.

Note

Carborundum that will work as a detector may be hard to find. Grinding wheels are not suitable as a source, because the carborundum is usually in fine particles mixed with other material. Best bet is to contact collectors of antique radio parts. But you can use this receiver to experiment with minerals for semiconductor operation. See the Workshop Section for information on mounting mineral sections for detector experiments.

4 COMPONENT PROJECTS

BOOK TUNING CAPACITOR

During the roaring 20's,the Crosly Radio Corporation used a type of tuning capacitor that had two plates hinged together on one edge. The dielectric was a sheet of mica between the two plates. This type of tuning capacitor was called a Book Condenser.

The tuning capacitor shown in the illustration is similar to the Crosly Book Condenser. It uses aluminum foil plates cemented to fixed and movable wood sections, and a plastic sheet dielectric (cut from thin transparent plastic notebook protector material).

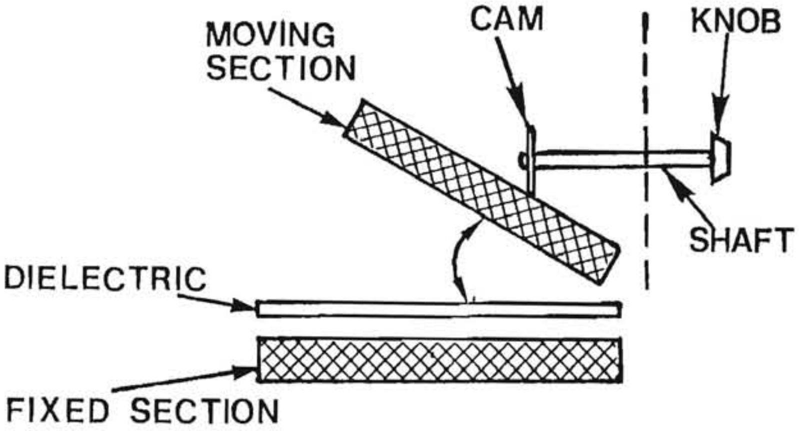

Adjusting the tuning knob causes a metal cam to rotate and control the movement of a spring loaded wood section. This varies the capacity between the two foil plates. As the plates are brought closer together, the capacity increases. As they are separated, the capacity decreases.

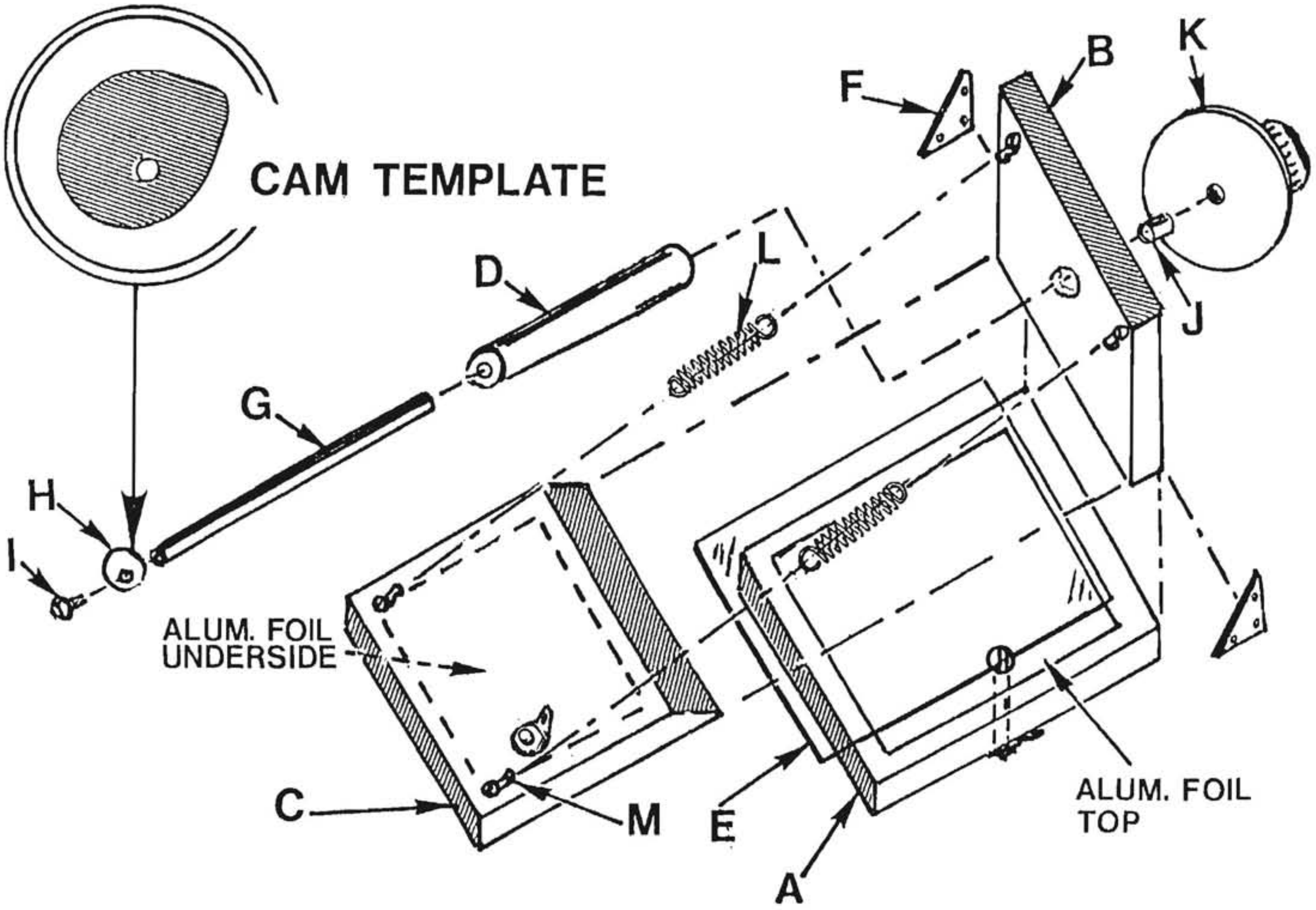

BOOK TUNING CAPACITOR

List of Materials

A - 3 x 3 1/2 X 3/8-inch wood section
B - 3 x 1 3/4 x 3/8-inch wood section
C - 3 x 3 1/8 x 3/8-inch wood section (one end beveled 45 degrees - see text).
D - 3/4 - inch diameter wood dowel, 2 1/4 inches long.
E - 3 1/2 x 3 -inch sheet plastic (See text).
F - 2 triangular 1-inch metal sections
G - 1/4-inch metal rod, 3 -inches long.
H - Metal cam (see text).
I - Machine screw (see text)
J - Bushing 3/8-inch long (to fit rod G).
K - Tuning knob (to fit rod G).
L - 2 springs 1/4-inch diameter by 1 1/4-inch long.
M - 4 solder lugs.
MISC. Small wood screws, nails, aluminum foil, machine screws, nuts, solder lugs and washers.

CONSTRUCTION

Start construction by cutting the wood sections from 3/8-thick wood to the sizes shown in the drawing. Section C has a 45 degree bevel at one end. This acts as a pivot point for the movable section. Drill and countersink a hole to fit a flathead machine screw in the places shown on sections A and C. Do not install the screws at this time.

Cement aluminum foil on the top of section A and on the bottom of section C. Then cut and remove a 1/2-inch strip of foil from the front edge of section A. Cut a 1/8-inch strip from the remaining edges. Also cut away a 1/8-inch strip from all the edges of the foil on section C.

Carefully slit the foil on top of the machine screw hole on section A and press the foil gently inside the hole. Install the flathead machine screw into the hole, making sure that it is in contact with the foil. Fasten the screw with a washer and nut. Make sure that the screw does not turn and rip the foil. Install a solder lug and nut on the free end of the screw. Repeat this operation with section C.

Cut the sheet plastic E to size and place it on top of section A. Then place section B on top of the plastic sheet and install it on the end of section A with wood screws. Install the two metal sections F with small nails.

Saw the metal rod G to size and tap one end to fit a machine screw. Cut the dowel D to size and center drill it to fit the rod G. Cut a flat on one side of the dowel.

Make a tracing of the cam H template and cement it on a section of heavy gauge sheet aluminumm. Cut the cam to size and drill a hole to fit the rod machine screw in the location shown. Install the cam with a lock washer on rod G. Insert the free end of the rod into dowel D. Place section C on top of the plastic sheet E on section A. Then temporarily position dowel D with rod G in the center of section B. Rotate the cam so that its long end touches the top of section C. Mark the placement of the dowel on section B. Drill a hole in section B to fit dowel D. Cement the dowel in place.

Locate and install solder lugs with wood screws on sections A and C as shown in the drawing. Bend over the ends of the solder lugs and install two springs L in the lugs.

Mount tuning knob K and bushing J on the free end of rod G. Adjust the knob and check that section C moves in and out with the cam rotation. changing the capacity between the foil plates.

You may have to experiment with the cam diameter for best operation of section C. File the cam edges in small increments only and recheck the operation often. Use very light springs to keep section C from pressing against the cam and moving it.

Reverse the cam on rod G to alter the direction of capacity (clockwise or counterclockwise). The capacitor can be installed vertically on a receiver project with a small metal bracket mounted on the bottom side of section A.

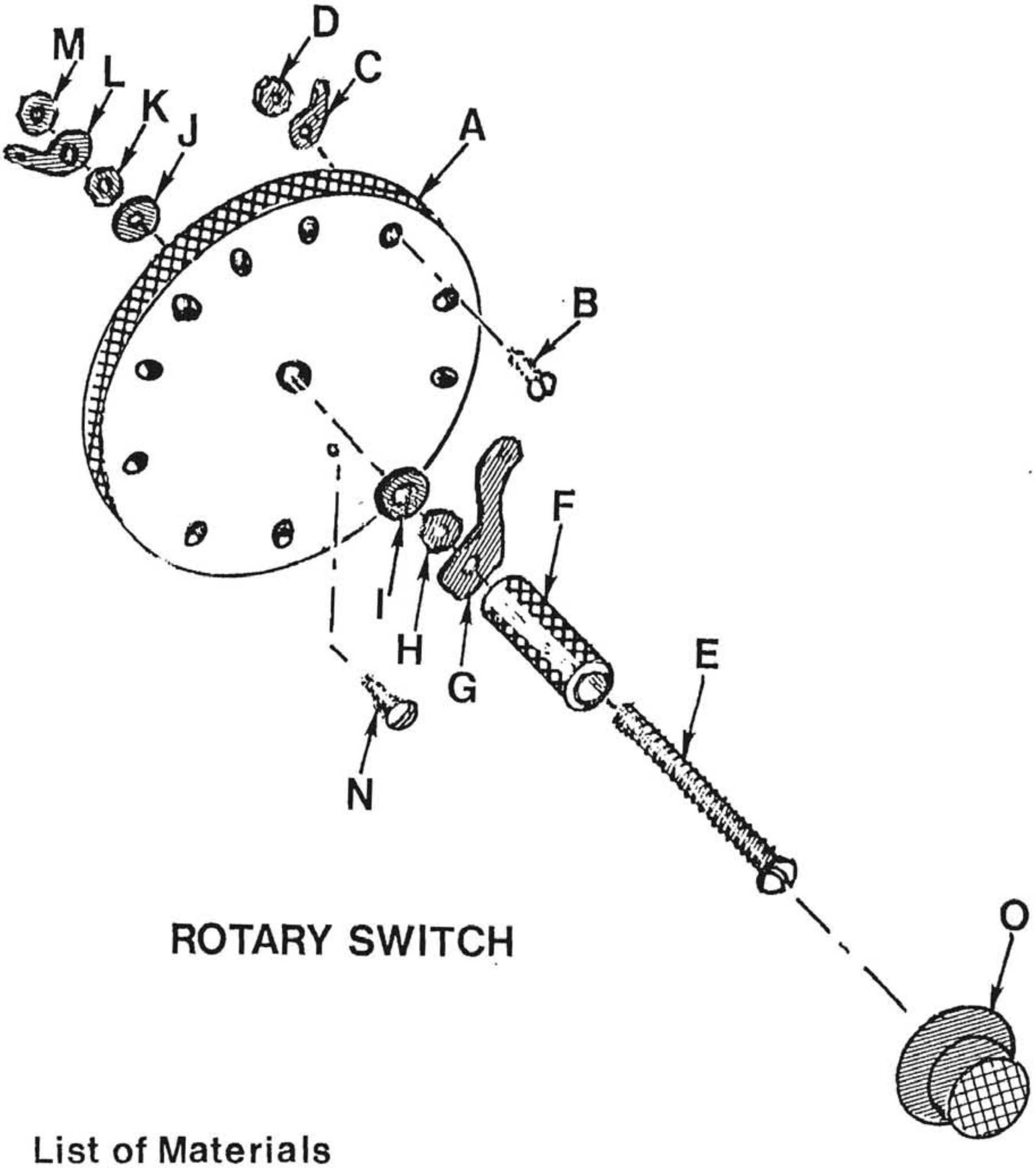

ROTARY SWITCH

List of Materials

A - 2 1/4 diameter x 3/8-inch wood section.
B - Flat head machine screws.
C,L - Solder lugs.
D - Nuts to fit B.
E - Machine screw 1 1/4-inches long.
F - 1/4 diameter x 1/2-inch long bushing (to fit E).
G - Switch arm 1 x 1/4-inch (sheet brass, see text).
H,K,M - Nuts to fit E.
I,J - Washers to fit B.
N - Small woodscrew.

ROTARY SWITCH

In the early days, radio experimenters could not buy parts that are readily available today. They had to build their radio components from wood sections and common hardware.The rotary switch ilustrated is similar to a type constructed for use with tapped coils of crystal sets.

The rotary switch shown uses flat head screws for contact points that are mounted on a wood section. The switch arm is cut from sheet brass and is installed on a machine screw.

CONSTRUCTION

Refer to the drawing of the rotary switch. Begin construction by cutting the 2 1/4-inch diameter section A from 3/8-inch thick wood. Locate, drill,and countersink the holes for the flathead machine screws B. The rotary switch shown has 10 machine screws, but you can space the hole locations for the number of switch contact points desired. Allow a space between the starting and ending contact points for the woodscrew N. This woodscrew is used as a stop for the rotary arm G. Locate and drill a center hole for the machine screw E. Install the screws B in section A with solder lugs C and nuts D. Install the woodscrew N.

Measure and cut the rotary arm G from a section of sheet brass. The arm should be long enough to reach the contacts. Make sure that it is not too wide, or it may short out to a nearby contact. Make a dent or "dimple" on the contact end, and drill a hole for screw E on the other end. Bend the rotary arm as shown in the drawing. Install screw E into bushing F, and arm G, and tighten the assembly with nut H. Place washer I on the screw and install screw E into the center hole of A. loosely fasten the screw with washer J and nut K. Then rotate the bushing F and arm G. Adjust the tightness of nut K as required to allow rotation of G with only a slight "drag". Install solder lug L on screw E with nut M, and bend the lug towards the screw end. Install knob O on bushing F, and recheck operation of the arm G. It should touch all of the contacts B and stop at screw N.

The rotary switch is used as shown in the Dual-Tuned Crystal Set Construction Project. Make sure that extra lead length is allowed for connection to the solder lug L. Bend the lead into a "pig-tail," so that it will not break as the solder lug L is rotated.

5

WORKSHOP

The construction projects in this book can be built with common hand tools found in an average home workshop.

Useful Hand Tools

Safety glasses or face shield
Steel rule
Square
Hack saw
Wood saw
Screwdrivers
Pliers
Wirecutters
Tin snips
Center punch
Files
Hammer
Soldering Iron

Wear safety glasses or face shield while working. Observe common sense safety precautions.

SOLDERING

Make sure that the part to be soldered is clean. Use only rosin core solder. Prepare the soldering iron tip as follows:

File each surface of the tip to remove oxidation. Plug in the iron and let it heat until you can melt solder on the tip (before the copper tip turns blue or bronze color). Melt enough solder until all sides of the tip are coated. Then wipe off excess solder with a damp sponge or cloth.

Make sure that the bare wire lead to be soldered is free of oxide. It is best to tin it first by melting a bit of rosin core solder on the lead end. Crimp the lead in the part hole to keep it from moving during soldering. Hold the iron tip under the part until it is hot enough to melt solder; Apply only enough rosin core solder to cover the surface of the part. Remove the iron. Do not move the part or wire while it is cooling.

PROJECT CONSTRUCTION TIPS

Tape a sheet of graph paper over a project wood section. Mark locations of the parts on the paper. Center punch mounting hole centers through the paper. Use a compass to draw circles the same size as the holes. Then drill holes through the paper.

Lettering on the projects can be done with a labelmaker that prints on strips of adhesive coated plastic. You can also use decals or dry transfer lettering sheets.

Small metal brackets can be made from heavy gauge sheet aluminum. Layout and drill the mounting holes and then cut it to size with a tin snips. Form the bracket by using a heavy mallet and a vise.

Tuning Capacitors, Knobs, and Dials

Old radios are a good source of components. The radios generally use two tuning capacitor sections ganged together. The receivers previously described will operate with one of the capacitor sections (365 mmf). You can cut out cardboard discs and cement them to radio knobs and use them as dials with the tuning capacitors. Mark the dials with dry transfer lettering, or black drawing ink.

Panels and Cabinets

The layout and construction of crystal sets is not critical. They can be fitted into many different types of wood cabinets. You can use almost any type of non-metallic box, but metal boxes are not recommended as sheet metal close to the tuning coil may lower its "Q". Black sheet plastic used for the front panel with white dry transfer lettering will give your receiver project an antique look.

MOUNTING MINERALS FOR CRYSTAL DETECTORS

Minerals (galena, etc) for experimentation as crystal detectors, will work best when mounted in a metallic base. For temporary mounting (while testing), wrap aluminum foil tightly around the sides and bottom of the mineral. Then place it into a sheet metal ring or cup that will fit into the detector assembly.

After testing, the mineral can be permanently mounted in a metal slug. Drill a shallow hole of a diameter equal to the detector assembly crystal in a block of wood. Fill the hole with melted solder. While the solder is still molten, carefully place your mineral section into the center. Hold the mineral in place with tweezers or long nose pliers until the solder cools. Then pry the metal slug out of the wood. Be sure that the top of the mineral section is free of solder.

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About the Author

Charles Green has been involved in the design and construction of electronic equipment for industry and the U.S. Government for 30 years. Much of his experience has been as a technical writer preparing operation and maintenance manuals. His continuing interest is in constructing radios and he has had over a hundred articles published in hobbyist magazines over the past two decades.

A sun-powered transistor amplifier makes this a—

Space-Age Crystal Set

By D. S. Halacy Jr.

LIGHT-POWERED RADIO plays indoors under artificial light, too. Performance is boosted by connecting antenna to TV aerial or telephone-dial finger stop; a short length of wire, with alligator clips at the ends, helps.

THIS tiny radio puts satellite technology in the palm of your hand. Like radios in artificial moons, it's powered by the sun—or any other light.

Basically, it's a 1960-model crystal set. A rugged sealed-in-glass diode has replaced the shaky catwhisker and galena crystal. The usually faint crystal-set signal is magnified many times by a transistor, in turn powered by a high-efficiency silicon solar cell.

This unit—and other parts—can probably be obtained locally for less than five dollars. All are standard parts, stocked by most retail and mail-order shops. In a pinch you can substitute the less-efficient International Rectifier B2M selenium cell for the quarter-round section of a Hoffman silicon solar battery.

First steps. Best place to begin construction is with the case for the radio—a small plastic box. You may find one in the medicine chest or at the druggist's. Start the necessary holes with a hot ice pick, then file or ream to size Keep try-

Author Halacy is an expert on the. sun. A couple of years ago he wrote Fabulous Fireball, *a book that tells the story of the sun and solar energy. Last fall. Macmillan also published his* Fun with the Sun. *a book describing how to make seven solar-energy projects at home. The present, article is an outgrowth of his research for the latter book.*

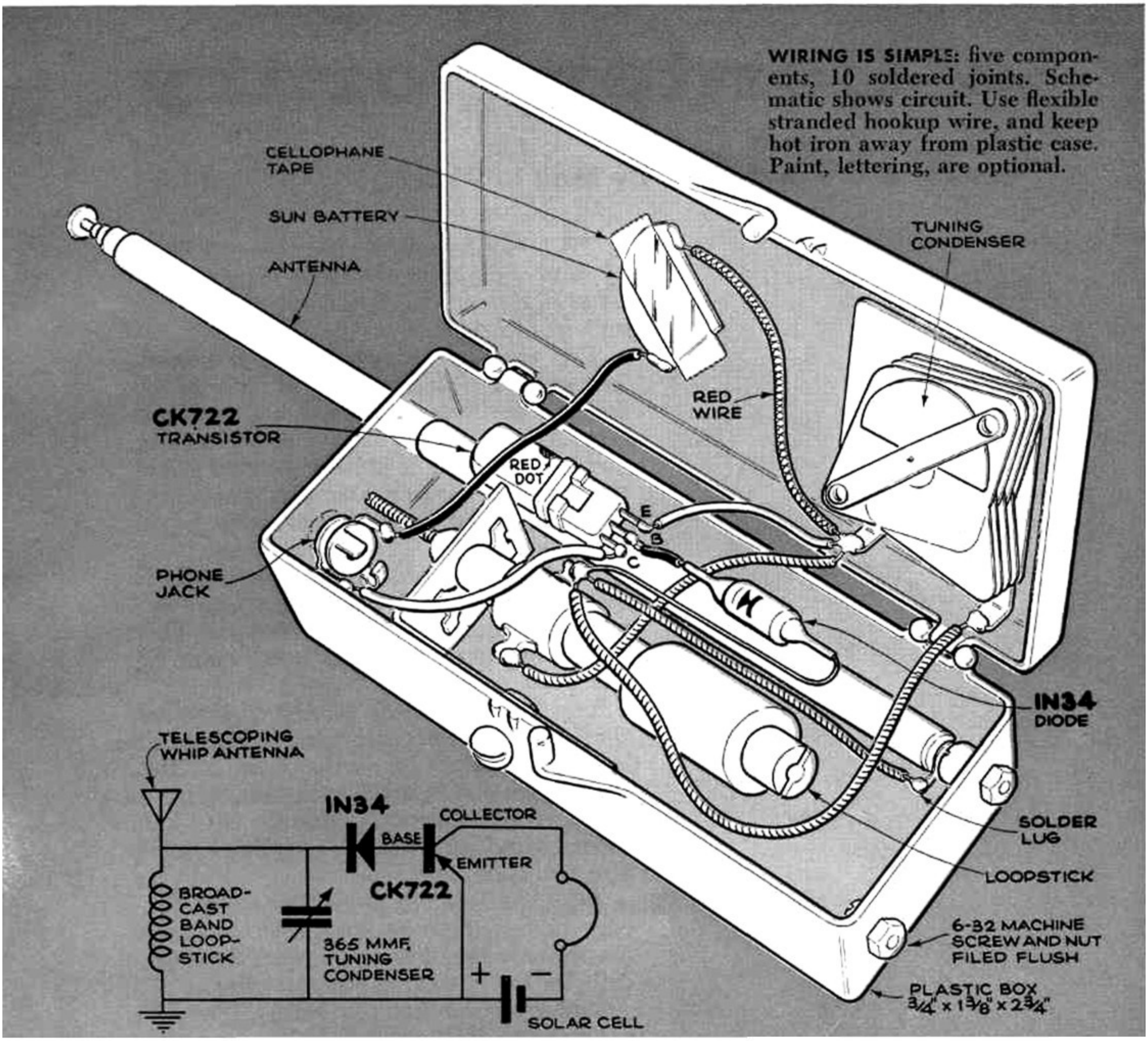
CELLOPHANE TAPE
SUN BATTERY
ANTENNA
TUNING CONDENSER
RED WIRE
CK722 TRANSISTOR
RED DOT
E
B
C
PHONE JACK
IN34 DIODE
SOLDER LUG
LOOPSTICK
6-32 MACHINE SCREW AND NUT FILED FLUSH
PLASTIC BOX 3/4" x 1 3/8" x 2 3/4"
TELESCOPING WHIP ANTENNA
IN34
BASE
COLLECTOR
EMITTER
CK722
BROAD-CAST BAND LOOP-STICK
365 MMF. TUNING CONDENSER
+
−
SOLAR CELL

WIRING IS SIMPLE: five components, 10 soldered joints. Schematic shows circuit. Use flexible stranded hookup wire, and keep hot iron away from plastic case. Paint, lettering, are optional.

ing the part as you enlarge the hole, to insure a snug fit.

The case can be painted or left transparent. The one pictured has a finish of Day-Glo spray paint, applied to the outside of the case. The paint softened the plastic slightly and created a wrinkled finish.

The hinged top is left clear and a piece of painted bond paper cut to fit inside. This paper was lettered, and cut to accept the dial shaft and solar battery. The lettering is pure whim—there's no trademark or commercial name.

After painting, go ahead with the assembly. Set the antenna mounting base through the bottom hole, put on the nut, cut off excess threads, and file smooth. Add a 6-32 screw and nut to the other side if you expect the radio to stand up.

Condenser and battery. Install the tuning condenser in the hinged top by first removing the dial and the small flathead screws. Remove both hex nuts; use one on the outside to hold the condenser in place. Then mount the dial and twist the silver center screw thumb tight. Place the solar battery in position over the opening in the bond paper, and fasten it in place with a strip of cellophane tape.

Bend the loopstick mounting bracket as shown, snap the loopstick in place, and fasten the bracket with a 6-32 screw and

[Continued on page 230]

Space-Age Crystal Set

[Continued from page 171]

nut. Install the phone jack, and the radio is ready for wiring.

Use stranded hookup wire; it can take the flexing imposed by opening and closing the case.

Pitfalls for amateurs. The wiring shown in the drawing is straightforward and follows the circuit schematic. If you're familiar with electronic wiring, you'll probably find some short cuts. If you're a beginner, stick to the diagram. If you run into trouble, don't hesitate to remove the parts, do the soldering outside, and then replace them.

Use care when soldering the diode and transistor—excess heat will damage them. Sidestep part of the risk by soldering to the lugs of a transistor socket, then slipping the transistor in place. You'll have to clip the transistor's leads to make it fit.

Bend the diode's leads to fit before soldering it between the base of the transistor and the loopstick.

Close the case when you've finished soldering, plug in the earphone, and listen. There's no on-off switch: The battery never wears out.

You should pick up stations at their proper position on the dial as indicated by the point of the battery or a dot on the lid. If the calibration is too far off, make a hole in the end of the case in line with the slotted screw on the loopstick. Turning this screw one way or the other will shift the stations enough to align the dial.

Outdoors, you'll find you don't have to point the Solar Mite at the sun—there is plenty of incident light for satisfactory operation. Keep the whip upright for maximum volume.

For stronger signals. Touching the silver center of the tuning dial may give you a stronger signal, since your body acts as a ground. Also try wetting your finger before touching the dial.

While the Solar Mite will play on the whip antenna, for peak performance connect the whip to your TV antenna. If you don't have an outdoor antenna of any kind, clip a lead on the finger stop of a telephone dial. You'll find that the radio works well enough to bring in a strong station even in the dark—acting as a crystal set without the help of its transistor amplifier.

No. 96

CRYSTAL SET CONSTRUCTION

SIMPLE INSTRUCTIONS FOR MAKING NINE CRYSTAL SETS

by B. B. BABANI

There is to-day a marked revival of interest in crystal receivers, and this book has been specially prepared to introduce the home constructor to the design and building of the various types. The text is simple and free from technicalities, so that even the young reader may confidently embark on the construction of any of the receivers shown.

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4. COILS.
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7. LONG DISTANCE RECEIVER.
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9. HIGH SELECTIVITY RECEIVER.
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11. MEDIUM AND LONG BAND RECEIVER.
12. ULTRA SENSITIVE ALL WAVE RECEIVER.
13. AN ADVANCED CRYSTAL DIODE RECEIVER.

THERE ARE 12 DIAGRAMS

LONDON: BERNARDS (PUBLISHERS) LIMITED

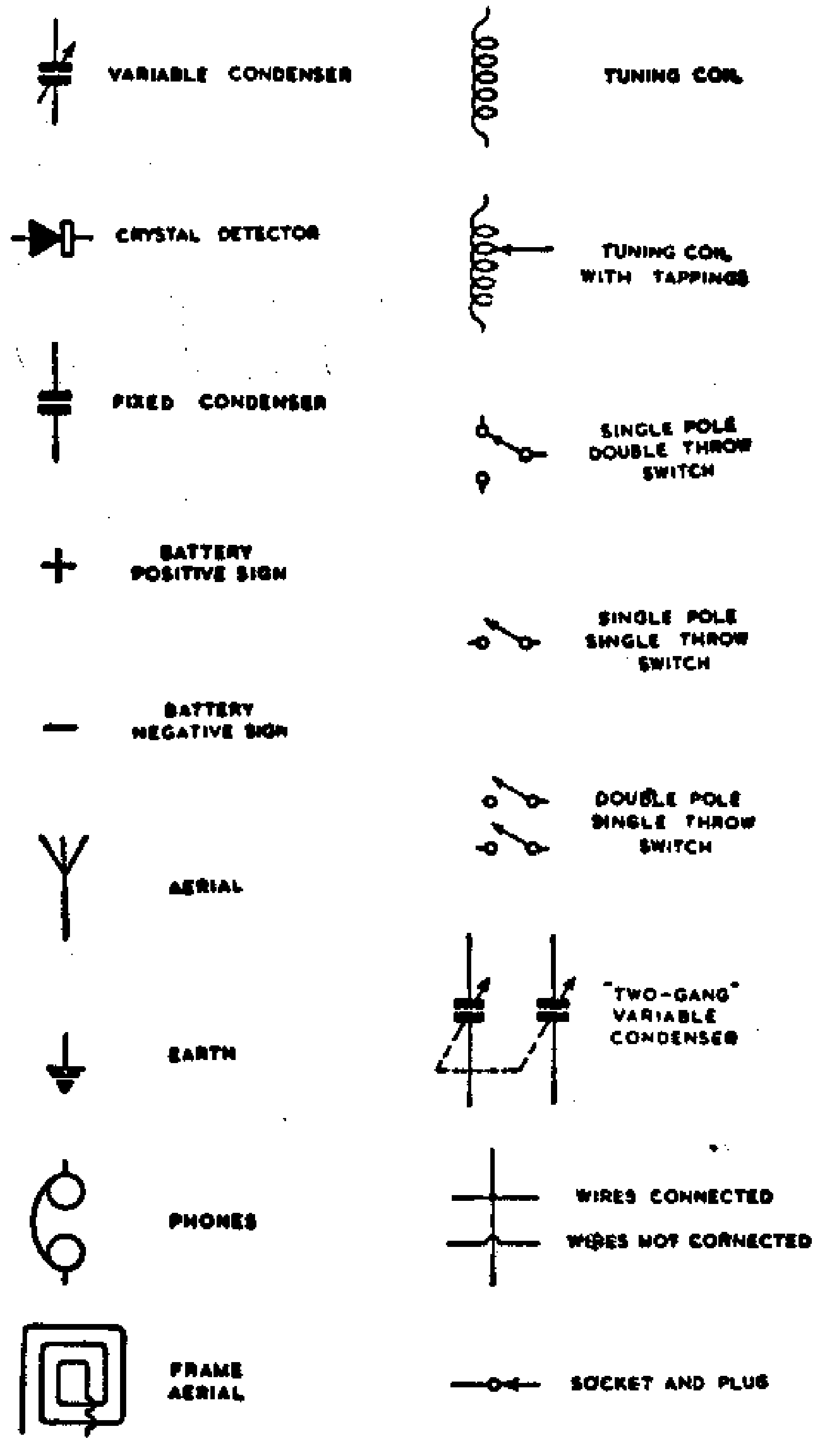
VARIABLE CONDENSER
CRYSTAL DETECTOR
FIXED CONDENSER
BATTERY POSITIVE SIGN
BATTERY NEGATIVE SIGN
AERIAL
EARTH
PHONES
FRAME AERIAL
TUNING COIL
TUNING COIL WITH TAPPINGS
SINGLE POLE DOUBLE THROW SWITCH
SINGLE POLE SINGLE THROW SWITCH
DOUBLE POLE SINGLE THROW SWITCH
"TWO-GANG" VARIABLE CONDENSER
WIRES CONNECTED
WIRES NOT CONNECTED
SOCKET AND PLUG

FIG. I SYMBOLS USED IN THE CIRCUITS DESCRIBED.

1. Aerials.

One of the essentials for satisfactory reception with crystal sets is an efficient aerial. Four different types are suggested and are shown in Fig. 2.

There are several important points to be noted when erecting an aerial for a crystal set.

(1) See that it is suspended as high as possible and is not screened by tall buildings, obstructions, etc.

(2) The aerial itself and the lead-in from the aerial must be adequately insulated. Be sure that the porcelain or plastic insulators do not permit the aerial or lead-in to touch the building, tree, or post from which they are suspended. The lead-in should be brought into the house through an insulated rod.

(3) It is exceedingly important to use insulated copper wire, either single or multi-stranded, for both the aerial and the lead-in.

2. Earths.

An adequate and efficient earth contributes to the good performance of any well-designed crystal set and Fig. 3 shows the best method of obtaining an efficient earth where there is a garden or patch of ground available at a short distance from the receiver.

Obtain a 3-ft. length of ½-in. galvanised iron pipe and at one end drill a hole right through. Insert a bolt with spring washer and locking nut in the hole. Connect the earth lead-in wire to the bolt; the other end of the lead-in to the earth connection on the receiver. Leave both ends of the pipe open. Insert the end opposite the bolt into the ground vertically until only 3-in. are showing above the surface of the surrounding earth.

It is important to see that the surrounding ground is kept damp, if necessary by occasionally pouring a pint or two of water down the open projecting end of the pipe.

Ready-made copper earthing rods with a pointed end for easy hammering into the earth are sometimes obtainable from radio dealers.

Should a garden not be available, an alternative earth is a cold water pipe coming from a rising main. Simply file very lightly the pipe at the back of the tap and wind the copper wire earth lead-in round the filed part and cover the joint with insulating tape.

In no circumstances should a gas pipe be used for an earth.

3. Crystal Detectors.

Most radio dealers can supply very efficient permanent or semi-permanent crystal detectors of proprietary makes. However, there are always available quite a number of ex-Government surplus units which are called crystal valves and, though these were originally designed for a very different use in service equipment, they are easily adaptable and will give extremely efficient results when used in circuits designed for them. To enable the constructor to purchase suitable types for this purpose—and they cost very little—the following list gives the Government reference numbers.

CV 101, CV 102, CV 103, CV 111, CV 112, CV 113, CV 226, CV 241, CV 246, CV 247, CV 253, CV 291, CV 351, CV 361, CV 364, CV 367, CV 727, CV 749, and CV 1785.

One of the satisfactory proprietary makes of this class of crystal detector is the BTH CS7A, which, incidentally, is the commercial equivalent of the CV 253.

For all these Government types, one connection should be made to each end by arranging a holder to fix them into or by carefully soldering the appropriate connecting wires to each end.

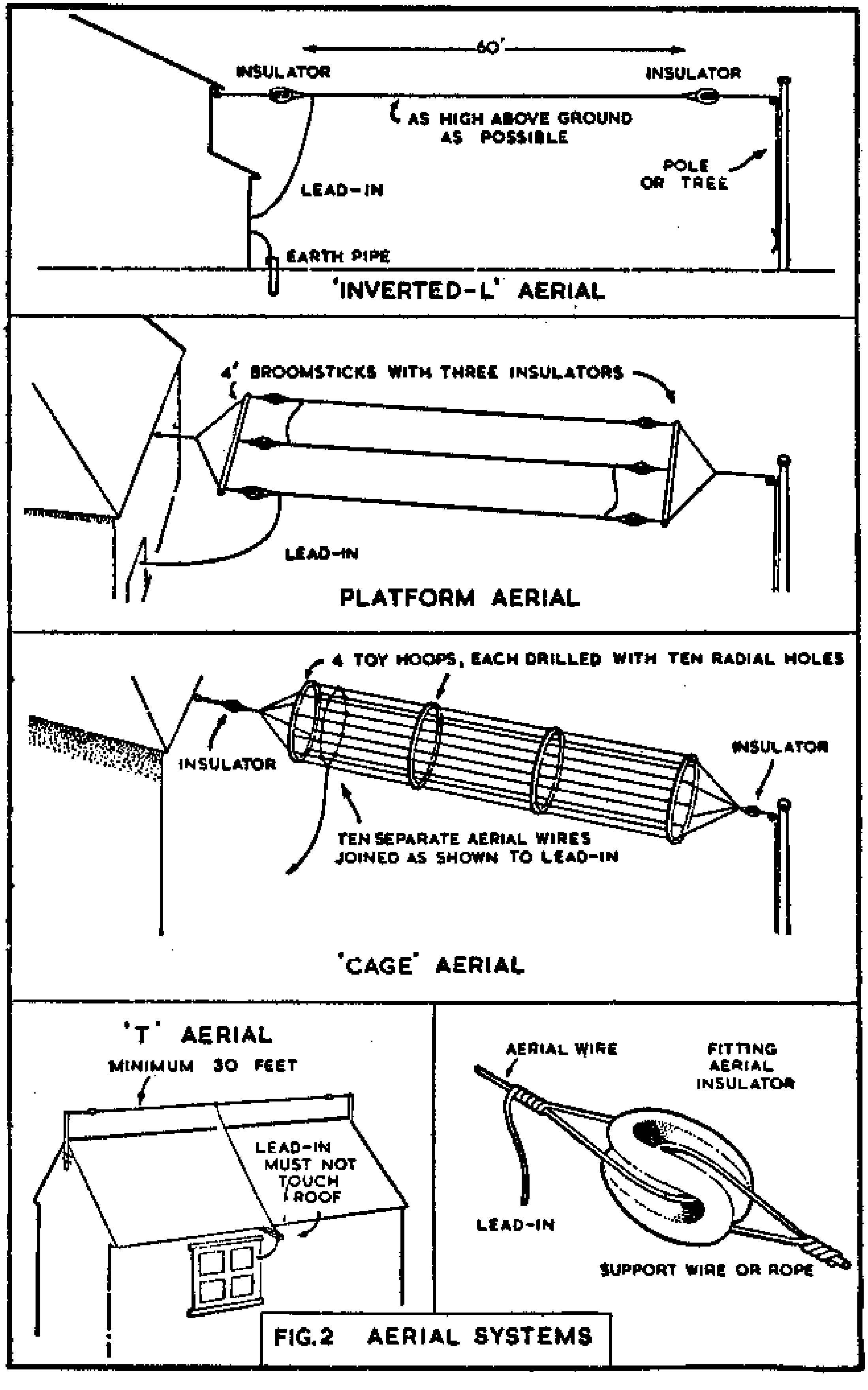
60'
INSULATOR
INSULATOR
AS HIGH ABOVE GROUND AS POSSIBLE
POLE OR TREE
LEAD-IN
EARTH PIPE
'INVERTED-L' AERIAL
4' BROOMSTICKS WITH THREE INSULATORS
LEAD-IN
PLATFORM AERIAL
4 TOY HOOPS, EACH DRILLED WITH TEN RADIAL HOLES
INSULATOR
INSULATOR
TEN SEPARATE AERIAL WIRES JOINED AS SHOWN TO LEAD-IN
'CAGE' AERIAL
'T' AERIAL
MINIMUM 30 FEET
LEAD-IN MUST NOT TOUCH ROOF
AERIAL WIRE
FITTING AERIAL INSULATOR
LEAD-IN
SUPPORT WIRE OR ROPE

FIG.2 AERIAL SYSTEMS

4. Coils.

In Fig. 3 two methods are shown of fixing the coil to the chassis. However, the ingenious constructor may evolve another arrangement.

The important thing to remember is that the coil should be fixed so that it is completely insulated from the metal chassis that may be used.

It is also important to remember that if a metal chassis is used, one must see that all components and wiring, with the exception of earth connections, are adequately insulated from this chassis so as to make sure that no short circuits take place. It is recommended that all crystal sets should be built on a panel, and that both panel and chassis should be of bakelite, paxolin or perspex, as these three materials are efficient insulators in themselves.

5. The Beginners' Crystal Receiver.

The popularity of the crystal receiver among beginners is undoubtedly due to the very modest outlay necessary, and the ease with which such receivers may be built. It is not always appreciated that, to obtain worth while results,

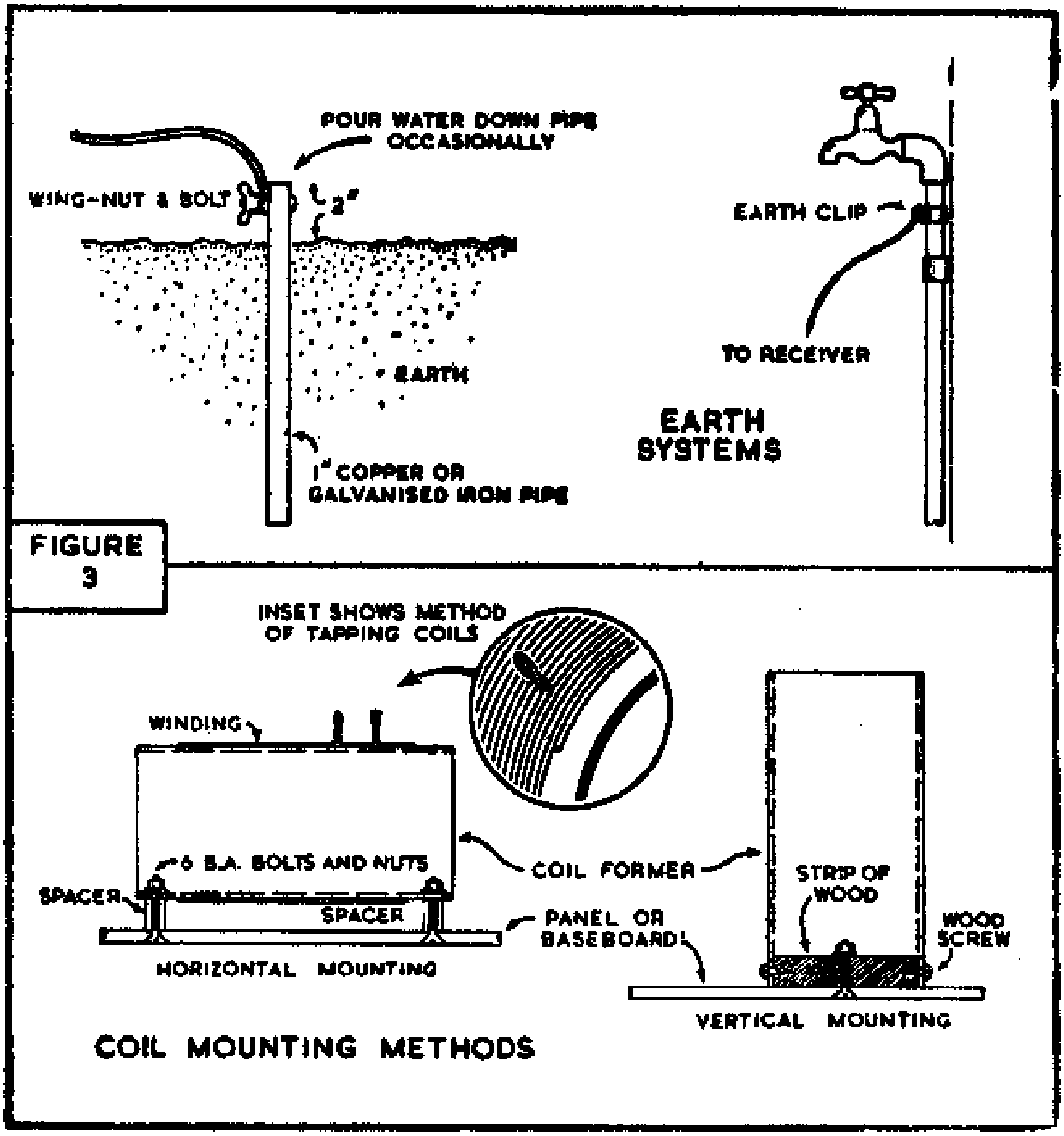
POUR WATER DOWN PIPE OCCASIONALLY
WING-NUT & BOLT
2"
EARTH
1" COPPER OR GALVANISED IRON PIPE
EARTH CLIP
TO RECEIVER
EARTH SYSTEMS
FIGURE 3
INSET SHOWS METHOD OF TAPPING COILS
WINDING
6 B.A. BOLTS AND NUTS
SPACER
SPACER
COIL FORMER
PANEL OR BASEBOARD
STRIP OF WOOD
WOOD SCREW
HORIZONTAL MOUNTING
VERTICAL MOUNTING
COIL MOUNTING METHODS

far more care in avoiding losses is necessary than with a three or four valve receiver. One reason for this is the fact that the crystal receiver can offer no help by way of amplification and it is therefore dependent on an efficient aerial/earth system, low loss design within the receiver itself, and the use of sensitive headphones. The experience gained is well worth the time expended since, when more ambitious receivers are attempted, the constructor will remember the benefits gained by efficient construction and installation with the result that each receiver attempted will be an instrument capable of giving a first class performance.

Losses within the receiver itself may be considerably reduced by efficient coil design. Unfortunately, selectivity is a factor which must not be overlooked; it is this factor which governs the sharpness of the tuning and permits the separation of adjacent powerful stations. The greater the selectivity, the greater the ease with which signals may be separated; but at maximum selectivity the received signals are at minimum strength. In Fig. 4, the coil is tapped at four points, which enables the best point between selectivity and sensitivity to be chosen. The nearer the aerial tap to the earth end of the coil, the greater the selectivity. The pre-set condenser C1 also aids selectivity; at minimum capacity the selectivity is high, and *vice versa*.

Used in conjunction with the coil taps, the constructor should have no difficulty in selecting a condenser setting and tapping point which permit the reception of strong signals and at the same time effect the required separation of powerful stations.

The coil is constructed on a former 3-in. diameter × 2-in., and consists of 50 turns 36 S.W.G. enamelled wire close wound and tapped at every tenth turn. These taps are brought out in the form of loops twisted firmly so that there is no actual break in the winding continuity. After completion the winding may be painted with Durafix to prevent any movement, and the taps and two free ends cleaned with emery cloth to remove the enamel. The layout and wiring is shown in Fig. 4. The headphones should have a resistance of some 4,000 ohms or more and should be of reputable manufacture. Any of the aerials previously described are suitable for use with this receiver.

C2 .0005 variable condenser.
C1 .0002 pre-set condenser.
C3 .001 mica condenser.
1 Crystal detector, semi-permanent pattern.
2 oz. 30 S.W.G. enamelled copper wire.
1 Coil former 3-in. dia. × 2-in.
1 Ebonite or Bakelite panel 6-in. × 5-in. × ¼-in.
4 terminals, connecting wire, etc.

6. Frame Aerial Receiver for Local Station use on Medium wave bands.

This receiver was specially designed for constructors who are within 5 to 10 miles of a powerful station and who have no facilities for constructing a good outdoor aerial.

The frame itself consists of two ¾-in. × ¾-in. square section wooden rods each 36-in. in length. These are placed together at their centre line to form a cross; they are fastened by a nut and bolt and these in turn pass through an upright piece of wood ½-in. × 1-in. section 2-ft. in length. This upright support is then screwed into a baseboard 8-in. × 8-in. × 1-in. thick. At each of the arms of the 36-in. cross a 4-in. strip of ½-in. square section wood is placed. Reference to Fig. 5B will give the details of the construction of this aerial quite clearly.

It will be noted that approximately 85-ft. of 20 S.W.G. double cotton-covered wire are required for the inductance to cover the medium wave broadcast band. The wire should be wound around the four crossbars, thereby creating

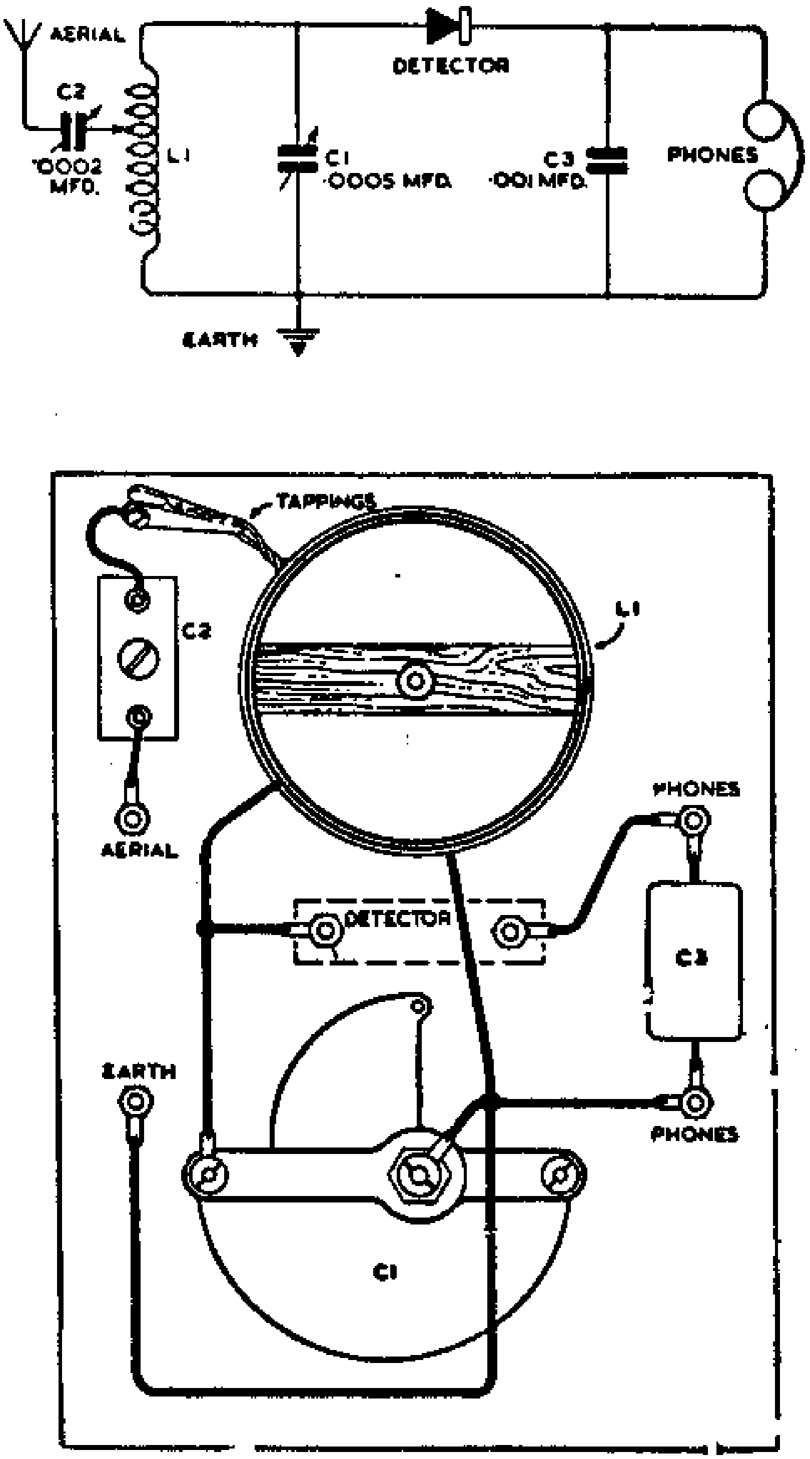
AERIAL
C2
·0002 MFD.
L1
C1
·0005 MFD.
DETECTOR
C3
·001 MFD.
PHONES
EARTH
TAPPINGS
L1
C2
AERIAL
PHONES
DETECTOR
C3
EARTH
PHONES
C1

FIG. 4 THE BEGINNER'S CRYSTAL RECEIVER.

a square wire frame, and each turn of the wire should be spaced approximately ⅛-in. The best way to effect this spacing accurately is to file on the 4-in. crossbars a number of small nicks at ⅛-in. intervals. The two ends of the wire should then be brought down on the two terminals which may be screwed into the square baseboard and two leads taken from there to the crystal set itself.

The actual set may be constructed on a small ebonite, paxolin or perspex panel 8-in. × 5-in. which may be screwed to one side of this base supporting piece of wood, thereby making the set virtually self-contained except for the earphones. Fig. 5A shows the circuit of the receiver.

To obtain the best results with this receiver, the aerial should be rotated by hand until the signals become loudest.

1 Semi-permanent crystal detector.
C1 1 .0005 mfd. variable condenser.
C2 1 .0005 mfd. fixed condenser.
1 condenser dial marked 0 to 100 or 0 to 180.
1 pair of high sensitivity earphones.
85-ft. to 90-ft. of 20 S.W.G. double cotton covered wire. (8oz.)
Sufficient connecting wire for wiring purposes.

7. Long Distance Receiver.

This receiver has been specially designed to achieve high sensitivity. With a sufficiently good outdoor aerial effective reception has been obtained up to 150 miles.

The circuit is quite straightforward, as can be seen from Fig. 6 and the only special point is in winding the coil L1.

This coil consists of a 2½-in. diameter former on which are wound a total of 51 turns using 24 S.W.G. double cotton wire. Starting at one end, tap every two turns until there are eight taps; wind a further 15 turns and tap; then a further 10 turns and tap; finally, add 10 turns to end the winding. The wire should be close wound, *i.e.*, with turns touching.

To obtain the best results, the two crocodile clips A and B should be tried on the various coil taps until the loudest reception is obtained. It may be found in use that the loudest reception of any particular station causes another station to be heard at the same time; care should, therefore, be taken to select the appropriate tapping point to separate any two powerful stations that may interfere with one another.

4 oz. 24 S.W.G. DCC copper wire.
Coil former 2½-in. dia. × 3-in.
C1-2 single variable condensers .00035 mfd.
2 Condenser dials marked from 0 to 100 or 0 to 180.
1 Permanent crystal detector.
C3 .001 fixed condenser.
1 pair of high sensitivity earphones (preferably between 4,000 ohms and 8,000 ohms impedance).
2 Crocodile clips.

8. High Gain Receiver.

This receiver has been designed to give good reception up to 50 miles distance from any normal power broadcasting station in the medium band. It is a very selective circuit and will therefore enable the user to separate closely situated stations.

It will be noticed in the circuit (Fig. 7) that the variable condenser C1, has an on/off switch S1 to throw it out of circuit if necessary. It is used to increase the selectivity of the receiver and, in operating, it should be tried with this condenser either in or out of circuit on the various tappings on the coil L1.

L1 consists of 90 turns of 22 S.W.G. double cotton covered wire wound on a 2-in. diameter former and tapped every ten turns. L2 separately wound on a 2-in. former, consists of 90 turns of 22 S.W.G. double cotton covered wire, also tapped as L1. The components required are given on page 9

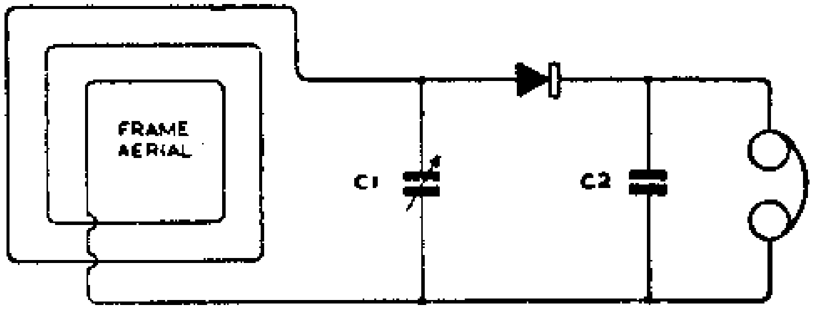
FRAME AERIAL
C1
C2

FIG. 5A FRAME AERIAL CRYSTAL RECEIVER

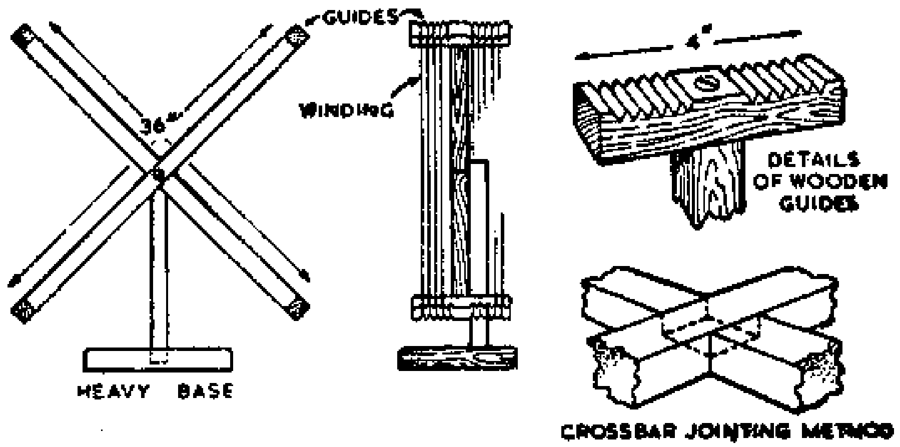
GUIDES
36"
WINDING
HEAVY BASE
4"
DETAILS OF WOODEN GUIDES
CROSSBAR JOINTING METHOD

FIG. 5B. DETAILS OF FRAME AERIAL

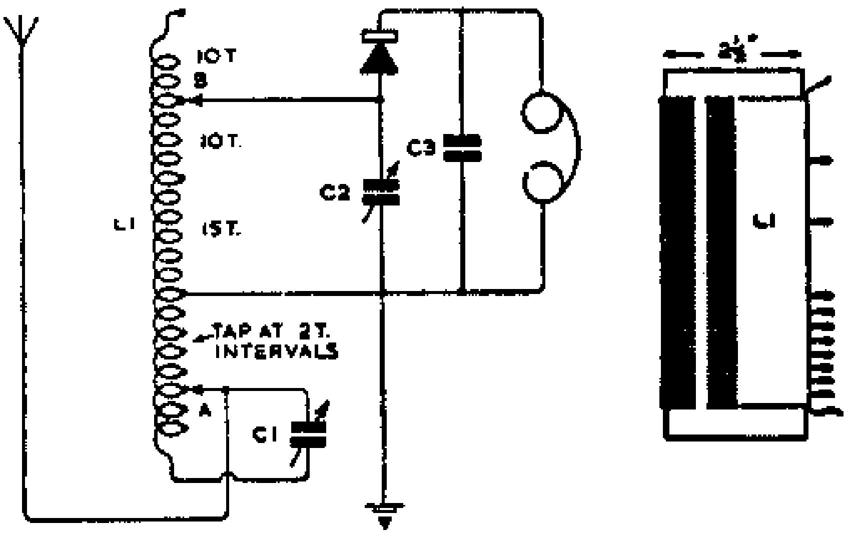
10T
B
10T.
L1
15T.
C2
C3
TAP AT 2T. INTERVALS
A
C1
2½"
L1

FIG. 6 LONG-DISTANCE CRYSTAL RECEIVER

C1-2 Single variable condensers .00035 mfd.
S1 Single pole single throw switch.
C5 .0001 preset condenser.
1 Permanent crystal detector.
C3-4 .001 mfd. fixed condenser.
1 Pair of high sensitivity earphones.
8 oz. 22 S.W.G. DCC.
2 Dials for variable condenser marked 0 to 100 or 0 to 180.

9. High Selectivity Receiver.

This circuit (see Fig. 8) is for use in high saturation strength areas where it is desired to separate powerful stations. The circuit is not complicated and is extremely effective.

It will be noted that C1 and C2, each .00035 mfd. capacity, are 2 gang unit.

The only special point in this set is the design of coils L1, 2 and 3, which are constructed as follows: L1, 60 turns of 22 S.W.G. double cotton covered wire on a 3 × 4 inches former tapped every five turns; L2, 15 turns of 22 S.W.G. double cotton covered wire on a 3 × 6 former; and L3, 85 turns of 22 S.W.G. double cotton covered wire wound on the same former as L2, the two windings being separated by approximately ¼-in. (see Fig. 8).

Note that the aerial lead is brought down to one of the tappings on wire L1. This should be tried on each of the tappings and the one giving the required selectivity should be used.

C1-2 2-gang variable condenser .00035 mfd.
2 3-in. formers for coils L1-2-3.
8 oz. 22 S.W.G. DCC.
C3 .0005 fixed condenser.
1 Semi-permanent crystal detector.

10. Battery-aided Crystal Receiver.

Fig. 9 shows a design which utilises a 9-volt grid bias battery to improve performance.

The charge built up in the .02 mfd. fixed condenser is changed to a positive current when it passes through the coil L1. This, in turn, is superimposed on the positive charge that is commencing to be rectified by the crystal detector and thereby increases the signal strength.

Coil L1 consists of a 4-in. diameter former wound with 85 turns of 24 S.W.G. double cotton covered wire tapped at 5, 25, 45 and 65 turns from the earth end. The earth end and these four taps are brought out to five small sockets and the connection from the earth is taken to a small socket. The plug should be tried in each of the five positions to find which one gives the greatest signal strength.

The 9-volt battery is connected across the .02 mfd. condenser and special care should be taken to see that the battery is connected correctly, *i.e.*, negative pole to earth.

1 Permanent crystal detector.
1 4-in. dia. × 3-in. former.
8 oz. 20 S.W.G. DCC copper wire.
C1 Variable condenser .0005 mfd.
C2 Fixed condenser .005 mfd.
C3 Fixed condenser .02 mfd.
1 pair of high sensitivity headphones.
1 Clix plug.
5 Clix sockets.
1 9-volt grid bias battery.

11. Medium and Long wave band Receiver.

This set has been designed for reception on two wave bands.

Care must be taken in winding the coils L1, 2, 3 and 4. These are wound on a single 3-in. diameter former. L1 consists of 30 turns of 28 S.W.G. DCC tapped at 8, 16 and 24 turns. L2, 60 turns of 32 S.W.G. DCC. L3, 40 turns of 28 S.W.G. DCC, and L4, 80 turns of 32 S.W.G. DCC. All are close wound and are separated from each other as follows: between L1 and L2, 3/16-in.;

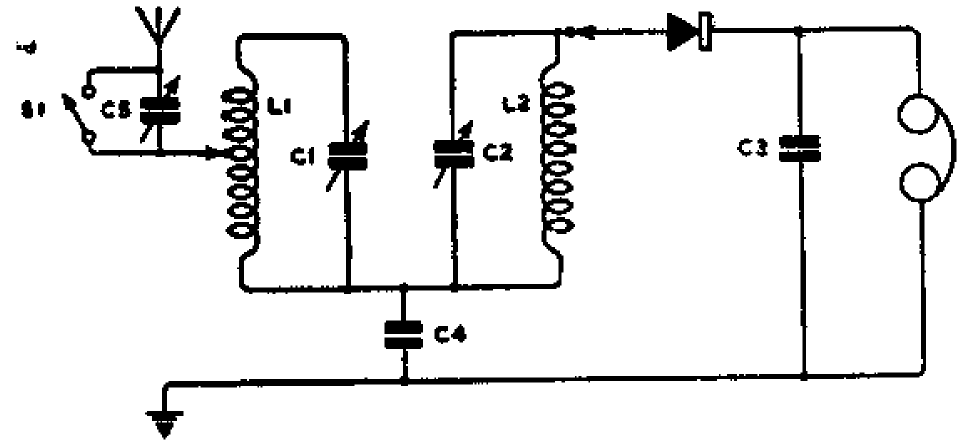
S1
C5
L1
C1
C2
L2
C3
C4

FIG. 7 HIGH-GAIN CRYSTAL RECEIVER

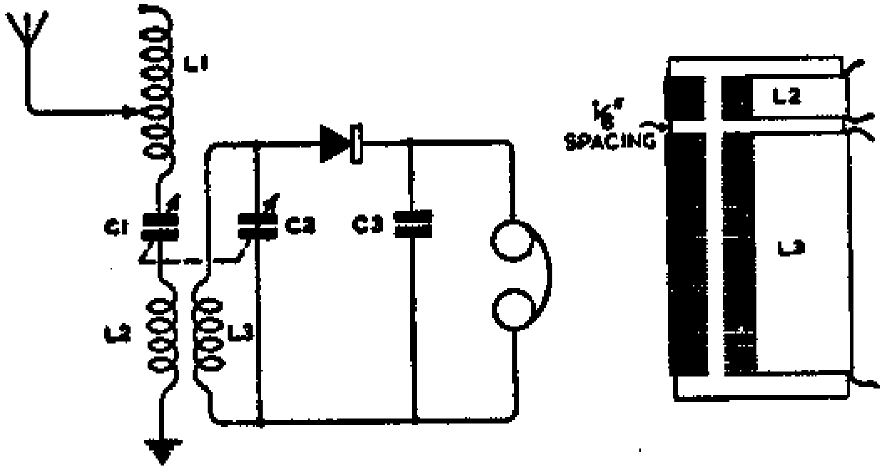
L1
C1
C2
C3
L2
L3
1/8"
SPACING
L2
L3

FIG. 8 HIGH SELECTIVITY CRYSTAL RECEIVER

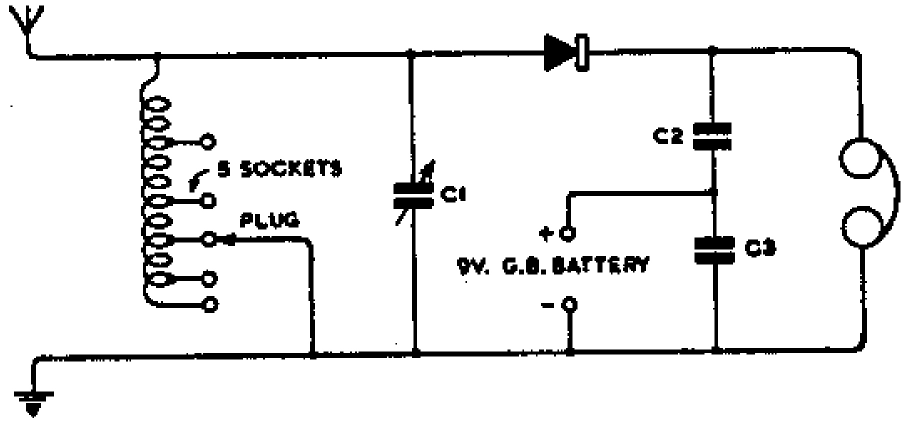
5 SOCKETS
PLUG
C1
C2
C3
+
9V. G.B. BATTERY
-

FIG. 9 BATTERY-AIDED CRYSTAL RECEIVER

between L2 and L3, 1-in.; and between L3 and L4, 3/16-in. See Fig. 10.

C1-2 single variable condensers .0005 mfd.
2 Variable condenser dials marked 0 to 100 or 0 to 180.
1 Clix plug.
3 Clix sockets.
S1 Single pole double throw switch.
C3 .001 mfd. fixed condenser.
1 Pair of high sensitivity earphones.
1 3-in. dia. × 8-in. former.
2oz of both 28 and 32 S.W.G. double cotton covered wire to make these 4 coils.
1 Permanent crystal detector.

In use, the plug should be tried in each of the three sockets to find the point which gives the best results. The switch is used as a wave band change switch.

12. Ultra Sensitive All Wave Receiver.

The receiver shown in Fig. 11 is for long distance reception. It is a novel circuit and, though apparently complicated in construction, it is really very simple to assemble with the minimum of tools and labour.

It will be seen from the circuit diagram that there are two banks of sockets, five black and six red. When using this set the appropriate black and red plugs should be inserted in whichever of the similar coloured sockets give the best results. The coil is quite easy to construct and consists of a primary winding which is inserted at the earth end of the secondary winding. For the medium wave band, the secondary winding L2 consists of 54 turns of 20 S.W.G. enamelled or cotton covered wire. This coil has four taps in addition to the starting point and the end connection, and these taps are taken at six turns, 14 turns, 27 turns and 40 turns from the earth end. The taps are taken out and a connection is made to an appropriate socket, as shown in the diagram.

The coil is wound on a 3-in. diameter former which may be a paper tube, bakelite, paxolin or perspex, and spacing is approximately 17 turns to the inch.

For short wave work down to about 30 metres, L2, the secondary coil, will consist of the same diameter former wound with 15 turns of the same gauge wire, the four taps being taken at 3, 6, 9 and 12 turns from the earth end.

L1, the primary coil, is used for both wave bands and consists of 11 turns of similar gauge wire to that used for L2, wound on a 2-in. × 1-in. former, the winding to be spaced the same as L2. The coil is then inserted at the earth end of whichever secondary coil L2 is being used.

The crystal detector may be one of the semi-permanent types freely available to-day; the old-fashioned cat's whisker pattern; or one of the silicon permanent detectors which are sold by many surplus dealers.

The 'phones should be of a standard type 4,000 ohms impedance although 'phones of other values will probably operate quite satisfactorily with this powerful receiver. It should, however, be stressed that the better the headhones used, the more satisfactory the reception.

Coils for other wave bands may be experimentally designed by the constructor, remembering that four tappings are advisable for the secondary coil L2.

A long aerial is very desirable with this receiver, placed as high as possible. It is recommended that a minimum length of 70-ft. be allowed, to include the aerial and lead-in.

The values of the components are shown in the following components list. The constructor should experience no difficulty in obtaining excellent results from this cleverly designed receiver.

C1 .0005 variable condenser.
C2 .002 fixed condenser.
1 semi-permanent crystal detector.
1 coil former 3-in. dia. × 4½-in.
1 coil former 2-in. dia. × 1-in.
½ lb. 20 S.W.G. enamelled or DCC copper wire.
6 red wander plug sockets.
6 black wander plug sockets.
1 red and 1 black wander plug.

Headphones, terminals, connecting wire

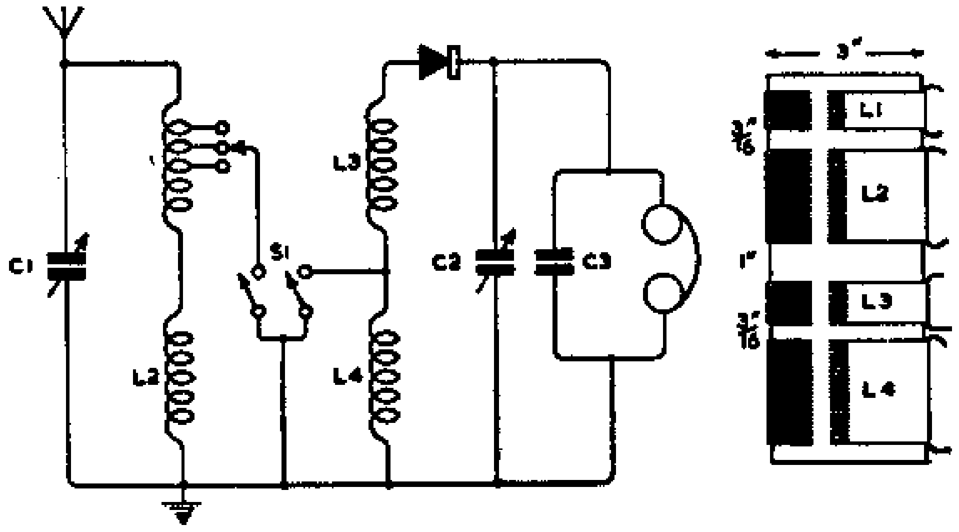
C1
L3
L2
S1
L4
C2
C3
3"
L1
3/16"
L2
1"
L3
3/16"
L4

FIG. 10 MEDIUM AND LONG-WAVE CRYSTAL RECEIVER

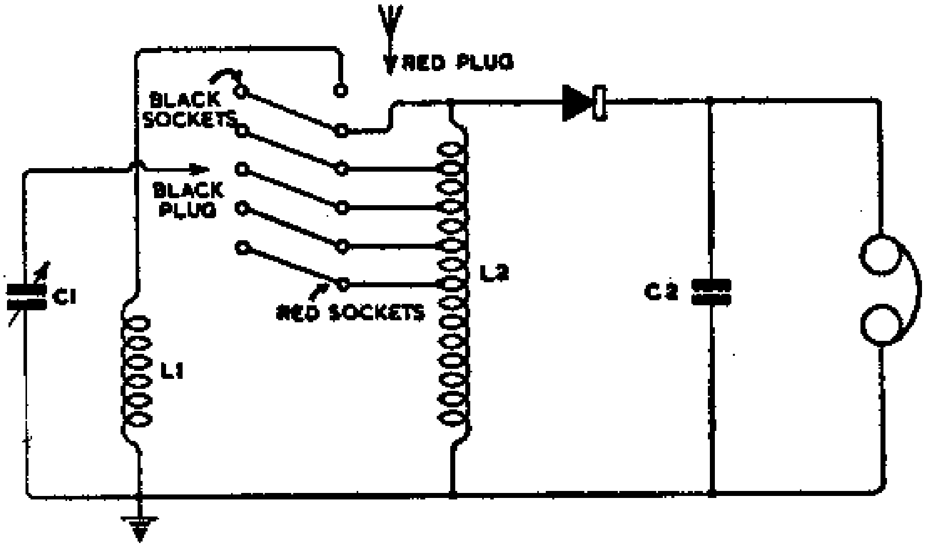
RED PLUG
BLACK SOCKETS
BLACK PLUG
C1
L1
L2
RED SOCKETS
C2

FIG. 11 ULTRA-SENSITIVE ALL-WAVE CRYSTAL RECEIVER

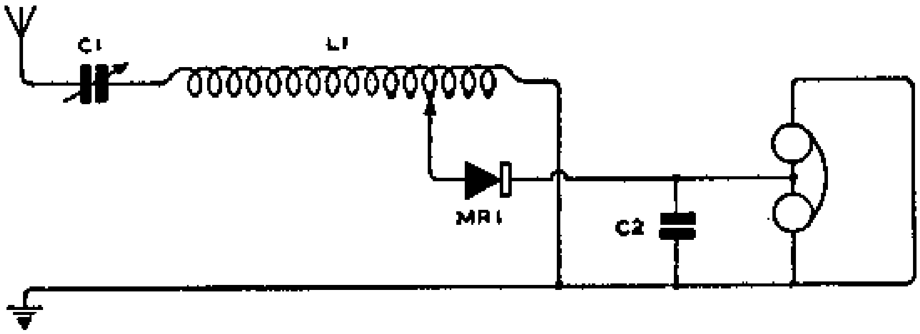

FIG. 12 ADVANCED CRYSTAL DIODE RECEIVER

13. An Advanced Crystal Diode Receiver.

The modern crystal diode of the radar type does not require any adjustment and thus has a distinct advantage over the ordinary crystal detector which needs delicate adjustment—even the semi-permanent type.

Such crystals are now obtainable on both the regular and the surplus markets, and a popular type is the B.T.H. CS7A silicon crystal (also coded as CV 253).

A rather different circuit from the usual crystal set arrangement is needed to suit the characteristics of a crystal diode. The diode must be tapped on to the tuning coil, and it is found that the tuning circuit itself gives best results if a series-tuned acceptor circuit is used. The circuit of a radar crystal receiver is shown in Fig. 12. The type of aerial used with this circuit has a very great bearing on the behaviour of the receiver for, in effect, the tuned circuit, with a series resistance equivalent to the reflected crystal load resistance, is in series with the capacitance of the aerial to earth and the aerial's effective series resistance.

At resonance—when the combination is tuned to any particular signal—the inductance resonates with the capacitances of the tuning condenser and the aerial in series, and the final effect is that the reflected load of the crystal, in series with the coil's R.F. resistance, is paralleled across the aerial's series resistance.

For maximum power transfer, the crystal load resistance must be made equal to the sum of the aerial series resistance and the coil R.F. resistance, and so the method in which the crystal is tapped into the tuning coil, and the exact capacitance required to tune the receiver to any required signal, must depend to a very great extent on the aerial itself.

At the same time the crystal resistance varies with the signal strength, the resistance being high for weak signals and dropping by as much as 50 per cent. and more for strong signals, so that this effect also has a bearing on the correct coil tap. The output impedance of the crystal also varies similarly, affecting the matching of the headphones into the crystal diode, and so for any set of conditions, the receiver requires to be matched up to both the aerial and the signal being received for best results. This would mean a series of coil taps and (theoretically, not practically) a matching transformer between the diode and the headphones; but in practice it will be found that a receiver using standard parts can be built up to give very good results under various conditions.

It has been shown already that the tuning of the receiver depends to a great extent on the characteristics of the aerial, and while a .0005 mfd. variable capacitor is shown in Fig. 12 as the tuner, the constructor must be prepared to experiment with different capacitance values until the required station is tuned in. The range of reception given by the receiver is quite good, if a really long and high aerial, and a good earth connection, are used; but no more than the local station signal can be expected, and the tuning therefore must be adjusted to suit the station frequency.

It must be mentioned that the headphones are shown parallel connected. High resistance headphones of the 4,000 ohm type must be used, and if two of these are connected in parallel rather than in the more usual series method, they will provide a roughly accurate match to the crystal. If more than one pair of headphones are to be connected in, then the pairs of headphones may be left series connected in the usual manner, the sets of headphones being connected in parallel.

The capacitor across the headphone terminals completes the crystal R.F. circuit, and any value between about 0.001 and 0.005 mfd. will serve. The higher capacitance will, of course, by-pass some of the higher audio frequencies, so that if good steady reception is obtained some experiment with this condenser is also worth while.

C1, .0005 mfd. variable condenser.
C2, .005 mfd. fixed condenser.
M.R.1 CV 253 Crystal diode.
Coil former 1½-in. dia. × 4½-in.
4oz. 26 S.W.G. enamelled copper wire.

Coil details are as follows: 150 turns of 26 S.W.G. tapped at 20, 25, 30, 35, 40 and 45 turns from the earth end. At each tapping-point the wire should be twisted up into a loop and the winding then continued without breaking the wire; when the coil is completed and the ends anchored the tapping loops can be bared.

BERNARDS RADIO BOOKS

No.		Price
56.	Radio Aerial Handbook	2/6
57.	Ultra-Shortwave Handbook	2/6
58.	Radio Hints Manual	2/6
64.	Sound Equipment Manual	2/6
68.	Frequency Modulation Receivers' Manual	2/6
73.	Radio Test Equipment Manual	2/6
83.	Radio Instruments and their Construction	2/6
96.	Crystal Set Construction	1/-
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	International Radio Tube Encyclopaedia—3rd Edition	63/-

THE BOY'S BOOK
of
CRYSTAL SETS

BY

W. J. MAY

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PREFACE

The Publishers make no apology for reviving interest in the crystal set. For too long the technical press has immersed itself in an orgy of complex superheterodyne receivers and television equipment, all of which is necessarily expensive. In the 1920's, crystal set construction was a fascinating and inexpensive pastime indulged in by the majority of boys of that day. Today this pleasurable hobby can be even more attractive, the introduction of the germanium crystal diode and high performance coils, has opened up new paths which will capture the interest of boys of all ages. Perhaps most important of all, not only can a receiver capable of impeccable reproduction be produced without any technical knowledge; but the cost is no greater than that of a few visits to the cinema

⁂

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INTRODUCTION

Before any attempt is made to construct a receiver, it is necessary to examine the problems which surround the crystal set, so that the best can be obtained from any of the designs attempted.

Firstly, it must be understood that the crystal set as it is to-day does **not** provide any amplification. It relies entirely on what is fed into it via the aerial and earth system and gives a very faithful replica of the original transmission.

From this it will be obvious that the aerial and earth system must be as efficient as possible if the final results are to be in any way outstanding. This because these are the only means by which the signals are fed to the receiver.

Secondly it is necessary to understand the nature of the transmitted signal, then it will be easy to understand the working of the set and to appreciate the function of each of the components.

When crystal sets first became popular, very little information was generally available, at least, not in a form that school-boys could understand.

We all built sets of all shapes and sizes, with coil designs that had to be seen to be believed, but very few of us had much idea of how they worked.

I well remember the case of a cousin of mine who, in those days acquired a magnificent variable capacitor or condenser as it was then called, this instrument had a most impressively engraved dial of polished ebonite, brass vanes and nickel plated end plates. Having observed similar dials on several highly priced commercial receivers in the town, he at once ripped out the somewhat tattered coil from the family receiver and replaced it with this device. The profound silence which ensued caused considerable amazement and dismay until a better informed adult explained the mysteries of L and C to him. Readers of this manual, however, will be better informed and there is no risk of failure with any of the designs described provided the instructions are carefully followed.

The Signal

To commence, we will assume that an orchestra is playing in a broadcasting studio. Since the principle of radio transmission is electrical it is necessary to change the sound produced by the orchestra into an electrical equivalent. This is carried out by the microphone, which picks up the sound and changes it into minute electric currents.

As they appear at the output of the microphone they are too small to be of use and accordingly are passed through a high power amplifier. These amplified currents could now be transmitted, but unfortunately, as we shall learn, owing to the inherent nature of the signal in this state, transmission over any useful distance would be impractical.

When the music from the orchestra is transformed into electrical currents they are in the form of alternating currents, usually called A.C., that is they rise to a maximum in one direction, fall to a minimum, rise to a maximum in the opposite direction and then fall to minimum again. This process is repeated over and over again. One complete rise and fall in each direction is called a cycle and is drawn in Fig. 1. Every time a note is struck on a piano, vibrations are sent out which reach the ear enabling you to hear it. These vibrations are also spoken of as cycles, they rise and fall in intensity the same way as an alternating current. The number of cycles radiated by any given note over a period of one second are referred to as its frequency. Middie C on the piano sends out 261 cycles every second and is known as having a frequency of 261. The microphone also "hears" the note and in the case of middie C produces minute A.C. at 261 cycles. This can be drawn as in Fig. 2, the only difference between Fig. 1 and 2 is, that the time factor is given so that the frequency can be identified. The higher the pitch of a note the higher the frequency and the lower the pitch the lower the frequency. On a piano the frequency of the top note is 3515 cycles and that of the lower 27 cycles. Those of you who have listened to an organ in a concert hall will have noticed that when a very deep note was played, it sounded like a growl to the ear, but the vibrating fre-

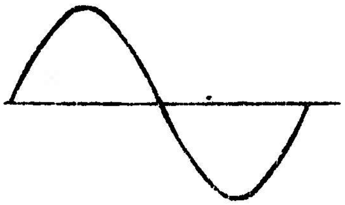

FIG 1

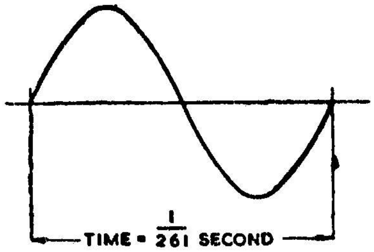

FIG 2

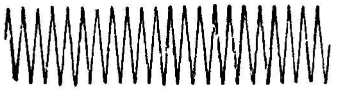

FIG 3

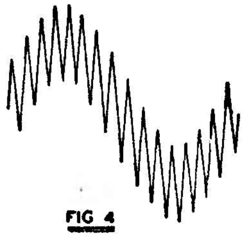

FIG 4

quency could be distinctly felt through the seat. Higher notes have too high a frequency to be observed in this manner.

The range of sounds which can be detected by the human ear are known as audio or low frequencies. From this you will understand that a low frequency amplifier is one which amplifies sound.

So that the transmitter will carry the programme over a useful distance it is necessary to radiate high frequencies. Now, as explained, the programme to be transmitted consists of low frequencies, and to overcome the difficulty, the transmitter generates A.C. of high frequency and combines it with the low frequencies. It will now be understood that the transmitted signal consists essentially of two different parts, a high and a low frequency content.

Fig. 3 gives a representation of the high frequency signal generated by the transmitter. In the case of the London Home Service, the frequency is 908000 cycles.

When referring to a high frequency signal on the medium or long wave-band it is usual to express the frequency in thousands of cycles, thus 908000 cycles becomes 908 kilo-cycles, which in turn may be abbreviated to 908 k/cs. It might at first be thought that by adding the low frequency or L.F. signal to the high frequency or H.F. carrier a form such as in Fig. 4 would result, such a combination is useless, and, so that the original L.F. content can be satisfactorily extracted by the receiver, the L.F. signal must vary the amplitude or output power of the H.F. signal as in Fig. 5.

It is in this form that the signal arrives at the receiving aerial. The aerial in itself is incapable of discriminating between one signal and another, and countless signals will be collected by the aerial at any one time. Many of these are too weak to be of use but the stronger ones must be sorted out since there is no point in receiving several programmes at once.

Fig. 6 shows the basic circuit of the input to a crystal. The coil L possesses a quality known as inductance, and the capacitor C, that of capacitance. If the coil had no capacitance whatever across it, all signals arriving at the aerial would be effectively short circuited to earth. As a matter of interest, it is impossible to obtain this state of affairs since even without any additional capacitor any coil **must** contain a certain amount of self capacitance.

By combining a coil and capacitor as in Fig. 6 a peculiar effect is observed, at one particular frequency, the signals are not short circuited to earth, but are developed across the coil. In other words the combined effect of L and C no longer provides a short circuit, **but only at one particular frequency.** If the value of C is altered the effect will be observed at a different frequency; likewise by altering L the frequency at which the effect will take place can be changed. There is a name for this phenomena, the frequency at which it occurs with any given L and C combination is known as the **resonant frequency.**

The values of the coils and capacitors shown in this manual have been carefully chosen so that resonance will be obtained at all frequencies where stations are broadcasting. Broadcasting stations work in bands of frequencies, those of major interest to crystal set constructors are the medium wave-band 1200 k/cs—600 k/cs and the long wave-band 300 kc/s—150 k/cs.

Usually a variable capacitor is used with a fixed inductance to cover one band and an additional coil switched in to increase the inductance to cover the other. In this way the L and C combination can be adjusted to provide resonance at the desired frequency of any given station. In other words you can select the station you want by varying C, that is turning the dial of the variable capacitor. This procedure is referred to as tuning. Having selected or tuned the required station it still remains necessary to change the form of the signal back to that of the original transmission. This process is called detection or de-modulation.

Examination of Fig. 5 will show that the signal has been duplicated, in other words, as it rises in one direction it also rises equally in the other. In this form the signal is useless since each half of the signal cancels the other, and if this signal is applied to a pair of headphones silence will result. Obviously some provision must be made to get rid of the unwanted half of the signal, and it is here that the crystal detector must be considered. This device will pass current in one direction only, ignoring any signal in the opposite direction, so that if the signal of Fig. 5 is passed through such a crystal, that of Fig. 7 will result. There is still the H.F. content to be reckoned

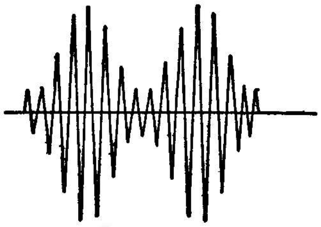

FIG 5

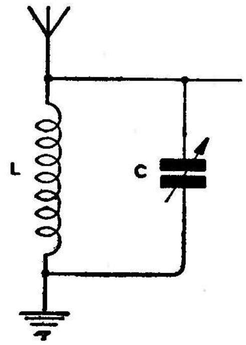

FIG 6

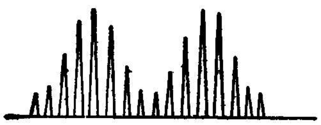

FIG 7

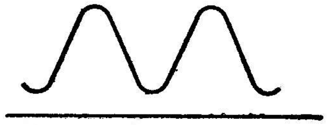

FIG 8

with, fortunately this is easily dealt with, a capacitor connected across the headphone terminals effectively disposes of this, leaving only the audio or L.F. content, as shown in Fig. 8. This audio content, which is a faithful replica of the original transmission is fed to the headphones. These in turn reverse the process of the microphone and transform the electrical currents into sound waves acceptable to the human ear.

Briefly then, your requirements are as follows:—

(1) A good aerial and earth installation, to make the most of the available signals.
(2) A receiver containing:—
  (a) Some form of coil and capacitor (L & C) combination to select or tune in the wanted station.
  (b) A crystal to get rid of the unwanted half of the signal (detection).
  (c) A fixed capacitor across the headphones to get rid of any remaining carrier.
(3) A pair of sensitive high resistance headphones.

Aerials

By this time the intending constructor will be able to appreciate the necessity of a good aerial. It is a point which cannot be over-emphasised. Assuming that you are in the fortunate position of being able to erect an outdoor aerial there are two main considerations, height and length.

One of the best that can be used is the inverted L shown diagramatically in Fig. 9.

It should be erected as high as is practical, every foot counts. The horizontal wire, that is the aerial proper, should have a minimum length of 60′ to which of course the length of the down lead is added. Where it is impossible to erect an aerial with an ideal horizontal length, a compromise must be effected.

Fig. 10 shows a three wire spreader aerial which gives quite a good effective length.

Suitable wire for a receiving aerial will not set any problems, stranded copper about 7/22 gauge is the best. 7/22 means that it consists of 7 strands of 22-gauge wire. This wire may be obtained covered, and for the present purpose is better than the plain or enamelled kind.

Note that insulators are used between the actual aerial wire and its anchoring supports, it is important that these are used, otherwise leakage will occur which will of course spoil its efficiency. Fig. 11 and 12 show how the wire may best be attached to two of the most common types of insulator available. Fig. 11 is of porcelain and is usually referred to as an egg insulator, whereas Fig. 12 shows a more modern (and more expensive) type in glass. If you are using the glass pattern, one is usually sufficient at each end of the aerial, but with the egg type two should be used. No doubt many readers will not be in a position to erect an out-door aerial, and must necessarily be content with an indoor installation.

The next best thing to a good out-door aerial is a replica constructed in a loft. If this form of construction is used, care must be taken when feeding the down lead to avoid close contact with the wall of the house. At the point where the lead feeds under the eaves, a length of rubber tubing can be used to cover the wire. The lead is fed through one of the small spaces left for ventilation purposes. A general idea is given by Fig. 13.

A less elaborate but quite effective aerial can be obtained by using a bed-spring. A length of 7/22 copper insulated wire is connected between the receiver and the spring. The spring should first be cleaned with emery cloth. Remove about 2″ of insulation from the wire and bind it tightly round the prepared spring. The joint may be covered with insulating tape which is obtainable from all electrical stores for a few pence.

Such aerials are quite popular since so many crystal sets are built for bedroom use.

When an aerial is required in the living room, the picture rail can be conveniently used. Insulated screw-eyes are fixed at intervals of about 3 feet along the rail, the wire is firmly anchored to one of them, and stretched right round the room until you arrive back at the starting point. By use of one of the insulated screw-eyes, the wire is secured and the down lead fed to the receiver. The idea is illustrated in Fig. 14.

Soldering

Before leaving the subject of aerials, a few words on soldering will not come amiss. Down leads on outdoor aerials should be soldered, and the same applies to loft types. Apart from aerial leads; earth leads and all the connections in the receiver will require soldering.

For the type of soldering necessary in radio construction an electric iron is the best solution. One of the small types marketed by Adcola or Henleys will be found admirable for the job. These are excellent for actual set construction but are hardly large enough for soldering the down lead to an outdoor type of aerial. Here the heat is dissipated much more quickly and a larger iron is required in order to get the solder to flow.

Ordinary irons which may be heated by a gas flame can be obtained very cheaply from most ironmongers' stores. Assuming the use of such an iron, first heat the iron until the copper bit is giving off a green coloured flame, the iron is now at the correct operating temperature. The bit is now discoloured or oxidised and its tip

✓

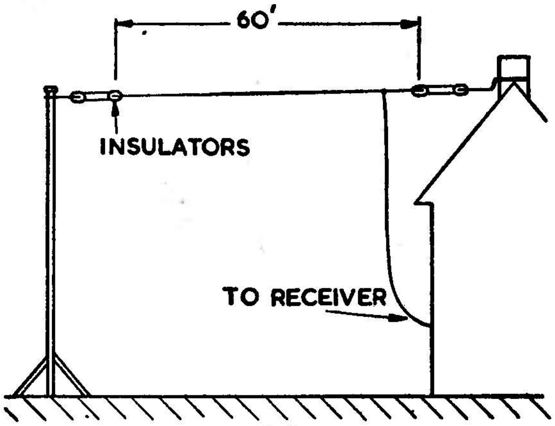
60′
INSULATORS
TO RECEIVER

INVERTED 'L' AERIAL

FIG. 9

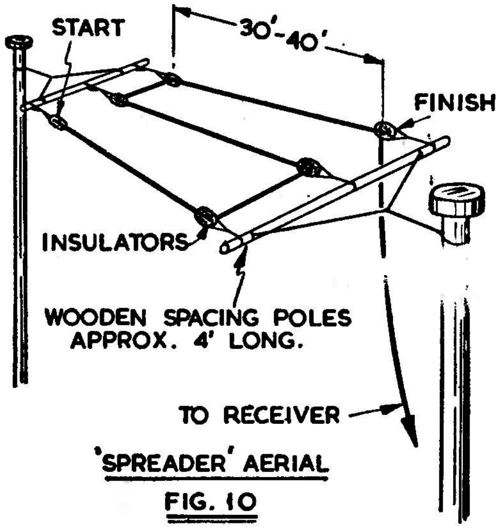
START
30′-40′
FINISH
INSULATORS
WOODEN SPACING POLES
APPROX. 4′ LONG.
TO RECEIVER

'SPREADER' AERIAL

FIG. 10

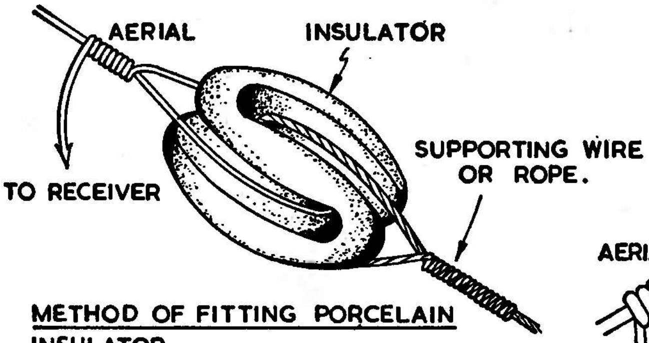
AERIAL
INSULATOR
TO RECEIVER
SUPPORTING WIRE
OR ROPE.

METHOD OF FITTING PORCELAIN INSULATOR

FIG. 11

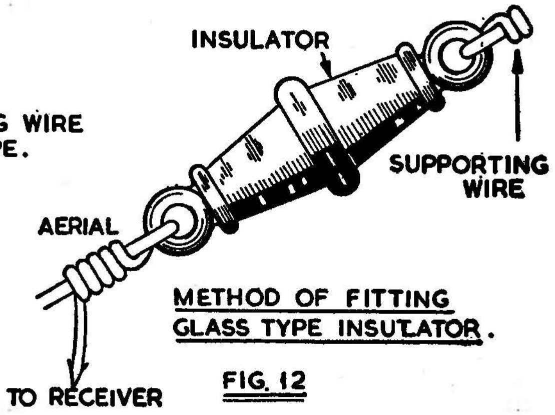
INSULATOR
SUPPORTING
WIRE
AERIAL
TO RECEIVER

METHOD OF FITTING GLASS TYPE INSULATOR.

FIG. 12

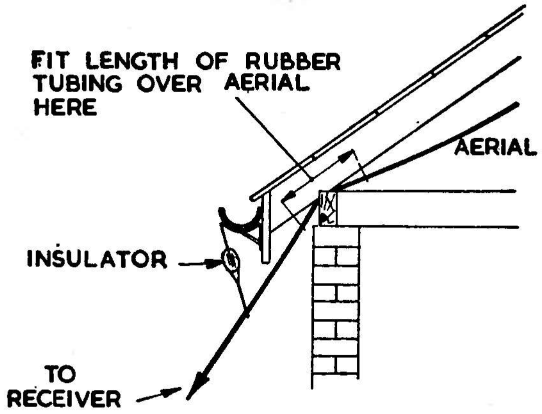
FIT LENGTH OF RUBBER
TUBING OVER AERIAL
HERE
AERIAL
INSULATOR
TO
RECEIVER

LOFT AERIAL.

FIG. 13

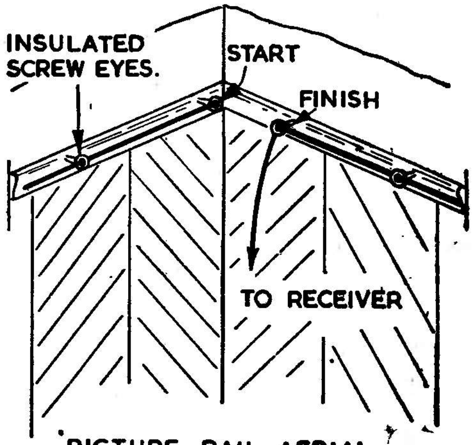
INSULATED
SCREW EYES.
START
FINISH
TO RECEIVER

'PICTURE RAIL AERIAL.'

FIG. 14

should be quickly cleaned with an **old** file which should be kept specially for the purpose. A better idea is to obtain a small block of sal-ammoniac and rub the tip of the hot iron on it. This will clean the tip of the bit perfectly. Next take a length of cored solder such as Ersin Multicore, and melt a little on to the prepared tip faces, now smooth it evenly over the surface with a piece of old rag (be very careful not to burn your fingers) the iron is now "tinned" and ready for use. When heating the iron, be very careful not to let the bit overheat or get red hot, otherwise the tinned surface will be destroyed and the whole process will have to be gone through again.

An electric iron will not overheat, and the tinning will last much longer than with ordinary types, and since the heat does not deteriorate there is less likelihood of making faulty joints.

Having obtained a tinned iron, the process of soldering joints is remarkably simple and anyone with a little patience can acquire the art in a very short time.

To solder two copper wires together: clean the wire with emery cloth, apply a prepared iron and some cored solder to it, the solder will flow evenly over the wire thus tinning it. Repeat the process with the remaining wire and then twist the two together. Now apply the iron to the joint from the underside and the cored solder to the joint on top. Solder will flow evenly over the joint. Remove both iron and solder and allow to set. The solder will harden or set in a few seconds but during this period the joint must not be touched or moved, as otherwise the joint will be "dry" and quite useless mechanically or electrically. On radio components, tags for soldering are already tinned though if they are old, or discoloured it is best to re-tin them. Normally, however, it is only necessary to twist the connecting wire to it and apply the iron and solder as explained.

Remember: **never** apply the solder to the iron and then the iron to the joint, always apply the iron **and** the solder to the joint. It is however a good thing to apply a little solder to the iron tip even when it is perfectly tinned just before making a new joint.

One final "DON'T," you will have noticed that the solder referred to is "cored," that is, it contains resin and other substances through its centre, plain solder as used by electricians and plumbers will not do, as it is the resin or flux

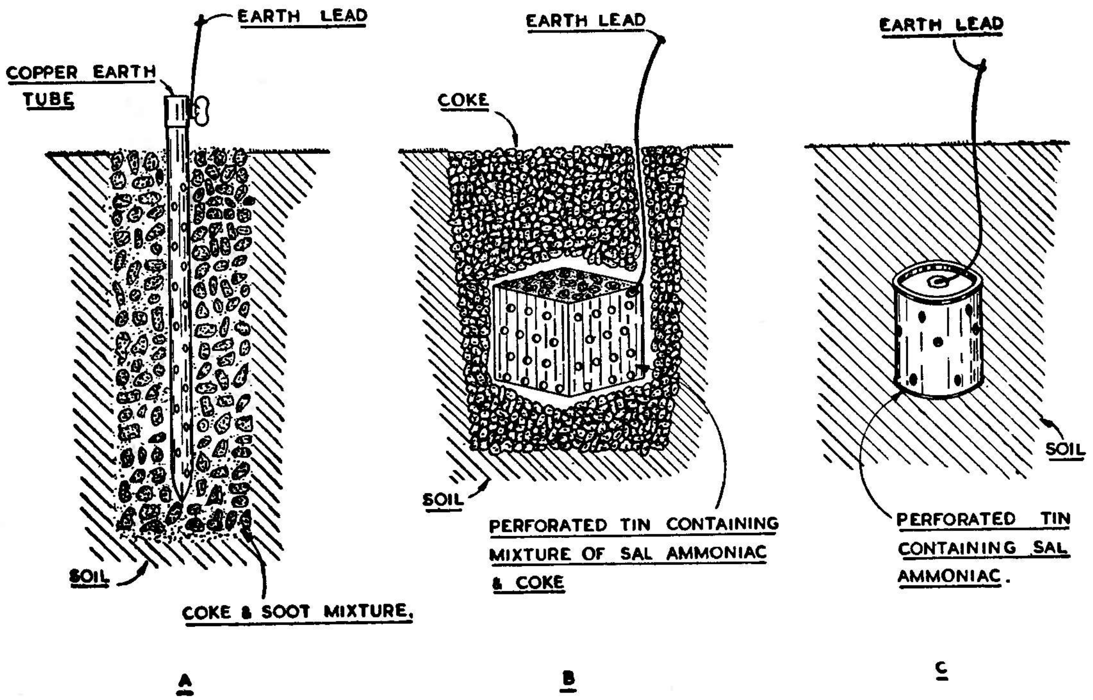
EARTH LEAD
COPPER EARTH TUBE
SOIL
COKE & SOOT MIXTURE.
A
EARTH LEAD
COKE
SOIL
PERFORATED TIN CONTAINING MIXTURE OF SAL AMMONIAC & COKE
B
EARTH LEAD
SOIL
PERFORATED TIN CONTAINING SAL AMMONIAC.
C

FIG. 15.

as it is called which makes the solder flow evenly and permits a good electrical joint.

Equally important do not attempt to use a separate flux or soldering fluid with plain solder or to "help" the cored solder; since these are almost certain to cause eventual corrosion and will destroy any components that have been contaminated.

Earths

The provision of a good earth is just as important as the rest of the installation.

Much disappointment would be avoided if this fact were not lost sight of, to avoid any slip up in this direction I am proposing to outline several well tried and efficient earth systems.

If it can be obtained, an earth rod, specially designed for the purpose provides the basis of a good earth connection. These were very popular some years ago when the majority of receivers were either crystal or battery operated, but in these days of modern mains driven sets they are not often used and consequently not always readily available.

Fig. 15 shows how it is used. First excavate a hole to a depth of three feet and fill with a mixture of soot and coke. Drive in the earth rod, which is a hollow copper tube, perforated. The lead to the receiver is connected at the top, and should be of covered 7/22 gauge, as used for the aerial system. Though not obvious it is important that this lead-in should be in covered wire, otherwise a number of indifferent earth contacts are likely to be made at various points along its length until it reaches the set. This is very undesirable and will spoil the efficiency of the system. It is essential to keep the soil surrounding the rod moist, which is one reason why the tube is hollow, and care must be taken to pour water into the tube at intervals.

A very efficient earth is the percolative type also popular at one time. Due to the chemicals used, it will extract moisture from its surroundings, thus maintaining a permanently moist earth.

It should be installed as in Fig. 15b.

The container is of copper or zinc, anything else will quickly rust away, again a good quantity of coke is used. Fill the container with a mixture of sal-ammoniac and coke, and then bury in coke as illustrated. This earth will not require further attention. It is possible to use powdered calcium chloride instead of sal-ammoniac but unless a chemist can be persuaded to make some up it is better to stick to sal-ammoniac.

If a zinc container is not available and you do not use or cannot easily get coke, Fig. 15c should be used. This makes a better earth than many so-called "earths" that I have come across. Obtain as large a tin as possible, make a number of holes as shown. Solder the lead in the bottom and fill it with sal-ammoniac. Replace the lid and bury in the ground. The tin will eventually rust away, but the replacement cost is negligible.

If it is quite impossible to make direct contact with the ground, a water pipe must be pressed into service. This should be a main pipe feeding straight to ground and not a hot water pipe or one fed from a tank. Scrape the pipe clean and twist the lead in tightly around it, a copper clip is even better. Do not attempt to solder on to the water pipe; since cold water is flowing through the pipe, it is extremely unlikely that your soldering iron will heat up the water supply sufficiently to allow a sound electrical joint, though you may spring a leak.

No attempt should be made to utilise gas pipes; the possibility of causing a fire is certainly very remote but, they make incredibly bad earth connections due to a number of joints made before true ground is reached. These joints are at best only semi-conductors, at least from an electrical standpoint.

Headphones

Since the late war there have been a large number of head-phone sets available on the surplus market. These may be roughly divided into two types, high-impedance and low-impedance. For the crystal sets detailed in this book high-impedance 'phones are required and the low-impedance pattern will not be suitable unless a matching transformer is used. As this is likely to cost more than the rest of the installation including the set, it will be as well to avoid them.

High-impedance types have an impedance of 2000Ω to 4000Ω whereas the low-impedance types are usually 600Ω.

The remaining consideration is weight; often cheap headphones are very heavy and uncomfortable to wear, every endeavour should be made to obtain 'phones as light in weight as possible.

Crystals

All the sets shown in this book have been designed to work with modern germanium crystals rather than the older galena crystal.

These germanium crystals require no adjustment, which, in itself, removes the main objection to this class of receiver. Suitable crystals are available from the following manufacturers and on the surplus market: Mullard, G.E.C., Brimar, Westinghouse and B.T.H. They are of robust construction, some in glass, others in ceramic or plastic, but must not be subjected to heavy knocks, otherwise the contact point may become dislodged.

From the information given, you should now be able to install an excellent aerial and earth system, and have some idea of how the crystal set works, so it is time to pass on to the actual receiver construction.

CONSTRUCTION 1

If you examine the following circuits you will find that each one is different. In most cases the difference lies in the coil design and/or the method by which the crystal and aerial is tapped into it. Each of these circuits has its own particular advantage to suit different conditions and the ideal circuit in some localities is not necessarily the best in others. It is not just a matter of a given circuit giving louder results than another, if it were there would be no point in showing more than one.

The main problem is to obtain adequate selectivity without reducing the volume level.

A receiver is said to be selective when it tunes sharply, a set with poor selectivity allows the stations to spread over the dial and when used near a transmitter will receive the local stations mixed together, which of course is useless.

Consider Fig. 16a, this is a very simple receiver, with no special attempt to provide any great amount of selectivity. In areas where signal

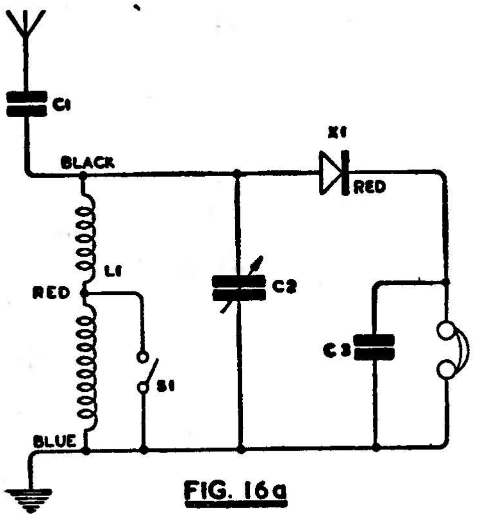

FIG. 16a

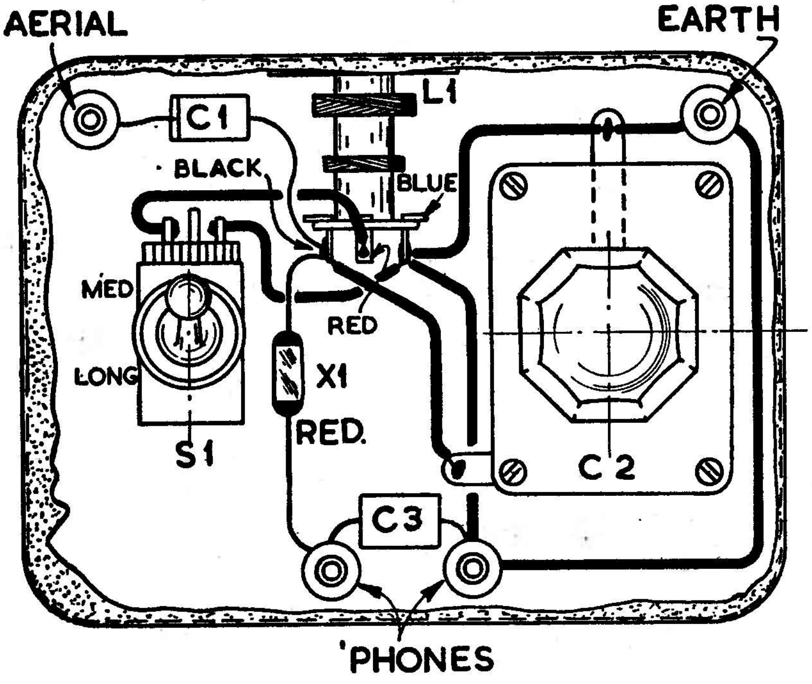

LID SHOWN BROKEN AWAY TO REVEAL POSITION OF COMPONENTS.

FIG 16 b

strength is not high, or a short aerial is used, it will probably be ideal.

It would have been quite easy to increase the selectivity by providing a tap on the coil for the aerial as in Fig. 17a, but unfortunately, as the selectivity is increased overall volume is likely to decrease, so that unless you live close enough to the transmitter to have a large signal available and therefore need the selectivity, the circuit of Fig. 16a will be quite satisfactory.

Capacitor C1 is to prevent the aerial damping the circuit too heavily because this would flatten the tuning unnecessarily, however with small aerials it may be better to take the aerial direct to the black tag on L1. The signals are selected or tuned by L1 and C2, X1 is the crystal and C3 the capacitor across the 'phones to prevent unwanted carrier or R.F. reaching the 'phones.

A practical diagram (Fig. 16b) is provided showing the layout and all the wiring. You will require nuts and bolts to fix the coil, about ½", 4BA size will do, the other parts have locking nuts provided. An old 2-oz. tobacco tin makes a very good container and keeps the size down. Note that the metal box is connected to earth. With the exception of AC/DC receivers the metal work on any receiver or amplifier is connected to earth.

When S1 is open as in the diagram, the set will tune in long-wave stations, but when closed the medium wave-band will be received.

Components List, Fig. 16a

C1	100pF mica capacitor.
C2	500pF tuning capacitor, solid dielectric.
C3	1000pF mica capacitor.
X1	Germanium crystal.
L1	Crystal Set Coil. R.E.P.
S1	Single Pole toggle switch.
4	Insulated wander-plug sockets and plugs.
1	2-oz. tobacco tin (or similar container).

Make sure that the wander-plug sockets are of the insulated type, otherwise the metal case will join all the sockets together electrically.

Try to follow the theoretical diagram when wiring, a little practice will soon enable you to wire up a set without a practical diagram, which is a great advantage because often only the theoretical diagram is given when circuits are detailed in the technical press.

Fig 28 on page 34 gives a list of symbols used on the theoretical diagrams, so that you can readily identify the components.

2

Fig. 17a circuit is similar in many respects to that of Fig. 16a. The difference is purely one of selectivity, tuning will certainly be sharper, and even with comparatively inefficient aerials the design will put up a very good performance. There is no reason why the construction should not follow the same lines as the previous receiver but, by enlarging the set a little and using an air spaced tuning capacitor, the efficiency is improved. Observe that the colour coding on the coil, an R.E.P. Dual Range (Blue Box) is different from that of the Crystal set coil used on the previous design, and make sure it is correctly wired in.

C1 is a mica compression capacitor, often referred to as a "trimmer" and because it is adjustable, permits the set to be matched to aerials of varying lengths. Construction is carried out on a square panel of bakelite, perspex or wood, as shown in Fig. 17b. Perspex being clear like glass presents a most attractive finish, provided the set is neatly wired. It must be drilled slowly, however, otherwise the generated heat of the drill will make the hole wander, and spoil the panel.

After the set has been wired and tested a small wooden container can be made to house the completed set.

When carrying out reception tests, a little experiment is well worth while, to get the best out of the set. Try removing the germanium crystal from the green tag on L1 and connecting it to yellow, at the same time removing the lead from C1 to yellow and connecting it to green. Once the best arrangement has been found the wiring

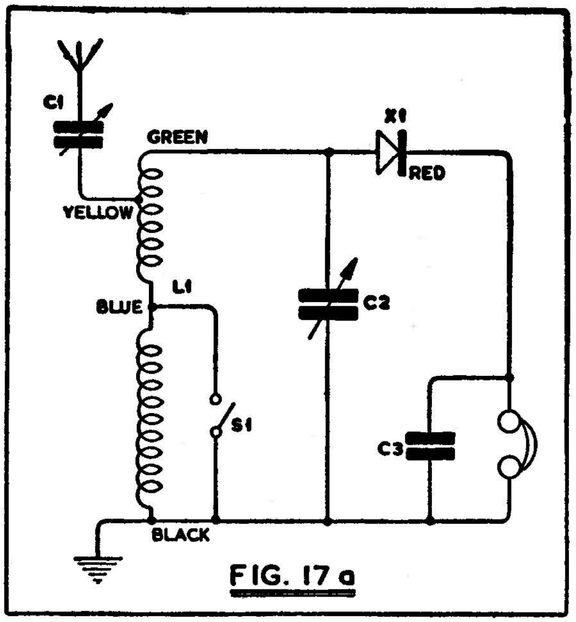

FIG. 17 a

can be left permanently in that position. Note that two tags on the coil are unused, this is intentional because on this circuit the extra winding connected to these tags is not required. With the switch S1 closed, the coil will cover the medium wave-band, and when open, long wave stations can be received. It is customary to abbreviate the expression medium wave-band to M.W. and long wave-band to L.W.

Components List, Fig. 17a

C1	100pF mica trimmer capacitor.
C2	500pF variable capacitor (air spaced).
C3	1000pF mica capacitor.
L1	Dual Range Coil R.E.P. (Blue Box).
S1	Single Pole toggle switch.
X1	Germanium Crystal.
4	Terminals or wander-plugs and sockets.
	Perspex, bakelite or wood for mounting panel.

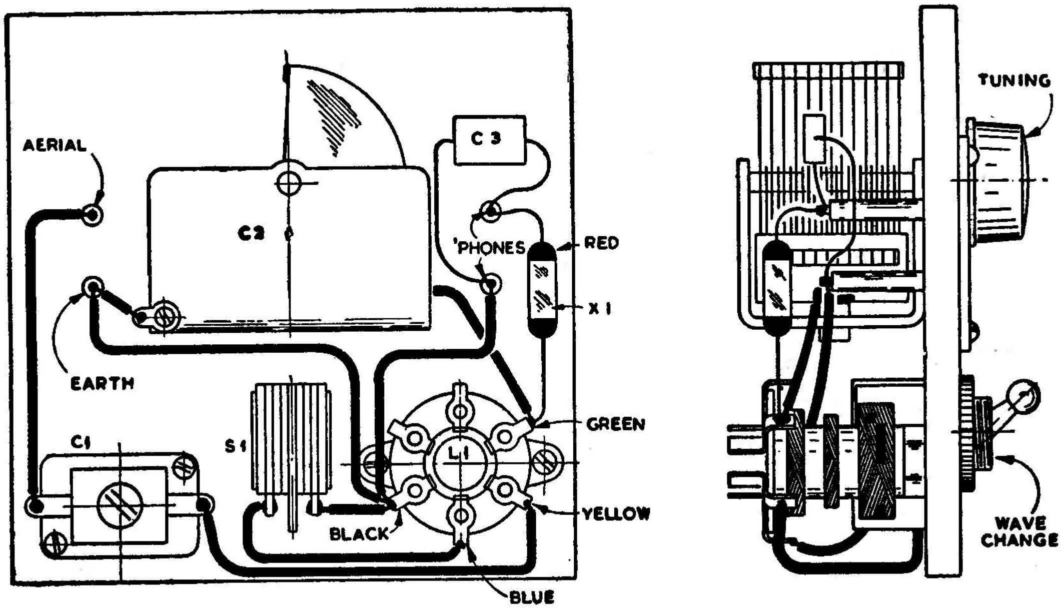

FIG. 17b

3

The design shown in Fig. 18a and 18b is more flexible than either of the preceding sets. That is, it can be varied to suit local conditions to a greater extent than the first two sets. This is made possible by the large number of taps provided on the coil.

You will notice that in this instance the coil is home-constructed on a cardboard former and is much larger than commercially produced coils. Coils wound in this manner are called **solenoids**, the turns are wound on side by side; in this case to a depth of some three inches. The diameter of the coil is made purposely large so as to obtain high efficiency. Modern commercial coils are invariably wave-wound and quite often are litzendraht which is the German for litz wire. This wire is made up of a number of strands of fine copper wire, each strand is enamelled to insulate it from the others, the whole is then silk covered. Litzendraht is more efficient than solid copper wire, and by using this and wave-winding, manufacturers can produce an efficient coil which is also small. Unfortunately wave-wound coils cannot be produced without a complex winding machine and home-constructed coils must take the solenoid form. It would be possible to use litzendraht but it is not easy to obtain by the reel, it is most expensive, and is difficult to handle. This last point is because at termination points, each strand must be cleaned of its enamel before a joint is made, and if one strand is broken, its advantage over plain copper wire is lost. How-

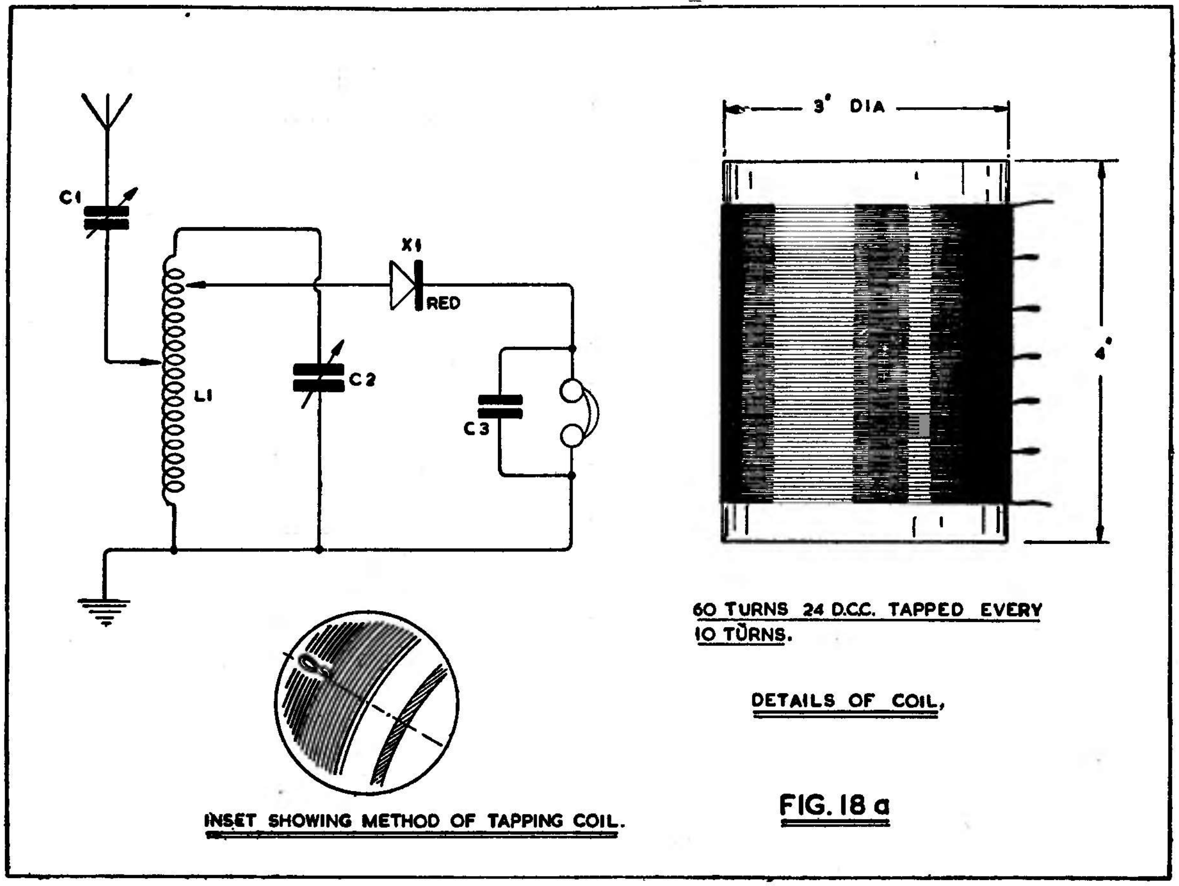

60 TURNS 24 D.C.C. TAPPED EVERY 10 TURNS.

DETAILS OF COIL,

INSET SHOWING METHOD OF TAPPING COIL.

FIG. 18 a

ever, by using a former of reasonably large dimensions an efficient coil can be produced cheaply using ordinary copper wire.

The wire must be firmly secured at the start and finish of the windings. Pierce three small holes about ¼" apart ½" from the end of the former. Pass the wire through the first from the outside, return it through the second and pass it back again through the third. Leave some 6" of wire at the end to make off the connection. It will now be possible to wind the turns on tightly without wire slipping.

Count on ten turns and make a loop 1" long. The method of preparing loops is shown in Fig. 18a, loops or taps should always be made in this manner, never by baring the wire and soldering a further length of wire to it. Carry on with the winding, making off the taps every ten turns as directed until the coil is complete.

Construction is carried out on a wooden base-board and front panel. Secure the coil to the base-board as shown on Fig. 18b, mount the remaining components and proceed with the wiring.

When testing out, it will be found that the further the aerial is tapped down the coil towards the earth end, the greater the selectivity. A position should be found which permits separation of local stations without excessive loss of sensitivity.

The crystal tap is adjusted for best results and different settings of C1 tried out, when choosing the best position for the aerial tap.

Components List, Fig. 18a

C1	450pF padder.
C2	500pF variable capacitor.
C3	1000pF mica capacitor.
L1	See text and Fig. 18a.
X1	Germanium Crystal.
2	Crocodile Clips (to connect leads to coil taps).
4	Wander-plugs and sockets.

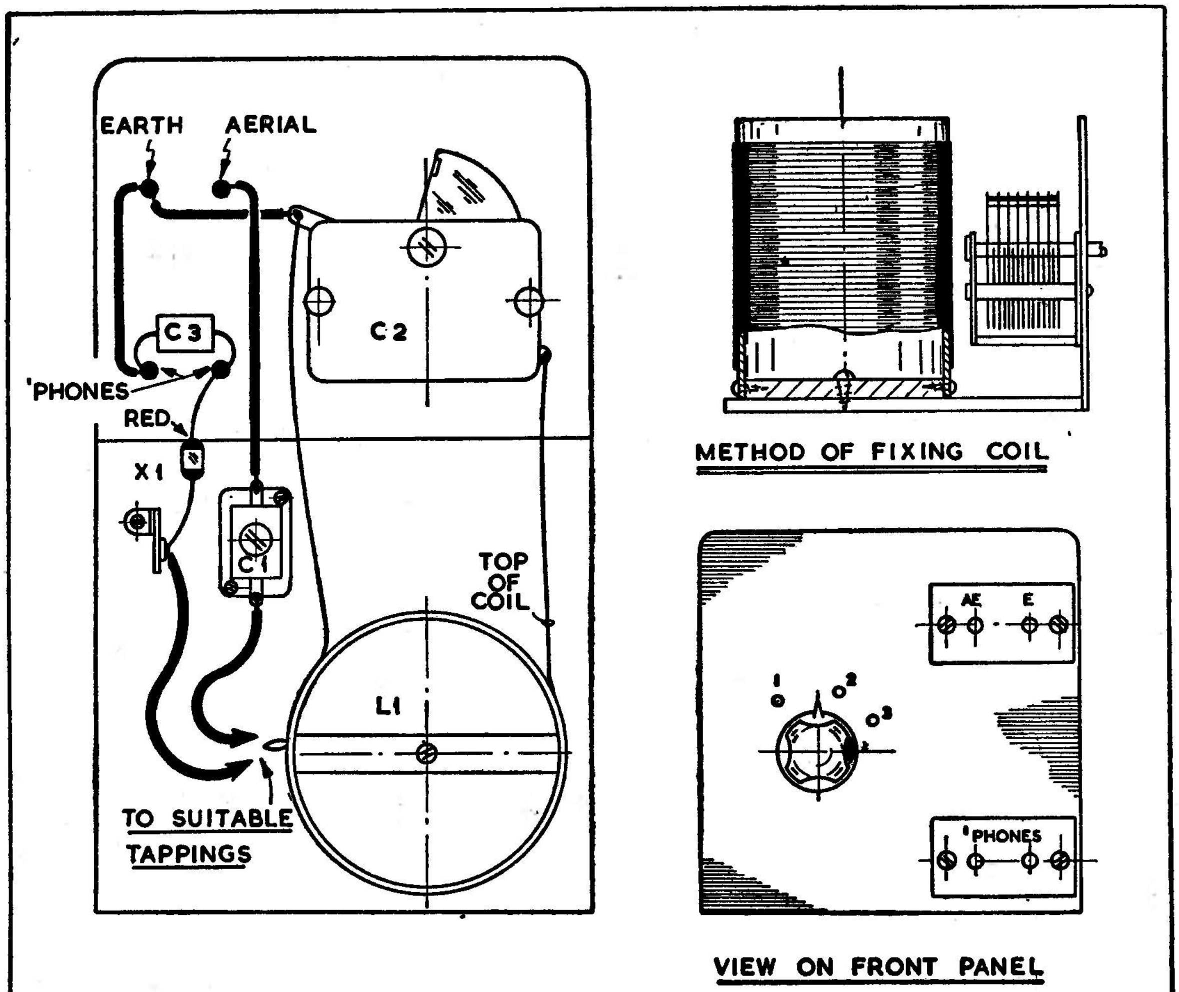

FIG. 18 b

4

A most unusual design is reproduced in Fig. 19a.

It first appeared in America about three years ago, and it certainly does offer some advantage over more conventional sets. The tuning circuits are duplicated and two crystals are used, so the circuit may be described as a full-wave receiver. Signals received will certainly be louder than with simple sets, but care must be taken with the coil winding, as with the other receivers using home-made coils, otherwise results will be disappointing. Be very careful to ensure that all three windings are in the same direction, this is very important.

The distance between each winding should be ¼". After the coil has been wound it is a good plan to warm it before a fire and paint the windings with "Durafix." Heating the coils makes the "Durafix" run freely. This substance sets quite hard and there will be no risk of the windings loosening. A small quantity of enamelled wire will cover the requirements of this coil, a 2 oz. reel will provide more than sufficient.

Before wiring in the germanium crystals, examine them carefully, note that one end is coloured red or in some cases marked with a positive sign thus +. You will notice, the sign is the same as the addition symbol used in arithmetic.

It is essential that both the red or positive ends are connected together, note that this is clearly marked on Fig. 19b. The receiver cannot work if

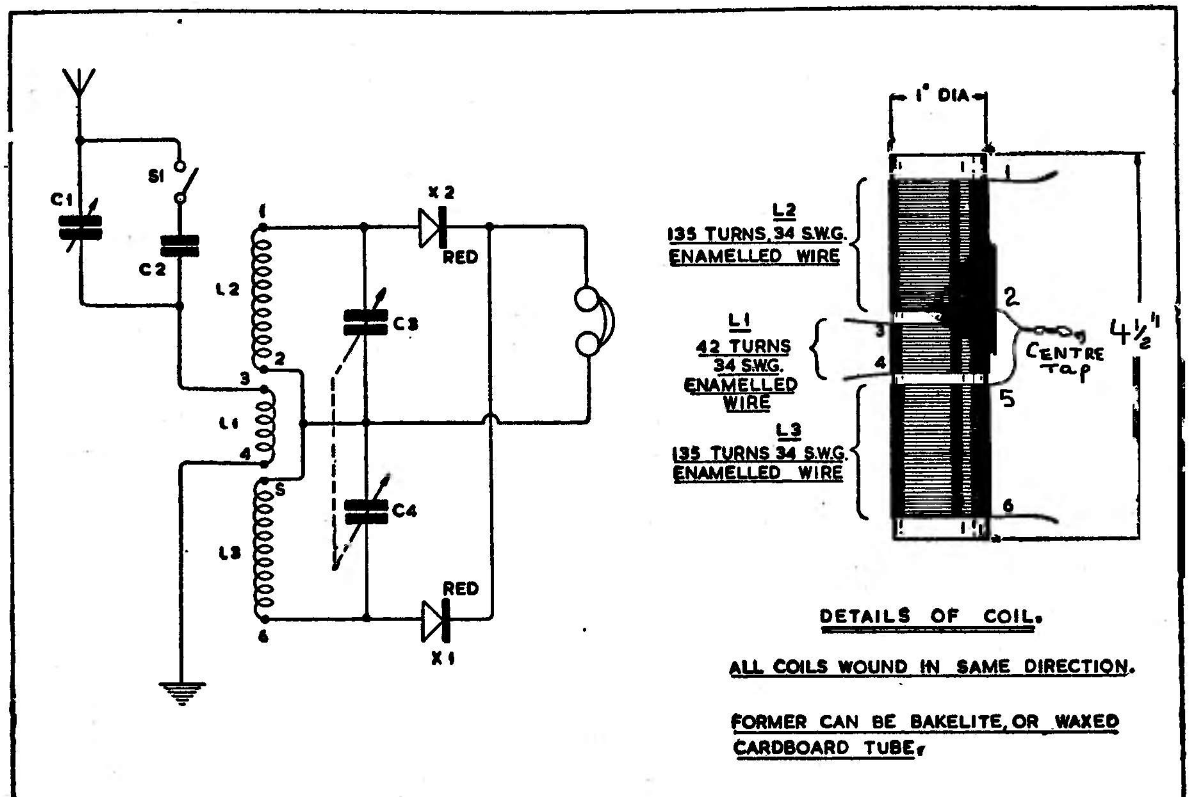
C1
S1
C2
L2
L1
L3
1
2
3
4
5
6
X2
RED
C3
C4
RED
X1
1" DIA
L2
135 TURNS 34 S.W.G.
ENAMELLED WIRE
L1
42 TURNS
34 S.W.G.
ENAMELLED
WIRE
L3
135 TURNS 34 S.W.G.
ENAMELLED WIRE
CENTRE
Tap
4½"
DETAILS OF COIL.
ALL COILS WOUND IN SAME DIRECTION.
FORMER CAN BE BAKELITE, OR WAXED
CARDBOARD TUBE.

FIG. 19a

one of the crystals is connected the reverse way round.

A baseboard and panel form of assembly is used for this set which looks quite attractive if housed in a small polished cabinet. Dimensions are not at all critical but Fig. 19b gives a general idea of the layout that should be used. To avoid any unnecessary losses the coil should be mounted on perspex.

Obtain two strips of perspex 5½" long by ½" wide, drill fixing holes at both ends of each strip. It is best to clamp the two together when drilling these holes. Place one strip on the board in position, then put the coil and remaining strip over the first one and screw down. The coil will be clamped neatly and rigidly into position.

Twin socket bakelite strips are used to carry the aerial/earth and 'phone connections, if desired terminals mounted on pieces of bakelite could be used. These socket strips can be purchased from most shops selling components. If feet are not provided, drill two holes and screw into the edge of the base-board. Tag-strips are used to anchor some of the wires from the coil, and the germanium crystals. These also can be purchased for a few pence. At least two tags are necessary on one, and three on the other, though if the strips have more tags than required it is of no consequence. C3-C4, the ganged tuning capacitors have trimmers fitted, this should be stipulated when purchasing, and when first operating the set these small trimming capacitances are set about half-way. The idea of these trimmers is, that they compensate for any difference between the self-capacity of the tuning coils. With the switch S.1 open, that is in the OFF position, turn

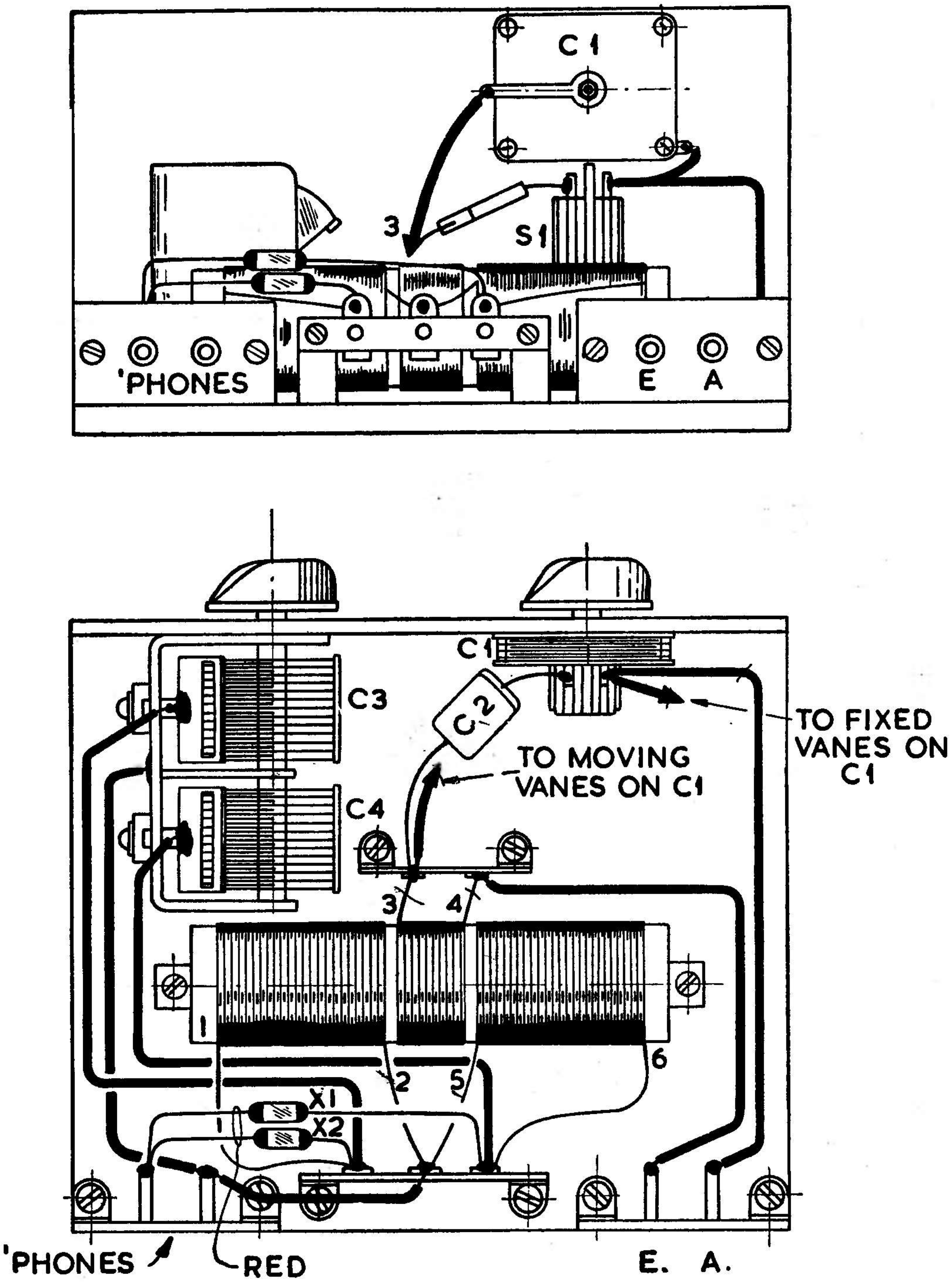
C1
3
S1
'PHONES
E
A
C3
C4
C1
C2
TO FIXED VANES ON C1
TO MOVING VANES ON C1
3
4
1
2
5
6
X1
X2
1
'PHONES
RED
E.
A.

FIG. 19 b

in a station at the high-frequency end of the band, that is with the vanes of C3-C4 towards the disengaged position. Adjust C1 for maximum volume, without interference from other stations. Now adjust the trimmers for loudest headphone strength. It may be necessary to run over the adjustments several times for best results. Once they are correctly set, the trimmers require no further adjustment. The tuning coil covers the M.W. band, 1500 kc/s. to 600 kc/s., as the capacitor C3-C4 is advanced and the vanes start to mesh, the frequency to which the receiver tunes **decreases** so that with the vanes disengaged the set is tuned to 1500 kc/s. approximately and at full mesh, 600 kc/s. Switch S1 is used as follows, for stations **lower** in frequency than 850 kc/s it should be in the ON position with the contact closed, but for stations **higher** in frequency, it is in the OFF position. As an example both the London Home Service and London Light Programme transmitters on the M.W. band operate at a higher frequency than 850 kc/s. If any doubt exists as to the operating frequency of a given station, reference should be made to the Radio Times which quotes both wave-lengths and frequency. If you know the wave-length in metres, it is simple to find the frequency. Divide 300,000 by the wave-length in metres, the dividend equals the frequency in kilocycles, i.e., 300,000 ÷ 300 metres = 1,000 kc/s. In the same way, dividing 300,000 by the frequency in kilocycles will produce the wave-length in metres.

To use the receiver, tune in the signal by C3-C4, adjust C1 for maximum volume without allowing stations to overlap.

Components List, Fig. 19a

C1	300pF solid dielectric variable capacitor.
C2	1000pF mica capacitor.
C3-4	500pF twin gang variable capacitor.
L1-2-3	See text and Fig. 19a.
X1-2	Germanium Crystal.
2	Tag-strips.
2	Twin socket strips.
S1	Single Pole toggle switch.

5

Whenever crystal sets are discussed, constructors are apt to think in terms of medium-wave reception. When you consider that at least 98% of published circuits are designed for this band (sometimes with the long-wave band thrown in as an afterthought) it is understandable. However, if you can provide a good outdoor aerial (and an equally good earth) there is a lot of fun to be had listening to the short-wave bands. This receiver is designed specially for short-wave reception.

A metal chassis is used for construction, these can be obtained ready made in aluminium from most good supply houses. It can be quite small and on the original model a 6" x 4" was used. Low loss components are used so as to obtain greatest efficiency on the short wave bands. The coil is a commercial product which plugs into a 4-pin base. Best results were obtained on the 3mc/s to 7mc/s band though coils covering other bands are available.

Note that the tuning capacitor C1 is smaller than normally used and has a maximum capacitance of 140pF.

Coil type 706/R covers the 3mc/s to 7mc/s band, but the set is equally satisfactory on the M.W. band, and to cover this coil type 706P should be used. This coil has an iron dustcore which can be adjusted to make the coil cover the required band. The effect of the core is as if turns were being added or removed from an ordinary coil. When dealing with the short waves it is customary to refer to the frequencies in terms of mega-cycles (mc/s) rather than kilo-cycles. One mega-cycle is equivalent to 1000 kilo-cycles, that is 1,000,000 cycles.

Layout and wiring can be clearly followed from Fig. 20b and a theoretical diagram is shown in Fig. 20a. Care should be taken when arranging a mounting for the aerial terminal. The best plan is to cut a 1" hole in the chassis, mount the aerial terminal on a piece of perspex and screw into the chassis. This avoids any unnecessary losses between aerial and chassis. The earth terminal is screwed directly into the chassis.

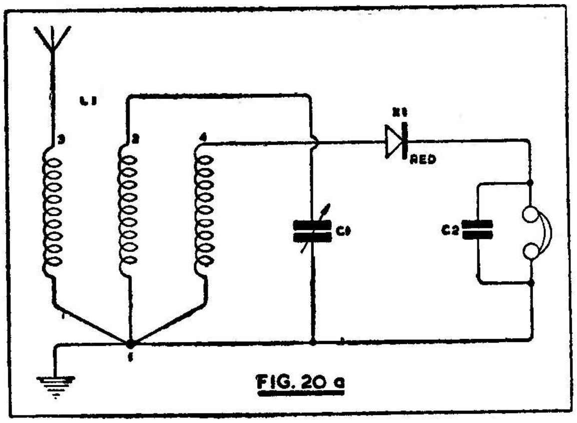

FIG. 20 a

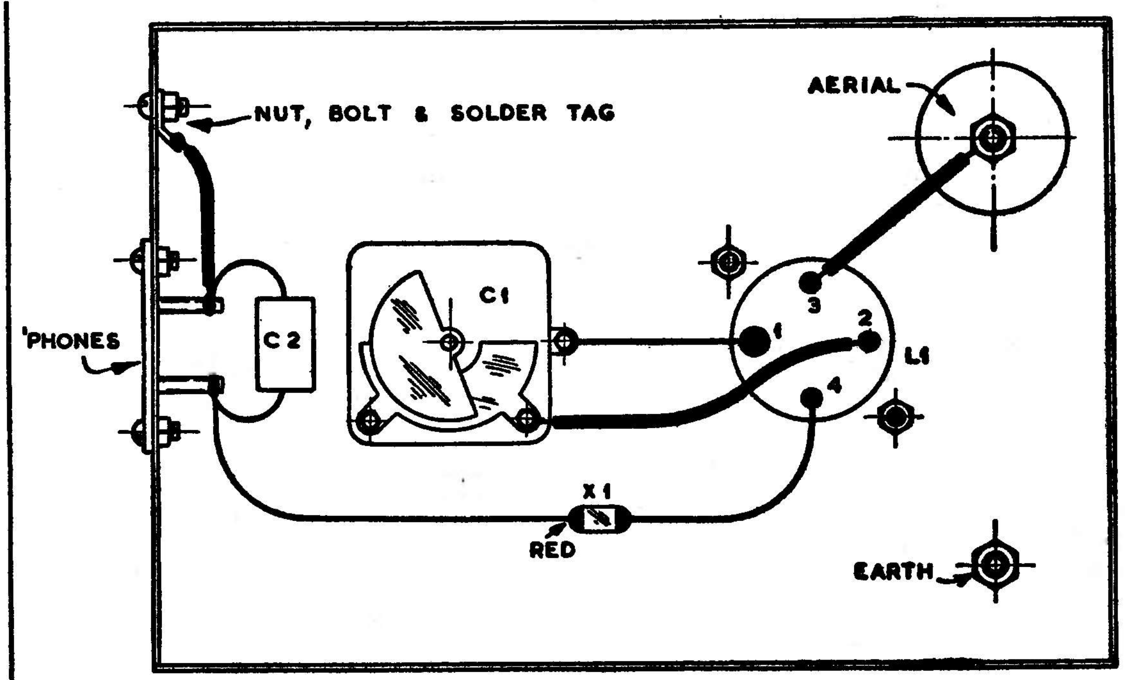

FIG. 20 b

Wiring as shown in Fig. 20a is likely to give the best results, but other arrangements are possible and to get the best out of the set they should be tried.

Refer to Fig. 20a. The aerial is connected to pin 3 on L1, C1 to pin 2 and X1 the crystal to pin 4. If you have a long aerial try this combination—Aerial to pin 4, C1 to pin 2, and the crystal to pin 3. Connections to pin 1 are not altered. In a few cases the following arrangement may prove best. Crystal and C1 to pin 2, aerial to pin 3, pin 4 left free and again pin 1 is unaltered.

Tuning on the short-wave bands is more critical than on the medium waves so tune very slowly over the band and remember signal strength is likely to vary from day to day.

Components List, Fig. 20a

C1	140pF variable capacitor Eddystone 586.
C2	1000pF mica capacitor.
1	Coil holder Eddystone 707.
L1	3m/c—7m/c coil Eddystone 706/R.
1	Engraved tuning dial.
1	6"x4"x2½" chassis.
2	Terminals (Aerial-Earth).
1	Twin socket strip ('phones).
X1	Germanium Crystal.

6

Fig. 21a-b is yet another design from America and appeared in Radio Craft some years ago, designed by Mr. W. J. Spain. The original used a silicon crystal which preceded the development of the germanium. Results are certainly very good though of course on the model built here, a germanium crystal was used. Selectivity can be adjusted to suit all conditions and even at short distances from local stations. Good volume can be obtained without the programmes overlapping. Home made coils are used and for best results a 75′ outdoor aerial is desirable.

Baseboard and panel construction is used, which can conveniently be housed in a small wooden cabinet.

Operation is a little more complicated than some of the other designs, but the results certainly merit the extra trouble taken. As with the other receivers much of the success obtainable is due to the coils and these must be carefully made otherwise results will be disappointing.

Layout and wiring can be followed quite easily from Fig. 21b and requires no special comment.

First make the coils. L1 is a tapped coil, the taps should be made in the same way as shown in Fig. 18b. It consists of 90 turns of 22 D.C.C. (double cotton covered) copper wire tapped at the following number of turns, 5, 10, 15, 25, 30, 40, 50, 60, 70 and 80. The former used has a diameter of 2". L2 is also wound on a 2" diameter former, this coil however is not tapped, it consists of 110 turns of 38 D.C.C. or enamelled copper wire. Great care must be taken when handling this wire, it is quite fine and in the hands of the inexperienced will easily break.

After wiring has been carried out the set can be put into operation.

Selectivity is controlled by S2, in position B tuning is broad but in position A it can be quite sharp.

When searching for a station switch S2 to B. Tune the station and switch S2 to A. The frequency range is controlled by the position of the tap on L1, a good plan is to start with the 5 turn tap on L1.

Components List, Fig. 21a

C1	500pF variable capacitor.
C2	500pF variable capacitor.
C3	1000pF Mica Capacitor.
X1	Germanium Crystal.
L1 & L2	See text.
S1	Single Pole toggle switch.
S2	Single Pole 2-way toggle switch.
2	Twin socket strips (Aerial/Earth and 'Phones).

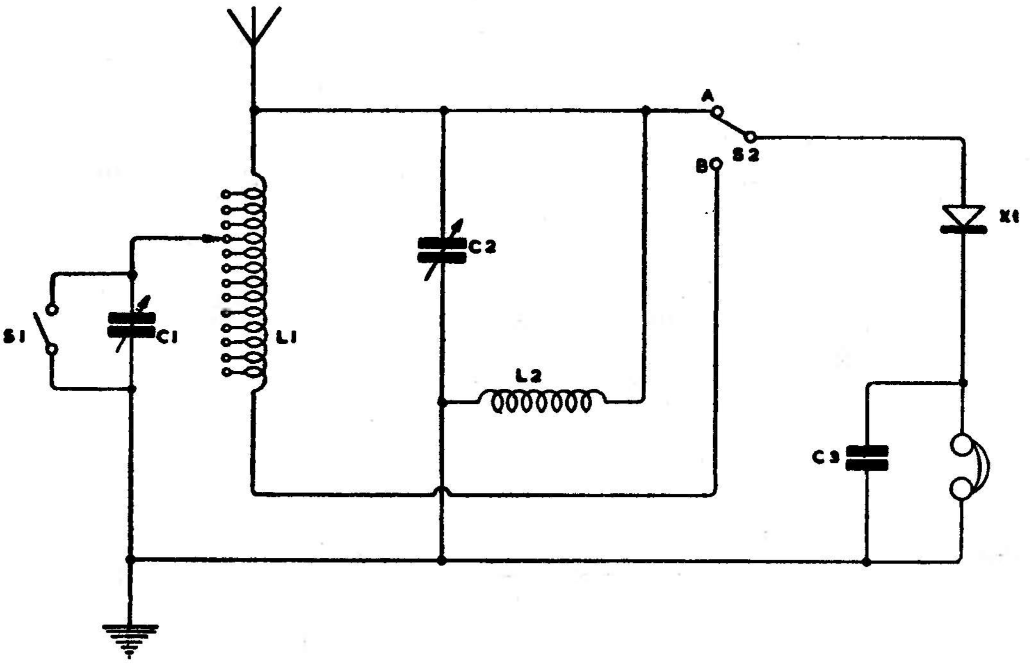

FIG. 21 a

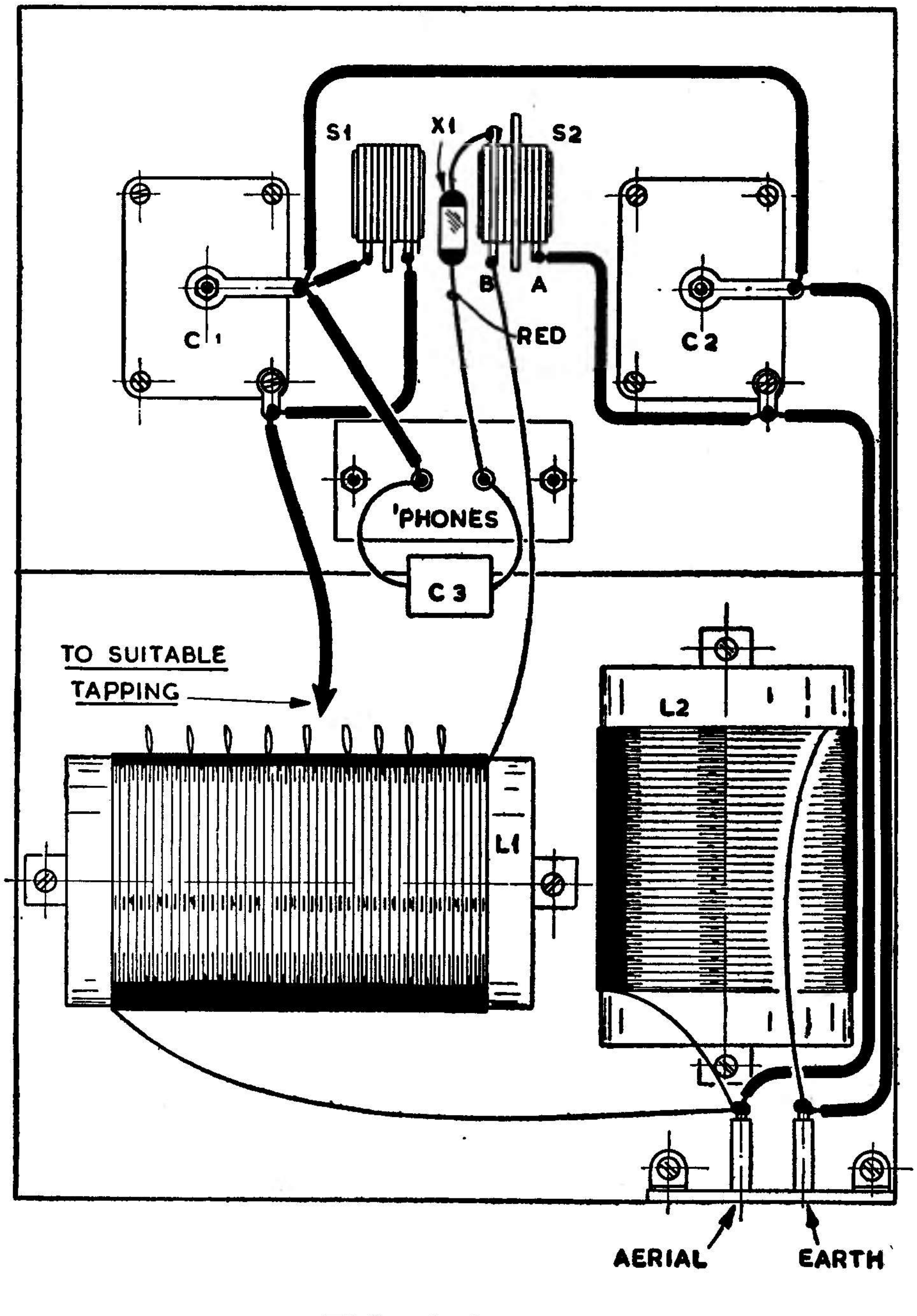
S1
X1
S2
B
A
RED
C 1
C 2
'PHONES
C 3
TO SUITABLE TAPPING
L2
L1
AERIAL
EARTH

FIG. 21 b

Keep S1 open and C1 for tuning, adjusting the tap on L1 for best results. Very powerful signals are best brought in with S1 closed. When using C1 and adjusting the taps on L1, switch S2 is kept in the A position.

It will be found that C2 acts as a fine control on C1. One division of the tuning dial on C1 is roughly equal to a movement of 20 divisions on C2.

Note that the coils are mounted at right angles to one another and that in this instance wood has been used as far as possible, an aluminium or other metal chassis is not suitable.

7

A very useful receiver for both medium and long-wave reception is possible with the circuit of Fig. 22a-b. A home-made coil is used. On the original a 1¼″ diameter former was used but in fact this is not very critical and a 1½″ former could be used. An interesting point is the construction of the long-wave coil section. Solenoid coils as used for the medium wave-band are not efficient if the length is too great relative to the diameter. Now as the long-wave section has 300 turns, if wound as a solenoid the winding length would be very great and a lot of efficiency would be lost. To overcome the difficulty the coil is pile wound. If the whole coil were to be wound in one pile it would still be inefficient because of the capacity formed in the winding, but by dividing it into five sections a coil of reasonable efficiency results. The same remarks concerning winding apply to this coil as to all the others in

Components List, Fig. 22a

C1	300pF Mica Capacitor.
C2	500pF Variable Capacitor.
C3	1000 Mica Capacitor.
X1	Germanium Crystal.
L1-2	See Text.
S1	Single Pole Toggle Switch.

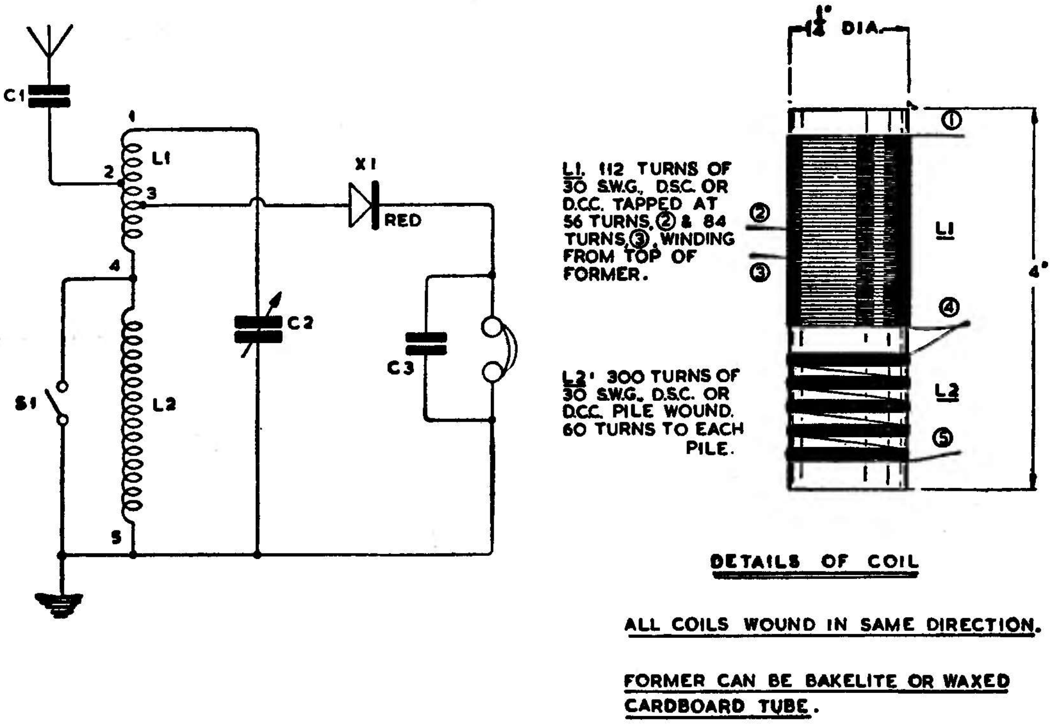
C1
1
2
3
4
5
L1
L2
X1
RED
C2
C3
S1
1¼" DIA.
①
②
③
④
⑤
L1
L2
4"
L1. 112 TURNS OF 30 S.W.G., D.S.C. OR D.C.C. TAPPED AT 56 TURNS ② & 84 TURNS ③, WINDING FROM TOP OF FORMER.
L2· 300 TURNS OF 30 S.W.G. D.S.C. OR D.C.C. PILE WOUND. 60 TURNS TO EACH PILE.
DETAILS OF COIL
ALL COILS WOUND IN SAME DIRECTION.
FORMER CAN BE BAKELITE OR WAXED CARDBOARD TUBE.

FIG. 22a

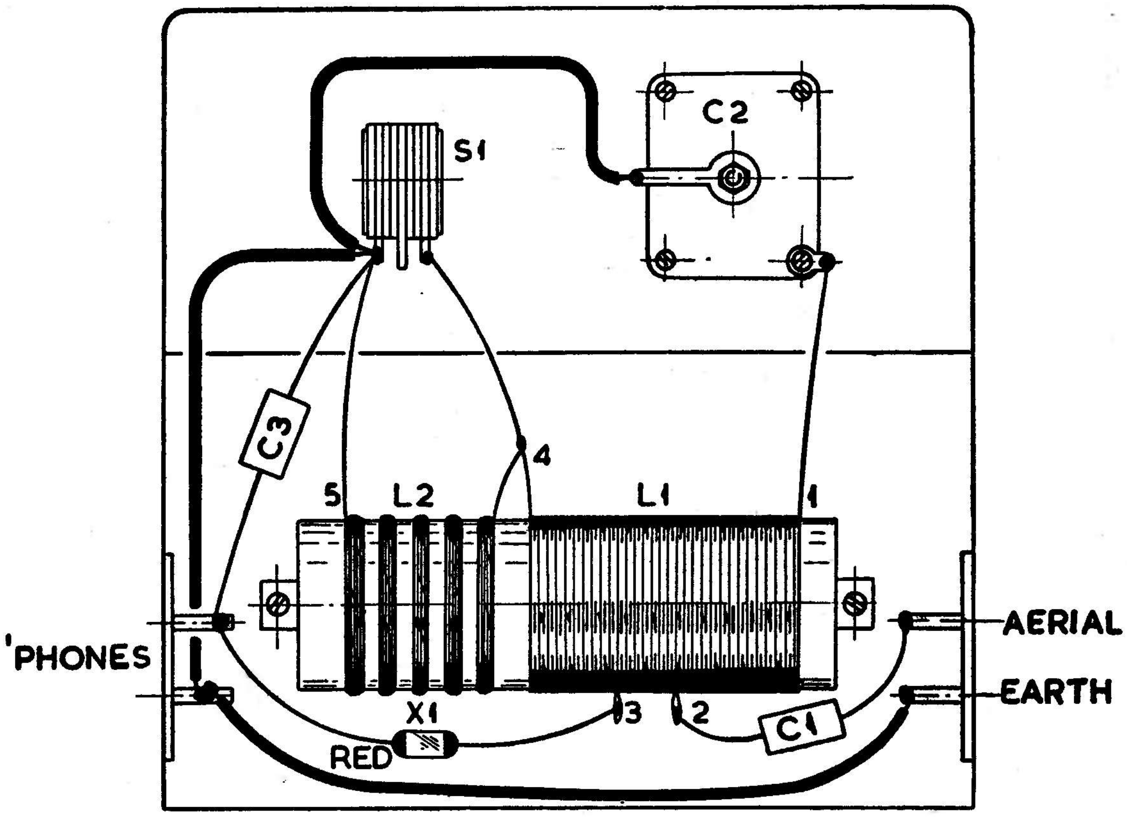

FIG. 22 b

this book, and readers should not, by this time, encounter any difficulties.

The design provides good selectivity with good sensitivity, and provided the set is not required to operate within a few miles of a powerful transmitter, no trouble will be encountered from interference between adjacent stations.

A wooden base-board and front panel is best for this design, and the wiring and layout can be clearly followed from Fig. 22b. Switch S1 is open for long-wave reception and closed for the medium-wave band.

Coil mounting can be on the same principle as for the full-wave design Fig. 19a-b.

8

If you look at all the other circuits shown in this book you will find that in each case the tuning capacitor and tuning coil are in parallel, this is by no means essential and the circuit of Fig. 23a shows a series arrangement that is the tuning capacitor is between the coil and earth instead of being wired up across it. This design also appeared in **Radio Craft** a few years ago.

An interesting point is that the coil is a conversion adapted from another type of component. To make this coil you must obtain an old I.F. transformer as used in superheterodyne receivers.

You will require one designed to work anywhere between 450 and 470 kc/s. Some of the very early ones worked at 110 kcs/ but these are unsuitable.

The I.F. transformer must also be of the type tuned by an iron dust core at each end.

Dismantle the transformer, remove the parallel capacitors and mounting wires so that you are left with two coil bobbins and their former. Be very careful when un-soldering the wires from the supports because the coils are usually wound in litzendraht and must remain intact. Remove 25% (approximately) of the turns from one coil which we will call the secondary, and completely remove the iron dust slug from this coil, now cut the former in half, and mount as in Fig. 23a. Warm the coils with heat from your soldering iron or from a fire and gently slide the coils into position at the ends of the former as in Fig. 23a. The wax will set again holding the coils in their new position.

Note that the wires from the coils are connected to tags on the mountings. These are pieces of bakelite, and usually the original end pieces used on the I.F. transformer can be used.

A word about soldering litzendraht. Do not attempt to use emery paper. Prepare the end of wire by removing the outer silk covering and dip the end in methylated spirits. Ignite with a match and after about five seconds wipe with a cloth held between finger and thumb. This will quench the flame and will remove all traces of enamel from the wire. It is a good plan to experiment with the odd length of wire removed from the secondary coil. If the coils prove to be constructed of ordinary copper wire, it can of course be prepared with fine emery cloth in the normal manner.

Components List, Fig. 23a

C1	500pF variable capacitor.
X1	Germanium Crystal.
L1	See Text.
4	Plugs and sockets or terminals.

Wiring is straight forward as can be seen from Fig. 23b and requires no explanation.

Operation is as follows, selectivity is controlled by varying the distance between coils with the wing nut, and to an extent by the position of the primary iron dust core. Remember that the aerial and earth installations are as important with this set as with any other crystal receiver. No parallel capacitance appears necessary across the 'phones, the set works quite happily relying on the self-capacitance of the head-phones.

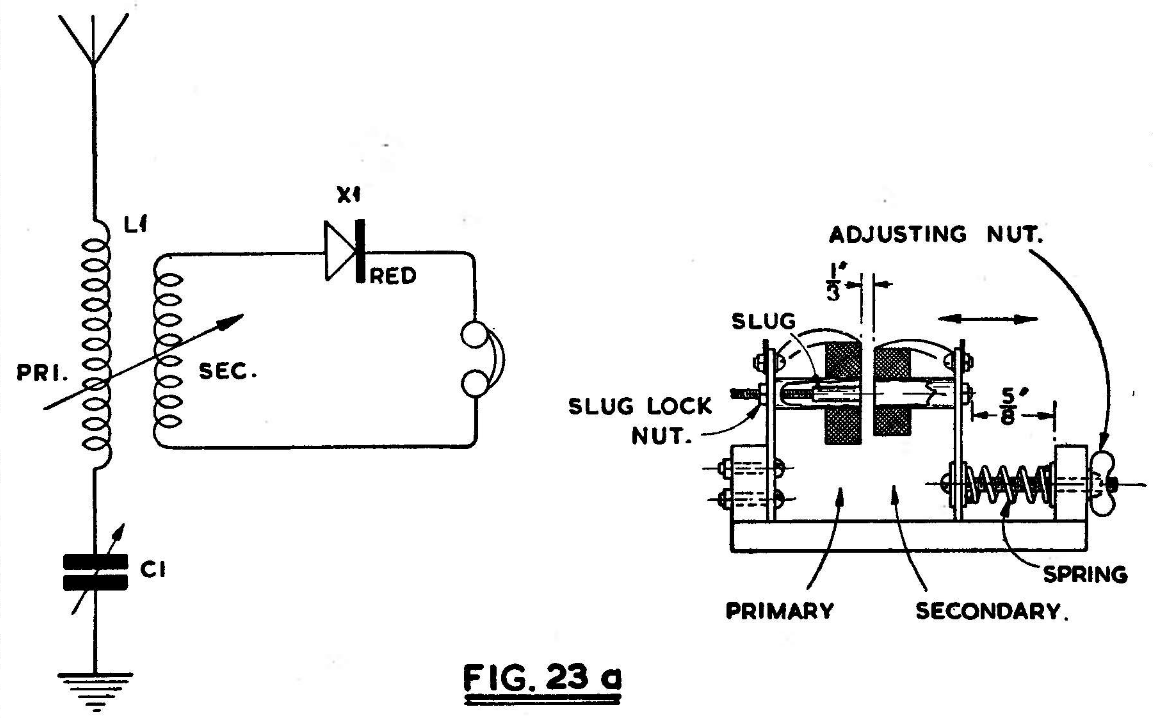

FIG. 23 a

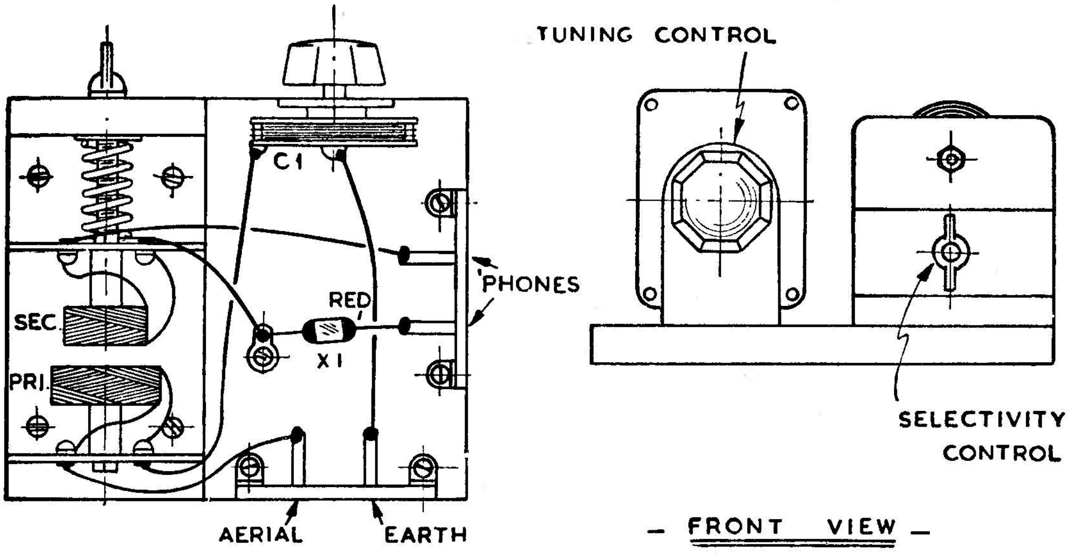
TUNING CONTROL
C1
SEC.
PRI.
RED
X1
PHONES
AERIAL
EARTH
SELECTIVITY CONTROL
— FRONT VIEW —

FIG. 23 b

9

So as to give a truly varied selection of circuits, some of the sets have been designed around commercial coils whilst others use coils which must be home-constructed.

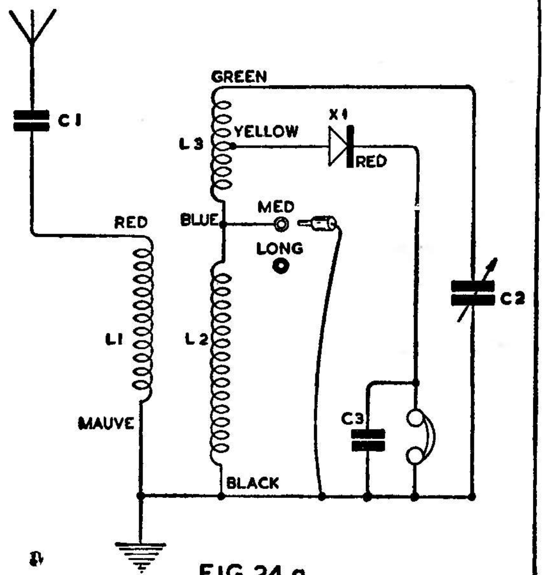
C1
GREEN
X1
YELLOW
L3
RED
RED
BLUE
MED
LONG
C2
L1
L2
C3
MAUVE
BLACK

FIG. 24 a

Most enthusiasts like to build their own coils but when it is a question of something really small combined with efficiency a commercial coil is the obvious choice.

Fig. 24a-b uses a tobacco tin or a similar container just as the design shown in Fig. 16a.

This receiver however is a little more selective and is more suitable than the earlier design, if you are near a transmitter or have a very long aerial. Take great care to connect the coil according to the colours shown on the diagrams. Sockets are used for wave-changing, this cheapens the cost a little and they are just as efficient.

Components List, Fig. 24a

C1	100pF Mica capacitor.
C2	500pF variable capacitor solid dielectric.
C3	1000pF Mica capacitor.
X1	Germanium crystal.
L1-2	R.E.P. dual range coil. Blue box.
6	Insulated wander-plug sockets.
5	Wander Plugs.
2oz.	Tobacco tin or similar container.

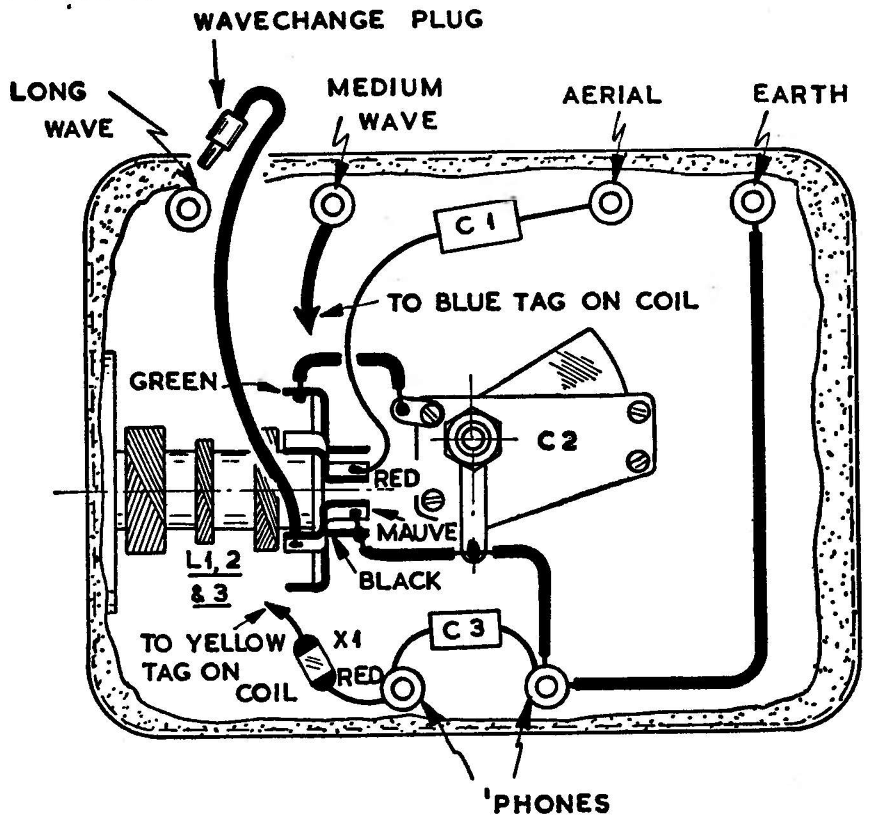

LID SHOWN BROKEN AWAY TO REVEAL POSITION OF COMPONENTS.

FIG. 24 b

10

In certain cases, signals from the local transmitter are too powerful to permit a crystal set with a normal coil to be of much use. I myself live in Hertfordshire a few miles from the London transmitters, and find a more elaborate circuit is necessary. Now in radio circles it is a well-known fact that the greater the number of tuned circuits, the greater the overall selectivity. Look at Fig. 25a, you will see that the usual L and C tuning arrangements have been duplicated. This type of circuit is known as a Band-Pass Filter. There are many kinds of such filters, this particular type is an inductively-coupled filter, note that energy from the first half (L2) is conveyed to L3 by way of two small inductors L1 and L4.

Tuning is quite sharp and the "feel" of the set is quite different from that of single coil designs. A small chassis is ideal for construction. 6"x4"x2½" was used on the original, though it could have been smaller.

Fig. 25b gives the layout and wiring.

Take particular notice that L1-2-3 is mounted horizontally and at right angles to L4-5-6, this is to prevent the coupling from being too "tight" which would ruin the idea of the filter. A good aerial and earth is of course necessary. It may be found on test that the selectivity is too great

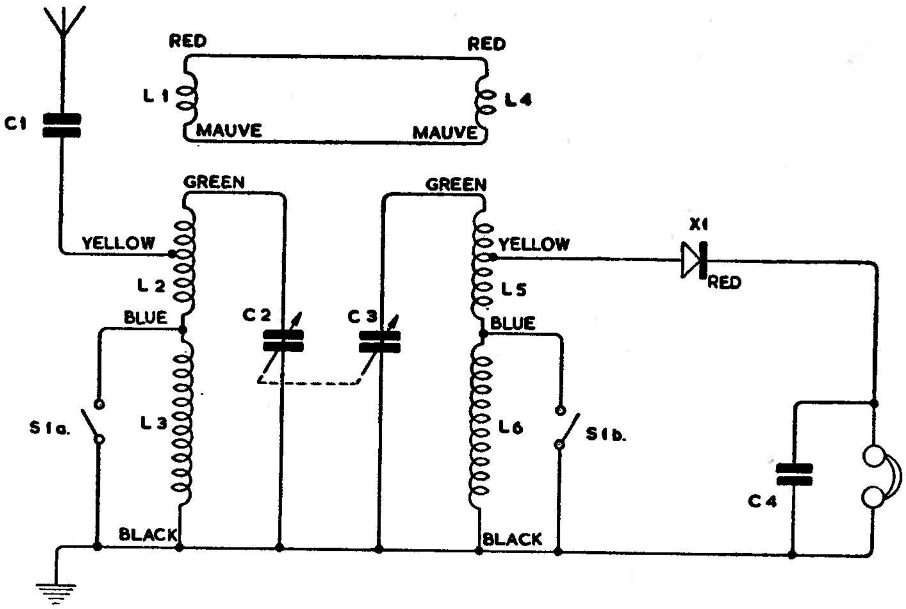

FIG. 25 a.

and that volume has suffered. This can be ingeniously overcome by connecting a very small capacitance between the two Green tags on the coils. The simplest way is to connect it across the fixed vane connections on C2-C3. Values for this extra capacitance are a matter for experiment usually a value between 10pF and 47pF is sufficient. A small 50pF trimmer could be used and adjusted to suit. The ideal setting is to enable powerful adjacent stations to be received just short of overlap so that as much volume as possible is obtained.

There is one point to be observed with the ganged capacitor. It should be of the type fitted with trimmers though of course, there is no reason why you should not fit them yourself. These are to allow for differences between coils to be balanced out, and consist of a small variable capacitance across each main section.

When setting up the receiver, first set each trimmer at half way and tune in a station near the high-frequency end of the band (vanes nearly out) adjust the trimmers for maximum volume. If extra coupling capacity is added as described, try adjusting them further.

Once properly set up, no further adjustment is necessary.

Components List, Fig. 25a

C1	100pF Mica capacitor.
C2-3	2 x 500pF variable capacitor (see text).
C4	1000pF Mica capacitor.
L1-2-3	Dual Range Coil R.E.P. (Blue Box).
L4-5-6	Dual Range Coil R.E.P. (Blue Box).
X1	Germanium Crystal.
S1a-b	2 pole single throw toggle switch.
4	Terminals or plugs and sockets.

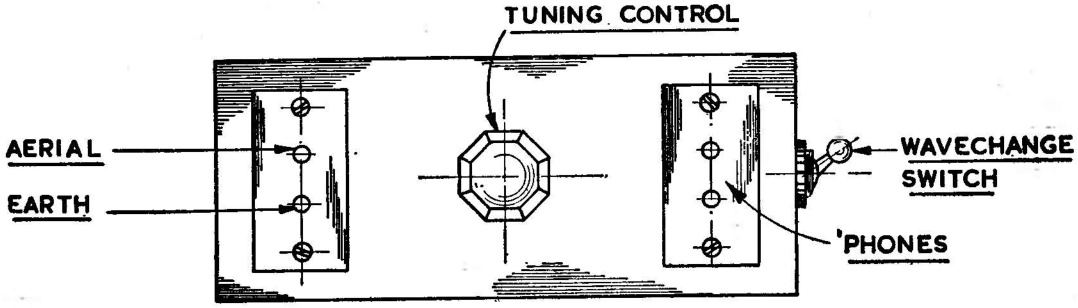
TUNING CONTROL
AERIAL
EARTH
WAVECHANGE SWITCH
'PHONES

FRONT OF COMPLETED RECEIVER.

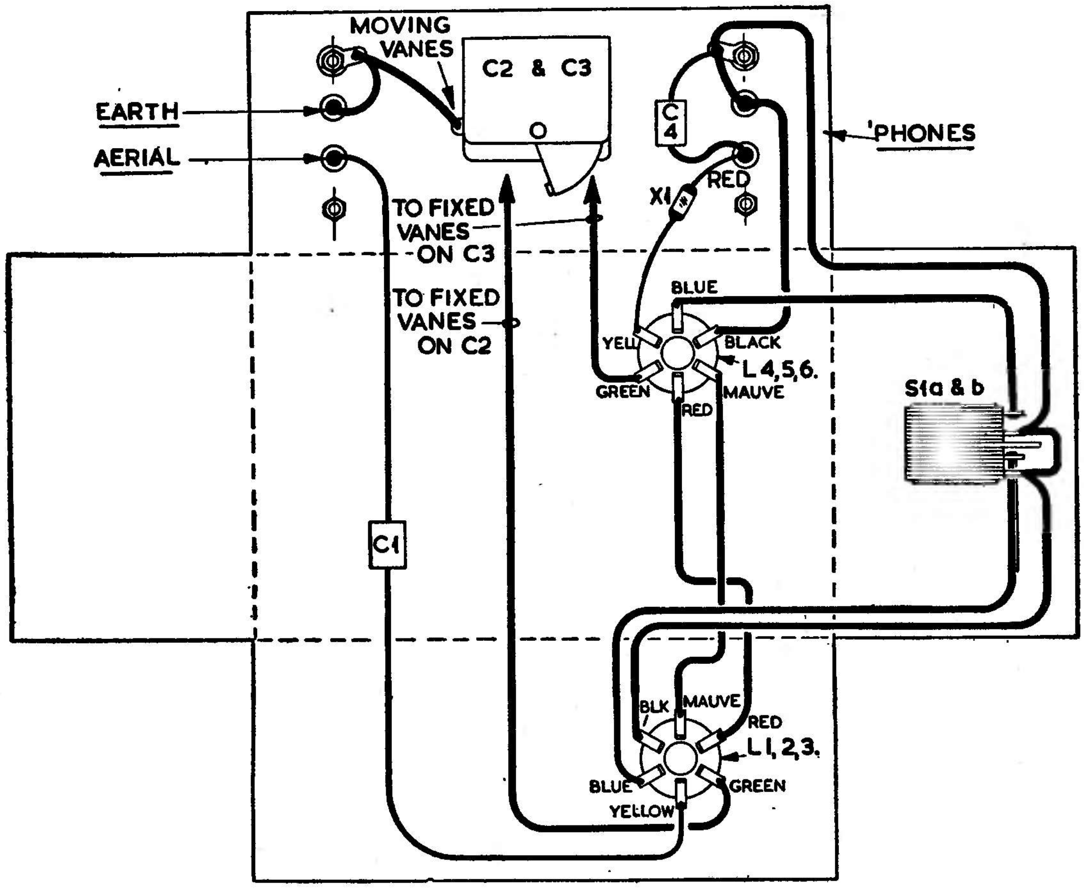
MOVING VANES
C2 & C3
EARTH
AERIAL
C4
'PHONES
X1
RED
TO FIXED VANES ON C3
TO FIXED VANES ON C2
BLUE
YEL
BLACK
L 4,5,6.
GREEN
RED
MAUVE
S1a & b
C1
BLK
MAUVE
RED
L1,2,3.
BLUE
YELLOW
GREEN

EXPLODED UNDER-CHASSIS VIEW

FIG. 25 b

11

Another band-pass circuit is shown in Fig. 26a. This time home-made coils are used. This filter is not inductively coupled but entirely capacitive, relying on C3. As in the previous circuit it must be adjusted to give just sufficient " broadness " to the tuning to provide adequate volume without station overlap. To avoid unwanted coupling a screen is mounted between the coils, this is necessary because due to the size of the coils they would be bound to couple quite tightly without it. Such precautions were not necessary with the circuit of Fig. 25a, as the commercial coils are much smaller physically and the risk of unwanted coupling reduced.

The coils for this receiver are for medium wave reception only, this keeps the size down. Coil winding procedure has already been fully explained, and covers all the requirements of these coils. Base-board and panel construction is used, and for more accurate tuning since the coils are home-made, separate tuning capacitors are recommended. Fig. 26b gives the layout and practical wiring.

Components List, Fig. 26a

C1	100pF Mica capacitor.
C2	500pF variable capacitor.
C3	50pF Mica trimmer.
C4	500pF variable capacitor.
C5	1000pF mica capacitor.
L1-2	See text.
X1	Germanium Crystal.
4	Terminals or plugs and sockets.

For those who do not wish to bother with these a ganged capacitor can be used, but tuning may not be as good as with separate ones. The screen mounted between the coils is of aluminium or copper and should be about 1″ higher than the coils and the same length as the baseboard depth.

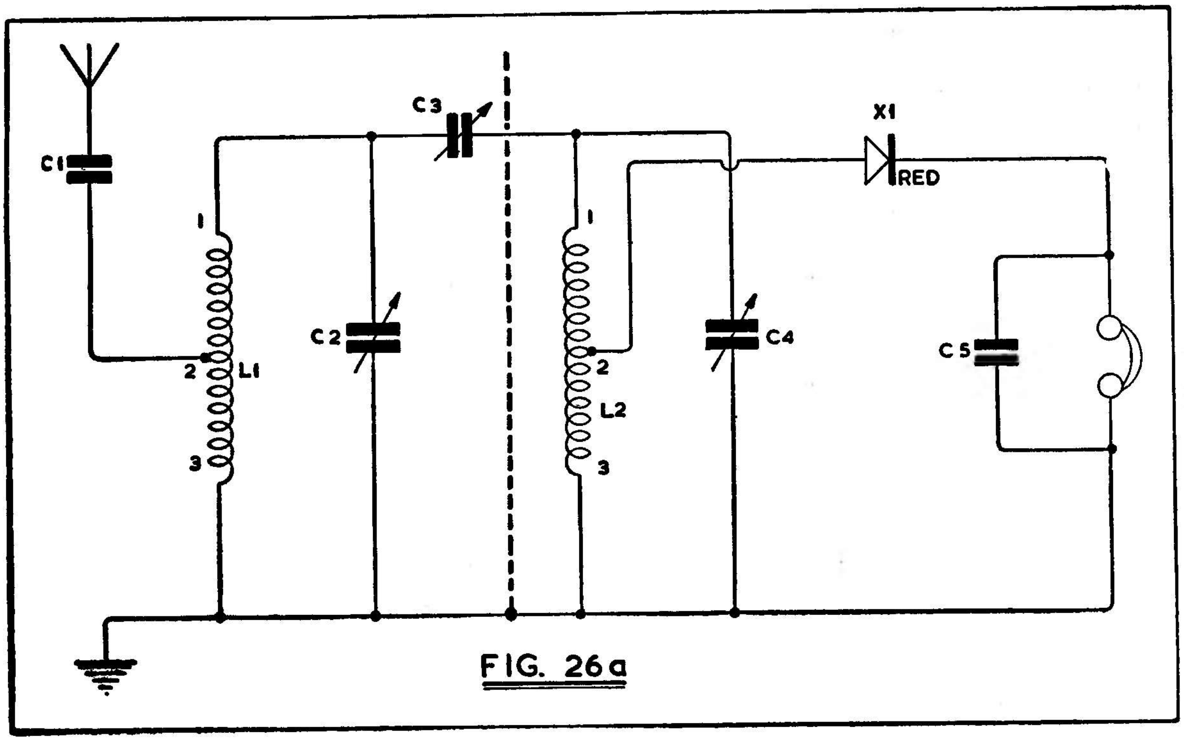

FIG. 26a

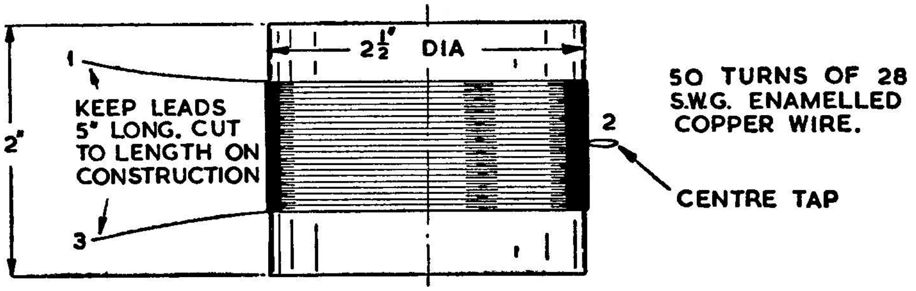
2½" DIA
1
KEEP LEADS
5" LONG. CUT
TO LENGTH ON
CONSTRUCTION
2"
3
2
50 TURNS OF 28
S.W.G. ENAMELLED
COPPER WIRE.
CENTRE TAP

COIL DETAILS.

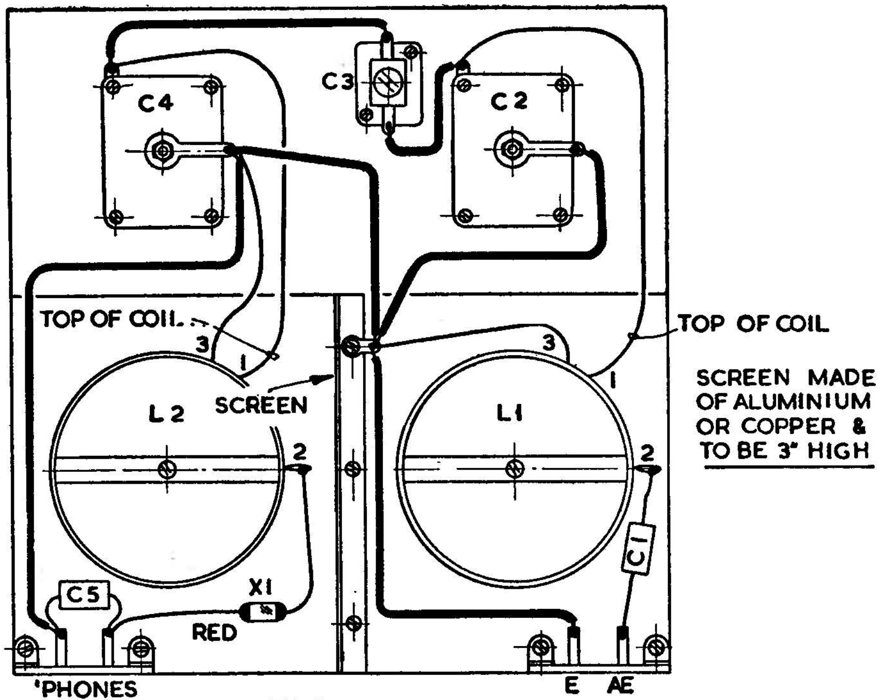
C4
C3
C2
TOP OF COIL
3
1
L 2
SCREEN
2
TOP OF COIL
3
1
L1
2
SCREEN MADE
OF ALUMINIUM
OR COPPER &
TO BE 3" HIGH
C1
C5
X1
RED
'PHONES
E
AE

FIG. 26 b

12

Fig. 27a-b uses a band-pass filter for tuning, and the coils are home-constructed.

With this design a ganged capacitor is quite suitable as the coils tune quite accurately. It is essential that the coupling condenser C3 is **non-inductive,** there will be no difficulty in obtaining a new component of this pattern but it is as well to avoid old components which may not employ this form of construction.

Receivers using this type of filter are used to the best advantage when situated a short distance from a powerful transmitter and if selectivity is not important this particular design is not the most suitable.

Both medium-waves and long-waves are catered for: consider L1-2-3, this is the first half of the filter.

L1 is the aerial coupling coil, with S1 closed, the medium-waves are received. This coil is inductively coupled to L2 and L3. Again with S2 open L2 and L3 combined cover the long-waves and when S2 is closed the medium waves are covered.

Tuning for this half of the filter is by means of the capacitor C1, which is one half of the ganged capacitor. A screen is erected between the two sets of coils comprising the filter, and coupling is effected by C3, an earth return for the coils is provided by R1.

L4 and L5 operated in a similar manner to L2 and L3, tuning is by means of C2, the remaining section of the ganged capacitor. You will realise that the coils must be accurately wound otherwise tuning will not remain constant between the two sections over the band.

The ganged capacitor should be fitted with trimmer capacitors when purchased so that the two circuits can be balanced.

You will have noticed that this circuit uses three sets of switch contacts. A three-pole two-way wafer switch is the best choice otherwise either two or even three separate switches are necessary. All the necessary coil details are given in the diagrams, the tap on L4 is made in the same way as shown for other coils in the manual. One other component used only on this design, is the resistor R1, its size is not important because the current flowing is so small it can be ignored.

A ¼ watt rating is adequate, its precise value is not critical so that a 20% tolerance component is quite suitable.

Resistors are coded by colours and the 1000Ω type you require will bear the following sequence. At one end will be painted three coloured rings.

Components List, Fig. 27a

C1-2	500pF 2 gang, variable capacitor.
C3	0.05mfd. non-inductive paper capacitor.
C4	1000pF mica capacitor.
R1	1000 ohm resistor.
X1	Germanium Crystal.
S1-2-3	3-pole 2-way wafer switch.
L1-2-3 & L4-5	See text.
4	Terminals (Aerial, Earth and 'Phones).
	Sheet copper or aluminium for screen.

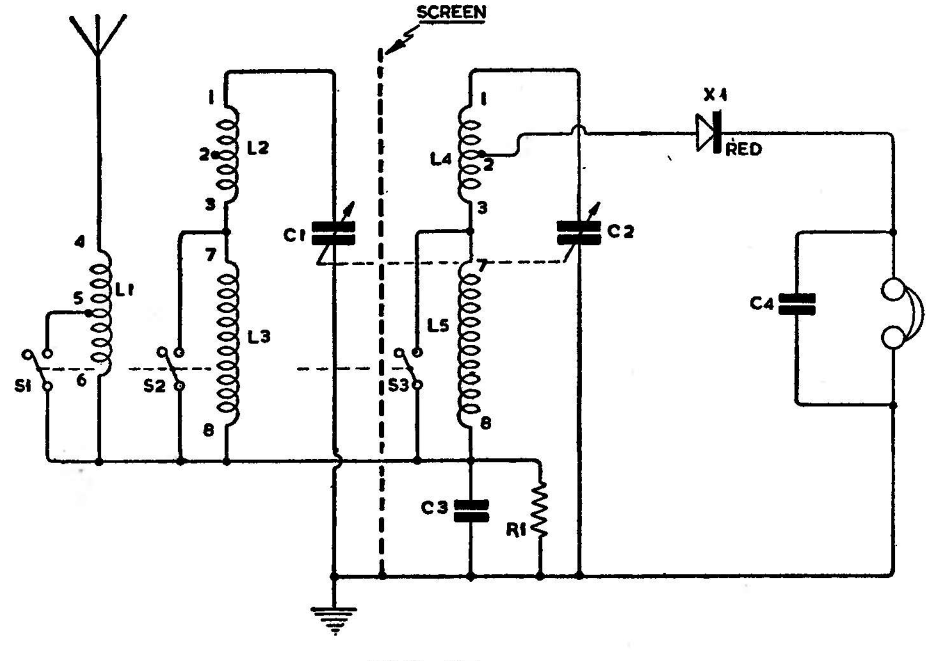

FIG. 27a

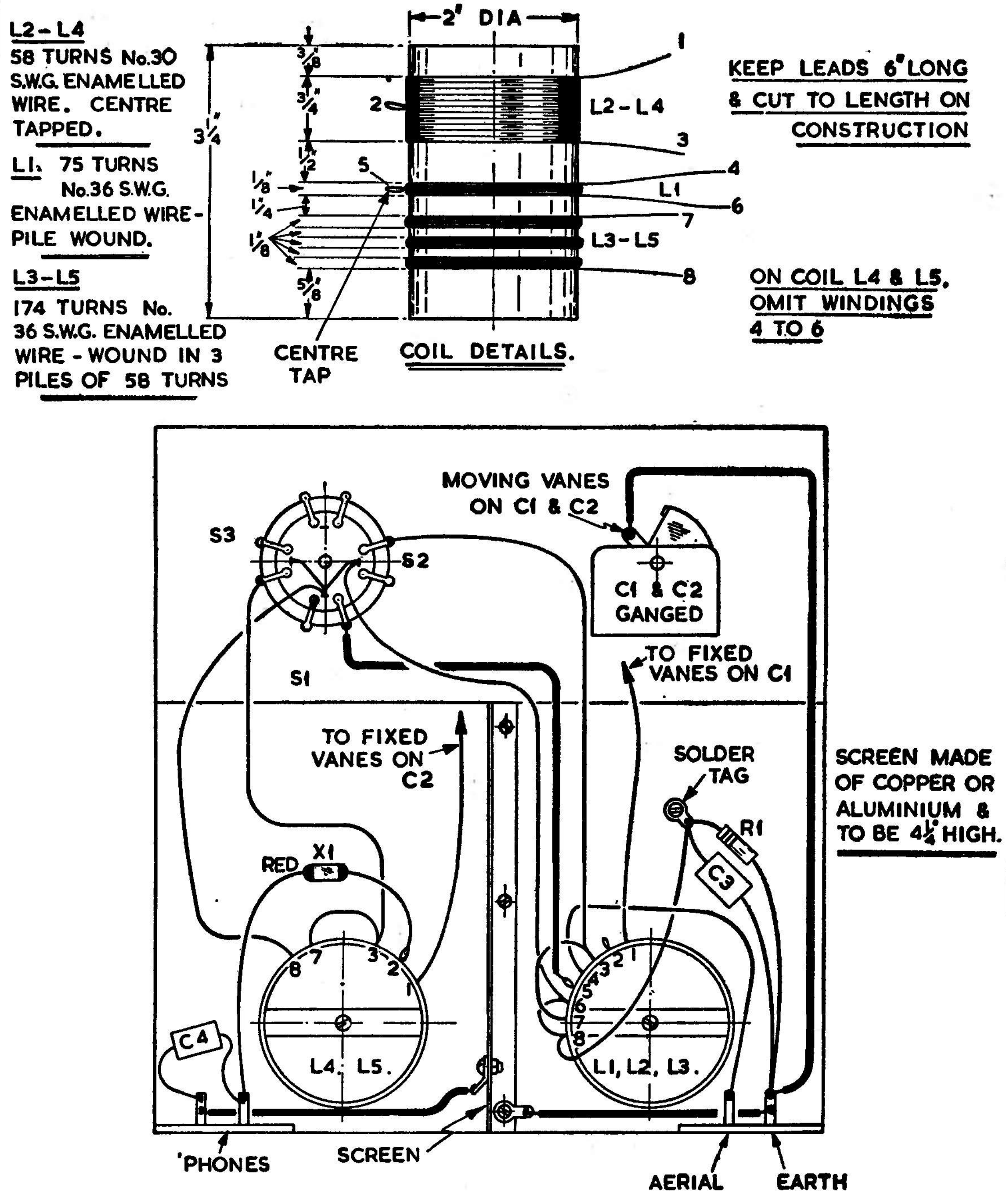
L2-L4
58 TURNS No.30 S.W.G. ENAMELLED WIRE. CENTRE TAPPED.
L1. 75 TURNS No.36 S.W.G. ENAMELLED WIRE-PILE WOUND.
L3-L5
174 TURNS No. 36 S.W.G. ENAMELLED WIRE-WOUND IN 3 PILES OF 58 TURNS
3¼"
2" DIA
3/8
3/4"
1/2"
1/8"
1/4"
1/8"
5/8"
1
2
3
4
5
6
7
8
L2-L4
L1
L3-L5
CENTRE TAP
COIL DETAILS.
KEEP LEADS 6" LONG & CUT TO LENGTH ON CONSTRUCTION
ON COIL L4 & L5, OMIT WINDINGS 4 TO 6
MOVING VANES ON C1 & C2
S3
S2
S1
C1 & C2 GANGED
TO FIXED VANES ON C1
TO FIXED VANES ON C2
SOLDER TAG
R1
C3
SCREEN MADE OF COPPER OR ALUMINIUM & TO BE 4½" HIGH.
RED
X1
C4
L4, L5.
L1, L2, L3.
'PHONES
SCREEN
AERIAL
EARTH

FIG. 27 b

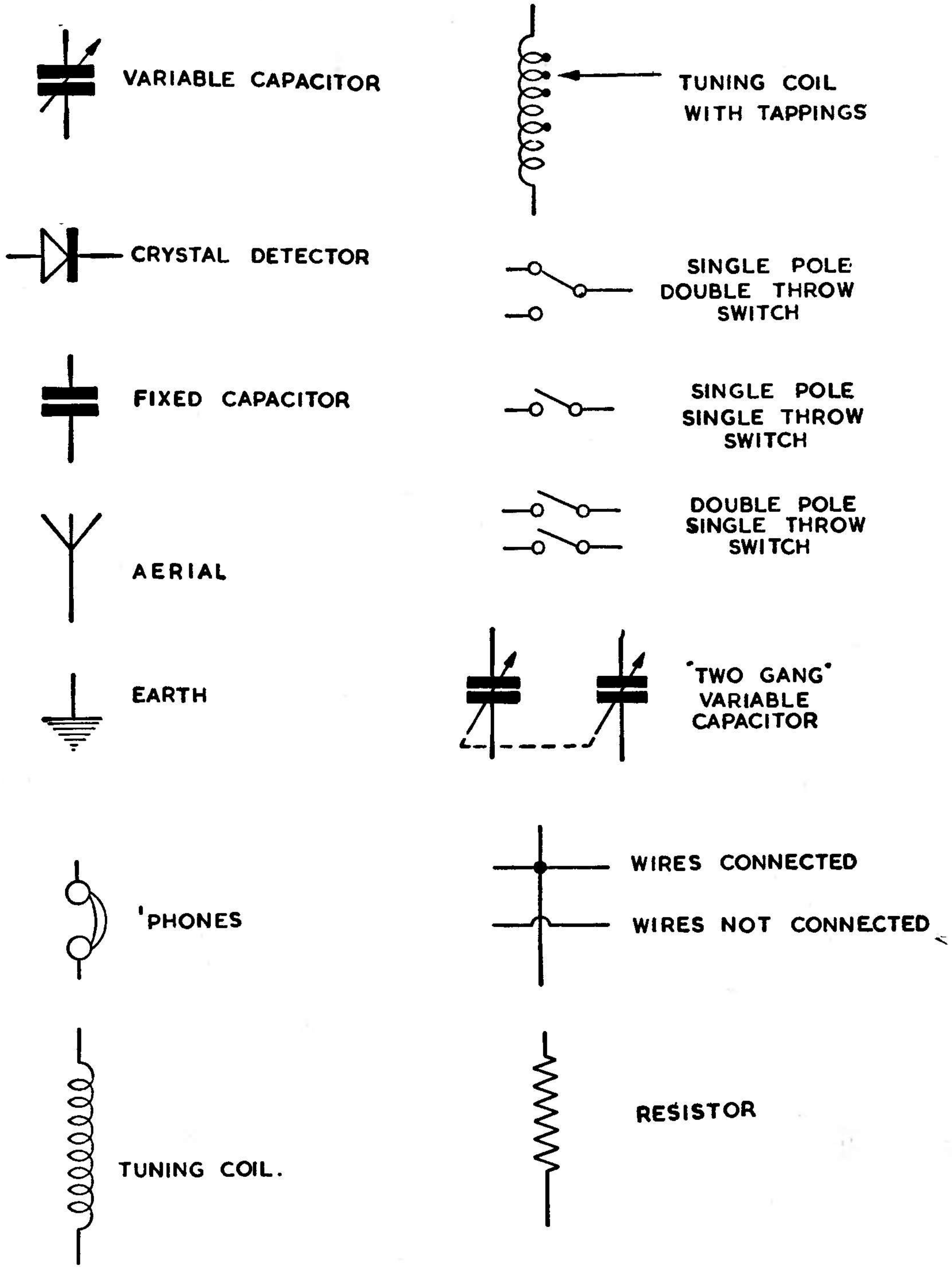
VARIABLE CAPACITOR
TUNING COIL WITH TAPPINGS
CRYSTAL DETECTOR
SINGLE POLE DOUBLE THROW SWITCH
FIXED CAPACITOR
SINGLE POLE SINGLE THROW SWITCH
DOUBLE POLE SINGLE THROW SWITCH
AERIAL
EARTH
'TWO GANG' VARIABLE CAPACITOR
WIRES CONNECTED
WIRES NOT CONNECTED
'PHONES
RESISTOR
TUNING COIL.

SYMBOLS USED IN THE CIRCUITS DESCRIBED.

FIG. 28

The first one is BROWN which represents 1, the first figure of the value, the second BLACK, this indicates the second numeral is nought, and the third colour is RED which tells us that two further ciphers or noughts are added to give the total value. From this you can see, we have 1 plus a nought equalling 10, plus two further noughts which total 1000. Some earlier types of resistor were painted differently, the whole body colour represented the first figure, one tip was coloured to represent the second figure, and a painted dot in the centre gave the number of ciphers to be added.

There are no other special points regarding construction except perhaps that if a long aerial is used, a small 100pF capacitor might be tried in the aerial lead to prevent damping the first tuned circuit.

When setting up the receiver, tune to a station at the high-frequency end of the M.W. band and set the trimmers for loudest volume, no other adjustments are necessary.

CONCLUSION

The twelve receivers described are representative of the best crystal set designs available to-day. Their construction will provide many hours of useful enjoyment, and the results will give lasting pleasure.

A final word about components, if no actual maker is specified, any good class component can be used. Switches, fixed and variable capacitors and crystals, are available from numerous manufacturers all of which are invariably of excellent quality. Where a particular manufacturer's product is called for, the specification should be adhered to. The commercial coils specified are freely available from most supply houses specialising in components for constructors, but in case of difficulty write to Bernards (Publishers) Ltd., The Grampians, Western Gate, London, W.6, who will, on receipt of a S.A.E. be pleased to supply the address of your nearest stockist. Coil formers are not always easy to obtain and in this case advice should be sought from Post Radio Supplies, 395, Queensbridge Road, London, E.8, who will be pleased to help in any way possible.

* *

advertisement

FREE ENERGY MICROWAVE

Technology (/technology/) > Electronics | by GEORGE CHANIOTAKIS (/member/GEORGE+CHANIOTAKIS/)

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Posted Dec. 22, 2015 | (cc) BY-NC-SA

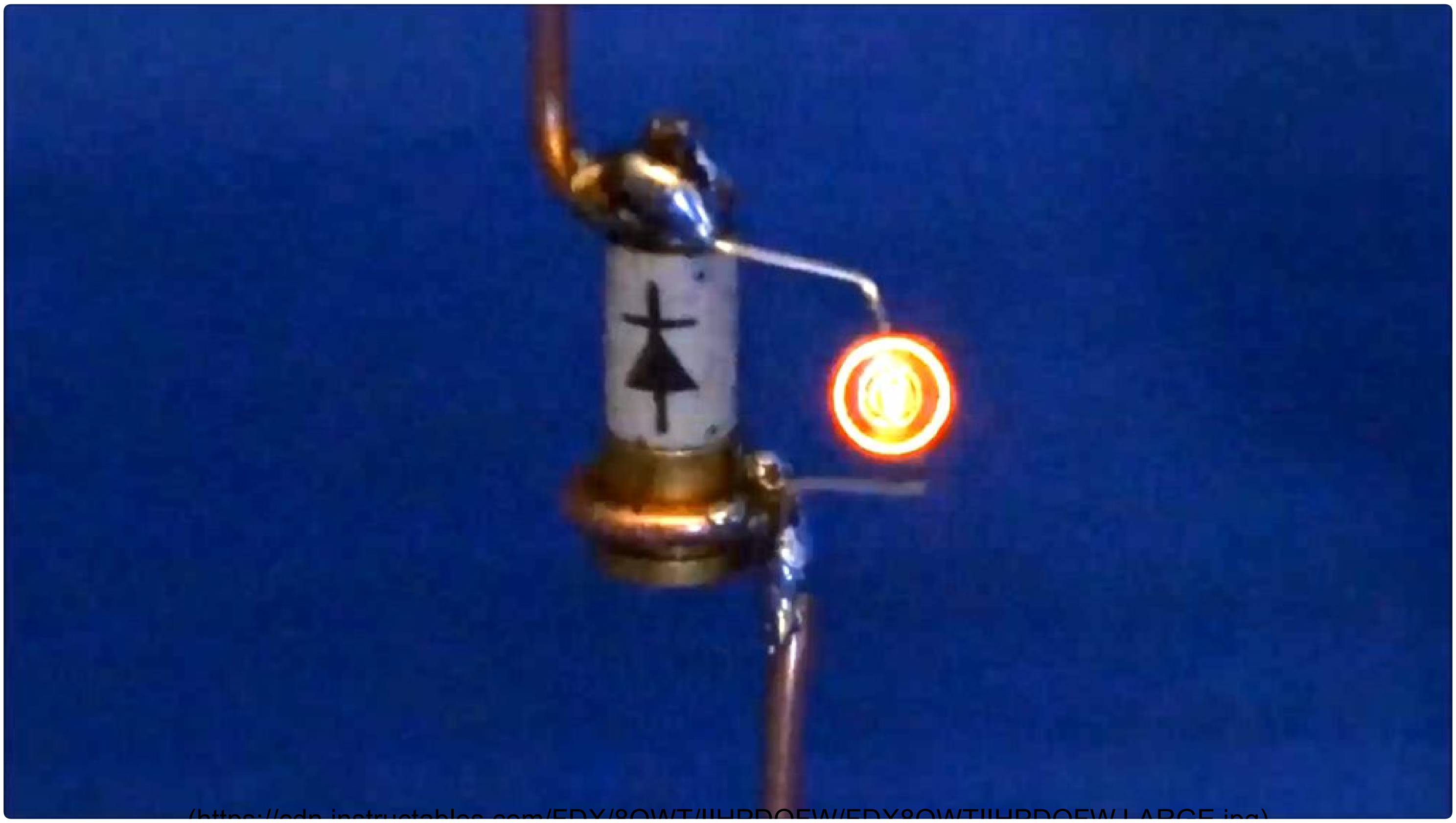

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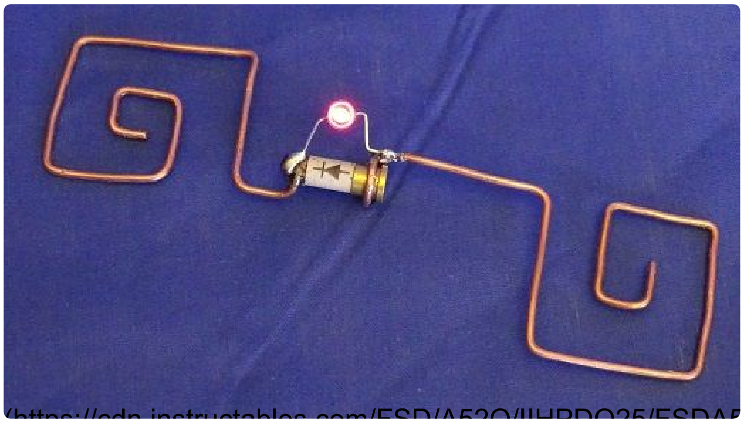
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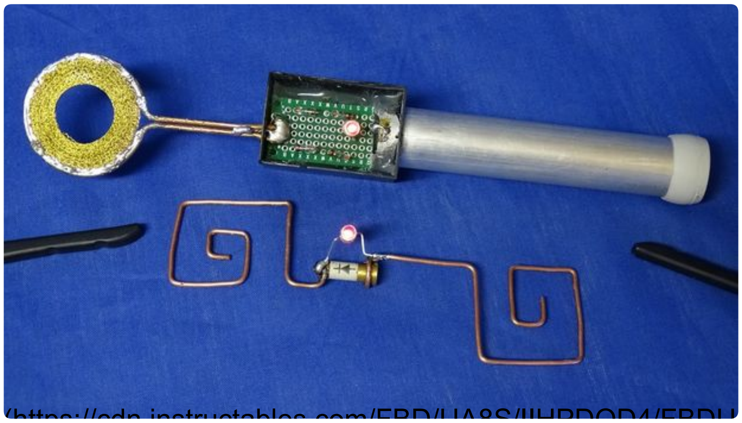
(https://cdn.instructables.com/FBD/UA8S/IIHRDQD4/FBDU

In electronics, a diode is a two-terminal electronic component that conducts primarily in one direction; it has low resistance to the flow of current in one direction, and high resistance in the other. A semiconductor diode, the most common type today, is a crystalline piece of semiconductor material with a p–n junction connected to two electrical terminals. A vacuum tube diode has two electrodes, a plate and a heated cathode. Semiconductor diodes were the first semiconductor electronic devices. The discovery of crystals' rectifying abilities was made by German physicist Ferdinand Braun in 1874. The first semiconductor diodes, called cat's whisker diodes, developed around 1906, were made of mineral crystals such as galena. Today, most diodes are made of silicon, but other semiconductors such as selenium or germanium are sometimes used.

This diode is able to detect RF signals and converts it to DC electricity to power a Led the amazing thing about this is that its completely passive and doesn't require any batteries... Gold Plated Slug 1N23B is Vintage U.S. ARMY Military for General Purpose UHF-MW Silicon Mixer. Primarily used in the Allies’ radar systems during World War II.

Add Tip Ask Question

Step 1:

PRELIMINARY PLANS TO RUN YOUR CAR ON TAP WATER!

IT ALSO WORKS ON YOUR
TRUCK / RV / MOTORCYCLE / AIRPLANE (ETC)

Will This Work?

These plans were sent to the Spirit of Ma'at anonymously, from someone who does not want his or her name printed (for obvious reasons).
We have had them checked by an expert who believes that they are real.
We also have talked with another individual who has patented a similar device, and we know by personal experience that the technology is sound.
So although we cannot guarantee it, we believe these plans will enable you to build a car that runs on water. If you test it out, though, do as the writer suggests and use an old car that doesn't represent a loss of value if you can't make it work. And leave everything intact so that you can always reconnect back to gas if you have to.

But if you do get it working, please send us your experience for our readers. You could be a national hero and help save our country and our world.

We know for certain that an automobile will run on water. So this could be an interesting project for you mechanical types, with a great reward of never having to purchase gasoline for the rest of your life - and helping humanity at the same time.

Re The Need to Rustproof Your Exhaust System

It is possible to make a hybrid of both gas and water (a system that is being tested now in Mexico), which would eliminate the need to open the head and remove the exhaust system. Just a thought. It takes only a small amount of gas to keep the system dry.

The text sent from the anonymous individual was edited slightly for better reading. The following is his/her words and drawings, which has been given into the public domain.
- Spirit of Ma'at LLC

Introduction

It is suggested you try this out to begin with on a second vehicle you own, one that you don't need to live with everyday, until you perfect this technology.

Do-it-yourself plans allow the individual (that's you and me, folks) to make a difference. This is the easiest and lowest-cost way to convert your car to run on (relatively) free energy.

Now, with existing technology, anyone can stand up and make a difference by reducing the local automotive pollution, eliminate gasoline expenses, help restore our atmosphere, and breathe a little easier.

In putting these plans into operation, you will be making use of your entire existing system except for the fuel tank and the catalytic converter.

The Plan

Build and install a low-cost alternative method for running your vehicle (internal combustion engine) on tap water, using off-the-shelf components.

This is simply an efficient way to convert ordinary tap water into gaseous hydrogen and oxygen, and then burn these vapors in the engine, instead of gasoline.

This "minisystem" runs easily from your existing battery and electrical system, and it plugs into your carburetor with simple off-the-shelf fittings.

You will be installing a plastic water tank, a control circuit, a reaction chamber, a hi-pressure carb/FI fitting, and 3 gauges, and then hooking into your existing carb/FI.

The simplicity comes from its being an "on-demand" system requiring no fancy storage or plumbing. You crank the gas pedal or throttle, and you electrically create more vapor for immediate consumption, on demand; low-high flow rate as needed, from idle to maximum power. The only real change is that you are using tap water as fuel, instead of the traditional petroleum-based fuel.

Given a choice, which way would you choose?

Frequently Asked Questions

Q: Does it really work ?
A: Yes; this is well-established technology dating back to stainless steel. But be sure to follow these instructions using the proper mechanical and electrical assembly techniques, as this plan incorporates the best qualities of several techniques.

Q: How does it qualify as "free energy"?
A: If you're paying someone for the water you use, then it is not strictly free. But the alternative is to keep buying into expen$ive ga$oline and its resultant hydrocarbon pollution.

Q: Is it safe?
A: Technically, it is safer than running on fossil fuel because you are no longer choking on your own emissions (health-wise). In general, it is practically as safe as your current gasoline arrangement. You will be installing a few simple safety devices, using current automotive standards.

Q: What kind of performance can I expect?
A: Properly adjusted, your modified vapor-only fuel system will run cooler, and at a modestly higher power level. The mileage performance expected from this design ranges from 50-300 mpg (of water), depending on your adjusting skills.

Q: Can I do the modification myself?
A: Why not? If you don't have any mechanical skills, and you know someone with basic mechanical and/or electrical skills, you can even delegate some of the construction. If you are using a fuel-injected engine, you may have to get a mechanic's opinion. [There will have to be an adapter inserted into the fuel-injection system, just as you would have to do if you were going to run on propane, hydrogen, or natural gas. Ed.)

Q: What is the environmental impact that my vehicle will have?
A: It will be producing H20 steam (water vapor) and unburnt O2 (Oxygen). Hence, it will be cleaning the environment, rather than dumping nauseous toxins into it. Plus you will be helping to save our dwindling supply of atmospheric oxygen. Any excess vapor in the reaction becomes either steam or oxygen. You can also expect to be receiving more than casual interest from those around you.

Q: Isn't this really a steam engine?
A: No. Really. Exceedingly high temperature and pressure are not used. This is strictly an internal-combustion engine (burning orthohydrogen) with residual steam in the exhaust as a by-product.

There are a few things you should know about gasoline:

Gasoline as a fuel is not necessary; it is optional.

Gasoline versus Water

There is a lot of thermochemical energy in gasoline, but there is even more energy in water. The DOE (Department of Energy) has quoted about 40%, so it is probably much more than that.

Most people are unaware that "internal combustion" is defined as "a thermo-vapor process" - as in "no liquid in the reaction." Most of the gasoline in a standard internal combustion engine is actually consumed, (cooked, and finally, broken down) in the catalytic converter after the fuel has been not-so-burnt in the engine. Sadly, this means that most of the fuel we use in this way is used only to cool down the combustion process, a pollution-ridden and inefficient means of doing that.

How It Works

Exceedingly simple. Water is pumped as needed to replenish and maintain the liquid level in the chamber. The electrodes are vibrated with a 0.5-5A electrical pulse which breaks $2(H_2O) \Rightarrow 2H_2 + O_2$. When the pressure reaches say 30-60 psi, you turn the key and go. You step on the pedal, you send more energy to the electrodes, and thus more vapor to the cylinders; i.e. fuel vapor on demand.

You set the idle max-flow rate to get the most efficient use of power, and you're off to the races.

In the big picture, your free energy is coming from the tap water in an open system, as the latent energy in the water is enough to power the engine and hence drive the alternator and whatever belt-driven accessories. And the alternator is efficient enough to run the various electrical loads (10 - 20 amps), including the additional low current to run this vapor reaction. No extra batteries are required.

STEP BY STEP CONSTRUCTION (Please refer to diagrams at the end of this document)

OVERVIEW - Here is the suggested sequence of steps:

1. Install the CHT (or EGT) gauge and measure your current operating temp range (gasoline), for comparison.

2. Build and test the controller to verify the correct pulse output.

3. Build the reaction chamber and test it with the controller (i.e pressure out).

4. Install the tank, controller, chamber, and pressure fittings.

5. Run engine and adjust the control circuit as necessary for best performance.

6. Install the stainless steel valves and get the pistons/cylinders coated with ceramic.

7. Coat the exhaust system with ceramic without the catalytic converter (or let it rust out and then replace the whole dang thang with stainless steel pipe sections).

YOU WILL NEED

plastic water tank with pump and level sensor.
control circuit, wiring, connectors, and epoxy.
reaction chamber with electrodes and fittings.
3/8" stainless steel flex-tubing, fittings and clamps.
carb/FI vapor-pressure fitting kit. - pressure, CHT (or EGT), & level gauges.
stainless steel valves.
copper mesh junction.
ceramic surface treatment for cylinders & pistons.
stainless steel or ceramic treated exhaust assembly.

BASIC TOOLS

drill, screwdriver and pliers
hole cutter
wire-wrap, solder-iron and clippers
DVM and oscilloscope.

REACTION CHAMBER

Construct as shown in the diagrams. Use a section of 4" PVC waste pipe with a threaded screw-cap fitting on one end and a standard end-cap at the other. Make sure to drill-and-epoxy or tap threads thru the PVC components for all fittings. Set and control the water level in the chamber so that it well submerses the pipe electrodes; yet leave some headroom to build up the hydrogen/oxygen vapor pressure. Use stainless steel wires inside the chamber or otherwise use a protective coating; use insulated wires outside. Ensure that the epoxy perfects the seal, or otherwise lay down a bead of water-proof silicone that can hold pressure.

The screw fitting may require soft silicone sealant, or a gasket; its purpose is to hold pressure and allow periodic inspection of the electrodes. No leaks, no problems. Make sure you get a symmetric 1-5mm gap between the 2 stainless steel pipes. The referenced literature suggests that the closer to 1mm you get, the better. You will want to get your chamber level sensor verified before you epoxy the cap on.

Make your solder connections at the wire/electrode junctions nice, smooth, and solid; then apply a water-proof coating, e.g. the epoxy you use for joining the pipes to the screw cap. This epoxy must be waterproof and be capable of holding metal to plastic under pressure. You will want to get your chamber level sensor verified before you epoxy the cap on.

CONTROL CIRCUIT

The diagrams show a simple circuit to control and drive this mini-system. You are going to make a 'square-pulse' signal that 'plays' the electrodes like a tuning fork; which you can watch on an oscilloscope. The premise given by the literature is: the faster you want do go down the road, the 'fatter' you make the pulses going into the reaction chamber. Duty cycle will vary with the throttle in the vicinity of 90%MARK 10%SPACE (OFF/ON).

There is nothing sacred about how the pulse waveform is generated; there are many ways to generate pulses, and the attached diagrams show a few. The diagram shows the NE555-circuit approach from the referenced patent. The output switching transistor must be rated for 1-5 amps @ 12VDC (in saturation).

Go with a plan that works for you or your friendly neighborhood technoid or mechanic, and go get all the circuit elements from your local electronics store, such as Radio-Shack or Circuits-R-Us, including the circuit board, IC sockets, and enclosure/box.

DigiKey has better selection, service, and knowledge; plus they have no minimum order. Be sure to use a circuit board with a built-in ground plane, and to accommodate room for mounting 2 or 3 of the gauges. Mounting the reaction chamber in the engine compartment will require running a stub to your pressure gauge where you can watch it.

You can easily make 30-gauge wire-wrap connections between the socket pins and thru-hole discrete components having wire leads. Also make sure to get spec sheets on any IC you use. More details of the best circuits to use will be announced pending prototype testing. You will want to get your chamber level sensor verified before you epoxy the cap on.

Throttle Control

If you have a throttle position sensor, you should be able to access the signal from the sensor itself OR from the computer connector. This signal is input to the circuit as the primary control (i.e. throttle level = pulse width = vapor rate).

If you don't have such a signal available, you will have to rig a rotary POT (variable resistor) to the gas linkage (i.e. coupled to something at the gas pedal or throttle cable running to the carb or FI. If you make the attachment at the carb/FI, be sure to use a POT that can handle the engine temp cycles. Don't use a cheezy-cheapy POT; get one rated for long life and mechanical wear; mount it securely to something sturdy and stationary that will not fall apart when you step on the gas.

Control Range. The full throttle RANGE (idle-max) MUST control the vapor rate, i.e. pulse-width (duty). The resistor values at the throttle signal must allow the throttle signal voltage, say 1-4 Volt swing, to drive the VAPOR RATE. You will be using this voltage swing to generate a 10% ON 'square' pulse. The patent implies using a 'resonant' pulse in the 10-250 KHz frequency range; but it is not explicitly stated so.

In this circuit, you will simply tune to whatever frequency makes the most efficient vapor conversion. You will have to get into the specs for each IC you use, to insure you connect the right pins to the right wires, to control the frequency and pulse width. You can use spare sockets to try out different discrete component values. Just keep the ones that are spec-compatible in the circuit, and get the job done.

You crank up the throttle signal and put more electrical energy (fatter pulses) into the electrodes; verify you can get 10% duty on the scope (2 - 100 usec on the horizontal time-base). Your averaging DVM will display the 90%-10% DC voltage across the output transistor (Vce or Vds or Output to Ground). Set and connect DVM in the supply current and measure .5 - 5 amps, without blowing the DVM fuse. Now verify that you got everything you wanted.

Verify your wiring connections using your DVM as a continuity detector. Check your wiring 1 at a time and yellow line your final schematic as you go. You can best use board-mount miniature POTs for anything you want to set-and-forget. The LEDs are there to give you a quick visual check of normal vs abnormal operation of your new creation. You will want to get your chamber level sensor verified before you epoxy the cap on.

CARB/FI CONNECTION

The diagram also shows that fittings are required to the carb/FI l. There are ready-made kits (such as by Impco) available for making your pressure fittings to the carburetor or fuel-injector as the case may be. You will necessarily be sealing the built-in vents and making a 1-way air-intake.

The copper mesh comprises the inadvertent backfire' protection for the reaction chamber. Make sure that all vapor/duct junctions are air-tight and holding full pressure without leakage. Your new 'system' is considered successful and properly adjusted when you get the full power range at lower temp and minimum vapor flow without blowing the pressure safety valve.

CHT (or EGT)

Monitor your engine temp with the CHT (cylinder head temp) or EGT (exhaust gas temp) instead of your original engine temp indicator (if any). Your existing gauge is too slow for this application and will not warn you against overheating until after you have burnt something. Make sure that your engine runs no hotter than in the gasoline arrangement. VDO makes a CHT gauge with a platinum sensor that fits under your spark plug against the cylinder head (make sure it is really clean before you re-install your spark plug (as this is also an electrical ground).

ENGINE/EXHAUST TREATMENT

Get the valves replaced with stainless steel ones and get the pistons/cylinders ceramic-treated ASAP when you have successfully converted and run your new creation. Do not delay as these items will rust, either by sheer use or by neglect (i.e. letting it sit). You could make max use of your current exhaust system by using it with your new deal until it rusts through, then have your mechanic or welder friend to fit a stainless steel exhaust pipe (no catalytic converter is required). But it could be easier and cheaper to send your existing exhaust system out for the ceramic treatment, and then simply re-attach it to the exhaust ports.

GENERAL

1. Do not discard or remove any of the old gasoline setup components, e.g. tank, carb/FI, catalytic converter, unless necessary. Better to always leave an easy way to revert back to something that at least runs, just in case. Some people are leaving their gasoline setup completely intact, and switching back and forth at will, just to have a backup plan.

2. Set your throttle circuit so that you get minimum vapor flow at idle, and maximum vapor flow at full power without blowing the pressure relief valve. In this way, you control how 'lean' your mixture is by the strength of the pulse (i.e. “fatness” at the optimum pulse frequency).

3. If you just don't get enough power (at any throttle setting), it means that you need to (1) change the pulse frequency, (2) change the gap between the electrodes, (3) change the size (bigger) electrodes, or (4) make a higher output pulse voltage (last resort). Always use an output transistor, such as a MOSFET, that is rated for the voltage and current you need to get the job done. OK so you might have to play around with it some. Isn't that where all the Fun is anyhow?

4. If you get any engine knock our loud combustions (not compensated by adjusting the timing), it means that you need to install an additional coil in the chamber, and drive the coil with an additional pulse signal (about 19 Hz on the .1sec time base (see diagram). Here,

you will be slowing down the burn rate just enough so that the vapors burn thru out the power stroke of the piston. Be sure to include a board-mount POT to set the correct strength of this 2nd pulse signal into the coil. This is a stainless steel coil of about 1500 turns (thin wire) that you can arrange like a donut around the center pipe (but NOT touching either electrode), directly over the circular 1-5mm gap. You want no knocking at any power/throttle setting; smooth power only, but also no excess hydrogen leftover from the combustion.

5. Build the canister(s) as tall as you can without compromising your ability to mount them conveniently near the dash panel, or in the engine compartment, as the case may be. This way, you can always make the electrodes bigger, if necessary without undue hardship. Remember that anything in the engine compartment should be mounted in a bullet-proof, vibration and temperature tolerant fashion.

6. If you have to drill a thru-hole for wiring or plumbing thru metal, make sure to also install a grommet for protection against chafing. Always watch your chamber pressure range from IDLE (15-25 psi) - FULL POWER (30-60 psi). Set your safety-pressure relief-valve to 75 psi and make sure it's rated for much higher.

7. Shut OFF the power switch and pull over if there is any malfunction of the system. Your engine will last longest when it still develops FULL POWER+ at some minimum temperature that we are sure you can find, by leaning back the Royal Vapor Flow and/or by making use of the water-vapor cooling technique (see diagram). Keep good mpg performance records, and periodic maintenance/inspection. Keep it clean; save some money; clean the air; heal the planet; happy motoring; tell a friend; enjoy your freedom and self-empowerment.

8. There lacks documented material for perfecting this vapor system thru a fuel injector; there may be some details you will discover on your own as working prototypes progress. For example, you may be restricted to inject the hydrogen/oxygen vapor without any water vapor, as it may rust the injectors. If engine temp and CHT is a problem, then you will want to re-think your plan, e.g. ceramic-coating the injectors. There is always “replacing the FI system with a Carb.”

9. If you install the water-vapor system (for lower operating temp/stress), you will want to lean the mixture (vapor/air) for minimum vapor flow rate to achieve any given throttle position (idle - max). Make sure that you get a minimum flow for IDLE and a modestly sufficient flow for MAX, that does the cooling job without killing the combustion.

10. If you cannot find stainless steel pipe combinations that yield the 1-5mm gap, you can always regress back to alternating plates of +/- electrodes.

11. If you are concerned about the water freezing in your system, you can (a) add some

98% isopropyl alcohol and re-adjust the pulse frequency accordingly; or (b) install some electric heating coils.

12. Do not let ANYONE ever compromise your dream, your freedom, your independence or your truth.

REFERENCES

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Stanley Meyer 'Method for the Production of a Fuel Gas' US Patent 4936961, uspto.gov
Creative Science & Research, 'Fuel From Water', fuelless.com
Carl Cella “A Water-Fuelled Car” Nexus Magazine Oct-Nov 1996
Peter Lindemann “Where in the World is All the Free Energy”, free-energy.cc <http://www.free-energy.cc/>
George Wiseman “The Gas-Saver and HyCO Series” eagle-research.com <http://www.eagle-research.com/>
C. Michael Holler “The Dromedary Newsletter” and “SuperCarb Techniques”
Stephen Chambers “Prototype Vapor Fuel System” xogen.com <http://www.xogen.com/>

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CONVERT YOUR ENGINE TO BURN HYDROGEN AND OXYGEN VAPOR FROM WATER....... ON DEMAND + POLLUTION-FREE

FIGURE 1

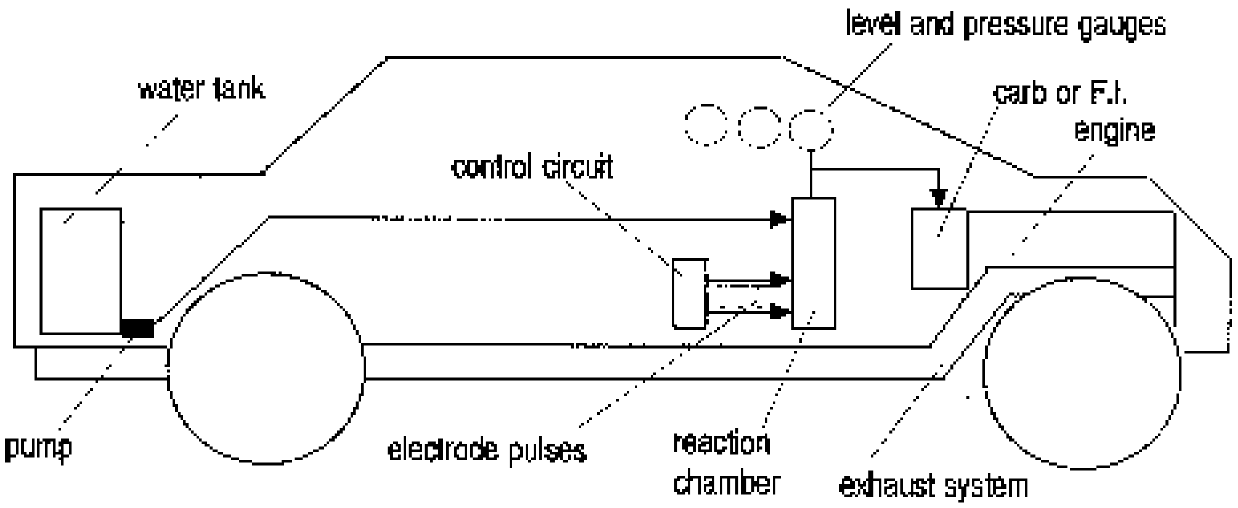
level and pressure gauges
water tank
carb or F.I.
engine
control circuit
pump
electrode pulses
reaction chamber
exhaust system

BUILD YOUR OWN WATER VAPOR SYSTEM CONTROLLER FROM THE-SHELF MATERIALS

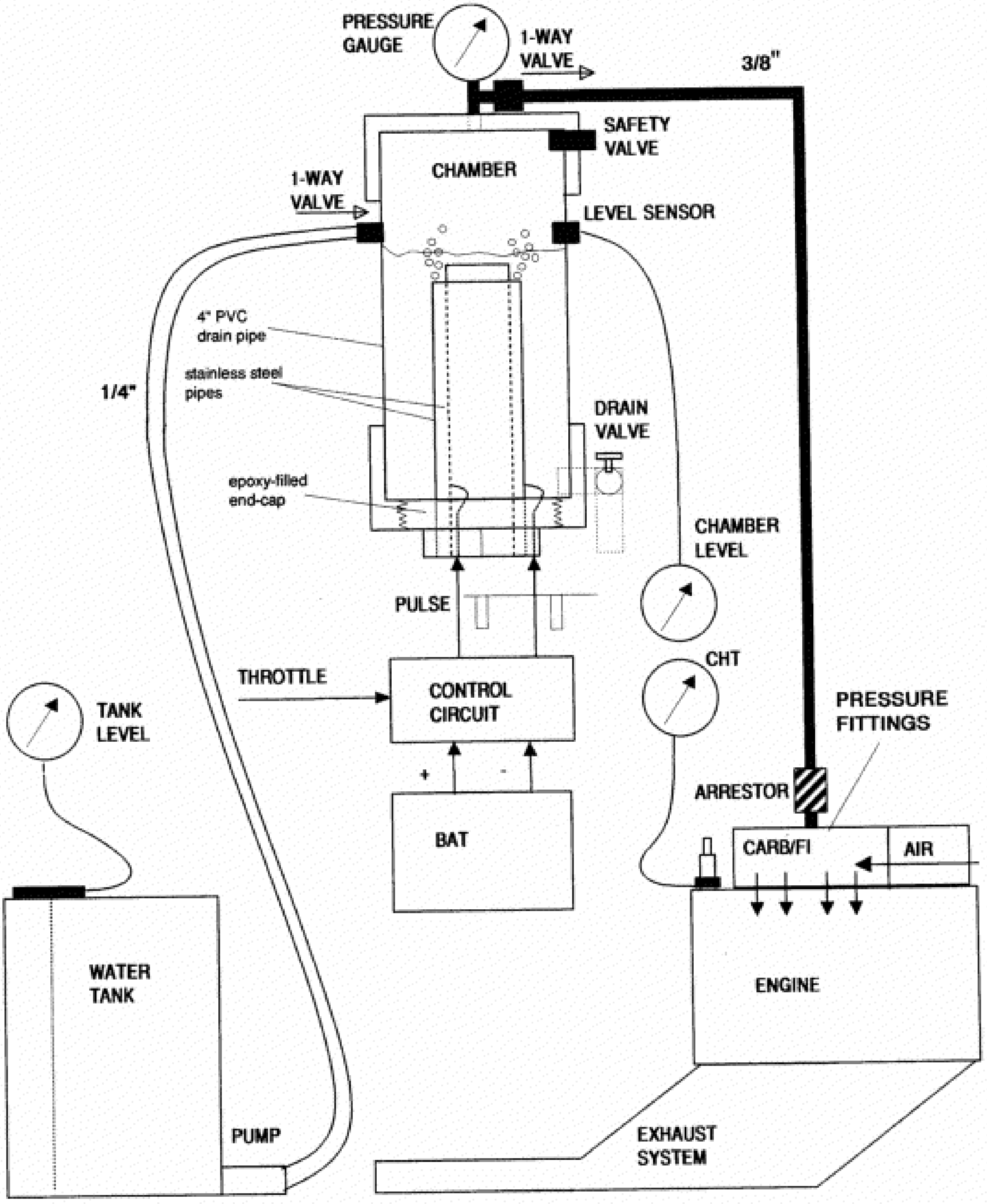
PRESSURE GAUGE
1-WAY VALVE
3/8"
SAFETY VALVE
CHAMBER
1-WAY VALVE
LEVEL SENSOR
4" PVC drain pipe
stainless steel pipes
1/4"
DRAIN VALVE
epoxy-filled end-cap
CHAMBER LEVEL
PULSE
CHT
THROTTLE
CONTROL CIRCUIT
PRESSURE FITTINGS
TANK LEVEL
+
-
ARRESTOR
BAT
CARB/FI
AIR
WATER TANK
ENGINE
EXHAUST SYSTEM
PUMP

FIGURE 2 BLOC DIAGRAM

BUILD YOUR OWN WATER VAPOR SYSTEM CONTROLLER FROM THE-SHELF MATERIALS

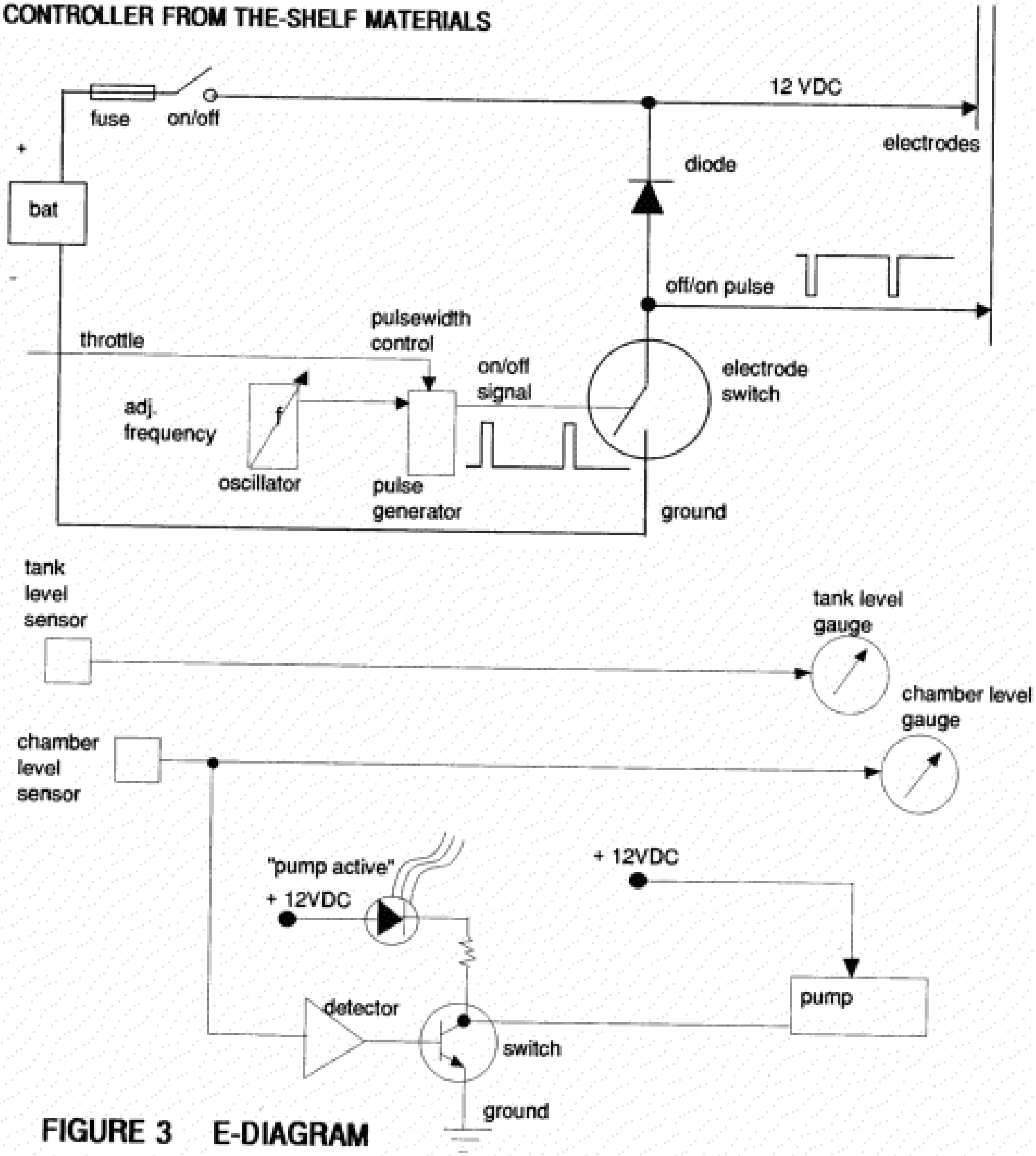

12 VDC
fuse
on/off
+
bat
-
electrodes
diode
off/on pulse
throttle
pulsewidth control
on/off signal
electrode switch
adj. frequency
f
oscillator
pulse generator
ground
tank level sensor
tank level gauge
chamber level gauge
chamber level sensor
"pump active"
+ 12VDC
+ 12VDC
pump
detector
switch
ground

FIGURE 3 E-DIAGRAM

BUILD YOUR OWN WATER VAPOR SYSTEM CONTROLLER FROM THE-SHELF MATERIALS

REV. A

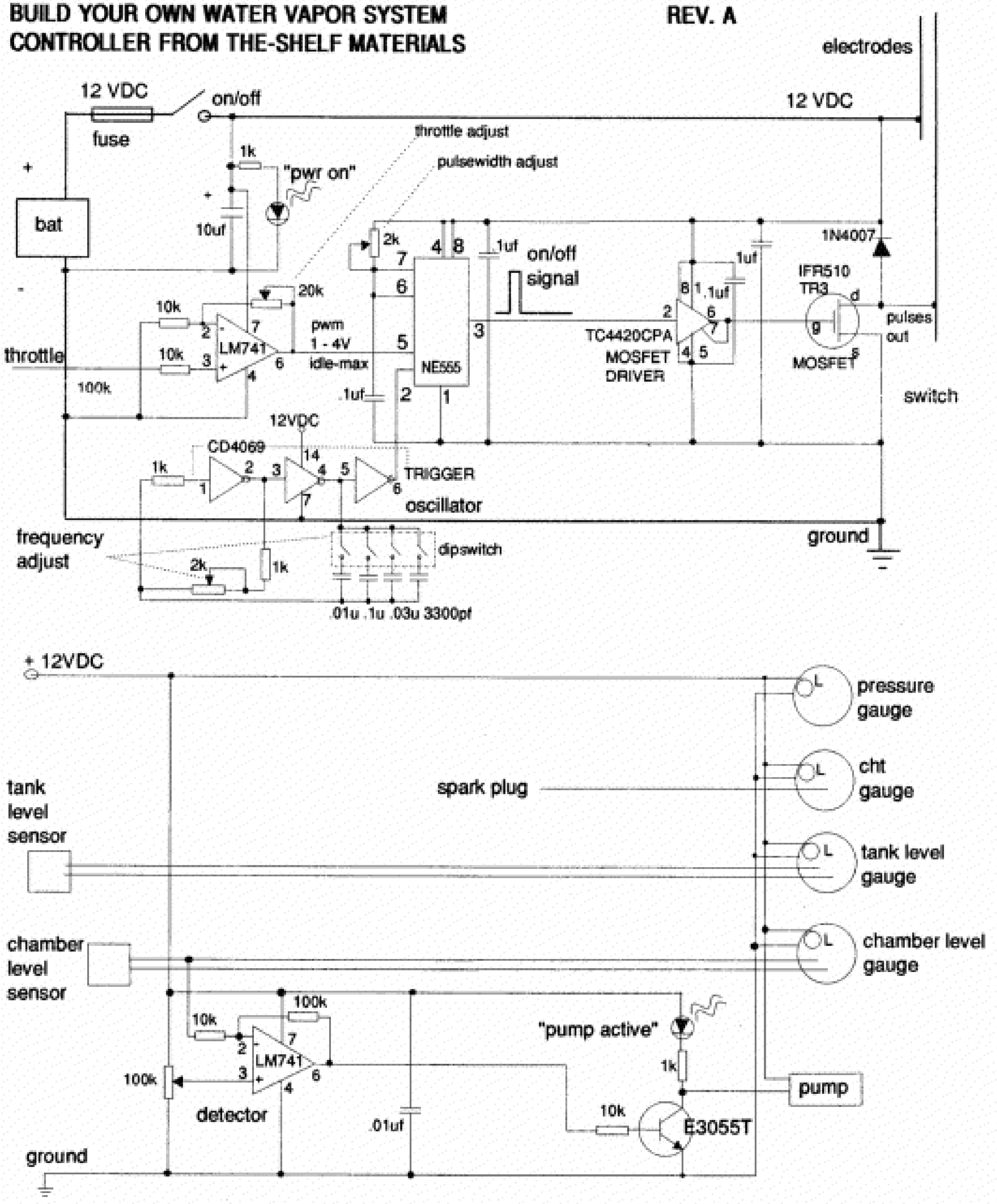
electrodes
12 VDC
on/off
fuse
12 VDC
+
bat
-
1k
"pwr on"
+
10uf
throttle adjust
pulsewidth adjust
2k
7
4
8
.1uf
on/off
signal
6
20k
10k
2
-
7
LM741
pwm
1 - 4V
idle-max
5
3
NE555
throttle
10k
3
+
6
4
100k
.1uf
2
1
1N4007
.1uf
8
1
.1uf
2
6
7
TC4420CPA
MOSFET
DRIVER
4
5
IFR510
TR3
d
g
s
MOSFET
pulses
out
switch
12VDC
CD4069
14
1k
1
2
3
4
7
5
6
TRIGGER
oscillator
ground
frequency
adjust
2k
1k
dipswitch
.01u
.1u
.03u
3300pf
+ 12VDC
L
pressure
gauge
L
cht
gauge
spark plug
tank
level
sensor
L
tank level
gauge
chamber
level
sensor
L
chamber level
gauge
100k
10k
2
-
7
LM741
3
+
6
4
100k
detector
.01uf
"pump active"
1k
pump
10k
E3055T
ground

FIGURE 4 E-SCHEMATIC

BUILD YOUR OWN WATER VAPOR SYSTEM CONTROLLER FROM THE-SHELF MATERIALS **REV. A**

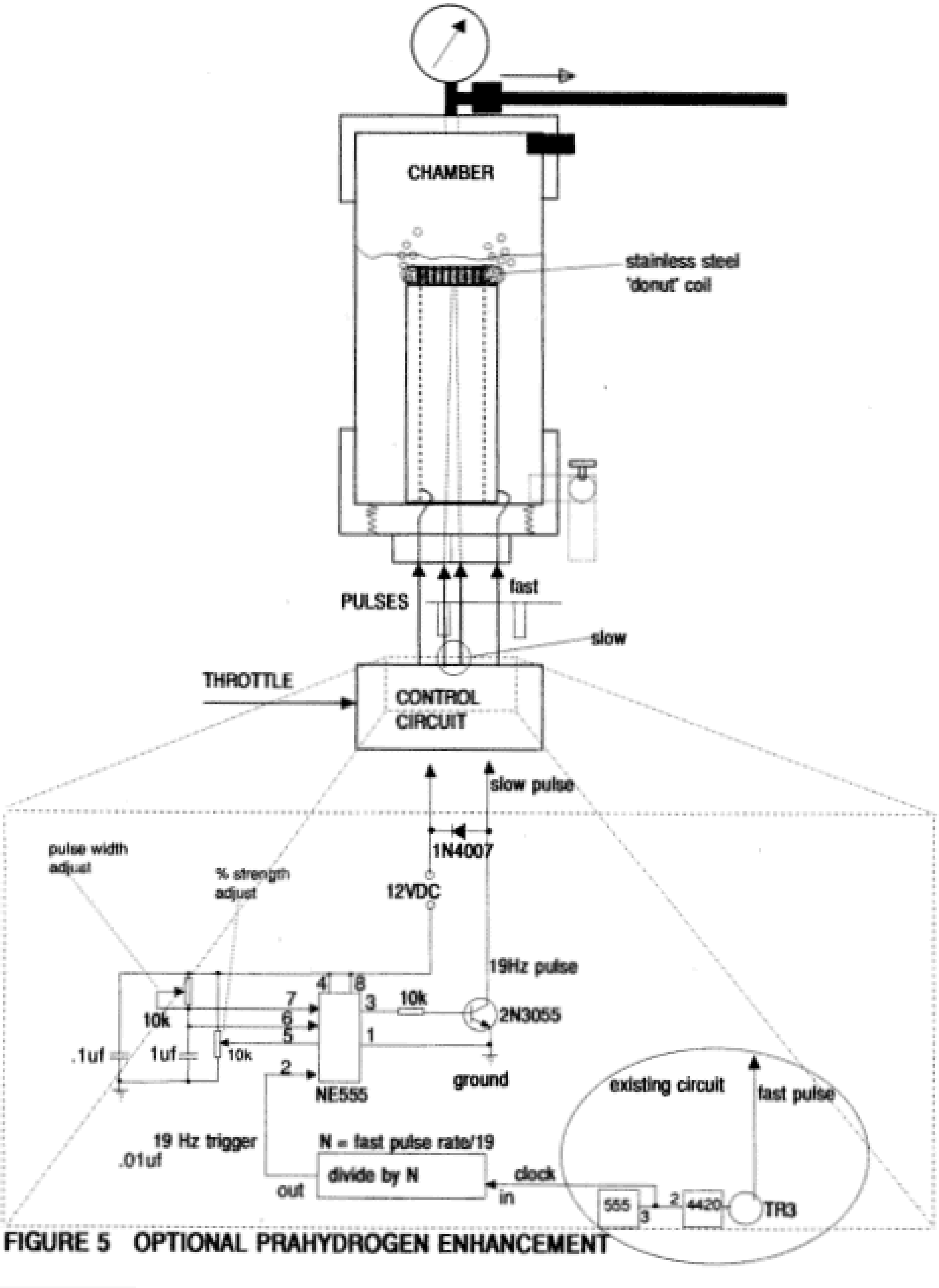
CHAMBER
stainless steel 'donut' coil
PULSES
fast
slow
THROTTLE
CONTROL CIRCUIT
slow pulse
1N4007
12VDC
pulse width adjust
% strength adjust
19Hz pulse
10k
4
8
7
6
5
3
1
2
2N3055
10k
.1uf
1uf
10k
ground
NE555
19 Hz trigger
.01uf
N = fast pulse rate/19
divide by N
out
clock
in
existing circuit
fast pulse
555
3
2
4420
TR3

FIGURE 5 OPTIONAL PRAHYDROGEN ENHANCEMENT

BUILD YOUR OWN WATER VAPOR SYSTEM CONTROLLER FROM THE-SHELF MATERIALS

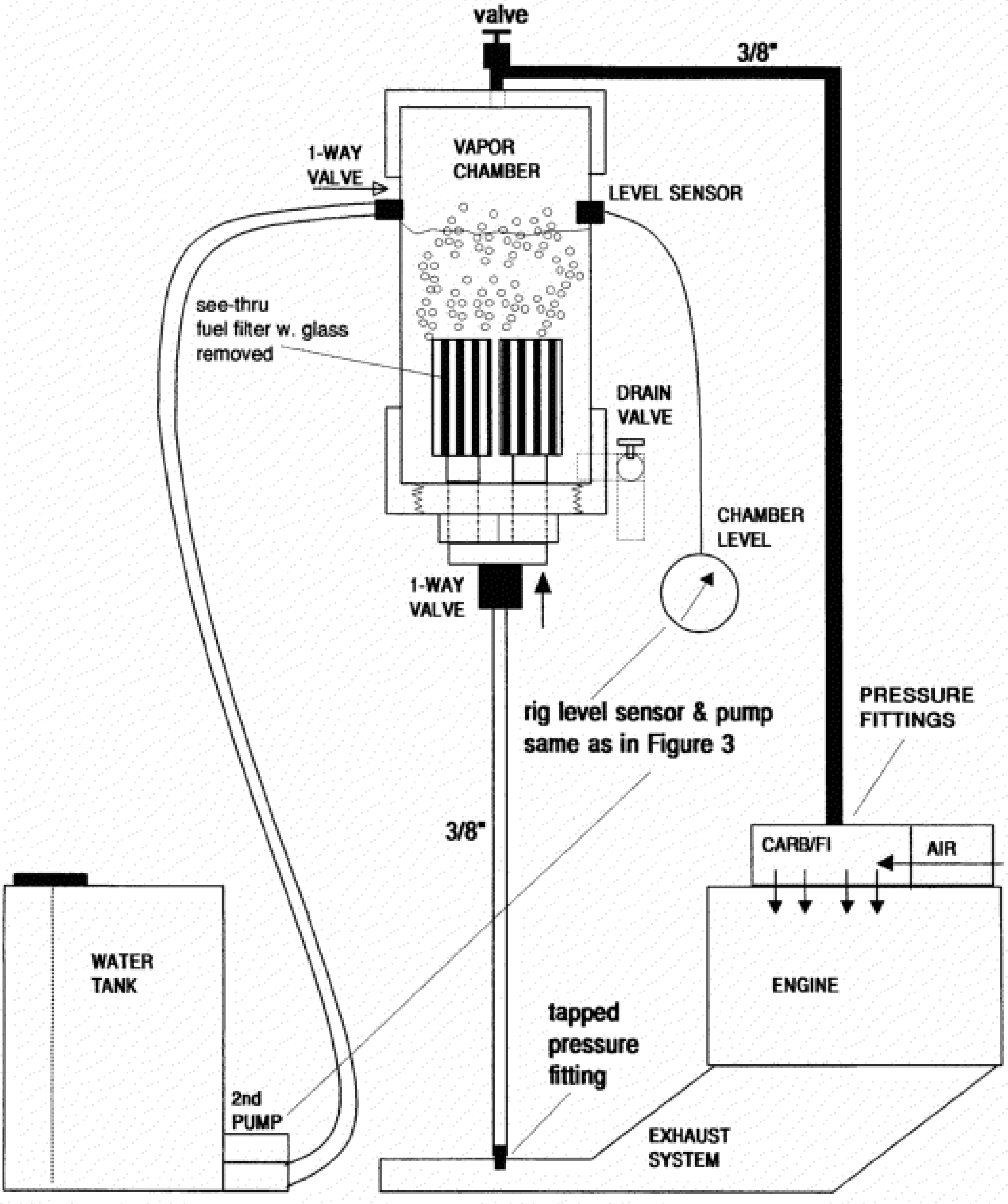
valve
3/8"
VAPOR CHAMBER
1-WAY VALVE
LEVEL SENSOR
see-thru fuel filter w. glass removed
DRAIN VALVE
CHAMBER LEVEL
1-WAY VALVE
rig level sensor & pump same as in Figure 3
PRESSURE FITTINGS
3/8"
CARB/FI
AIR
WATER TANK
ENGINE
tapped pressure fitting
2nd PUMP
EXHAUST SYSTEM

FIGURE 6 OPTIONAL WATER COOLING

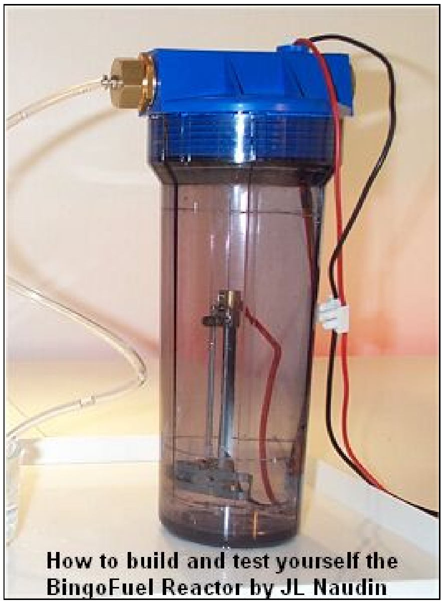
How to build and test yourself the
BingoFuel Reactor by JL Naudin

How to build yourself the BingoFuel Reactor v1.1

*created on April 2, 2003 - **JLN Labs** - Last update April 22, 2003*

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All informations and diagrams are published freely (freeware) and are intended for a private use and a non commercial use.

You will find in this page all the details for building and testing yourself the BingoFuel Reactor v1.1.

The BingoFuel Reactor v1.1 uses common parts which can be found easily in any plumbing shops, no machining and special tools are required. The main part used is a simple water filtration unit with its anti-scale cartdridge (see the photo below).

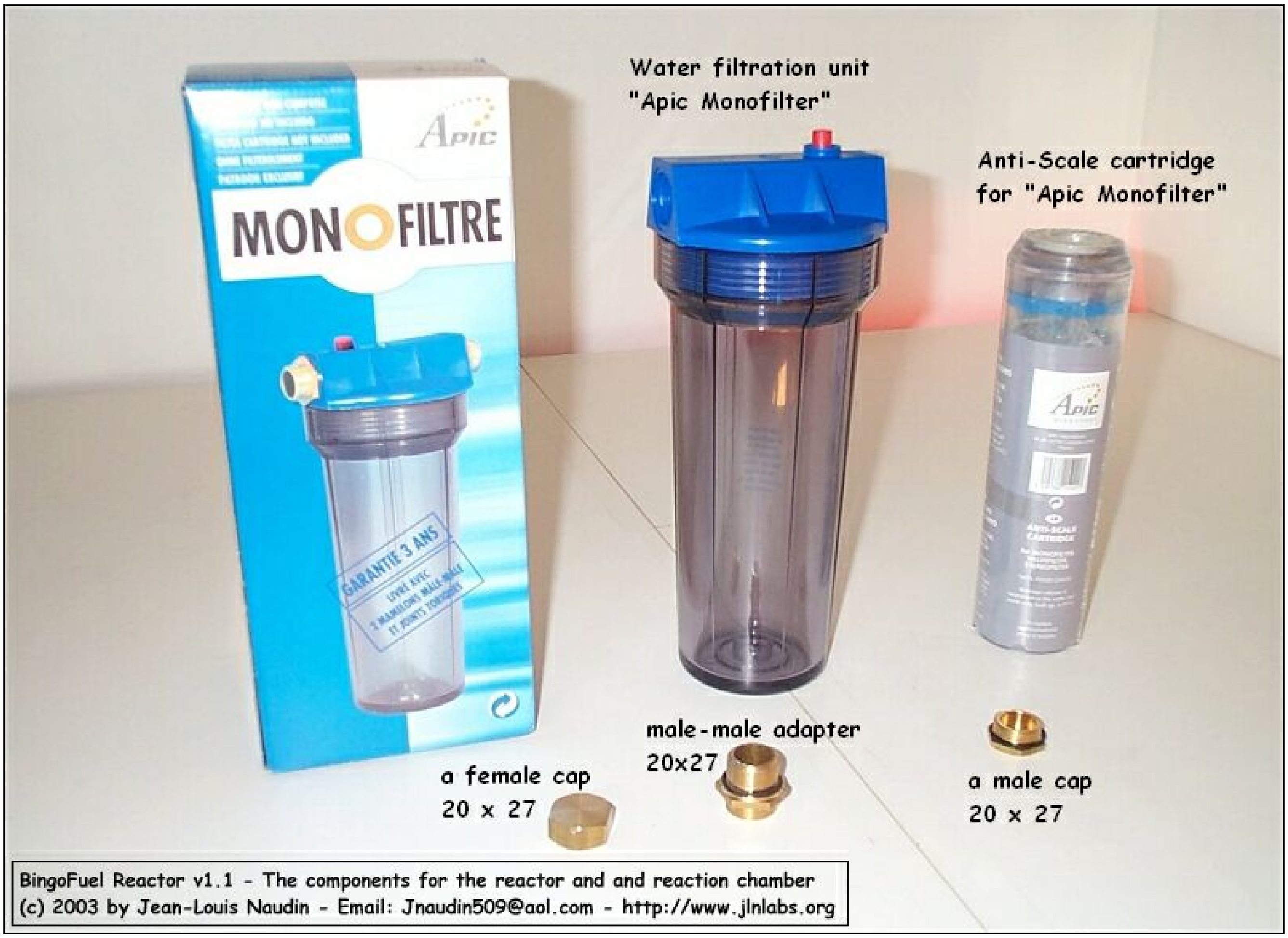
MONOFILTRE
Apic
GARANTIE 3 ANS
Water filtration unit
"Apic Monofilter"
Anti-Scale cartridge
for "Apic Monofilter"
male-male adapter
20x27
a female cap
20 x 27
a male cap
20 x 27

BingoFuel Reactor v1.1 - The components for the reactor and and reaction chamber
(c) 2003 by Jean-Louis Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

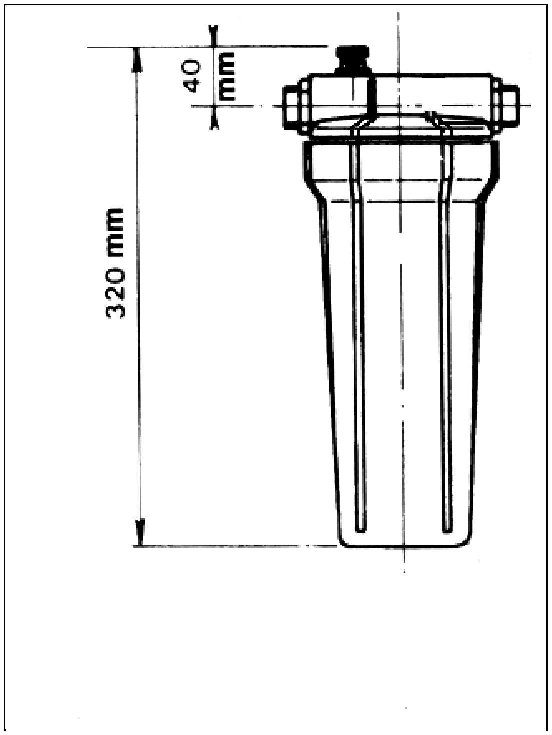

(c) 2003 JL Naudin

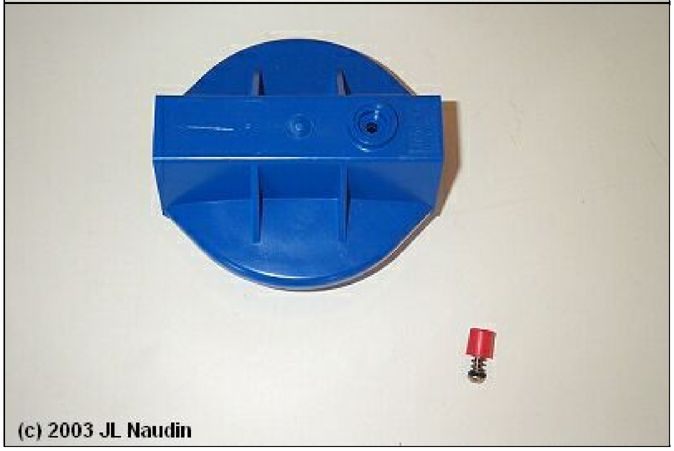
(c) 2003 JL Naudin

Step 1 : remove the purge valve (the red button) from the head of the water filtration unit.

(c) 2003 JL Naudin

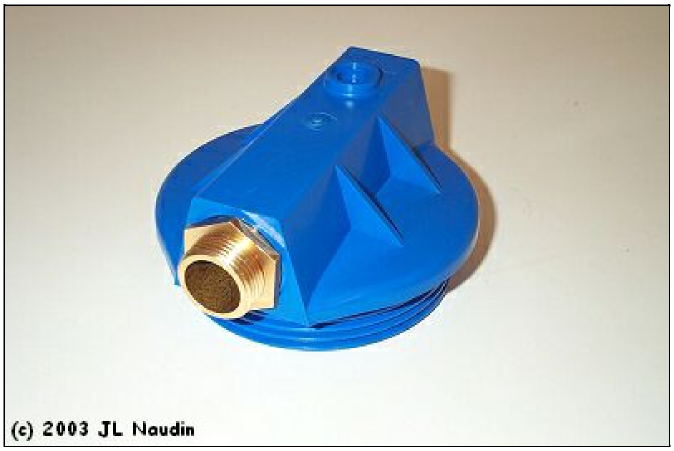

Step 2 : put the 20x27 brass cap at the input and the 20x27 female-female adapter on the device at the output
as shown in the pictures above

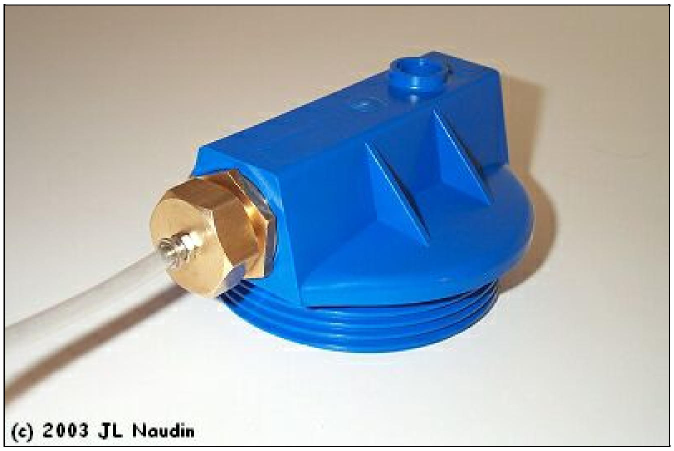

Step 3 : drill a small hole into the 20x27 female cap and put a silicon tube with an adapter on the cap,
and then screw the cap on the output of the head of the device

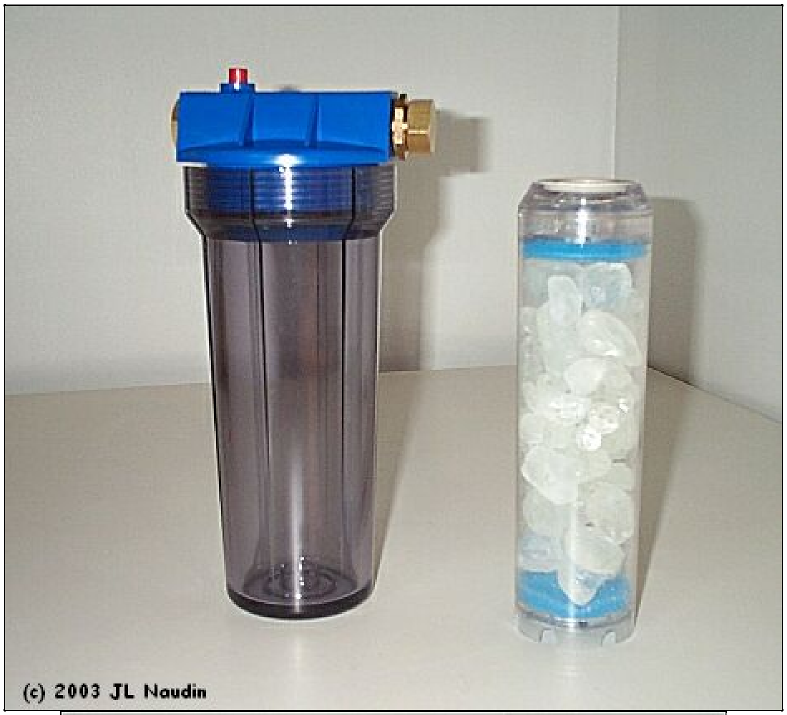
(c) 2003 JL Naudin

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Step 4 : Take the anti-scale cartridge and remove the bottom plastic grid and then all the crystals inside the cartdridge.

Below, all the components required for building the plasma reaction chamber.

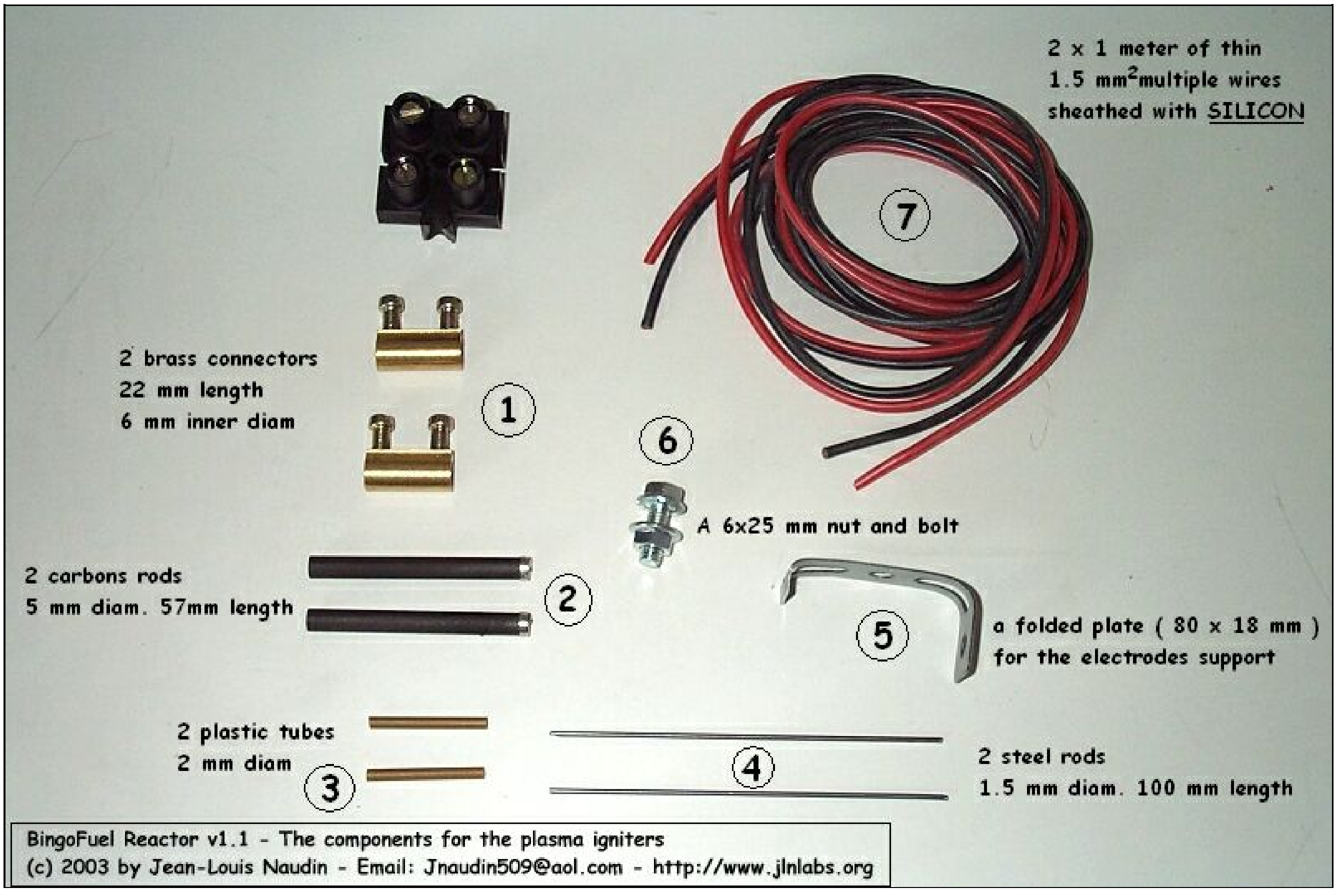
2 x 1 meter of thin
1.5 mm² multiple wires
sheathed with SILICON
7
2 brass connectors
22 mm length
6 mm inner diam
1
6
A 6x25 mm nut and bolt
2 carbons rods
5 mm diam. 57mm length
2
a folded plate (80 x 18 mm)
for the electrodes support
5
2 plastic tubes
2 mm diam
3
4
2 steel rods
1.5 mm diam. 100 mm length
BingoFuel Reactor v1.1 - The components for the plasma igniters
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Note : You must use two multiple thin wires cables (1.5 mm^2) sheated with silicon due to the overheating of the wire
produced by the strong current flow.

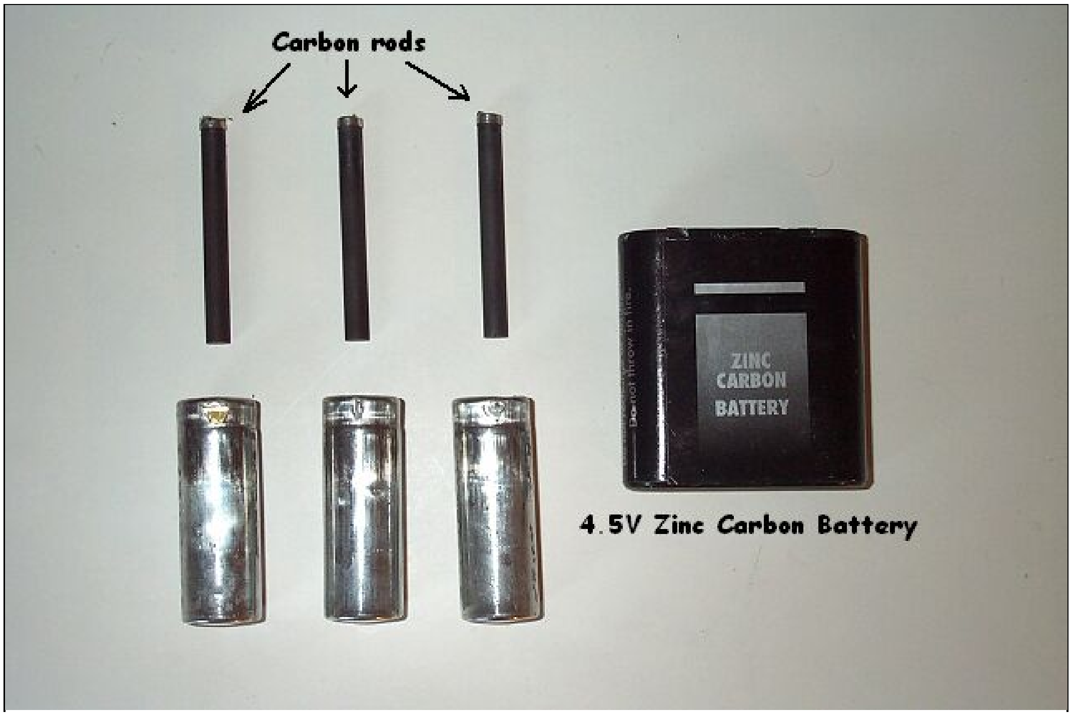
Carbon rods
ZINC
CARBON
BATTERY
Do not throw in fire
4.5V Zinc Carbon Battery

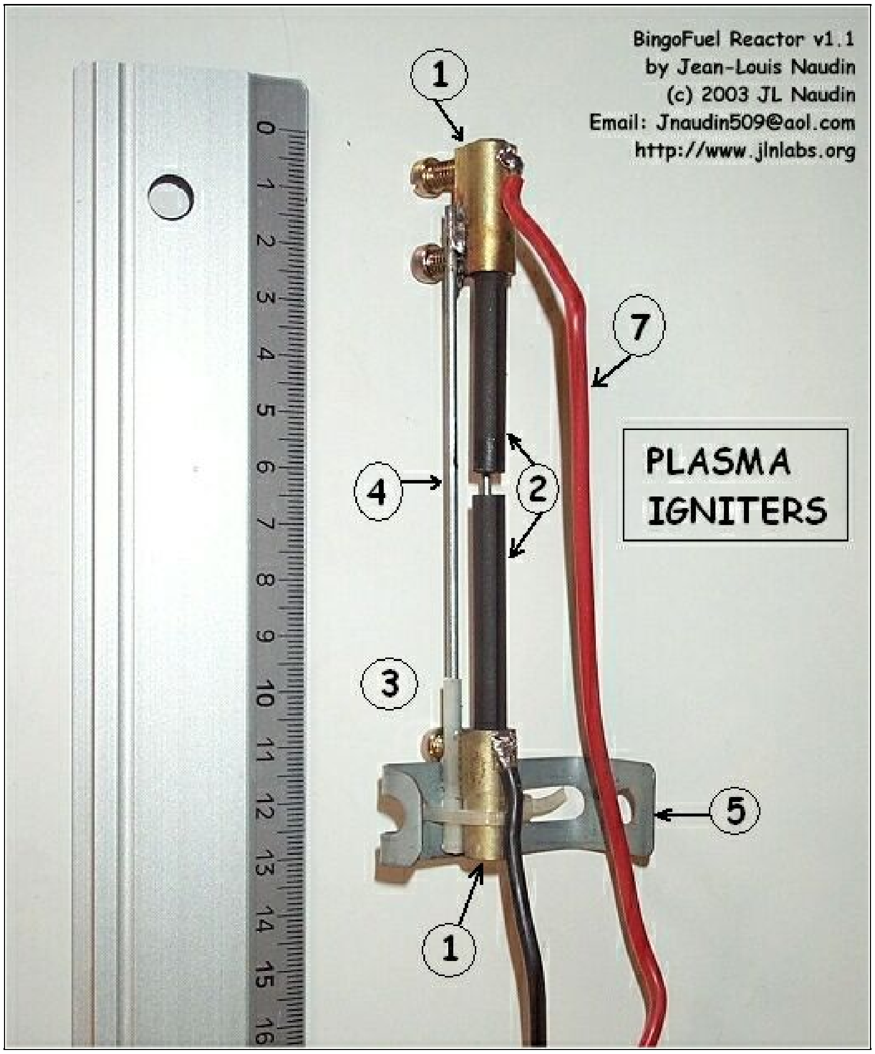
BingoFuel Reactor v1.1
by Jean-Louis Naudin
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PLASMA IGNITERS
1
2
3
4
5
7
1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Step 5 : Mount all the components as shown in the photo above

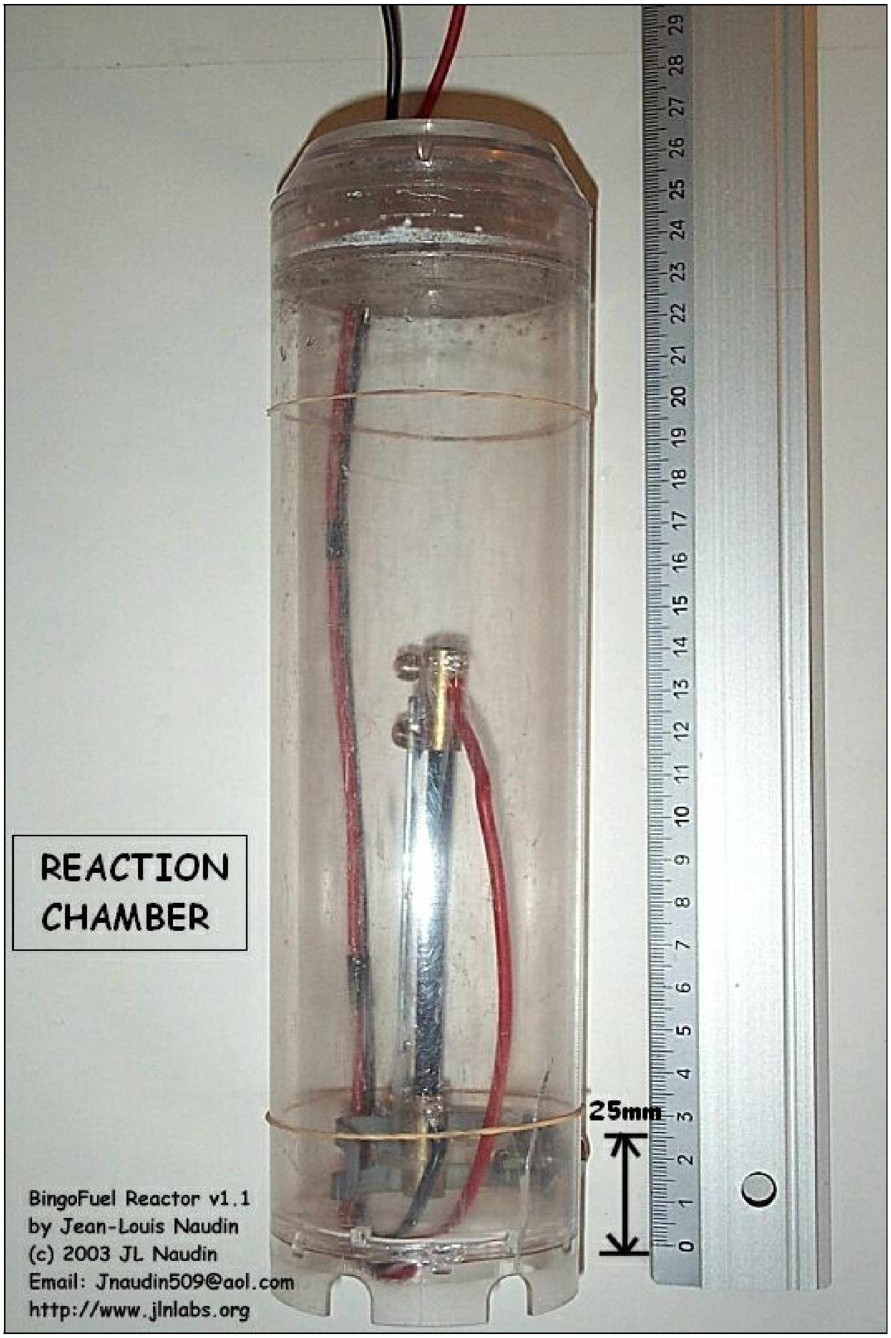
REACTION CHAMBER
25mm
BingoFuel Reactor v1.1
by Jean-Louis Naudin
(c) 2003 JL Naudin
Email: Jnaudin509@aol.com
http://www.jlnlabs.org

Step 6 : Drill a 6 mm diameter hole at 25 mm from the bottom of the plastic cartridge, then fix the plasma igniters with a 6x25 mm nut and a bolt as shown in the photo above

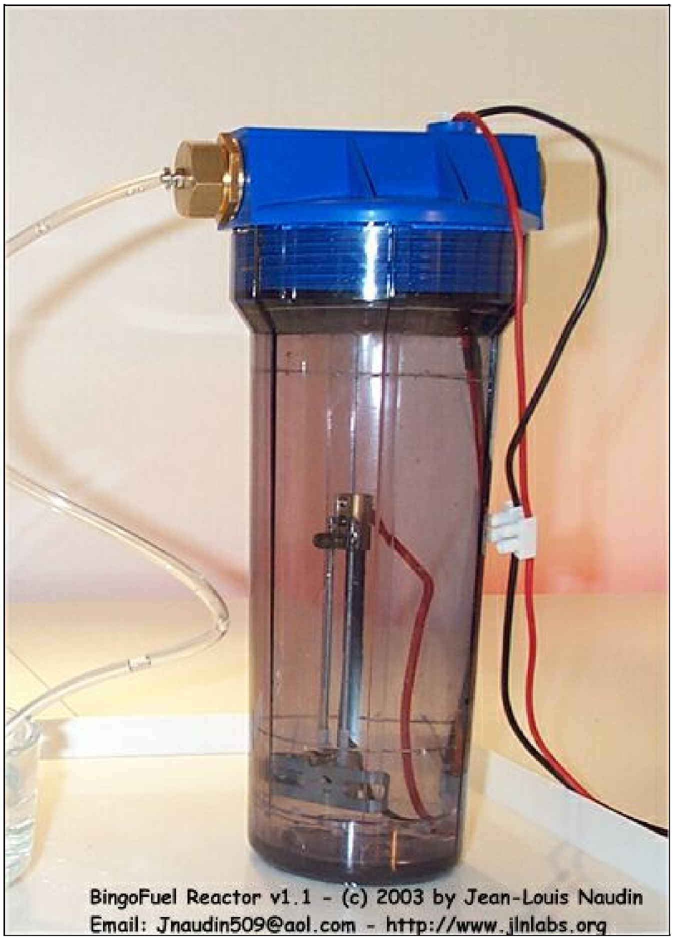
BingoFuel Reactor v1.1 - (c) 2003 by Jean-Louis Naudin
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Step 7 : Place the reaction chamber into the transparent tank then fill the reactor with ordinary tap water

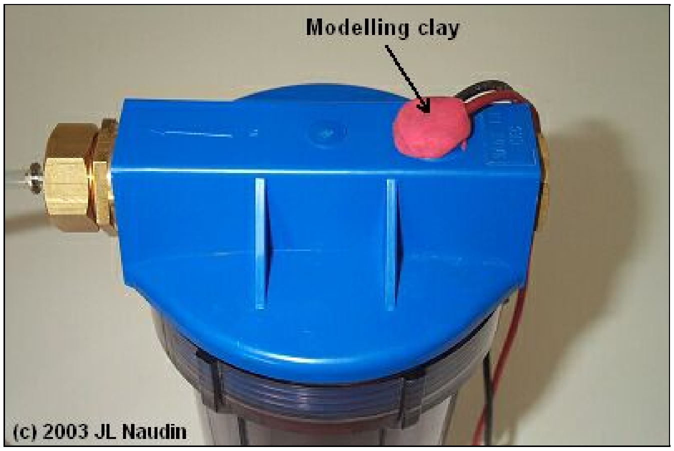
Modelling clay
(c) 2003 JL Naudin

Step 8 : Put modelling clay to close the hole around the electrical wires.

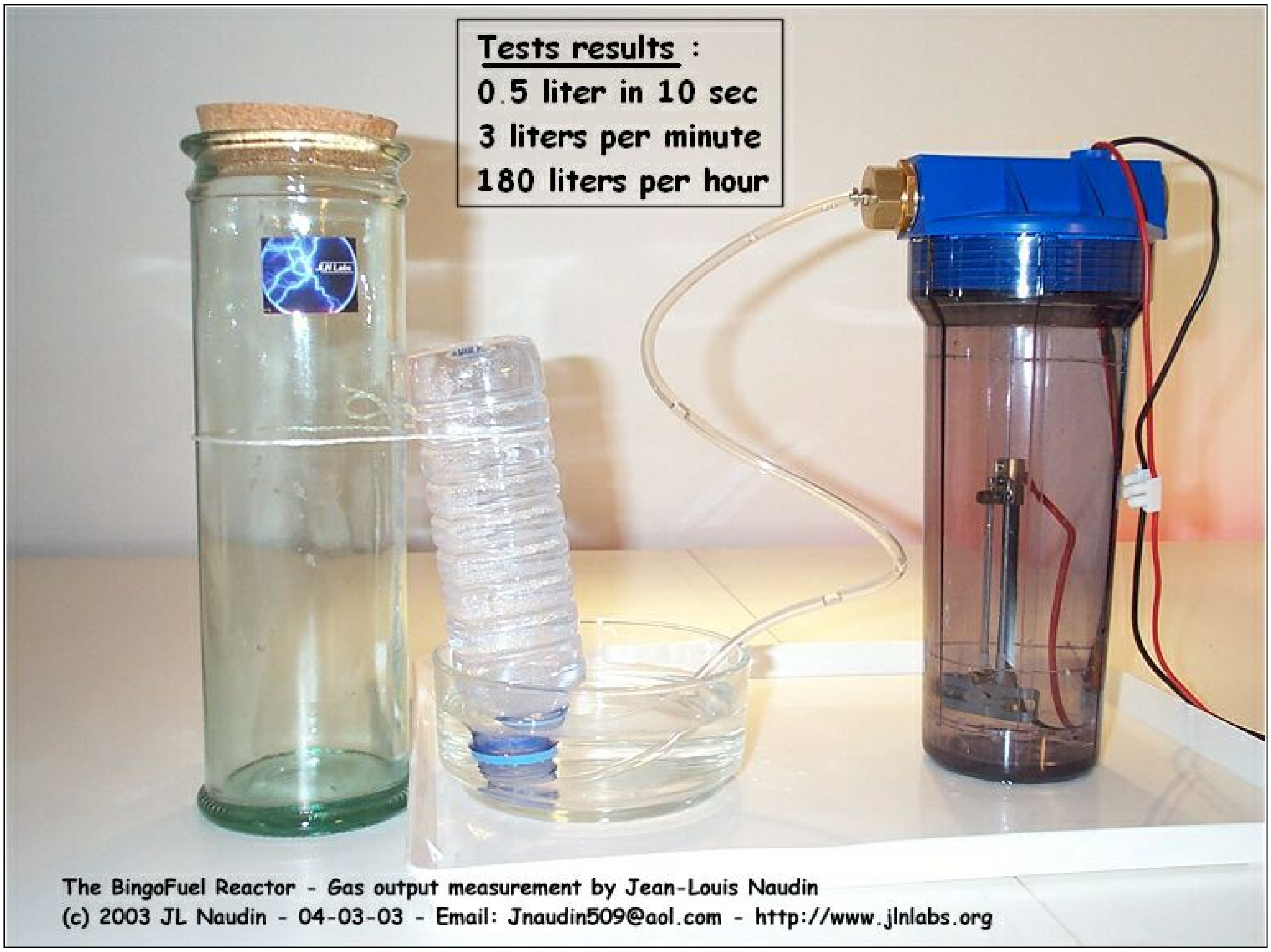
Tests results :
0.5 liter in 10 sec
3 liters per minute
180 liters per hour
JLN Labs
The BingoFuel Reactor - Gas output measurement by Jean-Louis Naudin
(c) 2003 JL Naudin - 04-03-03 - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

Notes from Jean-Louis Naudin : The BingoFuel Reactor v1.1 is only a demonstrator, this is a proof of concept device which shows that the device works really. This version is able to produce a great amount of synthetic gas during some minutes. A new version of the BingoFuel Reactor is under development, this version (v2.0) will be able to run for a long time without tuning and adjustment...

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See also :

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-
  CFR v1.2 for BingoFuel production
(c) 2003 by JL Naudin - May 13, 2003
  The CFR for producing BingoFuel...

Email : **JNaudin509@aol.com**

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return to the BingoFuel project home page

Free web stats

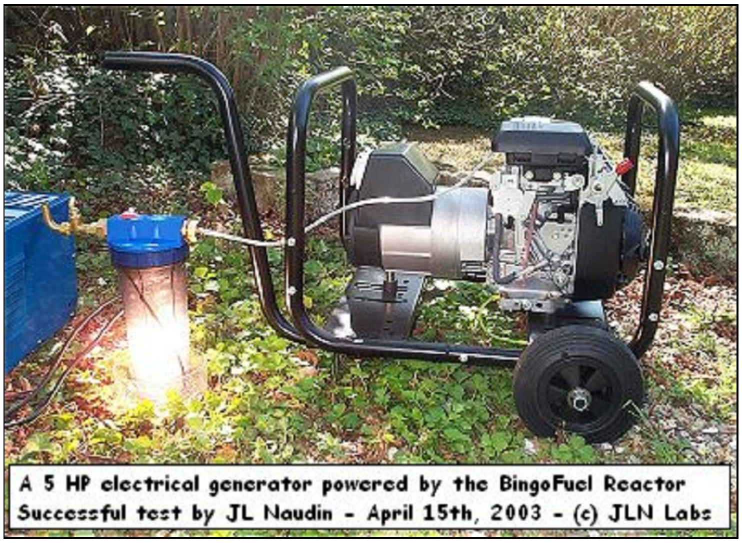
A 5 HP electrical generator powered by the BingoFuel Reactor
Successful test by JL Naudin - April 15th, 2003 - (c) JLN Labs

A 5HP Electrical Generator fully powered with the BingoFuel Reactor

*created on April 2, 2003 - **JLN Labs** - Last update April 18, 2003*

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On April 15th, 2003, an Electrical Generator powered with a 5HP (160 cm^3) 4-stroke combustion engine (a Honda GC160) has been tested successfully with the *BingoFuel Reactor*. The 5HP combustion engine has been fully powered with synthetic gas produced by the *BingoFuel Reactor*.

The Electrical Generator tested with the *BingoFuel Reactor* is a Ranger2500 from SDMO (see below) :

HONDA
GC160
5.0
SDMO
RANGER 2500
www.sdmo.com

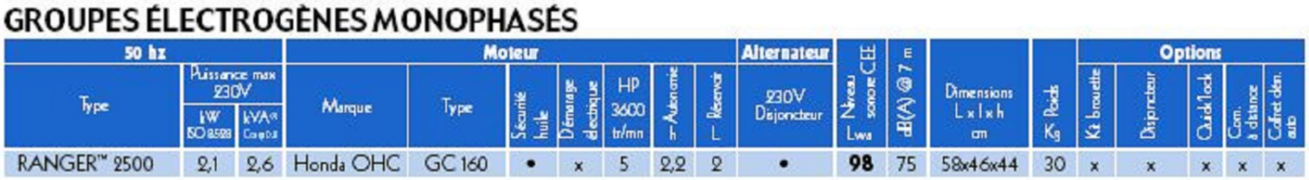

GROUPES ÉLECTROGÈNES MONOPHASÉS

50 hz			Moteur							Alternateur					Options				
	Puissance max 230V																		
Type	kW ISO 8528	kVA Cos φ 0,8	Marque	Type	Sécurité huile	Démarrage électrique	HP 3600 tr/mn	h Autonomie	L Réservoir	230V Disjoncteur	Niveau sonore CEE Lwa	dB(A) @ 7 m	Dimensions L x l x h cm	Kg Poids	Kit brouette	Disjoncteur	Quick'lock	Com. à distance	Coffret dém. auto
RANGER™ 2500	2,1	2,6	Honda OHC	GC 160	•	x	5	2,2	2	•	**98**	75	58x46x44	30	x	x	x	x	x

	ENGINE SPECIFICATIONS
MODEL	**HONDA GC160**
Type	4-stroke, overhead camshaft single cylinder
Total Displacement	160 cm^3 (9.8 cu in)
Bore & Strike	64 x 50 mm (2.5 x 2.0 in)
Max Horsepower (Gross)	3.7 kw [1](5.0hp) at 3,600 rpm
Max Torque (Gross)	10.3 N·m (1.05 kgf·m, 7.6 lbf·ft) at 2,500 rpm
Compression Ratio	8.5: 1
Fuel Consumption	313 g/kWh (230 g/HPh, 0.51 lb/HPh)
Cooling System	Forced-air
Ignition System	Transistorized magneto ignition
Ignition Timing	20° B.T.D.C
Spark Plug	BPR6ES (NGK)
Carburetor	Horizontal type, butterfly valve
Air Cleaner	Dry (paper) type
Governor	Centifugal mechanical governor
Lubricating System	Splash
Oil Capacity	0.58 lt (0.61 US qt, 0.55 Imp qt)
Recommended operating ambient tempature	-15°C to 40°C (5°F to 104°F)
Starting System	Recoil starter
Stopping System	ignition primary circuit ground
Fuel Used	Automotive unleaded gasoline (minimum 86 pump octane)
Fuel tank capacity	2.0 lt (0.53 US gal, 0.44 imp gal)
P.T.O. Shaft Rotation	Counterclockwise (viewed from P.T.O. side)

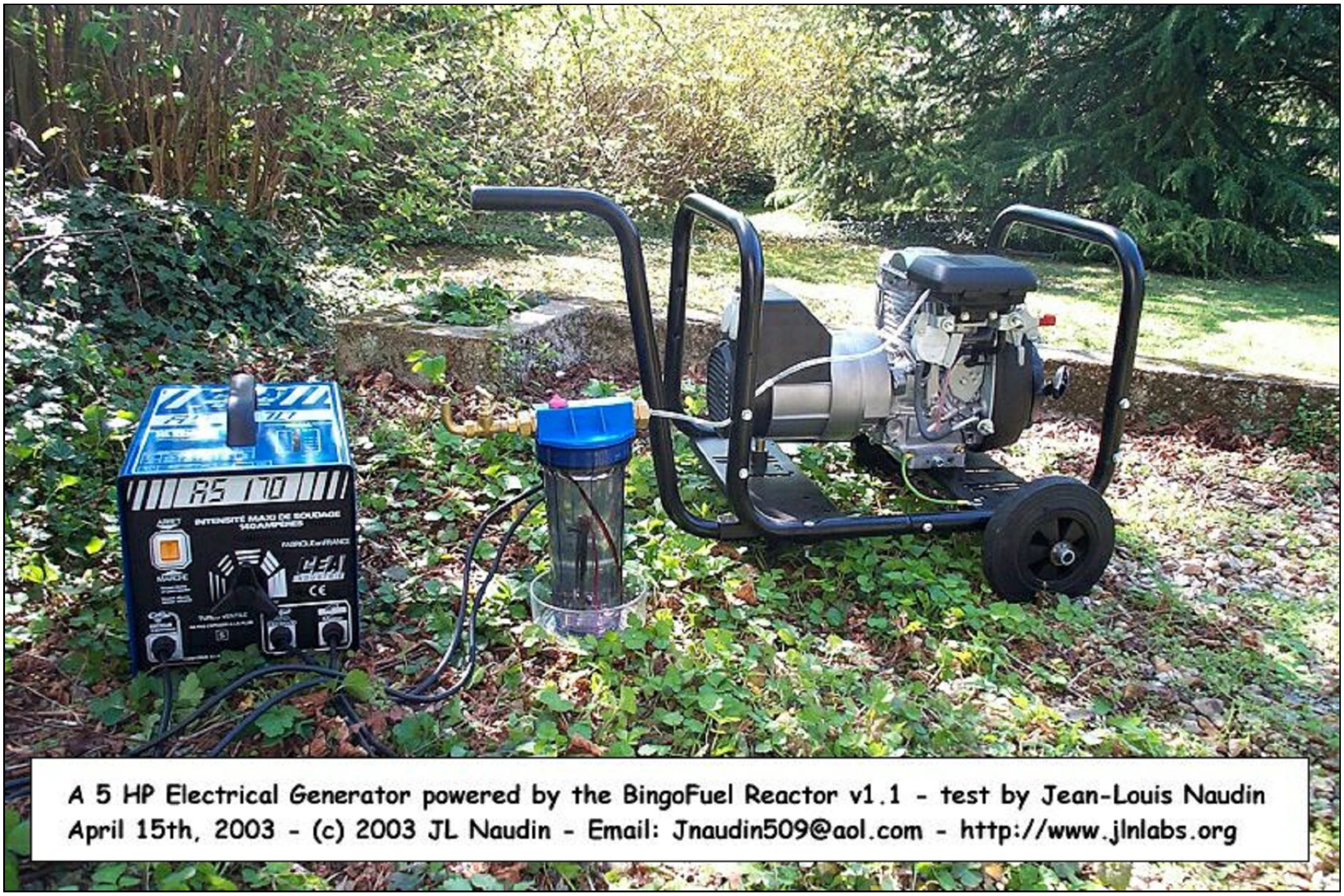
AS 170
INTENSITÉ MAXI DE SOUDAGE
140 AMPERES
CEA

A 5 HP Electrical Generator powered by the BingoFuel Reactor v1.1 - test by Jean-Louis Naudin
April 15th, 2003 - (c) 2003 JL Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

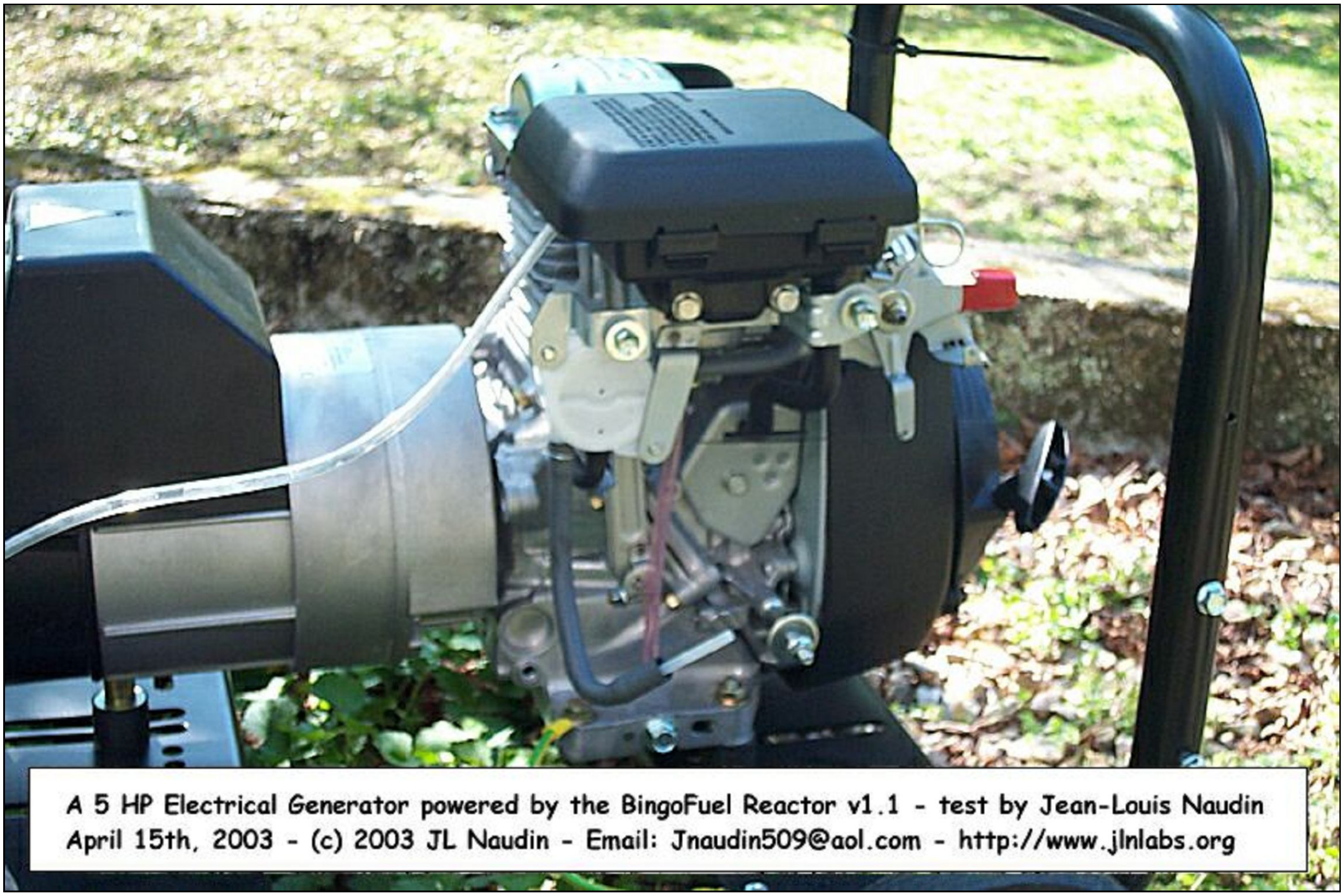

A 5 HP Electrical Generator powered by the BingoFuel Reactor v1.1 - test by Jean-Louis Naudin
April 15th, 2003 - (c) 2003 JL Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

Photo above: The fuel tank (not used here) has been completly removed for this test.

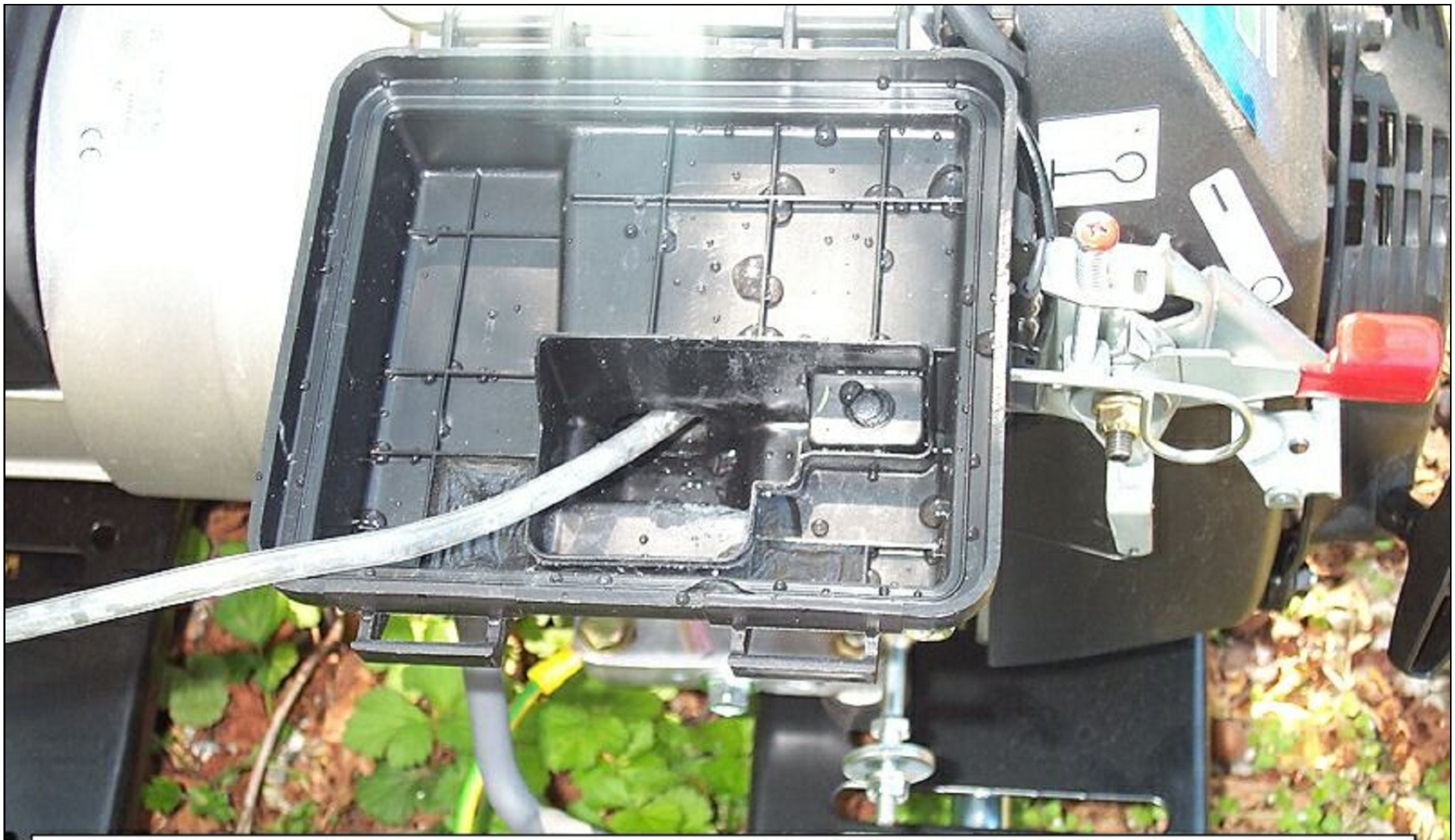

A 5 HP Electrical Generator powered by the BingoFuel Reactor v1.1 - test by Jean-Louis Naudin
April 15th, 2003 - (c) 2003 JL Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

Photo above: The air filter has been removed and the synthetic gas output is directly placed at the carburettor input.

Tests results with the BingoFuel Reactor v1.1

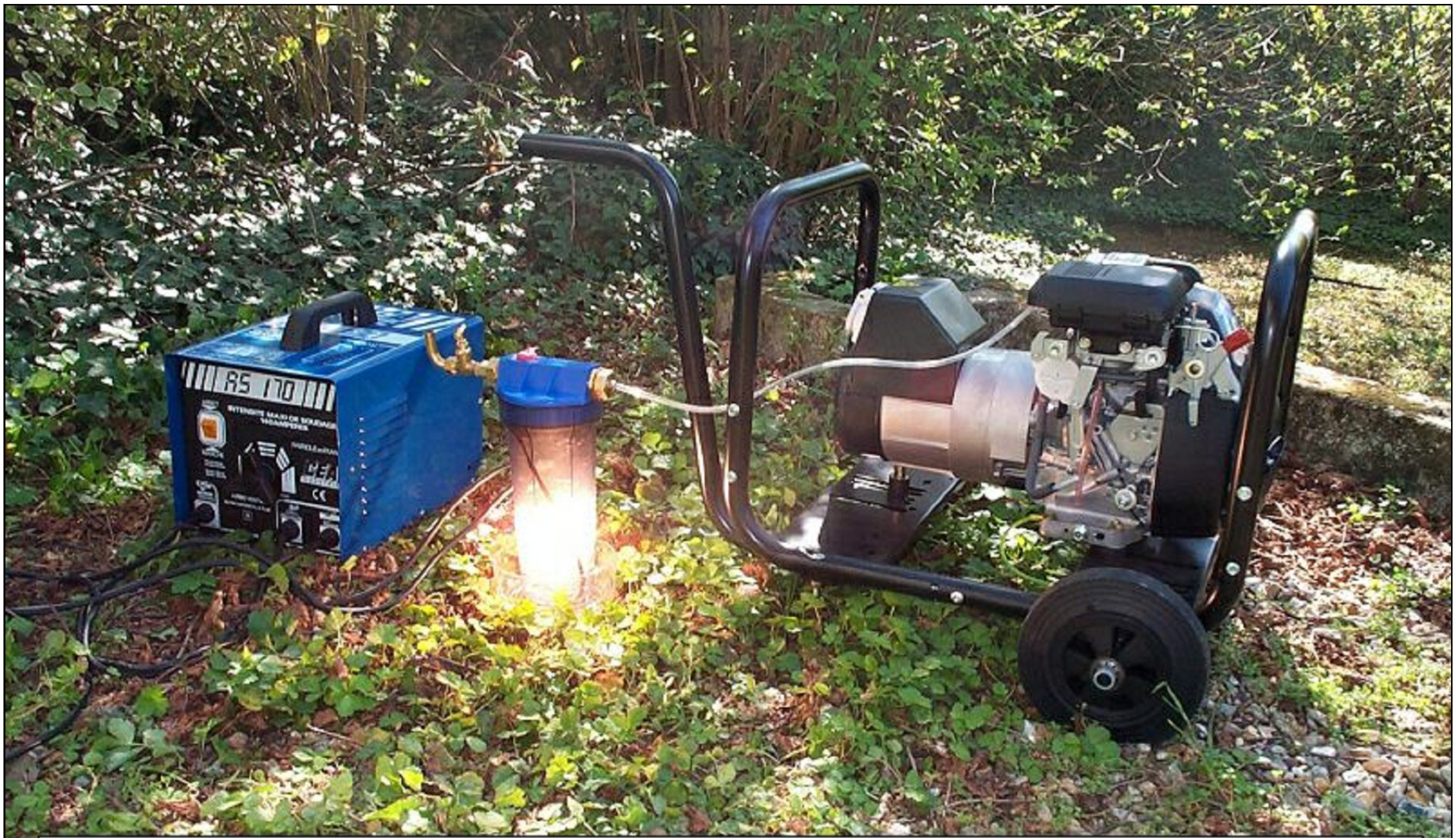

A 5 HP Electrical Generator powered by the BingoFuel Reactor v1.1 - test by Jean-Louis Naudin
April 15th, 2003 - (c) 2003 JL Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

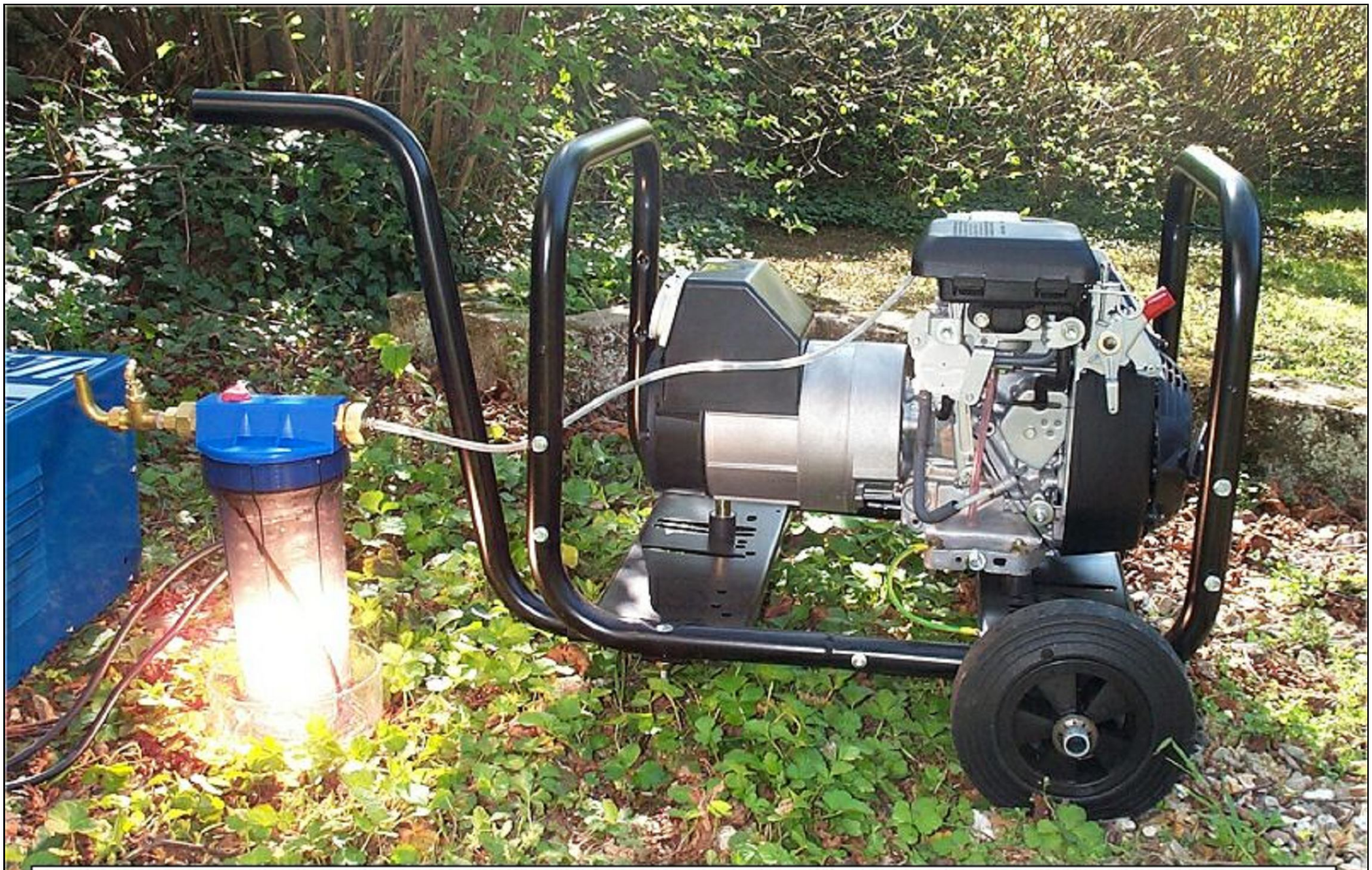

A 5 HP Electrical Generator powered by the BingoFuel Reactor v1.1 - test by Jean-Louis Naudin
April 15th, 2003 - (c) 2003 JL Naudin - Email: Jnaudin509@aol.com - http://www.jlnlabs.org

Two tests runs have been conducted successfully, in all the cases the 5HP engine has worked without any problem.

See the video of the 5HP engine fully powered with the BingoFuel Reactor

To see the video, the free downloadable RealPlayer is required real player FREE

You may download free the RealPlayer 8 Basic at : http://proforma.real.com/real/player/blackjack.html

RealOne Player
Fichier
A 5HP Electrical Generator powe…
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A 5 HP Power Generator
fully powered by the
BingoFuel Reactor v 1.1
April 15, 003
(c) 2003 by JL Naudin
Email: Jnaudin509@aol.com
http://www.jlnlabs.org

Click on the picture above to see the video (937 Kb)

Comments from JL Naudin : These tests are very encouraging and confirms fully that the synthetic gas generated by the *BingoFuel Reactor* can be used as fuel for a common combustion engine...

See also the previous tests :

- 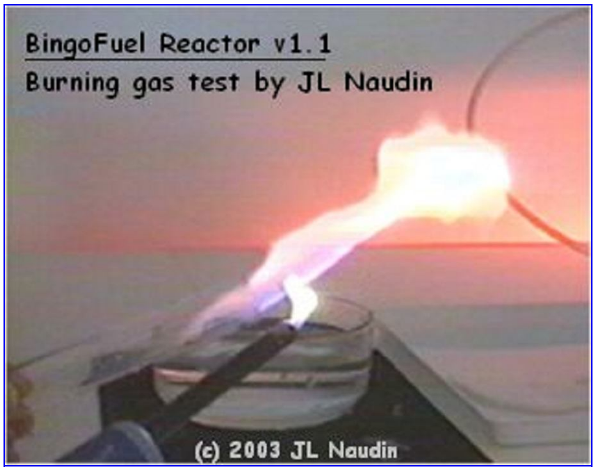
  BingoFuel Reactor v1.1
  Burning gas test by JL Naudin
  (c) 2003 JL Naudin
  Burning gas tests generated by the *BingoFuel Reactor*

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return to the BingoFuel project home page

Weboscope free

The Aquafuel(tm) Generator
by JL Naudin 12-06-98

The AquaFuel® generator

How to generate gas from water for use as Fuel

created on 12-06-98 - ***JLN Labs*** **-** last update on 04-03-2003

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On 12-06-98, I have built and reproduced successfully a very simple AquaFuel™ generator:
The AquaFuel™ is fully based on the Hilliary Eldridge patent US 603,058 "Electrical Retort" granted on April 26, 1898.

This is a non fossil combustible gas which is produced by an electric discharge of carbon arcs within distilled, fresh, salt or other types of water, thus being essentially composed of Hydrogen, Oxygen, Carbon and their compounds.

Today, there are a lot of names for this synthetic gas such as Aquafuel™, Aqualene™, Magnegas™, TrueFuel™, Carbo-hydrogen™....

AquaFuel: An example of the emerging new energies and the new methods for their scientific study

Author: Ruggero Maria Santilli
Comments: 22 pages, Texture
Report-no: TTL-98-004
Subj-class: General Physics
Journal-ref: Hadronic Journal Supplement, Vol. 13, pp. 1-22, 1998

In this paper we initiate studies of the emerging new forms of energy by using as a representative example the new combustible gas called AquaFuel, discovered and patented by William H. Richardson, jr., whose rights are now owned by Toups Technology Licensing, Inc. (TTL), of Largo, Florida. In essence, AquaFuel is a new energy converter capable of transforming Carbon and water into a new combustible gas via an electric discharge. We show that AquaFuel can be produced easily, safely and rapidly in large amounts, and exhibits greatly reduced emission pollutants as compared to fossil fuels of current use. Despite its simplicity,

the chemical and physical characteristics of AquaFuel are largely unknown at this writing. We then review nine basic experimental measurements which are necessary for a scientific appraisal of AquaFuel. We outline the limitations of quantum mechanics and chemistry for the treatment of {\it new} forms of energy, namely, energies which by definition should be {\it beyond} said theories. We finally point out the availability of broader theories specifically constructed for the study of new energies and point out available applications.

Link to this paper : http://arxiv.org/abs/physics/9805031

This generator produces a mixture of carbon monoxide and hydrogen (COH_2) and this is a gas wich burns very cleanly in oxygen or air, and it can be used as fuel for an internal combustion engine. When burned, COH_2 produces carbon dioxide and water vapor, so it generates very little, if any, pollution to the environnement.

Below, an analysis of this gas conducted by the NASA :

Hydrogen	46.483 %
Carbon Dioxide	9.329
Ethylene	0.049
Ethane	0.005
Acetylene	0.616
Oxygen	1.164
Nitrogen	3.818
Methane	0.181
Carbon Monoxide	38.370
Total	**100.015**

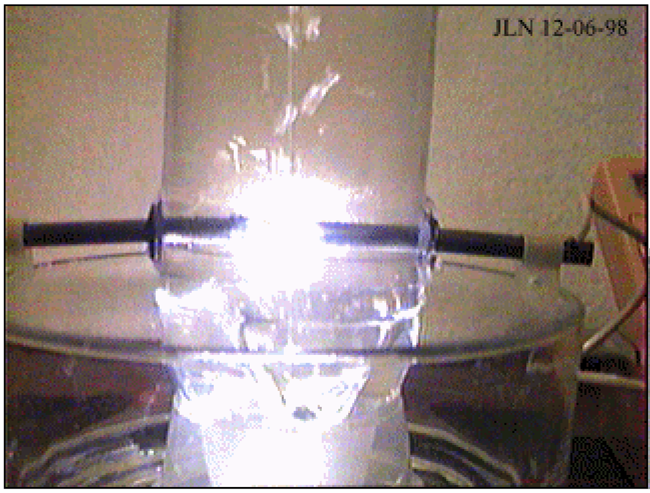

he AquaFuel(tm) Generator
Jean-Louis Naudin 12-08-98

This simple experiment is only for testing purposes and only for a proof of the concept. This small generator can't be used for a long working period and it must be used only for demonstration.

You need to get very few materials and it is very simple to build and test it....

Be Carefull, this device generates an explosive gas, *you must conduct this test in* ***a well ventiled room or better in open air****, you must not smoke during the test.. Don't forget that the carbon monoxide (CO) is a very toxic gas, so* ***never*** *breath this gas* ***before*** *burning it.* ***This experiment is not intended for the inexperienced.*** *User of* *this document should be very carefull to try anything out ! If you do it the risk of any results is just yours. I take no responsibility of anything that might happen, let it be of a wrong information or anything else.*

You need only to get :
- A little plastic soda bottle,
- two carbon rods (70mm length, 6mm diam)
- one 1 ohm 50Watts resistor
- a DC Power supply which is able to deliver 35v / 10A
- some wires, plugs and silicon cement.

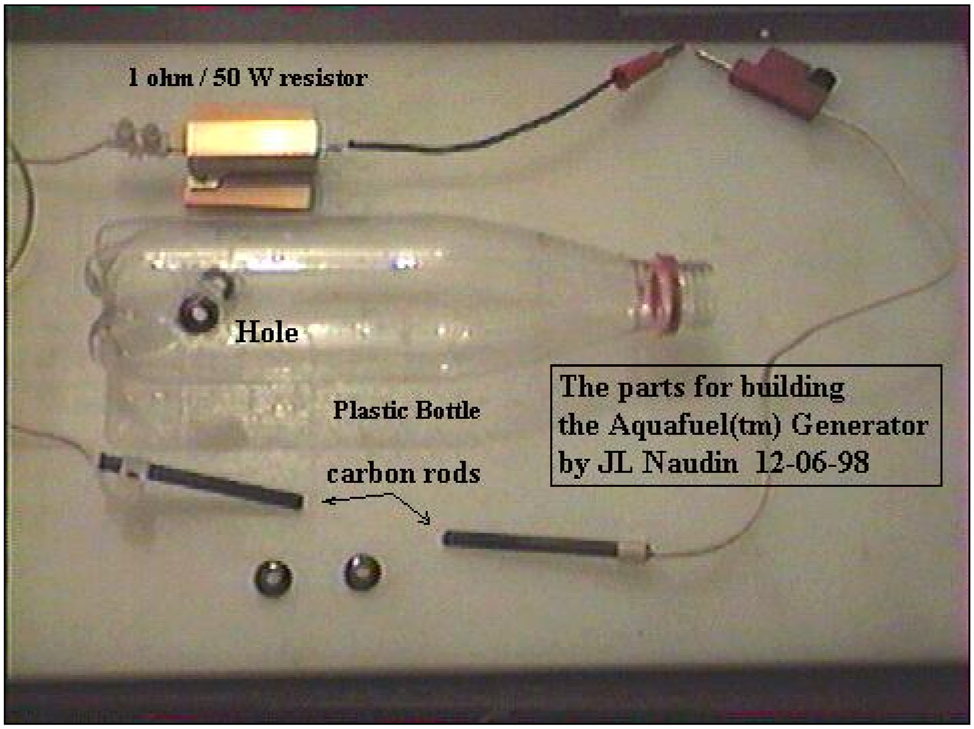
1 ohm / 50 W resistor
Hole
Plastic Bottle
carbon rods
The parts for building
the Aquafuel(tm) Generator
by JL Naudin 12-06-98

Very few material is needed.....

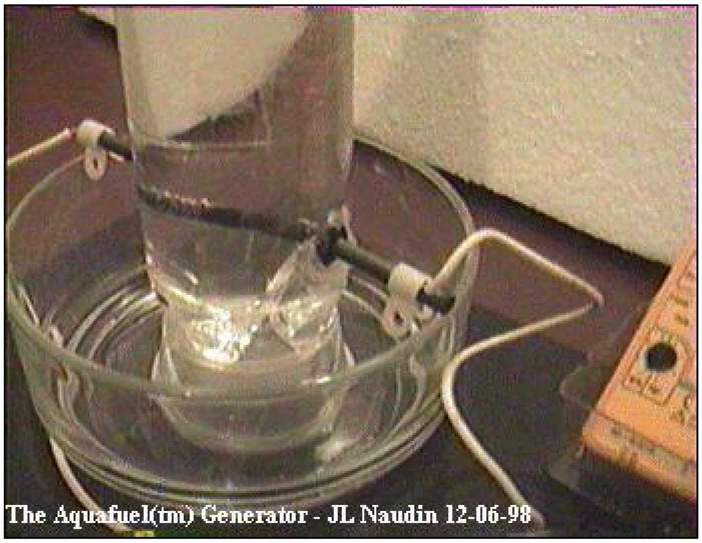
The Aquafuel(tm) Generator - JL Naudin 12-06-98

1) Drill two opposite holes (10mm diam) at 60mm from the bottom of the bottle and insert the carbon rods with a rubber washer and glue the washer with silicon cement. I suggest you to make one of the carbon rod into round shape. The two carbon rods must be just slightly in contact before you switch on (see below).

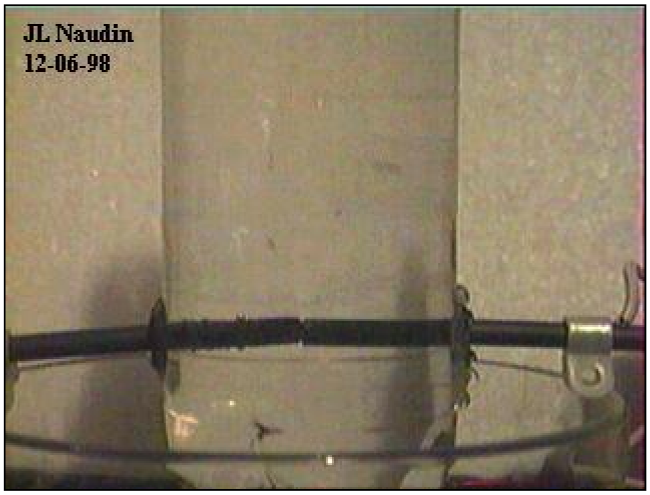
JL Naudin
12-06-98

2) Connect the 1 ohm 50W resistor in serie with one of carbon rod and one pole of your DC power supply (set for 34V/15A DC), the other pole of your power supply is connected to the other carbone rod. You may add some additional multimeters for measuring the Current and the Voltage input. Fill up your generator with only distilled or fresh water.

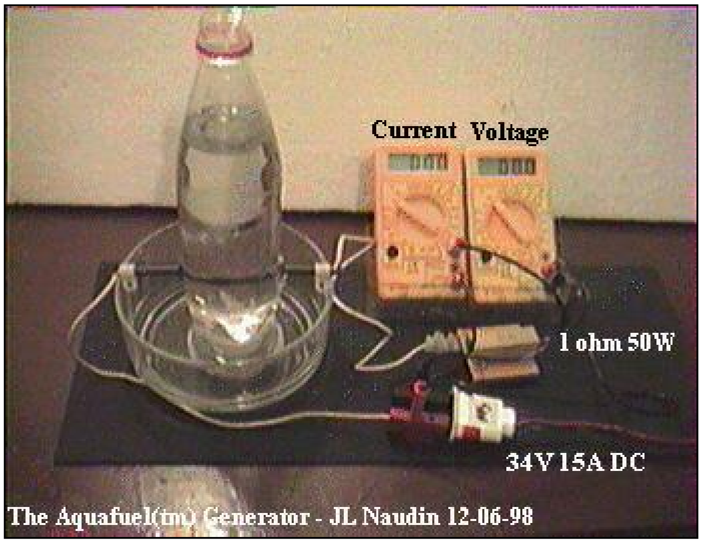
Current
Voltage
1 ohm 50W
34V 15A DC
The Aquafuel(tm) Generator - JL Naudin 12-06-98

3) Now, your are ready to produce AquaFuel™......

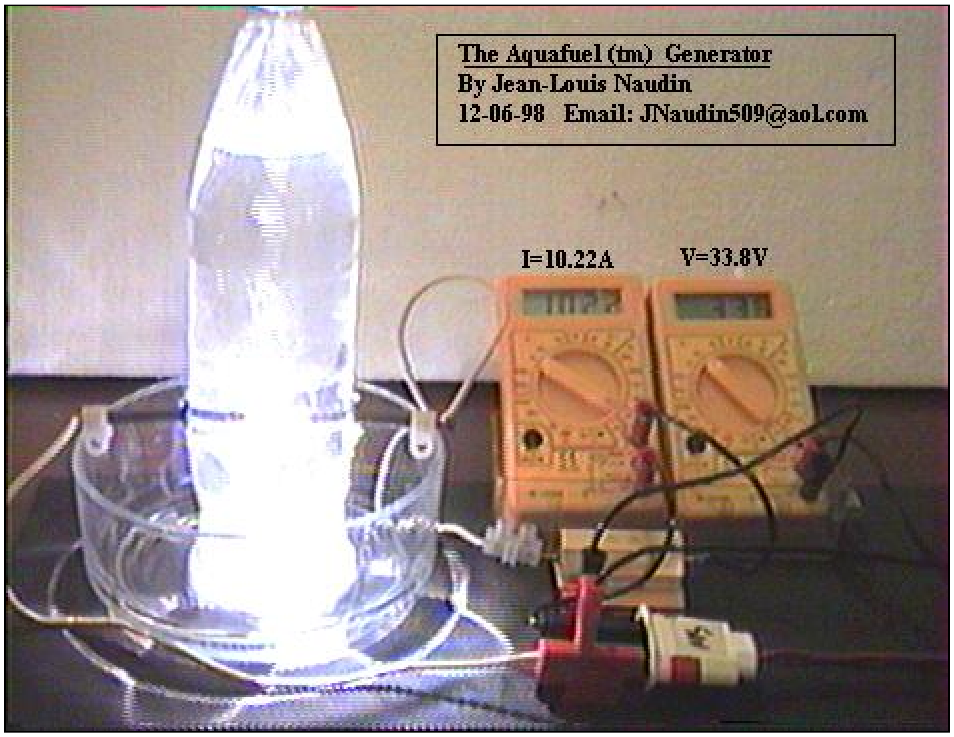
The Aquafuel (tm) Generator
By Jean-Louis Naudin
12-06-98 Email: JNaudin509@aol.com
I=10.22A
V=33.8V

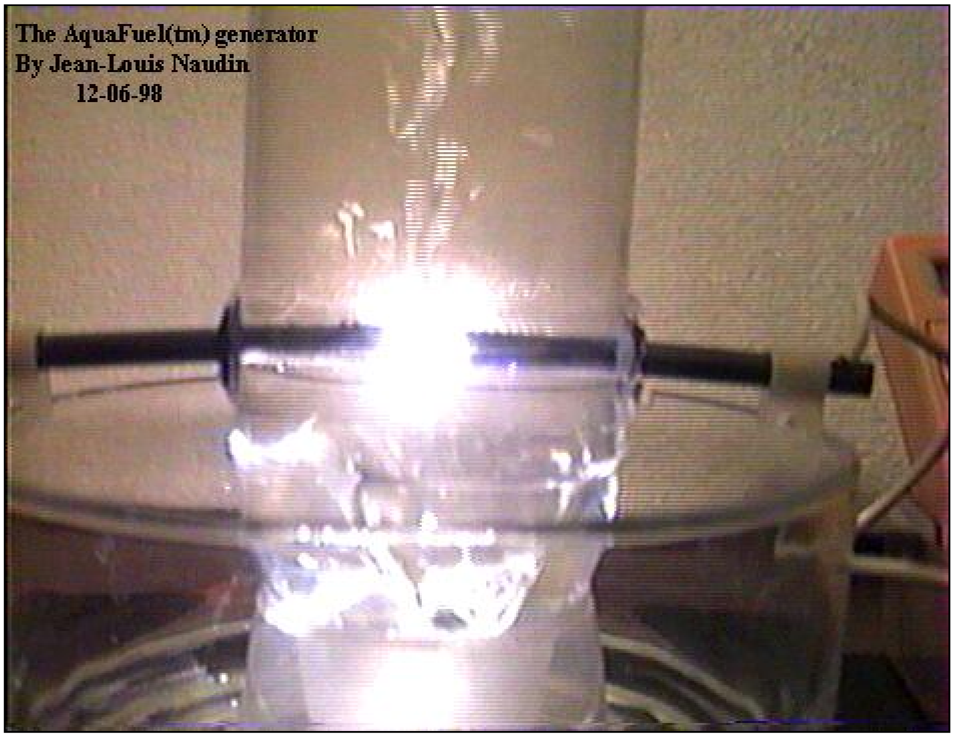
The AquaFuel(tm) generator
By Jean-Louis Naudin
12-06-98

The AquaFuel(tm) Generator
By Jean-Louis Naudin - 12-08-98

[Click here to see some animated videos of the AquaFuel(tm) generator in action]

You will see below some videos which show my AquaFuel(tm) in action and some personal comments.......

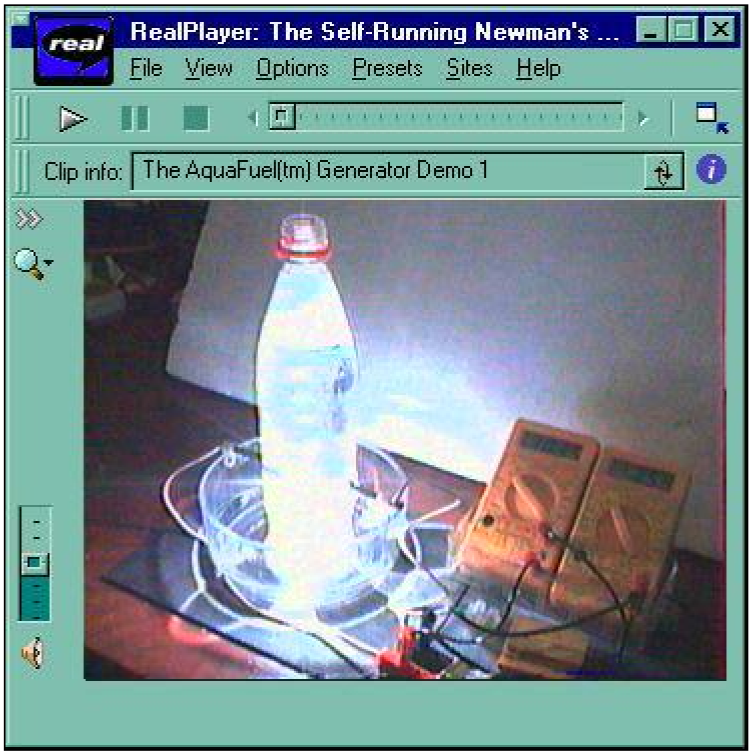
RealPlayer: The Self-Running Newman's ...
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Clip info: The AquaFuel(tm) Generator Demo 1

click here to see the [AquaFuel(tm) demo 1]() (277kb)

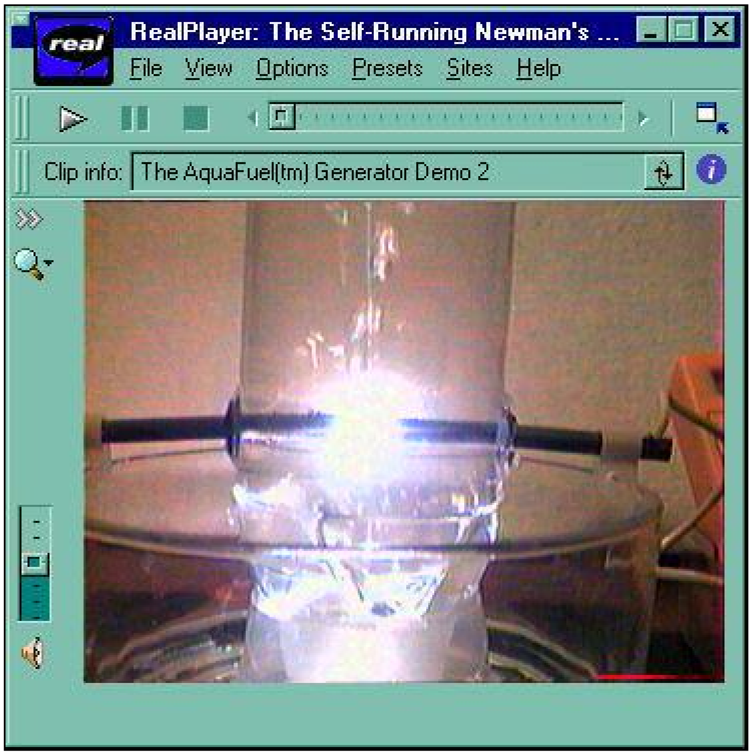
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Clip info: The AquaFuel(tm) Generator Demo 2

click here to see the [AquaFuel(tm) demo 2]() (90kb)

(if you don't have the RealPlayer 5.0, you may download it freely at : [http://www.real.com/products/player/]())

Some reference documents and web link :

United States Patent 6,183,604 - Santilli - February - 6, 2001

Durable and efficient equipment for the production of a combustible and non-pollutant gas from underwater arcs and method therefor

Abstract

A system for producing a clean burning combustible gas comprising an electrically conductive first electrode and an electrically conductive second electrode. A motor coupled to the first electrode is adapted to move the first electrode with respect to the second electrode to continuously move the arc away from the plasma created by the arc. A water tight container for the electrodes is provided with a quantity of water within the tank sufficient to submerge the electrodes.

Inventors: Santilli; Ruggero Maria (Palm Harbor, FL)
Assignee: Hadronic Press, Inc. (Palm Harbor, FL)

Field of the Invention

The present invention relates to durable and efficient equipment for the production of a combustible and non-pollutant gas from underwater arcs and method therefor and more particularly pertains to producing a combustible gas from the underwater arcing of electrodes moving with respect to each other.

Click here to see the full patent

Link to the MagneGas™ technology web site

United States Patent 6,217,713 - Lee , et al. - April 17, 2001

Process for producing aquafuel by using carbon fiber bundle electrodes

Abstract

The invention concerns a process for producing aquafuel by replacing conventional inflexible carbon bars with thin, flexible and tough carbon fiber bundles as consumptive electrodes which thereby can be sustainedly fed and can produce aquafuel continuously. Such carbon fiber bundle electrodes can be prepared by pultrusion, and electrodes may be further carbonized or graphitized in order to increase the conductivity and gas productivity thereof.

Inventors: Lee; Chi-Young (Hsin-Chu Hsien, TW); Chen; Swe-Kai (Hsin-Chu, TW); Tai; Nyan-Hwa (Hsin-Chu, TW)
Assignee: National Science Council of Republic of China (Taipei, TW)

Field of The Invention

The invention relates to a process for producing aquafuel by using carbon fiber bundle electrodes, and in particular, to a process for producing aquafuel by auto-feeding flexible carbon fiber bundle electrode in an electrolytic reaction, wherein said flexible carbon fiber bundle electrodes are formed by impregnating flexible, tough carbon fibers with a resin and said electrode can be used sustainedly in the electrolytic reaction of water under low voltage for a long period of time.

Click here to see the full patent

- **US 603,058 - Electrical Retort by Hilliary Eldridge April 26, 1898** (***the TRUE original Aquafuel patent***)
- **US 5,159,900 - Method and means of generating gas from water for use as a fuel** *(Aquafuel Patent)*
- **US 5,417,817 - Biomass gasification process and apparatus**

- **US 5,435,274 - Electrical Power Generation Without Harmful Emissions** *(Aquafuel Patent)*
- **US 5,692,459 - Pollution Free Vehicle Operation**
- **US 5,792,325 - Electric Arc Material Processing System** *(Aquafuel Patent)*
- **US 5,826,548 - Power Generation Without Harmful Emissions** *(Aquafuel Patent)*
- **US 6,299,738 - Fuel Gas production by underwater arcing** *(Aquafuel Patent)*
- **EP1227142 - Method and system for producing hydrogen from solid carbon materials and water**
- **Infinite Energy Vol.2, No9, 1996**
- **Infinite Energy Vol.2, No10, 1996**
- **Infinite Energy Vol.2, No11, 1997**
- **Infinite Energy Vol.4, No19, 1998**
- **Aqualux Corporation web site** ***(disabled)***
- **MagneGas™ technology web site** *from Hadronic Press Inc*
- **A new fuel produced from water and carbon** *by Alexander's Gaz and Oil production*
- **Le gaz à l'eau** ***(gaz de houille)***
- **The scientific research undelying Santilli's Plasm-Arc-Flow reactors, Magnegaz(Tm), and Magneliquids(Tm)** *from IBR*
- **AquaFuel** *by the Morgan Energy Group*
- **AquaFuel Vs Diesel**, *analysis the Morgan Energy Group*
- **AquaFuel Vs Gasoline**, *analysis the Morgan Energy Group*
- **The TrueFuel™ : Technical informations** *by Advanced Energy Research Corporation*
- *The Aquafuel™ is a trademark from Aqualux Corporation*
- *The Magnegas™ is a trademark from Hadronic Press Inc*
- *The TrueFuel™ is a trademark from Advanced Energy Research Corporation*
- *The Carbo-Hydrogen™ is a trademark from DW Energy Research*

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United States Patent [19]
Rogers, Sr.

[11] **4,292,804**
[45] **Oct. 6, 1981**

[54] **METHOD AND APPARATUS FOR OPERATING AN ENGINE ON COMPRESSED GAS**

[76] Inventor: **Leroy K. Rogers, Sr.,** #5 Capistrano Ct., Ft. Myers, Fla. 33908

[21] Appl. No.: **158,303**

[22] Filed: **Jun. 10, 1980**

[51] **Int. Cl.**^{3} **F15B 11/06**

[52] **U.S. Cl.** **60/407**; 91/187; 91/275

[58] **Field of Search** 60/407, 412; 91/187, 91/275, 364

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,881,399	5/1975	Sagi et al.	91/187 X
3,885,387	5/1975	Simington	60/407 X
4,018,050	4/1977	Murphy	60/412 X

Primary Examiner—Allen M. Ostrager
Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis

[57] **ABSTRACT**

The present invention relates to a method and apparatus for operating an engine having a cylinder and a piston reciprocable therein on compressed gas. The apparatus comprises a source of compressed gas connected to a distributor which distributes the compressed gas to the cylinder. A valve is provided to selectively admit compressed gas to the cylinder when the piston is in an approximately top dead center position. In one embodiment of the present invention the timing of the opening of the valve is advanced such that the compressed gas is admitted to the cylinder progressively further before the top dead center position of the piston as the speed of the engine increases. In a further embodiment of the present invention a valve actuator is provided which increases the length of time over which the valve remains open to admit compressed gas to the cylinder as the speed of the engine increases. A still further embodiment of the present invention relates to an apparatus for adapting a conventional internal combustion engine for operation on compressed gas.

22 Claims, 8 Drawing Figures

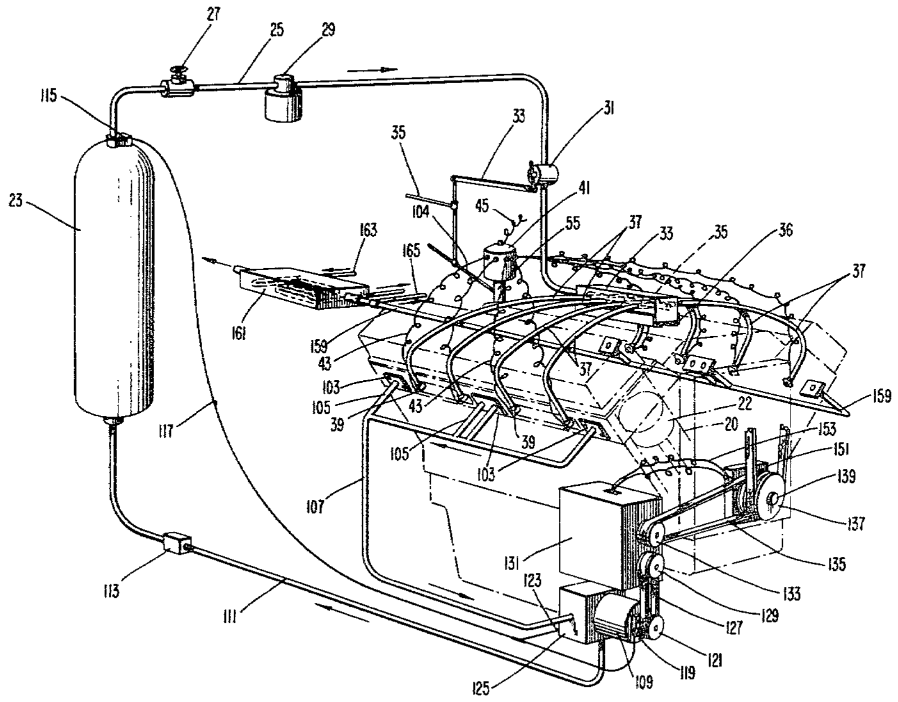

FIG. 1

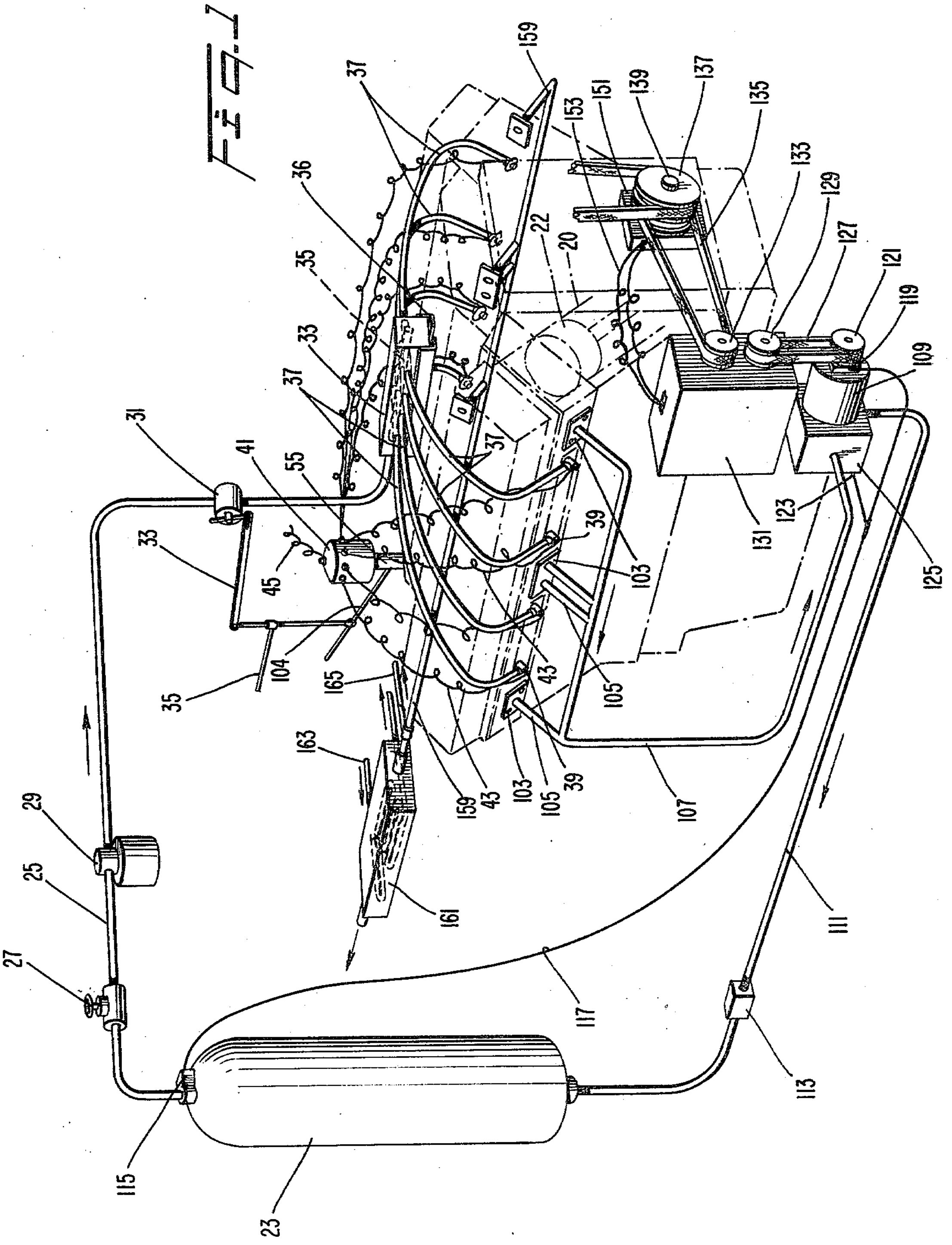

FIG. 6

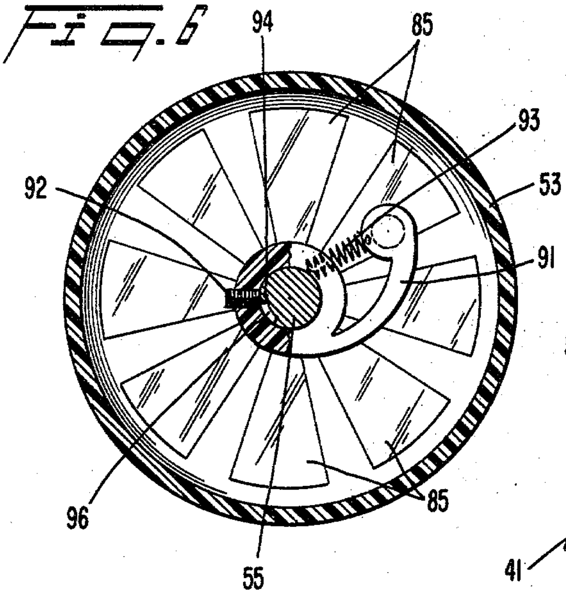
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FIG. 7

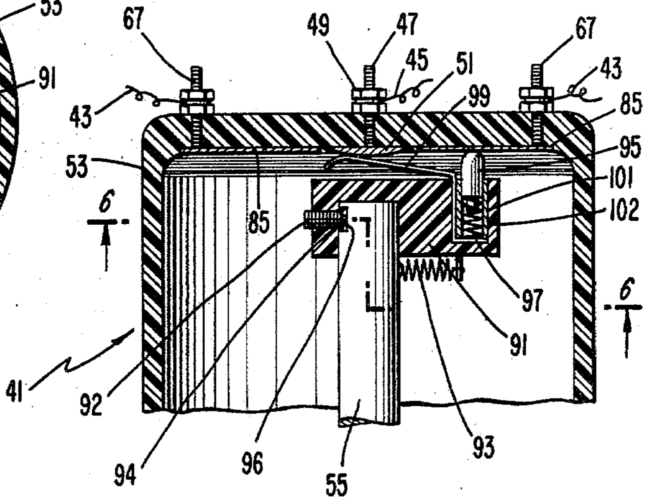
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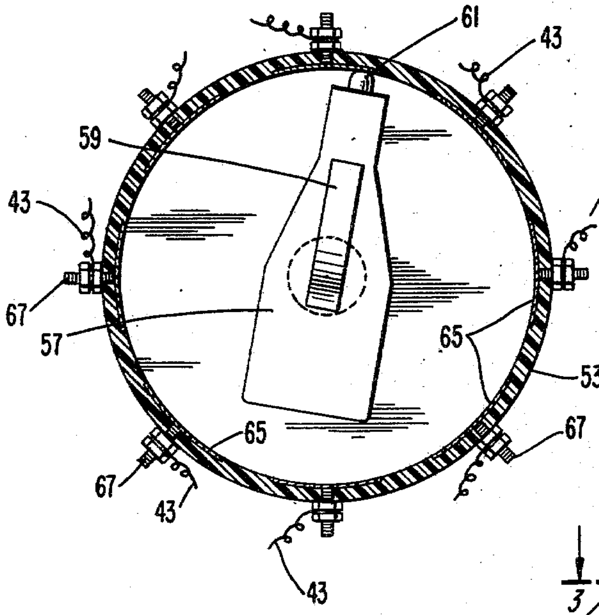
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FIG. 3

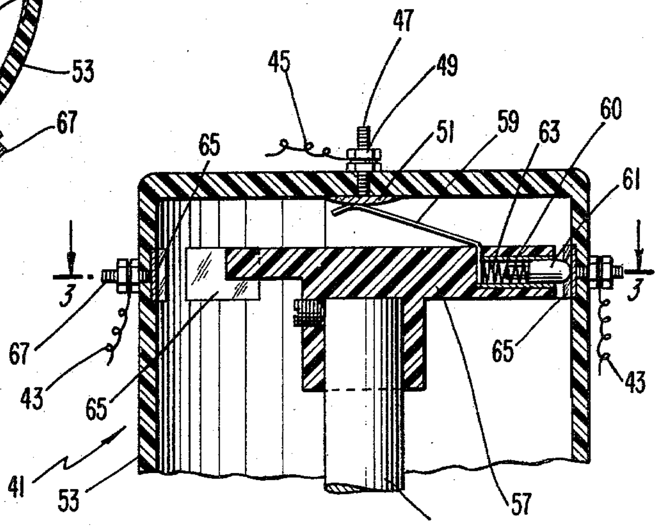
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FIG. 2

Fig. 5

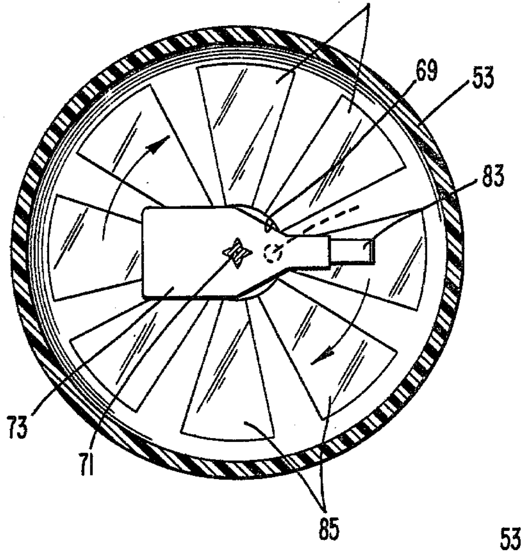
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85

Fig. 4

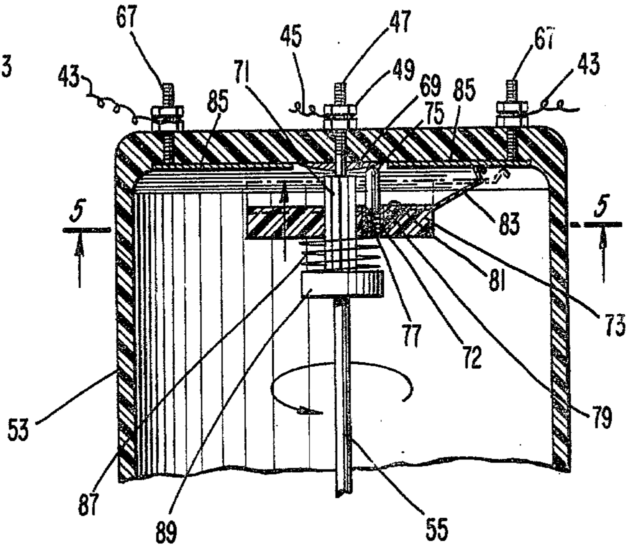
67
47
45
49
67
43
71
69
85
43
85
75
5
83
5
81
73
77
72
53
79
87
89
55

Fig. 6

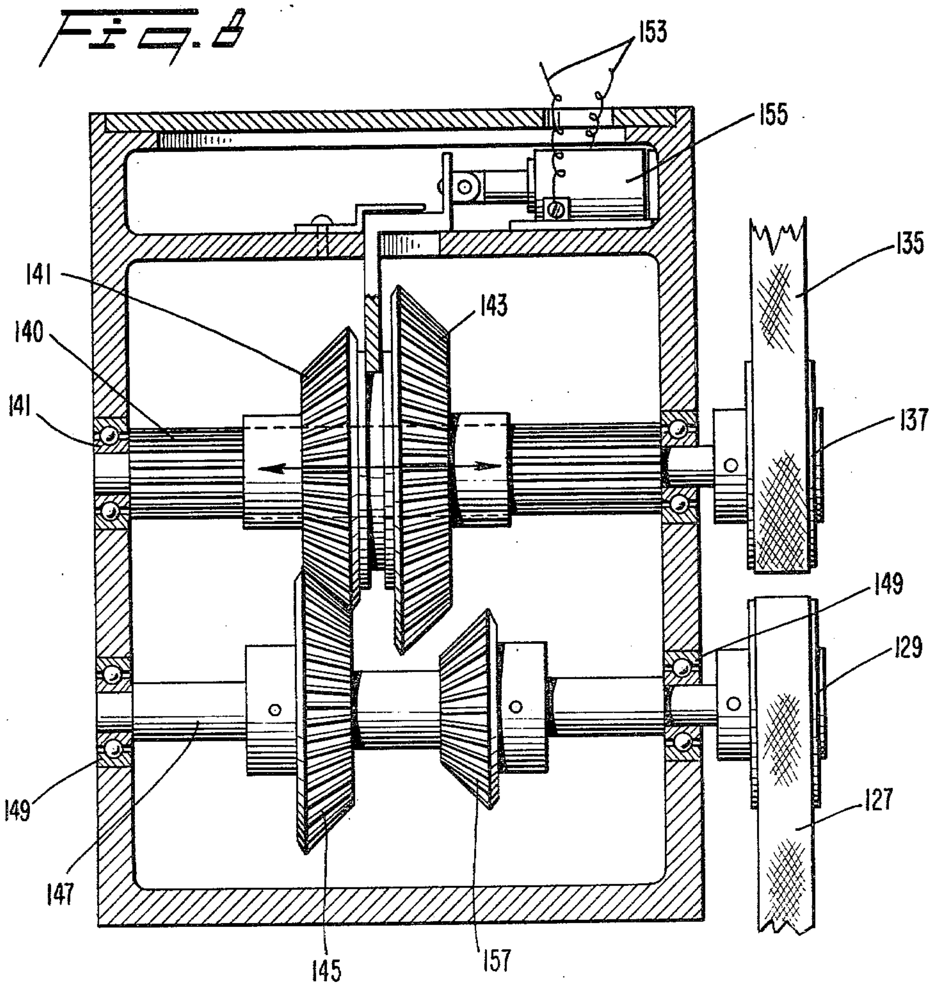
153
155
135
141
143
140
141
137
149
129
149
127
147
145
157

METHOD AND APPARATUS FOR OPERATING AN ENGINE ON COMPRESSED GAS

BACKGROUND AND SUMMARY OF THE PRESENT INVENTION

The present invention relates to a method and apparatus for operating an engine using a compressed gas as the motive fluid. More particularly, the present invention relates to a apparatus for adapting a pre-existing internal combustion engine for operation on a compressed gas.

Air pollution is one of the most serious problems facing the world today. One of the major contributors to air pollution is ordinary internal combustion engine which are used in most motor vehicles today. Various devices, including many items mandated by legislation, have been proposed in an attempt to limit the pollutants which an internal combustion engine exhausts to the air. However, most of these devices have met with limited success and are often both prohibitively expensive and complex. A clean alternative to the internal combustion engine is needed to power vehicles and other machinery.

A compressed gas, preferably air, would provide an ideal motive fluid for a engine since it would eliminate the usual pollutants exhausted from an internal combustion engine. An apparatus for converting an internal combustion engine for operation on compressed air is disclosed in U.S. Pat. No. 3,885,387 issued May 27, 1975 to Simington. The Simington patent discloses an apparatus including a source of compressed air and a rotating valve actuator which opens and closes a plurality of mechanical poppet valves. The valves deliver compressed air in timed sequence to the cylinders of an engine through adapters located in the spark plug holes. However, the output speed of an engine of this type is limited by the speed of the mechanical valves and the fact that the length of time over which each of the valves remains open cannot be varied as the speed of the engine increases.

Another apparatus for converting an internal combustion engine for operation on steam or compressed air is disclosed in U.S. Pat. No. 4,102,130 issued July 25, 1978 to Stricklin. The Stricklin patent discloses a device which changes the valve timing of a conventional four stroke engine such that the intake and exhaust valves open once for every revolution of the engine instead of once every other revolution of the engine. A reversing valve is provided which delivers live steam or compressed air to the intake valves and is subsequently reversed to allow the exhaust valves to deliver the expanded steam or air to the atmosphere. A reversing valve of this type however does not provide a reliable apparatus for varying the amount of motive fluid injected into the cylinders when it is desired to increase the speed of the engine. Further, a device of the type disclosed in the Stricklin patent requires the use of multiple reversing valves if the cylinders in a multi-cylinder engine were to be fired sequentially.

Therefore, it is an object of the present invention to provide a reliable method and apparatus for operating an engine or converting an engine for operation with a compressed gas.

A further object of the present invention is to provide a method and apparatus which is effective to deliver a constantly increasing amount of compressed gas to an engine as the speed of the engine increases.

A still further object of the present invention is to provide a method and apparatus which will operate an engine using compressed gas at a speed sufficient to drive a conventional automobile at highway speeds.

It is still a further object of the present invention to provide a method and apparatus which is readily adaptable to a standard internal combustion engine to convert the internal combustion engine for operation with a compressed gas.

Another object of the invention is to provide a method and apparatus which utilizes cool expanded gas, exhausted from a compressed gas engine, to operate an air conditioning unit and/or an oil cooler.

These and other objects are realized by a method and apparatus according to the present invention for operating an engine having at least one cylinder and a reciprocating piston therein using compressed gas as a motive fluid. The apparatus includes a source of compressed gas and a distributor connected with the source of the compressed gas for distributing the compressed gas to the at least one cylinder. A valve is provided for admitting the compressed gas to the cylinder when the piston is in approximately a top dead center position within the cylinder. An exhaust is provided for exhausting the expanded gas from the cylinder as the piston returns to approximately the top dead center position.

In a preferred embodiment of the present invention a device is provided for varying the duration of each engine cycle over which the valve remains open to admit compressed gas to the cylinder dependent upon the speed of the engine. In a further preferred embodiment of the present invention, an apparatus for advancing the timing of the opening of the valve is arranged to admit the compressed gas to the cylinder progressively further before the top dead center position of the piston as the speed of the engine increases.

Further features of the present invention include a valve for controlling the amount of compressed gas admitted to the distributor. Also, a portion of the gas which has been expanded in the cylinder and exhausted through the exhaust valve is delivered to a compressor to be recompressed and returned to the source of compressed gas. A gear train is selectively engagable to drive the compressor at different operating speed depending upon the pressure maintained at the source of compressed air and/or the speed of the engine. Still further, a second portion of the exhaust gas is used to cool a lubricating fluid for the engine or to operate an air conditioning unit.

In a preferred embodiment of the present invention, the valve for admitting compressed gas to the cylinder is electrically actuated. The device for varying the duration of each engine cycle over which the intake valve remains open as the speed of the engine increase comprises a rotating element whose effective length increases as the speed of the engine increases such that a first contact on the rotating element is electrically connected to a second contact for a longer period of each engine cycle. The second contact actuates the valve whereby the valve remains in an open position for a longer period of each engine cycle as the speed of the engine increases.

Still further features of the present invention include an adaptor plate for supporting the distributor above an intake manifold of a conventional internal combustion engine after a carburetor has been removed to allow air to enter the cylinders of the engine through the intake manifold and conventional intake valves. Another adaptor plate is arranged over an exhaust passageway of the internal combustion engine to reduce the cross-sectional area of the exhaust passageway.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of a method and apparatus for operating an engine according to the present invention will be described with reference to the accompanying drawings wherein like members bear like reference numerals and wherein:

FIG. 1 is a schematic representation of an apparatus according to the present invention arranged on an engine;

FIG. 2 is a side view of one embodiment of a valve actuator according to the present invention;

FIG. 3 is a cross-sectional view taken along the line 3—3 in FIG. 2;

FIG. 4 is a cross-sectional view of a second embodiment of a valve actuator according to the present invention;

FIG. 5 is a view taken along the line 5—5 in FIG. 4;

FIG. 6 is a cross-sectional view of a third embodiment of a valve actuator according to the present invention;

FIG. 7 is a view taken along the line 7—7 in FIG. 6;

FIG. 8 is a cross-sectional view of a gearing unit to drive a compressor according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, an engine block **21** (shown in phantom) having two banks of cylinders with each bank including cylinders **20** having pistons **22** reciprocable therein (only one of which is shown in phantom) in a conventional manner. While the illustrated engine is a V-8 engine, it will be apparent that the present invention is applicable to an engine having any number of pistons and cylinders with the V-8 engine being utilized for illustration purposes only. A compressed gas tank **23** is provided to store a compressed gas at high pressure. It may also be desirable to include a small electric or gas compressor to provide compressed gas to supplement the compressed gas held in the tank **23**. In a preferred embodiment, the compressed gas is air which can be obtained from any suitable source.

A line **25** transports the gas withdrawn from the tank **23** when a conventional shut off valve **27** is open. In addition, a solenoid valve **29** preferably operated by a suitable key operated switch (not shown) for the engine is also arranged in the line **25**. In normal operation, the valve **27** is maintained open at all times with the solenoid valve **29** operating as a selective shut off valve to start and stop the engine **21** of the present invention.

A suitable regulating valve **31** is arranged downstream from the solenoid valve **29** and is connected by a linkage **33** to a throttle linkage **35** which is operator actuated by any suitable apparatus such as a foot pedal (not shown). The line **25** enters an end of a distributor **33** and is connected to an end of a pipe **35** which is closed at the other end. A plurality of holes, which are equal to the number of cylinders in the engine **21**, are provided on either side of the pipe **35** along the length of the pipe **35**.

When the present invention is used to adapt a conventional internal combustion engine for operation on compressed gas, an adaptor plate **36** is provided to support the distributor **33** in spaced relation from the usual intake opening in the intake manifold of the engine after a conventional carburetor has been removed. In this way, air is permitted to enter the internal combustion engine through the usual passageways and to be admitted to the cylinders through suitable intake valves (not shown). The adaptor plate **36** is secured to the engine block **21** and the distributor **33** by any suitable apparatus, e.g., bolts.

Each of the holes in the pipe **35** is connected in fluid-tight manner to a single line **37**. Each line **37** carries the compressed gas to a single cylinder **20**. In a preferred embodiment, each of the lines **37** is $\frac{1}{2}$ inch high pressure plastic tubing attached through suitable connectors to the distributor **33** and the pipe **35**. Each of the lines **37** is connected to a valve **39** which is secured in an opening provided near the top of each of the cylinders **20**. In the case of a conversion of a standard internal combustion engine, the valves **39** can be conveniently screwed into a tapped hole in the cylinder **20** typically provided for a spark plug of the internal combustion engine. In a preferred embodiment, the valves **39** are solenoid actuated valves in order to provide a fast and reliable opening and closing of the valves **39**.

Each of the valves **39** is energized by a valve actuator **41** through one of a plurality of wires **43**. The valve actuator **41** is driven by a shaft of the engine similar to the drive for a conventional distributor of an internal combustion engine. That is, a shaft **55** of the valve actuator **41** is driven in synchronism with the engine **21** at one half the speed of the engine **21**.

A first embodiment of the valve actuator **41** (FIGS. 2 and 3) receives electrical power through a wire **45** which is energized in a suitable manner by a battery, and a coil if necessary (not shown) as is conventional in an internal combustion engine. The wire **45** is attached to a central post **47** by a nut **49**. The post **47** is connected to a conducting plate **51** arranged within a housing **53** for the valve actuator **41**. Within the housing **53**, the shaft **55** has an insulating element **57** secured to an end of the shaft **55** for co-rotation therewith when the shaft **55** is driven by the engine **21**. A first end of a flexible contact **59** is continuously biased against the conducting plate **51** to receive electricity from the battery or another suitable source. A second end of the contact **59** is connected to a conducting sleeve **60** which is in constant contact with a spring biased contact **61** which is arranged within the sleeve **60**. The contact **61** is biased by a spring **63** which urges the contact **61** towards a side wall of the housing **53**.

With reference to FIG. 3, a plurality of contacts **65** are spaced from one another and are arranged around the periphery of the housing **53** at the same level as the spring biased contact **61**. Each contact **65** is electrically connected to a post **67** which extends outside of the housing **53**. The number of contacts **65** is equal to the number of cylinders in the engine **21**. One of the wires **43**, which actuate the valves **39**, is secured to each of the posts **67**.

In operation, as the shaft **55** rotates in synchronism with the engine **21**, the insulating element **57** rotates and electricity is ultimately delivered to successive ones of the contacts **65** and wires **43** through the spring biased contact **61** and the flexible contact **59**. In this way, each of the electrical valves **39** is actuated and opened in the proper timed sequence to admit compressed gas to each of the cylinders **20** to drive the pistons **22** therein on a downward stroke.

The embodiment illustrated in FIGS. 2 and 3 is effective to actuate each of the valves 39 to remain open for a long enough period of time to admit sufficient compressed gas to each of the cylinders 20 of the engine 21 to drive the engine 21. The length of each of the contacts 65 around the periphery of the housing 53 is sufficient to permit the speed of the engine to be increased when desired by the operator by moving the throttle linkage 35 which actuates the linkage 33 to further open the regulating valve 31 to admit more compressed gas from the tank 23 to the distributor 33. However, it has been found that the amount of air admitted by the valves 39 when using the first embodiment of the valve actuator 41 (FIGS. 2 and 3) is substantially more than required to operate the engine 21 at an idling speed. Therefore, it may be desirable to provide a valve actuator 41 which is capable of varying the duration of each engine cycle over which the solenoid valves 39 are actuated, i.e., remain open to admit compressed gas, as the speed of the engine 21 is varied.

A second embodiment of a valve actuator 41 which is capable of varying the duration of each engine cycle over which each of the valves 39 remains open to admit compressed gas to the cylinders 20 dependent upon the speed of the engine 21 will be described with reference to FIGS. 4 and 5 wherein members corresponding to those of FIGS. 2 and 3 bear like reference numerals. The wire 45 from the electrical source is secured to the post 47 by the nut 49. The post 47 has a annular contact ring 69 electrically connected to an end of the post 47 and arranged within the housing 53. The shaft 55 rotates at one half the speed of the engine as in the embodiment of FIGS. 2 and 3.

At an upper end of the shaft 55, a splined section 71 slidably receives an insulating member 73. The splined section 71 of the shaft 55 positively holds the insulating member 73 for co-rotation therewith but permits the insulating member 73 to slide axially along the length of the splined section 71. Near the shaft 55, a conductive sleeve 72 is arranged in a bore 81 in an upper surface of the insulating element 73 generally parallel to the splined section 71. A contact 75, biased towards the annular contact ring 69 by a spring 77, is arranged within the conductive sleeve 72 in contact therewith. The conductive sleeve 72 also contacts a conductor 79 at a base of the bore 81.

The conductor 79 extends to the upper surface of the insulating element 73 near an outer periphery of the insulating element 73 where the conductor 79 is electrically connected to a flexible contact 83. The flexible contact 83 selectively engages a plurality of radial contacts 85 arranged on an upper inside surface of the housing 53. A weak spring 87 arranged around the splined section 71 engages a stop member 89 secured on the shaft 55 and the insulating element 73 to slightly bias the insulating element 73 towards the upper inside surface of the housing 53 to ensure contact between the flexible contact 83 and the upper inside surface of the housing 53. As best seen in FIG. 5, the radial contacts 85 on the upper inside surface of the housing 53 are arranged generally in the form of radial spokes extending from the center of the housing 53 with the number of contacts being equal to the number of cylinders 20 in the engine 21. The number of degrees covered by each of the radial contacts 85 gradually increases as the distance from the center of the upper inside surface of the housing 53 increases.

In operation of the device of FIGS. 4 and 5, as the shaft 55 rotates, electricity flows along a path through the wire 45 down through post 47 to the annular contact member 69 which is in constant contact with the spring biased contact 75. The electrical current passes through the conductive sleeve 72 to the conductor 79 and then to the flexible contact 83. As the flexible contact 83 rotates along with the insulating member 73 and the shaft 55, the tip of the flexible contact 83 successively engages each of the radial contacts 85 on the upper inside of the housing 53. As the speed of the shaft 55 increases, the insulating member 73 and the flexible contact 83 attached thereto move upwardly along the splined section 71 of the shaft 55 due to the radial component of the splines in the direction of rotation under the influence of centrifugal force. As the insulating member 73 moves upwardly, the flexible contact 83 is bent such that the tip of the contact 83 extends further radially outwardly from the center of the housing 53 (as seen in phantom lines in FIG. 4). In other words, the effective length of the flexible contact 83 increases as the speed of the engine 21 increases.

As the flexible contact 83 is bent and the tip of the contact 83 moves outwardly, the tip remains in contact with each of the radial contacts 85 for a longer period of each engine cycle due to the increased angular width of the radial contacts with increasing distance from the center of the housing 53. In this way, the length of time over which each of the valves 39 remains open is increased as the speed of the engine is increased. Thus, a larger quantity of compressed gas or air is injected into the cylinders as the speed increases. Conversely, as the speed decreases and the insulating member 73 moves downwardly along the splined section 71, a minimum quantity of air is injected into the cylinder due to the shorter length of the individual radial contact 85 which is in contact with the flexible contact 83. In this way, the amount of compressed gas that is used during idling of the engine 21 is at a minimum whereas the amount of compressed gas which is required to increase the speed of the engine 21 to a level suitable to drive a vehicle on a highway is readily available.

With reference to FIGS. 6 and 7, a third embodiment of a valve actuator 41 according to the present invention includes an arcuate insulating element 91 having a first end pivotally secured by any suitable device such as screw 92 to the shaft 55 for co-rotation with the shaft 55. The screw 92 is screwed into a tapped hole in the insulating element 91 such that a tab 94 at an end of the screw 92 engages a groove 96 provided in the shaft 55. In this way, the insulating element 91 positively rotates with the shaft 55. However, as the shaft 55 rotates faster, a second end 98 of the insulating element 91 is permitted to pivot outwardly under the influence of centrifugal force because of the groove 96 provided in the shaft 55. A spring 93 connected between the second end 98 of the element 91 and the shaft 55 urges the second end of the element 91 towards the center of the housing 53.

A contact 99 similar to the contact 59 (FIG. 2) is arranged such that one end of the contact 99 is in constant contact with the conducting plate 51 located centrally within the housing 53. The other end of the contact 99 engages a conductive sleeve 101 arranged in bore 102. A contact element 95 is arranged in the conductive sleeve 101 in constant contact with the sleeve 101. The bore 102 is arranged generally parallel to the shaft 55 near the second end of the arcuate insulating element **91**. The contact **95** is biased by a spring **97** towards the upper inside surface of the housing **53** for selective contact with each of the plurality of radial contacts **85** which increase in arc length towards the outer peripheral surface of the housing **53** (FIG. **6**).

In operation of the device of FIGS. **6** and **7**, as the shaft **55** rotates the arcuate insulating element **91** rotates with the shaft **55** and the second end **98** of the insulating element **91** tends to pivot about the shaft **55** due to centrifugal force. Thus, as the effective length of the contact **95** increases, i.e., as the arcuate insulating element **91** pivots further outwardly, the number of degrees of rotation over which the contact **95** is in contact with each of the radial contacts **85** on the upper inside surface of the housing **53** increases thereby permitting each of the valves **39** to remain open for a longer period of each engine cycle to admit more compressed gas to the respective cylinder **20** to further increase the speed of the engine **21**.

With reference to FIG. **1**, a mechanical advance linkage **104** which is connected to the throttle linkage **35**, advances the initiation of the opening of each valve **39** such that compressed gas is injected into the respective cylinder further before the piston **22** in the respective cylinder **20** reaches a top dead center position as the speed of the engine is increased by moving the throttle linkage **35**. The advance linkage **104** is similar to a conventional standard mechanical advance employed on an internal combustion engine. In other words, the linkage **104** varies the relationship between the angular positions of a point on the shaft **55** and a point on the housing **53** containing the contacts. Alternatively, a conventional vacuum advance could also be employed. By advancing the timing of the opening of the valves **39**, the speed of the engine can more easily be increased.

The operation of the engine cycle according to the present invention will now be described. The compressed gas injected into each cylinder of the engine **21** drives the respective piston **22** downward to drive a conventional crankshaft (not shown). The movement of the piston downwardly causes the compressed gas to expand rapidly and cool. As the piston **22** begins to move upwardly in the cylinder **20** a suitable exhaust valve (not shown) arranged to close an exhaust passageway is opened by any suitable apparatus. The expanded gas is then expelled through the exhaust passageway. As the piston **22** again begins to move downwardly a suitable intake valve opens to admit ambient air to the cylinder. The intake valve closes and the ambient air is compressed on the subsequent upward movement of the piston until the piston reaches approximately the top dead center position at which time the compressed gas is again injected into the cylinder **20** to drive the piston **22** downward and the cycle begins anew.

In the case of adapting a conventional internal combustion engine for operation on compressed gas, a plurality of plates **103** are preferably arranged over an end of the exhaust passageways in order to reduce the outlet size of the exhaust passageways of the conventional internal combustion engine. In the illustrated embodiment, a single plate having an opening in the center is bolted to the outside exhaust passageway on each bank of the V-8 engine while another single plate having two openings therein is arranged with one opening over each of the interior exhaust passageways on each bank of the V-8 engine. A line **105** is suitably attached to each of the adaptor places to carry the exhaust to an appropriate location. In a preferred embodiment, the exhaust lines **105** are 1½" plastic tubing.

In a preferred embodiment, the exhaust lines **105** of one bank of the V-8 engine are collected in a line **107** and fed to an inlet of a compressor **109**. The pressure of the exhaust gas emmanating from the engine **21** according to the present invention is approximately 25 p.s.i. In this way, the compressor **109** does not have to pull the exhaust into the compressor since the gas exhausted from the engine **21** is at a positive pressure. The positive pressure of the incoming fluid increases the efficiency and reduces wear on the compressor **109**. The exhaust gas is compressed in the compressor **109** and returned through a line **111** and a check valve **113** to the compressed gas storage tank **23**. The check valve **113** prevents the flow of compressed gas stored in the tank **23** back towards the compressor **109**.

A suitable pressure sensor **115** is arranged at an upper end of the tank **23** and sends a signal along a line **117** when the pressure exceeds a predetermined level and when the pressure drops below a predetermined level. The line **117** controls an electrically actuated clutch **119** disposed at a front end of the compressor **109**. The clutch **119** is operative to engage and disengage the compressor **109** from a drive pulley **121**. Also, the signal carried by the line **117** actuates a suitable valve **123** arranged on a compressor housing **125** to exhaust the air entering the compressor housing **125** from the line **107** when the clutch **119** has disengaged the compressor **109** from the drive pully **121**.

In a preferred embodiment, when the pressure is the tank **23** reaches approximately 600 p.s.i., the clutch **119** is disengaged and the compressor **109** is deactivated and the valve **123** is opened to exhaust the expanded gas delivered to the compressor **109** from the line **107** to the atmosphere. When the pressure within the tank **23** drops below approximately 500 p.s.i., the sensor **115** sends a signal to engage the clutch **119** and close the valve **123**, thereby operating the compressor **109** for supplying the tank **23** with compressed gas.

The pulley **121** which drives the compressor **109** through the clutch **119** is driven by a belt **127** which is driven by a pulley **129** which operates through a gear box **131**. With reference to FIGS. **1** and **8**, a second pulley **133** on the gear box is driven by a belt **135** from a pulley **137** arranged on a drive shaft **139** of the engine **21**. The pulley **137** drives a splined shaft **140** which has a first gear **141** and a second larger gear **143** arranged thereon for rotation with the splined shaft **140**. The splined shaft **140** permits axial movement of the gears **141** and **143** along the shaft **140**.

In normal operation (as seen in FIG. **8**), the first gear **141** engages a third gear **145** arranged on a shaft **147** which drives the pulley **129**. The shafts **140** and **147** are arranged in suitable bearings **149** arranged at each end thereof. When the speed of the engine **21** drops below a predetermined level, a suitable sensor **151** responsive to the speed of the drive shaft **139** of the engine **21** generates a signal which is transmitted through a line **153** to a solenoid actuator **155** arranged within the gear box **131**. The solenoid actuator **155** moves the first and second gears **141**, **143** axially along the splined shaft **140** to the right as seen in FIG. **8** such that the second, larger gear **143** engages a fourth smaller gear **157** which is arranged on the shaft **147**. The ratio of the second gear **143** to the fourth gear **157** is preferably approximately 3 to 1.

In this way, when the speed of the engine **21** drops below the predetermined level as sensed by the sensor **151** (which predetermined level is insufficient to drive the compressor **109** at a speed sufficient to generate the 500-600 pounds of pressure which is preferably in the tank **23**), the solenoid actuator **155** is energized to slide the gears **143**, **141** axially along the splined shaft **140** so that the second, larger gear **143** engages the fourth, smaller gear **157** to drive the pulley **129** and hence the compressor **109** at a higher rate of speed to generate the desired pressure. When the speed of the engine increases above the predetermined level, in a preferred embodiment approximately 1500 rpm, the solenoid actuator **155** is deactivated by the sensor **151** thereby moving the gears **143** and **141** to the left as seen in FIG. **8** such that the first gear **141** re-engages with the third gear **145** to effectuate a 1 to 1 ratio between the output shaft **139** of the engine **21** and the pulley **129**.

The other bank of the V-8 engine has its exhaust ports arranged with adapter plates **103** similar to those on the first bank. However, the exhaust from this bank of the engine **21** is not collected and circulated through the compressor **109**. In a preferred embodiment, a portion of the exhaust is collected in a line **159** and fed to an enlarged chamber **161**. A second fluid is fed through a line **163** into the chamber **161** to be cooled by the cool exhaust emmanating from the engine **21** in the line **159**. The second fluid in the line **163** may be either transmission fluid contained in a transmission associated with the engine **21** or a portion of the oil used to lubricate the engine **21**. A second portion of the exhaust from the second bank of the V-8 engine is removed from the line **159** in a line **165** and used as a working fluid in an air conditioning system or for any other suitable use.

It should be noted that the particular arrangement utilized for collecting and distributing the gas exhausted from the engine **21** would be determined by the use for which the engine is employed. In other words, it may be advantageous to rearrange the exhaust tubing such that a larger or smaller percentage of the exhaust is routed through the compressor **109**. It should also be noted that since the exhaust lines **105** are plastic tubing, a rearrangement of the lines for a different purpose is both simple and inexpensive.

In operation of the engine of the present invention, the engine **21** is started by energizing the solenoid valve **29** and any suitable starting device (not shown), e.g., a conventional electric starter as used on an internal combustion engine. Compressed gas from the full tank **23** flows through the line **25** and a variable amount of the compressed gas is admitted to the distributor **33** by controlling the regulator valve **31** through the linkage **33** and the operator actuated throttle linkage **35**. The compressed gas is distributed to each of the lines **37** which lead to the individual cylinders **20**. The compressed gas is admitted to each of the cylinders **20** in timed relationship to the position of the pistons within the cylinders by opening the valves **39** with the valve actuator **41**.

When it is desired to increase the speed of the engine, the operator moves the throttle linkage **35** which simultaneously admits a larger quantity of compressed gas to the distributor **33** from the tank **23** by further opening the regulator valve **31**. The timing of the valve actuator **41** is also advanced through the linkage **104**. Still further, as the speed of the engine **21** increases, the effective length of the rotating contact **83** (FIG. 4) or **95** (FIG. 6) increases thereby electrically contacting a wider portion of one of the stationary radial contacts **85** to cause each of the valves **39** to remain open for a longer period of each engine cycle to admit a larger quantity of compressed gas to each of the cylinders **20**.

As can be seen, the combination of the regulating valve **31**, the mechanical advance **104**, and the valve actuator **41**, combine to produce a compressed gas engine which is quickly and efficiently adaptable to various operating speeds. However, all three of the controls need not be employed simultaneously. For example, the mechanical advance **104** could be utilized without the benefit of one of the varying valve actuators **41** but the high speed operation of the engine may not be as efficient. By increasing the duration of each engine cycle over which each of the valves **39** remains open to admit compressed gas to each of the cylinders **20** as the speed increases, conservation of compressed gas during low speed operation and efficient high speed operation are both possible.

After the compressed gas admitted to the cylinder **20** has forced the piston **22** downwardly within the cylinder to drive the shaft **139** of the engine, the piston **22** moves upwardly within the cylinder **20** and forces the expanded gas out through a suitable exhaust valve (not shown) through the adapter plate **103** (if employed) and into the exhaust line **105**. The cool exhaust can then be collected in any suitable arrangement to be compressed and returned to the tank **23** or used for any desired purpose including use as a working fluid in an air conditioning system or as a coolant for oil.

When using the apparatus and method of the present invention to adapt a ordinary internal combustion engine for operation with compressed gas it can be seen that considerable savings in weight are achieved. For example, the ordinary cooling system including a radiator, fan, hoses, etc. can be eliminated since the compressed gas is cooled as it expands in the cylinder. In addition, there are no explosions within the cylinder to generate heat. Further reductions in weight are obtained by employing plastic tubing for the lines which carry the compressed gas between the distributor and the cylinders and for the exhaust lines. Once again, heavy tubing is not required since there is little or no heat generated by the engine of the present invention. In addition, the noise generated by an engine according to the present invention is considerably less than that generated by an ordinary internal combustion engine since there are no explosions taking place within the cylinders.

The principles of preferred embodiments of the present invention have been described in the foregoing specification. However, the invention which is intended to be protected is not to be construed as limited to the particular embodiments disclosed. The embodiments are to be regarded as illustrative rather than restrictive. Variations and changes may be made by others without departing from the spirit of the invention. Accordingly, it is expressly intended that all such variations and changes which fall within the spirit and the scope of the present invention as defined in the appended claims be embraced thereby.

What is claimed is:

1. An apparatus for operating an engine having at least one cylinder and a reciprocating piston therein comprising:

a source of compressed gas;

- distributor means connected with the source of compressed gas for distributing the compressed gas to the at least one cylinder;
- valve means for admitting the compressed gas to the at least one cylinder when the piston is in approximately a top dead center position within the cylinder;
- altering means for increasing the duration of each engine cycle over which the valve means admits compressed gas to the at least one cylinder as the speed of the engine increases; and
- exhaust means for exhausting gas as the piston subsequently approaches approximately the top dead center position.

2. The apparatus of claim **1** further comprising control means for controlling the amount of compressed gas admitted to the distributor means.

3. The apparatus of claim **1** wherein the valve means is a solenoid valve secured in an opening in the cylinder above the level of the piston at the top dead center position.

4. The apparatus of claims **1** or **2** further comprising means for advancing the timing of the valve means as the speed of the engine increases such that compressed gas is admitted progressively further before the top dead center position as the speed of the engine increases.

5. The apparatus of claim **4** wherein the means for advancing the timing comprises a mechanical linkage connected to an operator actuated accelerator linkage.

6. The apparatus of claim **1** wherein a portion of the gas exhausted through the exhaust means is compressed in a compressor driven by an output shaft of the engine and is returned to the source of compressed gas.

7. The apparatus of claim **1** wherein a portion of the gas exhausted through the exhaust means is used to cool transmission fluid for a transmission associated with the engine.

8. The apparatus of claim **1** wherein a portion of the gas exhausted through the exhaust means is used as a working fluid in an air conditioning system.

9. The apparatus of claim **6** further comprising first gearing means interposed between the output shaft of the engine and the compressor for increasing the speed at which the compressor is driven.

10. The apparatus of claim **6** further comprising clutch means attached to the compressor both for disengaging the compressor from the output shaft of the engine when a first predetermined pressure at the source of compressed gas is exceeded and for engaging the compressor with the output shaft of the engine when the pressure at the source of compressed gas drops below a second predetermined pressure.

11. The apparatus of claim **9** further comprising means for both disengaging the first gearing means when a predetermined speed of the engine is exceeded and engaging a second gearing means for driving the compressor at a speed slower than the first gearing means when the predetermined speed of the engine is exceeded.

12. The apparatus of claim **1** wherein the valve means is electrically actuated and wherein the altering means comprises:

- a rotating member timed with the at least one cylinder and arranged within a housing;
- first and second contacts arranged on a first end of the rotating member and on an inside surface of the housing, respectively;
- means for increasing the distance of the first contact from the rotational axis of the rotating member as the speed of the engine increases such that the first contact moves radially outwardly within the housing; and
- said second contact presenting a longer arc length to the first contact as the distance of the first contact from the rotational axis of the rotating member increases.

13. The apparatus of claim **12** wherein the rotating member comprises an arcuate arm and wherein the means for increasing the distance of the first contact comprises pivotally mounting a second end of the arcuate arm about the axis of rotation of the rotating member and spring means for biasing the first end of the arcuate arm towards a radially inward position whereby the first end of the arcuate arm pivots radially outwardly as the speed of the engine increases.

14. The apparatus of claim **12** wherein the rotating member is axially slidably received on a rotating shaft for co-rotation therewith, said shaft having splines with a radial component in the direction of rotation, and wherein the first contact comprises a flexible contact located on an upper surface of the rotating member, said flexible contact being biased against the inside surface of the housing which carries the second contacts whereby as the speed of the engine increases the rotating member is urged axially along the splined shaft towards the inside surface of the housing such that the flexible contact is forced radially outwardly along the inside surface.

15. The apparatus of claim **12** wherein the second contact comprises of radially extending conductor arranged on an upper inside surface of the housing, said conductor increasing in arc length as the conductor extends radially outwardly from a central portion of the housing.

16. An apparatus for adapting an internal combustion engine for operation with compressed gas, the internal combustion engine having at least one cylinder, a piston reciprocable within the at least one cylinder, intake and exhaust means disposed in the at least one cylinder, and a tapped hole in the at least one cylinder adapted to receive a spark plug, the apparatus comprising:

- a source of compressed gas;
- distributor means connected with the source of compressed gas for distributing the compressed gas to the at least one cylinder;
- valve means arranged in the tapped hole for admitting the compressed gas to the at least one cylinder when the piston is in approximately a top dead center position within the cylinder; and
- altering means for increasing the duration of each engine cycle over which the valve means remains open to admit the compressed gas as the speed of the engine increases.

17. An apparatus as in claim **16** further comprising first adapter plate means for supporting the distributor means above an intake manifold of the engine, which adaptor plate means allows ambient air to enter through the intake manifold.

18. The apparatus of claim **16** further comprising second adapter plate means for reducing the exit area of the exhaust means.

19. A method of operating an engine on compressed gas, said engine having at least one cylinder and a piston reciprocable therein comprising the steps of:

- delivering compressed gas from a source to a distributor;
- distributing the compressed gas to the at least one cylinder;
- admitting compressed gas to the at least one cylinder through an intake valve when the piston is at approximately a top dad center position;
- increasing the duration of each engine cycle over which compressed gas is admitted to the at least one cylinder as the engine speed increases; and
- exhausting the remaining gas when the piston subsequently reaches approximately the top dead center position.

20. The method of claim **19** further comprising the step of controlling the amount of compressed gas which is delivered to the distributor.

21. The method of claim **19** further comprising the step of advancing the timing of the opening of the intake valve as the speed of the engine increases.

22. An apparatus for operating an engine having at least one cylinder and a piston reciprocable therein on compressed gas comprising:

- a source of compressed gas;
- distributor means connected with the source of compressed gas for distributing the compressed gas to the at least one cylinder;
- electrically actuated valve means secured in an opening in the at least one cylinder for selectively admitting compressed gas to the at least one cylinder when the piston is in approximately a top dead center position; and
- means for advancing the timing of the valve means as the speed of the engine increases whereby compressed gas is admitted progressively further before the top dead center position as the speed of the engine increases.

* * * * *

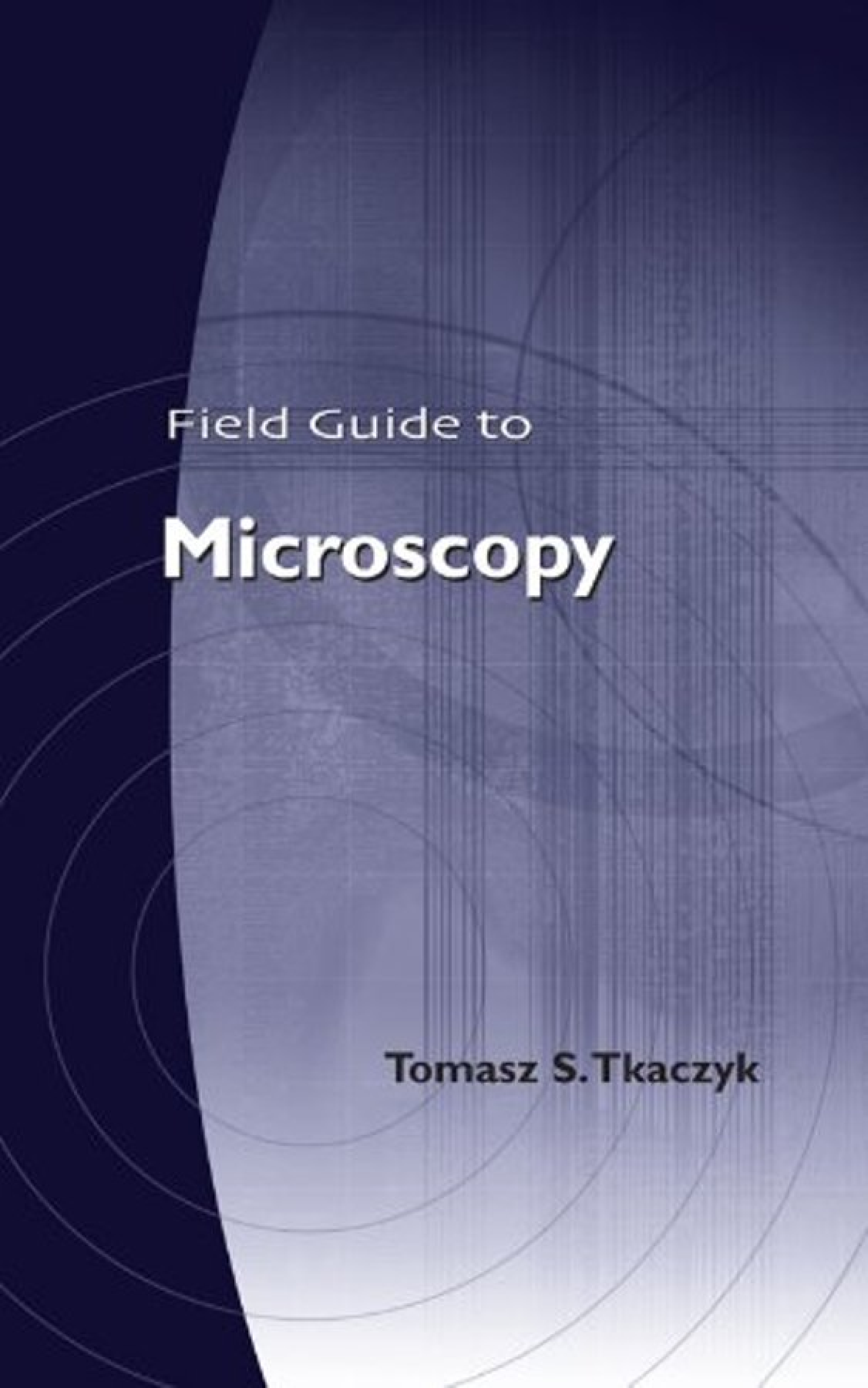

Field Guide to

Microscopy

Tomasz S. Tkaczyk

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Preface to the Field Guide to Microscopy

In the 17th century Robert Hooke developed a compound microscope, launching a wonderful journey. The impact of his invention was immediate; in the same century microscopy gave name to "cells" and imaged living bacteria. Since then microscopy has been the witness and subject of numerous scientific discoveries, serving as a constant companion in humans' quest to understand life and the world at the small end of the universe's scale.

Microscopy is one of the most exciting fields in optics, as its variety applies principles of interference, diffraction, and polarization. It persists in pushing the boundaries of imaging limits. For example, life sciences in need of nanometer resolution recently broke the diffraction limit. These new super-resolution techniques helped name microscopy the method of the year by *Nature Methods* in 2008.

Microscopy will critically change over the next few decades. Historically, microscopy was designed for visual imaging; however, enormous recent progress (in detectors, light sources, actuators, etc.) allows the easing of visual constrains, providing new opportunities. I am excited to witness microscopy's path toward both integrated, digital systems and nanoscopy.

This Field Guide has three major aims: (1) to give a brief overview of concepts used in microscopy; (2) to present major microscopy principles and implementations; and (3) to point to some recent microscopy trends. While many presented topics deserve a much broader description, the hope is that this Field Guide will be a useful reference in everyday microscopy work and a starting point for further study.

I would like to express my special thanks to my colleague here at Rice University, Mark Pierce, for his crucial advice throughout the writing process and his tremendous help in acquiring microscopy images.

This Field Guide is dedicated to my family: my wife, Dorota, and my daughters, Antonina and Karolina.

Tomasz Tkaczyk
Rice University

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Glossary of Symbols

$a(x, y)$, $b(x, y)$	Background and fringe amplitude
AO	Vector of light passing through amplitude Object
A_{R}, A_{S}	Amplitudes of reference and sample beams
b	Fringe period
c	Velocity of light
C	Contrast, visibility
C_{ac}	Visibility of amplitude contrast
C_{ph}	Visibility of phase contrast
$C_{\mathrm{ph\text{-}min}}$	Minimum detectable visibility of phase contrast
d	Airy disk dimension
d	Decay distance of evanescent wave
d	Diameter of the diffractive object
d	Grating constant
d	Resolution limit
D	Diopters
D	Number of pixels in the x and y directions (N_x and N_y, respectively)
DA	Vector of light diffracted at the amplitude object
DOF	Depth of focus
DP	Vector of light diffracted at phase object
$\mathrm{D}_{\mathrm{pinhole}}$	Pinhole diameter
d_{xy}, d_z	Spatial and axial resolution of confocal microscope
E	Electric field
E	Energy gap
E_x and E_y	Components of electric field
F	Coefficient of finesse
F	Fluorescent emission
f	Focal length
f_{C}, f_{F}	Focal length for lines C and F
f_{e}	Effective focal length
FOV	Field of view
FWHM	Full width at half maximum
h	Planck's constant
h, h'	Object and image height
H	Magnetic field
I	Intensity of light
i, j	Pixel coordinates
I_{o}	Intensity of incident light

Glossary of Symbols (cont.)

$I_{\max}$, $I_{\min}$	Maximum and minimum intensity in the image
I, I_t, I_r	Irradiances of incident, transmitted, and reflected light
I_1, I_2, I_3 …	Intensity of successive images
I_0, $I_{2\pi/3}$, $I_{4\pi/3}$	Intensities for the image point and three consecutive grid positions
k	Number of events
k	Wave number
L	Distance
l_c	Coherence length
m	Diffraction order
M	Magnification
$M_{\min}$	Minimum microscope magnification
MP	Magnifying power
MTF	Modulation transfer function
M_u	Angular magnification
n	Refractive index of the dielectric media
n	Step number
N	Expected value
N	Intensity decrease coefficient
N	Total number of grating lines
n_a	Probability of two-photon excitation
NA	Numerical aperture
n_e	Refractive index for propagation velocity of extraordinary wave
n_m, n_r	Refractive indices of the media surrounding the phase ring and the ring itself
n_o	Refractive index for propagation velocity of ordinary wave
n_1	Refractive index of media 1
n_2	Refractive index of media 2
o, e	Ordinary and extraordinary beams
OD	Optical density
OPD	Optical path difference
OPL	Optical path length
OTF	Optical transfer function
OTL	Optical tube length
P	Probability
P_{avg}	Average power
PO	Vector of light passing through phase object

Glossary of Symbols (cont.)

PSF	Point spread function
Q	Fluorophore quantum yield
r	Radius
r	Reflection coefficients
r, m, and o	Relative, media, or vacuum
r_{AS}	Radius of aperture stop
r_{PR}	Radius of phase ring
r_{λ}	Radius of filter for wavelength λ
s, s'	Shear between wavefront object and image space
S	Pinhole/slit separation
$\mathrm{s}_{\perp}$	Lateral shift in TIR perpendicular component of electromagnetic vector
$\mathrm{s}_{\parallel}$	Lateral shift in TIR for parallel component of electromagnetic vector
S_{FD}	Factor depending on specific Fraunhofer approximation
SM	Vector of light passing through surrounding media
SNR	Signal-to-noise ratio
SR	Strehl ratio
t	Lens separation
t	Thickness
t	Time
t	Transmission coefficient
T	Time required to pass the distance between wave oscillations
T	Throughput of a confocal microscope
t_{c}	Coherence time
u, u'	Object, image aperture angle
V_{d}, V_{e}	Abbe number as defined for lines d, F, C or e, F′, C′
V_{m}	Velocity of light in media
w	Width of the slit
x, y	Coordinates
z	Distance along the direction of propagation
z	Fraunhofer diffraction distance
z, z'	Object and image distances
z_{m}, z_{o}	Imaged sample depth, length of reference path

Glossary of Symbols (cont.)

α	Angle between vectors of interfering waves
α	Birefringent prism angle
α	Grating incidence angle in plane perpendicular to grating plane
α_s	Visual stereo resolving power
β	Grating diffraction angle in plane perpendicular to grating plane
γ	Angle of fringe localization plane
γ	Convergence angle of a stereo microscope
γ	Incidence / diffraction angle from the plane perpendicular to grating plane
Γ	Retardation
δ	Birefringence
δ	Excitation cross section of dye
δz	Depth perception
Δ_b	Axial phase delay
Δf	Variation in focal length
$\Delta\mathbf{k}$	Phase mismatch
Δz, $\Delta z'$	Object and image separations
$\Delta\lambda$	Wavelength bandwidth
$\Delta\nu$	Frequency bandwidth
$\Delta\varphi$	Phase delay
$\Delta\varphi$	Phase difference
$\Delta\varphi$	Phase shift
$\Delta\varphi_{min}$	Minimum perceived phase difference
ε	Angle between interfering beams
ε	Dielectric constant, i.e., medium permittivity
η	Quantum efficiency
θ'	Refraction angle
θ_{cr}	Critical angle
θ_i	Incidence angle
θ_r	Reflection angle
λ	Wavelength of light
λ_p	Peak wavelength for the m^{th} interference order
μ	Magnetic permeability
ν	Frequency of light
ν	Repetition frequency
ξ	Propagation direction
ρ	Spatial frequency
σ	Molecular absorption cross section

Glossary of Symbols (cont.)

σ_{dark}	Dark noise
σ_{photon}	Photon noise
σ_{read}	Read noise
τ	Integration time
τ	Length of a pulse
τ	Transmittance
φ	Incident photon flux
φ	Optical power
φ	Phase difference generated by a thin film
φ_o	Initial phase
φ_o	Phase delay through the object
φ_p	Phase delay in a phase plate
φ_{TF}	Phase difference generated by a thin film
ω	Angular frequency
ω	Bandgap frequency
$\perp$ and $\parallel$	Perpendicular and parallel components of the light vector

Nature of Light

Optics uses two approaches, termed the **particle** and **wave models,** to describe the nature of light. The former arises from atomic structure, where the transitions between energy levels are quantized. Electrons can be excited into higher energy levels via external processes with the release of a discrete quantum of energy (a photon) upon their decay to a lower level.

The wave model complements this corpuscular theory and explains optical effects involving diffraction and interference. The wave and particle models can be related through the frequency of oscillations, with the relationship between quanta of energy and frequency given by

$$E = h\nu \text{ [in eV or J]},$$

where $h = 4.135667\times10^{-15}$ [eV·s] $= 6.626068\times10^{-34}$ [J·s] is **Planck's constant**, and ν is the **frequency of light** [Hz]. The frequency ν of a wave is the reciprocal of its period T [s]:

$$\nu = \frac{1}{T}\,.$$

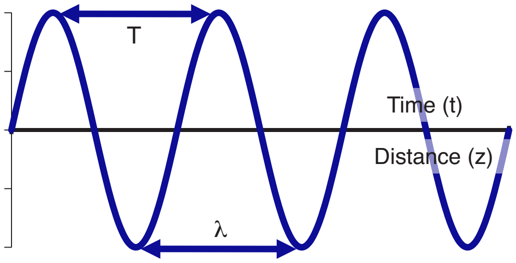

The period T [s] corresponds to one cycle of a wave or, if defined in terms of the distance required to perform one full oscillation, describes the **wavelength of light** λ [m]. The **velocity of light** in free space is 2.99792×10^8 m/s and is defined as the distance traveled in one period (λ) divided by the time taken (T):

$$c = \frac{\lambda}{T}\,.$$

Note that wavelength is often measured indirectly as time T required to pass the distance between wave oscillations.

The relationship for the velocity of light c can be rewritten in terms of wavelength and frequency as

$$c = \lambda\nu\,.$$

The Spectrum of Microscopy

The range of electromagnetic radiation is called the **electromagnetic spectrum**. Various microscopy techniques employ wavelengths spanning from **x-ray radiation** and **ultraviolet radiation** (UV) through the **visible spectrum** (VIS) to **infrared radiation** (IR). The wavelength in combination with the microscope parameters determines the resolution limit of the microscope (0.61λ/NA). The smallest feature resolved using light microscopy and determined by diffraction is approximately 200 nm for UV light with a high numerical aperture (for more details, see *Resolution Limit* on page 39). However, recently emerging super-resolution techniques overcome this barrier, and features are observable in the 20–50 nm range.

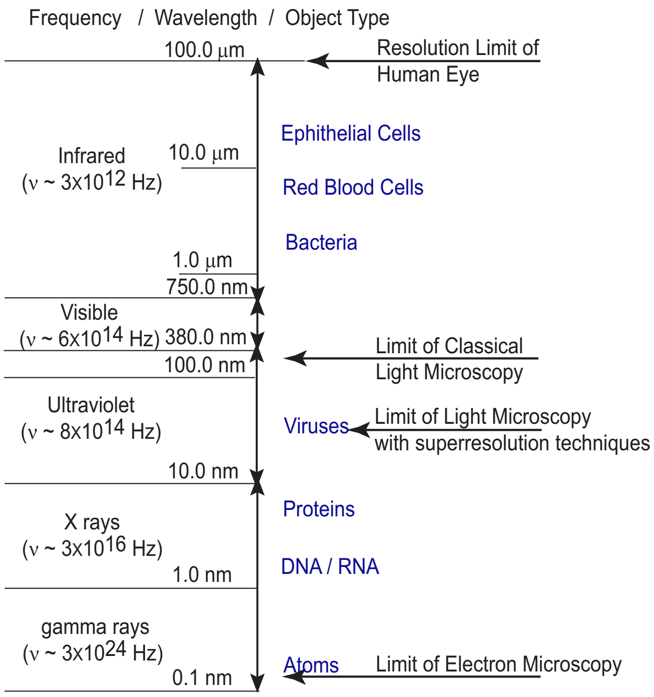
Frequency / Wavelength / Object Type
100.0 μm
Resolution Limit of Human Eye
Infrared (ν ~ 3x10^12 Hz)
10.0 μm
Ephithelial Cells
Red Blood Cells
Bacteria
1.0 μm
750.0 nm
Visible (ν ~ 6x10^14 Hz)
380.0 nm
Limit of Classical Light Microscopy
100.0 nm
Ultraviolet (ν ~ 8x10^14 Hz)
Viruses
Limit of Light Microscopy with superresolution techniques
10.0 nm
X rays (ν ~ 3x10^16 Hz)
Proteins
DNA / RNA
1.0 nm
gamma rays (ν ~ 3x10^24 Hz)
Atoms
Limit of Electron Microscopy
0.1 nm

Wave Equations

Maxwell's equations describe the propagation of an electromagnetic wave. For homogenous and isotropic media, magnetic (*H*) and electric (*E*) components of an electromagnetic field can be described by the wave equations derived from Maxwell's equations:

$$\nabla^2 \vec{E} - \varepsilon_\mathrm{m}\mu_\mathrm{m}\frac{\partial^2 \vec{E}}{\partial t^2} = 0$$

$$\nabla^2 \vec{H} - \varepsilon_\mathrm{m}\mu_\mathrm{m}\frac{\partial^2 \vec{H}}{\partial t^2} = 0 ,$$

where ε is a **dielectric constant,** i.e., **medium permittivity** while μ is a **magnetic permeability**:

$$\varepsilon_\mathrm{m} = \varepsilon_\mathrm{o}\varepsilon_\mathrm{r} \qquad \mu_\mathrm{m} = \mu_\mathrm{o}\mu_\mathrm{r}$$

Indices r, m, and o stand for relative, media, or vacuum, respectively.

The above equations indicate that the time variation of the electric field and the current density creates a time-varying magnetic field. Variations in the magnetic field induce a time-varying electric field. Both fields depend on each other and compose an electromagnetic wave. Magnetic and electric components can be separated.

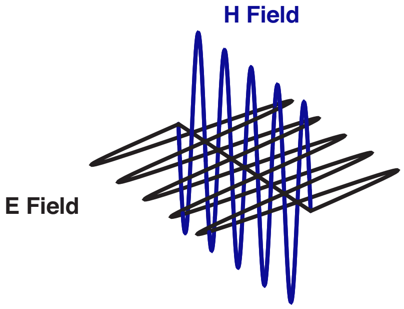

The electric component of an electromagnetic wave has primary significance for the phenomenon of light. This is because the magnetic component cannot be measured with optical detectors. Therefore, the magnetic component is most often neglected, and the electric vector $\vec{E}$ is called a light vector.

Wavefront Propagation

Light propagating through isotropic media conforms to the equation

$$E = A\sin\left(\omega t - kz + \varphi_o\right),$$

where t is time, z is distance along the direction of propagation, and ω is an **angular frequency** given by

$$\omega = \frac{2\pi}{T} = \frac{2\pi V_m}{\lambda}.$$

The term kz is called the **phase of light**, while φ_o is an initial phase. In addition, k represents the **wave number** (equal to $2\pi/\lambda$) and V_m is the velocity of light in media:

$$kz = \frac{2\pi}{\lambda} nz$$

The above propagation equation pertains to the special case when the electric field vector varies only in one plane.

The **refractive index** of the dielectric media n describes the relationship between the speed of light in a vacuum and in media. It is

$$n = \frac{c}{V_m},$$

where c is the speed of light in vacuum.

An alternative way to describe the propagation of an electric field is with an exponential (complex) representation:

$$E = A\exp\left[-i\left(\omega t - kz + \varphi_o\right)\right].$$

This form allows the easy separation of phase components of an electromagnetic wave.

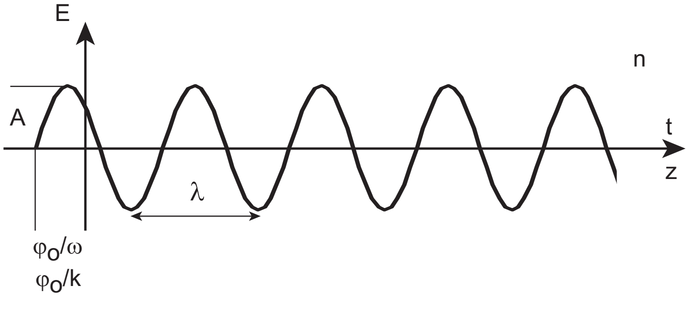

Optical Path Length (OPL)

Fermat's principle states that "The path traveled by a light wave from a point to another point is stationary with respect to variations of this path." In practical terms, this means that light travels along the minimum time path.

Optical path length (OPL) is related to the time required for light to travel from point P1 to point P2. It accounts for the media density through the refractive index:

$$t = \frac{1}{c}\int_{P1}^{P2} n\,ds$$

or

$$OPL = \int_{P1}^{P2} n\,ds\ ,$$

where

$$ds^2 = dx^2 + dy^2 + dz^2\ .$$

Optical path length can also be discussed in the context of the number of periods required to propagate a certain distance L. In a medium with refractive index n, light slows down and more wave cycles are needed. Therefore, OPL is an equivalent path for light traveling with the same number of periods in a vacuum:

$$OPL = nL\ .$$

Optical path difference (OPD) is the difference between optical path lengths traversed by two light waves:

$$OPD = n_1 L_1 - n_2 L_2\ .$$

OPD can also be expressed as a phase difference:

$$\Delta\varphi = 2\pi\frac{OPD}{\lambda}\ .$$

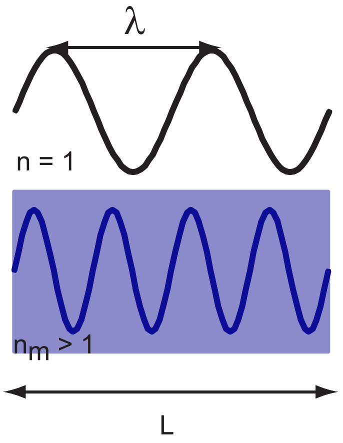

Laws of Reflection and Refraction

Light rays incident on an interface between different dielectric media experience reflection and refraction as shown.

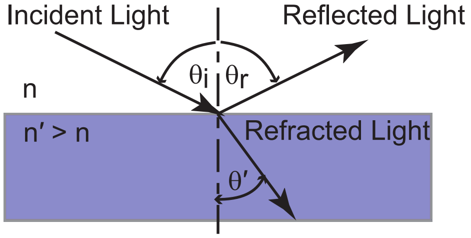

Reflection Law: Angles of **incidence** and **reflection** are related by

$$\theta_i = -\theta_r \, .$$

Refraction Law (**Snell's Law**): Incident and refracted angles are related to each other and to the refractive indices of the two media by Snell's Law:

$$n \sin\theta_i = n' \sin\theta' \, .$$

Fresnel reflection: The division of light at a dielectric boundary into transmitted and reflected rays is described for nonlossy, nonmagnetic media by the Fresnel equations:

Reflectance coefficients	**Transmission Coefficients**
$r_\perp = \frac{I_{r\perp}}{I_\perp} = \frac{\sin^2(\theta_i - \theta')}{\sin^2(\theta_i + \theta')}$	$t_\perp = \frac{I_{t\perp}}{I_\perp} = \frac{4\sin^2\theta' \cos^2\theta_i}{\sin^2(\theta_i + \theta')}$
$r_\parallel = \frac{I_{r\parallel}}{I_\parallel} = \frac{\tan^2(\theta_i - \theta')}{\tan^2(\theta_i + \theta')}$	$t_\parallel = \frac{I_{t\parallel}}{I_\parallel} = \frac{4\sin^2\theta' \cos^2\theta_i}{\sin^2(\theta_i + \theta')\cos^2(\theta_i - \theta')}$

t and r are transmission and reflection coefficients, respectively. I, I_t, and I_r are the irradiances of incident, transmitted, and reflected light, respectively. ⊥ and ‖ denote perpendicular and parallel components of the light vector with respect to the plane of incidence. θ_i and θ' in the table are the angles of incidence and reflection/refraction, respectively. At a normal incidence ($\theta' = \theta_i = 0$ deg), the Fresnel equations reduce to

$$r = r_\perp = r_\parallel = \frac{(n'-n)^2}{(n'+n)^2} \quad \text{and} \quad t = t_\perp = t_\parallel = \frac{4nn'}{(n'+n)^2} \, .$$

Total Internal Reflection

When light passes from one medium to a medium with a higher refractive index, the angle of the light in the medium bends toward the normal, according to Snell's Law. Conversely, when light passes from one medium to a medium with a lower refractive index, the angle of the light in the second medium bends away from the normal. If the angle of refraction is greater than 90 deg, the light cannot escape the denser medium, and it reflects instead of refracting. This effect is known as **total internal reflection** (TIR). TIR occurs only for illumination with an angle larger than the **critical angle**, defined as

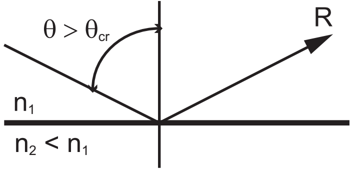

$$\theta_{cr} = \arcsin\left(\frac{n_1}{n_2}\right).$$

It appears, however, that light can propagate through (at a limited range) to the lower-density material as an **evanescent wave** (a nearly standing wave occurring at the material boundary), even if illuminated under an angle larger than θ_{cr}. Such a phenomenon is called **frustrated total internal reflection**. Frustrated TIR is used, for example, with thin films (TF) to build beam splitters. The proper selection of the film thickness provides the desired beam ratio (see the figure below for various split ratios). Note that the maximum film thickness must be approximately a single wavelength or less, otherwise light decays entirely. The effect of an evanescent wave propagating in the lower-density material under TIR conditions is also used in total internal reflection fluorescence (**TIRF**) microscopy.

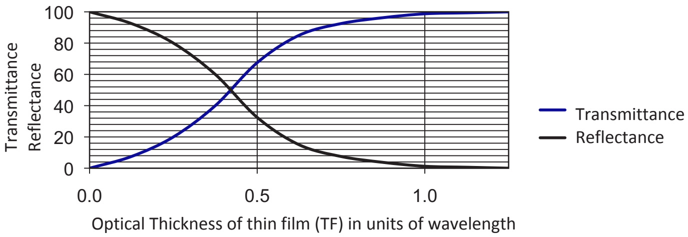

Evanescent Wave in Total Internal Reflection

A beam reflected at the dielectric interface during **total internal reflection** is subject to a small lateral shift, also known as the **Goos-Hänchen effect**. The shift is different for the parallel and perpendicular components of the electromagnetic vector.

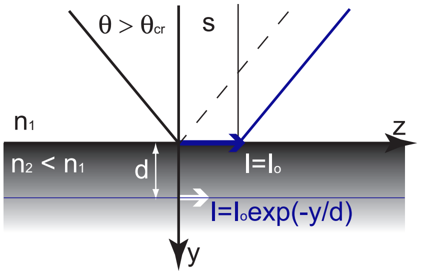

	Lateral shift in TIR
Parallel* component of e/m vector	$s_{\parallel} = \dfrac{\lambda n_1}{\pi n_2^2} \dfrac{\tan\theta}{\sqrt{\sin^2\theta - \sin^2\theta_c}}$
Perpendicular* component of e/m vector	$s_{\perp} = \dfrac{\lambda}{\pi n_1} \dfrac{\tan\theta}{\sqrt{\sin^2\theta - \sin^2\theta_c}}$
* to the plane of incidence	

The intensity of the illuminating beam decays exponentially with distance y in the direction perpendicular to the material boundary:

$$I = I_o \exp\left(-y/d\right).$$

Note that d denotes the distance at which the intensity of the illuminating light I_o drops by e. The decay distance is smaller than a wavelength. It is also inversely proportional to the illumination angle.

Decay distance (d) of evanescent wave	
Decay distance as a function of incidence and critical angles	$d = \dfrac{\lambda}{4\pi n_1} \dfrac{1}{\sqrt{\sin^2\theta - \sin^2\theta_c}}$
Decay distance as a function of incidence angle and refractive indices of media	$d = \dfrac{\lambda}{4\pi} \dfrac{1}{\sqrt{n_1^2 \sin^2\theta - n_2^2}}$

Propagation of Light in Anisotropic Media

In anisotropic media the velocity of light depends on the direction of propagation. Common anisotropic and optically transparent materials include **uniaxial crystals**. Such crystals exhibit one direction of travel with a single propagation velocity. The single velocity direction is called the **optic axis** of the crystal. For any other direction, there are two velocities of propagation.

The wave in birefringent crystals can be divided into two components: ordinary and extraordinary. An **ordinary wave** has a uniform velocity in all directions, while the velocity of an **extraordinary wave** varies with orientation. The extreme value of an extraordinary wave's velocity is perpendicular to the optic axis. Both waves are linearly polarized, which means that the electric vector oscillates in one plane. The vibration planes of extraordinary and ordinary vectors are perpendicular. Refractive indices corresponding to the direction of the optic axis and perpendicular to the optic axis are $n_o = c/V_o$ and $n_e = c/V_e$ respectively.

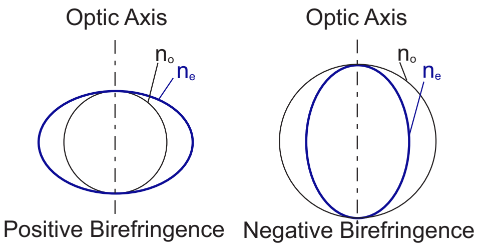

Uniaxial crystals can be positive or negative (see table). The **refractive index** $n(\xi)$ for velocities between the two extreme (n_o and n_e) values is

$$\frac{1}{n^2(\xi)} = \frac{\cos^2\xi}{n_o^2} + \frac{\sin^2\xi}{n_e^2}.$$

Positive Birefringence	$V_e \le V_o$
Negative Birefringence	$V_e \ge V_o$

Note that the propagation direction ξ (with regard to the optic axis) is slightly off from the ray direction, which is defined by the Poynting (energy) vector.

Uniaxial Crystal	**Refractive index**	**Abbe Number**	**Wavelength Range** [μm]
Quartz	$n_o = 1.54424$ $n_e = 1.55335$	70 69	0.18–4.0
Calcite	$n_o = 1.65835$ $n_e = 1.48640$	50 68	0.2–2.0
The refractive index is given for the *D* spectral line (589.2 nm).			

(Adapted from Pluta, 1988)

Polarization of Light and Polarization States

The orientation characteristic of a light vector vibrating in time and space is called the **polarization of light**. For example, if the vector of an electric wave vibrates in one plane, the state of polarization is linear. A vector vibrating with a random orientation represents unpolarized light.

The wave vector E consists of two components E_x and E_y.

$$E(z,t) = E_x + E_y$$

$$E_x = A_x \exp\left[-i\left(\omega t - kz + \varphi_x\right)\right]$$

$$E_y = A_y \exp\left[-i\left(\omega t - kz + \varphi_y\right)\right].$$

The **electric vector** rotates periodically (the periodicity corresponds to wavelength λ) in the plane perpendicular to the propagation axis (z) and generally forms an elliptical shape. The specific shape depends on the A_x and A_y ratios and the phase delay between the E_x and E_y components, defined as $\Delta\varphi = \varphi_x - \varphi_y$.

Linearly polarized light is obtained when one of the components E_x or E_y is zero, or when $\Delta\varphi$ is zero or π. **Circularly polarized light** is obtained when $E_x = E_y$ and $\Delta\varphi = \pm\pi/2$. The light is called right circularly polarized (RCP) if it rotates in a clockwise direction or left circularly polarized (LCP) if it rotates counterclockwise when looking at the oncoming beam.

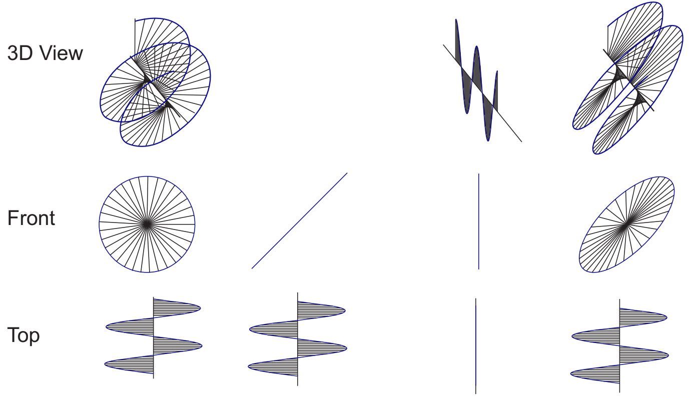

Polarization	Circular	Linear	Linear	Elliptical
Amplitudes	1 1	1 1	0 1	1 1
Δφ	π/2	0	0	π/4

Coherence and Monochromatic Light

An ideal light wave that extends in space at any instance to $\pm\infty$ and has only one wavelength λ (or frequency ν) is said to be **monochromatic**. If the range of wavelengths λ or frequencies ν is very small (around λ_o or ν_o, respectively), the wave is **quasi-monochromatic**. Such a wave packet is usually called a **wave group**.

Note that for monochromatic and quasi-monochromatic waves, no phase relationship is required, and the intensity of light can be calculated as a simple summation of intensities from different waves; phase changes are very fast and random, so only the average intensity can be recorded.

If multiple waves have a common phase relation dependence, they are **coherent** or **partially coherent**. These cases correspond to full- and partial-phase correlation respectively. A common source of a coherent wave is a laser where waves must be in resonance and therefore in phase. The average length of the wave packet (group) is called the **coherence length**, while the time required to pass this length is called **coherence time**. Both values are linked by the equations

$$\Delta\nu = \frac{1}{t_c} = \frac{V}{l_c}$$

where coherence length is

$$l_c = \frac{\lambda^2}{\Delta\lambda}.$$

The coherence length l_c and **temporal coherence** t_c are inversely proportional to the bandwidth $\Delta\lambda$ of the light source.

Spatial coherence is a term related to the coherence of light with regard to the extent of the light source. The fringe contrast varies for interference of any two spatially different source points. Light is **partially coherent** if its coherence is limited by the source bandwidth, dimension, temperature, or other effects.

Interference

Interference is a process of superposition of two coherent (correlated) or partially coherent waves. Waves interact with each other, and the resulting intensity is described by summing the **complex amplitudes** (**electric fields**) E_1 and E_2 of both wavefronts:

$$E_1 = A_1 \exp\left[-i\left(\omega t - kz + \varphi_1\right)\right]$$

and

$$E_2 = A_2 \exp\left[-i\left(\omega t - kz + \varphi_2\right)\right].$$

The resultant field is

$$E = E_1 + E_2 .$$

Therefore, the **interference** of the two beams can be written as

$$I = EE^*,$$

$$I = A_1^2 + A_2^2 + 2A_1A_2\cos(\Delta\varphi),$$

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos(\Delta\varphi),$$

$$I_1 = E_1E_1^*,\ \ I_2 = E_2E_2^*,\ \text{and}$$

$$\Delta\varphi = \varphi_2 - \varphi_1,$$

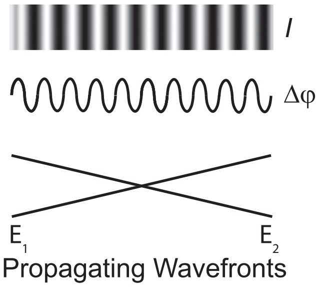

Propagating Wavefronts

where * denotes a conjugate function, I is the **intensity of light**, A is an amplitude of an electric field, and $\Delta\varphi$ is the phase difference between the two interfering beams. **Contrast** C (called also **visibility**) of the interference fringes can be expressed as

$$C = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}.$$

The fringe existence and visibility depends on several conditions. To obtain the interference effect,

- Interfering beams must originate from the same light source and be temporally and spatially coherent;
- The polarization of interfering beams must be aligned;
- To maximize the contrast, interfering beams should have equal or similar amplitudes.

Conversely, if two noncorrelated, random waves are in the same region of space, the sum of intensities (irradiances) of these waves gives a total intensity in that region: $I = I_1 + I_2$.

Contrast vs Spatial and Temporal Coherence

The result of interference is a periodic intensity change in space, which creates fringes when incident on a screen or detector. **Spatial coherence** relates to the contrast of these fringes depending on the extent of the source and is not a function of the phase difference (or OPD) between beams. The intensity of interfering fringes is given by

$$I = I_1 + I_2 + 2C\left(\text{Source Extent}\right)\sqrt{I_1 I_2}\cos\left(\Delta\varphi\right),$$

where C is a constant, depending on the extent of the source.

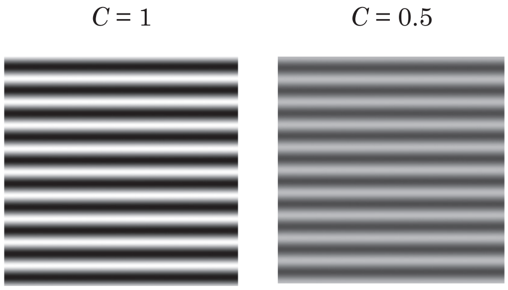

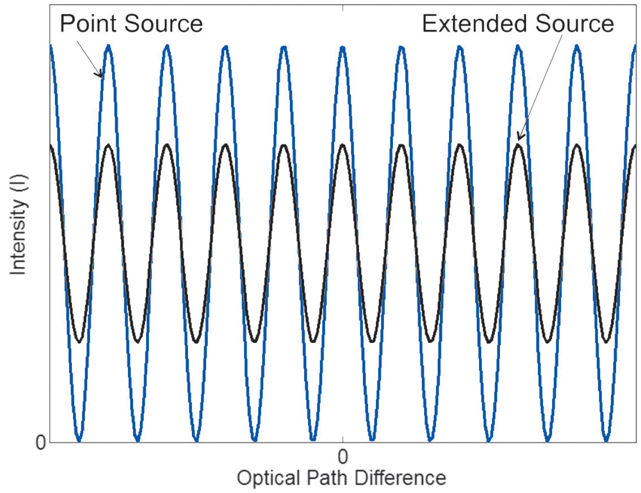

The spatial coherence can be improved through spatial filtering. For example, light can be focused on the pinhole (or coupled into the fiber) by using a microscope objective. In microscopy, spatial coherence can be adjusted by changing the diaphragm size in the conjugate plane of the light source.

Contrast vs Spatial and Temporal Coherence (cont.)

The intensity of the fringes depends on the OPD and the **temporal coherence** of the source. The fringe contrast trends toward zero as the OPD increases beyond the coherence length:

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\, C\left(OPD\right)\cos\left(\Delta\varphi\right).$$

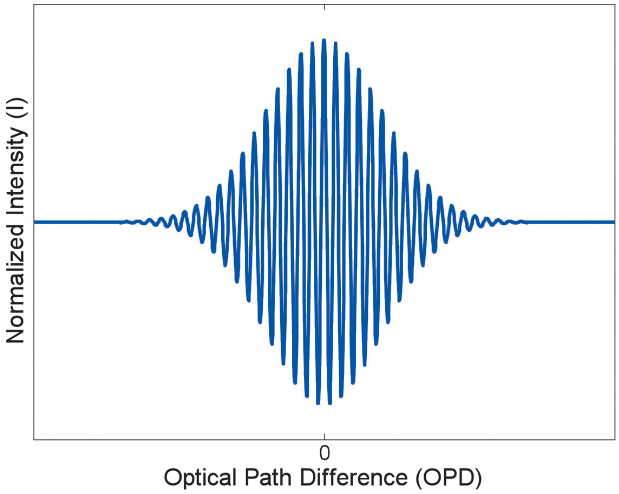

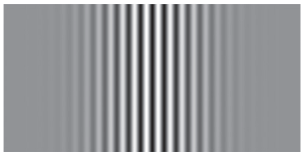

The spatial width of a fringe pattern envelope decreases with shorter temporal coherence. The location of the envelope's peak (with respect to the reference) and narrow width can be efficiently used as a gating mechanism in both imaging and metrology. For example, it is used in interference microscopy for optical profiling (white light interferometry) and for imaging using optical coherence tomography. Examples of short coherence sources include white light sources, luminescent diodes, and broadband lasers.

Long coherence length is beneficial in applications that do not naturally provide near-zero OPD, e.g., in surface measurements with a Fizeau interferometer.

Contrast of Fringes (Polarization and Amplitude Ratio)

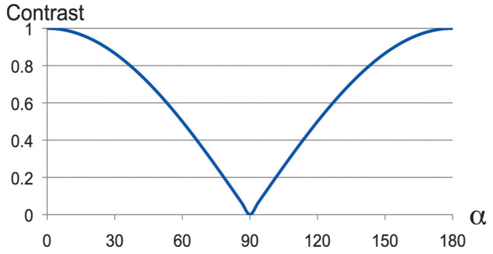

The contrast of fringes depends on the polarization orientation of the electric vectors. For linearly polarized beams, it can be described as $C = |\cos\alpha|$, where α represents the angle between polarization states.

Angle between Electric Vectors of Interfering Beams			
0	π/6	π/3	π/2
Interference Fringes			
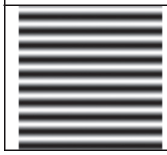	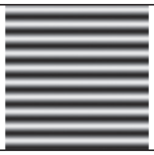	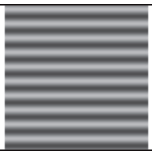	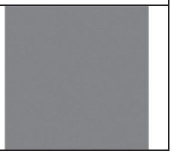

Fringe contrast also depends on the interfering beams' amplitude ratio. The intensity of the fringes is simply calculated by using the main interference equation. The contrast is maximum for equal beam intensities and for the interference pattern, defined as

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos(\Delta\varphi),$$

it is

$$C = \frac{2\sqrt{I_1 I_2}}{I_1 + I_2}.$$

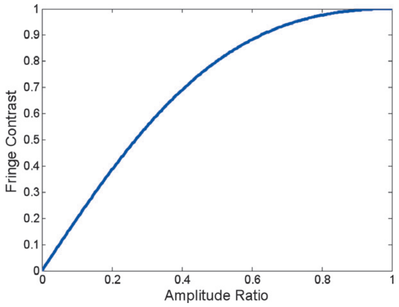

Ratio between Amplitudes of Interfering Beams			
1	0.5	0.25	0.1
Interference Fringes			
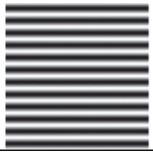	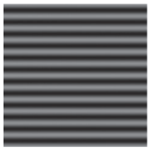	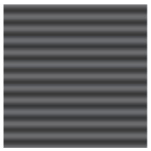	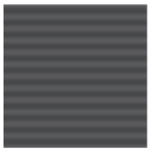

Multiple Wave Interference

If light reflects inside a thin film, its intensity gradually decreases and **multiple beam interference** occurs.

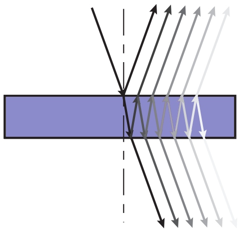

The intensity of reflected light is

$$I_r = I_i \frac{F \sin^2(\varphi/2)}{1 + F \sin^2(\varphi/2)} \ ,$$

and for transmitted light is

$$I_t = I_i \frac{1}{1 + F \sin^2(\varphi/2)} \ .$$

The coefficient of finesse F of such a resonator is

$$F = \frac{4r}{(1-r)^2} \ .$$

Because phase depends on the wavelength, it is possible to design selective **interference filters**. In this case, a dielectric thin film is coated with metallic layers. The peak wavelength for the m^{th} interference order of the filter can be defined as

$$\lambda_p = \frac{2nt \cos\theta'}{m - \left(\frac{\varphi_{TF}}{2\pi}\right)} \ ,$$

where φ_{TF} is the phase difference generated by a thin film of thickness t and a specific incidence angle. The **interference order** relates to the phase difference in multiples of 2π.

Interference filters usually operate for illumination with flat wavefronts at a normal incidence angle. Therefore, the equation simplifies as

$$\lambda_p = \frac{2nt}{m} \ .$$

The **half bandwidth** (HBW) of the filter for normal incidence is

$$HBW = \frac{1-r}{m\pi} \lambda_p \ [\mathrm{m}] \ .$$

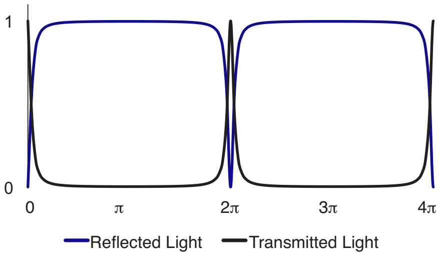

The peak intensity transmission is usually at 20% to 50%, or up to 90% of the incident light for metal-dielectric or multi-dielectric filters respectively.

Interferometers

Due to the high frequency of light, it is not possible to detect the phase of the light wave directly. To acquire the phase, interferometry techniques may be used. There are two major classes of interferometers, based on **amplitude splitting** and **wavefront splitting**.

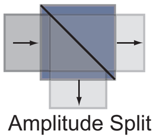
Amplitude Split

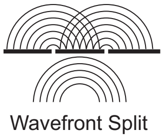
Wavefront Split

From the point of view of fringe pattern interpretation, interferometers can also be divided into those that deliver fringes, which directly correspond to the phase distribution, and those providing a derivative of the phase map (also called shearing interferometers). The first type is realized by obtaining the interference between the test beam and a reference beam. An example of such a system is the **Michelson interferometer**. **Shearing interferometers** provide the intereference of two shifted object wavefronts.

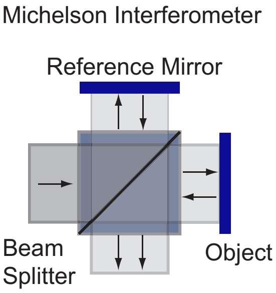
Michelson Interferometer
Reference Mirror
Beam Splitter
Object

There are numerous ways of introducing shear (linear, radial, etc.). Examples of shearing interferometers include the parallel or wedge plate, the grating interferometer, the **Sagnac**, and polarization interferometers (commonly used in microscopy). The **Mach-Zehnder interferometer** can be configured for direct and differential fringes, depending on the position of the sample.

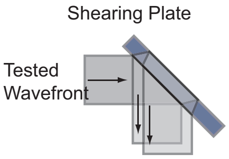
Shearing Plate
Tested Wavefront

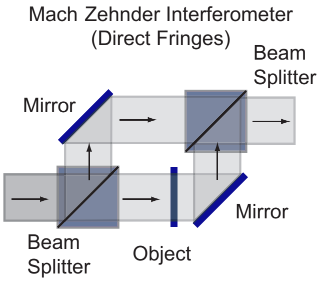
Mach Zehnder Interferometer (Direct Fringes)
Beam Splitter
Mirror
Mirror
Beam Splitter
Object

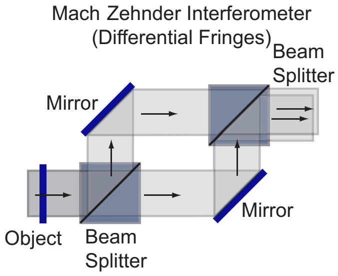
Mach Zehnder Interferometer (Differential Fringes)
Beam Splitter
Mirror
Mirror
Object
Beam Splitter

Diffraction

The bending of waves by apertures and objects is called **diffraction of light**. Waves diffracted inside the optical system interfere (for path differences within the coherence length of the source) with each other and create diffraction patterns in the image of an object.

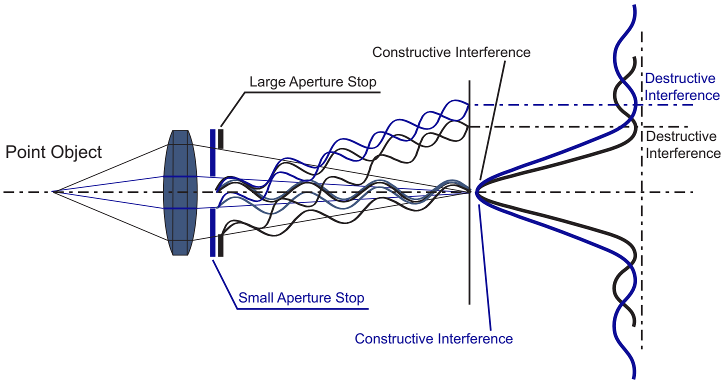
Constructive Interference
Large Aperture Stop
Destructive Interference
Destructive Interference
Point Object
Small Aperture Stop
Constructive Interference

There are two common approximations of diffraction phenomena: **Fresnel diffraction** (near-field) and **Fraunhofer diffraction** (far-field). Both diffraction types complement each other but are not sharply divided due to various definitions of their regions. Fraunhofer diffraction occurs when one can assume that propagating wavefronts are flat (collimated), while the Fresnel diffraction is the near-field case. Thus, Fraunhofer diffraction (distance z) for a free-space case is infinity, but in practice it can be defined for a region

$$z > S_{\mathrm{FD}} \frac{d^2}{\lambda},$$

where d is the diameter of the diffractive object, and S_{FD} is a factor depending on approximation. A conservative definition of the Fraunhofer region is $S_{\mathrm{FD}} = 1$, while for most practical cases it can be assumed to be 10 times smaller ($S_{\mathrm{FD}} = 0.1$).

Diffraction effects influence the resolution of an imaging system and are a reason for fringes (ring patterns) in the image of a point. Specifically, Fraunhofer fringes appear in the conjugate image plane. This is due to the fact that the image is located in the Fraunhofer diffracting region of an optical system's aperture stop.

Diffraction Grating

Diffraction gratings are optical components consisting of periodic linear structures that provide "organized" diffraction of light. In practical terms, this means that for specific angles (depending on illumination and grating parameters), it is possible to obtain constructive (2π phase difference) and destructive (π phase difference) interference at specific directions. The angles of constructive interference are defined by the diffraction grating equation and called **diffraction orders** (m).

Gratings can be classified as transmission or reflection (mode of operation), amplitude (periodic amplitude changes) or phase (periodic phase changes), or ruled or holographic (method of fabrication). Ruled gratings are mechanically cut and usually have a triangular profile (each facet can thereby promote select diffraction angles). Holographic gratings are made using interference (sinusoidal profiles).

Diffraction angles depend on the ratio between the grating constant and wavelength so various wavelengths can be separated. This makes them applicable for spectroscopic detection or spectral imaging. The **grating equation** is

$$m\lambda = d\cos\gamma\,(\sin\beta \pm \sin\alpha)$$

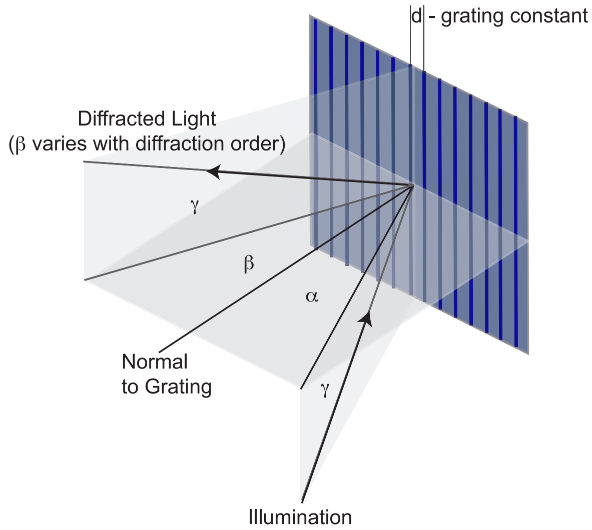

Diffraction Grating (cont.)

The sign in the diffraction grating equation defines the type of grating: A **transmission grating** is identified with a minus sign (–), and a **reflective grating** is identified with a plus sign (+).

For a grating illuminated in the plane perpendicular to the grating, its equation simplifies and is

$$m\lambda = d\left(\sin\beta \pm \sin\alpha\right).$$

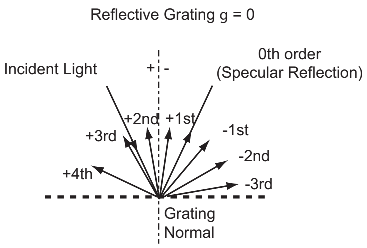
Reflective Grating g = 0
Incident Light
+
-
0th order
(Specular Reflection)
+2nd
+1st
+3rd
-1st
-2nd
+4th
-3rd
Grating
Normal

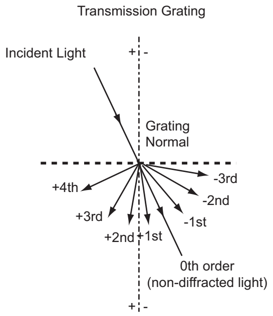
Transmission Grating
Incident Light
+
-
Grating
Normal
-3rd
+4th
-2nd
+3rd
-1st
+2nd
+1st
0th order
(non-diffracted light)
+
-

For normal illumination, the grating equation becomes

$$m\lambda = d\sin\beta.$$

The **chromatic resolving power** of a grating depends on its size (total number of lines *N*). If the grating has more lines, the diffraction orders are narrower, and the resolving power increases:

$$\frac{\lambda}{\Delta\lambda} = mN.$$

The **free spectral range** $\Delta\lambda$ of the grating is the bandwidth in the m^{th} order without overlapping other orders. It defines useful bandwidth for spectroscopic detection as

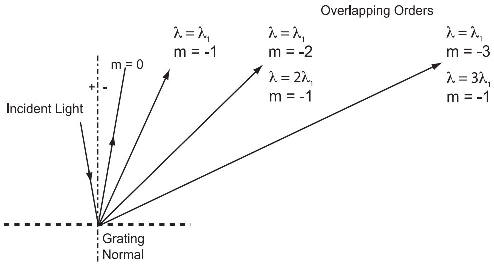
Overlapping Orders
λ = λ₁
m = -1
λ = λ₁
m = -2
λ = 2λ₁
m = -1
λ = λ₁
m = -3
λ = 3λ₁
m = -1
m = 0
+
-
Incident Light
Grating
Normal

$$\Delta\lambda = \frac{m+1}{m}\lambda_1 - \lambda_1 = \frac{\lambda_1}{m}.$$

Useful Definitions from Geometrical Optics

All optical systems consist of refractive or reflective interfaces (surfaces) changing the propagation angles of **optical rays**.

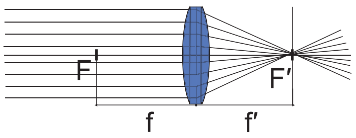

Rays define the propagation trajectory and always travel perpendicular to the wavefronts. They are used to describe imaging in the regime of geometrical optics and to perform optical design.

There are two **optical spaces** corresponding to each optical system: **object space** and **image space**. Both spaces extend from –∞ to +∞ and are divided into real and virtual parts. Ability to access the image or object defines the real part of the optical space.

Paraxial optics is an approximation assuming small ray angles and is used to determine first-order parameters of the optical system (image location, magnification etc.).

Thin lenses are optical components reduced to zero thickness and are used to perform first-order optical designs (see next page).

The **focal point** of an optical system is a location that collimated beams converge to or diverge from. Planes perpendicular to the optical axis at the focal points are called **focal planes**. **Focal length** is the distance between the lens (specifically, its principal plane) and the focal plane. For thin lenses, principal planes overlap with the lens.

Sign Convention: The common sign convention assigns positive values to distances traced from left to right (the direction of propagation) and to the top. Angles are positive if they are measured counterclockwise from normal to the surface or optical axis. If light travels from right to left, the refractive index is negative. The surface radius is measured from its vertex to its center of curvature.

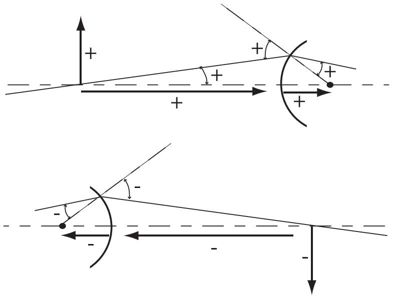

Image Formation

A simple model describing imaging through an optical system is based on thin lens relationships. A **real image** is formed at the point where rays converge.

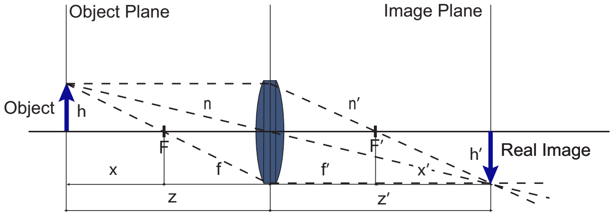
Object Plane
Image Plane
Object
h
n
n′
F
F′
h′
Real Image
x
f
f′
x′
z
z′

A **virtual image** is formed at the point from which rays appear to diverge.

For a lens made of glass, surrounded on both sides by air ($n = n' = 1$), the imaging relationship is described by the **Newtonian equation**

$$xx' = ff' \qquad \text{or} \qquad xx' = -f'^2 .$$

Note that Newtonian equations refer to the distance from the focal planes so, in practice, they are used with thin lenses.

Imaging can also be described by the **Gaussian imaging equation**

$$\frac{f}{z} + \frac{f'}{z'} = 1 .$$

The **effective focal length** of the system is

$$f_e = \frac{1}{\varphi} = -\frac{f}{n} = \frac{f'}{n'} ,$$

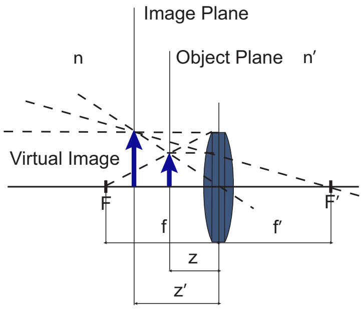
Image Plane
n
Object Plane
n′
Virtual Image
F
F′
f
f′
z
z′

where φ is the **optical power** expressed in diopters D [m^{-1}].

Therefore,

$$\frac{n'}{z'} = \frac{n}{z} + \frac{1}{f_e} .$$

For air, when n and n' are equal to 1, the imaging relation is

$$\frac{1}{z'} = \frac{1}{z} + \frac{1}{f_e} .$$

Magnification

Transverse magnification (also called **lateral magnification**) of an optical system is defined as the ratio of the image and object size measured in the direction perpendicular to the optical axis:

$$M = \frac{h'}{h} = -\frac{x'}{f'} = -\frac{f}{x} = \frac{z'}{z} = \frac{-f}{z-f} = \frac{-(z'-f')}{f'} .$$

Longitudinal magnification defines the ratio of distances for a pair of conjugate planes:

$$\frac{\Delta z'}{\Delta z} = \left(-\frac{f'}{f}\right) M_1 M_2 ,$$

where

$$\Delta z = z_2 - z_1$$

$$\Delta z' = z_2' - z_1'$$

and

$$M_1 = \frac{h_1'}{h_1}$$

$$M_2 = \frac{h_2'}{h_2} .$$

Angular magnification is the ratio of angular image size to angular object size and can be calculated with

$$M_u = \frac{u'}{u} = \frac{z}{z'} .$$

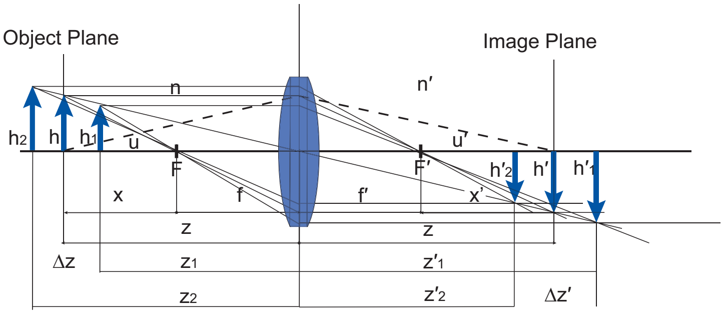

Stops and Rays in an Optical System

The primary stops in any optical system are the **aperture stop** (which limits light) and **field stop** (which limits the extent of the imaged object or the field of view). The aperture stop also defines the resolution of the optical system. To determine the aperture stop, all system diaphragms including the lens mounts should be imaged to either the image or the object space of the system. The aperture stop is determined as the smallest diaphragm or diaphragm image (in terms of angle) as seen from the on-axis object/image point in the same optical space.

Note that there are two important conjugates of the aperture stop in object and image space. They are called the **entrance pupil** and **exit pupil**, respectively.

The physical stop limiting the extent of the field is called the **field stop**. To find a field stop, all of the diaphragms should be imaged to the object or image space, with the smallest diaphragm defining the actual field stop, as seen from the entrance/exit pupil. Conjugates of the field stop in the object and image space are called the **entrance window** and **exit window**, respectively.

Two major rays that pass through the system are the **marginal ray** and the **chief ray**. The marginal ray crosses the optical axis at the conjugate of the field stop (and object) and the edge of the aperture stop. The chief ray goes through the edge of the field and crosses the optical axis at the aperture stop plane.

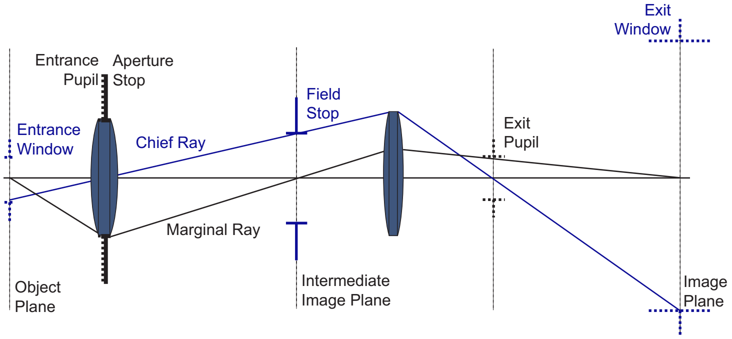

Aberrations

Individual spherical lenses cannot deliver perfect imaging because they exhibit errors called aberrations. All aberrations can be considered either **chromatic** or **monochromatic**. To correct for aberrations, optical systems use multiple elements, aspherical surfaces, and a variety of optical materials.

Chromatic aberrations are a consequence of the **dispersion** of optical materials, which is a change in the refractive index as a function of wavelength. The parameter-characterizing dispersion of any material is called the **Abbe number** and is defined as

$$V_{\mathrm{d}} = \frac{n_{\mathrm{d}} - 1}{n_{\mathrm{F}} - n_{\mathrm{C}}}.$$

Alternatively, the following equation might be used for other wavelengths:

$$V_{\mathrm{e}} = \frac{n_{\mathrm{e}} - 1}{n_{\mathrm{F'}} - n_{\mathrm{C'}}}.$$

λ [nm]	Symbol	Spectral Line
656	C	red hydrogen
644	C′	red cadmium
588	d	yellow helium
546	e	green mercury
486	F	blue hydrogen
480	F′	blue cadmium

In general, V can be defined by using refractive indices at any three wavelengths, which should be specified for material characteristics. Indices in the equations denote spectral lines. If V does not have an index, V_{d} is assumed.

Geometrical aberrations occur when optical rays do not meet at a single point. There are longitudinal and transverse ray aberrations describing the axial and lateral deviations from the paraxial image of a point (along the axis and perpendicular to the axis in the image plane), respectively.

Wave aberrations describe a deviation of the wavefront from a perfect sphere. They are defined as a distance (the optical path difference) between the wavefront and the reference sphere along the optical ray.

Chromatic Aberrations

Chromatic aberrations occur due to the dispersion of optical materials used for lens fabrication. This means that the refractive index is different for different wavelengths; consequently, various wavelengths are refracted differently.

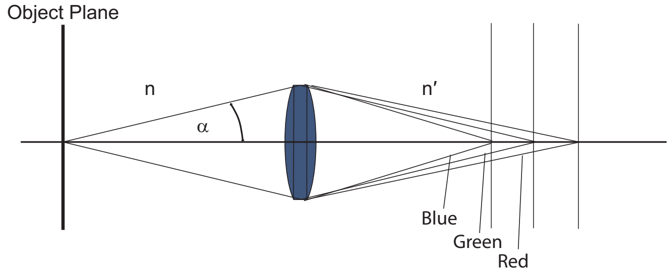

Chromatic aberrations include axial (longitudinal) or transverse (lateral) aberrations. **Axial chromatic aberration** arises from the fact that various wavelengths are focused at different distances behind the optical system. It is described as a variation in focal length:

$$\frac{\Delta f}{f} = \frac{f_F - f_C}{f} = \frac{1}{V}\,.$$

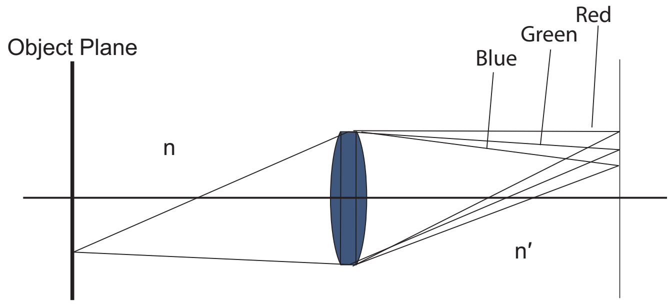

Transverse chromatic aberration is an off-axis imaging of colors at different locations on the image plane.

To compensate for chromatic aberrations, materials with low and high Abbe numbers are used (such as flint and crown glass). Correcting chromatic aberrations is crucial for most microscopy applications, but it is especially important for multi-photon microscopy. Obtaining multi-photon excitation requires high laser power and is most effective using short pulse lasers. Such a light source has a broad spectrum, and chromatic aberrations may cause pulse broadening.

Spherical Aberration and Coma

The most important wave aberrations are spherical, coma, astigmatism, field curvature, and distortion.

Spherical aberration (on-axis) is a consequence of building an optical system with components with spherical surfaces. It occurs when rays from different heights in the pupil are focused at different planes along the optical axis. This results in an axial blur. The most common approach for correcting spherical aberration uses a combination of negative and positive lenses. Systems that correct spherical aberration heavily depend on imaging conditions. For example, in microscopy a cover glass must be of an appropriate thickness and refractive index in order to work with an objective. Also, the media between the objective and the sample (such as air, oil, or water) must be taken into account.

Spherical Aberration

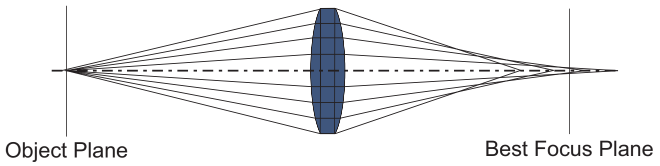

Coma (off-axis) can be defined as a variation of magnification with aperture location. This means that rays passing through a different azimuth of the lens are magnified differently. The name “coma” was inspired by the aberration’s appearance, because it resembles a comet’s tail as it emanates from the focus spot. It is usually stronger for lenses with a larger field, and its correction requires accommodation of the field diameter.

Coma

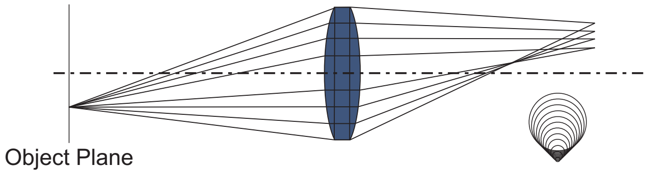

Astigmatism, Field Curvature, and Distortion

Astigmatism (off-axis) is responsible for different magnifications along orthogonal meridians in an optical system. It manifests as elliptical, elongated spots for the horizontal and vertical directions on opposite sides of the best focal plane. It is more pronounced for an object farther from the axis and is a direct consequence of improper lens mounting or an asymmetric fabrication process.

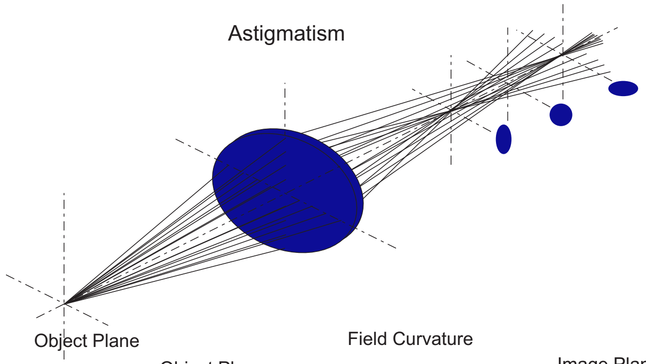

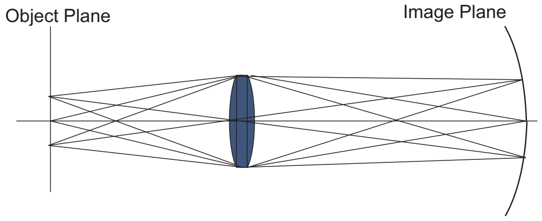

Field curvature (off-axis) results in a non-flat image plane. The image plane created is a concave surface as seen from the objective; therefore, various zones of the image can be seen in focus after moving the object along the optical axis. This aberration is corrected by an objective design combined with a tube lens or eyepiece.

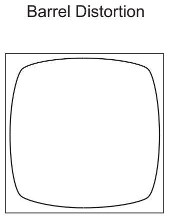

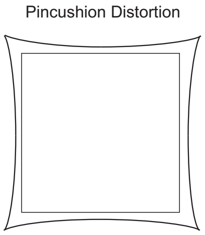

Distortion is a radial variation of magnification that will image a square as a pincushion or barrel. It is corrected in the same manner as field curvature. If preceded with system calibration, it can also be corrected numerically after image acquisition.

Performance Metrics

The major metrics describing the performance of an optical system are the **modulation transfer function** (MTF), the **point spread function** (PSF), and the **Strehl ratio** (SR).

The MTF is the modulus of the **optical transfer function** described by

$$OTF(\rho) = MTF(\rho)\exp\left[i\varphi(\rho)\right],$$

where the complex term in the equation relates to the phase transfer function. The MTF is a contrast distribution in the image in relation to contrast in the object as a function of spatial frequency ρ (for sinusoidal object harmonics) and can be defined as

$$MTF(\rho) = \frac{C(\rho)_{\text{image}}}{C(\rho)_{\text{object}}}.$$

The PSF is the intensity distribution at the image of a point object. This means that the PSF is a metric directly related to the image, while the MTF corresponds to spatial frequency distributions in the pupil. The MTF and PSF are closely related and comprehensively describe the quality of the optical system. In fact, the amplitude of the Fourier transform of the PSF results in the MTF.

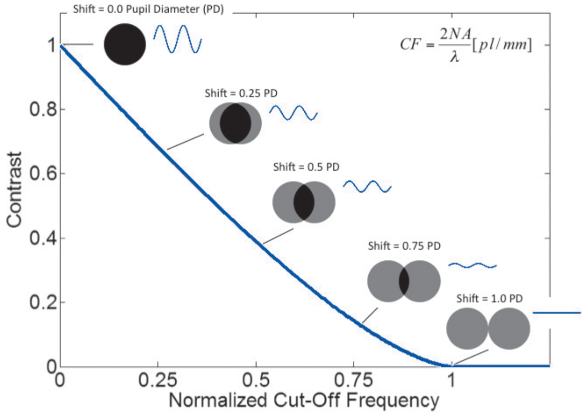

The MTF can be calculated as the autocorrelation of the **pupil function**. The pupil function describes the field distribution of an optical wave in the pupil plane of the optical system. In the case of a uniform pupil's transmission, it directly relates to the field overlap of two mutually shifted pupils where the shift corresponds to spatial frequency.

Performance Metrics (cont.)

The **modulation transfer function** has different results for coherent and incoherent illumination. For incoherent illumination, the phase component of the field is neglected since it is an average of random fields propagating under random angles.

For coherent illumination, the contrast of transferring harmonics of the field is constant and equal to 1 until the location of the spatial frequency in the pupil reaches its edge. For higher frequencies, the contrast sharply drops to zero since they cannot pass the optical system. Note that contrast for the coherent case is equal to 1 for the entire MTF range.

The **cutoff frequency** for an incoherent system is two times the cutoff frequency of the equivalent aperture coherent system and defines the **Sparrow resolution limit**.

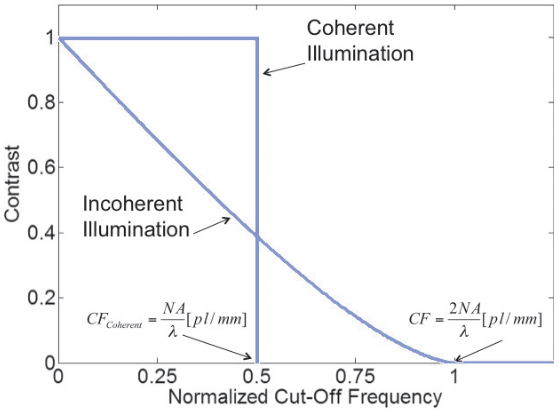

The **Strehl ratio** is a parametric measurement that defines the quality of the optical system in a single number. It is defined as the ratio of irradiance within the theoretical dimension of a diffraction-limited spot to the entire irradiance in the image of the point. One simple method to estimate the Strehl ratio is to divide the field below the MTF curve of a tested system by the field of the diffraction-limited system of the same numerical aperture. For practical optical design consideration it is usually assumed that the system is diffraction limited if the Strehl ratio is equal to or larger than 0.8.

The Compound Microscope

The primary goal of microscopy is to provide the ability to resolve the small details of an object. Historically, microscopy was developed for visual observation and, therefore, was set up to work in conjunction with the human eye. An effective high-resolution optical system must have resolving ability and be able to deliver proper magnification for the detector. In the case of visual observations, the detectors are the cones and rods of the retina.

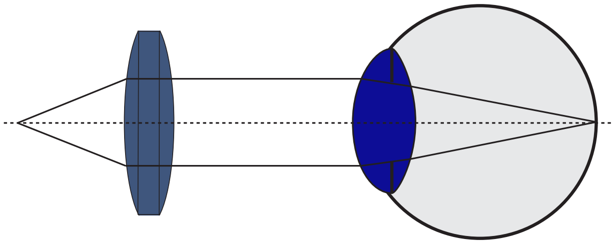

A basic microscope can be built with a single-element, short-focal-length lens (**magnifier**). The object is located in the focal plane of the lens and is imaged to infinity. The eye creates a final image of the object on the retina. The system stop is the eye's pupil.

To obtain higher resolution for visual observation, the **compound microscope** was first built in the 17th century by Robert Hooke. It consists of two major components: the **objective** and the **eyepiece**. The short-focal-length lens (objective) is placed close to the object under examination and creates a real image of an object at the focal plane of the second lens. The eyepiece (similar to the magnifier) throws an image to infinity, and the human eye creates the final image. An important function of the eyepiece is to match the eye's pupil with the system stop, which is located in the back focal plane of the microscope objective.

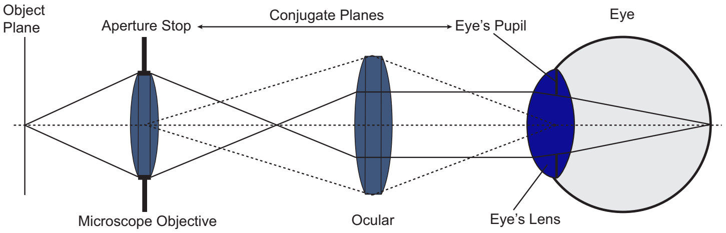

The Eye

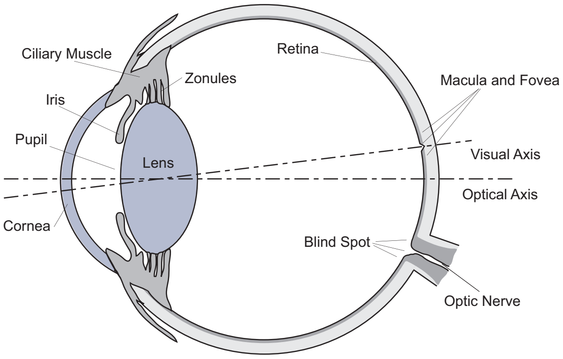

The **eye** was the first—and for a long time, the only—real-time detector used in microscopy. Therefore, the design of the microscope had to incorporate parameters responding to the needs of visual observation.

Cornea—the transparent portion of the sclera (the white portion of the human eye), which is a rigid tissue that gives the eyeball its shape. The cornea is responsible for two thirds of the eye's refractive power.

Lens—the lens is responsible for one third of the eye's power. Ciliary muscles can change the lens's power (accommodation) within the range of 15–30 diopters.

Iris—controls the diameter of the pupil (1.5–8 mm).

Retina—a layer with two types of photoreceptors: rods and cones. **Cones** (about 7 million) are in the area of the **macula** (~3 mm in diameter) and **fovea** (~1.5 mm in diameter, with the highest cone density), and they are designed for bright vision and color detection. There are three types of cones (red, green, and blue sensitive), and the spectral range of the eye is approximately 400–750 nm. **Rods** are responsible for night/low-light vision, and there are about 130 million located outside the fovea region.

It is arbitrarily assumed that the eye can provide sharp images for objects between 250 mm and infinity. A 250-mm distance is called the **minimum focus distance** or **near point**. The maximum eye resolution for bright illumination is 1 arc minute.

Upright and Inverted Microscopes

The two major microscope geometries are **upright** and **inverted.** Both systems can operate in reflectance and transmittance modes.

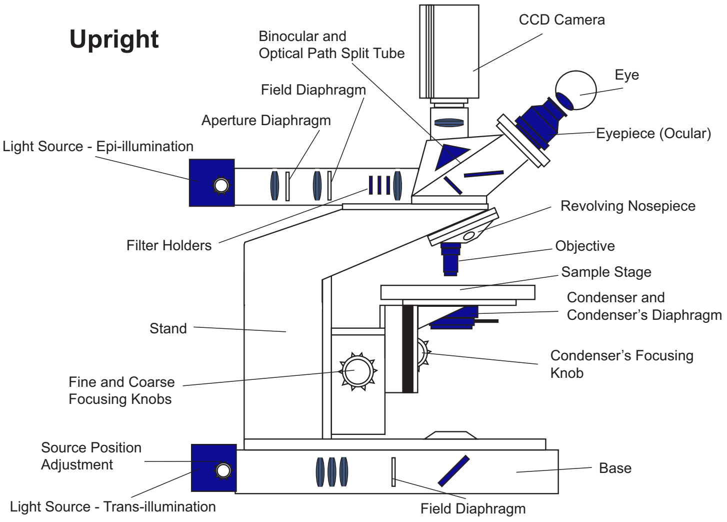
Upright
CCD Camera
Binocular and
Optical Path Split Tube
Eye
Field Diaphragm
Aperture Diaphragm
Eyepiece (Ocular)
Light Source - Epi-illumination
Revolving Nosepiece
Filter Holders
Objective
Sample Stage
Condenser and
Condenser's Diaphragm
Stand
Condenser's Focusing
Knob
Fine and Coarse
Focusing Knobs
Source Position
Adjustment
Base
Light Source - Trans-illumination
Field Diaphragm

The inverted microscope is primarily designed to work with samples in cell culture dishes and to provide space (with a long-working distance condenser) for sample manipulation (for example, with patch pipettes in electrophysiology).

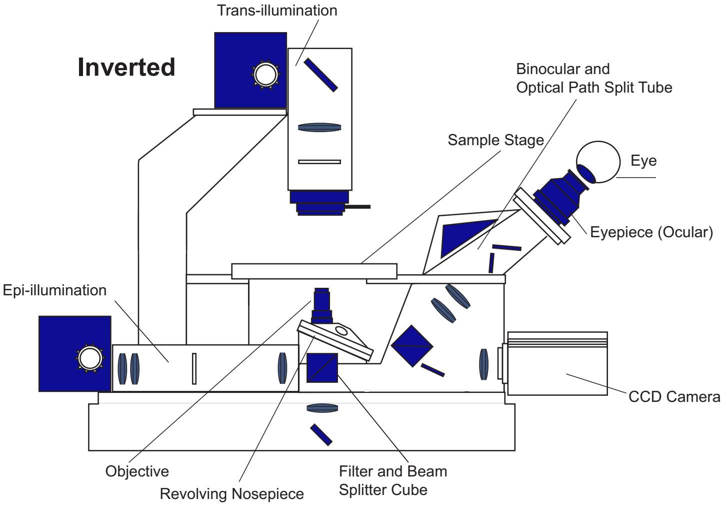
Trans-illumination
Inverted
Binocular and
Optical Path Split Tube
Sample Stage
Eye
Eyepiece (Ocular)
Epi-illumination
CCD Camera
Objective
Revolving Nosepiece
Filter and Beam
Splitter Cube

The Finite Tube Length Microscope

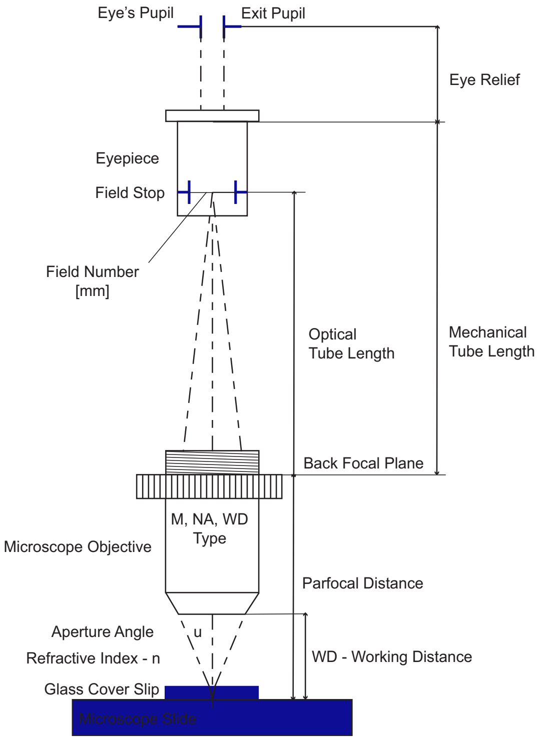
Eye's Pupil
Exit Pupil
Eye Relief
Eyepiece
Field Stop
Field Number
[mm]
Optical
Tube Length
Mechanical
Tube Length
Back Focal Plane
M, NA, WD
Type
Microscope Objective
Parfocal Distance
Aperture Angle
u
Refractive Index - n
WD - Working Distance
Glass Cover Slip
Microscope Slide

Historically, microscopes were built with a **finite tube length**. With this geometry, the microscope objective images the object into the tube end. This intermediate image is then relayed to the observer by an eyepiece. Depending on the manufacturer, different **optical tube lengths** are possible (for example, the standard tube length for Zeiss is 160 mm). The use of a standard tube length by each manufacturer unifies the optomechanical design of the microscope.

A constant **parfocal distance** for microscope objectives enables switching between different magnifications without defocusing. The **field number**, corresponding to the physical dimension (in millimeters) of the **field stop** inside the eyepiece, allows the microscope's field of view (FOV) to be determined according to

$$FOV = \frac{FieldNumber}{M_{\text{objective}}} \left[\text{mm}\right].$$

Infinity-Corrected Systems

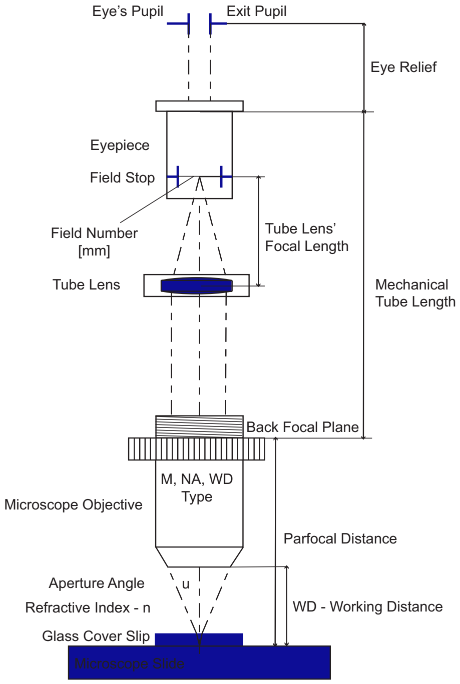
Eye's Pupil
Exit Pupil
Eye Relief
Eyepiece
Field Stop
Field Number [mm]
Tube Lens' Focal Length
Tube Lens
Mechanical Tube Length
Back Focal Plane
M, NA, WD Type
Microscope Objective
Parfocal Distance
Aperture Angle
u
Refractive Index - n
WD - Working Distance
Glass Cover Slip
Microscope Slide

Microscope objectives can be corrected for a conjugate located at infinity, which means that the microscope objective images an object into infinity. An infinite conjugate is useful for introducing beam splitters or filters that should work with small incidence angles. Also, an infinity-corrected system accommodates additional components like DIC prisms, polarizers. etc. The collimated beam is focused to create an intermediate image with additional optics, called a **tube lens**. The tube lens either creates an image directly onto a CCD chip or an intermediate image, which is further reimaged with an eyepiece. Additionally, the tube lens might be used for system correction. For example, Zeiss corrects aberrations in its microscopes with a combination objective-tube lens.

In the case of an **infinity-corrected objective**, the transverse magnification can only be defined in the presence of a tube lens that will form a real image. It is given by the ratio between the tube lens's focal length and the focal length of the microscope objective.

Manufacturer	Focal Length of Tube Lens
Zeiss	164.5 mm
Olympus	180.0 mm
Nikon	200.0 mm
Leica	200.0 mm

Telecentricity of a Microscope

Telecentricity is a feature of an optical system where the principal ray in object, image, or both spaces is parallel to the optical axis. This means that the object or image does not shift laterally, even with defocus; the distance between two object or image points is constant along the optical axis.

An optical system can be **telecentric** in

- Object space, where the entrance pupil is at infinity, and the aperture stop is in the back focal plane;
- Image space, where the exit pupil is at infinity, and the aperture stop is in the front focal plane; or
- Both (doubly telecentric), where the entrance and exit pupils are at infinity, and the aperture stop is at the center of the system, in the back focal plane of the element before the stop and front focal length of the element after the stop (afocal system).

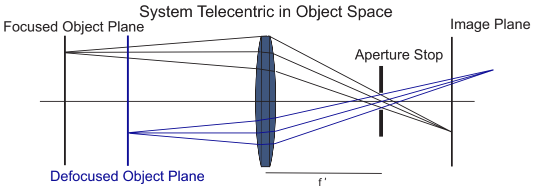
System Telecentric in Object Space
Focused Object Plane
Image Plane
Aperture Stop
Defocused Object Plane
f'

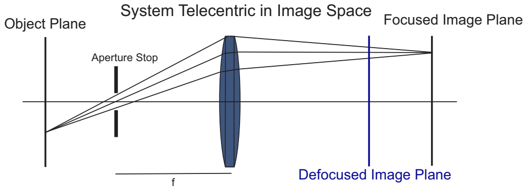
System Telecentric in Image Space
Object Plane
Focused Image Plane
Aperture Stop
Defocused Image Plane
f

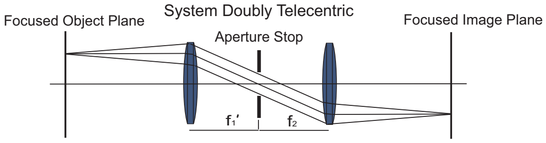
System Doubly Telecentric
Focused Object Plane
Focused Image Plane
Aperture Stop
f₁'
f₂

The aperture stop in a microscope is located at the back focal plane of the microscope objective. This makes the microscope objective telecentric in object space. Therefore, in microscopy, the object is observed with constant magnification, even for defocused object planes. This feature of microscopy systems significantly simplifies their operation and increases the reliability of image analysis.

Magnification of a Microscope

Magnifying power (MP) is defined as the ratio between the angles subtended by an object with and without magnification. The magnifying power (as defined for a single lens) creates an enlarged virtual image of an object. The angle of an object observed with magnification is

$$u' = \frac{h'}{z'-l} = \frac{h(f-z')}{f(z'-l)}.$$

Therefore,

$$MP = \frac{u'}{u} = \frac{d_o(f-z')}{f(z'-l)}.$$

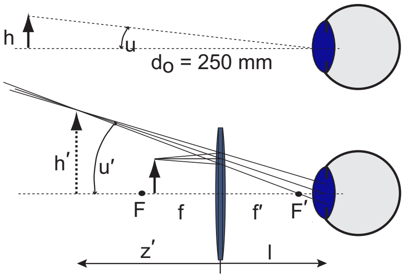

The angle for an unaided eye is defined for the **minimum focus distance** (d_o) of 10 inches or 250 mm, which is the distance that the object (real or virtual) may be examined without discomfort for the average population. A distance l between the lens and the eye is often small and can be assumed to equal zero:

$$MP \approx \frac{250\text{mm}}{f} - \frac{250\text{mm}}{z'}.$$

If the virtual image is at infinity (observed with a relaxed eye), $z' = -\infty$, and

$$MP \approx \frac{250\text{mm}}{f}.$$

The total magnifying power of the microscope results from the magnification of the microscope objective and the magnifying power of the eyepiece (usually 10×):

$$M_{\text{objective}} = \frac{OTL}{f_{\text{objective}}}$$

$$MP_{\text{microscope}} = M_{\text{objective}} MP_{\text{eyepiece}} = -\frac{OTL}{f_{\text{objective}}} \frac{250\text{mm}}{f_{\text{eyepiece}}}.$$

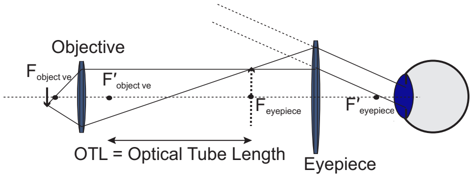

Numerical Aperture

The aperture diaphragm of the optical system determines the angle at which rays emerge from the axial object point and, after refraction, pass through the optical system. This acceptance angle is called the object space aperture angle. The parameter describing system throughput and this acceptance angle is called the **numerical aperture** (NA):

$$NA = n \sin u \, .$$

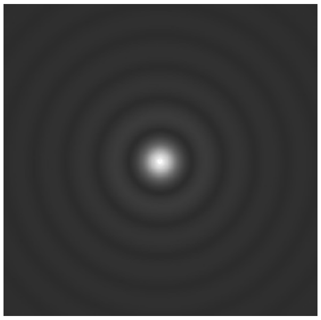

As seen from the equation, throughput of the optical system may be increased by using media with a high refractive index *n*, e.g., oil or water. This effectively decreases the refraction angles at the interfaces.

The dependence between the numerical aperture in the object space NA and the numerical aperture in the image space between the objective and the eyepiece NA′ is calculated using the objective magnification:

$$NA = NA' M_{\text{objective}} \, .$$

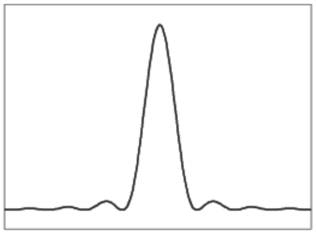

As a result of diffraction at the aperture of the optical system, self-luminous points of the object are not imaged as points but as so-called Airy disks. An **Airy disk** is a bright disk surrounded by concentric rings with gradually decreasing intensities. The disk diameter (where the intensity reaches the first zero) is

$$d = \frac{1.22\lambda}{n \sin u} = \frac{1.22\lambda}{NA} \, .$$

Note that the refractive index in the equation is for media between the object and the optical system.

Media	Refractive Index
Air	1
Water	1.33
Oil	1.45–1.6 (1.515 is typical)

Resolution Limit

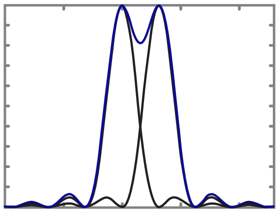

The lateral resolution of an optical system can be defined in terms of its ability to resolve images of two adjacent, self-luminous points. When two **Airy disks** are too close, they form a continuous intensity distribution and cannot be distinguished. The **Rayleigh resolution limit** is defined as occurring when the peak of the Airy pattern arising from one point coincides with the first minimum of the Airy pattern arising from a second point object. Such a distribution gives an intensity dip of 26%. The distance between the two points in this case is

$$d = \frac{0.61\lambda}{n \sin u} = \frac{0.61\lambda}{NA}\,.$$

The equation indicates that the resolution of an optical system improves with an increase in NA and decreases with increasing wavelength λ. For example, for λ = 450 nm (blue) and oil immersion NA = 1.4, the microscope objective can optically resolve points separated by less than 200 nm.

The situation in which the intensity dip between two adjacent self-luminous points becomes zero defines the **Sparrow resolution limit**. In this case $d = 0.5\lambda/NA$.

The **Abbe resolution limit** considers both the diffraction caused by the object and the NA of the optical system. It assumes that if at least two adjacent diffraction orders for points with spacing d are accepted by the objective, these two points can be resolved. Therefore, the resolution depends on both imaging and illumination apertures and is

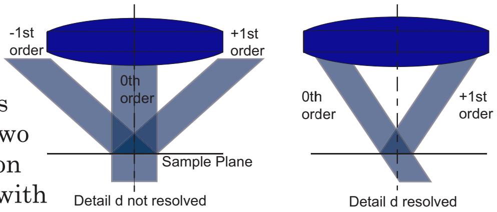

$$d = \frac{\lambda}{NA_{\text{objective}} + NA_{\text{condenser}}}\,.$$

Useful Magnification

For visual observation, the **angular resolving power** can be defined as 1.5 arc minutes. For unmagnified objects at a distance of 250 mm (the eye's minimum focus distance), 1.5 arc minutes converts to d_{eye} = 0.1 mm. Since microscope objectives by themselves do not usually provide sufficient magnification, they are combined with oculars or eyepieces. The resolving power of the microscope is then

$$d_{\text{mic}} = \frac{d_{\text{eye}}}{M_{\text{min}}} = \frac{d_{\text{eye}}}{M_{\text{obj}} M_{\text{eyepiece}}} .$$

In the Sparrow resolution limit, the minimum microscope magnification is

$$M_{\text{min}} = 2 d_{\text{eye}} NA / \lambda .$$

Therefore, a total minimum magnification M_{min} can be defined as approximately 250–500 NA (depending on wavelength). For lower magnification the image will appear brighter, but imaging is performed below the overall resolution limit of the microscope. For larger magnification, the contrast decreases and resolution does not improve. While a theoretically higher magnification should not provide additional information, it is useful to increase it to approximately 1000 NA to provide comfortable sampling of the object. Therefore, it is assumed that the **useful magnification** of a microscope is between 500 NA and 1000 NA. Usually, any magnification above 1000 NA is called **empty magnification**. The image size in such cases is enlarged, but no additional useful information is provided. The highest useful magnification of a microscope is approximately 1500 for an oil-immersion microscope objective with $NA = 1.5$.

Similar analysis can be performed for digital microscopy, which uses CCD or CMOS cameras as image sensors. Camera pixels are usually small (between 2 and 30 microns), and useful magnification must be estimated for a particular image sensor rather than the eye. Therefore, digital microscopy can work at lower magnification, and magnification of the microscope objective alone is usually sufficient.

Depth of Field and Depth of Focus

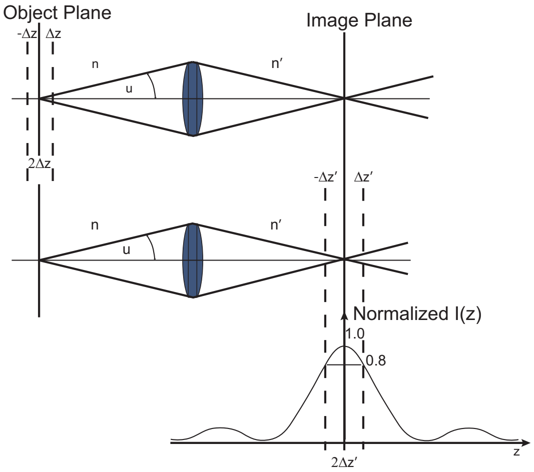

Two important terms are used to define axial resolution: **depth of field** and **depth of focus**. Depth of field refers to the object thickness for which an image is in focus, while depth of focus is the corresponding thickness of the image plane. In the case of a diffraction-limited optical system, the depth of focus is determined for an intensity drop along the optical axis to 80%, defined as

$$DOF = 2\Delta z' = \frac{n'\lambda}{NA'^2}.$$

The relation between depth of field ($2\Delta z$) and depth of focus ($2\Delta z'$) incorporates the objective magnification:

$$2\Delta z' = M^2_{\text{objective}} 2\Delta z \frac{n'}{n},$$

where n' and n are medium refractive indexes in the object and image space, respectively.

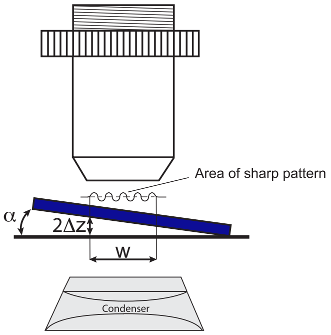

To quickly measure the depth of field for a particular microscope objective, the grid amplitude structure can be placed on the microscope stage and tilted with the known angle α. The depth of field is determined after measuring the grid zone w while in focus:

$$2\Delta z = nw \tan\alpha .$$

Magnification and Frequency vs Depth of Field

Depth of field for visual observation is a function of the total microscope magnification and the NA of the objective, approximated as

$$2\Delta z = n\frac{0.5\lambda}{NA^2} + n\frac{340}{M_{\text{microscope}}NA}.$$

Note that estimated values do not include eye accommodation. The graph below presents depth of field for visual observation. Refractive index n of the object space was assumed to equal 1. For other media, values from the graph must be multiplied by an appropriate n.

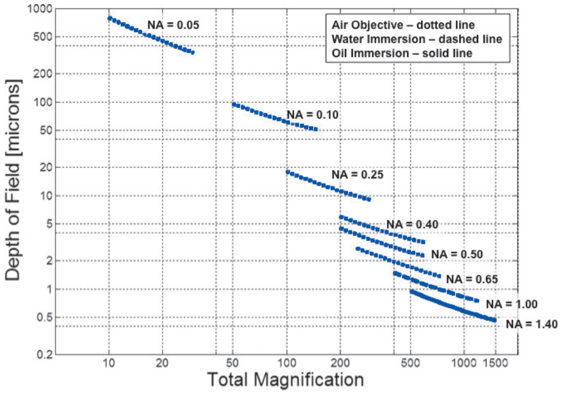

Depth of field can also be defined for a specific frequency present in the object because imaging contrast changes for a particular object frequency, as described by the modulation transfer function. The approximated equation is

$$2\Delta z = \frac{0.4}{\rho NA},$$

where ρ is the frequency in cycles per millimeter.

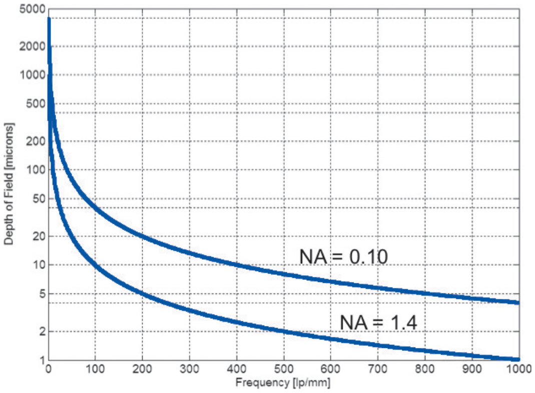

Köhler Illumination

One of the most critical elements in efficient microscope operation is proper set up of the illumination system. To assist with this, August Köhler introduced a solution that provides uniform and bright illumination over the field of view, even for light sources that are not uniform (e.g., a lamp filament). This system consists of a light source, a field-stop diaphragm, a condenser aperture, and collective and condenser lenses. This solution is now called **Köhler illumination** and is commonly used for a variety of imaging modes.

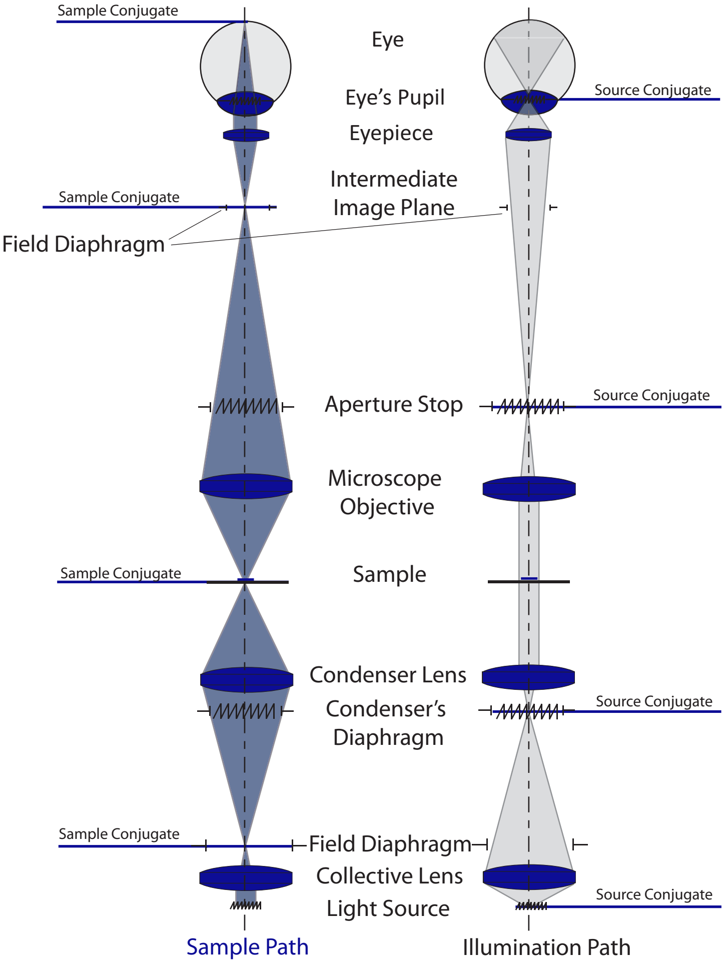
Sample Conjugate
Eye
Eye's Pupil
Source Conjugate
Eyepiece
Intermediate Image Plane
Sample Conjugate
Field Diaphragm
Aperture Stop
Source Conjugate
Microscope Objective
Sample Conjugate
Sample
Condenser Lens
Condenser's Diaphragm
Source Conjugate
Sample Conjugate
Field Diaphragm
Collective Lens
Light Source
Source Conjugate
Sample Path
Illumination Path

Köhler Illumination (cont.)

The illumination system is configured such that an image of the light source completely fills the condenser aperture.

Köhler illumination requires setting up the microscope system so that the field diaphragm, object plane, and intermediate image in the eyepiece's field stop, retina, or CCD are in conjugate planes. Similarly, the lamp filament, front aperture of the condenser, microscope objective's back focal plane (aperture stop), exit pupil of the eyepiece, and the eye's pupil are also at conjugate planes. Köhler illumination can be set up for both the transmission mode (also called **DIA**) and the reflectance mode (also called **EPI**).

The uniformity of the illumination is the result of having the light source at infinity with respect to the illuminated sample.

EPI illumination is especially useful for the biological and metallurgical imaging of thick or opaque samples.

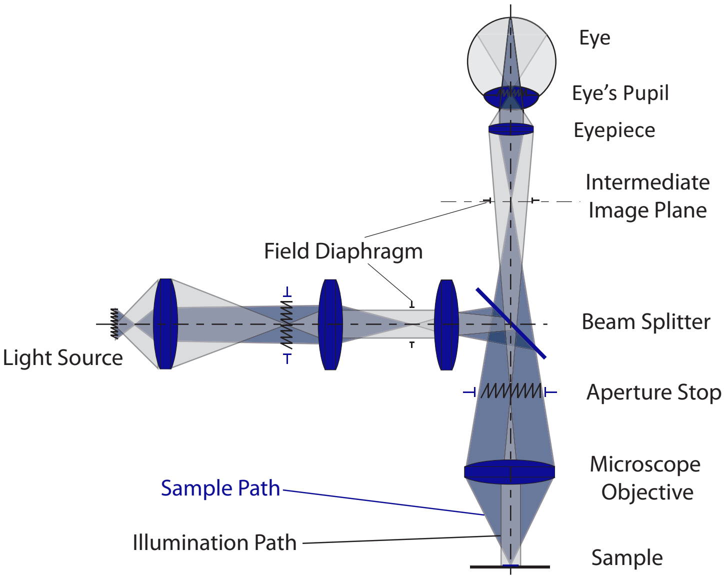
Eye
Eye's Pupil
Eyepiece
Intermediate Image Plane
Field Diaphragm
Beam Splitter
Light Source
Aperture Stop
Microscope Objective
Sample Path
Illumination Path
Sample

Alignment of Köhler Illumination

The procedure for **Köhler illumination** alignment consists of the following steps:

1. Place the sample on the microscope stage and move it so that the front surface of the condenser lens is 1–2 mm from the microscope slide. The condenser and collective diaphragms should be wide open.
2. Adjust the location of the source so illumination fills the condenser's diaphragm. The sharp image of the lamp filament should be visible at the condenser's diaphragm plane and at the back focal plane of the microscope objective. To see the filament at the back focal plane of the objective, a **Bertrand lens** can be applied (also see *Special Lens Components* on page 55). The filament should be centered in the aperture stop using the bulb's adjustment knobs on the illuminator.
3. For a low-power objective, bring the sample into focus. Since a microscope objective works at a parfocal distance, switching to a higher magnification later is easy and requires few adjustments.
4. Focus and center the condenser lens. Close down the field diaphragm, focus down the outline of the diaphragm, and adjust the condenser's position. After adjusting the x-, y-, and z-axis, open the field diaphragm so it accommodates the entire field of view.
5. Adjust the position of the condenser's diaphragm by observing the back focal objective plane through the Bertrand lens. When the edges of the aperture are sharply seen, the condenser's diaphragm should be closed to approximately three quarters of the objective's aperture.
6. Tune the brightness of the lamp. This adjustment should be performed by regulating the voltage of the lamp's power supply or, preferably, through the neutral density filters in the beam path. Do not adjust the brightness by closing the condenser's diaphragm because it affects the illumination setup and the overall microscope resolution.

Note that while three quarters of the aperture stop is recommended for initial illumination, adjusting the aperture of the illumination system affects the resolution of the microscope. Therefore, the final setting should be adjusted after examining the images.

Critical Illumination

An alternative to Köhler illumination is **critical illumination**, which is based on imaging the light source directly onto the sample. This type of illumination requires a highly uniform light source. Any source non-uniformities will result in intensity variations across the image. Its major advantage is high efficiency, since it can collect a larger solid angle than Köhler illumination and therefore provides a higher energy density at the sample. For parabolic or elliptical reflective collectors, critical illumination can utilize up to 85% of the light emitted by the source.

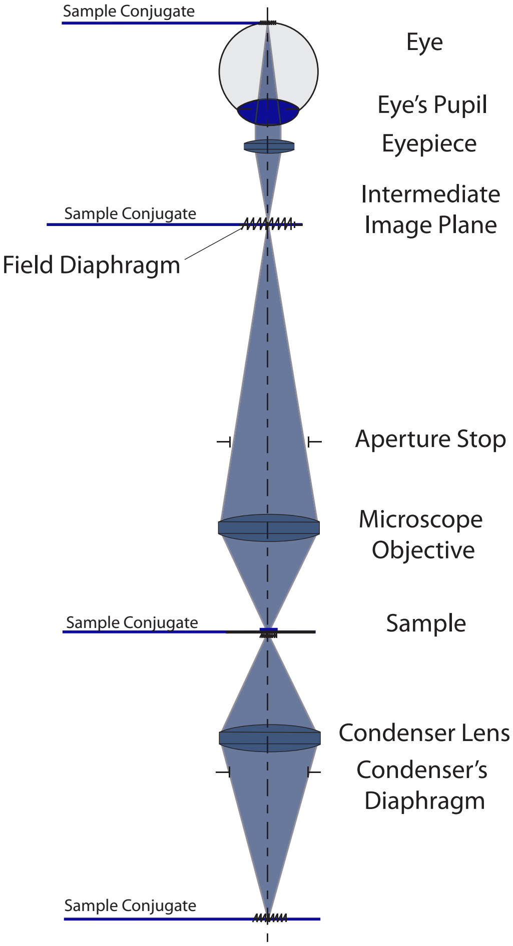
Sample Conjugate
Eye
Eye's Pupil
Eyepiece
Sample Conjugate
Intermediate Image Plane
Field Diaphragm
Aperture Stop
Microscope Objective
Sample Conjugate
Sample
Condenser Lens
Condenser's Diaphragm
Sample Conjugate

Stereo Microscopes

Stereo microscopes are built to provide depth perception, which is important for applications like micro-assembly and biological and surgical imaging. Two primary stereo-microscope approaches involve building two separate tilted systems, or using a common objective combined with a binocular system.

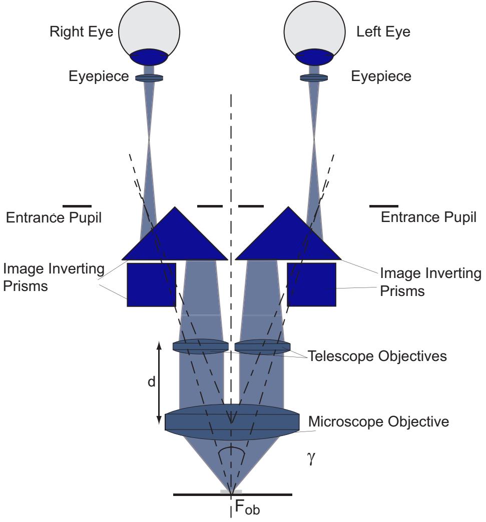
Right Eye
Left Eye
Eyepiece
Eyepiece
Entrance Pupil
Entrance Pupil
Image Inverting Prisms
Image Inverting Prisms
Telescope Objectives
d
Microscope Objective
γ
F_{ob}

In the latter, the angle of convergence γ of a stereo microscope depends on the focal length of a microscope objective and a distance d between the microscope objective and telescope objectives. The entrance pupils of the microscope are images of the stops (located at the plane of the telescope objectives) through the microscope objective.

Depth perception δz can be defined as

$$\delta z = \frac{250\alpha_s}{M_{\text{microscope}} \tan\gamma} [\text{mm}],$$

where α_s is a **visual stereo resolving power**, which for daylight vision is approximately 5–10 arc seconds.

Stereo microscopes have a convergence angle γ in the range of 10–15 deg. Note that γ is 15 deg for visual observation and 0 for a standard microscope. For example, depth perception for the human eye is approximately 0.05 mm (at 250 mm), while for a stereo microscope of $M_{\text{microscope}} = 100$ and $\gamma = 15$ deg, it is $\delta z = 0.5$ μm.

Eyepieces

The eyepiece relays an intermediate image into the eye, corrects for some remaining objective aberrations, and provides measurement capabilities. It also needs to relay an exit pupil of a microscope objective onto the entrance pupil of the eye. The location of the relayed exit pupil is called the **eye point** and needs to be in a comfortable observation distance behind the eyepiece. The clearance between the mechanical mounting of the eyepiece and the eye point is called **eye relief**. Typical eye relief is 7–12 mm.

An eyepiece usually consists of two lenses: one (closer to the eye) which magnifies the image, and a second working as a collective lens and also responsible for the location of the exit pupil of the microscope. An eyepiece contains a field stop that provides a sharp image edge.

Parameters like **magnifying power** of an eyepiece and **field number** (FN), i.e., field of view of an eyepiece, are engraved on an eyepiece's barrel: M × / FN. Field number and magnification of a microscope objective allow quick calculation of the imaged area of a sample (see also *The Finite Tube Length Microscope* on p. 34). Field number varies with microscopy vendors and eyepiece magnification. For 10× or lower magnification eyepieces, it is usually 20–28 mm while for higher magnification, wide-angle oculars can get down to approximately 5 mm.

The majority of eyepieces are **Huygens**, **Ramsden**, or derivations of them. The Huygens eyepiece consists of two plano-convex lenses with convex surfaces facing the microscope objective:

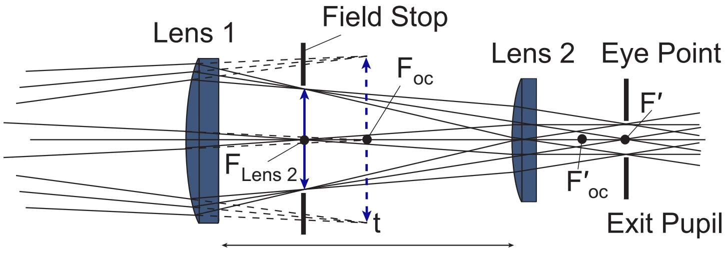

Eyepieces (cont.)

Both lenses are usually made with crown glass and allow for some correction of lateral color, coma, and astigmatism. To correct for color, the following conditions should be met:

$$f_1 \approx f_2 \quad \text{and} \quad t \approx 1.5 f_2 .$$

For higher magnifications, the exit pupil moves toward the ocular, making observation less convenient, and so this eyepiece is used only for low magnifications (≤10×). In addition, Huygens oculars effectively correct for chromatic aberrations, and therefore can be more effectively used with lower-end microscope objectives (e.g., achromatic).

The Ramsden eyepiece consists of two plano-convex lenses with convex surfaces facing each other. Both focal lengths are very similar, and the distance between lenses is smaller than f_2:

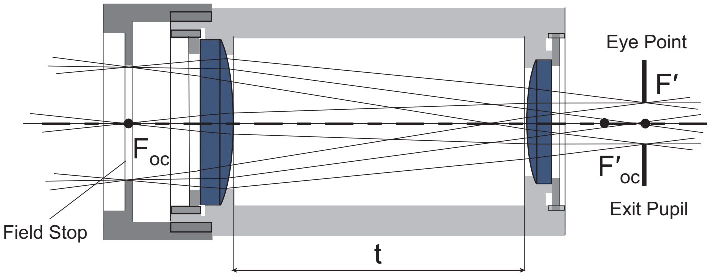

The field stop is placed in the front focal plane of the eyepiece. A collective lens does not participate in creating an intermediate image, so the Ramsden eyepiece works as a simple magnifier:

$$f_1 = f_2 \quad \text{and} \quad t < f_2 .$$

Compensating eyepieces work in conjunction with microscope objectives to correct for lateral color (apochromatic).

High-eye point oculars provide an extended distance between the last mechanical surface and the exit pupil of the eyepiece. They allow users with glasses to comfortably use a microscope. The convenient high eye-point location should be 20–25 mm behind the eyepiece.

Nomenclature and Marking of Objectives

Objective parameters include:

Objective correction—such as Achromat, Plan Achromat, Fluor, Plan Fluor, Apochromat (Apo), and Plan Apochromat.

Magnification—the lens magnification for a finite tube length, or for a microscope objective in combination with a tube lens. In infinity-corrected systems, magnification depends on the ratio between the focal lengths of a tube lens and a microscope objective. A particular objective type should be used only in combination with the proper tube lens.

Magnification	Zeiss Code
1×, 1.25×	Black
2.5×	Khaki
4×, 5×	Red
6.3×	Orange
10×	Yellow
16×, 20×, 25×, 32×	Green
25×, 32×	Green
40×, 50×	Light Blue
63×	Dark Blue
> 100×	White

Application—specialized use or design of an objective, e.g., H (bright field), D (dark field), DIC (differential interference contrast), RL (reflected light), PH (phase contrast), or P (polarization).

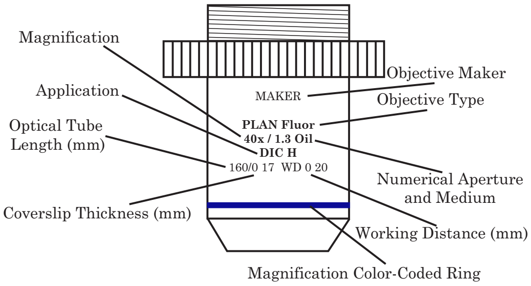
Magnification
Application
Optical Tube Length (mm)
Coverslip Thickness (mm)
MAKER
PLAN Fluor
40x / 1.3 Oil
DIC H
160/0 17 WD 0 20
Objective Maker
Objective Type
Numerical Aperture and Medium
Working Distance (mm)
Magnification Color-Coded Ring

Tube length—an infinity corrected (∞) or finite tube length in mm.

Cover slip—the thickness of the cover slip used (in mm). “0” or “–” means no cover glass or the cover slip is optional, respectively.

Numerical aperture (NA) and medium—defines system throughput and resolution. It depends on the media between the sample and objective. The most common media are air (no marking), oil (Oil), water (W), or Glycerine.

Working distance (WD)—the distance in millimeters between the surface of the front objective lens and the object.

Objective Designs

Achromatic objectives (also called **achromats)** are corrected at two wavelengths: 656 nm and 486 nm. Also, spherical aberration and coma are corrected for green (546 nm), while astigmatism is very low. Their major problems are a secondary spectrum and field curvature.

Achromatic objectives are usually built with a lower NA (below 0.5) and magnification (below 40×). They work well for white light illumination or single wavelength use. When corrected for field curvature, they are called plan-achromats.

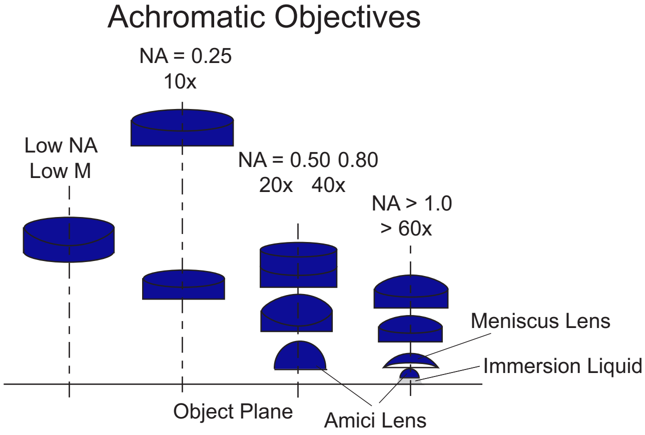

Fluorites or **semi-apochromats** have similar color correction as **achromats**; however, they correct for spherical aberration for two or three colors. The name “fluorites” was assigned to this type of objective due to the materials originally used to build this type of objective. They can be applied for higher NA (e.g., 1.3) and magnifications, and used for applications like immunofluorescence, polarization, or differential interference contrast microscopy.

The most advanced microscope objectives are **apochromats**, which are usually chromatically corrected for three colors, with spherical aberration correction for at least two colors. They are similar in construction to fluorites but with different thicknesses and surface figures. With the correction of field curvature, they are called plan-apochromats. They are used in fluorescence microscopy with multiple dyes and can provide very high NA (1.4). Therefore, they are suitable for low-light applications.

Objective Designs (cont.)

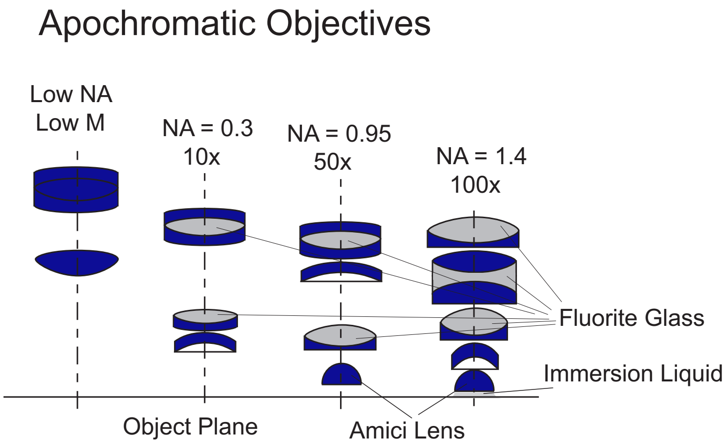
Apochromatic Objectives
Low NA
Low M
NA = 0.3
10x
NA = 0.95
50x
NA = 1.4
100x
Fluorite Glass
Immersion Liquid
Object Plane
Amici Lens

Type	**Number of wavelengths for spherical correction**	**Number of colors for chromatic correction**
Achromat	1	2
Fluorite	2–3	2–3
Plan-Fluorite	2–4	2–4
Plan-Apochromat	2–4	3–5

(Adapted from Murphy, 2001 and http://www.microscopyu.com/)

Examples of typical objective parameters are shown in the table below:

M	**Type**	**Medium**	***WD***	**NA**	***d***	**DOF**
10	Achromat	Air	4.4	0.25	1.34	8.80
20	Achromat	Air	0.53	0.45	0.75	2.72
40	Fluorite	Air	0.50	0.75	0.45	0.98
40	Fluorite	Oil	0.20	1.30	0.26	0.49
60	Apochromat	Air	0.15	0.95	0.35	0.61
60	Apochromat	Oil	0.09	1.40	0.24	0.43
100	Apochromat	Oil	0.09	1.40	0.24	0.43
Refractive index of oil is $n = 1.515$						

(Adapted from Murphy, 2001)

Special Objectives and Features

Special types of objectives include long working distance objectives, ultra-low-magnification objectives, water-immersion objectives, and UV lenses.

Long working distance objectives allow imaging through thick substrates like culture dishes. They are also developed for interferometric applications in Michelson and Mirau configurations. Alternatively, they can allow for the placement of instrumentation (e.g., micropipettes) between a sample and an objective. To provide a long working distance and high NA, a common solution is to use reflective objectives, or extend the working distance of a standard microscope objective by using a reflective attachment. While reflective objectives have the advantage of being free of chromatic aberrations, their serious drawback is a smaller field of view relative to refractive objectives. The central obscuration also decreases throughput by 15%–20%.

LWD Reflective Objective

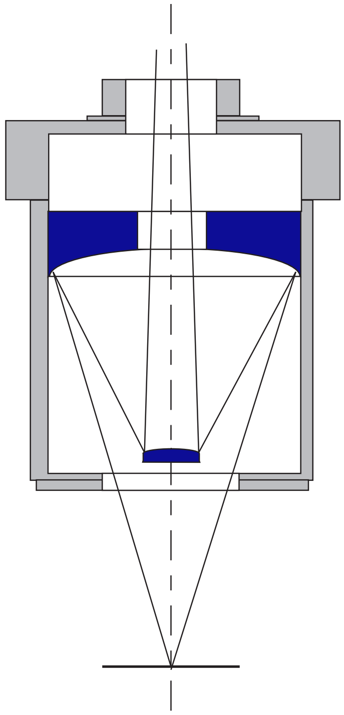

Special Objectives and Features (cont.)

Low magnification objectives can achieve magnifications as low as 0.5. However, in some cases they are not fully compatible with microscopy systems, and may not be telecentric in the image space. They also often require special tube lenses and special condensers to provide Köhler illumination.

Water immersion objectives are increasingly common, especially for biological imaging, because they provide a high NA and avoid toxic immersion oils. They usually work without a cover slip.

UV objectives are made using UV transparent, low-dispersion materials such as quartz. These objectives enable imaging at wavelengths from the near-UV through the visible spectrum, e.g., 240–700 nm. Reflective objectives can also be used for the IR bands.

Reflective Adapter to extend working distance WD

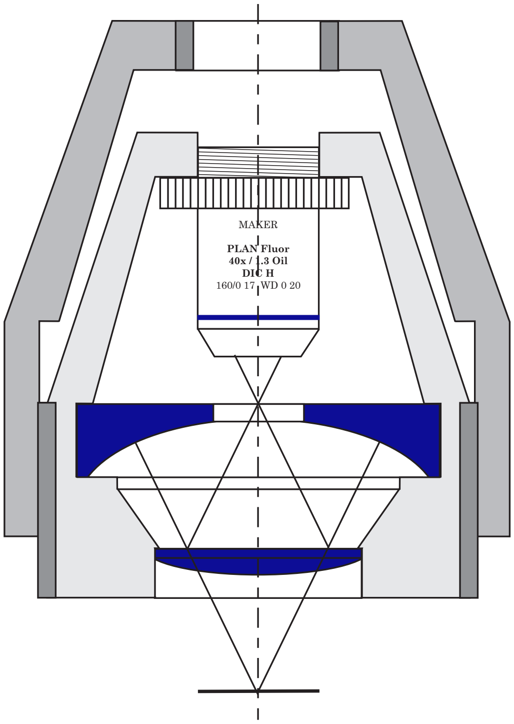

Special Lens Components

The **Bertrand lens** is a focusable eyepiece telescope that can be easily placed in the light path of the microscope. This lens is used to view the back aperture of the objective, which simplifies microscope alignment, specifically when setting up Köhler illumination.

To construct a high-numerical-aperture microscope objective with good correction, numerous optical designs implement the **Amici lens** as a first component of the objective. It is a thick lens placed in close proximity to the sample. An Amici lens usually has a plane (or nearly plane) first surface and a large-curvature spherical second surface. To ensure good chromatic aberration correction, an achromatic lens is located closely behind the Amici lens. In such configurations, microscope objectives usually reach an NA of 0.5–0.7.

To further increase the NA, an Amici lens is improved by either cementing a high-refractive-index meniscus lens to it or placing a meniscus lens closely behind the Amici lens. This makes it possible to construct well-corrected high magnification (100×) and high numerical aperture (NA > 1.0) oil-immersion objective lenses.

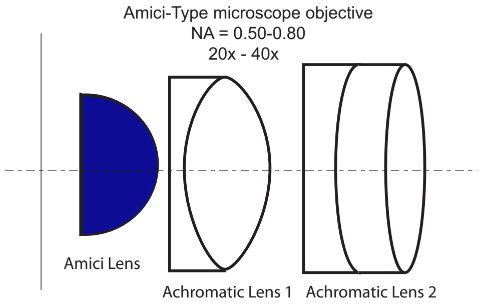
Amici-Type microscope objective
NA = 0.50-0.80
20x - 40x
Amici Lens
Achromatic Lens 1
Achromatic Lens 2

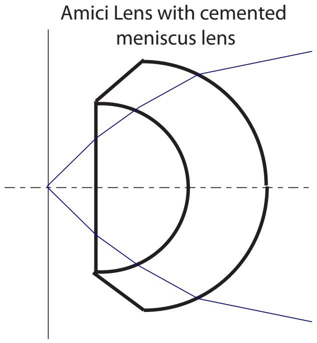
Amici Lens with cemented meniscus lens

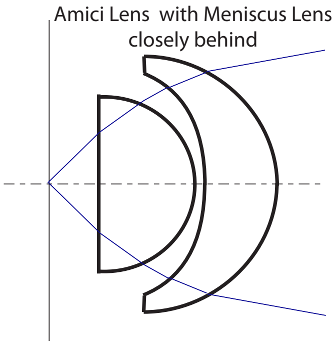
Amici Lens with Meniscus Lens closely behind

Cover Glass and Immersion

The **cover slip** is located between the object and the microscope objective. It protects the imaged sample and is an important element in the optical path of the microscope. Cover glass can reduce imaging performance and cause spherical aberration, while different imaging angles experience movement of the object point along the optical axis toward the microscope objective. The object point moves closer to the objective with an increase in angle.

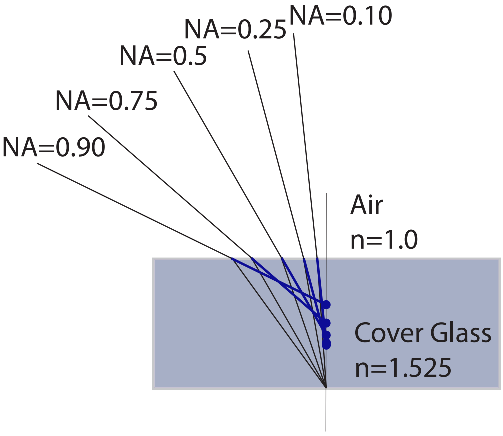

The importance of the cover glass increases in proportion to the objective's NA, especially in high-NA dry lenses. For lenses with an NA smaller than 0.5, the type of cover glass may not be a critical parameter, but should always be properly used to optimize imaging quality. Cover glasses are likely to be encountered when imaging biological samples. Note that the presence of a standard-thickness cover glass is accounted for in the design of high-NA objectives. The important parameters that define a cover glass are its thickness, index of refraction, and Abbe number. The ISO standards for refractive index and Abbe number are $n = 1.5255 \pm 0.0015$ and $V = 56 \pm 2$, respectively.

Microscope objectives are available that can accommodate a range of cover-slip thicknesses. An adjustable collar allows the user to adjust for cover slip thickness in the range from 100 microns to over 200 microns.

Cover Glass Grade Number	Thickness (in microns)
0	83–130
1	130–160
1.5	160–190
2	190–250

Cover Glass and Immersion (cont.)

The table below presents a summary of acceptable cover glass thickness deviations from 0.17 mm and the allowed thicknesses for Zeiss air objectives with different NAs.

NA of the Objective	Allowed Thickness Deviations (from 0.17 mm)	Allowed Thickness Range
<0.3	–	0.000–0.300
0.30–0.45	0.07	0.100–0.240
0.45–0.55	0.05	0.120–0.220
0.55–0.65	0.03	0.140–0.200
0.65–0.75	0.02	0.150–0.190
0.75–0.85	0.01	0.160–0.180
0.85–0.95	0.005	0.165–0.175

(Adapted from Pluta, 1988)

To increase both the microscope's resolution and system throughput, immersion liquids are used between the cover-slip glass and the microscope objective, or directly between the sample and objective. An **immersion liquid** effectively increases the NA and decreases the angle of refraction at the interface between the medium and the microscope objective. Common immersion liquids include oil (n = 1.515), water (n = 1.34), and glycerin (n = 1.48).

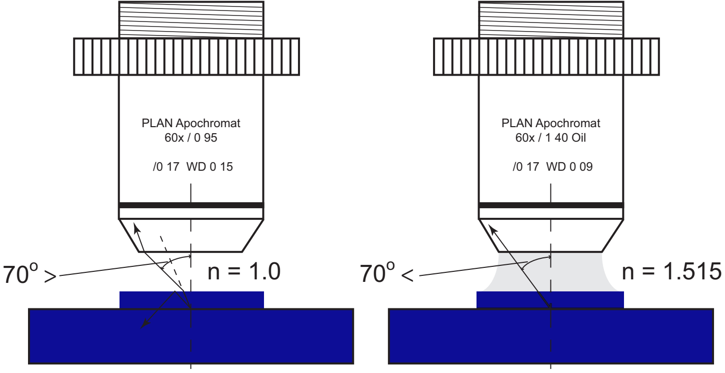

Water, which is more common, or glycerin immersion objectives are mainly used for biological samples, such as living cells or a tissue culture. They provide a slightly lower NA than oil objectives but are free of the toxicity associated with immersion oils. Water immersion is usually applied without a cover slip. For fluorescent applications it is also critical to use non-fluorescent oil.

Common Light Sources for Microscopy

Common light sources for microscopy include **incandescent lamps**, such as tungsten-argon and tungsten (e.g., quartz halogen) lamps. A **tungsten-argon lamp** is primarily used for bright-field, phase-contrast, and some polarization imaging. **Halogen lamps** are inexpensive and a convenient choice for a variety of applications that require a continuous and bright spectrum.

Arc lamps are usually brighter than incandescent lamps. The most common examples include xenon (XBO) and mercury (HBO) arc lamps. Arc lamps provide high-quality monochromatic illumination if combined with the appropriate filter. Arc lamps are more difficult to align, are more expensive, and have a shorter lifetime. Their spectral range starts in the UV range and continuously extends through visible to the infrared. About 20% of the output is in the visible spectrum, while the majority is in the UV and IR. The usual lifetime is 100–200 hours.

Common Mercury Lines	
Wavelength [nm]	**Color**
254	Far UV
366	Near UV
405	Violet
435	Deep Blue
546	Yellow-green
578	Yellow doublet

Another light source is the **gas-arc discharge lamp**, which includes mercury, xenon, and halide lamps. The **mercury lamp** has several strong lines, which might be 100 times brighter than the average output. About 50% is located in the UV range, and should be used with protective glasses. For imaging biological samples, the proper selection of filters is necessary to protect living cell samples and micro-organisms (e.g., UV-blocking filters/cold mirrors). The xenon arc lamp has a uniform spectrum, can provide an output power greater than 100 W, and is often used for fluorescence imaging. However, over 50% of its power falls into the IR; therefore, IR-blocking filters (hot mirrors) are necessary to prevent the overheating of samples.

Metal halide lamps were recently introduced as high-power sources (over 150 W) with lifetimes several times longer than arc lamps. While in general the metal-halide lamp has a spectral output similar to that of a mercury arc lamp, it extends further into longer wavelengths.

LED Light Sources

Light-emitting diodes (LEDs) are a new, alternative light source for microscopy applications. The LED is a semiconductor diode that emits photons when in forward-biased mode. Electrons pass through the depletion region of a p-n junction and lose an amount of energy equivalent to the bandgap of the semiconductor. The characteristic features of LEDs include a long lifetime, a compact design, and high efficiency. They also emit narrowband light with relatively high energy.

Wavelengths [nm] of High-power LEDs Commonly Used in Microscopy		**Total Beam Power [mW] (approximate)**
455	Royal Blue	225–450
470	Blue	200–400
505	Cyan	150–250
530	Green	100–175
590	Amber	15–25
633	Red	25–50
435–675	White Light	200–300

An important feature of LEDs is the ability to combine them into arrays and custom geometries. Also, LEDs operate at lower temperatures than arc lamps, and due to their compact design they can be cooled easily with simple heat sinks and fans.

The radiance of currently available LEDs is still significantly lower than that possible with arc lamps; however, LEDs can produce an acceptable fluorescent signal in bright microscopy applications. Also, the pulsed mode can be used to increase the radiance by 20 times or more.

LED Spectral Range [nm]	**Semiconductor**
350–400	GaN
400–550	$In_{1-x}Ga_xN$
550–650	$Al_{1-x-y}In_yGa_xP$
650–750	$Al_{1-x}Ga_xAs$
750–1000	$GaAs_{1-x}P_x$

Filters

Neutral density (ND) filters are neutral (wavelength wise) gray filters scaled in units of **optical density** (OD):

$$OD = \log_{10}\left(\frac{1}{\tau}\right),$$

where τ is the transmittance. ND filters can be combined to provide OD as a sum of the ODs of the individual filters. ND filters are used to change light intensity without tuning the light source, which can result in a spectral shift.

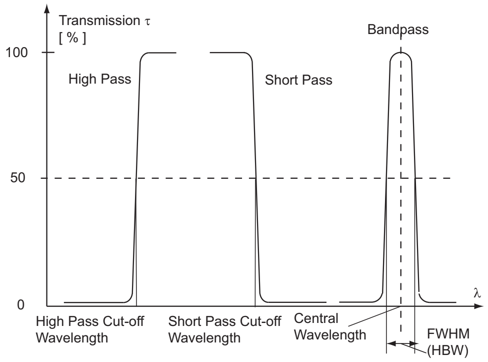

Color **absorption filters** and **interference filters** (also see *Multiple Wave Interference* on page 16) isolate the desired range of wavelengths: e.g. bandpass and edge filters.

Edge filters include short-pass and long-pass filters. Short-pass filters allow short wavelengths to pass and stop long wavelengths, and long-pass filters allow long wavelengths to pass while stopping short wavelengths. Edge filters are defined for wavelengths with a 50% drop in transmission.

Bandpass filters allow only a selected spectral bandwidth to pass and are characterized with a central wavelength and full-width-half-maximum (FWHM) defining the spectral range for transmission of at least 50%.

Color absorption glass filters usually serve as broad bandpass filters. They are less costly and less susceptible to damage than interference filters.

Interference filters are based on multiple beam interference in thin films. They combine between three to over 20 dielectric layers of $\lambda/2$ and $\lambda/4$, separated by metallic coatings. They can provide a sharp bandpass transmission down to the sub-nm range and full-width-half-maximum of 10–20 nm.

Polarizers and Polarization Prisms

Polarizers are built with birefringent crystals using polarization at multiple reflections, selective absorption (dichroism), form birefringance, or scattering.

For example, polarizers built with birefringent crystals (Glan-Thompson prisms) use the principle of total internal reflection to eliminate ordinary or extraordinary components (for positive or negative crystals).

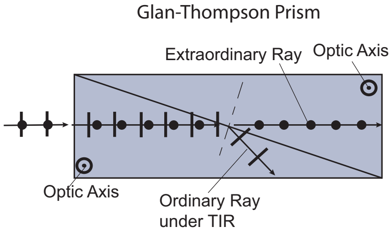
Glan-Thompson Prism
Extraordinary Ray
Optic Axis
Optic Axis
Ordinary Ray under TIR

Birefringent prisms are crucial components for numerous microscopy techniques, e.g., differential interference contrast. The most common birefringent prism is a **Wollaston prism**. It splits light into two beams with orthogonal polarization and propagates under different angles.

The angle between propagating beams is

$$\varepsilon = 2\left|n_e - n_o\right|\tan\alpha\,.$$

Both beams produce interference with fringe period b:

$$b = \frac{\lambda}{\varepsilon} = \frac{\lambda}{2\left|n_e - n_o\right|\tan\alpha}\,.$$

The localization plane of fringes is

$$\gamma = \frac{1}{2}\left(\frac{1}{n_e} + \frac{1}{n_o}\right)\alpha\,.$$

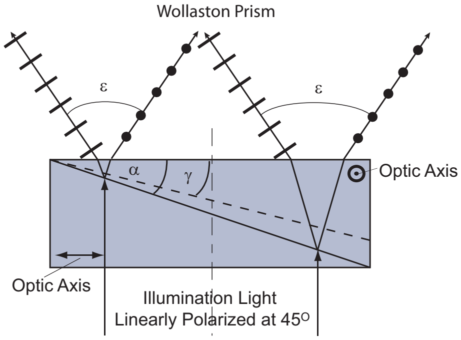
Wollaston Prism
ε
ε
α
γ
Optic Axis
Optic Axis
Illumination Light
Linearly Polarized at 45°

Polarizers and Polarization Prisms (cont.)

The fringe localization plane tilt can be compensated by using two symmetrical Wollaston prisms.

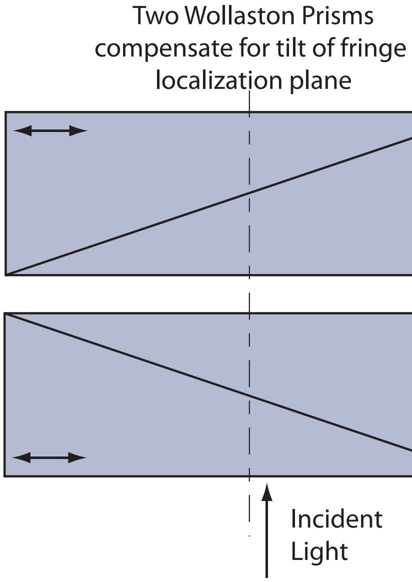
Two Wollaston Prisms compensate for tilt of fringe localization plane
Incident Light

Wollaston prisms have a fringe localization plane inside the prism. One example of a modified Wollaston prism is the **Nomarski prism**, which simplifies the DIC microscope setup by shifting the plane outside the prism, i.e., the prism does not need to be physically located at the condenser front focal plane or the objective's back focal plane.

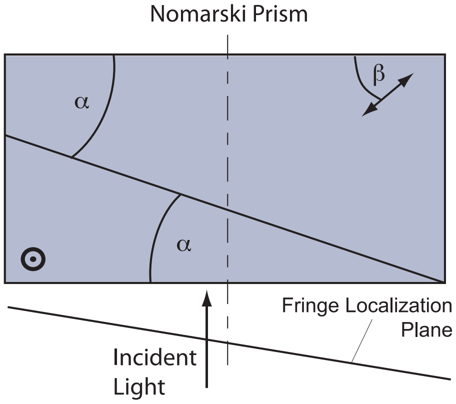
Nomarski Prism
α
β
α
Fringe Localization Plane
Incident Light

Amplitude and Phase Objects

The major object types encountered on the microscope are **amplitude** and **phase** objects. The type of object often determines the microscopy technique selected for imaging.

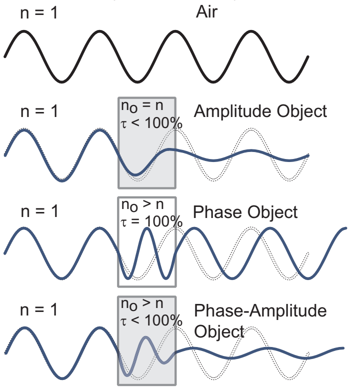

The amplitude object is defined as one that changes the amplitude and therefore the intensity of transmitted or reflected light. Such objects are usually imaged with bright-field microscopes. A stained tissue slice is a common amplitude object.

Phase objects do not affect the optical intensity; instead, they generate a phase shift in the transmitted or reflected light. This phase shift usually arises from an inhomogeneous refractive index distribution throughout the sample, causing differences in optical path length (OPL). Mixed amplitude-phase objects are also possible (e.g., biological media), which affect the amplitude and phase of illumination in different proportions.

Classifying objects as **self-luminous** and **non-self-luminous** is another way to categorize samples. Self-luminous objects generally do not directly relate their amplitude and phase to the illuminating light. This means that while the observed intensity may be proportional to the illumination intensity, its amplitude and phase are described by a statistical distribution (e.g., fluorescent samples). In such cases, one can treat discrete object points as secondary light sources, each with their own amplitude, phase, coherence, and wavelength properties.

Non-self-luminous objects are those that affect the illuminated beam in such a manner that discrete object points cannot be considered as entirely independent. In such cases, the wavelength and temporal coherence of the illuminating source needs to be considered in imaging. A diffusive or absorptive sample is an example of such an object.

The Selection of a Microscopy Technique

Microscopy provides several imaging principles. Below is a list of the most common techniques and object types:

Technique	Type of sample
Bright-field	Amplitude specimens, reflecting specimens, diffuse objects
Dark-field	Light-scattering objects
Phase contrast	Phase objects, light-scattering objects, light-refracting objects, reflective specimens
Differential interference contrast (DIC)	Phase objects, light-scattering objects, light-refracting objects, reflective specimens
Polarization microscopy	Birefringent specimens
Fluorescence microscopy	Fluorescent specimens
Laser scanning, Confocal microscopy, and Multi-photon microscopy	3D samples requiring optical sectioning, fluorescent and scattering samples
Super-resolution microscopy (**RESOLFT**, **4Pi**, **I^{5}M**, **SI**, **STORM**, **PALM**, and others)	Imaging at the molecular level; imaging primarily focuses on fluorescent samples where the sample is a part of an imaging system
Raman microscopy, **CARS**	Contrast-free chemical imaging
Array microscopy	Imaging of large FOVs
SPIM	Imaging of large 3D samples
Interference Microscopy	Topography, refractive index measurements, 3D coherence imaging

All of these techniques can be considered for transmitted or reflected light. Below are examples of different sample types:

Sample type	Sample Example
Amplitude specimens	Naturally colored specimens, stained tissue
Specular specimens	Mirrors, thin films, metallurgical samples, integrated circuits
Diffuse objects	Diatoms, fibers, hairs, micro-organisms, minerals, insects
Phase objects	Bacteria, cells, fibers, mites, protozoa
Light-refracting samples	Colloidal suspensions, minerals, powders
Birefringent specimens	Mineral sections, crystallized chemicals, liquid crystals, fibers, single crystals
Fluorescent specimens	Cells in tissue culture, fluorochrome-stained sections, smears and spreads

(Adapted from www.microscopyu.com)

Image Comparison

The images below display four important microscope modalities: **bright field**, **dark field**, **phase contrast**, and **differential interference contrast**. They also demonstrate the characteristic features of these methods. The images are of a blood specimen viewed with the Zeiss upright Axiovert Observer Z1 microscope. The microscope was set with an objective at 40×, NA = 0.6, Ph2, LD Plan Neofluor, and a cover slip glass of 0.17 mm. The pictures were taken with a monochromatic CCD camera.

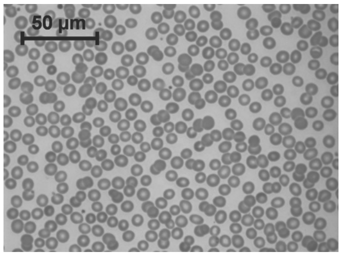 Bright Field	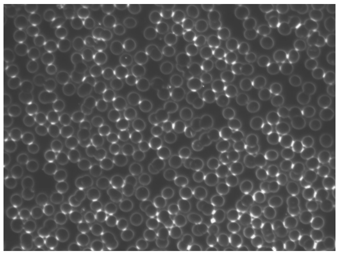 Dark Field
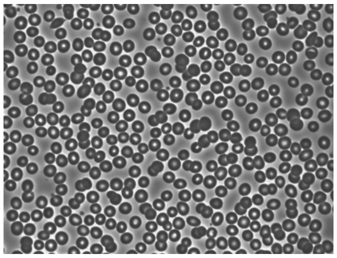 Phase Contrast	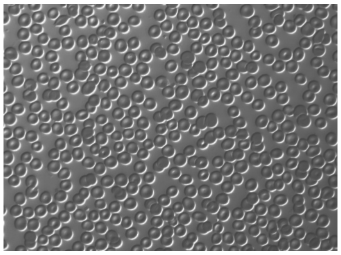 Differential Interference Contrast (DIC)

The bright-field image relies on absorption and shows the sample features with decreasing amounts of passing light. The dark-field image only shows the scattering sample components. Both the phase contrast and the differential interference contrast demonstrate the optical thickness of the sample. The characteristic halo effect is visible in the phase-contrast image. The 3D effect of the DIC image arises from the differential character of images; they are formed as a derivative of the phase changes in the beam as it passes through the sample.

Phase Contrast

Phase contrast is a technique used to visualize phase objects by phase and amplitude modifications between the direct beam propagating through the microscope and the beam diffracted at the phase object. An object is illuminated with monochromatic light, and a phase-delaying (or advancing) element in the aperture stop of the objective introduces a phase shift, which provides interference contrast. Changing the amplitude ratio of the diffracted and non-diffracted light can also increase the contrast of the object features.

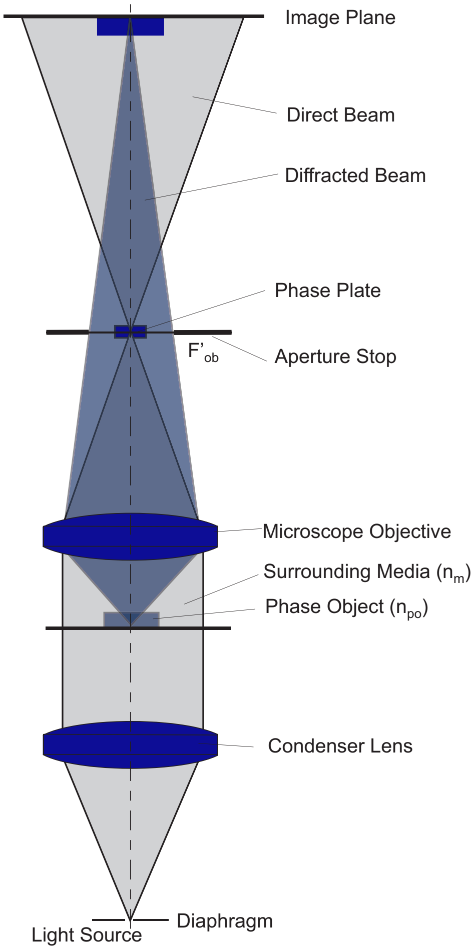
Image Plane
Direct Beam
Diffracted Beam
Phase Plate
F'_{ob}
Aperture Stop
Microscope Objective
Surrounding Media (n_m)
Phase Object (n_{po})
Condenser Lens
Diaphragm
Light Source

Phase Contrast (cont.)

Phase contrast is primarily used for imaging living biological samples (immersed in a solution), unstained samples (e.g., cells), thin film samples, and mild phase changes from mineral objects. In that regard, it provides qualitative information about the optical thickness of the sample. Phase contrast can also be used for some quantitative measurements, like an estimation of the refractive index or the thickness of thin layers. Its phase detection limit is similar to the **differential interference contrast** and is approximately $\lambda/100$. On the other hand, phase contrast (contrary to DIC) is limited to thin specimens, and phase delay should not exceed the depth of field of an objective. Other drawbacks compared to DIC involve its limited optical sectioning ability and undesired effects like halos or shading-off. (See also *Characteristic Features of Phase Contrast Microscopy* on page 71).

The most important advantages of phase contrast (over DIC) include its ability to image birefringent samples and its simple and inexpensive implementation into standard microscopy systems.

Presented below is a mathematical description of the phase contrast technique based on a vector approach. The phase shift in the figure (See page 68) is represented by the orientation of the vector. The length of the vector is proportional to amplitude of the beam. When using standard imaging on a transparent sample, the length of the light vectors passing through sample PO and surrounding media SM is the same, which makes the sample invisible. Additionally, vector PO can be considered as a sum of the vectors passing through surrounding media SM and diffracted at the object DP.

$$PO = SM + DP$$

If the wavefront propagating through the surrounding media can be the subject of an exclusive phase change (diffracted light DP is not affected), the vector SM is rotated by an angle corresponding to the phase change. This exclusive phase shift is obtained with a small circular or ring phase plate located in the plane of the aperture stop of a microscope.

Phase Contrast (cont.)

Consequently, vector *PO*, which represents light passing through a phase sample, will change its value to *PO′* and provide contrast in the image:

$$PO' = SM' + DP,$$

where *SM′* represents the rotated vector *SM***.**

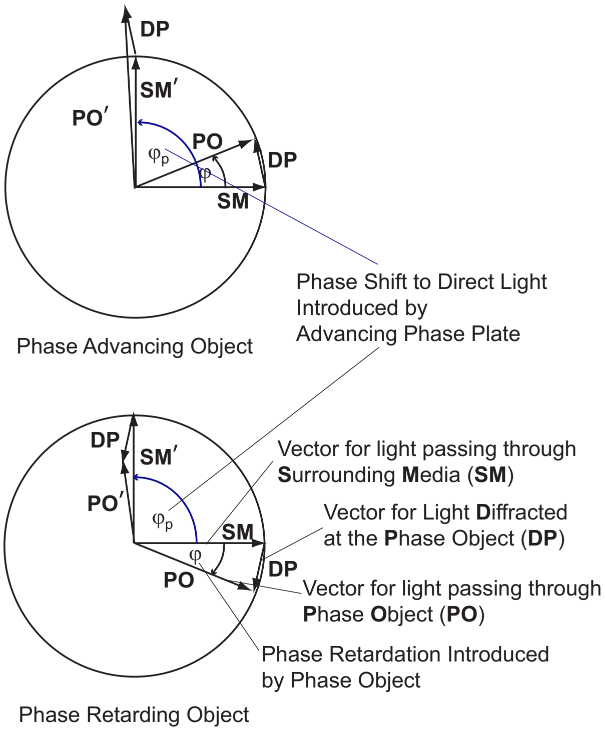
DP
SM′
PO′
PO
φ_p
φ
DP
SM
Phase Shift to Direct Light
Introduced by
Advancing Phase Plate
Phase Advancing Object
DP
SM′
PO′
φ_p
SM
φ
DP
PO
Vector for light passing through
Surrounding Media (SM)
Vector for Light Diffracted
at the Phase Object (DP)
Vector for light passing through
Phase Object (PO)
Phase Retardation Introduced
by Phase Object
Phase Retarding Object

Phase samples are considered to be **phase retarding objects** or **phase advancing objects** when their refractive index is greater or less than the refractive index of the surrounding media, respectively.

Phase plate	Object Type	Object Appearance
$\varphi_p = +\pi/2$ (+90°)	phase-retarding	brighter
$\varphi_p = +\pi/2$ (+90°)	phase-advancing	darker
$\varphi_p = -\pi/2$ (–90°)	phase-retarding	darker
$\varphi_p = -\pi/2$ (–90°)	phase-advancing	brighter

Visibility in Phase Contrast

Visibility of features in **phase contrast** can be expressed as

$$C_{\text{ph}} = \frac{I_{\text{media}} - I_{\text{object}}}{I_{\text{media}}} = \frac{|SM'|^2 - |PO'|^2}{|SM'|^2}.$$

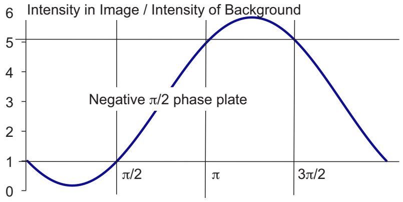

This equation defines the phase object's visibility as a ratio between the intensity change due to phase features and the intensity of surrounding media $|SM'|^2$. It defines the negative and positive contrast for an object appearing brighter or darker than the media, respectively. Depending on the introduced phase shift (positive or negative), the same object feature may appear with a **negative** or **positive contrast**. Note that C_{ph} relates to classical contrast C as

$$C = \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{max}} + I_{\text{min}}} = \frac{|I_1 - I_2|}{I_1 + I_2} = |C_{\text{ph}}| \frac{|SM'|^2}{|SM'|^2 + |PO'|^2}.$$

Contrast	**Phase Plate**
-2φ	$\varphi_p = +\pi/2$ (+90°)
$+2\varphi$	$\varphi_p = -\pi/2$ (–90°)

For phase changes in the 0–2π range, intensity in the image can be found using vector relations; small phase changes in the object $\varphi << 90$ deg can be approximated as $\pm 2\varphi$.

To increase the contrast of images, the intensity in the direct beam is additionally changed with beam attenuation τ in the phase ring. τ is defined as a transmittance, $\tau = 1/N$, where N is a dividing coefficient of intensity in a direct beam (intensity is decreased N times). The contrast in this case is

$$C_{\text{ph}} = -2\varphi / \sqrt{\tau} = -2\varphi\sqrt{N}$$

for a +π/2 phase plate, and

$$C_{\text{ph}} = +2\varphi / \sqrt{\tau} = +2\varphi\sqrt{N}$$

for –π/2 phase plate. The minimum perceived phase difference with phase contrast is

$$\Delta\varphi_{\text{min}} = \frac{C_{\text{ph-min}}\lambda}{4\pi\sqrt{N}}.$$

$C_{\text{ph-min}}$ is usually accepted at the contrast value of 0.02.

The Phase Contrast Microscope

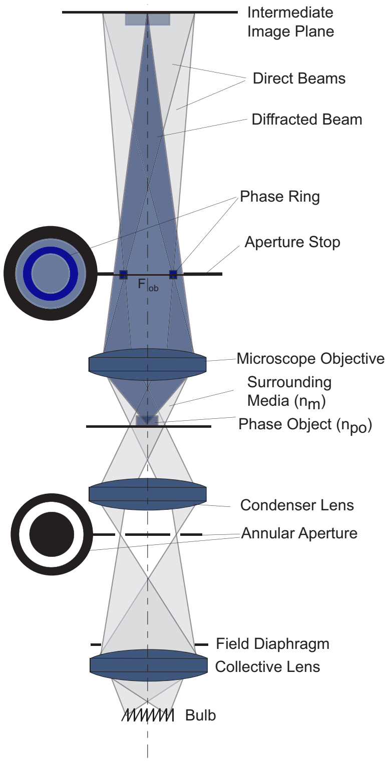
Intermediate Image Plane
Direct Beams
Diffracted Beam
Phase Ring
Aperture Stop
F_ob
Microscope Objective
Surrounding Media (nm)
Phase Object (npo)
Condenser Lens
Annular Aperture
Field Diaphragm
Collective Lens
Bulb

The common phase-contrast system is similar to the bright-field microscope but with two modifications:

1. The condenser diaphragm is replaced with an annular aperture diaphragm.
2. A ring-shaped phase plate is introduced at the back focal plane of the microscope objective. The ring may include metallic coatings, typically providing 75% to 90% attenuattion of the direct beam.

Both components are in conjugate planes and are aligned such that the image of the annular condenser diaphragm overlaps with the objective phase ring. While there is no direct access to the objective phase ring, the anular aperture in front of the condenser is easily accessible.

The phase shift introduced by the ring is given by

$$\varphi_{\mathrm{p}} = 2\pi\frac{OPD}{\lambda} = \frac{2\pi}{\lambda}\left(n_{\mathrm{m}} - n_{\mathrm{r}}\right)t\,,$$

where n_{m} and n_{r} are refractive indices of the media surrounding the phase ring and the ring itself, respectively. t is the physical thickness of the phase ring.

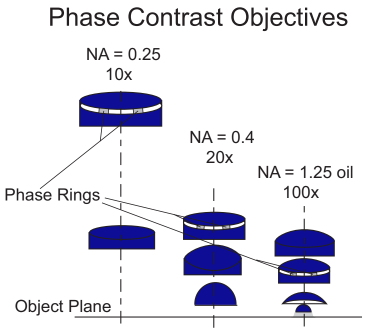
Phase Contrast Objectives
NA = 0.25
10x
NA = 0.4
20x
NA = 1.25 oil
100x
Phase Rings
Object Plane

Characteristic Features of Phase Contrast

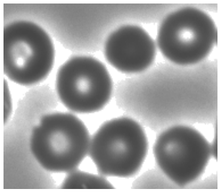

Images in phase contrast are dark or bright features on a background (positive and negative contrast, respectively). They contain undesired image effects called halo and shading-off, which are a result of the incomplete separation of direct and diffracted light. The **halo effect** is a phase contrast feature that increases light intensity around sharp changes in the phase gradient.

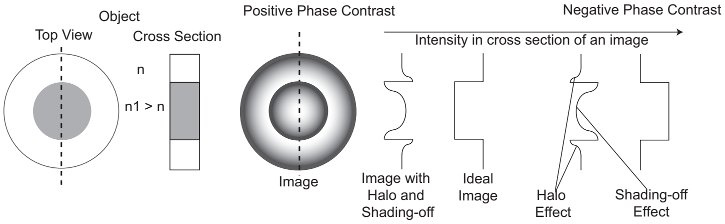
Object
Top View
Cross Section
n
n1 > n
Positive Phase Contrast
Image
Negative Phase Contrast
Intensity in cross section of an image
Image with Halo and Shading-off
Ideal Image
Halo Effect
Shading-off Effect

The **shading-off effect** is an increase or decrease (for dark or bright images, respectively) of the intensity of the phase sample feature.

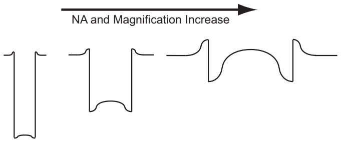
NA and Magnification Increase

Both effects strongly increase with an increase in numerical aperture and magnification. They can be reduced by surrounding the sides of a phase ring with ND filters.

Lateral resolution of the phase contrast technique is affected by the annular aperture (the radius of phase ring r_{PR}) and the aperture stop of the objective (the radius of aperture stop is r_{AS}). It is

$$d = f'_{\text{objective}} \frac{\lambda}{(r_{\text{AS}} + r_{\text{PR}})},$$

compared to the resolution limit for a standard microscope:

$$d = f'_{\text{objective}} \frac{\lambda}{r_{\text{AS}}}.$$

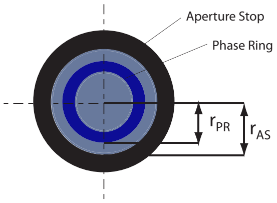
Aperture Stop
Phase Ring
r_{PR}
r_{AS}

Amplitude Contrast

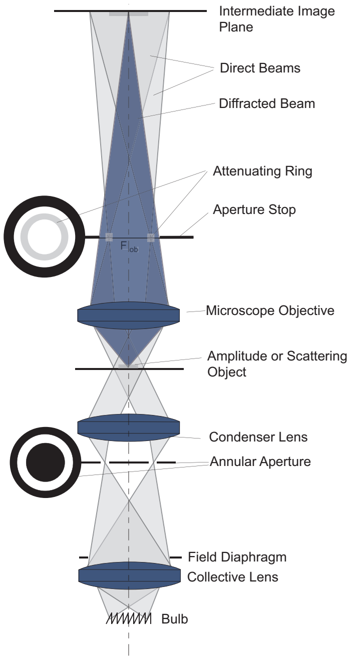
Intermediate Image Plane
Direct Beams
Diffracted Beam
Attenuating Ring
Aperture Stop
F_{ob}
Microscope Objective
Amplitude or Scattering Object
Condenser Lens
Annular Aperture
Field Diaphragm
Collective Lens
Bulb

Amplitude contrast changes the contrast in the images of absorbing samples. It has a layout similar to phase contrast; however, there is no phase change introduced by the object. In fact, in many cases a phase-contrast microscope can increase contrast based on the principle of amplitude contrast. The visibility of images is modified by changing the intensity ratio between the direct and diffracted beams.

A vector schematic of the technique is as follows:

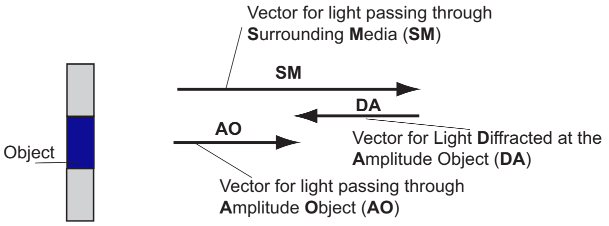
Vector for light passing through **S**urrounding **M**edia (**SM**)
SM
DA
AO
Object
Vector for Light **D**iffracted at the **A**mplitude Object (**DA**)
Vector for light passing through **A**mplitude **O**bject (**AO**)

Similar to visibility in phase contrast, image contrast can be described as a ratio of the intensity change due to amplitude features surrounding the media's intensity:

$$C_{\mathrm{ac}} = \frac{I_{\mathrm{media}} - I_{\mathrm{object}}}{I_{\mathrm{media}}} = \frac{2|SM||DA| - |DA|^2}{|SM|^2}.$$

Since the intensity of diffraction for amplitude objects is usually small, the contrast equation can be approximated with $C_{\mathrm{ac}} = 2|DA|/|SM|$. If a direct beam is further attenuated, contrast C_{ac} will increase by factor of $N^{-1} = 1/\tau^{-1}$.

Oblique Illumination

Oblique illumination (also called **anaxial illumination**) is used to visualize phase objects. It creates pseudo-profile images of transparent samples. These reliefs, however, do not directly correspond to the actual surface profile.

The principle of oblique illumination can be explained by using either refraction or diffraction and is based on the fact that sample features of various spatial frequencies will have different intensities in the image due to a nonsymmetrical system layout and the filtration of spatial frequencies.

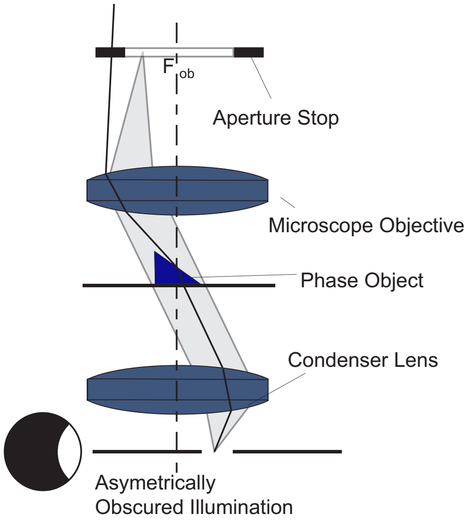

In practice, oblique illumination can be achieved by obscuring light exiting a condenser; translating the sub-stage diaphragm of the condenser lens does this easily.

The advantage of oblique illumination is that it improves spatial resolution over Köhler illumination (up to two times). This is based on the fact that there is a larger angle possible between the 0th and 1st orders diffracted at the sample for oblique illumination. In Köhler illumination, due to symmetry, the 0th and –1st orders at one edge of the stop will overlap with the 0th and +1st order on the other side. However, the gain in resolution is only for one sample direction; to examine the object features in two directions, a sample stage should be rotated.

Modulation Contrast

Modulation contrast microscopy (MCM) is based on the fact that phase changes in the object can be visualized with the application of multilevel gray filters.

The intensities of light refracted at the object are displayed with different values since they pass through different zones of the filter located in the stop of the microscope. MCM is often configured for oblique illumination since it already provides some intensity variations for phase objects. Therefore, the resolution of the MCM changes between normal and oblique illumination.

MCM can be obtained through a simple modification of a bright-field microscope by adding a slit diaphragm in front of the condenser and amplitude filter (also called the modulator) in the aperture stop of the microscope objective. The modulator filter consists of three areas: 100% (bright), 15% (gray), and 1% (dark). This filter acts in a similar way to the knife-edge in the Schlieren imaging techniques.

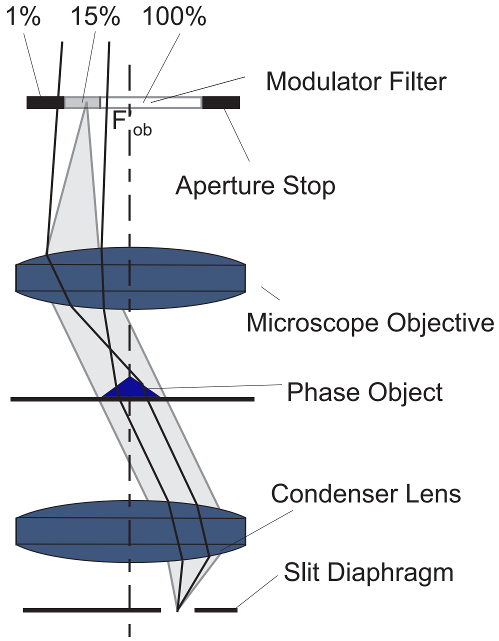
1%
15%
100%
Modulator Filter
F_{ob}
Aperture Stop
Microscope Objective
Phase Object
Condenser Lens
Slit Diaphragm

Hoffman Contrast

A specific implementation of MCM is **Hoffman modulation contrast**, which uses two additional polarizers located in front of the slit aperture. One polarizer is attached to the slit and obscures 50% of its width. A second can be rotated, which provides two intensity zones in the slit (for crossed polarizers, half of the slit is dark and half is bright; the entire slit is bright for the parallel position).

The major advantages of this technique include imaging at a full spatial resolution and a minimum depth of field, which allows optical sectioning. The method is inexpensive and easy to implement. The main drawback is that the images deliver a pseudo-relief image, which cannot be directly correlated with the object's form.

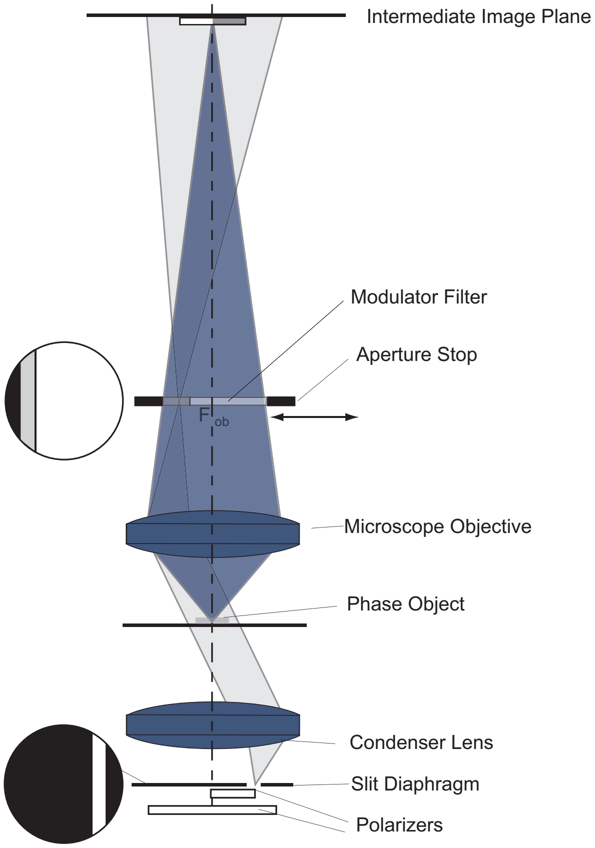
Intermediate Image Plane
Modulator Filter
Aperture Stop
F_{ob}
Microscope Objective
Phase Object
Condenser Lens
Slit Diaphragm
Polarizers

Dark Field Microscopy

In **dark-field microscopy**, the specimen is illuminated at such angles that direct light is not collected by the microscope objective. Only diffracted and scattered light are used to form the image.

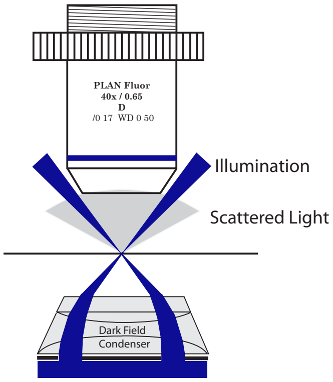
PLAN Fluor
40x / 0.65
D
/0 17 WD 0 50
Illumination
Scattered Light
Dark Field Condenser

The key component of the dark-field system is the condenser. The simplest approach uses an annular condenser stop and a microscope objective with an NA below that of the illumination cone. This approach can be used for objectives with NA < 0.65. Higher-NA objectives may incorporate an adjustable iris to reduce their NA below 0.65 for dark-field imaging. To image at a higher NA, specialized reflective dark-field condensers are necessary. Examples of such condensers include the **cardioid** and **paraboloid** designs, which enable dark-field imaging at an NA up to 0.9–1.0 (with oil immersion).

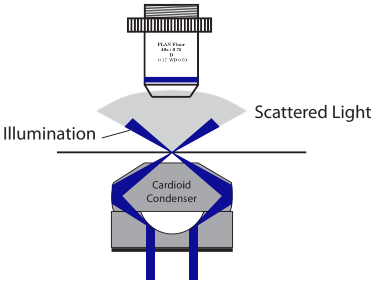
Scattered Light
Illumination
Cardioid Condenser

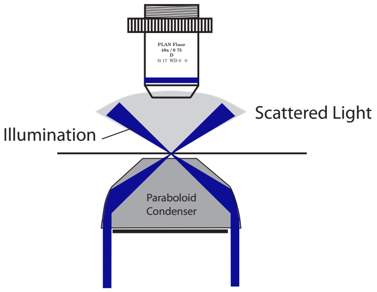
Scattered Light
Illumination
Paraboloid Condenser

For dark-field imaging in epi-illumination, objective designs consist of external illumination, and internal imaging paths are used.

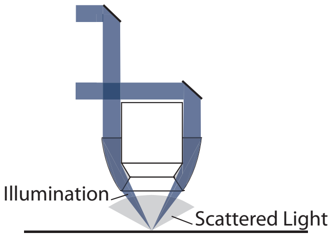
Illumination
Scattered Light

Optical Staining: Rheinberg Illumination

Optical staining is a class of techniques that uses optical methods to provide color differentiation between different areas of a sample**.**

Common Color Combinations	
Inner Filter	Annular Filter
Violet	Red
Blue	Yellow-Orange
Green	Red

Rheinberg illumination is a modification of dark-field illumination. Instead of an annular aperture, it uses two-zone color filters located in the front focal plane of the condenser. The overall diameter of the outer annular color filter is slightly greater than that corresponding to the NA of the system:

$$2r_{\lambda 2} > 2NAf'_{\text{condenser}} \,.$$

To provide good contrast between scattered and direct light, the inner filter is darker. Rheinberg illumination provides images that are a combination of two colors. Scattering features in one color are visible on the background of the other color.

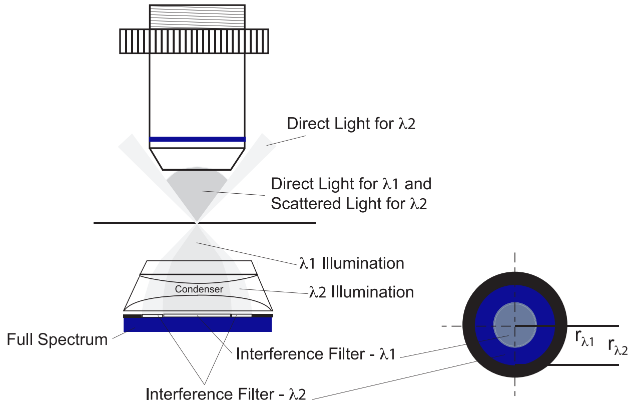
Direct Light for λ2
Direct Light for λ1 and Scattered Light for λ2
λ1 Illumination
Condenser
λ2 Illumination
Full Spectrum
Interference Filter - λ1
Interference Filter - λ2
$r_{\lambda 1}$
$r_{\lambda 2}$

Color-stained images can also be obtained in a simplified setup where only one (inner) filter is used. For such an arrangement, images will present white-light scattering features on the colored background. Other deviations from the above technique include double illumination where transmittance and reflectance are separated into two different colors.

Optical Staining: Dispersion Staining

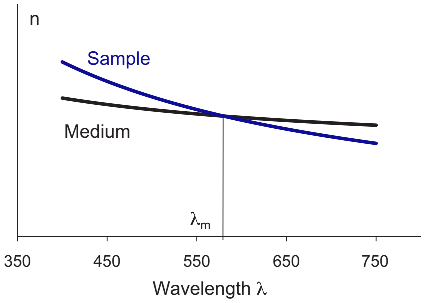

Dispersion staining is based on using highly dispersive media that matches the refractive index of the phase sample for a single wavelength λ_m (the matching wavelength). The system is configured in a setup similar to dark-field or oblique illumination. Wavelengths close to the matching wavelength will miss the microscope objective, while the other will refract at the object and create a colored dark-field image. Various configurations include illumination with a dark-field condenser and an annular aperture or central stop at the back focal plane of the microscope objective.

Color	λ Range [nm]	λ Mean [nm]
Violet	400–450	440
Blue	450–480	470
Blue-Green	480–510	495
Green	510–550	530
Green-Yellow	550–570	560
Yellow	570–590	580
Orange	590–630	605
Red	630–700	650

(Adapted from Pluta, 1989)

The annular-stop technique uses low-magnification (10×) objectives with a stop built as an opaque screen with a central opening, and is used for bright-field dispersion staining. The annular stop absorbs red and blue wavelengths and allows yellow through the system. A sample appears as white with yellow borders. The image background is also white.

The central-stop system absorbs unrefracted yellow light and direct white light. Sample features show up as purple (a mixture of red and blue) borders on a dark background. Different media and sample types will modify the color's appearance.

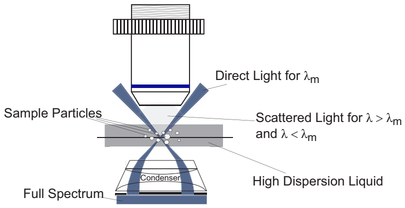
Direct Light for λ_m
Sample Particles
Scattered Light for $\lambda > \lambda_m$ and $\lambda < \lambda_m$
Condenser
High Dispersion Liquid
Full Spectrum

Shearing Interferometry: The Basis for DIC

Differential interference contrast (DIC) microscopy is based on the principles of shearing interferometry. Two wavefronts propagating through an optical system containing identical phase distributions (introduced by the sample) are slightly shifted to create an interference pattern. The phase of the resulting fringes is directly proportional to the derivative of the phase distribution in the object, hence the name "differential." Specifically, the intensity of the fringes relates to the derivative of the phase delay through the object (φ_o) and the local delay between wavefronts (Δ_b):

$$I \propto I_{\max} \cos^2\left(\Delta_b \pm \Delta\varphi_o\right)$$

or

$$I \propto I_{\max} \cos^2\left(\Delta_b \pm s\frac{d\varphi_o}{dx}\right),$$

where s denotes the shear between wavefronts, and Δ_b is the axial delay.

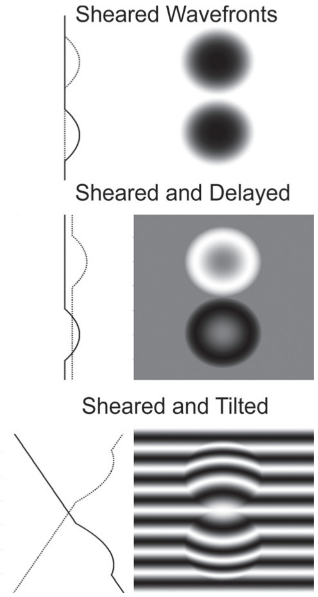

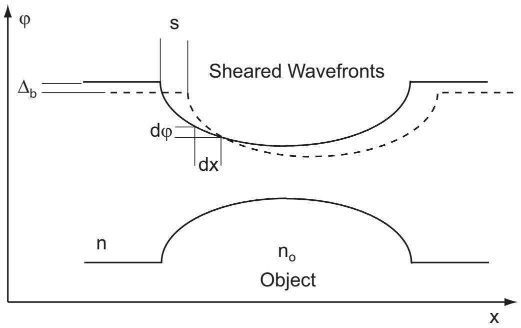

Wavefront shear is commonly introduced in DIC microscopy by incorporating a Mach-Zehnder interferometer into the system (e.g., Zeiss) or by the use of birefringent prisms. The appearance of DIC images depends on the sample orientation with respect to the shear direction.

DIC Microscope Design

The most common **differential interference contrast** (**Nomarski DIC**) design uses two **Wollaston** or **Nomarski birefringent prisms**. The first prism splits the wavefront into ordinary and extraordinary components to produce interference between these beams. Fringe localization planes for both prisms are in conjugate planes. Additionally, the system uses a crossed polarizer and analyzer. The polarizer is located in front of prism I, and the analyzer is behind prism II. The polarizer is rotated by 45 deg with regard to the shear axes of the prisms.

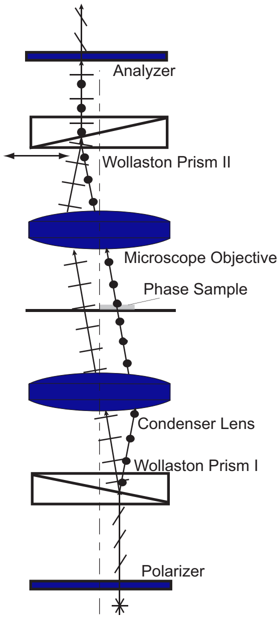

If prism II is centrally located, the intensity in the image is

$$I \propto \sin^2\left(\frac{\pi s \dfrac{d\varphi_o}{dx}}{\lambda}\right).$$

For a translated prism, phase **bias** Δ_b is introduced, and the intensity is proportional to

$$I \propto \sin^2 \frac{\pi\left(\Delta_b \pm s\dfrac{d\varphi_o}{dx}\right)}{\lambda}.$$

The sign in the equation depends on the direction of the shift. Shear s is

$$s = \frac{s'}{M_{\text{objective}}} = \varepsilon \frac{OTL}{M_{\text{objective}}},$$

where ε is the angular shear provided by the birefringent prisms, s' is the shear in the image space, and OTL is the optical tube length. The high spatial coherence of the source is obtained by the slit located in front of the condenser and oriented perpendicularly to the shear direction. To assure good interference contrast, the width of the slit w should be

$$w = \frac{\lambda f'_{\text{condenser}}}{4s}.$$

Low-strain (low-birefringence) objectives are crucial for high-quality DIC.

Appearance of DIC Images

In practice, shear between wavefronts in **differential interference contrast** is small and accounts for a fraction of a fringe period. This provides the differential character of the phase difference between interfering beams introduced to the interference equation.

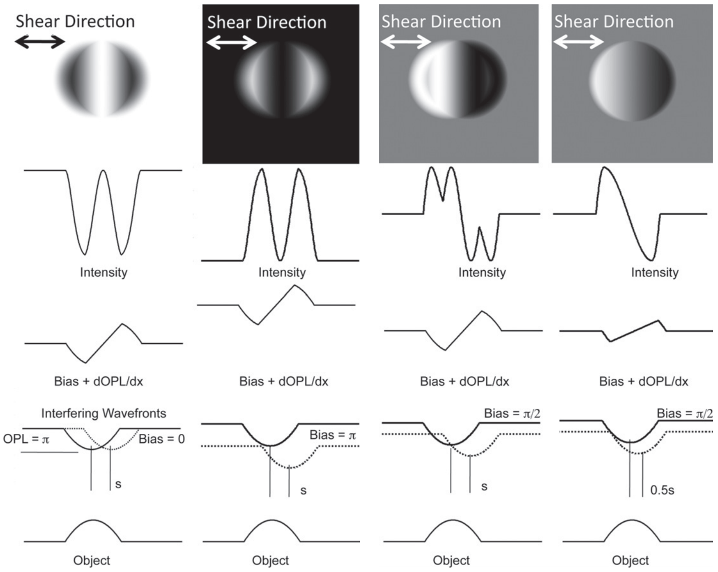
Shear Direction
Shear Direction
Shear Direction
Shear Direction
Intensity
Intensity
Intensity
Intensity
Bias + dOPL/dx
Bias + dOPL/dx
Bias + dOPL/dx
Bias + dOPL/dx
Interfering Wavefronts
OPL = π
Bias = 0
s
Bias = π
s
Bias = π/2
s
Bias = π/2
0.5s
Object
Object
Object
Object

Increased shear makes the edges of the object less sharp, while increased bias introduces some background intensity. Shear direction determines the appearance of the object.

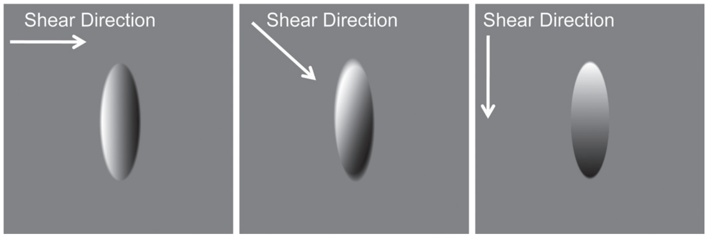
Shear Direction
Shear Direction
Shear Direction

Compared to phase contrast, DIC allows for larger phase differences throughout the object and operates in full resolution of the microscope (i.e., it uses the entire aperture). The depth of field is minimized, so DIC allows optical sectioning.

Reflectance DIC

A **Nomarski interference microscope** (also called a polarization interference contrast microscope) is a reflectance DIC system developed to evaluate roughness and the surface profile of specular samples. Its applications include metallography, microelectronics, biology, and medical imaging. It uses one Wollaston or Nomarski prism, a polarizer, and an analyzer. The information about the sample is obtained for one direction parallel to the gradient in the object. To acquire information for all directions, the sample should be rotated.

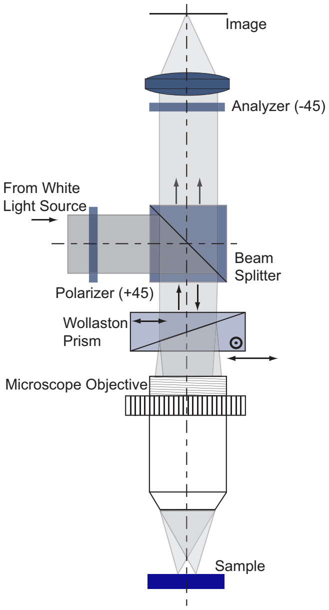
Image
Analyzer (-45)
From White Light Source
Beam Splitter
Polarizer (+45)
Wollaston Prism
Microscope Objective
Sample

If white light is used, different colors in the image correspond to different sample slopes. It is possible to adjust the color by rotating the polarizer.

Phase delay (**bias**) can be introduced by translating the birefringent prism. For imaging under monochromatic illumination, the brightness in the image corresponds to the slope in the sample. Images with no bias will appear as bright features on a dark background; with bias they will have an average background level, and slopes will vary between dark and bright. This way, it is possible to interpret the direction of the slope. Similar analysis can be performed for the colors from white-light illumination.

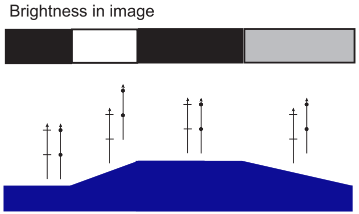
Brightness in image

Illumination with no bias

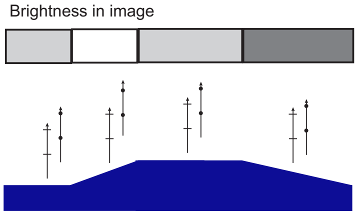
Brightness in image

Illumination with bias

Polarization Microscopy

Polarization microscopy provides images containing information about the properties of anisotropic samples. A polarization microscope is a modified compound microscope with three unique components: the **polarizer**, **analyzer**, and **compensator**. A linear polarizer is located between the light source and the specimen, close to the condenser's diaphragm. The analyzer is a linear polarizer with its transmission axis perpendicular to the polarizer. It is placed between the sample and the eye/camera, at or near the microscope objective's aperture stop. If no sample is present, the image should appear uniformly dark. The compensator (a type of retarder) is a birefringent plate of known parameters used for quantitative sample analysis and contrast adjustment.

Quantitative information can be obtained by introducing known retardation. Rotation of the analyzer correlates the analyzer's angular position with the retardation required to minimize the light intensity for object features at selected wavelengths. **Retardation** introduced by the compensator plate can be described as

$$\Gamma = \left(n_e - n_o\right) t \, ,$$

where t is the sample thickness, and subscripts e and o denote the extraordinary and ordinary beams. Retardation in concept is similar to the optical path difference for beams propagating through two different materials:

$$OPD = \left(n_1 - n_2\right) t = \left(n_e - n_o\right) t \, .$$

The phase delay caused by sample birefringence is therefore

$$\delta = \frac{2\pi OPD}{\lambda} = \frac{2\pi\Gamma}{\lambda} \, .$$

A polarization microscope can also be used to determine the orientation of the optic axis.

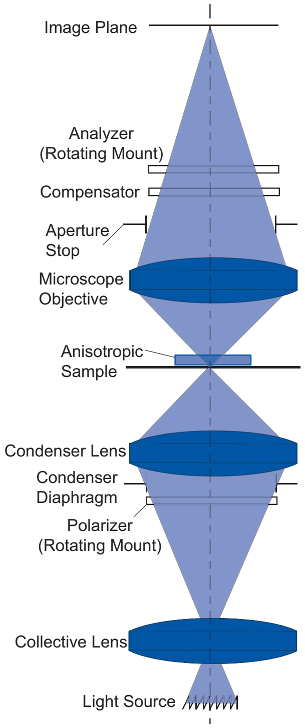
Image Plane
Analyzer (Rotating Mount)
Compensator
Aperture Stop
Microscope Objective
Anisotropic Sample
Condenser Lens
Condenser Diaphragm
Polarizer (Rotating Mount)
Collective Lens
Light Source

Images Obtained with Polarization Microscopes

Anisotropic samples observed under a **polarization microscope** contain dark and bright features and will strongly depend on the geometry of the sample. Objects can have characteristic elongated, linear, or circular structures:

- linear structures appear as dark or bright, depending on the orientation of the analyzer.
- circular structures have a "Maltese Cross" pattern with four quadrants of different intensities.

While polarization microscopy uses monochromatic light, it can also use white-light illumination. For broadband light, different wavelengths will be subject to different retardation; as a result, samples can provide different output colors. In practical terms, this means that color encodes information about retardation introduced by the object. The specific retardation is related to the image color. Therefore, the color allows for determination of sample thickness (for known retardation) or its retardation (for known sample thickness). If the polarizer and the analyzer are crossed, the color visible through the microscope is a complementary color to that having full wavelength retardation (a multiple of 2π, and the intensity is minimized for this color). Note that the two complementary colors combine into white light. If the analyzer could be rotated to be parallel to the analyzer, the two complementary colors will be switched (the one previously displayed will be minimized, while the other color will be maximized).

Polarization microscopy can provide quantitative information about the sample with the application of compensators (with known retardation). Estimating retardation might be performed visually or by integrating with an image acquisition system and CCD. This latter method requires one to obtain a series of images for different retarder orientations and calculate sample parameters based on saved images.

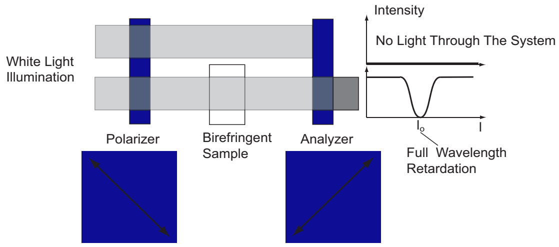

Compensators

Compensators are components that can be used to provide quantitative data about a sample's retardation. They introduce known retardation for a specific wavelength and can act as nulling devices to eliminate any phase delay introduced by the specimen. Compensators can also be used to control the background intensity level.

A **wave plate compensator** (also called a first-order red or red-I plate) is oriented at a 45-deg angle with respect to the analyzer and polarizer. It provides retardation equal to an even number of waves for 551 nm (green), which is the wavelength eliminated after passing the analyzer. All other wavelengths are retarded with a fraction of the wavelength and can partially pass the analyzer and appear as a bright red magenta. The sample provides additional retardation and shifts the colors towards blue and yellow. Color tables determine the retardation introduced by the object.

The **de Sénarmont compensator** is a quarter-wave plate (for 546 nm or 589 nm). It is used with monochromatic light for samples with retardation in the range of $\lambda/20$ to λ. A quarter-wave plate is placed between the analyzer and the polarizer with its slow ellipsoid axis parallel to the transmission axis of the analyzer. Retardation of the sample is measured in a two-step process. First, the sample is rotated until the maximum brightness is obtained. Next, the analyzer is rotated until the intensity maximally drops (the extinction position). The analyzer's rotation angle θ finds the phase delay related to retardation: $\Gamma_{\text{sample}} = 2\theta$.

A **Brace Köhler** rotating **compensator** is used for small retardations and monochromatic illumination. It is a thin birefringent plate with an optic axis in its plane. The analyzer and polarizer remain fixed while the compensator is rotated between the maximum and minimum intensities in the sample's image. Zero position (the maximum intensity) is determined for a slow axis being parallel to the transmission axis of the analyzer, and retardation is

$$\Gamma_{\text{sample}} = \Gamma_{\text{compensator}} \sin 2\theta \, .$$

Confocal Microscopy

Confocal microscopy is a scanning technique that employs pinholes at the illumination and detection planes so that only in-focus light reaches the detector. This means that the intensity for each sample point must be obtained in sequence through scanning in the x and y directions. An illumination pinhole is used in conjunction with the imaged sample plane and only illuminates the point of interest. The detection pinhole rejects the majority of out-of-focus light.

Confocal microscopy has the advantage of lowering the background light from out-of-focus layers, increasing spatial resolution, and providing the capability of imaging thick 3D samples, if combined with z scanning. Due to detection of only the in-focus light, confocal microscopy can provide images of thin sample sections. The system usually employs a photo-multiplier tube (PMT), avalanche photodiodes (APD), or a charge-coupled device (CCD) camera as a detector. For point detectors, recorded data is processed to assemble x-y images. This makes it capable of quantitative studies of an imaged sample's properties. Systems can be built for both reflectance and fluorescence imaging.

Spatial resolution of a confocal microscope can be defined as

$$d_{xy} \approx \frac{0.4\lambda}{NA},$$

and is slightly better than wide-field (bright-field) microscopy resolution. For pinholes larger than an Airy disk, the spatial resolution is the same as in a wide-field microscope. The **axial resolution** of a confocal system is

$$d_z \approx \frac{1.4n\lambda}{NA^2}.$$

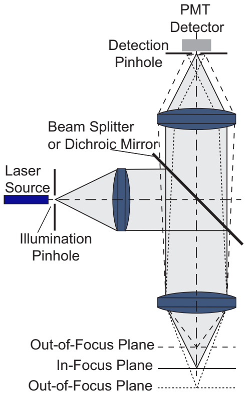

The optimum pinhole value is at the full width at half maximum (FWHM) of the Airy disk intensity. This corresponds to ~75% of its intensity passing through the system, minimally smaller than the Airy disk's first ring:

$$D_{\text{pinhole}} = \frac{0.5\lambda M}{NA}.$$

Scanning Approaches

A scanning approach is directly connected with the temporal resolution of confocal microscopes. The number of points in the image, scanning technique, and the frame rate are related to the signal-to-noise ratio SNR (through time dedicated to detection of a single point). To balance these parameters, three major approaches were developed: point scanning, line scanning, and disk scanning.

A **point-scanning confocal microscope** is based on point-by-point scanning using, for example, two mirror galvanometers or resonant scanners. Scanning mirrors should be located in pupil conjugates (or close to them) to avoid light fluctuations. Maximum spatial resolution and maximum background rejection are achieved with this technique.

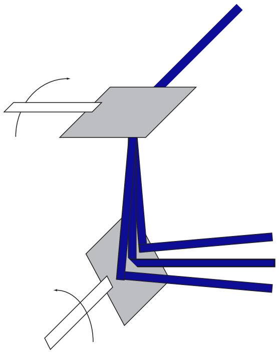

A **line-scanning confocal microscope** uses a slit aperture that scans in a direction perpendicular to the slit. It uses a cylindrical lens to focus light onto the slit to maximize throughput. Scanning in one direction makes this technique significantly faster than a point approach. However, the drawbacks are a loss of resolution and sectioning performance for the direction parallel to the slit.

Feature	**Point Scanning**	**Slit Slit Scanning**	**Disk Spinning**
z resolution	High	Depends on slit spacing	Depends on pinhole distribution
x,*y* resolution	High	Lower for one direction	Depends on pinhole spacing
Speed	Low to moderate	High	High
Light sources	Lasers	Lasers	Laser and other
Photobleaching	High	High	Low
QE of detectors	Low (PMT) Good (APD)	Good (CCD)	Good (CCD)
Cost	High	High	Moderate

Scanning Approaches (cont.)

Spinning-disk confocal imaging is a parallel-imaging method that maximizes the scanning rate and can achieve a 100–1000 speed gain over point scanning. It uses an array of pinholes/slits (e.g., Nipkow disk, Yokogawa, Olympus DSU approach). To minimize light loss, it can be combined (e.g., with the Yokogawa approach) with an array of lenses, so each pinhole has a dedicated focusing component. Pinhole disks contain several thousand pinholes, but only a portion is illuminated at one time.

	Throughput of a confocal microscope T [%]
Array of pinholes	$T_{\text{pinhole}} = 100 \times (D/S)^2$
Multiple slits	$T_{\text{slit}} = 100 \times (D/S)$
Equations are for a uniformly illuminated mask of pinholes/slits (array of microlenses not considered). D is the pinhole's diameter or slit's width respectively, while S is the pinhole/slit separation.	

Crosstalk between pinholes and slits will reduce the background rejection. Therefore a common pinhole/slit separation S is 5–10 times larger than the pinhole's diameter or the slit's width.

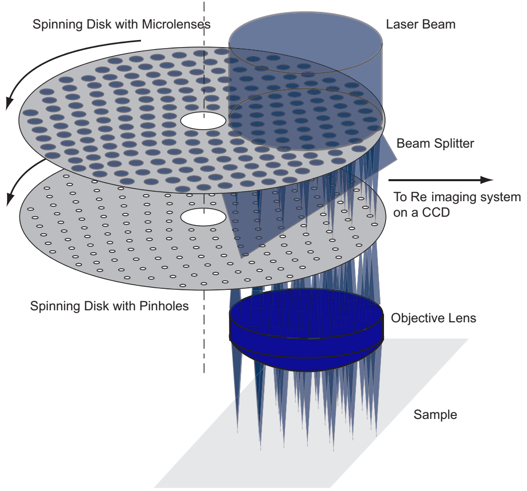
Spinning Disk with Microlenses
Laser Beam
Beam Splitter
To Re imaging system on a CCD
Spinning Disk with Pinholes
Objective Lens
Sample

Spinning-disk and slit-scanning confocal microscopes require high-sensitivity array image sensors (CCD cameras) instead of point detectors. They can use lower excitation intensity for fluorescence confocal systems; therefore, they are less susceptible to photobleaching.

Images from a Confocal Microscope

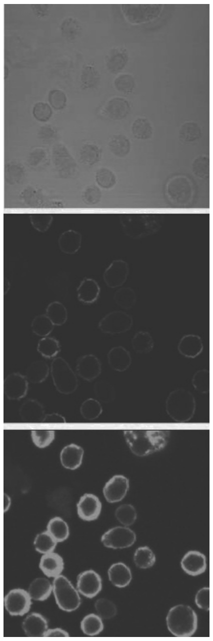

Laser-scanning confocal microscopy rejects out-of-focus light and enables optical sectioning. It can be assembled in reflectance and fluorescent modes. A 1483 cell line, stained with membrane anti-EGFR antibodies labeled with fluorecent Alexa488 dye, is presented here. The top image shows the bright-field illumination mode. The middle image is taken by a confocal microscope with a pinhole corresponding to approximately 2.5 Airy disks. In the bottom image, the pinhole was entirely open. Clear cell boundaries are visible in the confocal image, while all out-of-focus features were removed.

Images were taken with a Zeiss LSM 510 microscope using a 63× Zeiss oil-immersion objective. Samples were excited with a 488-nm laser source.

Another example of 1483 cells labeled with EGF-Alexa647 and proflavine obtained on a Zeiss LSM 510 confocal at 63× / 1.4 oil is shown below. The proflavine (staining nuclei) was excited at 488 nm, with emission collected after a 505-nm long-pass filter. The EGF-Alexa647 (cell membrane) was excited at 633 nm, with emission collected after a 650–710 nm bandpass filter. The sectioning ability of a confocal system is nicely demonstrated by the channel with the membrane labeling.

EGF-Alexa647
Channel (Red)

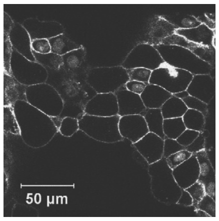

Proflavine Channel
(Green)

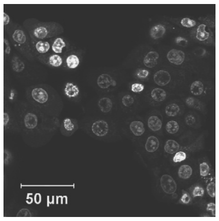

Combined Channels

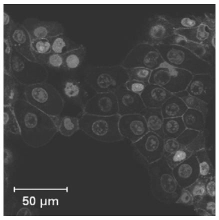

Fluorescence

Specimens can absorb and re-emit light through **fluorescence**. The specific wavelength of light absorbed or emitted depends on the energy level structure of each molecule. When a molecule absorbs the energy of light, it briefly enters an excited state before releasing part of the energy as fluorescence. Since the emitted energy must be lower than the absorbed energy, fluorescent light is always at longer wavelengths than the excitation light. Absorption and emission take place between multiple sub-levels within the ground and excited states, resulting in absorption and emission spectra covering a range of wavelengths. The loss of energy during the fluorescence process causes the **Stokes shift** (a shift of wavelength peak from that of excitation to that of emission). Larger Stokes shifts make it easier to separate excitation and fluorescent light in the microscope. Note that energy quanta and wavelength are related by $E = hc/\lambda$.

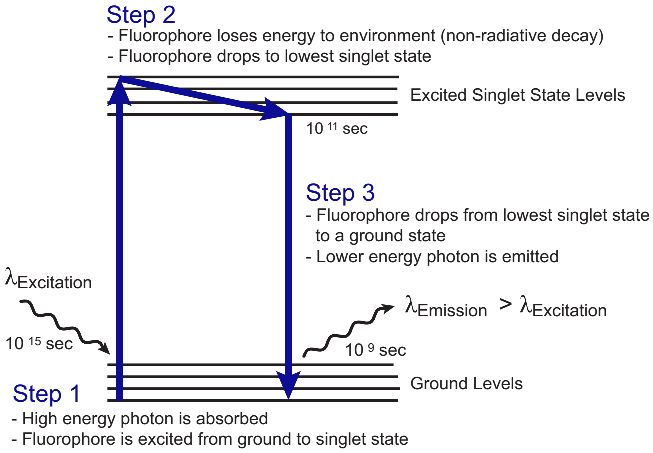
Step 2
- Fluorophore loses energy to environment (non-radiative decay)
- Fluorophore drops to lowest singlet state
Excited Singlet State Levels
10^{11} sec
Step 3
- Fluorophore drops from lowest singlet state to a ground state
- Lower energy photon is emitted
$\lambda_{Excitation}$
$\lambda_{Emission} > \lambda_{Excitation}$
10^{15} sec
10^{9} sec
Ground Levels
Step 1
- High energy photon is absorbed
- Fluorophore is excited from ground to singlet state

The fluorescence principle is widely used in fluorescence microscopy for both organic and inorganic substances. While it is most common for biological imaging, it is also possible to examine samples like drugs and vitamins.

Due to the application of filter sets, the fluorescence technique has a characteristically low background and provides high-quality images. It is used in combination with techniques like wide-field microscopy and scanning confocal-imaging approaches.

Configuration of a Fluorescence Microscope

A fluorescence microscope includes a set of three **filters**: an **excitation filter**, **emission filter**, and a **dichroic mirror** (also called a **dichroic beam splitter**). These filters separate weak emission signals from strong excitation illumination. The most common fluorescence microscopes are configured in epi-illumination mode. The dichroic mirror reflects incoming light from the lamp (at short wavelengths) onto the specimen. Fluorescent light (at longer wavelengths) collected by the objective lens is transmitted through the dichroic mirror to the eyepieces or camera. The transmission and reflection properties of the dichroic mirror must be matched to the excitation and emission spectra of the fluorophore being used.

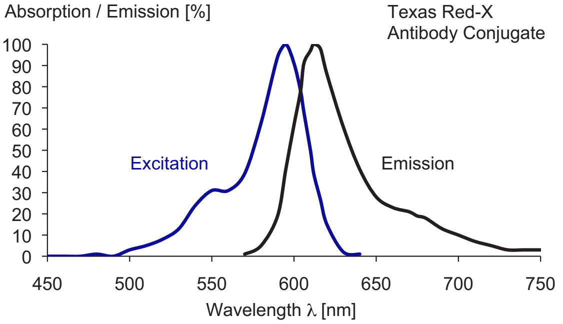

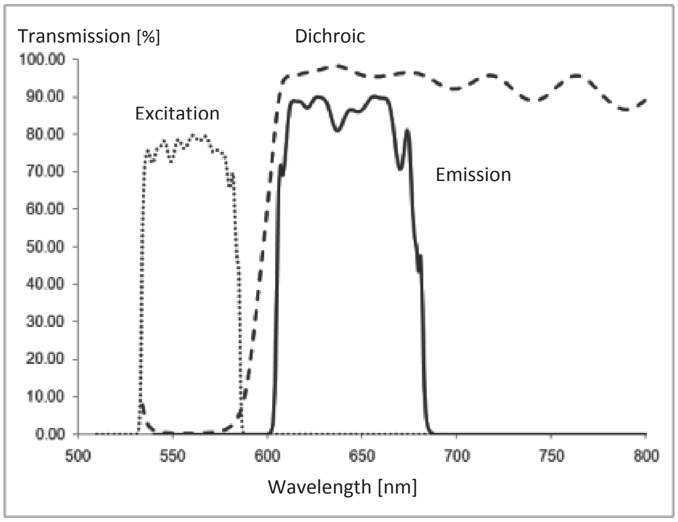

Configuration of a Fluorescence Microscope (cont.)

A sample must be illuminated with light at wavelengths within the excitation spectrum of the fluorescent dye. Fluorescence-emitted light must be collected at the longer wavelengths within the emission spectrum. Multiple fluorescent dyes can be used simultaneously, with each designed to localize or target a particular component in the specimen.

The **filter turret** of the microscope can hold several cubes that contain filters and dichroic mirrors for various dye types. Images are then reconstructed from CCD frames captured with each filter cube in place. Simultanous acquisition of emission for multiple dyes requires application of multiband dichroic filters.

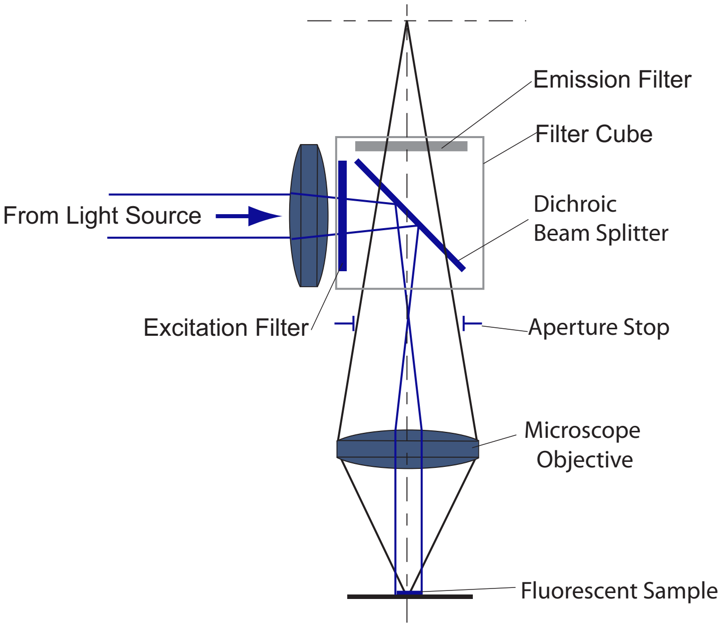
Emission Filter
Filter Cube
From Light Source
Dichroic Beam Splitter
Excitation Filter
Aperture Stop
Microscope Objective
Fluorescent Sample

Images from Fluorescence Microscopy

Fluorescent images of cells labeled with three different fluorescent dyes, each targeting a different cellular component, demonstrate fluorescence microscopy's ability to target sample components and specific functions of biological systems. Such images can be obtained with individual filter sets for each fluorescent dye, or with a multiband (a triple-band in this example) filter set, which matches all dyes.

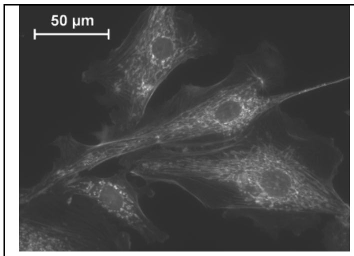

Triple-band Filter

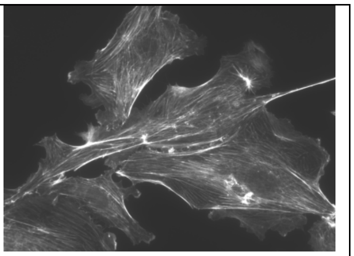

BODIPY FL phallacidin (F-actin)

MitoTracker Red CMXRos
(mitochondria)

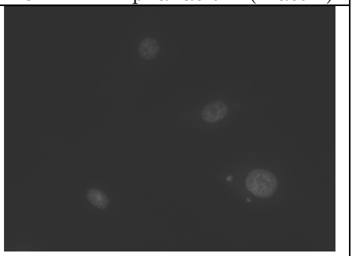

DAPI (nuclei)

<table>
<tr><td colspan="4">Sample: Bovine pulmonary artery epithelial cells (Invitrogen FluoCells No. 1)</td></tr>
<tr><td colspan="4">Components: Plan-apochromat 40×/0.95, MRm Zeiss CCD (1388×1040 mono)</td></tr>
<tr><td>Fluorescent labels:</td><td colspan="2">Peak Excitation</td><td>Peak Emission</td></tr>
<tr><td>DAPI</td><td colspan="2">358 nm</td><td>461 nm</td></tr>
<tr><td>BODIPY FL</td><td colspan="2">505 nm</td><td>512 nm</td></tr>
<tr><td>MitoTracker Red CMXRos</td><td colspan="2">579 nm</td><td>599 nm</td></tr>
<tr><td>Filter:</td><td>Excitation</td><td>Dichroic</td><td>Emission</td></tr>
<tr><td>Triple-band</td><td>395–415
480–510
560–590</td><td>435
510
600</td><td>448–472
510–550
600–650</td></tr>
<tr><td>DAPI</td><td>325–375</td><td>395</td><td>420–470</td></tr>
<tr><td>GFP</td><td>450–490</td><td>495</td><td>500–550</td></tr>
<tr><td>Texas Red</td><td>530–585</td><td>600</td><td>615LP</td></tr>
</table>

Properties of Fluorophores

Fluorescent emission F [photons/s] depends on the intensity of excitation light I [photons/s] and fluorophore parameters like the **fluorophore quantum yield** Q and **molecular absorption cross section** σ:

$$F = \sigma Q I ,$$

where the molecular absorption cross section is the probability that illumination photons will be absorbed by fluorescent dye. The intensity of excitation light depends on the power of the light source and throughput of the optical system. The detected fluorescent emission is further reduced by the quantum efficiency of the detector.

Quenching is a partially reversible process that decreases fluorescent emission. It is a non-emissive process of electrons moving from an excited state to a ground state.

Fluorescence emission and excitation parameters are bound through a photobleaching effect that reduces the ability of fluorescent dye to fluoresce. **Photobleaching** is an irreversible phenomenon that is a result of damage caused by illuminating photons. It is most likely caused by the generation of long-living (in triplet states) molecules of singlet oxygen and oxygen free radicals generated during its decay process. There is usually a finite number of photons that can be generated for a fluorescent molecule. This number can be defined as the ratio of emission quantum efficiency to bleaching quantum efficiency, and it limits the time a sample can be imaged before entirely bleaching. Photobleaching causes problems in many imaging techniques, but it can be especially critical in time-lapse imaging. To slow down this effect, optimizing collection efficiency (together with working at lower power at the steady-state condition) is crucial.

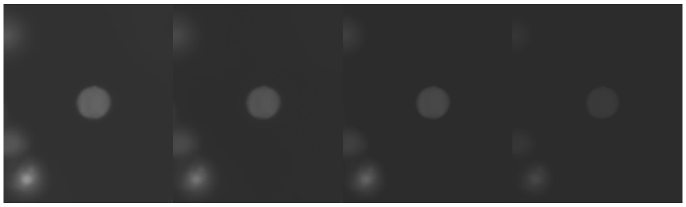

Photobleaching effect as seen in consecutive images

Single vs Multi-Photon Excitation

Multi-photon fluorescence is based on the fact that two or more low-energy photons match the energy gap of the fluorophore to excite and generate a single high-energy photon. For example, the energy of two 700-nm photons can excite an energy transition approximately equal to that of a 350-nm photon (it is not an exact value due to thermal losses). This is contrary to traditional fluorescence, where a high-energy photon (e.g., 400 nm) generates a slightly lower-energy (longer wavelength) photon. Therefore, one big advantage of multi-photon fluorescence is that it can obtain a significant difference between excitation and emission.

Fluorescence is based on stochastic behavior, and for single-photon excitation fluorescence, it is obtained with a high probability. However, multi-photon excitation requires at least two photons delivered in a very short time, and the probability is quite low:

$$n_a \propto \delta \left(\frac{P_{\text{avg}}^2}{\tau \nu^2} \right) \left(\pi \frac{NA^2}{hc\lambda} \right)^2 .$$

δ is the excitation cross section of dye, P_{avg} is the average power, τ is the length of a pulse, and ν is the repetition frequency. Therefore, multi-photon fluorescence must be used with high-power laser sources to obtain favorable probability. Short-pulse operation will have a similar effect, as τ will be minimized.

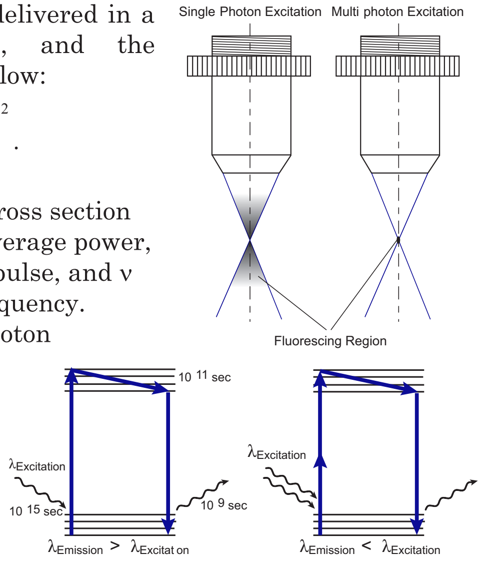

Due to low probability, fluorescence occurs only in the focal point. Multi-photon imaging does not require scanning through a pinhole and therefore has a high signal-to-noise ratio and can provide deeper imaging. This is also because near-IR excitation light penetrates more deeply due to lower scattering, and near-IR light avoids the excitation of several autofluorescent tissue components.

Light Sources for Scanning Microscopy

Lasers are an important light source for scanning microscopy systems due to their high energy density, which can increase the detection of both reflectance and fluorescence light. For laser-scanning confocal systems, a general requirement is a single-mode TEM_{00} laser with a short coherence length. Lasers are used primarily for point-and-slit scanning modalities. There are a great variety of laser sources, but certain features are useful depending on their specific application:

- Short-excitation wavelengths are preferred for fluorescence confocal systems because many fluorescent probes must be excited in the blue or ultraviolet range.
- Near-IR wavelengths are useful for reflectance confocal microscopy and multi-photon excitation. Longer wavelengths are less suseptible to scattering in diffused objects (like tissue) and can provide a deeper penetration depth.
- Broadband short-pulse lasers (like a Ti-Sapphire mode-locked laser) are particularily important for multi-photon generation, while shorter pulses increase the probability of excitation.

Laser Type	Wavelength [nm]
Argon-Ion	351, 364, 458, 488, 514
HeCd	325, 442
HeNe	543, 594, 633, 1152
Diode lasers	405, 408, 440, 488, 630, 635, 750, 810
DPSS (diode pumped, solid state)	430, 532, 561
Krypton-Argon	488, 568, 647
Dye	630
Ti-Sapphire*	710–920, 720–930, 750–850, 690–100, 680–1050

*High-power (1000mW or less), pulses between 1 ps and 100 fs

Non-laser sources are particularly useful for disk-scanning systems. They include arc lamps, metal-halide lamps, and high-power photo-luminescent diodes (See also pages 58 and 59).

Practical Considerations in LSM

A light source in laser-scanning microscopy must provide enough energy to obtain a sufficient number of photons to perform successful detection and a statistically significant signal. This is especially critical for non-laser sources (e.g., arc lamps) used in disk-scanning systems. While laser sources can provide enough power, they can cause fast photobleaching or photo-damage to the biological sample.

Detection conditions change with the type of sample. For example, fluorescent objects are subject to photobleaching and saturation. On the other hand, back-scattered light can be easily rejected with filter sets. In reflectance mode, out-of-focus light can cause background comparable or stronger than the signal itself. This background depends on the size of the pinhole, scattering in the sample, and overall system reflections.

Light losses in the optical system are critical for the signal level. Collection efficiency is limited by the NA of the objective; for example, a NA of 1.4 gathers approximately 30% of the fluorescent/scattered light. Other system losses will occur at all optical interfaces, mirrors, filters, and at the pinhole. For example, a pinhole matching the Airy disk allows approximately 75% of the light from the focused image point.

Quantum efficiency (QE) of a detector is another important system parameter. The most common photodetector used in scanning microscopy is the photomultiplier tube (PMT). Its quantum efficiency is often limited to the range of 10–15% (550–580 nm). In practical terms, this means that only 15% of the photons are used to produce a signal. The advantages of PMTs for laser-scanning microscopy are high speed and high signal gain. Better QE can be obtained for CCD cameras, which is 40–60% for standard designs and 90–95% for thinned, back-illuminated cameras. However, CCD image sensors operate at lower rates.

Spatial and temporal sampling of laser-scanning microscopy images imposes very important limitations on image quality. The image size and frame rate are often determined by the number of photons sufficient to form high-quality images.

Interference Microscopy

Interference microscopy includes a broad family of techniques for quantitative sample characterization (thickness, refractive index, etc.). Systems are based on microscopic implementation of interferometers (like the Michelson and Mach-Zehnder geometries), or polarization interferometers.

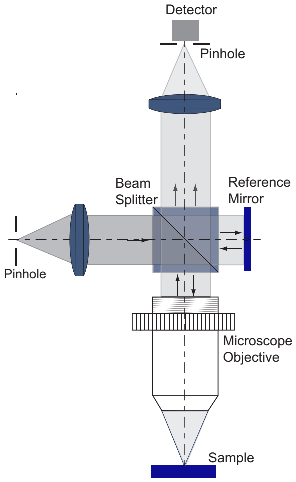

In interference microscopy, short coherence systems are particularly interesting and can be divided into two groups: **optical profilometry** and **optical coherence tomography** (OCT) [including **optical coherence microscopy** (OCM)]. The primary goal of these techniques is to add a third (z) dimension to the acquired data.

Optical profilers use interference fringes as a primary source of object height. Two important measurement approaches include **vertical scanning interferometry** (VSI) (also called **scanning white light interferometry** or **coherence scanning interferometry**) and **phase-shifting interferometry**. Profilometry techniques are capable of achieving nanometer-level resolution in the z direction while x and y are defined by standard microscope limitations.

Profilometry is used for characterizing the sample surface (roughness, structure, microtopography, and in some cases film thickness) while OCT/OCM is dedicated to 3D imaging, primarily of biological samples.

Both types of systems are usually configured using the geometry of the Michelson or its derivatives (e.g., Mirau).

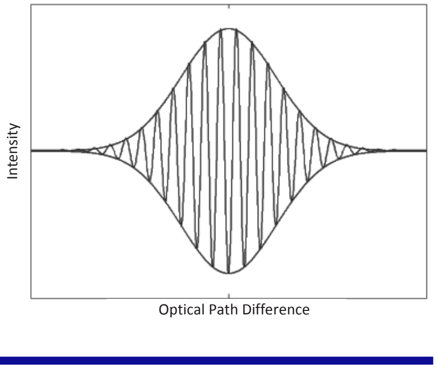

Optical Coherence Tomography/Microscopy

In early 3D coherence imaging, information about the sample was gated by the coherence length of the light source (**time-domain OCT**). This means that the maximum fringe contrast is obtained at a zero optical path difference, while the entire fringe envelope has a width related to the coherence length. In fact, this width defines the axial resolution (usually a few microns) and images are created from the magnitude of the fringe pattern envelope. **Optical coherence microscopy** is a combination of OCT and confocal microscopy. It merges the advantages of out-of-focus background rejection provided by the confocal principle and applies the coherence gating of OCT to improve optical sectioning over confocal reflectance systems.

In the mid-2000s, time-domain OCT transitioned to **Fourier-domain OCT** (FDOCT), which can acquire an entire depth profile in a single capture event. Similar to Fourier Transform Spectroscopy, the image is acquired by calculating the Fourier transform of the obtained interference pattern. The measured signal can be described as

$$I(k, z_o) = \int A_R A_S(z) \cos\left[k(z_m - z_o)\right] dz ,$$

where A_R and A_S are amplitudes of the reference and sample light, respectively, and z_m is the imaged sample depth (z_o is the reference length delay, and k is the wave number).

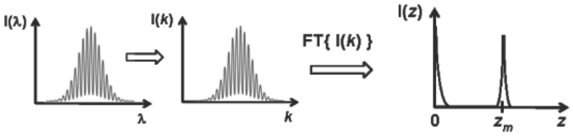

The fringe frequency is a function of wave number k and relates to the OPD in the sample. Within the Fourier-domain techniques, two primary methods exist: **spectral-domain OCT** (SDOCT) and **swept-source OCT** (SSOCT). Both can reach detection sensitivity and signal-to-noise ratios over 150 times higher than time-domain OCT approaches. SDOCT achieves this through the use of a broadband source and spectrometer for detection. SSOCT uses a single photodetector but rapidly tunes a narrow linewidth over a broad spectral profile. Fourier-domain systems can image at hundreds of frames per second with sensitivities over 100 dB.

Optical Profiling Techniques

There are two primary techniques used to obtain a surface profile using white-light profilometry: **vertical scanning interferomtry** (VSI) and **phase-shifting interferometry** (PSI).

VSI is based on the fact that a reference mirror is moved by a piezoelectric or other actuator, and a sequence of several images (in some cases hundreds or thousands) is acquired along the scan. During post-processing, algorithms look for a maximum fringe modulation and correlate it with the actuator's position. This position is usually determined with capacitance gauges; however, more advanced systems use optical encoders or an additional Michelson interferometer. The important advantage of VSI is its ability to ambiguously measure heights that are greater than a fringe.

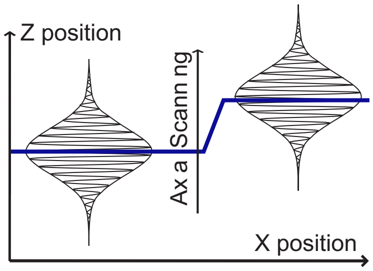

The PSI technique requires the object of interest to be within the coherence length and provides one order of magnitude or greater *z* resolution compared to VSI. To extend coherence length, an optical filter is introduced to limit the light source's bandwidth. With PSI, a phase-shifting component is located in one arm of the interferometer. The reference mirror can also provide the role of the phase shifter. A series of images (usually three to five) is acquired with appropriate phase differences to be used later in phase reconstruction. Introduced phase shifts change the location of the fringes. An important PSI drawback is the fact that phase maps are subject to 2π discontinuities. Phase maps are first obtained in the form of so-called phase fringes and must be unwrapped (a procedure of removing discontinuities) to obtain a continuous phase map.

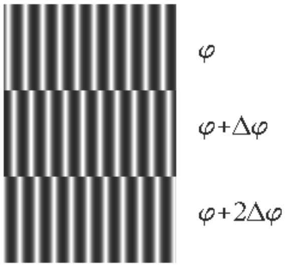

Note that modern short-coherence interference microscopes combine phase information from PSI with a long range of VSI methods.

Optical Profilometry: System Design

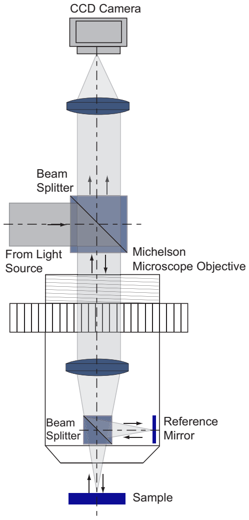
CCD Camera
Beam Splitter
From Light Source
Michelson Microscope Objective
Beam Splitter
Reference Mirror
Sample

Optical profilometry systems are based on implementing a Michelson interferometer or its derivatives into their design. There are three primary implementations: classical **Michelson** geometry, **Mirau**, and **Linnik**. The first approach incorporates a Michelson inside a microscope objective using a classical interferometer layout. Consequently, it can work only for low magnifications and short working distances. The Mireau objective uses two plates perpendicular to the optical axis inside the objective. One is a beam-splitting plate, while the other acts as a reference mirror. Such a solution extends the working distance and increases the possible magnifications.

Design	**Magnification**
Michelson	1× to 5×
Mireau	10× to 100×
Linnik	50× to 100×

The Linnik design utilizes two matching objectives. It does not suffer from NA limitation, but it is quite expensive and susceptible to vibrations.

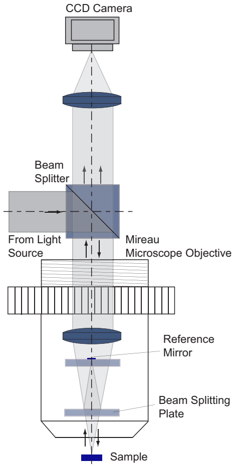
CCD Camera
Beam Splitter
From Light Source
Mireau Microscope Objective
Reference Mirror
Beam Splitting Plate
Sample

Linnik Microscope

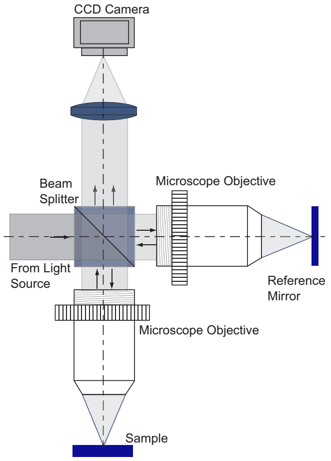
CCD Camera
Beam Splitter
Microscope Objective
From Light Source
Reference Mirror
Microscope Objective
Sample

Phase-Shifting Algorithms

Phase-shifting techniques find the phase distribution from interference images given by

$$I(x,y) = a(x,y) + b(x,y)\cos(\varphi + n\Delta\varphi),$$

where $a(x, y)$ and $b(x, y)$ correspond to background and fringe amplitude, respectively. Since this equation has three unknowns, at least three measurements (images) are required. For image acquisition with a discrete CCD camera, spatial (x, y) coordinates can be replaced by (i, j) pixel coordinates.

The most basic PSF algorithms include the **three-**, **four-**, and **five-image** techniques.

I denotes the intensity for a specific image (1st, 2nd, 3rd, etc.) in the selected i, j pixel of a CCD camera. The phase shift for a three-image algorithm is π/2. Four- and five-image algorithms also acquire images with π/2 phase shifts.

$$\varphi = \arctan\left(\frac{I_3 - I_2}{I_1 - I_2}\right)$$

$$\varphi = \arctan\left(\frac{I_4 - I_2}{I_1 - I_3}\right)$$

$$\varphi = \arctan\left(\frac{2[I_2 - I_4]}{I_1 - I_3 + I_5}\right)$$

A reconstructed phase depends on the accuracy of the phase shifts. π/2 steps were selected to minimize the systematic errors of the above techniques. Accuracy progressively improves between the three- and five-point techniques. Note that modern PSI algorithms often use seven images or more, in some cases reaching thirteen.

After the calculations, the wrapped phase maps (modulo 2π) are obtained (arctan function). Therefore, unwrapping procedures have to be applied to provide continuous phase maps.

Common unwrapping methods include the line by line algorithm, least square integration, regularized phase tracking, minimum spanning tree, temporal unwrapping, frequency multiplexing, and others.

Structured Illumination: Axial Sectioning

A simple and inexpensive alternative to confocal microscopy is the **structured-illumination technique**. This method uses the principle that all but the zero (DC) spatial frequencies are attenuated with defocus. This observation provides the basis for obtaining the **optical sectioning** of images from a conventional wide-field microscope. A modified illumination system of the microscope projects a single spatial-frequency grid pattern onto the object. The microscope then faithfully images only that portion of the object where the grid pattern is in focus. The structured-illumination technique requires the acquisition of at least three images to remove the illumination structure and reconstruct an image of the layer. The reconstruction relation is described by

$$I = \sqrt{\left(I_0 - I_{2\pi/3}\right)^2 + \left(I_0 - I_{4\pi/3}\right)^2 + \left(I_{2\pi/3} - I_{4\pi/3}\right)^2} \ ,$$

where I denotes the intensity in the reconstructed image point, while I_0, $I_{2\pi/3}$, and $I_{4\pi/3}$ are intensities for the image point and the three consecutive positions of the sinusoidal illuminating grid (zero, 1/3 and 2/3 of the structure period).

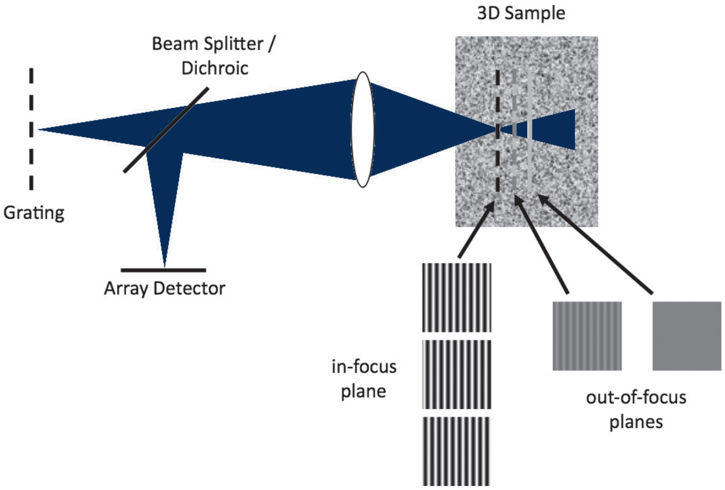

Note that the maximum sectioning is obtained for 0.5 of the objective's cut-off frequency. This sectioning ability is comparable to that obtained in confocal microscopy.

Structured Illumination: Resolution Enhancement

Structured illumination can be used to enhance the spatial resolution of a microscope. It is based on the fact that if a sample is illuminated with a periodic structure, it will create a low-frequency beating effect (Moiré fringes) with the features of the object. This new low-frequency structure will be capable of aliasing high spatial frequencies through the optical system. Therefore, the sample can be illuminated with a pattern of several orientations to accommodate the different directions of the object features. In practical terms, this means that system apertures will be doubled (in diameter), creating a new synthetic aperture.

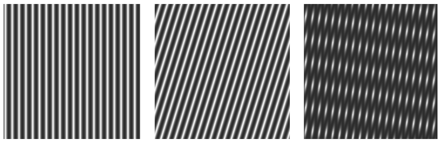

To produce a high-frequency structure, the interference of two beams with large illumination angles can be used. Note that the blue dots in the figure represent aliased spatial frequencies.

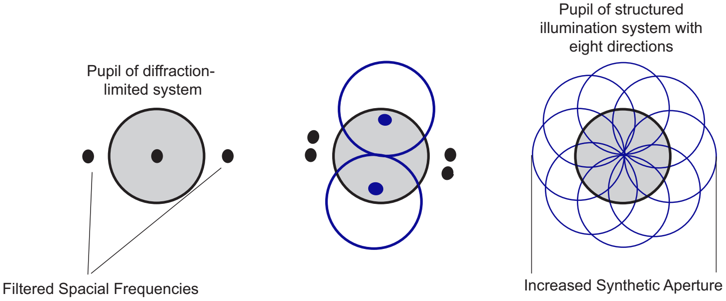

To reconstruct distribution, at least three images are required for one grid direction. In practice, obtaining a high-resolution image is possible with seven to nine images and a grid rotation, while a larger number can provide a more efficient reconstruction.

The linear-structured illumination approach is capable of obtaining two-fold resolution improvement over the diffraction limit. The application of nonlinear gain in fluorescence imaging improves resolution several times while working with higher harmonics. Sample features of 50 nm and smaller can be successfully resolved.

TIRF Microscopy

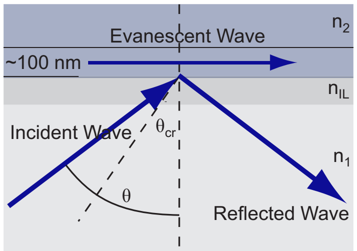

Total internal reflection fluorescence (TIRF) **microscopy** (also called evanescent wave microscopy) excites a limited width of the sample close to a solid interface. In TIRF, a thin layer of the sample is excited by a wavefront undergoing total internal reflection in the dielectric substrate, producing an **evanescent wave** propagating along the interface between the substrate and object.

The thickness of the excited section is limited to less than 100–200 nm. Very low background fluorescence is an important feature of this technique, since only a very limited volume of the sample in contact with the evanescent wave is excited.

This technique can be used for imaging cells, cytoplasmic filament structures, single molecules, proteins at cell membranes, micro-morphological structures in living cells, the adsorption of liquids at interfaces, or Brownian motion at the surfaces. It is also a suitable technique for recording long-term fluorescence movies.

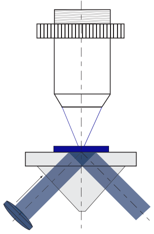

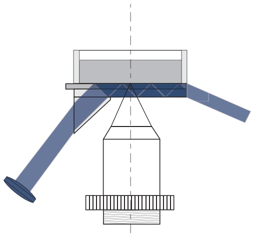

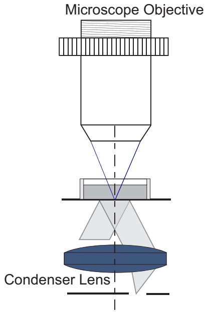

While an evanescent wave can be created without any layers between the dielectric substrate and sample, it appears that a thin layer (e.g., metal) improves image quality. For example, it can quench fluorescence in the first 10 nm and therefore provide selective fluorescence for the 10–200 nm region. TIRF can be easily combined with other modalities like optical trapping, multi-photon excitation, or interference. The most common configurations include oblique illumination through a high-NA objective or condenser and TIRF with a prism.

Solid Immersion

Optical resolution can be enhanced using **solid immersion** imaging. In the classical definition, the diffraction limit depends on the NA of the optical system and the wavelength of light. It can be improved by increasing the refractive index of the media between the sample and optical system or by decreasing the light's wavelength. The solid immersion principle is based on improving the first parameter by applying **solid immersion lenses** (SILs). To maximize performance, SILs are made with a high refractive index glass (usually greater than 2). The most basic setup for a SIL application involves a hemispherical lens. The sample is placed at the center of the hemisphere so the rays propagating through the system are not refracted (they intersect the SIL surface direction) and enter the microscope objective. The SIL is practically in contact with the object, but has a small sub-wavelength gap (<100 nm) between the sample and optical system; therefore, an object is always in an evanescent field and can be imaged with high resolution. Therefore, the technique is confined to a very thin sample volume (up to 100 nm) and can provide optical sectioning. Systems based on solid immersion can reach sub-100-nm lateral resolutions.

The most common solid-immersion applications are in microscopy, including fluorescence, optical data storage, and lithography. Compared to classical oil-immersion techniques, this technique is dedicated to imaging thin samples only (sub-100 nm), but provides much better resolution depending on the configuration and refractive index of the SIL.

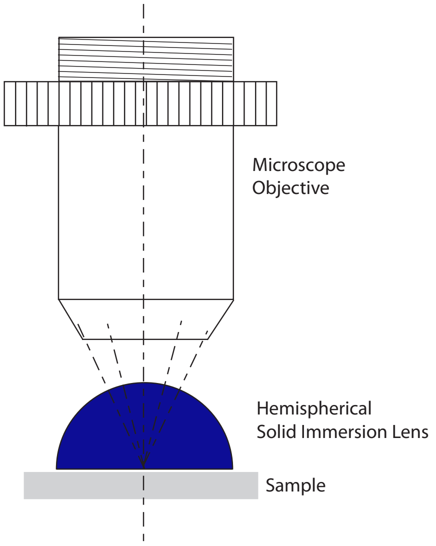

Stimulated Emission Depletion

Stimulated emission depletion (STED) microscopy is a fluorescence super-resolution technique that allows imaging with a spatial resolution at the molecular level. The technique has shown an improvement 5–10 times beyond the possible diffraction-resolution limit.

The STED technique is based on the fact that the area around the excited object point can be treated with a pulse (depletion pulse or STED pulse) that depletes high-energy states and brings fluorescent dye to the ground state. Consequently, an actual excitation pulse excites only the small sub-diffraction resolved area. The depletion pulse must have high intensity and be significantly shorter than the lifetime of the excited states. The pulse must be shaped, for example, with a half-wave phase plate and imaging optics to create a 3D doughnut-like structure around the point of interest. The STED pulse is shifted toward red with regard to the fluorescence excitation pulse and follows it by a few picoseconds. To obtain the complete image, the system scans in the *x*, *y*, and *z* directions.

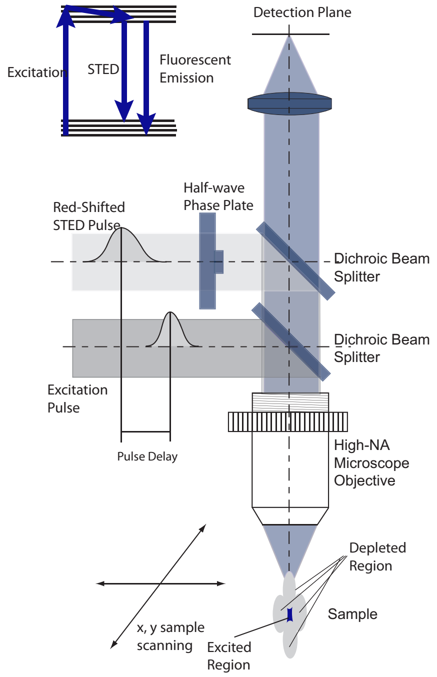
Excitation
STED
Fluorescent Emission
Detection Plane
Half-wave Phase Plate
Red-Shifted STED Pulse
Dichroic Beam Splitter
Dichroic Beam Splitter
Excitation Pulse
Pulse Delay
High-NA Microscope Objective
Depleted Region
Sample
x, y sample scanning
Excited Region

STORM

Stochastic optical reconstruction microscopy (STORM) is based on the application of multiple photo-switchable fluorescent probes that can be easily distinguished in the spectral domain. The system is configured in **TIRF** geometry. Multiple fluorophores label a sample, and each is built as a dye pair where one component acts as a fluorescence activator. The activator can be switched on or deactivated using a different illumination laser (a longer wavelength is used for deactivation—usually red). In the case of applying several dual-pair dyes, different lasers can be used for activation and only one for deactivation.

A sample can be sequentially illuminated with activation lasers, which generate fluorescent light at different wavelengths for slightly different locations on the object (each dye is sparsely distributed over the sample and activation is stochastic in nature). Activation for a different color can also be shifted in time. After performing several sequences of activation/deactivation, it is possible to acquire data for the centroid localization of various diffraction-limited spots. This localization can be performed with precision to about 1 nm. The spectral separation of dyes detects closely located object points encoded with a different color.

The STORM process requires 1000+ activation/deactivation cycles to produce high-resolution images. Therefore, final images combine the spots corresponding to individual molecules of DNA or an antibody used for labeling. STORM images can reach a lateral resolution of about 25 nm and an axial resolution of 50 nm.

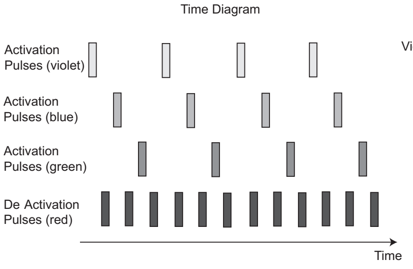
Time Diagram
Activation Pulses (violet)
Activation Pulses (blue)
Activation Pulses (green)
De Activation Pulses (red)
Time

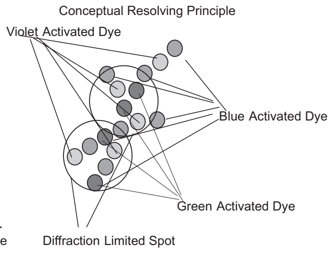
Conceptual Resolving Principle
Violet Activated Dye
Blue Activated Dye
Green Activated Dye
Diffraction Limited Spot

4Pi Microscopy

4Pi microscopy is a fluorescence technique that significantly reduces the thickness of an imaged section. The 4Pi principle is based on coherent illumination of a sample from two directions. Two constructively interfering beams improve the axial resolution by three to seven times. The possible values of z resolution using 4Pi microscopy are 50–100 nm and 30–50 nm when combined with STED.

The undesired effect of the technique is the appearance of side lobes located above and below the plane of the imaged section. They are located about λ/2 from the object. To eliminate side lobes, three primary techniques can be used:

- Combine 4Pi with confocal detection. A pinhole rejects some of the out-of-focus light.
- Detect in multi-photon mode, which quickly diminishes the excitation of fluorescence.
- Apply a modified 4Pi system, which creates interference at both the object and detection planes (two imaging systems are required).

It is also possible to remove side lobes through numerical processing, if they are smaller than 50% of the maximum intensity. However, side lobes increase with the NA of the objective; for an NA of 1.4, they are about 60–70% of the maximum intensity. Numerical correction is not effective in this case.

4Pi microscopy improves resolution only in the z direction; however, the perception of details in the thin layers is a useful benefit of the technique.

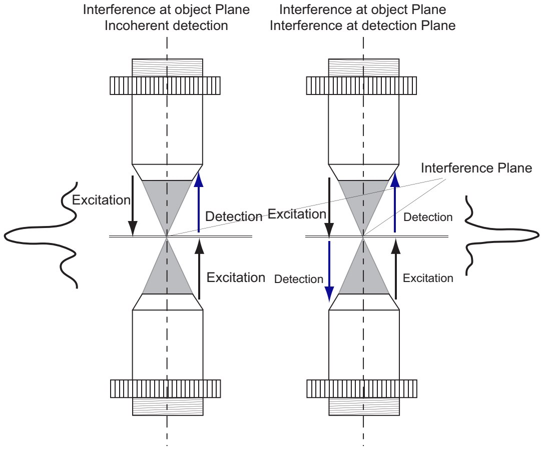
Interference at object Plane
Incoherent detection
Interference at object Plane
Interference at detection Plane
Interference Plane
Excitation
Detection
Excitation
Excitation
Detection
Detection
Excitation

The Limits of Light Microscopy

Classical light microscopy is limited by diffraction and depends on the wavelength of light and the parameters of an optical system (NA). However, recent developments in super-resolution methods and enhancement techniques overcome these barriers and provide resolution at a molecular level. They often use a sample as a component of the optical train [resolvable saturable optical fluorescence transitions (**RESOLFT**), saturated structured-illumination microscopy (**SSIM**), photoactivated localization microscopy (**PALM**) and **STORM**] or combine near-field effects (**4Pi, TIRF, solid immersion**) with far-field imaging. The table below summarizes these methods.

		Demonstrated Values	
Method	**Principles**	**Lateral**	**Axial**
Bright field	Diffraction	200 nm	500 nm
Confocal	Diffraction (slightly better than bright field)	200 nm	500 nm
Solid immersion	Diffraction / evanescent field decay	< 100 nm	< 100 nm
TIRF	Diffraction / evanescent field decay	200 nm	< 100 nm
4Pi / I5	Diffraction/ interference	200 nm	50 nm
RESOLFT (e.g.,STED)	Depletion, molecular structure of sample–fluorescent probes	20 nm	20 nm
Structured illumination (SSIM)	Aliasing, nonlinear gain in fluorescent probes (molecular structure)	25–50 nm	50–100 nm
Stochastic techniques (PALM, STORM)	Fluorescent probes (molecular structure), centroid localization, time-dependant fluorophore activation	25 nm	50 nm

Raman and CARS Microscopy

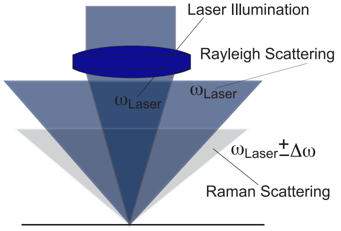

Raman microscopy (also called chemical imaging) is a technique based on inelastic **Raman scattering** and evaluates the vibrational properties of samples (minerals, polymers, and biological objects).

Raman microscopy uses a laser beam focused on a solid object. Most of the illuminating light is scattered, reflected, and transmitted, and preserves the parameters of the illumination beam (the frequency is the same as the illumination). However, a small portion of the light is subject to a shift in frequency: $\omega_{\mathrm{Raman}} = \omega_{\mathrm{laser}} \pm \Delta\omega$. This frequency shift between illumination and scattering bears information about the molecular composition of the sample. Raman scattering is weak and requires high-power sources and sensitive detectors. It is examined with spectroscopy techniques.

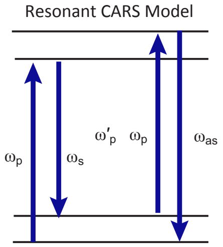

Coherent Anti-Stokes Raman Scattering (**CARS**) overcomes the problem of weak signals associated with Raman imaging. It uses a pump laser and a tunable Stokes laser to stimulate a sample with a four-wave mixing process. The fields of both lasers [pump field $E(\omega_p)$, Stokes field $E(\omega_s)$, and probe field $E'(\omega_p')$] interact with the sample and produce an anti-Stokes field [$E(\omega_{as})$] with frequency ω_{as}, so $\omega_{as} = 2\omega_p - \omega_s$.

CARS works as a resonant process, only providing a signal if the vibrational structure of the sample specifically matches $\omega_p - \omega_s$. It also must assure phase matching so that l_c (the coherence length) is greater than $\pi/\Delta\mathbf{k} = \pi/\left|\mathbf{k}_{as} - (2\mathbf{k}_p - \mathbf{k}_s)\right|$, where $\Delta\mathbf{k}$ is a phase mismatch. CARS is orders of magnitude stronger than Raman scattering, does not require any exogenous contrast, provides good sectioning ability, and can be set up in both transmission and reflectance modes.

SPIM

Selective plane illumination microscopy (SPIM) is dedicated to the high-resolution imaging of large 3D samples. It is based on three principles:

- The sample is illuminated with a **light sheet**, which is obtained with cylindrical optics. The light sheet is a beam focused in one direction and collimated in another. This way, the thin and wide light sheet can pass through the object of interest (see figure).
- The sample is imaged in the direction perpendicular to the illumination.
- The sample is rotated around its axis of gravity and linearly translated into axial and lateral directions.

Data is recorded by a CCD camera for multiple object orientations and can be reconstructed into a single 3D distribution. Both scattered and fluorescent light can be used for imaging.

The maximum resolution of the technique is limited by the longitudinal resolution of the optical system (for a high numerical aperture, objectives can obtain micron-level values). The maximum volume imaged is limited by the working distance of a microscope and can be as small as tens of microns or exceed several millimeters. The object is placed in an air, oil, or water chamber.

The technique is primarily used for bio-imaging, ranging from small organisms to individual cells.

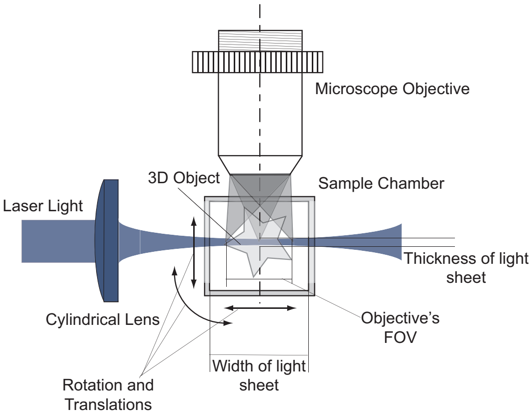
Microscope Objective
3D Object
Sample Chamber
Laser Light
Thickness of light sheet
Cylindrical Lens
Objective's FOV
Width of light sheet
Rotation and Translations

Array Microscopy

An **array microscope** is a solution to the trade-off between field of view and lateral resolution. In the array microscope, a miniature microscope objective is replicated tens of times. The result is an imaging system with a field of view that can be increased in steps of an individual objective's field of view, independent of numerical aperture and resolution. An array microscope is useful for applications that require fast imaging of large areas at a high level of detail. Compared to conventional microscope optics for the same purpose, an array microscope can complete the same task several times faster due to its parallel imaging format.

An example implementation of the array-microscope optics is shown. This array microscope is used for imaging glass slides containing tissue (histology) or cells (cytology). For this case, there are a total of 80 identical miniature 7×/0.6 microscope objectives. The summed field of view measures 18 mm. Each objective consists of three lens elements. The lens surfaces are patterned on three plates that are stacked to form the final array of microscopes. The plates measure 25 mm in diameter. Plate 1 is near the object at a working distance of 400 μm. Between plates 2 and 3 is a baffle plate. A second baffle is located between the third lens and the image plane. The purpose of the baffles is to eliminate cross talk and image overlap between objectives in the array.

The small size of each microscope objective and the need to avoid image overlap jointly dictate a low magnification. Therefore, the array microscope works best in combination with an image sensor divided into small pixels (e.g., 3.3 μm).

Focusing the array microscope is achieved by an up/down translation and two rotations: a pitch and a roll.

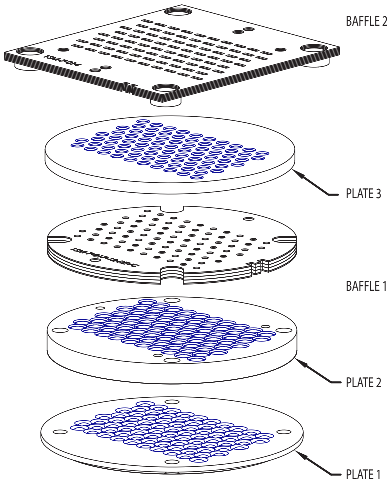

Digital Microscopy

Digital microscopy emerged with the development of electronic array image sensors and replaced the microphotography techniques previously used in microscopy. It can also work with point detectors when images are recombined in post or real-time processing. Digital microscopy is based on acquiring, storing, and processing images taken with various microscopy techniques. It supports applications that require:

- Combining data sets acquired for one object with different microscopy modalities or different imaging conditions. Data can be used for further analysis and processing in techniques like hyperspectral and polarization imaging.
- Image correction (e.g., distortion, white balance correction, or background subtraction). Digital microscopy is used in deconvolution methods that perform numerical rejection of out-of-focus light and iteratively reconstruct an object's estimate.
- Image acquisition with a high temporal resolution. This includes short integration times or high frame rates.
- Long time experiments and remote image recording.
- Scanning techniques where the image is reconstructed after point-by-point scanning and displayed on the monitor in real time.
- Low light, especially fluorescence. Using high-sensitivity detectors reduces both the excitation intensity and excitation time, which mitigates photobleaching effects.
- Contrast enhancement techniques and an improvement in spatial resolution. Digital microscopy can detect signal changes smaller than possible with visual observation.
- Super-resolution techniques that may require the acquisition of many images under different conditions.
- High throughput scanning techniques (e.g., imaging large sample areas).
- UV and IR applications not possible with visual observation.

The primary detector used for digital microscopy is a CCD camera. For scanning techniques, a photomultiplier or photodiodes are used.

Principles of CCD Operation

Charge-coupled device (CCD) sensors are a collection of individual photodiodes arranged in a 2D grid pattern. Incident photons produce electron-hole pairs in each pixel in proportion to the amount of light on each pixel. By collecting the signal from each pixel, an image corresponding to the incident light intensity can be reconstructed.

Here are the step-by-step processes in a CCD:

1. The CCD array is illuminated for integration time τ.
2. Incident photons produce mobile charge carriers.
3. Charge carriers are collected within the p-n structure.
4. The illumination is blocked after time τ (full-frame only).
5. The collected charge is transferred from each pixel to an amplifier at the edge of the array.
6. The amplifier converts the charge signal into voltage.
7. The analog voltage is converted to a digital level for computer processing and image display.

Each pixel (**photodiode**) is reverse biased, causing photoelectrons to move towards the positively charged electrode. Voltages applied to the electrodes produce a potential well within the semiconductor structure. During the integration time, electrons accumulate in the potential well, up to the full-well capacity. The full-well capacity is reached when the repulsive force between electrons exceeds the attractive force of the well. At the end of the exposure time, each pixel has stored a number of electrons in proportion to the amount of light received. These charge packets must be transferred from the sensor, from each pixel to a single amplifier without loss. This is accomplished by a series of parallel and serial shift registers. The charge stored by each pixel is transferred across the array by sequences of gating voltages applied to the electrodes. The packet of electrons follows the positive clocking waveform voltage from pixel-to-pixel or row-to-row. A potential barrier is always maintained between adjacent pixel charge packets.

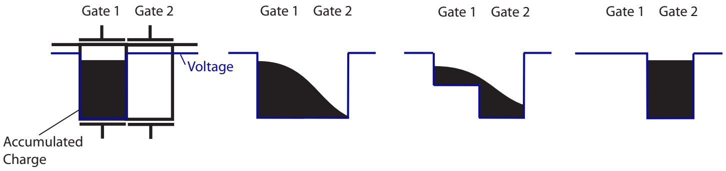

CCD Architectures

In a **full-frame architecture**, individual pixel charge packets are transferred by a parallel row shift to the serial register, then one-by-one to the amplifier. The advantage of this approach is a 100% photosensitive area, while the disadvantage is that a shutter must block the sensor area during readout, and consequently limits the frame rate.

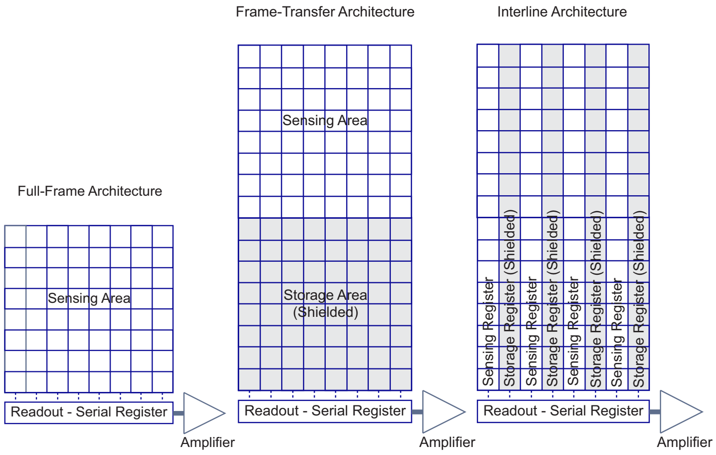
Full-Frame Architecture
Sensing Area
Readout - Serial Register
Amplifier
Frame-Transfer Architecture
Sensing Area
Storage Area (Shielded)
Readout - Serial Register
Amplifier
Interline Architecture
Sensing Register
Storage Register (Shielded)
Sensing Register
Storage Register (Shielded)
Sensing Register
Storage Register (Shielded)
Sensing Register
Storage Register (Shielded)
Readout - Serial Register
Amplifier

The **frame-transfer architecture** has the advantage of not needing to block an imaging area during readout. It is faster than full-frame, since readout can take place during the integration time. The significant drawback is that only 50% of the sensor area is used for imaging.

The **interline transfer architecture** uses columns with exposed imaging pixels interleaved with columns of masked storage pixels. A charge is transferred into an adjacent storage column for readout. The advantage of such an approach is a high frame rate due to a rapid transfer time (< 1 ms), while again the disadvantage is that 50% of the sensor area is used for light collection. However, recent interleaved CCDs have an increased fill factor due to the application of microlens arrays.

CCD Architectures (cont.)

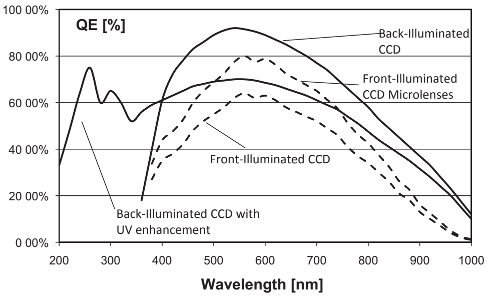

Quantum efficiency (QE) is the percentage of incident photons at each wavelength that produce an electron in a photodiode. CCDs have a lower QE than individual silicon photodiodes due to the charge-transfer channels on the sensor surface, which reduces the effective light-collection area. A typical CCD QE is 40–60%. This can be improved for back-thinned CCDs, which are illuminated from behind; this avoids the surface electrode channels and improves QE to approximately 90–95%.

Recently, **electron-multiplying CCDs** (EM-CCD), primarily used for biological imaging, have become more common. They are equipped with a gain register placed between the shift register and output amplifier. A multi-stage gain register allows high gains. As a result, single electrons can generate thousands of output electrons. While the read noise is usually low, it is therefore negligible in the context of thousands of signal electrons.

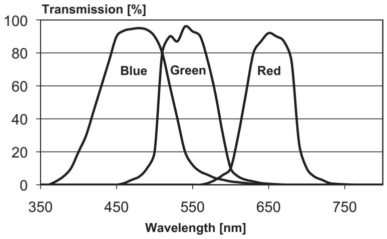

CCD pixels are not color sensitive, but use color filters to separately measure red, green, and blue light intensity. The most common method is to cover the sensor with an array of **RGB** (red, green, blue) filters, which combine four individual pixels to generate a single color pixel. The **Bayer mask** uses two green pixels for every red and blue pixel, which simulates human visual sensitivity.

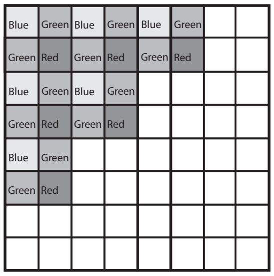

Blue	Green	Blue	Green	Blue	Green		
Green	Red	Green	Red	Green	Red		
Blue	Green	Blue	Green				
Green	Red	Green	Red				
Blue	Green						
Green	Red						

CCD Noise

The three main types of noise that affect CCD imaging are **dark noise**, **read noise**, and **photon noise**.

Dark noise arises from random variations in the number of thermally generated electrons in each photodiode. More electrons can reach the conduction band as the temperature increases, but this number follows a statistical distribution. These random fluctuations in the number of conduction band electrons results in a **dark current** that is not due to light. To reduce the influence of dark current for long time exposures, CCD cameras are cooled (which is crucial for the exposure of weak signals, like fluorescence, with times of a few seconds and more).

Read noise describes the random fluctuation in electrons contributing to measurement, due to electronic processes on the CCD sensor. This noise arises during the charge transfer, the charge-to-voltage conversion, and the analog-to-digital conversion. Every pixel on the sensor is subject to the same level of read noise, most of which is added by the amplifier.

Dark noise and read noise are due to the properties of the CCD sensor itself.

Photon noise (or **shot noise**) is inherent in any measurement of light, due to the fact that photons arrive at the detector randomly in time. This process is described by **Poisson statistics**. The probability P of measuring k events, given an expected value N is

$$P(k,N)=\frac{N^k e^{-N}}{k!}.$$

The standard deviation of the Poisson distribution is $N^{1/2}$. Therefore, if the average number of photons arriving at the detector is N, then the noise is $N^{1/2}$. Since the average number of photons is proportional to incident power, shot noise increases with $P^{1/2}$.

Signal-to-Noise Ratio and the Digitization of CCD

Total **noise** as a function of the number of electrons from all three contributing noises is given by

$$Noise\left[N_{\text{electrons}}\right] = \sqrt{\sigma^2_{\text{Photon}} + \sigma^2_{\text{Dark}} + \sigma^2_{\text{Read}}}\ ,$$

where

$\sigma_{\text{Photon}} = \sqrt{\varphi\eta\tau}$, $\sigma_{\text{Dark}} = \sqrt{I_{\text{Dark}}\tau}$, and $\sigma_{\text{Read}} = N_{\text{R}}$, I_{Dark} is dark current (electrons per second), and N_{R} is read noise (electrons, rms).

The quality of an image is determined by the **signal-to-noise ratio** (SNR). The signal can be defined as

$$Signal\left[N_{\text{electrons}}\right] = \varphi\eta\tau\ ,$$

where φ is the incident photon flux at the CCD (photons per second), η is the quantum efficiency of the CCD (electrons per photon), and τ is the integration time (in seconds). Therefore, SNR can be defined as:

$$SNR = \frac{\varphi\eta\tau}{\sqrt{\varphi\eta\tau + I_{\text{dark}}\tau + N_{\text{R}}^2}}\ .$$

It is best to use a CCD under photon-noise-limited conditions. If possible, it would be optimal to increase the integration time to increase the SNR and work in photon-noise-limited conditions. However, an increase in integration time is possible until reaching full-well capacity (saturation level):

$$SNR = \frac{\varphi\eta\tau}{\sqrt{\varphi\eta\tau}} = \sqrt{\varphi\eta\tau}.$$

The **dynamic range** can be derived as a ratio of full-well capacity and read noise. Digitization of the CCD output should be performed to maintain the dynamic range of the camera. Therefore, an analog-to-digital converter should support (at least) the same number of gray levels calculated by the CCD's dynamic range. Note that a high bit depth extends readout time, which is especially critical for large-format cameras.

CCD Sampling

The maximum spatial frequency passed by the CCD is one half of the sampling frequency—the **Nyquist frequency**. Any frequency higher than Nyquist will be aliased at lower frequencies.

Undersampling refers to a frequency where the sampling rate is not sufficient for the application. To assure maximum resolution of the microscope, the system should be optics limited, and the CCD should provide sampling that reaches the diffraction resolution limit. In practice, this means that at least two pixels should be dedicated to a distance of the resolution. Therefore, the maximum pixel spacing that provides the diffraction limit can be estimated as

$$d_{\text{pix}} = M\frac{0.61\lambda}{2NA},$$

where M is the magnification between the object and the CCD's plane. A graph representing how sampling influences the MTF of the system, including the CCD, is presented below.

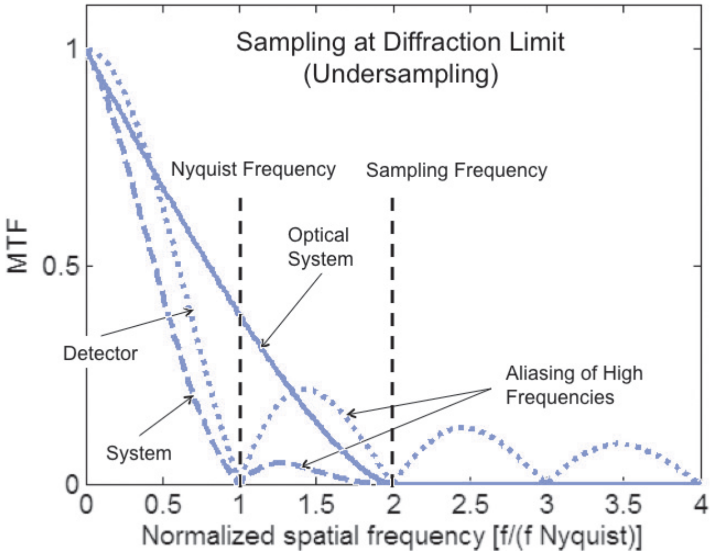

CCD Sampling (cont.)

Oversampling means that more than the minimum number of pixels, according to the Nyquist criteria, are available for detection, which does not imply excessive sampling of the image. However, excessive sampling decreases the available field of view of a microscope. The relation between the extent of field D, the number of pixels in the x and y directions (N_x and N_y, respectively), and the pixel spacing d_{pix} can be calculated from

$$D_x = \frac{N_x d_{\mathrm{pix}-x}}{M}$$

and

$$D_y = \frac{N_y d_{\mathrm{pix}-y}}{M}.$$

This assumes that the object area imaged by the microscope is equal to or larger than D. Therefore, the size of the microscope's field of view and the size of the CCD chip should be matched.

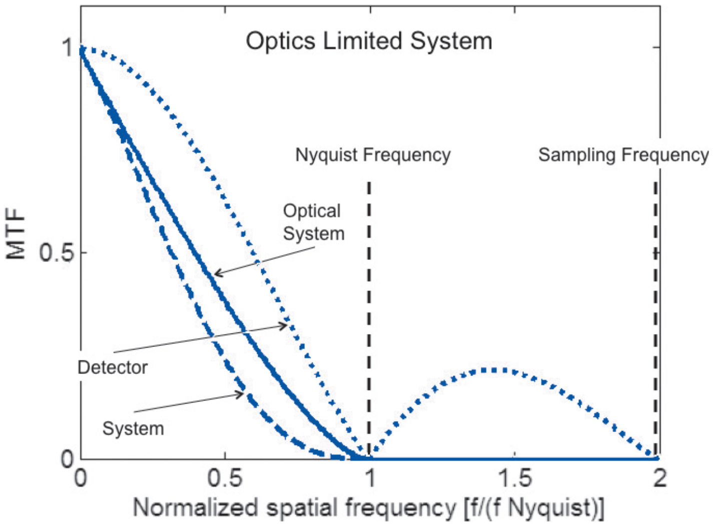

Equation Summary

Quantized Energy:

$$E = h\nu = hc/\lambda$$

Propagation of an electric field and wave vector:

$$E = A\sin\left(\omega t - kz + \varphi_o\right) = A\exp\left[-i\left(\omega t - kz + \varphi_o\right)\right]$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi V_m}{\lambda} \qquad E\left(z,t\right) = E_x + E_y$$

$$E_x = A_x\exp\left[-i\left(\omega t - kz + \varphi_x\right)\right] \qquad E_y = A_y\exp\left[-i\left(\omega t - kz + \varphi_y\right)\right]$$

Refractive index:

$$n = \frac{c}{V_m}$$

Optical path length:

$$\mathrm{OPL} = nL$$

$$\mathrm{OPL} = \int_{P1}^{P2} n\,ds$$

$$ds^2 = dx^2 + dy^2 + dz^2$$

Optical path difference and phase difference:

$$\mathrm{OPD} = n_1L_1 - n_2L_2$$

$$\Delta\varphi = 2\pi\frac{\mathrm{OPD}}{\lambda}$$

TIR:

$$\theta_{cr} = \arcsin\left(\frac{n_1}{n_2}\right)$$

$$I = I_o\exp\left(-y/d\right)$$

$$d = \frac{\lambda}{4\pi n_1}\frac{1}{\sqrt{\sin^2\theta - \sin^2\theta_c}}$$

Coherence length:

$$l_c = \frac{\lambda^2}{\Delta\lambda}$$

Equation Summary (cont'd)

Two-beam interference:

$$I = EE^*$$

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos(\Delta\varphi)$$

$$\Delta\varphi = \varphi_2 - \varphi_1.$$

Contrast:

$$C = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

Diffraction grating equation:

$$m\lambda = d(\sin\beta \pm \sin\alpha)$$

Resolving power of diffraction grating:

$$\frac{\lambda}{\Delta\lambda} = mN$$

Free spectral range:

$$\Delta\lambda = \frac{m+1}{m}\lambda_1 - \lambda_1 = \frac{\lambda_1}{m}.$$

Newtonian equation:

$$xx' = ff'$$

$$xx' = -f'^2$$

Gaussian imaging equation:

$$\frac{n'}{z'} = \frac{n}{z} + \frac{1}{f_e}$$

$$\frac{1}{z'} = \frac{1}{z} + \frac{1}{f_e}$$

$$f_e = \frac{1}{\varphi} = -\frac{f}{n} = \frac{f'}{n'}$$

Transverse magnification:

$$M = \frac{h'}{h} = -\frac{x'}{f'} = -\frac{f}{x} = \frac{z'}{z} = \frac{-f}{z-f} = \frac{-(z'-f')}{f'}$$

Longitudinal magnification:

$$\frac{\Delta z'}{\Delta z} = \left(-\frac{f'}{f}\right)M_1 M_2$$

Equation Summary (cont'd)

Optical transfer function:

$$\mathrm{OTF}(\rho) = \mathrm{MTF}(\rho)\exp\left[i\varphi(\rho)\right]$$

Modulation transfer function:

$$\mathrm{MTF}(\rho) = \frac{C(\rho)_{\mathrm{image}}}{C(\rho)_{\mathrm{object}}}$$

Field of view of microscope:

$$\mathrm{FOV} = \frac{FieldNumber}{M_{\mathrm{objective}}}[\mathrm{mm}]$$

Magnifying power:

$$\mathrm{MP} = \frac{u'}{u} = \frac{d_o\left(f - z'\right)}{f\left(z' - l\right)}$$

$$MP \approx \frac{250\ \mathrm{mm}}{f}$$

Magnification of the microscope objective:

$$M_{\mathrm{objective}} = \frac{OTL}{f_{\mathrm{objective}}}$$

Magnifying power of the microscope:

$$\mathrm{MP}_{\mathrm{microscope}} = M_{\mathrm{objective}}\mathrm{MP}_{\mathrm{eyepiece}} = -\frac{\mathrm{OTL}}{f_{\mathrm{objective}}}\frac{250\,\mathrm{mm}}{f_{\mathrm{eyepiece}}}$$

Numerical aperture:

$$NA = n\sin u$$

$$NA = NA'M_{\mathrm{objective}}$$

Airy disk:

$$d = \frac{1.22\lambda}{n\sin u} = \frac{1.22\lambda}{NA}$$

Rayleigh resolution limit:

$$d = \frac{0.61\lambda}{n\sin u} = \frac{0.61\lambda}{NA}$$

Sparrow resolution limit:

$$d = 0.5\lambda/NA$$

Equation Summary (cont'd)

Abbe resolution limit:

$$d = \frac{\lambda}{NA_{\text{objective}} + NA_{\text{condenser}}}$$

Resolving power of the microscope:

$$d_{\text{mic}} = \frac{d_{\text{eye}}}{M_{\text{min}}} = \frac{d_{\text{eye}}}{M_{\text{obj}} M_{\text{eyepiece}}}$$

Depth of focus and depth of field:

$$DOF = 2\Delta z' = \frac{n'\lambda}{\text{NA}'^2}$$

$$2\Delta z' = M^2_{\text{objective}}\, 2\Delta z \frac{n'}{n}$$

Depth perception of stereoscopic microscope:

$$\delta z = \frac{250\alpha_s}{M_{\text{microscope}} \tan\gamma} [\text{mm}]$$

Minimum perceived phase in phase contrast:

$$\Delta\varphi_{\min} = \frac{C_{\text{ph-min}}\lambda}{4\pi\sqrt{N}}$$

Lateral resolution of the phase contrast:

$$d = f'_{\text{objective}} \frac{\lambda}{(r_{\text{AS}} + r_{\text{PR}})}$$

Intensity in DIC:

$$I \propto \sin^2\left(\frac{\pi s \frac{d\varphi_o}{dx}}{\lambda}\right)$$

$$I \propto \sin^2 \frac{\pi\left(\Delta_b \pm s\frac{d\varphi_o}{dx}\right)}{\lambda}$$

Retardation:

$$\Gamma = (n_e - n_o)t$$

Equation Summary (cont'd)

Birefringence:

$$\delta = \frac{2\pi OPD}{\lambda} = \frac{2\pi\Gamma}{\lambda}$$

Resolution of a confocal microscope:

$$d_{xy} \approx \frac{0.4\lambda}{NA},$$

$$d_z \approx \frac{1.4n\lambda}{NA^2}$$

Confocal pinhole width:

$$D_{\text{pinhole}} = \frac{0.5\lambda M}{NA}$$

Fluorescent emission:

$$F = \sigma Q I$$

Probability of two-photon excitation:

$$n_{\text{a}} \propto \delta\left(\frac{P_{\text{avg}}^2}{\tau\nu^2}\right)\left(\pi\frac{NA^2}{hc\lambda}\right)^2$$

Intensity in FD-OCT:

$$I(k, z_{\text{o}}) = \int A_{\text{R}} A_{\text{S}}(z)\cos\left[k(z_{\text{m}} - z_{\text{o}})\right]dz$$

Phase-shifting equation:

$$I(x, y) = a(x, y) + b(x, y)\cos(\varphi + n\Delta\varphi)$$

Three-image algorithm (π/2 shifts):

$$\varphi = \arctan\left(\frac{I_3 - I_2}{I_1 - I_2}\right)$$

Four-image algorithm:

$$\varphi = \arctan\left(\frac{I_4 - I_2}{I_1 - I_3}\right)$$

Five-image algorithm:

$$\varphi = \arctan\left(\frac{2[I_2 - I_4]}{I_1 - I_3 + I_5}\right)$$

Equation Summary (cont'd)

Image reconstruction structure illumination (sectioning):

$$I = \sqrt{\left(I_0 - I_{2\pi/3}\right)^2 + \left(I_0 - I_{4\pi/3}\right)^2 + \left(I_{2\pi/3} - I_{4\pi/3}\right)^2}$$

Poisson statistics:

$$P\left(k, N\right) = \frac{N^k e^{-N}}{k!}$$

Noise:

$$Noise\left[N_{\text{electrons}}\right] = \sqrt{\sigma^2_{\text{Photon}} + \sigma^2_{\text{Dark}} + \sigma^2_{\text{Read}}}$$

$$\sigma_{\text{Photon}} = \sqrt{\varphi\eta\tau}\ ,\ \sigma_{\text{Dark}} = \sqrt{I_{\text{Dark}}\tau}\ ,\ \sigma_{\text{Read}} = N_{\text{R}}\ ,\ I_{\text{Dark}}$$

Signal-to-noise ratio (SNR):

$$\text{Signal}\left[N_{\text{electrons}}\right] = \varphi\eta\tau$$

$$\text{SNR} = \frac{\varphi\eta\tau}{\sqrt{\varphi\eta\tau + I_{\text{dark}}\tau + N_{\text{R}}^2}}$$

$$\text{SNR} = \frac{\varphi\eta\tau}{\sqrt{\varphi\eta\tau}} = \sqrt{\varphi\eta\tau}$$

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Tomasz S. Tkaczyk is an Assistant Professor of Bioengineering and Electrical and Computer Engineering at Rice University, Houston, Texas, where he develops modern optical instrumentation for biological and medical applications. His primary research is in microscopy, including endo-microscopy, cost-effective high-performance optics for diagnostics, and multi-dimensional imaging (snapshot hyperspectral microscopy and spectro-polarimetry).

Professor Tkaczyk received his M.S. and Ph.D. from the Institute of Micromechanics and Photonics, Department of Mechatronics, Warsaw University of Technology, Poland. Beginning in 2003, after his postdoctoral training, he worked as a research professor at the College of Optical Sciences, University of Arizona. He joined Rice University in the summer of 2007.

THE ORGONE ACCUMULATOR HANDBOOK

Construction Plans, Experimental Use and Protection Against Toxic Energy

by James DeMeo, Ph.D.

With a Foreword by Eva Reich, M.D.

The Orgone Accumulator Handbook

by James DeMeo, Ph.D., with a foreword by Eva Reich, M.D., and an appendix examining new experimental evidence demonstrating the effectiveness of the orgone energy accumulator.

Learn how to concentrate and work with *orgone* (life) energy using simple, readily-available materials. A limitless supply is freely available from the atmosphere. These experimental devices have been shown to stimulate plant growth and human physiology in controlled studies.

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In this edition Dr. DeMeo updates information on the construction of orgone energy blankets, shooters, box-type accumulators, bion packs and "draw buckets" for atmospheric cleansing, with many instructional diagrams and photographs, as well as a complete bibliography and resource guide for research.

About the Author: James DeMeo has been researching the topic of the life energy, and specifically the works of Dr. Wilhelm Reich since 1970. He has authored or edited dozens of published articles, books and research compendiums (including *Saharasia, Heretic's Notebook, On Wilhelm Reich & Orgonomy*, and the German-language *Nach Reich*) which subjected Reich's ideas to rigorous testing. DeMeo formally studied Environmental Science and Geography at Florida International Univ., and the Univ. of Kansas, where he earned his Ph.D. He served on the Faculty of Geography at Illinois State Univ. and the Univ. of Miami, and founded the Orgone Biophysical Research Laboratory in 1978.

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Cover: NASA photo of Apollo 12 astronaut walking on the surface of the moon (see Life Magazine, 12 Dec. 1969). His body orgone energy field is softly glowing a blue color in the lunar vacuum, possibly due to excitation by his high-frequency radio communications equipment. This blue coloration of the energy field in the photo, which has been seen in a few other lunar astronaut images, has been systematically ignored or explained away as an effect of "lunar dust" or "water vapor". In fact, it is a visible expression of the human orgone (life) energy field.

Acknowledgements

This book is the product of many years of study of the prior works of Wilhelm Reich, and other dedicated scientists, without whose research findings it would not have been possible. The reader will find their names and research papers listed in the reference section of this book. I have corresponded with, and learned from many of these researchers over the years. In particular, I thank Eva Reich and Jutta Espanca for their constructive criticisms of the first edition of this Handbook. Additionally, I thank my own mentors, Robert Morris, Robert Nunley, and Richard Blasband, from each of whom I learned different things about life energy. I thank Theirrie Cook and Don Bill, loyal friends who have helped with the progress of my research in many ways, and also Jim Martin for the initial ideas and encouragement to revise my original small Handbook into the present edition. Jim also prepared the typesetting and most of the graphics in this edition, providing many helpful points along the way. Thanks to Stephan Müschenich and Rainer Gebauer for the courage they showed in doing their double-blind, controlled study of the human physiological response to accumulator treatment, at the University of Marburg, and for the Appendix document. Thanks also to the various researchers and doctors in Germany, who today are openly working with the accumulator in a manner presently impossible in the USA. In particular, I thank Heiko Lassek, Dorothea Opferman-Fuckert and Manfred Fuckert from whom I learned about the possiblities and limitations of physical orgone therapy. Also thanks to Vince Wiberg, for the simple and inexpensive methods for detecting electromagnetic disturbances, presented here. And finally, thank you Wilhelm Reich, for the discovery of the orgone energy and the orgone accumulator.

Acknowledgements

This book is the product of many years of study of the [illegible]

"We consider the discovery of the orgone energy among the greatest events in human history."– from a letter to the American Medical Association, signed by 17 medical doctors in 1949.

"THE ORGONE ACCUMULATOR IS THE MOST IMPORTANT SINGLE DISCOVERY IN THE HISTORY OF MEDICINE, BAR NONE" – Theodore P. Wolfe, M.D., from *Emotional Plague Versus Orgone Biophysics*, 1948.

"It is justifiable that the discovery of orgone energy and its medical applications by means of the orgone accumulator, the orgone shooter, bionous earth, and orgone water have opened up an abundance of new and, it appears, amazingly good prospects." – Wilhelm Reich, M.D. from *The Cancer Biopathy (Discovery of the Orgone, Volume 2)*, 1948.

"What would you say of the leading philosophers here to whom I have offered a thousand times of my own accord to show my studies, but who with the lazy obstinacy of a serpent who has eaten his full have never consented to look at the planets, the moon, or telescope? To such people philosophy is a kind of book... where the truth is to be sought not in the Universe or in nature, but (I use their own words) by comparing texts." – Galileo Galilei, Italian astronomer of the 1600s who proved that the Earth moved in the heavens, shortly before being prosecuted and tortured by the Catholic Church.

"...the orgone energy does not exist."– Judge John D. Clifford, from a 1954 U.S. court ruling in which all of Dr. Reich's books and research journals were banned, and ordered burned in incinerators; Reich was sent to a Federal Penitentiary, where he died.

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1. Foreword

At last, thirty two years after the 1957 death of Wilhelm Reich, human beings can begin to study orgonomy like any other body of knowledge, helped by the *Orgone Accumulator Handbook*. This concise and informative book contains in a nutshell a condensed, clear account of the discovery, made usable by all who are interested in the cosmic life energy. Herein is printed: the scientific definition of the orgone energy; the history of how the steps of observation, experimentation, and theoretical insight led Reich to practical applications; the principles for construction and experimental uses of the orgone energy accumulator, with detailed suggestions for needed material, layering, and dimensions; and finally a very useful reference list. Professor J. DeMeo shows his thorough knowledge of the subject, which as yet is banned and omitted from the 20th Century academic curriculum, except for a few pioneering lecture courses (in New York and West Berlin).

Wilhelm Reich said that even though the life energy had been known for thousands of years, he managed to make it concretely usable, and that the era of its applications has just started. However, this *Handbook* is the first printed material in recent years on specifically how to concentrate the energy from the Earth's atmosphere. It is usable for a laboratory course on the subject of cosmic life energy. This material could be comprehended by intelligent high school or college students. It answers my almost fifty year old hope, for the inclusion of life energy facts in the body of knowledge that all educated people on Earth should learn in their schooling. Thank you James DeMeo.

Eva Reich, M.D.
West Berlin, March 1989

2. Author's Preface

When I was 12 years old, a favorite uncle of mine died a suffering death from lung cancer. The doctors had removed one of his lungs, and for a few months he lingered, being incapable of talking or moving very much, and in a great deal of pain. My aunts would not allow the children to see him in such sorry shape, except for one time, when he was dressed up for the entire family, which had gathered to quietly say good-bye. I was very sad when he died. When I was 15, my mother was diagnosed as having breast cancer. I was by her bed in the hospital when she recovered from surgery, and when she was told that her breast had been amputated in a radical mastectomy. I will never forget the look on her face. She survived the surgery, but the emotional resignation which she carried, and which preceded her cancer by several decades, was never diagnosed or discussed. Friends of our family had urged us to look into some alternative treatments for cancer, but everybody believed that the doctors in the hospital knew best. Listed as a "survivor" in the cancer statistics, my mother progressively declined after the surgery, and died about eight years later, having refused to undergo additional surgery.

My experience with relatives dying of cancer is not unusual, as degenerative disease is now at epidemic levels. The statistics today demonstrate that the "war on cancer" has been lost, and that in spite of all the radical surgeries, drugs and radiation treatments, patients today survive no longer or more frequently than they did in the 1950s. Indeed, degenerative disorders have today spread into youthful age groups and populations where they once were rare. Scientific evidence does not exist to support the assertion that surgery, radiation, and chemotherapy are effective forms of treatment for cancer, and traditional medicine today gives hardly more than lip service to preventative considerations. These troubling facts become all the more disturbing when one begins to study the various alternative, non-invasive and non-toxic cancer therapies. Dismissed for decades as "quackery" by organized medicine, most of these therapies appear to be reasonably or even remarkably effective. Their advocates and practitioners have often taken great risks to bring what they believe are safe and effective treatments to sick people. The organized medical community, with financial links to the pharmaceutical industry, has not cared to seriously look into these techniques. Instead, the techniques have been unwarrantedly attacked, and pseudo investigations have been launched, with predictable outcomes: clinics have been shut by brute police force, through court orders; medical records and research protocols have been seized, and jail sentences have been handed out. Books have also been burned. In this context, a great fraud has been perpetrated upon the American people, and upon our courts and legal system, by the larger organized medical associations, and related government bureaucracies.

In this short *Handbook*, I cannot give a history of these antiscientific and unethical abuses, but a few articles and books on the question are listed in the reference section. Clearly, a major reason for the impotence of modern medicine in dealing with degenerative diseases lies in the fact that the organized medical community has used police-state tactics to suppress important new findings, and the unorthodox practitioner, irrespective of any scientific evidence that exists. In fact, the most well documented and effective unorthodox therapies have been the most hotly attacked. Many, many promising therapies have been suppressed over the years, through an emotional collusion, and some outright conspiracy for economic motives, between medical interests, drug companies, plague journalists, prejudiced academics, and puritanical government bureaucrats and judges. In this process, the truth has been trampled badly, and the methods of science, discarded.

The most clear and telling example of how these social forces combine to kill a new discovery, and its discoverer, is the case of Dr. Wilhelm Reich and his orgone energy accumulator. Reich had been one of Freud's younger co-workers, and was a prime mover in the early psychoanalytic movement in Vienna and Berlin. However, his ideas were more revolutionary than those of the older psychoanalysts. He forcefully argued that human misery and mental illness were partly the result of social conditions, which could be changed to prevent neurosis. He urged reform in laws regarding the abusive treatment of children, and in the economic plight of women. He formed a viable social and political movement in pre-Hitler Germany, which urged reforms in laws restricting divorce and access to contraception, which were both then illegal. He championed the rights of young unmarried people to a healthy sexual life, and a loosening of the father's power and dominance over the family. He wrote extensively about these matters in the 1920s and 1930s, and exposed the roots of the Nazi movement in the obedience-demanding, patriarchal, sex-negative German family structure. For his writings on genitality, and his anti-fascist activities, Reich was eventually expelled from Freud's inner circle, and also from the International Psychoanalytic Association. German psychoanalysis was at that time leaning towards appeasement of the Nazis, and some analysts, such as Carl Jung, even became spokespersons or apologists for National Socialism. Reich was eventually placed on both Hitler's and Stalin's death lists in the 1930s, and had to flee to Scandinavia, and later from there to the United States. His writings were condemned to flames in both Germany and Russia.

By the time Reich arrived in the United States, in 1939, he had made a number of major scientific discoveries, and quickly attracted a group of young, enthusiastic scientists and doctors to assist with his work. The American period of his research, which lasted until his death in 1957, was particularly productive, in spite of the later court actions against him. It was during this period that Reich experimentally clarified, and made practical use of the biological and atmospheric life energy, which he called the orgone energy. The orgone energy, Reich observed, was a real, physical energy, which radiated from microbes, animals, humans, and from inorganic materials as well. It charged living creatures, yet also existed in the atmosphere in a free form. It could be accumulated in special enclosures, where it could be observed, felt, and measured.

Reich's orgone energy experiments attracted the hostile criticisms of many in the medical community, and a smear campaign in the press triggered an investigation by the U.S. Food and Drug Administration (FDA). In its efforts to stop Reich's work, the FDA did not seek to responsibly or accurately reproduce his experimental findings. Instead, FDA bureaucrats relied upon gossip and rumor, ignored available published evidence, and secured the testimony of "expert" witnesses who had no real familiarity with or interest in the scientific facts involved. Many breaches of the scientific method, and of legal, moral, and scientific ethics occurred, as government officials, and a number of psychiatrists, analysts, and physicists, sought to put an end to his work.

We also know a lot more today about the inner workings of the FDA regarding the Reich case, given that several scholarly reviews of FDA files, using the *Freedom of Information Act*, have taken place. These are cited in the reference section. Reich originally offered to cooperate with the FDA investigators regarding the orgone energy. But they refused his offer, as they were hot to "get Reich" on whatever charges they could, and had been urged in this direction by various highly-placed individuals within the medical communities. The *Bulletin of the Menninger Clinic*, and the *Journal of the American Medical Association*, for example, participated in the spreading of false gossip and rumors regarding Reich's work. Reich was aware of these unethical actions, and a number of his co-workers had been professionally hurt by the lies, and by the actions of the FDA. At no time did any governmental or private scientific or medical organization attempt to seriously review or replicate his experiments.

These kinds of attacks made Reich understandably furious, such that when the FDA finally sought a Complaint for Injunction against his activities, he refused to appear in court, to act, as he put it, "as a 'defendant' in matters of basic natural scientific research". Instead, he wrote a compelling *Response* ("Motion to Dismiss") to the judge. Reich's refusal to grant authority to the courts regarding the validity of his orgone research prompted a legal over-reaction, the likes of which we usually associate with despotic societies. In a judicial ruling that is, to the best of my knowledge, unique in American history, the FDA sought and obtained a Federal Court Decree of Injunction, which ruled that the orgone energy "does not exist". The court ordered a ban on the interstate shipment of books bearing the word "orgone". This included books into which the forbidden word appeared only in the preface, or introductory remarks. Additionally, all books and research journals discussing the orgone energy in detail were *ordered destroyed*, and devices using the energy, dismantled or destroyed. (Case #1056, March 19, 1954, US District Court, Portland, Maine, Judge John D. Clifford, Jr.)

"BANNED, until expunged of all references to the orgone energy:

- *The Discovery of the Orgone*
  - *Vol. I, The Function of the Orgasm*
  - *Vol. II, The Cancer Biopathy*
- *The Sexual Revolution*
- *Ether, God and Devil*
- *Cosmic Superimposition*
- *Listen, Little Man*
- *The Mass Psychology of Fascism*
- *Character Analysis*
- *The Murder of Christ*
- *People in Trouble*

BANNED and ORDERED DESTROYED:

- *The Orgone Energy Accumulator, Its Scientific and Medical Use*
- *The Oranur Experiment*
- *The Orgone Energy Bulletin*
- *The Orgone Energy Emergency Bulletin*
- *International Journal of Sex-Economy and Orgone Research*
- *Internationale Zeitschrift fur Orgonomie*
- *Annals of the Orgone Institute*"

And so, in the late 1950s and early 1960s, Reich's books and research journals, even those which were "only" banned, were periodically seized by FDA agents and Federal Marshals, and burnt in incinerators in Maine and New York. No scientific or professional organizations, journalists or writer's unions publicly objected to the book burnings, or acted to help Reich, whose laboratory headquarters was invaded by FDA agents, who destroyed instruments with axes. In addition to the above actions, the court ordered Reich to cease "disseminating information" on the orgone energy, effectively censoring his writing and speaking on the subject. Several years later, Reich was charged with Contempt of Court when his assistant committed a technical violation of the Injunction, at a time when Reich was more than a thousand miles away, engaged in field work in the deserts of Arizona. Though he appealed all the way to the Supreme Court, Reich lost the case, and was incarcerated in Lewisburg Federal Penitentiary, where he died in 1957. His death in prison occurred two weeks prior to his parole date, at a time when he was happily anticipating his freedom, and a life in Switzerland with his new wife.

Whatever we may think of Reich's response to the court challenge, the principles upon which he stood were very important, and date back at least to Galileo's trial by fire with the Catholic Church. The lesson from Galileo's time was that no Court, Tribunal, or religious or scientific organization on Earth has the capacity to say, on the basis of textual comparisons or divine revelation, just what is or is not Natural Law. The results of an experiment cannot be judged by those who have never reproduced it, and the unresearched opinions of scientists are no better than the unresearched opinions of anyone else, be they members of the American Medical Association, the National Academy of Sciences, or the same Country Club attended by the President. Galileo urged his critics to "look into the telescope", to verify his observations in a most direct and simple way. But they refused to do so on moral principle, and derisively mocked him. Reich's critics have taken the same approach, in their adamant refusal to reproduce his experiments, and in most cases, to even review the published evidence. Today, over 30 years since Reich's death, his most vocal critics still take the same anti-scientific approach, and condemn what they have not personally read or investigated.

Based upon these historical facts, it is clear that **the FDA, and indeed, all courts, academic bodies, and governmental agencies of all kinds, have forever relinquished any right to say anything about what the average citizen may or may not do with respect to the orgone energy accumulator**. The discovery of the orgone is in much safer hands among the average citizen, than in the hands of the various politicians, academies of science, and medical organizations. This *Handbook* is therefore not primarily directed towards an academic or medical audience. Instead, the case of Dr. Wilhelm Reich and the orgone energy accumulator is taken directly to the general public. Like the sunlight, the air and water, the orgone energy is a part of nature, existing everywhere, and ought to be available to everyone, free of restrictive regulation and control. As an invention, the orgone accumulator is also now in the public domain, unpatentable, and cannot be dominated by any single individual or corporation. It is also still *perfectly legal* for citizens to build, own, and use orgone accumulators.

Of course, with this right comes a great deal of responsibility, as the proper use and maintenance of an accumulator makes both social and environmental demands upon its owner. The cosmic orgone energy ocean is, like our air, food, and water, fast becoming contaminated and poisoned, and swift action by concerned people is required if life on the planet is to continue. This *Handbook* will give a basic overview of the orgone energy, the accumulator, and the construction and safe use of orgone accumulating devices. For the more precise scientific details and data, the reader is encouraged to obtain and review the published materials listed in the Reference and Information sections.

Three years after Reich's death, the trustees of his estate arranged for republication of his works. Today, most of his books have been republished, or are available in libraries, and through other sources. A group of Reich's co-workers also founded the American College of Orgonomy, and by 1967 had published the first issue of the *Journal of Orgonomy*. Since that time, interest in Reich's works has gradually increased, and many new studies verifying his findings on the orgone energy, and the accumulator, have taken place. College courses focusing upon Reich's life and works now exist, and he has been the subject of many reviews, biographies, and films. A younger generation of scientists and health practitioners is rediscovering Reich, and new journals devoted to orgone research or bioenergetic functions have appeared in the USA, Germany, France, Italy, England, Canada, and Japan. One major new study on the accumulator from Germany is summarized in the Appendix.

The effort to kill the discovery of the orgone has failed.

Part I: The Biophysics of the Orgone Energy

3. What Is the Orgone Energy?

Orgone energy is cosmic life energy, the fundamental creative force long known to people in touch with nature, and speculated about by natural scientists, but now physically objectified and demonstrated. The orgone was discovered by Dr. Wilhelm Reich, who identified many of its basic properties. For instance, the orgone energy charges and radiates from all living and non-living substance. It also can readily penetrate all forms of matter, though with varying rates of speed. All materials affect the orgone energy, by attracting and absorbing it, or by repelling or reflecting it. The orgone can be seen, felt, measured and photographed. It is a real, physical energy, and not just some metaphorical, hypothetical force.

The orgone also exists in a free form in the atmosphere, and in the vacuum of space. It is excitable, compressible, and spontaneously pulsatile, capable of expanding and contracting. The orgone charge within a given environment, or within a given substance, will vary over time, usually in a cyclical manner. The orgone is most strongly attracted to living things, to water, and to itself. Orgone energy can lawfully stream or flow from one location to another in the atmosphere, but it generally maintains a west to east flow, moving with, but slightly faster than the rotation of the Earth. It is a ubiquitous medium, a cosmic ocean of dynamic, moving energy, which interconnects the whole physical universe; all living creatures, weather systems, and planets respond to its pulsations and movements.

The orgone is related to, but quite different from other forms of energy. It can, for instance, impart a magnetic charge to ferromagnetic conductors, but it is not magnetic itself. It can likewise impart an electrostatic charge to insulators, but neither is it fully electrostatic in nature. It reacts with great disturbance to the presence of radioactive materials, or to harsh electromagnetism, much in the manner of irritated protoplasm. It can be registered on specially adapted Geiger counters. The orgone also is the *medium* through which electromagnetic disturbances are transmitted, much in the manner of the older concept of *aether*, though it is not itself electromagnetic in nature.

Streamings of orgone energy within the Earth's atmosphere affect changes in air circulation patterns; atmospheric orgone functions underlie the buildup of storm potentials, and influence air temperature, pressure, and humidity. Cosmic orgone energy functions also appear to be at work in space, affecting gravitational and solar phenomena. Still, the mass-free orgone energy is not any one of these physicomechanical factors, or even the sum of them. The properties of the orgone energy derive more from life itself, much in the manner of the older concept of a *vital force*, or *élan vital*; unlike those older concepts, however, the orgone also has been found to exist in a mass-free form, in the atmosphere and in space. It is primary, primordial cosmic *life energy*, while all other forms of energy are secondary in nature.

In the living world, orgone energy functions underlie major life processes; pulsation, streaming, and charge of the biological orgone determines the movements, actions, and behavior of protoplasm and tissues, as well as the strength of "bioelectrical" phenomena. Emotion is the ebb and flow, the charge and discharge of the orgone within the membrane of an organism, just as weather is the ebb and flow, the charge and discharge of the orgone in the atmosphere. Both organism and weather respond to the prevailing character and state of the life energy. Orgone energy functions appear across the whole of creation, in microbes, animals, stormclouds, hurricanes, and galaxies. Orgone energy not only charges and animates the natural world; we are immersed in a sea of it, much as a fish is immersed in water. More, it is the medium which communicates emotion and perception, through which we are connected to the cosmos, and made kin to all that is living.

4. Wilhelm Reich's Discovery of the Orgone Energy, and Invention of the Orgone Accumulator

Reich's initial work on the question of a biological energy began in the 1920's, when he was a student of Sigmund Freud, the originator of psychoanalysis. Freud's early theories on human behavior discussed in metaphorical terms the energy of the drives, which he termed the *libido.* While Freud and most other analysts eventually ceased using this term, Reich found it to be a very useful concept, and he continued to seek evidence for this force, which governed human emotion, behavior, and sexuality.

Reich's extensive clinical work led to the observation of *vegetative streamings* or *currents* of emotional energy in the body, which occurred in healthy individuals during states of great relaxation, as following a strong release of emotion, or after a very gratifying genital orgasm. The free, uninhibited expression of emotion, and natural sexual excitation and gratification during orgasm were identified by Reich as expressions of unimpeded energetic movement in the body. When the individual experienced great pain, as from childhood traumas, when the emotions were rigidly suppressed and held back ("big boys don't cry", "nice girls don't get angry"), or when chronic sexual stasis and starvation was experienced, the entire nervous system and musculature participated in the process of emotional suppression, or warding off of feeling. This "holding back" of feeling was also accompanied by a greater or lesser anxious retreat from pleasurable, or even potentially pleasurable situations, which would otherwise stir up suppressed and unpleasant feelings. Reich observed that when this kind of response to feeling and pleasure became chronic, so too did the individual experience a chronic stiffening and desensitization of the body, along with a reduction in respiration and contactfulness.

This chronic neuromuscular *armoring*, as Reich called it, was not a natural condition, though it had a certain rational survival value for situations of pain and trauma. When the armoring became chronic, however, as a *way of life*, it would thwart the individual's natural biological functioning, and affect their behavior even in circumstances where pain or trauma was not likely. The armoring effectively perpetuated the individual's pleasure-avoiding behaviors and emotion-censoring attitudes. Deep seated fears, and pressures to conform to the prevalent armored form of social life, usually prevented the individual from moving towards emotional health, or taking effective steps to change their situation. The bulk of Reich's early writings focused upon these social, sexual, and emotional concerns.

Reich also argued that the heterosexual genital orgasm played a central regulatory role in the energy economy of the individual, as a means to periodically discharge accumulated bioenergetic tension. The more intense the orgastic discharge of accumulated bioenergy, the more gratified, relaxed and pleasurably expansive one felt afterward. When sexual urges and other emotions were chronically frustrated, dammed-up, and repressed, however, great internal tension could build up to a bursting point, where neurotic symptoms or sadistic urges would appear. Reich developed therapeutic techniques for releasing dammed-up emotional energy within his patients, techniques which led to the release of long-buried feelings, and to a greater capacity for pleasure in life, particularly genital pleasure. As his patients became more healthy sexually, and as they reported an increase in genital gratification, he observed that their neurotic symptoms disappeared, as the quantity of dammed-up emotion and sexual tension was reduced. Some of Reich's early contributions to psychoanalytic theory and technique were at first welcomed. But later on, as he increasingly focused upon the consequences of child abuse and sexual repression, the more conservative analysts rejected and attacked him.

Reich eventually left psychoanalysis altogether, and he articulated his work under the new term, *Sex-Economy*.

Reich's early observations regarding human behavior, emotions, the orgasm, and vegetative streaming sensations strongly suggested a real, tangible nature to the emotional energy. He later used sensitive millivoltmeters to confirm this point of view, and to quantify bioelectrical energy currents, and their emotional correlates. However, he was convinced that the very low levels of observed bioelectrical activity could not fully explain the powerful energy forces observed in human behavior. This was particularly so regarding chronic immobilizing psychic disturbances in catatonic and other completely withdrawn mental patients. When their emotions were finally broken lose, these patients would experience a tremendous outpouring of sadness or rage. Afterward, they would also experience a dramatic relaxation of musculature, a spontaneous deepening of respiration, and a return to more contactful lucidity. In these cases, the patient's emotional energy was held down and bound up, until finally set free in the clinical setting. These observations of energy bound, and energy released, were reinforced by parallel observations regarding the discharge function of the orgasm. Based upon these kinds of observations, the question of exactly how and from where the organism acquired its emotional energy, and its exact nature, became increasingly important.

It was at this point in his research that Reich was forced to flee Germany for Scandinavia, following Hitler's rise to power. In Norway, Reich sought to find a way to confirm his model of human functioning. Pleasure, he observed, was identified by an increasing bioelectrical charge at the skin surface, while anxiety was accompanied by a loss of this same peripheral bioelectrical charge. Persons with a deep respiration and a relaxed posture would, he observed, regularly give stronger readings at the millivoltmeter than contracted, anxious, highly armored persons, who had a life-history of trauma, abuse, repressed emotion, and ungratified sexuality. As a child grew to adulthood, and became habituated or conditioned towards pleasure-seeking, or pleasure-avoiding (pain seeking) behaviors, so too would their skin charge, and other physiological measures, reflect a corresponding high or low energy charge. This movement of the organism, and their energy charge, in a direction "toward" or "away" from the world, he argued, was the result of one's life history. Life naturally moved towards pleasure, but retreated, and shrunk from pain. Chronic painful experience would eventually armor the organism, and make it difficult for them to reach out, towards the painful world. From this central set of observations, he postulated that a similar process could be duplicated and observed in lower organisms, such as the snail, earthworm, or even microscopic ameba.

Reich noted that the ameba had no "nervous system", or "brain", as with the higher animal, yet it expanded towards or contracted away from its environment in a manner similar to the higher animals. He believed that many of the functions attributed to the brain were really functions of whole-body processes, involving the participation of the autonomic nervous system, but primarily being the result of the energetic forces he had documented in a clinical and laboratory setting. These currents of biological energy, he argued, functioned the same in all living creatures, and he sought to test the idea by making millivoltmeter measurements of ameba during states of expansion and contraction. Reich went to the University of Oslo Microbiological Institute, and asked to obtain a culture of ameba. He was told that these kinds of simple organisms were never kept on hand in stored cultures, because they could be cultured directly from a moss or grass infusion. Reich was fully aware of the air germ theory, but was surprised to hear this, as the theory had not at that time been used to explain the genesis of more complex microbes, such as ameba and paramecium. These more complex microbes cannot be cultured directly from the air, for example.

Reich made the moss and grass infusions, but also made extended and careful microscopical observation of the process whereby the ameba developed. He did not see spores on the grass blades, swelling up to become new ameba. Instead, he observed that the moss and grass itself would disintegrate and break down into small blue-green vesicles. The tiny vesicles would, over a period of several days, develop and clump together, after which a new membrane would form around the clump; the clump of vesicles would roll and pulsate inside the membrane for a period, and eventually the whole thing would move away on its own, having *turned into a new ameba*. Moreover, Reich observed that a number of materials, both organic and inorganic, would, when allowed to disintegrate and swell in a sterile nutrient solution, form the tiny blue-green vesicles. These observations were greeted by the university microbiologists with skepticism, and Reich developed a series of stringent control tests to answer their objections, and to more clearly demonstrate the observable process. These control procedures involved lengthy autoclaving of nutrient solutions, and heating over flame, to incandescence, of the materials placed in the sterile nutrient medium. His control procedures and observations on this question were repeated and confirmed by other scientists of the day, and were presented to the French Academy of Science in 1938. But this did little to satisfy his critics, who shamelessly refused to reproduce the experiments, while simultaneously attacking him in the Norwegian newspapers.

Reich used very high magnifications, around 3500 to 4500 power, but not the usual microbiological stains or procedures which kill the life in the specimen. These facts made Reich's preparations very different from those of the average microbiologist, who to this day still kill and stain their preparations with a religious fervor, and see little value to observing living microbes in the light microscope above 1000 power. Standard electron microscope images, for example, can not be made of living specimens.

Reich gave a new name to the unusual microscopic vesicle he had discovered: the *bion*. Bions of similar size, shape, and motility would appear in the light microscope when various materials were subject to a process of slow swelling and disintegration, or when substances were heated to incandescence, and then immersed into sterile nutrient solutions.

Boiling, autoclaving, or heating samples to glowing incandescence would not eliminate the bions from the cultures, but could actually liberate them in greater numbers. Reich also studied the process of disintegration and decay of foodstuffs in the microscope, and noted that similar bionous processes were at work. The bions exhibited a *bluish* coloration, and radiant energy effects were likewise observed. It was during these microscopic observations of the bions that Reich first discovered the orgone radiation, and later, the principle of the orgone energy accumulator.

Like his findings on human behavior, Reich's bion experiments are far too intricate and important to be fully reviewed here, but it can be noted that they have been widely replicated by various scientists around the world. Classical microbiology of today has made confirming discoveries of very similar small vesicles, though Reich's priority has yet to be acknowledged. His findings on the bions also resolved two parallel riddles, the origins of protozoa from disintegrated dead plant tissue in the natural environment, and the origins of protozoan *cancer cells* from the energetically (emotionally) deadened tissues of the human body. Reich observed similar processes at work in both dead grass and deadened animal tissue: disintegration into bions, followed by a spontaneous reorganization of bions into protozoan forms. In both cases, of soil or tissues, Reich argued that the process was initiated by a *loss of life energy charge* of the tissues, followed by putrefaction and disintegration.

One special bion preparation, made from pulverized beach sand heated to incandescence and immersed into a sterile nutrient broth, yielded a powerful radiant energy phenomena. Lab workers developed conjunctivitis if they observed the preparations too long, while a skin inflammation could be developed by placing the bion solution close to the skin for a period. Working for extended hours in the laboratory, Reich developed a dark tan through his clothing, in the middle of winter. The radiation imparted a magnetic charge to nearby iron or steel implements, and a static charge to nearby insulators, such as rubber gloves. Film stored in nearby metal laboratory cabinets spontaneously fogged. He noted that whatever this bion radiation was, it was rapidly attracted to metals, but just as rapidly reflected away, or dissipated into the surrounding air. Organic materials, however, absorbed this radiation and held onto it. Attempts to identify the new radiation using traditional nuclear or electromagnetic radiation detectors failed.

Reich also noted that the air in rooms containing the special bion cultures would feel "heavy" or charged. When observed at night, in full darkness, the air would visibly scintillate and glow with a pulsing energy. He attempted to capture the energy radiating from his bion cultures inside a special cubical enclosure lined with sheet metal, which he felt would reflect and trap the radiations inside. As expected, the special metal-lined enclosure trapped and amplified the effects of the bion radiation. However, to his amazement, he found that the radiation was also present in the experimental enclosure *even when the bion cultures were removed*. In fact, there was nothing which could be done to make the observed radiation "go away". The special metal-lined enclosure appeared to pull the same form of radiation from the air which previously had been observed coming from the bion cultures.

Reich eventually became convinced that the special enclosures were capturing a free atmospheric form of the same energy that he also observed coming from living organisms. He called the newly discovered energy the *orgone*, and he developed ways to amplify the energy accumulating affects of the enclosure, mainly through multiple layering of the metallic and organic materials. No electricity, magnetism, electromagnetism, or nuclear radiations were employed in these accumulating structures, which were entirely passive in design. The special enclosures were thereafter called *orgone energy accumulators*.

The full sweep of Dr. Reich's clinical findings, his experiments with bioelectricality, the bions, on biogenesis and the origins of the cancer cell, and his discovery of the orgone energy and the orgone energy accumulator, cannot be given here, but a few points are summarized. The orgone accumulator was found to have specific life-positive effects upon plants and animals exposed to the concentrated life force inside it. A host of quantifiable effects upon the physical properties of the air, or other materials charged up inside the accumulators, were also discovered and documented. Reich and his co-workers published a host of research articles on the orgone energy accumulator, its unusual physical properties, and its life-positive biomedical effects. These effects have been repeatedly confirmed, and a research tradition in orgone biophysics continues to this day. Briefly, we may identify some of the known properties of the orgone energy, and effects of the orgone energy accumulator.

Properties of the Orgone Energy:

A) Ubiquitous, fills all space.
B) Mass-free; cosmic, primordial in nature.
C) Penetrates all matter, but at different rates of speed.
D) Spontaneously pulsates, expands and contracts, and flows with a spinning wave characteristic.
E) Directly observable and measurable.
F) Negatively entropic.
G) Strong mutual affinity and attraction to/by water.
H) Accumulated naturally by living organisms through foods, water, breath, and through the skin.
I) Mutual excitation and attraction of separate orgone energy streams, or of separate systems charged with orgone.
J) Excitability via secondary energies (nuclear, electromagnetism, electrical sparking, friction).

Physical effects of a strong orgone charge:

K) Slightly higher air temperature as compared to surroundings.

L) Higher electrostatic potential, with a slower electroscopical discharge rate as compared to surroundings.

M) Higher humidity and lower water evaporation rates as compared to surroundings.

N) Squelching of ionization effects inside gas-filled ionization Geiger-Muller tubes.

O) Development of ionization effects inside non-ionizable vacuum tubes (0.5 micron pressure or lower).

P) Ability to impede and absorb electromagnetism.

Biological effects of a strong orgone charge:

Q) General vagotonic, expansive effect on entire system.

R) Sensations of tingling and warmth at skin surface.

S) Increased core and skin temperature, flushing.

T) Moderation of blood pressure and pulse rate.

U) Increased peristalsis, deeper respiration.

V) Increased germination, budding, flowering and fruiting of plants.

W) Increased rates of tissue growth, repair, and wound healing, as determined through animal studies and human clinical trials.

X) Increased field strength, charge, integrity of tissues and immunity.

Y) Greater energy level, activity, and liveliness.

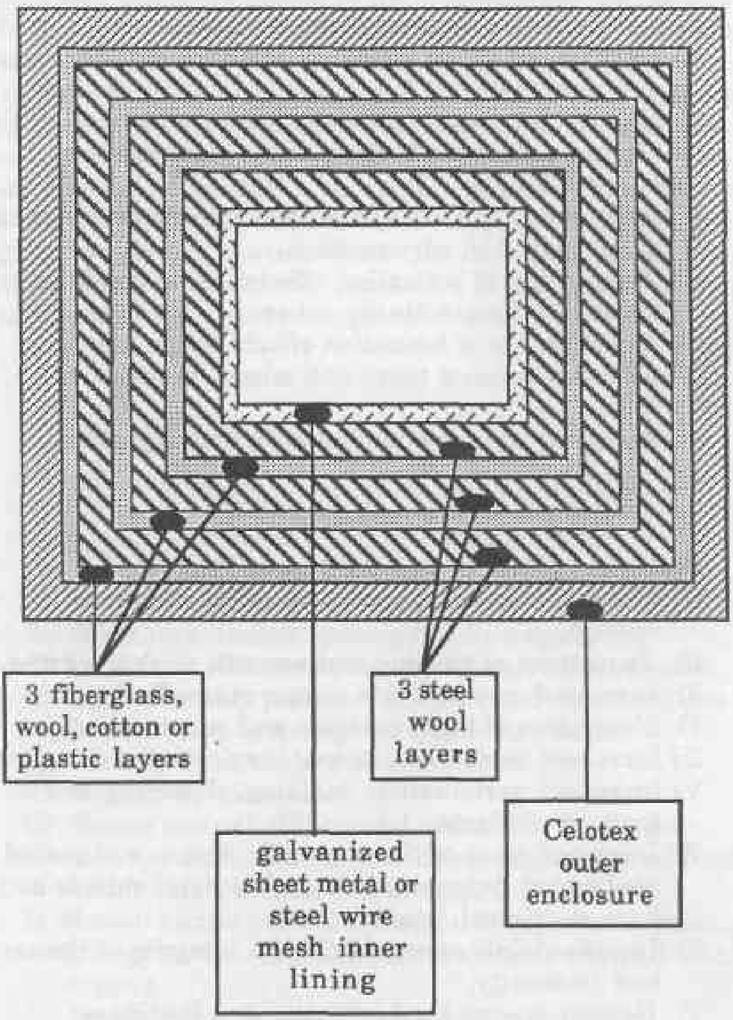
3 fiberglass, wool, cotton or plastic layers
3 steel wool layers
galvanized sheet metal or steel wire mesh inner lining
Celotex outer enclosure

Simplified Diagram of the Orgone Energy Accumulator

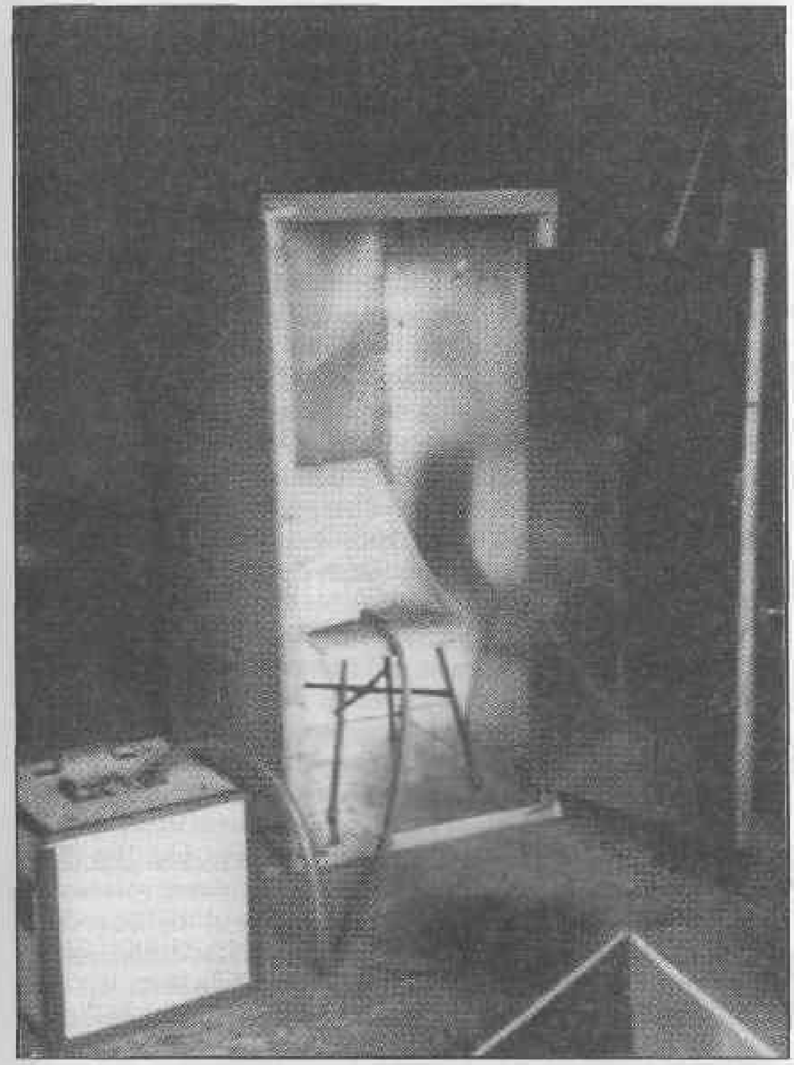

A three-ply accumulator in the author's laboratory. A ten-ply charger, with attached funnel shooter, is at the lower left. This charger normally sits inside the larger accumulator, under a wooden bench inside the accumulator.

5. Objective Demonstration of the Orgone Energy

A number of techniques have been developed over the years to document, measure, and objectify the orgone energy. These techniques are briefly listed, but the interested reader is directed to the references for more specific details.

A) Bioelectric Fields: Reich identified various bioelectrical phenomenon which he felt demonstrated a more powerful energy current at work in the body. The small millivolt currents of "bioelectricality", he argued, were only a small portion of this stronger energy current in the body, which he identified as being both emotional and sexual in nature, and which was later objectively identified as the orgone energy.

B) Radiant Effects from Bion Cultures: Special bion cultures derived from beach sand emitted a powerful radiation which could be felt and seen in darkrooms. This radiation did not register on instruments for detecting nuclear or electromagnetic energies. Additionally, the radiation could fog film, impart a static charge to insulators, and a magnetic charge to steel laboratory implements.

C) Darkroom and Atmospheric Observations, the Orgonoscope: Reich also observed and categorized various observable phenomena which could be seen by the dark-adjusted eye in the open air of darkrooms. Scintillating fog-like forms, and dancing, luminescent pin-points of light were observed, and numerous techniques were developed which demonstrated their real, objective nature. One of these techniques involved the development of a new instrument, the *orgonoscope*, which used hollow tubes, lenses, and a fluorescent screen for magnifying the various subjective light phenomena. Large room-sized orgone accumulators were also constructed, and observations made in these amplified and clarified many of the effects. A special corpuscular *orgone unit* was identified, whose lawful behavior changed according to cosmic and meteorological factors. These macroscopic particles were also observed in the daytime sky with the unaided eye, as a generally common phenomenon, visible to most people once they were pointed out. The Earth was observed to possess its own orgone energy envelope, or energy field, much as did individual living creatures.

D) X-Ray Photographs: Reich observed that the x-ray "ghost" phenomenon (spontaneous, unexplained fogging of x-ray films) could be explained as an effect of the orgone radiation, or life energy. He published several photos where the ghosts were purposefully created by excitation of orgone energy within the field of the x-ray machine.

E) Visible Light Photographs: Reich observed that his special radiating bion cultures would fog film stored in nearby metal cabinets. Culture dishes of radiating bions set directly upon the film would also render an image of the culture dish and its contents. More recently, Thelma Moss of UCLA has shown that life energy field photos can be made without electrical stimulation (as with Kirlian techniques), by energy field enhancement; living objects placed directly on a film for a few days within a darkened orgone accumulator will, under the proper conditions, render an image.

F) The Orgone Energy Field Meter: Reich developed this device to measure the strength of energy fields. Using a Tesla coil and special accumulator-like metal plates, the device could quantify the differences in energy level between people or objects.

G) The Orgone Energy Pulsation Demonstrator: Reich demonstrated that the energy field pulsations of a large metal sphere were capable of setting into motion a smaller metallic/organic pendulum suspended nearby.

H) The Accumulator Temperature Differential (To-T): An accumulator will spontaneously develop a slightly higher temperature than either its surroundings or a control enclosure, on those sunny and clear days when the orgone charge at the Earth's surface is strong. The effect vanishes during stormy, rainy weather, when the orgone charge at the

Earth's surface is weak (but strong in the Atmosphere). The results of this temperature experiment, which has been replicated many times, demonstrates that the orgone energy functions in opposition to the second law of thermodynamics.

I) The Accumulator Electrostatic Effects: An electroscope kept inside an orgone accumulator will dissipate its charge more slowly than an identical one kept in the open air, or inside of a control enclosure. A partly charged, or uncharged static electroscope which is kept inside an accumulator will sometimes spontaneously charge itself up. As with the temperature differential effect, the electrostatic effects vanished during rainy or overcast weather, when the orgone charge at the Earth's surface is weak.

J) The Accumulator Ionization Suppression/Amplification Effect: Geiger-Muller tubes and counters charged up inside a very strong accumulator for several weeks or months tend to go "dead" for a period, but may eventually yield an erratic count rate for background. Special vacuum tubes, which Reich had constructed and called vacor tubes (which mimic the design of the Geiger-Muller tube but are evacuated well below the level at which ionization could occur), will initially not yield any counts when hooked to a radiation detector. After charging up inside a very strong accumulator for weeks or months, however, these same vacor tubes will begin to yield very high counts per minute for background, even at very low exciting voltages. The results of this experiment run counter to the classical interpretation of the ionization effect inside the Geiger-Muller tube, and hence, to the classical particulate interpretation of radioactive decay.

K) The Accumulator Humidity/Water Evaporation Effect (EVo-EV): More recent studies have suggested that an accumulator tends to attract a slightly higher humidity into itself, and suppress the evaporation of water from an open vessel inside. As with other accumulator phenomena, this effect also diminishes or vanishes during rainy weather.

L) Atmospheric Energetic Pulsation, and the Reversed Orgonotic Potential: Based upon observations of the thermal, electroscopical, and ionization characteristics of the orgone accumulator, Reich identified a patterned and lawful energetic cycle at work within the atmosphere and energy field of the Earth. These observations likewise led to the identification of a reversed potential at work in the orgone energy, running counter to thermodynamic principles, which explained why natural orgonotic systems (organisms, weather systems, planets) maintained a higher concentration of energy than their surrounding environments. The stronger of two orgonotic systems will drain energy from the weaker system, and increase its own potential or charge, until the weaker system is drained, or some maximum capacity level is achieved. Discharge may occur thereafter. Under sunny, clear weather, the orgone charge at the Earth's surface is quite strong, and in a state of expansion, preventing any significant growth of clouds. Where overcast or stormy conditions prevail, the orgone charge at the Earth's surface is weak, while the charge in the atmosphere is strong and in a state of general contraction. This loss of charge at the Earth's surface during rainy weather slows down the activity of living creatures, and the accumulator will not function well at those times.

M) The Millivoltmeter: Virtually all objects and organisms within a given environment, to include the air, water, and the Earth itself, have a charge that will increase and decrease in a cyclical or pulsatory manner, timed to cosmic and meteorological factors. In living creatures, high potentials produce more active physical and emotional periods, while low potentials signal less active periods. In Nature, high atmospheric potentials signal cloudy periods with stronger storms, while high Earth potentials signal cloud-free conditions. The tiny currents are excellent predictors of powerful biological or environmental processes, but are themselves too slight and weak to be the causative agent. Reich, and other researchers who have examined these small voltage potentials (such as H.S. Burr), viewed them as indicative of a more powerful, ubiquitous natural phenomena which energetically linked together the Sun, Moon, Earth, weather systems, and all living creatures.

N) Plant Growth Enhancement Studies: Seeds and plants correctly charged up inside an accumulator demonstrate higher growth rates and yields of fruit. This is one of the more telling, and widely replicated experiments with the orgone accumulator. In my own trials, I have seen a six-fold increase in the length of mung bean sprouts inside a strong accumulator, as compared to a control group of sprouts. Germination rates, growth rates, budding, flowering and fruiting can be increased by charging seeds or growing plants directly inside the accumulator. The seeds can be sprouted directly inside the accumulator, or charged up for a few hours, days, or weeks prior to planting. Growth enhancement effects may also occur when the water alone is charged, and then externally given to the plants.

O) Non-Human Animal Studies: Controlled studies on the effects of orgone radiation from an accumulator on cancer mice and wounded mice have been performed. These studies generally confirm Reich's earlier arguments that tissues with a stronger energetic charge will heal more quickly, and develop tumors more slowly, or not at all, as compared to energetically weakened tissues. These findings invalidate many aspects of the DNA theory of cellular differentiation, which appears to be more directly under the structuring influence of the organism's own life energy field.

P) Human Studies: Aside from those clinical trials performed by Reich and his co-workers in the 1940s and 1950s, very little work has been done in the USA regarding the bioeffects of the accumulator on humans. All research into these questions was halted by medical police actions in the 1950s. Recent studies from Germany, however, have confirmed such bioeffects. In general, a person sitting inside an accumulator will feel a variety of warm, glowing, or sometimes tingling sensations at the skin surface; their body core temperature will rise and skin flush, while blood pressure and pulse rate will trend towards moderate levels, being neither too high or low. When properly used, it has a distinct vagotonic, enlivening effect. The chapter on

"Physiological and Biomedical Effects", as well as the Appendix article, will provide details on these questions.

6. Discovery of an Unusual Energy by Other Scientists

Studies by various natural scientists have, over the years, demonstrated energetic principles at work in the natural world which are similar to the orgone energy. Early Chinese medicine acknowledged the existence of such a force, called *Chi*, and the traditional method of acupuncture is based upon the existence of such an energy principle within the human body. Acupuncture points do not correspond directly with nerve endings, and the most able acupuncturists do not rely upon the Western models of physiology to explain its effects. Given the absence of a vital energy principle, Western medicine cannot explain acupuncture, and has resisted its adoption in the United States. Acupuncture furthermore works on animals, invalidating invocation of the placebo effect; ancient texts from India have also referred to the life energy, called *Prana*, and provide maps of *Nila points* (similar to acupuncture points) on elephants. The texts from ancient China and India speak about an energy that is taken in through the breath, and flows through the body along the various meridians. Health is constituted by a free, unimpeded flow of this energy, while sickness occurs when the flow of vital energy is blocked. This is very similar to Reich's ideas on the orgone energy, though the Asian sources say little about the free expression of emotion; they also often advocated a conscious control of emotions and sexual feeling (*orgasm avoidance)*. In contrast, Reich demonstrated that such chronic restraint or self-control was the reason why the life energy became blocked or dammed up in the first place.

In the Western tradition, the vitalists of the eighteenth and nineteenth centuries also discussed the existence of a biological energy or life force, which was called *animal magnetism*, the *odic force, psychic force, élan vital,* and so on.

Indeed, Mesmer spoke of animal magnetism as an atmospheric fluid which surrounded, charged, and animated living creatures, and could be projected across a distance by a therapist. Mesmer was a teacher of Charcot, who was, in turn, the teacher of Freud, who was one of Reich's early mentors. Reich also studied with other vitalists, such as Kammerer and Bergson, and the vitalist tradition has persisted as a quietly spoken minority viewpoint in biology. Besides Reich, the more recent advocates of a vital or dynamic energy principle in nature included the late Harold S. Burr of Yale University. Burr argued for the existence of a powerful *electrodynamic field* at work in nature, affecting both weather and living creatures. The biologist Rupert Sheldrake has similarly developed a theory on *morphogenetic fields* which also takes from this tradition. Like Burr's work, Sheldrake's theory provides a dynamic, energetic explanation for inheritance, making the biochemical DNA theory unnecessary. Most recently, editors for the academic publication *New Scientist* called Sheldrake's book the "best candidate for burning" they had seen in a while.

The surgeon Robert O. Becker developed these prior principles to a most amazing state of advancement. His early research led to the development of a class of devices for the electrical stimulation of bone healing and pain relief. His later work took these principles, and developed them to the point that he could artificially stimulate the *regenerative growth of amputated limbs of laboratory mice*, in a manner similar to the way in which a salamander or spider will regrow a lost limb. This kind of regrowth is by nature limited only to less complex creatures, and does not generally exist among mammals, such as mice, rabbits, and humans. Regrowth of an amputated limb had never been previously demonstrated in a mouse, or any mammal for that matter. Becker's work was a severe blow for both the biochemical DNA theory of cellular regulation, and the theory that the bioelectrical field of a creature was just a meaningless "byproduct" of chemical metabolism, like the electric field surrounding a running automobile engine. His work proved that the energy field of the animal was a primary determinant of growth and repair, as was the case with Reich's work. Becker was preparing to replicate the limb regrowth experiments on humans, when the biomedical community reacted with severe outrage against him, pulling dirty tricks of all sorts to have his research funding cancelled, and his laboratory shut down.

Another vitalist of our era is Bjorn Nordenstrom, director of the Karolinska Radiological Institute in Sweden. Nordenstrom, like Reich, made a study of the x-ray "ghost" phenomena, which is an unusual spontaneous fogging of x-ray films. It appears as a wispy, smoke-like or blob-like form on the x-ray images of patients, and sometimes can be seen on the monitors of airport baggage x-ray equipment. It cannot be predicted, and most radiologists consider it to be a nuisance. However, Nordenstrom studied it, and observed distinct patterns correlated to his patient's bioelectrical fields. Like Reich, he also discovered and measured currents of bioelectricality in the body. His meticulous research was summarized in a book titled *Biologically Closed Electric Circuits: Clinical, Experimental, and Theoretical Evidence for an Additional Circulatory System.* After being heavily advertised in medical journals in the USA, it sold less than 200 copies, evidencing a contempt among mainstream medical doctors for any new findings that would support the principle of a life energy, even one of a purely bioelectrical nature. Unable to find support for his work in the West, Nordenstrom recently went to China to pursue his clinical research.

Other biological scientists have inferred the existence of such a vital energy principle, on the basis of their experimental work. When they provide good confirming evidence, they are hotly attacked. The French scientist Louis Kervran, for example, spent years developing very elegant and simple experiments demonstrating that the basic elements of chemistry were being *transmuted* by living creatures. Chickens fed a diet free of calcium, for example, would not lay mushy or fragile eggs, unless dietary silica was restricted. With a restricted silica intake, however, they laid mushy and fragile eggs, and it did not matter how much calcium they ate. Likewise, laboratory mice would heal broken bones very quickly when fed a diet high in organic silica, but not so fast when silica was minimized and only calcium was provided. These experiments strongly suggested that dietary silica was being transmuted into calcium in the bodies of animals. Kervran also experimentally demonstrated other likely transmutations, and other scientists in Europe and Japan confirmed his findings. He eventually came to the conclusion that there had to be some unknown form of powerful biological energy at work to drive the transmutations. But when he wrote to a prominent American scientist for assistance in obtaining equipment for an important experiment, he was impolitely told to go "read an introductory textbook on biology". In the United States, Kervran is better known among homeopathic doctors and organic farmers than by university professors. However, if Kervran is right–and the experimental evidence suggests that he is–then the textbooks of biochemistry will need to be rewritten. As Kervran pointed out, biology and biochemistry are two entirely different disciplines and should not be confused. Biology is concerned with observable fact, while biochemistry attempts to explain observed facts by a chemical theory which assumes elemental constancy. And it is with this basic assumption that part of the error lies.

Another French scientist, Jacques Benveniste, actually demonstrated such an energy principle at work in homeopathic dilutions. His experimental work was successfully replicated by independent laboratories in other countries, to satisfy his obstinate critics. But that was not good enough. For making this offending discovery, which lent some support to homeopathic physicians (who are often prosecuted and jailed in the United States), the science journal *Nature* dispatched a "hit squad" of fraud investigators, debunking magicians, and skeptical editors to his laboratory, under the guise of "evaluating" his laboratory procedures. The *Nature* science cops made a mess of Benveniste's lab, distracting laboratory workers, performing slight-of-hand tricks, and shouting, before finally being told to leave. *Nature* subsequently tried to smear Benveniste in their editorials, but did not factually refute his work through replication of experiments. Such is the warp and weave of traditional academic science in the 1980s.

In the atmospheric sciences, the tradition of dynamic energy forces which affect entire regions was preserved for a period by older weather forecasters, who used streamline, rather than frontal theory to predict weather. Streamline analysis more coherently focused upon streaming movements of air, or jet streams as they are called today. For example, when you look at the dynamic images of clouds, as seen from a satellite in space, you do not see "fronts". But you do see *streaming movements of clouds*. Reich independently discovered the basic configurations of these streams, years before the first weather satellites were launched. Likewise, the older atmospheric scientists often argued for a great interconnectivity in the atmosphere. Charles G. Abbot, head of the Smithsonian Astrophysical Observatory in the 1950s, used related energetic concepts to predict the weather months into the future. But he was ignored and ridiculed for his findings, in spite of their uncanny accuracy. Irving Langmuir, one of the originators of cloudseeding techniques, once objectively demonstrated that cloudseeding in New Mexico would trigger rain storms all the way into Ohio, and he warned his fellow workers about this danger. The cloudseeders of today, funded by millions in Federal dollars, act as if Langmuir's work never took place, and refuse to replicated his simple experiment. They deny the existence of long distance effects from cloudseeding, knowing that if such effects became public knowledge, they would be forced to stop.

Among the physical scientists, the idea of an energy in space was embodied in the concept of an *aether,* which dates back hundreds of years. The theologian/physicist Isaac Newton forcefully argued that this aether *had to be static*, in order to prevent it from directly participating in the movement and ordering of the heavens. That role, Newton argued, belonged only to the anthropomorphic God (who at that time was demanding that unbelievers be ruthlessly tortured and burned at the stake). And, over the years, a dead, unmoving aether has never been detected. However, an *aether with more* *dynamic properties* was objectively demonstrated by the physicist Dayton Miller. Miller also explained why prior attempts to measure the aether had failed. First, he observed that the aether is *entrained* at the Earth's surface, and moves faster at higher altitudes than lower altitudes. Prior attempts to measure its movement had taken place only at lower altitudes, or in heavy stone buildings or basement locations. Second, Miller's aether was *reflected by metals*, and prior attempts to measure it used instruments with the critical parts housed inside metal enclosures. Miller found that by doing the crucial aether-drift experiments on a mountain top, inside a flimsy building without metals or dense window materials, that it was readily detectable and measurable. He made over 200,000 separate measurements, over the course of 30 years of investigation. Contrast this to the famous Michelson-Morley experiment, which involved a grand total of six hours of actual measurement time, made over four days in 1887. The Michelson-Morley experiment is widely misquoted as having completely failed in the detection of the aether. It was a hinge-point in the sciences, after which the idea of the aether was given up entirely for the "empty space" theories of relativity and quantum dynamics.

Miller's extensive work on the aether question was never rebutted when he was alive, but his research was contemptuously compared with "searching for perpetual motion". After his death, the adherents of the empty space theory breathed a heavy sigh of relief. Today, every physics textbook starts out with the falsehood that "the aether was never measured or demonstrated". It should be pointed out that the theories of relativity and quantum dynamics, plus the expanding universe and "big bang" theories, are utterly shattered by the discovery of an energy in space, and many physicists, who cling to their theories religiously, simply refuse to look at this kind of evidence. Worse, the discipline of physics has become a military-oriented growth industry, with multi-billion dollar funding for the sustenance of nuclear power and bomb-making technology, for fusion plants, particle accelerators, and "star wars" experiments. This kind of research has not brought forth any real benefits or fruits for humankind, but has become a self-perpetuating "research industry", a multi-billion dollar edifice which, like the medico-pharmaceutical industry, is threatened to the core by these discoveries of a primary, cosmic life energy. The physics community has unfortunately reacted to these new findings with the same arrogance and viciousness that characterizes the medical communities' reaction to the life energy. Einstein's followers, for example, have recently been accused, in print, of very nasty stab-in-the-back tactics of censorship and suppression. An entire new journal, *Scientific Ethics*, for a short period at least began to expose the whole stinking mess.

Of great interest for Reich's work is that Miller's dynamic aether was *more active at higher altitudes*, and *reflected by metals*. The capacity to be reflected by metals, with a more active state at higher altitudes, are basic properties of the orgone energy, as independently discovered by Reich. The orgone also satisfies many other of the basic properties and functions of an aether, being ubiquitous and mass-free, and by providing a medium for the transmission of electromagnetic excitation. However, the orgone also spontaneously pulses, superimposes, and directly participates in the creation of both matter and life. But even without using the taboo word "aether", or the more offending word "orgone", another group of physicists have detected or inferred the existence of dynamic energy currents at work in deep space. For example, the American astrophysicist Halton Arp made so many photographs of energy/matter bridges between deep-space objects, where those energy/matter bridges should not have been there, that he was actually banned from using the big American telescopes. His simple photos demolished the theories of empty space, the expanding universe, and the "big bang" with a single shutter click. So great was the hatred against his work that he ultimately had to go to Germany to continue with his research. Hannes Alfven, another famous physicist, also deeply offended his contemporaries by suggesting, like Reich, that space was filled with streaming currents of plasmatic energy. The space scientists to this day refuse to send satellite probes where he says they should, as to do so might confirm that space is energetically rich. In fact, physics of today is in a state of turmoil, and is desperately trying to explain away the newer evidence for an energy in space, to preserve the big bang theory, relativity, quantum dynamics, and the billions of dollars of research money that supports the "empty space" religion, and its institutional priesthood.

Few of the above ideas, nor the findings on sunspot-weather correlations, are given much funding or investigation today. Science journals still routinely carry the false statement that "no mechanism" has been found for solar-terrestrial correlations, just as physics textbooks carry the falsehood that "the aether had never been detected". And it is true that these relationships cannot be true, nor do they make any sense, from the standpoint of the "empty space" theories of physics. They require a medium in the atmosphere and in space, through which excitations and influences can pass, independent from thermal or pressure phenomena, a force which propagates in the atmosphere faster than air currents, and which can likewise quickly propagate influences across the depths of space. Again, Reich's orgone energy fits such a description.

Other research has been done to show that living creatures, and the physical chemistry of water, are sensitive to weather or cosmic factors in a manner than cannot be explained according to simple mechanical phenomena, such as light, temperature, humidity, or pressure. Frank Brown, of Northwestern University, spent decades demonstrating that the biological clocks of various living creatures were sensitive to lunar cycles and other cosmic forces. Nobody could refute him when he was alive, but today, after his death, his findings are widely ignored. Likewise the works of the Italian chemist, Giorgio Piccardi, who demonstrated that the physical chemistry of water was changed by magnetism, sunspots, and other cosmic phenomena. His work helped to fuel an interest in the magnetic treatment of water in Europe, leading to new methods for reducing scale deposits in household plumbing, and in industrial boilers. Magnetism, correctly applied, can alter the solubility characteristics of water, allowing dissolved substances to remain in solution at concentrations higher than normal for a given temperature. In the USA, these findings have been greeted with derision, as every physics textbook says magnetism has no effect upon water. Also, almost every chemical laboratory uses magnetic stirring devices to mix their chemical solutions, instead of the "old-fashioned" hand-operated glass stirring rods; these magnetic stirring devices would, if Piccardi is correct (and he is) alter the chemistry, precipitate quantity, and titration curves for every chemical reaction exposed to them. And so, the new findings are ignored in the USA, while abroad, new products based upon the discovery are entering the marketplace. Simple magnetic water treatment systems for the home are now common in Europe, replacing in many cases the ion-exchange water softeners, with their bags and bags of salt. In the USA, meanwhile, the water softener industry, in collusion with dogmatic academics and politicians, has managed to have laws passed in a few states to forbid the sale of magnetic water treatment devices.

Piccardi's work extends beyond the issue of simple magnetic treatment of water, however. At one point he attempted to isolate an unknown cosmic energy which was affecting his chemical experiments, in a manner similar to strong magnetism. In order to block out the unknown radiation, which was correlated to sunspots, he constructed an electromagnetic shield around his experiments, in the form of an Earth-grounded metal box enclosure. Then, in order to stabilize the temperature inside the metal box, he placed a layer of wool around the outside. To his amazement, the metal box did not extinguish the cosmic phenomena, but amplified it. He and his co-workers spent decades performing chemical experiments inside similar enclosures, which mirror the construction of Reich's orgone energy accumulator. This independent corroboration of the orgone accumulator principle by Piccardi was also confirmed, though in a less direct manner, by the biologist Brown. Brown observed that hermetically sealed *metal enclosures*, with a constant pressure, temperature, light and humidity inside, would not extinguish cosmic influences upon biological clocks, but would instead allow them to be more clearly observed, or even add an unusual dimension to their behavior. For example, inside the metal box, the metabolism of potatoes followed a cycle that correlated with lunar, solar, and galactic parameters. Potato metabolism additionally demonstrated a correlation to local weather; *not the weather today, but the weather two days into the future!* In the enclosure, the energized potato would respond to external energetic factors in the environment which were also determinants of future weather events.

The above are just a few of the kinds of evidence that exist for an energetic principle similar, or identical to the orgone energy. In many cases, these researchers had not known of Reich's work. In a few, they hated Reich's guts, and would hardly tolerate mention of his name by their students! And yet, the facts speak powerfully for a corroboration of Reich's orgone energy. It must be stated, however, that Reich's discovery on the orgone energy is far more inclusive, comprehensive, and tangible than any of the above concepts. In addition to having been quantified, photographed, and measured, the orgone can be seen, felt, and, as noted in this book, accumulated within special experimental enclosures.

An additional word must also be given regarding the response of the scientific and academic communities to these new discoveries. The reader will note that most, if not all, of the above researchers were hotly attacked, or isolated and ignored for their findings, irrespective of their credentials, reputations, or the amount of evidence they provided. This emotional reaction, of running away from or attacking disturbing new ideas, was explained by Reich as being the results of a specific emotional disorder, which he called the *emotional plague*. Virtually all scientists who have verified portions of this common natural energy principle have been assaulted by special *emotional plague characters*, who build their reputations not upon work or research, but upon political power, and the number of scalps they have taken. Gossip, slander, political tactics, the sneak attack, and even manipulation of the courts and police are standard tactics of the plague. Their secret goal, like the Grand Inquisitors of the Church, is to kill disturbing new findings, and the men and women who make them. The history of science is filled with evidence for this kind of behavior. The reader is encouraged to read Reich's discussion on the emotional plague, in *Character Analysis (3rd Ed.), People in Trouble*, and *The Murder of Christ*, as it still constitutes the major obstacle in the way of human social progress, and scientific research.

Part II: The Safe and Effective Use of Orgone Accumulating Devices

7. General Principles for Construction and Experimental Use of the Orgone Energy Accumulator

A) The interior surface of all accumulators must be composed of bare metal. Paints, varnishes or coatings on the metal will interfere with the accumulating effect, though zinc galvanizing does not.

B) The outer, exterior surface of all accumulators must be composed of an orgone-absorbing, generally organic, non-metallic substance.

C) Metals and non-metallic materials may be alternated in multiple layers within the walls of the accumulator for stronger energy accumulation. The more layers, the more powerful the accumulator, though one does not simply double the strength by doubling the layers. A three ply accumulator will have about 70% of the strength of a ten ply accumulator (one "ply" consists of a layer of metal plus a layer of non-metal). Accumulators of different sizes may also be nested one inside another, to develop an even stronger charge. Points A and B above must be strictly followed, however. In multiple ply accumulators, you can double-up the final outer organic, non-metal layer, and the innermost metal layer, for additional energy accumulating capacity.

D) A major common error made by some who reproduce Reich's orgone accumulator experiments is the use of inappropriate accumulator materials. For accumulators used on living systems, and particularly for human use, copper, aluminum, and other non-ferrous materials must be completely avoided as they yield *toxic effects*. Similarly, certain types of polyurethane foams, rigid or soft, do not have a good effect upon the living system when used in an accumulator. Any type of material impregnated with formaldehyde, or made with other highly toxic glues or resins should not be used.

Good non-metals	*Poor or toxic non-metals*
wool, raw cotton	wood or plywood
acrylic, styrene plastic	urethane or polyurethane
celotex (soundboard)	pressboard (very hard)
cork sheeting	organic materials containing formaldehyde, asbestos, or other toxic chemicals
glasswool, fibreglass	
rock wool	
bees wax, candle wax	
soil, water	

Good metals	*Poor or toxic metals*
steel or iron, sheet, screen	aluminum, sheet or screen
galvanized steel	lead
steel wool	copper
stainless steel	
steel/tin can alloy	

E) Some individuals have experimented with accumulators composed of buried metal boxes, surrounded with rich dark soil, free of pesticides and herbicides. The larger of these kinds of accumulators give the appearance of a root cellar or "burial mound". Some authors familiar with ancient archaeological sites have even speculated that the life energy principles were known and used by ancient peoples. Certain ancient mounds and structures have a layered characteristic, using clay soils or stone of high iron content, covered over with other layers of organic-rich soils or peat.

F) An exceptionally powerful accumulator can be made by using bees wax or other dielectrical materials for the outer, non-metallic layers. These materials may be quite expensive for a larger accumulator, and are also fragile. If you use a fragile or crumbly material for the outer non-metal layer, you can coat the outer surface with clear shellac. This has been tried by many people, and does not appear to interfere with the accumulation or life enhancing qualities of the energy. Never use shellac on the interior surfaces, however.

G) Experiments have demonstrated that the shape of the accumulator is a factor of lesser importance than its material composition. However, accumulators made in the shapes of cones, pyramids, or tetrahedrons have yielded occasional unexplainable life-negative effects. Unless one is testing for such effects, accumulators should be constructed in rectangular, cubical, or cylindrical shapes. These have given the best results, and are also easier to construct. One anecdote here: in 1980, the author was in Egypt, and went into the Great Pyramid of Cheops. While inside, I was struck down by a most intense choking, and could not get a breath. The feeling was relieved by emptying my canteen of water over my head and chest. Later, I heard reports of whole groups of tourists being similarly stricken, to the point that some people had fainted away, and had to be resuscitated outside. I cannot say if this is an effect of poor ventilation or not, but in my own case, I was the only one out of 8 people in a tour group to be badly affected. Given my observations of stunted and killed seedlings within conical and pyramidal accumulators, it seems possible to me that these effects are the result of a toxic accumulation or overcharge effect. More work needs to be done to clarify these factors related to shape, as well as accumulator use in energetically stagnated environments, such as deserts. See the chapter on "Warnings and Dangers" for more details.

H) Corners of accumulators do not have to be precisely constructed, nor do layers have to be air tight or precisely fitted, though one certainly wishes to have as neat and clean of construction as possible. In some cases, I have seen metal boxes loosely wrapped with layered steel wool and cotton, felt, or wool. Also, some have used tin cans, as used for food preservation, wrapped with plastic, and then placed inside another larger can which was, in turn, wrapped with more plastic. These tin-cans were nested inside each other to make reasonably effective four or five ply accumulators, for seed charging or other purposes. They do not look especially neat or "scientific", but they do function.

I) Accumulators should be kept where fresh air can circulate. The door or lid to the accumulator should also be kept partly open when not in use. Its interior may be kept fresh and sparkling by keeping an open basin of water sitting inside when not in use. Periodically wipe the interior and exterior clean with a damp cloth.

J) Larger accumulators used by humans or farm animals are best kept outdoors under a sheltered area, where rain will not fall on it. Good air circulation and sunlight will assist with the accumulation affect. The best location for accumulator research would be inside a large wooden barn in the countryside, away from all kinds of electrical transmission lines, electromagnetic devices, and nuclear facilities. This finding on the best environment for the life energy is in full agreement with more recent findings on *house ecology*, wherein a constructed habitat is critically reviewed for toxic effects upon its inhabitants. See the "Warnings and Dangers" chapter for more details.

K) The accumulator will not develop a strong charge during wet, rainy weather. On such days, the orgone charge at the Earth's surface is very low, most of it being taken up into the storm clouds overhead or at a distance. The strongest orgone charge is found in the accumulator on clear, sunny days, when the orgone charge at the Earth's surface is also quite strong.

L) Orgone accumulators used at higher altitudes tend to yield stronger charges than at lower altitudes; lower latitudes may yield stronger charges than higher latitudes; lower humidity atmospheres tend to yield stronger charges than higher humidity atmospheres. Periods with many sunspots and solar flares coincide with periods of stronger orgone charge, as compared to periods with few sunspots and flares. Alignments between the Earth, Sun and Moon, during full and new moon periods, appears to yield a stronger, more excited charge in the atmosphere, and within the accumulator.

M) If you run a controlled experiment with the accumulator, do not place any relevant instruments immediately adjacent to it. Remember that the accumulator has an energy field, and will partially influence nearby objects in a manner similar to those kept inside it. The electrical or electromagnetic fields of various instruments might also disturb or otherwise affect an accumulator, making this caution doubly important for the research scientist.

N) Do not use any household electrical appliances connected to a wall plug inside or near to the accumulator. Neither should portable computers, TV sets, or other radiating devices be used. These will disturb the energy inside. The interior metal walls also conduct electricity, and there may be a danger of electrical shock. For human-sized accumulators, use a battery powered reading lamp if light is desired, or place a strong lamp just outside the door opening. Many people use such a light to read a book while sitting inside. Radio *receivers* do not appear to have a negative effect if used in the room, but the effects of "walkman" type headsets inside the accumulator are unknown.

O) For experimental accumulators, realize that any organic or moisture-bearing materials which are placed inside will absorb the orgone charge. Do not unnecessarily store or bring items inside an accumulator.

P) For human sized accumulators, one wishes the exterior walls to be no more than 2 to 4 inches from the skin surface. When sitting inside, it is best to partially or completely disrobe, as heavy clothing will interfere with absorption of the orgone radiation. A wooden chair or bench may be used as dry lumber is a relatively poor absorber of the orgone. Metal chairs are also OK, but may be uncomfortably cold to sit on.

Q) **NOTE: A too-frequent or too-long use of the accumulator may lead to symptoms of overcharge, such as pressure in the head, slight nausea, general ill-feelings or dizziness. In such a case, leave the accumulator immediately and rest in the fresh air for a moment. Such symptoms will go away in a few minutes. However, Reich warned persons with a history of overcharged biopathies to use the accumulator only with caution, and then only for shorter periods. These overcharged biopathies include: hypertension, decompensated heart diseases, brain tumors, arteriosclerosis, glaucoma, epilepsy, heavy obesity, apoplexia, skin inflammations, and**

conjunctivitis.

R) The question of "how much is enough" is related to one's own energy level, and is primarily a subjective determination, different for each individual. No one ever tells you how much water to drink to quench a thirst. You simply drink until you have the feeling of "having enough". The same is true regarding the use of the accumulator. When you have the feeling of "enough", then get out. With most people, this will be sometime after they have reached the point where their own energy field is gently *luminating*, or glowing with a warm excitement at their skin surface, and after sweating has commenced. If you are unsure about these kinds of feelings, be patient, as with some people, it may require many sessions before they can really feel the energetic effects. A good rule of thumb is to limit the sitting period to no longer than about 30 to 45 minutes. It may be used more than once a day, however. One should not attempt to "nap" inside for prolonged periods. Additional information on these bioeffects is given in the chapter on "Physiological and Biomedical Effects".

S) The qualitative state of the orgone, as well as its absolute charge, are constantly varying at any given location on the Earth's surface. Weather cycles cause the accumulator to vary its charge, and toxic environmental conditions (oranur and dor, see below) may periodically or chronically contaminate the accumulator, making its use potentially unsafe. Experimental use of the accumulator therefore demands that one learn about weather cycles and other environmental factors.

8. Warnings and Dangers: The Effects of Oranur and Dor

A common problem with use of the accumulator is the difficulty in finding an energetically clean environment in which to use it. The orgone energy in the atmosphere is very sensitive to certain kinds of disturbance and agitation. Much in the manner of living protoplasm, orgone energy can be *excited* or *irritated*, and certain environmental influences can drive it towards a toxic condition. If the energetic atmosphere in your home or neighborhood has been made toxic in this manner, use of an accumulator is disadvised, or advised only with great caution, as it will be very difficult to accumulate anything except a toxic charge.

For example, **orgone accumulators, particularly those intended for biological experiments or human use, should never be used in rooms with the following orgone-irritating devices:**

fluorescent lights
television sets
computer or microcomputer
other cathode ray tube devices
microwave ovens, or eddy-current stoves
electric blankets (even if only plugged in, and off)
diathermy, x-ray machines
sparking electric motors
induction devices or coils
other electromagnetic devices
ionization-type radioactive smoke detectors
clocks, wristwatches, or other devices containing radioactive, glow-in-the-dark materials (phospholuminescent materials, which work on the principle of absorbed visible light, are OK)
other radioactive materials, or strong chemical fumes

Orgone accumulators should not be used even in the same buildings where the more powerful of the above kinds of devices (such as x-ray machines) are used, or were recently used. Experiments by Reich, and more recently by others in large German hospitals, have demonstrated that x-ray equipment will destroy the life-enhancing effects of the orgone radiation. Additionally, there is a *persistence effect*, wherein toxic energetic conditions remain for a time after the irritating devices are shut down and removed from a room or building. **Orgone accumulators should likewise not be used in the immediate neighborhoods or vicinities where the following facilities are located:**

airport radar systems
cellular telephone or microwave relay towers
very high-tension power lines
AM, FM, or TV broadcast towers
nuclear power plants, storage facilities,
  or nuclear waste dumps
military installations with nuclear bomb storage
past or present nuclear bomb testing areas

Reich and others associated with him made warnings about these devices in the 1940s and 1950s, but only today do we see epidemiological studies corroborating their life-negative effects. Part of this problem has hinged upon the difficulty that, by simply demonstrating a correlation between two events, you do not prove causality. One has to show or demonstrate just what the mechanism is, and objectively demonstrate each step between the two correlated events, before cause and effect are proven. This is in most cases a very wise policy, but it is very unevenly applied in the world of the sciences. Orthodox theorems are rarely subjected to valid critical review based upon their failures to meet this strict criteria (eg, "bad genes", "viruses", etc.), while unorthodox theories are denied funding or simply thrown out or repressed for whatever weaknesses they may have. Industrial polluters may also raise this issue to avoid taking responsibility for the environmental damage they have done.

Regarding energetic questions, according to the best calculations of the physical scientists, low-level radiation *ought not* to have a deleterious effect upon the living system. The energy present in the low-level radiation, *as detected with conventional radiation detection instruments*, is simply not sufficient to do significant damage. And yet, the damage occurs. I emphasize the concern about "conventional radiation detection instruments", because a major fallacy of physics is that if an instrument does not measure an environmental disturbance, then no disturbance has occurred. The error here lies in the false assumption that their energy detection instruments must be detecting 100% of any disturbance. This unprovable assumption is, of course, challenged by biological or epidemiological evidence which demonstrates that an effect does exist. There is furthermore a great distrust of the body in the modern sciences, in that average people who are made sick by our modern energy radiating devices often are not believed, or are viewed suspiciously.

It is precisely here that Reich's findings on the orgone energy provide a clarification, as the life energy (and disturbances within it) *cannot be detected with ordinary nuclear or electromagnetic sensing instruments.* One has to modify the instrument to pick it up, or use entirely different methods. The orgone is also an interconnecting energy continuum, which provides a connection between the offending facility or appliance (nuclear plant, microwave tower, fluorescent light, TV set) and the living creature that is affected. As the local orgone energy field of the Earth, or the energy field of a home is badly disturbed and agitated by these devices, so too does the orgone energy field of a person in that environment become disturbed.

Modern physics partly acknowledges these connections, in that all nuclear bombs, nuclear reactors, and related facilities are said to radiate unshieldable, undetectable, theoretical *neutrinos* in tremendous quantities. These neutrinos race out from the facilities, penetrating all forms of ra-be done only on a very crisp, clear, and sparkling day, when the orgone charge at the Earth's surface, and in the accumulator, is quite strong and lively. Otherwise, charging may have to take place for slightly longer periods. Also note that seeds can be overcharged; attempts at charging seeds for 30 days or more often result in little difference between controls and charged seedlings, or even stunted growth.

E) Orgone Charging of Potted Plants: This can be done by charging up seeds prior to planting, as discussed above, or by charging up soil or water before using. One can also make a "wrap around" accumulator, using a metal can with the ends removed, and plastic and steel wool layers wrapped around the outside. Be sure that the final outside layer of plastic is fairly thick, and do not use aluminum materials. Leave the steel wool in a fluffy condition; don't compress it.

F) Home Seed Sprouting Experiments: The life-positive effects of the accumulator may also be observed in the way it enhances seed sprouting. Build an accumulator to house your seed sprouting apparatus. Store one sprout container in a darkened area away from the orgone accumulator, and another inside the darkened orgone accumulator. Make sure the temperature, ventilation, and light exposure of the two groups is identical and, once again, keep both groups away from oranur-producing devices. Measure the quantity of seeds going into each container, and make sure the quantity of water in each is about the same. Observe and record any subsequent differences in growth and taste. The accumulator group should have a greater growth and yield.

G) Laboratory Seed Sprouting Experiments: Obtain two small shallow glass dishes with a flat bottom, or two shallow glass laboratory culture dishes, about 4" diameter with a 1" lip. Into each dish place around 20 or 30 dry mung beans, to form a single layer of beans on the bottom of the dish. Add a measured quantity of water to each dish, which only halfway covers up the beans. The tops of the beans should remain exposed to the air, while the bottoms are wet. Place one dish of beans into a small but strong orgone accumulator, and the other dish into a control wood or cardboard enclosure of similar dimensions, but with no metals. Cover both the accumulator and control enclosure with a layer of black plastic, to seal them against any intruding light. Place the enclosures in a well-ventilated area, of equal temperature, and out of the direct sunlight. The enclosures should be in nearly identical environments with respect to light and temperature, but not placed closer to each other than about a meter. Again, no oranur-producing devices should be nearby. Each day, open the enclosures up and add as much water as is needed to keep the bean dishes wet to approximately the same height as originally was necessary to cover the beans halfway. If one dish begins to grow more quickly it will require more water, and this should be provided on demand. After one of the dishes of sprouts has reached about 4" high, record your observations of germination rate, length or weight of sprouts, general appearance, and other characteristics. Contrast the two groups. The accumulator group should have a greater growth and germination rate.

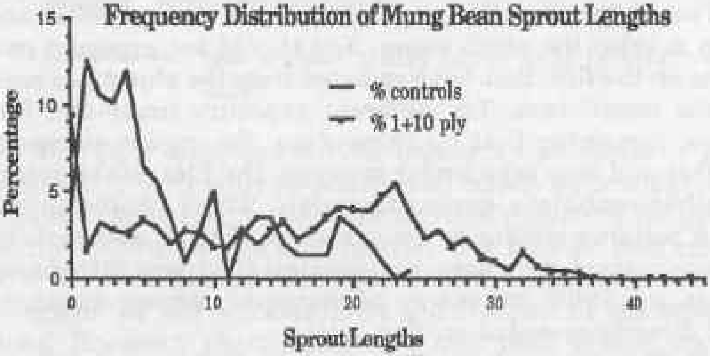

Contrast of mung bean sprout lengths between a group sprouted inside an orgone accumulator, and a group sprouted inside a control enclosure. (from DeMeo, J.: "Seed Sprouting Inside the Orgone Accumulator", *J. Orgonomy,* 12:253-258, 1978)

H) Passive Life Energy Photographs: Orgone energy field photographs can be made in a manner similar to that used to make *Kirlian* electrophotos, except that no electricity is needed. The techniques given here were developed by Thelma Moss, who pioneered the techniques of energy field electrophotography. From Dr. Moss' descriptions, you will need either a darkroom and photo lab, or access to a camera shop which can develop individual sheets of photo print paper. First, obtain some light-sensitive color or black and white print paper, making sure you do not open the package except in complete darkness. Obtain also a separate, empty, light-tight film box in which you can run your experiments. While in the dark, remove a piece of film paper and place it on the bottom of the empty film box. On top of the sheet of film, place a flower bud, leaf, piece of fruit, sprouting seedling, magnet, or other energized, living, or once-living object. Close the box and wrap it completely inside an orgone energy blanket, or place it inside a strong orgone accumulator. Make sure the film box is light-tight; cover it and the blanket with black plastic, or otherwise insure that no outside light will reach the film. Wait a day or two, or up to a week, and then develop the photo paper. You should see exposure patterns on the film that have radiated from the object you used in the experiment. Try different exposure times and film types; remember that on rainy days, the orgone charge is weaker and may take longer to expose the film. Make note of weather conditions during the trials. These photos should yield patterns similar to those seen on Kirlian electrophotographs, except that here, no electrical field was introduced. These are 100% *life energy photographs,* orgone-enhanced and directly recorded on film.

I) The Accumulator Temperature Differential Effect: Reich demonstrated that the warm glow felt inside the accumulator possessed an objective aspect which could be measured with a sensitive thermometer. An air-tight orgone accumulator will spontaneously warm up the air inside itself by a few tenths of a degree, up to several degrees. This temperature increase will make the accumulator interior slightly warmer than the surrounding air temperature, or

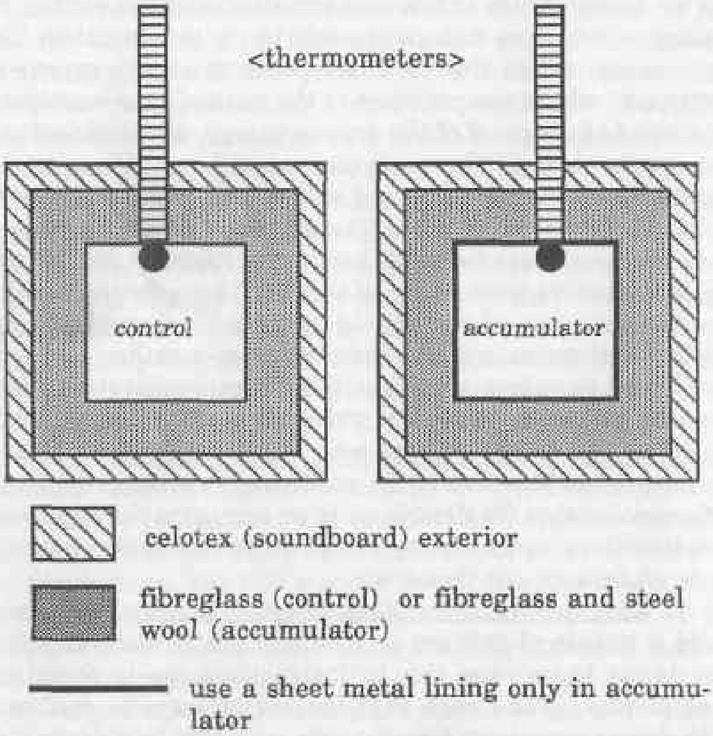
<thermometers>
control
accumulator
celotex (soundboard) exterior
fibreglass (control) or fibreglass and steel wool (accumulator)
use a sheet metal lining only in accumulator

The To-T Experiment: The orgone accumulator (right) and control (left) must be matched as closely as possible with respect to size, ventilation, and thermal dynamics for quantitative orgone energy experiments. The interior and exterior of the control enclosure should be the same size and dimensions as the accumulator, with identical lid dimensions. However, sheet metal and steel wool should not be used in the control enclosure. While metals are used in construction of the accumulator, they are strictly excluded from construction of the control. In the control, additional plastic or fibreglass layering is used in the place of steel wool. The thermal resistance *and* heat capacity *must be as closely matched as possible. A similar set of environmental conditions must also be maintained for the two enclosures.*

the air temperature inside a thermally-balanced control enclosure which does not use metals in its construction. This experiment, called the To-T (temperature in the orgone accumulator minus temperature of the control) was considered by Reich to be a proof of the orgone energy, and a violation of the second law of thermodynamics. Albert Einstein once replicated the experiment and called it a "bomb in physics"; a fascinating booklet titled *The Einstein Affair* documents the correspondence between Reich and Einstein on the matter. A definitive evaluation of the To-T experiment requires the construction of thermally balanced accumulator and control enclosures, careful monitoring of weather and environmental temperatures, sensitive thermometers capable of recording down to tenths of a degree, and prolonged systematic measurements. Those who wish to reproduce this experiment should consult the published reports given in the reference section for details. It is an area ripe for innovative investigation, and I strongly encourage the experimentalist to carefully seek out this effect.

J) The Accumulator Electrostatic Effects: Obtain or build a simple aluminum or gold leaf static electroscope. If you do not know what this is, instructions can be found in a good library. Make sure that the electroscope is calibrated with degree markings, from 0 to 90, such that its degree of deflection can be accurately measured. By running a plastic rod or comb through your dry hair, you can gather a significant static electrical charge and transfer it to the electroscope. Using a stopwatch, or a watch with a second hand, determine how long it takes for the electroscope to slowly lose its charge into the air, through a predetermined deflection angle. For example, you want to know how long it will take for the electroscope to discharge from a 50 to a 30 degree angle. You therefore should charge the electroscope up to a deflection angle *greater* than 50 degrees, waiting until it discharges to the 50 degree mark. Once this happens, you can count the number of elapsed seconds that pass until it reaches 30 degrees. The time elapsed is the *electroscopical discharge rate*. On sunny days, the discharge rate will be quite slow, while on rainy days, the discharge rate will be very quick, so quick that you might not even be able to measure it. If you time the electroscopical discharge rate inside an orgone accumulator, you will find that *it takes a longer time to discharge in the accumulator than in the open air*. The difference between the discharge rate inside the accumulator, and the discharge rate in the open air, is called the electroscopical discharge rate differential. This differential will be large on clear, sunny days, and minimal or zero on rainy overcast days. On rare occasions, an electroscope that is only weakly charged, or even completely discharged, may--if allowed to soak inside an orgone accumulator--spontaneously charge itself up to a higher level. All of these effects will vanish on rainy, overcast days. For more details, see the citations in the "Reference" section.

K) The Accumulator Evaporation Suppression Effect: This experiment requires a sensitive weighing scale that can measure to fractions of a gram. It also requires an accumulator and a thermally-balanced control enclosure of similar dimensions. For this control, do not use water-absorbent materials in the interior; instead, line the interior of the control with a non-metallic waterproofing material, such as plastic, enamel or varnish. Obtain and weigh two small, identically shaped and sized glass dishes of about 4" diameter and 1" high. Weight the dishes when empty, clean and dry. Next, add identical quantities of water to each vessel, filling them about halfway, and weigh again, calculating via subtraction the weight of water in each dish. Place one vessel of water inside the orgone accumulator, elevated on a small wood block, such that the bottom of the dish does not come into direct contact with the metal interior of the accumulator. The lid of the accumulator should be shut, but fixed open with a crack such that air may circulate. It should not be placed in a windy or sunlit area, however. Place the second vessel of water inside the control enclosure in a similar manner, on an identical wood block, and also prop its lid open. Place it in a location at least a meter away from the orgone accumulator, but with similar light, temperature, and wind characteristics. You may wish to drape a piece of black plastic over both the accumulator and control, in order to

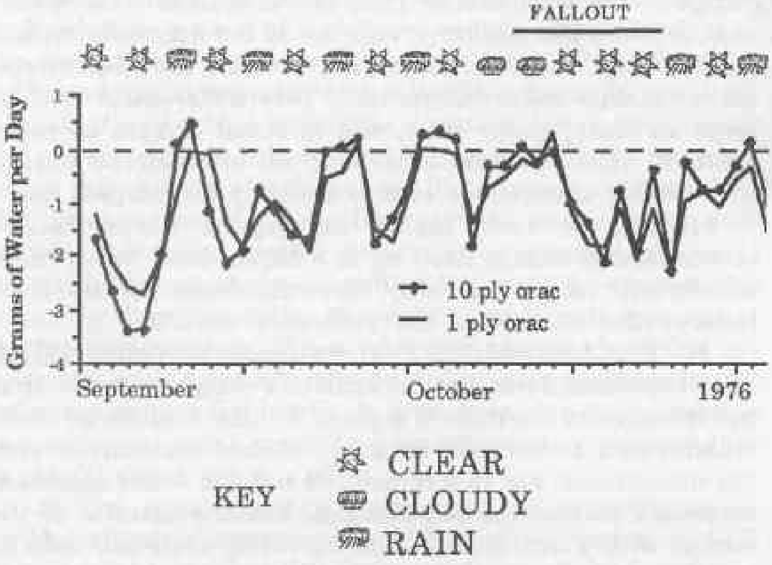

Water Evaporation Curve, EVo-EV: The curves identify the amount of water evaporated each day from a one cubic foot, ten ply orgone accumulator, and a similar one ply accumulator, minus the amount evaporated from a control enclosure. As the accumulator builds up its charge on clear, sunny days, it suppresses the evaporation of water inside itself. The control enclosure, however continues to evaporate moisture at a relatively high rate, up to several grams per day more than the accumulator. On wet, stormy days, the effect vanishes as orgone charge is lost at the Earth's surface, being taken up into the stormclouds. Disturbances in the regularity of the curve may also occur, such as (above) when radioactive fallout arrived at the laboratory site causing the accumulator to go temporarily "dead". (from DeMeo, J.: "Water Evaporation Inside the Orgone Accumulator", *J. Orgonomy*, 14:171-175, 1980) control for slight differences in light. Wait exactly 24 hours and remove the dishes of water, being careful not to spill any. Carefully weigh the dishes and compute the evaporative loss for the 24 hour period. Make this measurement once per day, preferably in the late evening, such that you can determine the amount of water evaporated each day from each container. You should find that the control enclosure evaporates significantly more moisture on clear, sunny days, when the accumulator suppresses water evaporation. On rainy days, when the accumulator no longer builds up a charge, the evaporation in the accumulator and control will be nearly identical. Subtract the quantity of water evaporated in the orgone accumulator from the quantity evaporated in the control for each 24 hour period. This quantity, called EVo-EV, will reveal the changing quantity of orgone energy charge in the local atmosphere, and in the accumulator. The evaporative values on any one day are less interesting than the dynamic manner in which the evaporation differential increases and decreases, according to the orgone energy charge at the Earth's surface.

14. Questions and Answers

- Q: If the orgone energy really exists, why don't we hear about it from scientists working in the universities?

A: Scientists working in the universities and research institutions have engaged in verifying research on the bions, orgone accumulator, and cloudbuster, and on the bioelectrical aspects of life, which Reich also pioneered. For example, Dr. James DeMeo, author of this *Handbook*, did research on the weather-related aspects of Reich's discoveries while he was a graduate student and Instructor at the University of Kansas. He continued with that research while a member of the faculty at Illinois State University and the University of Miami. Müschenich and Gebauer, of the University of Marburg in West Germany, recently completed a double-blind, controlled study on the physiological effects of the orgone accumulator on humans. Other scholars with a research or historical interest in the works of Wilhelm Reich have held positions at Harvard University, Temple University, the State University of New York, York University, McGill University, and elsewhere. Other research scientists have repeatedly verified and confirmed Reich's findings. Workshops and courses devoted to his works are now held at a few colleges and universities in the USA. Nonetheless, the history of science repeatedly shows that large institutions do not easily accommodate innovative research which may force radical changes in the major theories of science.

- Q: Can an accumulator be used during wet or cloudy weather?

A: Use of an accumulator during wet weather conditions will not be harmful, but it will be less effective, as the charge is significantly lower or absent at those times. It is best to use it during clear and sunny weather, when the atmospheric orgone energy continuum is strong and expansive, and the charge at the Earth's surface is greater.

- *Q: These accumulating devices are quite simple to construct. Aren't a lot of them accidentally constructed?*

A: A lot of "accumulators" are being constructed, without knowledge of the people involved. Every mobile home or house with a metal skin or side paneling will accumulate a charge, and a toxic one if aluminum is used. Oranur, and other toxic effects appear to readily occur in such houses, which are filled with all the modern orgone disturbing electromagnetic appliances, such as TV sets, microwave ovens, fluorescent lights, and so forth. Epidemiological studies that would address these general observations have never been performed.

- *Q: I have an old styrofoam beverage cooler. Can I line it with aluminum foil and make an accumulator?*

A: You can try this, but don't expect any firm results unless you comprehend and take into consideration virtually *all* of the procedures and warnings given in this *Handbook*. Styrofoam and aluminum are life-negative accumulating materials. If you run a biological experiment, you may wind up demonstrating only a life negative effect. For the scientist interested in orgone energy, these considerations are even more crucial and cannot be ignored.

- *Q: My accumulator gave very good charge the first months when it was in use, but now does not yield a good charge any more. Why is this?*

A: It is likely that the accumulator has been contaminated with dor. Some researchers have noted this effect, where the accumulator goes temporarily "dead", and hence keep their accumulators outdoors, sheltered from rain, but in the fresh air, with the lids or doors open so that air can circulate inside quite freely. You may be able to refresh a "dead" accumulator by wiping it inside and out with a damp cloth, every day for a week or so. Also, keep a bowl of water, or a draw bucket with draw tubes, inside it when it is not in use. Change the water in this bucket every day. Also, be certain that the accumulator is not near any of the oranur-producing devices previously identified, and that your neighborhood is as oranur-free as possible. The accumulator can also be sun-charged, by allowing it to sit in the direct sunlight for a few days. These steps should eliminate any dorish tendencies, and "rekindle" the charge.

- Q: I have heard that sitting inside an accumulator will make a person more sexually potent. Is this true?

A: This is mostly a false rumor propagated by Reich's enemies, who wrote smear articles in the 1940s and 1950s that branded Reich a lunatic, the accumulator a "sex box", and put false words into his mouth about the ability of the accumulator to restore lost sexual potency. However, Reich never made such a claim; in fact, he continually stressed the emotional and psychological foundations of sexual dysfunction, which could not be touched by treatment in an accumulator.

- Q: Is the orgone energy accumulator legal? Can I get in trouble with the law for building or using one?

A: There is no law against orgone energy, or the orgone energy accumulator. You may build, own, and use the blanket or accumulator in your own home, or elsewhere, as you choose. It can also be legally used for the self-treatment of any health-related condition, just as you can make very beneficial soups, purchase vitamins, or take soaking baths, without asking a doctor or the police. Understand, however, that forces within the medical community, pharmaceutical industry, and government are hard at work to make it illegal for you to do these things. If you are concerned about protecting your health freedoms, you should join forces with those social organizations that are working to preserve or extend those freedoms. *The price of liberty is eternal vigilance!*

Part III: Construction Plans for Orgone Accumulating Devices

15. Construction of a 2-Ply Orgone Energy Blanket

The orgone energy blanket is the most simple to construct of all the orgone charging and accumulating devices. They can be made at any size, and can be easily transported. You can use small ones while resting, or place large ones under and over a person who is immobilized in a bed. Like a standard accumulator, orgone blankets are not meant to be used for any prolonged period, though one can rest or nap with one if there is a need. In my experience, people will, even when sleeping, push off an uncomfortable orgone blanket just as they would a regular blanket. The following steps tell how to make an orgone energy blanket with final dimensions of 2' by 2'.

A) Obtain enough 100% wool fabric, or acrylic felt, to make three 2' x 2' squares. Also obtain several packages of very fine ("000" or "0000") steel wool pads.

B) Lay a 2' x 2' piece of fabric on a flat surface. Cover the exposed top surface of this fabric with a layer of steel wool, from unwrapped steel wool pads. Spread the steel wool out, so that it is not too thick. You should be able to see parts of the underlying fabric here and there.

C) On top of the steel wool, lay another 2' x 2' piece of fabric.

D) Cover the exposed top surface of this second fabric piece with another layer of steel wool.

E) Finish with another 2' x 2' piece of fabric, placed on top of the last steel wool layer. You now should have

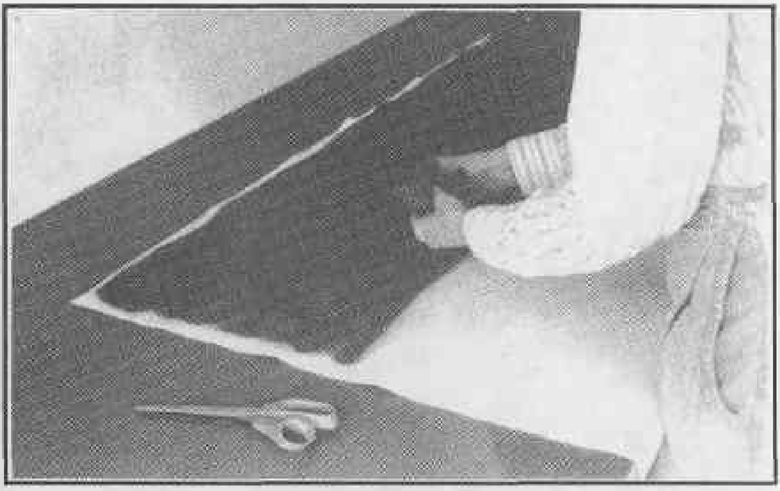

Spread steel wool loosely on section of cloth. Trim edges as shown.

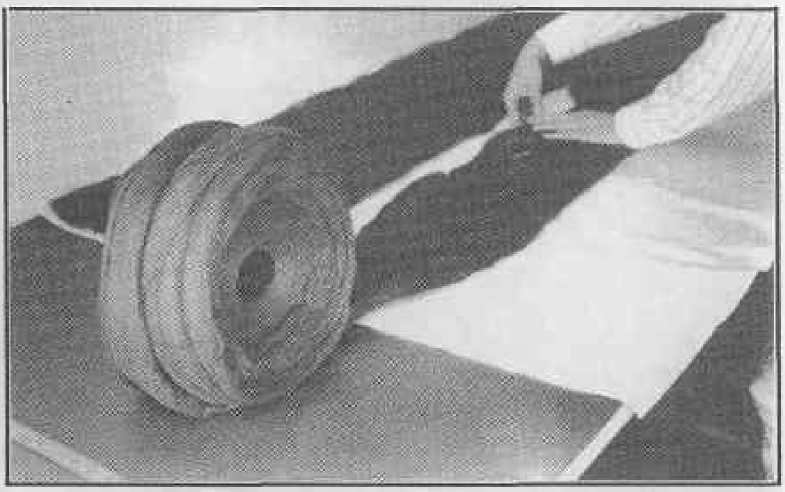

Rolls of steel wool can be purchased from manufacturers, or common steel wool pads, of "000" or "0000" grade, can be obtained at most hardware or paint stores.

Particle masks should be worn during construction to avoid breathing fine steel dust.

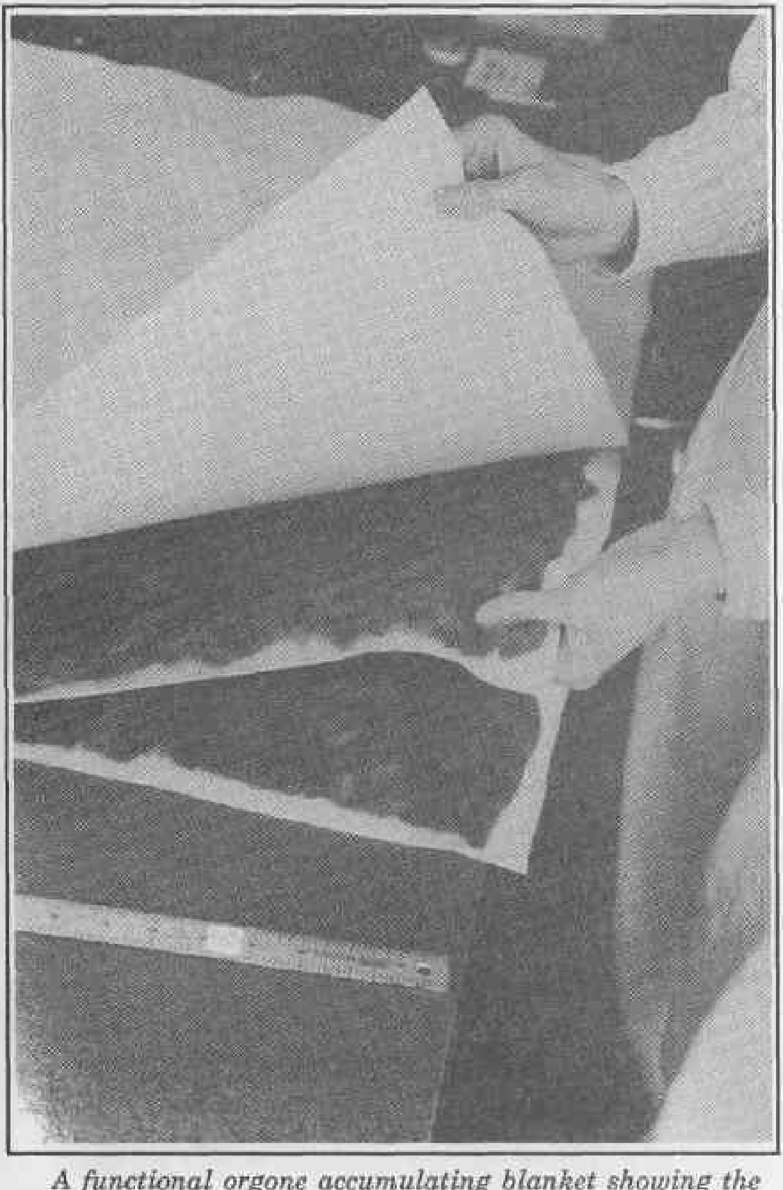

A functional orgone accumulating blanket showing the alternating layers of steel wool and cloth.

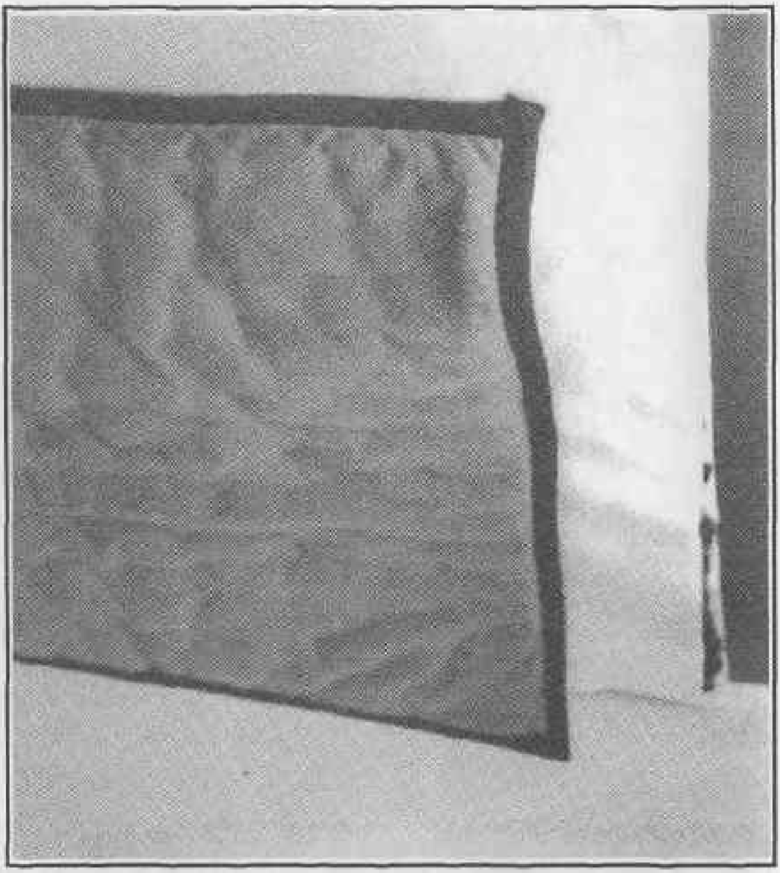

Finish off your blanket with a trim to keep everything together. Several quilt-stitches should be added to keep the insides from shifting around.

three pieces of fabric, with two layers of steel wool sandwiched in between.

F) Trim, stitch, and finish the borders, according to your own tastes and sewing skills.

G) Keep and use the blanket in an environment similar to that advised for a regular accumulator, away from any TV sets, microwave ovens, fluorescent lights, or other electromagnetic or radioactive gadgets. *Never use an orgone blanket with an electric blanket.* It can be stored on a hangar in the open air, or even inside a larger accumulator for greater charging.

H) Do not ever wash or dry clean your orgone blanket, as the steel wool will rust! Spot clean only with a *slightly* damp sponge.

I) Reich once made very heavy orgone blankets, composed of galvanized steel wire mesh, and alternating layers of wool and steel wool. While these work quite well, I find them to be uncomfortable and difficult to use. They do not appear to be any more effective than the simple design given here.

16. Construction of a 5-Ply Garden Seed Charger; The "Coffee Can" Accumulator

One can make a simple garden seed charger from a cleaned food container can or coffee can, using additional steel wool and fabric materials.

A) Empty a large coffee can or other steel or steel/tin food container (no aluminum!), clean it, remove all labels, and dry thoroughly. Make sure you save the cut-out metal lid, or make a replacement from another can, or from galvanized steel sheet metal. Use a can large enough to hold all the seeds you will be charging.

B) Obtain several yards of good 100% wool, or acrylic felt fabric. You will need enough fabric to go around the can about 5 times, plus enough for 5 round top pieces, and 5 similar bottom pieces.

C) Purchase several packages of very fine grade ("000" or "0000") steel wool. You will need enough unwrapped steel wool to cover an area equal to that of the fabric. Again, unwrap the steel wool pads as you need them, and spread it out.

D) Cut the fabric into a very long strip which is as wide as the can is tall. The length of this long strip should be about 6 times the circumference of the can. As you may not have a single strip of fabric this long. You can splice several pieces together.

E) Lay the long fabric strip out flat, and spread a thin layer of steel wool on top of it. Lay the empty can on one end of the steel wool/fabric strip and roll the can up inside the strip. Stop when the strip has been wrapped around the can about five times or more. Add a final layer of fabric to the outside, and stitch or tape it in place so that it will not unravel.

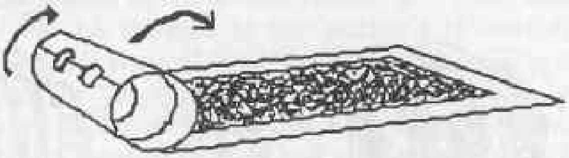

F) Measure the diameter across the top of the can, including the wrappings of fabric and steel wool. Cut out 10 circles of fabric material of this same diameter, 5 for the top, 5 for the bottom.

G) Sandwich steel wool between the fabric circles such that you have 4 layers of steel wool between 5 layers of fabric. Make two of these fabric/steel wool sandwiches, one of which will be used to cover the bottom of the can, and the other for the top.

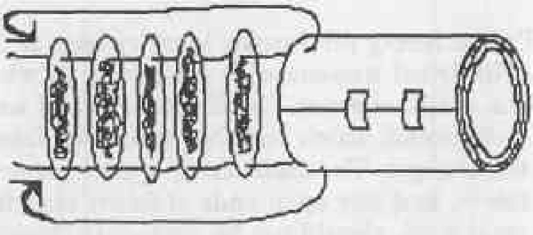

H) Take the metal disk cut from the top of the can and file smooth any jagged edges. Punch two small nail holes near the center, about 1/4" apart. Using a heavy upholstery or knitting needle, thread some heavy twine, wire, or yarn through the center of one of the steel wool/fabric sandwiches, and bring the twine through the holes in the metal can lid. Secure the can lid to the center of the steel wool/fabric sandwich. The steel wool/fabric sandwich should be about 2" wider in diameter than the metal can lid.

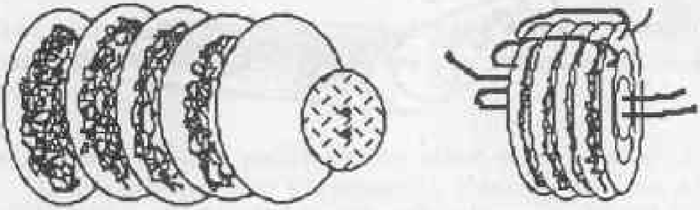

I) Using heavy thread, loosely stitch together the edges of the top steel wool/fabric sandwich (the one sewn to the metal can lid). Also loosely stitch the edges of the bottom steel wool/fabric sandwich together, and sew it to the bottom edge of the steel wool/fabric strip, wound around the can. Except for the top opening, the metal can should now be encased in the steel wool/fabric material.

J) Find a heavy pillowcase, laundry bag, or other larger cylindrical non-metallic container in which to keep the entire charger. Or, if you are good with a needle and thread, stitch together your own fabric cover for the charger. The main thing is that the outer layer of fabric, and any open ends of fabric showing pieces of steel wool, should not be subject to "knocking about" or moisture, such that it starts to fall apart or rust.

K) Review the section on seed charging, in the "Simple Experiments" chapter for instructions and additional ideas on the use of your charger. Or, as an alternative to constructing this accumulator, you could store your seeds inside a large metal cookie tin which would then be wrapped up inside the multiple folds of a very large orgone blanket, or be stashed inside one of the other, larger accumulators. Just realize that the greater the number of plys, and the greater the absolute quantity of materials going into the construction of the accumulator "pile", the stronger will be the charge. At the author's laboratory, for instance, the small 5- ply coffee can charger is stored inside the 10-ply, one-cubic foot accumulator, which in turn is stored inside the 3-ply large accumulator. This is a total of 18 plys, and yields a charge which is readily sensible.

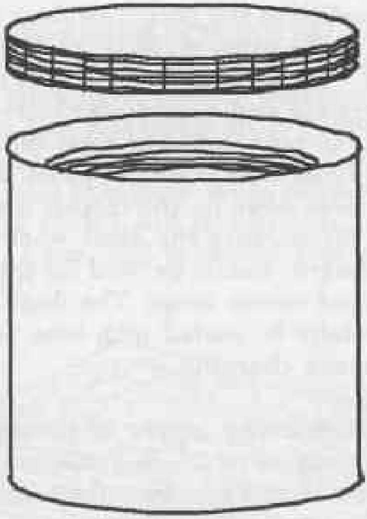

17. Construction of a 10-Ply Orgone Energy Accumulator

A very powerful, one-cubic foot, 10-ply accumulator can be made following the instructions below.

A) Cut six galvanized steel, 27 gauge sheet metal squares, measuring 1' x 1'. Use heavy tape, on the outer metal walls only, to construct a metal cube. Leave the top of the cube open, and do not tape it into place. The interior of the cube should remain bare metal, without any tape showing.

B) Use very fine ("000" or "0000") steel wool, and heavy clear plastic acrylic carpet protector material for construction of the plys. The clear plastic carpet protector is the same material used in model homes to protect carpets from wear, and is often sold on rolls in hardware and department stores. It is not cheap, but works very well. The clear plastic carpet runner should have rows of small tips on the side which normally faces down on the carpet; these tips work very nicely for holding the steel wool in place. Celotex (soundboard) should be used for the final outer layer, with wood corner strips. The final outer celotex may additionally be coated with bees wax and/or shellac to increase charging.

C) Ten alternating layers of plastic and steel wool roughly measure 2" in thickness. This being the case, you should construct the outer celotex casing in the shape of a cube, the interior dimensions of which will be 16" x 16" x 16". Cut six celotex panels with the following dimensions:

Celotex Panels:

top: 17" x 17"
bottom: 17" x 17"
2 sides: 17" x 16"
2 sides: 16" x 16"

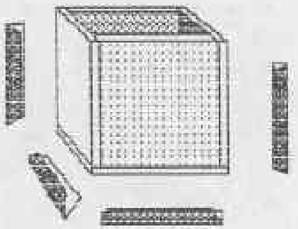

D) Use small nails and glue to fasten five of the six celotex panels together, to make a cube shape. Again, as with the metal box, do not attach the top. Add extra glue to the edges of the assembled celotex box, and allow it to dry before proceeding.

E) Using a mitre box, cut wood corner strips for the outside edges of the celotex box. Nail and glue these wood corner strips to the celotex box for added strength.

F) Cut 20 square pieces of plastic carpet runner, 16" x 16". Put ten of these squares aside for later use. Lay the other ten squares one at a time inside the bottom of the celotex box, tips facing up. In between each plastic square place a layer of steel wool, taken from unwrapped steel wool pads. When finished, the top of the last plastic square will face upward in the bottom of the celotex box, and it should also be covered with steel wool.

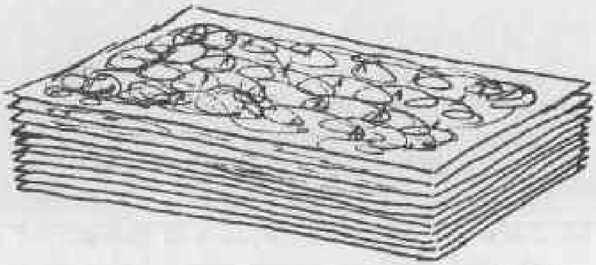

G) Place the galvanized steel sheet metal cube inside the celotex box, on top of the ten plys of plastic and steel wool. If you have constructed the celotex box correctly, the top of the metal cube should be about 2" below the top of the celotex box, and a space of about 2" should exist between the sides of the metal cube and the interior sides of the celotex box.

H) Cut 20 pieces of plastic, 12" x 16", and 20 more pieces, 12" x 12". These will be used to fill the side spaces between the metal cube and the celotex. Layer each plastic piece with steel wool, and stack into bunches of ten layers each. Do this on a flat surface before attempting to place them into a vertical position, in between the celotex and metal boxes.

I) Place the two stacks of 16" x 12" plastic/steel wool between the celotex and metal cube, on opposite sides of the metal cube. An outer layer of plastic should lay against the inner wall of the celotex box, while an inner layer of steel wool should rest against the outside of the metal box. The upper edge of the plastic should be nearly flush with the upper edge of the metal cube, both of which should remain about 2" below the upper edge of the celotex box.

J) Place the two stacks of 12" x 12" plastic/steel wool in the two remaining spaces between the celotex and metal cube, as given in the previous step.

K) Take the 10 remaining pieces of 16" x 16" plastic carpet runner and layer them with steel wool. Stack them up and set them aside. Unlike prior stacks, however, do not finish the final plastic layer with steel wool.

L) Take the remaining square of galvanized sheet metal, and drill or punch small holes in each corner, about 1/2" from each corner. The holes should be

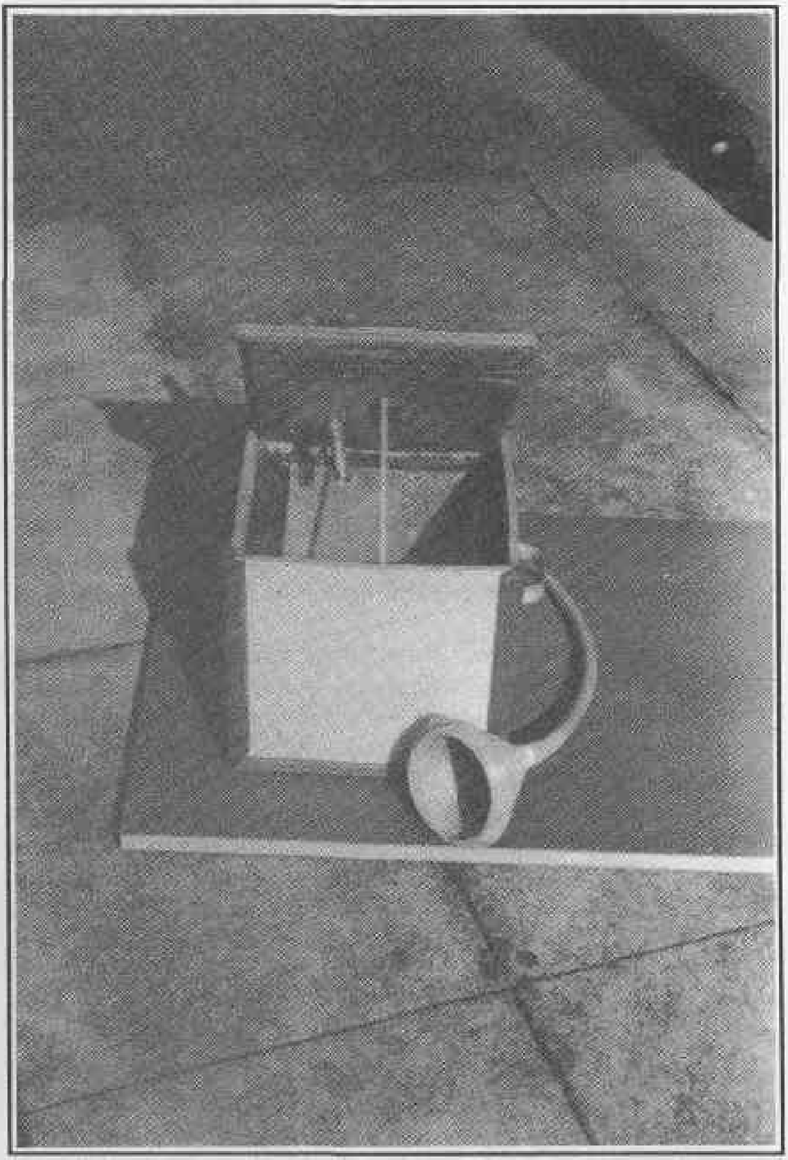

A one-cubic foot, 10-ply accumulator with attached funnel.

large enough to accommodate a long but narrow screw.

M) Find a rough wood or carpeted surface to work on. Lay the stack of plastic/steel wool squares on the last piece of celotex. Center it on the celotex; there should be about 1/2" of celotex appearing all around the stack. Now place the sheet metal square (with the holes) on top of the plastic/steel-wool/celotex stack, and center it also. There should be about 2" of plastic extending beyond the edge of the metal square on each side. Use some masking tape to temporarily hold the celotex/plastic/steel stack together.

N) Using an ice pick, carefully make four vertical holes through the plastic/steel wool stack, and through the celotex, using the corner holes in the sheet metal square as a guide. Do not use a drill, as the steel wool will spindle around the drill bit.

O) Using four skinny bolts, along with nuts and LARGE washers, secure the metal square and plastic/steel wool stack against the celotex square. Use a bolt no longer than necessary, such that the bolt ends will not protrude significantly. When completed, this whole lid assembly should fit snugly on top of the celotex box. The metal plate attached to the lid should closely, but not perfectly, align with the metal cube interior. With the lid in place, only bare metal should face to the interior of the accumulator.

P) For handles, first firmly glue a flat, wide and long wood strip to two outer sides of the celotex cube, near to the top. When completely dry, screw wood or metal handles to these wood strips. A handle should also be attached to the upper, outer side of the lid assembly, using a similar support mechanism. The celotex is simply too lightweight to accept screws or nails alone. You may likewise install a hinge between the lid assembly and the box, or coaster wheels to the bottom, but these are not necessary.

Q) For additional charging strength, the outer celotex walls may be coated with melted bees wax or paraffin (not really necessary), but in any case should be given several coats of protective natural shellac.

R) For additional charging strength, store this cubical accumulator in the bottom part of a larger, human-sized accumulator, under the bench that you normally sit upon. Be sure to maintain a clean and uncontaminated environment for your accumulator, as per the points given in the previous chapters. Prop the lid open when not in use, and store in a clean, dry place, without electromagnetic or nuclear contamination.

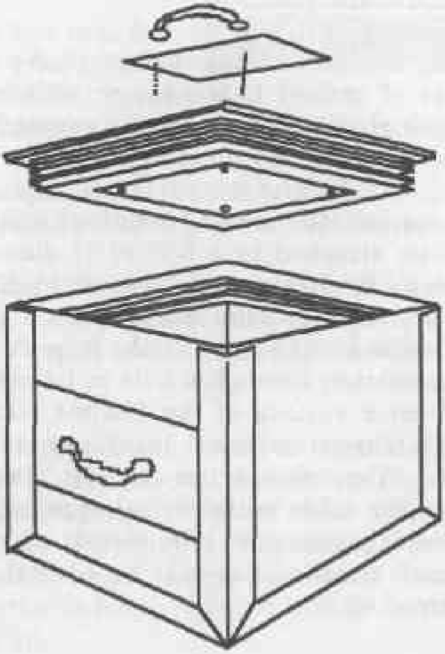

18. Construction of an Orgone Shooter Funnel

The shooter funnel is similar to other accumulating devices, but has an open face allowing for external irradiation of objects. It is often connected to a larger box accumulator, but this is not absolutely necessary.

A) Obtain a galvanized steel funnel with about 6" diameter at the large end, from a hardware, farm supply, or auto supply store. Auto supply stores sometimes sell these with a flexible metal hose already attached, for dispensing oil into a car engine, and this may help in the later attachment to a box accumulator.

B) Coat the outer metal surface of the funnel with a layer of melted bees-wax, or with strips of black plastic electrical tape, leaving exposed the bare metal surface of the funnel interior.

C) If desired, the small "draining" end of the funnel can be attached to a 3/4" or 1" diameter length of hollow, flexible metal "greenfield BX" cable (use galvanized steel, *not aluminum*). The other end of the cable is then run into the interior of a small box accumulator, through a hole in its side or lid. Wrap the outer surface of the flexible metal cable with black-plastic electrical insulation tape. (See page 121.) Your shooter funnel will then draw orgone down the cable to the funnel opening, increasing its radiating strength. Or, simply store the shooter funnel inside a box-type accumulator, to keep it charged up.

19. Construction of an Orgone Shooter Wand

The shooter wand is a very simple means for demonstrating the subjective sensations of the orgone radiation, and also for irradiation of orgone energy into body cavities. Simply store the completed shooter wand inside a well maintained accumulator, and remove it for use when necessary. Under relaxed conditions, most people can hold this wand in the hand, or place it on the solar plexus or upper lip, and readily feel the soft radiant glow of the orgone energy.

A) Obtain a pyrex test tube of about 3/4" to 1" diameter, and 6" to 9" long, from a laboratory or medical supply company.

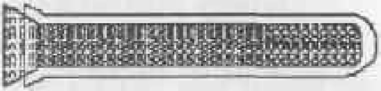

B) Fill the test tube full of fine grade ("000" or "0000") steel wool. Compress to a reasonable firmness.

C) Seal the open end of the test tube with a rubber stopper, and tape it shut with plastic electrical tape.

D) Place the shooter wand inside a small orgone accumulator for a period of several days or weeks before using. Keep it stored inside the accumulator in between uses.

E) If you use the shooter wand to irradiate the throat or other body cavities, or if the pyrex glass otherwise becomes soiled, wipe the glass clean with isopropyl alcohol prior to putting it back inside the accumulator. The wand should always be alcohol cleaned and air dried prior to being replaced into the accumulator for charging.

20. Construction of a Large 3-Ply Orgone Energy Accumulator

This accumulator is large enough to sit in, and is composed of 6 large rectangular panels. Each panel is made from a wood frame, galvanized steel sheet metal (27 gauge), steel wool, fibreglass (*without* aluminum backing), and celotex (soundboard). One side of each wood frame is faced with galvanized steel, the other with celotex, and the three alternating layers of fibreglass and steel wool are sandwiched in between.

A) First compute the size of the panels for an accumulator that will fit your personal needs, adding the necessary dimensions for overlap between the various panels. The side panels and back panel should physically sit on the edges of the bottom panel. The back panel should snuggle between the two side panels. The top panel should overlap and rest upon both side panels and the back panel, covering them. The door panel should, like the back panel, snuggle between the side panels when it is shut. I believe this arrangement is the simplest possible, and most efficient to build. Dimensions are given below for accumulators to accommodate people of varying sitting heights, but of average weight. As the distance of the body surface from the metal walls increases, there will be a reduction in effectiveness of the accumulator. The dimensions of the accumulator should be carefully selected to meet your needs. An additional 1/2" clearance is provided in the width dimension (1/4" each side), such that the door will open and shut freely.

Panel Dimensions:	*Large* *Size*	*Medium* *Size*	*Small* *Size*
Top:	29.5" x 35"	26.5" x 32"	23.5" x 28"
Bottom:	29.5" x 35"	26.5" x 32"	23.5" x 28"
Left side:	35" x 58"	32" x 54"	28" x 50"
Right side:	35" x 58"	32" x 54"	28" x 50"
Back:	25" x 58"	22" x 54"	19" x 50"
Door:	25" x 52"	22" x 48"	19" x 44"

Interior Dimensions:

Height:	58"	54"	50"
Width:	25"	22"	19"
Depth:	31"	28"	24"

You will need:
Height = height sitting erect in a chair + about 3"
Width = shoulder width + about 4" (2" each side)
Breadth = sitting, knee to back distance + about 3"

B) Make wood frames of 3/4" x 1-1/2" pine (called "one by two" in lumber yards), like picture frames, such that the outer edges conform to the computed dimensions for your accumulator panels. Nail and glue all joints.

C) Arrange the open wood frames together, as they will be when the accumulator is complete, to make sure that all dimensions have been properly calculated and cut. If there is an error in your calculations, now is the time to find out, before the more expensive celotex and galvanized sheet metal have been cut.

D) Cut the celotex panels to size, from 1/2" or 3/4" thick celotex sheet, to cover fully one side of each wood frame. Nail and glue the celotex panels to each wood frame. Use 1/4" plywood instead of celotex for the bottom panel (and only the bottom panel).

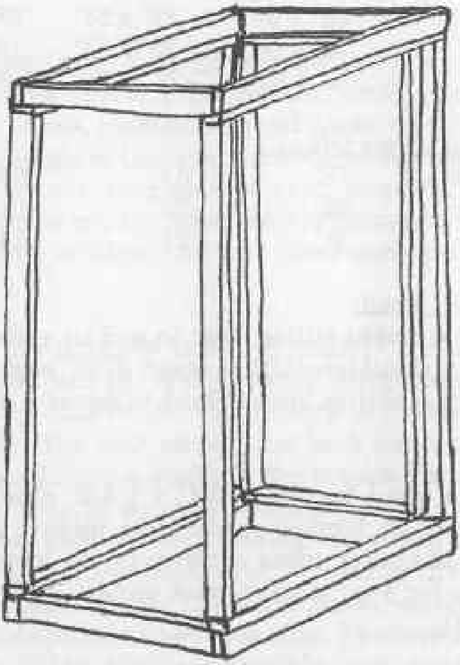

Assembled Wood Frames for Accumulator Panels

E) Cut batts of 1/4" thick fibreglass material to size and place a layer inside each of the open panel frames. Use gloves and a mask to protect yourself. Do not compress. Avoid lumps and holes. You can use wool, cotton, acrylic felt, or rock wool instead, if you wish, but for a large accumulator like this, the costs will be higher, and the accumulation will not be significantly stronger. These other materials may yield a different "feel" to the orgone charge, and if that is important to you, the cost may be justified.

F) Unroll very fine ("000" or "0000") steel wool pads and place a layer inside each of the open panel frames, on top of the fibreglass. Leave it fluffy, at around the same thickness as when unrolled, in as uniform a layer as possible. Some steel wool comes in large rolls which, if you can get it, will speed up construction for large accumulators.

G) Repeat steps E and F, placing a new layer of fibreglass on top of the previous steel wool layer, and another layer of steel wool on top of that.

H) Again repeat steps E and F, placing another new layer of fibreglass on top of the previous steel wool layer, and another layer of steel wool on top of that.

I) You should now have three alternating layers of fibreglass and steel wool contained in the open frame of each panel. The final layer facing you should be composed of steel wool. The panels should also be filling up, and may need to be slightly compressed before the final layer of galvanized steel sheet metal can be added. If you have used some other type of non-metallic material than fibreglass, and if the material lies loosely in the frame, you may have problems with slumping of the plys when the panels are finally sealed and placed in upright position. If this is the case, now is the time to do something to pre-

End Cross-Section of Side, Top, Back and Door Accumulator Panels

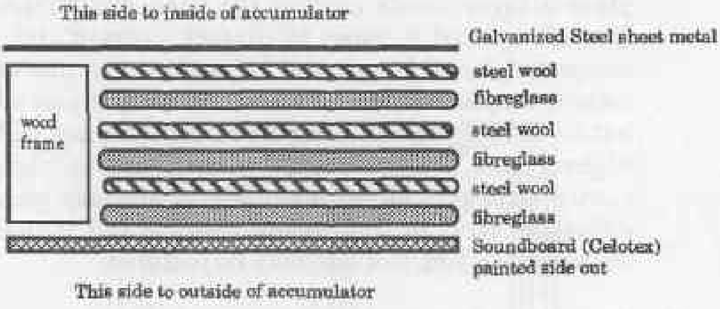
This side to inside of accumulator
Galvanized Steel sheet metal
steel wool
fibreglass
wood frame
steel wool
fibreglass
steel wool
fibreglass
Soundboard (Celotex) painted side out
This side to outside of accumulator

End Cross-Section of Bottom Accumulator Panel

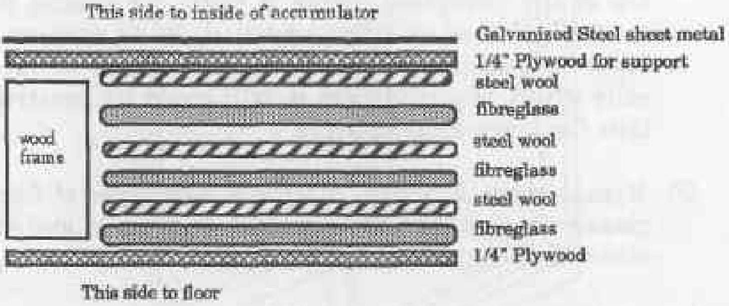
This side to inside of accumulator
Galvanized Steel sheet metal
1/4" Plywood for support
steel wool
fibreglass
wood frame
steel wool
fibreglass
steel wool
fibreglass
1/4" Plywood
This side to floor

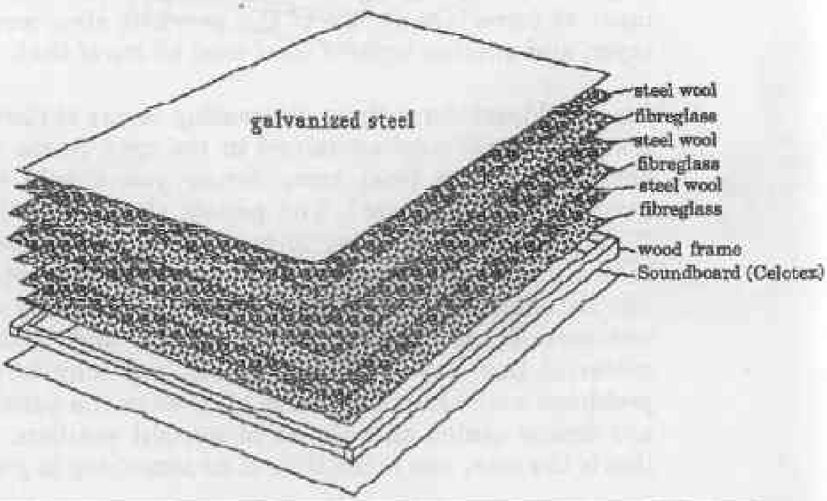
galvanized steel
steel wool
fibreglass
steel wool
fibreglass
steel wool
fibreglass
wood frame
Soundboard (Celotex)

Front View, full-size 3-ply accumulator

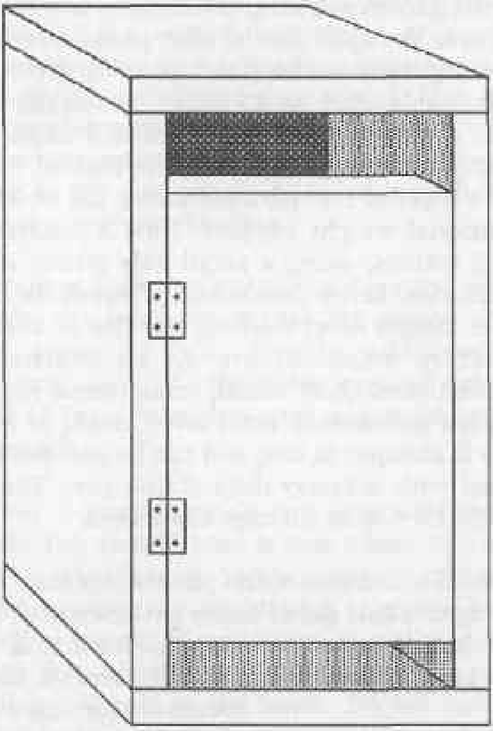

For Warmer, Tropical Climates: *Use door with 3" convection gaps at top and bottom, as per measurements on p.127. (Photo on p.23.) If needed, tack screen strips to door top and bottom, across gaps, to keep out insects.*

For Cooler or Cold Climates: *Use full height door with small window. (Photo on back cover.) Before cutting door materials, adjust door measurements (p.127) to only 1/4" less than full height of side panels. Before assembling door, cut matching 6" square openings in door sheet metal and celotex, centered at face height, then frame opening with 1x2" wood strips. Complete assembly as per instructions.*

Use hinges with removable hinge pins for easier assembly and take-down. Secure inside of door with hook and eye.

vent slumping.

J) Cut the galvanized steel sheet metal to size such that it fits over the open part of each panel, overlapping and covering the wood frames. Use the lightest sheet metal available, such as 27 gauge, which can be cut with hand shears for trimming, and still add to structural strength of the panels. For the bottom (floor) panel, add a layer of 1/4" plywood under the sheet metal, for additional weight support. Nail it securely onto the wood frames, using a small hole punch if necessary. Small steel tacks should easily penetrate through the sheet metal. After nailing, use file or shears to trim all sharp metal corners. As an alternative to galvanized steel sheet metal, some people have effectively used galvanized steel *wire mesh*, or *wire screen*. This is cheaper to use, and can be secured to the wood frame with a heavy duty staple gun. The steel wool should be visible through the screen.

K) Assemble and secure the panels together. Start by securing one side panel to the bottom panel, by using an "L" shaped metal brace at the front and rear of the side panel, near the bottom. Use screws, such that the accumulator can be taken apart later for easy moving. Secure the other side panel in a similar fashion, followed by the back panel. The back panel must be secured independently by small metal braces, placed between the wood frames of the bottom and back. Add the top panel, and secure it to the sides and back in a similar manner. The accumulator should now be quite sturdy, and is almost complete.

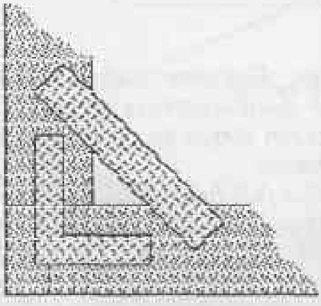

L) Carefully mark and drill holes for door hinges and attach them to the door panel and side panel. Make sure you center the door in a way that leaves equal space at the top and bottom, either for convection gaps (for the vented door style), or as clearance to allow the door to freely swing open and shut (for the full-height windowed door style). Use hinges with removable pins so that you can easily take the door off when moving the accumulator. After fixing the door to the side panel, it should open fully and close snugly, without binding.

M) Attach a hook and eye to the door and side panel opposite the hinge, such that the person sitting inside can secure it shut. Finally, add several coats of natural shellac to the outer exposed celetox, to protect it from humidity and add to its accumulating strength.

N) Your accumulator is now complete, except for a seat. You should have a seat which will allow you to place other accumulator chargers underneath. For this purpose, you might wish to specially construct a wooden bench. Wood is a good material to use, as it does not absorb the orgone energy significantly, and is not cold to the touch. Do not use woods that have been soaked in preservative or formaldehyde, however. Metal chairs are OK, but will be quite cold to sit on unless covered with a light fabric.

O) You may also wish to construct a *chest board,* or *orgone pillow,* for use inside the accumulator. As you sit inside, notice that there is a great distance from your chest to the front metal wall. This large distance inhibits orgone irradiation to your chest. An additional, small accumulator panel, similar to those used for the wall panels, could be constructed for use inside the larger box, to bring the radiation closer to the chest. However, a simpler way is to use a bundle of cotton, wool, or acrylic felt, rolled into a large pillow shape with equal layers of steel wool. The final outer layer should be composed of steel wool, and the entire bundle is then placed inside a thin cotton pillowcase. It should be large enough that it fits very snugly into the pillowcase. By holding this orgone pillow close to the chest, while you are in the accumulator, it will irradiate those frontal areas of your body that are not so well irradiated by the accumulator walls. Leave the orgone pillow inside the accumulator when not in use, to keep it charged up. You can also use this pillow outside of the accumulator, in a manner similar to the orgone blanket, with equally good results.

P) Do not connect electrical appliances to the accumulator. Follow the cautions given in the previous chapters. You can read a book while inside the accumulator, but should use either a strong *external* light source (to shine a beam of incandescent light into the accumulator), or you can use a battery-powered reading light inside. Again: *no fluorescent lights, television sets, heating blankets or pads, or other electrical or electromagnetic devices!!*

poor materials for orgone accumulator construction remain unchanged and time-tested.

Cautionary Note on New "Wireless" Electromagnetic Gadgets

On the subject of safe use of the accumulator (see Part II), we may add the following: Over the last decade, there has been an increased use of new "high tech" devices for telecommunications purposes which actively emit potentially toxic low-levels of electromagnetic radiation: cellular telephones and cell-phone relay systems (often located in populated areas) emit microwave radiations at potentially toxic levels, as well as new remote-control apparatus which employ *active far infrared (close to microwave) frequencies*, such as inventory scanners and various kinds of "wireless" technology. In all cases, orgone accumulators should not be located near to any of these devices, nor should any human being wish to live, work or sleep near them either! New electromagnetic devices should be viewed as contrary for safe use of orgone devices unless proven otherwise. On the other hand, various *passive* infra-red sensing devices (such as automated outdoor security lights) pose no problems.

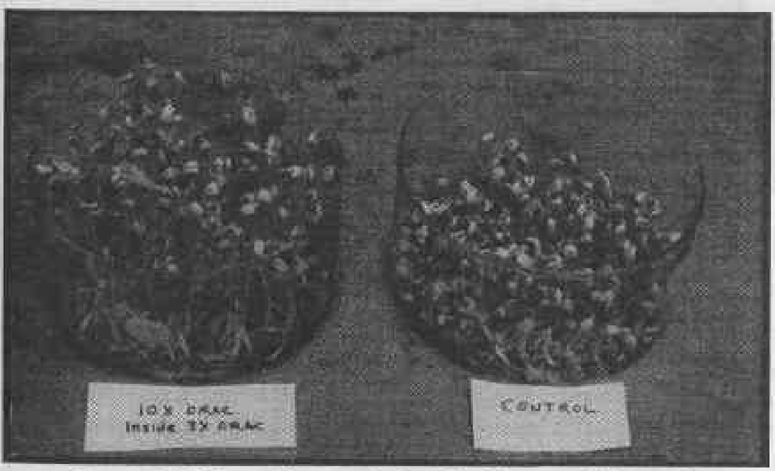

Sprouted Mung Beans: Left side, Orgone-Charged. Right side, Controls. (Experimental protocol p.96-97)

New Publications and Controlled Studies on the Human Bio-Effects of the Orgone Energy Accumulator

In recent years, mainstream publishers in Germany have expressed a growing interest in the works of Wilhelm Reich, and on the subject of his research findings (an interest not currently shared by any mainstream American publisher). Some examples of this interest are given below.

Appendix I of this *Handbook* (page 148-155) presents an extended abstract describing the first double-blind controlled study of human physiological response to the orgone accumulator, as undertaken by Stefan Müschenich and Rainer Gebauer. Their study was completed in 1986 at the University of Marburg in Germany. Dr. Müschenich subsequently wrote a major book on this same subject (in the German language):

Stefan Müschenich, *Der Gesundheitsbegriff im Werk des Arztes Wilhelm Reich (The Concept of Health in the Works of Dr. Wilhelm Reich)*, Doktorarbeit am Fachbereich Humanmedizin der Philipps-Universität Marburg, Verlag Görich & Weiershäuser, Marburg 1995, 425 pages. ISBN 3-922906-54-0.

In more recent years, another similar double-blind and controlled study was undertaken at the University of Vienna by Günter Hebenstreit, producing similar positive results. The Hebenstreit study, like that of Müschenich and Gebauer, used an orgone accumulator, a control dummy-box that looked like an accumulator, and a relaxation-chair in which test subjects were evaluated both before and after exposure to either the accumulator or control enclosure. It produced positive results, I am informed. Unfortunately, we do not have any printed protocols, but can give the exact citation for those who wish to obtain and read the original German-language publication:

Günter Hebenstreit, *Der Orgonakkumulator Nach Wilhelm Reich. Eine Experimentelle Untersuchung zur Spannungs-Ladungs-Formel*, Diplomarbeit zur Erlangung des Magistergrades der Philosophie an der Grung- und Integrativwissenschaftlichen Fakultät der Universität Wien, 1995.

Another German-language title of significance was published in 1998, containing the contributed research papers of

40 different scientific-professional authors on the subject of Wilhelm Reich's social and biophysical findings, to include many papers on the subject of bions, orgone energy, and the orgone energy accumulator:

James DeMeo & Bernd Senf, Editors, *Nach Reich: Neue Forschungen zur Orgonomie: Sexualökonomie, Die Entdeckung Der Orgonenergie (After Reich: New Research in Orgonomy: Sex-Economy, Discovery of the Orgone Energy)*, Zweitausendeins Verlag, Frankfurt, 1998. 898 pp. ISBN 3-86150-239-9.

An Orgone Energy Darkroom (room-sized accumulator) at the Orgone Biophysical Research Lab's high-altitude Greensprings Center near Ashland, Oregon. This structure is made in the form of a large accumulator, with a metal-lined interior and under-layering of fiberglass. Inside are several human-sized orgone accumulators and experimental chargers. The strength of the atmospheric orgone energy charge inside such an orgone room is dramatically increased. The orgone energy can be more easily felt and observed with the eye, and registers more clearly in experiments and with measuring apparatus.

About the Orgone Biophysical Research Lab (OBRL) and Greensprings Center

The Orgone Biophysical Research Lab is a non-profit science research and educational foundation, established in 1978. Over the years, OBRL has supported various laboratory and field research projects, educational lectures and seminars in both the USA and overseas, focused upon the sex-economic and orgone biophysical discoveries of the late, great natural scientist, Wilhelm Reich. OBRL also publishes a journal, *Pulse of the Planet*, on an irregular basis. The founder and director of OBRL, James DeMeo, has been investigating and extending Dr. Reich's original findings in both the social and natural sciences since 1971. Early in 1995, the *Greensprings Center* was established in a vibrant forested region of rural Oregon, to provide a better foundation for continued public outreach and in-depth study of orgone energy functions in nature. The *Center* also has the West Coast's only *Orgone Energy Darkroom*, for experiments requiring a higher energy charge, and for direct visual observation of orgone energy functions. New books (described at right) are also occasionally published, and public educational programs, the *Greensprings Seminars*, are held each summer. Accomplished scholars in the field of orgonomy are invited each year to share their knowledge and experience with interested students and professionals from around the world. Yearly seminars include: *Bions, Biogenesis and the Reich Blood Test, The Orgone Energy Accumulator,* and *Guided Independent Study*. Contact OBRL for an informative brochure and publications catalog, and to get on the international mailing list for seminar announcements.

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Ashland, Oregon 97520 USA
Tel/Fax: 541-552-0118 Email: demeo@mind.net
OBRL's Global Internet Web Site:
http://www.orgonelab.org

Additional Publications Available

(Contact OBRL for ordering information)

Heretic's Notebook (Pulse of the Planet #5): Emotions, Protocells, Ether-Drift and Cosmic Life-Energy, with New Research Supporting Wilhelm Reich, Edited by James DeMeo

Contains 28 insightful essays and research articles by 17 different authors, on natural childbirth, sexuality, archaeology of early human violence, Reich's orgonomic functionalism, exposés on Reich's detractors, Giordano Bruno's work, bion-biogenesis research, Dayton Miller's ether-drift discoveries, emotional effects in REG (psychokinesis) experiments, new detector for orgone energy, dowsing research, cloudbusting desert-greening experiments in Africa, plant growth stimulation in the orgone accumulator, the orgone energy motor and "free energy", plus UFO research, book reviews, and much more, with color cover photos, text- photos and illustrations.
272 pages, Large format $24 Softcover

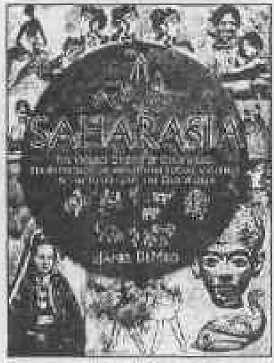

SAHARASIA: The 4000 BCE Origins of Child-Abuse, Sex-Repression, Warfare and Social Violence, In the Deserts of the Old World,

by James DeMeo

Dr. DeMeo's *magnum opus* on the origins of human violence and biophysical armoring, the first geographical, cross-cultural study of human behavior around the world, using Wilhelm Reich's sex-economic discoveries as a basic starting point, presenting world

maps of different behaviors and social institutions. Source-regions (Arabia and Central Asia) for patriarchal authoritarian culture were identified, and migratory-diffusion patterns were traced, back in time, to pinpoint where and how the human tragedy began. Solves the riddle of the origins of human violence and armoring. A breakthrough in the scientific study of human sexuality, psychology and anthropology, and must-reading for every parent, student, professor and clinical worker in the field of human health and behavior. 454 pages, with over 100 maps, photos, and illustrations. Large format with vivid full-color cover, extensive bibliography and index. Softcover $34
Author-Signed Limited Hardbound First Edition $90

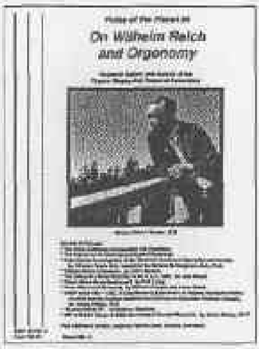
On Wilhelm Reich
and Orgonomy

On Wilhelm Reich and Orgonomy
(Pulse of the Planet #4)
Edited by James DeMeo

Contains Reich's milestone articles on psychic and somatic (mind-body) processes, and on the bioelectrical aspects of human emotion and sexuality, with articles by R.D. Laing on Reich, and a discussion on Reich's work in Denmark when he fled Nazi terror in Germany and was also expelled from the International Psychoanalytic Association. Other papers discuss: Reich's research on biogenesis and discovery of the microscopical *bion*; the discovery of orgone (life) energy, and the orgone energy accumulator. Also featured are articles about the Food & Drug Administration's attack upon Reich, and their present-day war against the natural health movement; the deadly effects from nuclear power plants, and an illuminating scientific challenge to the HIV theory of AIDS — plus other reports on current life energy research, weather anomalies from nuclear bomb tests, a cloudbusting desert-greening experiment in Israel, provocative book reviews, and more! 176 pp. Large format $20 Softcover.

PLANS

FOR
CONSTRUCTING

AN

ORGONE
ENERGY
ACCUMULATOR

Based on information originally distributed by the Wilhelm Reich Foundation

Notes Regarding the Use of the Orgone Accumulator

The Orgone Accumulator is built so as to collect the natural energy of the atmosphere (Orgone Energy) and to make this energy about five times more concentrated inside the accumulator than in the outside air. Since orgone is the same energy that is in the bodies of all living organisms, the accumulator has the effect of increasing the body energy of the user--increasing the natural charge of the user's tissue and blood--thus strengthening the user's resistance to disease.

Orgone is not electricity, and the orgone accumulator has no electrical connections. WARNING: DO NOT ALLOW EXPOSED ELECTRICAL WIRES TO COME IN CONTACT WITH THE ACCUMULATOR!

The accumulator should be used once or twice daily as follows: the user should sit inside the accumulator lightly clothed or without clothing until the user becomes quite warm, or for roughly 15 to 45 minutes. The effect of the orgone will be best if the user relaxes, breathing out deeply but not forcefully. Slight dizziness or heaviness in the head is a signal to come out. Fresh air will eliminate such effects immediately.

In humid weather, the normal time of use should be lengthened, as there is then less orgone in the atmosphere. Air the room in which the accumulator is kept every day, for the increased orgone concentration tends to make the air in the room heavy.

The funnel end from the shooter box-seat is used for local application of orgone. This unattached end should be held close to, but not quite touching, the region in question for between two and ten minutes, depending on the sensitivity of the region. If it is used on the eyes, they should be kept closed. A slight burning sensation in the region that is being treated is a signal that the body has had enough for the time being. In general, the tube should only be used until the area becomes warm. The shooter box-seat tube can be used several times a day.

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Questions Regarding the Use of the Orgone Accumulator

Q. Does it lessen the effect of the accumulator if any part of the body comes in direct contact with the metal walls?
A. It is better if no part of the body touches the metal walls. However this cannot always be avoided and it does not lessen the effect to any considerable degree.

Q. If two or three people use an accumulator rapidly in succession, is the orgone "used up"; does the last one to use it get energy?
A. The effect of the orgone accumulator consists of a mutual excitation of the orgone energy which is concentrated within the accumulator and the body-orgone energy of the user. It can be assumed that the successive use of the accumulator by several persons will not lessen the efficacy.

Q. Should you spend more or less time in the accumulator, depending on the humidity?
A. Since the orgone energy concentration in the atmosphere diminishes with high humidity, it is advisable to prolong the use of the accumulator on very humid days.

Q. Does the funnel for the pipe of the tube box have to be metal?
A. Yes, since plastic or other non-metallic material will tend to "hold" orgone energy, while the metal will give it off immediately.

Q. Can you use the tube box inside a larger accumulator for reasons of more intensity, or is it more advisable to use it outside?
A. The concentration of orgone energy in the tube box will be stronger if it is used within the larger accumulator.

Q. Is it all right to take objects into the accumulator while using it, such as books, magazines, notebook, pen, pillow?
A. There is no objection to taking reading or writing material into the accumulator or knitting or needlework, etc. We would advise against taking pillows into the accumulator because they will soak up orgone energy and thus divert it from the body.

Q. Is it all right to paint the accumulator to match walls?
A. As long as the paint does not contain lead or other metals, the accumulator can be painted in any color. It may also be covered with wallpaper.

Q. If one makes one's accumulator light-tight and then sits inside it, is it possible to see the orgone energy light phenomena that are described in The Cancer Biopathy?

A. No; bodily evaporation under these conditions creates too much humidity and the orgone phenomena cannot be seen when the humidity is high.

Q. What is the difference in strength between a one layer and three layer accumulator?

A. The one layer accumulator, has an orgone concentration, measured electroscopically, of about 3 times that of the surrounding atmosphere. The three layer accumulator, has an orgone concentration of about 4 to 5 times that of the surrounding atmosphere. However, the concentration of the orgone energy does not increase proportionally with the numbers of layers. Thus a tenfold accumulator will have a concentration of approximately 6 times that of the surroundings.

Q. My accumulator does not fit tightly together. Does this in any way lessen the effectiveness?

A. Occasionally when an accumulator is dismantled and put together again, the walls do not close tightly. These cracks, even if they are as large as one inch, do not in any way affect the strength of the accumulator. In fact, experimental accumulators have been built with openings at the top and bottom for circulation purposes.

Q. Can paper, felt or material other than fiberglass be used for the non-metallic layers of the accumulator?

A. Experiments have been made with other materials. However, all these materials are liable to absorb humidity, whereas the fiberglass will not absorb any humidity. Too strong an absorption of humidity would definitely lower the strength of the accumulator.

Q. If you go into the accumulator with a fever, is the fever increased?

A. In most cases, experience shows that the fever will be slightly increased while the person uses the accumulator, but that the temperature will drop below the previous level after the use of the accumulator.

Q. Is there any special time of day when the accumulator is more effective than at other times?

A. Electroscopic measurements show the greatest concentration of orgone energy between 12 noon and 2 p.m. However, these variations in a given day are so small that it will not make any significant difference at what time of the day the accumulator is used. It can easily be regulated by timing.

Construction of a Three-Fold Orgone Energy Accumulator

1. General information

a. The accumulator is made of six panels which are to be screwed together. All panels except the bottom are constructed in the same manner, and differ only in dimensions. Each panel consists of an inner surface of galvanized sheetmetal and an outer non-metallic surface of celotex which encloses a braced wood frame and alternate layers of fiberglass and steelwool.

b. The materials specified may, if necessary, be replaced by other materials: 1/4" plexiglass or 1/4" upsonite along with a 1/4" fiberglass layer may be used in place of the 1/2" celotex. If substitutions are made, some adjustments in dimensions of the frames may be necessary.

c. Consult the accompanying drawings and tables for dimensions, construction details, etc.

2. Construct the frames

a. Cut the 1 1/8" x 1 1/2" clear pine to the specified lengths (see fig. 1). Cut a 1/2" x 1/2" rabbet into one side of each piece (see fig. 2). The bottom panel frame requires two 1/4" x 1/2" rabbets (see fig. 3). Mitre the corners and join with carpenters' glue and 8-penny finish nails.

b. Brace each frame with two pieces of 1 1/8" x 1" clear pine (see fig. 4). Join with two 2 1/2" #8 drywall screws. The top and bottom frame do not need bracing.

3. Attach the outer surface

a. Cut the celotex to fit inside the rabbets of each frame except for the bottom frame. Fasten in place with 1" galvanized wire nails.

---

1. For a five-fold accumulator, increase the dimensions of the frames to allow for four more 1/4" layers, two layers of fiberglass and two layers of steelwool.

2. The 1/2" celotex (which has one side coated with white primer paint) may be known as: white construction board, soundboard, etc. It is basically a composite of wood fibers. Flakeboard, chipboard, etc. are not the same product and are too dense. There is a styrofoam product with the trademark name Celotex; do not use this.

3. fiberglass building insulation

4. What is referred to as 5/4" stock by the building industry actually measures 1 1/8 inch.

b. Cut two pieces of 1/4" finish grade plywood to fit inside the rabbets of the bottom frame. Fasten one piece in place with 1" galvanized wire nails.

4. Place the steelwool and fiberglass in the panels

a. Place a layer of steelwool upon the celotex inside one of the frames. Steelwool pads (oo fine or finer) when unrolled are the correct thickness. Make the layer as uniform as possible; leave the steel wool fluffy.

b. Next place a layer of fiberglass about 1/4" thick upon the steelwool layer. Avoid lumps and holes. Do not compress the fiberglass. The standard 3 1/2" x 15" fiberglass insulation comes in a roll with either a paper or foil backing. Peel off the paper or foil. This type of fiberglass is difficult to peel evenly. Try to peel it carefully into roughly 1/4" thick pieces. Too much unevenness in the layering will cause the sides of the accumulator to bulge. (There is a fiberglass insulation that peels more uniformly but might be difficult to purchase. It is a Manville product called 1/2" duct liner. It comes in a roll 48" wide by 100 feet long and may be available at your local heating and airconditioning shop.)

c. In a similar manner place the remaining alternate layers of steelwool and fiberglass in position (see fig 2).

d. Place the steelwool and fiberglass layers in the other panels.

e. The bottom panel has a different number of layers. Start with a layer of fiberglass upon the 1/4" plywood inside the frame (see fig. 3).

5. Attach the inner surfaces

a. Cut the sheetmetal slightly smaller than the frames. You might need to have the 26 or 28 gage galvanized sheetmetal cut at a sheetmetal shop. It can be cut by hand, but the results may be too rough. File the edges smooth and round the corners. Cut a 9" x 12" hole for the window in one of the 53" x 24" sheets. Figure 4 will give the exact location.

b. Drill 1/8" holes at 1" intervals around the edge of the sheetmetal. They should be 1/4" from the edge.

c. Nail the pieces of sheetmetal to the frames with 3/4" galvanized wire nails. Nail the remaining piece of 1/4" plywood to the bottom frame before nailing the final piece of sheetmetal over it. (See fig. 3)

---

5. Wear protective clothing and a dust mask when handling the steelwool and fiberglass.

6. Steelwool in long rolls can be purchased from an industrial supplier.

6. Attach supports to the bottom panel

   a. Cut two pieces of 1 1/8" x 1 1/2" clear pine 25" long.

   b. Screw them into the outer surface of the panel. (See fig 3.)

   c. Nail two furniture slides to the undersurface of each support.

7. Assemble the accumulator

Accuracy is necessary in fastening the sides, top, bottom and door of the accumulator. You will want to be able to take apart and put back together your accumulator in the event that you need to transport it. It is very bulky when assembled.

a. Pre-drill holes for the 2 1/2" #10 flathead philips screws with a 3/16" drill bit. So that the screw heads will countersink, drill a 1/2" hole 1/4" deep. Figure 5 gives the locations of these holes.

b. Lay the two side panels upright on their long sides. Place the bottom panel upright against the bottom ends of the two side panels and screw together. Then place the top panel upright against the top ends of the two side panels and screw together. Place the back panel onto the side panels between the overlaps of the top and bottom panels and screw together (figure 5).

c. Turn the box over onto its back and place the door on the side panels. Make sure that the door is flush with the top of the box (this will leave a one-inch gap at the bottom to allow air circulation). Mount the hinges to the side panel and to the door (fig. 6). You can hang the door to open either left or right.

d. Now stand the accumulator up.

e. You will need a hook and eye to hold the door closed while you sit in the accumulator. Place it where most convenient.

8. Assemble the seat for the accumulator

You have two options. The simplest is to suspend a piece of 3/4" x 14" x 22" wood on two supports fastened to the lower support braces of the two side panels. The other option is to turn the seat into a combination shooter box and chest panel.

Construct the shooter box-seat

a. Construct two panels in a manner similar to the other panels as explained in sections 2 through 6. 1/4" finish grade plywood is needed for the top and front of the seat panels (fig. 7).

b. Prepare supports to hold the shooter box-seat panels. Cut four pieces of 1 1/8" x 1 1/2" pine 12 1/2" long. Fasten two 12 1/2" pieces to the lower supports in the side panels with 2" #8 drywall screws. Then fasten the other two pieces vertically between the horizontal support and the floor of the accumulator with 2" screws. Fasten one 14" x 21 3/4" panel to the horizontal cleat A with 2 1/2" drywall screws. The other 14" x 21 3/4" panel will rest against the vertical cleats B (fig. 8). Do not fasten this panel. Attach a cabinet pull (metal or ceramic) to the front of this panel so you can easily remove it to use as a chest panel (fig. 9).

9. Construct a shooter funnel for the box seat

a. Take a four-foot length of 3/8" steel Greenfield casing. (Greenfield casing can be purchased from an electrical supply store. If you can't find it, you can substitute #12 BX electrical cable, but remove the wiring from the flexible metal casing before using.)

b. Insert the spout of a 3" diameter galvanized sheetmetal funnel into one end of the flexible metal casing. Wrap carefully the outside of both the flexible casing and the funnel with plastic electricians tape, so that no metal is showing. Drill a 5/8" hole through the top back corner of the accumulator box seat's top panel. Push the flexible tubing into the space below.

10. Optional

In order to draw stagnant orgone energy from the accumulator and shooter box seat:

a. You will need approximately three 48" lengths of 3/8" Greenfield casing. Use more or less than three depending on individual circumstances.

b. Drill three 5/8" holes (in a vertical row) through the wood frame of one of the side panels. Make sure that one hole will lead into the shooter box seat. Insert the three casings into the three holes. Make sure that the casings don't protrude inside of the accumulator.

---

7. Greenfield casing is a convenient hollow flexible metal tube. IT IS NOT an electrical connection and should NOT be used as one.

c. Place the loose ends of the three casings into a pail of clean water. You need to change the water every week.

#######

The principle of the accumulator box can be adapted to different shapes for specific needs. An orgone blanket, or a collar for the neck, or a large funnel for the breast can be made as long as the principle of alternating layers of non-metallic and metallic materials is maintained.

---

8. The inner surface should be made of a flexible metal screen instead of galvanized sheetmetal. Screen made from galvanized steel or stainless steel is good. Screen made from copper, aluminum and other metals that are not body-own are NOT recommended.

MATERIALS LIST

ITEM	**APPROXIMATE QUANTITY**
1/2" celotex	four 4' x 8' sheets
galvanized sheetmetal	
(26 or 28 gage)	2 pieces 53" x 26 1/2"
" " " "	2 pieces 53" x 24"
" " " "	2 pieces 28" x 24"
fiberglass insulation	3 1/2" x 15"(1 roll or 40 linear feet)
steelwool (oo fine or finer)	200 pads or 10 lbs.
1/4" plywood (finish grade)	one 4' x 8' sheet
clear white pine: 1 1/8" x 1 1/2"	80 linear feet
" " " 1 1/8 x 1"	20 linear feet
2 1/2" #10 philips flathead wood screws	30 pcs.
2 1/2 #8 drywall screws	30 pcs.
2" #8 drywall screws	10 pcs.
3" non-mortise or surface mounted hinges	one pair
hook and eye	one 2"
nail-on furniture glides	4 pcs.
nails: 3/4" galvanized wire nails	3 oz.
1" galvanized wire nails	3 oz.
6-penny finish nails	2 lbs.
carpenters' glue	one small bottle
For the shooter box seat panels:	
galvanized sheet metal (26 or 28 gage)	2 pieces 13" x 20 3/4"
clear white pine: 1 1/8" x 1 1/2"	16 linear feet
3" diameter galvanized sheetmetal funnel	one
3/8" Greenfield flexible metal casing	16 feet
electricians' tape (plastic tape)	one roll

(FIG. 1) TABLE OF DIMENSIONS

PANEL	LENGTH	WIDTH
TOP	29"	25"
BOTTOM	29"	25"
SIDES (2)	54"	27 1/2"
BACK	54"	25"
DOOR	54"	25"
SEATS (2)	14"	21 3/4"

(FIG. 2) DETAIL OF LAYERING OF SIDES (2) TOP, BACK AND DOOR PANELS

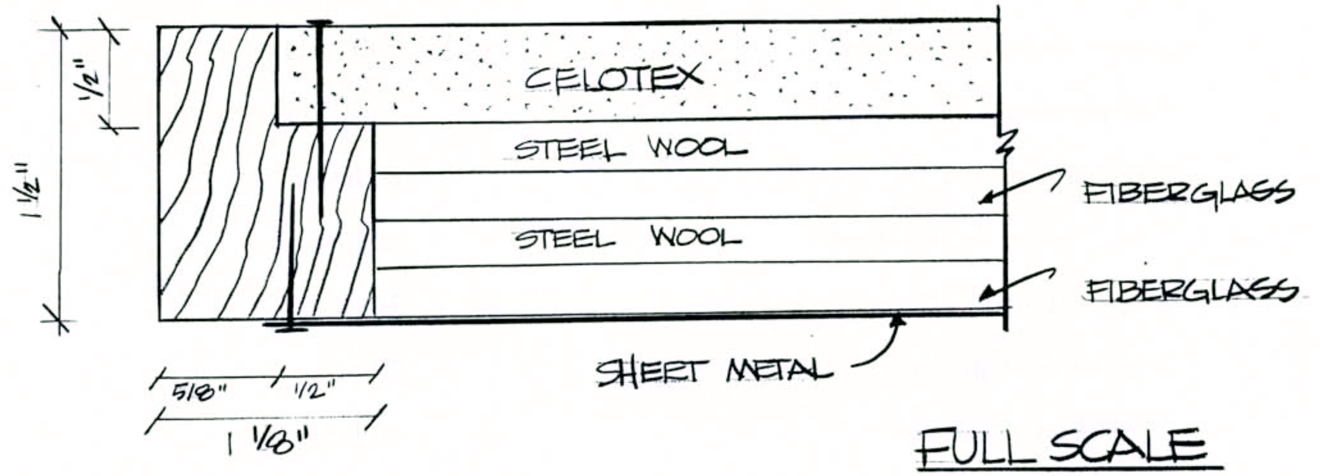
1/2"
1 1/2"
CELOTEX
STEEL WOOL
FIBERGLASS
STEEL WOOL
FIBERGLASS
SHEET METAL
5/8"
1/2"
1 1/8"

FULL SCALE

(FIG. 3) DETAIL OF LAYERING - BOTTOM PANEL

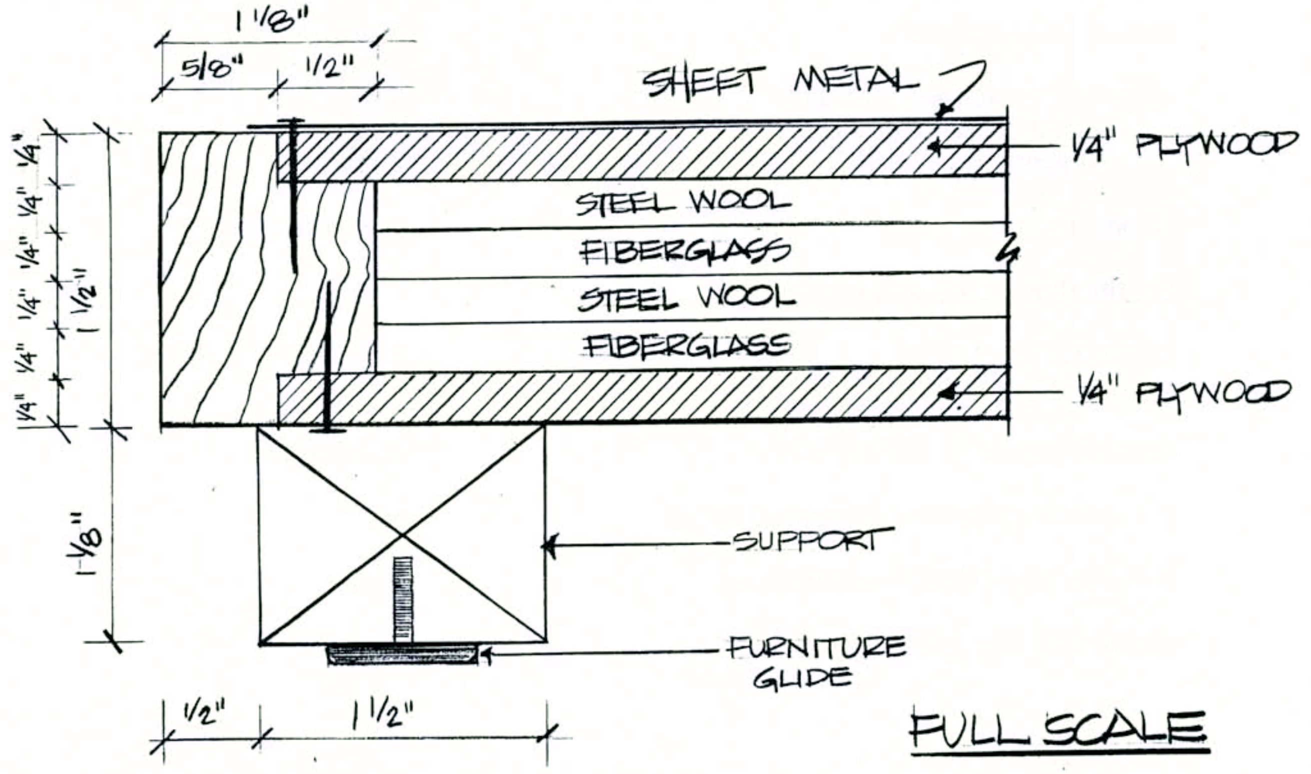
1 1/8"
5/8"
1/2"
SHEET METAL
1/4" PLYWOOD
STEEL WOOL
FIBERGLASS
STEEL WOOL
FIBERGLASS
1/4" PLYWOOD
1/4"
1/4"
1/4"
1/4"
1/4"
1/4"
1 1/2"
1-1/8"
SUPPORT
FURNITURE GLIDE
1/2"
1 1/2"

FULL SCALE

(FIG. 4) FRAMING DETAILS - SIDES (2), BACK, FRONT (DOOR), BOTTOM, TOP & SHOOTER BOX - SEAT (2)

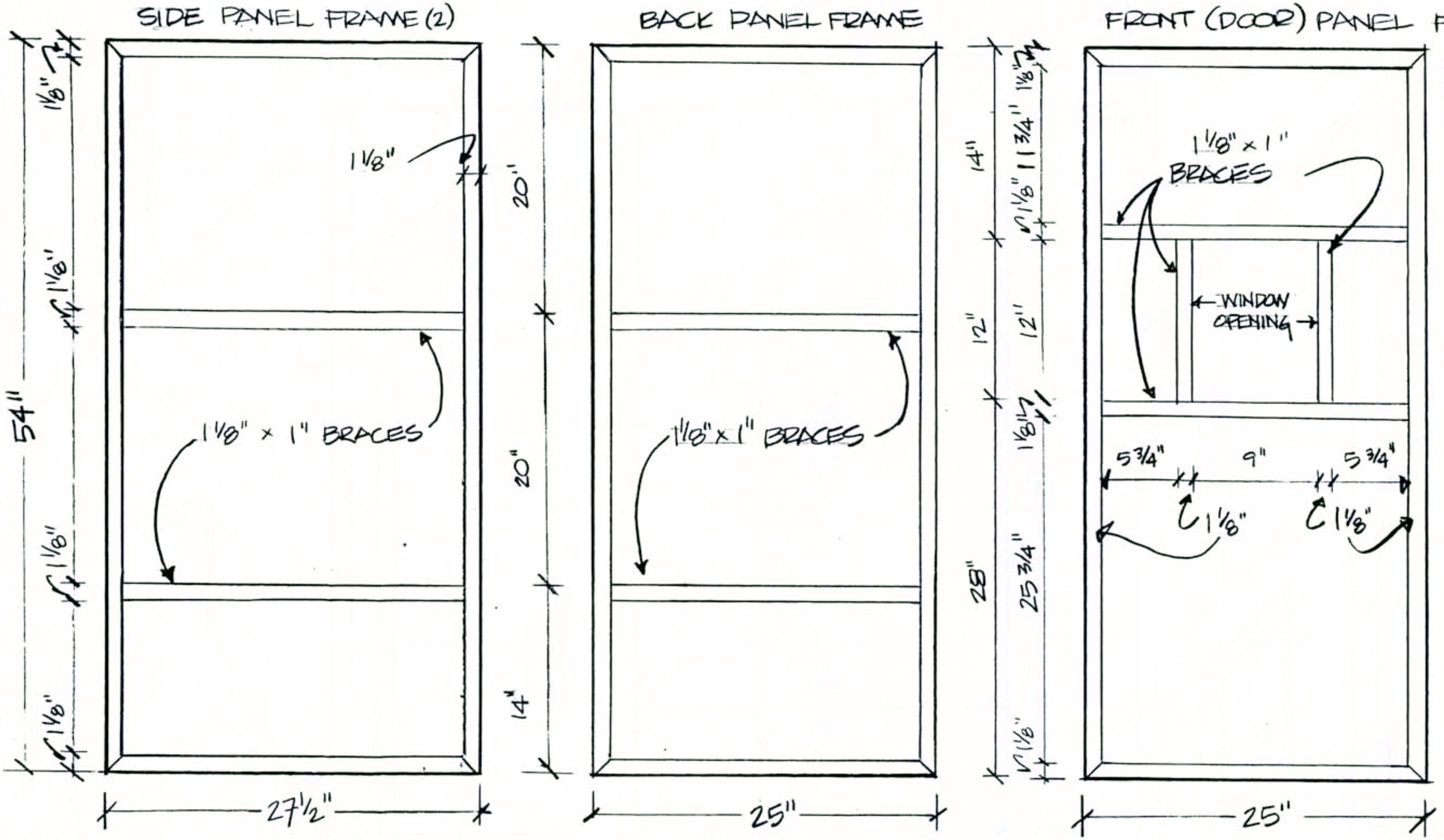
SIDE PANEL FRAME (2)
BACK PANEL FRAME
FRONT (DOOR) PANEL FRAME
54"
1 1/8"
1 1/8"
1 1/8"
1 1/8"
1 1/8"
1 1/8" x 1" BRACES
27 1/2"
20"
20"
14"
1 1/8" x 1" BRACES
25"
14"
12"
28"
1 1/8"
11 3/4"
1 1/8"
12"
1 1/8"
25 3/4"
1 1/8"
1 1/8" x 1"
BRACES
WINDOW
OPENING
5 3/4"
9"
5 3/4"
1 1/8"
1 1/8"
25"

SIDES (2), BACK & FRONT (DOOR) PANEL FRAMES TO BE 'FASHIONED' FROM 1 1/8" x 1 1/2" PINE WITH 1/2" x 1/2" RABBET (SEE FIG. 2)

BRACES TO BE 1 1/8" x 1" PINE.

SCALE: 1" = 1'-0"

NOTE: TOP & BOTTOM FRAMES HAVE SAME WIDTH, LENGTH AND THICKNESS.

BOTTOM FRAME CONSTRUCTED FROM 1 1/8" x 1 1/2" PINE WITH A 1/4" x 1/2" RABBET ON TWO SIDES (SEE FIG. 3)

TOP FRAME CONSTRUCTED FROM 1 1/8" x 1 1/2" PINE WITH A 1/2" RABBET ON ONE SIDE. (SEE FIG. 2)

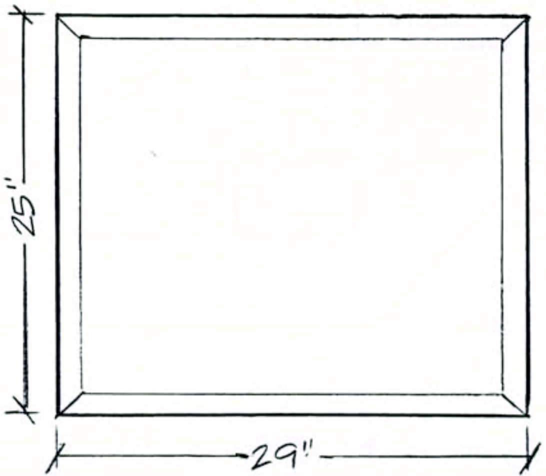

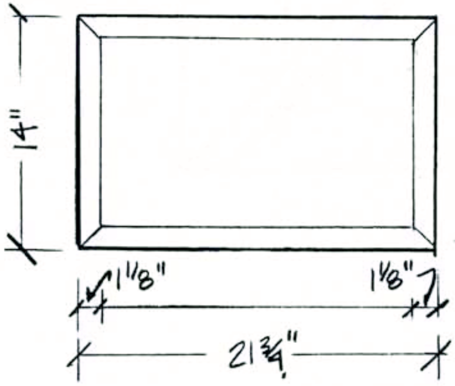
14"
1 1/8"
1 1/8"
21 3/4"

SHOOTER BOX SEAT (2)

FRAME TO BE CONSTRUCTED FROM 1 1/8" x 1 1/2" PINE WITH A 1/4" x 1/2" RABBET (SEE FIG. 7)

(FIG. 5)
ASSEMBLING THE PANELS

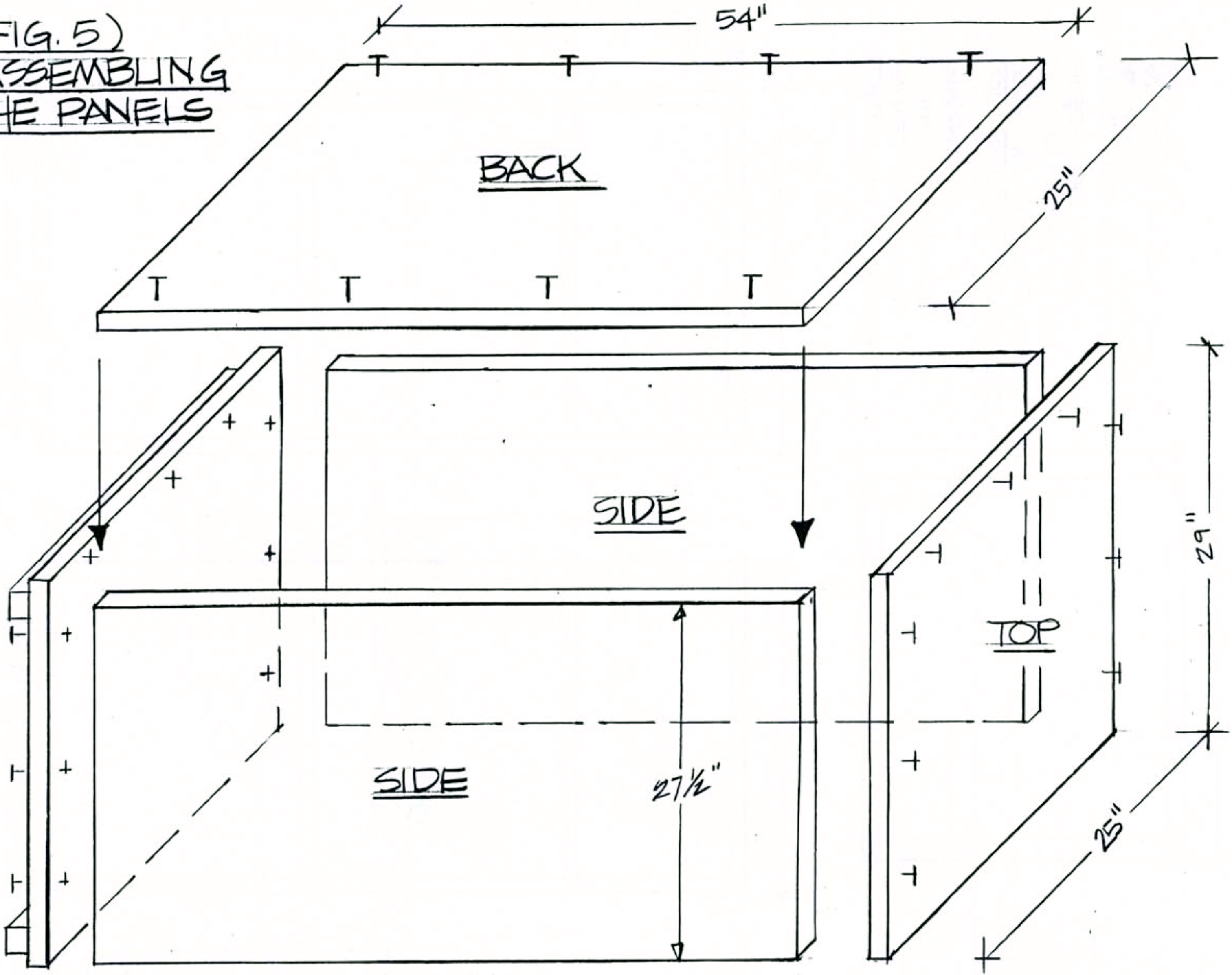

54"
BACK
25"
SIDE
29"
TOP
SIDE
27½"
25"
54"

T=2½" SCREWS

(FIG. 6)
ATTACH DOOR

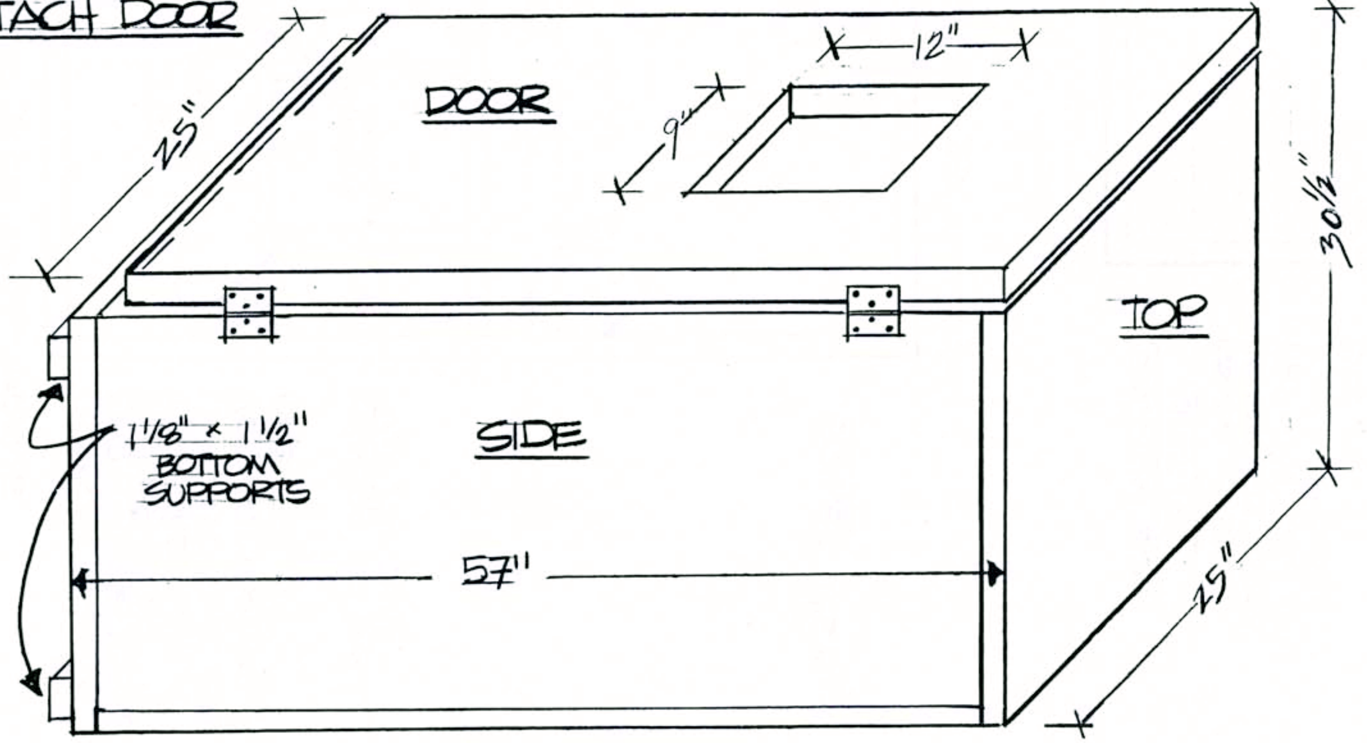

12"
DOOR
9"
25"
TOP
30½"
1⅛" × 1½"
BOTTOM SUPPORTS
SIDE
57"
25"

(FIG. 7) DETAIL FOR SHOOTER BOX - SEAT PANELS

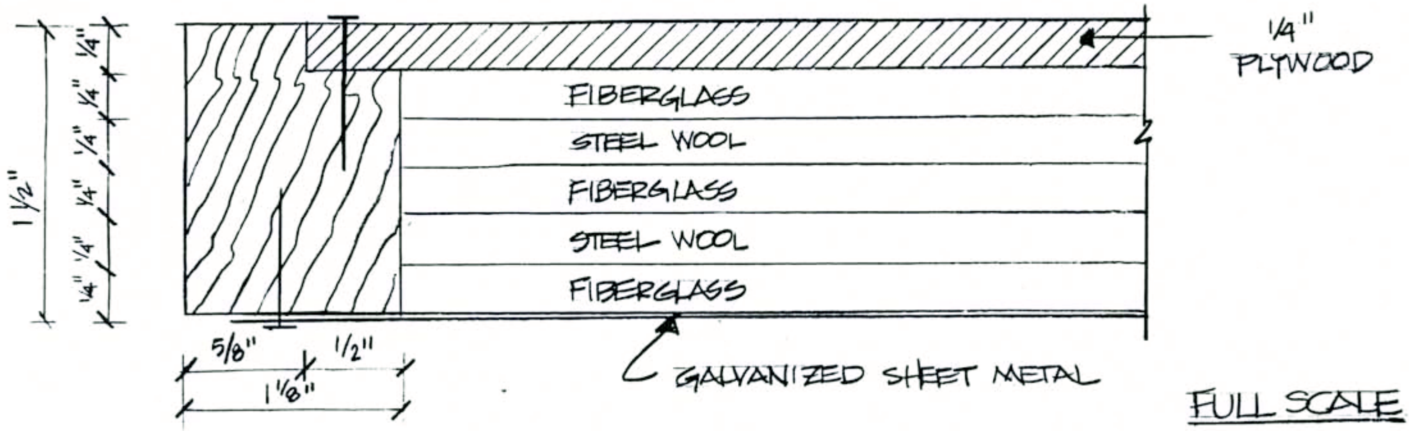
1/4"
1/4"
1/4"
1/4"
1/4"
1/4"
1 1/2"
1/4" PLYWOOD
FIBERGLASS
STEEL WOOL
FIBERGLASS
STEEL WOOL
FIBERGLASS
5/8"
1/2"
1 1/8"
GALVANIZED SHEET METAL

FULL SCALE

(FIG. 8) ASSEMBLING THE SHOOTER BOX - SEAT

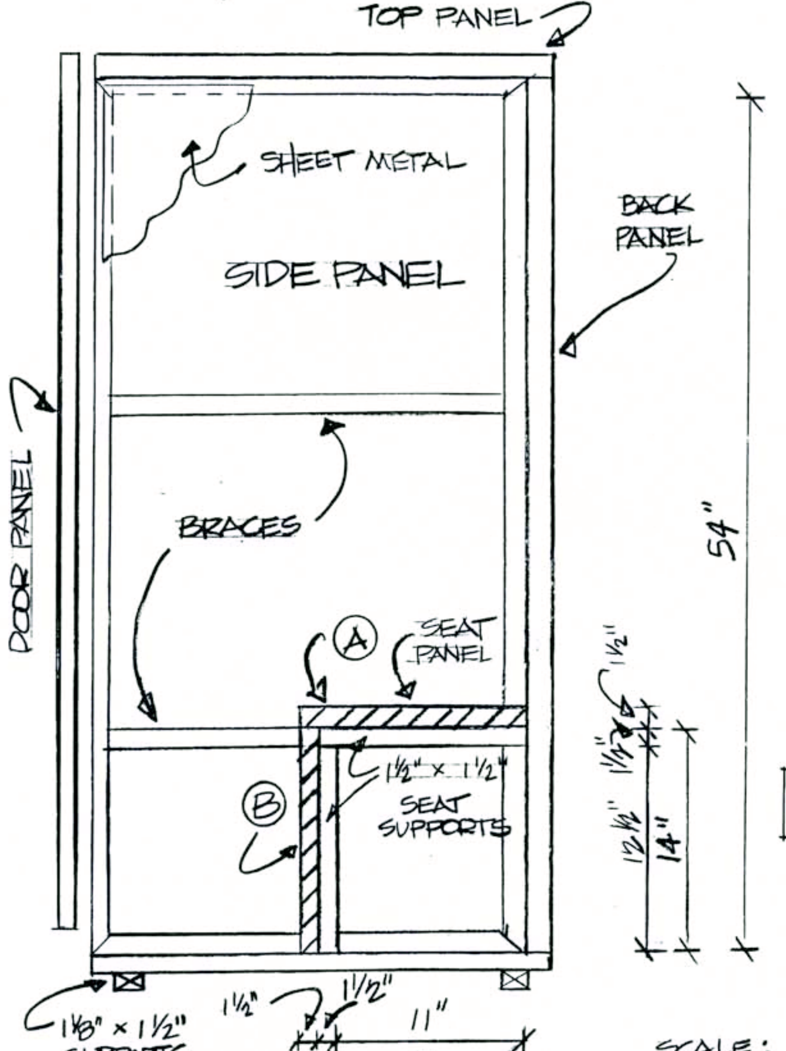
TOP PANEL
SHEET METAL
SIDE PANEL
BACK PANEL
DOOR PANEL
BRACES
A
SEAT PANEL
B
1 1/2" x 1 1/2" SEAT SUPPORTS
54"
1 1/2"
1 1/2"
12 1/2"
14"
1 1/8" x 1 1/2" SUPPORTS
1 1/2"
1 1/2"
11"
14"
27 1/2"

SCALE: 1" = 1'-0"

(FIG 9) HOW TO USE CHEST PANEL

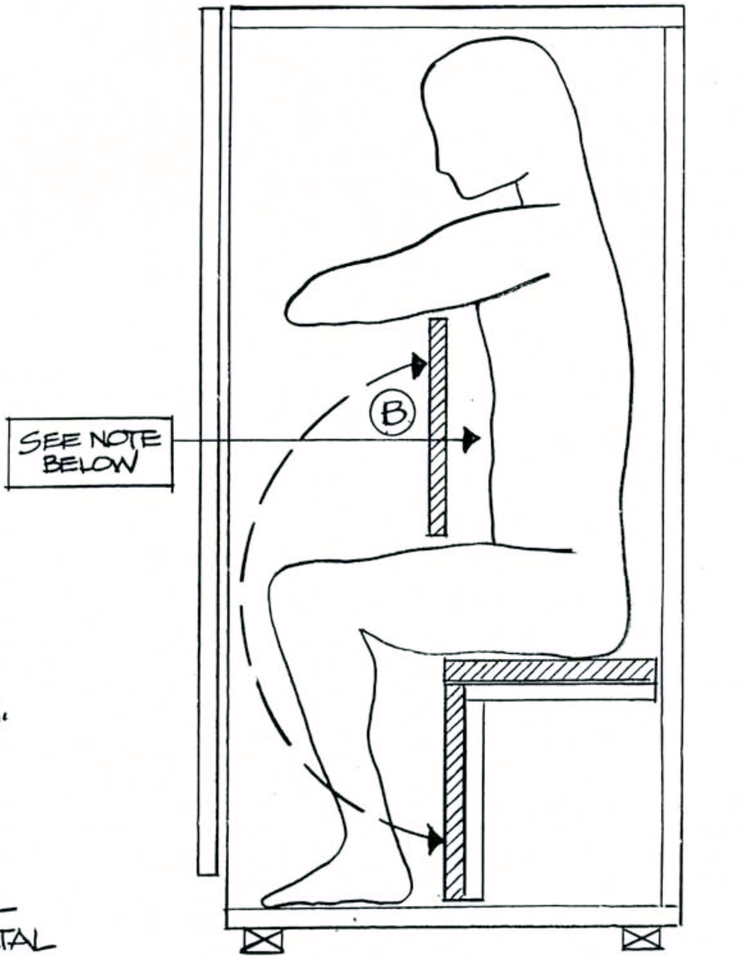
SEE NOTE BELOW
B

SCALE: 1" = 1'-0"

NOTE: ALLOW SPACE BETWEEN PANEL AND CHEST OF USER. SHEET METAL SIDE SHOULD FACE CHEST.

ELECTRONIC WARFARE FUNDAMENTALS

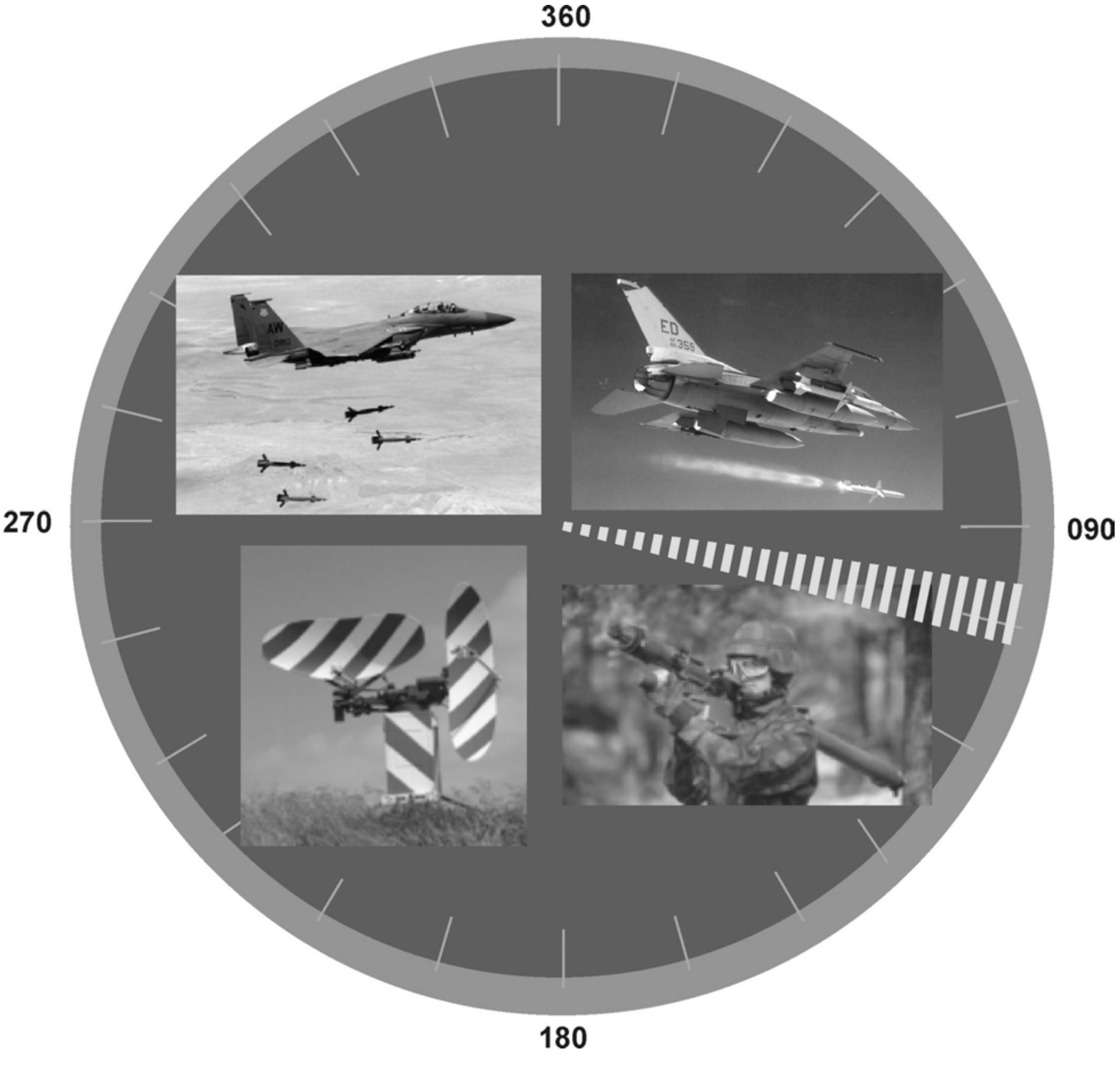
360
270
090
180

NOVEMBER 2000

PREFACE

Electronic Warfare Fundamentals **is a student supplementary text and reference book that provides the foundation for understanding the basic concepts underlying electronic warfare (EW). This text uses a practical building-block approach to facilitate student comprehension of the essential subject matter associated with the combat applications of EW.**

Since radar and infrared (IR) weapons systems present the greatest threat to air operations on today's battlefield, this text emphasizes radar and IR theory and countermeasures. Although command and control (C^2) systems play a vital role in modern warfare, these systems are not a direct threat to the aircrew and hence are not discussed in this book. This text does address the specific types of radar systems most likely to be associated with a modern integrated air defense system (IADS).

To introduce the reader to EW, ***Electronic Warfare Fundamentals*** **begins with a brief history of radar, an overview of radar capabilities, and a brief introduction to the threat systems associated with a typical IADS. The two subsequent chapters introduce the theory and characteristics of radio frequency (RF) energy as it relates to radar operations. These are followed by radar signal characteristics, radar system components, and radar target discrimination capabilities. The book continues with a discussion of antenna types and scans, target tracking, and missile guidance techniques.**

The next step in the building-block approach is a detailed description of countermeasures designed to defeat radar systems. The text presents the theory and employment considerations for both noise and deception jamming techniques and their impact on radar systems. This is followed by a chapter on decoys, both for defeating an IADS as well as for self-protection. Then, the next chapter discusses chaff characteristics, employment, and impact on specific radar systems.

The following two chapters are dedicated to the IR threat. The first covers IR theory, IR target detection and tracking, and advanced IR missile flare rejection techniques. The second chapter presents IR countermeasures to include flare employment, maneuvers, and missile warning equipment.

Electronic Warfare Fundamentals **then addresses an important aspect of EW, specifically electronic protection (EP). This section includes a description of the most common radar EP techniques designed to counter noise jamming, deception jamming, and chaff employment. The book concludes with an overview of the basic components and limitations of a typical radar warning receiver (RWR), current geolocation techniques, and it finally discusses the basic components of a self-protection jamming system.**

In addition to the textual material, the book also contains a detailed glossary of EW-related terms and acronyms for quick reference. A list of references is provided to acknowledge the source material used in the preparation of this text. These sources also provide the interested student with a supplementary reading list to learn more about a specific topic.

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CHAPTER 1. INTRODUCTION TO RADAR

1. INTRODUCTION

The word "RADAR" is an acronym for RAdio Detection And Ranging. As it was originally conceived, radio waves were used to detect the presence of a target and to determine its distance or range (Figure 1-1).

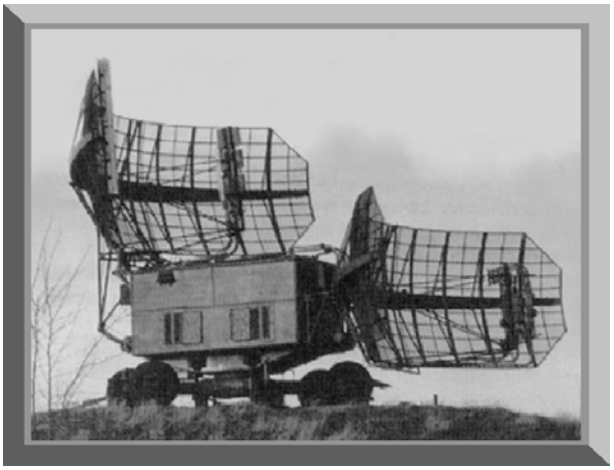

Figure 1-1. Radar System

2. HISTORY

The reflection of radio waves by objects was first noted more than a century ago. In 1903, the reflection of radio waves was employed in Germany to demonstrate detection of ships at sea (Figure 1-2). In 1922, Marconi presented the same idea in Britain but received little official interest. These early experiments used continuous wave, or CW, transmissions and relied on the reflection of a transmitted wave from a target to indicate the presence of a target. CW transmissions can detect the presence of an object and, if the radio wave is formed into a narrow beam, can also provide azimuth information. CW transmissions cannot provide range.

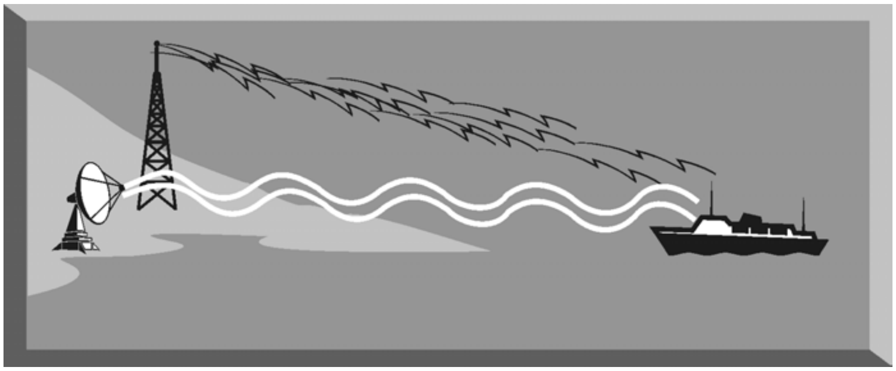

Figure 1-2. Early Continuous Wave Radar Experiments

a. The lack of range information was a serious limitation but was finally overcome by modulating the radio wave transmissions to send out a train of short pulses (Figure 1-3). The time between pulse transmission and an echo return to the receiver provides a direct measurement of range. Practical development of the pulse radar began in the 1930s, principally in the United States, Britain, and Germany. Due to deteriorating relations with Germany and the threat of invasion, the British intensified their efforts to develop a pulse radar in 1935. These efforts culminated in the development and deployment of multiple radar stations which formed the Chain Home System. These radar installations provided critical information to British pilots on the size and location of German bomber formations during the Battle of Britain.

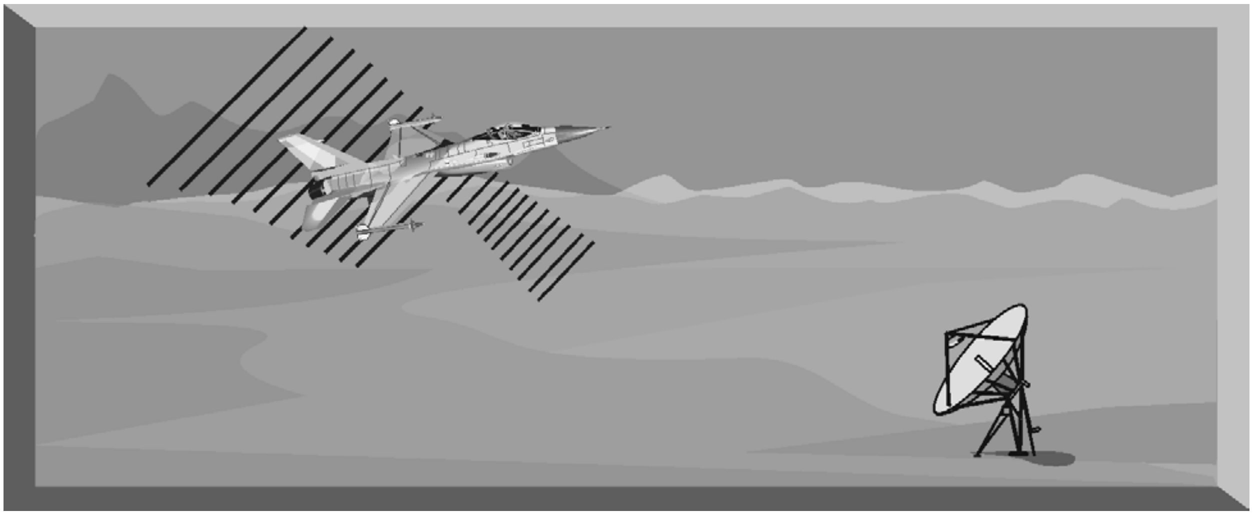

Figure 1-3. Pulse Radar Operation

b. The Chain Home System is considered the first integrated air defense system, or IADS. Radar development, with its obvious military and civilian applications, has continued unabated to the present day.

3. TARGET DISCRIMINANTS

The widespread military and civilian application of radar is based on its inherent advantages over the human eye (Figure 1-4). Radar can “see” farther than the human eye and more accurately assess the range or distance of an object. Radar works well in all-weather conditions and is relatively immune to smoke, haze, and clouds. What's more, radar works 24 hours a day because it can transmit its own energy and does not have to rely on sunshine or ambient radiation. There are some disadvantages of radar when compared to the human eye. First, radar does not have the resolution that the human eye has. While radar can detect the presence of an airplane, the human eye can discern, in great detail, the shape, size, color, and even markings. This can be a serious limitation if positive identification is required prior to engagement.

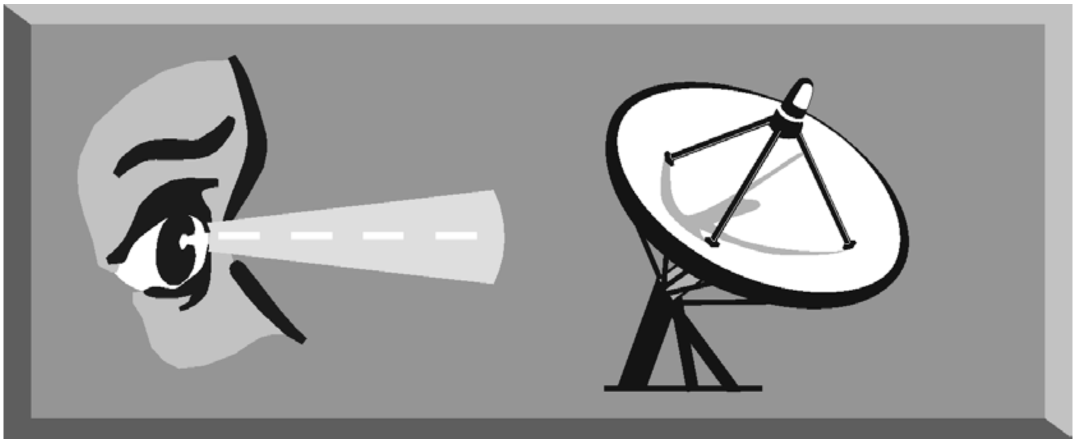

Figure 1-4. Radar Advantages and Disadvantages

Second, the human eye is not bothered by undesirable reflections, called clutter, the way radar sometimes is. Although metal is the best reflector of radio frequency (RF) energy, nearly any material will reflect some RF energy. Mountains, trees, buildings, rain, birds, and chaff all reflect RF energy. Radar systems must use target discriminants to isolate the desired target return from the clutter. These target discriminants include range, velocity, and angle (Figure 1-5).

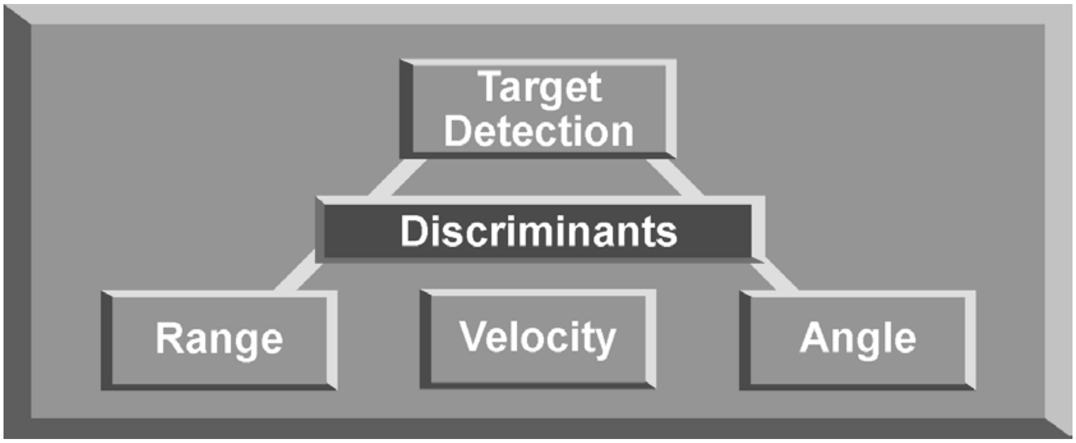

Figure 1-5. Radar Target Discriminants

a. The first target discriminant is range. The time an RF wave takes to go to, and return from, a target allows measurement of the range to that target. We know that RF energy travels at the speed of light, or "c" which is 3 x 10^8 meters per second. Target range can be determined by using the basic radar range equation (Equation 1-1), target range equals measured time, multiplied by the speed of light ("c"), divided by 2.

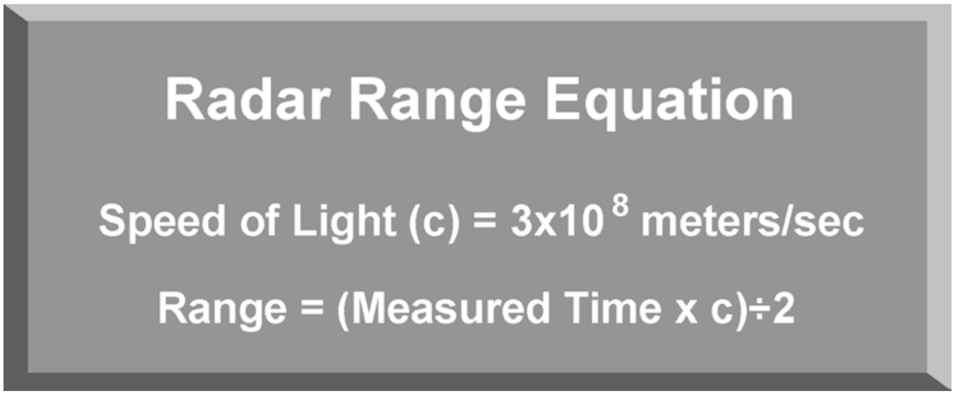

Radar Range Equation

Speed of Light (c) = $3\text{x}10^{8}$ meters/sec

Range = (Measured Time x c)÷2

Equation 1-1. Basic Radar Range Equation

b. Target angle discrimination is another critical capability of radar systems. In order for a radar system to detect a target, the antenna must be pointed at the target during the transmission and reception of RF energy. The ability of a radar system to accurately determine angle is a function of the horizontal beamwidth of the antenna. If the radar sweep is referenced to true North, the angle of a radar return can be measured relative to true North (Figure 1-6).

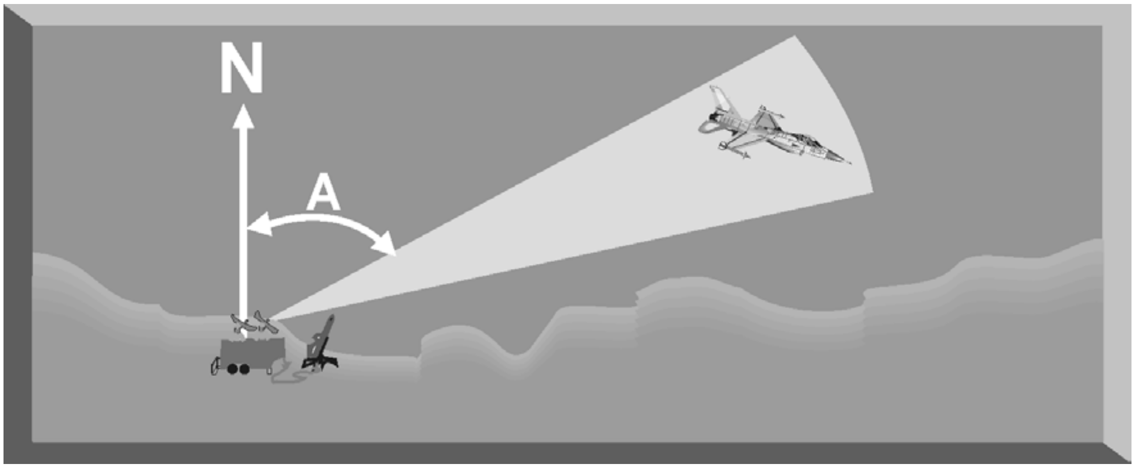

Figure 1-6. Angle Discrimination

c. Velocity discrimination is a specific capability of CW and pulse Doppler radar systems. The transmitters of CW radars send out continuous RF at a specific frequency (Figure 1-7). The reflected signal frequency is changed, or shifted, by a specific amount by a moving target. This frequency shift, called the Doppler effect, allows the measurement of the velocity of that target relative to the radar. The receiver measures this frequency difference which equates to a specific radial velocity. Pulse Doppler radars can measure the Doppler effect while still obtaining the range.

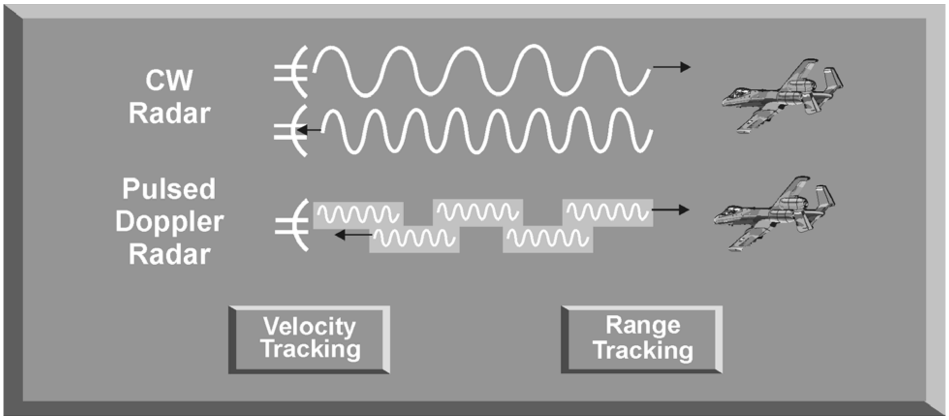
CW
Radar
Pulsed
Doppler
Radar
Velocity
Tracking
Range
Tracking

Figure 1-7. Velocity Discrimination

d. A basic pulse radar system consists of a transmitter, antenna, receiver, and a master timer (Figure 1-8). The transmitter sends electromagnetic energy (RF) to the antenna. This energy is radiated through the atmosphere. When this RF energy is interrupted by any object, such as a plane, ship, or the earth, a portion of the RF energy is reflected back to the antenna and processed by the receiver.

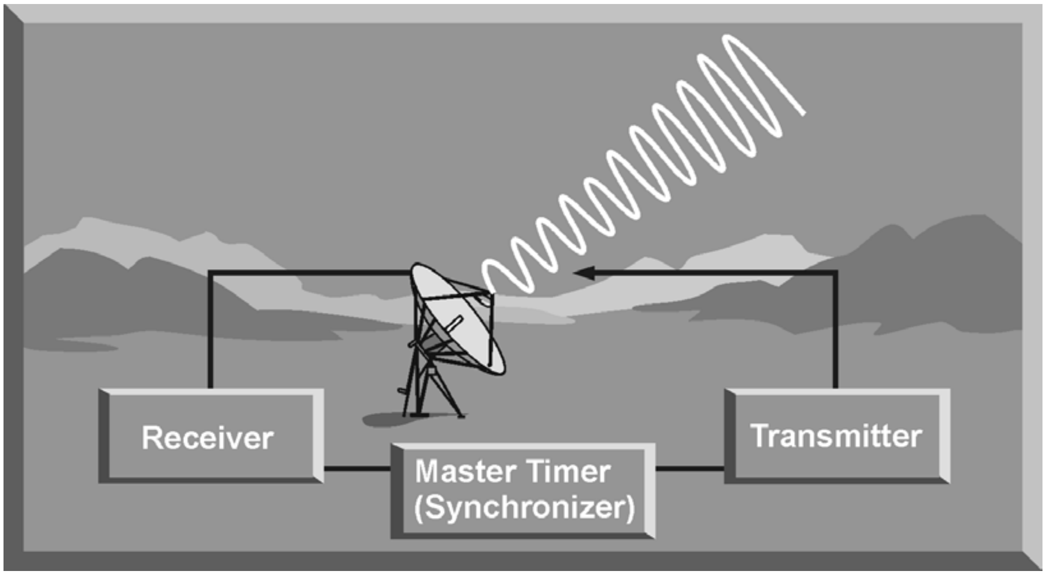
Receiver
Master Timer
(Synchronizer)
Transmitter

Figure 1-8. Basic Radar Operation

The reflection is called an echo, and the object interrupting the RF energy is called a target. The presence of an echo indicates target detection. If the target detected is the desired target, the echo is referred to as a target signal. If the echo is from undesired targets, such as the earth, the echo is referred to as clutter. This is especially true when the undesirable echoes make the detection of the desired target difficult. The capability of the antenna to focus the RF energy

affects the angular discrimination of the radar. The ability of the master timer to determine the time between RF transmission and target echo reception impacts the range determination capability of the radar. The ability of the receiver to analyze the Doppler frequency shift in the target echo determines the velocity discrimination capability of the radar and the ability of the radar to reject clutter.

4. INTRODUCTION TO INTEGRATED AIR DEFENSE SYSTEMS (IADS)

Radar systems have the inherent capability to determine accurate range, azimuth, and/or velocity information on airborne targets. Radar systems can provide this information in nearly all types of weather, day or night, and at distances that far exceed the capabilities of the human eye. Military commanders have taken advantage of these capabilities by employing radar systems to provide air defense for high-value targets. The primary missions of radar systems employed for air defense are attack warning and threat engagement.

a. Radar systems specifically designed to provide attack warning are called early warning (EW) radars (Figure 1-9). These radars are characterized by high power output, large antennas, and low frequencies. These same characteristics limit the accuracy of the target parameters available from early warning radars. The long-range detection of aircraft and the earliest possible attack warning capabilities of early warning radars provide the first line of defense for the air defense system.

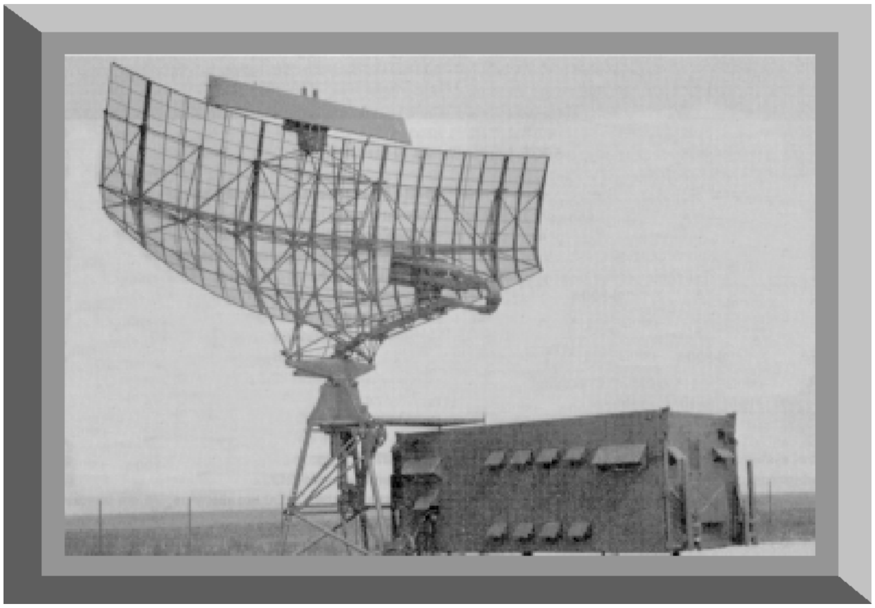

Figure 1-9. Early Warning Radar System

b. Radar systems designed to provide target engagement information include ground control intercept (GCI) radars, acquisition radars, target tracking radars (TTRs), and airborne interceptor (AI) radars.

(1) GCI radars are designed to provide sufficiently accurate target aircraft range, azimuth, and altitude information to vector AI assets to intercept and destroy attacking aircraft (Figure 1-10). To provide this data, early warning radars can be deployed along with specialized height finder radars. This combination of radar systems is commonly referred to as a GCI site. Newer GCI radar systems, employing phased array antennas and Doppler processing, can provide the required 3-dimensional target information. Any radar system, or combination of radar systems, that can determine 3-dimensional target data, and is equipped with the communication equipment to pass this information to AI assets, can act as a GCI site. GCI radar systems can be used to supplement early warning radar systems to provide critical attack warning.

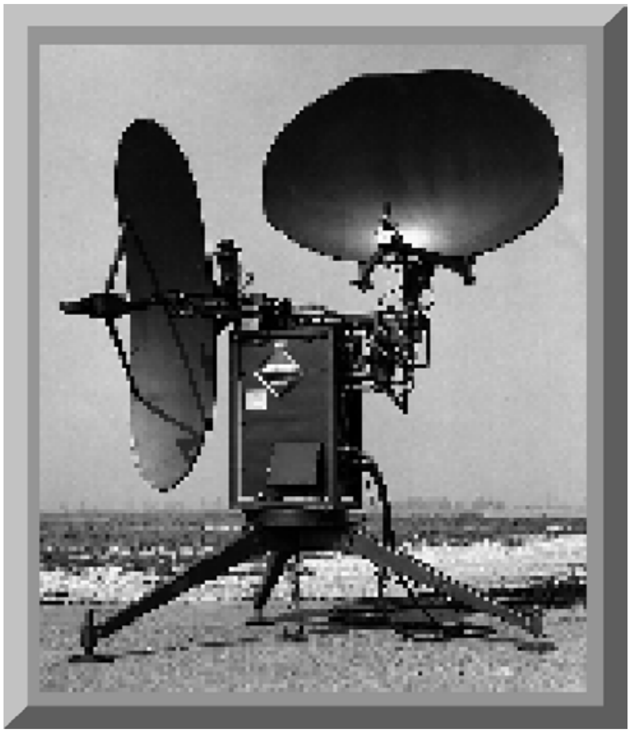

Figure 1-10. GCI Radar

(2) Acquisition radar systems are designed to act as GCI radars for ground based TTRs. Acquisition radar systems generally have shorter range capability than early warning radars and operate at higher frequencies. These radar systems provide accurate target range and azimuth data to TTRs to facilitate target engagement. Acquisition radars can be a distinct radar system (Figure 1-11) or be incorporated as part of the TTR (Figure 1-12).

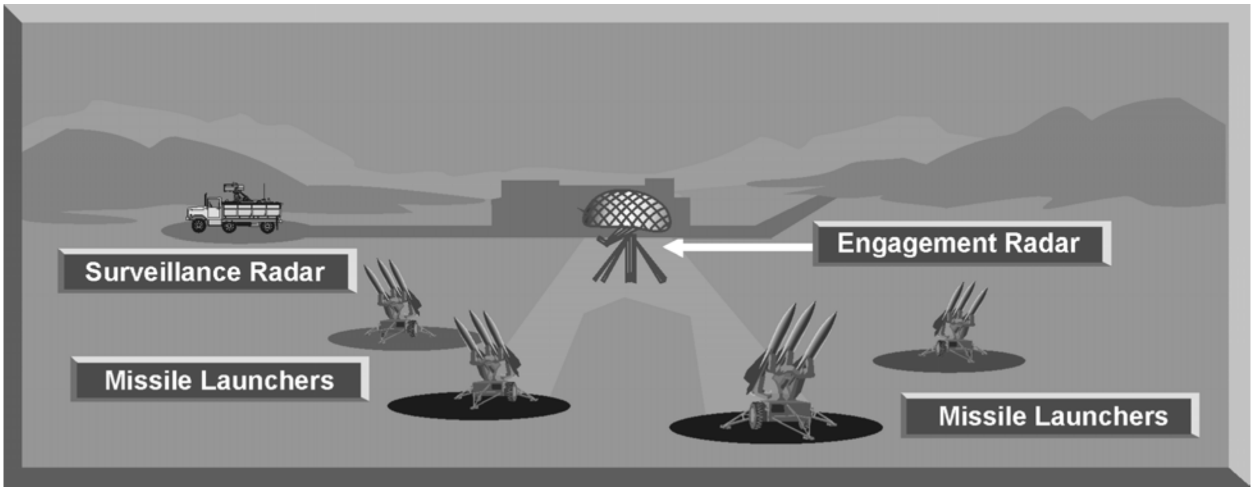
Surveillance Radar
Engagement Radar
Missile Launchers
Missile Launchers

Figure 1-11. Acquisition Radar and TTR

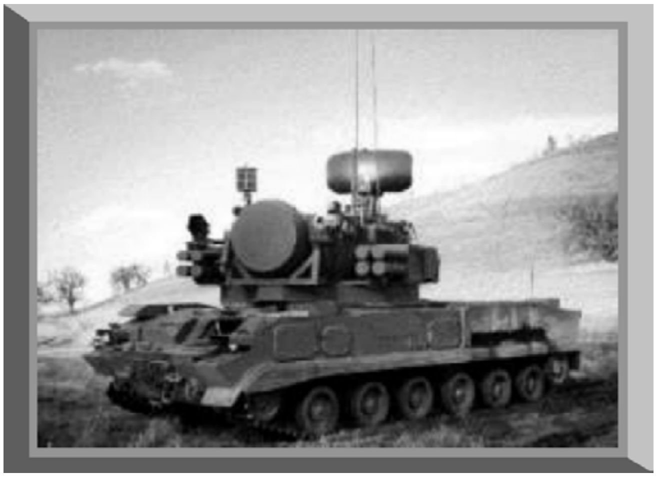

Figure 1-12. TTR with Acquisition

(3) The primary role of TTRs, in support of an air defense system, is to provide continuous and accurate target parameters to a fire control computer. The fire control computer uses this data to guide missiles or aim antiaircraft artillery (AAA) to destroy attacking aircraft. TTRs employ various tracking techniques to continuously update target parameters. TTRs generally employ high frequencies, narrow beamwidths, and computer signal processing to enhance the accuracy of target parameters provided to the fire control computer.

(4) AI radar systems are TTRs employed by fighter aircraft to engage and destroy airborne targets (Figure 1-13). These radar systems are characterized by high frequency, sophisticated computer processing, and accurate target tracking capability. They are designed to allow the AI asset to employ air-to-air missiles and guns/cannons. TTRs and AI radars constitute the highest radar threat associated with an air defense system.

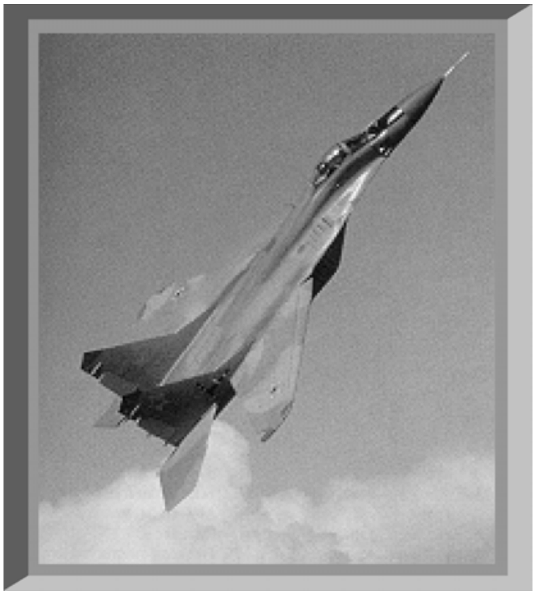

Figure 1-13. MiG-29

(5) Another growing lethal threat associated with an air defense system is infrared (IR) missiles. IR missile systems can be man-portable (Figure 1-14), mounted on vehicles, or employed by AI assets. These missile systems guide on the distinctive IR signature of aircraft. The recent proliferation and enhanced performance of IR systems has increased the contribution of these systems to air defense.

Figure 1-14. IR System

c. All these radar systems can be deployed to provide air defense for a particular country or geographical area. When the employment of these radar systems is integrated by a command and control (C^2) structure, this constitutes an IADS (Figure 1-15). The C^2 structure allows the military commander to take advantage of the threat warning provided by early warning radars. Based on this threat warning, the military commander can allocate specific assets (GCI and AI assets, or acquisition radars and TTRs) to engage airborne targets. This allocation decision is based on the capabilities of these systems and the tactical situation. This allocation process enables the military commander to maximize the capabilities of his forces to engage and destroy attacking aircraft.

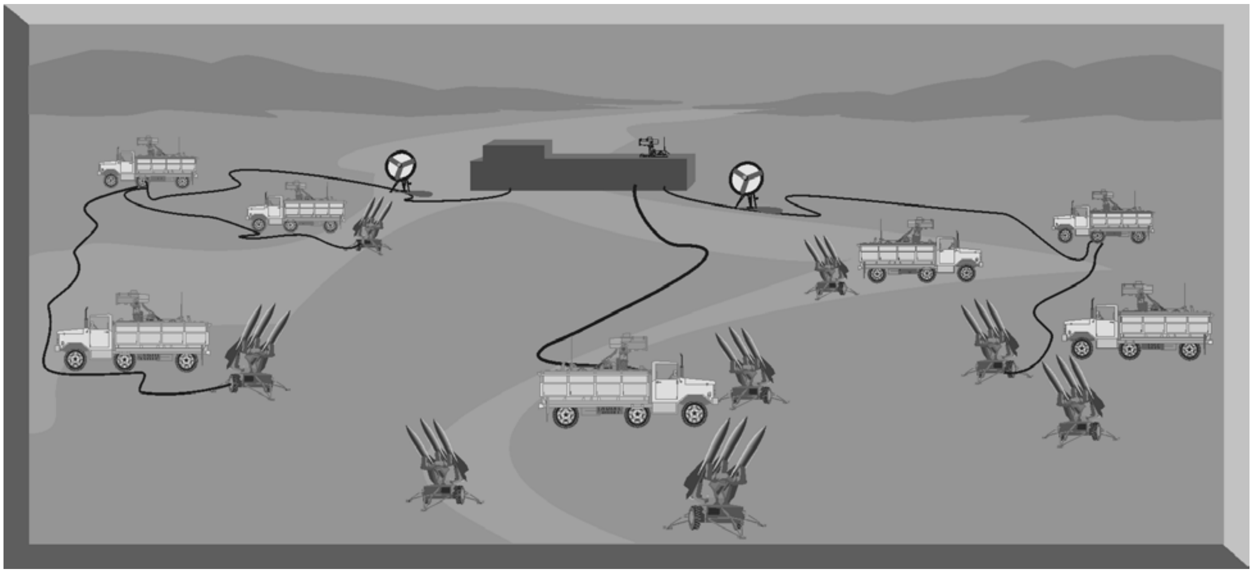

Figure 1-15. A Typical IADS

5. SUMMARY

Radar systems are the cornerstones of a modern IADS. Radar and IR threat systems operate at frequencies that span most of the electromagnetic spectrum. Each system has unique capabilities and operating characteristics that enable it to accomplish assigned tasks in support of the IADS. In order to effectively employ offensive air power on the modern battlefield, the systems that support the IADS must be negated. A basic knowledge of how radar and IR systems operate, their capabilities, limitations, and the available countermeasures is the key to defeating these systems. The purpose of this book is to provide this information.

CHAPTER 2. CHARACTERISTICS OF RF RADIATION

1. INTRODUCTION

In order for a radar system to determine range, azimuth, elevation, or velocity data, it must transmit and receive electromagnetic radiation. This electromagnetic radiation is referred to as radio frequency (RF) radiation. RF transmissions have specific characteristics that determine the capabilities and limitations of a radar system to provide these target discriminants, based on an analysis of the characteristics of the target return. The frequency of transmitted RF energy affects the ability of a radar system to analyze target return, based on time, to determine target range. RF frequency also affects the ability of the transmitting antenna to focus RF energy into a narrow beam to provide azimuth and elevation information. The wavelength and frequency of the transmitted RF energy impact the propagation of the radar signal through the atmosphere. The polarization of the RF signal affects the amount of clutter the radar must contend with. The ability of a radar system to use the Doppler effect in analyzing the radar return impacts the velocity discrimination capability of the radar. These characteristics of RF radiation will be discussed in this chapter.

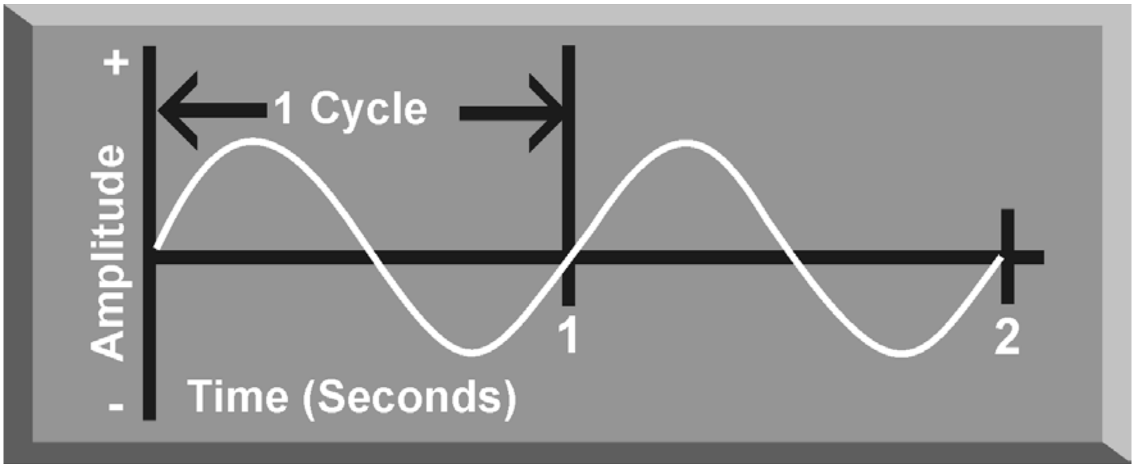

Figure 2-1. Radio Frequency

2. FREQUENCY

The output signal from a typical radio or radar system has several important characteristics that affect the capabilities and limitations of radio or radar systems. The first characteristic considered is usually RF. The frequency of the transmitted signal is the number of times per second the RF energy completes one cycle. The RF signal depicted in Figure 2-1 has a frequency of one cycle per second. The basic unit of measurement is the hertz (Hz). One hertz equals one cycle per second. Most radars have an RF in the millions of hertz, or megahertz (MHz).

3. WAVELENGTH

A characteristic of any RF signal is wavelength. Wavelength is a measure of the physical distance between peaks of a sine wave propagated in space (Figure 2-2).

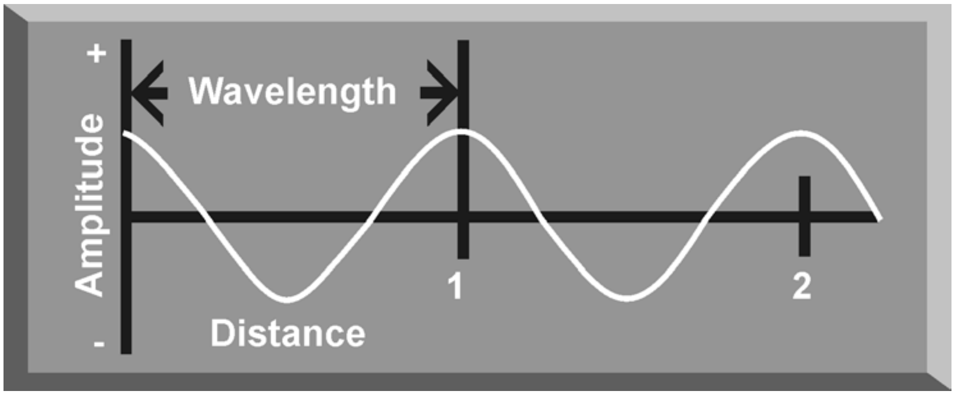

Figure 2-2. Radar Signal Wavelength

Though wavelength is measured in meters, most radar signals have wavelengths measured in centimeters or millimeters. The wavelength of a radar signal can be computed using the equation shown in Equation 2-1. The relationship between wavelength and frequency is inverse: the higher the frequency, the shorter the wavelength. In early radio and radar terminology, wavelength was used instead of frequency to describe operating characteristics of a system. Today, wavelength is used to describe systems operating at very high frequencies, such as millimeter wave, and for describing infrared (IR) systems.

$$\text{Wavelength}\ (\lambda) = \frac{c\ \ \text{(Speed of Light)}}{f\ \ \text{(Radar Frequency)}}$$

Equation 2-1. Basic Wavelength Equation

4. POLARIZATION

Another characteristic of a radio frequency wave is polarization. Polarization is determined by the radar antenna and refers to the orientation of the RF wave as it travels through space. There are two types of polarization: linear and circular.

a. Traveling electromagnetic energy has two components: an electrostatic field and a magnetic field. These two fields are always perpendicular to each other and perpendicular to the direction of travel. The polarization of the wave is defined in terms of the orientation to the electrostatic field. Many radar antennas are linearly polarized, either vertically or horizontally. The signal depicted in Figure 2-3 is vertically polarized.

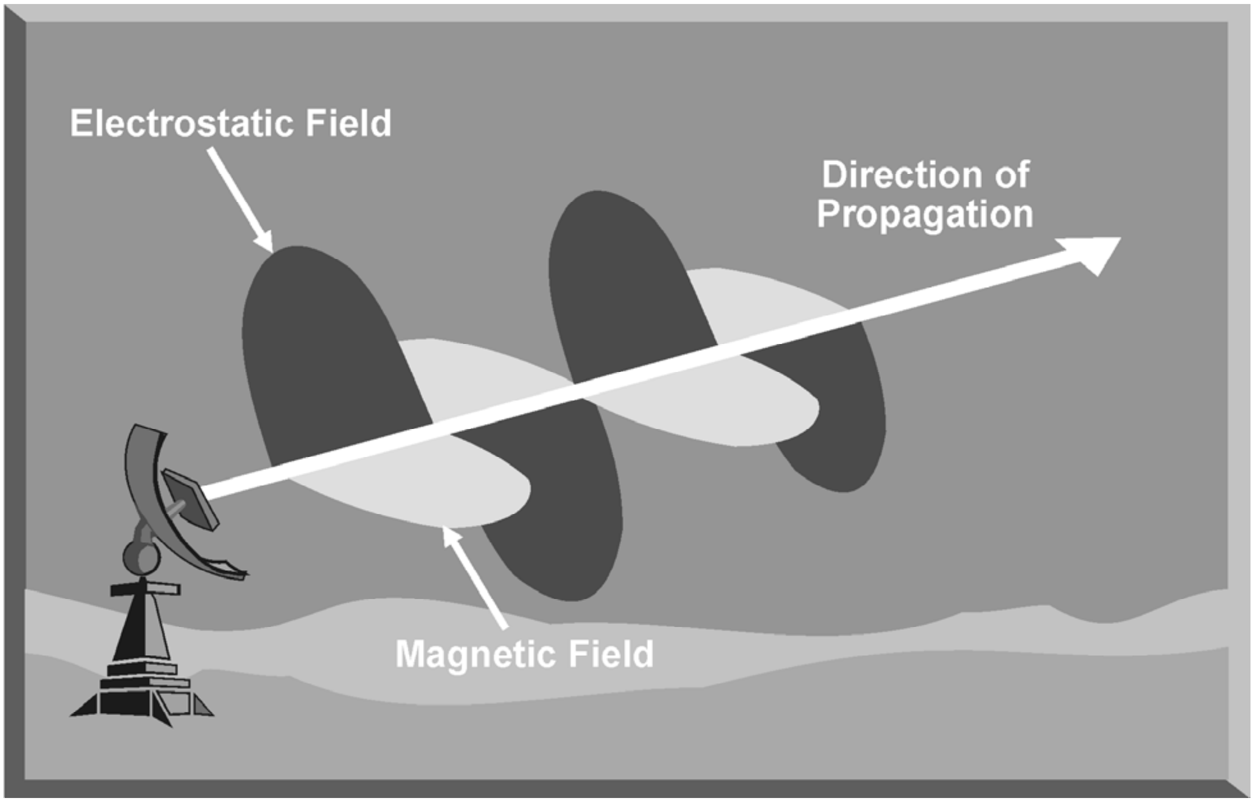

Figure 2-3. Radar Signal Vertical Polarization

b. Some radars use circular polarization to improve target detection in rain. Circular polarization can be right-hand, or left-hand orientation. For circular polarization, the direction of the electrostatic field varies with time and traces a circular locus about a fixed plane perpendicular to the direction of propagation. For a right-hand circular polarized signal, the electrostatic vector appears to rotate in a clockwise direction. For a left-hand circular polarized signal, the rotation is counterclockwise. Circular polarization can be visualized by pointing the thumb of either hand in the direction of propagation and curling the fingers in the direction of electrostatic field rotation (Figure 2-4).

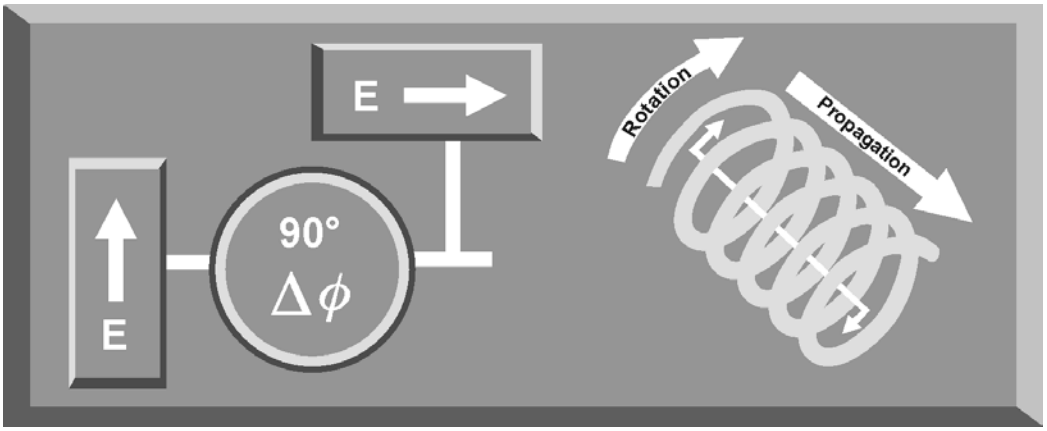
E
E
90°
$\Delta\phi$
Rotation
Propagation

Figure 2-4. Circular Polarization

c. The impact of polarization on receivers and transmitters is fairly straightforward. If an antenna is designed to receive a particular polarization, it will have difficulty receiving a signal with an opposite polarization. This situation is defined as cross polarization (Figure 2-5).

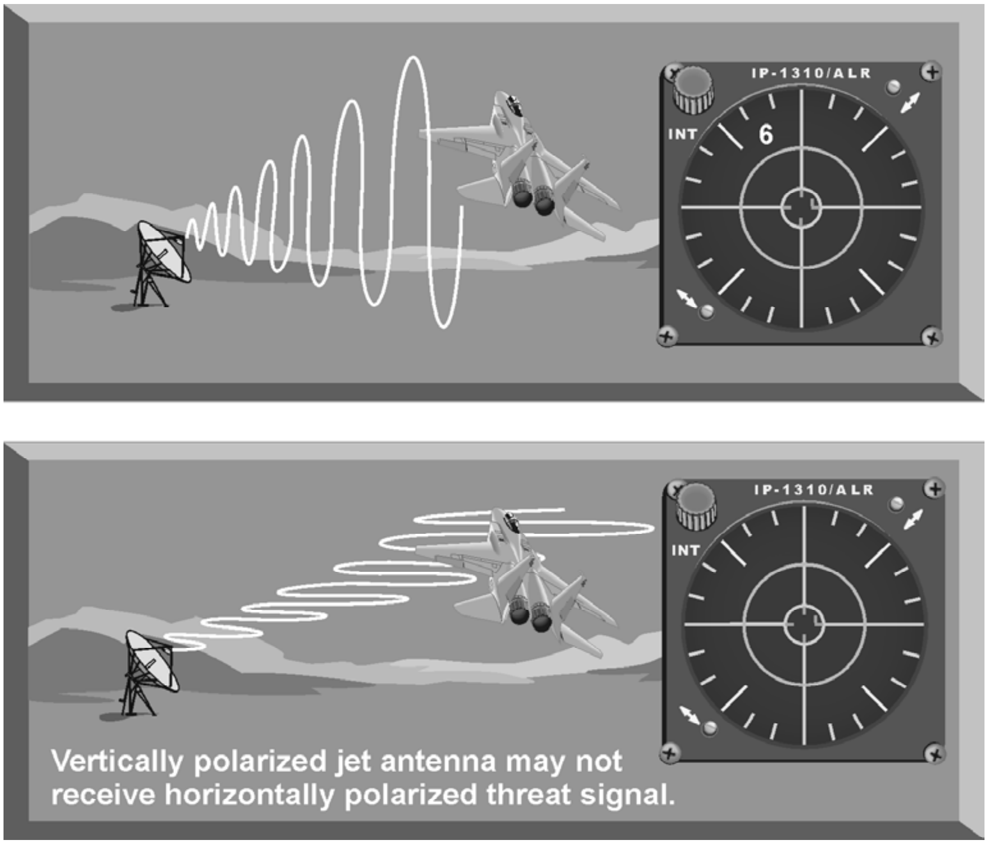
IP-1310/ALR
INT
6
IP-1310/ALR
INT
Vertically polarized jet antenna may not receive horizontally polarized threat signal.

Figure 2-5. Impact of Polarization

The impact of cross polarization on electronic combat can be dramatic. If a radar warning receiver antenna is polarized to receive vertically polarized signals, a threat system employing a horizontally polarized radar signal may not be detected, or may be displayed on the scope well after the threat has acquired the aircraft. In addition, if the jamming antenna on an electronic attack (EA) system is also vertically polarized, it may not be able to jam this system. Fortunately, this potentially lethal situation rarely occurs, but future threat systems may take advantage of this situation. Table 2-1 details the impact of polarization on selected transmit and receive antenna combinations.

Table 2-1. Antenna Polarization Loss

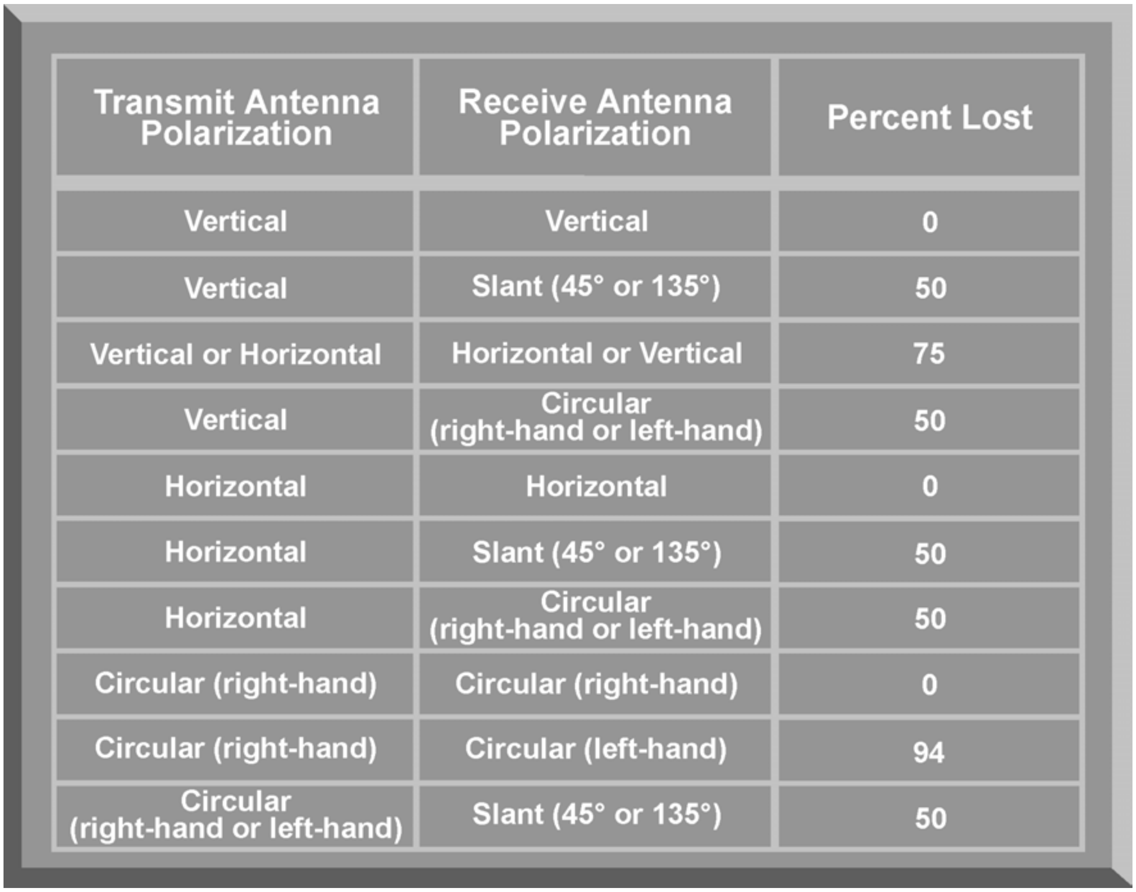

Transmit Antenna Polarization	Receive Antenna Polarization	Percent Lost
Vertical	Vertical	0
Vertical	Slant (45° or 135°)	50
Vertical or Horizontal	Horizontal or Vertical	75
Vertical	Circular (right-hand or left-hand)	50
Horizontal	Horizontal	0
Horizontal	Slant (45° or 135°)	50
Horizontal	Circular (right-hand or left-hand)	50
Circular (right-hand)	Circular (right-hand)	0
Circular (right-hand)	Circular (left-hand)	94
Circular (right-hand or left-hand)	Slant (45° or 135°)	50

5. DOPPLER EFFECT

The “Doppler effect” takes advantage of the fact that the frequency of RF waves will be changed or shifted when reflected from a target moving relative to the radar. The shifted frequency of the returning RF wave depends on the movement of the aircraft in relation to the radar. In Figures 2-6, 2-7, and 2-8, f_o is the transmitted frequency of the radar, and f_t is the frequency of the reflected RF

wave from the target. For a stationary target, the frequency of the reflected signal will equal the frequency of the transmitted signal (Figure 2-6).

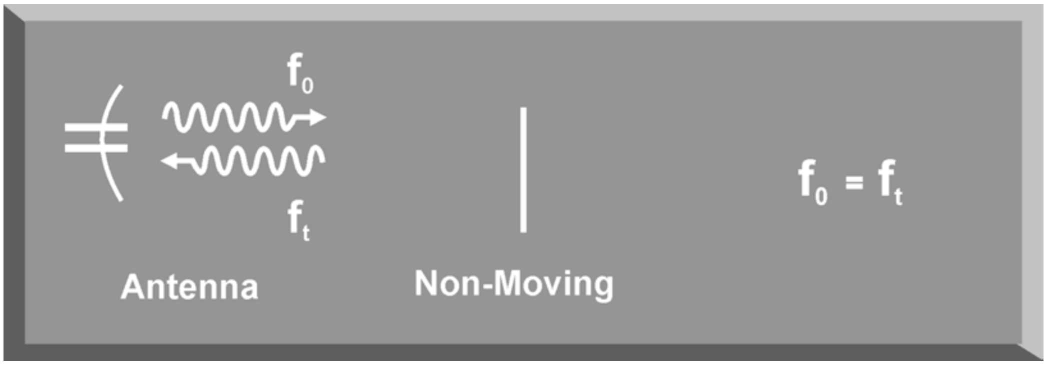
f_0
f_t
Antenna
Non-Moving
$f_0 = f_t$

Figure 2-6. Zero Doppler Effect – Stationary Target

a. For a target moving toward the radar, the frequency of the reflected signal will be higher than the transmitted signal (Figure 2-7).

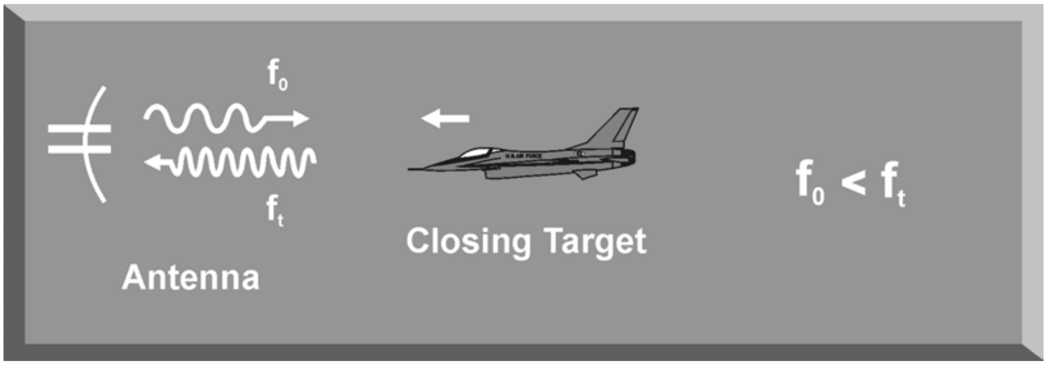
f_0
f_t
Closing Target
Antenna
$f_0 < f_t$

Figure 2-7. Doppler Effect – Closing Target

b. The reflected frequency for a target moving away from the radar will be lower than the transmitted frequency (Figure 2-8).

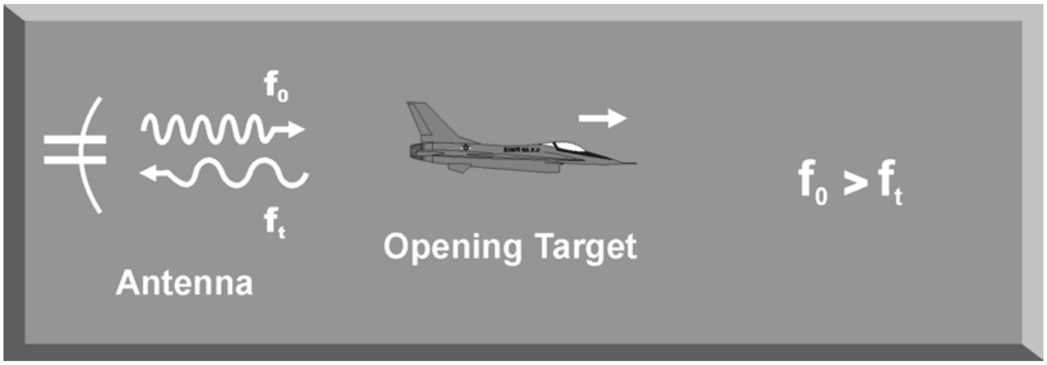
f_0
f_t
Opening Target
Antenna
$f_0 > f_t$

Figure 2-8. Doppler Effect – Opening Target

6. ELECTROMAGNETIC SPECTRUM

The portion of the electromagnetic spectrum (Figure 2-9) that today's electronic combat systems must deal with starts with radio waves and encompasses microwaves, infrared, and a small portion of the ultraviolet region. Communications systems generally operate in the HF, UHF, and VHF regions. Some satellite communications operate in the SHF region. Radars operate in the microwave region, normally from 0.2 – 200 gigahertz. Infrared systems operate in the region just below visible light.

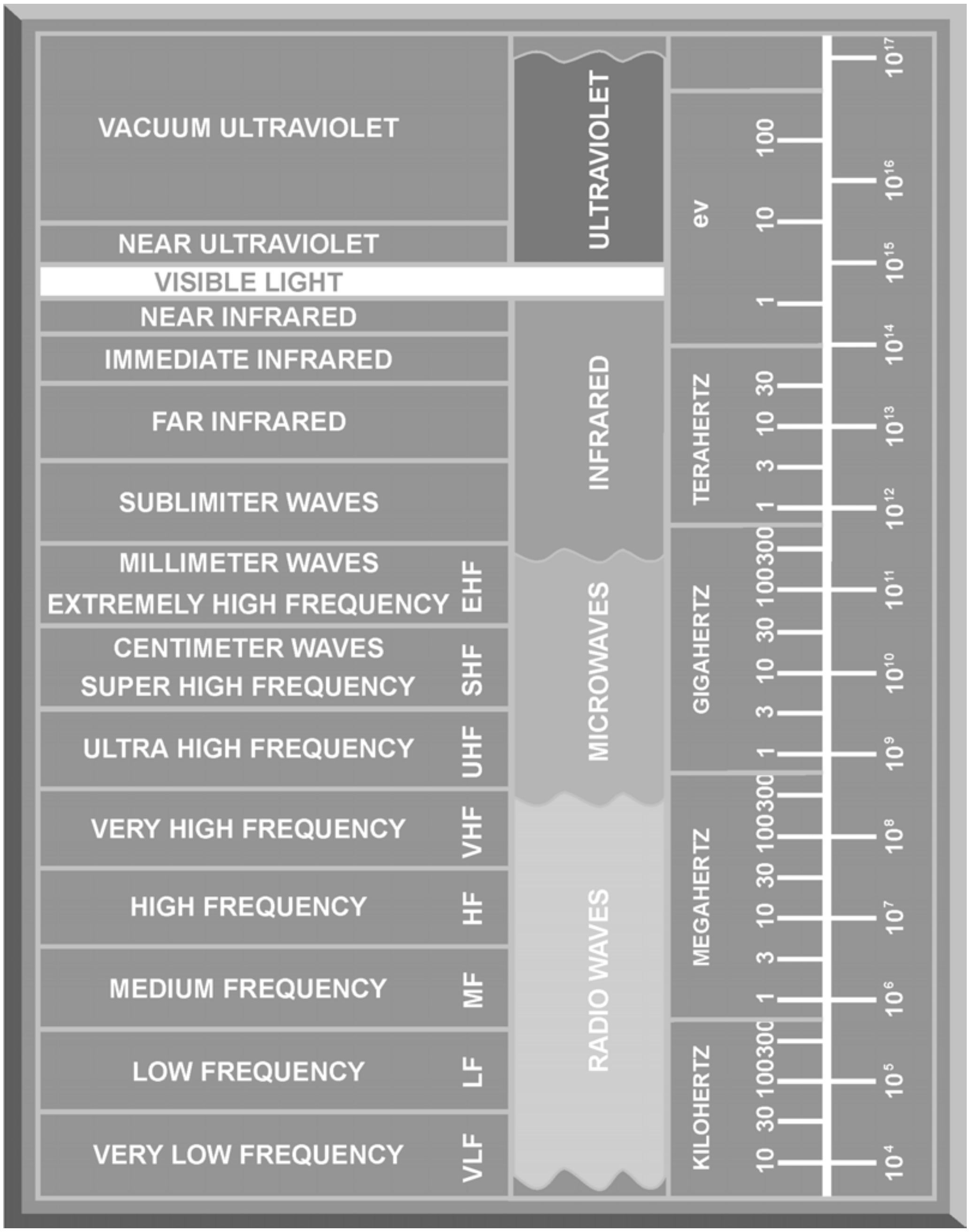
VACUUM ULTRAVIOLET
NEAR ULTRAVIOLET
VISIBLE LIGHT
NEAR INFRARED
IMMEDIATE INFRARED
FAR INFRARED
SUBLIMITER WAVES
MILLIMETER WAVES
EXTREMELY HIGH FREQUENCY
EHF
CENTIMETER WAVES
SUPER HIGH FREQUENCY
SHF
ULTRA HIGH FREQUENCY
UHF
VERY HIGH FREQUENCY
VHF
HIGH FREQUENCY
HF
MEDIUM FREQUENCY
MF
LOW FREQUENCY
LF
VERY LOW FREQUENCY
VLF
ULTRAVIOLET
INFRARED
MICROWAVES
RADIO WAVES
ev
1 10 100
TERAHERTZ
1 3 10 30
GIGAHERTZ
1 3 10 30 100 300
MEGAHERTZ
1 3 10 30 100 300
KILOHERTZ
10 30 100 300
10^4
10^5
10^6
10^7
10^8
10^9
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}

Figure 2-9. Electromagnetic Spectrum

a. Table 2-2 lists prefixes commonly used to indicate scientific notation and their abbreviations. These prefixes are often used when dealing with extremely high frequency radar signals or RF waves with extremely small wavelengths. For example, when dealing with extremely high frequency RF, it is simpler to use gigahertz, or GHz. One gigahertz is one thousand megahertz (MHz). For example, a radar operating at 3150 MHz is also operating at an RF of 3.150 GHz.

Table 2-2. Commonly Used Prefixes for Scientific Notation

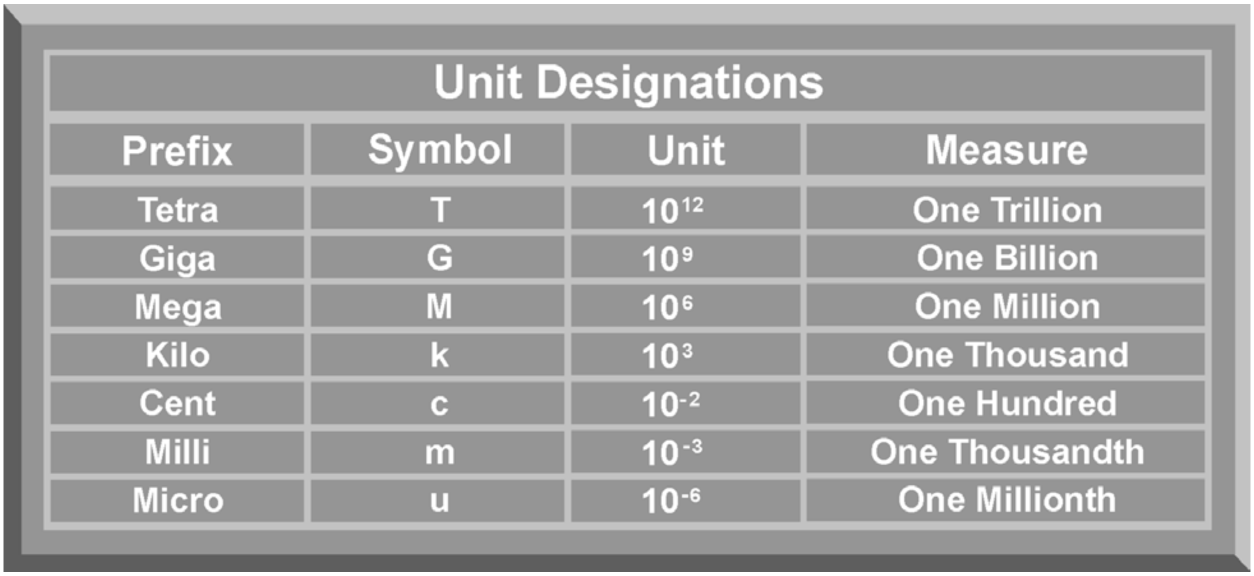

Unit Designations

Prefix	Symbol	Unit	Measure
Tetra	T	10^{12}	One Trillion
Giga	G	10^{9}	One Billion
Mega	M	10^{6}	One Million
Kilo	k	10^{3}	One Thousand
Cent	c	10^{-2}	One Hundred
Milli	m	10^{-3}	One Thousandth
Micro	u	10^{-6}	One Millionth

b. Frequency bands are often used when discussing radars and electronic combat systems. Radar designers use a frequency band designation system entirely different from the one used in electronic combat. Table 2-3 depicts both frequency band designation systems and the corresponding frequency ranges.

Table 2-3. Radar Frequency Band Designations

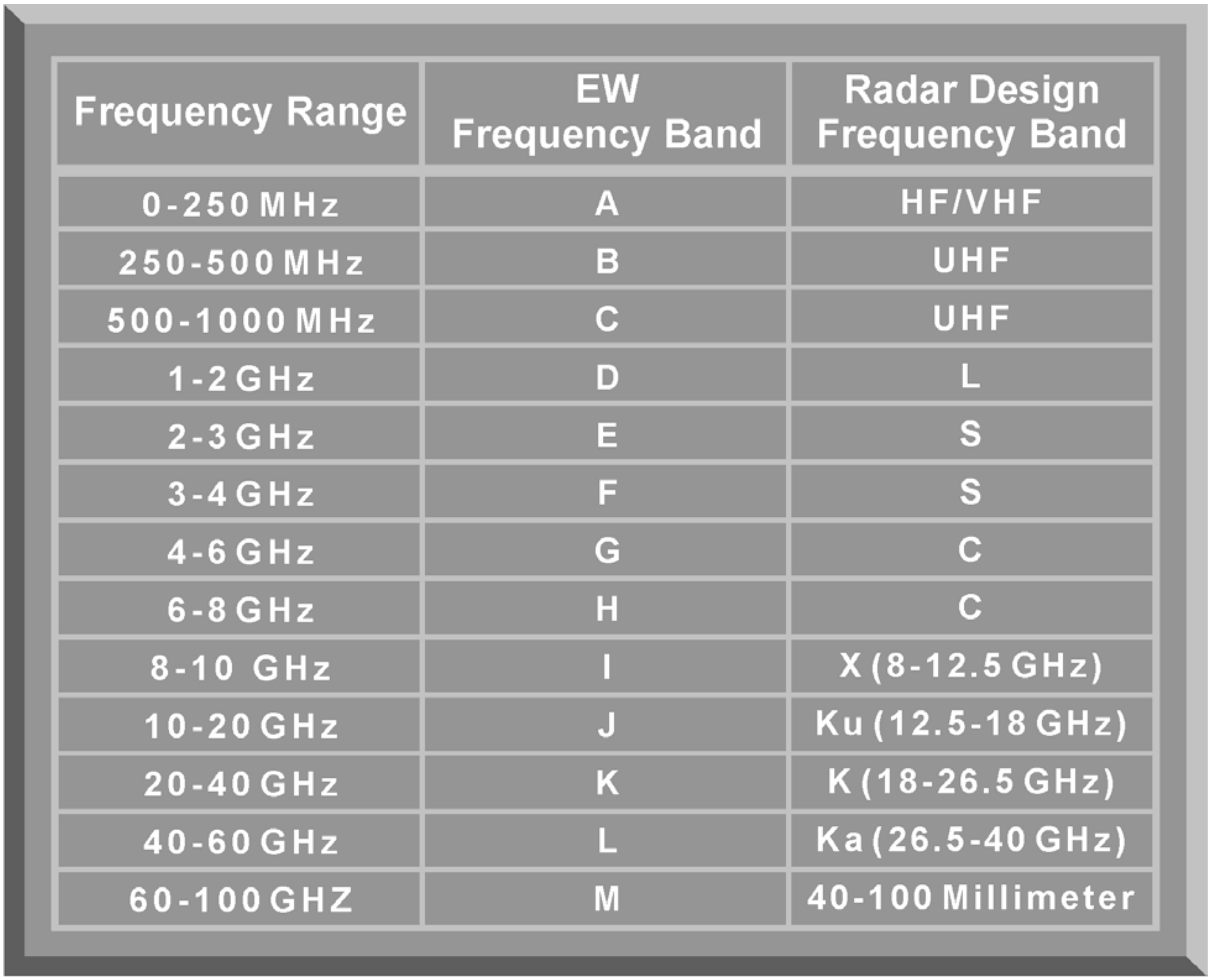

Frequency Range	EW Frequency Band	Radar Design Frequency Band
0-250 MHz	A	HF/VHF
250-500 MHz	B	UHF
500-1000 MHz	C	UHF
1-2 GHz	D	L
2-3 GHz	E	S
3-4 GHz	F	S
4-6 GHz	G	C
6-8 GHz	H	C
8-10 GHz	I	X (8-12.5 GHz)
10-20 GHz	J	Ku (12.5-18 GHz)
20-40 GHz	K	K (18-26.5 GHz)
40-60 GHz	L	Ka (26.5-40 GHz)
60-100 GHZ	M	40-100 Millimeter

7. RF PROPAGATION

Propagation characteristics of RF energy are profoundly affected by the earth's surface and atmospheric conditions. Any analysis of radar performance must take into account the propagation phenomena associated with RF radiation in a "real world" environment. The most important propagation phenomena include refraction, anomalous propagation (ducting), and attenuation.

a. In a vacuum, RF waves travel in a straight line. However, RF waves propagating within the earth's atmosphere do not travel in a straight line. The earth's atmosphere bends, or refracts, RF waves. One impact of the atmospheric refraction of RF waves is an increase in the line of sight (LOS) of the radar. This increase in radar LOS effectively extends the range of the radar system (Figure 2-10).

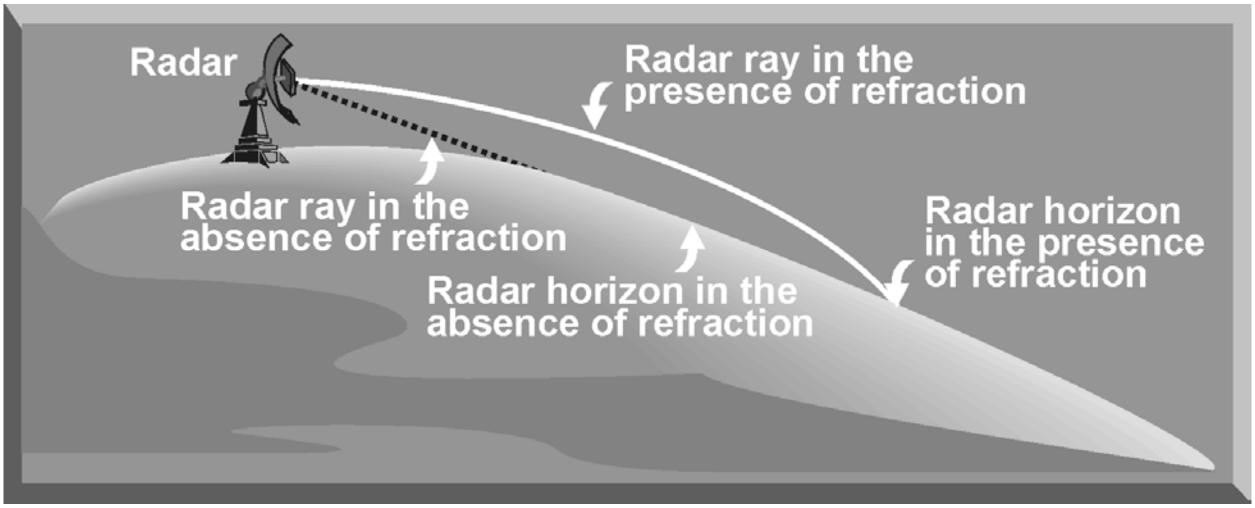
Radar
Radar ray in the presence of refraction
Radar ray in the absence of refraction
Radar horizon in the presence of refraction
Radar horizon in the absence of refraction

Figure 2-10. Impact of Refraction on RF Propagation

Atmospheric refraction of RF energy can also induce elevation measurement errors in radar systems (Figure 2-11).

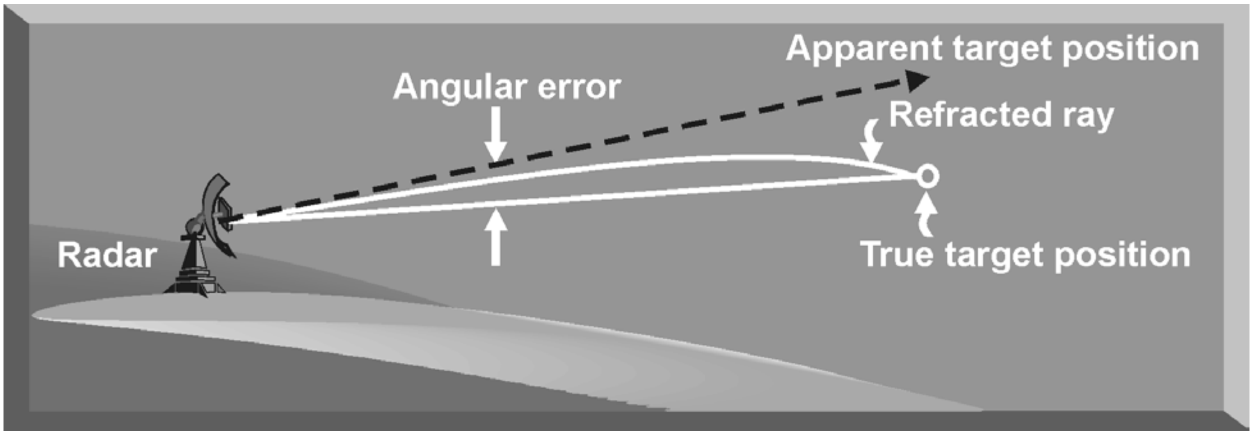
Apparent target position
Angular error
Refracted ray
Radar
True target position

Figure 2-11. Impact of Refraction on Target Elevation Determination

(1) The refraction of RF waves in the atmosphere is caused by the variation in the velocity of propagation with altitude. The index of refraction (n) is used to describe this velocity variation and is defined by Equation 2-2.

$$\text{Index of Refraction (n)} = \frac{\text{Velocity of Propagation in a Vacuum}}{\text{Velocity of Propagation in the Atmosphere}}$$

Equation 2-2. Index of Refraction

(2) The term refractivity (N) is used for predicting the impact of refraction on RF wave propagation. Refractivity is a “scaled up” expression for the index of refraction and is used by radar designers to calculate the impact of refraction on actual radar systems. At normal radar operating frequencies, the refractivity for air containing water vapor can be computed using Equation 2-3.

$$\text{Refractivity (N)} = (n-1)\times 10^{6} = \frac{77.6\,p}{T} + \frac{3.75 \times 10^{5} e}{T^{2}}$$

n = index of refraction

p = barometric pressure

e = partial pressure of water vapor

T = absolute temperature (degrees K)

Equation 2-3. Refractivity of RF Waves (Normal Radar Frequencies)

(3) As altitude increases, the barometric pressure and water vapor content decrease rapidly. At the same time, the absolute temperature decreases slowly based on the standard lapse rate. Using Equation 2-3, it can be seen that the refractivity of the atmosphere decreases with increasing altitude. This decrease in refractivity means that the velocity of RF waves increases with altitude. The result is a downward bending, or refraction, of RF waves as depicted in Figure 2-10. RF wave refraction primarily affects ground-based radar systems at low antenna elevation angles, especially at or near the horizon. For most radar applications, refraction is not a factor at elevation angles above 5 degrees.

b. The term anomalous, or nonstandard, propagation is used to describe atmospheric conditions that extend the propagation of RF waves and increase radar range. The most common anomalous propagation phenomena is called superrefraction, or ducting.

(1) A superrefracting duct is formed when the refractivity of the atmosphere (Equation 2-2) rapidly decreases with altitude. Based on Equation 2-2, this occurs when the temperature increases with altitude and/or the water vapor content decreases with altitude. An increase in temperature with altitude is called a temperature inversion. To produce a duct, the temperature inversion must be very pronounced.

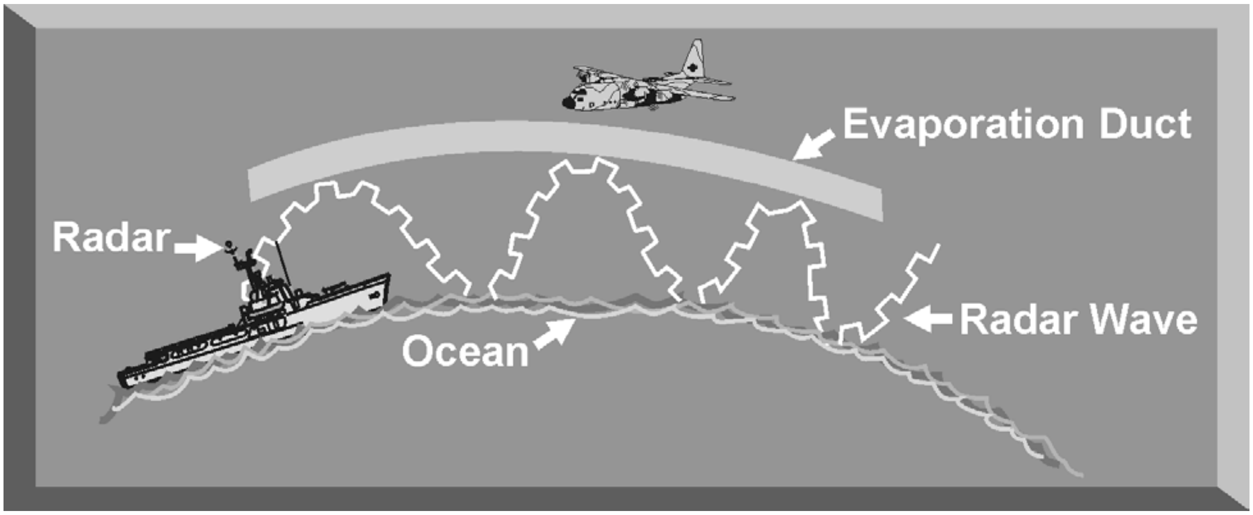

Figure 2-12. Superrefracting Surface Duct

(2) A superrefracting duct acts like a wave guide which traps the RF wave (Figure 2-12). This channels the radar signal and reduces attenuation. In order for an RF wave to propagate within a duct, the angle of the radar signal, in relation to the duct, should be less than one degree. The RF waves trapped by the duct take advantage of the decrease in refractivity and travel much further than normal. This can greatly extend the range of a radar system.

(3) The extension of radar range inside a duct can result in a reduction of radar coverage outside the duct. The area of reduced radar coverage because of ducting is called a radar hole. Due to radar holes, the extended radar range caused by ducting may result in a decrease in radar coverage along other paths of propagation. These holes can seriously degrade the effectiveness of early warning radar systems. For example, a radar system is taking advantage of a duct formed at the surface to extend low altitude radar range (Figure 2-12). Airborne targets flying just above the duct would normally be detected, but because of ducting, these targets may be missed.

(4) Water vapor content is a significant factor in producing ducts. Consequently, most ducts are formed over water and in warm climates. Any atmospheric phenomenon that results in a pronounced increase in temperature and/or a decrease in water vapor content as altitude increases can generate a superrefracting duct, of which there are three types. A superrefracting duct which is formed just above the surface of the earth is referred to as a surface duct. A surface duct formed just above the surface of the ocean is called an evaporation duct. A duct which is formed well above the surface of the earth is known as an elevated duct.

(a) Surface ducts formed over land are usually a result of the nighttime radiation of heat from the earth. Duct formation is especially prevalent during the

summer months when the ground is moist. As the earth loses heat, a temperature inversion is created at the surface coupled with a sharp decrease in the moisture content. These conditions are favorable to the formation of a surface duct. A superrefracting duct can also be produced by the diverging downdraft under a thunderstorm. The cool air that is dispersed creates a local temperature inversion while the water vapor content decreases due to rain. Surface ducts formed in conjunction with thunderstorms are difficult to predict and normally persist for a short period of time.

(b) A superrefracting surface duct that lies just above the surface of the ocean is a result of evaporated water, thus the term evaporation duct. The air in contact with the ocean is saturated with water vapor, while the air several feet above the ocean contains a much lower level. This rapid decrease in water vapor pressure with an increase in altitude creates an evaporation duct. An evaporation duct exists over the ocean almost all the time. The height of this duct varies from 20 to 100 feet based on the season, time of day, and wind speed. One positive aspect of an evaporation duct is the extended range available to a shipborne radar system with a properly aligned antenna. This extended range coverage against surface ships and low altitude aircraft is a definite advantage of ducted propagation.

(c) An elevated duct is generally formed by a temperature inversion in the upper atmosphere. To take maximum advantage of the increased radar range inside an elevated duct, both the radar and the target should be inside the elevated duct. In addition, radar systems operating below an elevated duct may also experience enhanced range performance.

(4) The presence of surface ducts and elevated ducts, especially over land, are extremely difficult to predict and may persist for very short periods of time. The atmospheric conditions favorable to duct formation are difficult to predict using conventional weather forecasting techniques.

c. The attenuation of RF energy in a clear atmosphere is due to the presence of oxygen and water vapor. Attenuation results when a portion of the RF energy strikes these molecules and is absorbed as heat. Figure 2-13 details the RF attenuation loss due to atmospheric gasses based on the frequency of the RF energy.

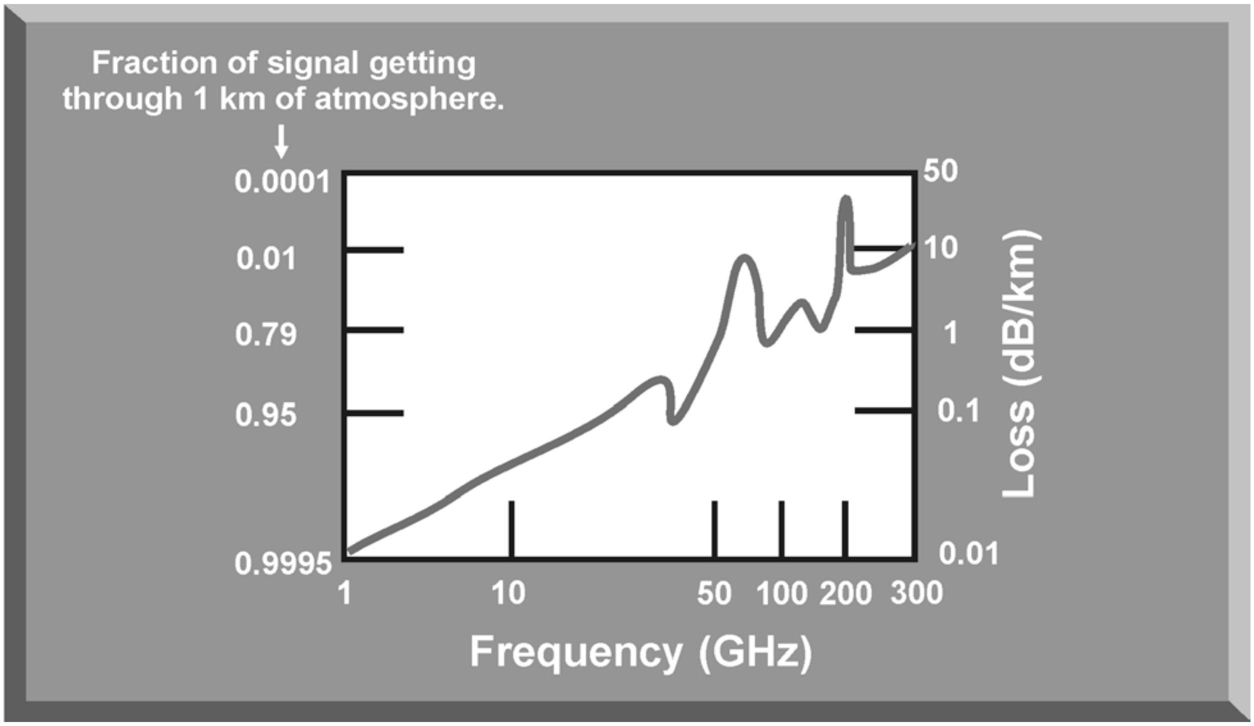

Figure 2-13. RF Atmospheric Attenuation

(1) At frequencies below 1 GHz, the effect of atmospheric attenuation is negligible. Above 10 GHz, atmospheric attenuation increases dramatically. This dramatic signal loss impacts the maximum detection range of radars operating in the millimeter wavelength band.

(2) RF energy attenuation decreases as altitude increases. The RF attenuation experienced by an air-to-air radar will depend on the altitude of the target as well as target range. For a ground-based radar, RF attenuation will decrease as antenna elevation increases.

8. SUMMARY

Since all radar operations depend on the transmission and reception of RF energy, a basic knowledge of RF frequency, wavelength, and polarization provides the basis for understanding the more complex radar characteristics. Since most modern radar systems employ some form of Doppler signal processing, the concept of the Doppler effect is fundamental to understanding modern radar operation. The concepts of refraction, anomalous propagation (ducting), and atmospheric attenuation are key to understanding how RF waves propagate in the atmosphere. The topics in this chapter provide a foundation for understanding radar and jamming system operation.

CHAPTER 3. RADAR SIGNAL CHARACTERISTICS

1. INTRODUCTION

Every radar produces a radio frequency (RF) signal with specific characteristics that differentiate it from all other signals and define its capabilities and limitations. Pulse width (pulse duration), pulse recurrence time (pulse repetition interval), pulse repetition frequency, and power are all radar signal characteristics determined by the radar transmitter. Listening time, rest time, and recovery time are radar receiver characteristics. An understanding of the terms used to describe these characteristics is critical to understanding radar operation.

2. PULSE WIDTH (PW)

Figure 3-1 depicts the output from a typical pulse radar. PW, sometimes called pulse duration (PD), is the time that the transmitter is sending out RF energy. PW is measured in microseconds. It has an impact on range resolution capability, that is, how accurately the radar can discriminate between two targets based on range.

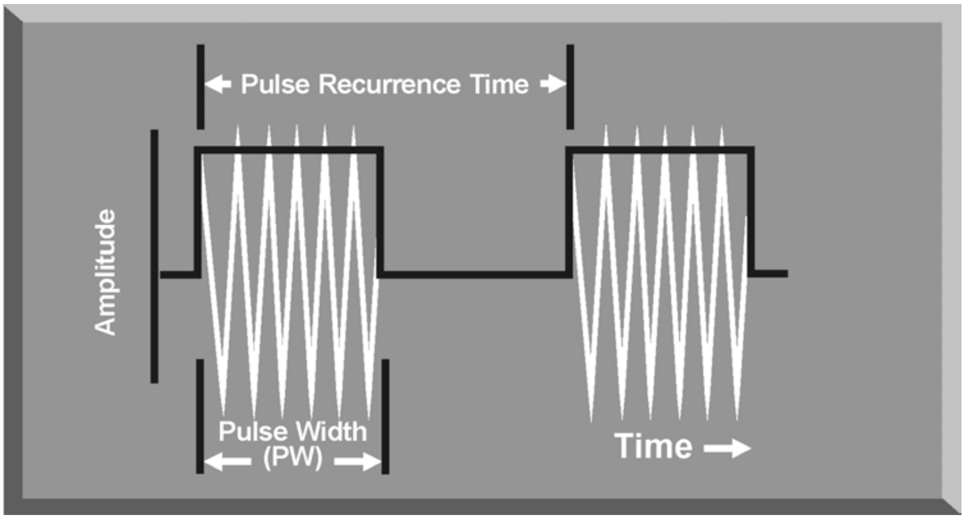

Figure 3-1. Typical Radar Pulse

3. PULSE RECURRENCE TIME (PRT)

Pulse recurrence time is also known as pulse repetition time. PRT is the time required for a complete transmission cycle. This is the time from the beginning of one pulse of RF energy to the beginning of the next. PRT is measured in microseconds. PRT is the same as pulse repetition interval (PRI), which is used in radar warning receivers and other electronic warfare support (ES) assets to discriminate between radar systems. It also affects maximum radar range.

4. PULSE REPETITION FREQUENCY (PRF)

One of the most important characteristics of a pulse radar signal is pulse repetition frequency. PRF is the rate at which pulses or pulse groups are transmitted. Generally, PRF is the number of pulses generated per second and is expressed in hertz (Hz). PRF and PRI are related in that PRI is the inverse of PRF. A word of caution—do not confuse the operating frequency of the radar, which is measured in Hz, with the pulse repetition frequency, which is also measured in Hz. They are entirely different characteristics of a pulsed radar signal.

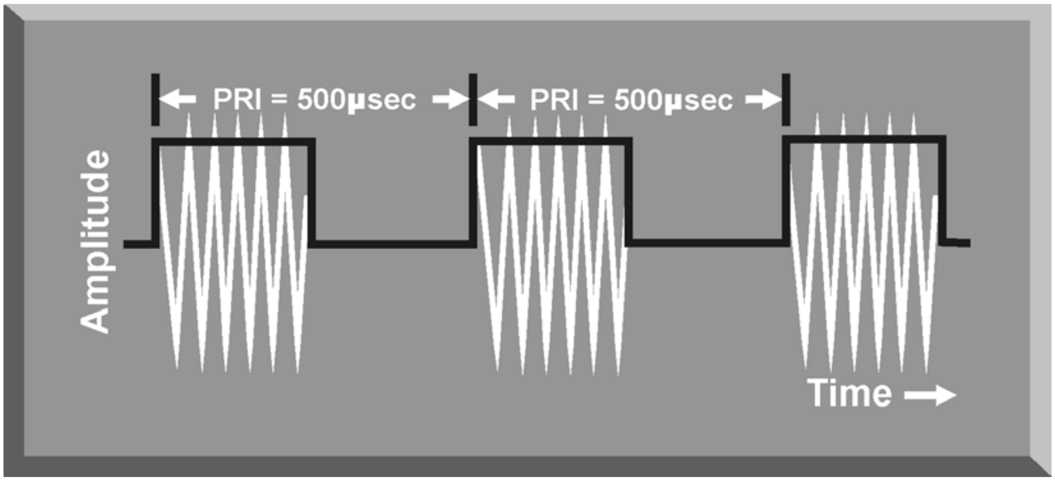

Figure 3-2. Constant PRF Radar Pulse

a. A pulse radar operating at an unvarying PRF is called a constant PRF radar (Figure 3-2). Pulse radar systems can employ PRF stagger or PRF jitter as an electronic protection (EP) technique against repeater or synchronous jammers. The time between each pulse is the PRI.

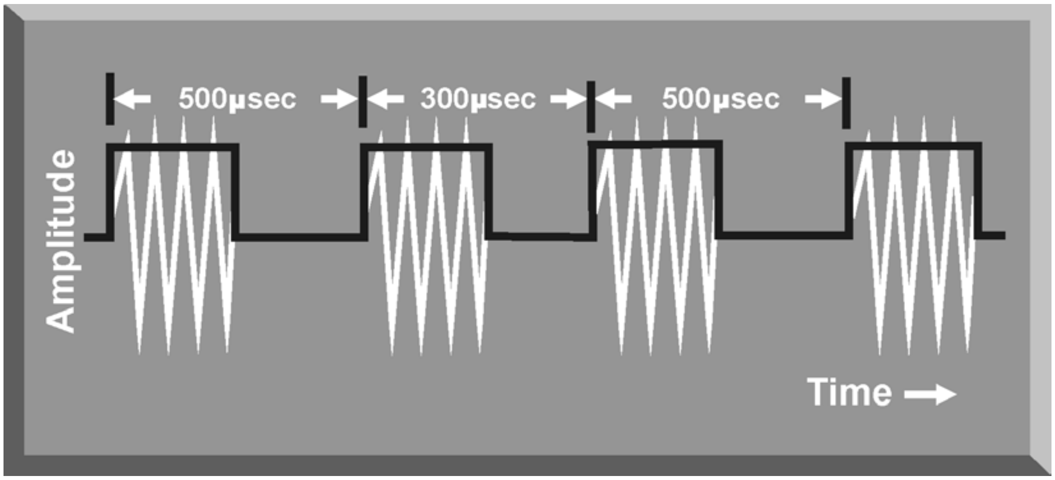

Figure 3-3. PRF Stagger

b. PRF stagger is accomplished by assuring that no adjacent PRIs are equal. The number of different PRIs generated is called the "position" of the stagger. Two-position stagger would have two PRI values, for example, 300 microseconds and 500 microseconds (Figure 3-3).

c. PRF jitter may be considered a random stagger. It is also an EP technique to counter synchronous jammers. PRF jitter has no repeating pattern of PRI values (Figure 3-4).

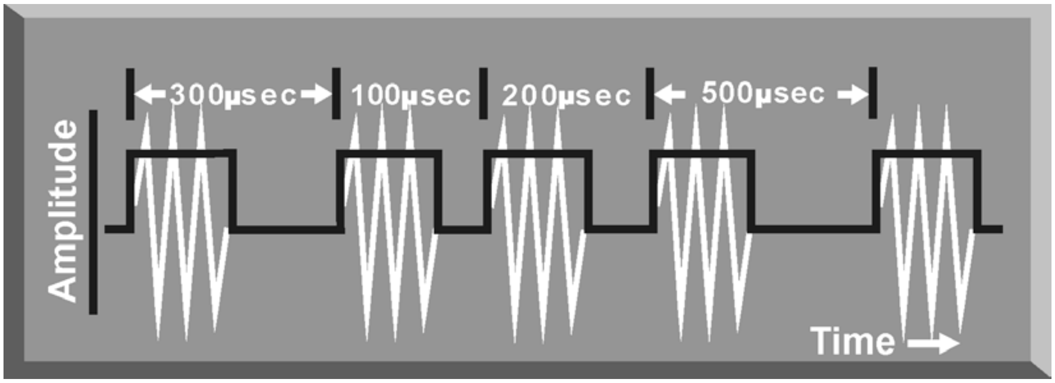
300μsec
100μsec
200μsec
500μsec
Amplitude
Time

Figure 3-4. PRF Jitter

5. RADAR RECEIVER CHARACTERISTICS

Pulse repetition frequency, pulse recurrence time, and pulse width are determined by the transmitter. The pulse radar signal characteristics that relate to receiver operation are rest time, recovery time (RT), and listening time (LT) (Figure 3-5).

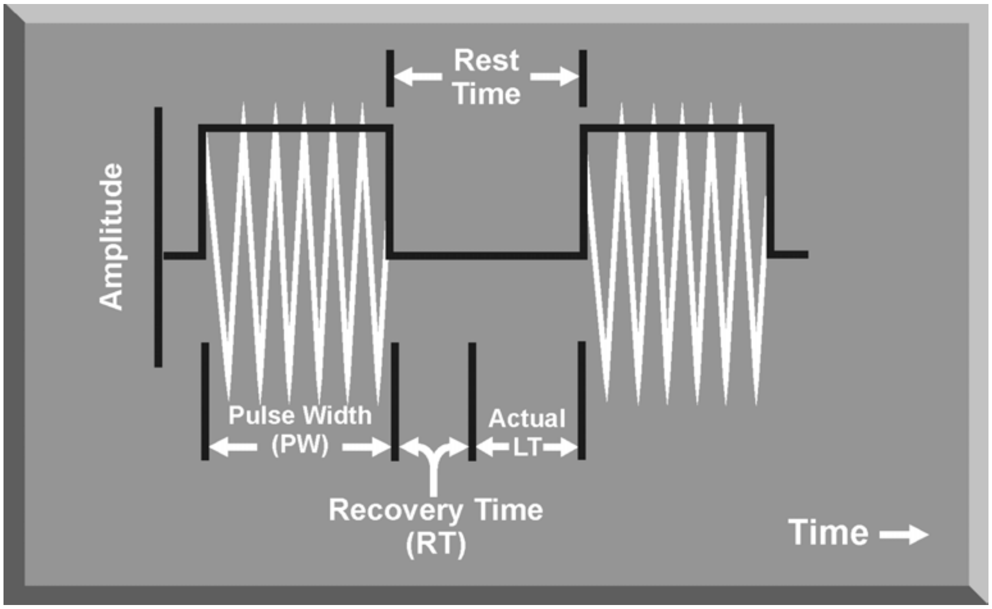
Rest Time
Amplitude
Pulse Width (PW)
Actual LT
Recovery Time (RT)
Time

Figure 3-5. Basic Radar Pulse

a. Rest time is the time between the end of one transmitted pulse and the beginning of the next. It represents the total time that the radar is not transmitting. Rest time is measured in microseconds.

b. Recovery time (RT) is the time immediately following transmission time during which the receiver is unable to process returning radar energy. RT is determined by the amount of isolation between the transmitter and receiver and the efficiency of the duplexer. A part of the high power transmitter output spills over into the receiver and saturates this system. The time required for the receiver to recover from this condition is RT.

c. Listening time (LT) is the time the receiver can process target returns. Listening time is measured from the end of the recovery time to the beginning of the next pulse, or PRT minus (PW + RT). Listening time is measured in microseconds.

6. DUTY CYCLE

Duty cycle is the ratio of the time the transmitter operates to the time it could operate during a given transmission cycle. The duty cycle of a radar can be computed by dividing the PW by the PRT, or by multiplying the PW times the PRF. Duty cycle has no units (Equation 3-1). CW radars have a duty cycle of 100%, while early warning radars may have a duty cycle of around 1%.

$$\text{Duty Cycle} = \frac{PW}{PRT} \text{ or } \text{Duty Cycle} = PW \times PRF$$

Equation 3-1. Duty Cycle

7. PEAK POWER

The power output of a radar is normally expressed in terms of peak power or average power (Figure 3-6). Peak power is the amplitude, or power, of an individual radar pulse. It is simply the power, measured in watts or megawatts, that is radiated when the transmitter is on. The power a radar transmits is normally used to determine the maximum detection range of that radar. However, it is the energy in a radar pulse that determines maximum radar detection range. Since power is the rate of flow of energy, the energy in a radar pulse is equal to the peak power multiplied by the time the radar is transmitting, or pulse width (Equation 3-2).

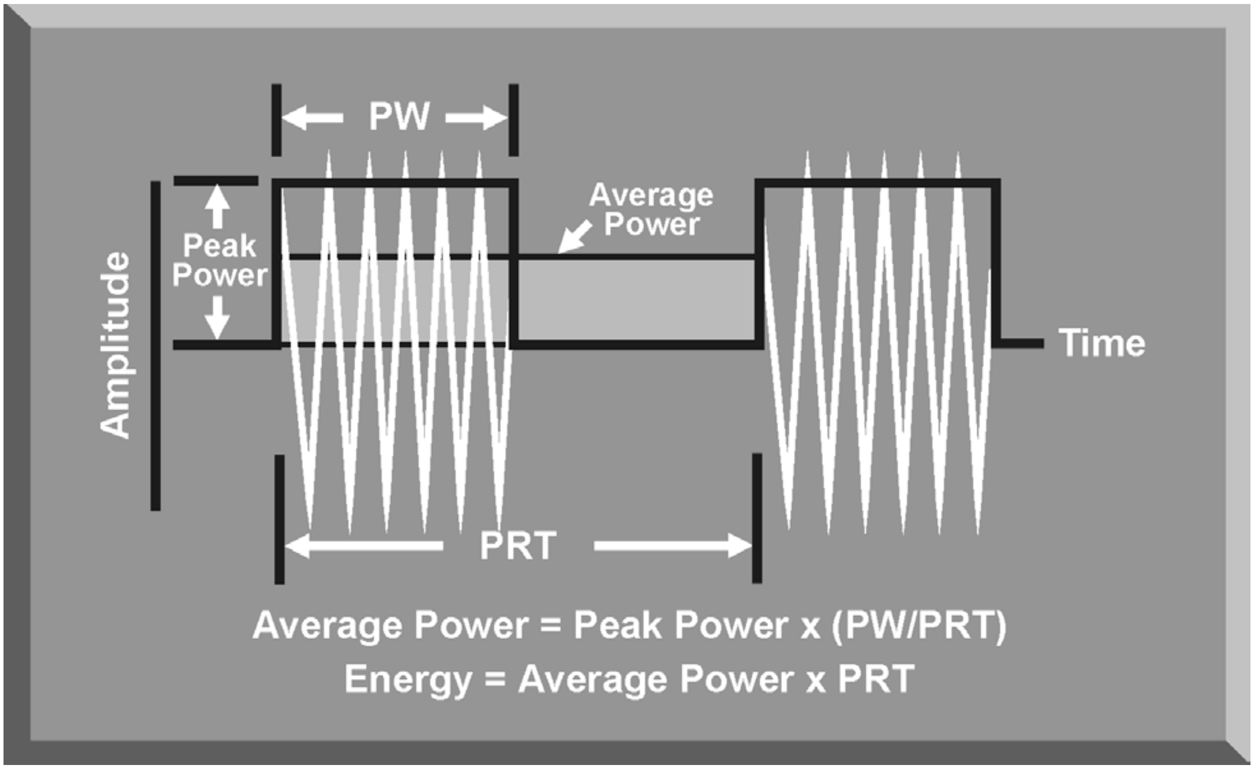

Average Power = Peak Power x (PW/PRT)

Energy = Average Power x PRT

Figure 3-6. Peak Power and Average Power

Energy Per Pulse = Peak Power x Pulse Width

Equation 3-2. Energy Per Pulse

8. AVERAGE POWER

Average power is the power distributed over the pulse recurrence time. It can be computed using the formula in Figure 3-6. The energy transmitted by average power can be computed by multiplying average power by PRT. Since the energy in a set of pulses determines detection range, average power or energy provides a better measure of the detection range of a radar than does peak power. Average power can be increased by increasing the PRF, by increasing the pulse width, or by increasing peak power (Figure 3-7).

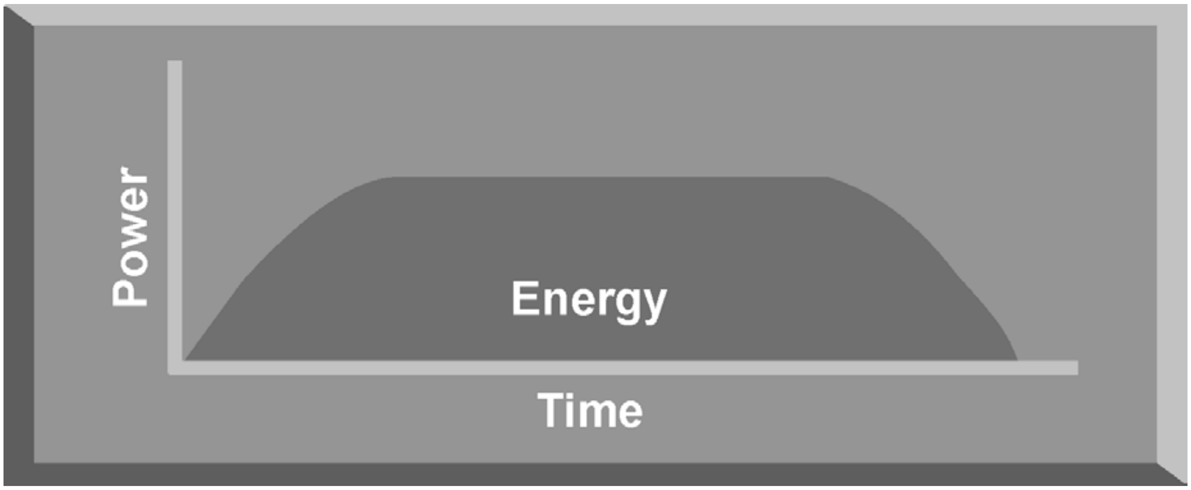

Figure 3-7. Radar Power and Energy

9. MODULATION

The characteristics of an RF signal must be changed in order to transmit information on the signal. This process is called modulation. Modulation is accomplished by combining a basic RF signal, called a carrier wave, with a modulating signal that contains the desired information. The resulting waveform is then used to transmit the desired information.

a. One basic modulation technique is amplitude modulation (AM). The carrier wave is combined with a modulating signal containing information of varying amplitude. Waveforms produced have the same frequency as the carrier wave but with a varying amplitude based on the information from the modulating signal. AM is used extensively in communications and broadcast radio transmissions (Figure 3-8).

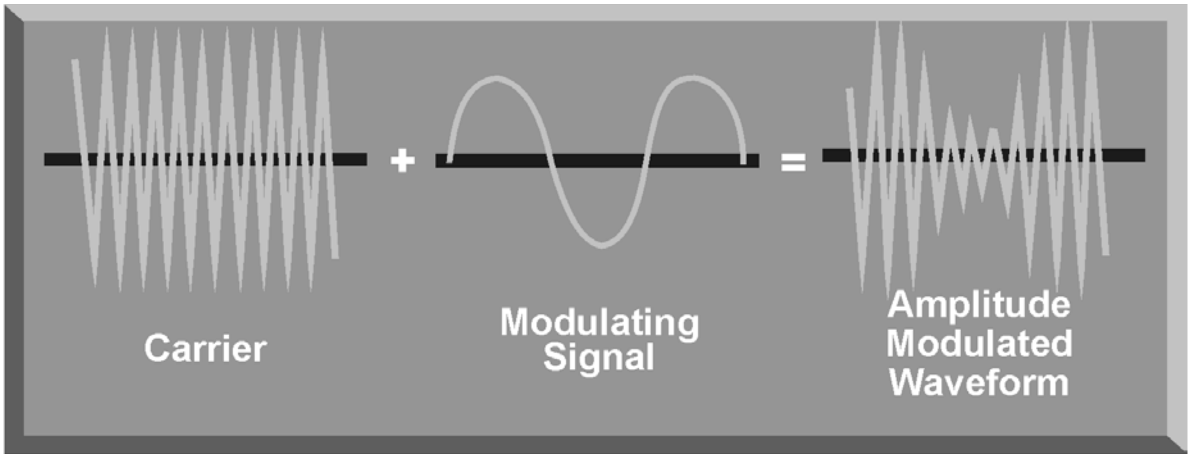

Figure 3-8. Amplitude Modulation

b. Frequency modulation (FM) is another means of impressing information on a carrier wave. Frequency modulation is accomplished by combining the carrier wave with a modulating signal containing information of varying frequency. The waveform produced has the same amplitude as the carrier wave, but the frequency varies based on the information from the modulating signal (Figure 3-9). FM is used extensively in communications and commercial radio. FM is also used with continuous wave (CW) radars to make them more resistant to jamming and to add range determination capability.

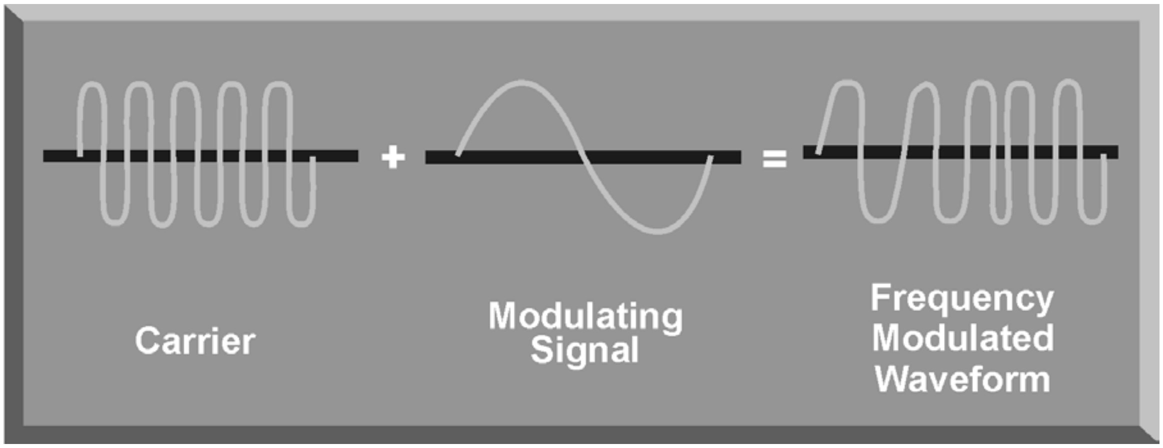

Figure 3-9. Frequency Modulation

c. A type of amplitude modulation known as pulse modulation (PM) is used in pulse radars to produce the short, powerful bursts of RF energy. PM combines the carrier wave with a rectangular pulse that acts like a switch. PM turns the transmitter on, leaves it on for a predetermined time, and then turns it off. The result is a waveform that produces radar pulses that can be used to measure range and angle to the target (Figure 3-10).

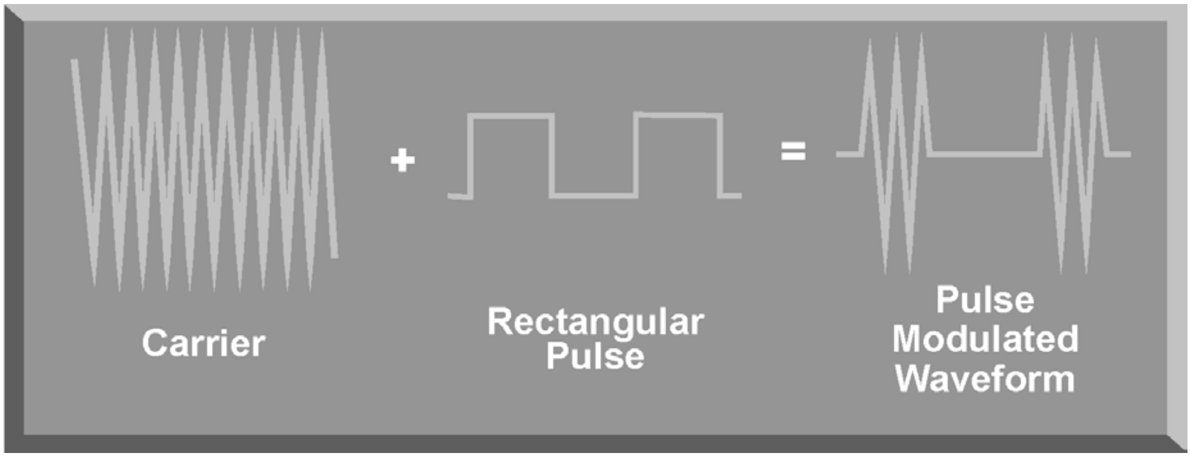

Figure 3-10. Pulse Modulation

10. SUMMARY

The radar signal characteristics of PW, PRI, PRF, and power determine the maximum range and the range resolution capability of a specific radar. When combined with the frequency of the carrier wave of the radar signal, these parameters provide a unique signature to identify a specific radar signal. Modulation is the method used to put information on an RF carrier wave. The primary modulation techniques used in radar signal generation include amplitude, frequency, and pulse modulation. The radar signal characteristics of PRF, PRI, power, and modulation are the keys to understanding radar operation and jamming techniques.

CHAPTER 4. RADAR SYSTEM COMPONENTS

1. INTRODUCTION

The individual components of a radar determine the capabilities and limitations of a particular radar system. The characteristics of these components also determine the countermeasures that will be effective against a specific radar system. This chapter will discuss the components of a basic pulse radar, a continuous wave (CW) radar, a pulse Doppler radar, and a monopulse radar.

2. PULSE RADAR SYSTEM

The most common type of radar design is the pulse radar system. The name describes a process of transmitting discrete bursts of RF energy at the frequency of the radar system. The time that pulses are transmitted determines the pulse repetition frequency (PRF) of the radar system. A pulse radar system can figure out range and azimuth. Range is determined by the time that it takes a pulse to go to a target and return. Target azimuth is determined by the relative position, or antenna orientation, when the pulse strikes the target. Figure 4-1 is a basic block diagram of a simple pulse radar system.

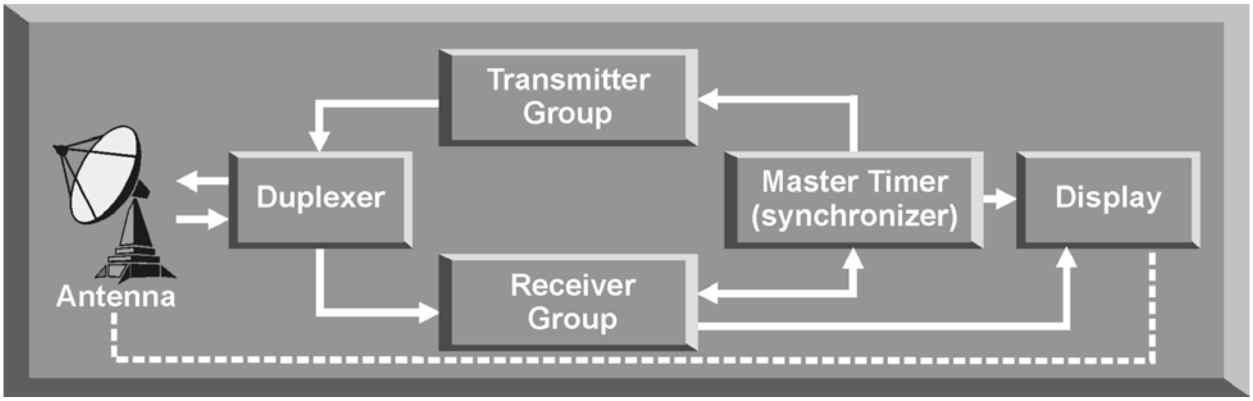

Figure 4-1. Pulse Radar Block Diagram

a. The purpose of the transmitter is to deliver a series of high-energy bursts of radio frequency (RF) energy to the antenna. The transmitter group of a modern pulse radar normally consists of a pulse generator or waveform generator, a modulator, and some kind of power amplifier (Figure 4-2).

(1) The purpose of the waveform generator is to generate the proper waveform or pulse, normally at a low power level, before delivery to the modulator. It is much easier to generate complex waveforms at a lower power level. These complex waveforms are required for coherent systems employing digital moving target indicator techniques and for pulse Doppler radar operations.

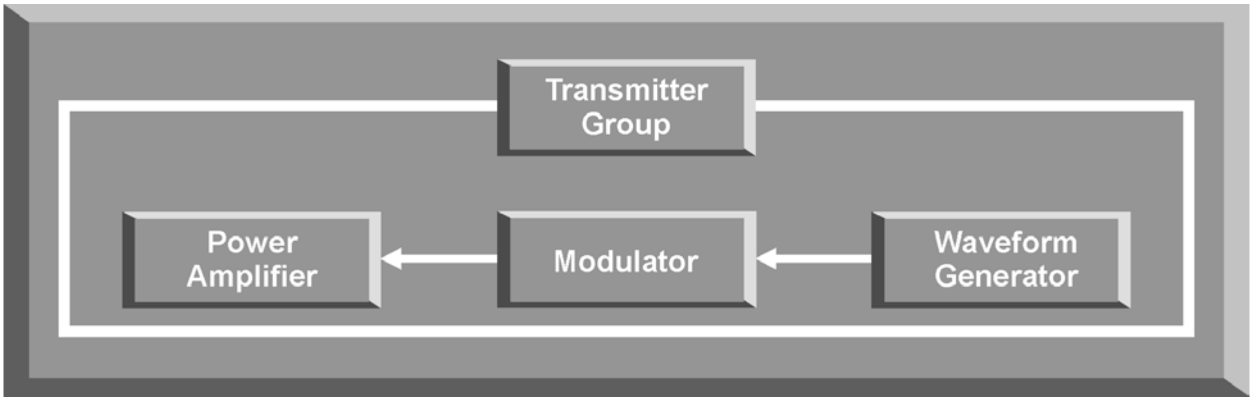

Figure 4-2. Transmitter Group

(2) The modulator is a major portion of the transmitter. The modulator provides an extremely powerful, very short pulse of direct current (DC) voltage to the power amplifier. This is similar to the ignition system of an automobile but with very stringent requirements. The modulator has an energy storage device and a switch. Between pulses, during the resting time of the transmitter, energy is accumulated and stored in the storage device. When keyed by the master timer, all this energy is switched to the power amplifier as a pulse. The waveform of this pulse is determined by the waveform generator.

(3) The power amplifier for a modern radar is normally a klystron, traveling wave tube, cross field amplifier, or solid state amplifier. Most common pulse radars use a klystron power amplifier. No matter what power amplifier is used, the purpose of the transmitter group is to produce a series of pulses at the correct amplitude, at the proper interval, with the exact waveform, and at the operating frequency of the radar.

b. A duplexer is required when both the transmitter and receiver use the same antenna. The duplexer acts as a rapid switch to protect the sensitive receiver from damage when the high-power transmitter is on. When the transmitter is off, the duplexer directs the weak target signals to the receiver. The duplexer's main purpose is to minimize power loss and maximize isolation. Power lost in the duplexer during transmission reduces the maximum detection range of the radar. Isolation refers to the amount of transmitter power that “bleeds through” the duplexer to the receiver during transmission. This “bleed through” must be extremely small to avoid receiver saturation or damage.

c. The capabilities of the receiver group are critical to radar performance (Figure 4-3). The ability of the radar receiver to detect the presence of the target return and extract the required information is limited primarily by noise. Noise can enter the receiver through the antenna along with the target return. This type of noise is called external noise. Noise generated within the receiver is called thermal noise. Radar noise can never be completely eliminated. Minimizing noise

is the most important consideration in the design of the sensitive receivers used with modern radars. In addition, relative immunity to noise makes a radar system more resistant to jamming.

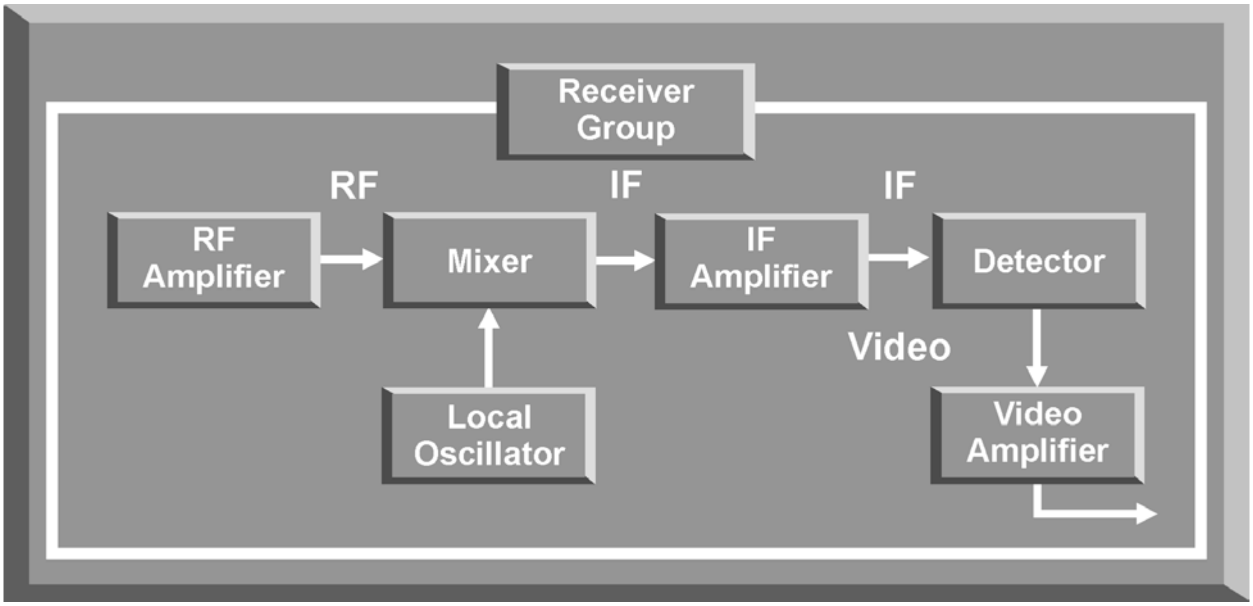

Figure 4-3. Receiver Group

(1) The most common pulse radar receiver is the superheterodyne receiver. A superheterodyne receiver consists of an RF amplifier, a mixer and local intermediate frequency (IF) amplifier, a detector, and a video amplifier.

(2) Radar target returns enter the receiver group via the antenna and duplexer. Since these signals are normally very low power, the RF amplifier boosts the signal gain and filters out as much external noise as possible. The capability of the RF amplifier to minimize noise determines the receiver sensitivity. The boosted RF signal is sent to the mixer where it is converted to a lower IF. This is accomplished by mixing the RF signal with the signal from the local oscillator to produce an IF that is easier to process. The IF amplifier increases the IF signal level and includes a matched filter. The matched filter maximizes the signal-to-noise ratio which enhances detection of the target return. The detector, which is usually a crystal diode, extracts the video modulation from the IF or converts the IF to a video signal.

d. The brain of a basic pulse radar is the master timer, or synchronizer, which coordinates the operation of the various parts of the radar (Figure 4-4). Exact timing within the radar is necessary to get accurate range. The master timer is an oscillator that triggers the transmitter to initiate transmission of a pulse. Simultaneously, the master timer sends a signal to initialize the display to ensure that range and azimuth information is accurately displayed.

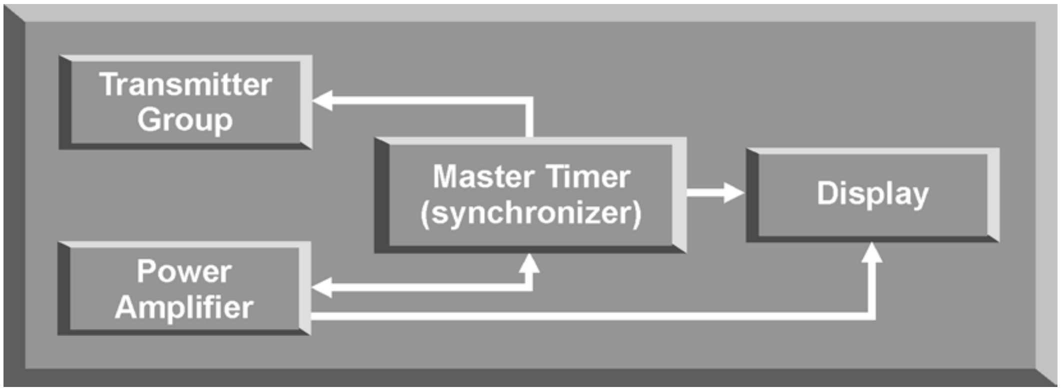

Figure 4-4. Master Timer/Synchronizer

e. The function of the antenna during transmission is to concentrate the radar energy from the transmitter into a shaped beam that points in the desired direction (Figure 4-5). During reception, or listening time, the function of the antenna is to collect the returning radar energy contained in the echo signals, and deliver these signals to the receiver. Radar antennas are characterized by directive beams that are usually scanned in a recognizable pattern.

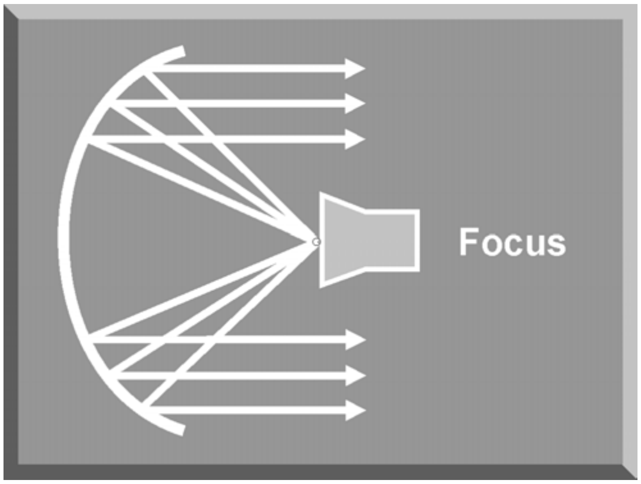

Figure 4-5. Parabolic Antenna

f. The purpose of the radar display is to take the information derived from a radar target in the receiver group and present it to the operator in a usable format. There are many different types of scope displays depending on the purpose of the radar and how the radar information is to be used. There are four basic types of radar displays: the A scope, B scope, range height indicator (RHI) scope, and plan position indicator (PPI) scope.

(1) The A scope is used to display target range or velocity (Figure 4-6). Threat systems using A scope displays include air interceptors (AIs) with range-only radar, surface-to-air missiles (SAMs), and radar-directed antiaircraft artillery (AAA) systems. SAM and AAA systems may use the A scope for range or velocity information, and other radar displays for azimuth and elevation data. The A scope displays range or velocity in relation to amplitude. The operator must distinguish the target return from other returns, including ground return and noise.

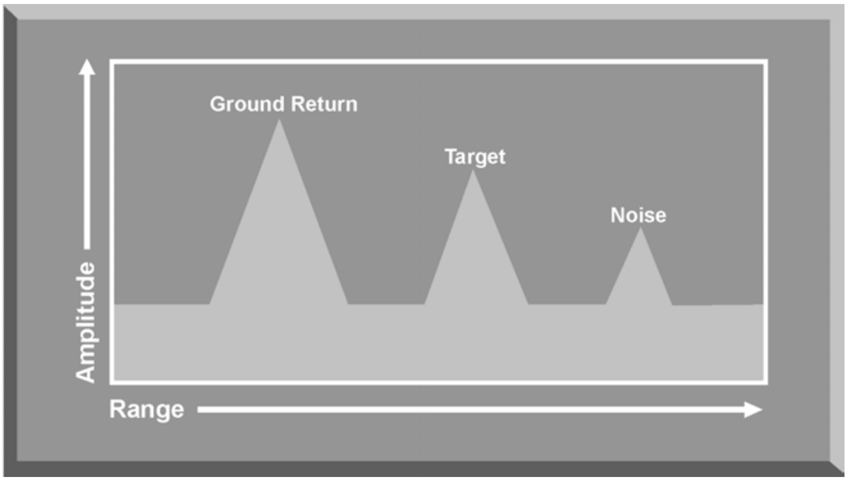

Figure 4-6. A Scope Display

(2) The B scope is used to display target range and azimuth (Figure 4-7). Threat systems using B scope displays include AI and SAM systems. The position of the target return to the right or left of the centerline of the screen shows the azimuth of the target. The position of the target return in relation to the bottom of the display, or zero range, shows target range.

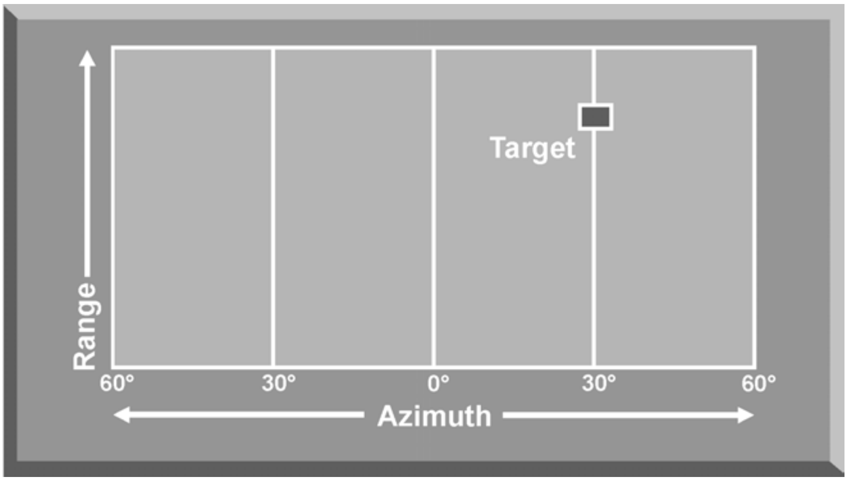

Figure 4-7. B Scope Display

(3) The RHI scope is used to display range and elevation (Figure 4-8). The RHI scope is used with height finder radars, and a modified RHI scope is used for ground-controlled approach (GCA) radars. The sweep trace of the display produces a fan-shaped display with the vertex at the lower left of the scope. The antenna sweeps up and down and is synchronized with the display.

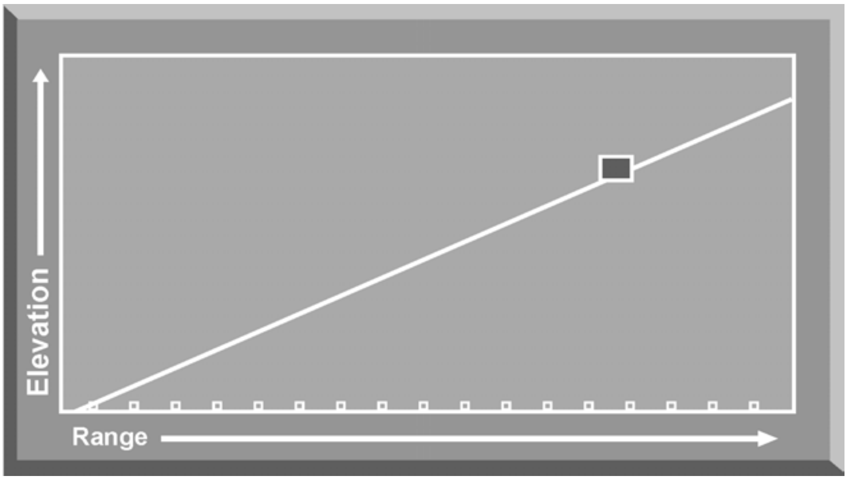

Figure 4-8. RHI Scope Display

(4) The PPI display is probably the best known radar display (Figure 4-9). The display represents a map picture of the area scanned by the radar beam, usually 360 degrees. The PPI display is used by early warning, acquisition, ground-controlled intercept (GCI), and SAM radar systems. The target return's angular position shows target azimuth, while distance from the center of the display shows range.

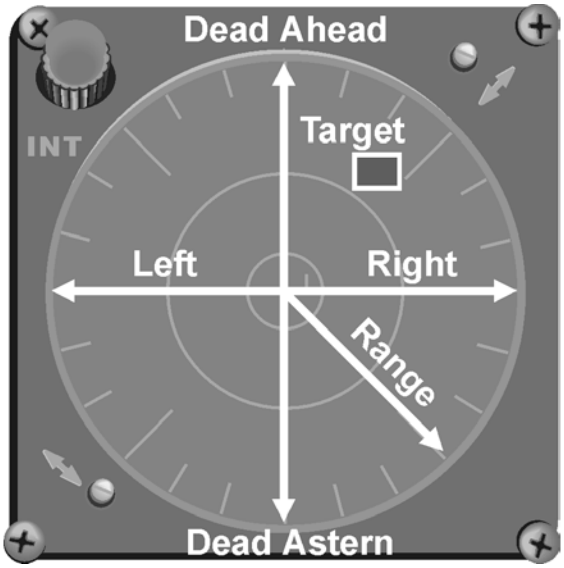

Figure 4-9. PPI Scope Display

3. CONTINUOUS WAVE (CW) RADAR

A continuous radar transmission from the antenna requires that classic CW radars have two antennas, one for transmission and one for reception (Figure 4-10). Since a continuous transmission results in a continuous echo signal, it is impossible to tell what part of the echo is associated with any particular part of the transmission. This makes conventional range determination (based on timing) impossible. However, the simple application of the Doppler principle provides a means for a CW radar to track a target. The Doppler principle deals with the fact that a radar return from a moving target will be shifted in frequency by an amount proportional to its radial velocity relative to the radar site. Using the difference in frequency from the transmitted signal to the received signal, a CW radar can separate the target return from clutter, based on a change in frequency. This type of radar is called a CW Doppler radar.

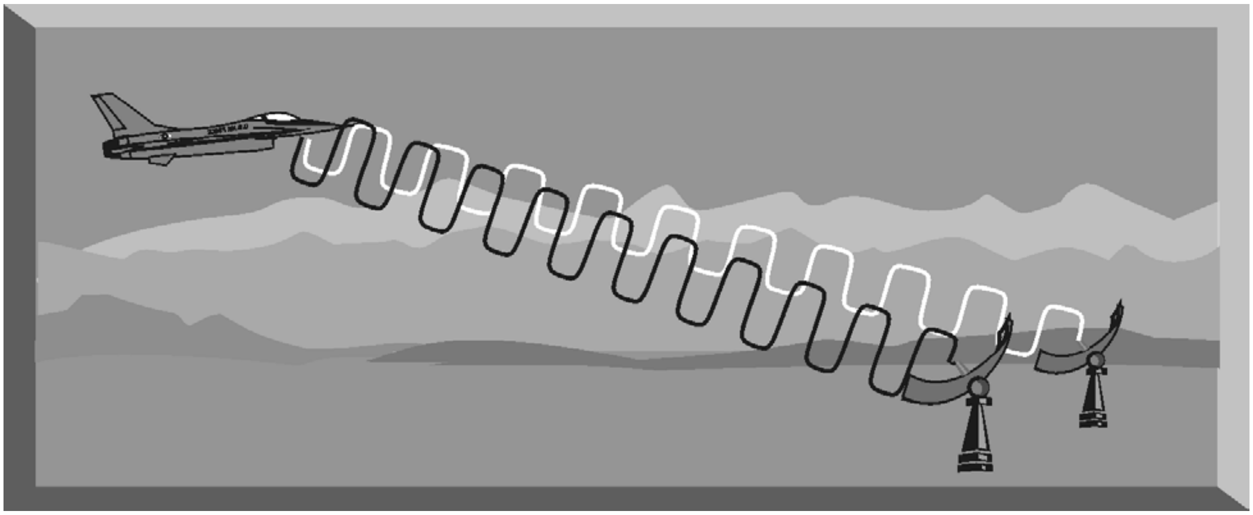

Figure 4-10. Continuous Wave Radar

a. Figure 4-11 depicts a basic CW Doppler radar. In a simple CW Doppler radar, the transmitter transmits a continuous signal at the radar's operating frequency. This signal is reflected by a moving target and travels back to the receiving antenna. The frequency of the reflected signal (f_d) is the frequency change due to the Doppler effect. This target frequency is passed to the detector. The transmitted frequency (f_o) is also fed to the detector as a reference. The detector notes the difference between the transmitted and received frequencies and passes this frequency to the Doppler filters. The Doppler filters only allow Doppler frequencies within a certain range to pass through. A filter is required for each Doppler frequency. The number of Doppler filters determines the number of targets that the radar can resolve in velocity.

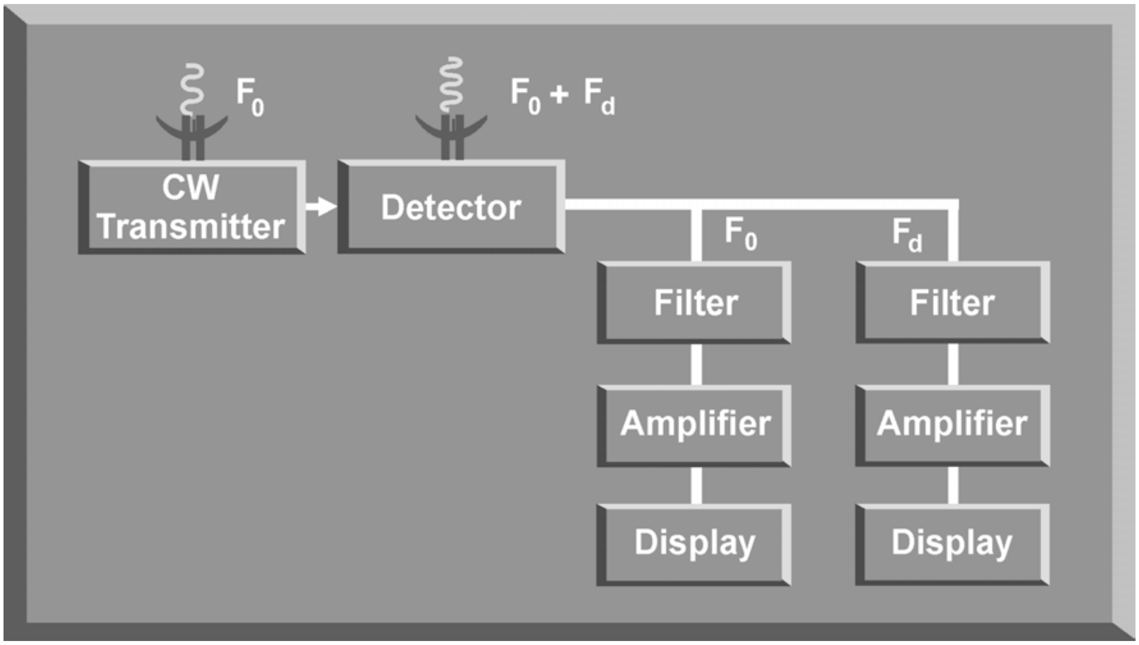
F_0
$F_0 + F_d$
CW Transmitter
Detector
F_0
F_d
Filter
Filter
Amplifier
Amplifier
Display
Display

Figure 4-11. Basic CW Doppler Radar

b. The output of each Doppler filter is amplified and passed to its own display. The display is normally an A scope as shown in Figure 4-12.

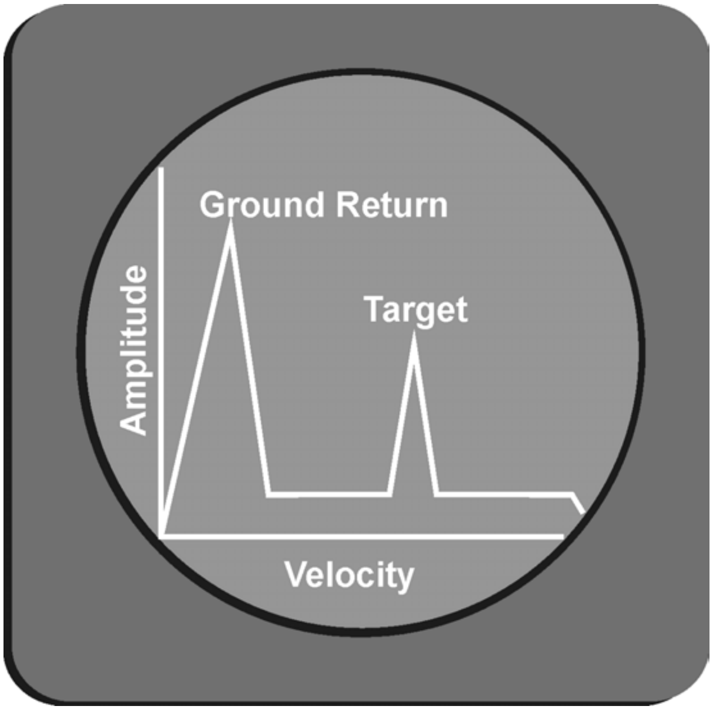
Ground Return
Target
Amplitude
Velocity

Figure 4-12. CW Doppler Radar Display

4. PULSE DOPPLER RADAR

Pulse Doppler radars combine the advantages of both pulse and Doppler radar systems (Figure 4-13). Because the signal is pulsed, the radar can determine range, azimuth, and elevation, similar to a conventional pulsed radar. A pulse Doppler radar can also compute overtake, or rate of closure, relative to the radar system on a pulse-to-pulse basis. Pulse Doppler radars also use multiple PRFs to eliminate target eclipsing and for range determination in medium PRF. The beauty of a pulse Doppler radar is that it eliminates ground clutter and provides range, azimuth, and velocity resolution.

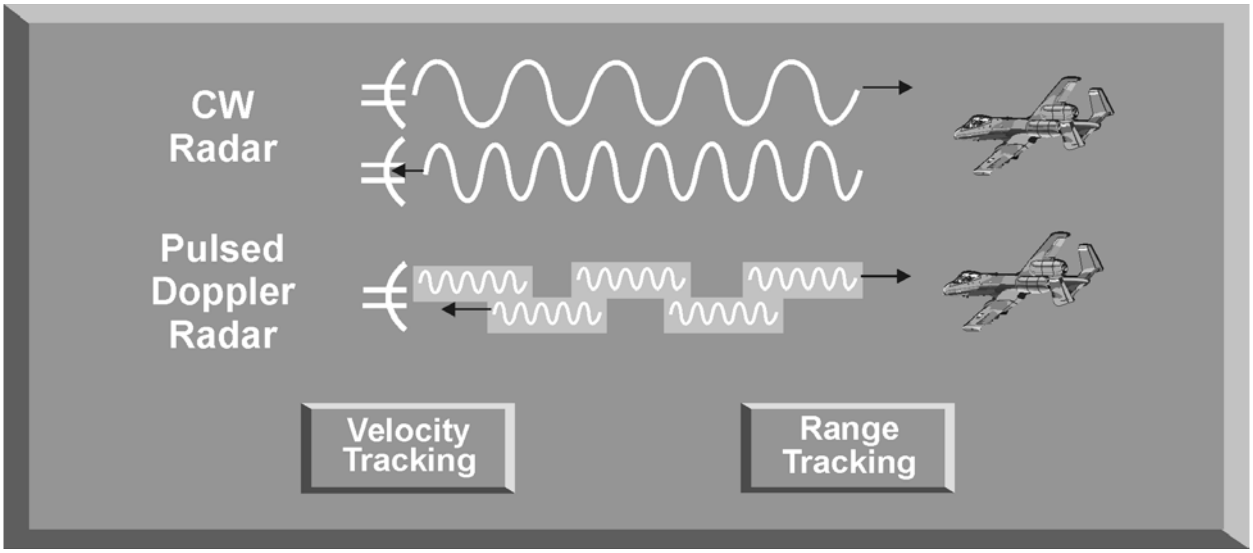

Figure 4-13. CW and Pulse Doppler Radar Comparison

a. A pulse Doppler radar transmits a box, or pulse, of coherent RF energy at the operating frequency of the radar. The frequency inside these boxes reacts the same way as the continuous waves of a CW radar. However, since the RF waves are pulsed, range determination can be accomplished by measuring the time it takes for the reflected pulse to return from the target. Velocity determination and tracking are accomplished by capturing and quantifying the Doppler shift of the frequencies in each box or pulse.

b. The basic block diagram of a coherent pulse Doppler radar (Figure 4-14) is similar to a pulse radar except for the addition of an exciter, a radar computer, and a digital signal processor. The exciter generates a continuous stable low power signal at the desired frequency and phase for the transmitter. It also sends this signal as a reference to the receiver. The digital signal processor performs the adding and subtracting functions required to find, track, and sort targets with respect to velocity and range. The radar computer performs all routine functions of the radar such as changing modes and accounting for aircraft flight parameters.

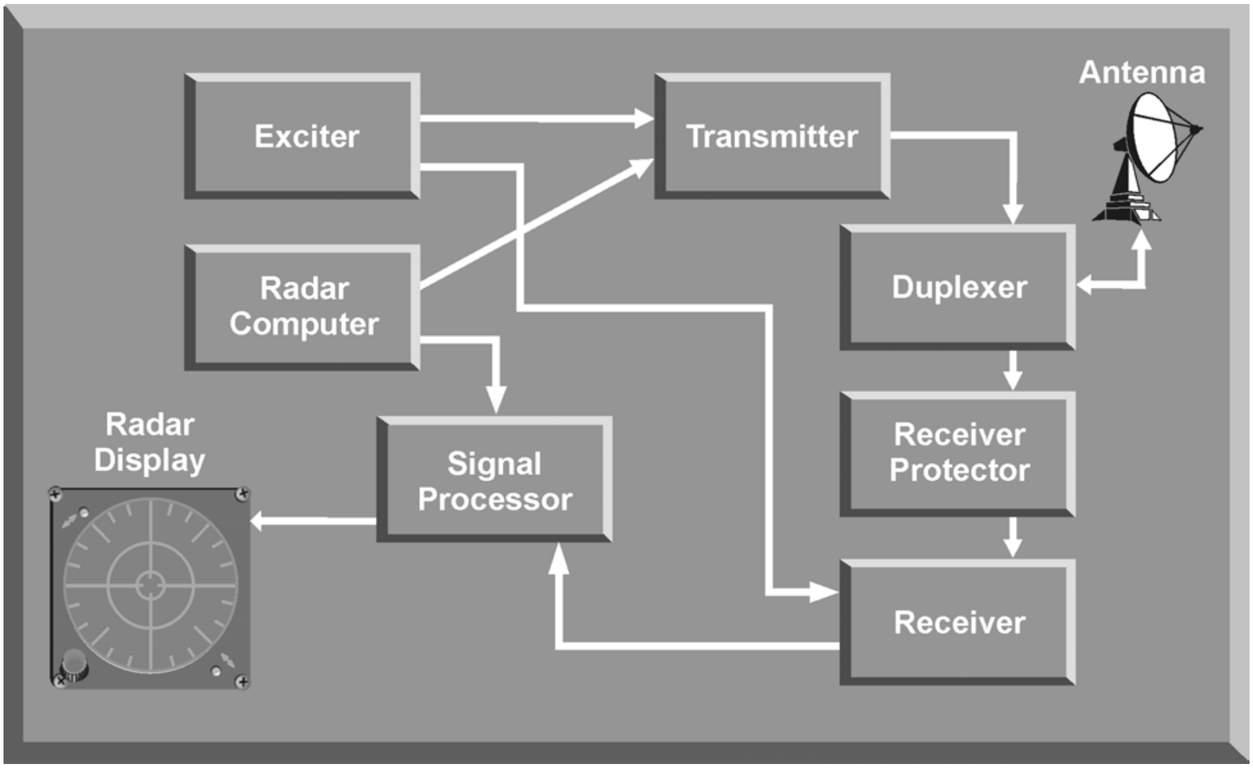

Figure 4-14. Basic Pulse Doppler Radar Diagram

5. MONOPULSE RADAR

The primary functions of monopulse radars include target tracking and weapon guidance. Monopulse radars were developed to overcome the limitations and jamming susceptibility of scanning radar systems. A monopulse radar typically receives returned radar energy in two, three, or four separate receivers, or channels, each looking at a different area. By comparing the returns from each receiver, track errors can be determined. For example, in Figure 4-15, this radar compares the amplitude, or signal strength, in each channel. Obviously, an aircraft in area "A" will produce a stronger return in receiver "A" since that receiver is focused in that direction. Since this type of system uses signal strength to determine position, typical noise jamming will only highlight an aircraft" position. Other coherent radars can measure phase differences verses the amplitude differences used in the last example. If a signal is directly ahead of the antenna, each quadrant will receive the returned signal at exactly the same time and therefore the same exact phase. However, if a return is off-center, the returned signal will strike part of the antenna slightly ahead of the opposite side and each quadrant will measure a different phase. This phase difference is used to determine azimuth error.

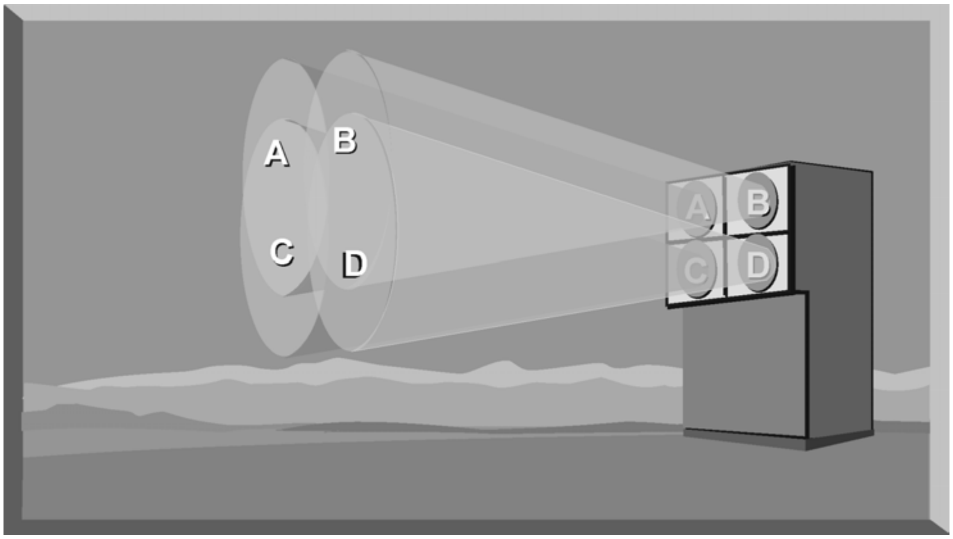

Figure 4-15. Monopulse Radar

a. Monopulse radars operate by comparing the amplitude or the phase of the received signal in each of the transmitted beams. A complex set of comparator circuits, called magic T's, do the addition and subtraction of the received signals based on the orientation of the magnetic field, or H-plane, and the electrostatic field, or E-plane (Figure 4-16). The received signal from antenna A enters the magic T in the H-plane arm while the signal from antenna B enters the magic T in the E-plane arm.

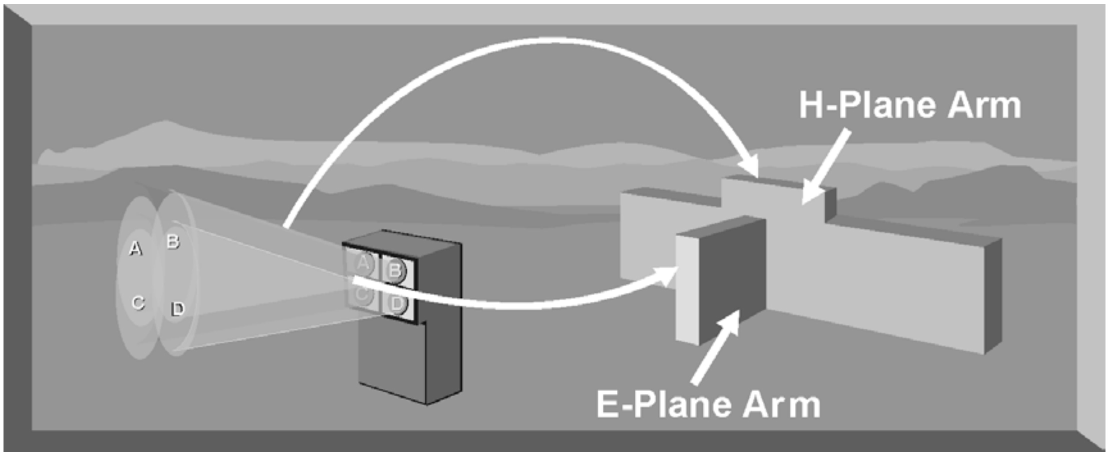

Figure 4-16. Monopulse Magic T’s

b. Figure 4-17 depicts the output of a magic T. Output is the sum and difference of the two input signals. These sum and difference values, in amplitude or phase, are used to generate azimuth and elevation error signals and to compute range.

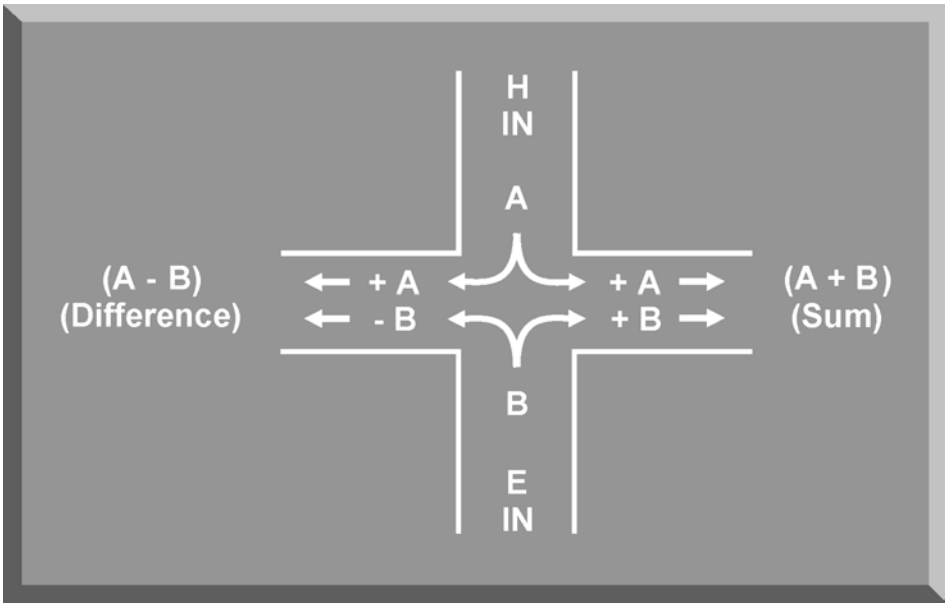
H
IN
A
(A - B)
(Difference)
+ A
- B
+ A
+ B
(A + B)
(Sum)
B
E
IN

Figure 4-17. Magic T Output Signals

c. These sum and differences computed by the magic T's are sent as signals to the monopulse tracking servos to generate both azimuth and elevation corrections to keep the monopulse antenna centered on the target (Figure 4-18). Target range is computed by calculating the difference of signal transmission time with the reception time of the target echo. Range information is displayed to the operator for range tracking.

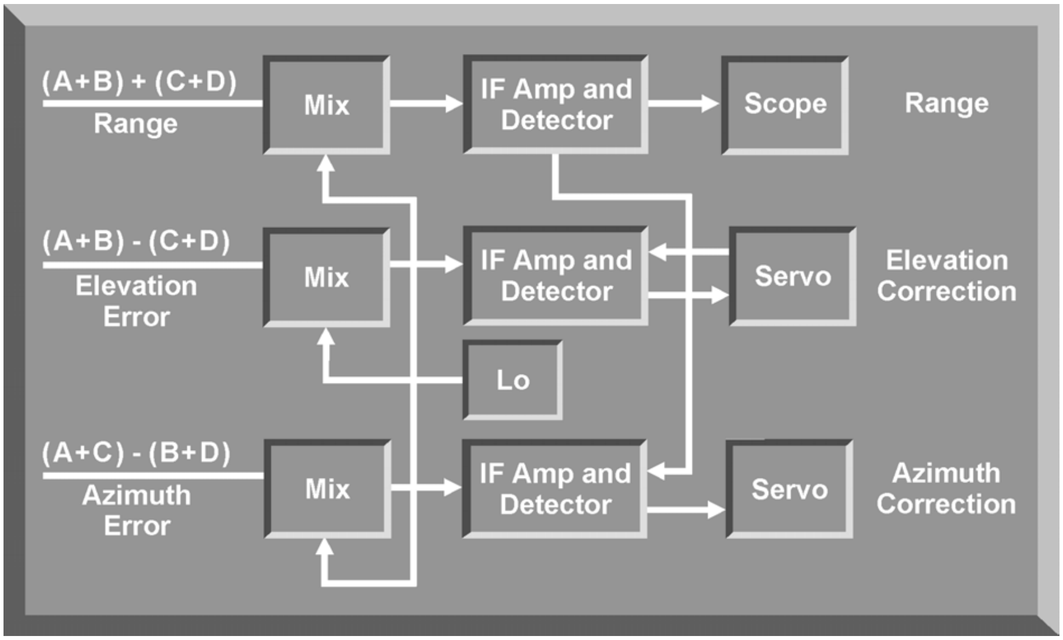
(A+B) + (C+D)
Range
Mix
IF Amp and Detector
Scope
Range
(A+B) - (C+D)
Elevation Error
Mix
IF Amp and Detector
Servo
Elevation Correction
Lo
(A+C) - (B+D)
Azimuth Error
Mix
IF Amp and Detector
Servo
Azimuth Correction

Figure 4-18. Monopulse Radar Track

d. If the signal in antenna A equals the signal in antenna B, equals the signal in antenna C, and equals the signal in antenna D, the target is in the center of the four radar beams (Figure 4-19). This is the condition the monopulse tracker attempts to maintain when tracking a target.

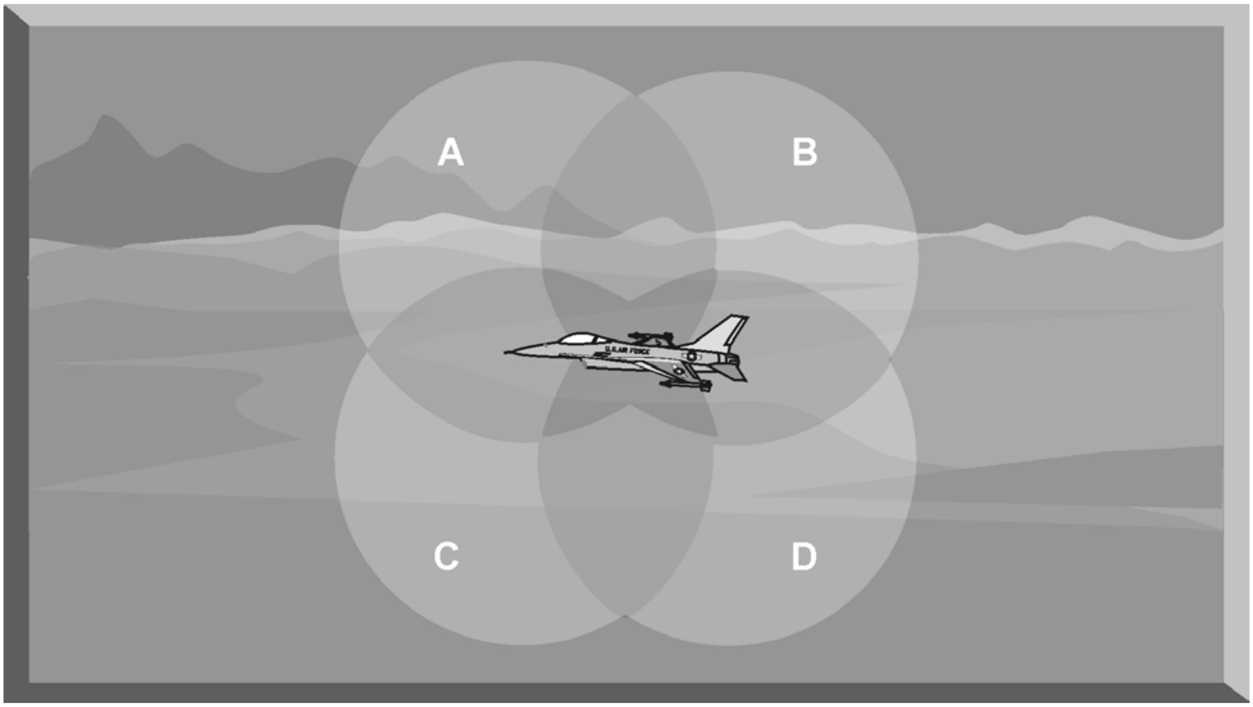

Figure 4-19. Monopulse Radar Track Logic

6. SUMMARY

This chapter has discussed the basic components of a simple pulse radar, a continuous wave radar, a pulse Doppler radar, and a monopulse radar. The characteristics of these components determine the capabilities and limitations of a particular radar system.

CHAPTER 5. RADAR PRINCIPLES

1. INTRODUCTION

The primary purpose of radar systems is to determine the range, azimuth, elevation, or velocity of a target. The ability of a radar system to determine and resolve these important target parameters depends on the characteristics of the transmitted radar signal. This chapter explains the relationship of radar frequency (RF), pulse repetition frequency (PRF), pulse width (PW), and beamwidth to target detection and resolution.

2. RADAR RANGE

A basic pulse radar system consists of four fundamental elements: the transmitter, the receiver, the antenna, and the synchronizer, or master timer.

a. The transmitter, through the antenna, sends out a pulse of RF energy at a designated frequency. The presence of a target is revealed when the RF energy bounces off the target, returns to the radar antenna, and goes into the receiver (Figure 5-1). The master timer measures the time between the transmission of a pulse and the arrival of a target echo.

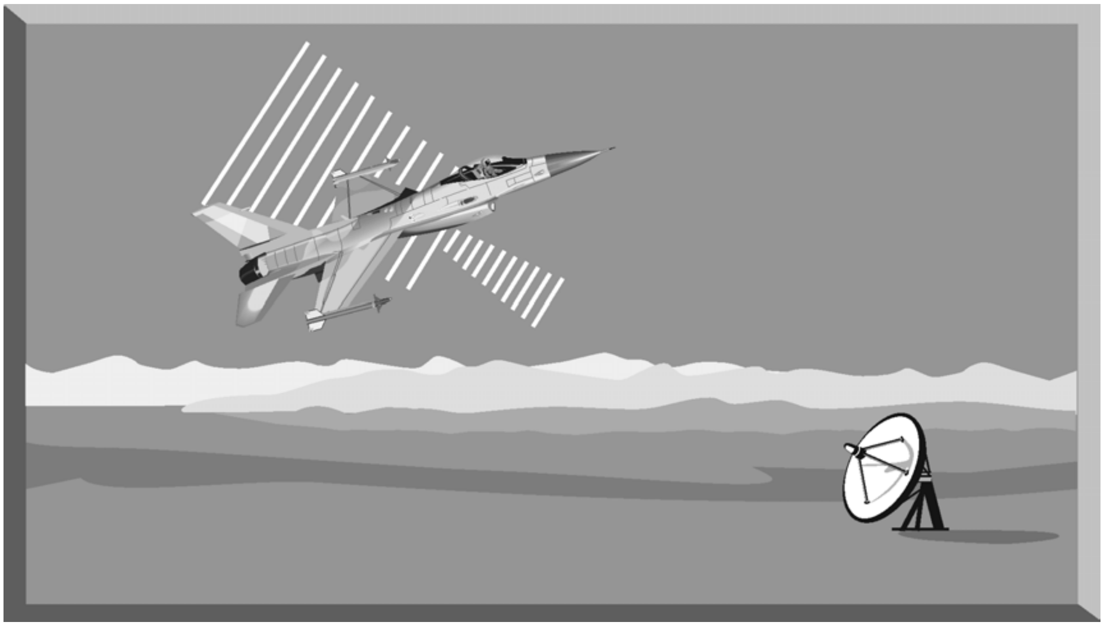

Figure 5-1. Basic Radar Pulse

(1) RF energy travels at the speed of light (c) which is 3 x 10^8 meters per second. Target range can be computed by using the basic radar range determination equation (Equation 5-1).

$$\text{Target Range} = \frac{\text{Measured Time x Speed of Light (c)}}{2}$$

Equation 5-1. Basic Radar Range Determination Equation

(2) Another useful measurement is the radar mile, which is the round trip time for an RF wave to travel to and from a target one nautical mile away (Figure 5-2). Solving the radar range equation for time results in Equation 5-2. Substituting the appropriate values into the equation and solving for time gives measured time of 12.4 microseconds for a one nautical mile (1853 meters) round trip.

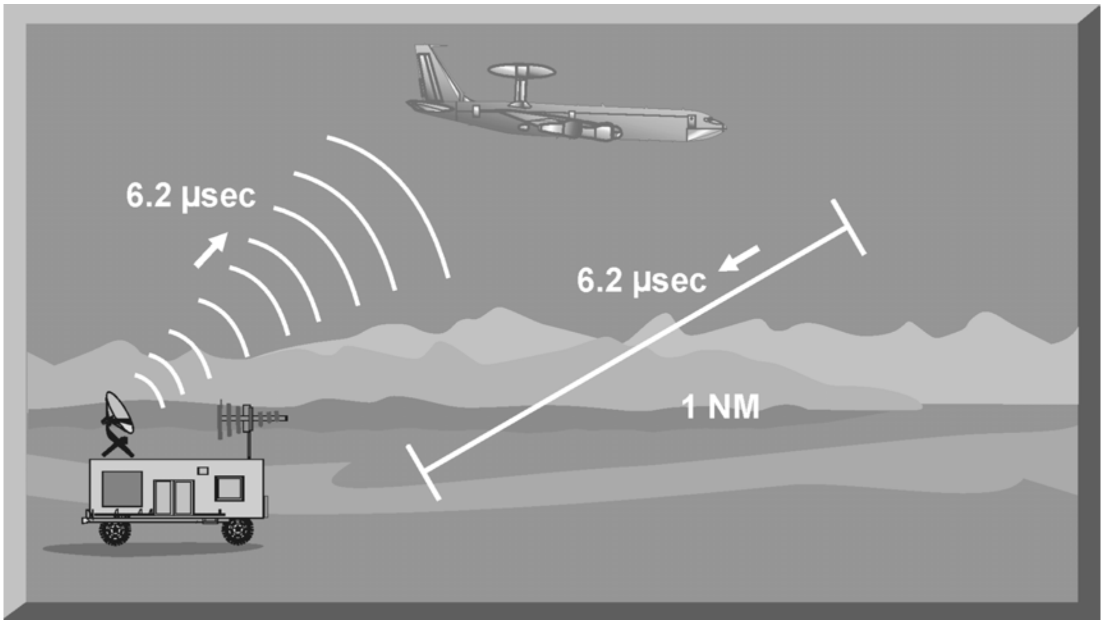

Figure 5-2. Radar Mile

$$\text{Measured Time} = \frac{\text{Target Range x 2}}{\text{Speed of Light (c)}} = \frac{\text{1853 meters x 2}}{3 \times 10^{8}\ \text{meters/second}} = 12.4\,\mu\text{sec}$$

Equation 5-2. Radar Mile

(3) A limitation on radar detection range is the concept of a second time around echo. A second time around echo occurs when a target echo associated with a particular radar pulse arrives at the antenna after another radar pulse has been transmitted. The radar master timer always assumes the target echo is associated with the last pulse transmitted. This makes the target echo ambiguous in range. Figure 5-3 depicts a radar signal with a pulse recurrence time (PRT) of 248 microseconds. Radar pulse A takes 372 microseconds to travel to the target and return. Using the range determination equation, actual target range is 30 nautical miles (nm). However, before the target echo returns to the antenna, radar pulse B is transmitted. The master timer associates the target echo of pulse A with radar pulse B, and calculates a target range of 10 nm. This ambiguous and false range is displayed to the operator.

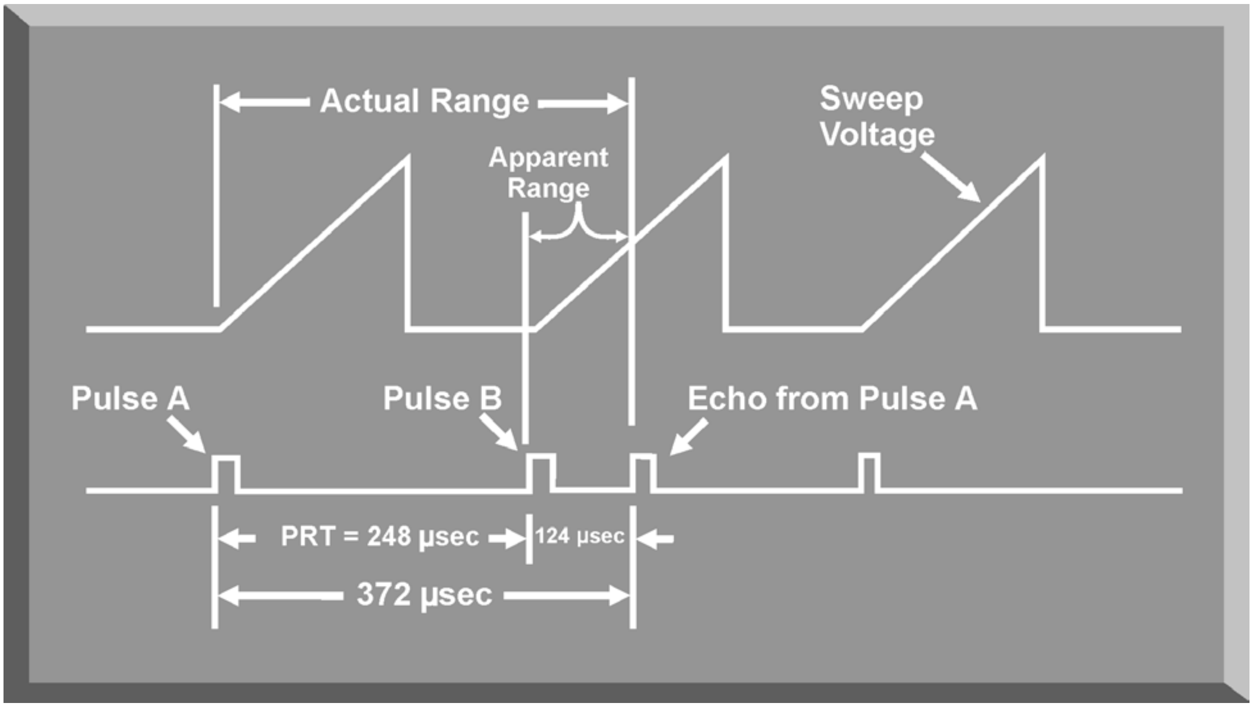

Figure 5-3. Second Time Around Echo

(4) Range ambiguities caused by second time around echoes limit the maximum unambiguous range of a radar system. This important capability can be calculated by using Equation 5-3. An analysis of this equation shows that a radar system designed for long-range detection should transmit a radar signal with a large PRT. In addition, as the PRF of a radar signal increases, the PRT decreases, and the maximum unambiguous range decreases.

$$\text{Maximum Unambiguous Range} = \frac{\text{PRT } (\mu\text{secs})}{12.4\ (\mu\text{secs/nm})}$$

Equation 5-3. Maximum Unambiguous Range

b. A critical aspect of range determination is range resolution. Range resolution is the ability of a radar to separate two targets that are close together in range and are at approximately the same azimuth (Figure 5-4). The range resolution capability is determined by pulse width. Pulse width is the time that the radar is transmitting RF energy. Pulse width is measured in microseconds.

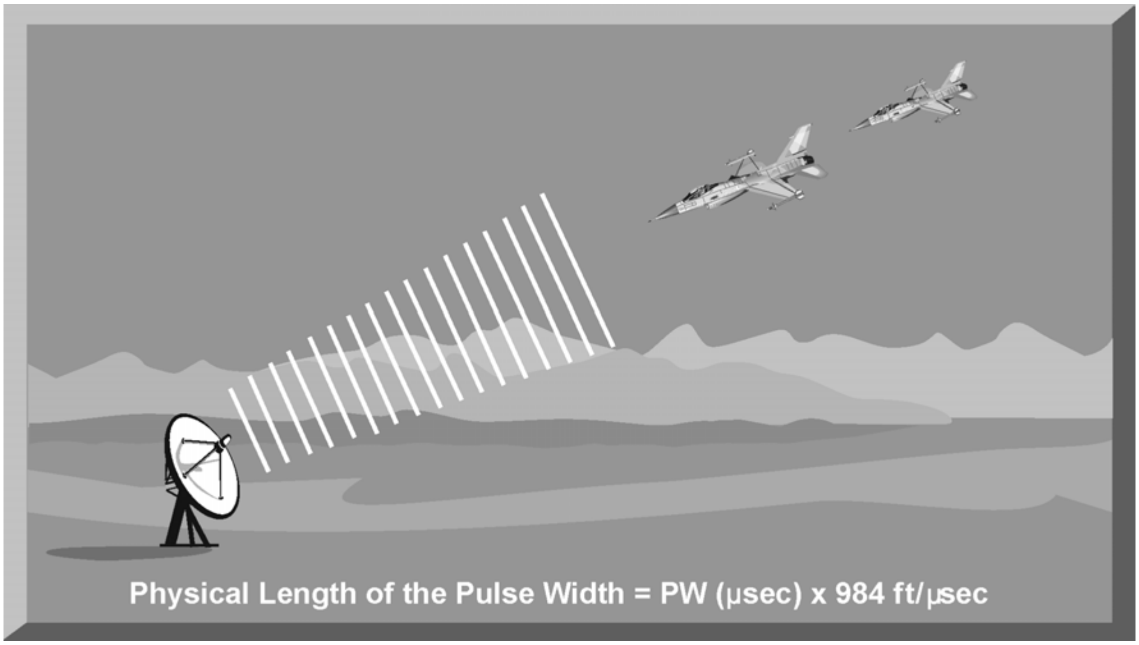

Physical Length of the Pulse Width = PW (µsec) x 984 ft/µsec

Figure 5-4. Radar Pulse

(1) A radar pulse in free space occupies a physical distance equal to the pulse width multiplied by the speed of light, which is about 984 feet per microsecond. If two targets are closer together than one-half of this physical distance, the radar cannot resolve the returns in range, and only one target will be displayed.

(2) To illustrate range resolution, consider Figure 5-5, in which two aircraft are separated by a distance of one-half the pulse width or less. At T1, the leading edge of the radar pulse hits the lead aircraft.

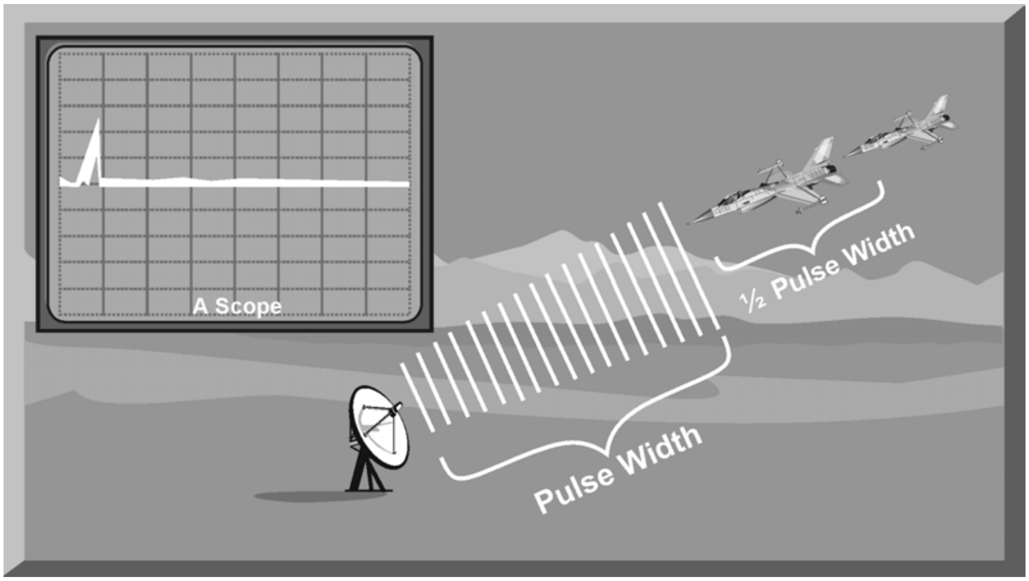

Figure 5-5. Radar Pulse at T1

(3) In Figure 5-6, at T2 the leading edge of this same pulse hits the trailing aircraft. Since the trailing aircraft is less than one-half the pulse width from the lead aircraft, the return echo from the lead aircraft is received by the antenna before the entire pulse has left the trailing aircraft.

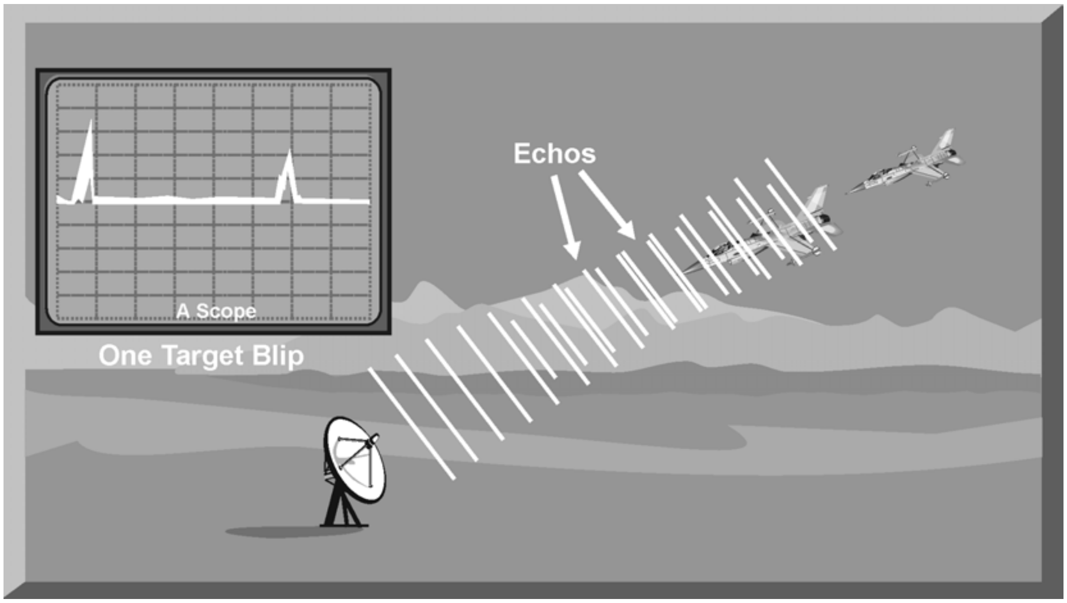

Figure 5-6. Radar Pulse at T2

(4) T3 depicts the merging target echoes at the radar (Figure 5-7). The radar would display only one target in this situation, such as the one shown on the radar scope in Figure 5-6.

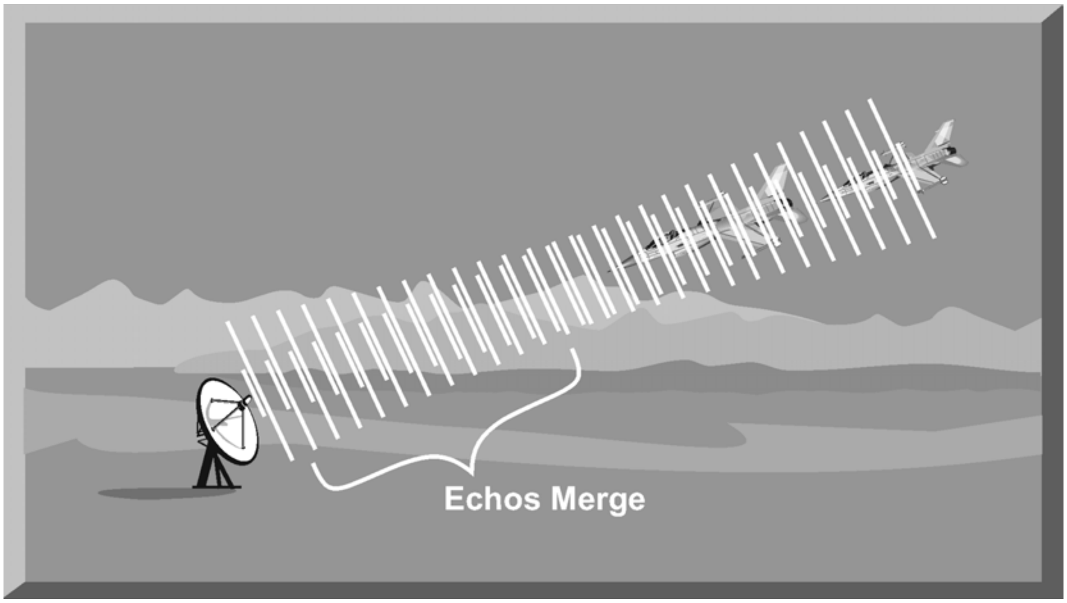

Figure 5-7. Radar Pulse at T3

(5) Two targets separated by more than one-half the pulse width, as in Figure 5-8, will be displayed as two targets. In this case, the transmitted pulse is completely past the lead aircraft before the return echo from the trailing aircraft reaches the antenna.

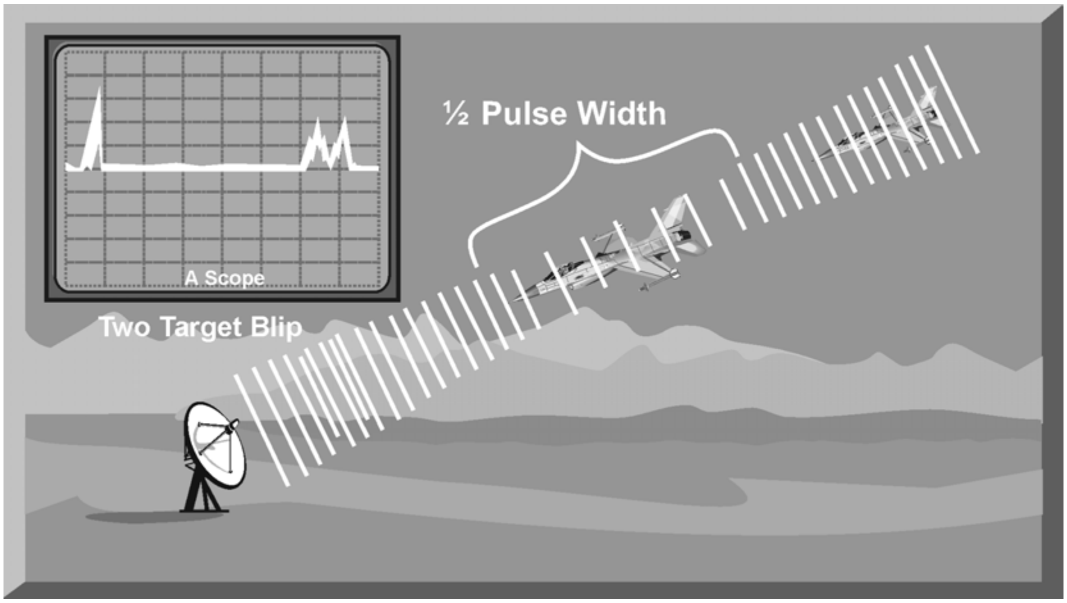

Figure 5-8. Radar Range Resolution

(6) The range resolution of the radar is usually expressed in feet and can be computed using Equation 5-4. It is the minimum separation required between two targets in order for the radar to display them separately on the radar scope.

$$\text{Range Resolution} = \frac{\text{Pulse Width} \times 984 \text{ feet}}{2}$$

Equation 5-4. Range Resolution

3. AZIMUTH DETERMINATION

The beamwidth of a radar system is the horizontal and vertical thickness of the radar beam (Figure 5-9). Beamwidth depends on antenna design and is normally measured in degrees from the center of the beam to the point at which the power drops off by half. This half-power point is -3 dB in power drop-off. Beamwidth governs the azimuth and elevation accuracy and resolution capability of a radar system in the same way that pulse width governs radar range accuracy and resolution.

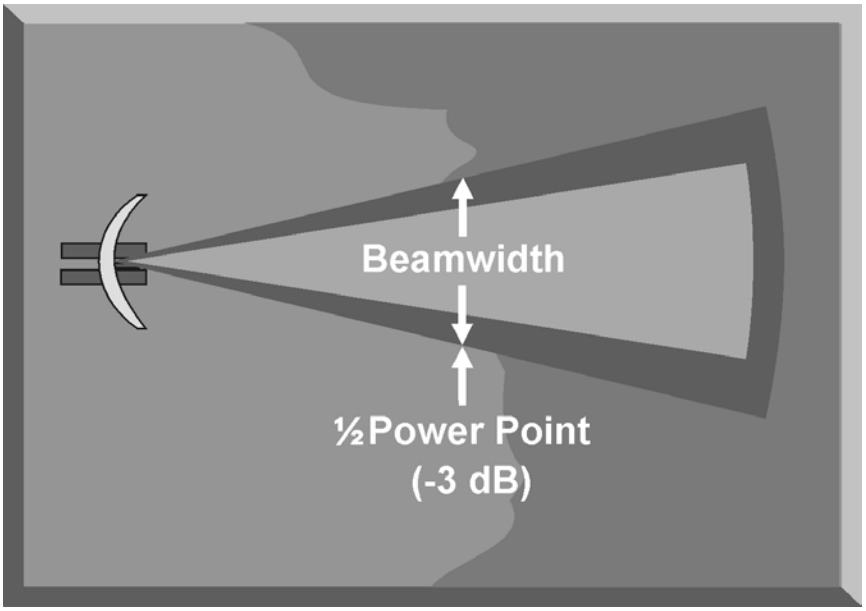

Figure 5-9. Radar Beamwidth

a. In order for a radar system to figure out target azimuth, the antenna must be aligned with a point of reference and pointed at the target during the transmission and reception of several pulses of radar energy. If the antenna is

referenced to true North, the azimuth of the target can be measured relative to true North (Figure 5-10). Azimuth determination is based on the position of the antenna when the target is being illuminated.

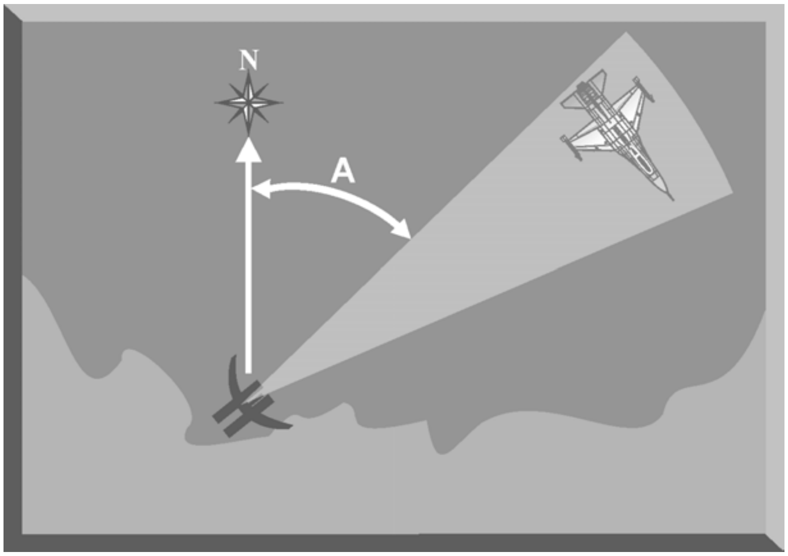

Figure 5-10. Azimuth Determination

(1) To provide accurate azimuth determination over a large area, many radars employ a narrow beam and scan the antenna in a predictable pattern. The most common scan pattern is a 360° circular scan at a constant rate (Figure 5-11). The plan position indicator (PPI) radar scope display is normally associated with this scan pattern. As the radar beam sweeps, a target is detected and displayed. The position of the antenna, when the target is displayed, shows the relative azimuth.

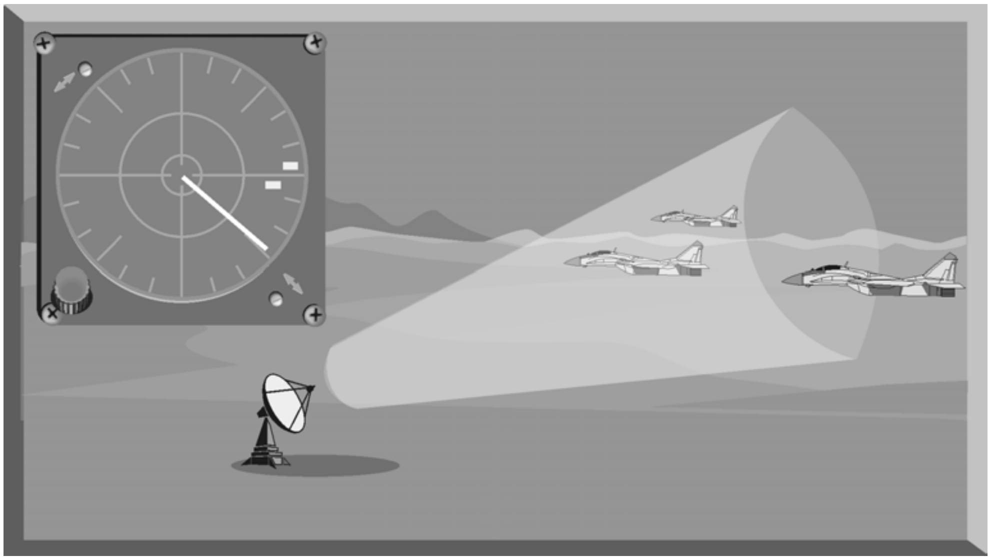

Figure 5-11. Antenna Scan

(2) The azimuth accuracy of a radar system is determined by the horizontal beamwidth (HBW). In Figure 5-12, radar system A has a horizontal beamwidth of 10°. As the beam sweeps, the target is illuminated for as long as it is in the beam. This means that the target covers 10° in azimuth on the PPI scope. Radar system B has a beamwidth of 1°. A target displayed on the PPI scope will cover 1° in azimuth. The narrower the horizontal beamwidth, the better the azimuth accuracy.

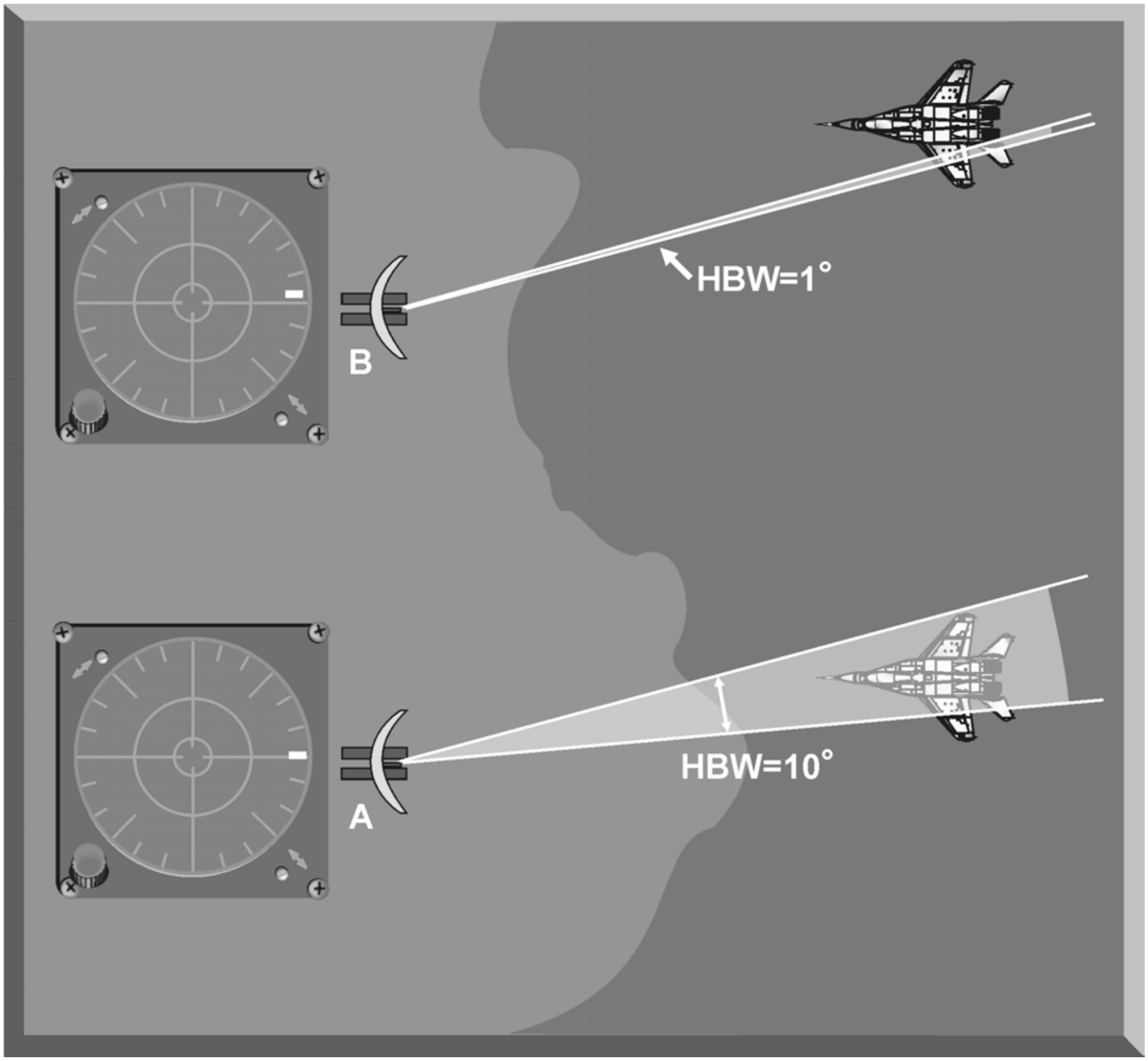

Figure 5-12. Horizontal Beamwidth Comparison

b. Azimuth resolution is the ability of a radar to display two targets flying at approximately the same range with little angular separation, such as two fighters flying line-abreast tactical formation. The azimuth resolution capability is usually expressed in nautical miles and corresponds to the minimum azimuth separation

required between two targets for separate display. Azimuth resolution depends on the horizontal beamwidth of the radar. The radar system in Figure 5-13 has a horizontal beamwidth of 10°. The two targets are so close in azimuth that the return echoes are blended into one return.

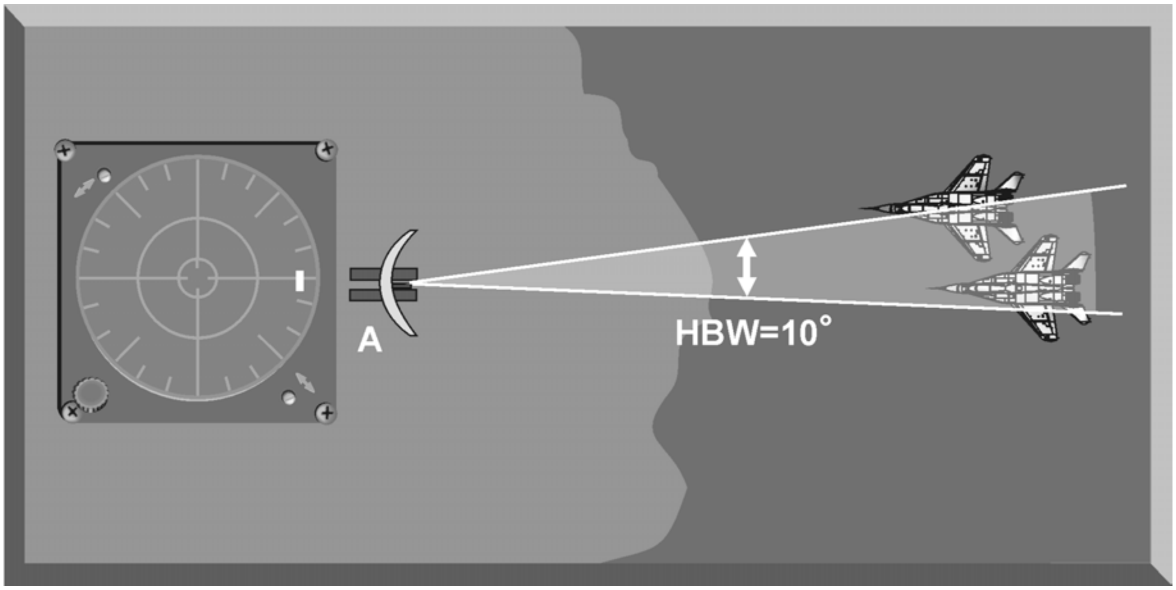

Figure 5-13. Horizontal Beamwidth and Azimuth Resolution

(1) The radar system in Figure 5-14 has a horizontal beamwidth of 1°. The radar beam not only hits the targets, but passes between them without causing a return. This allows the radars to display two distinct radar returns. A small horizontal beamwidth improves azimuth resolution.

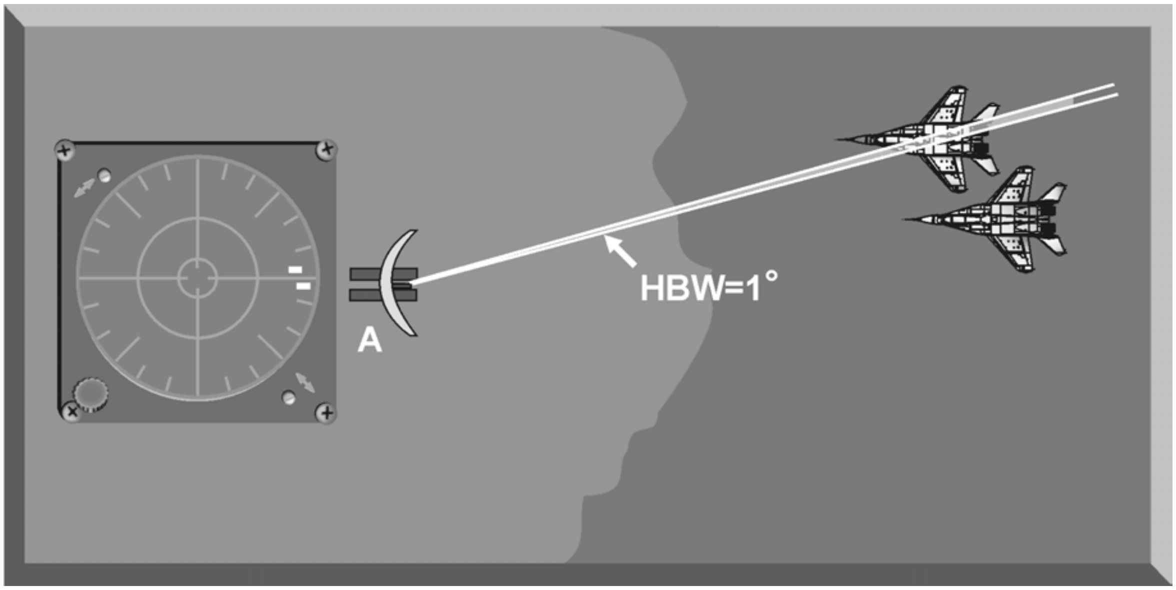

Figure 5-14. Azimuth Resolution

(2) Azimuth resolution, in nautical miles, can be computed using Equation 5-5. Notice that this equation is the "60 to 1 rule" used for navigation. A 1° beamwidth will yield a one-mile-wide cell at 60 nautical miles.

$$\text{Azimuth Resolution} = \frac{\text{Horizontal Beamwidth} \times \text{Range}}{60}$$

Equation 5-5. Azimuth Resolution

4. ELEVATION DETERMINATION

Since a radar beam is three-dimensional, the vertical beamwidth is the primary factor in determining altitude resolution capability. Altitude resolution is the ability of a radar to display two targets flying at approximately the same range and azimuth with little altitude separation, such as two fighters flying a vertical stack formation. The altitude resolution capability is usually expressed in feet and corresponds to the minimum altitude separation required between two targets for separate display. The radar system in Figure 5-15 has a vertical beamwidth of 10°. The two targets are so close in altitude that the return echoes depicted on the range height indicator (RHI) are blended into one.

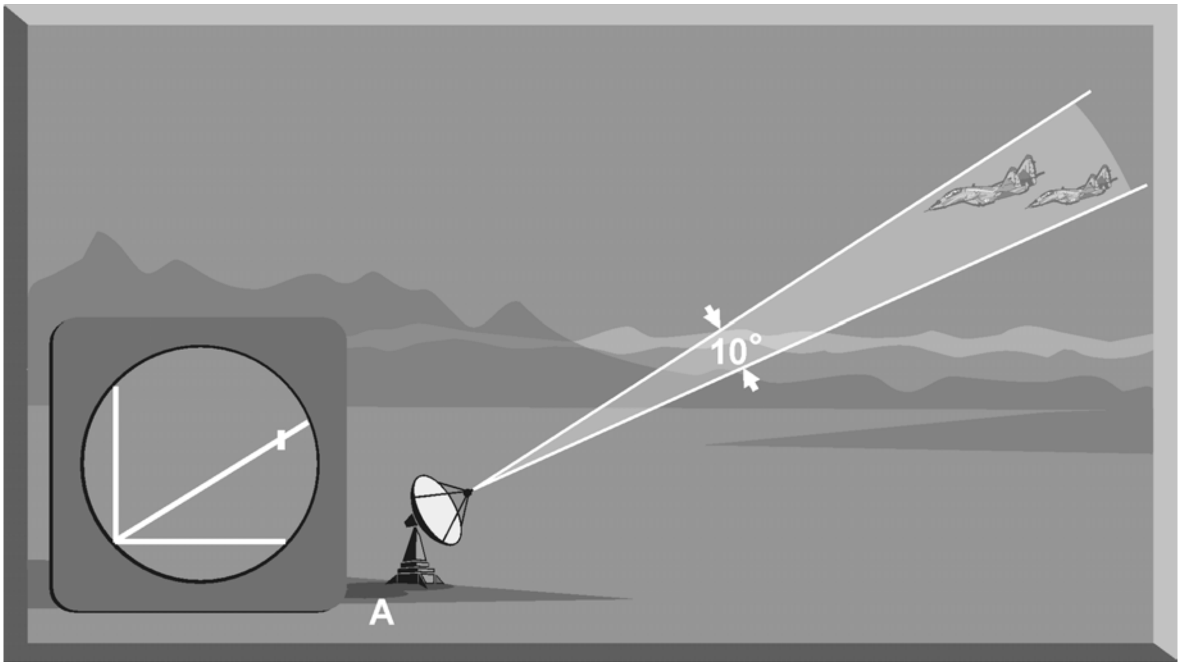

Figure 5-15. Vertical Beamwidth and Elevation Resolution

a. The radar system depicted in Figure 5-16 has a vertical beamwidth of 1°. This small beam not only hits the targets, but passes between them without causing a return. This allows the radar to display two distinct targets.

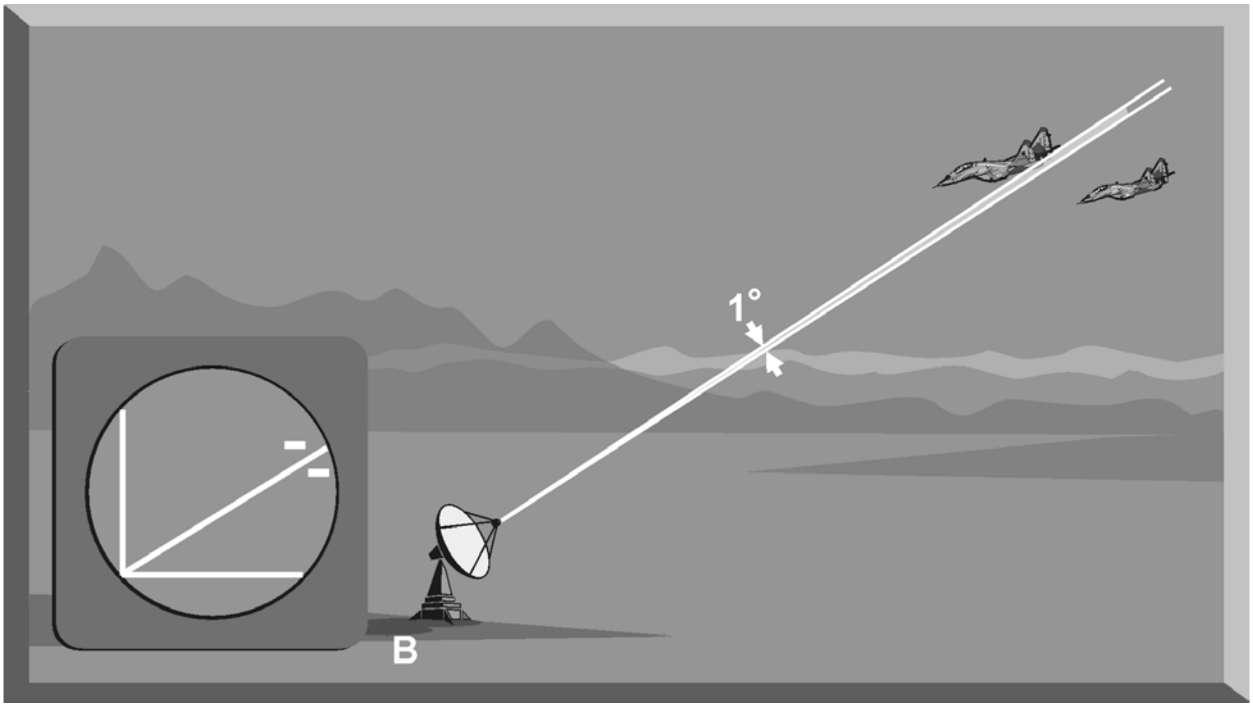

Figure 5-16. Elevation Resolution

b. Altitude/elevation resolution, in thousands of feet, can be computed using Equation 5-6.

$$\text{Altitude Resolution} = \frac{\text{Vertical Beamwidth} \times \text{Range}}{60}$$

Equation 5-6. Altitude Resolution

5. RADAR RESOLUTION CELL

A radar's pulse width, horizontal beamwidth, and vertical beamwidth form a three-dimensional resolution cell (RC) (Figure 5-17). A resolution cell is the smallest volume of airspace in which a radar cannot determine the presence of more than one target. The resolution cell of a radar is a measure of how well the radar can resolve targets in range, azimuth, and altitude. The horizontal and vertical

dimensions of a resolution cell vary with range. The closer to the radar, the smaller the resolution cell.

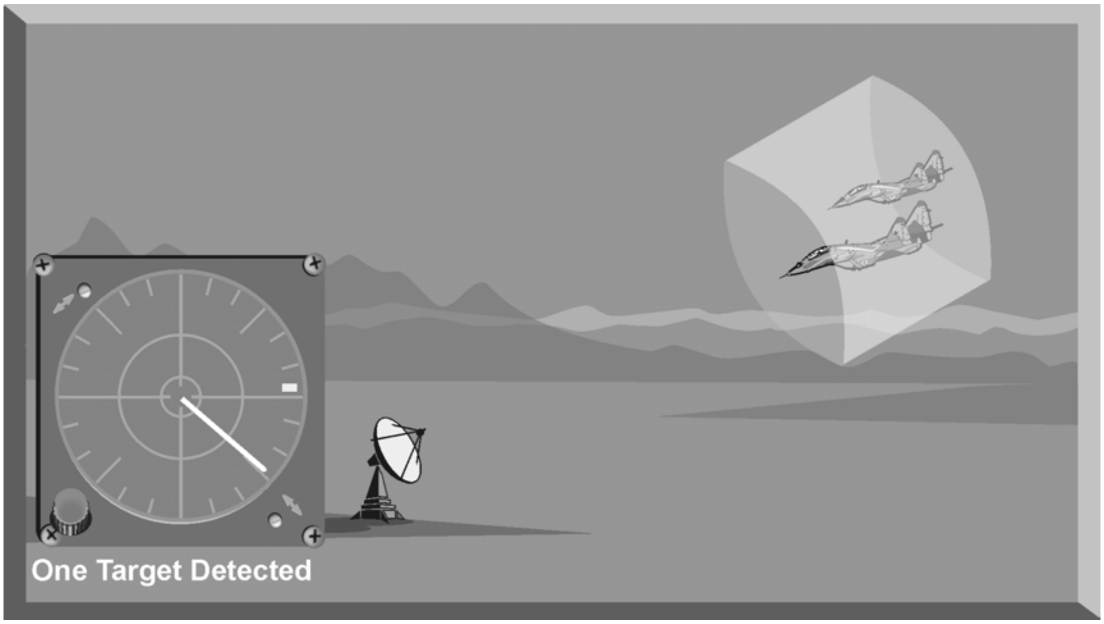

Figure 5-17. Radar Resolution Cell

a. The physical dimensions of a radar's resolution cell can be computed. For a radar with a pulse width of 1 microsecond, a horizontal beamwidth of 1°, and a vertical beamwidth of 10°, the formulas for range resolution, azimuth resolution, and altitude resolution can be used to compute the dimensions of the resolution cell. In the example in Figure 5-18, at a target range of 10 nm, the physical dimensions of the radar's resolution cell are 492 feet in range, by 1000 feet in azimuth, and 10,000 feet in altitude. These figures can be confirmed by using Equations 5-4, 5-5, and 5-6.

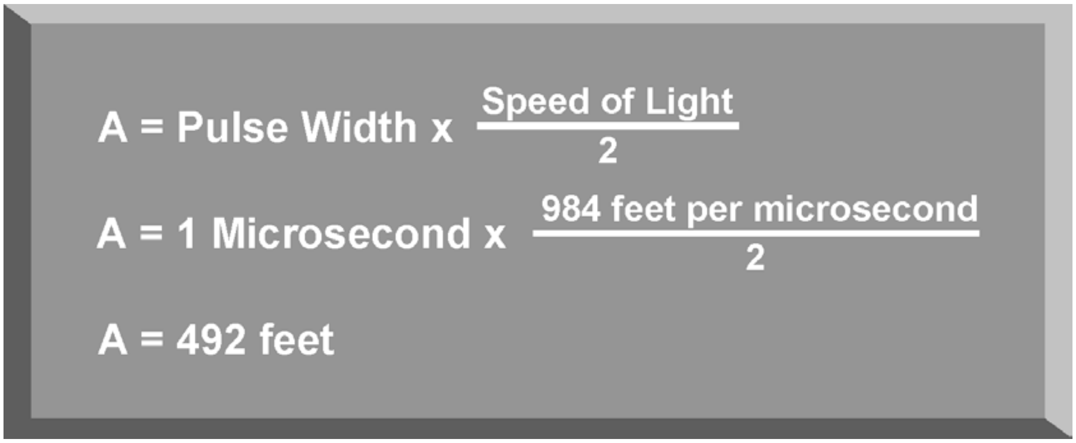

$$A = \text{Pulse Width} \times \frac{\text{Speed of Light}}{2}$$

$$A = 1 \text{ Microsecond} \times \frac{984 \text{ feet per microsecond}}{2}$$

$$A = 492 \text{ feet}$$

Figure 5-18. Radar Resolution Cell Dimensions

b. Based on these computations, two, or more, aircraft flying a trail formation closer than 492 feet would be displayed as a single target. Two, or more, aircraft flying line abreast closer than 1000 feet would be displayed as a single target. Two, or more, aircraft flying a vertical stack closer than 10,000 feet would be displayed as a single target. This also shows that the shorter the pulse width, the better the range resolution capability of a radar system. The narrower the horizontal beamwidth, the better the azimuth resolution capability. The narrower the vertical beamwidth, the better the altitude resolution capability.

c. Another type of resolution is velocity resolution. For a Doppler radar aircraft flying within the conventional resolution cell described above can be distinguished as separate targets if they have enough speed differential. Paragraph 6 below will describe how this is carried out.

6. PULSE DOPPLER VELOCITY DETERMINATION

To fully understand how a pulse Doppler radar determines target velocity, it is necessary to know more about the pulsed waveform. To generate a pulse modulated wave, a continuous carrier sine wave, like the output from a CW radar, is combined with a rectangular wave, like that of a pulse radar, to produce the pulse modulated waveform. Figure 5-19 depicts pulse modulation.

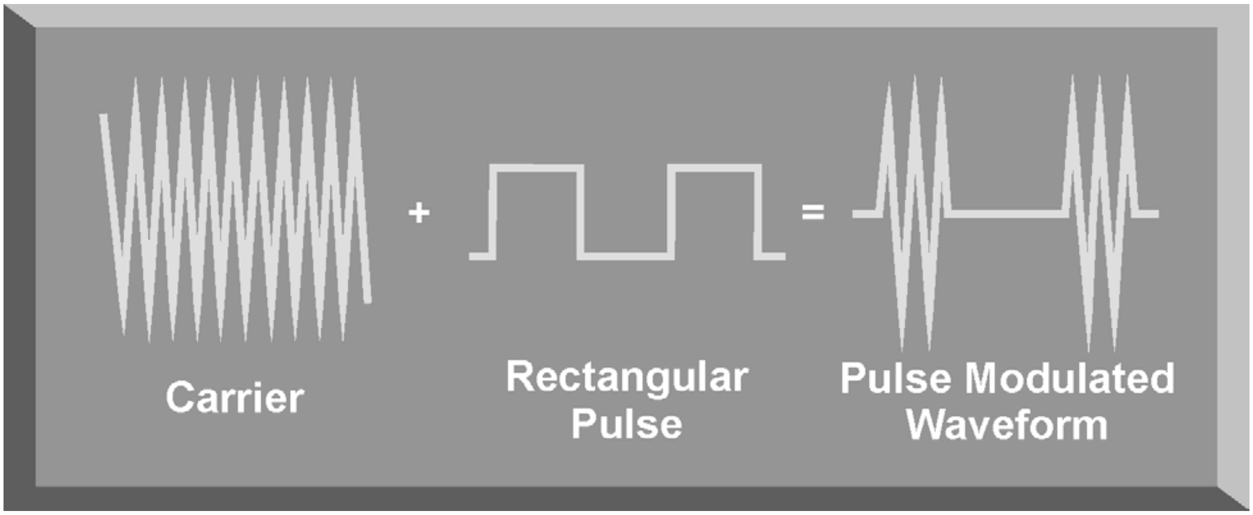

Figure 5-19. Pulse Modulation

a. Mathematically, any waveform other than a sine wave is composed of many different pure sine waves added in the proper amplitude and phase relationships (Figure 5-20). In a pulsed modulated waveform, the sine waves correspond to the fundamental frequency, which is the PRF, and the sum of all harmonics in the proper amplitude and phase. The frequency of the harmonic is the basic frequency plus or minus a multiple of the PRF.

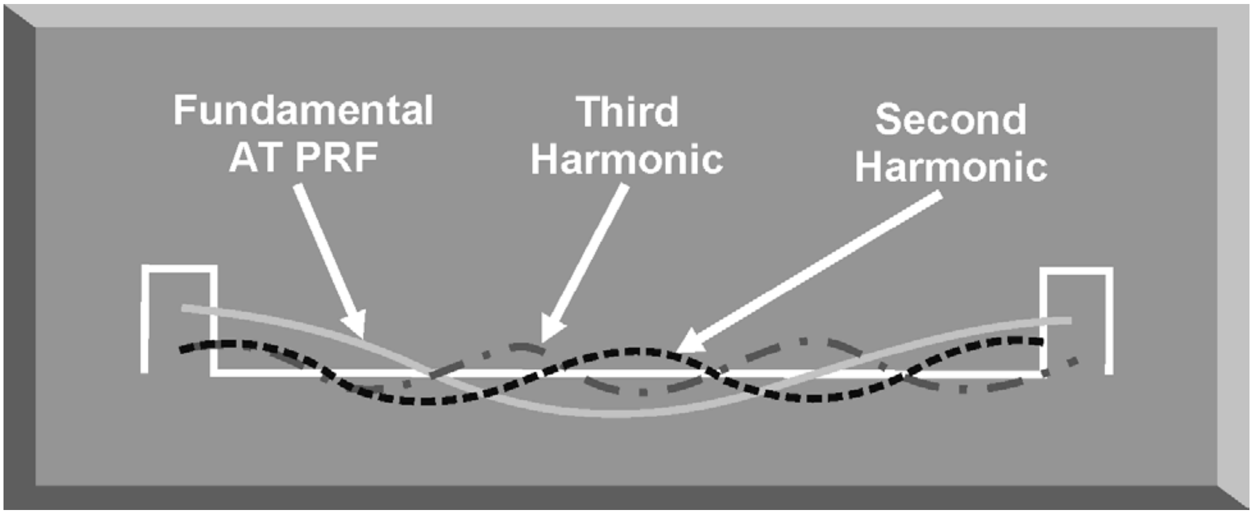
Fundamental
AT PRF
Third
Harmonic
Second
Harmonic

Figure 5-20. Harmonics of a Pulse Modulated Waveform

(1) Figure 5-21 is a plot of the harmonic content of a pulse modulated waveform operating at a carrier frequency of 2800 megahertz (MHz) with a PRF of 1 MHz. Note the loops of frequencies on either side of the carrier frequency. These are the additions and subtractions of all the frequencies in the rectangular pulse to the carrier frequency. The important thing to remember is that there are many frequencies present, and a pulse Doppler radar must deal with a crowded frequency spectrum. This becomes even more important when one considers the fact that every frequency present will experience a Doppler shift when it is reflected by a moving target. The individual frequencies shown are called spectral lines.

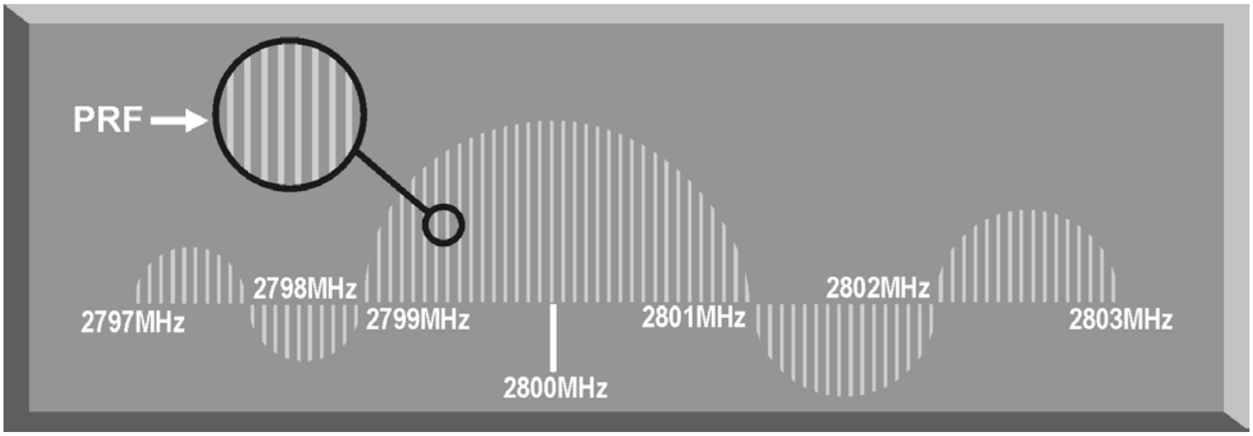
PRF
2797MHz
2798MHz
2799MHz
2800MHz
2801MHz
2802MHz
2803MHz

Figure 5-21. Harmonic Content

(2) For a pulse Doppler radar to accurately measure velocity, it must compare the frequency change, or Doppler shift, between the carrier frequency

and the frequency returning from the target. It is a difficult task for the radar to differentiate between the returning carrier and all the harmonic frequencies (Figure 5-22).

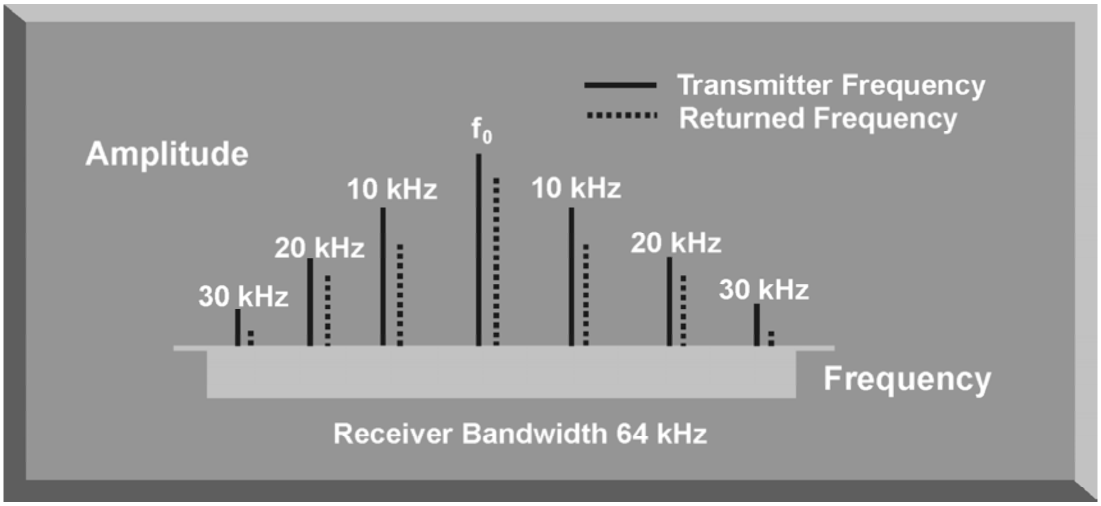
Transmitter Frequency
Returned Frequency
Amplitude
f_0
10 kHz
10 kHz
20 kHz
20 kHz
30 kHz
30 kHz
Frequency
Receiver Bandwidth 64 kHz

Figure 5-22. Spectral Line Frequencies

b. The radar differentiates between the returning carrier frequencies and all other harmonic frequencies by using clutter cancellers, or filters, at the known harmonic frequencies (Figure 5-23). The radar cannot process frequencies cancelled by these filters. The filters create “blind speeds” for the radar. The closer together the spectral lines, the more “blind speeds” the radar will have.

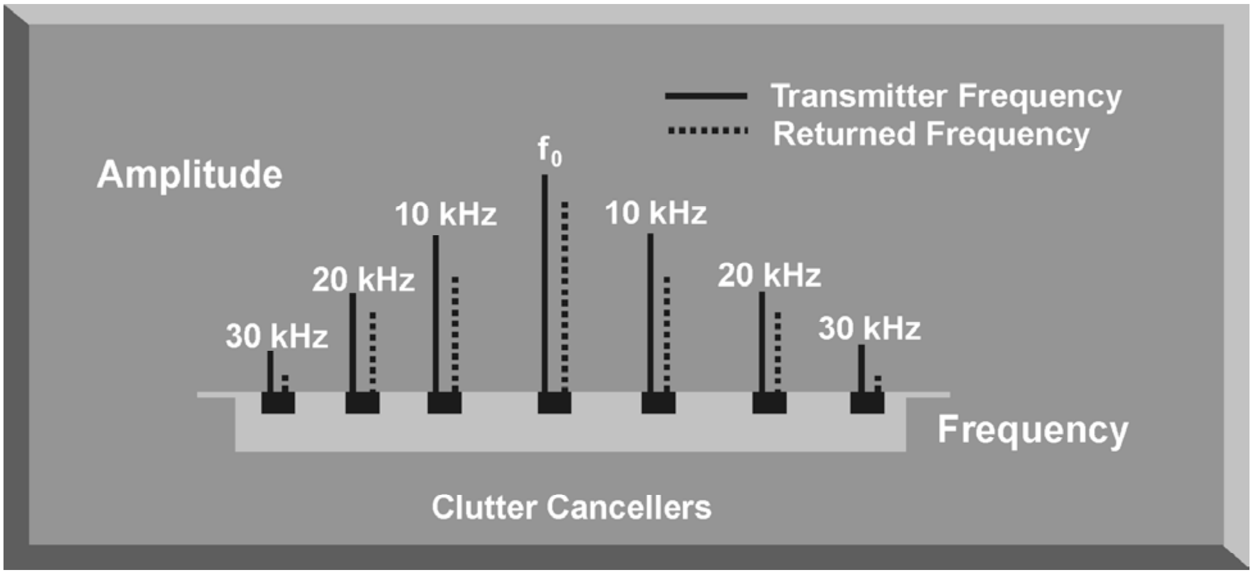
Transmitter Frequency
Returned Frequency
Amplitude
f_0
10 kHz
10 kHz
20 kHz
20 kHz
30 kHz
30 kHz
Frequency
Clutter Cancellers

Figure 5-23. Selective Clutter Canceling

(1) Since the position of the harmonics in relation to the carrier frequency is based on PRF, the number of blind speeds can be reduced by changing the PRF of the radar. The higher the PRF, the wider the spacing of the spectral lines and the fewer blind speeds due to selective clutter canceling. However, a high PRF increases the problem of range ambiguities. Most modern pulse Doppler radars employ a medium and high PRF mode. Medium PRF equates to fewer range ambiguities but more blind speeds. High PRF has fewer blind speeds but more range ambiguities (Figure 5-24).

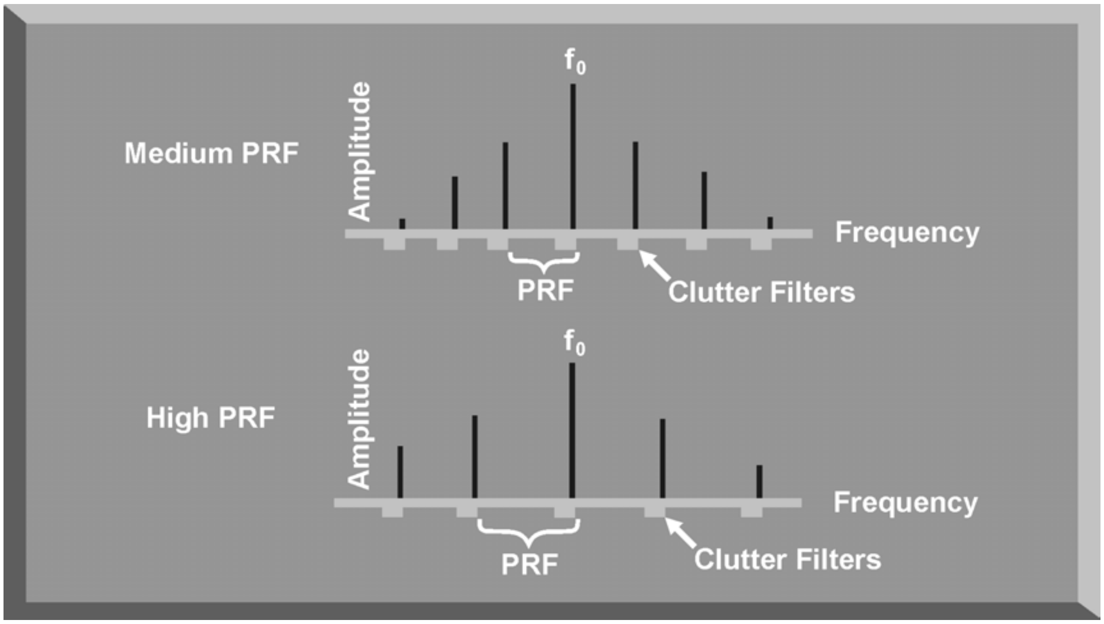

Figure 5-24. PRF and Spectral Lines

(2) To separate the returning target frequency shifts from all other frequencies in the returning waveform, the pulse Doppler radar employs filters to cancel the known harmonic frequency shifts. In addition, the radar cancels out all returns with no frequency shift, which equates to canceling all returns with no movement relative to the radar. However, if the radar has too many clutter filters, this creates multiple blind speeds, and targets will be missed. In Figure 5-25, the detection filters allow target frequencies to be processed, and clutter filters cancel unwanted frequency shifts. Target 1 will be detected, but Target 2 will be canceled.

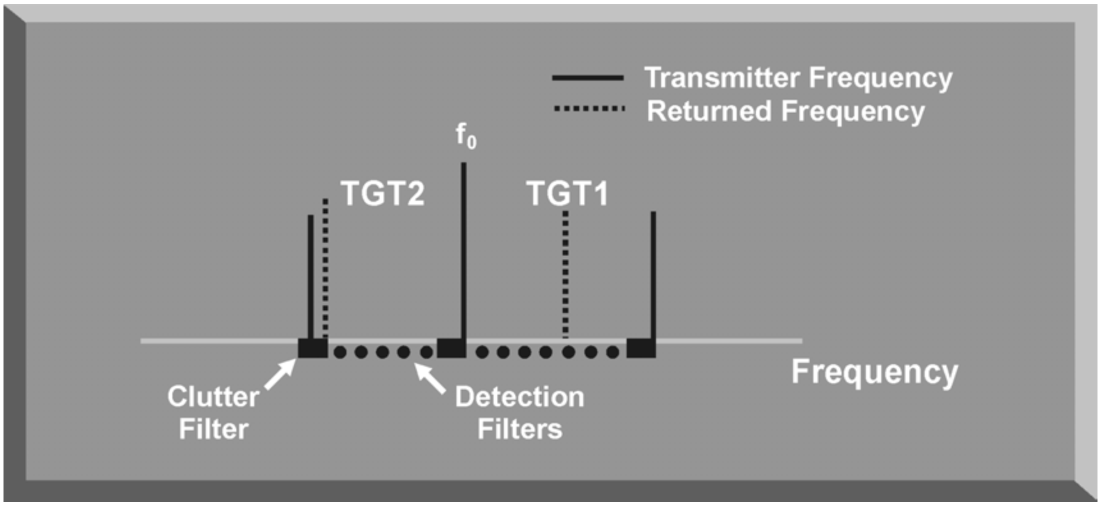

Figure 5-25. Pulse Doppler Filters

7. BASIC RADAR EQUATION

The basic radar equation relates the range of a radar system to the characteristics of the transmitter, receiver, antenna, and the target. The radar equation provides a means not only to figure out the maximum range of a particular radar system, but it can be used to understand the factors that affect radar operation. In this section, the simple forms of the radar equation are developed, starting with the power density of the transmitting antenna to the power received by the receiving antenna.

a. Power density is the power of a radio wave per unit of area normal to the direction of propagation. The power density generated by a practical antenna can be expressed in Equation 5-7.

$$\text{Power Density from Antenna} = \frac{P_T \times G}{4\pi r^2}$$

P_T = transmitted power
G = antenna gain
r = radius of the antenna

Equation 5-7. Power Density From an Antenna

b. As the radar beam propagates through space, it arrives at a target at some range (R) from the antenna. As the radar beam travels through space, the wavefront of the beam expands to a very large cross-sectional area, especially in relation to the target dimensions. The power density of the radar beam, across this wide area, at the target, is detailed in Equation 5-8.

$$\text{Power Density at Target} = \frac{P_T \times G}{4\pi R^2}$$

P_T = transmitted power
G = antenna gain
R = range to the target

Equation 5-8. Power Density at the Target

c. Since the cross-sectional area of the radar beam is so large, only a small portion of the total power in the beam can be reflected toward the antenna. The rest of the radar energy continues through space and is dissipated, absorbed, or reflected by other targets. The small portion of the radar beam that hits the target is reradiated in various directions. The measure of the amount of incident power intercepted by the target and reradiated back in the direction of the antenna depends on the radar cross section (RCS) of the target. Equation 5-9 details the power density of the target echo signal reflected back to the radar antenna.

$$\text{Power Density at Antenna} = \frac{P_T \times G}{4\pi R^2} \times \frac{\sigma}{4\pi R^2}$$

P_T = transmitted power
G = antenna gain
σ = RCS
R = range to the target

Equation 5-9. Power Density at the Antenna

d. As the target echo reaches the antenna, part of the echo is captured by the antenna based on the effective aperture (A_e). Equation 5-10 details the actual signal power received by the radar system. This is one form of the basic radar equation and is the signal strength of a radar return from a specific target at range (R) from the radar.

$$\text{Signal Power Density (S)} = \frac{P_T G \sigma A_e}{(4\pi)^2 R^4}$$

P_T = transmitted power

G = antenna gain

σ = RCS

R = range to the target

A_e = antenna aperture area

Equation 5-10. Signal Power Density

e. A detailed analysis of this equation is not required to draw some basic conclusions about the factors affecting the detection of an aircraft. If any factor in the numerator, such as transmitted power, is increased by a factor of three, the signal received by the radar will increase by only 30 percent. This clearly shows why radar system operation is characterized by the transmission of megawatts of power and the reception of microwatts of returning power. In addition, this equation shows that the most critical factor in determining radar detection is target range.

f. The maximum radar range (R_{MAX}) occurs when the signal power density received just equals the minimum detectable signal (S_{MIN}) for the receiver. Solving Equation 5-11 for range, and substituting S_{MIN}, yields the basic radar equation for R_{MAX} for a specific target. This is another form of the basic radar equation.

$$R_{MAX} = \frac{\left[P_T G \sigma A_e\right]^{1/4}}{\left[(4\pi)^2 S_{MIN}\right]}$$

P_T = transmitted power

G = antenna gain

σ = RCS

A_e = antenna aperture area

R = range to the target

Equation 5-11. Basic Radar Equation

g. It is important to note that the basic radar equations do not consider such factors as meteorological conditions, changes in aircraft RCS, the impact of clutter on gain, or operator abilities. The radar equation does explain why a radar system designed for long-range detection should transmit a very high power signal, concentrated into a narrow beam, collected by a large antenna, and processed by a very sensitive receiver.

8. SUMMARY

This chapter has discussed the methods employed by radar systems to determine target range, azimuth, elevation, and velocity. The relationship between pulse width and range resolution, beamwidth and azimuth/elevation resolution, and PRF and velocity resolution have been explained. In addition, an explanation of the complex radar equation has been presented. The capabilities and limitations of a specific radar system to determine these critical target parameters is the key to understanding the countermeasures designed to defeat this system.

CHAPTER 6. ANTENNA CHARACTERISTICS AND SCANS

1. INTRODUCTION

The function of the antenna during transmission is to concentrate the radar energy from the transmitter into a shaped beam that points in the desired direction. During reception, or listening time, the function of the antenna is to collect the returning radar energy, contained in the echo signals, and deliver these signals to the receiver. Radar antennas are characterized by directive beams that are usually scanned in a recognizable pattern. The primary antenna types in use today fall into three categories: parabolic, Cassegrain, or phased array antennas. Additionally, the method radar antennas employ to sample the environment is a critical design feature of the radar system. The scan type selected for a particular radar system often decides the employment of that radar in an integrated air defense system (IADS). The process the radar antenna uses to search airspace for targets is called scanning or sweeping. This chapter discusses circular, unidirectional, bidirectional, helical, raster, Palmer, and conical scans, and track-while-scan (TWS) radar systems.

2. PARABOLIC ANTENNA

One of the most widely used radar antennas is the parabolic reflector (Figure 6-1). The parabola-shaped antenna is illuminated by a source of radar energy, from the

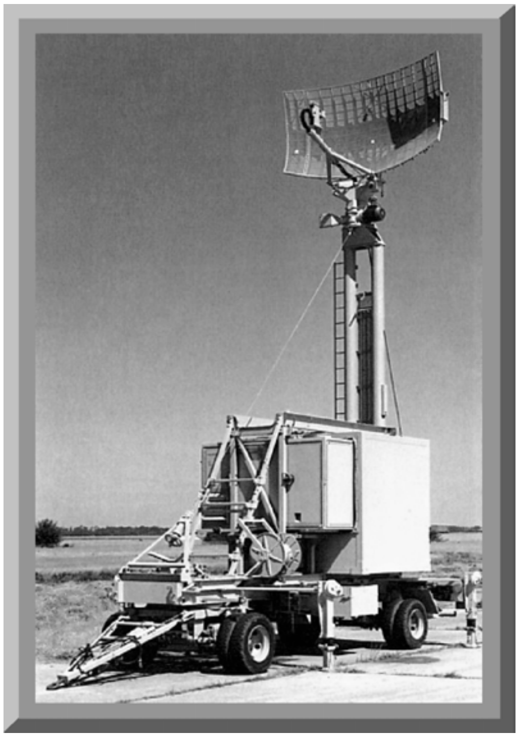

Figure 6-1. Parabolic Antenna

transmitter, called the feed. The feed is placed at the focus of the parabola, and the radar energy is directed at the reflector surface. Because a point source of energy, located at the focus, is converted into a wavefront of uniform phase, the parabola is well suited for radar antenna applications. By changing the size and shape of the parabolic reflecting surface, a variety of radar beam shapes can be transmitted.

a. The antenna depicted in Figure 6-1 generates a nearly symmetrical pencil beam that can be used for target tracking.

b. Elongating the horizontal dimensions of the parabolic antenna creates a radar antenna called the parabolic cylinder antenna (Figure 6-2). The pattern of this antenna is a vertical fan-shaped beam. Combining this antenna pattern with a circular scan technique creates a radar system well suited for long-range search and target acquisition.

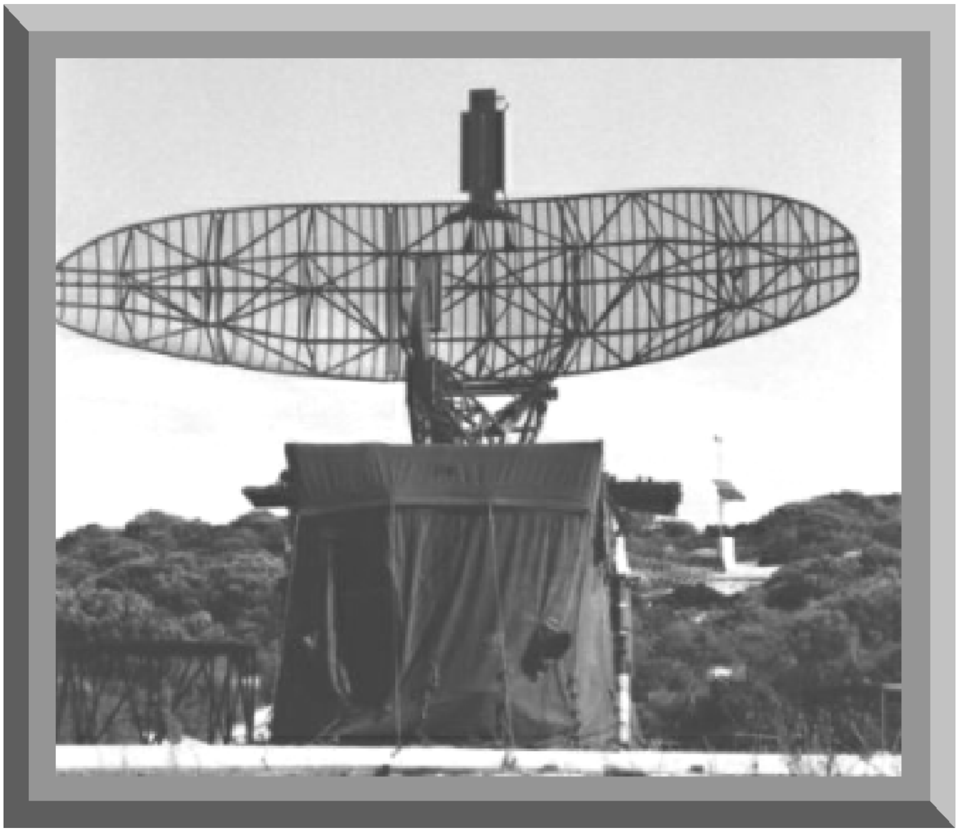

Figure 6-2. Parabolic Cylinder Antenna

c. Elongating the vertical dimensions of the parabola creates a radar antenna that generates a horizontal fan-shaped beam with a small vertical dimension (Figure 6-3). This type of antenna is generally used in height-finding radar systems.

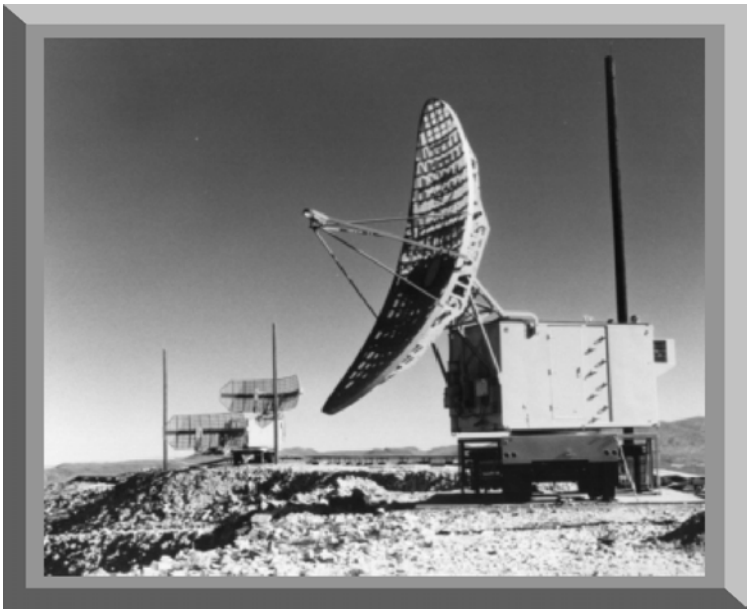

Figure 6-3. Height-Finder Parabolic Antenna

d. Another variation of the basic parabolic antenna includes using an array of multiple feeds instead of a single feed (Figure 6-4). This type of parabolic antenna can produce multiple radar beams, either symmetrical or asymmetrical, depending on the angle and spacing of the individual feeds.

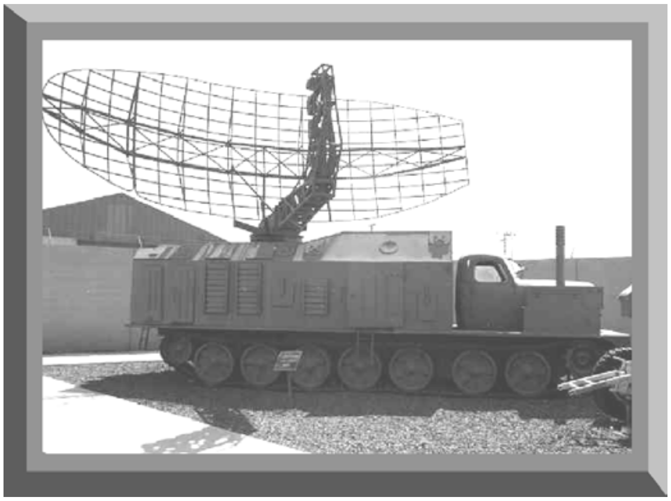

Figure 6-4. Multiple-Feed Parabolic Antenna

3. CASSEGRAIN ANTENNA

A Cassegrain antenna uses a two-reflector system to generate and focus a radar beam (Figure 6-5). The primary reflector uses a parabolic contour, and the secondary reflector, or subreflector, has a hyperbolic contour. The antenna feed

is located at one of the two foci of the hyperbola. Radar energy from the transmitter is reflected from the subreflector to the primary reflector to focus the radar beam. Radar energy returning from a target is collected by the primary reflector and reflected as a convergent beam to the subreflector. The radar energy is rereflected by the subreflector, converging at the position of the antenna feed. The larger the subreflector, the closer it can be to the primary reflector. This reduces the axial dimensions of the radar but increases aperture blockage due to the subreflector. A small subreflector reduces aperture blockage, but it must be positioned at a greater distance from the primary reflector.

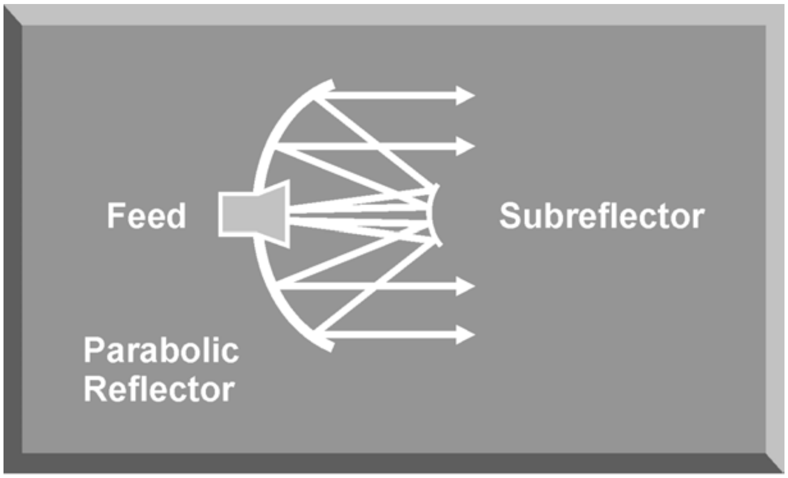
Feed
Subreflector
Parabolic Reflector

Figure 6-5. Cassegrain Antenna

a. To reduce the aperture blockage by the subreflector and to provide a method to rapidly scan the radar beam, the flat plate Cassegrain antenna was developed. This type of Cassegrain antenna is depicted in Figure 6-6.

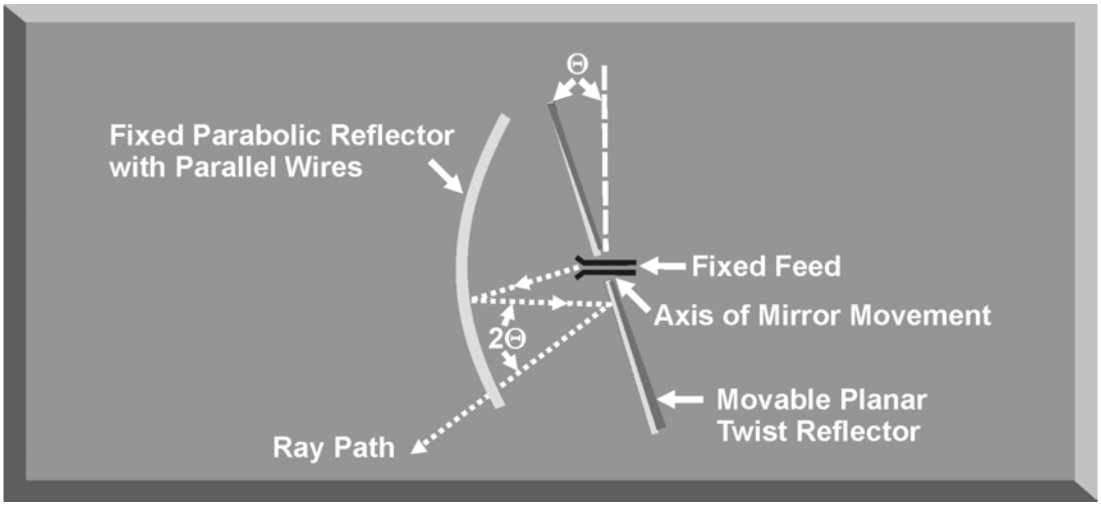
Θ
Fixed Parabolic Reflector with Parallel Wires
Fixed Feed
Axis of Mirror Movement
2Θ
Movable Planar Twist Reflector
Ray Path

Figure 6-6. Flat Plate Cassegrain Antenna

The fixed parabolic reflector is made up of parallel wires spaced less than a half wavelength apart and supported by a low-loss dielectric material. This makes the fixed parabolic reflector polarization sensitive. It will completely reflect one type of linear polarization and be transparent to the orthogonal polarization. The fixed antenna feed, in the middle of the moveable mirror, transmits a radar signal polarized to be reflected by the parabolic reflector. The moveable mirror is constructed as a twist reflector that changes the polarization of the radar signal by 90°. The signal from the feed is reflected by the parabolic reflector to the mirror, which rotates the polarization 90°. This rotation makes the transmitted signal transparent to the parabolic reflector, and the signal passes through with minimal attenuation. The radar beam can be scanned over a wide area by rotating the moveable mirror. A deflection of the mirror by the angle θ results in the beam scanning through an angle of 2θ.

b. The geometry of the Cassegrain antenna is especially well suited for monopulse tracking radar applications. Unlike the parabolic antenna, the complex feed assembly required for a monopulse radar can be placed behind the reflector to avoid aperture blocking.

4. PHASED ARRAY ANTENNA

The phased array radar is a product of the application of computer and digital technologies to the field of radar design. A phased array antenna is a complex arrangement of many individual transmitting and receiving elements in a particular pattern. A phased array antenna can, in effect, radiate more than one beam from the antenna by using a computer to rapidly and independently control groups of these individual elements. Multiple beams and computer processing of radar returns give the phased array radar the ability to track-while-scanning and engage multiple targets simultaneously. Figure 6-7 is a view of the phased array radar antenna.

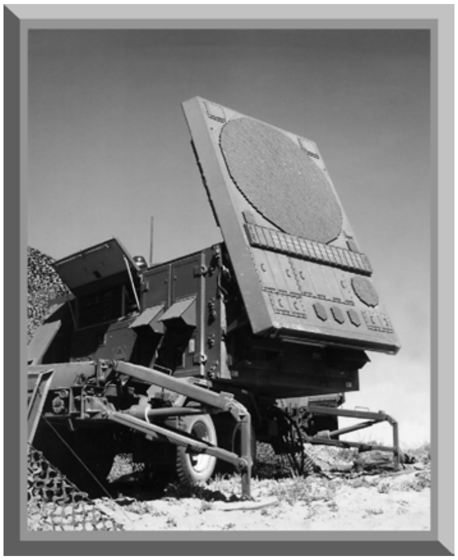

Figure 6-7. Phased Array Antenna

a. A phased array radar uses the principle of radar phase to control the individual transmitting and receiving elements. When two transmitted frequencies are in-phase, their amplitudes add together, and the radiated energy is doubled. When two transmitted frequencies are out-of-phase, they cancel each other. Phased array radars use this principle to control the shape of the transmitted radar beam (Figure 6-8).

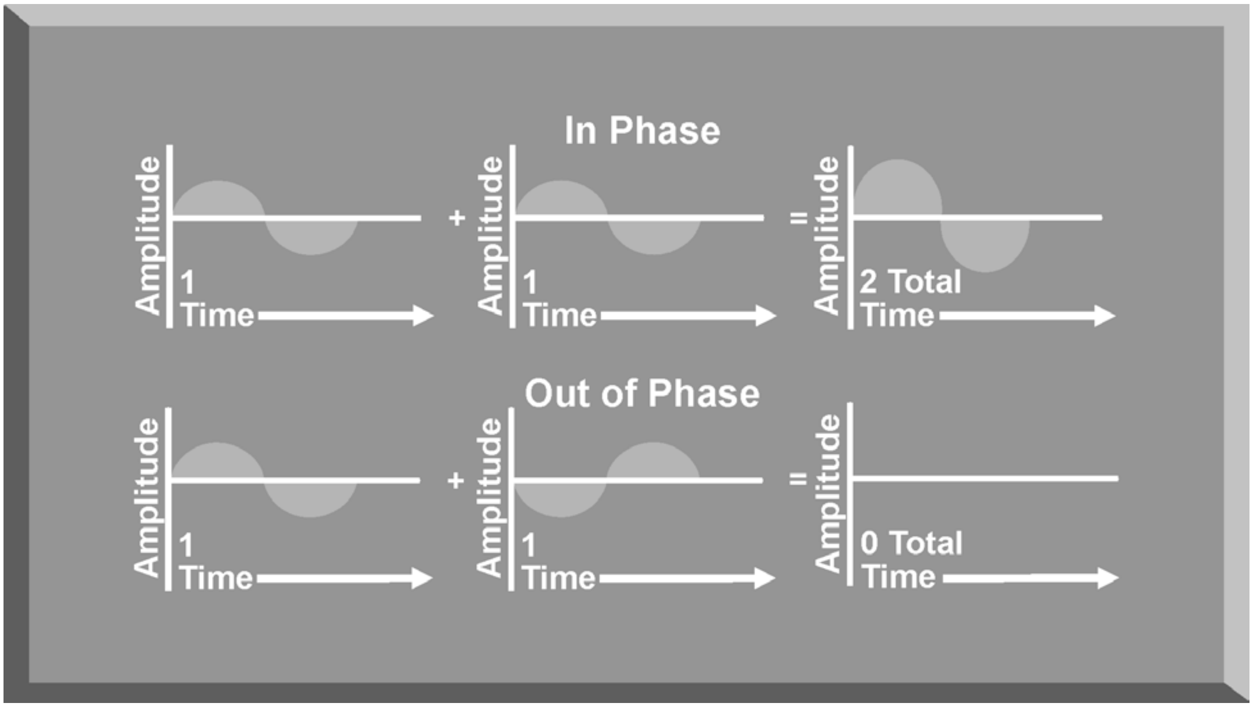

Figure 6-8. Phase Relationships

b. Phase relationships and antenna element spacing determine the orientation of the transmitted beam. In Figure 6-9, antenna elements A and B are separated by one-half wavelength and are radiating in-phase, that is, when one is at the positive peak, the other is also at a positive peak. Since the elements are one-half wavelength apart, when the positive peak radiated by A reaches B, B will be radiating a negative peak. As the peaks propagate along the X axis, they will cancel each other out. The total radiated power along that axis will be zero. Along the Y axis, however, the positive peaks from A will add to the positive peaks from B, causing the total radiation along this axis to be at its maximum value. This type of array is called a “broadside array” because most of the radiation is in the direction that is broadside to the line of the antenna array.

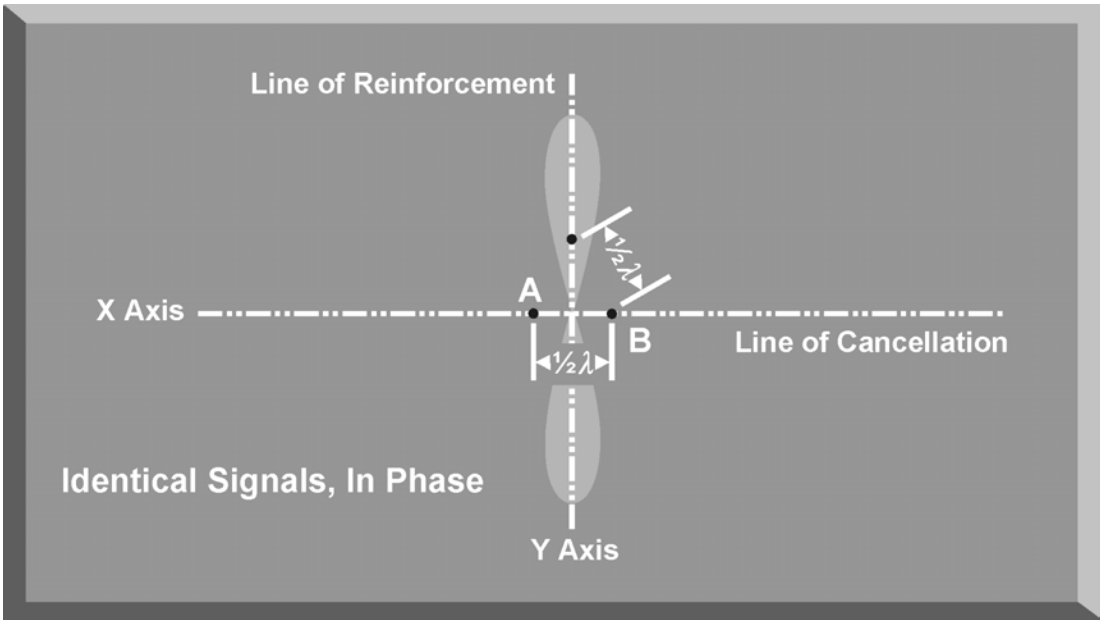
Line of Reinforcement
½λ
A
X Axis
B
Line of Cancellation
½λ
Identical Signals, In Phase
Y Axis

Figure 6-9. Broadside Array

c. If the same antenna elements are fed out-of-phase, the principal direction of radiation will be along the axis of the antenna elements. In Figure 6-10, when the positive peak from A arrives at B, B is now positive also. These energies interact to strengthen the energy being radiated from the ends of the array. Meanwhile, when the positive peak from A, radiating along the Y axis, meets the negative peak from B, they are canceled. This type of array is called an "end-fire array."

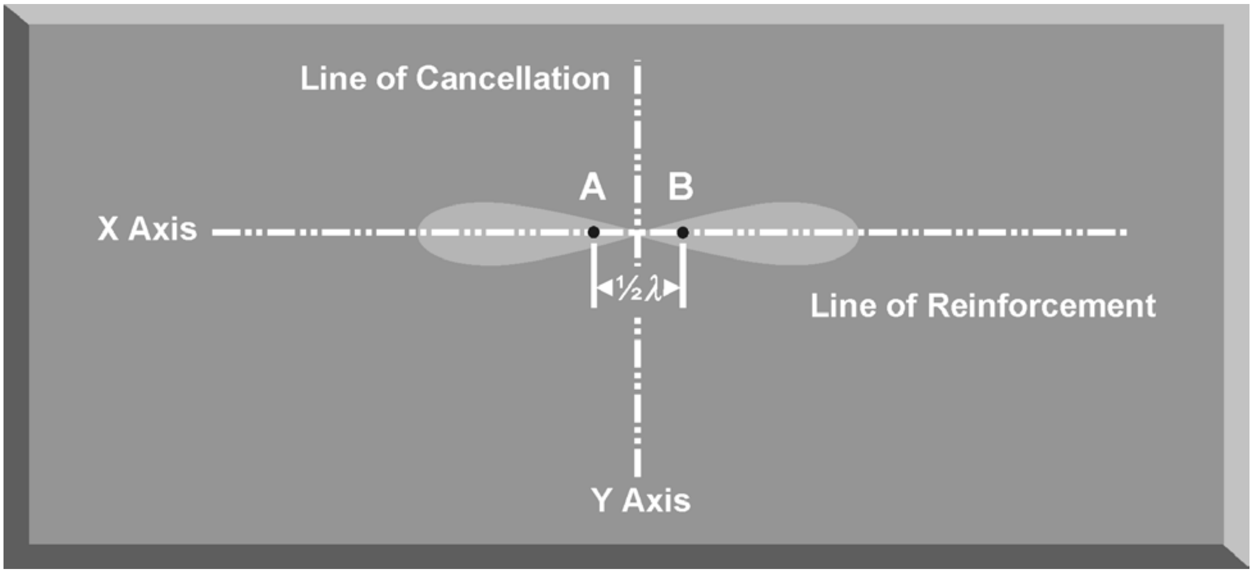
Line of Cancellation
A
B
X Axis
½λ
Line of Reinforcement
Y Axis

Figure 6-10. End-Fire Array

d. The computer controlling the phase of the signal delivered to each transmitting and receiving element of a phased array antenna controls the direction and shape of the radiated beam (Figure 6-11). By shifting the phase of the signals between 0° and 180°, the beam sweeps. This is the basic means of producing an antenna scan. In addition, the amplitude, or power, of the signal applied to each element can be varied to control the sidelobes. This alters the shape of the beam which affects the range capability and angular resolution of the radar.

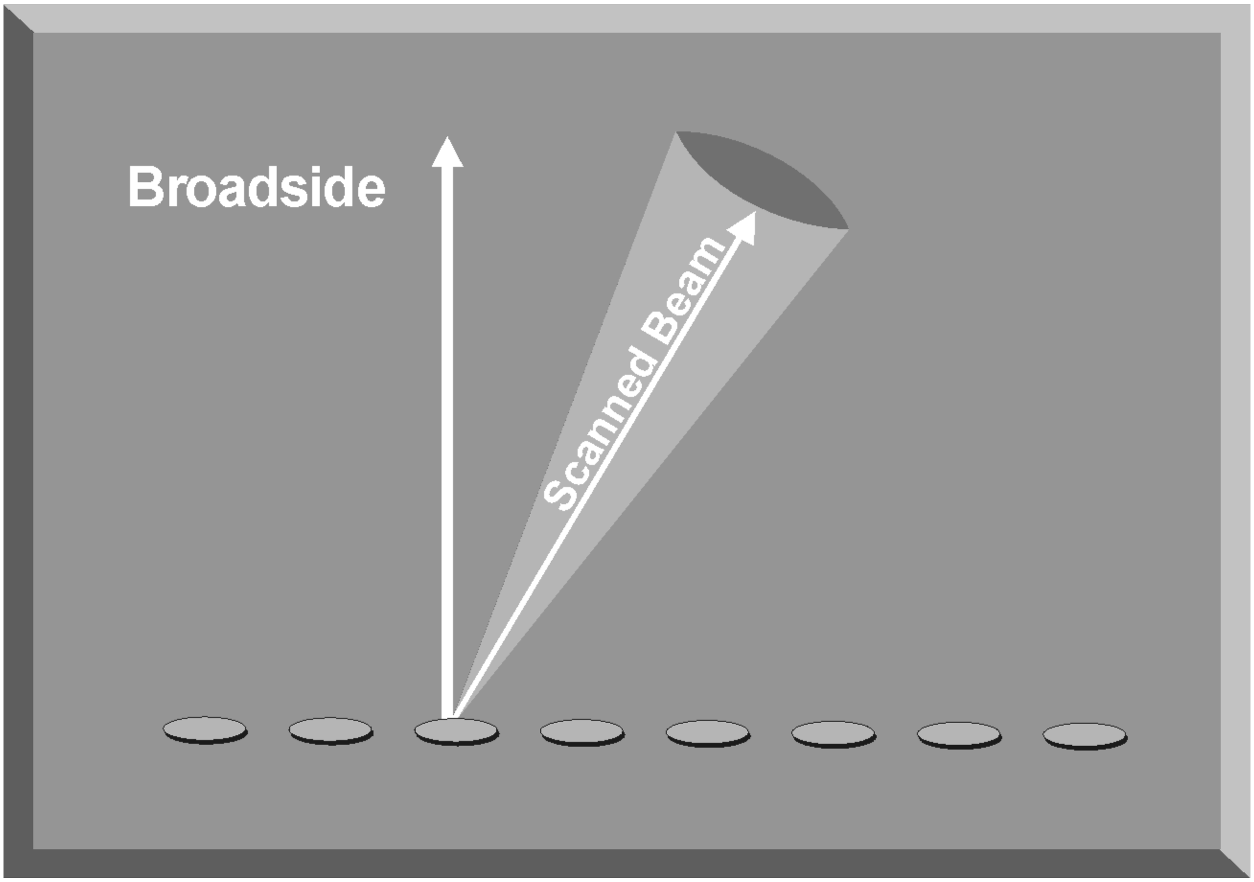

Figure 6-11. Phased Array Antenna Scan

e. Figure 6-12 depicts a variation of the phased array antenna, known as a planar array antenna. A planar array antenna uses transmit and receive elements in a linear array, but, unlike the phased array radar, the elements are smaller and are placed on a movable flat plate. The ability to simultaneously track several targets is one advantage of this type of radar.

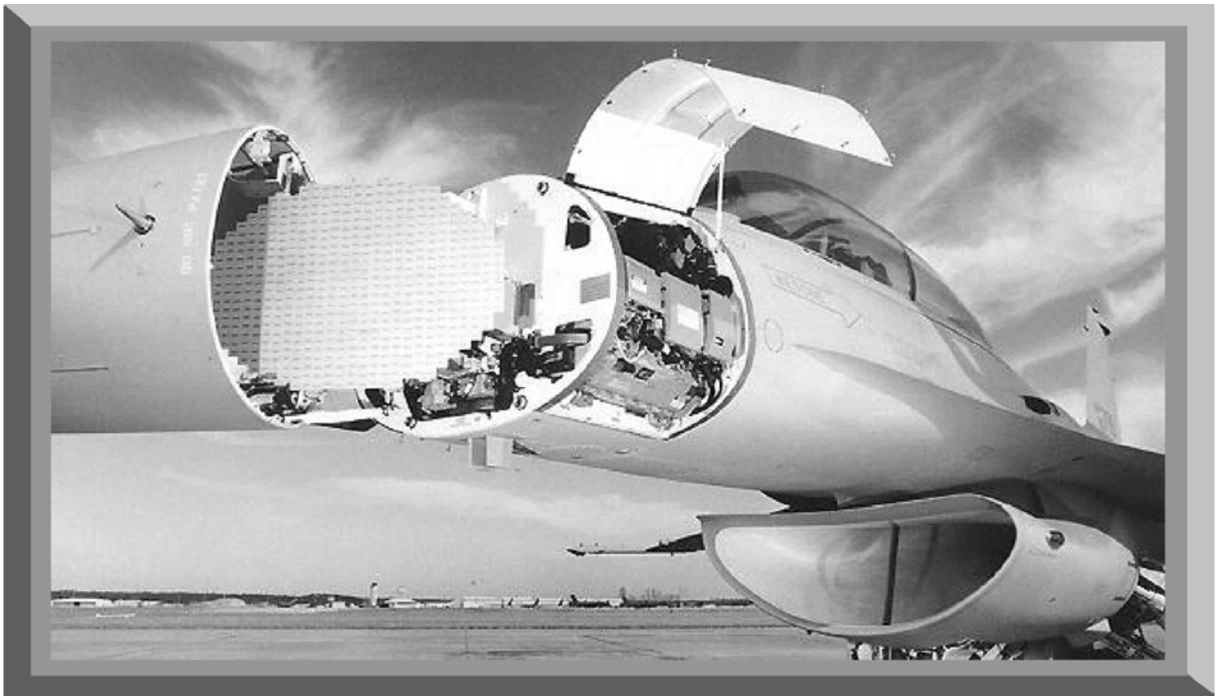

Figure 6-12. Planar Array Antenna

5. ANTENNA GAIN

The most important characteristic of any type of antenna is antenna gain. Antenna gain is a measure of the ability of an antenna to concentrate energy in the desired direction. Antenna gain should not be confused with receiver gain, which is designed to control the sensitivity of the receiver section of a radar system. There are two types of antenna gain: directive and power.

a. The directive gain of a transmitting antenna is the measure of signal intensity radiated in a particular direction. Directive gain is dependent on the shape of the radiation pattern of a specific radar antenna. The directive gain does not take into account the dissipative losses of the antenna. Directive gain is computed using Equation 6-1.

$$G_D \text{ (Directive Gain)} = \frac{\text{Maximum Radiation Intensity (Desired Direction)}}{\text{Average Radiation Intensity}}$$

Equation 6-1. Directive Gain

b. The power gain does include the antenna dissipative losses and is computed using Equation 6-2.

$$\text{G (Power Gain)} = \frac{\text{Maximum Radiation Intensity (Practical Antenna)}}{\text{Radiation Intensity of an Isotropic Antenna}}$$

Equation 6-2. Power Gain

c. The term isotropic antenna describes a theoretical spherical antenna that radiates with equal intensity in all directions. This results in a spherical radiation pattern. The power density for any point on an isotropic antenna is the radiation intensity and can be calculated by dividing the total power transmitted (P_T) by the total surface area of the sphere, as shown in Equation 6-3.

$$\text{Power Density (Isotropic Antenna)} = \frac{P_T\ \text{(Watts)}}{4\pi r^2\ (\text{Centimeters}^2)}$$

Equation 6-3. Power Density for an Isotropic Antenna

d. The radiation pattern of an isotropic, or spherical, antenna would provide neither azimuth or elevation resolution and would be unusable for radar applications. To provide azimuth and elevation resolution, a practical antenna must focus the radar energy. The power density of a practical antenna differs from the isotropic antenna only in terms of antenna gain (G). Solving Equation 6-3 for the power density of a practical antenna yields Equation 6-4.

$$\text{Power Density (Practical Antenna)} = \frac{P_T\, G}{4\pi r^2}$$

Equation 6-4. Power Density for a Practical Antenna

e. The actual power gain (G) of a practical antenna can be calculated by using Equation 6-5.

$$G = \frac{4\pi A_e}{\lambda}$$

A_e = effective area of aperture

λ = wavelength of the radar

NOTE: The effective area of aperture (A_e) is the effective antenna area presented to the returning radar echo.

Equation 6-5. Power Gain of a Practical Antenna

6. POWER DENSITY

The power density and gain of an antenna are a function of the antenna pattern of a radar system. Figures 6-13 and 6-14 illustrate the antenna pattern of a typical parabolic antenna. Most of the power density of the radar is concentrated in the main beam. However, since the radar is not a perfect reflector, some radar energy is transmitted in the sidelobes. In addition, there is spillover radiation due to the energy radiated by the feed that is not intercepted by the reflector. Finally, the radar has a back lobe caused by diffraction effects of the reflector and direct signal leakage. Sidelobes and backlobes are all undesirable radiations that adversely affect the maximum radar range and increases the vulnerability of the radar to certain jamming techniques.

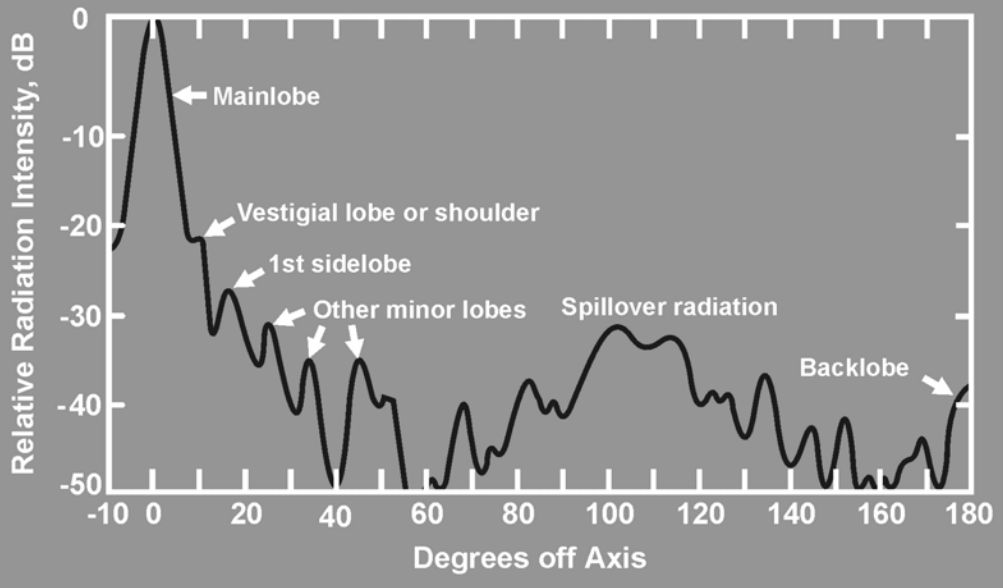

Figure 6-13. Radiation Pattern for a Parabolic Antenna

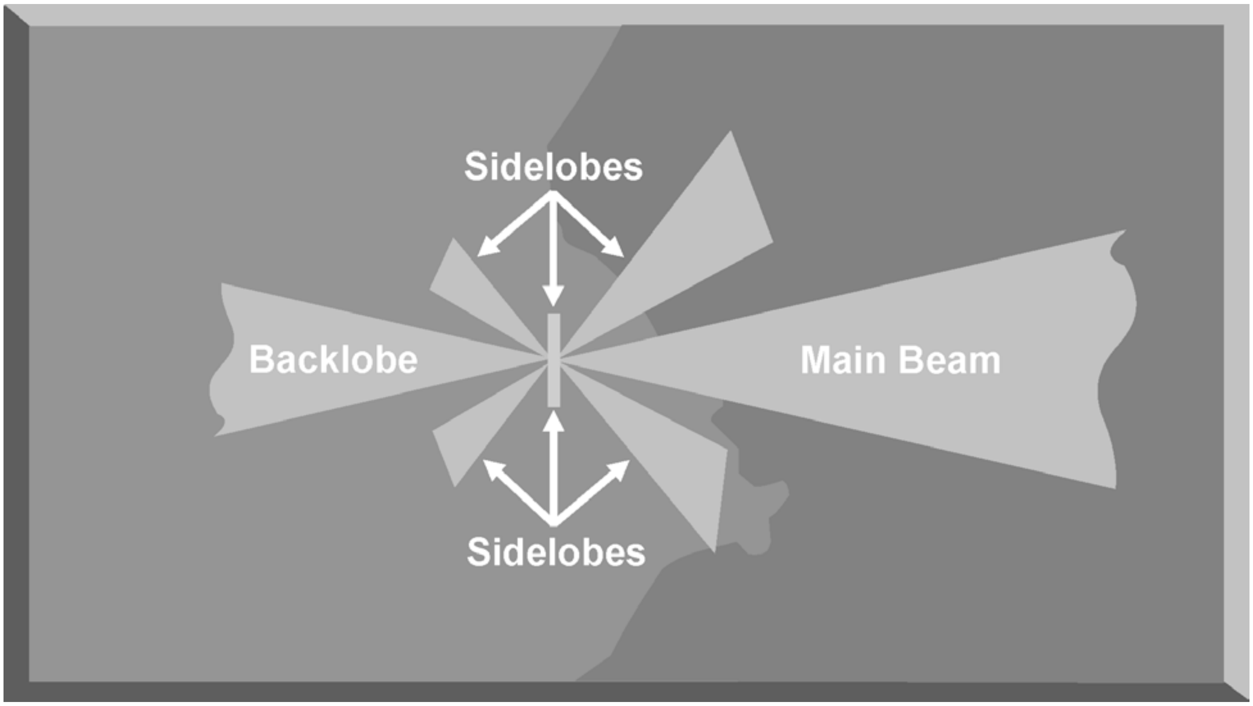

Figure 6-14. Radar Antenna Pattern

a. All radars have a primary main beam, which is where the radar has the most power and where target detection usually occurs. The dimensions of this main beam are highly dependent on the design of the antenna.

b. Besides the main beam, all radars have what is called a backlobe. This lobe is directly opposite to the location of the main beam. The sensitivity and signal strength associated with the backlobe is significantly less than that in the main beam.

c. Sidelobes add another dimension to the radar pattern. As with the backlobe, sidelobes do not have the signal strength or sensitivity associated with the main beam. Normally, the sensitivity associated with the sidelobes is 40-50 decibels (dBs) less than the main beam. The radar signal weakness in the backlobe and sidelobes of the main beam make these areas of the radar signal vulnerable to jamming. It is much easier to introduce jamming into these areas because of the reduced jamming-to-signal ratio needed to be effective. It is difficult for jamming to be effective in the main beam because the radar signal is very powerful in that region.

7. CIRCULAR SCAN

A circular scanning radar uses an antenna system that continuously scans 360° in azimuth (Figure 6-15). The time required for the antenna to sweep one complete 360° cycle is called the scan rate. Scan duration is the number of "hits per scan,"

or the number of pulses, reflected by a target as the radar beam crosses it during one full scan. Most pulse radars require 15 to 20 hits per scan to obtain sufficient information to display a target. The factors that determine the number of hits per scan the radar receives include pulse repetition frequency (PRF), antenna beamwidth, and scan duration.

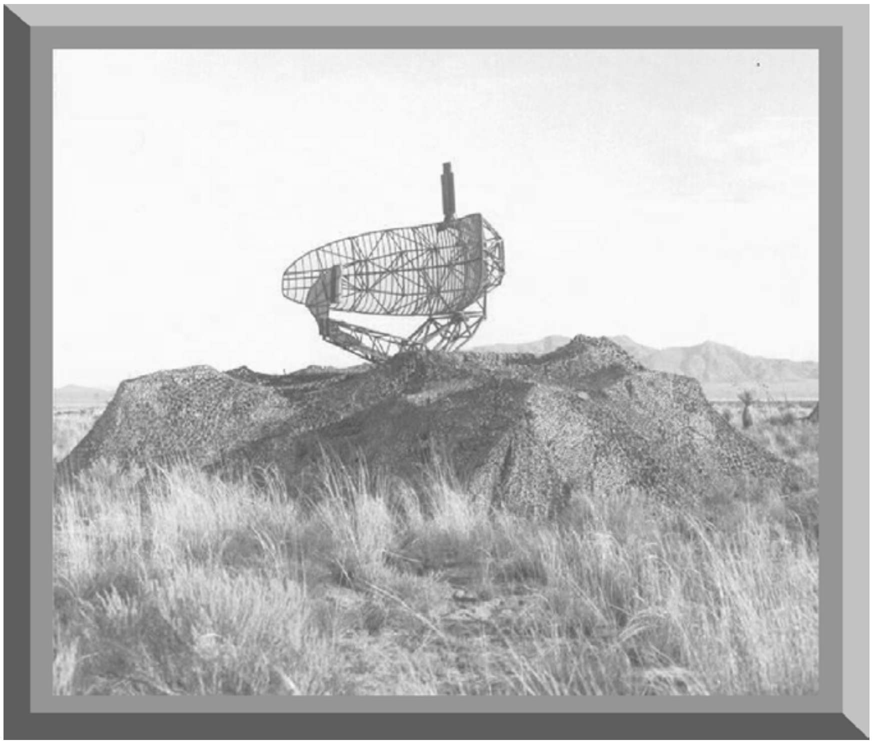

Figure 6-15. Circular Scan Radar

a. Circular scan radars provide accurate target range and azimuth information. This makes these radars ideal for the roles of early warning and initial target acquisition. To accomplish these missions, the antenna generates a fan beam that has a large vertical beamwidth and a small horizontal beamwidth. Since elevation information will normally be provided by height finder radars, the size of the vertical beamwidth is not a limitation. This antenna scan allows the radar to scan large volumes of airspace for early target detection. Since early detection is the primary goal of early warning radars, accurate altitude and azimuth resolution are secondary considerations.

b. Circular scan radars designed for early warning transmit a radar signal with a low PRF. A low PRF allows sufficient time for the radar pulse to travel long distances, and return, before another pulse is transmitted. This gives the radar system a long, unambiguous range capability. Circular scan radars with low PRFs generally use long pulse widths in order to increase their average power and long-range detection capability. The scan durations of early warning radars are relatively long to provide the required “hits per scan” for long-range target

detection. The plan position indicator (PPI) scope display is normally used with a circular scan radar (Figure 6-16).

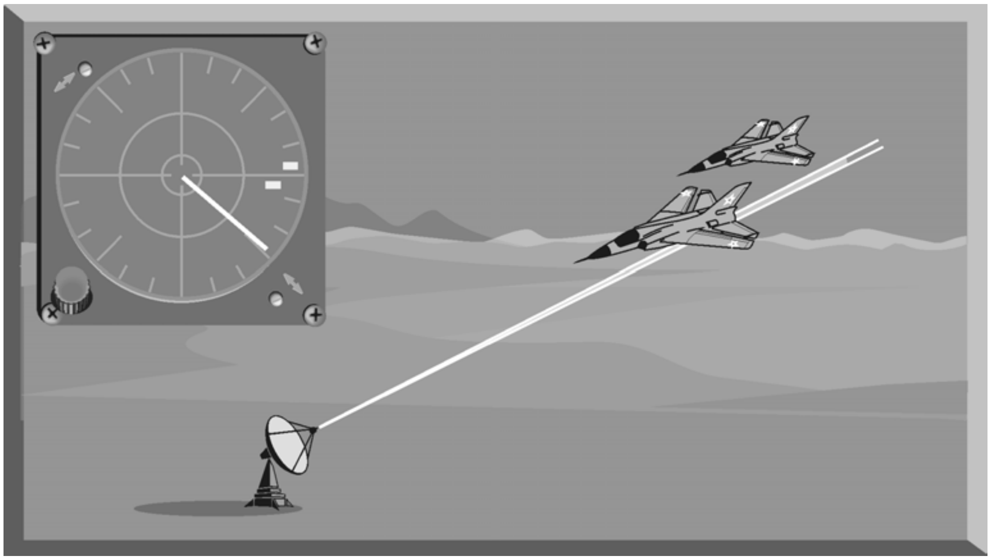

Figure 6-16. PPI Scope Display

c. In order to provide coverage for a large volume of airspace, the beamwidth associated with a circular scan radar is relatively wide. This wide beamwidth, coupled with the long pulse width and low PRF, gives the circular scan radar a large resolution cell, especially at long ranges (Figure 6-17). This limitation can be exploited to mask force size and composition. However, as range decreases, the dimensions of the resolution cell decrease, and a circular scan radar will begin to break out target formations.

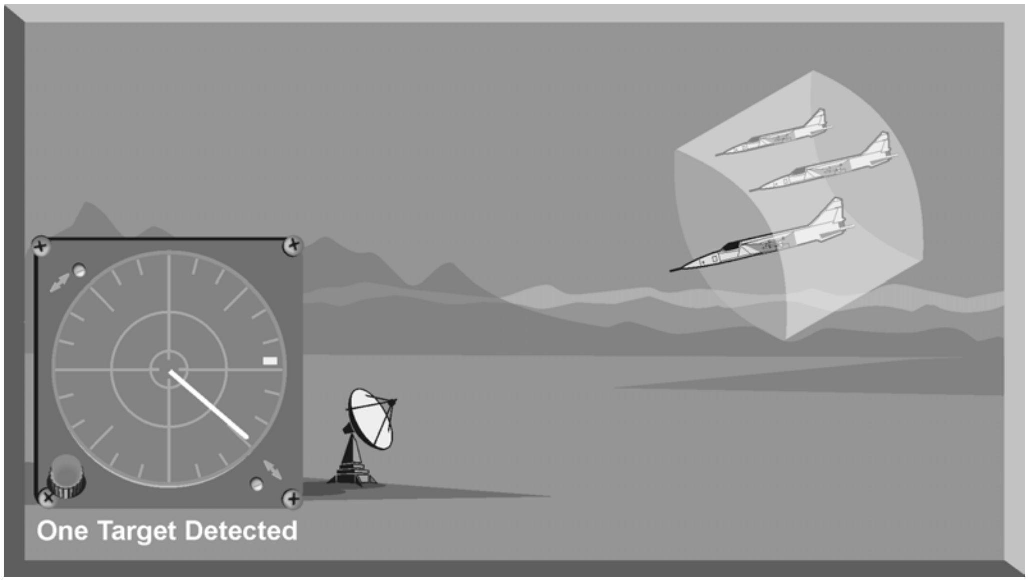

Figure 6-17. Resolution Cell

d. Circular scan radars provide range and azimuth information for both early warning and acquisition roles. Modified circular scan radars that can also provide elevation information may be used for ground control intercept (GCI) roles. Two modified circular scan radars that determine range, azimuth, and elevation are the V-beam and the stacked beam.

(1) The V-beam radar transmits two fan-shaped beams that are swept together (Figure 6-18). A vertical beam provides range and azimuth information. A second beam, rotated at some convenient angle, provides a measure of the altitude of the target.

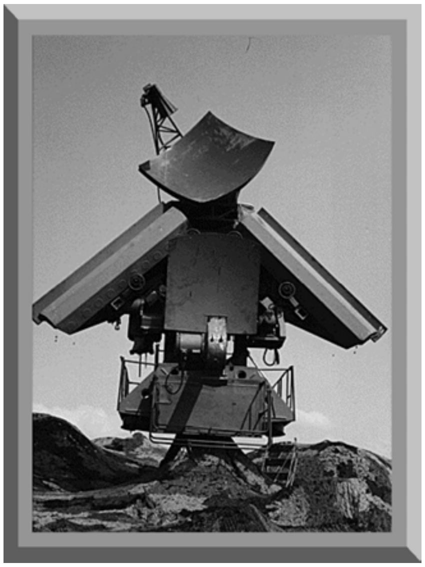

Figure 6-18. V-Beam Radar

(2) A stacked beam radar (Figure 6-19) employs a vertical stack of fixed elevation "pencil" beams which rotate 360°. Elevation information is obtained by noting which beam contains the target return. Range and azimuth information is determined in the same manner as in an early warning radar.

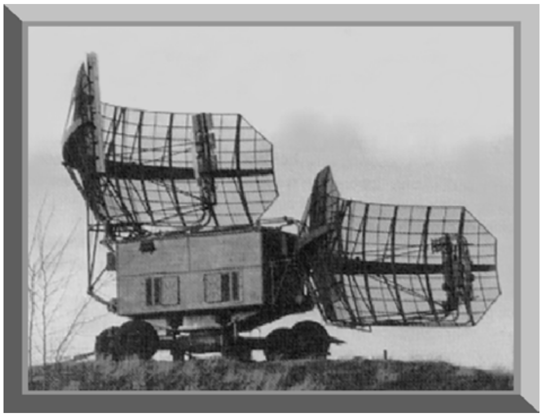

Figure 6-19. Stacked Beam Radar

8. LINEAR SCAN

Linear scan is a method used by some radar systems to sweep a narrow radar beam in a set pattern to cover a large volume of airspace. Linear scans can be oriented in a vertical direction for height finder radars or in a horizontal direction, or raster, for acquisition and target tracking radars. A unidirectional linear radar scans in a single direction then begins its sweep all over again (Figure 6-20). Generally, linear scans offer excellent single-axis coverage, and the narrow beam offers enhanced azimuth and elevation resolution.

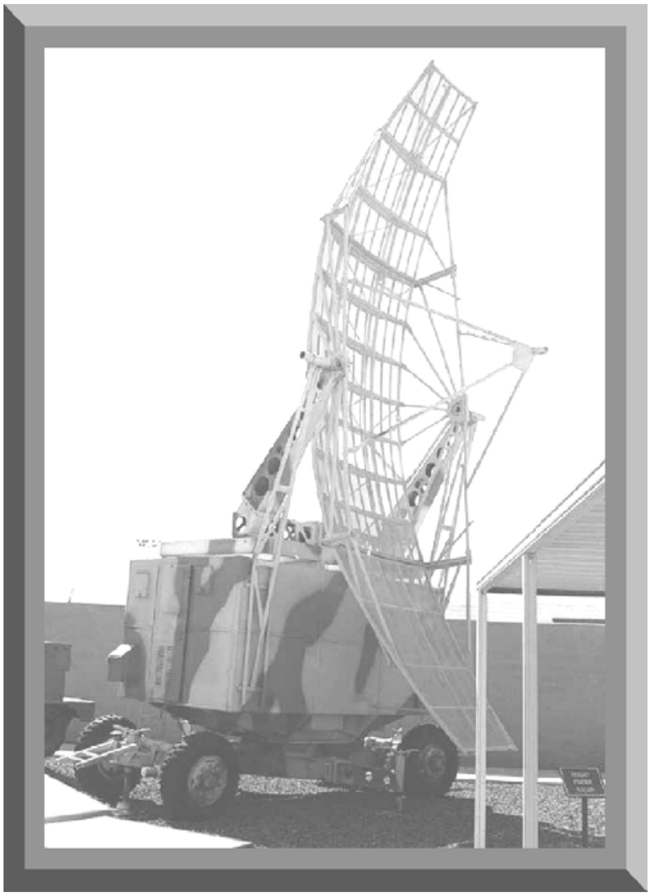

Figure 6-20. Unidirectional Linear Scan

9. UNIDIRECTIONAL SCAN

A helical scan is a unidirectional scan pattern that allows a "pencil" beam to search a 360° pattern. In Figure 6-21, the antenna sweeps a 360° sector in a clockwise direction. After each complete revolution, the antenna elevation is increased. This scan pattern is repeated for a specified number of revolutions, in this case, three, 360° sweeps. At the end of the scan pattern, the antenna elevation is reset to the initial elevation and the scan is repeated. A helical scan pattern is commonly used as a target acquisition mode for radar systems with narrow vertical and horizontal beamwidths.

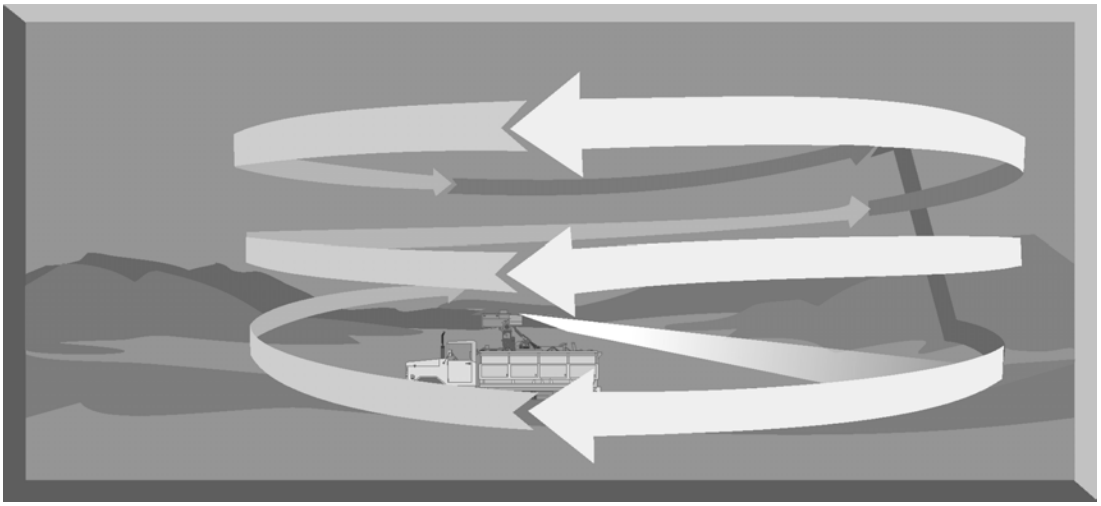

Figure 6-21. Helical Scan

10. BIDIRECTIONAL SCAN

A bidirectional linear scan, such as a raster scan, sweeps both horizontally and vertically (Figure 6-22). A raster scan uses a thin beam to cover a rectangular area by horizontally sweeping the area. The angle of elevation is incrementally stepped up or down with each horizontal sweep of the desired sector. After the sector has been covered, the angle of elevation is reset to the original value and the process is repeated. The number of raster bars is set by the number of horizontal sweeps in the basic raster pattern. Figure 6-22 shows a four-bar raster scan, which is normally associated with an airborne interceptor (AI) radar.

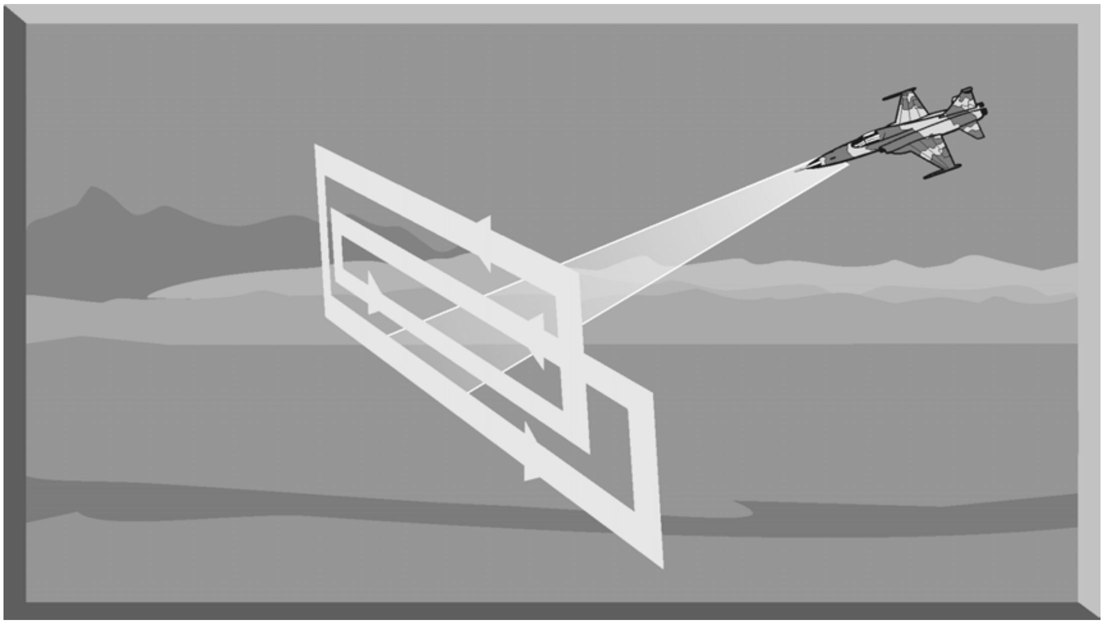

Figure 6-22. Raster Scan

11. CONICAL SCAN

A conical scan, or conscan, radar is generally used for precision target tracking. A conical scan radar (Figure 6-23) employs a pencil beam of radar energy that is continuously rotated around the target. This circular rotation of a pencil beam generates a cone-shaped scan pattern with the apex of the cone located at the antenna. Thus, the name conical scan.

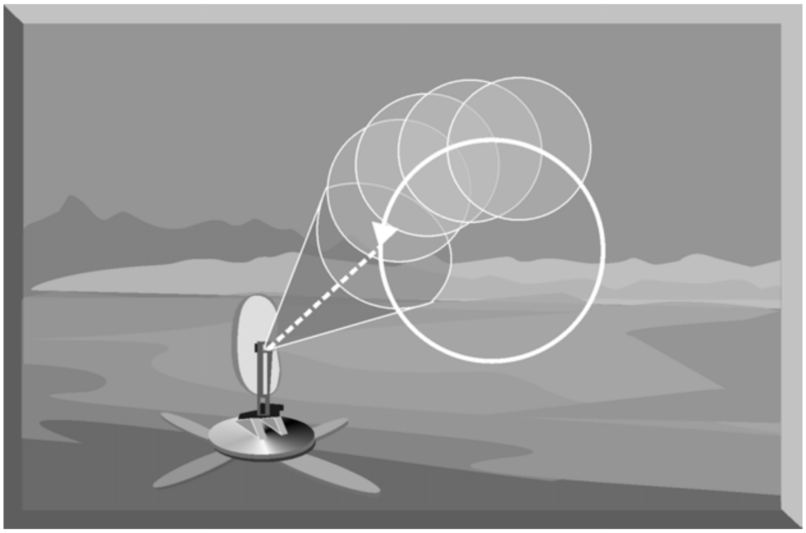

Figure 6-23. Conical Scan

a. As the pencil beam rotates, the circular scan patterns overlap in the center. This creates a central tracking area that has a much smaller effective beamwidth than the rotating pencil beam (Figure 6-24). This results in a very precise tracking solution.

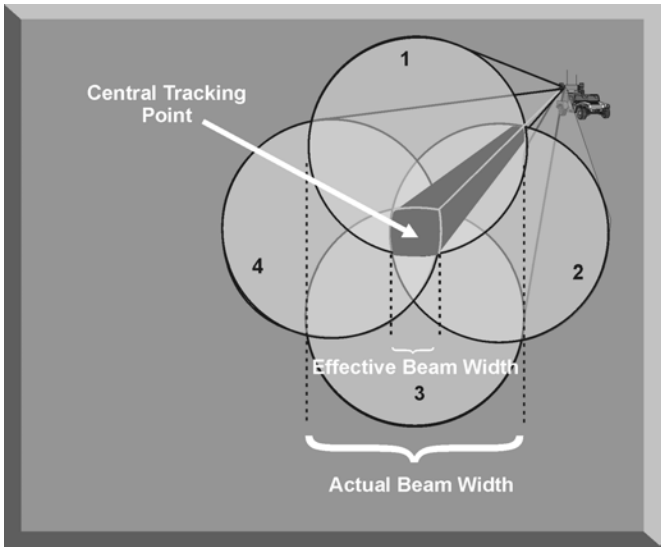

Figure 6-24. Conical Scan Tracking Area

b. Since conical scan radars are designed for precision target tracking, these radars normally operate at high frequencies, high PRF, narrow pulse widths, and narrow beamwidths. The rotation rate of the pencil beam can exceed 1,800 revolutions per minute. This means that both azimuth and elevation data can be updated about 30 times per second.

c. The combination of conical scan and raster scan is called a Palmer-raster scan (Figure 6-25). A Palmer-raster scan uses a thin beam, employing a conical scan searching pattern, for a specific sector of airspace. With each sweep of the sector, the angle of elevation is incrementally stepped up or down. After the vertical sector has been covered, the angle of elevation is set at the original elevation and the process is repeated. The number of bars is determined by the number of vertical search scans.

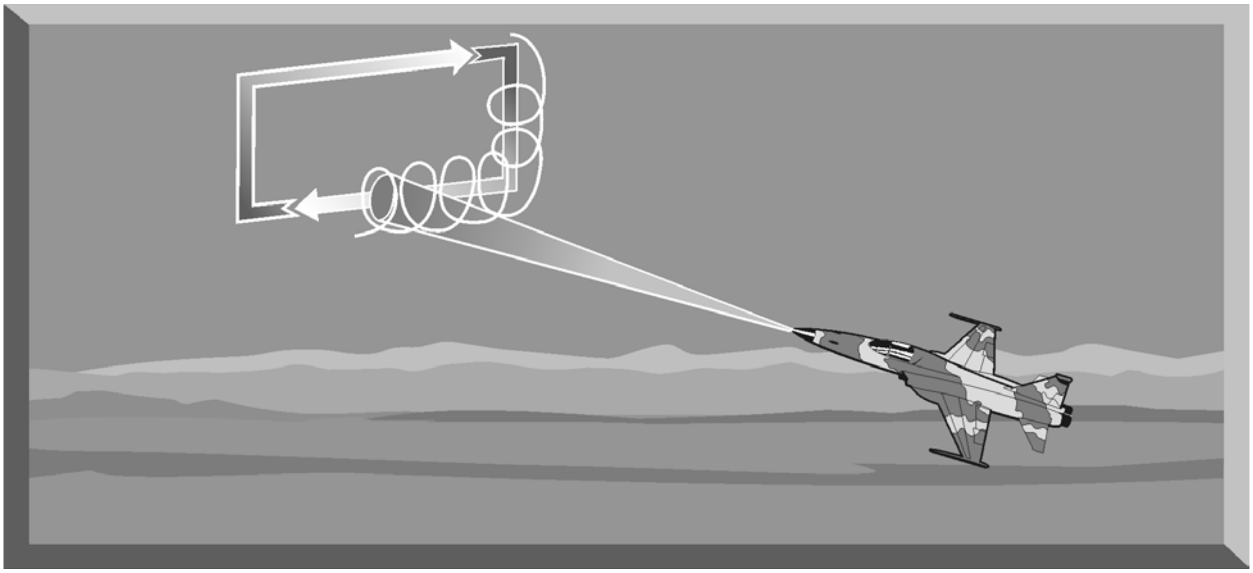

Figure 6-25. Palmer-Raster Scan

d. The combination of a conical scan and a circular scan is called a Palmer scan. Palmer scans incorporate a circular scanning antenna to search the entire horizon while simultaneously performing a conical scan. If the radar antenna is also performing a unidirectional altitude search in conjunction with this scan, it is employing a Palmer-helical scan (Figure 6-26).

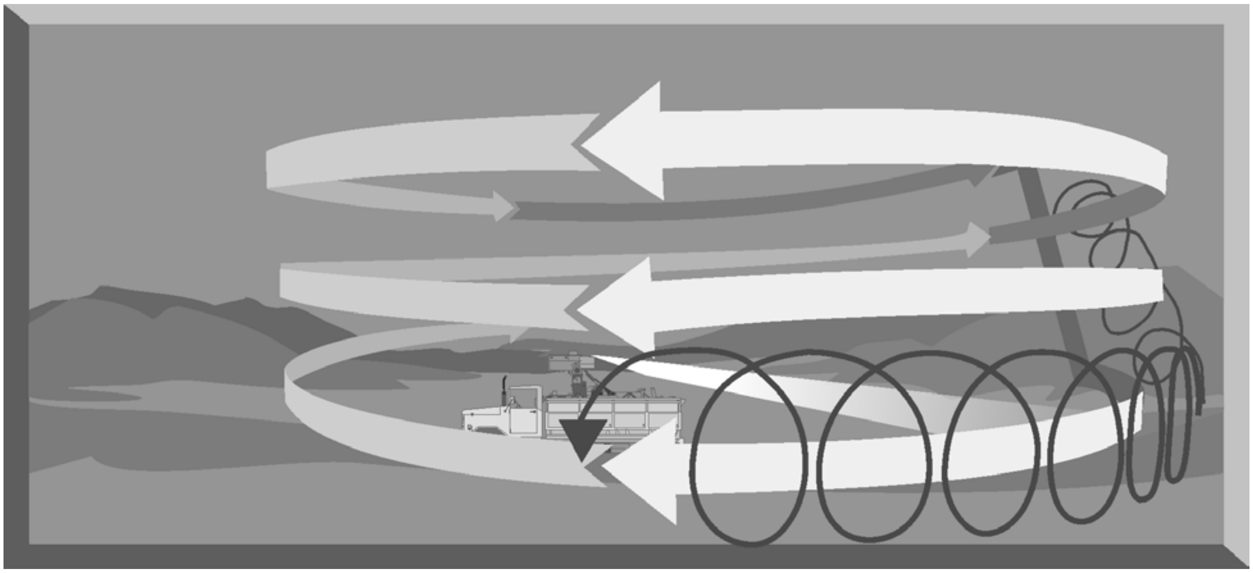

Figure 6-26. Palmer-Helical Scan

12. TRACK-WHILE-SCAN

A track-while-scan (TWS) system uses a technique that allows a radar to track one or more targets while scanning for others. Radar systems with a TWS capability must be able to generate two or more distinct radar beams.

a. A conventional TWS radar employs two antennas that work with each other to perform the scan function (Figure 6-27). Each antenna produces a separate unidirectional beam. Each beam is transmitted at a different frequency. The vertical antenna generates a beam employing a vertical sector scan similar to a height finder radar except the beamwidth is narrower and it scans at a higher rate. The horizontal antenna generates an identical beam employing a horizontal sector scan at a different frequency. The track function is accomplished in the area where the two beams pass through each other. A target that is within this center area is tracked, and positional information on range, elevation, and azimuth is updated each time the beams sweep through the area.

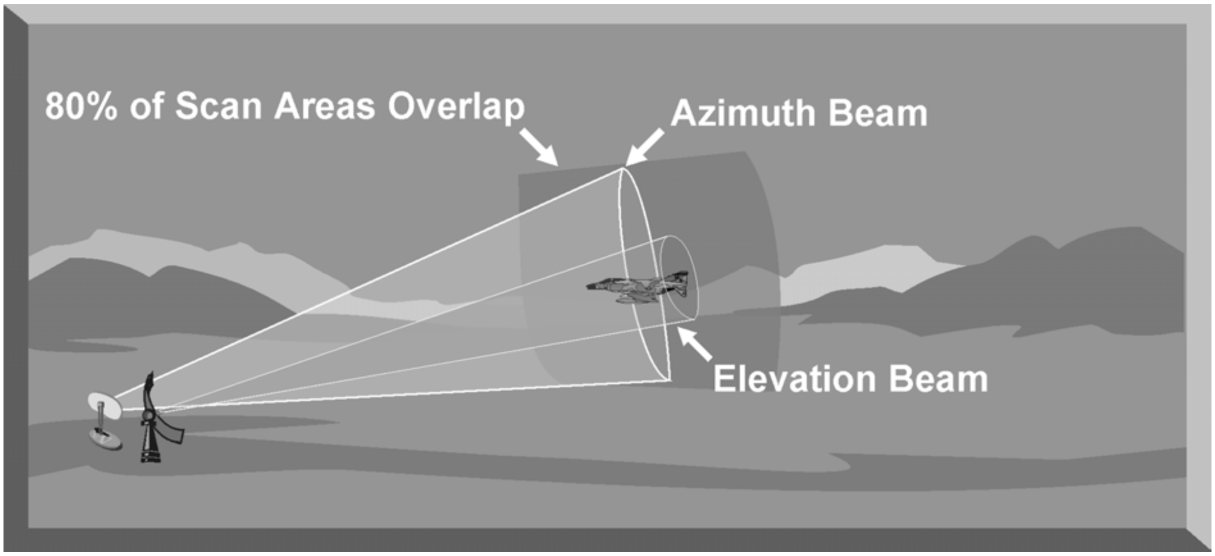

Figure 6-27. Conventional TWS Radar

b. The phased array radar is a product of the application of computer and digital technologies to the field of radar design. A phased array is a complex arrangement of many individual transmitting and receiving elements in a particular pattern (Figure 6-28). Common arrays include linear, planar, curved, and conformal, with linear being the most common. By using a computer to rapidly and independently control groups of these individual elements, a phased array antenna can, in effect, radiate more than one beam from the antenna. Multiple beams and computer processing of radar returns give the phased array radar the ability to perform the TWS function. The most common employment of the TWS capability of the phased array radar is in the air-to-air arena.

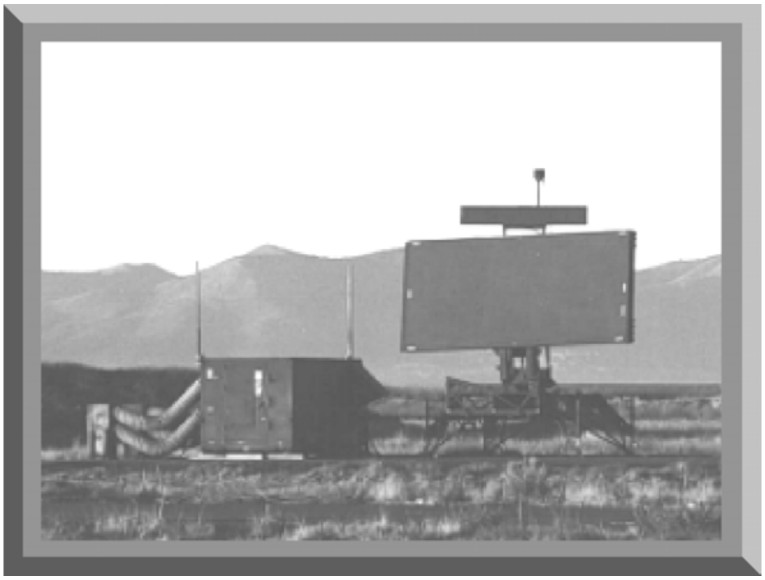

Figure 6-28. Phased Array Antenna

(1) The number of individual transmitting and receiving elements is limited by the size of the radar antenna. The number of targets a phased array radar can track is limited by the number of independent beams the antenna can generate. Many phased array radars, especially air-to-air radars, do not track and scan simultaneously, but rapidly switch between the two modes to overcome this limitation (Figure 6-29).

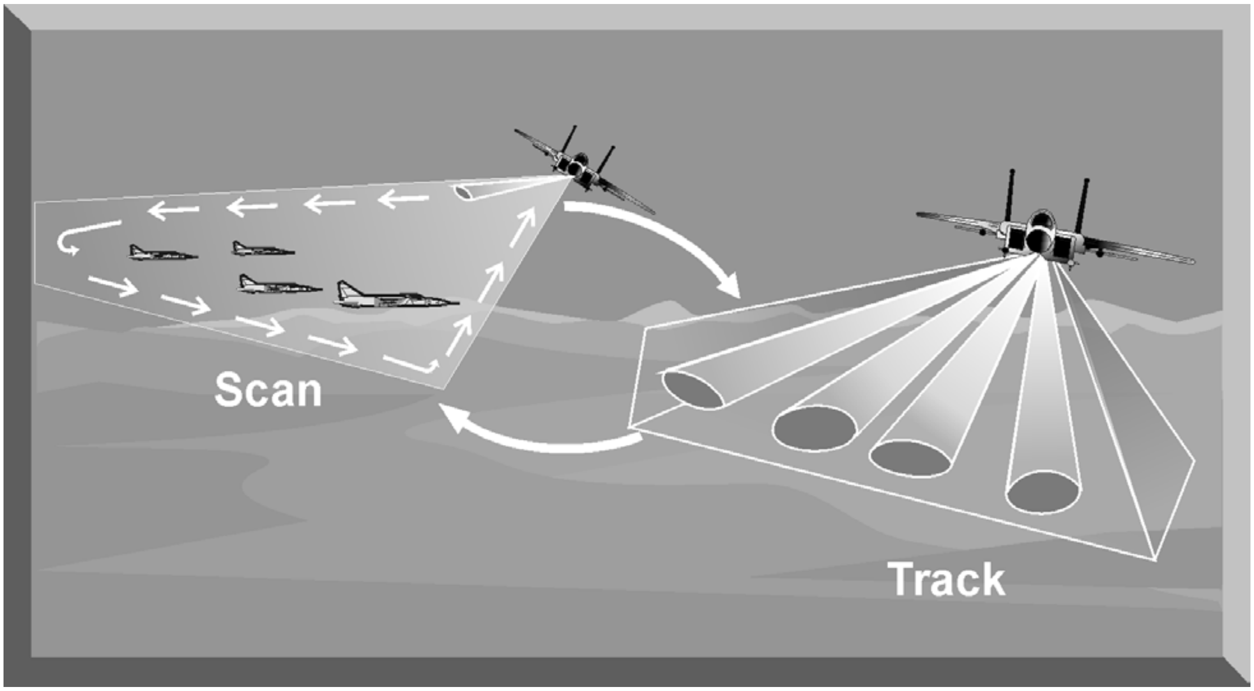

Figure 6-29. Phased Array TWS

(2) Modern TWS radars employ computer signal processing and complex computer algorithms to simplify the problem of target correlation (Figure 6-30). An air-to-air radar typically uses a raster scan to search a volume of airspace. In the search mode, the radar simply presents all targets detected in this airspace to the pilot on his radar display. In the TWS mode, the radar employs computer processing to figure out target correlation and update target information. This is done automatically, and the results are presented on the display.

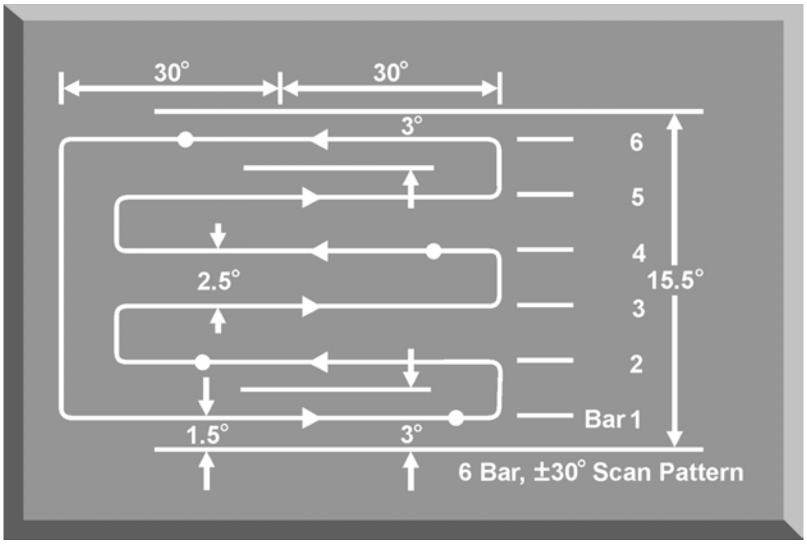

Figure 6-30. Phased Array TWS Radar Display

13. IMPACT OF TERRAIN ON RADAR SCANS

No matter what type of scan a radar system employs, terrain can limit radar line of sight (LOS) and target detection. The concepts of radar horizon, direct terrain masking, and indirect terrain masking are important factors in radar target detection and mission planning.

a. RF waves traveling in the atmosphere are bent, or refracted, and do not travel in a straight line. However, the degree of refraction depends on atmospheric conditions which vary significantly and are difficult to accurately quantify and predict. For these reasons, most radar computations are based on the assumption that RF waves travel in a straight line. The concept of the radar horizon is based on this assumption.

(1) The radar horizon shown in Figure 6-31 is the maximum range a radar system can detect a target due to the curvature of the earth. The distance (d) to the horizon for a radar antenna at a height (h) can be computed using Equation 6-6.

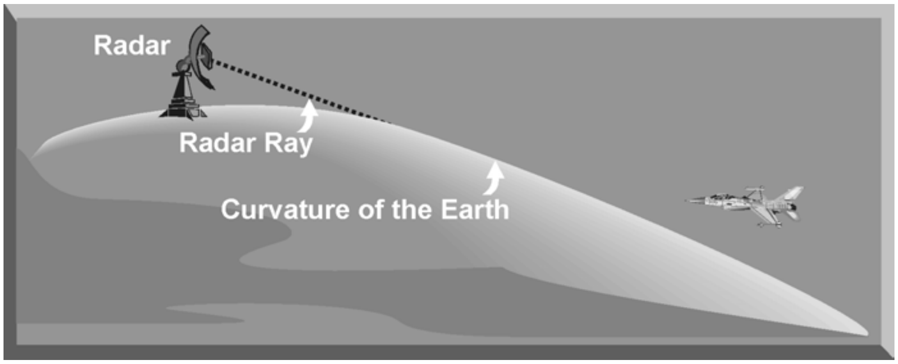

Figure 6-31. The Radar Horizon

$$\text{Distance to Horizon } (d) = \sqrt{2kah}$$

k = constant (4/3)
a = radius of earth
h = height of radar antenna

Equation 6-6. Basic Radar Horizon Equation

(2) In Equation 6-6, the constant, k, is commonly used to compensate for the assumption of straight line propagation of RF waves. Using the assumption that the height of the radar antenna is small compared to the radius of the earth, distance is measured in nautical miles (nm), and height is measured in feet, then Equation 6-6 reduces to Equation 6-7.

$$\text{Distance to Horizon } (d) = 1.06\sqrt{h}$$

Equation 6-7. Simplified Radar Horizon Equation

(3) Another application of Equation 6-7 is in calculating the range at which a radar antenna will achieve LOS with a low-altitude target. To compute this distance (D), Equation 6-8 can be used.

$$\text{Target Detection Distance } (D) = 1.06\left(\sqrt{h} + \sqrt{\text{target altitude}}\right)$$

Equation 6-8. Target LOS Distance

(4) To illustrate the use of Equations 6-7 and 6-8, consider the example of a radar antenna located at a height of 25 feet and a target aircraft flying at an altitude of 100 feet. From Equation 6-7, the radar horizon for this system would be 5.3 nm. From Equation 6-8, the radar antenna will have LOS with the target aircraft at 16 nm.

b. The previous discussions of the radar horizon assumes the radar is operating over water or level terrain. Radar operations over rough terrain can present other radar LOS limitations. As illustrated in Figure 6-32, prominent terrain features can limit radar detection. In this illustration, a mountain acts as a radar horizon and limits target LOS in one sector of the radar scan. This situation is called direct terrain masking. Placing prominent terrain features between the aircraft and threat radar systems effectively negates these systems and is an integral part of threat avoidance during combat mission planning.

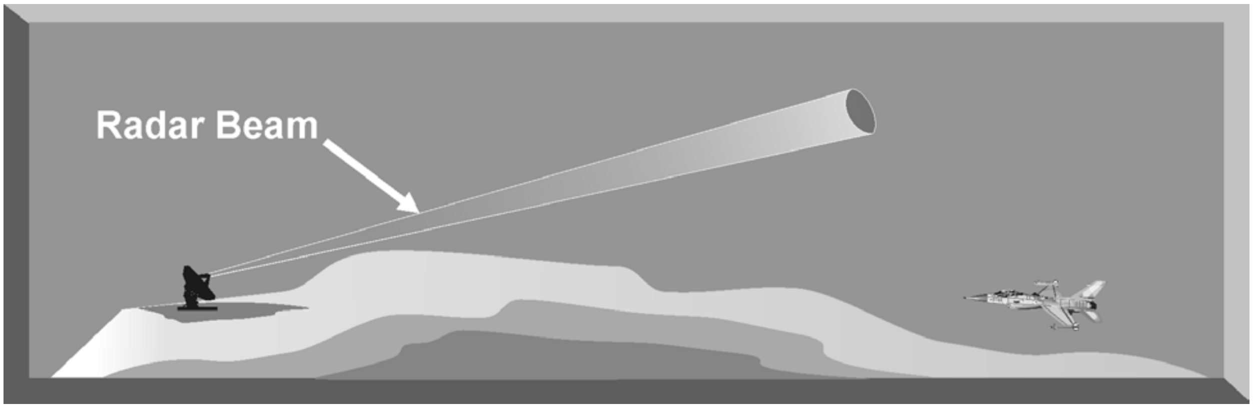

Figure 6-32. Direct Terrain Masking

c. Figure 6-33 depicts another impact of terrain on target detection/indirect terrain masking. When both the aircraft and a prominent terrain feature are illuminated by a radar beam, a pulse radar system may not be able to differentiate the target return from the return generated by the terrain. Indirect terrain masking is most effective when the aircraft is flying abeam the radar site. Pulse Doppler radars and radar systems employing moving target indicator (MTI) circuits may be able to negate the effectiveness of indirect terrain masking. However, indirect terrain masking is another important consideration for threat avoidance during combat mission planning.

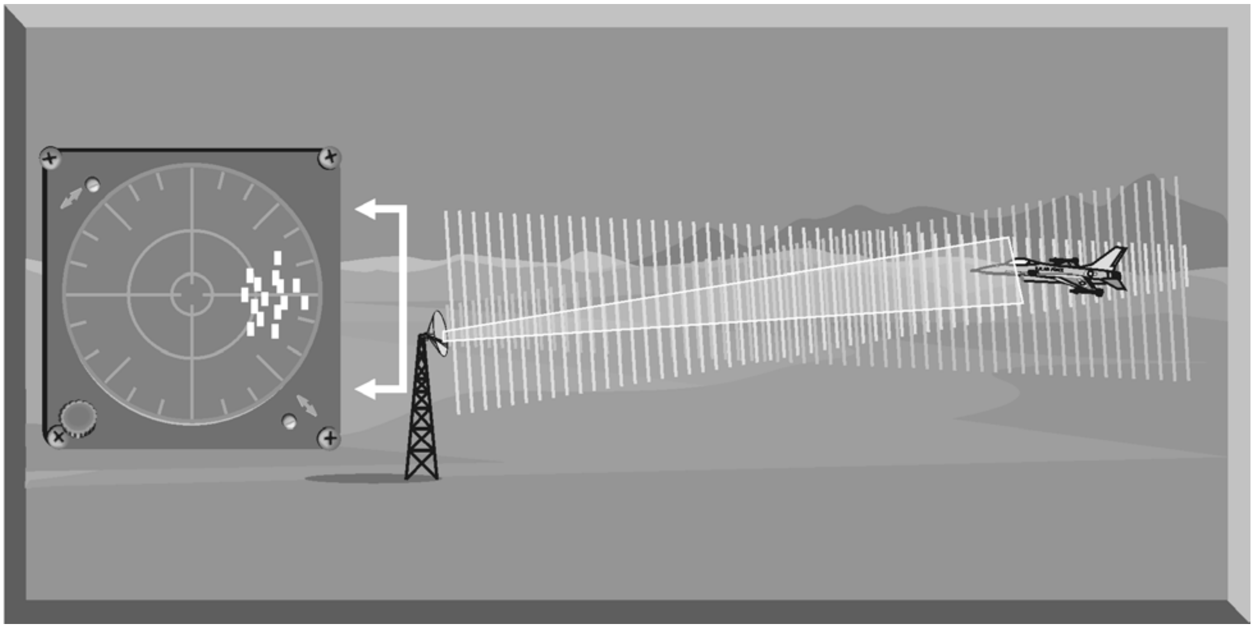

Figure 6-33. Indirect Terrain Masking

14. SUMMARY

This chapter has introduced basic antenna characteristics and how these characteristics influence their employment. The concepts of antenna gain and power density were also explained. The remainder of the chapter discussed the different types of radar scans. A radar's scan pattern is designed to enhance target detection and facilitate target tracking. The radar horizon, direct terrain masking, and indirect terrain masking are LOS limitations to all radar scans. The scan pattern chosen for a specific radar system determines the ability of that radar to provide accurate range, azimuth, elevation, or velocity of the detected target.

CHAPTER 7. TARGET TRACKING

1. INTRODUCTION

A target tracking radar (TTR) is designed to provide all the necessary information to guide a missile or aim a gun to destroy an aircraft. Once a target has been detected, either by a dedicated search radar or by using an acquisition mode, the TTR is designed to provide accurate target range, azimuth, elevation, or velocity information to a fire control computer.

a. A typical TTR has individual tracking loops to track a target in range, azimuth, elevation, or velocity. The antenna of the TTR is pointed at a single target, and the radar initiates acquisition and target track. TTRs normally employ automatic trackers to continuously measure target data. The range tracking loop employs an early gate/late gate range tracker to maintain automatic range tracking. The azimuth and elevation tracking loops generate error signals to position the antenna and maintain constant target illumination. The velocity tracking loop found on pulse Doppler and CW radars is used to reject clutter and generate accurate target radial velocity information. All this critical information is passed to a fire control computer for weapons employment.

b. The fire control computer is programmed with critical information on the capability of the weapon to be employed. For a missile, the fire control computer is programmed with the aerodynamic and range capabilities of the missile. For antiaircraft artillery (AAA), the fire control computer is programmed with the ballistics for the gun, rate of fire, and tracking rate. The fire control computer uses the precise target information from the TTR and the programmed weapon's parameters to compute a firing solution. Once a firing solution has been computed, the fire control computer either fires the weapon automatically or alerts the operator, who fires the weapon. For missile employment, the fire control computer may continue to provide missile guidance and fusing commands until missile impact or initiation of an active missile guidance mode. For AAA engagement, the fire control computer computes the required lead angle, aims the guns, and initiates firing.

c. To provide the required azimuth and elevation resolution, most TTRs use a high frequency to provide narrow antenna beamwidths for accurate target tracking. High frequency operation also allows the radar to transmit wide bandwidths. To provide the required range resolution, most TTRs employ narrow pulse widths and high pulse repetition frequencies (PRFs) to rapidly update target information. In this chapter, the target tracking techniques of conical scan, track-while-scan, lobe-on-receive-only, monopulse, Doppler radars, and pulse Doppler radars will be discussed.

2. RANGE TRACKING

In most TTR applications, the target is continuously tracked in range, azimuth, and elevation. Range tracking can be accomplished by an operator who watches an "A" scope presentation and manually positions a handwheel to maintain a marker over the desired target return. The setting of the handwheel is a measure of target range and is converted to a voltage used by the fire control computer. As target speeds and maneuvers increase, the operator may have extreme difficulty maintaining manual target range tracking. To avoid this situation, most TTRs employ an automatic range tracking loop. All pulse TTRs, which includes conical scan, track-while-scan, monopulse, and pulse Doppler radars, employ either a split gate or leading-edge automatic range tracking system. In a TTR, automatic range tracking serves two essential functions: (1) it provides the critical value of target range, and (2) it provides a target acceptance range gate that excludes clutter and interference from other returns. Since radar range is normally the first target discriminator used to initiate automatic target tracking, the second function is essential to the proper operation of the other tracking loops.

a. A range gate circuit is simply an electronic switch that is turned on for a period of time after a pulse has been transmitted. The time delay for switch activation corresponds to a specific range. Any target return that appears inside this range gate is automatically tracked. The most common type of automatic range tracking is accomplished by a split-gate tracker. Two range gates are generated as shown in Figure 7-1. The automatic range tracking loop attempts to keep the amount of energy from the target return in the early gate and late gate equal. The range tracking error is computed by subtracting the output of the late gate from the output of the early gate. The amount of the range tracking error signal is the difference between the center of the pulse and the center of the range gate. The sign of the error signal determines the direction in which the gates must be repositioned to continue to track the target.

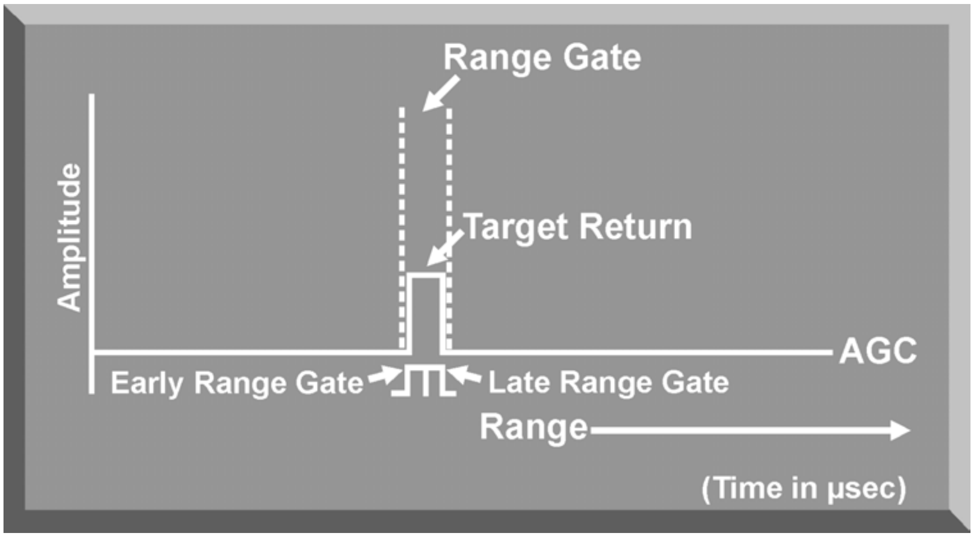

Figure 7-1. Split-Gate Range Tracker

b. Leading-edge range tracking is an electronic protection (EP) technique used to defeat range-gate-pull-off (RGPO) jamming. Figure 7-2 illustrates the application of leading-edge tracking. The leading-edge tracker obtains all range data from the leading edge of the target return. All RGPO cover pulse jamming tends to lag the target return by some increment of time (see (a) in Figure 7-2). By differentiating the entire return with respect to time, the target return can be separated from the jamming pulse (see (b) in Figure 7-2). Employing a split-gate tracker electronically positioned at the initial pan, or leading edge, of the returning pulse, the range tracking loop can track the target return and ignore any jamming signals. The range tracking loop then uses split-gate tracking logic to determine the magnitude and direction of range tracking errors and reposition the range gate.

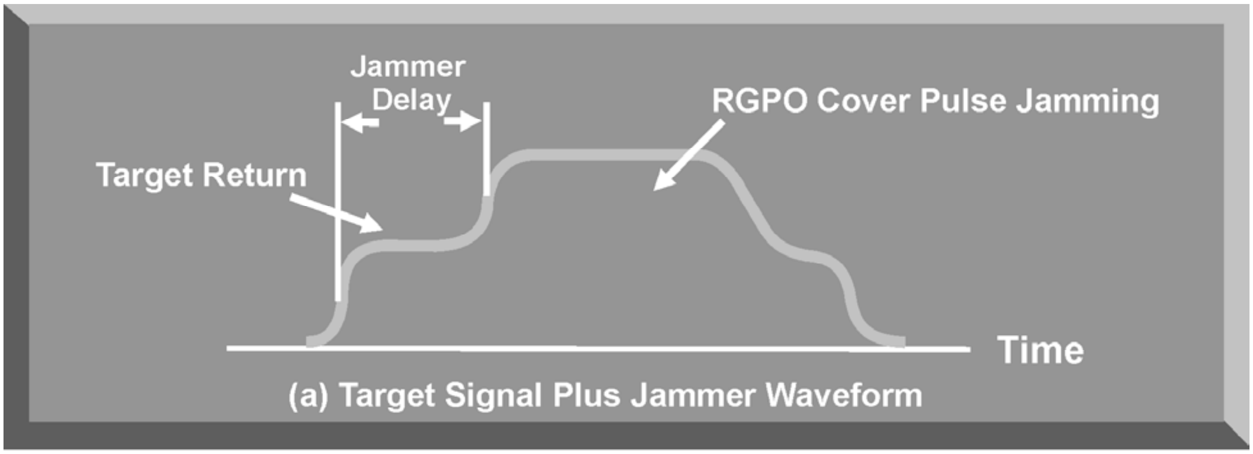

(a) Target Signal Plus Jammer Waveform

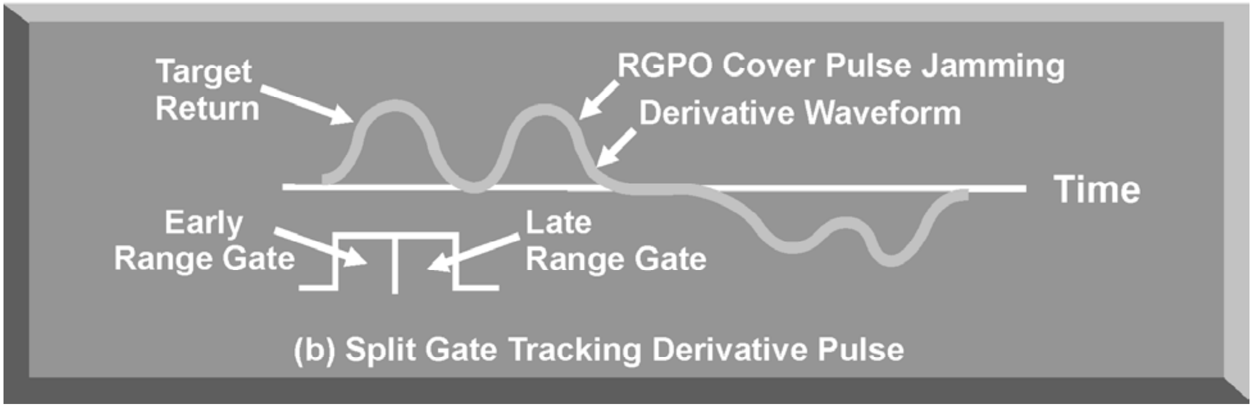

(b) Split Gate Tracking Derivative Pulse

Figure 7-2. Leading-Edge Range Tracker

c. The width of the tracking gate is an important radar design consideration. The range gate should be sufficiently narrow to effectively isolate the target from other returns at different ranges. It should be wide enough to allow sufficient energy from the target echo to be displayed. The width of the range tracking gate is normally equal to the pulse width of the radar.

d. Nearly all range tracking gates employ some form of automatic gain control (AGC). AGC is designed to limit target clutter and glint. It is also designed to avoid excessive false alarms.

3. CONICAL SCAN

A conical scan tracking system is a special form of sequential lobing. Sequential lobing implies that the radar antenna beam is sequentially moved between beam positions around the target to develop angle-error data. For a conical scan radar to generate azimuth and elevation tracking data, the beam must be switched between at least four beam positions as shown in Figure 7-3.

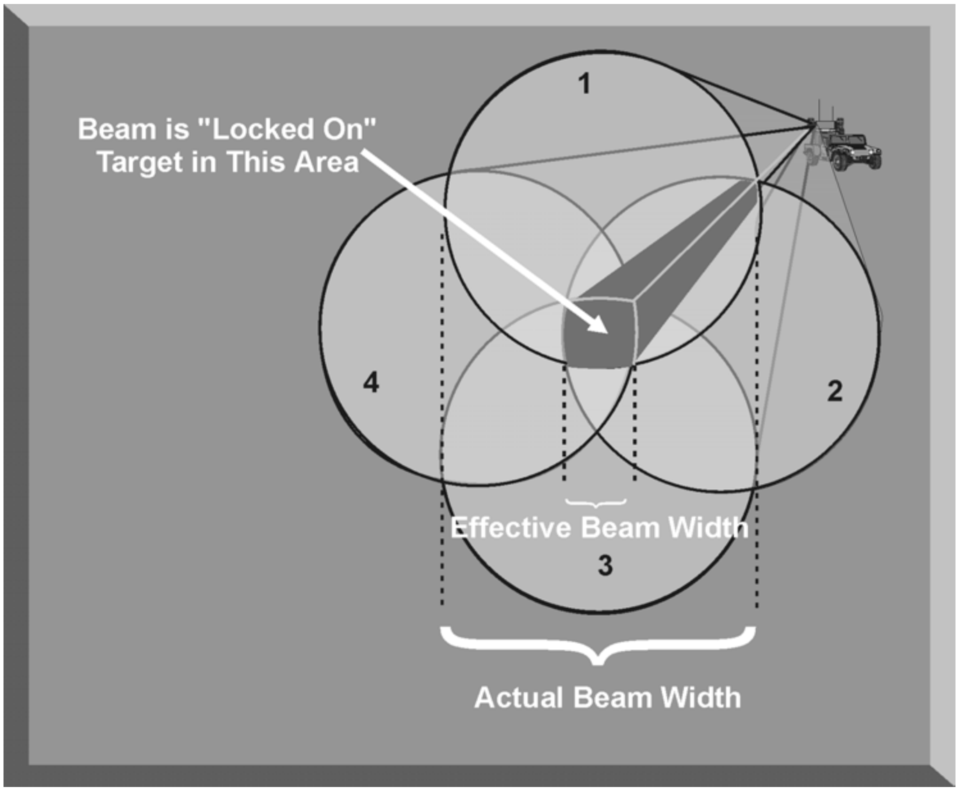

Figure 7-3. Conical Scan Positions

a. One of the simplest conical scan antennas is a parabola with an offset rear feed that rotates, or nutates, to maintain the plane of signal polarization. The radar beam is rotated at a fixed frequency around the target. The angle between the axis of rotation (normally the axis of the antenna) and the axis of the antenna beam is called the squint angle.

b. A conical scan radar first tracks the target aircraft in range. For azimuth and elevation tracking, the target return is modulated at a frequency equal to the rotation frequency of the radar beam. This results in a target signal output that resembles a sine wave (Figure 7-4). The azimuth and elevation tracking loops

drive servo motors to position the antenna to keep the energy level in each of the four positions equal. The amount of the modulated signal determines how far the target is off the antenna boresight while the phase of the modulation (positive or negative) determines the direction.

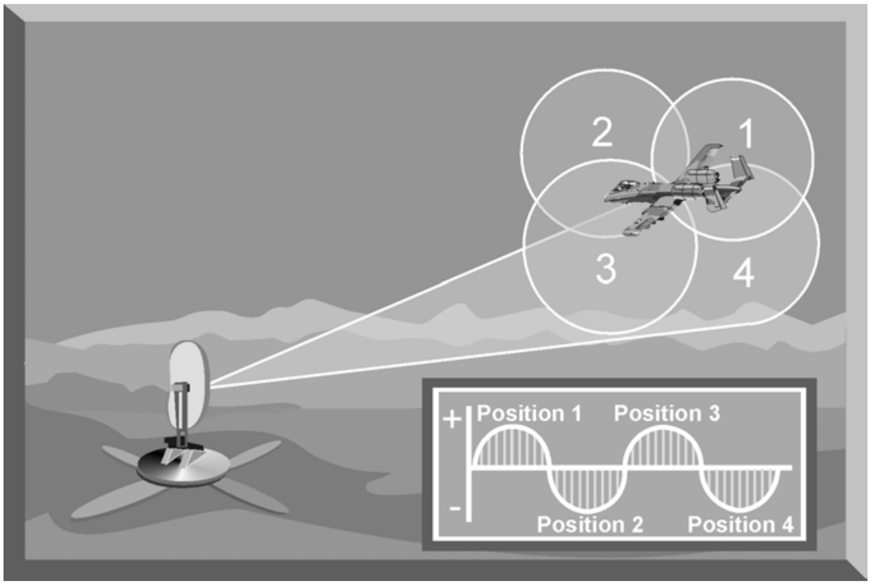
2
1
3
4
+
-
Position 1
Position 3
Position 2
Position 4

Figure 7-4. Conical Scan Modulation

c. In Figure 7-5, most of the target energy is in position 1, with a small amount of energy in position 4. The output from the elevation tracking loop is positive and drives the antenna servos upward. The output from the azimuth tracking loop moves the antenna to the right.

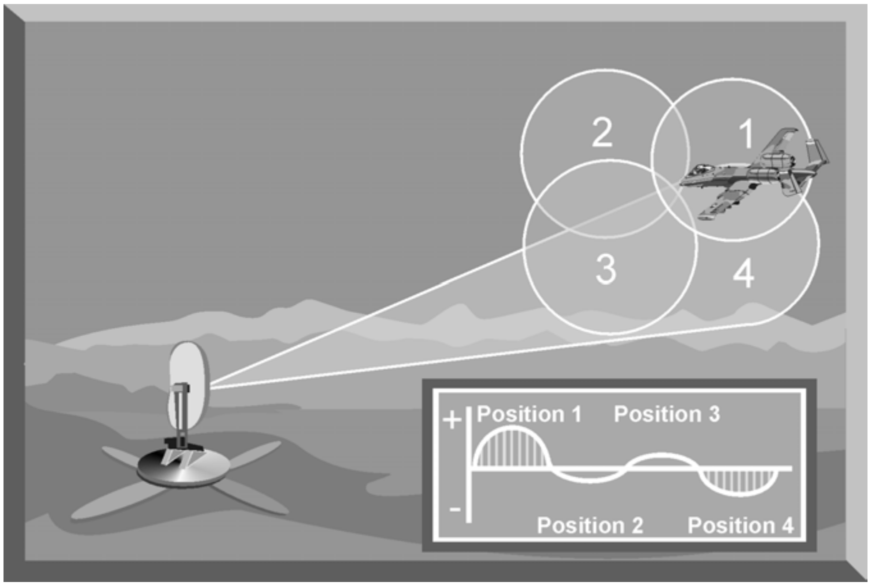
2
1
3
4
+
-
Position 1
Position 3
Position 2
Position 4

Figure 7-5. Conical Scan Tracking Errors

d. Once a balance of target energy in each scan position is achieved, the target is in the central tracking area (Figure 7-6). The azimuth and elevation tracking circuits continue to drive the antenna servos to maintain this energy balance which keeps the radar beam on the target.

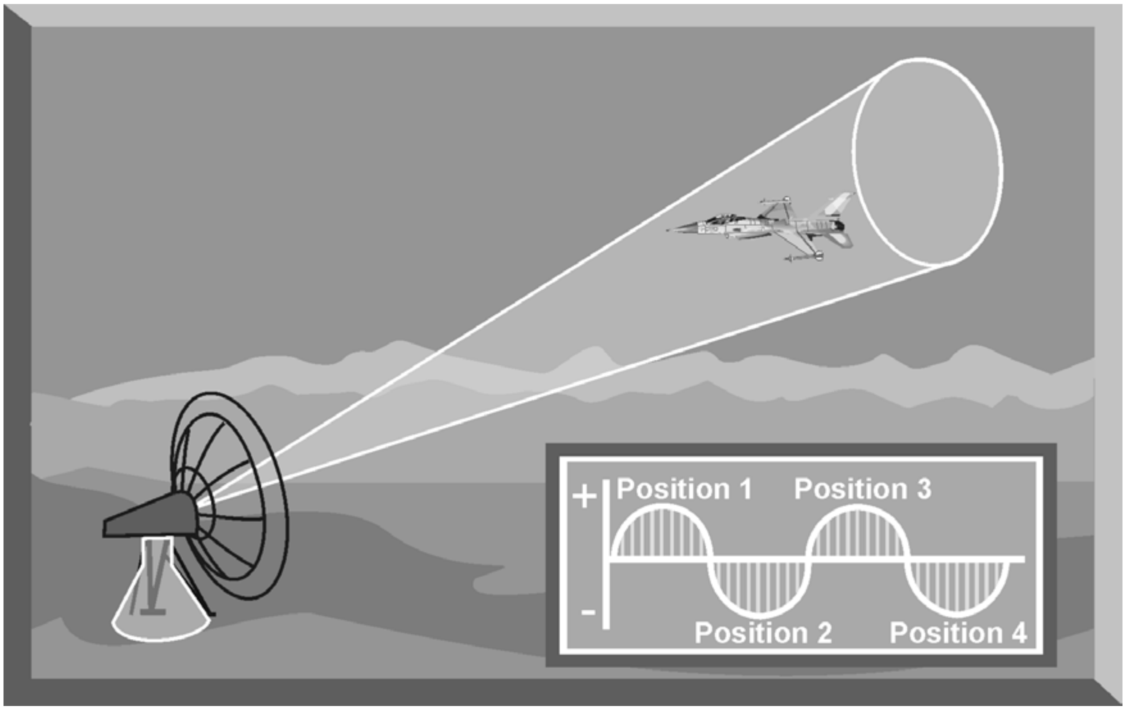

Figure 7-6. Conical Scan Tracking

e. The primary advantage of a conical scan radar is the small beamwidth which provides extremely accurate target tracking information. The primary disadvantages of conical scan include the following: (1) the narrow beamwidth makes target acquisition a problem. Even using a Palmer-helical scan, it may take considerable time to find and initiate track on a target; (2) conical scan radars are vulnerable to inverse gain modulation jamming based on the scanning frequency of the rotating beam; (3) a conical scan radar must analyze many radar return pulses to generate a tracking solution.

4. TRACK-WHILE-SCAN (TWS)

TWS is a combined search and tracking mode that sacrifices the continuous target observation capability of the dedicated tracker in return for the ability to monitor a finite sector of airspace. This is accomplished while maintaining tracks on multiple targets moving through the covered airspace. There are two types of radar systems capable of TWS operation: conventional and phased array.

a. Conventional track-while-scan threat radars use two separate antennas to generate two separate beams (Figure 7-7). These beams operate at two different

frequencies and are sectored so they overlap the same region of space. This overlap area provides a tracking area for a single target. One beam is sectored in the vertical plane to give range and elevation. The other beam is sectored in the horizontal plane to provide range and azimuth. Each beam scans its sector at a rate of 5 to 50 times per second. This provides a rapid update on target range, azimuth, and elevation.

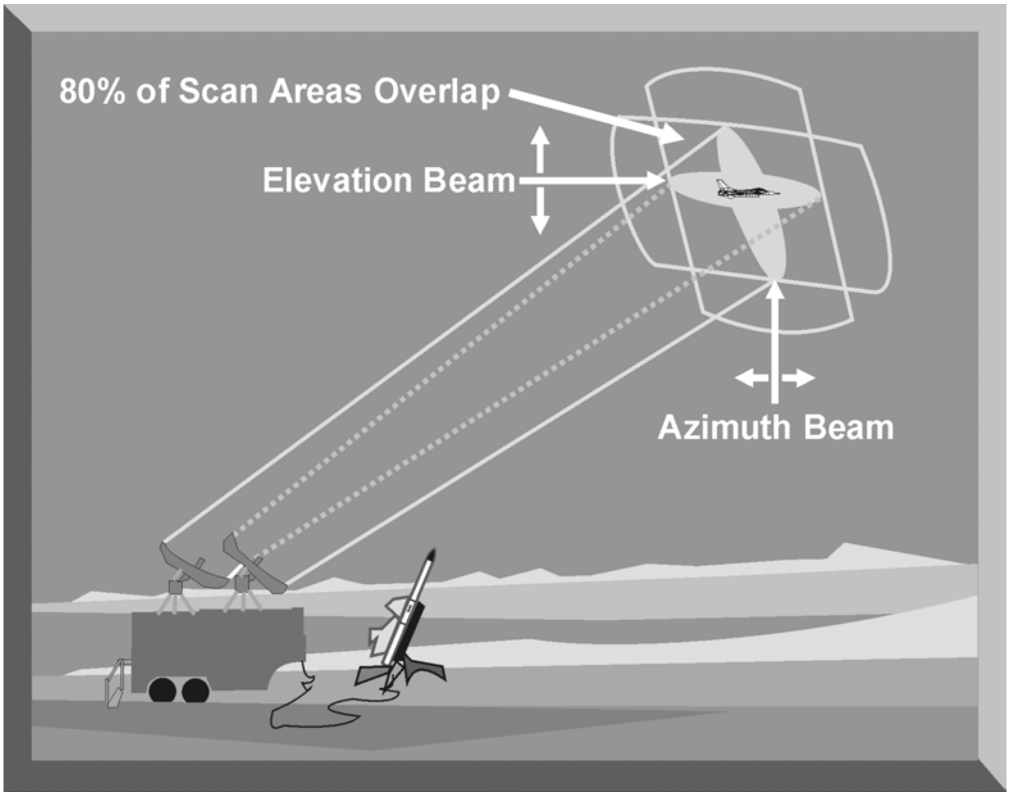

Figure 7-7. Conventional TWS Radar Beams

(1) The two TWS antennas generate their beams using an electro-mechanical principle. Each antenna provides inputs to its own display and provides angle and range information for all targets in the coverage of the radar. The display from the elevation beam is calibrated in range and elevation, while the display from the azimuth beam is calibrated in azimuth and range. Operators position a cursor over the returns on these displays using range as the primary parameter. Once a target has been designated for engagement, the radar automatically attempts to keep the tracking axis of the radar beams centered on the target.

(2) Once the target is designated by the operator, the range gate is enabled and tracks the target using a split-gate tracker. The azimuth and elevation tracking loops receive information only from targets inside the range gate. As the beams scan across the target, a burst of pulse returns is received that have an

amplitude envelope corresponding to the beam pattern. The azimuth beam pattern is shown in Figure 7-8.

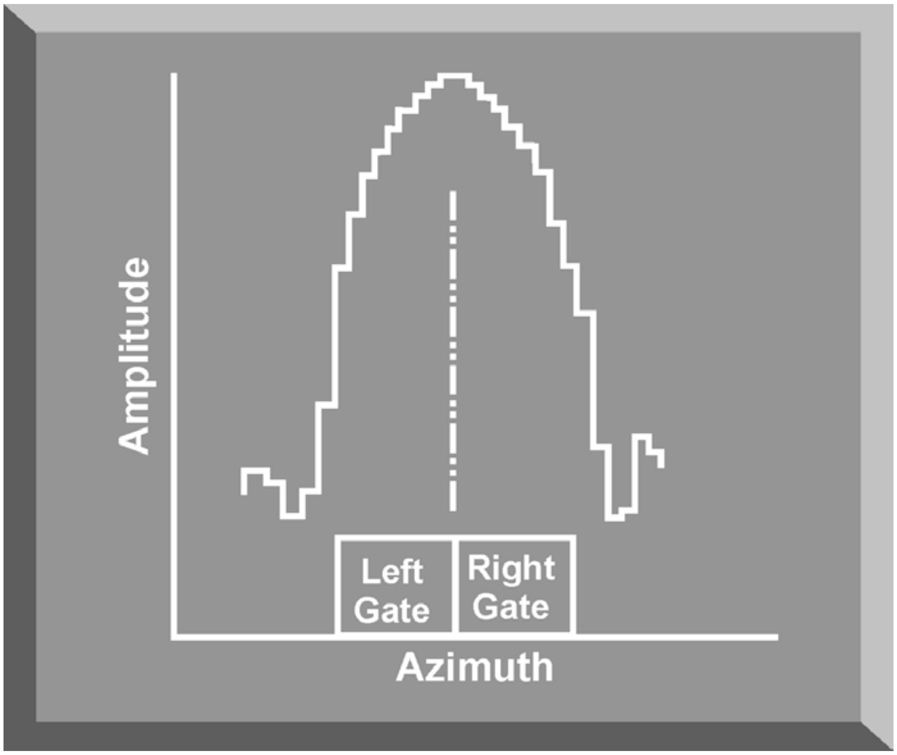

Figure 7-8. Conventional TWS Azimuth Tracking

(a) The azimuth tracker is typically a split-gate tracker, identical in concept to a split-gate range tracker. However, range delay time is replaced by azimuth scan time. The azimuth tracker uses a left gate and right gate. Each gate integrates its share of the target return to generate a voltage/time value. When the azimuth gate is centered on the target, the areas are equal and the error signal (right gate minus left gate) is zero. The azimuth tracking loop sends signals to the antenna servos to keep the target centered in the scan area.

(b) Elevation tracking is accomplished in the same manner by using an up gate and a down gate. The elevation tracking loop also sends signals to the antenna servos to keep the target centered in the scan area.

(3) Once the target is designated and the radar is automatically keeping the radar return centered in the tracking area, target range, azimuth, and elevation information is sent to a fire control computer. The radar continues to provide information on other targets in the scan area. The fire control computer indicates the firing solution has been achieved for the designated target, and a missile is launched. The radar tracks the target and the missile and provides in-flight corrections to the missile right up to the moment of missile impact. These corrections are based on both target and missile azimuth, range, and elevation

information. Information is passed to the missile from a dedicated antenna on the radar to special antennas on the missile. Commands from the radar to the missile are called uplink guidance commands. Information from the missile back to the radar and fire control computer is called downlink information.

(4) The advantages of a conventional TWS radar include the following: (1) TWS radars have the ability to maintain radar contact with all targets in the sector scan area while maintaining target track on a single target, and (2) the rapid sector scan rate provides a rapid update on target parameters. The primary disadvantages of a conventional TWS radar include: (1) a large resolution cell due to the wide azimuth and elevation beams, and (2) vulnerability to modulation jamming based on the scan rate of the independent beams.

b. Many modern radars employing a planar or phased array antenna system have a TWS mode. The radar does not really track and scan simultaneously, but rapidly switches between search and track (Figure 7-9).

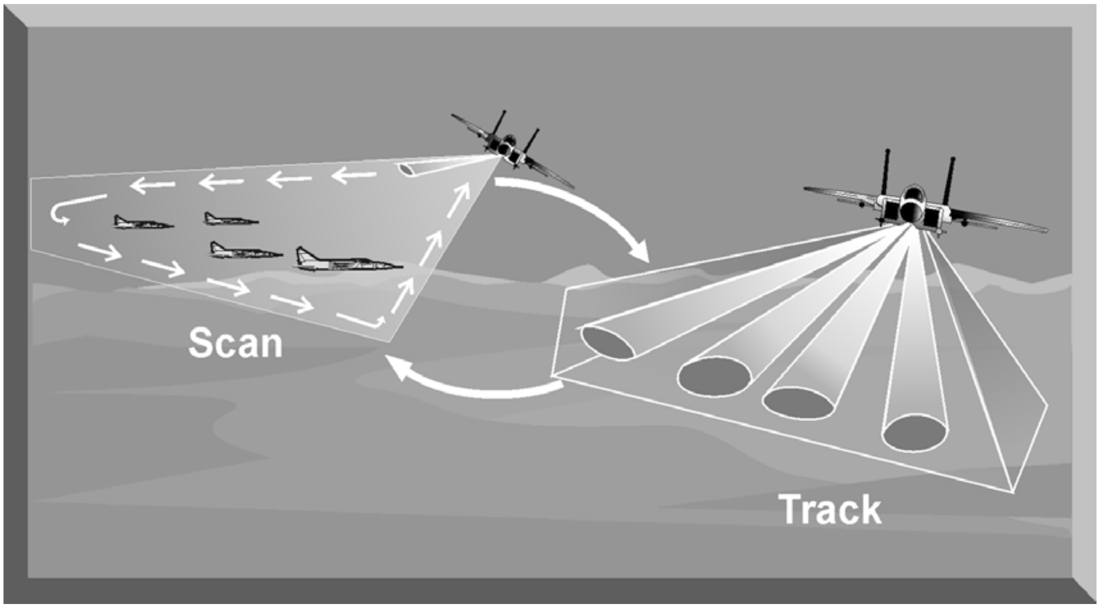

Figure 7-9. Phased Array TWS

(1) The most common air-to-air radar system uses a planar array antenna. In the scan mode, the radar antenna generates a pencil beam and uses a raster scan to detect targets in the search area. Targets detected are presented to the pilot on the aircraft's radar display (Figure 7-10).

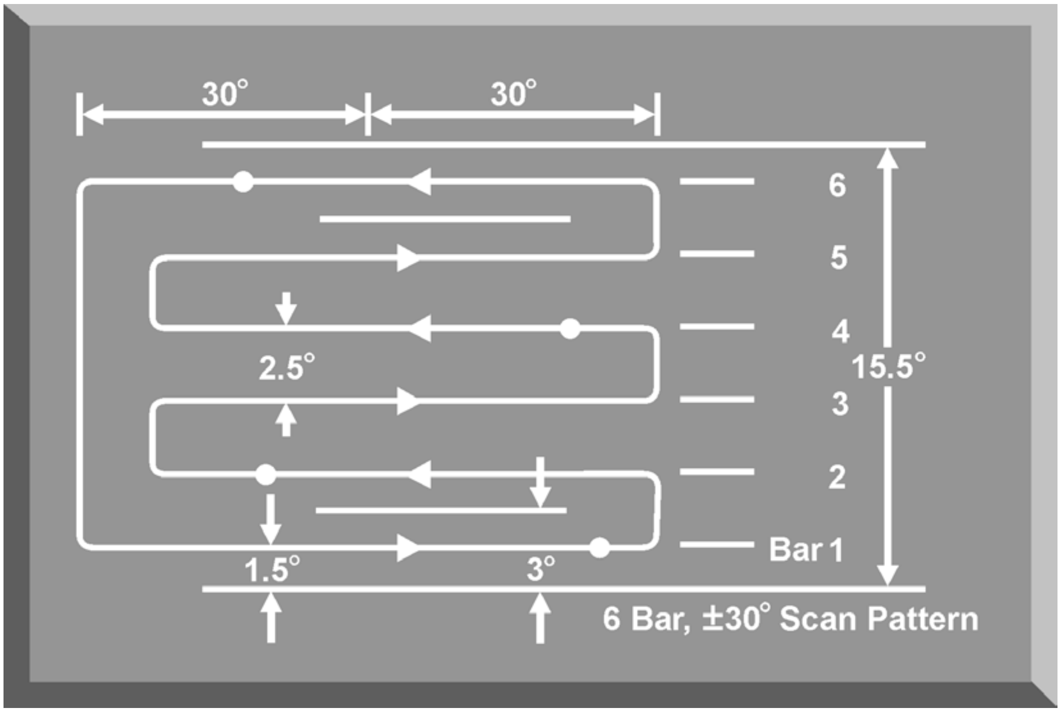
30°
30°
6
5
4
2.5°
15.5°
3
2
Bar 1
1.5°
3°
6 Bar, ±30° Scan Pattern

Figure 7-10. Air-to-Air TWS Display

(a) In the track mode, the antenna generates multiple beams to illuminate individual targets. The radar typically uses monopulse or pulse Doppler techniques to update target range, azimuth, elevation or velocity. These tracking techniques will be covered later in this chapter. The radar initiates a track file on each detected target that contains all current data on the target and an estimate of future target position.

(b) As the radar switches between track and scan modes, target parameters are updated in the tracking loop (Figure 7-11). The new target information is compared to the predicted information in the measurement data processing cell. If the two sets of data agree within certain limits, target position and information are updated. This process is called gating.

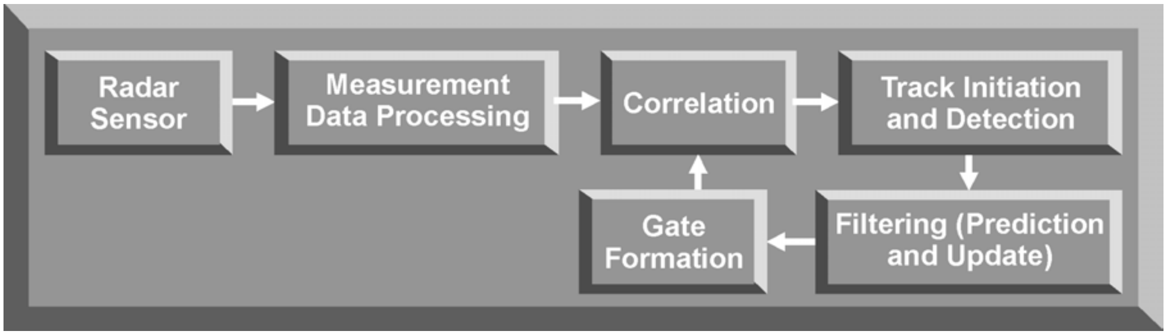
Radar Sensor
Measurement Data Processing
Correlation
Track Initiation and Detection
Gate Formation
Filtering (Prediction and Update)

Figure 7-11. Planar/Phased Array TWS Tracking Loop

(c) If the updated target information does not correspond to the predicted values, the information is sent to the correlation processor. The correlation processor attempts to resolve the conflict based on further refinement of target data. If the correlation processor cannot assign the target parameters to an existing track file, a new track file is generated and displayed.

(2) The obvious advantage of a planar/phased array TWS radar is that it can search a large volume of airspace while tracking individual targets. The number of targets that can be tracked is limited by the number of beams the radar can generate. Planar/phased array radars have increased peak and average power when compared to pulse radar systems. Since the radar beam of a planar/phased array radar is electronically controlled and can rapidly change beams and scans, it is resistant to many jamming techniques. The primary disadvantages of a planar/phased array TWS radar include its complexity, cost, and reliance on computer processing.

5. LOBE-ON-RECEIVE-ONLY (LORO)

LORO is a mode of radar operation developed as an EP feature for a track-while-scan radar. LORO can be employed by any radar that has the capability to passively track a target. In a LORO mode, the radar transmits a continuous signal from a set of illuminating antennas. This continuous signal hits the target, and the return echo is received by a different set of receive antennas (Figure 7-12). The receive antennas are passive and generate azimuth and elevation tracking signals by electronically scanning the reflected signal. The tracking signals are sent to the antenna servos to keep the illuminating antennas pointed at the target and centered in the receive antenna tracking area. The range tracking circuit uses the time delay between the transmission and reception of the illuminating antenna signals. A split-gate tracker is used to provide range tracking.

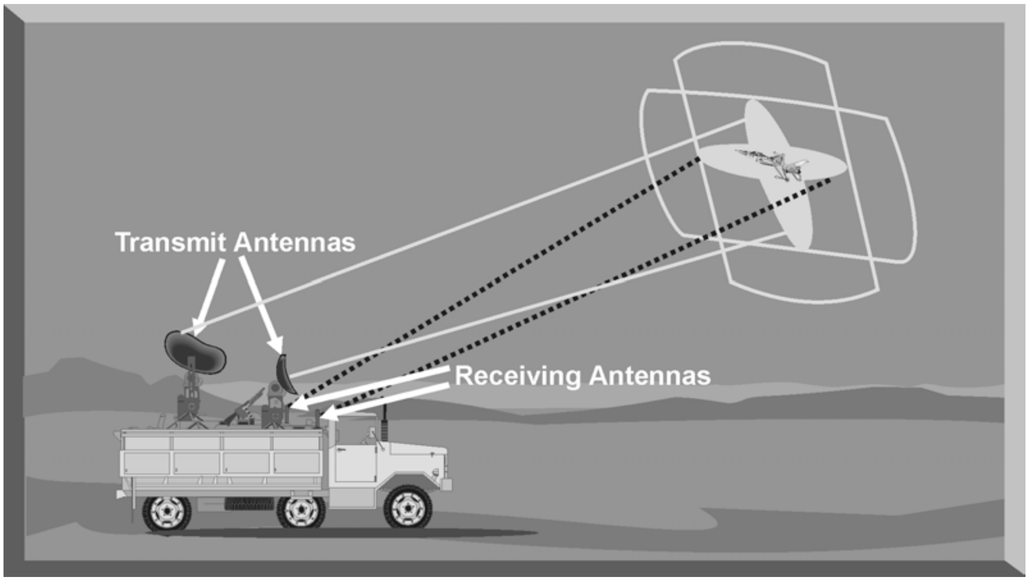

Figure 7-12. LORO Mode

a. The illuminating antennas used in the LORO mode have very narrow beamwidths and transmit at a high power level. This reduces the effectiveness of noise jamming techniques against a radar employing a LORO mode. In addition, the continuous signal from the illuminating antennas negate the effectiveness of most angle deception jamming techniques designed to defeat TWS radars. These specialized jamming techniques exploit the scan rate of TWS antennas. In the LORO mode, the illuminating antennas do not have a scan rate. The limited effectiveness of both noise and deception jamming techniques is the major advantage of the LORO mode.

b. The LORO mode also provides a track-on-jam (TOJ) capability to exploit noise jamming techniques. In a TOJ mode, the receive antennas passively track any detected noise jamming signals. The radar assumes that the most intense jamming signal is the target. The receive antennas process the strongest jamming signal as if it were a target echo from the transmit antenna signal. The receive antennas generate azimuth and elevation tracking signals to keep the jamming signal centered in the tracking area. The TOJ mode does not provide target range.

6. MONOPULSE RADAR

Monopulse radars are among the most complex radar systems. From a single pulse, a monopulse radar can derive all the data needed to update a target's position. It does this by comparing the relationship of two or more radar beams that are transmitted together from the same antenna but received separately. By comparing the phase or amplitude of the energy in these returned beams, target azimuth and elevation can be found. The speed that a monopulse radar updates the target's position, coupled with its azimuth/elevation accuracy and resistance to jamming, make this a popular choice amongst many newer TTRs.

a. The Magic T circuit allows monopulse radars to gather and process information from a single pulse that is transmitted and received using separate antennas. Figure 7-13 depicts a four-beam monopulse radar system. The Magic T is a sophisticated wave guide that can separate multiple signals by their phase relationships. This allows the radar tracking computer to compare the signal amplitude from the reflected pulses in several distinct ways. As the reflected energy enters the Magic T, it is separated by phase. The energy in the "H" arm will be in-phase and will exit from ports 1 and 2. The received energies entering the wave guide in the "E" arm exit at the number 1 port. This energy is exactly 180° out-of-phase with energy entering the H arm. This ensures there is no transfer of energy between the E and H plane arms. A typical monopulse radar would have eight Magic T's.

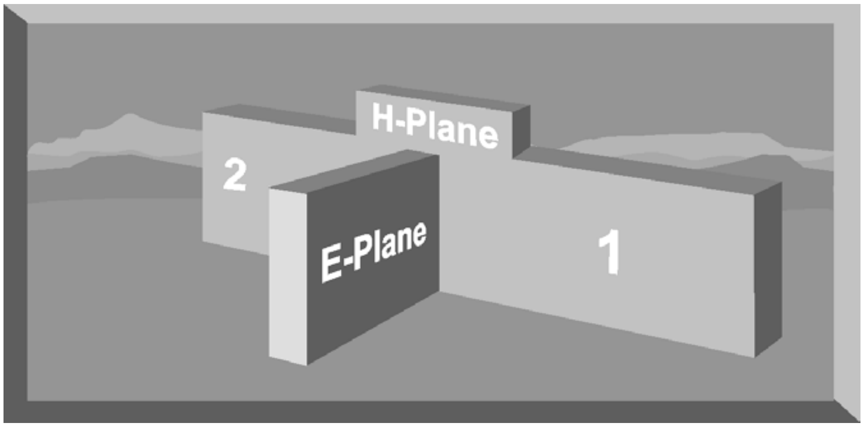

Figure 7-13. Monopulse Magic T

b. The output of a Magic T is the sum and difference of the two signals. These sum and difference values in amplitude or phase are used to generate azimuth and elevation error signals as well as to compute range. Monopulse radars may split the incoming signal as depicted in Figure 7-14. Upper antennas receive the A and B signals. Lower antennas receive the C and D signals. The various combinations of signals are processed and compared by simple addition and subtraction of the signal characteristics. From these steps, azimuth, range and elevation data are computed.

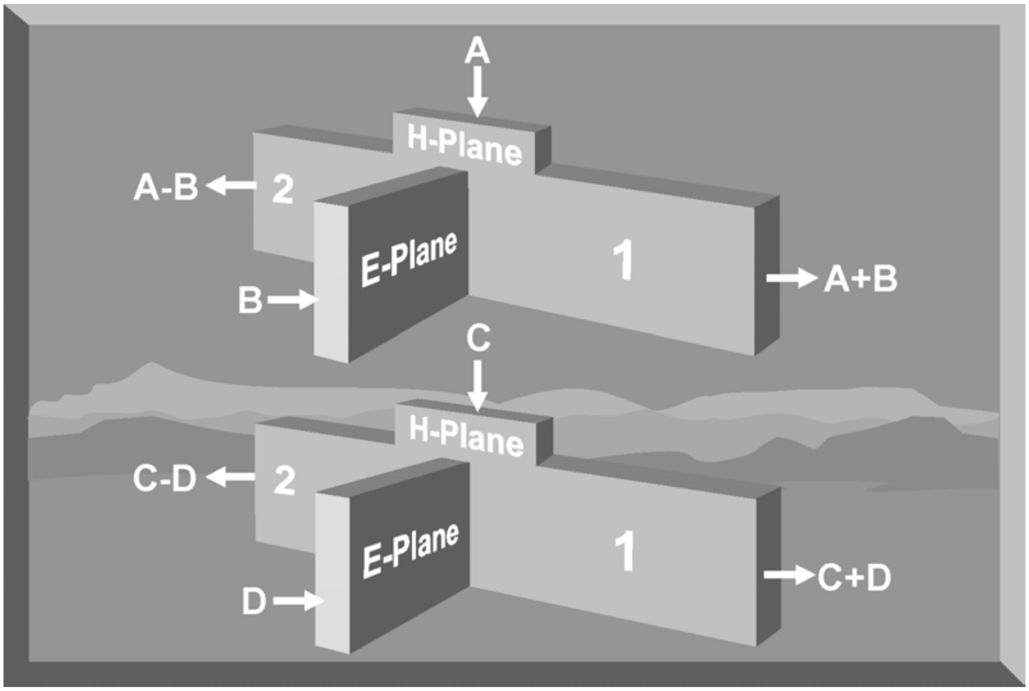

Figure 7-14. Magic T Output Signals

(1) The top equation in Figure 7-15 is used to compute target range. Target range is derived by adding the signal from the A scan to the signal from the B scan. This value is then added to the sum of the C and D scan signals. The output of these combinations is then passed to the range circuit which figures out the range of the target and displays it to the operator. Monopulse range tracking is accomplished by using either a leading-edge or split-gate tracking loop.

(2) Target elevation tracking error is derived using the middle equation from Figure 7-15. The signal from the A scan is added to the signal from the B scan. The signals from the C and D scans are also added. This time, however, the sum of A+B is subtracted from the sum of C+D. This value is then passed to the elevation circuit. Elevation signals are sent to the operator display and the servo mechanism, which corrects to the updated position of the target.

(3) The bottom equation from Figure 7-15 is used to compute the azimuth error. The signal from the A scan is added to the signal from the C scan. The B and D scans are also added together. The sums of these values are subtracted from each other. This difference equals the tracking error in azimuth. The radar system will then position the search beam to even the energy level between the two pairs of sums. When this occurs, the azimuth tracking error is zero.

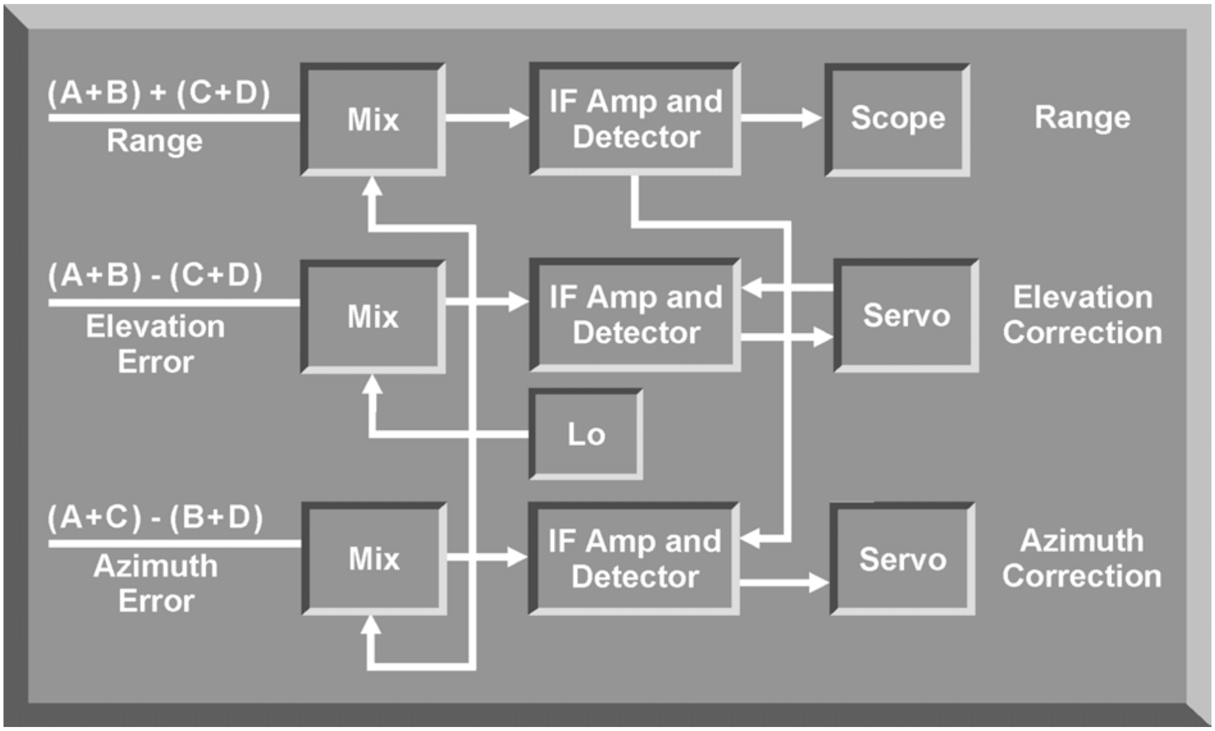
(A+B) + (C+D)
Range
Mix
IF Amp and Detector
Scope
Range
(A+B) - (C+D)
Elevation Error
Mix
IF Amp and Detector
Servo
Elevation Correction
Lo
(A+C) - (B+D)
Azimuth Error
Mix
IF Amp and Detector
Servo
Azimuth Correction

Figure 7-15. Monopulse Tracking Loops

c. A further illustration of the idea of signal combinations can be seen by referring to the F-16 in Figure 7-16. All the energy is received in the B scan area.

The A scan signal is added to the B scan signal. The signals from the C and D scans are also added. However, the sum of A+B is now subtracted from the sum of C+D. In this case, the values from the A scan and the C scan are zero. This total value of (A+B) - (C+D) is then passed to the elevation circuit.

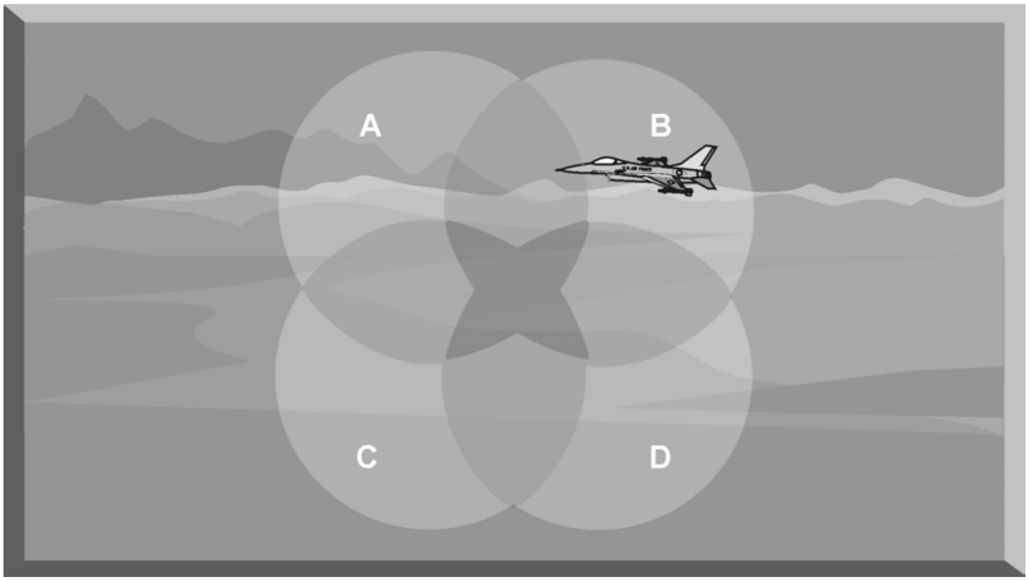

Figure 7-16. Monopulse Elevation Tracking Error

(1) The comparison in Figure 7-17 shows that all the energy is in the B scan. The radar will reposition the scan vertically to balance the energy between the B and D scans. When the energy level is balanced, the elevation error is zero.

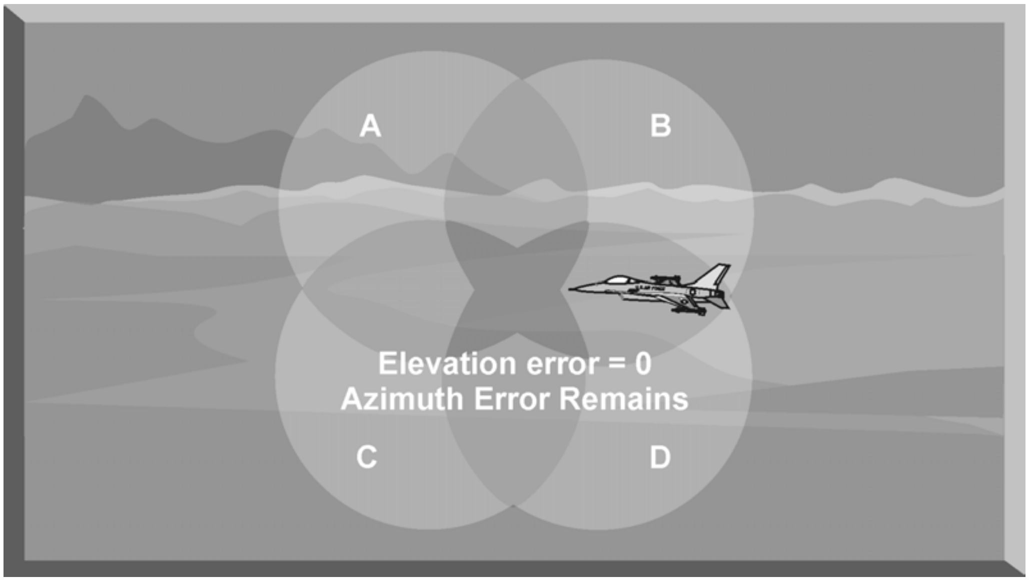

Figure 7-17. Monopulse Elevation Track

(2) Using the azimuth error equation from Figure 7-15, the azimuth tracking loop computes the azimuth error and repositions the antenna to equalize the received energy in all the beams. The monopulse radar has now established a tracking solution (Figure 7-18). All these computations are done instantaneously on a pulse-to-pulse basis.

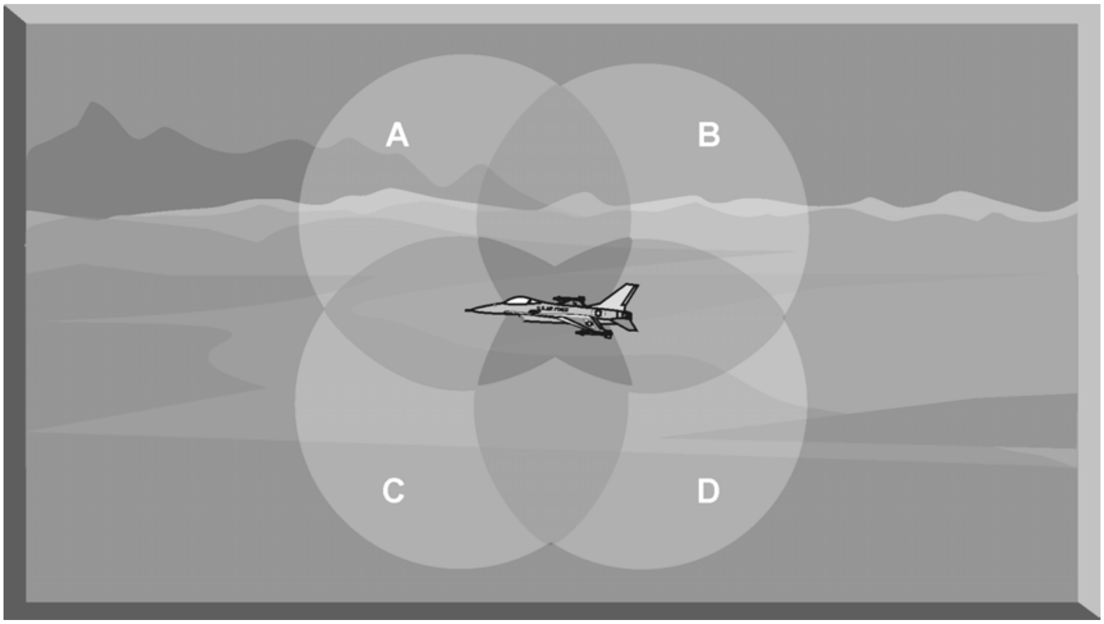

Figure 7-18. Monopulse Azimuth Track

7. CONTINUOUS WAVE (CW) RADARS

CW radar was one of the earliest forms of radar systems. Unlike pulse radar systems, CW radars emit a continuous beam of RF energy with no interruptions in the transmissions to detect returning echoes. A continuous radar transmission from the antenna requires that a classic CW radar have two antennas, one for transmission and one for reception (Figure 7-19).

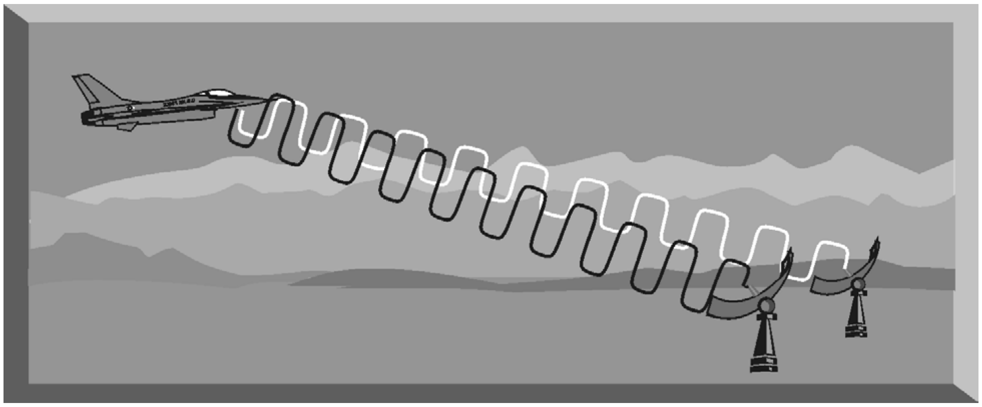

Figure 7-19. CW Radar

a. Since a continuous transmission results in a continuous echo signal, it is impossible to tell what part of the echo is associated with any particular part of the transmission. This makes range typical determination impossible. The azimuth and elevation tracking capability of a CW radar is based on the antenna position when the target is illuminated. The simple application of the Doppler principle provides a means for a CW radar to track a target in velocity and reject clutter. The Doppler principle deals with the fact that a radar return from a moving target will be shifted in frequency by an amount proportional to its radial velocity compared with the radar site. Using the difference in frequency from the transmitted signal to the received signal, a CW radar can separate the target return from clutter based on a change in frequency. This type of radar is called a CW Doppler radar.

b. The most serious disadvantage of a simple CW Doppler radar is that it does not provide any range information on the target. One method of obtaining range information from a CW radar uses frequency modulation (FM). The modulation can be sinusoidal, sawtooth, triangular, or any shape, as long as the rate of frequency change is known. The transmitter emits a continuous signal, but the frequency is changed in a known pattern. When the echo returns from the target, it is then compared to the frequency being transmitted. This frequency difference is directly proportional to the range of the target.

(1) Figure 7-20 shows how a FM CW radar measures range. Using a triangular wave for modulation, a plot of transmitted frequency over time would look like the solid line. It is important to note that this is not a depiction of the transmitted wave but a plot of how the frequency of the wave varies with time. For a target, without any relative motion, the frequency returning to the receiver is depicted by the dotted line. The target echo frequency lags the transmitted frequency by time (t). There is also a frequency difference between the transmitted and received signals. Range to the target may be computed by measuring this frequency difference and dividing by the rate of change of the transmitted frequency. The result is time. Dividing this time by 12.4 microseconds per radar mile yields range to the target. The frequency difference is constant for a target, without any relative motion, except for the brief intervals when the change in frequency goes from a positive to a negative slope. These “ditches” are negligible and can be disregarded when calculating range. The average amplitude is equal to target range.

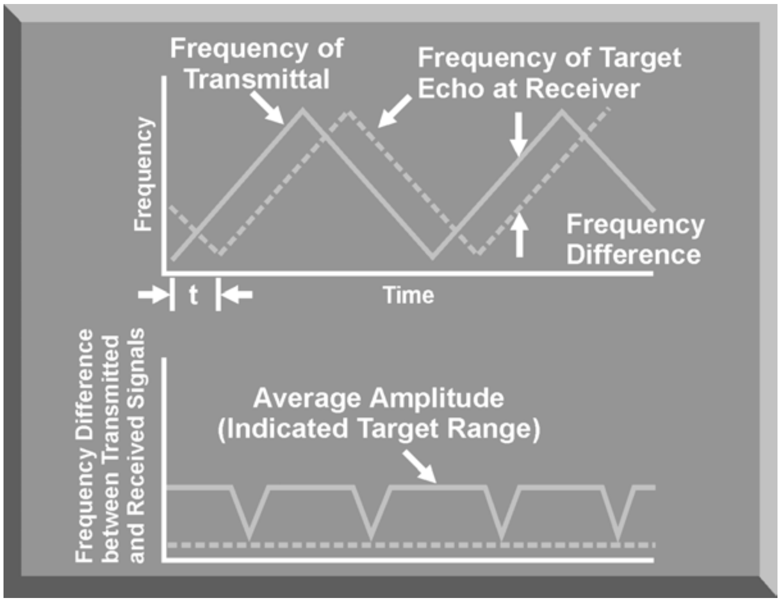
Frequency of Transmittal
Frequency of Target Echo at Receiver
Frequency
Frequency Difference
t
Time
Frequency Difference between Transmitted and Received Signals
Average Amplitude (Indicated Target Range)

Figure 7-20. FM CW Radar Range Determination (No Relative Motion)

(2) For a target moving toward the radar, the FM CW radar measures both target range and velocity. In Figure 7-21, the frequency of the return signal will be increased as depicted by the dotted line. Remember, this is a graph of frequency versus time, not a depiction of the radar wave. For a moving target, this results in a varying frequency difference. A plot of the frequency difference over time provides target range by averaging the difference, while target velocity is found by comparing the two frequency differences.

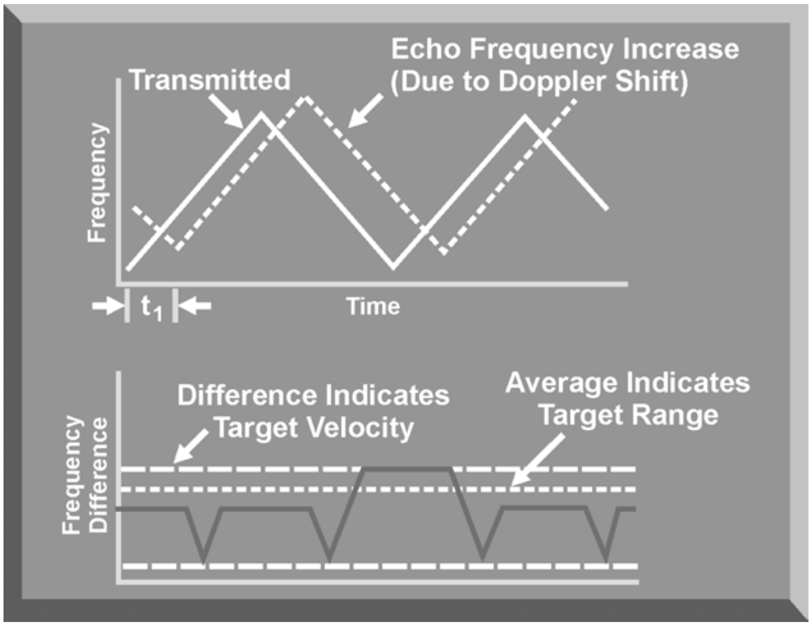
Transmitted
Echo Frequency Increase (Due to Doppler Shift)
Frequency
t1
Time
Frequency Difference
Difference Indicates Target Velocity
Average Indicates Target Range

Figure 7-21. FM CW Radar Range Determination (Relative Motion)

c. The primary advantage of the FM CW Doppler radar is its ability to combine the clutter rejection features of a simple CW Doppler radar with the capability to detect range. The widest application of FM CW Doppler radars is in radar altimeters for aircraft. In addition, the HAWK missile system uses an FM CW Doppler acquisition radar and a CW target illuminator.

d. Another method used for clutter rejection in a pulse radar system is to employ special circuits, or Doppler processing, to identify and reject clutter. These special circuits are added to the receiver section of a pulse radar and are called moving target indicators (MTIs). There are two types of MTIs, non-coherent and coherent.

(1) The earliest form of MTI was called non-coherent MTI or "area" MTI. Non-coherent MTI radars do not process Doppler frequencies. The returns from one scan are subtracted from returns from the next scan. All targets that move at least one resolution cell in the time between scans are displayed. All stationary objects, including fixed clutter, are cancelled and not displayed. In this type of MTI, clutter cancellation is based on the size and movement of the return. Due to changes in the clutter cross section, instabilities in radar operations, variations such as rain or clouds, and noise from the transmitter, clutter cancellation is never complete. In another form of non-coherent MTI, the radar returns from moving targets are compared to the returns from fixed targets, and the fixed targets are cancelled. These non-coherent MTIs are simple, but they do not provide the clutter rejection available from coherent MTI radars.

(2) A coherent MTI uses the fact that Doppler shifts appear to a pulse radar as phase shifts on the received target pulse. Coherent MTI uses sophisticated circuitry, including stable local oscillators (STALOs) and coherent local oscillators (COHOs) to capture and process these phase shifts. Further processing of these phase shifts yields velocities for each return. Those velocities associated with stationary targets are rejected and only moving targets are displayed. Coherent MTIs have a major problem called "blind speeds." Blind speeds occur for all target Doppler frequencies that are the exact PRF, or any multiple of the PRF, of the radar signal. When a target is moving at a velocity that produces this Doppler frequency, its return is cancelled along with fixed returns.

(3) There are three techniques to limit "blind speeds." The first technique is to use a PRF stagger. By staggering the PRF, the blind speed associated with one PRF will be covered by the other PRF. The second method is called the delay line and canceler. This involves delaying each pulse so it can be compared to the next pulse before processing. This method enhances Doppler frequency comparison and rejects clutter more effectively. The third way is to use range gates and Doppler filters. A range gate is simply a switch that opens for a time corresponding to the time a radar return would arrive for a target at a specific range. For example, a range gate for all targets between 10 and 11 nautical miles would open 124 microseconds after the transmitted pulse (12.4 microseconds per mile) and close 12.4 microseconds later. A target return at this range would trip

this gate and be processed by Doppler filters to find velocity. Fixed targets would trip the range gate and be eliminated by the Doppler filters. This is a sophisticated technique that is also used by pulse Doppler radars.

8. PULSE DOPPLER RADAR

Pulse Doppler radars combine the advantages of both pulse and Doppler radar systems. Because the signal is pulsed, the radar can find range, azimuth, and elevation, similar to a conventional pulsed radar. A pulse Doppler radar can also compute overtake, or rate of closure, compared with the radar system on a pulse-to-pulse basis. A pulse Doppler radar operates much like an MTI, and the terms are sometimes used interchangeably. However, an MTI uses Doppler frequency shifts only to reject clutter while a pulse Doppler radar uses Doppler frequency shifts to reject clutter and to track targets in velocity. A pulse Doppler radar transmits a box or pulse of RF energy at the operating frequency of the radar (Figure 7-22). The frequency inside these boxes reacts the same way as the continuous waves of a CW radar, but since the RF waves are pulsed, range determination can be accomplished by measuring the time it takes for the reflected pulse to return from the target. Velocity determination and tracking are accomplished by capturing and quantifying the Doppler shift of the frequencies in each pulse.

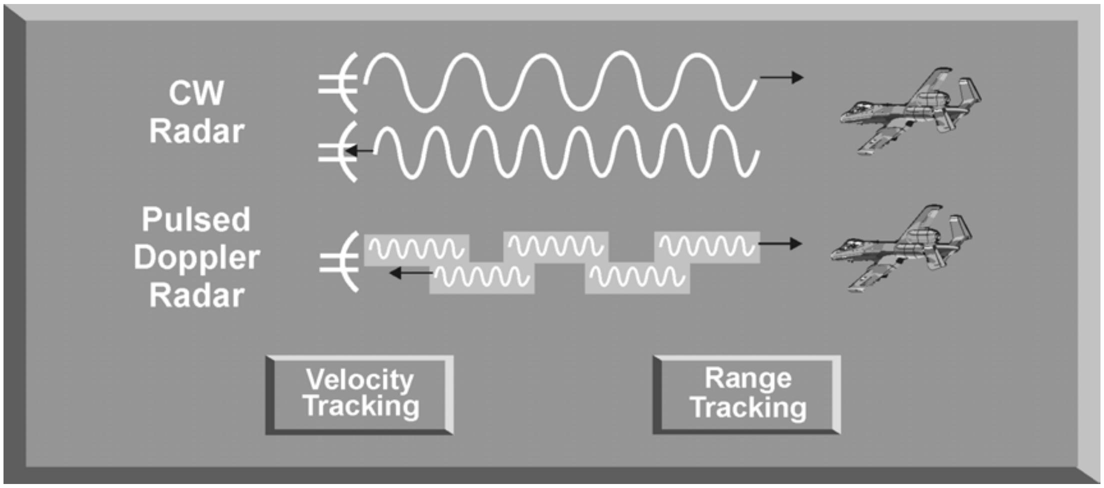

Figure 7-22. Comparison of CW Radar and Pulse Doppler Radar

a. A pulse Doppler radar tracks a single target in azimuth and elevation by employing either conical scan (sequential lobing) or monopulse tracking. Angle and elevation tracking employing these techniques is covered in Sections 3 and 6 of this chapter. The error signals generated by these techniques are sent to the antenna servos to keep the target return centered in the antenna beam.

b. Range tracking of a single target in a pulse Doppler radar is normally accomplished by a split-gate or leading-edge range tracking loop. Some pulse

Doppler radars employ an FM technique to provide range information during high PRF operations.

c. For velocity tracking, each range gate has a complete set of Doppler filter banks as depicted in Figure 7-23. Each pulse of RF energy is composed of many frequencies. To separate the returning target frequency from all other frequencies in the returning waveform, the pulse Doppler radar employs filters to cancel the unwanted frequencies. In addition, it cancels out all returns with no frequency shift, which equates to canceling all returns with no movement relative to the radar.

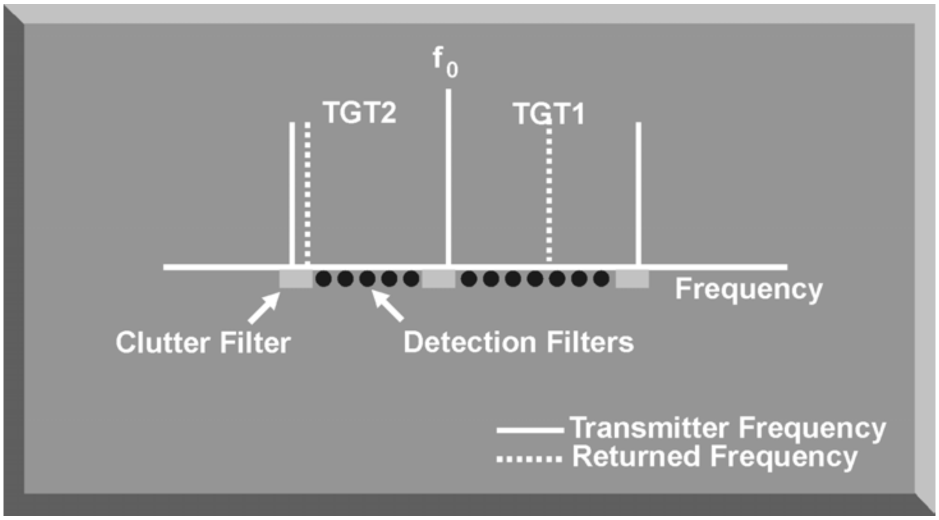

Figure 7-23. Range Ambiguity

d. The ability of a pulse Doppler radar to accomplish range, azimuth, and velocity tracking is dependent on the PRF of the radar. Table 7-1 summarizes these capabilities based on PRF. Low PRF tracking in velocity is extremely difficult due to the spacing of the spectral lines. Low PRF gives accurate range and azimuth as well as long, unambiguous range. Medium PRF tracking in range, azimuth, and velocity is easy for the radar to handle. High PRF provides excellent velocity resolution, but range ambiguities become a problem.

Table 7-1. Pulse Doppler Tracking Capabilities

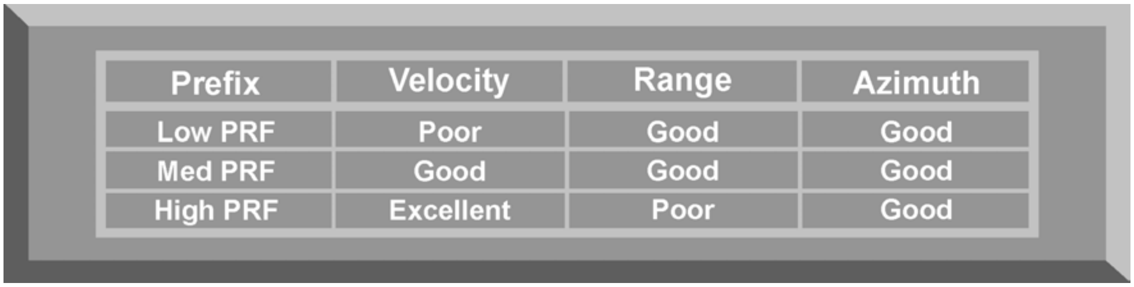

Prefix	Velocity	Range	Azimuth
Low PRF	Poor	Good	Good
Med PRF	Good	Good	Good
High PRF	Excellent	Poor	Good

e. Weaknesses of pulse Doppler radars include velocity blind speeds, range ambiguity, and range eclipsing.

(1) The primary operator exploitable weakness of a pulse Doppler radar takes advantage of the pulse Doppler radar's biggest strength. The pulse Doppler is designed to eliminate ground returns so that the attacker is able to track an aircraft that used to be able to hide in ground clutter. To remove the ground clutter and avoid tracking unwanted targets like cars on a road, a filter is designed in the radar to eliminate all targets with a low velocity relative to the radar. The key to breaking track of a pulse Doppler radar is to place the aircraft in a speed less than the speed gate relative to the radar (Figure 7-24), commonly referred to as the Doppler notch.

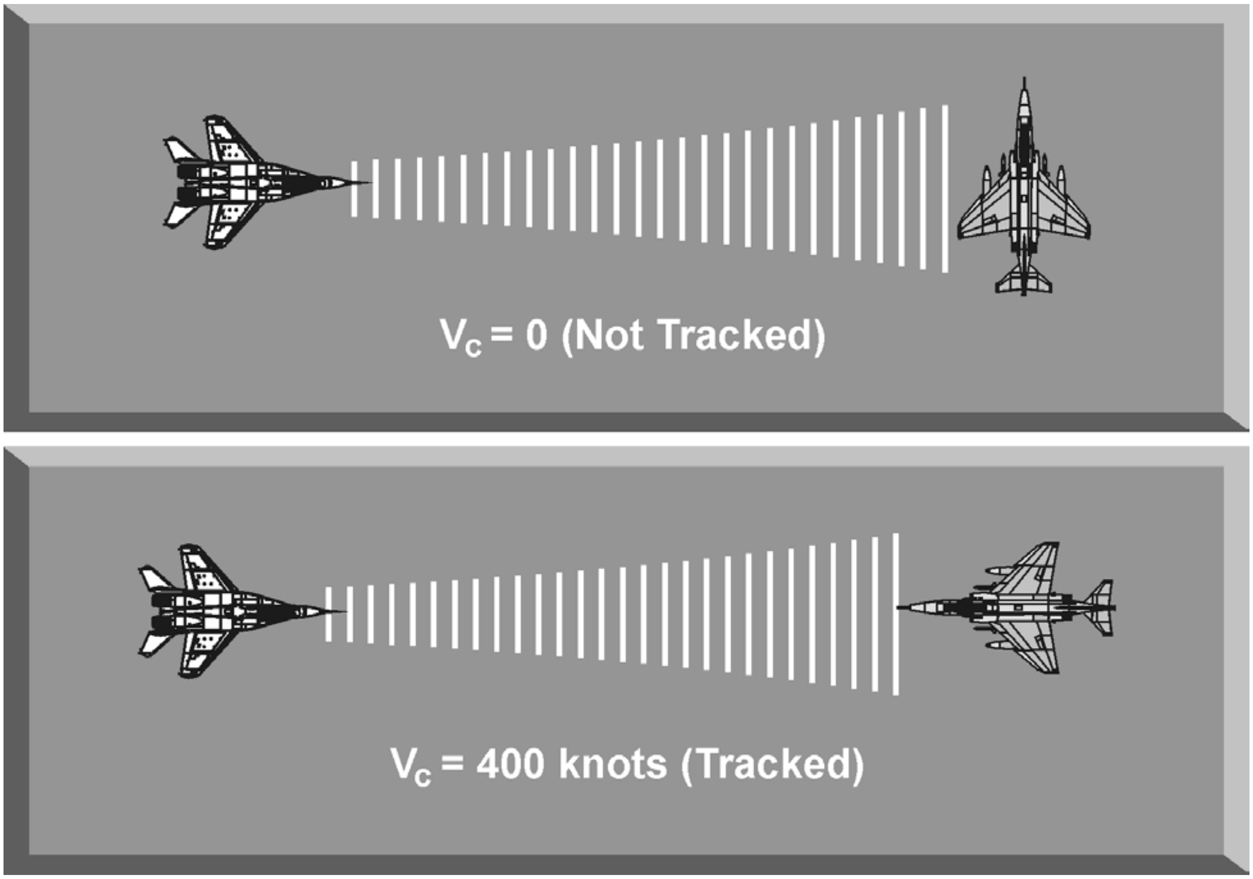

Figure 7-24. Pulse Doppler Speed Gate

(2) Range ambiguity occurs primarily with long-range targets when the return comes back to the radar after another pulse has already been transmitted (Figure 7-25). The radar will see this return and base its range calculations on the transmission time of the immediately preceding pulse, instead of the pulse that generated the return. The result will be an incorrect range calculation.

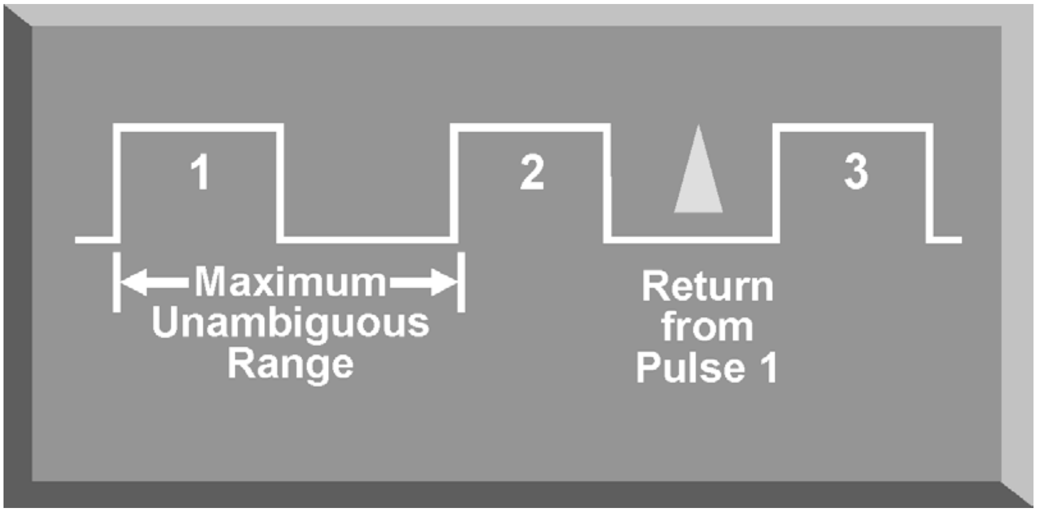

Figure 7-25. Range Ambiguity

(3) Range eclipsing occurs when a target return comes back to the radar antenna while a pulse is being transmitted (Figure 7-26). Since the radar cannot receive while transmitting, the return will not be displayed.

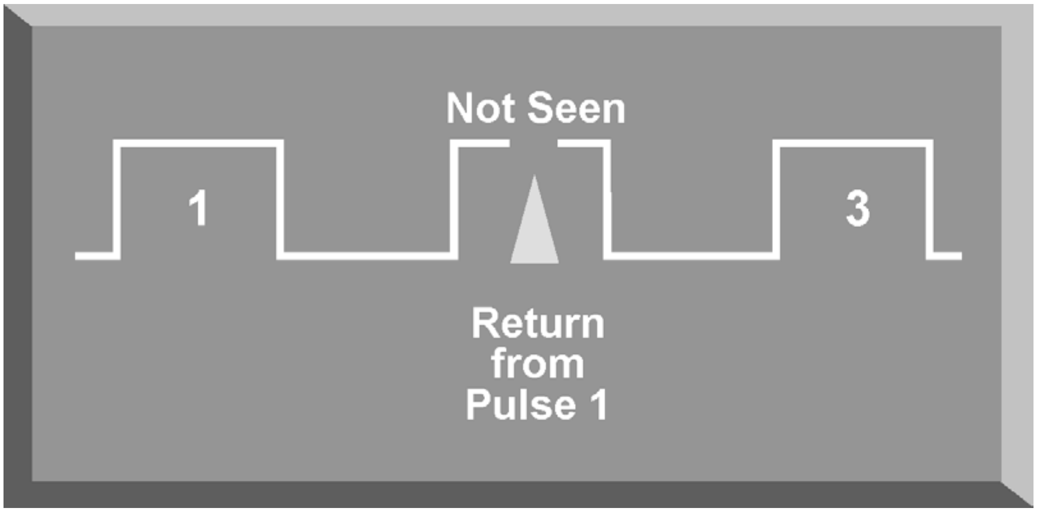

Figure 7-26. Range Eclipsing

(4) To solve the problems of range ambiguity and eclipsing, a pulse Doppler radar employs different PRFs and computer logic. In Figure 7-27, at PRF 1, the return from target 1 is eclipsed, and target 2 is ambiguous. By changing the PRF slightly, these range problems can be resolved. Notice that at PRF 2, neither target is eclipsed, and at PRF 3, target 2 is eclipsed. The computer logic needs to be extremely advanced to compensate for these problems. These simplistic examples show the complex problem of using multiple PRFs.

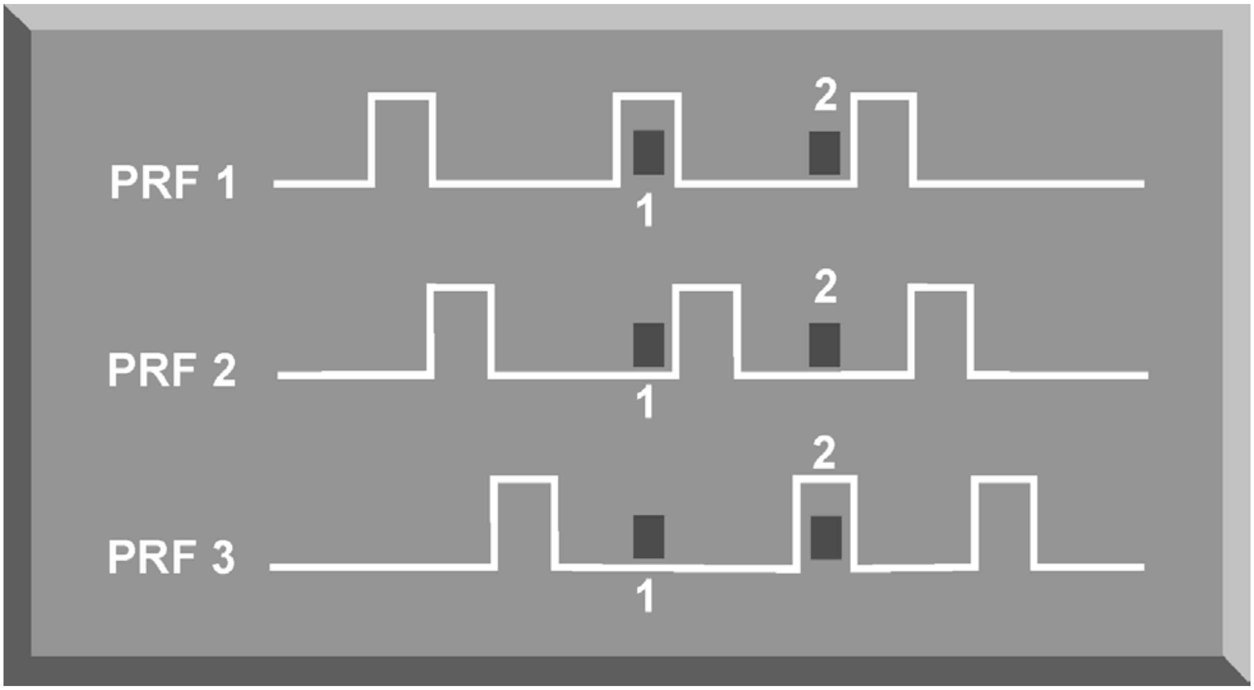

Figure 7-27. Resolving Range Ambiguity and Eclipsing

9. SUMMARY

This chapter has discussed the range, azimuth, elevation, and velocity tracking techniques employed by conical scan, TWS, LORO, monopulse, CW Doppler, and pulse Doppler radar systems. The method used by a specific radar system to track a target determines the type of jamming technique required to counter this system. A basic understanding of the target tracking techniques will enable you to understand the basic jamming techniques employed to defeat these threats.

CHAPTER 8. RADAR MISSILE GUIDANCE TECHNIQUES

1. INTRODUCTION

Once a target has been designated, acquired, and tracked by a radar system, the final stage in target engagement is to guide a missile or projectile to destroy the target. There are three basic requirements for successful missile guidance: (1) precise target tracking by a target tracking radar (TTR) to provide target parameters (range, azimuth, elevation, velocity, etc.), (2) a method to track the position of the missile compared with the target, and (3) a fire control computer to generate missile guidance commands based on target and missile position. The missile guidance techniques employed by modern air-to-air and surface-to-air missile (SAM) systems will be covered in this chapter. In addition, the target engagement techniques employed by antiaircraft artillery (AAA) systems will also be discussed. There are three distinct phases in any missile intercept: boost, mid-course, and terminal.

a. Nearly all missiles are unguided during the initial boost phase (Figure 8-1). During the boost phase, the missile electrical and hydraulic systems are activated and are coming up to operating parameters. The missile is gathering speed and normally will be in an unguided mode of flight.

Figure 8-1. Initial Boost Phase

b. During the mid-course phase, the missile is actively being guided to the target using some type of guidance signal (Figure 8-2). Guidance signals deflect

the control vanes of the missile to change its direction. These vanes change the roll, pitch, and yaw, in some combination, to control the missile flight path. Normally a gas grain generator powers a small hydraulic pump that deflects the control vanes in response to guidance signals. Each missile carries a limited supply of hydraulic fluid for maneuvering. The fluid is expended through vents with every control surface activation. The limited quantity of hydraulic fluid can be a significant factor during a long-range missile intercept.

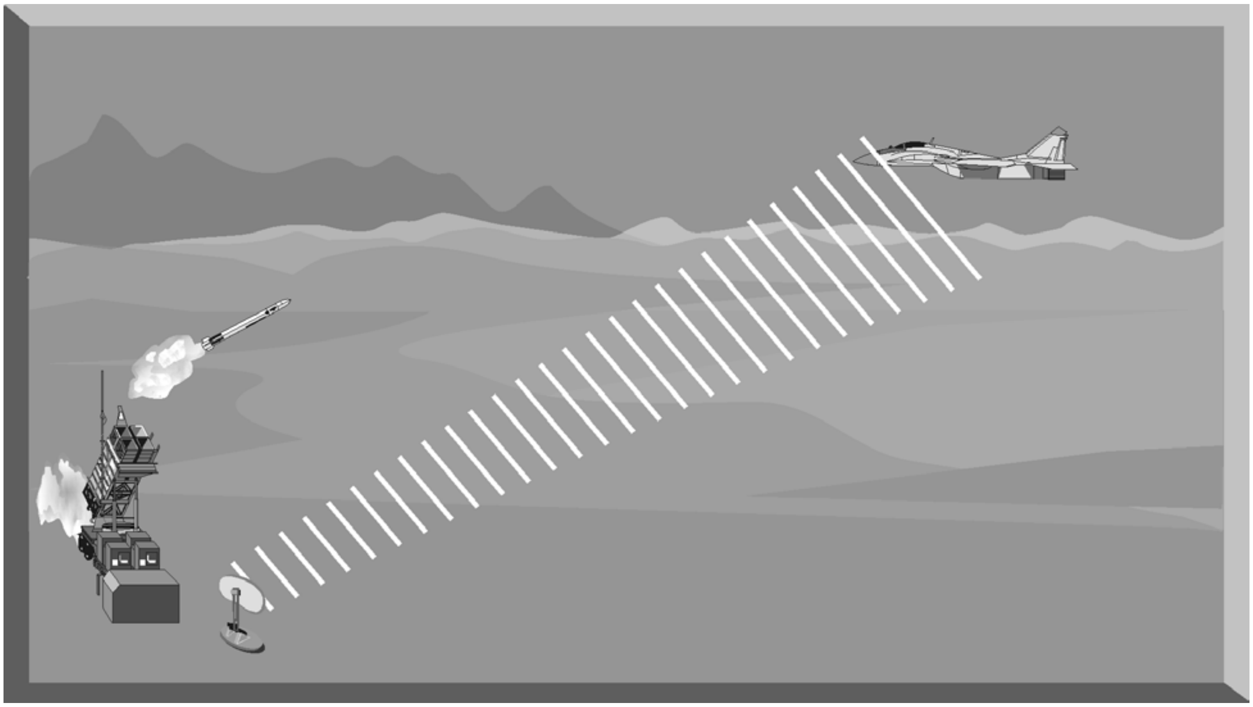

Figure 8-2. Mid-Course Guidance Phase

c. The final phase of an intercept is the terminal phase (Figure 8-3). During this phase, the missile attempts to pass close enough to the target to detonate the fuse while the target is within the lethal radius of the warhead. Modern missiles employ both a contact fuse and some type of proximity fuse. Proximity fuses range from command detonation for command-guided missiles, fractional Doppler gates for semi-active guided missiles, to active laser fuses for IR-guided missiles.

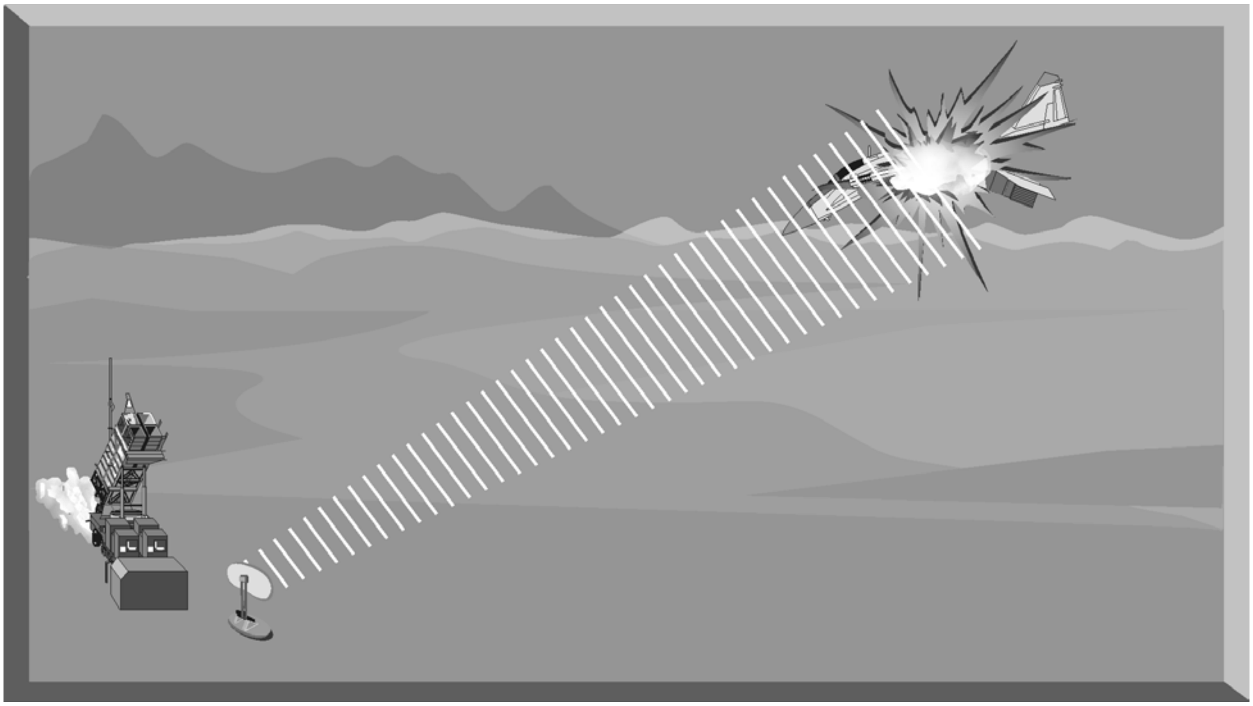

Figure 8-3. Terminal Guidance Phase

2. COMMAND GUIDANCE

Command guidance uses a fire control computer to constantly send course correction commands to the missile throughout its flight. These commands are a series of electrical missile guidance pulses called doublets or triplets. These pulses provide steering commands to the missile by varying the spacing between each guidance pulse. Each pulse, or pulse combination, relays some roll, pitch, and yaw command to the missile. These inputs are constantly corrected for the spatial relationship between the missile and the target's present position and rate of motion. Guidance commands are passed to the missile by specialized antennas on the TTR and an antenna installed on the missile, called a missile beacon. The beacon is a special radio receiver and transmitter that is attached to the rear of the missile. It acts like a transponder in that the TTR tracks and receives guidance commands. The guidance frequency may be widely separated from the target tracking radar frequency to minimize interference. This beacon is usually masked until missile booster separation. This results in the missile being launched unguided for the first 2-3 seconds. This type of delay is one of the reasons that all command-guided missile systems have a minimum launch range. Command guidance is used by the SA-2, SA-3, SA-4, and SA-8.

a. Command-guided missiles will generally fly a rectified (full or half) or three-point pursuit geometry during the mid-course portion of the intercept (Figure 8-4). However, a command-guided missile may transition to a pure pursuit geometry during the terminal phase of the intercept. Rectified geometry involves the prediction of where the target and the missile will be at some point in the future.

The target's direction and rate of movement is tracked and predicted. The missile is then launched, pulls lead on the target, and is guided to the point in the sky where the intercept is predicted to take place. This profile requires the constant update of both the target and missile positions.

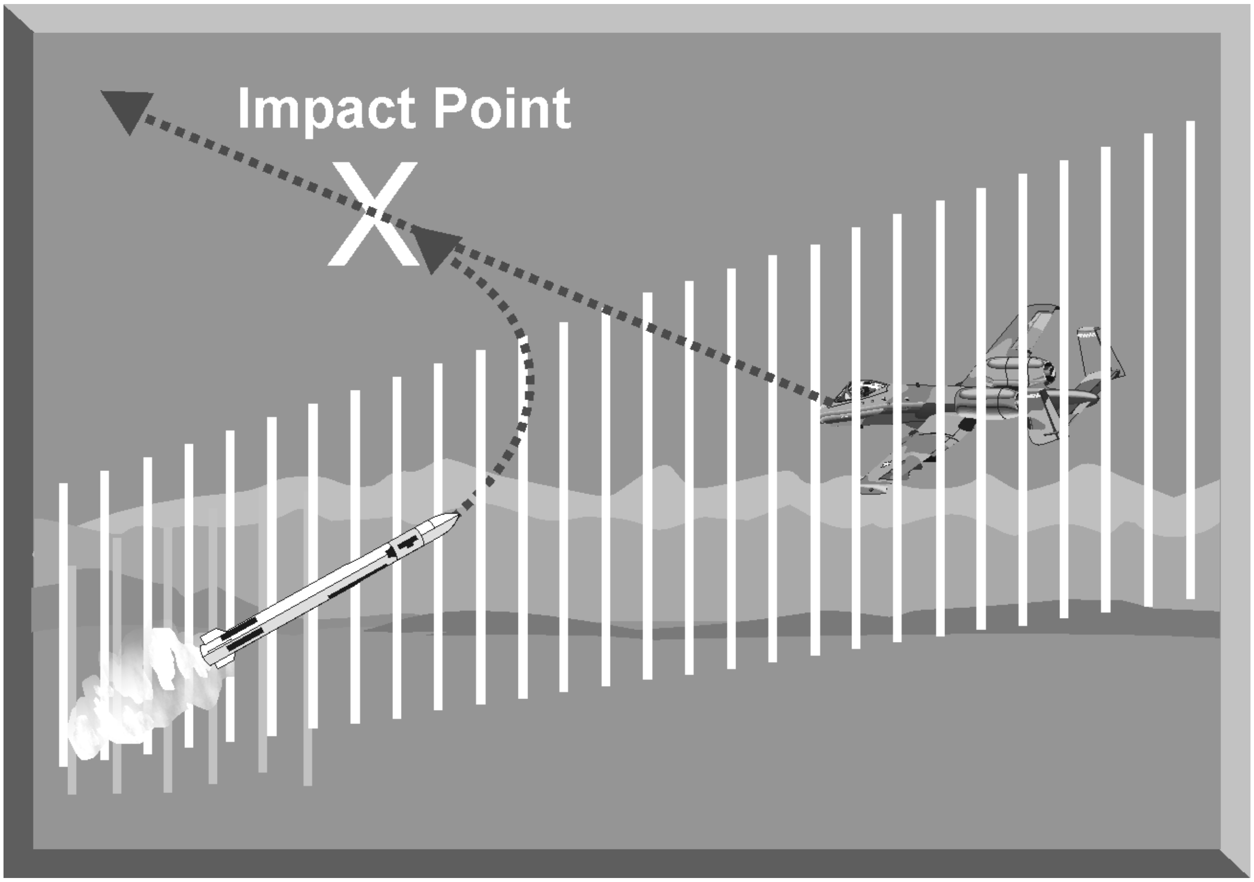

Figure 8-4. Rectified Flight Profile

b. Three-point pursuit geometry is often used when there is incomplete range tracking data on the target. In this case, it will be impossible to predict exactly where the target will be at some point in the future. In this profile, the target tracking radar constantly tracks the target. The missile location will be updated by the missile beacon. The fire control computer will direct the missile to fly directly down the tracking radar beam toward the target. In this geometry, the missile may start out on a direct intercept course and, depending on the target's direction and rate of movement, transition to a pure pursuit intercept. The three points in three-point missile geometry are depicted in Figure 8-5. Point one is the target tracking radar, point two is the missile itself, and point three is the target. By keeping all three points always in a line, the missile will intercept the target at some point, although the range of the target is unknown.

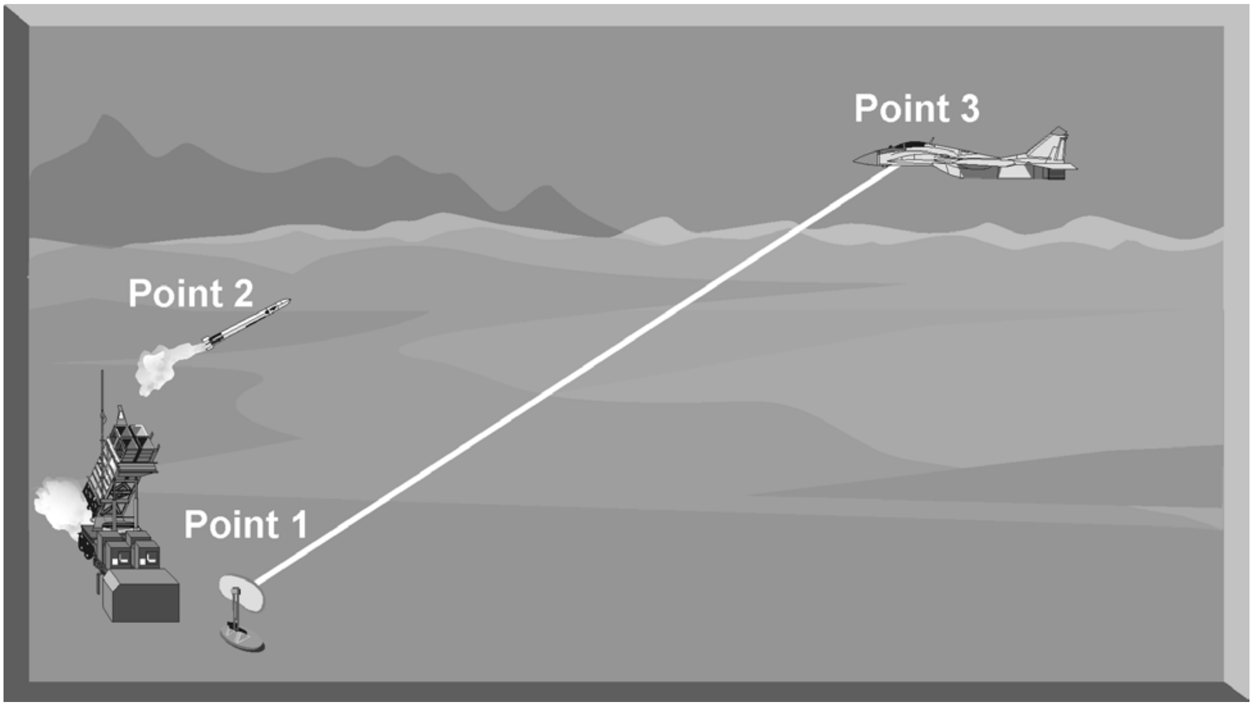

Figure 8-5. Command Guidance: Three-Point Pursuit

c. Command guidance techniques have many advantages. First, command-guided missiles can adjust their flight geometry throughout an intercept profile. Second, the missiles are uncomplicated since they do not carry onboard computers or target tracking equipment. The fire control computer associated with the TTR accomplishes all intercept calculations. Third, the primary intercept profile, a full- or half-rectified intercept, is the fastest and most fuel-efficient intercept. Fourth, command guidance is difficult to jam since the missile beacon antenna is at the rear of the missile and can be relatively high-powered. And finally, an intercept is possible even without accurate range information by using the three point intercept profile.

d. Command guidance has several disadvantages. First, the use of a missile beacon delays the capture of the missile by the tracking radar. This can cause a large dead zone which equates to a larger minimum engagement range. Second, the accuracy of the intercept geometry is only as good as the tracking information provided by the target tracking radar. Jamming, interference, or loss of signal will adversely affect the intercept accuracy. In addition, normal radar characteristics could produce sufficient errors to cause the missile to miss the target, especially at longer ranges. Third, with insufficient range information, the three-point intercept profile is very slow and could result in the missile running out of energy before it gets to the target. Fourth, command guidance is reactive. The fire control computer constantly updates the intercept geometry based on target maneuvering. This results in missile maneuvering lagging target maneuvers.

3. SEMI-ACTIVE GUIDANCE

Semi-active guidance is significantly different from command guidance, but only after launch. The first requirement is still for the target tracking radar to maintain a solid target track, with the tracking data being supplied to the fire control computer. The fire control computer then directs a target illumination antenna to point at the target and illuminates it with CW energy. The missile then passively homes on the reflected CW energy.

a. The missile used by a threat system that uses CW homing is vastly different from the missile being guided by a command guidance signal. The missile that homes on CW energy must be equipped with a seeker section composed of an antenna and an internal receiver. The seeker section processes and computes the necessary course corrections as it flies toward the target. It can do this by knowing the zero boresight line of the antenna within the missile (Figure 8-6). As the reflected CW energy is received by the seeker, there is normally some deviation from the zero reference position. The onboard computer then directs the control surfaces to change the flight path to reduce the reference errors in the antenna to zero, if possible. When the error between the antenna position and the boresight position is zero, the missile is pointed directly at the target.

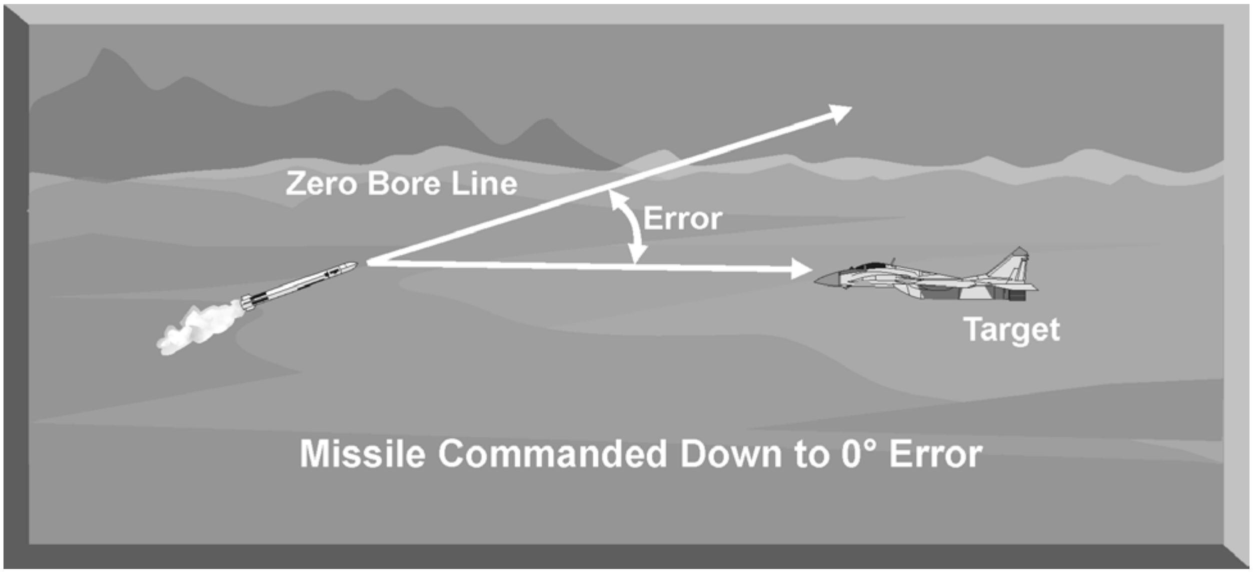

Figure 8-6. Semi-Active Guided Missile

b. Missile systems that use semi-active guidance normally use velocity as the primary target discriminator during the intercept. The missile seeker locks onto a reference Doppler signal provided by the fire control computer before launch. This Doppler signal establishes a tracking gate around the velocity of the target. After the missile is launched, it initially compares the reference Doppler to the target Doppler signal.

c. The mid-course phase for a semi-active missile is also different from that of a command-guided missile. A semi-active guided missile follows the reflected CW energy during the mid-course phase of the intercept and normally attempts to fly a lead pursuit profile to the target (Figure 8-7). If the target maneuvers, however, the missile may transition to a pure pursuit flight path. Unlike a command-guided missile, a semi-active guided missile does not use a missile beacon. The fire control computer does not need to know where the missile is to compute course corrections since all that is necessary is to illuminate the target with the CW illuminator. This also means that the missile can begin to track and guide when it is launched and locked on to the reference Doppler gate. Semi-active guidance is the primary mode of guidance for many surface-to-air missiles, and almost all radar-guided air-to-air missiles.

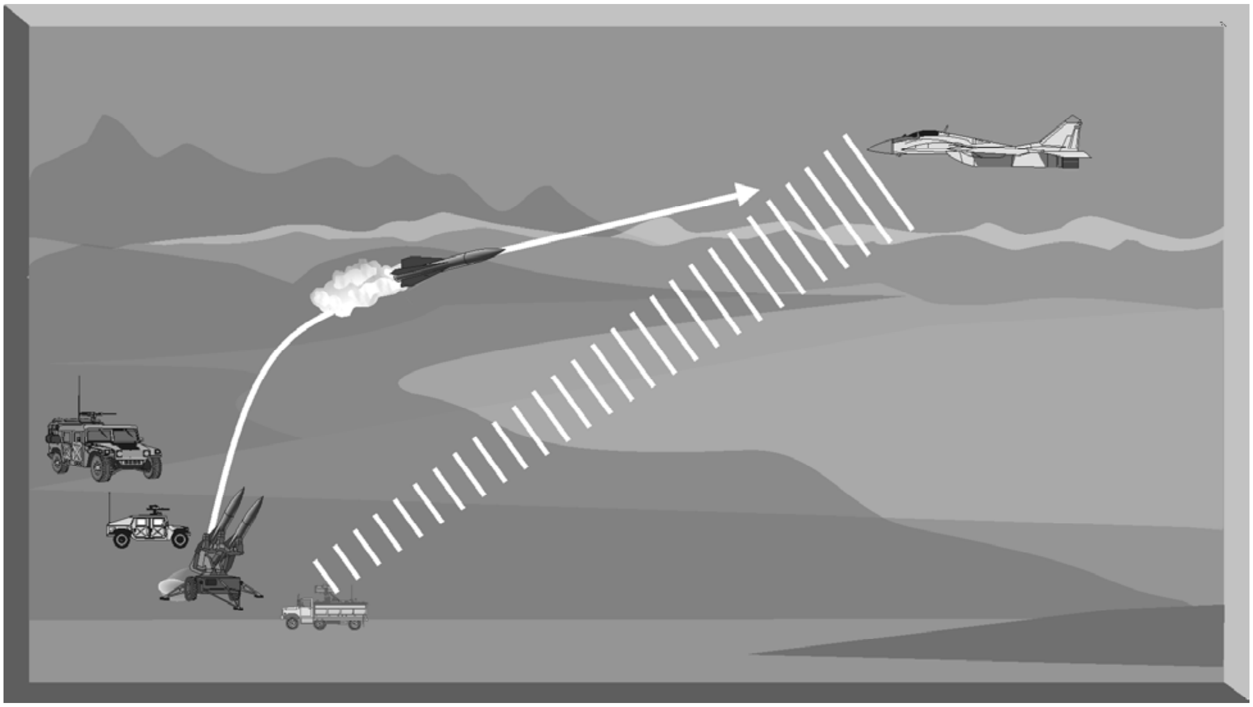

Figure 8-7. Semi-Active Guidance (Mid-Course)

d. As the missile enters the terminal phase of the intercept, there is no change in the guidance mode used by a CW homing missile. The missile may complete the terminal phase of the intercept geometry by going to a pure pursuit flight path, if necessary (Figure 8-8). The missile continues to home in on the reflected CW signal until it passes close enough for the fuse to function.

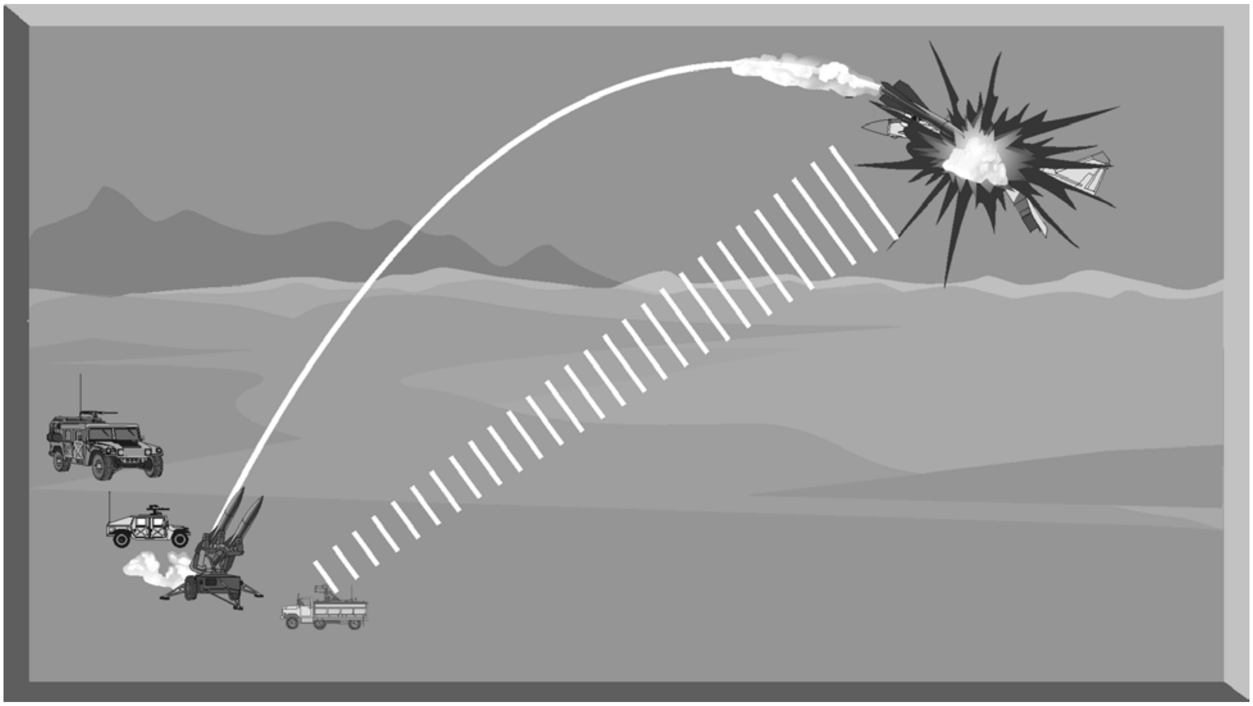

Figure 8-8. Semi-Active Guidance (Terminal Phase)

e. Semi-active missile guidance has many advantages. First, a semi-active guided missile is resistant to electronic jamming that may be used to deny range information. Second, a semi-active missile can be guided almost immediately after launch. This gives it a very small minimum range since it can maneuver almost as soon as it clears the launch rail. Third, it computes its own course corrections as necessary. This allows for a much quicker reaction to target maneuvers compared to a command-guided missile. Fourth, during a long-range intercept, a CW missile can be more accurate than a command-guided missile. This is accomplished by taking the inherent long-range radar tracking errors out of the equation. The target tracking radar only has to keep the target illuminated so that it can point the CW antenna at the target.

f. Although semi-active missile guidance is generally considered an excellent guidance technique, it does have some disadvantages. First, a semi-active guided missile normally requires reference Doppler values to be entered into the missile computer before launch. Without this reference, a semi-active missile cannot be launched (Figure 8-9). Second, a semi-active homing missile must maintain a lock onto the target Doppler. The use of chaff and beam maneuvers, which result in a near zero target Doppler, may cause a missile or radar to break lock. Third, if a break-lock occurs, a CW homing missile normally cannot regain target track and complete the intercept.

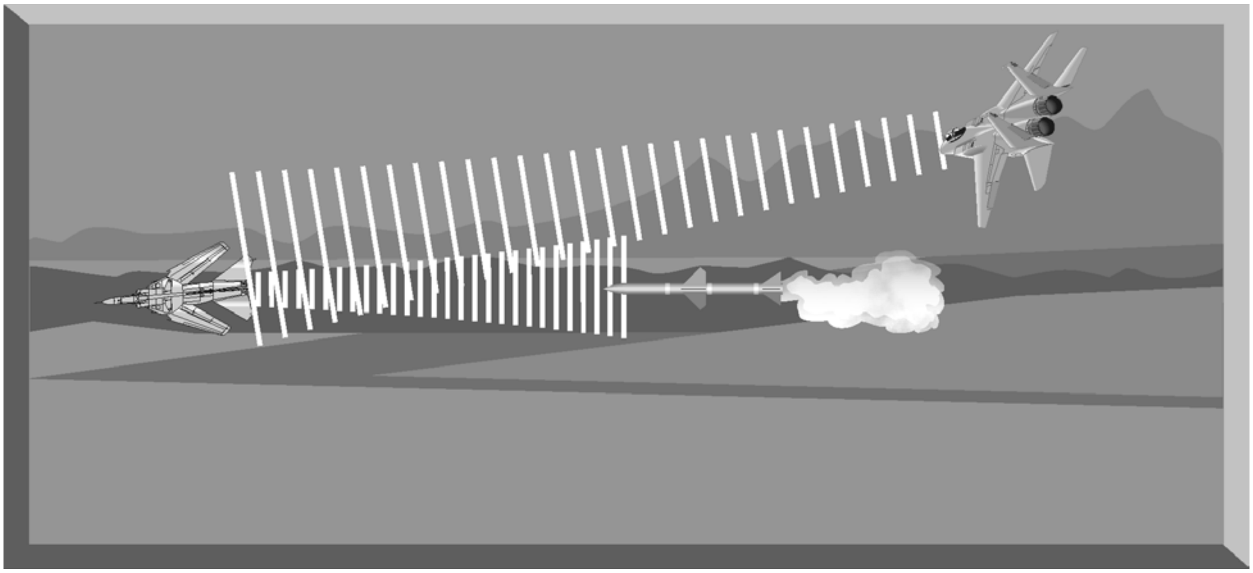

Figure 8-9. Semi-Active Guidance CW Reference Signal

4. ACTIVE GUIDANCE

Active guidance is an improvement that has been included in several new long-range missiles such as the AIM-54 Phoenix and the AIM-120 AMRAAM. This specialized guidance mode is only active during the terminal phase of flight. The mid-course phase usually employs semi-active or command guidance (Figure 8-10).

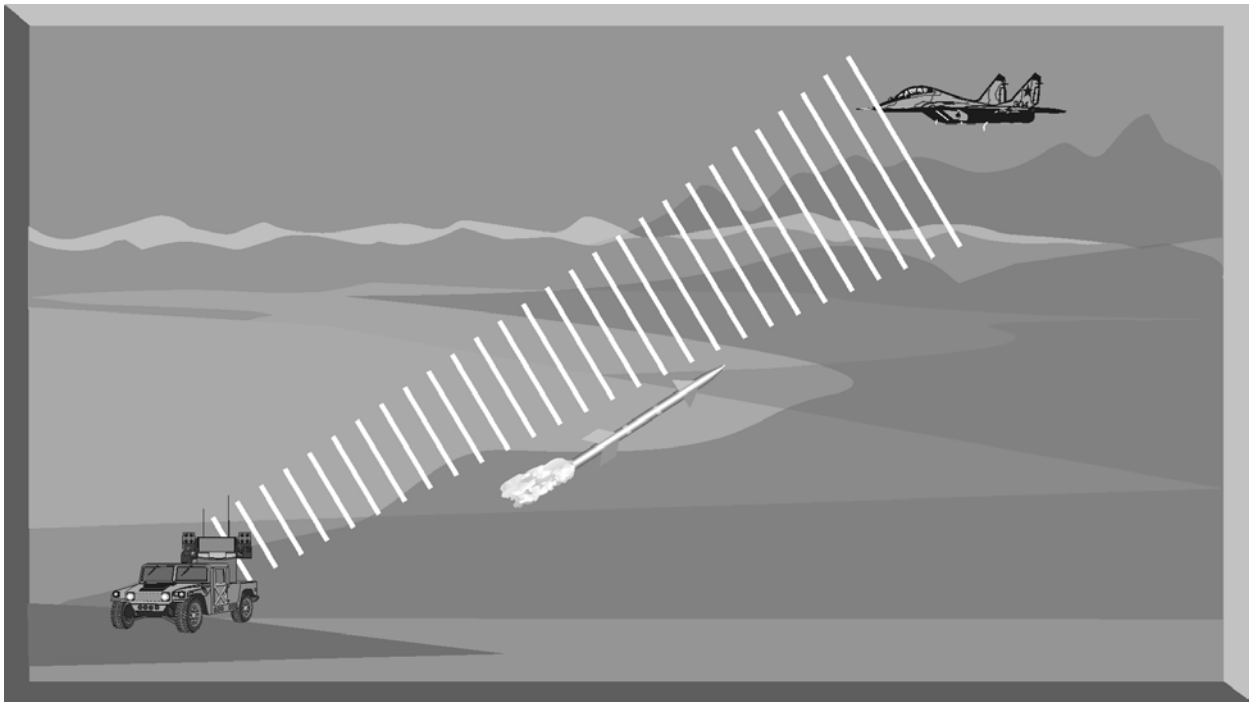

Figure 8-10. Active Guidance Mid-Course Intercept Phase

a. The range at which the missile goes "active" is dependent on the intercept geometry. High-aspect angle intercepts allow the activation of active guidance sooner than beam or tail-aspect intercepts. Missiles that employ active guidance carry a complete miniature radar system and fire control computer within the missile. As the missile nears the target, its internal radar system turns on and locks onto the target. The internal fire control computer directs control inputs to complete the intercept (Figure 8-11).

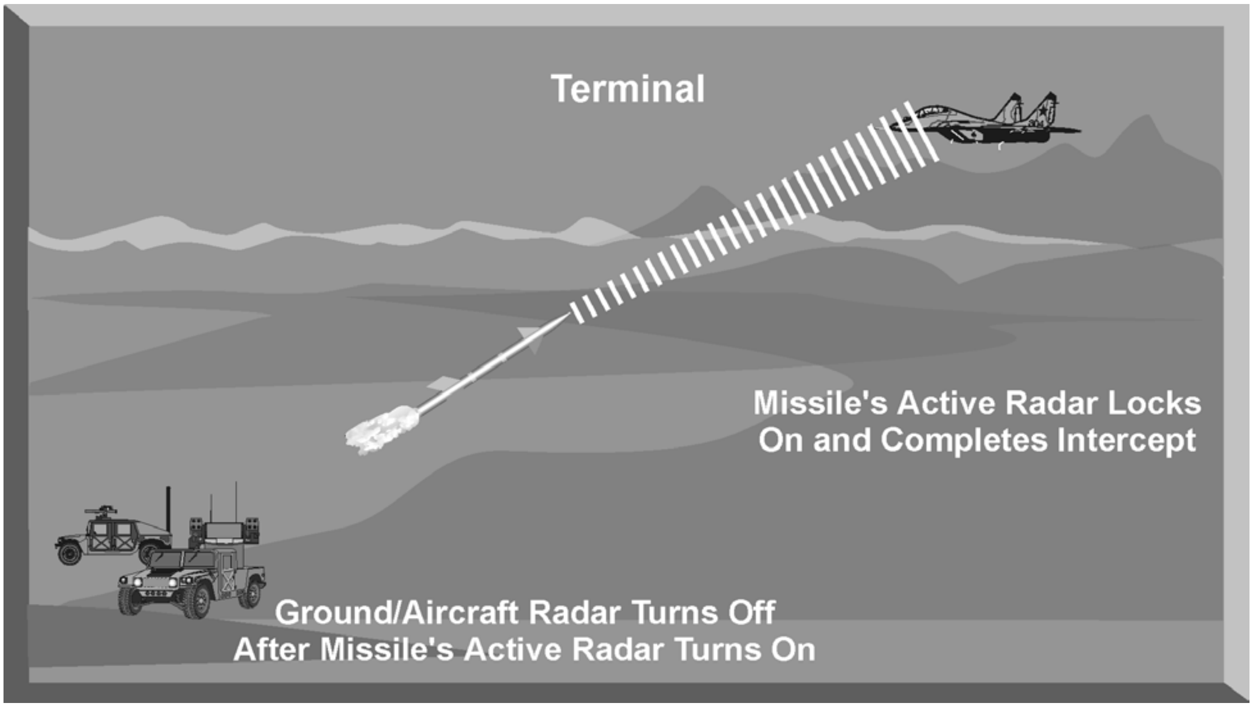
Terminal
Missile's Active Radar Locks On and Completes Intercept
Ground/Aircraft Radar Turns Off After Missile's Active Radar Turns On

Figure 8-11. Active Guidance Phase

b. Active-guided missiles have many advantages. First, active-guided missiles are very accurate at long ranges. This is because they do not rely on the target tracking radar once their internal radar takes over the intercept. Second, an active missile is extremely difficult to jam. It uses a narrow beam and its relative power is constantly increasing as it nears the target. Third, an active-guided missile is a fire-and-forget weapon. Command or semi-active missile guidance requires the target tracking radar to maintain lock-on until the intercept is completed. In an air-to-air engagement, this means the interceptor is predictable until the missile hits the target, and vulnerable to an enemy missile attack. An interceptor with an active missile, however, may launch the missile and, once it goes "active," can then turn around or maneuver defensively.

c. Active-guided missiles have a few disadvantages as well. First, the active homing missile is a complex missile integrating both command and active guidance modes. Second, the missile may still be susceptible to electronic jamming during the mid-course phase of flight. Remember, during the mid-course

phase, the missile relies on command or semi-active guidance. Jamming the target tracking radar may affect the missile's ability to "see" the target near the terminal phase.

5. SEEKER-AIDED GROUND GUIDANCE/TRACK-VIA-MISSILE GUIDANCE

In seeker-aided ground guidance (SAGG) and track-via-missile (TVM) guidance, the target is illuminated by the ground-based radar and the missile receives reflected energy from the target. Unlike conventional semi-active homing, the missile does not generate its own guidance commands. Instead, the missile transmits raw engagement data to the ground-based fire control system (FCS) in order to generate uplink guidance commands. TVM is similar to SAGG; however, additional processing is done on-board the missile prior to transmitting the engagement data to the ground-based FCS.

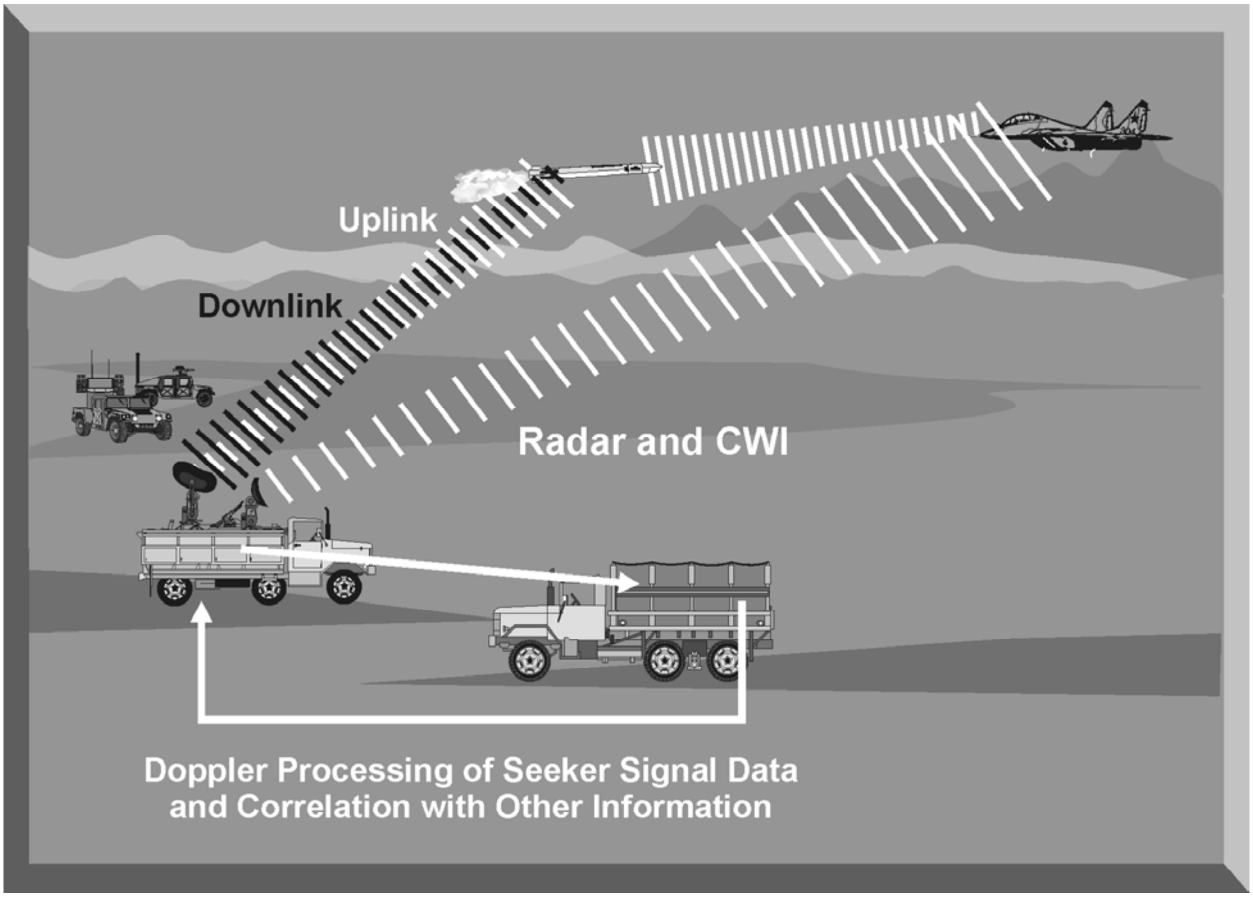
Uplink
Downlink
Radar and CWI
Doppler Processing of Seeker Signal Data and Correlation with Other Information

Figure 8-12. SAGG/Track-Via-Missile Guidance

a. Track-via-missile and seeker-aided ground guidance are two relatively new missile guidance techniques with similar advantages. First, they are extremely accurate at long ranges where the inherent radar tracking errors may be large

enough to cause a miss. Second, they can respond very quickly to any actions taken by the target since the missile seeker can track these changes and transmit the new position to the TTR fire control computer. Third, TVM and SAGG can be used with a large and capable fire control computer since most computations are accomplished by the TTR. Fourth, the integration of a phased array radar and the powerful TTR fire control computer allows the missile system to engage multiple targets. The Patriot missile battery, for example, can track and engage at least four targets simultaneously.

b. The major disadvantage of track-via-missile and seeker-aided ground guidance is that they are the most complex forms of missile guidance. They require the use of sophisticated computers to combine radar tracking data and data received from the missile. This required hardware is expensive and demands greater maintenance and logistical support. In addition, the missile itself needs to be large enough to store the appropriate hardware for computations and data transfer.

6. ANTIAIRCRAFT ARTILLERY (AAA)

The classic role of AAA is point defense. AAA systems provide close-in defense for high-value targets. AAA systems are deployed to defend cities, airfields, bridges, industrial centers, lines of communications, command and control centers, infantry/tank units, and SAM sites. There are two types of AAA systems: towed and mobile. Towed AAA is normally deployed in fixed sites around key targets. Mobile AAA systems are deployed to provide air defense for army units and to protect mobile SAM sites. The effectiveness of AAA systems, towed or mobile, depends on the ability of the system to predict an aircraft's future position to fire its unguided ballistic projectile to intercept the aircraft and destroy it. To accomplish this objective, AAA systems employ two primary tactics, aimed fire and sector/barrage fire.

a. Aimed AAA fire requires very accurate aircraft position information and an accurate prediction of future position. For aimed AAA fire, this information can be derived by using an optical sighting system on the gun or by employing a radar system coupled with a fire control computer. Smaller caliber AAA guns generally rely on optical target acquisition and firing (Figure 8-13). The high rate of fire, short range, and short projectile time of flight (TOF) simplifies the prediction and aiming problem for these systems. Smaller caliber AAA can also use tracer ammunition to help the gunner in correcting his optical firing solution. Larger caliber AAA systems, with slow rates of fire, long range, and long projectile TOF, generally use a TTR and a fire control computer to solve the problems associated with aimed fire (Figure 8-14).

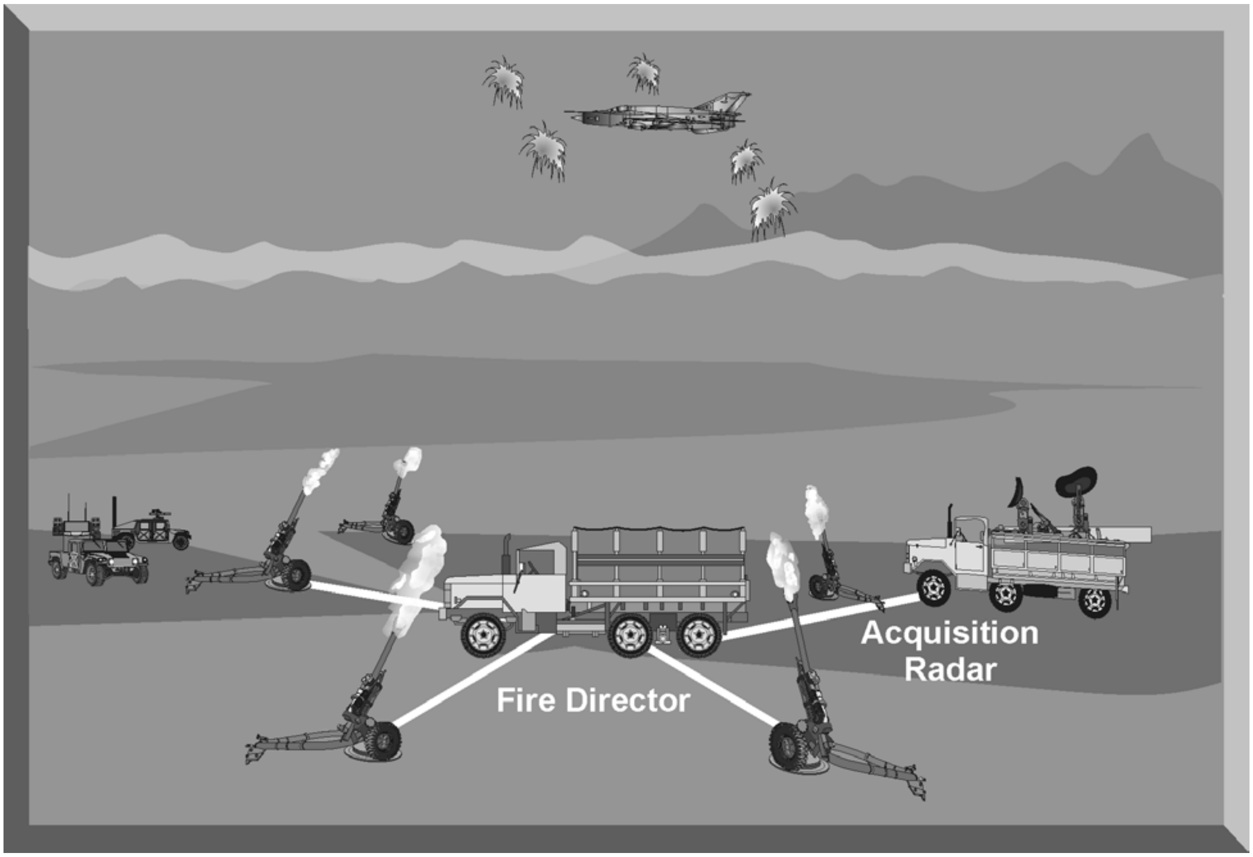

Figure 8-13. Optically Aimed AAA

(1) The typical engagement sequence for an aimed AAA engagement employing a TTR and fire control computer begins with initial target data from an acquisition radar. The guns and TTR are pointed toward the target. The TTR initiates search and lock-on to the target. The TTR associated with large caliber AAA is usually a conical scan radar to provide accurate target positioning information. Target information is fed into the fire control computer which calculates the aim point, points the guns, and initiates firing. The fire control computer uses the target kinematic data, gun ballistics, wind, air density, and projectile dispersion pattern to compute the required aim point. All these computations are based on the assumption that the target will continue on the same heading, at the same altitude, and at the same airspeed during the projectile TOF.

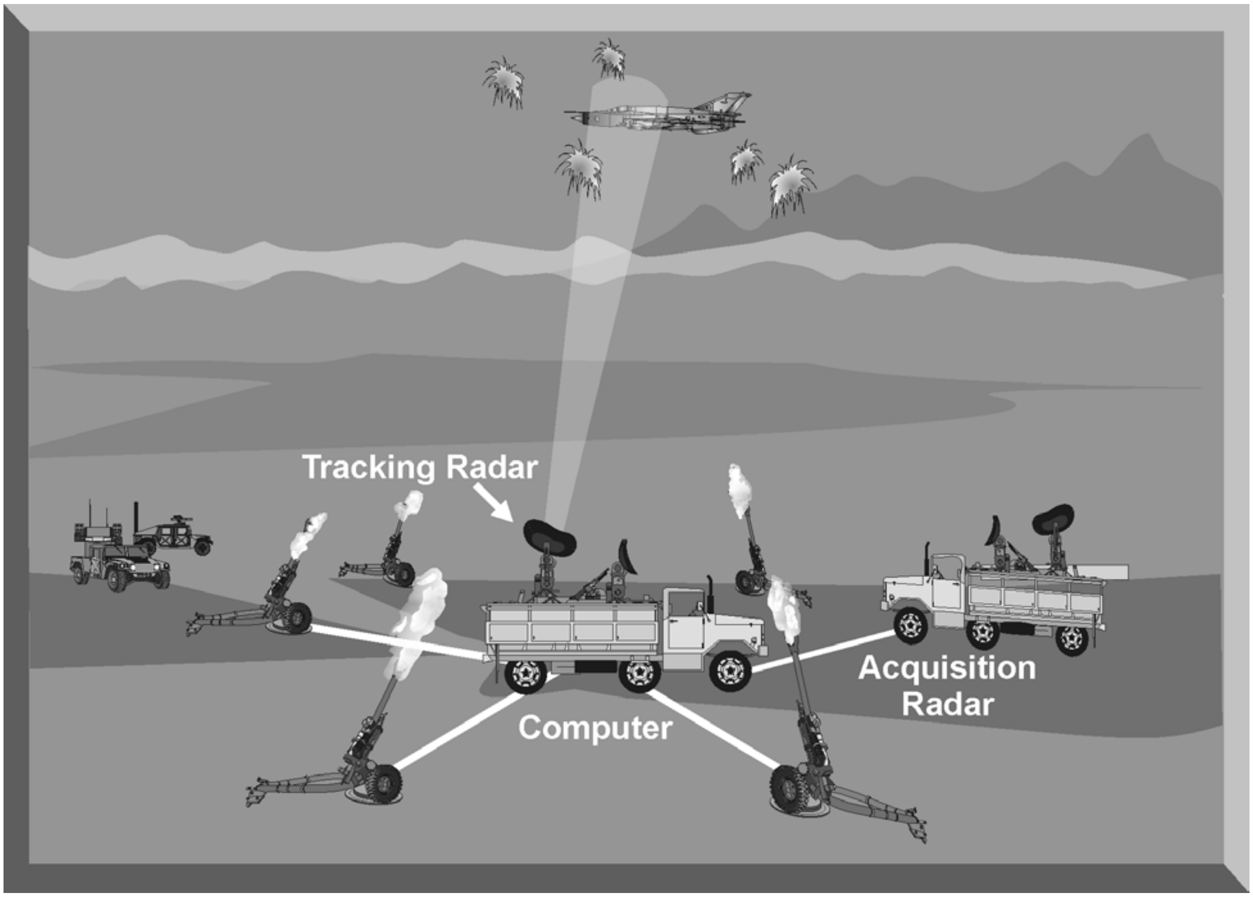

Figure 8-14. Radar-Directed AAA

(2) The typical engagement sequence for an aimed AAA engagement, employing optical target tracking begins with initial target information from an acquisition radar to the fire director. The fire director gives gross aiming commands to the individual guns. The gunners then visually search for the target and use the on-carriage gun sights to predict the required lead angle and initiate firing.

b. Sector or barrage fire tactics are employed when the aircraft cannot be accurately tracked (Figure 8-15). Acquisition information suggests an aircraft will traverse a volume of airspace or a specific sector. The fire director instructs the gunners to fire randomly into this sector in an effort to hit the aircraft with the barrage of AAA fire, or have the aircraft fly into a “curtain” of AAA fire. This tactic is especially effective for point defense for a fixed target. Attacking aircraft may have to fly a predictable flight path during weapons delivery. Sector/barrage fire can be directed to cover the expected attack directions and altitudes.

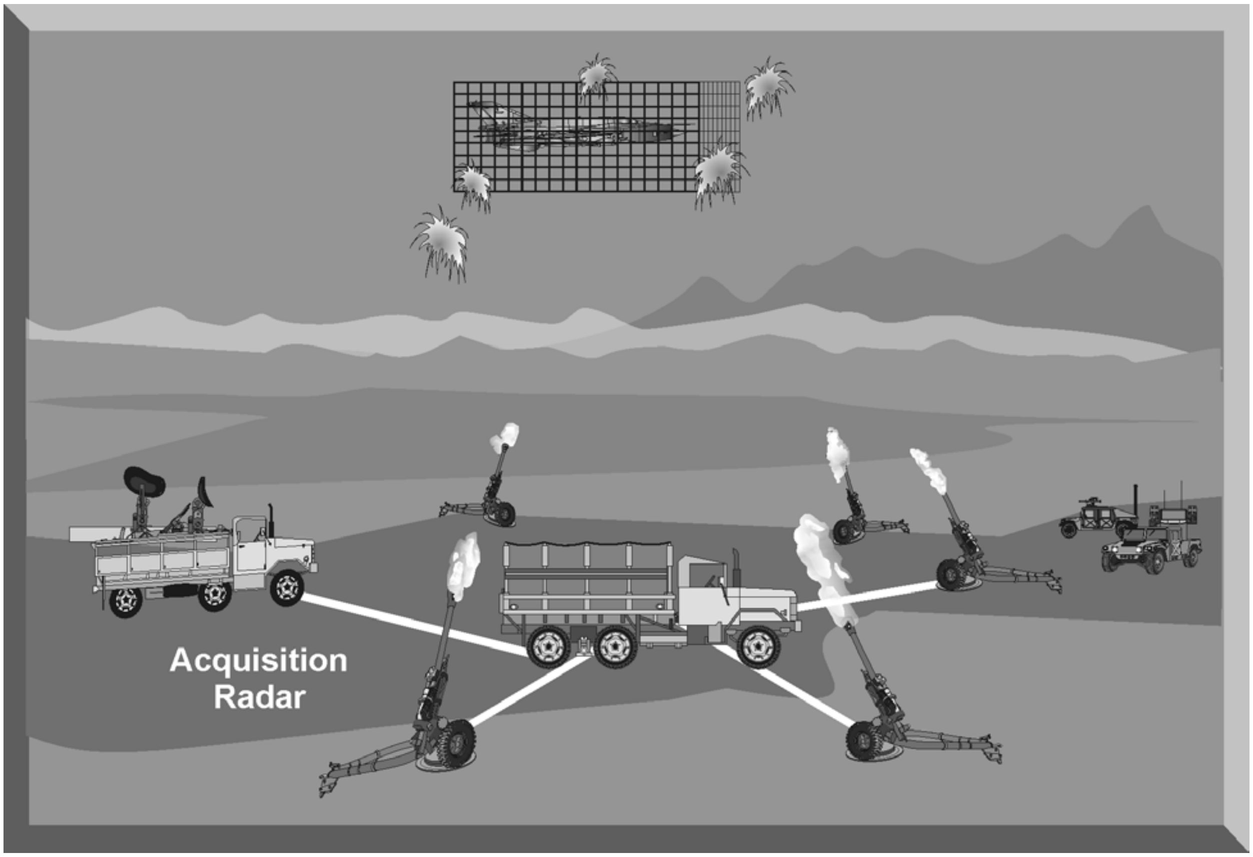

Figure 8-15. Sector/Barrage AAA

7. SUMMARY

This chapter has discussed the most common missile guidance techniques and AAA firing modes used by modern threat systems. A familiarity with the guidance technique employed by specific threat systems is the key to understanding the jamming techniques, chaff/flare employment settings, and tactical maneuvers designed to counter these systems.

CHAPTER 9. INTRODUCTION TO RADAR JAMMING

1. INTRODUCTION

Radar jamming is the intentional radiation or reradiation of radio frequency (RF) signals to interfere with the operation of a radar by saturating its receiver with false targets or false target information. Radar jamming is one principal component of electronic combat (EC). Specifically, it is the electronic attack (EA) component of electronic warfare (EW). Radar jamming is designed to counter the radar systems that play a vital role in support of an enemy integrated air defense system (IADS). The primary purpose of radar jamming is to create confusion and deny critical information to negate the effectiveness of enemy radar systems. This chapter will introduce the two types of radar jamming, the three radar jamming employment options, and discuss the fundamental principles that determine the effectiveness of radar jamming.

2. RADAR JAMMING TYPES

There are two types of radar jamming: noise and deception.

a. Noise jamming is produced by modulating a RF carrier wave with noise, or random amplitude changes, and transmitting that wave at the victim's radar frequency. It relies on high power levels to saturate the radar receiver and deny range and, occasionally, azimuth and elevation information to the victim radar (Figure 9-1). Noise jamming takes advantage of the extreme sensitivity of the radar receiver and the transmission pattern of the radar antenna to deny critical information to the victim radar.

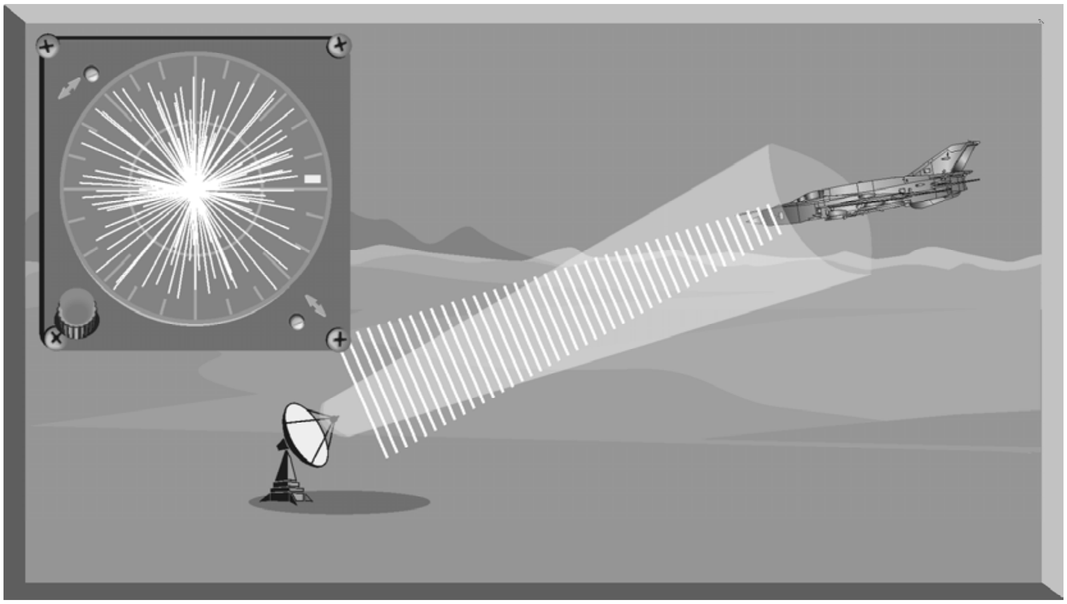

Figure 9-1. Noise Jamming

b. Deception jamming uses complex receiving and transmitting circuits to process and retransmit jamming pulses that appear as a real target to the victim radar. A deception jammer receives the signal from the victim radar and alters the signal to provide false range, azimuth, or velocity information. The altered signal is then retransmitted (Figure 9-2). The victim radar processes this signal, which disrupts the victim radar and confuses the radar operator. To be effective, deception jamming must match not only the victim radar's operating frequency, but all the other operating characteristics, including pulse repetition frequency (PRF), pulse repetition interval (PRI), pulse width, and scan rate.

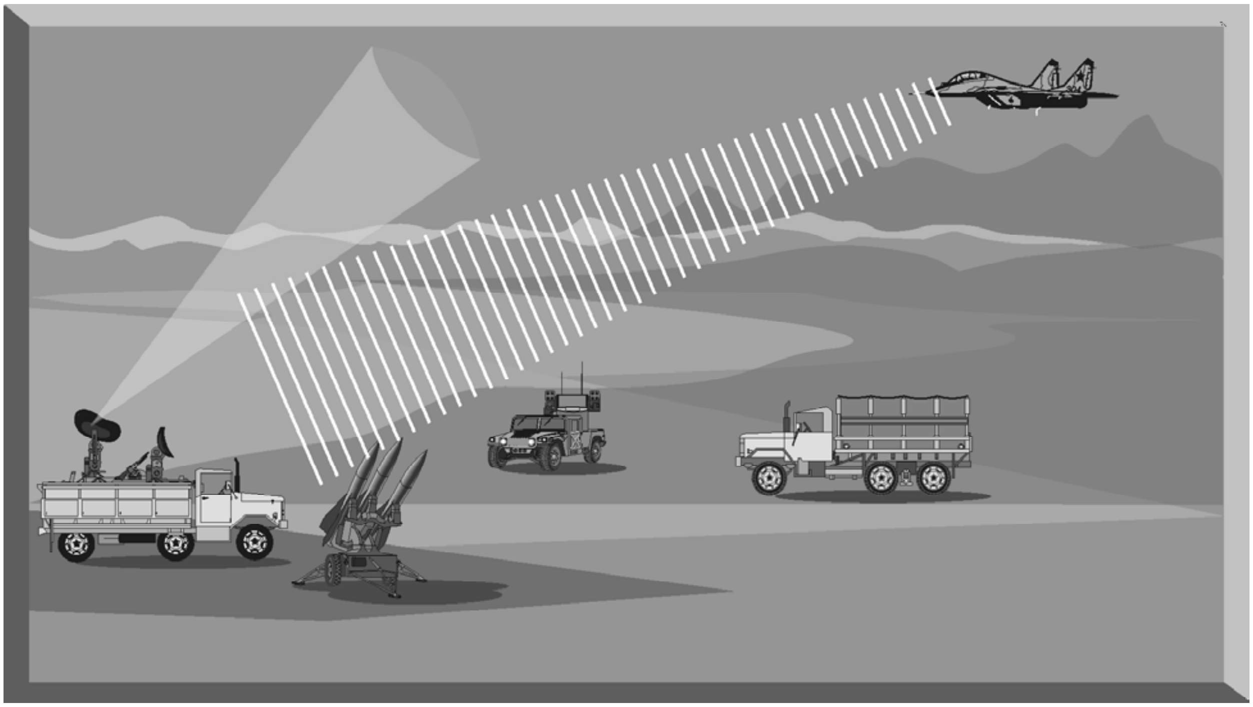

Figure 9-2. Deception Jamming

c. Both noise and deception jamming effectiveness are heavily dependent on another component of EW, specifically, electronic warfare support (ES). ES assets, either airborne or ground-based, provide the threat system specific radar parametric data and update this critical information based on observed threat system operations. This data provides the foundation for developing noise and deception jamming techniques. Intelligence and engineering assessment of this data are used to identify specific threat system weaknesses that can be exploited with the optimum noise, deception, or combination of jamming techniques. This information is then programmed into jamming systems to counter specific threats.

3. RADAR JAMMING EMPLOYMENT OPTIONS

There are currently two primary employment options for both noise and deception jamming techniques. These options are: (1) support jamming, and (2) self-protection jamming. Support jamming can be broken down further into stand-off jamming (SOJ), and escort jamming.

a. To counter early warning, ground control intercept (GCI), and acquisition radars associated with an enemy IADS, noise and deception jamming techniques are employed by specialized support jamming aircraft. The goal of support jamming is to create confusion and delays within the command and control structure of the IADS. Deny, delay or degrade the enemy's ability to engage friendly forces. Support jamming operations can be focused against a national level IADS through the use of a stand-off jamming (SOJ) profile (Figure 9-3) or against a target area threat array using an escort jamming profile.

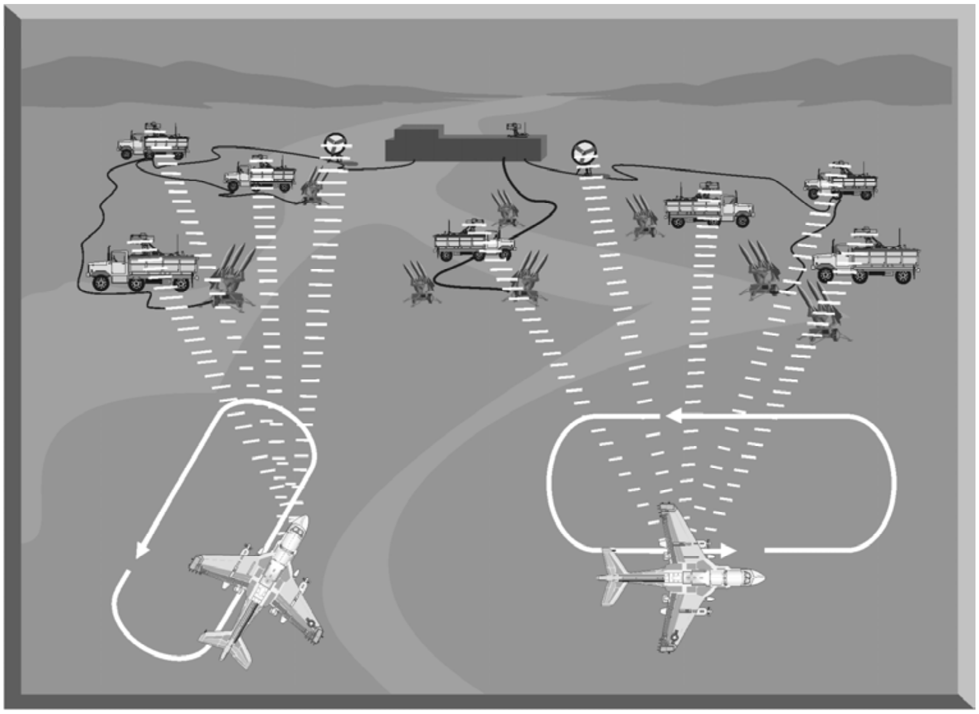

Figure 9-3. Stand-Off Jamming

(1) From an orbit area outside the surface-to-air missile (SAM) engagement zone, SOJ aircraft employ specialized jamming techniques to deny the enemy information about the attack package. SOJ aircraft employ specialized noise jamming techniques to generate jamming strobes on the victim radar display. This effectively denies range and azimuth information on aircraft ingressing and egressing the area covered by the noise jamming strobes. Intensity of the strobes is based on the power in the jamming. The area covered is based on the amount of jamming that can be injected into the main beam and sidelobes of the victim

radar. The effectiveness of SOJ noise jamming is determined by the power the jammer can generate relative to the power the victim radar can generate. This is called the jamming-to-signal (J/S) ratio.

(2) SOJ aircraft can also employ a deception technique to generate false targets to confuse the radar operator and mask the presence of real targets (Figure 9-4). In this specialized technique, the deception jammer must tune to the frequency, PRF, and scan rate of the victim radar. The jammer then transmits multiple jamming pulses that the victim radar receiver processes like real target returns. With enough power, the deception jammer can generate multiple false azimuth targets by injecting jamming pulses into the sidelobes of the victim radar. False moving targets and false range targets are generated by varying the time delay of the jamming pulses based on the PRF and scan rate of the victim radar.

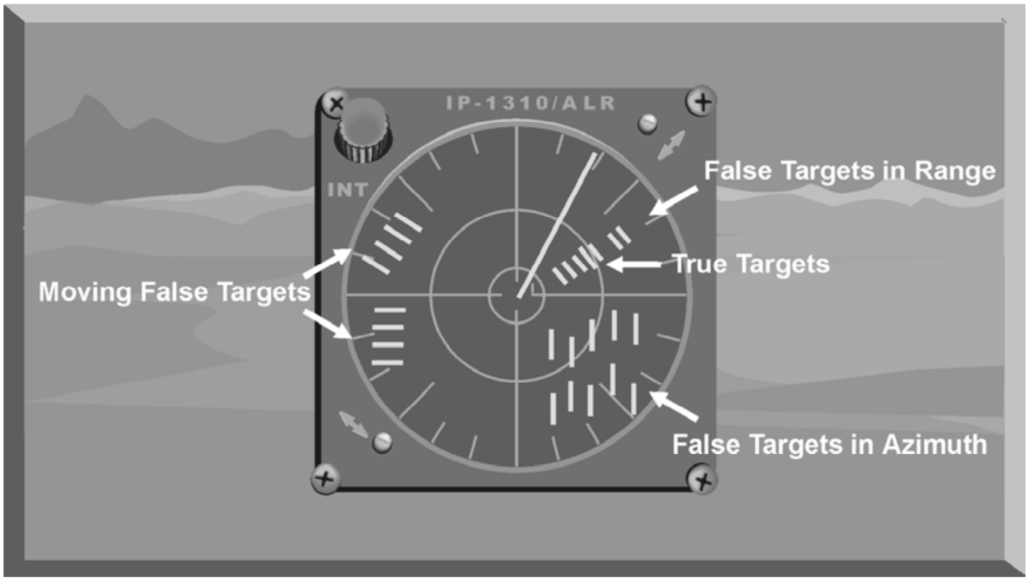

Figure 9-4. False Target Jamming

(3) Escort jamming is a specific tactic used by the EA-6B Prowler. The EA-6B is employed as an integral part of the attack package and is normally positioned behind and above the attack package (Figure 9-5).

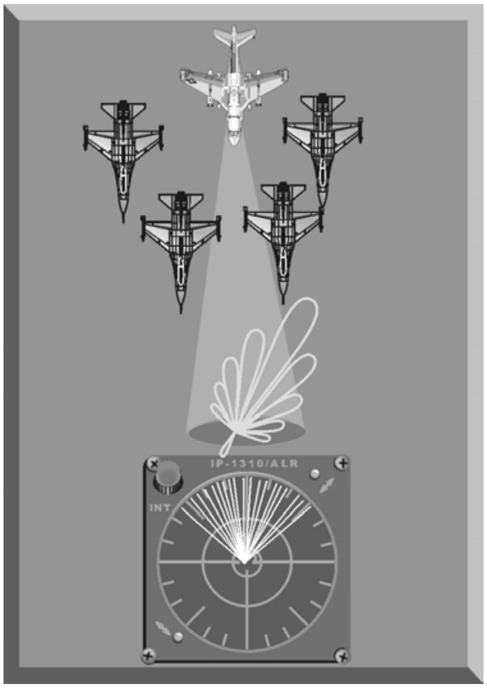

Figure 9-5. Escort Jamming

Using noise jamming, the EA-6B attempts to deny range and azimuth information to the victim radar by injecting high power signals into the main radar beam and sidelobes. To be effective, the EA-6B must be properly positioned in relation to the ingressing or egressing attack package (Figure 9-6).

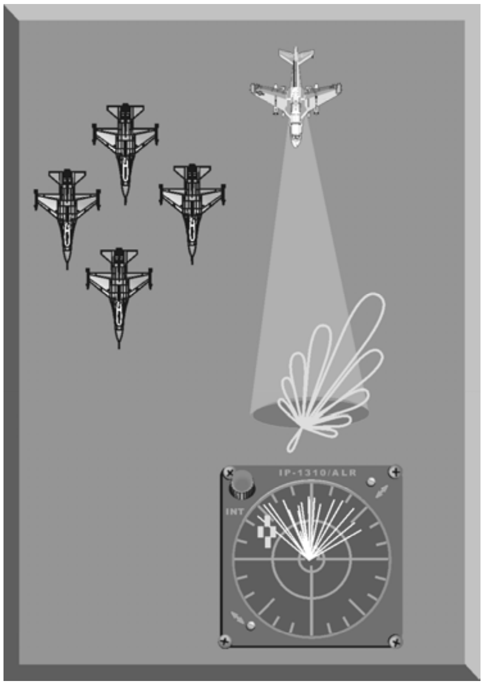

Figure 9-6. Escort Jamming Alignment

b. Self-protection radar jamming targets the radar systems that support jamming cannot negate. Self-protection jamming systems are part of a self-protection suite that includes a self-protection jamming pod, a chaff/flare dispenser, and on some aircraft, a towed decoy system. The overall purpose of these systems is individual aircraft survivability. These systems are designed to counter the individual SAM, AAA, and AI assets associated with the enemy IADS. They employ deception jamming techniques against the target tracking radars (TTRs) associated with these threats. They are designed to break the radar track or generate sufficient tracking errors to cause the missile or bullet to miss the aircraft.

(1) Self-protection radar jamming systems usually employ deception jamming techniques based on several factors. First, effective deception jamming techniques generally require less power than noise jamming techniques. Second, less power means less weight and space, which are very important considerations for modern tactical aircraft. Finally, deception jammers can be designed to jam multiple threats, which is a critical requirement for operations in a dense threat environment (Figure 9-7).

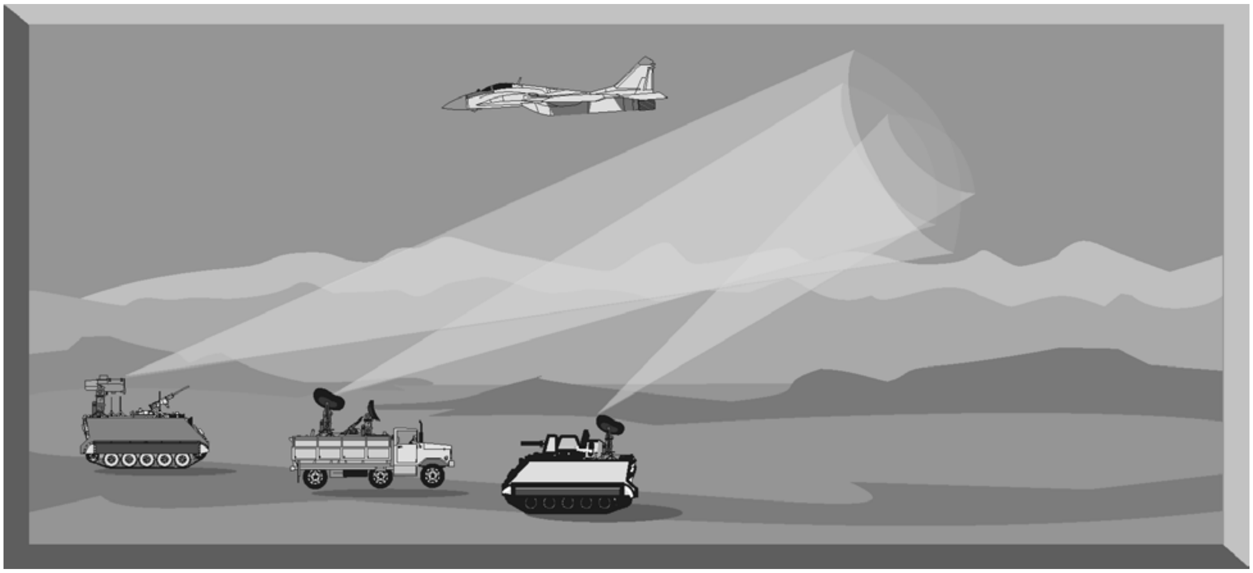

Figure 9-7. Self-Protection Jamming

(2) Despite the advantages of deception jamming techniques for self-protection jamming, there are some limitations that must be considered. First, deception jammers are complex electronic systems that must receive a victim radar's signal, memorize all its characteristics, modify the signal, and retransmit this modified signal at a high power level. Second, to be effective, deception jammers must be programmed with all the signal parameters (frequency, PRF, PRI, pulse width, scan rate, etc.) of the victim radar. Finally, because many deception techniques can be effective against specific threats, selecting optimum techniques to employ against these threats must be based on identified threat

system limitations. Identifying these specific threat systems limitations may be difficult.

4. FUNDAMENTALS OF RADAR JAMMING

There are some fundamental principles that apply to all types of jamming and to all jamming employment options. These principles are based on the characteristics of the jamming system and the characteristics of the victim radar. They include frequency matching, continuous interference, signal-to-noise ratio, jamming-to-signal ratio, and burnthrough range.

a. Based on the data provided by ES systems and intelligence evaluations, radar jamming systems must transmit signals at the frequency of the victim radar This applies to both noise and deception jamming. If a jamming signal does not match the transmitter frequency, the jamming signal is not received and displayed on the scope (Figure 9-8). When a jamming signal matches the transmitter frequency, the jamming signal is received and masks the target display (Figure 9-9).

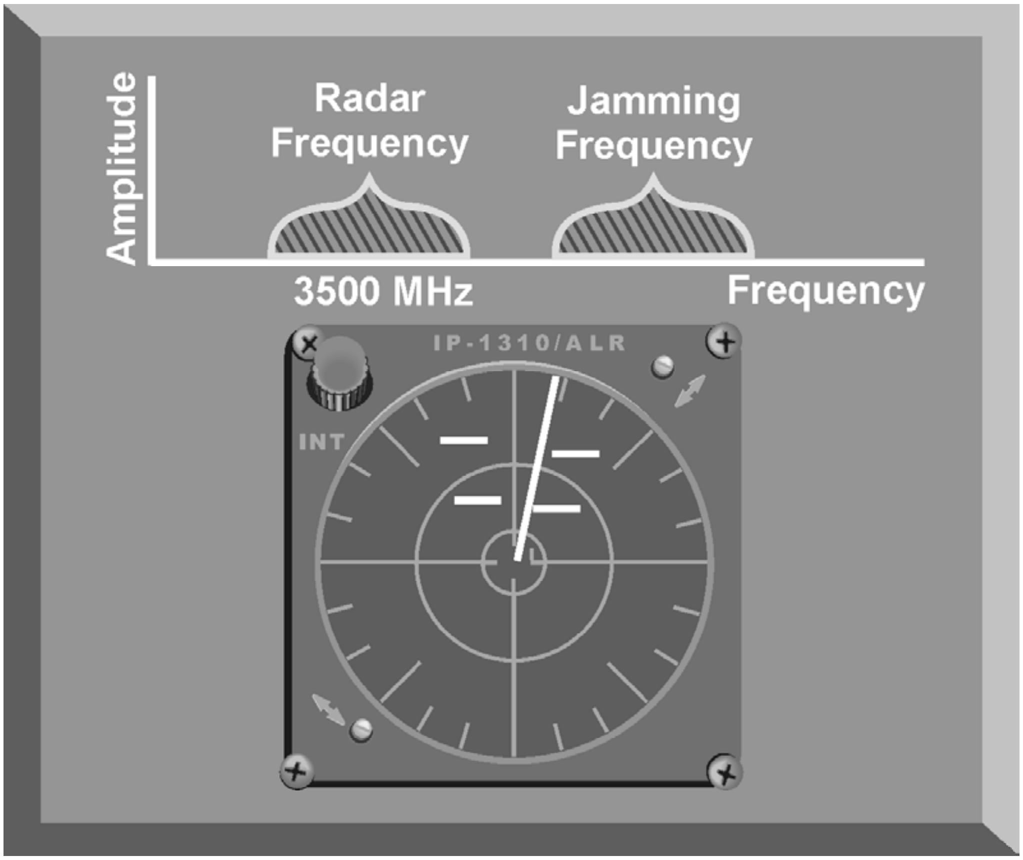

Figure 9-8. Jamming Frequency Error

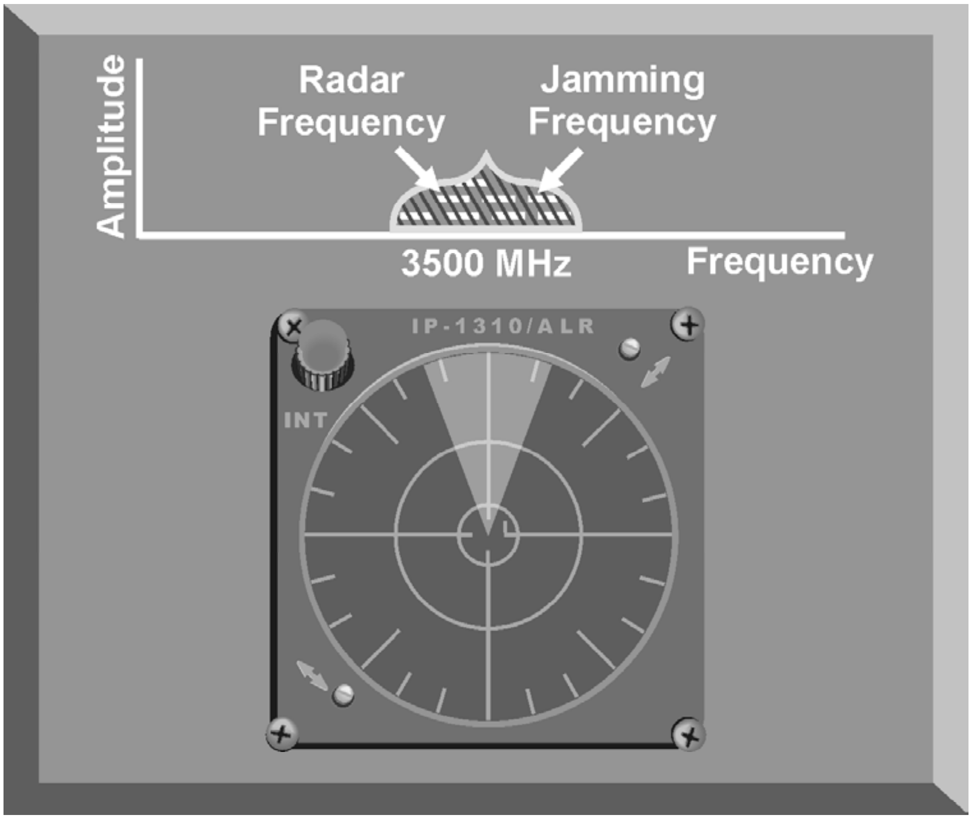

Figure 9-9. Correct Jamming Frequency Matching

b. For maximum effectiveness, a jamming transmitter should produce continuous interference. In much the same way intermittent static on a radio receiver does not completely block out a signal, intermittent jamming on a radar scope may not completely mask the target. An experienced radar operator or advanced automatic tracker can "read through" intermittent jamming and derive sufficient target information to negate jamming effectiveness. While true for noise jamming techniques, continuous interference also applies to deception techniques, especially when target reacquisition is considered.

c. The signal-to-noise (S/N) ratio is a measure of the ability of the victim radar to detect targets. It is also an indication of the vulnerability of the radar to certain jamming techniques, especially noise jamming.

(1) From the discussion of the basic radar equation in Chapter 5 (Equation 5-10), Equation 9-1 is the signal power density of a target return at the radar receiver. The signal power density of the target return is so weak that it requires very strong amplification before processing and display. Besides the signal power from the target, some level of thermal noise is also generated and amplified along with the target signal. For an "ideal" (no noise) amplifier, Equation 9-2 is used to compute the level of thermal noise generated by the amplifier.

$$\text{Signal Power Density} = \frac{P_T G \sigma A_e}{(4\pi)^2 R^4}$$

P_T = transmitted power
G = antenna gain
σ = target radar cross section (RCS)
A_e = antenna aperture area
R = range to the target

Equation 9-1. Signal Power Density

$$\text{Thermal Noise (N)} = KTBF$$

K = Boltzman's Constant (1.38×10^{-23} watts/Hz degrees K)
T = standard temperature (290° K)
B = radar receiver equivalent bandwidth
F = radar receiver noise figure (one for "ideal" receiver)

Equation 9-2. Thermal Noise

Note: The instantaneous bandwidth of a receiver is the frequency range over which the receiver can simultaneously amplify two or more signals to within a specified gain.

(2) The radar receiver amplifies both target signal and thermal noise. The output of the radar receiver will contain the target signal and the noise amplified across the bandwidth of the receiver. Separating the desired target signal from the undesired noise signal is one of the major problems confronting radar designers.

(3) Equation 9-3 is derived by dividing Equation 9-1 by Equation 9-2. Many factors in this equation fluctuate and must be estimated using statistical calculations. For example, target RCS fluctuates based on the changing angle of the antenna beam and corresponding changes in the reflected signal. Effective antenna aperture is also a statistical phenomenon based on the fluctuations in target RCS. The thermal noise generated by a receiver is also a fluctuating factor and must be treated statistically. This means that the S/N ratio is a statistical factor associated with a probability of target detection and a probability of a false alarm. A false alarm occurs when the radar operator or automatic tracking circuit designates a fluctuation in noise level as a target. The higher the S/N ratio, the

higher the probability of target detection with a corresponding reduction in the probability of a false alarm.

$$\text{Signal-to-Noise Ratio} = \frac{P_T G \sigma A_e \left(\dfrac{1}{(4\pi)^2 R^4}\right)}{KTBF}$$

P_T = transmitted power
G = antenna gain
σ = target radar cross section (RCS)
A_e = antenna aperture area
R = range to the target

K = Boltzman's Constant (1.38×10^{-23} watts/Hz degrees K)
T = standard temperature (290° K)
B = radar receiver equivalent bandwidth
F = radar receiver noise figure (one for "ideal" receiver)

Equation 9-3. Signal-to-Noise Ratio

(4) An analysis of Equation 9-3 suggests that any action that increases the power in the target signal (for example, increasing transmitted power, increasing antenna gain/aperture area, or decreasing target range) will improve the S/N ratio and improve the probability of target detection. It would also appear that decreasing the bandwidth of the radar receiver will increase the S/N ratio and enhance the probability of target detection. However, if the effective bandwidth of the receiver is reduced, this may eliminate a significant portion of the radar signal spectrum and decrease the probability of target detection.

(5) The S/N ratio is also an indication of the range at which a target will be detected. A plot of the receiver output of a typical radar is shown in Figure 9-10. The weak target signal at an extended range is just above the receiver noise level. The target at closer range is easily detected above the noise level. A radar operator or automatic target detector could mistake the very weak target return as a fluctuation in the receiver noise level. This could result in a missed detection. The lack of discrimination between noise and target returns because of a poor S/N ratio can also result in designating fluctuations in the noise level as actual target signals, known as false alarms.

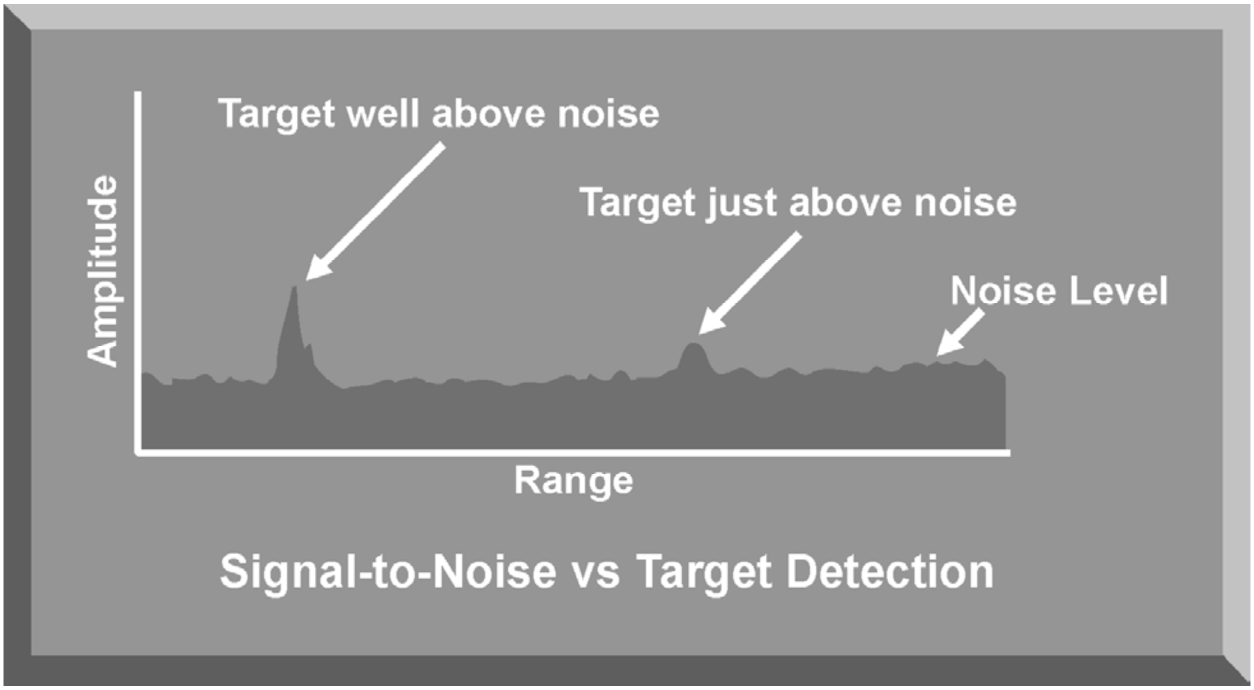

Figure 9-10. S/N Ratio and Target Detection

(6) To preclude, or minimize false alarms, the radar receiver may be equipped with electronic circuits to establish a false alarm threshold. If the signal strength of a radar return is below this threshold level, it will not be detected or displayed (Figure 9-11). This false alarm threshold also influences the probability of target detection. With the threshold set too high, many detected targets will not be displayed. Additionally, if the false alarm threshold is raised automatically in relation to the amplitude of the receiver noise, the radar receiver is more vulnerable to noise jamming.

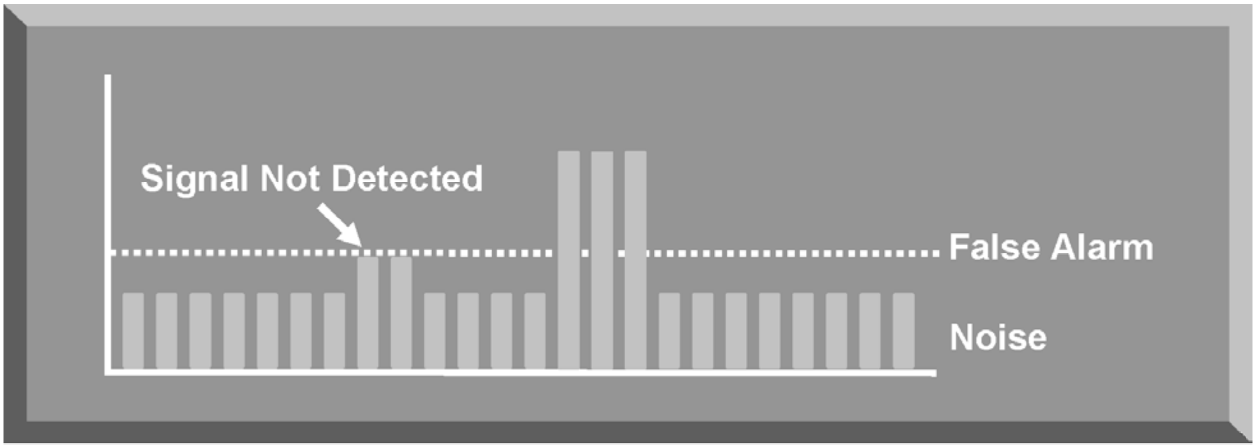

Figure 9-11. Receiver False Alarm Threshold

(7) For any target return to be detected by the radar, the S/N ratio must be greater than one. If the S/N ratio is less than one, the target will not be detected above the receiver noise level. The purpose of noise jamming is to raise the level of noise in the radar receiver to reduce the S/N ratio to less than one. This masks the presence of the true target return. If a false alarm threshold is used, noise jamming raises this threshold to further complicate target detection. Figure 9-12 depicts a S/N ratio greater than one. Figure 9-13 depicts a S/N ratio of less than one due to noise jamming.

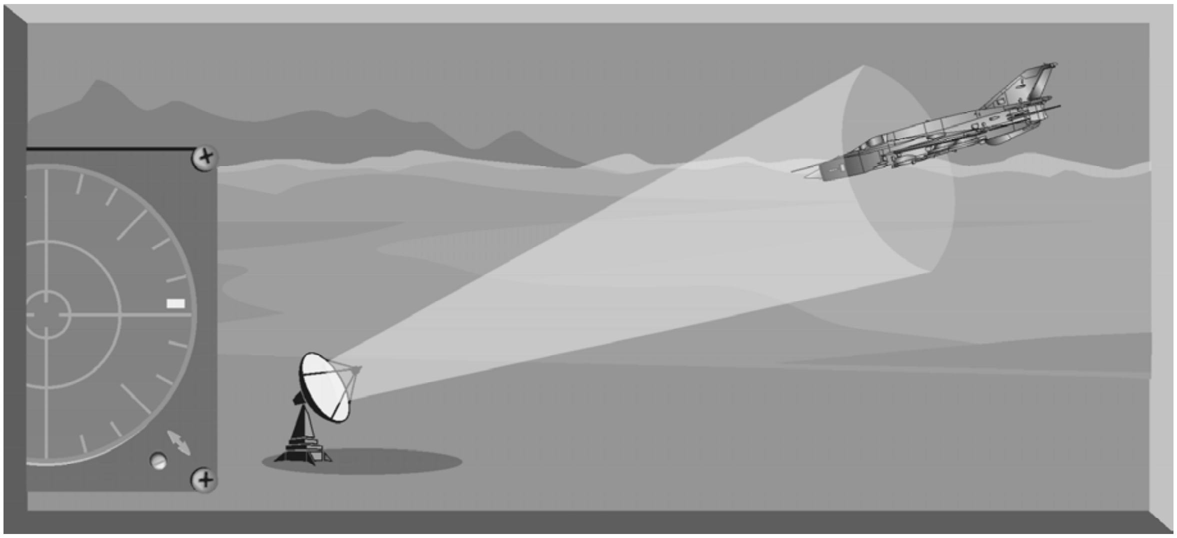

Figure 9-12. S/N Ratio Greater Than One

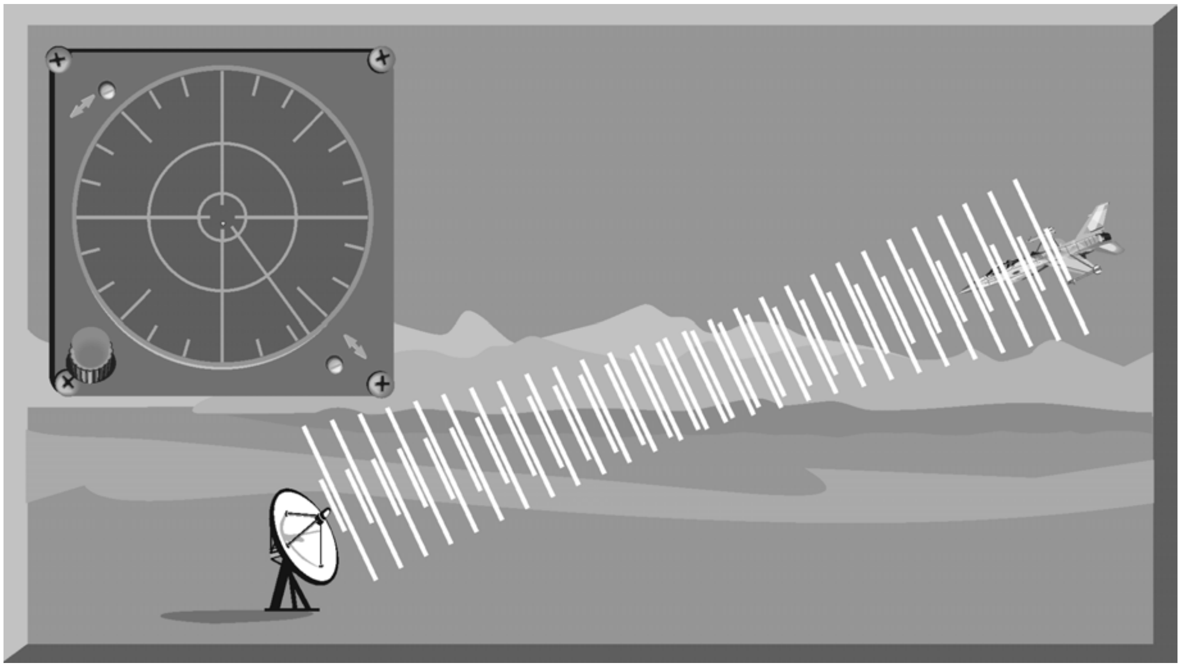

Figure 9-13. S/N Ratio Less Than One

d. The jamming-to-signal (J/S) ratio is a fundamental measure of jamming effectiveness. The J/S ratio compares the power in the jamming signal with the power in the radar return. Equation 9-4 is an expression of the J/S ratio. It is important to note that the J/S ratio should be measured at the output of the radar receiver. This will allow consideration of the receiver signal processing gain applied to the jamming signal.

$$\text{Jamming-to-Signal Ratio} = \frac{P_J G_J}{P_T G_T} \times \frac{4\pi R^2}{\sigma}$$

P_J = jamming power transmitted
G_J = jamming antenna gain
P_T = peak power transmitted by the radar
G_T = radar antenna gain
R = range from jammer to radar
σ = aircraft RCS

Equation 9-4. Jamming-to-Signal Ratio

(1) The most critical factor in both the S/N and the J/S ratios is range. The S/N ratio is calculated based on R to the fourth power. This equates to a signal traveling from the radar to the target, and back to the radar receiver. The J/S ratio is calculated using R to the second power. This factor reflects the “one way” transmission of the jamming pulse from the jammer to the victim radar's receiver.

(2) For a jamming signal to be effective, the J/S ratio must be greater than one. In general, threat radars, especially ground-based radars, transmit much more power than does an airborne jamming system. However, this power must travel twice as far as the airborne jamming signal. At long ranges, a low power jamming system can generate a J/S ratio much greater than one. In Figure 9-14, the jamming pulse completely masks the target return. As the jamming system approaches the target, the distance the radar pulse travels decreases with a corresponding increase of power in the radar return. This reduces the J/S ratio to a value less than one and the radar “sees” the target. This is called the burnthrough range (Figure 9-15).

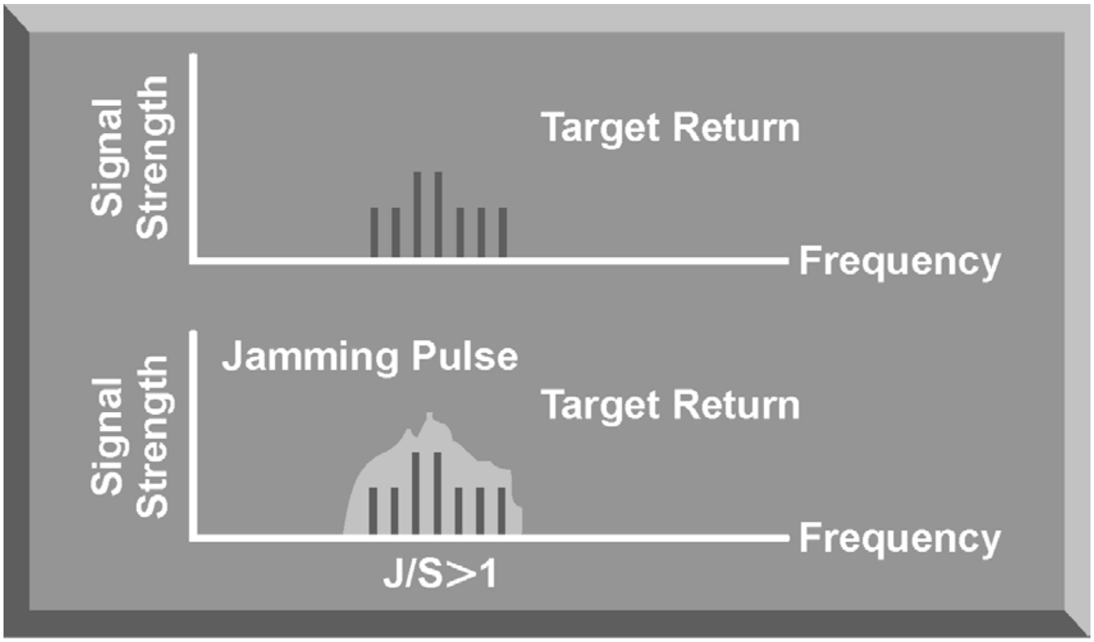
Signal Strength
Target Return
Frequency
Signal Strength
Jamming Pulse
Target Return
Frequency
J/S>1

Figure 9-14. J/S Ratio Greater Than One

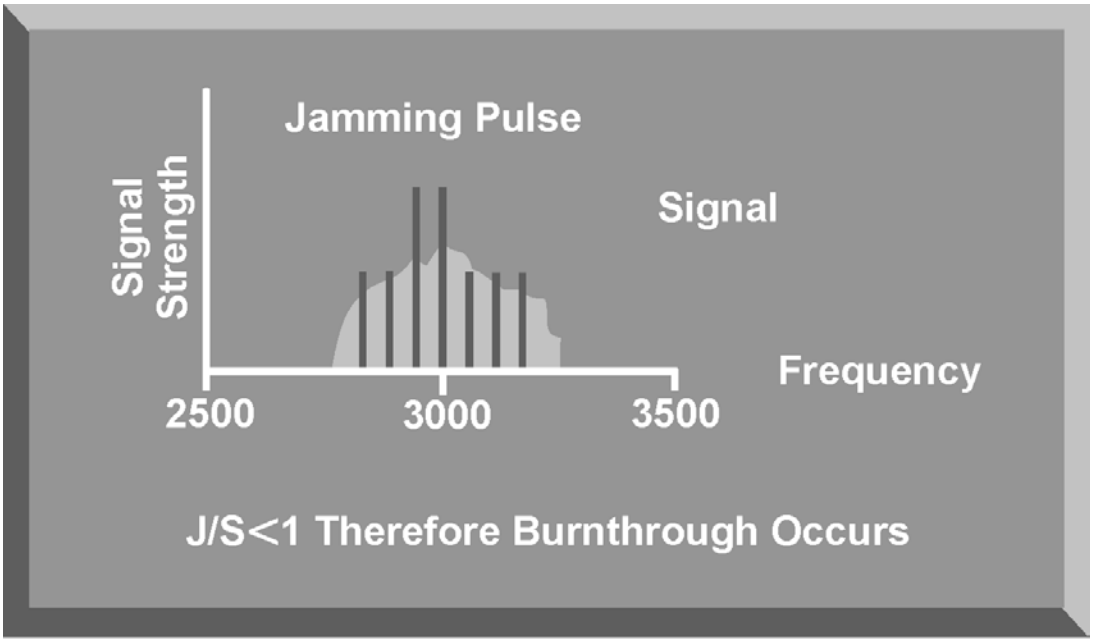
Jamming Pulse
Signal Strength
Signal
Frequency
2500
3000
3500
J/S<1 Therefore Burnthrough Occurs

Figure 9-15. J/S Ratio Less Than One

e. Burnthrough occurs when the power in the reflected target signal exceeds the power in the jamming signal. Even when an optimum and continuous jamming technique is transmitting on the exact frequency of the victim radar, the jamming starts to lose effectiveness as it nears the radar. For a particular radar

jamming technique, burnthrough range depends on the detection capability of the victim radar, expressed as the S/N ratio, and the capability of the aircraft's jamming system, expressed as the J/S ratio. The idea of burnthrough range explains why a jamming technique, especially noise jamming, loses its effectiveness as the aircraft approaches the radar. When plotting the jamming and signal power versus range (Figure 9-16), these two values intersect at the point where the J/S ratio is one. At closer ranges, the jamming pulse is no longer masking the aircraft, and the aircraft can be detected. Burnthrough range is the point where the radar can see through the jamming.

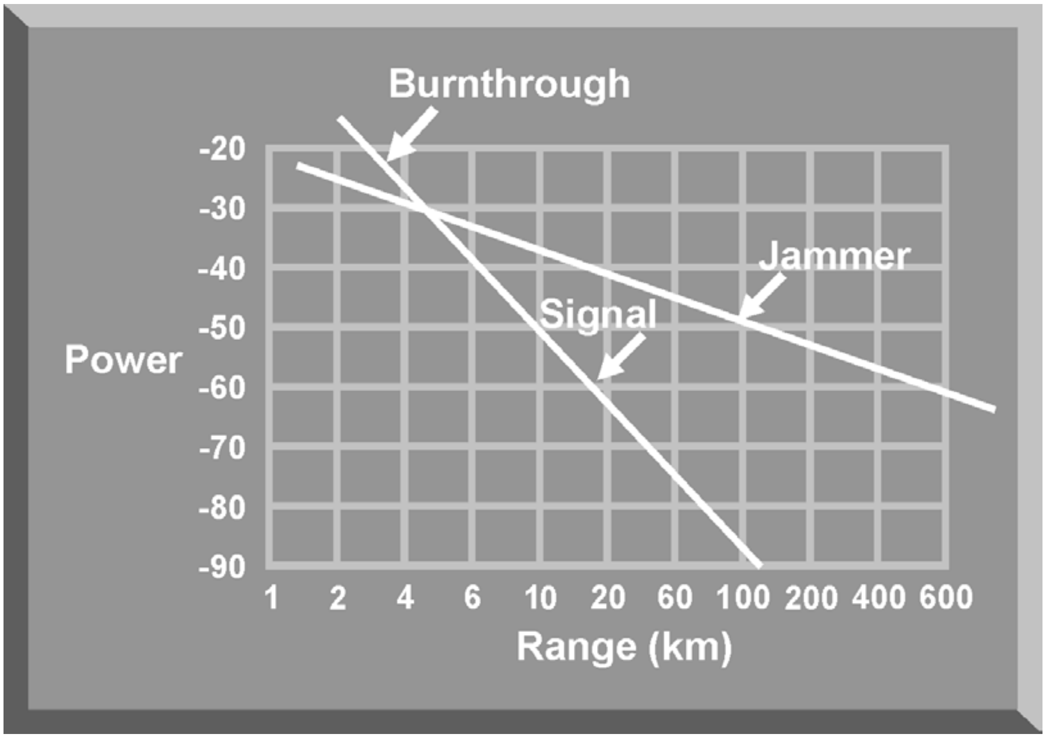

Figure 9-16. Burnthrough Range

5. SUMMARY

The purpose of radar jamming is to confuse or deny critical data to the radar systems that play a vital role in supporting the mission of an integrated air defense system. Two types of radar jamming, noise and deception, can be employed in a support-jamming role, or in a self-protection role for individual aircraft. The effectiveness of a jamming technique depends on the ability of the jamming system to generate a jamming signal that replicates the parameters of the victim radar, especially its frequency. The signal-to-noise ratio of the victim radar determines the vulnerability of the radar receiver to jamming while the jamming-to-signal ratio is an indication of the ability of the jamming system to effectively jam the victim radar. These basic radar jamming concepts are fundamental to understanding the impact of specific jamming techniques on radar systems.

CHAPTER 10. RADAR NOISE JAMMING

1. INTRODUCTION

A radar noise jamming system is designed to generate a disturbance in a radar receiver to delay or deny target detection. Since thermal noise is always present in the radar receiver, noise jamming attempts to mask the presence of targets by substantially adding to this noise level. Radar noise jamming can be employed by support jamming assets or as a self-protection jamming technique. Radar noise jamming usually employs high-power jamming signals tuned to the frequency of the victim radar. This chapter will discuss the factors that determine the effectiveness of radar noise jamming, radar noise jamming generation, and the most common noise jamming techniques. These noise jamming techniques include barrage, spot, swept spot, cover pulse, and modulated noise jamming.

2. RADAR NOISE JAMMING EFFECTIVENESS

The effectiveness of radar noise jamming depends on numerous factors. These factors include the jamming-to-signal (J/S) ratio, power density, the quality of the noise signal, and the polarization of the transmitted jamming signal (Figure 10-1).

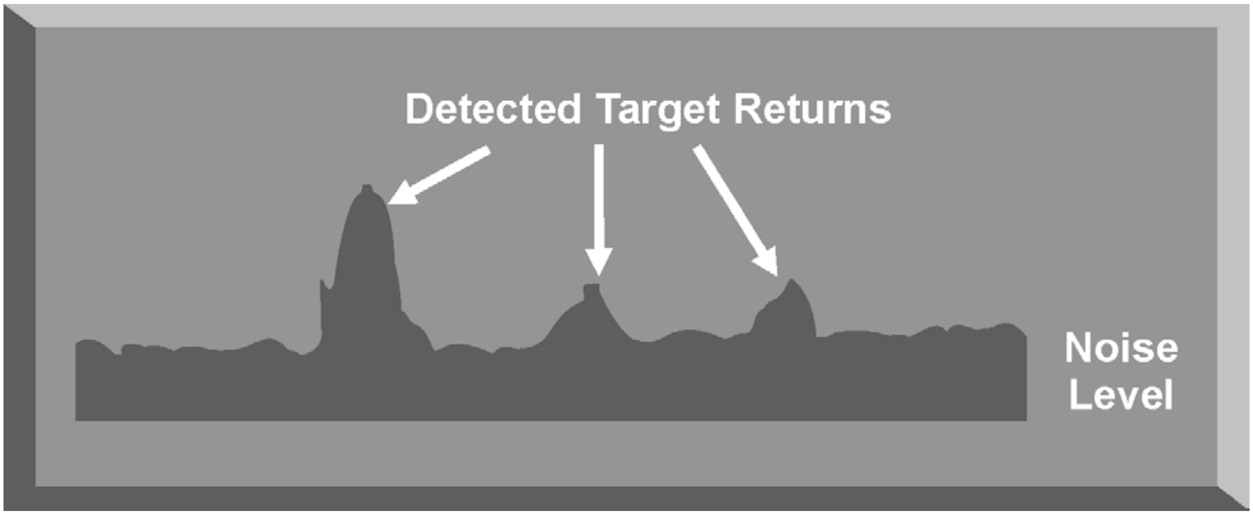

Figure 10-1. Noise Level in a Typical Radar Receiver Output

a. One of the most important factors that impacts the effectiveness of radar noise jamming is the J/S ratio (Figure 10-2). As discussed in Chapter 9, the power output of the noise jammer must be greater than the power in the target return, as measured at the output of the radar receiver. To achieve this level of jamming power, radar noise jammers usually generate high-power jamming signals. These high-power jamming signals can be introduced into the victim radar's main beam

to deny range information and into the victim radar's sidelobes to deny azimuth information.

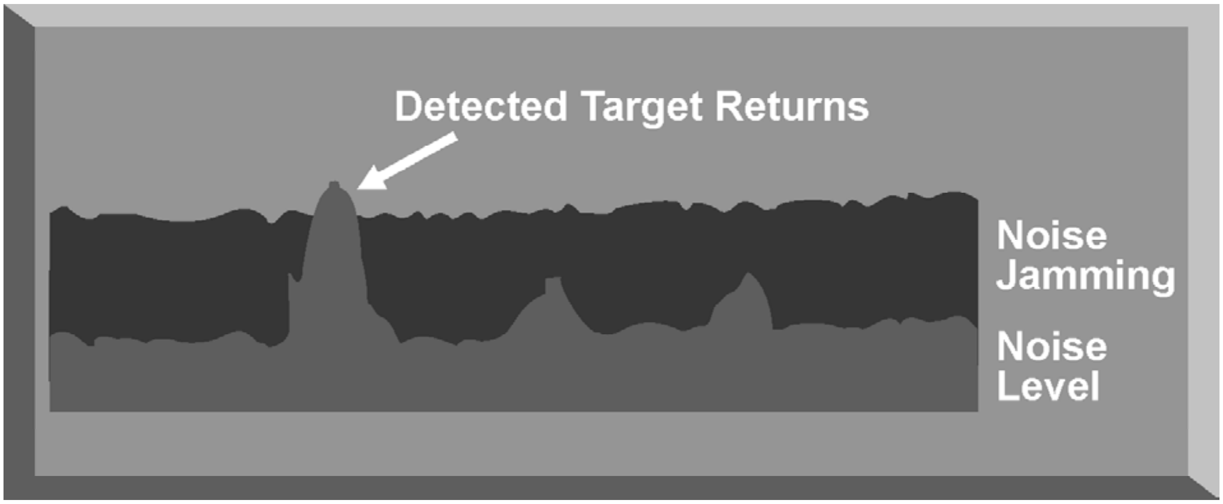
Detected Target Returns
Noise Jamming
Noise Level

Figure 10-2. Impact of Noise Jamming

b. Another factor which impacts the effectiveness of radar noise jamming is the power density. The power density of the noise jamming signal has a direct relation to the J/S ratio.

(1) If the noise jamming signal is centered on the frequency and bandwidth of the victim radar, the jamming signal has a high power density. The ability of a noise jammer to concentrate the jamming signal depends on the ability of the jammer to identify the exact frequency and bandwidth of the victim radar (Figure 10-3).

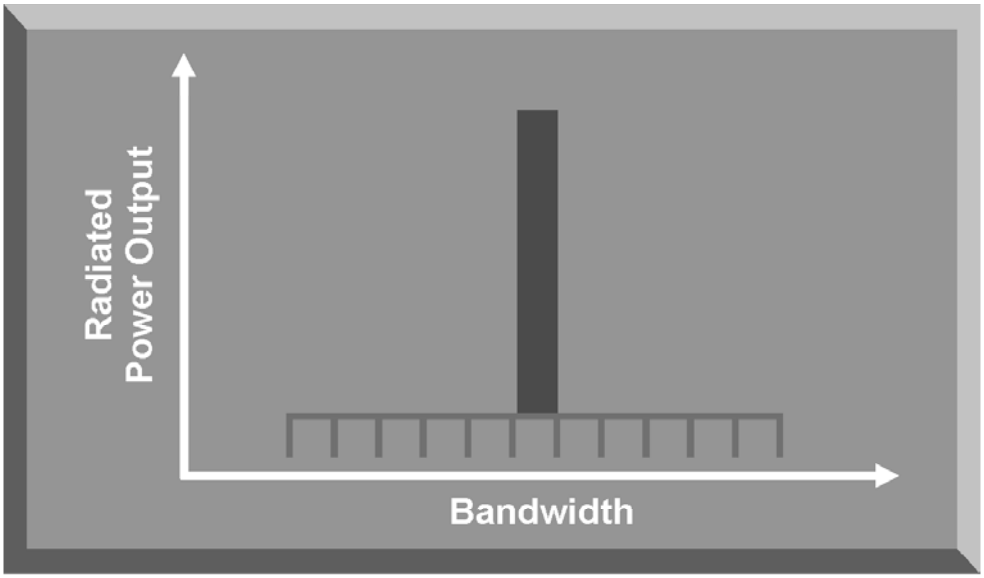
Radiated Power Output
Bandwidth

Figure 10-3. Power Density – Narrow Bandwidth

(2) If the generated noise jamming signal has to cover a wide bandwidth or frequency range, the power density at any one frequency is reduced (Figure 10-4). Radar systems that are frequency agile or that employ a wide bandwidth can reduce, or negate, the effectiveness of noise jamming by reducing the power density of the jamming signal.

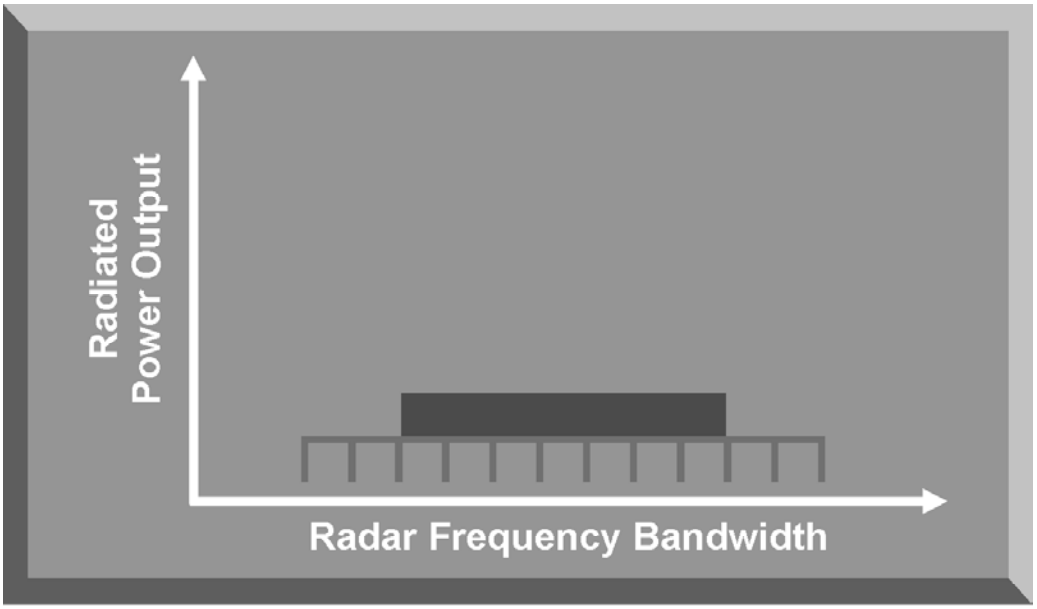

Figure 10-4. Power Density – Wide Bandwidth

c. The quality of the noise jamming also determines its effectiveness. To effectively jam a radar receiver with noise, the jamming signal must emulate the thermal noise generated by the receiver. This ensures that the radar operator or automatic detection circuit cannot distinguish between the noise jamming and normal thermal noise. Thermal noise is referred to as white noise and has a uniform spectrum. All of the frequencies in the bandwidth of the receiver have the same spectrum and an amplitude that varies based on Gaussian distribution. A Gaussian distribution is simply a bell-shaped distribution of amplitudes. In order to be effective, the jamming signal should exactly match the characteristics of the thermal noise signal of the victim radar receiver.

d. Polarization of the noise jamming signal is another significant factor that impacts its effectiveness. As discussed in Chapter 2, if the polarization of the jamming signal does not match the antenna polarization of the victim radar, there is a significant power loss in the jamming signal. Noise jamming systems designed to counter multiple threat radars, with various polarizations, generally use a transmitting antenna with a 45° slant or use circular polarization. Most threat systems are horizontally or vertically polarized. This results in a 50% reduction in effective radiated power (ERP) for most threat systems. A more serious power loss, nearly 100%, in ERP occurs when the jamming antenna is

orthogonally polarized with the victim antenna. The polarization of the noise jamming signal impacts the J/S ratio and the power density.

3. RADAR NOISE JAMMING GENERATION

Noise jamming is produced by modulating an RF carrier wave with random amplitude or frequency changes, called noise, and retransmitting that wave at the victim radar's frequency. Since noise from numerous sources is always present and displayed on a radar scope, noise jamming adds to the problem of target detection. Reflected radar pulses from target aircraft are extremely weak. To detect these pulses, a radar receiver must be very sensitive and be able to amplify the weak target returns. Noise jamming takes advantage of this radar characteristic to delay or deny target detection.

a. The simplest method of generating a high-power Gaussian noise jamming signal is to employ a highly amplified diode to generate a noise signal at the frequency of the victim radar. This signal is filtered and directly amplified to the maximum power that can be generated by the transmitter. This method is called direct noise amplification (DINA). The DINA method of noise generation has a serious limitation. The maximum power available from linear wideband power amplification is extremely limited. Employing any other form of power amplification would alter the Gaussian distribution of the jamming signal. This method of generating radar noise jamming was used extensively during WW II.

b. Modern noise jamming systems generate noise jamming signals by frequency modulating a carrier wave at the frequency of the victim radar. FM noise jammers employ a receiving antenna to intercept the victim's radar signal. The antenna passes the victim radar signal to the receiver for identification. The receiver also tunes the jamming signal generator to the correct frequency. The receiver uses an automatic frequency control (AFC) circuit to tune the voltage-controlled oscillator (VCO) to the frequency of the victim radar. A noise signal is generated by the jamming signal generator and added to the tuning voltage of the VCO to get an FM jamming signal. This signal is sent to a traveling wave tube (TWT) power transmitter. The TWT is normally operated in a saturated mode which produces a high-power jamming signal that covers a wider bandwidth than the victim radar. This reduces the power density of the signal, but the high power levels available from the TWT amplification of an FM signal compensate for this loss. The signal is sent to the transmitting antenna and directed toward the victim radar.

c. Figure 10-5 highlights an important feature of a modern radar noise jamming system: a look-through capability. A look-through mode allows the receiver to periodically sample the signal environment. The objective of the look-through mode is to allow the jammer to update victim radar parameters and change the jamming signal to respond to changes in the signal environment. This greatly enhances the effectiveness of noise jamming systems. One method used to provide a look-through capability is to isolate the transmit and receive

antennas to allow continuous operation of the receiver to update signal parameters. Another method is to switch off the jammer for a brief period to allow the receiver to sample the signal environment. Since this latter look-through method eliminates the jamming signal, the amount of time the jammer is switched off must be kept to a minimum.

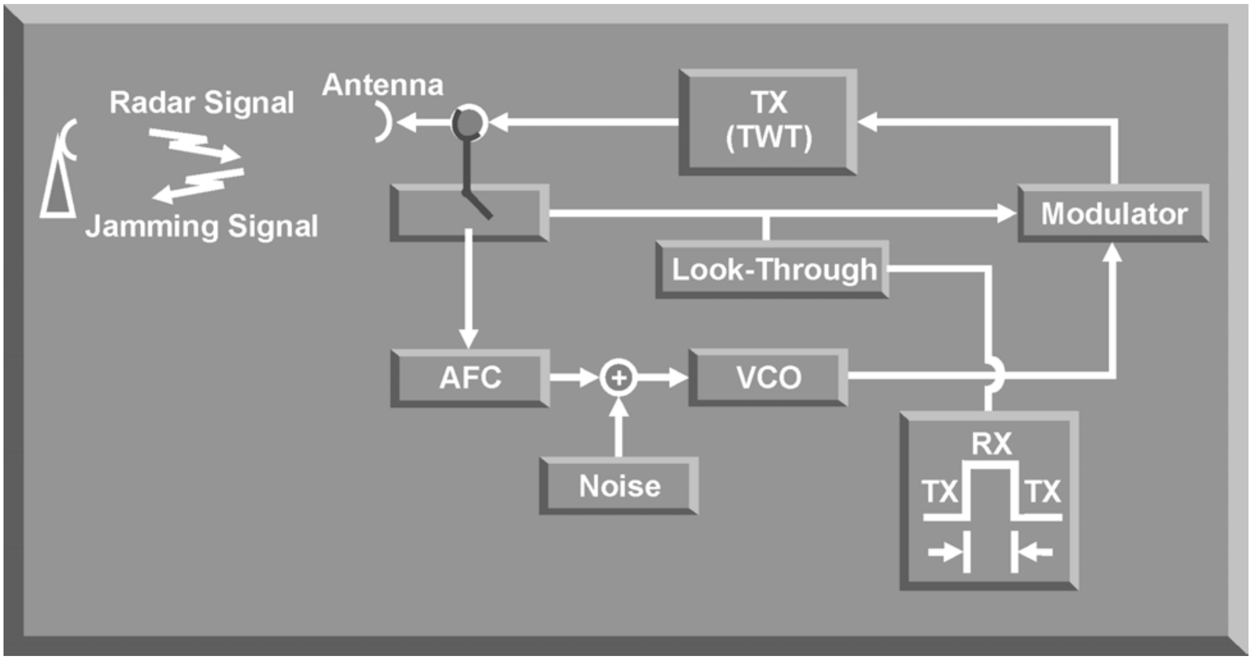

Figure 10-5. Frequency Modulated (FM) Noise Jamming System

4. BARRAGE JAMMING

An important aspect of jamming power is power density. Noise jamming depends on power density for its effectiveness. Power density is a function of the frequency range, or bandwidth, of the jamming signal. If a jammer covers a narrow frequency range, it can concentrate energy in a narrow band. If a jammer covers a wide frequency range, the energy is spread over that entire range. Since the jammer has fixed radiated power, this lowers the effective jamming power at a given frequency. Barrage jamming is a jamming technique where high power is sacrificed for the continuous coverage of several radar frequencies (Figure 10-6). The jamming signal is spread over a wide frequency range, which lowers the ERP at any one frequency. This type of jamming is useful against frequency-agile radars, against a radar system that uses multiple beams, or against multiple radar systems operating in a specific frequency range. By spreading the jamming over a wide frequency range, there is some level of jamming no matter what frequency the radar uses. Barrage jamming was used extensively during World War II. Advantages of barrage jamming are its simplicity and ability to cover a wide portion of the electromagnetic spectrum. The primary disadvantage is the low power density, especially when a high J/S ratio is needed against modern radars.

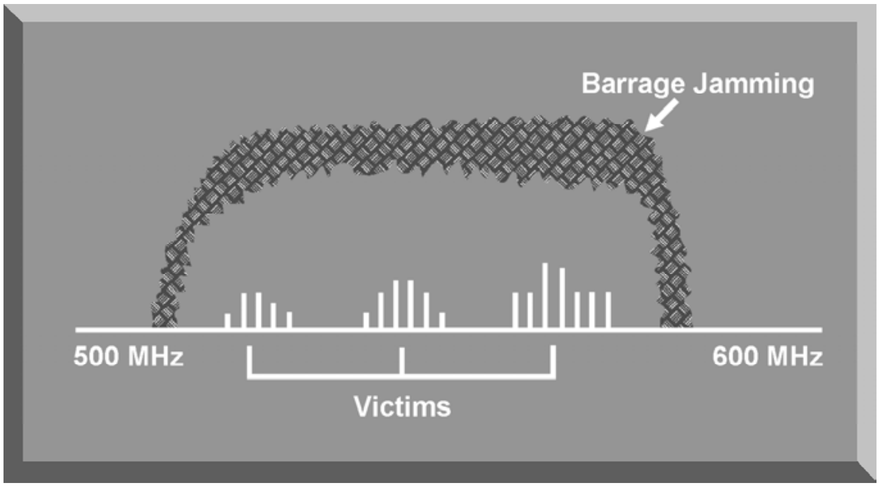

Figure 10-6. Barrage Jamming

5. SPOT JAMMING

One way to take advantage of the noise jammer's simplicity, but raise the jamming signal power, is to use a spot jammer. The earliest spot jammers were very narrow band jammers covering a bandwidth of 10 megahertz or less (Figure 10-7). This narrow band spot jammer was tuned to the anticipated frequency of the target radar. When it is necessary to jam a number of radars at different frequencies, more than one jammer is used. One problem that developed was of carrying the required number of spot jammers to counter a modern IADS. Also, radars that change their operating frequency, or are frequency-agile, defeat the spot jammer. Today, intercept panoramic receivers work with spot jammers to determine the frequency of the victim radar. A look-through capability is included in the system so that the target radar signal can be monitored to assess jamming effectiveness. The jamming signal can be adjusted for any changes in the operating frequency of the radar.

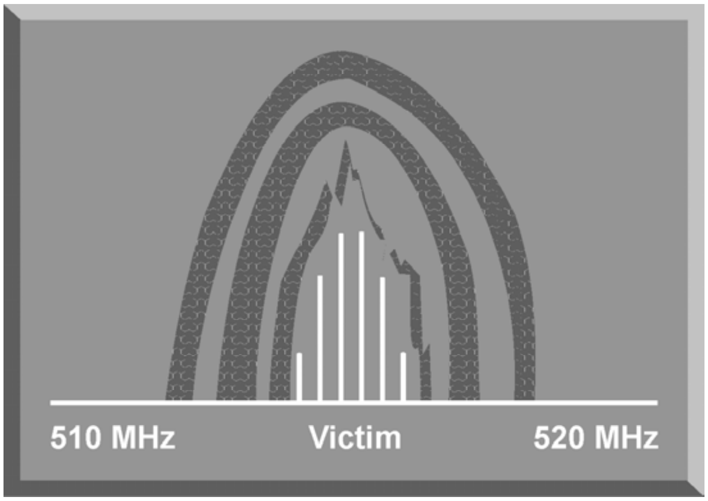

Figure 10-7. Spot Jamming

a. The primary advantage of spot jamming is its power density. Radar or communications receivers can be countered at longer ranges than when using a barrage jammer of equal output power (Figure 10-8).

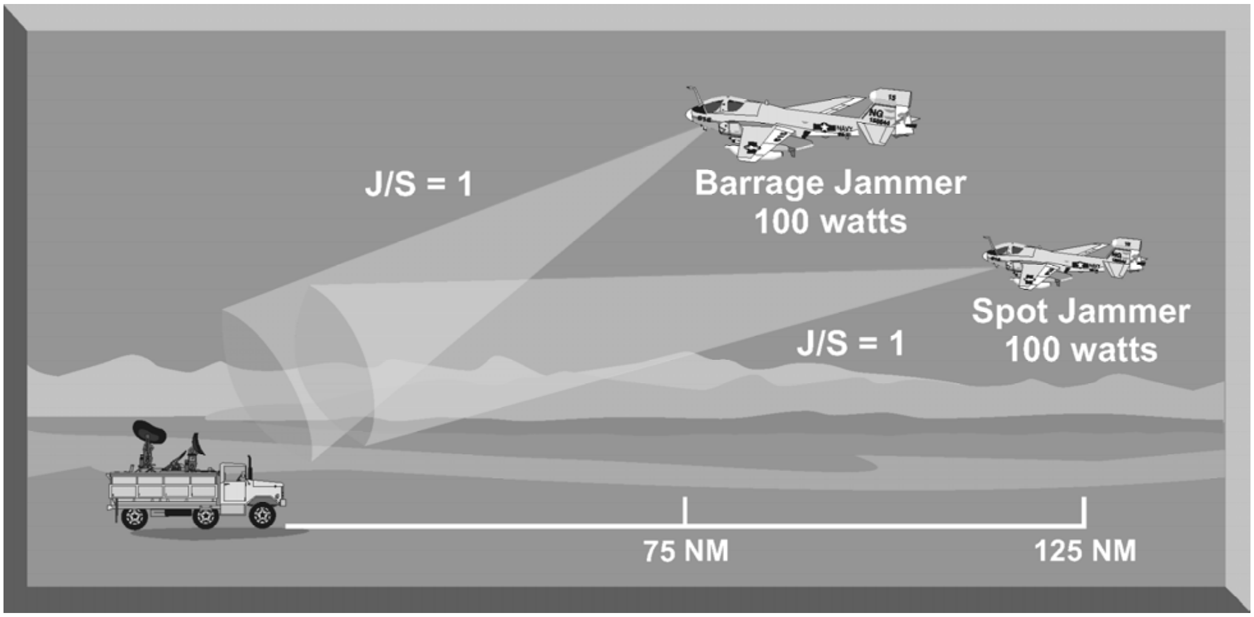

Figure 10-8. Spot Jamming Effectiveness

b. A disadvantage of the spot jammer is its coverage of a narrow band of the frequency spectrum. An operator or computer in the receiver must constantly monitor and tune the jamming signal to the target radar's frequency. The complexity of this process increases when jamming frequency-agile radars that can change frequencies with every pulse.

6. SWEPT-SPOT JAMMING

When high power density is required over a large bandwidth, one solution is to take spot jamming and sweep it across a wide frequency range (Figure 10-9). This preserves the high power density but allows the jamming to cover a large bandwidth. The jamming spot is swept across a broad frequency range at varying speeds. With this technique, a number of radar systems can be covered. Because of their high jamming power, swept-spot jammers are able to cover a number of radars operating in a broad frequency range. However, jamming is not continuous. Fast swept-spot jamming can approximate continuous jamming by causing a phenomenon known as “ringing.” Fast sweeping spot noise is like a burst of energy which sets up vibrations within the receiver section. When these vibrations last until the next burst of energy is received, this is known as ringing. Three factors determine swept-spot jamming effectiveness. The first is the power in the spot. The next is the bandwidth, or frequency range, the spot covers. The last is the sweep rate.

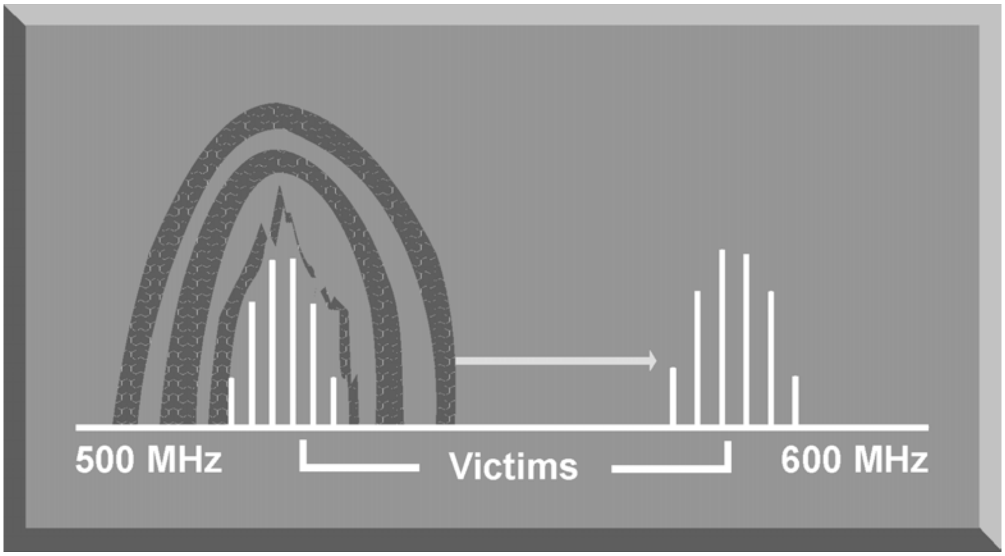

Figure 10-9. Swept-Spot Jamming

7. COVER PULSE JAMMING

Cover pulse jamming is a modification of swept-spot jamming. This is a "smart noise" technique that is responsive for a short period of time (Figure 10-10). A repeater jammer acts as a transponder. It receives several radar pulses and determines the PRF of the victim radar. It then uses this data to predict when the next radar pulse should arrive. Using an oscillator that is gated for a period of time based on predicted pulse arrival time, a noise-modulated signal is amplified and transmitted. This process works against a radar with a steady PRF, and allows a low-powered repeater to respond to a number of threats by time-sharing.

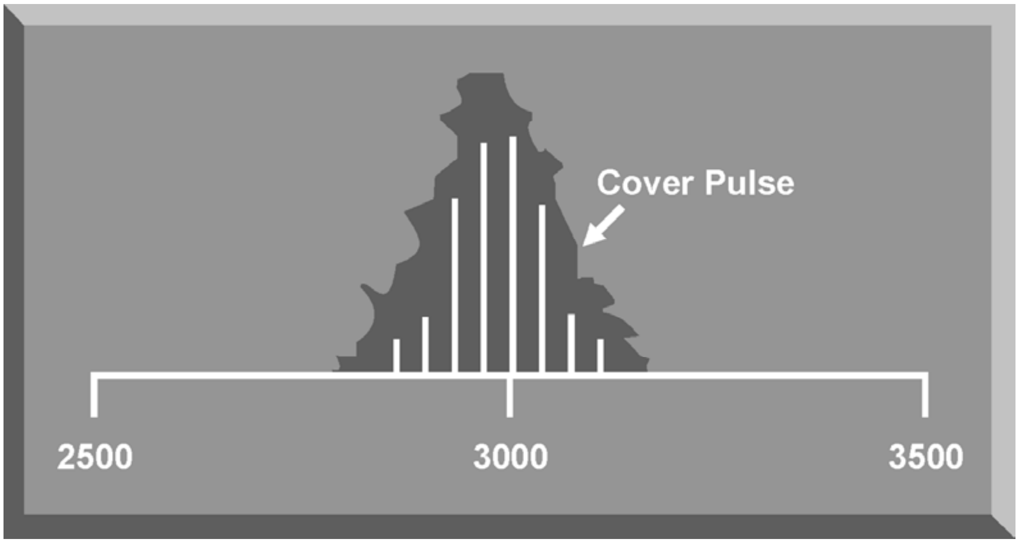

Figure 10-10. Cover Pulse Jamming

a. Cover pulse jamming is used to initiate a range gate pull-off (RGPO) deception jamming technique. The deception jammer transmits a noise jamming signal, or cover pulse, that is much stronger than the target return. The cover pulse raises the automatic gain inside the range gate, and the range tracking loop initiates tracking on the cover pulse. The deception jammer then increases the time delay in the jamming pulse and moves the range tracking gate away from the real target (Figure 10-11).

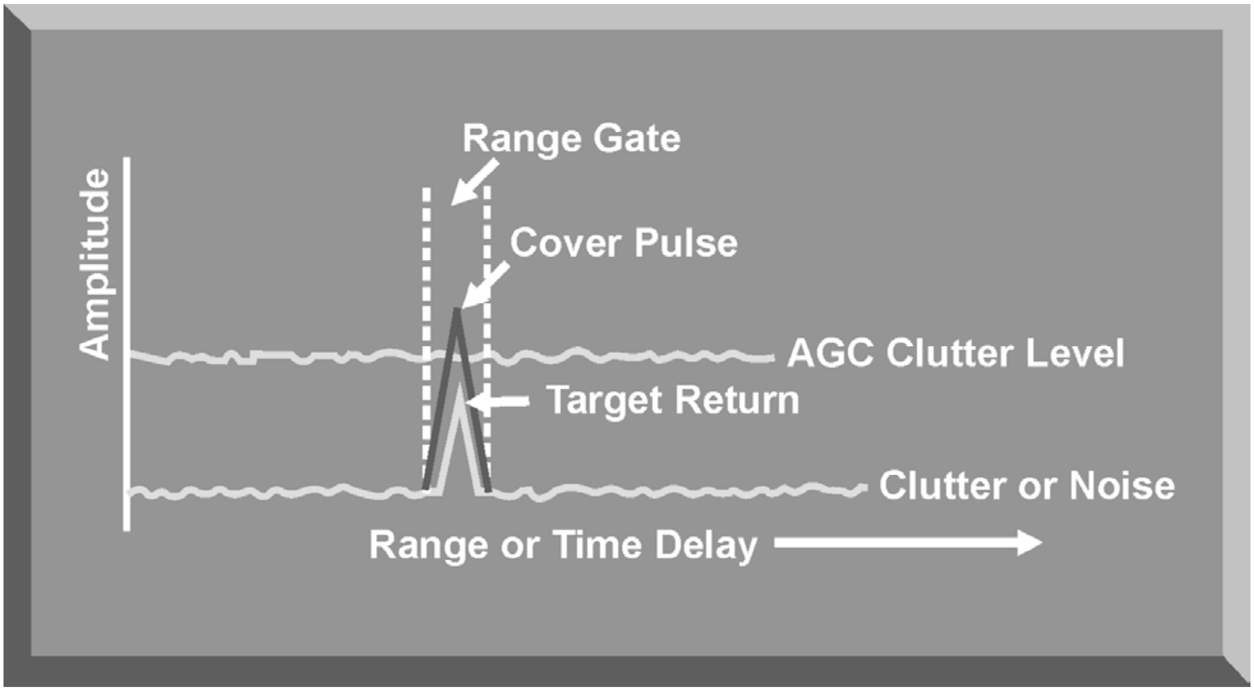

Figure 10-11. Range Gate Pull-Off Cover Pulse

b. A form of cover pulse jamming is also used to initiate a velocity gate pull-off (VGPO) technique against continuous wave and pulse Doppler radars. The cover pulse, in this case, is a strong jamming signal with the same frequency shift as the aircraft return. This cover pulse steals the velocity tracking gate and sets up the velocity tracking loop to steal the velocity tracking gate based on false target Doppler shifts (Figure 10-12).

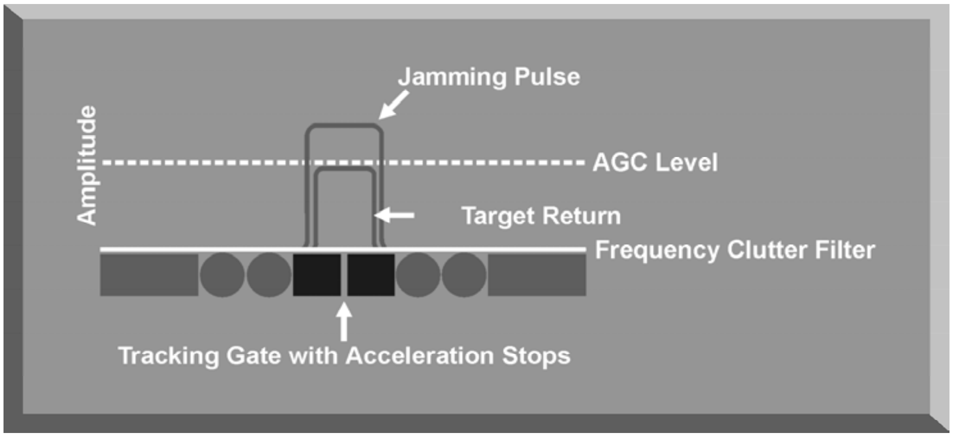
Jamming Pulse
Amplitude
AGC Level
Target Return
Frequency Clutter Filter
Tracking Gate with Acceleration Stops

Figure 10-12. Velocity Gate Pull-Off Cover Pulse

8. MODULATED NOISE JAMMING

Modulated jammers are special hybrid jammers which employ noise jamming that is either amplitude or frequency modulated. The purpose of this modulated noise is to defeat target tracking radars (TTRs) rather than deny range information. Modulated noise jamming has proven effective against conical scan and track-while-scan (TWS) TTRs.

a. Modulated jamming alters the noise jamming signal at a frequency that is related to the scan rate of the target radar. If modulated jamming is used against a conical scan radar, a sine wave signal is used (Figure 10-13). The frequency of the sine wave is slightly higher than the scan rate of the victim radar. The amplitude difference results in a constantly varying phase between the radar and the jamming signal. This phase differential produces false targets with a strong signal amplitude everywhere the signals reinforce each other. This causes the conical scan radar to track the false returns and lose the real target return. For this technique to work, the scan rate of the intended victim radar must be known.

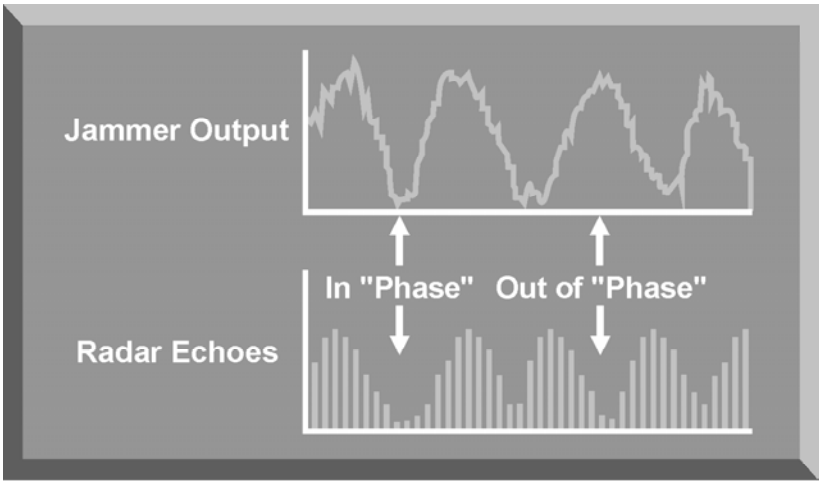
Jammer Output
In "Phase"
Out of "Phase"
Radar Echoes

Figure 10-13. Conical Scan Modulated Jamming

b. Against a TWS radar, a rectangular waveform is used to modulate the noise signal. The PRF of the modulation is set at some harmonic of the TWS rate. This synchronization results in a number of jamming strobes on the radar scope. Each jamming strobe is at a different azimuth or elevation depending on which radar beam is being jammed. The number of jamming strobes depends directly on the harmonic used to modulate the signal. In Figure 10-14, a modulating signal frequency that is four times the scan rate of the radar will produce four jamming strobes on the scope. If the jamming is slightly out of tune with the scan rate, the jamming strobes will appear to roll across the radar scope.

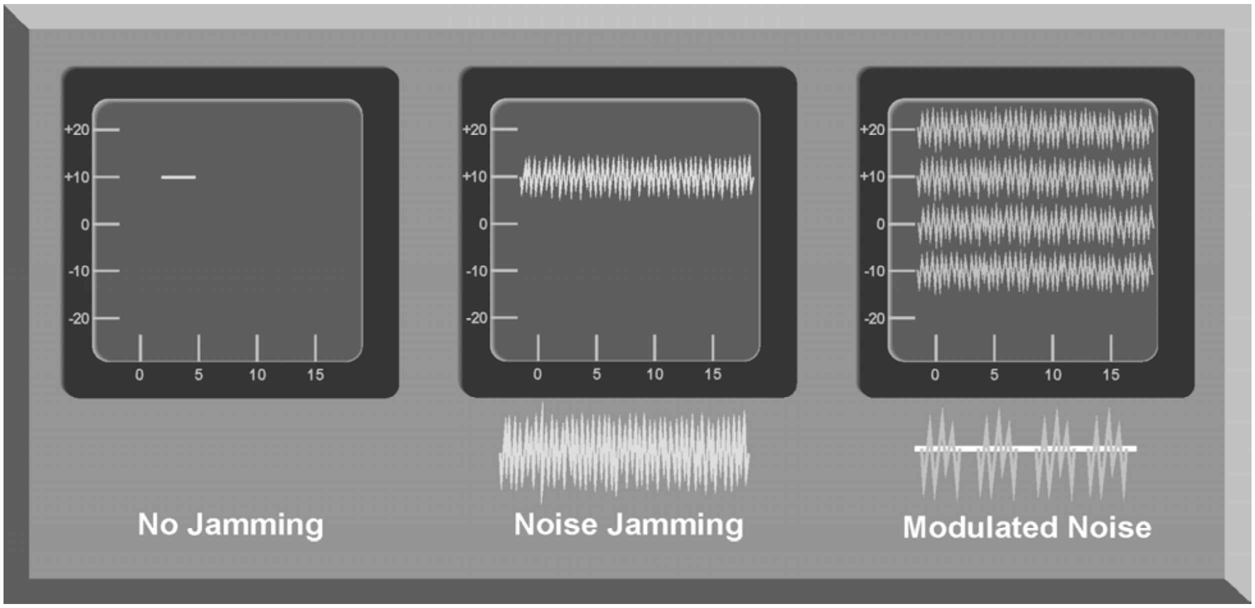

Figure 10-14. TWS Modulated Jamming

9. SUMMARY

Radar noise jamming is employed to deny target acquisition and target tracking data to a victim radar. This is accomplished by injecting amplitude or frequency modulated noise jamming signals into the victim radar's receiver. The radar noise jamming techniques discussed in this chapter included barrage, spot, swept-spot, cover pulse, and modulated jamming. The effectiveness of these noise jamming techniques depends on the power density of the jamming signal compared to the power in the radar return, or the J/S ratio. Radar noise jammers are generally simple, high-power systems which can be effectively employed in a support or self-protection role. Radar noise jamming can be employed in conjunction with deception jamming techniques to maximize the impact of jamming on victim radars.

CHAPTER 11. DECEPTION JAMMING

1. INTRODUCTION

Deception jamming systems are designed to inject false information into a victim radar to deny critical information on target azimuth, range, velocity, or a combination of these parameters. To be effective, a deception jammer receives the victim radar signal, modifies this signal, and retransmits this altered signal back to the victim radar. Because these systems retransmit, or repeat, a replica of the victim's radar signal, deception jammers are known as repeater jammers. The retransmitted signal must match all victim radar signal characteristics including frequency, pulse repetition frequency (PRF), pulse repetition interval (PRI), pulse width, and scan rate. However, the deception jammer does not have to replicate the power of the victim radar system.

a. A deception jammer requires significantly less power than a noise jamming system. The deception jammer gains this advantage by using a waveform that is identical to the waveform the radar's receiver is specifically designed to process. Therefore, the deception jammer can match its operating cycle to the operating cycle of the victim radar instead of using the 100% duty cycle required of a noise jammer. To be effective, a deception jammer's power requirements are dictated by the average power of a radar rather than the peak power required for a noise jammer. In addition, since the jammer waveform looks identical to the radar's waveform, it is processed like a real return. The jamming signal is amplified by the victim radar receiver, which increases its effectiveness. The reduced power required for effective deception jamming is particularly significant when designing and building self-protection jamming systems for tactical aircraft that penetrate a dense threat environment. Deception jamming systems can be smaller, lighter, and can jam more than one threat simultaneously. These characteristics give deception jammers a great advantage over noise jamming systems.

b. Although deception jammers require less power, they are much more complex than noise jammers (Figure 11-1). Memory is the most critical element of any deception jammer. The memory element must store the signal characteristics of the victim radar and pass these parameters to the control circuitry for processing. This must be done almost instantaneously for every signal that will be jammed. Any delay in the memory loop diminishes the effectiveness of the deception technique. Using digital RF memory (DRFM) reduces the time delay and enhances deception jammer effectiveness. Deception jamming employed in a self-protection role is designed to counter lethal radar systems. To be effective, deception jamming systems must be programmed with detailed and exact signal parameters for each lethal threat.

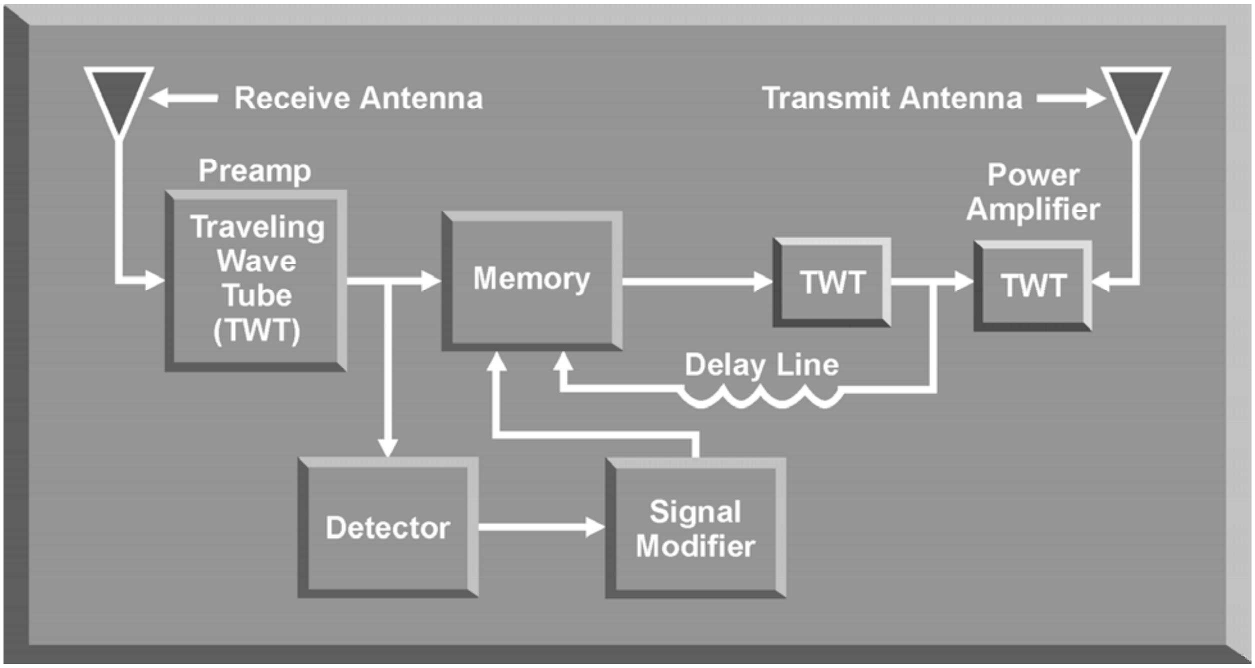

Figure 11-1. Deception Jamming System

c. The requirement for exact signal parameters increases the burden on electronic warfare support (ES) systems to provide and update threat information on operating frequency, PRF, PRI, power pulse width, scan rate, and other unique signal characteristics. An electronic intelligence (ELINT) architecture is required to collect, update, and provide changes to deception jamming systems. In addition, intelligence and engineering information on exactly how a specific threat system acquires, tracks and engages a target is essential in identifying system weaknesses. Once a weakness has been identified, an effective deception jamming technique can be developed and programmed into a deception jammer. For example, if a particular radar system relies primarily on Doppler tracking, a Doppler deception technique will greatly reduce its effectiveness. Threat system exploitation is the best source of detailed information on threat system capabilities and vulnerabilities. Effective deception jamming requires much more intelligence support than does noise jamming.

d. Most self-protection jamming techniques employ some form of deception against a target tracking radar (TTR). The purpose of a TTR is to continuously update target range, azimuth, and velocity. Target parameters are fed to a fire control computer that computes a future impact point for a weapon based on these parameters and the characteristics of the weapon being employed. The fire control computer is constantly updating this predicted impact point based on changes in target parameters. Deception jamming is designed to take advantage of any weaknesses in either target tracking or impact point calculation to maximize the miss distance of the weapon or to prevent automatic tracking. This chapter will discuss the most commonly employed deception jamming

techniques, including false target jamming, range deception jamming, angle deception jamming, velocity deception jamming, and monopulse jamming.

2. FALSE TARGET JAMMING

False target jamming is an effective jamming technique employed against acquisition, early warning, and ground control intercept (GCI) radars. The purpose of this type of jamming is to confuse the enemy radar operator by generating many false target returns on the victim radar scope. When false target deception jamming is successfully employed, the radar operator cannot distinguish between false targets and real targets (Figure 11-2).

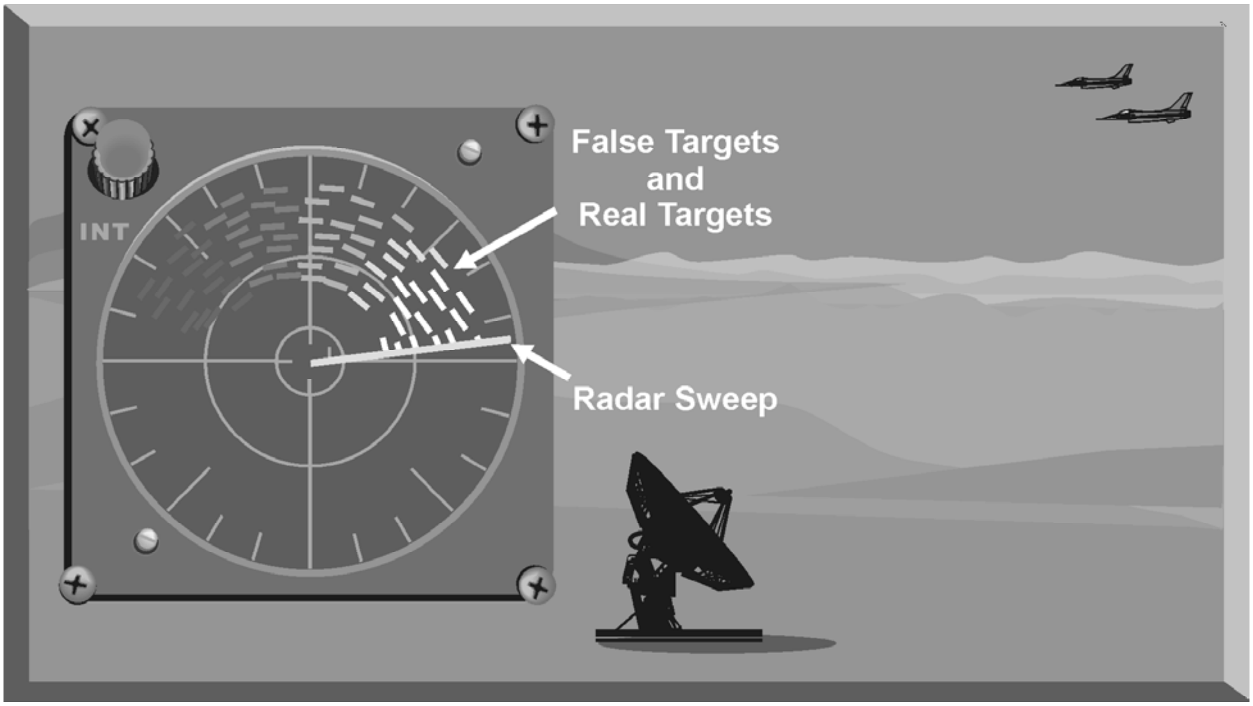
INT
False Targets and Real Targets
Radar Sweep

Figure 11-2. False Target Generation

a. To generate false targets, the deception jammer must tune to the frequency, PRF, and scan rate of the victim radar. The jamming pulse must appear on the radar scope exactly like a radar return from an aircraft. Multiple false targets greater in range than the jammer are generated by delaying the transmission of a jamming pulse until after the victim radar pulse has been received. False targets closer in range are generated by anticipating the arrival of a radar pulse and transmitting a jamming pulse before the victim radar pulse hits the aircraft. If the victim radar employs a jittered PRF, only targets greater in range can be generated.

b. To generate different azimuth false targets, the deception jammer synchronizes its transmitted pulse with the victim radar's sidelobes. Due to their

reduced power, when compared to the main beam, sidelobes are difficult to detect and analyze. The receiver in the deception jammer must be sensitive enough to detect these sidelobes and not be saturated by the power in the main radar beam. A false target deception jammer must inject a jamming pulse that looks like a target return into these sidelobes. To penetrate the radar sidelobes requires a lot of power. However, the power must be judiciously used. If a powerful jamming pulse is injected into the main beam, the false targets will be easy to detect. Most false target jammers vary the power in the jamming pulse inversely with the power in the received signal, on a pulse-by-pulse basis. This means the repeater jamming signal is at minimum power when the main beam of the victim radar is on the aircraft and at maximum power when the sidelobes are being jammed. To effectively generate false azimuth targets, the jammer must have a receiver with a wide dynamic range to detect both the main beam and the sidelobes. In addition, the jamming system must be able to generate high power that can be effectively controlled by the receiver.

c. To generate moving false targets, the deception jammer must synchronize with the main beam and the sidelobes in frequency, pulse width and PRF. Amplitude modulated jamming signals, with variable time delays, are transmitted into the sidelobes of the victim radar. The variable time delay provides a false target that changes range, either toward or away from the radar, depending on the time delay. The amplitude modulation provides false azimuth targets that appear to be moving.

d. The effectiveness of false target generation is based on the credibility of the generated false radar returns. If the victim radar can easily distinguish between false returns and target returns, the technique is a failure. The false returns must look identical to an aircraft return. The radar return on the victim radar scope should have the same intensity, depth, and width as a target return.

(1) Power determines the false target intensity when it is displayed on the victim radar scope. Varying jammer output power inversely with received power ensures that each false target has nearly the same intensity as a true target return. The depth, or thickness, of the false target depends on the pulse width of the victim radar. By matching the pulse width of the jamming pulse with the pulse width of the victim radar, the jammer can generate false targets with the same depth as a real target return.

(2) The width of the false target depends on the antenna pattern of the victim radar. This can pose a problem for false-target deception jammers. Because the jamming pulse is transmitted the entire time the radar beam is on the jammer, the width of a false target will tend to be greater than a real target return. Aircraft radar return varies with main beam cross-section. To correct this problem, most false target deception jammers use random modulation in the power of the transmitted pulses. This will vary the width of the false targets and make them look more like the variable returns of actual targets.

3. RANGE DECEPTION JAMMING

Although a specific TTR can track multiple targets and direct multiple weapons, the tracking circuit must select a single target return and track it while ignoring all other returns. Target selection is done by using gate bins. The range gate is used as the primary gate for target selection. A range gate is an electronic switch that is turned on for a period of microseconds based on a certain range or time delay after a pulse is transmitted (Figure 11-3).

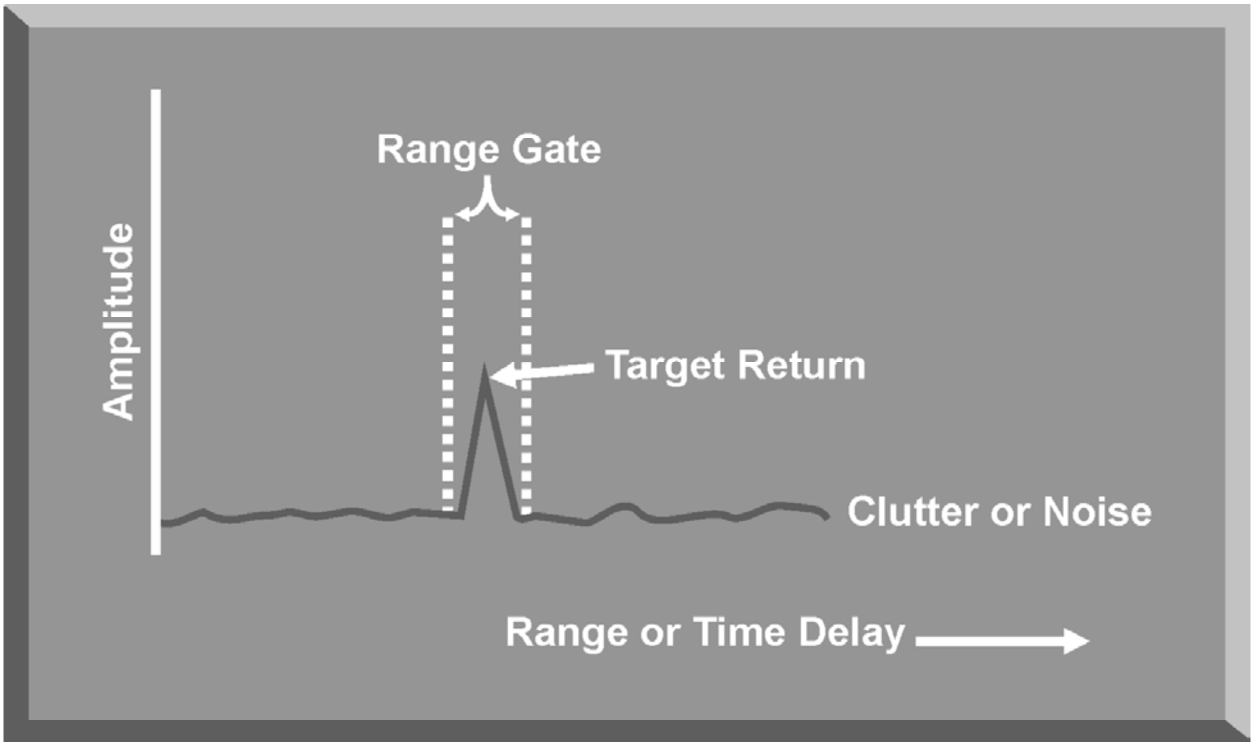

Figure 11-3. Range Gate Tracking

a. Range deception jamming exploits any inherent weakness in a TTR's automatic range gate tracking circuits. When a TTR's range gate locks on to an aircraft, the range deception jammer detects the radar signal. The range deception jammer then amplifies and retransmits a signal much stronger than the radar return. This retransmitted signal, called a cover pulse, is displayed in the range gate with the target signal (Figure 11-4).

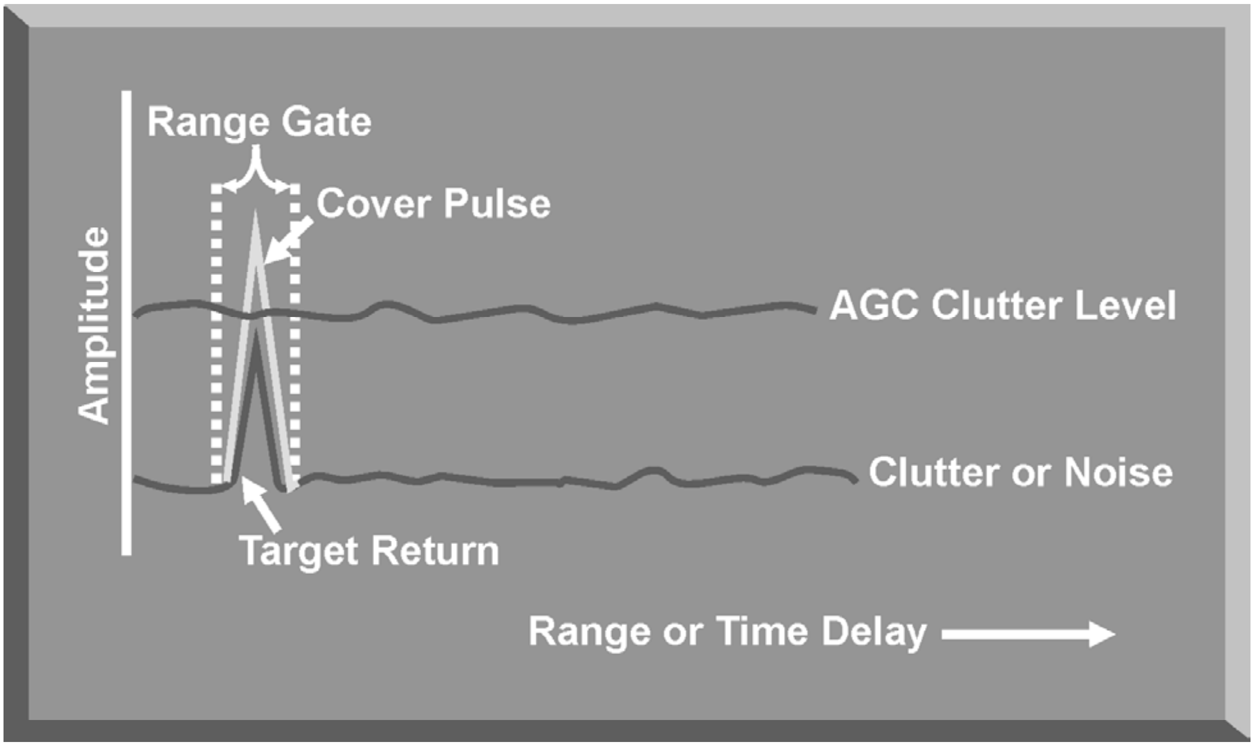

Figure 11-4. Range Gate Jamming Cover Pulse

b. The automatic gain control (AGC) circuit lowers the gain in the range tracking gate to control the amplitude of the cover pulse in the range gate. Reduced gain causes the real target return to be lost, and the range gate only tracks the jamming signal. This is known as range gate capture.

c. Once the range gate is captured by the cover pulse, a technique called range gate pull-off (RGPO) is employed (Figure 11-5). The deception jammer memorizes the radar signal and introduces a series of time delays before retransmitting. By increasing these time delays, the range gate will detect an increase in range and automatically move off to a false range. Once the range gate has moved well away from the real target, the range deception jammer shuts down, and the radar range gate is left with no target to track. The range gate breaks lock and the TTR must again go through the process of search, acquisition, and lock-on to re-engage the target.

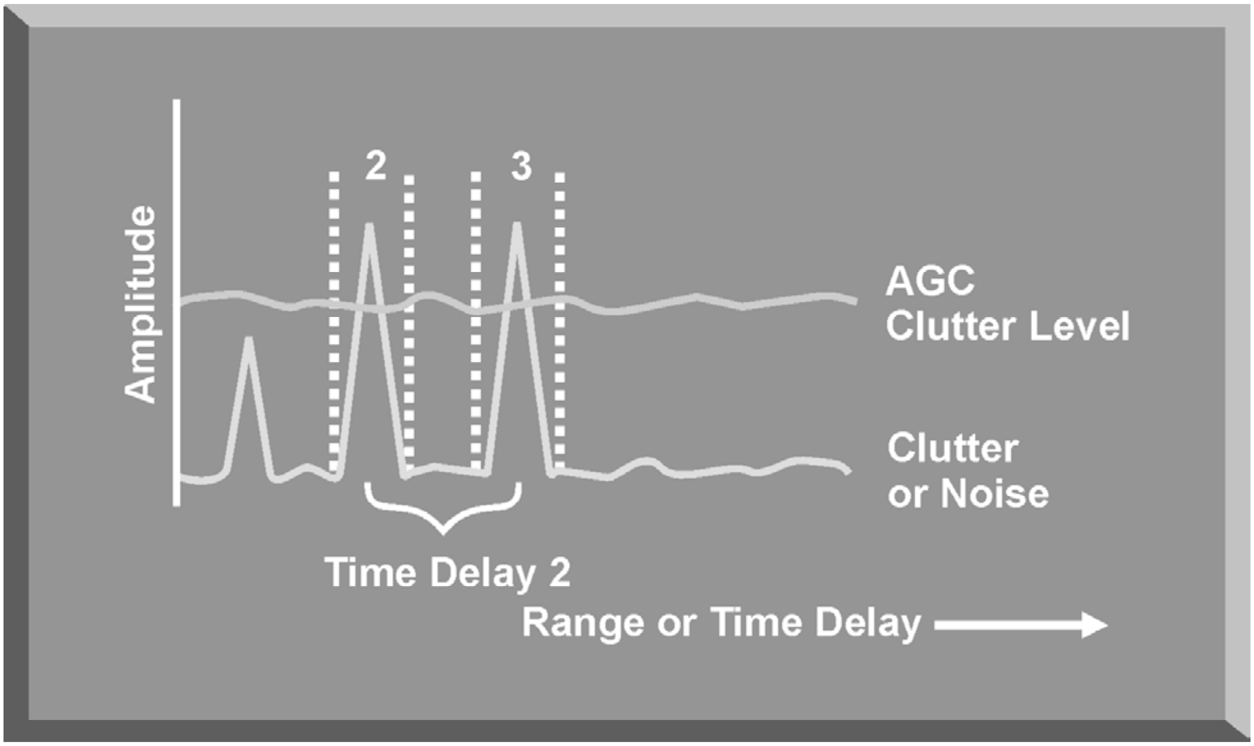

Figure 11-5. Range Gate Pull-Off

d. There are several advantages of range deception jamming, especially when used as a self-protection technique. It can generate sufficient errors to deny range information and is effective against most automatic range tracking systems. This technique does not require a large amount of power, just enough to cover the radar return of the aircraft. If the time delays are not exaggerated, an operator may not detect the loss of range lock-on until after a missile has been fired. The insidious nature of range deception jamming may generate enough miss distance to save the aircraft and pilot.

e. There are disadvantages to using range deception jamming. First, it can be defeated by a trained radar operator. If the operator detects a problem with the automatic range tracking circuit, the system can be switched to manual range tracking mode to defeat RGPO. Also, if the threat system is still able to track the aircraft's azimuth and elevation, range information may not be required to complete target engagement. To maximize range deception jamming effectiveness, it should be employed in conjunction with azimuth and elevation jamming. Finally, this type of range deception jamming is not effective against a leading-edge range tracking system. A leading-edge tracker will not see the delayed cover pulse. As the cover pulse moves off the target, AGC circuits reset the gain to continue tracking the real target. The only way to defeat a leading-edge range tracker is with a deceptive jammer that anticipates the next radar pulse and sends a jamming cover pulse before it reaches the aircraft. This jamming technique can also be defeated by randomly varying the radar PRF.

4. ANGLE DECEPTION JAMMING

Angle deception jamming is designed to exploit weaknesses in the angle tracking loop of the victim radar. The specific technique depends on the tracking method used to derive azimuth and elevation information. Inverse amplitude modulation jamming is the main angle deception technique used against TWS radars. For conical scan radars, scan rate modulation and inverse gain jamming are used. Swept square wave (SSW) jamming is used against LORO tracking radars. Monopulse angle deception jamming will be covered separately.

a. The azimuth and elevation tracking loop for a TWS radar is based on target signal amplitude modulation. The inverse amplitude modulation jammer generates a signal with modulation exactly opposite the expected return. To accomplish this, the angle deception jammer must receive the radar signals from the tracking beams. The jammer responds with a signal of the same frequency, PRF, and scan rate synchronized to the inverse of the radar antenna pattern (Figure 11-6). This induces an error in the angle tracking gate that, over a series of scans, causes the radar to lose target angle tracking.

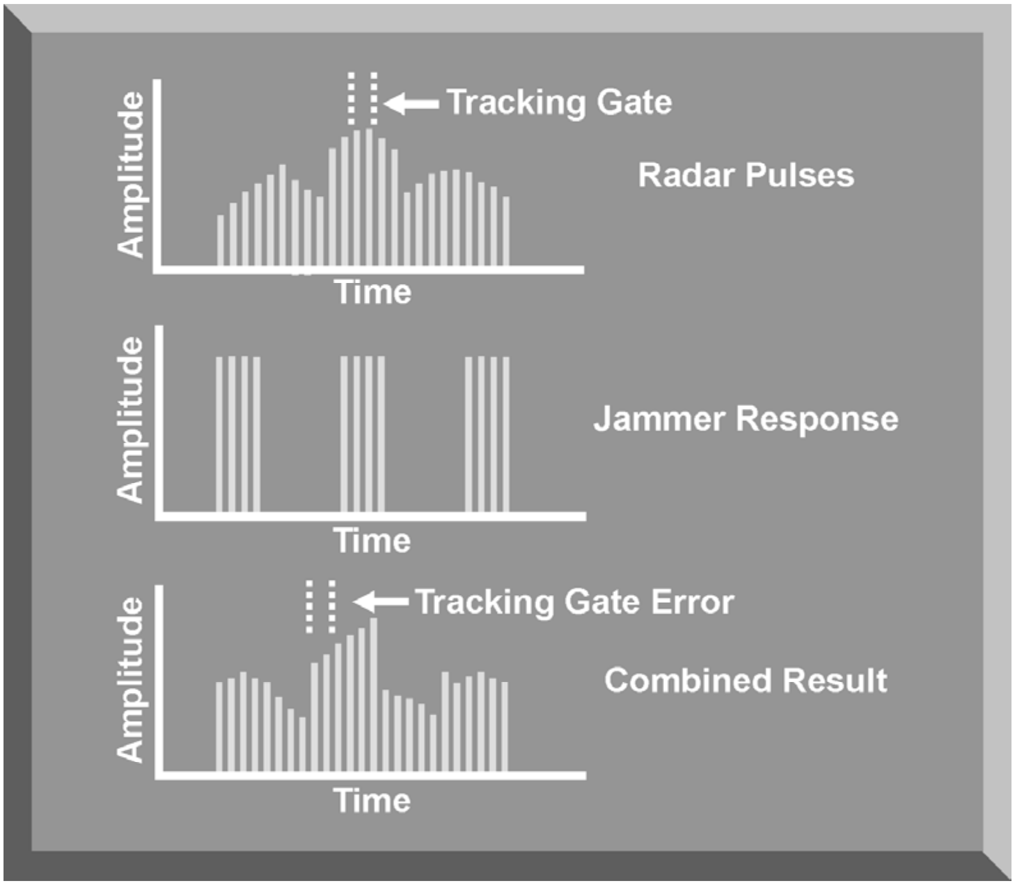

Figure 11-6. Inverse Amplitude Modulation Jamming

b. Inverse gain jamming is also effective against conical scan radars. Since conical scan radars use the phase of the target returns to generate error signals, an inverse gain deception jammer attempts to alter the phase by inducing fake signals into the antennas. In addition, by altering the amplitude of the signal, the jammer induces large errors into the tracking loop. To accomplish this, the jammer must determine the frequency, PRF, and scan rate of the victim radar. It then transmits signals that change the phase and amplitude of the target signal, resulting in a signal 180 degrees out of phase with the actual target (Figure 11-7). This 180-degree error rapidly drives the antenna off the target and causes break-lock.

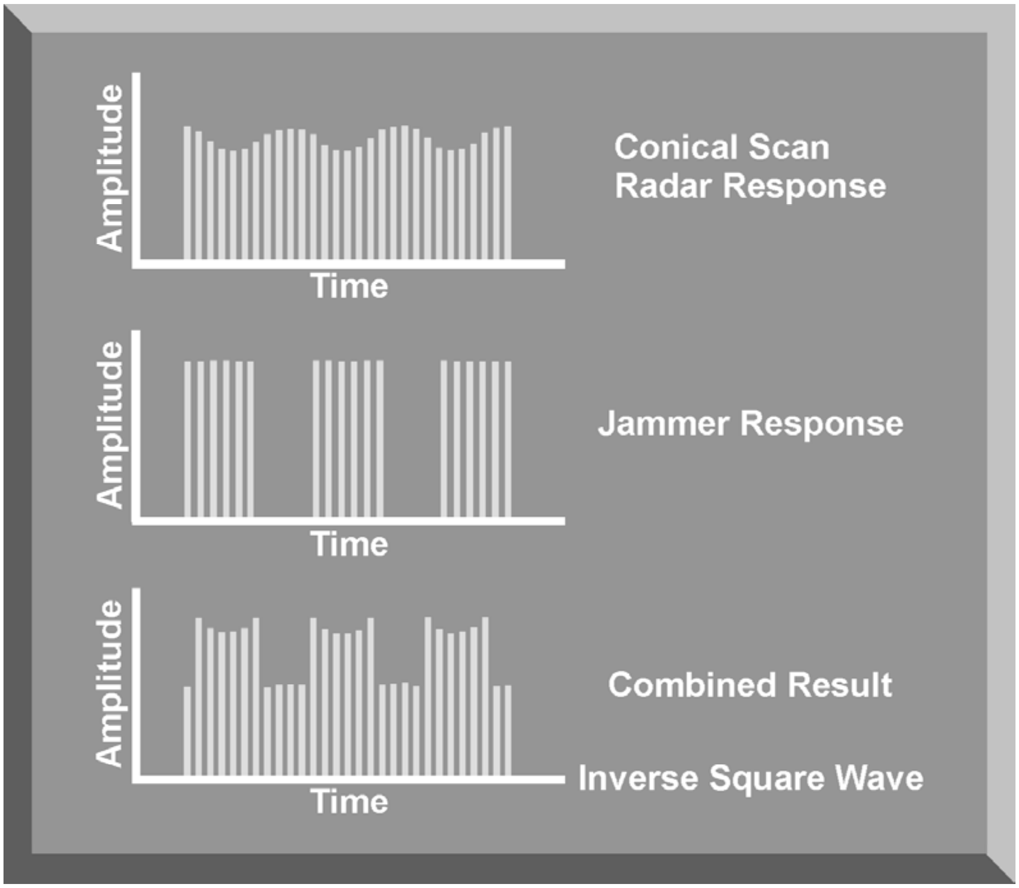

Figure 11-7. Inverse Gain Jamming

c. Scan rate modulation is also used against conical scan radars. This angle deception technique modulates the jamming pulse at or near the victim radar nutation frequency. As the modulation approaches the radar's nutation frequency, large error signals appear in the radar servo tracking loops, producing random gyrations in the antenna system, causing break-lock. This technique is most effective if the modulation jamming is slowly swept in frequency until it matches the nutation rate.

d. Both inverse scan and scan rate modulation jamming require very little power and have proven extremely effective against TWS and conical scan radars. To be effective, however, the angle deception jammer must find the precise scan rate of the victim radar. The jammer must concentrate on one signal at a time, limiting the number of threat systems that can be jammed simultaneously. In a dense threat environment, this can be a severe limitation.

e. The effectiveness of inverse gain and scan rate modulation jamming led radar designers to employ antennas that scan only during the receiving function of the radar system. Generally, this is accomplished by using two antennas. The transmitting antenna illuminates the target. Receiving antennas scan to produce the amplitude modulation of the reflected signal for effective angle tracking. This technique is called Lobe-On-Receive-Only (LORO). Since the transmitting antenna does not nutate, or scan, angle deception jammers cannot detect the modulation required to generate effective inverse gain modulation. Swept square wave (SSW) jamming is the angle deception technique developed to counter LORO angle tracking.

f. SSW jamming continuously varies the frequency of amplitude modulation on the jamming pulse over an expected range of nutation or scanning frequencies. This range is established by either electronic intelligence (ELINT) data on a particular system, or by exploitation. The dotted line in Figure 11-8 shows a threat's nutation or scan frequency. As the frequency of the modulated jamming pulse approaches the threat scan frequency, it induces errors in the angle tracking loop of the victim radar. The longer the SSW jamming stays near the scan frequency, the greater the induced errors. It is important that the sweep rate of the modulating jamming be slow enough to maximize its impact on the victim radar.

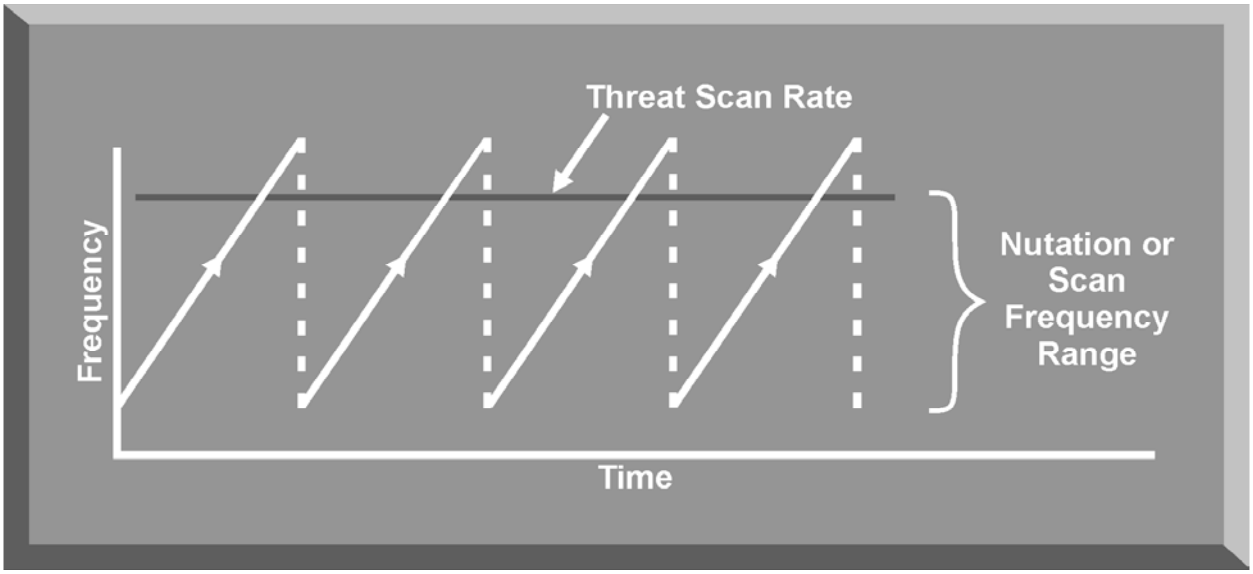

Figure 11-8. Swept Square Wave Jamming

5. VELOCITY DECEPTION JAMMING

Pulse Doppler and continuous wave (CW) radars track targets based on velocity or Doppler-shifted frequency (Figure 11-9). The objective of velocity deception jamming is to deny velocity tracking information and generate false velocity targets. The primary techniques include velocity gate pull-off (VGPO), Doppler noise, narrowband Doppler noise, and Doppler false targets.

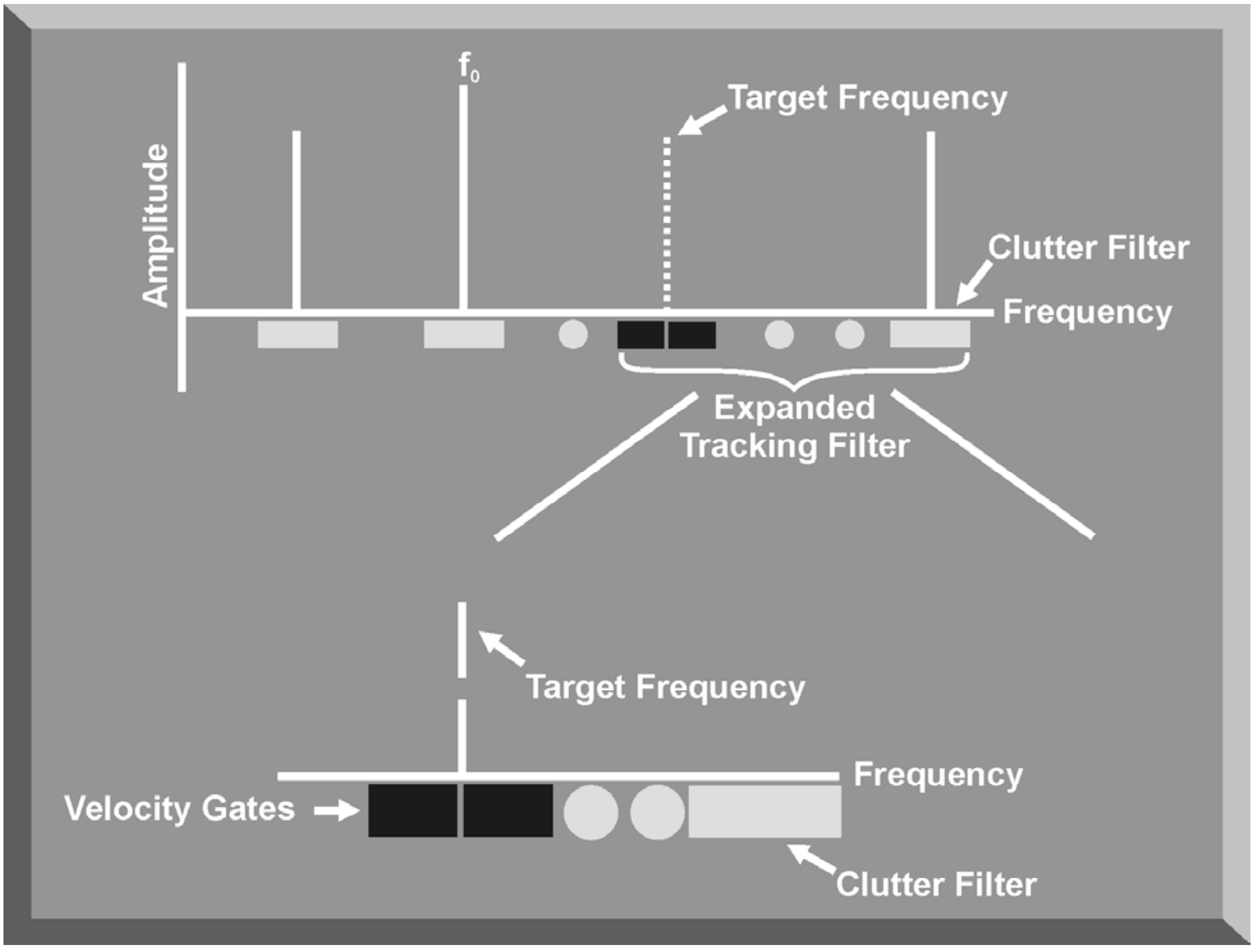
Amplitude
f_0
Target Frequency
Clutter Filter
Frequency
Expanded Tracking Filter
Target Frequency
Frequency
Velocity Gates
Clutter Filter

Figure 11-9. Velocity Tracking Gate

a. Velocity gate pull-off counters pulse Doppler or CW radars by stealing the velocity gate of their automatic tracking loop. The objective of VGPO is to capture the Doppler velocity tracking gate by transmitting an intense false Doppler signal. Then the frequency of the false signal is changed to move the tracking gate away from the true target Doppler. This is analogous to the RGPO technique used against the range gate tracking loop.

(1) To accomplish an effective VGPO technique, the jammer receives the CW or pulse Doppler signal. It then retransmits a CW or pulse Doppler signal that is higher in power than the return from the aircraft, but at approximately the same

Doppler frequency (Figure 11-10). It is important that the frequency of this initial jamming pulse appears within the same velocity tracking filters as the target return or the victim radar will disregard it. The frequency band of the Doppler tracking filters is an important piece of intelligence information. The velocity tracking gates are quite narrow, roughly 50 to 250 MHz. Once the jamming pulse appears in the tracking gate, the automatic gain control circuit gains out the target return, and the jamming pulse has captured the velocity gate.

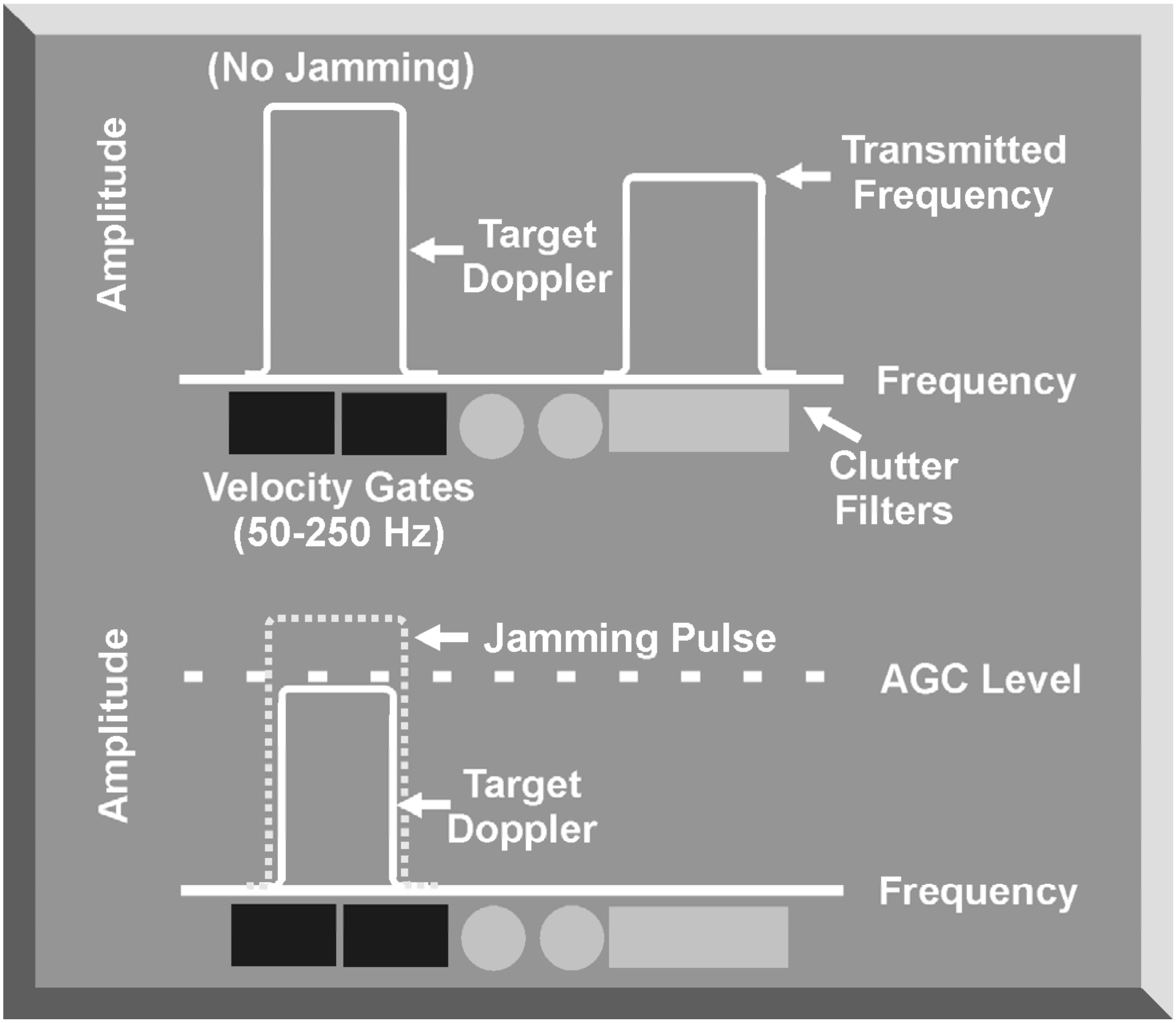
(No Jamming)
Amplitude
Transmitted Frequency
Target Doppler
Frequency
Clutter Filters
Velocity Gates (50-250 Hz)
Amplitude
Jamming Pulse
AGC Level
Target Doppler
Frequency

Figure 11-10. Velocity Gate Capture

(2) Once the jamming pulse has captured the tracking gate, the deception jammer slowly changes the Doppler frequency (Figure 11-11). This frequency shift is accomplished by several methods. The most common method uses frequency modulation (FM) within the jammer's traveling wave tube (TWT). By varying the TWT voltage, the Doppler frequency of the jamming pulse is changed

linearly, and the radar tracking gates follow the jamming pulse. By using FM, the jamming pulse can be moved in either a positive or negative direction, depending on the slope of the voltage. By slowly changing the frequency of the modulation, the jamming pulse pulls the tracking gates off the target. When the maximum offset has been achieved, nominally 5 to 50 kHz, the FM is "snapped back" to a minimum value, and the process is repeated to preclude target reacquisition.

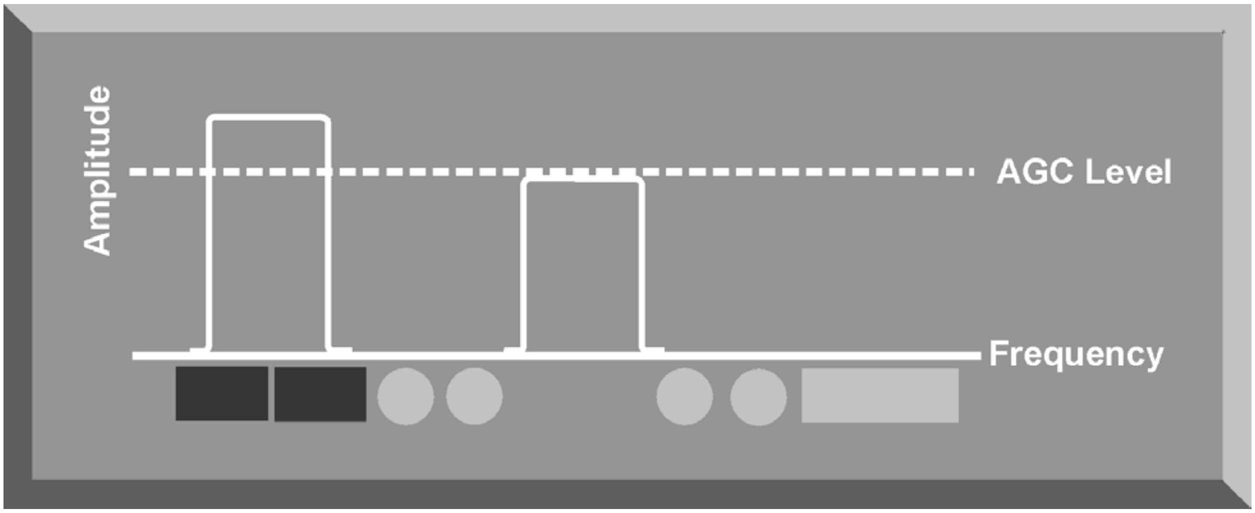

Figure 11-11. Velocity Gate Pull-Off

(3) The rate of change of frequency offset in a VGPO pulse is an extremely critical parameter. Many CW and pulse Doppler radars employ acceleration stops as part of the tracking gates. By differentiating the velocity outputs of the velocity tracking gates with respect to time, the velocity tracker computes target acceleration. Acceleration stops detect and reject unusually large changes in target acceleration. If the VGPO technique changes the frequency of the jamming pulse too rapidly, the tracking loop, with acceleration stops, will reject the jamming pulse and stay on the target. This means that an effective VGPO technique may take from one to ten seconds.

b. Doppler noise differs from most noise techniques in that it is a repeater technique. The jamming system must receive the pulse Doppler radar signal in order to generate an appropriate jamming pulse. Also, noise jamming output is done on a pulse-by-pulse basis and only lasts as long as the pulse duration, or pulse width, of the victim radar signal (Figure 11-12). The Doppler noise jammer receives each pulse and applies a random frequency shift, either positive or negative, to each pulse.

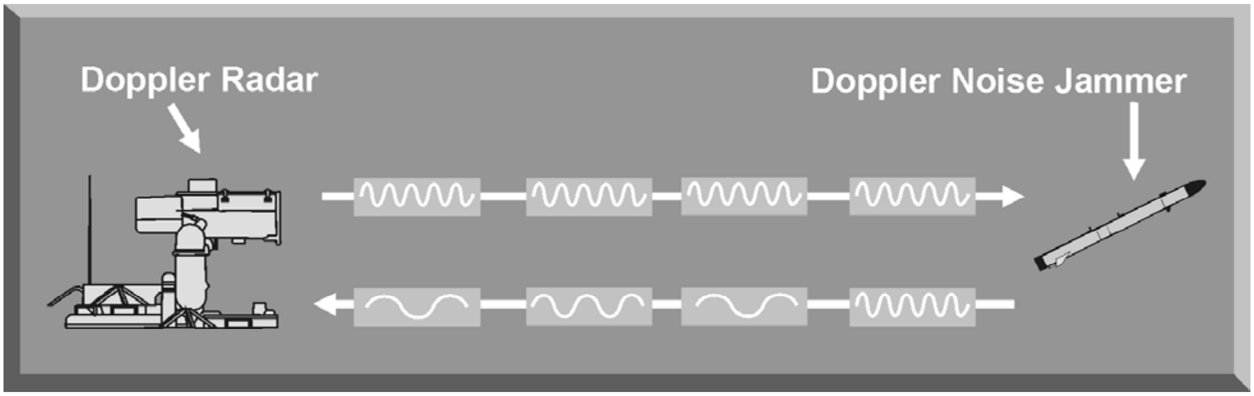
Doppler Radar
Doppler Noise Jammer

Figure 11-12. Doppler Noise Jamming

(1) When Doppler noise jamming pulses are processed by the signal processor, and the Doppler frequencies are sent to the velocity tracking gate, there are so many different velocities that the tracking gate cannot distinguish the target from the jamming. The random distribution of target velocities effectively masks the true target Doppler velocity. If the velocity tracking loop is not saturated, multiple false targets traveling at different speeds will be displayed.

(2) When a technique called Doppler noise blinking is employed, it interferes with the angle and velocity tracking within most semi-active radar missiles. Doppler noise blinking is accomplished by rapidly transmitting bursts of Doppler noise jamming (Figure 11-13).

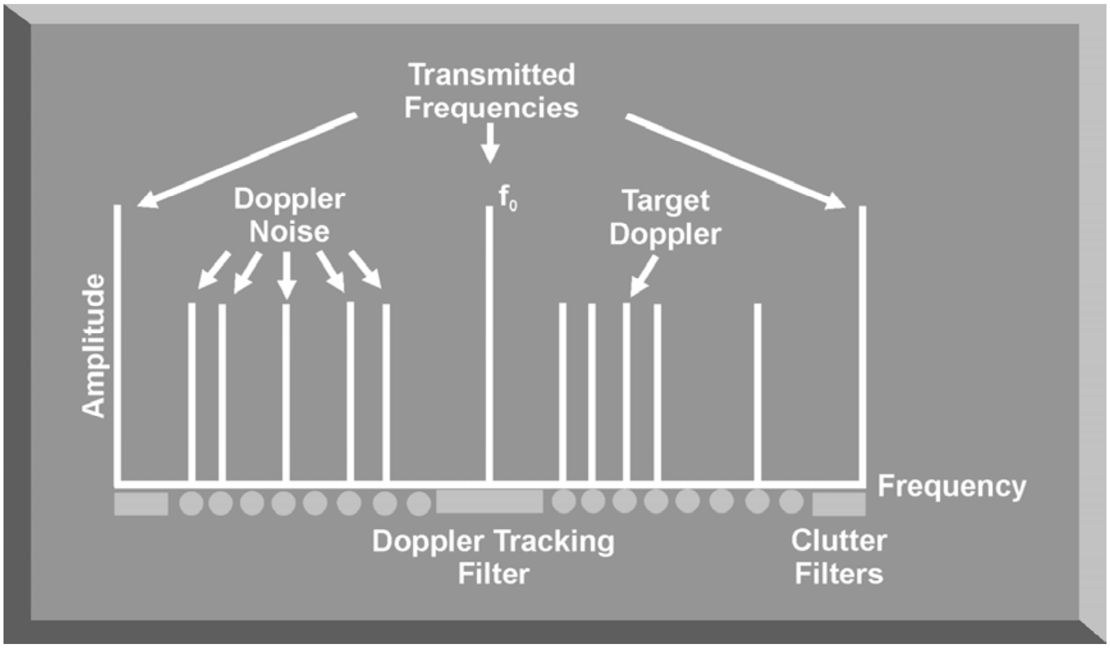
Transmitted Frequencies
Doppler Noise
f_0
Target Doppler
Amplitude
Frequency
Doppler Tracking Filter
Clutter Filters

Figure 11-13. Impact of Doppler Noise Jamming

(3) Doppler noise jamming is effective against most pulse Doppler radars and the semi-active missiles employed with these radars. One disadvantage, however, is that it is only effective against the velocity tracking loop. If range tracking is still available to the radar, Doppler noise may highlight the jamming aircraft. Another disadvantage is that Doppler noise requires a sophisticated jammer able to receive the victim radar pulse, generate random positive and negative frequency modulations on this pulse, and retransmit the jamming pulses at the PRF and pulse width of the victim radar. This requires an extremely fast signal processing capability and detailed intelligence information on the victim radar.

c. Narrowband Doppler noise is also a repeater technique. The jamming system receives the pulse Doppler radar signal and generates a noise jamming signal on a pulse-by-pulse basis (Figure 11-14). Narrowband Doppler noise requires detailed information on the frequency coverage of an individual velocity tracking filter, or velocity bin, employed by the victim radar. Once this frequency range is known, the jammer receives each pulse from the victim radar and transmits jamming pulses with a higher and lower frequency shift based on the real target Doppler. These frequency shifts are always within the frequency range of the velocity bin.

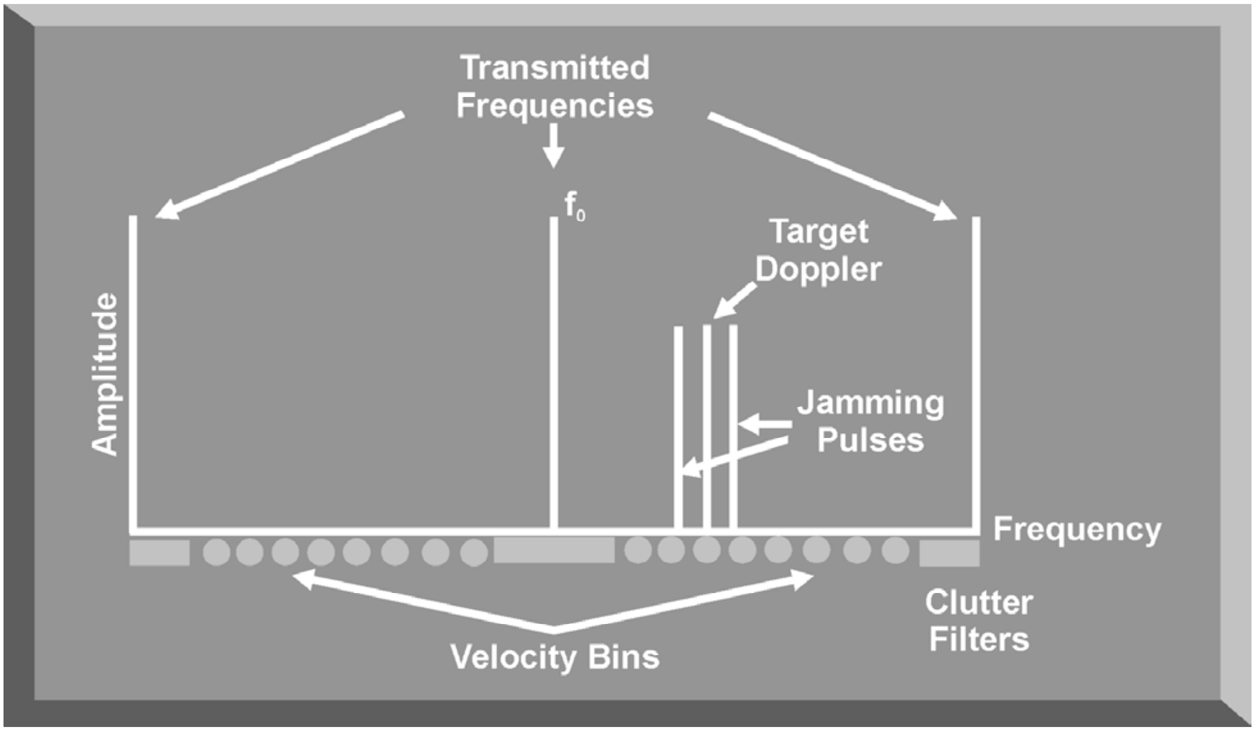

Figure 11-14. Narrowband Doppler Noise

(1) When these pulses are processed by the signal processor and the Doppler signals are sent to the velocity tracking gates, the particular bin that

contains the target Doppler also contains several other targets generated by the jammer. The victim radar signal processor attempts to distinguish the target Doppler from the jamming pulses. It raises the gain in the velocity tracking bins, thinking that the signal with the highest amplitude is the target. But, as the signal gain is increased, the target is "gained out" with the jamming signals and no target is displayed. This is called velocity bin masking and can completely deny target information to a pulse Doppler radar (Figure 11-15).

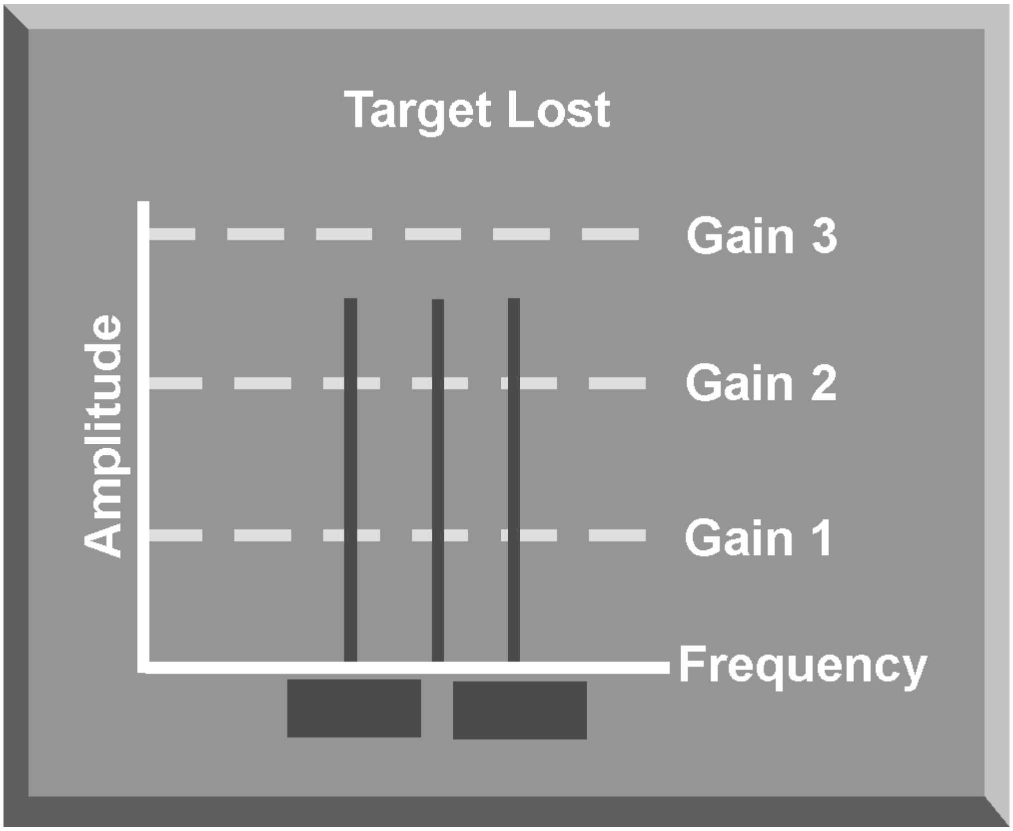

Figure 11-15. Velocity Bin Masking

(2) The advantage of narrowband Doppler noise is that it completely masks an aircraft's velocity from a pulse Doppler radar. The disadvantages include the following: When the victim radar can range-track an aircraft, narrowband Doppler noise highlights the aircraft's presence. To be effective, narrowband Doppler noise requires knowledge of the frequency range of the victim radar's velocity tracking bins, or filters. This detailed information may be available only through threat system exploitation. Finally, sophisticated signal processing and jamming systems are required to receive and transmit in the very narrow frequency band of the velocity bin.

d. Doppler false target jamming is normally used with narrowband Doppler noise or other deception techniques. Its purpose is to initially confuse the radar signal processor with multiple targets and then force the radar signal processor

to raise its gain levels in the velocity tracking loop. The Doppler false target jammer receives each pulse of the victim radar and applies a random frequency shift to a selected number of these pulses (Figure 11-16).

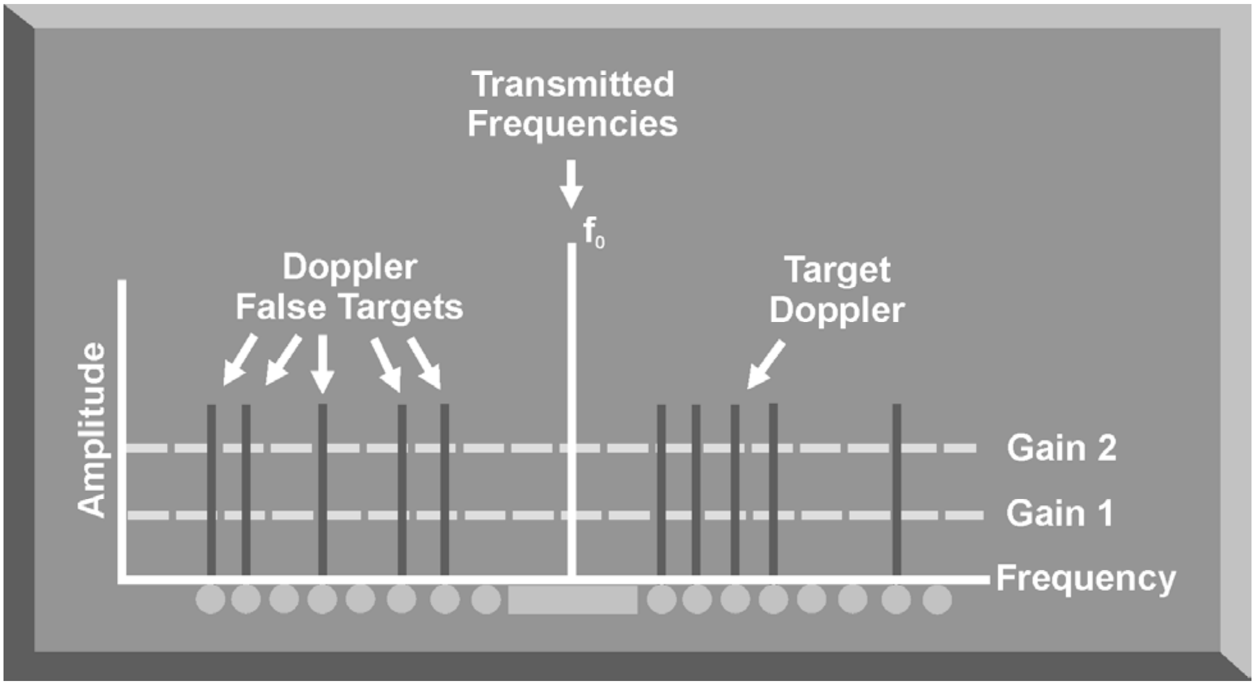

Figure 11-16. Impact of Doppler False Target Jamming

(1) The selected pulses are processed by the signal processor, and multiple Doppler frequencies are sent to the velocity tracking gate. In an attempt to distinguish the target from the jamming pulses, the signal processor increases the gain in each tracking filter, assuming the target Doppler has a higher amplitude than the jamming pulses. This increase in gain sets up the velocity tracking loop for a narrowband Doppler noise technique that will cause the real target to be lost among the generated false targets.

(2) The advantage of Doppler false target jamming is that it can initially confuse the radar signal processor and the radar operator as to the velocity of the real target. It also sets up the radar for narrowband Doppler noise technique and increases its effectiveness. The disadvantage is that the signal processor or the radar operator will eventually be able to distinguish the real target from the false targets based on its velocity. This jamming technique is much more effective when used in conjunction with other Doppler jamming techniques.

6. MONOPULSE DECEPTION JAMMING

The ability of monopulse tracking radars to obtain azimuth, range, and elevation information on a pulse-by-pulse basis make them extremely difficult to jam

(Figure 11-17). Amplitude modulation jamming used against conical scan or TWS radars, such as inverse scan and swept square wave, highlights a target, making monopulse tracking easier. Frequency modulation techniques, such as RGPO and VGPO, are equally ineffective. They serve as a beacon that aids the monopulse radar's target tracking ability. The monopulse radar may be able to track the jammer with more accuracy than tracking actual radar returns because target glint effects are absent from the jamming pulse. Monopulse angle jamming techniques can be divided into two main categories, system-specific and universal. Examples of system-specific jamming techniques include skirt frequency jamming, image jamming, and cross-polarization jamming. These techniques attempt to exploit weaknesses in the design and operation of specific monopulse radars. Cross-eye jamming, a universal technique, attempts to exploit all monopulse radar systems.

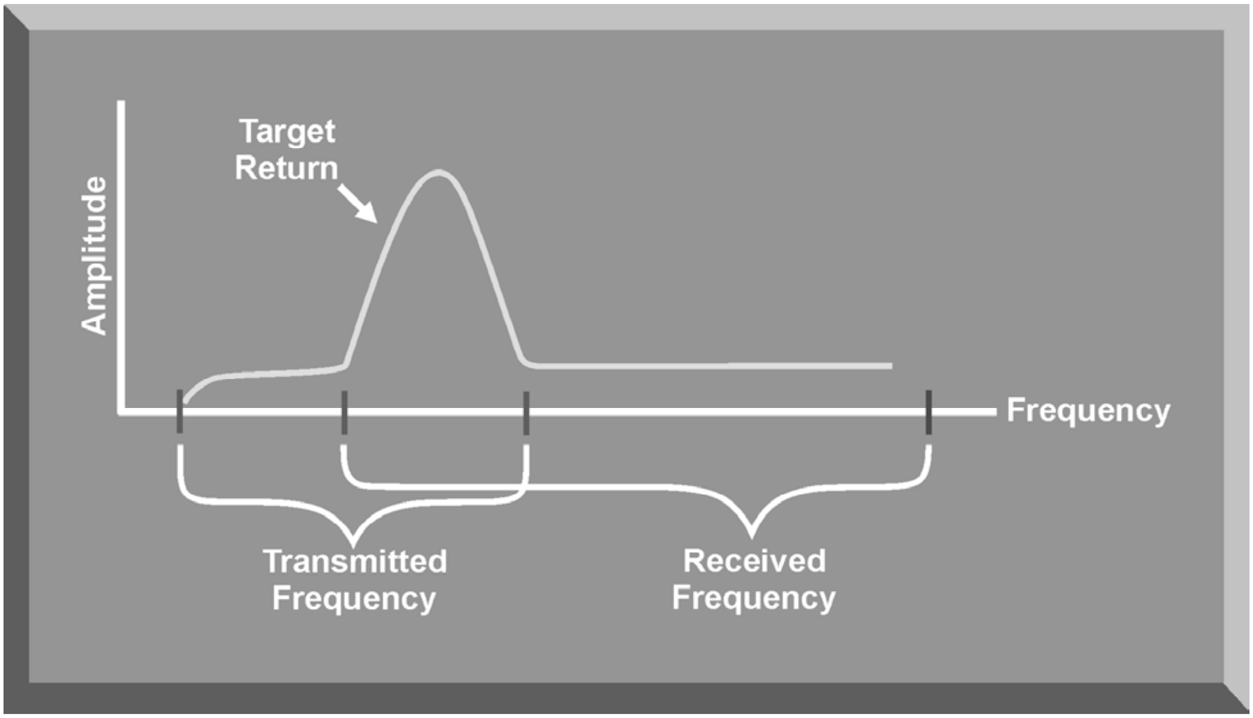

Figure 11-17. Monopulse Radar Receiver

a. Skirt frequency jamming, or filter skirt jamming, is designed to counter the monopulse receiver. Skirt frequency jamming is based on the fact that the intermediate frequency (IF) filter of the monopulse receiver must be correctly tuned to the transmitting frequency of the monopulse radar. It these two components are not exactly tuned, the target signal may be presented on the edge, or skirt, of the receiver IF filter. This offers an opportunity to inject a jamming signal into this skirt (Figure 11-18).

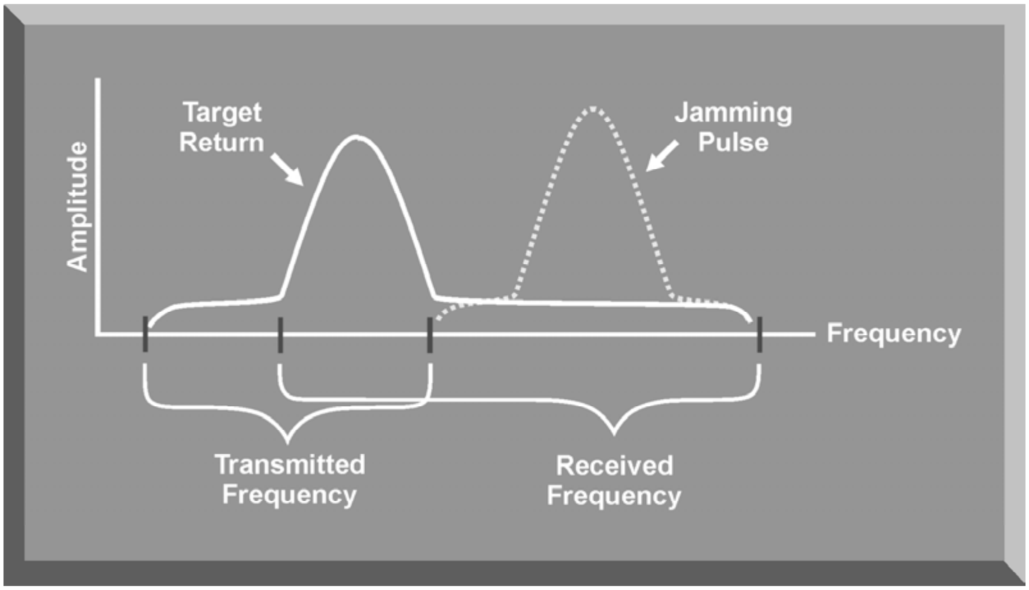
Target
Return
Jamming
Pulse
Amplitude
Frequency
Transmitted
Frequency
Received
Frequency

Figure 11-18. Filter Skirt Jamming Pulse

(1) Filter skirt jamming attempts to take advantage of this frequency imbalance by transmitting a jamming pulse tuned slightly off the radar transmitted frequency and in the middle of the receiver IF filter. This jamming pulse will generate a false error signal and drive the antenna away from the true target return.

(2) A well designed and maintained monopulse system does not have a frequency imbalance. The transmitter and IF filter frequencies will be identical. Jamming signals that are even slightly out of this narrow frequency range will not affect the monopulse tracking capability of the radar (Figure 11-19).

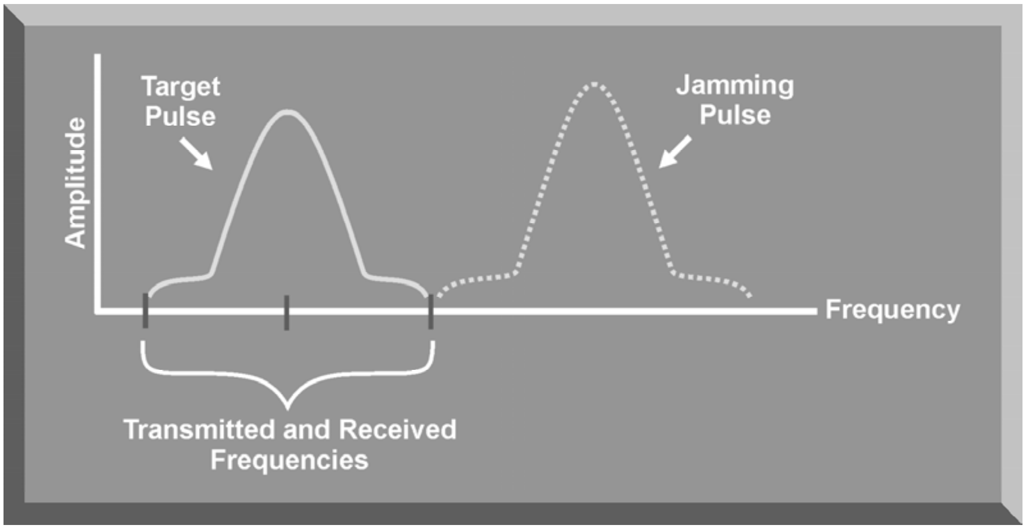
Target
Pulse
Jamming
Pulse
Amplitude
Frequency
Transmitted and Received
Frequencies

Figure 11-19. Ineffective Filter Skirt Jamming

(3) Effective filter skirt jamming requires extensive knowledge of the internal operation of the IF filter. This information can normally be obtained only by system exploitation. Variances from radar to radar and frequency imbalance exists from one radar IF filter to another. This creates a high degree of uncertainty in the effectiveness of this technique.

b. Image jamming exploits another potential weakness in the monopulse receiver (Figure 11-20). Some monopulse receivers have a wide-open front end with no preselection before the mixer. If the jammer transmits a pulse at the intermediate, or image, frequency, but out of phase with this frequency, the phase of the target tracking signal will be reversed and the antenna will be driven away from the target (Figure 11-21). Effective image jamming requires detailed information on the operation of the monopulse receiver. Of particular importance is the image, or intermediate, frequency and whether the local oscillation frequency is above or below the transmitted frequency. This may require exploitation of the monopulse threat system. In addition, a well-designed monopulse system has preselection in the front end and will reject signals that are out of phase with the transmitted frequencies. This capability renders image jamming ineffective.

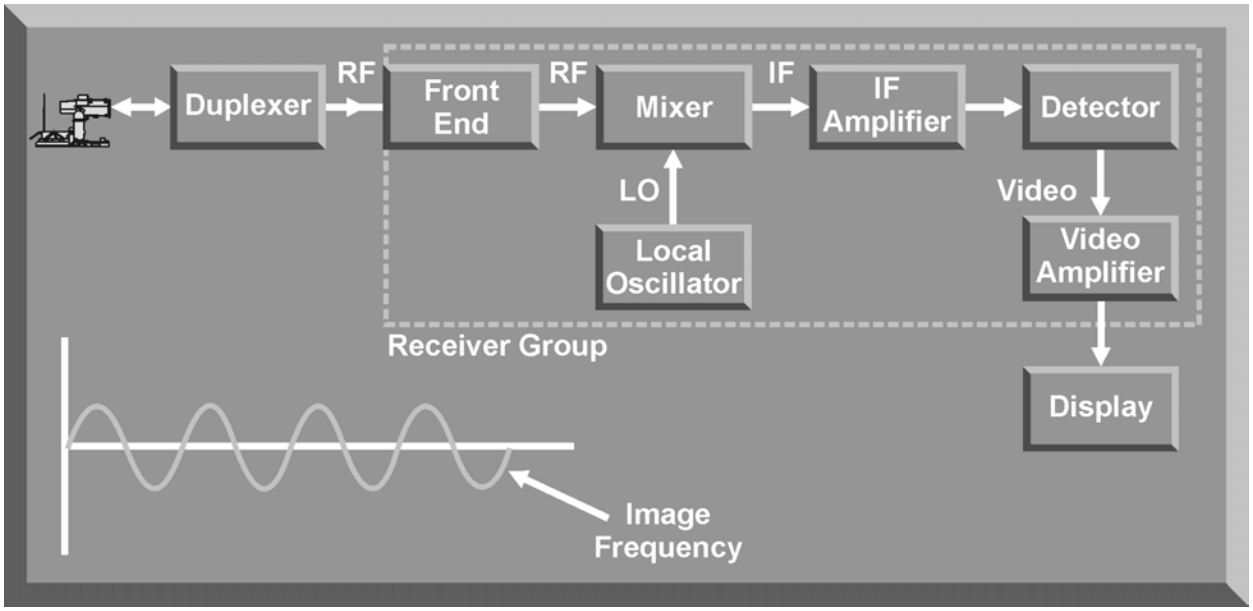

Figure 11-20. Monopulse Image Frequency

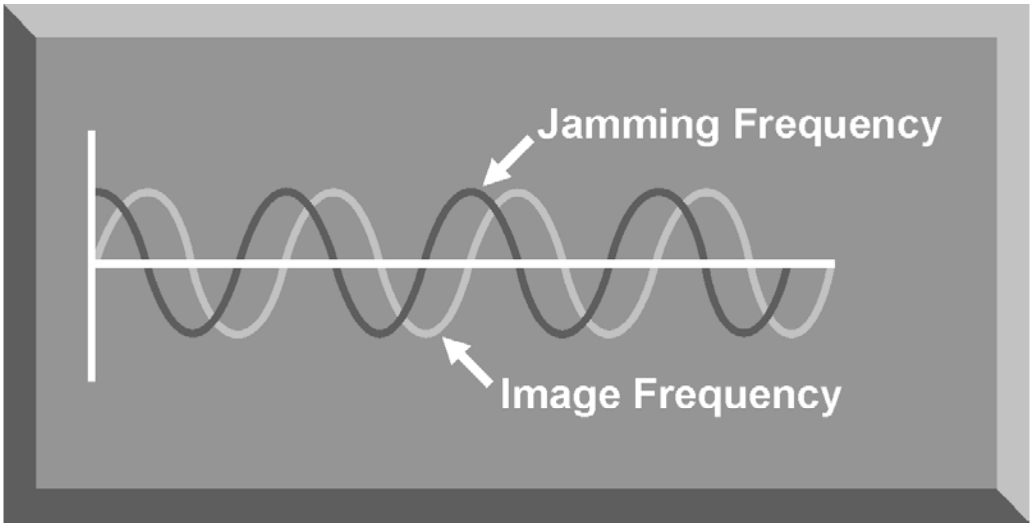
Jamming Frequency
Image Frequency

Figure 11-21. Monopulse Image Jamming

c. Cross-polarization jamming exploits the difference in the monopulse antenna pattern for a jamming pulse that is polarized orthogonal to the design polarization. The antenna pattern for a two-channel monopulse radar using sigma and delta beams shows the tracking point to be between the two beams (Figure 11-22). This is true if the radar is using its design polarization. However, the radar antenna also has a receiving pattern for a signal that is cross-polarized with the design frequency. For a cross-polarized signal, the tracking point is shifted one beamwidth to the right. This shift in the tracking point results in a target tracking signal that is 180° out of phase with the real signal. To be effective, a jamming signal polarized orthogonally to the design frequency of the radar would have to be 25 to 30 decibels, or about 1000 times, stronger than the radar signal.

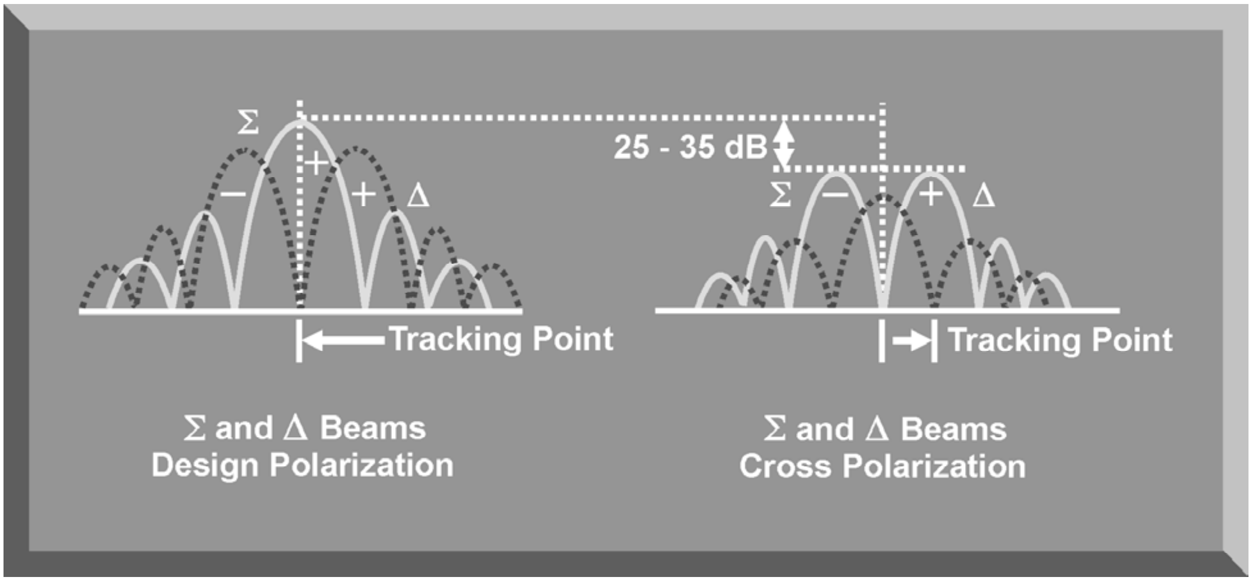
Σ
+
−
+
Δ
25 - 35 dB
Σ
−
+
Δ
Tracking Point
Tracking Point
Σ and Δ Beams
Design Polarization
Σ and Δ Beams
Cross Polarization

Figure 11-22. Cross-Polarization Antenna Pattern

(1) A cross-polarized jammer must receive and measure the polarization of the victim monopulse radar. The jammer then transmits a very high power jamming signal at the same frequency, but orthogonally polarized, to the victim radar. As a rule, the jamming signal must be 25 to 30 dBs stronger than the target return to exploit the tracking errors in the cross-polarized antenna pattern. Additionally, it must be as purely orthogonal to the design polarization as possible. Any jamming signal component that is not purely orthogonal will highlight the target and require more jamming power to cover the target return.

(2) A cross-polarized jammer must be able to generate a powerful jamming pulse that is polarized orthogonal to the victim radar. A cross-polarized jammer that generates the power and purity of polarization required to defeat monopulse angle tracking poses extreme technological challenges.

d. Cross-eye jamming is a complex technique that attempts to distort the wavefront of the beams in a monopulse radar and induce angle tracking errors. It exploits two basic assumptions of monopulse tracking logic in comparing target returns on a pulse-by-pulse basis. The first assumption is that a target return will always be a normal radar pulse echo. The second assumption is that any shift in amplitude or phase in a target return is due to the tracking antenna not pointing directly at a target. This condition generates an error signal and the antenna tries to null, but the amplitude or phase shifts.

(1) Cross-eye jamming attacks the two assumptions through a process of receiving and transmitting jamming pulses from different antennas separated as far apart as possible. In Figure 11-23, the phase front of a monopulse signal is received by the number 1 receive antenna, amplified by the repeater, and transmitted by the number 2 transmit antenna. The same phase front then hits receive antenna number 2, is shifted 180°, amplified by the repeater, and transmitted by the number 1 transmit antenna. These two out-of-phase signals must be matched in amplitude and must exceed the amplitude of the target return.

(2) When these jamming signals arrive at the victim radar, the tracking loop attempts to null out the amplitude and phase differences. With two widely spaced jamming sources at different phases, the antenna never achieves a null position or tracking solution. The distance between antenna pairs is an important parameter that determines the effectiveness of cross-eye jamming. The wider the spacing between antenna pairs, the more distortion in the victim's wave front near the true radar return. Most fighter aircraft do not provide sufficient spacing between the antennas to maximize effectiveness. Effectiveness is also lost when the aircraft is abeam or going away from the radar. To further complicate matters, when the radar is directly in front of the aircraft, the jamming pulses must have a power at least 20 dBs above the target return. Cross-eye jamming can also be defeated with a leading-edge tracker that rejects jamming signals arriving at the antenna behind the target return.

(3) Countering monopulse angle tracking is the greatest challenge for self-protection jamming systems. Skirt jamming and image jamming have had limited success. Cross-polarization and cross-eye jamming techniques require complex and sophisticated circuitry and much power.

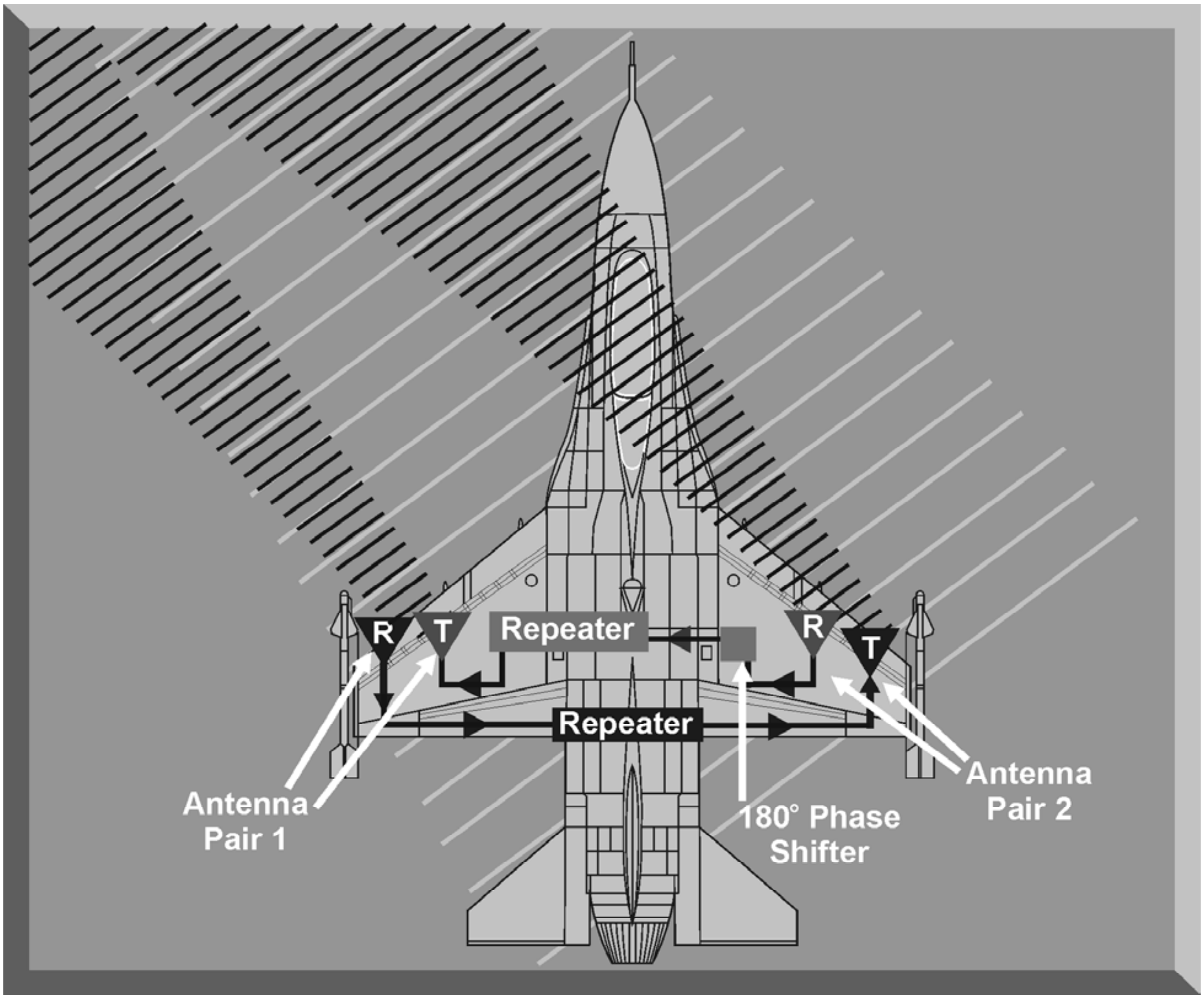

Figure 11-23. Cross-Eye Jamming

7. TERRAIN BOUNCE

Terrain bounce is a jamming technique used primarily at low altitude. It is used to counter semi-active, air-to-air missiles and monopulse tracking radars. The technique involves a repeater jammer that receives the radar or missile guidance signal. The jammer amplifies and directs this signal to illuminate the terrain directly in front of the aircraft. The missile or radar tracks the reflected energy from the spot on the ground instead of the aircraft (Figure 11-24).

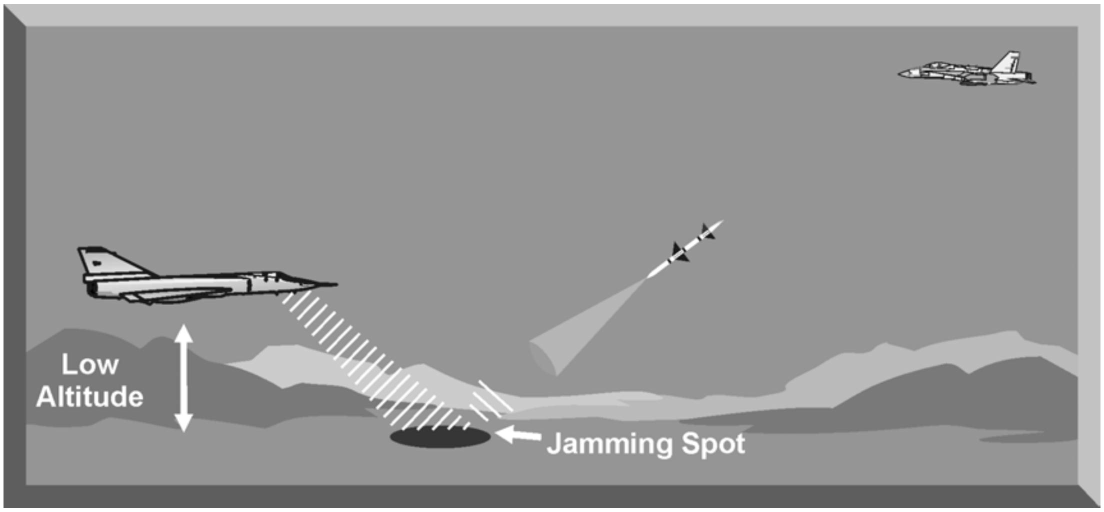

Figure 11-24. Terrain Bounce

a. To be effective, the terrain bounce jamming antennas should have a narrow elevation beamwidth and a broad azimuth beamwidth. This transmission pattern maximizes the energy directed toward the ground and minimizes the energy transmitted toward the missile or radar. To overcome signal losses associated with uncertain terrain propagation, the jamming system should also generate high jamming power. This ensures the energy reflected from the terrain is higher than the energy in the aircraft return. The terrain bounce jamming antennas should have very low sidelobes to preclude activation of any home-on-jam (HOJ) missile capability. For an air-to-air missile, the terrain bounce technique should be activated at long range. This will initially put the aircraft and the jamming spot in the same resolution cell. As the range decreases, the missile will be decoyed by the higher power in the jamming spot.

b. Some problems associated with terrain bounce jamming include the uncertainty of the signal scattering parameters of the various terrain features and the possible changes in signal polarization caused by terrain propagation. In addition, terrain bounce jamming can place maneuvering restrictions and maximum altitude limitations on the aircraft.

8. SUMMARY

There are several deception jamming techniques that can be employed to counter threat radar systems. The effectiveness of these techniques can be enhanced when they are employed in combination. For example, the effectiveness of an RGPO technique is enhanced when an angle deception technique is also employed. Determining the most effective deception technique, or combination of techniques, can present a challenge to intelligence and engineering analysts. However, when employed with maneuvers and chaff, deception techniques can mean the difference between success and failure on the modern battlefield.

CHAPTER 12. DECOYS

1. INTRODUCTION

A decoy is a device designed to look to an enemy radar more like an aircraft than the actual aircraft itself. Decoys do three primary missions: they saturate the enemy's integrated air defense system (IADS), coerce the enemy into exposing his forces prematurely, and defeat tracking by enemy radar. This chapter will discuss saturation decoys, towed decoys, and expendable active decoys. Chaff and flare systems will be discussed in separate chapters.

2. SATURATION DECOYS

A saturation decoy is usually an expendable vehicle designed to emulate a penetrating aircraft. Its mission is to deceive and saturate an enemy's IADS. Employing multiple saturation decoys can force an IADS to devote critical resources to engage these false targets. This depletes enemy assets available to engage penetrating aircraft. In addition, ground or air launched saturation decoys can be used to stimulate the IADS, to collect intelligence data, or to initiate attacks by suppression of enemy air defense (SEAD) assets. The three main characteristics of saturation decoys are their electronic signature, their flight program, and their mission type.

a. Saturation decoys must present an electronic signature, or radar return, that is indistinguishable from the aircraft they are protecting. Decoys can do this by either passive or active measures, or use a combination of both. A passive decoy is essentially a flying radar reflector. The size, shape, and materials used in the decoy are optimized to ensure that the proper amount of radar energy is returned to the enemy radars. Active decoys employ radar repeater systems to receive the enemy radar signal, amplify it and send back a radar return of the proper size to confuse the enemy. Reflecting or transmitting the proper size radar return is critical for both passive and active decoys. A return that is too large or too small will allow the enemy radar operator to differentiate between decoys and aircraft, causing the decoys to be ignored.

b. To continue deceiving an enemy IADS, a decoy must do more than provide the proper-sized radar return. Possessing flight characteristics similar to the aircraft it is protecting increases the probability that the decoy will effectively deceive an IADS for a sustained period of time. Modern decoys can either be powered with rockets, miniature engines, or simply glide for very long distances based upon the altitude and airspeed of the jet that releases them. Additionally, their flight paths can be pre-programmed into an onboard autopilot, allowing the decoy to fly an independent ground track, thus increasing their appearance as attack aircraft worth tracking.

c. Saturation decoys carry out two of the three decoy missions. Launched in significant numbers, they can saturate or overburden an IADS. Meanwhile, their realistic electronic image and preprogrammed flight paths entice the enemy to turn on radars and show his forces.

(1) Saturation decoys launched in coordination with an attacking strike package force the enemy to take time to process meaningless tracks and tie up critical assets. In this role, decoys primarily work against the early warning network of the enemy IADS by presenting the IADS with numerous targets to sort and track. Resources committed to tracking decoys may not be available to track actual aircraft. Additionally, if an enemy knows that decoys are present, he may not commit any resources against targets for fear they are just decoys.

(2) Time of radiation or “emission control” is a critical factor for acquisition and target tracking radars. To be effective and survive on the battlefield, ground threat radars radiate as little as possible; too much time radiating allows ELINT collectors to find their location and either direct aircraft to avoid them or call in an attack upon them. Therefore, when a decoy can get a radar to emit, the radar is now essentially compromised and can be avoided or attacked. Getting the enemy's radars to emit is called “stimulating the IADS,” which is generally a precursor to any threat suppression mission.

(3) An extremely successful example of using decoys to stimulate the IADS was carried out in the Bekaa Valley in 1982. The Israelis opened the conflict by launching saturation decoys to successfully simulate an attack. While the Syrians reloaded, Israeli fighters attacked, destroying 17 of 19 Syrian SA-6s in the beginning of the battle. With the ground threat neutralized, the Israeli Air Force went on to destroy 85 Syrian fighters in the pure air-to-air conflict that resulted.

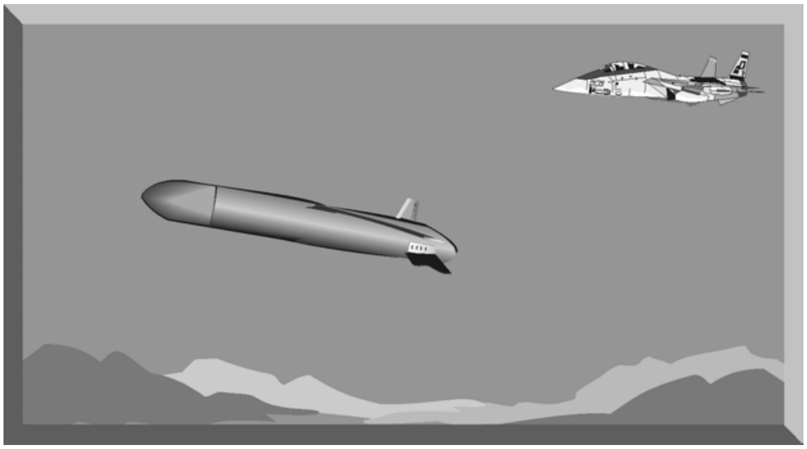

Figure 12-1. Tactical Air Launched Decoy

d. Two examples of saturation decoys are the Navy's Tactical Air Launched Decoy (TALD) in Figure 12-1 and the Air Force's proposed Miniature Air Launched

Decoy (MALD) in Figure 12-2. Both of these decoys can work actively or passively and both have pre-programmable flight paths. The TALD is an unpowered decoy normally launched from an F-14 Tomcat. The Air Force's MALD is a smaller jet-powered decoy also designed to be used by fighter aircraft. The MALD is 90 inches long, 6 inches in diameter, and has 25-inch wings that are foldable– essentially it is the size of an air-to-air missile. Because of its small size, the MALD can be carried into the target area before it is launched. Once launched it uses its speed, independent flight path, and electronically manipulated radar signature to make acquisition radars and target tracking radars mistake it for one of the attacking aircraft.

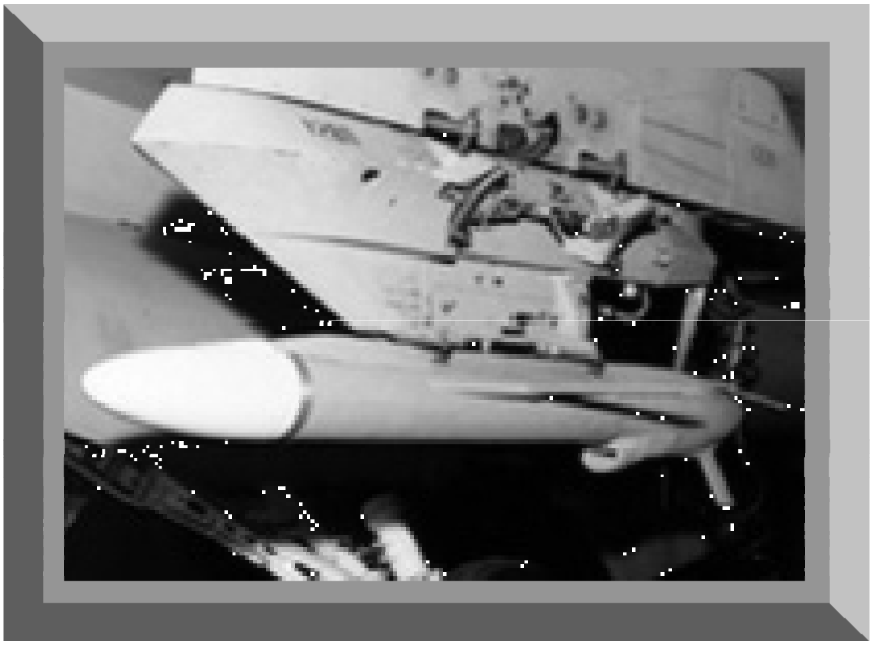

Figure 12-2. Miniature Air Launched Decoy (MALD)

3. TOWED DECOYS

A towed decoy is a small jammer that is physically attached to the aircraft (Figure 12-3). Unlike the saturation decoys that work against the IADS, the towed decoys are for individual aircraft survival. Towed decoys are designed to defeat enemy missiles in the final stages of an engagement; therefore, towed decoys, as well as other expendables, are known as endgame countermeasures. While towed decoys are primarily designed to provide sufficient miss distance between an attacking semi-active radar missile and the protected aircraft, they may also be effective against pulse Doppler radars and monopulse radars.

a. To be effective, the towed decoy must turn on within the threat radar's resolution cell after the radar is tracking the protected target. To successfully decoy the missile, the towed decoy must return radar signals with sufficient power to simulate a radar cross section (RCS) significantly larger than that of the

protected target. There are currently two generations of towed decoys on the market. Their primary difference lies in the connection each has with the aircraft towing it.

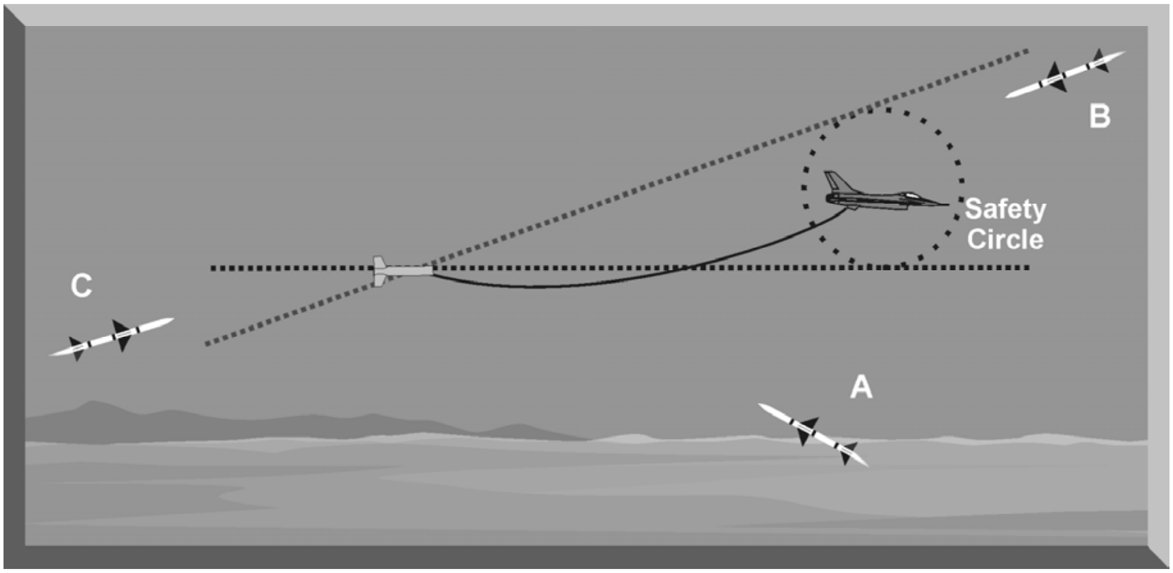

Figure 12-3. Towed Decoy

(1) The first generation of towed decoys contains a simple repeater jammer that enhances any signal it receives in the proper frequency range. The enhanced signal is stronger than the aircraft signal so the missile is lured towards the decoy. These decoys are stand-alone units that contain all the electronics, processors, receivers and transmitters within them. The only tie to the aircraft is for power and status. One of the big advantages of these simple repeater devices is that they do not require the exact frequency of the enemy radar systems to be effective, they will enhance any signal coming at them. An area of concern with the use of towed decoys is possible conflict between the onboard jamming system and the towed decoy. The onboard system could overpower the decoy, causing the attacking missile to ignore the decoy and track the aircraft.

(2) The second generation of decoys is tethered to the aircraft via fiber optic cable. Through this cable travels the different jamming modulations to be used by the decoy. These fiber optic towed decoys (FOTD) only contain the transmitters; the remaining items are in the jet or the pod. This system allows for more complex jamming through the decoy, including cooperative jamming between the aircraft and the decoy.

b. The separation required between the decoy and the aircraft is a primary consideration in developing a towed decoy system. The towed decoy should be positioned far enough behind the aircraft to preclude warhead fragments from missiles guiding on the decoy from also impacting the aircraft. Missile A in Figure

12-3 depicts a situation where the missile will detonate well outside of the aircraft's safety circle. From a pilot perspective, any restrictions on aircraft maneuvering imposed by a towed decoy are very important. The number of decoys that can be carried and the time required for decoy deployment are also important employment considerations.

c. Achieving 360° coverage is a primary limitation of a towed decoy system. When an aircraft equipped with a towed decoy is abeam a threat radar, the radar may be able to discriminate between the aircraft and the decoy. This is a function of the resolution cell of the radar. In addition, missiles approaching from a high-aspect angle, and above the aircraft (Figure 12-3 - Missile B), may fuse on the aircraft while guiding to the decoy. Missiles approaching from a low-aspect angle (Figure 12-3 - Missile C) may not fuse on the decoy and subsequently acquire and fuse on the aircraft. Finally, if the decoy is destroyed or lost, the time required to deploy a replacement decoy is critical, especially if the aircraft is engaged by multiple missiles.

d. An example of a fielded towed decoy system is the AN/ALE-50 (Figure 12-4). This first generation towed decoy system is found on Air Force F-16 and B-1 aircraft, and there is a version that is integrated into the ALQ-184 pod.

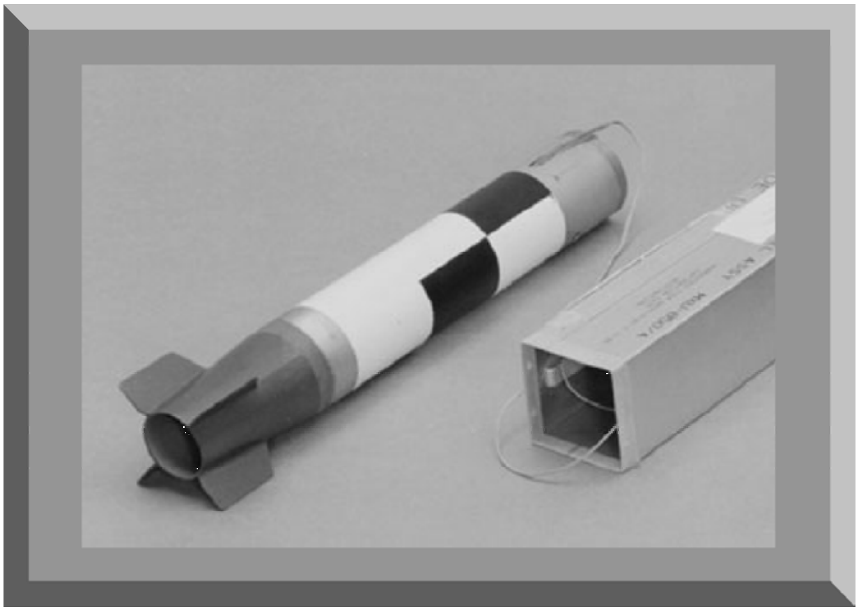

Figure 12-4. AN/ALE-50 System

(1) The system consists of a launch controller subsystem and towed decoys. The launch controller houses the decoy before it is launched, provides power to the decoy, and provides for the monitoring of the electronics. The decoy body is a factory sealed, self-contained unit with everything except for power. Power comes through the tether from the host aircraft; the decoy sends its operating status back through the tether to the aircraft.

(2) ALE-50 decoy use is cleared throughout the flight regime of the F-16 and B-1. Decoys can be deployed without being turned on, but once a decoy has been deployed, it cannot be reeled back in and must be severed before landing. Procedures are in place to reduce the chance that the onboard jamming system will negate the decoy.

(3) The ALE-50 towed decoy is a wideband RF repeater that provides self-protection EA by receiving, electronically amplifying, and retransmitting enemy radar RF signals. Upon receiving a threat radar signal, this simple repeater amplifies the signal and retransmits it. This provides the radar with two signals, one reflected from the aircraft and a stronger one from the decoy. With the signal from the decoy being the more attractive, the radar or missile guides towards the decoy. During combat operations over Kosovo, ALE-50 decoys were credited with saves for both F-16s and B-1s.

4. EXPENDABLE ACTIVE DECOYS

Expendable active decoys are designed to lure the tracking gates of an enemy's radar away from the aircraft. They are endgame countermeasures like towed decoys, but they differ in that expendable decoys free-fall or glide to the ground as opposed to being towed behind the aircraft.

a. Expendable decoys are small, active jamming systems designed to be expended by existing aircraft chaff and flare dispensers, such as the AN/ALE-40 or the AN/ALE-47. Expendable decoys can employ noise or deception jamming with noise jamming being the most common. Deception jamming techniques can be employed to enhance effectiveness against pulse Doppler radars. There are two challenges associated with expendable jammers: the amount of the time the jammer is effective and the packaging (Figure 12-5).

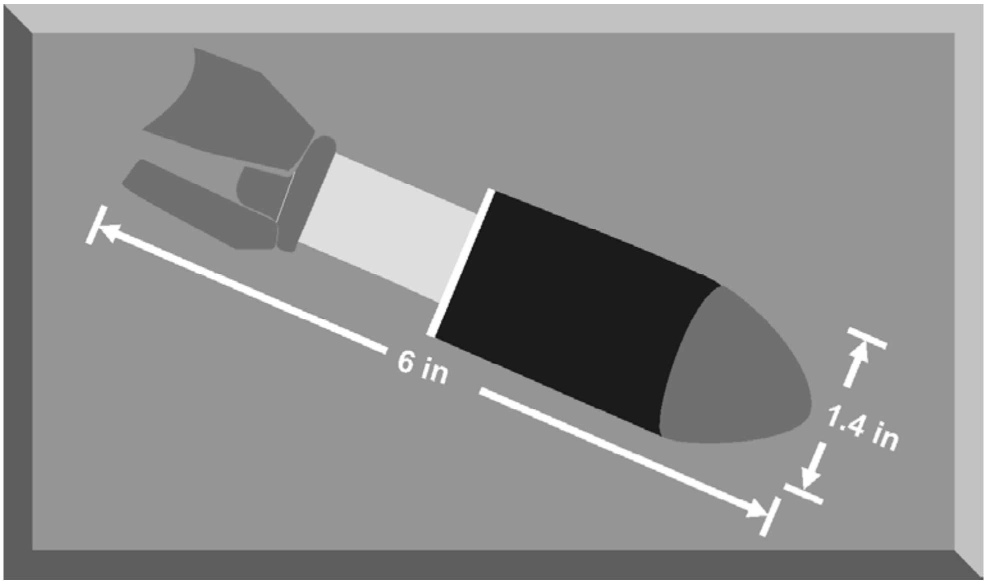

Figure 12-5. Generic Expendable

b. Expendable decoys are designed to provide protection for the dispensing aircraft for a specific period. The dispensing altitude and rate of fall determine this period of effective coverage. Expendable decoys can employ small parachutes of aerodynamic design to slow the rate of fall and increase the time of effective coverage. If the period of coverage is too short, multiple expendable decoys must be employed. This places a premium on timely employment and expendables management.

c. The primary components of an expendable decoy are the transmit and receive antennas, techniques generator, amplifier, and power supply. The transmit and receive antennas should be isolated and capable of high gain, wide bandwidth, and should use compatible polarization with the victim radar. The techniques generator must recognize the victim radar signal and generate the appropriate jamming response. The amplifier must be capable of generating a high power jamming signal over a wide frequency range. To meet these requirements, sophisticated computer and miniaturization techniques are used, and the components packaged to all fit in the aircraft dispenser. These factors impact the cost of expendable decoys and may limit the availability of these assets.

d. The Generic Expendable, RTE-1489, commonly called the GEN-X decoy is a fielded expendable active decoy. The decoy is sized to fit into a 1.4 x 1.4 x 5.8 inch cartridge and take advantage of new microwave/millimeter-wave integrated circuit (MMIC) technology. The GEN-X is programmable and features a broadband antenna and wide frequency coverage. After ejection, the decoy extends three small fins for stability. Its battery ignites to provide power, the receiver locks on to the threat radar signal, and a deception signal is generated and transmitted.

5. SUMMARY

Decoys simply provide the enemy with more targets to process. In the case of saturation decoys, this forces the enemy to commit resources against false targets, or show his defenses. For towed decoys and expendable active decoys, it makes the missile or tracking radar separate a real target from more electronically attractive decoys.

CHAPTER 13. CHAFF EMPLOYMENT

1. INTRODUCTION

Chaff was first used during World War II when the Royal Air Force, under the code name "WINDOW," dropped bales of metallic foil during a night bombing raid in July 1943 (Figure 13-1). The bales of foil were thrown from each bomber as it approached the target. The disruption of German AAA fire control and ground control intercept (GCI) radars rendered these systems almost totally ineffective. Based on this early success, chaff employment became a standard bomber tactic for the rest of the war.

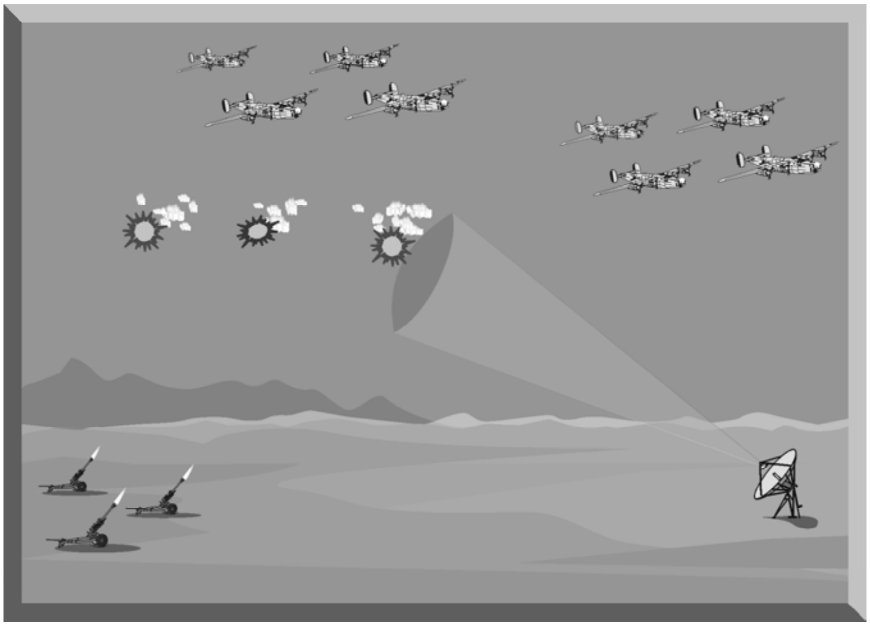

Figure 13-1. "WINDOW" – The First Operational Employment of Chaff

a. Chaff is one of the most widely used and effective expendable electronic attack (EA) devices. It is a form of volumetric radar clutter consisting of multiple metalized radar reflectors designed to interfere with and confuse radar operation. It is dispensed into the atmosphere to deny radar acquisition, generate false targets, and to deny or disrupt radar tracking. Chaff is designed to be dispensed from an aircraft and function for a limited period.

b. Even with the development and deployment of advanced radar threat systems, chaff continues to be an extremely effective EA device. Experience gained during the Vietnam conflict, the 1973 Yom Kippur War, and DESERT STORM clearly shows that chaff effectiveness against radar threats is still a factor with which the enemy must contend. This is especially true when chaff is employed with self-protection jamming and aircraft maneuvers.

c. Chaff screening and self-protection are the two basic chaff employment tactics. Chaff screening tactics, including area saturation and chaff corridor employment, are designed to confuse and deny acquisition information to the early warning, GCI, and acquisition radars supporting surface-to-air missile (SAM) systems. Self-protection tactics are designed to counter acquisition and target tracking radars (TTRs). When used with jamming and maneuvers, chaff can cause TTRs to break lock or generate survivable miss distances if a SAM is fired at the aircraft.

2. CHAFF CHARACTERISTICS

To understand how chaff affects radar systems, it is important to understand its characteristics. The most important chaff characteristics are radar cross section (RCS), frequency coverage, bloom rate, Doppler content, polarization, and persistence.

a. RCS is a measure of the net reradiated energy from a target to the illuminating radar. The RCS of an aircraft varies based on the size, shape, type of skin surface, configuration, and aspect to the illuminating radar. Figure 13-2 shows the effect of aspect on aircraft RCS. The RCS is greatest when the aircraft aspect is 90°, or abeam the radar. The lowest RCS occurs near the 30-70° and 110-150° of aspect. Since the aircraft RCS also varies based on frequency, the victim radar's frequency is a key factor. To be effective, chaff must be dispensed in large enough quantities to create an RCS greater than the aircraft RCS.

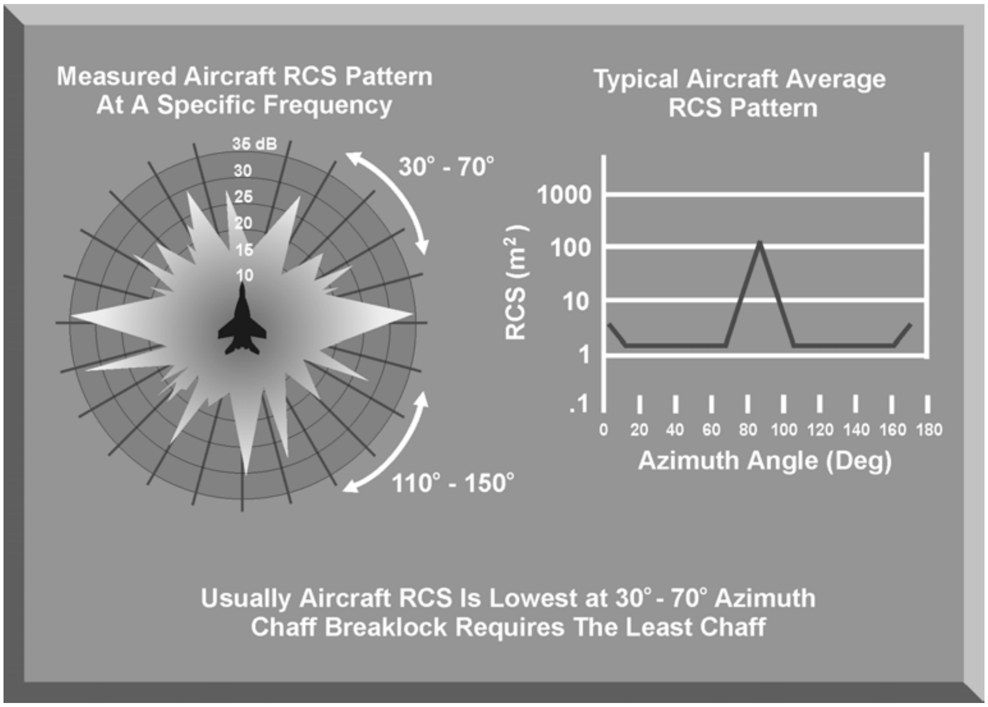

Figure 13-2. Aircraft Radar Cross Section (RCS)

(1) The RCS of a chaff bundle depends on the frequency of the victim radar and the dispensing aircraft's relative position, or aspect. Figure 13-3 shows the RCS of a single RR-170 chaff cartridge based on frequency. It shows that the largest RCS occurs at about 3 GHz. However, for the spectrum between 2-18 GHz, which includes most SAM TTRs, the RCS of the RR-170 cartridge is over 50 square meters. Since the typical fighter aircraft RCS varies between 1 and 10 square meters, depending upon frequency and aspect, the RR-170 chaff cartridge should provide a sufficient RCS to mask the aircraft RCS.

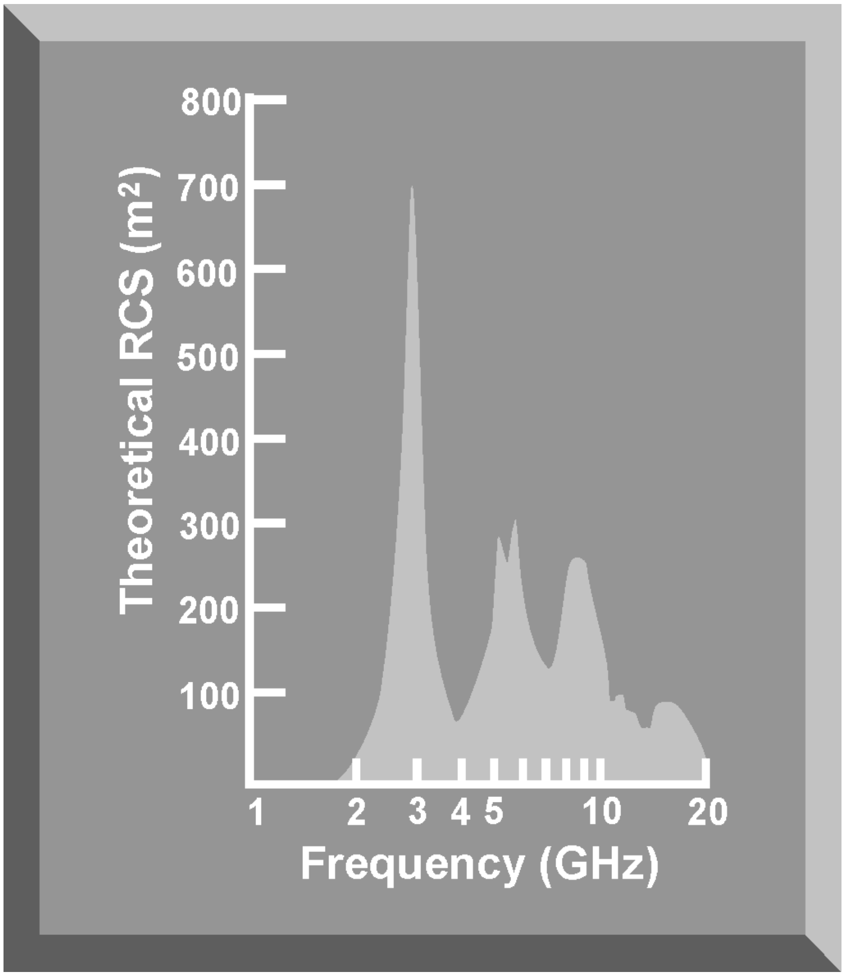

Figure 13-3. RR-170 Chaff Cartridge RCS

(2) The angular relationship, or aspect, between the aircraft and chaff bundle affects the chaff RCS presented to the victim radar. Chaff RCS is greatest when the chaff bundle and the aircraft are abeam the threat radar. It is smallest when the threat radar is off the nose or tail of the aircraft. Aspect is important when developing self-protection maneuvering and chaff dispensing tactics against threat radars (Figure 13-4).

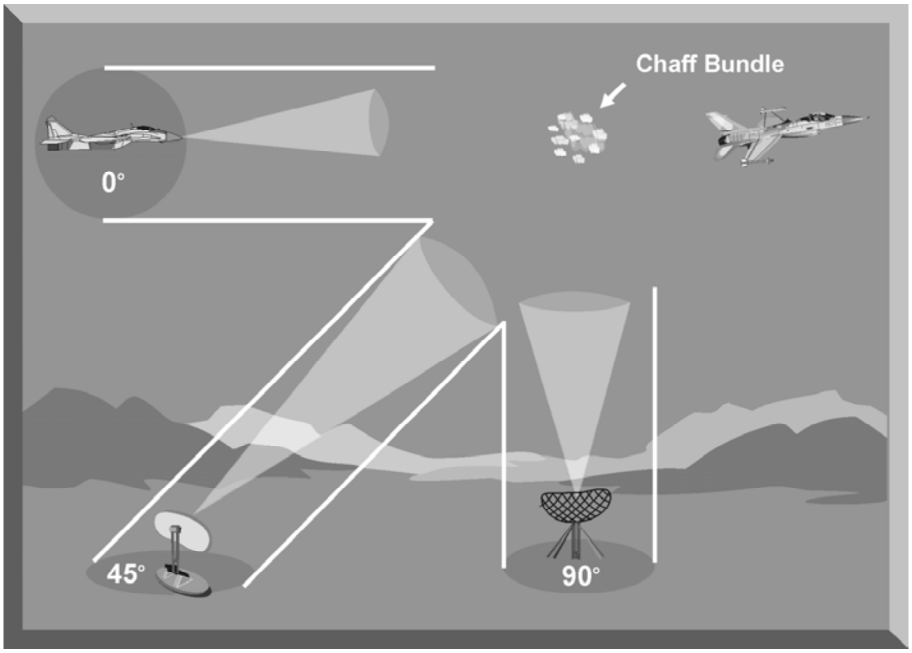
Chaff Bundle
0°
45°
90°

Figure 13-4. Threat Radar Aspect and Chaff RCS

(3) Dispensing multiple chaff bundles simultaneously does not necessarily increase chaff RCS. Multiple bundles increase the density of the chaff but do not directly enhance self-protection capabilities (Figure 13-5). This is an important consideration when developing chaff dispenser rates to counter threats.

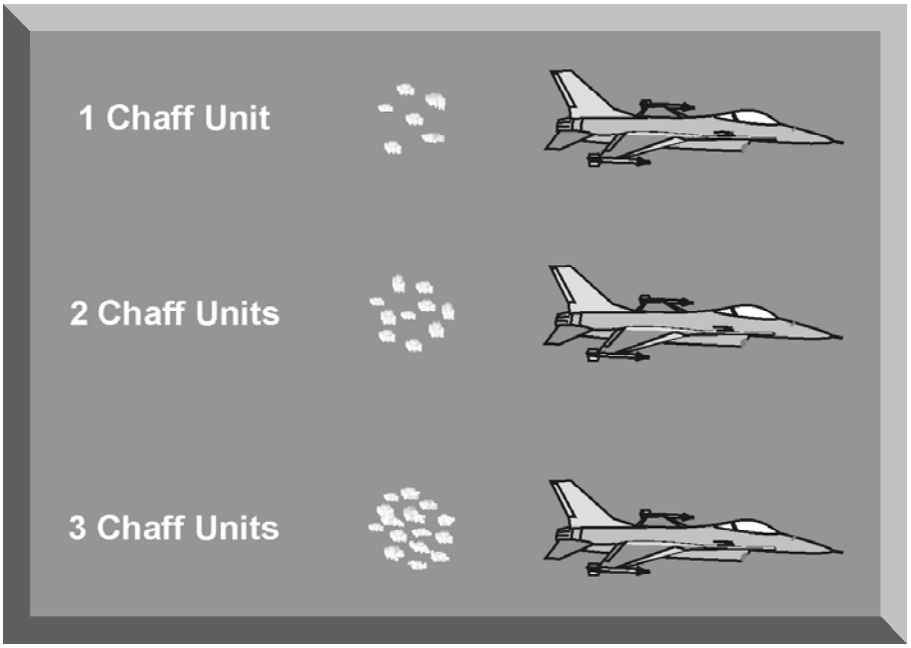
1 Chaff Unit
2 Chaff Units
3 Chaff Units

Figure 13-5. Impact of Multiple Chaff Cartridge Employment on Chaff RCS

b. Each strip of chaff is a dipole reflector that reradiates the electromagnetic energy received from an emitting radar and creates a radar echo. The optimum size is cut to about one-half the wavelength of the victim radar's RF. Since a single cut length is restricted in effectiveness to a narrow range of frequencies, different lengths are normally packaged together to provide coverage over a wide range of frequencies (Figure 13-6).

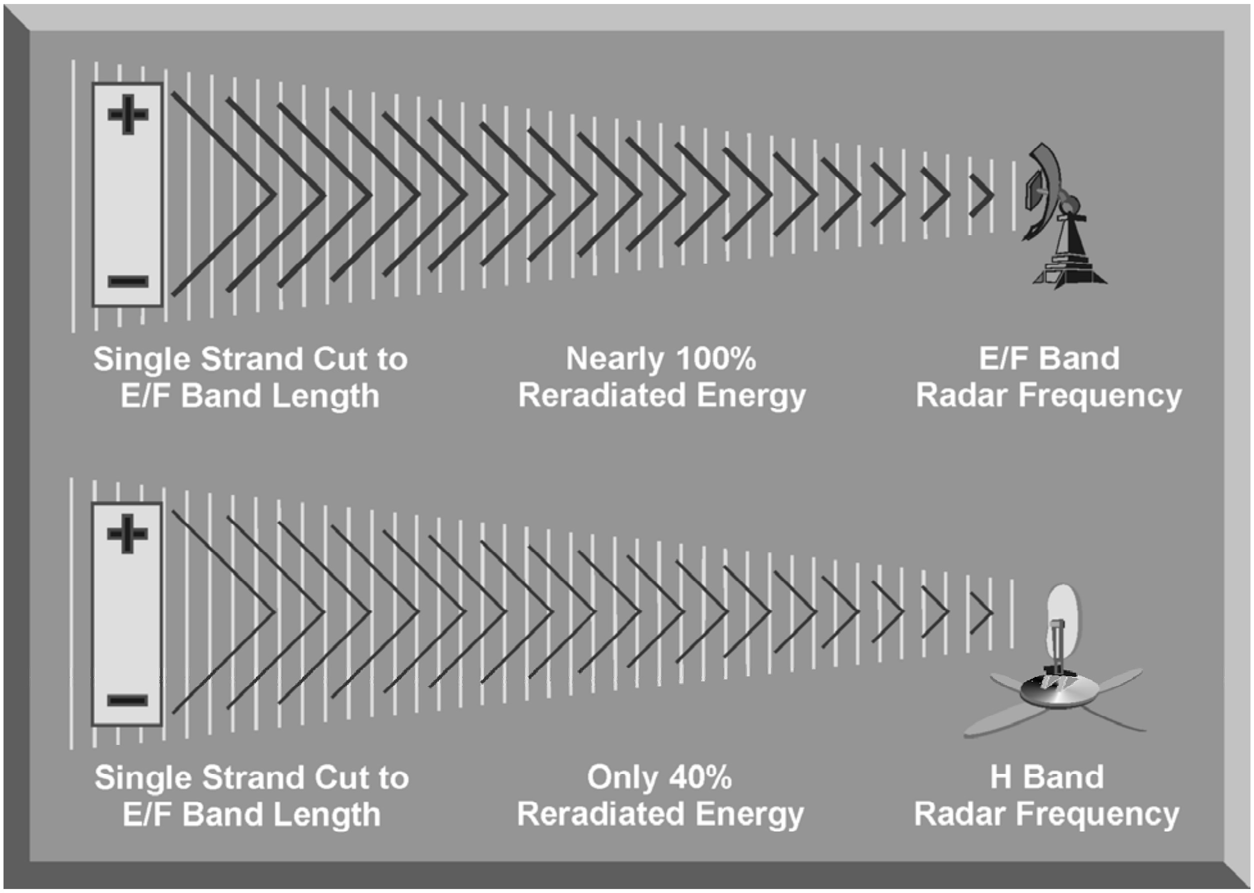
+
−
Single Strand Cut to E/F Band Length
Nearly 100% Reradiated Energy
E/F Band Radar Frequency
+
−
Single Strand Cut to E/F Band Length
Only 40% Reradiated Energy
H Band Radar Frequency

Figure 13-6. Chaff Length and Frequency Coverage

(1) Considerable research and development has reduced the size and increased the effectiveness of self-protection chaff. There are various chaff sizes, shapes, and materials. Most chaff carried on fighter aircraft are made of small aluminum strips, coated strips of nylon, or fiberglass. These strips are cut to various lengths and compressed into bundles that are small and light enough to allow the aircraft to carry and dispense multiple chaff bundles. These cuts of chaff are packaged into chaff cartridges and inserted into a dispenser on the aircraft. An explosive squib assembly ejects the cartridges from the dispenser and disperses the chaff (Figure 13-7).

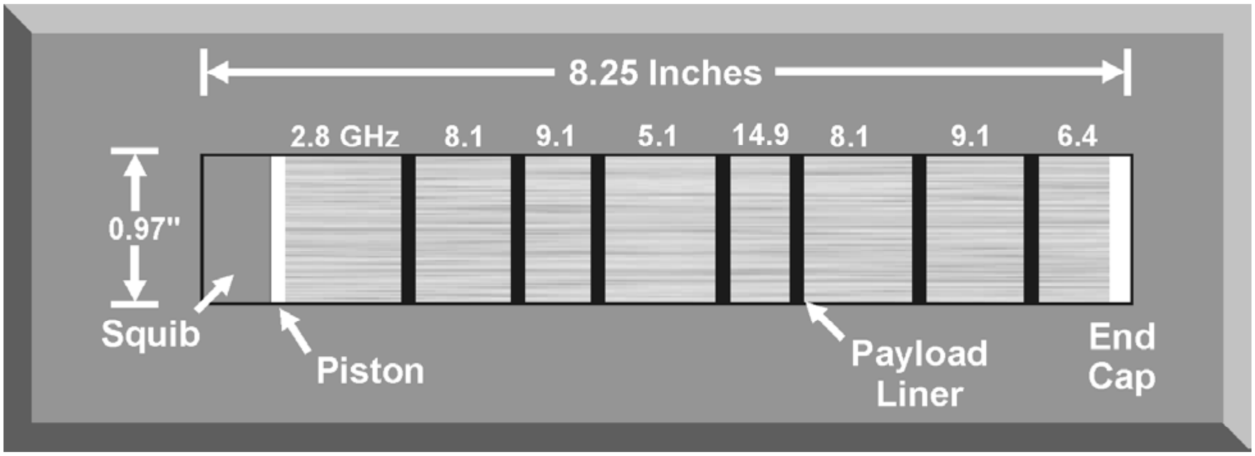

Figure 13-7. RR-170 Chaff Cartridge

(2) To provide as many dipoles as possible and present the maximum radar cross section, each chaff bundle has numerous chaff cuts to match a predetermined range of frequencies. Each chaff cartridge contains almost 3 million dipoles packaged in an eight inch by one-inch cartridge. The dipole frequencies cover the frequency range where most SAM TTRs and air-to-air radars operate (2 - 18 GHZ).

c. Bloom rate, the rate at which chaff will scatter, is also a very important characteristic of self-protection chaff. Self-protection chaff effectiveness is based on the relationship of bloom rate, chaff RCS, aircraft RCS, and the resolution cell of the threat radar system. The ability of chaff to effectively defeat a target tracking radar is directly related to the chaff dispense rate, which determines the chaff RCS, which should be larger than the aircraft's RCS. The chaff bundles must also bloom within the resolution cell of the radar.

(1) Chaff bloom rate is dependent on aerodynamic factors associated with the chaff type, the location of the dispenser on the aircraft, and the aircraft wake or turbulence. Heavy or dense chaff falls faster and blooms slower than lighter and less dense chaff. The location of the chaff dispenser on the aircraft affects the airflow in which the chaff will be dispensed. The ideal position for the dispenser is in the area where there is the most turbulence from the aircraft. Turbulence behind the aircraft is probably the most important factor affecting bloom rate. The more turbulent the airflow, the greater the bloom rate (Figure 13-8). Maneuvering the aircraft while dispensing chaff also enhances the chaff bloom rate.

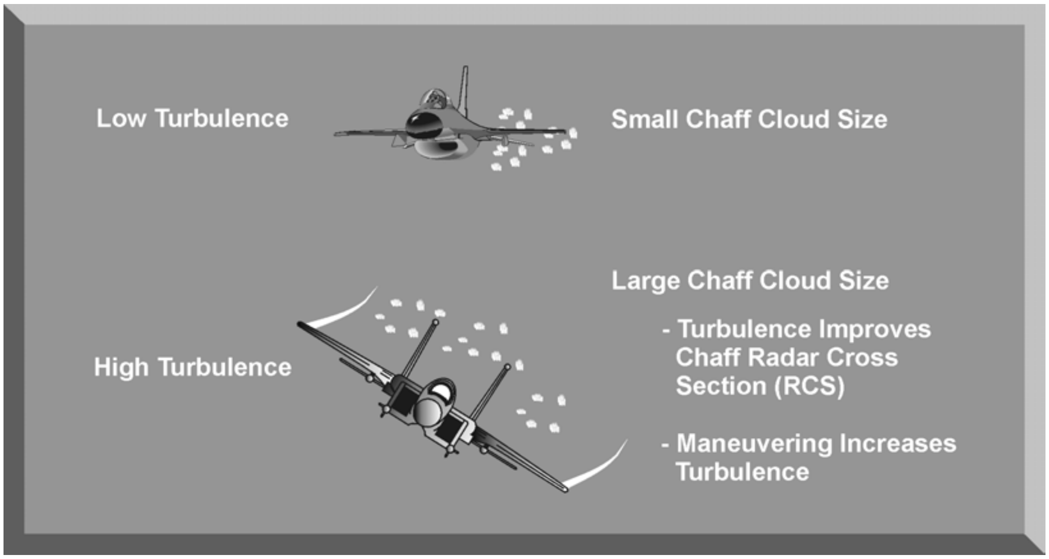
Low Turbulence
Small Chaff Cloud Size
Large Chaff Cloud Size
- Turbulence Improves Chaff Radar Cross Section (RCS)
High Turbulence
- Maneuvering Increases Turbulence

Figure 13-8. Impact of Turbulence and Chaff Bloom Rate

(2) To ensure that the victim radar is decoyed or that it transfers automatic tracking to the chaff, the chaff must bloom within the radar resolution cell. This resolution cell is a three-dimensional spheroid with dimensions based on the pulse width, horizontal beamwidth, vertical beamwidth, and the range of the aircraft (Figure 13-9). There are some rules of thumb that can be used when considering the bloom rate of chaff and the resolution cell of a particular radar. The shorter the pulse width of a radar, the faster the chaff has to bloom to be effective. The narrower the horizontal and vertical beamwidths, the faster the chaff has to bloom to be effective.

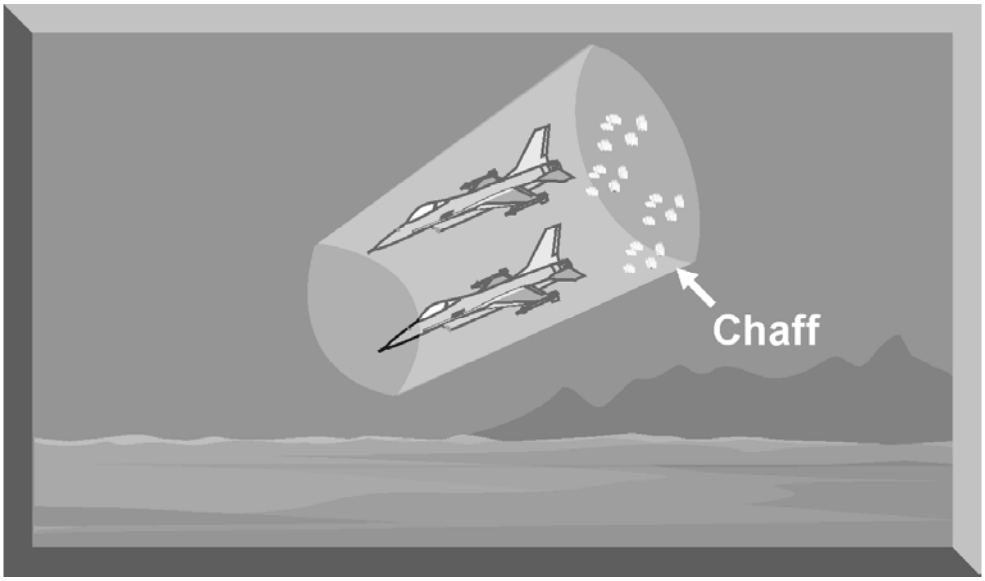

Figure 13-9. Chaff Bloom Rate and Radar Resolution Cell

d. Against Doppler radars, self-protection chaff is most effective when dispensed at or near the beam, relative to the threat radar. When chaff is dispensed in the airstream, the drag on an individual dipole is so great compared to its mass that it slows to the velocity of the surrounding air mass almost instantly. Since the relative velocity of the chaff, in relation to the radar, is zero, radar systems employing Doppler processing and tracking will not display the chaff. Doppler processing radars will continue to track the aircraft unless it also has a relative velocity of zero. This occurs when the aircraft is abeam the radar. Chaff corridor and area saturation tactics against Doppler tracking radars will have limited effectiveness.

e. Chaff persistence and polarization are two additional characteristics that are important employment considerations for area saturation or chaff corridor operations. These individual chaff element characteristics are directly related to the combined effects of aerodynamic, atmospheric, and gravitational influences.

(1) Chaff persistence is the length of time the chaff is at an effective altitude to screen ingressing aircraft during area saturation or chaff corridor operations. The time span depends on the fall rate of the chaff and varies according to the density of the dipoles. The prevailing atmospheric conditions, such as wind and temperature also affect chaff persistence. Generally, the longer cuts used for lower frequency radars fall faster than the shorter cuts used for higher frequency radars. Each type has its own rate of fall based on these conditions. The rate of fall is a critical mission planning consideration for determining the amount of time between chaff corridor or area saturation initiation and the arrival of the aircraft being screened. If the chaff is employed too early, it may not be at the correct altitude or may have dispersed to the point that it is not effective to screen ingressing aircraft.

(2) Each chaff strand is a polarized dipole with positive and negative ends. The orientation of these strands determine their polarity (Figure 13-10). Chaff cuts with the positive and negative ends oriented vertically are vertically polarized. Chaff cuts with the positive and negative ends oriented horizontally are horizontally polarized. Since chaff strands are initially buffeted by turbulence and airstream vortices, the dipole orientation and polarization, changes rapidly and randomly. Eventually, the strands separate into two groups; one descending horizontally, and one descending vertically. Since the vertically oriented strands tend to fall faster, the lower part of the chaff cloud tends to become more vertically polarized, while the upper portion is horizontally polarized. A threat radar that uses vertical polarization will receive minimal affects from the upper (horizontally polarized) portion of the chaff cloud. If the aircraft being screened are flying within this portion of the chaff cloud, they may be detected and engaged. This is another mission planning consideration for chaff area saturation or chaff corridor operations.

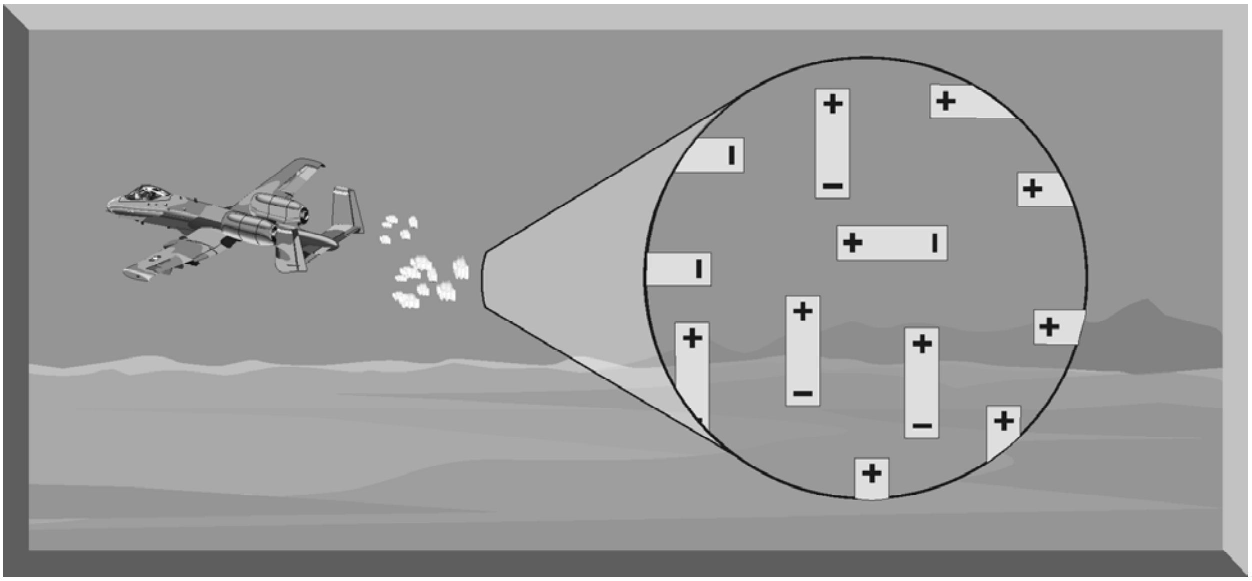

Figure 13-10. Impact of Chaff Polarization

3. CHAFF OPERATIONAL EMPLOYMENT

The two primary chaff employment tactics are force screening and self-protection. Force screening tactics include area saturation and corridor operations. Self-protection tactics include the reactive employment of chaff to negate a potentially lethal engagement. Different chaff dispensing techniques are used for each employment tactic and are important planning considerations for all chaff employment tactics. This section will discuss area saturation, corridor operations, and self-protection chaff employment.

a. The objective of area saturation operations is to present multiple false targets in a specific area in order to saturate radar systems and confuse the enemy integrated air defense system (IADS). Area saturation can be accomplished by fighter aircraft or drones equipped with chaff pods employing random chaff dispensing techniques. The chaff dispenser is set to release random bursts of chaff along the ingress and egress route of the attack package. Chaff pods may be supplemented with chaff bombs containing special fuses that provide false targets at varying altitudes. Attack aircraft can also contribute to area saturation by randomly dispensing self-protection chaff as they ingress and egress. However, this tactic can deplete the number of chaff bundles an attack aircraft may need to defeat a potentially lethal radar system encountered at a later time in the mission.

(1) The chaff cuts must provide frequency coverage for the threat radar systems. Also the RCS of each chaff burst should be large enough to present a realistic target to the victim radars. Multiple false targets created by chaff area saturation may confuse threat system operators and encourage them to expend missiles on false chaff targets.

(2) Saturation also masks the number of attacking aircraft (Figure 13-11). When used with false target deception jamming, area saturation can greatly enhance mission success. However, the technique is resource-intensive since aircraft employing chaff pods and chaff bombs cannot attack targets. These aircraft are vulnerable to attack and should be supported by standoff jamming. Area saturation tactics may have limited success against Doppler processing radars.

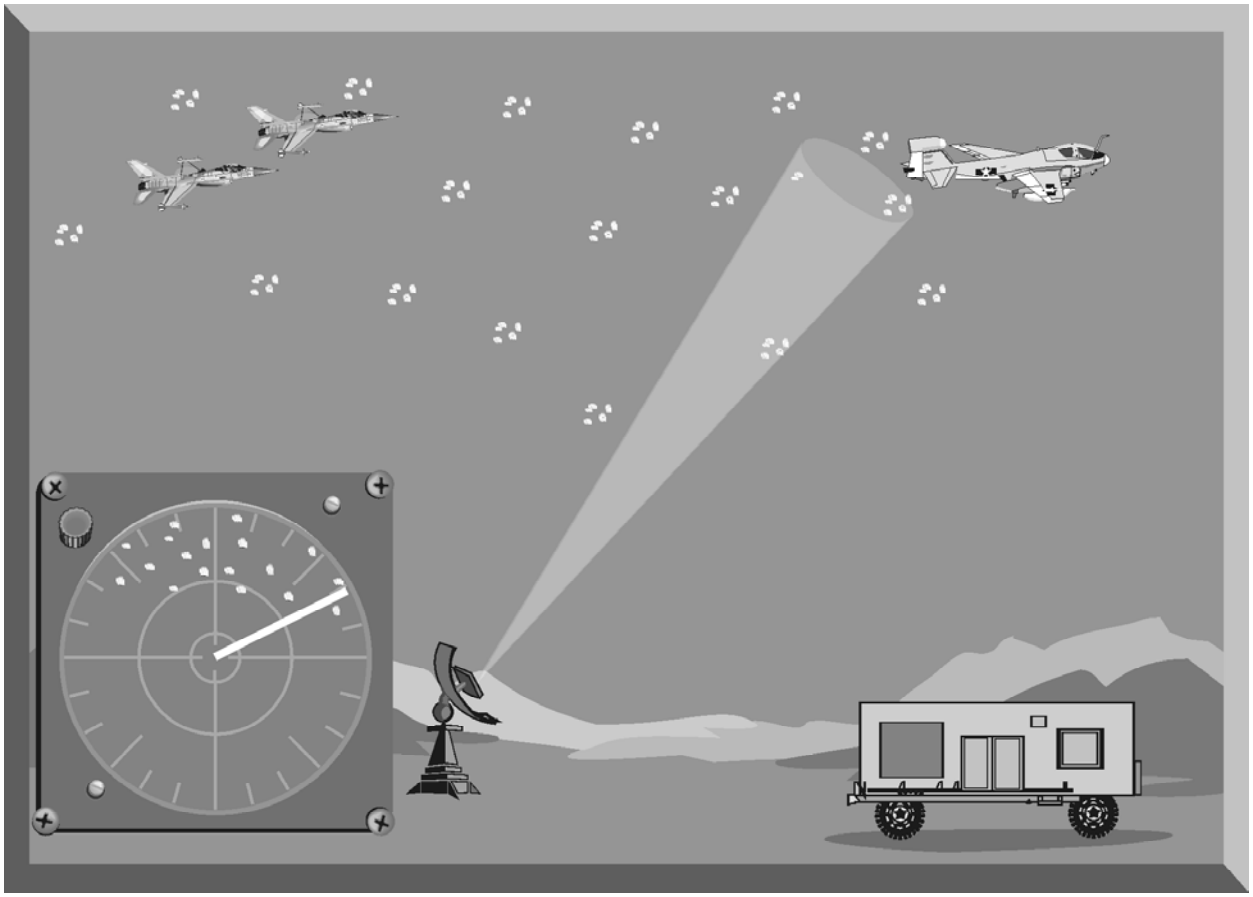

Figure 13-11. Area Saturation Tactics

b. The objective of chaff corridor operations is to screen the ingress and egress of an attack package by dispensing large quantities of chaff in a continuous "ribbon." Fighter aircraft, or drones equipped with chaff pods such as the ALE-38, employ a stream chaff dispensing technique to "lay" the chaff corridor. The pods are set to provide a continuous line of chaff dense enough to hide ingressing and egressing aircraft. The chaff cuts should provide frequency coverage for the radar systems that must be countered. Timing for the chaff aircraft in relation to the attack package must consider the fall rate and persistency of the chaff to ensure that the chaff corridor covers the required altitude for a time sufficient to allow the attack package to ingress and egress. An effective chaff corridor completely denies a radar's ability to distinguish between

the chaff and the attack aircraft. To do this, the radar cross section, or RCS, of the chaff within the resolution cell of the radar must exceed the RCS of the aircraft. This condition must be met throughout the length of the chaff corridor. When this condition is met, the chaff corridor will appear as a continuous return on the victim radar scope, and the attack package cannot be detected (Figure 13-12).

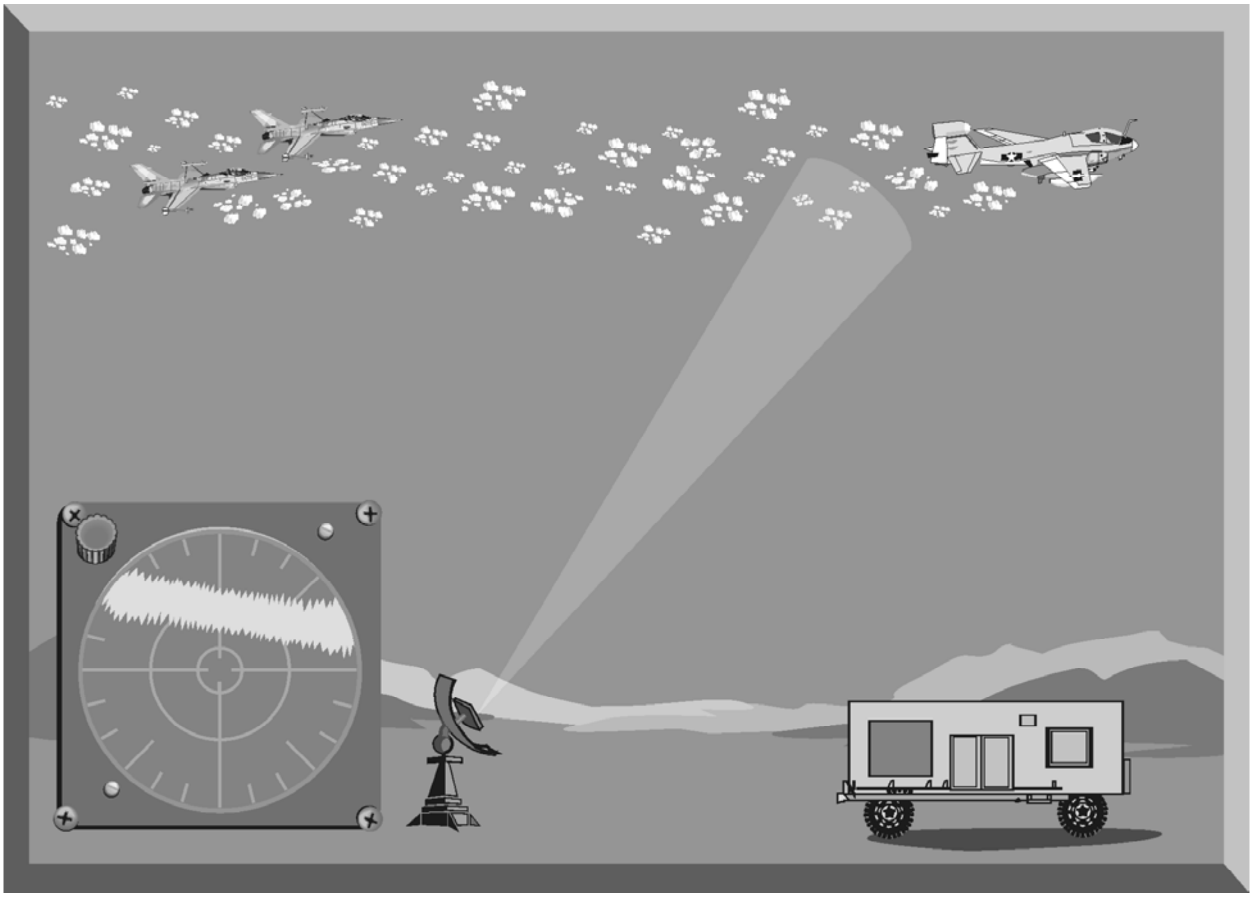

Figure 13-12. Chaff Corridor Tactics

(1) One advantage of a chaff corridor is that it can screen ingressing and egressing aircraft from pulse radar systems. However, chaff corridors are resource-intensive. Aircraft "laying" the corridor cannot strike critical targets. The chaff aircraft are also vulnerable to attack. Therefore, standoff jamming and self-protection jamming systems should be employed to provide some screening and protection for the chaff dispensing aircraft. Finally, chaff corridors may not be effective against radars with Doppler processing.

(2) To be effective, chaff corridor operations require detailed planning. Electronic combat (EC) planners must first determine that a chaff corridor is the most effective way to screen the attack force. This decision is based on the vulnerability of the attack aircraft to the anticipated threat radar systems and the availability of chaff assets. Once the decision is made to employ a chaff corridor,

planners must select the location, determine the length of the chaff corridor, select the ingress and egress altitudes, and establish the timing for the chaff aircraft and the attack package. Once the location of the chaff corridor is determined, planners must assess the threat radar systems that must be countered. The specific operating frequencies of the threat radars will determine the cuts of chaff that must be dispensed. The resolution cells of the threat radars will determine the density of chaff required. The length of the chaff corridor and the chaff density will determine the number of chaff aircraft required to seed the chaff corridor. The chaff fall rate and the atmospheric conditions impact the timing between the chaff aircraft and the attack package, and the altitude that the chaff dispensing aircraft must fly.

c. Self-protection chaff tactics are based on the use of chaff dispensers that use burst chaff dispensing techniques to defeat a TTR. Burst chaff dispensing, employed during the final phase of an engagement by air-to-air or surface-to-air weapons, can generate tracking errors or a radar break-lock. Burst chaff effectiveness is greatly enhanced when accompanied by jamming and evasive maneuvers (Figure 13-13).

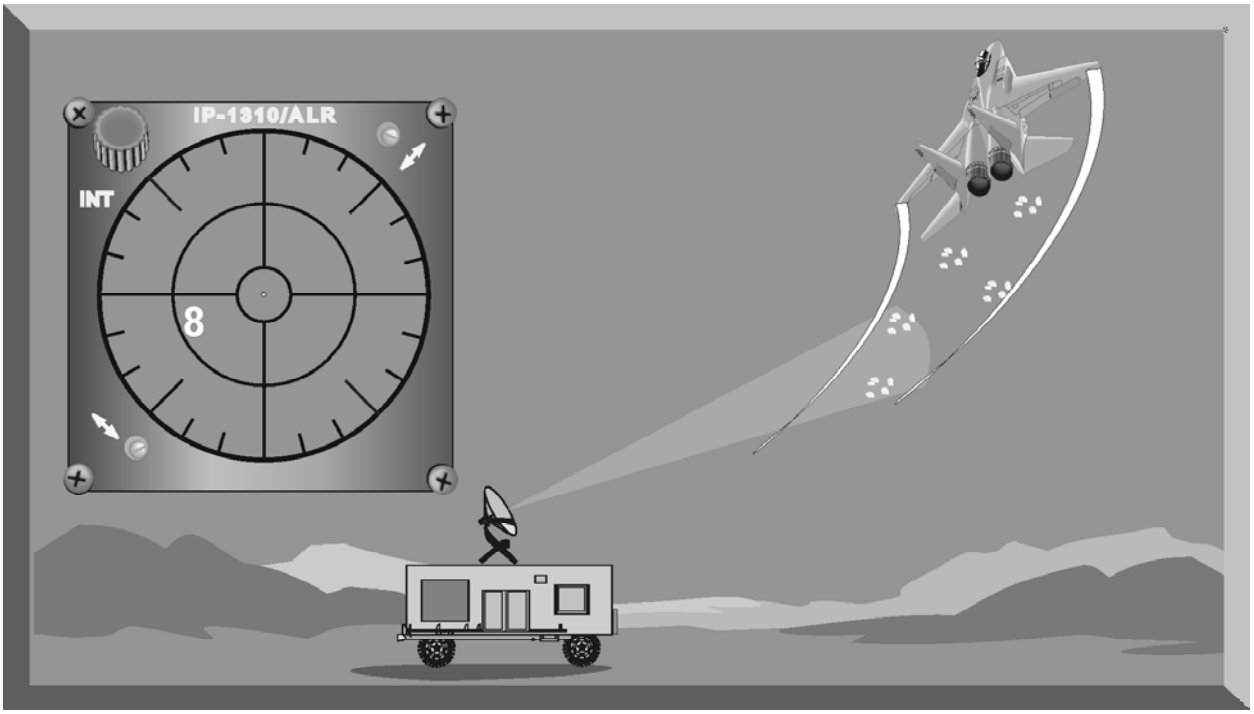

Figure 13-13. Self-Protection Chaff Tactics

(1) Self-protection chaff has proven effective against all pulse radar threat systems when employed with maneuvers and jamming. This is especially true for TTRs operating in an automatic tracking mode.

(a) Chaff employed against a track-while-scan (TWS) radar is designed to put multiple targets, with an RCS greater than the aircraft, in the resolution cell of the horizontal and vertical radar beams (Figure 13-14). Since the tracking loop tracks the largest return, the TWS radar will automatically switch to the chaff. After dispensing chaff, the pilot can maneuver vertically or horizontally to move the aircraft out of the resolution cell.

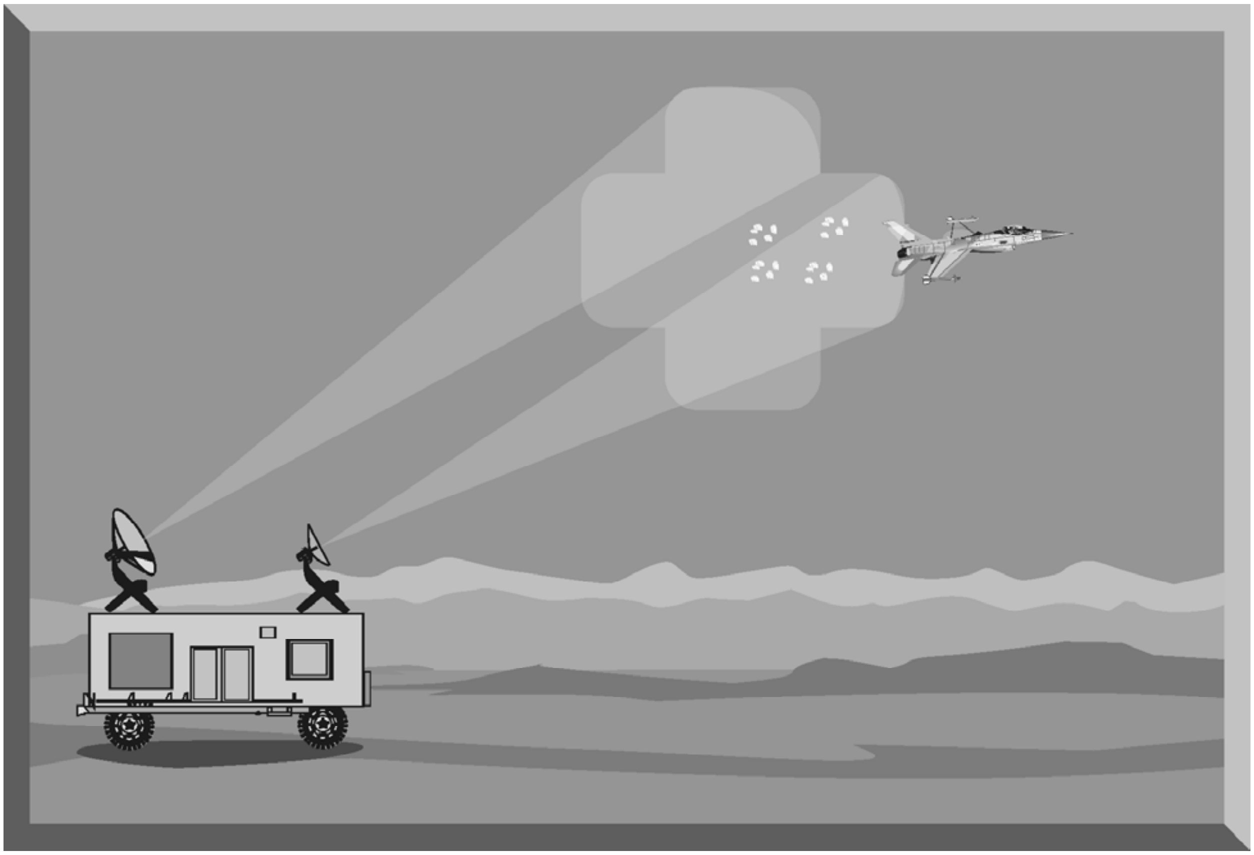

Figure 13-14. Self-Protection Chaff Effect on a TWS Radar

(b) Against a conical scan radar, chaff puts multiple, large RCS targets within the separate scans of the radar (Figure 13-15). These multiple targets generate error signals in the tracking loop and drive the separate scans off the aircraft return. As the conical scan radar tracking loop attempts to resolve these error signals, it will eventually lock on to the chaff. Maneuvering outside the overlapping scan area enhances chaff effectiveness and facilitates the transfer of radar lock-on to the chaff.

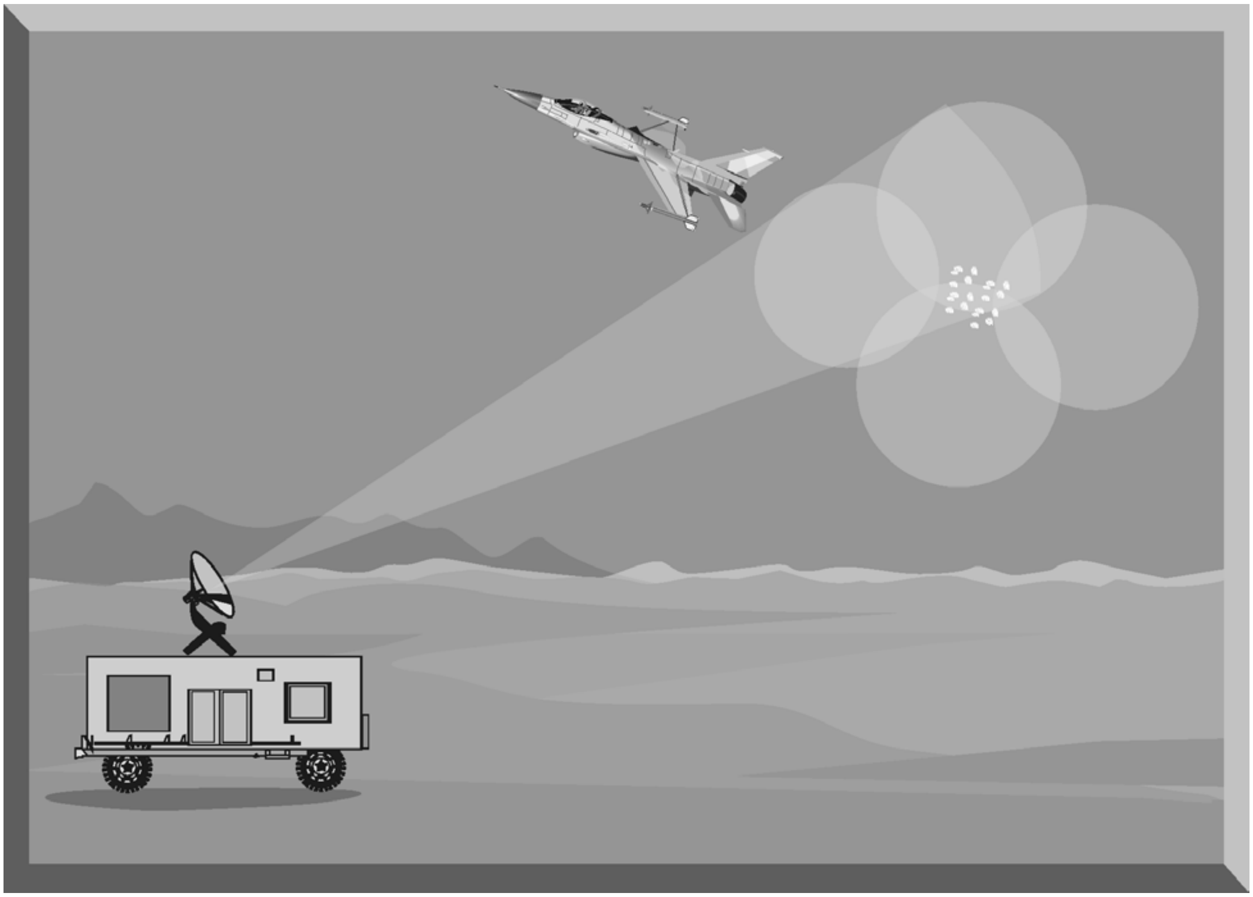

Figure 13-15. Self-Protection Chaff Impact on a Conical Scan Radar

(c) Chaff employed against a monopulse radar is designed to put multiple targets in at least two of the tracking beams (Figure 13-16). This generates errors in the azimuth, elevation, and range tracking circuits. Multiple chaff targets continue to generate azimuth and elevation errors that can eventually generate a break-lock condition, as the radar transfers lock-on to the chaff. Chaff is most effective against monopulse radars when employed on the beam in order to create the maximum angular tracking error.

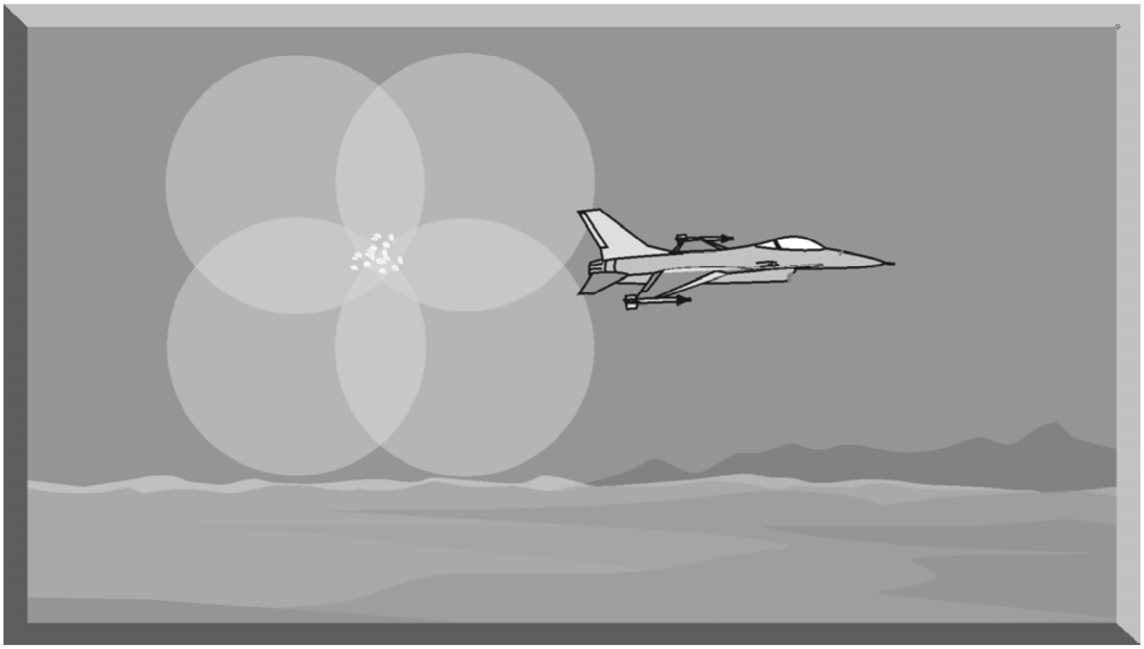

Figure 13-16. Self-Protection Chaff Impact on a Monopulse Radar

(d) Modern radars may employ some form of Doppler filtering to negate the effectiveness of chaff and other sources of clutter. Pulse Doppler and continuous wave radar systems track targets based on target velocity relative to the radar. Radars employing a moving target indicator (MTI) use relative target velocity to distinguish between targets and clutter. Chaff slows to near zero relative velocity almost immediately after dispensing. For self-protection chaff to be effective, the aircraft velocity relative to the radar site must also be near zero This occurs when the aircraft's aspect to the radar is 90°, or on the beam. By maneuvering to a beam aspect against a Doppler radar, the pilot is exploiting the "notch" where radar cannot discriminate targets based on Doppler frequency shift (Figure 13-17).

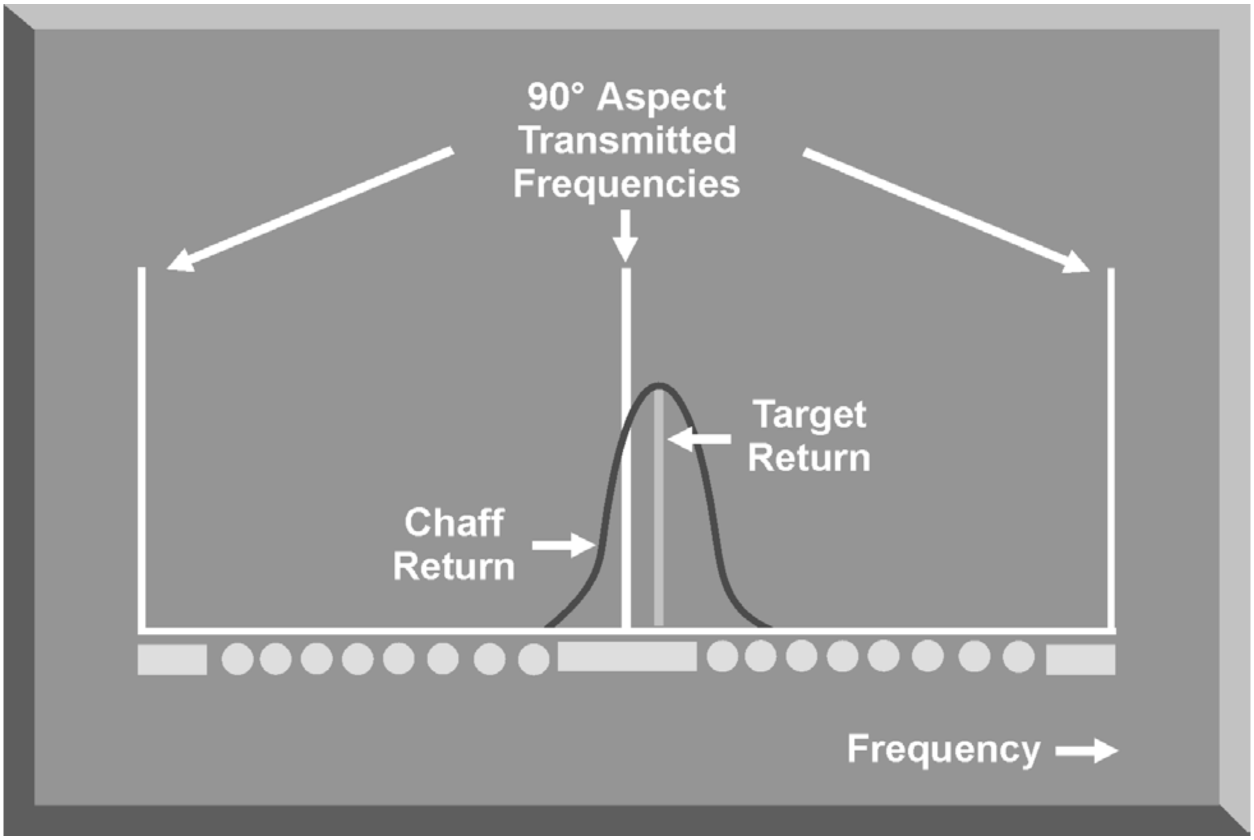
90° Aspect Transmitted Frequencies
Target Return
Chaff Return
Frequency

Figure 13-17. Self-Protection Chaff Impact on a Doppler Radar

4. SUMMARY

Chaff is one of the oldest and most effective pulse radar countermeasures. The fundamental characteristics of chaff (RCS, frequency coverage, bloom rate, Doppler content, polarization, and persistence) determine the effectiveness of chaff employment. The primary chaff employment tactics of force screening and self-protection are designed to maximize the impact of chaff on threat radar systems. Self-protection chaff, together with jamming and maneuvers, is often the "last line of defense" against lethal radar threat systems.

CHAPTER 14. IR FUNDAMENTALS

1. INTRODUCTION

Since their introduction in the 1950s, infrared (IR) missiles have been an increasing threat from both ground-based and airborne systems. The range, reliability, and effectiveness of IR missiles have been continuously improved by advanced detector materials and computer technology. Since IR missiles are passive, they are relatively simple and inexpensive to produce. These characteristics have contributed to the proliferation of IR missiles in the combat arena. Nearly every aircraft flying in either the air-to-air or air-to-surface role now carries an all-aspect IR missile. Additionally, every infantry unit down to the platoon level is equipped with shoulder-fired IR missiles (Figure 14-1). This chapter will cover basic IR theory, IR missile detection, IR seekers, and conclude with a section on IR flare rejection.

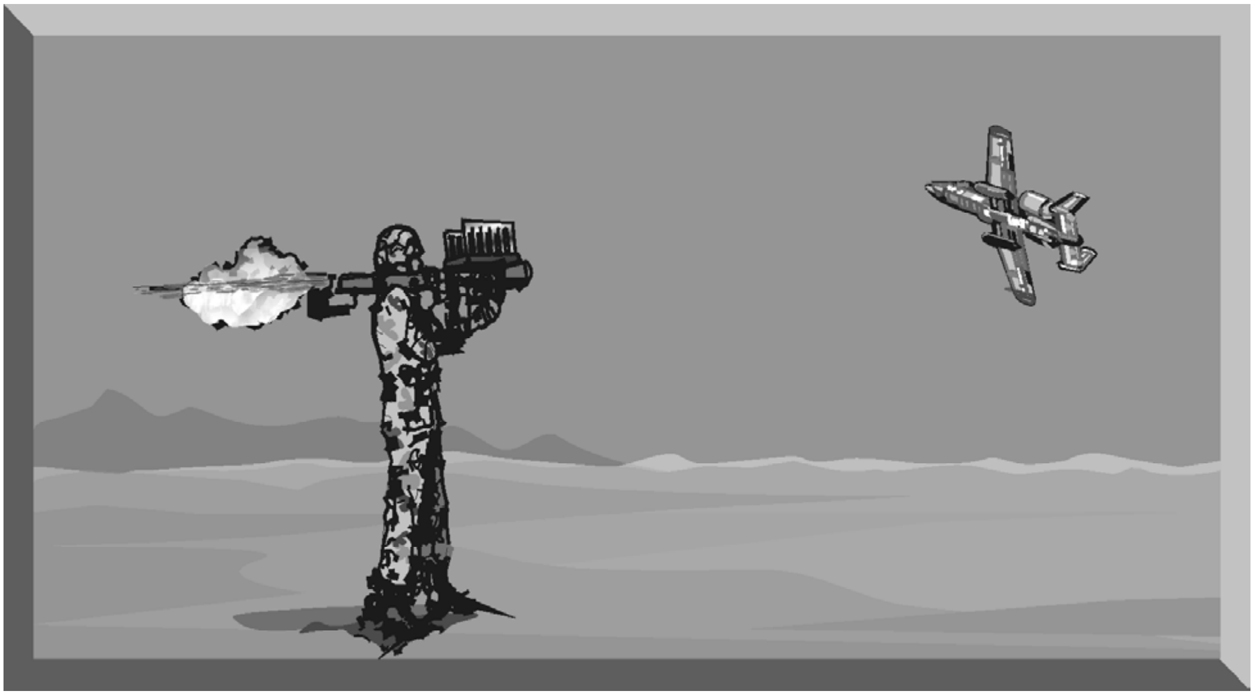

Figure 14-1. The IR Threat

2. BASIC IR THEORY

Because of its location in the frequency spectrum, IR radiation exhibits some of the characteristics and limitations of microwaves and visible light.

a. All warm objects emit IR energy. The object's temperature dictates the characteristics of this radiation. As the temperature of the material increases, the radiant intensity increases and shifts to shorter and shorter wavelengths or

higher and higher frequencies. The frequency band of IR radiation falls between the upper limit of microwaves and the lower limit of visible light. When discussing IR radiation, it is more convenient to refer to wavelength instead of frequency (Figure 14-2). The wavelength of the highest frequency IR is 0.72 x 10^{-6} meters. A unit of measure called the micron (μ), is one millionth, or 10^{-6}, of a meter and is used to designate IR wavelengths. IR energy falls in the electromagnetic spectrum between the wavelengths of 1000 and 0.72 microns, while visible light occupies the spectrum from 0.72 to 0.39 microns.

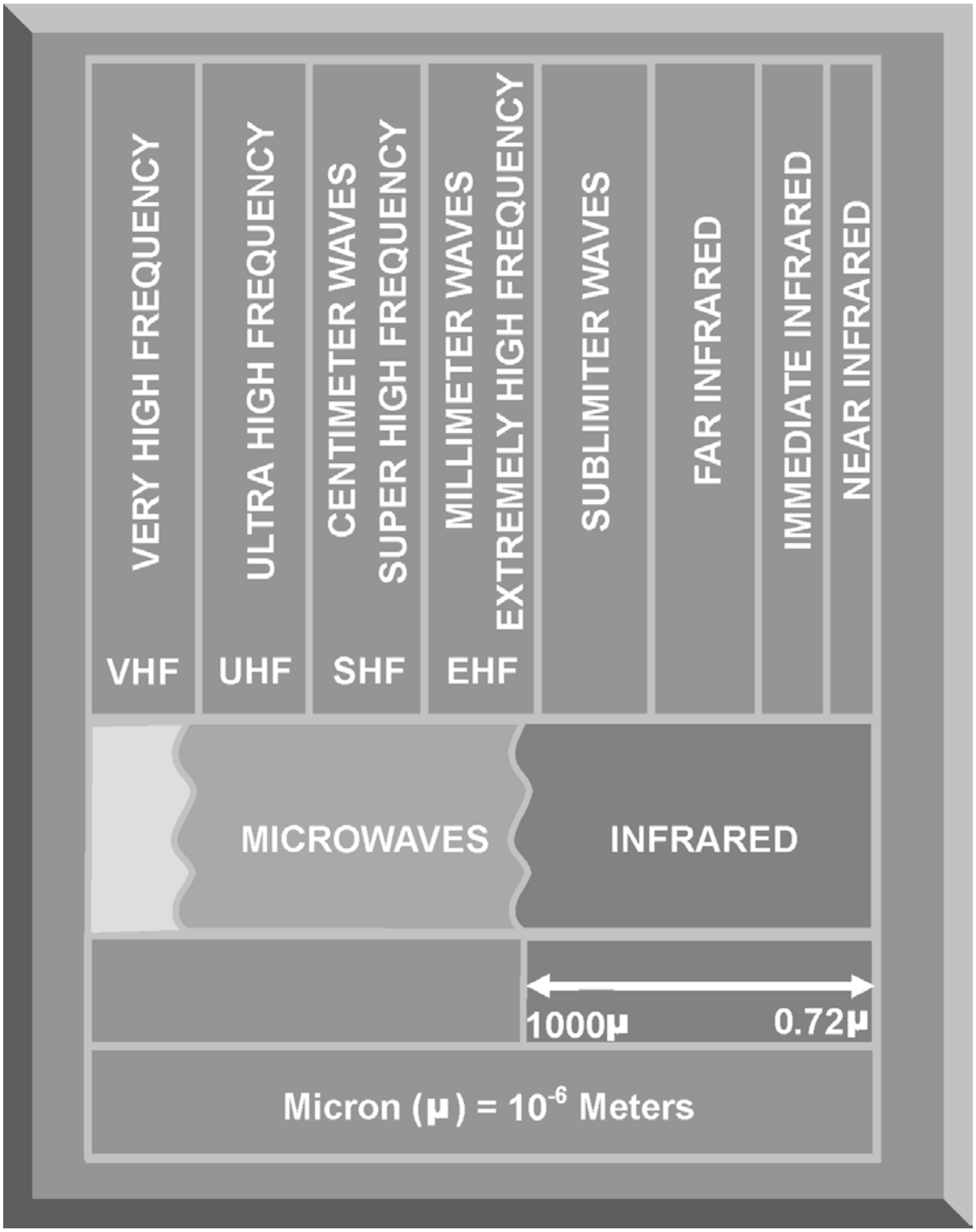
VERY HIGH FREQUENCY
VHF
ULTRA HIGH FREQUENCY
UHF
CENTIMETER WAVES
SUPER HIGH FREQUENCY
SHF
MILLIMETER WAVES
EXTREMELY HIGH FREQUENCY
EHF
SUBLIMITER WAVES
FAR INFRARED
IMMEDIATE INFRARED
NEAR INFRARED
MICROWAVES
INFRARED
1000μ
0.72μ
Micron (μ) = 10^{-6} Meters

Figure 14-2. IR Frequency Band

b. As the IR energy travels through the atmosphere, certain wavelengths are absorbed or attenuated. The greatest IR attenuator is atmospheric water vapor, which varies as the weather conditions vary, with negligible absorption at altitudes above 30,000 feet. Another significant attenuator is carbon dioxide. The percentage of carbon dioxide in the atmosphere is practically constant up to a height of 30 miles. Carbon dioxide absorption is predictable and occurs only in the IR region. Scattering is another form of atmospheric attenuation and is caused by dust particles and water droplets. Scattering is also largely dependent on weather conditions and cannot be predicted. Most of the scattering occurs at lower altitudes and at the shorter wavelengths. Other atmospheric elements cause little or no attenuation of IR energy. Figure 14-3 shows atmospheric IR transmission at sea level. There is a relatively large window of IR transmission in the region from one to five microns. This is the region where the aircraft engine heat signature is at its maximum intensity and where most IR missiles are designed to operate.

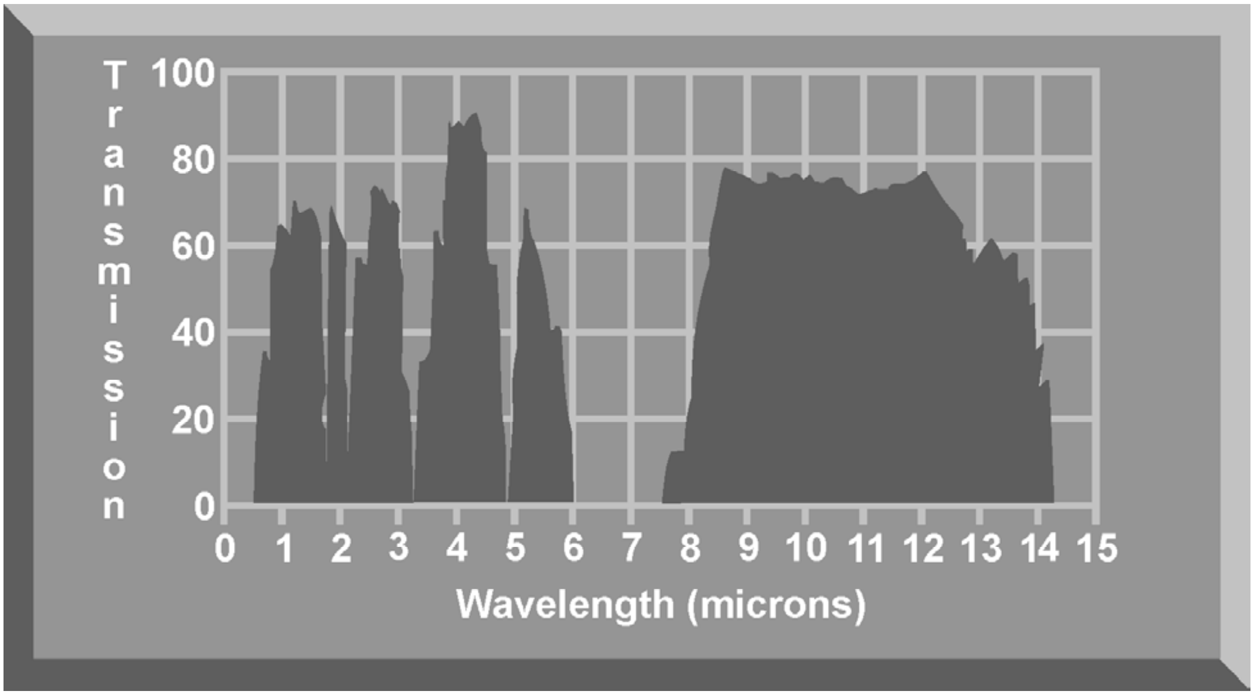

Figure 14-3. Atmospheric IR Transmission

c. IR energy exhibits some of the transmission characteristics of both RF energy and visible light. As with visible light, it can be optically focused by lenses and mirrors. This characteristic is used in the IR missile detector elements (Figure 14-4). As with RF energy, the intensity of IR radiation diminishes inversely with the square of the distance between the source and the receiver.

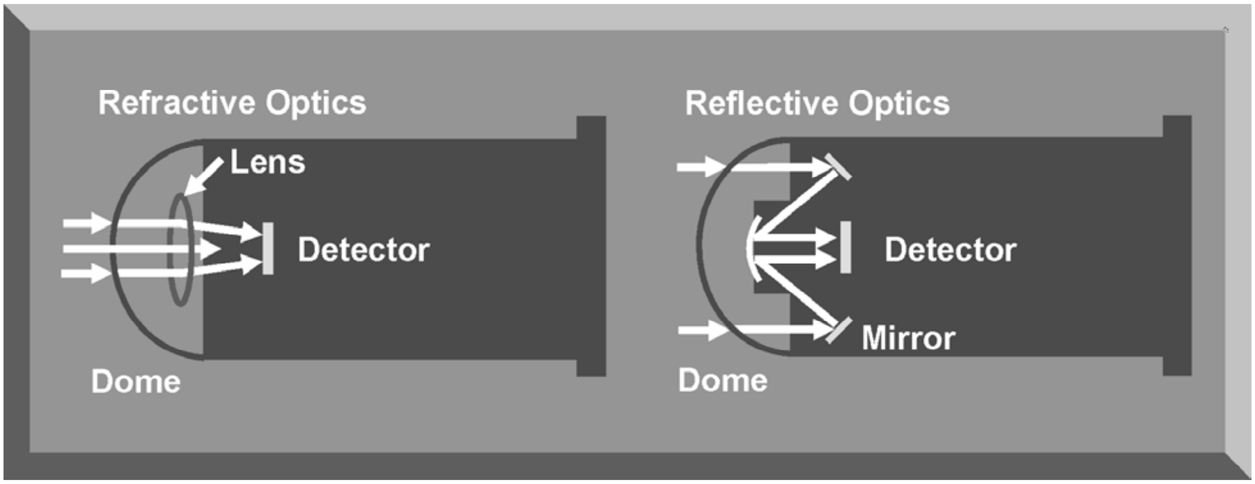
Refractive Optics
Lens
Detector
Dome
Reflective Optics
Detector
Mirror
Dome

Figure 14-4. IR Missile Seeker

d. If the intensity of the aircraft's IR signature, while in the military power setting, is plotted in relation to wavelength, it reaches a peak at approximately 3 microns (Figure 14-5). In afterburner, the aircraft's IR intensity reaches a peak at approximately 1.5 microns. Since IR missiles are designed to detect and track the aircraft's IR signature, most IR missiles operate in the region of 1 to 5 microns. To be effective, the IR intensity of a flare must also fall within this micron region.

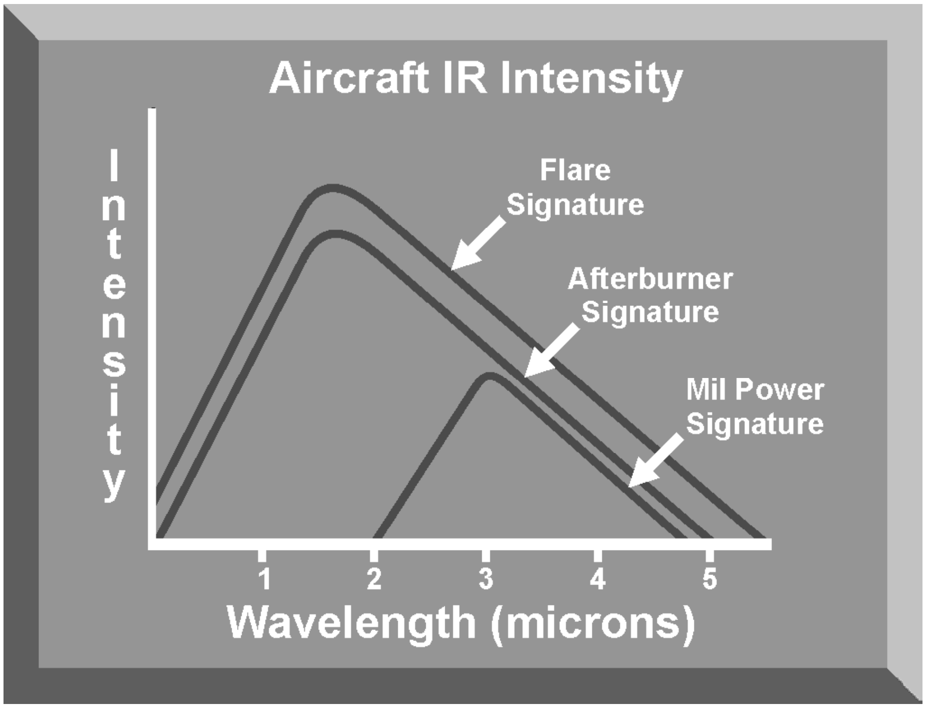

Figure 14-5. Aircraft IR Intensity

e. An aircraft's relative IR signature is based on aspect angle, airspeed, altitude, and afterburner status. The minimum relative IR intensity is at the nose and maximum at the tail. As airspeed increases, the relative IR intensity increases due to the heat generated by friction and increased engine temperatures. As altitude increases, the relative IR signature increases at all aspect angles, due to the reduction in atmospheric attenuation (Figure 14-6).

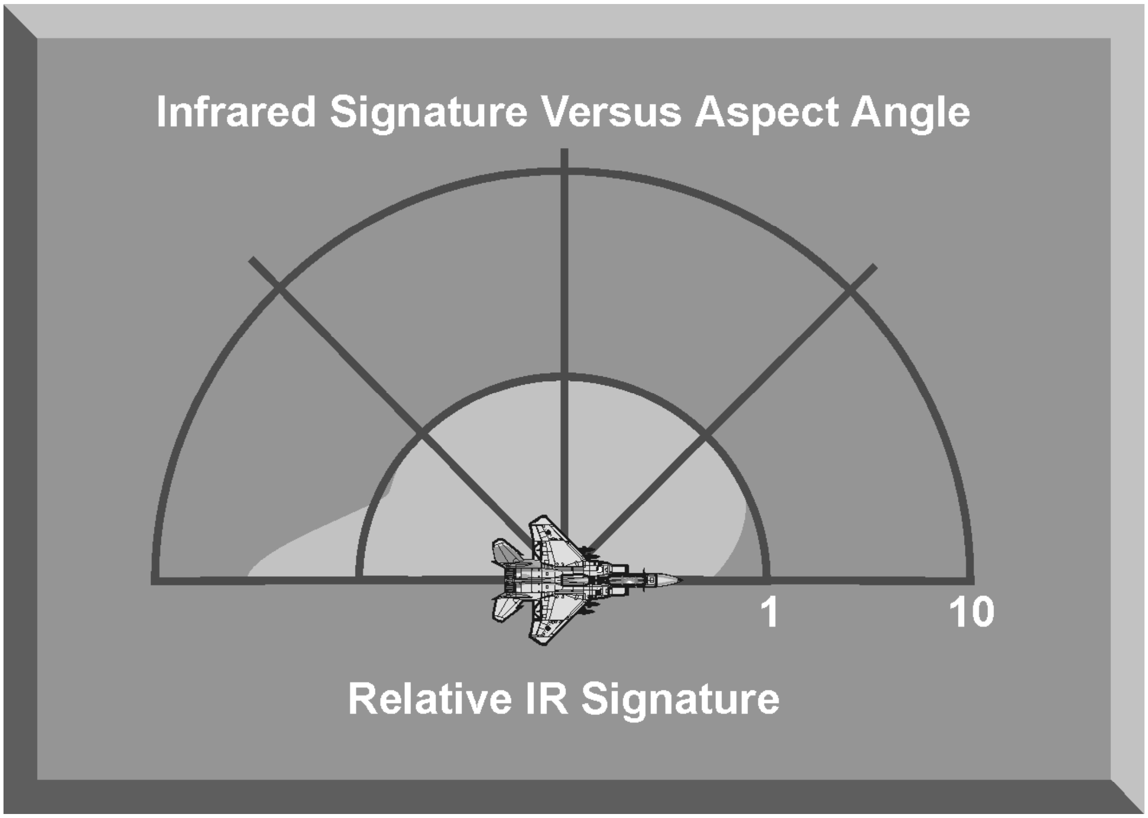

Figure 14-6. IR Signature Versus Aspect Angle

3. IR SIGNATURE SOURCES

IR guidance is based on the fact that every object with a temperature above zero degrees Kelvin emits IR radiation. The temperature of the object dictates the characteristics of this radiation. As the temperature of the object increases, the radiant intensity increases and shifts to higher and higher frequencies and correspondingly shorter and shorter wavelengths. The F-16 at Figure 14-7 demonstrates the different wavelengths found at different areas of the aircraft. Emissivity in Figure 14-7 is a relative measure of the IR energy emitted when a surface is directly viewed.

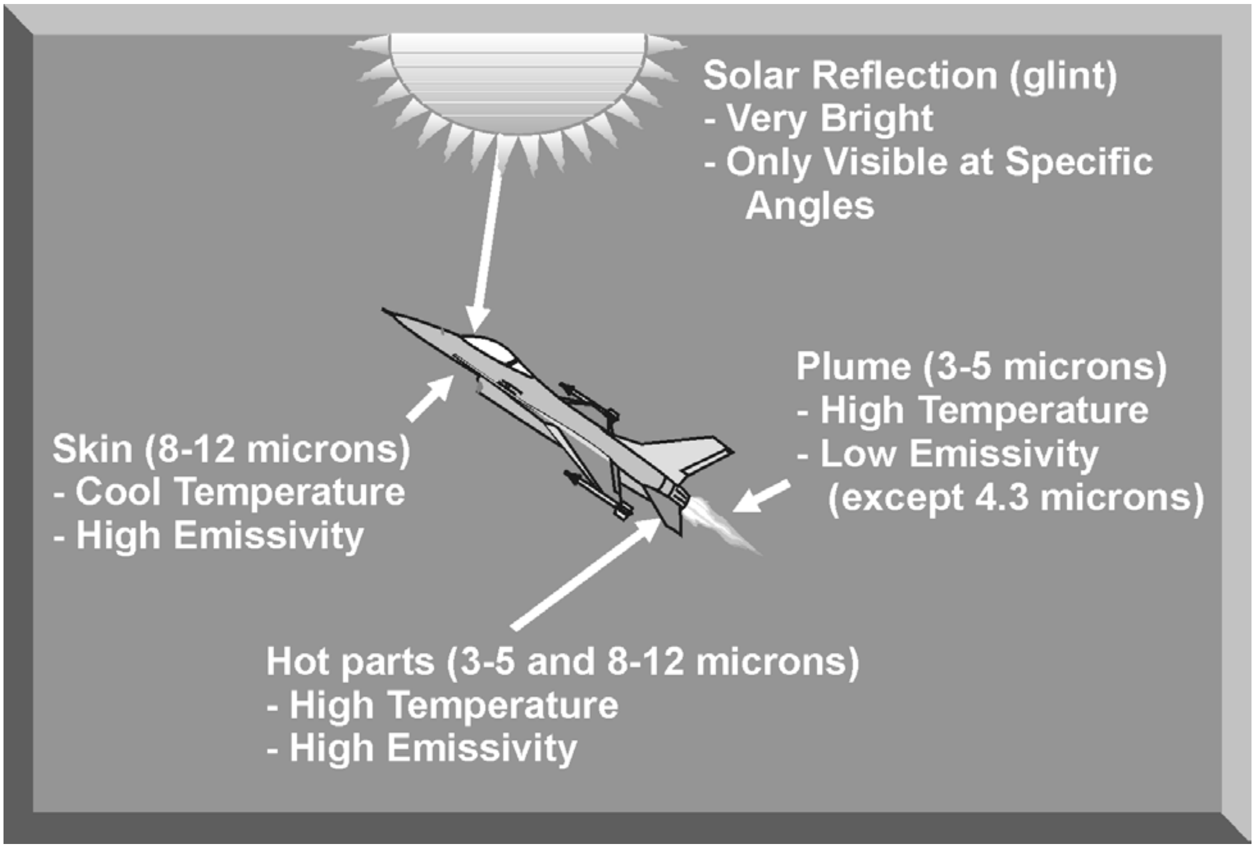
Solar Reflection (glint)
- Very Bright
- Only Visible at Specific Angles
Plume (3-5 microns)
- High Temperature
- Low Emissivity (except 4.3 microns)
Skin (8-12 microns)
- Cool Temperature
- High Emissivity
Hot parts (3-5 and 8-12 microns)
- High Temperature
- High Emissivity

Figure 14-7. Target Signature Sources

a. The main aircraft signature sources are the plume, the engine hot parts, and the skin. The skin is large in area, but usually fairly cool. Thus the best detection of the aircraft skin is usually in the long wave IR band (8-12 microns).

b. The engine hot parts offer excellent detection when one is looking at the right angle. They have high temperatures and high emissivity. However, depending on the viewing angle, they may have a low perceived area.

c. The plume has high temperatures and a high perceived area. This large perceived area allows near all-aspect detection. Unfortunately, it has a relatively low emissivity except near 4.2 microns. It is the strategy of the new breed of all-aspect missiles to detect the plume in the mid-wave IR, around 4.2 microns.

d. Figure 14-8 shows some of the common IR detector materials. Note that the cooled detectors are sensitive to longer wavelength (lower energy) photons, as discussed earlier.

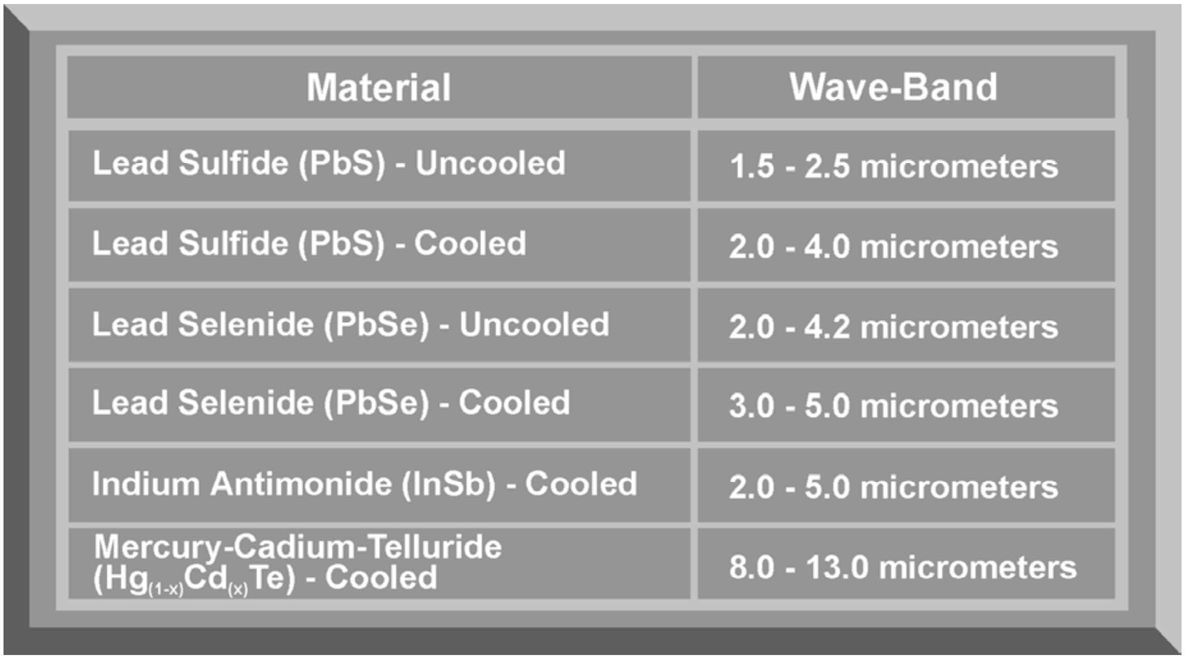

Material	Wave-Band
Lead Sulfide (PbS) - Uncooled	1.5 - 2.5 micrometers
Lead Sulfide (PbS) - Cooled	2.0 - 4.0 micrometers
Lead Selenide (PbSe) - Uncooled	2.0 - 4.2 micrometers
Lead Selenide (PbSe) - Cooled	3.0 - 5.0 micrometers
Indium Antimonide (InSb) - Cooled	2.0 - 5.0 micrometers
Mercury-Cadium-Telluride $(Hg_{(1-x)}Cd_{(x)}Te)$ - Cooled	8.0 - 13.0 micrometers

Figure 14-8. IR Detection Materials

4. IR SEEKER CHARACTERISTICS

Guidance units are designed to detect and home in on the IR radiation of the aircraft. The job of the seeker is to view the scene and output the estimated target position. Figure 14-9 shows the hardware that makes up the seeker of a generic IR missile system.

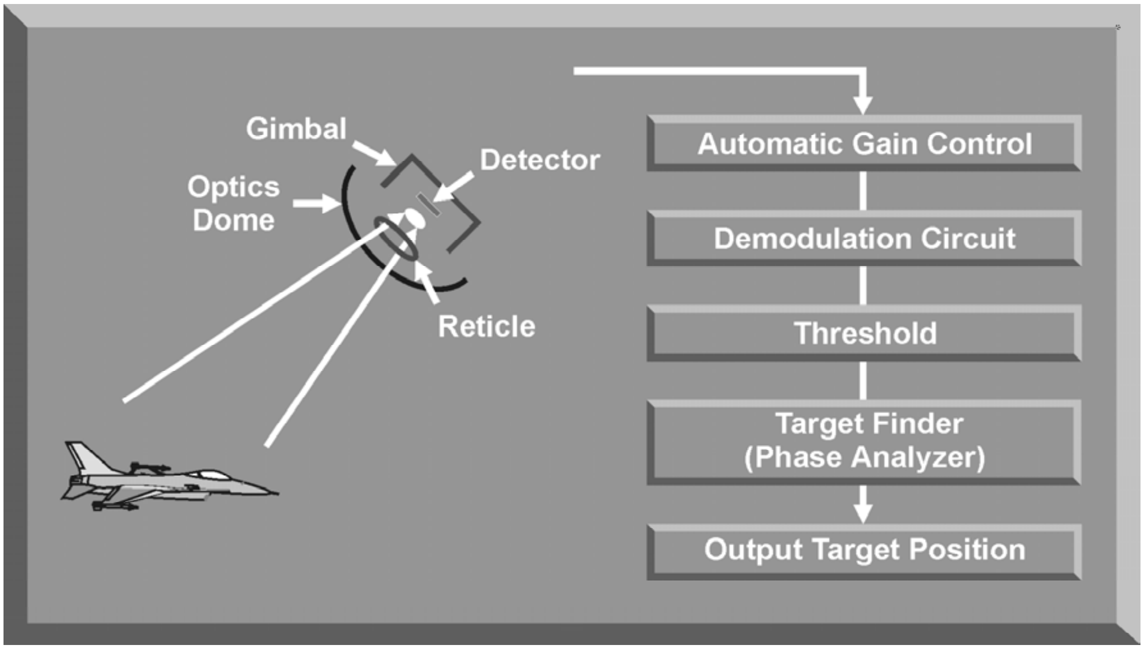
Gimbal
Optics Dome
Detector
Reticle
Automatic Gain Control
Demodulation Circuit
Threshold
Target Finder (Phase Analyzer)
Output Target Position

Figure 14-9. IR Missile Seeker

a. The dome acts as an IR transparent protective cover. Most IR missiles use the hemispherical dome because that shape does not alter the path of the incoming light rays. The optics focus the scene through the reticle onto the detector. The reticle pattern enables the detector output to "code" the position of the target.

b. The internal workings of the missile are similar to those found in a radar tracking system. There is an automatic gain control (AGC) to adjust the levels of the detector output so that it is not too large or too small. The demodulation circuit "decodes" the detector signal. The threshold circuit cancels signals that are below the specified threshold value, similar to the clutter rejection function found in radar systems. Finally, the phase analyzer reads the target position from the signal and sends the result to the autopilot. The autopilot then adjusts the missile's flight path to track the target.

c. IR systems employ filters and detectors to filter out unwanted IR radiation from the sun, sunlit clouds, smoke, the earth, and other background radiation sources (Figure 14-10). The detection unit is coupled with a guidance system to generate commands to the missile control vanes to keep the target centered in the field of view.

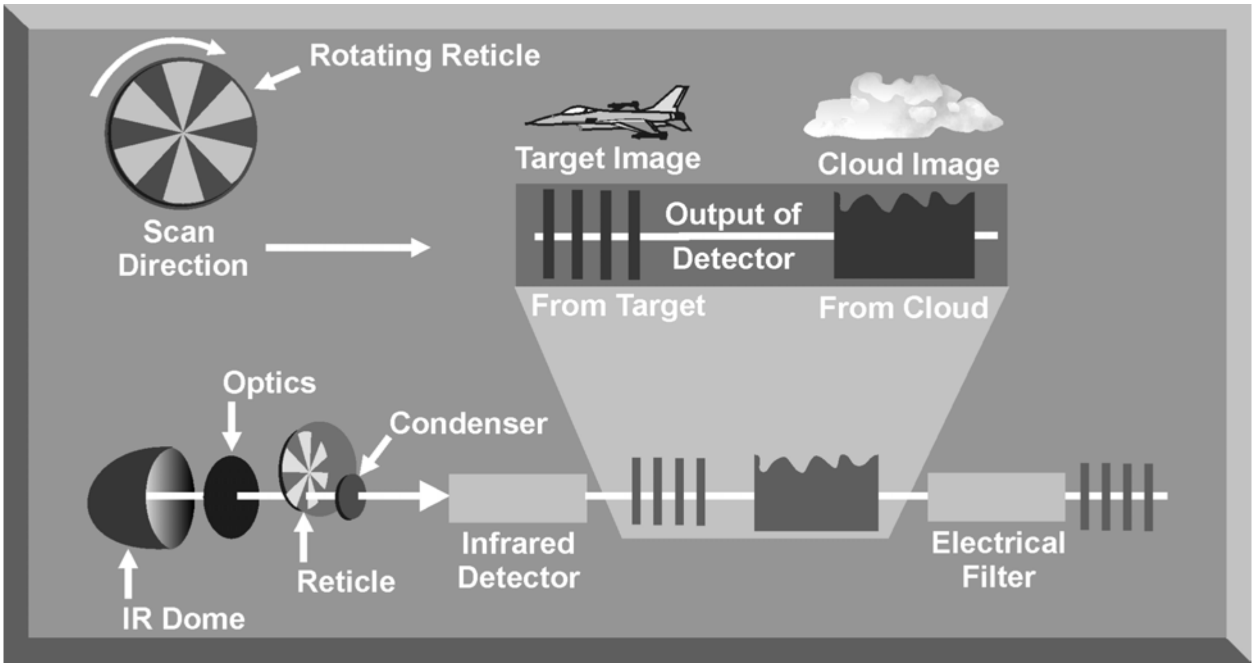

Figure 14-10. Spin Scan Reticle

d. A defining characteristic of an IR missile is its field of view (FOV) and field of regard (FOR) (Figure 14-11). The angular size of the image in degrees is called the field of view. To provide the greatest possibility of collecting IR radiation from the target, the receiver must have the greatest possible FOV. This in turn may

create problems. A large FOV increases the possibility that the receiver may not be able to distinguish the target from other sources of IR radiation. To avoid this problem, a relatively small FOV is scanned through a wider area. This wider area is referred to as the FOR. The gimbal enables the FOV to be scanned, so that an entire FOR can be searched.

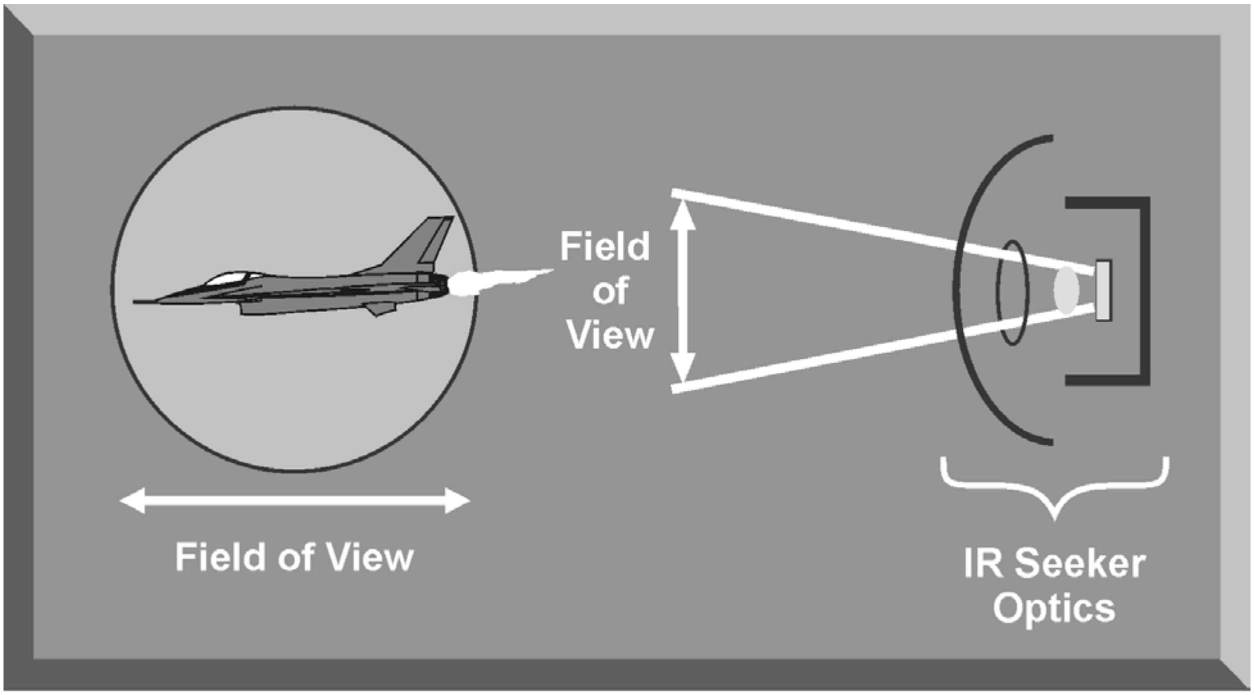

Figure 14-11. Missile Field of View

5. IR SEEKER TYPES

Through the years advances in seeker technology have resulted in significant changes to IR missile engagement tactics. This section will discuss spinning reticle, conical scan, cooled, and imaging IR seekers.

a. First generation IR missiles, like the SA-7, use a spinning reticle as the means to track the target. Due to their relatively low cost and ease of use, IR missiles of the first generation can still be encountered. The spinning reticle is inserted in the seeker just before the IR radiation reaches the detector. The reticle is a thin plate of optical material which has a transparent and opaque pattern on it. As the reticle is rotated, the IR energy is chopped at a rate determined by the reticle pattern. This system produces error signals when the target is not exactly centered in the field of view. Figure 14-12 is an example of a reticle pattern that can provide both azimuth and elevation information. If the target is located in the upper half of the pattern, the IR intensity on the detector is constant as the reticle rotates. As the pie-shaped half of the disc rotates over the target, the IR energy is pulsed and the amplitude of the pulses is an indication of relative elevation angle.

When the target moves to the right or left, the pulsing starts and stops at different times, indicating target azimuth. Center spun spin-scan seekers, also called center null reticles, are relatively insensitive when the target is in the center of the seeker scan where there is no tracking error. This is because the point target tends to bleed energy into all the spokes at once, eliminating the pulsed signal output of the detector. Once the target falls off the center of the reticle, the seeker generates an error signal that initiates guidance commands to recenter the target. This is the reason early IR missiles flew an undulating path toward the target.

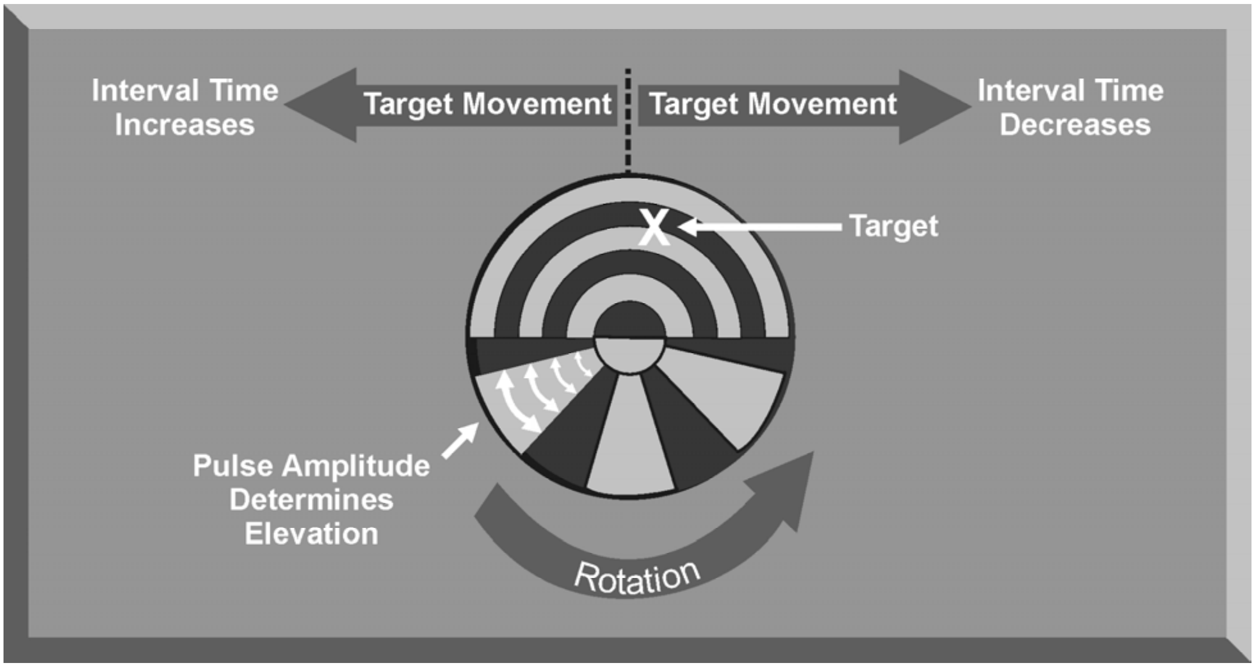

Figure 14-12. IR Missile Reticle

b. IR conical-scan (con-scan) seekers were developed to solve some of the problems with spin-scan seekers; notably the lack of error response when the target is near the center of the seeker field of view (FOV) (Figure 14-13). In a typical con-scan seeker, the reticle is fixed and does not spin. Instead, a secondary mirror is tilted and spun. This causes the target image to be scanned in a circular path around the outer edge of the reticle. When the target is centered in the seeker scan, the detector generates a pulsed output similar to that of the spin-scan seeker. However, as the target leaves the center, the output of the detector is a frequency modulated (FM) sine wave. The frequency of the modulation is directly proportional to the amount of target displacement from the center of the seeker scan. Con-scan optics are usually designed to spin the target very close to the edge of the reticle. This generates the greatest amount of FM modulation for a given target tracking error and gives the con-scan IR missile a more sensitive and tighter tracking loop. The center of the reticle is only used for acquisition.

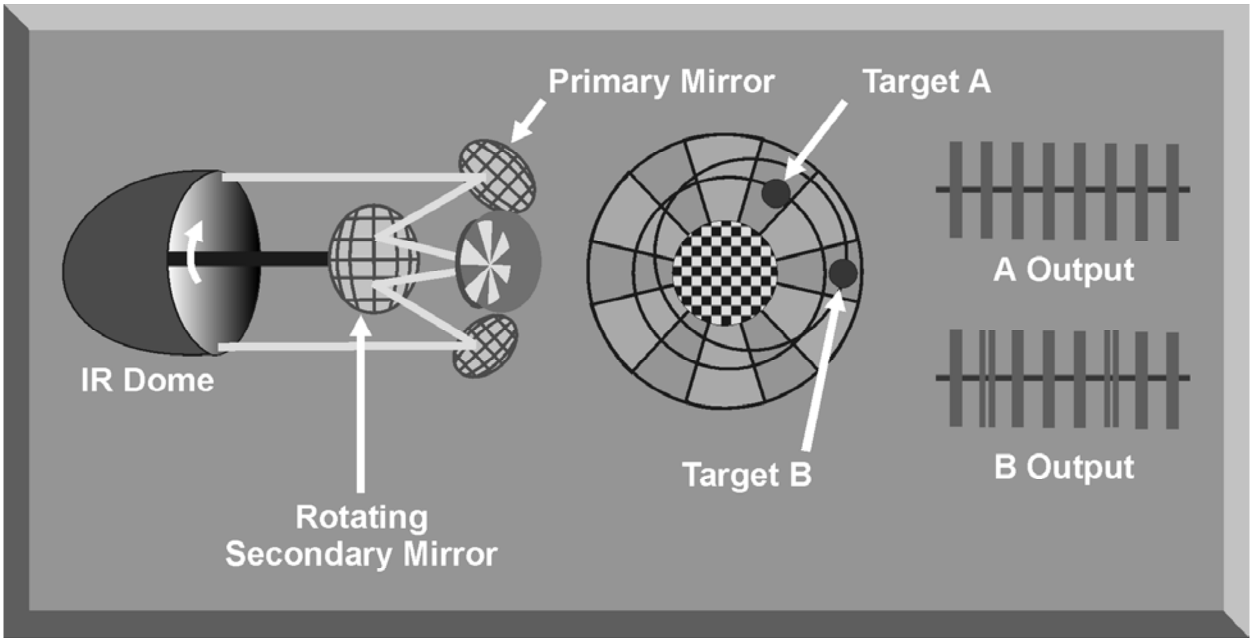

Figure 14-13. Conical Scan IR Seeker

c. A significant improvement to IR seekers resulted from the cooling of the detector with an inert gas such as argon. Older IR missiles, using uncooled lead-sulfide detectors, have a peak sensitivity in the 2 micron region. This limits these missiles, the SA-7 for example, to stern attacks because the missiles can only discriminate the IR signature of the engine turbine from background IR energy. By cooling the detector with an inert gas, like argon, the detectors of newer IR missiles can track longer wavelength IR radiation associated with airframe friction. Using newer detector materials like indium antimonide (InSb), require cooling to have increased target detection range and all-aspect tracking capability.

d. Imaging IR is the most recent advancement in IR seeker technology. The technology for these seekers is similar to that found in the AGM-65 Maverick missile. Imaging IR seekers are harder to decoy with flares than older seekers, and they are resistant to pulsed light jamming. Imaging detection involves creating an IR picture of the scene in one of two ways, scanning or staring. A scanning system uses one detector (or a mix of detectors and mirrors) which moves relative to the scene until the entire scene is scanned. This is an easy system to fabricate, but it can be noisy because the detector can't stay very long at each position, and it does not have a lot of time to measure the signal. A staring system uses many detectors, each of which detects a small portion of the scene. Each detector can “dwell” on its part of the scene for the entire frame time. However, such systems, also called focal plane arrays, are difficult to fabricate in a way such that each detector has the same sensitivity. One of the prime advantages with using imaging IR seekers is that they can be programmed

to track a particular IR shape or scene, significantly reducing the effectiveness of decoy flares.

6. IR MISSILE FLARE REJECTION

Flares are the primary countermeasure used to defeat the IR missile. Advanced IR missiles use different techniques to overcome the use of self-protection flares. There are two important characteristics of infrared (IR) missiles that influence the effectiveness of self-protection flares. The first is the ability of the IR missile seeker to discriminate between the IR signature of the aircraft and the IR signature of background interference, especially clouds. The second is the flare rejection capability built into the missile seeker and the missile guidance section.

a. The major source of IR background interference is sunlit clouds. Space filtering using a spinning reticle as described in the previous section is the method most widely used to suppress background interference and improve discrimination. IR energy from the target is gathered by the optical system and focused on the spinning reticle. The reticle chops the signal into a series of pulses that are focused onto the IR detector element. The signal output of a point source of IR energy, such as a target aircraft, will be a series of pulses. The signal output of a cloud, which covers several segments of the reticle, will be a single large pulse. An electrical filter eliminates the single large cloud pulse, and passes the multiple pulses generated by the target to the missile guidance section.

(1) IR missiles using spin-scan seekers have very little ability to reject flares. Flares provide the missile seeker with a hotter target than that of the aircraft, causing the spin-scan seeker to track the flare. The typical flare burns with a peak energy emission in the 2 micron range. Since the flare energy emission is greater than that of the target aircraft, the missile seeker transfers lock to the flare.

(2) Due to the scan pattern, con-scan seekers have some inherent resistance to flares. As described in the previous section, the reticle in a con-scan seeker is fixed and does not spin. Instead, a secondary mirror is tilted and spun. This causes the target image to be scanned in a circular path around the outer edge of the reticle. Because flares tend to drop away from the aircraft, they will drop off the con-scan reticle much faster than for a spin-scan reticle; therefore, flare resistance is built-in.

(3) Reducing the missile FOV is another method to help an IR missile discriminate the target IR signature from background IR (Figure 14-14). Limiting the FOV of the missile also makes the missile more resistant to flares. To decoy an IR missile seeker, the flare must create a heat source hotter than the aircraft and within the missile FOV. To decoy an IR missile with a narrow FOV, the flare must reach peak intensity almost immediately after ejection (Figure 14-15).

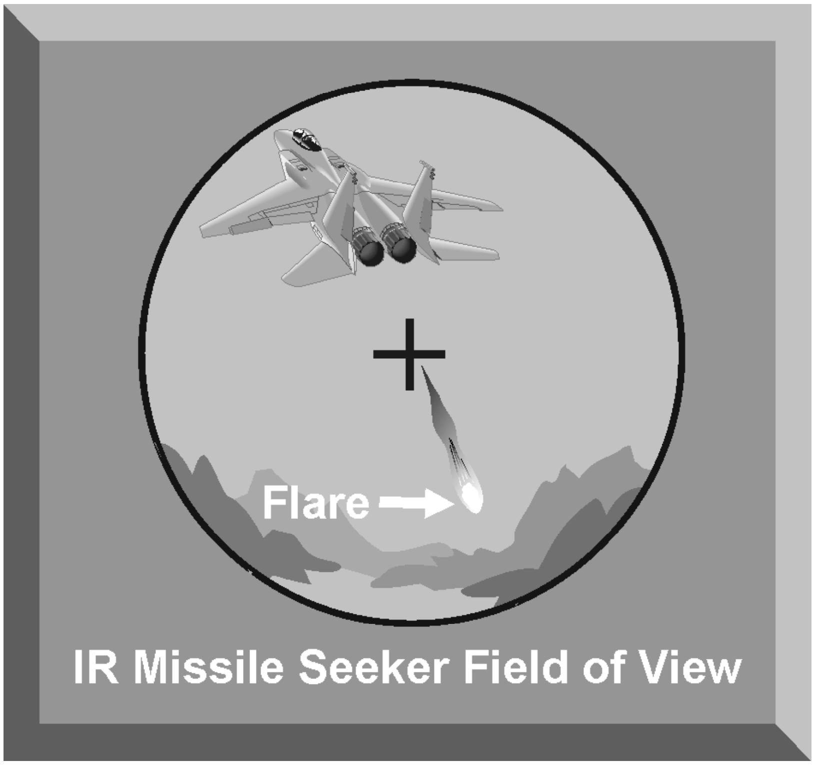
Flare
IR Missile Seeker Field of View

Figure 14-14. Impact of IR Missile Field of View

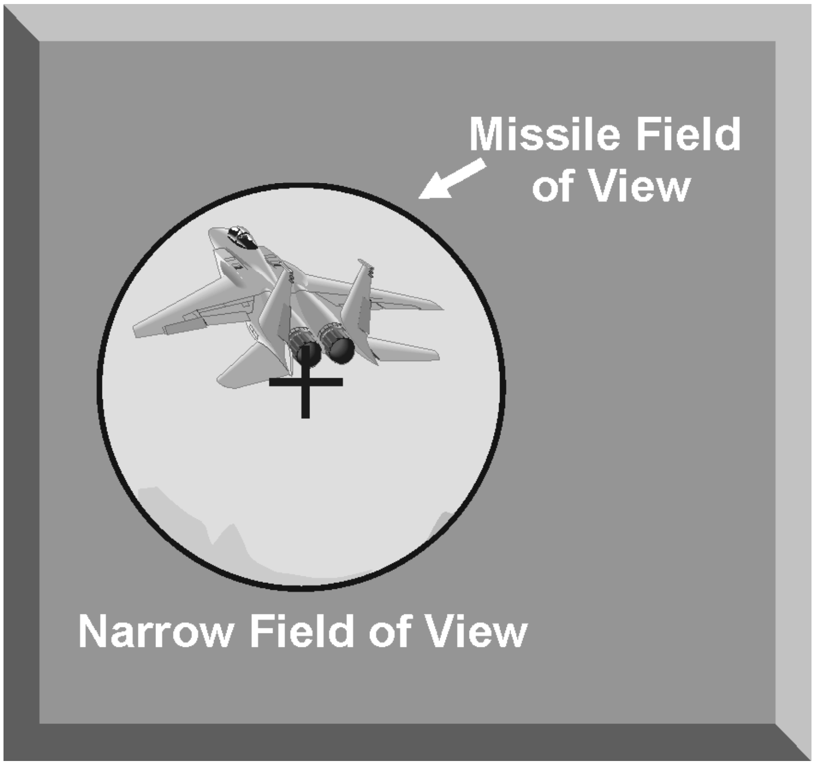
Missile Field of View
Narrow Field of View

Figure 14-15. IR Missile – Narrow Field of View

(4) The detector also influences the ability of an IR missile to discriminate target IR from background IR. Newer IR seekers can track longer wavelength IR radiation. The seeker's ability to track through a wider frequency range forces flares to decoy that wider frequency range to be successful. Additionally, the cooled seeker's ability to track from all angles could cause geometry problems, the missile may never see a flare ejected from the bottom rear of an aircraft.

b. IR missile designers have combined computer signal processing and modern IR missile seekers to detect the presence of flares and reject them as targets. This flare rejection capability, or IR counter-countermeasure (IRCCM), allows newer IR missiles to track the aircraft IR signature while rejecting multiple flares. Flare rejection is based on two computer functions. The first is called the "trigger," which detects the flare in the seeker field of view. The "trigger" function activates the "response" computer processing, the action the seeker takes to reject the flare. Both the "trigger" and "response" must operate to successfully reject flares. Each advanced IR missile employs different computer techniques for both the "trigger" and "response." A flare technique developed to counter one IR missile may not work against another IR missile that uses different flare rejection computer techniques.

(1) There are several "trigger" techniques that can be used by IR missiles to detect flares. Advanced IR missiles may employ one or more of these techniques to detect the presence of a flare in the seeker FOV. These "trigger" techniques include rise time, two-color, kinematic, and spatial.

(a) An IR missile using a rise time "trigger" monitors the IR energy level of the target. A sharp rise in the received IR energy within a specified time limit indicates a flare in the IR seeker FOV. When the missile detects this rapid rise in IR energy, the rise-time "trigger" triggers a flare "response." The "response" is switched off when the received IR energy drops to its original level. The thresholds for the rise in IR energy and the response time are set to preclude activating the rise time "trigger" when the aircraft selects afterburner. An IR missile using the rise time "trigger" can be decoyed by multiple flares with slow rise times.

(b) IR missiles using a two-color "trigger" to detect flares sample the energy level in two different wavelength bands. In Figure 14-16, a non-afterburning target would have more IR intensity in band B than in band A. The typical flare produces more IR intensity in band A than band B. A sudden increase in band A intensity compared to band B intensity indicates a flare in the seeker FOV. The two-color "trigger" would then trigger a flare "response." Advanced IR missiles using a two-color "trigger" can employ different detectors composed of different materials to monitor the intensity in two bands. A lead sulfide detector could be used for band A and indium antimonide for band B. IR missiles using a single detector can employ a reticle with different bandpass filters to monitor IR intensity in both bands. To track the target, IR missiles employing a two-color "trigger" may use either band, or use data from both

bands of a dual-channel tracker. An IR missile using the two-color "trigger" can be decoyed by multiple flares that provide equal IR intensity in each band.

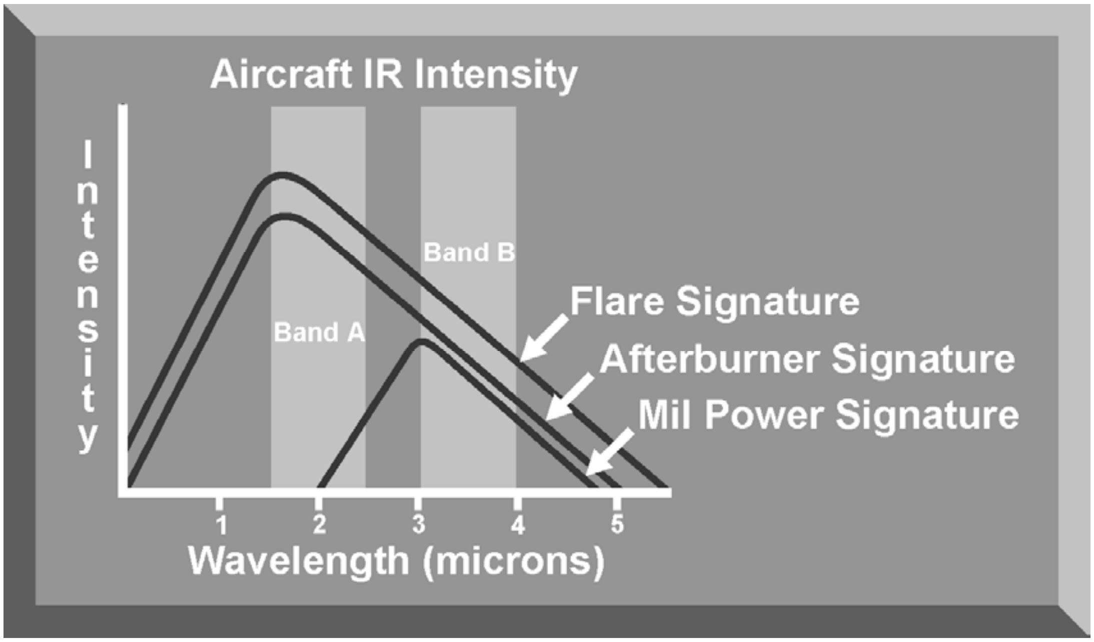

Figure 14-16. Two-Color IR "Trigger"

(c) A kinematic "trigger" takes advantage of the fact that flares separate very quickly from the dispensing aircraft due to aerodynamic drag. In a beam aspect engagement, an IR seeker that transfers track from the target to the flare will have a dramatic change in the line-of-sight rate due to the rapid separation of the flare from the aircraft. An IR missile employing a kinematic "trigger" detects this change and initiates the "response." IR missiles employing a kinematic "trigger" may have difficulty in flare detection in a head-on or stern engagement due to the small line-of-sight change between target and flare. Multiple flares dispensed at very short intervals will probably decoy an IR missile employing a kinematic "trigger".

(d) The spatial "trigger" operates like the kinematic "trigger" in that it uses the rapid separation of the flare from the aircraft to trigger the "response." An IR missile employing a spatial "trigger" uses the seeker to detect a flare. When the flare separates to the rear of the aircraft, the seeker will see the target on the edge of the FOV corresponding to the direction of target movement. The flare will be on the opposite side of the FOV. Once two hot objects on opposite sides of the FOV are distinguishable, the spatial "trigger" triggers the flare "response." IR missiles employing a spatial "trigger" can be decoyed by dispensing multiple flares at very short intervals.

(2) The seeker's "response" to the "trigger" is to reject the flare or limit its effect on target track. As long as the flare remains in the seeker FOV, the missile

is tracking the target in a degraded mode. Most IR seekers have a FOV of less than 2.5°. At long ranges, the flare will remain in the FOV for a relatively long period of time. At close range, the flare will be in the missile FOV for a relatively short period of time. Several different "response" techniques may be used, either alone or in combinations, to defeat a flare. These "response" techniques include simple memory, seeker push-ahead, seeker push-pull, and sector attenuation.

(a) When the simple memory "response" is initiated, the missile continues the maneuver it was performing just before the "trigger." This "response" assumes the flare will separate to the rear of the target. The missile rejects the seeker track data and maintains its motion relative to the target, waiting for the flare to leave the seeker FOV. The missile will continue to reject track data until the flare leaves the FOV or until the "trigger" times out. When the "trigger" times out, the "response" is discarded and the seeker operates in the normal track mode. If the "trigger" times out while a flare remains in the FOV, the seeker will usually transfer lock to the flare.

(b) The seeker push-ahead "response" causes the seeker gimbals to drive the seeker forward in the direction the target is moving (Figure 14-17). Pushing the seeker forward causes the flare to depart the FOV faster than with simple memory, minimizing the amount of time the missile is not tracking the target. The greater the amount of forward movement (called "bias"), the faster the flare will depart the FOV. If the amount of forward bias applied is too great, the seeker may be pushed forward of the target. This could cause both the target and the flare to depart the FOV and the missile would have to reacquire the target.

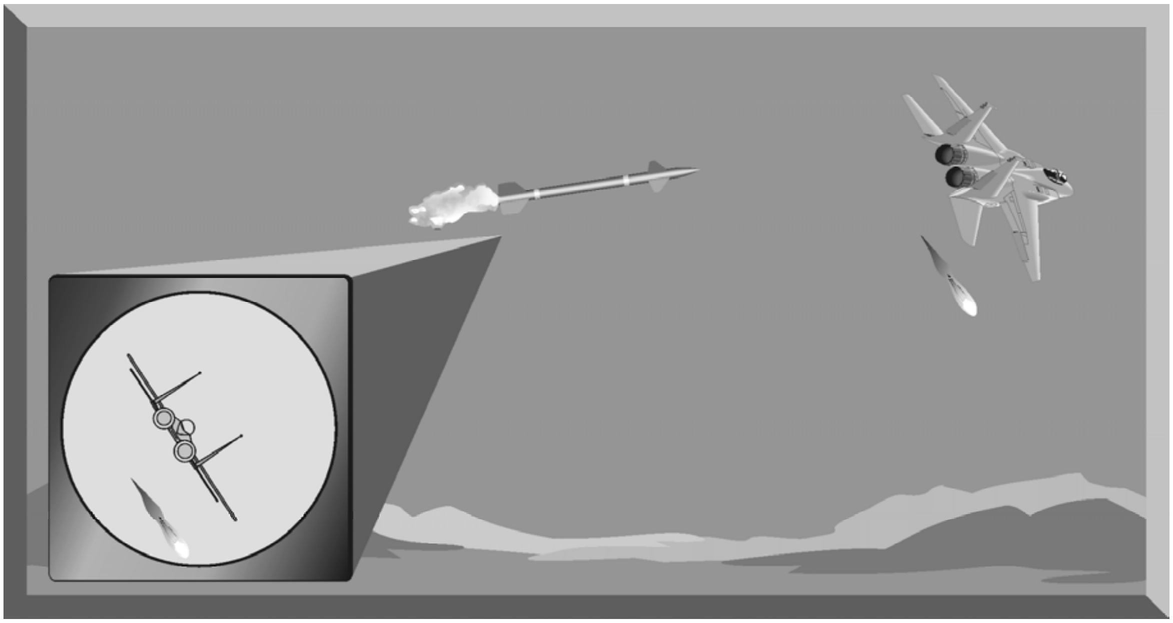

Figure 14-17. Seeker Push-Ahead "Response" Technique

(c) The seeker push-pull "response" assumes flares will have a higher intensity IR signature than the target. The "response" is initiated when the target and flare are on opposite sides of the seeker FOV (Figure 14-18). This corresponds to a spatial "trigger" condition. The received energy will rise and fall as the energy of the target and flare is scanned across the detector. When the flare energy is at a peak, the seeker gimbals drive the seeker away from the flare. When the lesser energy from the target is detected, the seeker's gimbals pull the seeker in the direction of the target. As a result, the seeker is moved away from the flare and toward the coolest IR source in the FOV, the target aircraft.

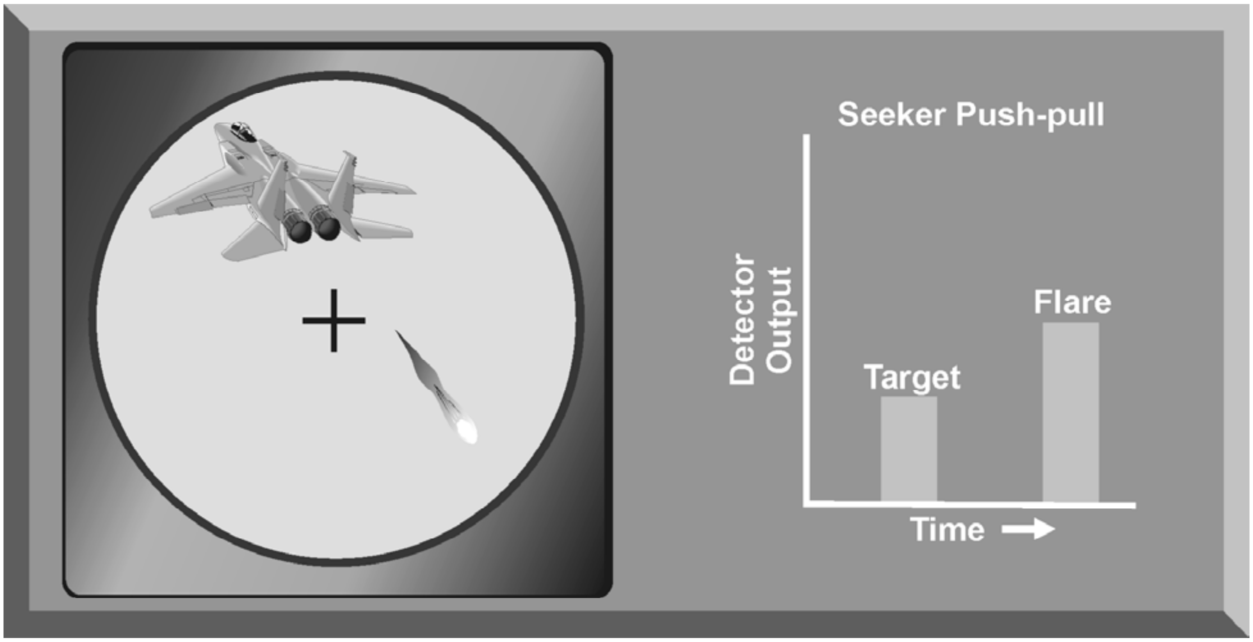

Figure 14-18. Seeker Push-Pull "Response" Technique

(d) The sector attenuation "response" is initiated by placing an attenuation filter across part of the seeker FOV (Figure 14-19). This filter reduces the seeker sensitivity in that part of the FOV. If the target being tracked is in the center of the FOV, then placing an attenuator in the quadrant below and to the rear of the target should reduce any energy received from a flare. If the attenuated flare energy is below that of the target energy, the seeker will continue to track the target.

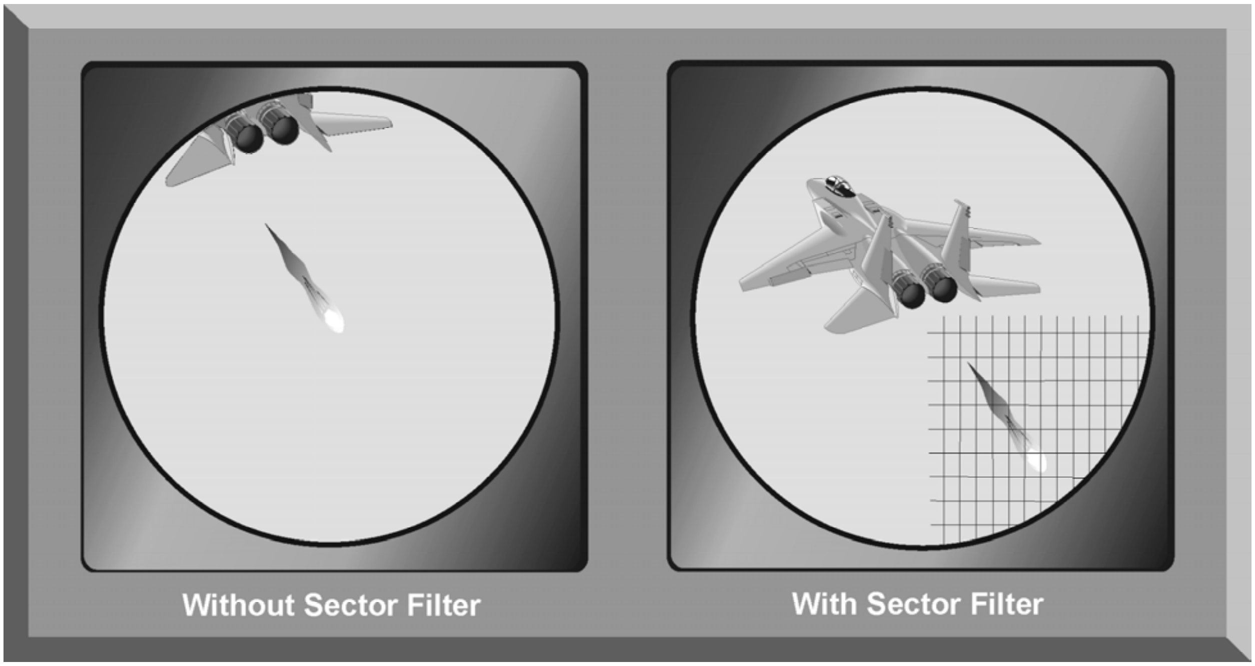

Figure 14-19. Sector Attenuation "Response" Technique

7. SUMMARY

This chapter provided some background on IR theory and IR detection, then went into some of the basics about the different types of IR missile seekers. Finally factors that impact the ability of an IR missile to reduce the effectiveness of self-protection flares were discussed. This ability depends on the discrimination capabilities of the missile seeker, the type of detector, the missile FOV, and the missile flare rejection capabilities. Modern IR missiles that employ sophisticated flare rejection techniques and advanced missile seeker technologies present a growing, and potentially lethal, threat.

CHAPTER 15. IR COUNTERMEASURES

1. INTRODUCTION

Defeating IR missiles used to be an afterthought placed well behind surviving the radar missile threat. Now with the proliferation of advanced IR missiles, defeating the IR threat is becoming more important and more difficult. The primary countermeasure used to defeat IR missiles is the self-protection flare. This chapter will discuss flare characteristics and employment considerations. One of the main difficulties in defeating an IR missile is knowing that one has been launched. This chapter will also discuss some of the methods currently available to detect an IR missile attack.

2. FLARE CHARACTERISTICS

Self-protection flares were developed to counter threat systems operating in the IR spectrum. Self-protection chaff and flare dispensers, such as the ALE-40, ALE-45, or the ALE-47, are designed to allow the pilot to dispense flare cartridges when engaged by an IR threat. These flare cartridges are pyrotechnic and pyrophoric devices designed to produce an IR source that is more attractive than the IR signature of the aircraft. To decoy an IR missile seeker, the flare must create a heat source more attractive than the aircraft, within the missile field of view. The most important flare characteristics that determine the ability of a flare to decoy an IR missile are IR wavelength matching, flare rise time, and flare burn time. The MJU-7 flare cartridge will be used as an example of a typical flare cartridge.

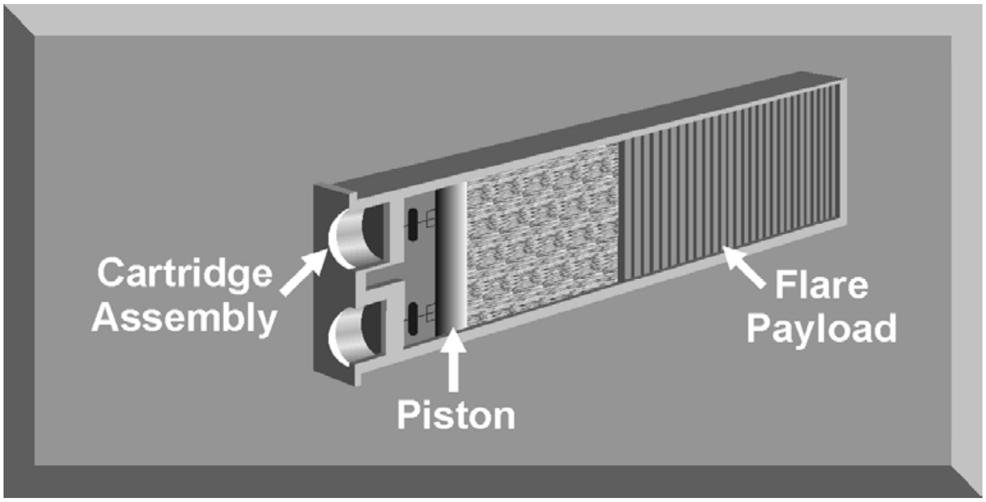

Figure 15-1. The MJU-7 Flare

a. The MJU-7 flare cartridge (Figure 15-1) is an example of a flare cartridge used in both the ALE-40 and the ALE-47 dispensers. The flare grain is composed of magnesium and tetraflouroethylene, or C_2F_4, which burns at 2000 to 2200°K. As the flare burns, it emits IR energy of different wavelengths from the luminous zone that emulates the aircraft IR signature. The burning flare also produces a large quantity of white smoke, which may highlight the position of the dispensing aircraft.

b. A flare must reach peak intensity shortly after ejection or it will not be effective in decoying the IR missile seeker. Flare rise time is the time required for the flare to reach peak intensity.

(1) To counter a short-range IR missile with a narrow field of view, a flare must reach peak intensity quickly. On the other hand, some advanced IR missiles now look for a rapid rise in IR energy as a trigger to know when a flare is trying to decoy it (Figure 15-2).

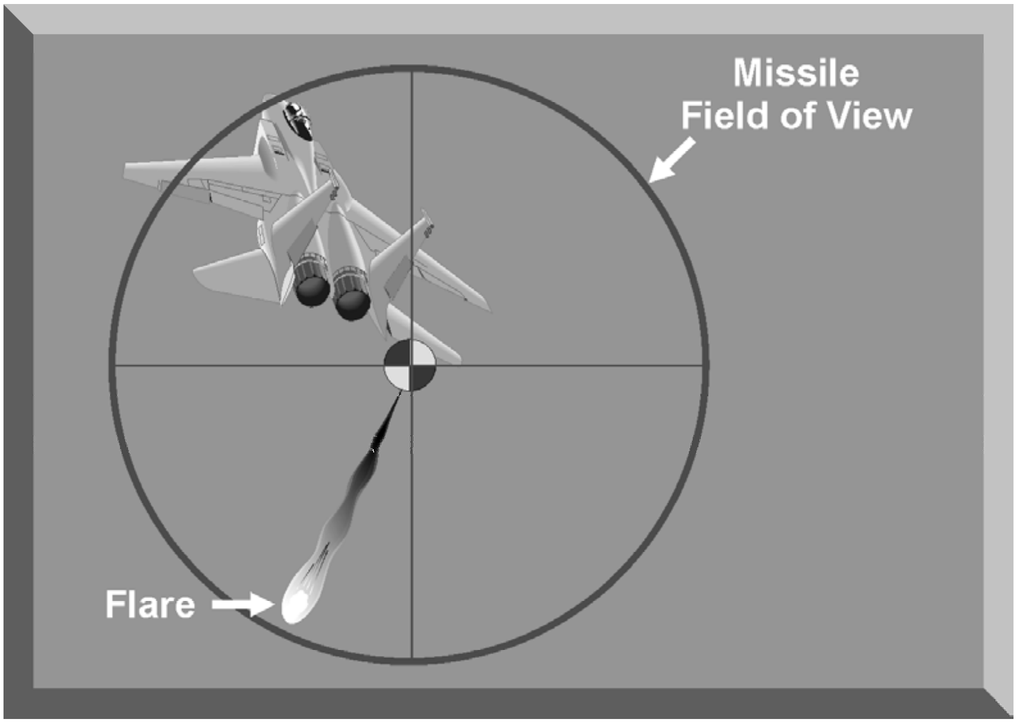

Figure 15-2. Impact of Flare Rise Time

(2) Flare rise time varies dramatically with altitude. The flare burns longer at high altitude, but it takes much longer to reach peak intensity. This increase in flare rise time at high altitude can impact the effectiveness of flares to decoy and defeat IR missiles particularly in the air-to-air combat environment.

c. Flare burn time is the time span that the flare burns and determines how far the IR seeker will be pulled off the target. The longer the burn time, the longer the

IR seeker is pulled off the target aircraft. The flare should burn long enough to ensure that the aircraft is no longer in the missile field of view. Flare burn time, like flare rise time, varies with altitude. A flare will burn longer, but at lower intensity, at higher altitudes. A longer flare burn time increases the probability the IR missile will be decoyed by a single flare.

3. ADVANCED FLARES

To counter the advances in IR missile seeker technology the Air Force and Navy formed the Advanced Strategic and Tactical Expendables program to develop and field advanced IR decoys. Two products to come out of this program are the kinematic flare, MJU-47, and the covert flare, MJU-50/51.

a. Kinematic Flares. A significant characteristic of conventional flares is that upon ejection they rapidly slow down and separate from the aircraft. As described in Chapter 14, modern IR missiles exploit this rapid separation between the aircraft and the flare. The rapid separation triggers a flare rejection response in the missile seeker causing it to ignore the flare and continue tracking the aircraft. The kinematic, or thrusted, flare delays the missile response by propelling itself in the direction of the aircraft and negating or delaying the missile's flare rejection trigger. The MJU-47 is the same size as the currently fielded MJU-10 flares. The flare's decoying pyrotechnics are vectored out the end of the flare to provide a means of propulsion (Figure 15-3).

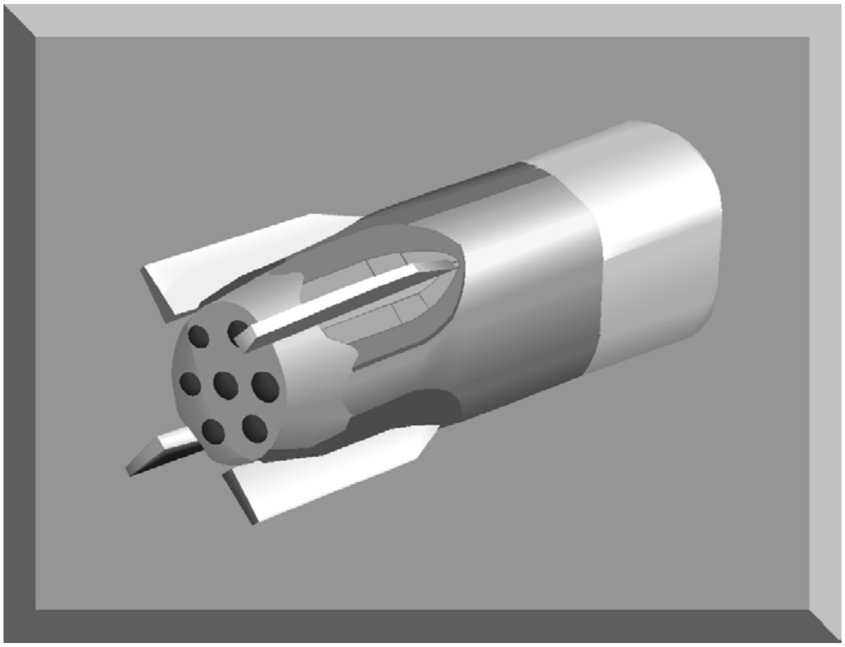

Figure 15-3. Kinematic Flare

b. Covert Flares. Though an effective tactic at defeating MANPADS, pre-emptively dropping flares in a target area carries a significant risk. The risk is that enemy air defense systems that may not have known the aircraft's location will surely see the flares, day or night, and any chance for surprise is lost. Figure 15-4 shows the visual signature of conventional flares. The danger of highlighting oneself becomes even more likely as aircraft become fitted with chaff and flare systems that automatically dispense expendables based upon inputs from the RWR or a missile attack warning system (MAWS). Automatic systems tend to error on the side of caution which means expendables will be dropped if there is any ambiguity. Visually covert flares, named the MJU-50 and MJU-51, remove this problem by not leaving a visual signature such as smoke or flame. These covert flares are made of material that oxidizes, pyrophoric instead of pyrotechnic, when released in the air. The MJU-50 is the size of the small M-206 flare while the MJU-51 is the size of the MJU-7 flare.

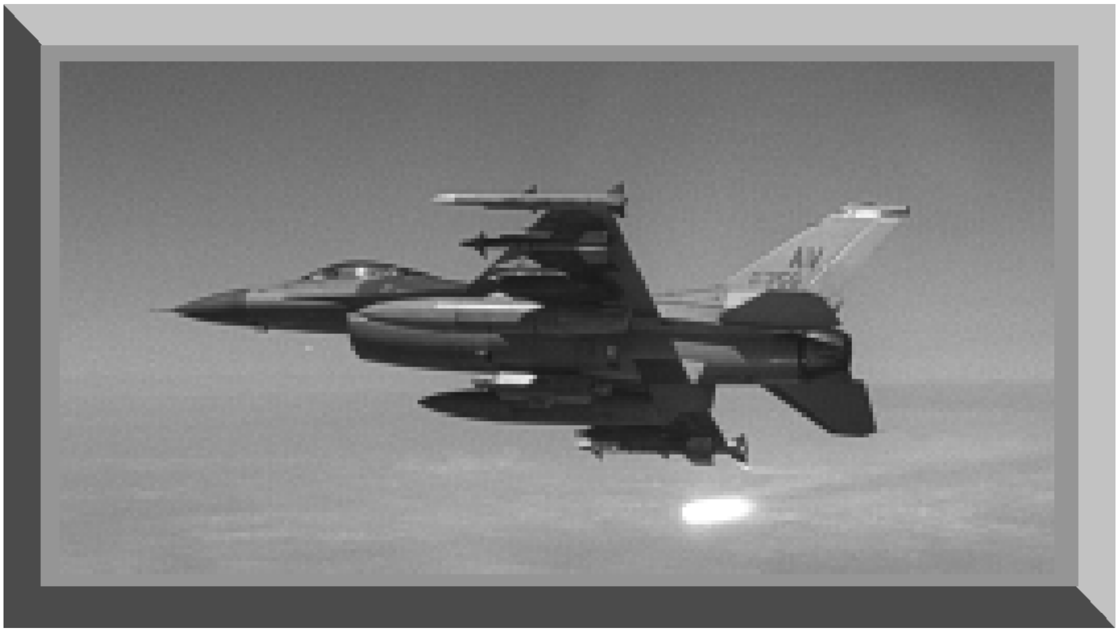

Figure 15-4. Flare Visual Signature

4. FLARE EMPLOYMENT

The purpose of employing a self-protection flare cartridge is to decoy the seeker head of an IR missile. This is accomplished by presenting the IR missile with a second heat source with an IR signature that exceeds the aircraft signature. The flare or IR source must appear in the field of view of the IR missile at the same time as the aircraft. As the flare separates from the aircraft, the IR missile seeker tracks the most intense IR signature, which ideally is the flare, and is decoyed away from the aircraft.

a. It is important to perform maneuvers along with flare employment to effectively defeat IR missiles. Maneuvers compound the IR missile's tracking problems and increase the distance between the aircraft and flare. Maneuvers that put the aircraft outside the IR missile field of view increase the ability of the flare to decoy the missile. When engaged by an IR threat, one tactic is to immediately dispense a flare and maneuver to put the missile on the beam. This increases the line-of-sight rate the missile guidance system must process and gives maximum separation between the aircraft and the flare (Figure 15-5).

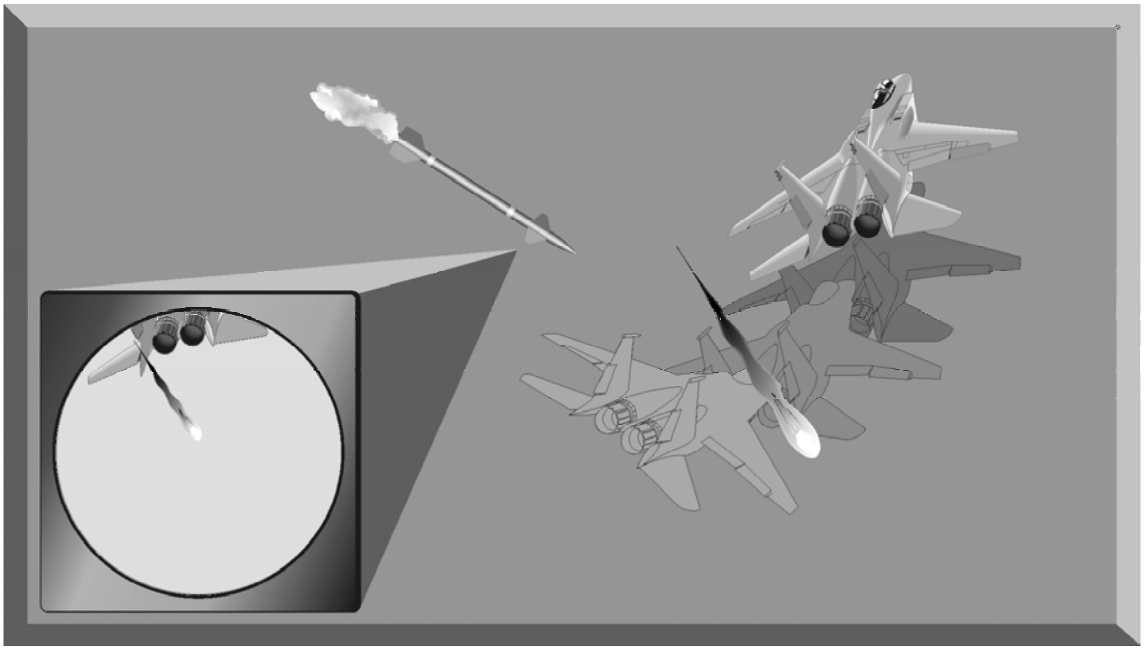

Figure 15-5. Initial Maneuver and Flare Employment

b. With the IR threat on the beam, the pilot has the best chance for achieving a "tally-ho" on the missile to determine range and keep the missile on the beam. Visually acquiring the missile increases the chances of surviving the encounter. Modern chaff and flare dispensers, such as the ALE-47 and ALQ-213, can be programmed to dispense flares in a sequence optimized to defeat specific IR missiles. Programs are selected by the pilot based upon the most likely threat. Classified tactics manuals provide aircraft specific maneuvers and flare dispensing programs to defeat the IR threat.

5. IRCM TACTICS

Besides maneuvers and flare employment, there are other IR countermeasures that can reduce the effectiveness of IR threat systems. The first is to reduce the intensity of the heat signature of the aircraft by reducing the power setting. The engines produce the largest IR signature and are the only source of IR radiation that the pilot can influence. By reducing the power setting, the IR signature is

reduced and the required flare intensity is thereby reduced. Use of afterburner should be minimized for exactly the same reason; the required flare intensity necessary to cover an aircraft in afterburner is difficult to obtain. The pilot should not reduce the power setting below the minimum required to maintain sufficient maneuvering airspeed.

a. Another effective IRCM is to use the sun. Maneuvering into the sun masks the aircraft's IR signature from most IR threat systems. When attacking a target defended by IR systems, an attack axis that places the sun behind the attacker may limit the effectiveness of these systems.

b. Clouds or smoke can also confuse IR threat systems (Figure 15-6). The water vapor making up clouds diffuses the IR energy making it difficult for an IR system to get a point to track, similar to how sun's light is diffused on a cloudy day. The particles found in smoke can have a similar effect on IR energy. The final IRCM is to reduce the IR signature of the aircraft by careful design of the engines and exhaust system. For example, the F-117 was specifically designed to provide the lowest possible IR signature.

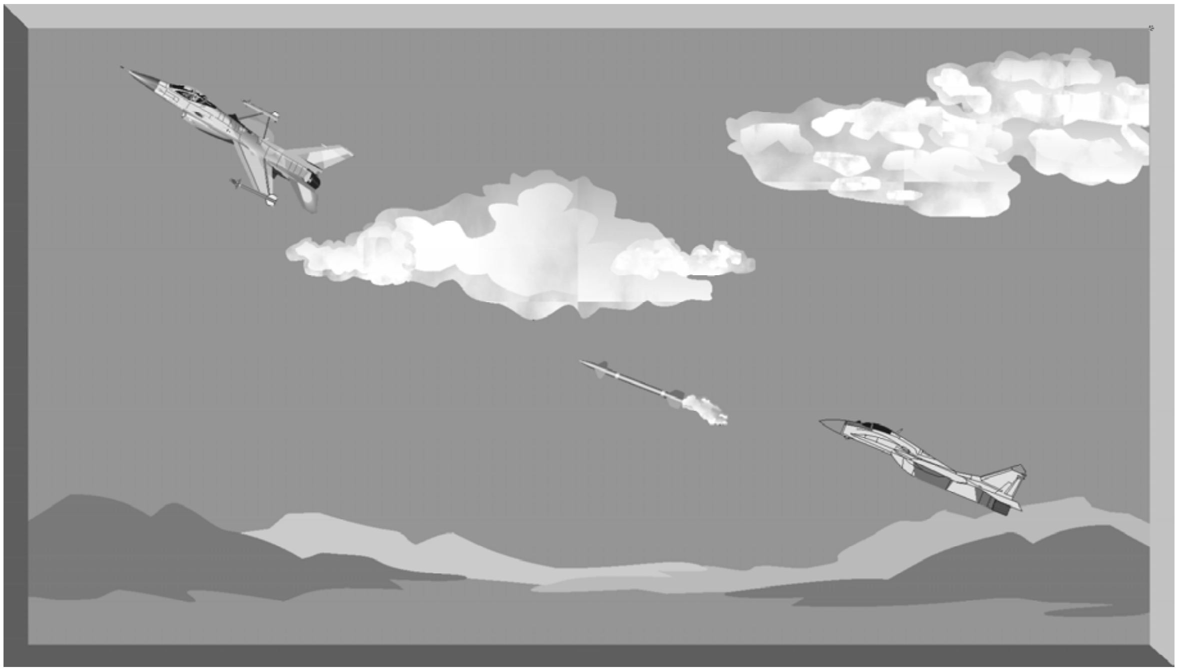

Figure 15-6. IRCM

6. MISSILE APPROACH WARNING SYSTEMS (MAWS)

One of the most important factors in defeating an IR missile attack is knowing that an attack is in progress. Since IR threat systems are generally passive, the radar warning receiver (RWR) will provide no attack warning unless the threat uses some detectable radar energy for acquisition prior to launching an IR

missile. MAWS are designed to provide the crew some warning of an ongoing missile attack. These systems have been widely deployed on larger aircraft. Advances in technology allowing them to be smaller and promising lower false alarm rates have increased the possibility that fighter size aircraft may be outfitted with this equipment.

a. The two primary requirements for MAWS are timeliness and reliability. An IR missile engagement is an extremely short event providing very little time for the targeted aircraft to respond with maneuvers and flares. Secondly, there must be a very low false alarm rate. In earlier systems the sun, flares, or the wingman's aircraft have been known to cause false alarms. Aside from being annoying, a false alarm can become a tactical problem if the MAWS is tied directly into the countermeasures dispenser set allowing for automatic dispensing of chaff and flares when the MAWS senses an attack. False alarms in this type of scenario would only serve to highlight a previously untargeted aircraft.

b. MAWS detect incoming missiles either actively or passively. The active MAWS use a pulse Doppler radar to detect and track the in-flight approach of an attacking missile. Pulse Doppler radar is used for this purpose because of its ability to use relative velocity to pull targets out of clutter. An incoming missile will have a high velocity relative to the surrounding background. Range and time to impact are computed automatically, updated continuously, and provided to the crew to assist in defensive maneuvers (Figure 15-7). The down side to active MAWS is the requirement to continuously radiate for long periods of time to ensure protection. This contradicts the common tactic of keeping radar transmissions to a minimum to avoid being tracked via passive detection measures. This situation has led to the latest generation of MAWS being mostly of the passive type.

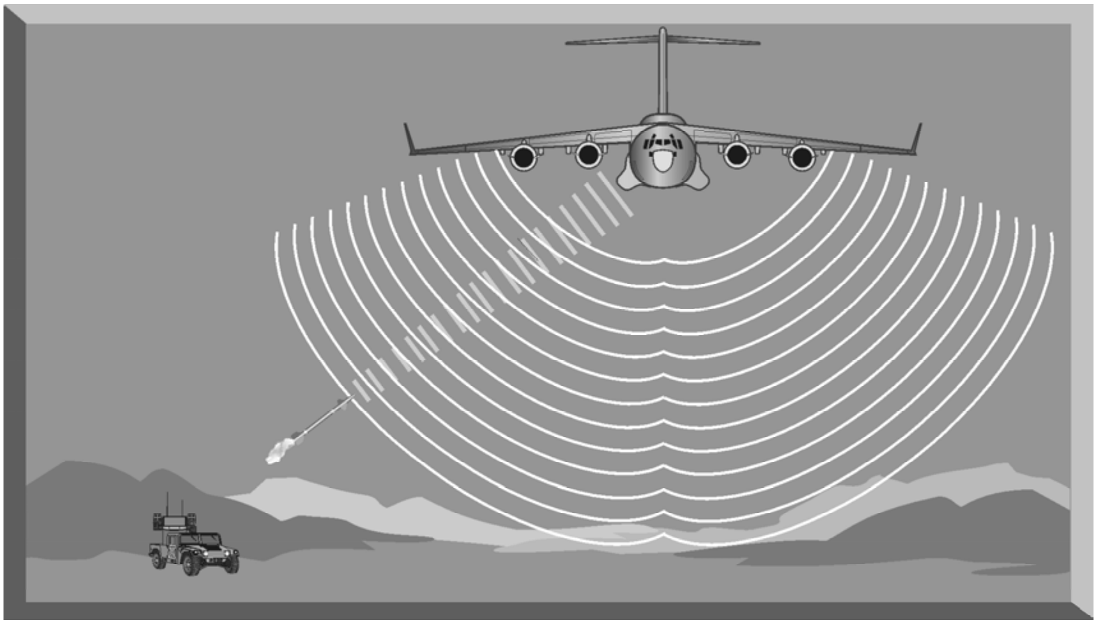

Figure 15-7. Missile Alert Warning System (MAWS)

c. The passive MAWS operate in either the ultraviolet, or the infrared frequency spectrum. These systems are tuned to look for the IR signature of a missile's rocket motor, then pass a warning and the position of the inbound threat to the pilot. To obtain all-aspect missile warning, multiple MAWS sensors must be positioned on the aircraft in a similar fashion to RWR antennas. All-aspect MAWS face the same challenges that RWR systems face: false multiple targets due to maneuvers and accurate threat position reporting, to name a few.

7. SUMMARY

The proliferation of IR threat systems has elevated the importance of IRCM to survival on the modern battlefield. The most effective IRCM is still the employment of flares in conjunction with maneuvers. The specific flare characteristics of IR spectrum coverage, rise time, and burn time are critical factors in determining flare effectiveness. Other IRCM tactics are designed to enhance the effectiveness of flares and take advantage of IR missile limitations. The effectiveness of all IRCM tactics depends on some type of attack warning. The new generation of MAWS should provide some measure of warning to the crews and in some cases automatically defeat the IR missile.

CHAPTER 16. RADAR ELECTRONIC PROTECTION (EP) TECHNIQUES

1. INTRODUCTION

Electronic warfare (EW) is defined as military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the enemy. Nearly every military action, from command and control of an entire integrated air defense system (IADS) to precision guidance of an individual weapon, depends on effective use of the electromagnetic spectrum. Radar systems have become a vital element of nearly every military operation. Since these systems operate across the entire electromagnetic spectrum, much of the EW effort is concerned with countering radar systems. All of the jamming techniques discussed in Chapters 10 and 11 and the chaff employment options discussed in Chapter 13 are specifically designed to counter radar systems. These actions are classified as electronic attack (EA), which is a part of EW.

a. EW is somewhat like a chess game—a series of moves and countermoves within the electromagnetic spectrum. As we develop jamming techniques to counter radar systems, our adversaries develop counter-countermeasures to negate the effectiveness of these techniques. In response, we develop newer techniques and our adversaries respond with new modifications to their radar systems. This series of moves and countermoves can continue for decades. The development and application of radar counter-countermeasures are classified as electronic protection (EP), also a part of EW.

b. The continuing battle to control the electromagnetic spectrum for unrestricted radar employment has resulted in over 150 radar EP techniques. These techniques are designed to negate the effectiveness of electronic jamming and chaff on radar systems. These radar EP techniques can be incorporated into the design of a radar system or added to an existing radar system in response to a jamming technique. It is beyond the scope of this text to discuss all the radar EP techniques in use today. This chapter will discuss the most common EP techniques. They have been organized by function of the technique within the radar. These functions include radar receiver protection, jamming avoidance, jamming signal exploitation, overpowering the jamming signal, pulse duration discrimination, angle discrimination, bandwidth discrimination, Doppler discrimination, and time discrimination.

2. RADAR RECEIVER PROTECTION

The following are some of the most common radar counter-countermeasures designed to prevent receiver overload or saturation.

a. Sensitivity time control (STC) is used to counter close-in chaff or close-in clutter. Receiver gain is set at normal for long ranges and reduced for close-in ranges. One problem with using STC is that close-in targets may be missed if STC is improperly adjusted.

b. Automatic gain control (AGC) is used to counter chaff, clutter, and most types of transmitted jamming. AGC senses the signal level of a receiver's output and develops a back-bias, producing a constant output level. This technique has a slow response time compared to fast AGC and instantaneous AGC, both of which are employed instead of AGC. Also, it cannot maintain correct IF output levels for different intensity signals that are close in range because the bias voltage has a long buildup and decay time.

c. Fast automatic gain control (FAGC) is also employed against chaff, clutter, and most types of transmitted jamming. FAGC works by sensing the signal level of receiver output and develops a back-bias, tending to hold output constant. Response time is within milliseconds, permitting fast response and recovery as the antenna traverses the jammer's bearing. There are several precautions to note when using FAGC. First, targets may be suppressed and lost without the operator knowing that jamming is present. Second, a strong pulse or echo may cause ensuing weak targets to be lost. Lastly, FAGC has difficulty getting an accurate bearing on the jamming source.

d. Instantaneous automatic gain control (IAGC) is another technique to counter chaff, clutter, and most types of transmitted jamming. IAGC senses the signal level of each echo or jamming pulse and develops a back-bias that holds the stage output constant. Gain control response time is within milliseconds and extends the dynamic range of the receiver. There are several precautions to note when using IAGC. First, it is not effective against signals whose "in band" time is less than the IAGC response time. Also, with continuous duty cycle jammers, targets may be lost without the operator knowing that jamming is present. Finally, it is difficult to get an accurate bearing on the jamming source.

e. Automatic noise leveling (ANL) counters noise jamming and modulated or unmodulated constant wave jamming. ANL samples receiver noise content at the end of each PRF and sets the gain accordingly for the next pulse interval. Continuous jamming reduces gain to keep output the same as the original noise level. ANL also follows the scanning rate of the antenna so that receiver noise output is constant as the antenna rotates. When using ANL, targets may be suppressed and lost without the operator knowing that jamming is present. Also, receiver gain is unstable when pulses or swept jamming enter the sampling gate intermittently.

f. The logarithmic receiver (LOG) counters most types of transmitted jamming by amplifying and demodulating large dynamic-range signals in logarithmic amplifiers. This produces "amplitude compression" of the strong

signals. However, when using LOG, output is nearly constant so the operator cannot easily tell when jamming is present.

g. The logarithmic receiver with fast time constant (LOG-FTC) counters narrowband jamming, chaff, and clutter. This technique amplifies and demodulates large dynamic-range signals in logarithmic amplifiers, producing “amplitude compression” of the strong signals. Video is coupled through FTC circuits to eliminate rectified carrier and low frequency sideband products. There are problems with using LOG-FTC. First, the receiver output is nearly constant, so the operator cannot always tell when jamming is present. Second, LOG-FTC is not effective against wideband, or fast-swept, short pulse jamming. Lastly, LOG-FTC causes a broadening of displayed jam sector. as well as degrading bearing accuracy on the jam source.

h. Dicke-fix (DF) counters wideband and fast-swept jamming and is similar in employment to wideband limiting (WBL). DF amplifies without ringing, clips down all pulses to a common level, then amplifies the narrowband echo signal more than the wideband jamming. Noise level is held constant, independent of jamming intensity. There are precautions to note when using DF. Jamming that enters the wideband limiter can capture limiters, causing poor receiver sensitivity. Targets may be suppressed without the operator knowing that jamming is present. Also, resolution and target detection range are reduced, even in a non-jamming environment. Finally, DF is ineffective against extremely fast-swept spot jamming.

i. WBL is used to counter wideband jamming and fast-swept jamming. WBL amplifies without ringing, clips down all pulses to a common level, then amplifies the narrowband echo signal more than the wideband jamming. Noise level is held constant, independent of jamming intensity. However, jamming that enters the wideband limiter can capture limiters and cause poor receiver sensitivity. Resolution and target detection range is reduced, even in a clear environment. Targets may be suppressed without the operator knowing that jamming is present. Finally, WBL is ineffective against fast-swept spot jamming.

j. Adaptive video processing (AVP) counters chaff corridors, weather, sea clutter, and most types of transmitted jamming. AVP combines the adaptive threshold, beam-to-beam correlation, and wide-pulse blanking in frequency-scanning three-dimensional radars to avoid collapsing undesired returns on the PPI display. However, when using AVP, there is a decreased probability of detection in some multiple target situations. Also, targets may be suppressed without the operator knowing that jamming is present. Finally, AVP passes all point targets.

3. JAMMING SIGNAL AVOIDANCE

The following are some EP techniques used to avoid jamming signals.

a. Frequency agility (FA) counters narrowband jamming and some types of repeater and deception jamming. FA enables the radar to make rapid changes of transmitter and receiver operating frequency, sometimes on a pulse-to-pulse basis. Manual frequency changes may cause mutual interference with other radars and services.

b. Frequency diversity works against narrowband jamming and some types of repeaters and transponders. It is a multiple-radar coordination procedure in which radars are assigned operating frequencies that are separated to reduce mutual interference and their susceptibility to a single jammer. It is important to note that other radars may be operating at the same allocated operating frequency.

c. Polarization diversity is used to counter chaff, weather, and transmitted jamming. Polarization diversity attenuates jamming input to a radar receiver by using antenna polarization different from jammer polarization, and usually involves separate radars of different polarization. There are two precautions when using polarization diversity: (1) ground clutter worsens on vertical polarization, and (2) close coordination is necessary if separate radars are used; for example, one horizontally polarized search radar and one vertically polarized search radar.

d. Circular polarization (CP) works against chaff, weather, and transmitted jamming. CP attenuates jamming input to a radar receiver by using antenna polarization different from jammer polarization, and usually involves separate radars of different polarization. CP also improves target detection in rain clutter.

e. Conical-scan-on-receive-only (COSRO) is employed against inverse conical scan jamming to deny a jammer the ability to sense and upset scan angle tracking information. A constantly transmitted illumination beam is received and scanned to derive target angle information. However, the jammer can still degrade angle tracking if it can approximate the received signal scan rate.

f. Speedgate tracking is used against all types of transmitted jamming. The technique provides a very narrow bandpass having a center frequency related to Doppler shift. Only jamming within the restricted band is effective. It has the advantages of accurate target Doppler discrimination and good target tracking at low target levels. However, the speedgate can be stolen by gate stealers and some types of swept jamming.

g. Leading-edge track (LET) is used to counter an incoming target dropping chaff by allowing target tracking on the leading edge of the target. Trailing edge track (TET) is used to counter a receding target dropping chaff.

h. Track coast is used to counter chaff, clutter, multiple targets, range gate stealers, jam fades, and blinking jamming by placing tracking radar in a rate-aided coast condition. The system "estimates" target position to avoid interrupting the fire control solution. A lock-on or return to acquisition mode terminates the track coast condition. Track coast requires adequate storage of rate-aided information, and no true tracking information will be developed while track coast is operating.

i. Guard gates work against chaff, clutter, multiple targets, range gate stealers, jam fades, and blinking jamming. Guard gates provide automatic detection of a foreign signal and "estimates" target position to avoid interrupting fire control solutions. Like track coast, guard gates require an adequate store of rate-aided information with no true tracking information developed.

4. JAMMING SIGNAL EXPLOITATION

The following are some EP techniques that use the jamming signal for target acquisition and engagement.

a. Passive angle tracking (PAT) counters most types of transmitted jamming by allowing the radar to acquire and angle-track the source of jamming signals. There are some problems with this technique. Blinking jamming can cause severe instability, and the range of the jammer is unavailable until the target reaches burnthrough range.

b. Home-on-jamming (HOJ) counters most types of transmitted jamming by allowing the missile or radar to use the jamming signals, locate the source, and home on it. However, blinking jamming can cause severe instability, and the range of the jammer is unavailable until burnthrough.

c. Jamming signals produce recognizable sounds that help in their detection and identification. Aural recognition allows an operator to listen to the Doppler frequency associated with a moving target. It is used to counter most types of jamming.

d. The local oscillator off technique counters continuously transmitted jamming. No receiver output occurs unless a target echo signal and a jamming signal are present. Limitations of this technique include: targets only display in an area where jamming is present; and, if the antenna rotates away from the jammer, or if jamming is turned off, no targets are displayed on the radar scope.

e. The jamming strobe indicator counters any transmitted jamming with high-duty-cycle modulation. The indicator is a variable marker strobe on the radar display that moves in range proportional to jamming strength. The indicator traces an antenna lobe pattern on the display, showing the azimuth of the jamming source. There are some problems with the jamming strobe indicator. First, it interrupts normal video in some radars. Second, inverse or sidelobe

jamming can cause erroneous strobes. Finally, the jam strobe does not react to unmodulated CW or low-duty-cycle jamming for some radar systems.

f. The jamming indicator lamp, located on the operator console, is used on radars with automatic noise leveling (ANL) to counter continuous transmitted jamming. The lamp alerts the operator to the presence of jamming, and the ANL is manually shut off. This action allows the operator to determine jammer bearing.

g. Clean strobe generation (CSG) counters any transmitted jamming by using the sidelobe blanking circuits of a radar. An azimuth strobe appears when the jamming level in the main antenna exceeds the jamming level in the sidelobe auxiliary antennas. The operator is alerted to the presence and bearing of a jamming source, even with a constant false alarm radar (CFAR) receiver.

h. Jamming attenuation (JAM ATTEN) counters both clutter and any type of jamming. Receiver gain is reduced to avoid receiver saturation by inserting an attenuator pad that enables the operator to recognize presence, type, and bearing of a jamming source. When using JAM ATTEN, however, the reduced gain may cause loss of targets, even in non-jammed sectors. Also, any improvement in signal-to-jam ratio is not possible.

i. Receiver manual IF gain (MAN GAIN or IF GAIN) also counters clutter and jamming. Receiver gain is reduced to avoid jamming saturation by manually reducing stage gain, allowing the operator to identify jammer presence, type, and bearing. When using IF GAIN, the reduced gain may cause a loss of targets, even in non-jammed sectors. Also, any improvement in signal-to-jam ratio is not possible.

5. OVERPOWERING THE JAMMING SIGNAL

Following are some EP techniques a radar system can employ to overpower jamming and reduce the jamming-to-signal (J/S) ratio to less than one.

a. Burnthrough counters most types of transmitted jamming. Energy in the target pulse is raised by increasing the peak power, that is, the PRF or pulse width, or by increasing the time the radar illuminates the target by reducing the scan rate or scan angle. Some radars have modes in which the radar concentrates its power in narrow azimuth and elevation sectors about the suspected target position. However, burnthrough can degrade general radar performance by overloading the receiver if a large radar cross section target is detected. High power may impact radar operation in clutter or dense chaff environments.

b. Narrowband long pulse (NBLP or NLP) counters most types of transmitted jamming by using a high-energy long pulse. The signal uses a narrowband receiver for reception, and increases detection range for targets in jamming and

in the clear. Simultaneously, it reduces resolution, which causes poor radar performance in chaff and clutter.

6. PULSE DURATION DISCRIMINATION

The following are some radar counter-countermeasures that use pulse duration to discriminate between radar and jamming signals.

a. The fast time constant (FTC) is used to counter chaff, clutter, and narrowband jamming. A video circuit provides low frequency attenuation to reject carrier and low frequency modulation jamming. FTC passes normal radar pulse lengths with little attenuation, but causes some loss of receiver sensitivity.

b. Pulse width discrimination (PWD), clutter eliminate (CE), and wide pulse blanking (WPB) are designed to counter chaff, most types of jamming, EMI, and some types of deception jammers. A video coincidence gate, involving a delay line matched to the expected signal duration, senses if a return is the proper pulse width. PWD, CE, and WPB provide an enabling path for qualified signals. However, weak signals may be lost in the signal processing.

c. Pulse expansion-compression (PC) is used to counter most types of noise jamming and some types of deception jamming. An expanded pulse is coded for transmission. This expanded pulse is transmitted and decoded on return. Echo responses are then compressed in a decoding process. This expansion/compression is equivalent to NLP, which provides longer detection ranges, and wideband short pulse, which provides increased resolution. Using PC is not without problems. Unwanted residues may cause loss of weak targets. Additionally, range error proportional to the Doppler shift, or radial velocity, affects the accuracy of the PC.

7. ANGLE DISCRIMINATION

The following techniques use angle discrimination to distinguish between radar returns and jamming signals.

a. Sidelobe blanking (SLB) and sidelobe cancellation (SLC) are types of sidelobe suppression (SLS) used to counter sidelobe response to chaff, clutter, transmitted jamming, sidelobe jamming, and deception jamming. An auxiliary antenna approximates the pattern and gain of sidelobes of the main antenna and produces a signal for comparison with the signal received in the main antenna. If the signal in the auxiliary antenna is greater, the signal in the main antenna channel is blanked. This permits bearings to be obtained on a jamming source and rejects sidelobe jamming. SLB is useful only for determining the bearing to the jamming source.

b. Antenna manual positioning, antenna traverse and elevation angle offset, antenna jog, and antenna slow scan are EP techniques used to counter main

beam and sidelobe jamming and deception. These techniques are designed to increase the antenna scans across the jammed sector to increase the blip-scan ratio. These techniques increase the number of pulses integrated, as well as the operators' sorting capability.

8. BANDWIDTH DISCRIMINATION

The following are EP techniques that use bandwidth to distinguish between radar jamming and target returns.

a. Dicke-fix (DF) counters wideband and fast-swept jamming. A wideband limiter amplifies without ringing and clips all pulses down to a common level. Then an amplifier increases narrowband target echo signals more than the wideband jamming. There are some problems associated with DF. Any jamming entering the wideband limiter can “capture” the limiters and cause poor receiver sensitivity. Targets may be suppressed without the operator knowing that jamming is present. Resolution and target range is reduced, even in a clear environment. Finally, DF is ineffective, even harmful, when the jamming bandwidth is near the bandwidth of the desired echo signal.

b. Transmitter pulse lengthening (TPL) counters wideband and fast-swept jamming. TPL concentrates power into a narrow band about the carrier frequency by lengthening the transmitting pulse. While this allows use of a narrowband receiver, it impairs resolution, causing poor chaff and clutter performance.

c. Transmitter pulse shaping (TPS) counters wideband and fast-swept jamming. The sideband range is limited by shaping the transmitted pulse. This allows use of a narrowband receiver, but impairs resolution, causing poor performance in chaff and clutter.

d. Narrowband pulse limiting (NBLP or NLP) is a form of transmitter pulse lengthening that counters wideband jamming and fast-swept jamming. NBLP concentrates power into a narrow band in the carrier frequency by lengthening the transmitting pulse. This allows use of a narrowband receiver, but impairs resolution, causing poor chaff and clutter performance.

e. The fast time constant (FTC) is used to counter chaff, clutter, and narrowband jamming. A video circuit provides low frequency attenuation to reject carrier and low frequency modulation of jamming. FTC passes normal radar pulse lengths with little attenuation, but causes some loss of receiver sensitivity.

f. High video pass (HVP) is used to counter chaff, clutter, and narrowband jamming. It is similar to FTC. A video circuit provides low frequency attenuation to reject carrier and low frequency modulation jamming. HVP passes only the leading edge of the received pulses. HVP can cause some loss of receiver sensitivity.

g. The wideband short pulse (WSP) counters chaff, clutter, and narrowband jamming by transmitting a short pulse and using a wideband receiver for reception. Echo resolution and accuracy are improved, and performance against narrowband jamming is enhanced. However, the maximum detection range is decreased and system vulnerability to wideband jamming is increased.

h. Narrowband limiting (NBL) counters chaff, clutter and narrowband jamming. A narrowband filter positioned in the front of the amplifier section allows only the target signal bandwidth to enter the limiter, reducing wideband and off-frequency jamming. The limiter clips all signals and noise to a common level. This technique is useful only when followed by pulse compression or other "decode" techniques. NBL is not effective against wideband jammers capable of causing "ringing" of the NBL bandpass filters. Targets may be suppressed and lost without the operator knowing that jamming is present. Finally, target detection and resolution are poor.

9. DOPPLER DISCRIMINATION

EP techniques that use Doppler frequency discrimination between radar and jamming signals to negate jamming effectiveness include the following:

a. Moving target indication (MTI) is used to counter chaff and clutter. The phase of returned target echoes is compared on a pulse-to-pulse basis. Those with no phase change (no change in radial velocity) are cancelled using a delay-line canceler. Sensitivity using MTI is poor for weak targets, even in the clear. Also, it is blind to targets that have a Doppler frequency that is equal to a multiple of the radar PRF, unless PRF stagger is used. Finally, limited dynamic range does not allow full cancellation of strong clutter echoes.

b. Compensated coherent MTI, also known as compensated COHO MTI, counters chaff and clutter by comparing the phase of returned target echoes on a pulse-to-pulse basis. Those pulses with no phase change, that is, no change in radial velocity, are cancelled. Corrections to the coherent oscillator are applied to compensate for motion of the platform and radar antenna. Sensitivity is poor for weak targets, even in the clear, and it is blind to targets that have a Doppler frequency equal to, or a multiple of, the radar PRF, unless PRF stagger is used.

10. TIME DISCRIMINATION

The following EP techniques use time discrimination between radar and jamming signals to negate jamming effectiveness.

a. Video integration (VINT) and integrate-multiply (INT-MULT) counter any form of transmitted jamming not synchronous with radar PRF. The video continuously circulates through a delay line, delaying signals exactly one pulse recurrence time (PRT), then combines them with signals from the next PRT. Synchronous target signals add together to increase video output, but noise and

random pulses are suppressed. Unless MTI and FTC are employed, VINT and INT-MULT will enhance chaff, clutter, and jamming along with target returns. Also, feedback control, or loop gain, must be carefully adjusted for optimum results.

b. PRF stagger and jitter are EP techniques designed to counter quasi-synchronous jamming, EMI, MTI blind-speeds, "second trip" echoes, and repeater jammers simulating "closer-than-real" targets. The transmitter pulse interval is varied to break up synchronous patterns. Received signals must be "de-staggered" for use with MTI or integration. When using any of these techniques, video de-stagger balance must be accurate or "double video" occurs. These techniques are not effective against exact synchronous deception jamming.

c. Pulse-to-pulse correlation (PPC) is used to counter slow-swept blinking or pulsed jamming not synchronized with radar PRF, and some types of deception jammers. To be displayed, target video must exceed a threshold voltage for two successive pulses. The technique avoids displaying non-synchronous jamming and EMI, but is not effective against synchronous jamming, and may cause weak targets to be missed.

d. Beam-to-beam correlation (BBC) is used to counter slow-swept blinking or pulse jamming not synchronous with radar PRF and some types of repeaters and transponders. It is used in three-dimensional frequency scanning or frequency agile radars. To be displayed, the target return echo signal must exceed a threshold value in two adjacent antenna beams. BBC is not effective against synchronous jamming. It may also cause weak targets to be missed.

e. Single beam blanking (SBB) is used to counter slow-swept, blinking, pulsed jamming, and narrowband jamming. It is used in three-dimensional frequency scanning or frequency agile radars to avoid displaying vertical beams containing jamming. A blanking pulse is generated for vertical beams containing jamming so that they are not displayed. The technique is not used on RHI video. Also, it can cause a loss of targets at the jammed elevation angle on the PPI display.

11. SUMMARY

This chapter has discussed some of the most widely employed EP techniques designed to counter radar jamming. The capabilities of the individual radar operator were not discussed. However, the radar operator is as important as the EP techniques designed for the radar system. Many of the most effective EP techniques are designed to ease operator interpretation of the radar display. In the chess game of EW, the capabilities of individual radar operators can be as important as the sophisticated EP techniques in determining the final outcome.

CHAPTER 17. RADAR WARNING RECEIVER (RWR) BASIC OPERATIONS AND GEOLOCATION TECHNIQUES

1. INTRODUCTION

Radar surveillance and radar-directed weapons represent the biggest threat to aircraft survival on the modern battlefield. The first step in countering these threat systems is to provide the pilot or crew with timely information on the signal environment. The radar warning receiver (RWR) is designed to provide this vital information to the pilot. The RWR system is an example of an electronic warfare support (ES) system. The primary purpose of an RWR system is to provide a depiction of the electronic order of battle (EOB) that can have an immediate impact on aircraft survival. Though the RWR system is complex, the basic operations of the various components are straightforward. A step above RWR systems is threat geolocation. While an RWR provides the EOB for a single aircraft, threat geolocation systems can provide accurate threat location data for numerous aircraft over an entire region. Threat location data is used for aircraft threat avoidance and, more common today, the preemptive attacking of enemy radar sites. This chapter will discuss the functions of the various components of a RWR system including the antennas, receiver/amplifiers, signal processor, emitter identification (EID) tables, RWR scope, RWR audio, and limitations to RWR systems. This chapter will then go on to discuss three of the methods used to geolocate radar threat systems.

2. RWR ANTENNAS

Antennas are designed to receive radar pulses from threat radar systems. Factors that impact the operation of the RWR antennas include location, pattern, sensitivity, and polarization.

a. The physical location of the RWR antennas on the aircraft can affect its ability to detect a radar signal. Antennas are arranged to cover a predetermined area of horizontal and vertical space around the aircraft (Figure 17-1).

b. The antennas and their patterns play an essential part in displaying the spatial relationship of a threat radar to the aircraft. The antenna patterns are the areas, or “footprints,” that the antennas are specifically designed to cover. These footprints are directly affected by the relative position of the antennas to the threat systems. This is because the signal processor measures and compares signal strength from all the aircraft antennas to compute threat signal location relative to the aircraft. This relative location is then presented on the RWR scope display. Aircraft movement and maneuvering shifts these relative positions during flight and can distort the true threat position on the RWR scope. Precise position determination is not possible with most RWRs.

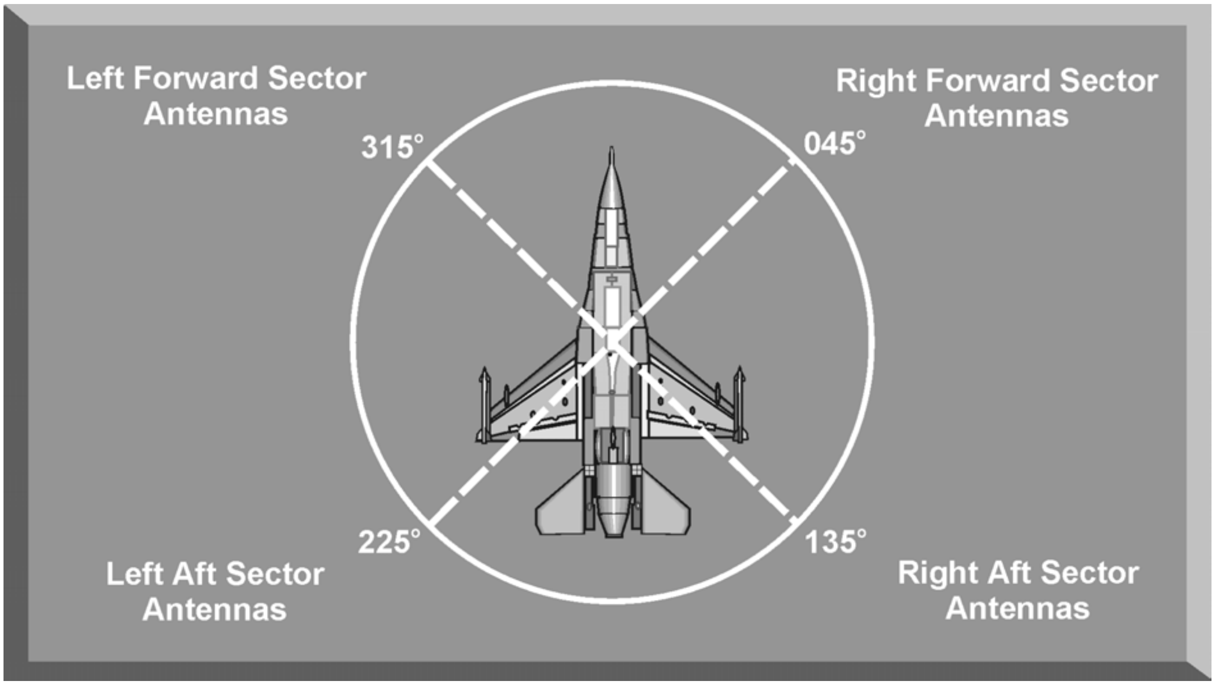
Left Forward Sector Antennas
Right Forward Sector Antennas
315°
045°
225°
135°
Left Aft Sector Antennas
Right Aft Sector Antennas

Figure 17-1. Radar Warning Receiver (RWR) Antennas

c. The sensitivity of an RWR antenna directly affects its ability to detect a radar signal. The more sensitive the antenna, the further it can detect a signal. The sensitivity of a system and its ability to intercept a radar signal is usually expressed in decibels relative to milliwatts or dBm units. A 10 dBm change in sensitivity can result in a 25 nm range difference in target detection. In general, sensitivity levels of -50 to -60 dBms are required to detect signals at long ranges (Figure 17-2).

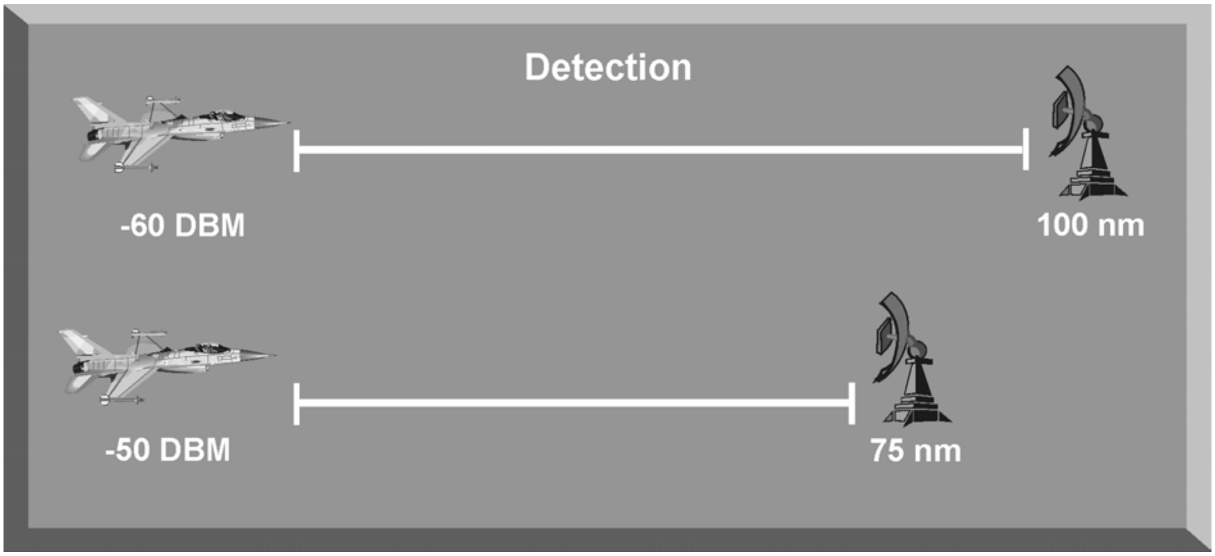
Detection
-60 DBM
100 nm
-50 DBM
75 nm

Figure 17-2. RWR Antenna Sensitivity

d. Another factor affecting antenna detection range is the polarization of the antennas. If the polarization of the RWR antenna and the threat system antenna are mismatched, or cross-polarized, initial detection of a threat signal could be delayed until the aircraft is within the lethal range of a threat system. In this situation, the aircraft could be engaged with minimal warning (Figure 17-3).

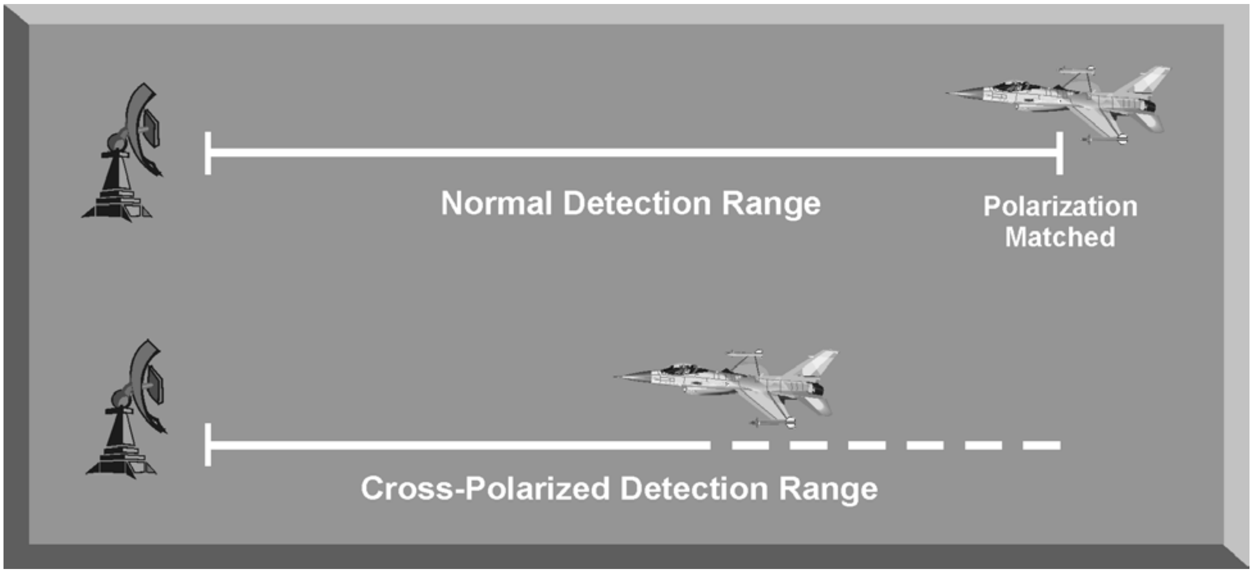

Figure 17-3. RWR Antenna Polarization

3. RWR RECEIVER/AMPLIFIERS

The RWR receiver/amplifier section processes the radar signals from the antennas. Most RWR systems use frequency bands to differentiate signals. Nominal band designations are summarized in Table 17-1. There are two types of receivers currently used in RWR systems: the crystal video receiver and the superheterodyne receiver.

Table 17-1. RWR Frequency Band Designators

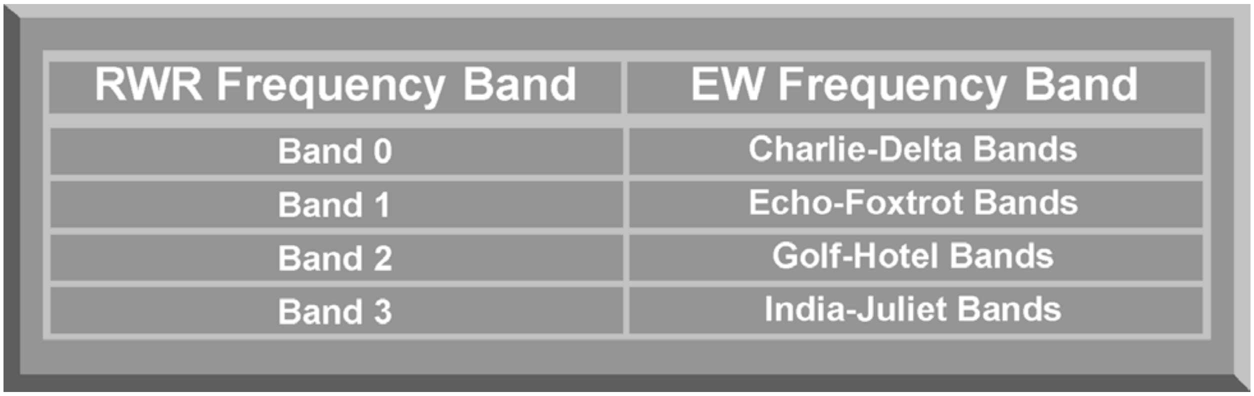

RWR Frequency Band	EW Frequency Band
Band 0	Charlie-Delta Bands
Band 1	Echo-Foxtrot Bands
Band 2	Golf-Hotel Bands
Band 3	India-Juliet Bands

a. A crystal video receiver (CVR) is the simplest type of microwave receiver. It is used primarily for detection of pulse radar signals in the 2 to 18 GHz band. A CVR used in a radar warning receiver incorporates crystal detectors for each designated frequency band. A pulse radar signal is detected by the antenna and passed to the multiplexer. The multiplexer divides the received radar signals by frequency band and sends the signals to the appropriate band channel. The RF amplifier boosts the radar signal and passes it to the crystal detector (Figure 17-4).

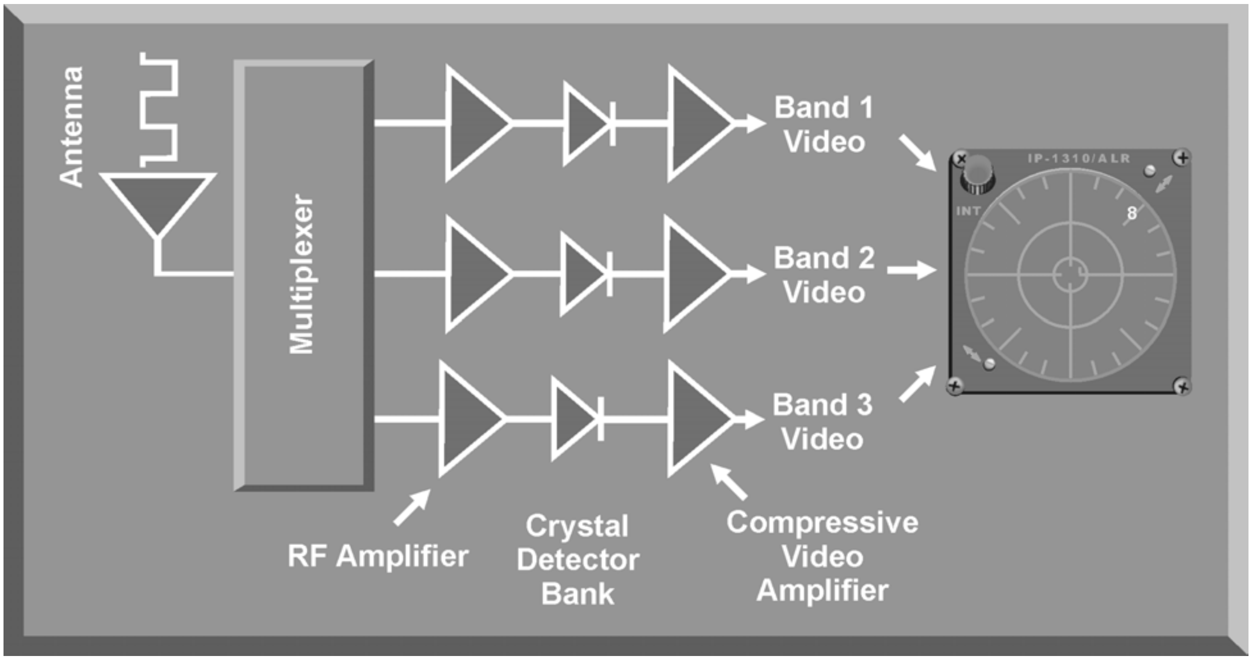

Figure 17-4. Crystal Video RWR Receiver

(1) The crystal detector is an RF diode, which converts the RF signal into a video signal. The voltage level of the output video signal is dependent only on the amplitude of the input signal and not on the frequency or phase. The sensitivity of a CVR is limited by the sensitivity of these crystal detectors. The sensitivity of crystal detectors currently available is generally adequate to detect main beam radiation from most threat radars. The video output of the crystal detectors is amplified by a high-grain compressive video amplifier and sent to the RWR scope for display.

(2) A CVR is extremely fast, sensitive, and covers a wide frequency range. These characteristics coupled with low cost and small size make CVRs ideal for use in radar warning receivers. The primary disadvantage of a CVR is that it is indiscriminate in reception and can be saturated in a dense signal environment. Multiple signals in the same band can cause amplitude distortion which can mask key threat signals.

b. A superheterodyne RWR receiver uses a pre-selector filter, mixer, and a local oscillator to translate the received signal to a lower intermediate frequency (IF). This lower IF allows the receiver to amplify and filter the received signal to provide greater sensitivity and frequency selectivity than a CVR (Figure 17-5).

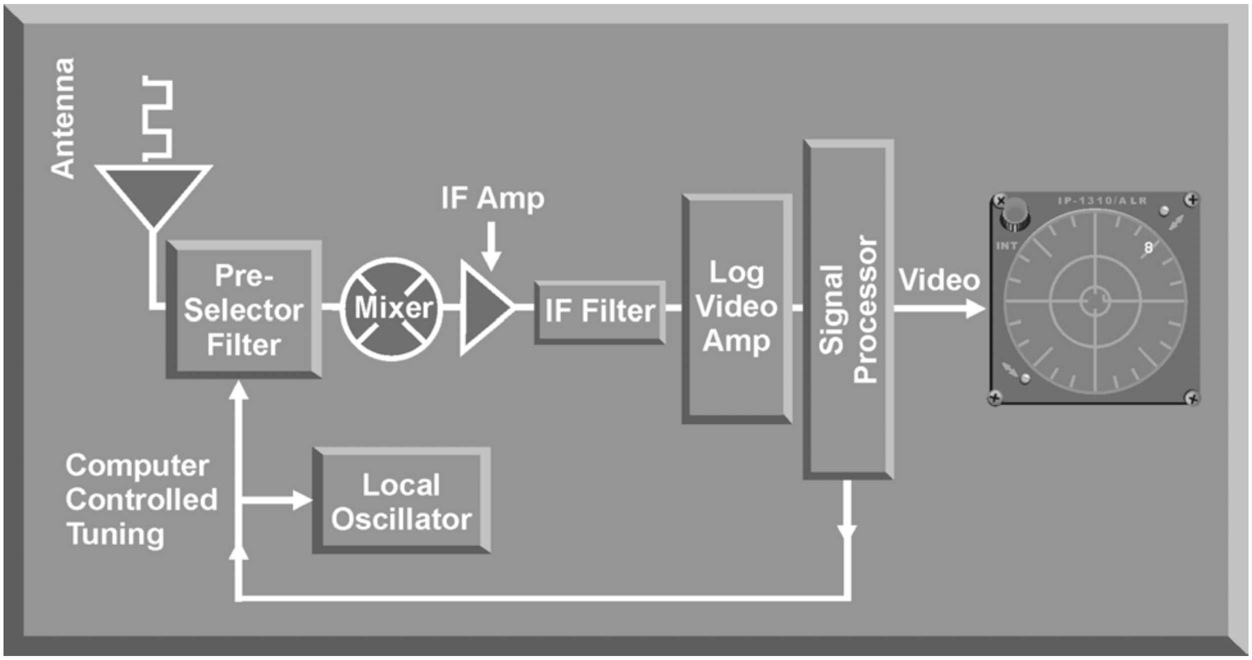

Figure 17-5. Superheterodyne RWR Receiver

(1) Superheterodyne RWR receivers use special scanning techniques controlled by the signal processor to tune the pre-selector filter and the local oscillator to rapidly scan selected threat system frequency bands. If the receiver detects activity in any of these bands, the scan stops to allow the processor to analyze the detected signals. The signal is combined with the local oscillator signal to lower the frequency to the IF. This signal is amplified, filtered, and amplified again before it reaches the signal processor. The signal processor classifies the threat and displays the proper threat symbol to the pilot. This entire process is accomplished in a matter of microseconds.

(2) The scanning superheterodyne receiver has important features that make it effective for RWR system application. It has excellent sensitivity and selectivity. It also has good frequency resolution. These features give the superheterodyne receiver a very low false alarm rate. The major disadvantage of the scanning superheterodyne receiver is its limited capability to receive signals from threat systems employing scanning antenna patterns. This limitation can be overcome with specific computer-controlled tuning to look for these threat signals.

4. SIGNAL PROCESSOR

The signal processor is the heart of the radar warning receiver. The signal processor is also known as the digital processor or analysis processor in different RWR systems. Its primary functions are to process numerous complex radar signals and identify, among the thousands of similar signals, those generated by lethal threat systems. The signal processor accomplishes this task continuously over the duration of the mission and displays the identified threat system to the aircrew almost instantly.

a. Signal processing begins when RF energy strikes the receive antennas on the aircraft. The received signals are then boosted in strength by intermediate amplifiers or antenna receivers. These amplified signals are then sent to the signal processor, or digital processor, where they are assigned a track file for reference to other signal characteristics. Data in these files is compared to those in the emitter identification (EID) table to process the signal for identification. Once identification is complete, a video and, if necessary, an audio signal, is sent to the cockpit display. The audio and video signals alert the aircrew to the electronic environment around the aircraft. This whole process takes less than a microsecond (Figure 17-6).

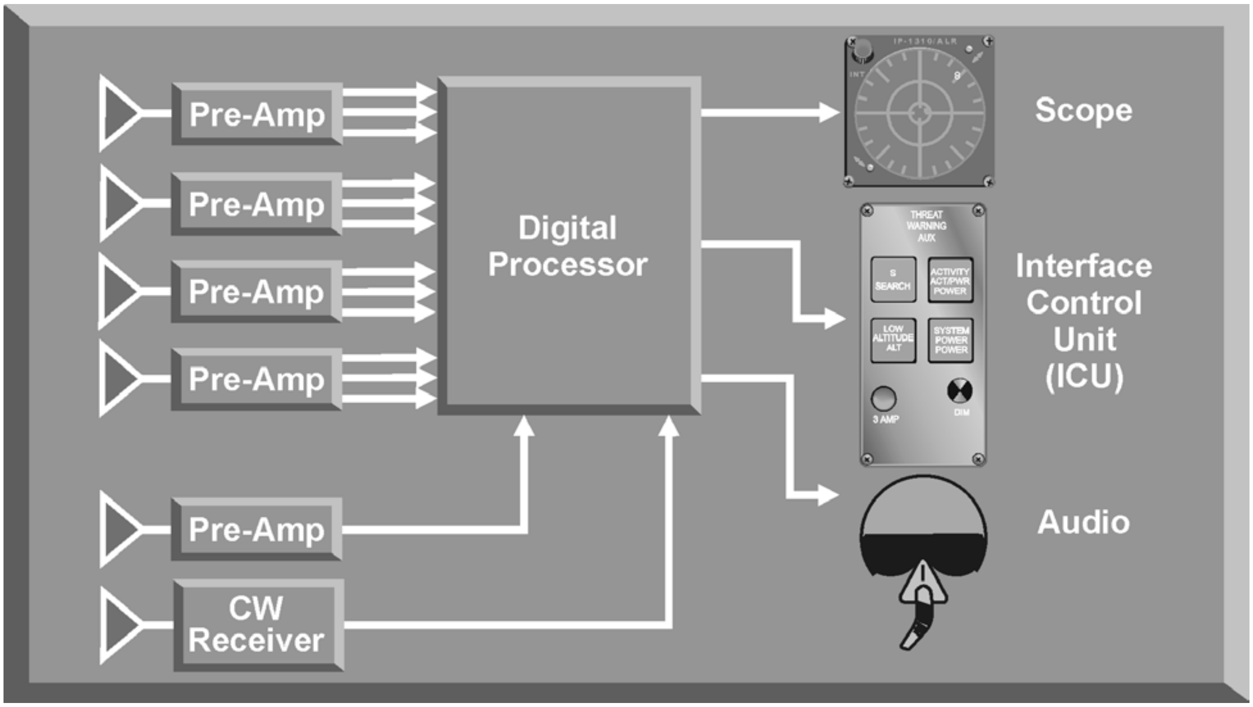

Figure 17-6. RWR System

b. Since many signals may be present, the amplifier detectors boost the signal strength, and also tag each signal by certain characteristics such as its time of arrival, direction of arrival, and/or frequency. These signals, along with their respective tags, are sent to the signal processor for further processing and

identification. The signal processor then makes a track file for each signal it receives from the amplifier detector.

c. The signal processor classifies each received signal and corresponding track file by its unique radar signal characteristics. Identifying characteristics used by a signal processor can include radio frequency, pulse width, pulse repetition frequency, EP techniques, and more. Characteristics of one signal may be identical to characteristics from different signals, while certain other characteristics can be as unique as a human fingerprint. The signal processor uses these primary characteristics to identify specific signals. When the primary characteristics of two or more signals are similar, the signal processor uses additional signal characteristics to resolve any confusion between two or more signals.

d. The signal processor ranks the track files based on priorities determined from tests it conducts on the signal characteristics and the threat priorities contained in the EID tables. It then quickly processes signals belonging to lethal threats before it processes signals belonging to non-lethal threats. For example, three signals enter the processor together and separate track files are established for each signal (Figure 17-7). A test on the first characteristic discriminant, frequency, will delay the further processing of Signal 3, since no lethal threat systems operate at a frequency less than 2000 megahertz. A further test on the remaining prioritized signals may eliminate Signal 2 as a threat system signal, leaving more processor time for the identification of the threat system which generated Signal 1. These tests do not stop the processor from attempting to identify all received signals. The signal processor merely delays the identifying sequence until all high priority signals have been processed.

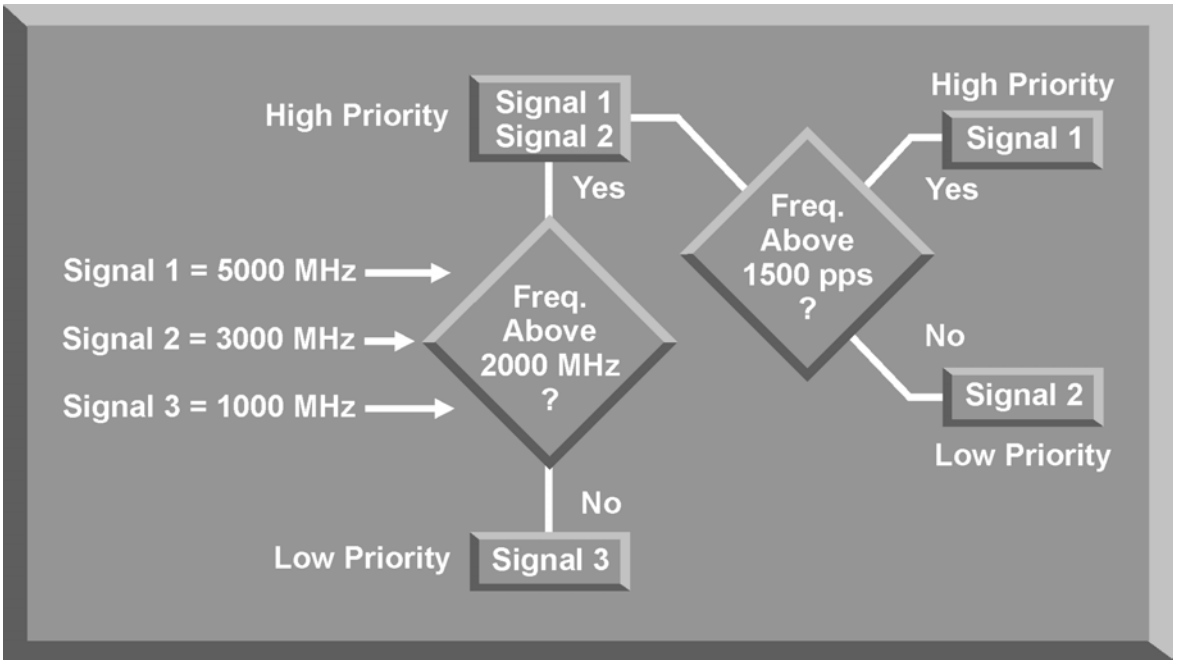

Figure 17-7. Signal Processor Signal Priority

5. EMITTER IDENTIFICATION (EID) TABLES

The signal characteristics in each track file are filled with processed data, and are constantly updated based on the time of arrival and location of the received signals. In addition, the track files are constantly compared to the EID table installed in the signal processor's computer memory. The EID table is a predefined table of radar characteristics associated with known radar systems (Figure 17-8). It is created from information gathered from electronic warfare support (ES) assets and intelligence sources. This table can be changed and updated as necessary to reflect the most current radar characteristics available for the anticipated threats in the planned theater of conflict. Each RWR system has unique procedures to reprogram the signal processor and update the EID tables. Emergency reprogramming actions, such as would be taken if a new threat appears that is not part of the current EID, are called a Pacer Ware.

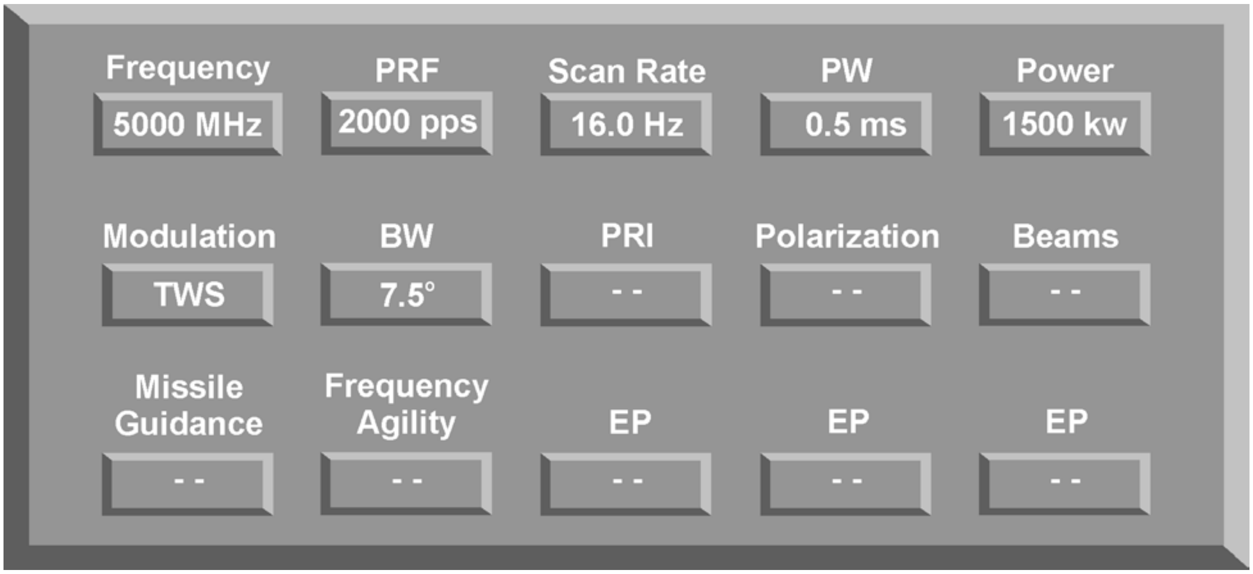

Frequency	PRF	Scan Rate	PW	Power
5000 MHz	2000 pps	16.0 Hz	0.5 ms	1500 kw
Modulation	BW	PRI	Polarization	Beams
TWS	7.5°	- -	- -	- -
Missile Guidance	Frequency Agility	EP	EP	EP
- -	- -	- -	- -	- -

Figure 17-8. Sample EID Table

6. RWR SCOPE DISPLAY

The signal processor continually compares signal characteristics in the track files with the data in the EID tables. Once the signal processor has determined that enough of the signal characteristics match the information in the EID tables, it generates and positions a video symbol on the RWR scope. The video symbol represents a specific threat, and each threat system has its own unique symbol. In addition, an audio tone is generated to alert the pilot. The signal processor also generates symbols and audio associated with specific threat system actions, including search, track, and missile launch. The position of the threat symbol on the RWR scope always represents the relative position of the threat in relation to the aircraft which is the center of the RWR scope. The signal processor compares the received signal strength in the different antennas to determine the proper location of the threat symbol. Figure 17-9 depicts a situation where the two

forward antennas receive equal signal strength therefore the signal processor places the symbol at the 12 o'clock position.

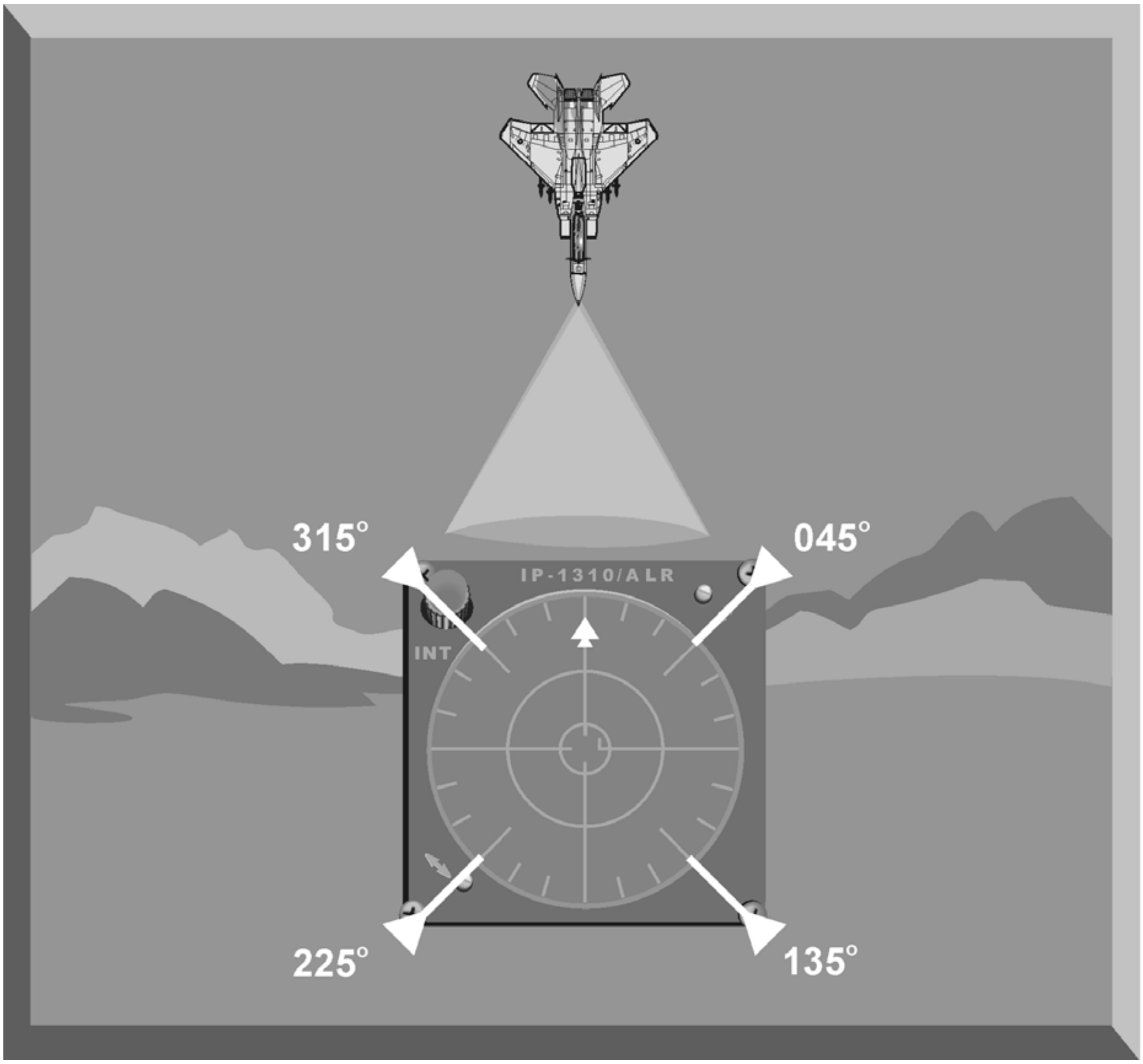

Figure 17-9. RWR Scope Azimuth Positioning

7. RWR AUDIO

In addition to generating threat symbols for each identified threat, the signal processor also generates threat audio. Threat audio first alerts the aircrew to the detection of a threat system. This RWR audio is generally referred to as "new guy" alert audio. The signal processor can also present constant audio from a selected threat. The aircrew controls this function through the interface control unit. The constant audio provided by an RWR system can be either "real" or synthetic. "Real" audio is normally based on the actual pulse repetition frequency (PRF) of the threat system radar whether the signal processor has identified it or not. Synthetic audio is based on the classification of the threat (SAM, AI, etc.) as

determined by the signal processor. The signal processor also generates a launch warning audio when the signal characteristics of the threat indicate a missile launch condition exists.

8. RWR INTERFACE CONTROL UNIT (ICU)

Every RWR system has some type of an ICU which provides the aircrew interface with the signal processor (Figure 17-10). The buttons on the ICU control specific functions of the signal processor. The ICU allows the aircrew to optimize the RWR system based on mission tactics. This optimization includes selecting appropriate priority lists based on ingress and egress tactics, controlling threat audio presentation, and determining the number and types of threats displayed. In addition, the ICU provides an additional visual indication of missile launch. All system test functions are controlled by the ICU to allow the aircrew to monitor the status of the RWR system.

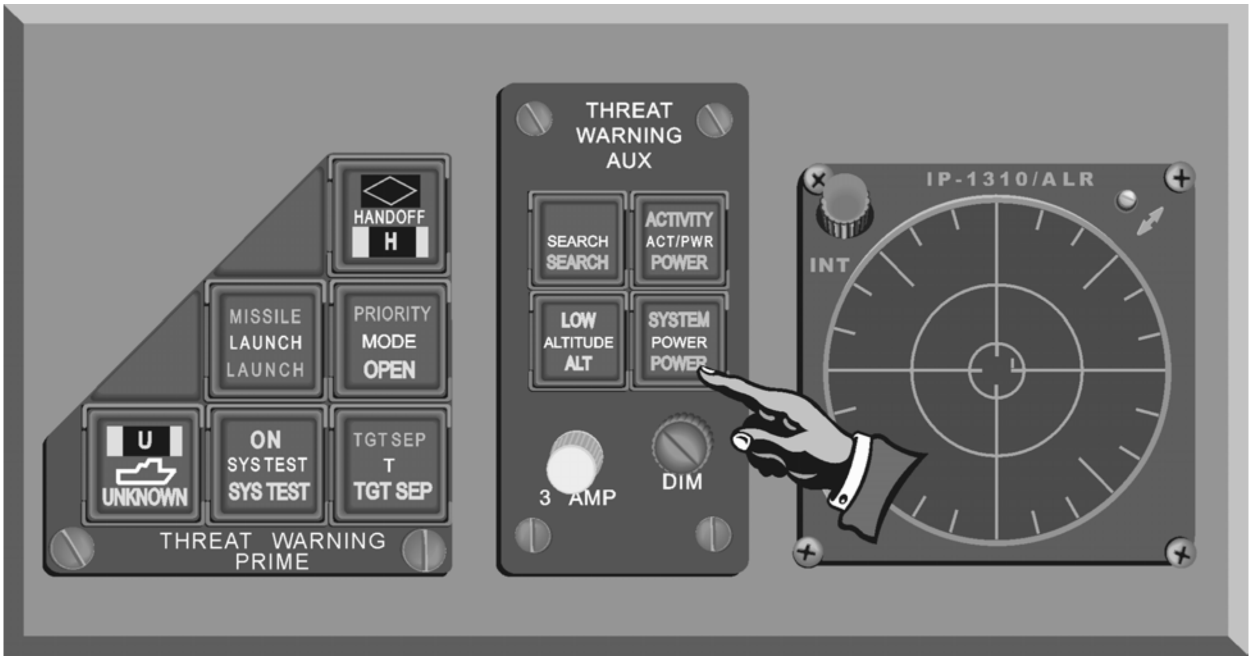
HANDOFF
H
MISSILE
LAUNCH
LAUNCH
PRIORITY
MODE
OPEN
U
UNKNOWN
ON
SYS TEST
SYS TEST
TGT SEP
T
TGT SEP
THREAT WARNING
PRIME
THREAT
WARNING
AUX
SEARCH
SEARCH
ACTIVITY
ACT/PWR
POWER
LOW
ALTITUDE
ALT
SYSTEM
POWER
POWER
3 AMP
DIM
IP-1310/ALR
INT

Figure 17-10. RWR Interface Control Unit

9. RWR LIMITATIONS

There are several limitations associated with all RWR systems. The most important limitations include ambiguities, impact of maneuvering, and electromagnetic interference (EMI).

a. The sheer number and diversity of radar systems associated with an enemy IADS greatly compound the problem of threat identification and warning for RWRs. Adding to this problem is the fact that many different threat systems use operating modes that are parametrically similar. When an RWR processes a

radar signal that has the same characteristics of a signal from a different system, an ambiguity may occur. An RWR ambiguity is defined as the display of more than one symbol for a specific threat signal. RWR ambiguities may occur from both enemy and friendly radar systems.

(1) Figure 17-11 depicts a number of friendly and threat signals that operate between 8000 and 10,000 megahertz. On any given combat mission, it is quite possible that the RWR will receive signals from one or more of these threat systems at the same time. If frequency is the only signal characteristic available for processing, the RWR will not be able to determine which system the signal represents. Since threat systems operating in this frequency range are potentially lethal systems, the signal processor will attempt to match the frequency with a threat system from the EID table.

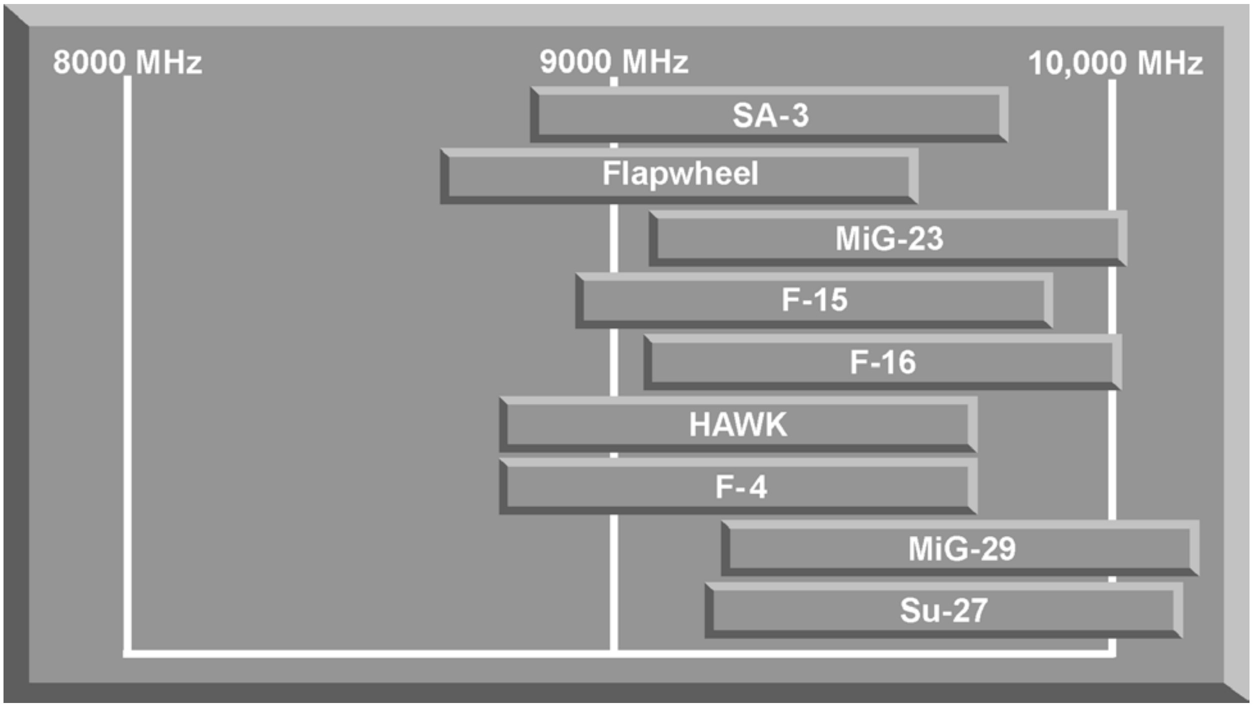

Figure 17-11. Signal Frequency Spectrum

(2) Matching partially processed signals to threat systems in the EID table may result in the wrong threat symbol being displayed, or numerous symbols being displayed on top of each other, making it difficult for the pilot to distinguish the exact threat. Incorrect threat symbology, or numerous combined symbols, are called RWR ambiguities.

b. RWRs are designed to provide accurate threat positioning information when the aircraft is flying straight and level. Most RWRs will also provide accurate threat positioning information when the aircraft is maneuvering up to certain limits of bank angle and turn rate. If aircraft maneuvering exceeds these

limits, RWR threat positioning data becomes unreliable. The two RWR limitations associated with aggressive maneuvering are inaccurate threat azimuth and multiple threat symbols.

(1) In Figure 17-12, the right forward and right aft RWR antennas detect a threat signal from a TTR. The left forward and left aft antennas are shielded by the aircraft and do not detect the signal. The signal processor determines the threat position, using the azimuth positioning algorithm, and displays the threat symbol at the 2 o'clock position.

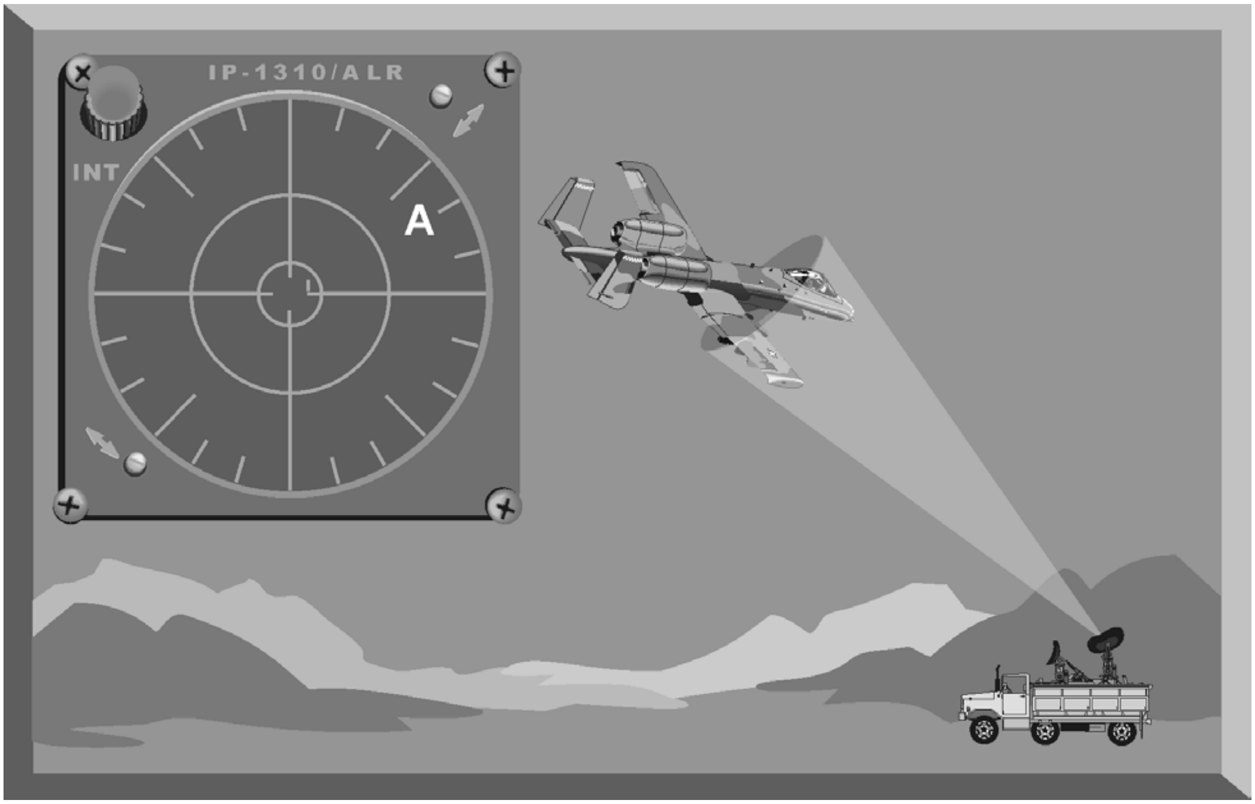

Figure 17-12. RWR Threat Azimuth Position Determination

(2) When the pilot maneuvers aggressively to put the threat symbol on the beam, he exceeds the RWR maneuvering limitations (Figure 17-13). Now all four RWR antennas detect the TTR signal. The signal strength in the right and left forward antennas is nearly equal. Based on this information, the signal processor displays the RWR symbol at the one o'clock position while the threat is actually at the three o'clock position.

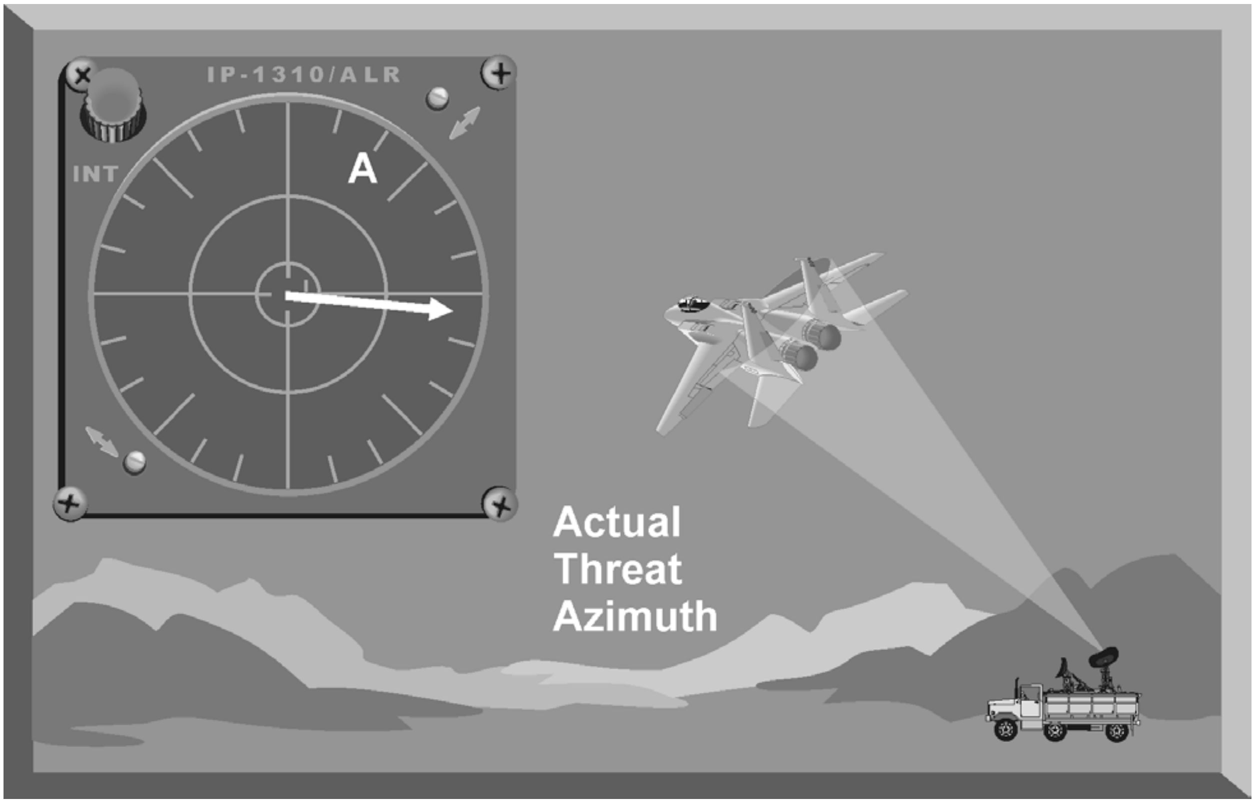

Figure 17-13. RWR Azimuth Error

(3) During aggressive maneuvering, the RWR signal processor may generate multiple symbols for a single threat emitter. In Figure 17-14, as the aircraft maneuvers, the relative azimuth of the threat position changes rapidly causing signal strength detected by each antenna to also change rapidly. The signal processor interprets these changing signals as new and different threat systems with the same signal characteristics. The number of "false" threat symbols displayed for a single threat is determined by the processing speed of the signal processor and a parameter called the symbol "age-out" time. Symbol age-out is the time, normally in seconds, that the RWR will continue to display a threat symbol after the signal processor has determined that the threat is no longer transmitting. The symbol age-out time is set for each threat in the EID tables.

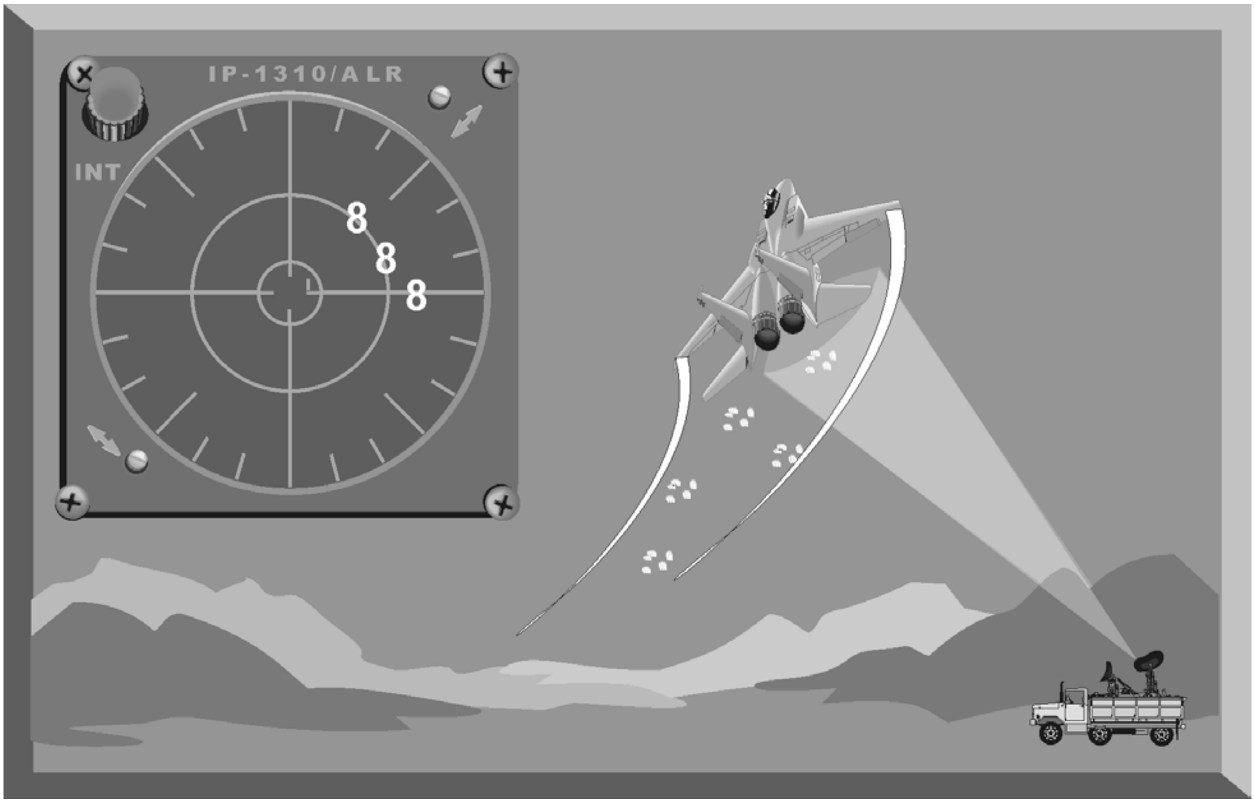

Figure 17-14. RWR Multiple Threat Symbols

c. Electromagnetic interference (EMI) is defined as any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronic systems. EMI can be induced intentionally, by way of jamming, or unintentionally as a result of spurious emissions and modulations. Certain RWR characteristics make them susceptible to EMI. Modern RWR systems are designed to receive and process signals in a wide frequency range, nominally 0.5 to 18 GHz, where most threats operate. This broad frequency coverage combined with the sensitive antennas make RWR systems susceptible to EMI. The primary source of EMI that impacts RWR operation is noise and deception jamming designed to counter enemy threat systems.

(1) High power noise jamming, such as that provided by a stand-off jamming aircraft, causes the RWR to raise the receiver threshold in the frequency band of the jamming. This effectively reduces the sensitivity of the RWR receiver and could delay the display of threat signals in that band. The reduction in sensitivity depends on the power that the jammer is transmitting, the beamwidth of the jamming beam, and the distance from the jammer to the aircraft. High power jamming may also generate multiple threat symbols on the RWR scope at the approximate azimuth to the jammer's position relative to the aircraft. Additionally, jamming from a wingman's self-protection system can generate multiple threat symbols and reduced sensitivity.

(2) A limitation of all RWR systems, related to EMI, is the problem of inaccurately identifying threat radar systems as friendly radar systems. This occurs when the parameters of a friendly radar are similar to the parameters of a threat radar system. The RWR will either display a threat radar symbol or an ambiguity associated with a threat radar. These RWR misidentifications are especially prevalent for AI radar systems.

(3) The impact of EMI on the operation of an RWR system depends on the signal environment. The pilot has little control over the number and diversity of friendly and enemy signals the RWR system must process. EMI is an unfortunate consequence of the reliance of modern military forces on operations in the electromagnetic spectrum. Aircrews should be keenly aware that EMI will impact RWR operation and be must be familiar with common RWR displays of EMI.

10. THREAT GEOLOCATION TECHNIQUES

The purpose of threat geolocation is to put a defined position, normally coordinates, on a threat radar. This information can be used to simply warn other aircraft about the threat or, if the coordinates are accurate enough, to allow for targeting and attack of the threat. Until recently, threat geolocation could only be performed by strategic assets and specialized tactical aircraft, specifically the F-4G Wild Weasel. Due to inherent time delays, data provided through strategic channels often did not apply to mobile threat systems. The mobile systems would relocate making the data obsolete. This section will discuss three techniques used to geolocate, also known as direction finding (DF), emitting radars that can be used by tactical assets to rapidly locate radar threat systems. The three are triangulation, interferometry, and time of arrival. All three techniques are heavily dependent upon the receiving aircraft's ability to accurately determine its present position, and the advent of GPS receivers has made this significantly easier.

a. Triangulation is the most basic form of DF available. It involves taking direction measurements from more than one source. The intersection of the azimuth measurements, called “lines of bearing”, is the likely location of the emitter (Figure 17-15). To be effective, the participating aircraft must have accurate data of their current positions when getting the lines of bearing.

(1) Triangulation can be carried out by multiple aircraft equipped with receiver equipment or by one aircraft over a period of time. The advantage of having multiple aircraft providing azimuth measurements is the increased angle-off and the speed of interception. In triangulation the best azimuth cuts are those that approach 90° angles. The speed of interception comes into play because threat emitters, knowing that DF operations are underway, attempt to transmit for as little time as possible. The disadvantage of multiple platforms is the communication required to ensure that all the platforms are measuring the same radar. In a dense radar environment this can be a difficult task.

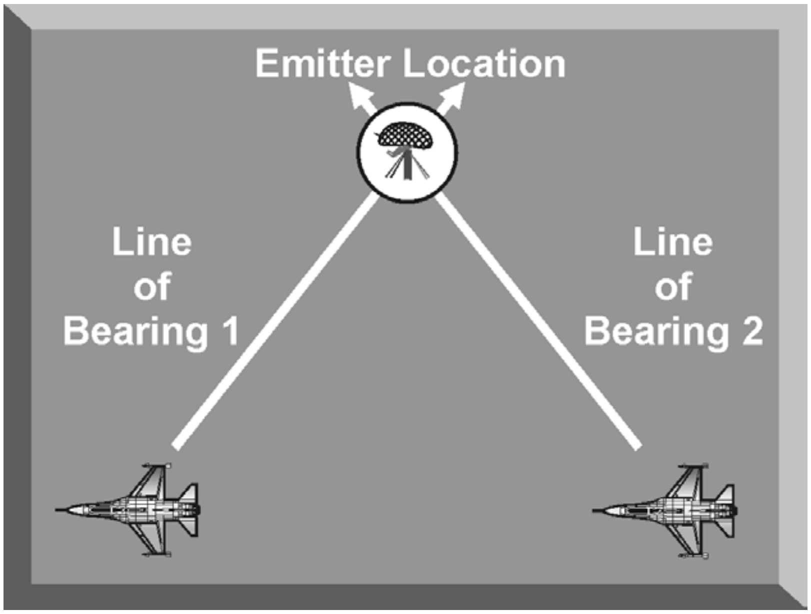

Figure 17-15. Triangulation

(2) Single aircraft triangulation eliminates the problem of signal coordination with other aircraft, but it also requires that the aircraft transit some distance to get multiple azimuth measurements. The accuracy of single ship DF operations is a function of the quality of the receiver equipment, distance away from the targeted radar, speed of the aircraft, and the amount of time that the targeted radar radiates.

b. The second technique is called interferometry. This technique is also known as phase interferometry, or phase difference of arrival. These systems operate by comparing the phase of a radar wave as it impacts two or more DF antennas; this phase difference is then used to compute an angle of arrival (AOA). For aircraft, the desire is to have these DF antennas on different parts of the same aircraft. Multiple AOA measurements are then used to provide the range and position of the threat.

(1) The key elements in an interferometer system are two antennas in fixed locations with matched receivers, a phase comparator, and a processor (Figure 17-16). An intermediate frequency output from each receiver is passed to a phase comparator, which measures the relative phase of the two signals. This relative phase position is passed to a processor, which calculates the AOA relative to the orientation of the two antennas (called the baseline). In most systems, the processor also accepts information about the orientation of the baseline (relative to true North or local horizontal) to determine the true azimuth or elevation angle to the emitter.

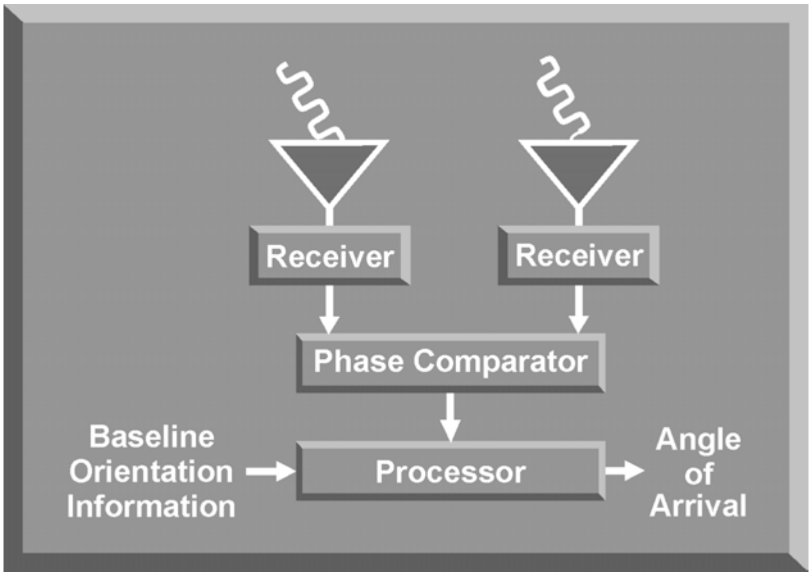
Receiver
Receiver
Phase Comparator
Baseline Orientation Information
Processor
Angle of Arrival

Figure 17-16. Interferometer Components

(2) To obtain rapid emitter locations some interferometer systems use multiple receive antennas in an array setup. This allows for simultaneous azimuth and elevation measurements to rapidly locate the emitter. An array allows for the mixing of long and short baselines in different patterns by selecting different pairs of antennas (Figure 17-17). The terms long baseline and short baseline are often used to designate the distance between the antenna elements in an interferometer system. Long baselines have the advantage of providing a quick and accurate location of the emitter, but they can suffer from ambiguities resulting from different wavefronts hitting the different antenna elements. In addition to the array depicted in Figure 17-17, a long baseline system could be created by using the existing RWR antennas on an aircraft, and supplementing these with a small short baseline system to compensate for the ambiguities.

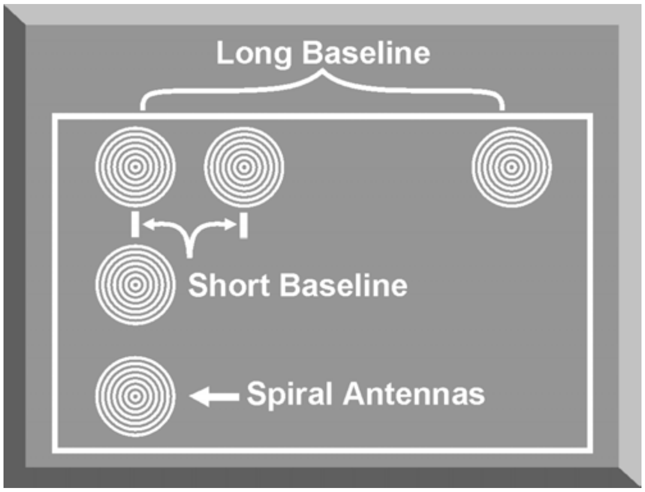
Long Baseline
Short Baseline
Spiral Antennas

Figure 17-17. Interferometer Array

c. Time of arrival (TOA) and time difference of arrival (TDOA) techniques are the final type of location techniques to be covered in this section. Both techniques are based around the fact that radar signals travel at approximately the speed of light. Both techniques, using the speed of light as a constant, solve for the distance that the emitter is away from the receiver using the equation distance equals rate multiplied by time. Because there is not any directional information, the equation represents the radius of a circle around the receiving antenna; multiple distance measurements taken from multiple receivers are then overlayed. The intersection of the circles is the position of the emitter. If only two receivers are used, a simple DF technique can solve the ambiguity of which intersection represents the emitter (Figure 17-18).

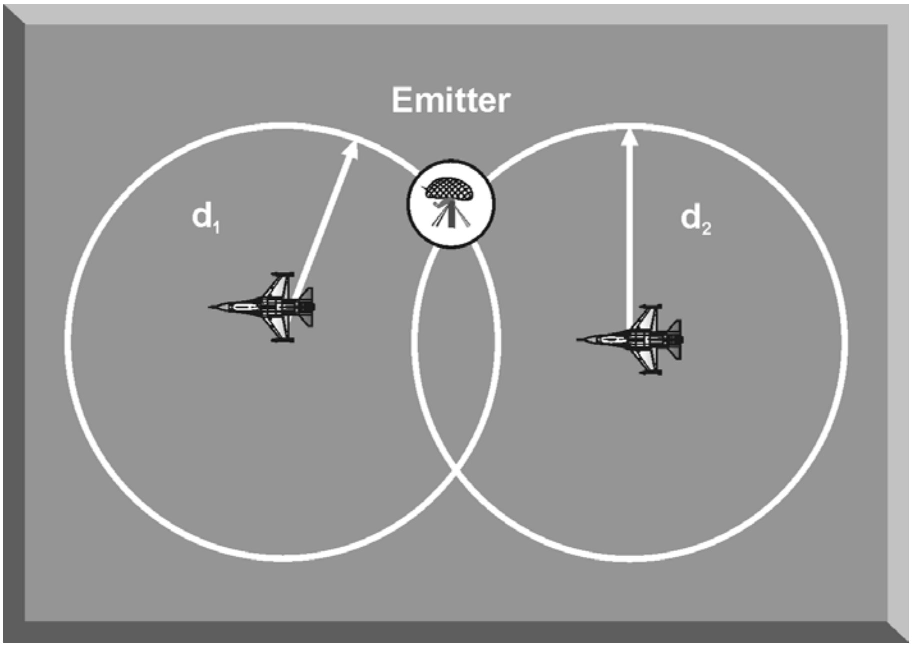

Figure 17-18. Time of Arrival Measurements

(1) TOA positioning is calculated by taking the time that a signal leaves a radar, measuring its arrival time at the receiver and mathematically solving for distance using the techniques described above. One of the primary challenges involved with TOA positioning is determining when the measured signal was transmitted, this requires either a very cooperative enemy or a radar signal with some type of exploitable time reference. Another challenge involves insuring that multiple receivers are timing the same signal. This is especially difficult in a threat intensive environment.

(2) TDOA is used when it is not possible to determine when a signal was transmitted. TDOA uses most of the same principles as TOA except that it must compensate for not knowing the time the signal was transmitted. It does this by using an extra receiver a known distance from the first receiver to generate a distance curve. The arrival of the signal is precisely measured at the two

receivers, the theory is that a signal that arrives at the two receivers at times t1 and t2 had to originate from a point on a curve defined by that difference in arrival time. For example, if the signal arrives at the two points at exactly the same time, then the transmitter must be equal distance from the two receivers. In this case the curve is actually a line of possible locations equal distance from the receivers and can easily be drawn. For situations where the signal arrives at different times at the receivers, a hyperbolic curve instead of a straight line denotes all the possible locations of the transmitter. Figure 17-19 shows an example of when the signal arrives at a different time, the constant value is the time difference multiplied by the speed of light yielding a distance. To solve for the emitter's location using TDOA another antenna receiver is required that is not in line with the first two receivers to generate an independent curve that will cross the first curve at the transmitter location.

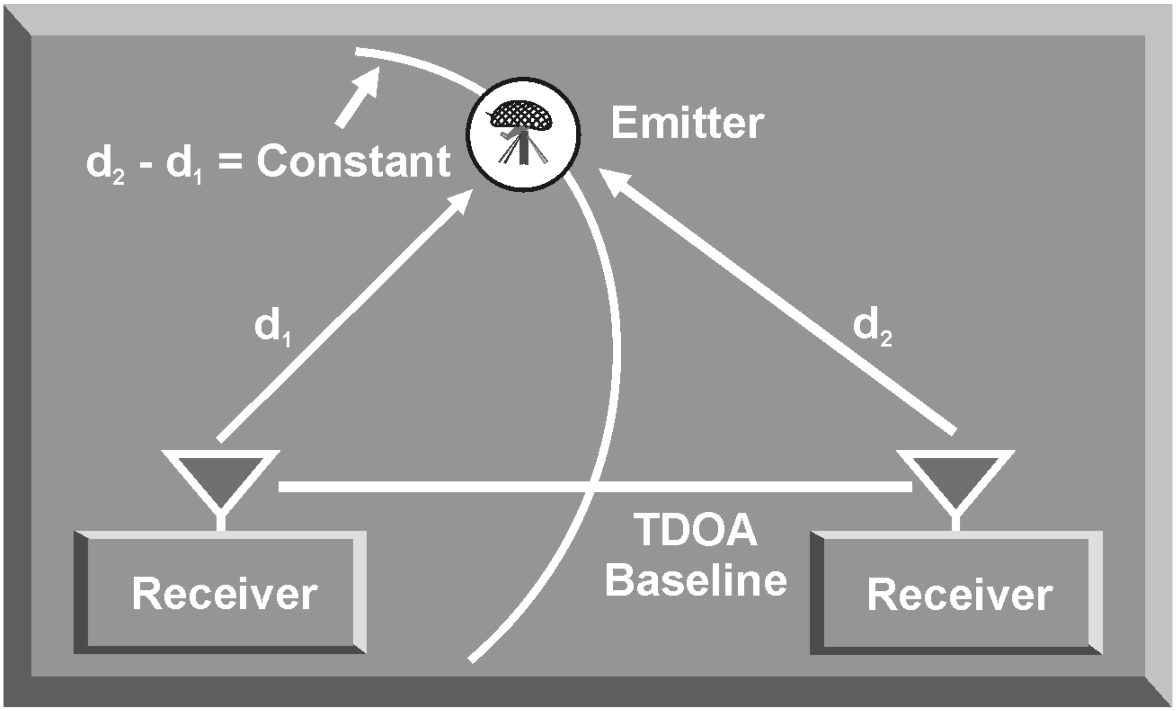

Figure 17-19. Time Difference of Arrival Measurements

(3) Timing techniques require very good timing accuracy in the receiving systems. If the receivers are far apart, such as different aircraft, then a separate time measurement is required at the source before sending to a processor. As with triangulation, one of the major challenges of multiple aircraft measurements is the coordination to ensure that the same signal is being looked at by all aircraft involved.

(4) Timing techniques are affected by the type of radar that they are trying to locate. Pure CW radars are not practical for a timing technique because there

is not a pulse to time. Pulsed signals, on the other hand, are much more susceptible to this type of location technique.

11. SUMMARY

An RWR system is designed to provide a picture of the electronic order of battle (EOB) operating in the vicinity of an aircraft. The signal processor is the heart of the RWR system and controls the function of all other system components. The signal processor, using inputs from the antennas and the receiver/amplifiers, compares the signal parameters with the parameters in the EID tables. The identified signals are displayed on the RWR scope with the appropriate audio. The ICU provides the aircrew interface with the signal processor to allow the aircrew to customize RWR operation for each combat mission. Modern RWR systems have some limitations that can effect aircrew survival. These limitations include ambiguous threat displays, maneuvering limitations, and EMI. Despite these limitations, an operational RWR system is one of the keys to survival on today's electronic battlefield. A product of advances on the electronic battlefield is rapid threat geolocation. New threat geolocation techniques are designed to provide advanced threat information to allow pilots to avoid, suppress, or destroy the mobile threat. The three most common techniques are basic triangulation using lines of bearing, interferometry using phase difference of arrival, and time difference of arrival using time differences to determine distance curves.

CHAPTER 18. SELF-PROTECTION JAMMING SYSTEM OPERATIONS

1. INTRODUCTION

Self-protection jamming systems are designed to counter surface-to-air missile (SAM), airborne interceptor (AI), and antiaircraft artillery (AAA) acquisition and target tracking radars. Self-protection jamming systems generate noise and deception jamming techniques to either deny threat system automatic tracking capability or generate sufficient tracking errors to prevent a successful engagement.

a. To counter the diverse array of threats and their associated frequencies in an integrated air defense system (IADS), a self-protection jamming system must be able to simultaneously jam multiple signals operating in a wide frequency range. The system must also be able to generate sufficient power to mask the radar return of the aircraft. Since many modern self-protection jamming systems are carried internally or externally on aircraft, their size, shape, and weight must be carefully controlled to minimize adverse effects on aircraft performance and handling. These design requirements may require a trade-off between additional power or capability and aircraft compatibility.

b. A self-protection jamming system must have receive antennas to receive radar signals, a system processor to identify received signals, a jamming techniques generator to produce an optimum jamming technique for the identified threat, and transmit antennas to transmit the required jamming techniques. These system components will be discussed in this chapter.

c. There are numerous internal and externally mounted self-protection jamming systems in use today. To simplify the discussion, the ALQ-184 pod will be used as an example of a modern, self-protection jamming system (Figure 18-1). The functions and operations of the ALQ-184 components are representative of currently deployed self-protection systems.

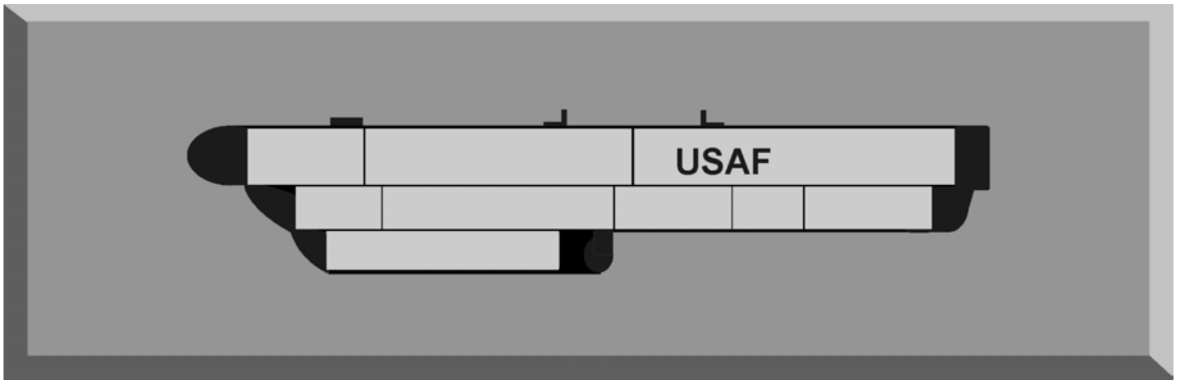

Figure 18-1. ALQ-184 Pod

2. RECEIVE ANTENNAS

The ALQ-184 pod has two sets of receive antenna assemblies located on the front and rear of the lower pod "gondola" (Figure 18-2). Each receive antenna assembly set consists of a low-band antenna and a mid/high-band antenna. The low-band antenna's signals are combined to form the input for the low-band receiver. The mid/high-band antennas provide signals to the separate mid/high-band portion of the pod.

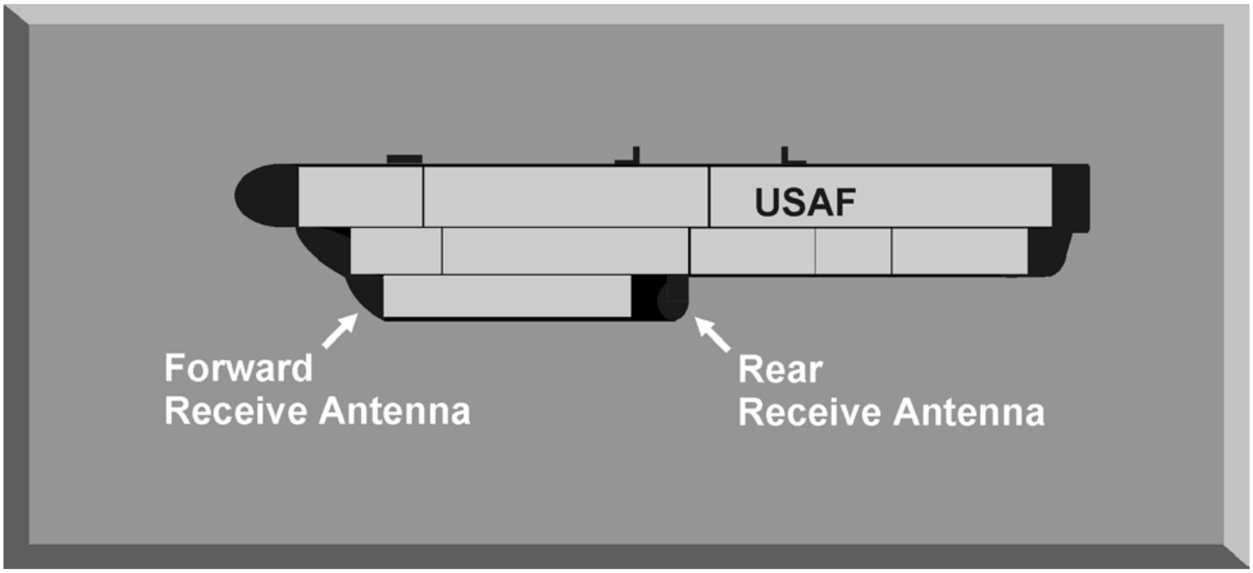

Figure 18-2. ALQ-184 Receive Antenna Location

a. The low-band receive antennas are circularly polarized spiral arrays. The mid/high-band receive antenna covers eight sub-bands via an eight element array that corresponds to the eight element transmit array. The mid/high-band antenna is also circularly polarized.

b. Each signal received via the receive antenna generates a corresponding transmit signal through a crystal video receiver. The angle of arrival (AOA) of each signal is determined by comparing the output of the crystal video receiver for each antenna.

3. RECEIVER SECTION

The forward and aft receive antennas detect radar signals and send them to the receiver section. The receiver section contains an AOA receiver and a multiplexer that separates frequencies. The AOA receiver determines the AOA of a signal based on the output signal level of each antenna element. The AOA data is passed to the system processor to control the angle of transmission of the jamming signal. The multiplexer separates all received threat signals into eight frequency sub-bands consisting of five mid-band and three high-band frequency

ranges. The multiplexer categorizes the received radar signals by sub-band and azimuth and then sends them to the system processor and the exciter.

4. SYSTEM PROCESSOR

The system processor is the "brain" of the ALQ-184 pod. It receives the threat signals from the receiver section that have already been categorized by sub-band and distinguished by AOA. Each received signal and its corresponding AOA is counted. When the signal count exceeds a pre-set threshold, the system processor validates the signal and identifies it using the emitter identification (EID) tables. Based on this threat identification, the system processor directs the techniques generator to initiate a jamming program through the exciter. At the same time, the system processor, through a signal switch control, directs the transmitter section to use either the forward or aft transmit antenna array, and specifies the transmit angle for the jamming program based on AOA.

a. The system processor also controls the low-band portion of the pod (Figure 18-3). The forward or aft low-band antenna receives and combines the threat signal and sends it to the multiplexer. The multiplexer channelizes this signal into one of two low sub-bands. The signal then passes to the modulator where the voltage controlled oscillators (VCOs) generate a jamming technique as directed by the system processor techniques generator. This ensures the jamming technique is at the proper frequency and modulation to provide maximum effect against the threat system. The generated jamming signal passes to a second multiplexer and then to a solid state amplifier for amplification. The amplified jamming signal is then sent to the two low-band traveling wave tubes (TWTs) and transmitted from the forward and aft low-band transmit antennas.

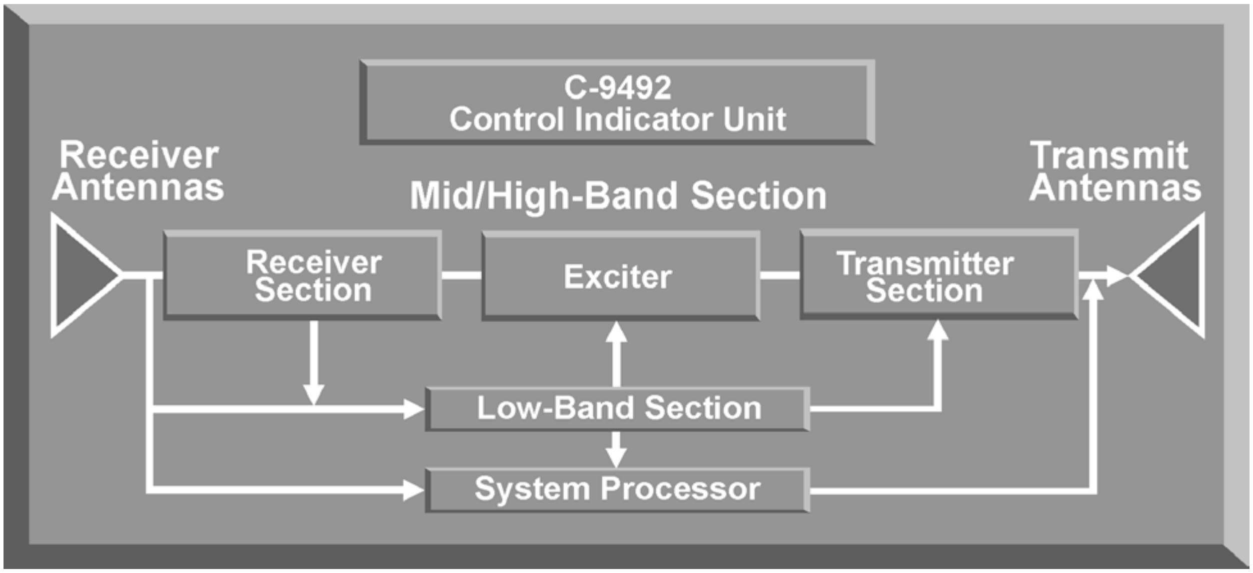

Figure 18-3. ALQ-184 Simplified Block Diagram

b. The system processor periodically performs a background built-in-test (B-BIT), to check the status and calibration of the ALQ-184. The system processor software is updated or reprogrammed as required from a memory loader verifier (MLV). The system processor uses two major software programs. The operational flight program (OFP) manages the receiver and transmitter functions, signal processing, and techniques generation. The mission data generator (MDG) contains the threat EID tables and the jamming techniques matrix for these threats.

5. JAMMING TECHNIQUES GENERATOR

The exciter section contains the VCOs and the keyed oscillators, which generate the jamming waveforms that are directed by the system processor. The exciter takes the threat signal from the receiver and modifies it with deception modulation or generates a noise program based on the techniques generator in the system processor. The selected jamming technique is then sent to the transmitter section.

6. TRANSMIT ANTENNAS

The transmitter section contains antenna switching circuits, a signal forming network, and TWTs. The antenna switching circuits are controlled by the system processor to ensure the transmitted jamming pulse is radiated at the proper azimuth. The signal-forming network controls the phase of each jamming signal. There are sixteen TWTs in the transmitter section, one for each front and aft antenna. The TWTs amplify the jamming signal for transmission from the appropriate transmit antenna.

a. The ALQ-184 has two sets of transmit antenna assemblies. One set is located on the front and one on the rear of the main pod assembly (Figure 18-4).

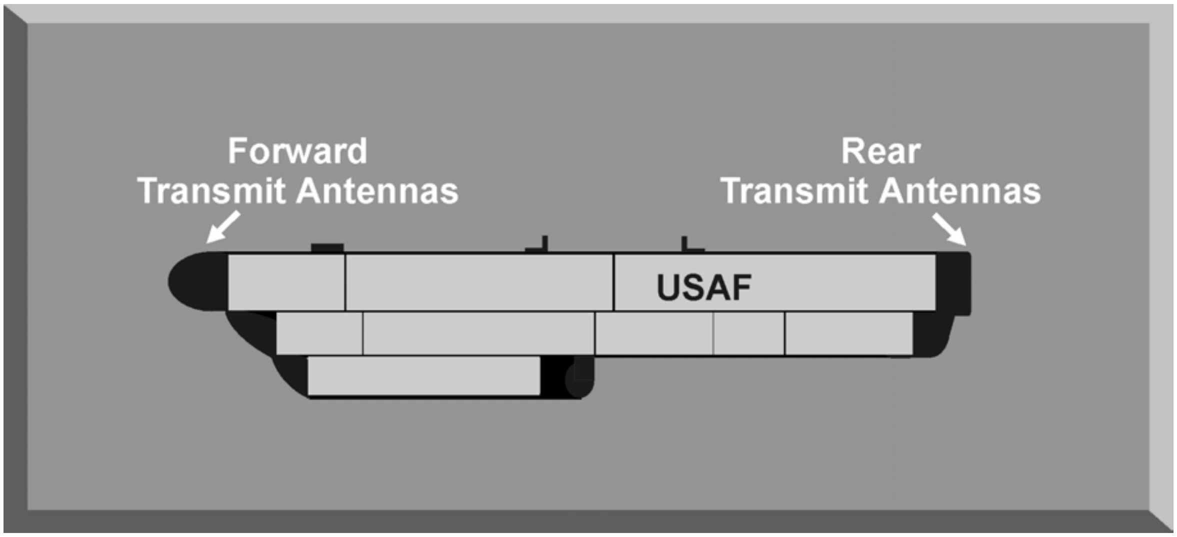

Figure 18-4. ALQ-184 Transmit Antenna Location

Each set has a low-band and mid/high-band antenna. The transmit antennas have opposite polarization from the receive antennas. This enables the pod to transmit and receive at the same time while preventing pod “ringing.” Ringing occurs when the pod receives its own jamming signal and generates a jamming program to counter its own signal. This condition can highlight the aircraft to enemy radar and seriously degrade pod effectiveness.

b. The low-band transmit horn antennas are circularly polarized. The mid/high-band transmit antennas have the same eight-element array as the receive antennas. The transmit antennas generate a directional jamming signal for pulsed radar signals based on the AOA determined by the receive antennas. Detailed information on the antenna jamming pattern is contained in the ALQ-184 ECM Handbook.

7. C-9492 CONTROL INDICATOR UNIT

The C-9492 Control Indicator Unit (CIU) provides control of all functions of the ALQ-184. It allows the aircrew to control system power, select jamming techniques, and monitor system status (Figure 18-5).

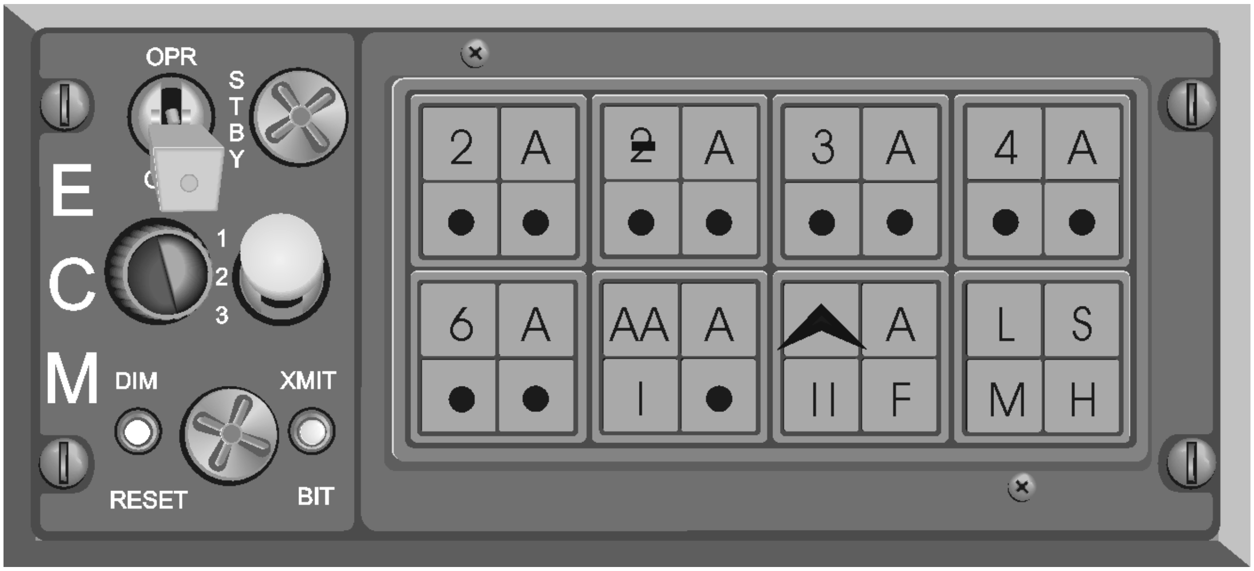

Figure 18-5. C-9492 Control Indicator Unit

8. JAMMING POD CONSIDERATIONS

Unfortunately, jamming pods do not make the aircraft completely invisible from enemy threat systems. When used in conjunction with the RWR, expendables, and threat countertactics they do drastically increase the probability of surviving a threat engagement. This section contains some items of consideration to ensure that your self-protection jamming is being properly utilized. These considerations include highlighting, burnthrough, and reprogramming.

a. If used improperly a self-protection pod can actually highlight the aircraft. This happens when a pod transmits a jamming program constantly or when another type of radar, not targeted for jamming but in the same frequency range, sees the jamming. Highlighting is normally associated with noise programs that transmit constantly. Most pods today avoid this by transmitting only when a threat requires it. Additionally, some aircraft have pod inhibit switches that allow the pod to remain in a standby condition until the pilot switches the pod to operate. What makes this system effective is that the switch is either on the stick or throttle allowing the pilot to rapidly go to operate without looking inside the cockpit (Figure 18-6).

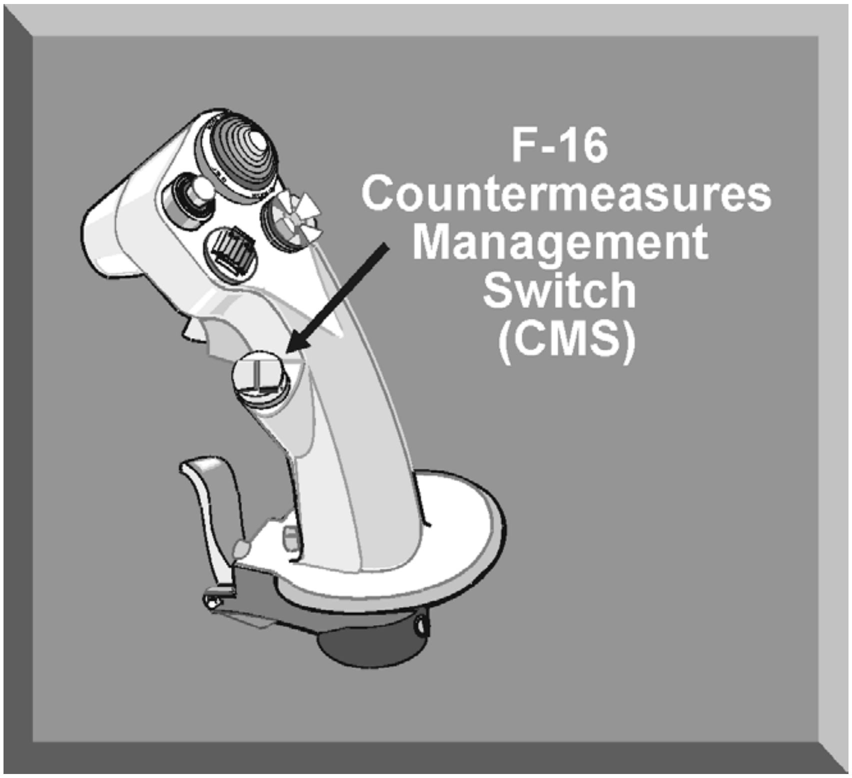

Figure 18-6. F-16 ECM CMS

b. Burnthrough is described as the range that the aircraft's radar return is stronger than its jamming signal. Basically, the jet has gotten so close to the threat radar that the threat radar is overpowering the jamming pod. The range that this occurs varies for different radars, but it should be planned for particularly when there are threats in the target area. Burnthrough is also a consideration for support jamming systems; there is a range at which the support jammer's signal will be overpowered and the protected aircraft can be seen.

c. Many self-protection jamming systems are what is called software-reprogrammable. This means that jamming programs can be rapidly changed to adjust for changes in enemy radar systems. These updates can be made to

systems while they are still on the jet, and can take as little as 15 minutes using an MLV. The process of changing electronic warfare systems is known as a Pacer Ware change. An exercise to check the ability to make changes is known as a Serene Byte exercise. The pilot of the aircraft carrying the self-protection system has one responsibility in this process: to ensure that his jamming system is carrying the most current software program, usually referred to as a software version. While Pacer Ware changes are not common during peacetime operations, they do happen quickly during combat operations often to fine tune the jamming systems for the particular theater of combat.

9. SUMMARY

The effective employment of self-protection jamming is one of the factors that can mean the difference between success and failure on the modern battlefield. When employed in concert with chaff and maneuvers, self-protection jamming can be extremely effective in negating potentially lethal attacks. Despite their limitations, self-protection jamming systems are an important part of the "bag of tricks" aircrews can employ to put bombs on target.

ANNEX A
GLOSSARY

Absorption - Dissipation of energy of electromagnetic waves, sound, and light waves into other forms of energy because of interaction with matter. Absorption characteristics of specific materials are used as blankets, coatings, or structural and surface materials for aircraft to reduce effective radar cross-sections.

Acoustic jamming - The deliberate radiation of mechanical or electro-acoustic signals with the objectives of obliterating or obscuring signals which the enemy is attempting to receive, and of deterring enemy weapon systems.

Acquire –

1. When applied to acquisition radars: the process of detecting the presence and location of a target in sufficient detail to permit identification.

2. When applied to tracking radars: the process of positioning a radar beam so that a target is in that beam to permit the effective employment of weapons.

Acquisition radar - A radar set that detects an approaching target and feeds approximate position data to a fire control or missile guidance radar that then takes over the function of tracking the target.

Active array radar - A phased array radar in which each radiating element contains a transmitter and receiver front end, as opposed to a single transmitter/receiver serving all phased array elements. Advantages attributed to active array radars include efficient use of prime power, no waveguide losses, very wide bandwidth, and extreme reliability due to the lack of single point of failure.

Active homing guidance - A system of homing guidance in which both the source for illuminating the target, and the receiver for detecting the energy reflected from the target as the result of illumination, are carried within the missile.

Aerosols - Solid particles dispersed in the atmosphere that have resonant size particles with a high index of refraction. The particles both scatter and absorb visual and laser-directed energy so as to lessen the effect of weapon systems directed by these techniques.

Airborne early warning and control - Air surveillance and control provided by airborne early warning vehicles that are equipped with search and height finding radar and communications equipment for controlling weapons.

Airborne interceptor (AI) - A manned aircraft used for identification and/or engagement of airborne objects. (An AI may or may not be equipped with radar to assist in the interception.)

Airborne Warning and Control System (AWACS) - An aircraft suitably equipped to provide control, surveillance, and communications capability for strategic defense and/or tactical air operations.

Air defense - All defensive measures designed to destroy attacking enemy aircraft or missiles in the earth's envelope of atmosphere, or to nullify or reduce the effectiveness of such attack.

Air surveillance radar (ASR) - A radar displaying range and azimuth that is normally employed in a terminal area as an aid to approach and departure control.

Air-to-air missile (AAM) - A missile launched from an airborne carrier at a target above the surface.

Air-to-surface missile (ASM) - A missile launched from an airborne carrier to impact on a surface target.

Alternating current (AC) - An electric current that reverses its direction at regularly recurring intervals, the frequency being determined by the frequency of the alternator supplying the current.

AM-CW jamming - Jamming in which a carrier wave is modulated at a constant recurring rate. The recurrence rate of amplitude modulation is variable, and reflects a noticeable change in the radar scope. Because of the spiraling or chaining effect produced, AM-CW jamming is easily identified.

Amplifier - An electronic circuit usually used to obtain amplification of voltage, current, or power.

Amplitude shift keying - A method of impressing a digital signal upon a carrier signal by causing the carrier amplitude to take different values corresponding to the different values of the digital signal.

Amplitude modulation (AM) - A method of impressing a message upon a carrier signal by causing the carrier amplitude to vary proportionally to the message waveform.

Angle jamming - A deception jamming technique used to deny azimuth and elevation information to a TTR by transmitting a jamming pulse similar to the radar pulse, but with modulation information out of phase with the returning target azimuth modulation information.

Angle tracking - Accomplished through the use of pulses to determine angular definition of a target.

Antenna - A device used for transmitting or receiving RF energy. The function of the antenna during transmission is to concentrate the radar energy from the transmitter into a shaped beam that points in the desired direction. During reception, or listening time, the function of the antenna is to collect the returning radar energy, contained in the echo signals, and deliver these signals to the receiver. Radar antennas are characterized by directive beams that are usually scanned in a recognizable pattern. The primary radar antenna types in use today fall into three categories: parabolic, Cassegrain, and phased array antennas.

Antenna cross talk - A measure of undesired power transfer through space from one antenna to another. Ratio of power received by one antenna to power transmitted by the other usually expressed in decibels.

Antenna gain - See Gain

Antenna polarization - See Polarization

Antenna sidelobes - See Sidelobes

Antiaircraft artillery (AAA) - Guns used to shoot unguided projectiles at airborne aircraft. Usually used in the air defense system.

Anti-clutter circuits (in radar) - Circuits that attenuate undesired reflections to permit detection of targets otherwise obscured by such reflections.

Antiradiation missile (ARM) - A missile that homes passively on a radiation source.

Area defense - The concept of locating defense units to intercept enemy attacks, remote from, and without reference to, individual vital installations, industrial complexes, or population centers.

Asynchronous pulsed jamming - An effective form of pulsed jamming where the jammer nearly matches the PRF of the radar then transmits multiples of the PRF. It is more effective if the jammer pulse width is greater than that of the radar. Asynchronous pulsed jamming is similar to synchronous jamming except that the target lines tend to curve inward or outward and appear fuzzy in the jammed sector of the radar scope.

Attenuation - The decrease in amplitude of a signal during its transmission from one point to another. Attenuation increases as distance increases. The higher the frequency of the propagating signal, the higher the rate of attenuation.

Automatic frequency control (AFC) - Circuits in a receiver that automatically correct the local oscillator frequency to prevent receiver drift in tuned frequency.

Automatic gain control (AGC) –

1. A feature involving special circuitry designed to maintain the output of a radio, radar, or television receiver essentially constant, or to prevent its exceeding certain limits, despite variations in the strength of the incoming signal. In a radio receiver, in particular, though something of a misnomer, also known as automatic volume control.

2. A self-acting compensating device that maintains the output of a transmission system constant with narrow limits, even in the face of wide variations in the attenuation of the system.

3. A radar circuit that prevents saturation of the radar receiver by long blocks of receiver signals, or by a carrier modulated at low frequency.

Automatic search jamming - An intercept receiver and jamming transmitting system that automatically searches for and jams enemy signals of specific radiation characteristics.

Automatic tracking - Tracking in which a system employs some mechanism, e.g., servo or computer, to automatically follow some characteristics of the signal.

Azimuth resolution - The ability of a radar to distinguish two targets in close azimuth proximity and distance.

Backlobe - The portion of the radiation pattern of an antenna that is oriented 180° in relation to the main beam. The antenna backlobe is a result of diffraction effects of the reflector and direct leakage through the reflector surface.

Backward wave oscillator (BWO) - A special traveling wave tube in which oscillatory currents are produced by using an oscillatory electromagnetic field to bunch the electrons as they flow from cathode to anode.

Ballistic missile - Any missile that does not rely upon aerodynamic surfaces to produce lift and consequently follows a ballistic trajectory when thrust is terminated.

Bandpass filter - A filter that allows a select range of frequencies to pass while attenuating all frequencies outside the range.

Bandwidth - The range of frequencies within which performance, with respect to some characteristics, falls with specific limits (i.e., the width of frequency of a barrage noise package).

Barrage noise jamming - Noise jamming spread in frequency to deny the use of multiple radar frequencies to effectively deny range information. Although this is attractive because it enables one jammer to simultaneously jam several radars of different frequencies, it does have the inherent problem that the wider the jamming spread, the less jamming power available per radar.

Beam rider - A missile guided by an electronic beam.

Beam-to-beam correlation (BBC) - Used by frequency scan radars to reject pulse jamming and jamming at swept frequencies. Correlation is made from two adjacent beams (pulses). The receiver rejects those targets (signals) that do not occur at the same place in two adjacent beams.

Beamwidth - The width of a radar beam measured between lines of half-power points on the polar pattern of the antenna. This width is measured at the 3 dB points.

Beat frequency oscillator (BFO) - Any oscillator whose output is intended to be mixed with another signal to produce a sum or difference beat frequency. Used particularly in reception of CW transmissions.

Bistatic radar - A radar where the transmitting and receiving antennas are separated by a considerable distance. Bistatic operation provides several advantages for its user. The covert positioning of the receivers poses problems for a potential attacking force since ELINT techniques locate the transmitter not the receiver. The proper placement of jamming assets is difficult, since the receiving sites are unknown. In addition, if a stand-off jammer is directed at the transmitter, its effectiveness in the direction of the covert receiver is diminished.

Jammers not in the same beam as the wanted targets will be attenuated by the receiver's sidelobe protection and these targets will be more readily detected.

Blanking –

1. The cutting off of the electronic beam in a cathode-ray tube when the picture is not being formed. The beam is blanked while the spot is returning to the starting position (normally right to left).

2. Process of making a channel or device noneffective for a desired interval.

Blinking - A jamming technique employed by two aircraft separated by a short distance and within the same azimuth resolution to appear as one target to a tracking radar. The two aircraft alternately spot jam, causing the radar system to oscillate from one plane to another, making an accurate solution of fire control problem impossible. However, keep in mind that too high a blinking frequency can cause the tracker to average the data while too low a frequency will cause a missile to home-in on one of the jammers.

Broad pulse jamming - Transmission of broad pulses for control system jamming when little is known about the command pulse group. For example, a broad pulse might cover a whole group of command pulses, thus jamming that command.

Burnthrough range - The ability of a radar to see through jamming. Usually described as the point when the radar's target return is stronger than the jamming signal.

Burst chaff - The formation of a reflective volume of chaff from an individual bundle.

Buzzer - Code name for airborne jamming.

Capture - Where the jammer takes control over the guidance signal by active jamming.

Capture effect - The tendency of a receiver to suppress the weaker of two signals within its bandpass.

Capture of AGC - Domination of the radar's automatic gain control (AGC) level by a strong transmitted jamming signal.

Carrier frequency - Frequency of an unmodulated radio wave emanated from a radio, radar, or other type of transmitter.

Carrier wave - Electromagnetic radiation used to "carry" information from one point to another.

Centroid homing - When applied to antiradiation missiles, the effect on a missile that has two or more radiation sources in its field of view causing it to home on the centroid of the power from the radiating sources.

Chaff - Ribbon-like pieces of metallic materials or metalized plastic that are dispensed by aircraft to mask or screen other aircraft or to cause a tracking radar to break lock. The foil materials are generally cut into small pieces for which the size is dependent upon the radar interrogation frequency (approximately 1/2 wavelength of the victim radar frequency). Being 1/2 wavelength long, chaff acts as a resonant dipole and reflects much of the energy back to the radar.

Chaff corridor - Operational technique of dropping large quantities of chaff for a continuous period of time. This results in a "ribbon" or "stream" of returns many miles long on radar scopes. The penetrating strike force can then use the resulting chaff corridor to mask its penetration.

Chirp - A pulse compression technique characterized by linear frequency modulation on pulse (LFMOP).

Chirp radar - Radar in which a swept-frequency signal is transmitted, received from a target, and then compressed in time to give a final narrow pulse called the chirp signal. It has high immunity to jamming and an inherent rejection of random noise signals.

Circularly polarized jamming - The techniques of radiating jamming energy in both planes of polarization. With this method, there is a 3-dB loss of effective power in either plane, but the enemy cannot cross-polarize his antenna to escape jamming.

Circular scan - The pattern generated by an antenna that is continuously rotating in one direction.

Clipped noise modulation - A clipping action is performed to increase the. bandwidth of the jamming signal. Results in more energy in the sidebands, correspondingly less energy in the carrier, and an increase in the ratio of average power to peak power.

Clutter - Unwanted signals, echoes, or images on the face of a scope that interferes with the observation of desired signals. Also called noise. This tends to mask the true target from detection or cause a tracking radar to break lock.

Clutter elimination - The clutter eliminator circuit discriminates against any target echo that exceeds three times the transmitted pulse width, and will not display it on the indicator. It is normally employed on the lower beams of a high frequency radar. This will allow targets above a preset signal strength to be presented, while the clutter (land) will be eliminated.

Clutter gating - A technique that provides switching between MTI and normal videos. It results in the normal video being displayed in regions with no clutter and the MTI video being switched in only for the clutter areas. Clutter gating is achieved automatically by the PW discrimination or the use of storage tubes. It also can be achieved by a manually operated range azimuth gate. The clutter gate vastly increases the effectiveness of noncoherent MTI against chaff.

Coherent MTI (in radar MTI) - A system in which the target echo is selected based on its Doppler frequency when compared to a local reference frequency maintained by a coherent oscillator.

Coherent noise jamming - Noise-like jamming signal that is repetitive and in synch with the PRI of the radar.

Coherent repeater jammer - A jammer that uses the phase information of the receiver radar signal in creating false targets thus transmitting a signal that is acceptable to the receiver processor of a victim coherent radar.

Command and control warfare (C2W) - The integrated use of operations security (OPSEC), military deception, psychological operations (PSYOP), electronic warfare (EW), and physical destruction, mutually supported by intelligence to deny information, influence, degrade, or destroy adversary C^2 capabilities while protecting friendly C^2 capabilities.

Command, control, communications, and computer systems (C4) - The process of, and means for, the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the commander's mission.

Command guidance - A guidance system in which intelligence transmitted to the missile from an offboard source causes the missile to traverse a directed flight path.

Communications intelligence (COMINT) - Intelligence derived from the interception of enemy communications signals.

Communications security (COMSEC) - The protection resulting from all measures designed to deny unauthorized persons information of value that might be derived from the possession and study of telecommunications, or to mislead unauthorized persons in their interpretation of the results of such possession and study. COMSEC includes: 1. Cryptosecurity; 2. transmission security; 3. emission security; and 4. physical security of communications security material and information.

1. **Cryptosecurity** - The component of communications security that results from the provision of technically sound cryptosystems and their proper use.

2. **Transmission security** - The component of communications security from which all measures designed to protect transmissions from interception and exploitation by means other than cryptoanalysis.

3. **Emission security** - The component of communications security that results from all measures taken to deny unauthorized persons information of value that might be derived from intercept and analysis of compromising emanations from crypto equipment and telecommunications systems.

4. **Physical security** - The component of communications security that results from all physical measures necessary to safeguard classified equipment, material, and documents from access thereto or observation thereof by being within a friendly power.

Complex pulse - A pulse train in which there is more than one pulse width and/or more than one pulse repetition interval.

Conformal antenna - An antenna which conforms to a surface whose shape is determined by considerations other than electromagnetic, for example, an antenna shaped to aerodynamically fit the side of an aircraft.

Conical scan (CONSCAN) - A type of scanning in which the axis of the RF beam is tilted away from the axis of the reflector and rotated about it, thus generating a cone.

Constant false alarm rate (CFAR) receiver - A radar receiver with automatic detection circuits designed to produce a constant number of erroneous target detections independent of noise level at the receiver input. CFAR techniques are intended to prevent receiver saturation and overload, to present clear video information to the display, and a constant noise level to an automatic detector. A device that accomplishes these objectives may respond to the signal-to-noise ratio, for example, rather than the absolute signal level above a fixed threshold. CFAR does not usually permit the detection of a target if the target is weaker than the jamming, but it does attempt to remove the confusing jamming effects.

Continuous wave (CW) - A constant, single-frequency, unmodulated carrier wave that is transmitted and then reflected. A good system for determining velocity.

Correlation detection (modulation systems) - Detection based on the averaged product of the received signal and locally generated function possessing some known characteristics of the transmitted wave. Note the following caveats:

1. The averaged product can be formed, for example, by multiplying and integrating, or by using a matched filter whose impulse response, when reversed in time, is the locally generated function.

2. Strictly, the above definition applies to detection based on cross-correlation. The term correlation detection may also apply to detection involving autocorrelation, in which case the locally generated function is merely a delayed form of the received signal.

Countdown - A technique for forcing the radar AGC to continuously change value and oscillate. The jammer rapidly changes the duty cycle of the deception pulses.

Countdown blink - Self-screening AGC deception using a gated repeater or noise source; the period of which is short compared to the victim's AGC time constant.

Cover pulse - A jammer covers the radar return with an AM pulse usually much wider than the radar pulse. Since tracking circuits are looking for largest return, they will transfer to the cover pulse, thereby denying range information.

Cross-eye - A jamming technique used to produce angular errors in monopulse and other passive lobing radars. Jammer is a two-source interferometer that causes the phase front of the signal reaching the radar to be highly distorted. With such a technique, it is difficult for the radar to determine the points from which the transmissions are originating. Requires a high jam-to-signal ratio or the skin echo will show up in the pattern nulls.

Cross-gated CFAR - A CFAR technique employed to achieve the fast switching required for an optimum combination of normal and MTI modes. Here, the MTI video signals are used to “gate” on the normal video when the MTI indicates a target in clutter. CFAR action is achieved by the wideband as in the zero-crossing and Dicke fix CFARs.

Cross polarization - or “Cross Pole,” is a monopulse jamming technique where a cross-polarized signal is transmitted to give erroneous angle data to the radar. The component of the jamming signal with the same polarization as the radar must be very small.

Cross polarization jamming - A technique whereby the received signal is retransmitted cross-polarized and at a much higher power than the skin return-effective against some monopulse radars by generating erroneous angle information.

CW jamming - The transmission of constant-amplitude, constant-frequency, unmodulated jamming signals to change the signal-to-noise ratio of a radar receiver.

Data link - A communications link which permits automatic transmission of information in digital form.

Deception - Those measures designed to mislead the enemy by manipulation, distortion, or falsification of evidence to induce him to react in a manner prejudicial to his interests. (See Electronic Deception, or Manipulative Deception.)

Deception jamming - Any means of jamming consisting of false signals that have similar characteristics to the victim radar thereby deceiving the operator into erroneous conclusions.

Decibel (dB) - A dimensionless unit for expressing the ratio of two values, the number of decibels being 10 times the logarithm to the base 10 of a power ratio, or 20 times the logarithm to the base 10 of a voltage of current ratio. A power increase by 3 dB indicates a doubling of the original power.

(dBm) - Same as dBw except the reference level is one milliwatt instead of one watt.

(dBw) - Unit used to describe the ratio of the power at any point in a transmission system to a referenced level of one watt. The ratio expresses decibels above and below the reference level of one watt.

Defense suppression - A term applied to weapons systems that are intended to eliminate or degrade enemy detection, acquisition, or tracking equipment.

Delayed opening chaff - Chaff that blooms at a specific elapsed time after it is dispensed.

Detector balanced bias - Controlling circuit used in radar systems for anti-clutter purposes.

Dicke fix - A technique specifically designed to protect the receiver from ringing caused by noise, fast-sweep, or narrow-pulse jamming. The basic configuration

consists of a broadband limiting IF amplifier, followed by an IF amplifier of optimum bandwidth. The limit level is preset at approximately the peak amplitude of receiver noise. The bandwidth may vary from 10 to 20 MHz, depending on the jamming environment. The device provides excellent discrimination against fast-sweep jamming (10 - 500 MHz), usually something about 20 to 40 dB, without appreciable loss in sensitivity. However, strong CW jamming will seriously degrade the performance of the Dicke fix because the CW signal captures the radar signal in the limiter.

Dicke fix CFAR - Constant False Alarm Rate.

Dicke fix MT CFAR - An MTI CFAR technique similar to Dicke fix CFAR. Limiting and narrowbanding follow wideband amplification, phase detection, and cancellation so as not to impair the MTI performance.

Digital radio frequency memory (DRFM) - A computer-controlled digital device used in radar jamming systems. DRFM provides an extremely fast and accurate storage capability for victim radar signal parameters. Jamming systems employing DRFM can rapidly and accurately generate coherent jamming based on the memorized victim radar signal.

DINA - See Direct Amplified Noise.

Diode - An electron device having two electrodes, a cathode, and an anode.

Diplex - Two transmitters operating alternately on approximately the same RF and using a common antenna. The normal procedure is to pulse each transmitter at ½ the desired PRF, 180° out-of-phase. The advantage is that higher peak power per transmitter is possible because each transmitter is operating at ½ the normal duty cycle.

Dipole antenna - A straight, center-fed, ½ wavelength antenna. Horizontally polarized, it produces a figure-eight radiation pattern with maximum radiation at right angles to the plane of the antenna.

Direction finding (DF) - A procedure for obtaining bearings of radio frequency emitters with the use of a highly directional antenna and a display unit on an intercept receiver or ancillary equipment.

Direct amplified noise (DINA) - DINA without a carrier frequency is used for increasing (saturating) the radar receiver's noise level. This is called video stealing. The biggest danger from this type of jamming is that the radar operator may not realize he is being jammed when automatic gain control (AGC) or automatic noise leveling (ANL) are employed. This is a barrage type of jamming

with a bandwidth normally more than 50 MHz. DINA appears as a bright, high intensity wedge when the manual gain is employed. Thus, all useful radar scope information is lost.

Doppler (effect) - Continuous wave (CW) Doppler radar modules are sensors that measure the shift in frequency created when an object moves. A transmitter emits energy at a specific frequency which, when reflected, can indicate both speed and direction of the target. When objects move closer to the Doppler source, they increase in shift (positive value), and when they move further away, they decrease in shift (negative value).

Doppler radar - A radar system that measures the velocity of a moving object by the apparent shift in carrier frequency of the returned signal as it approaches or recedes.

Downlink - The signal from a transponder beacon located on a surface-to-air missile (SAM) used to provide a traceable radar return for missile guidance.

Downlink jamming (DLJ) - Some command guidance missiles carry a beacon (downlink) which is used by the parent radar to track the missile. If this beacon reply can be hidden from the parent tracking radar, the missile guidance solution can be defeated. Hence, downlink (beacon) jamming is intended to screen the missile beacon signal from the parent radar's view.

Ducting - The bending of radar rays due to atmospheric conditions. Ducting can either extend radar coverage beyond normal line of sight or it can deny the radar picture above a duct. Ducting is also called Anomalous Propagation.

Dummy antenna - A device that has the necessary impedance characteristics of an antenna and the necessary power-handling capabilities, but does not radiate or receive radio waves. Note: In receiver practice, that portion of the impedance not included in the signal generator is often called a dummy antenna.

Dummy load (radio transmission) - A dissipative but essentially nonradiating substitute device having impedance characteristics simulating those of the substituted device. This allows power to be applied to the radar unit without radiating into free space.

Duplex - In radar, a condition of operation when two identical and interchangeable equipments are provided—one in an active state, and the other immediately available for operation.

Duplexer - A switching device used in radar to permit alternate use of the same antenna for both transmitting and receiving.

Duty cycle - The ratio of the time the transmitter is actually on versus the time it could be on in a given transmission cycle. Mathematically, it can be expressed as:

$$\text{Duty Cycle} = \frac{PD}{PRT} \quad \text{or} \quad \text{Duty Cycle} = PD \times PRF$$

Dynamic range –

1. The difference, in decibels, between the overload level and the minimum acceptable signal level in a system or transducer. Note: The minimum acceptable signal level of a system or transducer is ordinarily fixed by one or more of the following: noise level, low-level distortion, interference, or resolution level.

2. Ratio of the specified maximum signal level capability of a system or component to its noise or resolution level, usually expressed in decibels.

Early warning radar - A radar set or system used near the periphery of a defended area to provide early notification of hostile aircraft approaching the area.

EA pod - A jamming system that is designed to be carried externally on an aircraft.

Effective radiated power (ERP) - Input power to antenna time multiplied by the gain of the antenna, expressed in watts.

Electromagnetic interference (EMI) - Any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronic systems. EMI can be induced intentionally, by way of jamming, or unintentionally because of spurious emissions and modulations.

Electromagnetic pulse (EMP) - The generation and radiation in a transmission medium of a very narrow and very high-amplitude pulse of electromagnetic noise. The term is associated with the high-level pulse because of a nuclear detonation and with an intentionally generated narrow, high-amplitude pulse for EA applications. In nuclear detonations, the EMP signal consists of a continuous spectrum with most of its energy distributed throughout the low frequency band of 3 to 30 kHz.

Electromagnetic radiation - Radiation made up of oscillating electric and magnetic fields and propagated with the speed of light. Includes gamma radiation, x-rays, ultraviolet, visible and infrared radiation, plus radar and radio waves.

Electromagnetic spectrum - The total range of frequencies (or wavelengths) over which any form of electromagnetic radiation occurs.

Electromagnetic test environment (EMTE) - A range complex of radars, such as those located at Eglin AFB, FL, operating in different frequency bands and modes to provide a very flexible test facility for evaluating aircraft antenna patterns, reflectivity measurements, infrared, reconnaissance, airborne interceptors, and electronic warfare devices and techniques.

Electronic attack (EA) - The use of electromagnetic energy, directed energy, or antiradiation weapons to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability. Action taken to reduce the enemy's effective use of the electromagnetic spectrum. EA is a division of electronic warfare (EW).

Electronic combat (EC) - Action taken in support of military operations against the enemy's electromagnetic capabilities. EC is task-oriented and includes electronic warfare (EW), command and control warfare (C2W), and suppression of enemy air defenses (SEAD).

Electronic protection (EP) - Active and passive means taken to protect personnel, facilities, and equipment from any effects of friendly or enemy employment of electronic warfare that degrade, neutralize or destroy friendly combat capability. EP is a division of electronic warfare (EW).

Electromagnetic deception - The deliberate radiation, reradiation, alteration, absorption, or reflection of electromagnetic radiations in a manner intended to mislead an enemy in the interpretation of, or use of, information received by his electronic systems. There are two categories of electronic deception:

1. **Manipulative deception** - The alteration or simulation of friendly electromagnetic radiation to accomplish deception.

2. **Imitative deception** - The introduction of radiations into enemy channels that imitate his own emissions.

Electronic intelligence (ELINT) - The intelligence information product of activities engaged in the collection and processing for subsequent intelligence purposes of foreign, noncommunications, electromagnetic radiations emanating from other than nuclear detonations or radioactive sources.

Electronic intelligence parameter limit list (EPL) - A compilation of identified signals with assigned ELINT notations.

Electronic jammers –

1. **Expendable** - A transmitter designed for special use such as being dropped behind enemy lines.

2. **Repeater** - A receiver-transmitter device that, when triggered by enemy radar impulses, returns synchronized false signals to the enemy equipment. The returned impulses are spaced and timed to produce false echoes or bearing errors in the enemy equipment. See Expendable and Repeater Jammers.

Electronic jamming - The deliberate radiation, reradiation, or reflection of electromagnetic energy with the object of impairing the use of electronic devices, equipment, or systems.

Electronic order of battle - A listing of all the electronic radiating equipment of a military force giving location, type function, and other pertinent data.

Electronic reconnaissance - Specific reconnaissance directed toward the collection of electromagnetic radiations. Examples:

COMINT	Communications Intelligence
ELINT	Electronic Intelligence
OPINT	Optical Intelligence
RINT	Radiated Intelligence
SIGINT	Signal Intelligence

Electronic warfare (EW) - Military action involving the use of electromagnetic energy and directed energy to control the electromagnetic spectrum. EW has three divisions: electronic attack (EA), electronic protection (EP), and electronic warfare support (ES).

Electronic warfare support (ES) - Actions taken to search for, intercept, identify, and locate sources of intentional radiated electromagnetic energy for the purpose of immediate threat recognition. Surveillance of the electromagnetic spectrum that directly supports an operational commander's electromagnetic information needs. ES is a division of EW.

Electro-optics (EO) - The interaction between optics and electronics leading to the transformation of electrical energy into light, or vice versa, with the use of an optical device.

Electro-optic counter-countermeasures (EOCCM) - Actions taken to ensure the effective friendly use of the electro-optic spectrum despite the enemy's use of countermeasures in that spectrum.

Emission control (EMCON) –

1. The management of electromagnetic radiations to counter an enemy's capability to detect, identify, or locate friendly emitters for exploitation by hostile action.

2. Controlling the radiation of an active system to minimize detection by enemy sensors.

Endgame - The period of military engagement 3-5 seconds before missile impact.

Endgame countermeasures (EGCM) - Actions taken to defeat a tracking missile. This includes expendables, decoys, and maneuvers.

Essential elements of information (EEI) - The critical items of information regarding the enemy and his environment needed by the commander by a particular time to relate with other available information and intelligence to be able to reach a logical decision.

Expendable jammer - A nonrecoverable jammer. Early expendables were limited to chaff and flare deployments; however, various radiating jamming systems exist that use noise or repeater techniques. These are dispensed by aircraft or other delivery systems and are designed to disrupt or deceive a victim radar for a short period of time.

Extremely high frequency (EHF) - Frequencies in the range of 30 to 300 GHz.

False target - Radiated bundle of electromagnetic energy that is displaced in time from the echo that creates a response in the receiver where no reflecting surface exists.

False target generator - Device for generating electromagnetic energy of the correct frequency of the receiver that is displaced in time from the reflected energy of the target.

Fast automatic gain control (FAGC) - An AGC scheme characterized by a response time that is long with respect to a PW and short with respect to the target. An ultra fast FAGC will reduce the CW capture effect on the Dicke fix.

Fast time constant circuit (in radar) –

1. A circuit with short time constant used to emphasize signals of short duration to produce discrimination against extended clutter, long-pulse jamming, or noise.

2. A resistance-capacitance differentiating network with a time constant about equal to the transmitted pulse width and employed in the video portion of the receiver to provide the discrimination against jamming with low modulating frequencies. FTC is effective against CW, long jamming pulses, swept jamming, and clutter. It is also fairly effective against chaff corridors. Based on time, the radar receiver will allow only pulses equal to its own pulse width to pass and be presented on the indicators as targets. Because of this, only the leading edges of long pulses will be displayed.

Fence –

1. Line or network of early warning radars.

2. Concentric steel fence erected around a ground radar transmitting antenna to serve as an artificial horizon and suppress ground clutter that would otherwise drown out weak signals returning at a low angle from the target.

Ferret - An aircraft, ship, or vehicle especially equipped for the detection, location, recording, and analyzing of electromagnetic radiations.

Field of view (FOV) - The maximum solid angle visible by an optical or electro-optic system.

Fire control radar - Specialized radar systems used to locate and track airborne and surface targets, compute an optimum weapons firing point, and control the firing and sometimes guidance of its weapons.

FM-by-noise modulation - A method of frequency modulating with effective jamming method against AM and fix-tuned FM receivers. Not very effective against continuously tunable PFM receivers; careful tuning can defeat a great portion of the jamming signal. For this reason, FM-by-noise is not considered optimum as a type of modulation for jamming FM receivers.

FM jamming - Technique consisting of a constant amplitude RF signal that is varied in frequency around a center frequency to produce a signal over a band of frequencies.

Forward edge of the battle area (FEBA) - The foremost limits of a series of areas in which ground combat units are deployed, excluding the areas in which the covering or screening forces are operating, designated to coordinate fire support, the positioning of forces, or the maneuver of units.

Frequency agility - A radar's ability to change frequency within its operating band, usually on a pulse-to-pulse basis. This is an EP technique employed to avoid spot jamming and to force the jammer to go into a less effective barrage mode.

Frequency band designations –

1. As decided upon by the Atlantic City Radio Convention of 1947, and later modified by Comite Consultatif International Radio (CCIR) Recommendation No. 142 in 1953:

Band	RF Range	Band	RF Range
VLF	0-30 kHz	VHF	30-300 MHz
LF	30-300 kHz	UHF	300-3000 MHz
MF	300-3000 kHz	SHF	3-30 GHz
HF	3-30 MHz	EHF	30-300 GHz

2. Electronic warfare uses the following designations:

A	0-250 MHz	H	6-8 GHz
B	250-500 MHz	I	8-10 GHz
C	500-1000 MHz	J	10-20 GHz
D	1000-2000 MHz	K	20-40 GHz
E	2-3 GHz	L	40-60 GHz
F	3-4 GHz	M	60-100 GHz
G	4-6 GHz		

Frequency bandpass - The number of hertz where maximum output is obtained between two limits usually defined and bounded by lower and upper half power (3 dB) points.

Frequency hopping - An anti-jamming technique used by a radar system. The carrier frequency of the pulsed transmissions are periodically or continuously shifted within limits on each successive pulse.

Frequency diversity - Method of transmission and/or reception using several frequencies simultaneously to minimize the effects of selective fading, deliberate jamming, or interference.

Frequency modulated CW (FM-CW) jamming - FM of a CW signal to produce a wide band of signals when the exact operating frequency of the victim is not known within the CW limits.

Frequency modulation (FM) - A method of impressing a message upon a carrier signal by causing the carrier frequency to vary proportionally to the message waveform.

Frequency shift keying (FSK) - A form of FM where the carrier is mined code. In multiple FSK, the carrier is shifted to more than two frequencies. FSK is used principally with teletype communications.

Frequency spectrum - The entire range of frequencies of electromagnetic radiation.

G - Acceleration due to gravity (32.2 ft/sec^2).

Gain (manual) - The receiver gain control allows the operator to vary the receiver sensitivity. It is not designed as an AJ feature; however, when properly employed it may greatly reduce the effects of jamming. The radar detection capability is also reduced by an equal amount.

Gain (transmission gain) - The increase in signal power in transmission from one point to another under static conditions. Note: Power gain is usually expressed in decibels.

Glint (in radar) –

1. The random component of target location error caused by variations in the phase front of the target signal (as contrasted with scintillation error). GLINT may affect angle, range of Doppler measurements, and may have peak values corresponding to locations beyond the true target extent in the measured coordinate.

2. Electronic countermeasures that use the scintillating, or flashing, effect of shuttered or rotating reflectors to degrade tracking or seeking functions of an enemy weapons system.

Ground controlled intercept (GCI) - Vectoring an interceptor aircraft to an airborne target by means of information relayed from a ground-based radar site that observes both the interceptor and target.

Guidance system (missile) - A system that evaluates flight information, correlates it with target data, determines the desired flight path of the missile, and communicates the necessary commands to the missile flight control system.

Guided missile - An unmanned vehicle moving above the surface of the earth, whose trajectory of flight path is capable of being altered by an external or internal mechanism.

Height finder - A radar used to detect the angular elevation, slant range and height of objects in the vertical sight plane. An air defense ground radar used specifically to accurately determine aircraft altitude for tracking and ground controlled intercepts.

Hertz (Hz) - The unit of frequency, equal to one cycle of variation per second. It supersedes the unit cycle per second (cps).

High frequency (HF) - Frequencies from 3000 - 30,000 kHz.

Home-on-jam (HOJ) - A missile mode of operation in which a jamming signal is used to develop steering information for the missile to home in on the jamming source.

Homing guidance - A system by which a missile steers itself toward a target by means of a self-contained mechanism which is activated by some distinguishing characteristics of the target.

Identification, friend or foe (IFF) - A system using radar transmission to which equipment carried by friendly forces automatically responds, for example, by emitting pulses, thereby distinguishing themselves from enemy forces. It is the primary method or determining the friendly or unfriendly character of aircraft and ships by other aircraft and ships, and by ground forces employing radar detection equipment and associated identification, friend or foe units.

Image frequency - An undesired input frequency capable of producing the selected frequency by the same process. NOTE: An image frequency is a frequency which differs from, but has a certain symmetrical relationship to, that which a superheterodyne receiver is tuned. Consequently, the image frequency can be mistakenly accepted and processed as a true frequency by the receiver.

Image jamming - Jamming at the image frequency of the radar receiver. Barrage jamming is made most effective by generating energy at both the normal operating and imaging frequency of the radar. Image jamming inverts the phase of the response and is thereby useful as an eagle deception technique. Not effective if the radar uses image rejection.

Imitative deception - The introduction of radiations into enemy channels which imitates their own emissions.

Imitative jamming - The jamming technique of transmitting a signal identical to the original guidance signal.

Infrared (IR) - That portion of the frequency spectrum lying between the upper end of the millimeter wave region and the lower (red) end of the visible spectrum. In wavelength, the IR lies between 0.78 and 300 microns; in frequency, it lies between one and 400 terahertz (THz).

Infrared counter-countermeasures (IRCCM) - Actions taken to effectively employ our own infrared radiation equipment and systems in spite of the enemy's actions to counter their use.

Infrared countermeasures (IRCM) –

1. Countermeasures used specifically against enemy threats operating in the infrared spectrum.

2. Actions taken to prevent or reduce the effectiveness of enemy equipment and tactics employing infrared radiation.

Instantaneous automatic gain control (IAGC) –

1. That portion of a system that automatically adjusts the gain of an amplifier with varying input pulse amplitudes. The adjustment is sufficiently fast to operate while a pulse is passing through the amplifier.

2. In radar, a quick-acting automatic gain control that responds to variations of mean clutter level, or jamming over different range or angular regions, avoiding receiver saturation (also known as back-bias). IAGC automatically adjusts the gain of the radar receiver so that strong signals do not block adjoining weak signals. IGAC is not quick enough to block short pulse jamming, extended clutter, or chaff.

Instantaneous frequency CFAR (IFCFAR) - A technique similar to the IF DICKE FIX CFAR, except for having a phase detector instead of a frequency discriminator. The primary use of this technique, combined with rapid random frequency changes, is to make chaff signals appear noise-like so they can be handled conventionally.

Instantaneous inverse gain - Pulse-by-pulse amplification, modulation, and reradiation of the victim's radar pulse to obscure angle data.

Intercept point - A computed point in space toward which an interceptor is vectored to complete an interception.

Interference (electronic) - An electrical or electromagnetic disturbance that causes undesirable responses on electronic equipment. Electrical interference refers specifically to interference caused by the operation of electrical apparatus that is not designed to radiate electromagnetic energy.

Interferometer - As pertains to radar, a receiving system which determines the angle of arrival of a wave by phase comparison of the signals received at separate antennas or separate points on the same antenna.

Interleaved jamming - Time sharing of a jammer's output around many threats usually to cover pulse jamming.

Intermediate frequency (IF) –

1. A fixed frequency to which all carrier waves are converted in a superheterodyne receiver.

2. A frequency to which a signaling wave is shifted locally as an intermediate step during transmission or reception.

3. A frequency resulting from the combination of the received signal and that of the local oscillator in a superheterodyne receiver.

Intermediate frequency jamming - Form of CW jamming that is accomplished by transmitting two CW signals separated by a frequency equal to the center frequency of the radar receiver IF amplifier.

Interrogator - A device used to transmit pulse-coded challenges to an IFF transponder and then evaluates the pulse-coded reply for identification purposes.

Intrapulse modulation repeater - A classified deception jamming technique.

Intrusion –

1. The entry of a nonfriendly aircraft or system into friendly air space.

2. The intentional interference in a communication system by which the intruder attempts to confuse, delay, or cause error by the selective introduction of additional data.

Inverse conscan - One method of confusing a radar operator or fire control radar system is to provide erroneous target bearings. This is accomplished by first sensing the radar antenna scan rate and then modulating repeater amplifier gain so that the weapons systems will fire at some bearing other than the true target bearing. The angle deception technique is used to break lock on CONSCAN radars.

Inverse gain - Amplification, inverse modulation, and reradiation of a radar's pulse train at the rotation rate of the radar scan. Deceives a conical scanning radar in angle.

Inverse-gain repeater jammer - A form of repeater in which the jammer creates false targets by varying the output power inverse with the strength of the received radar signal.

Jaff - Expression for the combination of electronic and chaff jamming. An ECM tactic involving the use of jammers to illuminate chaff corridors or chaff bursts to produce false targets.

Jam attenuator control - Used to prevent receiver saturation from any strong signals, including electronic jamming, chaff, or clutter. It also permits the determination of the bearing and elevation of jammers that would cause wide sectors of the scope to be obscured. The control reduces all signals equally, jamming as well as targets. This control should be used in the jammed sector only and not for an entire antenna revolution. Targets in the jammed sector would only be seen if they were stronger than the jamming. However, the jammed sector may be reduced enough in size to allow the operator to determine either bearing or elevation.

Jammer - A device used to deprive, limit, or degrade the use of communications or radar systems. Radio frequency jammers include noise, discrete frequency repeater, and deceptive equipment.

Jamming-to-signal (J/S) ratio - The relative power ratio of jamming to the radar return signal at the radar antenna. The inverse of the signal-to-jamming ratio.

Jam strobe - Also called JAVA (jamming amplitude versus azimuth). A circuit that generates a marker on the PPI to indicate signal strength as a function of bearing. It does this by sampling the jamming intensity once each repetition period. Besides showing the direction of the jammer, it also indicates the severity of main beam and sidelobe jamming.

Jet engine modulation (JEM) - Modulation present in the radar returns received from a jet aircraft, caused by the rotation of the fan or turbine blades of the aircraft's engines.

Jittered pulse repetition frequency (jittered PRF) - The PRF is rapidly varied at a random rate so that false targets appear to jitter or appear fuzzy on the scope. An alternative to jittered PRF is to change the PRF momentarily. This causes the false targets to change their position on the scope. It provides a discrimination against repeater-type jammers.

Klystron - A very stable microwave amplifier that provides high gain at good efficiency. This is accomplished by velocity modulating (accelerating a beam of electronics flowing from its cathode to its anode.

Laser target designation - The use of a laser to direct a light beam onto the target so that appropriate sensors can track or home on the reflected energy.

Leading-edge tracker - A tracking radar that obtains its data from the leading edge of the echo pulse from the target.

Light amplification by stimulated emission of radiation (LASER) - A process of generating coherent light. The process uses a natural molecular (and atomic) phenomenon whereby molecules absorb incident electromagnetic energy at specific frequencies. It then stores this energy for short but usable periods, then releases the stored energy as light at particular frequencies, and in an extremely narrow frequency band.

Lobe - One of the three-dimensional sections of the radiation pattern of a directional antenna bounded by 1-2 cones of nulls.

Lobe-on-receive-only (LORO) - Mode of operation consisting of transmitting on one antenna system and receiving the reflected energy on another system (TWS, conical, or monopulse).

Local oscillator off - A simple expedient of shutting off the local oscillator during barrage jamming. The barrage jammer will not be seen unless there is a beating signal such as a target; therefore, targets will appear. Since targets will not

appear in directions where no jamming arises, either an automatic azimuth switch or an additional receiver display is required.

Logarithmic fast time constant log (LOG-FTCL) - A device consisting of a logarithmic IF amplifier followed by an FTC circuit. The LOG-FTC combination is very effective in removing variations in the video output noise level caused by spot noise, wideband noise, and slow sweep noise modulated AM jamming.

Logarithmic receiver - A receiver whose response approximates the logarithm of the strength of the incoming signal. A special type of receiver having a large dynamic range of automatic gain control that gives considerable protection against receiver saturation by strong jamming on interference signals. Useful against weather, clutter, chaff, and spot jamming.

Look-down, shoot-down - Refers to an air interceptor (AI) equipped with a pulse Doppler radar, or a radar that has a moving target indicator (MTI) feature, that can detect and lock-on to a target within ground return clutter enabling the AI to track and shoot the target.

Look-through –

1. When jamming, a technique by which the jamming emission is interrupted irregularly for extremely short periods to allow monitoring of the victim signal during jamming operations.

2. When being jammed, the technique of observing or monitoring a desired signal during interruptions in the jamming signals.

Low frequency (LF) - Frequencies from 30 - 300 kHz.

Low power spread spectrum radar - A low power, high duty cycle radar whose spectrum is spread 100 MHz or more. Since this radar has a broad output spectrum and a high duty cycle, neither time nor frequency can be effectively used to resolve these signals. This leaves direction as the prime method of resolution. The spectrum of these radars is spread over the bandwidth by any of the pseudo random noise modulating techniques commonly used in communications. Techniques such as bi-phase modulation, quaternary phase modulation, chirp, random frequency jumping, etc., may be used to spread either a CW signal or a very high duty cycle signal. Such signals have a very good range resolution—approximately equal to the reciprocal of the bandwidth.

Magnetron - A radar microwave device whose operation is based on the motion of electrons (AC) under the influence of combined electric and magnetic fields.

Mainlobe - The lobe of a transmitting or receiving antenna centered on the directivity axis of the antenna.

Manipulative deception - The alteration or simulation of friendly electromagnetic radiations to accomplish the deception.

Meaconing, interference, jamming, and intrusion (MIJI) - An acronym of four component parts to determine the intent and technique of electromagnetic radiation.

Meaconing - a system of receiving radio beacon signals and rebroadcasting them on the same frequency to confuse navigation. Interference - unintentional electromagnetic radiation that may cause interference with electronic equipment.

Jamming - the deliberate radiation, reradiation, or reflection of electromagnetic energy with the intent of impairing the use of electronic devices, equipment, or systems being used by the enemy.

Intrusion - the intentional insertion of electromagnetic energy into transmission paths in any manner with the objective of deceiving operators or causing confusion.

Medium frequency (MF) - Frequencies from 300 to 3,000 kHz.

Micron - A unit of length equal to a micrometer (10^{-6} meters).

Microwave amplification by stimulated emission or radiation (MASER) - A low-noise, radio-frequency amplifier. The emission of energy stored in a molecular or atomic system by a microwave power supply is stimulated by the input signal.

Microwave communications - Line-of-sight communications, the frequency of which is higher than 300 MHz.

Millimeter waves - Frequencies (30 GHz to 300 GHz) in the millimeter portion of the electromagnetic spectrum.

Miss distance - The distance measured between the closest paths of a target and interceptor (i.e., aircraft and missile). One objective of self-protection jamming systems is to increase the miss distance to avoid destruction if missile launch cannot be prevented.

Missile approach warning system (MAWS) - A system used to detect and provide warning of approaching missiles. MAWS may be partitioned into active MAWS and passive MAWS.

1. **Active missile approach warning system (AMAWS)** - Generally employs pulse Doppler radar as its sensor. This radar is able to discern a moving target in stationary or slow-moving background clutter.

2. **Passive missile approach warning system (PMAWS)** - An ultraviolet (UV) or infrared-based detector system with the ability to detect and distinguish threat missiles from surrounding clutter and non-lethal missiles.

Modulated barrage jamming - A technique that varies the amplitude of the output power of a barrage jammer with sinusoidal or complex modulation.

Modulated CW jamming - A CW carrier waveform that has been modulated with another signal (such as noise, low, medium, or high frequencies), and is transmitted for the purpose of deception. May be AM, FM, pulse modulated (PM), etc.

Modulated PRF (MPRF) - The deliberate modulation of the interpulse spacing in a pulse train. See PRF Jitter and PRF Stagger.

Modulation - The variation of amplitude, frequency, or phase of an electromagnetic wave by impressing another wave on it.

Modulator - A device (such as an electron tube) for modulating a carrier wave or signal for the transmission of intelligence of some sort.

Monopinch - Anti-jam application of the monopulse technique where the error signal is used to provide discrimination against jamming signals.

Monopulse - A method of pulse generation that allows the simultaneous determining of azimuth, elevation and range, and/or speed from a single pulse.

Monopulse radar - A radar using a receiving antenna system having two or more partially overlapping lobes in the radiation patterns. Sum and difference channels in the receiver compare the amplitudes or the phases of the antenna outputs to determine the angle of arrival of the received signal relative to the antenna boresight. A well-designed monopulse tracking system will achieve a more accurate track under conventional jamming techniques than on the skin return. Certain monopulse trackers are susceptible to angular jamming techniques such as skirt and image jamming. Techniques such as “CROSS EYE” are designed to

attack all monopulse tracking systems. Monopulse deception is a major area of advanced R&D with no clear "best technique" yet in sight.

Moving target indicator (MTI) - A radar presentation that shows only targets that are in motion. Signals from stationary targets are subtracted out of the return signal by the output of a suitable memory circuit.

MTI CFAR - A technique that provides CFAR capability in an MTI receiver. The cancellation of ground clutter is not impaired during radar jamming.

Multiband radar - Radar that simultaneously operates on more than one frequency band through a common antenna. This technique allows for many sophisticated forms of video processing and requires that a jammer must jam all channels simultaneously.

Multiplex - Simultaneous transmission of two or more signals on a common carrier wave. The three types of multiplex are called time division, frequency division, and phase division.

Multitarget generator jamming - A technique where a generator takes the radar's PRF, scan rate, and antenna lobe pattern and computes when to transmit false targets at the radar's frequency. The targets appear as true targets, but normally only about 20 percent of the targets are programmed to give a logical course and speed. The many targets saturate the tracking operator's capability by the sudden appearance of multiple targets, and/or many targets either stationary or on illogical courses and speeds, or maneuvers such as 90 degree turns at high speeds but with no displacement. Also, targets may appear in back and sidelobe positions.

Music - In air intercept, a term meaning electronic jamming.

Narrowband (NB-1) - Narrows the receiver frequency making it more selective. It limits the target signals and the jamming signal to a set level of amplitude and reduces the level of a jamming signal if the jammer is not tuned to the radar's exact frequency.

Narrow pulse jamming - Jamming where the jammer pulse width is less than the radar's pulse width. Technique may be required by interleaved jamming.

Noise –

1. Any unwanted disturbance within a dynamic electrical or mechanical system, such as undesired electromagnetic radiation, and any transmission channel or device.

2. Uncontrolled random disturbances that arise in a guided missile system because of various physical phenomena.

Noise jamming - Direct (straight) AM or FM noise on a carrier frequency that has a highly variable bandwidth for the purpose of increasing (saturating) the radar receiver's noise level.

Nuclear effects - The electromagnetic phenomena resulting from a nuclear explosion. The phenomena are listed as follows:

1. **Argus phenomena (trapped electrons)**. The trapping in the earth's magnetic field of electrons produced by a nuclear burst.

2. **Blackout (radio frequency interference)**. An effect that is the result of ionization produced by a nuclear explosion in or above the atmosphere. This ionization can cause interference (blackout) by attenuating, reflecting, cluttering, and scattering radar electromagnetic pulses in a high-intensity burst of electromagnetic radiation, predominantly in the radio frequency range of the spectrum.

3. **Optical phenomena**. Intense radiations covering all parts of the optical spectrum are produced by the interactions between the atmosphere and the nuclear radiation and fission products resulting from a nuclear detonation. The resulting auroras and airglows are created as an optical background that can affect reconnaissance, tracking, warning and homing systems, and personnel.

4. **Transient radiation effects on electronics**. Nuclear radiation impinging on electronic systems or components can substantially alter the operation and output of these systems. The word transient refers to the type of environment and not to the duration of the effect since the effect may be either transient or permanent.

Nulls - Points of no radiation in an antenna radiation pattern.

Obscuration - Effects produced by masking-type jammers. Denial of either range or angle is achieved by submerging data interference caused by noise or noise-like signals.

Off-frequency spot jamming - A type of spot jamming in which the jammer frequency is off the radar operating frequency but still within the radar receiver bandpass.

Optical countermeasures - Applications of electronic countermeasures in the visible light portion of the electromagnetic spectrum. Actions taken to prevent or reduce an enemy's effective use of the visible spectrum.

Oscillator - Electronic circuit or device capable of converting direct current (DC) into alternating current (AC) at a frequency determined by the inductive and the capacitive constants of the oscillator.

Over-the-horizon radar - A radar system that makes use of the ionosphere to extend its range of detection beyond line-of-sight. Over-the-horizon radars may be either forward scatter or backscatter systems.

Palmer scan - Conical scan superimposed on another type of scan pattern-usually a spiral pattern.

Passive angle tracking (PAT) - A target may be tracked “passively” if that target emits electromagnetic radiation; i.e., jamming radio, radar signal of sufficient duration that a DF bearing may be obtained. The emission from the target is DF-ed in azimuth and/or elevation. No range information will be available unless cross DF techniques are used by two or more passively tracking sites.

Passive detection and tracking - By combining azimuth data on jamming strobes from several stations, intersections are obtained which indicate the position of the jammers. The number of ghosts can be reduced by increasing the number of friendly stations and obtaining elevation angles of strobes when available.

Passive electronic countermeasures - Electronic countermeasures based on the reflection, absorption or modification of the enemy's electromagnetic energy. This distinction between active and passive countermeasures is not currently used, but is based on the presence or absence of an electronic transmitter.

Passive homing guidance - A system of homing guidance in which the receiver in the missile uses radiations only from the target.

Peak power - Maximum power output during transmission time. Expressed in watts or megawatts.

Penetration aids - Techniques and/or devices employed by aerospace systems to increase the probability of weapon system penetration of any enemy defense.

Examples are: Low altitude profiles, trajectory adjustments, reduced radar cross-sections of attack vehicles, improved vehicle hardness to effects of defense engagements, terrain avoidance radar, bomber defense missiles, decoys, chaff, electronic countermeasures, etc. Penetration aids are used by an offensive system to penetrate enemy defenses more effectively. Also called PENAIDS.

Phase modulation - A method of impressing a message upon a carrier signal by causing the carrier phase to vary proportionally to the waveform.

Phase shift keying - A method of impressing a digital signal upon a carrier signal by causing the carrier phase to take different values corresponding to the different values of the digital signal.

Phased array radar - Radar using many antenna elements that are fed out-of-phase to each other. The direction of the beam can be changed as rapidly as the phase relationships (usually less than 20 μsec). Thus, the antenna remains stationary while the beam is moved electronically. The use of many antenna elements allows for very rapid and high directivity of the beam(s) with a large peak and/or average power.

Point defense - The defense of specified geographical areas, cities, and vital installations. One distinguishing feature of point defense missiles is that their guidance information is received from radars located near the launching sites.

Polarization - The direction of an electrical field is considered the direction of polarization. When a half-wave dipole antenna is horizontally oriented, the emitted wave is horizontally polarized. A vertical polarized wave is emitted when the antenna is erected vertically.

Polarization diversity - The variation of polarization (such as horizontal, vertical, circular, or elliptical for radar use) either simultaneously or singularly.

Power management - Generally classified methods to optimize all related EW activities and facilities-usually in reference to a coordinate, optimized EW suite.

PPI scope - A radar display yielding range and azimuth information via an intensity modulated display and a circular sweep of a radial line. The radar is located at the center of the display.

PRF jitter - PRF rapidly varied at a random rate so that false targets appear to jitter, or appear fuzzy, on the scope. An alternative to jittered PRF is to momentarily change the PRF. This causes the false targets to change their position on the scope.

PRF stagger - The technique of switching PRF or PRI to different values on a pulse-to-pulse basis such that the various intervals follow a regular pattern. This is useful in compensating for “blind speeds” in pulsed MTI radars. Interpulse intervals differ but follow a regular pattern.

Pseudo noise - A modulation technique resulting in low signal selectability and decreased vulnerability to jamming.

Pulse compression - A scheme whereby a specifically modulated, medium power long pulse is stretched and transmitted. The returned pulse is compressed in the receiver demodulation process to obtain the advantage of narrow pulse operation. Long pulses provide the advantage of long range detection and short (compressed) pulses provide the advantage of better resolution and accuracy. This technique uses matched filter techniques for discriminating against signals that do not correspond to the transmitted code. It permits an increase in average transmitted power (without an increase in peak power) with no loss in range resolution. Pulse compression is a special form of pulse coding and correlation.

Pulse deception jamming - Any of the many false target techniques used to deceive a pulse radar, as opposed to obscurative noise techniques.

Pulse discriminator - Device that responds only to a pulse that has a particular characteristic, such as duration or period.

Pulse Doppler radar - A highly complex radar system that employs a very high pulse repetition frequency (usually 10,000 PPS or higher) to reduce “blind speeds” and measure the Doppler frequency shift to resolve target velocity. Pulse Doppler is applied principally to radar systems requiring the detection of moving targets in a ground clutter environment. It uses pulse modulation to achieve higher peak power, greater range, less susceptibility to unfriendly detection, and enhanced range resolution.

Pulse duration - The time in microseconds that the radar set is transmitting RF energy. Generally, the greater the pulse duration, the higher the average power, but the poorer the range resolution. Also known as pulse width. More technically, it is the time interval, measured at the half-amplitude points, from the leading edge to the trailing edge of a pulse.

Pulse group - In complex pulse trains, two or more pulses that are recognizably distinct from the others.

Pulse interference suppression and blanking (PISAB) - An EP automatic interference blanking device that will blank all video signals not synchronous with the radar PRF. PISAB does not require any trigger and operates on both normal and MTI modes. It is effective against random pulse signals.

Pulse jitter - Random variation of interpulse interval.

Pulse modulation (PM) - A special case of amplitude modulation in which the carrier wave is varied at a pulsed rate. This series of pulses is generally for transmitting data. The result is a short, powerful burst of electromagnetic radiation that can be used for measuring the distance from a radar set to a target.

Pulse modulated jamming - Use of jamming pulses of various widths and repetition rates.

Pulse position modulation - Modulation by variation of the interval that elapses between the pulse to be modulated in a group of pulses and a synchronizing pulse, usually the first pulse of the group.

Pulse repetition frequency (PRF) - The rate at which pulses or pulse groups are transmitted from a radar set. Generally, PRF is the number of pulses generated per second and is expressed in hertz (Hz).

Pulse repetition interval (PRI) - The interval of time between two transmitted radar pulses, usually expressed in microseconds. PRI is the inverse of PRF.

Pulse recurrence time (PRT) - Time elapsing between the start of one transmitted pulse and the start of the next. It is the reciprocal of PRF.

Pulse recurrence time (PRT) agility - Ability of the radar set to vary the number of pulses per set.

Pulse width (PW) - See Pulse Duration.

Pulse width discrimination (PWD) - An EP technique used to discriminate against received pulses that do not have the same duration as the radar transmitted pulse. PWD is used in eliminating the effects of pulse type interference when the interference pulses are not the same length as the real radar pulse. Since this circuit generates a blanking gate that shuts off the receiver whenever a pulse of improper length is sensed, loss of valid target data can result. PWD offers good discrimination against long-pulse jamming and jamming signals employing low frequency noise modulation. It affords little or no discrimination against short pulses and HF noise modulations.

Pulse width discriminator - A device that measures the pulse length of video signals and passes only those pulses whose time duration tails into some predetermined design tolerances. A pulse width discriminator will generally provide some gain against barrage jamming, similar to that of a matched filter in the video.

“Rabbits” - Interference from another radar on or near the frequency of the receiving radar. Shows on the indicators as interference at the rate of the relative PRF of the interfering radar.

Radar - From Radio Detection And Ranging. A device used to detect a distant target and determine and display its relative direction (azimuth) and its relative distance (range).

Radar absorbent material (RAM) - Material used as a radar camouflage device to reduce the echo area of an object.

Radar beacon - A receiver-transmitter combination that sends out a coded signal when triggered by the proper type of pulse enabling determination of range and bearing information by the interrogating station or aircraft.

Radar cross section - The equivalent area intercepted by a radiated signal and, if scattered uniformly in all directions, produces an echo at the radar receiver equal to that of the target. Typical radar cross sections of aircraft vary from one to over 1,000 square meters. The RCS of ships may exceed 10,000 square meters.

Radar definition - The accuracy with which a radar obtains target information such as range, azimuth, or elevation.

Radar homing - Homing on the source of a radar beam.

Radar homing and warning (RHAW) - Typically consists of an airborne, wideband video receiver designed to intercept, identify, and display the direction to pulse-type emitters.

Radar resolution - A measure of a radar's ability to separate targets that are close together in some aspect of range, azimuth, or elevation into individual returns.

Radar warning receiver (RWR) - A receiver onboard an aircraft that analyzes the hostile radar environment and determines radar threat by type, frequency, relative bearing, and relative distance. The threat is displayed to the aircrew by means of display lights, video symbols, and aural tones.

Radio frequency (RF) - Electromagnetic energy radiated at some frequency.

Radio frequency interference - An unintentional interfering signal capable of being propagated into electronic equipment, usually derived from sources outside the system.

Railing –

1. Pertains to radar pulse jamming at high recurrence rates (50 to 150 kHz). It results in an image on a radar indicator resembling fence railing.

2. The name given to that pattern produced on an “A” scope by CW modulated with a high frequency signal. Railings appear as a series of vertical lines resembling target echoes along the baseline.

Random modulation CW jamming - The use of a nonperiodic function to an AM, FM, or AM/FM CW carrier. The effects produced on a radar are similar to those produced by DINA.

Random noise - Electromagnetic energy having no particular modulation or pattern. May be generated by either natural atmospheric phenomena or by electromagnetic radiation devices.

Random pulse jamming - The technique by which a pulse transmission system is pulsed irregularly by random noise signals.

Range - The distance from one object to another.

Range gate - A gate voltage used to select radar echoes from a very short range interval.

Range gate capture - A jamming technique using a spoofer radar transmitter to produce a false target echo that can make a target tracking radar move off the real target and follow the false one.

Range gate pull-in (RGPI) - Same as range gate pull-off (see next text entry) except that the deceptive pulse is transmitted before the radar pulse is received. This is accomplished by digital storage of the pulse repetition period which must be extremely stable.

Range gate pull-off (RGPO) - A deception technique used against pulse tracking radars using range gates. The jammer initially repeats the skin echo with minimum time delay at a high power to capture the AGC circuitry. The delay is progressively increased, forcing the tracking gates to be pulled away ("walked off") from the target echo. Frequency memory loops (FML) or transponders provide the variable delay.

Range gate tracker - A radar system that tracks targets in range by measuring the elapsed time from the transmitted pulse to the echo return.

Range tracking - Pulse radars measure the time difference between radar pulse transmission and echo reception. The range gate is positioned at a range where the target is expected. The receiver is blanked off except during the period where the range gate is positioned. Range tracking may occur at the leading edge of the return pulse or between ON and OFF gates.

Recovery time (RT) - The time that a radar requires to "get ready" to receive after a pulse is sent out. Time is required to get ready because the high-powered pulse tends to fill the sensitive radar receiver with RF energy, which prevents target returns from being seen. A short "damping out" period occurs after the pulse width during which time the RF energy dissipates, allowing weak target echoes to once again be detected.

Rectifier - A device (such as a vacuum tube) for converting alternating current (AC) into direct current (DC).

Repeater - A receiver-transmitter combination that amplifies the received signal and retransmits it.

Repeater jammer - Equipment used to confuse or deceive the enemy by causing his equipment to present false information. This is done by a system that intercepts and reradiates a signal on the frequency of the enemy equipment. The reradiated signal is modified to present erroneous data on azimuth, range, number of targets, etc.

Repeater jamming - Interception and reradiation of a signal with the reradiation of a signal being modified to give erroneous azimuth, range, velocity, acceleration, or number of targets.

Resolution - The ability of a system to distinguish between two adjacent objects and to display them separately.

Resolution cell - The minimum volume in space in which a radar can discriminate between targets. It is determined numerically-for a conventional radar-by the width of the beam in angle, the pulse width in range, and the velocity gate width in speed.

Response noise jammer - A repeater jammer that transmits spot noise over the received radar frequency even in the case of radar frequency agility.

Ringing - The undesired oscillation or triggering of an electrical device by its own transmitter.

Rope - An element of chaff consisting of a long roll of metallic foil or wire that is designed for broad low frequency response. (See Chaff.)

Rope chaff - Chaff that contains one or more rope elements. (See Chaff.)

Rotating polarization - The result of a rotating feed. This should not be confused with circular polarization where the electric field rotates about the axis of propagation at the radar frequency.

SAM - Surface-to-air missile.

Saturating signal - In radar, a signal of an amplitude greater than the dynamic range of the receiving system.

Sawtooth modulated jamming - Electronic countermeasure technique when a high-level jamming signal is transmitted, thus causing large AGC voltages to be developed at the radar receiver that, in turn, causes the target return and receiver noise to completely disappear.

Scan - The process of directing a beam of RF energy successively over a given region, or the corresponding process in reception.

Scan interval - The time interval from the peak of one mainlobe in a scan pattern to the peak of the next mainlobe.

Scan period - The time period of basic scan types (except conical and lobe switching) or the period of the lowest repetitive cycle of complex scan combinations. The basic unit of measurement is degrees/mils per second or seconds per cycle.

Scan rate modulation - Modulation of the deception jamming signal with one or more frequencies that are related to the scan rate of the radar.

Scan type - The path made in space by a point on the radar beam, for example, circular, helical, conical, spiral, or sector.

Search –

1. A term applied to that phase of radar operation when the lobe, or beam of radiated energy, is directed in such a way to search for targets in the area.

2. A systematic examination of space to locate and identify targets of interest.

Sector scan - A scan in which the antenna sweeps back and forth through a selected angle.

Selective identification feature (SIF) - A capability which, when added to the basic IFF system, provides the means to transmit, receive, and display selected coded replies.

Self-protection jamming - Jamming to protect the vehicle upon which the jammer is deployed.

Semiactive radar homing - Semiactive homing guidance combines principles from both the beam rider and the active radar homing missile. Track on the target is established by the AI's radar; the missile is launched when the target comes within its effective range. During missile flight, the AI maintains track on the target. Radar returns from the target are received by the missile. Guidance commands are generated within the missile from the radar returns.

Sensitivity time control (STC) - Programmed variation of the gain (sensitivity) of a radar receiver as a function of time within each pulse repetition interval or observation time. STC prevents overloading of the receiver by strong echoes from targets or clutter at close ranges. STC reduces the gain of the radar receiver for detection of close-in targets. It is particularly effective in removing close-in clutter and strong nearby signals. STC also refers to a circuit that reduces the gain of the radar receiver immediately following the transmission of the radar pulse so that the receiver is not saturated by strong radar returns from nearby objects.

Serrodyne - A method of “pulling off” the velocity gate of a Doppler radar by using a voltage-controlled phase shifter, usually a traveling wave tube (TWT). This introduces a frequency shift from zero to some maximum value, pulling the Doppler tracking gate away from the skin echo. The phase shift is usually accomplished by modulating the TWT's helix voltages.

Sidelobe - Part of the beam from an antenna, other than the mainlobe. Sidelobe gain is usually less than mainlobe gain. Given that the mainlobe radiates most of the power at zero degrees azimuth, sidelobes inherently radiate significant power in the direction of +20°, 90°, and 150° relative to the mainlobe.

Sidelobe blanking (SLB) - A device that employs an auxiliary wide angle antenna and receiver to sense whether a received pulse originates in the sidelobe region of the main antenna and to gate it from the output signal if it does. This technique uses an omnidirectional antenna and compares relative signal strength between the omni and the radar antenna. The omnichannel (plus receiver) has slightly more gain than the sidelobes of the normal channel, but less gain than the main beam. Any signal that is greater in the omnichannel must have been received from a sidelobe and is blanked. This technique is effective in removing spoofed signals with a duty cycle up to 50%.

Sidelobe canceller (SLC) - A device that employs one or more auxiliary antennas and receivers to allow linear subtraction of interfering signals from the desired output if they are sensed to originate in the sidelobe of the main antenna. This technique employs the same antenna and receiver configurations of the SLB, except that a gain matching and canceling process takes place. Extraneous signals entering the sidelobes of the main antenna are canceled while the targets remain. This type of system exhibits cancellation roughly 20 dB against a single noise jammer. With multiple jammers at various azimuths, the performance of this device rapidly deteriorates.

Sidelobe jamming - Jamming through a sidelobe of the receiving antenna in an attempt to obliterate the desired signal received through the mainlobe of the receiving antenna at fixed points.

Sidelobe suppression - The suppression of that portion of the beam from a radar antenna other than the mainlobe.

Sidewinder - A solid-propellant, air-to-air missile with nonnuclear warhead and an infrared guidance system. Designated as the AIM-9 missile.

Signal intelligence (SIGINT) - Intelligence derived from the interception of enemy communications and noncommunication signals. A generic term that includes both COMINT and ELINT.

Signal-to-jamming ratio (S/J) - The ratio of the signal power to the jamming power or intentional interference at some point in the system. This ratio is often expressed in decibels.

Signal-to-noise ratio (S/N) - Ratio of the power of the signal to the power of the noise.

Signature - The set of parameters that describes the characteristics of a radar target or an RF emitter and distinguishes one emitter from another. Signature parameters include the RF of the carrier, the modulation characteristics (typically the pulse modulation code), and the scan pattern.

Sine-wave modulated jamming - Jamming signal produced by modulating a CW signal with one or more sine waves.

Single beam blanking (SBB) - Used by phased array radars as an alternative method of Beam to Beam Correlation (BBC). It is effective, to some degree, against many multiple target generators and swept frequency jammers. Because of overlapping beamwidths, a target signal will appear in more than one beam as the beams are scanned past a true target. When jamming signals are transmitted along one beam, that beam is blanked by the radar receiver.

Skirt jamming - Jamming that places the signal somewhat off the radar center frequency but within the IF skirts. The technique will degrade the tracking accuracy of some monopulse radars; however, good radar design makes the technique ineffective.

Smart jamming - Selective jamming of threat radars with an optimized modulation signal at a correct time. Power management techniques are used to control smart jamming systems.

Smith modulation - Deceptive technique that operates on the servo loop of the victim's radar. Two RF carriers are transmitted with a few cycles difference.

Spiral scan - A pencil beam scan which moves around a central axis describing the surface of a cone in an ever-increasing cone size.

Spot jamming - Narrow frequency band jamming concentrated against radar at a particular frequency. The jamming bandwidth is comparable to the radar bandpass. Used to deny range and sometimes angle information.

Spread spectrum - Use of broader frequency bandwidths than normally required to transmit information, in order to gain advantages in interference rejection (anti-jam), message privacy/security, low probability of intercept (LPI), deny frequency resolution, multiplexing of more than one message in the same bandwidth, or high resolution range measurement.

Spurious radiation - Emissions from a radio transmitter at frequencies outside its assigned or intended emission frequency. Spurious emission includes harmonic emission, parasitic emission, and intermodulation products, but excludes emissions in the immediate vicinity of the necessary band that are a result of the modulation process for the transmission of information.

Spurious response –

1. Any response, other than the desired response, of an electric transducer or device.

2. A term used in electronic warfare to describe the undesirable signal images in the intercept receiver resulting from the mixing of the intercepted signal with harmonics of the local oscillators in the receiver.

Staggered PRF - A technique of using more than one PRF to reduce the blind speeds associated with MTI radars. PRF switching occurs on a pulse-to-pulse basis.

Stand-off jammer (SOJ) - A powerful jammer that remains at a safe range while providing jamming coverage (masking) for the attacking elements. The Navy EA-6B is an example of a SOJ aircraft.

Stand-off jamming (SOJ) - A jamming aircraft that orbits outside the maximum range of the SAM threat. As the attack package penetrates, the jamming aircraft directs jamming against all significant radars in the area.

Stream - Dispensing of chaff (solid/random interval/bursts).

Stream chaff - Operational technique of dropping large quantities of chaff for a continuous period of time. This results in a “ribbon” or “stream” of returns many miles in length on victim radar scopes. The penetrating attack package can then use the resulting chaff corridor to mask their penetration.

Super high frequency (SHF) - Frequencies from 3 to 30 GHz.

Support jamming - A tactic by which aircraft carrying electronic jamming equipment orbit at a safe distance from the enemy threat defenses or fly escort with the strike force for the primary purpose of screening them from the threat radars.

Suppression of enemy air defenses (SEAD) - That activity which neutralizes, destroys, or temporarily degrades enemy air defense systems in a specific area by using physical attack, deception, and/or electronic warfare.

Surface-to-air missile (SAM) - A missile launched from a surface launcher at a target above the surface.

Sweep jammer - Electronic jammer that sweeps a narrow band of electronic energy over a broad bandwidth.

Sweep lock-on jammer - A transmitter in which a narrowband jamming signal can be tuned over a broad frequency band and the signal locked on a particular frequency.

Swept audio - Jamming technique usually employed against conical scan-on-receive-only (COSRO) radars. The received pulses are amplified and retransmitted by the target and amplitude modulated at a frequency close to the suspected receiver antenna scan frequency.

Swept jamming - An EA technique of barrage jamming in which a CW carrier or noise source is swept over a selected bandwidth.

Swept-spot jamming - A jamming technique in which an oscillator is swept over a specific range of frequencies in the band of interest in order to be assured of exciting a receiver tuned to any frequency in that band.

Synchronized-pulse jamming - The technique of attempting to insert jamming pulses into a receiver each time the receiver gate opens.

Synchronous-pulsed jamming - A jamming technique that matches exactly the PRF of the victim's radar; then transmits multiples of the PRF. It is most effective if the jammer also matches the PW of the radar. Synchronous-pulsed jamming is easily recognized since the spacing between successive target lines is equal and each target line is the same in depth from the center outward. The width of the jammed sector is dependent upon the range of the jammer from the radar.

Synthetic aperture radar (SAR) - A high-resolution ground mapping technique in which advantage is taken of the forward motion of a coherent pulsed radar to synthesize the equivalent of a very long sidelooking array antenna from the radar returns received over a period of up to several seconds or more.

Target acquisition - The detection, identification, and location of a target in sufficient detail to permit the effective employment of weapons.

Terminal guidance –

1. The guidance applied to a guided missile between mid-course and arrival in the vicinity of the target.

2. Electronic, mechanical, visual, or other assistance given to aircraft pilots to facilitate arrival at, operation within or over, landing upon or departure from an air landing or air drop facility.

Terminal threat - The weapon systems, generally near a target, used to directly engage an aircraft in order to destroy it.

Terrain-avoidance radar - An airborne radar that provides a display of terrain ahead of low-flying aircraft to permit horizontal avoidance of obstacles.

Terrain-following radar (TFR) - An airborne radar that provides a display of terrain ahead of low-flying aircraft to permit manual control, or signals for automatic control to maintain constant altitude above the ground.

Thermal crossover - The natural phenomenon which normally occurs twice daily when temperature conditions are such that there is a loss of contrast between two adjacent objects on infrared imagery.

Threshold - The minimum value of a signal that can be detected by a system or sensor under consideration.

Time-of-arrival (TOA) - A method of locating a distant pulse emitter by measuring the difference in the time-of-arrival of its pulses at three separate locations. This method is also called Inverse LORAN.

Track –

1. A series of related contacts displayed on a plotting board.

2. To display or record the successive positions of a moving object.

3. To lock onto a point of radiation and obtain guidance from it.

4. To keep a gun properly aimed, or to continuously point a target-locating instrument at a moving target.

5. The actual path of an aircraft above, or a ship on, the surface of the earth. The course is the path that is planned; the track is the path that is taken.

Tracking - The continuous monitoring of range, velocity, or position of a target in space from a reference position. This is accomplished via radar and/or optical means.

Tracking radar - A radar that measures the range, azimuth, elevation, and/or velocity of the target and provides data that may be used by the fire control computer to determine the target path and predict its future position.

Track-on-jam - A method of passive target tracking using the jamming signal emitted by the target.

Track-while-scan (TWS) radar - Although it is not really a tracking radar in the true sense of the word, it does provide complete and accurate position information for missile guidance by using two separate beams produced by two separate antennas on two different frequencies. The system uses electronic computer techniques whereby raw data are used to track an assigned target, compute target velocity, and predict its future position while maintaining normal sector scan.

Transceiver - A combined radio transmitter and receiver in which some circuits other than those of the power supply are common to both transmitter and receiver, and not providing for simultaneous transmission and reception.

Transponder - A transmitter-receiver capable of accepting the electronic challenge of an interrogator and automatically transmitting an appropriate reply.

Traveling wave tube (TWT) - An electron tube in which a beam of electrons interacts continuously with a guided electromagnetic wave to produce amplification at microwave frequencies. A TWT capable of providing high amplification (60 dB) in frequencies over several octaves without adjustment. TWTs are classified by:

1. Power Output:

    Low (less than one watt)
    High (more than 10 watts)
    Intermediate (one to 10 watts)

2. **Noise Characteristics:**

   Low (less than 20 dB)

3. **Operating Mode:**

   Pulse
   CW
   Dual Mode (pulse or CW)

4. **Method of Focusing:**

   PPM (periodic permanent magnet)
   Solenoid (single electromagnet)
   Coupled Cavity

5. **Terms associated with TWT operation:**

   a. **Gain Compression:** Change in amplification a device provides as it operates near saturation.

   b. **Overdrive:** TWT is operating beyond the point of saturation.

   c. **Saturation Gain:** Ratio of output power to input power when the device is being driven at maximum output.

   d. **Serrodyne:** Linear translation of the phase of a signal on the helix of a TWT by a linear sawtooth waveform that enables the TWT to operate as a single sideband frequency translator.

   e. **Small Signal Gain:** Ratio of output power to input power when the TWT is operating linearly.

Two-signal jamming (also called straddle jamming) - Jamming whereby two signals are transmitted on two RF frequencies slightly separated. Effective against certain types of radar where receiver bandwidth is narrow enough to defeat noise jamming.

Ultra high frequency (UHF) - Frequencies from 300 to 3,000 MHz.

Unit prefixes - Prefixes used to indicate scientific units:

Multiple	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Unmodulated CW jamming - The transmission of a high power carrier frequency that causes an overload effect to occur in the radar receiver. Used against bandpass radars that have a limited tuning capability. Unmodulated CW jamming can be identified by a blackening of the scope background (no video present) in a wedge-shaped sector, or by a solid brightening of a wedge or sector, normally exceeding one bandwidth.

Uplink - The missile guidance signal that passes command guidance intelligence from the site to the missile.

Velocity gate pull-off (VGPO) - Method of capturing the velocity gate of a Doppler radar and moving it away from the skin echo. Similar to the RGPO, but used against Doppler radar systems. The target Doppler frequency, which is amplified and retransmitted, is shifted in frequency to provide an apparent rate change or Doppler shift.

Very high frequency (VHF) - Frequencies from 30 to 300 MHz.

Very low frequency (VLF) - Frequencies from 3 to 30 kHz.

Video frequency –

1. A band of frequencies extending from approximately 100 Hz to several MHz.

2. The frequency of the voltage resulting from television scanning. Range from zero to 4 MHz or more.

Warning receiver - A receiver with the primary function of warning the user that his unit is being illuminated by an electromagnetic signal of interest.

Wideband constant false alarm rate receiver (WB-1) - Used against individual or combinations of rapidly swept FM-CW, noise, or CW jamming. This mode has nonlinear limiting and gives poor resolution of overlapping targets.

Window –

1. Strips of frequency-cut metal foil, wire, or bars that may be dropped from aircraft or missiles, or expelled from shells or rockets as a radar countermeasure. A confusion reflector.

2. A passive radar deception or confusion device; usually consisting of some metallic structure, designed in size and shape to effectively reflect impinging signals, to simulate a true target.

3. British name for chaff.

Wobbulation - A periodic and usually slow variation of a parameter (such as frequency, amplitude, or period) about a central value. A low frequency modulation of a jamming carrier that appears on a radar display as a "wobbling" target. This effect is an undesired result of an angle deception or time-varying barrage technique.

Wooden round - An ordnance round (shell, missile, etc.) requiring no maintenance or preparation time prior to loading for firing.

ANNEX B
EC-RELATED ABBREVIATIONS AND ACRONYMS

A

AAA	**Antiaircraft artillery**
AAM	**Air-to-air missile**
AAS	**ARM alarm sensor**
AC	**Alternating current**
ACET	**Automatic cancellation of extended targets**
ACQ	**Acquisition**
AC&W	**Aircraft control and warning**
ADA	**Air defense artillery**
ADF	**Automatic direction finding**
ADL	**Automatic data link**
AEW	**Airborne early warning**
AF	**Air Force/audio frequency**
AFB	**Air Force Base**
AFC	**Automatic frequency control**
AFRES	**Air Force Reserves**
AGC	**Automatic gain control**
AGI	**Auxiliary general intelligence (ship)**
AGL	**Above ground level**
AGM	**Air-to-ground missile**
AI	**Airborne interceptor**
AJ	**Anti-jamming**
AM	**Amplitude modulation**
AM-CW	**Amplitude modulated continuous wave**
AMOP	**Amplitude modulation on pulse**
AMP	**Amplifier**
AMRAAM	**Advanced medium range air-to-air missile**
AMTI	**Airborne moving target indicator**
ANG	**Air National Guard**
ANL	**Automatic noise limiting**
AOA	**Angle of arrival/angle of attack**
AOJ	**Angle-on-jam**
ARM	**Antiradiation missile**
ASK	**Amplitude shift keying**
ASM	**Air-to-surface missile**
ASR	**Air surveillance radar**
ASW	**Anti-submarine warfare**
ATC	**Air traffic control**
ATD	**Automatic target detector**
ATR	**Antenna, transmit receive**

ATV	**Automatic threshold variation**
AVNL	**Automatic video noise leveling**
AVP	**Adaptive video processing**
AWACS	**Airborne warning and control system**
AZ	**Azimuth**

B

BBC	**Beam-to-beam correlation**
BCC	**Battery control center**
BFO	**Beat frequency oscillator**
BIT	**Built-in test**
BMEWS	**Ballistic Missile Early Warning System**
BN	**Barrage noise**
BSE	**Boresight error**
BTE	**Battery terminal equipment**
BW	**Bandwidth**
BWO	**Backward wave oscillator**

C

C	**Degree centigrade**
C^2	**Command and control**
C^3	**Command, control, and communications**
C^2W	**Command and control warfare**
CAP	**Combat air patrol**
CAS	**Close air support**
CE	**Clutter eliminator**
CEP	**Circular error probable**
CFAR	**Constant false alarm rate**
CIJ	**Close-in jamming**
CIU	**Control indicator unit**
CM	**Countermeasures**
COHO	**Coherent oscillator**
COMINT	**Communications intelligence**
COMSEC	**Communication security**
CONSCAN	**Conical scan**
COSRO	**Conical scan-on-receive-only**
CPAC	**Coded pulse anti-clutter**
CP	**Circular polarization**
CRT	**Cathode ray tube**
CSG	**Clean strobe generator**
CSLC	**Coherent sidelobe canceler**
CV	**Coincident video**
CVR	**Crystal video receiver**

CW	**Continuous wave**
CWAR	**Continuous wave acquisition radar**
CWI	**Continuous wave illuminator**

D

dB	**Decibel**
dBm	**Decibels relative to 1 milliwatt**
dBw	**Decibels relative to 1 watt**
DBB	**Detector back bias**
DBF	**Digital beam forming**
DC	**Direct current**
DET	**Detector**
DF	**Direction finder/Dicke fix**
DINA	**Direct amplified noise**
DIFM	**Digital instantaneous frequency measurement**
DME	**Distance measuring equipment**
DOA	**Direction of arrival/dead on arrival**
DOF	**Degrees of freedom**
DPI	**Detected pulse interference**
DR	**Dynamic range/dead reckoning**
DRFM	**Digital radio frequency memory**
DSB	**Double sideband**
DTM	**Data transfer module**

E

EA	**Electronic attack**
EC	**Electronic combat**
ECCM	**Electronic counter-countermeasures**
ECM	**Electronic countermeasures**
ECP	**Electronic combat pilot**
EDAC	**Error detection and correction**
EHF	**Extremely high frequency**
EID	**Emitter identification (table)**
EL	**Elevation**
ELINT	**Electronic intelligence**
ELSCAN	**Elevation scan**
EMCON	**Emission control**
EMI	**Electromagnetic interference**
EMP	**Electromagnetic pulse**
EO	**Electro-optical**
EOB	**Electronic order of battle**
EP	**Electronic protection**
ER	**Electronic reconnaissance**

ERP	**Effective radiated power**
ES	**Electronic warfare support**
EVIL	**Evaluated vs. integrated log**
EW	**Electronic warfare**
EWO	**Electronic warfare officer**
EWWS	**Electronic warfare warning set**

F

F	**Degrees Fahrenheit**
FA	**Frequency agility**
FC	**Fire control**
FAAR	**Forward area alerting radar**
FAGC	**Fast automatic gain control**
FCR	**Fire control radar**
FCS	**Fire control system**
FEBA	**Forward edge of the battle area**
FFO	**Fixed frequency oscillator**
FFT	**Fast Fourier transform**
FLIR	**Forward looking infrared**
FM	**Frequency modulation**
FM-CW	**Frequency modulation continuous wave pulsed**
FMOP	**Frequency modulation on pulse**
FOJ	**Fuse-on-jam**
FOR	**Field of regard**
FOTD	**Fiber optic towed decoy**
FOV	**Field of view**
FRESCAN	**Frequency scanning**
FS	**Frequency sector**
FSK	**Frequency shift keying**
ft	**Feet**
FTC	**Fast time constant**

G

G	**Antenna gain/acceleration due to gravity**
GAS	**Ground aided seeker**
GCA	**Ground controlled approach**
GCI	**Ground controlled intercept**
GEN	**Generator**
GHz	**Gigahertz**

H

HARM	**High-speed antiradiation missile**
HAWK	**Homing all-the-way killer**
HBW	**Horizontal beam width**
HF	**High frequency/height finder**
HFDF	**High frequency direction finding**
HIPIR	**High-power illuminator radar**
HOJ	**Home-on-jam**
HOT	**Home-on-target**
HQ	**Headquarters**
HUMINT	**Human intelligence**
HVP	**High video pass**
HVPS	**High voltage power supply**
Hz	**Hertz**

I

I	**Improved**
IADS	**Integrated air defense system**
IAGC	**Instantaneous automatic gain control**
ICD	**Imitative communications deception**
ICW	**Interrupted continual wave**
IF	**Intermediate frequency**
IFC	**Instantaneous frequency correlator**
IFF	**Identification, friend or foe**
IPM	**Instantaneous position memory**
IR	**Infrared**
IRCM	**Infrared countermeasures**

J

JAT	**Jam angle track**
JAVA	**Jamming amplitude versus azimuth**
JCS	**Joint Chiefs of Staff**
JLT	**Jammer look-through**
J/S	**Jamming-to-signal (ratio)**
JTIDS	**Joint Tactical Information Distribution System**

K

K	**Degrees Kelvin**
kHz	**Kilohertz**
km	**Kilometer**

KO	**Keyed oscillation**
kV	**Kilovolts**
kW	**Kilowatts**

L

LASER	**Light amplification by stimulated emission of radiation**
LET	**Leading-edge tracker**
LF	**Low frequency**
LFMOP	**Linear frequency modulation on pulse (chirp)**
LIN	**Linear**
LIN-LOG	**Linear-logarithmic amplifier**
LLLTV	**Low light level television**
LO	**Local oscillator**
LOG	**Logarithmic**
LOG-FTC	**Logarithmic receiver with fast time constant**
LORO	**Lobe-on-receive-only**
LOS	**Line of sight**
LPI	**Low probability of intercept**
LT	**Listening time**
LVA	**Log video amplifier**

M

M	**Meter**
MALD	**Miniature air launched decoy**
MASER	**Microwave amplification by stimulated emission of radiation**
MANPADS	**Manportable air defense system**
MAWS	**Missile approach warning system**
MBB	**Main beam blanking**
MCG	**Midcourse guidance**
MCD	**Manipulative communications deception**
MDT	**Mission data type**
MDF	**Mission data file**
MDG	**Mission data generator**
MF	**Medium frequency**
MFAR	**Multifunction array radar**
MG	**Missile guidance**
MGC	**Manual gain control**
MHz	**Megahertz**
MIC	**Microwave integrated circuit**
MIJI	**Meaconing, Intrusion, Jamming, and Interference**
MLC	**Mainlobe cancellation**
MLV	**Memory loader verifier**
mm	**Millimeter**

MMIC	**Monolithic microwave integrated circuit**
MMW	**Millimeter wave**
MOE	**Measure of Effectiveness**
MOPA	**Master oscillator power amplifier**
msec	**Millisecond**
MTD	**Moving target detector**
MTI	**Moving target indicator**
MUX	**Multiplexer**
MW	**Megawatts**

N

NBFM	**Narrowband frequency modulation**
NBL	**Narrowband limiting**
NBLP	**Narrowband long pulse**
nm	**Nautical mile**
NLP	**Narrowband long pulse**
NOTAM	**Notice to airmen**
NSPS	**Nonsynchronous pulse suppression**

O

OFP	**Operational flight program**
OOB	**Order of battle**
OOK	**On-off keying**
OOK CW	**Interrupted CW**
OPDEC	**Operational deception**
OPSEC	**Operational security**
OTH	**Over-the-horizon**

P

PAM	**Pulse amplitude modulation**
PAR	**Pulse acquisition radar/precision approach radar**
PAT	**Passive angle track**
PC	**Pulse compression**
PCM	**Pulse code modulation**
PD	**Pulse Doppler/pulse duration (same as PW)**
PDM	**Pulse duration modulation**
PENAIDS	**Penetration aids**
PFM	**Pulse frequency modulation**
PFN	**Pulse-forming network**
PHOTOINT	**Photographic intelligence**
PIE	**Pulse interference elimination**

PISAB	**Pulse interference suppression and blanking**
PLD	**Pulse length discrimination (same as PWD)**
PM	**Phase modulation**
PN	**Pseudo noise**
PPC	**Pulse-to-pulse correlation**
PPI	**Plan position indicator**
PPM	**Pulse position modulation**
PPS	**Pulses per second**
PRF	**Pulse repetition frequency**
PRI	**Pulse repetition interval**
PRT	**Pulse recurrence time**
PSK	**Phase shift keying**
PW	**Pulse width**
PWD	**Pulse width discrimination**
PWM	**Pulse width modulation**

R

RADAR	**Radio detection and ranging**
RAGM	**Range angle gate memory**
RAM	**Radar absorbing material/repeater amplitude modulation**
RANRAP	**Random range program**
RC	**Resolution cell**
RCS	**Radar cross section**
RDF	**Radio direction finding**
RF	**Radio frequency**
RFD	**Radio frequency discriminator**
RFI	**Radio frequency interference**
RGM	**Range gate memory**
RGPI	**Range gate pull in**
RGPO	**Range gate pull off**
RHAW	**Radar homing and warning**
RHI	**Range height indicator**
ROB	**Radar order of battle**
ROR	**Range only radar**
R/P	**Receiver/processor**
RPD	**Random pulse discrimination**
RPJ	**Random pulse jamming**
RPM	**Revolutions per minute**
RPS	**Random pulse suppression**
RPV	**Remotely piloted vehicle**
RSBN	**Radio short-range beacon for navigation**
RT	**Recovery time**
R/T	**Receiver/transmitter**
RWR	**Radar warning receiver**

S

SAM	**Surface-to-air missile**
SAR	**Synthetic aperture radar**
SASE	**Semi-automatic support equipment**
SATCOM	**Satellite communications**
SBB	**Single beam blanking**
SCV	**Sub-clutter visibility**
SEAD	**Suppression of enemy air defenses**
sec	**Seconds**
SHF	**Super high frequency**
SIF	**Selective identification feature**
SIGINT	**Signals intelligence**
S/J	**Signal-to-jamming (ratio)**
SLAR	**Side-looking airborne radar**
SLB	**Sidelobe blanking**
SLC	**Sidelobe cancellation**
SLS	**Sidelobe suppression**
S/N	**Signal-to-noise (ratio)**
SOJ	**Stand-off jamming**
SORO	**Scan-on-receive-only**
SRM	**Swept rectangular modulation**
SS	**Swept-spot**
SSB	**Single sideband**
SSN	**Swept-spot noise/social security number**
SRW	**Swept rectangular wave**
SSW	**Swept square wave**
STALO	**Stable local oscillator**
STC	**Sensitivity time control**
SWC	**Scan with compensation**

T

TA	**Target acquisition**
TACAN	**Tactical air navigation**
TALD	**Tactical air launched decoy**
TBM	**Track break modulation**
TDD	**Target detection device**
TDOA	**Time difference of arrival**
TEL	**Transporter-erector-launcher**
TELAR	**Transporter-erector-launcher and radar**
TET	**Trailing edge tracker**
TEWS	**Tactical electronic warfare system**
TFR	**Terrain following radar**
TGT	**Target**
TJS	**Tactical jamming system**

TOA	**Time of arrival**
TOF	**Time of flight**
TOJ	**Track-on-jam**
TPL	**Transmitter pulse lengthening**
TPS	**Transmitter pulse shaping**
TTR	**Target tracking radar**
TV	**Television**
TVM	**Track-via-missile**
TWS	**Track-while-scan**
TWT	**Traveling wave tube**

U

UHF	**Ultra high frequency**
µsec	**Microseconds**

V

VCO	**Voltage controlled oscillator**
VDL	**Video data link**
VGPO	**Velocity gate pull off**
VHF	**Very high frequency**
VHSIC	**Very high speed integrate circuit**
VINT	**Video integration**
VLF	**Very low frequency**
VSRW	**VGPO with swept rectangular wave**
VSWR	**Voltage standing-wave ratio**

W

W	**Watts**
WBFM	**Wideband frequency modulation**
WBL	**Wideband limiting**
WPB	**Wide pulse blanking**
WSP	**Wideband short pulse**

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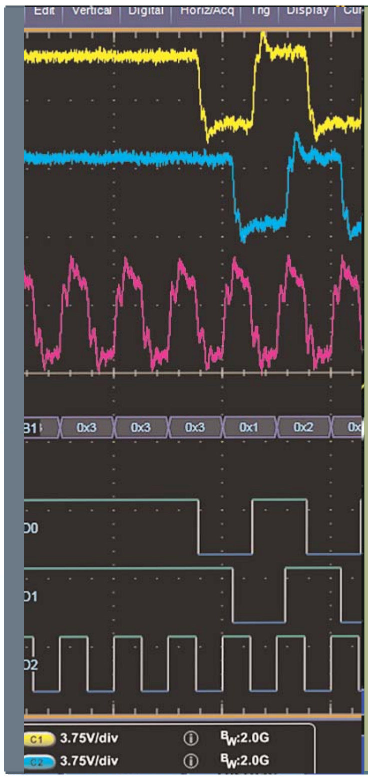
Edit
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Digital
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B1
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C2 3.75V/div
BW:2.0G
BW:2.0G

XYZs of Oscilloscopes

Primer

Tektronix®

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Introduction

Nature moves in the form of a sine wave, be it an ocean wave, earthquake, sonic boom, explosion, sound through air, or the natural frequency of a body in motion. Energy, vibrating particles and other invisible forces pervade our physical universe. Even light – part particle, part wave – has a fundamental frequency, which can be observed as color.

Sensors can convert these forces into electrical signals that you can observe and study with an oscilloscope. Oscilloscopes enable scientists, engineers, technicians, educators and others to "see" events that change over time.

Oscilloscopes are indispensable tools for anyone designing, manufacturing or repairing electronic equipment. In today's fast-paced world, engineers need the best tools available to solve their measurement challenges quickly and accurately. As the eyes of the engineer, oscilloscopes are the key to meeting today's demanding measurement challenges.

The usefulness of an oscilloscope is not limited to the world of electronics. With the proper sensor, an oscilloscope can measure all kinds of phenomena. A sensor is a device that creates an electrical signal in response to physical stimuli, such as sound, mechanical stress, pressure, light, or heat. A microphone is a sensor that converts sound into an electrical signal. Figure 1 shows an example of scientific data that can be gathered by an oscilloscope.

Oscilloscopes are used by everyone from physicists to repair technicians. An automotive engineer uses an oscilloscope to correlate analog data from sensors with serial data from the engine control unit. A medical researcher uses an oscillscope to measure brain waves. The possibilities are endless.

The concepts presented in this primer will provide you with a good starting point in understanding oscilloscope basics and operation.

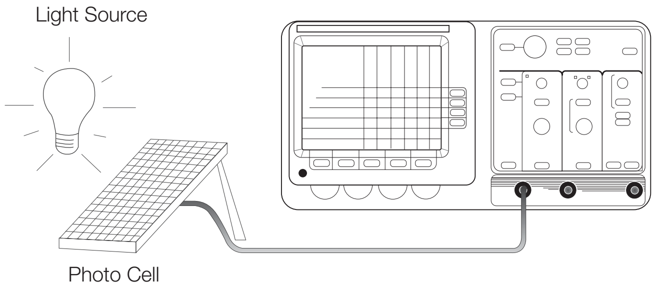

Figure 1. An example of scientific data gathered by an oscilloscope.

The glossary in the back of this primer will give you definitions of unfamiliar terms. The vocabulary and multiple-choice written exercises on oscilloscope theory and controls make this primer a useful classroom aid. No mathematical or electronics knowledge is necessary.

After reading this primer, you will be able to:

- Describe how oscilloscopes work
- Describe the differences between various oscilloscopes
- Describe electrical waveform types
- Understand basic oscilloscope controls
- Take simple measurements

The manual provided with your oscilloscope will give you more specific information about how to use the oscilloscope in your work. Some oscilloscope manufacturers also provide a multitude of application notes to help you optimize the oscilloscope for your application-specific measurements.

Should you need additional assistance, or have any comments or questions about the material in this primer, simply contact your Tektronix representative, or visit **www.tektronix.com**.

Signal Integrity

The Significance of Signal Integrity

The key to any good oscilloscope system is its ability to accurately reconstruct a waveform – referred to as signal integrity. An oscilloscope is analogous to a camera that captures signal images that we can then observe and interpret. Two key issues lie at the heart of signal integrity.

- When you take a picture, is it an accurate picture of what actually happened?
- Is the picture clear or fuzzy?
- How many of those accurate pictures can you take per second?

Taken together, the different systems and performance capabilities of an oscilloscope contribute to its ability to deliver the highest signal integrity possible. Probes also affect the signal integrity of a measurement system.

Signal integrity impacts many electronic design disciplines. But until a few years ago, it wasn't much of a problem for digital designers. They could rely on their logic designs to act like the Boolean circuits they were. Noisy, indeterminate signals were something that occurred in high-speed designs – something for RF designers to worry about. Digital systems switched slowly and signals stabilized predictably.

Processor clock rates have since multiplied by orders of magnitude. Computer applications such as 3D graphics, video and server I/O demand vast bandwidth. Much of today's telecommunications equipment is digitally based, and similarly requires massive bandwidth. So too does digital high-definition TV. The current crop of microprocessor devices handles data at rates up to 2, 3 and even 5 GS/s (gigasamples per second), while some DDR3 memory devices use clocks in excess of 2 GHz as well as data signals with 35 ps rise times.

Importantly, speed increases have trickled down to the common IC devices used in automobiles, consumer electronics, and machine controllers, to name just a few applications.

A processor running at a 20 MHz clock rate may well have signals with rise times similar to those of an 800 MHz processor. Designers have crossed a performance threshold that means, in effect, almost every design is a high-speed design.

Without some precautionary measures, high-speed problems can creep into otherwise conventional digital designs. If a circuit is experiencing intermittent failures, or if it encounters errors at voltage and temperature extremes, chances are there are some hidden signal integrity problems. These can affect time-to-market, product reliability, EMI compliance, and more. These high-speed problems can also impact the integrity of a serial data stream in a system, requiring some method of correlating specific patterns in the data with the observed characteristics of high-speed waveforms.

Why is Signal Integrity a Problem?

Let's look at some of the specific causes of signal degradation in today's digital designs. Why are these problems so much more prevalent today than in years past?

The answer is speed. In the "slow old days," maintaining acceptable digital signal integrity meant paying attention to details like clock distribution, signal path design, noise margins, loading effects, transmission line effects, bus termination, decoupling and power distribution. All of these rules still apply, but…

Bus cycle times are up to a thousand times faster than they were 20 years ago! Transactions that once took microseconds are now measured in nanoseconds. To achieve this improvement, edge speeds too have accelerated: they are up to 100 times faster than those of two decades ago.

This is all well and good; however, certain physical realities have kept circuit board technology from keeping up the pace. The propagation time of inter-chip buses has remained almost unchanged over the decades. Geometries have shrunk, certainly, but there is still a need to provide circuit board real estate for IC devices, connectors, passive components, and of course, the bus traces themselves. This real estate adds up to distance, and distance means time – the enemy of speed.

It's important to remember that the edge speed – rise time – of a digital signal can carry much higher frequency components than its repetition rate might imply. For this reason, some designers deliberately seek IC devices with relatively "slow" rise times.

The lumped circuit model has always been the basis of most calculations used to predict signal behavior in a circuit. But when edge speeds are more than four to six times faster than the signal path delay, the simple lumped model no longer applies.

Circuit board traces just six inches long become transmission lines when driven with signals exhibiting edge rates below four to six nanoseconds, irrespective of the cycle rate. In effect, new signal paths are created. These intangible connections aren't on the schematics, but nevertheless provide a means for signals to influence one another in unpredictable ways.

Sometimes even the errors introduced by the probe/instrument combination can provide a significant contribution to the signal being measured. However, by applying the "square root of the sum of the squares" formula to the measured value, it is possible to determine whether the device under test is approaching a rise/fall time failure. In addition, recent oscilloscope tools use special filtering techniques to de-embed the measurement system's effects on the signal, displaying edge times and other signal characteristics.

At the same time, the intended signal paths don't work the way they are supposed to. Ground planes and power planes, like the signal traces described above, become inductive and act like transmission lines; power supply decoupling is far less effective. EMI goes up as faster edge speeds produce shorter wavelengths relative to the bus length. Crosstalk increases.

In addition, fast edge speeds require generally higher currents to produce them. Higher currents tend to cause ground bounce, especially on wide buses in which many signals switch at once. Moreover, higher current increases the amount of radiated magnetic energy and with it, crosstalk.

Viewing the Analog Origins of Digital Signals

What do all these characteristics have in common? They are classic analog phenomena. To solve signal integrity problems, digital designers need to step into the analog domain. And to take that step, they need tools that can show them how digital and analog signals interact.

Digital errors often have their roots in analog signal integrity problems. To track down the cause of the digital fault, it's often necessary to turn to an oscilloscope, which can display waveform details, edges and noise; can detect and display transients; and can help you precisely measure timing relationships such as setup and hold times. Modern oscilloscopes can help to simplify the troubleshooting process by triggering on specific patterns in parallel or serial data streams and displaying the analog signal that corresponds in time with a specified event.

Understanding each of the systems within your oscilloscope and how to apply them will contribute to the effective application of the oscilloscope to tackle your specific measurement challenge.

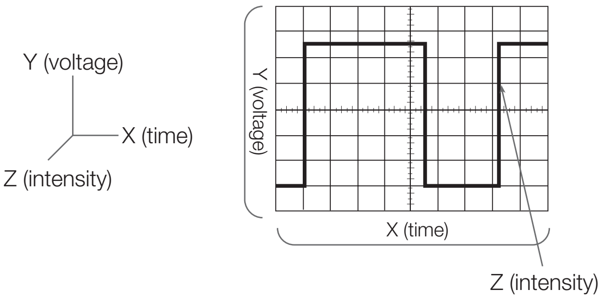

Figure 2. X, Y, and Z components of a displayed waveform.

The Oscilloscope

What is an oscilloscope and how does it work? This section answers these fundamental questions.

The oscilloscope is basically a graph-displaying device – it draws a graph of an electrical signal. In most applications, the graph shows how signals change over time: the vertical (Y) axis represents voltage and the horizontal (X) axis represents time. The intensity or brightness of the display is sometimes called the Z axis, as shown in Figure 2. In DPO oscilloscopes, the Z axis can be represented by color grading of the display, as seen in Figure 3.

This simple graph can tell you many things about a signal, such as:

- The time and voltage values of a signal
- The frequency of an oscillating signal
- The “moving parts” of a circuit represented by the signal
- The frequency with which a particular portion of the signal is occurring relative to other portions
- Whether or not a malfunctioning component is distorting the signal
- How much of a signal is direct current (DC) or alternating current (AC)
- How much of the signal is noise and whether the noise is changing with time

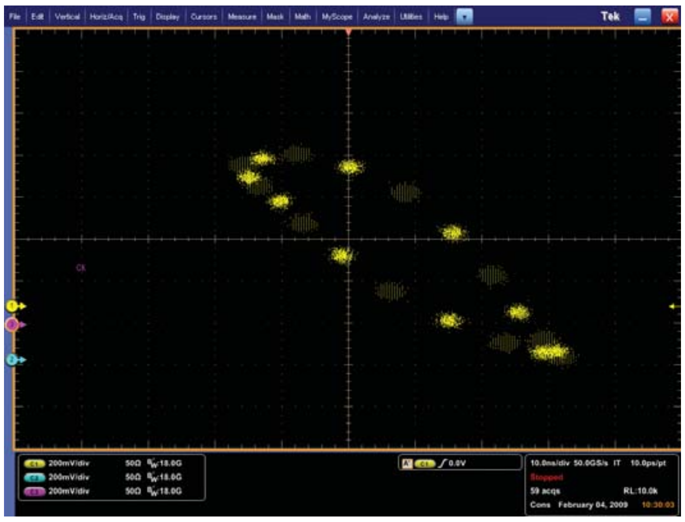

Figure 3. Two offset clock patterns with Z axis intensity grading.

Understanding Waveforms and Waveform Measurements

The generic term for a pattern that repeats over time is a wave – sound waves, brain waves, ocean waves, and voltage waves are all repetitive patterns. An oscilloscope measures voltage waves. Remember as mentioned earlier, that physical phenomena such as vibrations or temperature or electrical phenomena such as current or power can be converted to a voltage by a sensor. One cycle of a wave is the portion of the wave that repeats. A waveform is a graphic representation of a wave. A voltage waveform shows time on the horizontal axis and voltage on the vertical axis.

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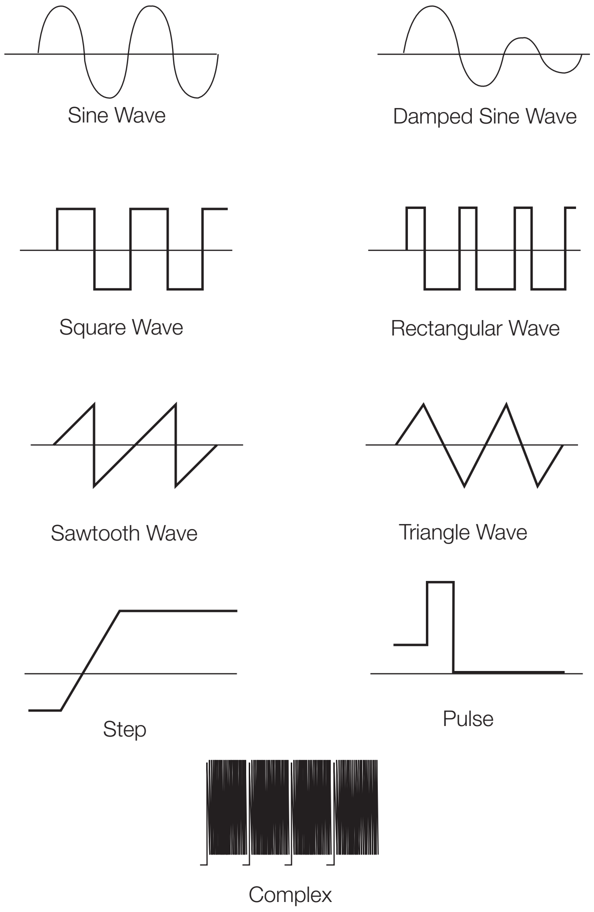
Sine Wave
Damped Sine Wave
Square Wave
Rectangular Wave
Sawtooth Wave
Triangle Wave
Step
Pulse
Complex

Figure 4. Common waveforms.

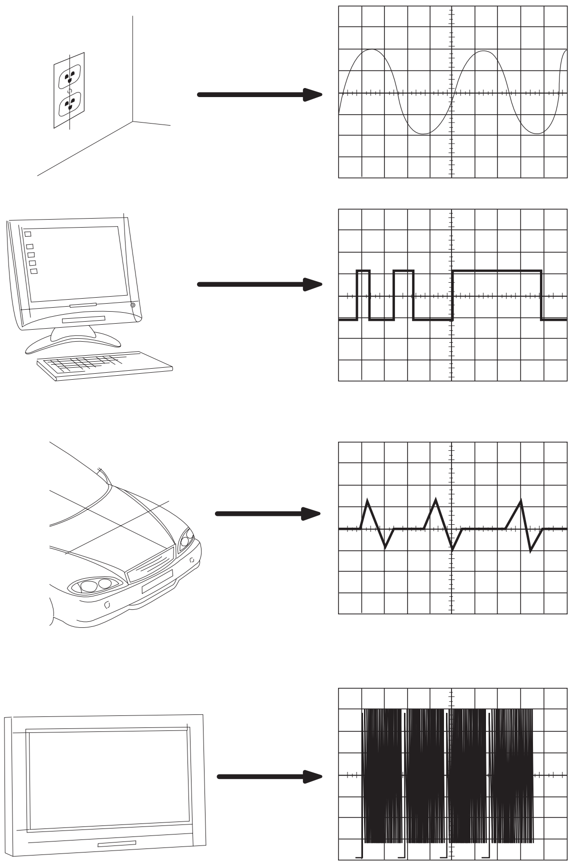

Figure 5. Sources of common waveforms.

Waveform shapes reveal a great deal about a signal. Any time you see a change in the height of the waveform, you know the voltage has changed. Any time there is a flat horizontal line, you know that there is no change for that length of time. Straight, diagonal lines mean a linear change – rise or fall of voltage at a steady rate. Sharp angles on a waveform indicate sudden change. Figure 4 shows common waveforms and Figure 5 displays sources of common waveforms.

Types of Waves

You can classify most waves into these types:

- Sine waves
- Square and rectangular waves
- Sawtooth and triangle waves
- Step and pulse shapes
- Periodic and non-periodic signals
- Synchronous and asynchronous signals
- Complex waves

Sine Waves

The sine wave is the fundamental wave shape for several reasons. It has harmonious mathematical properties – it is the same sine shape you may have studied in trigonometry class. The voltage in your wall outlet varies as a sine wave. Test signals produced by the oscillator circuit of a signal generator are often sine waves. Most AC power sources produce sine waves. (AC signifies alternating current, although the voltage alternates too. DC stands for direct current, which means a steady current and voltage, such as a battery produces.)

The damped sine wave is a special case you may see in a circuit that oscillates, but winds down over time.

Square and Rectangular Waves

The square wave is another common wave shape. Basically, a square wave is a voltage that turns on and off (or goes high and low) at regular intervals. It is a standard wave for testing amplifiers – good amplifiers increase the amplitude of a square wave with minimum distortion. Television, radio and computer circuitry often use square waves for timing signals.

The rectangular wave is like the square wave except that the high and low time intervals are not of equal length. It is particularly important when analyzing digital circuitry.

Sawtooth and Triangle Waves

Sawtooth and triangle waves result from circuits designed to control voltages linearly, such as the horizontal sweep of an analog oscilloscope or the raster scan of a television. The transitions between voltage levels of these waves change at a constant rate. These transitions are called ramps.

Step and Pulse Shapes

Signals such as steps and pulses that occur rarely, or non-periodically, are called single-shot or transient signals. A step indicates a sudden change in voltage, similar to the voltage change you would see if you turned on a power switch.

A pulse indicates sudden changes in voltage, similar to the voltage changes you would see if you turned a power switch on and then off again. A pulse might represent one bit of information traveling through a computer circuit or it might be a glitch, or defect, in a circuit. A collection of pulses traveling together creates a pulse train. Digital components in a computer communicate with each other using pulses. These pulses may be in the form of serial data stream or multiple signal lines may be used to represent a value in a parallel data bus. Pulses are also common in x-ray, radar, and communications equipment.

Periodic and Non-periodic Signals

Repetitive signals are referred to as periodic signals, while signals that constantly change are known as non-periodic signals. A still picture is analogous to a periodic signal, while a moving picture can be equated to a non-periodic signal.

Synchronous and Asynchronous Signals

When a timing relationship exists between two signals, those signals are referred to as synchronous. Clock, data and address signals inside a computer are an example of synchronous signals.

Asynchronous is a term used to describe those signals between which no timing relationship exists. Because no time correlation exists between the act of touching a key on a computer keyboard and the clock inside the computer, these are considered asynchronous.

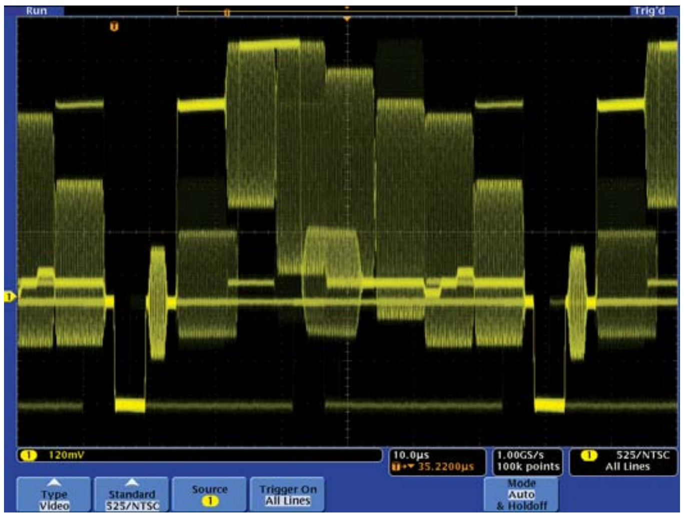
Run
Trig'd
1 120mV
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35.2200µs
1.00GS/s
100k points
1 525/NTSC
All Lines
Type
Video
Standard
525/NTSC
Source
1
Trigger On
All Lines
Mode
Auto
& Holdoff

Figure 6. An NTSC composite video signal is an example of a complex wave.

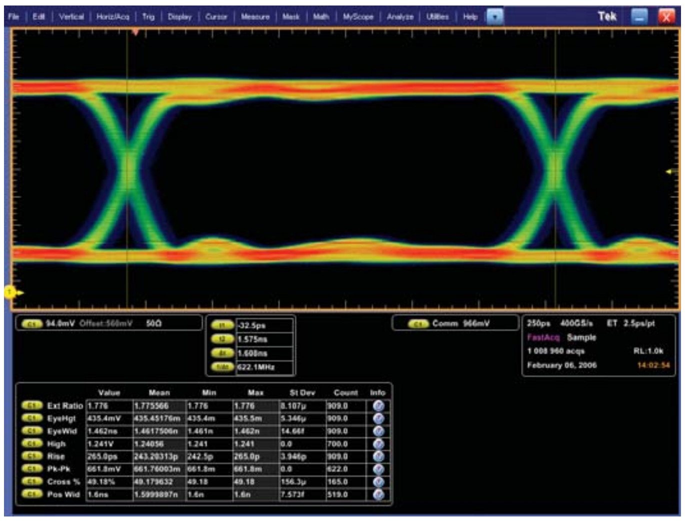
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Vertical
Horiz/Acq
Trig
Display
Cursor
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
C1 94.0mV Offset:560mV 50Ω
-32.5ps
1.575ns
1.608ns
622.1MHz
C1 Comm 966mV
250ps 400GS/s ET 2.5ps/pt
FastAcq Sample
1 008 960 acqs RL:1.0k
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	Value	Mean	Min	Max	St Dev	Count	Info
C1 Ext Ratio	1.776	1.775566	1.776	1.776	8.107µ	909.0	
C1 EyeHgt	435.4mV	435.45176m	435.4m	435.5m	5.346µ	909.0	
C1 EyeWid	1.462ns	1.4617506n	1.461n	1.462n	14.66f	909.0	
C1 High	1.241V	1.24056	1.241	1.241	0.0	700.0	
C1 Rise	265.0ps	243.20313p	242.5p	265.0p	3.946p	909.0	
C1 Pk-Pk	661.8mV	661.76003m	661.8m	661.8m	0.0	622.0	
C1 Cross %	49.18%	49.179632	49.18	49.18	156.3µ	165.0	
C1 Pos Wid	1.6ns	1.5999897n	1.6n	1.6n	7.573f	519.0	

Figure 7. 622 Mb/s serial data eye pattern.

Complex Waves

Some waveforms combine the characteristics of sines, squares, steps, and pulses to produce complex waveshapes. The signal information may be embedded in the form of amplitude, phase, and/or frequency variations. For example, although the signal in Figure 6 is an ordinary composite video signal, it is composed of many cycles of higher-frequency waveforms embedded in a lower-frequency envelope.

In this example, it is usually most important to understand the relative levels and timing relationships of the steps. To view this signal, you need an oscilloscope that captures the low-frequency envelope and blends in the higher-frequency waves in an intensity-graded fashion so that you can see their overall combination as an image that can be visually interpreted. Digital phosphor oscilloscopes are most suited to viewing complex waves, such as video signals, illustrated in Figure 6. Their displays provide the necessary frequency-of-occurrence information, or intensity grading, that is essential to understanding what the waveform is really doing.

Some oscilloscopes allow for displaying certain types of complex waveforms in special ways. For example, telecommunications data may be displayed as an eye pattern or a constellation diagram.

Telecommunications digital data signals can be displayed on an oscilloscope as a special type of waveform referred to as an eye pattern. The name comes from the similarity of the waveform to a series of eyes, as seen in Figure 7. Eye patterns are produced when digital data from a receiver is sampled and applied to the vertical input, while the data rate is used to trigger the horizontal sweep. The eye pattern displays one bit or unit interval of data with all possible edge transitions and states superimposed in one comprehensive view.

A constellation diagram is a representation of a signal modulated by a digital modulation scheme such as quadrature amplitude modulation or phase-shift keying.

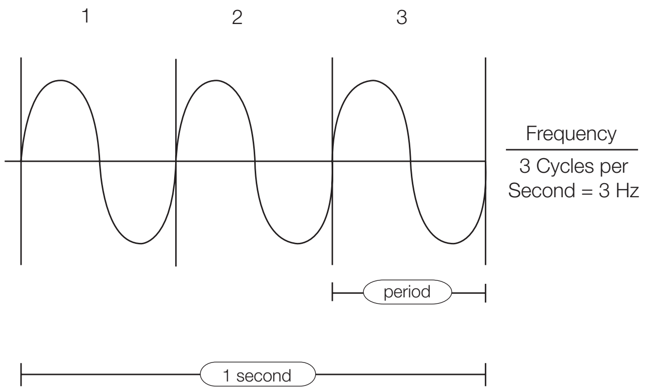

Figure 8. Frequency and period of a sine wave.

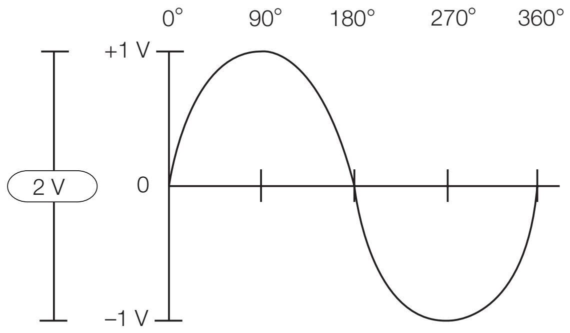

Figure 9. Amplitude and degrees of a sine wave.

Waveform Measurements

Many terms are used to describe the types of measurements that you make with your oscilloscope. This section describes some of the most common measurements and terms.

Frequency and Period

If a signal repeats, it has a frequency. The frequency is measured in Hertz (Hz) and equals the number of times the signal repeats itself in one second, referred to as cycles per second. A repetitive signal also has a period, which is the amount of time it takes the signal to complete one cycle. Period and frequency are reciprocals of each other, so that 1/period equals the frequency and 1/frequency equals the period. For example, the sine wave in Figure 8 has a frequency of 3 Hz and a period of 1/3 second.

Voltage

Voltage is the amount of electric potential, or signal strength, between two points in a circuit. Usually, one of these points is ground, or zero volts, but not always. You may want to measure the voltage from the maximum peak to the minimum peak of a waveform, referred to as the peak-to-peak voltage.

Amplitude

Amplitude refers to the amount of voltage between two points in a circuit. Amplitude commonly refers to the maximum voltage of a signal measured from ground, or zero volts. The waveform shown in Figure 9 has an amplitude of 1 V and a peak-to-peak voltage of 2 V.

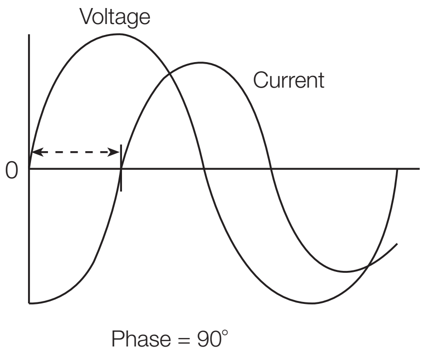

Figure 10. Phase shift.

Phase

Phase is best explained by looking at a sine wave. The voltage level of sine waves is based on circular motion. Given that a circle has 360°, one cycle of a sine wave has 360°, as shown in Figure 9. Using degrees, you can refer to the phase angle of a sine wave when you want to describe how much of the period has elapsed.

Phase shift describes the difference in timing between two otherwise similar signals. The waveform in Figure 10 labeled “current” is said to be 90° out of phase with the waveform labeled “voltage,” since the waves reach similar points in their cycles exactly 1/4 of a cycle apart (360°/4 = 90°). Phase shifts are common in electronics.

Waveform Measurements with Digital Oscilloscopes

Modern digital oscilloscopes have functions that make waveform measurements easier. They have front-panel buttons and/or screen-based menus from which you can select fully automated measurements. These include amplitude, period, rise/fall time, and many more. Many digital instruments also provide mean and RMS calculations, duty cycle, and other math operations. Automated measurements appear as on-screen alphanumeric readouts. Typically these readings are more accurate than is possible to obtain with direct graticule interpretation.

Examples of fully automated waveform measurements:

- Period
- Frequency
- Width +
- Width -
- Rise time
- Fall time
- Amplitude
- Extinction ratio
- Mean optical power
- Duty Cycle +
- Duty Cycle -
- Delay
- Phase
- Burst width
- Peak-to-peak
- Mean
- Cycle mean
- Cycle area
- High
- Low
- Minimum
- Maximum
- Overshoot +
- Overshoot -
- RMS
- Cycle RMS
- Jitter

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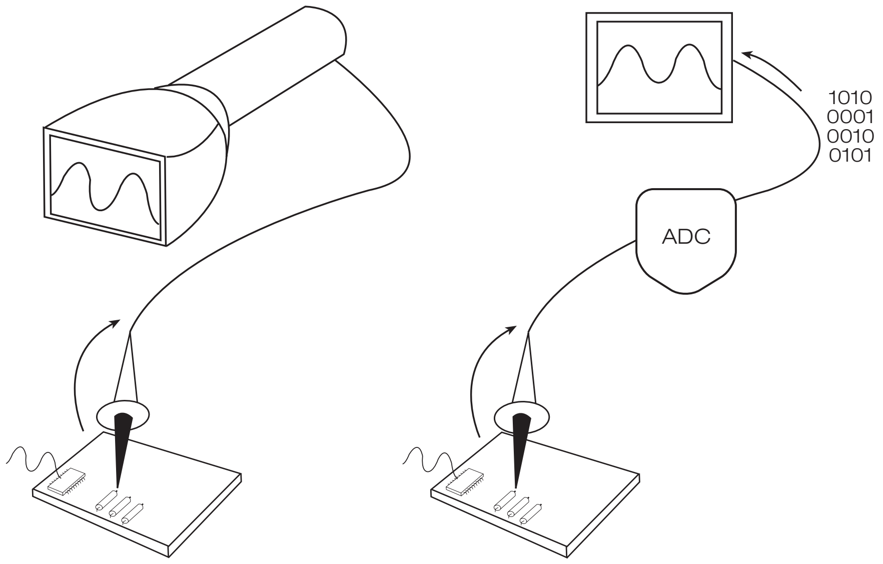

Analog Oscilloscopes Trace Signals

Digital Oscilloscopes Samples Signals and Construct Displays

Figure 11. Analog oscilloscopes trace signals, while digital oscilloscopes sample signals and construct displays.

The Types of Oscilloscopes

Electronic equipment can be classified into two categories: analog and digital. Analog equipment works with continuously variable voltages, while digital equipment works with discrete binary numbers that represent voltage samples. A conventional phonograph is an analog device, while a compact disc player is a digital device.

Oscilloscopes can be classified similarly – as analog and digital types. In contrast to an analog oscilloscope, a digital oscilloscope uses an analog-to-digital converter (ADC) to convert the measured voltage into digital information. It acquires the waveform as a series of samples, and stores these samples until it accumulates enough samples to describe a waveform. The digital oscilloscope then re-assembles the waveform for display on the screen, as seen in Figure 11.

Digital oscilloscopes can be classified into digital storage oscilloscopes (DSOs), digital phosphor oscilloscopes (DPOs), mixed signal oscilloscopes (MSOs), and digital sampling oscilloscopes.

The digital approach means that the oscilloscope can display any frequency within its range with stability, brightness, and clarity. For repetitive signals, the bandwidth of the digital oscilloscope is a function of the analog bandwidth of the front-end components of the oscilloscope, commonly referred to as the –3 dB point. For single-shot and transient events, such as pulses and steps, the bandwidth can be limited by the oscilloscope's sample rate. Please refer to the Sample Rate section under Performance Terms and Considerations for a more detailed discussion.

Digital Storage Oscilloscopes

A conventional digital oscilloscope is known as a digital storage oscilloscope (DSO). Its display typically relies on a raster-type screen rather than the luminous phosphor found in an older analog oscilloscope.

Digital storage oscilloscopes (DSOs) allow you to capture and view events that may happen only once – known as transients. Because the waveform information exists in digital form as a series of stored binary values, it can be analyzed, archived, printed, and otherwise processed, within the oscilloscope itself or by an external computer. The waveform need not be continuous; it can be displayed even when the signal disappears. Unlike analog oscilloscopes, digital storage oscilloscopes provide permanent signal storage and extensive waveform processing. However, DSOs typically have no real-time intensity grading; therefore, they cannot express varying levels of intensity in the live signal.

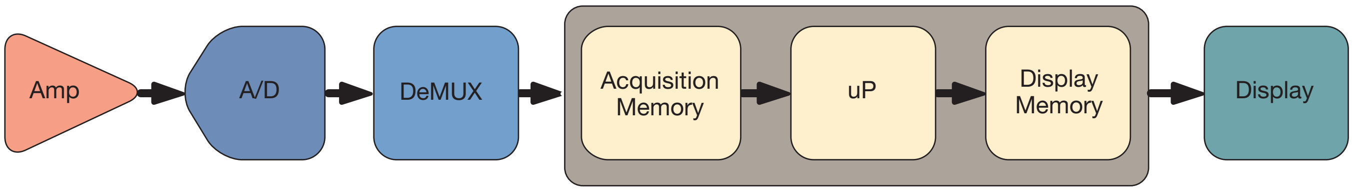

Figure 12. The serial-processing architecture of a digital storage oscilloscope (DSO).

Some of the subsystems that comprise DSOs are similar to those in analog oscilloscopes. However, DSOs contain additional data-processing subsystems that are used to collect and display data for the entire waveform. A DSO employs a serial-processing architecture to capture and display a signal on its screen, as shown in Figure 12. A description of this serial-processing architecture follows.

Serial-processing Architecture

Like an analog oscilloscope, a DSO's first (input) stage is a vertical amplifier. Vertical controls allow you to adjust the amplitude and position range at this stage. Next, the analog-to-digital converter (ADC) in the horizontal system samples the signal at discrete points in time and converts the signal's voltage at these points into digital values called sample points. This process is referred to as digitizing a signal.

The horizontal system's sample clock determines how often the ADC takes a sample. This rate is referred to as the sample rate and is expressed in samples per second (S/s).

The sample points from the ADC are stored in acquisition memory as waveform points. Several sample points may comprise one waveform point. Together, the waveform points comprise one waveform record. The number of waveform points used to create a waveform record is called the record length. The trigger system determines the start and stop points of the record.

The DSO's signal path includes a microprocessor through which the measured signal passes on its way to the display. This microprocessor processes the signal, coordinates display activities, manages the front panel controls, and more. The signal then passes through the display memory and is displayed on the oscilloscope screen.

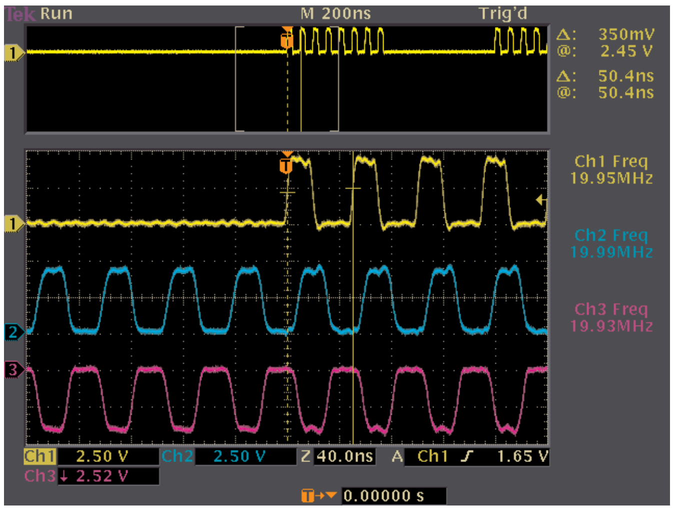

Figure 13. The digital storage oscilloscope delivers high-speed, single-shot acquisition across multiple channels, increasing the likelihood of capturing elusive glitches and transient events.

Depending on the capabilities of your oscilloscope, additional processing of the sample points may take place, which enhances the display. Pre-trigger may also be available, enabling you to see events before the trigger point. Most of today's digital oscilloscopes also provide a selection of automatic parametric measurements, simplifying the measurement process.

As shown in Figure 13, a DSO provides high performance in a single-shot, multi-channel instrument. DSOs are ideal for low-repetition-rate or single-shot, high-speed, multi-channel design applications. In the real world of digital design, an engineer usually examines four or more signals simultaneously, making the DSO a critical companion.

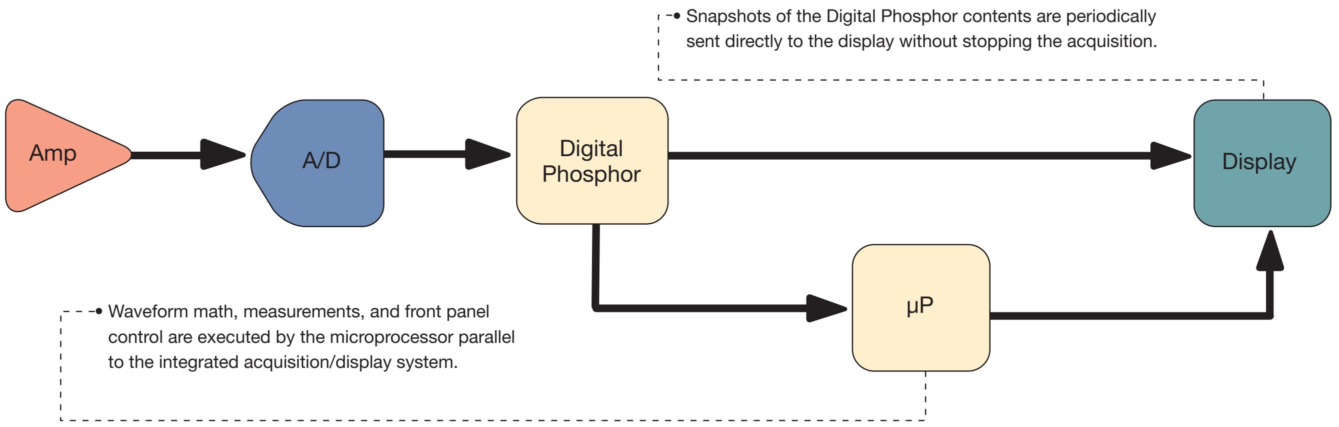

Snapshots of the Digital Phosphor contents are periodically sent directly to the display without stopping the acquisition.

Waveform math, measurements, and front panel control are executed by the microprocessor parallel to the integrated acquisition/display system.

Figure 14. The parallel-processing architecture of a digital phosphor oscilloscope (DPO).

Digital Phosphor Oscilloscopes

The digital phosphor oscilloscope (DPO) offers a new approach to oscilloscope architecture. This architecture enables a DPO to deliver unique acquisition and display capabilities to accurately reconstruct a signal.

While a DSO uses a serial-processing architecture to capture, display and analyze signals, a DPO employs a parallel-processing architecture to perform these functions, as shown in Figure 14. The DPO architecture dedicates unique ASIC hardware to acquire waveform images, delivering high waveform capture rates that result in a higher level of signal visualization. This performance increases the probability of witnessing transient events that occur in digital systems, such as runt pulses, glitches and transition errors, and enables additional analysis capability. A description of this parallel-processing architecture follows.

Parallel-processing Architecture

A DPO's first (input) stage is similar to that of an analog oscilloscope – a vertical amplifier – and its second stage is similar to that of a DSO – an ADC. But, the DPO differs significantly from its predecessors following the analog-to-digital conversion.

For any oscilloscope – analog, DSO or DPO – there is always a holdoff time during which the instrument processes the most recently acquired data, resets the system, and waits for the next trigger event. During this time, the oscilloscope is blind to all signal activity. The probability of seeing an infrequent or low-repetition event decreases as the holdoff time increases.

It should be noted that it is impossible to determine the probability of capture by simply looking at the display update rate. If you rely solely on the update rate, it is easy to make the mistake of believing that the oscilloscope is capturing all pertinent information about the waveform when, in fact, it is not.

The digital storage oscilloscope processes captured waveforms serially. The speed of its microprocessor is a bottleneck in this process because it limits the waveform capture rate.

The DPO rasterizes the digitized waveform data into a digital phosphor database. Every 1/30th of a second – about as fast as the human eye can perceive it – a snapshot of the signal image that is stored in the database is pipelined directly to the display system. This direct rasterization of waveform data, and direct copy to display memory from the database, removes the data-processing bottleneck inherent in other architectures. The result is an enhanced "real-time" and lively display update. Signal details, intermittent events, and dynamic characteristics of the signal are captured in real-time. The DPO's microprocessor works in parallel with this integrated acquisition system for display management, measurement automation and instrument control, so that it does not affect the oscilloscope's acquisition speed.

A DPO faithfully emulates the best display attributes of an analog oscilloscope, displaying the signal in three dimensions: time, amplitude and the distribution of amplitude over time, all in real-time.

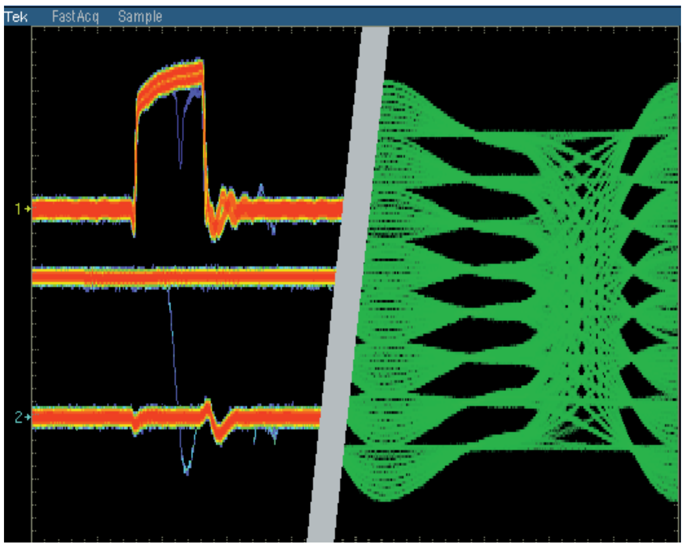

Figure 15. Some DPOs can acquire millions of waveform in just seconds, significantly increasing the probability of capturing intermittent and elusive events and revealing dynamic signal behavior.

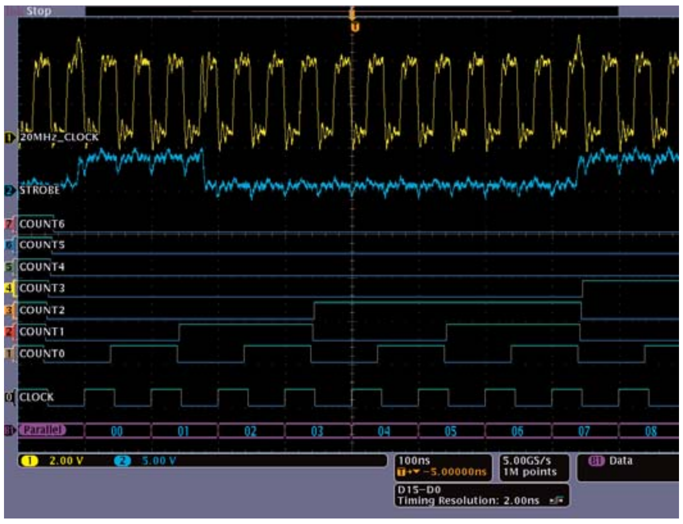

Figure 16. The MSO provides 16 integrated digital channels, enabling the ability to view and analyze time-correlated analog and digital signals.

Unlike an analog oscilloscope's reliance on chemical phosphor, a DPO uses a purely electronic digital phosphor that's actually a continuously updated database. This database has a separate "cell" of information for every single pixel in the oscilloscope's display. Each time a waveform is captured – in other words, every time the oscilloscope triggers – it is mapped into the digital phosphor database's cells. Each cell that represents a screen location and is touched by the waveform is reinforced with intensity information, while other cells are not. Thus, intensity information builds up in cells where the waveform passes most often.

When the digital phosphor database is fed to the oscilloscope's display, the display reveals intensified waveform areas, in proportion to the signal's frequency of occurrence at each point – much like the intensity grading characteristics of an analog oscilloscope. The DPO also allows the display of the varying frequency-of-occurrence information on the display as contrasting colors, unlike an analog oscilloscope. With a DPO, it is easy to see the difference between a waveform that occurs on almost every trigger and one that occurs, say, every 100th trigger.

Digital phosphor oscilloscopes (DPOs) break down the barrier between analog and digital oscilloscope technologies. They are equally suitable for viewing high and low frequencies, repetitive waveforms, transients, and signal variations in real-time. Only a DPO provides the Z (intensity) axis in real-time that is missing from conventional DSOs.

A DPO is ideal for those who need the best general-purpose design and troubleshooting tool for a wide range of applications, as seen in Figure 15. A DPO is exemplary for advanced analysis, communication mask testing, digital debug of intermittent signals, repetitive digital design and timing applications.

Mixed Signal Oscilloscopes

The mixed signal oscilloscope (MSO) combines the performance of a DPO with the basic functionality of a 16-channel logic analyzer, including parallel/serial bus protocol decoding and triggering. The MSO's digital channels view a digital signal as either a logic high or logic low, just like a digital circuit views the signal. This means as long as ringing, overshoot and ground bounce do not cause logic transitions, these analog characteristics are not of concern to the MSO. Just like a logic analyzer, a MSO uses a threshold voltage to determine if the signal is logic high or logic low.

The MSO is the tool of choice for quickly debugging digital circuits using its powerful digital triggering, high resolution acquisition capability, and analysis tools. The root cause of many digital problems is quicker to pinpoint by analyzing both the analog and digital representations of the signal, as shown in Figure 16, making a MSO ideal for verifying and debugging digital circuits.

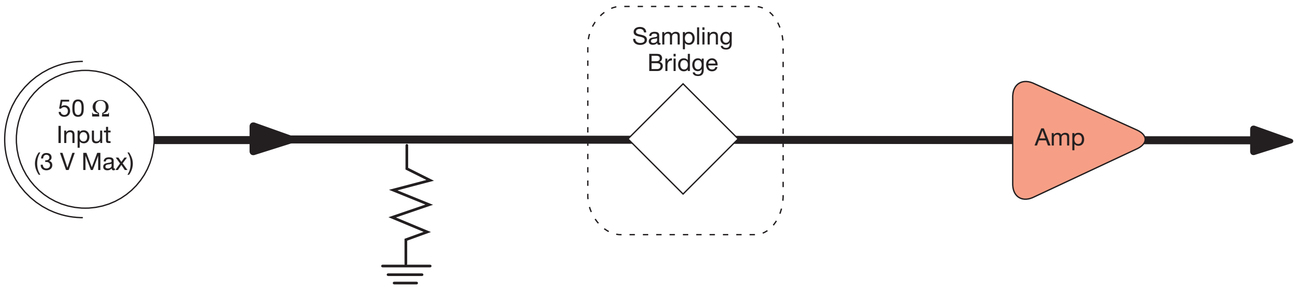

Figure 17. The architecture of a digital sampling oscilloscope.

Digital Sampling Oscilloscopes

In contrast to the digital storage and digital phosphor oscilloscope architectures, the architecture of the digital sampling oscilloscope reverses the position of the attenuator/amplifier and the sampling bridge, as shown in Figure 17. The input signal is sampled before any attenuation or amplification is performed. A low bandwidth amplifier can then be utilized after the sampling bridge because the signal has already been converted to a lower frequency by the sampling gate, resulting in a much higher bandwidth instrument.

The tradeoff for this high bandwidth, however, is that the sampling oscilloscope's dynamic range is limited. Since there is no attenuator/amplifier in front of the sampling gate, there is no facility to scale the input. The sampling bridge must be able to handle the full dynamic range of the input at all times. Therefore, the dynamic range of most sampling oscilloscopes is limited to about 1 V peak-to-peak. Digital storage and digital phosphor oscilloscopes, on the other hand, can handle 50 to 100 volts.

In addition, protection diodes cannot be placed in front of the sampling bridge as this would limit the bandwidth. This reduces the safe input voltage for a sampling oscilloscope to about 3 V, as compared to 500 V available on other oscilloscopes.

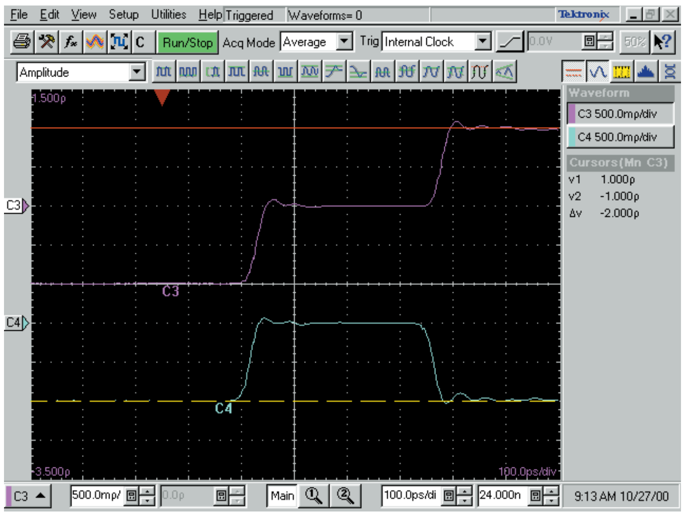

Acq Mode Average

Trig Internal Clock

C3 500.0mp/div

C4 500.0mp/div

v1 1.000p

v2 -1.000p

Δv -2.000p

C3 500.0mp/ 0.0p

100.0ps/di 24.000n

Figure 18. Time domain reflectometry (TDR) display from a digital sampling oscilloscope.

When measuring high-frequency signals, the DSO or DPO may not be able to collect enough samples in one sweep. A digital sampling oscilloscope is an ideal tool for accurately capturing signals whose frequency components are much higher than the oscilloscope's sample rate, as seen in Figure 18. This oscilloscope is capable of measuring signals of up to an order of magnitude faster than any other oscilloscope. It can achieve bandwidth and high-speed timing ten times higher than other oscilloscopes for repetitive signals. Sequential equivalent-time sampling oscilloscopes are available with bandwidths to 80 GHz.

The Systems and Controls of an Oscilloscope

This section briefly describes the basic systems and controls found on analog and digital oscilloscopes. Some controls differ between analog and digital oscilloscopes; your oscilloscope probably has additional controls not discussed here.

A basic oscilloscope consists of four different systems – the vertical system, horizontal system, trigger system, and display system. Understanding each of these systems will enable you to effectively apply the oscilloscope to tackle your specific measurement challenges. Recall that each system contributes to the oscilloscope's ability to accurately reconstruct a signal.

The front panel of an oscilloscope is divided into three main sections labeled vertical, horizontal, and trigger. Your oscilloscope may have other sections, depending on the model and type. See if you can locate these front-panel sections in Figure 19, and on your oscilloscope, as you read through this section.

When using an oscilloscope, you need to adjust three basic settings to accommodate an incoming signal:

- Vertical: The attenuation or amplification of the signal. Use the volts/div control to adjust the amplitude of the signal to the desired measurement range.
- Horizontal: The time base. Use the sec/div control to set the amount of time per division represented horizontally across the screen.
- Trigger: The triggering of the oscilloscope. Use the trigger level to stabilize a repeating signal, or to trigger on a single event.

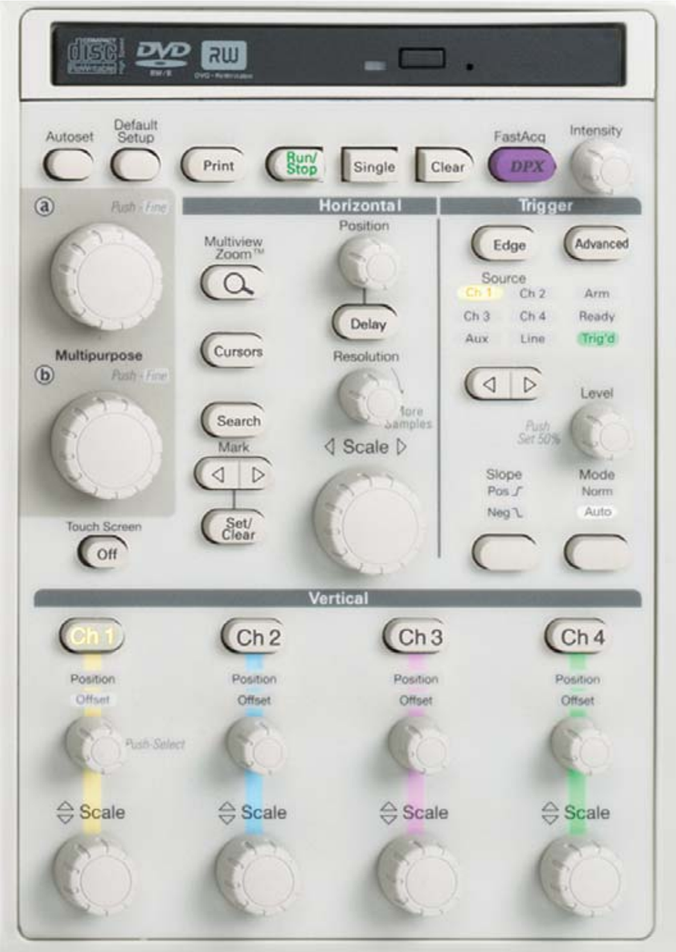
DVD
RW
Autoset
Default Setup
Print
Run/Stop
Single
Clear
FastAcq
DPX
Intensity
Horizontal
Trigger
Multipurpose
Multiview Zoom
Position
Delay
Resolution
Edge
Advanced
Source
Ch 1
Ch 2
Arm
Ch 3
Ch 4
Ready
Aux
Line
Trig'd
Cursors
Search
Mark
Scale
Level
Slope
Pos
Neg
Mode
Norm
Auto
Touch Screen
Off
Set/Clear
Vertical
Ch 1
Ch 2
Ch 3
Ch 4
Position
Offset
Scale

Figure 19. Front-panel control section of an oscilloscope.

Common vertical controls include:

- Termination
  - 1M ohm
  - 50 ohm
- Coupling
  - DC
  - AC
  - GND
- Bandwidth
  - Limit
  - Enhancement
- Position
- Offset
- Invert – On/Off
- Scale
  - Fixed steps
  - Variable

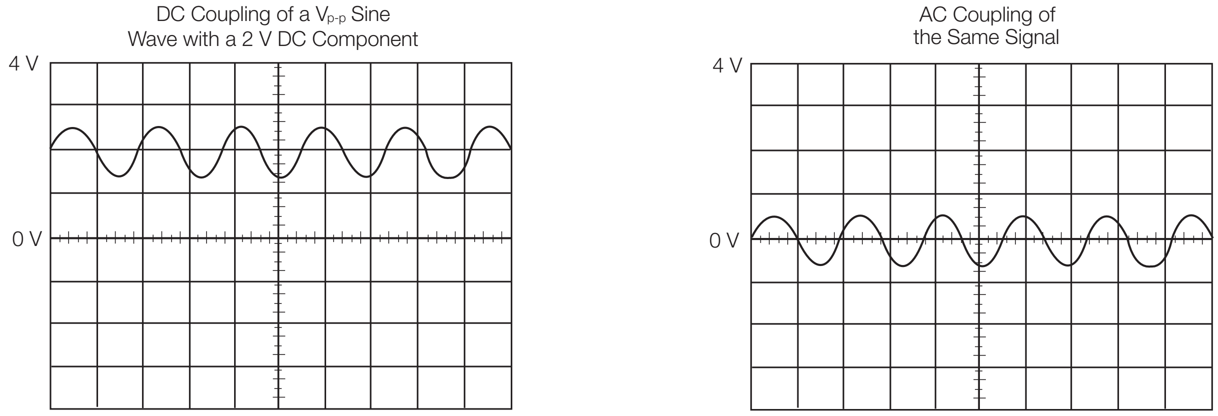

Figure 20. AC and DC input coupling.

Vertical System and Controls

Vertical controls can be used to position and scale the waveform vertically, set the input coupling, and adjust other signal conditioning.

Position and Volts per Division

The vertical position control allows you to move the waveform up and down exactly where you want it on the screen.

The volts-per-division setting (usually written as volts/div) is a scaling factor that varies the size of the waveform on the screen. If the volts/div setting is 5 volts, then each of the eight vertical divisions represents 5 volts and the entire screen can display 40 volts from bottom to top, assuming a graticule with eight major divisions. If the setting is 0.5 volts/div, the screen can display 4 volts from bottom to top, and so on. The maximum voltage you can display on the screen is the volts/div setting multiplied by the number of vertical divisions. Note that the probe you use, 1X or 10X, also influences the scale factor. You must divide the volts/div scale by the attenuation factor of the probe if the oscilloscope does not do it for you.

Often the volts/div scale has either a variable gain or a fine gain control for scaling a displayed signal to a certain number of divisions. Use this control to assist in taking rise time measurements.

Input Coupling

Coupling refers to the method used to connect an electrical signal from one circuit to another. In this case, the input coupling is the connection from your test circuit to the oscilloscope. The coupling can be set to DC, AC, or ground. DC coupling shows all of an input signal. AC coupling blocks the DC component of a signal so that you see the waveform centered around zero volts. Figure 20 illustrates this difference. The AC coupling setting is useful when the entire signal (alternating current + direct current) is too large for the volts/div setting.

The ground setting disconnects the input signal from the vertical system, which lets you see where zero volts is located on the screen. With grounded input coupling and auto trigger mode, you see a horizontal line on the screen that represents zero volts. Switching from DC to ground and back again is a handy way of measuring signal voltage levels with respect to ground.

Bandwidth Limit

Most oscilloscopes have a circuit that limits the bandwidth of the oscilloscope. By limiting the bandwidth, you reduce the noise that sometimes appears on the displayed waveform, resulting in a cleaner signal display. Note that, while eliminating noise, the bandwidth limit can also reduce or eliminate high-frequency signal content.

Bandwidth Enhancement

Some oscilloscopes may provide a DSP arbitrary equalization filter which can be used to improve the oscilloscope channel response. This filter extends the bandwidth, flattens the oscilloscope channel frequency response, improves phase linearity, and provides a better match between channels. It also decreases rise time and improves the time domain step response.

Horizontal System and Controls

An oscilloscope's horizontal system is most closely associated with its acquisition of an input signal – sample rate and record length are among the considerations here. Horizontal controls are used to position and scale the waveform horizontally.

Acquisition Controls

Digital oscilloscopes have settings that let you control how the acquisition system processes a signal. Look over the acquisition options on your digital oscilloscope while you read this description. Figure 21 shows you an example of an acquisition menu.

Acquisition Modes

Acquisition modes control how waveform points are produced from sample points. Sample points are the digital values derived directly from the analog-to-digital converter (ADC). The sample interval refers to the time between these sample points. Waveform points are the digital values that are stored in memory and displayed to construct the waveform. The time value difference between waveform points is referred to as the waveform interval.

Common horizontal controls include:

- Time Base
- XY
- Scale
- Trace Separation
- Record Length
- Resolution
- Sample Rate
- Trigger Position
- Zoom/Pan
- Search

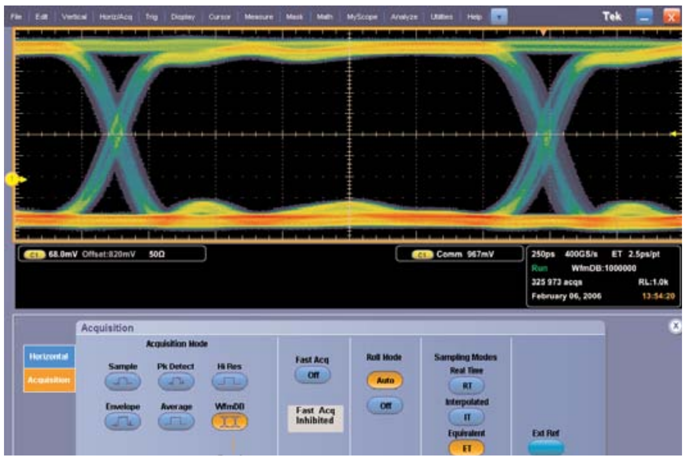
File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursor
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
C1 68.0mV Offset:820mV 50Ω
C1 Comm 967mV
250ps 400GS/s ET 2.5ps/pt
Run WfmDB:1000000
325 973 acqs RL:1.0k
February 06, 2006 13:54:20
Acquisition
Horizontal
Acquisition
Acquisition Mode
Sample
Pk Detect
Hi Res
Envelope
Average
WfmDB
Fast Acq
Off
Fast Acq Inhibited
Roll Mode
Auto
Off
Sampling Modes
Real Time
RT
Interpolated
IT
Equivalent
ET
Ext Ref

Figure 21. Example of an acquisition menu.

The sample interval and the waveform interval may, or may not, be the same. This fact leads to the existence of several different acquisition modes in which one waveform point is comprised of several sequentially acquired sample points.

Additionally, waveform points can be created from a composite of sample points taken from multiple acquisitions, which provides another set of acquisition modes. A description of the most commonly used acquisition modes follows.

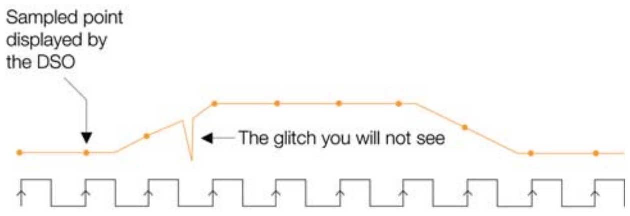
Sampled point displayed by the DSO
The glitch you will not see

Figure 22. Sample rate varies with time base settings - the slower the time based setting, the slower the sample rate. Some digital oscilloscopes provide peak detect mode to capture fast transients at slow sweep speeds.

Types of Acquisition Modes

- Sample Mode: This is the simplest acquisition mode. The oscilloscope creates a waveform point by saving one sample point during each waveform interval.
- Peak Detect Mode: The oscilloscope saves the minimum and maximum value sample points taken during two waveform intervals and uses these samples as the two corresponding waveform points. Digital oscilloscopes with peak detect mode run the ADC at a fast sample rate, even at very slow time base settings (slow time base settings translate into long waveform intervals) and are able to capture fast signal changes that would occur between the waveform points if in sample mode, as shown in Figure 22. Peak detect mode is particularly useful for seeing narrow pulses spaced far apart in time, as demonstrated in Figure 23.
- Hi-Res Mode: Like peak detect, hi res mode is a way of getting more information in cases when the ADC can sample faster than the time base setting requires. In this case, multiple samples taken within one waveform interval are averaged together to produce one waveform point. The result is a decrease in noise and an improvement in resolution for low-speed signals. The advantage of Hi Res Mode over Average is that Hi-Res Mode can be used even on a single shot event.
- Envelope Mode: Envelope mode is similar to peak detect mode. However, in envelope mode, the minimum and maximum waveform points from multiple acquisitions are combined to form a waveform that shows min/max accumulation over time. Peak detect mode is usually used to acquire the records that are combined to form the envelope waveform.

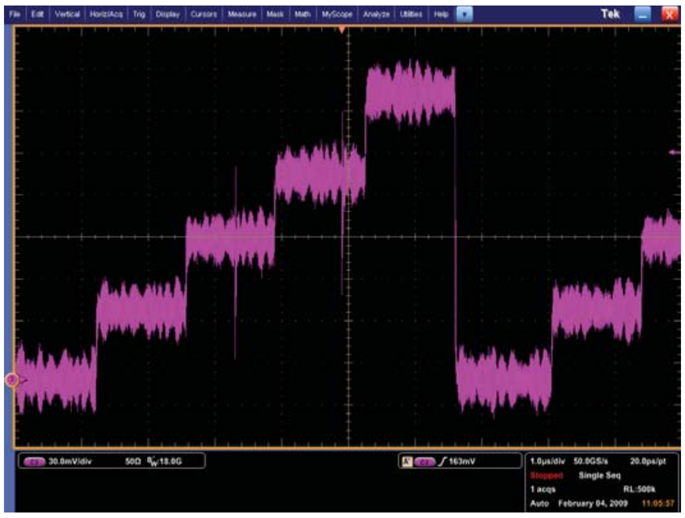

Figure 23. Peak detect mode enables the oscilloscope to capture extremely brief transient anomalies.

- Average Mode: In average mode, the oscilloscope saves one sample point during each waveform interval as in sample mode. However, waveform points from consecutive acquisitions are then averaged together to produce the final displayed waveform. Average mode reduces noise without loss of bandwidth, but requires a repeating signal.
- Waveform Database Mode: In waveform database mode, the oscillocope accumulates a waveform database that provides a three-dimensional array of amplitude, time, and counts.

Starting and Stopping the Acquisition System

One of the greatest advantages of digital oscilloscopes is their ability to store waveforms for later viewing. To this end, there are usually one or more buttons on the front panel that allow you to start and stop the acquisition system so you can analyze waveforms at your leisure. Additionally, you may want the oscilloscope to automatically stop acquiring after one acquisition is complete or after one set of records has been turned into an envelope or average waveform. This feature is commonly called single sweep or single sequence and its controls are usually found either with the other acquisition controls or with the trigger controls.

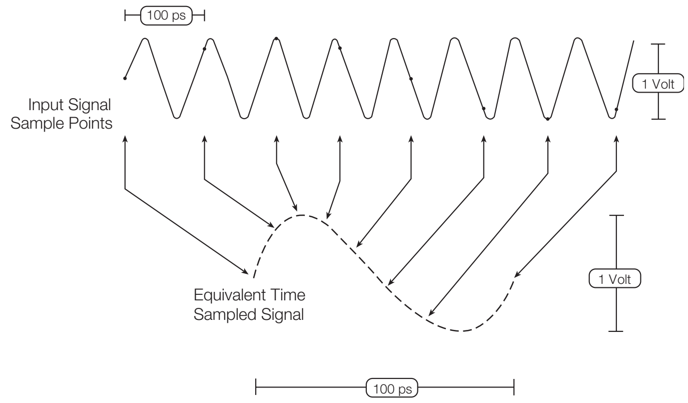

Figure 24. Basic sampling, showing sample points are connected by interpolation to produce a continuous waveform.

Sampling

Sampling is the process of converting a portion of an input signal into a number of discrete electrical values for the purpose of storage, processing and/or display. The magnitude of each sampled point is equal to the amplitude of the input signal at the instant in time in which the signal is sampled.

Sampling is like taking snapshots. Each snapshot corresponds to a specific point in time on the waveform. These snapshots can then be arranged in the appropriate order in time so as to reconstruct the input signal.

In a digital oscilloscope, an array of sampled points is reconstructed on a display with the measured amplitude on the vertical axis and time on the horizontal axis, as illustrated in Figure 24.

The input waveform in Figure 24 appears as a series of dots on the screen. If the dots are widely spaced and difficult to interpret as a waveform, the dots can be connected using a process called interpolation. Interpolation connects the dots with lines, or vectors. A number of interpolation methods are available that can be used to produce an accurate representation of a continuous input signal.

Sampling Controls

Some digital oscilloscopes provide you with a choice in sampling method – either real-time sampling or equivalent-time sampling. The acquisition controls available with these oscilloscopes will allow you to select a sample method to acquire signals. Note that this choice makes no difference for slow time base settings and only has an effect when the ADC cannot sample fast enough to fill the record with waveform points in one pass. Each sampling method has distinct advantages, depending on the kind of measurements being made.

Controls are typically available on modern oscilloscopes to give you the choice of three horizontal time base modes of operations. If you are simply doing signal exploration and want to interact with a lively signal, you will use the Automatic or interactive default mode that provides you with the liveliest display update rate. If you want a precise measurement and the highest real-time sample rate that will give you the most measurement accuracy, then the Constant Sample Rate mode is for you. It will maintain the highest sample rate and provide the best real-time resolution. The last mode is called the Manual mode because it ensures direct and independent control of the sample rate and record length.

Real-time Sampling Method

Real-time sampling is ideal for signals whose frequency range is less than half the oscilloscope's maximum sample rate. Here, the oscilloscope can acquire more than enough points in one "sweep" of the waveform to construct an accurate picture, as shown in Figure 25. Real-time sampling is the only way to capture fast, single-shot, transient signals with a digital oscilloscope.

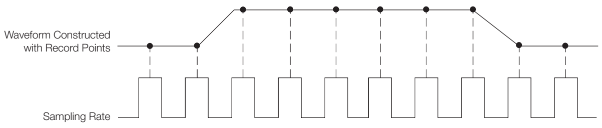

Figure 25. Real-time sampling method.

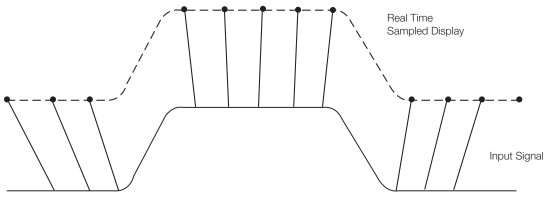

Figure 26. In order to capture this 10 ns pulse in real-time, the sample rate must be high enough to accurately define the edges.

Real-time sampling presents the greatest challenge for digital oscilloscopes because of the sample rate needed to accurately digitize high-frequency transient events, as shown in Figure 26. These events occur only once, and must be sampled in the same time frame that they occur.

If the sample rate isn't fast enough, high-frequency components can "fold down" into a lower frequency, causing aliasing in the display, as demonstrated in Figure 27. In addition, real-time sampling is further complicated by the high-speed memory required to store the waveform once it is digitized. Please refer to the Sample Rate and Record Length sections under Performance Terms and Considerations for additional detail regarding the sample rate and record length needed to accurately characterize high-frequency components.

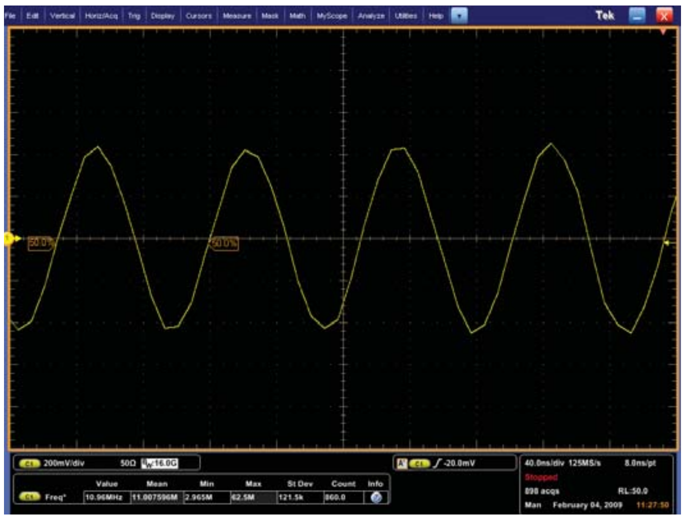

C1 200mV/div 50Ω 16.0G

A C1 -20.0mV

40.0ns/div 125MS/s 8.0ns/pt
Stopped
898 acqs RL:50.0
Man February 04, 2009 11:27:50

	Value	Mean	Min	Max	St Dev	Count	Info
C1 Freq*	10.96MHz	11.007596M	2.965M	62.5M	121.5k	860.0	

Figure 27. Undersampling of a 100 MHz sine wave introduces aliasing effects.

Real-time sampling with interpolation, dgital oscilloscopes take discrete samples of the signal that can be displayed. However, it can be difficult to visualize the signal represented as dots, especially because there can be only a few dots representing high-frequency portions of the signal. To aid in the visualization of signals, digital oscilloscopes typically have interpolation display modes.

In simple terms, interpolation "connects the dots" so that a signal that is sampled only a few times in each cycle can be accurately displayed. Using real-time sampling with interpolation, the oscilloscope collects a few sample points of the signal in a single pass in real-time mode and uses interpolation to fill in the gaps. Interpolation is a processing technique used to estimate what the waveform looks like based on a few points.

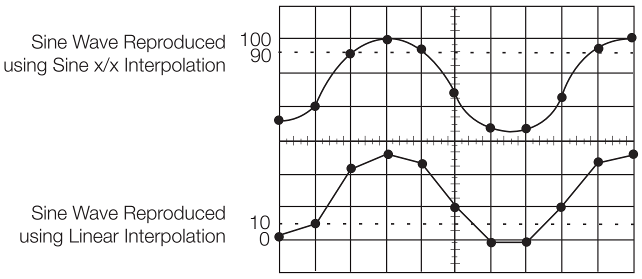

Figure 28. Linear and sin x/x interpolation.

Linear interpolation connects sample points with straight lines. This approach is limited to reconstructing straight-edged signals, as illustrated in Figure 28, which better lends itself to square waves.

The more versatile sin x/x interpolation connects sample points with curves, as shown in Figure 28. Sin x/x interpolation is a mathematical process in which points are calculated to fill in the time between the real samples. This form of interpolation lends itself to curved and irregular signal shapes, which are far more common in the real world than pure square waves and pulses. Consequently, sin x/x interpolation is the preferred method for applications where the sample rate is 3 to 5 times the system bandwidth.

Equivalent-time Sampling Method

When measuring high-frequency signals, the oscilloscope may not be able to collect enough samples in one sweep. Equivalent-time sampling can be used to accurately acquire signals whose frequency exceeds half the oscilloscope's sample rate, as illustrated in Figure 29. Equivalent-time digitizers (samplers) take advantage of the fact that most naturally occurring and man-made events are repetitive. Equivalent-time sampling constructs a picture of a repetitive signal by capturing a little bit of information from each repetition. The waveform slowly builds up like a string of lights, illuminating one-by-one. This allows the oscilloscope to accurately capture signals whose frequency components are much higher than the oscilloscope's sample rate.

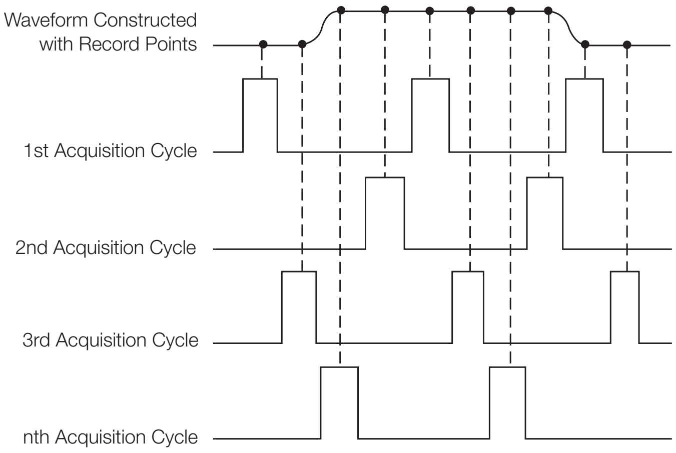

Figure 29. Some oscilloscopes use equivalent-time sampling to capture and display very fast, repetitive signals.

There are two types of equivalent-time sampling methods: random and sequential. Each has its advantages. Random equivalent-time sampling allows display of the input signal prior to the trigger point, without the use of a delay line. Sequential equivalent-time sampling provides much greater time resolution and accuracy. Both require that the input signal be repetitive.

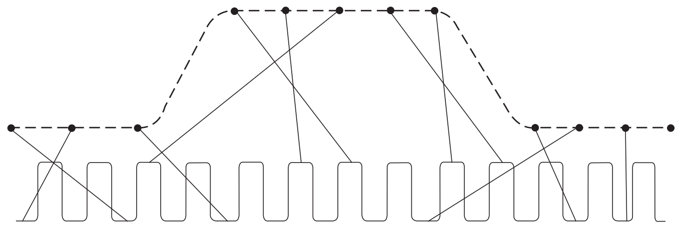

Figure 30. In random equivalent-time sampling, the sampling clock runs asynchronously with the input signal and the trigger.

Random Equivalent-time Sampling

Random equivalent-time digitizers (samplers) utilize an internal clock that runs asynchronously with respect to the input signal and the signal trigger, as illustrated in Figure 30. Samples are taken continuously, independent of the trigger position, and are displayed based on the time difference between the sample and the trigger. Although samples are taken sequentially in time, they are random with respect to the trigger – hence the name "random" equivalent-time sampling. Sample points appear randomly along the waveform when displayed on the oscilloscope screen.

The ability to acquire and display samples prior to the trigger point is the key advantage of this sampling technique, eliminating the need for external pretrigger signals or delay lines. Depending on the sample rate and the time window of the display, random sampling may also allow more than one sample to be acquired per triggered event. However, at faster sweep speeds, the acquisition window narrows until the digitizer cannot sample on every trigger. It is at these faster sweep speeds that very precise timing measurements are often made, and where the extraordinary time resolution of the sequential equivalent-time sampler is most beneficial. The bandwidth limit for random equivalent-time sampling is less than for sequential-time sampling.

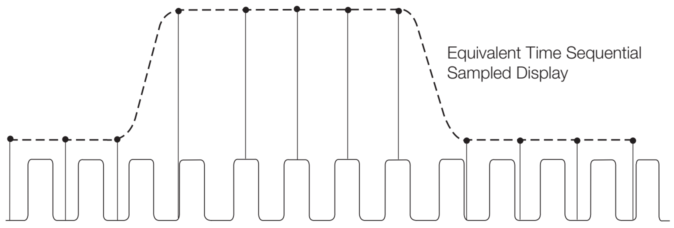

Figure 31. In sequential equivalent-time sampling, the single sample is taken for each recognized trigger after a time delay which is incremented after each cycle.

Sequential Equivalent-time Sampling

The sequential equivalent-time sampler acquires one sample per trigger, independent of the time/div setting, or sweep speed, as illustrated in Figure 31. When a trigger is detected, a sample is taken after a very short, but well-defined, delay. When the next trigger occurs, a small time increment – delta t – is added to this delay and the digitizer takes another sample. This process is repeated many times, with "delta t" added to each previous acquisition, until the time window is filled. Sample points appear from left to right in sequence along the waveform when displayed on the oscilloscope screen.

Technologically speaking, it is easier to generate a very short, very precise "delta t" than it is to accurately measure the vertical and horizontal positions of a sample relative to the trigger point, as required by random samplers. This precisely measured delay is what gives sequential samplers their unmatched time resolution. Since, with sequential sampling, the sample is taken after the trigger level is detected, the trigger point cannot be displayed without an analog delay line, which may, in turn, reduce the bandwidth of the instrument. If an external pretrigger can be supplied, bandwidth will not be affected.

Position and Seconds per Division

The horizontal position control moves the waveform left and right to exactly where you want it on the screen.

The seconds-per-division setting (usually written as sec/div) lets you select the rate at which the waveform is drawn across the screen (also known as the time base setting or sweep speed). This setting is a scale factor. If the setting is 1 ms, each horizontal division represents 1 ms and the total screen width represents 10 ms, or ten divisions. Changing the sec/div setting enables you to look at longer and shorter time intervals of the input signal.

As with the vertical volts/div scale, the horizontal sec/div scale may have variable timing, allowing you to set the horizontal time scale between the discrete settings.

Time Base Selections

Your oscilloscope has a time base, which is usually referred to as the main time base. Many oscilloscopes also have what is called a delayed time base – a time base with a sweep that can start (or be triggered to start) relative to a pre-determined time on the main time base sweep. Using a delayed time base sweep allows you to see events more clearly and to see events that are not visible solely with the main time base sweep.

The delayed time base requires the setting of a time delay and the possible use of delayed trigger modes and other settings not described in this primer. Refer to the manual supplied with your oscilloscope for information on how to use these features.

Zoom/Pan

Your oscilloscope may have special horizontal magnification settings that let you display a magnified section of the waveform on-screen. Some oscilloscopes add pan functions to the zoom capability. Knobs are used to adjust zoom factor or scale and the pan of the zoom box across the waveform.

Search

Some oscilloscopes offer search and mark capabilities, enabling you to quickly navigate through long acquisitions looking for user-defined events.

XY Mode

Most oscilloscopes have an XY mode that lets you display an input signal, rather than the time base, on the horizontal axis. This mode of operation opens up a whole new area of phase shift measurement techniques, explained in the Measurement Techniques section of this primer.

Z Axis

A digital phosphor oscilloscope (DPO) has a high display sample density and an innate ability to capture intensity information. With its intensity axis (Z axis), the DPO is able to provide a three-dimensional, real-time display similar to that of an analog oscilloscope. As you look at the waveform trace on a DPO, you can see brightened areas – the areas where a signal occurs most often. This display makes it easy to distinguish the basic signal shape from a transient that occurs only once in a while – the basic signal would appear much brighter. One application of the Z axis is to feed special timed signals into the separate Z input to create highlighted “marker” dots at known intervals in the waveform.

XYZ Mode with DPO and XYZ Record Display

Some DPOs can use the Z input to create an XY display with intensity grading. In this case, the DPO samples the instantaneous data value at the Z input and uses that value to qualify a specific part of the waveform. Once you have qualified samples, these samples can accumulate, resulting in an intensity-graded XYZ display. XYZ mode is especially useful for displaying the polar patterns commonly used in testing wireless communication devices – a constellation diagram, for example. Another method of displaying XYZ data is XYZ record display. In this mode the data from the acquisition memory is used rather than the DPO database.

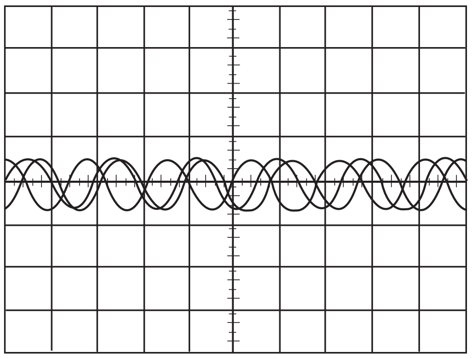

Figure 32. Untriggered display.

Trigger System and Controls

An oscilloscope's trigger function synchronizes the horizontal sweep at the correct point of the signal, essential for clear signal characterization. Trigger controls allow you to stabilize repetitive waveforms and capture single-shot waveforms.

The trigger makes repetitive waveforms appear static on the oscilloscope display by repeatedly displaying the same portion of the input signal. Imagine the jumble on the screen that would result if each sweep started at a different place on the signal, as illustrated in Figure 32.

Edge triggering, available in analog and digital oscilloscopes, is the basic and most common type. In addition to threshold triggering offered by both analog and digital oscilloscopes, many digital oscilloscopes offer numerous specialized trigger settings not offered by analog instruments. These triggers respond to specific conditions in the incoming signal, making it easy to detect, for example, a pulse that is narrower than it should be. Such a condition would be impossible to detect with a voltage threshold trigger alone.

Advanced trigger controls enable you to isolate specific events of interest to optimize the oscilloscope's sample rate and record length. Advanced triggering capabilities in some oscilloscopes give you highly selective control. You can trigger on pulses defined by amplitude (such as runt pulses), qualified by time (pulse width, glitch, slew rate, setup-and-hold, and time-out), and delineated by logic state or pattern (logic triggering).

Other advanced trigger functions include:

- **Pattern Lock Triggering:** Pattern lock triggering adds a new dimension to NRZ serial pattern triggering by enabling the oscilloscope to take synchronized acquisitions of a long serial test pattern with outstanding time base accuracy. Pattern lock triggering can be used to remove random jitter from long serial data patterns. Effects of specific bit transitions can be investigated, and averaging can be used with mask testing.
- **Serial Pattern Triggering:** Serial pattern triggering can be used to debug serial architectures. It provides a trigger on the serial pattern of an NRZ serial data stream with built-in clock recovery and correlates events across the physical and link layer. The instrument can recover the clock signal, identify transitions, and allow you to set the desired encoded words for the serial pattern trigger to capture.
- **A & B Triggering:** Some trigger systems offer multiple trigger types only on a single event (A event), with delayed trigger (B event) selection limited to edge type triggering and often do not provide a way to reset the trigger sequence if the B event doesn't occur. Modern oscilloscopes can provide the full suite of advanced trigger types on both A and B triggers, logic qualification to control when to look for these events, and reset triggering to begin the trigger sequence again after a specified time, state, or transition so that even events in the most complex signals can be captured.
- **Search & Mark Triggering:** Hardware triggers watch for one event type at a time, but Search can scan for multiple event types simultaneously. For example, scan for setup or hold time violations on multiple channels. Individual marks can be placed by Search indicating events that meet search criteria.
- **Trigger Correction:** Since the trigger and data acquisition systems share different paths there is some inherent time delay between the trigger position and the data acquired. This results in skew and trigger jitter. With a trigger correction system the instrument adjusts the trigger position and compensates for the difference of delay there is between the trigger path and the data acquisition path. This will eliminate virtually any trigger jitter at the trigger point. In this mode, the trigger point can be used as a measurement reference.

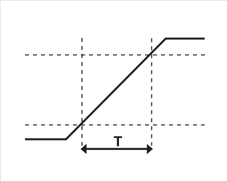

Slew Rate Triggering. High frequency signals with slew rates faster than expected or needed can radiate troublesome energy. Slew rate triggering surpasses conventional edge triggering by adding the element of time and allowing you to selectively trigger on fast or slow edges.

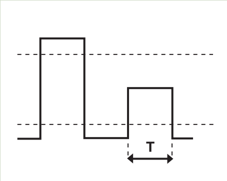

Runt Pulse Triggering. Runt triggering allows you to capture and examine pulses that cross one logic threshold, but not both.

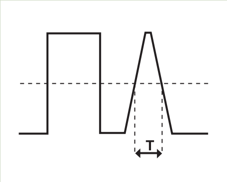

Glitch Triggering. Glitch triggering allows you to trigger on digital pulses when they are shorter or longer than a user-defined time limit. This trigger control enables you to examine the causes of even rare glitches and their effects on other signals

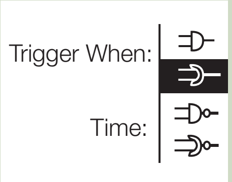

Logic Triggering. Logic triggering allows you to trigger on any logical combination of available input channels – especially useful in verifying the operation of digital logic.

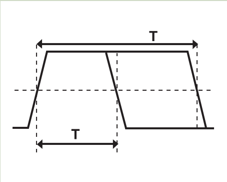

Pulse Width Triggering. Using pulse width triggering, you can monitor a signal indefinitely and trigger on the first occurrence of a pulse whose duration (pulse width) is outside the allowable limits.

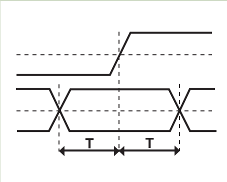

Setup-and-Hold Triggering. Only setup-and-hold triggering lets you deterministically trap a single violation of setup-and-hold time that would almost certainly be missed by using other trigger modes. This trigger mode makes it easy to capture specific signal quality and timing details when a synchronous data signal fails to meet setup-and-hold specifications.

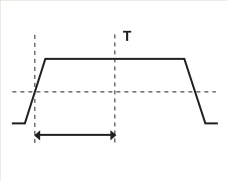

Time-out Triggering. Time-out triggering lets you trigger on an event without waiting for the trigger pulse to end, by triggering based on a specified time lapse.

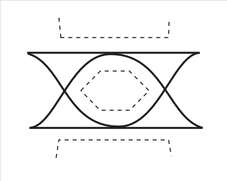

Communication Triggering. Optionally available on certain oscilloscope models, these trigger modes address the need to acquire a wide variety of Alternate-Mark Inversion (AMI), Code-Mark Inversion (CMI), and Non-Return to Zero (NRZ) communication signals.

Figure 33. Common trigger types.

- **Serial Triggering on Specific Standard Signals I^{2}C, CAN, LIN, etc.)** - Some oscilloscopes provide the ability to trigger on specific signal types for standard serial data signals such as CAN, LIN, I^{2}C, SPI, and others. The decode of these signal types is also available on many oscilloscopes today.
- **Parallel Bus Triggering** - Multiple parallel buses can be defined and displayed at one time to easily view decoded parallel bus data over time. By specifying which channels are the clock and data lines, you can create a parallel bus display on some oscilloscopes that automatically decodes bus content. Countless hours can be saved by using parallel bus triggers to simplify capture and analysis.

Optional trigger controls in some oscilloscopes are designed specifically to examine communications signals as well. Figure 33 highlights a few of these common trigger types in more detail. The intuitive user interface available in some oscilloscopes also allows rapid setup of trigger parameters with wide flexibility in the test setup to maximize your productivity.

Trigger Position

Horizontal trigger position control is only available on digital oscilloscopes. The trigger position control may be located in the horizontal control section of your oscilloscope. It actually represents the horizontal position of the trigger in the waveform record.

Varying the horizontal trigger position allows you to capture what a signal did before a trigger event, known as pre-trigger viewing. Thus, it determines the length of viewable signal both preceding and following a trigger point.

Digital oscilloscopes can provide pre-trigger viewing because they constantly process the input signal, whether or not a trigger has been received. A steady stream of data flows through the oscilloscope; the trigger merely tells the oscilloscope to save the present data in memory.
In contrast, analog oscilloscopes only display the signal – that is, write it on the CRT – after receiving the trigger. Thus, pre-trigger viewing is not available in analog oscilloscopes, with the exception of a small amount of pre-trigger provided by a delay line in the vertical system.

Pre-trigger viewing is a valuable troubleshooting aid. If a problem occurs intermittently, you can trigger on the problem, record the events that led up to it and, possibly, find the cause.

Trigger Level and Slope

The trigger level and slope controls provide the basic trigger point definition and determine how a waveform is displayed, as illustrated in Figure 34.

The trigger circuit acts as a comparator. You select the slope and voltage level on one input of the comparator. When the trigger signal on the other comparator input matches your settings, the oscilloscope generates a trigger.

The slope control determines whether the trigger point is on the rising or the falling edge of a signal. A rising edge is a positive slope and a falling edge is a negative slope. The level control determines where on the edge the trigger point occurs.

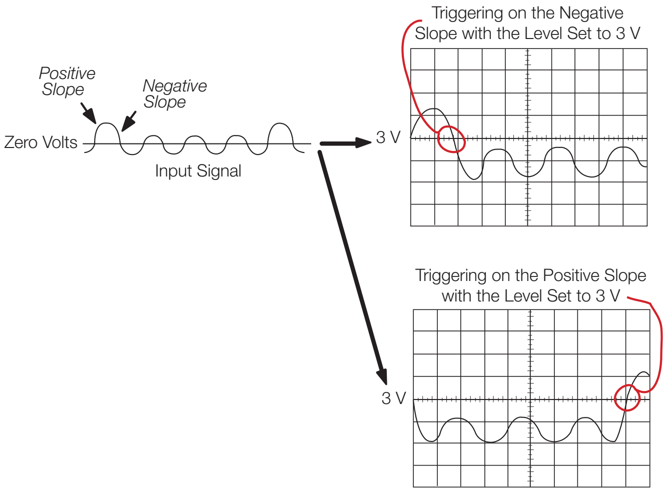
Triggering on the Negative Slope with the Level Set to 3 V
Positive Slope
Negative Slope
Zero Volts
Input Signal
3 V
Triggering on the Positive Slope with the Level Set to 3 V
3 V

Figure 34. Positive and negative slope triggering.

Trigger Sources

The oscilloscope does not necessarily need to trigger on the signal being displayed. Several sources can trigger the sweep:

- Any input channel
- An external source other than the signal applied to an input channel
- The power source signal
- A signal internally defined by the oscilloscope, from one or more input channels

Most of the time, you can leave the oscilloscope set to trigger on the channel displayed. Some oscilloscopes provide a trigger output that delivers the trigger signal to another instrument.

The oscilloscope can use an alternate trigger source, whether or not it is displayed, so you should be careful not to unwittingly trigger on channel 1 while displaying channel 2, for example.

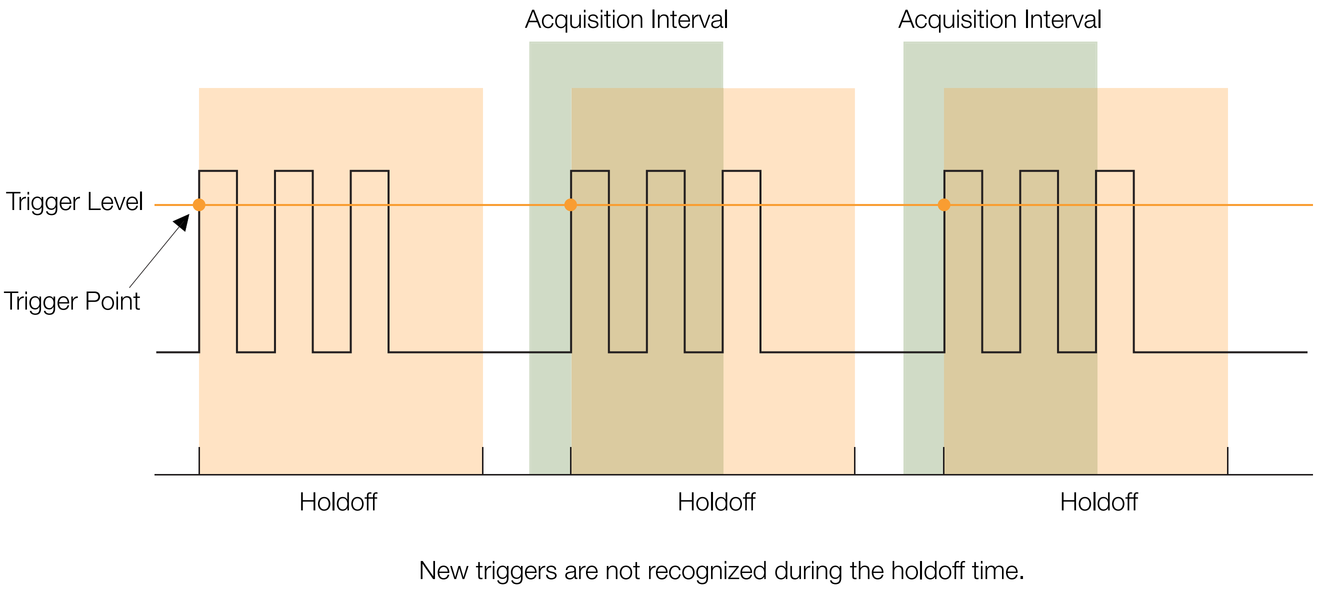

Figure 35. Trigger holdoff.

Trigger Modes

The trigger mode determines whether or not the oscilloscope draws a waveform based on a signal condition. Common trigger modes include normal and auto.

In normal mode the oscilloscope only sweeps if the input signal reaches the set trigger point; otherwise (on an analog oscilloscope) the screen is blank or (on a digital oscilloscope) frozen on the last acquired waveform. Normal mode can be disorienting since you may not see the signal at first if the level control is not adjusted correctly.

Auto mode causes the oscilloscope to sweep, even without a trigger. If no signal is present, a timer in the oscilloscope triggers the sweep. This ensures that the display will not disappear if the signal does not cause a trigger.

In practice, you will probably use both modes: normal mode because it lets you see just the signal of interest, even when triggers occur at a slow rate, and auto mode because it requires less adjustment.

Many oscilloscopes also include special modes for single sweeps, triggering on video signals, or automatically setting the trigger level.

Trigger Coupling

Just as you can select either AC or DC coupling for the vertical system, you can choose the kind of coupling for the trigger signal.

Besides AC and DC coupling, your oscilloscope may also have high frequency rejection, low frequency rejection, and noise rejection trigger coupling. These special settings are useful for eliminating noise from the trigger signal to prevent false triggering.

Trigger Holdoff

Sometimes getting an oscilloscope to trigger on the correct part of a signal requires great skill. Many oscilloscopes have special features to make this task easier.

Trigger holdoff is an adjustable period of time after a valid trigger during which the oscilloscope cannot trigger. This feature is useful when you are triggering on complex waveform shapes, so that the oscilloscope only triggers on an eligible trigger point. Figure 35 shows how using trigger holdoff helps create a usable display.

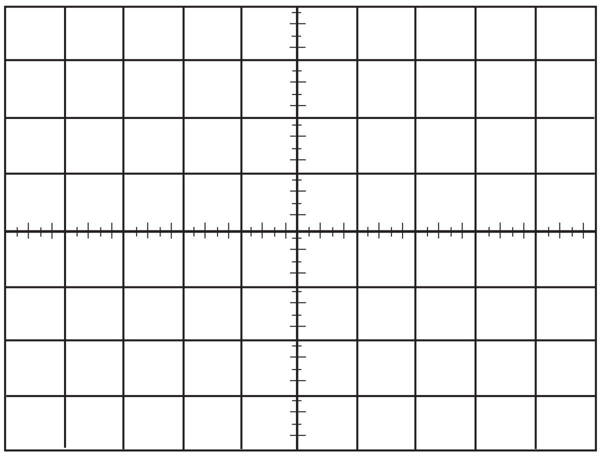

Figure 36. An oscilloscope graticule.

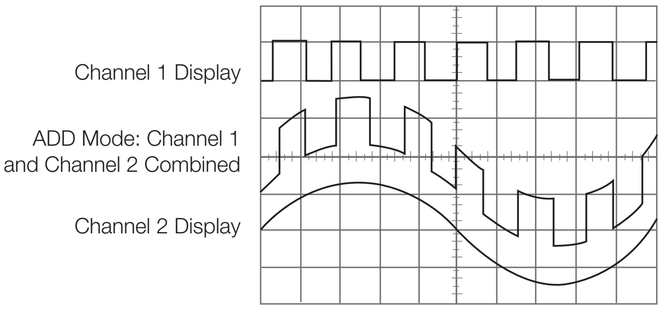

Figure 37. Adding channels.

Display System and Controls

An oscilloscope's front panel includes a display screen and the knobs, buttons, switches, and indicators used to control signal acquisition and display. As mentioned at the front of this section, front-panel controls are usually divided into vertical, horizontal and trigger sections. The front panel also includes input connectors.

Take a look at the oscilloscope display. Notice the grid markings on the screen – these markings create the graticule. Each vertical and horizontal line constitutes a major division. The graticule is usually laid out in an 8-by-10 or 10-by-10 division pattern. Labeling on the oscilloscope controls (such as volts/div and sec/div) always refers to major divisions. The tick marks on the center horizontal and vertical graticule lines, as shown in Figure 36, are called minor divisions. Many oscilloscopes display on the screen how many volts each vertical division represents and how many seconds each horizontal division represents.

Other Oscilloscope Controls

Math and Measurement Operations

Your oscilloscope may also have operations that allow you to add waveforms together, creating a new waveform display. Analog oscilloscopes combine the signals while digital oscilloscopes create new waveforms mathematically. Subtracting waveforms is another math operation. Subtraction with analog oscilloscopes is possible by using the channel invert function on one signal and then using the add operation. Digital oscilloscopes typically have a subtraction operation available. Figure 37 illustrates a third waveform created by combining two different signals.

Using the power of their internal processors, digital oscilloscopes offer many advanced math operations: multiplication, division, integration, Fast Fourier Transform, and more. This advanced signal processing capability can also perform functions such as the insertion of a filter block which can be used de-embed the characteristics of the fixture on the device under test or implement a filter block with desired frequency response such as a low pass filter. The processing block is flexible – not dedicated; it can perform as an arbitrary filter instead, for example for simulation of pre-emphasis/de-emphasis schemes.

Digital Timing and State Acquisitions

Digital channels provided by a mixed signal oscilloscope enable acquisition capabilities similar to those found on logic analyzers. There are two major digital acquisition techniques. The first technique is timing acquisition in which the MSO samples the digital signal at uniformly spaced times determined by the MSO's sample rate. At each sample point, the MSO stores the signal's logic state and creates a timing diagram of the signal. The second digital acquisition technique is state acquisition. State acquisition defines special times that the digital signal's logic state is valid and stable. This is common in synchronous and clocked digital circuits. A clock signal defines the time when the signal state is valid. For example, the input signal stable time is around the rising clock edge for a D-Flip-Flop with rising edge clocking. The output signal stable time is around the falling clock edge for a D-Flip-Flop with rising edge clocking. Since the clock period of a synchronous circuit may not be fixed, the time between state acquisitions may not be uniform as it is in a timing acquisition.

A mixed signal oscilloscope's digital channels acquire signals similar to how a logic analyzer acquires signals in timing acquisition mode. The MSO then decodes the timing acquisition into a clocked bus display, and event table which is similar to the logic analyzer's state acquisition display, providing you with important information during debug.

We have described the basic oscilloscope controls that a beginner needs to know about. Your oscilloscope may have other controls for various functions. Some of these may include:

- Automatic parametric measurements
- Measurement cursors
- Keypads for mathematical operations or data entry
- Printing capabilities
- Interfaces for connecting your oscilloscope to a computer or directly to the Internet

Look over the other options available to you and read your oscilloscope's manual to find out more about these other controls.

The Complete Measurement System

Probes

Even the most advanced instrument can only be as precise as the data that goes into it. A probe functions in conjunction with an oscilloscope as part of the measurement system. Precision measurements start at the probe tip. The right probes matched to the oscilloscope and the device-under-test (DUT) not only allow the signal to be brought to the oscilloscope cleanly, they also amplify and preserve the signal for the greatest signal integrity and measurement accuracy.

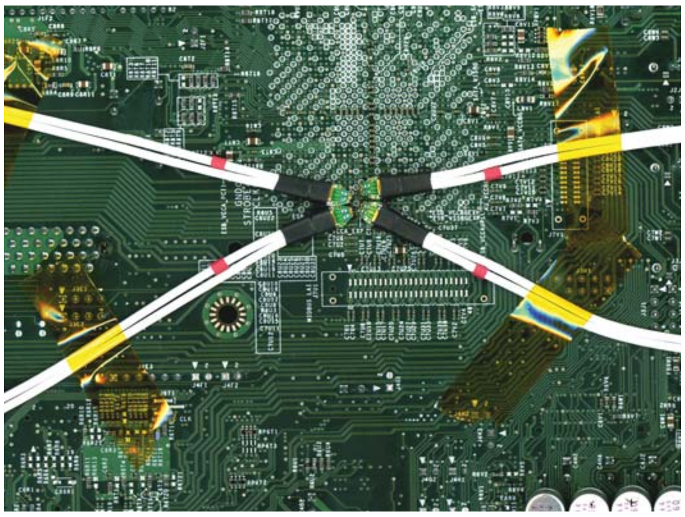

Figure 38. Dense devices and systems require small form factor probes.

To ensure accurate reconstruction of your signal, try to choose a probe that, when paired with your oscilloscope, exceeds the signal bandwidth by 5 times.

Probes actually become part of the circuit, introducing resistive, capacitive and inductive loading that inevitably alters the measurement. For the most accurate results, the goal is to select a probe with minimal loading. An ideal pairing of the probe with the oscilloscope will minimize this loading, and enable you to access all of the power, features and capabilities of your oscilloscope.

Another connectivity consideration is the probe's form factor. Small form factor probes provide easier access to today's densely packed circuitry, as shown in Figure 38.

A brief description of the types of probes follows. Please refer to the Tektronix ABCs of Probes primer for more information about this essential component of the overall measurement system.

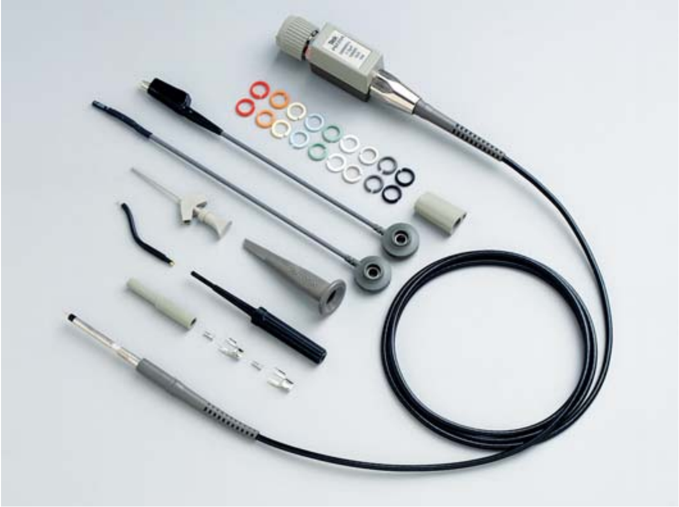

Figure 39. A typical passive probe with accessories.

Passive Probes

For measuring typical signal and voltage levels, passive probes provide ease-of-use and a wide range of measurement capabilities at an affordable price. The pairing of a passive voltage probe with a current probe will provide you with an ideal solution for measuring power.

Most passive probes have some attenuation factor, such as 10X, 100X, and so on. By convention, attenuation factors, such as for the 10X attenuator probe, have the X after the factor. In contrast, magnification factors like X10 have the X first.

The 10X (read as “ten times”) attenuator probe reduces circuit loading in comparison to a 1X probe and is an excellent general-purpose passive probe. Circuit loading becomes more pronounced for higher frequency and/or higher impedance signal sources, so be sure to analyze these signal/probe loading interactions before selecting a probe. The 10X attenuator probe improves the accuracy of your measurements, but also reduces the signal’s amplitude at the oscilloscope input by a factor of 10.

Because it attenuates the signal, the 10X attenuator probe makes it difficult to look at signals less than 10 millivolts peak-to-peak. The 1X probe is similar to the 10X attenuator probe but lacks the attenuation circuitry. Without this circuitry, more interference is introduced to the circuit being tested.

Use the 10X attenuator probe as your general-purpose probe, but keep the 1X probe accessible to measure slow-speed, low-amplitude signals. Some probes have a convenient feature for switching between 1X and 10X attenuation at the probe tip. If your probe has this feature, make sure you are using the correct setting before taking measurements.

Many oscilloscopes can automatically detect whether you are using a 1X or 10X probe and adjust their screen readouts accordingly. However with some oscilloscopes, you must set the type of probe you are using or read from the proper 1X or 10X marking on the volts/div control.

The 10X attenuator probe works by balancing the probe’s electrical properties against the oscilloscope’s electrical properties. Before using a 10X attenuator probe you need to adjust this balance for your particular oscilloscope. This adjustment is known as compensating the probe and is described in more detail in the Operating the Oscilloscope section of this primer.

Passive probes, such as the one shown in Figure 39, provide excellent general-purpose probing solutions. However, general-purpose passive probes cannot accurately measure signals with extremely fast rise times, and may excessively load sensitive circuits. The steady increase in signal clock rates and edge speeds demands higher speed probes with less loading effects. High-speed active and differential probes provide ideal solutions when measuring high-speed and/or differential signals.

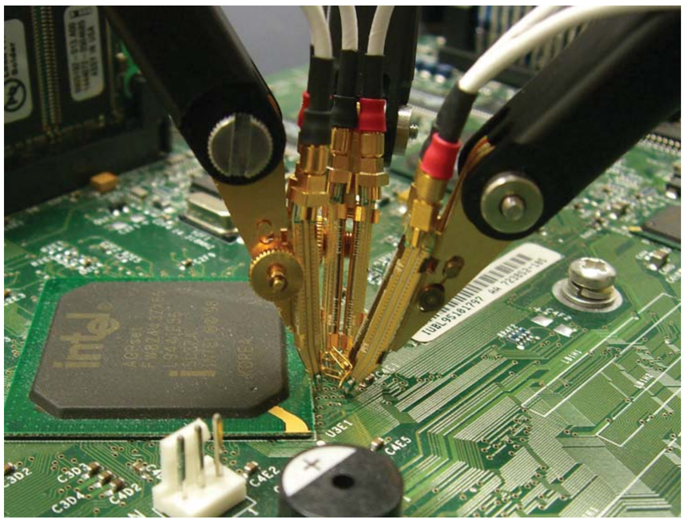

Figure 40. High-performance probes are critical when measuring the fast clocks and edges found in today's computer buses and data transmission lines.

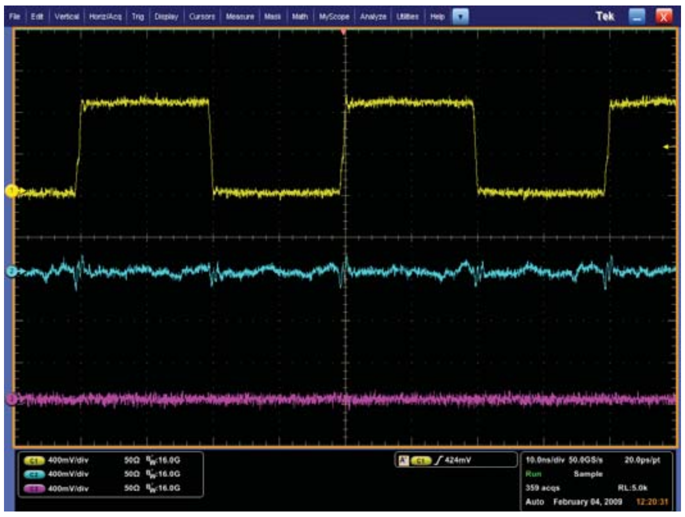
File Edit Vertical Horiz/Acq Trig Display Cursors Measure Mask Math MyScope Analyze Utilities Help
Tek
C1 400mV/div 50Ω BW:16.0G
C2 400mV/div 50Ω BW:16.0G
C3 400mV/div 50Ω BW:16.0G
A C1 ∫ 424mV
10.0ns/div 50.0GS/s 20.0ps/pt
Run Sample
359 acqs RL:5.0k
Auto February 04, 2009 12:20:31

Figure 41 Differential probes can separate common-mode noise from the signal content of interest in today's fast, low-voltage applications - especially important as digital signals continue to fall below typical noise thresholds found in integrated circuits.

Active and Differential Probes

Increasing signal speeds and lower-voltage logic families make accurate measurement results difficult to achieve. Signal fidelity and device loading are critical issues. A complete measurement solution at these high speeds includes high-speed, high-fidelity probing solutions to match the performance of the oscilloscope, as shown in Figure 40.

Active and differential probes use specially developed integrated circuits to preserve the signal during access and transmission to the oscilloscope, ensuring signal integrity. For measuring signals with fast rise times, a high-speed active or differential probe will provide more accurate results, as highlighted in Figure 41.

Newer probe types provide the advantage of being able to use one setup, and get three types of measurements without adjusting probe tip connections. These probes can make differential, single-ended and common mode measurements from the same probe setup.

Logic Probes

The logic probe shown in Figure 42 offers two eight-channel pods. Each channel ends with a probe tip featuring a recessed ground for simplified connection to the device-under-test. The coax on the first channel of each pod is colored blue making it easy to identify. The common ground uses an automotive style connector making it easy to create custom grounds for connecting to the device-under-test. When connecting to square pins, you can use an adapter that attaches to the probe head extending the probe ground flush with the probe tip so you can attach to a header. These probes offer outstanding electrical characteristics with minimal capacitive loading.

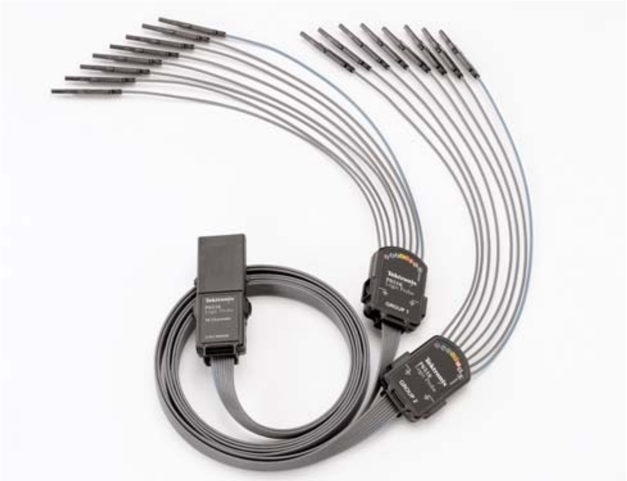

Figure 42. Logic probes for a mixed signal oscilloscope (MSO) simplify digital connectivity to your device.

Specialty Probes

In addition to the previously mentioned probe types, there are also a variety of other specialty probes and probing systems. These include current, high-voltage, and optical probes, just to name a few.

Probe Accessories

Many modern oscilloscopes provide special automated features built into the input and mating probe connectors. In the case of intelligent probe interfaces, the act of connecting the probe to the instrument notifies the oscilloscope about the probe's attenuation factor, which in turn scales the display so that the probe's attenuation is figured into the readout on the screen. Some probe interfaces also recognize the type of probe – that is, passive, active or current. The interface may act as a DC power source for probes. Active probes have their own amplifier and buffer circuitry that requires DC power.

Ground lead and probe tip accessories are also available to improve signal integrity when measuring high-speed signals. Ground lead adapters provide spacing flexibility between probe tip and ground lead connections to the DUT, while maintaining very short lead lengths from probe tip to DUT.

Please refer to the Tektronix ABCs of Probes primer for more information about probes and probe accessories.

Performance Terms and Considerations

As previously mentioned, an oscilloscope is analogous to a camera that captures signal images that we can observe and interpret. Shutter speed, lighting conditions, aperture and the ASA rating of the film all affect the camera's ability to capture an image clearly and accurately.

Like the basic systems of an oscilloscope, the performance considerations of an oscilloscope significantly affect its ability to achieve the required signal integrity.

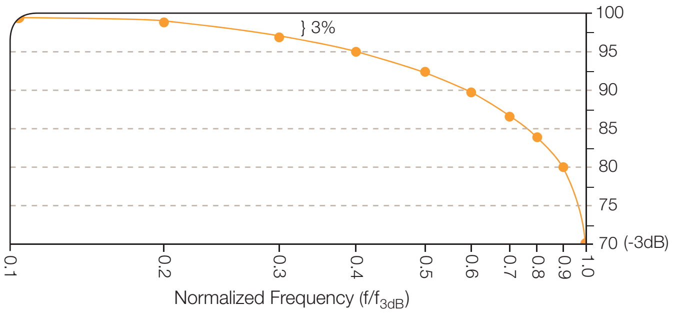

Figure 43. Oscilloscope bandwidth is the frequency at which a sinusoidal input signal is attenuated to 70.7% of the signal's true amplitude, known as the -3 dB point.

Learning a new skill often involves learning a new vocabulary. This idea holds true for learning how to use an oscilloscope. This section describes some useful measurement and oscilloscope performance terms. These terms are used to describe the criteria essential to choosing the right oscilloscope for your application. Understanding these terms will help you to evaluate and compare your oscilloscope with other models.

Bandwidth

Bandwidth determines an oscilloscope's fundamental ability to measure a signal. As signal frequency increases, the capability of the oscilloscope to accurately display the signal decreases. This specification indicates the frequency range that the oscilloscope can accurately measure.

Oscilloscope bandwidth is specified as the frequency at which a sinusoidal input signal is attenuated to 70.7% of the signal's true amplitude, known as the –3 dB point, a term based on a logarithmic scale, as seen in Figure 43.

Without adequate bandwidth, your oscilloscope will not be able to resolve high-frequency changes. Amplitude will be distorted. Edges will vanish. Details will be lost. Without adequate bandwidth, all the features, bells and whistles in your oscilloscope will mean nothing.

To determine the oscilloscope bandwidth needed to accurately characterize signal amplitude in your specific application, apply the "5 Times Rule."

$$\text{Oscilloscope Bandwidth} \geq \frac{\text{Highest Frequency}}{\text{Component of Signal}} \; x \;\; 5$$

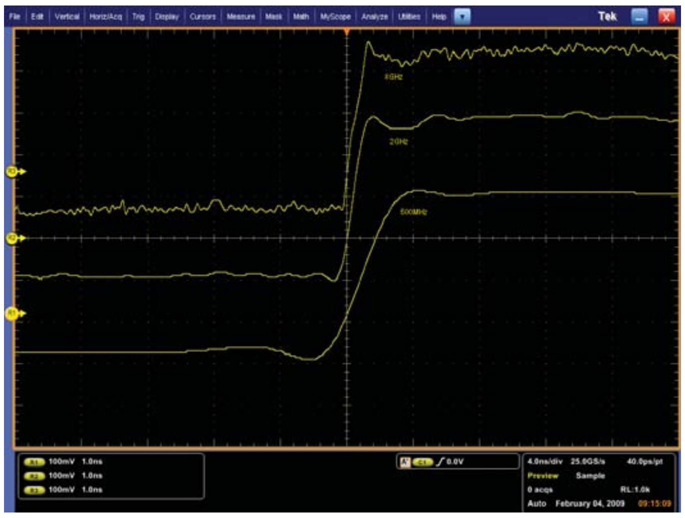
File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursors
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
4GHz
2GHz
500MHz
R1 100mV 1.0ns
R2 100mV 1.0ns
R3 100mV 1.0ns
C1 0.0V
4.0ns/div 25.0GS/s 40.0ps/pt
Preview Sample
0 acqs RL:1.0k
Auto February 04, 2009 09:15:09

Figure 44. The higher the bandwidth, the more accurate the reproduction of your signal, as illustrated with a signal captured at 250 MHz, 1 GHz and 4 GHz bandwidth levels.

An oscilloscope selected using the 5 Times Rule will give you less than ±2% error in your measurements – typically sufficient for today's applications. However, as signal speeds increase, it may not be possible to achieve this rule of thumb. Always keep in mind that higher bandwidth will likely provide more accurate reproduction of your signal, as demonstrated in Figure 44.

Some oscilloscopes provide a method of enhancing the bandwidth through digital signal processing. A DSP arbitrary equalization filter can be used to improve the oscilloscope channel response. This filter extends the bandwidth, flattens the oscilloscope's channel frequency response, improves phase linearity, and provides a better match between channels. It also decreases rise time and improves the time-domain step response.

Rise Time

In the digital world, rise time measurements are critical. Rise time may be a more appropriate performance consideration when you expect to measure digital signals, such as pulses and steps. As shown in Figure 45, your oscilloscope must have sufficient rise time to accurately capture the details of rapid transitions.

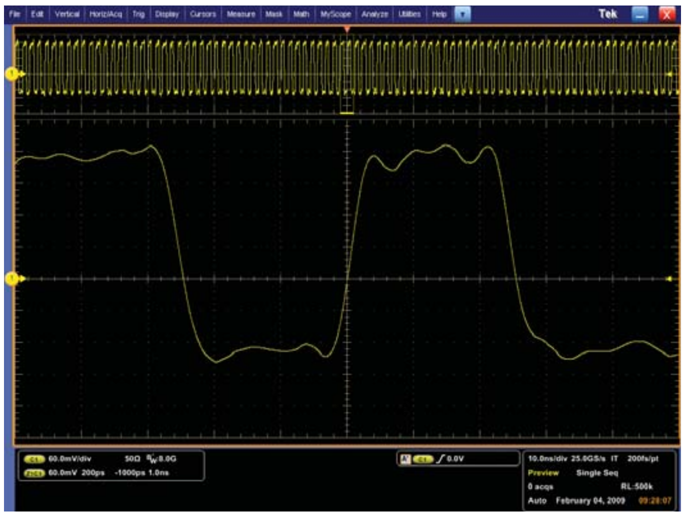
File
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MyScope
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Tek
C1 60.0mV/div 50Ω BW:8.0G
Z C1 60.0mV 200ps -1000ps 1.0ns
C1 0.0V
10.0ns/div 25.0GS/s IT 200fs/pt
Preview Single Seq
0 acqs RL:500k
Auto February 04, 2009 09:28:07

Figure 45. Rise time characterization of a high-speed digital signal.

Rise time describes the useful frequency range of an oscilloscope. To calculate the oscilloscope rise time required for your signal type, use the following equation:

$$\text{Oscilloscope Rise Time} \leq \text{Fastest Rise Time of Signal} \;x\; \frac{1}{5}$$

Note that this basis for oscilloscope rise time selection is similar to that for bandwidth. As in the case of bandwidth, achieving this rule of thumb may not always be possible given the extreme speeds of today's signals. Always remember that an oscilloscope with faster rise time will more accurately capture the critical details of fast transitions.

In some applications, you may know only the rise time of a signal. A constant allows you to relate the bandwidth and rise time of the oscilloscope, using the equation:

$$\text{Bandwidth} = \frac{k}{\text{Rise Time}}$$

where k is a value between 0.35 and 0.45, depending on the shape of the oscilloscope's frequency response curve and pulse rise time response. Oscilloscopes with a bandwidth of <1 GHz typically have a 0.35 value, while oscilloscopes with a bandwidth of > 1 GHz usually have a value between 0.40 and 0.45.

Logic Family	Typical Signal Rise Time	Calculated Signal Bandwidth
TTL	2 ns	175 MHz
CMOS	1.5 ns	230 MHz
GTL	1 ns	350 MHz
LVDS	400 ps	875 MHz
ECL	100 ps	3.5 GHz
GaAs	40 ps	8.75 GHz

Figure 46. Some logic families produce inherently faster rise times than others.

Some logic families produce inherently faster rise times than others, as illustrated in Figure 46.

Sample Rate

Sample rate – specified in samples per second (S/s) – refers to how frequently a digital oscilloscope takes a snapshot or sample of the signal, analogous to the frames on a movie camera. The faster an oscilloscope samples (i.e., the higher the sample rate), the greater the resolution and detail of the displayed waveform and the less likely that critical information or events will be lost, as shown in Figure 47. The minimum sample rate may also be important if you need to look at slowly changing signals over longer periods of time. Typically, the displayed sample rate changes with changes made to the horizontal scale control to maintain a constant number of waveform points in the displayed waveform record.

How do you calculate your sample rate requirements? The method differs based on the type of waveform you are measuring, and the method of signal reconstruction used by the oscilloscope.

In order to accurately reconstruct a signal and avoid aliasing, the Nyquist theorem states that the signal must be sampled at least twice as fast as its highest frequency component. This theorem, however, assumes an infinite record length and a continuous signal. Since no oscilloscope offers infinite record length and, by definition, glitches are not continuous, sampling at only twice the rate of highest frequency component is usually insufficient.

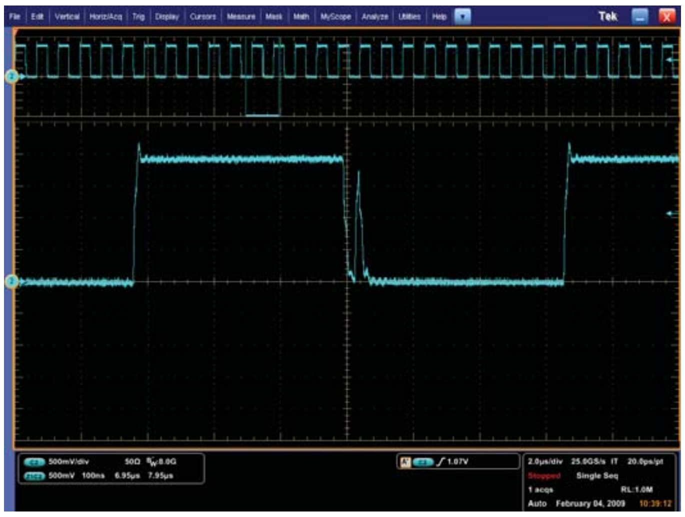

Figure 47. A higher sample rate provides greater signal resolution, ensuring that you'll see intermittent events.

In reality, accurate reconstruction of a signal depends on both the sample rate and the interpolation method used to fill in the spaces between the samples. Some oscilloscopes let you select either sin (x)/x interpolation for measuring sinusoidal signals, or linear interpolation for square waves, pulses and other signal types.

> For accurate reconstruction using sin(x)/x interpolation, your oscilloscope should have a sample rate at least 2.5 times the highest frequency component of your signal. Using linear interpolation, the sample rate should be at least 10 times the highest frequency signal component.

Some measurement systems with sample rates to 50 GS/s and bandwidths to 20 GHz have been optimized for capturing very fast, single-shot and transient events by oversampling up to 5 times the bandwidth.

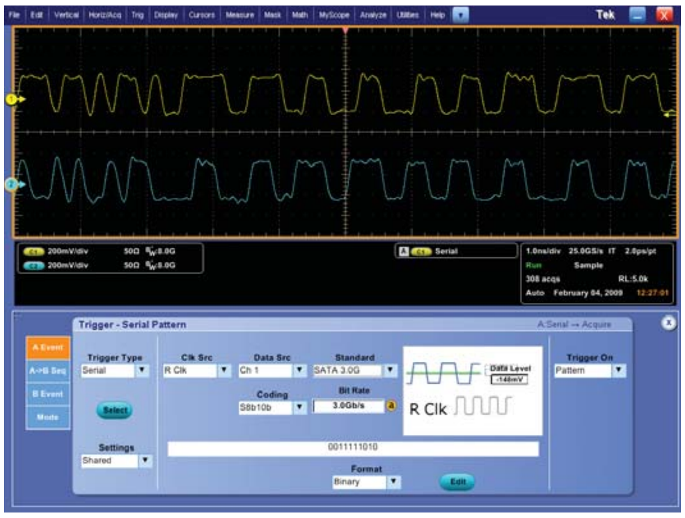
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Mask
Math
MyScope
Analyze
Utilities
Help
Tek
C1 200mV/div 50Ω 8.0G
C2 200mV/div 50Ω 8.0G
A C1 Serial
1.0ns/div 25.0GS/s IT 2.0ps/pt
Run Sample
308 acqs RL:5.0k
Auto February 04, 2009 12:27:01
A Event
A->B Seq
B Event
Mode
Select
Edit
A:Serial → Acquire
R Clk

Trigger - Serial Pattern

Trigger Type: Serial

Clk Src: R Clk

Data Src: Ch 1

Standard: SATA 3.0G

Coding: 8b10b

Bit Rate: 3.0Gb/s

Data Level: -148mV

Trigger On: Pattern

Settings: Shared

0011111010

Format: Binary

Figure 48. A DPO provides an ideal solution for non-repetitive, high-speed, multi-channel digital design applications.

Waveform Capture Rate

All oscilloscopes blink. That is, they open their eyes a given number of times per second to capture the signal, and close their eyes in between. This is the waveform capture rate, expressed as waveforms per second (wfms/s). While the sample rate indicates how frequently the oscilloscope samples the input signal within one waveform, or cycle, the waveform capture rate refers to how quickly an oscilloscope acquires waveforms.

Waveform capture rates vary greatly, depending on the type and performance level of the oscilloscope. Oscilloscopes with high waveform capture rates provide significantly more visual insight into signal behavior, and dramatically increase the probability that the oscilloscope will quickly capture transient anomalies such as jitter, runt pulses, glitches and transition errors.

Digital storage oscilloscopes (DSOs) employ a serial-processing architecture to capture from 10 to 5,000 wfms/s. Some DSOs provide a special mode that bursts multiple captures into long memory, temporarily delivering higher waveform capture rates followed by long processing dead times that reduce the probability of capturing rare, intermittent events.

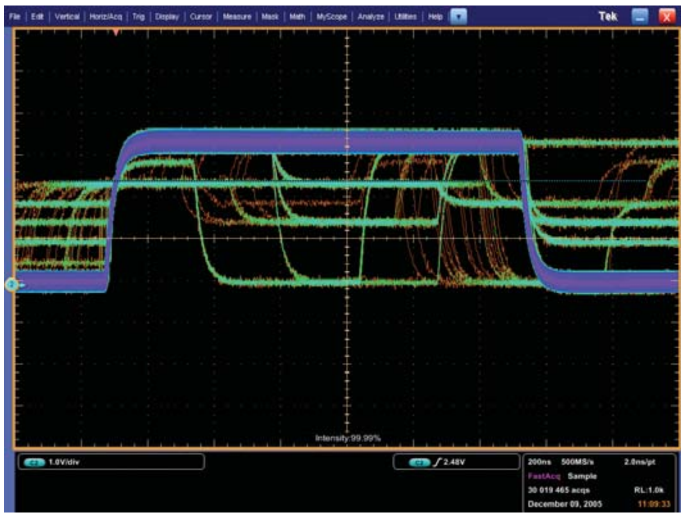
File
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Measure
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Math
MyScope
Analyze
Utilities
Help
Tek
Intensity:99.99%
C1 1.0V/div
C1 ∫ 2.48V
200ns 500MS/s 2.0ns/pt
FastAcq Sample
30 019 465 acqs RL:1.0k
December 09, 2005 11:09:33

Figure 49. A DPO enables a superior level of insight into signal behavior by delivering vastly greater waveform capture rates and three-dimensional display, making it the best general-purpose design and troubleshooting tool for a wide range of applications.

Most digital phosphor oscilloscopes (DPOs) employ a parallel-processing architecture to deliver vastly greater waveform capture rates. As seen in Figure 48, some DPOs can acquire millions of waveforms in just seconds, significantly increasing the probability of capturing intermittent and elusive events and allowing you to see the problems in your signal more quickly. Moreover, the DPO's ability to acquire and display three dimensions of signal behavior in real time – amplitude, time and distribution of amplitude over time – results in a superior level of insight into signal behavior, as shown in Figure 49.

Record Length

Record length, expressed as the number of points that comprise a complete waveform record, determines the amount of data that can be captured with each channel. Since an oscilloscope can store only a limited number of samples, the waveform duration (time) will be inversely proportional to the oscilloscope's sample rate.

$$\text{Time Interval} = \frac{\text{Record Length}}{\text{Sample Rate}}$$

Modern oscilloscopes allow you to select record length to optimize the level of detail needed for your application. If you are analyzing an extremely stable sinusoidal signal, you may need only a 500 point record length, but if you are isolating the causes of timing anomalies in a complex digital data stream, you may need a million points or more for a given record length, as demonstrated in Figure 50.

Triggering Capabilities

An oscilloscope’s trigger function synchronizes the horizontal sweep at the correct point of the signal, essential for clear signal characterization. Trigger controls allow you to stabilize repetitive waveforms and capture single-shot waveforms.

Please refer to the Trigger section under Performance Terms and Considerations for more information regarding triggering capabilities.

Effective Bits

Effective bits represent a measure of a digital oscilloscope's ability to accurately reconstruct a sinewave signal’s shape. This measurement compares the oscilloscope's actual error to that of a theoretical “ideal” digitizer. Because the actual errors include noise and distortion, the frequency and amplitude of the signal must be specified.

Frequency Response

Bandwidth alone is not enough to ensure that an oscilloscope can accurately capture a high frequency signal. The goal of oscilloscope design is a specific type of frequency response: Maximally Flat Envelope Delay (MFED). A frequency response of this type delivers excellent pulse fidelity with minimum overshoot and ringing. Since a digital oscilloscope is composed of real amplifiers, attenuators, ADCs, interconnects, and relays, MFED response is a goal that can only be approached. Pulse fidelity varies considerably with model and manufacturer.

Vertical Sensitivity

Vertical sensitivity indicates how much the vertical amplifier can amplify a weak signal – usually measured in millivolts (mV) per division. The smallest voltage detected by a general-purpose oscilloscope is typically about 1 mV per vertical screen division.

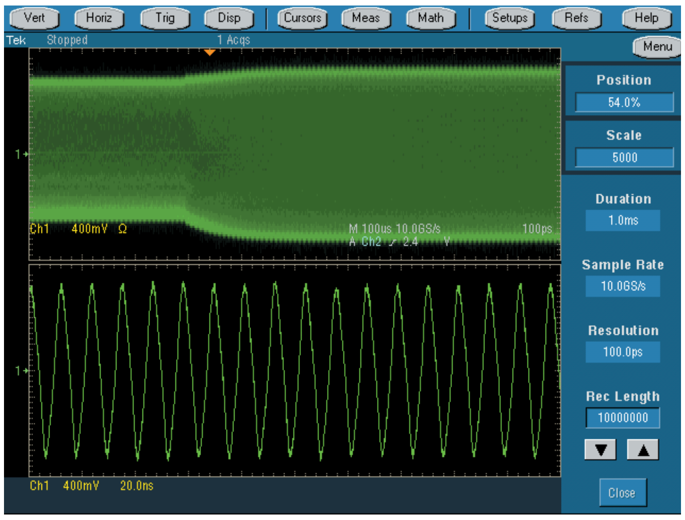

Position 54.0%
Scale 5000
Duration 1.0ms
Sample Rate 10.0GS/s
Resolution 100.0ps
Rec Length 10000000

Figure 50. Capturing the high frequency detail of this modulated 85 MHz carrier requires high resolution sampling (100 ps). Seeing the signal’s complete modulation envelope requires a long time duration (1 ms). Using long record length (10 MB), the oscilloscope can display both.

Sweep Speed

Sweep speed indicates how fast the trace can sweep across the oscilloscope screen, enabling you to see fine details. The sweep speed of an oscilloscope is represented by time (seconds) per division.

Gain Accuracy

Gain accuracy indicates how accurately the vertical system attenuates or amplifies a signal, usually represented as a percentage error.

Horizontal Accuracy (Time Base)

Horizontal, or time base, accuracy indicates how accurately the horizontal system displays the timing of a signal, usually represented as a percentage error.

Vertical Resolution (Analog-to-Digital Converter)

Vertical resolution of the ADC, and therefore, the digital oscilloscope, indicates how precisely it can convert input voltages into digital values. Vertical resolution is measured in bits. Calculation techniques can improve the effective resolution, as exemplified with hi-res acquisition mode.

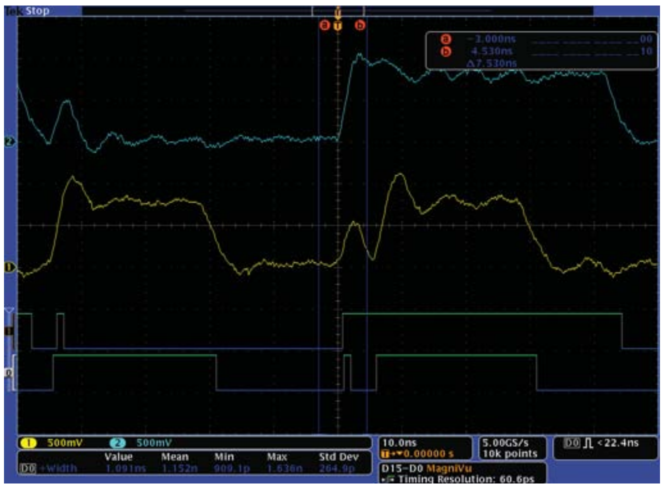
Stop
a
T
b
a -3.000ns
b 4.530ns
Δ7.530ns
1 500mV
2 500mV
Value Mean Min Max Std Dev
D0 +Width 1.091ns 1.152n 909.1p 1.636n 264.9p
10.0ns
T→▼0.00000 s
5.00GS/s
10k points
D0 <22.4ns
D15–D0 MagniVu
Timing Resolution: 60.6ps

Figure 51. The MSO provides 16 integrated digital channels, enabling the ability to view and analyze time-correlated analog and digital signals. A high speed timing acquisition provides more resolution to reveal narrow events such as glitches.

Timing Resolution (MSO)

An important MSO acquisition specification is the timing resolution used for capturing digital signals. Acquiring a signal with better timing resolution provides a more accurate timing measurement of when the signal changes. For example, a 500 MS/s acquisition rate has 2 ns timing resolution and the acquired signal edge uncertainty is 2 ns. A smaller timing resolution of 60.6 ps (16.5 GS/s) decreases the signal edge uncertainty to 60.6 ps and captures faster changing signals.

Some MSOs internally acquire digital signals with two types of acquisitions at the same time. The first acquisition is with standard timing resolution, and the second acquisition uses a high speed resolution. The standard resolution is used over a longer record length while the high speed timing acquisition offers more resolution around a narrow point of interest, as shown in Figure 51.

Connectivity

The need to analyze measurement results remains of utmost importance. The need to document and share information and measurement results easily and frequently has also grown in importance. The connectivity of an oscilloscope delivers advanced analysis capabilities and simplifies the documentation and sharing of results. As shown in Figure 52, standard interfaces (GPIB, RS-232, USB, Ethernet) and network communication modules enable some oscilloscopes to deliver a vast array of functionality and control.

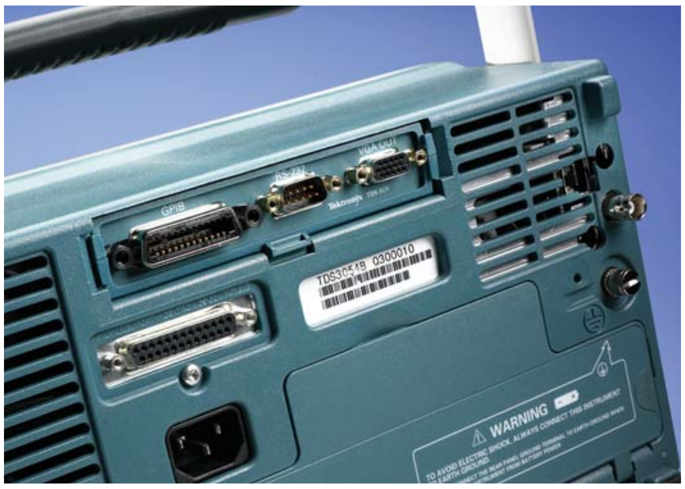
GPIB
RS-232
VGA OUT
TDS3054B
WARNING

Figure 52. Today's oscilloscopes provide a wide array of communications interfaces, such as a standard Centronics port and optional Ethernet/RS-232, GPIB/RS-232, and VGA/RS-232 modules. There is even a USB port (not shown) on the front panel.

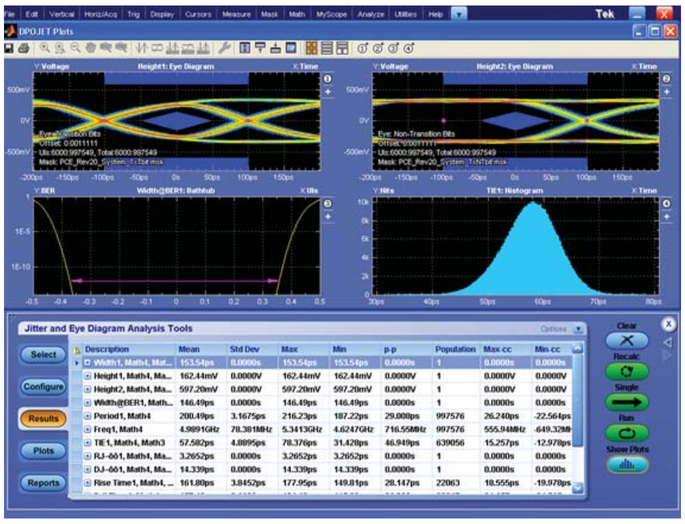
Tek
DPOJET Plots
Height1: Eye Diagram
Height2: Eye Diagram
Width@BER1: Bathtub
TIE1: Histogram
Jitter and Eye Diagram Analysis Tools
Options
Select
Configure
Results
Plots
Reports
Clear
Recalc
Single
Run
Show Plots

Description	Mean	Std Dev	Max	Min	p-p	Population	Max-cc	Min-cc
Width1, Math4, Mat...	153.54ps	0.0000s	153.54ps	153.54ps	0.0000s	1	0.0000s	0.0000s
Height1, Math4, Ma...	162.44mV	0.0000V	162.44mV	162.44mV	0.0000V	1	0.0000V	0.0000V
Height2, Math4, Ma...	597.20mV	0.0000V	597.20mV	597.20mV	0.0000V	1	0.0000V	0.0000V
Width@BER1, Math...	146.49ps	0.0000s	146.49ps	146.49ps	0.0000s	1	0.0000s	0.0000s
Period1, Math4	200.49ps	3.1675ps	216.23ps	187.22ps	29.008ps	997576	26.240ps	-22.564ps
Freq1, Math4	4.9891GHz	78.381MHz	5.3413GHz	4.6247GHz	716.55MHz	997576	555.94MHz	-649.32MHz
TIE1, Math4, Math3	57.582ps	4.8895ps	78.376ps	31.428ps	46.949ps	639056	15.257ps	-12.978ps
RJ-δδ1, Math4, Ma...	3.2652ps	0.0000s	3.2652ps	3.2652ps	0.0000s	1	0.0000s	0.0000s
DJ-δδ1, Math4, Ma...	14.339ps	0.0000s	14.339ps	14.339ps	0.0000s	1	0.0000s	0.0000s
Rise Time1, Math4, ...	161.80ps	3.8452ps	177.95ps	149.81ps	28.147ps	22063	18.555ps	-19.978ps

Figure 53. Analysis software packages are specifically designed to meet jitter and eye measurement needs of today's high-speed digital designers.

Some advanced oscilloscopes also let you:

- Create, edit and share documents on the oscilloscope – all while working with the instrument in your particular environment
- Access network printing and file sharing resources
- Access the Windows® desktop
- Run third-party analysis and documentation software
- Link to networks
- Access the Internet
- Send and receive e-mail

Expandability

An oscilloscope should be able to accommodate your needs as they change. Some oscilloscopes allow you to:

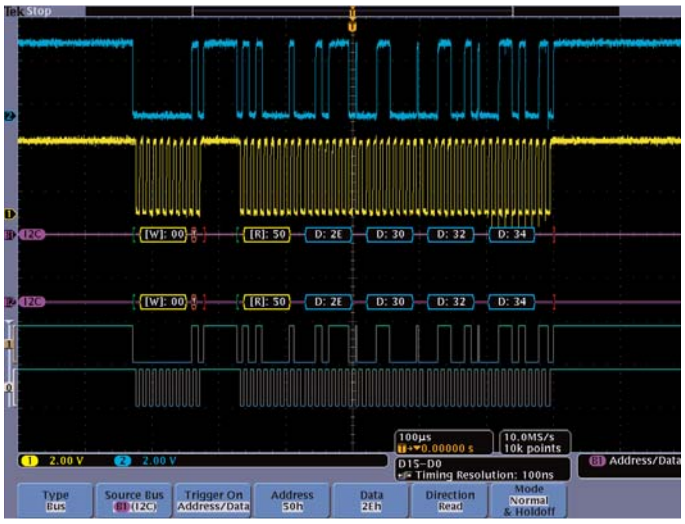
Stop
I2C
[W]: 00
[R]: 50
D: 2E
D: 30
D: 32
D: 34
100µs
10.0MS/s
10k points
D15–D0
Timing Resolution: 100ns
2.00 V
Address/Data
Type
Bus
Source Bus
(I2C)
Trigger On
Address/Data
Address
50h
Data
2Eh
Direction
Read
Mode
Normal
& Holdoff

Figure 54. Serial bus analysis is accelerated with automated trigger, decode, and search on serial packet context.

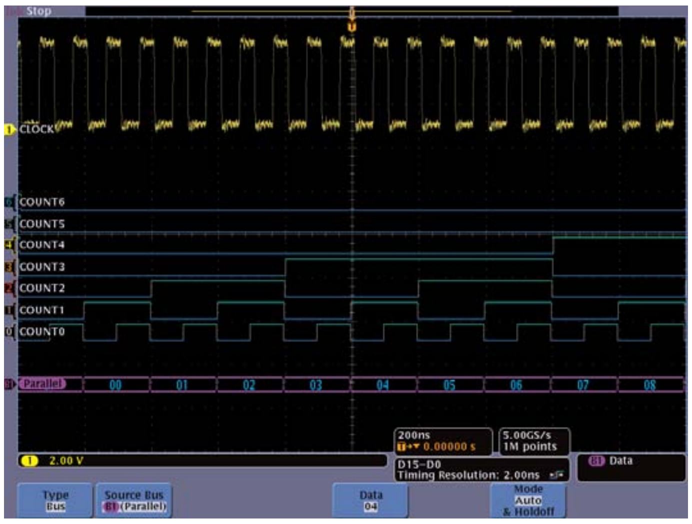
Stop
CLOCK
COUNT6
COUNT5
COUNT4
COUNT3
COUNT2
COUNT1
COUNT0
Parallel
00
01
02
03
04
05
06
07
08
200ns
0.00000 s
5.00GS/s
1M points
D15–D0
Timing Resolution: 2.00ns
2.00 V
Data
Type
Bus
Source Bus
(Parallel)
Data
04
Mode
Auto
& Holdoff

Figure 55. Automatically trigger, decode, and search on clocked or unclocked parallel bus data.

- Add memory to channels to analyze longer record lengths
- Add application-specific measurement capabilities
- Complement the power of the oscilloscope with a full range of probes and modules
- Work with popular third-party analysis and productivity Windows-compatible software
- Add accessories, such as battery packs and rackmounts

Application modules and software may enable you to transform your oscilloscope into a highly specialized analysis tool capable of performing functions such as jitter and timing analysis, microprocessor memory system verification, communications standards testing, disk drive measurements, video measurements, power measurements and much more. Figures 53 - 58 highlight a few of these examples.

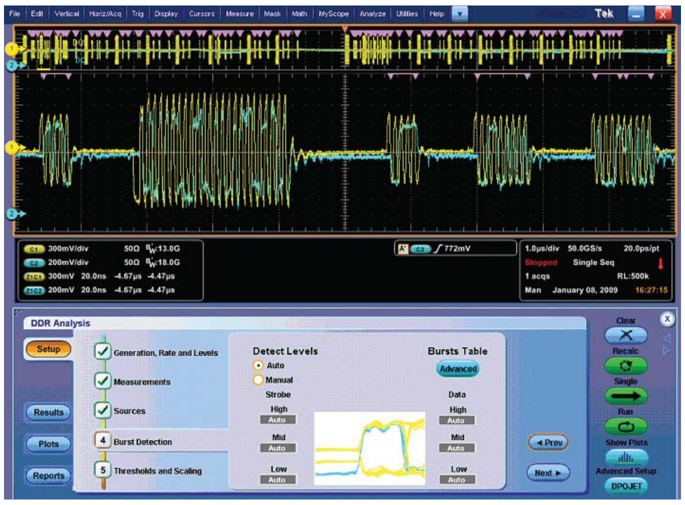
File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursors
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
DDR Analysis
Setup
Generation, Rate and Levels
Measurements
Sources
Burst Detection
Thresholds and Scaling
Results
Plots
Reports
Detect Levels
Auto
Manual
Strobe
High
Mid
Low
Bursts Table
Advanced
Data
◄ Prev
Next ►
Clear
Recalc
Single
Run
Show Plots
Advanced Setup
DPOJET

Figure 56. Advanced DDR analysis tools automate complex memory tasks like separating read/write bursts and performing JEDEC measurements.

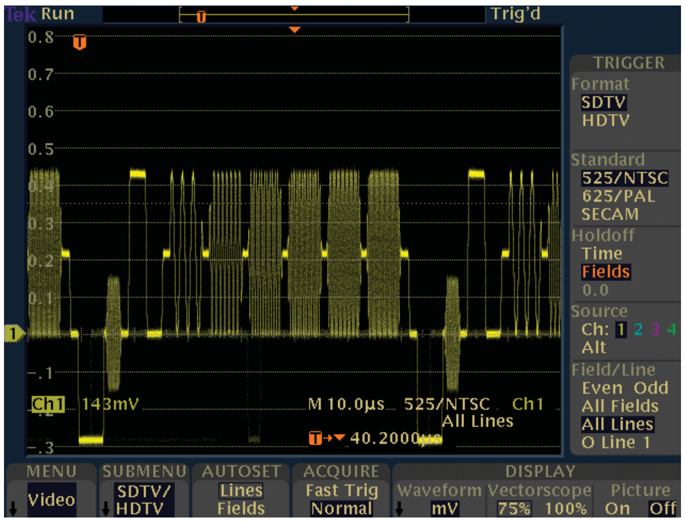
Run
Trig'd
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
−.1
−.3
Ch1 143mV
M 10.0µs
525/NTSC
Ch1
All Lines
40.2000µs
TRIGGER
Format
SDTV
HDTV
Standard
525/NTSC
625/PAL
SECAM
Holdoff
Time
Fields
0.0
Source
Ch: 1 2 3 4
Alt
Field/Line
Even Odd
All Fields
All Lines
0 Line 1
MENU
Video
SUBMENU
SDTV/
HDTV
AUTOSET
Lines
Fields
ACQUIRE
Fast Trig
Normal
DISPLAY
Waveform
mV
Vectorscope
75%
100%
Picture
On
Off

Figure 57. Video application modules make the oscilloscope a fast, tell-all tool for video troubleshooting.

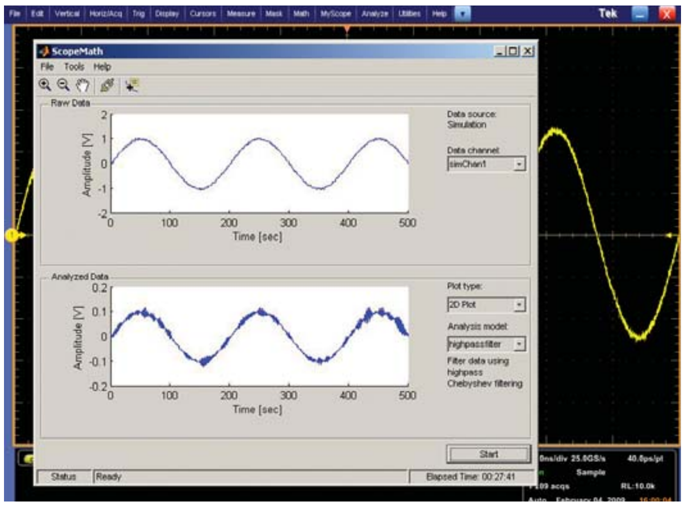
ScopeMath
File
Tools
Help
Raw Data
Amplitude [V]
Time [sec]
0
100
200
300
400
500
2
1
0
-1
-2
Data source:
Simulation
Data channel:
simChan1
Analyzed Data
0.2
0.1
0
-0.1
-0.2
Plot type:
2D Plot
Analysis model:
highpassfilter
Filter data using highpass Chebyshev filtering
Start
Status
Ready
Elapsed Time: 00:27:41
Tek

Figure 58. Advanced analysis and productivity software, such as MATLAB®, can be installed in Windows-based oscilloscopes to accomplish local signal analysis.

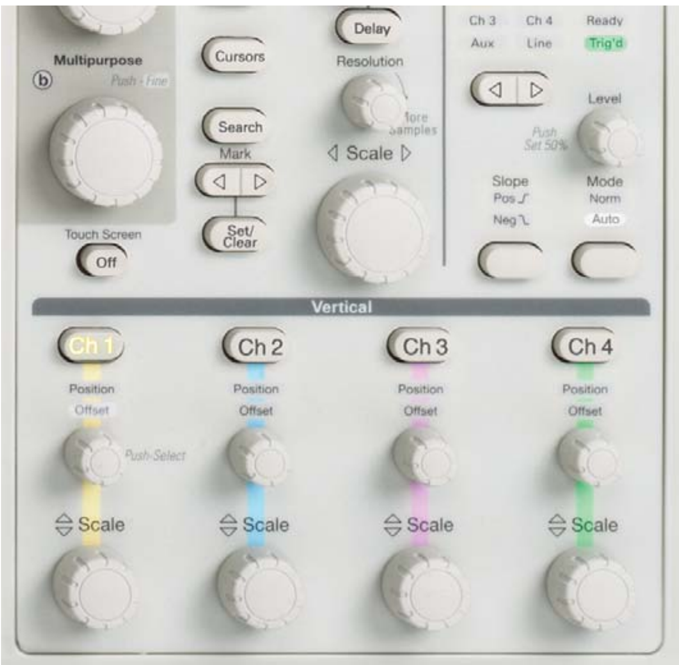
Multipurpose
Push - Fine
Cursors
Delay
Resolution
More Samples
Search
Mark
Set/Clear
Scale
Touch Screen
Off
Ch 3
Ch 4
Ready
Aux
Line
Trig'd
Level
Push Set 50%
Slope
Pos
Neg
Mode
Norm
Auto
Vertical
Ch 1
Ch 2
Ch 3
Ch 4
Position
Offset
Push-Select
Scale

Figure 59. Traditional, analog-style knobs control position, scale, intensity, etc. – precisely as you would expect.

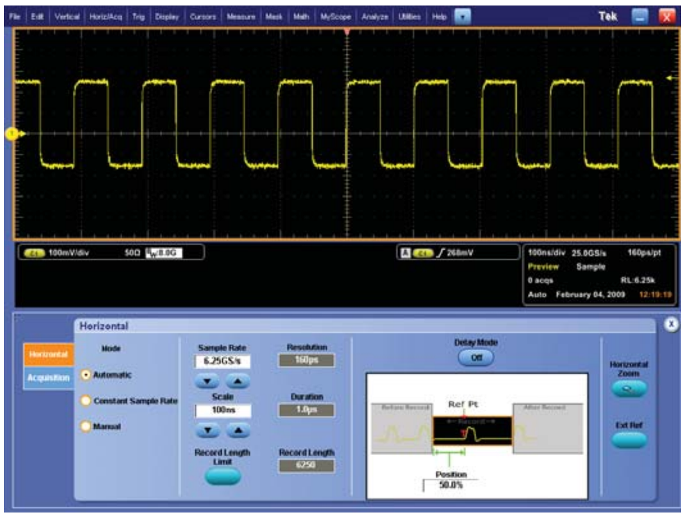
File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursors
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
100mV/div
50Ω
268mV
100ns/div
25.0GS/s
160ps/pt
Preview
Sample
0 acqs
RL:6.25k
Auto
February 04, 2009
Horizontal
Acquisition
Mode
Automatic
Constant Sample Rate
Manual
Sample Rate
6.25GS/s
Scale
100ns
Record Length Limit
Resolution
160ps
Duration
1.0µs
Record Length
6250
Delay Mode
Off
Ref Pt
Position
50.0%
Horizontal Zoom
Ext Ref

Figure 60. Use graphical control windows to access even the most sophisiticated functions with confidence and ease.

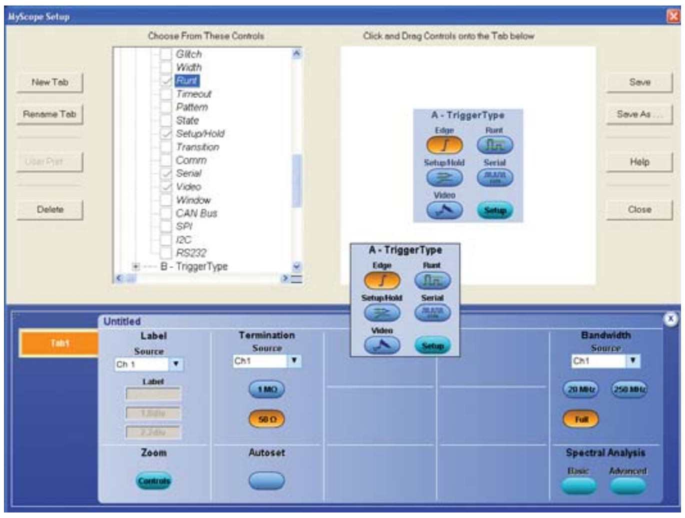
MyScope Setup
Choose From These Controls
Click and Drag Controls onto the Tab below
New Tab
Rename Tab
Delete
Glitch
Width
Runt
Timeout
Pattern
State
Setup/Hold
Transition
Comm
Serial
Video
Window
CAN Bus
SPI
I2C
RS232
B - TriggerType
A - TriggerType
Edge
Runt
Setup/Hold
Serial
Video
Setup
Save
Save As
Help
Close
Untitled
Tab1
Label
Source
Ch 1
Termination
1 MΩ
50 Ω
Zoom
Controls
Autoset
Bandwidth
20 MHz
250 MHz
Full
Spectral Analysis
Basic
Advanced

Figure 61. Touch-sensitive display naturally solves issues with cluttered benches and carts, while providing access to clear, on-screen buttons.

Ease-of-Use

Oscilloscopes should be easy to learn and easy to use, helping you work at peak efficiency and productivity. Allowing you to focus on your design, rather than the measurement tools. Just as there is no one typical car driver, there is no one typical oscilloscope user. Regardless of whether you prefer a traditional instrument interface, or that of a Windows® interface, it is important to have flexibility in your oscilloscope's operation.

Many oscilloscopes offer a balance between performance and simplicity by providing the user with many ways to operate the instrument. A front-panel layout, in Figure 59, provides dedicated vertical, horizontal and trigger controls. An icon-rich graphical user interface, as shown in Figure 60, helps you understand and intuitively use advanced capabilities. Touch-sensitive displays solve issues with cluttered benches and carts, while providing access to clear, on-screen buttons, as seen in Figure 61. Online help provides a convenient, built-in reference manual. Intuitive controls allow even occasional oscilloscope users to feel as comfortable driving the oscilloscope as they do driving a car, while giving full-time users easy access to the oscilloscope's most advanced features. In addition, many oscilloscopes are portable, such as the one shown in Figure 62, making the oscilloscope efficient in many different operating environments – in the lab or in the field.

Figure 62. The portability of many oscilloscopes makes the instrument efficient in many operating environments.

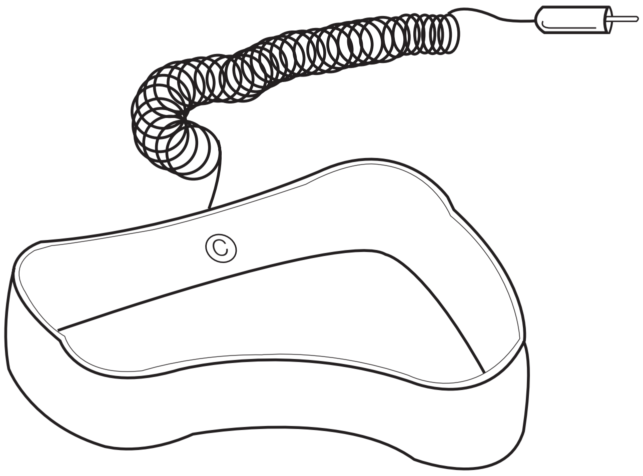

Figure 63. Typical wrist-type grounding strap.

Operating the Oscilloscope

This section briefly describes how to set up and start using an oscilloscope – specifically, how to properly ground the oscilloscope and yourself, set the oscilloscope controls, calibrate the oscilloscope, connect the probes, and compensate the probes.

Proper grounding is an important step when setting up to take measurements or work on a circuit. Proper grounding of the oscilloscope protects you from a hazardous shock and grounding yourself protects your circuits from damage.

Proper Grounding

To ground the oscilloscope means to connect it to an electrically neutral reference point, such as earth ground. Ground your oscilloscope by plugging its three-pronged power cord into an outlet grounded to earth ground.

Grounding the oscilloscope is necessary for safety. If a high voltage contacts the case of an ungrounded oscilloscope – any part of the case, including knobs that appear insulated – it can give you a shock. However, with a properly grounded oscilloscope, the current travels through the grounding path to earth ground rather than through you to earth ground.

Grounding is also necessary for taking accurate measurements with your oscilloscope. The oscilloscope needs to share the same ground as any circuits you are testing.

Some oscilloscopes do not require separate connection to earth ground. These oscilloscopes have insulated cases and controls, which keeps any possible shock hazard away from the user.

If you are working with integrated circuits (ICs), you also need to ground yourself. Integrated circuits have tiny conduction paths that can be damaged by static electricity that builds up on your body. You can ruin an expensive IC simply by walking across a carpet or taking off a sweater and then touching the leads of the IC. To solve this problem, wear a grounding strap, as shows in Figure 63. This strap safely sends static charges on your body to earth ground.

Setting the Controls

After plugging in the oscilloscope, take a look at the front panel. As described previously, the front panel is typically divided into three main sections labeled vertical, horizontal, and trigger. Your oscilloscope may have other sections, depending on the model and type.

Notice the input connectors on your oscilloscope – this is where you attach the probes. Most oscilloscopes have at least two input channels and each channel can display a waveform on the screen. Multiple channels are useful for comparing waveforms. As mentioned earlier, MSOs also have digital inputs as well.

Some oscilloscopes have AUTOSET and/or DEFAULT buttons that can set up the controls in one step to accommodate a signal. If your oscilloscope does not have this capability, it is helpful to set the controls to standard positions before taking measurements.

General instructions to manually set up the oscilloscope in standard positions are as follows:

- Set the oscilloscope to display channel 1
- Set the vertical volts/division scale and position controls to mid–range positions
- Turn off the variable volts/division
- Turn off all magnification settings
- Set the channel 1 input coupling to DC
- Set the trigger mode to auto
- Set the trigger source to channel 1
- Turn trigger holdoff to minimum or off
- Set the horizontal time/division and position controls to mid-range positions
- Adjust channel 1 volts/division such that the signal occupies as much of the 10 vertical divisions as possible without clipping or signal distortion

Calibrating the Instrument

In addition to proper oscilloscope setup, periodic instrument self-calibration is recommended for accurate measurements. Calibration is needed if the ambient temperature has changed more than 5° C (9° F) since the last self-calibration or once a week. In the oscilloscope menu this can sometimes be initiated as “Signal Path Compensation”. Refer to the manual that accompanied your oscilloscope for more detailed instructions.

Connecting the Probes

Now you are ready to connect a probe to your oscilloscope. A probe, if well-matched to the oscilloscope, will enable you to access all of the power and performance in the oscilloscope and will ensure the integrity of the signal you are measuring.

Measuring a signal requires two connections: the probe tip connection and the ground connection. Probes often come with a clip attachment for grounding the probe to the circuit under test. In practice, you attach the grounding clip to a known ground in the circuit, such as the metal chassis of a product you are repairing, and touch the probe tip to a test point in the circuit

Compensating the Probes

Passive attenuation voltage probes must be compensated to the oscilloscope. Before using a passive probe, you need to compensate it – to balance its electrical properties to a particular oscilloscope.

You should get into the habit of compensating the probe every time you set up your oscilloscope. A poorly adjusted probe can make your measurements less accurate. Figure 64 illustrates the effects on a 1 MHz test signal when using a probe that is not properly compensated.

Most oscilloscopes have a square wave reference signal available at a terminal on the front panel used to compensate the probe. General instructions to compensate the probe are as follows:

- Attach the probe to a vertical channel
- Connect the probe tip to the probe compensation, i.e. square wave reference signal
- Attach the ground clip of the probe to ground
- View the square wave reference signal
- Make the proper adjustments on the probe so that the corners of the square wave are square

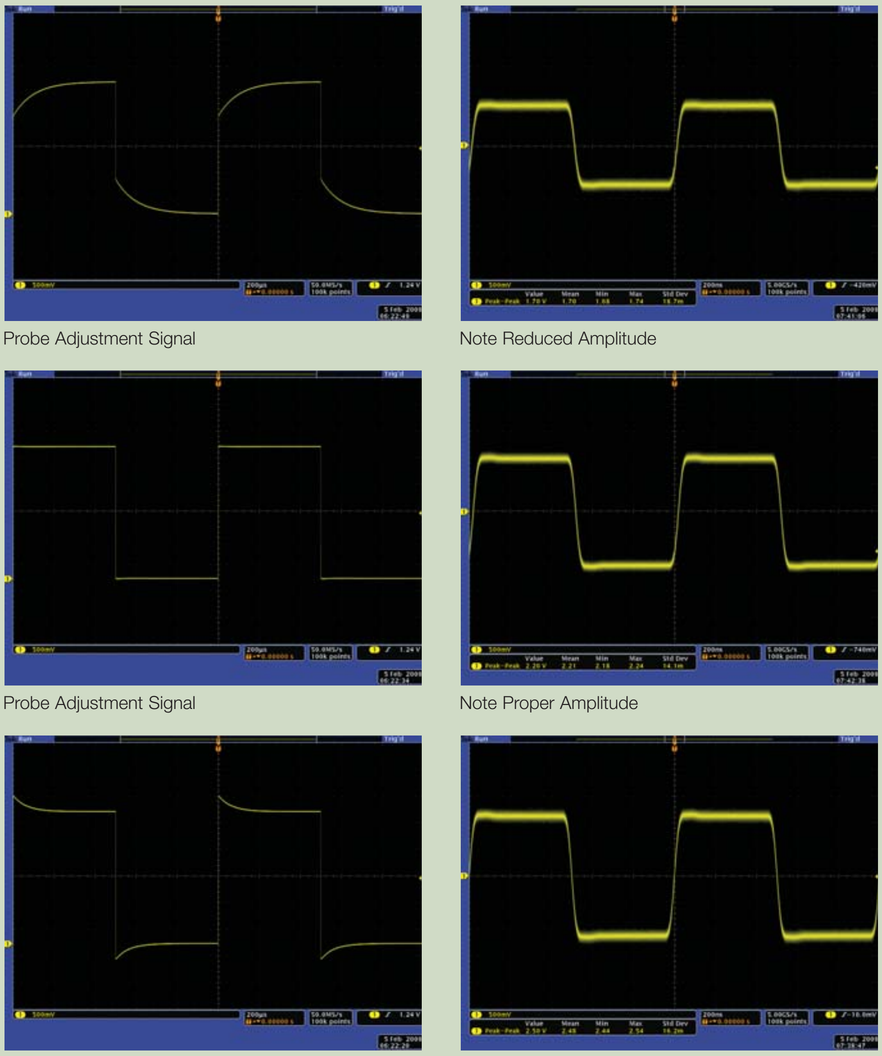

Probe Undercompensated.

Probe Adjustment Signal

Note Reduced Amplitude

Probe Compensated Correctly.

Probe Adjustment Signal

Note Proper Amplitude

Probe Overcompensated.

Probe Adjustment Signal

Note Increased Amplitude

Figure 64. The effects of improper probe compensation.

When you compensate the probe, always attach any accessory tips you will use and connect the probe to the vertical channel you plan to use. This will ensure that the oscilloscope has the same electrical properties as it does when you take measurements.

Oscilloscope Measurement Techniques

This section reviews basic measurement techniques. The two most basic measurements you can make are voltage and time measurements. Just about every other measurement is based on one of these two fundamental techniques.

This section discusses methods for taking measurements visually with the oscilloscope screen. This is a common technique with analog instruments, and also may be useful for "at-a-glance" interpretation of digital oscilloscope displays.

Note that most digital oscilloscopes include automated measurement tools that simplify and accelerate common analysis tasks, thus improving the reliability and confidence of your measurements. However, knowing how to make measurements manually as described here will help you understand and check the automatic measurements.

Voltage Measurements

Voltage is the amount of electric potential, expressed in volts, between two points in a circuit. Usually one of these points is ground (zero volts), but not always. Voltages can also be measured from peak-to-peak – from the maximum point of a signal to its minimum point. You must be careful to specify which voltage you mean.

The oscilloscope is primarily a voltage-measuring device. Once you have measured the voltage, other quantities are just a calculation away. For example, Ohm's law states that voltage between two points in a circuit equals the current times the resistance. From any two of these quantities you can calculate the third using the following formula:

$$\text{Voltage} = \text{Current } x \text{ Resistance}$$

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

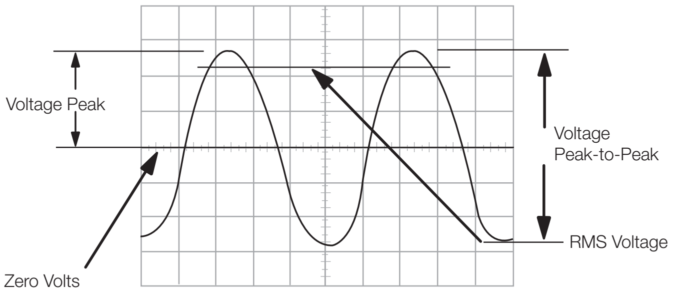

Figure 65. Voltage peak (V_p) and peak-to-peak voltage (V_{p-p})

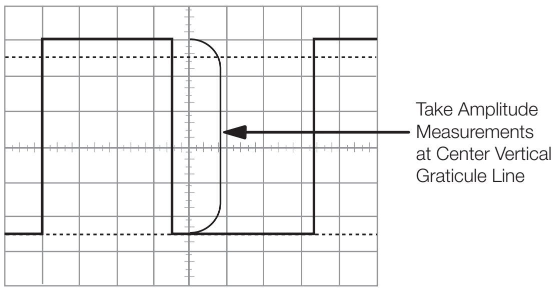
Take Amplitude Measurements at Center Vertical Graticule Line

Figure 66. Measure voltage on the center vertical graticule line.

Another handy formula is the power law, which states that the power of a DC signal equals the voltage times the current. Calculations are more complicated for AC signals, but the point here is that measuring the voltage is the first step toward calculating other quantities. Figure 65 shows the voltage of one peak (V_p) and the peak-to-peak voltage (V_{p-p}).

The most basic method of taking voltage measurements is to count the number of divisions a waveform spans on the oscilloscope's vertical scale. Adjusting the signal to cover most of the display vertically makes for the best voltage measurements, as shown in Figure 66. The more display area you use, the more accurately you can read the measurement.

Many oscilloscopes have cursors that let you make waveform measurements automatically, without having to count graticule marks. A cursor is simply a line that you can move across the display. Two horizontal cursor lines can be moved up and down to bracket a waveform's amplitude for voltage measurements, and two vertical lines move right and left for time measurements. A readout shows the voltage or time at their positions.

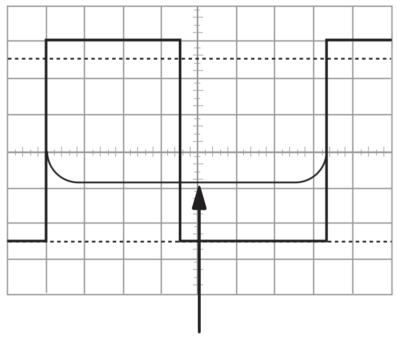

Figure 67. Measure time on the center horizontal graticule line.

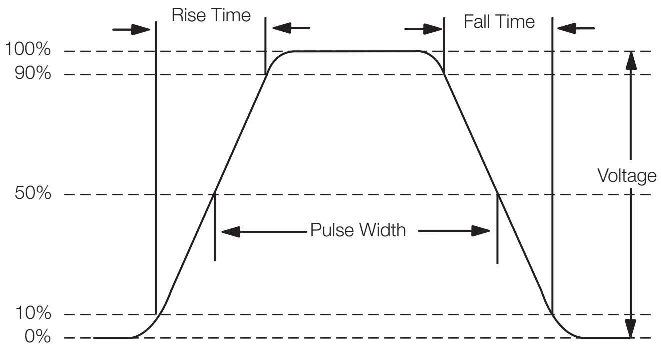

Figure 68. Rise time and pulse width measurement points.

Time and Frequency Measurements

You can make time measurements using the horizontal scale of the oscilloscope. Time measurements include measuring the period and pulse width of pulses. Frequency is the reciprocal of the period, so once you know the period, the frequency is one divided by the period. Like voltage measurements, time measurements are more accurate when you adjust the portion of the signal to be measured to cover a large area of the display, as illustrated in Figure 67.

Pulse Width and Rise Time Measurements

In many applications, the details of a pulse's shape are important. Pulses can become distorted and cause a digital circuit to malfunction, and the timing of pulses in a pulse train is often significant.

Standard pulse measurements are pulse rise time and pulse width. Rise time is the amount of time a pulse takes to go from a low to high voltage. By convention, the rise time is measured from 10% to 90% of the full voltage of the pulse. This eliminates any irregularities at the pulse's transition corners. Pulse width is the amount of time the pulse takes to go from low to high and back to low again. By convention, the pulse width is measured at 50% of full voltage. Figure 68 illustrates these measurement points.

Pulse measurements often require fine-tuning the triggering. To become an expert at capturing pulses, you should learn how to use trigger holdoff and how to set the digital oscilloscope to capture pretrigger data, as described in the Systems and Controls of an Oscilloscope section. Horizontal magnification is another useful feature for measuring pulses, since it allows you to see fine details of a fast pulse.

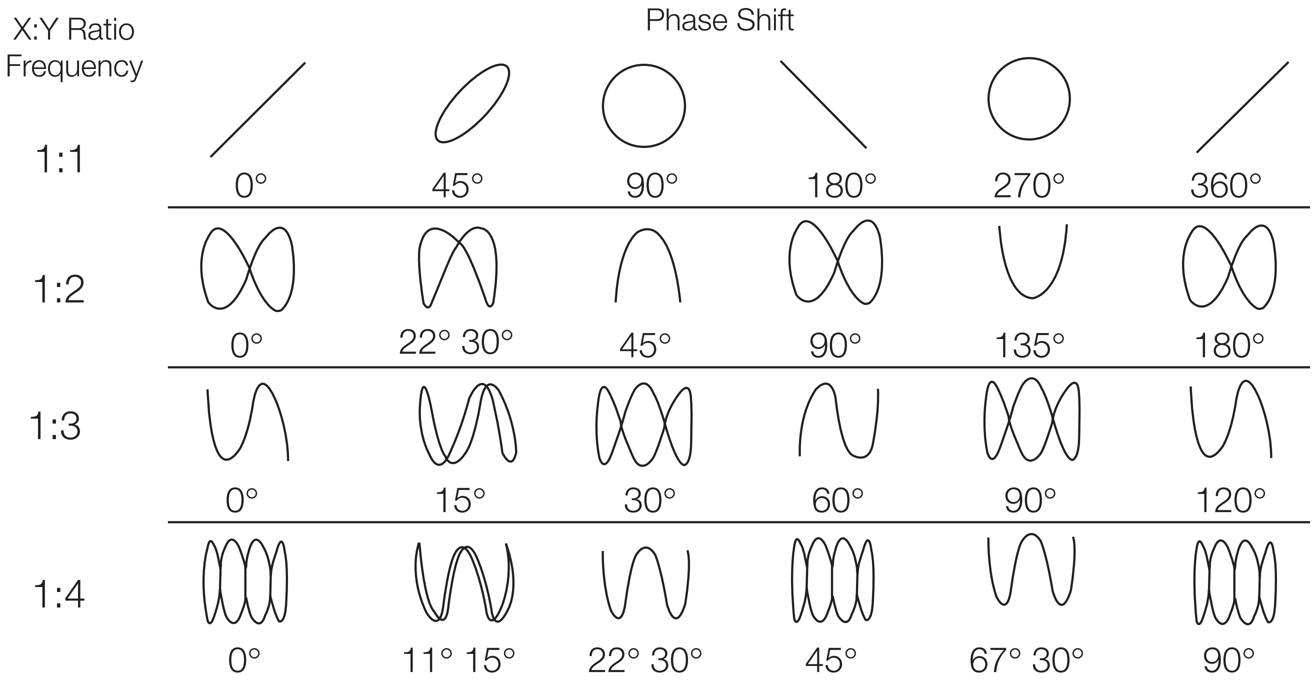

Figure 69. Lissajous patterns.

Phase Shift Measurements

One method for measuring phase shift – the difference in timing between two otherwise identical periodic signals – is to use XY mode. This measurement technique involves inputting one signal into the vertical system as usual and then another signal into the horizontal system – called an XY measurement because both the X and Y axis are tracing voltages. The waveform that results from this arrangement is called a Lissajous pattern (named for French physicist Jules Antoine Lissajous and pronounced LEE–sa–zhoo). From the shape of the Lissajous pattern, you can tell the phase difference between the two signals. You can also tell their frequency ratio. Figure 69 shows Lissajous patterns for various frequency ratios and phase shifts.

The XY measurement technique originated with analog oscilloscopes. DSOs may have difficulty creating real-time XY displays. Some DSOs create an XY image by accumulating triggered data points over time, then displaying two channels as an XY display.

DPOs, on the other hand, are able to acquire and display a genuine XY mode image in real-time, using a continuous stream of digitized data. DPOs can also display an XYZ image with intensified areas. Unlike XY displays on DSOs and DPOs, these displays on analog oscilloscopes are typically limited to a few megahertz of bandwidth.

Other Measurement Techniques

This section has covered basic measurement techniques. Other measurement techniques involve setting up the oscilloscope to test electrical components on an assembly line, capturing elusive transient signals, and many others. The measurement techniques you will use will depend on your application, but you have learned enough to get started. Practice using your oscilloscope and read more about it. Soon its operation will be second nature to you.

Written Exercises

This section contains written exercises that cover information in this primer. These are divided into two parts, Part I and Part II, with vocabulary and application exercises for each.

Check how well you have absorbed the information in these sections by verifying your responses against the answer key at the end of this section on page 54.

Part I covers information presented in these sections:

- The Oscilloscope
- Performance Terms and Considerations

Part II covers information presented in sections:

- The Systems and Controls of an Oscilloscope
- Operating the Oscilloscope
- Measurement Techniques

Part I A: Vocabulary Exercise

Write the letter of the definitions in the right column next to the correct words in the left column.

	Term		Definition
1. ___	Acquisition	**A**	The unit of electric potential difference.
2. ___	Analog	**B**	A performance measurement indicating the precision of an ADC, measured in bits.
3. ___	Bandwidth	**C**	Term used when referring to degree points of a signal's period.
4. ___	Digital Phosphor	**D**	The number of times a signal repeats in one second.
5. ___	Frequency	**E**	The amount of time it takes a wave to complete one cycle.
6. ___	Glitch	**F**	A stored digital value that represents the voltage of a signal at a specific point in time on the display.
7. ___	Period	**G**	A common waveform shape that has a rising edge, a width, and a falling edge.
8. ___	Phase	**H**	A performance measurement indicating the rising edge speed of a pulse.
9. ___	Pulse	**I**	Oscilloscope circuitry that controls the timing of the sweep.
10. ___	Waveform Point	**J**	An intermittent spike in a circuit.
11. ___	Rise Time	**K**	A signal measured by an oscilloscope that only occurs once.
12. ___	Sample Point	**L**	The oscilloscope's process of collecting sample points from the ADC, processing them, and storing them in memory.
13. ___	Digital Storage	**M**	Something that operates with continuously changing values.
14. ___	Time Base	**N**	Digital oscilloscope that captures 3 dimensions of signal information in real-time.
15. ___	Transient	**O**	Digital oscilloscope with serial processing.
16. ___	ADC Resolution	**P**	A sine wave frequency range, defined by the – 3 dB point.
17. ___	Volt	**Q**	The raw data from an ADC used to calculate and display waveform points.

Part I B: Application Exercise

Circle the best answers for each statement. Some statements have more than one right answer.

1. With an oscilloscope you can:

a. Calculate the frequency of a signal.

b. Find malfunctioning electrical components.

c. Analyze signal details.

d. All the above.

2. The difference between analog and digitizing oscilloscopes is:

a. Analog oscilloscopes do not have on-screen menus.

b. Analog oscilloscopes apply a measurement voltage directly to the display system, while digital oscilloscopes first convert the voltage into digital values.

c. Analog oscilloscopes measure analogs, whereas digitizing oscilloscopes measure digits.

d. Analog oscilloscopes do not have an acquisition system.

3. An oscilloscope's vertical section does the following:

a. Acquires sample points with an ADC.

b. Starts a horizontal sweep.

c. Lets you adjust the brightness of the display.

d. Attenuates or amplifies the input signal.

4. The time base control of the oscilloscope does the following:

a. Adjusts the vertical scale.

b. Shows you the current time of day.

c. Sets the amount of time represented by the horizontal width of the screen.

d. Sends a clock pulse to the probe.

5. On an oscilloscope display:

a. Voltage is on the vertical axis and time is on the horizontal axis.

b. A straight diagonal trace means voltage is changing at a steady rate.

c. A flat horizontal trace means voltage is constant.

d. All the above.

6. All repeating waves have the following properties:

a. A frequency measured in Hertz.

b. A period measured in seconds.

c. A bandwidth measured in Hertz.

d. All the above.

7. If you probe inside a computer with an oscilloscope, you are likely to find the following types of signals:

a. Pulse trains.

b. Ramp waves.

c. Sine waves.

d. All the above.

8. When evaluating the performance of an analog oscilloscope, some things you might consider are:

a. The bandwidth.

b. The vertical sensitivity.

c. The ADC resolution.

d. The sweep speed.

9. The difference between digital storage oscilloscopes (DSO) and digital phosphor oscilloscopes (DPO) is:

a. The DSO has a higher bandwidth.

b. The DPO captures three dimensions of waveform information in real-time.

c. The DSO has a color display.

d. The DSO captures more signal details.

Part II A: Vocabulary Exercise

Write the letter of the definitions in the right column next to the correct words in the left column.

	Term		Definition
1. ___	Averaging Mode	**A**	The unintentional interaction of the probe and oscilloscope with the circuit being tested which distorts a signal.
2. ___	Circuit Loading	**B**	A conductor that connects electrical currents to the Earth.
3. ___	Compensation	**C**	A sampling mode in which the digital oscilloscope collects as many samples as it can as the signal occurs, then constructs a display, using interpolation if necessary.
4. ___	Coupling	**D**	A sampling mode in which the digital oscilloscope constructs a picture of a repetitive signal by capturing a little bit of information from each repetition.
5. ___	Earth Ground	**E**	A device that converts a specific physical quantity such as sound, pressure, strain, or light intensity into an electrical signal.
6. ___	Equivalent-Time	**F**	A test device for injecting a signal into a circuit input.
7. ___	Graticule	**G**	A processing technique used by digital oscilloscopes to eliminate noise in a displayed signal.
8. ___	Interpolation	**H**	The method of connecting two circuits together.
9. ___	Real Time	**I**	A “connect-the-dots” processing technique to estimate what a fast waveform looks like based on only a few sampled points.
10. ___	Signal Generator	**J**	The grid lines on a screen for measuring oscilloscope traces.
11. ___	Single Sweep	**K**	A trigger mode that triggers the sweep once, must be reset to accept another trigger event.
12. ___	Sensor	**L**	A probe adjustment for 10X attenuator probes that balances the electrical properties of the probe with the electrical properties of the oscilloscope.

Part II B: Application Exercise

Circle the best answers for each statement. Some statements have more than one right answer.

1. To operate an oscilloscope safely, you should:

a. Ground the oscilloscope with the proper three-pronged power cord.

b. Learn to recognize potentially dangerous electrical components.

c. Avoid touching exposed connections in a circuit being tested even if the power is off.

d. All the above.

2. Grounding an oscilloscope is necessary:

a. For safety reasons.

b. To provide a reference point for making measurements.

c. To align the trace with the screen's horizontal axis.

d. All the above.

3. Circuit loading is caused by:

a. An input signal having too large a voltage.

b. The probe and oscilloscope interacting with the circuit being tested.

c. A 10X attenuator probe being uncompensated.

d. Putting too much weight on a circuit.

4. Compensating a probe is necessary to:

a. Balance the electrical properties of the 10X attenuator probe with the oscilloscope.

b. Prevent damaging the circuit being tested.

c. Improve the accuracy of your measurements.

d. All the above.

5. The trace rotation control is useful for:

a. Scaling waveforms on the screen.

b. Detecting sine wave signals.

c. Aligning the waveform trace with the screen's horizontal axis on an analog oscilloscope.

d. Measuring pulse width.

6. The volts per division control is used to:

a. Scale a waveform vertically.

b. Position a waveform vertically.

c. Attenuate or amplify an input signal.

d. Set the numbers of volts each division represents.

7. Setting the vertical input coupling to ground does the following:

a. Disconnects the input signal from the oscilloscope.

b. Causes a horizontal line to appear with auto trigger.

c. Lets you see where zero volts is on the screen.

d. All the above.

8. The trigger is necessary to:

a. Stabilize repeating waveforms on the screen.

b. Capture single-shot waveforms.

c. Mark a particular point of an acquisition.

d. All the above.

9. The difference between auto and normal trigger mode is:

a. In normal mode the oscilloscope only sweeps once and then stops.

b. In normal mode the oscilloscope only sweeps if the input signal reaches the trigger point; otherwise the screen is blank.

c. Auto mode makes the oscilloscope sweep continuously even without being triggered.

d. All the above.

10. The acquisition mode that best reduces noise in a repeating signal is:

a. Sample mode.

b. Peak detect mode.

c. Envelope mode.

d. Averaging mode.

11. The two most basic measurements you can make with an oscilloscope are:

a. Time and frequency measurements.

b. Time and voltage measurements.

c. Voltage and pulse width measurements.

d. Pulse width and phase shift measurements.

12. If the volts/division is set at 0.5, the largest signal that can fit on the screen (assuming an 8 x 10 division screen) is:

a. 62.5 millivolts peak-to-peak.

b. 8 volts peak-to-peak.

c. 4 volts peak-to-peak.

d. 0.5 volts peak-to-peak.

13. If the seconds/division is set at 0.1 ms, the amount of time represented by the width of the screen is:

a. 0.1 ms.

b. 1 ms.

c. 1 second.

d. 0.1 kHz.

14. By convention, pulse width is measured:

a. At 10% of the pulse's peak-to-peak (pk-pk) voltage.

b. At 50% of the pulse's peak-to-peak (pk-pk) voltage.

c. At 90% of the pulse's peak-to-peak (pk-pk) voltage.

d. At 10% and 90% of the pulse's peak-to-peak (pk-pk) voltage.

15. You attach a probe to your test circuit but the screen is blank. You should:

a. Check that the screen intensity is turned up.

b. Check that the oscilloscope is set to display the channel that the probe is connected to.

c. Set the trigger mode to auto since norm mode blanks the screen.

d. Set the vertical input coupling to AC and set the volts/division to its largest value since a large DC signal may go off the top or bottom of the screen.

e. Check that the probe isn't shorted and make sure it is properly grounded.

f. Check that the oscilloscope is set to trigger on the input channel you are using.

g. All of the above.

Answer Key

This section provides the answers to all written exercises in the previous section.

Part IA: Vocabulary Exercise Answers

1. L	5. D	9. G	13. O
2. M	6. J	10. F	14. I
3. P	7. E	11. H	15. K
4. N	8. C	12. Q	16. B
			17. A

Part IB: Application Exercise Answers

1. D	3. D	5. D	7. A
2. B,D	4. C	6. A,B	8. A,B,D
			9. B

Part IIA: Vocabulary Exercise Answers

1. G	4. H	7. J	10. F
2. A	5. B	8. I	11. K
3. L	6. D	9. C	12. E

Part IIB: Application Exercise Answers

1. D	5. C	9. B,C	13. B
2. A,B	6. A,C,D	10. D	14. B
3. B	7. D	11. B	15. G
4. A,C	8. D	12. C	

Glossary

A

Acquisition Mode – Modes that control how waveform points are produced from sample points. Some types include sample, peak detect, hi res, envelope, average, and waveform data base.

Alternating Current (AC) – A signal in which the current and voltage vary in a repeating pattern over time. Also used to indicate signal coupling type.

Amplification – An increase in signal amplitude during its transmission from one point to another.

Amplitude – The magnitude of a quantity or strength of a signal. In electronics, amplitude usually refers to either voltage or power.

Analog-to-Digital Converter (ADC) – A digital electronic component that converts an electrical signal into discrete binary values.

Analog Oscilloscope – An instrument that creates a waveform display by applying the input signal (conditioned and amplified) to the vertical axis of an electron beam moving across a cathode-ray tube (CRT) screen horizontally from left to right. A chemical phosphor coated on the CRT creates a glowing trace wherever the beam hits.

Analog Signal – A signal with continuously variable voltages.

Attenuation – A decrease in signal amplitude during its transmission from one point to another.

Averaging – A processing technique used by digital oscilloscopes to reduce noise in a displayed signal.

B

Bandwidth – A frequency range, usually limited by –3 dB.

C

Circuit Loading – The unintentional interaction of the probe and oscilloscope with the circuit being tested, distorting the signal.

Compensation – A probe adjustment for passive attenuation probes that balances the capacitance of the probe with the capacitance of the oscilloscope.

Coupling – The method of connecting two circuits together. Circuits connected with a wire are directly coupled (DC); circuits connected through a capacitor or transformer are indirectly (AC) coupled.

Cursor – An on–screen marker that you can align with a waveform to make more accurate measurements.

D

Delayed Time Base – A time base with a sweep that can start (or be triggered to start) relative to a pre-determined time on the main time base sweep. Allows you to see events more clearly and to see events that are not visible solely with the main time base sweep.

Digital Signal – A signal whose voltage samples are represented by discrete binary numbers.

Digital Oscilloscope – A type of oscilloscope that uses an analog-to-digital converter (ADC) to convert the measured voltage into digital information. Types include: digital storage, digital phosphor, mixed signal, and digital sampling oscilloscopes.

Digital Phosphor Oscilloscope (DPO) – A type of digital oscilloscope that closely models the display characteristics of an analog oscilloscope while providing traditional digital oscilloscope benefits (waveform storage, automated measurements, etc.) The DPO uses a parallel-processing architecture to pass the signal to the raster-type display, which provides intensity-graded viewing of signal characteristics in real time. The DPO displays signals in three dimensions: amplitude, time and the distribution of amplitude over time.

Digital Sampling Oscilloscope – A type of digital oscilloscope that employs equivalent-time sampling method to capture and display samples of a signal, ideal for accurately capturing signals whose frequency components are much higher than the oscilloscope's sample rate.

Digital Signal Processing – The application of algorithms to improve the accuracy of measured signals.

Digital Storage Oscilloscope (DSO) – A digital oscilloscope that acquires signals via digital sampling (using an analog-to-digital converter). It uses a serial-processing architecture to control acquisition, user interface, and the raster display.

Digitize – The process by which an analog-to-digital converter (ADC) in the horizontal system samples a signal at discrete points in time and converts the signal's voltage at these points into digital values called sample points.

Direct Current (DC) – A signal with a constant voltage and/or current. Also used to indicate signal coupling type.

Division – Measurement markings on the oscilloscope graticule indicating major and minor marks.

E

Earth Ground – A conductor that will connect electrical currents to the Earth.

Effective Bits – A measure of a digital oscilloscope's ability to accurately reconstruct a sine wave signal's shape. This measurement compares the oscilloscope's actual error to that of a theoretical “ideal” digitizer.

Envelope – The outline of a signal's highest and lowest points acquired over many displayed waveform repetitions.

Equivalent-time Sampling – A sampling mode in which the oscilloscope constructs a picture of a repetitive signal by capturing a little bit of information from each repetition. Two types of equivalent-time sampling: random and sequential.

F

Focus – The analog oscilloscope control that adjusts the cathode-ray tube (CRT) electron beam to control the sharpness of the display.

Frequency – The number of times a signal repeats in one second, measured in Hertz (cycles per second). The frequency equals 1/period.

Frequency Response – Frequency response curves of an oscilloscope define the accuracy in amplitude representation of the input signal in function of the signals frequency. In order to obtain maximum signal fidelity, it is important that the oscilloscope has a flat (stable) frequency response across the entire specified oscilloscopes bandwidth.

G

Gain Accuracy – An indication of how accurately the vertical system attenuates or amplifies a signal, usually represented as a percentage error.

Gigahertz (GHz) – 1,000,000,000 Hertz; a unit of frequency.

Glitch – An intermittent, high-speed error in a circuit.

Graticule – The grid lines on a display for measuring oscilloscope traces.

Ground –

1. A conducting connection by which an electric circuit or equipment is connected to the earth to establish and maintain a reference voltage level.
2. The voltage reference point in a circuit.

H

Hertz (Hz) – One cycle per second; the unit of frequency.

Horizontal Accuracy (Time Base) – An indication of how accurately the horizontal system displays the timing of a signal, usually represented as a percentage error.

Horizontal Sweep – The action of the horizontal system that causes a waveform to be drawn.

I

Intensity Grading – Frequency-of-occurrence information that is essential to understanding what the waveform is really doing.

Interpolation – A “connect-the-dots” processing technique to estimate what a fast waveform looks like based on only a few sampled points. Two types: linear and sin x/x.

K

Kilohertz (kHz) – 1,000 Hertz; a unit of frequency.

L

Loading – The unintentional interaction of the probe and oscilloscope with the circuit being tested which distorts a signal.

Logic Analyzer – An instrument used to make the logic states of many digital signals visible over time. It analyzes the digital data and can represent the data as real-time software execution, data flow values, state sequences, etc.

M

Megahertz (MHz) – 1,000,000 Hertz; a unit of frequency.

Megasamples per second (MS/s) – A sample rate unit equal to one million samples per second.

Microsecond (µs) – A unit of time equivalent to 0.000001 seconds.

Millisecond (ms) – A unit of time equivalent to 0.001 seconds.

Mixed Signal Oscilloscope (MSO) – A type of digital oscilloscope that combines the basic functionality of a 16-channel logic analyzer with the trusted performance of a 4-channel digital phosphor oscilloscope.

N

Nanosecond (ns) – A unit of time equivalent to 0.000000001 seconds.

Noise – An unwanted voltage or current in an electrical circuit.

O

Oscilloscope – An instrument used to make voltage changes visible over time. The word oscilloscope comes from “oscillate,” since oscilloscopes are often used to measure oscillating voltages.

P

Peak (V_p) – The maximum voltage level measured from a zero reference point.

Peak Detection – An acquisition mode available with digital oscilloscopes that enables you to observe signal details that may otherwise be missed, particularly useful for seeing narrow pulses spaced far apart in time.

Peak-to-peak (V_{p-p}) – The voltage measured from the maximum point of a signal to its minimum point.

Period – The amount of time it takes a wave to complete one cycle. The period equals 1/frequency.

Phase – The amount of time that passes from the beginning of a cycle to the beginning of the next cycle, measured in degrees.

Phase Shift – The difference in timing between two otherwise similar signals.

Pre-trigger Viewing – The ability of a digital oscilloscope to capture what a signal did before a trigger event. Determines the length of viewable signal both preceding and following a trigger point.

Probe – An oscilloscope input device, usually having a pointed metal tip for making electrical contact with a circuit element, a lead to connect to the circuit’s ground reference, and a flexible cable for transmitting the signal and ground to the oscilloscope.

Pulse – A common waveform shape that has a fast rising edge, a width, and a fast falling edge.

Pulse Train – A collection of pulses traveling together.

Pulse Width – The amount of time the pulse takes to go from low to high and back to low again, conventionally measured at 50% of full voltage.

R

Ramps – Transitions between voltage levels of sine waves that change at a constant rate.

Raster – A type of display.

Real-time Sampling – A sampling mode in which the oscilloscope collects as many samples as possible from one triggered acquisition. Ideal for signals whose frequency range is less than half the oscilloscope’s maximum sample rate.

Record Length – The number of waveform points used to create a record of a signal.

Rise Time – The time taken for the leading edge of a pulse to rise from its low to its high values, typically measured from 10% to 90%.

S

Sampling – The conversion of a portion of an input signal into a number of discrete electrical values for the purpose of storage, processing and/or display by an oscilloscope. Two types: real-time sampling and equivalent-time sampling.

Sample Point – The raw data from an ADC used to calculate waveform points.

Sample Rate – Refers to how frequently a digital oscilloscope takes a sample of the signal, specified in samples per second (S/s).

Sensor – A device that converts a specific physical quantity such as sound, pressure, strain, or light intensity into an electrical signal.

Signal Integrity – The accurate reconstruction of a signal, determined by the systems and performance considerations of an oscilloscope, in addition to the probe used to acquire the signal.

Signal Source – A test device used to inject a signal into a circuit input; the circuit’s output is then read by an oscilloscope. Also known as a signal generator.

Sine Wave – A common curved wave shape that is mathematically defined.

Single Shot – A signal measured by an oscilloscope that only occurs once (also called a transient event).

Single Sweep – A trigger mode to display one triggered screen of a signal and then stop.

Slope – On a graph or an oscilloscope display, the ratio of a vertical distance to a horizontal distance. A positive slope increases from left to right, while a negative slope decreases from left to right.

Square Wave – A common wave shape consisting of repeating square pulses.

Sweep – One horizontal pass of an anlog oscilloscope's electron beam from left to right across the CRT screen.

Sweep Speed – Same as the time base.

T

Time Base – Oscilloscope circuitry that controls the timing of the sweep. The time base is set by the seconds/division control.

Trace – The visible shapes drawn on a CRT by the movement of the electron beam.

Transient – A signal measured by an oscilloscope that only occurs once (also called a single–shot event).

Trigger – The circuit that references a horizontal sweep on an oscilloscope.

Trigger Holdoff – A control that allows you to adjust the period of time after a valid trigger during which the oscilloscope cannot trigger.

Trigger Level – The voltage level that a trigger source signal must reach before the trigger circuit initiates a sweep.

Trigger Mode – A mode that determines whether or not the oscilloscope draws a waveform if it does not detect a trigger. Common trigger modes include normal and auto.

Trigger Slope – The slope that a trigger source signal must reach before the trigger circuit initiates a sweep.

V

Vertical Resolution (Analog-to-Digital Converter) – An indication of how precisely an analog-to-digital converter (ADC) in a digital oscilloscope can convert input voltages into digital values, measured in bits. Calculation techniques, such as hi res acquisition mode, can improve the effective resolution.

Vertical Sensitivity – An indication of how much the vertical amplifier can amplify a weak signal – usually measured in millivolts (mV) per division.

Volt – The unit of electric potential difference.

Voltage – The difference in electric potential, expressed in volts, between two points.

W

Wave – The generic term for a pattern that repeats over time. Common types include: sine, square, rectangular, sawtooth, triangle, step, pulse, periodic, non-periodic, synchronous, asynchronous.

Waveform – A graphic representation of a voltage varying over time.

Waveform Capture Rate – Refers to how quickly an oscilloscope acquires waveforms, expressed as waveforms per second (wfms/s).

Waveform Point – A digital value that represents the voltage of a signal at a specific point in time. Waveform points are calculated from sample points and stored in memory.

Writing Speed – The ability of an analog oscilloscope to provide a visible trace of the movement of a signal from one point to another. This ability is restrictive for low-repetition signals that have fast-moving details, such as digital logic signals.

XY Mode – A measuremenbt technique that involves inputting one signal into the vertical system, as usual, and one into the horizontal system to trace voltages on both the X and Y axis.

Z

Z Axis – The display attribute on an oscilloscope that shows brightness variations as the trace is formed.

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HOME WIRING

A Comprehensive Manual from Basic Repairs to Advanced Projects

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Introduction

In everything from food preparation to climate control, from entertainment to work, electricity plays a critical role in our lives. Knowing about your electrical system and how it works will allow you to make sensible, effective, and economical decisions for your home's functionality, convenience, and safety.

This newly updated and revised edition of the top-selling *The Complete Guide to Home Wiring* is a comprehensive tour through the sometimes intimidating subject of electricity. With easy-to-understand definitions, step-by-step instructions, and clear color photos, you will recognize that most electrical work around your home, from basic repairs to advanced wiring projects, is work you yourself can easily accomplish.

Even if you choose to hire professionals to replace fixtures or install new circuits, your increased understanding of what is required will help you work with these contractors and make the best use of your money. *The Complete Guide to Home Wiring* provides everything you need to know to understand and successfully do electrical work around your home.

The first section of the book covers basic electrical repairs. Each major component of your home's electrical system is clearly defined and thoroughly covered. Definitions for and discussions about all types of wires and cables, fuse boxes and breaker panels, switches and receptacles will help you identify and work with the existing materials and fixtures in your home. You will learn how to troubleshoot and fix virtually any switch, receptacle, lamp, ceiling fixture, or thermostat as problems arise. All the tools and materials necessary for performing the repairs are shown, as well as professional techniques for using them. You also see how mapping your home's electrical system makes it much simpler and safer to do work. There is also a review of the problems that an electrical inspector would point out and the instructions to fix them.

The second section of the book presents complete wiring projects for your home. Whether you are remodeling and working in new construction or making changes within the existing structure, these detailed projects can be easily adapted to your home's particular needs. There are 26 up-to-code circuit maps designed to simplify wiring layouts. You will also learn each step to planning a major wiring project, from learning electrical code requirements to designing a layout that best suits your needs. Whether your wiring project involves a kitchen, bathroom, basement, attic remodel, or room addition, all the information you need can be found.

The third section of the book features a new area in the home electrical system: the home network wiring system. Computer, video, and telecommunication needs in the home are rapidly expanding. This increased use of technology creates a new demand for stronger and faster transference of data. A low-voltage structured wiring system provides the pathway. After learning what a home network wiring system is and how it will benefit you, the discussions of components will help you put together a system tailored to your specific needs.

This newly revised edition of *The Complete Guide to Home Wiring* will help you navigate through all of your home electrical projects, whether in repair or improvement. The thorough instructions and helpful tips will make this book an invaluable resource for years to come.

NOTICE TO READERS

This book provides useful instructions, but we cannot anticipate all of your working conditions or the characteristics of your materials and tools. For safety, you should use caution, care, and good judgment when following the procedures described in this book. Consider your own skill level and the instructions and safety precautions associated with the various tools and materials shown. Neither the publisher nor Black & Decker® can assume responsibility for any damage to property or injury to persons as a result of misuse of the information provided.

The instructions in this book conform to "The Uniform Plumbing Code," "The National Electrical Code Reference Book," and "The Uniform Building Code" current at the time of its original publication. Consult your local Building Department for information on building permits, codes, and other laws as they apply to your project.

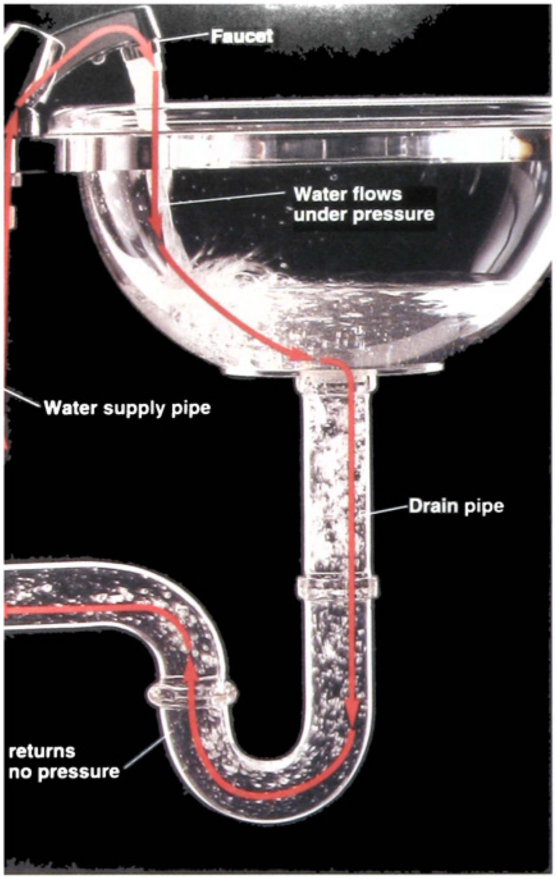
Faucet
Water flows under pressure
Water supply pipe
Drain pipe
returns no pressure

Understanding Electricity

A household electrical system can be compared with a home's plumbing system. Electrical current flows in wires in much the same way that water flows inside pipes. Both electricity and water enter the home, are distributed throughout the house, do their “work, and exit.

In plumbing, water first flows through the pressurized water supply system. In electricity, current first flows along hot wires. Current flowing along hot wires also is pressurized. The pressure of electrical current is called **voltage.**

Large supply pipes can carry a greater volume of water than small pipes. Likewise, large electrical wires carry more current than small wires. This current-carrying capacity of wires is called **amperage.**

Water is made available for use through the faucets, spigots, and showerheads in a home. Electricity is made available through receptacles, switches, and fixtures.

Water finally leaves the home through a drain system, which is not pressurized. Similarly, electrical current flows back through neutral wires. The current in neutral wires is not pressurized and is said to be at zero voltage

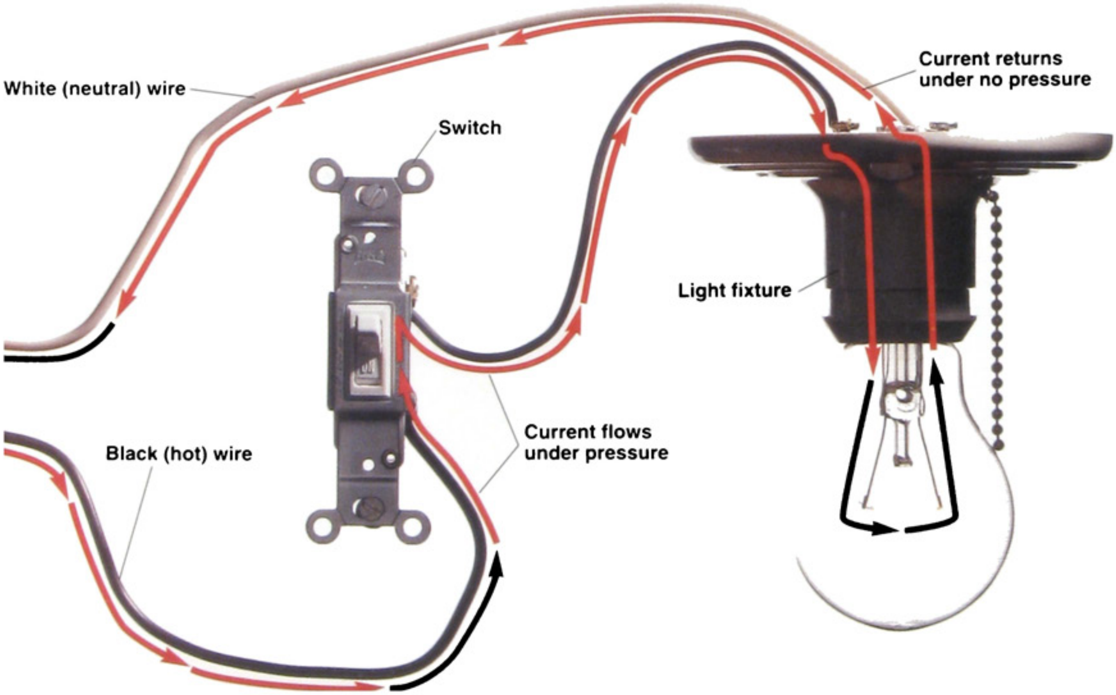
White (neutral) wire
Switch
Current returns under no pressure
Light fixture
Black (hot) wire
Current flows under pressure

Glossary of Electrical Terms

ampere (or **amp**): Refers to the rate at which electrical power flows to a light, tool, or appliance.

armored cable: Two or more wires that are grouped together and protected by a flexible metal covering.

box: A device used to contain wiring connections.

BX: See **armored cable.**

cable: Two or more wires that are grouped together and protected by a covering or sheath.

circuit: A continuous loop of electrical current flowing along wires or cables.

circuit breaker: A safety device that interrupts an electrical circuit in the event of an overload or short circuit.

conductor: Any material that allows electrical current to flow through it. Copper wire is an especially good conductor

conduit: A metal or plastic tube used to protect wires.

continuity: An uninterrupted electrical pathway through a circuit or electrical fixture.

current: The movement of electrons along a conductor.

duplex receptacle: A receptacle that provides connections for two plugs.

feed wire: A conductor that carries 120-volt current uninterrupted from the service panel.

fuse: A safety device, usually found in older homes, that interrupts electrical circuits during an overload or short circuit.

Greenfield: See **armored cable.**

grounded wire: See **neutral wire.**

grounding wire: A wire used in an electrical circuit to conduct current to the earth in the event of a short circuit. The grounding wire often is a bare copper wire.

hot wire: Any wire that carries voltage. In an electrical circuit, the hot wire usually is covered with black or red insulation.

insulator: Any material, such as plastic or rubber, that resists the flow of electrical current. Insulating materials protect wires and cables.

junction box: See **box.**

meter: A device used to measure the amount of electrical power being used.

neutral wire: A wire that returns current at zero voltage to the source of electrical power. Usually covered with white or light gray insulation. Also called the grounded wire.

outlet: See **receptacle.**

overload: A demand for more current than the circuit wires or electrical device was designed to carry. Usually causes a fuse to blow or a circuit breaker to trip.

pigtail: A short wire used to connect two or more circuit wires to a single screw terminal.

polarized receptacle: A receptacle designed to keep hot current flowing along black or red wires, and neutral current flowing along white or gray wires.

power: The result of hot current flowing for a period of time. Use of power makes heat, motion, or light.

receptacle: A device that provides plug-in access to electrical power.

Romex: A brand name of plastic-sheathed electrical cable that is commonly used for indoor wiring.

screw terminal: A place where a wire connects to a receptacle, switch, or fixture.

service panel: A metal box usually near the site where electrical power enters the house. In the service panel, electrical current is split into individual circuits. The service panel has circuit breakers or fuses to protect each circuit.

short circuit: An accidental and improper contact between two current-carrying wires, or between a current-carrying wire and a grounding conductor

switch: A device that controls electrical current passing through hot circuit wires. Used to turn lights and appliances on and off.

UL: An abbreviation for Underwriters Laboratories, an organization that tests electrical devices and manufactured products for safety.

voltage (or **volts**): A measurement of electricity in terms of pressure.

wattage (or **watt**): A measurement of electrical power in terms of total energy consumed. Watts can be calculated by multiplying the voltage times the amps.

wire connector: A device used to connect two or more wires together. Also called a wire nut.

Electricity & Safety

Safety should be the primary concern of anyone working with electricity. Although most household electrical repairs are simple and straightforward, always use caution and good judgment when working with electrical wiring or devices. Common sense can prevent accidents.

The basic rule of electrical safety is: **Always turn off power to the area or device you are working on.** At the main service panel, remove the fuse or shut off the circuit breaker that controls the circuit you are servicing. Then check to make sure the power is off by testing for power with a neon circuit tester (page 18). Restore power only when the repair or replacement project is complete.

Follow the safety tips shown on these pages. Never attempt an electrical project beyond your skill or confidence level. Never attempt to repair or replace your main service panel or service entrance head (pages 12 to 13). These are jobs for a qualified electrician and require that the power company shuts off power to your house.

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15
Fustat

Shut off power to the proper circuit at the fuse box or main service panel before beginning work.

Make a map of your household electrical circuits (pages 30 to 33) to help you turn the proper circuits on and off for electrical repairs.

DO NOT TOUCH

Close service panel door and post a warning sign to prevent others from turning on power while you are working on electrical projects.

Keep a flashlight near your main service panel. Check flashlight batteries regularly

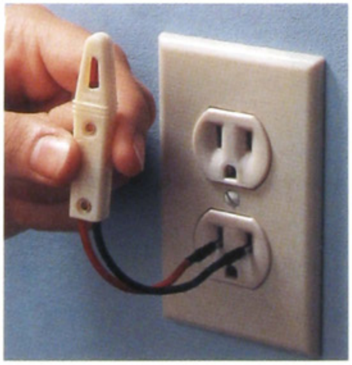

Always check for power at the fixture you are servicing before you begin any work.

Electracraft
Quik-connect
double switch
QUIET Single Pole
UL

Use only UL approved electrical parts or devices. These devices have been tested for safety by Underwriters Laboratories.

Wear rubber-soled shoes while working on electrical projects. On damp floors, stand on a rubber mat or dry wooden boards.

Use fiberglass or wood ladders when making routine household repairs near the service head.

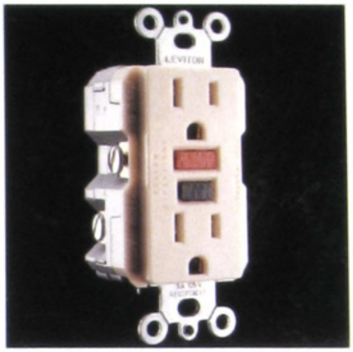

Use GFCI receptacles (ground-fault circuit-interrupters) where specified by local electrical codes (pages 74 to 77).

Protect children with receptacle caps or childproof receptacle covers (page 69).

Use extension cords only for temporary connections. Never place them underneath rugs or fasten them to walls, baseboards, or other surfaces.

Electracraft
plug
fuses

Use correct fuses or breakers in the main service panel (pages 28 to 29). Never install a fuse or breaker that has a higher amperage rating than the circuit wires.

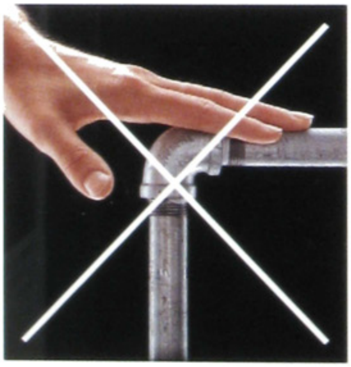

Do not touch metal pipes, faucets, or fixtures while working with electricity. The metal may provide a grounding path, allowing electrical current to flow through your body.

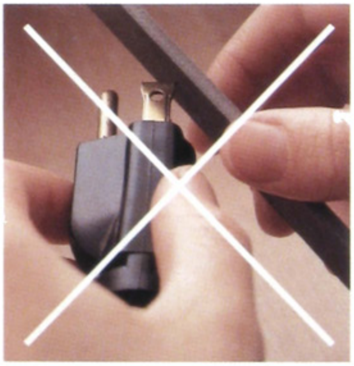

Never alter the prongs of a plug to fit a receptacle. If possible, install a new grounded receptacle.

Do not drill walls or ceilings without first shutting off electrical power to the circuits that may be hidden. Use double-insulated tools.

Your Electrical System

Electrical power that enters the home is produced by large **power plants.** Power plants are located in all parts of the country and generate electricity with turbines that are turned by water, wind, or steam. From these plants electricity enters large "step-up" transformers that increase voltage to half a million volts or more.

Electricity flows easily at these large voltages and travels through high-voltage transmission lines to communities that can be hundreds of miles from the power plants. "Step-down" transformers located at **substations** then reduce the voltage for distribution along street lines. On **utility power poles,** smaller transformers further reduce the voltage to ordinary 120-volt current for household use.

Lines carrying current to the house either run underground or are strung overhead and attached to a post called a **service head.** Most homes built after 1950 have three wires running to the service head: two power lines, each carrying 120 volts of current, and a grounded neutral wire. Power from the two 120-volt lines may be combined at the **service panel** to supply current to large, 240-volt appliances like clothes dryers or electric water heaters.

Many older homes have only two wires running to the service head, with one 120-volt line and a grounded neutral wire. This older two-wire service is inadequate for today's homes. Contact an electrical contractor and your local power utility company to upgrade to a three-wire service.

Incoming power passes through an **electric meter** that measures power consumption. Power then enters the service panel, where it is distributed to circuits that run throughout the house. The service panel also contains fuses or circuit breakers that shut off power to the individual circuits in the event of a short circuit or an overload. Certain high-wattage appliances, like microwave ovens, are usually plugged into their own individual circuits to prevent overloads.

Voltage ratings determined by power companies and manufacturers have changed over the years. Current rated at 110 volts changed to 115 volts, then 120 volts. Current rated at 220 volts changed to 230 volts, then 240 volts. Similarly, ratings for receptacles, tools, light fixtures, and appliances have changed from 115 volts to 125 volts. These changes will not affect the performance of new devices connected to older wiring. For making electrical calculations, such as the ones shown in "Evaluating Circuits for Safe Capacity" (pages 34 to 35), use a rating of 120 volts or 240 volts for your circuits.

Power plants supply electricity to thousands of homes and businesses. Step-up transformers increase the voltage produced at the plant, making the power flow more easily along high-voltage transmission lines.

Substations are located near the communities they serve. A typical substation takes current from high-voltage transmission lines and reduces it for distribution along street lines.

Utility pole transformers reduce the high-voltage current that flows through power lines along neighborhood streets. A utility pole transformer reduces voltage from 10,000 volts to the normal 120-volt current used in households.

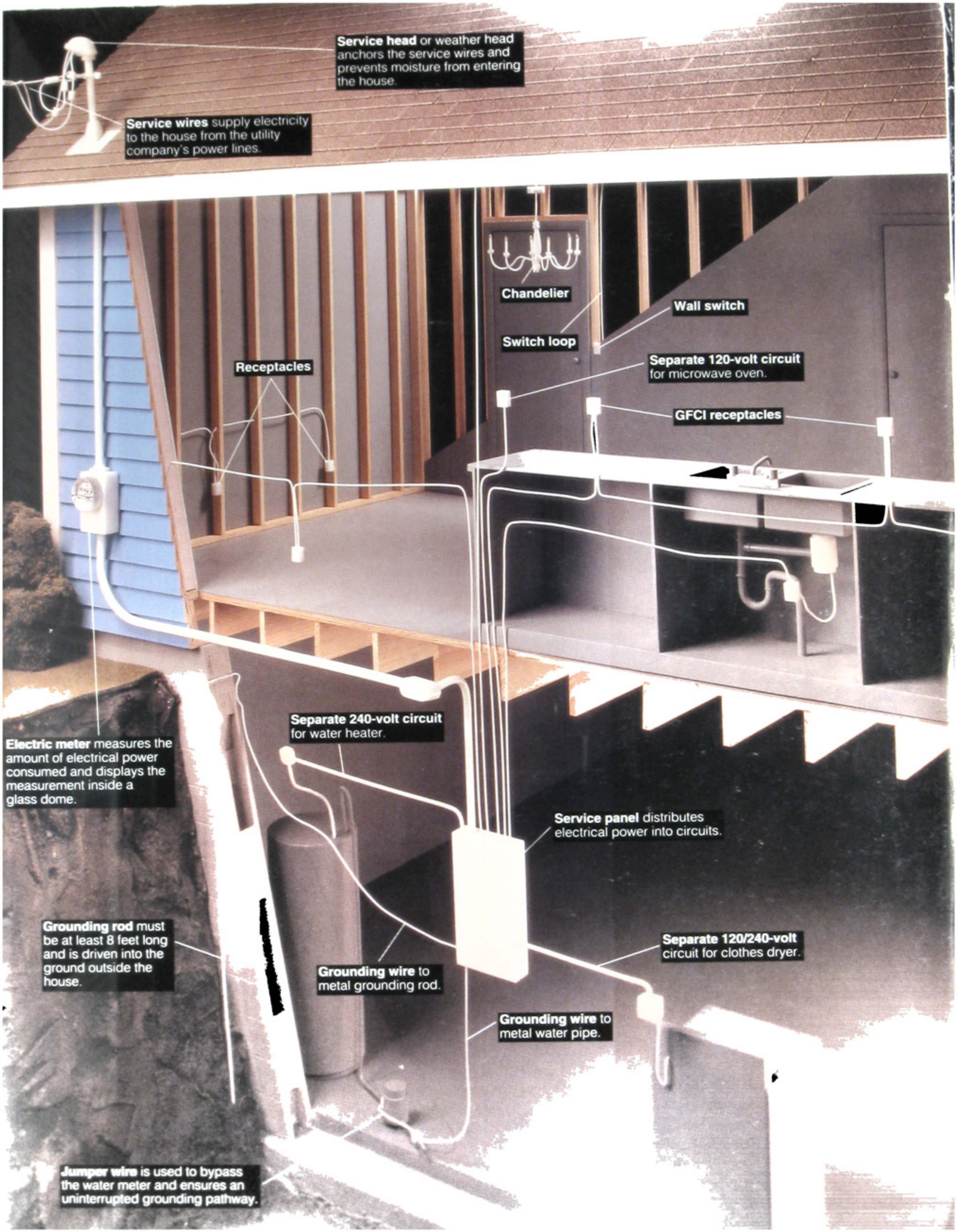

Service head or weather head anchors the service wires and prevents moisture from entering the house.

Service wires supply electricity to the house from the utility company's power lines.

Separate 120-volt circuit for microwave oven.

Separate 240-volt circuit for water heater.

Electric meter measures the amount of electrical power consumed and displays the measurement inside a glass dome.

Service panel distributes electrical power into circuits.

Grounding rod must be at least 8 feet long and is driven into the ground outside the house.

Separate 120/240-volt circuit for clothes dryer.

Grounding wire to metal grounding rod.

Grounding wire to metal water pipe.

Jumper wire is used to bypass the water meter and ensures an uninterrupted grounding pathway.

Parts of the Electrical System

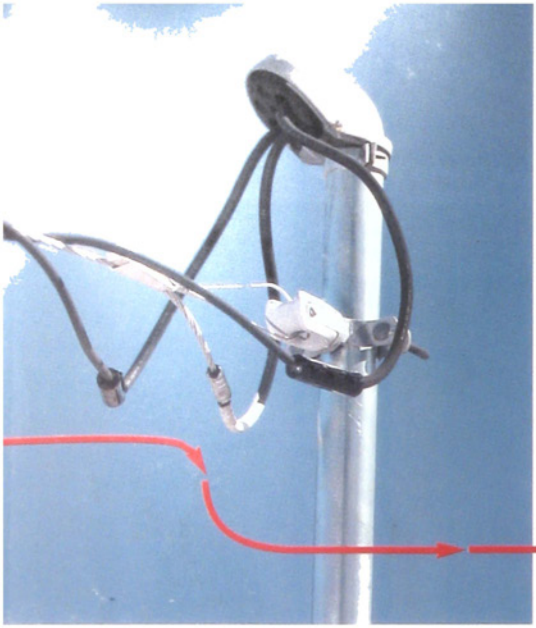

The service head, sometimes called the weather anchors the service wires to the home Three ovide the standard 240-volt service neces- he average home Older homes may have re service that provides only 120 volts of T ire service should be upgraded to service by an electrical contractor

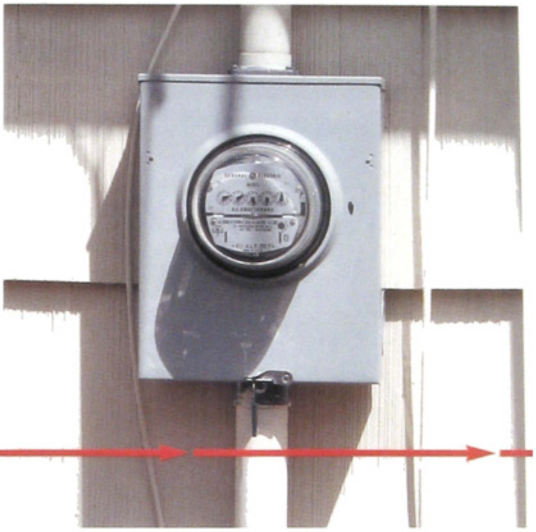

The electric meter measures the amount of electrical power consumed It is usually attached to the side of the house and connects to the service head A thin metal disc inside the meter rotates when power is used The electric meter belongs to your local power utility company If you suspect the meter is not functioning properly contact the power company

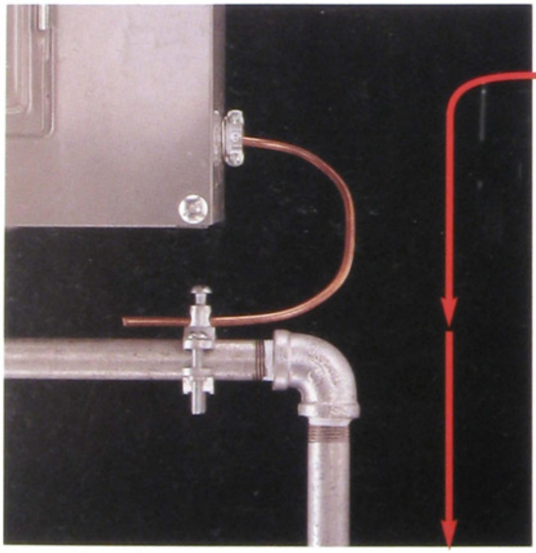

Grounding wire connects the electrical system to the earth through a cold water pipe and a grounding rod In the event of an overload or short circuit, the grounding wire allows excess electrical power to find its way harmlessly to the earth.

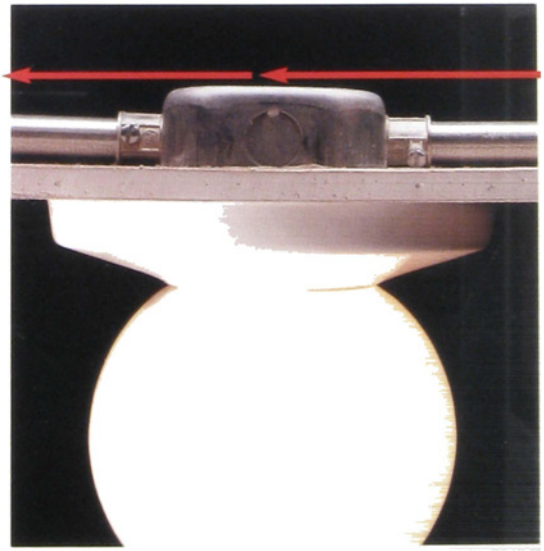

Light fixtures attach directly to a household electrical system They are usually controlled with wall switches The two common types of light fixtures ar **incandescent** (page 78) and **fluorescent** (page 90).

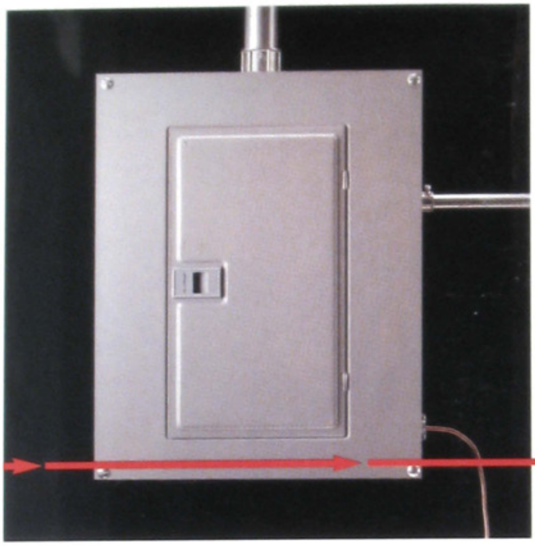

The main service panel, fuse
box breaker box

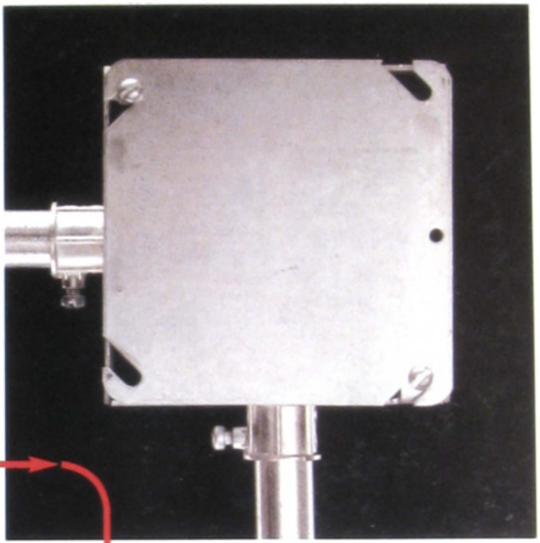

Electrical boxes
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Switches

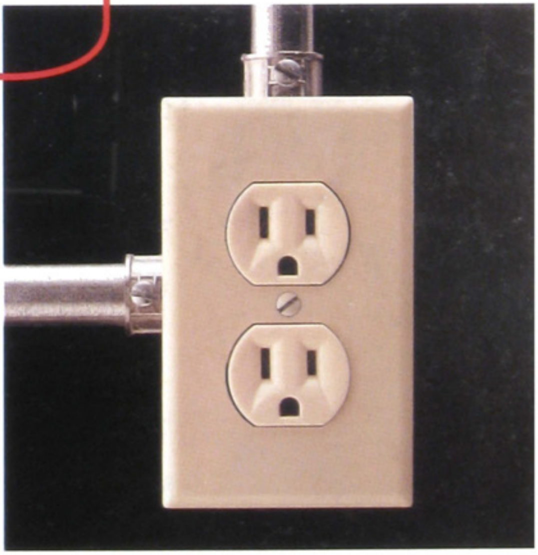

Receptacles, alled outlets.
access
receptacl
receptacle
Most receptacles e
called **duplex receptacles.**

Understanding Circuits

An electrical circuit is a continuous loop. Household circuits carry power from the main service panel, throughout the house, and back to the main service panel. Several switches, receptacles, light fixtures, or appliances may be connected to a single circuit.

Current enters a circuit loop on hot wires and returns along neutral wires. These wires are color coded for easy identification. Hot wires are black or red, and neutral wires are white or light gray. For safety, most circuits clude a bare copper or green insulated grounding wire. The grounding wire conducts current in the event of a short circuit or overload, and helps reduce the chance of severe electrical shock. The service panel also has a grounding wire connected to a metal water pipe and metal grounding rod buried underground (pages 16 to 17).

If a circuit carries too much power, it can overload. A fuse or a circuit breaker protects each circuit in case of overloads (pages 28 to 29). To calculate how much power any circuit can carry, see "Evaluating Circuits for Safe Capacity" (pages 34 to 35).

Current returns to the service panel along a neutral circuit wire. Current then becomes part of a main circuit and leaves the house on a large neutral service wire that returns it to the utility pole transformer.

Anatomy of a Circuit

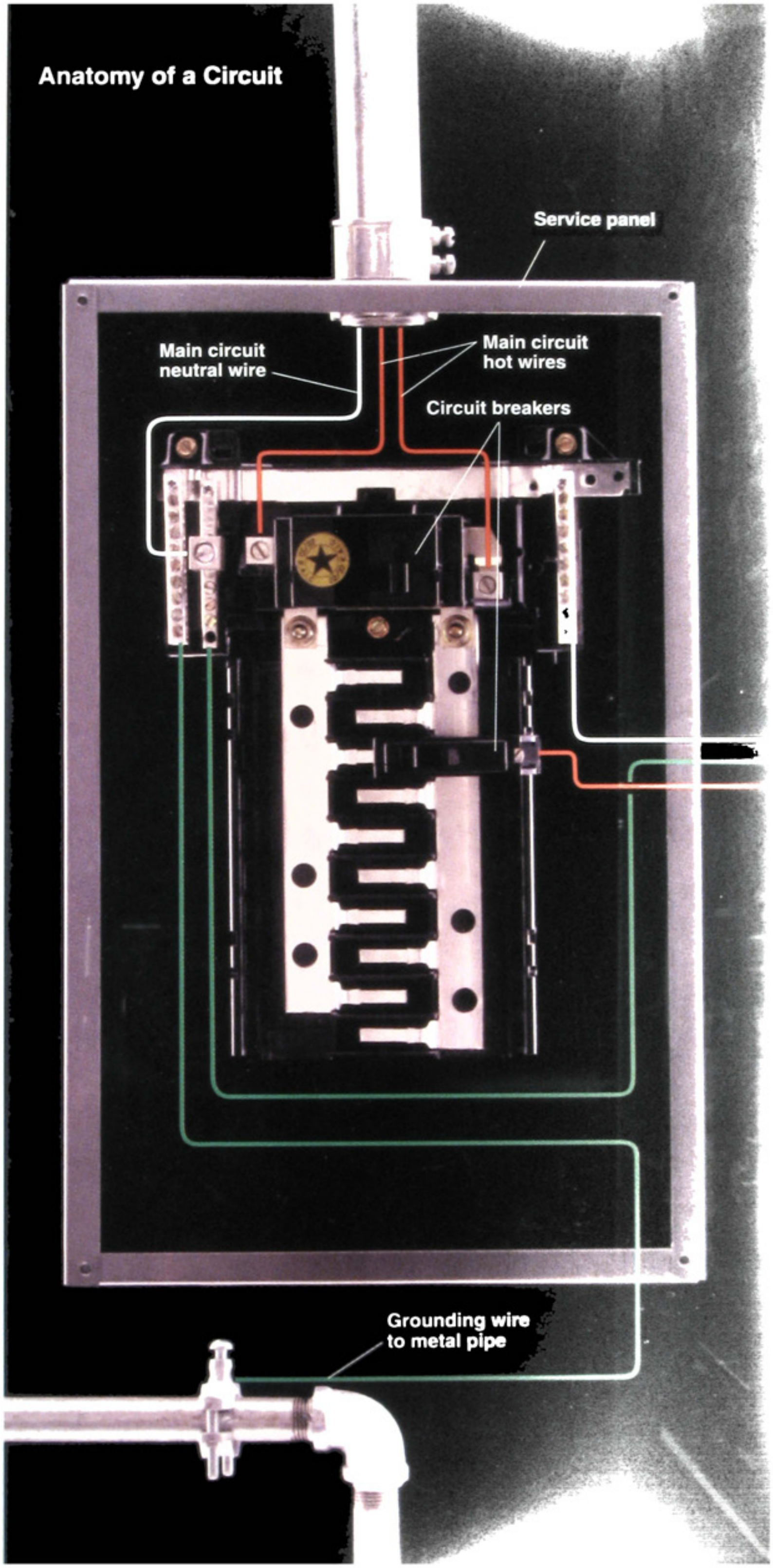

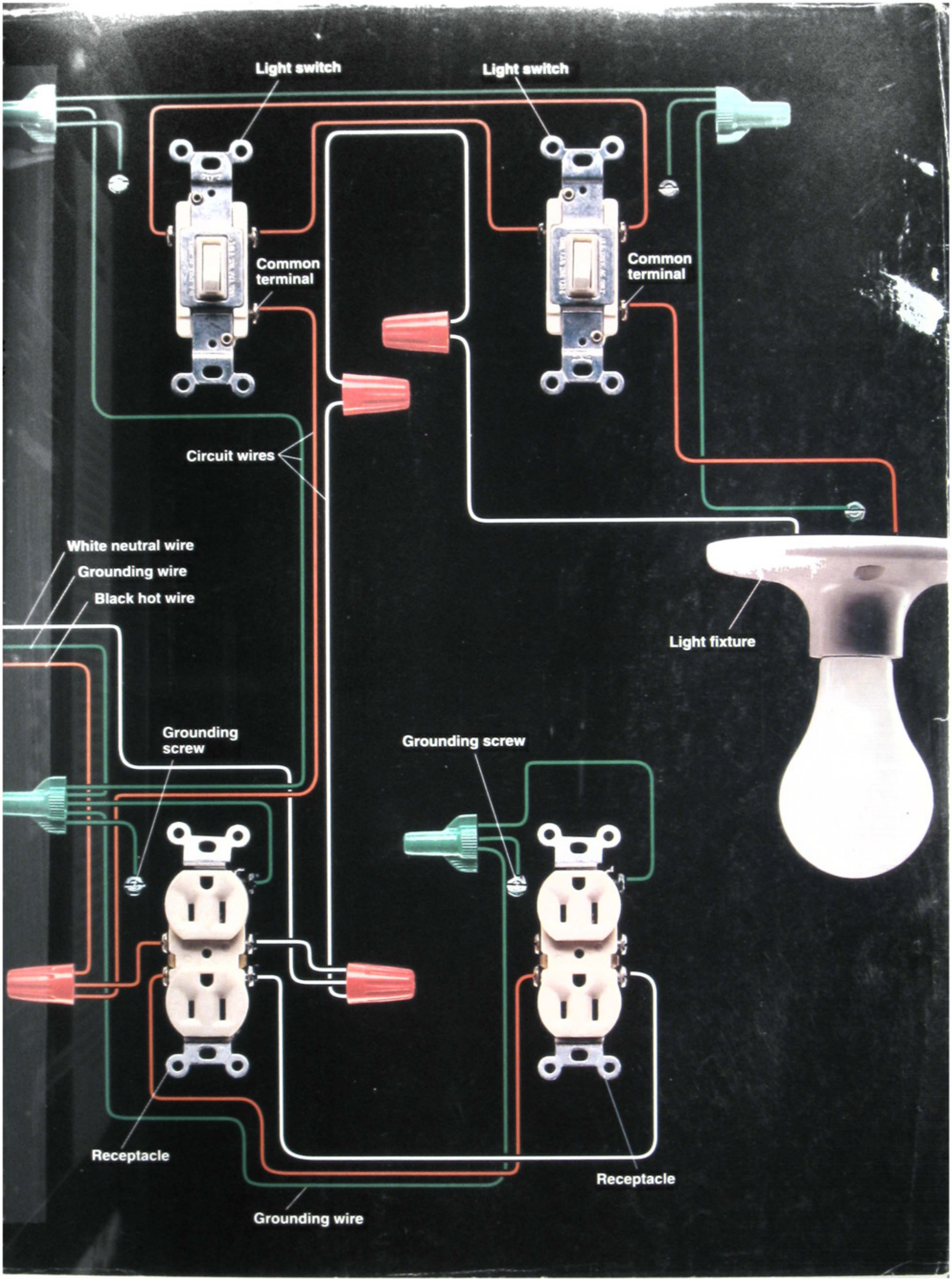
Light switch
Light switch
Common terminal
Common terminal
Circuit wires
White neutral wire
Grounding wire
Black hot wire
Light fixture
Grounding screw
Grounding screw
Receptacle
Receptacle
Grounding wire

Grounding & Polarization

Electricity always seeks to return to its source and complete a continuous circuit. In a household wiring system, this return path is provided by white neutral wires that return current to the main service panel. From the service panel, current returns along a neutral service wire to a power pole transformer.

A **grounding wire** provides an additional return path for electrical current. The grounding wire is a safety feature. It is designed to conduct electricity if current seeks to return to the service panel along a path other than the neutral wire, a condition known as a **short circuit**.

A short circuit is a potentially dangerous situation. If an electrical box, tool, or appliance becomes short circuited and is touched by a person, the electrical current may attempt to return to its source by passing through that person's body.

However, electrical current always seeks to move along the easiest path. A grounding wire provides a safe, easy path for current to follow back to its source. If a person touches an electrical box, tool, or appliance that has a properly installed grounding wire, any chance of receiving a severe electrical shock is greatly reduced.

In addition, household wiring systems are required to be connected directly to the earth. The earth has a unique ability to absorb the electrons of electrical current. In the event of a short circuit or overload, any excess electricity will find its way along the grounding wire to the earth, where it becomes harmless.

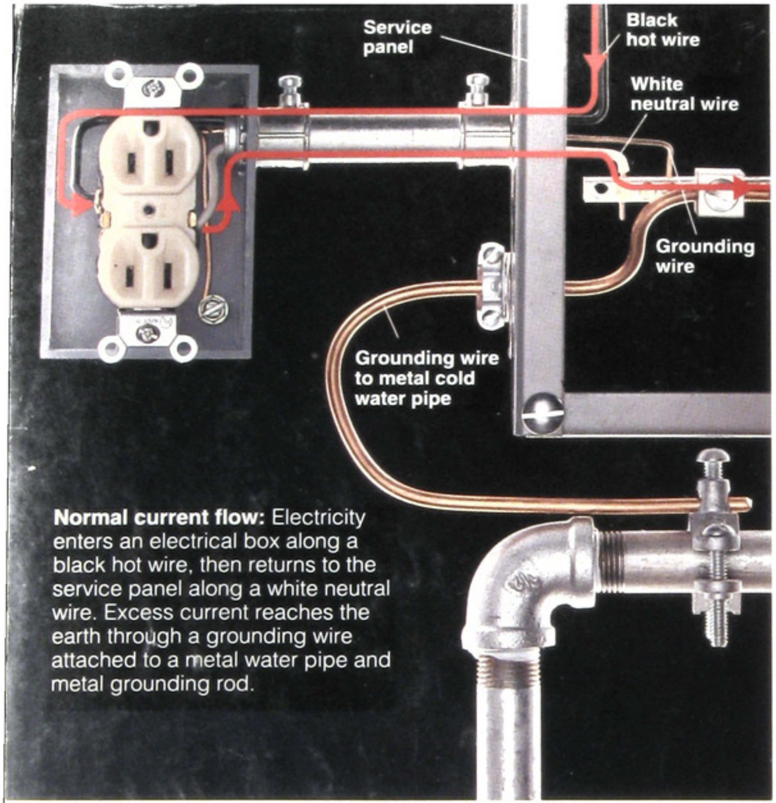

Normal current flow: Electricity enters an electrical box along a black hot wire, then returns to the service panel along a white neutral wire. Excess current reaches the earth through a grounding wire attached to a metal water pipe and metal grounding rod.

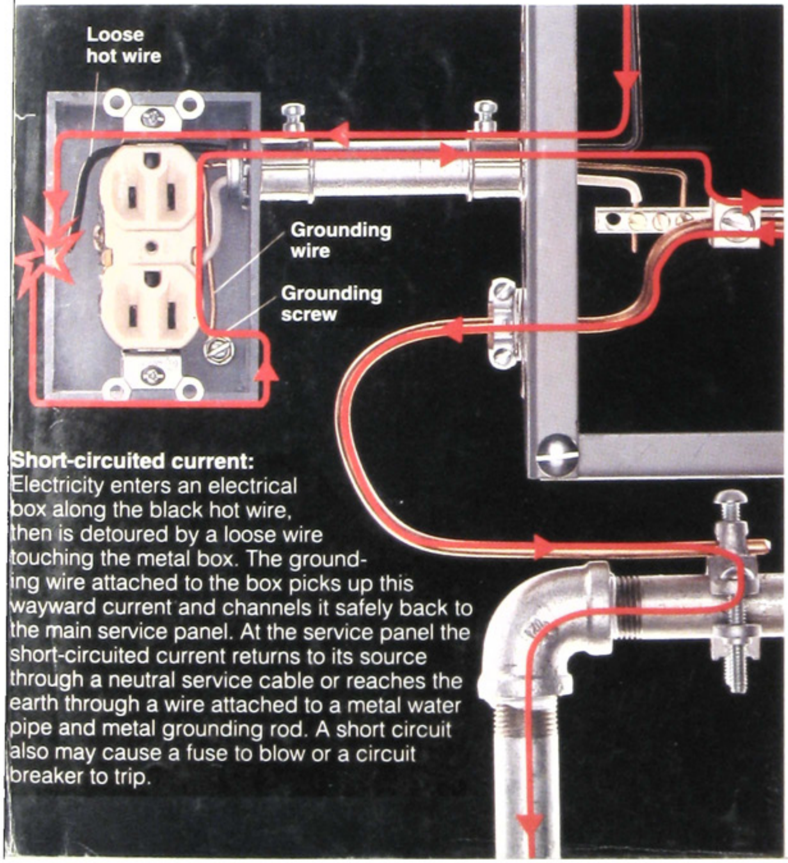

Short-circuited current: Electricity enters an electrical box along the black hot wire, then is detoured by a loose wire touching the metal box. The grounding wire attached to the box picks up this wayward current and channels it safely back to the main service panel. At the service panel the short-circuited current returns to its source through a neutral service cable or reaches the earth through a wire attached to a metal water pipe and metal grounding rod. A short circuit also may cause a fuse to blow or a circuit breaker to trip.

This additional grounding is completed by wiring the household electrical system to a metal cold water pipe and a metal grounding rod that is buried underground

After 1920, most American homes included receptacles that accepted **polarized plugs**. While not a true grounding method, the two-slot polarized plug and receptacle was designed to keep hot current flowing along black or red wires, and neutral current flowing along white or gray wires

Armored cable and metal conduit, widely installed in homes during the 1940s, provided a true grounding path. When connected to metal junction boxes, it provided a metal pathway back to the service panel

Modern cable includes a green insulated or bare copper wire that serves as the grounding path This grounding wire is connected to all three-slot receptacles and metal boxes to provide a continuous pathway for any short-circuited current. By plugging a three-prong plug into a grounded three-slot receptacle, appliances and tools are protected from short circuits

Use a receptacle adapter to plug three-prong plugs into two-slot receptacles, but use it only if the receptacle connects to a grounding wire or grounded electrical box Adapters have short grounding wires or wire loops that attach to the receptacle's coverplate mounting screw The mounting screw connects the adapter to the grounded metal electrical box.

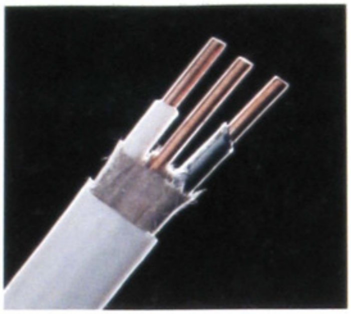

Modern NM (nonmetallic) cable, found in most wiring systems installed after 1965, contains a bare copper wire that provides grounding for receptacle and switch boxes

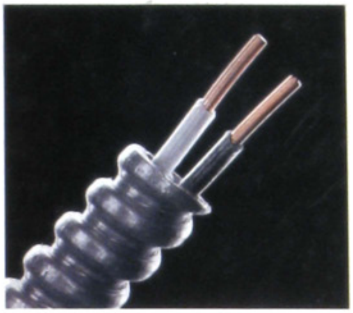

Armored cable, sometimes called BX or Greenfield cable has a metal sheath that serves as the grounding pathway Short-circuited current flows through the metal sheath back to the service panel

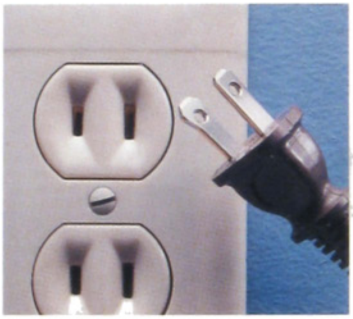

Polarized receptacles have a long slot and a short slot. Used with a polarized plug, the polarized receptacle keeps electrical current directed for safety

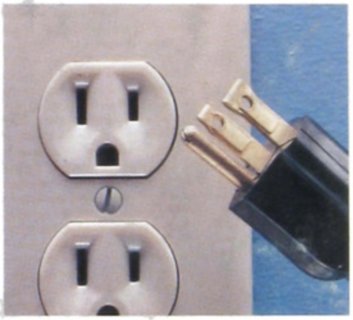

Three-slot receptacles are required by code for new homes They are usually connected to a standard two-wire cable with ground (above left)

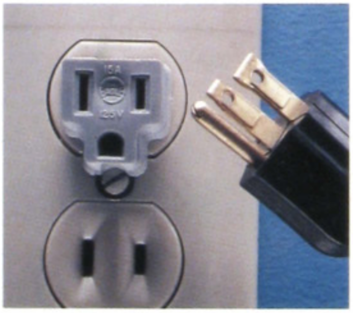

Receptacle adapter allows three-prong plugs to be inserted into two-slot receptacles The adapter can be used only with grounded receptacles, and the grounding loop or wire of the adapter must be attached to the coverplate mounting screw of the receptacle.

Double-insulated tools have nonconductive plastic bodies to prevent shocks caused by short circuits. Because of these features, double-insulated tools can be used safely with ungrounded receptacles

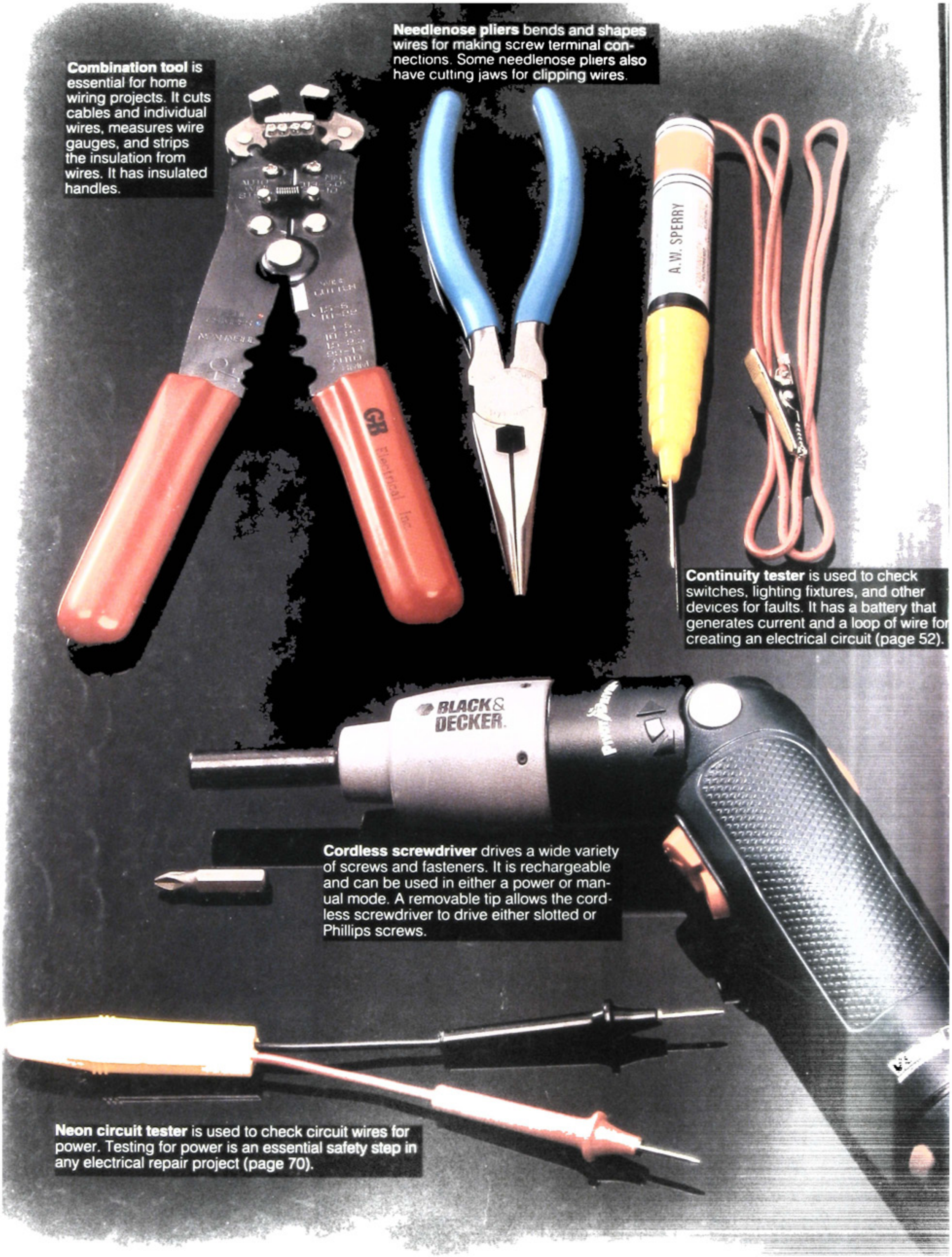

Combination tool is essential for home wiring projects. It cuts cables and individual wires, measures wire gauges, and strips the insulation from wires. It has insulated handles.

Needlenose pliers bends and shapes wires for making screw terminal connections. Some needlenose pliers also have cutting jaws for clipping wires.

Continuity tester is used to check switches, lighting fixtures, and other devices for faults. It has a battery that generates current and a loop of wire for creating an electrical circuit (page 52).

Cordless screwdriver drives a wide variety of screws and fasteners. It is rechargeable and can be used in either a power or manual mode. A removable tip allows the cordless screwdriver to drive either slotted or Phillips screws.

Neon circuit tester is used to check circuit wires for power. Testing for power is an essential safety step in any electrical repair project (page 70).

Tools for Electrical Repairs

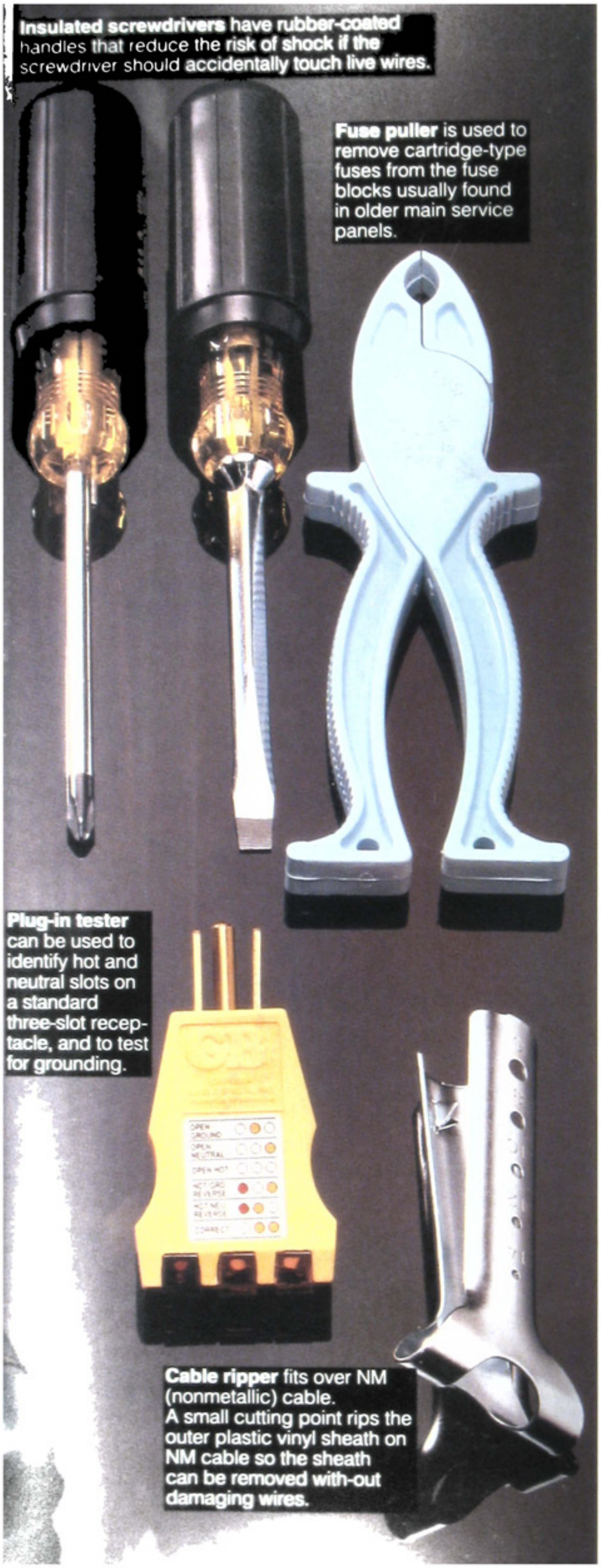

Insulated screwdrivers have rubber-coated handles that reduce the risk of shock if the screwdriver should accidentally touch live wires.

Fuse puller is used to remove cartridge-type fuses from the fuse blocks usually found in older main service panels.

Plug-in tester can be used to identify hot and neutral slots on a standard three-slot receptacle, and to test for grounding.

Cable ripper fits over NM (nonmetallic) cable. A small cutting point rips the outer plastic vinyl sheath on NM cable so the sheath can be removed with-out damaging wires.

Home electrical repairs require only a few inexpensive tools. As with any tool purchase, invest in quality when buying tools for electrical repairs.

Keep tools clean and dry, and store them securely. Tools with cutting jaws, like needlenose pliers and combination tools, should be resharpened or discarded if the cutting edges become dull.

Several testing tools are used in electrical repair projects. Neon circuit testers (page 70), continuity testers (page 52), and multi-testers (below) should be checked periodically to make sure they are operating properly. Continuity testers and multi-testers have batteries that should be replaced regularly.

P-7
DCV
1000
OFF
1000 ACV
250
50
10
2.5
1.5V
250
50
10
X10
0.5
DC
25
500
mA
+

Multi-tester is a versatile, battery-operated tool frequently used to measure electrical voltages. It also i used to test for continuity in switches, light fixtures, and other electrical devices. An adjustable control makes it possible to measure current ranging from 1 to 1000 volts. A multi-tester is an essential tool for measuring current in low-voltage transformers, like those used to power doorbell and thermostat systems (pages 100 to 113)

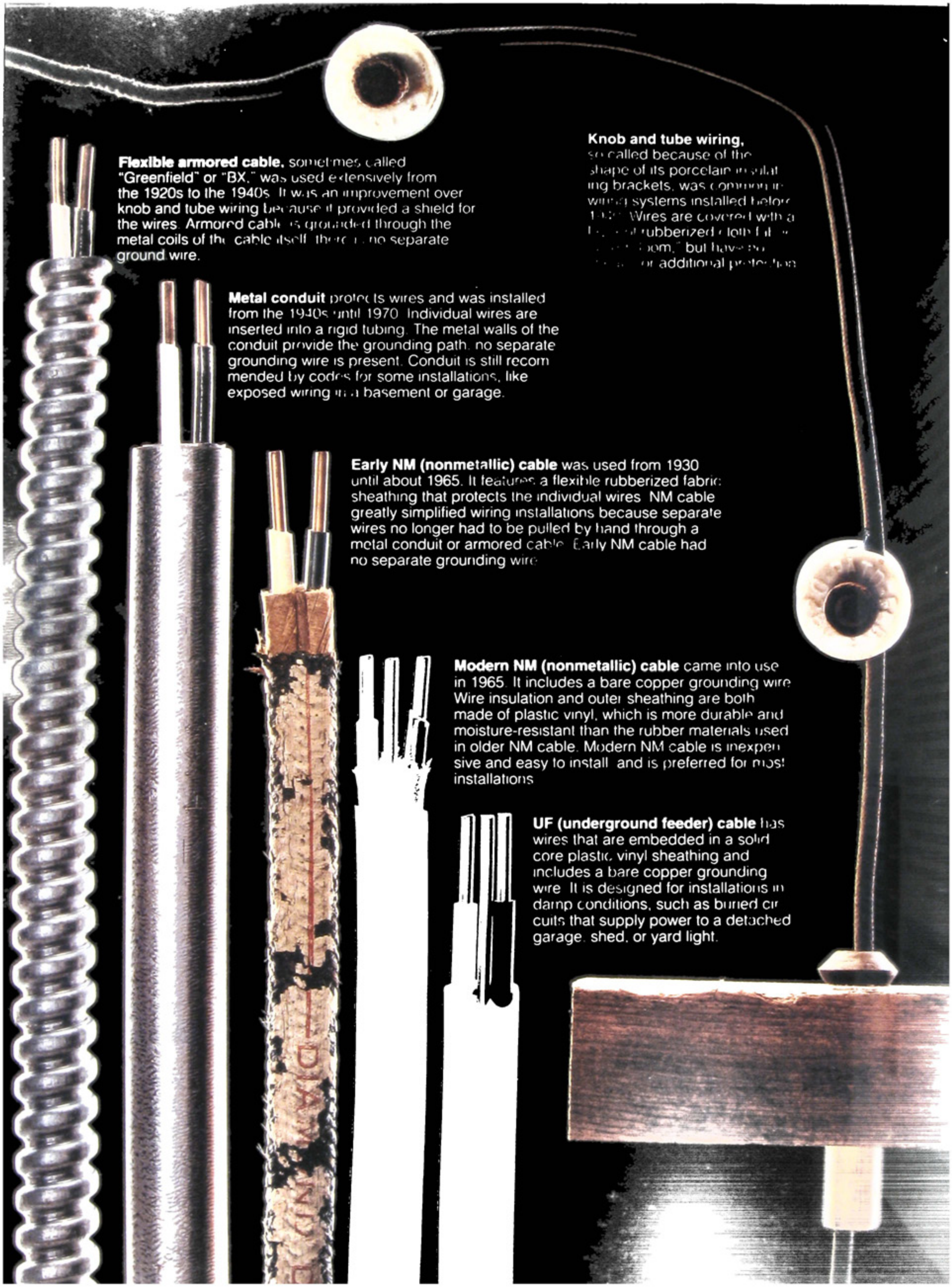

Flexible armored cable, sometimes called "Greenfield" or "BX," was used extensively from the 1920s to the 1940s. It was an improvement over knob and tube wiring because it provided a shield for the wires. Armored cable is grounded through the metal coils of the cable itself; there is no separate ground wire.

Knob and tube wiring, so called because of the shape of its porcelain insulating brackets, was common in wiring systems installed before 1930. Wires are covered with a layer of rubberized cloth fabric called "loom," but have no [illegible] or additional protection.

Metal conduit protects wires and was installed from the 1940s until 1970. Individual wires are inserted into a rigid tubing. The metal walls of the conduit provide the grounding path; no separate grounding wire is present. Conduit is still recommended by codes for some installations, like exposed wiring in a basement or garage.

Early NM (nonmetallic) cable was used from 1930 until about 1965. It features a flexible rubberized fabric sheathing that protects the individual wires. NM cable greatly simplified wiring installations because separate wires no longer had to be pulled by hand through a metal conduit or armored cable. Early NM cable had no separate grounding wire.

Modern NM (nonmetallic) cable came into use in 1965. It includes a bare copper grounding wire. Wire insulation and outer sheathing are both made of plastic vinyl, which is more durable and moisture-resistant than the rubber materials used in older NM cable. Modern NM cable is inexpensive and easy to install, and is preferred for most installations.

UF (underground feeder) cable has wires that are embedded in a solid core plastic vinyl sheathing and includes a bare copper grounding wire. It is designed for installations in damp conditions, such as buried circuits that supply power to a detached garage, shed, or yard light.

Wires & Cables

Wires are made of copper, aluminum, or aluminum covered with a thin layer of copper. Solid copper wires are the best conductors of electricity and are the most widely used. Aluminum and copper-covered aluminum wires require special installation techniques. They are discussed on page 22.

A group of two or more wires enclosed in a metal, rubber, or plastic sheath is called a **cable** (photo, page opposite). The sheath protects the wires from damage. Metal conduit also protects wires, but it is not considered a cable.

Individual wires are covered with rubber or plastic vinyl insulation. An exception is a bare copper grounding wire, which does not need an insulation cover. The insulation is color coded (chart, right) to identify the wire as a hot wire, a neutral wire, or a grounding wire.

In most wiring systems installed after 1965, the wires and cables are insulated with plastic vinyl. This type of insulation is very durable and can last as long as the house itself.

Before 1965, wires and cables were insulated with rubber. Rubber insulation has a life expectancy of about 25 years (see "Evaluating Old Wiring, pages 134 to 137). Old insulation that is cracked or damaged can be reinforced temporarily by wrapping the wire with plastic electrical tape. However, old wiring with cracked or damaged insulation should be inspected by a qualified electrician to make sure it is safe.

Wires must be large enough for the amperage rating of the circuit (chart, right). A wire that is too small can become dangerously hot. Wire sizes are categorized according to the American Wire Gauge (AWG) system. To check the size of a wire, use the wire stripper openings of a combination tool (page 18) as a guide.

Everything You Need

Tools: cable ripper, combination tool, screwdriver, needlenose pliers.

Materials: wire connectors, pigtail wires (if needed).

See Inspector's Notebook:

- Common Cable Problems (pages 124 to 125).
- Checking Wire Connections (pages 126 to 127).
- Electrical Box Inspection (pages 128 to 129).

Wire Color Chart

Wire color		Function
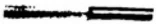	White	Neutral wire carrying current at zero voltage.
	Black	Hot wire carrying current at full voltage.
	Red	Hot wire carrying current at full voltage.
	White, black markings	Hot wire carrying current at full voltage.
	Green	Serves as a grounding pathway.
	Bare copper	Serves as a grounding pathway.

Individual wires are color coded to identify their function. In some circuit installations, the white wire serves as a hot wire that carries voltage. If so, this white wire may be labeled with black tape or paint to identify it as a hot wire.

Wire Size Chart

Wire gauge		Wire capacity & use
	#6	60 amps, 240 volts; central air conditioner, electric furnace.
	#8	40 amps, 240 volts; electric range, central air conditioner.
	#10	30 amps, 240 volts; window air conditioner, clothes dryer.
	#12	20 amps, 120 volts; light fixtures, receptacles, microwave oven.
	#14	15 amps, 120 volts; light fixtures, receptacles.
	#16	Light-duty extension cords.
	#18 to 22	Thermostats, doorbells, security systems.

Wire sizes (shown actual size) are categorized by the American Wire Gauge system. The larger the wire size, the smaller the AWG number.

Reading NM (Nonmetallic) Cable

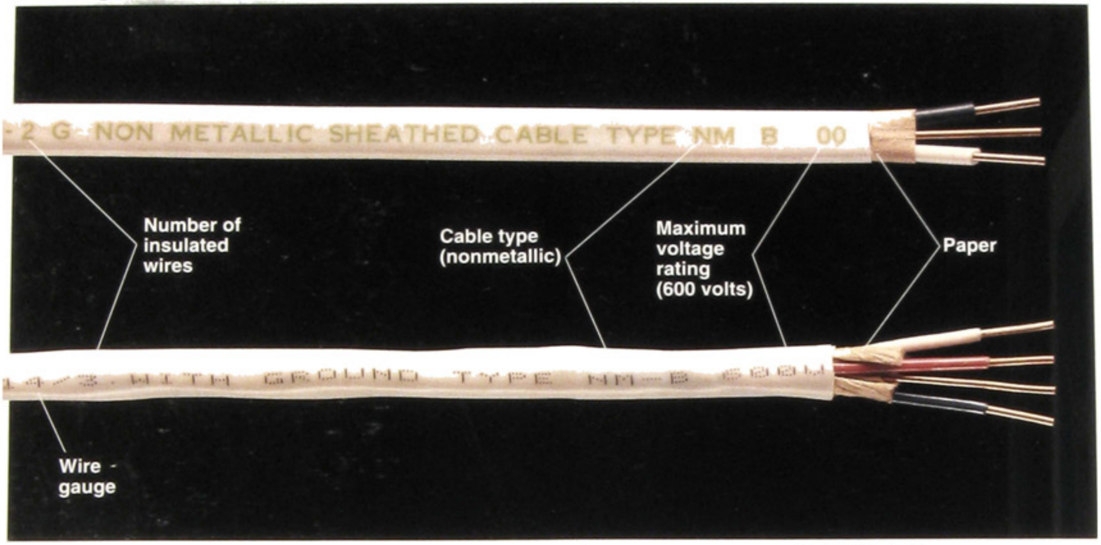
2 G NON METALLIC SHEATHED CABLE TYPE NM B 00
Number of insulated wires
Cable type (nonmetallic)
Maximum voltage rating (600 volts)
Paper
14/3 WITH GROUND TYPE NM-B 600V
Wire gauge

NM (nonmetallic) cable is labeled Cabl 14 3 WITH GROUND The bare unding

Aluminum Wire

Inexpensive aluminum wire was used in place of copper in many wiring systems installed during the late 1960s and early 1970s, when copper prices were high Aluminum wire is identified by its silver color

2 WITH GROUND TYPE NM 600V

by the AL stamp on the cable sheathing A variation copper-clad aluminum wire has a thin coating of copper bonded to a solid aluminum core

By the early 1970s all-aluminum wire was found to pose a safety hazard if connected to a switch or receptacle ith brass or copper screw terminals Because umi expands and contracts at a different rate or brass the wire connections could In some instances, fires resulted

xisting aluminum wiring in homes is considered if proper installation methods have been followed and if the wires are connected to special switches and receptacles designed to be used with aluminum wire If you have aluminum wire in your home have a qualified electrical inspector review the system Copper-coated aluminum wire is not a hazard.

For a short while, switches and receptacles with an Underwriters Laboratories (UL) wire compatibility rating of AL-CU were used with both aluminum and copper wiring However these devices proved to be hazardous when connected to aluminum wire ALCU devices should not be used with aluminum wiring

In 1971 switches and receptacles designed for use with aluminum wiring were introduced They are marked CO/ALR This mark is now the only approved rating for aluminum wires If your home has aluminum wires connected to a switch or receptacle without a CO/ALR rating stamp replace the device with a switch or receptacle r ted CO/ALR

A switch r receptacle that has no wire compatibility rating printed on the mounting strap or casin should not be used with aluminum wires These devices are designed for use with copper wires only.

How to Strip NM (Nonmetallic) Cable & Wires

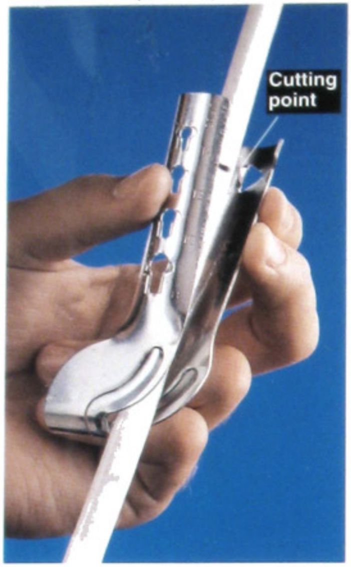

1 Measure and mark the cable 8" to 10" from end. Slide the cable ripper onto the cable, and squeeze tool firmly to force cutting point through plastic sheathing.

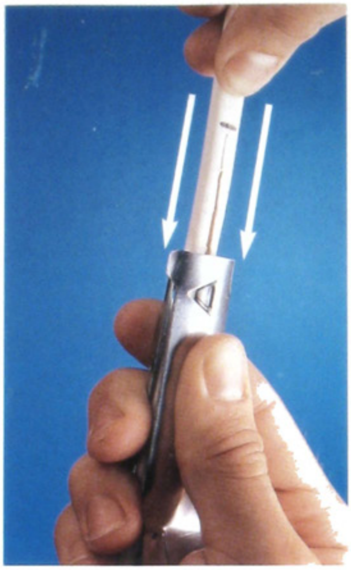

2 Grip the cable tightly with one hand, and pull the cable ripper toward the end of the cable to cut open the plastic sheathing

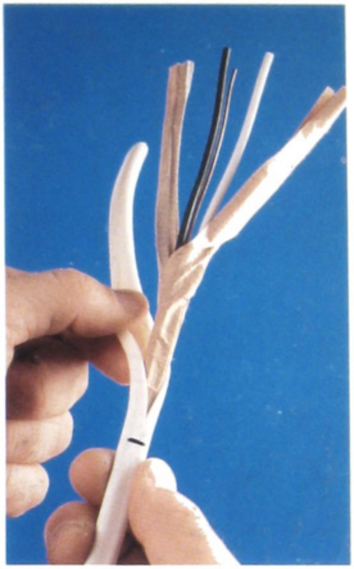

3 Peel back the plastic sheathing and the paper wrapping from the individual wires

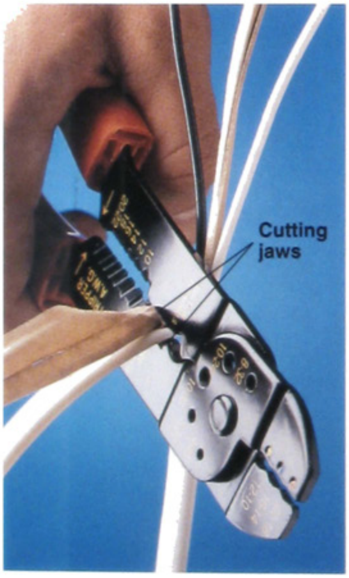

4 Cut away the excess plastic sheathing and paper wrapping, using the cutting jaws of a combination tool.

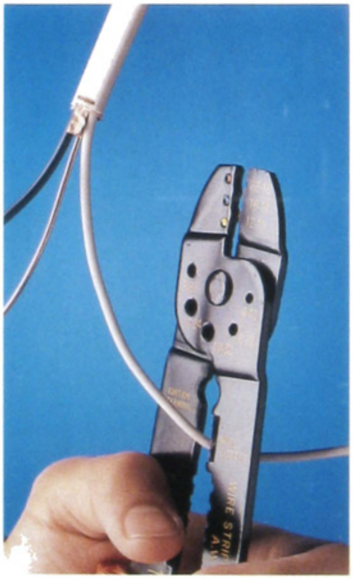

5 Cut the individual wires, if necessary, using the cutting jaws of the combination tool.

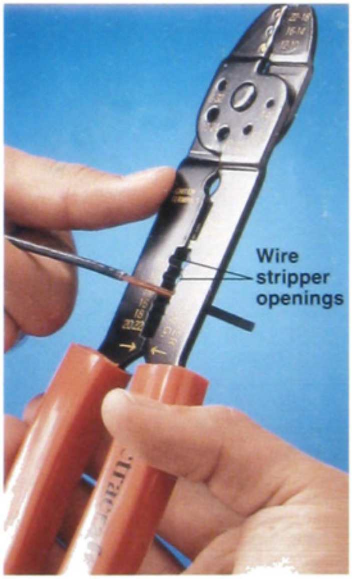

6 Strip insulation for each wire, using the stripper openings. Choose the opening that matches the gauge of the wire, and take care not to nick or scratch the ends of the wires.

How to Connect Wires to Screw Terminals

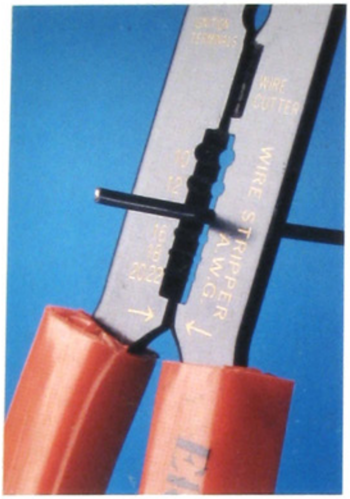
WIRE CUTTER
WIRE STRIPPER A.W.G.

1 Strip about of insulation from each wire, using a combination tool Choose the stripper opening that matches the gauge of the wire then clamp wire in tool Pull the wire firmly to remove plastic insulation

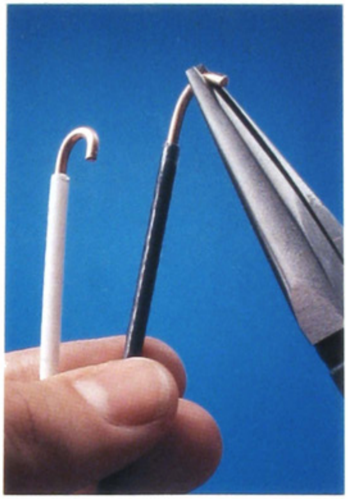

2 Form a C-shaped loop in the end of each wire, using a needlenose pliers The wire should have no scratches or nicks

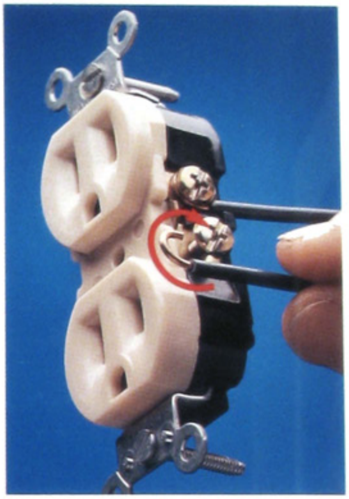

3 Hook each wire around the screw terminal so it forms a clockwise loop Tighten screw firmly Insulation should just touch head of screw Never place the ends of two wires under a single screw terminal Instead, use a pigtail wire (page opposite)

How to Connect Wires with Push-in Fittings

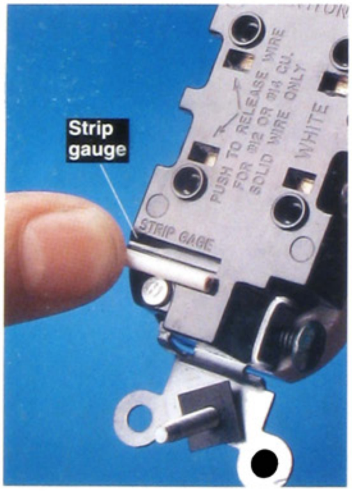
Strip gauge
STRIP GAGE
PUSH TO RELEASE WIRE
FOR #12 OR #14 CU.
SOLID WIRE ONLY
WHITE

1 Mark the amount of insulation to be stripped from each wire, using the strip gauge on the back of the switch or receptacle. Strip the wires using a combination tool (step 1, above). Never use push-in fittings with aluminum wiring.

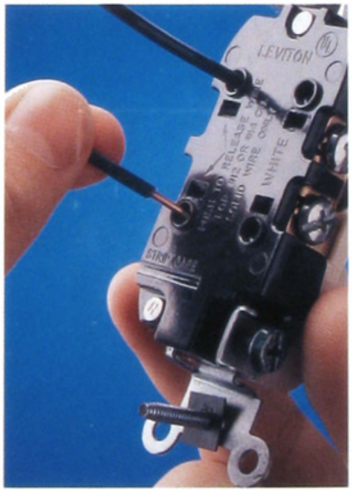

2 Insert the bare copper wires firmly into the push-in fittings on the back of the switch or receptacle. When inserted, wires should have no bare copper exposed. NOTE: Although push-in fittings are convenient, most experts believe screw terminal connections (above) are more dependable.

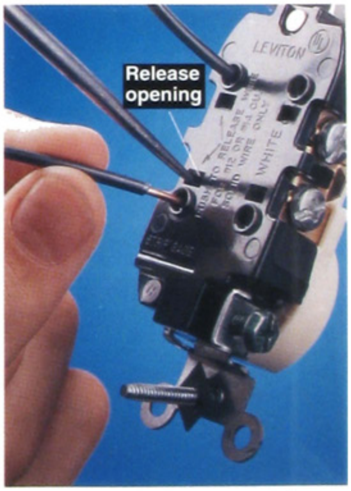
Release opening
LEVITON

Remove a wire from a push-in fitting by inserting a small nail or screwdriver in the release opening next to the wire Wire will pull out easily

How to Connect Two or More Wires with a Wire Connector

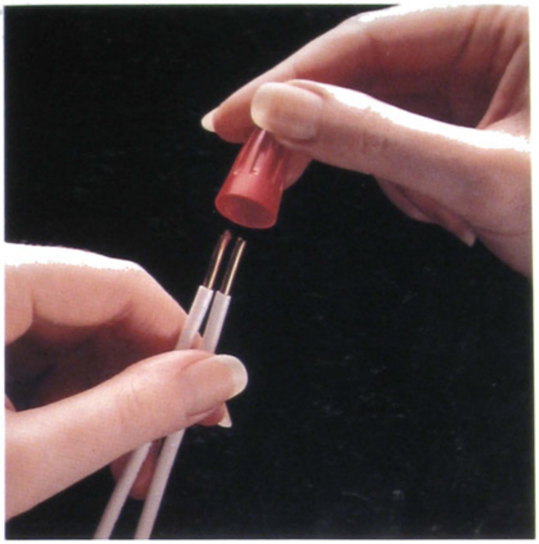

1 wire connector rated for the size and ires you are connecting Wire con- color-coded by size but the coding ries according to manufacturer Strip nsulation off each ire to be connect

2 Hold the wires together down onto them and snug Tug gently to make su In a proper connectio exposed

How to Pigtail Two or More Wires

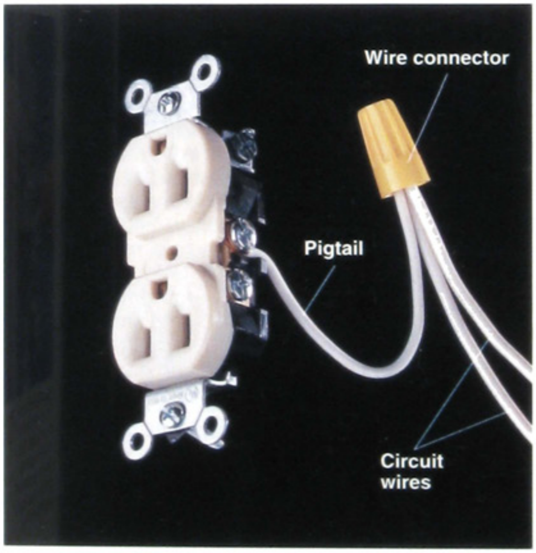

Connect two or more wires to a single screw termi- ith a pigtail A pigtail is a short piece of wire of the pigtail connects to a screw terminal, other end connects to circuit wires using a connector A pigtail also can be used to circuit wires that are too short (page 128).

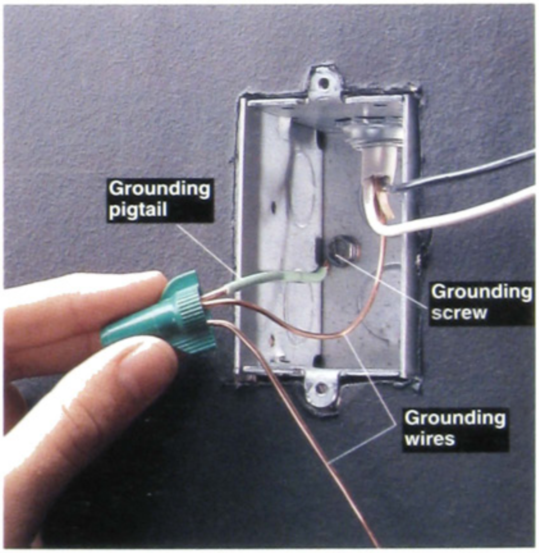

Grounding pigtail has green insulation and is available with a preattached grounding screw This grounding screw connects to the grounded metal electrical box The end of the pigtail wire connects to the bare copper grounding wires with a wire connector

Service Panels

Every home has a main service panel that distributes electrical current to the individual circuits. The main service panel usually is found in the basement, garage, or utility area, and can be identified by its metal casing. Before making any repair to your electrical system, you must shut off power to the correct circuit at the main service panel. The service panel should be indexed (pages 30 to 33) so circuits can be identified easily.

Service panels vary in appearance, depending on the age of the system. Very old wiring may operate on 30-amp service that has only two circuits. New homes can have 200-amp service with 30 or more circuits. Find the size of the service by reading the amperage rating printed on the main fuse block or main circuit breaker

Regardless of age, all service panels have **fuses** or **circuit breakers** (pages 28 to 29) that control each circuit and protect them from overloads. In general, older service panels use fuses, while newer service panels use circuit breakers.

In addition to the main service panel, your electrical system may have a subpanel that controls some of the circuits in the home. A subpanel has its own circuit breakers or fuses, and is installed to control circuits that have been added to an existing wiring system.

The subpanel resembles the main service panel but is usually smaller. It may be located near the main panel, or it may be found near the areas served by the new circuits. Garages and attics that have been updated often have their own subpanels. If your home has a subpanel, make sure that its circuits are indexed correctly.

When handling fuses or circuit breakers, make sure the area around the service panel is dry. Never remove the protective cover on the service panel. After turning off a circuit to make electrical repairs, remember to always test the circuit for power before touching any wires.

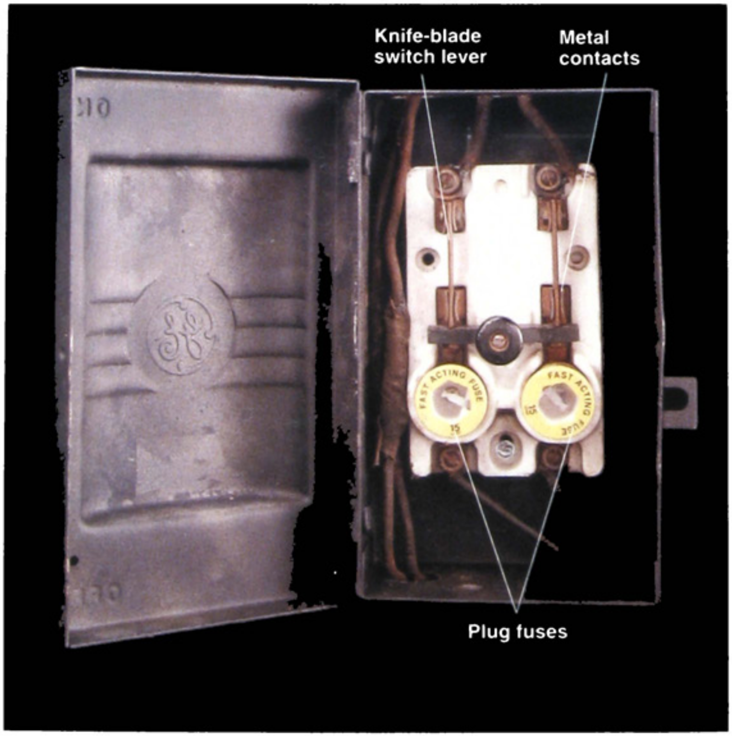

A 30-amp service panel, common in systems installed before 1950, is identified by a ceramic fuse holder containing two plug fuses and a "knife-blade" switch lever The fuse holder sometimes is contained in a black metal box mounted in an entryway or basement. This 30-amp service panel provides only 120 volts of power and now is considered inadequate. For example, most home loan programs, like the FHA (Federal Housing Administration), require that 30-amp service be updated to 100 amps or more before a home can qualify for mortgage financing

To shut off power to individual circuits in a 30-amp panel, carefully unscrew the plug fuses, touching only the insulated rim of the fuse To shut off power to the entire house, open the knife-blade switch Be careful not to touch the metal contacts on the switch

A 60-amp fuse panel often is [illegible] wiring systems installed [illegible] 1950 and 1965 It usually [illegible]ed [illegible] a gray metal cabinet [illegible] contains four individual plug [illegible] plus one or two pull-out fuse [illegible] that hold cartridge fuses [illegible]ne of panel is regarded as [illegible] for a small 1100-square-[illegible] house that has no more than [illegible]0- [illegible] appliance Many [illegible]owners update 60-amp ser[illegible] 100 amps or more so that [illegible]itional lighting and appliance circuits can be added to the sys[illegible]ne loan programs also require that 60-amp service [illegible]dated before a home can [illegible] for financing

[illegible] off power to a circuit care[illegible] unscrew the plug fuse touch[illegible] its insulated rim To shut off power to the entire house hold the handle of the main fuse block and pull sharply to remove it Major appliance circuits are controlled with another cartridge fuse block [illegible] off the appliance circuit by pulling out this fuse block

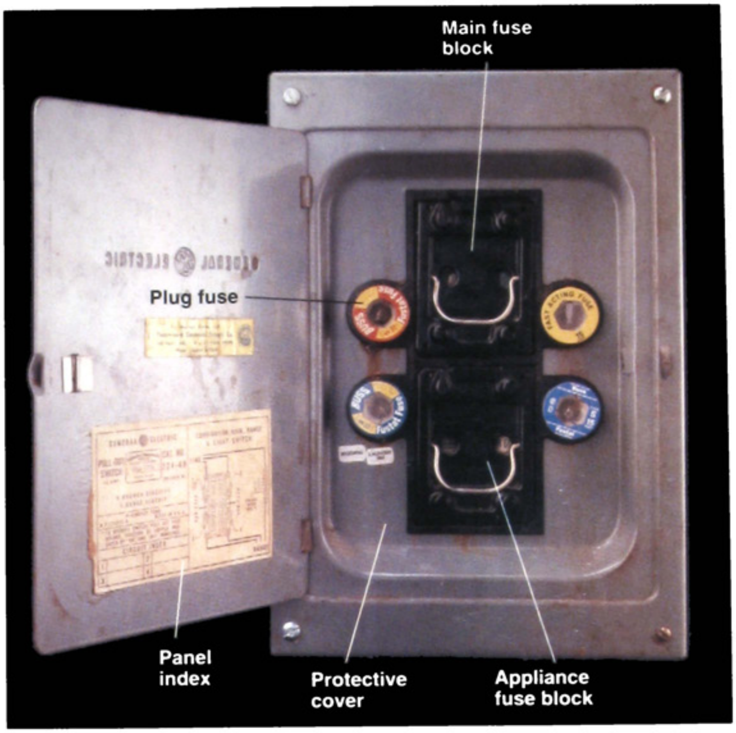

A circuit breaker panel providing 100 amps or more of power is common in wiring systems installed during the 1960s and later A circuit breaker panel is housed in a gray metal cabinet that contains two rows of individual circuit breakers The size of the service can be identified by reading the amperage rating of the main cir[illegible]it breaker which is located at [illegible] top of the main service panel

A 100-amp service panel is now the minimum standard for most [illegible] housing It is considered adequate for a medium-sized house with no more than three major electric appliances However larger houses with more electrical appli[illegible]ces require a service panel that [illegible]rovides 150 amps or more

[illegible] off power to individual circuit [illegible] a circuit breaker panel flip the le[illegible]er on the appropriate circuit breaker to the OFF position To [illegible] off the power to the entire [illegible]urn the main circuit [illegible] the OFF position

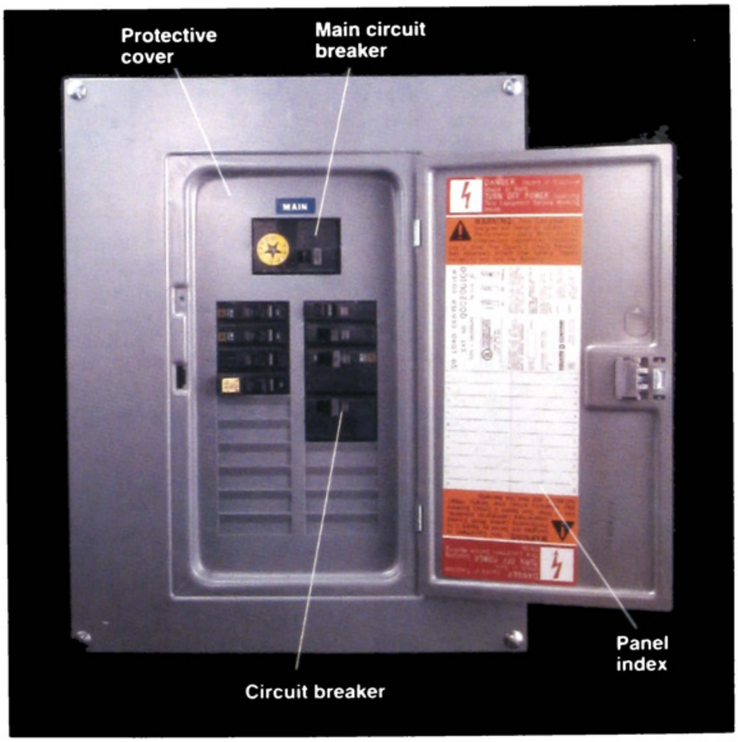

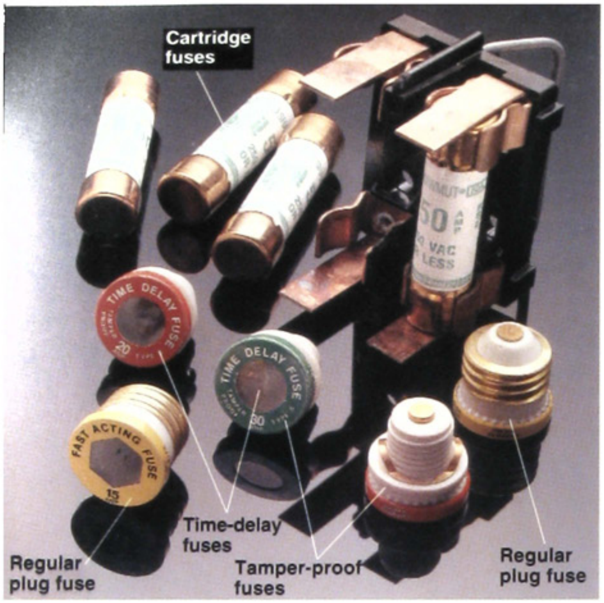

Fuses are used in older service panels. Plug fuses usually control 120-volt circuits rated for 15, 20, or 30 amps. Tamper-proof plug fuses have threads that fit only matching sockets, making it impossible to install a wrong-sized fuse. Time-delay fuses absorb temporary heavy power loads without blowing. Cartridge fuses control 240-volt circuits and range from 30 to 100 amps.

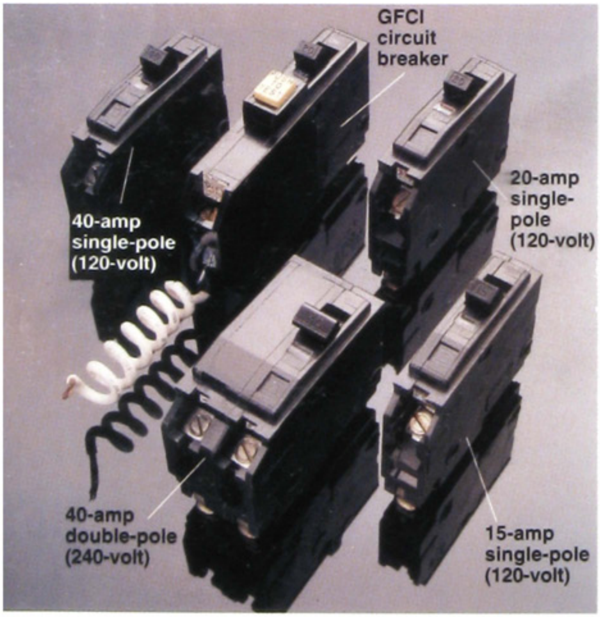
GFCI circuit breaker
40-amp single-pole (120-volt)
20-amp single-pole (120-volt)
40-amp double-pole (240-volt)
15-amp single-pole (120-volt)

Circuit breakers are used in newer service panels. Single-pole breakers control 120-volt circuits. Double-pole breakers rated for 20 to 50 amps control 240-volt circuits. GFCI (ground-fault circuit-interrupter) breakers provide shock protection for the entire circuit.

Fuses & Circuit Breakers

Fuses and circuit breakers are safety devices designed to protect the electrical system from short circuits and overloads. Fuses and circuit breakers are located in the main service panel.

Most service panels installed before 1965 rely on fuses to control and protect individual circuits. Screw-in plug fuses protect 120-volt circuits that power lights and receptacles. Cartridge fuses protect 240-volt appliance circuits and the main shutoff of the service panel.

Inside each fuse is a current-carrying metal alloy ribbon. If a circuit is overloaded, the metal ribbon melts and stops the flow of power. A fuse must match the amperage rating of the circuit. Never replace a fuse with one that has a larger amperage rating.

In most service panels installed after 1965, circuit breakers protect and control individual circuits. Single-pole circuit breakers protect 120-volt circuits, and double-pole circuit breakers protect 240-volt circuits. Amperage ratings for circuit breakers range from 15 to 100 amps.

Each circuit breaker has a permanent metal strip that heats up and bends when voltage passes through it. If a circuit is overloaded, the metal strip inside the breaker bends enough to "trip" the switch and stop the flow of power. If a circuit breaker trips frequently even though the power demand is small, the mechanism inside the breaker may be worn out. Worn circuit breakers should be replaced by an electrician.

When a fuse blows or a circuit breaker trips, it is usually because there are too many light fixtures and plug-in appliances drawing power through the circuit. Move some of the plug-in appliances to another circuit, then replace the fuse or reset the breaker. If the fuse blows or the breaker trips again immediately, there may be a short circuit in the system. Call a licensed electrician if you suspect a short circuit.

Everything You Need

Tools: fuse puller and continuity tester (for cartridge fuses only).

Materials: replacement fuse.

How to Identify & Replace a Blown Plug Fuse

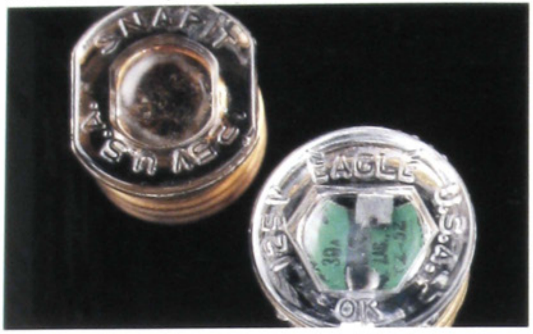

1 Go to the main service panel and locate the blown fuse. If the metal ribbon inside fuse is cleanly melted (right), the circuit was overloaded. If window in fuse is discolored (left), there was a short circuit in the system.

2 Unscrew the fuse, being careful to touch only the insulated rim of the fuse. Replace it with a fuse that has the same amperage rating.

How to Remove, Test & Replace a Cartridge Fuse

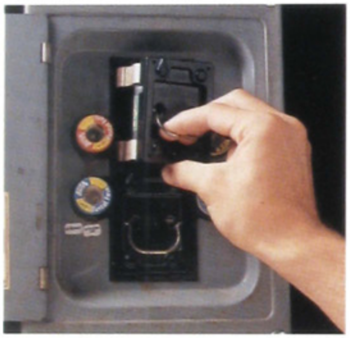

1 Remove cartridge fuses by gripping the handle of the fuse block and pulling sharply.

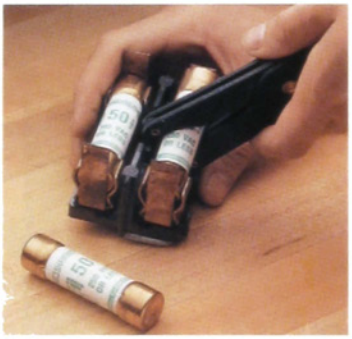

2 Remove the individual cartridge fuses from the block, using a fuse puller.

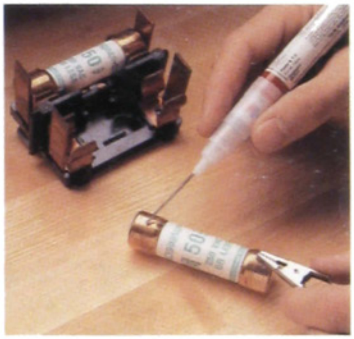

3 Test each fuse using a continuity tester. If the tester glows, the fuse is good. If the tester does not glow, replace the fuse with one that has the same amperage rating.

How to Reset a Circuit Breaker

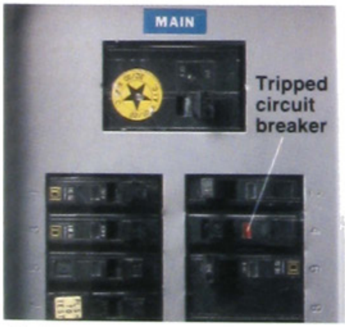

1 Open the service panel and locate the tripped breaker. The lever on the tripped breaker will be either in the OFF position, or in a position between ON and OFF.

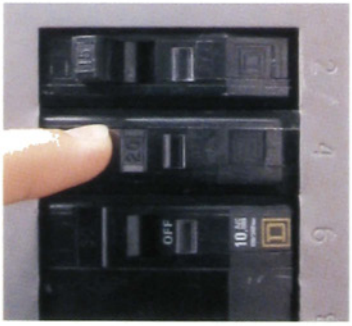

2 Reset the tripped circuit breaker by pressing the circuit breaker lever all the way to the OFF position, then pressing it to the ON position.

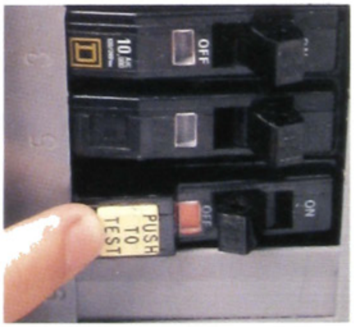

Test GFCI circuit breakers by pushing the TEST button. Breaker should trip to the OFF position. If not, the breaker is faulty and must be replaced by an electrician.

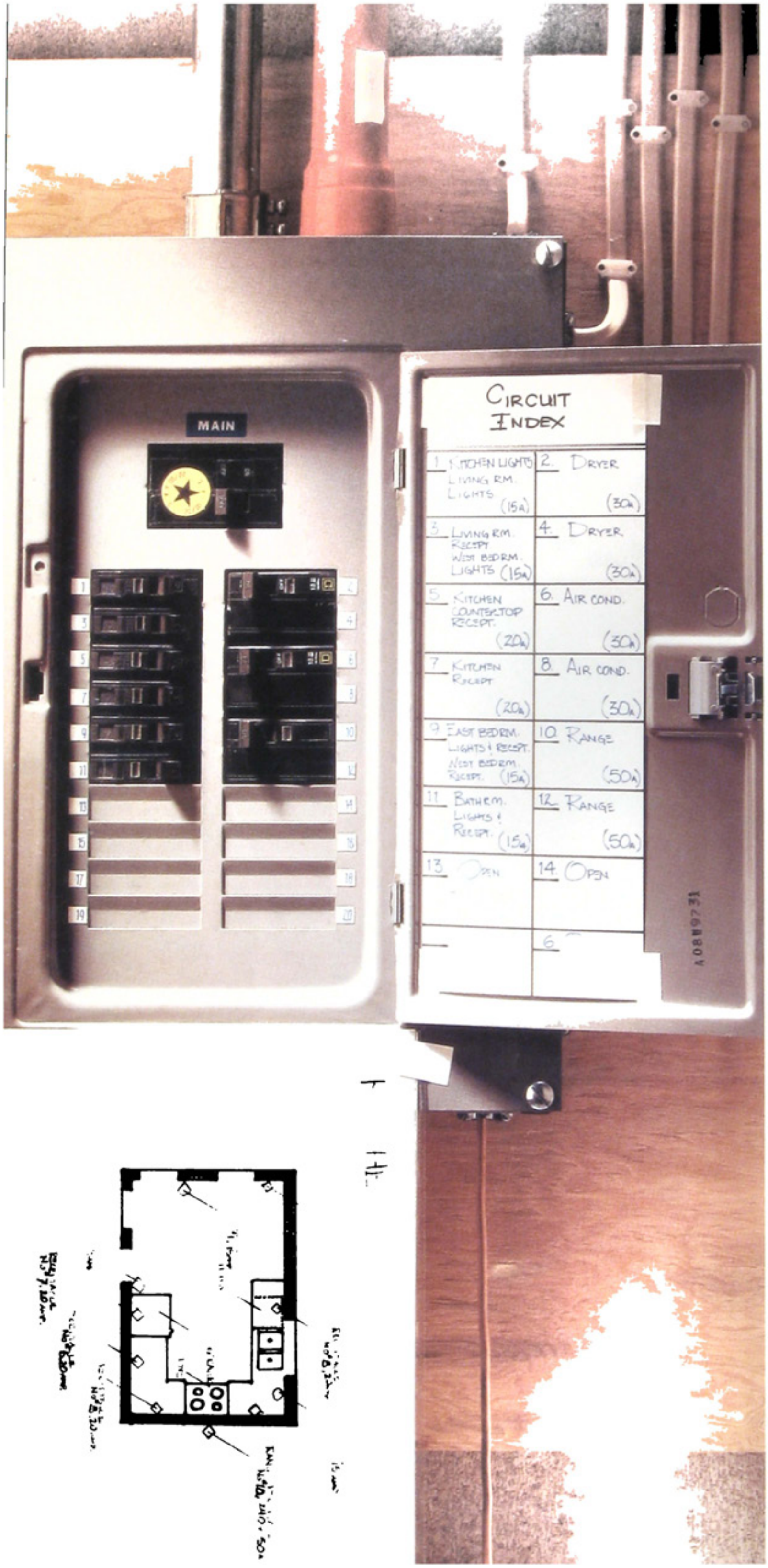

CIRCUIT INDEX

1 KITCHEN LIGHTS LIVING RM. LIGHTS (15A)	2. DRYER (30A)
3 LIVING RM. RECEPT. WEST BEDRM. LIGHTS (15A)	4. DRYER (30A)
5 KITCHEN COUNTERTOP RECEPT. (20A)	6. AIR COND. (30A)
7 KITCHEN RECEPT (20A)	8. AIR COND. (30A)
9 EAST BEDRM. LIGHTS & RECEPT. WEST BEDRM. RECEPT. (15A)	10. RANGE (50A)
11 BATHRM. LIGHTS & RECEPT. (15A)	12. RANGE (50A)
13 OPEN	14. OPEN
	6

Mapping Circuits & Indexing the Service Panel

Making repairs to an electrical system is easier and safer if you have an accurate, up-to-date map of your home's electrical circuits. A circuit map shows all lights, appliances, switches, and receptacles connected to each circuit. The map allows you to index the main service panel so that the correct circuit can be shut off when repairs are needed.

Mapping all the circuits and indexing the main service panel requires four to six hours. If your service panel was indexed by a previous owner, it is a good idea to make your own circuit map to make sure the old index is accurate. If circuits have been added or changed, the old index will be outdated.

The easiest way to map circuits is to turn on one circuit at a time and check to see which light fixtures, receptacles, and appliances are powered by the circuit. All electrical devices must be in good working condition before you begin.

A circuit map also will help you evaluate the electrical demands on each circuit (pages 34 to 35). This information can help you determine if your wiring system needs to be updated.

Everything You Need

Tools: pens, circuit tester.

Materials: graph paper, masking tape.

See Inspector's Notebook:

- Service Panel Inspection (page 123).

How to Map Circuits & Index a Service Panel

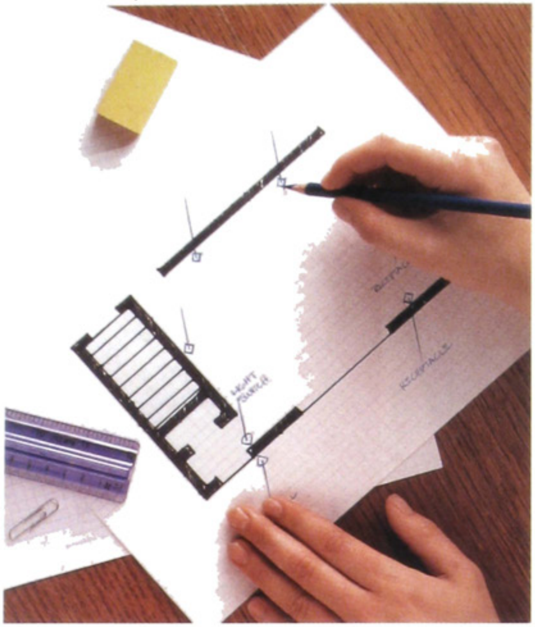

1 Make a sketch of each room in the house on graph paper. Include the hallways, basement and attic, and all utility areas. Or use a blueprint of your house.

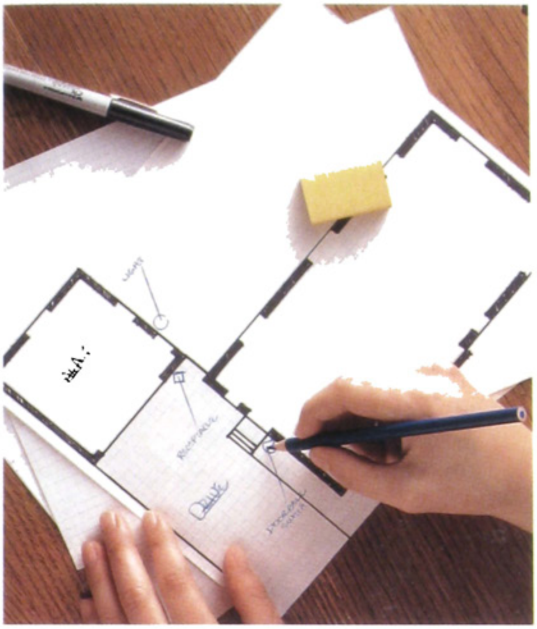

2 Make a sketch of the outside of the house, the garage, and any other separate structures that wired for electricity.

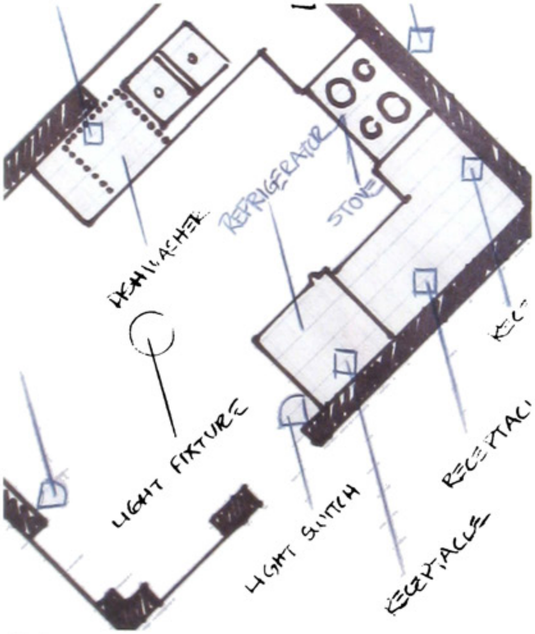
DISHWASHER
REFRIGERATOR
STOVE
LIGHT FIXTURE
LIGHT SWITCH
RECEPTACLE
RECEPTACLE

3 On each sketch, indicate the location of all receptacles, light fixtures, switches, appliances, doorbells, thermostats, heaters, fans, and air conditioners.

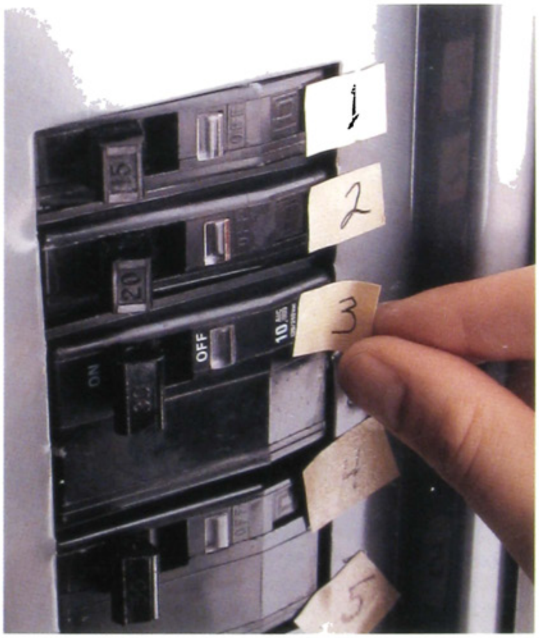
1
2
3
4
5
15
20
10
OFF
ON

4 At the main service panel, number each circuit breaker or fuse. Turn off all the circuit breakers or loosen all the fuses, but leave the main shutoff in the ON position.

(continued next page)

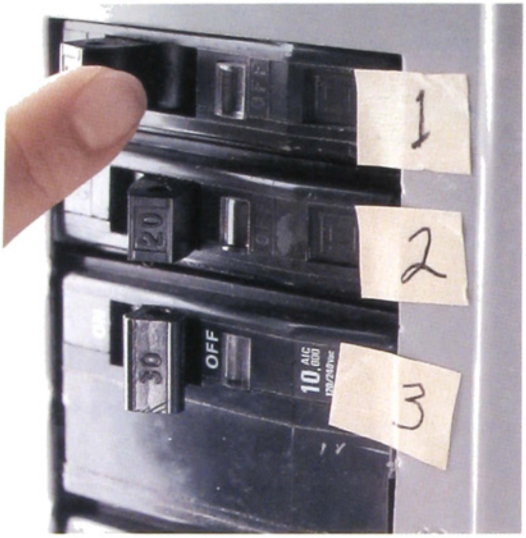

5 Turn on one circuit at a time by flipping the circuit breaker lever or tightening the correct fuse. Note the amperage rating printed on the circuit breaker lever or on the rim of the fuse (page 28)

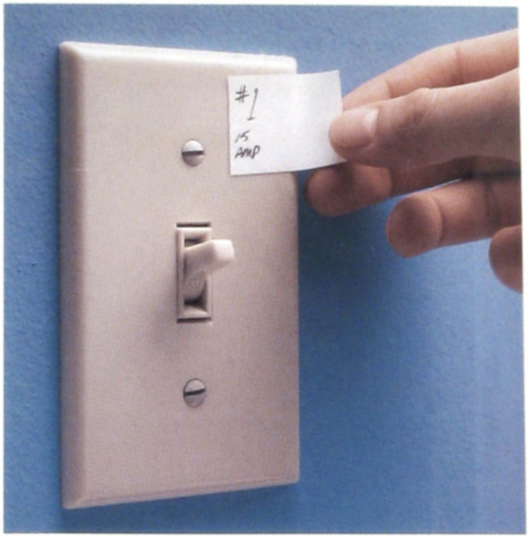

6 Turn on switches, lights, and appliances throughout the house, and identify those that are powered by the circuit. Write the circuit number and amperage rating on a piece of masking tape. The tape makes a handy temporary reference.

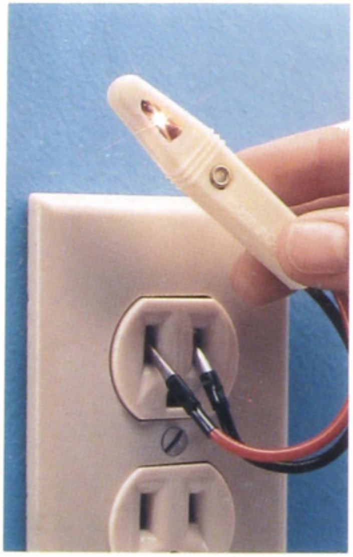

7 Test receptacles for power, using a neon circuit tester Make sure to check both halves of the receptacle.

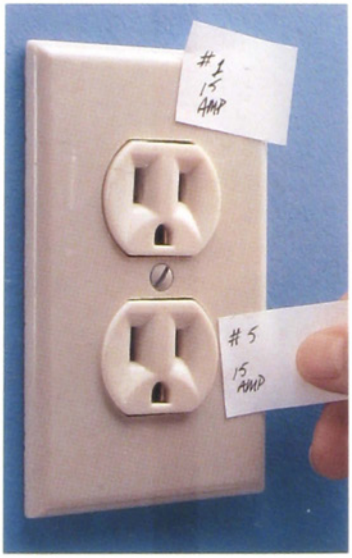

8 Indicate which circuit supplies power to each receptacle. Although uncommon, remember that receptacles can be wired so that each half of the receptacle is powered by a different circuit.

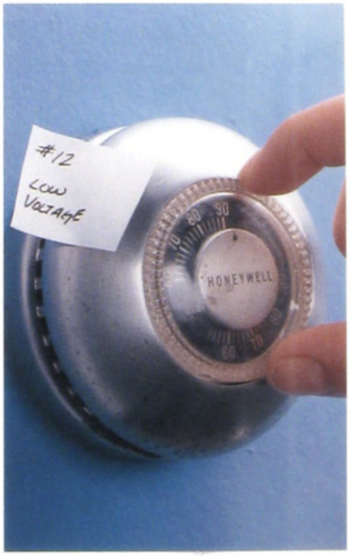

9 To check the furnace for power, set thermostat to highest temperature setting. Furnaces and their low-voltage thermostats are on the same circuit. If the circuit is hot, the furnace will begin running. The lowest temperature setting will turn on the central air conditioner.

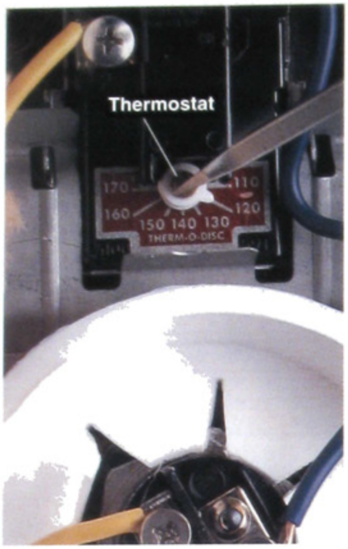
Thermostat
170
160
150 140 130
120
110
THERM-O-DISC

10 Check the electric water heater for power by setting its thermostat to highest temperature setting. Water heater will begin to heat if it is powered by the circuit.

11 Check the doorbell system for power by ringing all of the doorbells.

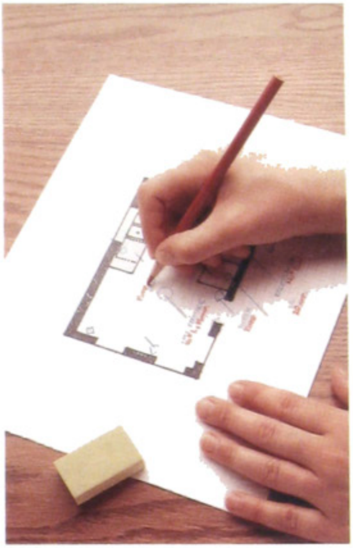

12 On the circuit maps, indicate the circuit number, the voltage, and the amperage rating of each receptacle, switch, light fixture, and appliance.

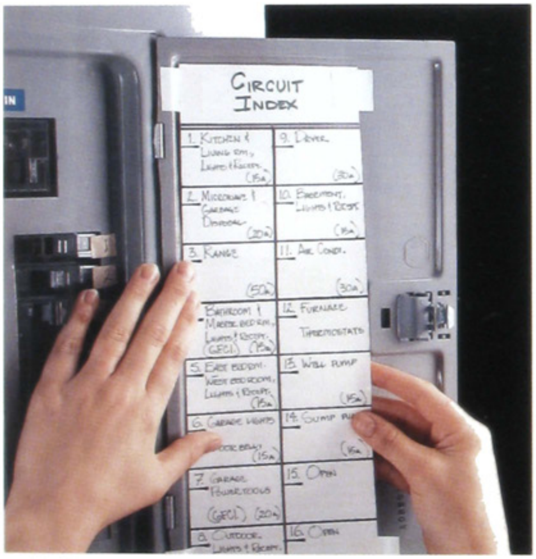
CIRCUIT INDEX
1. Kitchen & Living rm, Lights & Recepts (15A)
9. Dryer (30A)
2. Microwave & Garbage Disposal (20A)
10. Basement, Lights & Recepts (15A)
3. Range (50A)
11. Air Cond. (30A)
4. Bathroom & Master bedrm, Lights & Recepts (GFCI) (15A)
12. Furnace Thermostats
5. East bedrm, West bedroom, Lights & Recepts (15A)
13. Well pump (15A)
6. Garage lights (15A)
14. Sump pump (15A)
7. Garage Power tools (GFCI) (20A)
15. Open
8. Outdoor Lights & Recepts
16. Open

13 On the door of the main service panel, tape an index that provides a brief summary of all the fixtures, receptacles, and appliances that are powered by each circuit.

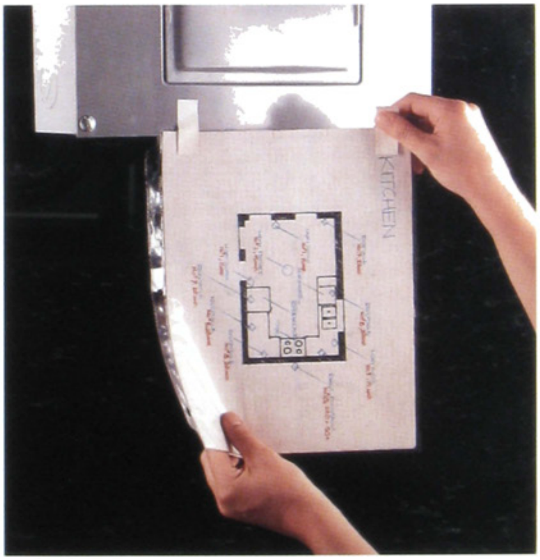

14 Attach the completed circuit maps to the main service panel, and make sure the power is turned on for all the circuits.

Evaluating Circuits for Safe Capacity

Every electrical circuit in a home has a "safe capacity. Safe capacity is the total amount of power the circuit wires can carry without tripping circuit breakers or blowing fuses. According to the National Electrical Code, the power used by light fixtures, lamps, tools, and appliances, called the "demand, must not exceed the safe capacity of the circuit.

Finding the safe capacity and the demand of a circuit is easy. Make these simple calculations to reduce the chances of tripped circuit breakers or blown fuses, or to help plan the location of new appliances or plug-in lamps.

First, determine the amperage and voltage rating of the circuit. If you have an up-to-date circuit map (pages 30 to 33) these ratings should be indicated on the map. If not, open the service panel door and read the amperage rating printed on the circuit breaker or on the rim of the fuse. The type of circuit breaker or fuse (page 28) indicates the voltage of the circuit.

Use the amperage and voltage ratings to find the safe capacity of the circuit. Safe capacities of the most common household circuits are given in the table at right.

Safe capacities can be calculated by multiplying the amperage rating by voltage. The answer is the total capacity, expressed in watts, a unit of electrical measurement. To find the safe capacity, reduce the total capacity by 20%.

Next, compare the safe capacity of the circuit to the total power demand. To find the demand, add the wattage ratings for all light fixtures, lamps, and appliances on the circuit. For lights, use the wattage rating printed on the light bulbs. Wattage ratings for appliances often are printed on the manufacturer's label. Approximate wattage ratings for many common household items are given in the table on the opposite page. If you are unsure about the wattage rating for a tool or appliance, use the highest number shown in the table to make calculations.

Compare the power demand to the safe capacity. The power demand should not exceed the safe capacity of the circuit. If it does, you must move lamps or appliances to another circuit. Or make sure that the power demand of the lamps and appliances turned on at the same time does not exceed the safe capacity of the circuit.

Amps × Volts	Total capacity	Safe capacity
15 A × 120 V =	1800 watts	1440 watts
20 A × 120 V =	2400 watts	1920 watts
25 A × 120 V =	3000 watts	2400 watts
30 A × 120 V =	3600 watts	2880 watts
20 A × 240 V =	4800 watts	3840 watts
30 A × 240 V =	7200 watts	5760 watts

How to Find Wattage & Amperage Ratings

GE
40
WATT
ELECTRIC

Light bulb wattage ratings are printed on the top of the bulb. If a light fixture has more than one bulb, remember to add the wattages of all the bulbs to find the total wattage of the fixture.

120 VOLTS 1500 WATTS
50-60 Hz A.C. ONLY
HOUSEHOLD USE ONLY
BLACK & DECKER

Appliance wattage ratings are often listed on the manufacturer's label. Or use the table of typical wattage ratings on the opposite page.

Professional
3030
DANGER / WARNING:

Amperage rating can be used to find the wattage of an appliance. Multiply the amperage by the voltage of the circuit. For example, a 13-amp, 120-volt circular saw is rated for 1560 watts.

Sample Circuit Evaluation

Circuit #_____ Amps_____ Volts_____ Total capacity________(watts) Safe capacity________(watts)

Appliance or fixture	**Notes**	**Wattage rating**
	Total demand:	**(watts)**

Photocopy this sample circuit evaluation to keep a record of the power demand of each circuit. The words and numbers printed in blue will not reproduce on photocopies. In this sample kitchen circuit, the demand on the circuit is very close to the safe capacity Adding another appliance, such as an electric frying pan, could overload the circuit and cause a fuse to blow or a circuit breaker to trip.

Typical Wattage Ratings (120-volt Circuit Except Where Noted)

Appliance	Amps	Watts	Appliance	Amps	Watts
Air conditioner (central)	13 to 36 (240-v)	3120 to 8640	Garbage disposer	3.5 to 7.5	420 to 900
Air conditioner (window)	6 to 13	720 to 1560	Hair dryer	5 to 10	600 to 1200
Blender	2 to 4	240 to 480	Heater (portable)	7 to 12	840 to 1440
Broiler	12.5	1500	Microwave oven	4 to 10	480 to 1200
Can opener	1.2	144	Range (oven/stove)	5.5 to 10.8 (240-v)	1320 to 2600
Circular saw	10 to 12	1200 to 1440	Refrigerator	2 to 4	240 to 600
Coffee maker	4 to 8	480 to 960	Router	8	960
Clothes dryer	16.5 to 34 (240-v)	3960 to 8160	Sander (portable)	2 to 5	240 to 600
Clothes iron	9	1080	Saw (table)	7 to 10	840 to 1200
Computer	4 to 7	480 to 840	Sewing machine	1	120
Dishwasher	8.5 to 12.5	1020 to 1500	Stereo	2.5 to 4	300 to 480
Drill (portable)	2 to 4	240 to 480	Television (color)	2.5	300
DVD player	2.5 to 4	300 to 480	Toaster	9	1080
Fan (ceiling)	3.5	420	Trash compactor	4 to 8	480 to 960
Fan (portable)	2	240	Vacuum cleaner	6 to 11	720 to 1320
Freezer	2 to 4	240 to 600	Waffle iron	7.5	900
Frying pan	9	1080	Washing machine	12.5	1500
Furnace, forced-air gas	6.5 to 13	780 to 1560	Water heater	15.8 to 21 (240-v)	3800 to 5040

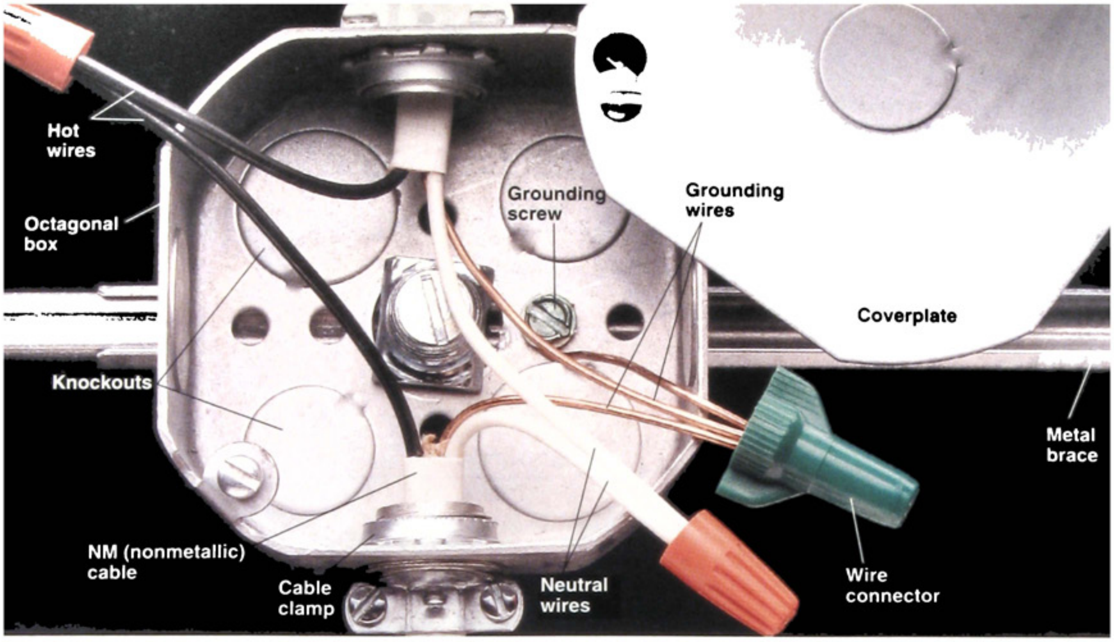

Octagonal boxes usually contain wire connections for ceiling fixtures. Cables are inserted into the box through knockout openings and are held with cable clamps. Because the ceiling fixture attaches directly to the box, the box should be anchored firmly to a framing member. Often, it is nailed directly to a ceiling joist. However, metal braces are available that allow a box to be mounted between joists or studs. A properly installed octagonal box can support a ceiling fixture weighing up to 35 pounds. Any box must be covered with a tightly fitting coverplate, and the box must not have open knockouts.

Electrical Boxes

The National Electrical Code requires that wire connections or cable splices be contained inside an approved metal or plastic box. This shields framing members and other flammable materials from electrical sparks. If you have exposed wire connections or cable splices, protect your home by installing electrical boxes.

Electrical boxes come in several shapes. Rectangular and square boxes are used for switches and receptacles. Rectangular (2" × 3") boxes are used for single switches or duplex receptacles. Square (4" × 4") boxes are used anytime it is convenient for two switches or receptacles to be wired or "ganged" in one box, an arrangement common in kitchens or entry hallways. Octagonal electrical boxes contain wire connections for ceiling fixtures.

All electrical boxes are available in different depths. A box must be deep enough so a switch or receptacle can be removed or installed easily without crimping and damaging the circuit wires. Replace an undersized box with a larger box, using the Electrical Box Chart (right) as a guide. The NEC also says that all electrical boxes must remain accessible. Never cover an electrical box with drywall, paneling, or wallcoverings.

See Inspector's Notebook:

- Electrical Box Inspection (pages 128 to 129).
- Common Cable Problems (pages 124 to 125).

Electrical Box Chart

Box shape		**Maximum number of individual wires in box***	
		14-gauge	12-gauge
2" × 3" rectangular	2½" deep	3	3
	3½" deep	5	4
4" × 4" square	1½" deep	6	5
	2⅛" deep	9	7
Octagonal	1½" deep	4	3
	2⅛" deep	7	6

*Do not count pigtail wires or grounding wires.

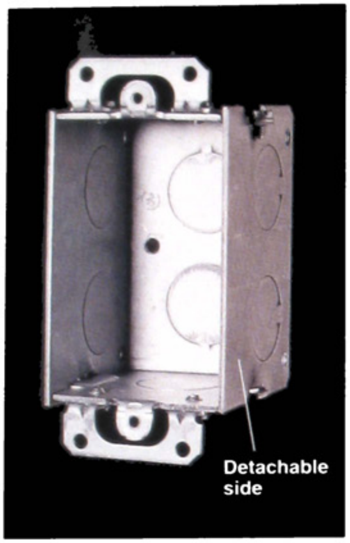

Rectangular boxes are used [illegible] tches and duplex recep[illegible] ngle-size rectangular [illegible] shown above) may have [illegible] des that allow them [illegible] ganged together [illegible] form [illegible] -size boxes

Adapter cover

Square 4" × 4" boxes are enough for most [illegible] ing appli[illegible] ions. They are used for cab[illegible] splices and ganged receptac[illegible] or switches. To install one swit[illegible] or receptacle in a square box [illegible] an adapter [illegible] ver

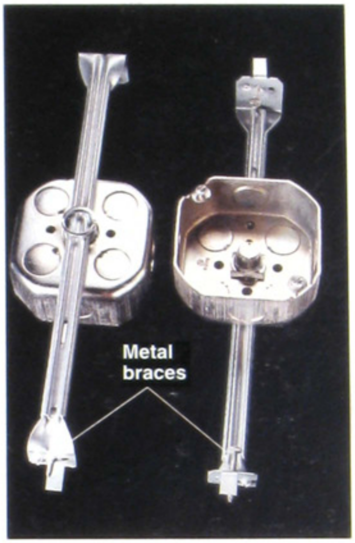

Braced octagonal boxes fit between [illegible] The braces ex[illegible] ng and [illegible] fram[illegible]

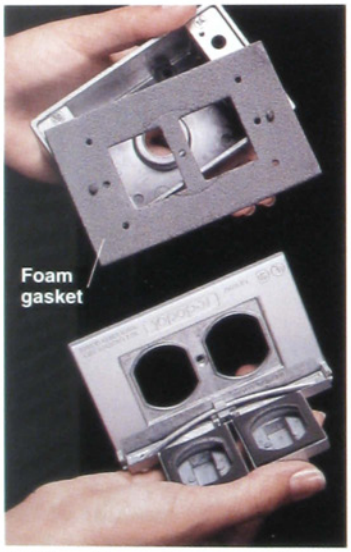

Outdoor boxes have sealed [illegible] and foam gaskets to guard [illegible] or receptacle against [illegible] Corrosion-resistant coat[illegible] protect all metal parts.

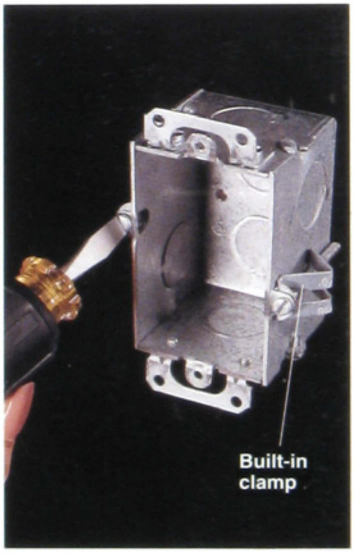

Retrofit boxes upgrade older boxes to larger sizes. One type (above) has built-in clamps that tighten against the inside of a wall and hold the box in place. A retrofit box with flexible brackets is shown on page 41.

Plastic boxes are common in new construction. They can be used only with NM (nonmetallic) cable. Box may include preattached nails for anchoring the box to framing members. Wall switches must have grounding screws if installed in plastic boxes.

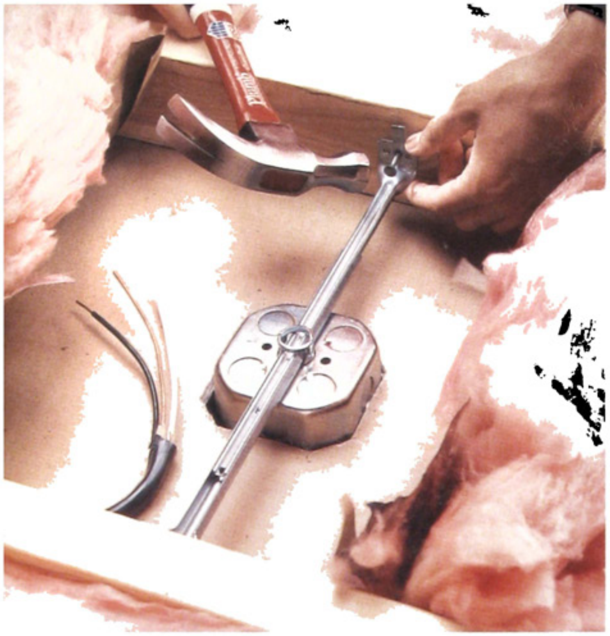

Electrical boxes are required for all wire connections. The box protects wood and other flammable materials from electrical sparks (arcing). Electrical boxes should always be anchored to joists or studs.

Installing an Electrical Box

Install an electrical box any time you find exposed wire connections or cable splices. Exposed connections sometimes can be found in older homes, where wires attach to light fixtures. Exposed splices (page 125) can be found in areas where NM (nonmetallic) cable runs through uncovered joists or wall studs, such as in an unfinished basement or utility room.

When installing an electrical box, make sure there is enough cable to provide about 8" of wire inside the box. If the wires are too short, you can add pigtails to lengthen them (page 128). If the electrical box is metal, make sure the circuit grounding wires are pigtailed to the box.

Everything You Need

Tools: neon circuit tester, screwdriver, hammer.

Materials: screws or nails, electrical box, cable clamps, locknuts, pigtail wire, wire connectors.

How to Install an Electrical Box for Cable Splices

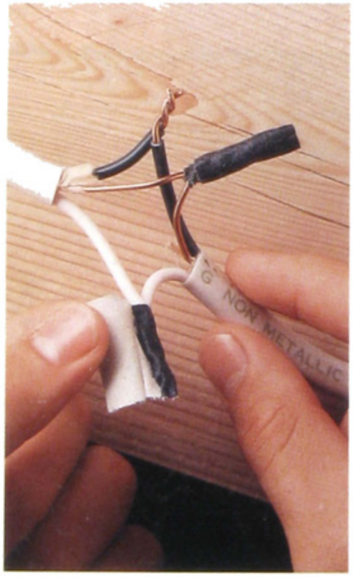

1 Turn off power to circuit wires at the main service panel. Carefully remove any tape or wire connectors from the exposed splice. Avoid contact with the bare wire ends until the wires have been tested for power.

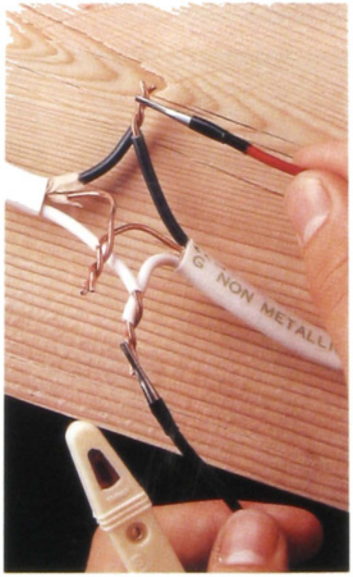

2 Test for power. Touch one probe of a circuit tester to the black hot wires, and touch other probe to the white neutral wires. The tester should not glow. If it does, the wires are still hot. Shut off power to correct circuit at the main service panel. Disconnect the spliced wires.

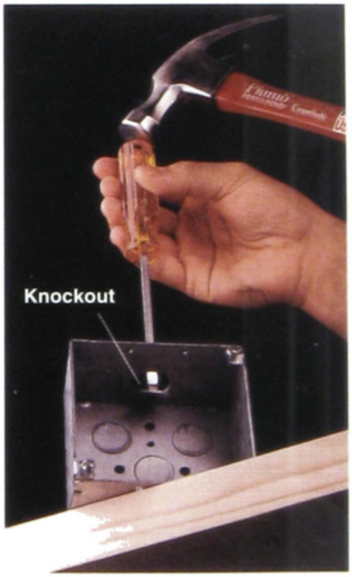

3 Open one knockout for each cable that will enter the box, using a hammer and screwdriver. Any unopened knockouts should remain sealed.

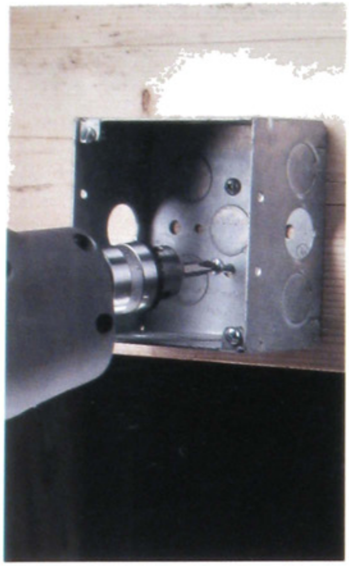

4 lectrical box to a
ing member usi

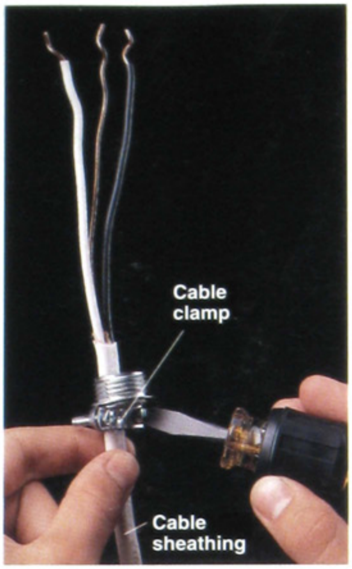
Cable clamp
Cable sheathing

5 Thread each cable
cable clamp Tighten
with a screwdriv Do not
nten Ov

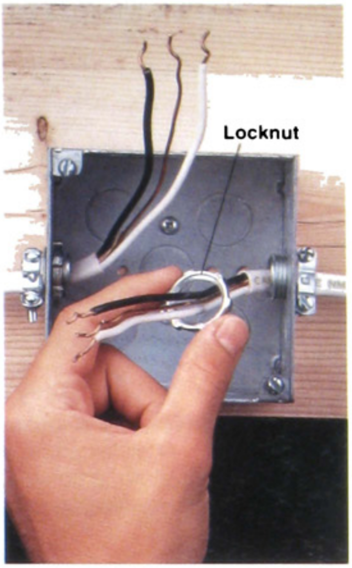

6

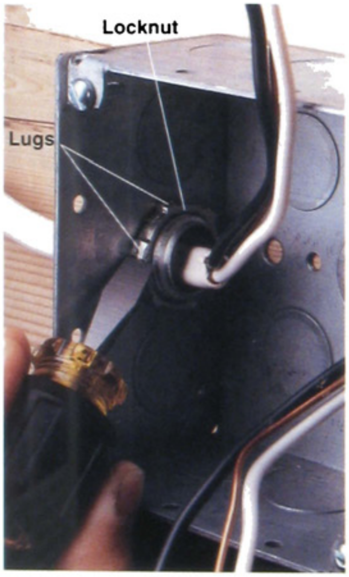
Locknut
Lugs

7 T
locknuts by pushing
lugs with the blade

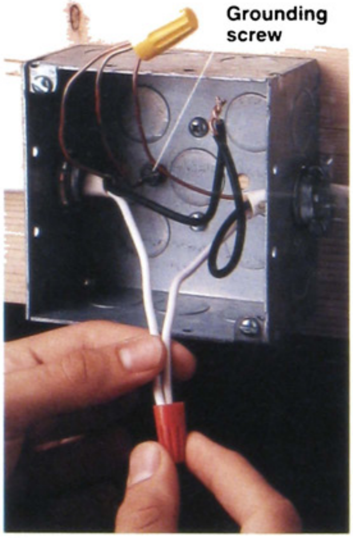
Grounding screw

8 Use wire connectors to reconnect the wires Pigtail the copper grounding wires to the green grounding screw in the back of the box

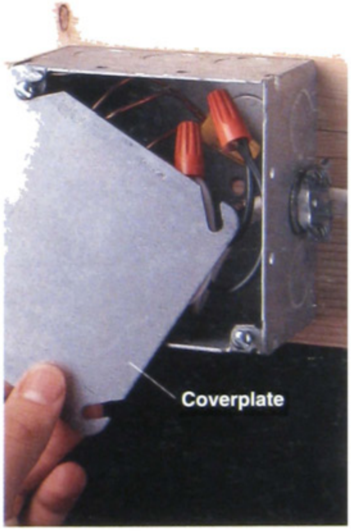
Coverplate

9 Carefully tuck the wires into the box and attach the coverplate Turn on the power to the circuit at the main service panel Make sure the box remains accessible and is not covered with finished walls or ceilings

Replacing an Electrical Box

Replace any electrical box that is too small for the number of wires it contains. Forcing wires into an undersized box can damage wires, disturb wire connections, and create a potential fire hazard.

Boxes that are too small often are found when repairing or replacing switches, receptacles, or light fixtures. If you find a box so small that you have difficulty fitting the wires inside, replace it with a larger box. Use the chart on page 36 as a guide when choosing a replacement box.

Metal and plastic retrofit electrical boxes are available in a variety of styles and can be purchased at any hardware store or home center. Most can be installed without damaging the wall surfaces.

Everything You Need

Tools: screwdriver, neon circuit tester, reciprocating saw, hammer, needlenose pliers.

Materials: string, electrical tape, retrofit electrical box with flexible brackets, grounding screw.

How to Replace an Electrical Box

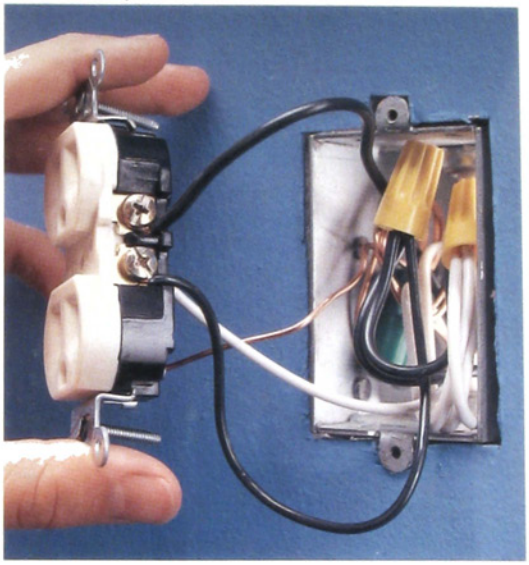

1 Shut off the power to the circuit at the main service panel. Test for power with a neon circuit tester (switches, page 57 receptacles, page 70; light fixtures, page 80). Disconnect and remove receptacle, switch, or fixture from the existing box.

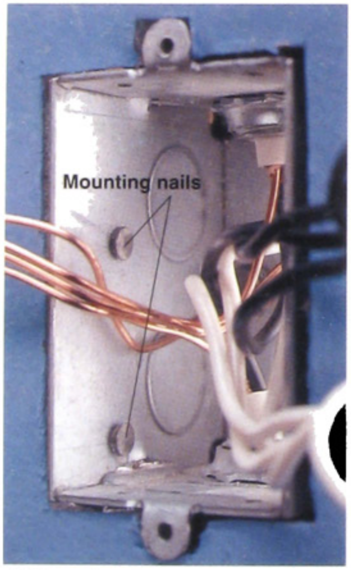

2 Examine the box to determine how it was installed. Most older metal boxes are attached to framing members with nails, and the nail heads will be visible inside the box.

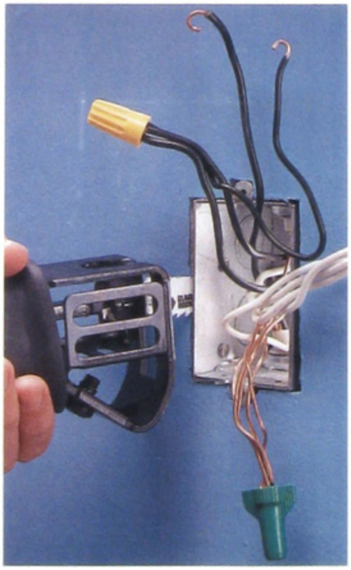

3 Cut through the mounting nails, using a reciprocating saw equipped with a metal-cutting blade. Take care not to damage the circuit wires. Disconnect wires.

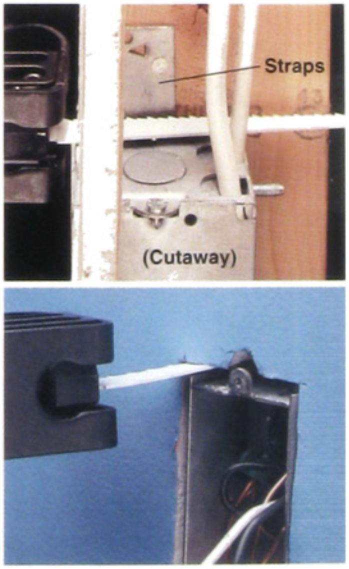

If box is mounted with straps (shown with wall cut away) remove the box by cutting through the straps, using a reciprocating saw and metal-cutting blade. Take care not to damage the wires.

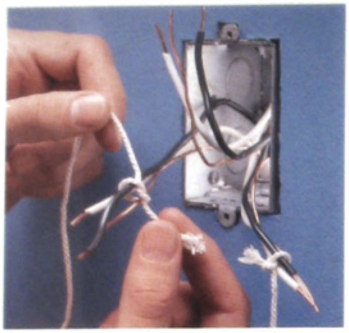

4 To prevent wires from falling into wall cavity, gather wires from each cable and tie them together, using pieces of string.

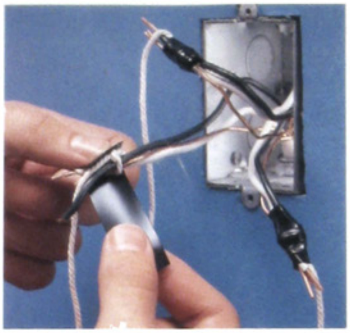

5 Secure the string to the wires, using a piece of plastic electrical tape.

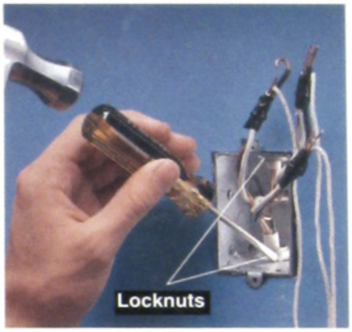

6 Disconnect the internal clamps or locknuts that hold the circuit cables to the box.

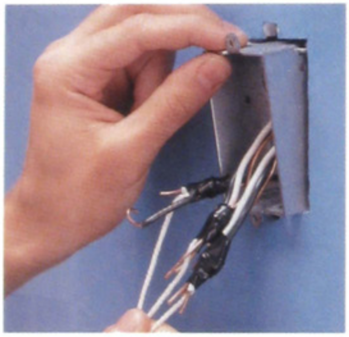

7 Pull old electrical box from wall. Take care not to damage insulation on circuit wires, and hold on to string to make sure wires do not fall inside wall cavity

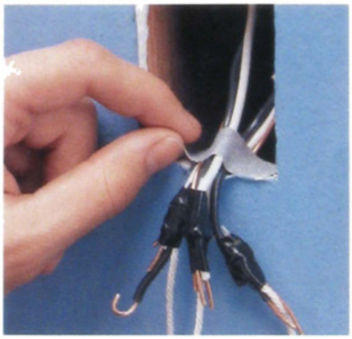

8 Tape the wires to the edge of the wall cutout.

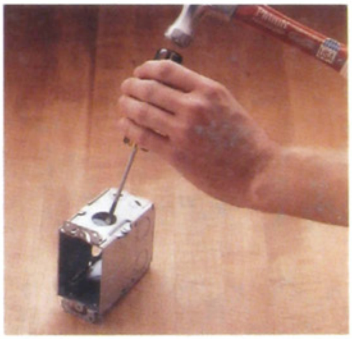

9 Punch out one knockout for each cable that will enter the new electrical box, using a screwdriver and hammer

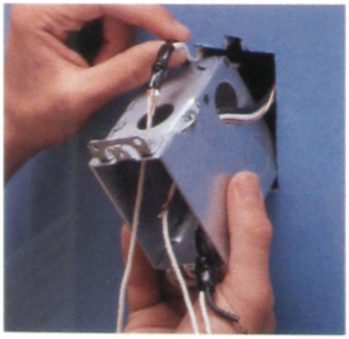

10 Thread cables into the new electrical box, and slide the box into the wall opening. Tighten the internal clamps or locknuts holding the circuit cables to the electrical box. Remove the strings.

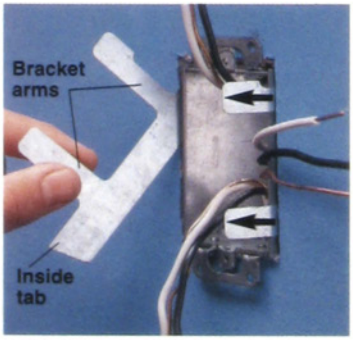

11 Insert flexible brackets into the wall on each side of the electrical box. Pull out bracket arms until inside tab is tight against inside of the wall.

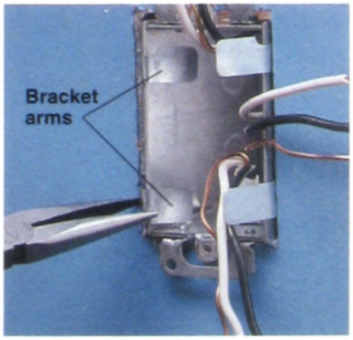

12 Bend bracket arms around walls of box, using needlenose pliers. Reinstall the fixture, and turn on the power to the circuit at the main service panel.

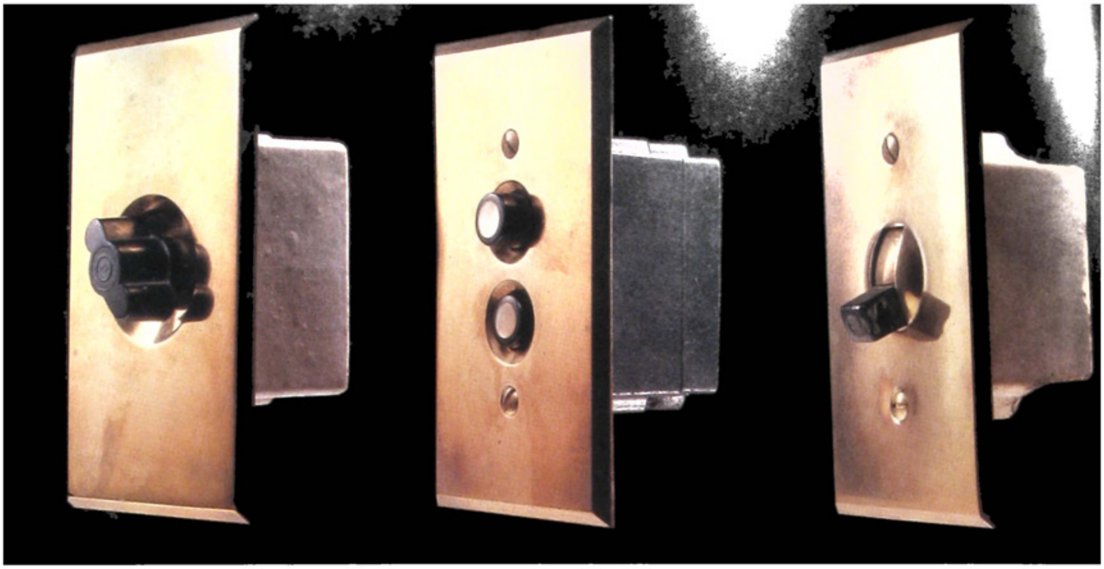

Rotary snap switches are found many installations completed betw 1900 and 1920. Handle is twisted clockwise to light on and off. The swi is encl in a ceramic housing.

Push-button switches were widely used from 1920 until about 1940. Many switches of this type are still in operation. Reproductions of this switch type are available for restoration projects.

Toggle switches were introduced the 1930s. This early design has a switch mechanism that mounted a ceramic housing sealed with of insulating paper.

Common Wall-switch Problems

An average wall switch is turned on and off more than 1,000 times each year. Because switches receive constant use, wire connections can loosen and switch parts gradually wear out. If a switch no longer operates smoothly, it must be repaired or replaced.

The methods for repairing or replacing a switch vary slightly, depending on the switch type and its location along an electrical circuit. When working on a switch, use the photographs on pages 44 to 51 to identify your switch type and its wiring configuration. Individual switch styles may vary from manufacturer to manufacturer, but the basic switch types are universal.

It is possible to replace most ordinary wall switches with a specialty switch, like a timer switch or an electronic switch. When installing a specialty switch (pages 50 to 51), make sure it is compatible with the wiring configuration of the switch box.

See Inspector's Notebook:

- Common Cable Problems (pages 124 to 125).
- Checking Wire Connections (pages 126 to 127).
- Inspecting Switches (page 133).

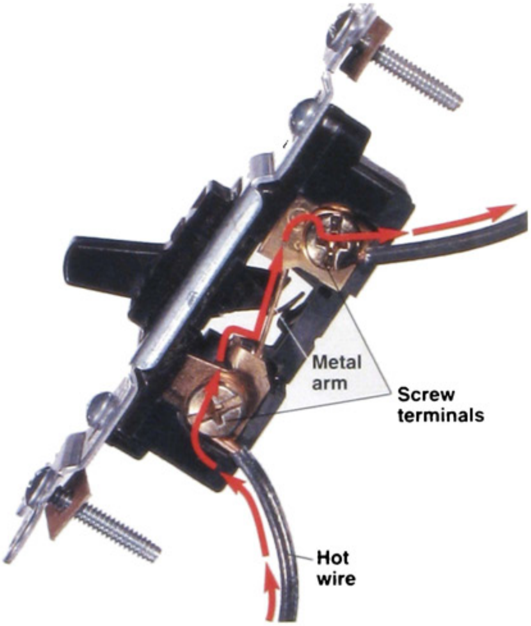

Typical wall switch has a movable metal arm that opens and closes the electrical circuit. When the switch is ON, the arm completes the circuit and power flows between the screw terminals and through the black hot wire to the light fixture. When the switch is OFF, the arm lifts away to interrupt the circuit, and no power flows. Switch problems can occur if the screw terminals are not tight or if the metal arm inside the switch wears out.

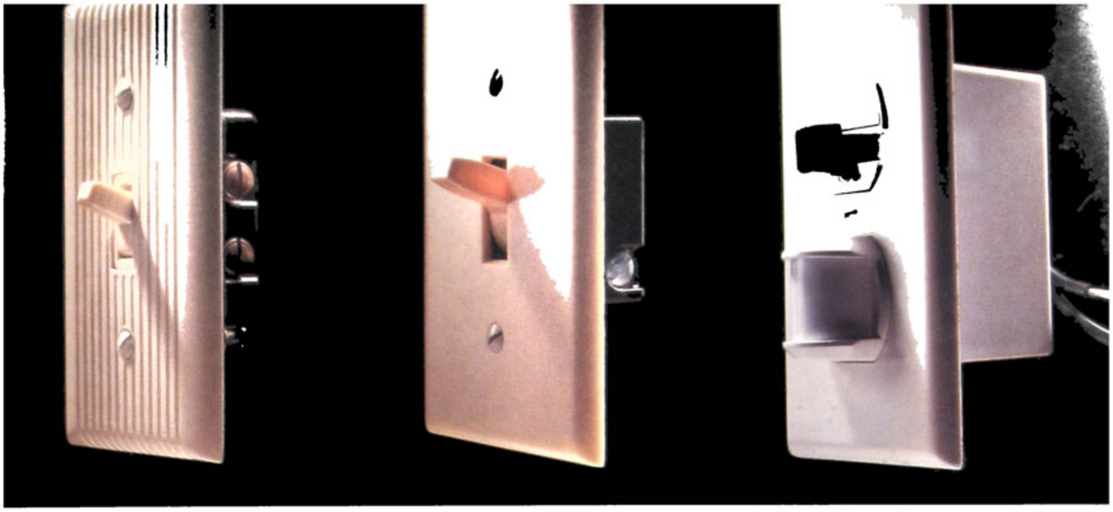

Toggle switches **Mercury switches** **Electronic motion-sensor switch**

th ear 196 Tr

Problem		Repair
	Fuse burns out or circuit breaker trips when the switch is turned on.	1 Tighten any loose wire connections on switch (pages 56 to 57). 2. Move lamps or plug-in appliances to other circuits to prevent overloads (page 34). 3. Test switch (pages 52 to 55), and replace, if needed (pages 56 to 59). 4. Repair or replace faulty fixture (pages 78 to 95) or faulty appliance.
	Light fixture or permanently installed appliance does not work.	1 Replace burned-out light bulb. 2. Check for blown fuse or tripped circuit breaker to make sure circuit is operating (pages 28 to 29). 3. Check for loose wire connections on switch (pages 56 to 57) 4. Test switch (pages 52 to 55), and replace, if needed (pages 56 to 59). 5. Repair or replace light fixture (pages 78 to 95) or appliance
	Light fixture flickers.	1 Tighten light bulb in the socket. 2. Check for loose wire connections on switch (pages 56 to 57) 3. Repair or replace light fixture (pages 78 to 95) or switch (pages 56 to 59).
	Switch buzzes or is warm to the touch.	1 Check for loose wire connections on switch (pages 56 to 57). 2. Test switch (pages 52 to 55), and replace, if needed (pages 56 to 59) 3. Move lamps or appliances to other circuits to reduce demand (page 34).
	Switch lever does not stay in position.	Replace worn-out switch (pages 56 to 59).

Wall-switch Basics

NOTE: Position of the screw terminals on switch may vary, depending on manufacturer

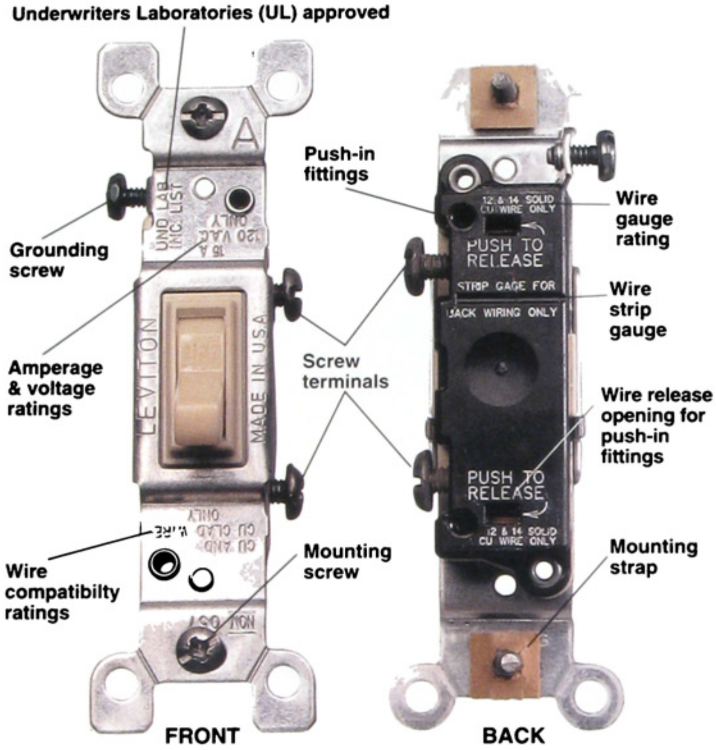
Underwriters Laboratories (UL) approved
Grounding screw
Amperage & voltage ratings
Wire compatibilty ratings
Push-in fittings
Screw terminals
Mounting screw
Wire gauge rating
Wire strip gauge
Wire release opening for push-in fittings
Mounting strap
FRONT
BACK
LEVITON
MADE IN USA
UND. LAB. INC. LIST
15 A 120 VAC ONLY
CU AND CU CLAD WIRE ONLY
12 & 14 SOLID CU WIRE ONLY
PUSH TO RELEASE
STRIP GAGE FOR BACK WIRING ONLY
PUSH TO RELEASE
12 & 14 SOLID CU WIRE ONLY

A wall switch is connected to circuit wires with screw terminals or with push-in fittings on the back of the switch. A switch may have a stamped strip gauge that indicates how much insulation must be stripped from the circuit wires to make the connections.

The switch body is attached to a metal mounting strap that allows it to be mounted in an electrical box. Several rating stamps are found on the strap and on the back of the switch. The abbreviation UL or UND. LAB. INC. LIST means that the switch meets the safety standards of the Underwriters Laboratories. Switches also are stamped with maximum voltage and amperage ratings. Standard wall switches are rated 15A, 125V Voltage ratings of 110, 120, and 125 are considered to be identical for purposes of identification.

For standard wall switch installations, choose a switch that has a wire gauge rating of #12 or #14. For wire systems with solid-core copper wiring, use only switches marked COPPER or CU. For aluminum wiring (page 22), use only switches marked CO/ALR. Switches marked AL/CU can no longer be used with aluminum wiring, according to the National Electrical Code.

Wall switches are available in three general types. To repair or replace a switch, it is important to identify its type.

Single-pole switches are used to control a set of lights from one location. **Three-way switches** are used to control a set of lights from two different locations and are always installed in pairs. **Four-way switches** are used in combination with a pair of three-way switches to control a set of lights from three or more locations.

Identify switch types by counting the screw terminals. Single-pole switches have two screw terminals, three-way switches have three screw terminals, and four-way switches have four.

Most switches include a grounding screw terminal, which is identified by its green color. Technically, grounded switches are required only when the switch is installed in a plastic box. However, many electricians make it a practice to always install grounded switches. When pigtailed to the grounding wires, a grounding screw provides added protection against shock.

When replacing a switch, choose a new switch that has the same number of screw terminals as the old one. The location of the screws on the switch body varies, depending on the manufacturer, but these differences will not affect the switch operation.

Whenever possible, connect switches using the screw terminals rather than push-in fittings. Some specialty switches (pages 50 to 51) have wire leads instead of screw terminals. They are connected to circuit wires with wire connectors.

Single-pole Wall Switches

A single-pole switch is the most common type of wall switch. It usually has ON-OFF markings on the switch lever and is used to control a set of lights, an appliance, or a receptacle from a single location. A single-pole switch has two screw terminals and a grounding screw. When installing a single-pole switch, check to make sure the ON marking shows when the switch lever is in the up position.

In a correctly wired single-pole switch, a hot circuit wire is attached to each screw terminal. However, the color and number of wires inside the switch box will vary, depending on the location of the switch along the electrical circuit.

If two cables enter the box, then the switch lies in the middle of the circuit. In this installation, both of the hot wires attached to the switch are black.

If only one cable enters the box, then the switch lies at the end of the circuit. In this installation (sometimes called a switch loop), one of the hot wires is black, but the other hot wire usually is white. A white hot wire sometimes is coded with black tape or paint.

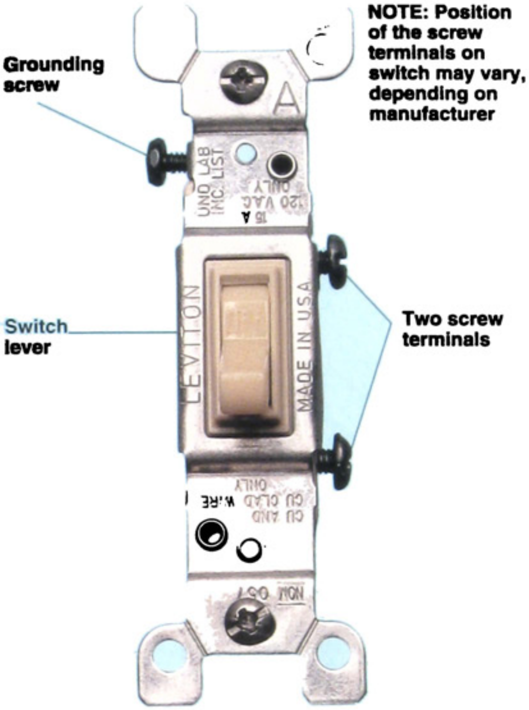
Grounding screw
NOTE: Position of the screw terminals on switch may vary, depending on manufacturer
Switch lever
Two screw terminals
LEVITON
MADE IN USA

Typical Single-pole Switch Installations

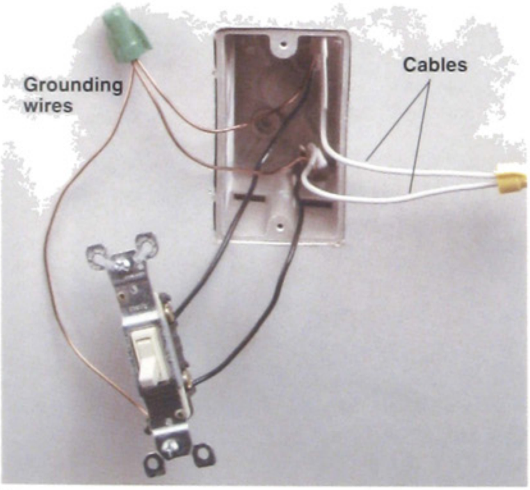

Two cables enter the box when a switch is located in the middle of a circuit. Each cable has a white and a black insulated wire, plus a bare copper grounding wire. The black wires are hot and are connected to the screw terminals on the switch. The white wires are neutral and are joined together with a wire connector. Grounding wires are pigtailed to the switch.

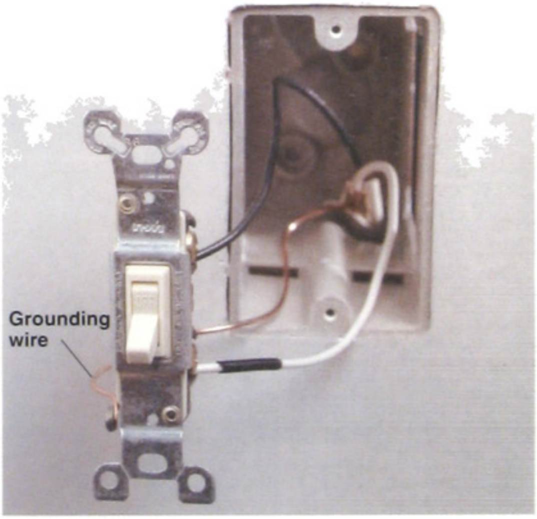

One cable enters the box when a switch is located at the end of a circuit. The cable has a white and a black insulated wire, plus a bare copper grounding wire. In this installation, both of the insulated wires are hot. The white wire may be labeled with black tape or paint to identify it as a hot wire. The grounding wire is connected to the switch grounding screw.

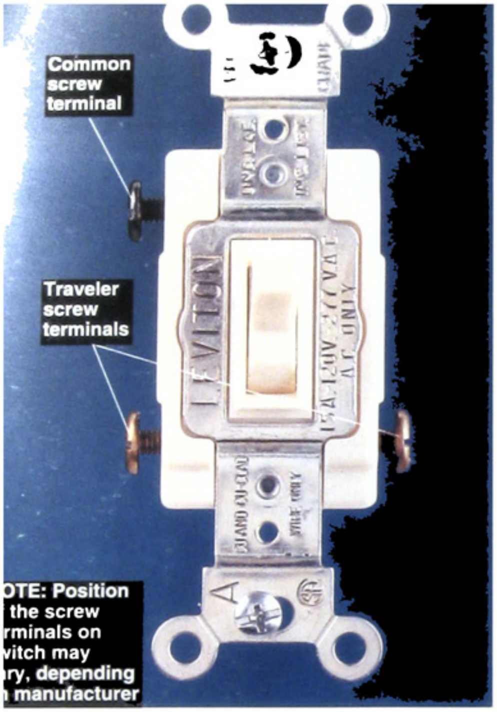
Common screw terminal
Traveler screw terminals
OTE: Position
the screw
rminals on
vitch may
ry, depending
manufacturer

Three-way Wall Switches

Three-way switches have three screw terminals and do not have ON-OFF markings. Three-way switches are always installed in pairs and are used to control a set of lights from two locations.

One of the screw terminals on a three-way switch is darker than the others. This screw is the **common screw terminal.** The position of the common screw terminal on the switch body may vary, depending on the manufacturer. Before disconnecting a three-way switch, always label the wire that is connected to the common screw terminal. It must be reconnected to the common screw terminal on the new switch.

The two lighter-colored screw terminals on a three-way switch are called the **traveler screw terminals.** The traveler terminals are interchangeable, so there is no need to label the wires attached to them.

Because three-way switches are installed in pairs, it sometimes is difficult to determine which of the switches is causing a problem. The switch that receives greater use is more likely to fail, but you may need to inspect both switches to find the source of the problem.

Typical Three-way Switch Installations

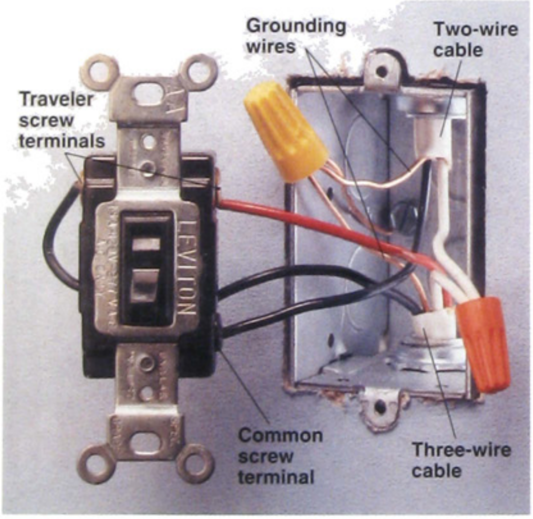
Grounding wires
Two-wire cable
Traveler screw terminals
Common screw terminal
Three-wire cable

Two cables enter the box if the switch lies in the middle of a circuit. One cable has two wires, plus a bare copper grounding wire; the other cable has three wires, plus a ground. The black wire from the two-wire cable is connected to the dark, common screw terminal. The red and black wires from the three-wire cable are connected to the traveler screw terminals. The white neutral wires are joined together with a wire connector, and the grounding wires are pigtailed to the grounded metal box.

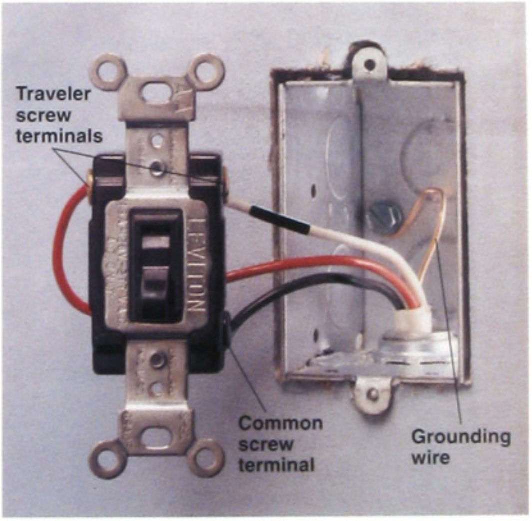
Traveler screw terminals
Common screw terminal
Grounding wire

One cable enters the box if the switch lies at the end of the circuit. The cable has a black wire, red wire, and white wire, plus a bare copper grounding wire. The black wire must be connected to the common screw terminal, which is darker than the other two screw terminals. The white and red wires are connected to the two traveler screw terminals. The bare copper grounding wire is connected to the grounded metal box.

Four-way Wall Switches

Four-way switches have four screw terminals and do not have ON-OFF markings. Four-way switches are always installed between a pair of three-way switches. This switch combination makes it possible to control a set of lights from three or more locations. Four-way switches are common in homes where large rooms contain multiple living areas, such as a kitchen opening into a dining room. Switch problems in a four-way installation can be caused by loose connections or worn parts in a four-way switch or in one of the three-way switches (page opposite).

In a typical installation, there will be a pair of three-way cables that enter the box for the four-way switch. With most switches, the white and red wires from one cable should be attached to the bottom or top pair of screw terminals, and the white and red wires from the other cable should be attached to the remaining pair of screw terminals. However, not all switches are configured the same way, and wiring configurations in the box may vary, so always study the wiring diagram that comes with the switch.

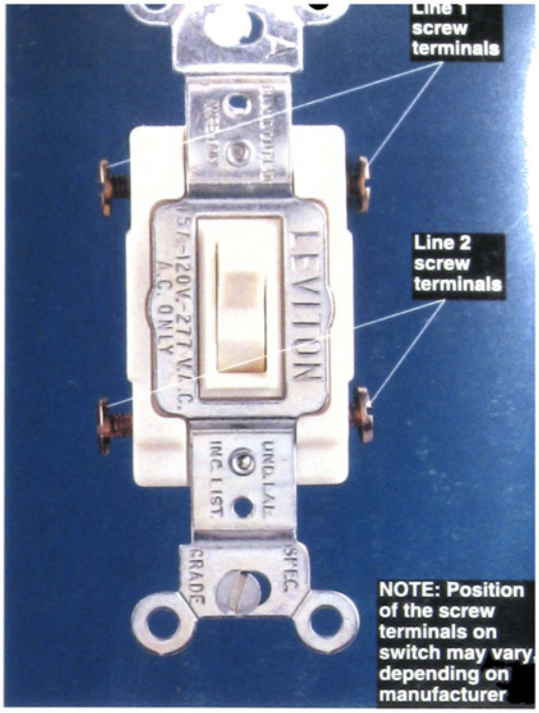

NOTE: Position of the screw terminals on switch may vary, depending on manufacturer

Typical Four-way Switch Installation

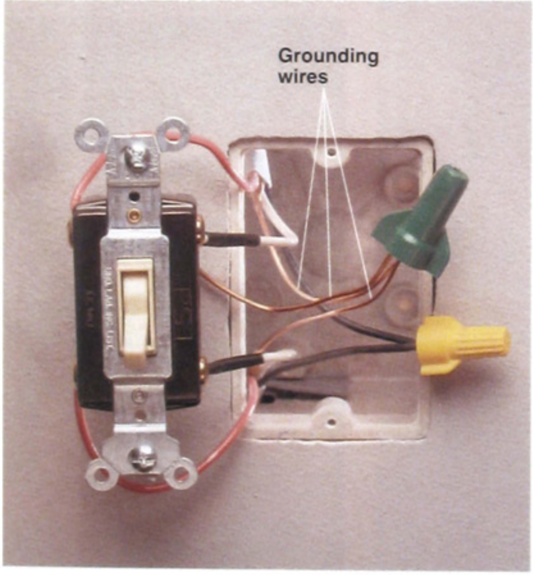

Four wires are connected to a four-way switch. The red and white wires from one cable are attached to the top pair of screw terminals, while the red and white wires from the other cable are attached to the bottom screw terminals.

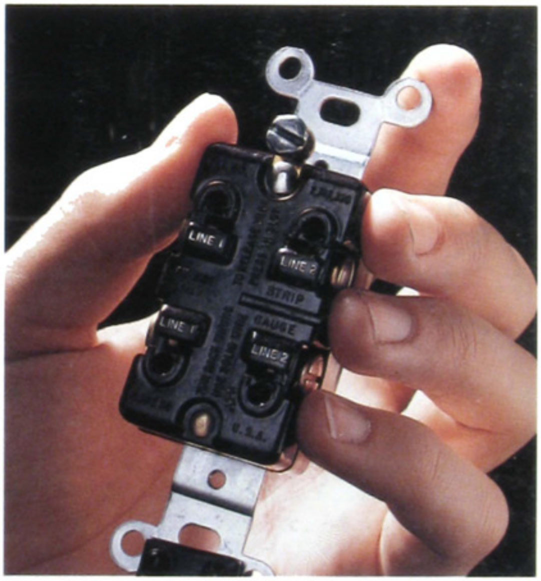

Switch variation: Some four-way switches have a wiring guide stamped on the back to help simplify installation. For the switch shown above, one pair of color-matched circuit wires will be connected to the screw terminals marked LINE 1, while the other pair of wires will be attached to the screw terminals marked LINE 2.

Double Switches

A double switch has two switch levers in a single housing It is used to control two light fixtures or appliances from the same switch box.

In most installations, both halves of the switch are powered by the same circuit. In these **single-circuit** installations, three wires are connected to the double switch. One wire, called the "feed" wire, supplies power to both halves of the switch. The other wires carry power out to the individual light fixtures or appliances.

In rare installations, each half of the switch is powered by a separate circuit. In these **separate-circuit** installations, four wires are connected to the switch, and the metal connecting tab joining two of the screw terminals is removed (photo below).

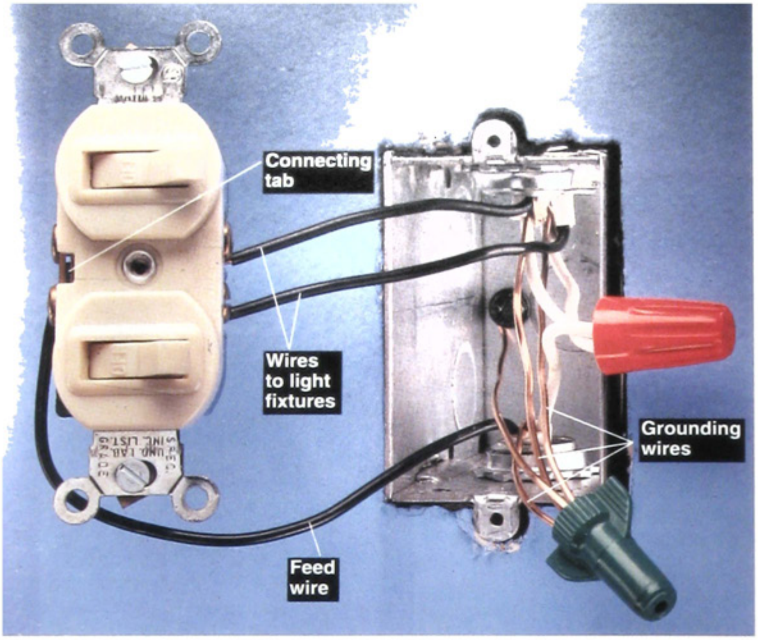

Single-circuit wiring: Three black wires are attached to the switch. The black feed wire bringing power into the box is connected to the side of the switch that has a connecting tab The wires carrying power out to the light fixtures or appliances are connected to the side of the switch that **does not** have a connecting tab The white neutral wires are connected together with a wire connector

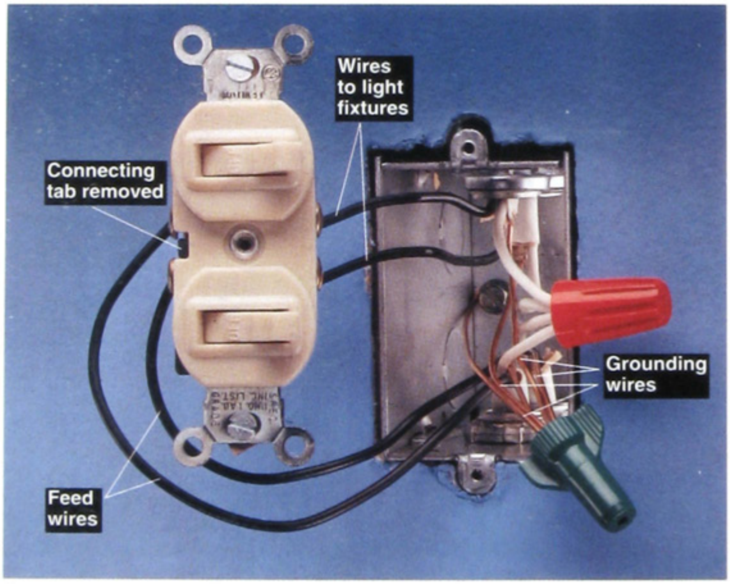

Separate-circuit wiring: Four black wires are attached to the switch. Feed wires from the power source are attached to the side of switch that has a connecting tab, and the connecting tab is removed (photo, right). Wires carrying power from the switch to light fixtures or appliances are connected to the side of the switch that **does not** have a connecting tab. White neutral wires are connected together with a wire connector.

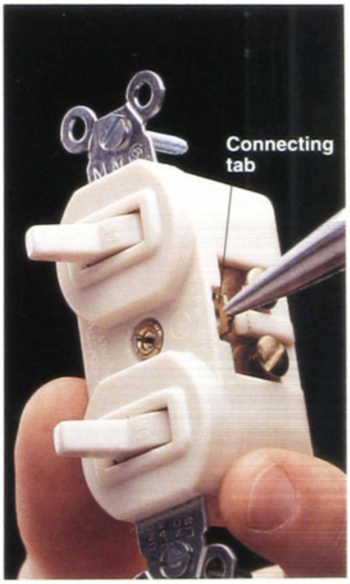

Remove the connecting tab on a double switch when wired in a separate-circuit installation. The tab can be removed with needle-nose pliers or a screwdriver.

Pilot-light Switches

A pilot-light switch has a built-in bulb that glows when power flows through the switch to a light fixture or appliance. Pilot-light switches often are installed for convenience if a light fixture or appliance cannot be seen from the switch location. Basement lights, garage lights, and attic exhaust fans frequently are controlled by pilot-light switches.

A pilot-light switch requires a neutral wire connection. A switch box that contains a single two-wire cable has only hot wires and cannot be fitted with a pilot-light switch.

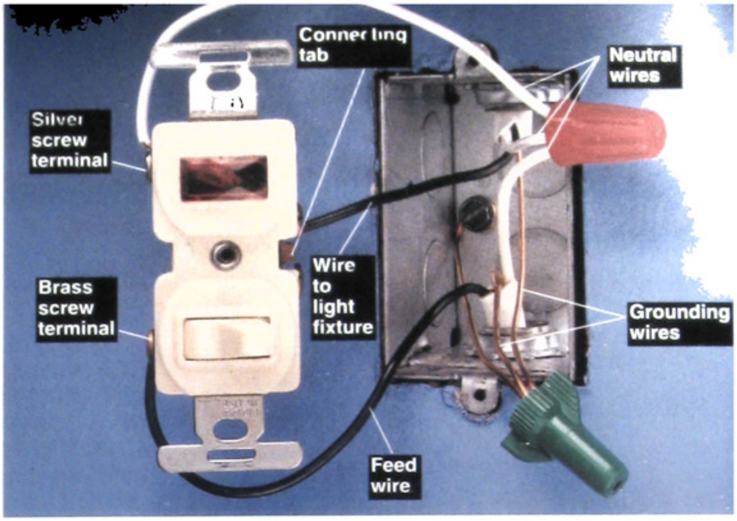
Connecting tab
Neutral wires
Silver screw terminal
Wire to light fixture
Brass screw terminal
Grounding wires
Feed wire

Pilot-light switch wiring: Three wires are connected to the switch. One black wire is the feed wire that brings power into the box. It is connected to the brass screw terminal on the side of the switch that **does not** have a connecting tab. The white neutral wires are pigtailed to the silver screw terminal. Black wire carrying power out to light fixture or appliance is connected to screw terminal on side of the switch that has a connecting tab

Switch/receptacles

A switch/receptacle combines a grounded receptacle with a single-pole wall switch. In a room that does not have enough wall receptacles, electrical service can be improved by replacing a single-pole switch with a switch/receptacle.

A switch/receptacle requires a neutral wire connection. A switch box that contains a single two-wire cable has only hot wires and cannot be fitted with a switch/receptacle.

A switch/receptacle can be installed in one of two ways. In the most common installations, the receptacle is hot even when the switch is off (photo, right).

In rare installations, a switch/receptacle is wired so the receptacle is hot only when the switch is on. In this installation, the hot wires are reversed, so that the feed wire is attached to the brass screw terminal on the side of the switch that does not have a connecting tab.

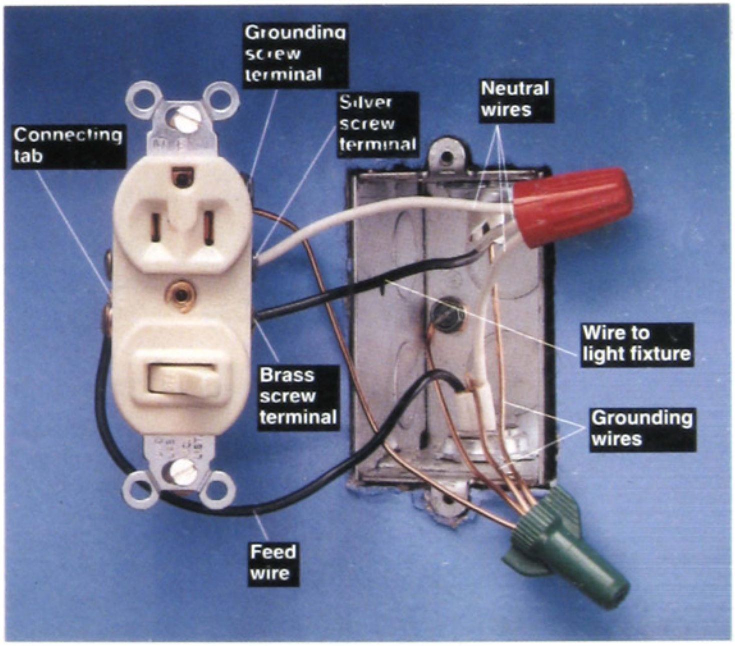
Grounding screw terminal
Silver screw terminal
Neutral wires
Connecting tab
Wire to light fixture
Brass screw terminal
Grounding wires
Feed wire

Switch/receptacle wiring: Three wires are connected to the switch/receptacle. One of the hot wires is the feed wire that brings power into the box. It is connected to the side of the switch that has a connecting tab. The other hot wire carries power out to the light fixture or appliance. It is connected to the brass screw terminal on the side that **does not** have a connecting tab. The white neutral wire is pigtailed to the silver screw terminal. The grounding wires must be pigtailed to the green grounding screw on the switch/receptacle and to the grounded metal box.

Specialty Switches

Specialty switches are available in several types. **Dimmer switches** (pages 60 to 61) are used frequently to control light intensity in dining and recreation areas. **Timer switches** and **time-delay switches** (below) are used to control light fixtures and exhaust fans automatically. New **electronic switches** (page opposite) provide added convenience and home security, and are easy to install. Electronic switches are durable, and they rarely need repair.

Most standard single-pole switches can be replaced with a specialty switch. Most specialty switches have preattached wire leads instead of screw terminals and are connected to circuit wires with wire connectors. Some motor-driven timer switches require a neutral wire connection and cannot be installed in switch boxes that have only one cable with two hot wires.

If a specialty switch is not operating correctly, you may be able to test it with a continuity tester (pages 52 to 55). Timer switches and time-delay switches can be tested for continuity, but dimmer switches cannot be tested. With electronic switches, the manual switch can be tested for continuity (page 55), but the automatic features cannot be tested.

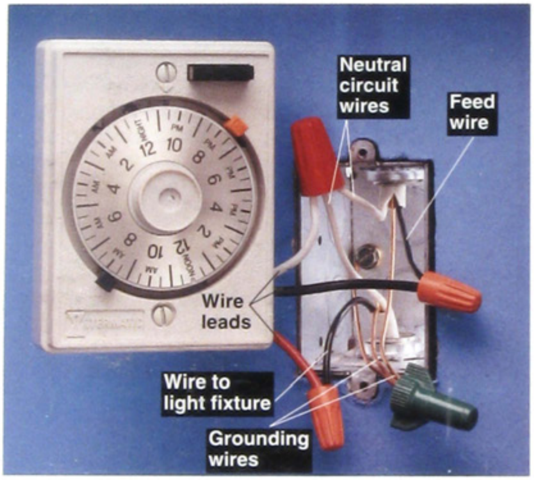

Timer Switches

Timer switches have an electrically powered control dial that can be set to turn lights on and off automatically once each day. They are commonly used to control outdoor light fixtures.

Timer switches have three preattached wire leads. The black wire lead is connected to the hot feed wire that brings power into the box, and the red lead is connected to the wire carrying power out to the light fixture. The remaining wire lead is the neutral lead. It must be connected to any neutral circuit wires. A switch box that contains only one cable has no neutral wires, so it cannot be fitted with a timer switch.

After a power failure, the dial on a timer switch must be reset to the proper time.

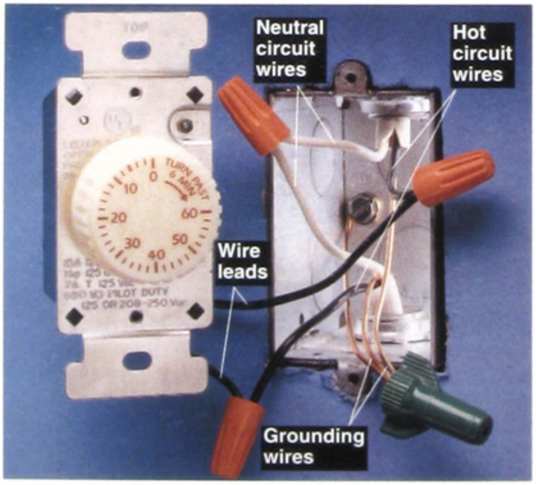

Time-delay Switches

A time-delay switch has a spring-driven dial that is wound by hand. The dial can be set to turn off a light fixture after a delay ranging from 1 to 60 minutes. Time-delay switches often are used for exhaust fans, electric space heaters, bathroom vent fans, and heat lamps.

The black wire leads on the switch are connected to the hot circuit wires. If the switch box contains white neutral wires, these are connected together with a wire connector. The bare copper grounding wires are pigtailed to the grounded metal box.

A time-delay switch needs no neutral wire connection, so it can be fitted in a switch box that contains either one or two cables.

Automatic Switches

An automatic switch uses a narrow infrared beam to detect movement. When a hand passes within a few inches of the beam, an electronic signal turns the switch on or off. Some automatic switches have a manual dimming feature.

Automatic switches can be installed wherever a standard single-pole switch is used. Automatic switches are especially convenient for children and persons with disabilities.

Automatic switches require no neutral wire connections. For this reason, an automatic switch can be installed in a switch box containing either one or two cables. The wire leads on the switch are connected to hot circuit wires with wire connectors.

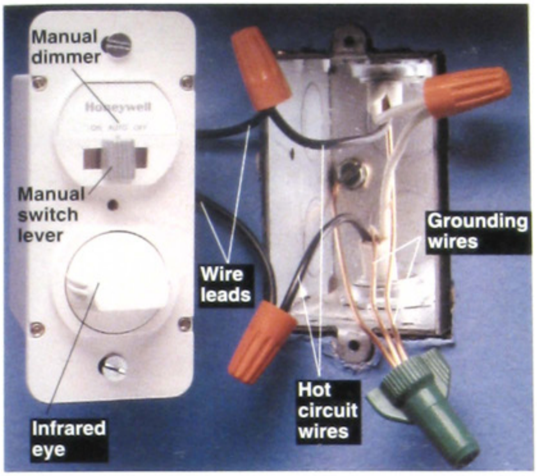
Manual dimmer
Manual switch lever
Infrared eye
Wire leads
Grounding wires
Hot circuit wires

Motion-sensor Security Switches

A motion-sensor switch uses a wide-angle infrared beam to detect movement over a large area and turns on a light fixture automatically. A time-delay feature turns off lights after movement stops.

Most motion-sensor switches have an override feature that allows the switch to be operated manually. Better switches include an adjustable sensitivity control and a variable time-delay shutoff control.

Motion-sensor switches require no neutral wire connections. They can be installed in switch boxes containing either one or two cables. The wire leads on the switch are connected to hot circuit wires with wire connectors.

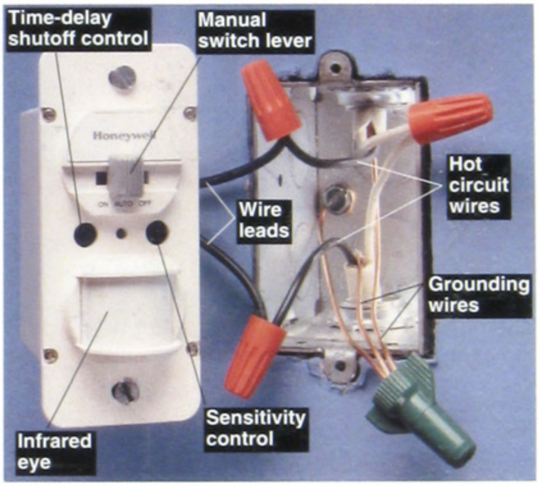
Time-delay shutoff control
Manual switch lever
Hot circuit wires
Wire leads
Grounding wires
Sensitivity control
Infrared eye

Programmable Switches

Programmable switches represent the latest in switch design. They have digital controls and can provide four on-off cycles each day.

Programmable switches frequently are used to provide security when a homeowner is absent from the house. Law enforcement experts say that programmed lighting is a proven crime deterrent. For best protection, programmable switches should be set to a random on-off pattern.

Programmable switches require no neutral wire connections. They can be installed in switch boxes containing either one or two cables. The wire leads on the switch are connected to hot circuit wires with wire connectors.

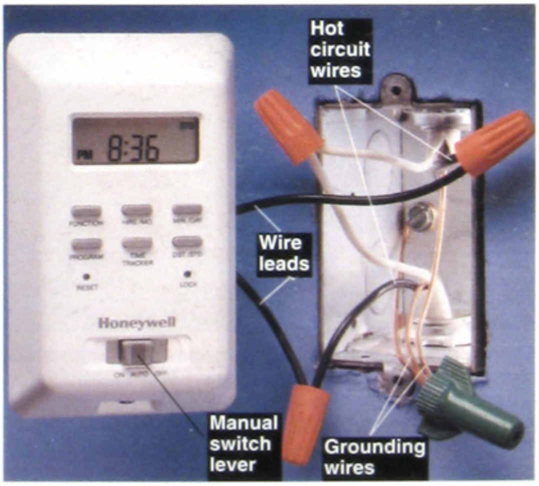
Hot circuit wires
PM 8:36
Honeywell
Wire leads
Manual switch lever
Grounding wires

THE DALLES-WASCO COUNTY
PUBLIC LIBRARY
722 Court St.
The Dalles, OR 97058

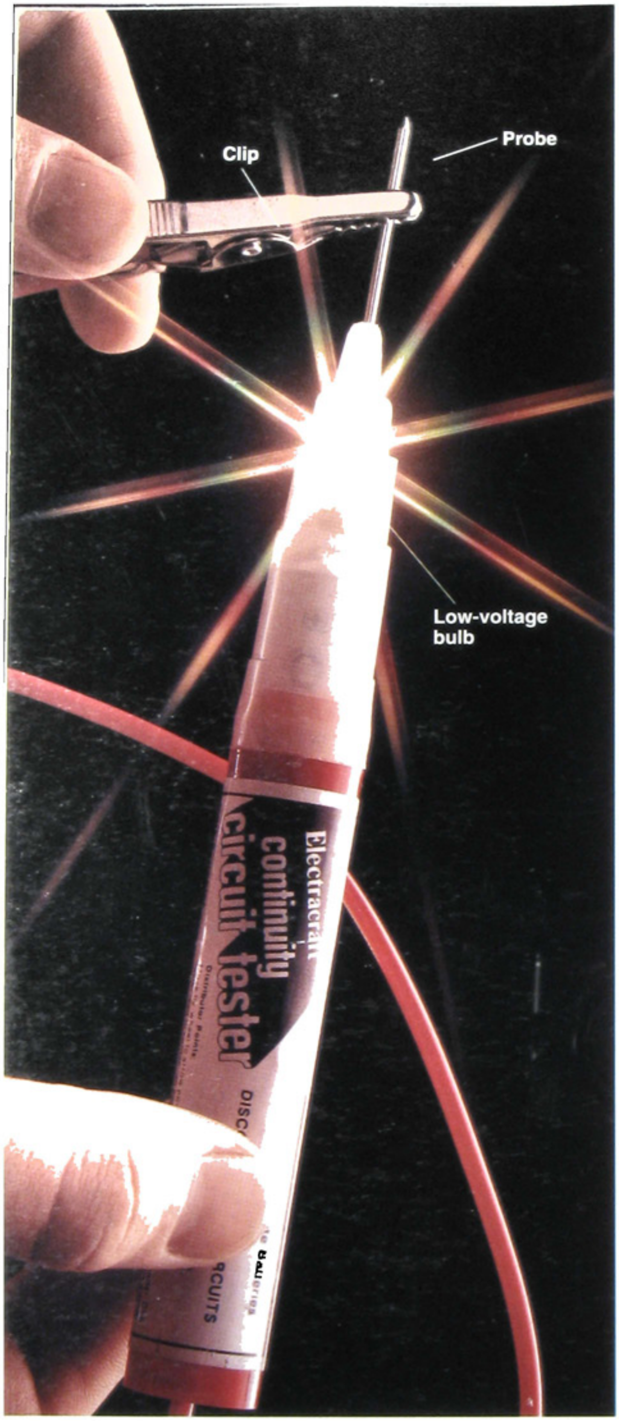

Continuity tester uses battery-generated current to test the metal pathways running through switches and other electrical fixtures. Always "test" the tester before use. Touch the tester clip to the metal probe. The tester should glow. If not, then the battery or light bulb is dead and must be replaced.

Testing Switches for Continuity

A switch that does not work properly may have worn or broken internal parts. Test for internal wear with a battery-operated continuity tester. The continuity tester detects any break in the metal pathway inside the switch. Replace the switch if the continuity tester shows the switch to be faulty.

Never use a continuity tester on wires that might carry live current. Always shut off the power and disconnect the switch before testing for continuity.

Some specialty switches, like dimmers, cannot be tested for continuity. Electronic switches can be tested for manual operation using a continuity tester, but the automatic operation of these switches cannot be tested.

Everything You Need

Tools: continuity tester.

How to Test a Single-pole Wall Switch

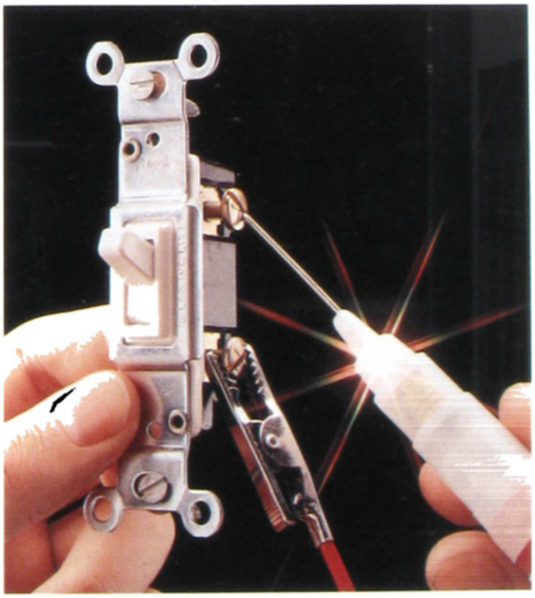

Attach clip of tester to one of the screw terminals. Touch the tester probe to the other screw terminal. Flip switch lever from ON to OFF If switch is good, tester glows when lever is ON, but not when OFF

How to Test a Three-way Wall Switch

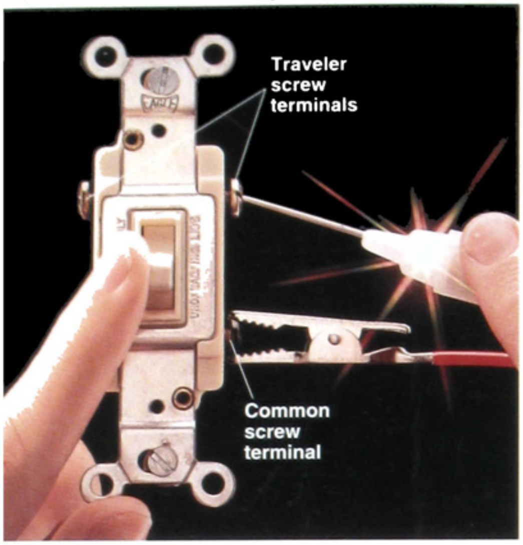
Traveler screw terminals
Common screw terminal

1

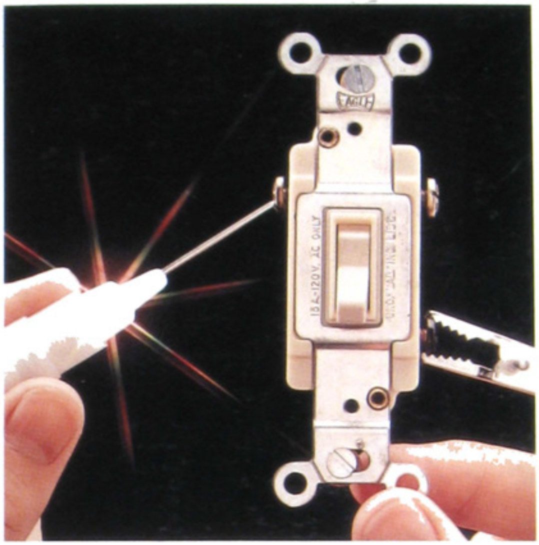

2 Touc

go

How to Test a Four-way Wall Switch

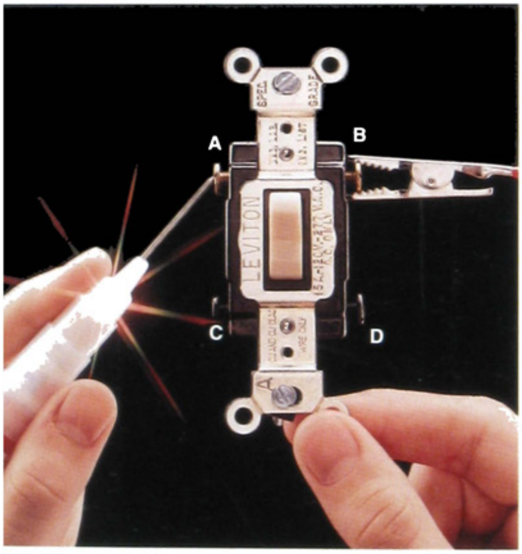

1 switch by touc probe and clip of continuity
cn pair terminals (A-B C-D
B-D) The test should show continuous
diff rent pairs of screw termi-
ite position and repeat test
pathways between tw
als

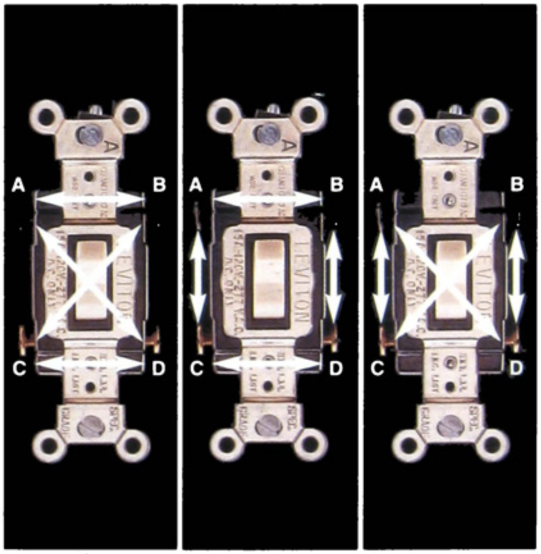
A
B
C
D
A
B
C
D
A
B
C
D

2 witch is good test show total of fou
uous pathways between scr terminals—
pathways for each lever position If not then switch
faulty and must be replaced (The arrangement of the pathways may differ depending on the switch manufacturer The photo above shows the three possible pathway arrangements

How to Test a Pilot-light Switch

1

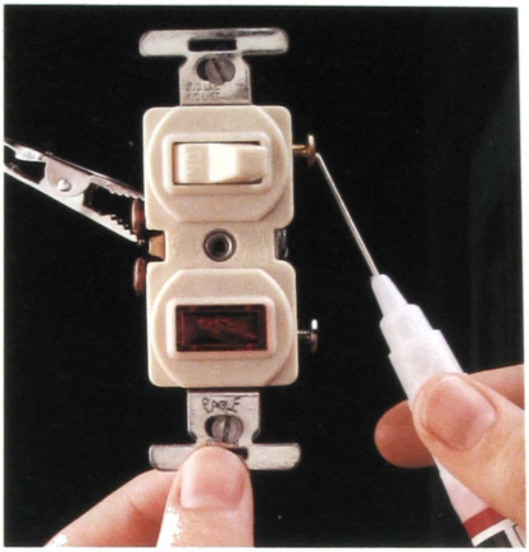

2

How to Test a Timer Switch

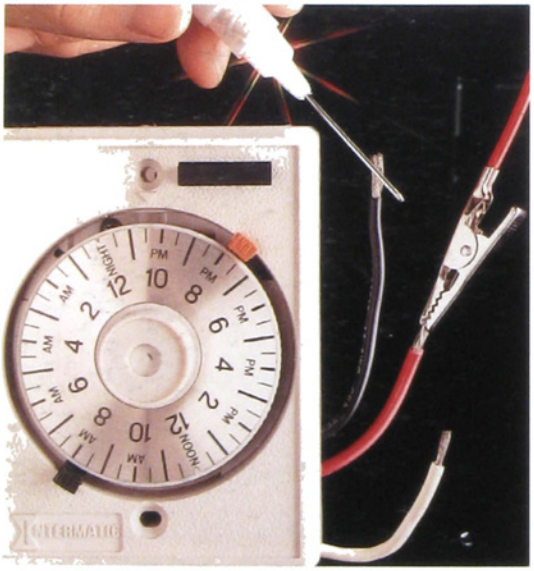
INTERMATIC

1

black Ro
ON tab pas
does

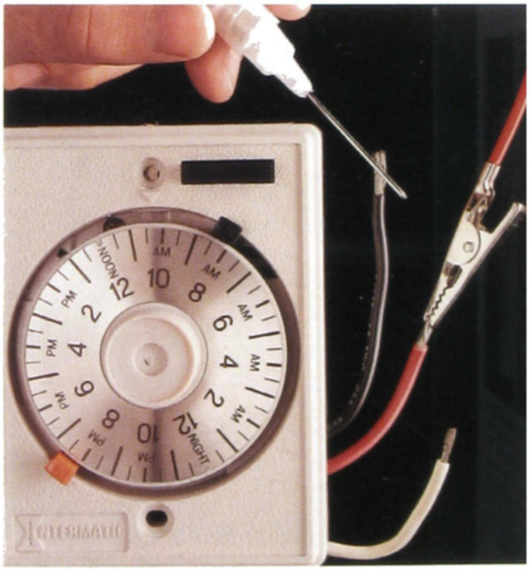
INTERMATIC

2 Rotate the dial clockwise until the OFF tab pass
marker. Tester should not glow. If
does, the switch is faulty and must be replac

How to Test Switch/receptacle

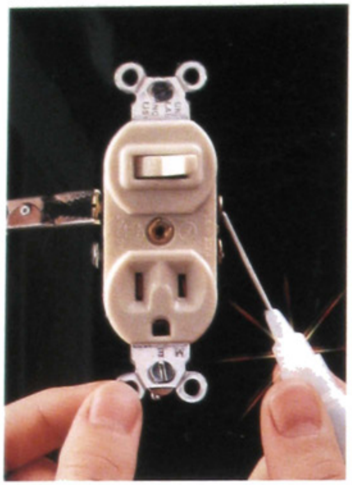

Attach tester clip
T

How to Test a Double Switch

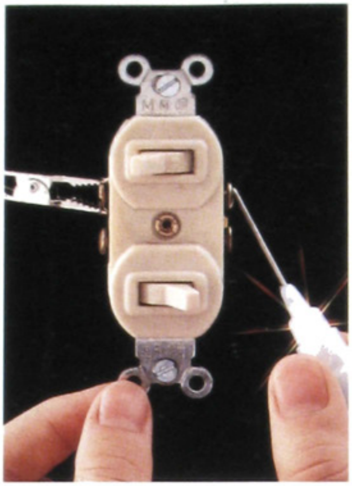

Test each half of switch b
ing the

How to Test a Time-delay Switch

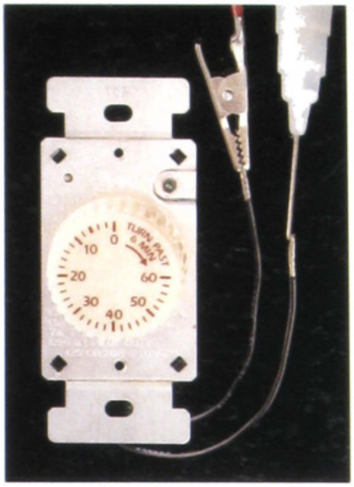
TURN PAST 6 MIN
0
10
20
30
40
50
60

Attach tester clip
ire ads
probe

How to Test Manual Operation of Electronic Switches

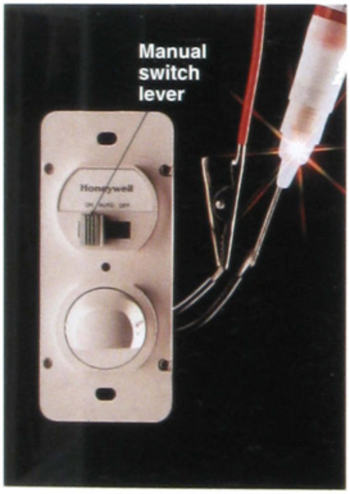
Manual switch lever
Honeywell
ON AUTO OFF

Automatic switch:
plack

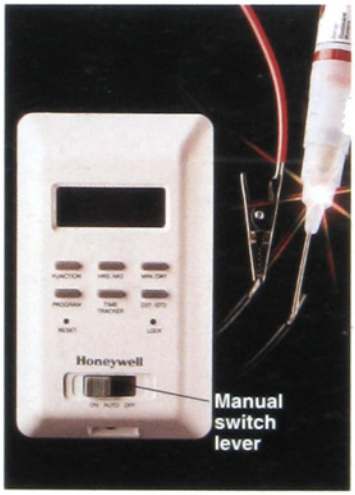
Honeywell
ON AUTO OFF
Manual switch lever

Programmable switch: Att the
to a ire lead
the tes probe to the
Flip the manual switch
ON to OFF position If the switch
working correctly the tester will
when the switch lever is ON
when OFF

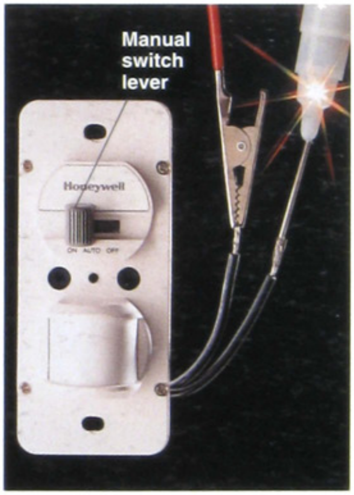
Manual switch lever
Honeywell
ON AUTO OFF

Motion-sensor switch:
tester d

Fixing & Replacing Wall Switches

Most switch problems are caused by loose wire connections. If a fuse blows or a circuit breaker trips when a switch is turned on, a loose wire may be touching the metal box. Loose wires also can cause switches to overheat or buzz.

Switches sometimes fail because internal parts wear out. To check for wear, the switch must be removed entirely and tested for continuity (pages 52 to 55). If the continuity test shows the switch is faulty, replace it.

Everything You Need

Tools: screwdriver, neon circuit tester, continuity tester, combination tool.

Materials: fine sandpaper, antioxidant paste (for aluminum wiring), masking tape.

See Inspector's Notebook:

- Common Cable Problems (pages 124 to 125).
- Checking Wire Connections (pages 126 to 127).
- Electrical Box Inspection (pages 128 to 129).
- Inspecting Switches (page 133).

How to Fix or Replace a Single-pole Wall Switch

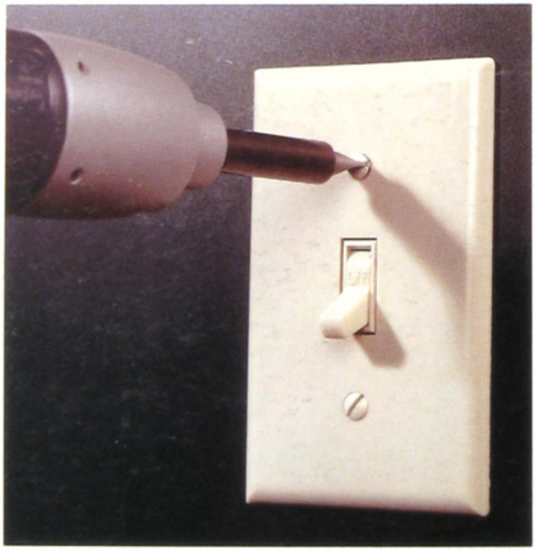

1 Turn off the power to the switch at the main service panel, then remove the switch coverplate.

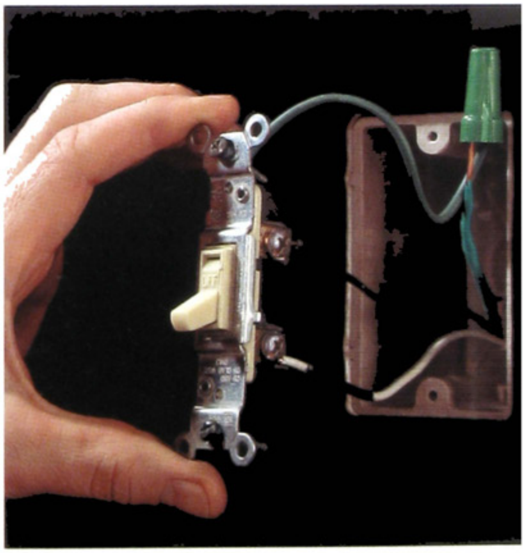

2 Remove the mounting screws holding the switch to the electrical box. Holding the mounting straps carefully, pull the switch from the box. Be careful not to touch any bare wires or screw terminals until the switch has been tested for power.

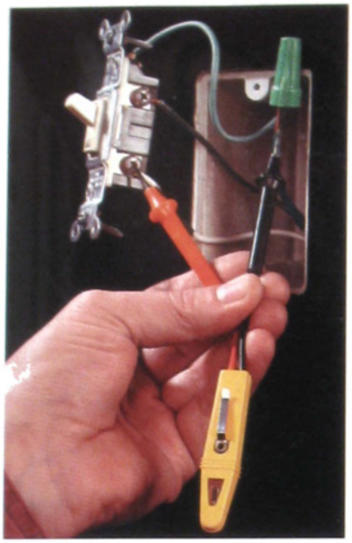

3 uching on
test

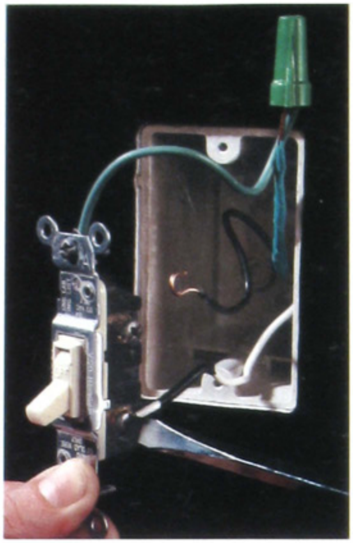

4 Disconnect
and remov
the switch for
and buy a repl
swi faulty
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igtail

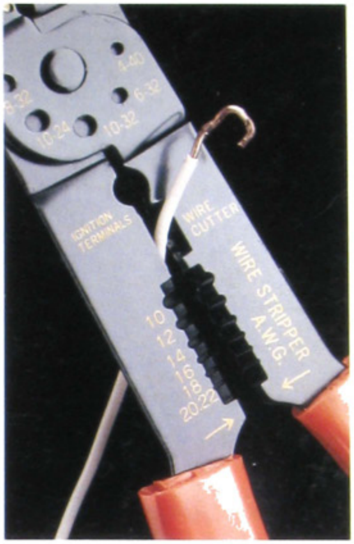
8-32
4-40
6-32
10-24
10-32
IGNITION TERMINALS
WIRE CUTTER
WIRE STRIPPER A.W.G.
10
12
14
16
18
20-22

5

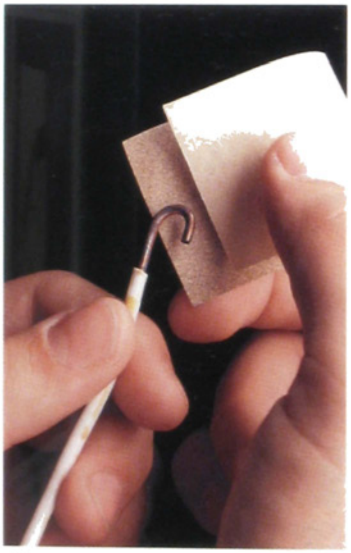

6 copper
it the
necting the wires

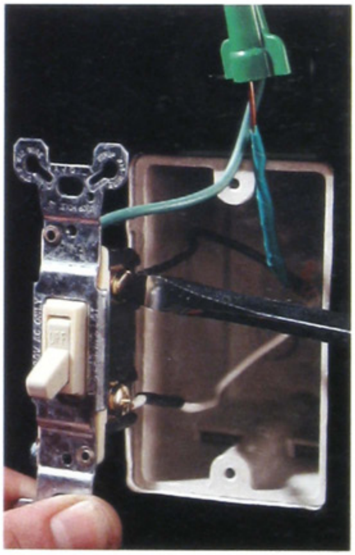

7 Connect the wires to the screw terminals on the switch. Tighten the screws firmly, but do not overtighten. Overtightening may strip the screw threads.

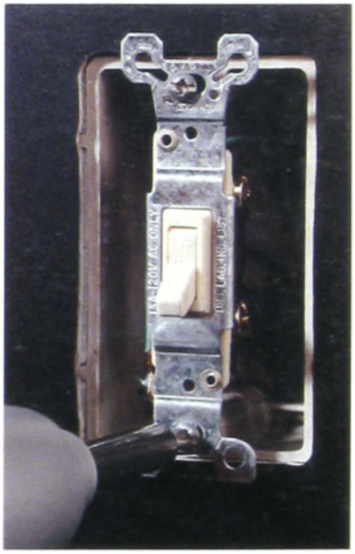

8 Remount the switch, carefully tucking the wires inside the box. Reattach the switch coverplate, and turn on the power to the switch at the main service panel.

How to Fix or Replace a Three-way Wall Switch

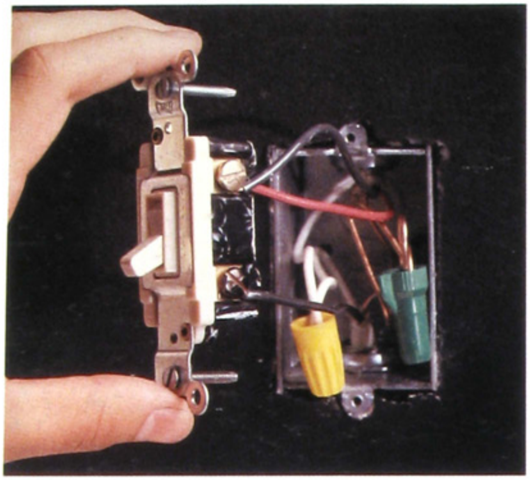

1 Turn off the power to the switch at the main servi panel then remove the switch coverplate and mounting screws Holding the mounting strap carefully pull the switch from the box Be careful not to touch the bare wires or screw terminals until they have been tested for power

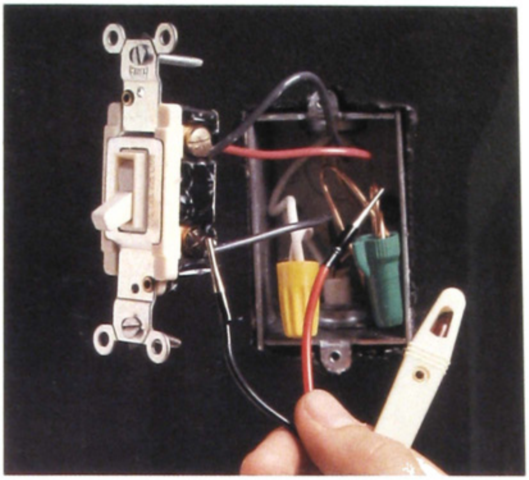

2 Test for power by touching one probe of the neon circuit tester to the grounded metal box or to the bare copper grounding wire and touching the other probe to each screw terminal Tester should not glow If it does there is still power entering the box Return to the service panel and turn off the correct circuit

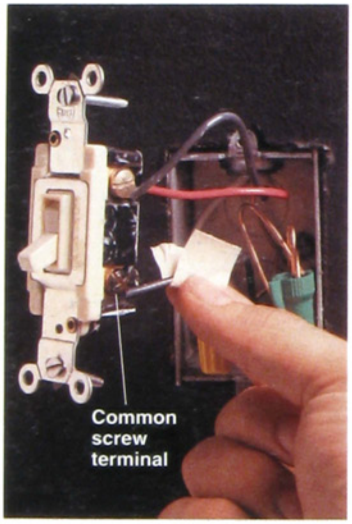

3 Locate dark common screw terminal, and use masking tape to label the "common wire attached to it Disconnect wires and remove switch Test switch for continuity (page 53) If it tests faulty,buy a replacement Inspect wires for nicks and scratches If necessary clip damaged wires and strip them (page 23).

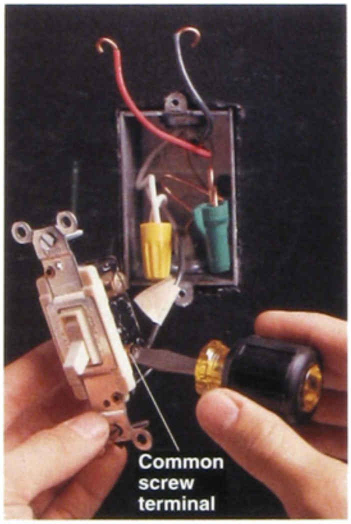

4 Connect the common wire to the dark common screw terminal on the switch On most three-way switches the common screw terminal is copper Or it may be labeled with the word COMMON stamped on the back of the switch If the switch has a grounding screw connect it to the circuit grounding wires with a pigtail.

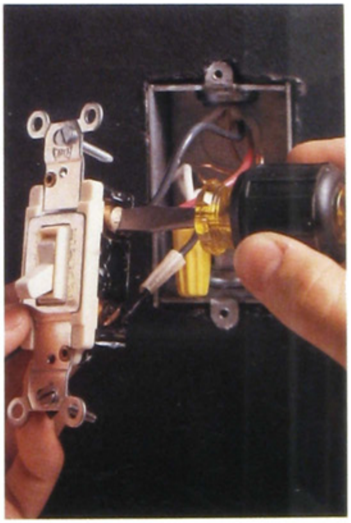

5 Connect the remaining two circuit wires to the screw terminal These wires are interchangeable and can be connected to either screw terminal Carefully tuck the wires into the box Remount the switch, and attach the coverplat Turn on the power at the main service panel.

How to Fix or Replace a Four-way Wall Switch

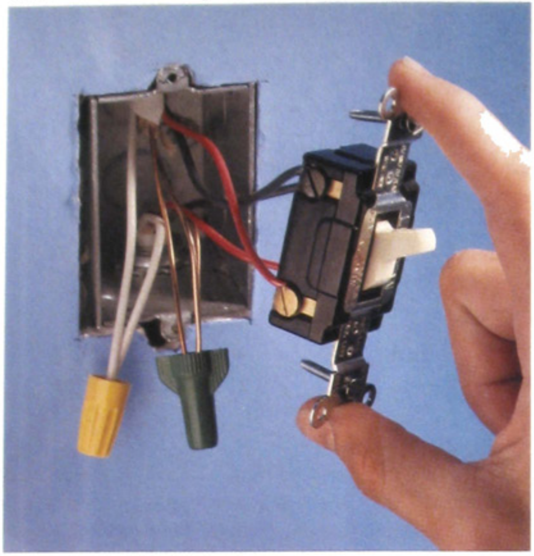

1 Turn off the power to the switch at the main service panel, then remove the switch coverplate and mounting screws. Holding the mounting strap carefully, pull the switch from the box. Be careful not to touch any bare wires or screw terminals until they have been tested for power.

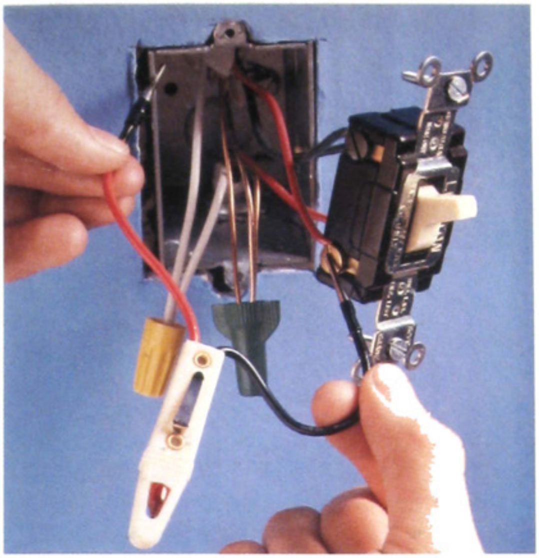

2 Test for power by touching one probe of the neon circuit tester to the grounded metal box or bare copper grounding wire, and touching the other probe to each of the screw terminals. Tester should not glow. If it does, there is still power entering the box. Return to the service panel, and turn off the correct circuit.

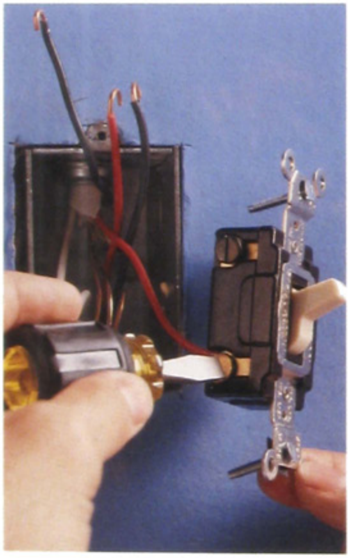

3 Disconnect the wires and inspect them for nicks and scratches. If necessary, clip damaged wires and strip them (page 23). Test the switch for continuity (page 53). Buy a replacement if the switch tests faulty.

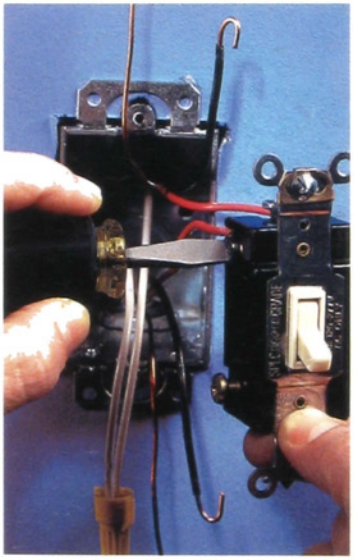

4 Connect two wires from one incoming cable to the top set of screw terminals.

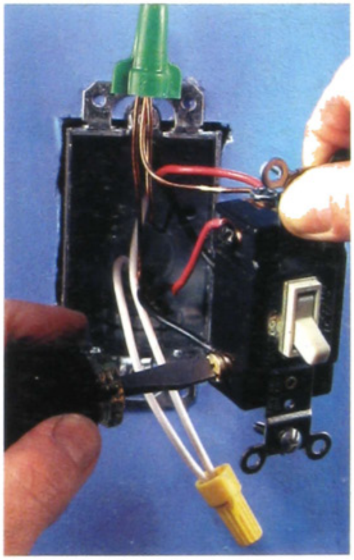

5 Attach remaining wires to the other set of screw terminals. Pigtail the grounding wires to the grounding screw. Carefully tuck the wires inside the switch box, then remount the switch and coverplate. Turn on power at main service panel.

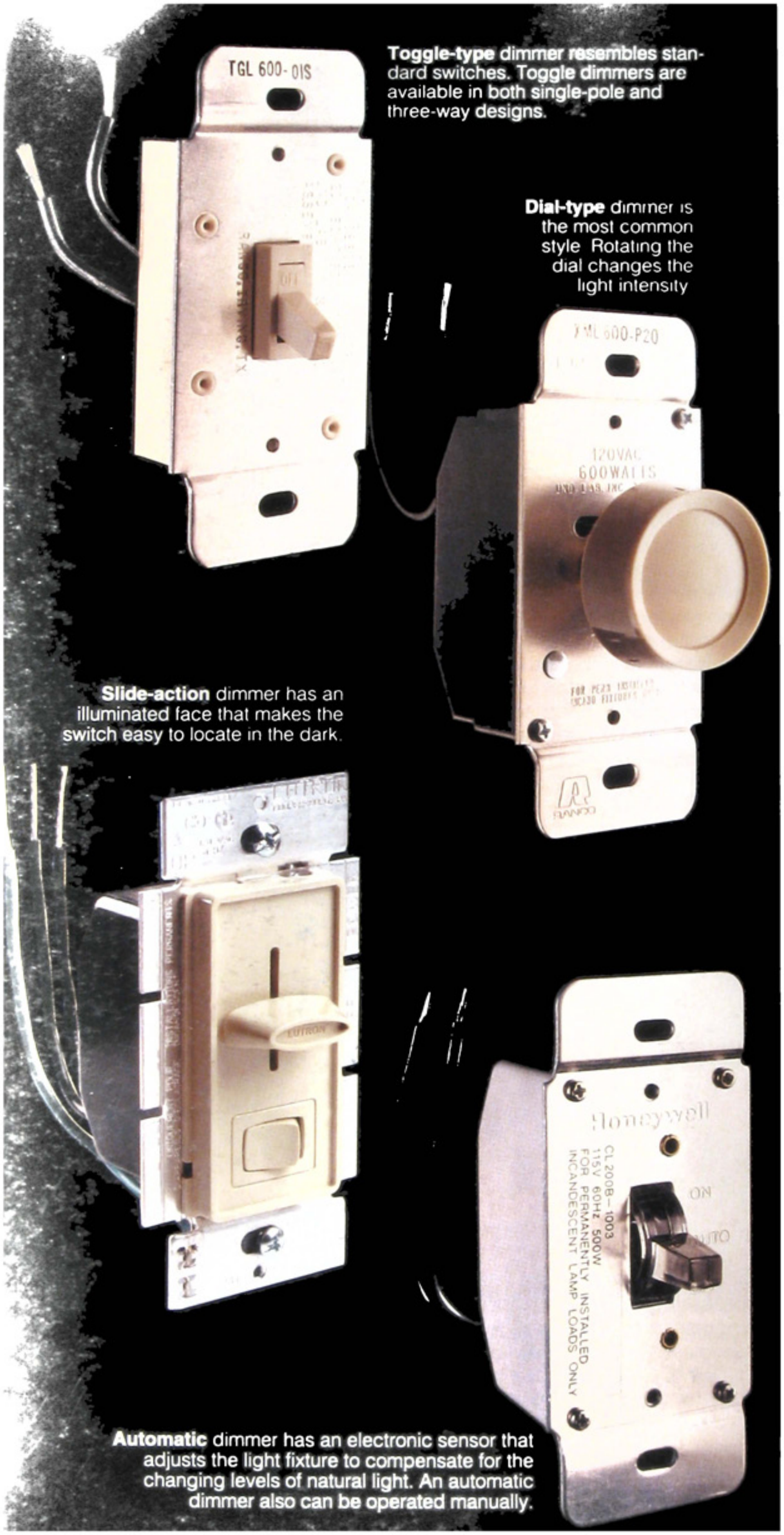

Toggle-type dimmer resembles standard switches. Toggle dimmers are available in both single-pole and three-way designs.

Dial-type dimmer is the most common style Rotating the dial changes the light intensity

Slide-action dimmer has an illuminated face that makes the switch easy to locate in the dark.

Automatic dimmer has an electronic sensor that adjusts the light fixture to compensate for the changing levels of natural light. An automatic dimmer also can be operated manually.

Dimmer Switches

A dimmer switch makes it possible to vary the brightness of a light fixture Dimmers are often installed in dining rooms recreation areas or bedrooms

Any standard single-pole switch can be replaced with a dimmer as long as the switch box is of adequate size Dimmer switches have larger bodies than standard switches They also generate a small amount of heat that must dissipate For these reasons dimmers should not be installed in undersized electrical boxes or in boxes that are crowded with circuit wires Always follow the manufacturer specifications for installation

In lighting configurations that use three-way switches (pages 46 to 47) one of the three-way switches can be replaced with a special three-way dimmer [illegible] is arrangement, all switches will turn the light fixture on and off but light intensity will be controlled only from the dimmer switch

Dimmer switches are available in several styles (photo left) All types have wire leads instead of screw terminals and they are connected to circuit wires using wire connectors Some types have a green grounding lead that should be connected to the grounded metal box or to the bare copper grounding wires

Everything You Need

Tools: screwdriver, neon circuit tester, needlenose pliers.

Materials: wire connectors, masking tape.

See Inspector's Notebook:

- Electrical Box Inspection (pages 128 to 129).

How to Install a Dimmer Switch

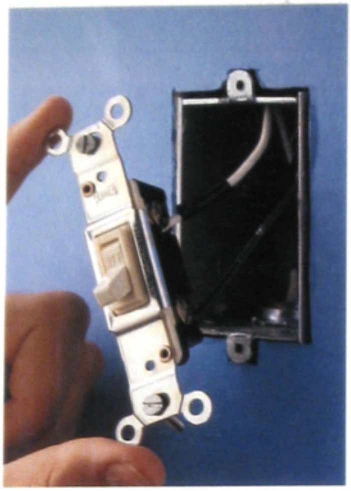

1 Turn off power to switch at the main service panel, then remove the coverplate and mounting screws. Holding the mounting straps carefully pull switch from the box. Be careful not to touch bare wires or screw terminals until they have been tested for power

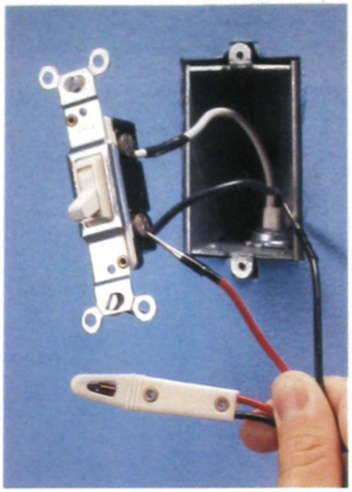

2 Test for power by touching one probe of neon circuit tester to the grounded metal box or to the bare copper grounding wires, and touching other probe to each screw terminal. Tester should not glow If it does, there is still power entering the box. Return to the service panel and turn off the correct circuit.

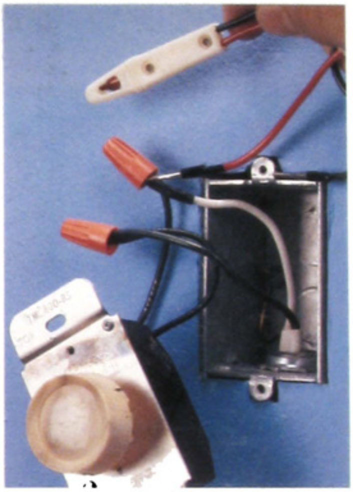

If replacing an old dimmer, test for power by touching one probe of circuit tester to the grounded metal box or bare copper grounding wires, and inserting the other probe into each wire connector Tester should not glow If it does, there is still power entering the box Return to the service panel, and turn off the correct circuit.

3 Disconnect the circuit wires and remove the switch. Straighten the circuit wires, and clip the ends, leaving about ½" of the bare wire end exposed.

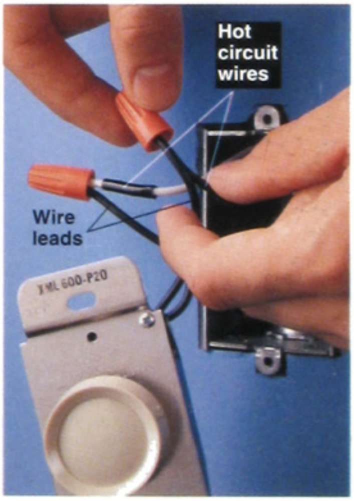

4 Connect the wire leads on the dimmer switch to the circuit wires, using wire connectors. The switch leads are interchangeable and can be attached to either of the two circuit wires.

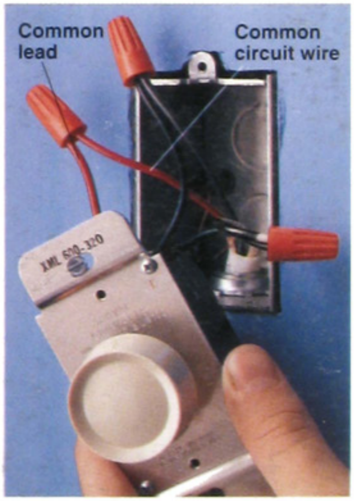

Three-way dimmer has an additional wire lead. This "common" lead is connected to the common circuit wire. When replacing a standard three-way switch with a dimmer, the common circuit wire is attached to the darkest screw terminal on the old switch (page 58).

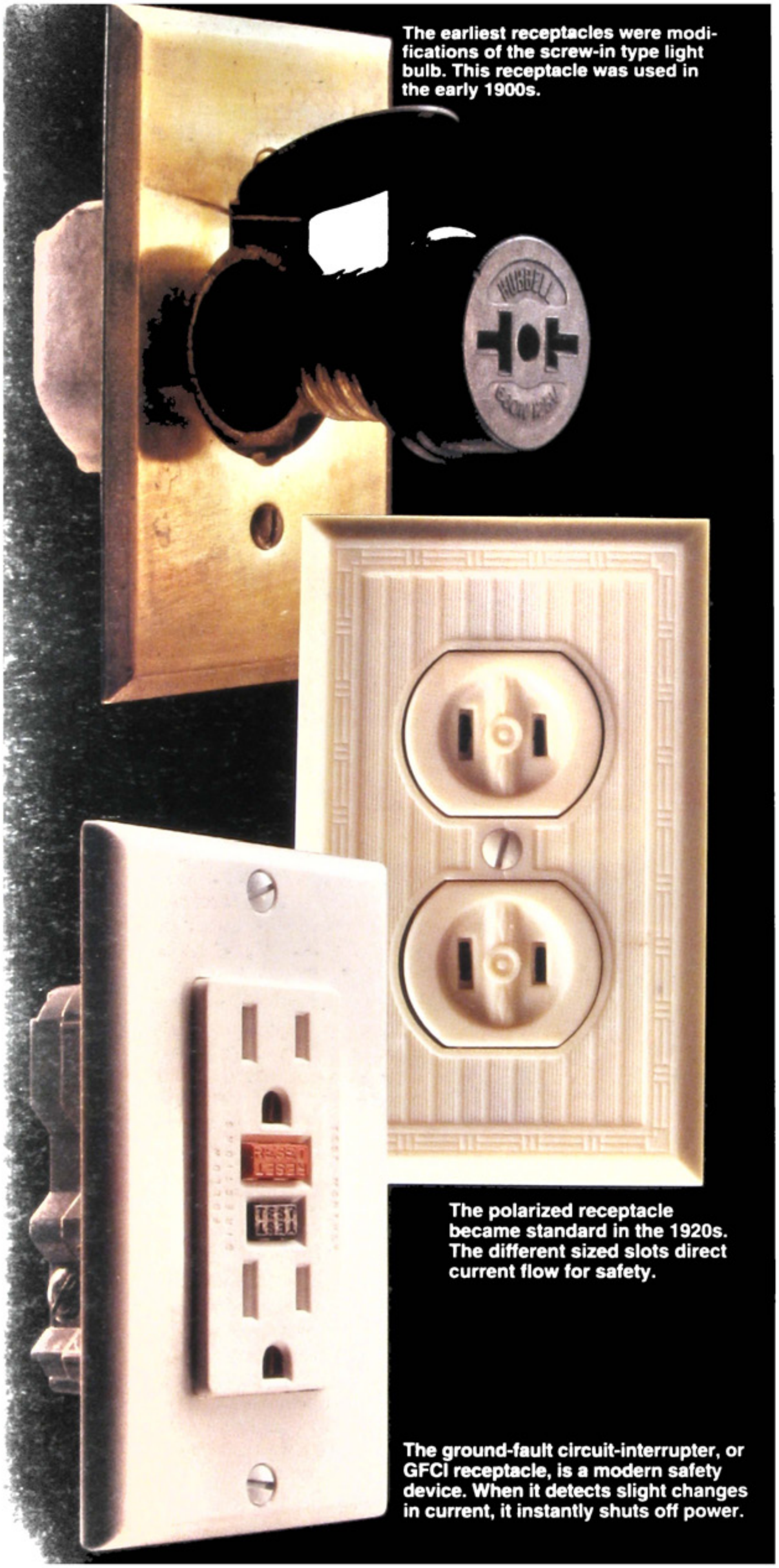

The earliest receptacles were modifications of the screw-in type light bulb. This receptacle was used in the early 1900s.

The polarized receptacle became standard in the 1920s. The different sized slots direct current flow for safety.

The ground-fault circuit-interrupter, or GFCI receptacle, is a modern safety device. When it detects slight changes in current, it instantly shuts off power.

Common Receptacle Problems

Household receptacles also called outlets have no moving parts to wear out and usually last for many years without servicing Most problems associated with receptacles are actually caused by faulty lamps and appliances or their plugs and cords However the constant plugging in and removal of appliance cords can wear out the metal contacts inside a receptacle Any receptacle that does not hold plugs firml should be replaced

A loose wire connection is another possible problem A loose connection can spark (called arcing) trip a circuit breaker or cause heat to build up in the receptacle box creating a potential fire hazard

Wires can come loose for a number of reasons Everyday vibrations caused by walking across floors or from nearby street traffic may cause a connection to shake loose In addition because wires heat and cool with normal use the ends of the wires will expand and contract slightly This movement also may cause the to come loose from the scr terminal connections

See Inspector's Notebook:

- Checking Wire Connections (pages 126 to 127).
- Electrical Box Inspection (pages 128 to 129).
- Inspecting Receptacles (pages 132 to 133).

Problem	Repair
Circuit breaker trips repeatedly, or fuse burns out immediately after being replaced.	1. Repair or replace worn or damaged lamp or appliance cord. 2. Move lamps or appliances to other circuits to prevent overloads (page 34). 3. Tighten any loose wire connections (pages 72 to 73). 4. Clean dirty or oxidized wire ends (page 72).
Lamp or appliance does not work.	1. Make sure lamp or appliance is plugged in. 2. Replace burned-out bulbs. 3. Repair or replace worn or damaged lamp or appliance cord. 4. Tighten any loose wire connections (pages 72 to 73). 5. Clean dirty or oxidized wire ends (page 72). 6. Repair or replace any faulty receptacle (pages 72 to 73).
Receptacle does not hold plugs firmly.	1. Repair or replace worn or damaged plugs (pages 96 to 97). 2. Replace faulty receptacle (pages 72 to 73).
Receptacle is warm to the touch, buzzes, or sparks when plugs are inserted or removed.	1. Move lamps or appliances to other circuits to prevent overloads (page 34). 2. Tighten any loose wire connections (pages 72 to 73). 3. Clean dirty or oxidized wire ends (page 72). 4. Replace faulty receptacle (pages 72 to 73).

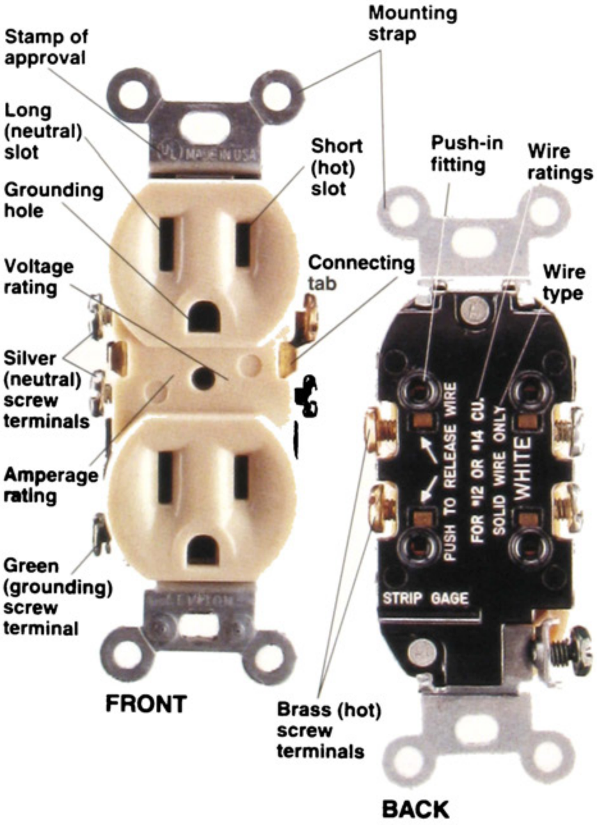
Stamp of approval
Mounting strap
Long (neutral) slot
Short (hot) slot
Push-in fitting
Wire ratings
Grounding hole
Connecting tab
Wire type
Voltage rating
Silver (neutral) screw terminals
Amperage rating
Green (grounding) screw terminal
Brass (hot) screw terminals
UL MADE IN USA
LEVITON
PUSH TO RELEASE WIRE
FOR #12 OR #14 CU. SOLID WIRE ONLY
WHITE
STRIP GAGE
FRONT
BACK

The standard duplex receptacle has two halves for receiving plugs. Each half has a long (neutral) slot, a short (hot) slot, and a U-shaped grounding hole. The slots fit the wide prong, narrow prong, and grounding prong of a three-prong plug. This ensures that the connection between receptacle and plug will be polarized and grounded for safety (page 16).

Wires are attached to the receptacle at screw terminals or push-in fittings. A connecting tab between the screw terminals allows a variety of different wiring configurations. Receptacles also include mounting straps for attaching to electrical boxes.

Stamps of approval from testing agencies are found on the front and back of the receptacle. Look for the symbol UL or UND. LAB. INC. LIST to make sure the receptacle meets the strict standards of Underwriters Laboratories.

The receptacle is marked with ratings for maximum volts and amps. The common receptacle is marked 15A, 125V Receptacles marked CU or COPPER are used with solid copper wire. Those marked CU-CLAD ONLY are used with copper-coated aluminum wire. Only receptacles marked CO/ALR may be used with solid aluminum wiring (page 22). Receptacles marked AL/CU no longer may be used with aluminum wire, according to code.

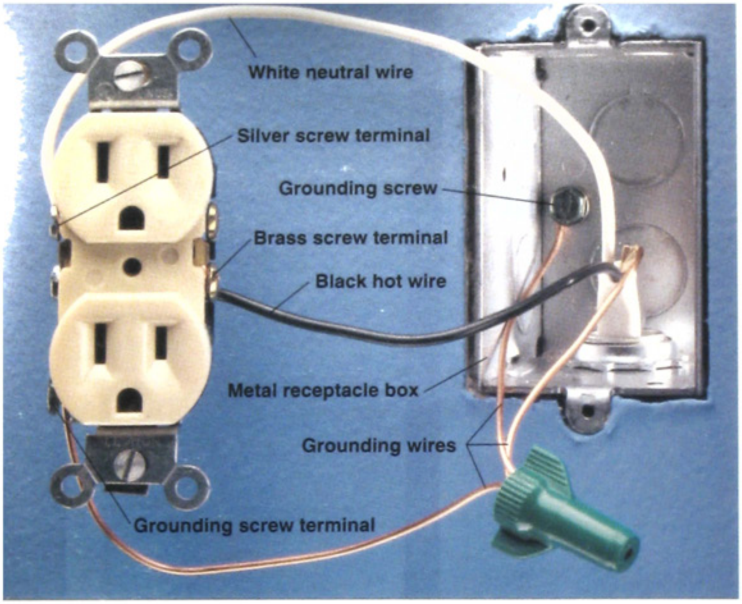
White neutral wire
Silver screw terminal
Grounding screw
Brass screw terminal
Black hot wire
Metal receptacle box
Grounding wires
Grounding screw terminal

Single cable entering the box indicates end-of-run wiring. The black hot wire is attached to a brass screw terminal, and the white neutral wire is connected to a silver screw terminal. If the box is metal, the grounding wire is pigtailed to the grounding screws of the receptacle and the box. In a plastic box, the grounding wire is attached directly to the grounding screw terminal of the receptacle.

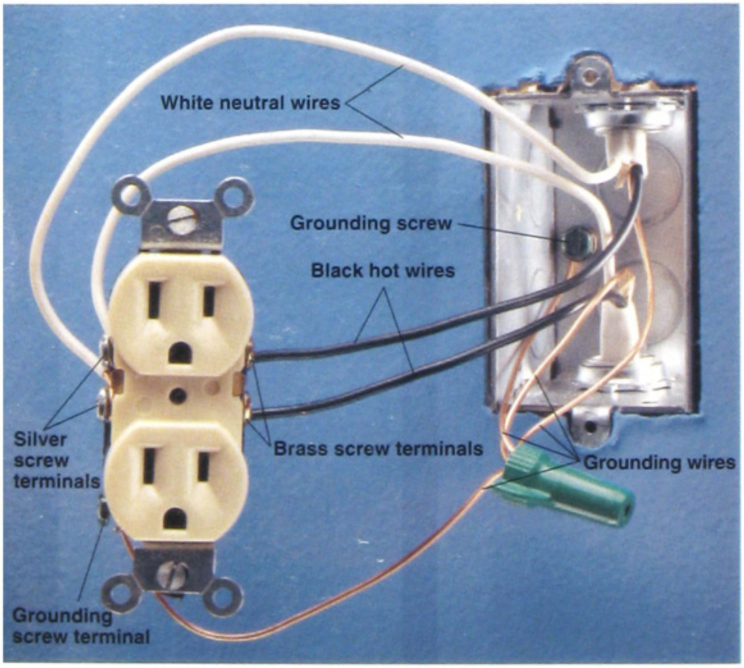
White neutral wires
Grounding screw
Black hot wires
Silver screw terminals
Brass screw terminals
Grounding wires
Grounding screw terminal

Two cables entering the box indicate middle-of-run wiring. Black hot wires are connected to brass screw terminals, and white neutral wires to silver screw terminals. The grounding wire is pigtailed to the grounding screws of the receptacle and the box.

Receptacle Wiring

A 125-volt duplex receptacle can be wired to the electrical system in a number of ways. The most common are shown on these pages.

Wiring configurations may vary slightly from these photographs, depending on the kind of receptacles used, the type of cable, or the technique of the electrician who installed the wiring. To make dependable repairs or replacements, use masking tape and label each wire according to its location on the terminals of the existing receptacle.

Receptacles are wired as either **end-of-run** or **middle-of-run.** These two basic configurations are easily identified by counting the number of cables entering the receptacle box. End-of-run wiring has only one cable, indicating that the circuit ends. Middle-of-run wiring has two cables, indicating that the circuit continues on to other receptacles, switches, or fixtures.

A split-circuit receptacle is shown on the opposite page. Each half of a split-circuit receptacle is wired to a separate circuit. This allows two appliances of high wattage to be plugged into the same receptacle without blowing a fuse or tripping a breaker. This wiring configuration is similar to a receptacle that is controlled by a wall switch. Code requires a **switch-controlled receptacle** in any room that does not have a built-in light fixture operated by a wall switch.

Split-circuit and switch-controlled receptacles are connected to two hot wires, so use caution during repairs or replacements. Make sure the connecting tab between the hot screw terminals is removed.

Two-slot receptacles are common in older homes. There is no grounding wire attached to the receptacle, but the box may be grounded with armored cable or conduit (page 20).

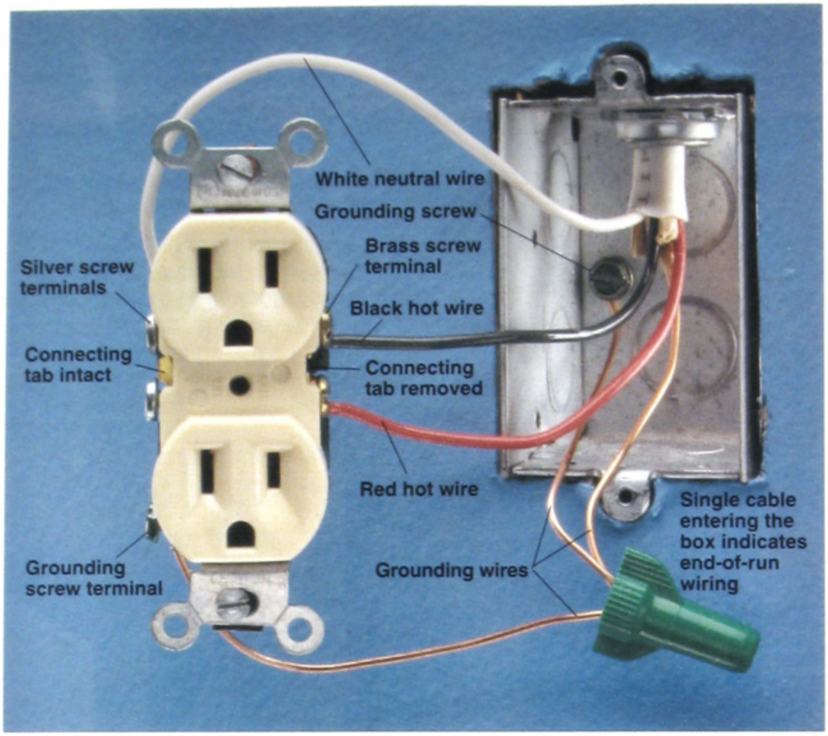
White neutral wire
Grounding screw
Brass screw terminal
Silver screw terminals
Black hot wire
Connecting tab intact
Connecting tab removed
Red hot wire
Single cable entering the box indicates end-of-run wiring
Grounding wires
Grounding screw terminal

Split-circuit receptacle is attached to a black hot wire, a red hot wire, a white neutral wire, and a bare grounding wire. The wiring is similar to a switch-controlled receptacle.

The hot wires are attached to the brass screw terminals, and the connecting tab or fin between the brass terminals is removed. The white wire is attached to a silver screw terminal, and the connecting tab on the neutral side remains intact. The grounding wire is pigtailed to the grounding screw terminal of the receptacle and to the grounding screw attached to the box.

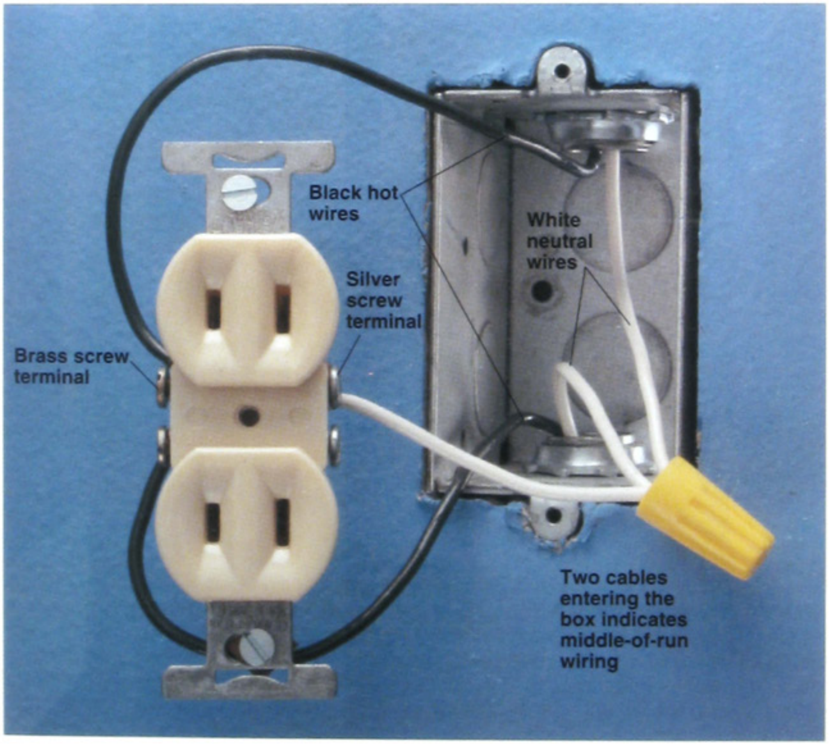
Black hot wires
White neutral wires
Silver screw terminal
Brass screw terminal
Two cables entering the box indicates middle-of-run wiring

Two-slot receptacle is often found in older homes. The black hot wires are connected to the brass screw terminals, and the white neutral wires are pigtailed to a silver screw terminal

Two-slot receptacles may be replaced with three-slot types, but only if a means of grounding exists at the receptacle box.

Basic Types of Receptacles

Several different types of receptacles are found in the typical home. Each has a unique arrangement of slots that accepts only a certain kind of plug, and each is designed for a specific job.

Household receptacles provide two types of voltage: normal and high voltage. Although voltage ratings have changed slightly over the years, normal receptacles should be rated for 110, 115, 120, or 125 volts. For purposes of replacement, these ratings are considered identical. High-voltage receptacles are rated at 220, 240, or 250 volts. These ratings are considered identical

When replacing a receptacle, check the amperage rating of the circuit at the main service panel, and buy a receptacle with the correct amperage rating (page 28).

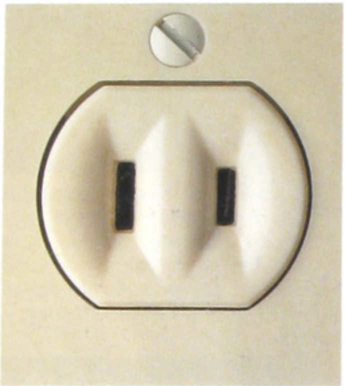

15 amps, 125 volts. Polarized two-slot receptacle is common in homes built before 1960 Slots are different sizes to accept polarized plugs.

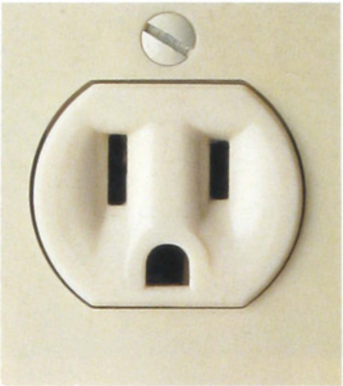

15 amps, 125 volts. Three-slot grounded receptacle has two different size slots and a U-shaped hole for grounding. It is required in all new wiring installations.

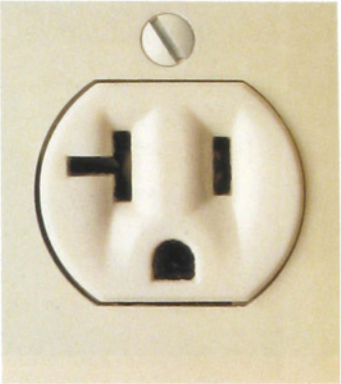

20 amps, 125 volts. This three-slot grounded receptacle features a special T-shaped slot. It is installed for use with large appliances or portable tools that require 20 amps of current.

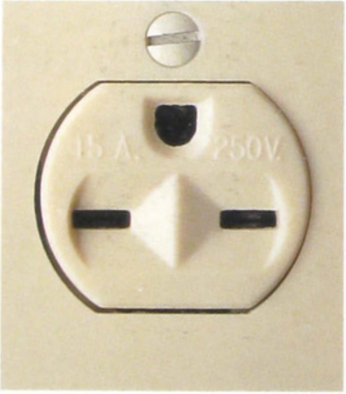

15 amps, 250 volts. This receptacle is used primarily for window air conditioners. It is available as a single unit or as half of a duplex receptacle with the other half wired for 125 volts.

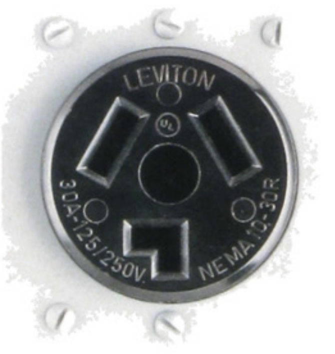

30 amps, 125/250 volts. This receptacle is used for clothes dryers. It provides high-voltage current for heating coils and 125-volt current to run lights and timers.

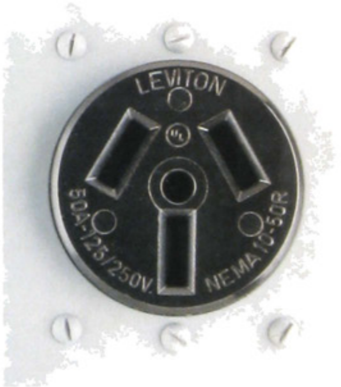

50 amps, 125/250 volts. This receptacle is used for ranges. The high-voltage current powers heating coils, and the 125-volt current runs clocks and lights.

Older Receptacles

Older receptacles may look different from more modern types, but most will stay in good working order. Follow these simple guidelines for evaluating or replacing older receptacles:

- Never replace an older receptacle with one of a different voltage or higher amperage rating.
- Any two-slot, unpolarized receptacle should be replaced with a two- or three-slot polarized receptacle.
- If no means of grounding is available at the receptacle box, install a GFCI (pages 74 to 77).
- If in doubt, seek the advice of a qualified electrician.

Never alter the prongs of a plug to fit an older receptacle. Altering the prongs may remove the grounding or polarizing features of the plug.

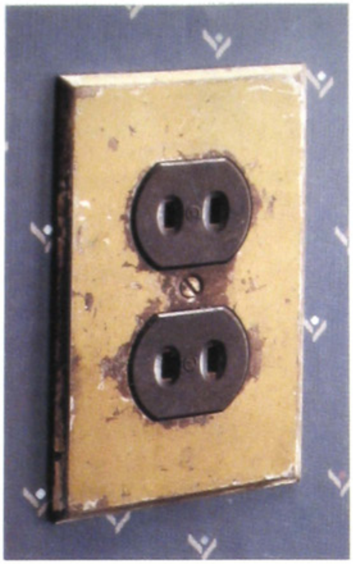

Unpolarized receptacles have slots that are the same length. Modern plug types may not fit these receptacles. Never modify the prongs of a polarized plug to fit the slots of an unpolarized receptacle

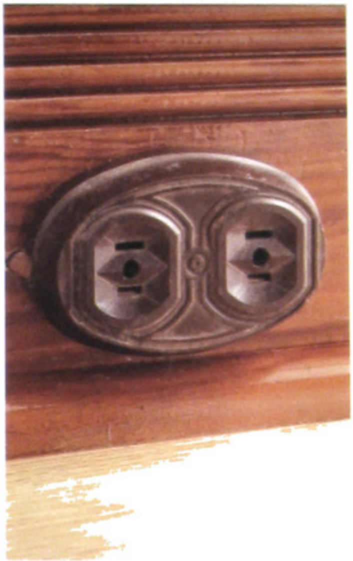

Surface-mounted receptacles were popular in the 1940s and 1950s for their ease of installation Wiring often ran in the back of hollowed-out base moldings. Surface-mounted receptacles are usually ungrounded

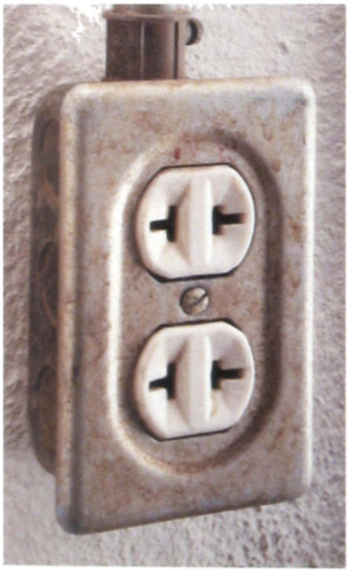

Ceramic duplex receptacles were manufactured in the 1930s. They are polarized but ungrounded, and they can be wired for either 125 volts or 250 volts.

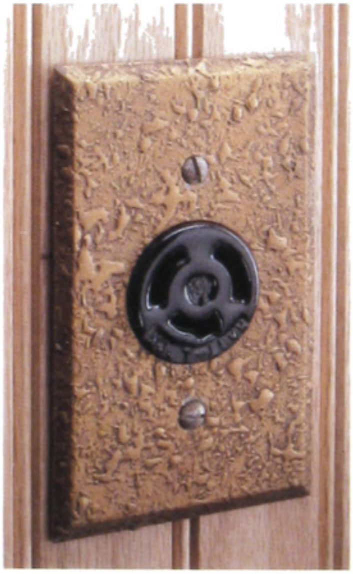

Twist-lock receptacles are designed to be used with plugs that are inserted and rotated. A small tab on the end of one of the prongs prevents the plug from being pulled from the receptacle.

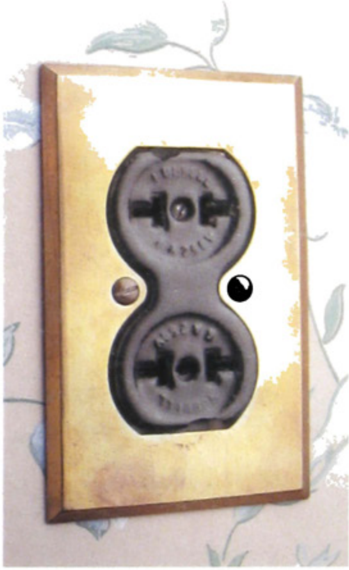

Ceramic duplex receptacle has a unique hourglass shape. The receptacle shown above is rated for 250 volts but only 5 amps, and would not be allowed by today's electrical codes.

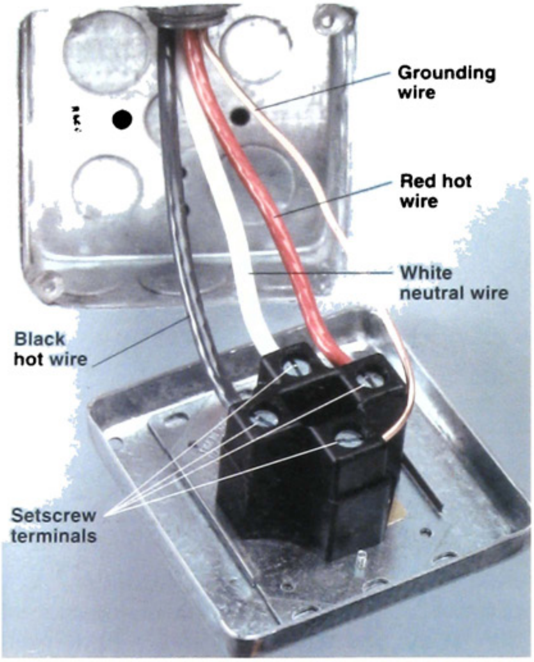
Grounding wire
Red hot wire
White neutral wire
Black hot wire
Setscrew terminals

A receptacle rated for 125/250 volts
carrying 125 vol'
copper groundi
setscre.. terminal

High-voltage Receptacles

High-voltage receptacles provide current to large appliances like clothes dryers, ranges, water heaters, and air conditioners The slot configuration of a high-voltage receptacle (page 66) will not accept a plug rated for 125 volts

A high-voltage receptacle can be wired in one of two ways In a standard high-voltage receptacle voltage is brought to the receptacle with two hot wires, each carrying a maximum of 125 volts No white neutral wire is necessary but a grounding wire should be attached to the receptacle and to the metal receptacle box Conduit can also act as a ground from the metal receptacle box back to the service panel

A clothes dryer or range also may require normal current (a maximum of 125 volts) to run lights, timers and clocks If so, a white neutral wire will be attached to the receptacle The appliance itself will split the incoming current into a 125-volt circuit and a 250-volt circuit

Repair or replace a high-voltage receptacle using the techniques shown on pages 72 to 73 It is important to identify and tag all wires on the existing receptacle so that the new receptacl will be properly wired

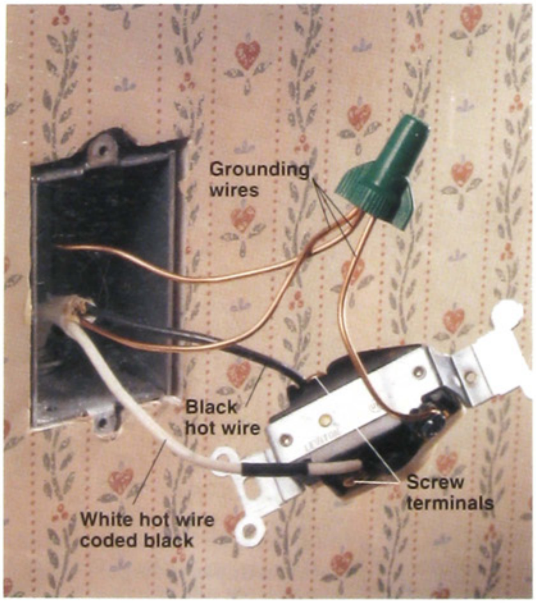
Grounding wires
Black hot wire
White hot wire coded black
Screw terminals

Standard receptacle rated for 250 volts has two incoming hot wires and no neutral wire A grounding wire is pigtailed to the receptacle and to the metal receptacle box.

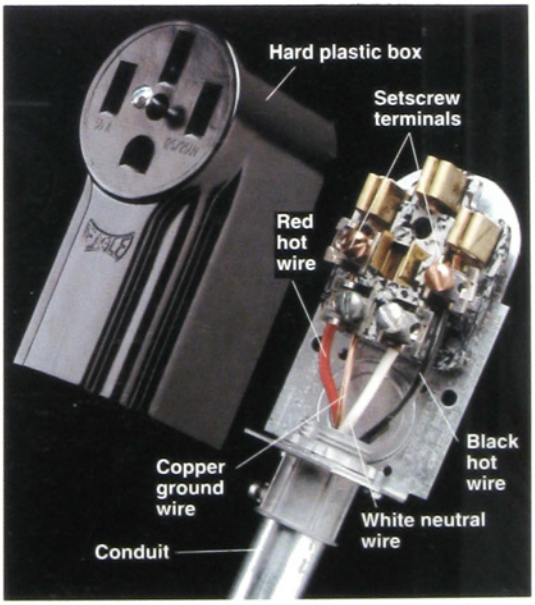
Hard plastic box
Setscrew terminals
Red hot wire
Black hot wire
Copper ground wire
White neutral wire
Conduit

Surface-mounted receptacle rated for 250 volts has a hard plastic box that can be installed on concrete or block walls Surface-mounted receptacles are often found in basements and utility rooms.

Childproof Receptacles & Other Accessories

Childproof your receptacles or adapt them for special uses by adding receptacle accessories Before installing an accessory, be sure to read the manufacturer's instructions

Homeowners with small children should add inexpensive caps or covers to guard against accidental electric shocks.

Plastic caps do not conduct electricity and are virtually impossible for small children to remove A receptacle cover attaches directly to the receptacle and fits over plugs. preventing the cords from being removed

Protect children against the possibility of electrical shock Place protective caps in any receptacles that are not being used

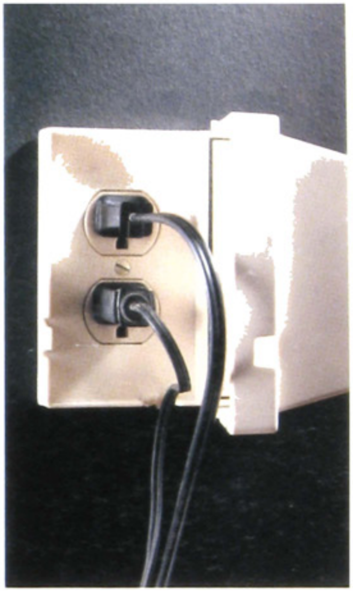

Prevent accidents by
receptacle cover to pre
and plugs from being

Install more than two plugs in a single duplex receptacle by using a multi-outlet power strip A multi-outlet strip should have a built-in circuit breaker or fuse to protect against overloads.

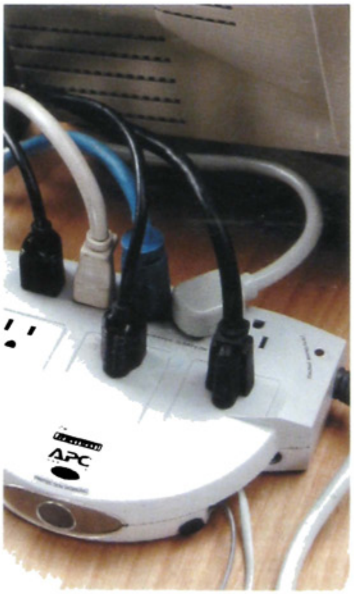

Protect electronic equipment, such as a home computer or stereo. with a surge protector The surge protector prevents any damage to sensitive wiring or circuitry caused by sudden drops or surges in power.

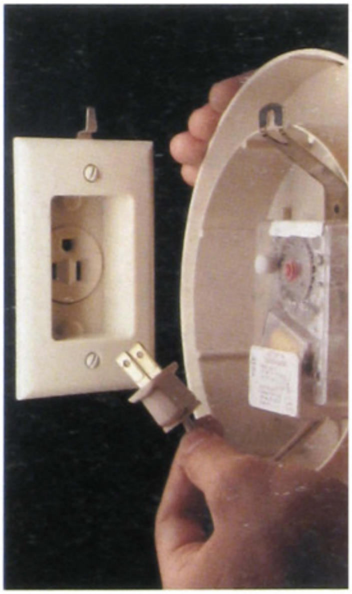

Recessed wall receptacle permits a plug-in clock to be hung flush against a wall surface

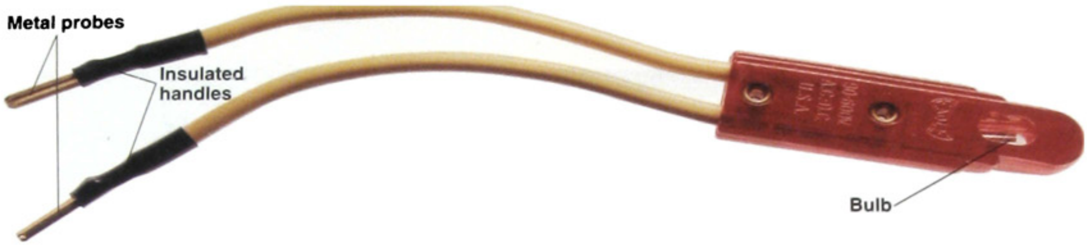

Testing Receptacles for Power, Grounding & Polarity

Test for power to make sure that live voltage is not reaching the receptacle during a repair or replacement project.

Test for grounding to plan receptacle replacements. The test for grounding will indicate how an existing receptacle is wired and whether a replacement receptacle should be a two-slot polarized receptacle, a grounded three-slot receptacle, or a GFCI

If the test indicates that the hot and neutral wires are reversed (page 133), make sure the wires are installed correctly on the replacement receptacle.

Test for hot wires if you need to confirm which wire is carrying live voltage

An inexpensive neon circuit tester makes it easy to perform these tests. It has a small bulb that glows when electrical power flows through it.

Remember that the tester only glows when it is part of a complete circuit. For example, if you touch one probe to a hot wire and do not touch anything with the other probe, the tester will not glow, even though the hot wire is carrying power. When using the tester, take care not to touch the metal probes.

When testing for power or grounding, always confirm any negative (tester does not glow) results by removing the coverplate and examining the receptacle to make sure all wires are intact and properly connected. Do not touch any wires without first turning off the power at the main service panel.

Everything You Need

Tools: neon circuit tester, screwdriver.

How to Test a Receptacle for Power

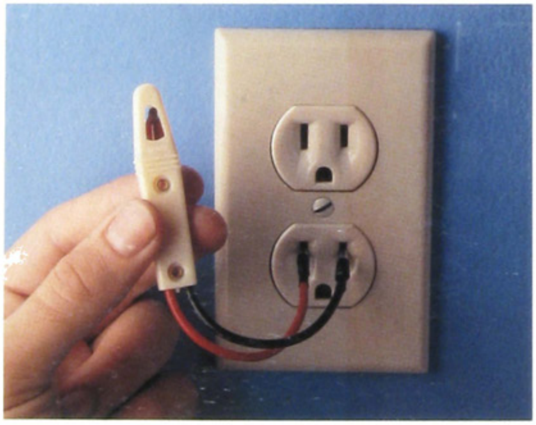

1 Turn off power at the main service panel. Place one probe of the tester in each slot of the receptacle. The tester should not glow If it does glow, the correct circuit has not been turned off at the main service panel. Test both ends of a duplex receptacle. Remember that this is a preliminary test. You must confirm that power is off by removing the coverplate and testing for power at the receptacle wires (step 2).

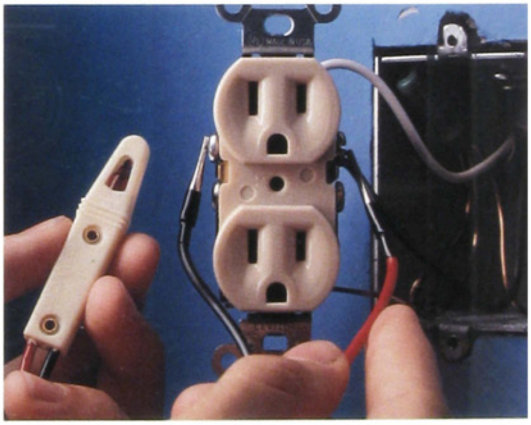

2 Remove the receptacle coverplate. Loosen the mounting screws and carefully pull the receptacle from its box. Take care not to touch any wires. Touch one probe of the neon tester to a brass screw terminal and one probe to a silver screw terminal. The tester should not glow If it does, you must shut off the correct circuit at the service panel. If wires are connected to both sets of terminals, test both sets.

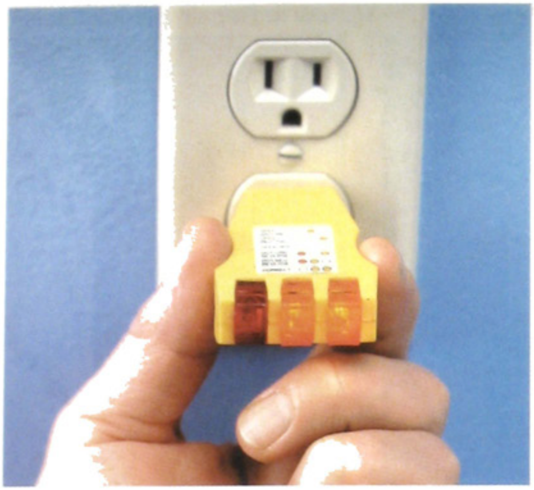

Use a plug-in tester to test a three-slot receptacle. With the power on, insert the tester into the suspect outlet. The face of the tester has three colored lights that will light up in different combinations, according to the outlet's problem. A reference chart is provided with tester, and many have a chart on the tester itself.

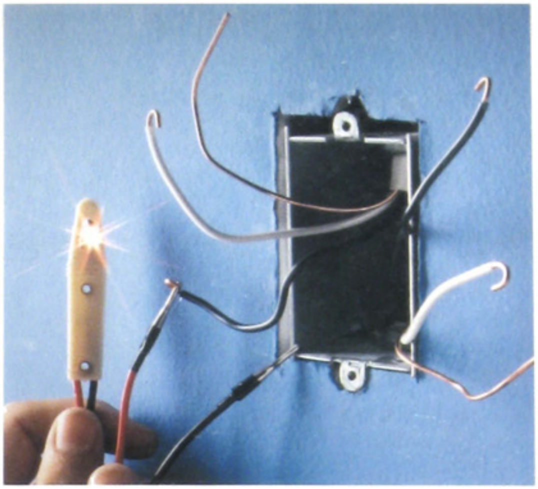

Test for hot wires. Occasionally, you may need to determine which wire is hot. With the power turned off, carefully separate all ends of wires so that they do not touch each other or anything else. Restore power to the circuit at the main service panel. Touch one probe of the neon tester to the bare grounding wire or grounded metal box, and the other probe to the ends of each of the wires. Check all wires. If the tester glows, the wire is hot. Label the hot wire for identification, and turn off power at the service panel before continuing work.

How to Test a Two-slot Receptacle for Grounding

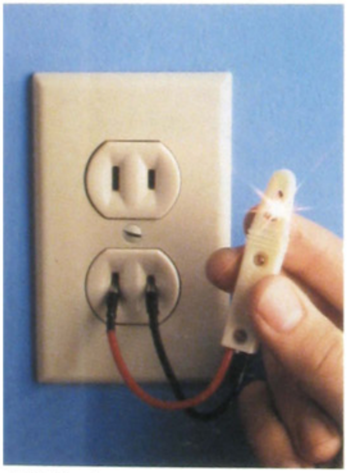

1 With the power turned on, place one probe of the neon tester in each slot. The tester should glow If it does not glow, then there is no power to the receptacle.

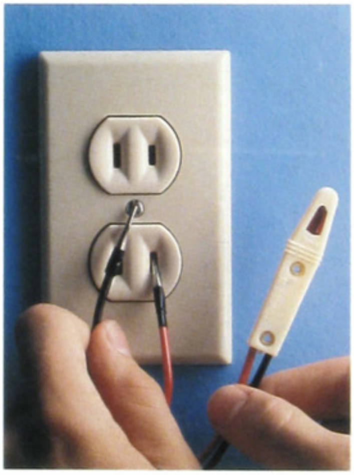

2 Place one probe of the tester in the short (hot) slot, and touch the other probe to the coverplate screw. The screw head must be free of paint, dirt, and grease. If the tester glows, the receptacle box is grounded. If it does not glow, proceed to step 3.

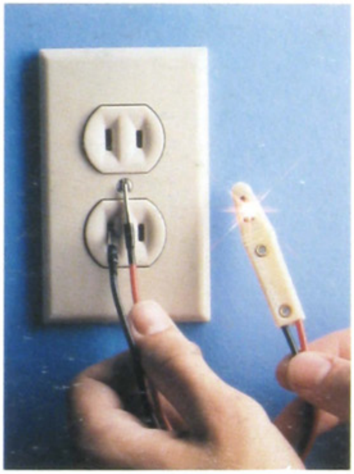

3 Place one probe of the tester in the long (neutral) slot and touch the other to the coverplate screw. If the tester glows, the receptacle box is grounded but hot and neutral wires are reversed (page 133). If tester does not glow, the box is not grounded.

Repairing & Replacing Receptacles

Receptacles are easy to repair. After shutting off power to the receptacle circuit, remove the coverplate and inspect the receptacle for any obvious problems such as a loose or broken connection, or wire ends that are dirty or oxidized. Remember that a problem at one receptacle may affect other receptacles in the same circuit. If the cause of a faulty receptacle is not readily apparent, test other receptacles in the circuit for power (page 70).

When replacing a receptacle, check the amperage rating of the circuit at the main service panel, and buy a replacement receptacle with the correct amperage rating (page 34).

When installing a new receptacle, always test for grounding (pages 70 to 71). Never install a three-slot receptacle where no grounding exists. Instead, install a two-slot polarized or GFCI receptacle.

Everything You Need

Tools: neon circuit tester, screwdriver, vacuum cleaner (if needed).

Materials: fine sandpaper, antioxidant paste, masking tape (if needed).

See Inspector's Notebook:

- Electrical Box Inspection (pages 128 to 129).
- Inspecting Switches and Receptacles (pages 132 to 133).

How to Repair a Receptacle

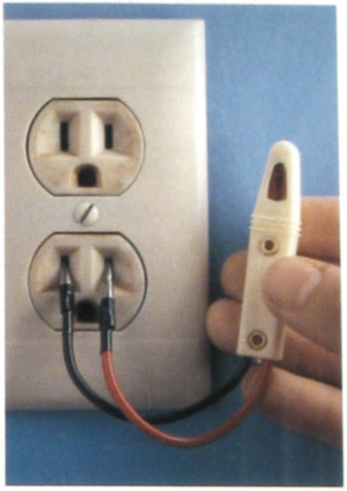

1 Turn off power at the main service panel. Test the receptacle for power with a neon circuit tester (page 70). Test both ends of a duplex receptacle. Remove the coverplate, using a screwdriver.

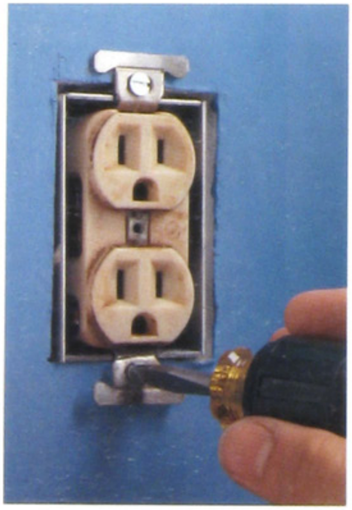

2 Remove the mounting screws that hold the receptacle to the box. Carefully pull the receptacle from the box. Take care not to touch any bare wires.

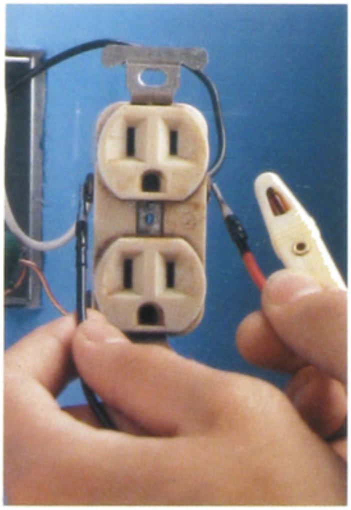

3 Confirm that the power to the receptacle is off (page 70), using a neon circuit tester. If wires are attached to both sets of screw terminals, test both sets. The tester should not glow. If it does, you must turn off the correct circuit at the service panel.

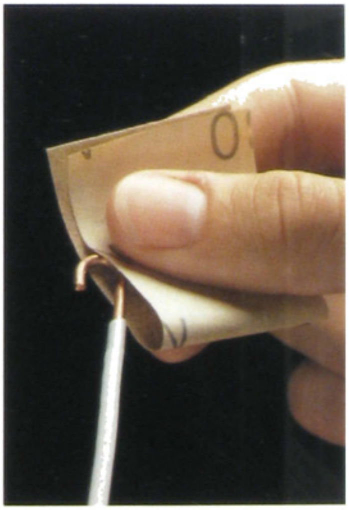

4 If the ends of the wires appear darkened or dirty, disconnect them one at a time, and clean them with fine sandpaper. If the wires are aluminum, apply an antioxidant paste before reconnecting. Antioxidant paste is available at hardware stores.

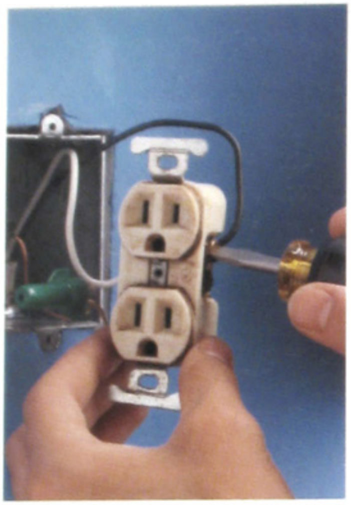

5 Tighten all connections, using a screwdriver. Take care not to overtighten and strip the screws.

6 Check the box for dirt or dust and, if necessary, clean it with a vacuum cleaner and narrow nozzle attachment.

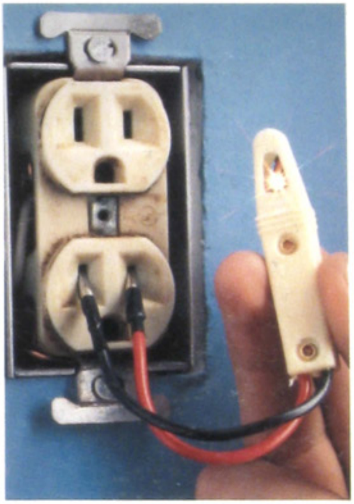

7 Reinstall the receptacle, and turn on power at the main service panel. Test the receptacle for power with a neon circuit tester. If the receptacle does not work, check other receptacles in the circuit before making a replacement.

How to Replace a Receptacle

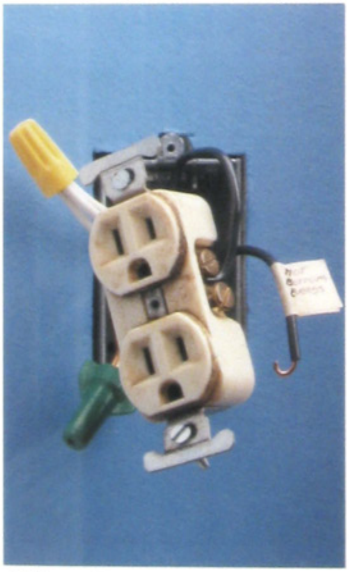

1 To replace a receptacle, repeat steps 1 to 3 on the opposite page. With the power off, label each wire for its location on the receptacle screw terminals, using masking tape and a felt-tipped pen.

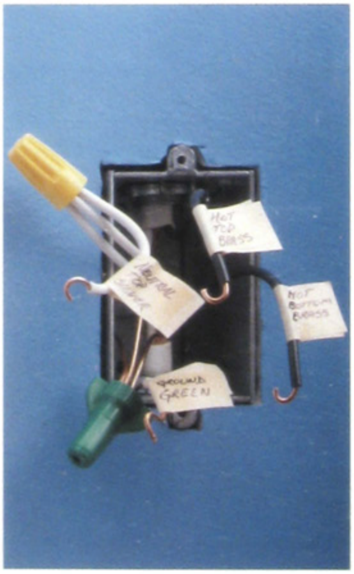

2 Disconnect all wires and remove the receptacle.

3 Replace the receptacle with one rated for the correct amperage and voltage (page 28). Replace coverplate, and turn on power. Test receptacle with a neon circuit tester (pages 70 to 71).

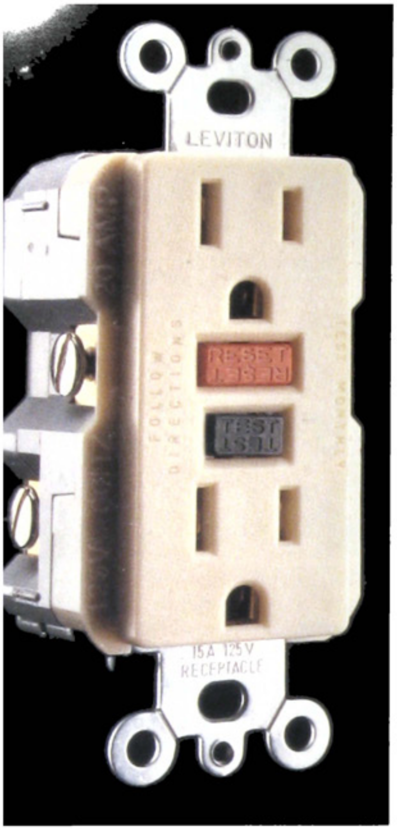
LEVITON
RESET
TEST
FOLLOW DIRECTIONS
15A 125V
RECEPTACLE

GFCI Receptacles

The ground-fault circuit-interrupter (GFCI) receptacle protects against electrical shock caused by a faulty appliance, or a worn cord or plug It senses small changes in current flow and can shut off power in as little as of a second

GFCIs are now required in bathrooms, kitchens, garages, crawl spaces, unfinished basements, and outdoor receptacle locations Consult your local codes for any requirements regarding the installation of GFCI receptacles Most GFCIs use standard screw terminal connections, but some have wire leads and are attached with wire connectors. Because the body of a GFCI receptacle is larger than a standard receptacle, small crowded electrical boxes may need to be replaced with more spacious boxes (pages 40 to 41)

The GFCI receptacle may be wired to protect only itself (single location), or it can be wired to protect all receptacles, switches, and light fixtures from the GFCI "forward" to the end of the circuit (multiple locations)

Because the GFCI is so sensitive it is most effective when wired to protect a single location The more receptacles any one GFCI protects, the more susceptible it is to "phantom tripping, shutting off power because of tiny normal fluctuations in current flow

Everything You Need

Tools: neon circuit tester, screwdriver.

Materials: wire connectors, masking tape.

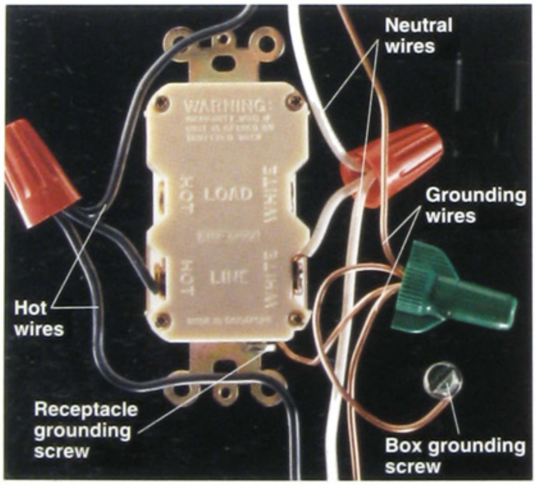
Neutral wires
Grounding wires
Hot wires
Receptacle grounding screw
Box grounding screw
WARNING
HOT
LOAD
WHITE
LINE

A GFCI wired for single-location protection (shown from the back) has hot and neutral wires connected only to the screw terminals marked LINE A GFCI connected for single-location protection may be wired as either an end-of-run or middle-of-run configuration (page 64).

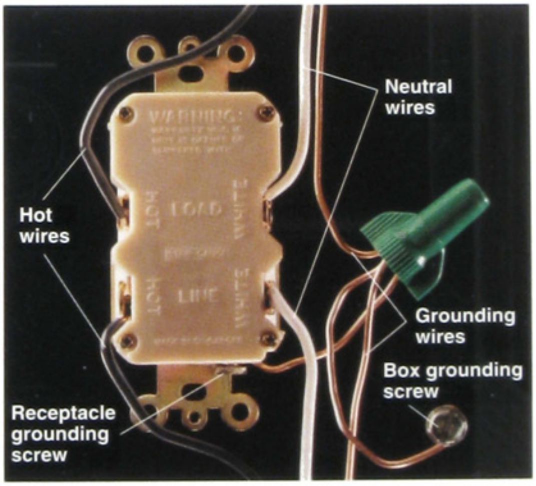
Neutral wires
Hot wires
Grounding wires
Box grounding screw
Receptacle grounding screw
WARNING
HOT
LOAD
WHITE
LINE

A GFCI wired for multiple-location protection (shown from the back) has one set of hot and neutral wires connected to the LINE pair of screw terminals and the other set connected to the LOAD pair of screw terminals A GFCI receptacle connected for multiple-location protection may be wired only as a middle-of-run configuration.

How to Install a GFCI for Single-location Protection

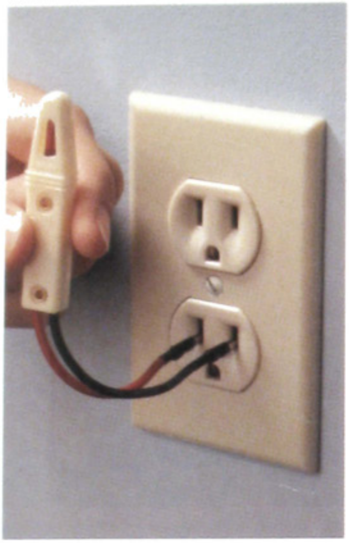

1 Shut off power to the receptacle at the main service panel. Test for power with a neon circuit tester (page 70). Be sure to check both halves of the receptacle.

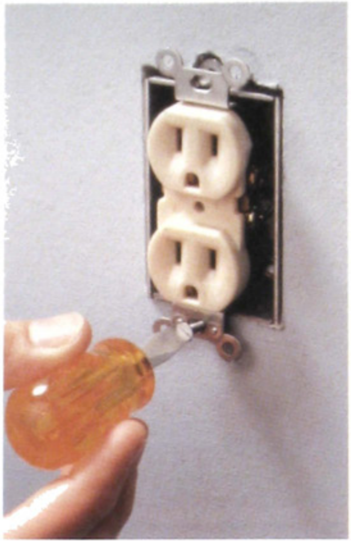

2 Remove coverplate. Loosen mounting screws, and gently pull receptacle from the box. Do not touch wires. Confirm power is off with a circuit tester (page 70).

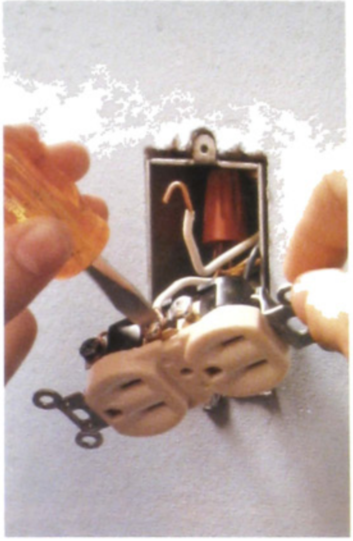

3 Disconnect all white neutral wires from the silver screw terminals of the old receptacle.

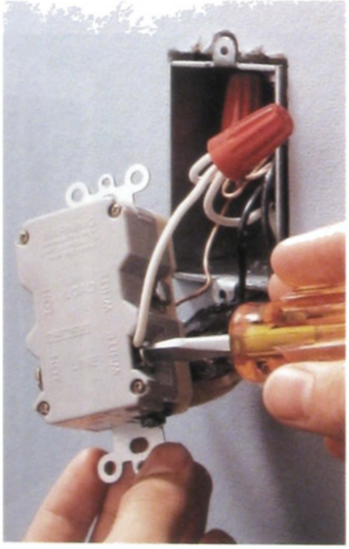

4 Pigtail all the white neutral wires together, and connect the pigtail to the terminal marked WHITE LINE on the GFCI (see photo on opposite page).

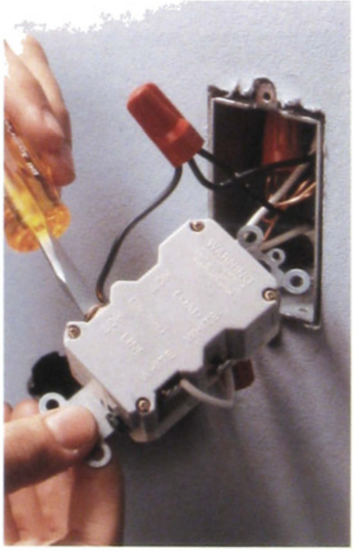

5 Disconnect all black hot wires from the brass screw terminals of the old receptacle. Pigtail these wires together, and connect them to the terminal marked HOT LINE on the GFCI.

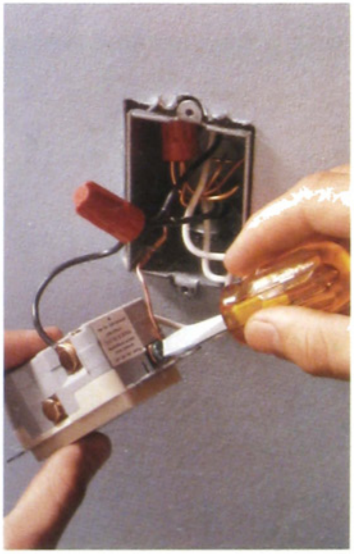

6 If a grounding wire is available, connect it to the green grounding screw terminal of the GFCI. Mount the GFCI in the receptacle box, and reattach the coverplate. Restore power, and test the GFCI according to the manufacturer's instructions.

How to Install a GFCI for Multiple-location Protection

GFCI
recept circuit #1
light fixture circuit #1
KITCHEN
recept circuit #1 GFCI protected
recept circuit #1 GFCI protected

1 Use a map of your house circuits (pages 30 to 33) to determine a location for your GFCI. Indicate all receptacles that will be protected by the GFCI installation.

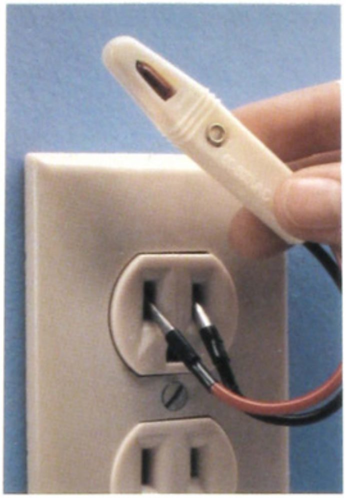

2 Turn off power to the correct circuit at the main service panel. Test all the receptacles in the circuit with a neon circuit tester to make sure the power is off. Always check both halves of each duplex receptacle.

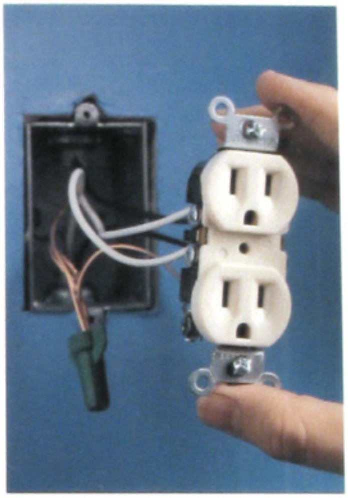

3 Remove the coverplate from the receptacle that will be replaced with the GFCI. Loosen the mounting screws and gently pull the receptacle from its box. Take care not to touch any bare wires. Confirm the power is off with a neon circuit tester (page 70).

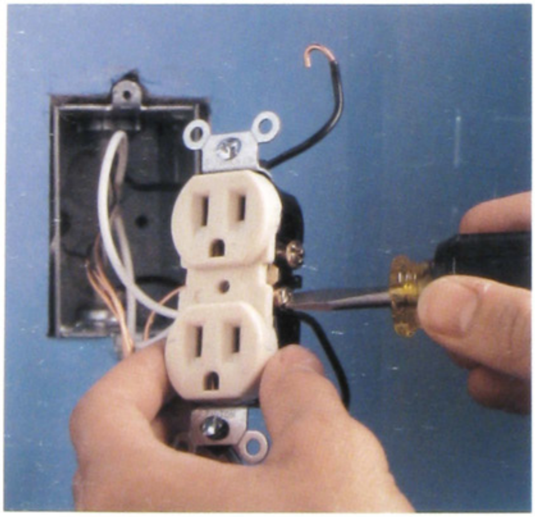

4 Disconnect all black hot wires. Carefully separate the hot wires and position them so that the bare ends do not touch anything. Restore power to the circuit at the main service panel. Determine which black wire is the "feed" wire by testing for hot wires (page 71). The feed wire brings power to the receptacle from the service panel. Use caution: This is a "live" wire test, during which the power is turned on temporarily.

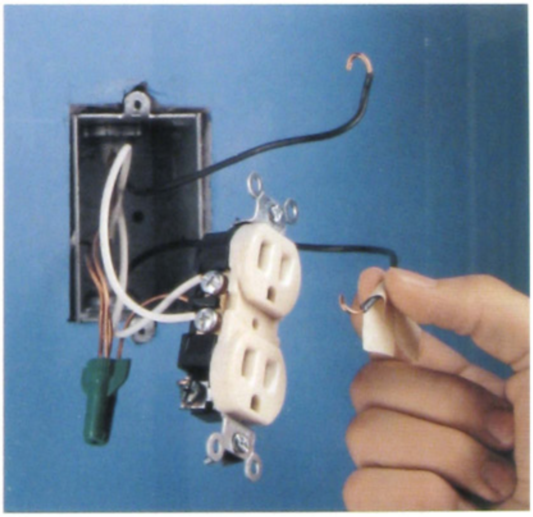

5 When you have found the hot feed wire, turn off power at the main service panel. Identify the feed wire by marking it with masking tape.

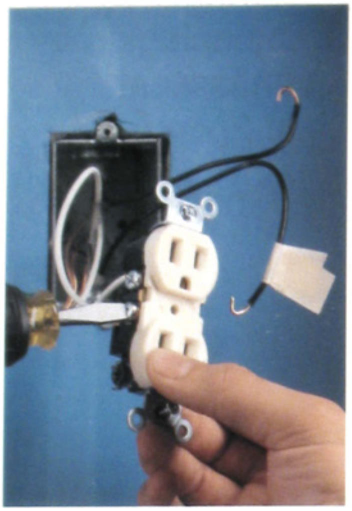

6 Disconnect the white neutral wires from the old receptacle. Identify the white feed wire and label it with masking tape. The white feed wire will be the one that shares the same cable as the black feed wire.

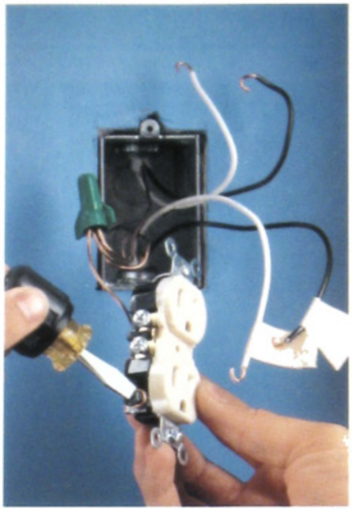

7 Disconnect the grounding wire from the grounding screw terminal of the old receptacle. Remove the old receptacle. Connect the grounding wire to the grounding screw terminal of the GFCI.

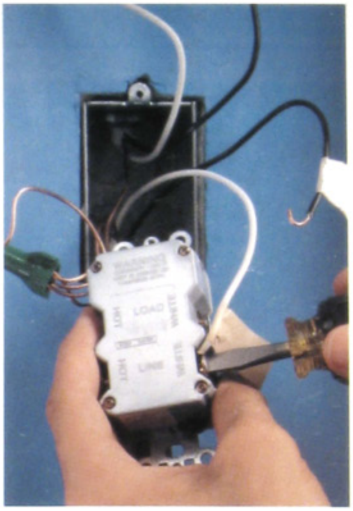

8 Connect the white feed wire to the terminal marked WHITE LINE on the GFCI Connect the black feed wire to the terminal marked HOT LINE on the GFCI

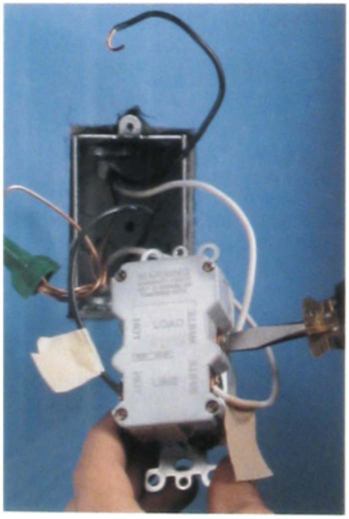

9 Connect the other white neutral wire to the terminal marked WHITE LOAD on the GFCI.

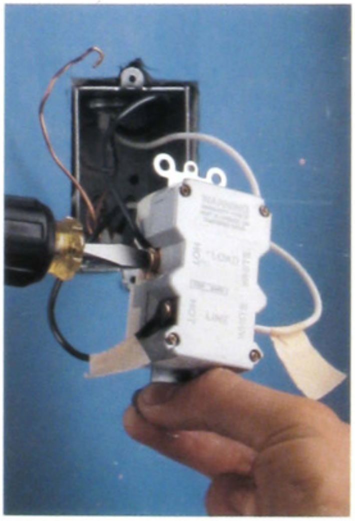

10 Connect the other black hot wire to the terminal marked HOT LOAD on the GFCI.

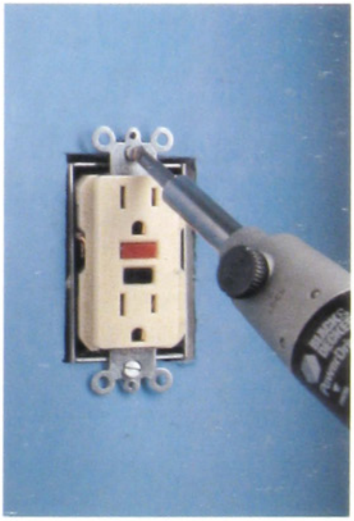

11 Carefully tuck all wires into the receptacle box. Mount the GFCI in the box and attach the coverplate. Turn on power to the circuit at the main service panel. Test the GFCI according to the manufacturer's instructions.

612:195

THE GOLDEN BOOK OF CHEMISTRY EXPERIMENTS

HOW TO SET UP A HOME LABORATORY—OVER 200 SIMPLE EXPERIMENTS

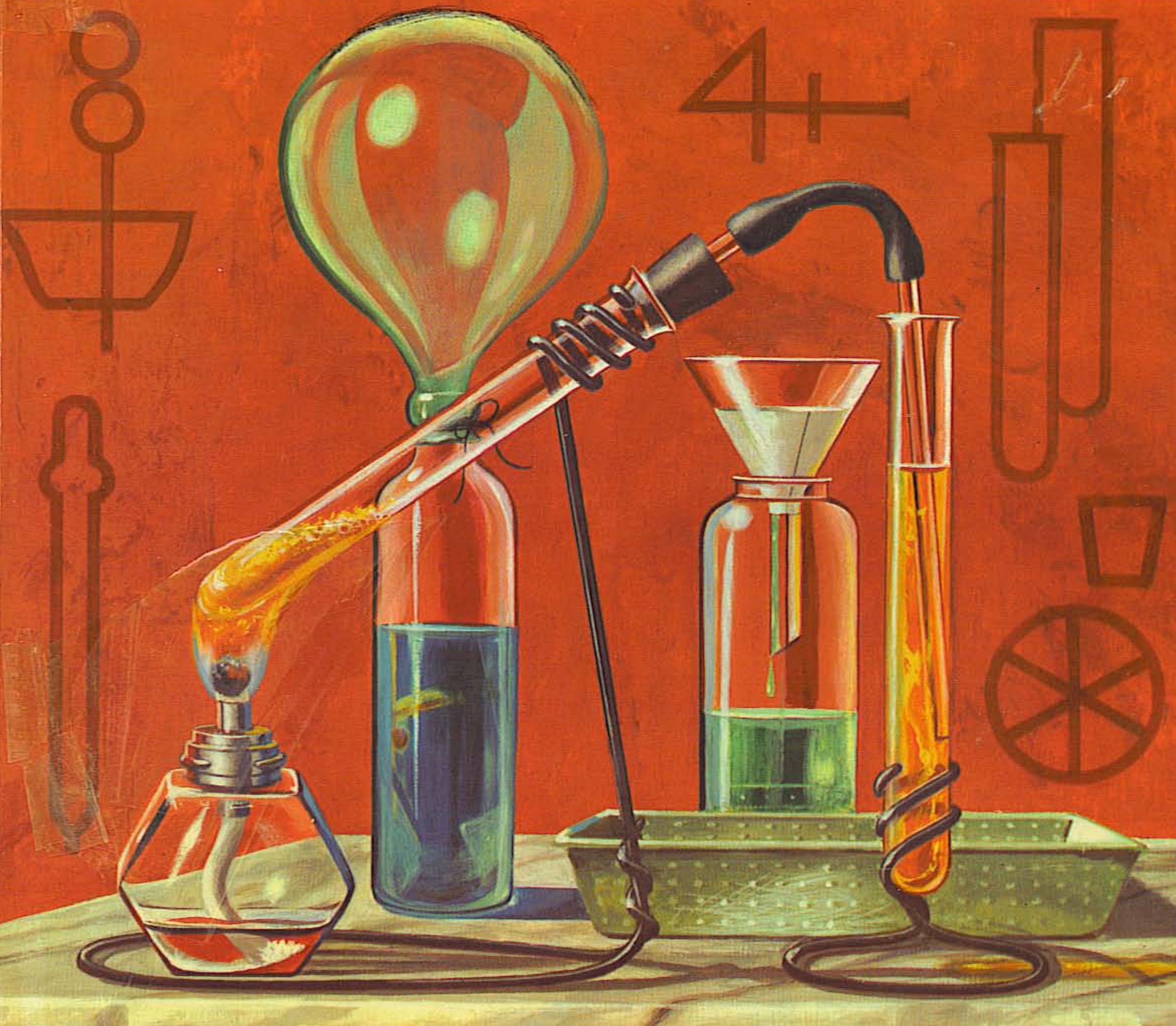

THE GOLDEN BOOK OF
Chemistry Experiments

How to Set Up a Home Laboratory—
Over 200 Simple Experiments

BY ROBERT BRENT

ILLUSTRATED BY HARRY LAZARUS

GOLDEN PRESS NEW YORK

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Words Used by Chemists

Acid: a hydrogen-containing compound that releases hydrogen ions in solution.

Alloy: a material made up by combining two or more metals.

Analysis: breaking down a compound into two or more substances.

Anhydrous: free from water.

Atom: the smallest unit of an element that can enter into the making of a chemical compound.

Atomic weight: the weight of an atom compared with the weight of an oxygen atom set at 16.

Base: a compound containing the hydroxide group (OH).

Catalyst: a substance that helps in a chemical reaction without itself being changed.

Chemical change: a change of a substance into another substance having different properties.

Chemistry: a branch of science dealing with the compositions of substances and the changes that can be made in them.

Combustion: burning; a chemical change that produces heat and light.

Compound: a substance consisting of two or more different kinds of atoms in definite proportions by weight.

Crystal: a solid in which atoms or molecules are arranged in a definite pattern.

Density: the weight of a liquid or a solid in grams per cm^3 or milliliter.

Distillate: a liquid that has been turned into vapor and again cooled into a liquid.

Distillation: the process of producing a distillate.

Ductile: capable of being drawn out into a wire.

Electrolysis: breaking down a substance by passing an electric current through it.

Electrolyte: a substance that, when in a solution or when melted, will conduct an electric current.

Element: a substance that contains only one kind of atoms.

Equation: a complete description of a chemical reaction by the use of symbols, formulas, and signs.

Evaporation: the changing of a substance into vapor; also the process of removing water by heating.

Filtrate: a liquid obtained by filtration.

Filtration: the process of straining a liquid from a solid through porous material, usually filter paper.

Formula: a group of symbols and numbers giving the composition of a compound.

Hydrate: a compound containing loosely bound water of hydration (water of crystallization) that can be driven off by heating.

Hydroxide: a compound that contains the hydroxyl (OH) radical.

Ion: an electrically charged atom or group of atoms (radical).

Malleable: capable of being hammered or rolled into a thin sheet.

Matter: anything that takes up space and has weight.

Metal: an element that is a good conductor of electricity, has luster, and whose oxide forms a base with water.

Metalloid: an element that has properties of both metals and nonmetals.

Mixture: a mingling of substances not combined chemically.

Molecular weight: the sum of the atomic weights of the atoms that make up a molecule of a compound.

Molecule: the smallest unit of a compound that can exist in the free state.

Neutralization: the reaction of an acid and a base to give a salt and water.

Nonmetal: an element that is a poor conductor of electricity, does not have luster, and whose oxide forms an acid when combined with water.

Organic chemistry: the chemistry of the carbon compounds.

Oxidation: the process by which a substance combines with oxygen.

Precipitate: an insoluble solid formed in a solution by chemical reaction.

Radical: a group of atoms that behave chemically as a single atom.

Reaction: a chemical change.

Reduction: removal of oxygen; the opposite of oxidation.

Salt: compound (other than water) formed by the reaction of an acid and a base.

Saturated solution: a solution that contains the maximum amount of solute under the conditions.

Solubility: the number of grams of a solute needed to make a saturated solution in 100 grams of solvent.

Solute: the substance dissolved in a solvent.

Solution: a non-settling mixture of a solute in a solvent.

Solvent: a liquid in which a solute is dissolved.

Sublimation: a process by which a solid is turned into vapor and again cooled into a solid without passing through a liquid stage.

Subscript: a small numeral indicating the number of atoms of a certain element in the formula of a compound.

Substance: any specific kind of matter whether element, compound, or mixture.

Symbol: a letter or two letters representing one atom of an element.

Synthesis: the making up of a compound from simpler compounds or from elements; the opposite of analysis.

Valence: the number of hydrogen atoms which one atom of an element can displace or with which it can unite.

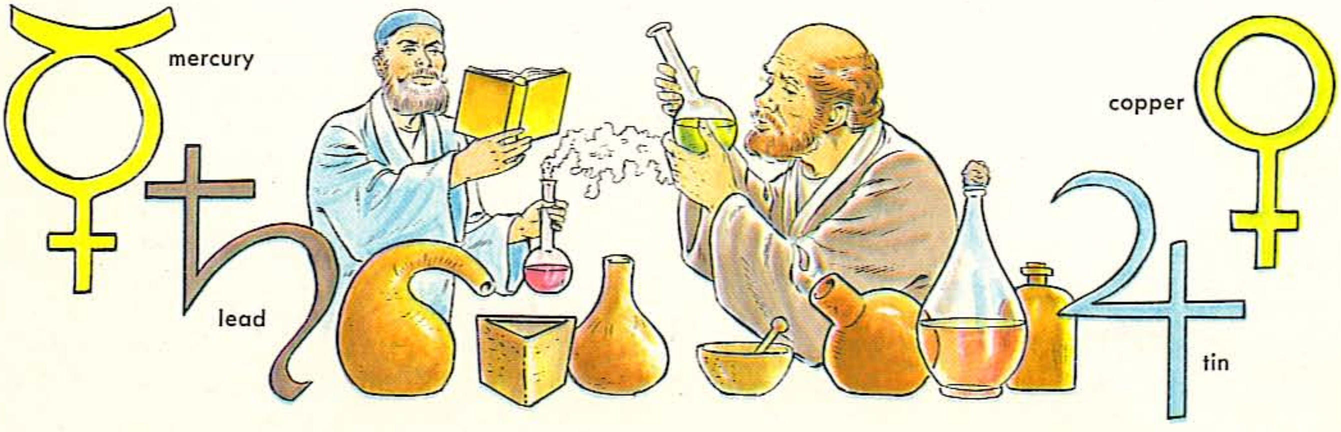

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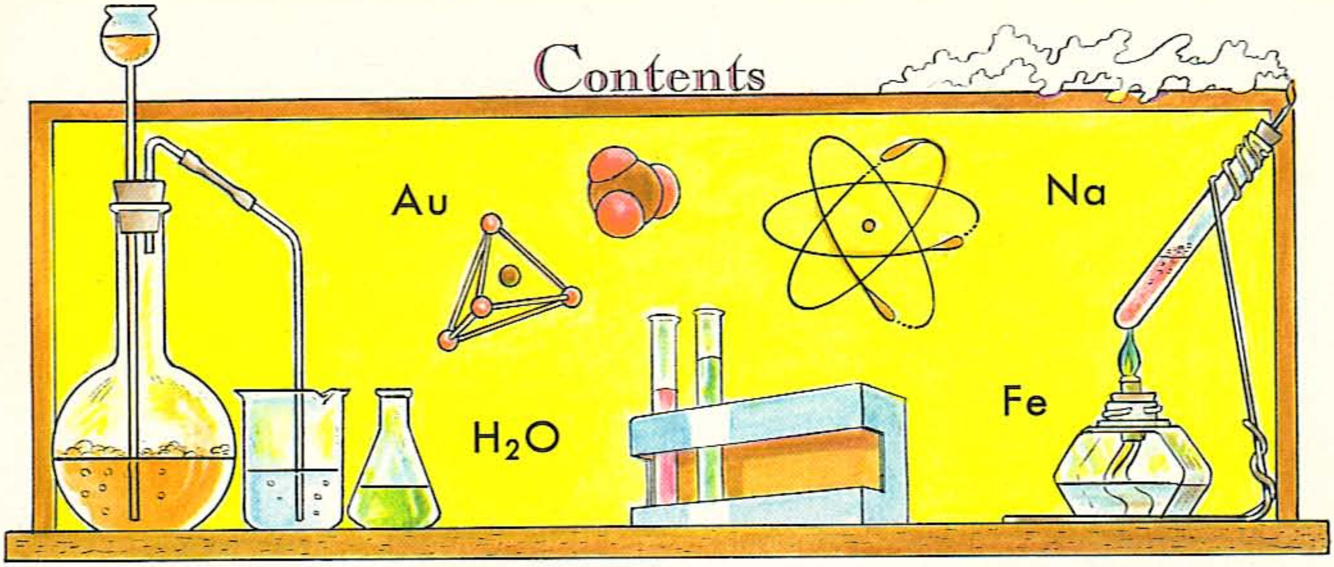

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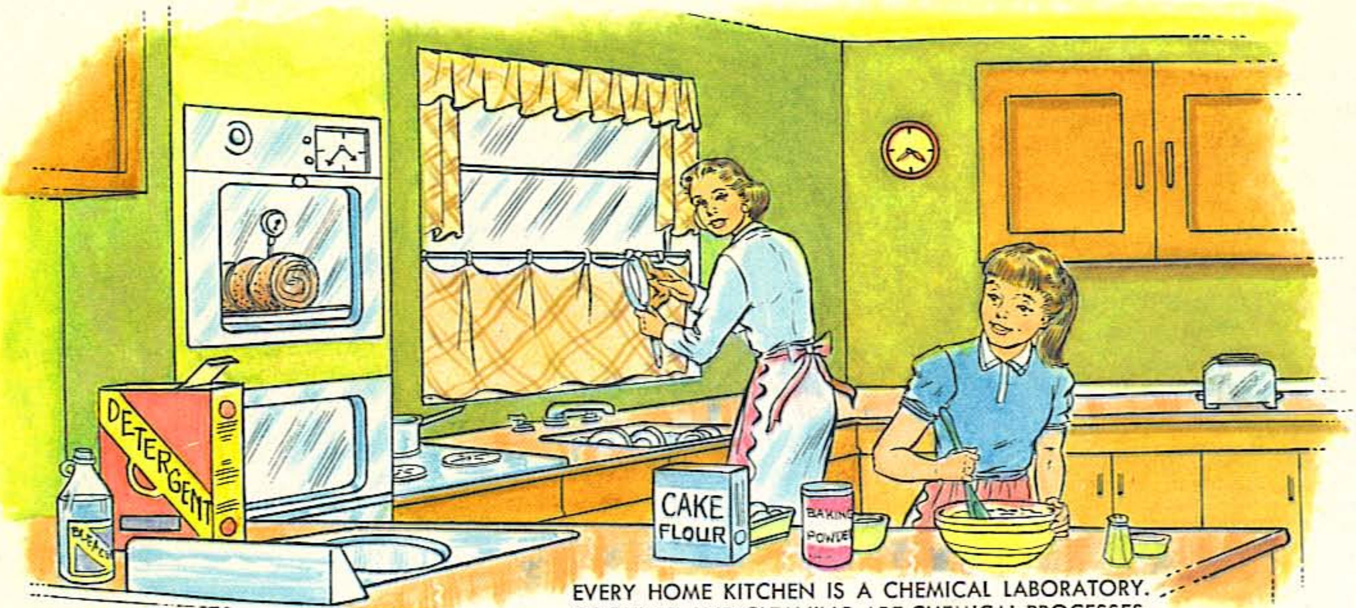

EVERY HOME KITCHEN IS A CHEMICAL LABORATORY.
COOKING AND CLEANING ARE CHEMICAL PROCESSES.

The Importance of Chemistry

THERE IS HARDLY a boy or a girl alive who is not keenly interested in finding out about things. And that's exactly what chemistry is: FINDING OUT ABOUT THINGS — finding out what things are made of and what changes they undergo.

What things? Any thing! Every thing!

Take a look around you. All the things you see — and lots of things you can't see — have to do with the science of chemistry.

Let's start with yourself. The air you breathe is a mixture of chemical substances and the process of breathing is a chemical reaction. The foods you eat are all chemical products and the ways in which your body turns them into muscles and bones and nerves and brain cells are some of the greatest of all chemical mysteries.

The clothes you wear, the books you read, the medicine you take, the house in which you live — all these are products of chemistry. So is the family car — the metal in it, the rubber on which it rolls, the gas that moves it.

Nature itself is a tremendous chemical laboratory. Everything in nature is forever passing through chemical changes. Here on earth, plants and animals

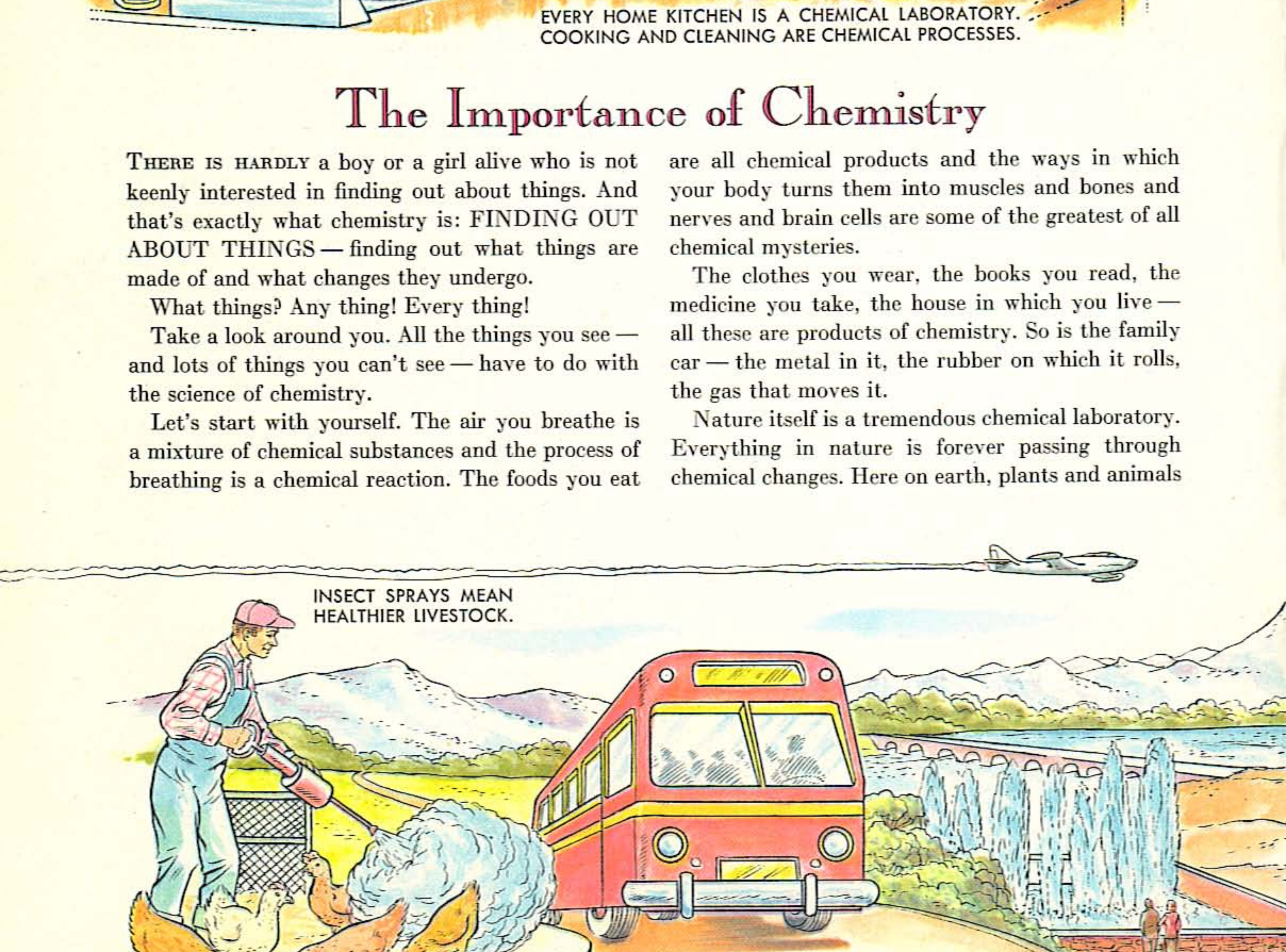

INSECT SPRAYS MEAN HEALTHIER LIVESTOCK.

CHEMISTRY PROVIDES FUEL FOR ALL KINDS OF TRANSPORTATION.

PURIFICATION OF WATER

grow, die, and decay; rocks crack and crumble under the influence of air and water. In the universe, new stars are formed, others fade. The sun that gives us heat and light and energy is a flaming furnace of chemical processes that will eventually burn itself out, billions of years from now.

Chemistry is one of the most important of all sciences for human welfare.

Chemistry means the difference between poverty and starvation and the abundant life. The proper use of chemistry makes it possible for farmers to feed the world's ever-increasing population, for engineers to develop new means of transportation and communication that will bring the peoples of the world closer together, for doctors to cure the diseases of mankind, for manufacturers to produce the thousands of items that are necessary for better and richer living.

And this is only the beginning.

Within recent years, scientists have succeeded in penetrating into the innermost secrets of chemical substances and have begun to make use of the tremendous force that lies hidden in them. This atomic power opens up amazing possibilities for the future.

You will live in a world in which chemistry will become ever more important. To understand that world it is necessary to understand the truths and laws on which modern chemistry is based and to learn how chemists of the past unraveled them.

This book will help you get this insight — not alone by your reading it, but also by your conscientiously doing the experiments described and learning what each of them has to tell you.

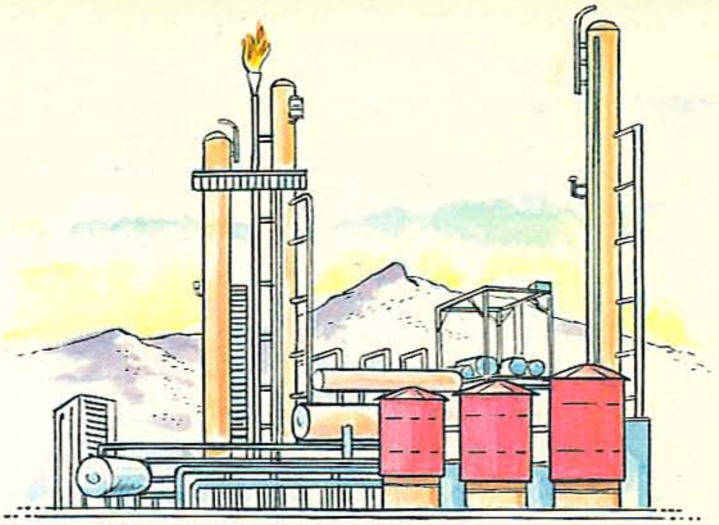

OIL IS THE BASIS FOR COUNTLESS CHEMICAL PRODUCTS.

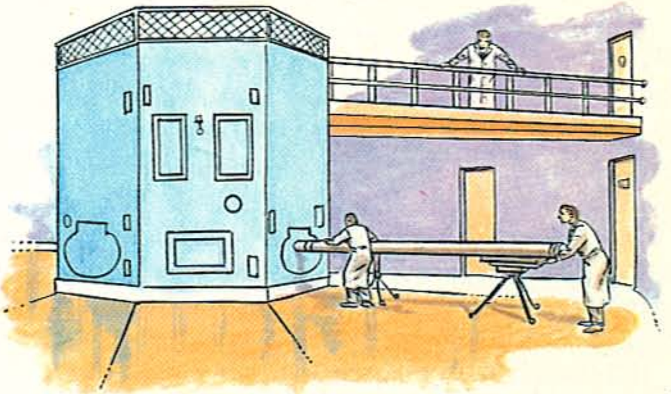

ATOMIC ENERGY FOR THE FUTURE

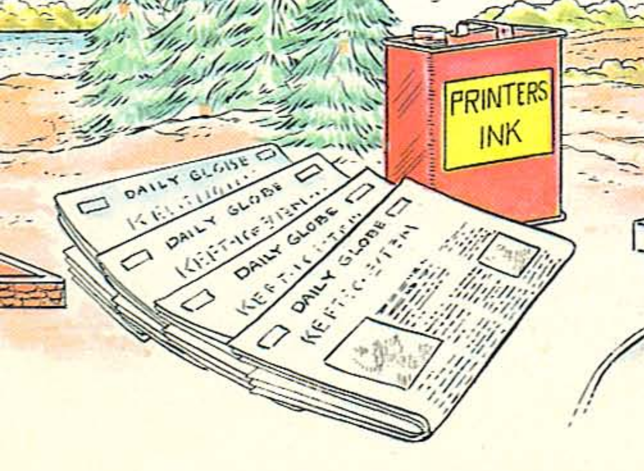

PAPER AND PRINTERS' INK ARE MADE WITH HELP OF CHEMISTRY.

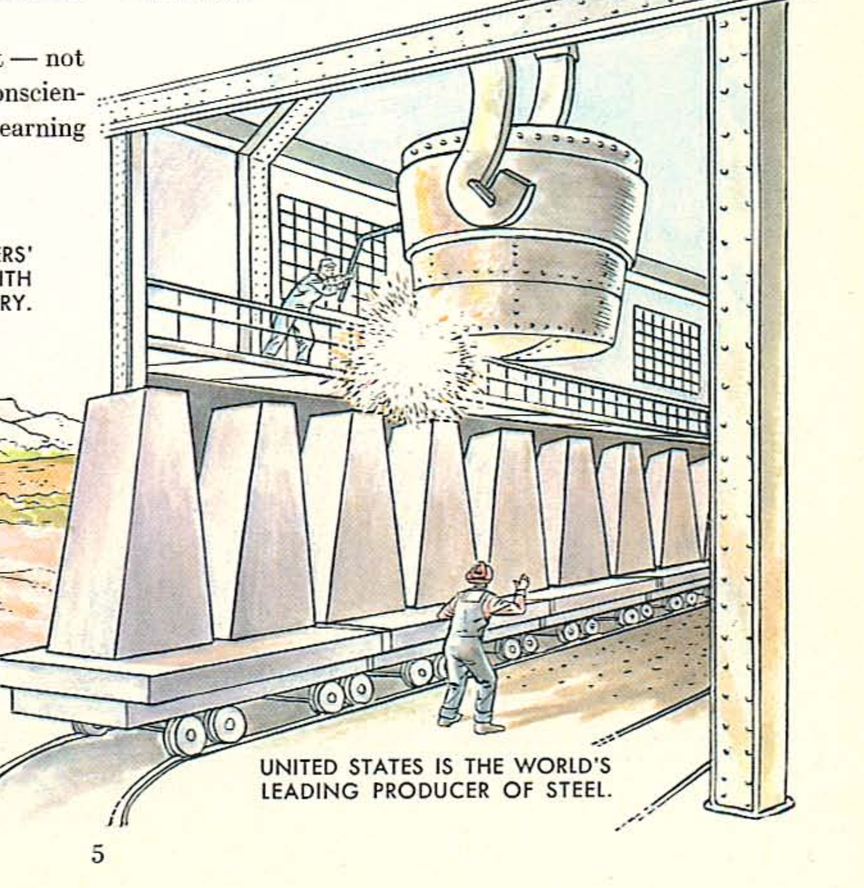

UNITED STATES IS THE WORLD'S LEADING PRODUCER OF STEEL.

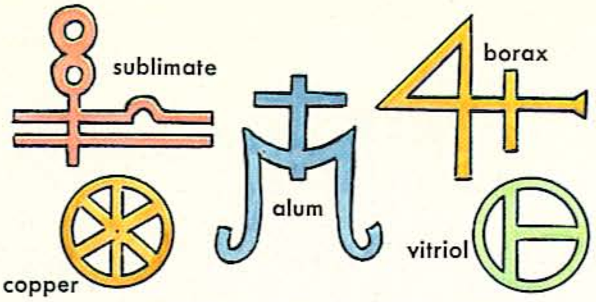

SYMBOLS USED BY ALCHEMISTS

Chemists of the Past

MANY THOUSAND years ago, an early ancestor of yours pushed a stick into the hot lava flowing from an erupting volcano. The stick burst into fire. He held it up as a torch. It gave off light and heat and finally turned into ashes.

This ancient man might be considered the world's first chemist. He had actually taken a substance called wood and had, by a chemical process called combustion or burning, turned it into something else.

The discovery of the use of fire was the first great step leading toward modern chemistry. Fire made it possible to turn raw foodstuffs into edible meals, to bake shaped clay into pottery, to make glass, to drive metals out of their ores.

For thousands of years people were chiefly interested in the results of what they did — they didn't care about what happened or why it happened. It was only about 2,500 years ago that philosophers began to wonder about what things were made of and what happened when a thing changed into something else.

Around 400 B. C., in Greece, a thinker by the name of Empedocles came up with an idea that seemed to make sense. He explained that everything in the world was made from just four things which he called "elements": fire, water, air, and earth. Think of that burning stick mentioned above. It gave off fire — so, obviously, the stick had to contain fire. It sizzled — which meant there was water in it. It smoked — and smoke would be some kind of air. It left ashes — and ashes are earth, as certainly everyone should know.

Everyone — except another Greek, Democritus, born around the time when Empedocles died. He had a different notion — that all matter was made up of tiny particles which he called *atomos* — something that cannot be cut further.

But Democritus didn't get very far with his idea. The greatest Greek philosopher of the day, Aristotle, held out for the four elements. And because of his great reputation this false idea governed the thinking of scientists for two thousand years — because no one dared suggest that he knew better than the great Aristotle!

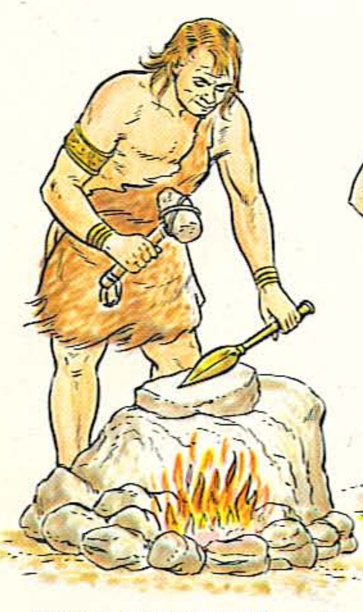

BRONZE-AGE MAN WAS ONE OF THE EARLIEST CHEMISTS.

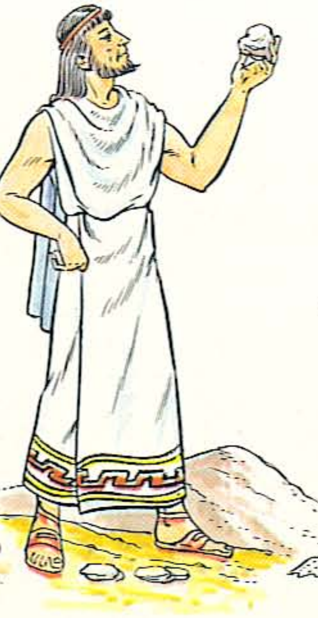

DEMOCRITUS INSISTED THAT MATTER CONSISTS OF ATOMS.

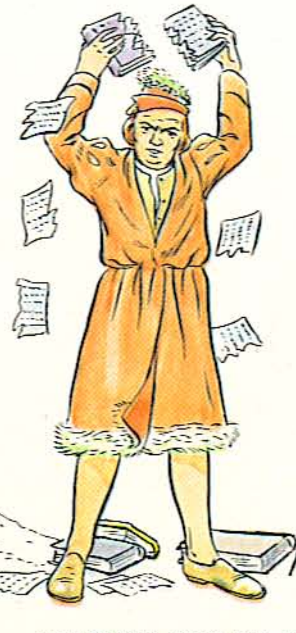

PARACELSUS TOLD HIS PUPILS TO USE EXPERIMENTS.

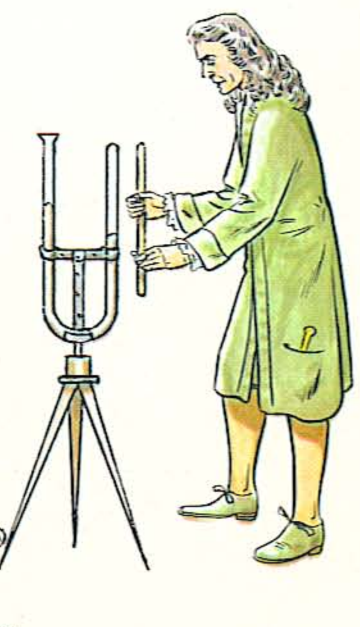

BOYLE INVESTIGATED GASES AND BROKE OLD TRADITIONS.

In the meantime, scientists of Arabia began work in a subject they called alchemy — from Arabic *al*, the, and *kimia*, pouring together. They mixed things and boiled and distilled and extracted in the hope, some day, of finding a way of making GOLD! They discovered a great number of things not previously known, developed many sound laboratory methods, and gave the science of chemistry its name — but they never created the slightest speck of gold. Neither did a great number of European alchemists.

For hundreds of years chemistry made little headway. Then, in 1525, a Swiss doctor and scientist spoke up. He had the imposing name of Theophrastus Bombastus Paracelsus von Hohenheim. He challenged his students to tear up their books with the old theories that had been developed through reasoning only and to find out for themselves *through experiments* whether a scientific theory was right or wrong. But only a few people paid attention to him.

More than a hundred years passed before an Englishman, Robert Boyle, in 1661, succeeded in killing off the old idea of the four elements. He did it by establishing that there are many elements — substances that cannot be formed by other substances and cannot be broken into other substances.

Another hundred years went by. Then, at the time of the American Revolution, the day finally dawned for modern chemistry.

A Swede, Karl Scheele, and an Englishman, Joseph Priestley, discovered oxygen, and a Frenchman, Antoine Laurent Lavoisier, explained the true nature of burning and made up the first scientific listing of all known elements — twenty-eight at the time.

Within a few years, more elements were found. With the help of electricity, an English chemist, Humphry Davy, in a single year brought to light six new metals — among them sodium, potassium, calcium, and magnesium.

Twenty years later, in 1828, another important break-through occurred. A German chemist, Friedrich Wohler, working in his laboratory produced a chemical, urea, that had never before been made outside the body of a living animal.

More and more things were happening. New elements were discovered, new chemicals created. The advances in chemistry greatly influenced industry, agriculture and medicine.

And then, in 1898, the Polish-born Marie Curie and her French husband, Pierre, discovered the "miracle element," radium. This opened up a whole new age in chemistry.

Within the last fifty years, chemistry has moved forward with giant steps. But not a single one of these steps would have been possible without the dedicated work of the chemists of the past who laid the foundation on which modern chemistry rests.

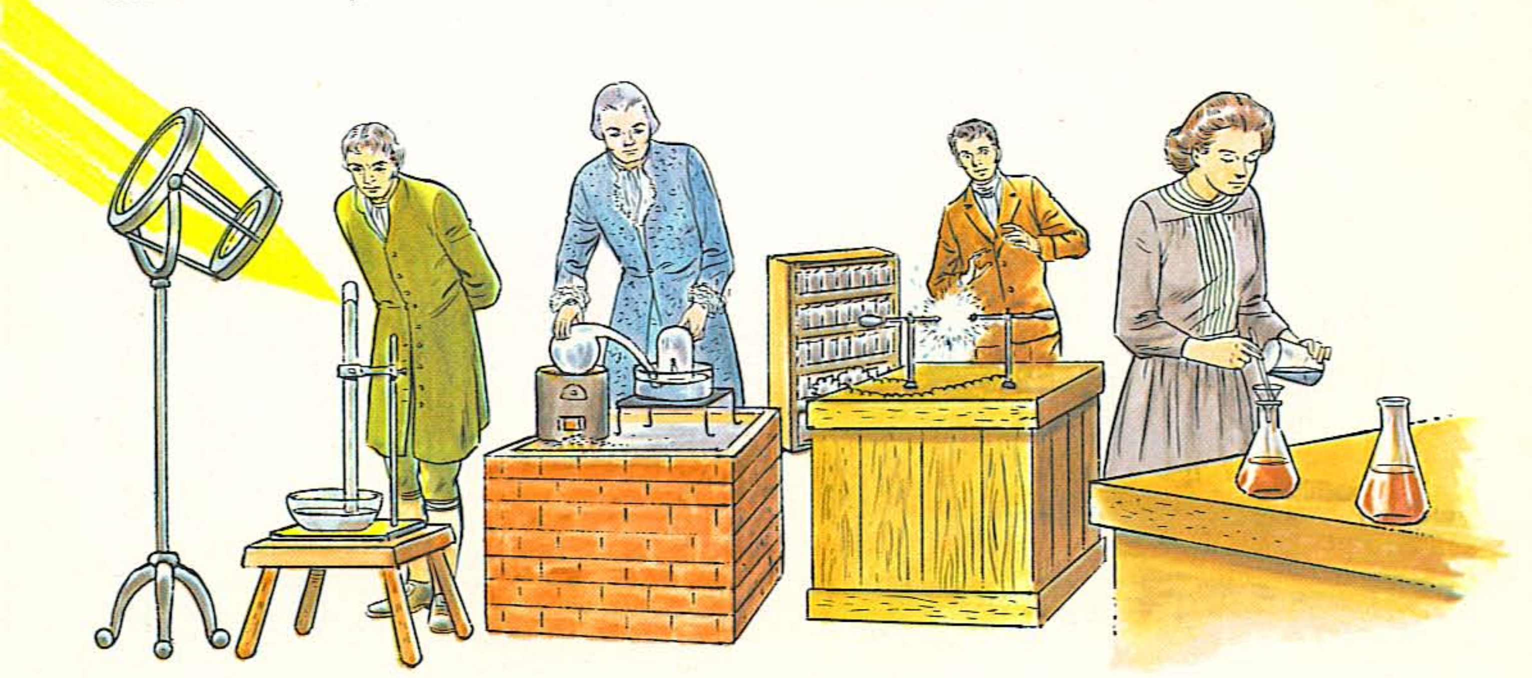

PRIESTLEY USED HEAT OF SUN TO PRODUCE OXYGEN.

LAVOISIER GAVE THE RIGHT EXPLANATION OF BURNING.

DAVY BROUGHT ELECTRICITY INTO CHEMICAL RESEARCH.

MARIE CURIE AND HER HUSBAND DISCOVERED RADIUM.

REGULAR LABORATORY WARE

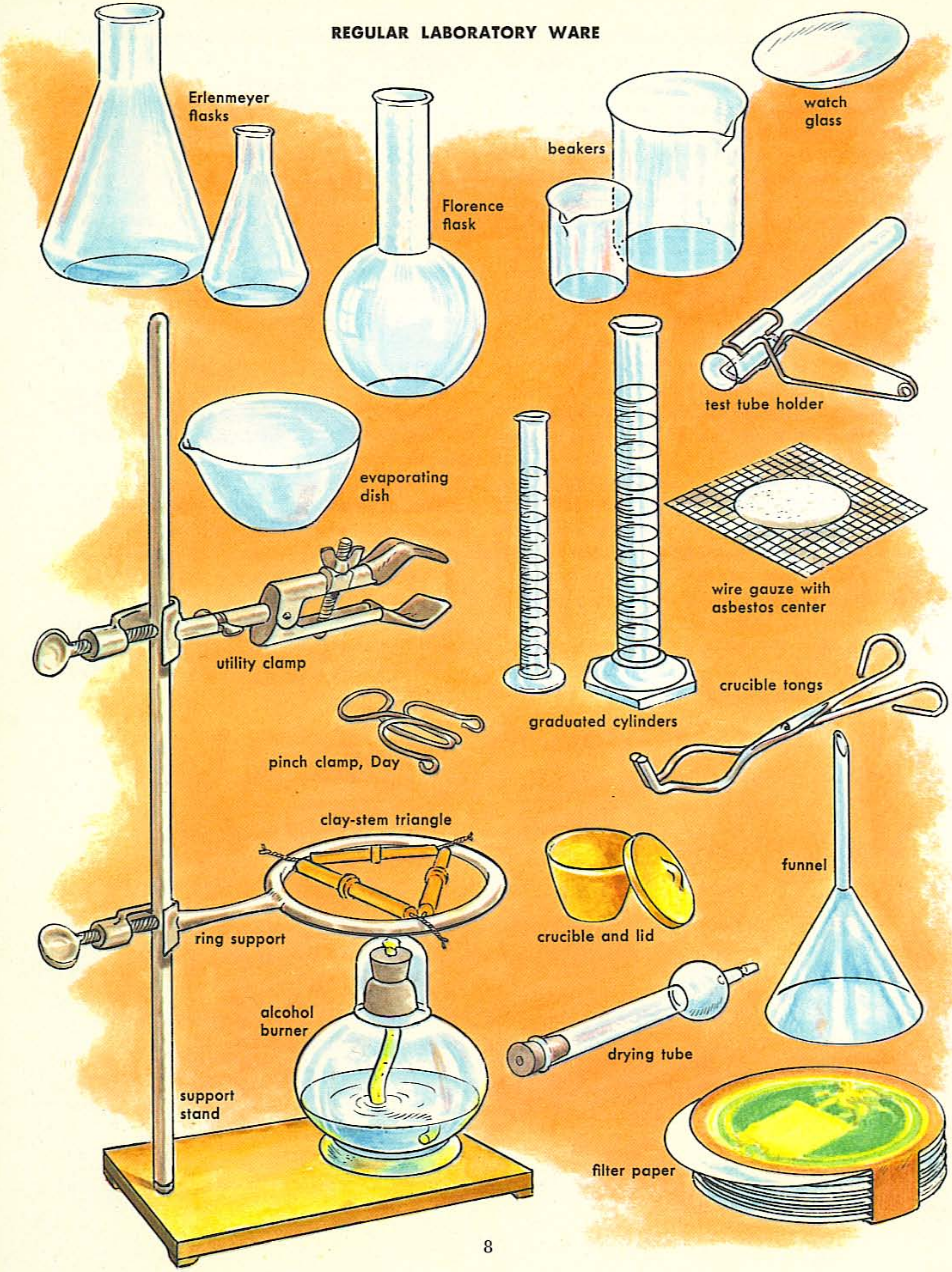
Erlenmeyer flasks
Florence flask
beakers
watch glass
test tube holder
evaporating dish
wire gauze with asbestos center
utility clamp
graduated cylinders
crucible tongs
pinch clamp, Day
clay-stem triangle
funnel
crucible and lid
ring support
alcohol burner
drying tube
support stand
filter paper

Equipment for Chemistry

Some of the greatest discoveries in chemistry were made by scientists who had no special equipment but simply used whatever was at hand.

In your home lab experiments it will pay you to follow the example of these early chemists. Put your imagination to work. Use whatever suitable equipment you can find around the house (as suggested in column to the right) and buy only what is absolutely necessary (as shown below). Some items may be purchased in a local drugstore or scientific supply shop. If not, you can buy them from one of the suppliers listed on page 110.

Later on — if you really get excited about chemistry — you may want to use your pocket money for some of the lab equipment shown on page 8.

LABORATORY WARE FOR HOME LAB

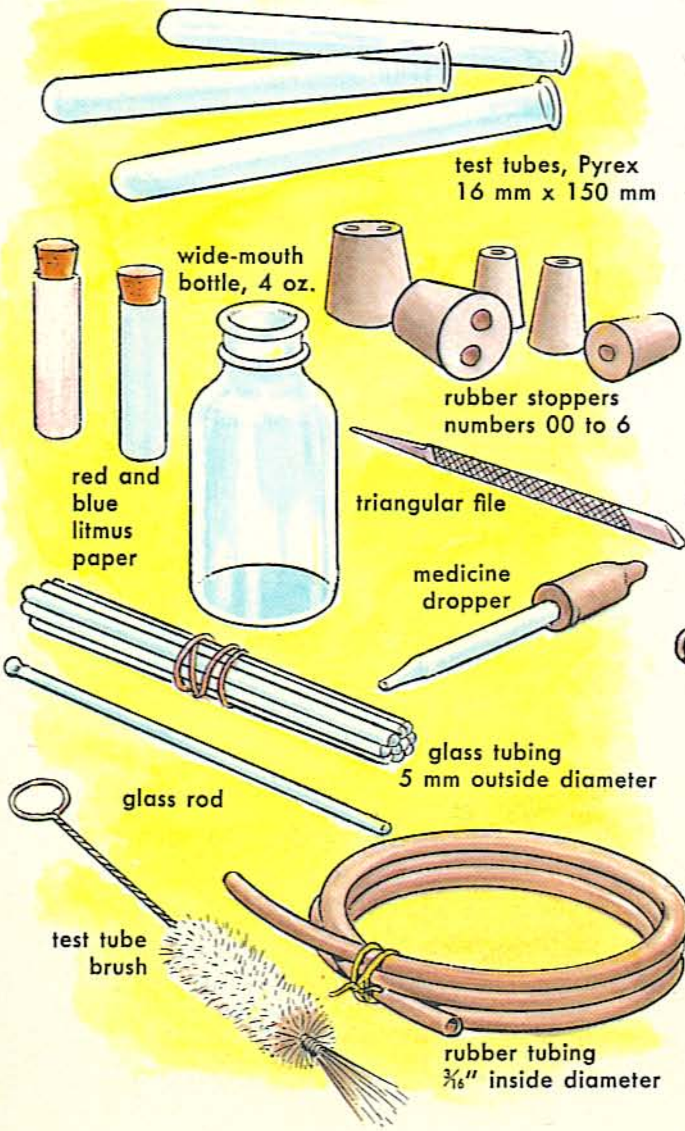
test tubes, Pyrex
16 mm x 150 mm
wide-mouth bottle, 4 oz.
rubber stoppers numbers 00 to 6
red and blue litmus paper
triangular file
medicine dropper
glass tubing 5 mm outside diameter
glass rod
test tube brush
rubber tubing 3/16" inside diameter

IMPROVISED EQUIPMENT FOR HOME LAB

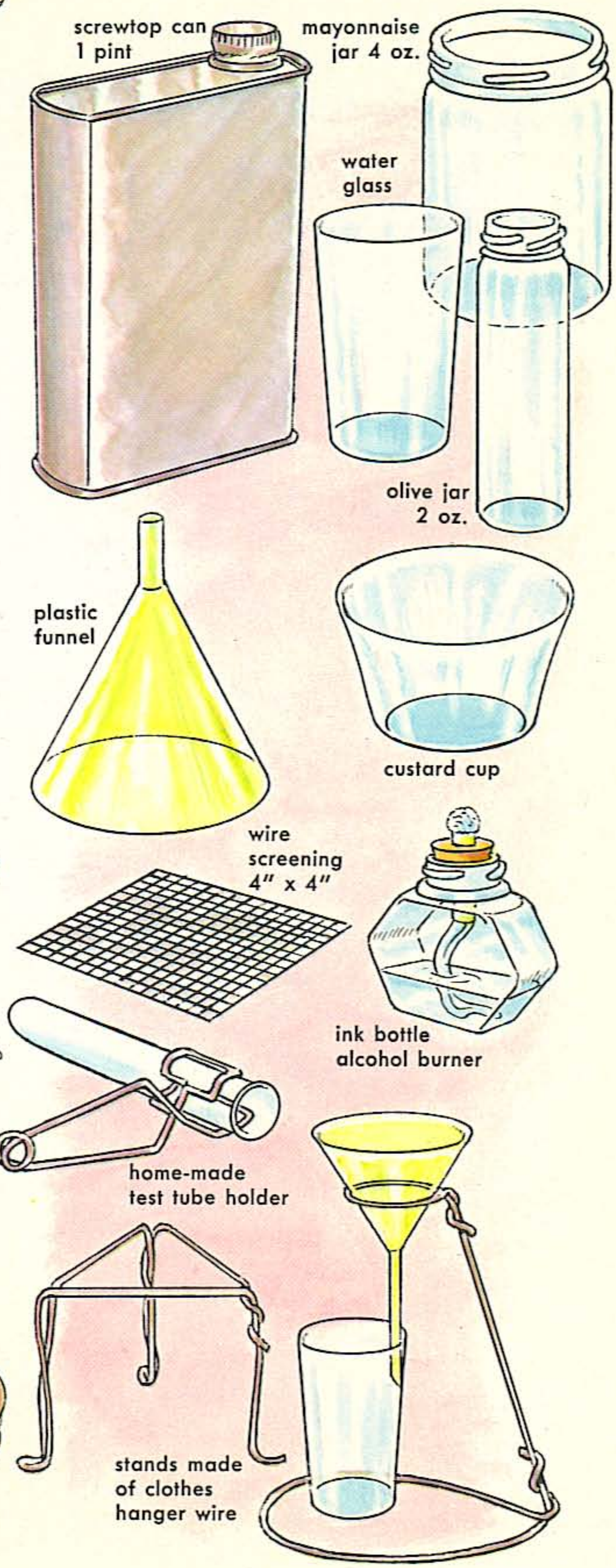
screwtop can 1 pint
mayonnaise jar 4 oz.
water glass
olive jar 2 oz.
plastic funnel
custard cup
wire screening 4" x 4"
ink bottle alcohol burner
home-made test tube holder
stands made of clothes hanger wire

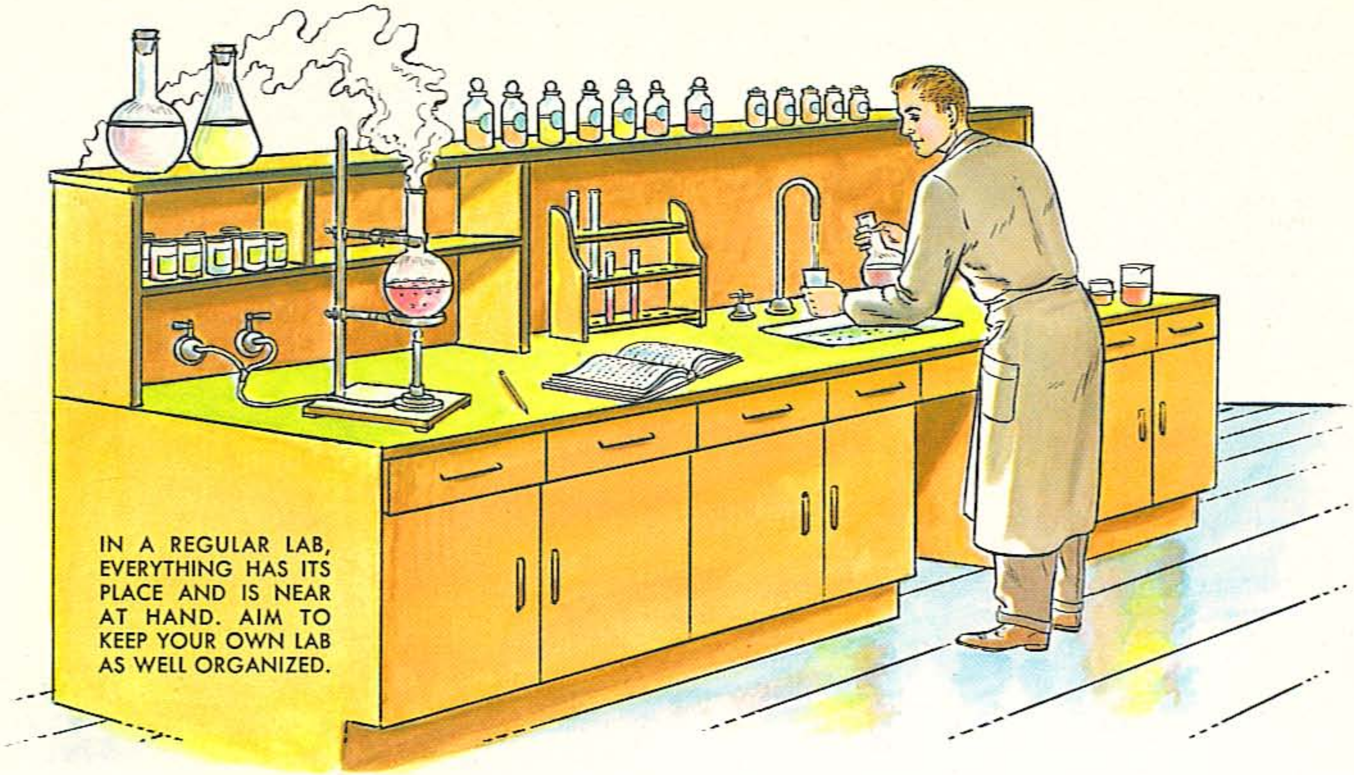

IN A REGULAR LAB, EVERYTHING HAS ITS PLACE AND IS NEAR AT HAND. AIM TO KEEP YOUR OWN LAB AS WELL ORGANIZED.

Setting Up Your Home Laboratory

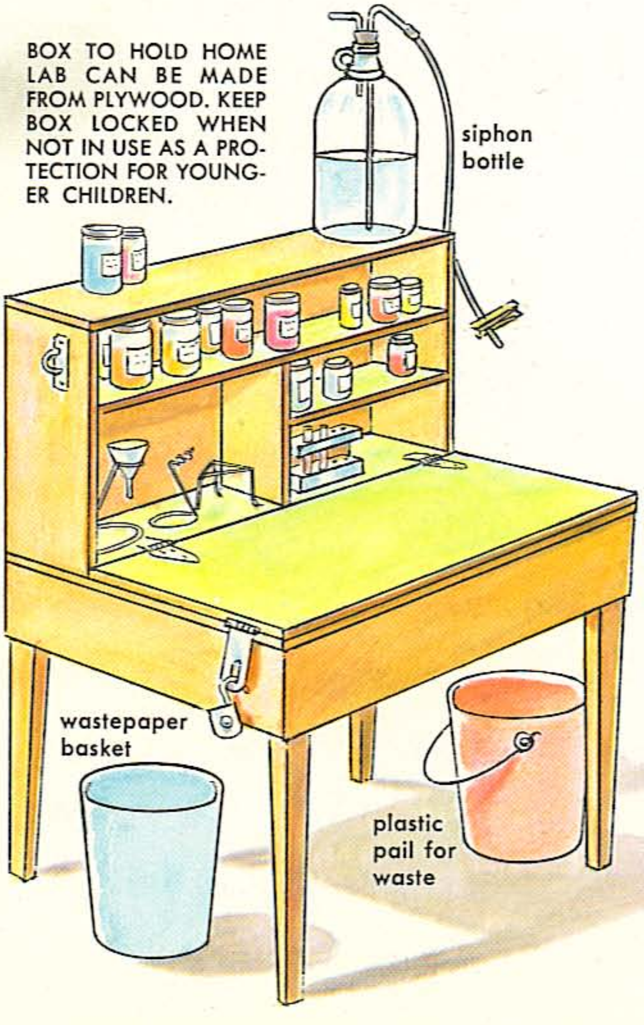

BOX TO HOLD HOME LAB CAN BE MADE FROM PLYWOOD. KEEP BOX LOCKED WHEN NOT IN USE AS A PROTECTION FOR YOUNGER CHILDREN.

It is possible that you may be permitted to work at the kitchen table when this is not in use. But it is far better if you have a place where you will not be disturbed and where you can store your equipment — a corner in your room, or in the basement or the garage.

These are the things you'll need in your lab:

Work Table. An old, sturdy table will do. Cover it with a plastic top to protect the wood.

Water Supply. If you have a faucet nearby, fine. Otherwise, make a siphon bottle (page 11).

Waste Disposal. If you can dump your waste directly into the kitchen *drain* (NOT into the sink), you are all right. If not, collect it in a plastic pail to be thrown out when you're finished.

Source of Heat. In the regular laboratory, special gas burners are used. In the home lab, you can use a burner for denatured alcohol. Have a shallow metal pan under the burner for fire safety.

Storage. If there's no one around to disturb your chemicals and equipment, an open shelf is OK. Otherwise, use a box that can be locked up.

Containers. Keep chemicals in glass jars and bottles. LABEL THEM ALL CLEARLY.

Stands. Make your own test tube stand as well as stands for holding glassware for heating.

IF YOU DO NOT HAVE RUNNING WATER IN YOUR LAB, MAKE SIPHON FROM A 1-GALLON BOTTLE. START SIPHON BY BLOWING THROUGH L-SHAPED GLASS TUBE. SPRING CLOTHES PIN REGULATES WATER FLOW.

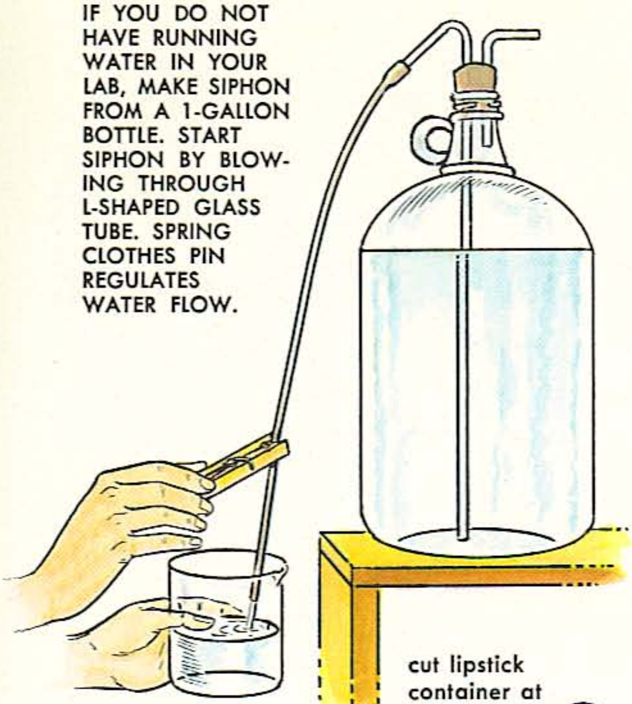

YOU CAN MAKE A SIMPLE TEST TUBE STAND FROM A SALT BOX. CUT OUT SIDE AND USE CUT-OUT SECTION TO KEEP TEST TUBES LINED UP STRAIGHT.

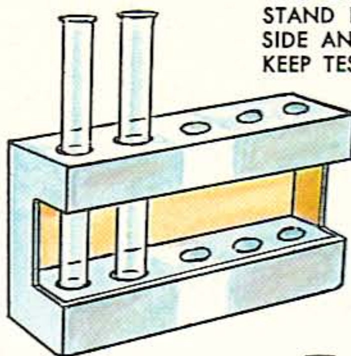

REGULAR LAB STAND FOR TEST TUBES CAN BE PRODUCED FROM STRIPS OF ¼-INCH WOOD. FOLLOW PATTERNS BELOW TO MAKE TWO SIDES AND THREE HORIZONTAL PIECES. DRILL HOLES. ASSEMBLE WITH THIN TACKS.

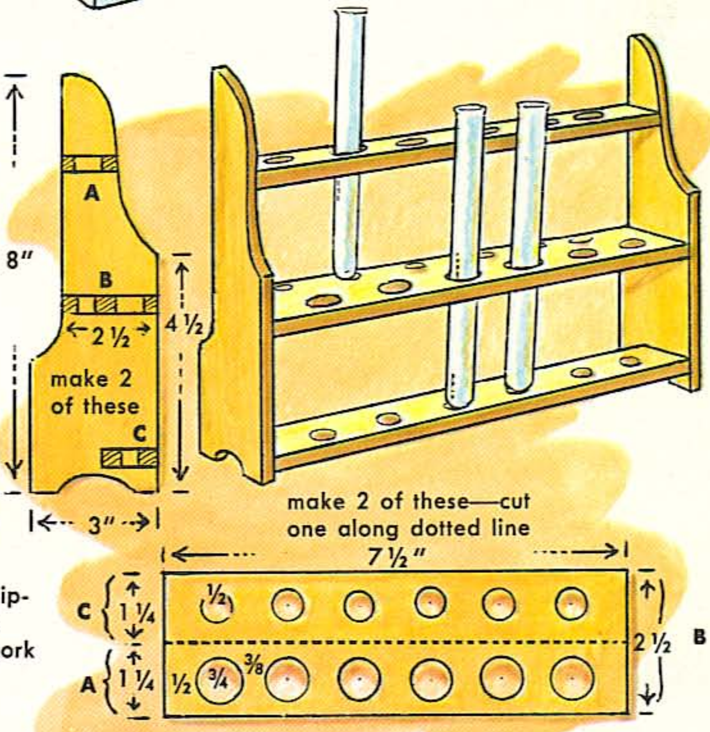

make 2 of these—cut one along dotted line

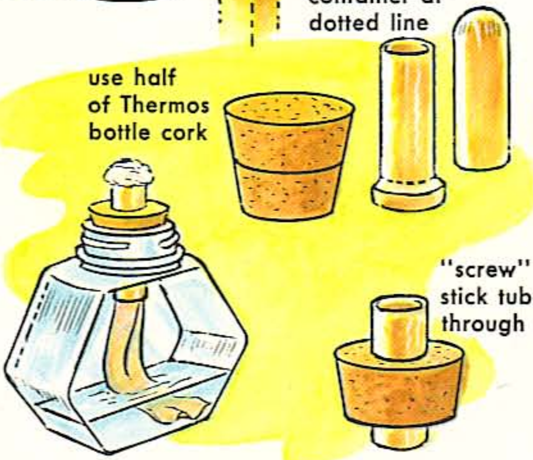

cut lipstick container at dotted line

use half of Thermos bottle cork

"screw" lipstick tube through cork

MAKE AN ALCOHOL BURNER FROM INK BOTTLE, THERMOS BOTTLE CORK, AND LIPSTICK CONTAINER. BUY WICK AT A HARDWARE STORE.

USE A PAIR OF PLIERS FOR MAKING THESE STANDS FROM CLOTHES HANGER WIRE. ALSO MAKE THE FUNNEL STAND ILLUSTRATED ON PAGE 9.

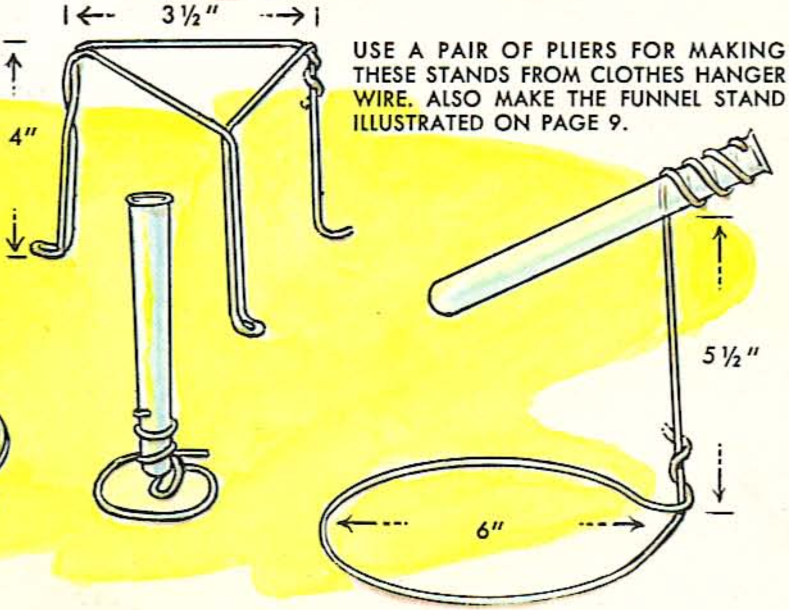

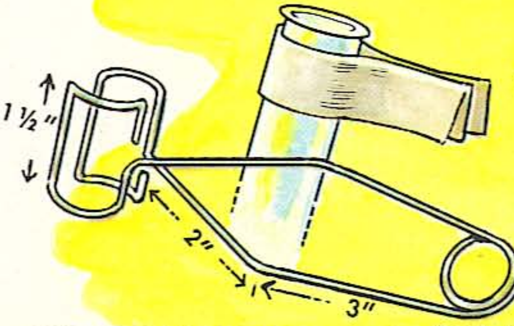

STRIP OF THIN CARDBOARD MAKES AN ADEQUATE TEST TUBE HOLDER. IF YOU LIKE, YOU CAN MAKE A HOLDER FROM CLOTHES HANGER WIRE AS SHOWN HERE.

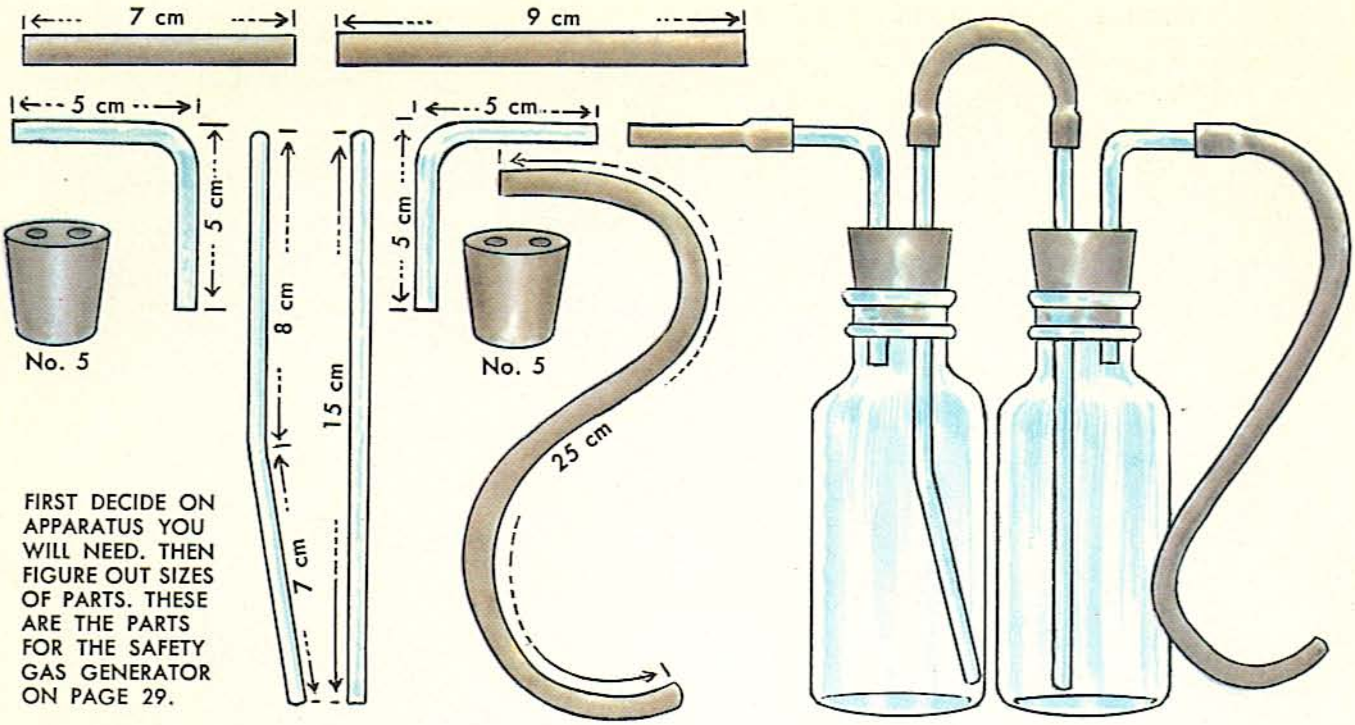

FIRST DECIDE ON APPARATUS YOU WILL NEED. THEN FIGURE OUT SIZES OF PARTS. THESE ARE THE PARTS FOR THE SAFETY GAS GENERATOR ON PAGE 29.

Making Apparatus for Experiments

Most of your chemical experiments you will perform in test tubes and jars. But occasionally you will need an apparatus — a device consisting of bottles and stoppers, glass and rubber tubing.

A good chemist takes pride in his apparatus. He makes it with great care — not just for looks but, more important, for safety. An apparatus that leaks flammable gas can be very dangerous.

Before you start to put an apparatus together, make a simple drawing of it so that you will know what it will consist of. Then get out the various parts you will need to put it together.

To make an apparatus, you need to know how to cut a glass tube, how to bend it, and how to draw it to a jet point. See page 13.

It is wise to use glass tubes of one diameter only, with rubber tubing to fit. Glass tubes of an *outside* diameter of 6 millimeters fit snugly into the holes in the usual rubber stoppers. Rubber tubing of an *inside* diameter of $\frac{3}{16}$" fits over the 6mm glass tubes.

To determine the right size stoppers to use in the bottles of your apparatus, measure the mouths of the bottles against the stoppers shown below in actual size. Order stoppers by number. Keep a selection of different sizes on hand.

Follow the safety precautions on page 16.

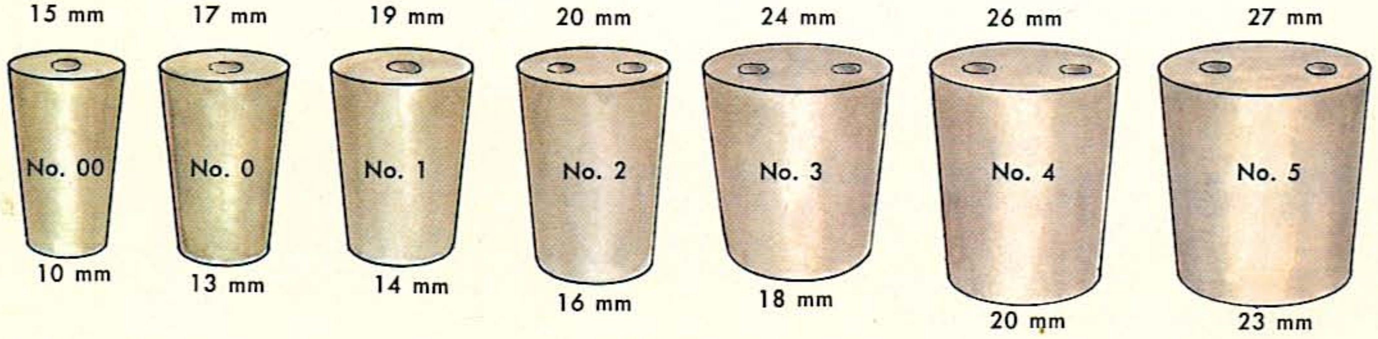

THESE ARE THE ACTUAL SIZES OF RUBBER STOPPERS. BY MEASURING THEM AGAINST YOUR LAB WARE YOU WILL KNOW WHICH TO ORDER. No. 0 FITS THE 16 mm TEST TUBE. No. 5 FITS 4-OZ. WIDE-MOUTH BOTTLE.

CUTTING GLASS TUBES

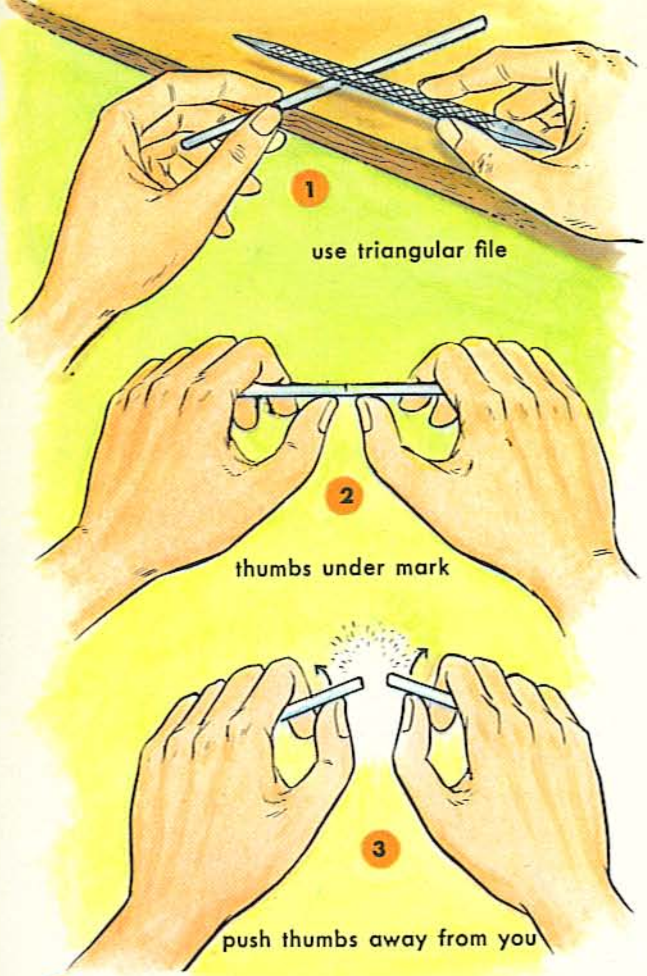
1
use triangular file
2
thumbs under mark
3
push thumbs away from you

1 MAKE SINGLE SCRATCH WITH FILE—DO NOT "SAW."

2 HOLD TUBE WITH BOTH HANDS, THUMBS BELOW MARK.

3 SNAP TUBE INTO TWO PIECES WITH A QUICK JERK.

FIRE GLAZING CUT EDGES

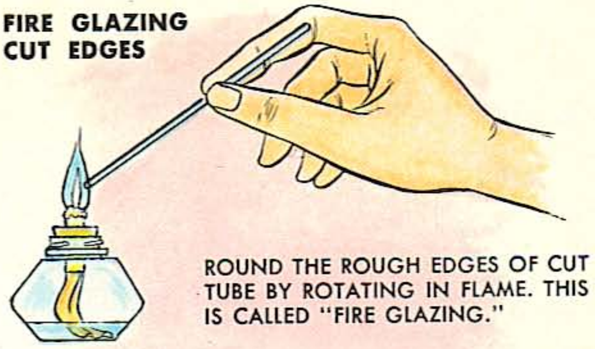

ROUND THE ROUGH EDGES OF CUT TUBE BY ROTATING IN FLAME. THIS IS CALLED "FIRE GLAZING."

MAKING JET POINT

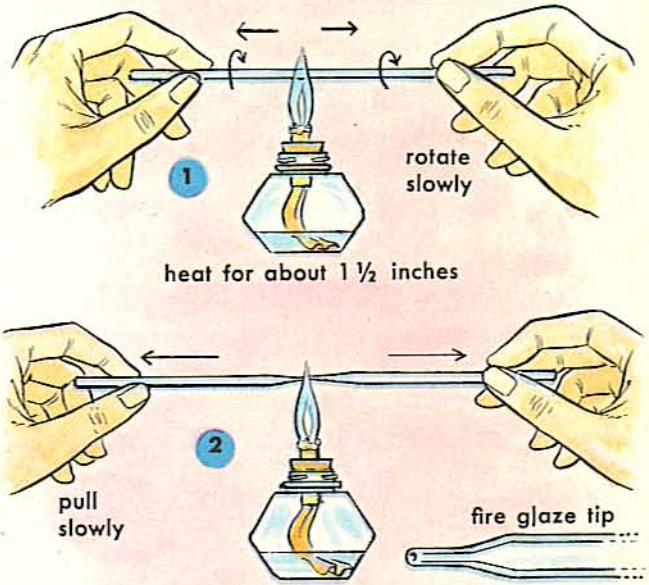
1
rotate slowly
heat for about 1 ½ inches
2
pull slowly
fire glaze tip

1 HEAT SECTION OF TUBE EVENLY WHERE YOU WANT TO FORM JET POINT, BY ROLLING IT IN THE FLAME.

2 WHEN SOFT, PULL SLOWLY. CUT APART WHEN HARD.

BENDING GLASS TUBES

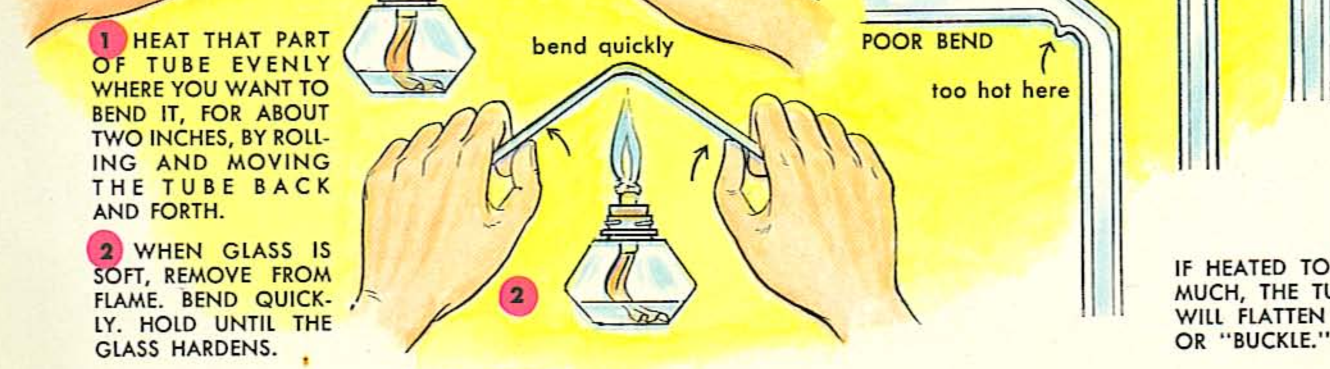
roll slowly
1
bend quickly
2
GOOD BEND
too hot here
POOR BEND
POOR BEND
too hot here

1 HEAT THAT PART OF TUBE EVENLY WHERE YOU WANT TO BEND IT, FOR ABOUT TWO INCHES, BY ROLLING AND MOVING THE TUBE BACK AND FORTH.

2 WHEN GLASS IS SOFT, REMOVE FROM FLAME. BEND QUICKLY. HOLD UNTIL THE GLASS HARDENS.

IF HEATED TOO MUCH, THE TUBE WILL FLATTEN OR "BUCKLE."

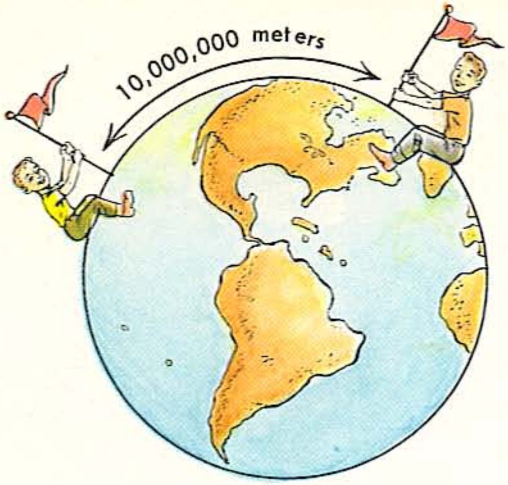

Scientific Measurements

In science, the metric system is preferred over our usual system. It is much easier to work with when once you have learned it — for instead of dividing or multiplying by 12 or 32 or 16 to go from one unit to the next, you simply move the decimal point. Just remember these two things:

1. That the names of the basic units are meter for lengths, liter for volumes, grams for weights — abbreviated to m, l, and g (without a period after them).
2. That 1000 of a kind are called kilo; 100, hekto; 10, deca; 1/10 is called deci; 1/100, centi; 1/1000, milli.

METRIC UNITS OF LENGTH

1000 meters (m) = 1 kilometer (km)
1 meter (m) = 1000 millimeters (mm)
1 meter (m) = 39.37 inches
2.540 centimeters (cm) = 1 inch

METRIC UNITS OF VOLUME

1 liter (l) = 1000 cubic centimeters (cm^3 or cc)
1 liter (l) = 1000 milliliters (ml)
1 liter (l) = 1.06 quarts (liquid)
0.946 liter (l) = 1 quart (liquid)

METRIC UNITS OF WEIGHT

1000 grams (g) = 1 kilogram (kg)
1 gram (g) = 1000 milligrams (mg)
1 gram (g) = 0.035 ounces avoirdupois
28.350 grams (g) = 1 ounce avoirdupois

1 cubic centimeter =
1 cm^3 = 1 cc =
1 milliliter =
1 ml

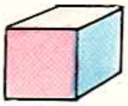

Making a Model of a Cubic Centimeter

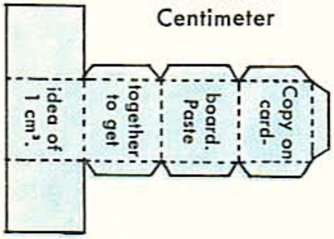

BOTTOM LINE OF FIGURE TO THE RIGHT IS 1 DECIMETER (1 dm) OR 10 CENTIMETERS (10 cm) OR 100 MILLIMETERS (100 mm).

FRONT SURFACE OF FIGURE IS 1 SQUARE DECIMETER (1 dm^2) OR 100 SQUARE CENTIMETERS (100 cm^2).

VOLUME OF WHOLE FIGURE IS 1 CUBIC DECIMETER (1 dm^3) OR 1000 CUBIC CENTIMETERS (1000 cm^3 OR 1000 cc) OR 1000 MILLILITERS (1000 ml) OR 1 LITER (1 l). 1 l WATER WEIGHS 1 KILOGRAM (1 kg).

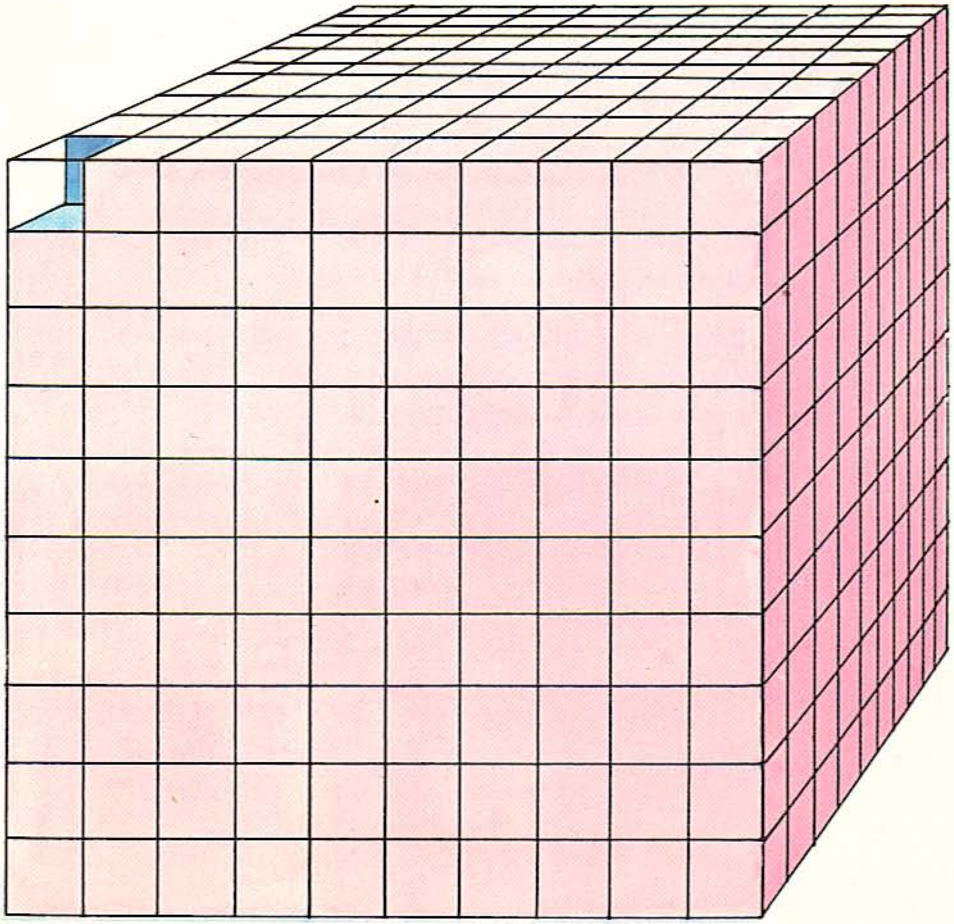

1 cubic decimeter = 1 liter = 1000 cubic centimeters = 1000 milliliters

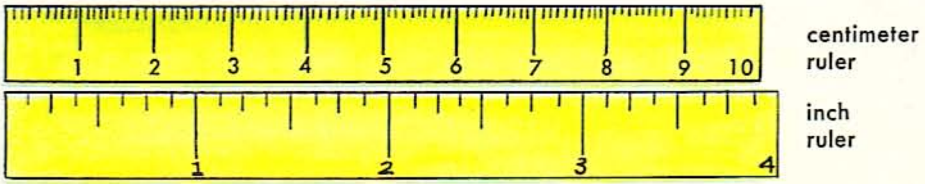

MAKING A HAND BALANCE

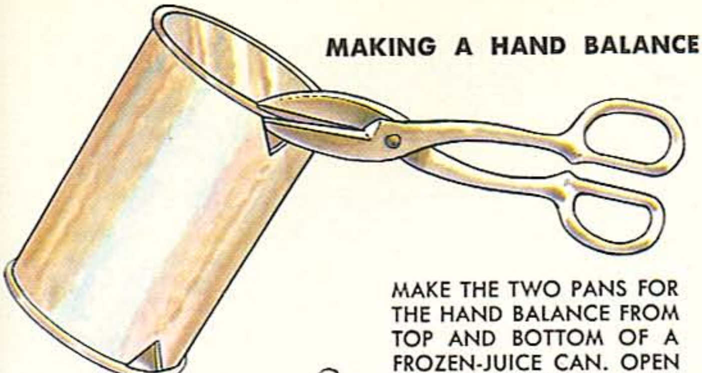

MAKE THE TWO PANS FOR THE HAND BALANCE FROM TOP AND BOTTOM OF A FROZEN-JUICE CAN. OPEN CAN AT SIDE. CUT THE PANS WITH TIN SNIPS.

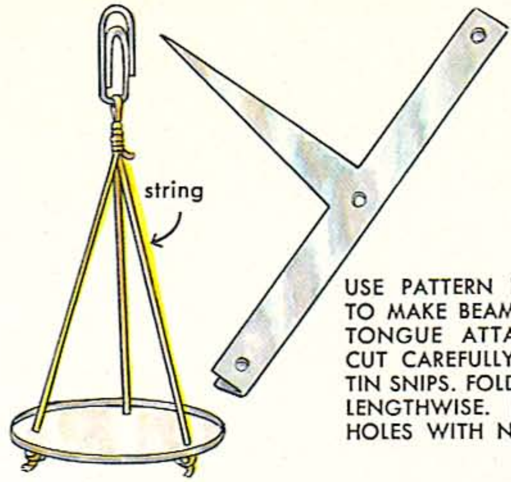

USE PATTERN BELOW TO MAKE BEAM WITH TONGUE ATTACHED. CUT CAREFULLY WITH TIN SNIPS. FOLD BEAM LENGTHWISE. PUNCH HOLES WITH NAIL.

FOR MANY EXPERIMENTS YOU NEED TO WEIGH CHEMICALS. FOR THIS, MAKE A HAND BALANCE.

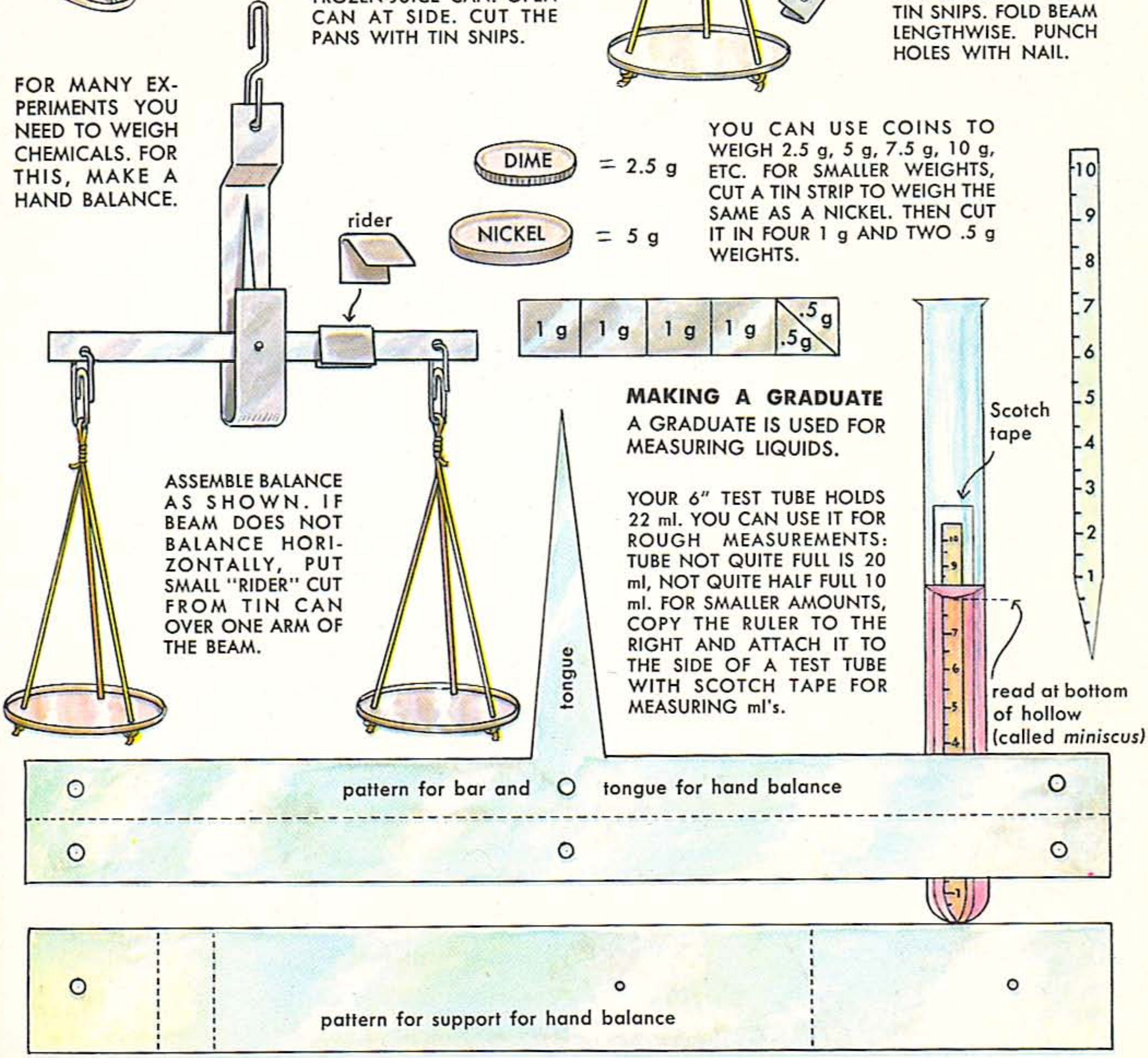
rider
DIME
= 2.5 g
NICKEL
= 5 g
1 g
1 g
1 g
1 g
.5 g
.5 g
10
9
8
7
6
5
4
3
2
1
Scotch tape
read at bottom of hollow (called *miniscus*)
tongue
pattern for bar and tongue for hand balance
pattern for support for hand balance

YOU CAN USE COINS TO WEIGH 2.5 g, 5 g, 7.5 g, 10 g, ETC. FOR SMALLER WEIGHTS, CUT A TIN STRIP TO WEIGH THE SAME AS A NICKEL. THEN CUT IT IN FOUR 1 g AND TWO .5 g WEIGHTS.

ASSEMBLE BALANCE AS SHOWN. IF BEAM DOES NOT BALANCE HORIZONTALLY, PUT SMALL "RIDER" CUT FROM TIN CAN OVER ONE ARM OF THE BEAM.

MAKING A GRADUATE

A GRADUATE IS USED FOR MEASURING LIQUIDS.

YOUR 6" TEST TUBE HOLDS 22 ml. YOU CAN USE IT FOR ROUGH MEASUREMENTS: TUBE NOT QUITE FULL IS 20 ml, NOT QUITE HALF FULL 10 ml. FOR SMALLER AMOUNTS, COPY THE RULER TO THE RIGHT AND ATTACH IT TO THE SIDE OF A TEST TUBE WITH SCOTCH TAPE FOR MEASURING ml's.

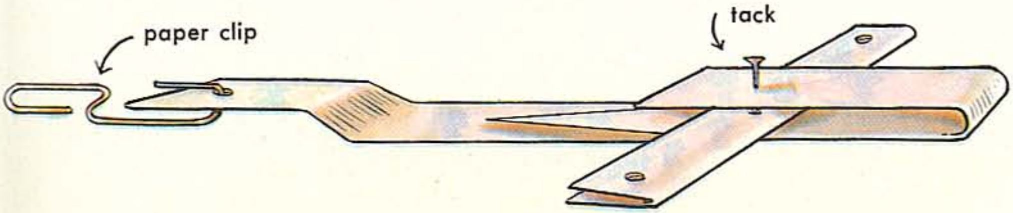
paper clip
tack

COPY THE PATTERNS ABOVE ONTO A PIECE OF PAPER. TRANSFER DESIGNS TO PIECE OF TIN CAN. CUT OUT AND BEND AS SHOWN TO THE LEFT.

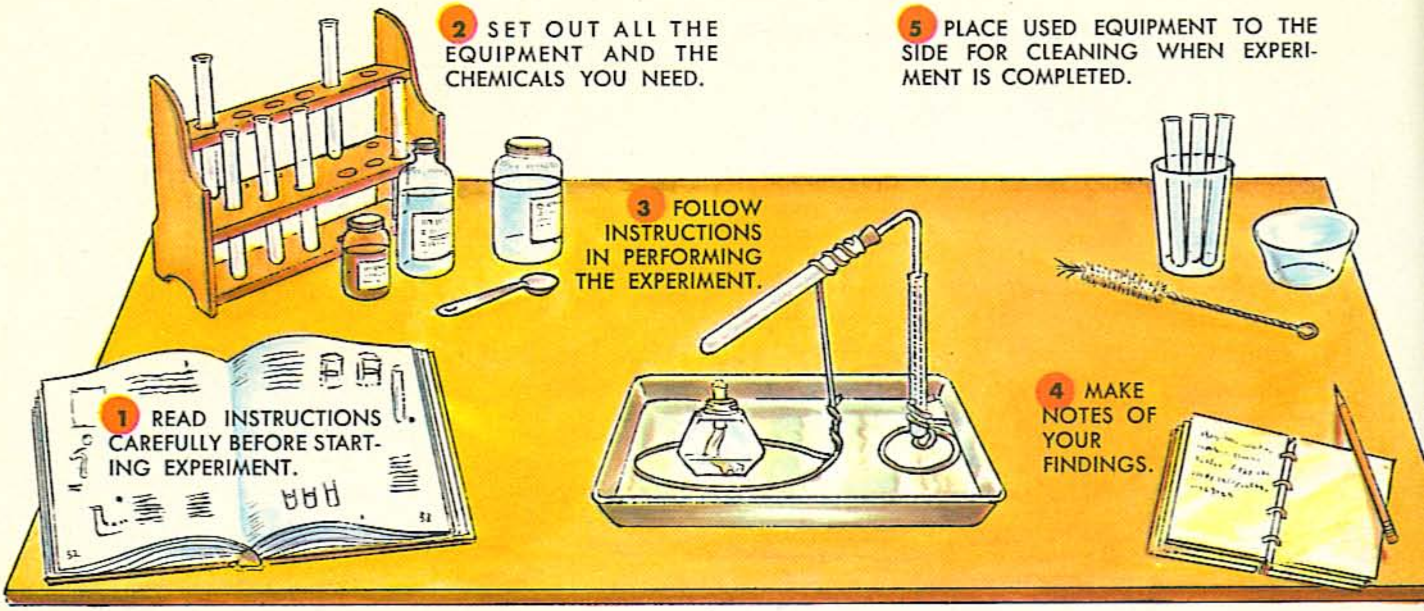
1 READ INSTRUCTIONS CAREFULLY BEFORE STARTING EXPERIMENT.
2 SET OUT ALL THE EQUIPMENT AND THE CHEMICALS YOU NEED.
3 FOLLOW INSTRUCTIONS IN PERFORMING THE EXPERIMENT.
4 MAKE NOTES OF YOUR FINDINGS.
5 PLACE USED EQUIPMENT TO THE SIDE FOR CLEANING WHEN EXPERIMENT IS COMPLETED.

Correct Laboratory Techniques

In your home laboratory, three considerations are of the greatest importance: SAFETY, NEATNESS, and EXACTNESS.

SAFETY — All the experiments in this book are safe when done in the correct laboratory way as shown on these pages.

Treat chemicals with respect. Never taste anything unless specifically told to do so. If there are younger children in the family, lock up your chemicals when you are not working with them.

Protect your clothes with a plastic apron.

Be careful with fire. When you use your alcohol burner, have a metal pan under it for safety.

NEATNESS — Get the habit of lining up equipment and chemicals you need on one side and placing used items on the opposite side — keeping the space between them clear for your experiments.

Put chemicals away and clean glassware as soon as you have finished an experiment.

EXACTNESS — Label all bottles and jars containing chemicals clearly and correctly.

Where amounts of chemicals are not given, use the smallest amount that will tell you what you want to know.

Observe the chemical reactions carefully and make complete notes of them as you go along.

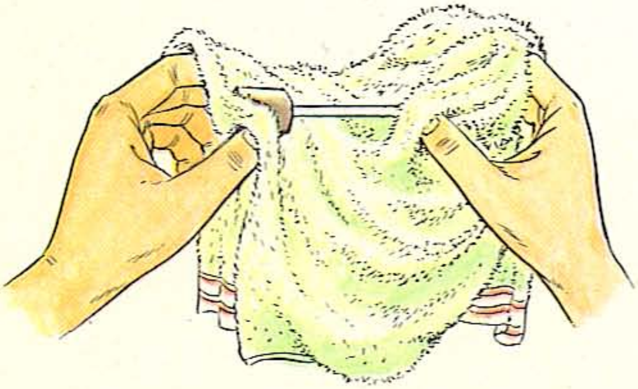

PLAY SAFE WHEN YOU PUT A GLASS TUBE IN A STOPPER. PROTECT YOUR HANDS BY WRAPPING TOWEL AROUND THEM. MOISTEN GLASS TUBE AND STOPPER WITH WATER, THEN PUSH THE TUBE INTO THE STOPPER WITH A SCREWDRIVER MOTION.

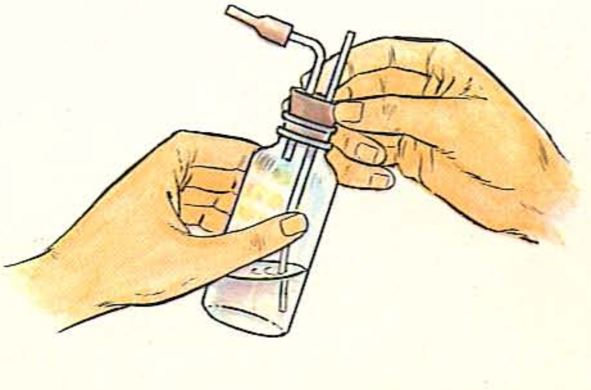

WHEN YOU MAKE AN APPARATUS FOR A CHEMICAL EXPERIMENT, MAKE SURE THAT ALL CONNECTIONS ARE AIRTIGHT. USE THE RIGHT SIZE STOPPER FOR MOUTH OF CONTAINER, GLASS TUBES THAT FIT SNUGLY INTO THE STOPPER HOLES, AND TIGHT-FITTING RUBBER TUBING.

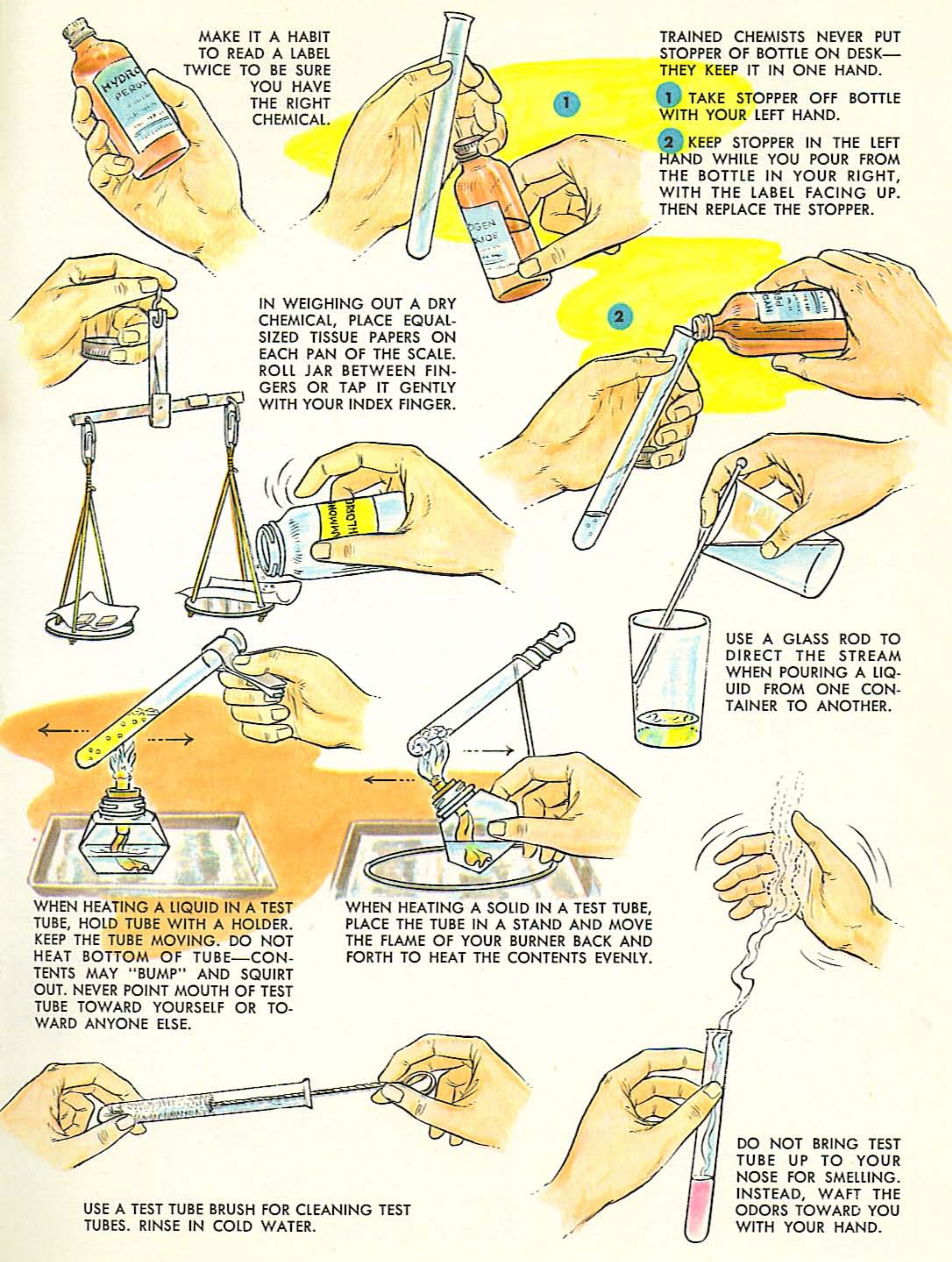

MAKE IT A HABIT TO READ A LABEL TWICE TO BE SURE YOU HAVE THE RIGHT CHEMICAL.

TRAINED CHEMISTS NEVER PUT STOPPER OF BOTTLE ON DESK—THEY KEEP IT IN ONE HAND.

1 TAKE STOPPER OFF BOTTLE WITH YOUR LEFT HAND.

2 KEEP STOPPER IN THE LEFT HAND WHILE YOU POUR FROM THE BOTTLE IN YOUR RIGHT, WITH THE LABEL FACING UP. THEN REPLACE THE STOPPER.

IN WEIGHING OUT A DRY CHEMICAL, PLACE EQUAL-SIZED TISSUE PAPERS ON EACH PAN OF THE SCALE. ROLL JAR BETWEEN FINGERS OR TAP IT GENTLY WITH YOUR INDEX FINGER.

USE A GLASS ROD TO DIRECT THE STREAM WHEN POURING A LIQUID FROM ONE CONTAINER TO ANOTHER.

WHEN HEATING A LIQUID IN A TEST TUBE, HOLD TUBE WITH A HOLDER. KEEP THE TUBE MOVING. DO NOT HEAT BOTTOM OF TUBE—CONTENTS MAY "BUMP" AND SQUIRT OUT. NEVER POINT MOUTH OF TEST TUBE TOWARD YOURSELF OR TOWARD ANYONE ELSE.

WHEN HEATING A SOLID IN A TEST TUBE, PLACE THE TUBE IN A STAND AND MOVE THE FLAME OF YOUR BURNER BACK AND FORTH TO HEAT THE CONTENTS EVENLY.

USE A TEST TUBE BRUSH FOR CLEANING TEST TUBES. RINSE IN COLD WATER.

DO NOT BRING TEST TUBE UP TO YOUR NOSE FOR SMELLING. INSTEAD, WAFT THE ODORS TOWARD YOU WITH YOUR HAND.

Mr. Faraday's Candle

In the winter of 1859, Michael Faraday, a great British scientist, gave a number of lectures for young people. The talks dealt with one subject only: the features or "phenomena" of — a candle!

"There is not a law," Faraday told his listeners, "under which any part of this universe is governed which does not come into play and is touched upon in these phenomena. There is no better, there is no more open door by which you can enter into the study of natural philosophy than by considering the phenomena of a candle." He then set out to prove his point by lighting a candle and demonstrating all the processes involved.

In burning a candle you start with a SOLID substance that turns, first, into a LIQUID, then into a GAS (or, more correctly, into a gas-like vapor). The melted candle grease is held in a level position by GRAVITY yet seems to defy gravity by rising in the wick by a force called CAPILLARY ACTION. In burning, the candle produces ENERGY in the form of LIGHT and HEAT. At the same time, it goes into CHEMICAL REACTIONS that reveal what it is made of.

As you enter the study of chemistry, you can do no better than to repeat for yourself some of the experiments that Mr. Faraday demonstrated to his young audience.

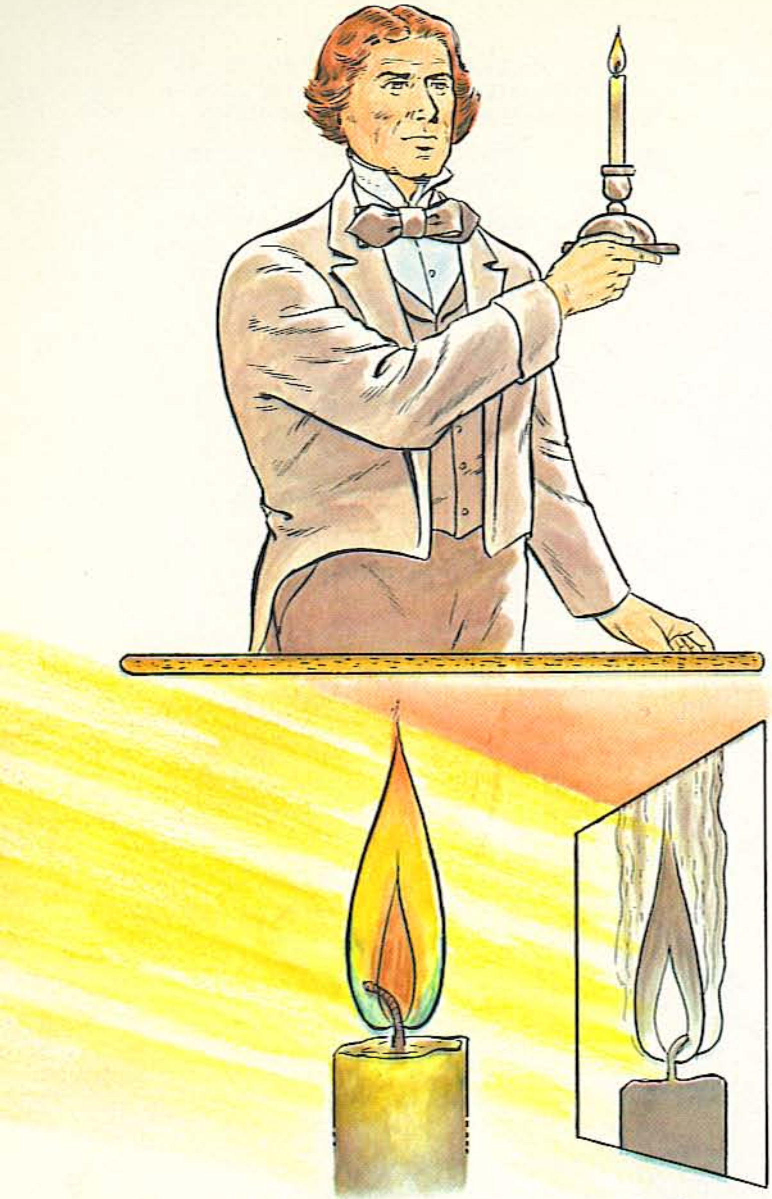

PLACE A BURNING CANDLE IN THE SUN AND CATCH THE SHADOW ON A PIECE OF WHITE PAPER. YOU WILL DISCOVER THAT IT IS THE BRIGHTEST PART OF THE FLAME THAT CASTS THE DARKEST SHADOW.

CANDLE FLAME IS BURNING VAPOR

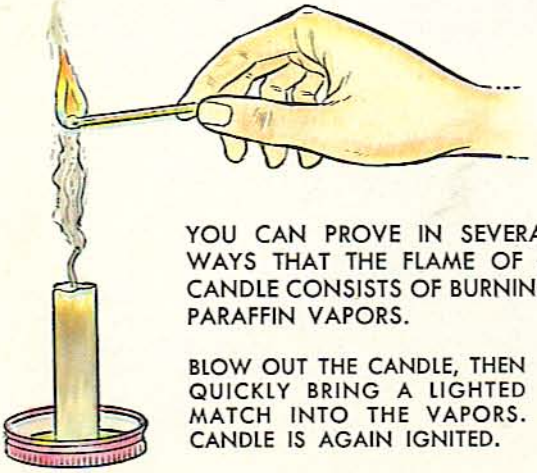

YOU CAN PROVE IN SEVERAL WAYS THAT THE FLAME OF A CANDLE CONSISTS OF BURNING PARAFFIN VAPORS.

BLOW OUT THE CANDLE, THEN QUICKLY BRING A LIGHTED MATCH INTO THE VAPORS. CANDLE IS AGAIN IGNITED.

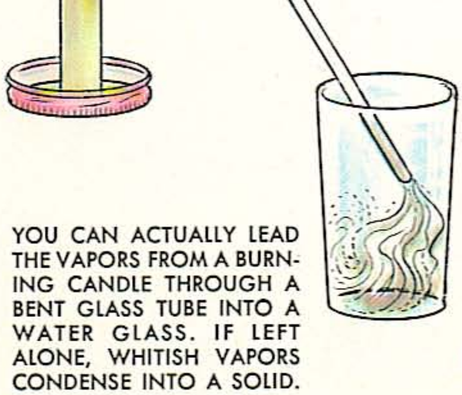

YOU CAN ACTUALLY LEAD THE VAPORS FROM A BURNING CANDLE THROUGH A BENT GLASS TUBE INTO A WATER GLASS. IF LEFT ALONE, WHITISH VAPORS CONDENSE INTO A SOLID.

MAKE A GAS WORKS FROM A CANDLE BY HOLDING A GLASS TUBE, DRAWN TO A POINT, IN THE FLAME AND LIGHTING THE VAPORS AT THE END OF TUBE.

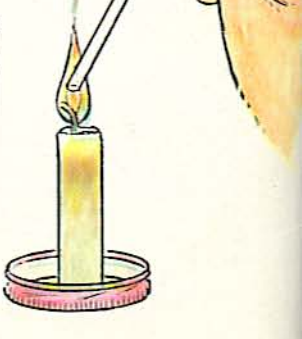

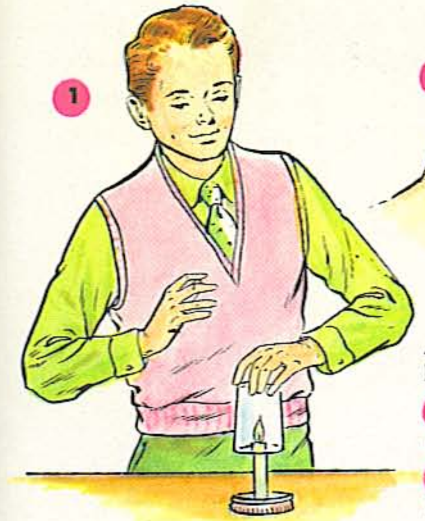

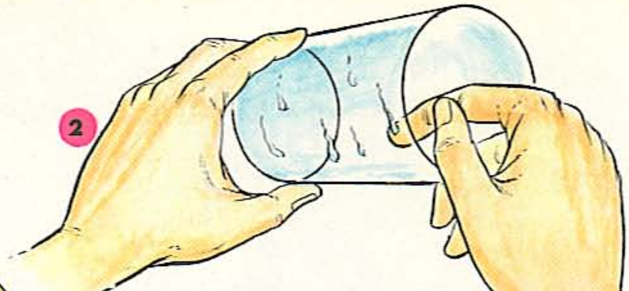

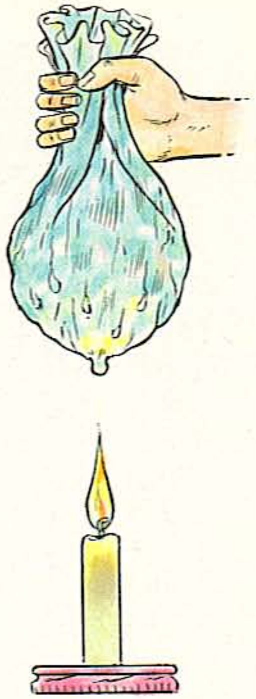

CANDLE CONTAINS HYDROGEN

A CANDLE FORMS WATER WHEN IT BURNS. ONLY HYDROGEN BURNING IN OXYGEN FORMS WATER.

① HOLD A COLD GLASS FOR A FEW MOMENTS OVER A BURNING CANDLE. DEW FORMS ON THE INSIDE.

② BY WIPING FINGER INSIDE THE GLASS YOU CAN MAKE DEW FLOW TOGETHER INTO WATER DROPS.

CRUSH A FEW ICE CUBES AND SPRINKLE THEM WITH SALT. WRAP IN ALUMINUM FOIL. HOLD OVER BURNING CANDLE. WATER DROPS WILL FORM ON THE OUTSIDE OF THE FOIL.

CANDLE CONTAINS CARBON

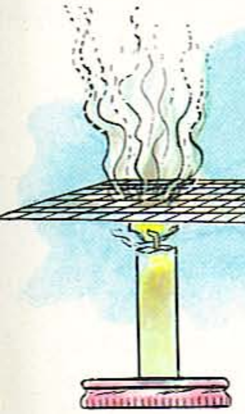

PLACE PIECE OF WIRE SCREENING OVER FLAME. SCREENING COOLS THE FLAME AND SOOT FORMS. THE SOOT IS CARBON.

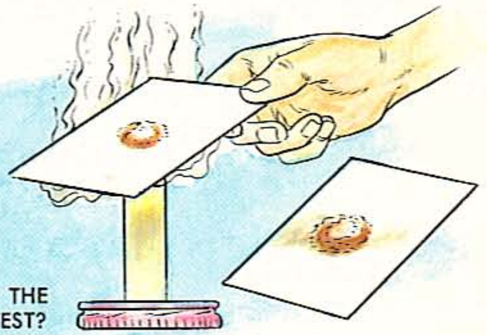

WHAT PART OF THE FLAME IS HOTTEST? TO FIND OUT, PUSH PIECE OF CARDBOARD SIDEWAYS INTO FLAME. OUTSIDE OF FLAME SCORCHES A SOOTY RING.

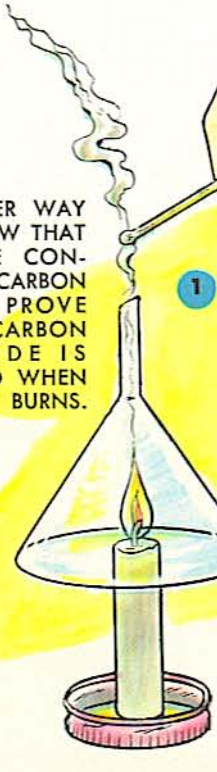

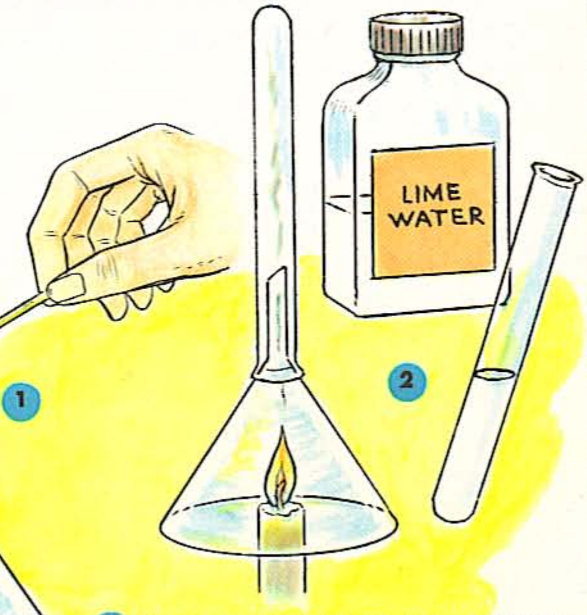
1
LIME WATER
2

ANOTHER WAY TO SHOW THAT CANDLE CONTAINS CARBON IS TO PROVE THAT CARBON DIOXIDE IS FORMED WHEN CANDLE BURNS.

① PLACE FUNNEL OVER FLAME. HOLD LIGHTED MATCH IN HOT AIR FROM FLAME. MATCH GOES OUT IN THIS AIR.

② PLACE TEST TUBE OVER FUNNEL AND COLLECT HOT AIR. POUR LIME WATER INTO TUBE AND SHAKE. LIME WATER GETS CLOUDY FROM CARBON DIOXIDE.

WHAT YOU FOUND OUT

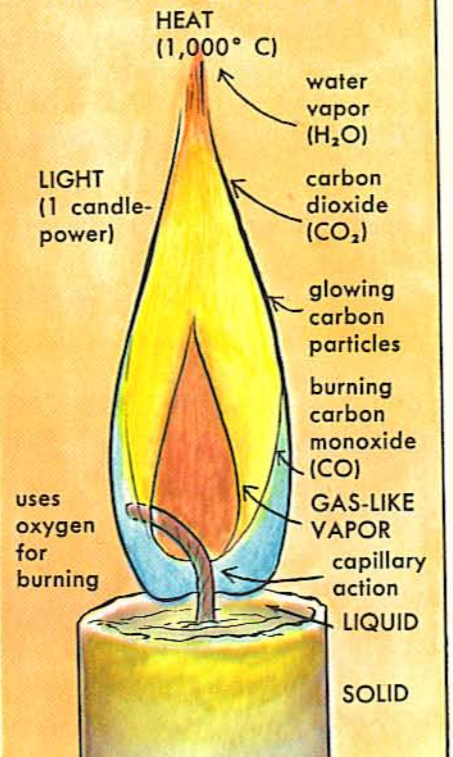
HEAT
(1,000° C)
water vapor (H_2O)
LIGHT (1 candle-power)
carbon dioxide (CO_2)
glowing carbon particles
burning carbon monoxide (CO)
uses oxygen for burning
GAS-LIKE VAPOR
capillary action
LIQUID
SOLID

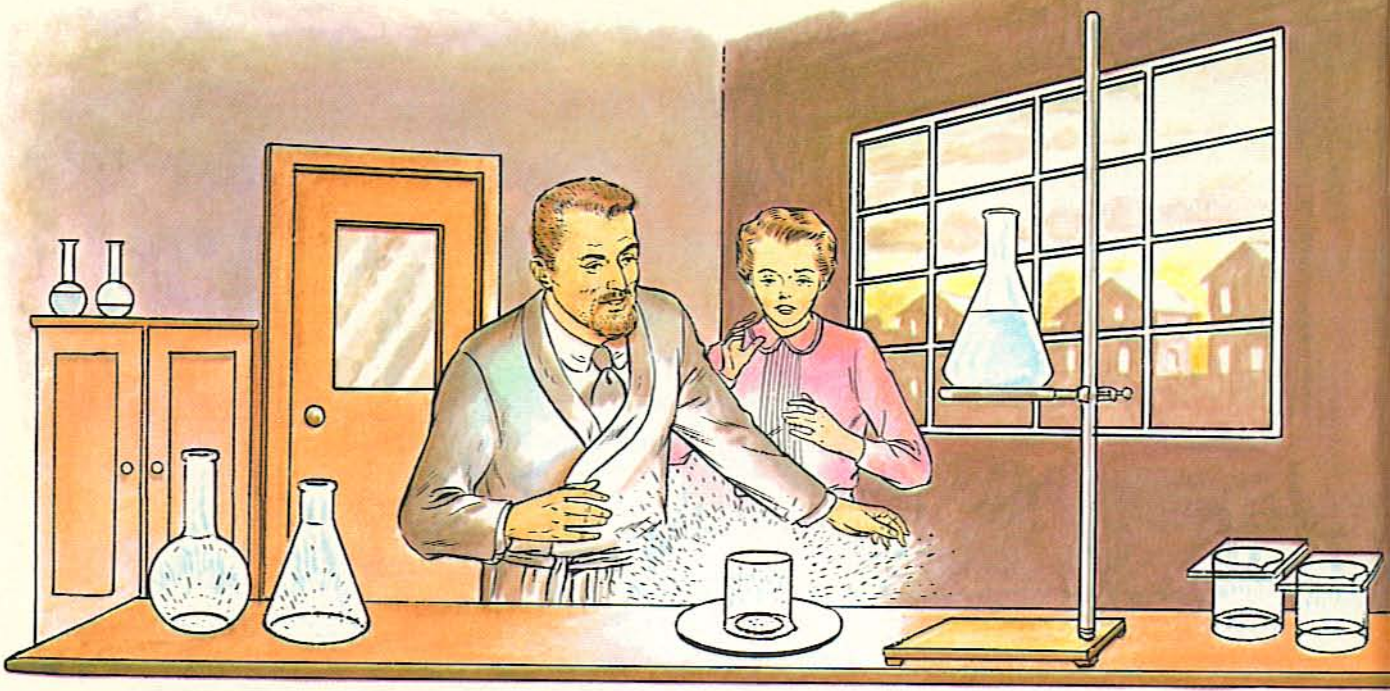

You—Scientist!

In 1896, a young Polish chemist, Marie Curie, and her French husband, Pierre, decided to find out why a certain uranium ore called pitchblende gave off rays that were much stronger than the uranium content of the ore could explain.

They secured a whole ton of powdered ore from a mine in northern Bohemia and set to work. First the powder had to be boiled with strong acids to extract the mysterious substance hidden in it. Then the solution had to be filtered and boiled down. What remained had to be purified by various processes which the Curies had to invent themselves.

After two years of back-breaking work they reached their goal. One night they went to the shed in which they had been working. They opened the door and stepped in without putting on the lights. All around them, the containers that held the solutions of the new substance glowed in the dark! They had discovered a new element — radium — a million times more active than uranium.

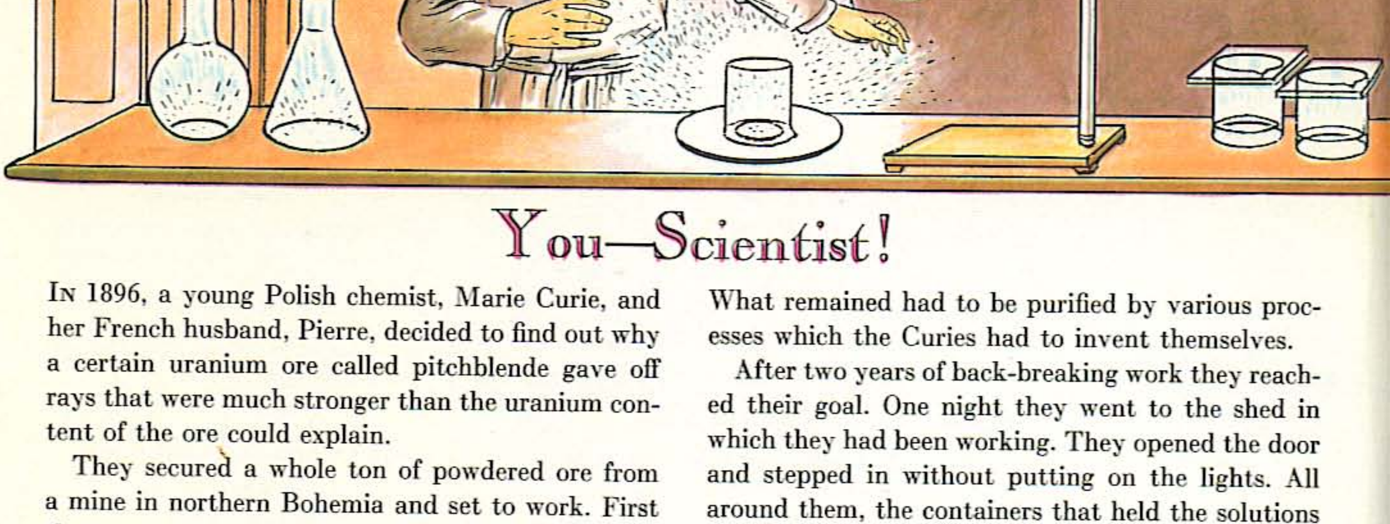
fold filter paper in half
fold in quarter
cut
open and place in funnel

SOLUTION—STIR WATER INTO THE MIXTURE OF SALT AND DIRT. THE WATER WILL DISSOLVE THE SALT BUT NOT THE DIRT. YOU NOW HAVE THE SALT IN "WATERY SOLUTION."

DECANTATION—LET DIRT-MIXED SALT SOLUTION STAND UNTIL MOST OF THE DIRT HAS SETTLED. THEN POUR OFF THE LIQUID. THIS PROCESS IS CALLED "DECANTATION."

FILTRATION 1—THE LIQUID IS PROBABLY STILL MURKY. TO CLEAR IT, IT NEEDS TO BE FILTERED BY LETTING IT RUN THROUGH FILTER PAPER (PAPER TOWELING WILL DO).

Why tell again the story of the discovery of radium? Because it contains all the features that show the nature of the true scientist.

Curiosity first. The Curies were curious about the mystery that lay in that greyish-black powder. They became obsessed with a desire to find out — not in the hope of gaining money or fame but to establish a scientific truth.

Before starting their work, the Curies gathered all the known facts about the material with which they were to work. To this knowledge they added their own imagination, figuring out the method they had to use to arrive at the result they were seeking.

For the next two years they literally slaved in the drafty shed that was their laboratory.

After they had made their discovery, the Curies made their method of extracting radium known to the world so that other scientists could check and test what they had done.

As an example of the scientific method the Curies used, let us follow in their footsteps — but with a much simpler problem:

1 MIX THOROUGHLY ONE TABLESPOON OF DIRT AND ONE TEASPOON OF ORDINARY TABLE SALT. NOW DECIDE THAT YOU WANT TO EXTRACT THE SALT FROM THIS MIXTURE AS EARNESTLY AS THE CURIES DECIDED TO EXTRACT THE MYSTERIOUS SUBSTANCE FROM PITCHBLENDE —WITH THE EXCEPTION THAT YOU KNOW WHAT YOU ARE AFTER.

2 GET THE FACTS TOGETHER. DIRT IS "DIRTY," SALT IS WHITE. DIRT PARTICLES ARE OF MANY DIFFERENT SHAPES, SALT CONSISTS OF TINY CUBES. DIRT DOES NOT DISSOLVE IN WATER, SALT DOES.

3 NEXT FIGURE OUT A SUITABLE WAY OF SEPARATING THE TWO SUBSTANCES. ON THE BASIS OF WHAT YOU KNOW YOU SHOULD BE ABLE TO SEPARATE THEM WITH A PAIR OF TINY TWEEZERS—BUT IT WOULD PROBABLY TAKE YOU A YEAR TO DO IT. OR YOU COULD DISSOLVE THE SALT IN WATER AND SEPARATE THE SOLUTION FROM THE INSOLUBLE DIRT.

4 YOU DECIDE ON THE SECOND WAY, USING THE STEPS SHOWN ON THE BOTTOM OF THESE PAGES. IN DOING THIS, YOU DO WHAT THE CURIES DID IN EXTRACTING RADIUM AND LEARN, IN THE PROCESS, THE IMPORTANT LABORATORY TECHNIQUES OF SOLUTION, DECANTATION, FILTRATION, EVAPORATION, AND CRYSTALLIZATION.

5 FINALLY, YOU CHECK THE RESULT. THE WHITE SUBSTANCE LEFT AFTER EVAPORATION SHOULD BE SALT—BUT IS IT? IT LOOKS LIKE SALT. IT TASTES LIKE SALT. BY CHEMICAL TESTS YOU CAN PROVE THAT IT *IS* SALT.

By using the same procedure in all other experiments in this book you are learning the methods that real scientists follow in their work — you are becoming a scientist yourself.

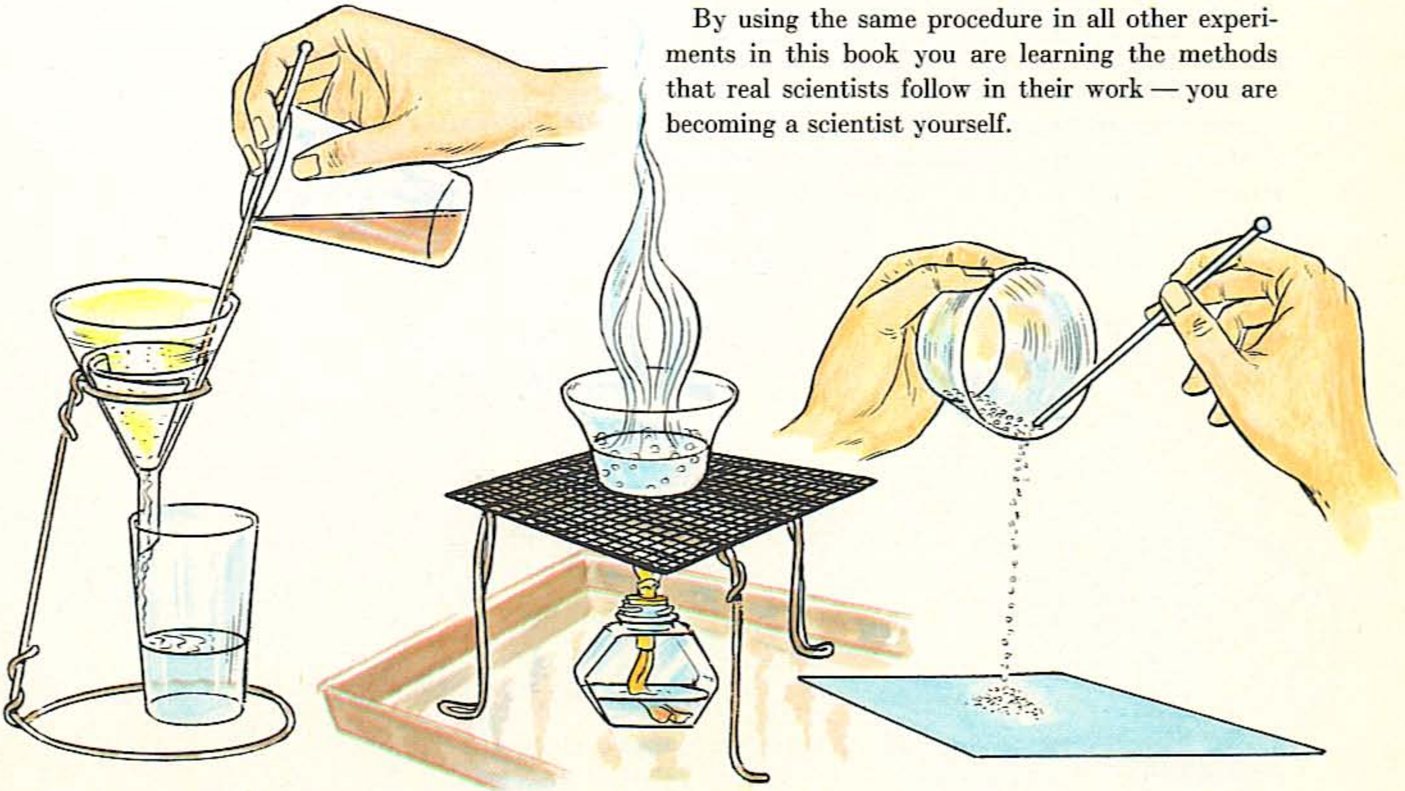

FILTRATION 2—FOLD FILTER PAPER AS SHOWN ON OPPOSITE PAGE AND FIT IT IN FUNNEL. POUR LIQUID ONTO FILTER PAPER. CLEARED LIQUID IS CALLED "FILTRATE."

EVAPORATION—THE FILTRATE CONTAINS THE SALT. THE SALT CAN NOW BE FREED BY REMOVING THE WATER BY BOILING IT AWAY. THIS IS KNOWN AS "EVAPORATION."

CRYSTALLIZATION—AS WATER IS REMOVED, THERE IS TOO LITTLE OF IT LEFT FOR THE SALT TO STAY IN SOLUTION. THE SALT MAKES ITS APPEARANCE AS TINY CRYSTALS.

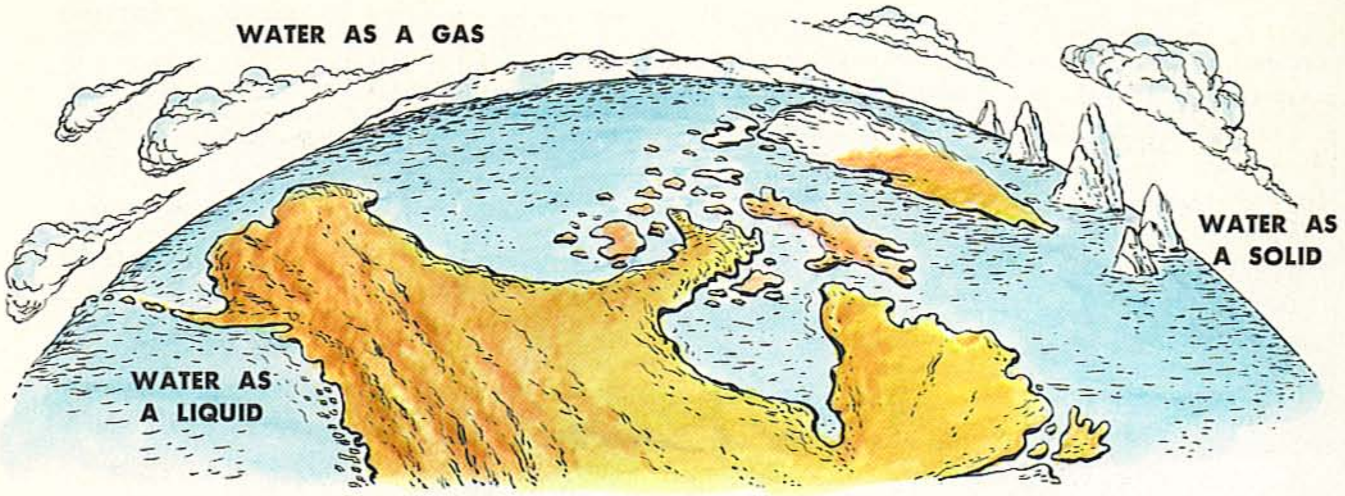

Elements, Compounds, and Mixtures

In all your experiments in chemistry, you will be dealing with "matter."

Matter is anything that takes up room and has weight (or "mass"). An iron bar is matter — it takes up room and is heavy, as you very well know. Water is matter — it takes up room when you fill a pail with it, and a full pail weighs plenty. The air around you is matter — it takes up lots of room; it may not seem very heavy, yet the earth's atmosphere presses down on every square inch of your body with a weight of almost fifteen pounds.

Matter has three distinct forms. Iron, for instance, is a SOLID. Water is a LIQUID. Air has the form of a GAS.

If you should take iron and divide it again and again until you couldn't divide it any further, every tiny particle would still be iron. A thing that consists of one kind of matter only is called an ELEMENT.

Take water, on the other hand. You will learn to break water up into two kinds of matter — each of them an element. A thing in which two or more elements are combined chemically is called a COMPOUND. In a compound the proportions of the different elements that make it up are always exactly the same.

Air also consists of different kinds of matter, but they are not combined chemically — they are simply mixed together. When you make a MIXTURE, you can mix the ingredients together in any proportions that suit you.

TWO ELEMENTS AND A MIXTURE

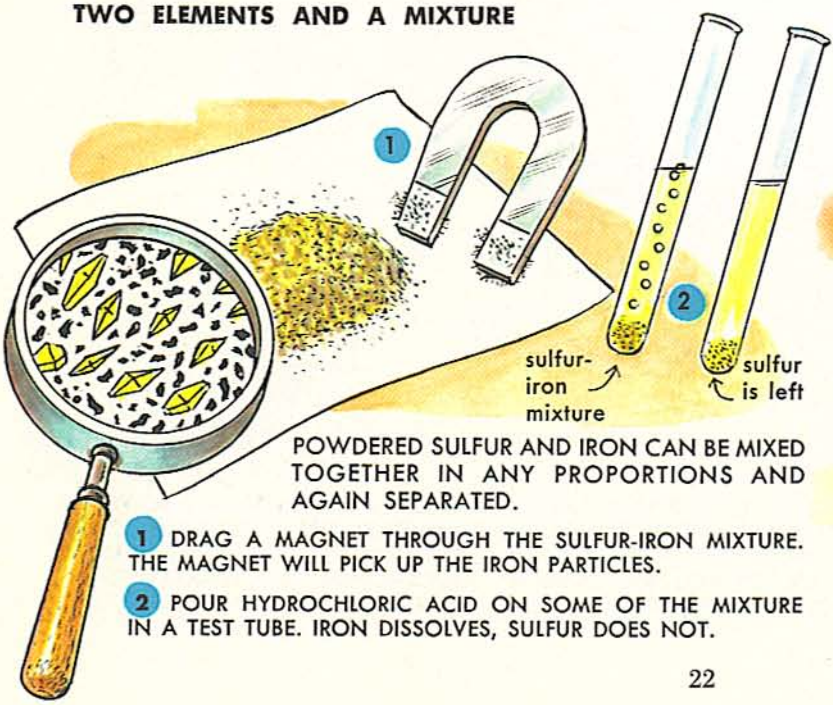

POWDERED SULFUR AND IRON CAN BE MIXED TOGETHER IN ANY PROPORTIONS AND AGAIN SEPARATED.

① DRAG A MAGNET THROUGH THE SULFUR-IRON MIXTURE. THE MAGNET WILL PICK UP THE IRON PARTICLES.

② POUR HYDROCHLORIC ACID ON SOME OF THE MIXTURE IN A TEST TUBE. IRON DISSOLVES, SULFUR DOES NOT.

MAKING A COMPOUND

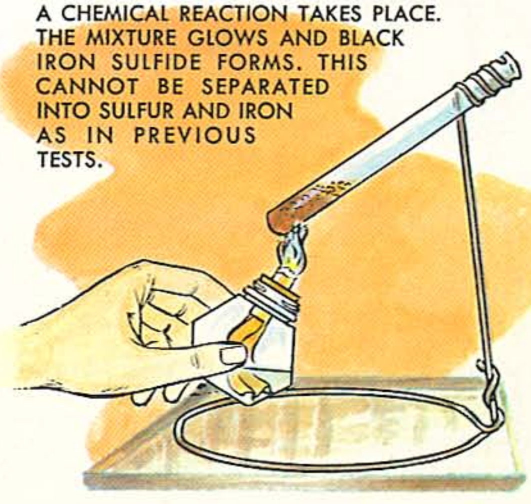

MIX TOGETHER 2 g OF FLOWERS OF SULFUR AND 3.5 g OF IRON FILINGS. PLACE MIXTURE IN A DAMAGED TEST TUBE. HEAT. SHORTLY A CHEMICAL REACTION TAKES PLACE. THE MIXTURE GLOWS AND BLACK IRON SULFIDE FORMS. THIS CANNOT BE SEPARATED INTO SULFUR AND IRON AS IN PREVIOUS TESTS.

ELEMENTS ARE SUBSTANCES THAT CONSIST OF ONE KIND OF MATTER ONLY. THEY CAN BE DIVIDED INTO METALS, METALLOIDS (METAL-LIKE), NONMETALS. SEVERAL OF THE NONMETALS ARE GASES.

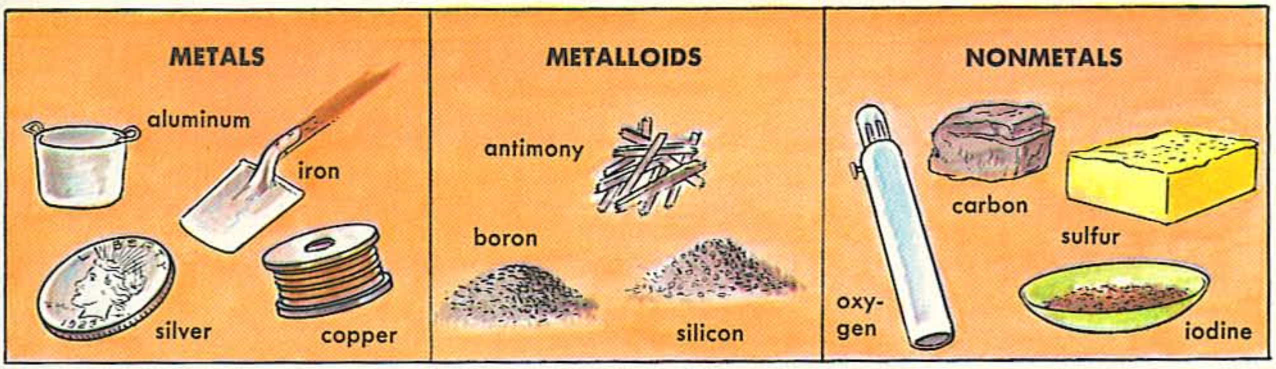
METALS
aluminum
iron
silver
copper
METALLOIDS
antimony
boron
silicon
NONMETALS
carbon
sulfur
oxygen
iodine

COMPOUNDS—INORGANIC. ALL COMPOUNDS CONSIST OF TWO OR MORE ELEMENTS. INORGANIC COMPOUNDS (WITH A FEW EXCEPTIONS) ARE THOSE THAT DO NOT CONTAIN THE ELEMENT CARBON.

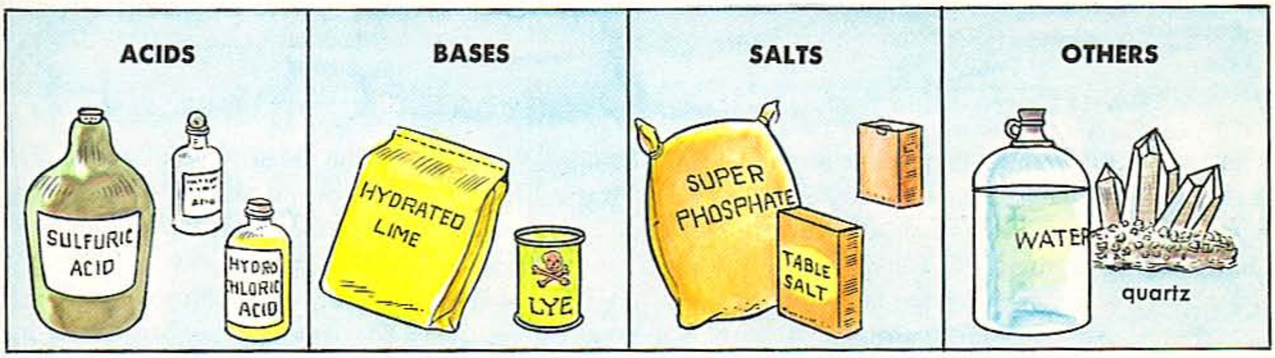
ACIDS
SULFURIC ACID
HYDROCHLORIC ACID
BASES
HYDRATED LIME
LYE
SALTS
SUPER PHOSPHATE
TABLE SALT
OTHERS
WATER
quartz

CARBON COMPOUNDS—ORGANIC. ORIGINALLY, COMPOUNDS MADE BY LIVING THINGS (PLANTS AND ANIMALS) WERE CALLED "ORGANIC." TODAY ORGANIC CHEMISTRY COVERS THE CARBON COMPOUNDS.

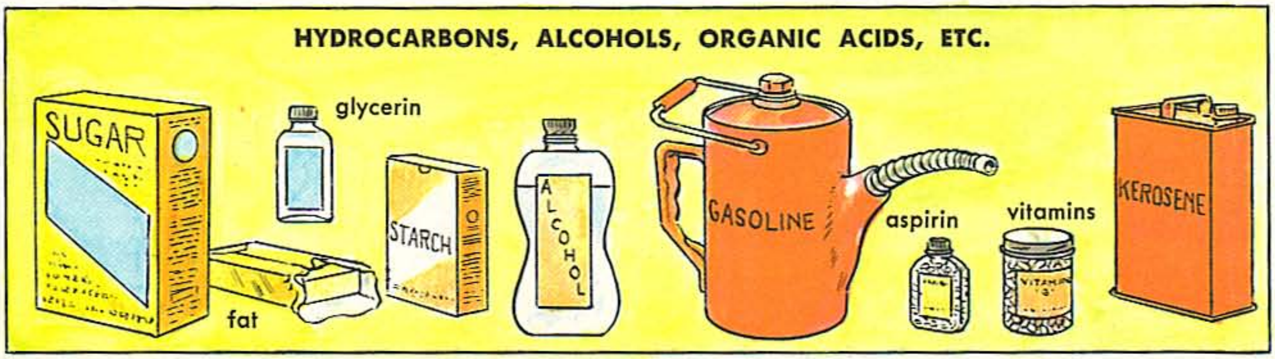
HYDROCARBONS, ALCOHOLS, ORGANIC ACIDS, ETC.
SUGAR
glycerin
fat
STARCH
ALCOHOL
GASOLINE
aspirin
vitamins
KEROSENE

MIXTURES CAN CONSIST OF ELEMENTS OR COMPOUNDS. SOME MIXTURES ARE COARSE. SOME (COLLOIDS) CONTAIN TINY PARTICLES. STILL OTHERS (SOLUTIONS) ARE OF SAME STRUCTURE THROUGHOUT.

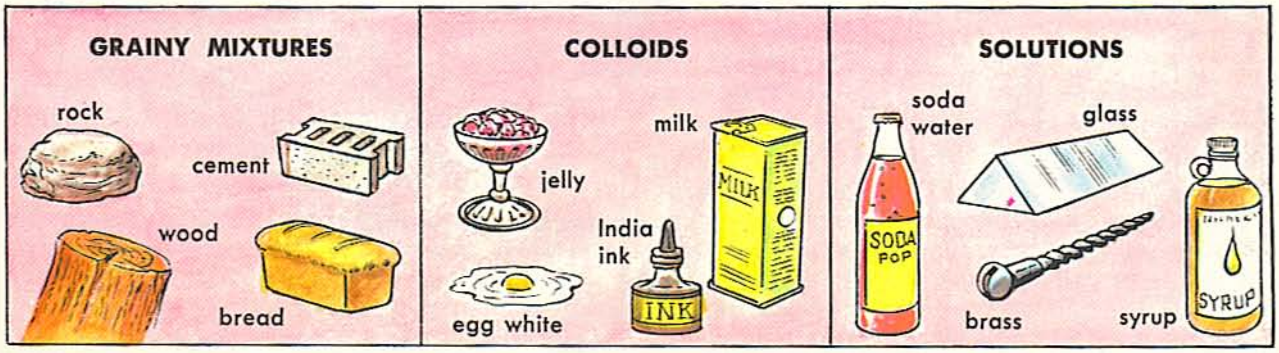
GRAINY MIXTURES
rock
cement
wood
bread
COLLOIDS
jelly
milk
MILK
India ink
INK
egg white
SOLUTIONS
soda water
SODA POP
glass
brass
syrup
SYRUP

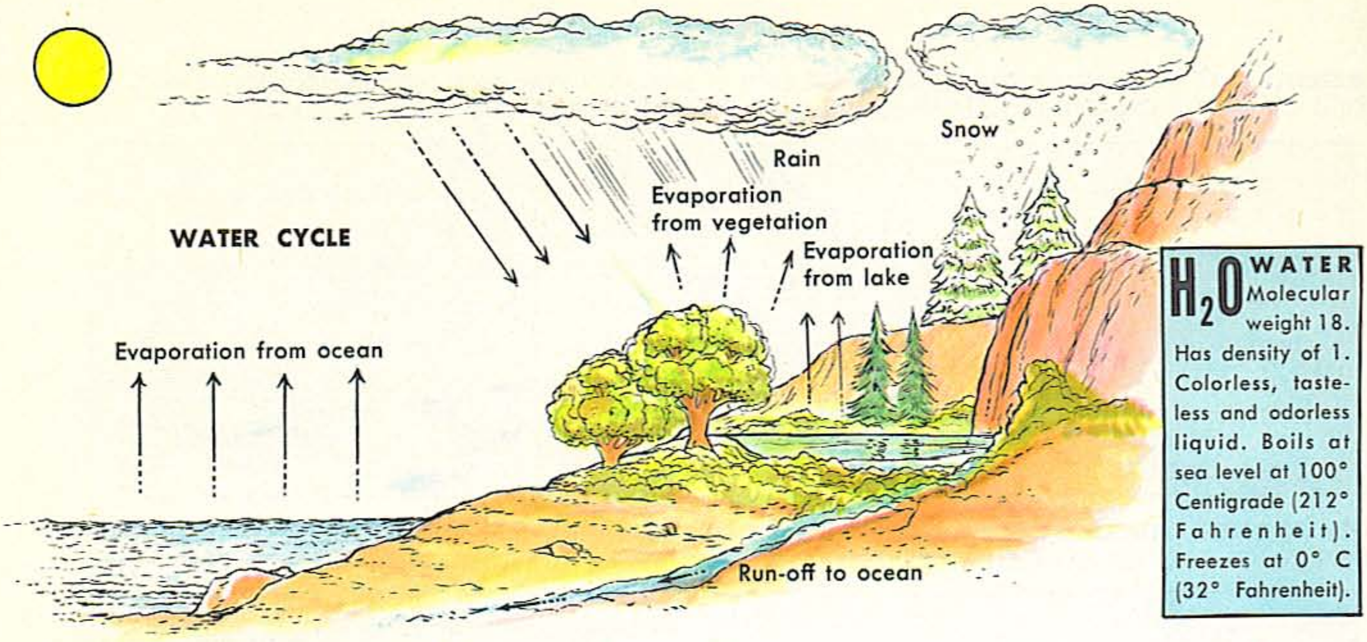

H_2O WATER Molecular weight 18. Has density of 1. Colorless, tasteless and odorless liquid. Boils at sea level at 100° Centigrade (212° Fahrenheit). Freezes at 0° C (32° Fahrenheit).

Water—Our Most Important Compound

Yes, water is the most important of all chemical compounds. Without it, there would be no life — all human beings and all animals would thirst to death, and all plant life would wilt and die.

Fortunately, water is also the most common compound in the world. Almost three quarters of the earth's surface is covered by water. This water is forever traveling. It is turned into invisible vapor by evaporation from oceans and lakes and growing things. When cooled, the vapor forms clouds of tiny water drops. Further cooling makes the drops fall to earth as rain or snow that fill up rivers and lakes and oceans and continue the water cycle.

Chemists use nature's method to produce chemically pure water. They turn ordinary tap water into steam by boiling, then turn the steam back into water by cooling. This process is called distillation and the water is called distilled water.

WATER AS A SOLVENT

THE MOST IMPORTANT FUNCTION OF WATER IN CHEMICAL EXPERIMENTS IS AS A SOLVENT—THAT IS, A LIQUID IN WHICH CHEMICALS MAY BE DISSOLVED. FIND OUT BY AN EASY EXPERIMENT WHETHER HEATING THE WATER HELPS IN DISSOLVING A CHEMICAL.

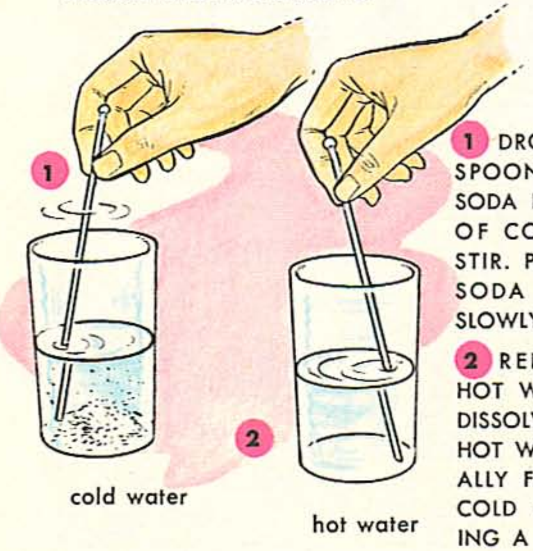

① DROP 1 TABLESPOON WASHING SODA IN ½ GLASS OF COLD WATER. STIR. PART OF THE SODA DISSOLVES SLOWLY.

② REPEAT WITH HOT WATER. SODA DISSOLVES QUICKLY. HOT WATER IS USUALLY FASTER THAN COLD FOR PREPARING A SOLUTION.

WATER AS A CATALYST

WATER HELPS BRING ABOUT MANY CHEMICAL REACTIONS WITHOUT ITSELF ENTERING INTO THEM. A SUBSTANCE THAT ACTS THIS WAY IS CALLED A CATALYST.

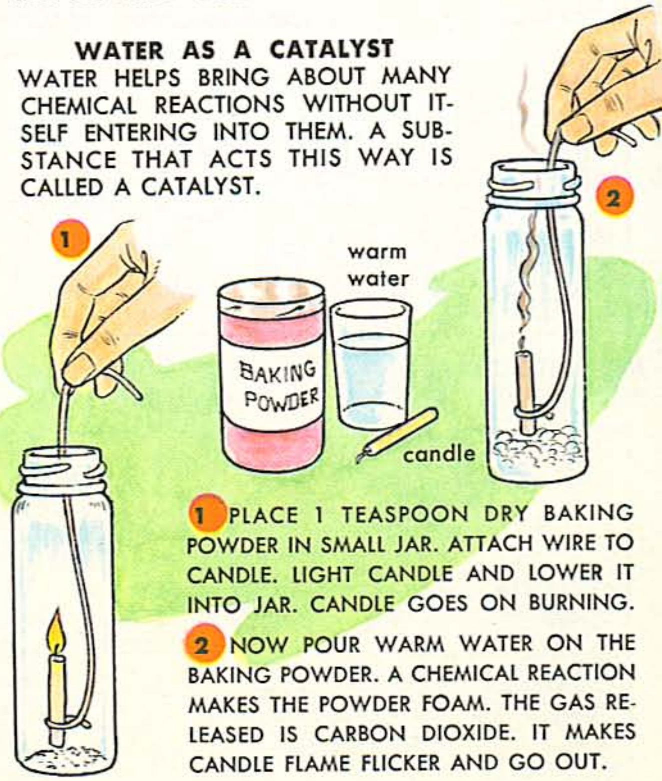

① PLACE 1 TEASPOON DRY BAKING POWDER IN SMALL JAR. ATTACH WIRE TO CANDLE. LIGHT CANDLE AND LOWER IT INTO JAR. CANDLE GOES ON BURNING.

② NOW POUR WARM WATER ON THE BAKING POWDER. A CHEMICAL REACTION MAKES THE POWDER FOAM. THE GAS RELEASED IS CARBON DIOXIDE. IT MAKES CANDLE FLAME FLICKER AND GO OUT.

ELECTROLYSIS OF WATER

ELECTRICITY CAN BE USED TO BREAK WATER APART INTO THE TWO ELEMENTS OF WHICH IT CONSISTS —THE GASES HYDROGEN AND OXYGEN.

YOU CAN GET THE REQUIRED ELECTRICITY FROM THREE OR FOUR ORDINARY FLASHLIGHT BATTERIES. YOU WILL ALSO NEED TWO PIECES OF INSULATED COPPER WIRE AND TWO "ELECTRODES" MADE FROM CARBON RODS.

Making Electrodes

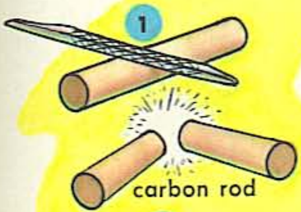

1 SCORE THE MIDDLE OF THE CARBON ROD FROM AN OLD FLASHLIGHT BATTERY, USING A FILE. BREAK THE ROD INTO TWO PIECES.

2 BARE THE WIRE FOR 2" AT EACH END OF TWO 18" LENGTHS OF INSULATED WIRE. TIE ONE BARED WIRE AROUND END OF EACH OF CARBON ROD HALVES.

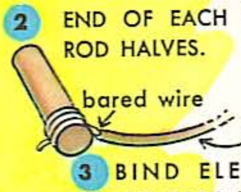

3 BIND ELECTRICIAN'S TAPE FIRMLY AROUND CARBON RODS SO THAT NO WIRE IS EXPOSED.

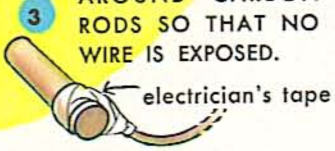

Setting up Electrolysis

WATER IS A POOR CONDUCTOR OF ELECTRICITY—SO YOU DISSOLVE 1 TABLESPOON OF WASHING SODA IN 1 PINT OF WATER AND FILL A WATER GLASS AND TWO TEST TUBES WITH THIS SOLUTION. THEN SET UP THE APPARATUS AS SHOWN AT RIGHT.

MATERIALS FOR EXPERIMENTS

AN ORDINARY FLASHLIGHT BATTERY WILL GIVE YOU MATERIALS YOU NEED FOR EXPERIMENTS ON THIS AND SEVERAL FOLLOWING PAGES.

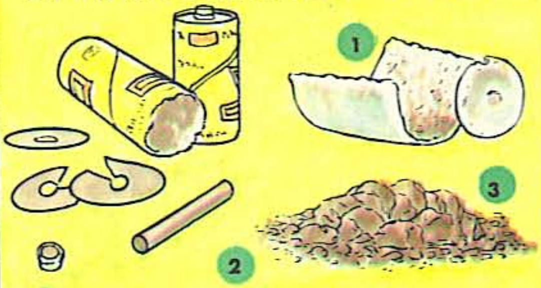

1 OPEN UP BATTERY CASE CAREFULLY WITH A CAN OPENER AND CLEAN THE ZINC CASING.

2 SCRAPE CARBON ROD CLEAN WITH DULL KNIFE.

3 DRY OUT THE MOIST BLACK POWDER, WHICH IS MOSTLY MANGANESE DIOXIDE. STORE IN JAR. THROW REMAINING PARTS OF THE BATTERY AWAY.

Performing the Electrolysis

1 SLIP THE TOP OF A CARBON ELECTRODE UP INTO EACH OF THE TWO TEST TUBES.

2 BIND THREE—OR, BETTER, FOUR—FLASHLIGHT BATTERIES TOGETHER WITH ADHESIVE TAPE, TOP OF ONE TOUCHING BOTTOM OF THE NEXT.

3 WITH ADHESIVE TAPE FASTEN THE BARED END OF THE WIRE LEADING FROM ONE CARBON ROD ELECTRODE TO THE TOP OF THE FIRST BATTERY.

4 TAPE THE BARED END OF THE WIRE FROM THE OTHER ELECTRODE TO BOTTOM OF LAST BATTERY.

AS SOON AS CONNECTION IS MADE, AIR BUBBLES BEGIN TO COLLECT IN THE TWO TEST TUBES—ABOUT TWICE AS FAST IN ONE AS IN THE OTHER.

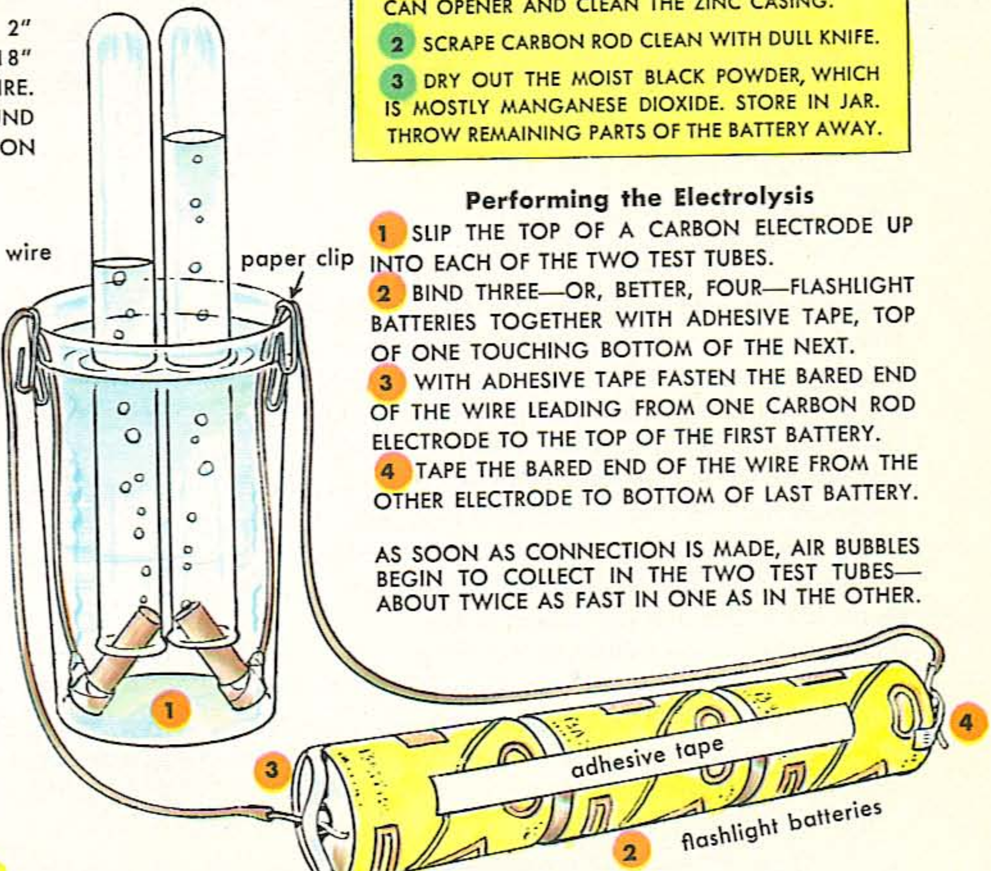

TEST FOR HYDROGEN

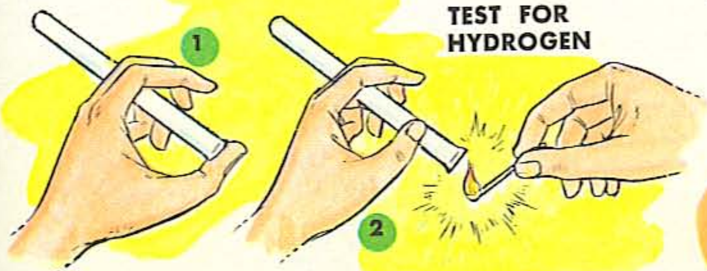

1 WITH YOUR THUMB, CLOSE THE MOUTH OF THE TEST TUBE FIRST FILLED WITH GAS. LIFT THE TUBE OUT OF THE WATER, MOUTH DOWN.

2 BRING LIGHTED MATCH TO THE MOUTH OF THE TUBE. CONTENTS BURN WITH A SOFT "POP!" THIS IS THE TEST FOR HYDROGEN.

TEST FOR OXYGEN

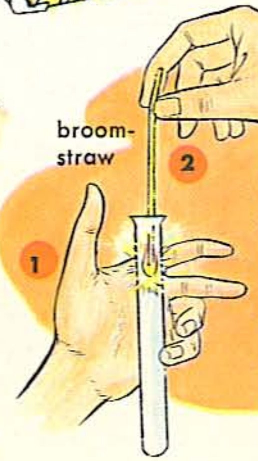

1 WHEN SECOND TUBE IS FULL OF GAS, CLOSE ITS MOUTH WITH YOUR THUMB. LIFT THE TUBE OUT OF THE WATER WITH MOUTH UP.

2 LIGHT A BROOMSTRAW. BLOW OUT THE FLAME. BRING THE GLOWING END DOWN IN THE TEST TUBE. GLOWING EMBER BURSTS INTO BRIGHT FLAME. THIS IS TEST FOR OXYGEN.

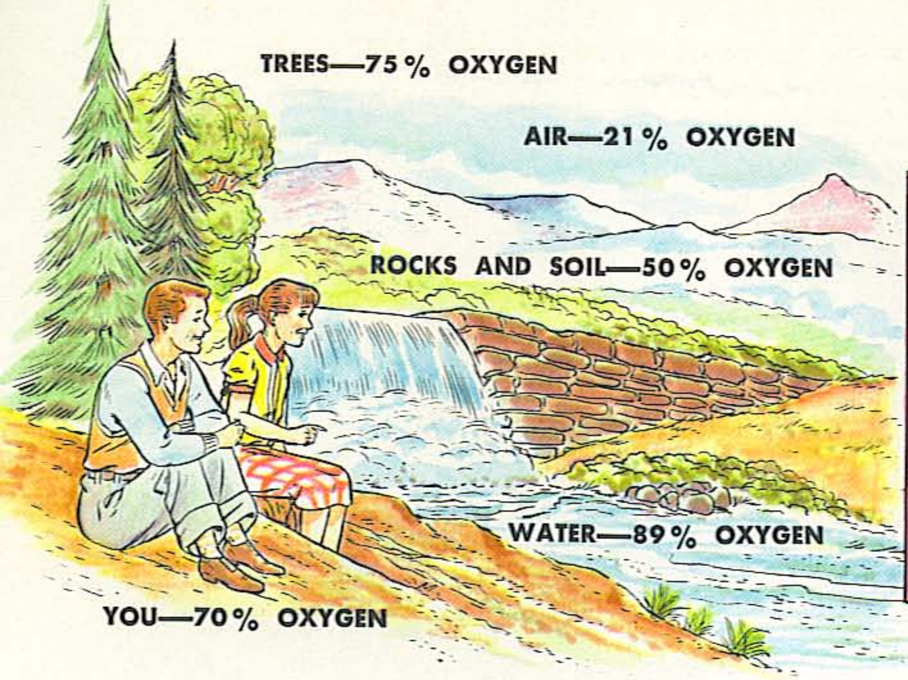

O OXYGEN Element 8. Atomic wt. 16. Colorless, odorless gas, supporting combustion (burning). 1.1 weight of air. Slightly soluble in water—3 volumes in 100 volumes at 20° C. Oxygen is the most common element on earth.

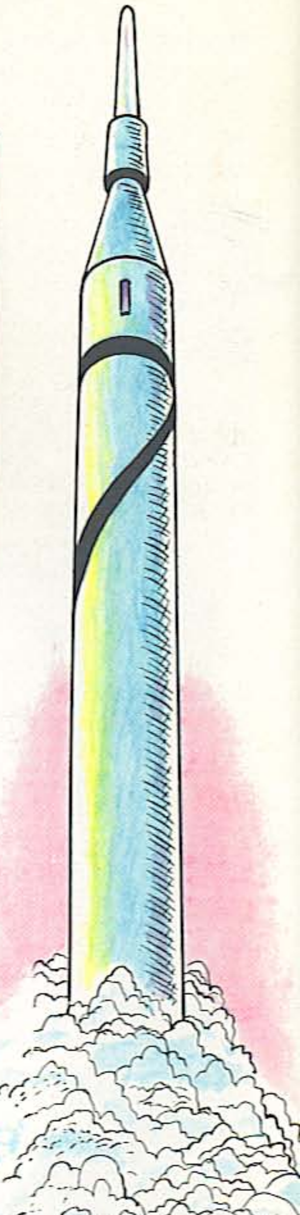

Oxygen—The Breath of Life

If you could hold your breath for a few minutes so that no air could get into your lungs, you would die.

For thousands of years, people have known that no human being can live without air. But it was not until Karl Scheele, a Swedish chemist, in 1772, and Joseph Priestley, an Englishman, in 1774, discovered and described oxygen that people knew that it is the oxygen in the air that is important to life.

Both of these scientists discovered that things burn more fiercely in pure oxygen than they do in the mixture of oxygen and other gases called "air."

In the lab, oxygen is produced by driving it out of certain oxygen-containing compounds. A good one to use in the home lab is hydrogen peroxide. You can get it at a drug store in a 3% solution. Hydrogen peroxide is related to water.

Water, as you know, consists of 2 parts of hydrogen to 1 part of oxygen. You could write it: Hydrogen 2 — Oxygen 1. That's pretty much what chemists do — except that they abbreviate the names to initials, use small numbers, and don't bother about the number 1. The formula becomes H_2O.

Hydrogen peroxide contains 2 parts of hydrogen to every 2 parts of oxygen. How would you write it in chemical language?

H_2O_2? You're perfectly right!

H_2O_2 becomes water (H_2O) and gives off oxygen (O) when you throw a catalyst into it. For a catalyst, you can use the manganese dioxide from an old flashlight battery (page 25).

IT'S A LONG STEP FROM THE DISCOVERY OF OXYGEN IN 1772 TO ITS PRESENT-DAY USE IN INDUSTRY AND HOSPITALS, AIRPLANES AND SPACE SHIPS, AND FOR SENDING SATELLITES INTO ORBIT.

THE ATMOSPHERE CONTAINS OXYGEN

1 FASTEN A SMALL CANDLE TO MIDDLE OF PIE PLATE WITH CANDLE DRIPPINGS. FILL PIE PLATE WITH WATER. LIGHT CANDLE. PLACE AN EMPTY JAR OVER CANDLE.

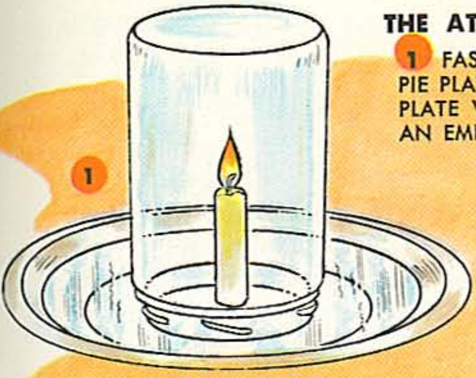

2 A MOMENT LATER, CANDLE GOES OUT. WATER RISES IN JAR TO REPLACE OXYGEN USED.

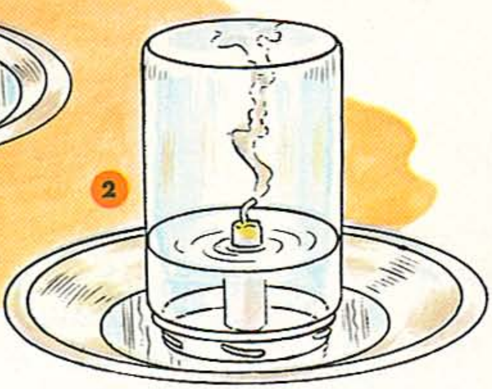

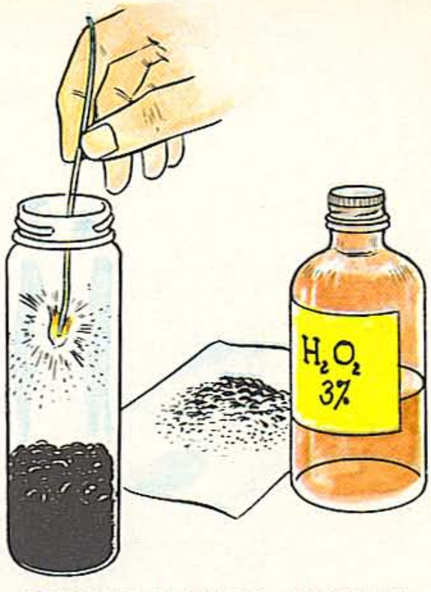

MAKING A SMALL AMOUNT OF OXYGEN

FILL JAR ¼ FULL OF 3% HYDROGEN PEROXIDE. ADD PINCH OF MANGANESE DIOXIDE FROM FLASHLIGHT BATTERY (SEE PAGE 25). TEST FOR OXYGEN WITH GLOWING BROOMSTRAW. EMBER GLOWS BRIGHTER AND MAY BURST INTO FLAME.

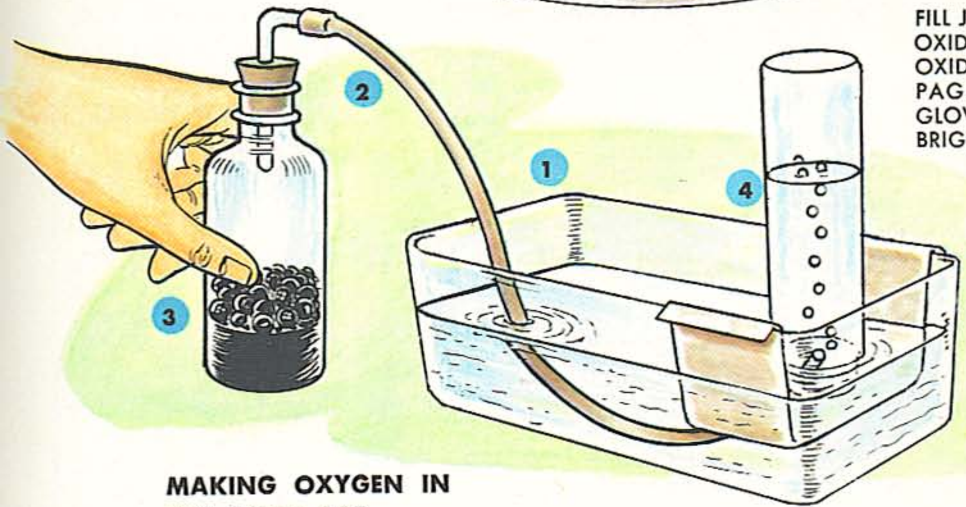

MAKING OXYGEN IN THE HOME LAB

1 TO COLLECT OXYGEN, YOU NEED A "PNEUMATIC TROUGH." THIS IS A DEEP, WATER-FILLED TRAY WITH METAL "BRIDGE."

2 FIT BOTTLE WITH STOPPER WITH L-SHAPED GLASS TUBE AND RUBBER TUBE LONG ENOUGH TO REACH HOLE OF BRIDGE.

3 FILL BOTTLE ¼ FULL OF 3% HYDROGEN PEROXIDE. ADD ⅛ TEASPOON OF MANGANESE DIOXIDE. PUT THE STOPPER IN.

4 FILL JAR WITH WATER AND PLACE IT UPSIDE DOWN ON THE BRIDGE IN SUCH A WAY THAT THE OXYGEN BUBBLES INTO IT AND FILLS IT BY FORCING OUT AND REPLACING THE WATER

5 WHEN JAR IS FULL OF OXYGEN, SLIDE A GLASS PLATE UNDER OPENING (OR PUT STOPPER IN IT). TURN JAR RIGHT SIDE UP—QUICKLY, TO PREVENT THE OXYGEN FROM ESCAPING.

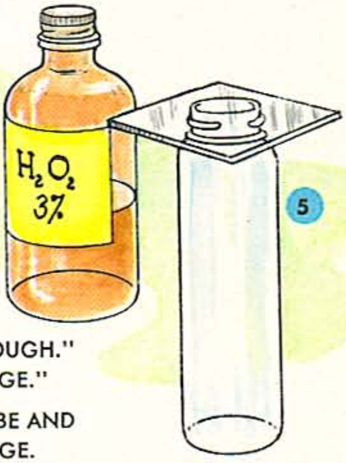

oxygen is slightly heavier than air —so keep mouth of jar up

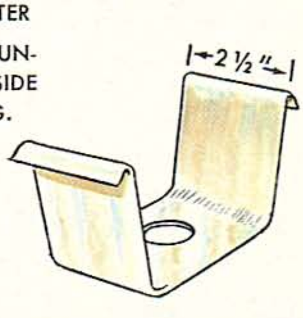

"BRIDGE" FOR "PNEUMATIC TROUGH" MADE FROM 2½" STRIP OF TIN CAN.

MANY MATERIALS BURN IN OXYGEN

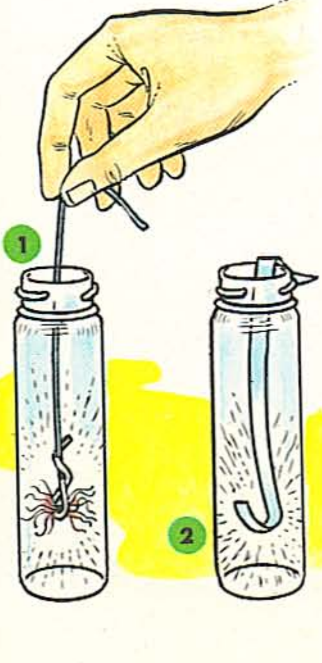

1 ATTACH TUFT OF STEEL WOOL TO WIRE. HEAT TO RED HEAT OVER ALCOHOL BURNER. LOWER INTO JAR OF OXYGEN. IRON BURSTS INTO FLAME.

2 PLACE SMALL PIECE OF SULFUR IN CROOK OF BENT STRIP OF TIN CUT FROM CAN. IGNITE SULFUR WITH MATCH. LOWER INTO JAR OF OXYGEN. SULFUR BURNS WITH A BRILLIANT, BLUE LIGHT.

Hydrogen—Lightest of All

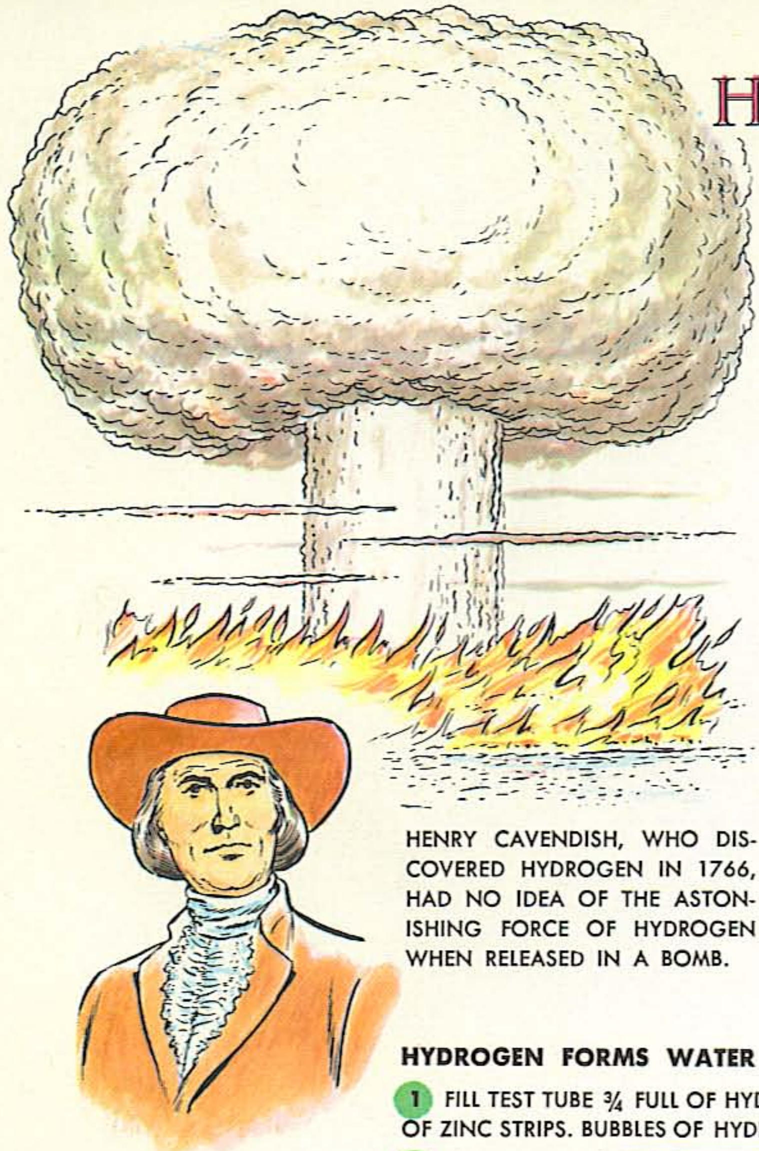

HENRY CAVENDISH, WHO DISCOVERED HYDROGEN IN 1766, HAD NO IDEA OF THE ASTONISHING FORCE OF HYDROGEN WHEN RELEASED IN A BOMB.

HYDROGEN is the lightest element in existence—1/14 the weight of air. For this reason one of its early uses was for filling balloons. The first man-carrying gas balloon was sent up by the Frenchman, Jacques Charles, in 1783. The danger of using an explosive gas for this purpose was demonstrated in 1937 in the *Hindenburg* disaster, when the hydrogen-filled Zeppelin dirigible exploded on arriving at Lakehurst, New Jersey, after a trip across the Atlantic Ocean. Thirty-six people lost their lives.

Hydrogen is one of the most important of all the elements. It is found in all living things — your own body is approximately 10 per cent hydrogen. Water, as you know, is part hydrogen. So is the food you eat, the milk you drink, the clothes you wear, and such common, everyday things as gasoline and fuel oil and cooking gas.

In the home lab, you can make hydrogen by adding strips of zinc from a flashlight battery to hydrochloric acid which consists of hydrogen (H) and another gas called chlorine (Cl). The zinc forms a compound ($ZnCl_2$) with the chlorine and sets the hydrogen free (H_2).

HYDROGEN FORMS WATER WHEN IT BURNS

1 FILL TEST TUBE ¾ FULL OF HYDRO-CHLORIC ACID. ADD A COUPLE OF ZINC STRIPS. BUBBLES OF HYDROGEN FORM IMMEDIATELY.

2 CLOSE TEST TUBE WITH RUBBER STOPPER WITH GLASS TUBE DRAWN TO JET POINT. COVER APPARATUS WITH A TOWEL.

3 PLACE EMPTY TEST TUBE OVER GLASS TUBE. AFTER 1 MINUTE, TEST THIS TUBE FOR HYDROGEN WITH LIGHTED MATCH. IF TUBE "BARKS," PUT IT BACK. AFTER ANOTHER MINUTE, TRY AGAIN. WHEN SOFT "POP" TELLS YOU GAS IS PURE, LIGHT JET.

4 HOLD A COLD GLASS OVER HYDROGEN FLAME. DEW COVERING THE INSIDE OF THE GLASS SHOWS THAT WATER IS FORMING.

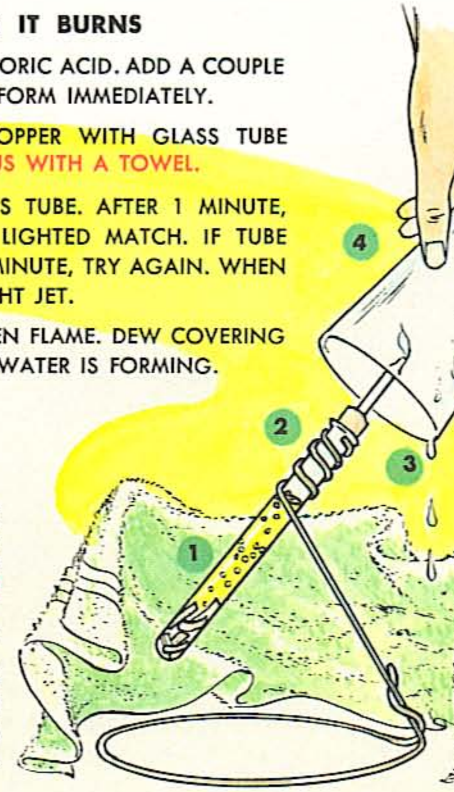

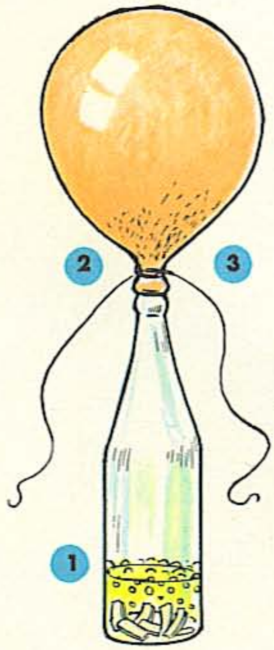

HYDROGEN IS LIGHTEST GAS KNOWN

1 FILL A POP BOTTLE ¼ FULL OF HALF-AND-HALF MIXTURE OF HYDROCHLORIC ACID AND WATER. DROP IN HALF A DOZEN ZINC STRIPS. LET NO FLAME COME NEAR!

2 FIT BALLOON ON MOUTH OF BOTTLE.

3 WHEN BALLOON IS INFLATED, TIE OPENING WITH STRING AND REMOVE FROM BOTTLE. IF PERMITTED, BALLOON WILL RISE TO CEILING INDOORS. OUTDOORS, IT WILL SOAR UP IN THE SKY.

MAKING HYDROGEN IN THE LAB

1 MAKE THE SAFETY GAS GENERATOR DESCRIBED ON PAGE 12.

2 SET UP PNEUMATIC TROUGH AS ON PAGE 27.

3 FILL BOTTLE **A** ⅔ FULL OF MIXTURE OF EQUAL PARTS OF HYDROCHLORIC ACID AND WATER.

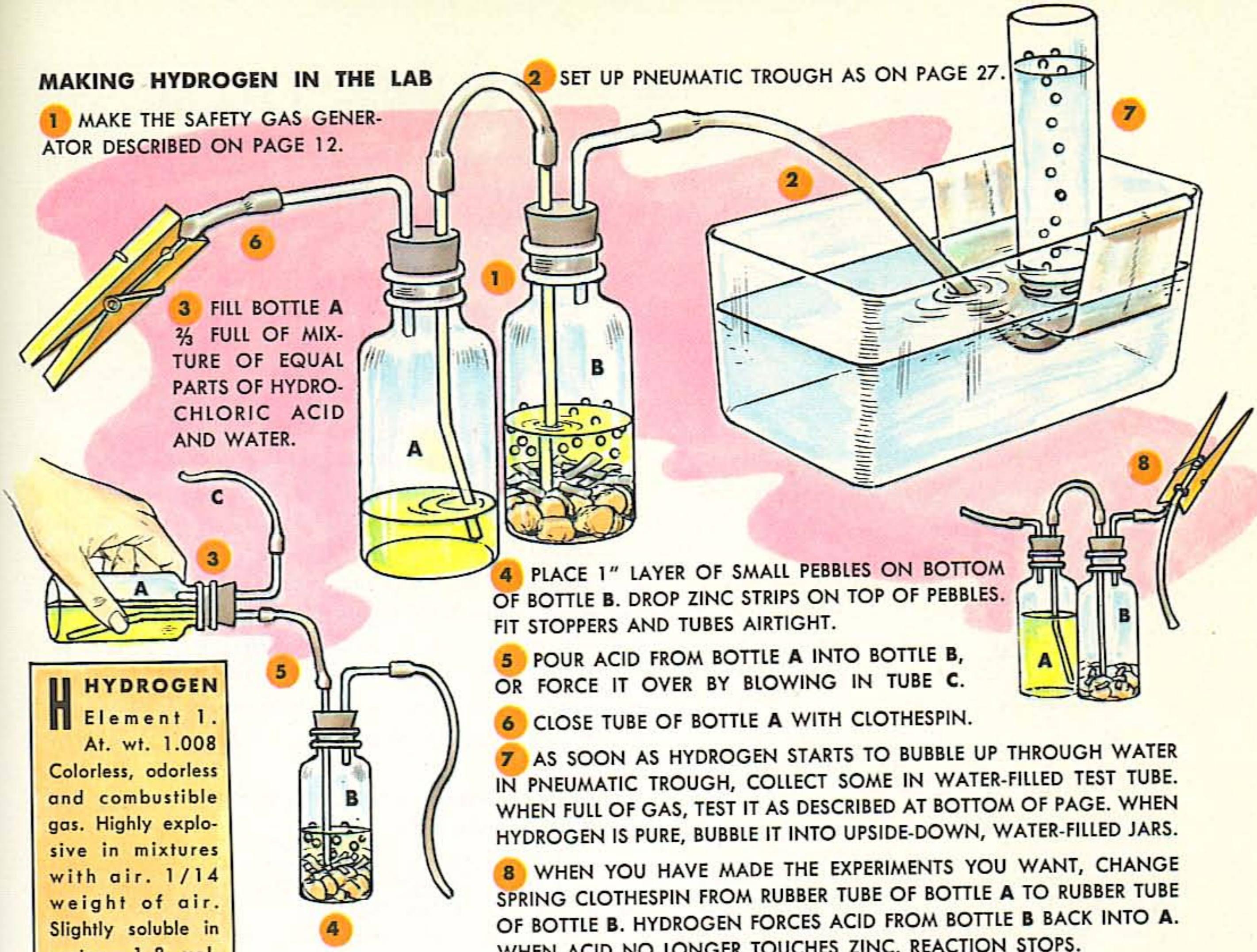

4 PLACE 1" LAYER OF SMALL PEBBLES ON BOTTOM OF BOTTLE **B**. DROP ZINC STRIPS ON TOP OF PEBBLES. FIT STOPPERS AND TUBES AIRTIGHT.

5 POUR ACID FROM BOTTLE **A** INTO BOTTLE **B**, OR FORCE IT OVER BY BLOWING IN TUBE **C**.

6 CLOSE TUBE OF BOTTLE **A** WITH CLOTHESPIN.

7 AS SOON AS HYDROGEN STARTS TO BUBBLE UP THROUGH WATER IN PNEUMATIC TROUGH, COLLECT SOME IN WATER-FILLED TEST TUBE. WHEN FULL OF GAS, TEST IT AS DESCRIBED AT BOTTOM OF PAGE. WHEN HYDROGEN IS PURE, BUBBLE IT INTO UPSIDE-DOWN, WATER-FILLED JARS.

8 WHEN YOU HAVE MADE THE EXPERIMENTS YOU WANT, CHANGE SPRING CLOTHESPIN FROM RUBBER TUBE OF BOTTLE **A** TO RUBBER TUBE OF BOTTLE **B**. HYDROGEN FORCES ACID FROM BOTTLE **B** BACK INTO **A**. WHEN ACID NO LONGER TOUCHES ZINC, REACTION STOPS.

H **HYDROGEN**

Element 1.
At. wt. 1.008
Colorless, odorless and combustible gas. Highly explosive in mixtures with air. 1/14 weight of air. Slightly soluble in water—1.8 volumes in 100 volumes at 20° C.

PLAYING SAFE WITH HYDROGEN

IN MIXTURES WITH AIR, HYDROGEN IS HIGHLY EXPLOSIVE. FOLLOW SAFETY RULES BELOW.

- MAKE ONLY SMALL AMOUNTS OF HYDROGEN IN THE HOME LAB. A 4-OZ. GENERATOR BOTTLE WILL GIVE YOU ALL THE HYDROGEN YOU NEED. MAKE ALL CONNECTIONS AIRTIGHT.
- TEST HYDROGEN FOR PURITY BY COLLECTING A TEST TUBE FULL OF IT AND BRINGING A LIGHTED MATCH TO MOUTH OF TUBE, AS SHOWN ON PAGE 25. HYDROGEN MIXED WITH AIR EXPLODES WITH A SHARP "BARK." PURE HYDROGEN BURNS WITH A QUIET "POP."
- KEEP FLAME AWAY FROM YOUR MAIN GENERATOR BOTTLE.
- IGNITE HYDROGEN ONLY FROM TEST TUBE GENERATOR DESCRIBED ON OPPOSITE PAGE, AND THEN ONLY AFTER YOU HAVE TESTED IT FOR PURITY.

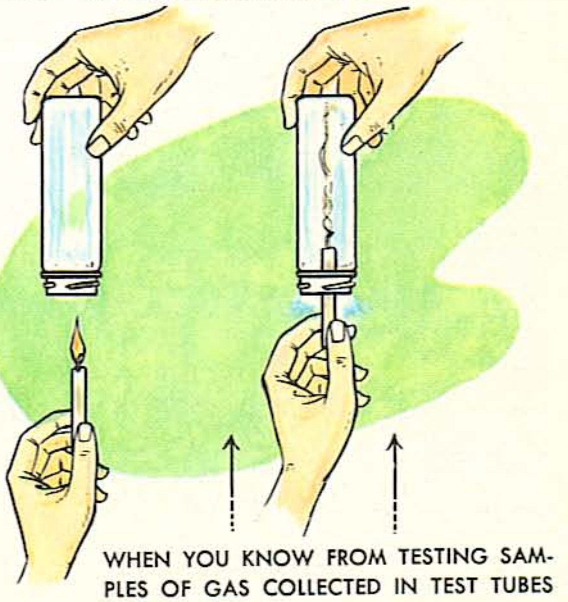

WHEN YOU KNOW FROM TESTING SAMPLES OF GAS COLLECTED IN TEST TUBES THAT HYDROGEN IS PURE, FILL SMALL JAR WITH IT. LIFT JAR OUT OF WATER, MOUTH DOWN. BRING LIGHTED CANDLE UP INTO JAR. HYDROGEN BURNS AT MOUTH OF JAR. CANDLE GOES OUT.

Carbon Dioxide

You HAVE already learned in experimenting with a burning candle that when something containing carbon burns in the air, a gas, carbon dioxide (CO_2), is formed. This is one of the most important gases for human life. The reason is that green plants, in sunlight, are able to take the carbon out of the carbon dioxide in the air and, by combining it with oxygen and hydrogen from water and with various minerals in the soil, produce all the vegetable matter that humans and animals eat.

You cannot see the CO_2 in the air — but you can see it when it has been cooled and compressed into a solid block of "dry ice." When dissolved in water (H_2O), carbon dioxide (CO_2) forms a weak acid (H_2CO_3). You know the taste of this acid from soda water — the bubbles are CO_2 being set free.

Carbonic acid combines with many metals to make "carbonates." You can drive the CO_2 out of most carbonates with the help of a weak acid — even with vinegar, which is diluted acetic acid.

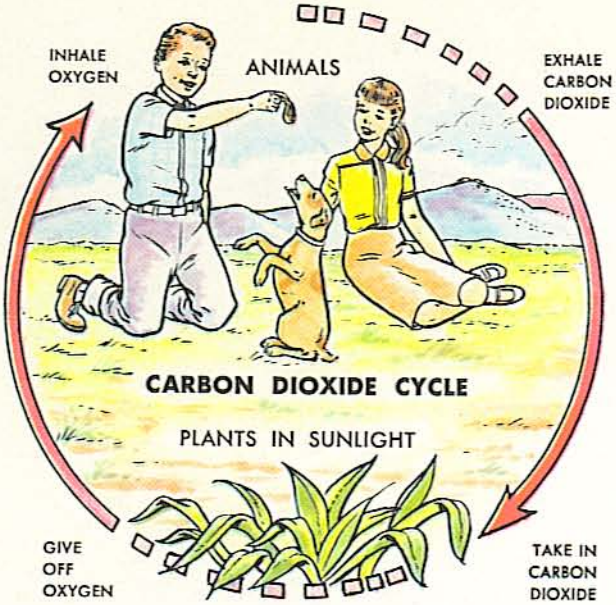

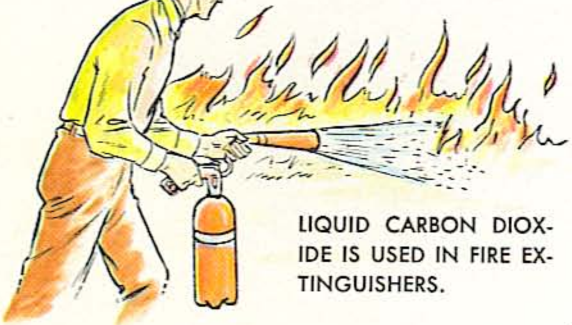

LIQUID CARBON DIOXIDE IS USED IN FIRE EXTINGUISHERS.

MAKING A FIRE EXTINGUISHER MODEL

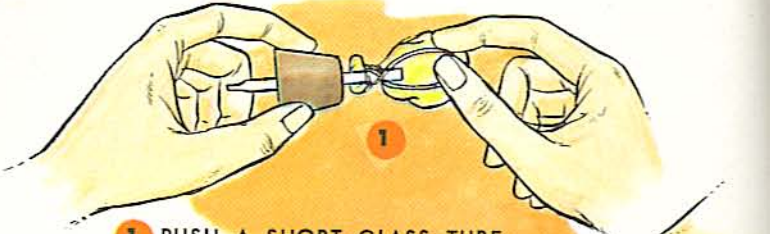

1 PUSH A SHORT GLASS TUBE WITH A JET TIP INTO A RUBBER STOPPER. WRAP BICARBONATE OF SODA IN A SHEET OF TOILET TISSUE. ATTACH SODA PACKAGE TO TUBE WITH A RUBBER BAND.

2 FILL BOTTLE HALF FULL OF MIXTURE OF 1 PART VINEGAR AND 1 PART WATER. PUT IN THE STOPPER.

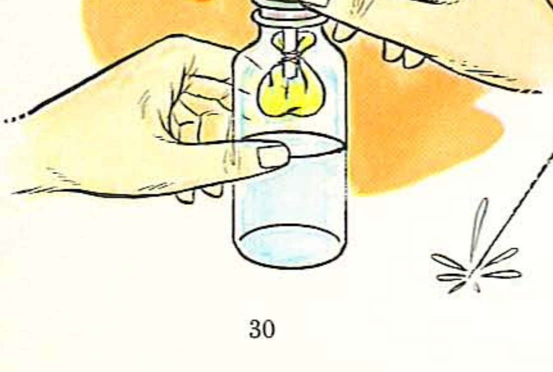

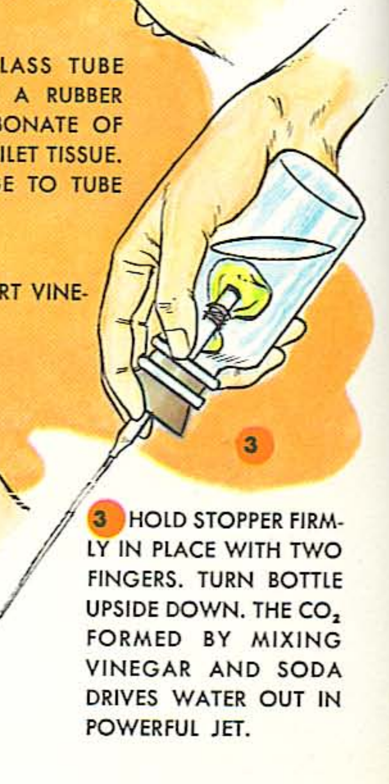

3 HOLD STOPPER FIRMLY IN PLACE WITH TWO FINGERS. TURN BOTTLE UPSIDE DOWN. THE CO_2 FORMED BY MIXING VINEGAR AND SODA DRIVES WATER OUT IN POWERFUL JET.

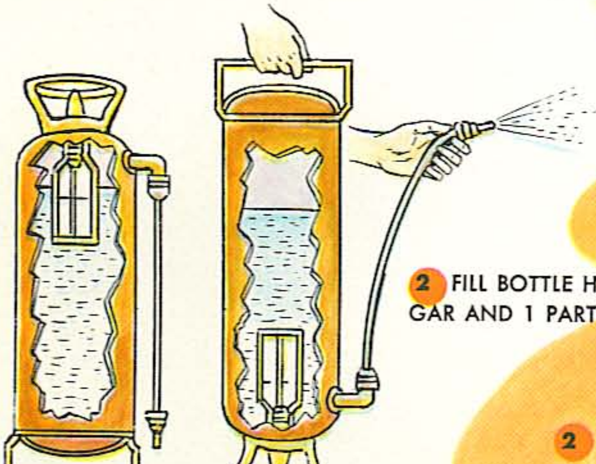

CHEMICAL FIRE EXTINGUISHERS CONTAIN SOLUTION OF BAKING SODA AND A BOTTLE OF SULFURIC ACID. WHEN TURNED UPSIDE DOWN, THE CHEMICALS MIX AND FORM CARBON DIOXIDE WHICH FORCES OUT THE WATER.

CO_2 CARBON DIOXIDE

Compound.

Molecular wt. 44. Colorless, odorless gas. Does not burn. Does not support combustion (burning). 1.529 weight of air. Fairly soluble in water—88 volumes in 100 volumes at 20° C.

FEATURES OF CARBON DIOXIDE

CO_2 IS HEAVIER THAN AIR AND DOES NOT SUPPORT BURNING. YOU CAN PROVE BOTH POINTS:

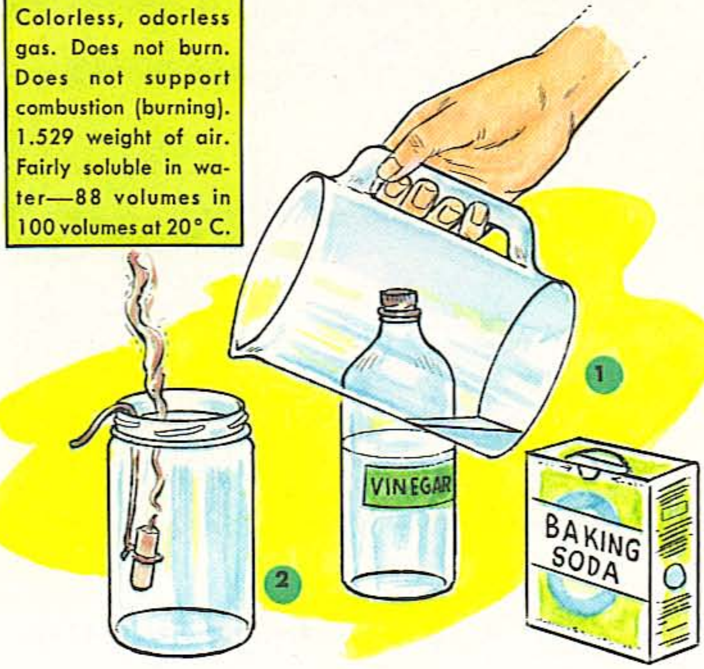

① PLACE 1 TEASPOON OF BAKING SODA IN A PITCHER. POUR A SMALL AMOUNT OF WHITE VINEGAR OVER THE SODA.

② HANG A LIGHTED CANDLE IN A JAR BY A WIRE. POUR THE CARBON DIOXIDE FORMED IN THE PITCHER INTO THE JAR THE WAY YOU WOULD POUR WATER. WHEN THE CARBON DIOXIDE REACHES THE TOP OF THE CANDLE, THE FLAME GOES OUT.

MAKING LIME WATER

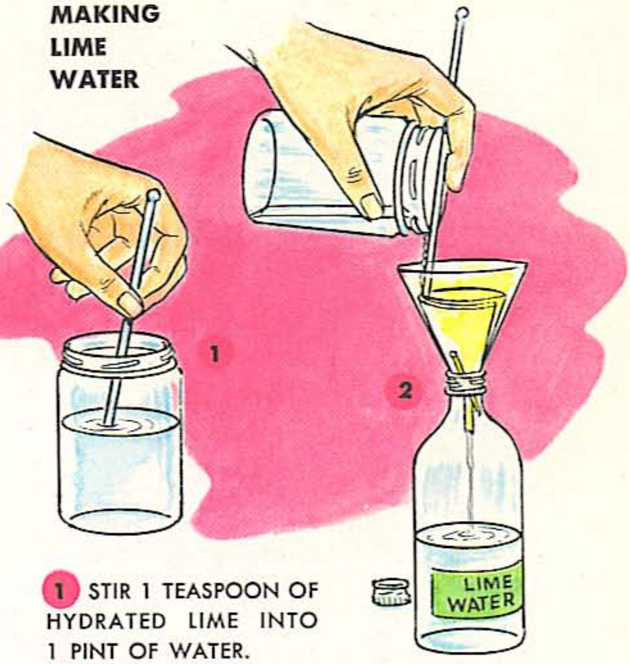

① STIR 1 TEASPOON OF HYDRATED LIME INTO 1 PINT OF WATER.

② LET STAND UNTIL LIME SINKS TO THE BOTTOM. FILTER LIQUID INTO A BOTTLE. CLOSE BOTTLE TIGHTLY.

BURNING PRODUCES CARBON DIOXIDE

HANG BURNING CANDLE IN JAR CONTAINING A FEW ml LIME WATER. COVER TOP WITH A GLASS PLATE. WHEN CANDLE HAS GONE OUT, SHAKE LIME WATER UP WITH THE AIR. MILKINESS PROVES THAT CO_2 HAS BEEN PRODUCED.

MAKING CO_2 FROM MARBLE

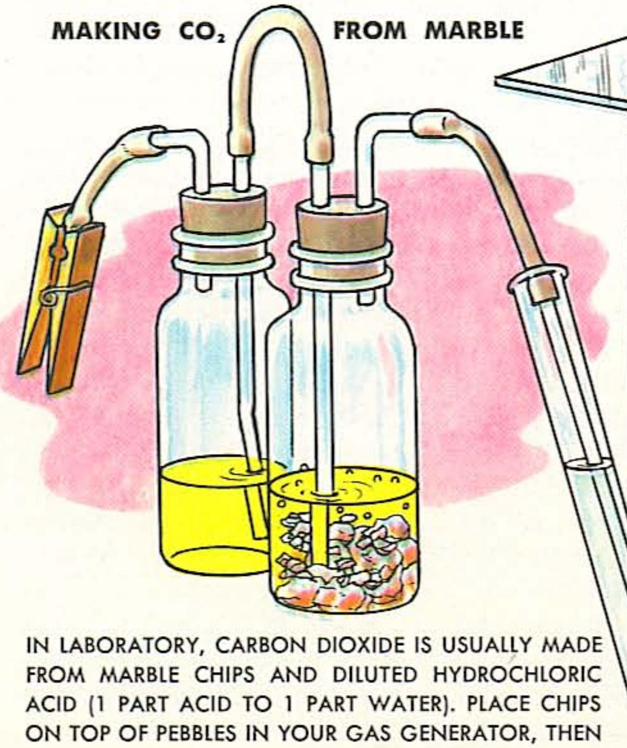

IN LABORATORY, CARBON DIOXIDE IS USUALLY MADE FROM MARBLE CHIPS AND DILUTED HYDROCHLORIC ACID (1 PART ACID TO 1 PART WATER). PLACE CHIPS ON TOP OF PEBBLES IN YOUR GAS GENERATOR, THEN PROCEED AS FOR MAKING HYDROGEN (PAGE 29).

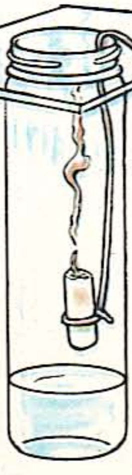

TEST FOR CO_2

CO_2 TURNS LIME WATER MILKY BY CHANGING CALCIUM HYDROXIDE TO CALCIUM CARBONATE.

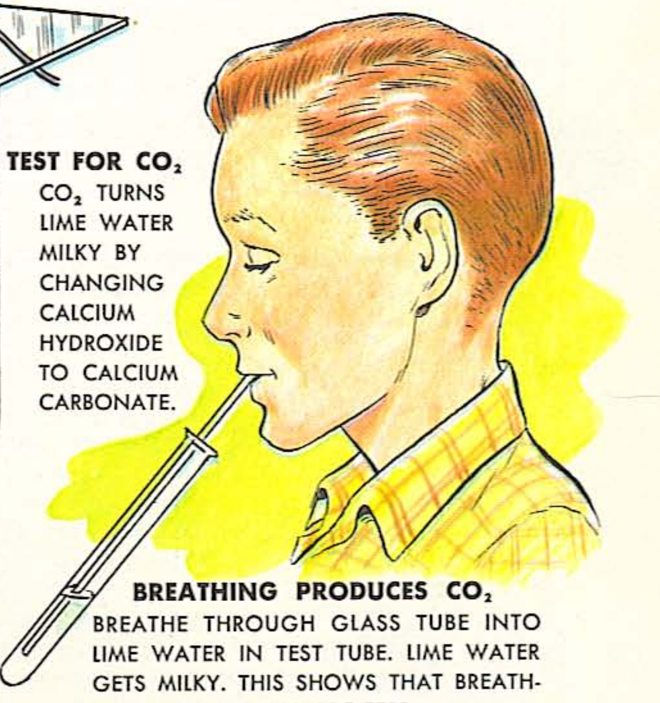

BREATHING PRODUCES CO_2

BREATHE THROUGH GLASS TUBE INTO LIME WATER IN TEST TUBE. LIME WATER GETS MILKY. THIS SHOWS THAT BREATHING IS A BURNING PROCESS.

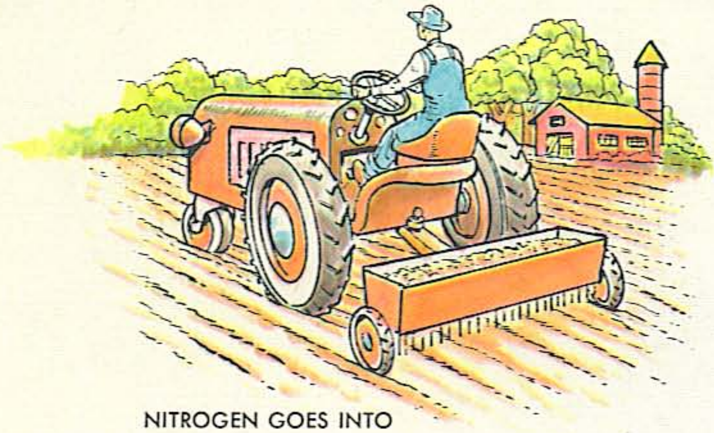

NITROGEN GOES INTO BOTH FERTILIZERS AND EXPLOSIVES.

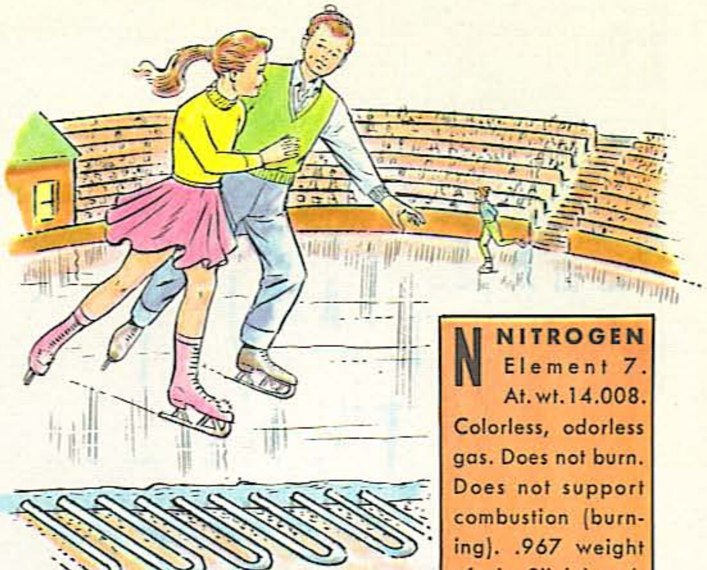

DRY AMMONIA GAS IS USED IN THE LARGE-SCALE PRODUCTION OF ICE.

N **NITROGEN** Element 7. At. wt. 14.008. Colorless, odorless gas. Does not burn. Does not support combustion (burning). .967 weight of air. Slightly soluble in water—1.5 volumes in 100 vols. at 20°C.

Nitrogen and Its Compounds

When you burn anything in the air, only about one-fifth of the air goes into chemical combination with what you are burning. The rest (except for a small fraction) does not enter into the process. It is a gas called nitrogen (N) — the most abundant free element on earth.

Nitrogen is what you might call a "lazy" element. It does not help in burning nor does it burn if you try to ignite it. It is only at high temperatures and under great pressures that a chemist can make nitrogen combine with another element, hydrogen, to form ammonia gas (NH_3), from which other nitrogen compounds can be made.

Yet, in nature, tiny bacteria on the roots of certain plants can take nitrogen from the air and make it combine with oxygen and minerals in the soil into "nitrates." And that is of tremendous importance to all of us — for all plants need nitrates if they are to thrive. If plants do not get nitrates naturally, the farmer must add them to his soil in the form of some kind of fertilizer.

You will not have much satisfaction out of working with nitrogen itself, but you will find it interesting to deal with some of its compounds — especially with ammonia gas (NH_3). You will also want to have a look at one of the half dozen combinations nitrogen makes with oxygen, the brown gas called nitrogen dioxide (NO_2).

NITROGEN FROM THE ATMOSPHERE

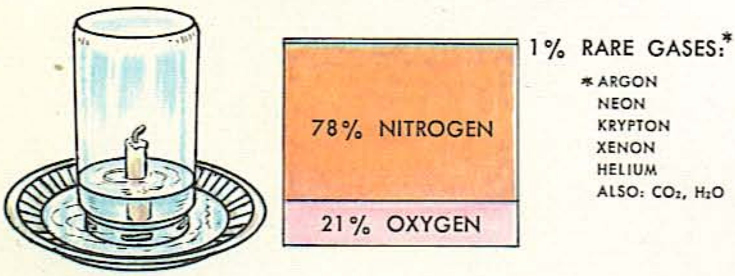

REPEAT CANDLE-BURNING EXPERIMENT ON PAGE 27. UNUSED GAS IS ALMOST ALL NITROGEN—WITH SMALL PERCENTAGE OF RARE GASES AND CARBON DIOXIDE.

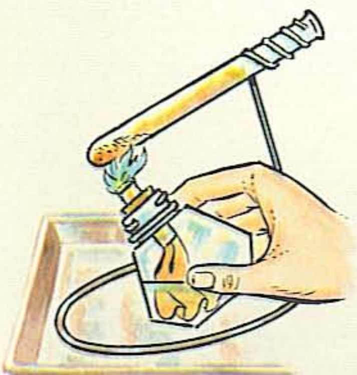

NITROGEN DIOXIDE

IN A WELL-VENTILATED ROOM, HEAT EQUAL AMOUNTS OF SALTPETER AND SODIUM BISULFATE IN DRY TEST TUBE. IN A MOMENT, A BROWN GAS FORMS. IT IS NITROGEN DIOXIDE. DO NOT INHALE —GAS IS VERY IRRITATING.

NH_3 AMMONIA

Compound. Molecular weight 17. Colorless gas with strong, penetrating odor. .596 weight of air. Highly soluble in water—70,000 vols. in 100 vols. at 20°C.

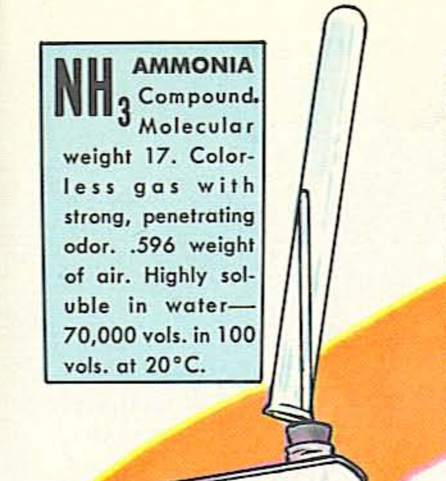

PRODUCING AMMONIA

SIMPLEST WAY OF PRODUCING AMMONIA IS TO GET IT FROM ITS SOLUTION AS HOUSEHOLD AMMONIA.

FILL PINT CAN ONE QUARTER FULL OF HOUSEHOLD AMMONIA. FIT STOPPER WITH 6" GLASS TUBE IN OPENING. PLACE TEST TUBE OVER GLASS TUBE. HEAT CAN OVER LOW FLAME. TEST TUBE IS FULL OF AMMONIA WHEN MOIST, RED LITMUS PAPER HELD AT ITS MOUTH TURNS BLUE.

SOLUBILITY OF AMMONIA

REMOVE A FILLED TEST TUBE FROM GAS GENERATOR CAN, MOUTH DOWN. CLOSE MOUTH OF TUBE WITH THUMB. OPEN TUBE UNDER WATER. AMMONIA DISSOLVES EASILY, WATER RUSHES IN AND FILLS TUBE.

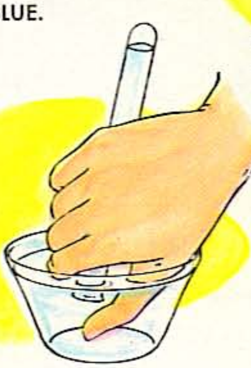

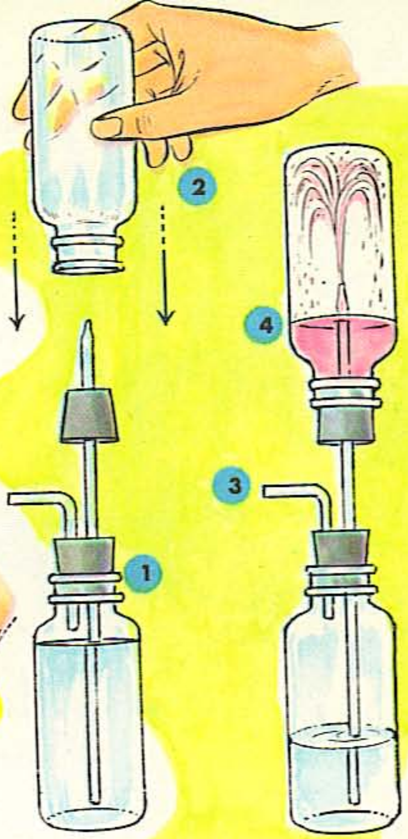

THE AMMONIA FOUNTAIN

AMMONIA'S EXTRAORDINARY SOLUBILITY CAN BE SHOWN IN A SPECTACULAR DEMONSTRATION.

1 MAKE UP APPARATUS AS SHOWN IN ILLUSTRATION. FILL IT WITH WATER. ADD 5 DROPS OF PHENOLPHTHALEIN SOLUTION.

2 FILL DRY, EMPTY BOTTLE WITH AMMONIA FROM GENERATOR CAN. KEEPING BOTTLE UPSIDE DOWN, PLACE IT FIRMLY ON TOP STOPPER OF APPARATUS.

3 BLOW INTO L-SHAPED GLASS TUBE TO DRIVE A FEW DROPS OF WATER UP INTO THE UPPER BOTTLE.

4 SUDDENLY, WATER SPURTS FROM LOWER BOTTLE UP INTO UPPER BOTTLE IN A FOUNTAIN THAT TURNS PINK AS AMMONIA REACTS ON PHENOLPHTHALEIN.

MOIST, RED LITMUS PAPER TURNS BLUE IN AMMONIA.

MAKING AMMONIA FROM SAL AMMONIAC

1 ON A PIECE OF PAPER, MIX 1 PART OF SAL AMMONIAC WITH 2 PARTS OF HYDRATED LIME. ADD A FEW DROPS OF WATER. DROP MIXTURE INTO A TEST TUBE. PROVIDE TUBE WITH STOPPER AND L-SHAPED GLASS TUBE. THEN HEAT OVER LOW FLAME.

2 COLLECT AMMONIA IN DRY TEST TUBE. TEST IT WITH LITMUS PAPER AND FOR SOLUBILITY.

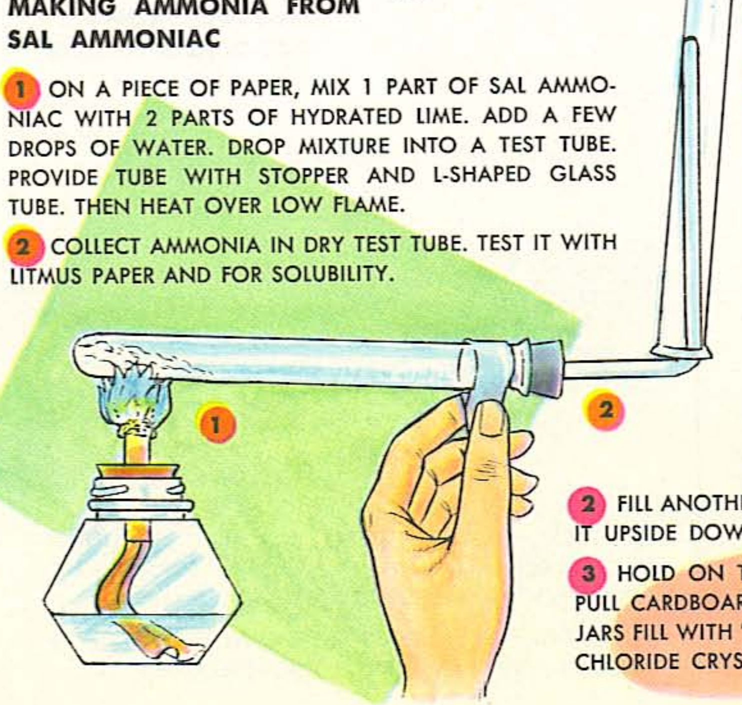

THE WHITE SMOKE MYSTERY

1 MOISTEN INSIDE OF JAR WITH SMALL AMOUNT OF HYDROCHLORIC ACID. POUR EXCESS ACID BACK INTO ITS BOTTLE. COVER JAR WITH SQUARE OF CARDBOARD.

2 FILL ANOTHER JAR WITH AMMONIA. PLACE IT UPSIDE DOWN ON CARDBOARD.

3 HOLD ON TO AMMONIA-FILLED JAR AND PULL CARDBOARD AWAY. IMMEDIATELY, BOTH JARS FILL WITH "SMOKE" OF TINY AMMONIUM CHLORIDE CRYSTALS.

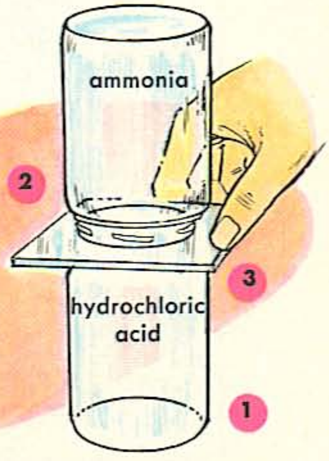

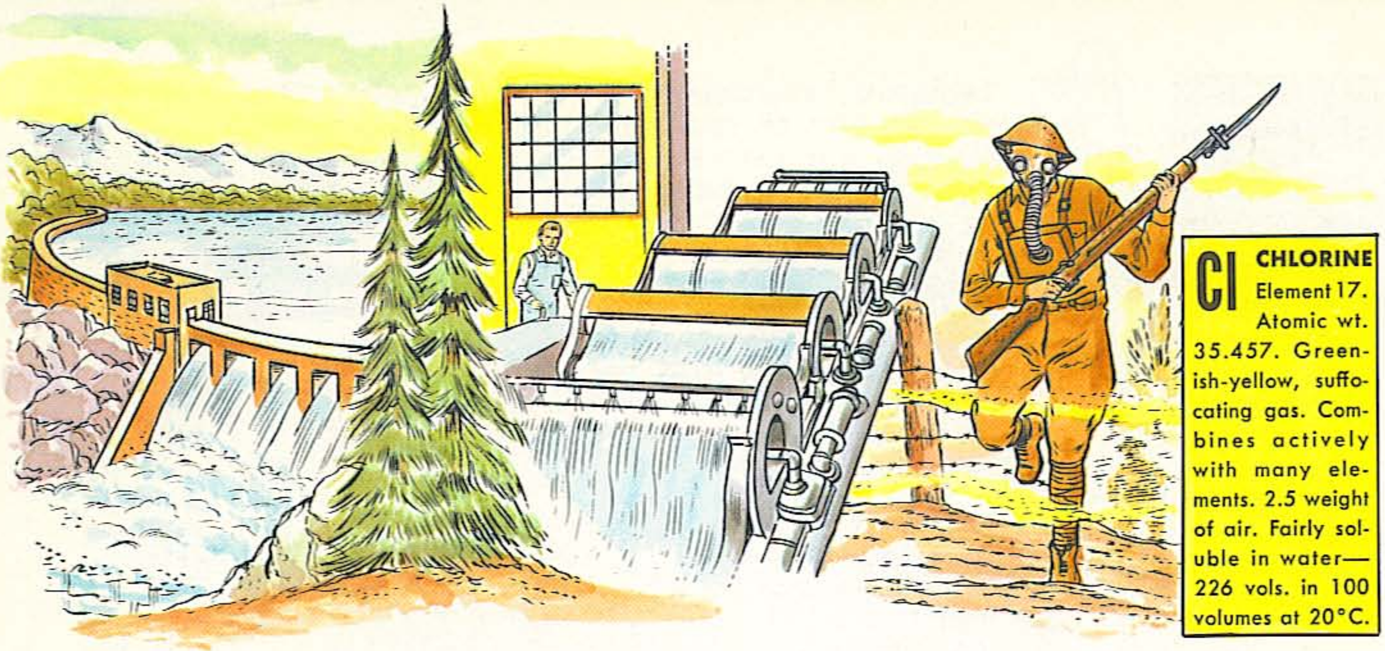

Cl **CHLORINE** Element 17. Atomic wt. 35.457. Greenish-yellow, suffocating gas. Combines actively with many elements. 2.5 weight of air. Fairly soluble in water—226 vols. in 100 volumes at 20°C.

Chlorine—Friend and Foe

Chlorine is a gas of great importance. We wouldn't be certain of safe drinking water in our cities if it weren't for chlorine — a small amount of it in the water kills the dangerous germs that may lurk in it. Chlorine is also used extensively in bleaching.

Chlorine is a friendly gas when it is used correctly. But it is dangerous when used improperly because it affects the lungs. As a "poison gas" it caused many casualties in World War I.

You can produce chlorine as a greenish-yellow gas by driving it out of one of its compounds — hydrochloric acid (HCl), which consists of hydrogen (H) and chlorine (Cl), or a common laundry bleach ("Clorox" or others), which is a solution of sodium hypochlorite ($NaClO$).

Have a bottle of diluted household ammonia (90% water, 10% household ammonia) on hand. Sniff this if you get too strong a whiff of chlorine.

NOTE: Perform these experiments out-of-doors or before an open window. Be careful not to breathe fumes.

MAKING TEST PAPER FOR CHLORINE

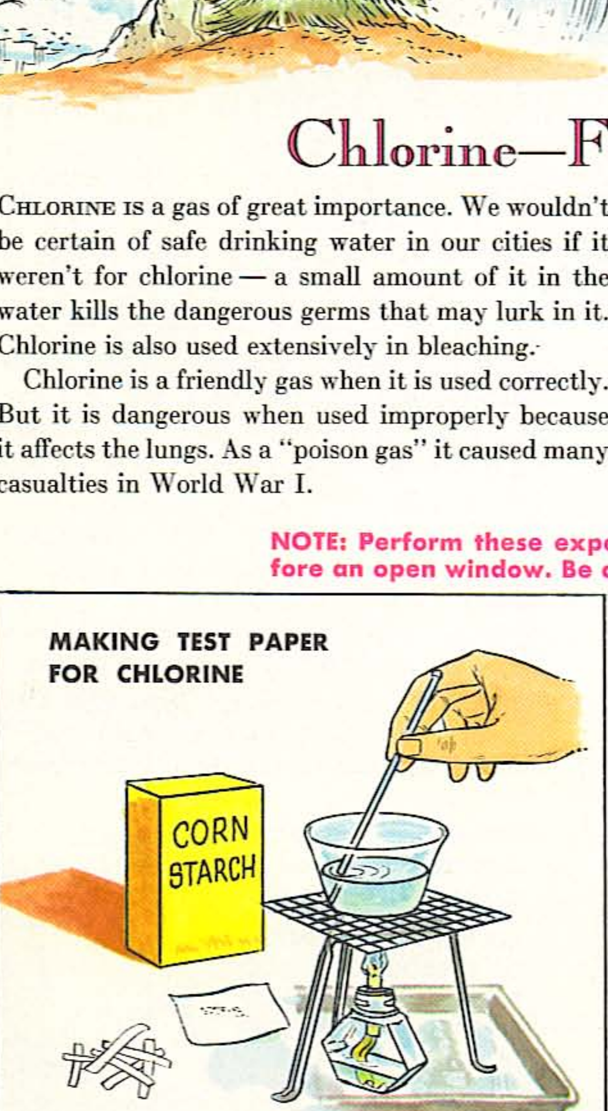

MIX .5 g (¼ TEASPOON) STARCH WITH 30 ml WATER. BRING TO BOIL. DISSOLVE IN MIXTURE A SMALL AMOUNT OF POTASSIUM IODIDE (AS MUCH AS TWO GRAINS OF RICE). DIP STRIPS OF FILTER PAPER IN MIXTURE; THEN DRY THEM.

CHLORINE FROM HYDROCHLORIC ACID

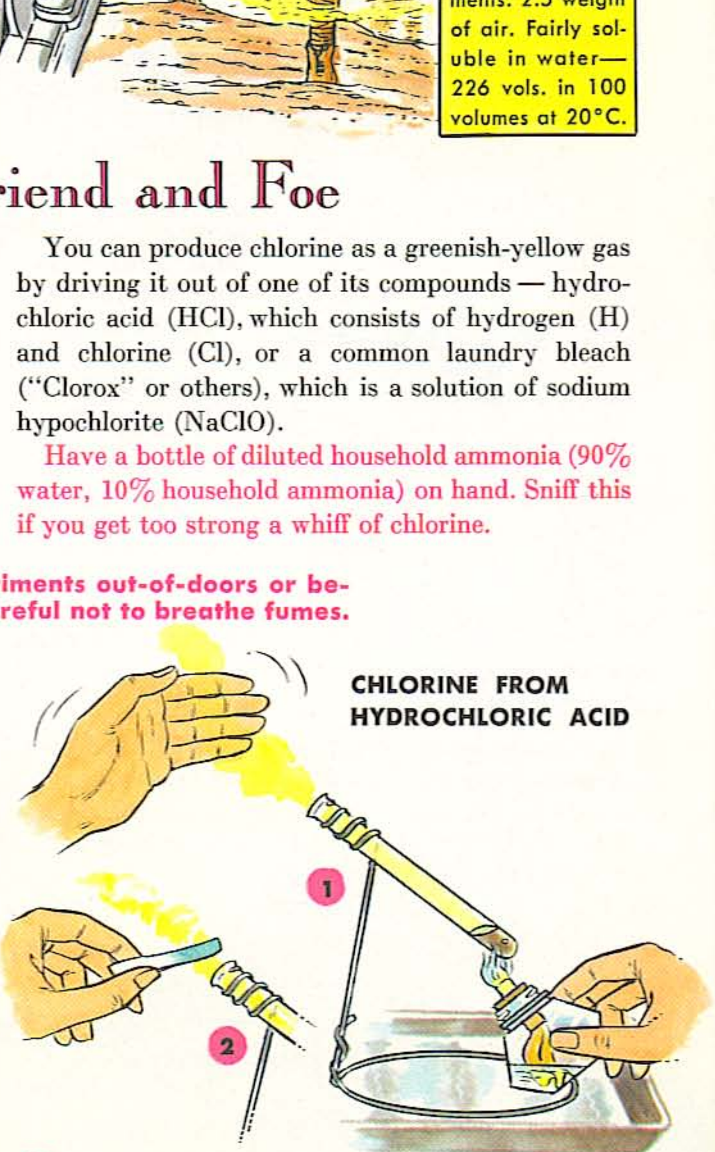

① Put .5 g (⅛ TEASPOON) MANGANESE DIOXIDE INTO TEST TUBE. ADD 3 ml (⅛ TEST TUBE) UNDILUTED HYDROCHLORIC ACID. HEAT GENTLY. CHLORINE FORMS. WAFT A LITTLE CAREFULLY TOWARD YOU FOR A SNIFF.

② TEST GAS BY HOLDING MOISTENED STARCH-IODIDE PAPER AT MOUTH OF TUBE. PAPER TURNS BLUE.

MAKING CHLORINE IN THE HOME LAB

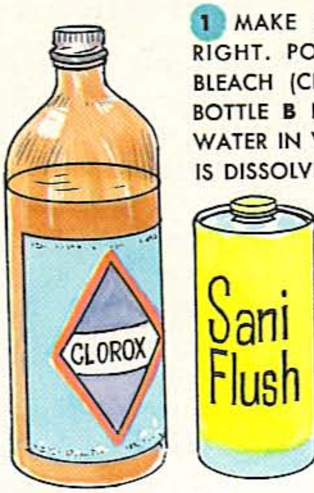

1 MAKE APPARATUS SHOWN AT RIGHT. POUR 1 INCH OF LIQUID BLEACH (CLOROX) INTO BOTTLE **A**. BOTTLE **B** IS EMPTY. BOTTLE **C** HAS WATER IN WHICH ½ TEASPOON LYE IS DISSOLVED.

2 TAKE STOPPER OUT OF BOTTLE **A**. DROP IN ½ TEASPOON SODIUM BISULFATE (SANI-FLUSH). REPLACE THE STOPPER.

3 CHLORINE GAS FORMS AND FILLS **B**.

4 LYE WATER IN BOTTLE **C** ABSORBS EXCESS OF CHLORINE GAS.

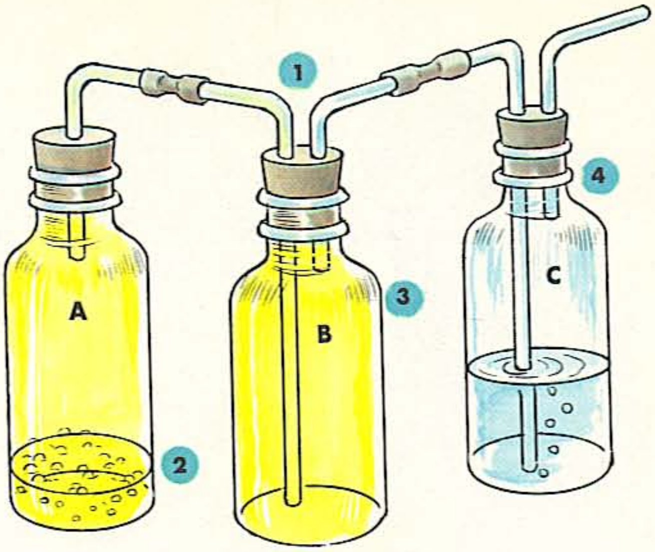

WHEN REACTION SLOWS
ADD MORE SODIUM BISULFATE

EXPERIMENTS WITH CHLORINE

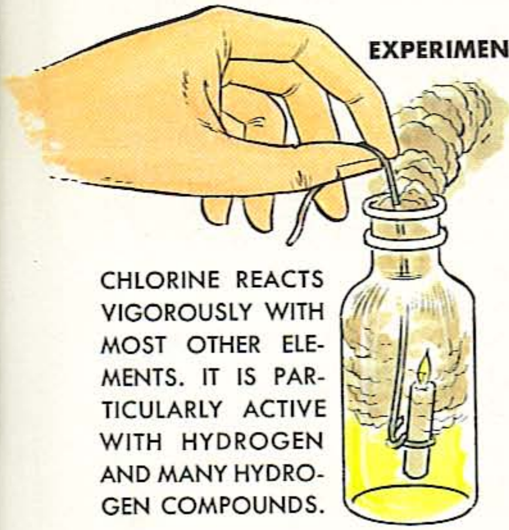

CHLORINE REACTS VIGOROUSLY WITH MOST OTHER ELEMENTS. IT IS PARTICULARLY ACTIVE WITH HYDROGEN AND MANY HYDROGEN COMPOUNDS.

LOWER A BURNING CANDLE INTO A BOTTLE OF CHLORINE GAS. A DENSE SMOKE OF CARBON IS FORMED. THE CHLORINE COMBINES WITH THE HYDROGEN OF THE CANDLE AND SETS THE CARBON IN IT FREE AS SOOT.

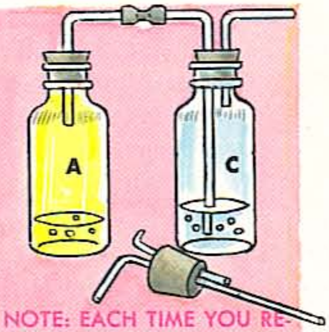

NOTE: EACH TIME YOU REMOVE THE GAS-COLLECTING BOTTLE **B** FOR EXPERIMENT, CONNECT BOTTLES **A** AND **C** TO PREVENT CHLORINE FROM GETTING OUT IN THE ROOM.

CHLORINE WILL COMBINE DIRECTLY WITH SEVERAL METALS. IRON ACTUALLY BURNS IN CHLORINE GAS!

FASTEN A SMALL WAD OF STEEL WOOL TO A PIECE OF WIRE. HEAT IT WITH A MATCH AND LOWER IT INTO CHLORINE-FILLED BOTTLE. A HEAVY BROWN SMOKE OF IRON CHLORIDE POURS OUT.

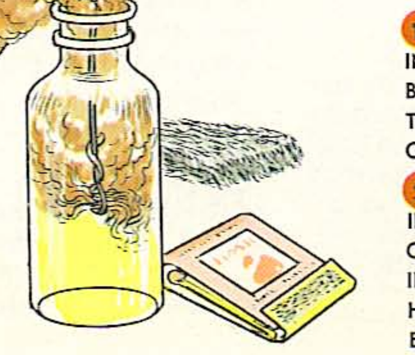

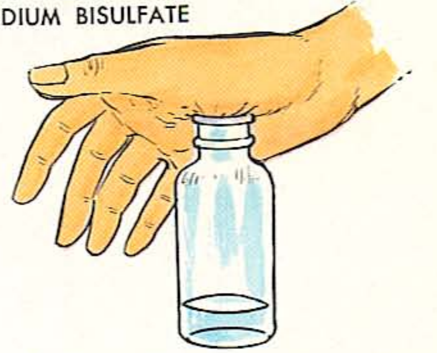

TO SHOW THE SOLUBILITY OF CHLORINE, POUR A SMALL AMOUNT OF WATER INTO A CHLORINE-FILLED BOTTLE. CLOSE THE BOTTLE MOUTH WITH YOUR PALM. SHAKE. THE CHLORINE DISSOLVES AND THE BOTTLE STICKS TO YOUR PALM FROM THE SUCTION CREATED.

CHLORINE HAS GREAT USE IN BLEACHING COTTON AND LINEN AND WOOD PULP. YET IT IS NOT THE CHLORINE THAT PERFORMS THE BLEACHING.

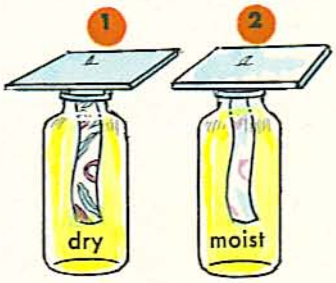

1 FILL A BOTTLE WITH CHLORINE GAS. HANG IN IT (FROM A CORK OR FROM A PIECE OF CARDBOARD) A STRIP OF DRY, BRIGHTLY COLORED COTTON CLOTH. NOTHING HAPPENS. COLOR OF CLOTH IS NOT AFFECTED.

2 MOISTEN THE CLOTH AND AGAIN HANG IT IN THE CHLORINE. SOON THE COLORS FADE—ONLY TRULY "FAST" COLORS REMAIN. CHLORINE, IN CONTACT WITH WATER, COMBINES WITH THE HYDROGEN AND LIBERATES OXYGEN. THE LIBERATED OXYGEN DOES THE BLEACHING.

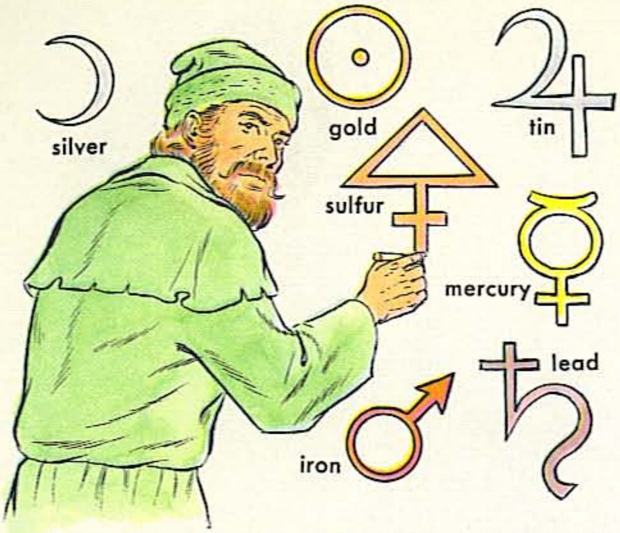

THE ALCHEMISTS USED FANCIFUL FIGURES TO REPRESENT THE CHEMICALS WITH WHICH THEY WORKED.

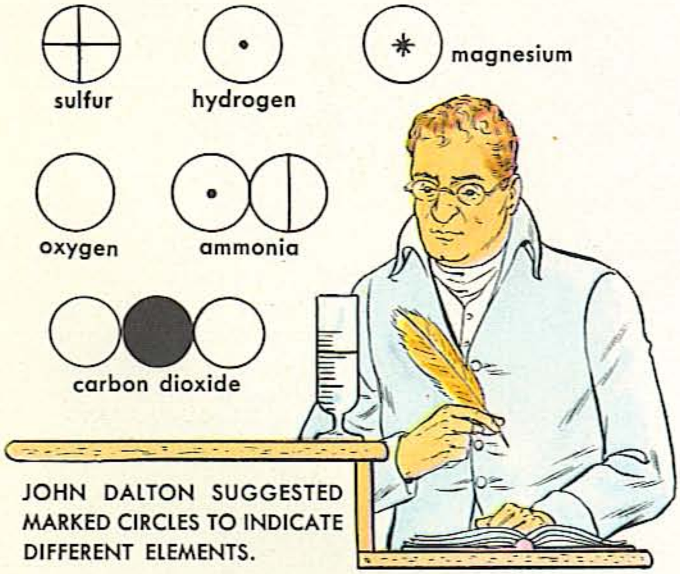

JOHN DALTON SUGGESTED MARKED CIRCLES TO INDICATE DIFFERENT ELEMENTS.

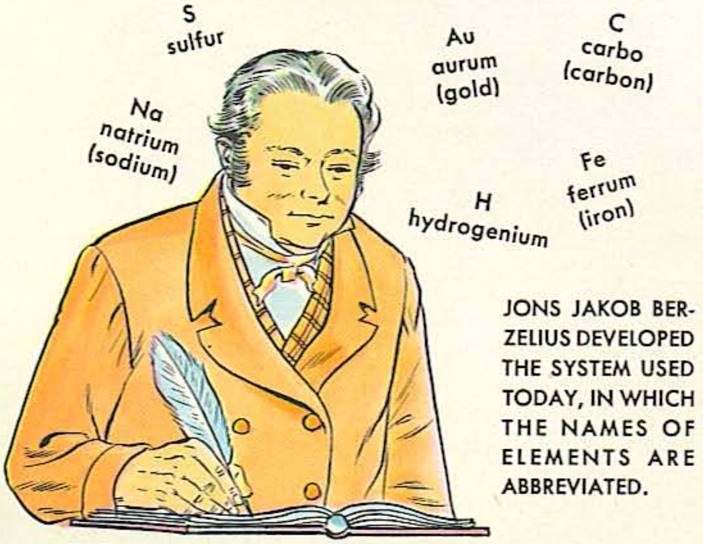

JONS JAKOB BERZELIUS DEVELOPED THE SYSTEM USED TODAY, IN WHICH THE NAMES OF ELEMENTS ARE ABBREVIATED.

Chemical Shorthand

So far you have experimented with oxygen and hydrogen, carbon dioxide and nitrogen, and chlorine; you have also separated water into the two elements of which it consists, and have combined the two elements iron and sulfur into a chemical compound. In taking notes of your experiments you are certain to have learned that it is much quicker to write "H" than "hydrogen," and easier to write "CO_2" than "carbon dioxide." Before long, it will seem the simplest and most logical thing in the world to use these abbreviations of the names of the different elements rather than the full names.

Yet it took chemists hundreds of years before they settled on this uniform method of writing out their chemical formulas.

In the early days of chemistry no one bothered to do much writing about it. But it became necessary for the alchemists to write down their experiments — how else could they retrace their steps in case they actually hit upon the gold they were seeking? They invented a whole line of complicated symbols that only they could understand.

As chemists delved deeper and deeper into the mysteries of matter it became more and more important for them to write out their experiments in such a way that all other chemists would know what they were trying to explain.

The first to invent a usable system was John Dalton, an English scientist. The invention was almost forced upon him.

In his study of chemistry he had become convinced that all chemical reactions could be explained in terms of the tiniest possible part of one element reacting with the tiniest possible part of another. These particles he called "atoms." The smallest possible part of the compound that resulted he called a "compound atom"— today we call it a "molecule."

To explain his "atomic theory" Dalton made use of circles, each with a marking to indicate a specific element. These circles served to explain Dalton's theory but they were too difficult to work with to show complicated chemical reactions.

A Swedish chemist, Jons Jakob Berzelius, worked out a simpler system — the same system scientists use today.

For his symbols he took the first letter of the Latin name of each element — C for "carbo," S for "sulfur." Where two names started with the same letter, he added a small letter to one of the symbols to distinguish the two elements from each other — he used Ca for "calcium," for instance, to distinguish it from carbon (C).

But Berzelius went an important step further.

By then the French chemist, Joseph Louis Proust, had discovered that whenever elements form compounds these are always of a very definite composition — the "Law of Definite Composition." Water molecules, for example, always contain the same number of hydrogen and oxygen atoms. And Dalton had found that when two elements combine in different ways they do this in simple proportions — the "Law of Multiple Proportions." One atom of carbon and one atom of oxygen make carbon monoxide; one atom of carbon and two atoms of oxygen make carbon dioxide.

To describe these things in a simple way Berzelius made each of his symbols stand not only for a specific element but also for its relative weight as compared to the weight of other elements—its "atomic weight." To show the composition of a compound he simply put together the symbols for the elements into a "formula"—CO, HCl, FeS, and so on. "CO" then not only meant that one atom of carbon and one atom of oxygen combine to make one molecule of carbon monoxide, but also that 12 weight units of carbon (12 being the atomic weight of carbon) combine with 16 weight units of oxygen (16 being the atomic weight of oxygen) to form 28 weight units of the compound carbon monoxide.

When a compound contained several atoms of the same element Berzelius indicated this by placing a number in front of the symbol. It was later found necessary to change this to a smaller number, called a "subscript," placed at the lower right of the symbol — H_2O, CO_2.

In recent years it has been necessary to change Dalton's idea of an atom as being the smallest indivisible part of an element. Nowadays we have machines, such as the cyclotron, that can bombard, or "smash" atoms into still smaller parts—neutrons, and electrically charged protons and electrons. According to today's atomic theory protons and neutrons form the nucleus of the atom and electrons whirl around the nucleus with such tremendous speed that they seem to form a "shell" around it.

But even with our new idea of an atom, Dalton's main theory is still useful for explaining chemical reactions, and Berzelius' method is still the simplest "shorthand" method any scientist has ever devised for writing them down.

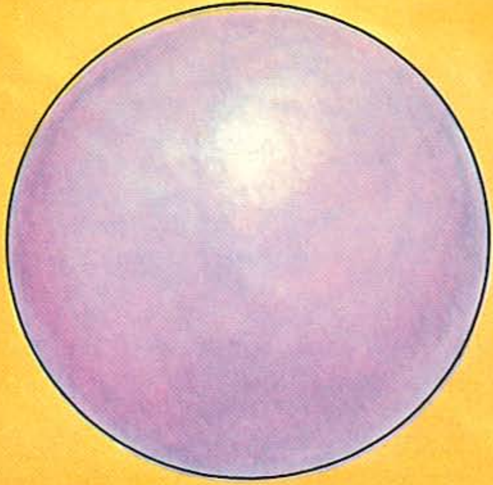

AN ATOM MIGHT LOOK LIKE A BALL SUCH AS THIS IF YOU ENLARGED IT A BILLION TIMES. THE "SHELL" IS NOT SOLID—IT CONSISTS OF ELECTRONS MOVING SO FAST THAT THEY SEEM TO FORM A SOLID SHELL.

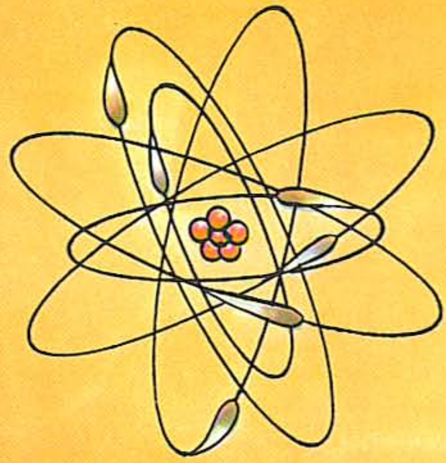

IF YOU COULD SLOW DOWN AN ENLARGED CARBON ATOM YOU MIGHT SEE TWO OF ITS ELECTRONS TRAVELING AROUND THE NUCLEUS IN AN "INNER SHELL" AND FOUR MORE WHIRLING AROUND IN AN "OUTER SHELL."

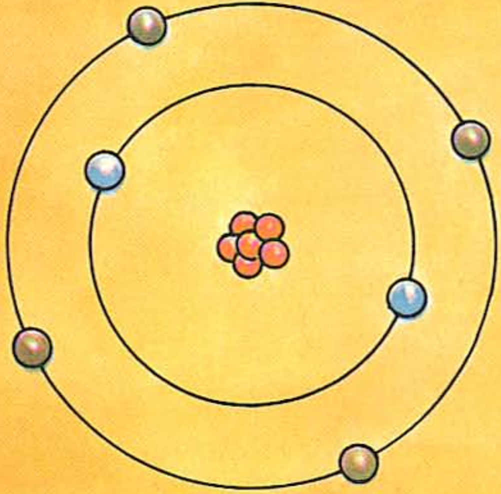

IF YOU COULD HALT AN ENLARGED CARBON ATOM COMPLETELY, IT WOULD LOOK A LOT LIKE OUR SOLAR SYSTEM, WITH A "SUN" (PROTONS AND NEUTRONS) IN THE CENTER AND "PLANETS" (ELECTRONS) AROUND IT.

The Periodic Table of the Elements

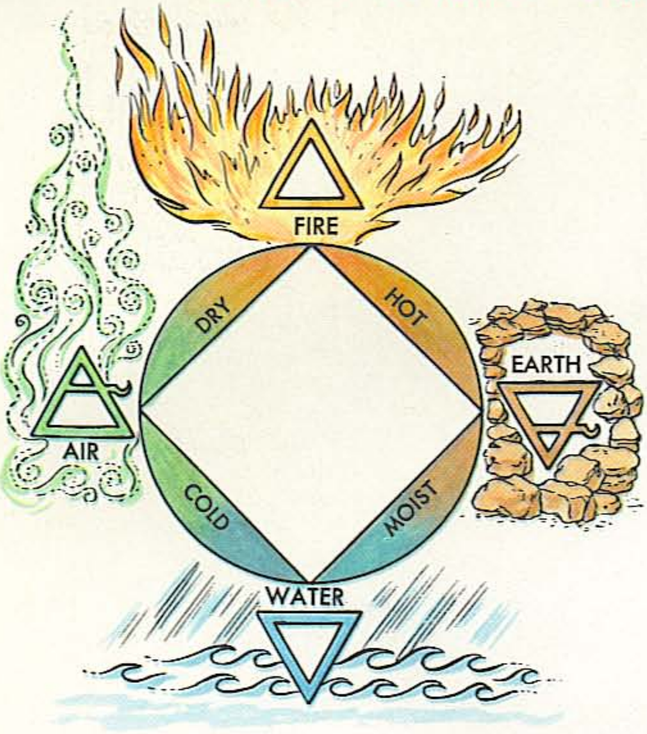

FROM THE earliest times people have tried to explain what "matter" was made of. Most early philosophers agreed that "matter" was made up of what they called "elements." But their idea of an "element" was quite different from what we mean by that word today.

The early Greek philosophers thought the entire universe was composed of only four basic substances: fire, earth, water, and air. This explanation made sense at the time and was not seriously challenged for many centuries.

The old Romans actually knew nine of the substances we call elements today. They called them, of course, by their Latin names (the same we use today in chemical symbols): *carbo* (carbon — C), *sulfur* (S), *aurum* (gold — Au), *argentum* (silver —

FOR MORE THAN A THOUSAND YEARS PHILOSOPHERS INSISTED THAT ALL SUBSTANCES WERE MADE UP OF FOUR ELEMENTS: FIRE THAT WAS DRY AND HOT, EARTH THAT WAS HOT AND MOIST, WATER THAT WAS MOIST AND COLD, AIR THAT WAS COLD AND DRY. WE KNOW BETTER NOW!

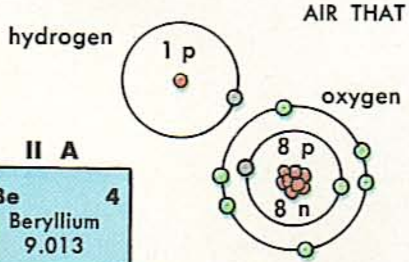

THE MODERN PICTURE OF AN ATOM HAS A NUCLEUS IN THE CENTER, CONSISTING OF PROTONS (p) AND NEUTRONS (n), WITH ELECTRONS IN RINGS AROUND IT.

THE PERIODIC TABLE OF THE ELEMENTS

	O	I A	II A	III A	IV A	V A	VI A	VII A	
1		**H** 1 Hydrogen 1.008							
2	**He** 2 Helium 4.003	**Li** 3 Lithium 6.940	**Be** 4 Beryllium 9.013						
3	**Ne** 10 Neon 20.183	**Na** 11 Sodium 22.991	**Mg** 12 Magnesium 24.32						
4	**A** 18 Argon 39.944	**K** 19 Potassium 39.1	**Ca** 20 Calcium 40.08	**Sc** 21 Scandium 44.96	**Ti** 22 Titanium 47.9	**V** 23 Vanadium 50.95	**Cr** 24 Chromium 52.01	**Mn** 25 Manganese 54.94	**Fe** 26 Iron 55.85
5	**Kr** 36 Krypton 83.8	**Rb** 37 Rubidium 85.48	**Sr** 38 Strontium 87.63	**Y** 39 Yttrium 88.92	**Zr** 40 Zirconium 91.22	**Nb** 41 Niobium 92.91	**Mo** 42 Molybdenum 95.95	**Tc** 43 Technetium 99	**Ru** 44 Ruthenium 101.1
6	**Xe** 54 Xenon 131.3	**Cs** 55 Cesium 132.91	**Ba** 56 Barium 137.36	57-71 Lanthanons	**Hf** 72 Hafnium 178.50	**Ta** 73 Tantalum 180.95	**W** 74 Tungsten 183.86	**Re** 75 Rhenium 186.22	**Os** 76 Osmium 190.2
7	**Rn** 86 Radon 222	**Fr** 87 Francium 223	**Ra** 88 Radium 226.05	89-103 Actinons					

🟥 INERT GASES

🟨 ALKALI METALS

🟦 ALKALINE EARTH METALS

La 57 Lanthanum 138.92	**Ce** 58 Cerium 140.13	**Pr** 59 Praseodymium 140.92	**Nd** 60 Neodymium 144.27	**Pm** 61 Promethium 145	**Sm** 62 Samarium 150.35
Ac 89 Actinium 227	**Th** 90 Thorium 232.05	**Pa** 91 Protactinium 231	**U** 92 Uranium 238.07	**Np** 93 Neptunium 237	**Pu** 94 Plutonium 242

ROWS RUNNING FROM LEFT TO RIGHT ARE CALLED PERIODS. COLUMNS RUNNING FROM TOP TO BOTTOM ARE CALLED GROUPS. THE ELEMENTS WITHIN A GROUP HAVE MANY TRAITS IN COMMON.

Ag), *ferrum* (iron — Fe), *cuprum* (copper — Cu), *stannum* (tin — Sn), *plumbum* (lead — Pb), *hydrargyrum* (mercury—Hg).

By 1800, thirty-four elements had been discovered. Within the next ten years, thirteen more had been added and had been given made-up Latin names — among them *natrium* (sodium — Na), *kalium* (potassium — K), and *aluminium* (aluminum — Al). By the beginning of the twentieth century, eighty-four elements were known.

Today the number has reached 102 — the last ten man-made, produced by splitting the atoms of other elements. Within a short time, Element 103 will probably be discovered.

In this table you will find listed the 102 elements that are known today. Each element is described by its chemical symbol, its atomic number, its full name, and its atomic weight.

magnesium

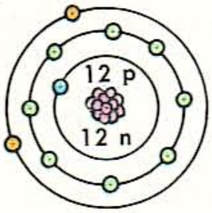

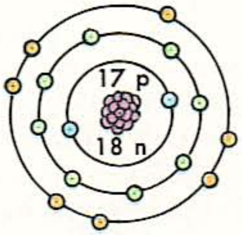

chlorine

MANY SCIENTISTS HAD NOTICED THAT IF YOU LINE UP THE ELEMENTS ACCORDING TO ATOMIC WEIGHTS, CERTAIN CHEMICAL TRAITS OCCUR PERIODICALLY. THE RUSSIAN SCIENTIST, DMITRI MENDELEEFF, ON THIS BASIS DISCOVERED THE PERIODIC LAW AND DEVELOPED THE PERIODIC TABLE.

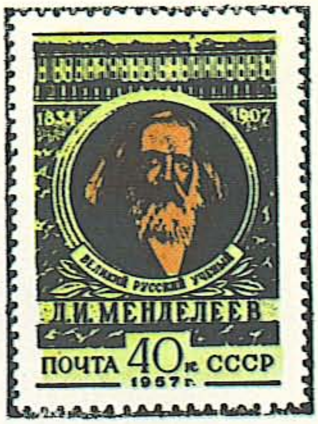

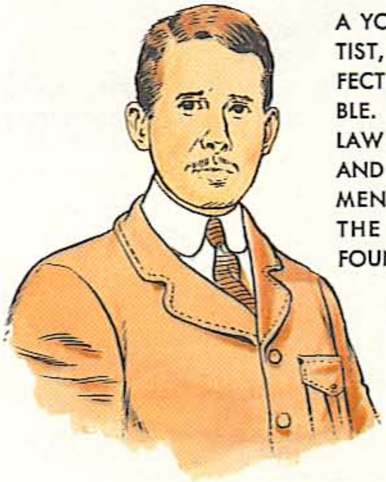

A YOUNG ENGLISH SCIENTIST, HENRY MOSELEY, PERFECTED THE PERIODIC TABLE. HE DISCOVERED THE LAW OF ATOMIC NUMBERS AND ARRANGED THE ELEMENTS ACCORDING TO THE ELECTRIC CHARGE FOUND IN THE NUCLEUS.

THE NUMBER OF PROTONS IN AN ATOM IS ITS ATOMIC NUMBER. AN ATOM ALWAYS HAS THE SAME NUMBER OF PROTONS AND ELECTRONS. HYDROGEN IS THE SIMPLEST OF ALL ATOMS.

VIII		I B	II B	III B	IV B	V B	VI B	VII B
				B 5 Boron 10.82	C 6 Carbon 12.011	N 7 Nitrogen 14.008	O 8 Oxygen 16	F 9 Fluorine 19
				Al 13 Aluminum 26.98	Si 14 Silicon 28.09	P 15 Phosphorus 30.975	S 16 Sulfur 32.066	Cl 17 Chlorine 35.457
Co 27 Cobalt 58.94	Ni 28 Nickel 58.71	Cu 29 Copper 63.54	Zn 30 Zinc 65.38	Ga 31 Gallium 69.72	Ge 32 Germanium 72.6	As 33 Arsenic 74.91	Se 34 Selenium 78.96	Br 35 Bromine 79.916
Rh 45 Rhodium 102.91	Pd 46 Palladium 106.4	Ag 47 Silver 107.88	Cd 48 Cadmium 112.41	In 49 Indium 114.82	Sn 50 Tin 118.7	Sb 51 Antimony 121.76	Te 52 Tellurium 127.61	I 53 Iodine 126.91
Ir 77 Iridium 192.2	Pt 78 Platinum 195.09	Au 79 Gold 197	Hg 80 Mercury 200.61	Tl 81 Thallium 204.39	Pb 82 Lead 207.21	Bi 83 Bismuth 209	Po 84 Polonium 210	At 85 Astatine 210

🟥 HEAVY METALS

⬜ METAL-LOIDS

🟩 NON-METALS

🟧 RARE EARTH METALS

🟨 UNSTABLE ELEMENTS

Eu 63 Europium 152	Gd 64 Gadolinium 157.26	Tb 65 Terbium 158.93	Dy 66 Dysprosium 162.51	Ho 67 Holmium 164.94	Er 68 Erbium 167.27	Tm 69 Thulium 168.94	Yb 70 Ytterbium 173.04	Lu 71 Lutetium 174.99
Am 95 Americium 243	Cm 96 Curium 247	Bk 97 Berkelium 249	Cf 98 Californium 249	E 99 Einsteinium 254	Fm 100 Fermium 255	Mv 101 Mendelevium 256	No 102 Nobelium 251	? 103

The Mysteries of Solutions

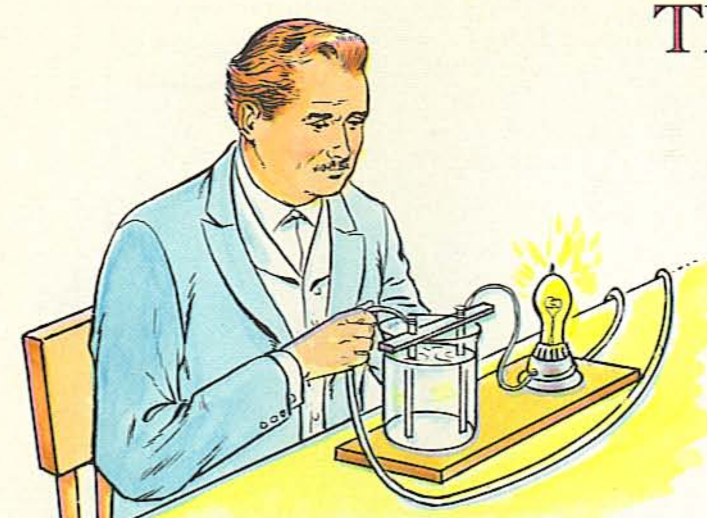

SVANTE ARRHENIUS DEVELOPED THEORY TO EXPLAIN HOW SOLUTIONS CONDUCT ELECTRICITY.

FROM THE earliest days, scientists experimenting with chemistry have worked with solutions. The liquid they used for making a solution (usually water) they called the "solvent." The chemical dissolved was the "solute."

When chemists began to use electricity as one of their tools, they discovered that different solutions behaved in different ways. The solution in water of a great number of chemicals — sugar among them — did not let electricity pass through. They were "non-conductors." Some chemicals, on the other hand, conducted electricity very easily. They were good conductors — "electrolytes."

In 1874 a Swedish scientist named Svante Arrhenius developed a theory to help explain the mysterious behavior of solutions. He was only 25 years old at the time.

His idea was that when a chemical that conducts electricity is dissolved in water, each molecule is broken up — "dissociated" — into electrically charged atoms or groups of atoms. These atoms or groups of atoms Arrhenius called "ions" from a Greek word that means "to wander." His new theory came to be called "Arrhenius' theory of ionization."

When table salt (sodium chloride, NaCl), for instance, is dissolved in water, it ionizes into positively charged sodium ions (Na^+) and negatively charged chlorine ions (Cl^-). These ions "wander" about in all directions until an electric current is applied to the solution. When that happens, the negative ions rush to the positive pole, the positive ions to the negative pole. It is the ions that conduct the current through the solution.

The reason that non-conductors do not conduct electricity is that they do not dissociate into ions.

Arrhenius' theory of ionization helped explain a great number of things that have puzzled chemists. His theory has been modified somewhat over the years but in most respects holds true today.

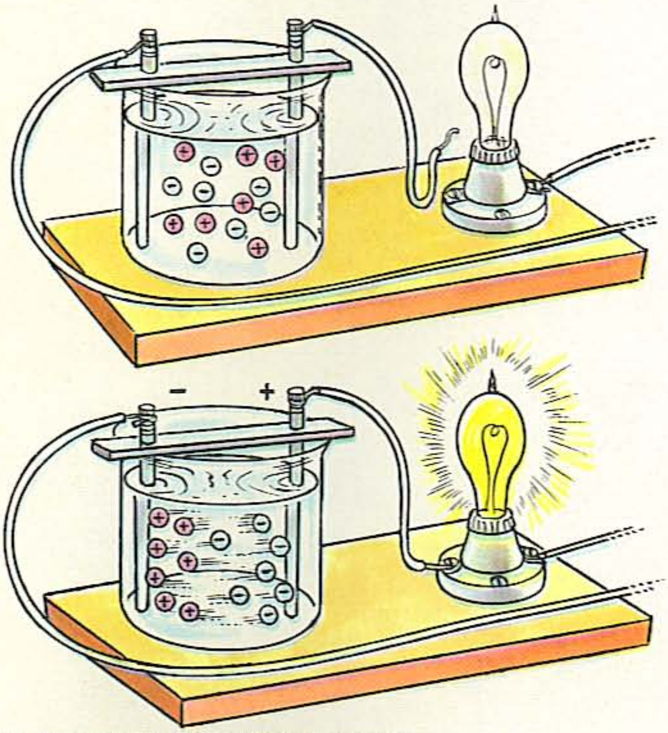

IN HIS EARLY EXPERIMENTS, SVANTE ARRHENIUS USED A SIMPLE SET-UP. YOU CAN EASILY REPEAT SOME OF HIS EXPERIMENTS IN YOUR OWN LAB, USING FLASHLIGHT BATTERIES.

TESTING CONDUCTIVITY OF SOLUTIONS

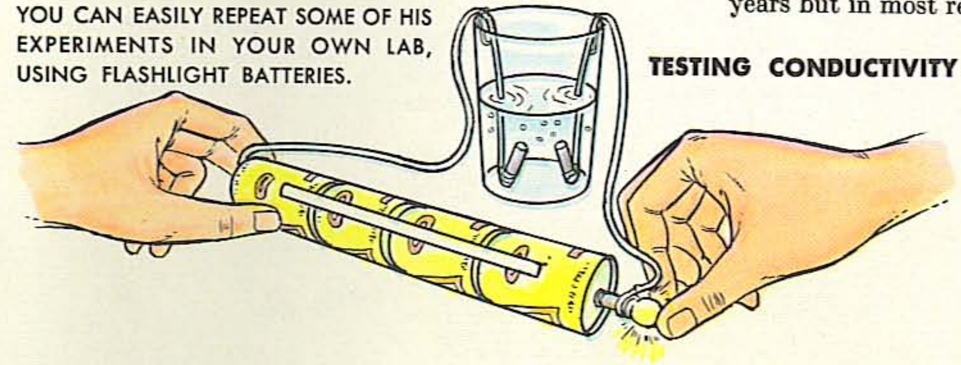

SET UP THE SAME APPARATUS AS ON PAGE 25. ADD FLASHLIGHT BULB TO END OF ONE WIRE. TRY DIFFERENT SOLUTIONS IN GLASS. SOME CONDUCT ELECTRICITY AND BULB LIGHTS UP. OTHERS DO NOT AND THE BULB DOES NOT LIGHT UP.

SATURATED SOLUTIONS

A SATURATED SOLUTION IS ONE IN WHICH NO MORE OF THE CHEMICAL WILL GO IN SOLUTION AT THAT PARTICULAR TEMPERATURE.

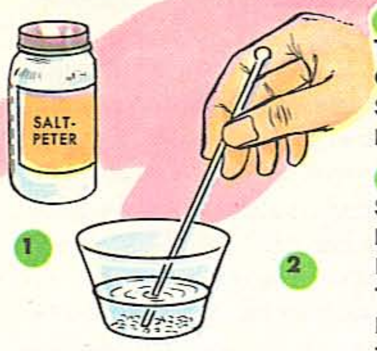

1 POUR 20 ml WATER OF ROOM TEMPERATURE INTO A CUSTARD CUP. ADD 6 g SALTPETER (POTASSIUM NITRATE). STIR. ALL THE SALTPETER DISSOLVES.

2 ADD 3 g MORE SALTPETER. STIR. SOME OF THE ADDED SALTPETER DOES NOT DISSOLVE. CLEAR LIQUID IS SATURATED AT ROOM TEMPERATURE. (AT 20°C., 6.3 g KNO_3 MAKES SATURATED SOLUTION IN 20 ml WATER.)

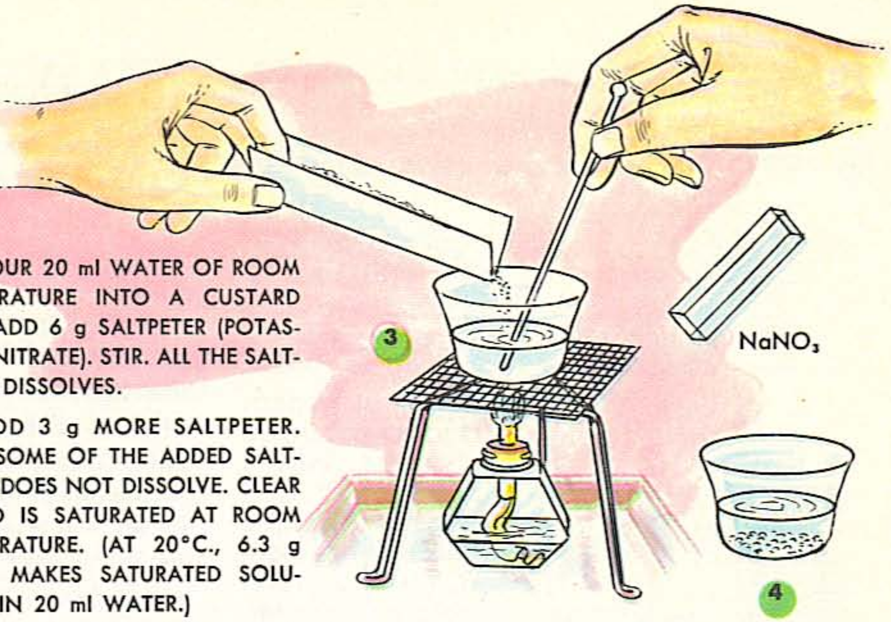

3 PLACE CUSTARD CUP OVER ALCOHOL BURNER. ADD 10 g MORE SALTPETER. SOON ALL SALTPETER IS DISSOLVED. AT HIGHER TEMPERATURES IT TAKES MORE SOLUTE TO MAKE A SATURATED SOLUTION. (AT BOILING, 20 ml H_2O DISSOLVES 49 g SALTPETER.)

4 TAKE SOLUTION OFF FIRE. AS IT COOLS, MUCH OF THE SALTPETER COMES OUT AS CRYSTALS BY SLOW CRYSTALLIZATION. LIQUID IS AGAIN A SOLUTION SATURATED AT ROOM TEMPERATURE.

BEHAVIOR OF SOLUTIONS

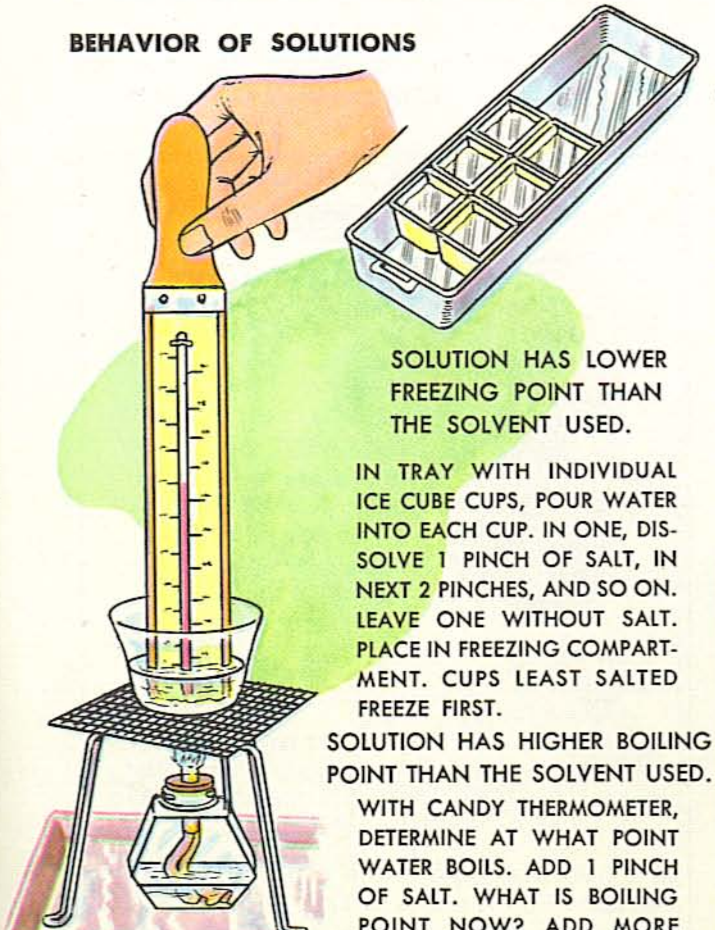

SOLUTION HAS LOWER FREEZING POINT THAN THE SOLVENT USED.

IN TRAY WITH INDIVIDUAL ICE CUBE CUPS, POUR WATER INTO EACH CUP. IN ONE, DISSOLVE 1 PINCH OF SALT, IN NEXT 2 PINCHES, AND SO ON. LEAVE ONE WITHOUT SALT. PLACE IN FREEZING COMPARTMENT. CUPS LEAST SALTED FREEZE FIRST.

SOLUTION HAS HIGHER BOILING POINT THAN THE SOLVENT USED.

WITH CANDY THERMOMETER, DETERMINE AT WHAT POINT WATER BOILS. ADD 1 PINCH OF SALT. WHAT IS BOILING POINT NOW? ADD MORE SALT. READ AGAIN.

CRYSTALLIZATION

YOU CAN FOLLOW CRYSTALLIZATION OF $MgSO_4$. IN TEST TUBE, HEAT MIXTURE OF 5 ml WATER AND 1 TEASPOON EPSOM SALT UNTIL SALT DISSOLVES. POUR HOT SOLUTION OVER PANE OF GLASS CLEANED WITH DETERGENT. CRYSTALS MAKE NEEDLE-LIKE NETWORK.

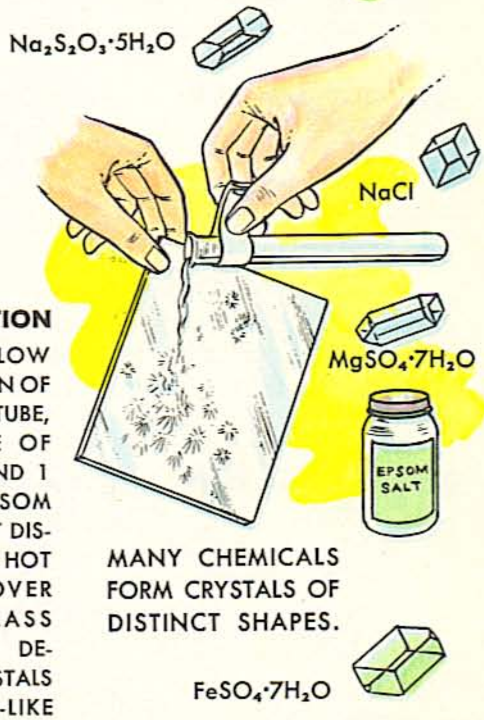

MANY CHEMICALS FORM CRYSTALS OF DISTINCT SHAPES.

MAKING SOLUTIONS

MAKE 50 ml GRADUATE FIRST: MEASURE 50 ml WATER INTO A NARROW JAR, USING 10 ml TEST TUBE GRADUATE SHOWN ON PAGE 15. MAKE A MARK AT 50 ml LEVEL.

10% (10 PER CENT) SOLUTION: MEASURE 40 ml WATER INTO A CUSTARD CUP. ADD 5 g OF THE CHEMICAL. STIR. (TO MAKE IT DISSOLVE QUICKER, YOU MAY WANT TO HEAT THE WATER SLIGHTLY.) POUR SOLUTION INTO 50 ml GRADUATE. ADD WATER TO THE 50 ml MARK.

2% SOLUTION: MEASURE 40 ml WATER INTO CUSTARD CUP. ADD 1 g OF THE CHEMICAL. STIR TO DISSOLVE. POUR INTO 50 ml GRADUATE. ADD WATER TO 50 ml.

HOW DO YOU KNOW AN ACID?

1. ACIDS TASTE SOUR.

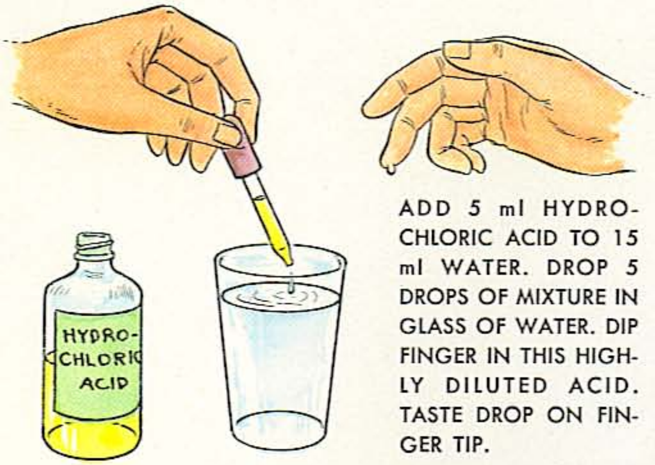

ADD 5 ml HYDROCHLORIC ACID TO 15 ml WATER. DROP 5 DROPS OF MIXTURE IN GLASS OF WATER. DIP FINGER IN THIS HIGHLY DILUTED ACID. TASTE DROP ON FINGER TIP.

2. ACIDS ACT WITH INDICATORS.

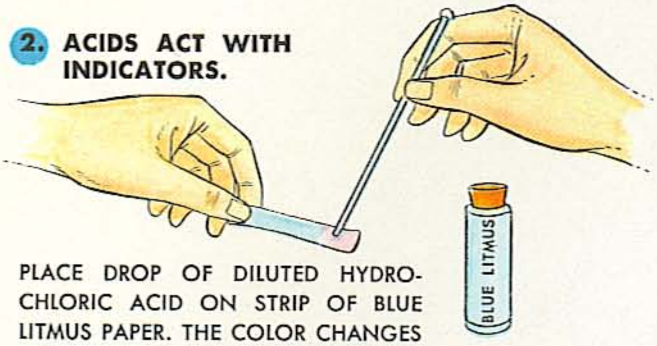

PLACE DROP OF DILUTED HYDROCHLORIC ACID ON STRIP OF BLUE LITMUS PAPER. THE COLOR CHANGES TO RED.

3. ACIDS ACT WITH METALS.

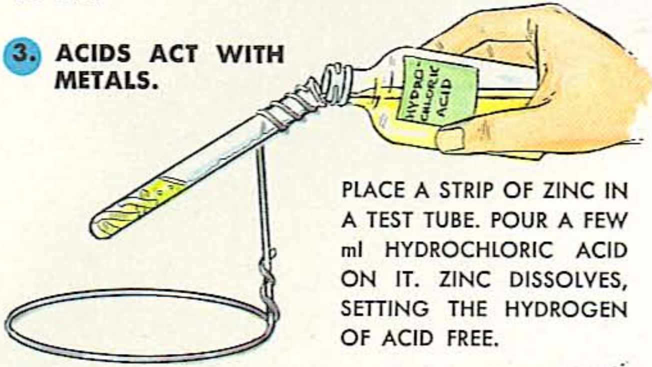

PLACE A STRIP OF ZINC IN A TEST TUBE. POUR A FEW ml HYDROCHLORIC ACID ON IT. ZINC DISSOLVES, SETTING THE HYDROGEN OF ACID FREE.

4. ACIDS NEUTRALIZE BASES.

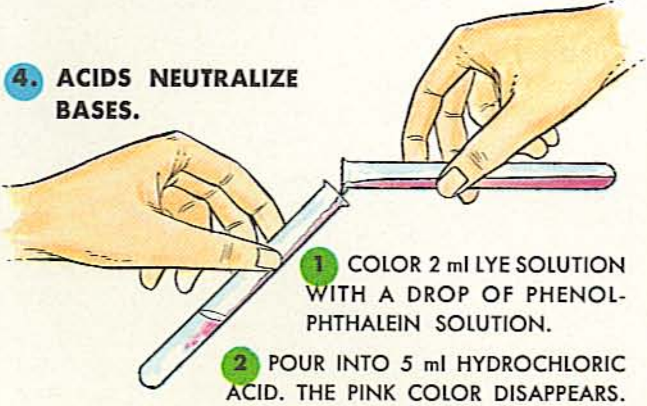

1 COLOR 2 ml LYE SOLUTION WITH A DROP OF PHENOLPHTHALEIN SOLUTION.

2 POUR INTO 5 ml HYDROCHLORIC ACID. THE PINK COLOR DISAPPEARS.

Working With Acids

ACIDS have many traits in common. They taste sour. They change the color of certain plant substances—which are called "indicators." They contain hydrogen (H) that can be replaced by a metal. They neutralize bases.

But what *is* an acid? Earlier, the "acidic" traits were used to define an acid. But with the modern understanding of the atom, a different definition is used. You will remember that the nucleus of an atom contains positively charged protons. Acids in solution liberate protons as ions (H^+). And so we say that an acid is a substance that will give up — or "donate" — protons to another substance. Acids are "proton donors." The foremost acids used in industry are sulfuric acid (H_2SO_4), nitric acid (HNO_3), and hydrochloric acid (HCl).

The first two — sulfuric acid and nitric acid — should NEVER be used in the home lab. They are much too DANGEROUS. They destroy the skin and might blind you if you got them in the eyes. (Wherever a chemical experiment would ordinarily call for sulfuric acid, this book uses sodium acid sulfate — $NaHSO_4$, sodium bisulfate, "Sani-Flush"; wherever

(CONTINUED ON PAGE 44)

HOME-MADE INDICATORS

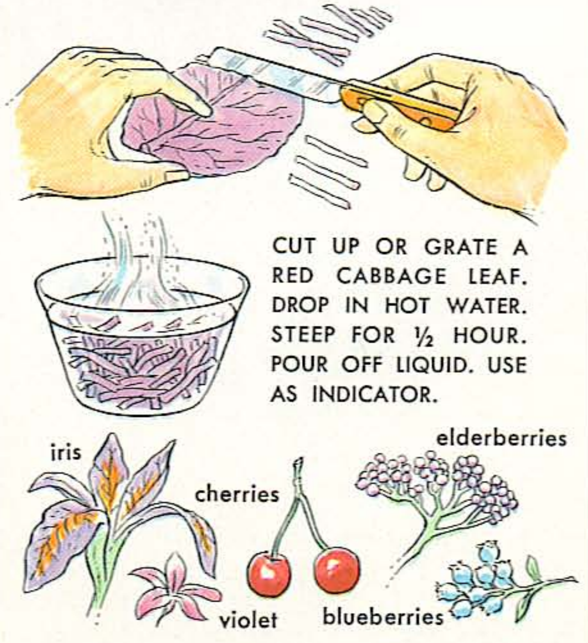

CUT UP OR GRATE A RED CABBAGE LEAF. DROP IN HOT WATER. STEEP FOR ½ HOUR. POUR OFF LIQUID. USE AS INDICATOR.

MANY FLOWERS AND FRUITS CONTAIN COLORING MATTER WHICH YOU CAN EXTRACT WITH HOT WATER AND USE AS AN INDICATOR FOR ACIDS AND BASES.

Working With Bases

BASES taste brackish. They change the color of "indicators." They contain a combination of oxygen and hydrogen atoms called "hydroxyl" (OH). They neutralize acids.

But what *is* a base? When a base is dissolved in water it liberates negatively charged hydroxyl ions (OH^-). When a base is neutralized, these ions take on — or "accept"— positively charged protons from another substance. A base is a substance that will accept and combine with protons from another substance. Bases are "proton acceptors." The most important bases are sodium hydroxide ("lye," NaOH), ammonium hydroxide ("ammonia," NH_4OH), and calcium hydroxide ("slaked lime," $Ca(OH)_2$).

The first of these — sodium hydroxide — is used in many households to clean sluggish drains and to keep sinks from stopping up ("Drano"). USE IT WITH GREAT CARE in your experiments. Do not touch lye flakes with your fingers and do not get the solution on your skin — it dissolves the natural oil. It is particularly dangerous to get lye in your eyes. If you get lye on you, dilute it quickly with LOTS OF WATER.

(CONTINUED ON PAGE 45)

LABORATORY INDICATORS

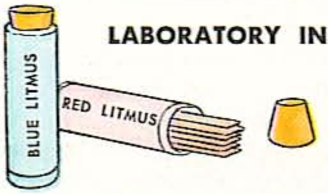

LITMUS PAPER IS MOST COMMONLY USED INDICATOR. AN ACID TURNS BLUE LITMUS RED. BASES TURN RED LITMUS BLUE.

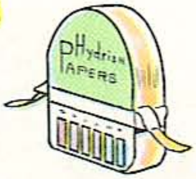

pHYDRION PAPER IS MORE EXACT INDICATOR FOR ACIDS AND BASES.

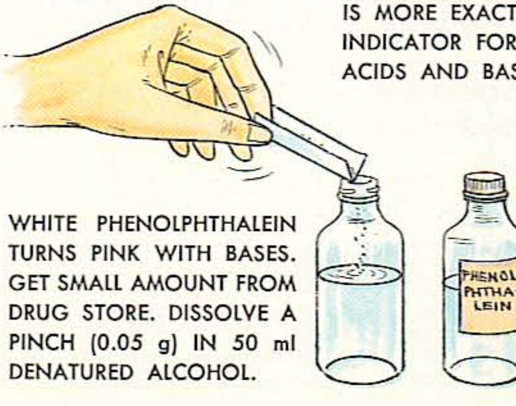

WHITE PHENOLPHTHALEIN TURNS PINK WITH BASES. GET SMALL AMOUNT FROM DRUG STORE. DISSOLVE A PINCH (0.05 g) IN 50 ml DENATURED ALCOHOL.

HOW DO YOU KNOW A BASE?

1. BASES TASTE BRACKISH.

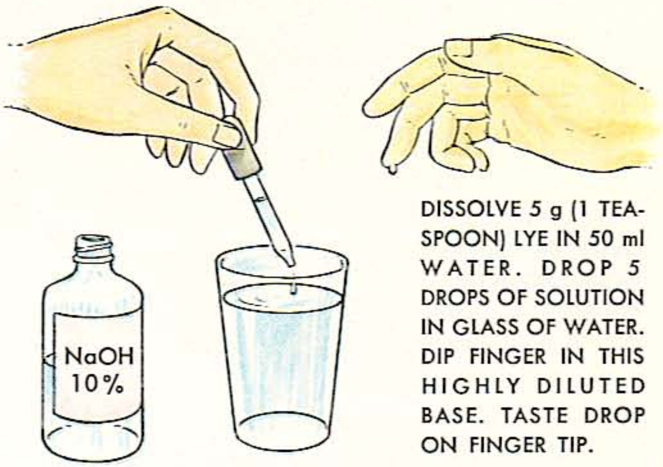

DISSOLVE 5 g (1 TEASPOON) LYE IN 50 ml WATER. DROP 5 DROPS OF SOLUTION IN GLASS OF WATER. DIP FINGER IN THIS HIGHLY DILUTED BASE. TASTE DROP ON FINGER TIP.

2. BASES ACT WITH INDICATORS.

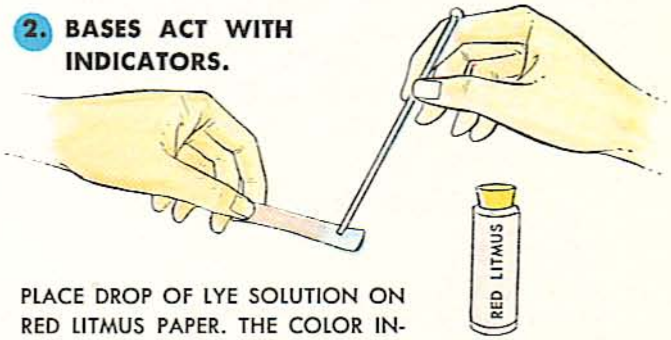

PLACE DROP OF LYE SOLUTION ON RED LITMUS PAPER. THE COLOR INSTANTLY CHANGES TO BLUE.

3. BASES ACT WITH FAT.

ADD TINY LUMP OF FAT TO 5 ml LYE SOLUTION. HEAT GENTLY. FAT DISSOLVES TO FORM SOAP.

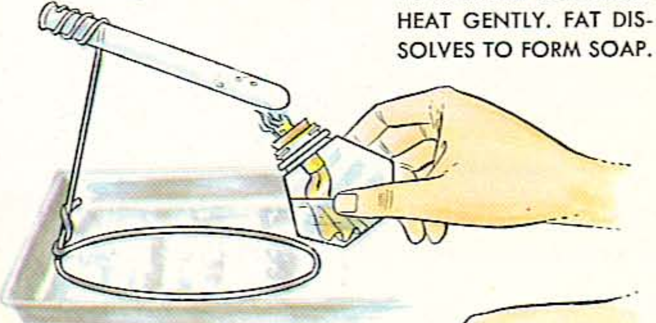

4. BASES NEUTRALIZE ACIDS.

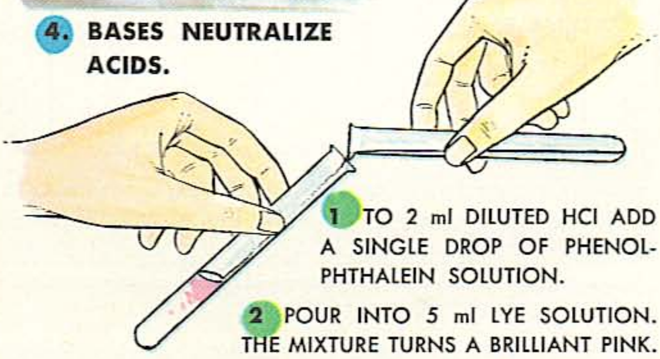

1 TO 2 ml DILUTED HCl ADD A SINGLE DROP OF PHENOLPHTHALEIN SOLUTION.

2 POUR INTO 5 ml LYE SOLUTION. THE MIXTURE TURNS A BRILLIANT PINK.

HOUSEHOLD ITEMS CONTAINING ACIDS

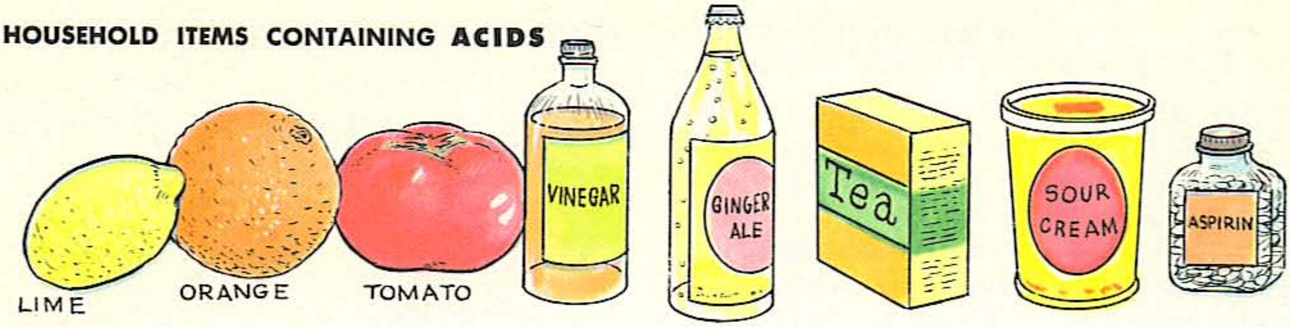

Acids—Continued

nitric acid would be called for, this book produces it in a mixture of a nitrate, KNO_3, and sodium bisulfate.)

Hydrochloric acid is used in many households under the name of "muriatic acid." Whenever you use hydrochloric acid in an experiment; USE IT WITH GREAT CARE. If any of it gets on you, dilute it quickly with LOTS OF WATER. Or neutralize it with bicarbonate of soda (but not if in the eyes).

ACID FROM NON-METALLIC OXIDE

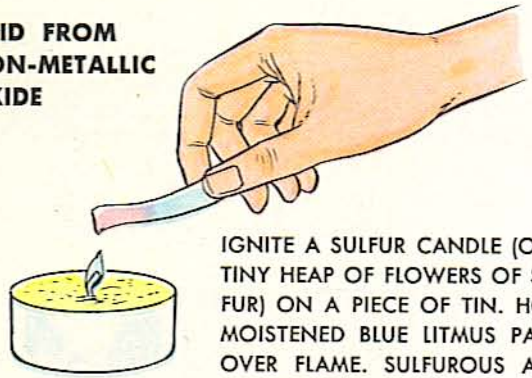

IGNITE A SULFUR CANDLE (OR A TINY HEAP OF FLOWERS OF SULFUR) ON A PIECE OF TIN. HOLD MOISTENED BLUE LITMUS PAPER OVER FLAME. SULFUROUS ACID FORMED TURNS IT RED.

ACID FROM A SALT

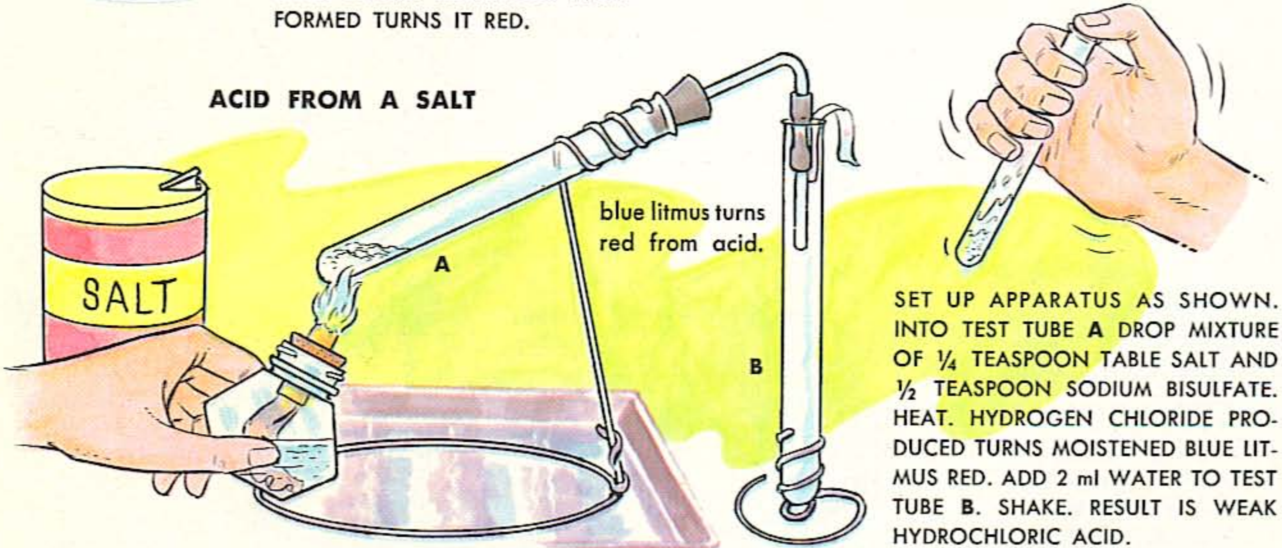

blue litmus turns red from acid.

SET UP APPARATUS AS SHOWN. INTO TEST TUBE **A** DROP MIXTURE OF ¼ TEASPOON TABLE SALT AND ½ TEASPOON SODIUM BISULFATE. HEAT. HYDROGEN CHLORIDE PRODUCED TURNS MOISTENED BLUE LITMUS RED. ADD 2 ml WATER TO TEST TUBE **B**. SHAKE. RESULT IS WEAK HYDROCHLORIC ACID.

pH SYSTEM IS A WAY OF DESCRIBING THE RELATIVE ACIDITY OR ALKALINITY OF A SOLUTION. PURE WATER IS NEUTRAL WITH pH7. THE LOWER THE NUMBER BELOW 7, THE MORE ACID THE SOLUTION. THE HIGHER

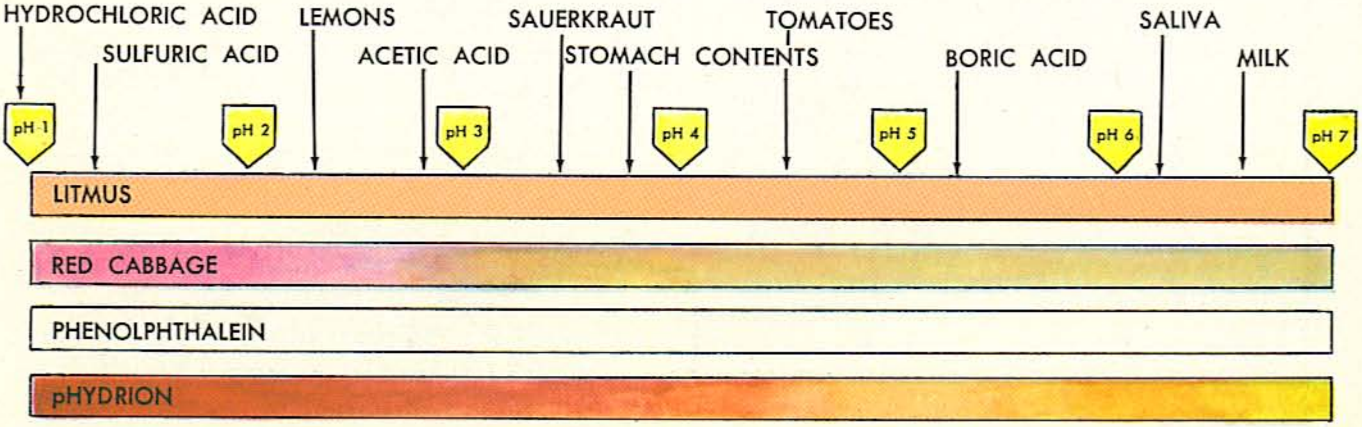

HOUSEHOLD ITEMS CONTAINING BASES

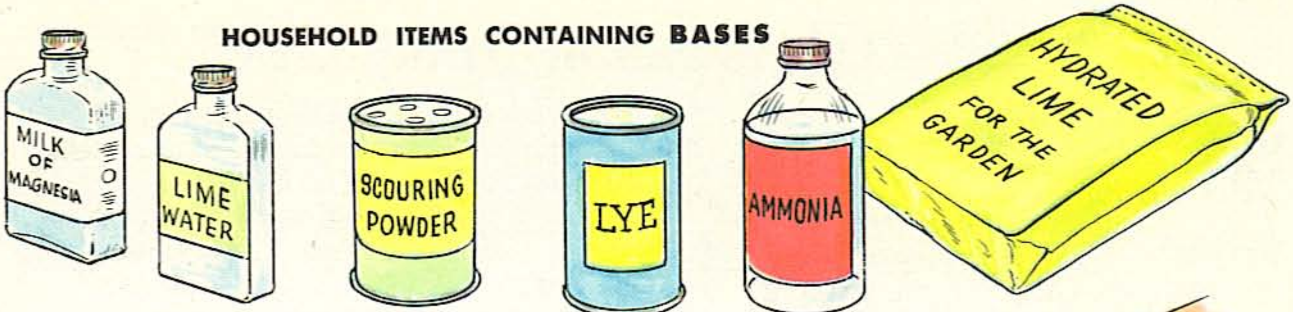

Bases—Continued

You can also neutralize it with vinegar (but not if in the eyes).

Ammonia is a common household cleaning liquid. Ammonia should also be handled with care and should be washed off quickly if you get it on you. Also watch your nose when you work with ammonia. It has a very strong smell.

Calcium hydroxide is a white powder. You will use it in a great number of experiments.

BASE FROM METALLIC OXIDE

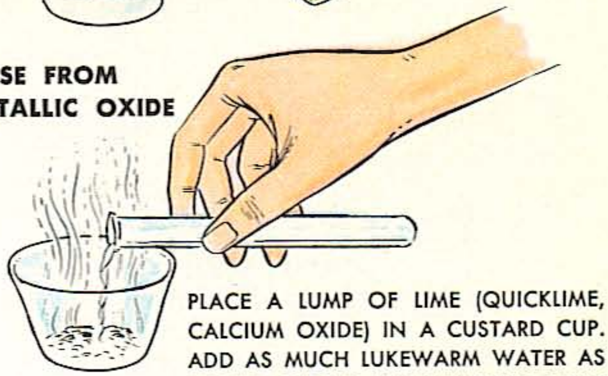

PLACE A LUMP OF LIME (QUICKLIME, CALCIUM OXIDE) IN A CUSTARD CUP. ADD AS MUCH LUKEWARM WATER AS IT WILL ABSORB. LIME HEATS UP, GIVES OFF STEAM, CRUMBLES INTO POWDER OF SLAKED LIME (CALCIUM HYDROXIDE).

BASE FROM A SALT

IN A CUSTARD CUP, DISSOLVE 1 TEASPOON SAL SODA (WASHING SODA, SODIUM CARBONATE) IN 50 ml WATER. HEAT SLIGHTLY. ADD SLAKED LIME MIXED WITH WATER. STIR. CHEMICAL REACTION PRODUCES SODIUM HYDROXIDE AND CALCIUM CARBONATE. FILTER. CLEAR LIQUID CONTAINS THE SODIUM HYDROXIDE (LYE). THE CALCIUM CARBONATE IS HELD BACK BY THE FILTER.

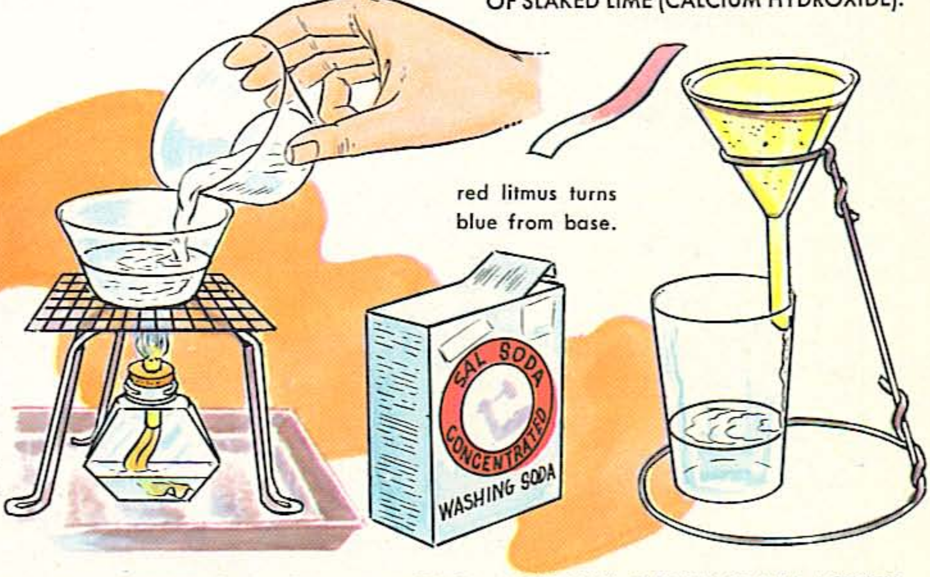

red litmus turns blue from base.

THE NUMBER ABOVE 7, THE MORE ALKALINE THE SOLUTION. WHEN YOU KNOW AT WHAT pH AN INDICATOR CHANGES COLOR, YOU CAN DETERMINE THE ACIDITY OR ALKALINITY OF THE SOLUTION YOU ARE TESTING.

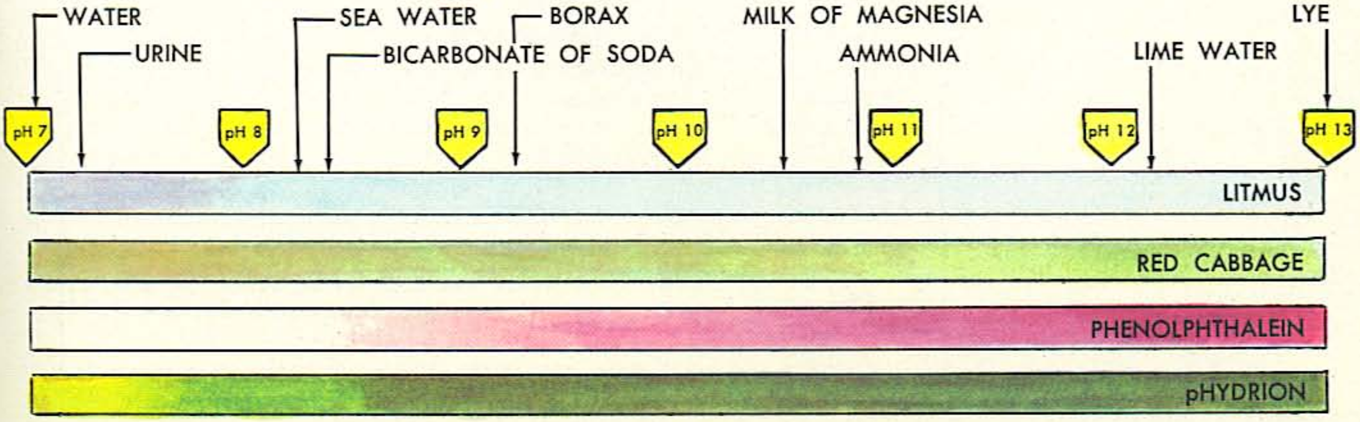

Salts—Chemicals of Many Uses

NEUTRALIZATION IS USED EXTENSIVELY IN CHEMICAL ANALYSIS IN A TECHNIQUE CALLED **TITRATION**.

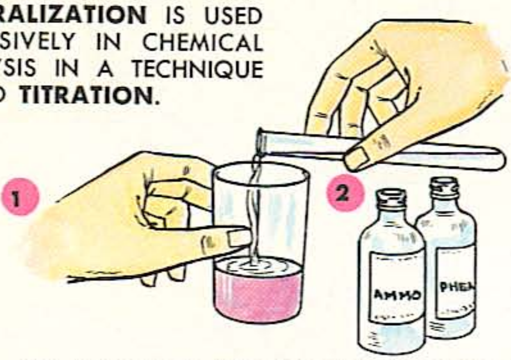

TO DETERMINE THE UNKNOWN STRENGTH OF A BASE, THE CHEMIST DROPS INTO IT FROM A LONG TUBE—A BURETTE—AS MUCH ACID OF KNOWN STRENGTH AS IS NECESSARY TO NEUTRALIZE IT. BY CHECKING ACID USED HE FIGURES STRENGTH OF BASE.

1 FOR A TRY AT TITRATION, MIX A FEW ml OF HOUSEHOLD AMMONIA WITH 40 ml WATER. ADD A DROP OF PHENOLPHTHALEIN. THIS WILL COLOR THE MIXTURE A DEEP PINK.

2 POUR 10 ml DILUTED HYDROCHLORIC ACID INTO MEASURING TUBE. POUR SOME OF THIS ACID INTO THE AMMONIA UNTIL COLOR HAS ALMOST VANISHED.

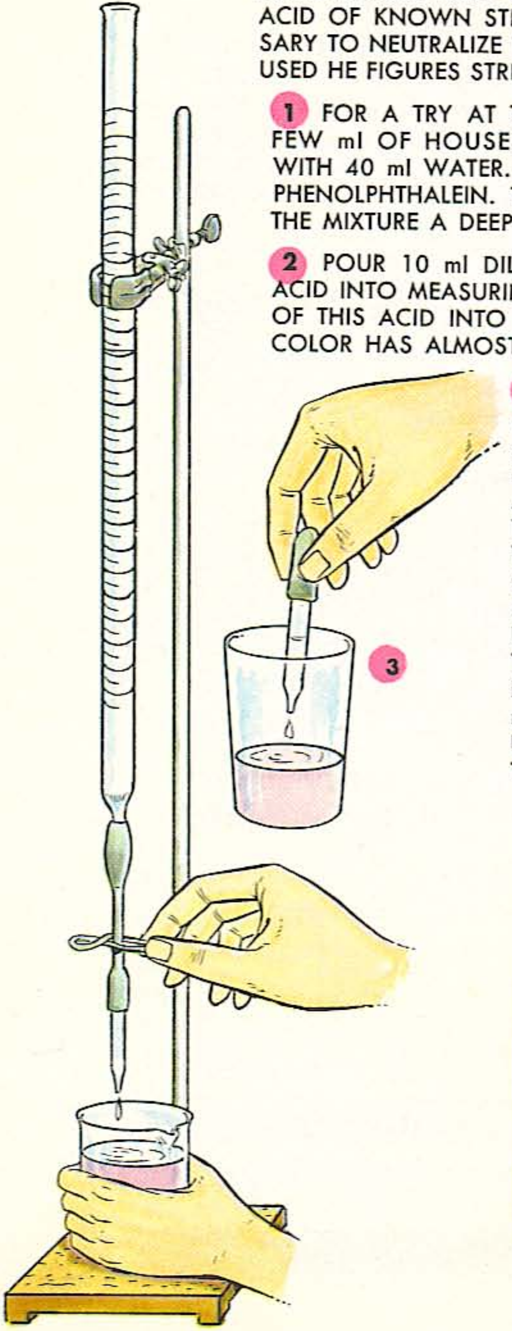

3 PICK UP A FEW ml OF THE MEASURED ACID IN AN EYE DROPPER (PIPETTE). DROP ACID SLOWLY INTO THE AMMONIA MIXTURE UNTIL COLOR IS COMPLETELY GONE. RETURN ACID NOT USED TO MEASURING TUBE. YOU NOW KNOW HOW MANY ml ACID YOU HAD TO USE TO NEUTRALIZE THE AMMONIA.

WHAT HAPPENS when you neutralize an acid with a base or a base with an acid? The hydrogen atoms (H^+ ions) of the acid combine with the hydroxyl groups (OH^- ions) of the base to form water, and the metal atoms of the base combine with what remains of the acid to form a salt. Or simply:

BASE plus ACID turns into
WATER plus SALT

This, for example, is what happens when you neutralize sodium hydroxide with hydrochloric acid:

$$NaOH + HCl \rightarrow HOH + NaCl$$

The result is water and sodium chloride — ordinary table salt which has given its name to other substances of a similar nature.

Of all the salts used in industry, table salt ($NaCl$) and washing soda (Na_2CO_3) are of greatest importance. Numerous other chemicals are produced from them. Our way of life would be completely disrupted if our country's industry did not have enough of these two salts.

Many other salts are necessary for our well-being. You'll probably find at least half a dozen different salts used daily in your home — in cooking and baking, in gardening, for cleaning.

In your chemical experiments you'll be working with two classes of salts: *normal salts* (such as $NaCl$, Na_2CO_3, KI) which contain no free hydrogen or hydroxyl ions, and *acid salts* (such as $NaHSO_4$, $NaHCO_3$) which contain replaceable hydrogen.

Some of these salts dissolve easily in water — all the nitrates (salts of nitric acid) and most of the chlorides (salts of hydrochloric acid). Many salts, on the other hand, are insoluble — most of the carbonates (salts of carbonic acid) and most sulfides (salts of hydrosulfuric acid).

HOW THE NAMES OF SALTS ARE MADE UP

THE ACID	FORMULA AND NAME OF ACID		FORMULA AND NAME OF SALT	
SULFURIC ACID	H_2SO_4	HYDROGEN SULFATE	Na_2SO_4	SODIUM SULFATE
NITRIC ACID	HNO_3	HYDROGEN NITRATE	$NaNO_3$	SODIUM NITRATE
CARBONIC ACID	H_2CO_3	HYDROGEN CARBONATE	Na_2CO_3	SODIUM CARBONATE
ACETIC ACID	$HC_2H_3O_2$	HYDROGEN ACETATE	$NaC_2H_3O_2$	SODIUM ACETATE
HYDROCHLORIC ACID	HCl	HYDROGEN CHLORIDE	$NaCl$	SODIUM CHLORIDE
HYDROSULFURIC ACID	H_2S	HYDROGEN SULFIDE	Na_2S	SODIUM SULFIDE
SULFUROUS ACID	H_2SO_3	HYDROGEN SULFITE	Na_2SO_3	SODIUM SULFITE
NITROUS ACID	HNO_2	HYDROGEN NITRITE	$NaNO_2$	SODIUM NITRITE
CHLOROUS ACID	$HClO_2$	HYDROGEN CHLORITE	$NaClO_2$	SODIUM CHLORITE

REMEMBER: **-IC** ACIDS FORM **-ATE** SALTS;
HYDRO- -IC ACIDS FORM **-IDE** SALTS; **-OUS** ACIDS FORM **-ITE** SALTS

HOUSEHOLD ITEMS CONTAINING SALTS

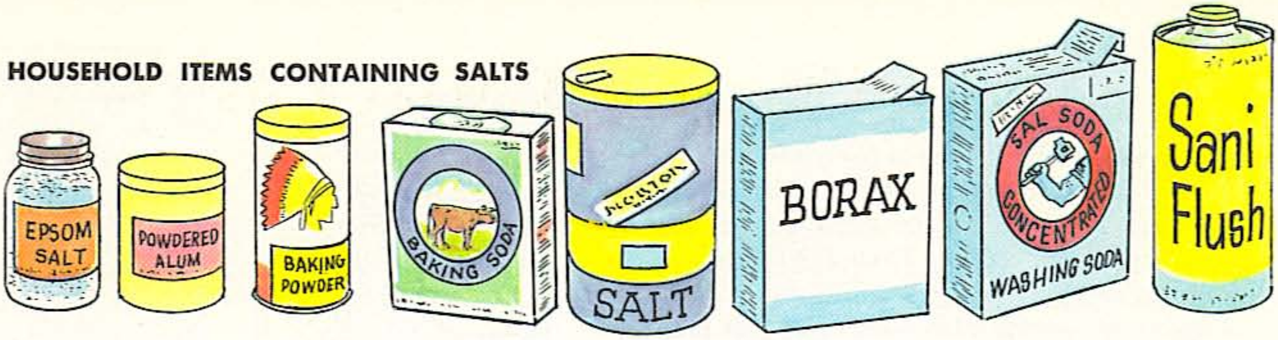

DIFFERENT WAYS OF PRODUCING SALTS

SALT FROM METAL AND ACID

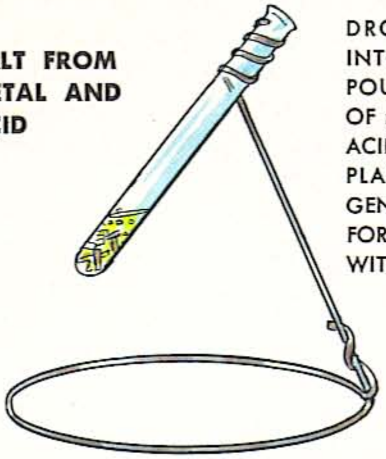

DROP ZINC STRIPS INTO A TEST TUBE. POUR IN A COUPLE OF ml HYDROCHLORIC ACID. THE ZINC DISPLACES THE HYDROGEN OF THE ACID TO FORM A SALT ($ZnCl_2$) WITH THE CHLORINE.

SALT FROM METAL OXIDE AND ACID

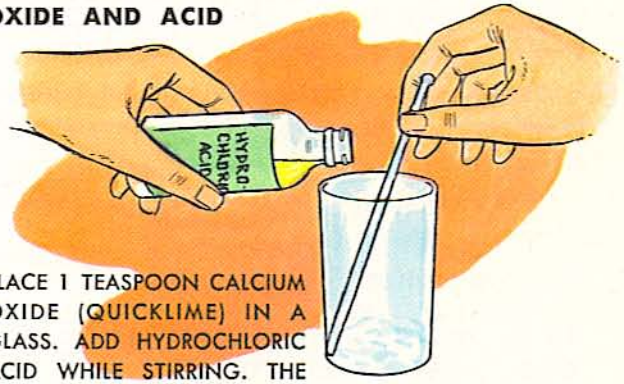

PLACE 1 TEASPOON CALCIUM OXIDE (QUICKLIME) IN A GLASS. ADD HYDROCHLORIC ACID WHILE STIRRING. THE QUICKLIME DISSOLVES IN THE ACID, FORMING CALCIUM CHLORIDE AND WATER.

SALT FROM ANOTHER SALT AND ACID

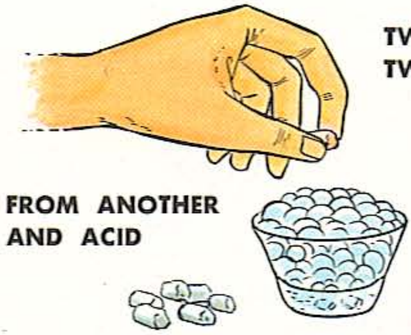

DROP PIECES OF CHALK, MARBLE, OR OYSTER SHELLS (ALL OF THEM CALCIUM CARBONATES) IN A FEW ml HYDROCHLORIC ACID. RESULT IS CALCIUM CHLORIDE AND CARBONIC ACID (WHICH BREAKS UP INTO CARBON DIOXIDE AND WATER).

TWO SALTS FROM TWO OTHER SALTS

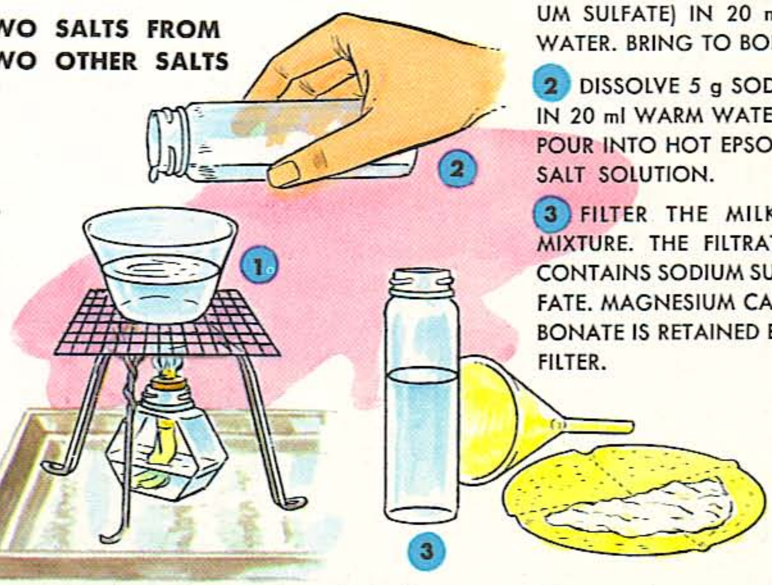

① DISSOLVE 5 g EPSOM SALTS (MAGNESIUM SULFATE) IN 20 ml. WATER. BRING TO BOIL.

② DISSOLVE 5 g SODA IN 20 ml WARM WATER. POUR INTO HOT EPSOM SALT SOLUTION.

③ FILTER THE MILKY MIXTURE. THE FILTRATE CONTAINS SODIUM SULFATE. MAGNESIUM CARBONATE IS RETAINED BY FILTER.

THERE ARE many ways of producing a salt in addition to neutralization.

When you made iron sulfide directly from the two elements iron and sulfur, you produced a salt:

$$Fe + S \rightarrow FeS$$

When you caused zinc metal to react with hydrochloric acid, you made a salt:

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

When you made sodium hydroxide, you used a base and a salt to form a new base and a new salt:

$$Ca(OH)_2 + Na_2CO_3 \rightarrow 2NaOH + CaCO_3$$

A salt and an acid often form another salt and another acid:

$$CaCO_3 + 2HCl \rightarrow$$
$$CaCl_2 + H_2CO_3 \ (H_2O + CO_2)$$

Two soluble salts may also form two other salts—one of them insoluble:

$$Na_2CO_3 + MgSO_4 \rightarrow MgCO_3 + Na_2SO_4$$

Iodine—Violet or Brown?

I **IODINE**
Element 53.
At. wt. 126.91.
Gray-black crystals of a peculiar odor. Sublimes with violet color. Combines directly with metals and nonmetals. It has a density of 4.9.

IODIZED SALT
TINCTURE OF IODINE 2%

Iodine is an interesting element to experiment with. It is easily driven out of its compounds as beautiful, violet fumes that turn into grayish-black, metallic-looking crystals on cooling. These crystals can be further purified by turning them into vapor again, and again cooling them into crystal form. This process is called "sublimation."

You are probably familiar with the 2% alcoholic solution of iodine known as "tincture of iodine." It is found in almost every home medicine cabinet and is used as a disinfectant for wounds. Iodine has many other uses — in photography and in the preparation of various medicines and dyes.

Iodine has the bad habit of staining practically everything with which it comes in contact with a brown stain that won't come off in washing. That's why it is advisable to have sodium thiosulfate — photographer's fixing salt, "hypo"— around when you work with iodine. Hypo in solution forms a colorless compound with iodine.

Be careful not to breathe fumes.

MAKING IODINE

① IN A PYREX CUSTARD CUP MIX TOGETHER 2 g POTASSIUM IODIDE, 2 g MANGANESE DIOXIDE, 4 g SODIUM BISULFATE. HEAT MIXTURE GENTLY. SOON VIOLET FUMES EMERGE.

② DROP HALF A DOZEN ICE CUBES INTO A JAR. ADD A LITTLE WATER. PLACE JAR AS A LID ON TOP OF CUSTARD CUP. THE VIOLET FUMES SETTLE ON BOTTOM OF JAR AS GRAYISH-BLACK, SHINY IODINE CRYSTALS.

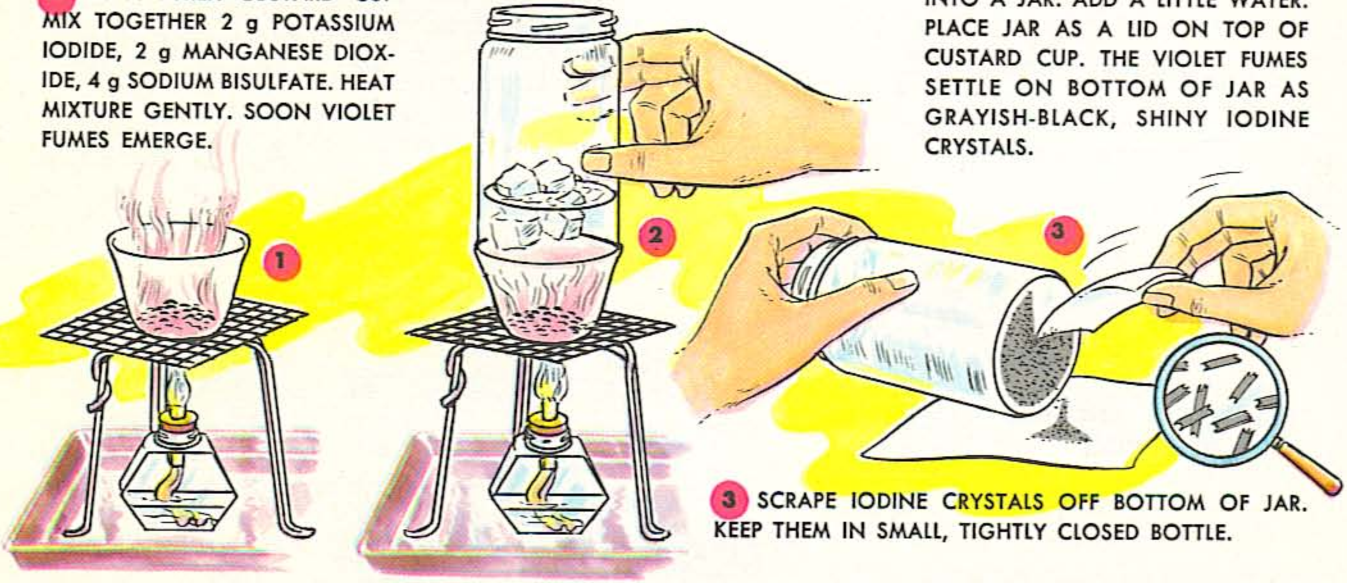

③ SCRAPE IODINE CRYSTALS OFF BOTTOM OF JAR. KEEP THEM IN SMALL, TIGHTLY CLOSED BOTTLE.

SOLUBILITY OF IODINE

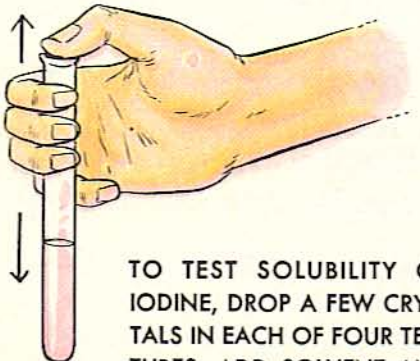

TO TEST SOLUBILITY OF IODINE, DROP A FEW CRYSTALS IN EACH OF FOUR TEST TUBES. ADD SOLVENT AND SHAKE TUBE.

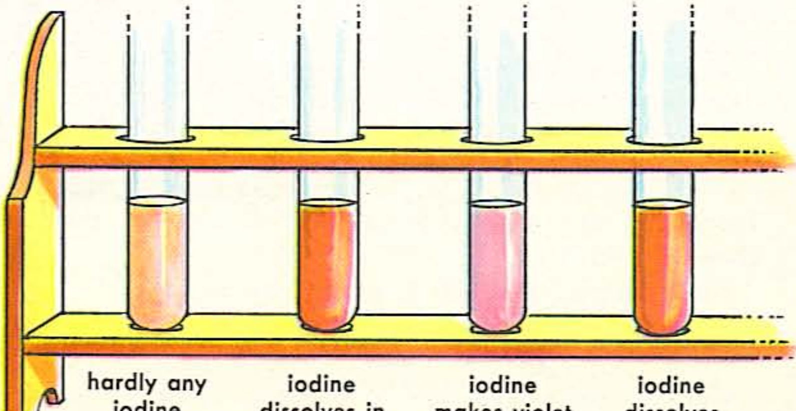

hardly any iodine dissolves when put in plain water.	iodine dissolves in water if you add potassium iodide.	iodine makes violet solution in carbon tetrachloride.	iodine dissolves with brown color in alcohol.

IODINE FREED BY CHLORINE

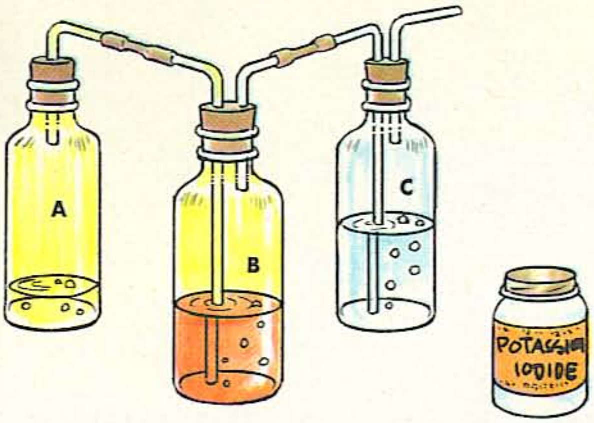

SET UP APPARATUS AS DESCRIBED ON PAGE 35 WITH THIS EXCEPTION: IN BOTTLE **B**, MAKE SOLUTION OF ½ g POTASSIUM IODIDE IN 40 ml WATER. AS CHLORINE BUBBLES THROUGH THIS SOLUTION IT TURNS BROWN FROM THE FREED IODINE. WITH MORE CHLORINE IT CLEARS AGAIN WHEN COLORLESS IODIC ACID FORMS.

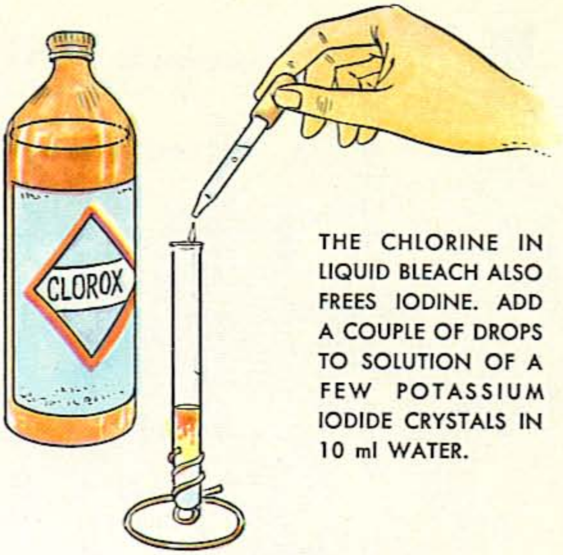

THE CHLORINE IN LIQUID BLEACH ALSO FREES IODINE. ADD A COUPLE OF DROPS TO SOLUTION OF A FEW POTASSIUM IODIDE CRYSTALS IN 10 ml WATER.

IODINE BY OXIDATION

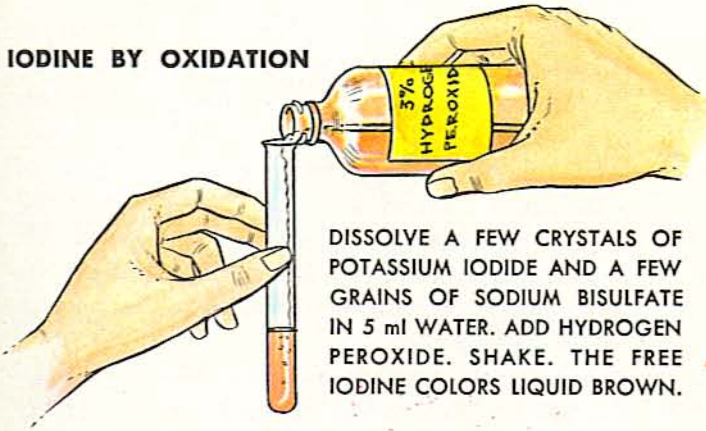

DISSOLVE A FEW CRYSTALS OF POTASSIUM IODIDE AND A FEW GRAINS OF SODIUM BISULFATE IN 5 ml WATER. ADD HYDROGEN PEROXIDE. SHAKE. THE FREE IODINE COLORS LIQUID BROWN.

MAKING HYDROGEN IODIDE

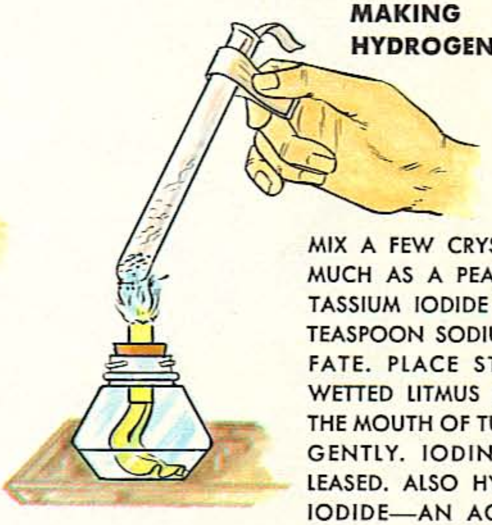

MIX A FEW CRYSTALS (AS MUCH AS A PEA) OF POTASSIUM IODIDE WITH ¼ TEASPOON SODIUM BISULFATE. PLACE STRIPS OF WETTED LITMUS PAPER AT THE MOUTH OF TUBE. HEAT GENTLY. IODINE IS RELEASED. ALSO HYDROGEN IODIDE—AN ACID THAT TURNS BLUE LITMUS RED.

STARCH TEST FOR IODINE

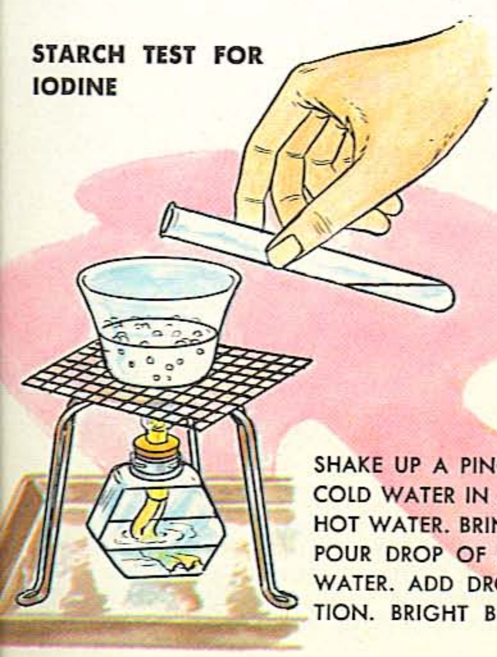

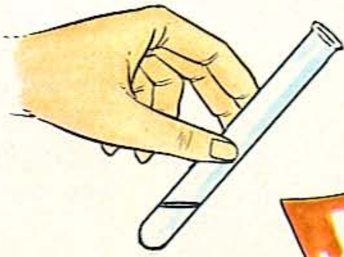

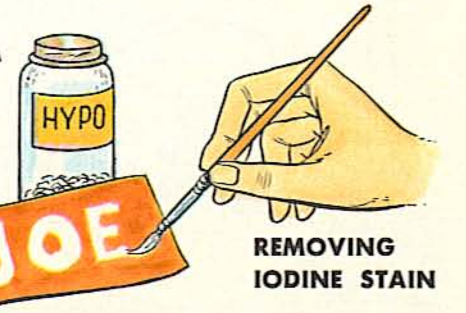

REMOVING IODINE STAIN

PAINT PAPER WITH IODINE. DISSOLVE A FEW CRYSTALS OF SODIUM THIOSULFATE ("HYPO") IN WATER. PAINT WITH THIS SOLUTION OVER THE BROWN COLOR. YOU WILL GET WHITE LETTERS AS HYPO FORMS COLORLESS COMPOUND WITH IODINE.

SHAKE UP A PINCH OF STARCH WITH COLD WATER IN A TEST TUBE. ADD TO HOT WATER. BRING TO A BOIL. COOL. POUR DROP OF MIXTURE INTO 10 ml WATER. ADD DROP OF IODINE SOLUTION. BRIGHT BLUE COLOR RESULTS.

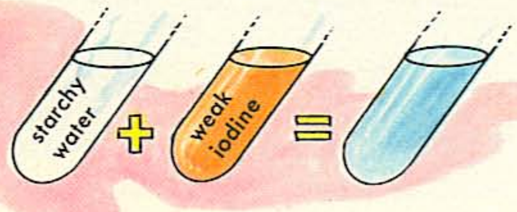

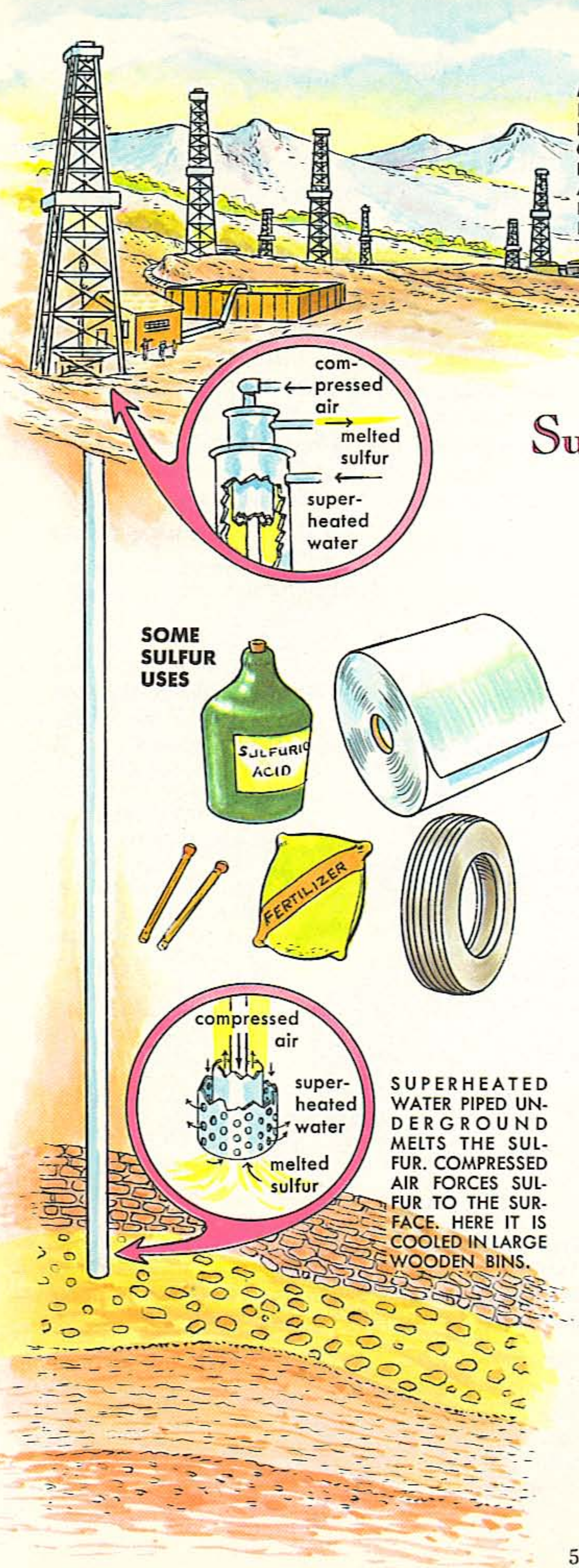
com-pressed air
melted sulfur
super-heated water
SOME SULFUR USES
SULFURIC ACID
FERTILIZER
compressed air
super-heated water
melted sulfur

MOST OF OUR SULFUR IS PRODUCED BY DRIVING IT OUT OF THE GROUND IN MELTED FORM BY A PROCESS INVENTED BY HERMAN FRASCH.

SUPERHEATED WATER PIPED UNDERGROUND MELTS THE SULFUR. COMPRESSED AIR FORCES SULFUR TO THE SURFACE. HERE IT IS COOLED IN LARGE WOODEN BINS.

S **SULFUR**
Element 16.
Atomic wt.: 32.066. Density: 2.07. Yellow crystals. Insoluble in water. Melts at 119°C. Boils at 444°C. Burns in air with blue flame.

Sulfur and Its Compounds

In the old days, sulfur was called "brimstone" ("burning stone" — from an old word, *brennen*, to burn). When it burned with a blue flame and a suffocating smell, people were certain that the devil himself was around.

Until fairly recently, most sulfur came from the volcanic Italian island of Sicily. But today, America produces most of the world's sulfur. About a hundred years ago, big deposits were found in Louisiana, several hundred feet underground. The problem of getting it up was solved in 1894 in a very clever way by a young German emigrant, Herman Frasch. He piped superheated water underground to melt the sulfur, then forced the melted sulfur to the top with compressed air.

Sulfur itself is used for many purposes. By a process called "vulcanization" it turns sticky, gummy raw rubber into elastic rubber usable for automobile tires and other rubber products. Sulfur also goes into such things as matches and gunpowder and medical preparations.

But by far the greatest use of sulfur is in the preparation of sulfuric acid (H_2SO_4). This acid enters into the

(CONTINUED ON PAGE 52)

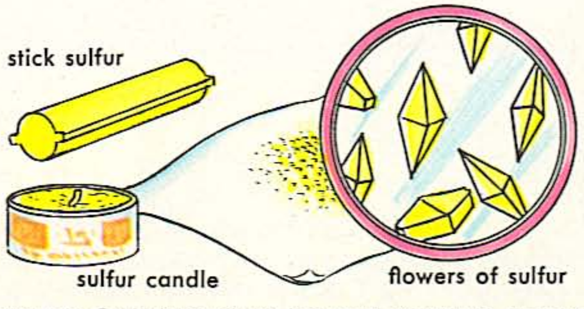
stick sulfur
sulfur candle
flowers of sulfur

SULFUR CAN USUALLY BE BOUGHT IN THREE DIFFERENT FORMS: AS STICK SULFUR, SULFUR CANDLES, AND AS A POWDER (FLOWERS OF SULFUR). UNDER MICROSCOPE, SULFUR POWDER PROVES TO BE RHOMBIC CRYSTALS.

MELTING SULFUR

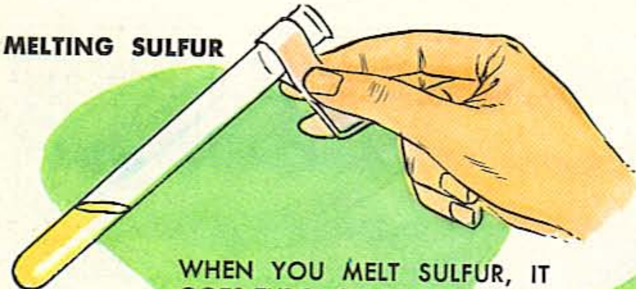

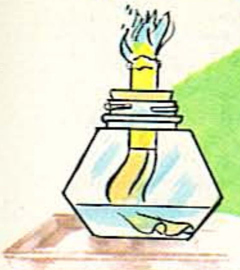

WHEN YOU MELT SULFUR, IT GOES THROUGH FOUR STAGES:

1. IT FIRST MELTS INTO A WATERY, STRAW-COLORED LIQUID.
2. IT NEXT BECOMES SLOW-FLOWING, CARAMEL-BROWN.
3. IT TURNS ALMOST SOLID.
4. IT BECOMES LIQUID AGAIN AND BOILS WITH YELLOW VAPOR.

MAKING MONOCLINIC CRYSTALS OF SULFUR

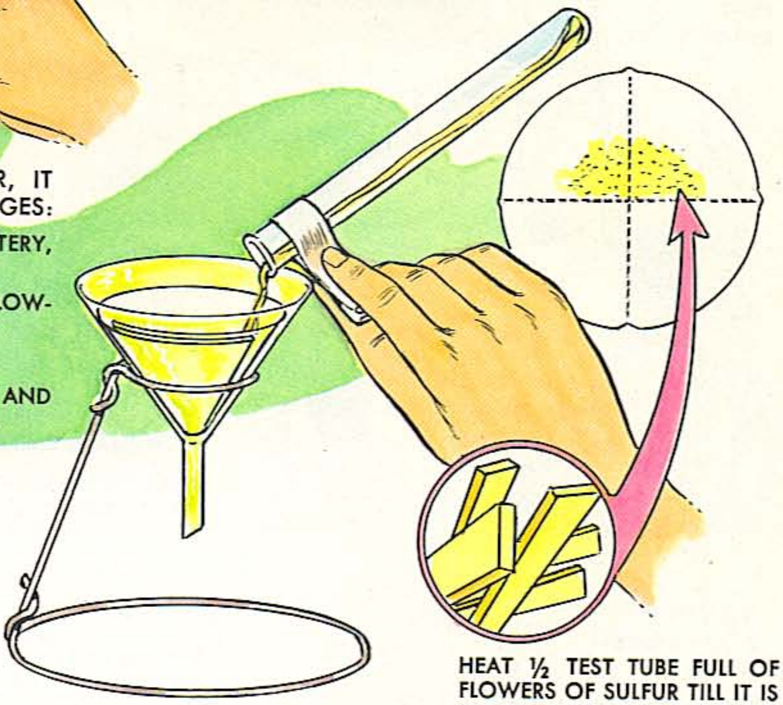

HEAT ½ TEST TUBE FULL OF FLOWERS OF SULFUR TILL IT IS MELTED WITH LIGHT COLOR. POUR MELTED SULFUR INTO A DRY FILTER. AS SOON AS CRUST FORMS ON TOP, OPEN UP FILTER PAPER. YOU WILL SEE THAT SULFUR HAS FORMED TINY NEEDLE-LIKE CRYSTALS.

CASTING WITH SULFUR

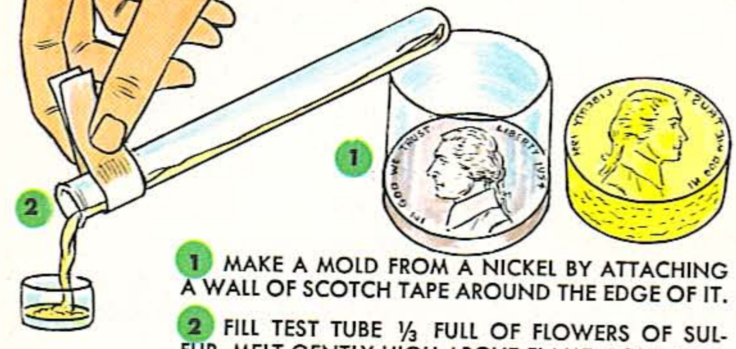

1 MAKE A MOLD FROM A NICKEL BY ATTACHING A WALL OF SCOTCH TAPE AROUND THE EDGE OF IT.

2 FILL TEST TUBE ⅓ FULL OF FLOWERS OF SULFUR. MELT GENTLY HIGH ABOVE FLAME. POUR INTO MOLD. WHEN COOLED YOU HAVE A PERFECT CAST.

PLASTIC SULFUR

1 MELT ½ TEST TUBE POWDERED SULFUR. CONTINUE HEATING. SOON IT NO LONGER FLOWS. YOU CAN TURN TUBE UPSIDE DOWN WITHOUT ANYTHING COMING OUT.

2 HEAT THE THICKENED SULFUR FURTHER UNTIL IT FLOWS FREELY AGAIN. THEN POUR THE DARK FLUID INTO COLD WATER. IT TURNS INTO A PLASTIC MASS. IN A FEW DAYS THIS AGAIN BECOMES YELLOW SULFUR.

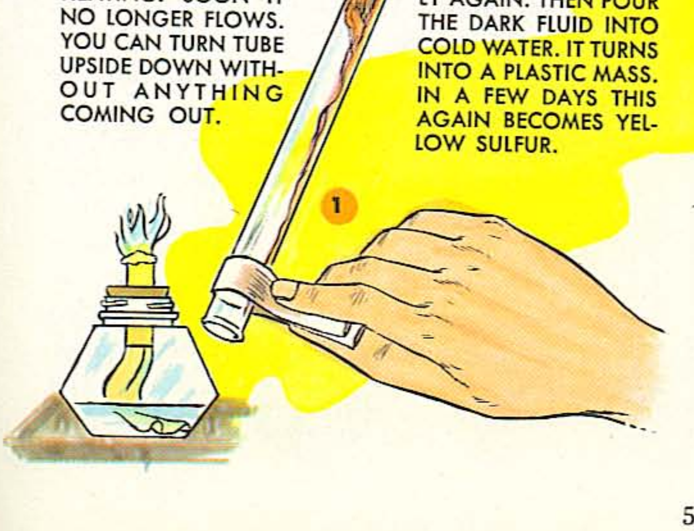

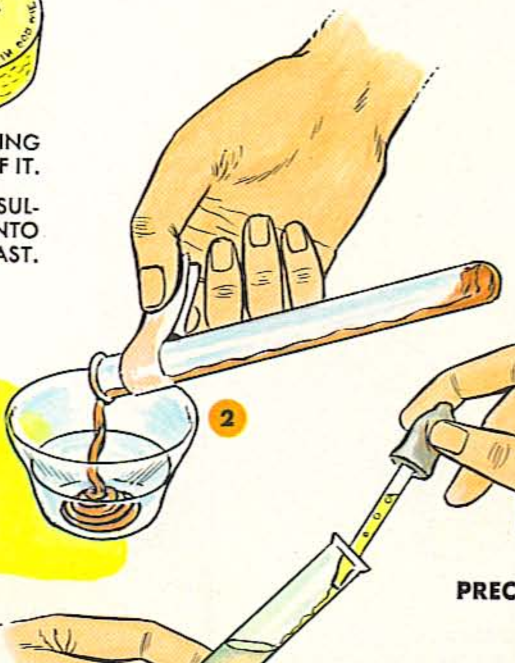

PRECIPITATED SULFUR

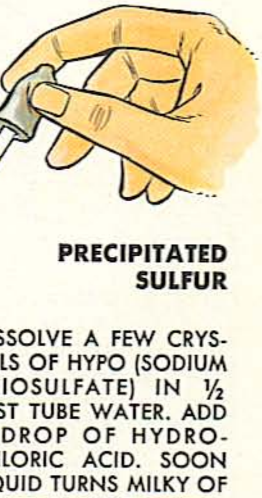

DISSOLVE A FEW CRYSTALS OF HYPO (SODIUM THIOSULFATE) IN ½ TEST TUBE WATER. ADD 1 DROP OF HYDROCHLORIC ACID. SOON LIQUID TURNS MILKY OF EXCEEDINGLY FINE PARTICLES OF SULFUR.

SULFUR DIOXIDE FOR BLEACHING

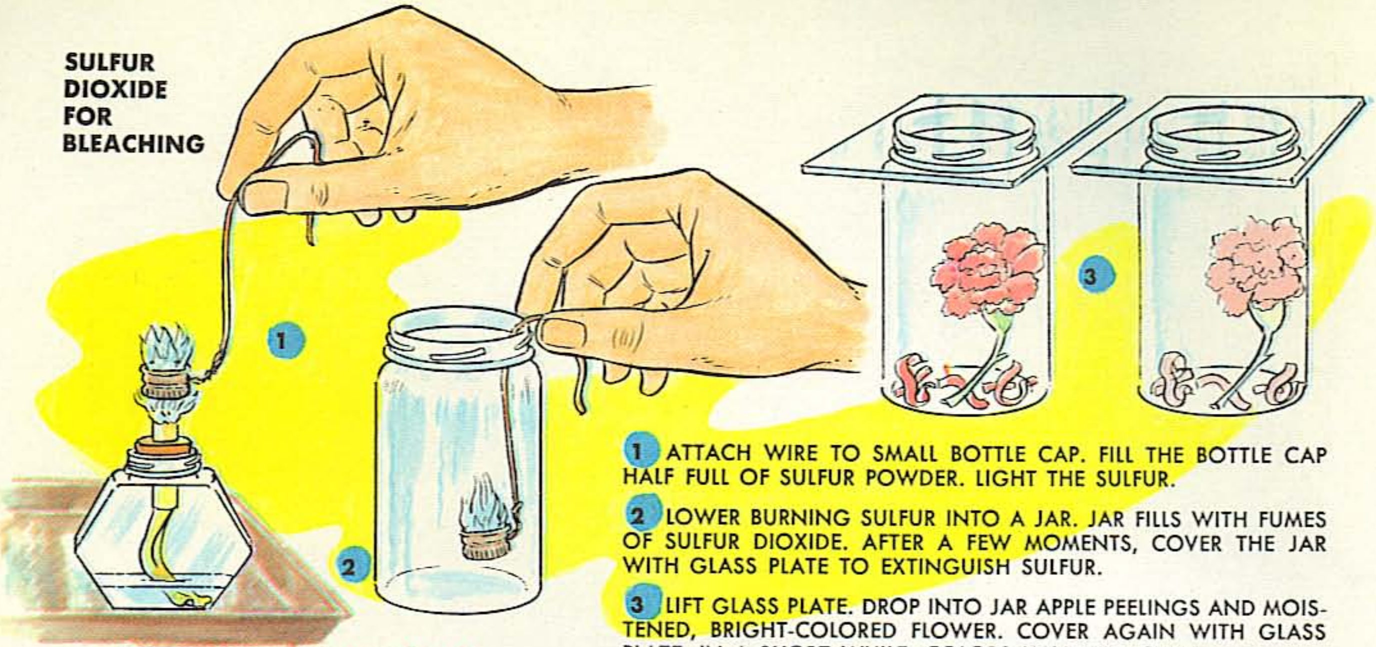

1 ATTACH WIRE TO SMALL BOTTLE CAP. FILL THE BOTTLE CAP HALF FULL OF SULFUR POWDER. LIGHT THE SULFUR.

2 LOWER BURNING SULFUR INTO A JAR. JAR FILLS WITH FUMES OF SULFUR DIOXIDE. AFTER A FEW MOMENTS, COVER THE JAR WITH GLASS PLATE TO EXTINGUISH SULFUR.

3 LIFT GLASS PLATE. DROP INTO JAR APPLE PEELINGS AND MOISTENED, BRIGHT-COLORED FLOWER. COVER AGAIN WITH GLASS PLATE. IN A SHORT WHILE, COLORS HAVE BLEACHED.

Be careful not to breathe fumes.

MAKING SULFUROUS ACID

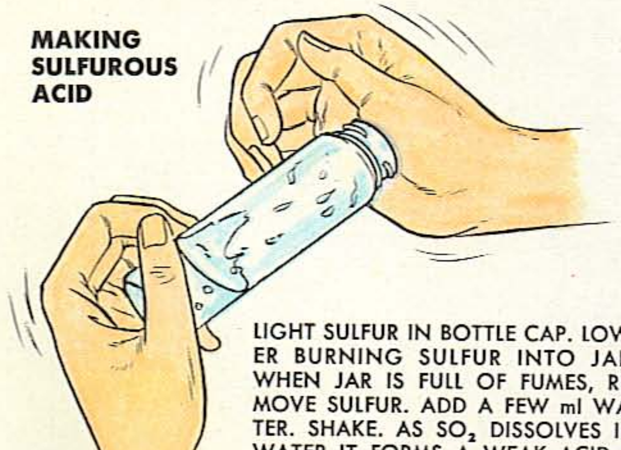

LIGHT SULFUR IN BOTTLE CAP. LOWER BURNING SULFUR INTO JAR. WHEN JAR IS FULL OF FUMES, REMOVE SULFUR. ADD A FEW ml WATER. SHAKE. AS SO_2 DISSOLVES IN WATER IT FORMS A WEAK ACID—SULFUROUS ACID, H_2SO_3. TEST FOR ACID WITH BLUE LITMUS PAPER.

SULFUR DIOXIDE FROM A SALT

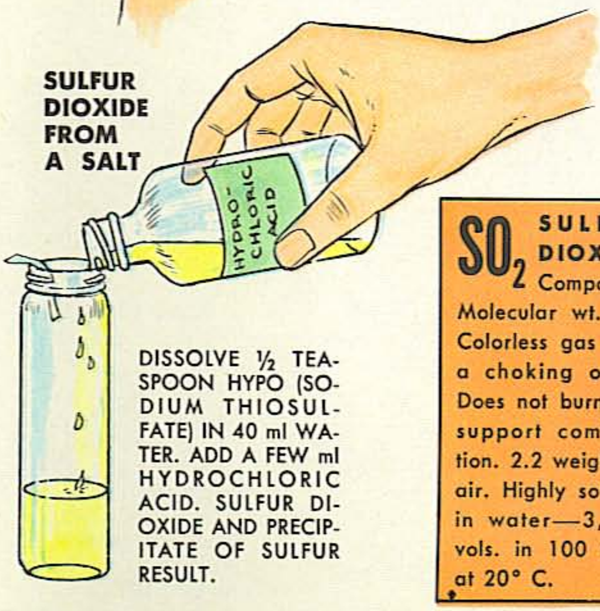

DISSOLVE ½ TEASPOON HYPO (SODIUM THIOSULFATE) IN 40 ml WATER. ADD A FEW ml HYDROCHLORIC ACID. SULFUR DIOXIDE AND PRECIPITATE OF SULFUR RESULT.

SO_2 SULFUR DIOXIDE Compound. Molecular wt. 64. Colorless gas with a choking odor. Does not burn nor support combustion. 2.2 weight of air. Highly soluble in water—3,937 vols. in 100 vols. at 20° C.

Sulfur—Continued

production — directly or indirectly — of practically every manufactured article we use today. It is used in refining gasoline, in making steel and paper, fibers and films, plastics and explosives, and thousands of other chemicals.

Sulfur Dioxide — The first step in making sulfuric acid from sulfur is to burn the sulfur.

When burning in the air, each atom of sulfur takes on two atoms of oxygen to make one molecule of sulfur dioxide gas (SO_2).

By a special, complicated process, sulfur dioxide can be forced to take on another oxygen atom and form sulfur trioxide (SO_3). With water, this makes sulfuric acid:

$$H_2O + SO_3 \rightarrow H_2SO_4$$

Hydrogen Sulfide — Many sulfur compounds have unpleasant, penetrating smells. Some of these compounds have very complex molecules — just imagine a skunk producing a chemical with this formula: $CH_3CH_2CH_2CH_2SH$! The smell of rotten eggs, on the other hand, comes from the simple compound hydrogen sulfide (H_2S).

Hydrogen sulfide is used in chemical analysis to determine what metals are found in a certain substance. It combines with metals into salts (sulfides) that can be distinguished from each other by their colors and by the way they react with acids and other chemicals.

NOTE: Perform these experiments out-of-doors or before an open window. Be careful not to breathe fumes.

H_2S HYDROGEN SULFIDE Compound. Molecular wt. 34. Colorless gas with odor of rotten eggs. Burns with a blue flame to form SO_2. 1.17 weight of air. Fairly soluble in water—258 vols. in 100 vols. at 20° C.

HYDROGEN SULFIDE

IS AN IMPORTANT LAB TOOL FOR CHEMICAL ANALYSIS.

HYDROGEN SULFIDE HAS SMELL OF ROTTEN EGGS

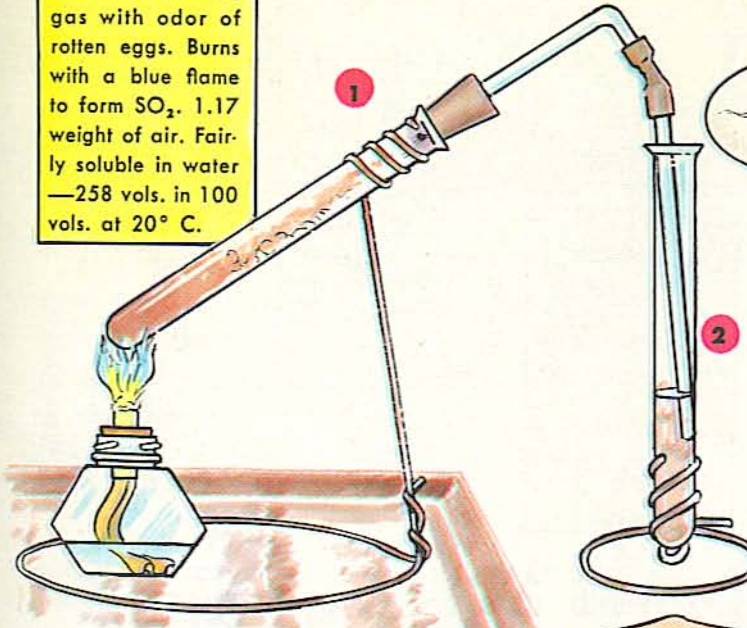

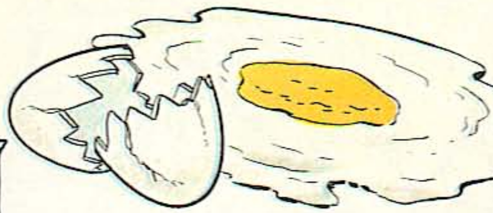

① DROP INTO A DRY TEST TUBE ¼ TEASPOON POWDERED SULFUR AND A LUMP OF CANDLE WAX AS LARGE AS A PEA. SET UP APPARATUS AS SHOWN.

② MAKE SOLUTION IN TEST TUBE OF CHEMICAL YOU WANT TO ANALYZE. LEAD GLASS TUBE INTO THE SOLUTION.

③ HEAT TEST TUBE WITH SULFUR MIXTURE. HYDROGEN SULFIDE BUBBLES INTO TEST SOLUTION. IF THIS CONTAINS SALT OF ONE OF THE HEAVY METALS, A PRECIPITATE WILL FORM.

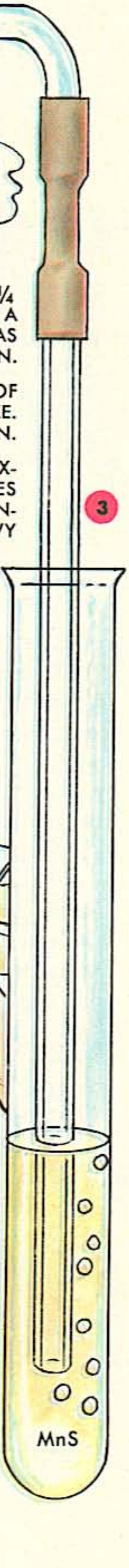

HYDROGEN SULFIDE FROM FeS

MAKE IRON SULFIDE AS DESCRIBED ON PAGE 22. BREAK THE TEST TUBE (IN A PAPER BAG). CRUSH THE FeS WITH A HAMMER. DROP SMALL PIECES IN ANOTHER TEST TUBE. BY ADDING HYDROCHLORIC ACID YOU MAKE H_2S.

EXPERIMENTS WITH H_2S

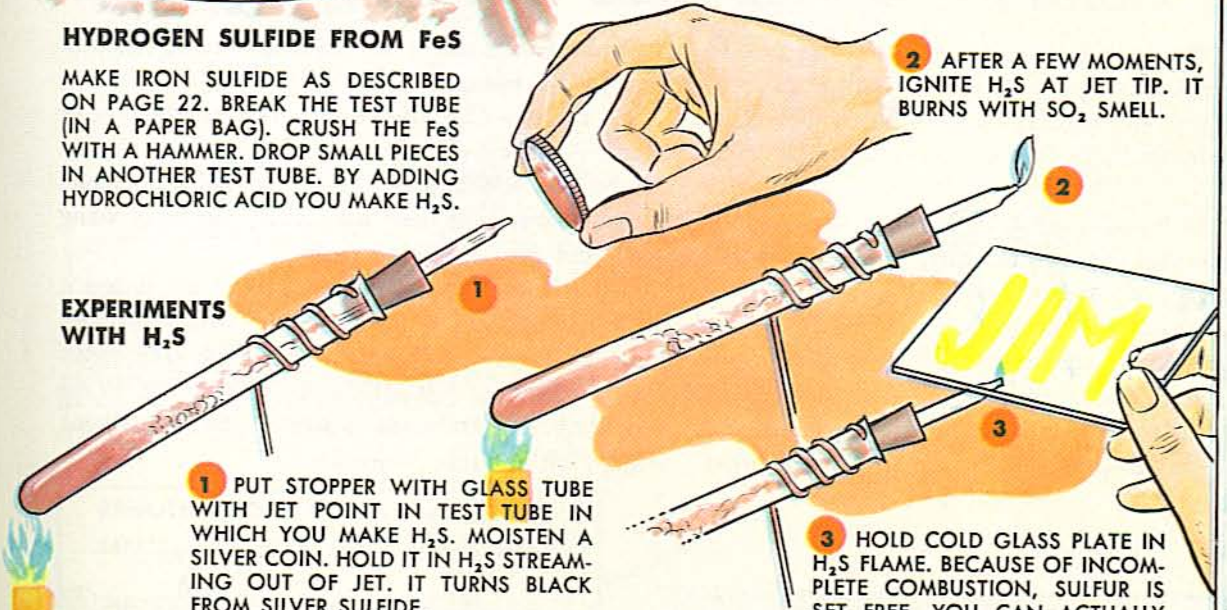

① PUT STOPPER WITH GLASS TUBE WITH JET POINT IN TEST TUBE IN WHICH YOU MAKE H_2S. MOISTEN A SILVER COIN. HOLD IT IN H_2S STREAMING OUT OF JET. IT TURNS BLACK FROM SILVER SULFIDE.

② AFTER A FEW MOMENTS, IGNITE H_2S AT JET TIP. IT BURNS WITH SO_2 SMELL.

③ HOLD COLD GLASS PLATE IN H_2S FLAME. BECAUSE OF INCOMPLETE COMBUSTION, SULFUR IS SET FREE. YOU CAN ACTUALLY "DRAW" WITH THE H_2S FLAME.

THE COLOR OF THE SULFIDE FORMED WHEN YOU LEAD H_2S INTO A SOLUTION CONTAINING A SALT OF A HEAVY METAL WILL HELP TELL YOU WHAT METAL IS FOUND IN THE SALT.

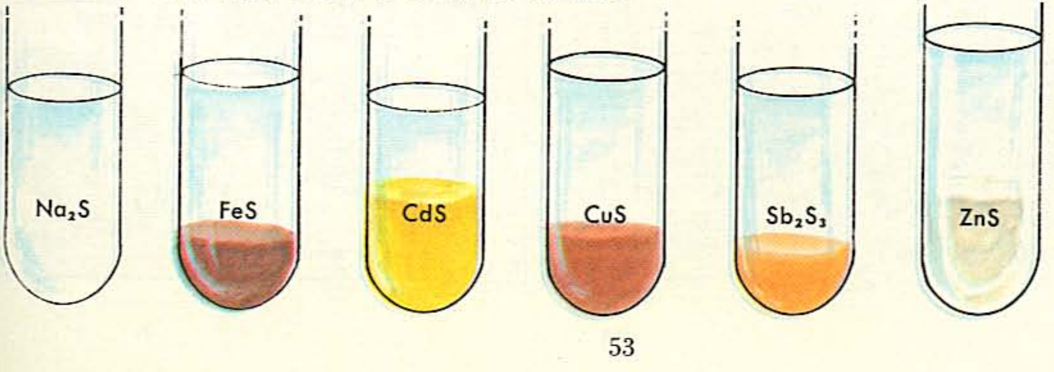

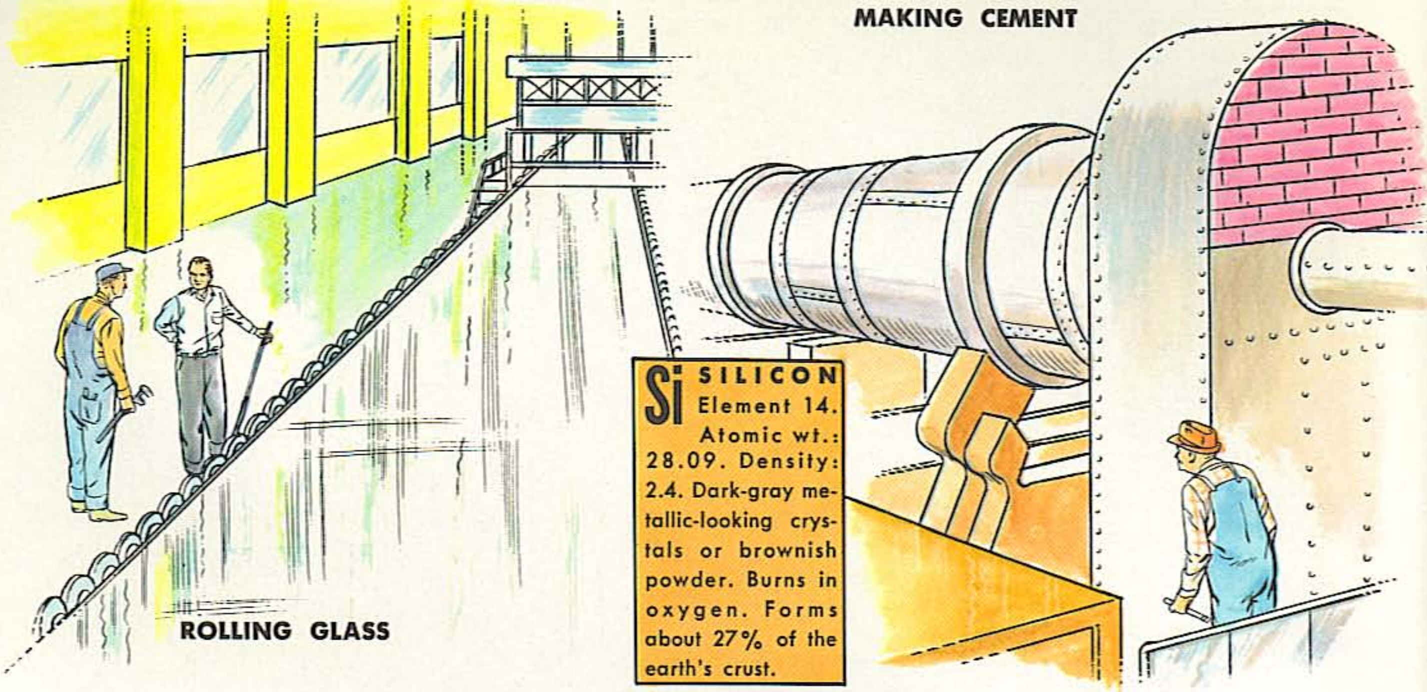

Si **SILICON** Element 14. Atomic wt.: 28.09. Density: 2.4. Dark-gray metallic-looking crystals or brownish powder. Burns in oxygen. Forms about 27% of the earth's crust.

Silicon—The Element You Step On

SILICON (from the Latin *silex*, flint) is the second most abundant element on earth — after oxygen. Whether you are walking on sand or clay, rock or cement, almost half of what you're stepping on is silicon.

Silicon is found in nature in combination with oxygen (mostly the dioxide, SiO_2) and in different silicates (salts of various silicic acids).

With few exceptions, silicon compounds are insoluble in water. And that is a good thing for all of us. The glass of our windows and the glasses from which we drink are silicates. So are the glazes on our cups and the enamel on our bathtubs. Most glass and many glazes are made by fusing together sand (SiO_2), limestone, and soda.

The silicates of sodium and potassium dissolve in water. A concentrated solution of sodium silicate (Na_2SiO_3) is sold in hardware stores under the name of waterglass. It is used as a glue, for fireproofing wood and for preserving eggs.

Within recent years, chemists have developed a whole line of new silicon compounds called silicones. Some of them are oil-like. Some look like putty ("Silly Putty"). Still others are rubber-like. Paper and cloth can be made water-repellent by being treated with suitable silicones.

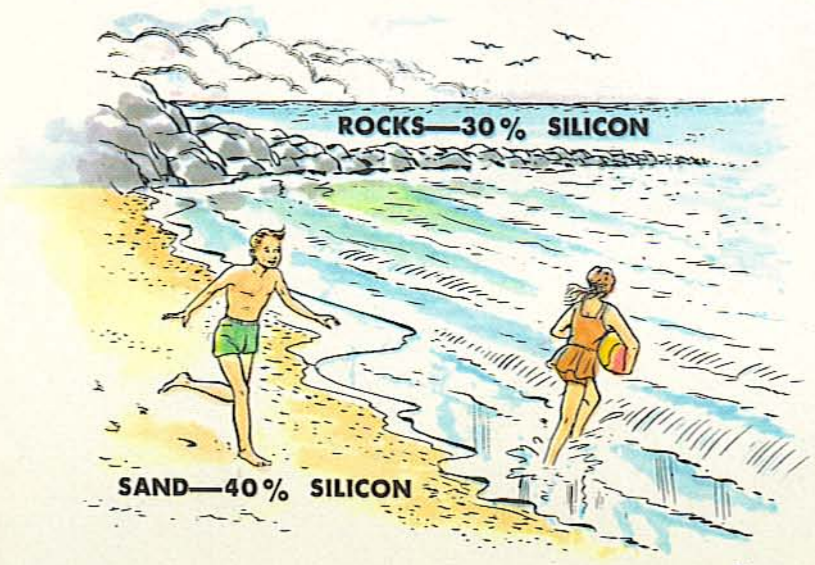

MINERALS AND PRECIOUS STONES

MANY ARE SILICON OXIDES OR SILICATES.

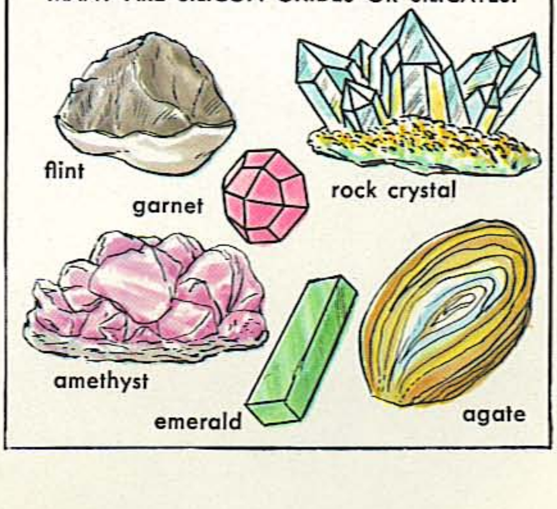

MAKING SILICIC ACID

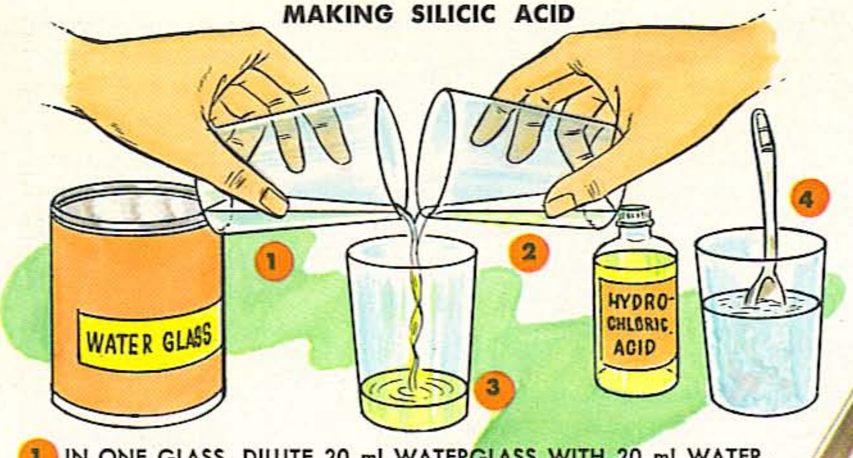

1 IN ONE GLASS, DILUTE 20 ml WATERGLASS WITH 20 ml WATER.

2 IN ANOTHER, MIX 10 ml HYDROCHLORIC ACID AND 10 ml WATER.

3 POUR THE TWO MIXTURES AT ONE TIME INTO A THIRD GLASS.

4 STAND SPOON UPRIGHT IN THE MIXTURE WHICH, ALMOST IMMEDIATELY, TURNS INTO A JELLY ("GEL") SO STIFF THAT SPOON STANDS BY ITSELF AND YOU CAN TURN THE GLASS UPSIDE DOWN.

MAKING SILICON DIOXIDE

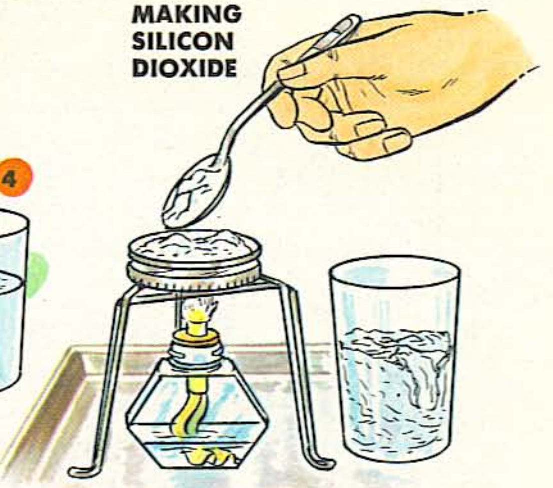

PLACE SOME OF THE GEL ON A METAL JAR LID. HEAT. THE SILICIC ACID (H_2SiO_3) GIVES UP WATER (H_2O) AND TURNS INTO A GRAYISH-WHITE POWDER OF SILICON DIOXIDE (SiO_2).

WEAKNESS OF SILICIC ACID

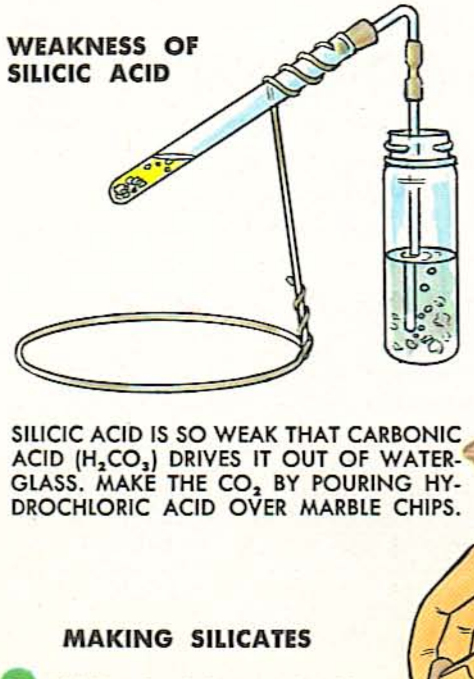

SILICIC ACID IS SO WEAK THAT CARBONIC ACID (H_2CO_3) DRIVES IT OUT OF WATERGLASS. MAKE THE CO_2 BY POURING HYDROCHLORIC ACID OVER MARBLE CHIPS.

MAKING WATER-GLASS

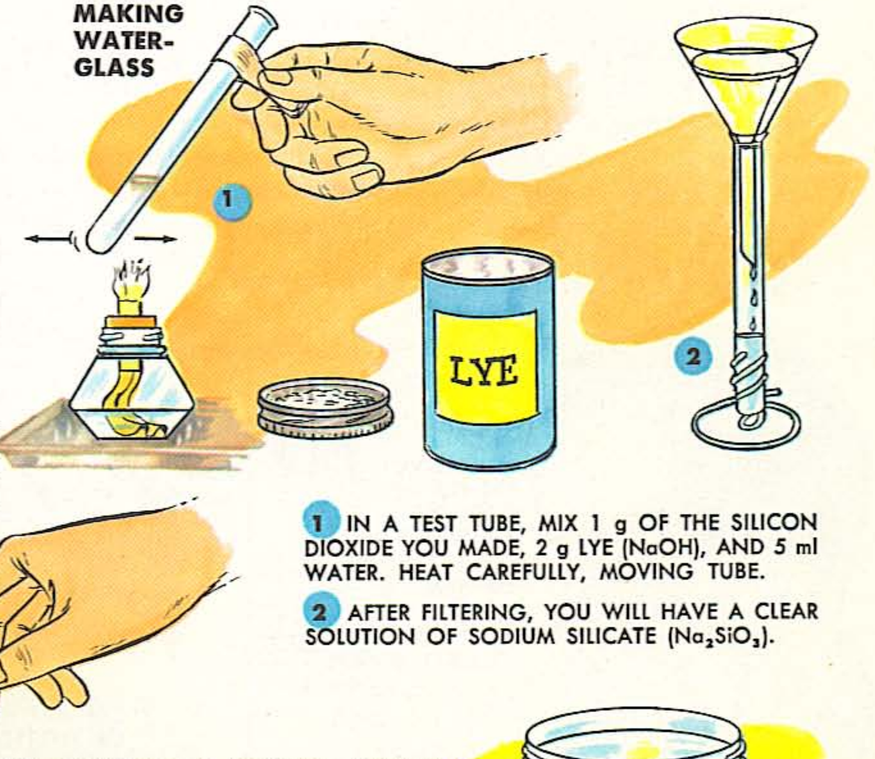

1 IN A TEST TUBE, MIX 1 g OF THE SILICON DIOXIDE YOU MADE, 2 g LYE (NaOH), AND 5 ml WATER. HEAT CAREFULLY, MOVING TUBE.

2 AFTER FILTERING, YOU WILL HAVE A CLEAR SOLUTION OF SODIUM SILICATE (Na_2SiO_3).

MAKING SILICATES

1 DILUTE 5 ml WATERGLASS (Na_2SiO_3) WITH 5 ml WATER.

2 DISSOLVE SMALL CRYSTAL OF COPPER SULFATE IN WATER.

3 ADD A FEW DROPS TO THE WATERGLASS TO GET PRECIPITATE OF COPPER SILICATE.

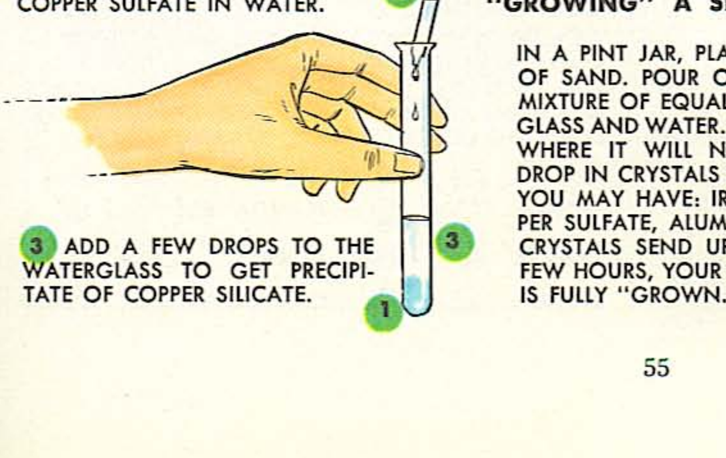

"GROWING" A SILICON "JUNGLE"

IN A PINT JAR, PLACE ½-INCH LAYER OF SAND. POUR ON TOP OF THIS A MIXTURE OF EQUAL PARTS OF WATERGLASS AND WATER. PLACE IT IN A SPOT WHERE IT WILL NOT BE DISTURBED. DROP IN CRYSTALS OF VARIOUS SALTS YOU MAY HAVE: IRON SULFATE, COPPER SULFATE, ALUM, EPSOM SALT. THE CRYSTALS SEND UP "SHOOTS." IN A FEW HOURS, YOUR SILICATE "JUNGLE" IS FULLY "GROWN."

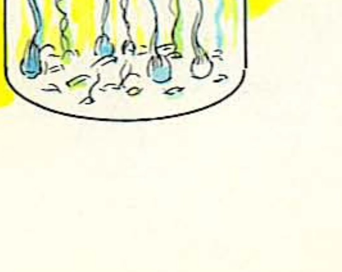

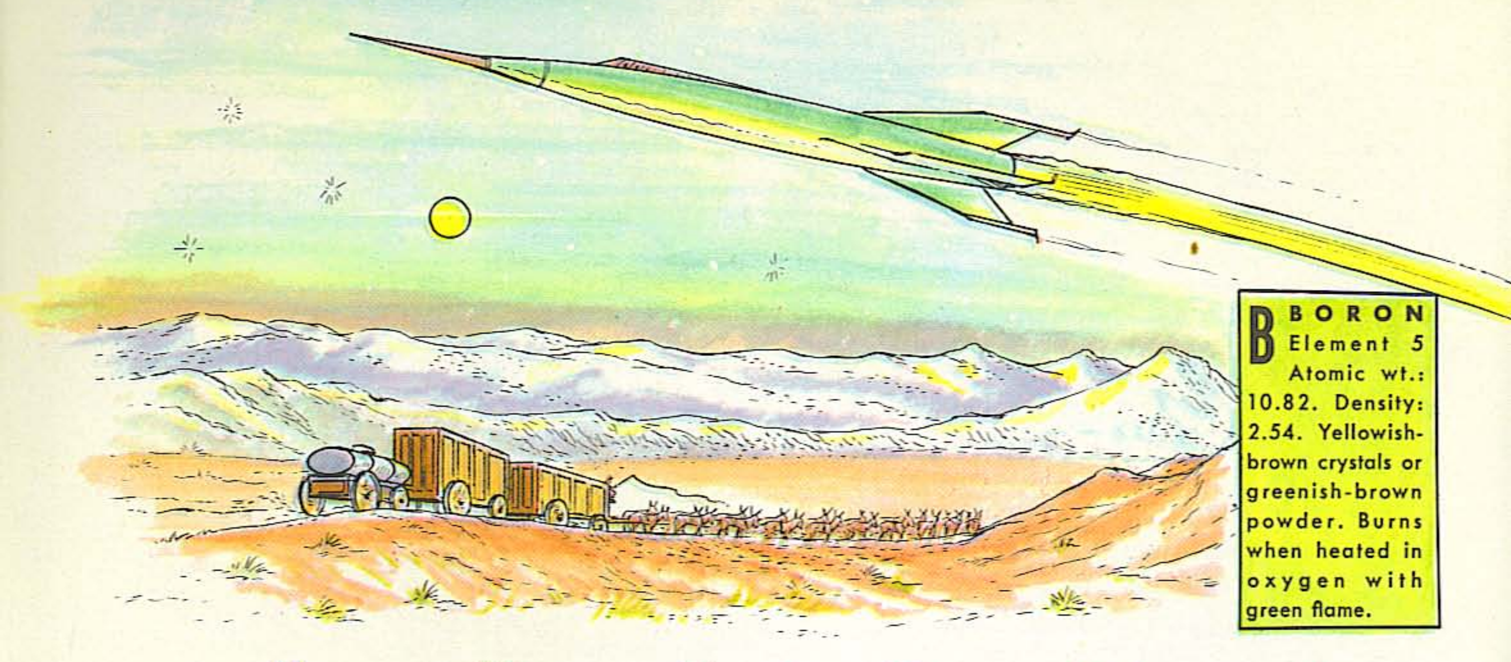

B **BORON**
Element 5
Atomic wt.: 10.82. Density: 2.54. Yellowish-brown crystals or greenish-brown powder. Burns when heated in oxygen with green flame.

Boron—Future Rocket-Power Element?

Less than a hundred years ago, a mineral called borax, containing the element boron, was carted out of Death Valley in California by twenty-mule teams — about the slowest transportation you can think of. Someday, boron may be put in zip-fuels for space missiles — the fastest form of transportation imaginable. Boron has the ability (as does carbon) to combine with hydrogen in a number of ways. When these boranes or boron hydrides burn, they develop a tremendous amount of power.

Boron can be isolated as a hard, brownish-black powder. Its carbon compound, boron carbide (B_4C), is almost as hard as diamond.

But you are probably more familiar with boron

BORAX BEAD TEST IN CHEMICAL ANALYSIS

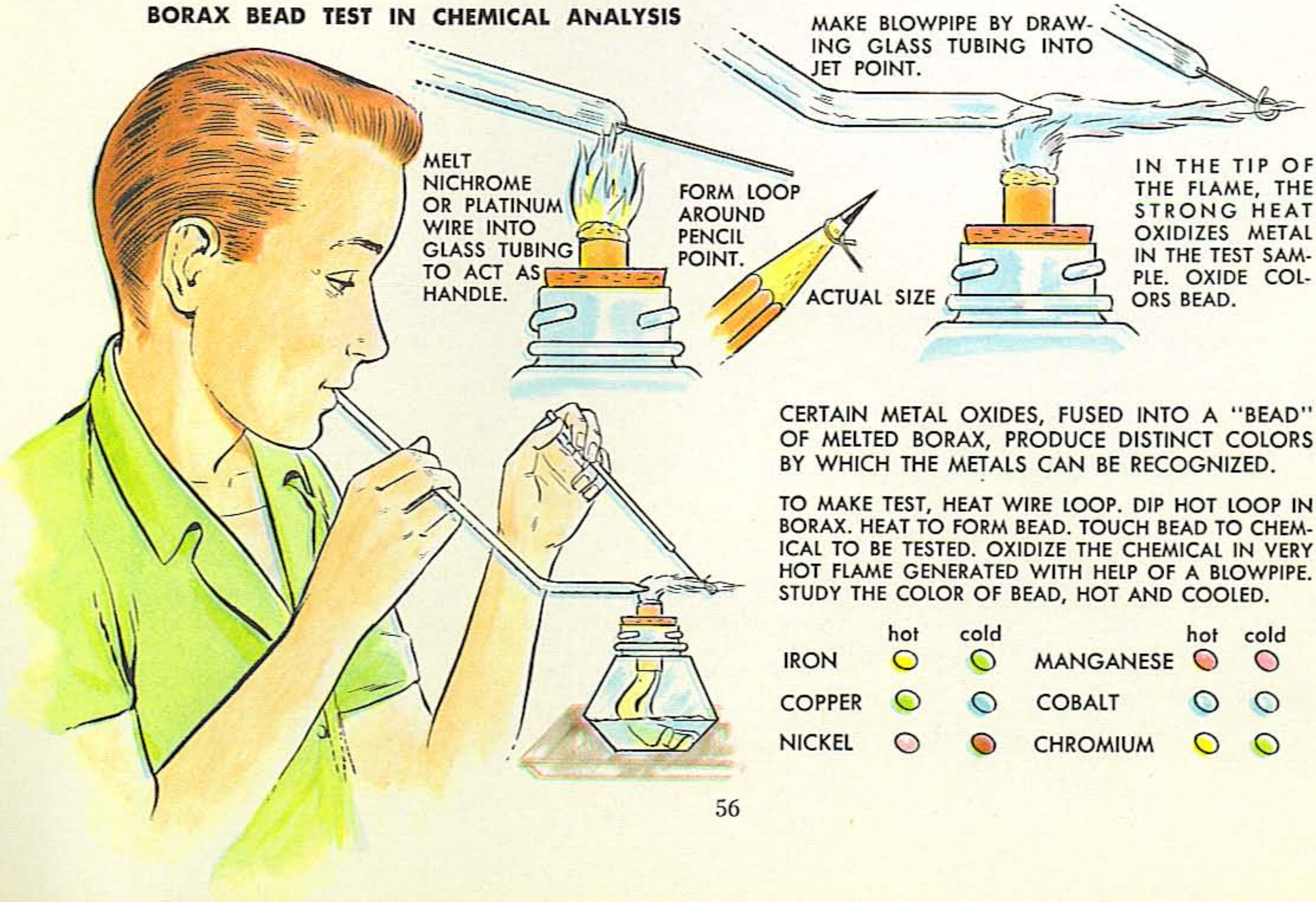
MAKE BLOWPIPE BY DRAWING GLASS TUBING INTO JET POINT.
MELT NICHROME OR PLATINUM WIRE INTO GLASS TUBING TO ACT AS HANDLE.
FORM LOOP AROUND PENCIL POINT.
ACTUAL SIZE
IN THE TIP OF THE FLAME, THE STRONG HEAT OXIDIZES METAL IN THE TEST SAMPLE. OXIDE COLORS BEAD.

CERTAIN METAL OXIDES, FUSED INTO A "BEAD" OF MELTED BORAX, PRODUCE DISTINCT COLORS BY WHICH THE METALS CAN BE RECOGNIZED.

TO MAKE TEST, HEAT WIRE LOOP. DIP HOT LOOP IN BORAX. HEAT TO FORM BEAD. TOUCH BEAD TO CHEMICAL TO BE TESTED. OXIDIZE THE CHEMICAL IN VERY HOT FLAME GENERATED WITH HELP OF A BLOWPIPE. STUDY THE COLOR OF BEAD, HOT AND COOLED.

	hot	cold		hot	cold
IRON	🟡	🟢	MANGANESE	🔴	🔴
COPPER	🟢	🔵	COBALT	🔵	🔵
NICKEL	🔴	🟤	CHROMIUM	🟡	🟢

through two of its compounds which are found in almost every household: boric acid (H_3BO_3), used as a mild antiseptic, and borax (sodium tetraborate, $Na_2B_4O_7 \cdot 10H_2O$), used for cleaning purposes and as a water softener.

Borax has a great number of uses outside the home. It is used for soldering, for producing certain kinds of soap, and for making other boron compounds.

The glass industry uses large quantities of borax for making boron-aluminum-silicate glass. You know this kind of glass by its trade name, Pyrex. Kitchen utensils and laboratory ware made of Pyrex glass have the great advantage over ordinary glass that they can be placed directly on the fire and do not break so easily when they are subjected to sudden heating or cooling.

MAKING BORIC ACID

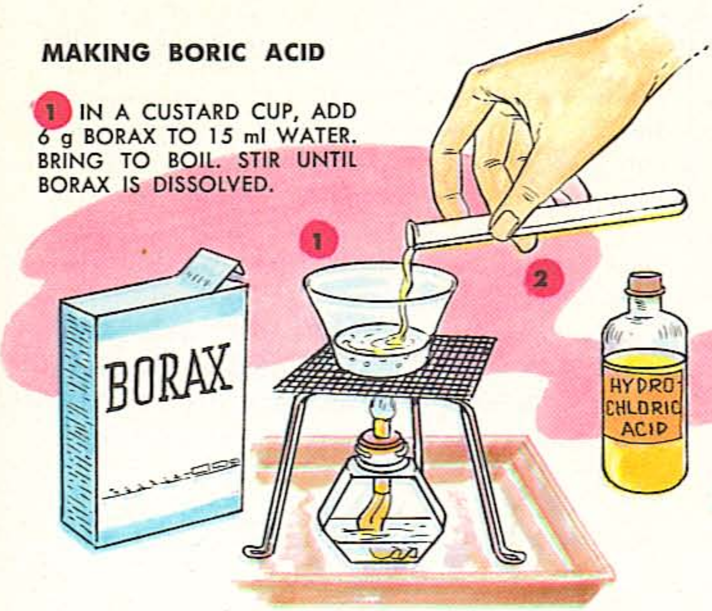

1 IN A CUSTARD CUP, ADD 6 g BORAX TO 15 ml WATER. BRING TO BOIL. STIR UNTIL BORAX IS DISSOLVED.

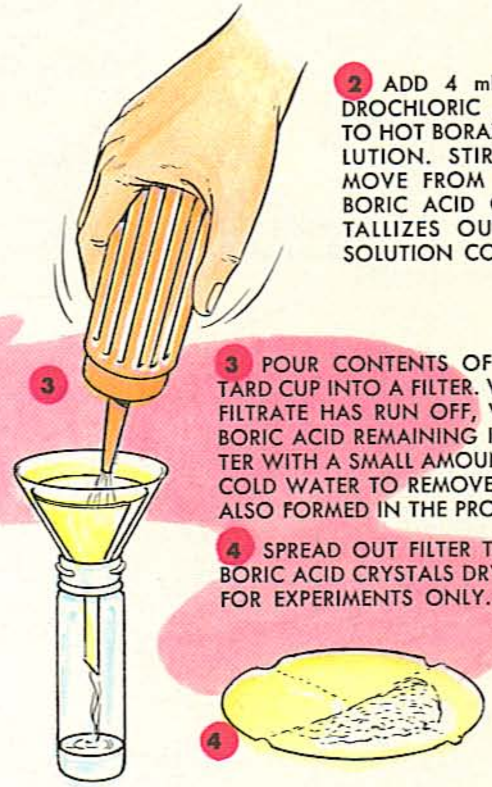

2 ADD 4 ml HYDROCHLORIC ACID TO HOT BORAX SOLUTION. STIR. REMOVE FROM FIRE. BORIC ACID CRYSTALLIZES OUT AS SOLUTION COOLS.

3 POUR CONTENTS OF CUSTARD CUP INTO A FILTER. WHEN FILTRATE HAS RUN OFF, WASH BORIC ACID REMAINING IN FILTER WITH A SMALL AMOUNT OF COLD WATER TO REMOVE NaCl ALSO FORMED IN THE PROCESS.

4 SPREAD OUT FILTER TO LET BORIC ACID CRYSTALS DRY. USE FOR EXPERIMENTS ONLY.

TESTS FOR BORIC ACID

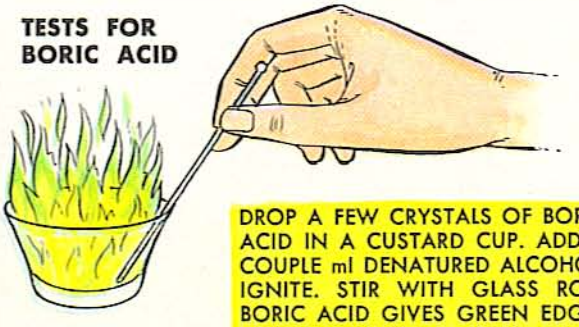

DROP A FEW CRYSTALS OF BORIC ACID IN A CUSTARD CUP. ADD A COUPLE ml DENATURED ALCOHOL. IGNITE. STIR WITH GLASS ROD. BORIC ACID GIVES GREEN EDGES TO THE FLAMES.

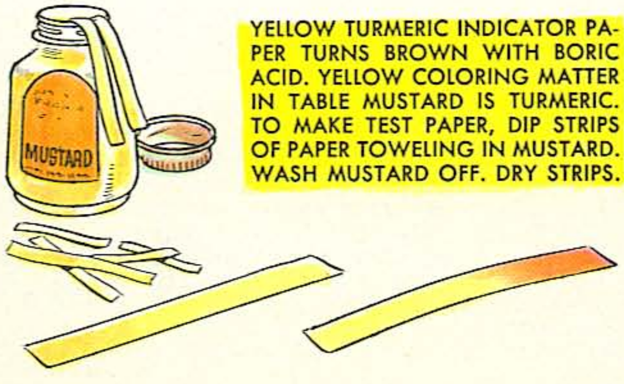

YELLOW TURMERIC INDICATOR PAPER TURNS BROWN WITH BORIC ACID. YELLOW COLORING MATTER IN TABLE MUSTARD IS TURMERIC. TO MAKE TEST PAPER, DIP STRIPS OF PAPER TOWELING IN MUSTARD. WASH MUSTARD OFF. DRY STRIPS.

MAKING BORIC OXIDE

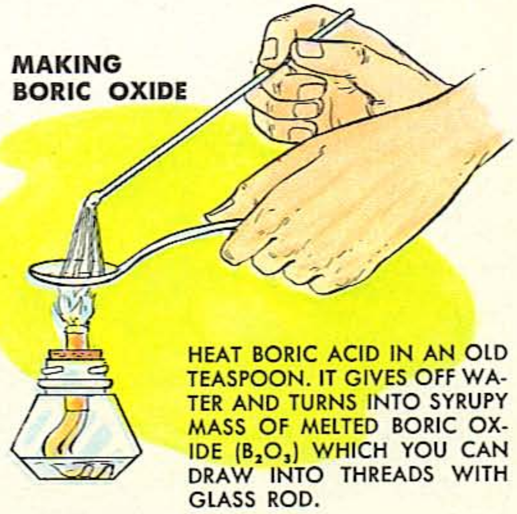

HEAT BORIC ACID IN AN OLD TEASPOON. IT GIVES OFF WATER AND TURNS INTO SYRUPY MASS OF MELTED BORIC OXIDE (B_2O_3) WHICH YOU CAN DRAW INTO THREADS WITH GLASS ROD.

Sodium and Potassium

THE SALTS of sodium and potassium have been used for thousands of years in making soap and glass and for a great number of other purposes.

Sodium chloride (NaCl) is the most common sodium salt — it is the chemical that makes ocean water "salty." Plants growing in the ocean take up so much of the sodium that people along the seacoasts of the world used to burn dried seaweed to secure "soda ash" (sodium carbonate, Na_2CO_3). Inland plants, on the other hand, pick up potassium from the soil. Inland people boiled out wood ashes in large pots to get "potash" (potassium carbonate, K_2CO_3).

In 1807, the British scientist, Humphry Davy, succeeded in isolating the metals found in these salts. They proved to be wax-soft and silvery. He called them sodium (from soda ash) and potassium (from potash). These are still their English names. But in chemical formulas they are referred to as natrium (Na) and kalium (K) — from abbreviations of the Arabic names of the ashes: *natrun* and *al qili* (alkali).

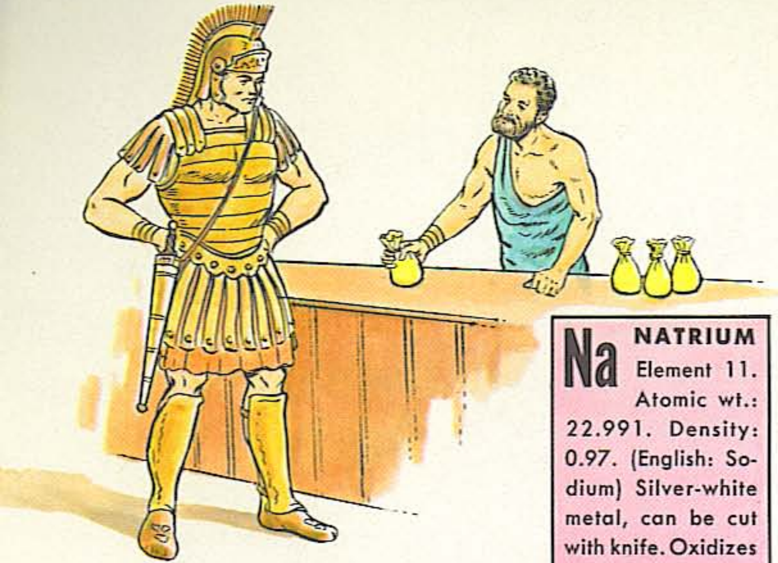

"SALARY" COMES FROM *SALARIUM* —THE WAGES PAID IN SALT TO ROMAN SOLDIERS.

Na **NATRIUM** Element 11. Atomic wt.: 22.991. Density: 0.97. (English: Sodium) Silver-white metal, can be cut with knife. Oxidizes in air. Reacts with water. Burns with yellow flame.

CRYSTALLIZING SALT BY EVAPORATION

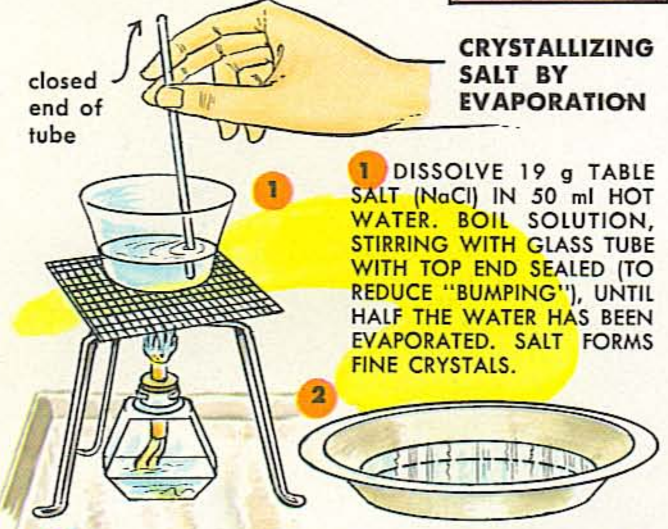

① DISSOLVE 19 g TABLE SALT (NaCl) IN 50 ml HOT WATER. BOIL SOLUTION, STIRRING WITH GLASS TUBE WITH TOP END SEALED (TO REDUCE "BUMPING"), UNTIL HALF THE WATER HAS BEEN EVAPORATED. SALT FORMS FINE CRYSTALS.

② POUR CLEAR LIQUID INTO LARGE PIE PLATE. PLACE IN SUNNY WINDOW FOR WATER TO EVAPORATE SLOWLY. THE CRYSTALS FORMED WILL BE MUCH LARGER.

MAKING NORMAL SALT FROM ACID SALT

SODIUM SULFATE IS PRODUCED BY HEATING SODIUM ACID SULFATE WITH SODIUM CHLORIDE.

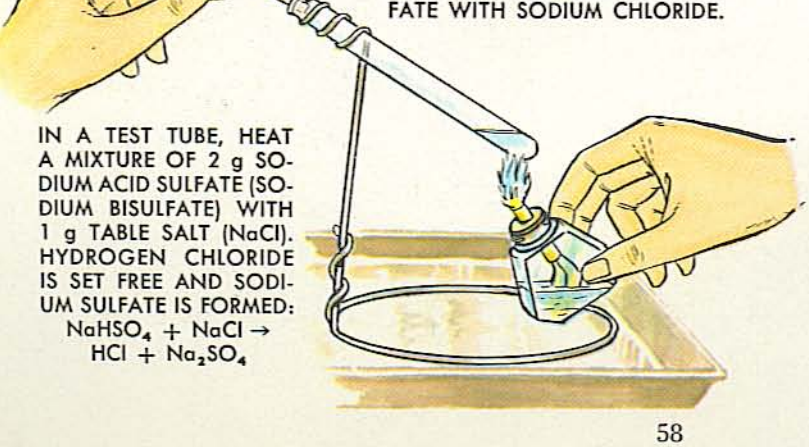

IN A TEST TUBE, HEAT A MIXTURE OF 2 g SODIUM ACID SULFATE (SODIUM BISULFATE) WITH 1 g TABLE SALT (NaCl). HYDROGEN CHLORIDE IS SET FREE AND SODIUM SULFATE IS FORMED:

$$NaHSO_4 + NaCl \rightarrow HCl + Na_2SO_4$$

MAKING ACID SALT FROM NORMAL SALT

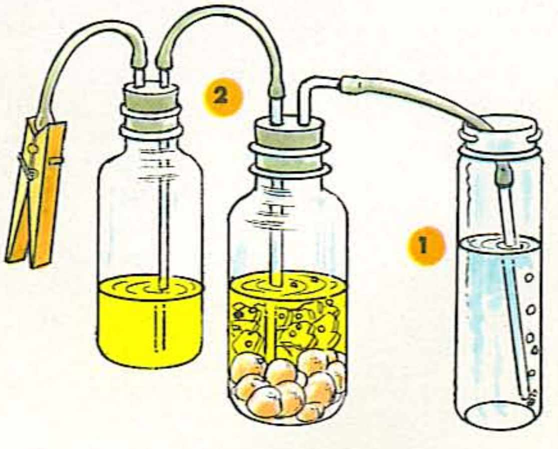

THE ACID CARBONATE ($NaHCO_3$) IS MADE BY LEADING CO_2 TO NORMAL CARBONATE (Na_2CO_3).

① MAKE SATURATED SOLUTION BY SHAKING 3 TEASPOONS WASHING SODA IN 30 ml COOL, BUT NOT COLD, WATER. FILTER IT.

② SET UP APPARATUS FOR MAKING CO_2 AS SHOWN ON PAGE 31. LEAD CO_2 INTO SODA SOLUTION FOR 10 MINUTES. THEN SET ASIDE. SHORTLY $NaHCO_3$ CRYSTALS APPEAR.

K KALIUM Element 19. Atomic wt.: 39.100. Density: 0.87. (English: Potassium) Silver-white metal, so soft it can be cut with knife. Oxidizes in air. Reacts with water. Burns with violet flame.

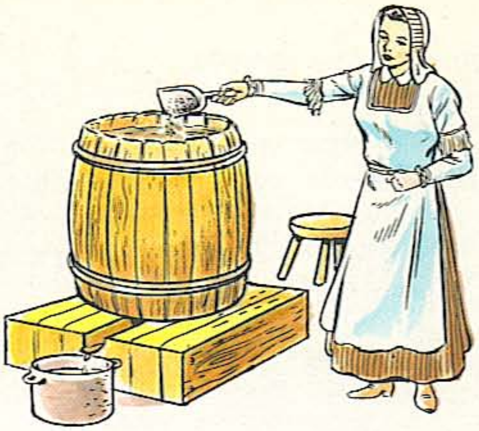

PIONEER WOMEN MADE POTASH FROM WOOD ASHES.

NITRATE TO NITRITE

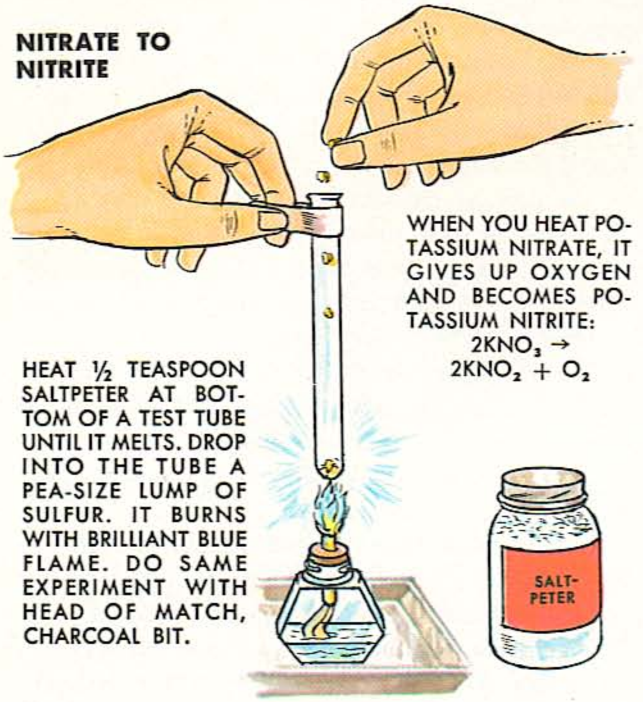

HEAT ½ TEASPOON SALTPETER AT BOTTOM OF A TEST TUBE UNTIL IT MELTS. DROP INTO THE TUBE A PEA-SIZE LUMP OF SULFUR. IT BURNS WITH BRILLIANT BLUE FLAME. DO SAME EXPERIMENT WITH HEAD OF MATCH, CHARCOAL BIT.

WHEN YOU HEAT POTASSIUM NITRATE, IT GIVES UP OXYGEN AND BECOMES POTASSIUM NITRITE:

$$2KNO_3 \rightarrow 2KNO_2 + O_2$$

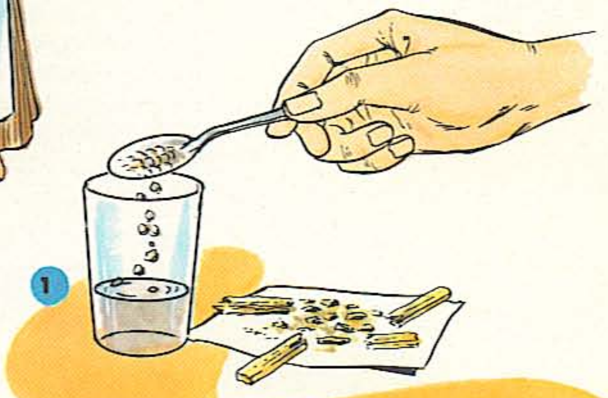

MAKING POTASH

1 STIR UP SEVERAL TEASPOONS OF FRESH WOOD ASHES WITH WARM WATER. SKIM OFF WOOD REMAINS.

2 FILTER THE MIXTURE OF ASHES AND WATER. COLLECT FILTRATE IN A CUSTARD CUP. EVAPORATE MOST OF WATER. THEN COOL TO PERMIT K_2CO_3 TO CRYSTALLIZE OUT.

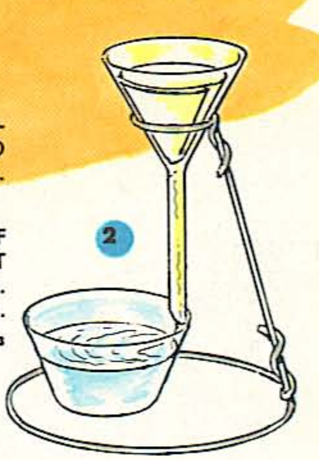

FLAME COLOR TEST FOR SODIUM AND POTASSIUM

THE COMPOUNDS OF CERTAIN METALS GIVE DISTINCT COLORS TO A FLAME. DIP NICHROME WIRE IN HCl TO CLEAN IT. HEAT IT. THEN DIP LOOP IN COMPOUND AND HOLD IN FLAME.

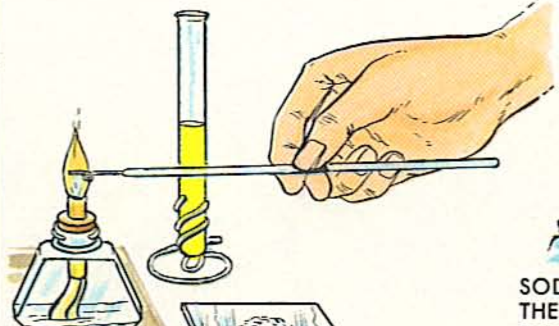

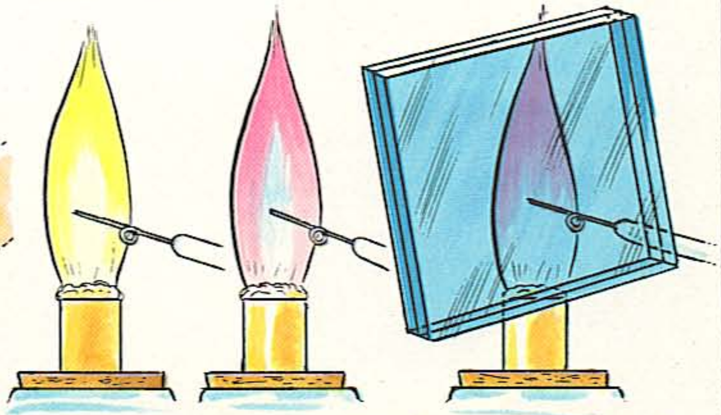

SODIUM COMPOUNDS GIVE THE FLAME A BRIGHT YELLOW-RED COLOR. POTASSIUM COMPOUNDS GIVE VIOLET FLAME.

TO SEE VIOLET COLOR OF POTASSIUM IN MIXTURE WITH Na, USE BLUE GLASS TO SCREEN OUT YELLOW OF Na.

Calcium—for Building

STAND UP STRAIGHT. You can do it because your bones contain calcium. Tell a mason to put up a brick house. He can do it with mortar containing calcium. Tell a master builder to build a monument. He will make it from marble — calcium again. Tell a hen to "go lay an egg." She can do it if she gets enough calcium in her feed to make the shell.

Calcium carbonate ($CaCO_3$) is the starting point for most calcium compounds — and for other chemicals as well. It is found in nature in cliffs and mountain ranges in the form of chalk and limestone and marble. And it makes up the shells of clams and mussels and billions of tiny sea creatures.

Calcium carbonate is almost insoluble in water. But if the water contains carbon dioxide, some goes in solution as calcium bicarbonate ($Ca(HCO_3)_2$). This explains the formations in our famous limestone caves. Rainwater containing carbon dioxide seeped through the ground and dissolved a small amount of limestone. In falling from the cave ceiling and drying, the drops gave up H_2O and CO_2 and left $CaCO_3$ behind. The minute deposits of falling drops during thousands of years created the stalactites hanging from the roof of the caves and the stalagmites rising from the floor.

A widespread mineral called gypsum is the sulfate of calcium. In this, each molecule of sulfate has two molecules of water attached to it ($CaSO_4 \cdot 2H_2O$). When gypsum is heated, it loses three quarters of its water and becomes plaster of Paris ($2CaSO_4 \cdot H_2O$). When you mix plaster of Paris and water, it again takes on the full amount of H_2O and hardens into a hydrate similar to the original gypsum.

The name of calcium was given to the metal hidden in limestone by its discoverer, Humphry Davy. It comes from *calx*, the old Latin name for lime.

Ca **CALCIUM**
Element 20
Atomic wt.: 40.08. Density: 1.54. Silver-white metal with bright luster. Reacts with moist air and water to form hydroxide. When heated burns with brilliant light.

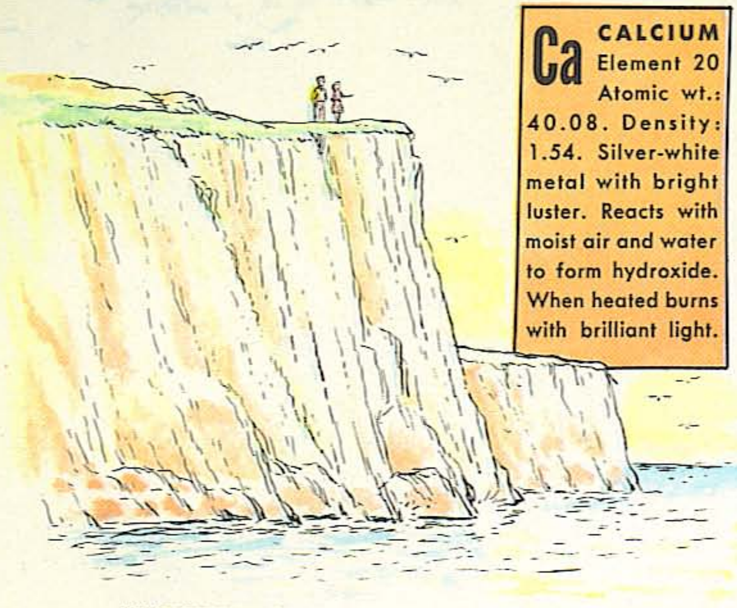

"THE WHITE CLIFFS OF DOVER" CONSIST OF ALMOST PURE CALCIUM CARBONATE IN THE FORM OF CHALK.

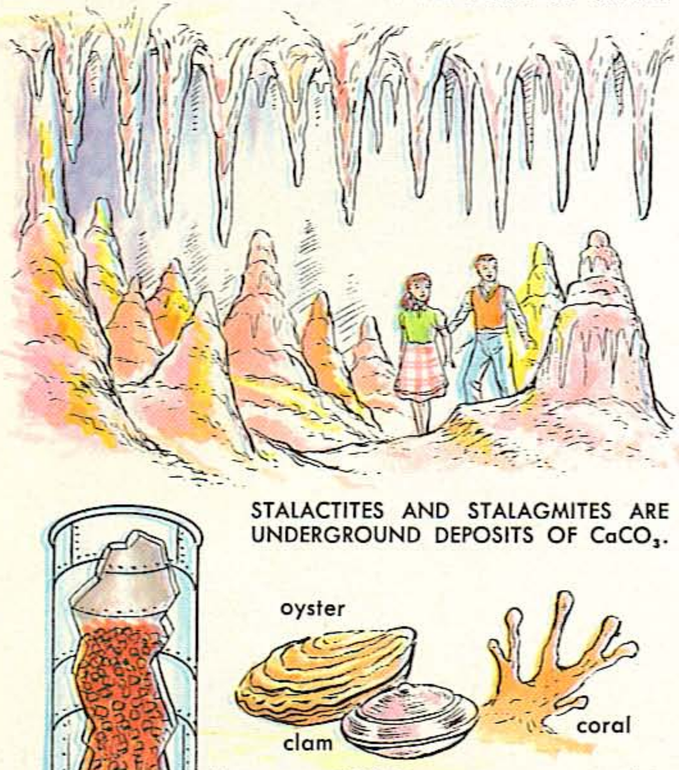

STALACTITES AND STALAGMITES ARE UNDERGROUND DEPOSITS OF $CaCO_3$.

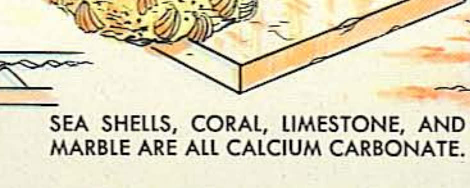

SEA SHELLS, CORAL, LIMESTONE, AND MARBLE ARE ALL CALCIUM CARBONATE.

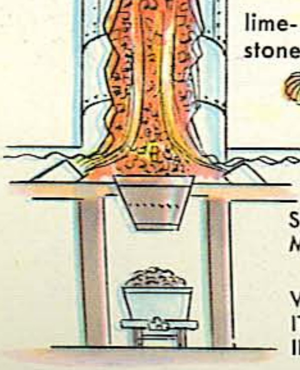

WHEN LIMESTONE IS HEATED IN KILNS, IT LOSES CARBON DIOXIDE AND TURNS INTO QUICKLIME—CALCIUM OXIDE.

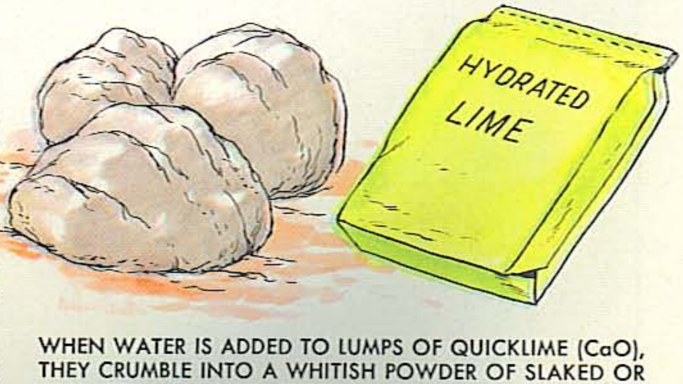

WHEN WATER IS ADDED TO LUMPS OF QUICKLIME (CaO), THEY CRUMBLE INTO A WHITISH POWDER OF SLAKED OR HYDRATED LIME ($Ca(OH)_2$). (SEE ALSO PAGE 45.)

TESTING HARDNESS OF WATER

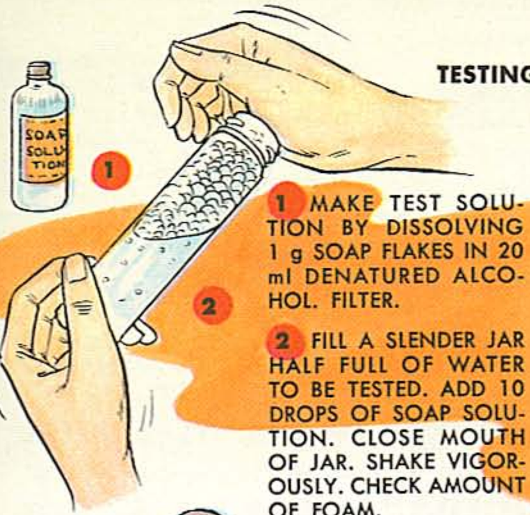
SOAP SOLUTION
1
2

1 MAKE TEST SOLUTION BY DISSOLVING 1 g SOAP FLAKES IN 20 ml DENATURED ALCOHOL. FILTER.

2 FILL A SLENDER JAR HALF FULL OF WATER TO BE TESTED. ADD 10 DROPS OF SOAP SOLUTION. CLOSE MOUTH OF JAR. SHAKE VIGOROUSLY. CHECK AMOUNT OF FOAM.

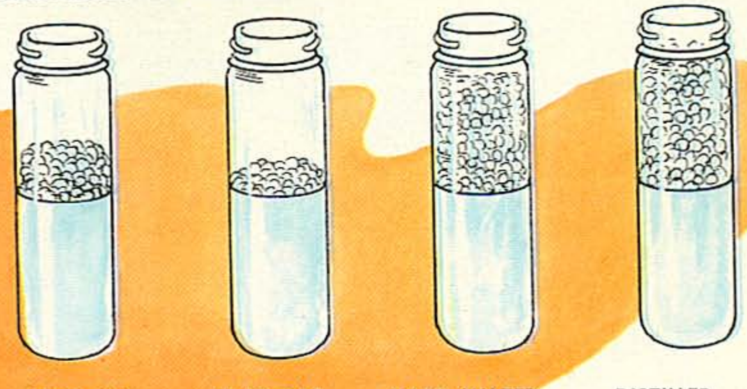

SOFT TAP WATER GIVES FAIR AMOUNT OF FOAM.

HARD TAP WATER MAKES VERY LITTLE FOAM.

HARD WATER SOFTENED WITH WASHING SODA MAKES FOAM.

DISTILLED WATER MAKES LARGE AMOUNT OF FOAM.

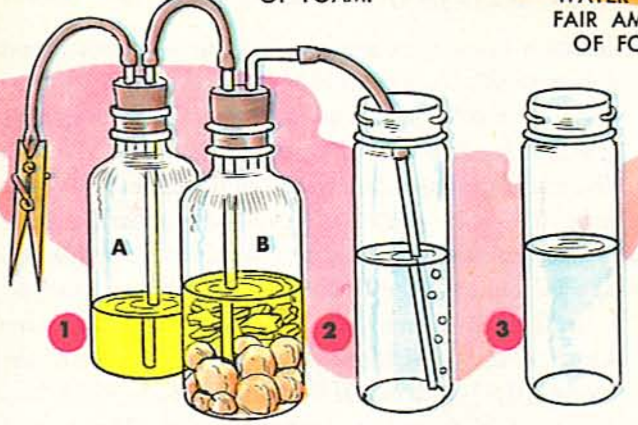

MAKING "HARD" WATER

1 SET UP GAS GENERATOR AS SHOWN ON PAGE 31. BOTTLE **A** CONTAINS HYDROCHLORIC ACID. IN BOTTLE **B**, PLACE MARBLE CHIPS ON TOP OF PEBBLES. POUR ACID ON MARBLE CHIPS TO MAKE CO_2.

2 LEAD THE CARBON DIOXIDE INTO LIME WATER. IT TURNS MILKY THROUGH FORMATION OF $CaCO_3$.

3 CONTINUE LEADING CO_2 INTO MILKY SOLUTION. MILKINESS DISAPPEARS. INSOLUBLE $CaCO_3$ HAS BEEN TURNED INTO SOLUBLE $Ca(HCO_3)_2$. THIS IS THE SUBSTANCE THAT MAKES MOST HARD WATER "HARD."

DISTILLING WATER

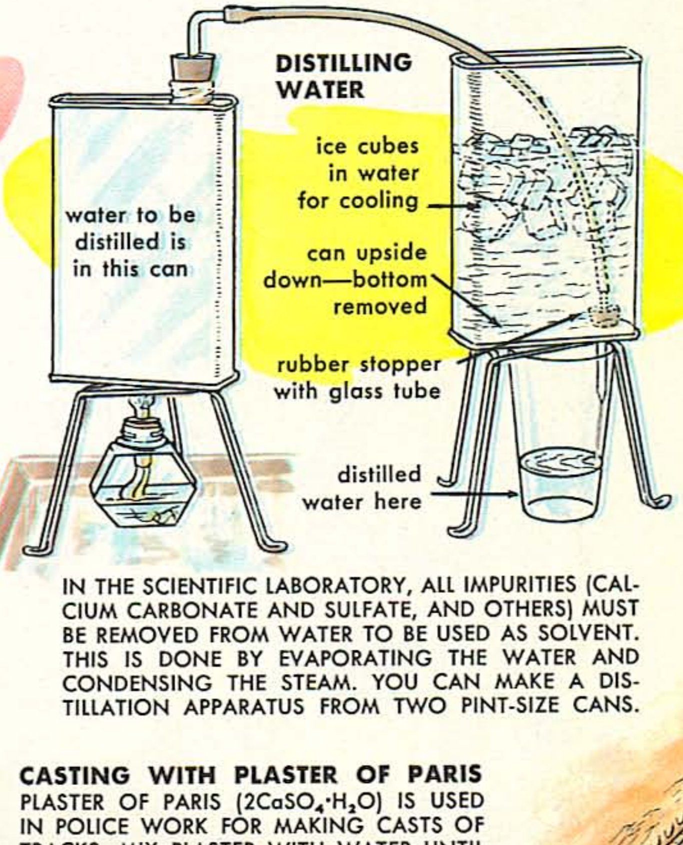
ice cubes in water for cooling
water to be distilled is in this can
can upside down—bottom removed
rubber stopper with glass tube
distilled water here

IN THE SCIENTIFIC LABORATORY, ALL IMPURITIES (CALCIUM CARBONATE AND SULFATE, AND OTHERS) MUST BE REMOVED FROM WATER TO BE USED AS SOLVENT. THIS IS DONE BY EVAPORATING THE WATER AND CONDENSING THE STEAM. YOU CAN MAKE A DISTILLATION APPARATUS FROM TWO PINT-SIZE CANS.

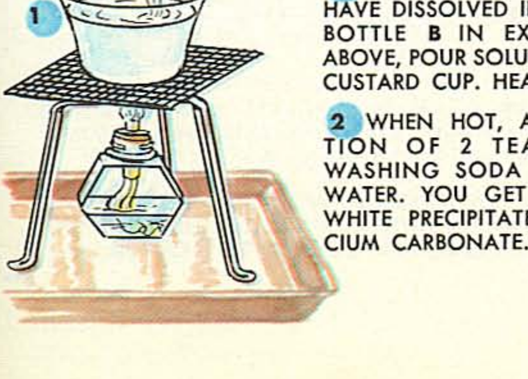

PRECIPITATED CALCIUM CARBONATE

1 WHEN MARBLE CHIPS HAVE DISSOLVED IN ACID IN BOTTLE **B** IN EXPERIMENT ABOVE, POUR SOLUTION INTO CUSTARD CUP. HEAT.

2 WHEN HOT, ADD SOLUTION OF 2 TEASPOONS WASHING SODA IN 50 ml WATER. YOU GET A HEAVY WHITE PRECIPITATE OF CALCIUM CARBONATE.

CASTING WITH PLASTER OF PARIS

PLASTER OF PARIS ($2CaSO_4 \cdot H_2O$) IS USED IN POLICE WORK FOR MAKING CASTS OF TRACKS. MIX PLASTER WITH WATER UNTIL IT HAS CONSISTENCY OF MEDIUM CREAM. POUR IN TRACK. LEAVE TO SET ONE HOUR.

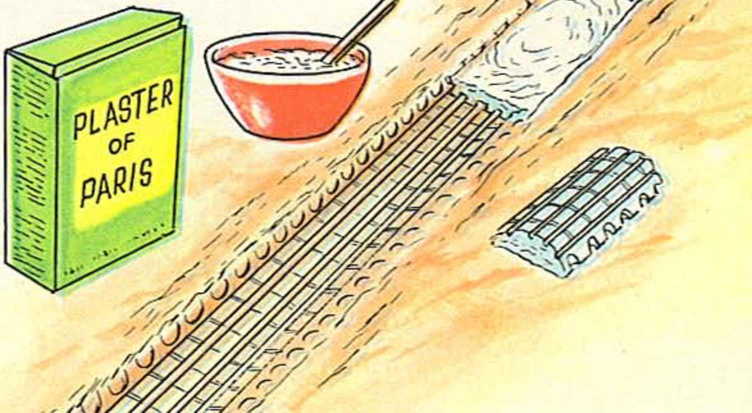
PLASTER OF PARIS

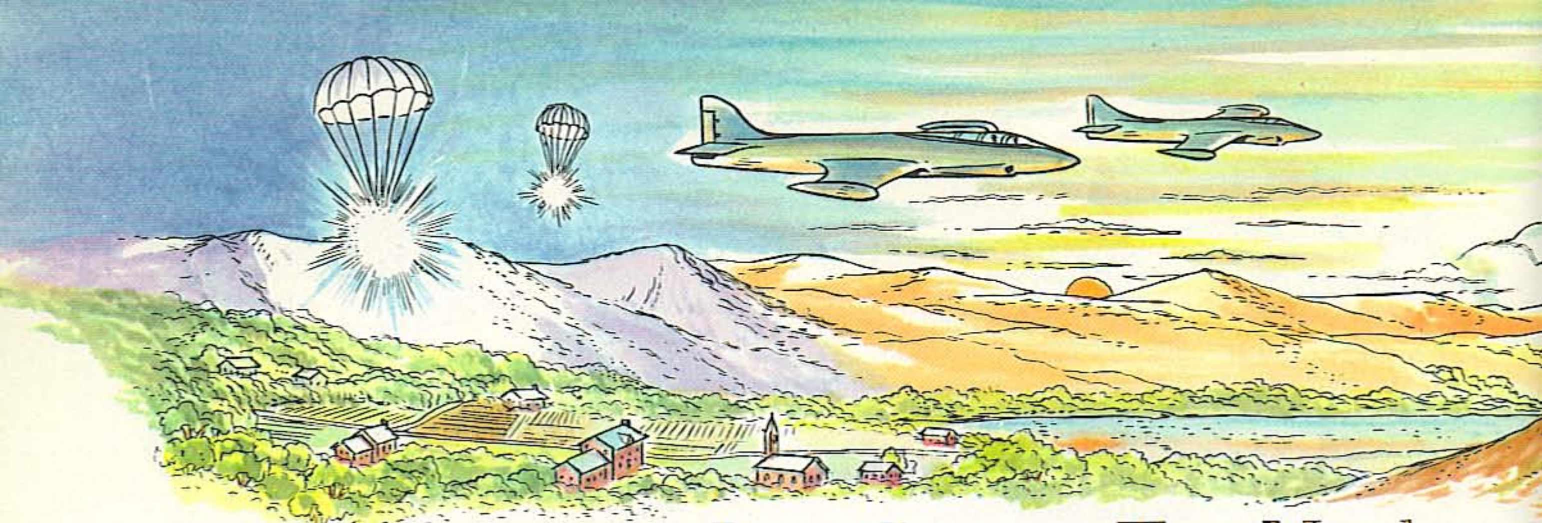

Let's Compare Two Metals

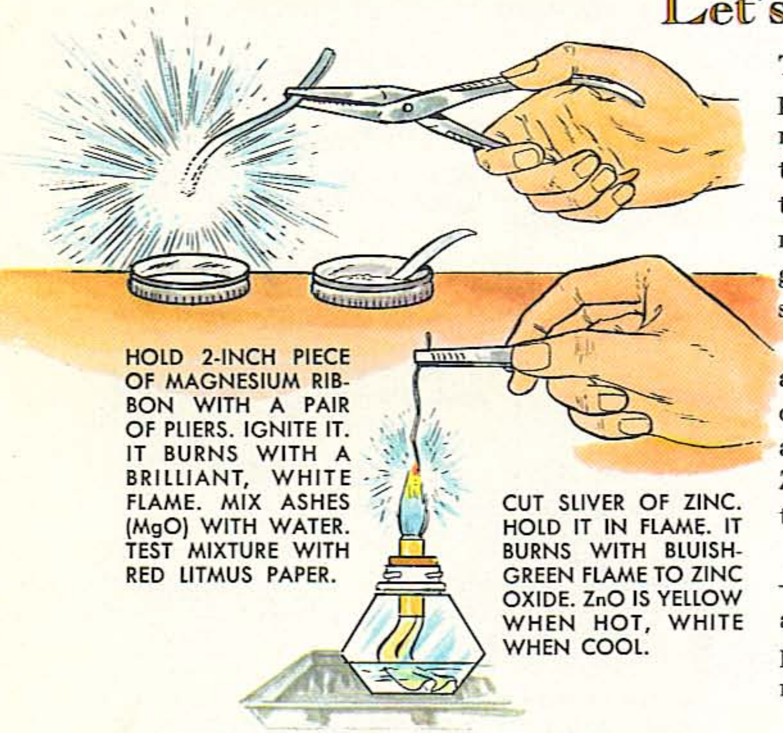

HOLD 2-INCH PIECE OF MAGNESIUM RIBBON WITH A PAIR OF PLIERS. IGNITE IT. IT BURNS WITH A BRILLIANT, WHITE FLAME. MIX ASHES (MgO) WITH WATER. TEST MIXTURE WITH RED LITMUS PAPER.

CUT SLIVER OF ZINC. HOLD IT IN FLAME. IT BURNS WITH BLUISH-GREEN FLAME TO ZINC OXIDE. ZnO IS YELLOW WHEN HOT, WHITE WHEN COOL.

TAKE A LOOK at the periodic table of elements on pages 38-39. In column IIA you find the metal magnesium, in column IIB the metal zinc. The fact that the two families in which they are found both have the Roman numeral II would indicate that they are related. But the fact that they are in separate "subgroups" would suggest that they differ in certain respects. That is exactly the case.

In their compounds they are very much alike. One atom combines with one atom of oxygen to form the oxide (MgO and ZnO), and one atom replaces two atoms of hydrogen in forming a salt ($MgCl_2$ and $ZnCl_2$, for instance). But in some of their reactions they do not behave alike — as you will learn.

Before World War II, magnesium had little use — mainly in flash photography because it burns with a blinding, white light. But the metal became important when lightweight planes were needed — melted together with other metals it forms an "alloy"

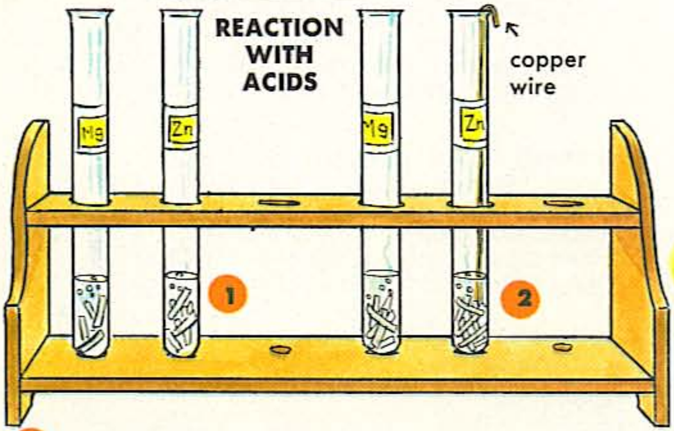

① BOTH METALS REACT WITH WEAK ACIDS, EVEN WITH VINEGAR—Mg WITH COLD VINEGAR, Zn WITH HOT.

② POUR SOLUTION OF 1 g SODIUM BISULFATE IN 10 ml WATER ON Mg AND Zn. Mg REACTS FAST, Zn SLOWLY. NOW TOUCH ZINC WITH A COPPER WIRE. REACTION SPEEDS UP, CAUSED BY ELECTRIC PROCESS.

REPLACEMENT OF COPPER

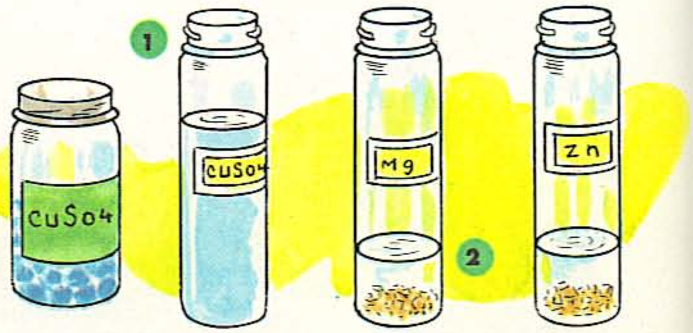

① DISSOLVE 4 g COPPER SULFATE IN 40 ml WATER. POUR HALF OF THE SOLUTION OVER STRIPS OF MAGNESIUM, THE OTHER HALF OVER SLIVERS OF ZINC.

② COPPER IS FORCED OUT AND Mg AND Zn GO INTO SOLUTION. IF ENOUGH METAL IS USED, THE BLUE COLOR DISAPPEARS. $MgSO_4$ AND $ZnSO_4$ ARE COLORLESS.

MILK
MILK
MILK

that is light yet very strong. Some magnesium compounds are used in medicine: milk of magnesia ($Mg(OH)_2$) and Epsom salt ($MgSO_4 \cdot 7H_2O$).

Zinc has been used for ages to coat iron pails and pipes to prevent them from rusting — "galvanized iron." Zinc is also a part of many alloys (German silver and brass) and is important in the making of dry-cell batteries.

MAKING THE CARBONATES

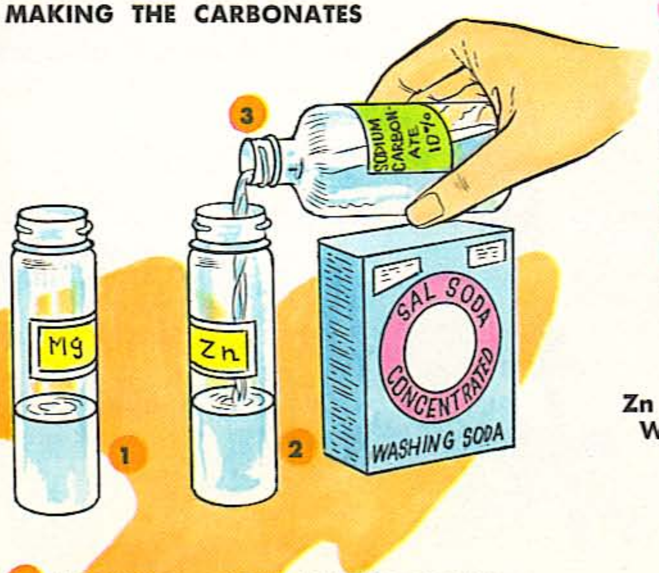

1 DISSOLVE 2 g EPSOM SALT (MAGNESIUM SULFATE, $MgSO_4 \cdot 7H_2O$) IN 20 ml WATER.

2 GET FROM HARDWARE STORE SMALL BOTTLE OF "TINNERS' FLUID." THIS IS A STRONG SOLUTION OF ZINC CHLORIDE. DILUTE 5ml OF FLUID WITH 15 ml WATER.

3 MAKE SOLUTION OF 5 g WASHING SODA (SODIUM CARBONATE) IN 50 ml WATER. ADD SOME OF THIS SOLUTION TO THE OTHER TWO. IN BOTH JARS YOU WILL GET A HEAVY WHITE PRECIPITATE. IN THE Mg JAR, THIS IS NORMAL MAGNESIUM CARBONATE ($MgCO_3$). IN Zn JAR, CO_2 IS SET FREE AND BASIC ZINC CARBONATE ($Zn(OH)_2, ZnCO_3$) RESULTS.

Mg **MAGNESIUM** Element 12. Atomic wt.: 24.32. Density: 1.75. Silver-white metal. Ductile, malleable. Reacts with boiling water. Burns in air with very brilliant white light.

Zn **ZINC** Element 30. Atomic wt.: 65.38. Density: 7.1. Bluish-white metal. Ductile and malleable. Distils when heated to boiling. Can be made to burn with bluish flame.

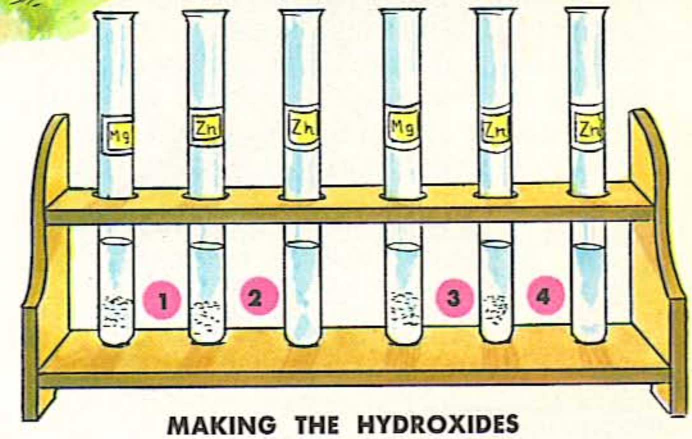

MAKING THE HYDROXIDES

1 ADD SODIUM HYDROXIDE SOLUTION TO SOLUTION OF MAGNESIUM SULFATE. WHITE $Mg(OH)_2$ FORMS.

2 ADD SMALL AMOUNT OF NaOH SOLUTION TO DILUTED TINNERS' FLUID ($ZnCl_2$). $Zn(OH)_2$ IS FORMED. ADD MORE NaOH. PRECIPITATE DISSOLVES WITH FORMATION OF SODIUM ZINCATE (Na_2ZnO_2).

3 ADD AMMONIA (AMMONIUM HYDROXIDE) TO MAGNESIUM SULFATE SOLUTION. AGAIN $Mg(OH)_2$ FORMS.

4 ADD SMALL AMOUNT OF AMMONIA TO DILUTED TINNERS' FLUID. $Zn(OH)_2$ FORMS. ADD MORE. THE $Zn(OH)_2$ DISSOLVES, FORMING COMPOUND WITH NH_3.

Zn AND Mg WITH H_2S

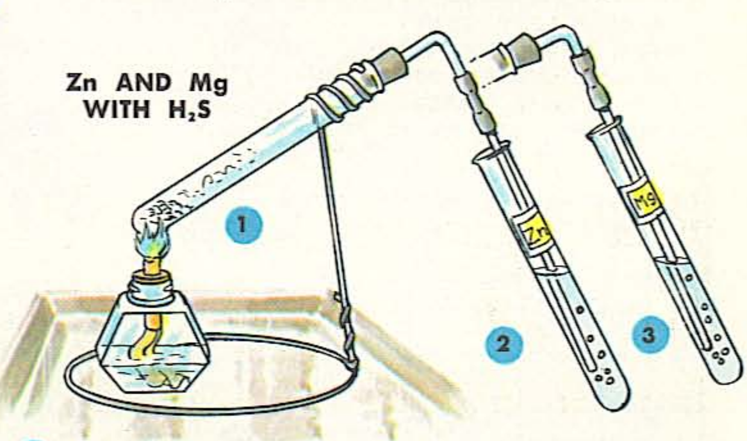

1 SET UP HYDROGEN SULFIDE APPARATUS SHOWN ON PAGE 53.

2 LEAD HYDROGEN SULFIDE (H_2S) INTO DILUTED TINNERS' FLUID ($ZnCl_2$). YOU GET A WHITE PRECIPITATE OF ZnS.

3 LEAD H_2S INTO SOLUTION OF EPSOM SALT ($MgSO_4$). HERE ALSO YOU GET WHITE PRECIPITATE. BUT NOT OF MAGNESIUM SULFIDE. THIS REACTS WITH THE WATER TO MAKE $Mg(OH)_2$.

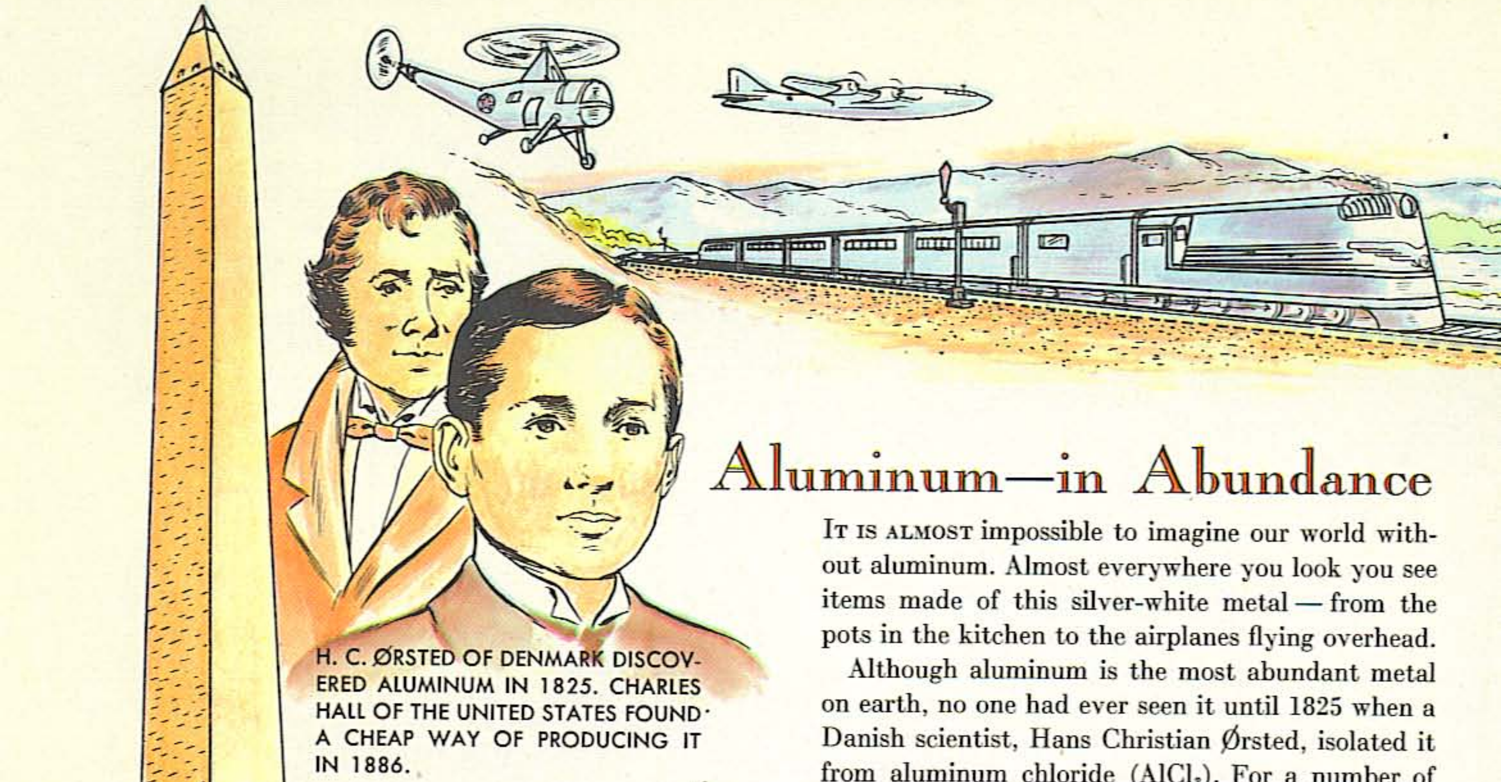

H. C. ØRSTED OF DENMARK DISCOVERED ALUMINUM IN 1825. CHARLES HALL OF THE UNITED STATES FOUND A CHEAP WAY OF PRODUCING IT IN 1886.

Aluminum—in Abundance

It is almost impossible to imagine our world without aluminum. Almost everywhere you look you see items made of this silver-white metal — from the pots in the kitchen to the airplanes flying overhead.

Although aluminum is the most abundant metal on earth, no one had ever seen it until 1825 when a Danish scientist, Hans Christian Ørsted, isolated it from aluminum chloride ($AlCl_3$). For a number of years aluminum was so expensive that it was considered in class with gold and silver. The solid aluminum cap placed on top of the Washington Monument in 1884 was first put on public display so that everyone could have a look at such a great rarity. Two

Al **ALUMINUM** Element 13. Atomic wt.: 26.98. Density: 2.70. Silver-white metal; ductile, malleable, able to take a high polish. Amphoteric. Will burn in oxygen with white flame.

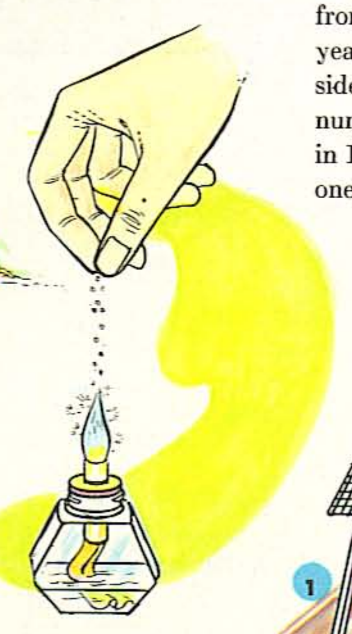

MAKE A SMALL AMOUNT OF ALUMINUM POWDER BY FILING IT OFF AN OLD ALUMINUM POT. SPRINKLE IN FLAME TO MAKE SPARKS OF BURNING ALUMINUM.

DISSOLVING ALUMINUM

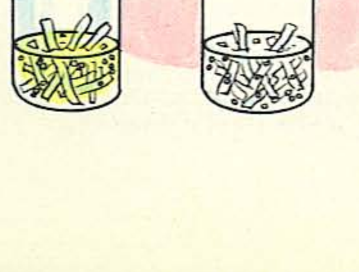

1 CUT ALUMINUM FOIL IN SMALL STRIPS. DROP THEM IN A LITTLE DILUTED HYDROCHLORIC ACID. HYDROGEN IS RELEASED; ALUMINUM CHLORIDE IS FORMED.

2 DROP STRIPS OF ALUMINUM FOIL IN 10% NaOH SOLUTION. HYDROGEN IS FREED AND SODIUM ALUMINATE ($NaAlO_2$) IS FORMED.

GROWING ALUM CRYSTALS

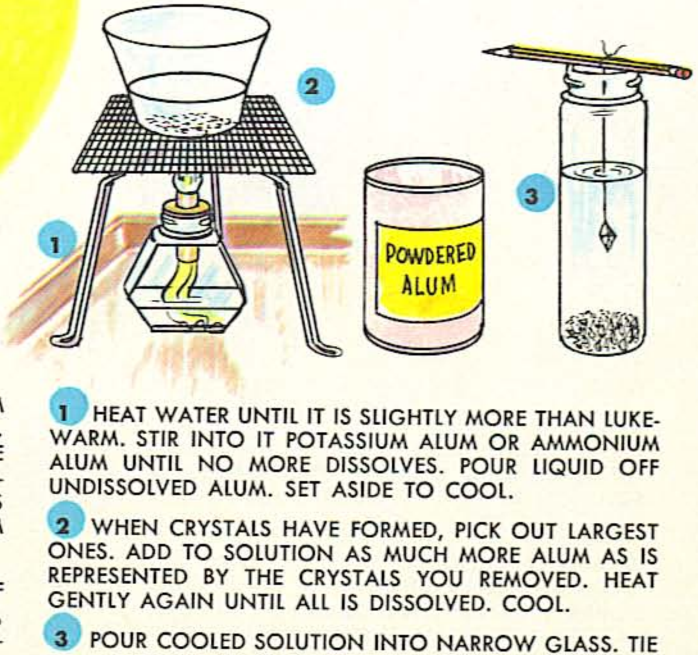

1 HEAT WATER UNTIL IT IS SLIGHTLY MORE THAN LUKEWARM. STIR INTO IT POTASSIUM ALUM OR AMMONIUM ALUM UNTIL NO MORE DISSOLVES. POUR LIQUID OFF UNDISSOLVED ALUM. SET ASIDE TO COOL.

2 WHEN CRYSTALS HAVE FORMED, PICK OUT LARGEST ONES. ADD TO SOLUTION AS MUCH MORE ALUM AS IS REPRESENTED BY THE CRYSTALS YOU REMOVED. HEAT GENTLY AGAIN UNTIL ALL IS DISSOLVED. COOL.

3 POUR COOLED SOLUTION INTO NARROW GLASS. TIE THREAD TO LARGEST CRYSTAL YOU PICKED. HANG THIS IN SOLUTION FROM A PENCIL. PLACE IN QUIET SPOT. LET THE CRYSTAL GROW FOR A WEEK OR MORE.

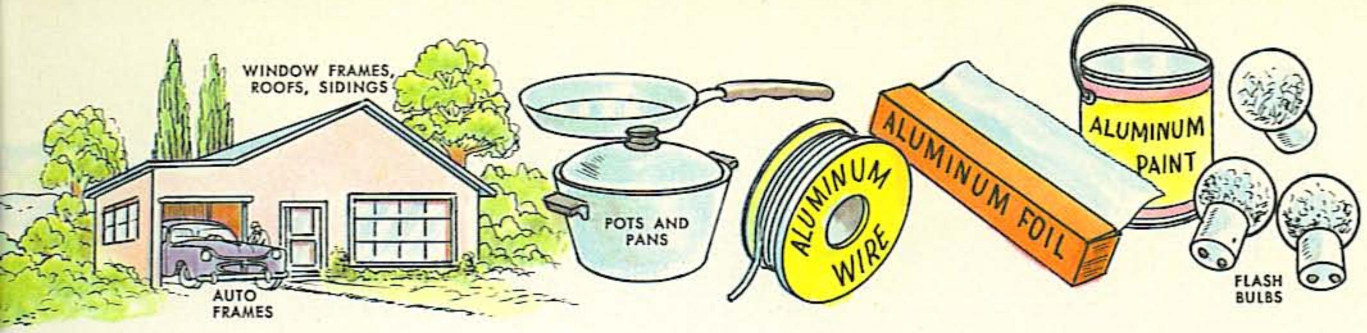

years later, a 22-year-old American chemist, Charles Martin Hall, invented a way of producing aluminum cheaply from aluminum oxide (Al_2O_3). Since then aluminum has become one of the most popular of all metals — mostly because of its lightness.

The mineral bauxite ($AlHO_2, Al(OH)_3$) is our main source of aluminum. But aluminum is also found in nature as oxide and in many complex silicates. Clay, for instance, is an aluminum silicate.

Two things about aluminum will interest you as a chemist. One is that aluminum is an "amphoteric" element, which means that it can form not only a base ($Al(OH)_3$), but also an acid ($HAlO_2$). The other is that aluminum sulfate ($Al_2(SO_4)_3$) has the ability to combine with potassium sulfate (K_2SO_4) and ammonium sulfate ($(NH_4)_2SO_4$) into beautiful cubic crystals of double salts called "alums"— $KAl(SO_4)_2 \cdot 12H_2O$ and $NH_4Al(SO_4)_2 \cdot 12H_2O$.

MAKING ALUMINUM HYDROXIDE

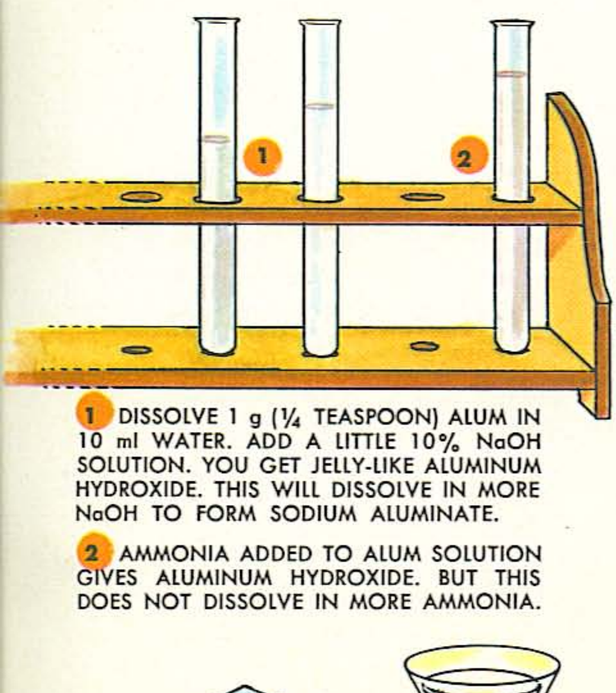

1 DISSOLVE 1 g (¼ TEASPOON) ALUM IN 10 ml WATER. ADD A LITTLE 10% NaOH SOLUTION. YOU GET JELLY-LIKE ALUMINUM HYDROXIDE. THIS WILL DISSOLVE IN MORE NaOH TO FORM SODIUM ALUMINATE.

2 AMMONIA ADDED TO ALUM SOLUTION GIVES ALUMINUM HYDROXIDE. BUT THIS DOES NOT DISSOLVE IN MORE AMMONIA.

CLEARING WATER WITH ALUM

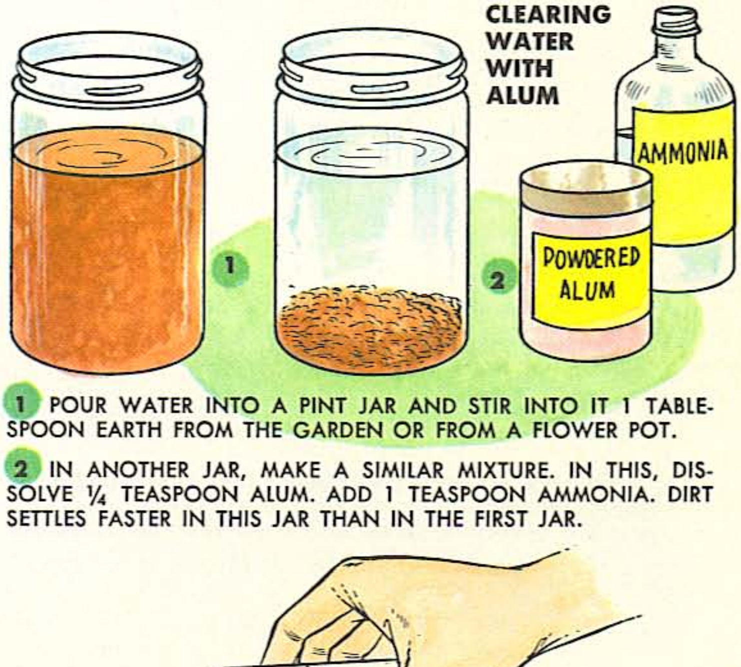

1 POUR WATER INTO A PINT JAR AND STIR INTO IT 1 TABLESPOON EARTH FROM THE GARDEN OR FROM A FLOWER POT.

2 IN ANOTHER JAR, MAKE A SIMILAR MIXTURE. IN THIS, DISSOLVE ¼ TEASPOON ALUM. ADD 1 TEASPOON AMMONIA. DIRT SETTLES FASTER IN THIS JAR THAN IN THE FIRST JAR.

ALUM AND SODA

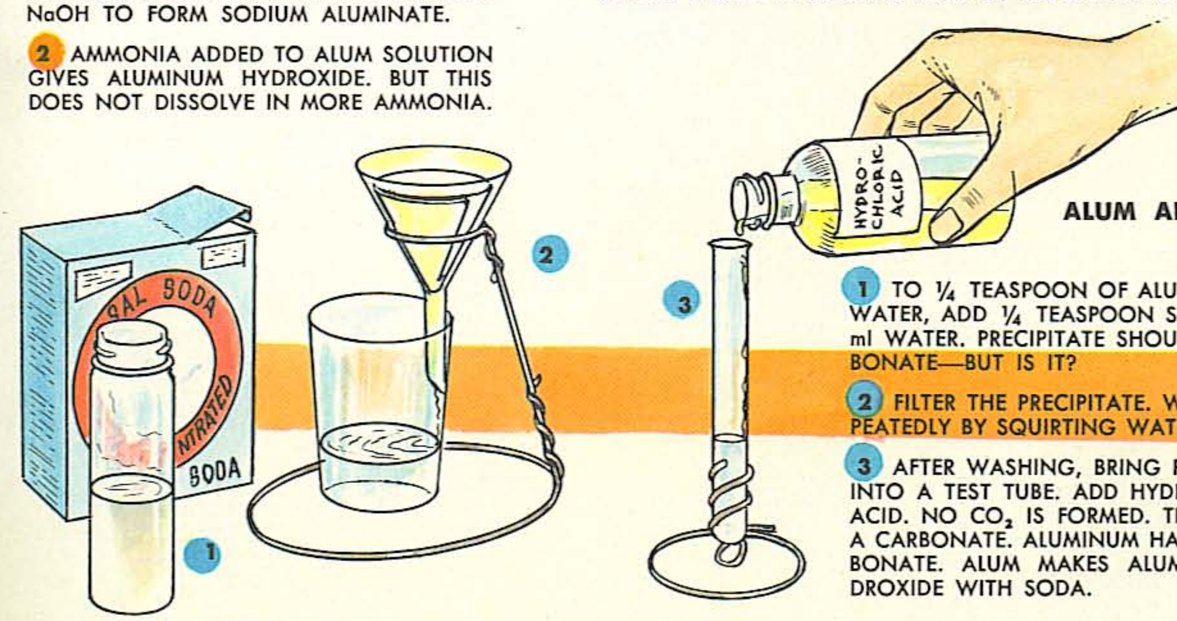

1 TO ¼ TEASPOON OF ALUM IN 20 ml WATER, ADD ¼ TEASPOON SODA IN 20 ml WATER. PRECIPITATE SHOULD BE CARBONATE—BUT IS IT?

2 FILTER THE PRECIPITATE. WASH IT REPEATEDLY BY SQUIRTING WATER INTO IT.

3 AFTER WASHING, BRING PRECIPITATE INTO A TEST TUBE. ADD HYDROCHLORIC ACID. NO CO_2 IS FORMED. THIS IS NOT A CARBONATE. ALUMINUM HAS NO CARBONATE. ALUM MAKES ALUMINUM HYDROXIDE WITH SODA.

MANGANESE DIOXIDE TO MANGANESE SULFATE

MANGANESE SULFATE TO MANGANESE HYDROXIDE

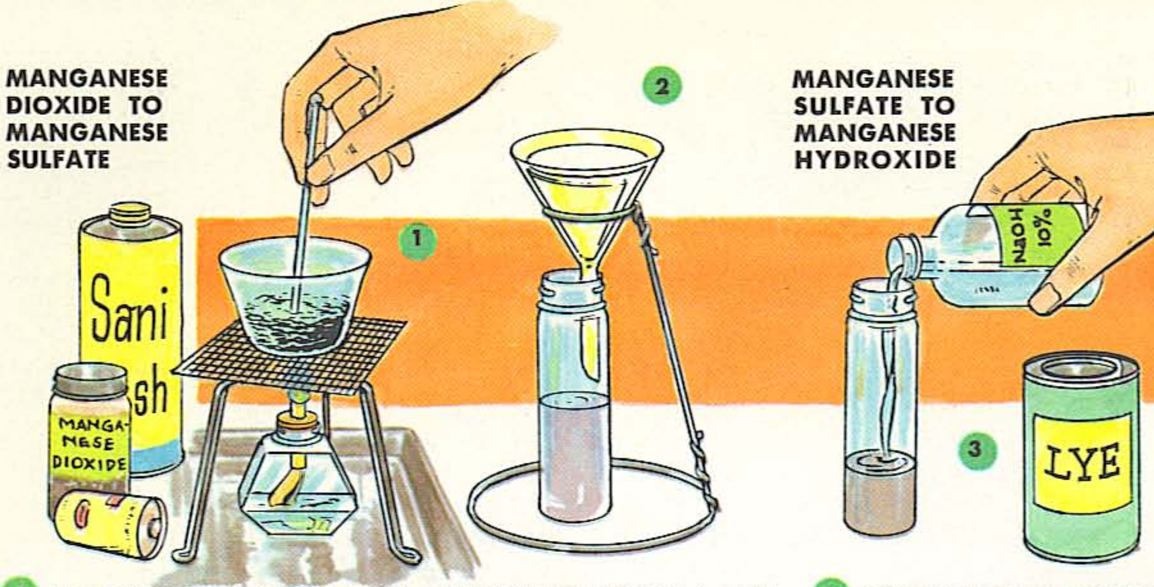

① IN A PYREX CUSTARD CUP, MIX 2 g MANGANESE DIOXIDE, 6 g SODIUM BISULFATE, AND 10 ml WATER. HEAT MIXTURE GENTLY. IT WILL BUBBLE VIGOROUSLY BECAUSE OXYGEN IS SET FREE.

② AFTER A FEW MINUTES, ADD 30 ml WATER. FILTER. FILTRATE CONTAINS MANGANESE SULFATE ($MnSO_4$) AND SODIUM SULFATE.

③ INTO HALF OF THE MANGANESE SULFATE SOLUTION YOU HAVE MADE, POUR 10% SOLUTION OF NaOH UNTIL NO MORE PRECIPITATE FORMS. WHITISH $Mn(OH)_2$ OXIDIZES INTO BROWN $MnO(OH)$.

Manganese—Metal of Many Colors

METALLIC MANGANESE has no use by itself. But add up to 15 per cent of it to steel and the result is an alloy — "manganese steel" — so hard that it is suitable for machine parts that are exposed to a lot of rough wear.

The most common ore from which manganese is extracted goes under the name of "pyrolusite." This is nothing but your old friend manganese dioxide (MnO_2) which you found in your flashlight battery and have already used in a great number of your chemical experiments.

The compounds of manganese come in almost any color you can think of: black and brown, white and pink and red, violet and green. In working with these compounds, your fingers and glassware may get brown. You can get rid of this stain easily with diluted hydrochloric acid. Rinse thoroughly with water afterwards.

EXPERIMENTS WITH POTASSIUM PERMANGANATE

$KMnO_4$ WILL GIVE YOU AN IDEA OF SMALLNESS OF MOLECULE.

① DISSOLVE ½ g POTASSIUM PERMANGANATE IN 50 ml WATER. THIS GIVES A SOLUTION OF 1 TO 100, OR 1/100.

② DILUTE 5 ml OF THIS SOLUTION WITH 45 ml WATER. YOU NOW HAVE A SOLUTION OF 1 TO 1,000, OR 1/1,000.

③ AGAIN, 5 ml TO 45 ml WATER FOR SOLUTION 1/10,000.

④ AGAIN, 5 ml TO 45 ml WATER FOR SOLUTION 1/100,000.

⑤ AGAIN, 5 ml TO 45 ml WATER FOR SOLUTION 1/1,000,000. COLOR YOU STILL SEE IS CAUSED BY THE PRESENCE OF MORE THAN 600,000,000,000,000,000 MOLECULES OF $KMnO_4$.

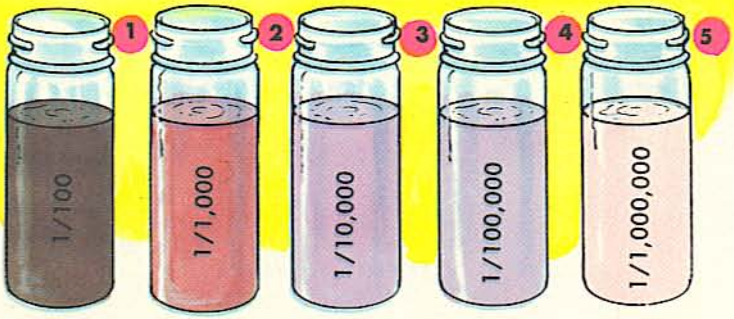

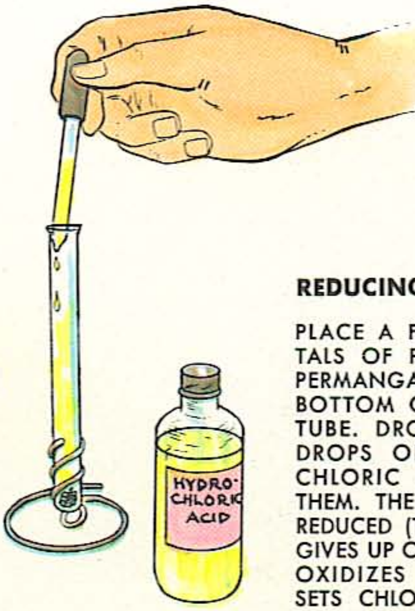

REDUCING $KMnO_4$

PLACE A FEW CRYSTALS OF POTASSIUM PERMANGANATE ON BOTTOM OF A TEST TUBE. DROP A FEW DROPS OF HYDROCHLORIC ACID ON THEM. THE $KMnO_4$ IS REDUCED (THAT IS, IT GIVES UP OXYGEN). IT OXIDIZES HCl AND SETS CHLORINE FREE.

THE EXPERIMENTS ALONG THE TOP OF THESE PAGES SHOW HOW IT IS POSSIBLE TO MOVE FROM ONE COMPOUND TO ANOTHER.

MANGANESE SULFATE TO MANGANESE CARBONATE

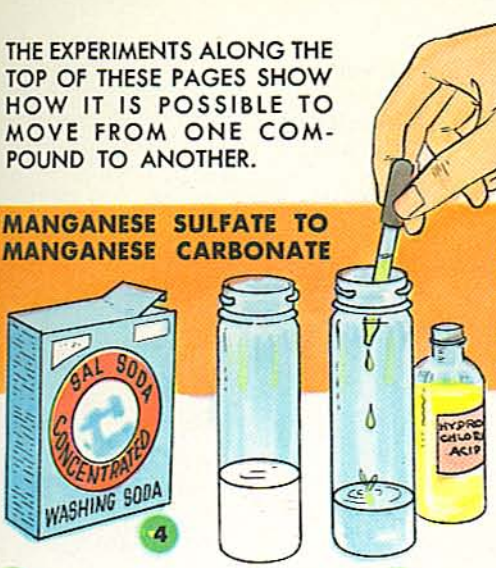

MANGANESE CARBONATE TO MANGANESE CHLORIDE

5

MANGANESE CHLORIDE TO MANGANESE SULFIDE

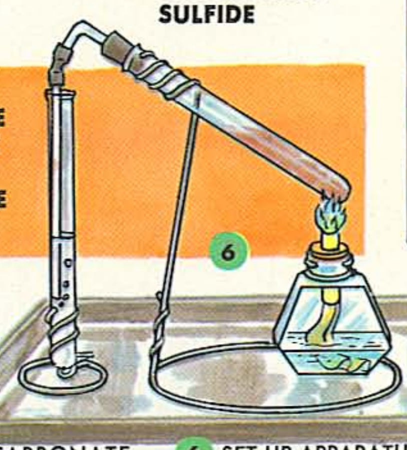

Mn **MANGANESE**
Element 25.
Atomic wt.: 54.94.
Density: 7.44. Silvery-gray metal with reddish tinge. Reacts with water. Its compounds with oxygen range from bases to acids.

4 INTO SECOND HALF OF SOLUTION, POUR SOLUTION OF 4 g SODIUM CARBONATE IN 10 ml WATER. WHITE PRECIPITATE IS $MnCO_3$.

5 LET MANGANESE CARBONATE SETTLE. POUR LIQUID OFF PRECIPITATE. ADD HYDROCHLORIC ACID BY THE DROP UNTIL DISSOLVED. RESULT IS MANGANESE CHLORIDE ($MnCl_2$).

6 SET UP APPARATUS FOR MAKING HYDROGEN SULFIDE (SEE PAGE 53). POUR SOLUTION OF $MnCl_2$ INTO TEST TUBE. DILUTE IT IF NECESSARY. LEAD H_2S INTO IT. YOU GET MANGANESE SULFIDE.

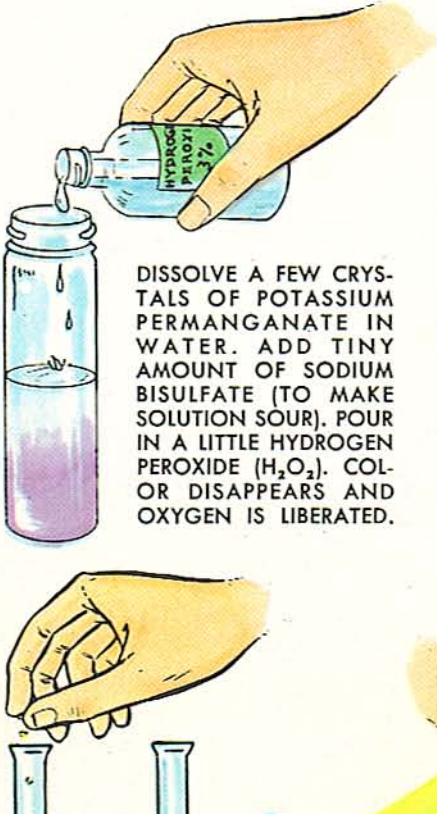

DISSOLVE A FEW CRYSTALS OF POTASSIUM PERMANGANATE IN WATER. ADD TINY AMOUNT OF SODIUM BISULFATE (TO MAKE SOLUTION SOUR). POUR IN A LITTLE HYDROGEN PEROXIDE (H_2O_2). COLOR DISAPPEARS AND OXYGEN IS LIBERATED.

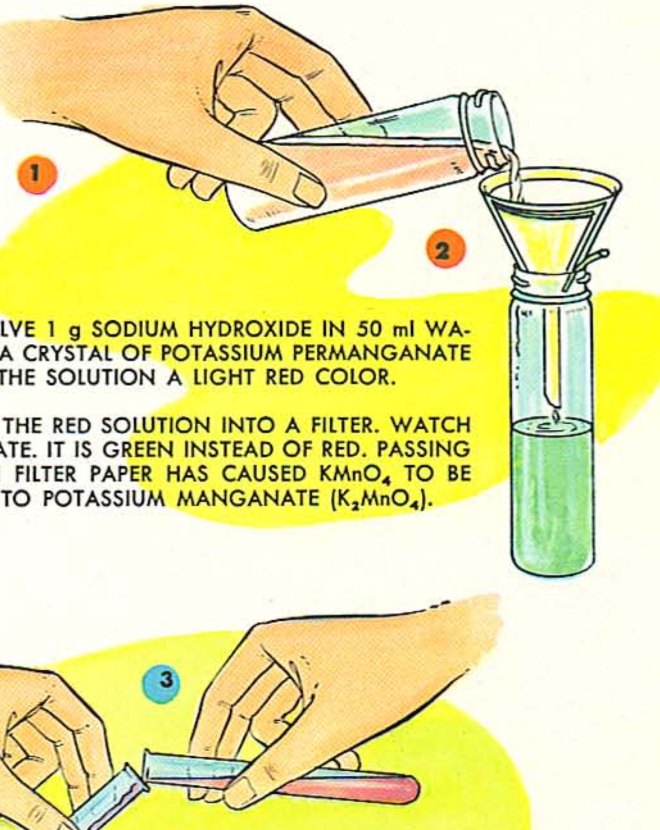

1 DISSOLVE 1 g SODIUM HYDROXIDE IN 50 ml WATER. ADD A CRYSTAL OF POTASSIUM PERMANGANATE TO GIVE THE SOLUTION A LIGHT RED COLOR.

2 POUR THE RED SOLUTION INTO A FILTER. WATCH THE FILTRATE. IT IS GREEN INSTEAD OF RED. PASSING THROUGH FILTER PAPER HAS CAUSED $KMnO_4$ TO BE REDUCED TO POTASSIUM MANGANATE (K_2MnO_4).

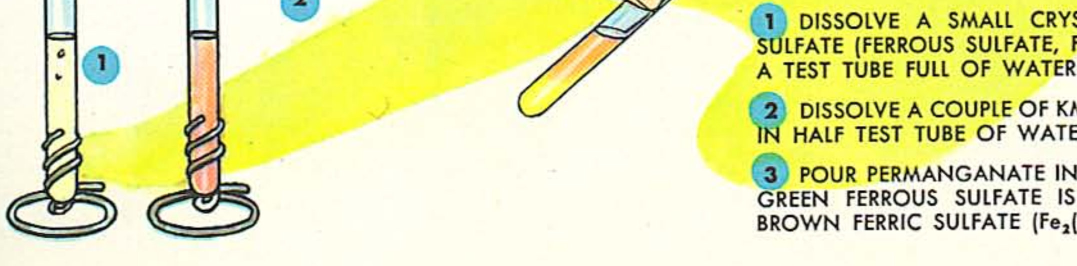

1 DISSOLVE A SMALL CRYSTAL OF IRON SULFATE (FERROUS SULFATE, $FeSO_4$) IN HALF A TEST TUBE FULL OF WATER.

2 DISSOLVE A COUPLE OF $KMnO_4$ CRYSTALS IN HALF TEST TUBE OF WATER.

3 POUR PERMANGANATE INTO IRON SALT. GREEN FERROUS SULFATE IS OXIDIZED TO BROWN FERRIC SULFATE ($Fe_2(SO_4)_3$).

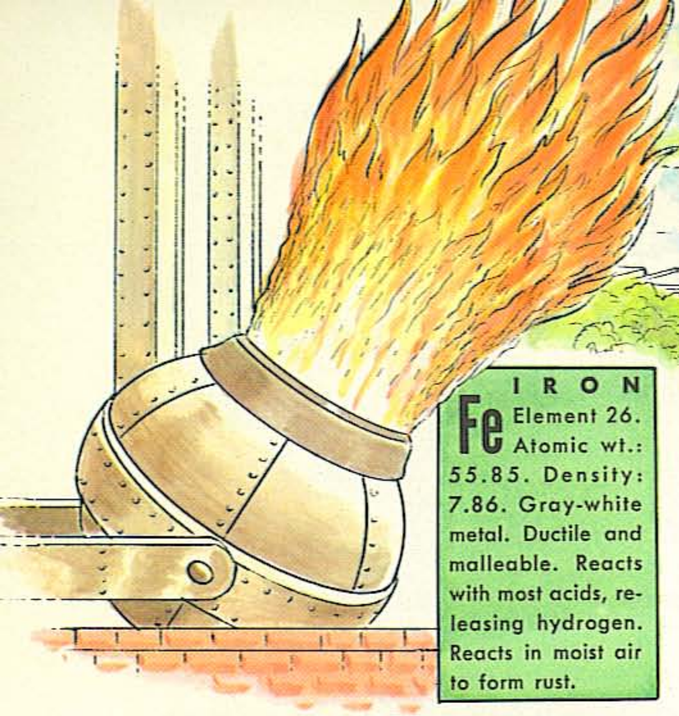

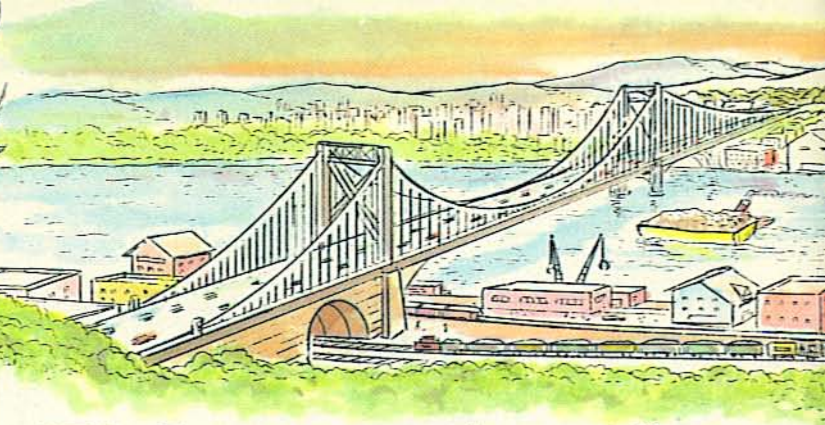

IRON
Fe Element 26. Atomic wt.: 55.85. Density: 7.86. Gray-white metal. Ductile and malleable. Reacts with most acids, releasing hydrogen. Reacts in moist air to form rust.

We Live in an Age of Iron

IRON METAL has the peculiar quality of being magnetic — that is, of being attracted and influenced by a force called magnetism. If you should walk around your home and touch different things with a magnet, you would be surprised at the large number of them that would prove to contain iron. They would range in size from the car in the garage and the refrigerator and stove in the kitchen to the nails in the walls and the needles and pins in your mother's sewing box.

The moment you step outdoors and look around, you will be even more amazed. Skyscrapers and

TWO KINDS OF IRON COMPOUNDS

IRON FORMS TWO KINDS OF COMPOUNDS. IN FERROUS SALTS, EACH IRON ATOM HAS REPLACED TWO HYDROGEN ATOMS. IN FERRIC SALTS, EACH IRON ATOM HAS REPLACED THREE HYDROGEN ATOMS. GREEN FERROUS SALTS EASILY OXIDIZE INTO RED-BROWN FERRIC SALTS.

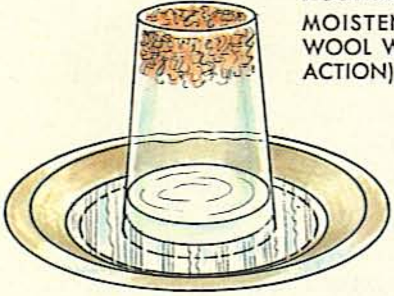

RUSTING OF IRON

MOISTEN A WAD OF FINE STEEL WOOL WITH VINEGAR (TO SPEED UP ACTION). WEDGE IT IN BOTTOM OF A GLASS. INVERT GLASS IN PIE PLATE OF WATER. IN A FEW DAYS, WATER HAS RISEN IN GLASS. IRON HAS REACTED WITH OXYGEN AND MOISTURE TO FORM RUST—$(Fe_2O_3)_2 \cdot 3H_2O$.

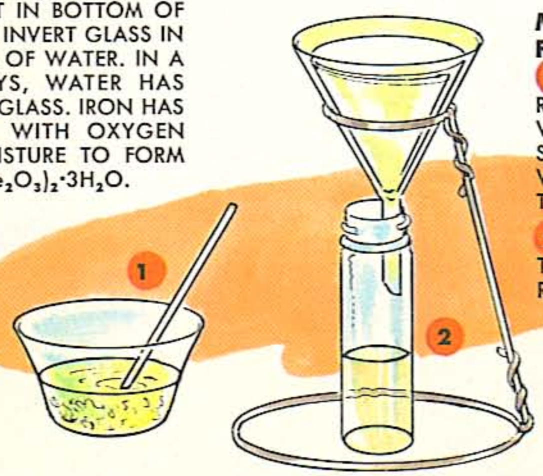

MAKING A FERROUS SALT

1 POUR HYDROCHLORIC ACID OVER STEEL WOOL. HYDROGEN IS SET FREE AS STEEL WOOL DISSOLVES. FILTER THE SOLUTION.

2 LIGHT-GREEN FILTRATE CONTAINS FERROUS CHLORIDE ($FeCl_2$).

MAKING A FERRIC SALT

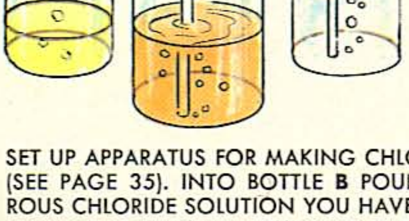

SET UP APPARATUS FOR MAKING CHLORINE (SEE PAGE 35). INTO BOTTLE **B** POUR FERROUS CHLORIDE SOLUTION YOU HAVE JUST MADE. THE CHLORINE TURNS THE GREEN FERROUS CHLORIDE ($FeCl_2$) INTO A BROWN FERRIC CHLORIDE ($FeCl_3$).

TEST FOR IRON SALTS

1 IN ONE TEST TUBE, DILUTE SOME FERRIC CHLORIDE SOLUTION WITH WATER.

2 IN ANOTHER, DILUTE SOME OF THE FERROUS CHLORIDE SOLUTION WITH WATER.

3 TO EACH, ADD A FEW DROPS OF SOLUTION OF ¼ TEASPOON POTASSIUM FERROCYANIDE IN 50 ml WATER. FERRIC SALT MAKES A DEEP BLUE PRECIPITATE OF PRUSSIAN BLUE. FERROUS SALT MAKES LIGHT BLUE PRECIPITATE.

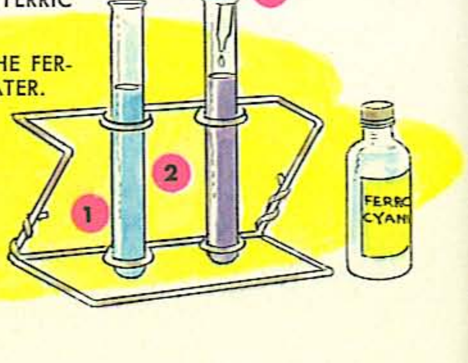

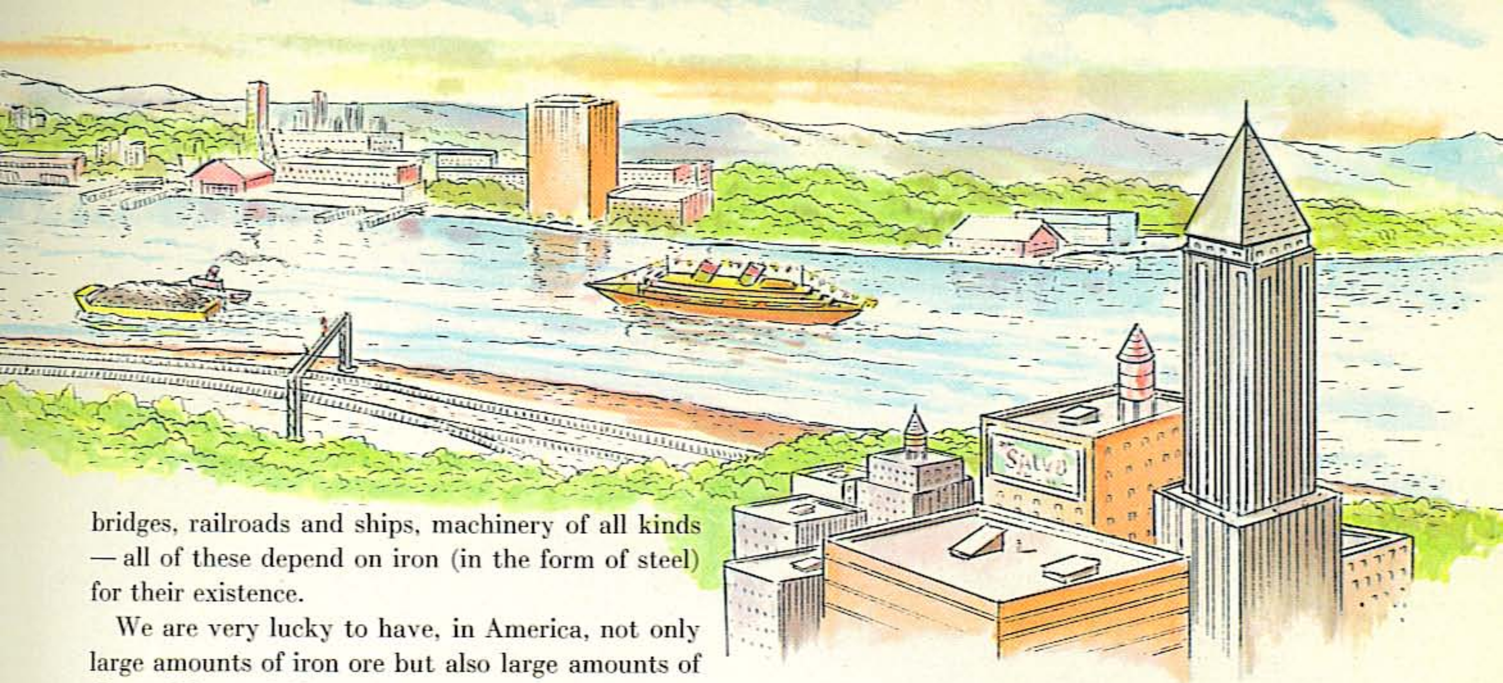

bridges, railroads and ships, machinery of all kinds — all of these depend on iron (in the form of steel) for their existence.

We are very lucky to have, in America, not only large amounts of iron ore but also large amounts of the coal from which to make the coke that goes into iron production.

The iron is driven out of its ore (mostly Fe_2O_3) in huge furnaces. Each furnace can make as much as 1,000 tons of iron at one time from 2,000 tons of ore, 1,000 tons of coke, and 500 tons of limestone. A blast of hot air is forced through the mixture. The coke burns with great heat to carbon dioxide. This, with more coke, forms carbon monoxide, and this, in turn, reduces the iron oxide to metallic iron. In chemical language, this is what happens:

$$C + O_2 \rightarrow CO_2 \text{ plus heat}$$
$$CO_2 + C \rightarrow 2CO$$
$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

At the same time, the limestone combines with various impurities to form a glass-like compound called "slag." This is removed when the white-hot iron is poured out into moulds and cooled into bars of "pig iron."

The pig iron is brittle because it contains close to 5 per cent carbon. To turn it into steel, the carbon must be burned out until only from .5 to 1.5 per cent remains. This is done either by the Bessemer process (named for an Englishman, Henry Bessemer) or by the open-hearth process. The finished steel is molded into "ingots" and shipped to manufacturing plants all over the country.

In chemical experiments, the most commonly used iron compound is the iron sulfate (ferrous sulfate, $FeSO_4 \cdot 7H_2O$) — also called "green vitriol" and "copperas." Don't let the last name mislead you— it has nothing to do with copper but comes from an old French word, *couperose.*

FROM FERROUS SALT TO FERRIC

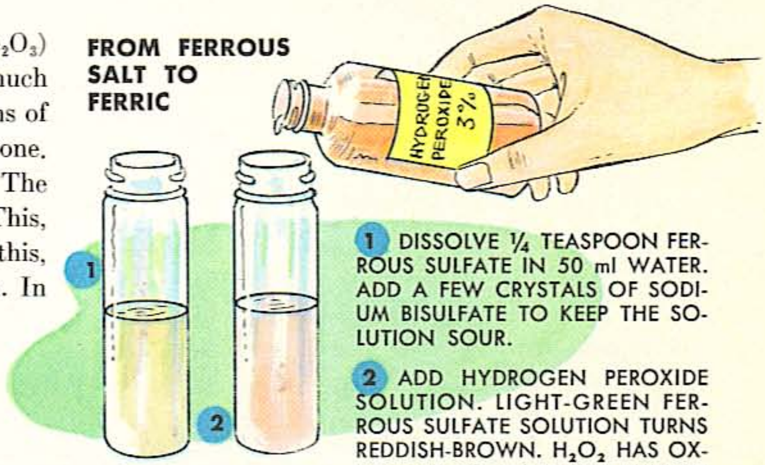

1 DISSOLVE ¼ TEASPOON FERROUS SULFATE IN 50 ml WATER. ADD A FEW CRYSTALS OF SODIUM BISULFATE TO KEEP THE SOLUTION SOUR.

2 ADD HYDROGEN PEROXIDE SOLUTION. LIGHT-GREEN FERROUS SULFATE SOLUTION TURNS REDDISH-BROWN. H_2O_2 HAS OXIDIZED $FeSO_4$ TO FERRIC SULFATE ($Fe_2(SO_4)_3$).

IRON HYDROXIDES AND CARBONATE

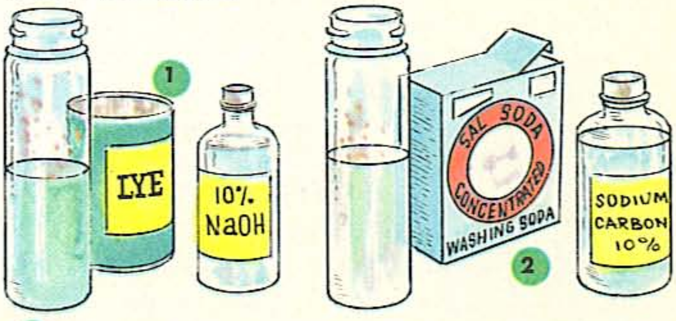

1 TO SOLUTION OF ¼ TEASPOON FERROUS SULFATE IN 50 ml WATER, ADD SOLUTION OF SODIUM HYDROXIDE. PURE FERROUS HYDROXIDE IS WHITE. BECAUSE OF IMPURITIES, YOU GET DIRTY-GREEN PRECIPITATE OF $Fe(OH)_2$, SOON OXIDIZING TO BROWN FERRIC HYDROXIDE.

2 TO ANOTHER PORTION OF FERROUS SULFATE SOLUTION ADD SODIUM CARBONATE SOLUTION. PURE CARBONATE MADE WITH NO OXYGEN PRESENT IS WHITE— BUT YOU GET MUDDY, WHITISH-GREEN PRECIPITATE OF FERROUS CARBONATE, EVENTUALLY TURNING INTO FERRIC HYDROXIDE.

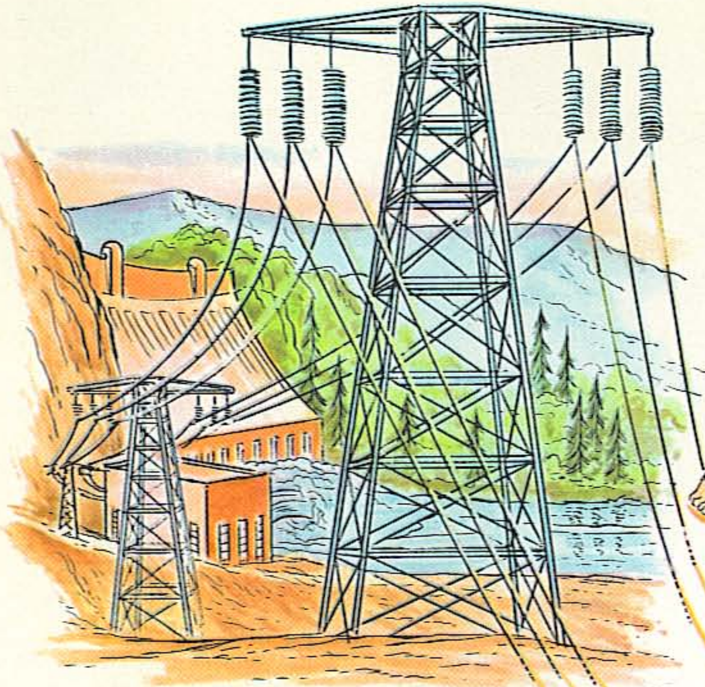

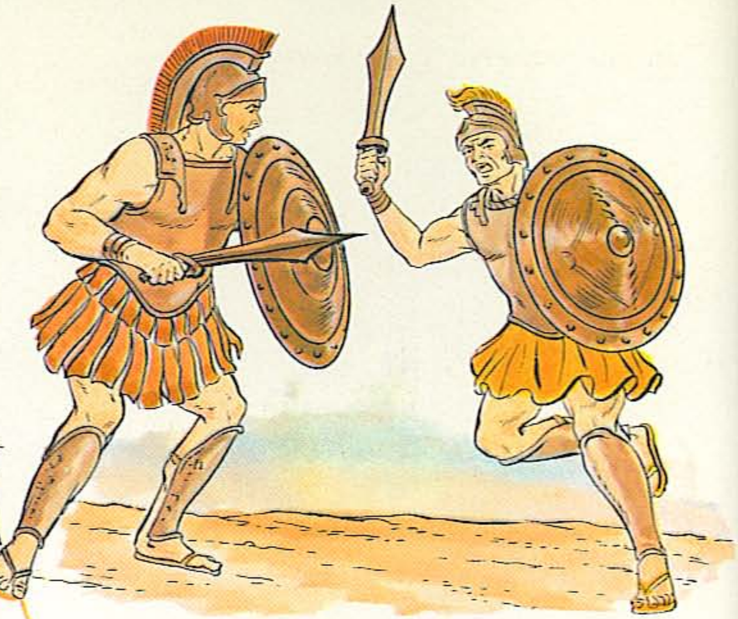

THE GREEK AND TROJAN WARRIORS FIGHTING BEFORE THE GATES OF TROY USED SWORDS AND SHIELDS OF BRONZE—AN ALLOY MADE UP OF COPPER AND TIN.

Copper—Yesterday, Today

Copper is one of the few metals found free in nature. That is why it was used long before historic times for weapons and utensils. The main trouble with it was its softness. This was remedied when some early coppersmith discovered that copper and tin (also found free in nature) melted together formed an alloy that was much harder than either of the two metals. This alloy gave its name to more than two thousand years of human history — the period called the "Bronze Age."

A great number of weapons from the Bronze Age have been found in Greece. When they were dug out of the ground, they were covered with a green "rust." This deposit was called verdigris — literally "green of Greece" (from old French, *vert de Grèce*). It consists of basic cupric carbonate — the same compound you will see on a bronze statue or a copper-clad church spire exposed to wind and weather.

Copper became especially valuable less than a hundred years ago when a satisfactory method for producing a steady flow of electricity was invented. After silver, copper is the best conductor of electricity. Today, the most important use for copper is for electrical purposes. It serves to bring the current from the place where it is produced to the place where it is to be used (although, within recent years, some aluminum has taken its place for high-tension wires). You will find copper in the wiring in your own home and in every electrical gadget you use.

Copper makes two kinds of salts. In cuprous salts, one copper atom has taken the place of one hydrogen atom; in cupric salts, one copper atom has taken the place of two hydrogen atoms. Cuprous salts (such as cuprous chloride, $CuCl$) are colorless, while cupric salts (such as cupric sulfate, $CuSO_4 \cdot 5H_2O$) are bright blue in color.

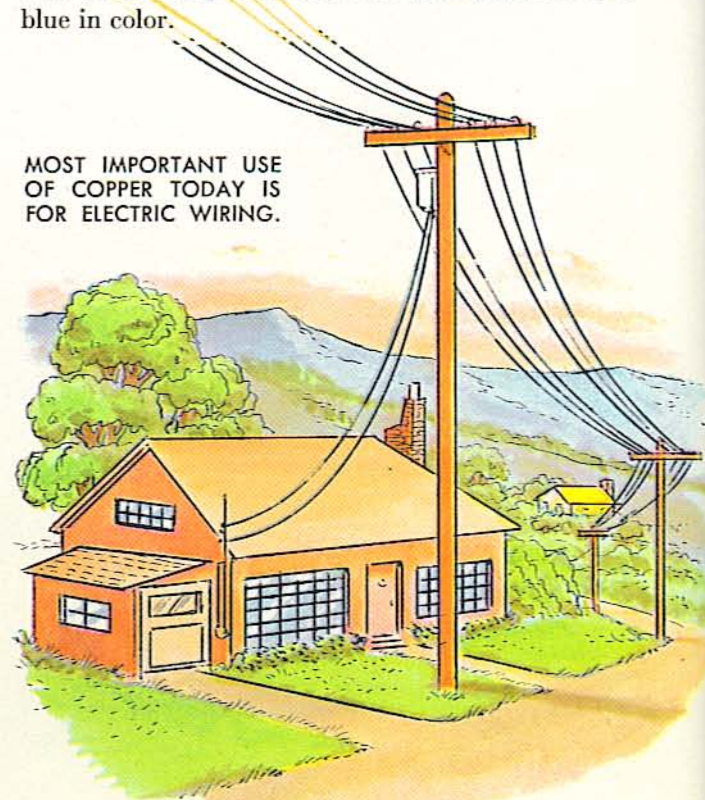

MOST IMPORTANT USE OF COPPER TODAY IS FOR ELECTRIC WIRING.

MAKING COPPER COMPOUNDS

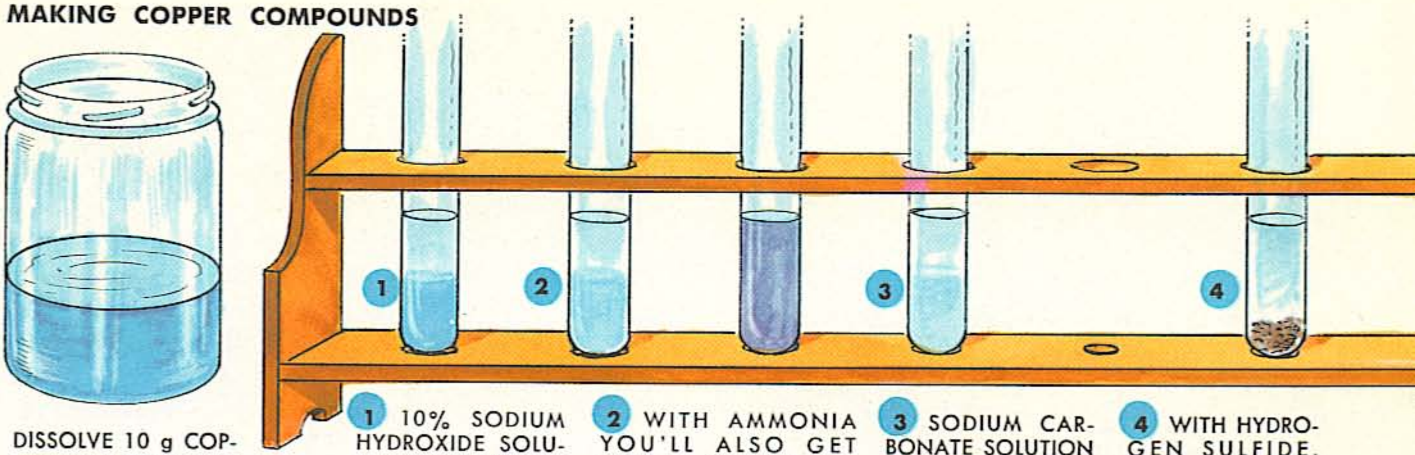

DISSOLVE 10 g COPPER SULFATE IN 100 ml WATER. POUR 10 ml INTO EACH OF FOUR TEST TUBES.

1 10% SODIUM HYDROXIDE SOLUTION PRECIPITATES DIRTY-BLUE CUPRIC HYDROXIDE ($Cu(OH)_2$).

2 WITH AMMONIA YOU'LL ALSO GET $Cu(OH)_2$, BUT THIS DISSOLVES IN MORE AMMONIA WITH DEEP BLUE COLOR.

3 SODIUM CARBONATE SOLUTION GIVES BLUE-GREEN CUPRIC CARBONATE PRECIPITATE.

4 WITH HYDROGEN SULFIDE, BROWNISH-BLACK PRECIPITATE OF CUPRIC SULFIDE.

FROM CUPRIC SALT TO CUPROUS SALT

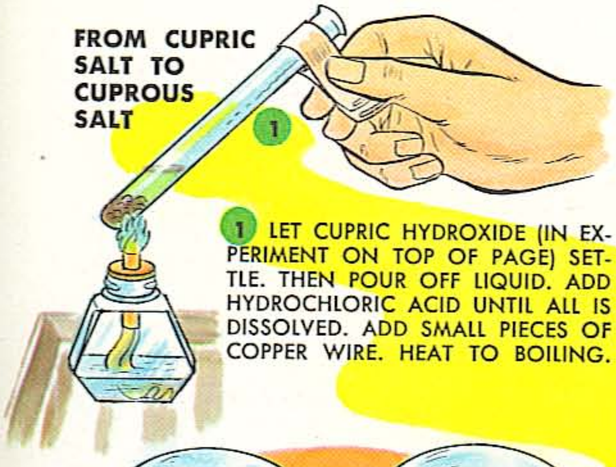

1 LET CUPRIC HYDROXIDE (IN EXPERIMENT ON TOP OF PAGE) SETTLE. THEN POUR OFF LIQUID. ADD HYDROCHLORIC ACID UNTIL ALL IS DISSOLVED. ADD SMALL PIECES OF COPPER WIRE. HEAT TO BOILING.

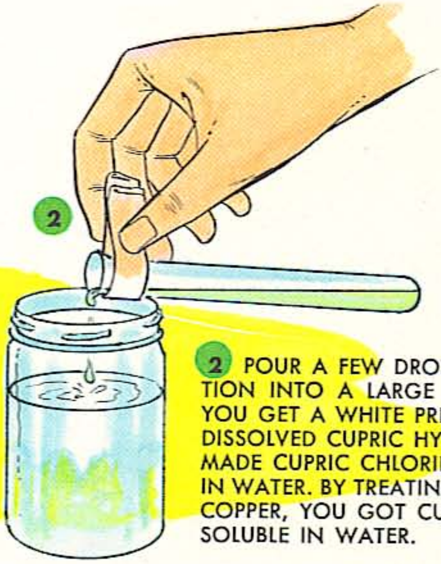

2 POUR A FEW DROPS OF THE HOT SOLUTION INTO A LARGE AMOUNT OF WATER. YOU GET A WHITE PRECIPITATE. WHEN YOU DISSOLVED CUPRIC HYDROXIDE IN HCl, YOU MADE CUPRIC CHLORIDE WHICH IS SOLUBLE IN WATER. BY TREATING THIS WITH METALLIC COPPER, YOU GOT CUPROUS CHLORIDE, INSOLUBLE IN WATER.

Cu **COPPER** Element 29. Atomic wt.: 63.54. Density: 8.97. Soft metal of reddish color. Easily rolled and drawn into wire. Next to silver, is the best conductor of electricity.

COPPER SULFATE IN CHEMICAL ANALYSIS

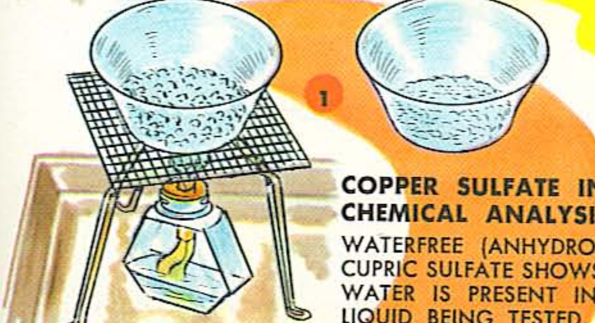

WATERFREE (ANHYDROUS) CUPRIC SULFATE SHOWS IF WATER IS PRESENT IN A LIQUID BEING TESTED.

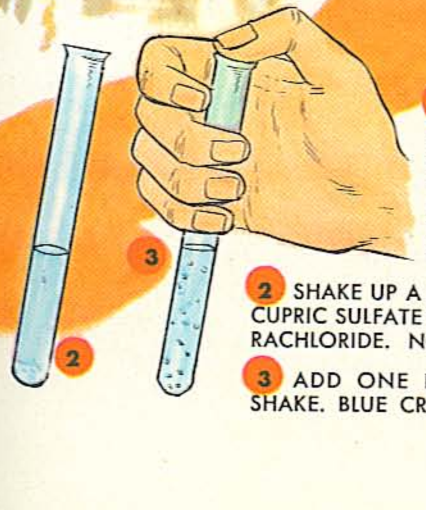

1 CRUSH A FEW CUPRIC SULFATE CRYSTALS. HEAT WHILE STIRRING UNTIL THEY HAVE TURNED INTO A WHITE POWDER.

2 SHAKE UP A LITTLE ANHYDROUS CUPRIC SULFATE WITH CARBON TETRACHLORIDE. NOTHING HAPPENS.

3 ADD ONE DROP OF WATER. SHAKE. BLUE CRYSTALS FORM.

REPLACING COPPER WITH IRON

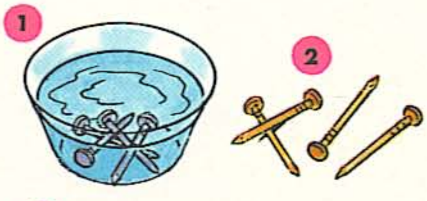

1 DROP SEVERAL CLEAN NAILS INTO A SOLUTION OF COPPER SULFATE. LEAVE FOR HALF AN HOUR.

2 NAILS ARE NOW COATED WITH METALLIC COPPER AND THE SOLUTION CONTAINS FERROUS SULFATE.

METALS CAN BE ARRANGED IN A REPLACEMENT SERIES. ANY METAL IN THE SERIES WILL DRIVE OUT ANOTHER METAL BELOW IT AND TAKE ITS PLACE IN THE SALT.

REPLACEMENT SERIES

POTASSIUM
SODIUM
CALCIUM
MAGNESIUM
ALUMINUM
ZINC
CHROMIUM
IRON
NICKEL
TIN
LEAD
COPPER
MERCURY
SILVER
PLATINUM
GOLD

Silver—One of the "Noble" Metals

SILVER — LIKE COPPER and gold — is found free in nature and was therefore known to man long before he learned to extract metals from their ores.

Pure silver has one drawback — it is almost as soft as copper. That's why most silver is alloyed with copper to make it harder. Sterling silver — a famous alloy used for jewelry — contains 7.5 parts copper to 92.5 parts silver. Only $\frac{9}{10}$ of American silver coins is silver — the rest is copper.

When you take a snapshot, you get yourself involved in a series of complicated, chemical processes — all of them having to do with silver. It is hard to believe that the blacks and grays you see when you look at a photograph are various concentrations of metallic silver.

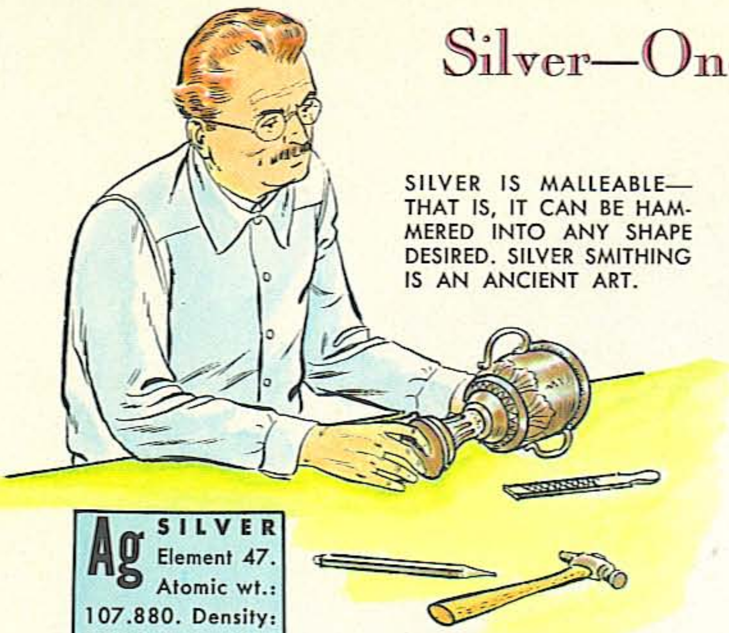

SILVER IS MALLEABLE—THAT IS, IT CAN BE HAMMERED INTO ANY SHAPE DESIRED. SILVER SMITHING IS AN ANCIENT ART.

Ag **SILVER** Element 47. Atomic wt.: 107.880. Density: 10.54. Soft, white metal with bright luster. Easily hammered out and drawn into wire. Best known conductor of electricity.

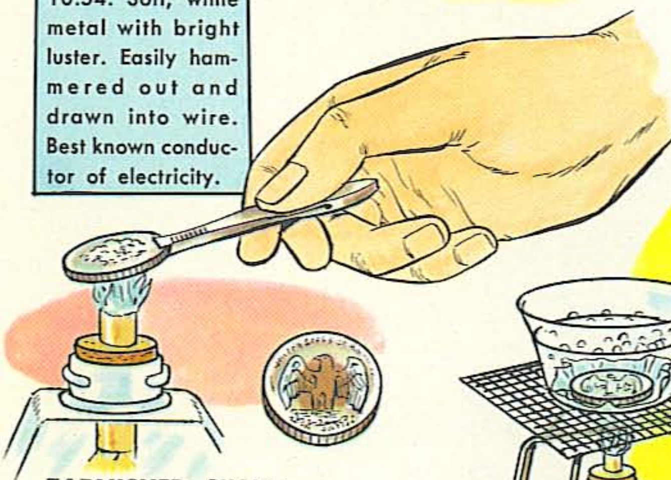

TARNISHED SILVER

SILVER TARNISHES WHEN IT IS EXPOSED TO SULFUR. PLACE A FEW CRYSTALS OF SODIUM THIOSULFATE ("HYPO") ON A SILVER COIN. HEAT UNTIL HYPO MELTS. WASH. HYPO HAS LEFT STAIN OF BROWN-BLACK SILVER SULFIDE.

REMOVING TARNISH FROM SILVER

1 LINE BOTTOM OF CUSTARD CUP WITH ALUMINUM FOIL. PLACE TARNISHED COIN ON FOIL. POUR CUP HALF FULL OF WATER. ADD ¼ TEASPOON SODIUM CARBONATE. BOIL GENTLY. TARNISH VANISHES.

2 YOU CAN USE THIS METHOD FOR CLEANING SILVERWARE. PLACE SILVER TO BE CLEANED IN ALUMINUM TRAY. ADD WATER AND SODA. BRING TO A BOIL. THE SILVER BECOMES SHINY AGAIN.

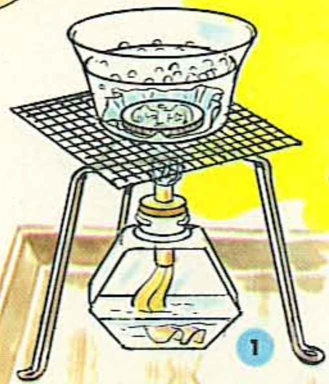

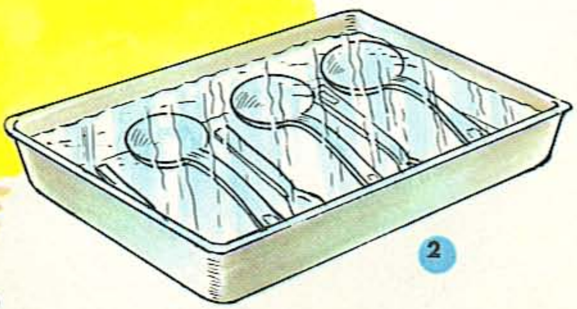

SILVER COMPOUNDS

GET 5 g SILVER NITRATE IN YOUR LOCAL DRUG STORE. DISSOLVE IN 50 ml WATER.

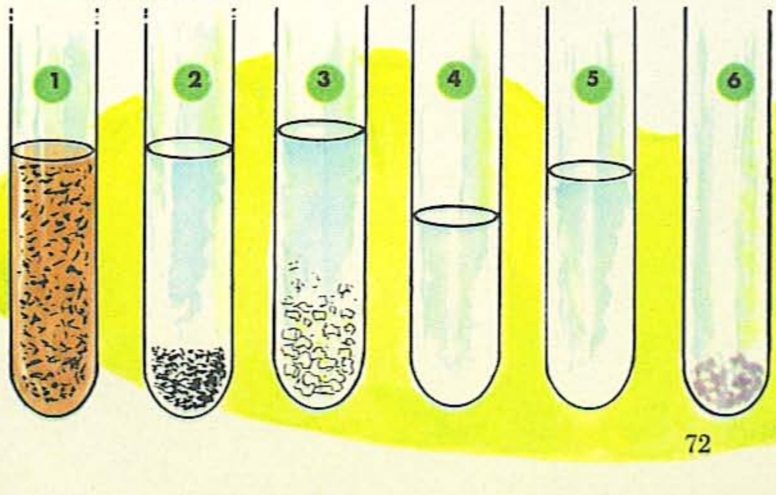

1 TO 5 ml SILVER NITRATE ($AgNO_3$) SOLUTION, ADD SODIUM HYDROXIDE SOLUTION. YOU GET DARK-BROWN PRECIPITATE—NOT OF HYDROXIDE, BUT OF SILVER OXIDE.

2 TO 5 ml $AgNO_3$ SOLUTION, ADD AMMONIA. PRECIPITATE OF SILVER OXIDE DISSOLVES WHEN YOU ADD MORE AMMONIA.

3 TO 5 ml $AgNO_3$ SOLUTION, ADD TABLE SALT ($NaCl$) SOLUTION. CHEESELIKE PRECIPITATE IS SILVER CHLORIDE ($AgCl$).

4 TO PART OF $AgCl$ PRECIPITATE, ADD AMMONIA. SILVER CHLORIDE DISSOLVES.

5 TO ANOTHER PART OF $AgCl$, ADD SODIUM THIOSULFATE SOLUTION. $AgCl$ DISSOLVES.

6 PLACE REMAINING $AgCl$ IN THE SUN. IT TURNS VIOLET FROM METALLIC SILVER.

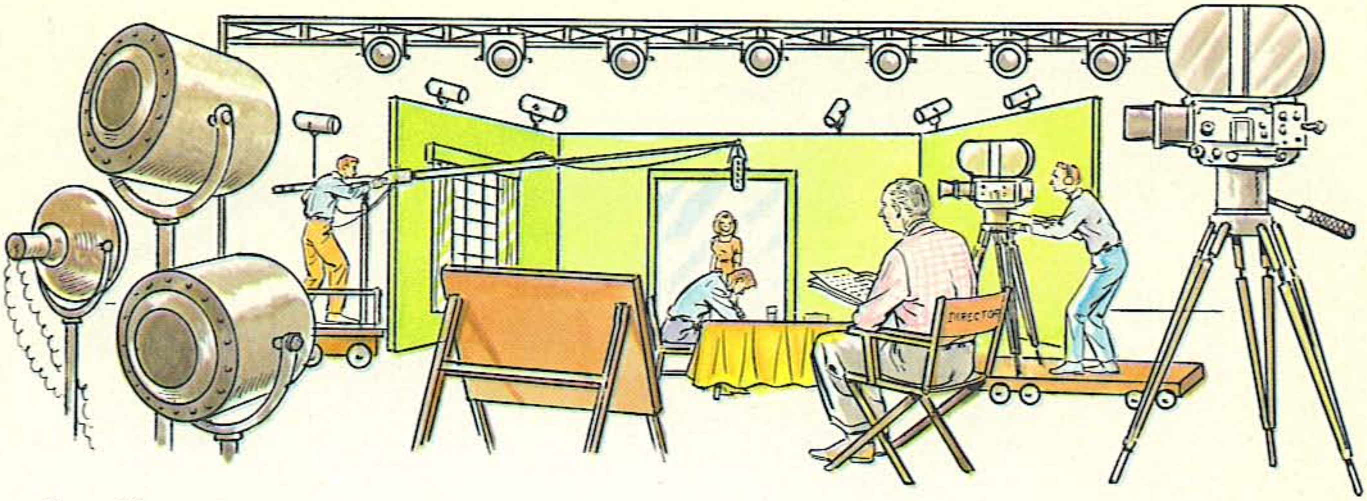

In making a photographic film, the manufacturer spreads an emulsion of gelatin that contains silver bromide ($AgBr$) over a transparent sheet of cellulose acetate. When the silver bromide is exposed to light, a certain amount of it gives up metallic silver ($AgBr \rightarrow Ag + Br$). More of this silver is brought out in the developing bath. When fully developed, the film is placed in a fixing bath which removes all unexposed silver bromide. After washing and drying, you have a photographic negative in which the white parts you photographed appear black and the black parts appear white.

To make a natural-looking picture, you place the negative on a piece of photographic paper and go through a similar procedure, as above, of exposing, developing, fixing, washing, and drying.

MORE THAN 150 TONS OF SILVER ARE USED EACH YEAR IN MAKING FILM FOR THE MOVIES.

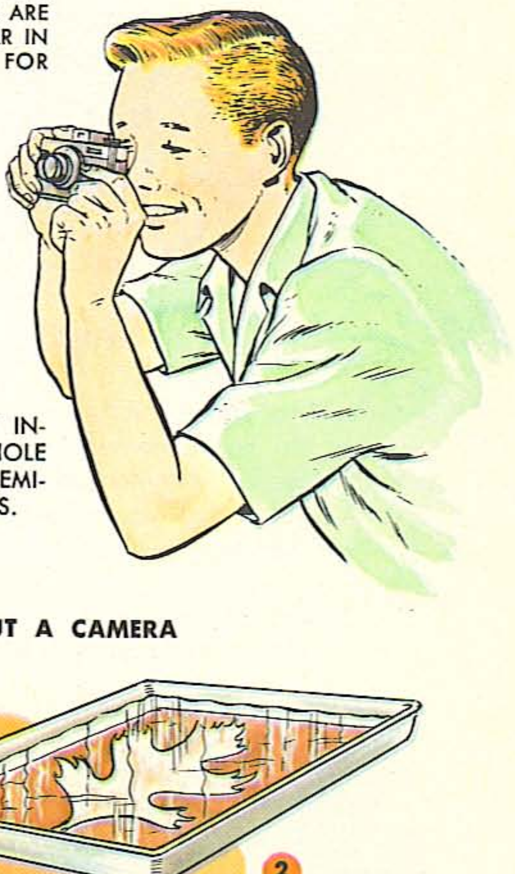

PHOTOGRAPHY INVOLVES A WHOLE SERIES OF CHEMICAL PROCESSES.

PHOTOGRAPHING WITHOUT A CAMERA

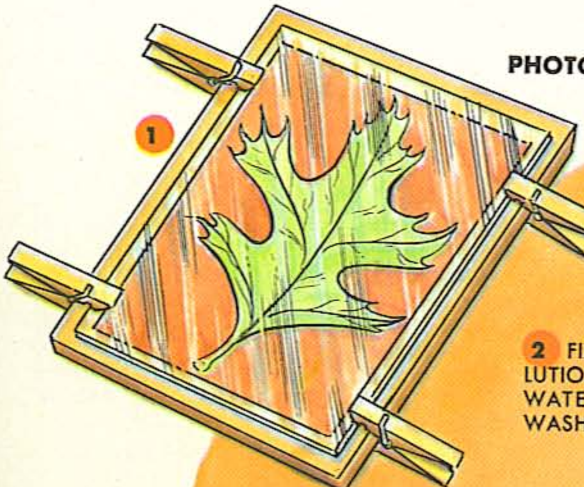

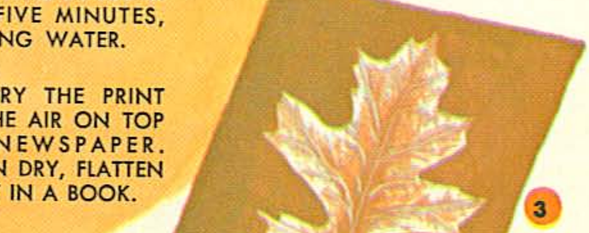

2 FIX THE LEAF PRINT IN A SOLUTION OF 10 g HYPO IN 100 ml WATER. AFTER FIVE MINUTES, WASH IN RUNNING WATER.

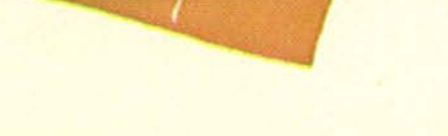

3 DRY THE PRINT IN THE AIR ON TOP OF NEWSPAPER. WHEN DRY, FLATTEN PRINT IN A BOOK.

1 FROM A COMMERCIAL PHOTOGRAPHER, GET A FEW SHEETS OF "PRINTING-OUT PAPER," A SLOW PHOTOGRAPHIC PAPER. IN THE SHADE, PLACE SHEET ON PIECE OF PLYWOOD, SENSITIZED SIDE UP. ON TOP OF IT, LAY A LEAF AND A SHEET OF GLASS. HOLD IN POSITION WITH SPRING CLOTHES PINS. EXPOSE TO SUN UNTIL PAPER IS BLACKISH-VIOLET.

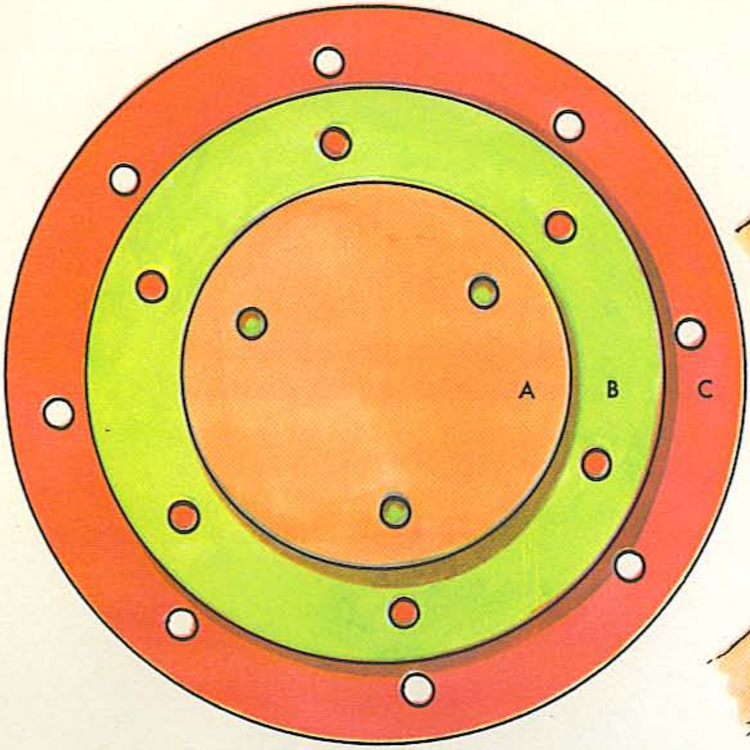

TRACE EACH OF THE CIRCLES SHOWN ABOVE ONTO CARDBOARD. PUNCH HOLES AS INDICATED. USE AS PATTERNS FOR CUTTING CIRCLES OF CONSTRUCTION BOARD.

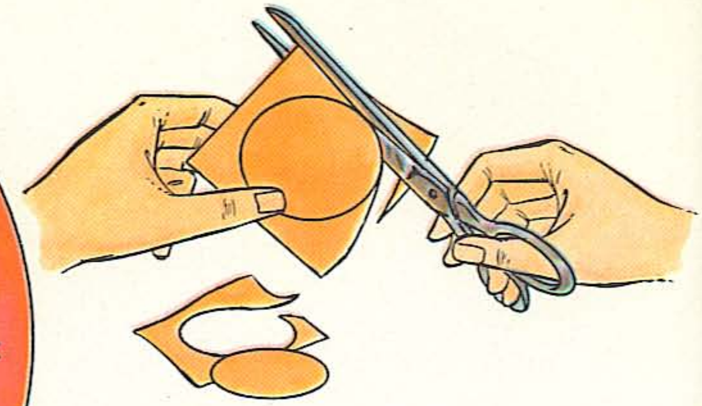

USING PATTERNS AT LEFT, CUT OUT SEVERAL CIRCLES OF CONSTRUCTION BOARD IN VARIOUS COLORS.

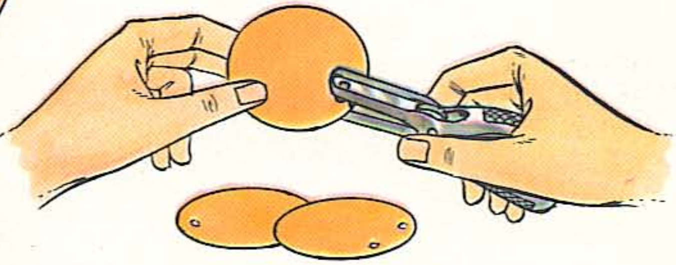

PUNCH THE HOLES NECESSARY TO INDICATE VALENCES.

Valences and Formulas

As you have studied the chemical formulas in the text, you will have noticed that one atom of hydrogen combines with one atom of chlorine (HCl), two hydrogen atoms with one atom of oxygen (H_2O), and three hydrogen atoms with one atom of nitrogen (NH_3).

The capacity of one atom to hold on to other atoms is called its valence (from Latin *valentia*, strength). No atom has a lower valence than the hydrogen atom, so we use hydrogen as our starting point and give it a valence of 1. Two hydrogen atoms combine with one oxygen atom — that gives oxygen a valence of 2. Nitrogen has a valence of 3. Two oxygen atoms combine with one carbon atom to make CO_2. Carbon has a valence of 4.

The chart on page 75 shows some of the common

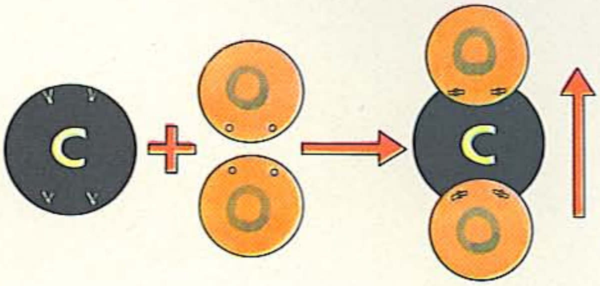

THESE DIAGRAMS SHOW WHAT HAPPENS WHEN YOU BURN CARBON AND TEST FOR CO_2. ONE CARBON ATOM (WITH FOUR POSITIVE VALENCES) COMBINES WITH TWO ATOMS OF OXYGEN (EACH WITH TWO NEGATIVE VALENCES) TO FORM ONE MOLECULE OF CO_2 (ARROW POINTING UP INDICATES THAT THIS IS A GAS). ONE MOLECULE CARBON DIOXIDE COMBINES WITH ONE MOLECULE CALCIUM HYDROXIDE TO FORM ONE MOLECULE OF CALCIUM CARBONATE (ARROW POINTING DOWN INDICATES THAT IT IS A PRECIPITATE) AND ONE MOLECULE OF WATER.

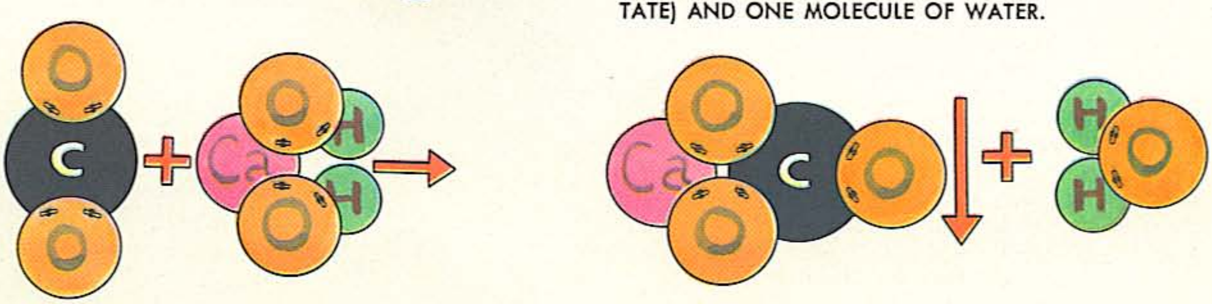

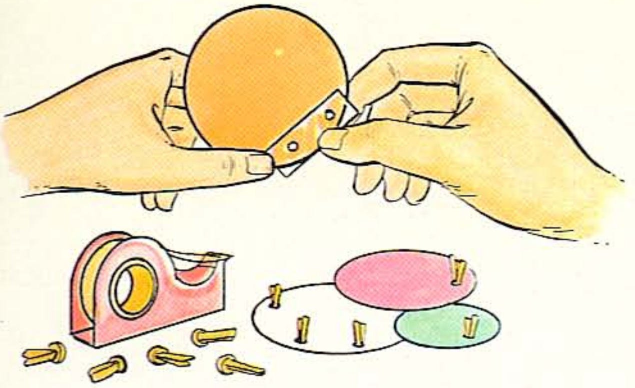

PUT 1/4" BRASS CLIPS IN HOLES SHOWING POSITIVE VALENCES. HOLD THEM IN PLACE WITH SCOTCH TAPE.

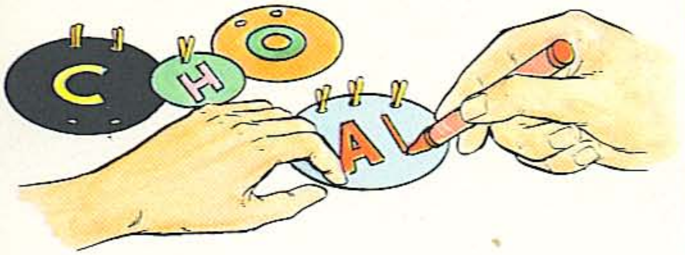

WRITE THE NAMES OF THE ELEMENTS WITH CRAYONS.

SOME COMMON VALENCES

Positive Valences			Negative Valences		
Item	Valence	Circle	Item	Valence	Circle
Ag	+1	A	Cl	−1	A
Al	+3	C	I	−1	A
B	+3	C	N	−3	B
C	+4	C	O	−2	B
Ca	+2	B	S	−2	C
Cu	+1+2	B			
Fe	+2+3	B			
H	+1	A			
K	+1	A			
Mg	+2	B			
Mn	+2	B	CO_3	−2	B
Na	+1	A	NO_3	−1	A
S	+4+6	C	OH	−1	A
Si	+4	C	SO_3	−2	B
NH_4	+1	A	SO_4	−2	B

valences for making up formulas. Most of the items are elements, but some of them are "radicals" — that is, groups of atoms that hang together in chemical reactions, such as the ammonium radical (NH_4) that behaves as a metal, and the sulfate radical (SO_4) that goes into the making of salts.

Notice that some valences have plus (+) signs, others have minus (—) signs. When you make up the formula for a compound, there must be the same number of pluses and minuses. Hydrogen with one plus (H^+) and oxygen with two minuses (O^{--}) would not fit together — you need H_2 to combine with O. Similarly, C with + 4 (C^{++++}) takes two O, each with —2 (O^{--}), in order to balance.

To get a clear understanding of chemical formulas, make yourself a set of atom models as shown on these pages. With these models you will be able to figure out how compounds are made up and what happens in the various chemical reactions you will cause in your experiments.

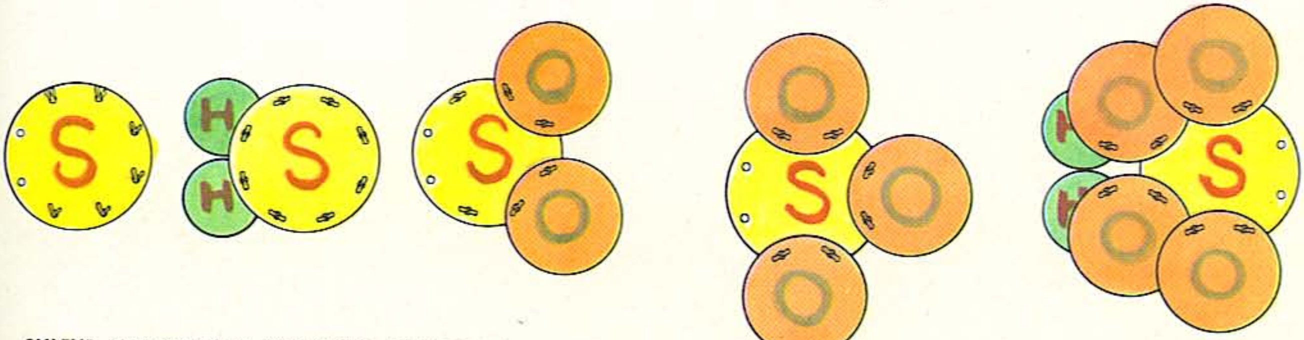

SULFUR HAS SEVERAL VALENCES. IT HAS A VALENCE OF −2 IN H_2S, OF +4 IN SO_2, AND OF +6 IN SO_3 AND IN SULFURIC ACID (H_2SO_4). IN MAKING THE CIRCLE FOR SULFUR, YOU CAN SHOW THESE VALENCES WITH TWO EMPTY HOLES AND SIX BRASS CLIPS.

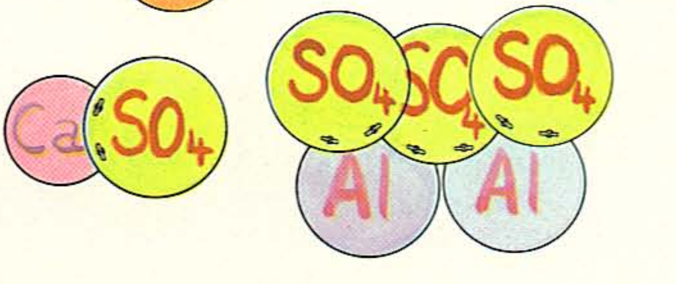

INSTEAD OF USING ONE SULFUR CIRCLE AND FOUR OXYGEN CIRCLES TO INDICATE A SULFATE, YOU CAN MAKE UP A SINGLE CIRCLE TO STAND FOR THE SULFATE RADICAL (SO_4) WITH TWO NEGATIVE VALENCES.

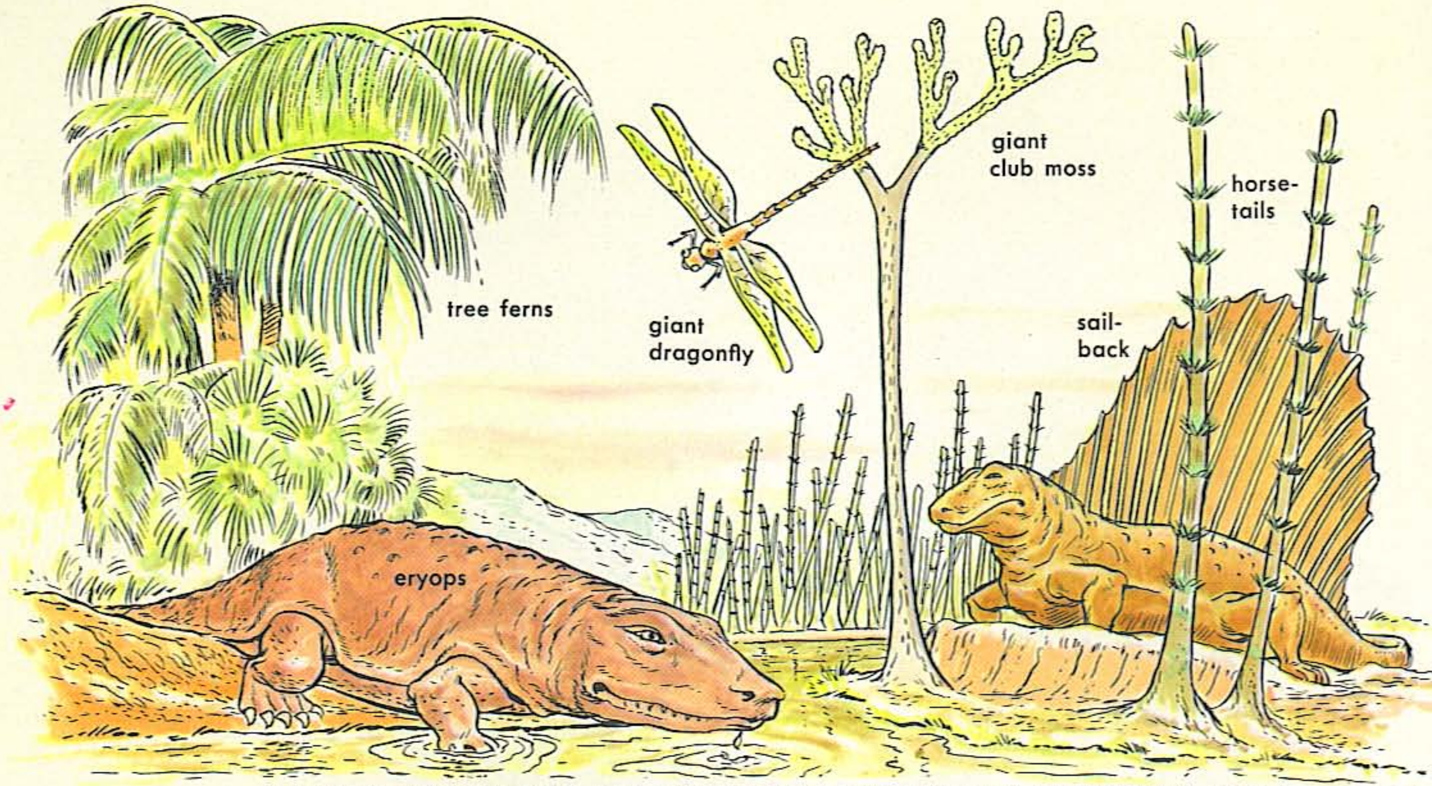

A LANDSCAPE IN THE COAL AGE, APPROXIMATELY THREE HUNDRED MILLION YEARS AGO.

Carbon—Element of a Million Compounds

To THE OLD ROMANS, *carbo* meant coal — a black rock that would burn. To the modern chemist, carbon is an element found in all living things — plants and animals — and in many dead things. It is hidden in the whitest sugar and the reddest rose and the greenest apple, in hundreds of thousands of compounds produced by nature and in many thousands more created in the laboratory.

The soot from a smoking candle is almost pure carbon. So is also the graphite that forms the "lead" of your pencil and the diamond in the jeweler's window. The coal that we use for fuel contains from 80 to 90 per cent carbon — the other 10 to 20 per cent is made up of various substances from which a great number of important and valuable chemical compounds are made.

All the coal we mine deep underground today is made up of the remains of plants that grew around three hundred million years ago — huge tree ferns, giant club mosses and horsetails. They thrived in the hot, humid climate, died and tumbled to the ground. During the ages they were covered by other dead trees and by layers upon layers of mud. Eventually, pressure and heat turned them into coal.

PRESSURE AND HEAT TURNED TREES AND OTHER PLANTS INTO THE COAL WE USE TODAY.

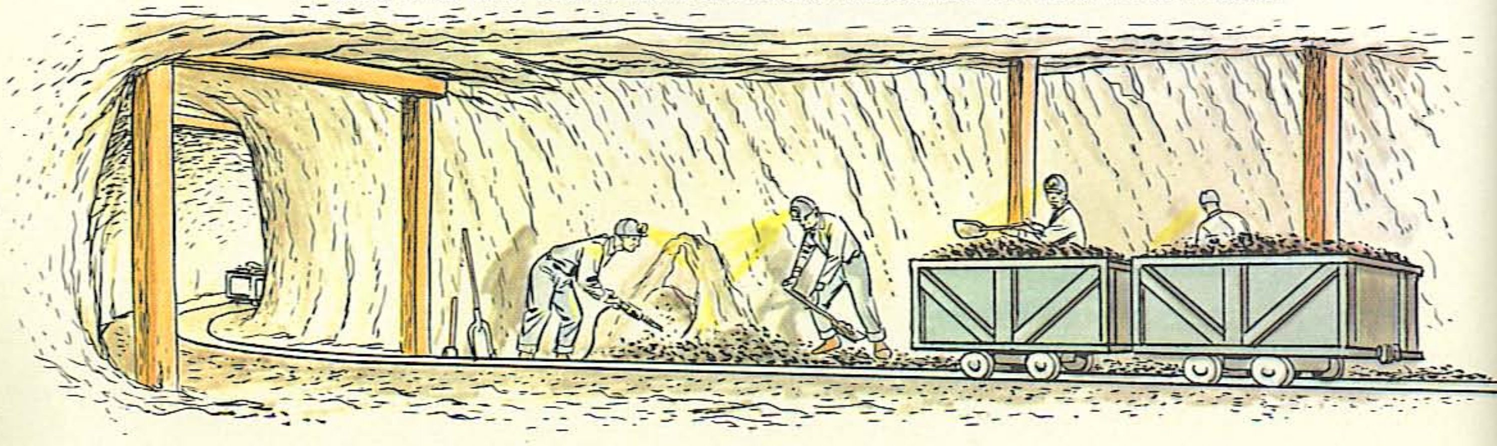

C CARBON Element 6. Atomic wt.: 12.011. Found in nature as diamond (density 3.52), as graphite (density 2.25), and as coal. Diamond burns in oxygen, coal in air.

THREE FORMS OF CARBON

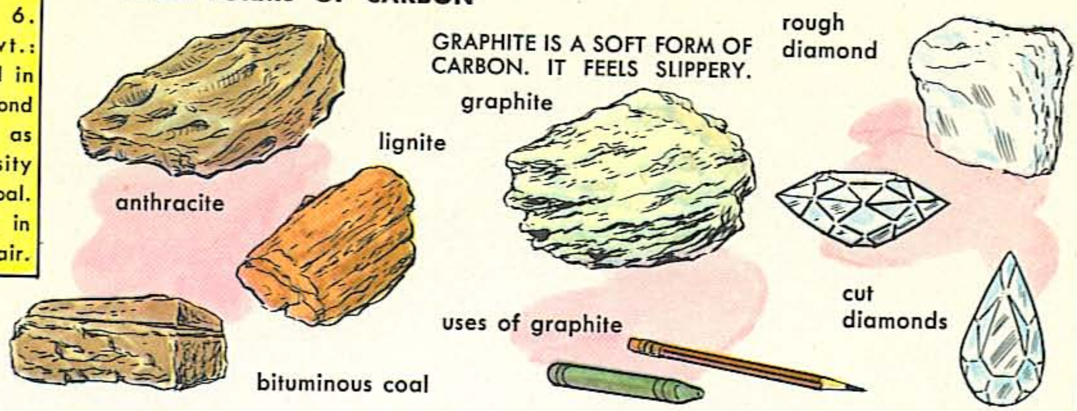

ANTHRACITE IS ALSO CALLED HARD COAL. BITUMINOUS COAL IS SOFT COAL. LIGNITE IS BROWN COAL. GRAPHITE IS A SOFT FORM OF CARBON. IT FEELS SLIPPERY. DIAMOND IS THE HARDEST SUBSTANCE KNOWN.

DESTRUCTIVE DISTILLATION

IN REGULAR DISTILLATION (SEE PAGE 61), A CHEMICAL IS PURIFIED. IN DESTRUCTIVE OR DRY DISTILLATION, THE SUBSTANCE IS BROKEN INTO SEVERAL DIFFERENT CHEMICALS.

for dry distillation of wood, whittle twig into slivers, or use wooden matches without heads.

for dry distillation of coal, crush lump of bituminous coal into powder.

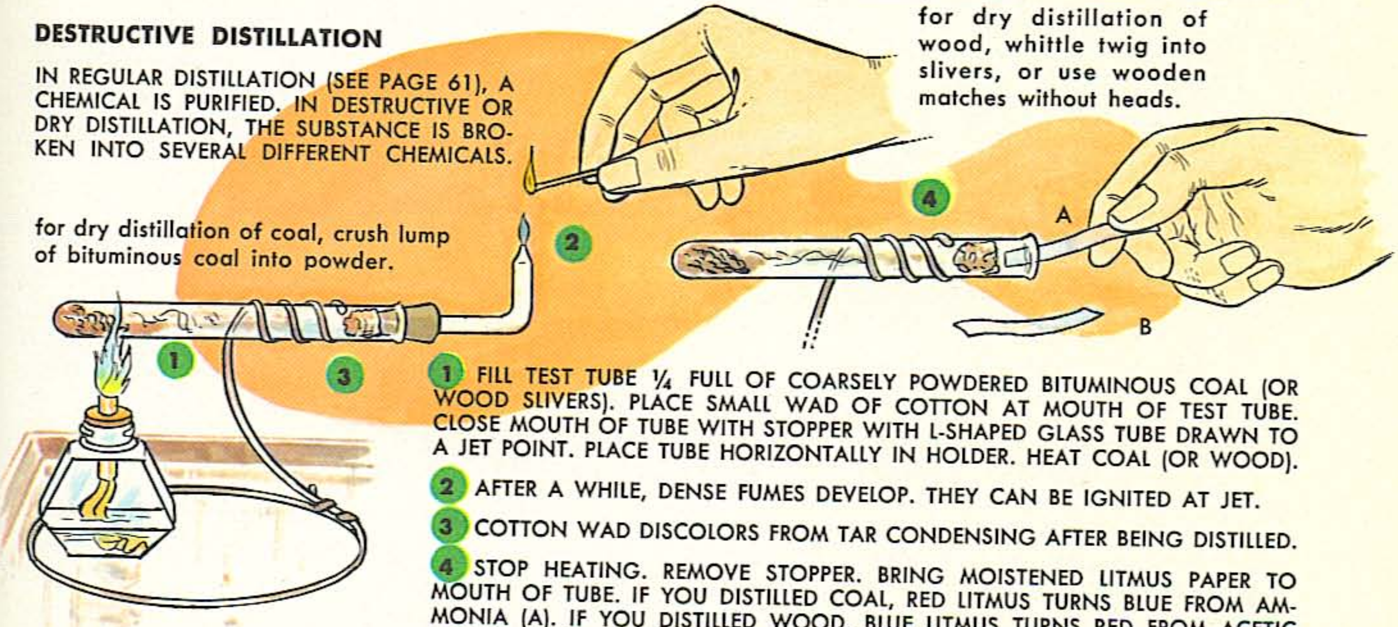

① FILL TEST TUBE ¼ FULL OF COARSELY POWDERED BITUMINOUS COAL (OR WOOD SLIVERS). PLACE SMALL WAD OF COTTON AT MOUTH OF TEST TUBE. CLOSE MOUTH OF TUBE WITH STOPPER WITH L-SHAPED GLASS TUBE DRAWN TO A JET POINT. PLACE TUBE HORIZONTALLY IN HOLDER. HEAT COAL (OR WOOD).

② AFTER A WHILE, DENSE FUMES DEVELOP. THEY CAN BE IGNITED AT JET.

③ COTTON WAD DISCOLORS FROM TAR CONDENSING AFTER BEING DISTILLED.

④ STOP HEATING. REMOVE STOPPER. BRING MOISTENED LITMUS PAPER TO MOUTH OF TUBE. IF YOU DISTILLED COAL, RED LITMUS TURNS BLUE FROM AMMONIA (A). IF YOU DISTILLED WOOD, BLUE LITMUS TURNS RED FROM ACETIC ACID (B). COAL HAS TURNED TO COKE, WOOD HAS BECOME CHARCOAL.

CARBON IN SUGAR

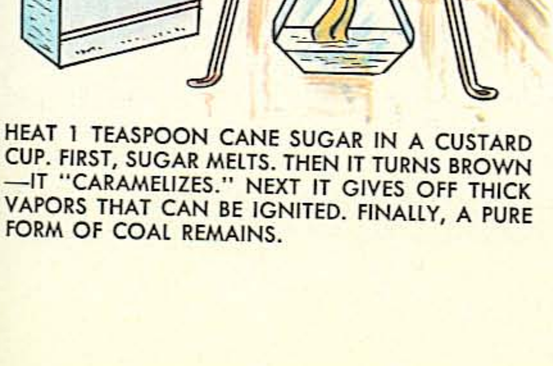

HEAT 1 TEASPOON CANE SUGAR IN A CUSTARD CUP. FIRST, SUGAR MELTS. THEN IT TURNS BROWN —IT "CARAMELIZES." NEXT IT GIVES OFF THICK VAPORS THAT CAN BE IGNITED. FINALLY, A PURE FORM OF COAL REMAINS.

YOU CAN PROVE PRESENCE OF CARBON IN THE FOOD YOU EAT BY HEATING SMALL SAMPLES OF CHEESE, BREAD, MEAT, SUGAR. BE SURE TO DO THIS OUTDOORS TO PREVENT EXPERIMENTS FROM SMELLING UP THE WHOLE HOUSE.

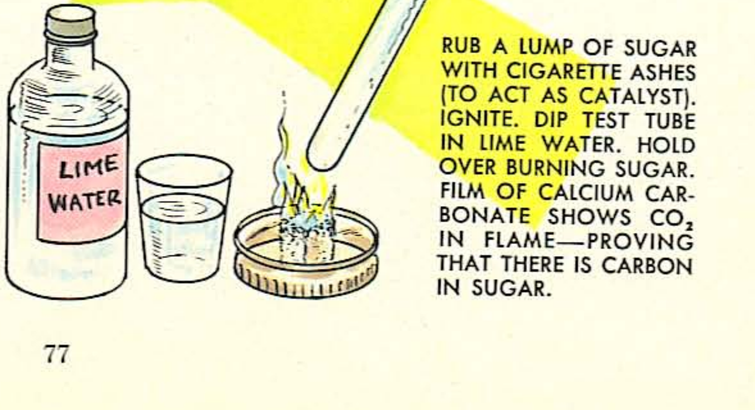

RUB A LUMP OF SUGAR WITH CIGARETTE ASHES (TO ACT AS CATALYST). IGNITE. DIP TEST TUBE IN LIME WATER. HOLD OVER BURNING SUGAR. FILM OF CALCIUM CARBONATE SHOWS CO_2 IN FLAME—PROVING THAT THERE IS CARBON IN SUGAR.

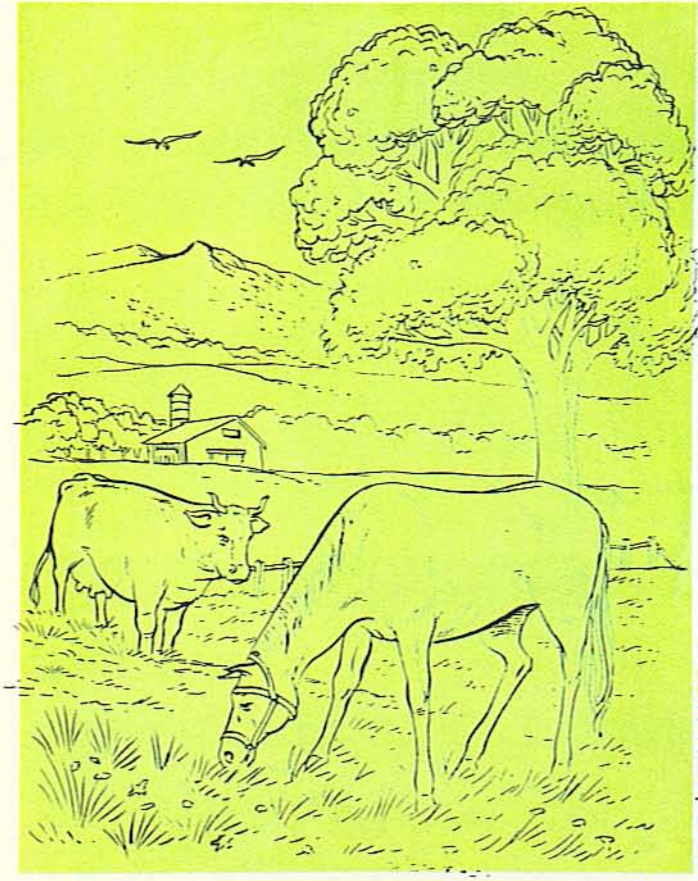

IT WAS ONCE BELIEVED THAT ORGANIC COMPOUNDS COULD BE PRODUCED ONLY BY LIVING ORGANISMS.

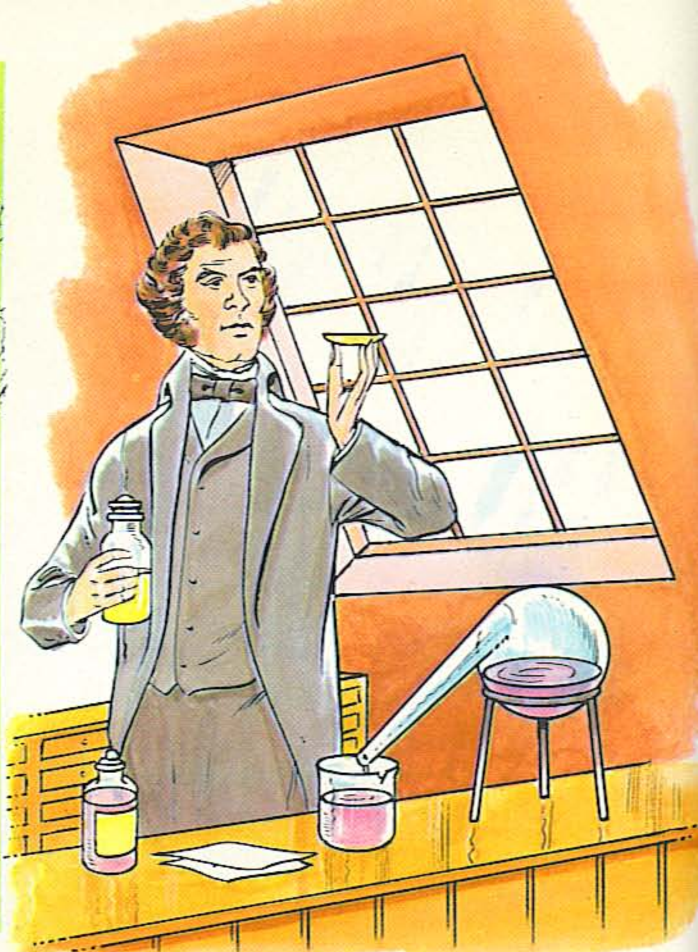

IN 1828, FRIEDRICH WÖHLER SUCCEEDED IN MAKING AN ORGANIC COMPOUND ARTIFICIALLY IN HIS LABORATORY.

The Chemistry of Carbon Compounds

THE CHEMISTS of about two hundred years ago divided all compounds very neatly into two groups — organic and inorganic. The organic compounds were those produced by living organisms — that is, plants and animals. The inorganic compounds were made up of dead things — rocks and minerals, water and various gases. No organic compound, these chemists insisted, could ever be produced artificially — they required the force we call "life" for their creation. And then, in 1828, a German chemist, Friedrich Wohler, completely upset this idea.

In his laboratory, Wöhler had mixed ammonium sulfate ($(NH_4)_2SO_4$) and potassium cyanate (KCNO), expecting to get ammonium cyanate. After evaporating, he analyzed the compound he had made. To his amazement he discovered that it was not ammonium cyanate at all, but urea — a compound produced in the kidneys of living animals, including man. The atoms of the ammonium cyanate molecule had rearranged themselves into a urea molecule.

NH_4 CNO had turned into $(NH_2)_2CO$.

A few years later, another organic compound — acetic acid — was made artificially. And then the lid really blew off. More and more products of plant and animal life were put together — synthesized — in the laboratory. And as if this were not enough, chemists began producing organic compounds that were not even found in nature.

It became clear that the old meaning of organic chemistry no longer was right. And so, the definition was changed. Today, organic chemistry is defined as "the chemistry of the carbon compounds." This definition is almost, but not 100 per cent, correct. The metallic carbonates, for instance, are still considered to be inorganic compounds, and carbon dioxide and carbonic acid are regarded as being both organic and inorganic.

You may think it odd that a whole branch of chemistry should deal with the compounds of a single element. But you will not be surprised at all when you start experimenting with a few of the close to 1,000,000 carbon compounds.

HYDROCARBONS CONTAIN TWO ELEMENTS ONLY: CARBON AND HYDROGEN. HYDROCARBONS WITH FEW ATOMS TO THEIR MOLECULES ARE GASES. OTHERS WITH MANY ATOMS ARE LIQUIDS AND SOLIDS.

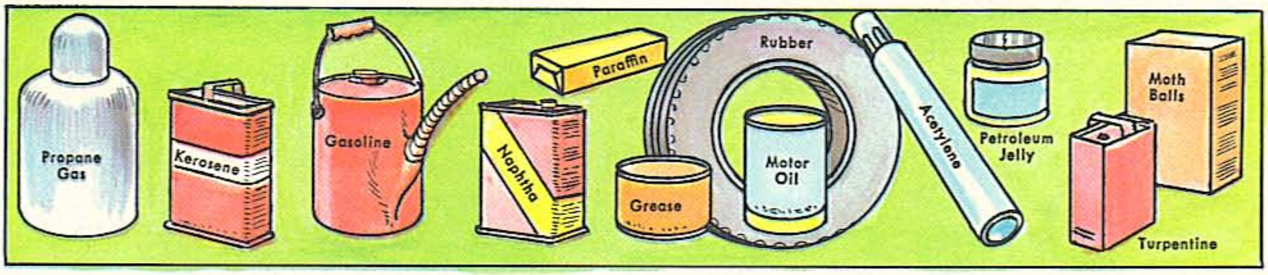
Propane Gas
Kerosene
Gasoline
Paraffin
Naphtha
Grease
Rubber
Motor Oil
Acetylene
Petroleum Jelly
Moth Balls
Turpentine

ALCOHOLS MAY BE CONSIDERED HYDROCARBONS IN WHICH A HYDROGEN ATOM IS REPLACED BY OH.

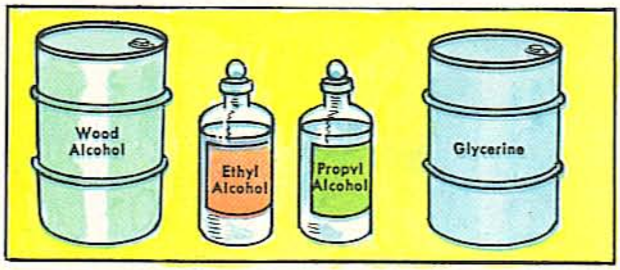
Wood Alcohol
Ethyl Alcohol
Propyl Alcohol
Glycerine

CARBOHYDRATES ARE IN MANY OF OUR MOST VALUABLE FOODSTUFFS AS STARCH AND SUGARS.

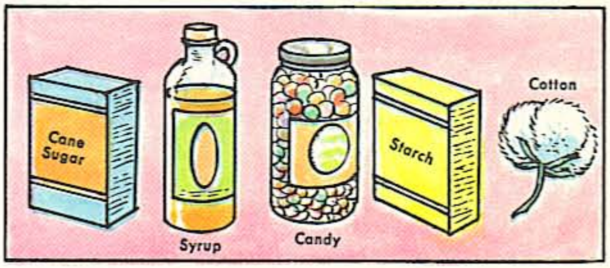
Cane Sugar
Syrup
Candy
Starch
Cotton

ESTERS IN ORGANIC CHEMISTRY CAN BE COMPARED TO SALTS IN INORGANIC CHEMISTRY. FATS AND OILS ARE THE MOST IMPORTANT ESTERS. THESE ARE THE "SALTS" OF GLYCERINE AND FATTY ACIDS.

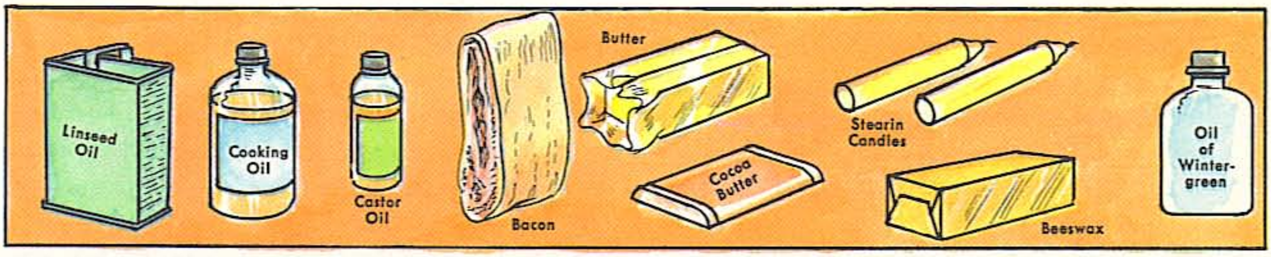
Linseed Oil
Cooking Oil
Castor Oil
Bacon
Butter
Cocoa Butter
Stearin Candles
Beeswax
Oil of Wintergreen

CARBOXYLIC ACIDS ARE NAMED FOR THE CARBOXYL GROUP—COOH—FOUND IN THEIR FORMULAS.

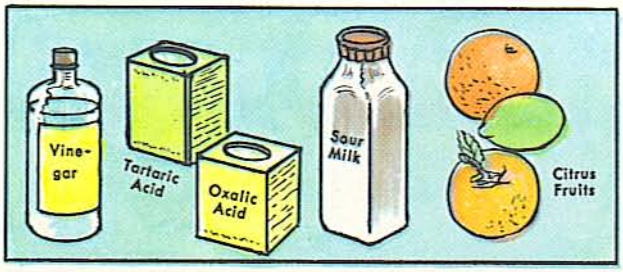
Vinegar
Tartaric Acid
Oxalic Acid
Sour Milk
Citrus Fruits

PROTEINS ARE COMPLEX COMPOUNDS THAT CONTAIN CARBON, HYDROGEN, OXYGEN, NITROGEN.

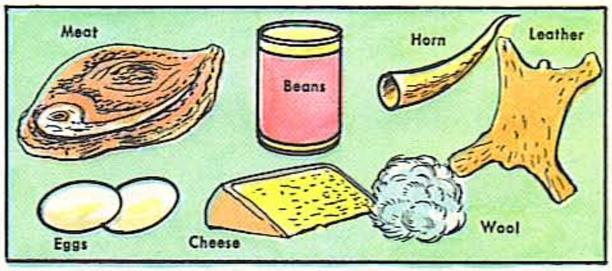
Meat
Beans
Horn
Leather
Eggs
Cheese
Wool

OTHER CARBON COMPOUNDS—IN ADDITION TO THE MAIN GROUPS ILLUSTRATED ABOVE, THERE ARE NUMEROUS OTHER KINDS OF CARBON COMPOUNDS. MANY HAVE VERY COMPLICATED FORMULAS.

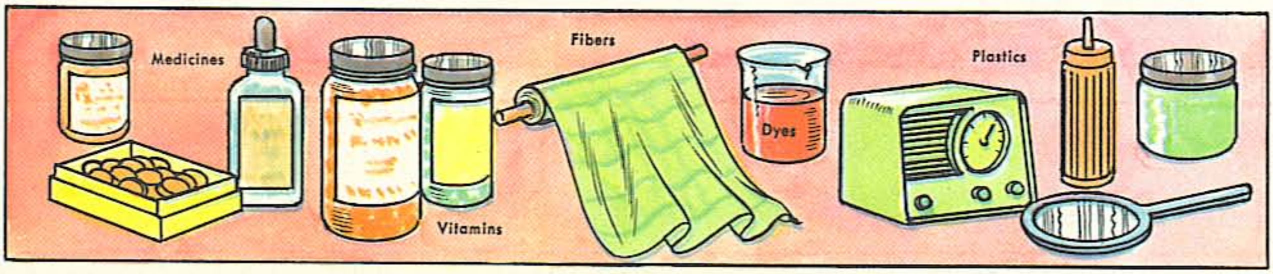
Medicines
Vitamins
Fibers
Dyes
Plastics

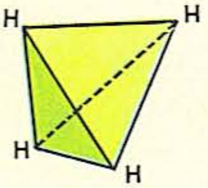

methane, CH_4

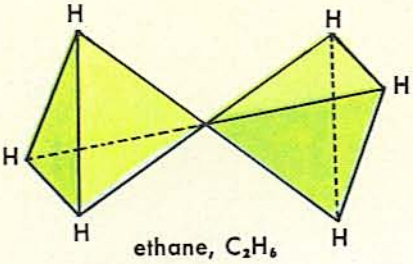

ethane, C_2H_6

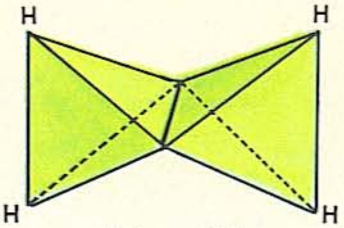

ethylene, C_2H_4

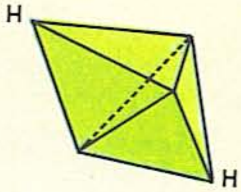

acetylene, C_2H_2

The Formulas of Carbon Compounds

How is it possible for carbon to make so many different compounds of such tremendous variety? That was one of the great questions facing chemists during the last century.

It was easy enough to explain carbon dioxide. Carbon has a valence of 4, oxygen of 2 — the formula had to be CO_2. It was also easy to explain the molecule of the simple hydrocarbon methane (CH_4). But how explain compounds consisting of two atoms of carbon and six of hydrogen (C_2H_6, ethane), or two atoms of carbon and four of hydrogen (C_2H_4, ethylene), or two of carbon and only two of hydrogen (C_2H_2, acetylene)?

A German chemist and professor, Friedrich August Kekulé, came up with the solution. The answer was quite simple:

While the atoms of most elements "hook on" to the atoms of other elements according to their valences, the atoms of carbon "hook on" to each other as well. To understand this, write out carbon atoms with four lines to indicate the valence bonds, but arrange the lines in these three different ways:

$$\equiv C- \quad -C\equiv \quad =C=$$

Then hook them together, two by two, in these three different ways:

$$\equiv C-C\equiv \quad =C=C= \quad -C\equiv C-$$

Now add a hydrogen atom to each of the free bonds — and there you have the formulas for the three hydro-carbons — ethane (C_2H_6), ethylene (C_2H_4), and acetylene (C_2H_2):

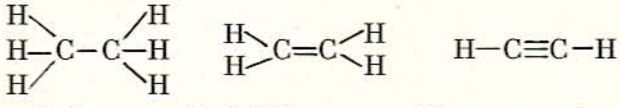

$$H_3C-CH_3 \qquad H_2C=CH_2 \qquad H-C\equiv C-H$$

So far so good. But there were still many carbon compound formulas that would not line up in this kind of arrangement. C_6H_6, for instance — benzene, an important hydrocarbon obtained by distillation of coal.

Again, it was Kekulé who offered the explanation. This time it came to him in a dream. He had been

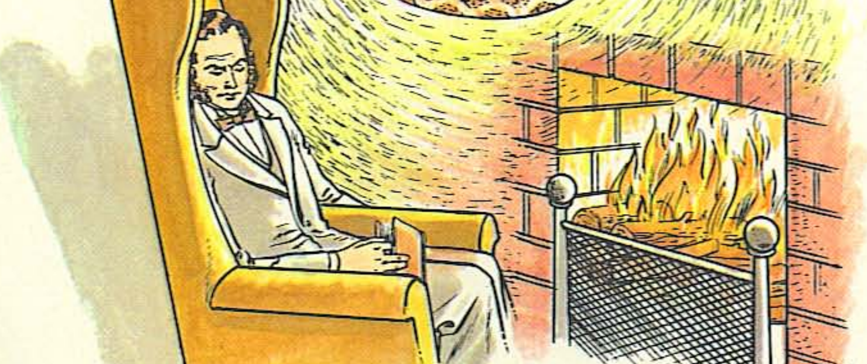

KEKULÉ'S BENZENE RING

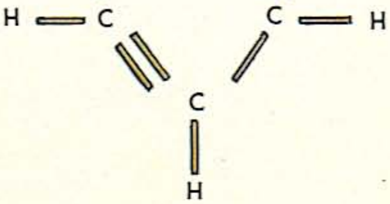

AUGUST KEKULE HIT UPON THE STRUCTURE OF THE BENZENE MOLECULE IN A DREAM. A SNAKE SEEMED TO WHIRL IN A RING BEFORE HIS EYES. BY ARRANGING THE SIX CARBON ATOMS IN A RING, THE PROBLEM WAS SOLVED.

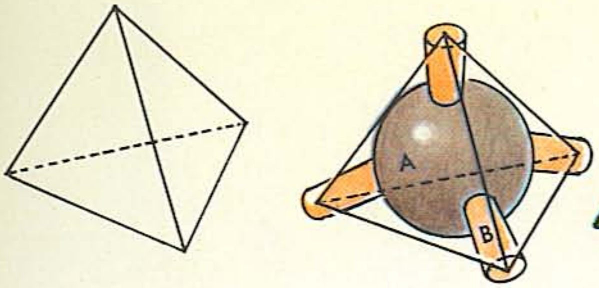

IN A CARBON ATOM (A), THE FOUR VALENCE BONDS POINT AWAY FROM THE CENTER (NUCLEUS) TOWARD THE CORNERS OF A TETRAHEDRON—A FIGURE MADE UP OF FOUR TRIANGLES. IN MODELS OF CARBON ATOMS, VALENCE BONDS ARE SHOWN BY RODS (B).

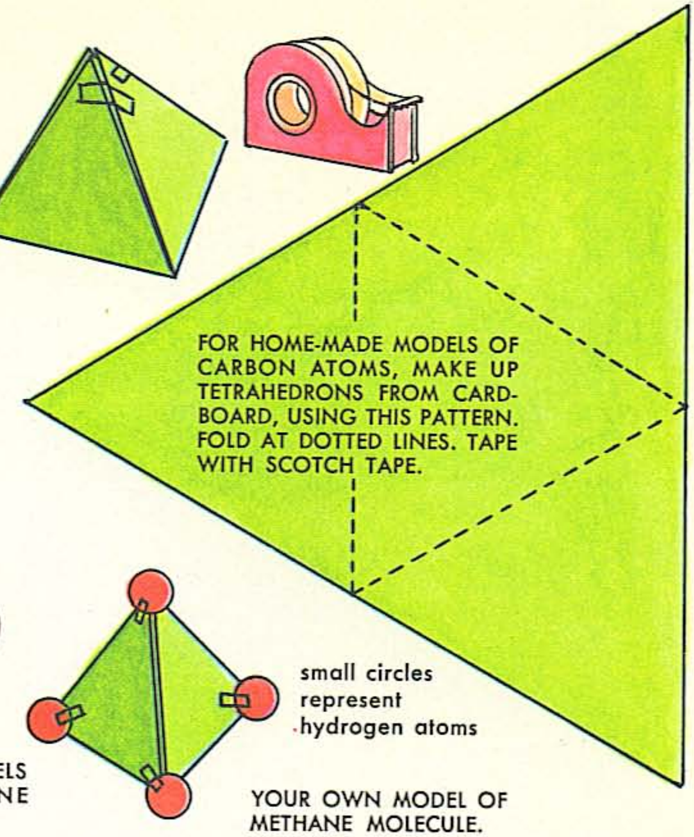

FOR HOME-MADE MODELS OF CARBON ATOMS, MAKE UP TETRAHEDRONS FROM CARDBOARD, USING THIS PATTERN. FOLD AT DOTTED LINES. TAPE WITH SCOTCH TAPE.

small circles represent hydrogen atoms

YOUR OWN MODEL OF METHANE MOLECULE.

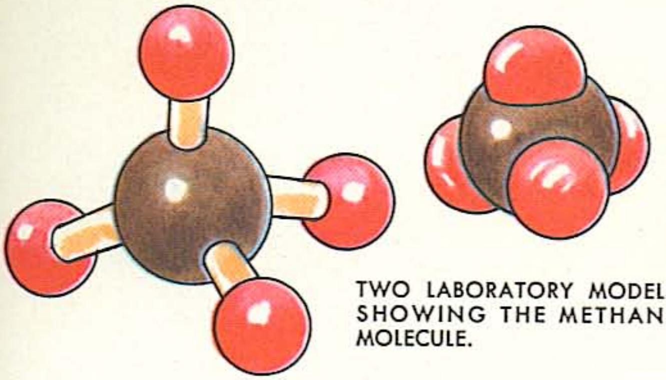

TWO LABORATORY MODELS SHOWING THE METHANE MOLECULE.

working all day with long lines of organic formulas. In the evening he dozed before the fire. In his dream, the lines of formulas turned into snakes, twisting and twining — until suddenly one of the snakes grasped its own tail and whirled around in a ring. This dream gave Kekule the clue: the carbon atoms in benzene hang together in a ring, each atom using three of its bonds to hang on to the atoms next to it, with one bond free to hook onto a hydrogen atom.

Starting from these very simple formulas, modern scientists can figure out the most complicated chemical formulas.

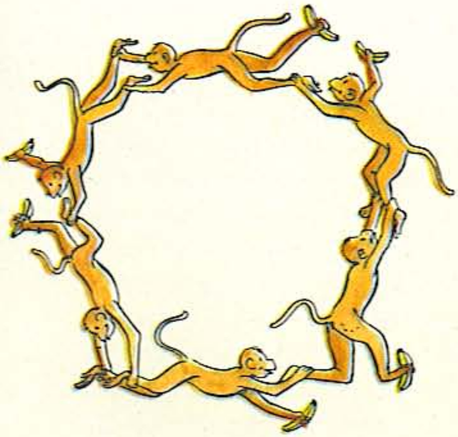

YOU CAN THINK OF THE BENZENE RING AS SIX MONKEYS HANGING ON TO EACH OTHER WITH ONE OR TWO HANDS, HOLDING BANANAS IN THEIR FREE HANDS.

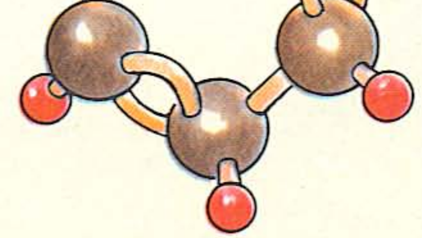

THIS IS THE WAY THE BENZENE MOLECULE LOOKS WHEN IT IS CONSTRUCTED FROM PARTS USED TO MAKE UP LABORATORY MODELS FOR DEMONSTRATION.

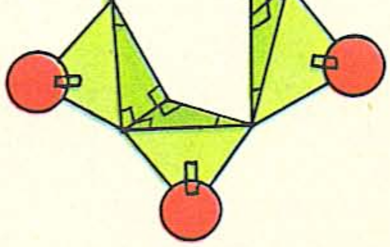

THIS IS HOW THE BENZENE MOLECULE WILL LOOK WHEN YOU P TOGETHER FROM HOME-MADE BON ATOMS. YOU CAN DO WITH SCOTCH TAPE.

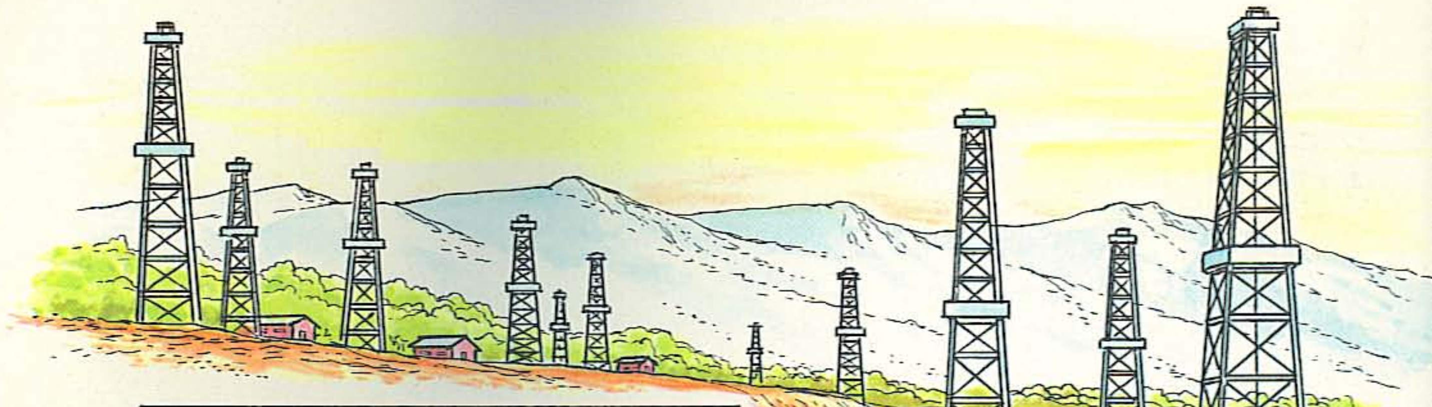

A HUNDRED YEARS AFTER THE FIRST OIL WELL IN PENNSYLVANIA, OIL FIELDS ARE FOUND IN SEVERAL STATES.

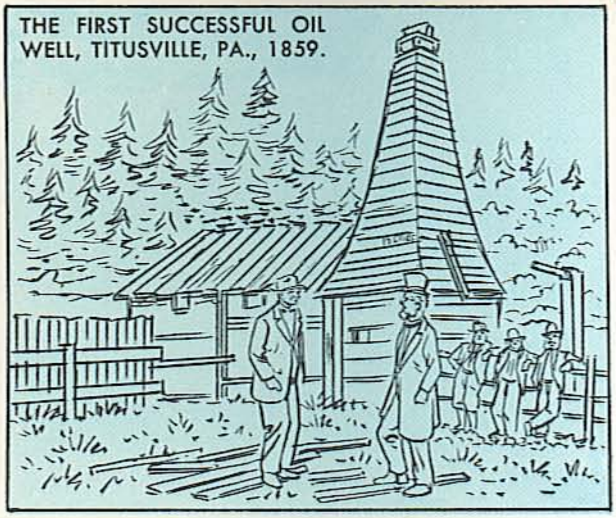

THE FIRST SUCCESSFUL OIL WELL, TITUSVILLE, PA., 1859.

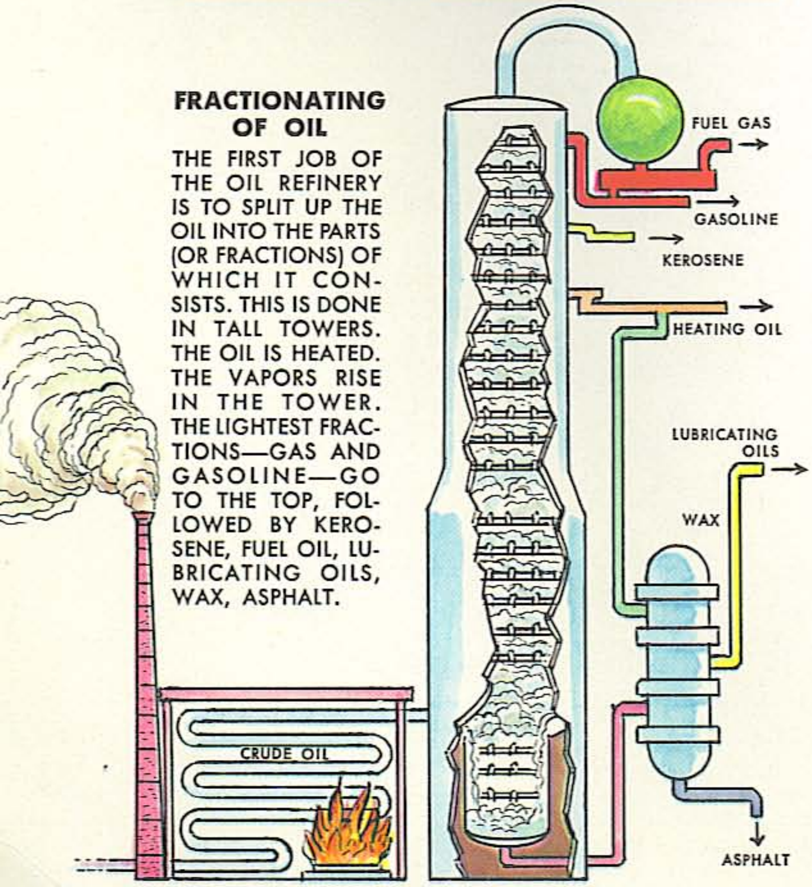

FRACTIONATING OF OIL

THE FIRST JOB OF THE OIL REFINERY IS TO SPLIT UP THE OIL INTO THE PARTS (OR FRACTIONS) OF WHICH IT CONSISTS. THIS IS DONE IN TALL TOWERS. THE OIL IS HEATED. THE VAPORS RISE IN THE TOWER. THE LIGHTEST FRACTIONS—GAS AND GASOLINE—GO TO THE TOP, FOLLOWED BY KEROSENE, FUEL OIL, LUBRICATING OILS, WAX, ASPHALT.

A Lot of Hydrocarbons

THE FAMILY CAR stops at the service station.

"Fill 'er up!" The attendant pours what may be a hexane-septane-octane-nonane mixture into the gas tank. "Check your oil, mister?" Into the engine goes another hydrocarbon mixture — possibly along the line of $C_{20}H_{42}$-$C_{21}H_{44}$-$C_{22}H_{46}$. And so you take off— on hydrocarbon tires. Yes, gasoline, motor oil, and rubber are all hydrocarbons — compounds that contain only hydrogen and carbon.

A great number of hydrocarbons come from petroleum (crude oil). Coal and natural gas provide several others. Many more are produced by nature — natural rubber, turpentine, camphor, to mention a few. Even the red coloring of tomatoes and the yellow of carrots are hydrocarbons.

One of the remarkable things about hydrocarbons is that it is possible to combine some of those with small molecules into others with larger ones (as in making synthetic rubber), as well as to "crack" those with large molecules into others with smaller ones (as when a heavy oil is "cracked" into gasoline). But that is only the beginning. By replacing one or more hydrogen atoms with hydroxyl groups (OH) or carboxyl groups (COOH) or chlorine atoms (Cl), for instance, it is possible to build up more complicated compounds — which can then be built up further and further. And that is exactly what chemists are doing today — giving us medicines and dyes, plastics and explosives, and countless other things.

METHANE—CH_4

1 HAMMER LUMPS OF BITUMINOUS COAL INTO A COARSE POWDER. FILL FUNNEL WITH IT. BRING FUNNEL INTO LARGE JAR.

2 TURN JAR UPSIDE DOWN. FILL JAR WITH WATER. PLACE A WATER-FILLED TEST TUBE OVER FUNNEL. IN A FEW DAYS, TUBE IS FILLED WITH METHANE.

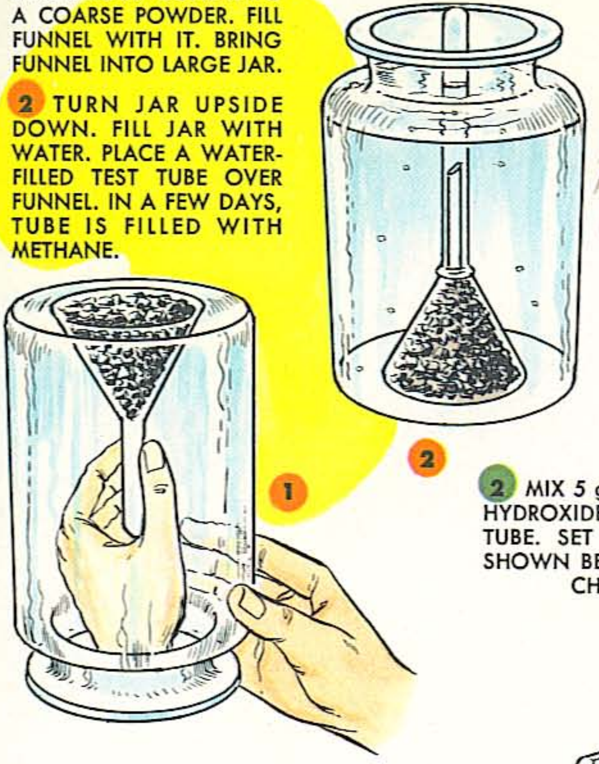

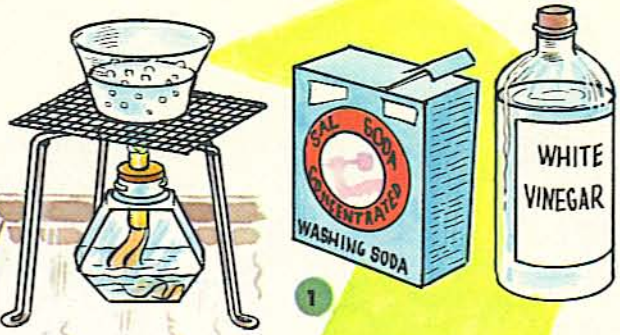

IN THE LABORATORY, METHANE IS MADE BY HEATING WATER-FREE SODIUM ACETATE WITH "SODA LIME."

1 TO MAKE SODIUM ACETATE, ADD WASHING SODA TO ½ CUSTARD CUP VINEGAR UNTIL NO MORE CO_2 IS GIVEN OFF. EVAPORATE MIXTURE AT LOW HEAT TO GET WHITE POWDER OF SODIUM ACETATE.

2 MIX 5 g SODIUM ACETATE (CH_3COONa), 5 g SODIUM HYDROXIDE, AND 5 g CALCIUM OXIDE. DROP INTO TEST TUBE. SET UP APPARATUS FOR COLLECTING GAS AS SHOWN BELOW. HEAT TO MAKE METHANE:

$$CH_3COONa + NaOH \rightarrow CH_4 + Na_2CO_3$$

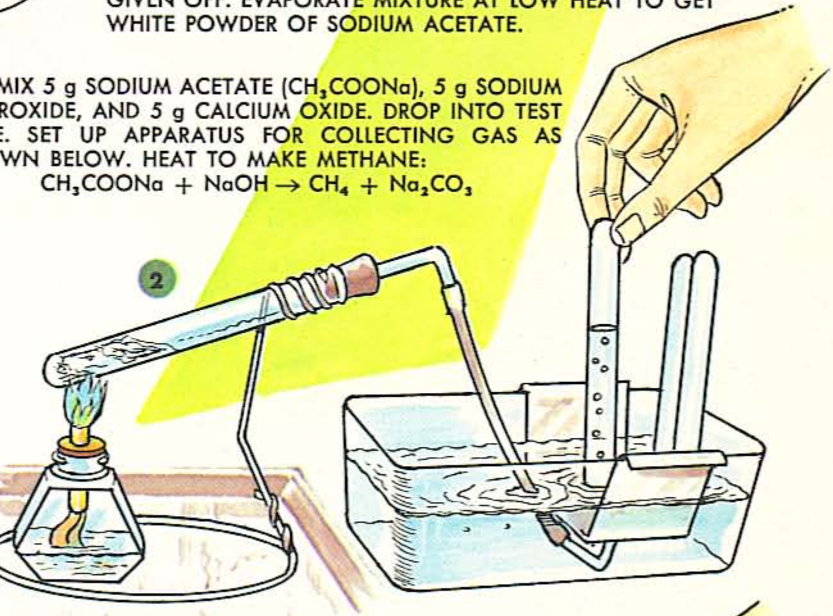

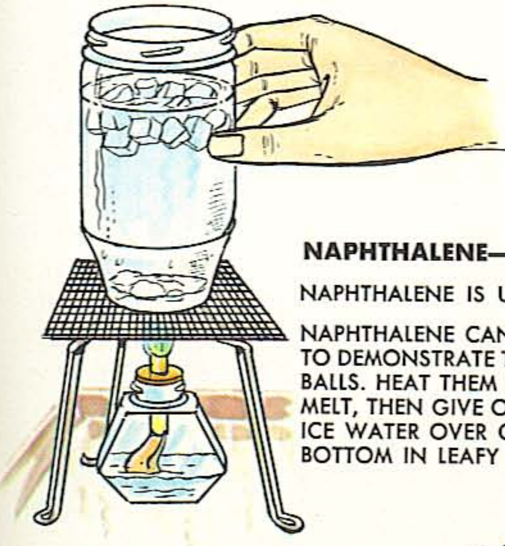

NAPHTHALENE—$C_{10}H_8$

NAPHTHALENE IS USED IN MAKING MOTH BALLS.

NAPHTHALENE CAN BE PURIFIED BY SUBLIMATION. TO DEMONSTRATE THIS, CRUSH A COUPLE OF MOTH BALLS. HEAT THEM IN A CUSTARD CUP. FIRST THEY MELT, THEN GIVE OFF VAPOR. PUT JAR FILLED WITH ICE WATER OVER CUP. NAPHTHALENE SETTLES ON BOTTOM IN LEAFY CRYSTALS.

TURPENTINE—$C_{10}H_{16}$

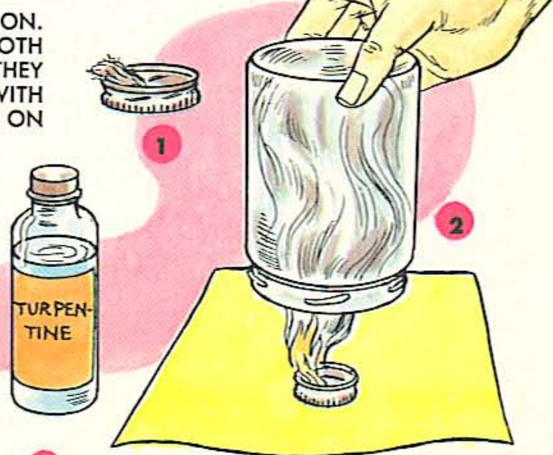

1 POUR A LITTLE TURPENTINE INTO A BOTTLE CAP. PLACE A SMALL WICK IN IT.

2 PLACE BOTTLE CAP ON PIECE OF PAPER. IGNITE TURPENTINE. IT BURNS INCOMPLETELY, GIVING OFF A BLACK SMOKE OF CARBON WHICH YOU CAN COLLECT IN A JAR.

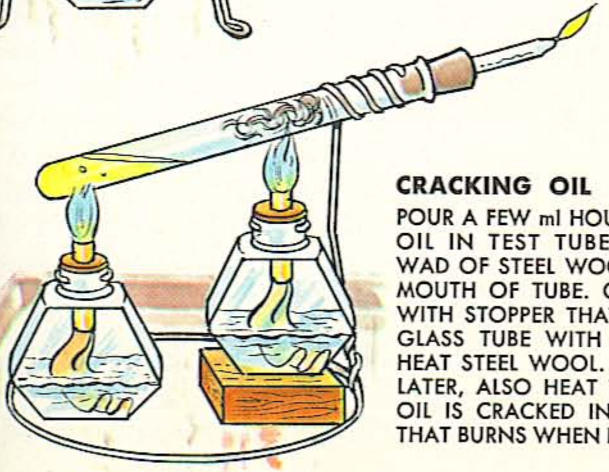

CRACKING OIL

POUR A FEW ml HOUSEHOLD OIL IN TEST TUBE. PLACE WAD OF STEEL WOOL NEAR MOUTH OF TUBE. CLOSE IT WITH STOPPER THAT HAS A GLASS TUBE WITH JET TIP. HEAT STEEL WOOL. A LITTLE LATER, ALSO HEAT THE OIL. OIL IS CRACKED INTO GAS THAT BURNS WHEN IGNITED.

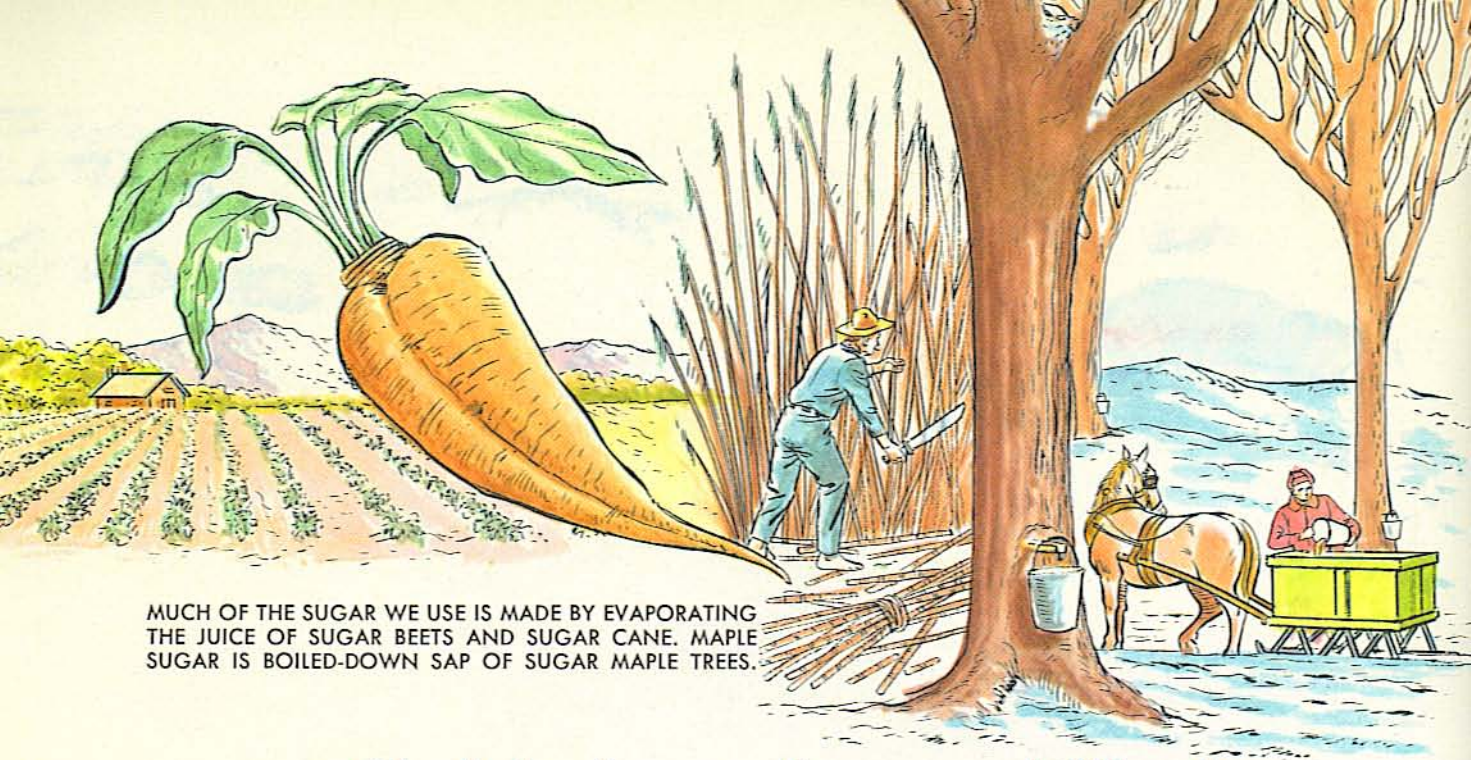

MUCH OF THE SUGAR WE USE IS MADE BY EVAPORATING THE JUICE OF SUGAR BEETS AND SUGAR CANE. MAPLE SUGAR IS BOILED-DOWN SAP OF SUGAR MAPLE TREES.

Carbohydrates—Sweet and Bland

USUALLY, when we talk about "hydrates" we mean chemicals that contain water. But when we talk about carbohydrates we mean organic compounds of carbon, hydrogen, and oxygen in which the proportion between hydrogen and oxygen is the same as in water (H_2O) — that is, twice as much hydrogen as oxygen. And so we find carbohydrates that have 22 atoms of hydrogen and 11 atoms of oxygen to 12 atoms of carbon ($C_{12}H_{22}O_{11}$), or 12 hydrogen and 6 oxygen to 6 carbon ($C_6H_{12}O_6$), or 10 and 5 to 6 carbon atoms ($C_6H_{10}O_5$).

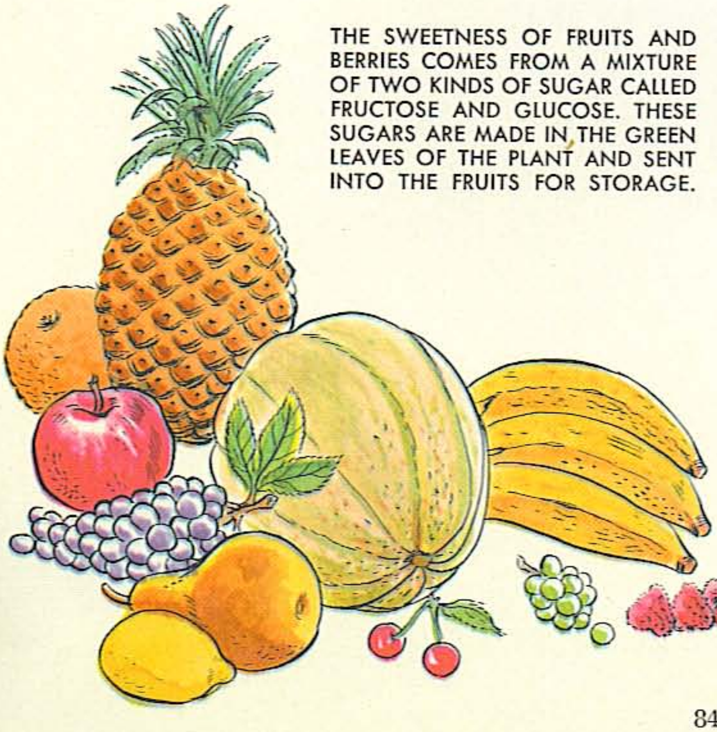

THE SWEETNESS OF FRUITS AND BERRIES COMES FROM A MIXTURE OF TWO KINDS OF SUGAR CALLED FRUCTOSE AND GLUCOSE. THESE SUGARS ARE MADE IN THE GREEN LEAVES OF THE PLANT AND SENT INTO THE FRUITS FOR STORAGE.

Carbohydrates are produced by plants by a remarkable process called photosynthesis — "putting things together with the help of light." When green leaves are exposed to sunlight, the chlorophyll in them combines the hydrogen from water with carbon dioxide from the air, while setting oxygen free — along this line:

$$6H_2O + 6CO_2 + \text{sunlight} \rightarrow C_6H_{12}O_6 + 6O_2 \uparrow$$

Carbohydrates are of tremendous importance to all of us. They make up a large part of our food supply in the form of sugars and starches. Another carbohydrate called cellulose helps to clothe us (cotton, linen) and shelter us (wood).

SUGARS — Most of our sugar comes from sugar beets or sugar cane. The juice is pressed out, cleared, filtered, and evaporated. The result is pure, white crystals of a sugar with the chemical name sucrose ($C_{12}H_{22}O_{11}$).

Another sugar called glucose ($C_6H_{12}O_6$) is found in ripe fruits, often in the company of still another sugar of the same formula called fructose ($C_6H_{12}O_6$). These two sugars can be made in the laboratory by treating the more complicated sucrose with an acid. The sucrose picks up water and splits into glucose and fructose by a process known as inversion:

$$\underset{\text{(sucrose)}}{C_{12}H_{22}O_{11}} + H_2O \rightarrow \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(fructose)}}{C_6H_{12}O_6}$$

(CONTINUED ON PAGE 86)

TEST FOR GLUCOSE SUGAR

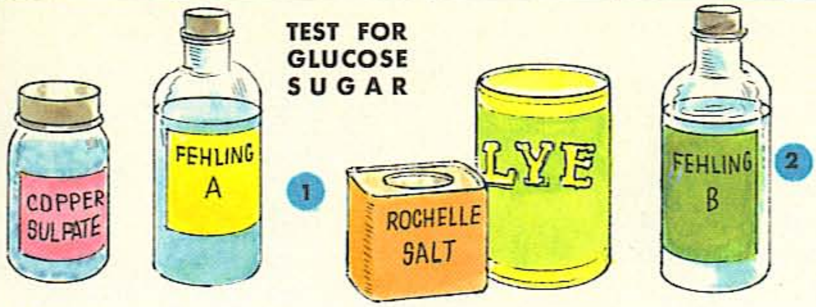

A GERMAN SCIENTIST, HERMAN FEHLING, THOUGHT UP THE TEST FOR GLUCOSE THAT HAS HIS NAME. FOR THIS TEST, TWO SOLUTIONS ARE REQUIRED. THEY ARE MIXED JUST BEFORE USE.

1 FEHLING A. DISSOLVE 5 g COPPER SULFATE IN 70 ml WATER.

2 FEHLING B. DISSOLVE 7 g SODIUM HYDROXIDE IN 70 ml WATER. IN THIS SOLUTION, DISSOLVE 25 g ROCHELLE SALT (SODIUM-POTASSIUM TARTRATE) FROM YOUR LOCAL DRUG STORE.

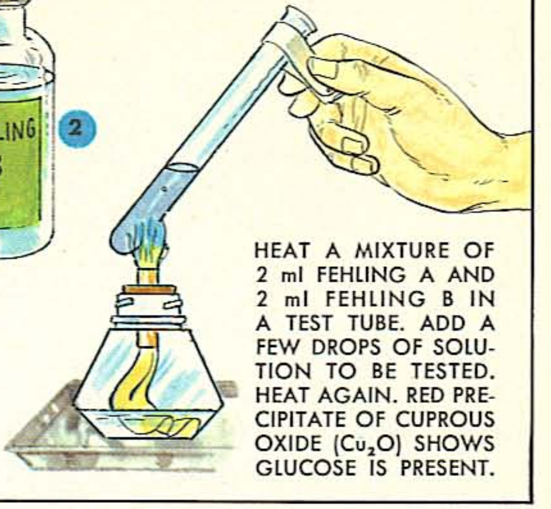

HEAT A MIXTURE OF 2 ml FEHLING A AND 2 ml FEHLING B IN A TEST TUBE. ADD A FEW DROPS OF SOLUTION TO BE TESTED. HEAT AGAIN. RED PRECIPITATE OF CUPROUS OXIDE (Cu_2O) SHOWS GLUCOSE IS PRESENT.

Karo SYRUP
MAPLE SYRUP
MOLASS
MILK
HONEY
PRUNES

USE FEHLING TEST TO FIND OUT IF DIFFERENT SWEET-TASTING FOODS CONTAIN GLUCOSE SUGAR: CORN SYRUP, MAPLE SYRUP, MOLASSES, HONEY. ALSO TRY JUICES OF VARIOUS FRUITS: PRUNES, ORANGES, LEMONS, BERRIES. SEVERAL CONTAIN GLUCOSE AND GIVE RED PRECIPITATE. SUGAR IN MILK (LACTOSE) GIVES Cu_2O PRECIPITATE.

TEST CANE SUGAR WITH FEHLING. YOU DO NOT GET RED PRECIPITATE. CANE SUGAR IS NOT GLUCOSE BUT ANOTHER SUGAR CALLED SUCROSE.

CANE SUGAR
CANE SUGAR DARK BROWN
CUBE SUGAR

SUCROSE TO GLUCOSE

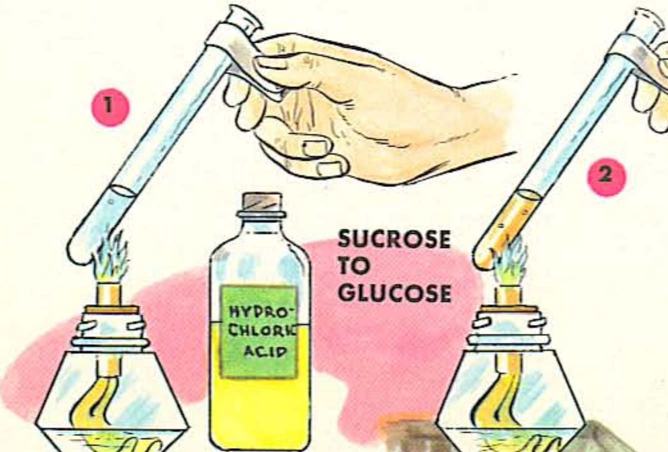

1 DISSOLVE 1 g CANE SUGAR IN 10 ml WATER IN A TEST TUBE. ADD 10 DROPS HYDROCHLORIC ACID. HEAT GENTLY FOR A FEW MINUTES WITHOUT BOILING.

2 HEAT FEHLING SOLUTION IN ANOTHER TEST TUBE. ADD A FEW ml SUGAR SOLUTION. HEAT AGAIN. YOU GET RED PRECIPITATE. GLUCOSE HAS BEEN FORMED.

MAKING SUGAR CANDY

IT IS EASY TO MAKE LOLLIPOPS. OVER LOW HEAT AND WHILE STIRRING, DISSOLVE ½ CUP SUGAR IN 2 TABLESPOONS WATER AND 2 TABLESPOONS LIGHT SYRUP. THEN CONTINUE HEATING WITHOUT STIRRING UNTIL A SAMPLE DROPPED INTO COLD WATER FORMS BRITTLE THREAD. SPOON OUT TABLESPOONFULS ONTO A SHEET OF GREASED ALUMINUM FOIL. PUSH STICK IN EACH BLOB. REMOVE WHEN COLD.

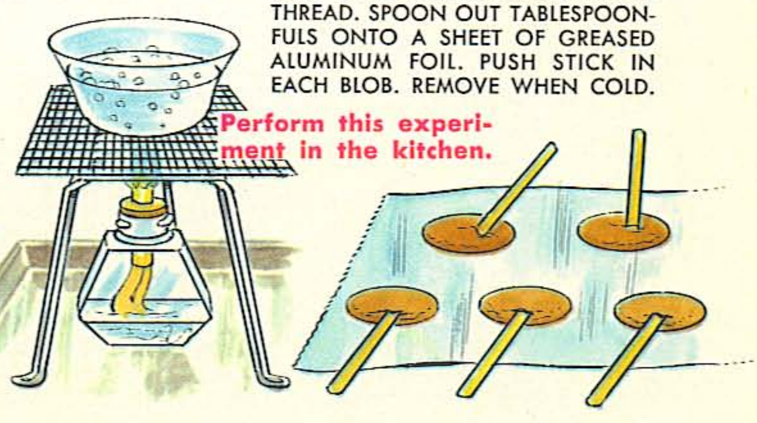

Perform this experiment in the kitchen.

Carbohydrates—Continued

STARCHES — Starch is distributed in most plant parts. It is a carbohydrate with very large molecules. Take a look at its formula: $(C_6H_{10}O_5)_x$. At first glance it looks quite simple. But note that little x — it stands for "any number of times." A single molecule of starch may weigh 6,000 times as much as a single molecule of glucose.

You can break this polysaccharide ("many-sugar") into the monosaccharide ("single-sugar") glucose by treating it with an acid.

CELLULOSE is the building material of the plant world. It makes up the cell walls of leaves and stalks, wood and fibers. Cotton is 95 per cent cellulose. The paper on which this book is printed is specially treated cellulose. So is the cellophane around your candy and the rayon that goes into ladies' dresses. For more about cellulose in natural fibers and rayon, see pages 102-103.

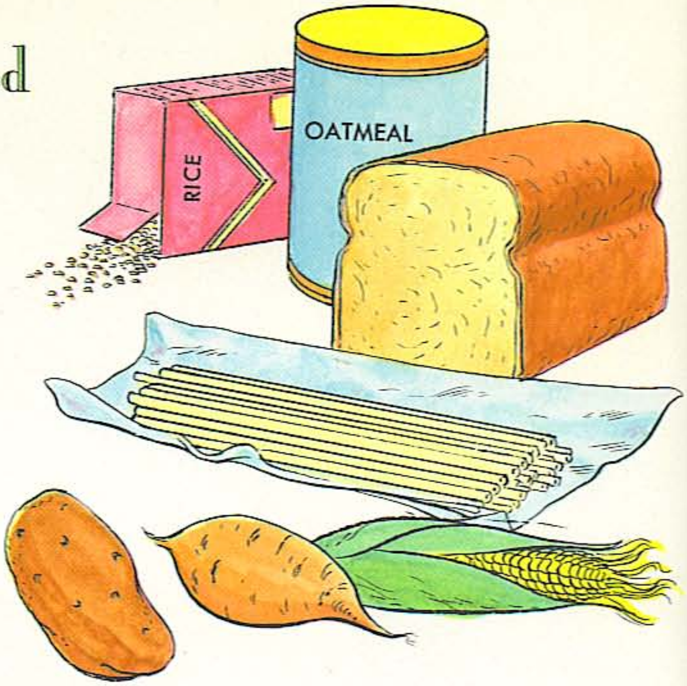

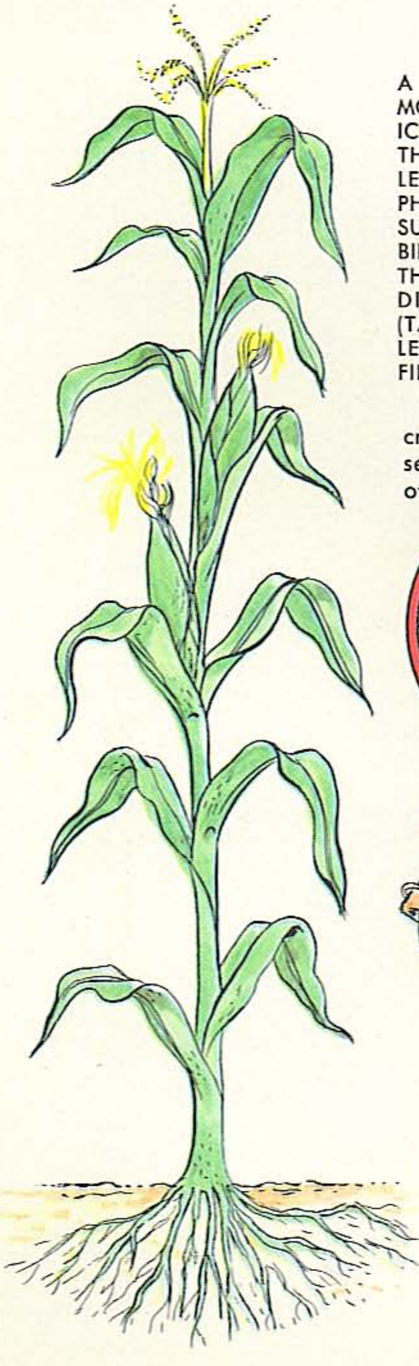

A GROWING PLANT IS THE MOST ASTONISHING CHEMICAL FACTORY ON EARTH. THE GREEN SUBSTANCE IN LEAVES—CALLED CHLOROPHYLL—WITH THE HELP OF SUNLIGHT IS ABLE TO COMBINE WATER (TAKEN IN BY THE ROOTS) WITH CARBON DIOXIDE FROM THE AIR (TAKEN IN THROUGH THE LEAVES) TO FORM SUGAR FIRST AND THEN STARCH.

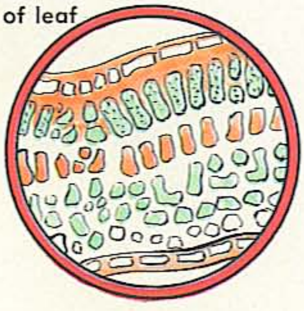

cross section of leaf

EXPERIMENTS WITH PHOTOSYNTHESIS

① POT UP A NASTURTIUM OR GERANIUM PLANT AND PLACE IT IN THE DARK FOR A COUPLE OF DAYS. THEN FASTEN STRIPS OF BLACK PAPER ACROSS BOTH SIDES OF ONE OR MORE LEAVES. NOW EXPOSE THE GROWING PLANT TO THE SUNLIGHT FOR TWO HOURS.

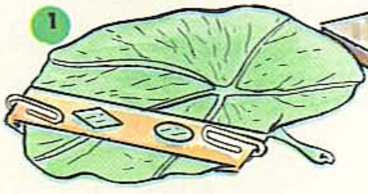

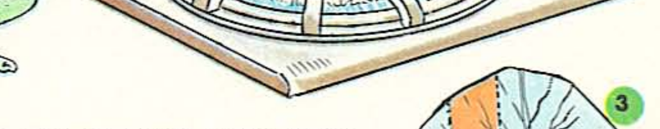

② PICK OFF A LEAF. REMOVE BLACK PAPER STRIPS. DIP IN BOILING WATER FOR A MOMENT TO KILL THE LEAF. THEN DROP IT INTO DENATURED ALCOHOL IN A CUSTARD CUP. PLACE CUSTARD CUP IN A POT OF BOILING WATER. AS ALCOHOL GETS HOT, IT EXTRACTS THE CHLOROPHYLL FROM THE LEAF. KEEP LEAF IN ALCOHOL UNTIL ALL CHLOROPHYLL IS OUT.

③ PLACE LEAF IN IODINE TEST SOLUTION. PARTS EXPOSED TO SUN TURN BLUE. THIS PROVES PRESENCE OF STARCH. UNEXPOSED PARTS BECOME BROWN.

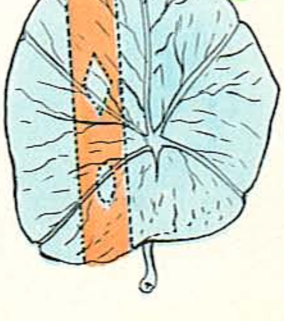

PREPARING STARCH

IT IS A SIMPLE MATTER TO GET STARCH FROM POTATOES.

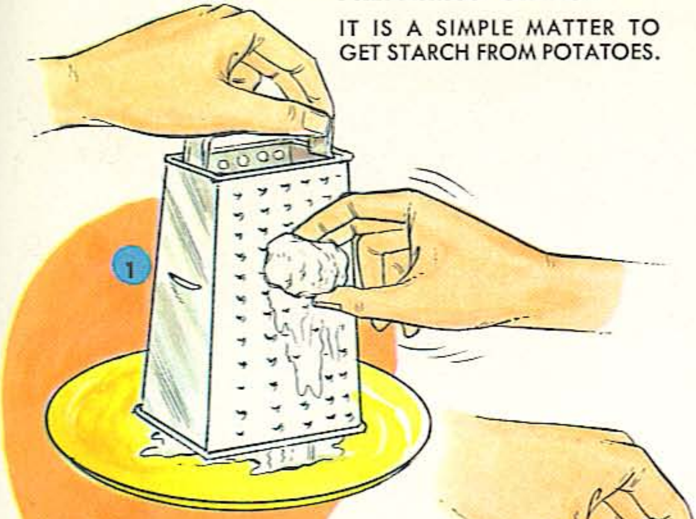

TEST FOR STARCH

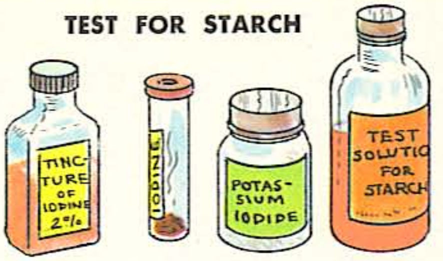

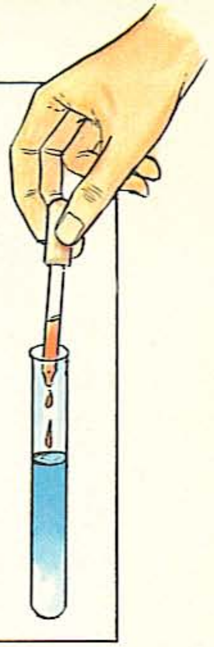

SOLUTION FOR TESTING STARCH CAN BE MADE BY DILUTING 5 ml REGULAR TINCTURE OF IODINE WITH 45 ml WATER.

OR YOU CAN MAKE IT BY DISSOLVING A FEW IODINE CRYSTALS (FROM EXPERIMENT ON PAGE 48) IN A SOLUTION OF 1 g POTASSIUM IODIDE IN 50 ml WATER. IODINE GIVES A BLUE COLOR TO STARCH.

1 PEEL A COUPLE OF POTATOES. GRATE THEM UP ON FINE SIDE OF GRATER.

2 PLACE POTATO PULP ON DOUBLE LAYER OF CHEESE CLOTH. FOLD UP AND TIE. DIP BAG IN POT OF WATER. SQUEEZE. DIP AND SQUEEZE UNTIL MOST STARCH IS OUT.

3 LET STARCH SETTLE IN POT. POUR OFF MOST OF WATER. POUR REST INTO A JAR FOR FURTHER SETTLING.

4 AGAIN, POUR WATER OFF UNTIL VERY LITTLE IS LEFT. POUR THE REST ONTO A PLATE. PLACE IN A WARM SPOT TILL STARCH IS DRY.

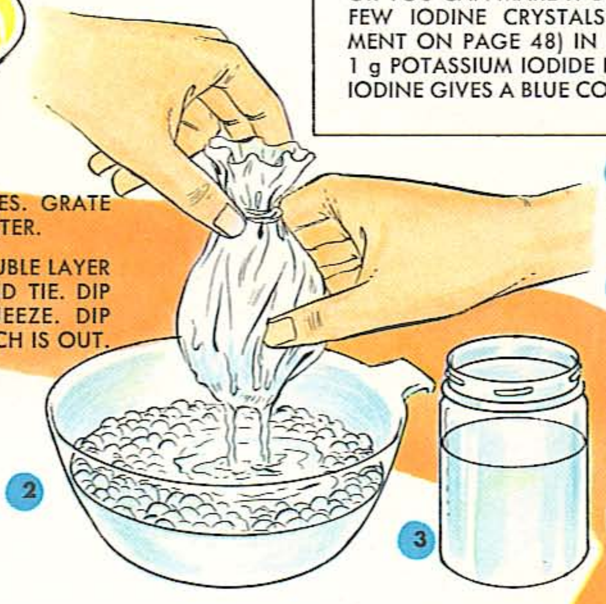

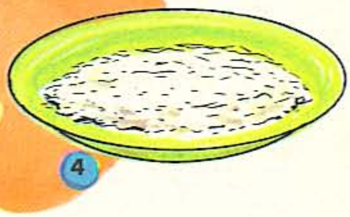

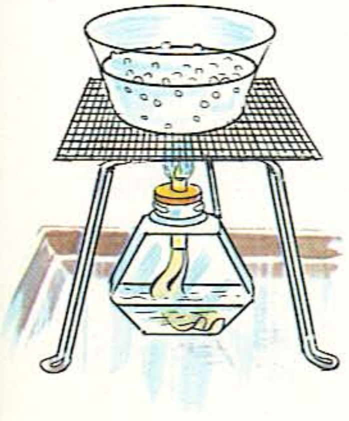

EXPERIMENTS WITH STARCH

TO MAKE 1 PER CENT STARCH SOLUTION, STIR ½ g STARCH IN 5 ml COLD WATER. ADD 45 ml MORE WATER. BRING TO BOIL WHILE STIRRING, THEN COOL SOLUTION.

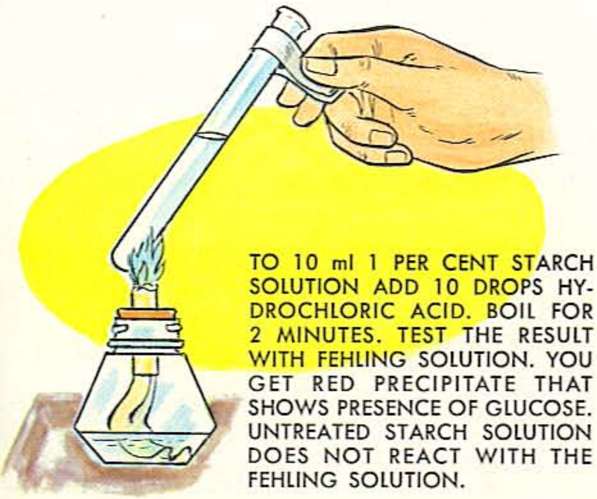

TO 10 ml 1 PER CENT STARCH SOLUTION ADD 10 DROPS HYDROCHLORIC ACID. BOIL FOR 2 MINUTES. TEST THE RESULT WITH FEHLING SOLUTION. YOU GET RED PRECIPITATE THAT SHOWS PRESENCE OF GLUCOSE. UNTREATED STARCH SOLUTION DOES NOT REACT WITH THE FEHLING SOLUTION.

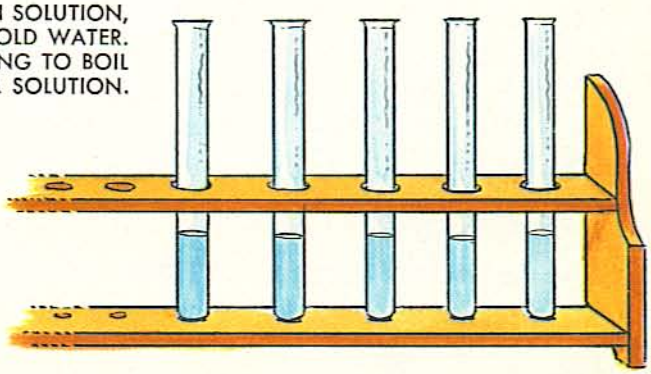

LINE UP FIVE TEST TUBES, EACH CONTAINING 5 ml WATER AND 1 DROP IODINE TEST SOLUTION. IN ANOTHER TEST TUBE, ADD 2 DROPS OF SALIVA (SPITTLE) TO 5 ml STARCH SOLUTION. PLACE THIS IN GLASS OF WARM (NOT HOT) WATER. WITH 2-MINUTE INTERVALS, DROP 3 DROPS SALIVA-STARCH MIXTURE INTO A TEST TUBE WITH IODINE SOLUTION. SHAKE. COLOR GETS LESS AND LESS BLUE. SALIVA DIGESTS THE STARCH AND TURNS IT INTO A SUGAR, MALTOSE.

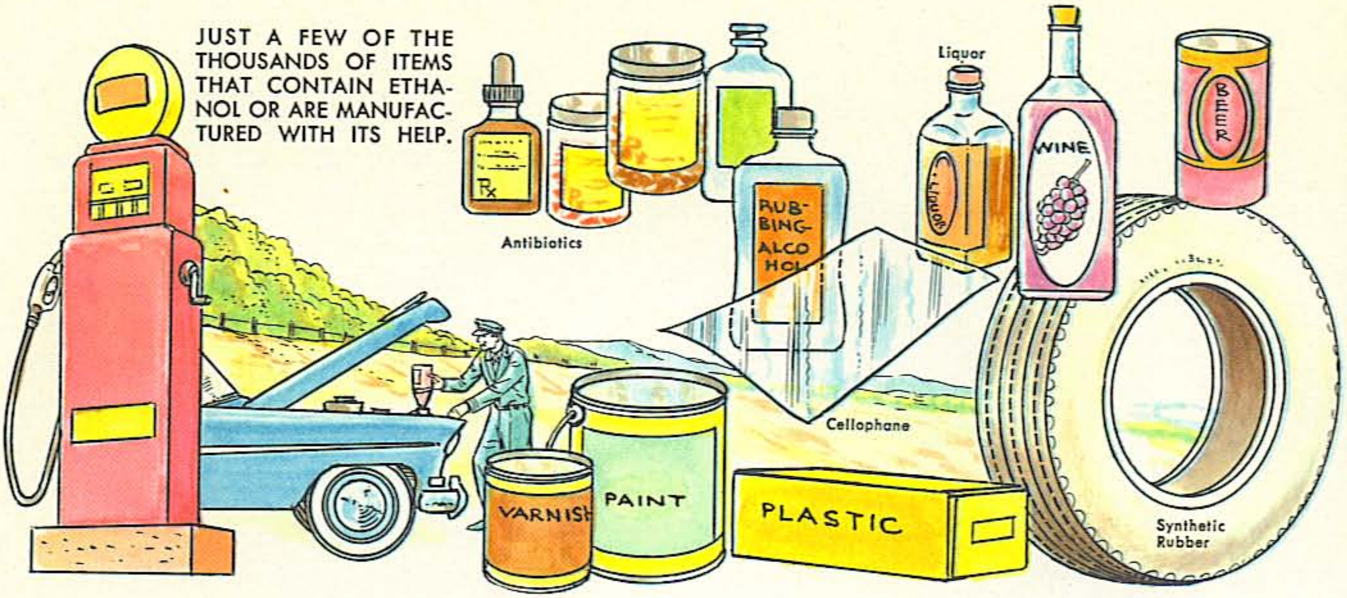

JUST A FEW OF THE THOUSANDS OF ITEMS THAT CONTAIN ETHANOL OR ARE MANUFACTURED WITH ITS HELP.

Rx
Antibiotics
RUBBING ALCOHOL
Liquor
LIQUOR
WINE
BEER
Cellophane
VARNISH
PAINT
PLASTIC
Synthetic Rubber

Many Kinds of Alcohols

To most people, alcohol is the strong stuff in beer, wine, and hard liquor. But to a chemist, this is just one of many alcohols.

Alcohols may be considered hydrocarbons in which one or more hydrogen (H) atoms are replaced by hydroxyl (OH) groups. Their names are made up from the names of the hydrocarbons to which they are related by giving these an "-ol" ending. In this way, CH_4, methane, becomes CH_3OH, methanol (also called methyl alcohol); C_2H_6, ethane, becomes C_2H_5OH, ethanol (also known as ethyl or grain alcohol); and so on. Methanol (CH_3OH) was originally called wood alcohol because it was made by the destructive distillation of wood. It is very poisonous and is therefore used to "denature" ethanol, making this unfit for drinking.

Ethanol (C_2H_5OH) is produced today, to a great extent, in the same way in which it was made thousands of years ago, by a process called fermentation. In this, the tiny plant cells of yeast are made to grow in the solution of a simple sugar, such as glucose ($C_6H_{12}O_6$). In growing, the yeast cells give off a substance called zymase. This acts as a catalyst and turns the glucose into ethanol and carbon dioxide:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 \uparrow$$

The ethanol is finally separated from the watery liquid by distillation.

Glycerol ($C_3H_5(OH)_3$) is still another alcohol which you probably know better under the name of glycerin. Glycerol may be considered a product of propane (C_3H_8) in which not one but three H atoms have been replaced by OH.

THE "FAMILY TREE" OF ETHANOL—WITH SOME OF ITS CHILDREN, GRANDCHILDREN, AND GREAT-GRANDCHILDREN.

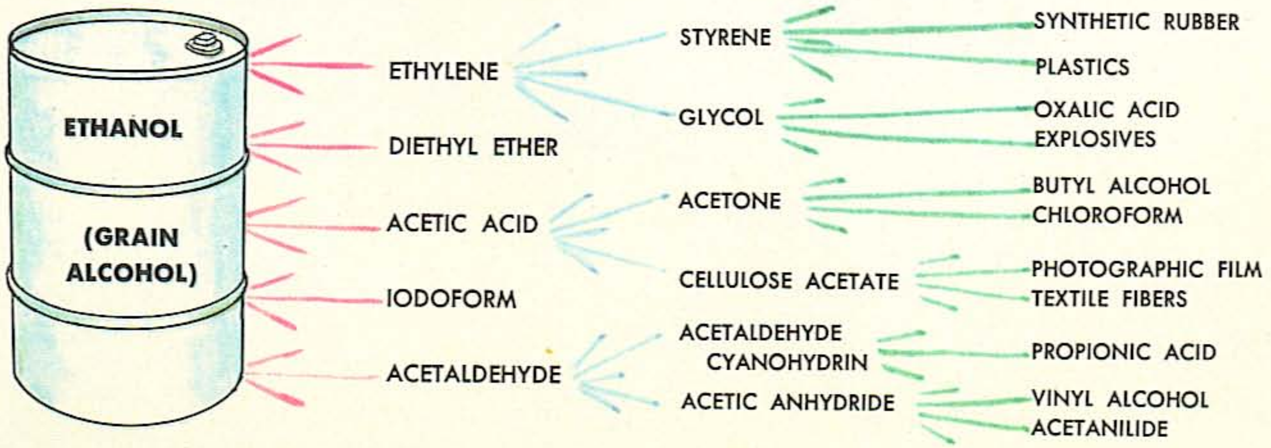

ETHANOL
(GRAIN ALCOHOL)
ETHYLENE
DIETHYL ETHER
ACETIC ACID
IODOFORM
ACETALDEHYDE
STYRENE
GLYCOL
ACETONE
CELLULOSE ACETATE
ACETALDEHYDE CYANOHYDRIN
ACETIC ANHYDRIDE
SYNTHETIC RUBBER
PLASTICS
OXALIC ACID
EXPLOSIVES
BUTYL ALCOHOL
CHLOROFORM
PHOTOGRAPHIC FILM
TEXTILE FIBERS
PROPIONIC ACID
VINYL ALCOHOL
ACETANILIDE

METHYL ALCOHOL—METHANOL

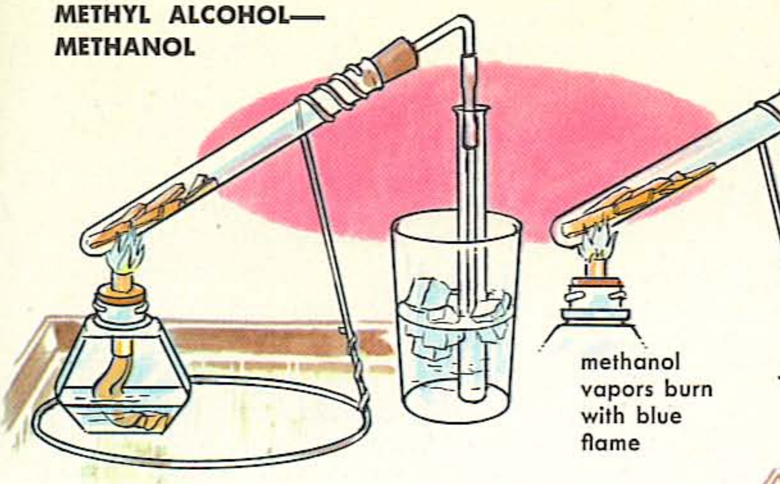
methanol vapors burn with blue flame

METHANOL CAN BE PRODUCED BY DRY DISTILLATION OF WOOD. FILL A TEST TUBE ONE THIRD FULL OF SLIVERS OF WOOD. HEAT. LEAD VAPORS THROUGH L-SHAPED GLASS TUBE INTO TEST TUBE IN MIXTURE OF WATER AND ICE.

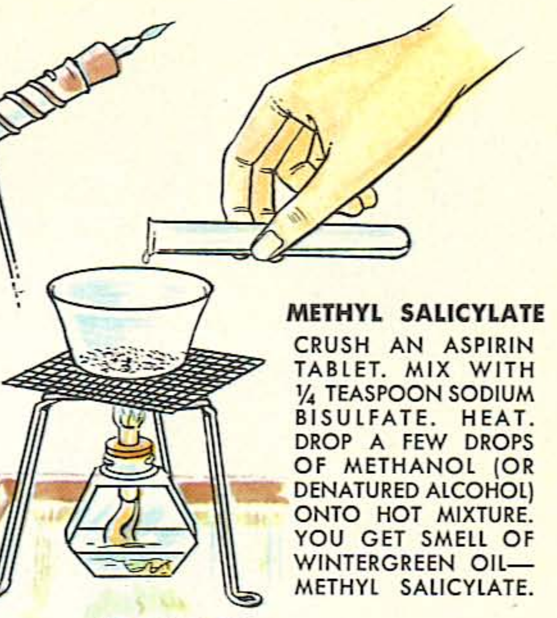

METHYL SALICYLATE

CRUSH AN ASPIRIN TABLET. MIX WITH ¼ TEASPOON SODIUM BISULFATE. HEAT. DROP A FEW DROPS OF METHANOL (OR DENATURED ALCOHOL) ONTO HOT MIXTURE. YOU GET SMELL OF WINTERGREEN OIL—METHYL SALICYLATE.

ETHYL ALCOHOL—ETHANOL

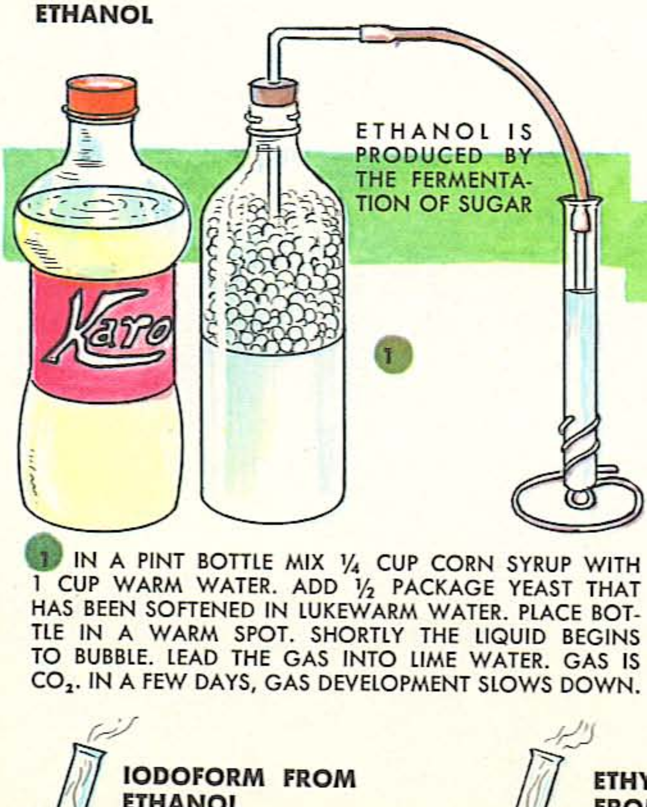

ETHANOL IS PRODUCED BY THE FERMENTATION OF SUGAR

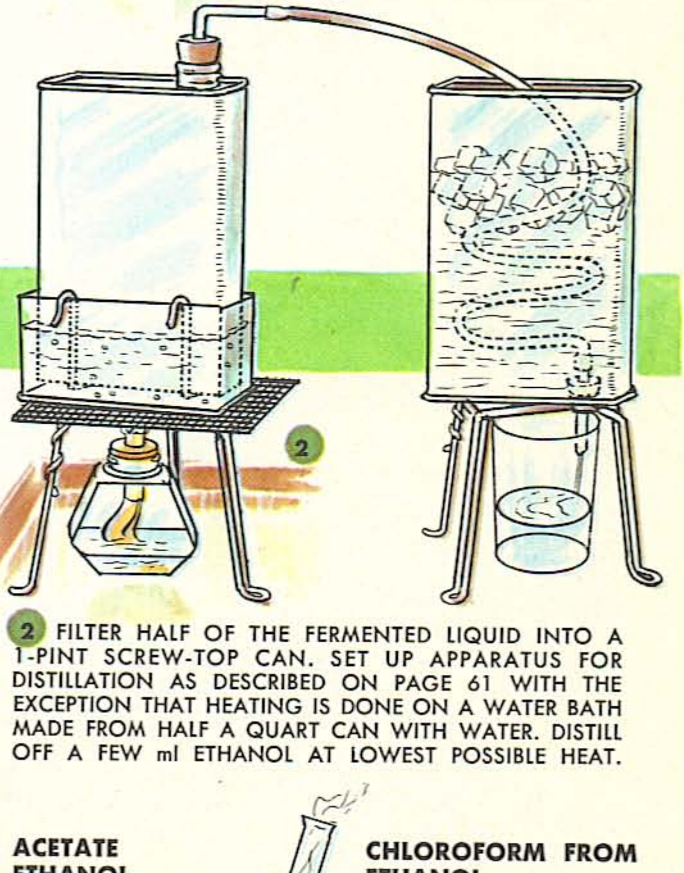

① IN A PINT BOTTLE MIX ¼ CUP CORN SYRUP WITH 1 CUP WARM WATER. ADD ½ PACKAGE YEAST THAT HAS BEEN SOFTENED IN LUKEWARM WATER. PLACE BOTTLE IN A WARM SPOT. SHORTLY THE LIQUID BEGINS TO BUBBLE. LEAD THE GAS INTO LIME WATER. GAS IS CO_2. IN A FEW DAYS, GAS DEVELOPMENT SLOWS DOWN.

② FILTER HALF OF THE FERMENTED LIQUID INTO A 1-PINT SCREW-TOP CAN. SET UP APPARATUS FOR DISTILLATION AS DESCRIBED ON PAGE 61 WITH THE EXCEPTION THAT HEATING IS DONE ON A WATER BATH MADE FROM HALF A QUART CAN WITH WATER. DISTILL OFF A FEW ml ETHANOL AT LOWEST POSSIBLE HEAT.

IODOFORM FROM ETHANOL

TO A SOLUTION OF 1 g POTASSIUM IODIDE IN 5 ml WATER ADD IODINE CRYSTALS TO GET DARK BROWN COLOR. ADD 5 ml ETHANOL. ADD 10% NaOH SOLUTION UNTIL COLOR DISAPPEARS. HEAT GENTLY TWO MINUTES. LET COOL. THE YELLOW PRECIPITATE IS IODOFORM—CHI_3.

ETHYL ACETATE FROM ETHANOL

IN A TEST TUBE, MIX 3 ml ETHANOL WITH 2 g SODIUM BISULFATE AND 3 ml WHITE VINEGAR. HEAT IT GENTLY. SNIFF CAREFULLY. THE SOUR SMELL OF VINEGAR HAS TURNED INTO THE FRUITY SMELL OF ETHYL ACETATE ($CH_3COOC_2H_5$). IT IS A MUCH-USED SOLVENT.

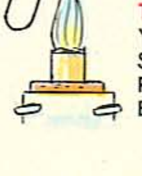

CHLOROFORM FROM ETHANOL

MIX 5 ml ETHANOL WITH 5 ml SODIUM HYPOCHLORITE SOLUTION ("CLOROX"). HEAT MIXTURE GENTLY FOR A FEW MOMENTS WITHOUT BOILING. THEN SNIFF CAREFULLY. YOU GET THE PECULIAR SWEETISH ODOR OF CHLOROFORM. THE C_2H_5OH HAS BEEN TURNED INTO $CHCl_3$.

Carboxylic Acids

CAN YOU THINK of anything more refreshing than a glass of cold lemonade on a hot summer's day? Or anything better than cranberry sauce for adding a tangy taste to the Thanksgiving dinner?

The tartness of lemonade and cranberry sauce comes from organic acids.

These acids are found ready-made in nature in great numbers. Some of them occur as free acids (citric acid, tannic acid, malic acid), others as esters (products of acids and alcohols, such as fats and oils and the flavors of many fruits and the odors of many flowers). Still other of these organic acids are produced by the action of bacteria (acetic acid from wine or cider, lactic acid when milk turns sour, butyric acid in rancid butter).

Some organic acids can be extracted directly from the plant parts in which they are found. But to get them in pure and concentrated form it is usually necessary to turn them into sodium or calcium salts and then free the acids from the salts with a stronger acid. Many of the acids which were formerly obtained from plant parts can now be made artificially in the laboratory.

Organic acids have one thing in common. They all contain a combination of one carbon atom, one oxygen atom, and one hydroxyl group (OH). This COOH combination, called a carboxyl group (from a joining-up of the words *carb*on and hydr*oxyl*), has given the organic acids their scientific name, carboxylic acids. When these acids form salts it is the H in the carboxyl group that is replaced by a metal, as, for instance, when CH$_3$COOH (acetic acid) forms CH$_3$COONa (sodium acetate).

ACETIC ACID IS WHAT MAKES VINEGAR TASTE SOUR. VINEGAR MEANS "SOUR WINE." THAT IS WHAT IT USED TO BE.

TANNIC ACID, USED FOR TANNING, IS FOUND IN THE BARK OF A NUMBER OF TREES AND IN GALL APPLES ON OAK TREES.

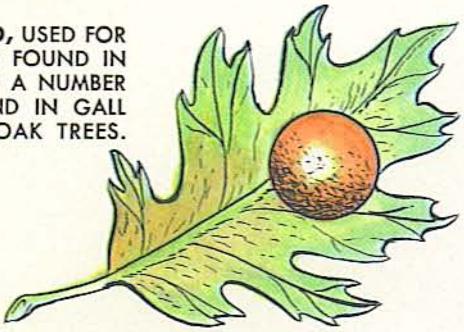

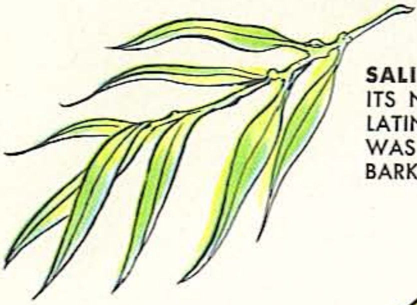

SALICYLIC ACID GOT ITS NAME FROM *SALIX,* LATIN FOR WILLOW. IT WAS FIRST MADE FROM BARK OF WILLOW TREES.

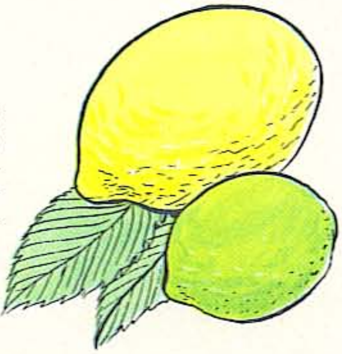

CITRIC ACID GIVES THE TART TASTE TO CITRUS FRUITS—LEMONS, LIMES, GRAPEFRUITS, AND ORANGES.

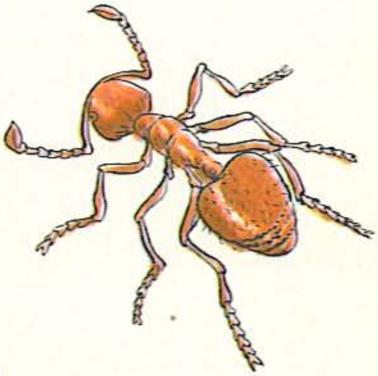

MALIC ACID IS FOUND IN MANY UNRIPE FRUITS—GREEN APPLES, PLUMS, CURRANTS, AND A GREAT NUMBER OF OTHERS. NAME COMES FROM LATIN *MALUS*—APPLE TREE.

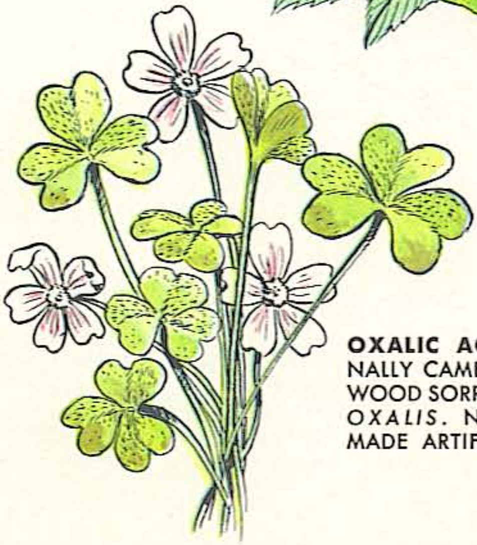

OXALIC ACID ORIGINALLY CAME FROM THE WOOD SORREL PLANT—*OXALIS*. NOW IT IS MADE ARTIFICIALLY.

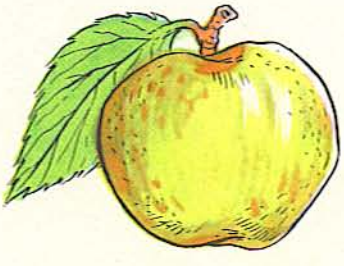

FORMIC ACID IS THE HIGHLY IRRITATING ACID THAT ANTS *(FORMICA)* PUMP INTO YOU WHEN THEY BITE YOU.

ACETIC ACID

YOU HAVE ALREADY MADE SODIUM ACETATE (ON PAGE 83).

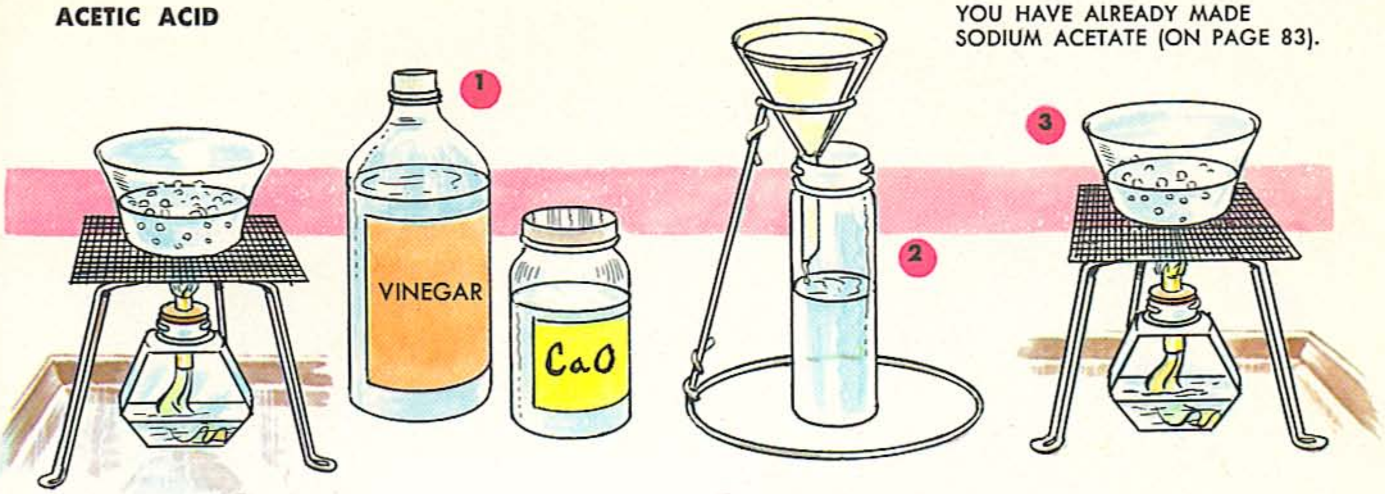

VINEGAR IS DILUTED ACETIC ACID. SEVERAL OF ITS SALTS—ACETATES—CAN BE MADE FROM VINEGAR. USE LIME FOR MAKING THE CALCIUM SALT—$(CH_3COO)_2Ca$.

1 WARM 50 ml WHITE VINEGAR IN A CUSTARD CUP. ADD CALCIUM OXIDE UNTIL NO MORE DISSOLVES.

2 FILTER SOLUTION TO REMOVE UNDISSOLVED CALCIUM OXIDE. FILTRATE CONTAINS CALCIUM ACETATE.

3 EVAPORATE SOLUTION UNTIL ALMOST DRY. DO NOT OVERHEAT—IF YOU DO, THE ACETATE BREAKS UP INTO CALCIUM CARBONATE AND ACETONE (CH_3COCH_3).

YOU CAN AGAIN DRIVE ACETIC ACID OUT OF ITS CALCIUM SALT.

MIX CALCIUM ACETATE WITH AN EQUAL AMOUNT OF SODIUM BISULFATE. PLACE IN DRY TEST TUBE. HEAT GENTLY. YOU GET SHARP ODOR OF ACETIC ACID. MOISTENED BLUE LITMUS PAPER AT MOUTH OF TUBE TURNS RED.

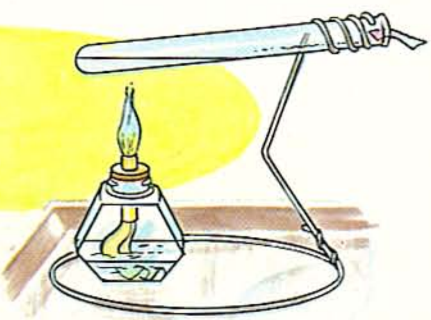

SALICYLIC ACID

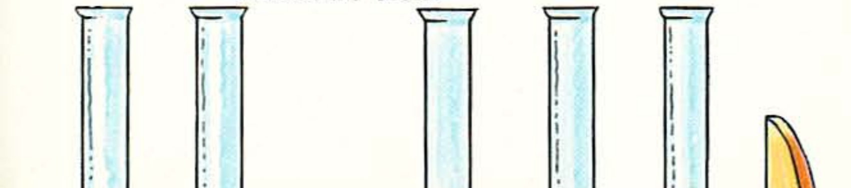

1 SHAKE UP 1 g SALICYLIC ACID WITH 10 ml WATER. IT DOES NOT GO INTO SOLUTION.

2 ADD 10 PER CENT NaOH SOLUTION BY THE DROP UNTIL ALL SALICYLIC ACID IS DISSOLVED. YOU NOW HAVE A SODIUM SALICYLATE SOLUTION.

3 WITH IRON SULFATE, SODIUM SALICYLATE GIVES RED-BROWN FERROUS SALICYLATE.

4 A FERRIC SALT GIVES WINE-RED FERRIC SALICYLATE.

5 COPPER SULFATE GIVES THE GREEN COPPER SALICYLATE.

TANNIC ACID

TANNIC ACID IS FOUND IN TEA.

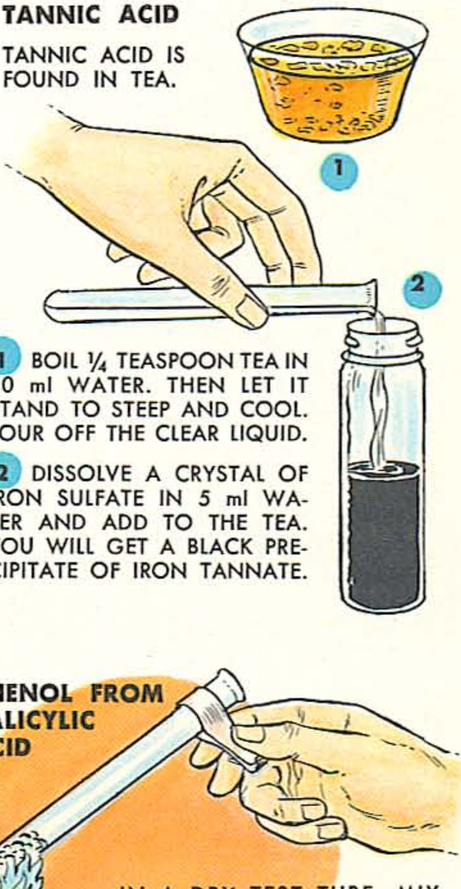

1 BOIL ¼ TEASPOON TEA IN 50 ml WATER. THEN LET IT STAND TO STEEP AND COOL. POUR OFF THE CLEAR LIQUID.

2 DISSOLVE A CRYSTAL OF IRON SULFATE IN 5 ml WATER AND ADD TO THE TEA. YOU WILL GET A BLACK PRECIPITATE OF IRON TANNATE.

PHENOL FROM SALICYLIC ACID

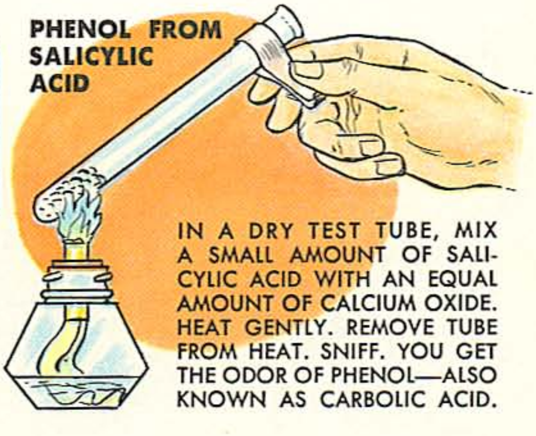

IN A DRY TEST TUBE, MIX A SMALL AMOUNT OF SALICYLIC ACID WITH AN EQUAL AMOUNT OF CALCIUM OXIDE. HEAT GENTLY. REMOVE TUBE FROM HEAT. SNIFF. YOU GET THE ODOR OF PHENOL—ALSO KNOWN AS CARBOLIC ACID.

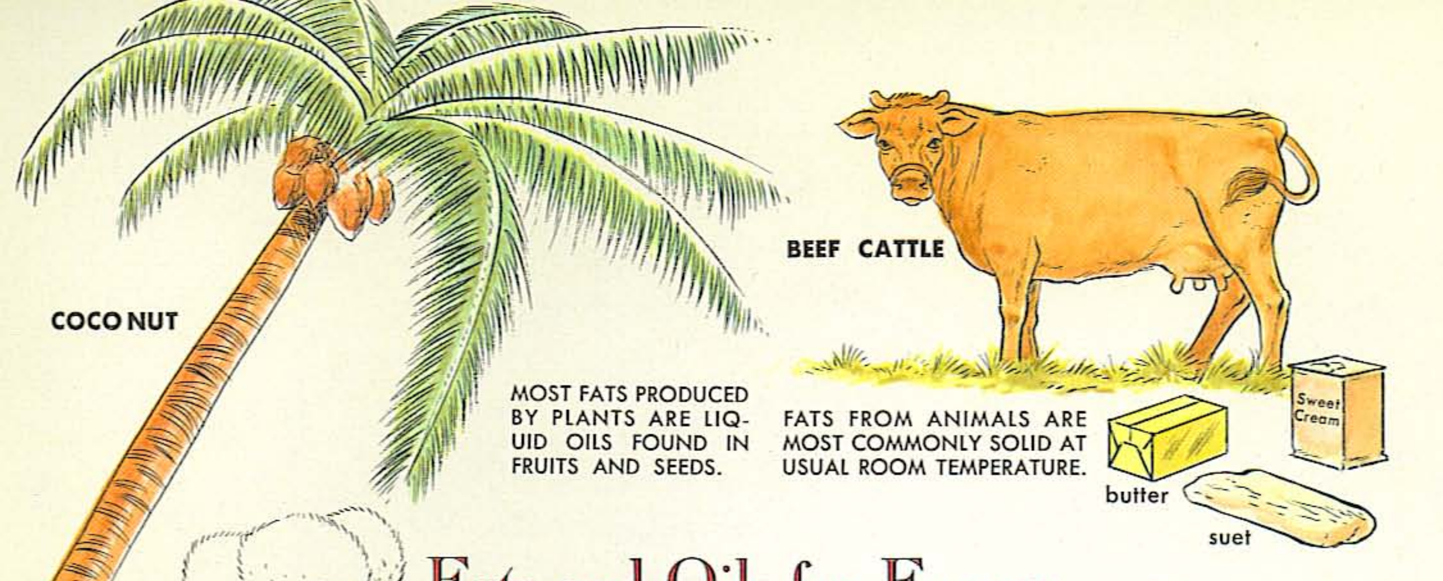
COCO NUT
BEEF CATTLE
Sweet Cream
butter
suet

MOST FATS PRODUCED BY PLANTS ARE LIQUID OILS FOUND IN FRUITS AND SEEDS.

FATS FROM ANIMALS ARE MOST COMMONLY SOLID AT USUAL ROOM TEMPERATURE.

Fats and Oils for Energy

Some of the food you eat is used for your growth, some of it for giving you the energy to do all the things you want to do. Much of this energy comes from carbohydrates (sugars and starches). The rest you get from fats — the most concentrated energy foods available.

All fats are esters, that is, combinations of fatty acids with the alcohol, glycerol (glycerin). Some fats (butter, lard) are solid at usual room temperature, others are liquid (olive oil, corn oil). But when heated, the solid fats melt, and, when cooled, the liquid fats turn solid.

Liquid fats can be turned completely into solid fats by a process called hydrogenation. In this, more hydrogen atoms are added to their molecules with the help of a catalyst. That is how vegetable shortenings and margarine are made. The liquid olein in peanut, cottonseed, and soybean oils is made to pick up hydrogen and become a solid fat known as stearin:

$$\underset{\text{(olein)}}{(C_{17}H_{33}COO)_3C_3H_5} + 3H_2 \rightarrow \underset{\text{(stearin)}}{(C_{17}H_{35}COO)_3C_3H_5}$$

Fats and oils are used for many other things in addition to their use as food. Soap and candles are made from fats. So are paints and varnishes, printers' inks and some of the detergents.

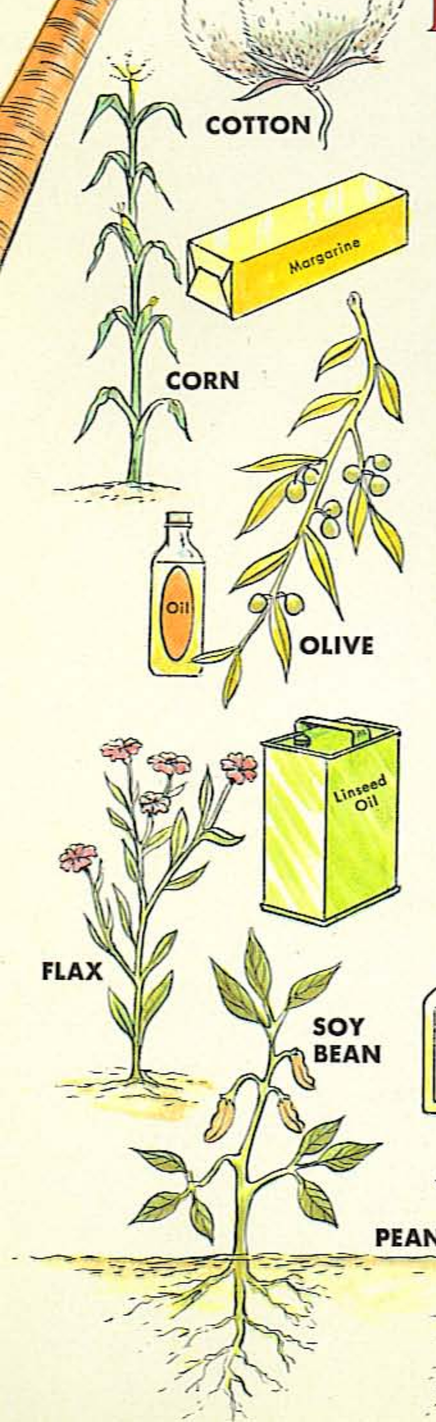
COTTON
Margarine
CORN
Oil
OLIVE
Linseed Oil
FLAX
SOY BEAN

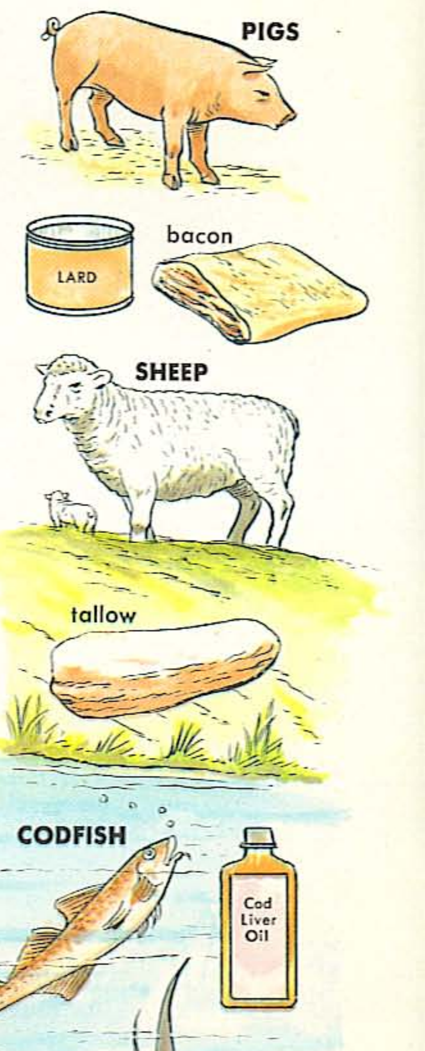
PIGS
LARD
bacon
SHEEP
tallow
CODFISH
Cod Liver Oil

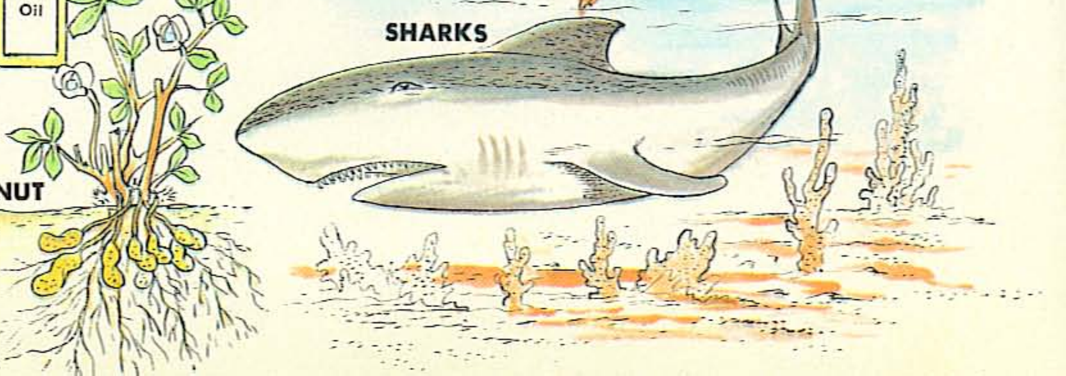
Peanut Oil
PEANUT
SHARKS

EXTRACTING FAT

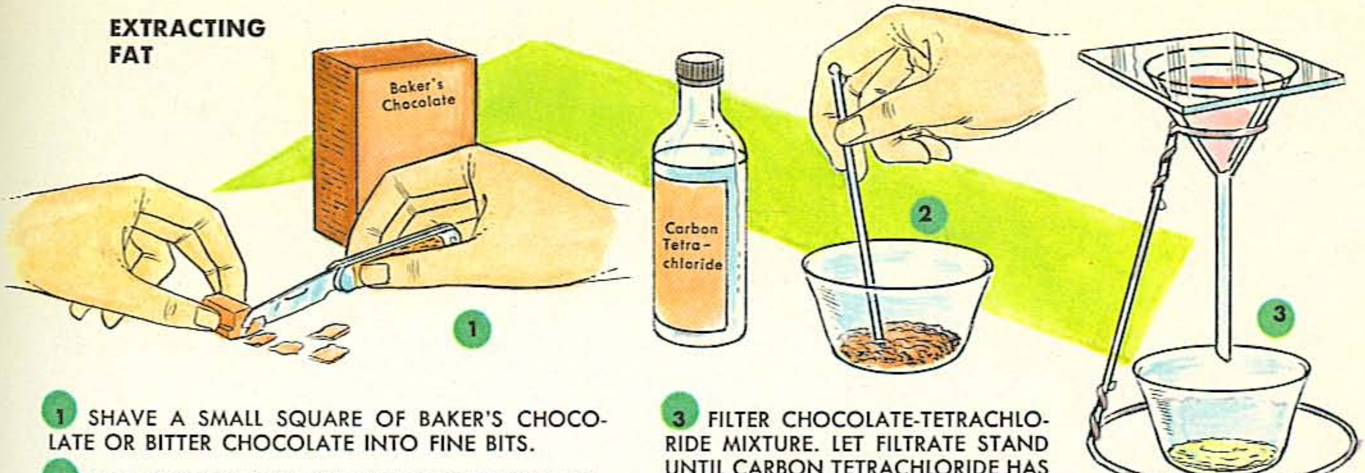

① SHAVE A SMALL SQUARE OF BAKER'S CHOCOLATE OR BITTER CHOCOLATE INTO FINE BITS.

② IN A CUSTARD CUP, POUR CARBON TETRACHLORIDE OVER THE CUT-UP CHOCOLATE AND STIR.

③ FILTER CHOCOLATE-TETRACHLORIDE MIXTURE. LET FILTRATE STAND UNTIL CARBON TETRACHLORIDE HAS EVAPORATED AND YELLOW-WHITE COCOA BUTTER IS LEFT.

Be careful not to breathe fumes.

RENDERING FAT

"RENDERING" IS THE MOST COMMON METHOD OF EXTRACTING FAT.

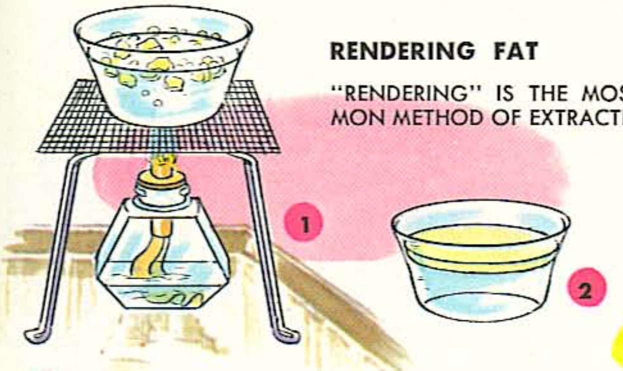

① CUT UP A SMALL AMOUNT OF SUET—THE FAT FROM A PIECE OF BEEF. DROP IT INTO HOT WATER. BOIL WATER FOR TEN MINUTES OR MORE.

② REMOVE THE RENDERED-OUT SUET. PLACE CUSTARD CUP IN REFRIGERATOR. AFTER COOLING YOU CAN LIFT OFF THE FAT AS A SOLID DISK.

TEST FOR FAT

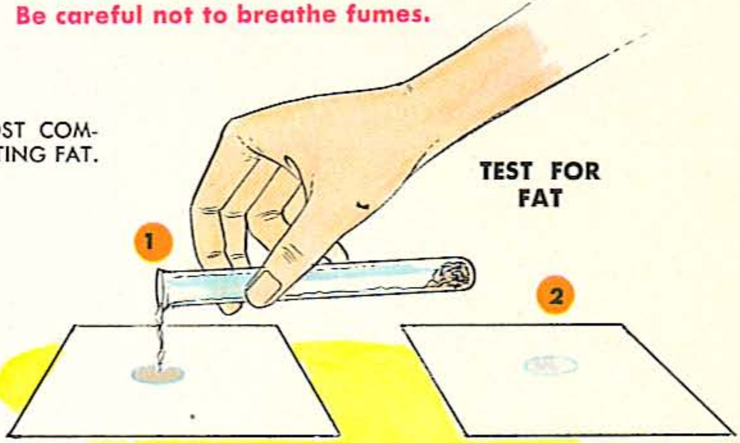

① CRUSH A COUPLE OF PEANUTS. DROP THEM IN A TEST TUBE. COVER THEM WITH CARBON TETRACHLORIDE AND LET STAND ABOUT 5 MINUTES. POUR A FEW DROPS ON A PIECE OF PAPER. LET CARBON TETRACHLORIDE EVAPORATE.

② LOOK AT THE PAPER AGAINST THE LIGHT. THE ALMOST TRANSPARENT "GREASE SPOT" IS A TEST FOR FAT.

TEST FOR GLYCEROL (GLYCERIN)

IN A DRY TEST TUBE ADD ¼ TEASPOON SODIUM BISULFATE TO 1 ml VEGETABLE OIL AND HEAT GENTLY. WAFT THE IRRITATING ODOR TOWARD YOU AND SNIFF CAUTIOUSLY. THE SMELL IS FROM ACROLEIN WHICH IS PRODUCED BY BREAKING DOWN THE GLYCERIN IN THE FAT.

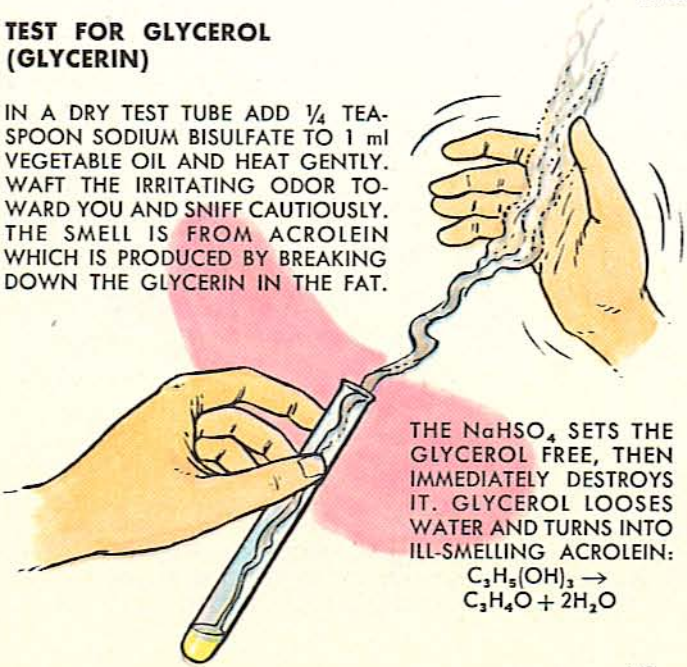

THE $NaHSO_4$ SETS THE GLYCEROL FREE, THEN IMMEDIATELY DESTROYS IT. GLYCEROL LOOSES WATER AND TURNS INTO ILL-SMELLING ACROLEIN:

$$C_3H_5(OH)_3 \rightarrow C_3H_4O + 2H_2O$$

FATTY ACIDS

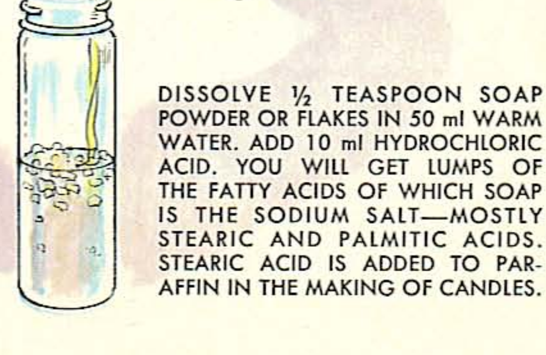

DISSOLVE ½ TEASPOON SOAP POWDER OR FLAKES IN 50 ml WARM WATER. ADD 10 ml HYDROCHLORIC ACID. YOU WILL GET LUMPS OF THE FATTY ACIDS OF WHICH SOAP IS THE SODIUM SALT—MOSTLY STEARIC AND PALMITIC ACIDS. STEARIC ACID IS ADDED TO PARAFFIN IN THE MAKING OF CANDLES.

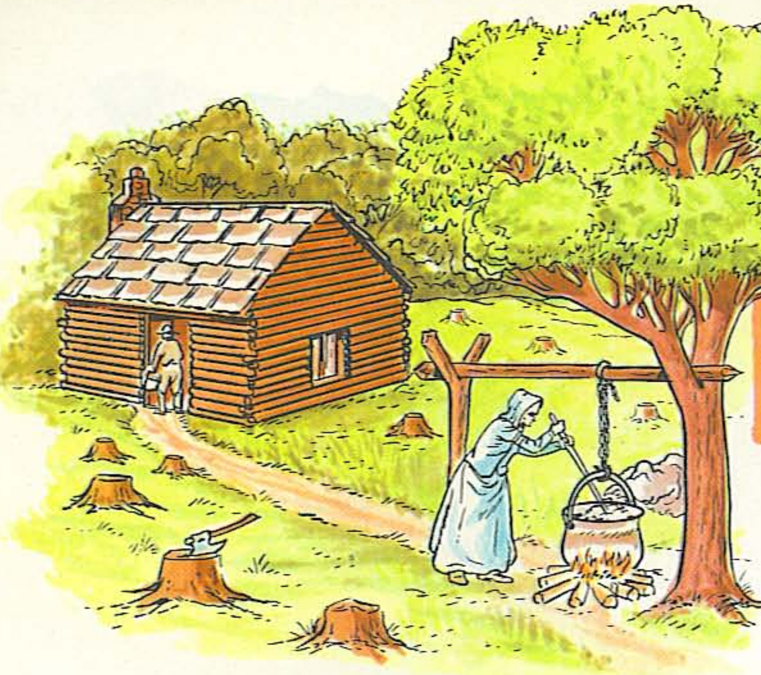

IN THE OLD-FASHIONED SOAP KETTLE, ONLY A FEW GALLONS OF SOAP COULD BE MADE AT ONE TIME.

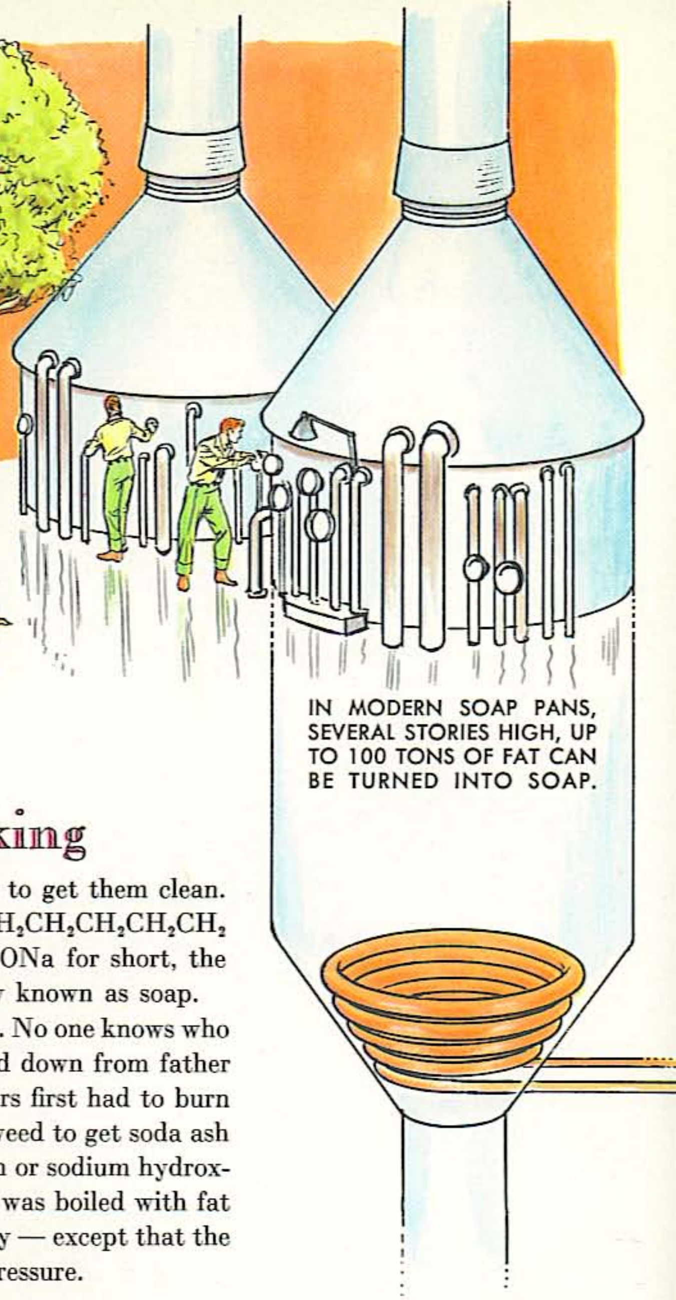

IN MODERN SOAP PANS, SEVERAL STORIES HIGH, UP TO 100 TONS OF FAT CAN BE TURNED INTO SOAP.

Soap and Soap Making

WHENEVER YOUR HANDS get dirty, it is an easy matter to get them clean. All you need is water and plenty of $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2COONa$ — $C_{17}H_{35}COONa$ for short, the sodium salt of stearic acid, a substance more generally known as soap.

Soap has been used for cleaning for thousands of years. No one knows who invented it — but the method for making it was passed down from father to son, from mother to daughter. The early soap makers first had to burn wood to get potash (K_2CO_3—see page 59) or dried seaweed to get soda ash (Na_2CO_3). This was treated with lime to make potassium or sodium hydroxide (KOH or NaOH — see page 45), and this, in turn, was boiled with fat to make soap. Very much the same method is used today — except that the boiling is done in tremendous soap pans under steam pressure.

STRONG SOAP BUBBLES RESULT WHEN YOU ADD GLYCERIN TO THE SOAP SOLUTION. HERE IS A RECIPE: 5 g SOAP, 100 ml WATER, AND 10 ml GLYCERIN.

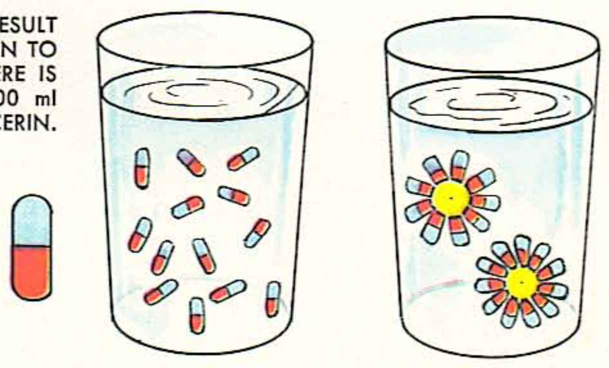

THIS IS THE WAY SCIENTISTS BELIEVE THAT SOAP ACTS: ONE END OF THE SOAP MOLECULE IS SOLUBLE IN WATER, THE OTHER END IN OIL. WHEN OIL IS SHAKEN UP IN SOAPY WATER, THE OIL DROPS ARE SURROUNDED BY THE SOAP MOLECULES DIPPING THE OIL-DISSOLVING ENDS INTO THE OIL. THE WATER-SOLUBLE ENDS HOLD THE OIL DROPLETS SUSPENDED.

MAKING SOAP

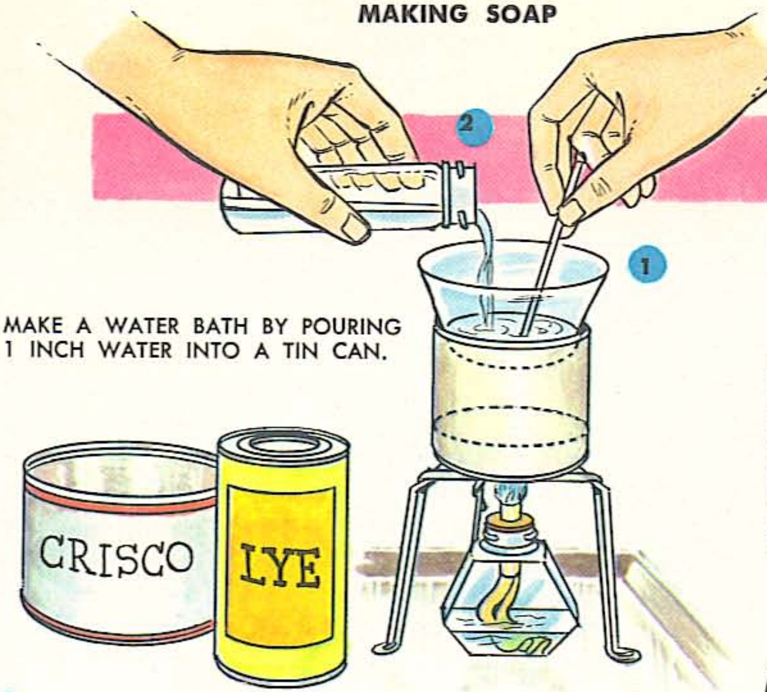

MAKE A WATER BATH BY POURING 1 INCH WATER INTO A TIN CAN.

1 MELT 10 g SHORTENING ("CRISCO" OR SIMILAR PRODUCT) IN A CUSTARD CUP ON THE WATER BATH.

2 DISSOLVE 5 g SODIUM HYDROXIDE (NaOH) IN 15 ml WATER. ADD 15 ml DENATURED ALCOHOL (TO SPEED UP THE ACTION). POUR THIS SOLUTION INTO THE MELTED SHORTENING WHILE STIRRING. CONTINUE HEATING AND STIRRING UNTIL A SMALL SAMPLE DISSOLVES COMPLETELY IN ½ TEST TUBE WATER. THE SOAP MAKING (SAPONIZATION) IS THEN COMPLETED.

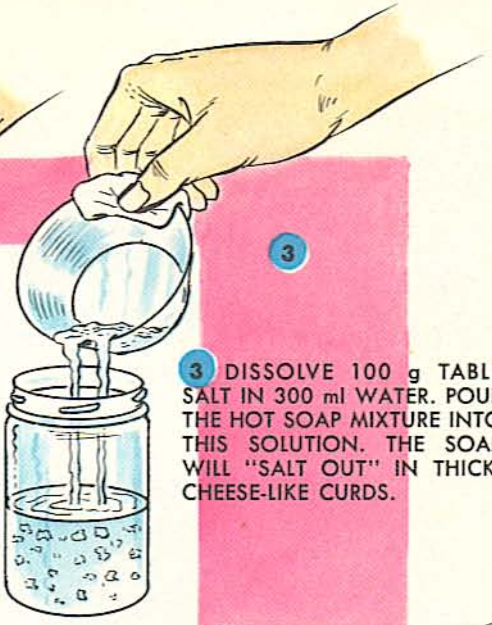

3 DISSOLVE 100 g TABLE SALT IN 300 ml WATER. POUR THE HOT SOAP MIXTURE INTO THIS SOLUTION. THE SOAP WILL "SALT OUT" IN THICK, CHEESE-LIKE CURDS.

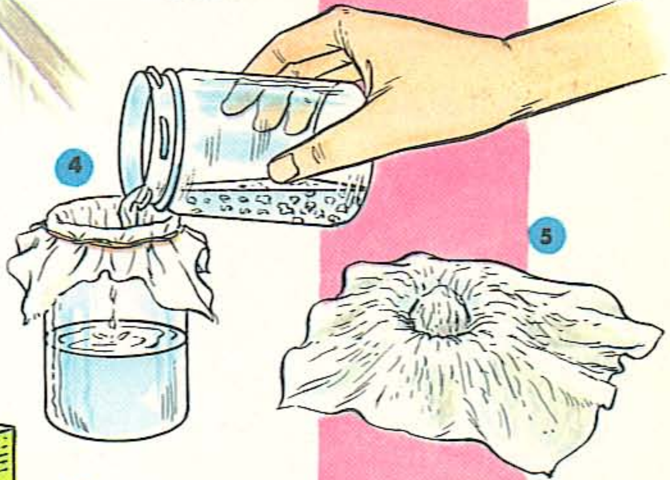

4 TIE A PIECE OF CHEESE CLOTH OVER THE TOP OF A JAR. POUR THE SALT SOLUTION WITH THE SOAP CURDS INTO CHEESE CLOTH AND LET SALT SOLUTION DRAIN OFF. WASH THE SOAP BY POURING TWO TEST TUBES OF ICE-COLD WATER THROUGH IT TO REMOVE MOST OF THE SALT THAT'S STILL ON IT.

5 FINALLY, SQUEEZE OUT THE WATER AND SPREAD OUT THE CHEESE CLOTH TO LET THE SOAP DRY.

TESTING SOAP AND DETERGENTS

DISSOLVE 1 g OF YOUR HOMEMADE SOAP IN 50 ml LUKEWARM WATER. ALSO MAKE SOLUTIONS IN 50 ml WATER OF 1 g TOILET SOAP, 1 g SOAP FLAKES, 1 g SOAP POWDER, 1 g POWDERED DETERGENT, AND 1 ml LIQUID DETERGENT.

JOY
Soap Flakes

1 POUR 10 ml OF THE SOAP AND DETERGENT SOLUTIONS INTO SEPARATE TEST TUBES. TEST EACH SOLUTION FOR ACID AND BASE WITH LITMUS PAPER AND PHENOLPHTHALEIN.

2 SHAKE 5 DROPS OF OIL INTO EACH SOLUTION. NOTE THE DIFFERENCE IN THE WAY THE SOLUTIONS MAKE EMULSION WITH OIL.

3 AGAIN, POUR 10 ml OF EACH SOLUTION INTO SEPARATE TEST TUBES. ADD 5 ml LIMEWATER TO EACH. SHAKE AND NOTICE THE DIFFERENCE IN THE AMOUNT OF FOAM MADE BY EACH SOLUTION IN THIS "HARD" WATER.

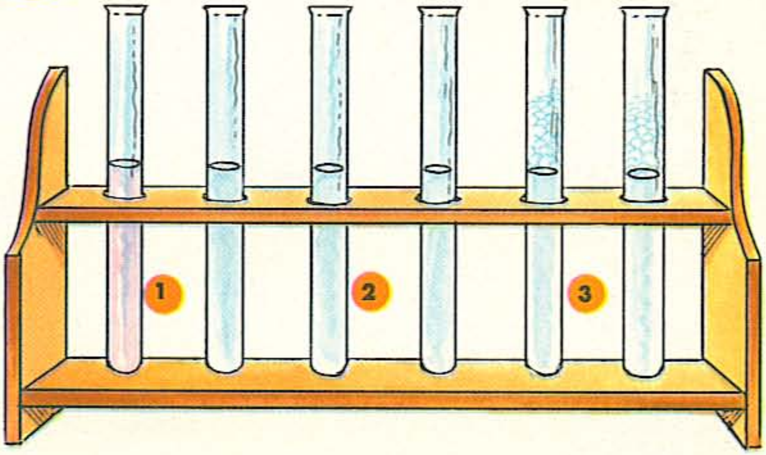

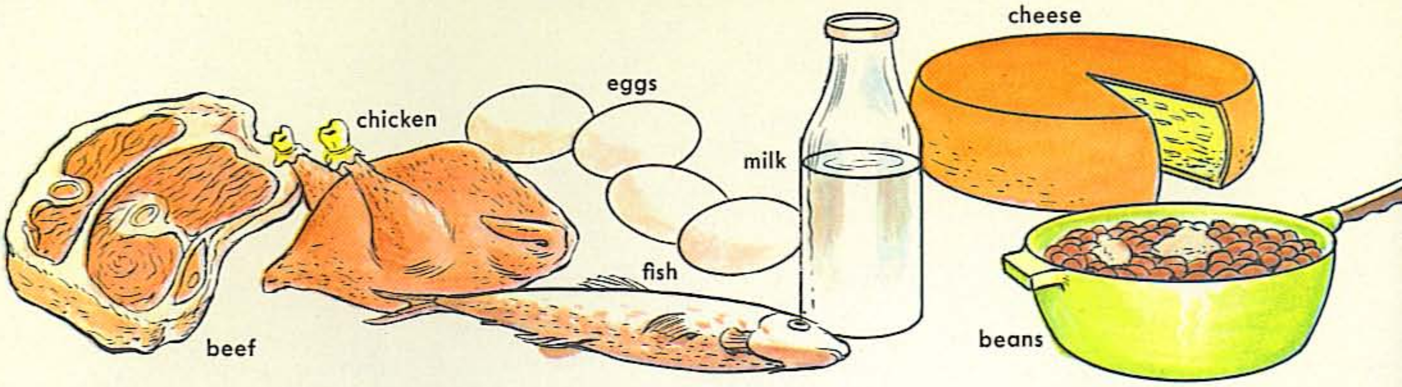

Proteins—the Body-Building Foods

AT ALMOST every meal, we look forward especially to the proteins: ham and eggs for breakfast, hamburgers or frankfurters for lunch, steak or chicken for dinner. We drink milk mostly for the sake of its proteins. Even many of our desserts are protein products — from ice cream to Jell-O.

While most other foodstuffs, such as carbohydrates and fats, consist of carbon, hydrogen, and oxygen, the proteins also contain nitrogen and, for the most part, sulfur. Their molecules are "giants" compared with the molecules of other chemical compounds. One of them, albumin in egg, has this estimated formula: $C_{696}H_{1125}O_{200}N_{190}S_{18}$.

Not all proteins are edible. You would hardly think of eating hair and nails, furs and feathers — yet these are all proteins. (CONTINUED ON PAGE 99)

PROTEIN IN EGG

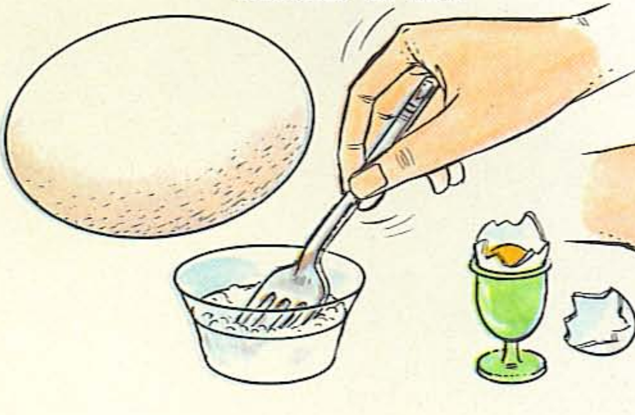

CRACK AN EGG. SEPARATE WHITE FROM YOLK BY LETTING WHITE FLOW INTO A CUP WHILE RETAINING YOLK IN EGG SHELL. BEAT WHITE WITH FORK.

THE PROTEIN IN EGG IS CALLED ALBUMIN

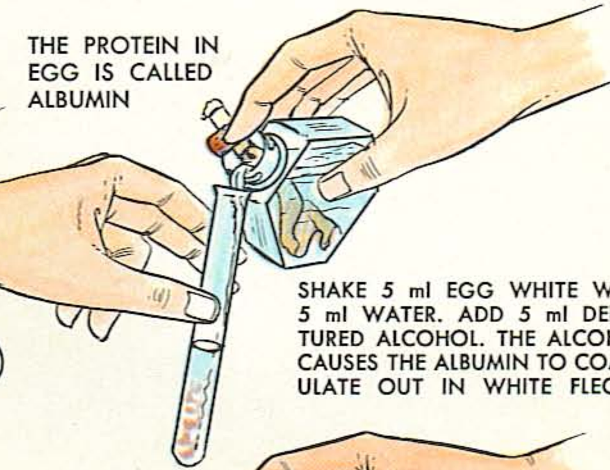

SHAKE 5 ml EGG WHITE WITH 5 ml WATER. ADD 5 ml DENATURED ALCOHOL. THE ALCOHOL CAUSES THE ALBUMIN TO COAGULATE OUT IN WHITE FLECKS.

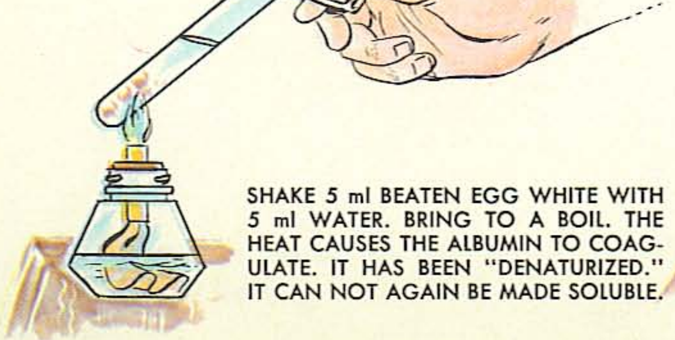

SHAKE 5 ml BEATEN EGG WHITE WITH 5 ml WATER. BRING TO A BOIL. THE HEAT CAUSES THE ALBUMIN TO COAGULATE. IT HAS BEEN "DENATURIZED." IT CAN NOT AGAIN BE MADE SOLUBLE.

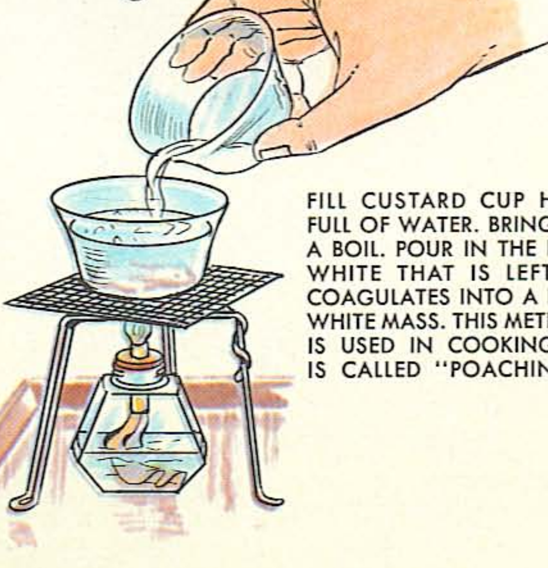

FILL CUSTARD CUP HALF FULL OF WATER. BRING TO A BOIL. POUR IN THE EGG WHITE THAT IS LEFT. IT COAGULATES INTO A FIRM WHITE MASS. THIS METHOD IS USED IN COOKING. IT IS CALLED "POACHING."

THE ITEMS ON THE TOP OF THESE TWO PAGES ALL CONTAIN PROTEINS.

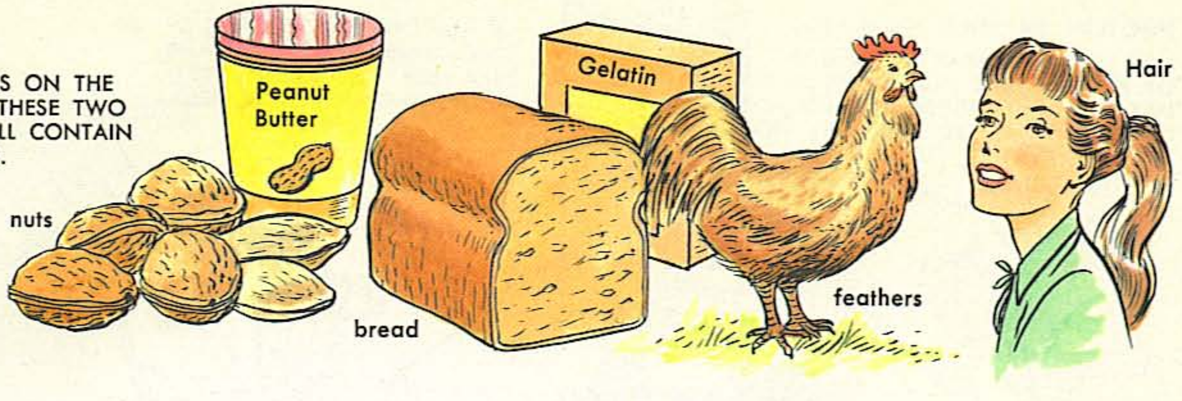

WHAT DOES ALBUMIN CONSIST OF?

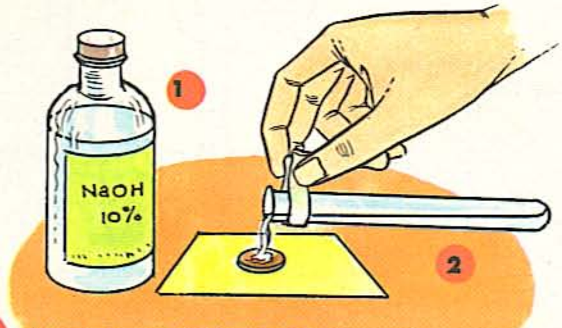

1 DROP A SMALL PIECE OF COAGULATED EGG WHITE INTO A TEST TUBE. COVER IT WITH 5 ml 10% NaOH SOLUTION. HEAT. WHITE GOES IN SOLUTION.

2 POUR A FEW DROPS OF THE EGG WHITE SOLUTION ONTO A BRIGHT SILVER COIN. IN A FEW MINUTES SILVER COIN TURNS BROWNISH-BLACK FROM SILVER SULFIDE, PROVING THAT ALBUMIN CONTAINS SULFUR.

1 PLACE A SMALL PIECE OF COAGULATED EGG WHITE ON A PIECE OF TIN. HEAT. VAPORS SMELL OF AMMONIA AND TURN WETTED RED LITMUS PAPER BLUE. AMMONIA IS NH$_3$. ALBUMIN MUST CONTAIN N AND H.

ALBUMIN IS FOUND IN EGGS, BLOOD, MILK, AND GRAIN.

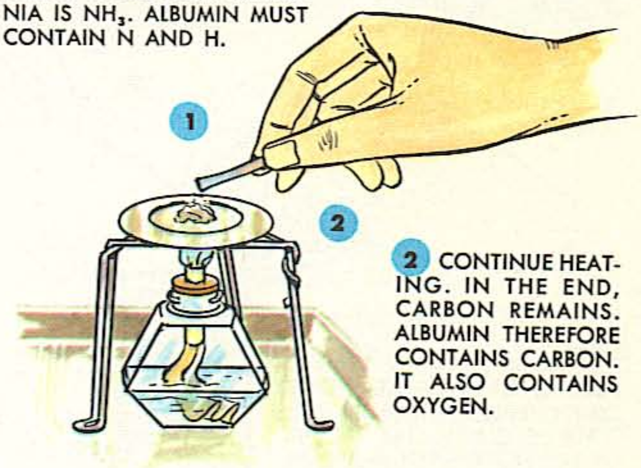

2 CONTINUE HEATING. IN THE END, CARBON REMAINS. ALBUMIN THEREFORE CONTAINS CARBON. IT ALSO CONTAINS OXYGEN.

TEST FOR SOLID WHITE PROTEIN

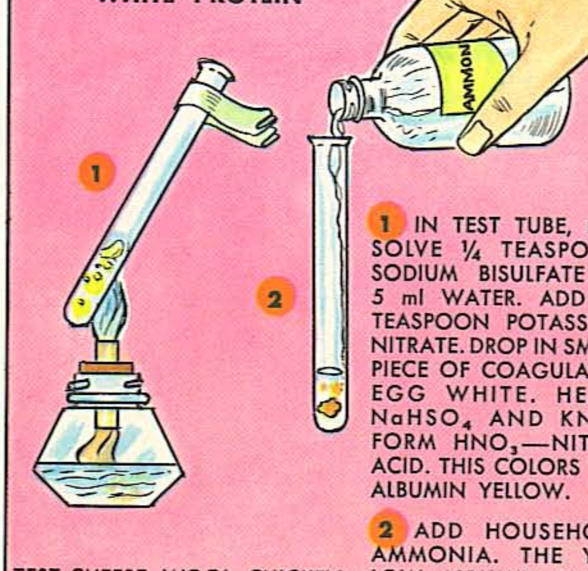

1 IN TEST TUBE, DISSOLVE ¼ TEASPOON SODIUM BISULFATE IN 5 ml WATER. ADD ¼ TEASPOON POTASSIUM NITRATE. DROP IN SMALL PIECE OF COAGULATED EGG WHITE. HEAT. NaHSO$_4$ AND KNO$_3$ FORM HNO$_3$—NITRIC ACID. THIS COLORS THE ALBUMIN YELLOW.

2 ADD HOUSEHOLD AMMONIA. THE YELLOW ALBUMIN TURNS BRIGHT ORANGE.

TEST CHEESE, WOOL, CHICKEN, LIMA BEANS THE SAME WAY.

WHAT DOES EGG YOLK CONTAIN?

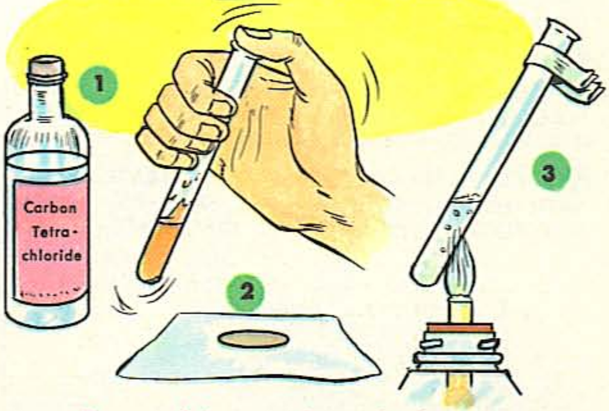

Be careful not to breathe fumes.

1 SHAKE 5 ml OF THE YOLK WITH 5 ml CARBON TETRACHLORIDE TO FIND OUT IF IT CONTAINS FAT.

2 POUR A LITTLE OUT ON PAPER. LET CARBON TETRACHLORIDE EVAPORATE. GREASE SPOT REMAINS.

3 HEAT THE MIXTURE. YOU GET A WHITE COAGULATION. YOLK AND WHITE BOTH CONTAIN ALBUMIN.

PROTEIN IN MILK

MILK IS AN IMPORTANT SOURCE OF PROTEIN. THE PROTEIN IN MILK IS CALLED CASEIN. CHEESE IS SPECIALLY TREATED CASEIN.

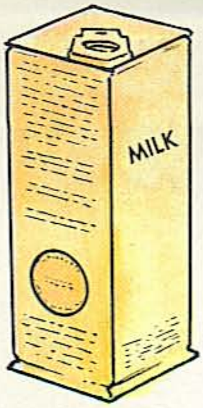

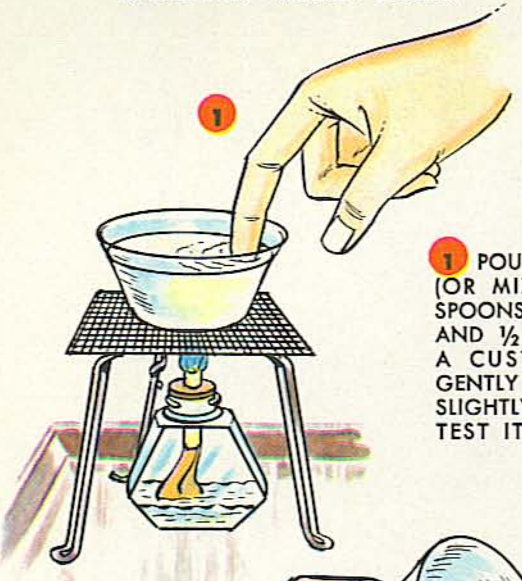

① POUR ½ CUP SKIM MILK (OR MIXTURE OF 8 TEASPOONS SKIM MILK POWDER AND ½ CUP WATER) INTO A CUSTARD CUP. HEAT GENTLY UNTIL IT FEELS JUST SLIGHTLY WARM WHEN YOU TEST IT WITH A FINGER.

② ADD ONE TEST TUBE FULL OF WHITE VINEGAR TO THE WARM SKIM MILK. THE CASEIN SEPARATES IN HEAVY, WHITE CURDS.

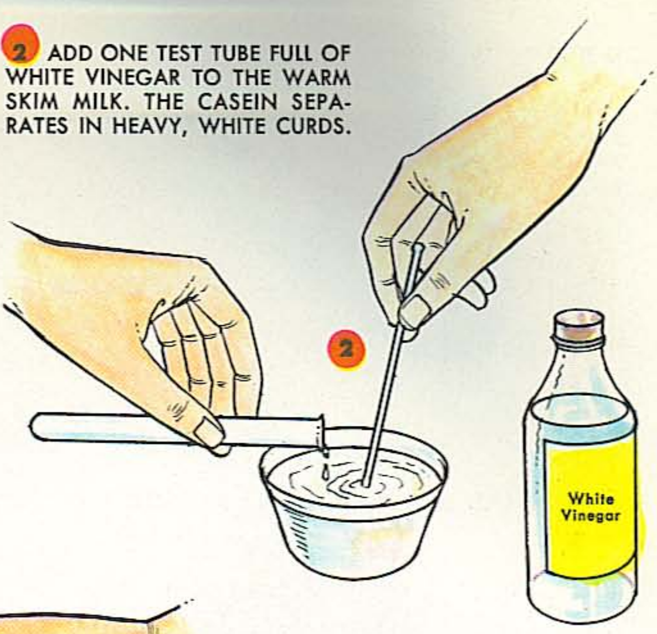

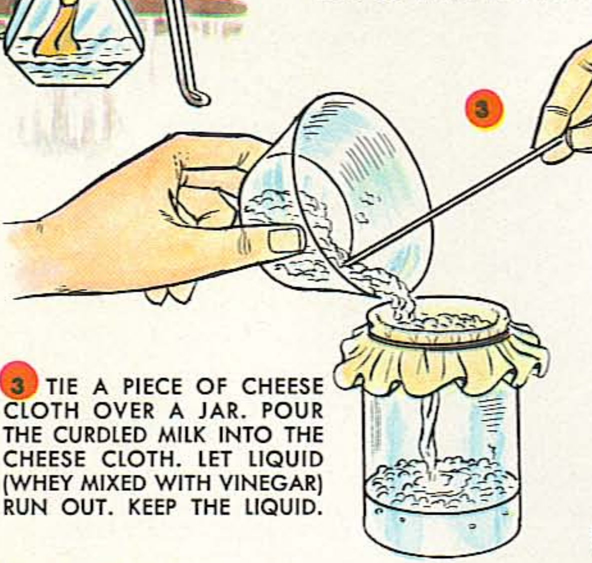

③ TIE A PIECE OF CHEESE CLOTH OVER A JAR. POUR THE CURDLED MILK INTO THE CHEESE CLOTH. LET LIQUID (WHEY MIXED WITH VINEGAR) RUN OUT. KEEP THE LIQUID.

④ FOLD CHEESE CLOTH UP AROUND THE CASEIN. DIP THE BAG IN WATER AND SQUEEZE SEVERAL TIMES TO WASH OUT WHEY AND VINEGAR.

⑤ SQUEEZE THE CASEIN ALMOST DRY. SPREAD OUT THE CHEESE CLOTH TO LET THE CASEIN DRY.

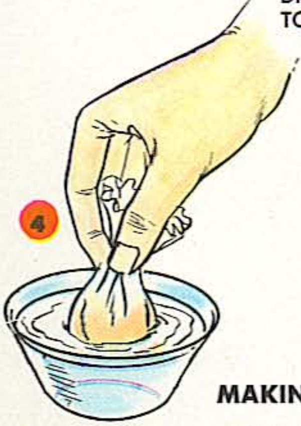

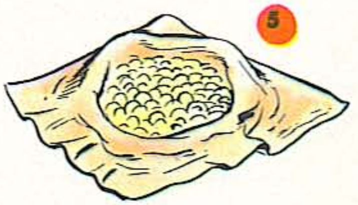

WHAT ELSE IS IN MILK?

① POUR THE VINEGAR-MIXED WHEY INTO A CUSTARD CUP AND BRING IT TO A BOIL. YOU WILL SEE TINY WHITE FLECKS. THESE ARE ALBUMIN COAGULATED OUT BY THE HEAT.

② FILTER THE WHEY. TEST THE FILTRATE WITH FEHLING SOLUTION (SEE PAGE 85). MILK SUGAR GIVES RED Cu_2O PRECIPITATE.

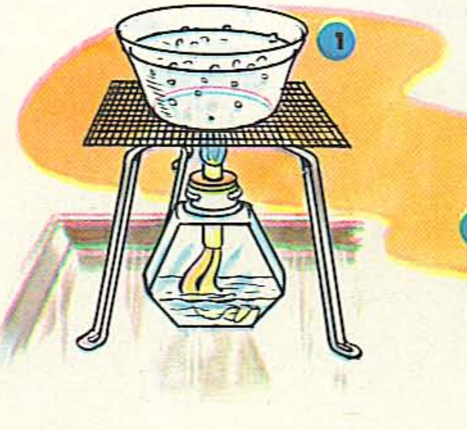

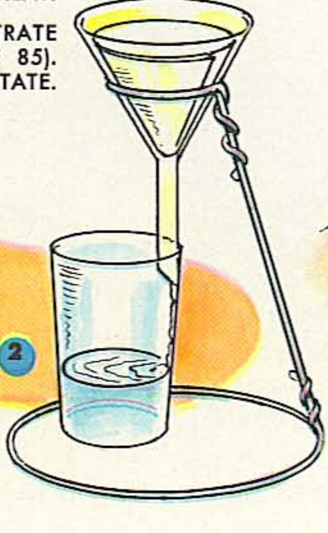

MAKING CASEIN GLUE

SOFTEN 4 g CASEIN WITH 4 ml WATER. SHAKE UP 1 g CALCIUM OXIDE IN 4 ml WATER. POUR THE CALCIUM OXIDE MIXTURE INTO THE CASEIN WHILE STIRRING. THE RESULTING SMOOTH PASTE IS AN EXCELLENT GLUE FOR PAPER AND FOR WOOD.

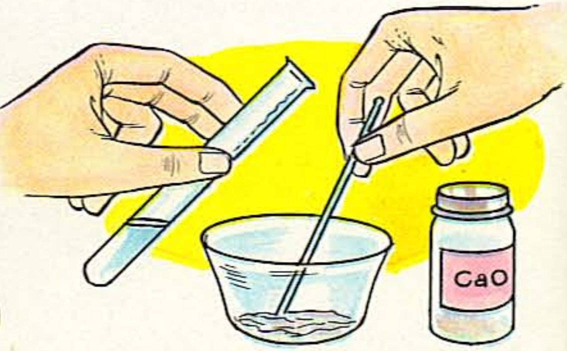

GELATIN IS A PROTEIN

GELATIN IS MADE FROM ANIMAL BONES AND HIDES.

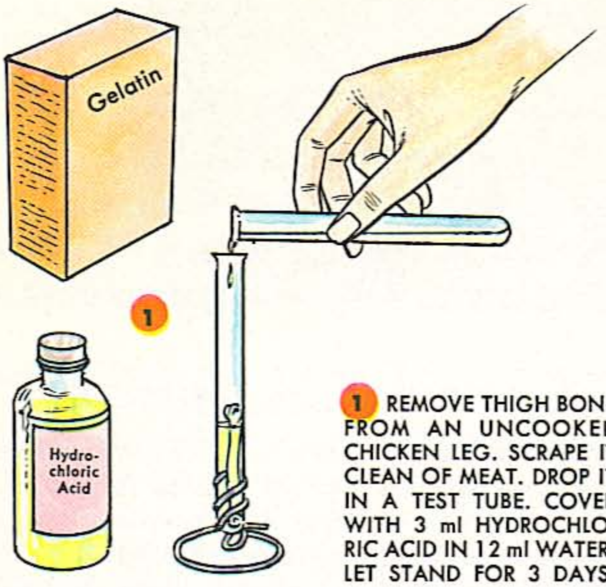

1 REMOVE THIGH BONE FROM AN UNCOOKED CHICKEN LEG. SCRAPE IT CLEAN OF MEAT. DROP IT IN A TEST TUBE. COVER WITH 3 ml HYDROCHLORIC ACID IN 12 ml WATER. LET STAND FOR 3 DAYS.

2 THE DILUTED HYDROCHLORIC ACID DISSOLVES THE CALCIUM SALTS IN THE BONE, LEAVING A FLEXIBLE SUBSTANCE CALLED OSSEIN. WASH OFF THE ACID. EXTRACT THE GELATIN IN THE OSSEIN BY BOILING IN WATER.

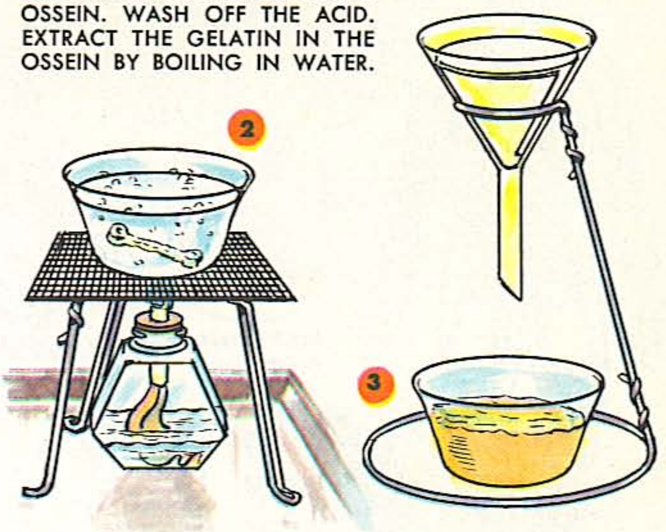

3 FILTER THE SOLUTION. ON COOLING, IT BECOMES JELLY-LIKE. IT HAS TURNED FROM "SOL" TO "GEL."

Proteins—Continued

You are certain to be familiar with three common, pure proteins: albumin in eggs, casein in milk, and gelatin.

ALBUMIN — Egg white contains around 13 per cent albumin — from Latin *albus*, white.

When you shake up egg white with water, you get what looks like an almost clear solution. But this is not a "true" solution such as you get when you dissolve salt or sugar — it is another kind of "solution" called a "colloidal dispersion." For more about colloidal dispersions, see pages 100-101.

As long as egg white is kept cool, it stays transparent and almost liquid. But what happens when you heat it? You know from frying or boiling an egg: It hardens — coagulates — into a solid white mass which you can not again "dissolve" in water. The chemist's term for this change is "denaturation" — the egg white has changed its nature.

CASEIN — Casein is another protein that goes into your diet. Some of the casein you drink (milk), some of it you eat (ice cream and cheese).

In cheese making, the casein is separated from the liquid part of the milk — the whey. It is then pressed and stored until ripe. The flavors of cheeses are caused mostly by esters created during the ripening.

GELATIN — Gelatin is a protein made from animal skins and bones, horns and hooves.

Gelatin behaves in a peculiar manner with water. In cold water it merely swells, but in hot water it "dissolves" readily, forming a colloidal dispersion. As long as you keep this dispersion warm, it remains in a liquid form that is called a "sol." When cooled, it turns into a jelly-like form called a "gel."

TEST FOR LIQUID PROTEINS

MIX 5 ml OF LIQUID TO BE TESTED WITH 5 ml 10% SOLUTION OF NaOH. ADD TWO DROPS OF A 2% SOLUTION OF COPPER SULFATE (1 g IN 50 ml WATER). LIQUID WILL TURN REDDISH-VIOLET.

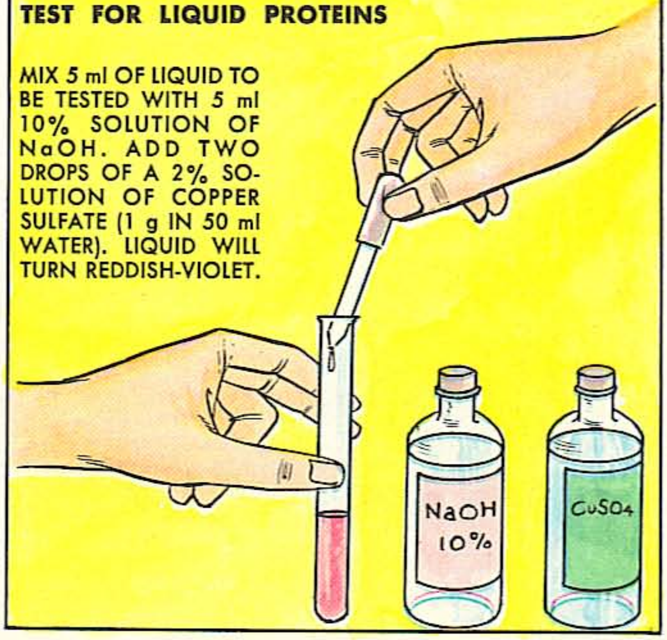

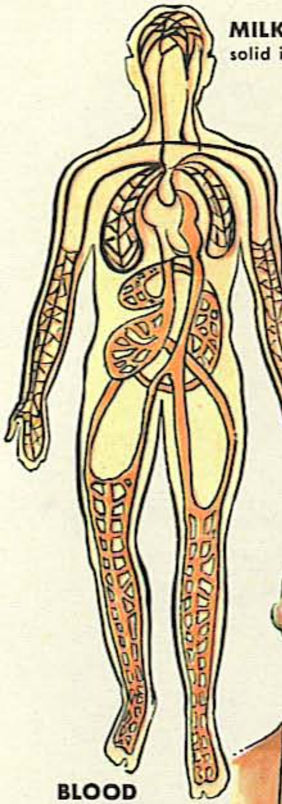

BLOOD
solid in liquid

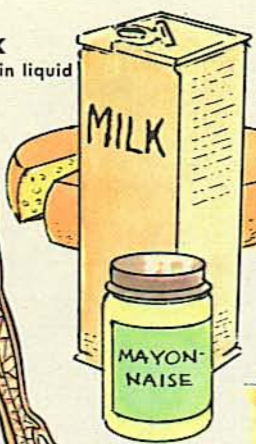

MILK
solid in liquid

CHEESE
liquid in solid

MAYONNAISE
liquid in liquid

IN 1862, A SCOTTISH CHEMIST, THOMAS GRAHAM, PRESENTED HIS IDEAS ABOUT COLLOIDS.

Colloidal Dispersions

WOULD YOU WALK up to a soda fountain and order "a triple, chocolate-flavored colloidal dispersion"? No? Yet that's what you do when you ask for a chocolate sundae. Ice cream is a colloidal dispersion of solids in a liquid; so is chocolate syrup. Whipped cream is a colloidal dispersion of air in a liquid.

It was a Scot, Thomas Graham, who explained colloids, in 1862. He noticed that some solutions passed through parchment paper, others didn't. He discovered that most of those that filtered through were of chemicals that formed crystals — he called them "crystalloids." The others he called "colloids" — from Greek *kollodes*, glue-like.

When a colloid is mixed with water, it does not form a solution but a dispersion. In a solution, the molecules of the dissolved chemical are too small to be seen even with the strongest microscope. In a colloidal dispersion, the much larger particles can be seen in an ultra-microscope — and you can see them as a light effect when you pass a light beam through the dispersion.

Colloidal dispersions can be formed by gases, liquids, and solids. Eight combinations are possible:

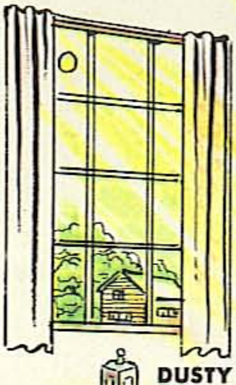

DUSTY AIR
solid in gas

COLORED GLASS
solid in solid

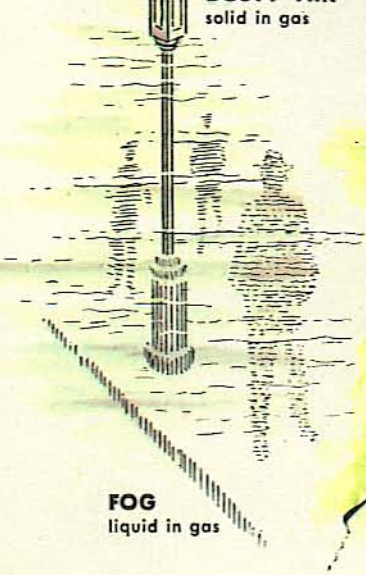

FOG
liquid in gas

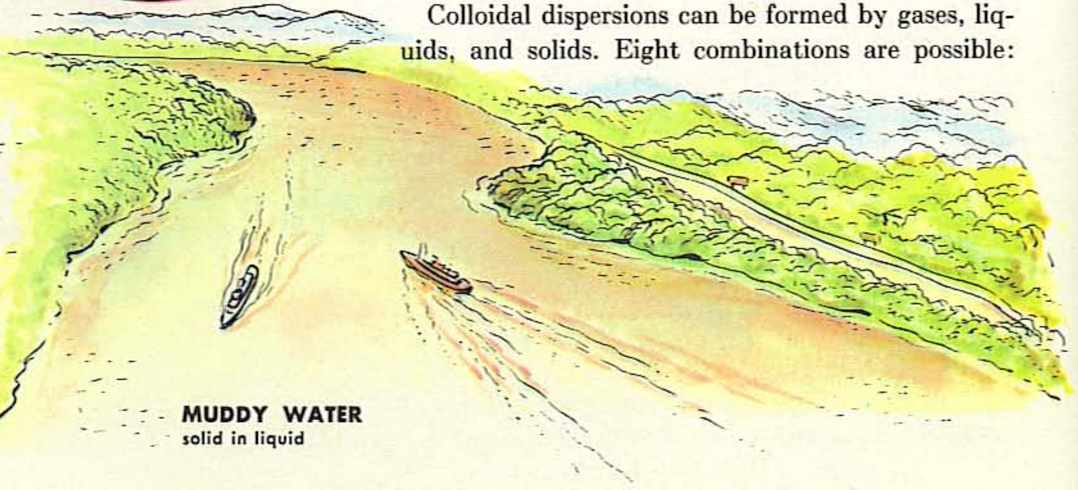

MUDDY WATER
solid in liquid

LIGHT TEST FOR COLLOIDS

THE PARTICLES OF A COLLOIDAL DISPERSION REFLECT LIGHT AND MAKE THE PATH OF A LIGHT BEAM VISIBLE.

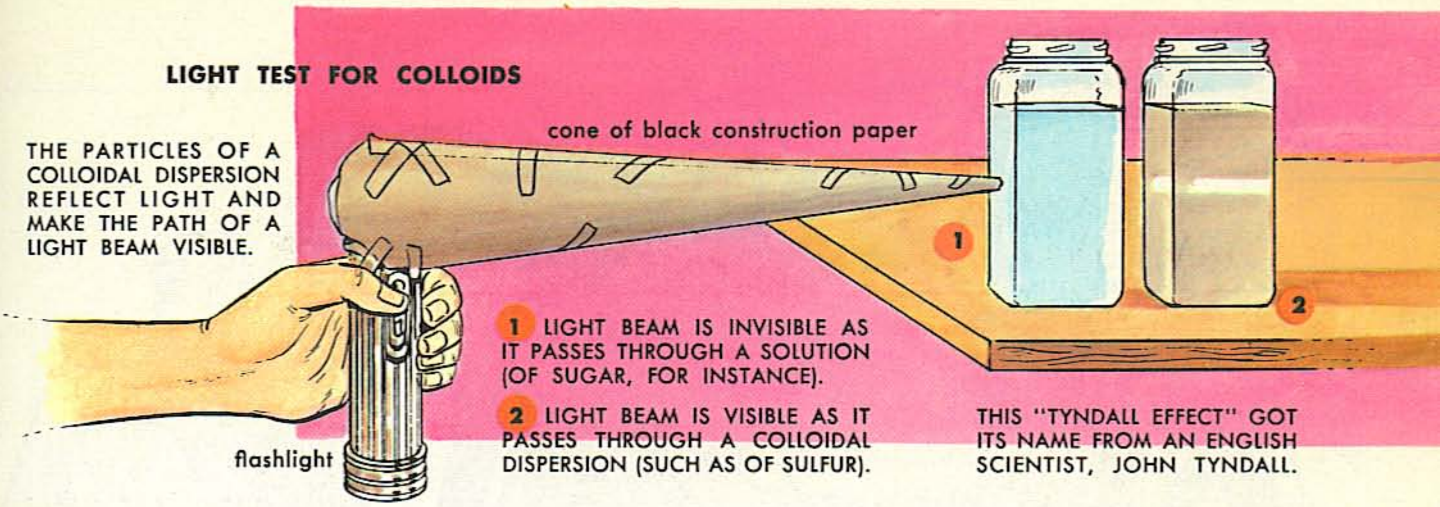
cone of black construction paper
flashlight
1
2

1 LIGHT BEAM IS INVISIBLE AS IT PASSES THROUGH A SOLUTION (OF SUGAR, FOR INSTANCE).

2 LIGHT BEAM IS VISIBLE AS IT PASSES THROUGH A COLLOIDAL DISPERSION (SUCH AS OF SULFUR).

THIS "TYNDALL EFFECT" GOT ITS NAME FROM AN ENGLISH SCIENTIST, JOHN TYNDALL.

gases in liquids and in solids; liquids in gases, in other liquids, and in solids; solids in gases, in liquids, and in other solids. The illustrations show some of these possibilities — you can think of many others.

The colloidal state is important to life. It is the way in which we get most of our food, the way we digest it, and the way the blood carries nourishment throughout our bodies.

IN **PEPTIZATION,** LARGE PARTICLES ARE BROKEN DOWN INTO SMALLER PARTICLES OF COLLOIDAL SIZE.

1 SHAKE UP 1 g STARCH WITH 100 ml COLD WATER. IF LEFT UNDISTURBED, STARCH QUICKLY SETTLES TO BOTTOM.

2 POUR THE MIXTURE OF STARCH AND WATER INTO A CUSTARD CUP. BRING TO A BOIL, THEN COOL. STARCH HAS NOW FORMED A COLLOIDAL DISPERSION.

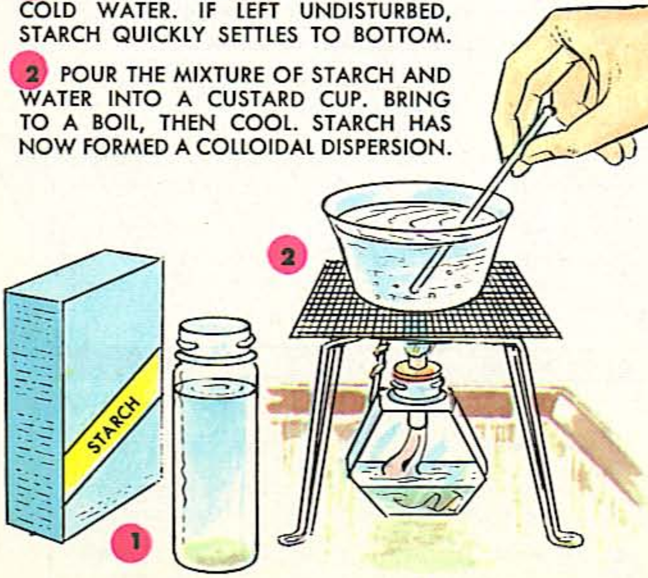

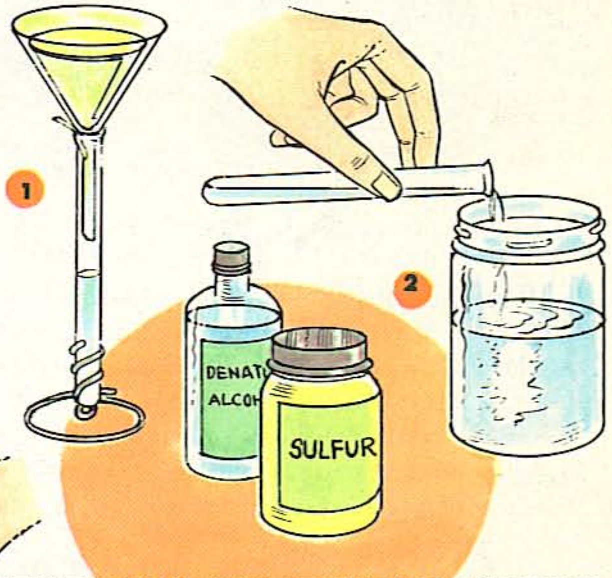

IN **COAGULATION,** MANY MOLECULES OF A SUBSTANCE JOIN TOGETHER INTO PARTICLES OF COLLOIDAL SIZE.

1 SHAKE 1 g FLOWERS OF SULFUR WITH 10 ml DENATURED ALCOHOL. A SMALL AMOUNT OF SULFUR GOES IN SOLUTION. FILTER OUT THE UNDISSOLVED SULFUR.

2 POUR THE ALCOHOLIC SOLUTION OF SULFUR INTO A LARGE AMOUNT OF WATER. YOU WILL SEE A WHITE CLOUD OF FINELY DISPERSED COLLOIDAL SULFUR.

IN **EMULSIFICATION,** ONE LIQUID IS DISPERSED IN ANOTHER. EMULSIONS CAN BE TEMPORARY OR PERMANENT.

1 SHAKE 5 ml KEROSENE AND 5 ml WATER TOGETHER IN A TEST TUBE. LET STAND FOR A SHORT TIME. LIQUIDS SEPARATE. THE EMULSION WAS TEMPORARY.

2 SHAKE 5 ml KEROSENE WITH SOLUTION OF ½ g SOAP IN 5 ml WARM WATER. THEN LET STAND. LIQUIDS DO NOT SEPARATE. THIS IS A PERMANENT EMULSION.

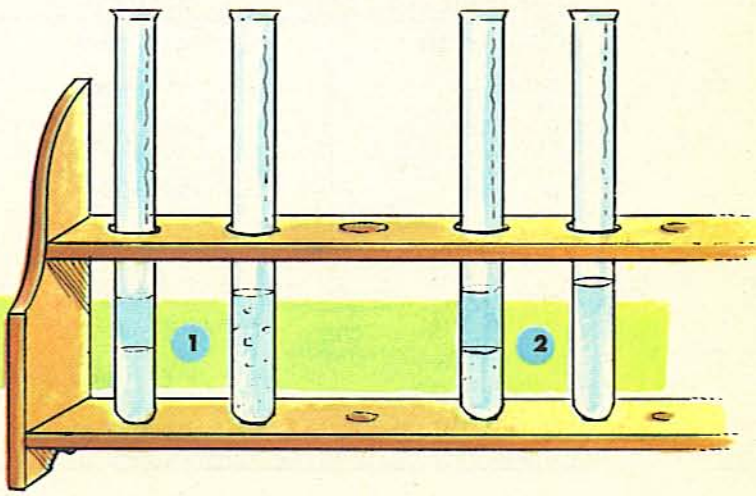

VEGETABLE FIBERS COME FROM PLANTS: COTTON, FLAX (LINEN).

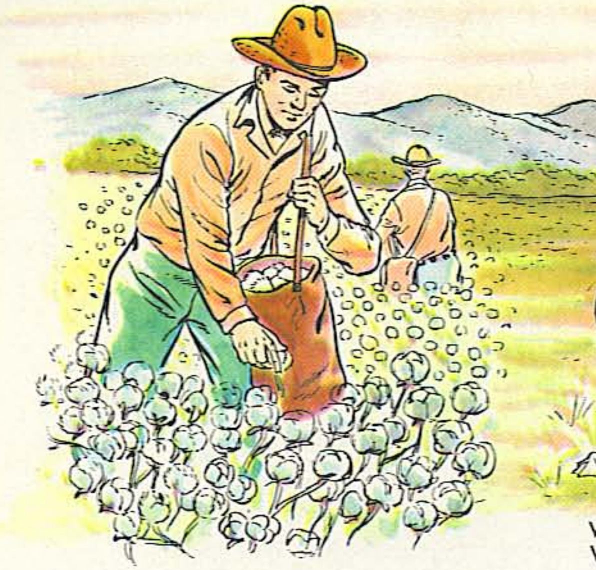

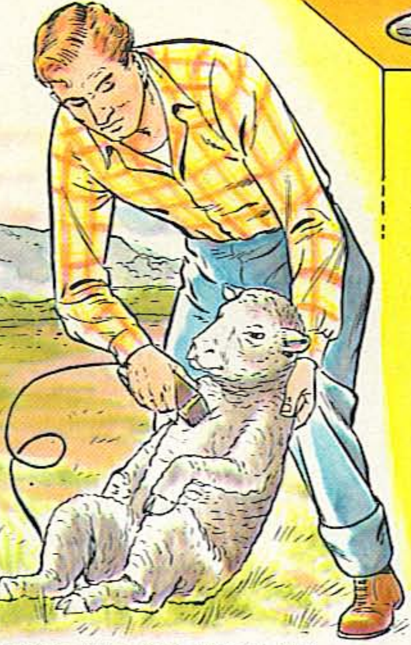

WOOL AND SILK (FROM SILK WORMS) ARE ANIMAL FIBERS.

ARTIFICIAL FIBERS ARE VERY POPULAR: NYLON, DACRON, ORLON.

Natural and Artificial Fibers

It would be tough to get along without fibers in the modern world. Fibers are spun into thread, and the thread is made into cloth for clothing and bedsheets, curtains and towels, and many other things around the house. Fibers also go into such articles as string and rope, rugs and auto tires. Some of these fibers come from the plant and animal worlds, others are manufactured synthetically with coal or petroleum for their starting point.

Fibers belong in different groups of chemical compounds. Animal fibers are proteins; vegetable fibers are cellulose. Artificial fibers such as nylon, Orlon and Dacron are very complex chemical compounds and have enormously long molecules.

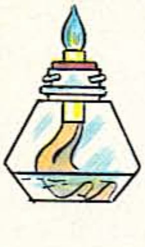

BURNING TEST FOR FIBERS

CUT HALF-INCH STRIPS OF DIFFERENT FABRICS. IGNITE EACH STRIP IN TURN. NOTICE HOW FABRIC BURNS, THE SMELL, AND ASH LEFT BEHIND.

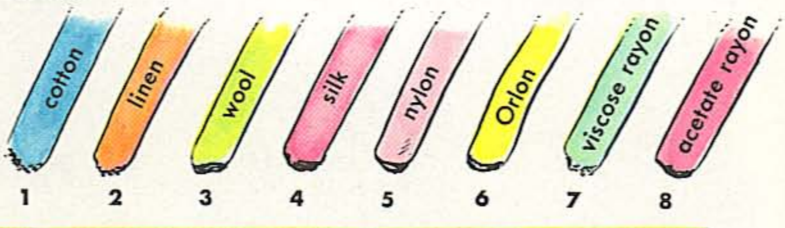

	KIND	FLAME	SMELL	ASH
1	COTTON	Rapid, yellow flame	Like burning paper	Small, fine, gray
2	LINEN	Fairly fast, yellow flame	Like cotton	Like cotton
3	WOOL	Slow, sizzling flame	Like burning hair	Hollow, black bead, easy to crush
4	SILK	Small, slow flame	Like wool	Shiny, round bead, easy to crush
5	NYLON	Melts; no flame	Like celery	Melts to black bead, hard to crush
6	ORLON	Melts and burns	Like broiled fish	Black bead, hard to crush
7	VISCOSE RAYON	Rapid, yellow flame	Like cotton	Like cotton
8	CELLULOSE ACETATE	Rapid flame with small sparks; melts	Like vinegar	Black bead, hard to crush

CHEMICAL TESTS FOR FIBERS

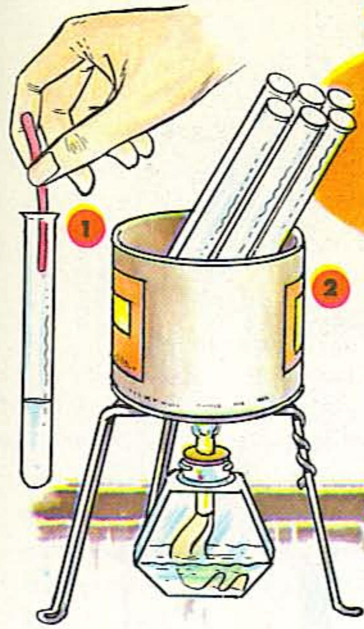

1 POUR 5 ml 10% NaOH SOLUTION INTO EACH OF SIX TEST TUBES AND DROP IN STRIPS OF SIX KINDS OF CLOTH. MARK EACH TEST TUBE SO YOU KNOW WHAT IS IN EACH.

2 PLACE TEST TUBES IN A CAN OF HOT WATER. BOIL FOR TEN MINUTES.

3 PLACE TEST TUBES IN STAND. NOTE RESULT. WOOL AND SILK HAVE DISSOLVED, THE OTHERS NOT.

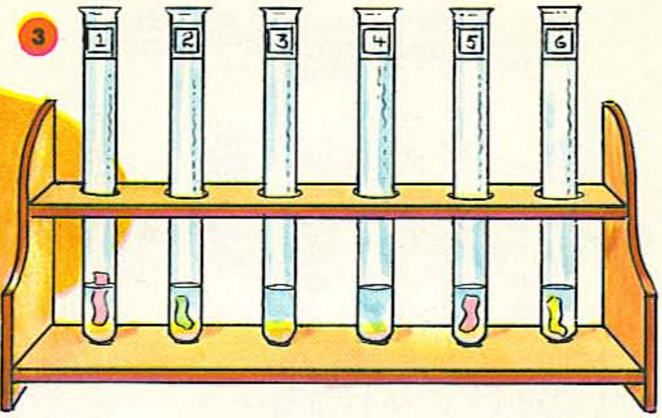

TRY SAME EXPERIMENT WITH STRONG HCl. SILK AND RAYON DISSOLVE. BUT THE WOOL DOES NOT.

MAKING RAYON

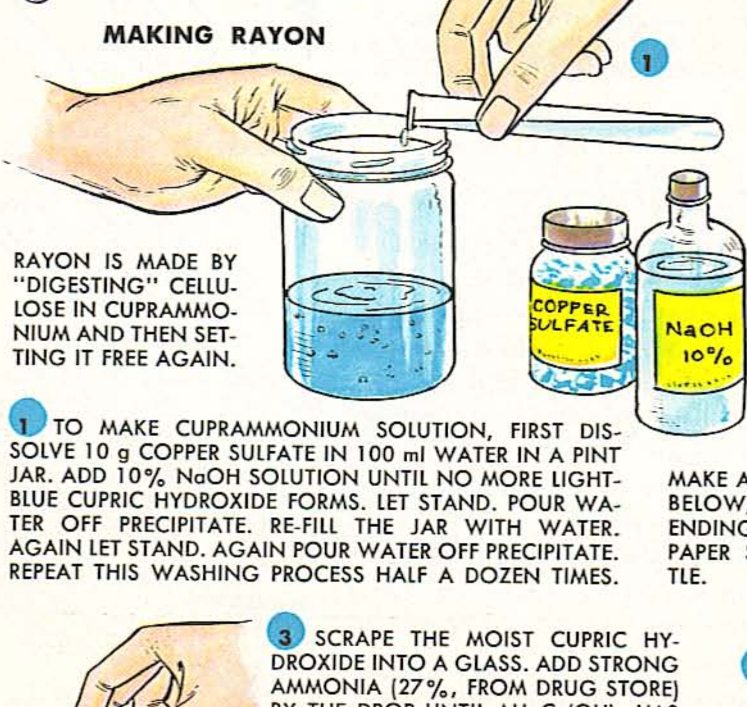

RAYON IS MADE BY "DIGESTING" CELLULOSE IN CUPRAMMONIUM AND THEN SETTING IT FREE AGAIN.

1 TO MAKE CUPRAMMONIUM SOLUTION, FIRST DISSOLVE 10 g COPPER SULFATE IN 100 ml WATER IN A PINT JAR. ADD 10% NaOH SOLUTION UNTIL NO MORE LIGHT-BLUE CUPRIC HYDROXIDE FORMS. LET STAND. POUR WATER OFF PRECIPITATE. RE-FILL THE JAR WITH WATER. AGAIN LET STAND. AGAIN POUR WATER OFF PRECIPITATE. REPEAT THIS WASHING PROCESS HALF A DOZEN TIMES.

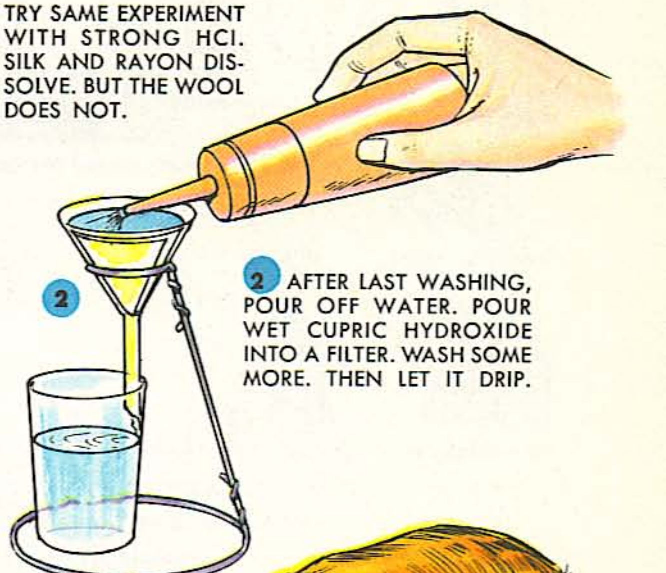

2 AFTER LAST WASHING, POUR OFF WATER. POUR WET CUPRIC HYDROXIDE INTO A FILTER. WASH SOME MORE. THEN LET IT DRIP.

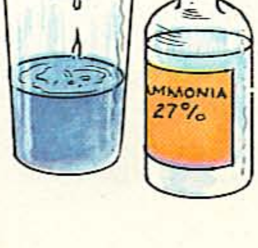

3 SCRAPE THE MOIST CUPRIC HYDROXIDE INTO A GLASS. ADD STRONG AMMONIA (27%, FROM DRUG STORE) BY THE DROP UNTIL ALL $Cu(OH)_2$ HAS DISSOLVED AND HAS BECOME DEEP-BLUE $Cu(NH_3)_4(OH)_2$. THIS SOLUTION IS CALLED "SCHWEITZER'S REAGENT."

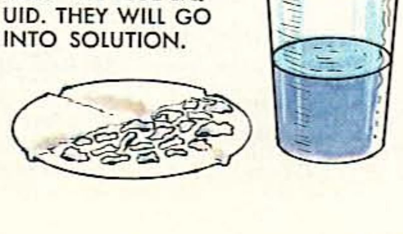

4 TEAR UP 3 TO 4 PIECES OF FILTER PAPER. STIR THEM INTO THE BLUE LIQUID. THEY WILL GO INTO SOLUTION.

MAKE APPARATUS AS SHOWN BELOW, WITH GLASS TUBE ENDING IN FINE JET TIP. POUR PAPER SOLUTION INTO BOTTLE.

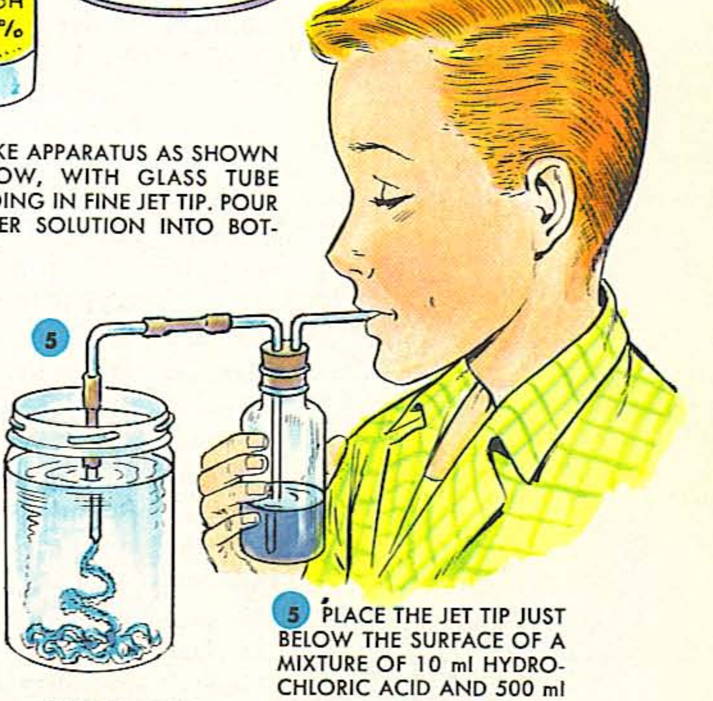

5 PLACE THE JET TIP JUST BELOW THE SURFACE OF A MIXTURE OF 10 ml HYDROCHLORIC ACID AND 500 ml WATER. BLOW. AS BLUE LIQUID STREAMS OUT INTO THE DILUTED ACID, IT TURNS INTO WHITISH STRAND OF RAYON THAT SETTLES ON BOTTOM.

THE MAKING OF A TYPICAL THERMOSETTING PLASTIC PHENOLICS

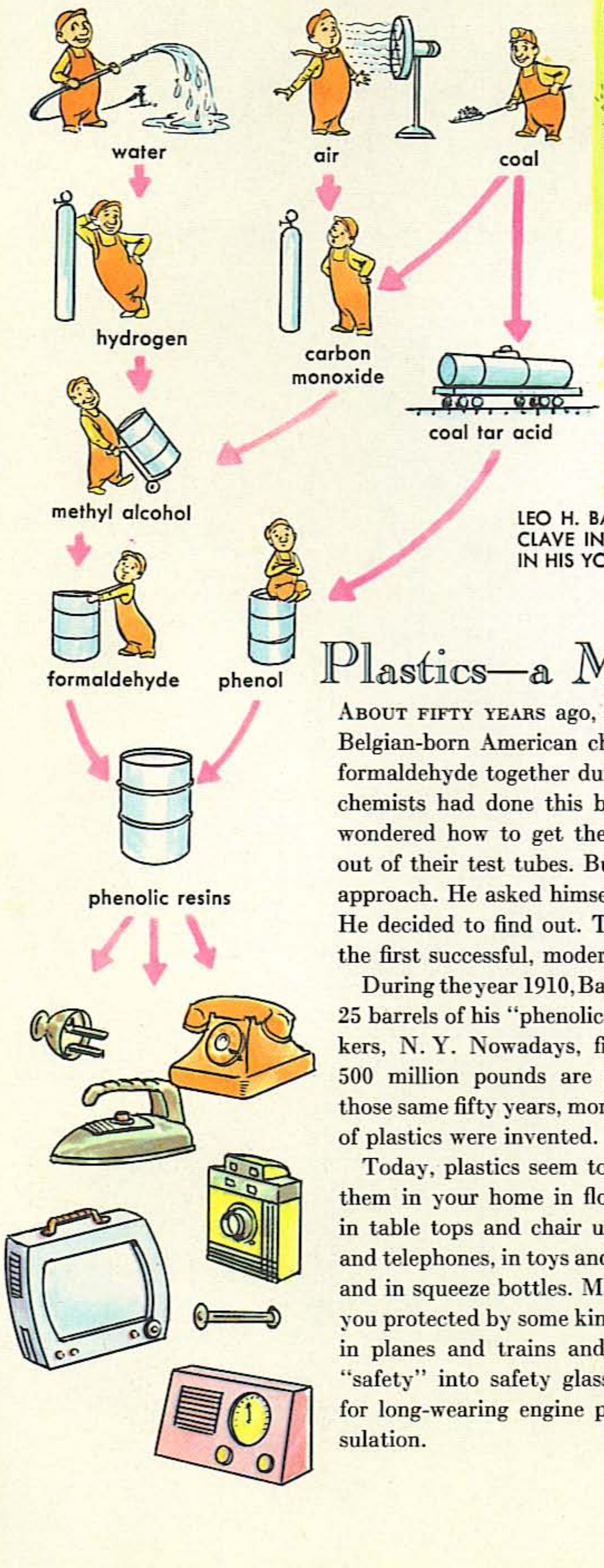

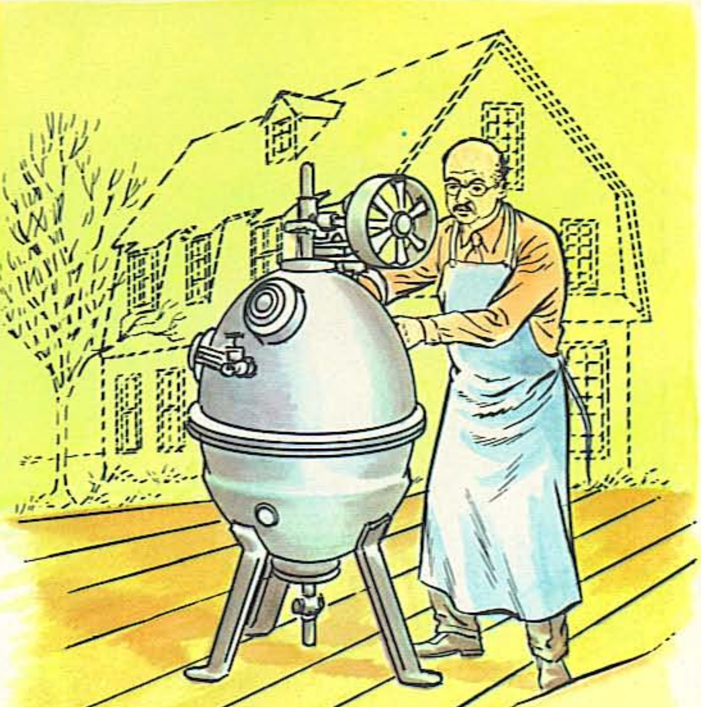

LEO H. BAEKELAND WITH THE AUTOCLAVE IN WHICH HE MADE BAKELITE IN HIS YONKERS, N. Y., LABORATORY.

Plastics—a Modern Giant

About fifty years ago, Dr. Leo H. Baekeland, a Belgian-born American chemist, mixed phenol and formaldehyde together during an experiment. Other chemists had done this before Baekeland and had wondered how to get the messy goo that resulted out of their test tubes. But Baekeland had another approach. He asked himself, "What is it good for?" He decided to find out. The result was Bakelite — the first successful, modern plastic.

During the year 1910, Baekeland produced less than 25 barrels of his "phenolic" plastic in a barn in Yonkers, N. Y. Nowadays, fifty years later, close to 500 million pounds are produced yearly. During those same fifty years, more than a dozen other types of plastics were invented.

Today, plastics seem to be everywhere. You find them in your home in flooring and wall coverings, in table tops and chair upholstery, in TV cabinets and telephones, in toys and games, in rigid containers and in squeeze bottles. Much of your food comes to you protected by some kind of plastic. They are used in planes and trains and cars. A plastic puts the "safety" into safety glass. Other plastics are used for long-wearing engine parts and for electrical insulation.

HEAT TEST

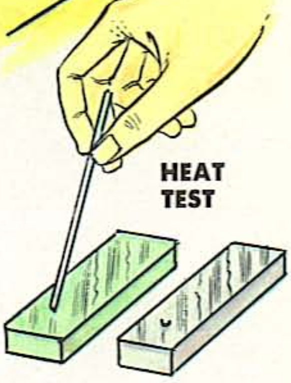

HEAT TIP OF GLASS ROD SLOWLY IN FLAME OF ALCOHOL BURNER. PRESS HOT TIP AGAINST PLASTIC. IT MAKES A DENT IN THERMOPLASTIC, NOT IN THE THERMOSETTING.

BURNING TEST

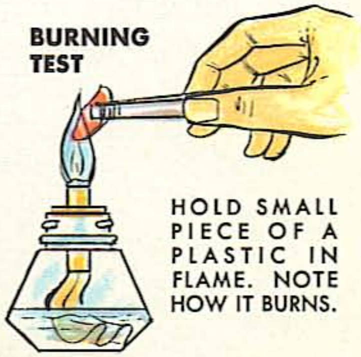

HOLD SMALL PIECE OF A PLASTIC IN FLAME. NOTE HOW IT BURNS.

MOST THERMOSETTING PLASTICS GIVE OFF STRONG ODOR BUT DO NOT BURN. MOST THERMOPLASTICS BURN BUT SOME OF THEM STOP BURNING WHEN REMOVED FROM FLAME.

Plastics are made from a few simple raw materials — some just from water, air, and coal, others with the help of petroleum or natural gas, limestone and salt. The plastics chemist breaks down the comparatively simple molecules of these materials, then builds them up anew into very complex molecules.

Plastics may be divided into two main groups according to their special properties. One group consists of the thermosetting plastics. These can be molded by heat and pressure, but can not be remelted and remolded. They are along the lines of egg white which, once set by heat, stays set. The phenolics and ureas are important thermosetting plastics.

The other group contains the thermoplastics. These are soft when heated, hard when cooled, but can be softened and hardened repeatedly. You can compare them to sulfur and candle wax. The polyethylenes, polystyrenes, vinyls, and acrylics are in the thermoplastics "family."

THE MAKING OF A TYPICAL THERMOPLASTIC VINYL

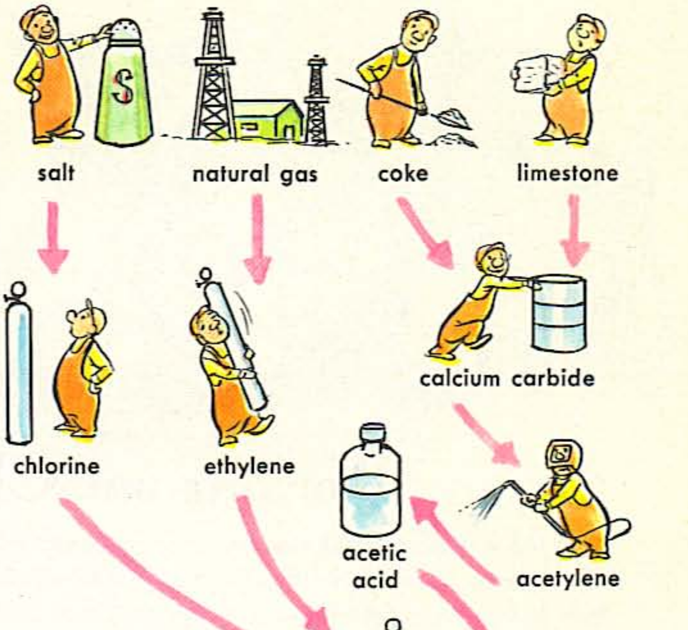

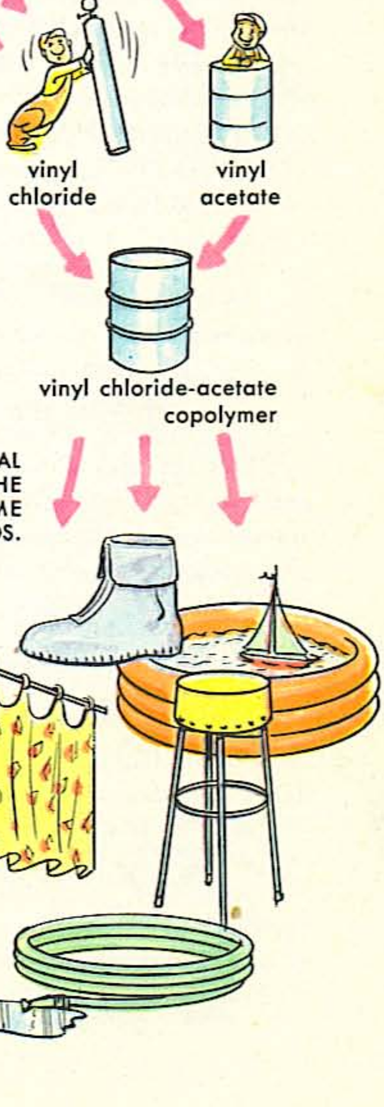

HEAT SHAPING. THERMOPLASTICS BECOME SOFT WHEN HEATED. YOU CAN THEN SHAPE THEM AT WILL.

BRING A POT OF WATER TO A BOIL. DROP IN AN OLD VINYL RECORD. WHEN SOFT, SHAPE IT WITH TWO LONG STICKS. IT BECOMES HARD AGAIN WHEN IT IS REMOVED FROM THE HOT WATER AND COOLED.

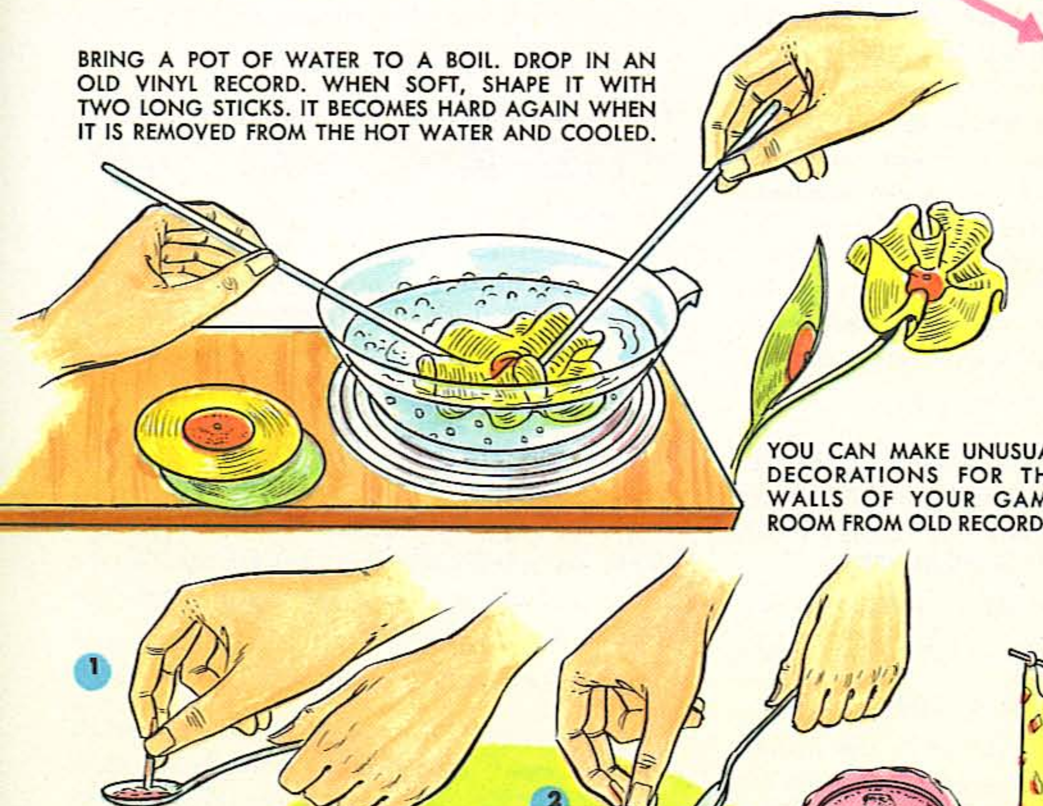

YOU CAN MAKE UNUSUAL DECORATIONS FOR THE WALLS OF YOUR GAME ROOM FROM OLD RECORDS.

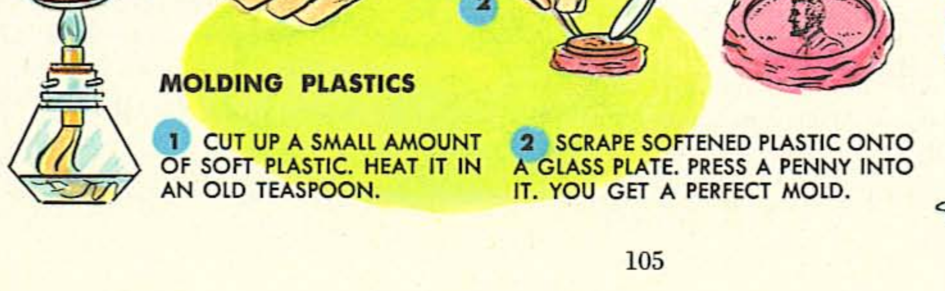

MOLDING PLASTICS

1 CUT UP A SMALL AMOUNT OF SOFT PLASTIC. HEAT IT IN AN OLD TEASPOON.

2 SCRAPE SOFTENED PLASTIC ONTO A GLASS PLATE. PRESS A PENNY INTO IT. YOU GET A PERFECT MOLD.

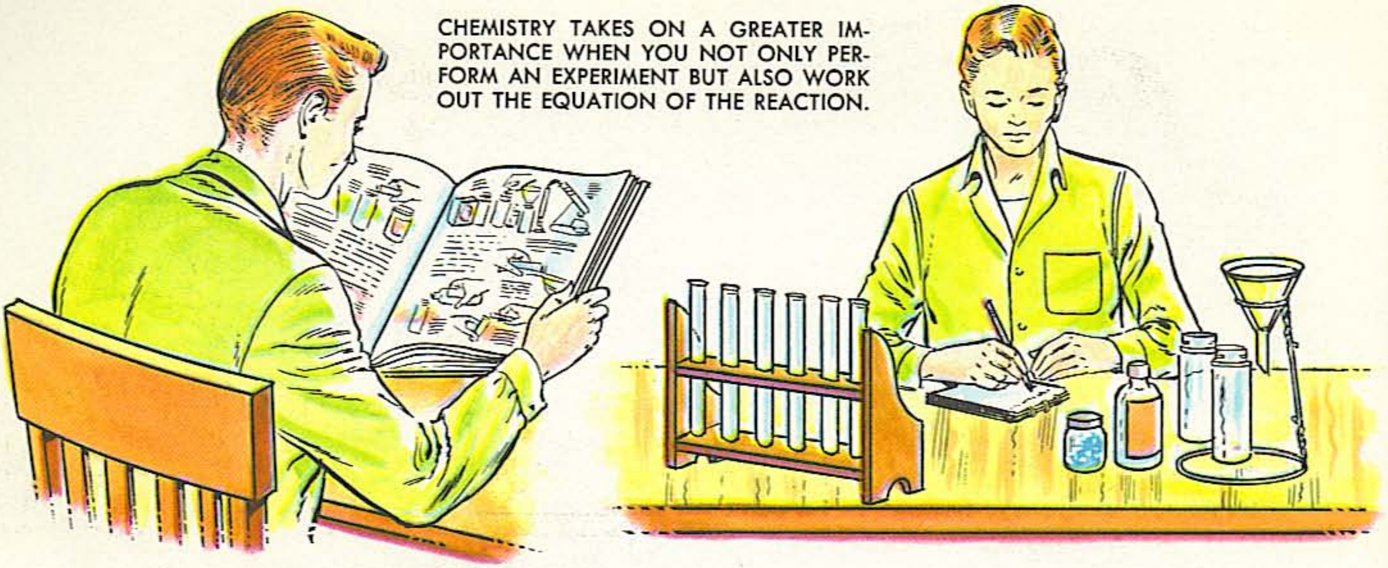

CHEMISTRY TAKES ON A GREATER IMPORTANCE WHEN YOU NOT ONLY PERFORM AN EXPERIMENT BUT ALSO WORK OUT THE EQUATION OF THE REACTION.

Working out Chemical Equations

YOU HAVE DONE a great number of experiments by now. You have worked with gases, liquids, and solids. You have precipitated and decanted, filtered and distilled. As you think back over the experiments you will discover that they fall into four main groups of chemical reactions.

The simplest of these reactions is the DIRECT COMBINATION. In this, two or more substances combine to form a single more complex substance, as when iron and sulfur form iron sulfide:

$$Fe + S \rightarrow FeS$$

or when quicklime (calcium oxide) reacts with water to make slaked lime (calcium hydroxide):

$$CaO + H_2O \rightarrow Ca(OH)_2$$

DECOMPOSITION is the opposite of chemical combination. In this, a substance is broken down into simpler substances. This was the case when you separated the two elements found in water:

$$H_2\,O\,H_2\,O \rightarrow 2H_2\uparrow + O_2\uparrow$$

or when you made oxygen from hydrogen peroxide:

$$H_2O_2\,H_2\,O_2 \rightarrow 2H_2O + O_2\uparrow$$

In a SINGLE DISPLACEMENT, one element takes the place of another in a compound, as when you made hydrogen from zinc and hydrochloric acid:

$$Zn + H\,Cl\,H\,Cl \rightarrow H_2\uparrow + ZnCl_2$$

or when you set copper free by dropping a nail in a solution of copper sulfate:

$$Fe + Cu\,SO_4 \rightarrow Cu\downarrow + FeSO_4$$

In a DOUBLE DISPLACEMENT, the two compounds change partners with each other. Think of the time when you precipitated silver chloride from solutions of salt and silver nitrate:

$$Na\,Cl + Ag\,NO_3 \rightarrow AgCl\downarrow + NaNO_3$$

or when you mixed Epsom salt and washing soda:

$$Mg\,SO_4 + Na_2\,CO_3 \rightarrow MgCO_3\downarrow + Na_2SO_4$$

In studying the chemical shorthand above, you notice that, in every instance, there is an equal number of atoms of each element on either side of the arrow that indicates that a reaction takes place. Because of this equal arrangement, these chemical descriptions are called equations.

Many of these equations are scattered throughout this book. Many more are found in advanced chemistry textbooks. But very often, a chemist has to work out an equation from scratch.

Let's say you want to figure out the equation for dissolving aluminum foil in hydrochloric acid. You write out a trial equation:

$$Al + HCl \rightarrow AlCl + H\uparrow$$

But is AlCl correct? Look at the valence chart on page 75. Aluminum has three valence bonds, chlorine only one. One Al atom therefore takes on three Cl atoms, and aluminum chloride must be $AlCl_3$. H isn't right, either. Hydrogen exists in the free state only in molecules containing two atoms (H_2). So you change the equation to this:

$$Al + HCl \rightarrow AlCl_3 + H_2\uparrow$$

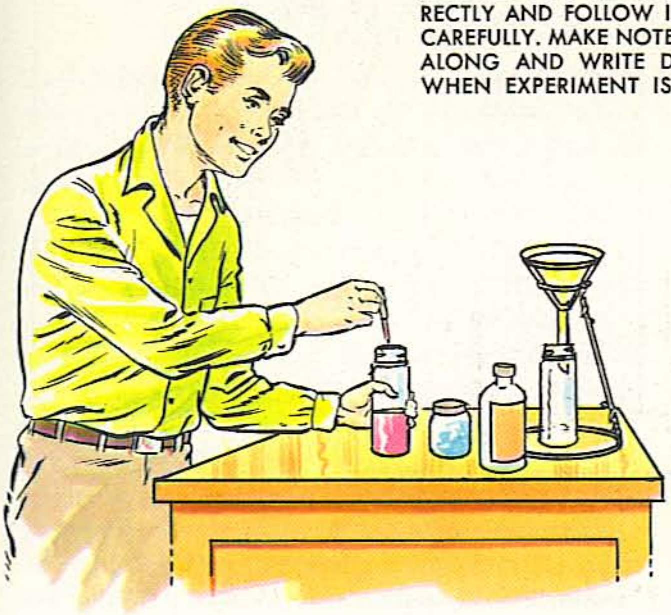

MEASURE OUT ALL CHEMICALS CORRECTLY AND FOLLOW INSTRUCTIONS CAREFULLY. MAKE NOTES AS YOU GO ALONG AND WRITE DOWN RESULT WHEN EXPERIMENT IS COMPLETED.

Now you need an amount of HCl that will give you Cl by the 3's and H by the 2's. 6HCl will do this. So you write in 6HCl and change the rest until the equation balances:

$$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2 \uparrow$$

Equations tell you what happens — but they tell far more than that.

Take the simple equation:

$$Fe + S \rightarrow FeS$$

APPROXIMATE ATOMIC WEIGHTS FOR CALCULATIONS					
Element	Symbol	Atomic Weight	Element	Symbol	Atomic Weight
ALUMINUM	Al	27	MAGNESIUM	Mg	24
BORON	B	11	MANGANESE	Mn	55
CALCIUM	Ca	40	NITROGEN	N	14
CARBON	C	12	OXYGEN	O	16
CHLORINE	Cl	36	POTASSIUM	K	39
COPPER	Cu	64	SILICON	Si	28
HYDROGEN	H	1	SILVER	Ag	108
IODINE	I	127	SODIUM	Na	23
IRON	Fe	56	SULFUR	S	32
LEAD	Pb	207	ZINC	Zn	65

This not only tells you that iron and sulfur make iron sulfide but also that it takes one iron atom and one sulfur atom to produce one molecule of FeS. Further, by inserting the atomic weights for the two elements from the chart on page 107, the equation tells you how much iron and sulfur are needed and how much iron sulfide you should get:

$$\begin{array}{lll} Fe & + \; S & \rightarrow FeS \\ 56 & \;\; 32 & 56 + 32 = 88 \end{array}$$

You can use the atomic weight numerals to indicate numbers of grams or any other unit of weight. By dividing by 16 you get the number of grams you used for experiment on page 22.

Now take a more complicated equation.

Let's say you want to produce magnesium carbonate. The chart of solubilities on page 108 tells you that $MgCO_3$ is insoluble. You should therefore be able to precipitate it from a soluble magnesium salt — the sulfate, for instance — and soluble sodium carbonate:

$$MgSO_4 + Na_2CO_3 \rightarrow MgCO_3 \downarrow + Na_2SO_4$$

Now you need to know how much $MgSO_4$ and how much Na_2CO_3 you need, and how much $MgCO_3$ you will get.

Before you start figuring from the equation above, check the chart on page 108, top right. Here you will discover that each molecule of magnesium sulfate has seven molecules of water of hydration ($7H_2O$) attached to it, and each sodium carbonate molecule,

(CONTINUED ON PAGE 108)

SOLUBILITY OF SALTS AND HYDROXIDES

NITRATES—**SOLUBLE**—WITHOUT EXCEPTIONS.

ACETATES—**SOLUBLE**—WITHOUT EXCEPTIONS.

CHLORIDES—**SOLUBLE**—EXCEPT Ag, Hg (MERCUROUS), AND Pb.

SULFATES—**SOLUBLE**—EXCEPT Pb, Ba, Sr (Ca, Ag AND Hg SLIGHTLY SOLUBLE).

NORMAL CARBONATES, PHOSPHATES, SILICATES, SULFIDES—**INSOLUBLE**—EXCEPT Na, K, NH_4.

HYDROXIDES—**INSOLUBLE**—EXCEPT Na, K, NH_4, Ba. (Ca AND Sr SLIGHTLY SOLUBLE.)

WATER OF HYDRATION
(WATER OF CRYSTALLIZATION)

$AgNO_3$
$CaCl_2 \cdot 6H_2O$
$(CaSO_4)_2 \cdot H_2O$
$CuSO_4 \cdot 5H_2O$
$FeCl_3 \cdot 6H_2O$
$FeCl_2 \cdot 4H_2O$
$FeSO_4 \cdot 7H_2O$
$KAl(SO_4)_2 \cdot 12H_2O$
KNO_3
$MgSO_4 \cdot 7H_2O$
$NH_4Al(SO_4)_2 \cdot 12H_2O$
NH_4Cl
$Na_2B_4O_7 \cdot 10H_2O$
$Na_2CO_3 \cdot 10H_2O$
$NaCl$
$NaHCO_3$
$NaHSO_4 \cdot H_2O$
$NaOH$
$Na_2SO_4 \cdot 10H_2O$
$Na_2S_2O_3 \cdot 5H_2O$

Equations—Continued

ten molecules of water ($10H_2O$). These do not enter into the chemical reaction — but you have to include them in the weight of the chemicals.

Write the atomic weight below each element. Then figure the molecular weight of each compound by adding the atomic weights of all the atoms found in the molecule.

This is what you get:

$$\begin{array}{llllllll} Mg & S & O_4 & \cdot 7H_2O+ & Na_2 & C & O_3 & \cdot 10H_2O \rightarrow \\ 24 & 32 & 16x4 & 7x18 & 23x2 & 12 & 16x3 & 10x18 \\ 24+ & 32+ & 64+ & 126 & 46+ & 12+ & 48+ & 180 \\ & & 246 & & & & 286 & \end{array}$$

$$\begin{array}{lllllll} Mg & C & O_3\downarrow + & Na_2 & S & O_4 & 17H_2O \\ 24 & 12 & 16x3 & 23x2 & 32 & 16x4 & 17x18 \\ 24+ & 12+ & 48 & 46+ & 32+ & 64 & 306 \\ 84 & & & & 142 & & 306 \end{array}$$

(When a formula contains subscripts — the small numerals that indicate how many of a kind — be certain to multiply the atomic weight by the number indicated by the subscript. In cases where the formula is preceded by a large number, be sure to multiply the molecular weight by this number.)

Your finished calculation tells you that 246 g (or 24.6 g or 2.46 g) of magnesium sulfate crystals and 286 g (or 28.6 g or 2.86 g) of sodium carbonate crystals will give you 84 g (or 8.4 g or .84 g) magnesium carbonate.

When you get even deeper into chemical mathematics you will be able to figure out the percentage of elements in a compound for which you know the formula, or the formula of a compound when you know the percentage of elements, or the numbers of liters of a gas you prepare in a chemical reaction.

CHEMISTRY AS A HOBBY WILL GIVE YOU MANY HOURS OF ENJOYMENT.

CHEMISTRY AS A SCIENCE TRAINS YOUR REASONING AND OBSERVATION.

What's Ahead in Chemistry?

THE CHEMICAL WONDERS of today are amazing enough — but they are like nothing compared to the wonders the future holds in store for the welfare of all humanity.

FOOD — The fertilizers of tomorrow will greatly increase the crops grown on farms throughout the world. Insect and disease-destroying chemicals will make cattle and poultry healthier and better producers of meat, milk, and eggs. Chemicals unknown today will make it possible to keep food fresh without refrigeration in any climate.

HOMES — The houses of the future will be built of more durable materials than any we have today. Floors and wall covering will last almost indefinitely. New paints will add never-fading colors.

CLOTHING — Many more man-made fibers will be added to those we use today — fibers with longer wear; fabrics that are cool in summer, warm in winter, easy to keep clean.

HEALTH — The miracle drugs of today have wiped out diseases that ranked among our greatest killers just a few years ago. In years to come many more diseases will disappear from the surface of the world under the onslaught of still more effective drugs created in the chemical laboratory.

TRAVEL — Much of the travel of the future will be at supersonic speeds. Planes and rockets will require materials that can stand tremendous heat and new fuels capable of producing enormous energy. Chemistry will provide them.

ATOMIC ENERGY — The force hidden in the atom will be turned into light and heat and power for everyday uses. Chemists of the future, working with their brother-scientists, the physicists, will find new ways of harnessing and using the atoms of numerous elements — some of them unknown to the scientists of today.

Do you want to share in the making of that astonishing and promising future?

If you have enjoyed performing the experiments in this book, figuring out formulas and equations, jotting down observations, you are the kind of person who has the qualifications for making a successful career in chemistry.

If you care to look further into the matter, speak to your science teacher about it and drop a line to one or all three of the organizations mentioned below and ask for their pamphlets on becoming a chemist:

American Chemical Society,
1155 16th Street, N. W., Washington 6, D. C.

American Institute of Chemical Engineers,
25 West 45th Street, New York 36, N. Y.

Manufacturing Chemists' Association,
1625 I Street, N. W., Washington 6, D. C.

But whatever you decide for the future, keep up your interest in chemistry as a hobby. In addition to giving you fun and enjoyment, your chemical hobby will sharpen your powers of observation and reasoning and train your mind for whatever occupation you decide upon for a lifework.

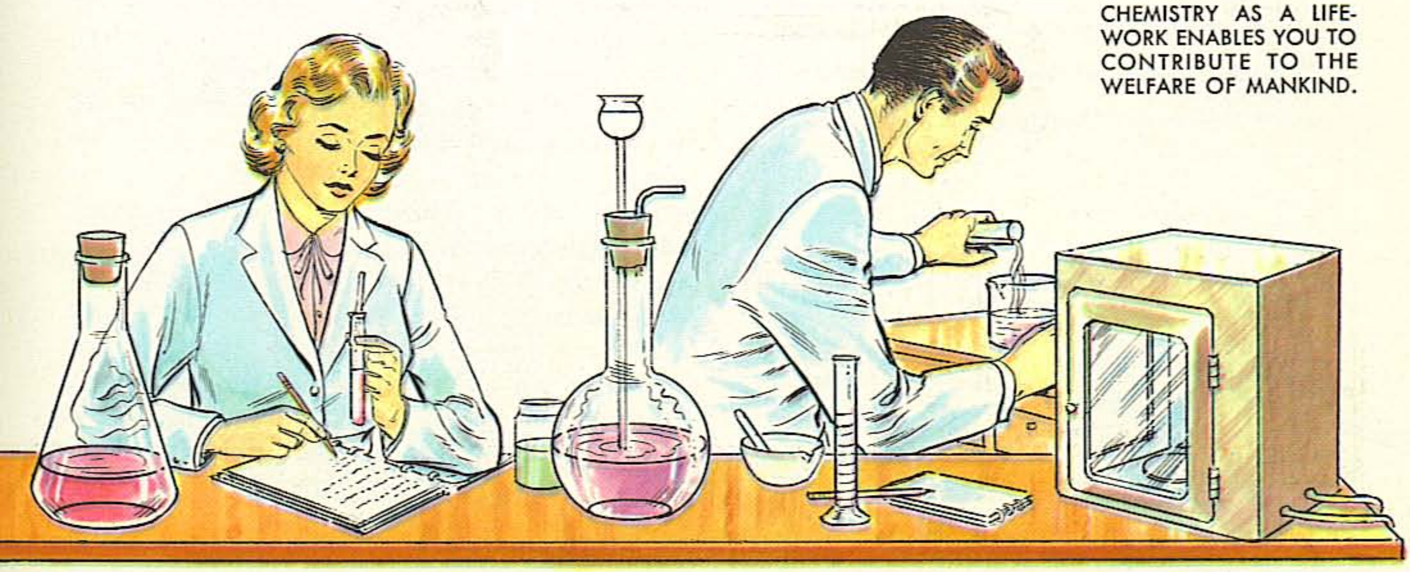

CHEMISTRY AS A LIFEWORK ENABLES YOU TO CONTRIBUTE TO THE WELFARE OF MANKIND.

Where to Get Chemicals and Equipment

A GREAT MANY of the experiments in this book can be performed with equipment found around the house: water glasses, custard cups, jars, bottles, cans, and funnel. For the rest, the following pieces of regular chemical laboratory equipment are needed:

6 test tubes, regular, 150 mm x 16 mm
3 test tubes, Pyrex, 150 mm x 16 mm
1 test tube brush, small
3 wide-mouth bottles, 4 ozs.
6 ft. glass tubing, 6 mm outside diameter
3 ft. rubber tubing, 3/16″ inside diameter
2 No. 0 rubber stoppers, one hole
1 No. 5 rubber stopper, one hole
3 No. 5 rubber stoppers, two holes
1 triangular file, 4″
1 glass stirring rod, 5″
1 pkg. filter paper, 12.5 cm, 50 pieces
1 vial litmus paper strips, blue
1 vial litmus paper strips, red

If you can not secure this equipment locally, write to one of the companies below asking for price list or catalog, including cost of catalog where called for. When you receive the answer, mail your order and the correct amount by bank check or money order.

Science Mail Co., 17-33 Murray St., Whitestone 57, N. Y. (Price list free)
Winn Chemical Co., 124 West 23rd St., New York 11, N. Y. (Catalog 25¢)
N. Y. Scientific Supply Co., 28 West 30th St., New York 1, N. Y. (Catalog 50¢)
Home Lab Supply, 511 Homestead Ave., Mount Vernon, N. Y. (Price list free)
Biological Supply Co., 1176 Mt. Hope Ave., Rochester 20, N. Y. (Catalog 25¢)
A. C. Gilbert Co., P. O. Box 1610, New Haven 6, Conn. (Price list free)
Bio-Chemical Products, 30 Somerset St., Belmont, Mass. (Catalog 25¢)
Laboratory Sales, P. O. Box 161, Brighton, Mass. (Catalog 25¢)
The Porter Chemical Co., Hagerstown, Md. (Price list free)
Tracey Scientific Laboratories, P. O. Box 615, Evanston, Ill. (Catalog 25¢)
National Scientific Co., 13 South Park Ave., Lombard, Ill. (Catalog 35¢)
Hagenow Laboratories, Manitowoc, Wis. (Catalog 20¢)

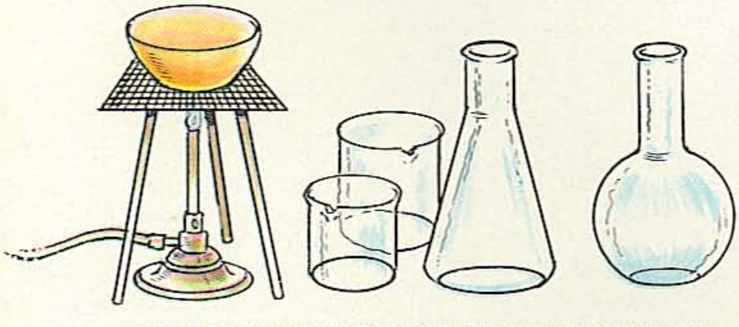

IF YOU DECIDE TO USE REGULAR LABORATORY WARE IN YOUR HOME LAB, GET PRICE LIST FROM SUPPLIER.

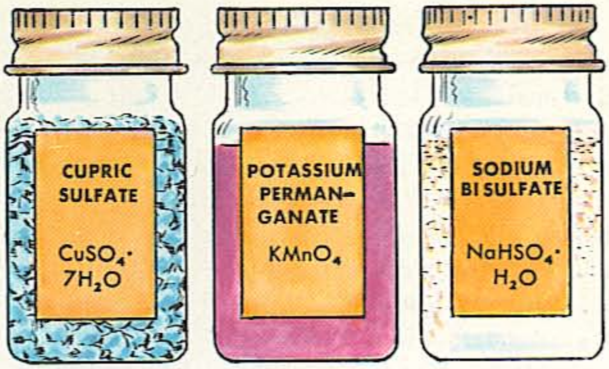

CHEMICALS FOR HOME EXPERIMENTS ARE AVAILABLE IN JARS OF UNIFORM SIZE, ALL PROPERLY LABELED.

WHENEVER YOU NEED a chemical for one of the experiments described in this book, check the list of common chemicals on page 111 to find out where to buy it.

All of these chemicals are, of course, available through chemical supply houses. The trouble is that many of these houses do not sell to individuals but only to schools and established laboratories. Also, the chemicals usually come in a standard amount of ¼ lb. — or even 1 lb. — where, in home experiments, you would need 1 ounce or less. The same is often the case when you buy chemicals in a local store. The minimum-sized packages or jars may be so large that you couldn't possibly use up the contents in a year of experiments. You will probably also have to repack what you actually need into glass jars of suitable size for efficiency and to fit your storage space.

Because of this and the inconvenience of having to shop around, you may find it advantageous to buy your chemicals by the kit, in uniform-sized screw-top glass containers. Such kits are available in the science department of many hobby and model supply stores.

Chem-Kit No. 1 contains the ten chemicals marked 🟥 on the opposite page. Chem-Kit No. 2 contains the ten chemicals marked 🟨. The kits contain sufficient amounts of chemicals to perform each experiment many times over.

You can also make up your own set of chemicals in amounts suitable for home experiments by getting them from one of the companies listed to the left. Be certain to add the cost of the catalog when you write for one and to send the correct amount when you order.

Common Chemicals and Their Formulas

	CHEMICAL NAME	FORMULA	COMMON NAME	WHERE TO BUY
🟦	ACETIC ACID	$CH_3COOH + H_2O$	5% solution: white vinegar	Grocery
🟥	AMMONIUM CHLORIDE	NH_4Cl	sal ammoniac	Drug store
🟦	AMMONIUM HYDROXIDE	$NH_4OH + H_2O$	10% solution: household ammonia 27% solution: strong ammonia	Grocery Drug store
🟦	BORIC ACID	H_3BO_3	boric acid	Drug store
🟥	CALCIUM CARBONATE	$CaCO_3$	chunks: marble, limestone powder: precipitated chalk	Builders' supplies Drug store
🟦	CALCIUM HYDROXIDE	$Ca(OH)_2$	slaked lime, garden lime	Hardware store
🟨	CALCIUM OXIDE	CaO	quicklime	Builders' supplies
🟦	CALCIUM SULFATE	$(CaSO_4) \cdot H_2O$ $CaSO_4 \cdot 2H_2O$	plaster of Paris gypsum	Hardware store Chemical supplies
🟦	CARBON TETRACHLORIDE	CCl_4	carbon tet	Hardware store
🟨	COPPER SULFATE	$CuSO_4 \cdot 5H_2O$	blue vitriol	Drug store
🟨	FERROUS SULFATE	$FeSO_4 \cdot 7H_2O$	iron sulfate, green vitriol, copperas	Drug store
🟦	GLUCOSE	$C_6H_{12}O_6 + H_2O$	solution: corn syrup	Grocery
🟦	HYDROCHLORIC ACID	$HCl + H_2O$	25% solution: muriatic acid	Hardware store
🟦	HYDROGEN PEROXIDE	$H_2O_2 + H_2O$	3% solution: peroxide	Drug store
🟥	IRON, METAL, POWDER	Fe	powdered iron	Chemical supplies
🟨	MAGNESIUM, METAL	Mg	magnesium ribbon	Chemical supplies
🟦	MAGNESIUM SULFATE	$MgSO_4 \cdot 7H_2O$	Epsom salts	Drug store
🟥	MANGANESE DIOXIDE	MnO_2	pyrolusite	Hardware store (flashlight battery)
🟦	NAPHTHALENE	$C_{10}H_8$	moth balls	Hardware store
🟥	PHENOLPHTHALEIN	$C_6H_4COOC(C_6H_4OH)_2$	phenolphthalein	Drug store
🟨	POTASSIUM ALUMINUM SULFATE	$KAl(SO_4)_2 \cdot 12H_2O$	alum, potassium alum	Drug store
🟨	POTASSIUM FERROCYANIDE	$K_4Fe(CN)_6 \cdot 3H_2O$	potassium ferrocyanide	Chemical supplies
🟥	POTASSIUM IODIDE	KI	potassium iodide	Drug store
🟦	POTASSIUM NITRATE	KNO_3	saltpeter, niter	Drug store
🟨	POTASSIUM PERMANGANATE	$KMnO_4$	potassium permanganate	Drug store
🟨	SALICYLIC ACID	$C_6H_4OHCOOH$	salicylic acid	Drug store
🟦	SILVER NITRATE	$AgNO_3$	lunar caustic	Drug store
🟦	SODIUM BICARBONATE	$NaHCO_3$	baking soda, bicarb	Grocery
🟥	SODIUM BISULFATE	$NaHSO_4 \cdot H_2O$	82% of Sani-Flush®	Grocery
🟦	SODIUM CARBONATE	$Na_2CO_3 \cdot 10H_2O$ $Na_2CO_3 \cdot H_2O$	sal soda, crystal washing soda concentrated washing soda	Grocery Grocery
🟦	SODIUM CHLORIDE	$NaCl$	salt, table salt	Grocery
🟦	SODIUM HYDROXIDE	$NaOH$	lye, caustic soda, Drano®	Grocery
🟦	SODIUM HYPOCHLORITE	$NaClO + H_2O$	5% solution: laundry bleach, Clorox®	Grocery
🟨	SODIUM POTASSIUM TARTRATE	$NaKC_4H_4O_6 \cdot 4H_2O$	Rochelle salt	Drug store
🟦	SODIUM SILICATE	$Na_2SiO_3 + H_2O$	solution: water glass	Hardware store
🟨	SODIUM TETRABORATE	$Na_2B_4O_7 \cdot 10H_2O$	borax	Drug store
🟥	SODIUM THIOSULFATE	$Na_2S_2O_3 \cdot 5H_2O$	hypo	Photo store
🟦	SUCROSE	$C_{12}H_{22}O_{11}$	cane sugar	Grocery
🟥	SULFUR	S	powder: flowers of sulfur block: sulfur candle	Drug store Hardware store
🟥	ZINC, METAL	Zn	zinc	Hardware store (flashlight battery)
🟦	ZINC CHLORIDE	$ZnCl_2 + H_2O$	tinners' fluid	Hardware store

Note: Chemicals marked 🟦—many of them liquids—are most easily secured in local stores. Chemicals marked 🟥 are found in Chem-Kit No. 1, chemicals marked 🟨 in Chem-Kit No. 2 (see opposite page).

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